## PLANE-WAVE SCATTERING OF A PERIODIC CORRUGATED CYLINDER

by

Samuel Garcia

A Dissertation Submitted to the Faculty of

College of Engineering & Computer Science

In Partial Fulfillment of the Requirements for the Degree of

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Samuel Garcia

This dissertation was prepared under the direction of the candidate's dissertation advisor. Dr. Jonathan Bagby, Department of Computer & Electrical Engineering and Computer Science, and has been approved by the members of his supervisory committee. It was submitted to the faculty of the College of Engineering & Computer Science and was accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

SUPERVISORY COMMITTEE: Jonathan Bagby, Ph D. **Dissertation Advisor** Vichate Ungylchian, Ph D. Valentine Aalo, Ph D. 1.10.0 William Rhodes, Ph

Nurgun Erdol, Ph.D. Chair, Department of Computer & Electrical Engineering & Computer

Grigoriy Kreymerman, Ph D.

Science

Mohammad Ilyas, Ph.D. Dean, College of Engineering & Computer Science

Deborah L. Floyd, Ed.D.

Dean, Graduate College

ril 12, 2017 Date

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### ABSTRACT

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In this dissertation, a novel approach to modeling the scattered field of a periodic corrugated cylinder, from an oblique incident planewave, is presented. The approach utilizes radial waveguide approximations for fields within the corrugations, which are point matched to approximated scattered fields outside of the corrugation to solve for the expansion coefficients. The point matching is done with  $TM_z$  and  $TE_z$  modes simultaneously, allowing for hybrid modes to exist.

The derivation of the fields and boundary conditions used are discussed in detail. Axial and radial propagating modes for the scattered fields are derived and discussed. Close treatment is given to field equations summation truncation and conversion to matrix form, for numerical computing. A detailed account of the modeling approach using Mathematica® and NCAlgebra for the noncommutative algebra, involved in solving for the expansion coefficients, are also given. The modeling techniques offered provide a full description and prediction of the scattered field of a periodic corrugated cylinder. The model is configured to approximate a smooth cylinder, which is then compared against that of a textbook standard smooth cylinder. The methodology and analysis applied in this research provide a solution for computational electromagnetics, RF communications, Radar systems and the like, for the design, development, and analysis of such systems. Through the rapid modeling techniques developed in this research, early knowledge discovery can be made allowing for better more effective decision making to be made early in the design and investigation process of an RF project.

## DEDICATION

First and foremost, this manuscript is dedicated to my late father. It's because of him I had any interest in becoming an electrical engineering. He always encouraged me to study and work hard. Growing up, he always gave me electrical projects to work on and challenge me. He started this PhD journey with me, but now, wherever he is, I know he'd be proud.

I also dedicated this to my girlfriend, Ivette Morazzani, who not only spent many years putting up with my research, she's also spent a lot of time reviewing my work and helping me code my work.

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### CHAPTER 1 INTRODUCTION

## 1.1 Objective

The scattered field due to a large periodic corrugated cylinder of quasi-infinite length is formulated and numerically determined in this dissertation. It is assumed that the boundaries and structure of the corrugated cylinder are constructed of Perfect Electrical Conductors (PECs). The present research provides an alternate technique for evaluating near-field scattering of a corrugated cylinder due to an incident plane wave while improving the computational efficiency of infinite array scattering using Floquet modes. The effect on the total electric field from variations of relative dimensions of the corrugated cylinder is also investigated.

Problems of scattering from periodic corrugated cylinders have been treated in the past. There has been investigation into the use of radial waveguide representation of the corrugated region [1] [2], asymptotic corrugation boundary conditions [3] [4], metallic ring representation [5], tensor permeability and tensor permittivity [6], and surface roughness function for corrugation representation [7]. However, treatment of this problem utilizing radial waveguide representation for the region within the corrugations and simultaneously working with Transverse Magnetic (TM) and Transverse Electric (TE) modes appears to be a new contribution to the field of computational electromagnetics, specifically with regards to scattering structures.

## 1.2 Background

In today's modern era of increasingly use of high-tech radio frequency (RF) communications and radar systems, it has become increasingly important to understand and mitigate the effects of RF or electromagnetic field scattering from common objects and geometries involved in those systems. That's because the more bandwidth and the greater sensitivity these instruments require, the more impactful inadvertent scattering off of nearby objects can be. The effect would cause an increase to the noise floor and distortion of intended signals, which reduces the overall quality and bandwidth of the data sent through the system. In the case of a 'stealth' type aircraft, unintended scattering would increase the aircraft's Radar Cross Section (RCS) which would improve an adversarial radar system's ability to detect that aircraft.

A common shape seen across all these systems is the cylinder. The fuselage of an aircraft and many external payloads are approximately cylindrical. The supporting struts for the transmitter/receiver on parabolic dishes (Figure 1-1), as such used in satellite communication, radio astronomy, etc. also tend to be cylindrical in shape. The present research provides a method of analysis for a modified geometry of these cylindrical structures, utilizing a periodic corrugation, in effect to optimize the design of them through assessment of their scattering.

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Figure 1-1 Example of a parabolic dish used in communications

## 1.3 Chapter-Wise Organization

In order to provide a coherent and orderly research documentation, this dissertation has been organized categorically into chapters, which are summarized here:

□ Chapter 1 Introduction

This chapter (current) is an introduction to the present research. It provides context and motivation for the field of research. It also provides a summary for the structure of the dissertation.

 Chapter 2 Periodic Corrugated Cylinder: Physical Description And Electromagnetic Application

This chapter describes the problem space in which the research is set. A detailed description of the geometry and electromagnetic treatment are discussed. The characteristics of the problem space that are varied are also

described. Floquet modes are invoked to represent the phase shift of the fields due to the periodicity of the structure. The nomenclature for the components, regions and other aspects of the problem space are established. Also, well established electromagnetic waveguide equations are represented and discussed. The overall approach for achieving solutions is also discussed as well as its validity.

□ Chapter 3 Incident Field

The incident plane-wave for TM & TE modes is described. The fields are further derived into their respective cylindrical coordinate components for both E-fields and H-fields.

□ Chapter 4 Region I – Radial Waveguide Field Equations

The fields between the corrugations are examined. Radial waveguide field equations were derived, based on Maxwell's equations. Boundary conditions are established as part of the derivation and further reduction of the equations. Finally, equations are developed for each respective cylindrical coordinate component for both E-fields and H-fields. Unknown coefficients are identified for solving in subsequent chapters.

□ Chapter 5 Region II – Scattered Field Equations

The scattered fields are derived and boundary conditions are established. Equations are developed for each respective cylindrical coordinate component for both E-fields and H-fields. Unknown coefficients are identified for solving in the subsequent chapter.
- □ Chapter 6 Boundary Conditions & Point Matching Method
   A point matching method is established for solving all the unknown
   coefficients. Equation sets are established for boundary conditions intended
   for point matching. All the field equations' summations are truncated from +∞
   and -∞, to integers.
- Chapter 7 Results, Comparisons and Future Research
   Results are presented and discussed. General description of mathematical
   software tool and use are provided. Expressions identified for full description
   of solution space. A description of future research is also discussed.

# CHAPTER 2 PERIODIC CORRUGATED CYLINDER: PHYSICAL DESCRIPTION AND ELECTROMAGNETIC APPLICATION

# 2.1 Physical Description

The subject of this paper is on the scatterer shown in Figure 2-1. It is a periodic corrugated cylinder of approximately infinite length, discussed further in the following section. The different dimensions of its components are referenced in Figure 2-1(b) with letter reference designators.

The corrugated cylinder is lined vertically with its center axis being on the z-axis. The inner radius of the corrugation is  $\rho_1$  and the outer radius is  $\rho_2$  along the  $\rho$  axis. The corrugated cylinder is symmetrical all along the  $\phi$  axis. These corrugation pieces, also referred to here as discs, have a thickness (height in z direction) of b. The spacing between the corrugation (or discs) have a dimension of a. The values of these dimensions are discussed further in later chapters and will be described in terms of  $\lambda$ , wavelength of the incident plane-wave.



Figure 2-1 Representation of a Segment of a Periodic Corrugated Cylinder: (a) 3D view of the Periodic Corrugated Cylinder (b) Cross-sectional view of the Periodic Corrugated Cylinder with Referenced Dimensions

# 2.2 Infinite Length Approximation

When a periodic structure of infinite length, in this case a corrugated cylinder, is radiated by an incident field, the scattered field produced will contain multiple modes or space harmonics, which are coupled to the boundary conditions in which they must satisfy [8, p. 625]. These spatially periodic fields can be represented through Floquet modes. Floquet modes are modes of propagating waves that take on the symmetry of the periodic structure that wave has interfaced with. This is based on Floquet theory, in which a single period of the periodic structure is used to define the wave and accounting for the phase shift along the axis of propagation, which is also the axis of periodicity of the structure. A further description of Floquet modes and Floquet theory can be found in [9, pp. 264-266] and [8, pp. 605-608].

Practically, one works with smaller and finite length periodic structures and not infinitely long ones. However, sufficiently long periodic scatterers can be approximated as infinitely long allowing for simplification for mathematical models of the scattering fields [10], [11].

# 2.3 Problem Space

Consider a PEC periodic corrugated cylinder of infinite length as shown in Figure 2-2. Now consider that same corrugated cylinder in the presence of an incident planewave. That corrugated cylinder will perturb the incident planewave by behaving as a scatterer. Many have approached the problem of calculating the scattered field, such as Manara [1] [2], Kishk [4], Freni [5] and Hillion [7].



Figure 2-2 PEC periodic corrugated cylinder of infinite length, radiated by incident planewave

However, the method proposed in this paper describes the simultaneous use of the Transverse Magnetic ( $TM_z$ ) and the Transverse Electric ( $TE_z$ ) field modes, with respect to the z-axis, to solve the problem of predicting the scattered fields. As implied by Constantine A. Balanis in his work on describing scattering by a conducting circular cylinder of an oblique planewave, a cylinder structure that deviates from a smooth cylinder can experience depolarizations of the fields due to the scattering [12, p. 615]. Based on this statement, this work makes the assumption of a hybrid mode when scattering from a corrugated cylinder. Therefore, the  $TM_z$  and the  $TE_z$  modes shall be accounted for simultaneously and depolarization of the fields from one mode to another can occur.

Along with  $TM_z$  and the  $TE_z$  modes, this approach also utilizes a radial waveguide representation of the fields within the corrugations (region I) which the full solution for is formulated in conjunction with the fields outside of the corrugations (region II). The radial waveguide method has been investigated by Manara [1]. The combination of  $TM_z$  and the  $TE_z$  modes with the radial waveguide representation provides a more complete description of the scattered field from a periodic corrugated cylinder, that is novel and has not been observed by the author in previous literature.

2.4 Solution Approach

Having been presented with a description of the problem space, the reader can now follow along with the solution approach, a step-by-step guide on how to utilize the problem space components provided in order to solve the problem (predicting the scattered fields) of a known PEC periodic corrugated cylinder.

Step 1: Identify the incident planewaves

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Step 2: Derive solutions to Helmholtz equations for the fields in region IStep 3: Derive solutions to Helmholtz equations for the scattered fields in region IIStep 4: Truncate all summation equations to finite ranges and represent in matrix formStep 5: Apply boundary conditions for fields in region I and region II to solve forunknown coefficients

Step 6: Symbolically and numerically compute solutions for unknown coefficients

This is the solution approach that is represented in this paper. Steps 1, 2 and 3 are described in chapters 3, 4 and 5 respectively. Steps 4, 5 and 6 are covered in chapter 6. Step 6 is where a great deal of time and effort was spent by the author in developing the appropriate numerical computing approach.

In this paper, the fields and incident planewaves are considered to be time harmonic, as shown in equations (2-1) and (2-2). Only the vector phasor component,  $\vec{E}(x, y, z)$ , will be considered and the  $e^{j\omega t}$  will be omitted for simplification.

$$\vec{E}(x,y,z,t) = Re\left[\vec{E}(x,y,z)\right]e^{j\omega t}$$
(2-1)

$$\vec{H}(x, y, z, t) = Re\left[\vec{H}(x, y, z)\right]e^{j\omega t}.$$
(2-2)

The field equations and solutions to them, presented in this paper will be in the cylindrical coordinate form (i.e.  $\hat{\rho}$ ,  $\hat{\varphi}$ , and  $\hat{z}$  axes), with the exception of the introduction of the incident field in Chapter 3.

#### **CHAPTER 3 INCIDENT FIELD**

Now consider an unbounded medium, referred to here as region II, which is a near infinite media and void of any scatterers. This description allows for the easy modeling of a propagating incident planewave. An idealistic view as such is incomplete, with regards to the scattered field, in the presence of a scatterer (as in the case of the periodic corrugated cylinder). In order to appropriately describe the total fields ( $E^t$ ,  $H^t$ ), superposition can be used, as shown in equations (3.1) and (3.2), in which the incident field ( $E^i$ ,  $H^i$ ) is added to the scattered field ( $E^s \& H^s$ , field created by a scatterer in the presence of a propagating field) in order to get the total field. Deriving the scattered field is the subject of chapter 5. This chapter will focus on the incident field.

$$E^t = E^i + E^s \tag{3-1}$$

$$H^t = H^i + H^s. (3-2)$$

The problem space and solution approach require that the solution set be driven by two sets of modes, the TM and TE modes. Separate treatment will be given to these modes when describing the field components. However, when solving for boundary conditions at the point matching phase, these modes will be combined through invoking superposition. For now, the driving incident field will be separated in its TM and TE modes. It's also important to note here that the present work is done on oblique incident planewaves and not normal incident planewaves.



Figure 3-1 Incident field shown with respect to corrugated cylinder for  $TM_z$  mode (a) and  $TE_z$  mode (b)

Depicted in Figure 3-1(a) is a TM<sub>z</sub> mode planewave, in region II, which is incident to a periodic corrugated cylinder. In Figure 3-1(b), the same structure is shown only now with a TE<sub>z</sub> mode planewave that's incident. In both scenarios, the planewave is traveling in the same direction, as indicated by  $\theta^i$  (angle of incidence) and the wave vector  $\vec{k}^i$ , which is given by

$$\vec{k}^{i} = k[\hat{x}\sin\theta^{i} - \hat{z}\cos\theta^{i}]$$
(3-3)

where  $k = \omega \sqrt{\mu \varepsilon}$  is the wavenumber. In region II, as is the case for the incident field,  $k = \omega \sqrt{\mu_{II} \varepsilon_{II}}$  where  $\mu = \mu_{II}$  and  $\varepsilon = \varepsilon_{II}$ . In region I, covered in detail in Chapter 4,  $k = \omega \sqrt{\mu_{I} \varepsilon_{I}}$  where  $\mu = \mu_{I}$  and  $\varepsilon = \varepsilon_{I}$ .

Here is a brief description of  $TM_z$  and  $TE_z$  modes of a propagating wave, to aid the reader through this paper. A transverse magnetic mode, with respect to the z-axis  $(TM_z)$ , of a propagating wave, is that of a wave that has its magnetic field components in a plane that is perpendicular (transverse) to the z-axis. Therefore, there is no magnetic field component on the z-axis, or  $H_z=0$ , for a TM<sub>z</sub> mode.

A transverse electric mode, with respect to the z-axis (TE<sub>z</sub>), of a propagating wave, follows the same logic as that of the transverse magnetic, but rather now it's the electric field component that is perpendicular (transverse) to the z-axis. In this case of a TE<sub>z</sub> mode, there is no electric field component on the z-axis, or  $E_z=0$ .

## 3.1 Incident Field TM<sub>z</sub> mode

In the case of the TM<sub>z</sub> incidence, the equation for the electric field is given by equation (3.4) for rectangular coordinates and (3.5) for cylindrical coordinates. The component  $Z = \sqrt{\frac{\mu_{II}}{\epsilon_{II}}}$  is intrinsic impedance of region II. Conversion of a vector field between coordinate system types can be found in [12, pp. 920-923].

$$\vec{E}^{i} = E_0[\hat{x}\cos\theta^{i} + \hat{z}\sin\theta^{i}]e^{-jk[x\sin\theta^{i} - z\cos\theta^{i}]}$$
(3-4)

$$\vec{E}^{i} = E_{0}[\hat{\rho}\cos\varphi\cos\theta^{i} - \hat{\varphi}\sin\varphi\cos\theta^{i} + \hat{z}\sin\theta^{i}]e^{jkz\cos\theta^{i}}\sum_{n=-\infty}^{\infty}j^{-n}J_{n}(k\rho\sin\theta^{i})e^{jn\varphi} \qquad (3-5)$$

The corresponding magnetic fields are given using and expanding on Maxwell's curl equations, which a full example can be found in [12, pp. 616-618] to get equations ( 3-6) for rectangular coordinates and (3-7) for cylindrical coordinates.

$$\vec{H}^{i} = \frac{1}{Z} \hat{k} \times \vec{E}^{i} = \frac{E_{0}}{Z} [\hat{x} \sin \theta^{i} - \hat{z} \cos \theta^{i}] \times [\hat{x} \cos \theta^{i} + \hat{z} \sin \theta^{i}] e^{-jk[x \sin \theta^{i} - z \cos \theta^{i}]}$$

$$= -\hat{y} \frac{E_{0}}{Z} e^{jkz \cos \theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n} (k\rho \sin \theta^{i}) e^{jn\varphi}$$
(3-6)

$$\vec{H}^{i} = \frac{E_{0}}{Z} \left[ -\hat{\rho} \sin\varphi - \hat{\varphi} \cos\varphi \right] e^{jkz\cos\theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho\sin\theta^{i}) e^{jn\varphi}$$
(3-7)

## Further breaking down the electric and magnetic field equations into their

coordinate constituents, we get equations

$$E_{z^{II}}^{i} = E_{0} \sin \theta^{i} e^{jkz \cos \theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho \sin \theta^{i}) e^{jn\varphi}$$
(3-8)

$$E_{\rho_{-}TM^{II}}^{i} = E_0 \cos\varphi \cos\theta^i e^{jkz\cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^i) e^{jn\varphi}$$
(3-9)

$$E^{i}_{\varphi\_TM^{II}} = -E_0 \sin\varphi\cos\theta^i e^{jkz\cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^i) e^{jn\varphi}$$
(3-10)

$$H^{i}_{\rho_{TM^{II}}} = -\frac{E_0}{Z} \sin\varphi \, e^{jkz\cos\theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^{i}) e^{jn\varphi} \tag{3-11}$$

$$H^{i}_{\varphi_{-}TM^{II}} = -\frac{E_{0}}{Z}\cos\varphi \,e^{jkz\cos\theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho\sin\theta^{i})e^{jn\varphi} \qquad (3-12)$$

which now provides a more manageable description of the  $TM_z$  mode incident field as will be seen in the later chapters.

## 3.2 Incident Field TE<sub>z</sub> mode

In the case of the  $TE_z$  incidence, the equation for the magnetic field is given by equation (3-13) for rectangular coordinates and (3-14) for cylindrical coordinates.

$$\vec{H}^{i} = H_0[\hat{x}\cos\theta^{i} + \hat{z}\sin\theta^{i}]e^{-jk[x\sin\theta^{i} - z\cos\theta^{i}]}$$
(3-13)

$$\vec{H}^{i} = H_{0}[\hat{\rho}\cos\varphi\cos\theta^{i} - \hat{\varphi}\sin\varphi\cos\theta^{i} + \hat{z}\sin\theta^{i}]e^{jkz\cos\theta^{i}}\sum_{n=-\infty}^{\infty}j^{-n}J_{n}(k\rho\sin\theta^{i})e^{jn\varphi}.$$
(3-14)

The corresponding electric fields are given by (3-15) for rectangular coordinates and (3-16) for cylindrical coordinates.

$$\vec{E}^{i} = Z\vec{H}^{i} \times \hat{k} = ZH_{0}[\hat{x}\cos\theta^{i} + \hat{z}\sin\theta^{i}] \times [\hat{x}\sin\theta^{i} - \hat{z}\cos\theta^{i}]e^{-jk[x\sin\theta^{i} - z\cos\theta^{i}]} =$$

$$\hat{y}ZH_{0}e^{jkz\cos\theta^{i}}\sum_{n=-\infty}^{\infty} j^{-n}J_{n}(k\rho\sin\theta^{i})e^{jn\varphi}$$
(3-15)

$$\vec{E}^{i} = ZH_{0}[\hat{\rho}\sin\varphi + \hat{\varphi}\cos\varphi]e^{jkz\cos\theta^{i}}\sum_{n=-\infty}^{\infty} j^{-n}J_{n}(k\rho\sin\theta^{i})e^{jn\varphi}$$
(3-16)

As was done in the incident Field  $TM_z$  mode section, a further breakdown of the  $TE_z$  mode field equations into their coordinate constituents gives

$$H_{z^{II}}^{i} = H_{0} \sin \theta^{i} e^{jkz \cos \theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho \sin \theta^{i}) e^{jn\varphi}$$
(3-17)

$$E_{\rho\_TE^{II}}^{i} = ZH_0 \sin\varphi \, e^{jkz\cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^i) e^{jn\varphi} \tag{3-18}$$

$$E_{\varphi_{-}TE^{II}}^{i} = ZH_0 \cos\varphi \, e^{jkz\cos\theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^{i}) e^{jn\varphi}$$
(3-19)

$$H^{i}_{\rho_{-}TE^{II}} = H_{0}\cos\varphi\cos\theta^{i}e^{jkz\cos\theta^{i}}\sum_{n=-\infty}^{\infty}j^{-n}J_{n}(k\rho\sin\theta^{i})e^{jn\varphi}$$
(3-20)

$$H^{i}_{\varphi_{-}TE^{II}} = -H_{0} \sin\varphi \cos\theta^{i} e^{jkz\cos\theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho\sin\theta^{i}) e^{jn\varphi}$$
(3-21)

completing the full component breakdown description of the incident field.

# 3.3 Total Incident Field

Due to the hybrid nature of the corrugated cylinder, both  $TM_z$  and  $TE_z$  modes will be used simultaneously. Therefore, the  $TM_z$  and  $TE_z$  mode fields in the cylindrical coordinate orientation will be combined to form

$$E_{z^{II}}^{i} = E_{0} \sin \theta^{i} e^{jkz \cos \theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho \sin \theta^{i}) e^{jn\varphi}$$
(3-22)

$$E_{\rho^{II}}^{i} = [E_0 \cos\varphi\cos\theta^i + ZH_0 \sin\varphi]e^{jkz\cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^i)e^{jn\varphi}$$
(3-23)

$$E_{\varphi^{II}}^{i} = \left[-E_0 \sin\varphi\cos\theta^i + ZH_0\cos\varphi\right] e^{jkz\cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^i) e^{jn\varphi}$$
(3-24)

$$H_{z^{II}}^{i} = H_{0} \sin \theta^{i} e^{jkz \cos \theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} J_{n}(k\rho \sin \theta^{i}) e^{jn\varphi}$$
(3-25)

$$H_{\rho^{II}}^{i} = \left[-\frac{E_{0}}{Z}\sin\varphi + H_{0}\cos\varphi\cos\theta^{i}\right]e^{jkz\cos\theta^{i}}\sum_{n=-\infty}^{\infty}j^{-n}J_{n}(k\rho\sin\theta^{i})e^{jn\varphi}$$
(3-26)

$$H^{i}_{\varphi^{II}} = \left[ -\frac{E_0}{Z} \cos\varphi - H_0 \sin\varphi \cos\theta^i \right] e^{jkz\cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho\sin\theta^i) e^{jn\varphi}.$$
(3-27)

#### CHAPTER 4 REGION I – RADIAL WAVEGUIDE FIELD EQUATIONS

This chapter will focus on deriving the field equations for region I, the region between the corrugations as can be seen in Figure 3-1. The approach to deriving the equations shown is to start with the Fundamental Equations of Guided Waves (FEGW) in cylindrical form, given by

$$E_{\rho} = \frac{-j}{k_{\rho}^{2}} \left[ k_{z} \frac{\partial E_{z}}{\partial \rho} + \frac{\omega \mu}{\rho} \frac{\partial H_{z}}{\partial \varphi} \right]$$
(4-1)

$$E_{\varphi} = \frac{-j}{k_{\rho}^2} \left[ \frac{k_z}{\rho} \frac{\partial E_z}{\partial \varphi} - \omega \mu \frac{\partial H_z}{\partial \rho} \right]$$
(4-2)

$$H_{\rho} = \frac{j}{k_{\rho}^{2}} \left[ \frac{\omega \varepsilon}{\rho} \frac{\partial E_{z}}{\partial \varphi} - k_{z} \frac{\partial H_{z}}{\partial \rho} \right]$$
(4-3)

$$H_{\varphi} = \frac{-j}{k_{\rho}^{2}} \left[ \omega \varepsilon \frac{\partial E_{z}}{\partial \rho} + \frac{k_{z}}{\rho} \frac{\partial H_{z}}{\partial \varphi} \right]$$
(4-4)

where

$$k_{\rho} = \sqrt{k^2 - k_z^2} \tag{4-5}$$

and as mentioned in Chapter 3,  $k = \omega \sqrt{\mu_I \varepsilon_I}$ , when referring to the wavenumber k in equations from region I. These equations are derived from Maxwell's equations and can be found in any electromagnetic textbook [13, p. 118].

Note that these FEGWs are in terms of  $H_z$  and  $E_z$ . When utilizing these equations for  $TM_z$  or  $TE_z$  modes,  $H_z$  or  $E_z$  respectively can be set to zero further simplifying the equations. This will be useful in the subsequent sections, in order to derive the appropriate form for many of the equations.

## 4.1 TM<sub>z</sub> Mode Equations for Region I

For the TMz mode, the FEGWs can be rewritten as

$$E_{\rho} = \frac{-j}{k_{\rho}^2} \left[ k_z \frac{\partial E_z}{\partial \rho} \right] \tag{4-6}$$

$$E_{\varphi} = \frac{-j}{k_{\rho}^{2}} \left[ \frac{k_{z}}{\rho} \frac{\partial E_{z}}{\partial \varphi} \right]$$
(4-7)

$$H_{\rho} = \frac{j}{k_{\rho}^{2}} \left[ \frac{\omega \varepsilon}{\rho} \frac{\partial E_{z}}{\partial \varphi} \right]$$
(4-8)

$$H_{\varphi} = \frac{-j}{k_{\rho}^2} \left[ \omega \varepsilon \frac{\partial E_z}{\partial \rho} \right] \tag{4-9}$$

by substituting in H<sub>z</sub>=0.

It is now apparent that all the FEGWs equations are in terms of  $E_z$ . The only term now left to develop an equation for is  $E_z$ . In order to derive a vector field wave equation for  $E_z$ , region I will be assumed to be lossless and source free, in order to simplify the mathematics. This will allow for the use of the Helmholtz vector wave equation in the form

$$\nabla^2 E_z + k^2 E_z = 0 \tag{4-10}$$

which can be used to derive an equation for  $E_z$ . Further detail and derivation of the Helmholtz equations can be found in [13, p. 116].

The other assumption is that  $E_z$ , being composed of all the cylindrical field components, or  $E_z = E_z(\rho, \varphi, z)$ , is separable into its constituent components, such that

$$E_z = R_z(\rho)\phi_z(\varphi)Z_z(z). \qquad (4-11)$$

Now, substituting equation (4-11) into equation (4-10) yields 3 sets of differential second order equations, one for each coordinate component. Since this is a common process in the field of electromagnets, details of these steps are will not be shown here but can be found in [13, p. 118]. However, solutions to these second order homogenous differential equations take the form of

$$R_{z}(\rho) = \begin{cases} A_{1}J_{n}(k_{\rho}\rho) + B_{1}Y_{n}(k_{\rho}\rho) \leftarrow \text{Standing Wave} \\ C_{1}H_{n}^{(1)}(k_{\rho}\rho) + D_{1}H_{n}^{(2)}(k_{\rho}\rho) \leftarrow \text{Traveling Wave} \end{cases}$$
(4-12)

$$\phi_{z}(\varphi) = \begin{cases} A_{2} \cos n\varphi + B_{2} \sin n\varphi \leftarrow \text{Standing Wave} \\ C_{2}e^{-jn\varphi} + D_{2}e^{+jn\varphi} \leftarrow \text{Traveling Wave} \end{cases}$$
(4-13)

$$Z_{z}(z) = \begin{cases} A_{3}\cos k_{z}z + B_{3}\sin k_{z}z \ \leftarrow \ Standing \ Wave \\ C_{3}e^{-jk_{z}z} + D_{3}e^{+jk_{z}z} \ \leftarrow \ Traveling \ Wave \end{cases}.$$
(4-14)

It is important to note the geometry of the structure of region I, which behaves as a radial waveguide, in order to appropriately select the standing wave or traveling wave solution for each of the  $E_z$  subcomponents. The structure allows for traveling waves in the  $\rho$  and  $\phi$  direction. However, in the z direction, only a standing wave can exist as depicted in Figure 4-1. Therefore, the solutions for each of the  $E_z$  subcomponents will be selected as

$$R_{z}(\rho) = C_{1}H_{n}^{(1)}(k_{\rho}\rho) + D_{1}H_{n}^{(2)}(k_{\rho}\rho) \leftarrow Traveling Wave \qquad (4-15)$$

$$\phi_z(\varphi) = C_2 e^{-jn\varphi} + D_2 e^{+jn\varphi} \leftarrow Traveling Wave \qquad (4-16)$$

$$Z_z(z) = A_3 \cos k_z z + B_3 \sin k_z z \leftarrow Standing Wave \qquad (4-17)$$

which leads to

$$E_{z} = \left(C_{1}H_{n}^{(1)}(k_{\rho}\rho) + D_{1}H_{n}^{(2)}(k_{\rho}\rho)\right)\left(C_{2}e^{-jn\varphi} + D_{2}e^{+jn\varphi}\right)\left(A_{3}\cos k_{z}z + B_{3}\sin k_{z}z\right).$$
(4-18)



Figure 4-1 Standing wave depicted in region I along the z-axis

# 4.1.1 Deriving $R_z(\rho)$ of $E_z$ in Region I

From here, the next step is to reduce each  $E_z$  subcomponents starting with  $R_z(\rho)$ .

This can be done with using the using boundary condition  $\rho = \rho_1$  where  $R_z(\rho) = 0$  or

$$C_1 H_n^{(1)} (k_\rho \rho_1) + D_1 H_n^{(2)} (k_\rho \rho_1) = 0$$
(4-19)

Now solve for  $D_1$  which will give

$$D_1 = -C_1 \frac{H_n^{(1)}(k_\rho \rho_1)}{H_n^{(2)}(k_\rho \rho_1)}.$$
(4-20)

Plug  $D_1$  back into equation (4-15) to give

$$C_{1}H_{n}^{(1)}(k_{\rho}\rho) - C_{1}\frac{H_{n}^{(1)}(k_{\rho}\rho_{1})}{H_{n}^{(2)}(k_{\rho}\rho_{1})}H_{n}^{(2)}(k_{\rho}\rho) = C_{1}\left(H_{n}^{(1)}(k_{\rho}\rho) - \frac{H_{n}^{(1)}(k_{\rho}\rho_{1})}{H_{n}^{(2)}(k_{\rho}\rho_{1})}H_{n}^{(2)}(k_{\rho}\rho)\right).$$
(4-21)

#### 4.1.2 Deriving $\Phi_z(\varphi)$ of $E_z$ in Region I

Simplifying  $\Phi_z(\varphi)$  is a little bit easier, as it requires very little manipulation. Since the two terms are exponentials each multiplied by a coefficient, have the same exponents but just with opposite signs, and will be incorporated into a summation that has 'n' going from  $-\infty$  to  $+\infty$ , the two terms can be written as a single term inside a summation. Doing so yields

$$\sum_{n=-\infty}^{\infty} A_n e^{jn\varphi} \tag{4-22}$$

where  $A_n$  is the coefficient with an 'n' subscript representing the index where, 'n' represents the circumferential ( $\phi$ ) variations.

#### 4.1.3 Deriving $Z_z(z)$ of $E_z$ in Region I

The remaining term (z), for  $E_z$ ,  $Z_z$ , can be simplified using the boundary condition of  $z=\pm a/2$  where  $\frac{\partial Z_z(z)}{\partial z}$  is set equal to 0. This is possible due to the boundary condition of  $E_\rho$  and  $E_\phi$  being equal to zero at  $z=\pm a/2$  and both having components of  $\partial E_z / \partial z$  as shown by

$$E_{\varphi} \sim E_{\rho} \sim \frac{\partial Z_z(z)}{\partial z} = \frac{\partial (A_3 \cos k_z z + B_3 \sin k_z z)}{\partial z} = Z'_z(z) = -A_3 k_z \sin k_z z + k_z B_3 \cos k_z z \qquad (4-23)$$

which will need to be set to zero for this boundary condition. As shown in Figure 4-2,  $E_{\varphi}$  and  $E_{\rho}$  are tangential to the PEC at z=±a/2 and therefore equal to zero, leading to

$$-A_{3}k_{z}\sin k_{z}z + k_{z}B_{3}\cos k_{z}z = 0 = \begin{cases} -A_{3}k_{z}\sin \left(k_{z}\frac{a}{2}\right) + B_{3}k_{z}\cos \left(k_{z}\frac{a}{2}\right) = 0 & , z = \frac{a}{2} \\ -A_{3}k_{z}\sin \left(-k_{z}\frac{a}{2}\right) + B_{3}k_{z}\cos \left(-k_{z}\frac{a}{2}\right) = 0 & , z = -\frac{a}{2} \end{cases}$$
(4-24)



Figure 4-2 Cross-sectional view of corrugated cylinder with multiple boundaries identified

Choosing the equation form where  $z = \frac{a}{2}$ , the coefficient A<sub>3</sub> can be solved for, which yields

$$A_{3} = \frac{B_{3}k_{z}\cos(k_{z}\frac{a}{2})}{k_{z}\sin(k_{z}\frac{a}{2})}.$$
 (4-25)

Plug  $A_3$  back into the  $Z_z(z)$  equation to get

$$Z_{z}(z) = \frac{B_{3}k_{z}\cos(k_{z}\frac{a}{2})}{k_{z}\sin(k_{z}\frac{a}{2})}\cos k_{z}z + B_{3}\sin k_{z}z = B_{3}\left(\sin k_{z}z + \frac{\cos(k_{z}\frac{a}{2})}{\sin(k_{z}\frac{a}{2})}\cos k_{z}z\right).$$
(4-26)

Since  $k_z$  is anticipated to be a constant, a new constant  $B'_3 = B_3 / \sin k_z \frac{a}{2}$  can be defined and plugged back into  $Z_z(z)$  equation giving

$$Z_{z}(z) = B'_{3}\left(\sin k_{z} \frac{a}{2} \sin k_{z} z + \cos k_{z} \frac{a}{2} \cos k_{z} z\right).$$
(4-27)

This expression can be simplified further using the trigonometric identity

$$\cos(x - y) = (\sin x \sin y + \cos x \cos y) \tag{4-28}$$

which gives

$$Z_z(z) = B'_3 \cos\left(k_z z - k_z \frac{a}{2}\right) \tag{4-29}$$

$$\frac{\partial Z_z(z)}{\partial z} = Z'_z(z) = -B'_3 k_z \sin\left(k_z z - k_z \frac{a}{2}\right).$$
(4-30)

Up to this point in region I, the k<sub>z</sub> has been left in its general form. Now, k<sub>z</sub> needs

to be defined so that  $\frac{\partial Z_z(z)}{\partial z}$  equals zero whenever  $z = \pm \frac{a}{2}$ , which leads to

$$k_{Z_m}\left(z - \frac{a}{2}\right) = k_{Z_m}\left(\pm \frac{a}{2} - \frac{a}{2}\right) = -k_{Z_m}a = 0 \tag{4-31}$$

$$\theta = m\pi \rightarrow k_{Z_m} a = -m\pi \rightarrow k_{Z_m} = \frac{-m\pi}{a}$$
(4-32)

and therefore, provides the final form of the  $Z_z(z)$  equation as

$$Z_{z}(z) = B'_{3} \cos k_{Z_{m}} \left( z - \frac{a}{2} \right)$$
(4-33)

Note that axial wavenumber  $k_z$  is now  $k_{z_m}$  where the 'm' sub-subscript identifies propagating mode for region I in integer intervals, much the way a classic waveguide does. This will be used in the TE<sub>z</sub> mode as well.

# 4.1.4 Deriving TM<sub>z</sub> Mode Equations for Region I

Now that the subcomponents to  $E_z$  have been defined, they can come together into a summation as given by

$$E_{z}^{I} = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \left( A_{nm} \cos k_{Z_{m}} \left( z - \frac{a}{2} \right) \right) \left( H_{n}^{(1)} (k_{\rho_{m}} \rho) - \frac{H_{n}^{(1)} (k_{\rho_{m}} \rho_{1})}{H_{n}^{(2)} (k_{\rho_{m}} \rho_{1})} H_{n}^{(2)} (k_{\rho_{m}} \rho) \right)$$
(4-34)

where  $A_{nm}$  is the combined coefficients and  $k_z = k_{z_m}$ ,  $k_\rho = k_{\rho_m}$  and the radial wavenumber,  $k_{\rho_m}$ , is derived as  $k_{\rho_m} = \sqrt{k^2 - k_{Z_m}^2}$ . From here,  $E_z$  is plugged into the modified FEGWs

given by equations (4-6) through (4-9) to yield

$$E_{\rho\_TM}^{I} = -j \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{z_m}}{k_{\rho_m}^2} \left( A_{nm} \cos k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( \left( k_{\rho_m} H_{n-1}^{(1)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(1)}(k_{\rho_m} \rho) \right) - \frac{h_n^{(1)}(k_{\rho_m} \rho_1)}{H_n^{(2)}(k_{\rho_m} \rho_1)} \left( k_{\rho_m} H_{n-1}^{(2)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(2)}(k_{\rho_m} \rho) \right) \right)$$

$$E_{\varphi\_TM}^{I} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} ne^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{z_m}}{k_{\rho_m}^2} \left( A_{nm} \cos k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( H_n^{(1)}(k_{\rho_m} \rho) - \frac{H_n^{(1)}(k_{\rho_m} \rho)}{H_n^{(2)}(k_{\rho_m} \rho_1)} + \frac{H_n^{(2)}(k_{\rho_m} \rho)}{H_n^{(2)}(k_{\rho_m} \rho)} \right)$$

$$(4-36)$$

$$H_{\rho_{-TM}}^{I} = -\frac{\omega\varepsilon}{\rho} \sum_{n=-\infty}^{\infty} ne^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{1}{k_{\rho_{m}}^{2}} \left( A_{nm} \cos k_{Z_{m}} \left( z - \frac{a}{2} \right) \right) \left( H_{n}^{(1)}(k_{\rho_{m}}\rho) - \frac{H_{n}^{(1)}(k_{\rho_{m}}\rho_{1})}{H_{n}^{(2)}(k_{\rho_{m}}\rho_{1})} H_{n}^{(2)}(k_{\rho_{m}}\rho) \right)$$
(4-37)

$$H_{\varphi_{-TM}}^{I} = -j\omega\varepsilon\sum_{n=-\infty}^{\infty} e^{jn\varphi}\sum_{m=-\infty}^{\infty} \frac{1}{k_{\rho_{m}}^{2}} \left(A_{nm}\cos k_{Z_{m}}\left(z-\frac{a}{2}\right)\right) \left(\left(k_{\rho_{m}}H_{n-1}^{(1)}(k_{\rho_{m}}\rho)-\frac{n}{\rho}H_{n}^{(1)}(k_{\rho_{m}}\rho)\right)\right) - \frac{H_{n}^{(1)}(k_{\rho_{m}}\rho_{1})}{H_{n}^{(2)}(k_{\rho_{m}}\rho_{1})} \left(k_{\rho_{m}}H_{n-1}^{(2)}(k_{\rho_{m}}\rho)-\frac{n}{\rho}H_{n}^{(2)}(k_{\rho_{m}}\rho)\right)\right)$$
(4-38)

#### 4.2 TE<sub>z</sub> Mode Equations for Region I

The  $TE_z$  mode will follow the same approach as with the  $TM_z$  mode starting with rewriting the FEGWs as

$$E_{\rho} = \frac{-j}{k_{\rho}^{2}} \left[ \frac{\omega \mu}{\rho} \frac{\partial H_{z}}{\partial \varphi} \right] \tag{4-39}$$

$$E_{\varphi} = \frac{-j}{k_{\rho}^2} \left[ -\omega \mu \frac{\partial H_z}{\partial \rho} \right] \tag{4-40}$$

$$H_{\rho} = \frac{j}{k_{\rho}^2} \left[ -k_z \frac{\partial H_z}{\partial \rho} \right] \tag{4-41}$$

$$H_{\varphi} = \frac{-j}{k_{\rho}^{2}} \left[ \frac{k_{z}}{\rho} \frac{\partial H_{z}}{\partial \varphi} \right]$$
(4-42)

by substituting in E<sub>z</sub>=0.

In the case of the  $TM_z$  mode, the FEGWs were in terms of  $E_z$ . For the  $TE_z$  case, they're in terms of  $H_z$ . Just as in the  $TM_z$  mode, the Helmholtz vector wave equation will be used, but in the form

$$\nabla^2 H_z + k^2 H_z = 0 \tag{4-43}$$

along with the assumption of  $H_z = H_z(\rho, \varphi, z)$ , and that it is separable into its constituent components, such that

$$H_z = R_z(\rho)\phi_z(\varphi)Z_z(z). \qquad (4-44)$$

Using the same solutions from equations (  $4\mathchar`-15$  ) through (  $4\mathchar`-17$  ),  $H_z$  can be found to be

$$H_{z} = \left(C_{1}H_{n}^{(1)}(k_{\rho}\rho) + D_{1}H_{n}^{(2)}(k_{\rho}\rho)\right)\left(C_{2}e^{-jn\varphi} + D_{2}e^{+jn\varphi}\right)\left(A_{3}\cos k_{z}z + B_{3}\sin k_{z}z\right).$$
(4-45)

# 4.2.1 Deriving $R_z(\rho)$ of $H_z$ in Region I

Now, the next step is to reduce each H<sub>z</sub> subcomponents starting with R<sub>z</sub> ( $\rho$ ). This approach is similar to the approach taking for E<sub>z</sub>. However, a boundary condition for H<sub>z</sub> is not directly available but one can be derived from the relationship  $E_{\varphi} \sim \frac{\partial H_z}{\partial \rho} \sim \frac{\partial R_z(\rho)}{\partial \rho} = 0$  at the boundary  $\rho = \rho_1$ , which is given by

$$\frac{\partial R_z(\rho)}{\partial \rho} = C_1 \left( k_{\rho_m} H_{n-1}^{(1)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(1)}(k_{\rho_m} \rho) \right) + D_1 \left( k_{\rho_m} H_{n-1}^{(2)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(2)}(k_{\rho_m} \rho) \right) = (4-46)$$

This equation can be rearranged to become

$$D_{1} = -C_{1} \frac{\left(k_{\rho_{m}} H_{n-1}^{(1)}(k_{\rho_{m}} \rho_{1}) - \frac{n}{\rho_{1}} H_{n}^{(1)}(k_{\rho_{m}} \rho_{1})\right)}{\left(k_{\rho_{m}} H_{n-1}^{(2)}(k_{\rho_{m}} \rho_{1}) - \frac{n}{\rho_{1}} H_{n}^{(2)}(k_{\rho_{m}} \rho_{1})\right)}$$
(4-47)

which can be plugged into  $R_z(\rho)$  to give

$$R_{z}(\rho) = C_{1}H_{n}^{(1)}(k_{\rho_{m}}\rho) - C_{1}\frac{\left(k_{\rho_{m}}H_{n-1}^{(1)}(k_{\rho_{m}}\rho_{1}) - \frac{n}{\rho_{1}}H_{n}^{(1)}(k_{\rho_{m}}\rho_{1})\right)}{\left(k_{\rho_{m}}H_{n-1}^{(2)}(k_{\rho_{m}}\rho_{1}) - \frac{n}{\rho_{1}}H_{n}^{(2)}(k_{\rho_{m}}\rho_{1})\right)}H_{n}^{(2)}(k_{\rho_{m}}\rho) = C_{1}\left(H_{n}^{(1)}(k_{\rho_{m}}\rho) - \frac{\left(k_{\rho_{m}}H_{n-1}^{(1)}(k_{\rho_{m}}\rho_{1}) - \frac{n}{\rho_{1}}H_{n}^{(1)}(k_{\rho_{m}}\rho_{1})\right)}{\left(k_{\rho_{m}}H_{n-1}^{(2)}(k_{\rho_{m}}\rho_{1}) - \frac{n}{\rho_{1}}H_{n}^{(2)}(k_{\rho_{m}}\rho_{1})\right)}H_{n}^{(2)}(k_{\rho_{m}}\rho)\right).$$

$$(4-48)$$

# 4.2.2 Deriving $\Phi_z(\phi)$ of $H_z$ in Region I

Deriving  $\Phi_z(\phi)$  H<sub>z</sub> follows the same process as E<sub>z</sub>. Both terms can be combined within a summation forming

$$\sum_{n=-\infty}^{\infty} B_n e^{jn\varphi}.$$
 (4-49)

# 4.2.3 Deriving $Z_z(z)$ of $H_z$ in Region I

The last term for H<sub>z</sub>, Z<sub>z</sub>(z), will require a boundary condition in order for it to be simplified. Z<sub>z</sub>(z) is found to have a relationship with  $E_{\varphi} \sim Z_z(z)$ , and  $E_{\varphi}$  is equal to zero at the boundary where z=±a/2. This boundary condition will be sufficient to simplify Z<sub>z</sub>(z). First, the relationship of  $E_{\varphi} \sim Z_z(z)$  needs to be established by using the definitions of  $E_{\rho}$  from equation (4-39) and

$$H_{\varphi} = \frac{1}{k_{\rho_m}^2 \rho} \frac{\partial^2 H_z}{\partial \varphi \partial z} \tag{4-50}$$

which is an alternate form of a FEGW as described in [14, p. 202].  $E_{\rho}$  and  $H_{\varphi}$  can be related as

$$\frac{\partial E_{\rho}}{\partial z} = -j\omega\mu H_{\varphi} \tag{4-51}$$

and therefore  $\frac{\partial E_{\rho}}{\partial z} \sim \frac{\partial H_z}{\partial z}$  and  $E_{\rho} \sim H_z$ .

Now  $Z_z(z)$ , which takes the form of equation (4-17), can be equated to zero at the prescribed boundary condition yielding

$$A_{3}\cos k_{z}z + B_{3}\sin k_{z}z = 0 = \begin{cases} A_{3}\cos\left(k_{z}\frac{a}{2}\right) + B_{3}\sin\left(k_{z}\frac{a}{2}\right) = 0 & , \quad z = \frac{a}{2} \\ A_{3}\cos\left(-k_{z}\frac{a}{2}\right) + B_{3}\sin\left(-k_{z}\frac{a}{2}\right) = 0 & , \quad z = -\frac{a}{2} \end{cases}$$
(4-52)

which can now be solved for  $A_3$  in the form

$$A_3 = \frac{-B_3 \sin\left(k_z \frac{a}{2}\right)}{\cos\left(k_z \frac{a}{2}\right)}, z = \frac{a}{2}.$$
 (4-53)

Plugging A<sub>3</sub> back into  $Z_z(z)$  yields

$$Z_{z}(z) = \frac{-B_{3}\sin(k_{z}\frac{a}{2})}{\cos(k_{z}\frac{a}{2})}\cos k_{z}z + B_{3}\sin k_{z}z = B_{3}\left(\sin k_{z}z - \frac{\sin(k_{z}\frac{a}{2})}{\cos(k_{z}\frac{a}{2})}\cos k_{z}z\right).$$
(4-54)

Since  $k_z$  is anticipated to be a constant as was in the derivation for  $E_z$ , a new constant

 $B'_3 = B_3 / \sin k_z \frac{a}{2}$  can be defined and plugged back into  $Z_z(z)$  equation giving

$$Z_{z}(z) = B'_{3}\left(\cos\left(k_{z}\frac{a}{2}\right)\sin k_{z}z - \sin\left(k_{z}\frac{a}{2}\right)\cos k_{z}z\right).$$

$$(4-55)$$

The trigonometric identity

$$\sin(x - y) = (\sin x \cos y - \cos x \sin y) \tag{4-56}$$

is then used to simplify the  $Z_z(z)$  to give the form

$$Z_{z}(z) = B'_{3} \sin\left(k_{z} z - k_{z} \frac{a}{2}\right) = B'_{3} \sin k_{z} \left(z - \frac{a}{2}\right)$$
(4-57)

and since  $k_z = k_{z_m}$ 

$$Z_{z}(z) = B'_{3} \sin k_{Z_{m}} \left( z - \frac{a}{2} \right).$$
(4-58)

# 4.2.4 Deriving TE<sub>z</sub> Mode Equations for Region I

The subcomponents for  $H_z$  have been defined and are combined as

$$H_{z}^{I} = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \left( B_{nm} \sin k_{Z_{m}} \left( z - \frac{a}{2} \right) \right) \left( H_{n}^{(1)} (k_{\rho_{m}} \rho) - \frac{k_{\rho_{m}} H_{n-1}^{(1)} (k_{\rho_{m}} \rho_{1}) - \frac{n}{\rho_{1}} H_{n}^{(1)} (k_{\rho_{m}} \rho_{1})}{k_{\rho_{m}} H_{n-1}^{(2)} (k_{\rho_{m}} \rho_{1}) - \frac{n}{\rho_{1}} H_{n}^{(2)} (k_{\rho_{m}} \rho_{1})} H_{n}^{(2)} (k_{\rho_{m}} \rho) \right)$$

$$(4-59)$$

within summation form. Just as in the  $TM_z$  mode,  $B_{nm}$  is the combined coefficients and

$$k_z = k_{z_m}, k_\rho = k_{\rho_m} \text{ and } k_{\rho_m} = \sqrt{k^2 - k_{Z_m}^2}.$$

Following the same steps as in the  $TM_z$  mode,  $H_z$  is plugged into the modified FEGWs given by equations (4-39) through (4-42) to yield

$$-\frac{n}{\rho}H_{n}^{(1)}(k_{\rho_{m}}\rho)\right) - \frac{k_{\rho_{m}}H_{n-1}^{(1)}(k_{\rho_{m}}\rho_{1}) - \frac{n}{\rho_{1}}H_{n}^{(1)}(k_{\rho_{m}}\rho_{1})}{k_{\rho_{m}}H_{n-1}^{(2)}(k_{\rho_{m}}\rho_{1}) - \frac{n}{\rho_{1}}H_{n}^{(2)}(k_{\rho_{m}}\rho_{1})}\left(k_{\rho_{m}}H_{n-1}^{(2)}(k_{\rho_{m}}\rho) - \frac{n}{\rho}H_{n}^{(2)}(k_{\rho_{m}}\rho)\right)\right)$$

$$(4-62)$$

$$H_{\varphi_{-}TE}^{I} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{Zm}}{k_{\rhom}^{2}} \left( B_{nm} \sin k_{Zm} \left( z - \frac{a}{2} \right) \right) \left( H_{n}^{(1)} \left( k_{\rho_{m}} \rho \right) - \frac{k_{\rhom} H_{n-1}^{(1)} \left( k_{\rho_{m}} \rho_{1} \right) - \frac{n}{\rho_{1}} H_{n}^{(1)} \left( k_{\rho_{m}} \rho_{1} \right)}{k_{\rho_{m}} H_{n-1}^{(2)} \left( k_{\rho_{m}} \rho_{1} \right) - \frac{n}{\rho_{1}} H_{n}^{(2)} \left( k_{\rho_{m}} \rho_{1} \right)} H_{n}^{(2)} \left( k_{\rho_{m}} \rho \right) \right) .$$

$$(4-63)$$

#### CHAPTER 5 REGION II – SCATTERED FIELD EQUATIONS

This chapter will focus on the derivation of the scattered field in region II. This is the same region in which the incident fields were described in Chapter 3. By the end of this chapter, all the fields in region II would will be covered.

According to [12, p. 615], a perfectly smooth cylinder that is infinitely long and a PEC does not depolarize an incident wave. Balanis continues on to describe that deviations from this can cause depolarization of the incident wave [12, p. 615]. Though not explicitly stated by Balanis, his statement can be interpreted to be applied to that of the periodic corrugated cylinder which would depolarize an incident plane wave. Therefore, as stated in section 2.3, a hybrid mode of TM<sub>z</sub> and TE<sub>z</sub> can exist for the periodic corrugated cylinder and will be examined as such. The field equations for the TM<sub>z</sub> and TE<sub>z</sub> modes will be derived separately, but through the principle of superposition will be combined in Chapter 5 when finding solutions for the fields.

When deriving the field equations for the scattered field, the FEGWs presented in Chapter 4, equations (4-1) through (4-4), will be made much use of. Also from Chapter 4, deriving the  $E_z$  and  $H_z$  scattered fields will use the same Helmholtz equation representation from (4-10) and (4-43) respectively, as well as the same coordinate constituent separable equations from (4-11) and (4-44) respectively. Use of the known solutions for the Helmholtz equation described in equations (4-12) through (4-14) will also be made in this chapter. 5.1 Equations for the TM<sub>z</sub> Mode Scattered Field of Region II

The steps to derive the equations representing the  $TM_z$  mode of the scattered field in region II will be the same as that for the  $TM_z$  mode in region I. This starts with choosing the appropriate field representation from equations (4-12) through (4-14) based on geometry and expected behavior in order to describe  $E_z$ . Since there are no restrictive boundaries in region II, the traveling wave representation is chosen for each constituent and replaced into (4-11) to give

$$E_{z} = \left(C_{1}H_{n}^{(1)}(k_{\rho}\rho) + D_{1}H_{n}^{(2)}(k_{\rho}\rho)\right)\left(C_{2}e^{-jn\varphi} + D_{2}e^{+jn\varphi}\right)\left(C_{3}e^{-jk_{z}z} + C_{3}e^{jk_{z}z}\right).$$
(5-1)

Now, the first and second term of Ez, which make up  $R_z(\rho)$  represent inward and outward traveling waves respectively. Since at the boundary of region II, whether with the conductive surface or with region I, there is no scattered field expected, the inward traveling wave portion (the first term) can be eliminated leaving

$$E_{z} = D_{1}H_{n}^{(2)}(k_{\rho}\rho)(C_{2}e^{-jn\varphi} + D_{2}e^{+jn\varphi})(C_{3}e^{-jk_{z}z} + C_{3}e^{jk_{z}z}).$$
(5-2)

This equation can be further simplified by bringing it into summation terms as was done in Chapter 4 yielding

$$E_{z^{II}}^{s} = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} C_{nl} e^{-jk_{z_{l}}z} H_{n}^{(2)}(k_{\rho_{l}}\rho) .$$
(5-3)

Note that axial wavenumber  $k_z$  has been replaced by  $k_{z_l}$  and radial wavenumber  $k_\rho$  has been replaced by  $k_{\rho_l}$ , where  $k_{\rho_l} = \sqrt{k^2 - k_{z_l}^2}$ . Here, the sub-subscript 'l' identifies the propagating mode for region II in the same way 'm' is for region I. To understand the relationship of the propagating mode with the geometry, a derivation of  $k_{z_l}$ , is required. This is due to the fact that a propagating wave interfacing with a structure, in this case the scattered field with the periodic corrugated cylinder, takes on the symmetry of said structure as depicted in Figure 5-1. This  $k_{z_l}$  is known as the Floquet harmonic or Floquet

wavenumber [9, p. 265] or a Bloch wavenumber [15] because of the non-uniqueness and ability to represent a periodic medium.



Figure 5-1 A depiction of the vector decomposition of the wavenumber in region II



Figure 5-2 A depiction of constructive interference for a propagating wave along a periodic surface

First, for wave modes to exist, a constructive interference relationship needs to be established along the path of propagation. This is how wave modes are established within waveguides and periodic structures. It can be seen from Figure 5-2 that an integer

multiple 'l' to the wavelength ' $\lambda$ ' would provide a description of the propagating modes along the prescribed surface where constructive interface would occur. Also, the relationship

$$l\lambda = (a+b)\sin\theta^i \tag{5-4}$$

is established. The relationship for the scattered field wave vector

$$\vec{k}^s = -\hat{z}\,k\,\cos\theta^s + \hat{x}\,k\,\sin\theta^s \tag{5-5}$$

is established from Figure 5-1 where the magnitude of  $\vec{k}^s$ , which will be referred to as

 $k_{z_l}$ , the axial wavenumber in region II, is

$$k_{z_i} = k\cos\theta^i + k\sin\theta^i. \tag{5-6}$$

when substituting in the relationship of  $\theta^s = \pi - \theta^i$  as per [12, p. 615]. Substituting in the definition  $k = \frac{2\pi}{\lambda}$  for the second term yields

$$k_{z_l} = k \cos \theta^i + \frac{2\pi}{\lambda} \sin \theta^i$$
 (5-7)

which can further be reduced by using equation (5-4) to give

$$\frac{l\lambda}{(a+b)} = \sin\theta^i \tag{5-8}$$

$$k_{z_l} = k\cos\theta^i + \frac{2\pi}{\lambda}\frac{l\lambda}{(a+b)} = k\cos\theta^i + \frac{2\pi l}{(a+b)}$$
(5-9)

which completes the derivation for  $k_{z_l}$ . This also completes the definition for  $E_{z_l}^s$ .

Next, the remaining  $TM_z$  mode scattered field equations are derived. This is done by substituting  $E_{z^{II}}^{s}$  into equations (4-6) through (4-9) to produce

$$E_{\rho_{-}TM^{II}}^{s} = -j\sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_{l}}}{k_{\rho_{l}}^{2}} C_{nl} e^{-jk_{z_{l}}z} \left( k_{\rho_{l}} H_{n-1}^{(2)}(k_{\rho_{l}}\rho) - \frac{nH_{n}^{(2)}(k_{\rho_{l}}\rho)}{\rho} \right)$$
(5-10)

$$E_{\varphi_{-}TM^{II}}^{s} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_{l}}}{k_{\rho_{l}}^{2}} C_{nl} e^{-jk_{z_{l}}z} H_{n}^{(2)}(k_{\rho_{l}}\rho)$$
(5-11)

$$H^{s}_{\rho_{-TM}II} = -\frac{\omega\varepsilon}{\rho} \sum_{n=-\infty}^{\infty} ne^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_{l}}^{2}} C_{nl} e^{-jk_{z_{l}}z} H^{(2)}_{n} \left(k_{\rho_{l}}\rho\right)$$
(5-12)

$$H_{\varphi_{-TM}II}^{s} = -j\omega\varepsilon\sum_{n=-\infty}^{\infty}e^{jn\varphi}\sum_{l=-\infty}^{\infty}\frac{1}{k_{\rho_{l}}^{2}}C_{nl}e^{-jk_{z_{l}}z}\left(k_{\rho_{l}}H_{n-1}^{(2)}(k_{\rho_{l}}\rho) - \frac{nH_{n}^{(2)}(k_{\rho_{l}}\rho)}{\rho}\right).$$
 (5-13)

# 5.2 Equations for the TE<sub>z</sub> Mode Scattered Field of Region II

For the TE<sub>z</sub> mode,  $H_z$  is derived much the same way as was in the TE<sub>z</sub> mode in region I. Once applying the same assumptions from the geometry and expected field behavior described in section 5.1 for the TM<sub>z</sub> mode case, onto the equations (4-12) through (4-14) and to equation (4-44),  $H_z$  is defined as

$$H_{z^{II}}^{s} = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} D_{nl} e^{-jk_{z_{l}}z} H_{n}^{(2)}(k_{\rho_{l}}\rho) .$$
(5-14)

where  $D_{nl}$  represents the combined coefficients and  $k_{z_l}$  and  $k_{\rho_l}$  are the axial and radial wavenumbers defined in section 5.1 respectively.

Now with a fully defined  $H_{z^{II}}^{s}$ , the remaining equations can be found by plugging  $H_{z^{II}}^{s}$ into equations (4-39) through (4-42) to yield

$$E_{\rho_{-}TE^{II}}^{s} = -j\omega\mu * j\sum_{n=-\infty}^{\infty} ne^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_{l}}^{2}\rho} D_{nl} e^{-jk_{z_{l}}z} H_{n}^{(2)}(k_{\rho_{l}}\rho)$$
(5-15)

$$E_{\varphi_{-}TE^{II}}^{s} = j\omega\mu \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_{l}}^{2}} D_{nl} e^{-jk_{z_{l}}z} \left( k_{\rho_{l}} H_{n-1}^{(2)}(k_{\rho_{l}}\rho) - \frac{nH_{n}^{(2)}(k_{\rho_{l}}\rho)}{\rho} \right)$$
(5-16)

$$H_{\rho_{-}TE^{II}}^{s} = -j \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_{l}}}{k_{\rho_{l}}^{2}} D_{nl} e^{-jk_{z_{l}}z} \left( k_{\rho_{l}} H_{n-1}^{(2)}(k_{\rho_{l}}\rho) - \frac{nH_{n}^{(2)}(k_{\rho_{l}}\rho)}{\rho} \right)$$
(5-17)

$$H_{\varphi_{-}TE^{II}}^{s} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_{l}}}{k_{\rho_{l}}^{2}} D_{nl} e^{-jk_{z_{l}}z} H_{n}^{(2)}(k_{\rho_{l}}\rho) .$$
(5-18)

#### CHAPTER 6 BOUNDARY CONDITIONS & POINT MATCHING METHOD

At this point, the equations for region I and region II have been defined. However, the equations for region I and the scattered field equations for region II have unknown coefficients that need to be solved for in order to have a complete representation, and therefore to be able to calculate and predict the scattered field. In order to achieve this, boundary conditions need to be established to provide equation sets that allow for algebraic solving of the unknown coefficients. The equation relationships are established by point matching, equating points from different equations, that establishes an equal number of point matches to unknowns.

## 6.1 General Boundary Conditions

There are two main boundary regions that are utilized in this paper for point matching, as can be observed from Figure 6-1, which are boundary 'a' and boundary 'b'. **Boundary 'a':** 

- □ Boundary between region I and II at  $\rho = \rho_2$  for a z range of  $\frac{-a}{2} \le z \le \frac{a}{2}$ .
- □ The available matching points,  $p_j(\rho, \varphi, z)$ , of a quantity 'j' are:  $\rho = \rho_2, \frac{-a}{2} \le z \le \frac{a}{2}$  and  $0 \le \varphi \le 2\pi$ .
- □ Tangential electric fields from region II,  $E_z^{II}$  and  $E_{\varphi}^{II}$ , are equal to tangential electric fields from region I,  $E_z^{I}$  and  $E_{\varphi}^{I}$ , hence  $E_z^{II} = E_z^{I}$  and  $E_{\varphi}^{II} = E_{\varphi}^{I}$  [16, p. 178].
- □ Tangential magnetic fields from region II,  $H_z^{II}$  and  $H_{\varphi}^{II}$ , are equal to tangential magnetic fields from region I,  $H_z^{I}$  and  $H_{\varphi}^{I}$ , hence  $H_z^{II} = H_z^{I}$  and  $H_{\varphi}^{II} = H_{\varphi}^{I}$  when the

conductivity is finite, hence, not a PEC which is the case at this boundary [16, p. 234].

- $\hfill\square$  Used to solve for the unknown expansion coefficients  $A_{nm}$  and  $B_{nm}$  from region I.
- Used to solve for the unknown expansion coefficients  $C_{nl}$  and  $D_{nl}$  from region II, which are distinct for each boundary, therefore these will have superscript of (a) to identify them:  $C_{nl}^{(a)}$  and  $D_{nl}^{(a)}$ .

# **Boundary 'b':**

- □ Boundary between region II and outer conducting surface of corrugated cylinder at  $\rho = \rho_2$  for a z range of  $\frac{a}{2} \le z \le \frac{a}{2} + b$ .
- □ The available matching points,  $p_j(\rho, \varphi, z)$ , of a quantity 'j' are:  $\rho = \rho_2, \frac{a}{2} \le z \le \frac{a}{2} + b$  and  $0 \le \varphi \le 2\pi$ .
- □ Tangential electric fields from region II are equal to zero based on the Dirichlet boundary condition [9, pp. 97-100]:  $E_z^{II} = 0$  and  $E_{\phi}^{II} = 0$ .
- $\Box$  Used to solve for the unknown expansion coefficients  $C_{nl}$  and  $D_{nl}$  from region II, which are distinct and will have superscript (b) to identify them,  $C_{nl}^{(b)}$  and  $D_{nl}^{(b)}$ .



Figure 6-1 A depiction for the general boundary conditions utilized to solve for the unknown coefficients

## 6.2 Matrix Form of Field Equations

In order to effectively apply the boundary conditions and to solve for the unknown expansion coefficients, the field equations described in Chapter 3, Chapter 4 and Chapter 5 will be represented in matrix form. This will aid in the algebraic manipulation and solving of the coefficients.

There are a few things to note about the matrix form and indices. The expansion coefficients of each region need to have the same shape as each other for point matching, therefore the  $n \times m$  size matrices of region I need to match the  $n \times l$  matrices of region II. This is accomplished by making "n" of each region equal to each other and having "m" of region I equal to "l" of region II.

The matrices that contain a subscript "j" indicate that there are z's and  $\varphi$ 's referenced in them, where  $\rho$  is always  $\rho_2$  for point matches. Each "j" is a matching point,

which is provided by z's and  $\varphi$ 's variation on the specified boundary with a fixed  $\rho_2$  and z range indicated. The number of matching points, which is the number of "j" points, is equal to n \* m or n \* l, thus there's a matching point for every expanded "n" and "m" or "n" and "l". Also, the number of equation matches equals the number of expansion coefficients. The number of matching points times the number of equation matches equals the total number of unknown expanded coefficients which provides a complete system of equations.

In order to separate the coefficients from the rest of the terms for each equation, the matrices of the unknown expansion coefficients are flattened into an array of a single column with n \* m or n \* l rows and the remainder of the term can stay in a matrix form of "j" rows and n \* m or n \* l columns. When multiplied back together, it produces the summation equation. The incident fields are also "j" rows, but of a single column of which each entry is a full summation solution.

## 6.2.1 Matrix form of Region I Equations

The following are the matrix form of the subcomponents of the region I equations described in Chapter 4. The equations listed below capture the fields  $E_z^I$ ,  $H_z^I$ ,  $E_{\varphi}^I$ ,  $H_{\varphi}^I$ ,  $E_{\rho}^I$  and  $H_{\rho}^{I}$  in matrix form. For each equation in the list, the corresponding matrix form in which it's used is provided. Also, the equation's substituted form is identified and located within the matrix form through the use of highlighting and bolding the font.

$$\begin{bmatrix} h_{nmj} \end{bmatrix} = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \left( \cos k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( H_n^{(1)} (k_{\rho_m} \rho) - \frac{H_n^{(1)} (k_{\rho_m} \rho_1)}{H_n^{(2)} (k_{\rho_m} \rho_1)} H_n^{(2)} (k_{\rho_m} \rho) \right)$$

$$\leftarrow From E_z^I = \begin{bmatrix} h_{nmj} \end{bmatrix} [A_{nm}]$$

$$(6-1)$$

$$[i_{nmj}] = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \left( \sin k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( H_n^{(1)}(k_{\rho_m} \rho) - \frac{1}{\rho_1} H_n^{(1)}(k_{\rho_m} \rho_1)} H_n^{(2)}(k_{\rho_m} \rho) \right) \leftarrow From H_n^l = [i_{mml}] [B_{nm}]$$

$$(6-2)$$

$$\frac{k_{\rho_m}H_{n-1}^{(1)}(k_{\rho_m}\rho_1) - \frac{n}{\rho_1}H_n^{(1)}(k_{\rho_m}\rho_1)}{k_{\rho_m}H_{n-1}^{(2)}(k_{\rho_m}\rho_1) - \frac{n}{\rho_1}H_n^{(2)}(k_{\rho_m}\rho_1)}H_n^{(2)}(k_{\rho_m}\rho)\right) \leftarrow From H_z^I = \begin{bmatrix} i_{nmj} \end{bmatrix} [B_{nm}]$$

$$\begin{bmatrix} k_{nmj} \end{bmatrix} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{Zm}}{k_{\rho_m}^2} \left( \cos k_{Zm} \left( z - \frac{a}{2} \right) \right) \left( H_n^{(1)} \left( k_{\rho_m} \rho \right) - \frac{H_n^{(1)}(k_{\rho_m} \rho_1)}{H_n^{(2)}(k_{\rho_m} \rho_1)} H_n^{(2)} \left( k_{\rho_m} \rho \right) \right) \leftarrow From E_{\varphi}^I = \begin{bmatrix} k_{nmj} \end{bmatrix} [A_{nm}] + \begin{bmatrix} l_{nmj} \end{bmatrix} [B_{nm}]$$

$$(6-3)$$

$$\begin{bmatrix} l_{nmj} \end{bmatrix} = j\omega\mu\sum_{n=-\infty}^{\infty} e^{jn\varphi}\sum_{m=-\infty}^{\infty} \frac{1}{k_{\rho_m}^2} \left(\sin k_{Z_m} \left(z - \frac{a}{2}\right)\right) \left(\left(k_{\rho_m} H_{n-1}^{(1)}(k_{\rho_m}\rho) - \frac{n}{2}H_{n-1}^{(1)}(k_{\rho_m}\rho_1) - \frac{n}{2}H_{n-1}^{(1)}(k_{\rho_m}\rho_1)}{k_{\rho_m} H_{n-1}^{(2)}(k_{\rho_m}\rho_1) - \frac{n}{2}H_{n-1}^{(2)}(k_{\rho_m}\rho_1)} \left(k_{\rho_m} H_{n-1}^{(2)}(k_{\rho_m}\rho) - \frac{n}{2}H_{n-1}^{(2)}(k_{\rho_m}\rho)\right)\right) \leftarrow From E_{\varphi}^{l} = \begin{bmatrix} k_{nmj} \end{bmatrix} [A_{nm}] + \begin{bmatrix} l_{nmj} \end{bmatrix} [B_{nm}]$$

$$\begin{bmatrix} o_{nmj} \end{bmatrix} = -j\omega\varepsilon \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{1}{k_{\rho_m}^2} \left( \cos k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( \left( k_{\rho_m} H_{n-1}^{(1)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(1)}(k_{\rho_m} \rho) \right) - \frac{H_n^{(1)}(k_{\rho_m} \rho_1)}{H_n^{(2)}(k_{\rho_m} \rho_1)} \left( k_{\rho_m} H_{n-1}^{(2)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(2)}(k_{\rho_m} \rho) \right) \right) \leftarrow From H_{\varphi}^l =$$

$$\begin{bmatrix} o_{nmj} \end{bmatrix} [A_{nm}] + [p_{nmj}] [B_{nm}]$$

$$(6-5)$$

$$\left[ p_{nmj} \right] = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{z_m}}{k_{\rho_m}^2} \left( \sin k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( H_n^{(1)} \left( k_{\rho_m} \rho \right) - \frac{k_{\rho_m} H_{n-1}^{(1)} \left( k_{\rho_m} \rho_1 \right) - \frac{n}{\rho_1} H_n^{(1)} \left( k_{\rho_m} \rho_1 \right)}{k_{\rho_m} H_{n-1}^{(2)} \left( k_{\rho_m} \rho_1 \right) - \frac{n}{\rho_1} H_n^{(2)} \left( k_{\rho_m} \rho_1 \right)} H_n^{(2)} \left( k_{\rho_m} \rho \right) \right) \leftarrow From H_{\varphi}^{I} = \left[ o_{nmj} \right] \left[ A_{nm} \right] + \left[ p_{nmj} \right] \left[ B_{nm} \right]$$

$$[r_{nmj}] = -j \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{zm}}{k_{\rhom}^2} \left( \cos k_{Zm} \left( z - \frac{a}{2} \right) \right) \left( \left( k_{\rho_m} H_{n-1}^{(1)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(1)}(k_{\rho_m} \rho) \right) - \frac{H_n^{(1)}(k_{\rho_m} \rho_1)}{H_n^{(2)}(k_{\rho_m} \rho_1)} \left( k_{\rho_m} H_{n-1}^{(2)}(k_{\rho_m} \rho) - \frac{n}{\rho} H_n^{(2)}(k_{\rho_m} \rho) \right) \right) \leftarrow From E_{\rho}^{I} = [r_{nmj}] [A_{nm}] + [s_{nmj}] [B_{nm}]$$

$$(6-7)$$

$$\begin{bmatrix} s_{nmj} \end{bmatrix} = \frac{\omega\mu}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{1}{k_{\rho_m}^2} \left( \sin k_{Z_m} \left( z - \frac{a}{2} \right) \right) \left( H_n^{(1)} \left( k_{\rho_m} \rho \right) - \frac{k_{\rho_m} H_{n-1}^{(1)} \left( k_{\rho_m} \rho_1 \right) - \frac{n}{\rho_1} H_n^{(1)} \left( k_{\rho_m} \rho_1 \right)}{k_{\rho_m} H_{n-1}^{(2)} \left( k_{\rho_m} \rho_1 \right) - \frac{n}{\rho_1} H_n^{(2)} \left( k_{\rho_m} \rho_1 \right)} H_n^{(2)} \left( k_{\rho_m} \rho \right) \right) \leftarrow From E_{\rho}^I = \begin{bmatrix} r_{nmj} \end{bmatrix} [A_{nm}] + \begin{bmatrix} s_{nmj} \end{bmatrix} [B_{nm}]$$
(6-8)

$$\begin{bmatrix} t_{nmj} \end{bmatrix} = -\frac{\omega\varepsilon}{\rho} \sum_{n=-\infty}^{\infty} ne^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{1}{k_{\rho m}^{2}} \Big( \cos k_{Z_{m}} \left( z - \frac{a}{2} \right) \Big) \Big( H_{n}^{(1)}(k_{\rho_{m}}\rho) - \frac{H_{n}^{(1)}(k_{\rho_{m}}\rho_{1})}{H_{n}^{(2)}(k_{\rho_{m}}\rho_{1})} H_{n}^{(2)}(k_{\rho_{m}}\rho) \Big) \leftarrow From H_{\rho}^{I} = \begin{bmatrix} t_{nmj} \end{bmatrix} [A_{nm}] + \begin{bmatrix} u_{nmj} \end{bmatrix} [B_{nm}]$$

$$\begin{bmatrix} u_{nmj} \end{bmatrix} = -j \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{m=-\infty}^{\infty} \frac{k_{Z_{m}}}{k_{\rho m}^{2}} \Big( \sin k_{Z_{m}} \left( z - \frac{a}{2} \right) \Big) \left( \left( k_{\rho_{m}} H_{n-1}^{(1)}(k_{\rho_{m}}\rho) - \frac{n}{\rho} H_{n}^{(1)}(k_{\rho_{m}}\rho) - \frac{n}{\rho} H_{n}^{(1)}(k_{\rho_{m}}\rho) - \frac{n}{\rho} H_{n}^{(2)}(k_{\rho_{m}}\rho) - \frac{n}{\rho} H_{n}^{(2)}(k_{\rho_{m}}\rho) - \frac{n}{\rho} H_{n}^{(2)}(k_{\rho_{m}}\rho) \Big) \right) \right) \leftarrow From H_{\rho}^{I} = \begin{bmatrix} t_{nmj} \end{bmatrix} [A_{nm}] + \begin{bmatrix} u_{nmj} \end{bmatrix} [B_{nm}]$$

$$(6-10)$$

The TM<sub>z</sub> mode region I field expansion coefficient is represented by  $[A_{nm}]$  and the TE<sub>z</sub> mode region I field expansion coefficient is represented by  $[B_{nm}]$ . The remaining are region I field components of the respective mode to the coefficient it's a product with. 6.2.2 Matrix form of Region II Equations

The following are the matrix form of the subcomponents of the region II equations described in Chapter 3 and Chapter 5. This includes the superposition of all the region II fields within the same coordinate axis, including  $TM_z$  and  $TE_z$  modes for both the scattered and incident field. Hence, the total field for each axis is summarized as

$$E_z^{II} = E_{z^{II}}^i + E_{z\_TM}^s$$
(6-11)

$$E_{\rho}^{II} = E_{\rho^{II}}^{i} + E_{\rho_{-}TM^{II}}^{s} + E_{\rho_{-}TE^{II}}^{s}$$
(6-12)

$$E_{\varphi}^{II} = E_{\varphi^{II}}^{i} + E_{\varphi_{-TM}^{II}}^{s} + E_{\varphi_{-TE}^{II}}^{s}$$
(6-13)

$$H_{z}^{II} = H_{z^{II}}^{i} + H_{z_{z}TE^{II}}^{s}$$
(6-14)

$$H_{\rho}^{II} = H_{\rho^{II}}^{i} + H_{\rho_{-TM}^{II}}^{s} + H_{\rho_{-TE}^{II}}^{s}$$
(6-15)

$$H_{\varphi}^{II} = H_{\varphi^{II}}^{i} + H_{\varphi_{-}TM^{II}}^{s} + H_{\varphi_{-}TE^{II}}^{s}$$
(6-16)

Below are the field components of  $E_z^{II}$ ,  $H_z^{II}$ ,  $E_{\varphi}^{II}$ ,  $H_{\varphi}^{II}$ ,  $E_{\rho}^{II}$  and  $H_{\rho}^{II}$  in matrix form. Just as in section 6.2.1, the equation's substituted form is identified and located within the matrix form through the use of highlighting and bolding the font.

$$\begin{bmatrix} b_{nj} \end{bmatrix} = E_0 \sin \theta^i e^{jkz \cos \theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho \sin \theta^i) e^{jn\varphi} \leftarrow From E_z^{II} = \begin{bmatrix} b_{nj} \end{bmatrix} + \begin{bmatrix} a_{nl} \end{bmatrix} \begin{bmatrix} C_{nl} \end{bmatrix}$$
(6-17)

$$\left[a_{nlj}\right] = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} e^{-jk_{zl}z} H_n^{(2)}\left(k_{\rho_l}\rho\right) \leftarrow From E_z^{II} = \left[b_{nj}\right] + \left[a_{nl}\right]\left[C_{nl}\right]$$
(6-18)

$$\left[f_{nj}\right] = H_0 \sin \theta^i \, e^{jkz \cos \theta^i} \, \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho \sin \theta^i) e^{jn\varphi} \leftarrow From \, H_z^{II} = \left[f_{nj}\right] + \left[g_{nl}\right] \left[D_{nl}\right] \tag{6-19}$$

$$\left[g_{nlj}\right] = \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} e^{-jk_{z_l}z} H_n^{(2)}\left(k_{\rho_l}\rho\right) \leftarrow From H_z^{II} = \left[f_{nj}\right] + \left[g_{nlj}\right]\left[D_{nl}\right]$$
(6-20)

$$\begin{bmatrix} d_{nj} \end{bmatrix} = \begin{bmatrix} -E_0 \sin \varphi \cos \theta^i + ZH_0 \cos \varphi \end{bmatrix} e^{jkz \cos \theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho \sin \theta^i) e^{jn\varphi} \leftarrow From$$
$$E_{\varphi}^{II} = \begin{bmatrix} d_{nj} \end{bmatrix} + \left( \begin{bmatrix} c_{nlj} \end{bmatrix} \begin{bmatrix} C_{nl} \end{bmatrix} + \begin{bmatrix} e_{nlj} \end{bmatrix} \begin{bmatrix} D_{nl} \end{bmatrix} \right)$$
(6-21)

$$\begin{bmatrix} c_{nlj} \end{bmatrix} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_l}}{k_{\rho_l}^2} e^{-jk_{z_l}z} H_n^{(2)}(k_{\rho_l}\rho) \leftarrow From E_{\varphi}^{II} = \begin{bmatrix} d_{nj} \end{bmatrix} + \\ \left( \begin{bmatrix} c_{nlj} \end{bmatrix} [C_{nl}] + \begin{bmatrix} e_{nlj} \end{bmatrix} [D_{nl}] \right)$$
 (6-22)

$$[e_{nlj}] = j\omega\mu \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_l}^2} e^{-jk_{z_l}z} \left( k_{\rho_l} H_{n-1}^{(2)}(k_{\rho_l}\rho) - \frac{nH_n^{(2)}(k_{\rho_l}\rho)}{\rho} \right) \leftarrow From E_{\varphi}^{II} =$$

$$[d_{nj}] + \left( [c_{nlj}] [C_{nl}] + [e_{nlj}] [D_{nl}] \right)$$

$$(6-23)$$

$$\begin{bmatrix} m_{nj} \end{bmatrix} = \begin{bmatrix} -\frac{E_0}{Z} \cos \varphi - H_0 \sin \varphi \cos \theta^i \end{bmatrix} e^{jkz \cos \theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho \sin \theta^i) e^{jn\varphi} \leftarrow From$$

$$H_{\varphi}^{II} = \begin{bmatrix} m_{nj} \end{bmatrix} + \left( [n_{nlj}] [C_{nl}] + [q_{nlj}] [D_{nl}] \right)$$
(6-24)

$$\begin{bmatrix} n_{nlj} \end{bmatrix} = -j\omega\varepsilon \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_l}^2} e^{-jk_{z_l}z} \left( k_{\rho_l} H_{n-1}^{(2)}(k_{\rho_l}\rho) - \frac{nH_n^{(2)}(k_{\rho_l}\rho)}{\rho} \right) \leftarrow From H_{\varphi}^{II} =$$

$$\begin{bmatrix} m_{nj} \end{bmatrix} + \left( \begin{bmatrix} n_{nlj} \end{bmatrix} [C_{nl}] + \begin{bmatrix} q_{nlj} \end{bmatrix} [D_{nl}] \right)$$

$$\begin{bmatrix} q_{nlj} \end{bmatrix} = \frac{1}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_l}}{k_{\rho_l}^2} e^{-jk_{z_l}z} H_n^{(2)}(k_{\rho_l}\rho) \leftarrow From H_{\varphi}^{II} = \begin{bmatrix} m_{nj} \end{bmatrix} + \\ (\begin{bmatrix} n_{nlj} \end{bmatrix} \begin{bmatrix} C_{nl} \end{bmatrix} + \begin{bmatrix} q_{nlj} \end{bmatrix} \begin{bmatrix} D_{nl} \end{bmatrix})$$
 (6-26)

$$\begin{bmatrix} \gamma_{nj} \end{bmatrix} = \begin{bmatrix} E_0 \cos \varphi \cos \theta^i + ZH_0 \sin \varphi \end{bmatrix} e^{jkz \cos \theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho \sin \theta^i) e^{jn\varphi} \leftarrow From$$

$$E_{\rho}^{II} = \begin{bmatrix} \gamma_{nj} \end{bmatrix} + \left( \begin{bmatrix} v_{nlj} \end{bmatrix} \begin{bmatrix} C_{nl} \end{bmatrix} + \begin{bmatrix} w_{nlj} \end{bmatrix} \begin{bmatrix} D_{nl} \end{bmatrix} \right)$$

$$(6-27)$$

$$\begin{bmatrix} v_{nlj} \end{bmatrix} = -j \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_l}}{k_{\rho_l}^2} e^{-jk_{z_l}z} \left( k_{\rho_l} H_{n-1}^{(2)}(k_{\rho_l} \rho) - \frac{nH_n^{(2)}(k_{\rho_l} \rho)}{\rho} \right) \leftarrow From E_{\rho}^{II} =$$

$$\begin{bmatrix} \gamma_{nj} \end{bmatrix} + \left( \begin{bmatrix} v_{nlj} \end{bmatrix} [C_{nl}] + \begin{bmatrix} w_{nlj} \end{bmatrix} [D_{nl}] \right)$$

$$(6-28)$$

$$\begin{bmatrix} w_{nlj} \end{bmatrix} = \frac{\omega\mu}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_l}^2} e^{-jk_{z_l}z} H_n^{(2)} (k_{\rho_l}\rho) \leftarrow From E_{\rho}^{II} = [\gamma_{nj}] + ([v_{nlj}][C_{nl}] + [w_{nlj}][D_{nl}])$$

$$(6-29)$$

$$\begin{bmatrix} \delta_{nj} \end{bmatrix} = \begin{bmatrix} -\frac{E_0}{Z} \sin \varphi + H_0 \cos \varphi \cos \theta^i \end{bmatrix} e^{jkz \cos \theta^i} \sum_{n=-\infty}^{\infty} j^{-n} J_n(k\rho \sin \theta^i) e^{jn\varphi} \leftarrow From$$

$$H_{\rho}^{II} = \begin{bmatrix} \delta_{nj} \end{bmatrix} + \left( \begin{bmatrix} x_{nlj} \end{bmatrix} \begin{bmatrix} C_{nl} \end{bmatrix} + \begin{bmatrix} y_{nlj} \end{bmatrix} \begin{bmatrix} D_{nl} \end{bmatrix} \right)$$
(6-30)

$$\begin{bmatrix} x_{nlj} \end{bmatrix} = -\frac{\omega\varepsilon}{\rho} \sum_{n=-\infty}^{\infty} n e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{1}{k_{\rho_l}^2} e^{-jk_{z_l}z} H_n^{(2)}(k_{\rho_l}\rho) \leftarrow From H_{\rho}^{II} = [\delta_{nj}] + (\begin{bmatrix} x_{nlj} \end{bmatrix} [C_{nl}] + \begin{bmatrix} y_{nlj} \end{bmatrix} [D_{nl}])$$

$$(6-31)$$

$$\begin{bmatrix} y_{nlj} \end{bmatrix} = -j \sum_{n=-\infty}^{\infty} e^{jn\varphi} \sum_{l=-\infty}^{\infty} \frac{k_{z_l}}{k_{\rho_l}^2} e^{-jk_{z_l}z} \left( k_{\rho_l} H_{n-1}^{(2)}(k_{\rho_l}\rho) - \frac{nH_n^{(2)}(k_{\rho_l}\rho)}{\rho} \right) \leftarrow From H_{\rho}^{II} =$$

$$\begin{bmatrix} \delta_{nj} \end{bmatrix} + \left( \begin{bmatrix} x_{nlj} \end{bmatrix} \begin{bmatrix} C_{nl} \end{bmatrix} + \begin{bmatrix} y_{nlj} \end{bmatrix} \begin{bmatrix} D_{nl} \end{bmatrix} \right)$$

The components  $[b_{nj}]$ ,  $[f_{nj}]$ ,  $[d_{nj}]$ ,  $[m_{nj}]$ ,  $[\gamma_{nj}]$  and  $[\delta_{nj}]$  represent the incident field of the corresponding cylindrical orientation with both TM<sub>z</sub> and TE<sub>z</sub> mode combined. The TM<sub>z</sub> mode scattered field expansion coefficient is represented by  $[C_{nl}]$  and the TE<sub>z</sub> mode scattered field expansion coefficient is represented by  $[D_{nl}]$ . The remaining are scattered field components of the respective mode to the coefficient it's a product with.

# 6.2.3 Matrix Equation Matches for Point Matching

There are 6 unknown expansion coefficients, each of which expand out to either n \* m or n \* l quantities of unknowns. This means that there needs to be at least 6 matrix equation matches in order to solve for the unknowns. Based on the boundary conditions discussed in section 6.1 the following 6 equations will provide a system of equations to solve for the unknowns.

For boundary 'a':

$$[E_z^I] = [E_z^{II(a)}] \to [h_{nmj}][A_{nm}] = [b_{nj}] + [a_{nlj}][C_{nl}^{(a)}]$$
(6-33)

$$\begin{bmatrix} E_{\varphi}^{I} \end{bmatrix} = \begin{bmatrix} E_{\varphi}^{II(b)} \end{bmatrix} \to \begin{bmatrix} k_{nmj} \end{bmatrix} \begin{bmatrix} A_{nm} \end{bmatrix} + \begin{bmatrix} l_{nmj} \end{bmatrix} \begin{bmatrix} B_{nm} \end{bmatrix} = \begin{bmatrix} d_{nj} \end{bmatrix} + \left( \begin{bmatrix} c_{nlj} \end{bmatrix} \begin{bmatrix} C_{nl}^{(a)} \end{bmatrix} + \begin{bmatrix} e_{nlj} \end{bmatrix} \begin{bmatrix} D_{nl}^{(a)} \end{bmatrix} \right)$$
(6-34)

$$[H_z^I] = [H_z^{II(a)}] \to [i_{nmj}][B_{nm}] = [f_{nj}] + [g_{nlj}][D_{nl}^{(a)}]$$
(6-35)

$$[H_{\varphi}^{I}] = [H_{\varphi}^{II(a)}] \rightarrow [o_{nmj}][A_{nm}] + [p_{nmj}][B_{nm}] = [m_{nj}] + ([n_{nlj}][C_{nl}^{(a)}] + [q_{nlj}][D_{nl}^{(a)}])$$
(6-36)

For boundary 'b':

$$0 = [E_z^{II(b)}] \to 0 = [b_{nj}] + [a_{nlj}][C_{nl}^{(b)}]$$
(6-37)

$$0 = [E_{\varphi}^{II(b)}] \to 0 = [d_{nj}] + ([c_{nlj}][C_{nl}^{(b)}] + [e_{nlj}][D_{nl}^{(b)}])$$
(6-38)

A partially expanded matrix form provides a good aid of the matrix form which is represented here as well. Subscripts within the matrices will be further observable and the
matrix shape made obvious. Though, a few notes on the sub-subscripts need to be made. A sub-subscript of 1 on the subscript "n", "m", and "l" signifies the first increment of that index. A sub-subscript of "n\_max", m"\_max", or "l\_max" signifies the last increment of that index, which are on "n", "m", or "l" respectively.

For boundary 'a':

$$\begin{split} [E_{z}^{I}] &= \left[E_{z}^{II(a)}\right] \rightarrow \begin{bmatrix} h_{n_{1}m_{1}j_{1}} & \cdots & h_{n_{n}max}m_{m,max}j_{1} \\ \vdots & \ddots & \vdots \\ h_{n_{1}m_{1}j_{1}max} & \cdots & h_{n_{n,max}m_{m,max}j_{1}max} \end{bmatrix} \begin{bmatrix} A_{n_{1}m_{1}} \\ \vdots \\ A_{n_{n}max}m_{m,max}m_{m,max} \end{bmatrix} \\ &= \begin{bmatrix} b_{nj_{1}} \\ \vdots \\ b_{nj_{1}max} \end{bmatrix} + \begin{bmatrix} a_{j_{1}n_{1}l_{1}} & \cdots & a_{j_{1}n_{n}max}l_{l,max}} \\ a_{n_{1}l_{1}j_{1}max} & \cdots & a_{n_{n,max}l_{l,max}} \end{bmatrix} \begin{bmatrix} C_{n_{1}l_{1}} \\ \vdots \\ C_{n_{n,max}l_{l,max}}^{(b)} \end{bmatrix} \\ &= \begin{bmatrix} E_{\varphi}^{II(a)} \end{bmatrix} \rightarrow \begin{bmatrix} k_{n_{1}m_{1}j_{1}} & \cdots & k_{j_{1}n_{n}max}m_{m,maxj_{1}} \\ \vdots & \ddots & \vdots \\ k_{n_{1}m_{1}j_{1}max} & \cdots & k_{n_{n,max}m_{m,max}j_{1}max} \end{bmatrix} \begin{bmatrix} A_{n_{1}m_{1}} \\ \vdots \\ A_{n_{n,max}m_{m,max}} \end{bmatrix} \\ &+ \begin{bmatrix} l_{n_{1}m_{1}j_{1}} & \cdots & l_{n_{n,max}m_{m,maxj_{1}}max} \\ \vdots & \ddots & \vdots \\ l_{n_{1}m_{1}j_{1}max} & \cdots & l_{n_{n,max}m_{m,maxj_{1}}max} \end{bmatrix} \begin{bmatrix} B_{n_{1}m_{1}} \\ \vdots \\ B_{n_{n,max}m_{m,max}} \end{bmatrix} \\ &= \begin{bmatrix} c_{n}l_{1}l_{1}l_{1} & \cdots & c_{n_{n,max}l_{1}maxj_{1}} \\ \vdots & \ddots & \vdots \\ c_{n_{1}l_{1}j_{1}max} & \cdots & c_{n_{n,max}l_{1}maxj_{1}} \end{bmatrix} \\ &+ \begin{bmatrix} c_{n_{1}l_{1}j_{1}} & \cdots & c_{n_{n,max}l_{1}maxj_{1}} \\ \vdots & \ddots & \vdots \\ e_{n_{1}l_{1}j_{1}max} & \cdots & e_{n_{n,max}l_{1}maxj_{1}} \end{bmatrix} \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n,max}l_{1}max} \end{bmatrix} \\ &+ \begin{bmatrix} e_{n_{1}l_{1}j_{1}max} & \cdots & e_{n_{n,max}l_{1}maxj_{1}} \\ \vdots & \ddots & \vdots \\ e_{n_{1}l_{1}j_{1}max} & \cdots & e_{n_{n,max}l_{1}maxj_{1}} \end{bmatrix} \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n,max}l_{1}max} \end{bmatrix} \\ &= \begin{bmatrix} H_{z}^{II(a)} \end{bmatrix} \rightarrow \begin{bmatrix} i_{n_{1}m_{1}j_{1}} & \cdots & i_{n_{n,max}m_{m,max}j_{1}max} \\ \vdots & \ddots & \vdots \\ i_{n_{1}m_{1}j_{1}max} & \cdots & i_{n_{n,max}m_{m,max}j_{1}max} \end{bmatrix} \begin{bmatrix} B_{n_{1}m_{1}} \\ \vdots \\ B_{n_{n,max}l_{1}max} \end{bmatrix} \\ &= \begin{bmatrix} f_{nj_{1}} \\ \vdots \\ f_{nj_{1}max} \end{bmatrix} + \begin{bmatrix} g_{j_{1}n_{1}l_{1}} & \cdots & g_{n_{n,max}l_{1}max} \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n,max}l_{1}max} \end{bmatrix} \\ \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n,max}l_{1}max} \end{bmatrix} \\ &= \begin{bmatrix} f_{nj_{1}} \\ \vdots \\ f_{nj_{1}max} \end{bmatrix} + \begin{bmatrix} g_{j_{1}n_{1}l_{1}} & \cdots & g_{n_{n}max}l_{1}max} \end{bmatrix} \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n,max}l_{1}max} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} H_{\varphi}^{a} \end{bmatrix} = \begin{bmatrix} H_{\varphi}^{ll(a)} \end{bmatrix} \rightarrow \begin{bmatrix} o_{n_{1}l_{1}j_{1}} & \cdots & o_{n_{n}\max l_{l}\max j_{1}} \\ \vdots & \ddots & \vdots \\ o_{n_{1}l_{1}j_{j}\max } & \cdots & o_{n_{n}\max l_{l}\max j_{j}\max j_{1}} \\ &+ \begin{bmatrix} p_{n_{1}l_{1}j_{1}} & \cdots & p_{n_{n}\max l_{l}\max j_{1}} \\ \vdots & \ddots & \vdots \\ p_{n_{1}l_{1}j_{j}\max } & \cdots & p_{n_{n}\max l_{l}\max j_{j}\max j_{1}} \\ &= \begin{bmatrix} m_{nj_{1}} \\ \vdots \\ m_{nj_{j}\max } \end{bmatrix} \\ &+ \begin{pmatrix} \begin{bmatrix} n_{n_{1}l_{1}j_{1}} & \cdots & n_{n_{n}\max l_{l}\max j_{1}} \\ \vdots & \ddots & \vdots \\ n_{n_{1}l_{1}j_{j}\max } & \cdots & n_{n_{n}\max l_{l}\max j_{1}} \\ \vdots & \ddots & \vdots \\ n_{n_{1}l_{1}j_{j}\max } & \cdots & n_{n_{n}\max l_{l}\max j_{1}} \end{bmatrix} \begin{bmatrix} C_{n_{1}l_{1}} \\ \vdots \\ C_{n_{n}\max l_{l}\max j_{1}} \\ \vdots \\ D_{n_{n}\max l_{l}\max j_{1}} \\ \vdots \\ D_{n_{n}\max l_{l}\max j_{1}} \end{bmatrix} \\ &+ \begin{bmatrix} q_{n_{1}l_{1}j_{1}} & \cdots & q_{n_{n}\max l_{l}\max j_{1}} \\ \vdots & \ddots & \vdots \\ q_{n_{1}l_{1}j_{j}\max } & \cdots & q_{n_{n}\max l_{l}\max j_{1}\max j_{1}} \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n}\max l_{l}\max j_{1}\max j_{1}} \\ \vdots \\ D_{n_{n}\max l_{l}\max j_{1}\max j_{1}} \end{bmatrix} \end{pmatrix}$$

For boundary 'b':

$$0 = \begin{bmatrix} E_{z}^{II(b)} \end{bmatrix} \rightarrow 0 = \begin{bmatrix} b_{nj_{1}} \\ \vdots \\ b_{nj_{j}max} \end{bmatrix} + \begin{bmatrix} a_{n_{1}l_{1}j_{1}} & \cdots & a_{n_{n}max^{l}l_{max}j_{1}} \\ \vdots & \ddots & \vdots \\ a_{n_{1}l_{1}j_{j}max} & \cdots & a_{n_{n}max^{l}l_{max}j_{j}max} \end{bmatrix} \begin{bmatrix} C_{n_{1}l_{1}} \\ \vdots \\ C_{n_{n}max^{l}l_{max}} \end{bmatrix}$$

$$0 = \begin{bmatrix} E_{\varphi}^{II(b)} \end{bmatrix} \rightarrow 0$$

$$= \begin{bmatrix} d_{nj_{1}} \\ \vdots \\ d_{nj_{j}max} \end{bmatrix}$$

$$+ \left( \begin{bmatrix} c_{n_{1}l_{1}j_{1}} & \cdots & c_{n_{n}max^{l}l_{max}j_{1}} \\ \vdots & \ddots & \vdots \\ c_{n_{1}l_{1}j_{j}max} & \cdots & c_{n_{n}max^{l}l_{max}j_{1}} \end{bmatrix} \begin{bmatrix} C_{n_{1}l_{1}} \\ \vdots \\ C_{n_{n}max^{l}l_{max}} \end{bmatrix}$$

$$+ \begin{bmatrix} e_{n_{1}l_{1}j_{1}} & \cdots & e_{n_{n}max^{l}l_{max}j_{1}} \\ \vdots & \ddots & \vdots \\ e_{n_{1}l_{1}j_{j}max} & \cdots & e_{n_{n}max^{l}l_{max}j_{1}} \end{bmatrix} \begin{bmatrix} D_{n_{1}l_{1}} \\ \vdots \\ D_{n_{n}max^{l}l_{max}} \end{bmatrix}$$

# 6.3 Summation Truncation

It's also important to note that the summations for all the equations, and therefore the matrices, need to be truncated from an infinite to a finite length indices. This is required prior to numerical computation. Truncation can reduce accuracy, so it follows that smaller truncated values can be less accurate than when truncated to higher values. However, it is a fair trade off between computer computational power and available processing time versus accuracy. That's due to the fact that the higher "n", "m", and "l" indices represent higher orders and wave numbers of waves that either don't propagate because they're evanescent or contribute very little overall amplitude and can be neglected. Also, computing solutions that contribute little to the final solution can be computationally burdensome. A result of this trade ultimately leads to the truncated size selection for the summation ranges and matrix sizes.

An example for finding evanescent modes of higher order "m" can be seen when examining equation (4-32) with  $k_{\rho_m} = \sqrt{k^2 - k_{Z_m}^2}$ . At larger values of "m", it can be seen that  $k^2 < k_{Z_m}^2$  which makes  $k_{\rho_m}$  imaginary, representing evanescent radial wave modes. When  $k = \omega \sqrt{\mu_I \varepsilon_I}$  and (4-32) are substituted into  $k^2 > k_{Z_m}^2$ , where  $k_{\rho_m}$  is still real, the relationship

$$\omega^2 \mu_I \varepsilon_I > \frac{m^2 \pi^2}{a^2} \rightarrow \frac{a^2 \omega^2 \mu_I \varepsilon_I}{\pi^2} > m^2 \rightarrow \frac{a * \omega \sqrt{\mu_I \varepsilon_I}}{\pi} > \pm m \tag{6-45}$$

can be established, setting the upper limit for "m". The same can be done for  $k_{\rho_l}$  and  $k_{z_l}$ . Following the same approach but using equations  $k = \omega \sqrt{\mu_{II} \varepsilon_{II}}$  and (5-9), the relationship

$$\omega^{2}\mu_{II}\varepsilon_{II} > \left(k\cos\theta^{i} + \frac{2\pi l}{(a+b)}\right)^{2} \rightarrow \omega\sqrt{\mu_{II}\varepsilon_{II}} > k\cos\theta^{i} + \frac{2\pi l}{(a+b)} \rightarrow \frac{(a+b)(\omega\sqrt{\mu_{II}\varepsilon_{II}} - k\cos\theta^{i})}{2\pi} > l \rightarrow \frac{(a+b)k(1-\cos\theta^{i})}{2\pi} > l$$
(6-46)

will provide an upper limit for "I". These equations are implemented in the code, which will be discussed in the following sections, as checks for the user to compare his or her inputs. Violating these limits can prove challenging for the code to find solutions to the field equations, producing nonsensical, erroneous results with values of orders of magnitudes 10's to 100's of times greater than expected. In summary, the "m" and "l" max values are selected in order to restrict the values of both  $k_{\rho_l}$  and  $k_{\rho_m}$  to the real domain, which also drives the size of the matrices, for the following reasons:

- □ Imaginary of  $k_{\rho_l}$  and  $k_{\rho_m}$  produce rapidly decaying evanescent fields that contribute little to the overall amplitude
- Computationally it can be burdensome to compute and in some cases challenging to find a solution.

It's also important to note here that this restriction is acceptable to the author. In any approximation technique, there will be areas where computations are truncated and simplification assumptions are made. The results and comparisons in Chapter 7 will provide a guide for when the approach presented by this paper is most valid, with respect to the dimensions of the corrugated cylinder structure when compared to the wavelength of the incident plane-wave. It will be left for a future endeavor to stress the model approach presented in this research, to determine the exact limitations of specific assumptions (e.g. under what conditions can the restricting of  $k_{\rho_l}$  and  $k_{\rho_m}$  being real be considered unacceptable).

6.4 Numeric Computation Techniques and Tool Methodology

6.4.1 Tool Selection and Use

This next stage requires that of all the equations get implemented into a computational tool. There are many computational tools to choose from, however this author chose to use Mathematica® [17] based on its ability to handle math symbolically. Also, another significant driver for the selection of Mathematica® is the availability of a

free toolbox add-on to Mathematica®, available online from UC San Diego known as NCAlgebra [18], which can handle noncommutative algebra.

NCAlgebra makes it easy in manipulating matrices and vectors algebraically and symbolically. Its key use in this paper was to solve for each of the unknown expansion coefficients in terms of known terms, using the matching equations from (6-33) to (6-38). Essentially, a solve function native to the tool is used, which, once that is done, numeric values for each of terms are computed, plugged in, computed again and the coefficients would be solved for.

However, there were some convergence issues in the results. The issue was not fully identified but at this point, it is important to mention that when NCAlgebra produces solutions, it checks and validates it. This validation check produced a warning describing that the solution may be prone to error for certain circumstances, not described, since it could not guarantee the solution's accuracy. Based on the results and the NCAlgebra warning, the fully derived NCAlgebra method was commented out of the code. It was replaced by a loop solve algorithm developed for this research. However, NCAlgebra was still used to derive some of the unknown expansion coefficient equations where the solution check was validated, and were also used to spot check solutions from the loop solve algorithm used to replace it.

The loop solve algorithm was used to solve partially solved unknown coefficients. The solve function in Mathematica® was used within a loop to solve for the large matrix system of equations. As the loop solve algorithm increments, it solves an equation in terms of an unknown, then plugs that unknown into the equation of the next loop solve iteration. This process eliminates an unknown with each step. At the last step, the

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unknown is found to have a value. At this point, another loop is implemented working backwards and plugging in values until all the unknowns are known.

During the numerical computational effort, there were issues that arose in solving for the unknown coefficients. They were attributed to ill-conditioned matrices which will be described in the next section.

#### 6.4.2 Ill-Conditioned Matrices

It turned out that during the computation iterations in the process of this work, the computational tool would produce errors indicating ill-conditioned matrices. This was found during the inversion process of many of the matrices.

There has been much work behind ill-conditioned matrices, particularly in such a case as this one, where an ill-conditioned system of linear equations is involved in an engineering problem. The driving source is from an ill-posed problem, which does not necessarily stem from an ill-conceived design, but rather a fundamental physical limitation to the data at hand [19]. Described in such work, are suggestions for the use of the Moore–Penrose pseudoinverse, which relates to the least squares regression method in finding the shortest length solution to a problem [20]. Both the pseudoinverse and least squares method are made use of in the code, in order to eliminate the ill-conditioned errors and solve for the unknown expansion coefficients.

#### 6.4.3 Tool Methodology

The following section will describe the high-level workflow on how the computational tools are used. It will show how the tools mentioned in section 6.4.1 are used in conjunction with the solving methods mentioned in section 6.4.2. The workflow

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below will describe the code in an already existing state and therefore the workflow steps describe the sequential flow of data, and not the creation of code.

- Step 1: The boundary 'b' equations, (6-37) and (6-38), are used to solve for  $C_{nl}^{(b)}$  and  $D_{nl}^{(b)}$  using the least squares method with tool's built-in least squares solver function. Equations were rearranged to solve for the specified expansion coefficient per the least squares solver function required arrangement [21]. See Figure 6-3 for pictorial form.
- Step 2: The boundary 'a' equations (6-33) and (6-35) are used to solve for  $A_{nm}$  and  $B_{nm}$ . They are rearranged using manual matrix manipulation method with noncommutative algebra and solve for  $A_{nm}$  and  $B_{nm}$  in terms of known of field components,  $C_{nl}^{(a)}$  and  $D_{nl}^{(a)}$
- Step 3: The boundary 'a' equation (6-34) is now used to solve for  $C_{nl}{}^{(a)}$  in terms of  $D_{nl}{}^{(a)}$  using the same method as in step 2.
- Step 4: The new form of  $C_{nl}{}^{(a)}$  (in terms of  $D_{nl}{}^{(a)}$ ) is plugged into the new form of  $A_{nm}$  (in terms of  $C_{nl}{}^{(a)}$ ) in order to put  $A_{nm}$  in terms of  $D_{nl}{}^{(a)}$
- Step 5: The boundary 'a' equation (6-36) is now used to solve for D<sub>nl</sub><sup>(a)</sup> in terms of known of field components, A<sub>nm</sub>, and B<sub>nm</sub>, where A<sub>nm</sub>, and B<sub>nm</sub> are substituted by the solutions in the previous step.
- Step 6:  $D_{nl}^{(a)}$  is now expanded and solved for all the expanded coefficients within the loop algorithm referenced earlier as the loop solve algorithm. Once complete,  $D_{nl}^{(a)}$  is fully solved for numerically.

Step 7: Dnl(a) is plugged into  $C_{nl}^{(a)}$  and solved for. Both of which are now plugged into

 $A_{nm}$  and  $B_{nm}$ , which are solved for as well, completing the numerical solving of

the expansion coefficients. Steps 2 - 7 can be seen in Figure 6-4.

A pictorial overview of this workflow can be seen in Figure 6-2. It includes additional steps required for configuration and result generation.



Figure 6-2 Software Process Workflow



Figure 6-3 Solving for Boundary 'b' Unknown Coefficients Flow Chart



Figure 6-4 Solving for Boundary 'a' Unknown Coefficients Flow Chart

#### CHAPTER 7 RESULTS, COMPARISONS AND FUTURE RESEARCH

# 7.1 Model Configuration and Parameters

Many configurations and parameters were set up to support the research in this paper. This section will attempt to describe the key configurations and parameters in order to facilitate understanding of the results. Note, this model is composed of multiple smaller models, most centered on the periodic corrugated cylinder. However, there's also a smooth cylinder model incorporated, which will be discussed in section 7.3.

# 7.1.1 Parameters Relative to Lambda

The model computes and displays many of the results in terms of the wavelength  $\lambda$ , where  $\lambda = \frac{c}{f}$ , where 'f' is the frequency of the incident field and 'c' is the speed of light. Also, the dimensions of the corrugated cylinder are described in units of  $\lambda$ , which include the corrugation opening denoted by 'a', thickness of the metallic corrugation portion denoted by 'b, the inner corrugation radius  $\rho_1$  and the exterior corrugation radius  $\rho_2$ . Note that the period of the corrugation is equal to 'a + b'. This includes the plots displayed later in this chapter, which vary in  $\rho$  and have an axis in units of  $\lambda$ , displayed as  $\rho/\lambda$ . This allows the model to display results that are independent of a specified frequency/wavelength. However, parameters do have values thus a  $\lambda$  is chosen and can be varied while fixing the geometry, if so desired. For the purpose of this paper,  $\lambda$  is fixed and the geometry and other parameters are varied.

In the results section, multiple scenarios were run with different parameter changes. One such parameter was labeled 'd' which signifies a relative 'dimension' to  $\lambda$ , which the physical dimension parameters of the corrugated and smooth cylinders are linked to. For example, the dimension 'b', the thickness of the protruding part of the corrugation, is always set equal to 'd' in all the scenarios, unless explicitly stated otherwise. The parameter 'd' allows for the description of 3 different groupings of relative physical dimensions which are  $d \gg \lambda$  by setting  $d = 20\lambda$ ,  $d \approx \lambda$  by setting  $d = 2\lambda$ , and  $d \ll \lambda$  by setting  $d = 0.1\lambda$ . This was done in order to more clearly gauge the performance of the model relative to the different scattering regimes laid out by the figure, as per described in [22]. Also, according to Fuhs [23, p. 18], when in the Rayleigh scattering region ( $d \gg \lambda$ ), polarization is not important for the magnitude of RCS.



Figure 7-1 Relative relationship of target size to illuminated wavelength with associated regions of scattering approximation, courtesy of Wikipedia [24]

# 7.1.2 Incident Field Parameters

The incident field amplitudes are driven by the E<sub>0</sub> value for the TM<sub>z</sub> mode and the H<sub>0</sub> value for the TE<sub>z</sub> mode. Since these modes are independent of each other, E<sub>0</sub> and H<sub>0</sub> values can be selected independent of each other. It is important to note at this point, that the H-fields amplitudes in the TM<sub>z</sub> mode are driven by the E<sub>0</sub>, where the H-field amplitude is equal to  $\frac{E_0}{Z}$ , where  $Z = \sqrt{\frac{\mu_{II}}{\varepsilon_{II}}}$  and is the impedance of the medium in which the incident field is in. The same holds true for the E-fields in the TE<sub>z</sub> mode, in that it's dependent on the H<sub>0</sub> value, where the E-field amplitude is equal to  $ZH_0$ .

# 7.1.3 Point Matching Selection

As discussed in Chapter 6, point matching is required for the numerical solution of the unknown expansion coefficients. There are various points that could be selected with the prescribed range for that boundary condition, with  $\rho$  always being equal to  $\rho_2$ . The type and quantity of matching points can worsen or improve the numerical results, though a minimum of 'j' quantity, expansion number of the coefficients, is required.

Different matching point techniques were attempted during the development of the model. When the NCAlgebra method was first utilized, it allowed for an overdetermined solution where there were more equations (or 'j' points), than unknowns, (or expansion count of coefficients). That's because it was fully defined in the pseudoinverse and least squares method. However, due to its limitations as described in section 6.4.1, the NCAlgebra method was abandoned and the new technique did not allow for an overdetermined solution in its current form.

Two main matching point techniques were maintained in the model. One was fixing  $\varphi$  to an arbitrary  $\varphi$  value from 0 to  $2\pi$  while varying z 'j' times, evenly spaced

spanning the distance of the boundary, being 'a' or 'b' depending on that boundary. The other was to fix z to an arbitrary z value within the boundary, while varying  $\varphi$  'j' times evenly from 0 to  $2\pi$ .

The results computed were done fixing z and varying  $\varphi$ . This produces more accurate results, which is due to the fact that the computed comparison results did not vary z values, but did vary  $\varphi$  in the changing  $\varphi$  results. Therefore, the selection in matching points that is best suited is the matching points that would reinforce the intended computational analysis, which was to vary  $\varphi$ .

# 7.1.4 Total E-Field Calculation

The total E-field calculation finds the magnitude of the combined fields. The method is fairly straight forward. The fields are converted from cylindrical coordinates to rectangular coordinates, which can be found in [12, p. 923] to form

$$E_x = E_\rho \cos \phi + E_\phi \sin \phi \tag{7-1}$$

$$E_Y = E_\rho \sin \phi + E_\phi \cos \phi \tag{7-2}$$

$$E_Z = E_Z \tag{7-3}$$

Then, each of the rectangular coordinate forms of fields are squared, summed together and then the square root of that number is attained.

$$\sqrt{E_x^2 + E_Y^2 + E_Z^2} = E_{Total}$$
(7-4)

This is done for every data point to generate the total E-field data.

#### 7.1.5 Reconciliation of Boundary 'a' and Boundary 'b'

Up to this point, the equations for boundary 'a' and boundary 'b' have been given separate treatment. However, results were computed for the separate field equations and results plotted and incorporated into the results section. At the near field, where  $\rho \le \lambda$ , the boundaries can be treated separately.

For the far field,  $\rho \gg \lambda$ , boundary 'a' and boundary 'b' solutions are examined for their accuracy. Either technique alone should produce a gross representation of the scatter, though within certain regions the approximations of the field amplitudes can be poor. However, the hybrid nature of the problem formulation allows for the depolarization representation of the periodic corrugated cylinder.

A technique described by Kishk et al [25], the asymptotic boundary condition method, utilizes coefficients that vary with the z axis, and are weighted by a ratio factor w/p, where 'w' is the dimension of the corrugation opening and 'p' is the corrugation period. This is done at the boundary condition to develop a complete field solution, where more detail can be found in [26]. This technique and variations thereof were investigated but not implemented.

In the present work, the field solutions for boundary 'a' is added with that of boundary 'b'. This superposition of fields, produces the results shown for the runs labeled "Run a\_plus\_b...". The results are compared to that of a smooth cylinder as well as to alternate methods for computing the scattered field of a corrugated cylinder [27]. This treatment of superposition of fields is done in [28], where the field of a cylinder without accounting for the corrugated perturbations, represented as metallic rings, and then added to the scattering due to the metallic rings.

## 7.2 RCS Computation

The model produces various Radar Cross Section (RCS) plots, as this is a typical convention in the electromagnetics scattering community, to display and compare

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scattered fields. The RCS symbol,  $\sigma$ , is the designated symbol to represent the RCS value, which is in units of m<sup>2</sup>. The formula representing  $\sigma$  is derived from the free-space loss factor cause by the spherical spreading of a propagating planewave, which a full description of its derivation can be found in [29, p. 96]. This model uses  $\sigma$  in the form

$$\sigma = \lim_{R \to \infty} \left[ 4\pi R^2 \frac{|E^s|^2}{|E^i|^2} \right]$$
(7-5)

where 'R' is the distance of observation from the target, meters. The value 'R' needs to be large enough where R>> than the largest physical dimension of the target and wavelength so that the propagating planewave representation holds and the formula remains valid. The RCS,  $\sigma$ , can also be calculated in decibels, dB, in order to display a large range of data. The units are in decibels per square meter or dBsm. This is calculated as

$$\sigma_{dBsm} = \lim_{R \to \infty} \left[ 10 \log_{10} 4\pi R^2 \frac{|E^s|^2}{|E^i|^2} \right].$$
(7-6)

It is important to take note of the aspect angles,  $\varphi$ , that are used in the  $\sigma$  calculations, as the computed results can vary. There is the  $\varphi$  of the incidence field,  $\varphi_i$ , and the  $\varphi$  of the observed or of the scattered field,  $\varphi_s$ . In each of the variations,  $\varphi_s$  values are typically swept through from 0 to  $2\pi$ . The following are the different methods for varying the  $\varphi$  values in order to get the different  $\sigma$  results:

- $\square RCS \varphi Sweep Method 1: \varphi_s \text{ is swept through 0 to } 2\pi \text{ and } \varphi_i \text{ is kept at a fixed}$ constant value between 0 to  $2\pi$ .
- $\square RCS \varphi Sweep Method 2: \varphi_s \text{ is swept through 0 to } 2\pi \text{ and } \varphi_i = \varphi_s. \text{ This is typically}$ referred to as a monostatic RCS since it assumes the transmitter and receiver, for typical radar applications, are at the same location.

□ *RCS*  $\varphi$  *Sweep Method 3:*  $\varphi_s$  is swept through 0 to  $2\pi$  and  $\varphi_i = \varphi_s + \varphi_{offset}$ , where  $\varphi_{offset}$  is an offset value of  $\varphi$ . This is typically referred to as a bistatic RCS since it assumes the transmitter and receiver, for typical radar applications, are at separate locations.

The technique used in this paper is RCS  $\varphi$  sweep method 1.

# 7.3 Smooth Cylinder Comparison Model

In order to have a comparison model for the periodic corrugated cylinder, a smooth cylinder was modeled. The dimensions of the corrugated cylinder can be adjusted to approximate a smooth cylinder and then compared to the smooth cylinder model.

A smooth cylinder model of oblique incidence planewave is found in [12, pp. 614-624]. This textbook model provided the basis for the TM<sub>z</sub> mode scattered equations

$$E_{\rho}^{s \ (TM)} = \tag{7-7}$$

$$jE_{0} \cos \theta^{i} e^{+jk \cdot z \cdot \cos \theta^{i}} \sum_{n=-\infty}^{\infty} j^{-n} \frac{J_{n}(k\rho_{2} \sin \theta^{i})}{H_{n}^{(2)}(k\rho_{2} \sin \theta^{i})} \left(\frac{H_{n-1}^{(2)}(k\rho \sin \theta^{i}) - H_{n+1}^{(2)}(k\rho \sin \theta^{i})}{2}\right) e^{jn\varphi}$$

$$E_{\varphi}^{s\,(TM)} = jE_0 \frac{\cot\theta^i}{k\rho} e^{+jk\cdot z\cdot\cos\theta^i} \sum_{n=-\infty}^{\infty} nj^{-n+1} \frac{J_n(k\rho_2\sin\theta^i)}{H_n^{(2)}(k\rho\sin\theta^i)} H_n^{(2)}(k\rho\sin\theta^i) e^{jn\varphi}$$
(7-8)

$$E_z^{s\,(TM)} = E_0 \sin\theta^i \, e^{+jk \cdot z \cdot \cos\theta^i} \sum_{n=-\infty}^{\infty} j^{-n} \frac{J_n(k\rho_2 \sin\theta^i)}{H_n^{(2)}(k\rho_2 \sin\theta^i)} H_n^{(2)}(k\rho \sin\theta^i) e^{jn\varphi} \tag{7-9}$$

and the  $TE_z$  mode scattered equations

$$E_{\rho}^{s\,(TE)} = -j \frac{H_0}{\omega \varepsilon \rho} \frac{e^{+jk \cdot z \cdot \cos\theta^i}}{\sin\theta^i} \sum_{n=-\infty}^{\infty} n j^{-n+1} \frac{J_{n-1}(k\rho_2 \sin\theta^i) - J_{n+1}(k\rho_2 \sin\theta^i)}{H_{n-1}^{(2)}(k\rho_2 \sin\theta^i) - H_{n+1}^{(2)}(k\rho_2 \sin\theta^i)} H_n^{(2)}(k\rho \sin\theta^i) e^{jn\varphi}$$
(7-10)

$$E_{\varphi}^{s\,(TE)} = \tag{7-11}$$

$$jH_0\sqrt{\frac{\mu}{\varepsilon}}e^{+jk\cdot z\cdot\cos\theta^i}\sum_{n=-\infty}^{\infty}j^{-n}\frac{J_{n-1}(k\rho_2\sin\theta^i)-J_{n+1}(k\rho_2\sin\theta^i)}{H_{n-1}^{(2)}(k\rho_2\sin\theta^i)-H_{n+1}^{(2)}(k\rho_2\sin\theta^i)}\binom{H_{n-1}^{(2)}(k\rho\sin\theta^i)-H_{n+1}^{(2)}(k\rho\sin\theta^i)}{2}e^{jn\varphi}$$

$$E_z^{s(TE)} = 0.$$
 (7-12)

)

The Hankel and Bessel order 'n' is set to the same 'n' as used in the corrugated cylinder model. The radius of the smooth cylinder is  $\rho_2$ , the same dimension as the larger radius of the corrugated cylinder.

Note that only the electric field components were used. Using only the electric fields provides an adequate comparison, as there is no polarization and therefore no need to fully represent a system of each  $TM_z$  and  $TE_z$  mode as in the corrugated case. Each mode will have the fields calculated separately and then, through the principle of superposition, combined with each other on certain plots in the following section. Also, the incident field is the same as that incident onto the corrugated cylinder in the model described in Chapter 3.

The smooth cylinder results are computed and displayed alongside the periodic corrugated cylinder results. Since the periodic corrugated cylinder is of a hybrid mode, both  $TM_z$  and  $TE_z$  modes exist within the periodic corrugated cylinder scattered field. However, the data displayed for the smooth cylinder is made available to show the separate  $TM_z$  and  $TE_z$  modes, as well as the superposition combined modes. The data sets were created for the different cylindrical coordinate axes.

A subset of the data is collected and analytically compared between periodic corrugated cylinder and the smooth cylinder, in order to calculate the mean of percent error between them. This data set is composed of the superposition combined modes, in RCS dBsm, for each of the cylindrical coordinate axes and the total field. The data points at each  $\varphi$ , for the smooth and corrugated cylinders, are subtracted from each other and the absolute value of that is divided by the smooth cylinder dBsm value, and finally multiplied by 100% to give the percent error, as in equation (7-13).

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$$\frac{|\sigma_{dBsm\,[smooth]} - \sigma_{dBsm\,[corr]}|}{\sigma_{dBsm\,[smooth]}} \cdot 100\% = \% \ error \ of \ \sigma_{dBsm} \ .$$
(7-13)

Then, the mean of the percent error is found for each of the data subsets.

# 7.4 Alternate Corrugated Cylinder Method Comparison

In order to fully validate the results of the periodic corrugated cylinder scattered field, a comparison to an alternate method for the same geometry is merited. The chosen comparison method was from A. Freni et al [27] where results for a Finite Element Method (FEM) and the Method of Moments (MoM) are captured in figure 3 of that paper. The geometry referenced in figure 3 of [27] was utilized and the cross-polar plot was recreated in this paper, by extracting the FEM and MoM data curves, shown in Figure 7-150. Also captured in Figure 7-150 are the results using this research's technique. Data was extracted from figure 3 of [27] using a curve mapping and data extraction tool called WebPlotDigitizer [30]. The data plotted is,  $\sigma_{\phi\theta}/\lambda_0$  (dB), which is the cross-polar scatter width derived from

$$\sigma_{\phi\theta} = \lim_{\rho \to \infty} \left[ 2\pi \rho \frac{\left| E_{\phi}^{s} \right|^{2}}{\left| E_{\theta}^{i} \right|^{2}} \right]$$
(7-14)

which the first subscript is the polarization of the scattered field and the second subscript is the polarization of the incident field [28]. A comparison of this technique can also be found in [31] by the author of this research.

## 7.5 Results

A variety of different runs were executed, as was discussed earlier. Table 1 captures a summary of the boundary 'a' simulation runs with the adjusted parameters identified, on runs comparing the corrugated cylinder to that of the smooth cylinder. Also, boundary 'b' runs were generated (see Table 2), using the same parameters as the subset runs of boundary 'a' shown in this chapter, except with a z position in the boundary 'b' region. Table 3 captures a summary of the boundary 'a' plus boundary 'b' runs, which represent the final solution approach. The different runs captured in the subsequent sections use a title scheme described by the example in Figure 7-1, in order to help identify the configuration for each run and the plots captured in that section.



Figure 7-2 A run title example describing each component of the title and how it relates to the run's configuration

From Table 1, it can be seen that some of the runs have a status of 'Bad Data/Ill-Condition'. These were mostly runs that had 'm' or 'l' that were exceeding their max allowable value, allowing  $k_{\rho}$  to become imaginary. As mentioned in section 6.3, these modes in which  $k_{\rho}$  are imaginary, produce evanescent waves which decay rapidly when moving away from the field source at the cylinder edge, and thus can be ignored.

Another item to note, is that all the runs were kept at n=3. This an acceptable mode or Hankel function order as much of the work with similar scattering geometries have been conducted at n=1 or n=2, such as [32]. This upper limit was also a computational limitation. Orders above n=3 would not produce a solution with the capability and the time allotted for the computer systems used.

The following subsections provide a subset of the simulation runs collected as part of this research effort. They are pertinent comparative material between the periodic corrugated cylinder model and the comparison model which are used to draw conclusions from. The mean error, as described in section 7.3 are shown for boundary 'a'(Figure 7-3), boundary 'b'(Figure 7-4) and boundary 'a+b'(Figure 7-5).

Each of the presented runs are in their own section with multiple plots. Each section consists of the following:

- $\Box$  1 detailed summary table of all the  $\varphi$  changing plot parameters,
- $\Box$  4 Polar Plots of RCS dBsm (Ez, E  $\rho$ , E  $\phi$  and E<sub>Total</sub> of TM<sub>z</sub> +TE<sub>z</sub> modes)
- $\Box$  4 XY Plots of RCS dBsm (Ez, E  $\rho$ , E  $\phi$  and E<sub>Total</sub> of TM<sub>z</sub> +TE<sub>z</sub> modes)
- $\Box$  1 detailed summary table of all the  $\rho$  changing plot parameters
- $\begin{tabular}{ll} \hline $8$ XY field amplitude plots (Absolute value of the fields : Ez, E $\rho$, E $\phi$ and $E_{Total}$ of $TM_z$ +TE_z$ modes, for scattered field and for scattered + incident field)... \end{tabular}$

Additional results are also provided here. As mentioned in section 7.4, an alternate method in representing scattering of a corrugated cylinder is discussed with results in section 7.5.10. Also, the relative dielectric constant in region I is varied and compared, showing the effects of dielectric loading and lossy dielectric loading, with results in section 7.5.11.



Figure 7-3 Mean of %error between corrugated cylinder and smooth cylinder model, for boundary 'a'



Figure 7-4 Mean of %error between corrugated cylinder and smooth cylinder model, for boundary 'b'



Figure 7-5 Mean of %error between corrugated cylinder and smooth cylinder model, for boundary 'a+b'

	Run Title	b	а	ρ2	ρ1	pfar	n	m	Status	Plot Location	Max Allowable "m" or "l"
	Run a.20.100.0	20*λ	b*1	20*λ	ρ2*0.99	ρ2*10	3	0	Complete	Appendix	17
	Run a.20.100.1	20*λ	b*1	20*λ	ρ2*0.99	ρ2*10	3	1	Complete		17
	Run a.20.75.0	20*λ	b*.75	20*λ	ρ2*0.99	ρ2*10	3	0	Complete		14
	Run a.20.75.1	20*λ	b*.75	20*λ	ρ2*0.99	ρ2*10	3	1	Complete		14
۷*0	Run a.20.50.0	20*λ	b*.5	20*λ	ρ2*0.99	ρ2*10	3	0	Complete		12
d=2	Run a.20.50.1	20*λ	b*.5	20*λ	ρ2*0.99	ρ2*10	3	1	Complete		12
	Run a.20.25.0	20*λ	b*.25	20*λ	ρ2*0.99	ρ2*10	3	0	Complete		10
	Run a.20.25.1	20*λ	b*.25	20*λ	ρ2*0.99	ρ2*10	3	1	Complete		10
	Run a.20.0.0	20*λ	b*.001	20*λ	ρ2*0.99	ρ2*10	3	о	Complete	Chapter 7	0
	Run a.20.0.0	20*λ	b*.001	20*λ	ρ2*0.99	ρ2*10	3	1	Bad Data/III- Conditioned	N/A	0
	Run a.2.100.0	2*λ	b*1	2*λ	p2*0.99	p2*10	3	0	Complete	Appendix	4
	Run a.2.100.1	2*λ	b*1	2*λ	p2*0.99	p2*10	3	1	Complete		4
	Run a.2.75.0	2*λ	b*.75	2*λ	p2*0.99	p2*10	3	0	Complete		3
	Run a.2.75.1	2*λ	b*.75	2*λ	p2*0.99	p2*10	3	1	Complete		3
2*λ	Run a.2.50.0	2*λ	b*.5	2*λ	p2*0.99	p2*10	3	0	Complete		2
e di	Run a.2.50.1	2*λ	b*.5	2*λ	p2*0.99	p2*10	3	1	Complete		2
	Run a.2.25.0	2*λ	b*.25	2*λ	p2*0.99	p2*10	3	0	Complete		1
	Run a.2.25.1	2*λ	b*.25	2*λ	p2*0.99	p2*10	3	1	Could not solve for 'a' coefficients "Input	N/A	1
	Run a.2.0.0	2*λ	b*.001	2*λ	p2*0.99	p2*10	3	о	Complete	Chapter 7	0
	Run a.2.0.1	2*λ	b*.001	2*λ	p2*0.99	p2*10	3	1	Bad Data/III- Conditioned	N/A	0
	Run a.0.1.100.0	.1*λ	b*1	.1*λ	p2*0.99	p2*10	3	0	Complete	Appendix	0
	Run a.0.1.100.1	.1*λ	b*1	.1*λ	p2*0.99	p2*10	3	1	Bad Data/III- Conditioned	N/A	0
	Run a.0.1.75.0	.1*λ	b*.75	.1*λ	p2*0.99	p2*10	3	0	Complete		0
	Run a.0.1.75.1	.1*λ	b*.75	.1*λ	p2*0.99	p2*10	3	1	Bad Data/III- Conditioned	N/A	0
.1*λ	Run a.0.1.50.0	.1*λ	b*.5	.1*λ	p2*0.99	p2*10	3	0	Complete		0
d=0	Run a.0.1.50.1	.1*λ	b*.5	.1*λ	p2*0.99	p2*10	3	1	Bad Data/III- Conditioned	N/A	0
	Run a.0.1.25.0	.1*λ	b*.25	.1*λ	p2*0.99	p2*10	3	0	Complete		0
	Run a.0.1.25.1	.1*λ	b*.25	.1*λ	p2*0.99	p2*10	3	1	Bad Data/III- Conditioned	N/A	0
	Run a.0.1.0.0	.1*λ	b*.001	.1*λ	p2*0.99	p2*10	3	0	Complete	Chapter 7	0
	Run a.0.1.0.1	.1*λ	b*.001	.1*λ	p2*0.99	p2*10	3	1	Bad Data/III- Conditioned	N/A	0

 Table 1 Summary of boundary 'a' simulation runs conducted and adjusted parameters for comparing the corrugated cylinder and smooth cylinder models

 Table 2 Summary of boundary 'b' simulation runs conducted and adjusted parameters for comparing the corrugated cylinder and smooth cylinder models

D T'4			- 0		c			<u><u> </u></u>	Plot	Max Allowable
Kun Title	D	а	p2	ρι	piar	n	m	Status	Location	"m" or "l"
Run b.20.0.0	20*λ	b*.001	20*λ	ρ2*0.99	ρ2*10	3	0	Complete	Chapter 7	0
Run b.2.0.0	2*λ	b*.001	2*λ	p2*0.99	p2*10	3	0	Complete	Chapter 7	0
Run b.0.1.0.0	.1*λ	b*.001	.1*λ	p2*0.99	p2*10	3	0	Complete	Chapter 7	0

 

 Table 3 Summary of boundary 'a+b' simulation runs conducted and adjusted parameters for comparing the corrugated cylinder and smooth cylinder models

Dun Title	h		-	. 1	n fan			Status	Plot	Max Allowable
Kun Title	D	a	ρz	ρι	piar	п	ш	Status	Location	"m" or "l"
Run a_plus_b.20.0.0	20*λ	b*.001	20*λ	ρ2*0.99	ρ2*10	3	0	Complete	Chapter 7	0
Run a_plus_b2.0.0	2*λ	b*.001	2*λ	p2*0.99	p2*10	3	0	Complete	Chapter 7	0
Run a_plus_b0.1.0.0	.1*λ	b*.001	.1*λ	p2*0.99	p2*10	3	0	Complete	Chapter 7	0

For sections 7.5.1 through 7.5.9, refer to Figure 7-2 to interpret the title of each section in order to understand the overall configuration of the model for the plots captured in that section. Also, the first table in each section will provide a more detailed set of configuration parameters specifically for the polar plots, preceding the polar plots. The second table in each section, after the polar plots but prior to the XY phi plots, will provide a detailed set of configuration parameters, as not all results had these sets of plots), after the XY phi plots but prior to the XY rho plots, will provide a detailed set of configuration plots.

7.5.1 Run a.20.0.0 (b= $20\lambda$ , a=b\*.001,  $\rho$ 2= $20\lambda$ , m=0)

	value	min	max	delta	Qty of Points	
EO	1. V/m	-	-	-	-	
HO	0.00265258 A/m	-	-	-	-	
λ	$1.50105 \times 10^{10} \text{ Hz}$	-	T	-	-	
Frequency	0.019986 m	-	-	-	-	
a	0.02λ	-	-	-	-	
b	20.λ	-	-	-	-	
ρ1	19.98λ	-	=	-	-	
ρ2	20.λ	-	-	-	-	
$\phi$ range	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550	
$\rho$ (observed)	200.λ	-	-	-	-	
z (observed)	0.25 a & & 0.005 λ	-	-	-	-	
Matching Points	-	-	-	-	7	
θi	55. Deg	1 <b>—</b> 1	-	-	-	
¢i	37. Deg	-	-	-	-	
n	-	- 3	3	1	7	
1	-	0	0	1	1	
m	-	0	0	1	1	
max allowable m	0.04	-	-	-	-	
max allowable 1	8.537	-	-	-	-	
Boundary	Boundary a	-	_	-	-	

Table 4 Detailed parameters summary for changing  $\varphi$  plots of Run a.20.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-6 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.*20.0.0



Figure 7-7 Polar Plot form of RCS dBsm for  $E\rho$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.20.0.0

 $E_{\phi}$  TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



Figure 7-8 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.20.0.0



Figure 7-9 Polar Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0



*Figure 7-10 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.*20.0.0



Figure 7-11 XY Plot form of RCS dBsm for  $E_{\rho}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0



Figure 7-12 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0



Figure 7-13 XY Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0

	-					
	value	min	max	delta	Qty of Points	
EO	1. V/m	-	-	-	-	
HO	0.00265258 A/m		-	-	-	
λ	0.019986 m	-	-	-	-	
Frequency	$1.50105 \times 10^{10} \text{ Hz}$		-	-	-	
a	0.02λ	-	-	-	-	
b	20.λ		-	-	-	
ρ1	19.98λ	· · · ·	-	-	-	
ρ2	20.λ	-	-	-	-	
ρ range		17.982λ	30. λ	0.0218907 λ	550	
$\phi$ (observed)	37. Deg	-	-	-	-	
z (observed)	0.25 a & & 0.005 λ		-	-	-	
Matching Points	-	-	-	-	7	
θi	55. Deg		-	-	-	
φi	37. Deg	-	-	-	-	
n	-	-3	3	1	7	
1	-	0	0	1	1	
m	-	Ō	0	1	1	
max allowable m	0.04	-	-	-		
max allowable 1	8.537	-	-	-	-	
Boundary	Boundary a	-	-	-	-	

Table 5 Detailed parameters summary for changing  $\rho$  plots of Run a.20.0.0



*Figure 7-14 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.*20.0.0



*Figure 7-15 XY Plot of Scattered + Incident Field Amplitude, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.*20.0.0



*Figure 7-16 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.*20.0.0



Figure 7-17 XY Plot of Scattered + Incident Field Amplitude, for  $E\rho$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0



*Figure 7-18 XY Plot of Scattered Field Amplitude Only, for*  $E\varphi$ *, of the Smooth Cylinder TM* + *TE mode and Corrugated Cylinder hybrid mode for Run a.*20.0.0



Figure 7-19 XY Plot of Scattered + Incident Field Amplitude, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0



Figure 7-20 XY Plot of Scattered Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0



Figure 7-21 XY Plot of Scattered + Incident Field Amplitude, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.20.0.0

# 7.5.2 Run a.2.0.0 (b= $2\lambda$ , a=b\*.001, $\rho 2=2\lambda$ , m=0)

		•				
	value	min	max	delta	Qty of Points	
EO	1. V/m	-	-	-	-	
HO	0.00265258 A/m	-	-	-	-	
λ	$1.50105 \times 10^{10} \text{ Hz}$	-	-	-	-	
Frequency	0.019986 m	-	-	·-	- 1	
a	0.002λ	-	-	-	-	
b	2.λ	-	-		-	
ρ1	1.998 λ	-	-	-	-	
ρ2	2.λ	-	-	-	-	
<pre></pre>	-	0.327273 Deg	359.673 Deg 0.6545451		550	
$\rho$ (observed)	20.λ	-	-	-	-	
z (observed)	0.25 a & & 0.0005 λ	-	-	-	-	
Matching Points	-	-	-	-	7	
θi	55. Deg	-	-	-	-	
φi	37. Deg	-	-	-	-	
n	-	- 3	3	1	7	
1	-	0	0	1	1	
m	-	0	0	1	1	
max allowable m	0.004	1	-	-	-	
max allowable 1	0.8537	-	-	1 <del></del>	-	
Boundary	Boundary a	-		2 <b>-</b>	-	

Table 6 Detailed parameters summary for changing  $\varphi$  plots of Run a.2.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-22 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.2.0.0* 



Figure 7-23 Polar Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.2.0.0

 $E_{\phi}$  TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



Figure 7-24 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.2.0.0



Figure 7-25 Polar Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0



*Figure 7-26 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0* 



*Figure 7-27 XY Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0*


Figure 7-28 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0



Figure 7-29 XY Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	0.019986 m	-	-	-	-
Frequency	$1.50105 \times 10^{10} \text{ Hz}$	-	-	-	-
a	0.002λ	-	-		-
b	2.λ	-	-	-	-
ρ1	1.998 λ	-	-	-	-
ρ2	2.λ	-	-	-	-
ρ range		1.7982 λ	12.λ	0.0185825 λ	550
$\phi$ (observed)	37. Deg	-	-	-	-
z (observed)	0.25 a & & 0.0005 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg		-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1		0	0	1	1
m	-	0	0	1	1
max allowable m	0.004	-	-	-	-
max allowable 1	0.8537	-	-	-	-
Boundary	Boundary a	-	-	-	-

Table 7 Detailed parameters summary for changing  $\rho$  plots of Run a.2.0.0



*Figure 7-30 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.*2.0.0



*Figure 7-31 XY Plot of Scattered + Incident Field Amplitude, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.*2.0.0



*Figure 7-32 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0* 



E<sub>p</sub> TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

Figure 7-33 XY Plot of Scattered + Incident Field Amplitude, for  $E\rho$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0



*Figure 7-34 XY Plot of Scattered Field Amplitude Only, for*  $E\varphi$ *, of the Smooth Cylinder TM* + *TE mode and Corrugated Cylinder hybrid mode for Run a.*2.0.0



E<sub>p</sub> TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

Figure 7-35 XY Plot of Scattered + Incident Field Amplitude, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0



Figure 7-36 XY Plot of Scattered Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0



Figure 7-37 XY Plot of Scattered + Incident Field Amplitude, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.2.0.0

# 7.5.3 Run a.0.1.0.0 (b=0.1 $\lambda$ , a=b\*.001, $\rho$ 2=0.1 $\lambda$ , m=0)

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	$1.50105 \times 10^{10} \text{ Hz}$	-	-	-	-
Frequency	0.019986 m	-	-	-	-
a	0.0001λ	-	-	-	-
b	0.1λ	-	-	-	-
ρ1	0.0999λ		-	-	-
ρ2	0.1λ	-	-	-	-
<pre></pre>	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
$\rho$ (observed)	1.λ	-	-	-	-
z (observed)	$0.25 a \& \& 0.000025 \lambda$	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	8 <del></del>	-	-	-
φi	37. Deg	-	-	-	-
n	-	- 3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.0002		-	-	
max allowable 1	0.042685	-	-	-	-
Boundary	Boundary a	-	-	-	-

#### Table 8 Detailed parameters summary for changing $\varphi$ plots of Run a.0.1.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



Figure 7-38 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.0.1.0.0

 $E_{\rho}$  TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



Figure 7-39 Polar Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.0.1.0.0



Figure 7-40 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a.0.1.0.0

ETotal TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-41 Polar Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.1.0.0* 



*Figure 7-42 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.1.0.0* 



Figure 7-43 XY Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.1.0.0



Figure 7-44 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.1.0.0



Figure 7-45 XY Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.1.0.0

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-		-	-
λ	0.019986 m	-	-	-	-
Frequency	$1.50105 \times 10^{10} \text{ Hz}$	-	-	-	-
a	0.0001λ	-	-	-	-
b	0.1λ	-	-	-	-
ρ1	0.0999λ	-	-	-	-
ρ2	0.1λ	-	-	-	-
ρ range	-	0.08991 λ	10.1λ	0.0182333λ	550
$\phi$ (observed)	37. Deg	-	-	-	-
z (observed)	0.25 a & & 0.000025 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.0002	-	-	-	-
max allowable 1	0.042685	-	-	-	-
Boundary	Boundary a	-	-	-	-

Table 9 Detailed parameters summary for changing  $\rho$  plots of Run a.0.1.0.0



*Figure 7-46 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0* 



Figure 7-47 XY Plot of Scattered + Incident Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0



Figure 7-48 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0



Figure 7-49 XY Plot of Scattered + Incident Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0



Figure 7-50 XY Plot of Scattered Field Amplitude Only, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0



Figure 7-51 XY Plot of Scattered + Incident Field Amplitude Only, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0



Figure 7-52 XY Plot of Scattered Field Amplitude Only, for E<sub>Total</sub>, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0



Figure 7-53 XY Plot of Scattered + Incident Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a.0.10.0.0

# 7.5.4 Run b.20.0.0 (b=20 $\lambda$ , a=b\*.001, $\rho$ 2=20 $\lambda$ , m=0)

-					
	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	$1.50105 \times 10^{10}$ Hz	-	-	-	-
Frequency	0.019986 m	-	-	-	
a	0.02λ	-	-	-	-
b	20.λ	-	-	-	-
ρ1	19.98 λ	-		100 C	=
ρ2	20.λ	-	-	-	-
<pre></pre>	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
$\rho$ (observed)	200.λ	-	-	-	-
z (observed)	$500.5 a \&\& 10.01 \lambda$	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	-	30 <del>-</del>	-	<b>1</b> 3
φi	37. Deg	-	-	-	-
n	-	- 3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.04	-	-	-	-
max allowable 1	8.537	-		10	-
Boundary	Boundary b	-	-	-	-

Table 10 Detailed parameters summary for changing  $\varphi$  plots of Run b.20.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-54 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.20.0.0* 



Figure 7-55 Polar Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.20.0.0

 $E_{\phi}$  TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-56 Polar Plot form of RCS dBsm for Eq of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.20.0.0* 



Figure 7-57 Polar Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0



*Figure 7-58 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0* 



Figure 7-59 XY Plot form of RCS dBsm for  $E_{\rho}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0



Figure 7-60 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0



Figure 7-61 XY Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	0.019986 m	-	-	-	-
Frequency	$1.50105 \times 10^{10} \text{ Hz}$	-	-	-	-
a	0.02λ	-	-		-
b	20.λ	-	-	-	-
ρ1	19.98 λ	-	-	-	-
ρ2	20.λ	-	-	-	-
ρ range	-	17.982 λ	30. λ	0.0218907λ	550
$\phi$ (observed)	37. Deg	-	-	-	-
z (observed)	500.5 a & & 10.01 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg		-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.04	-	-	-	-
max allowable 1	8.537	-	-	-	-
Boundary	Boundary b	-	-	-	-

Table 11 Detailed parameters summary for changing  $\rho$  plots of Run b.20.0.0



*Figure 7-62 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0* 



*Figure 7-63 XY Plot of Scattered + Incident Field Amplitude, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0* 



*Figure 7-64 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0* 



Figure 7-65 XY Plot of Scattered + Incident Field Amplitude, for  $E\rho$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0



*Figure 7-66 XY Plot of Scattered Field Amplitude Only, for*  $E\varphi$ *, of the Smooth Cylinder TM* + *TE mode and Corrugated Cylinder hybrid mode for Run* b.20.00



Figure 7-67 XY Plot of Scattered + Incident Field Amplitude, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0



Figure 7-68 XY Plot of Scattered Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0



Figure 7-69 XY Plot of Scattered + Incident Field Amplitude, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.20.0.0

#### 7.5.5 Run b.2.0.0 (b= $2\lambda$ , a=b\*.001, $\rho 2=2\lambda$ , m=0)

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m		-	-	-
λ	1.50105 × 10 <sup>10</sup> Hz	121		-	1
Frequency	0.019986 m	-	<u></u>	21	100
a	0.002λ	-	-	-	
b	2.λ	-		=	-
ρ1	1.998 λ	-	-	-	-
ρ2	2.λ	-	-	-	-
$\phi$ range	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
$\rho$ (observed)	20.λ	-	100 C	-	-
z (observed)	$500.5 a \&\& 1.001 \lambda$	-	-	-	-
Matching Points	-	-		=	7
θi	55. Deg	-	а- С	-	-
¢i	37. Deg	-	-	-	-
n	-4	- 3	3	1	7
1	-0	0	0	1	1
m	-	0	0	1	1
max allowable m	0.004	-	· · · · · ·	-	8-2 -
max allowable 1	0.8537	-	· · · · · ·	-	-
Boundary	Boundary b	-	-	-	-

Table 12 Detailed parameters summary for changing  $\varphi$  plots of Run b.2.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-70 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.2.0.0

Ep TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-71 Polar Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.2.0.0* 



Figure 7-72 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.2.0.0

ETotal TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-73 Polar Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0



*Figure 7-74 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0* 



*Figure 7-75 XY Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0* 



Figure 7-76 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0

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*Figure 7-77 XY Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0* 

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	(-)
HO	0.00265258 A/m	-	-	-	-
λ	0.019986 m		-	-	-
Frequency	1.50105 × 10 <sup>10</sup> Hz	-		1774	100
a	0.002λ		-	1	-
b	2.λ		-	( <del></del> )	-
ρ1	1.998 λ	-	-	-	-
ρ2	2.λ	-	-	-	-
$\rho$ range	120	1.7982 λ	12.λ	$0.0185825 \lambda$	550
<pre></pre>	37. Deg		5	-	-
z (observed)	$500.5 a \&\& 1.001 \lambda$		-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg		-	-	-
φi	37. Deg	-	-	-	-
n	_	-3	3	1	7
1		0	0	1	1
m		0	0	1	1
max allowable m	0.004	-	-	-	-
max allowable 1	0.8537	-	-	-	-
Boundary	Boundary b	-	-		5 S <u>-</u>

Table 13 Detailed parameters summary for changing  $\rho$  plots of Run b.2.0.0



*Figure 7-78 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0* 



Ez TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

*Figure 7-79 XY Plot of Scattered + Incident Field Amplitude, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0* 



*Figure 7-80 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0* 



Ep TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

Figure 7-81 XY Plot of Scattered + Incident Field Amplitude, for  $E\rho$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0



*Figure 7-82 XY Plot of Scattered Field Amplitude Only, for*  $E\varphi$ *, of the Smooth Cylinder TM* + *TE mode and Corrugated Cylinder hybrid mode for Run* b.2.0.0



E<sub>0</sub> TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

Figure 7-83 XY Plot of Scattered + Incident Field Amplitude, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0



Figure 7-84 XY Plot of Scattered Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0



Figure 7-85 XY Plot of Scattered + Incident Field Amplitude, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.2.0.0

# 7.5.6 Run b.0.1.0.0 (b=0.1 $\lambda$ , a=b\*.001, $\rho$ 2=0.1 $\lambda$ , m=0)

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
но	0.00265258 A/m	() — ()	-	-	-
λ	1.50105 × 10 <sup>10</sup> Hz	12	_	-	-
Frequency	0.019986 m			121	
a	0.0001λ		-	-	-
b	0.1λ	-	-	( <del>) -</del> 0	-
ρ1	0.0999λ	-	-	-	-
ρ2	0.1λ	() — ()	-	-	-
<pre></pre>	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
ρ (observed)	1.λ	-	-	-	-
z (observed)	500.5 a & & 0.05005 λ	1.00	-	-	-
Matching Points	-	(c <del></del> )	-		7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	- 3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.0002		-	-	-
max allowable 1	0.042685	-	-	-	-
2 Boundary	Boundary b	_	2		_

Table 14 Detailed parameters summary for changing  $\varphi$  plots of Run b.0.1.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-86 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.0.1.0.0
Ep TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



*Figure 7-87 Polar Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.0.1.0.0* 



Figure 7-88 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run b.0.1.0.0

ETotal TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-89 Polar Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.1.0.0* 



*Figure 7-90 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.1.0.0* 



*Figure 7-91 XY Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.1.0.0* 



Figure 7-92 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.1.0.0



Figure 7-93 XY Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.1.0.0

	value	min	max	delta	Qty of Points
EO	1. V/m	-	<u></u>	-	-
HO	0.00265258 A/m	-	19 <del>-</del> 1	-	-
λ	0.019986 m	-	874	-	-
Frequency	1.50105 × 10 <sup>10</sup> Hz	-	25	-	15
a	0.0001λ	-	10-	-	-
b	0.1λ	-	8 <b>-</b> -	-	-
ρ1	0.0999λ	-	-	-	-
ρ2	0.1λ	-	-	-	-
$\rho$ range	-	$0.08991 \lambda$	$10.1\lambda$	0.0182333λ	550
<pre></pre>	37. Deg	-	25	· · · · · · · · · · · · · · · · · · ·	
z (observed)	500.5 a &  0.05005 λ	-	8.0	-	-
Matching Points	-	-	· -	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	- 3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.0002	_		10 00 <u>-</u> 2	-
max allowable 1	0.042685	-		1	-
Boundary	Boundary b			10 10 <u>1</u>	

Table 15 Detailed parameters summary for changing  $\rho$  plots of Run b.0.1.0.0



Figure 7-94 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0



Figure 7-95 XY Plot of Scattered + Incident Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0



*Figure 7-96 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.00* 



Ep TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

Figure 7-97 XY Plot of Scattered + Incident Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0



E<sub>0</sub> TM+TE Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

Figure 7-98 XY Plot of Scattered Field Amplitude Only, for Eq, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0



E<sub>d</sub> TM+TE Inc + Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)

*Figure 7-99 XY Plot of Scattered + Incident Field Amplitude Only, for Eq, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0* 



Figure 7-100 XY Plot of Scattered Field Amplitude Only, for E<sub>Total</sub>, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0



Figure 7-101 XY Plot of Scattered + Incident Field Amplitude Only, for ETotal, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run b.0.10.0.0

## 7.5.7 Run a\_plus\_b.20.0.0 (b=20 $\lambda$ , a=b\*.001, $\rho$ 2=20 $\lambda$ , m=0)

Table	e 16	Detaile	d parameters	summary f	or cl	hanging	φ pl	lots of	Run a_	plus_	_b.20.0.0	)
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	value	min	max	delta	Qty of Points
EO	1.V/m	-	-	-	-
HO	0.00265258 A/m		-	-	-
λ	$1.50105 \times 10^{10} \text{ Hz}$		-	-	-
Frequency	0.019986m	-	-	-	-
a	0.02λ	-	-	-	-
b	20.λ	-	-	-	-
ρ1	<b>19.98</b> λ	-	-	-	-
ρ2	20.λ	-	-	-	-
$\phi$ range	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
$\rho$ (observed)	200.λ	-	-	-	-
z (observed)	0.25 a &  0.005 λ	-	-	-	-
Matching Points	-	-	-	E .	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.04	-	-	-	-
max allowable 1	8.537	- 1 - 1	-	-	-
Boundary	Boundary a+b	-	-	-	-

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-102 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0* 



Figure 7-103 Polar Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0

 $E_{\phi}$  TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-104 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-105 Polar Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



*Figure 7-106 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0* 



Figure 7-107 XY Plot form of RCS dBsm for  $E_{\rho}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-108 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-109 XY Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0

	value	min	max	delta	Qty of Points
EO	1.V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	0.019986 m	-	-	-	-
Frequency	1.50105×10 <sup>10</sup> Hz	-	-	-	-
a	0.02 λ	-	-	-	-
b	20.λ	-	-	-	-
ρ1	<b>19.98</b> λ	-	-	-	-
ρ2	20.λ	-	-	-	-
$\rho$ range	-	17.982 λ	30.λ	0.0218907 λ	550
$\phi$ (observed)	37. Deg	-	-	-	-
z (observed)	0.25 a &  0.005 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.04	-	-	-	-
max allowable 1	8.537	-	-	-	-
Boundary	Boundary a+b	-	-	-	-

Table 17 Detailed parameters summary for changing ρ plots of Run a\_plus\_b.20.0.0



*Figure 7-110 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0* 



*Figure 7-111 XY Plot of Scattered + Incident Field Amplitude, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0* 



*Figure 7-112 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0* 



Figure 7-113 XY Plot of Scattered + Incident Field Amplitude, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-114 XY Plot of Scattered Field Amplitude Only, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-115 XY Plot of Scattered + Incident Field Amplitude, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-116 XY Plot of Scattered Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0



Figure 7-117 XY Plot of Scattered + Incident Field Amplitude, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.20.0.0

## 7.5.8 Run a\_plus\_b.2.0.0 (b= $2\lambda$ , a=b\*.001, $\rho 2=2\lambda$ , m=0)

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	$1.50105 \times 10^{10} \text{ Hz}$		-	-	-
Frequency	0.019986 m	-	-	-	-
a	0.002λ	-	-	-	-
b	2.λ	-	-	-	-
ρ1	1.998 λ	-	-	-	-
ρ2	2.λ	-	-	-	-
$\phi$ range	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
$\rho$ (observed)	20.λ	-	-	-	-
z (observed)	0.25 a &  0.0005 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.004	-	-	-	-
max allowable 1	0.8537	-	-	-	-
Boundary	Boundary a+b	-	-	-	-

Table 18 Detailed parameters summary for changing  $\varphi$  plots of Run a\_plus\_b.2.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-118 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0

Ep TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-119 Polar Plot form of RCS dBsm for  $E\rho$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0



Figure 7-120 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0

ETotal TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-121 Polar Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



*Figure 7-122 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



*Figure 7-123 XY Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



Figure 7-124 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0



*Figure 7-125 XY Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 

	value	min	max	delta	Qty of Points
EO	1.V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	0.019986 m	-	-	-	-
Frequency	1.50105×10 <sup>10</sup> Hz	-	-	-	-
a	0.002λ	-	-	-	-
b	2.λ	-	-	-	-
ρ1	1.998 λ	-	-	-	-
ρ2	2.λ	-	-	-	-
$\rho$ range	-	1.7982 λ	12.λ	$0.0185825 \lambda$	550
$\phi$ (observed)	37. Deg	-	-	-	-
z (observed)	0.25 a & & 0.0005 λ	-	-	-	-
Matching Points		-	-	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.004	-	-	-	-
max allowable 1	0.8537	-	-		-
Boundary	Boundary a+b	-	-	-	-

Table 19 Detailed parameters summary for changing  $\rho$  plots of Run a\_plus\_b.2.0.0



*Figure 7-126 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



*Figure 7-127 XY Plot of Scattered + Incident Field Amplitude, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



Figure 7-128 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0



*Figure 7-129 XY Plot of Scattered + Incident Field Amplitude, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



*Figure 7-130 XY Plot of Scattered Field Amplitude Only, for Eq, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0* 



Figure 7-131 XY Plot of Scattered + Incident Field Amplitude, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0



Figure 7-132 XY Plot of Scattered Field Amplitude Only, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0



Figure 7-133 XY Plot of Scattered + Incident Field Amplitude, for  $E_{Total}$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.2.0.0

## 7.5.9 Run a\_plus\_b.0.1.0.0 (b=0.1λ, a=b\*.001, ρ2=0.1λ, m=0)

	value	min	max	delta	Qty of Points
EO	1.V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	1.50105 × 10 <sup>10</sup> Hz	-	-	-	
Frequency	0.019986 m	-	-	-	-
a	0.0001λ	-	-	-	-
b	0.1λ	-	-	-	-
ρ1	0.0999λ	-	-	-	-
ρ2	0.1λ	-	-	-	-
<pre></pre>	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
ρ (observed)	1.λ	-	-	-	-
z (observed)	0.25 a & & 0.000025 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.0002	-	-	-	-
<pre>max allowable 1</pre>	0.042685	-	-	-	-
Boundary	Boundary a+b	-	-	-	-

Table 20 Detailed parameters summary for changing  $\varphi$  plots of Run a\_plus\_b.0.1.0.0

Ez TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



Figure 7-134 Polar Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0

Ep TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)



Figure 7-135 Polar Plot form of RCS dBsm for  $E\rho$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0



Figure 7-136 Polar Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE modes and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0

ETotal TM+TE RCS (dBsm) Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)



*Figure 7-137 Polar Plot form of RCS dBsm for ETotal of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0* 



*Figure 7-138 XY Plot form of RCS dBsm for Ez of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0* 



*Figure 7-139 XY Plot form of RCS dBsm for Ep of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0* 



Figure 7-140 XY Plot form of RCS dBsm for  $E\varphi$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0



Figure 7-141 XY Plot form of RCS dBsm for  $E_{Total}$  of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.1.0.0

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	0.00265258 A/m	-	-	-	-
λ	0.019986 m	-	-	-	-
Frequency	1.50105×10 <sup>10</sup> Hz	-	-	-	-
a	$0.0001 \lambda$	-	-	-	-
b	0.1λ	-	-	-	-
ρ1	0.0999λ	-	-	-	-
ρ2	0.1λ	-	-	-	-
$\rho$ range	-	$0.08991 \lambda$	$10.1\lambda$	$0.0182333 \lambda$	550
$\phi$ (observed)	37. Deg	-	-	-	-
z (observed)	0.25 a & £ 0.000025 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	55. Deg	-	-	-	-
φi	37. Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m		0	0	1	1
max allowable m	0.0002	-	-	-	-
max allowable 1	0.042685	-	-	-	-
Boundary	Boundary a+b	-	-	-	-

Table 21 Detailed parameters summary for changing  $\rho$  plots of Run a\_plus\_b.0.1.0.0



Figure 7-142 XY Plot of Scattered Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0



Figure 7-143 XY Plot of Scattered + Incident Field Amplitude Only, for Ez, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0



Figure 7-144 XY Plot of Scattered Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0



Figure 7-145 XY Plot of Scattered + Incident Field Amplitude Only, for Ep, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0



Figure 7-146 XY Plot of Scattered Field Amplitude Only, for  $E\varphi$ , of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0


*Figure 7-147 XY Plot of Scattered + Incident Field Amplitude Only, for Eq, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0* 



Figure 7-148 XY Plot of Scattered Field Amplitude Only, for E<sub>Total</sub>, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0



Figure 7-149 XY Plot of Scattered + Incident Field Amplitude Only, for ETotal, of the Smooth Cylinder TM + TE mode and Corrugated Cylinder hybrid mode for Run a\_plus\_b.0.10.0.0

# 7.5.10 Comparison to Other Corrugated Cylinder Methods

	value	min	max	delta	Qty of Points
EO	1. V/m	-	-	-	-
HO	2.65258×10 <sup>-7</sup> A/m	-	-	-	-
λ	1.50105 × 10 <sup>10</sup> Hz	-	-	-	-
Frequency	0.019986 m	-	-	-	-
a	0.2λ	-	-	-	-
b	0.1λ	-	-	-	-
ρ1	0.4λ	-	-	-	-
ρ2	0.5λ	-	-	-	-
φ range	-	0.327273 Deg	359.673 Deg	0.654545 Deg	550
ρ (observed)	10.λ	-	-	-	-
z (observed)	0.25 a & & 0.05 λ	-	-	-	-
Matching Points	-	-	-	-	7
θi	85. Deg	-	-	-	-
φi	0.01 Deg	-	-	-	-
n	-	-3	3	1	7
1	-	0	0	1	1
m	-	0	0	1	1
max allowable m	0.4	-	-	-	-
max allowable 1	0.273853	-	-	-	-
Boundary	Boundary a+b	-	-	-	-

*Table 22 Detailed parameters summary for changing \varphi plots of Run a\_plus\_b.compare* 



Figure 7-150 XY Plot form of Cross-Polar Corrugated Cylinder  $\sigma_{\phi\theta}/\lambda_0$  (dB) for Run a\_plus\_b.Compared with results of the finite element method (FEM) and method of moments (MoM) from [27]

### 7.5.11 Varied Dielectric Constant with Comparisons

The scattered axial field ( $E_z$  for  $TM_z$  mode) vs  $\varphi$  is plotted below in Figure 7-151 for several cases of interest with a varying dielectric constant,  $\varepsilon_r$ ., where  $\varepsilon_r$  is selected to be a real value only. It is evident that the corrugated cylinder with dielectric loading has a generally reduced scattered field compared to the smooth cylinder.



Figure 7-151 Comparison of scattered axial fields of a smooth cylinder (solid line) with the corrugated cylinder (dotted line) with lossless dielectric loading of dielectric constant:  $\varepsilon_r=1$  a)  $\varepsilon_r=4$ ; b)  $\varepsilon_r=9$ ; c)

Now, the case of lossy dielectric loading ( $\epsilon_r$  is a complex value) is examined with results of the scattered axial field ( $E_z$  for TM<sub>z</sub> mode) vs  $\phi$  is plotted below in Figure 7-152 for several cases.  $\epsilon_r$ .



Figure 7-152 Axial scattered fields of a smooth cylinder (solid line) and corrugated cylinder (dotted line) with lossy dielectric loading. Dielectric constants: a)  $\varepsilon_r=4-j1$ ; b)  $\varepsilon_r=6.29$ ; c)  $\varepsilon_r=6.29-j1.73$ 

It is evident that a complex permittivity yields a generally smaller scattered field. The dielectric constants in (b) and (c) were chosen to correspond to those found in [33]. These results can also be found in [34] with some additional discussion.

# 7.6 Conclusions

This dissertation presented an alternate method to calculate the scattered field of a corrugated cylinder. The method of utilizing a hybrid mode of  $TM_z$  and  $TE_z$  with a radial waveguide representation of the corrugation was demonstrated.

In the comparison between the periodic corrugated cylinder model from this research and the model of a smooth cylinder, there was a lot of agreement between the fields of both models with the exception of the  $E_{\phi}$  fields. There are a few reasons for this:

 $\Box$  This technique is an approximation and as such, will have errors

- More specifically, the corrugated cylinder is approximated to a smooth cylinder, by shrinking the 'a' dimension, though not eliminated, so there will be some artifacts that make it different than a smooth cylinder
- Also, the cross-polarization nature of the problem allows fields to manifest themselves between TE and TM modes

What's important to note is what the limitations are and what the capabilities are of a given method, to know when to best apply it or to seek an alternative method.

Overall, good agreement was attained between the periodic corrugated cylinder model from this research and the model of a smooth cylinder, for small corrugation openings approximating a smooth cylinder, where the relative dimensions of the corrugated cylinder where much greater than  $\lambda$  (optical region as indicated in Figure 7-1). There was some agreement in this same comparison at the Rayleigh scattering region, where the relative dimensions of the corrugated cylinder where much less than  $\lambda$ . There was also good agreement attained between the periodic corrugated model of this research when compared to the referenced periodic corrugated cylinder FEM and MoM techniques, which was modeled in the Rayleigh scattering region.

It is concluded that the techniques discussed in this dissertation is most suitable for the optical region, where the  $\lambda$  of interest is much smaller than the dimensions of the periodic corrugated cylinder of interest. Also, from the results when compared to the FEM and MoM techniques, it is concluded that the Rayleigh scattering region, where the  $\lambda$  of interest is much larger than the dimensions of the periodic corrugated cylinder of interest, is suitable for the technique presented in this research.

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# 7.7 Open Questions for Future Research

There were limitations discovered of the presented method that merits future research. Many challenges were faced, especially in the numerical solving of the unknown expansion coefficients which could benefit from improved methods. Also, there were many techniques that were investigated but not implemented. Here is a list of future work that can enhance or build on this research:

- □ Improve or replace the computationally expensive loop solve method.
- $\Box$  Summation truncation using the symmetry of the summation as in [12, p. 603].
- □ Using Poisson's sum formula to reduce any of the infinite series equations prior to truncation [34].
- Comparison models for varying the permittivity of region I, representing the dielectric loading of the periodic corrugated cylinder
- Using Eigenvalues and Eigenvectors solutions approach for solving the unknown expansion coefficients
- Using a continuous periodic function approximation to asymptotically represent the periodicity of the corrugated cylinder
- Applying the asymptotic boundary condition method, [26], for improving solution agreement in regimes where the relative dimensions of the corrugated cylinder are that of  $\lambda$ .
- □ Construction and testing of a physical model for further comparison

APPENDICES

# APPENDIX A

Mathematica<sup>®</sup> code for the modeling and comparison of the scattered field of a periodic cylinder and smooth circular cylinder



Equations [NOT USED]

Here EIz[Ann\_] := hnmj + + Anm; h(00755)- HIz[Bnn\_] := inmj\*\*Bnm;

- r(44758)- EIphi[Anm\_, Bnm\_] := (knmj \*\* Anm) + (1nmj \*\* Bnm);
- HIphi[Anm\_, Bnm\_] := (onmj ++ Anm) + (pnmj ++ Bnm);

r(44758)= EIrho[Anm\_, Bnm\_] := (rnmj \*\* Anm) + (snmj \*\* Bnn); (01759)- HIrho[Anm\_, Bnm\_] := (tnmj \*\* Anm) + (unmj \*\* Bnm);

### Variables

 $\operatorname{humjeq}[\phi_{-}, z_{-}, \rho_{-}] := e^{i\pi\phi} \operatorname{Cos}[kzm[m] * (z - \frac{a}{2})]$  $\left( \texttt{HankelH1}[n, \ \texttt{k} \textit{\rhom}[m] \ \textit{\rho}] - \frac{\texttt{HankelH2}[n, \ \texttt{k} \textit{pm}[m] \ \textit{\rho}] \ \texttt{HankelH1}[n, \ \texttt{k} \textit{\rhom}[m] \ \textit{\rho}]}{\texttt{HankelH2}[n, \ \texttt{k} \textit{\rhom}[m] \ \textit{\rho}]} \right);$ . inmjeq[\$\phi\_, z\_, \$\rho\_] :=

 $e^{in\phi} \operatorname{Sin}\left[kzm[m]\left(z-\frac{a}{2}\right)\right] \left(\operatorname{RankelHi}[n, k\rho m[m]\rho] - \left(\operatorname{RankelH2}[n, k\rho m[m]\rho]\right)\right]$  $\left(k\rho m[m] \text{HankelHi}[n-1, k\rho m[m] \rho 1] - \frac{n \text{HankelHi}[n, k\rho m[m] \rho 1]}{\rho 1}\right)\right)$  $\left(k\rho m[m] \operatorname{HankelH2}[n-1, k\rho m[m], \rho 1] - \frac{n \operatorname{HankelH2}[n, k\rho m[m], \rho 1]}{\alpha 1}\right)\right)$ ;

$$\begin{split} & \max_{1 \leq i \leq n} \max_{k \in \mathcal{M}} \log[d_{k-1} = a_{i-1} \rho_{i-1}^{k-1} + \frac{k \operatorname{mn}(n)}{k \operatorname{con}(n)} \cdot \operatorname{Cost}\left[\left(a - \frac{k}{2}\right) k \operatorname{cm}(n)\right] \\ & \left(\operatorname{Rankelist}(n, k \operatorname{cm}(n) \rho_{i}) - \frac{\operatorname{Rankelist}(n, k \operatorname{cm}(n) \rho_{i})}{\operatorname{Rankelist}(n, k \operatorname{cm}(n) \rho_{i})}\right); \\ & \operatorname{Rankelist}(n, k \operatorname{cm}(n) \rho_{i}) - \frac{\operatorname{Rankelist}(n, k \operatorname{cm}(n) \rho_{i})}{\operatorname{Rankelist}(n, k \operatorname{cm}(n) \rho_{i})}; \end{split}$$

 $\texttt{P(FOTED: lnmjeq[$\phi_-, $z_-, $\rho_-] := $i$ $\mu$ left $e^{i$ $n$ $\phi$}$} \frac{1}{k \rho \texttt{m[m]}^2} Sin[\left(z - \frac{a}{2}\right) k\texttt{zm[m]}]$  $\left(\frac{1}{2} \text{ k}\rho m[m] \left(\text{HankelH1}[n-1, k\rho m[m] \rho] - \text{HankelH1}[n+1, k\rho m[m] \rho]\right)\right)$ 

 $(k\rho m[m] (HankelH2[n-1, k\rho m[m] \rho] - HankelH2[n+1, k\rho m[m] \rho])$  $\left[k\rhom[m] \operatorname{HankelHl}[n-1, k\rhom[m] \rho 1] - \frac{n \operatorname{HankelHl}[n, k\rhom[m] \rho 1]}{\rho 1}\right]$ 

 $\left(2\left(k\rho m[m] \text{ HankelH2}[n-1, k\rho m[m] \rho 1] - \frac{n \text{ HankelH2}[n, k\rho m[m] \rho 1]}{\rho 1}\right)\right)\right);$ 

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MankelH1[n, kom[m] p1]) / (2 MankelH2[n, kom[m] p1]));  $\begin{array}{l} \mathsf{nmjeq[}(\phi_{-}, \ z_{-}, \ \rho_{-}] := & \\ \frac{1}{\rho} \ n \ e^{h+\mu} \ \frac{k \operatorname{nm}[n]}{k \rho \operatorname{m}[n]^2} \ \mathrm{Sin}\left[\left(z - \frac{a}{2}\right) \ k \operatorname{nm}[n]\right] \left( \mathsf{HankelH1}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ k \rho \operatorname{m}[n] \ \rho] - \left( \mathsf{HankelH2}[n, \ h \rho] - \left($  $\begin{pmatrix} \rho \\ k\rho m[m] \text{ HankelH2}[n-1, k\rho m[m] \rho 1] - \frac{n \text{ HankelH2}[n, k\rho m[m] \rho 1]}{\rho 2} \end{pmatrix};$ 

,  $\rho_1 = \beta_1$ mmige[ $\phi_1$ ,  $z_-$ ,  $\rho_-$ ] := -i e<sup>1-s</sup>  $\frac{k \tan[m]}{k om(m)^2} \cos \left[k \tan[m] \left(z - \frac{a}{2}\right)\right]$   $\left[\frac{1}{2} k \cos[m] (\text{HankelHi}(n-1, k om(m) \rho) - \text{HankelHi}(n+1, k om(m) \rho)\right] - \frac{1}{2}$ 2 (kρm[m] (HankelH2[n-1, kρm[m] ρ] - HankelH2[n+1, kρm[m] ρ])  $RankelH1[n, kom[m] \rho 1]) / (2 RankelH2[n, kom[m] \rho 1]);$ 

sumptions sumjeq[ $\phi_{-}$ ,  $z_{-}$ ,  $\rho_{-}$ ] :=  $\frac{(\mu 1 \omega 0)}{\rho} n e^{i n \phi} \frac{1}{k \rho m [n]^2}$ 
$$\begin{split} & \text{mjeq}(\phi_{-}, z_{-}, \rho_{-}) := \frac{1}{\rho_{-}} n e^{-r_{-}} \frac{1}{kon(n)^{2}} \\ & \text{Sin}\Big[ \left( z - \frac{n}{2} \right) kzn(n) \Big] \left( kankelH1(n, kom(m) \rho) - \left[ \text{MankelH2}(n, kom(m) \rho) \right] \left( kom(m) \text{ RankelH1}(n, 1, kom(m) \rho) - \frac{n \text{ MankelH1}(n, kom(m) \rho)}{\rho 1} \right) \Big] / \end{split}$$
 $\rho_1$   $\left(k\rho m[m] \text{ HankelH2}[n-1, k\rho m[m] \rho_1] - \frac{n \text{ HankelH2}[n, k\rho m[m] \rho_1]}{\rho_1}\right)$ ;

$$\begin{split} & - \operatorname{tran} \operatorname{jeq} \left[ \phi_{-}, \, x_{-}, \, \rho_{-} \right] \, := \, - \frac{\omega \sigma \, \epsilon \, 1}{\rho} \, n \, e^{1 + \alpha} \, \frac{1}{k \, con(n)}^{-1} \, \operatorname{con} \left[ \operatorname{kmn} \left[ n - \frac{\kappa}{2} \right] \right] \\ & \left[ \operatorname{KankelHI} \left[ n, \, k \, \rho m \right] \, \rho \right] - \, \frac{\operatorname{KankelHI} \left[ n, \, k \, \rho m \right] \, n \, \rho \, 1 \right]}{\operatorname{KankelHI} \left[ n, \, k \, \rho m \left[ n \right] \, \rho \, 1 \right]} \right]; \end{split}$$

 $\left( k\rho m[m] \left( HankelH2[n-1, k\rho m[m] \rho \right] - HankelH2[n+1, k\rho m[m] \rho ] \right)$  $\left[k\rho m[m] BankelB1[n-1, k\rho m[m] \rho 1] - \frac{n BankelB1[n, k\rho m[m] \rho 1]}{n BankelB1[n, k\rho m[m] \rho 1]}\right]$ 

 $\left(2 \left( k\rho m[m] \operatorname{HankelH2}[n-1, k\rho m[m] \rho 1] - \frac{n \operatorname{HankelH2}[n, k\rho m[m] \rho 1]}{n \operatorname{HankelH2}[n, k\rho m[m] \rho 1]} \right) \right)\right)$ 

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	200 Nesterion Garos_2466[44,1.08   1.3			
	Phi Value and Range			
r(44880)+	$\phi = \phi a;$			
1(4881)-	phidelta = (2 * Pi) / phisteps;			
<pre>r(walle)- phirange = N[Range[(0.5*phidelta), (2*Pi) - (0.5*phidelta), phidelta]];</pre>				
	Matching Points - z's and $\phi$ 's			
Reality .	zateps = joty:			
	jsteps = jqty;			
	(a) matching point optionsa)			
	(+2 ) Changing g's with fixed de)			
	(+B.) Changing d's with fixed z+)			
	(+C.) Changing z's with fixed half \$\$\phi=0\$ and half \$\$\phi=Pi/2+\$)			
	(+D.) Requires overdetermined matrix form.			
	more 1's matching points than unknowns+)			
	(* Changing \$\$ with for multiple z			
	points based on matching point multiplier, mp *)			
	(* D. is not yet implemented *)			
	(**)			
	(* Boundary 'b' z matching points*)			
	(* Boundary 'b' z matching points*)			
	(* Boundary 'b' z matching points*)			
	(*zjblength=b/2;*)			
	(*zjbstep=zjblength/zsteps;*)			
	(*zjb=N[Range[(a/2)+(0.5*zjbstep),(b/2)+(a/2)-(0.5*zjbstep),zjbstep]];*)			
	zjbstart = (a/2) + ((b/zsteps));			
	zjbstop = ((a/2) + b) - ((b/zsteps));			
	zjbstep = (zjbstop - zjbstart) / (zsteps - 1);			
	<pre>zjb = N[Range[zjbstart, zjbstop, zjbstep]];</pre>			
	( $\star$ updated matching points to negate prior matching points -			
Fixed zpoint matching method for varying phi point matches *)				
	<pre>zjb = ConstantArray[zpointb, jsteps];</pre>			
	(**)			
	(**)			
	(* Boundary 'a' z matching points*)			
	(* Boundary 'a' z matching points*)			

(+----

 $\begin{array}{l} (* \; Boundary \;\; ^{i_{1}} \; \times \; matching \; points*) \\ (*rjalengthag/2; +) \\ (*rjalengthight) (rateps; +) \\ (*rjalengthight) (rateps; +) \\ (*rjalengthight) (stapp) (s/2) - (0.5*rjaleng) , rjaleng ] \; ] \; ; \; *) \end{array}$ 

signstart = (-a/2) + ((a/zsteps)); signstop = (+a/2) - ((a/zsteps)); signstop = (signstop - zignstart) / (ssteps - 1); sign = N[Range[zignstart, zignstop, zignstep]];

(\* updated matching points to negate prior matching points -Fixed rpoint matching method for varying phi point matches \*) rjs=ConstantArray[rpoints, jsteps];

-\*1

-\*)

]; (\* updated matching points to negate prior matching points\*) (\*#m=ConstantArray[&a,jsteps]; \*)

(\* updated matching points to negate prior matching points+) (\*matching points of 0 to 201+) detart = (0 + ((3 + 2 + 1 / steps))); detart = (2 + 1) - (((3 + 2 + 1 / steps))); detare = (42 + 1) - (((3 + 2 + 1 / steps))); detare = (42 + 1) - (((3 + 2 + 1 / steps))); dm = M[Bange[detart, detap, detap]];

(\*dm=ConstantArray[da,jsteps];\*) (\*for z matching points\*)
(\*

Numerical Computation of Coefficients and Fields

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lnmjarray = ConstantArray[0, jqty];

(\*Empty Matrices for EqS set, Boundary 'b'+) fnjbprematris + Array[fnjb, (jqty]]; gnj5prematris + Array[fnjb, (qty, lqty, iqty]]; gnj5praray - ConstantArray[0, jqty]; Fnjprematris + Array[fnl, (qty, lqty]]; dnj1prematris + Array[fnl, (qty, lqty]]; dnj1prematris + Array[fnl, (qty, lqty]]; dnj1paray = ConstantArray[0, jqty];

(AEmpty Matrices for Eq6 set, Boundary 'a'+) fnjeprematina Array(fnja, (jqty)]; qnljaprematina Array(fnja, (qty), lqty, jqty); gnljaarray = ConstantArray[0, jqty]; Bongrematina Array[Imm, (mty, lqty)]; inmjørematina Array[Imm, (mty, lqty)]; inmjørematina Array[Imm, (mty, lqty)]; inmjørematina Array[Imm, (mty, lqty)];

('Bapy Matrices for Bg? mat, Boundary 'b') moltparamites array(mab, (styl); moltparamites - Array(mab, (styl); doilynematris - Array(mab, (styl); doily

Completions for tgl est. Roundary (\*\*) migprematiks Array(moj, (syty)); mijaprematiks Array(moj, (syty)); mijaprematiks Array(moj, (syty)); mijaprematiks Array(moj, (syty), laty, (syty)); mijaprematiks Array(moj, (syty), laty, (syty)); mijaprematiks Array(moj, (syty), laty, (sty)); mijaprematiks Array(moj, (syty), laty, (sty)); mijaprematiks Array(moj, (syty), laty, (sty)); mijaprematiks Array(moj, (syty)); mijaprematiks Array(moj, (syty)); mijarray = ConstantArray(6, (syty));

Numerically Solving for Field Components

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Setting Empty Matrices to Solve for Coefficients and Field Components

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(\*Empty Matrices for Eq2 set, Boundary 's'+) Chlaprematik = Array(Chla, (nety. lety)]; anljaprematik = Array(anja, (nety, lety, lety)); anljaprematik = Array(Inja, (nety, lety)]; Angrematik = Array(Inja, (nety, lety)]; Amgrematik = Array(Inja, (nety, lety)]; homjarrasi = Array(Inja, (nety, lety)]; homjarrasi = ConstantArray[0, jety];

(\*Empty Matrices for Eq3 set, Boundary 'b'\*) Dulbprematrix - Array[Dulb, [ngty, lqty]]; (\*Cilb already defined\*) cnl5prematrix - Array[an]5b, [ngty, lqty]]; cnl5prematrix - Array[an]5b, [ngty]; enl5prematrix - Array[an]5b, [ngty]; dnj5prematrix - Array[dnjb, [jqty]]; dnj5prematrix - Array[dnjb, [jqty]];

('Ropty Matrices for Eq4 set, Boundary 's'+) Diapermetris + Array[Onis, (mdy, lqty]); (-Chis and Ama lendy defined) onijoprematris + Array[onis, (mdy, lqty, jqty]); onijoprematris + Array[onis, (mdy, lqty, jqty]); anijoprematris + Array[onis, (mdy, lqty, jqty]); anijoprematris + Array[onis, (mdy, lqty, jqty]); kmajreematris + Array[onis, (mdy, lqty, jqty]); kmajreematris + Array[kms], (mdy, lqty, jqty]); lmajreematris + Array[kms], (mdy, lqty, jqty]);

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PhD Research Garcie_Final_v4.1.nb 21	22 PhD Research Garcia_Final_v4.1.nb
For a count - natu accust > 1 accust	(-Terms TeastSomereallonderray /bodesreamstrik.en]deerray Celall)
For   loount = lqty, loount ≥ 1, loount,	<pre>spinoi; (*Anne LeastSquares[nnmjarray,(DDjaprematrix+an1jaarray.cnia)]; *)</pre>
index = ((ncount - 1) + (lqty)) + lcount;	<pre>weided:// eshibite Least Squares[inmjarray,(injaprematrix+gnijaarray.Dnia)]; *)</pre>
<pre>If[index = jqty,</pre>	Franks America for Staning Field Solutions - Changing Bha
(+TRUE+) Dnlasol((index)) = Flatten(Dnlatemp2((index))):	Empty Arrays for Storing Field Solutions - Changing Rho
Dnlaeq2 = Flatten[Dnlasol[[index]]];	
·	Corrugated Cylinder Empty Arrays
(*FALSE*)	
Dnlaeq2 = Flatten[Append[Flatten[Dnlaeq2], Dnlasol[[index]]]];	Scattered + Incident Arrays
1)	<pre>bitter: Eztemp = ConstantArray[0, Length[rhorange]];</pre>
1	<pre>Ephitemp = ConstantArray[0, Length[rhorange]];</pre>
j'	<pre>krnotemp = ConstantArray[0, Length[rhorange]];</pre>
Hersel - Price (Philabol)	Scattered Only Arrays
second. Dala = Daladoi[[All, 2]];	ExternS = ConstantArrau[0 langth[rhorange]]
<pre>r(coss)= Chia = FullSimplify[chiatems / . Dhiasoi];</pre>	<pre>EphitempS = ConstantArray[0, Length[rhorange]];</pre>
Henry: Ann = FullSimplify[Anntemp2 /. Driasol];	ErhotempS = ConstantArray[0, Length[rhorange]];
<pre>&gt;&gt;&gt; Bnm = FullSimplify[Bnmtemp / . Dnlasol];</pre>	
Solve for Coefficients Cnla, Dnla, Anm, and Bnm - NCAlgebra Method - NOT	Incident Only Arrays
USED	<pre>MASSING- EztempI = ConstantArray[0, Length[rhorange]];</pre>
	EphitempI = ConstantArray[0, Length[rhorange]]; ErhotempI = ConstantArray[0, Length[rhorange]];
Henry (* NCSolve Only Method *)	
(+Dnla =-PseudoInverse[ gnliaarrav_pnmiarrav_PseudoInverse[inmiarrav] gnliaarrav] mnianramitriv.	Regular ("Smooth") Cylinder Empty Arrays
qua jaantay-yuunjantay.reessoonivetee(innjarray).guljaarray).mujaprematrix+ PseudoInverse(quljaarray-pumjarray.PseudoInverse(innjarray).guljaarray).	
onnjarray.PseudoInverse[hnmjarray].bnjaprematrix+	Scattered + Incident Arrays (TM and TE)
FseudoInverse[qnljaarray-pnmjarray.FseudoInverse[inmjarray].gnljaarray]. pnmjarray.FseudoInverse[inmjarray].frianvessiv(v)	<pre>w(coop)- EzregcylTMSandI = ConstantArray[0, Length[rhorange]];</pre>
	ErhoregcylTMSandI = ConstantArray[0, Length[rhorange]];
dnjaprematrix-PseudoInverse[	EphiregcylTMSandI = ConstantArray[0, Length[rhorange]];
cnljaarray-knmjarray.PseudoInverse[hnmjarray].anljaarray].enljaarray.Dnla+	ErhoregcylTESandI = ConstantArray[0, Length[rhorange]];
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Rimjarray. Pseudoinverse[nnmjarray].onjaprematrix+ Pseudoinverse[cnljaarray-knmjarray.Pseudoinverse[hnmjarray].anljaarray].	
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PRD Research Gards, /Tod_vid_Lob   23 Scattered Only Arrays (TM and TE) News. EurogryTMS = ConstantArray(0, Length[rhorange]]; EnhoresysyTMS = ConstantArray(0, Length[rhorange]]; EnhoresysTMS = ConstantArray(0, Length[rhorange]]; EurogryTMS = ConstantArray(0, Length[rhorange]];	<pre>24   POD Research Garcis, Find, willow     (*Begion II temp variables, Total Piald*)     IIIItatemp = 0;     IIIItatemp = 0;     IIIItatemp = 0;     IIIItatemp = 0;     IIIItatemp = 0;</pre>
PAD Research Garcia, Print, ex1.nb 23 Scattered Only Arrays (TM and TE) Entroregoy1786 = ConstantArray(0, Langth[incrange]]; Entroregoy178 = ConstantA	<pre>24   MC Research Gruin, Mail, Milleb (.Region II temp variables, Total Fields) IIIItemp. 0; IIIIItemp. 0; IIIIItemp. 0; IIIIIthtemp. 0; IIIIIthtemp. 0;</pre>
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PRO Research Garcia / Nail (v4.Lnt) 23 Scattered Only Arrays (TM and TE) Sectored Only Arrays (TM and TE) Sectoresystem = ConstantAcray(0, Jangth[:horange]]; Exploresystem =	<pre>24   MC Reserve Great, Foot, will no</pre>
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<pre>23 Scattered Only Arrays (TM and TE) %************************************</pre>	<pre>24 [ MC Reserve Great, Foot, will no</pre>
<pre>23 Scattered Only Arrays (TM and TE) ####################################</pre>	<pre>24   MO Reserve Server, Freq. + M. + + + (+Region II temp variables, Total Fields) IIIItemp = 0; IIIItemp = 0;</pre>
23 Scattered Only Arrays (TM and TE) Sca	<pre>24   MC Ammarkh Gaves, Fool, +4.1.0</pre>
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23 Scattered Only Arrays (TM and TE)  ***********************************	<pre>24   MO Reserve Great, Mail, vel.net ( +Region II temp variables, Total Fields) IIIItemp = 0; IIIItemp = 0; IIIItemp = 0; IIIItemp = 0; IIIItemp = 0; IIItemp = 0; IIIItemp = 0; IIIIItemp = 0; IIIIItemp = 0; IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII</pre>
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# PhD Research Garcia\_Final\_v4.1.nb 25 26 | PhD Research Garcia\_Final\_v4.1.nb $$\begin{split} & \texttt{RIIstemp} + \texttt{RIIstemp} + \texttt{gnljeq}(\phi, x, \rho) + \texttt{Dnla[[index]];} \\ & \texttt{HIphistemp} + \texttt{HIphistemp} + \texttt{(mliqe}(\phi, z, \rho) + \texttt{Dnla[[index]];} \\ & \texttt{(mliqe}(\phi, z, \rho) + \texttt{Dnla[[index]]} + \texttt{qnljeq}(\phi, z, \rho) + \texttt{Dnla[[index]]} + \texttt{mliqe}(\phi, z, \rho) + \texttt{Dnla[[index]]} \\ & \texttt{mliqe}(\phi, z, \rho) + \texttt{Dnla[[index]]} \\ & \texttt{Infinetemp} + \texttt{(mliqe}(\phi, z, \rho) + \texttt{Cnla[[index]]} + \texttt{mliqe}(\phi, z, \rho) + \texttt{Cnla[[index]]} + \texttt{mliqe}(\phi, z, \rho) + \texttt{Dnla[[index]]} ); \end{split}$$ $$\label{eq:stress} \begin{split} & \texttt{EthoregoylTES[{out}]} = \texttt{EthocylTES[{$\phi$, $z$, $\rho$}];} \\ & \texttt{EphiregcylTESandI[{out}]} = \texttt{EphicylTESandI[{$\phi$, $z$, $\rho$}];} \\ & \texttt{EphiregcylTES[{cout}]} = \texttt{EphicylTES[{$\phi$, $z$, $\rho$}];} \end{split}$$ l; tf[cld:(scheck to see if inide conductor or not\*) tf[-c/2(scheck[cld:( 1: ]; ]; (-\*dd Incident and Scattered Field+) EIIstamp = bnjeq(\$i, x, \$\omega] + EIIstamp; EIIsphitamp = dnjeq(\$i, x, \$\omega] + EIIsistamp; HIIstamp = fnjeq(\$i, x, \$\omega] + HIIstamp; HIIsthitamp = nnjeq(\$i, x, \$\omega] + HIIstamp; HIIshotamp = ynjeq(\$i, x, \$\omega] + HIIsthotamp; HIIshotamp = \$njeq(\$i, x, \$\omega] + HIIshostamp; (\*Scattered Field Only\*) EIIzstemp = EIIzstemp; EIIphistemp = EIIphistemp; EIIrhostemp = EIIrhostemp; ]; $$\begin{split} & \text{Hiphitamp}: \\ & \text{Hiphitamp}: (omign(\phi, x, \rho) + Ann([index]] + posign(\phi, x, \rho) + Bnn([index]]); \\ & \text{Erbotamp}: Erbotamp: (rmsjer((\phi, x, \rho) + Ann([index]] + \\ & \text{ansjer(}, x, \rho) + Bnn([index]); \\ & \text{Hirbotamp}: Hirbotamp: (rmsjer((\phi, x, \rho) + Ann([index]] + \\ & \text{unsjer(}, x, \rho) + Ann([index]); \end{split}$$ ]; ]; (..., CRegion II fields, boundary 's'+) For[nouns +1, nocumt : angly, nocumt ++, s = nranses[(noruml)]; rel[locumt]; i = nranses[(locumt]]; inds = ([locumt]]; inds = ([locumt]]; inds = ([locumt]]; IIIIntemp = ETietemp = nalge[[0, z, o] = Cha[[index]]; IIITphixemp = XT[phiXemp = ((ml)pe[[0, z, o]) = Cha[[index]] + enlpe[[0, z, o] = Chal[[index]]; ); (; ); EztempS[[count]] = EztempS[[count]] + 0; EphitempS[[count]] = EphitempS[[count]] + 0 ErhotempS[[count]] = ErhotempS[[count]] + 0 Httemp[[count]] = Httemp[[count]] + 0; Hphitemp[[count]] = Hphitemp[[count]] + 0; Hrhotemp[[count]] = Hrhotemp[[count]] + 0; («Region II fields, boundary 'b'+) For[ncount = 1, ncount ≤ nqty, ncount++, n = nrange[[ncount]]; For[lcount = 1, lcount ≤ lqty, lcount++, PhD Research Garcia\_Final\_v4.1.nb | 27 28 | PhD Research Garcia\_Final\_v4.1.nb i = image[[ioomt]]; = image[[ioomt]]; = image[[ioomt]]; (=bostneed Field Partian Firsts) IIIsseens = illustance, ansigneed, s. a) = Colb[[index]]; IIIsseens = IIIsseense, angle, s. a) = Colb[[index]]; IIIsseense = IIIsseense = Ansigneed (a) = Ansigneed (b); IIIsseense = IIIsseense = Ansigneed (b) = Ansigneed (b); IIIsseense = IIIsseense = Ansigneed (b) = Ansigneed (b); IIIsseense = IIIsseense = Ansigneed (b) = Ansigneed (b); IIIsseense = IIIsseense = Ansigneed (b) = Ansigneed (b); IIIsseense = IIIsseense = Ansigneed (b); IIIIsseense = IIIsseense = Ansigneed (b); IIIIsseense = IIIIsseense = Ansigneed (b); Ji Ji (\*All E-fields zeros\*) ]; Eztemp[[count]] = EIztemp + EIIztemp; Ephitemp[[count]] = EIphitemp + EIIphitemp; Erhotemp[[count]] = EIrhotemp + EIIrhotemp; ExtempS[[count]] = ExtempS[[count]] + EIIzstemp; EphitempS[[count]] = EphitempS[[count]] + EIIphistemp ErhotempS[[count]] = ErhotempS[[count]] + EIIrhostemp Hztemp[[count]] = HIztemp + HIIztemp; Hphitemp[[count]] = HIphitemp + HIIphitemp; Hrhotemp[[count]] = HIrhotemp + HIIrhotemp; 1: count = count + 1; , {p, rhomin, rhomax, rhodelta}]; (\*Close of 'Do loop'\*) ]; (\*Add Incident and Scattered Field\*) $$\begin{split} & \texttt{Elixtemp} = \texttt{bnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Elixtemp}; \\ & \texttt{Eliphitemp} = \texttt{dnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Eliphitemp}; \\ & \texttt{Hirtemp} = \texttt{dnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Hirtextemp}; \\ & \texttt{Hirtphitemp} = \texttt{nnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Hirphitemp}; \\ & \texttt{Eirhetemp} = \texttt{nnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Hirtphitemp}; \\ & \texttt{Hirhetemp} = \texttt{dnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Hirhotemp}; \\ & \texttt{Hirhetemp} = \texttt{dnjeq}[\texttt{\phii}, \texttt{x}, \rho] + \texttt{Hirhotemp}; \end{split}$$ Solution for Plots - Corrugated Cylinder $\phi=\phi a;\,(*scattered field \,\phi,\ possibly\ incident\ \phi\ as\ well*)$ (\*#1=0;\*) # = # value; (\*Only if considered unique and distinct from scattered field\*) (+Scattered Field Only+) EIIzstemp = EIIzstemp; EIIphistemp = EIIphistemp; EIIrhostemp = EIIrhostemp; ]; ] (\*END IF STATEMENT\*);; Extemp[[count]] \* Extemp[[count]] \* 0; Ephitemp[[count]] \* Ephitemp[[count]] \* 0; Exhotemp[[count]] = Exhotemp[[count]] \* 0; ExtempS[[count]] = ExtempS[[count]] + 0; Ephitemp5[[count]] = Ephitemp5[[count]] + 0; Erhotemp5[[count]] = Erhotemp5[[count]] + 0; Rztemp[[count]] = Hztemp[[count]] + 0; Rphitemp[[count]] = Hphitemp[[count]] + 0; Hzhotemp[[count]] = Hzhotemp[[count]] + 0;

### PhD Research Garcia\_Final\_v4.1.nb 29 30 PhD Research Garcia\_Final\_v4.1.nb F(FORM): (\*Incident + Scattered Solution\*) SolEz = N[Abs[Extemp]]; dataEz = Transpose[{rhorange/lambda0, SolEz}]; TM Mode Solutions (+Incident + Scattered Solution\*) SolErregcylTMSandI = N{Abs[ErregcylTMSandI];; dataErregcylTMSandI = Transpose[{rborange / lambda0, SolErregcylTMSandI}]; SolEphi = N[Abs[Ephitemp]]; dataEphi = Transpose[{rhorange/lambda0, SolEphi}]; SolErhoregcylTMSandI = N[Abs[ErhoregcylTMSand]]; dataErhoregcylTMSandI = Transpose[{rhorange/lambda0, SolErhoregcylTMSandI}]; SolErho = N[Abs[Erhotemp]]; dataErho = Transpose[{rhorange/lambda0, SolErho}]; SolEphiregcylTMSandI = N[Abs[EphiregcylTMSandI]]; dataEphiregcylTMSandI = Transpose[{rhorange/lmbSandI}]; SolEAllSandI = N{Abs[Sqrt[((Erhotemp) + Cos[\$] - (Ephitemp) + Sin[\$])^2 + ((Erhotemp) + Sin[\$] + (Ephitemp) + Cos[\$] ^2 + (Ertemp)^2]]; dataEAllSandI = Transpose[{rhorange/lambda0, SolEAllSandI}]; SolEAlITMSandI = M[Abs[Sqrt[([EncreqcylTMSandI] + Cos(\$) - (EphireqcylTMSandI] + Sin[\$]) \*2 + (EthroregylTMSandI) + Sin[\$] + (EphireqcylTMSandI) + Cos[\$]) \*2 + (EtroregylTMSandI) \*2]; dataEAlITMSandI = Transpose[{thorasge/lambds0, SolEAlITMSandI}]; (+Scattered Only Solution+) SolEzS = W[Abs[Estemp5]]; dataEzS = Transpose[{thorange/lambda0, SolEzS}]; SolEphiS = N[Abs[EphitempS]]; dataEphiS = Transpose[{rhorange/lambda0, SolEphiS}]; (\*Scattered Only Solution\*) SolEzregcylTMS = N[Abs[EzregcylTMS]]; dataEzregcylTMS = Transpose[{rhorange/lambda0, SolEzregcylTMS}]; SolErhoS = N[Abs[ErhotempS]]; dataErhoS = Transpose[{rhorange/lambda0, SolErhoS}]; SolErhoregcylTMS = N{Abs[ErhoregcylTMS]}; dataErhoregcylTMS = Transpose[{rhorange/lambda0, SolErhoregcylTMS}]; SolEAllS = N{Abs[Sqrt[(ErhotempS + Cos[\$] - EphitempS + Sin[\$]) ^2 + (ErhotempS + Sin[\$] + EphitempS - Cos[\$]) ^2 + (ExtempS) ^2]]]; dataEAllS = Transpose[{thorange/lambda0, SolEAllS}]; SolEphiregcylTMS = N{Abs[EphiregcylTMS]]; dataEphiregcylTMS = Transpose[{rhorange/lambda0, SolEphiregcylTMS]]; SolEAllTMS = N{Abs[Sqrt[(Enhoregcy1TMS+Cos[d] - Ephiregcy1TMS+Sin[d])^2+ (Enhoregcy1TMS+Sin[d]+ sphiregcy1TMS+Cos[d])^2+(Estregcy1TMS-2]]]; dataEAllTMS = Transpose[{thorange/lambda0, SolEAllTMS}]; Solution for Plots - Regular "Smooth" Cylinder $\phi = \phi a$ ; (\*scattered field $\phi$ , possibly incident $\phi$ as well\*) $(* \theta i = \theta ; *)$ $\theta i = \theta i value; (* Only if considered unique and distinct from scattered field*)$ PhD Research Garcia\_Final\_v4.1.nb | 31 32 | PhD Research Garcia\_Final\_v4.1.nb TE Mode Solutions TM + TE Mode Solutions - (+Incident + Scattered Solution+) SolExregcylTESandI = H[Abs[ErregcylTESandI]]; dataExregcylTESandI = Transpose[{rhorange/lambda0, SolExregcylTESandI}]; www.isingterms.is SolErhoregcylTESandI = M[Abs{ErhoregcylTESandI]]; dataErhoregcylTESandI = Transpose[{rhorange/lambda0, SolErhoregcylTESandI}]; SolErhoregcylTMplusTESandI = N{Abs[ErhoregcylTESandI = ErhoregcylTMSandI]]; dstaErhoregcylTMplusTESandI = Transpose[{thorange/lambda0, SolErhoregcylTMplusTESandI]]; SolEphiregcylTESandI = N[Abs[EphiregcylTESandI]]; dataEphiregcylTESandI = Transpose[{rhorange/lambda0, SolEphiregcylTESandI}]; SolEphiregcylTMplusTESandI = N{Abs{EphiregcylTESandI+ EphiregcylTMSandI]; dataEphiregcylTMylusTESandI = Transpose[{rhorange/lambda0, SolEphiregcylTMplusTESandI}]; SulEALITESendI doulAliTERANUI: Mulba[Sqrt[((throrespcylTESand))\*Cos[d]-(tphirespcylTESand])\*Sin[d])^2. ((throrespcylTESand):\*Sin[d])\*(tphirespcylTESand])\*Cos[d])\*2. (TerspcylTESand):\*2]); dataEkllTEEand1:\*Transpose[[throresps/lambdo, SolEkllTEEand1]]; SolEALIYBplusTESandI - N[Aks[Sqrt[(EchoregcylTEEsndI+ErhoregcylTEEsndI)\*Cos[d] (EphiregcylTEEndI+EphiregcylTEEndI) = Sta[d]) - 2 + (EthoregcylTEEndI+ErhoregcylTEEndI) = Sta[d]) -(EthoregcylTEEsndI+ErhoregcylTEEndI) = Sta[d]) - 2 + (EtrogcylTEEsndI+EregcylTEEndI) = Cos[d]) - 2 + (EtrogcylTEEsndI+=Terogram[]/EndI] = SolEALIYBplusTESsnd]]; (\*Scattered Only Solutions) SolExreqcylTES = N{Abs[ExreqcylTES]]; dataExreqcylTES = Transpose[{thorange/lambda0, SolExreqcylTES}]; (+Scattered Only Solution+) SolErregcylTMplusTES = N{Abs[ErregcylTES + ErregcylTM5]]; dataErregcylTMplusTES = Transpose[{thorange/lambda0, SolErregcylTMplusTES]]; SolErhoregcylTES = N{Abs{ErhoregcylTES}}; dataErhoregcylTES = Transpose[{rhorange/lambda0, SolErhoregcylTES}]; SolEphiregcylTES = N[Abs[EphiregcylTES]]; dataEphiregcylTES = Transpose[{thorange/lambda0, SolEphiregcylTES}]; SolErhoregcylTMplusTES = N[Abs[ErhoregcylTES + ErhoregcylTMS]]; dataErhoregcylTMplusTES = Transpose[{rhorange/lambda0, SolErhoregcylTMplusTES}]; SolEAllTES = N(Abs[Sqrt[(ErhoregcylTES \* Cos[\$] - EphireqcylTES \* Sin[\$]) ^2 + (ErhoreqcylTES + Sin[\$] \* EphireqcylTES \* Cos[\$]) ^2 + (ErreqcylTES) ^2]]]; dataEAllTES = Transpose[{rhorange/lambda0, SolEAllTES}]; SolEphiregcylTMplusTES = N{Abs{EphireqcylTES + EphireqcylTMS}]; dataEphiregcylTMplusTES = Transpose[{rhorange/lambda0, SolEphiregcylTMplusTES}]; SolEAllTMplusTES = N[Abs[Sqrt[((ErhoregcylTES+ErhoregcylTMS) \* Cos[\$]-SolALITEPULITES = [Loss [q] - ([LETOOSQU'LES = Enrology[LES] = \cos[q] - (Rphiregoy]TES = histograp(MS) = his[q] + (Rehoregoy]TES = Enhoregoy]TES = his[q] + (Sphiregoy]TES = Enhoregoy]TES = his[q] + (Sphiregoy]TES = FreqU'LES = his[q] + (Sphiregoy]TES = histograp(MS) = 1) ]; dataEAllTMplusTES = Transpose[{rhorms/lambda, SolEAllTMplusTES}];

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# PhD Research Garcia\_Final\_v4.1.nb 33 34 | PhD Research Garcia\_Final\_v4.1.nb Changing Rho XY Plots Corrugated Cylinder Plots Table of Parameters Plot Ez (Scattered) Electors + ListimePlot[dstaRs5, PlotEtuge +> [[rhourin/lambda0, rhomsa/lambda0], (0, Mas(SolEE5])], PlotEtuge +> (Eds, Dashd0], massEtyle -> AbsoluteThichraes[2], PlotEtugie->, Eds, Dashd0], massEtyle -> AbsoluteThichraes[2], PlotEtugie->, Bene, Frankladt -> ("cyl.", "Ver"), GridLines -> [[[n2] lambda0, (Thick, Gray, Dashed]]), Automatie], Bacdground -> Milts, TamgBdis -> 700, BaseStyle -> (FortSize -> 14, FontHeight -> "Bold")]; Plot Ez (Inc + Scattered) FECORETART \* ListLineTot [dstEs. PlotRegs >> {[chosin/lambda0, rhoms/lambda0], {0. Mas[50IE;]}, PlotStyle >> {Red\_bashd, BassEtyle >> AbsoluteThickness[2]. PlotMarkers >> Non, PlotLabel >> "L, Corrupted Cylinder [Incident + Seattered Field]", Frame >> Tree, Franklable >> {Color, "y(m), GridLens >> {[cl2], lambda0, (mick, Gray, Dashd)}}, Automatic], BaseStyle >> {(Fourtisze >> 14, FourtMeight >> "Bold")]; >(+ChangingRhoXYTable = TableForm[tablevalues,TableHeadings+(tabler ding, table ding)]\*) Heimy: ChangingRhoTable = Grid[ArrayFlatten[({{{ " }} )}, {tablecolheading}), {List /# tablerowheading, ArrayFlatten[tablewalues]}], ItemStyle + (Bold, 20), Frame + All, Background + ([LightGray), [LightGray);] Plot Erho (Scattered) r(erost)= Export[ToString[StringForm["``.jpg", RhoTableName]], ChangingRhoTable] $$\label{eq:constraint} \begin{split} & \mbox{Ficture} \{ [astarhos, max/lashds), (0, Max[dolkrhos]) \}, \\ & \mbox{PiotRays} \rightarrow \{ [rhosin/lashds0, rhoss/lashds0, (0, Max[dolkrhos]) ], \\ & \mbox{PiotRy}(a) = (Md, Dahad), masstyle \rightarrow \lambdahooluteThickness[2], \\ & \mbox{PiotRy}(a) = (Md, Dahad), masstyle \rightarrow \lambdahooluteThickness[2], \\ & \mbox{PiotRx}(a) = (Md, Dahad), masstyle \rightarrow \lambdahooluteThickness[2], \\ & \mbox{PiotRx}(a) = (max], masslyle \rightarrow (Tork, "Yan], \\ & \mbox{Grindens} = ([max], max], max], max], \\ & \mbox{Rays}(a) = ([max], max], max], \\ & \mbox{Rays}(a) = ([max], max], max], \\ & \mbox{Rays}(a) = ([max], max], \\ & \mbox{Rays}$$ PhD Research Garcia\_Final\_v4.1.nb | 35 36 | PhD Research Garcia\_Final\_v4.1.nb Plot Erho (Inc + Scattered) Plot EAll (Scattered) Findorsful = ListLineFiel(dataEtho, Piotkange -> {[rhostn/lambda0], rhoss/lambda0], (0, Mas(SolEtho)]}, Piotkyle-> (Red, Dahad), masstyle -> AbsoluteThickness[2], PiotKarkers -> Nose, PiotLabel -> Te, Corrugsted Cylinder (Incident + Scattered Field)", Frame -> True, Franchalel -> (70/λ, "VPT), GridLines -> [[(pi2]imbda0, (Thick, Gray, Dahed]]}, Automatic], Background -> Min(s, TamgeHise -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> "Bold"]]; FileCords = instituteFice[dstall], FlottAmage -> {{thein/lumbdsd, homas/lambds(), {0, Max{SolEll3}}}, Flottyle, > (Mad, Dahed), BaseByle -> AbsoluteThickness[2], FlotMackers -> Non, FlotLabl. -> "Equal Corrupted Cylinder (Sattered Field)", Frame -> Tree, Franched -> ("DA', "V"), GridLines -> {[[d'lumbdsd, (Thick, Gray, Dashed]}], Automatic], Background - White, Ruggeline -> 70, BaseByle -> (FortSise -> 14, FoutHwight -> "Bold")]; Plot EAll (Inc + Scattered) Plot Ephi (Scattered) $$\label{eq:response} \begin{split} & \mbox{Relative} \left\{ [\mbox{homse}/\mbox{labels}), \mbox{(labels}), \mbox{(labels}), \mbox{Relative} : \mbox{(labels}), \mbox{Relative} : \mbox{(labels}), \mbox{Relative} : \mbox{(labels}), \mbox{Relative} : \mbox{Rel}, \mbox{(labels}), \mbox{Rel}, \mbox{(labels}), \mbox{Rel}, \mbox{(labels}), \mbox{Rel}, \mbox{Rel}, \mbox{(labels}), \mbox{Rel}, \mbox{Rel}, \mbox{Rel}, \mbox{Rel}, \mbox{Rel}, \mbox{(labels}), \mbox{Rel}, \$$ $$\label{eq:constraints} \begin{split} & \text{Elitorismulti} \quad \text{ListLineFlot}[dstaff.] Isodf, \\ & \text{PlotReage} \rightarrow \{[\text{rhomin} | \text{ListLineFlot}], \text{Rankpin} | \text{ListLineFlot}] \}, \\ & \text{PlotReage} \sim \{[\text{rhomin} | \text{ListLineFlot}], \text{Rankpin} | \text{ListLineFlot}], \\ & \text{PlotReage} > \\ & \text{Rankpin}, \text{Rankpin}, \text{Corrupted Qlinder (Incident + Sottered Pield)}, \\ & \text{Prame} \rightarrow \text{Trees}, \text{Frankpin}, \text{Corrupted Qlinder (Incident + Sottered Pield)}, \\ & \text{GridLines} \rightarrow \{[(nZ \mid \text{Linebid}), (\text{Thick}, \text{Gray}, \text{Lashed})]\}, \\ & \text{Rankpinod}, \\ & \text{Misc, TangeSter > 70}, \\ & \text{BaseStyle} \rightarrow (\text{FontSize} \rightarrow 14, \text{ FontMeight} \rightarrow \text{TRoils}]; \end{split}$$ Plot Ephi (Inc + Scattered) Summary TM Plots bplCorriandr = ListLinePic [dataBphi, PictStange -> [[hosin/lambdo, homax/lambdo], (0, Max[501Bphi]]], PictStyle > [Red, Dashed), BaseStyle -> AbsoluteThichnese[2], PictStarker None, PictLabal -> "E, Corrugated Cylindse [Incident + Scattered Field)", Frame -> True, Franzhab -> "(p/A", "W"), Griddines -> ([[02] lambdod, (Thick, Gray, Dashed)]), Automatic], BaseStyle -> (FoctSize -> 14, FoctMsight -> "Bold"]]; biddes: GraphicsGrid[{ExcOrrS, ExcOrrSandI}, (ErhoCorrS, ErhoCorrSandI}, {EphiCorrS, EphiCorrSandI}, {EAllCorrS, EAllCorrSandI}, Spacings -> {Scaled[0], Scaled[0]};; arkers ->

### Smooth Cylinder Plots - TM Plots

### Ez (TM Scattered)

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### Ez (TM Inc + Scattered)

Hange ->> EzRegCylTMSandI = ListLinePlot dataEzregcylTMSandI, PlotRange -> 
$$\label{eq:states} \begin{split} & \operatorname{Hot}(\operatorname{Hot}$$

### Erho (TM Scattered)

 $\label{eq:constraint} \begin{array}{l} \label{eq:constraint} \\ \mbox{PiotRamp} \sim \left[ \{ \mbox{Homsin} | \m$ 

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### EAII (TM Scattered)

### EAII (TM Inc + Scattered)

District Status (intervention) Failescy(1958ad1 = intinePole[dstaEli1958ad2, PicEtyp(1958ad1 = intinePole), shows/lambdad), (0, Max[SolEli1958ad3])}, PicEtyp(is > Elus, BaseStyla > MacUateThickness(2), FicHarkers > Nome, PicLabal >\* Sp<sub>041</sub> Bmooth Qilodar (W Incident : Scattered Field)\*, Frame > Trans, Frankanbal >\* (\*/a\*, "y\*/m"), Gridlines >> [[(a\*] lambdad, (Thick, Gray, Dashed)]}, Automatic], Background >> Mints, magnitus >> 700, BaseStyle -> (FontSize -> 14, FontMeight >\* %bd(\*)];

### Summary TM Plots

GraphicsGrid[{{ErRegCylTMS, ExRegCylTMSandI}, {ErhoRegCylTMS, ErhoRegCylTMSandI}, [EphiRegCylTMS, EphiRegCylTMSandI], [EallRegCylTMS, EallRegCylTMSandI}, Spacings -> (Scaled[0], Scaled[0]};

### Smooth Cylinder Plots - TE Plots

### Ez (TE Scattered)

ElseGoyTHE \*:ListLinePlot[distErregoyITES, PlotEdyne > [[thomin]limbds0, thomax/limbds0], (0, Max[SolErregoyITES]]], PlotEdyne > Bius, BaseStyle > MacDietEnkonses[2], PlotHarkers >> None, PlotEtabal -> \*E, Bmosh Cylloder (TE Seattered Field)\*, Freme >> Tere, Franchab-1 < (plot, "v"), GridLinne > [[[folllimbds0, (Thick, Gray, Dashed]]], Automatic], BaseStyle -> (FontElse -> 10, FontMeight >> %Bold\*)];

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### Erho (TM Inc + Scattered)

tholegcylTMSand1 = ListLinePlot[dstaRthoregoylTMSand1, PlotRange ->
{{tholms/lambda0, thomax/lambda0, (0. Mat[dstRhoregoylTMSand1],)
PlotStyle-> Buo, BaseStyle-> MsolvEstMinkes[2], FlotRand2],
PlotLinda -> Two, Buonh Cylindar (M Incident = Sattered Field)\*,
Prame >> Texe, Frantable >> (\*p/A\*, "Vm\*),
dridtines ~> [{[d2]lambda0, (Thick, Gray, Dashed]}), Automatie],
Rackground >> Mult, TangeDise >> 70,
RaseStyle -> (FontElse >> 14, FontMeight >> "Bold\*]];

### Ephi (TM Scattered)

PohlasgVJTMS = ListLinePlot[dstaRphiregvyITMS, PlotEnge >> [[rhomin/lambdo, rhomax/lambdo], (0, Max[SolEphiregvyITMS]]), PlotEngl=> Blue, BassEtyl=> AlkosliteThickenses[], PlotEngl=> None, PlotLabel >> Te, Bmosth Cylinder (TM Bosttered Teld)\*, Prems >> Tree, Franctalel >> (r/s/\*, "Vr"), GridLines >> [[[s21:lambdo, (Thick, Gray, Dashed]]), Automatic], Racdground >= Multe, Tamgdist >> T00, BassEtyl= > (FontSize >> 14, FontWeight -> "Bold"]];

Ephi (TM Inc + Scattered)

print(vinte - interimeText) Eph/msgv/TMEandT = istinePlot[dataTphiregov/TMEandT, PlotRange -> {{chemin/lambdab, homes/lambdab}, (o. Mac[Galphiregov/TMEandT]}, PlotStyle - Nuc, BaseStyle - AbsoluteThinkons(2), PlotMackers -> None, PlotLabel -> TE, Smooth Cylinder (TM Incident = Scattered Field)\*, Frame -> True, Franklab -> (Vol/\*, 'Vol\*), distince -> [[orl/:massion(rosy, Dashed]], Automatie], BaseStyle -> (FontSize -> 14, FontMeight -> "Bold"];

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### Ez (TE Inc + Scattered)

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### Erho (TE Scattered)

### Erho (TE Inc + Scattered)

$$\begin{split} & \text{ETRO} \left\{ | \mathbf{k} \mid \mathbf{n} \mathbf{n}^* \text{ scattered} \mathbf{v}_0 \right\} \\ & = \text{InchessivelyTestand : listicaleslot[dataEchoreqcyITEstandI], PlotBayes > \\ & \left\{ | \text{choss} / \text{lambdab} | \text{ choss} / \text{lambdab} \rangle, \left\{ \mathbf{0}, \text{ Max}[\text{coltrhoreqcyITEstandI]} \right\}, \\ & \text{PlotEstyles - Nuls, BassEvies - MasslessMithtess > N \\ & \text{PlotEstyles - Nuls, BassEvies - MasslessMithtess > N \\ & \text{PlotEstyles - Nuls, FassEvies - (Tanlidet - Stattsred Field)^*, \\ & \text{Frame > Tree, FranceMassless ( - T(n)A^*, "V^m), \\ & \text{GridLines } \sim \left\{ \left( \left[ \text{Coll lambdab}, (\text{Thick, Gray, Dashed] \right] \right), \text{ Automatic} \right\}, \\ & \text{BassByle } \rightarrow (\text{FortSize } \rightarrow 14, \text{ FontWeight } \rightarrow \text{ Thol}^m) \}; \end{split}$$
None

### Ephi (TE Scattered)

privation of the second s

### Ephi (TE Inc + Scattered)

The ReplingCylTEEnedI = ListinsFlot[detaRphiregcylTEEnedI]); {(thomin lambdd, chomas/lambdd); (0, Mat[SalRphiregcylTEEnedI]); FlotStyle = Blue, Basedyle > Abolutthichnese[2]; FlotBarkers -> Nome, FlotLabel -> "E, Booth CylInder (TE Incident = Soutered Field"; Frame >> "rue, Franslabel > ("pl/1,"""); GridLines -> ([[gl/lambddo, (Thick, Gray, Dashed])}, Automatic], Background > White, ImageSize >> 70, BaseStyle -> (FontSize >> 14, FontWeight -> "Bold");

### EAII (TE Scattered)

EXIDegCyTES = ListimeDis[distabilitE; PictRangs > [[chomin/lambdu0], chomax/lambdu0], (0, Mas[0olEllITE3]]], PictRangs > [[chomin/lambdu0], chomax/lambdu0], (0, Mas[0olEllITE3]]], PictBabl -> Storma, Sanoth Cylinder ((TE Scatteres Field)\*, Frame > True, Frankable >> (0/a/\*, "VWN'), Gridlines => [[[cholLimbdu0, (Thiak, Gray, Dashad]]), Astematis], Background >> Mutts, amgeSites >> 700, Basedtyle -> (FontElse >> 14, FontMeight >> "Bold\*]];

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### Erho (TM+TE Scattered)

Linkeg(v)TpDiurTSS = ListimsPiot[distErhorego;IThplusTES, PiotRange ->
{{hhomin/lambds, hhomsn/lambds), (0, Max[SolErhorego;IThplusTES],}
PiotEtyl=-> Blue, Basetyl=-> AlkeolUterbiliness[2], PiotEtyl=-> Bon
PiotLabel -> "%, Bmostb Cyllader (H + TE Seattered)",
Prame > Trom, Franchabel -> ("(r/,", "(r/,"),"),"),"
GridLines -> [[(n21 lambda0, (Thick, Gray, Dashed]], Automatic),
BaseStyle -> (Tontise -> 14, FontWeight -> "Bold"];

### Erho (TM+TE Inc + Scattered)

EndbegryThPhileTERanif = ListLineFlot[distEthoregoyITMpileTEEandf, PiotRange -[[thomin]imbids, nhomas[imbids], (0, Nax[bolthroregoyITMpileTEEandf]], PiotStyle = Blace, ReseViet > AlsolitethicKess[2], FiotRetArrar > None, PiotLabel > "%, Monoth Cylinder (M = "R Inc and Scattered]", Frame > True, Franciabal > (%), ("M"), GridLines > {[[of/lmbids, (Thick, Gray, Dashed]]], Astromatic], Reckground > Mbits, ImageSites > 300, RasStyle > (FontSise > 14, FontMeight > "Bold"]];

### Ephi (TM+TE Scattered)

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### EAII (TE Inc + Scattered)

$$\begin{split} & = \text{Relinegey/TESendl} = \text{LietLinePlot}[dataEllITESendl, \\ & = \text{PlotExtage} \rightarrow \{[\text{chomin}/\text{lumbds}], \text{mbask}/\text{lumbds}], \\ & = \text{PlotExtage} \rightarrow \text{Subs}, \text{Reselves} \rightarrow \text{Nobs}, \\ & = \text{PlotExtage} \rightarrow \text{Blue}, \text{Reselves} \rightarrow \text{Nobs}, \\ & = \text{PlotExtage} \rightarrow \text{Blue}, \\ & = \text{PlotExtage} \rightarrow \text{Nobs}, \\ & = \text{PlotExtage} \rightarrow \text{Nobs}, \\ & = \text{Nobs}, \\ & = \text{Reselves}, \\ & = \text$$

### Summary TE Plots

sponse GraphicsGrid[{{ExRegCylTES, XzRegCylTESandI}, {ExchoRegCylTES, ExchoRegCylTESandI}, {EphiRegCylTES, EphiRegCylTESandI}, {EAlIRegCylTES, EAlIRegCylTESandI}}, Spacings -> {Scaled[0], Scaled[0]};

### Smooth Cylinder Plots - TM + TE Plots

### Ez (TM+TE Scattered)

 $\begin{array}{l} \label{eq:constraint} E. SchweightfieluwTES - ListLinePlot[dataEregeylTMpluwTES - PlotRange -> \\ { [fromin/lambda0, rhomas/lambda0], (0, Max[SolTeregeylTMpluwTES]]}, \\ PlotByie - Nice, NaesWeighte -> NaoluteNthomes[3], FlotBarkers -> None, \\ PlotLabal -> TE, Boosch Cylinder (UN = TE Ecattered)^*, \\ Preme -> True, Franzabal -> ([Jol / lambda0, (Thick, Gray, Dashed)]}, Automatic], \\ Background -> White, ImageSime -> 00, \\ BaseStyle -> (FortSize -> 14, FortWeight -> "Bold")]; \\ \end{array}$ 

### Ez (TM+TE Inc + Scattered)

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### Ephi (TM+TE Inc + Scattered)

$$\label{eq:constraint} \begin{split} & = \left[ c_{1}^{1} + c_{2}^{1} + c_{3}^{1} + c_{3}^{1}$$

### EAII (TM+TE Scattered)

$$\label{eq:linear_states} \begin{split} & EalBegCylTMplusTES + listLineflot[datEAllIMplusTES, \\ & PictEknys & ([dnomin]lambds, chomas/lambds], [o. Mas[SolEllIMplusTES]]), \\ & PictEkyis & Diss, BaseStyles & A BeslutEniness(2), FictEarkers & None, \\ & PictEkyis & Diss, BaseStyle & A BeslutEniness(2), FictEarkers & None, \\ & PictEkyis & Content (N + TE Seattered)^*, \\ & Frames > Tree, Frankeds - (cfu/A^*, V^{exp}), \\ & GridLines & ([[dot]lambds(, (Thick, Gray, Dashed])], Automatic], \\ & BaseStyle & (TootSize > 14, FontHeight -> "Bol4")]; \end{split}$$

### EAII (TM+TE Inc + Scattered)

 $\begin{array}{l} \label{eq:constraints} \\ = & \mbox{RingeyTreplantEand} + \mbox{ListInsFort} \left[ \mbox{destRillPhyterEisedI}, \mbox{FlortRange} \rightarrow \\ \left\{ \left[ \mbox{fromin} \left[ \mbox{listRingeyTreplantEand} \right], \mbox{flortRange} \right], \mbox{flortRange} \\ = & \mbox{Ringer} \left[ \mbox{listRingeyTreplantEand} \right], \mbox{flortRange} \\ = & \mbox{Ringer} \left[ \mbox{flortRange} \right], \mbox{flortRange} \\ = & \mbox{flortRange} \\$ 

### Summary TM+TE Plots

GraphicsGrid[([EzRegCylTHplusTES, EzRegCylTMplusTESand]), (EzhoRegCylTMplusTES, EzhoRegCylTMplusTESand]), (EphiRegCylTMplusTES, EphiRegCylTMplusTESand]), (ExllRegCylTMplusTES, ExllRegCylTMplusTESand]), Spacings -> (Scaled[0], Scaled[0]));

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### Compare (Smooth vs Corrugated) Plots

### TM Compare

<section-header><code-block><code-block><code-block><code-block></code></code></code></code>

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$$\label{eq:product} \begin{split} & \operatorname{PlotLabel} \to ``K_B \mbox{TK} fostlered Bmooth Cylinder (Blue) & w Corrupsted Cylinder (Bed. --)']. \\ & \operatorname{Rowleys TKHandl, Epidconstandl, FlotLaps -> {[rhomin/lambda0, rhoma/lambda0], (0. Mas(SuiphireycytTKHandl, Suichard), Finandyleys -> (Function -> 10, Formiestyth -> Thold'). \\ & \operatorname{Faces} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Franchabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Frankabi -> ('r/A', `'W'). \\ & \operatorname{Fischer} > Tran, Fra$$
PlotLabel -> "E: TE Scattered Smooth Cylinder (Blue) }];

### TM+TE Compare

sGrid

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$$\label{eq:constraints} \begin{split} & rhomas/lambdal}, \{0, Max[SolExl15, SolExl15M]\},\\ & maxdeyla \rightarrow \{romtime \rightarrow 14, Fourbaight \rightarrow "Bold"\},\\ & Frame \rightarrow Tran, Franchabel \rightarrow \{r_D/A^{-}, V/ar^2\},\\ & Foltabel \rightarrow Sensel M Solerator flowed by Cylinder\\ & (Bio) vs Corrupated Cylinder (Med, <math>\rightarrow^{-1}\},\\ & for[XhingdyzMandI, Eulorandi, FloitAmage \rightarrow \{[rhomin/lambdal, homas/lambdal]\},\\ & rhomas/lambdal, (0, Max[SolExlIMMindI, BolExlIsmar]]\},\\ & FameSystem > Tran, Franchabel \rightarrow \{r_D/A^{-}, V/a^{-1}, V$$
}];

### TE Compare

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11;

### TM. TE. TM+TE Compare

ITP, IC, ITP/IE Compare
([Mow]EnkegSylTEG, ExCord, FlotRange ->
([chomin/lambda0, chomay/lambda0], (0, Mas[SalEreseylTEG, SolEn3]),
Basseflyla-([contin-v[RomElambda-1], [containing the "Bold"),
Frame -> True, Framalaba1-> ("c/A", "V/m"),
FlotLaba1-> "E, Mic Gostraed Rosch CylLinder (Blue)
vs Corrugated CylLinder (Bed, --)"],
"En Tios Bot Exist",
Bhoy[EnkegSylTED]attS, ExCord, FlotRange -> [[chomin/lambda0,
chomas/jandba0], (0, Mas[SalEreseylBulueTE, SolEn3]),
BassEtyle -> (FontSize -> 14, FontWeight -> "Bold"),
BassEtyle -> (FontSize -> 14, FontWeight -> "Bold"),

$$\label{eq:rame-strue} \begin{split} & \mbox{FrameLabel} \to \{\mbox{$^{-}$}\rho/\lambda^*,\ \mbox{$^{-}$} V/m^*\}, \\ & \mbox{PioLabel} \to \ \mbox{$^{-}$} E_{\rm E} \ \mbox{${\rm M}$} M^* E \ \mbox{Scattered Smooth Cylind} \\ & \mbox{(Blue) vs Corrugated Cylinder (Red, --)^*]}, \end{split}$$

(mim) 's Corrupted (ylumer (Me, ->)], (how[sheeg)(Head), Ecotoradi, Distange (>) reguliMEandI, SolFs]), BaseStyle >- (rontise >-1 k. ronWaight >- Neal\*), Fames > True, Frankahal >- ('a/A', 'W'\*), Distabal >- XT. MT ne Schutzed Booth Cylinder (Blue) vs Corrupted Cylinder (Red, --)\*], 'R. TE Des Hot Emist', Bow[EksegSylTBplurTBplurTBeandI, EcocortandI, Piothange > {[(homin/lambdd), thomex/lambdd), (0, Max[SolFreegorTBplurTBeandI, EcorretandI, FlortAnge > {[(homin/lambdd), thomex/lambdd], (0, Max[SolFreegorTBplurTBeandI, BaseStyle >- (rontise >-1 k, rontWaight >- TSald'), Frame > True, Framatabal > ('a/A', 'W'\*), Distabal >- X. The'E Ton is Soctared Booth Cylinder (Blue) vs Corrugated Cylinder (Red, --)\*]],

(Blue) vs Corrugated Cylinder (Med, →)\*]], {Blow[EnchesgCylIMS, EnchCorts, FlotRangs → {[chemin/lambdo, cheman/lambdo], (J. Mar[SolfhorseycylIMS, SolE BareStylm → [FentSimin → 14, FortKnight → \*Enld\*), Frans → Trues, Franzlakis ∪ (Fo/A\*, \*VMe), Fieldsaki → %, TH Sontared Booth Cylinder (Blue) vs Corrugated Cylinder (Bare, →)\*], Bhow[EnchesgCylIMS, EnchCorts, FlotRangs → {[[chemin/lambdo], frame / Intex, Franzlakis ∪ (Fo/A\*, \*VMe), Frans → Trues, Franzlakis ∪ (Fo/A\*, \*VMe), Frans → Trues, Franzlakis ∪ (Fo/A\*, \*VMe), Frans → Trues, Franzlakis ∪ (Fo/A\*, \*VMe), FlotEshal → %, TH Sontared Booth Cylinder (Blue) vs Corrugated Cylinder (BoothChesgCylIMSE, EnchCorts, FlotRangs → {[[chemin/lambdo], frames/Intex, Franzlakis ∪ (Fo/A\*, \*VMe), Frans → True, Franzlakis ∪ (Fo/A\*, \*VMe), Frans → True, Franzlakis ∪ (Fo/A\*, \*VMe), FlotEshal → %, The Sontared Booth Cylinder (Blue) vs Corrugated Cylinder (Med, →)\*]], FlotMegCylIMSedL, PhenCorstant, Platease → {[[chemin/lambdo], (Blue][EnchesgCylIMSedL, PhenCorstant, Platease → {[[chemin/lambdo], [[chemin/lambdo], (Blue][EnchesgCylIMSedL, PhenCorstant, Platease → {[[chemin/lambdo], [[chemin/lambdo], (Blue][EnchesgCylIMSedL, PhenCorstant, Platease → {[[chemin/lambdo], [[chemin/lambdo], [[c lErhoregcylTMS, SolErhoS] } }

[Bhow[EshoBagCylTHEand], EchoCorrEand], FlotRange -> {[chonin/lambda], chomax/lambda], (6), Mar[GolEshoreseylTHEand], SolEvol]}, BaseStyle -> (rootEsta -> 14, rootEsight -> "fold"), Frame -> Trum, FrameLabel -> ("p/X", "Vy"), FlotLabel -> "F, M The + Southered Month Cylinder

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$$\begin{split} & \mbox{Piotabel} \rightarrow \mbox{"K}, \mbox{TE Inc} + \mbox{Southered Smooth Cylinder (Blue) vs Corrugated \\ & \mbox{Qilinder} (Bed, \rightarrow)^+], \mbox{Boundary Southered Smooth Cylinder (Blue)}, \\ & \mbox{(b)} \mbox{Extransport Piotames - 0 [[Contisten > 14, contained and 0], \\ & \mbox{(b)} \mbox{Extransport Piotames - 0 [[Contisten > 14, contained and 0], \\ & \mbox{Baseltyle - 0 (Contisten > 14, contained and 0, contained and 0, \\ & \mbox{Frame label} \mbox{(contained and 0, contained and 0, contained$$

(Blue) vs Corregaed Cylinder (Red., -)^1], (fhour[HallRegCylTHS, EALICorrS, PlotRange -> { [rhour].humbdo.hum

# (Biss) vs Ocrugated Cylindsr (Med. ~-)^]]; (Show[EillBecyCHEand], EillCorrEnnl, FlotEnnge > {[[chomin/lambds], rhomar/lambds], (G, Med[DiallTemand], SolIAlIBend[]]); BaseStyle > [PostEins >> 14, Fouthwight > \*Bold"), Frame > Trans, Franchabel > (Fo/A\*, "Web"); BlotEnbel > \*Enum; Franchabel > (Fo/A\*, "Web"); BlotEnbel > \*Enum; Thine & Scattared Smooth Cylinder (BillBecyCHEbulerEised), EditorFinant, FoltEnge >> {[[rhomin/lambds]]}, BaseStyle > [PostEins >> 14, Fouthwight > \*Bold"), Frame > Trans, Franchabel > (Fo/A\*, "Web"), Frame > Trans, Franchabel > (Fo/A\*, "Web"), Frame > Trans, Franchabel > (Fo/A\*, "Web"), FoltEnbel > \*Enum; Franchabel > (Fo/A\*, "Web"), FoltEnbel > \*Enum; Franchabel > (Fo/A\*, "Web"), BlotElBelpy(:PhylarEised, ElioLEITBelpacet Send, solFished), rhomar, Headbel), (O, Med ElioLEITBelpacet Send, solFished)], BaseStyle > (PostEins >> 14, FortWeight > \*Bold"), BaseStyle > (PostEins >> 14, PostWeight > \*Bold"),

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(Else) we Corrugated Cylinder (Red. --)\*], Show[XrholagCylTESnod], EncloarFand], FlotRange → {{rhomin/lambda0, rhomax/lambda0}, (0, Max[SolIrhosegcylTESnod], SolIrhol]}, BaseStyle → (rontise → 14, rontwight → SolA'), Frame → Trum, FrameLabel → ('p/A\*, 'YW'), FlotLabel → '#, RT in + Southead Bacoth Cylinder (Blue) we Corrugated Cylinder (Red. ->)\*], How[EncloseQc)TheplasTESnod], EncloseTeSnot, Pottampe → {{Ichomin/lambda0}, hemax/lambda0}, (0, Max[SolIrhoregoy]TheplasTESnod], following), HaseStyle → (Trontise → 14, rontWeight → SolIrho)], Frame → Trum, FrameLabel → ('p/A\*, 'YW'), Frame → Trum, FrameLabel → ('p/A\*, 'YW'), FlotLabel → '#, UHTT Ine < Soltened Bhoth Cylinder (Blue) we Corrugated Cylinder (Bacd, --)\*]},

{Buck\_pcplrHsudf.philoCorrdant, FlotAmays > {[inter, lambdad, shows/lambdad, (0, Mac[DilphiregoylWBandf, SolEphi]]}, BaceStyle of (PostLise > 1.4, FortWangle > "SolEphi]]; Frame >> True, Framalabal > ("p/1", "y/m"), FieldLabal > %\_B Thi on = Santread Bacoch Oplinder (klum) we Corrupated Sylinder (Med, --)"]. Box [philoSolPyIWBandf, Robicorreland, FlotAmage > {[rhomin/lambdad, rhomes/lambdad], (0, New[DilphiregoylWBandf, SolEphi]]}, BaceStyle > (PostLise > (\*h.0\*\*, "sole"), Frame >> True, Framelabal > ("p/1", "Y/m"), Frame >> True, Framelabal > ("p/1", "Y/m"),

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Frame -> True, FrameLabel -> (\*p/\k", "V/m"),
PlotLabel -> "Eretal TM+TE Inc + Scattered Smooth
Cylinder (Blue) vs Corrugated Cylinder (Red, --)"]} }]

xport[ToString[StringForm["``.jpg", RhoXYPlotsName]], RhoXYPlots]; Speak["The rho plots are done"]

### Empty Arrays for Storing Field Solutions - Changing Phi

### Corrugated Cylinder Empty Arrays

Scattered + Incident Arrays

Extemp = ConstantArray[0, Length[phirange]]; Ephitemp = ConstantArray[0, Length[phirange]]; Erhotemp = ConstantArray[0, Length[phirange];

Scattered Only Arrays

ExtempS = ConstantArray[0, Length[phirange]]; EphitempS = ConstantArray[0, Length[phirange]]; ErhotempS = ConstantArray[0, Length[phirange]];

- Incident Only Arrays
- > ExtempI = ConstantArray[0, Length[phirange]]; EphitempI = ConstantArray[0, Length[phirange]]; ErhotempI = ConstantArray[0, Length[phirange]];

### Regular ("Smooth") Cylinder Empty Arrays

### Scattered + Incident Arrays (TM and TE)

ErregcylTMEandI - ConstantArray[0, Length[phirange]]; ErhoregcylTMEandI - ConstantArray[0, Length[phirange]]; EnregcylTMEandI - ConstantArray[0, Length[phirange]]; ErregcylTMEandI - ConstantArray[0, Length[phirange]]; EphiregcylTMEandI - ConstantArray[0, Length[phirange]];

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Sectored Only Amount (TM and TE)	HITphistemp = 0;
Scattered Only Arrays (TPI and TE)	Hirnostemp = 0;
<pre>resises EzregcylTHS = Constant&amp;rray[0, Length[phirange]];</pre>	(*Region II temp variables, Incident Field Component*)
Erhoregcy1TMS = ConstantArray[0, Length[phirange]];	EIIzItemp = 0;
EphiregcylTMS = ConstantArray[0, Length[phirange]];	EIIphiltonp = 0;
Eregeying = Constanterray(0, Length[phirange]); Erborange/1955 = Constanterray(0, Length[phirange]);	Ellrholtemp = 0;
Ephiregcy17ES = ConstantArray[0, Length[phirange]];	( Barley II have excluding Barbi Birld)
	(*Region i temp variables, iotal Fleide) RTT+temp - 0-
Incident Only Arrays (TM and TE)	EIIphitemp = 0;
	HIIztemp = 0;
<pre>kestel: Ezregcy17M1 = ConstantArray[0, Length[phirange]]; Erboregcy17M1 = ConstantArray[0, Length[phirange]];</pre>	HIIphitemp = 0;
EphiregcylTMI = ConstantArray[0, Length[phirange]];	<pre>Ellrhotemp = 0;</pre>
<pre>EzregcylTEI = ConstantArray[0, Length[phirange]];</pre>	Hirnotemp = 0;
ErhoregcylTEI = ConstantArray[0, Length[phirange]];	(*Region I temp variables*)
<pre>EphiregcylTEI = ConstantArray[0, Length[phirange]];</pre>	EIztemp = 0;
	Elphitemp = 0;
	HIztemp = 0;
Changing Phi Do Loop Calculation	HIphitemp = 0;
00	Errotemp = 0
Delese	Alliotemp = 0)
D8 1880	(*Smooth Cylinder*)
<pre>s(estr)- count = 1;</pre>	If[p <p2,< th=""></p2,<>
h(4):172)- ncount = 1;	(*TRUE*)
lcount = 1;	<pre>EgregcylTMSandI[[count]] = 0;</pre>
jcount = 1;	<pre>EzregcylTMS[[count]] = 0;</pre>
	ErboregcylTMI[[count]] = 0; ErboregcylTMSandI[[count]] = 0;
$\rho = \rho far;$ (*Observation $\rho$ for use in polar plots*)	<pre>ErhoregcylTHS[[count]] = 0;</pre>
pol	<pre>ErhoregcylTMI[[count]] = 0;</pre>
(*¢i=¢;*)	EphiregcylTMSandI[[count]] = 0;
<pre> \$\$\phi = \phi value; (*Only if considered unique and distinct from scattered field*) </pre>	Ephiregcy17MS[[count]] = 0;
	<pre>EpiregcylTMI[[count]] = 0; EpiregcylTMI[[count]] = 0;</pre>
(*Region II temp variables, Scattered Field Component*)	ErregcylTES[[count]] = 0;
Elizatemp = 0;	EmregcylTEX[[count]] = 0;
Ellrhostemp = 0;	ErhoregcylTESandI[[count]] = 0;
	ErhoregcylTES[[count]] = 0;
HIIzstemp = 0;	<pre>Ethoregy1TEI[[cout]] = 0;</pre>
	sphiregoyirssandi[[count]] = 0;
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	1
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making and the second of the second of the second	
EphiregeviTES[[count]] = 0;	<pre>Index = ((ncount - 1) * (iqty)) + icount; Elstemp = Elstemp + (hnmisel(é, z, o) * Ann([index]]);</pre>
,	Elphitamp = Elphitamp +
(*FALSE*)	$(\operatorname{knm}_{\operatorname{pq}}(\phi, z, \rho) * \operatorname{Anm}[\operatorname{index}] * \operatorname{Inm}_{\operatorname{pq}}(\phi, z, \rho) * \operatorname{Enm}[\operatorname{index}]);$
<pre>EzregcylTMSandI[[count]] = EzcylTMSandI[\$\phi\$, \$\phi\$, z, \$\rho\$];</pre>	<pre>HIxtemp = HIxtemp + (inmjeq[\$\phi, \$\pi, \$\rho] * Bnm[[index]]);</pre>
ErregcylTMS[[count]] = ErcylTMS[\$	HIphitemp = HIphitemp +
$EzregcylTMI[{count}] = EzcylTMI[\phii, z, \rho];$	$(\text{onm} \text{jeq}(\phi, \pi, \rho) * \text{Anm}[(\text{index})] * \text{pnm} \text{jeq}(\phi, \pi, \rho) * \text{Bnm}[(\text{index})]);$
Prhorecry [WGandI [ count]] - Prhory [WGandI [ 4 ] 4 ]	structure structure + (rum)seq(e, x, p) * Ann([nuex]) +
<pre>ExhoregcylTMS[[count]] = ErhocylTMS[\$\u03c4, \$\u03c4, \$\u03c4</pre>	HIRhotemp = HIRhotemp + (tnmjeq[\$\u03c4, \u03c6] * Anm[[index]] +
<pre>ErhoregcylTMI[[count]] = ErhocylTMI[\$</pre>	$unmjeq[\phi, z, \rho] * Bnm[[index]]);$
	] /
<pre>EphiregcylTMSandI[[count]] = EphicylTMSandI[\$\$\phi\$, \$\$\$\$\$\$\$\$\$\$\$\$\$\$, \$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$</pre>	] 2
<pre>spiiregeyiftS[[count]] = EphicylTMS[0, z, p]; EnhiregeylTMI[[count]] = EnhicylTMI[6], z, c];</pre>	(aBerion II fields, houndary 'a's)
	For nount = 1, nount ≤ nqty, nount ++,
<pre>EzregcylTESandI[[count]] = EzcylTESandI[\$\u00e0i, \$\u00e0, z, \$\u00e0];</pre>	n = nrange[[ncount]];
<pre>EzregcylTES[[count]] = EzcylTES[\$\phi\$, \$z\$, \$\rho\$];</pre>	<pre>Por[lcount = 1, lcount ≤ lqty, lcount++,</pre>
<pre>EzregcylTEI[[count]] = EzcylTEI[\$</pre>	<pre>l = lrange[[lcount]];</pre>
	<pre>m = lrange[[lcount]]; i=t=t= ((count_1); (t=t=t)); l=t=t=t;</pre>
<pre>srnoregcylfESandI[[count]] = ErhocylTESandI[\$\$, \$\$, \$\$, \$\$]; ErhoregcylTES[[count]] = ErhocylTES[\$\$, \$\$, \$\$\$];</pre>	<pre>index = ((ncount - 1) * (lqty)) + lcount; (*Scattered Field Portion Firsts)</pre>
ErhoregcylTEI[[count]] = ErhocylTEI[\$	<pre>EIIzstemp = EIIzstemp + anljeq[d, z, p] + Cnla[[index]];</pre>
· · · · · · · · · · · · · · · · · · ·	EIIphistemp = EIIphistemp +
$\mathbf{EphiregcylTESandI[[count]]} = \mathbf{EphicylTESandI[\phii, \phi, z, \rho]};$	<pre>(cnljeq[\$\u03c6, z, \u03c6] * Cnla[[index]] * enljeq[\$\u03c6, z, \u03c6] * Dnla[[index]]);</pre>

spniregcylTESandl[[count]] = SpnicylTESandl[0] EphiregcylTES[[count]] = EphirylTES[0, z, p]; EphiregcylTEI[[count]] = EphirylTEI[0, z, p];

### 1;

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HIPshatemp : HIPshatemp : (caljed(0, z, c) - chi[(index]] + caljed(0, z, c) - bhal[[index]]); HITstatemp = HITsteremp , caljed(0, z, c) - bhal[[index]]; HITshitemp : HIPshitemp : (caljed(0, z, c) - chil[[index]] + caljed(0, z, c) + bhal[[index]]); HITshitemp : HITshitemp : caljed(0, z, c) + chil[[index]] + wijed(0, z, c) + chil[[index]]); HITshitemp : HITshitemp : caljed(0, z, c) + chil[[index]] + ynjed(0, z, c) + chil[[index]]); ]; ]; (xdd Incident and Scattered Field+) HITsteremp = hojed(0, z, c) + HITshitemp; HITshitemp - chil[(z, z, c) + HITshitemp; HITshitemp (\*Incident Fields Only\*)

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# (\*Scattered Field Only\*) (\*Scattered Field Only\*) Elizatemp = Elizatemp; Eliphistemp = Eliphistemp; Elirhostemp = Elirhostemp; ExtempS[[count]] = ExtempS[[count]] + 0; EphitempS[[count]] = EphitempS[[count]] + 0; ErhotempS[[count]] = ErhotempS[[count]] + 0;

Hatemp[[count]] + Hatemp[[count]] + 0; Rphitemp[[count]] + Rphitemp[[count]] + 0; Rhotemp[[count]] + Rhotemp[[count]] + 0; (sequent II islade, boundary I's+ For[nount - 1, nount is nety, nooust +, n = nanope[[count]]; For[[count]]; n = tranepe[[count]]; irresp([icount]; inde = ([acount]; (dey)) + (count; (doattered Teal Fortion First) Hifstemp = Hifstemp = anjse(s, z, p) = Chb[[indes]]; Hifstemp = Hifstemp = anjse(s, z, p) = Chb[[indes]]; Mirtemp = Hifstemp = anjse(s, z, p) = Chb[[indes]]; Mirtemp = Hifstemp = anjse(s, z, p) = Chb[[indes]]; Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]]; Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]]; Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]]; Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]] = Ni set (z, p) = Chb[[indes]]; Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]] = Ni Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]] = Ni Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]] = Ni Hifstemp = Hifstemp = Ni Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]] = Ni Hifstemp = Hifstemp = Ni Hifstemp = Hifstemp = (vn)jse(s, z, p) = Chb[[indes]] = Ni Hifstemp = Hifstemp = Ni Hifstemp = Hifstemp = Ni Hifstemp = Hifstemp = Ni Hifstemp = Ni

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Estemp5[[count]] = Estemp5[[count]] + ElIstemp; Ephitemp5[[count]] = Ephitemp5[[count]] + ElIphistemp; Esthotemp5[[count]] = Esthotemp5[[count]] + ElIsthotemp;

Hrtemp[[count]] = HIrtemp + HIIrtemp; Hphitemp[[count]] = HIphitemp + HIIphitemp Hrhotemp[[count]] = HIrhotemp + HIIrhotemp

nt + 1: (\*, (#, phirange[[]], phirange[[Length[phirange]]], phidelta]]; (\*Close of 'Do loop'\*)

Solution for Plots - Corrugated Cylinder

(\*Incident + Scattered Solution\*)
SolEz = N[Abs[Eztemp]];
dataEz = Transpose[(phirange, SolEz)];

SolEphi = N[Abs[Ephitemp]]; dataEphi = Transpose[{phirange, SolEphi}];

SolErho = N[Abs[Erhotemp]]; dataErho = Transpose[(phirange, SolErho)];

SolEAliSandI = N(Rbo(Egrt(((Echotemp) + Cos[phirange] - (Ephitamp) + Sin[phirange]) ^2 + ((Echotemp) + Sin[phirange] + (Ephitamp) + Cos[phirange]) ^2 + (Estemp) ^2]]]; dstaEAliSandI = Cranspose[(phirange, SolEAliSandI)];

(\*Scattered Only Solution\*)
SolEzS = N[Abs[ExtempS]];
dataEzS = Transpose[{phirange, SolEzS}];

SolEphiS = N[Abs[EphitempS]]; dataEphiS = Transpose[{phirange, SolEphiS}];

SolErhoS = N[Abs[ErhotempS]];

dataErhoS = Transpose[{phirange, SolErhoS}];

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ynljeq[\$\phi, z, \$\rho] \* Dnlb[[index]]);

(\*Add Incident and Scattered Fields)

$$\begin{split} & \texttt{Ellatemp} = \texttt{hojeq}(\texttt{§}i, \texttt{x}, \rho) + \texttt{Ellatemp}; \\ & \texttt{Ellphitemp} = \texttt{dnjeq}(\texttt{§}i, \texttt{x}, \rho) + \texttt{Ellphitemp}; \\ & \texttt{HIltemp} = \texttt{fnjeq}(\texttt{§}i, \texttt{x}, \rho) + \texttt{HIltentemp}; \\ & \texttt{HIlphitemp} = \texttt{mjeq}(\texttt{§}i, \texttt{x}, \rho) + \texttt{HIlphitemp}; \\ & \texttt{Ellhotemp} = \texttt{njeq}(\texttt{§}i, \texttt{x}, \rho) + \texttt{Ellhotemp}; \\ & \texttt{HIlphitemp} = \texttt{hilphitemp}, \texttt{[Hilphitemp]}; \\ & \texttt{HIlphitemp} = \texttt{fnjeq}(\texttt{§}i, \texttt{x}, \rho) + \texttt{HIlthotemp}; \end{split}$$

(\*Incident Fields Only\*)
ExtempI[[count]] = bnjeq[éi, z, p];
EphitempI[[count]] = dnjeq[éi, z, p];
ErhotempI[[count]] = ynjeq[éi, z, p];

(\*Scattered Field Only\*) EIIzstemp = EIIzstemp; EIIphistemp = EIIphistemp, EIIrhostemp = EIIrhostemp

]; ] (\*END IF STATEMENT\*);, Extemp[[count]] \* Extemp[[count]] \* 0; Ephitemp[[count]] = Ephitemp[[count]] \* 0; Erhotemp[[count]] = Erhotemp[[count]] + 0;

ExtempS[[count]] = ExtempS[[count]] + 0; EphitempS[(count]] = EphitempS[(count]] + 0; ErhotempS[[count]] = ErhotempS[[count]] + 0;

Hstemp[[count]] = Hstemp[[count]] + 0; Hphitemp[[count]] = Hphitemp[[count]] + 0; Hrhotemp[[count]] = Hrhotemp[[count]] + 0;

(\*All E-fields zeros\*)

Extemp[[count]] = EIxtemp + EIIxtemp; Ephitemp[[count]] = Elphitemp + EIIphitemp; Erhotemp[[count]] = EIrhotemp + EIIrhotemp;

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\*RCS Solutio  $\begin{array}{l} (\text{RCSSolEz} = \left(4 * \text{Pi} * \left(\rho^{2}\right)\right) * \left(\left(\text{Abs[ExtempS]}\right)^{2}\right) / \left(\left(\text{Abs[ExtempS]}\right)^{2}\right) \right); \\ \text{RCSdataEz} = \text{Transpose[(phirange, RCSSolEz)];} \end{array}$ 

 $\begin{array}{l} & \texttt{RCSSolErho} = \left( \texttt{4} * \texttt{Pi} * \left( p^{2} \right) \right) * \left( \left( \texttt{Abs[Erhotemp5]} \right)^{2} \right) / \left( \texttt{Abs[Erhotemp5]} \right)^{2} \right) ; \\ & \texttt{RCSdataErho} = \texttt{Transpose[[phirange, RCSSolErho]]}; \end{array}$ 

 $\mathbb{RCSSolEphi} = (4 * Pi * (\rho^2)) * (((Abs[EphitempS])^2) / ((Abs[EphitempI])^2)); \\ \mathbb{RCSdataBphi} = Transpose((phirage, RCSSolEphi));$ 

$$\begin{split} & \texttt{RCS501B115} = \texttt{Sqrt}\{(\texttt{Ehotemp5} + \texttt{Cos}[\texttt{phirange}] - \texttt{Rphirange} + \texttt{Sin}[\texttt{phirange}])^2 + (\texttt{Ehotemp5} + \texttt{Sin}[\texttt{phirange}] + \texttt{Sphirange} + \texttt{Cos}[\texttt{phirange}])^2 + (\texttt{Etemp5})^2 + \texttt{Sin}[\texttt{phirange}] + \texttt{Cos}[\texttt{phirange}] + \texttt{Sin}[\texttt{phirange}] + \texttt{Cos}[\texttt{phirange}] + \texttt{Sin}[\texttt{phirange}] + \texttt{Cos}[\texttt{phirange}] + \texttt{Sin}[\texttt{phirange}] + \texttt{Sin}[\texttt{phirange}]$$
^2));

(+RCS Solution - in dB+) RCSdataRidB = Transpose[{phirange, 10+Log10[RCSSolHz]}]; RCSdataRhidB = Transpose[{phirange, 10+Log10[RCSSolHzh]]; RCSdataRhidB = Transpose[{phirange, 10+Log10[RCSSolEAl]}];

### Solution for Plots - Regular "Smooth" Cylinder

TM Mode Solutions

www.www.icident + Scattered Solution+) SolErregcylTMSandI = N[Abs[ErregcylTMSandI]]; dataErregcylTMSandI = Transpose[[phirange, SolErregcylTMSandI]];

SolErhoregcylTMSandI = N[Abs[ErhoregcylTMSandI]]; dataErhoregcylTMSandI = Transpose[(phirange, SolErhoregcylTMSandI)];

SolEphireqcylTMSandI = N[Abs[EphireqcylTMSandI]]; dataEphireqcylTMSandI = Transpose[(phirange, SolEphireqcylTMSandI)];

Solealitms = H[Mas[Sqt]([throregcylTMS - Cos[phirange] - EphiregcylTMS + En[phirange]) ^2 + (EthoregcylTMS + Sin[phirange] - EphiregcylTMS + Cos[phirange]) ^2 + (EtroregcylTMS - 21]); dataEkllTMS = Transpose[(phirange, SolEkllTMS]);

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PhD Research Garcia\_Final\_v4.1.nb | 61 (+Scattered Only Solution+) SolExregcy1TMS = N[Abs[Exregcy1TMS]]; dataExregcy1TMS = Transpose[{phirange, SolExregcy1TMS]]; SolErhoregcylTMS = N{Abs[ErhoregcylTMS]]; dataErhoregcylTMS = Transpose[{phirange, SolErhoregcylTMS}]; SolEphiregcylTMS = N[Abs[EphiregcylTMS]]; dataEphiregcylTMS = Transpose[{phirange, SolEphiregcylTMS}]; SolEAlITMEandI = N[Abs[Sqrt[ ([EnhoregoyITMEandI) + Cos[phirange] - (EphiragoyITMEandI) + Sin[phirange]) ^2 + ([ErhoregoyITMEand] + Sin[phirange] + (EphiragoyITMEandI) + Cos[phirange]) ^2 + (ErregoyITMEandI \* 21]])

dataEAllTMSandI = Transpose[{phirange, SolEAllTMSandI}];

# $\begin{array}{l} (+RCS \;\; \text{Bolutions}) \\ \text{RCSSolExregory17M} = \\ & \left( + 2 i \left( - 2 \right) \right) + \left( \left( \text{Abs} \left[ \text{Exregory17MS} \right] \right) ^2 \right) \Big/ \left( \left( \text{Abs} \left[ \text{Exregory17MI} \right) ^2 \right) \right); \\ \text{RCSdataErregory17M} = \\ \text{Transpose} \left\{ \left\{ \text{phirange, RCSSolErregory17MI} \right\} \right\}; \end{array} \right.$ regcylTH

RCSSolErb  $\begin{array}{l} \left(4 + \text{Pi} + \left[\rho^{-2}\right]\right) + \left(\left(\text{Abs[ErhoregcylTM5]}\right)^{2}\right) / \left(\left(\text{Abs[ErhoregcylTM1]}\right)^{2}\right)\right); \\ \text{RCSdataErhoregcylTM} = \text{Transpose[(phirange, RCSSolErhoregcylTM)]}; \end{array}$ 

$$\begin{split} & \texttt{RCSSolEphiregcylTM} = \\ & \left(4*\texttt{Pi}*\left(p^22\right)\right)*\left(\left(\texttt{Abs[EphiregcylTMS]}\right)^2\right) / \left(\texttt{Abs[EphiregcylTMI]}\right)^2\right)); \\ & \texttt{RCSdataEphiregcylTM} = \texttt{Transpose}\{\texttt{phirange}, \texttt{RCSSolEphiregcylTM}\}; \end{split}$$

RCSSolEregcylTMAllS = 

RCSS

(\*RCS Solution - in dB\*)

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 $\left(4*Pi*\left(\rho^22\right)\right)*\left(\left(Abs[ErhoregcylTE]\right)^2\right)/\left(Abs[ErhoregcylTE]\right)^2\right); \\ CSdataErhoregcylTE = Transpose[{phirange, RCSSolErhoregcylTE}]; \\ \label{eq:rescaled}$ BCSdataE

$$\begin{split} & \texttt{RCSSolEphiregcylTE} * \\ & \left( 4 * \texttt{Pi} * \left( \rho^2 \right) \right) * \left( \left\{ (\texttt{Abs[EphiregcylTES]}) \uparrow^2 \right) \middle/ \left( (\texttt{Abs[EphiregcylTEI]}) \uparrow^2 \right) \right); \\ & \texttt{RCSdataEphiregcylTE} = \texttt{Transpose[(phirange, RCSSolEphiregcylTE)];} \end{split}$$

RCB60EregcyITE81E8 -Sett [kthoregcyITE8 + Cos[phirescy] - RphiregcyITE8 + Sin[phirescy] ^ / (EthoregcyITE8 + Sin[phirescyITE8 + Cos[phirescy] ^ 2 + (EtregcyITE8) ^ 2]; RCB61EregcyITE81E1 = Set[ el)^2+

RCSDIFEqcylTELLI: Sgrt[ (EthorogeylTET: cSglphirange] -EphirageylTET & Sin[phirange]) '2 + (EthorogeylTET: cSglphirange] + EphirageylTET & CSg[phirange]) '2 + (EtracegylTET: 2]; RCSDIFEqcylTELLi + (4 + 91 + (c^2)) + ((ides[RCSDiFEqcylTELLI]) '2) / (ides[RCSDiFEqcylTELLI]) \*2]); RCSDifatAEregylTELLi + Transpose([phirange, RCSSolFeqcylTELLI]);

(+RCS Solution - in dB+) RCSdataRhroegoylTMSB = Transpose[[phirange, 10+Log10[RCSSolErhoregoylTMS]]]; RCSdataRhroegoylTMSB = Transpose[[phirange, 10+Log10[RCSSolEregoylTMS]]]; RCSdataRegoylTMAIdB = Transpose[[phirange, 10+Log10[RCSSolEregoylTMAI]]];

### TM + TE Mode Solutions

(+Incident + Scattered Solution\*) SolErregcylTMplusTESandI = N[Abs[ZeregcylTESandI + ErregcylTMSandI]]; dataErregcylTMplusTESandI = Transpose[{phirange, SolErregcylTMplusTESandI];;

SolErhoregcylTMplusTESandI = N{Abs[ErhoregcylTESandI + ErhoregcylTMSandI]]; dataErhoregcylTMplusTESandI = Transpose[{phirange, SolErhoregcylTMplusTESandI}];

SolEphiregcylTMplusTESandI = N{Abs[EphiregcylTESandI + EphiregcylTMSandI]]; dataEphiregcylTMplusTESandI = Transpose[{phirange, SolEphiregcylTMplusTESandI}];

### SolEAllTMplusTESandI =

DIALIT@piarfisadf -[Bhli@piarfisadf -[Bhli@pirfi@horegoylTHEandf + ErhoregoylTHEandf] - Cos[Phlimape] -[Bhli@pylTHEandf + ErhoregoylTHEandf + a Sin[Phlimape] - 2 -(ErhoregoylTHEandf + ErhoregoylTHEandf + con[Phlimape]) \* 2 -(ErsegoylTHEandf + ErhoregolTHEandf) - Con[Phlimape]) \* 2 -(ErsegoylTHEandf + ErhoregolTHEandf) = Con[Phlimape]) \* 2 -(ErsegolTHEandf + ErhoregolTHEandf) = Con[Phlimape]) \* 2 -(ErhoregolTHEandf + E

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RCSdataExregoy1TMSB = Transpose[{bhirange, 10 + Log10[RCSSolExregoy1TM]]}; RCSdataExhoregoy1TMSB = Transpose[{bhirange, 10 + Log10[RCSSolExhoregoy1TM]]} RCSdataExphiragoy1TMSB = Transpose[{bhirange, 10 + Log10[RCSSolExhoregoy1TM]]}

### TE Mode Solutions

(\*Incident + Scattered Solution\*) SolErregcylTESandI = N[Abs[ErregcylTESandI]]; dataErregcylTESandI = Transpose[{phirange, SolErregcylTESandI}];

SolErhoregcylTESandI = N{Abs{ErhoregcylTESandI}; dataErhoregcylTESandI = Transpose[{phirange, SolErhoregcylTESandI}];

SolEphiregcylTESandI = N[Abs[EphiregcylTESandI]]; dataEphiregcylTESandI = Transpose[(phirange, SolEphiregcylTESandI)];

SolEAlITEEsand1 = N[Abs[Sqrt[ ([Enbrorego]ITESand1) = Cos[phirange] - (Ephiragey]ITESand1) = Sin[phirange]) \*2 + ((Enbrorego]ITESand1) = Lin[phirange] + (Ephiragey]ITESand1) = Cos[phirange]) \*2 + (dersego;ITESand1) = J]]]; diaZAIIITESand1 = Transpose[[phirange, SolEAlITESand1]];

(\*Scattered Only Solution\*) SolEzregcylTES = N[Abs[EzregcylTES]]; dataEzregcylTES = Transpose[{phirange, SolEzregcylTES}];

SolErhoregcylTES = N[Abs[ErhoregcylTES]]; dataErhoregcylTES = Transpose[{phirange, SolErhoregcylTES}];

SolEphiregcylTES = N[Abs[EphiregcylTES]]; dataEphiregcylTES = Transpose[{phirange, SolEphiregcylTES}];

SolEAlTES + WikhieSqrt([Schoregoy]TES + Cos[phirange] - TphiregoyITES + Ein[phirange]) \* 2 + (EntorogoyITES + Ein[phirange] + TphiregoyITES + Cos[phirange]) \* 2 + (EntorogoyITES) \* 2]];; dtaEAlITES + reaspose([phirange, BolEAlITES]);

(\*RCS Solution\*) (\*RCS Solution\*)
(\*RCSSolEzregcylTE = DNE;\*)
(\*RCSdataEzregcylTE =DNE;\*)
RCSSolErhoregcylTE =

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dataEAllTMplusTESandI = Transpose[{phirange, SolEAllTMplusTESandI}];

(\*Scattered Only Solution\*) SolErregcylTMplusTES = N[Abs[ErregcylTES + ErregcylTMS]]; dataErregcylTMplusTES = Transpose[(phirange, SolErregcylTMplusTES)];

SolErhoregcylTMplusTES = N{Abs[ErhoregcylTES + ErhoregcylTMS]]; dataErhoregcylTMplusTES = Transpose[{phirange, SolErhoregcylTMplusTES}];

SolEphireqcylTMplusTES = N{Abs{EphireqcylTES+EphireqcylTMS]]; dataEphireqcylTMplusTES=Transpose{{phiraqe, SolEphireqcylTMplusTES}];

SolEALITMplusTES = N[Abs[Sqrt]([Efroregoy]TES = Erhoregoy]TES) = Cos[phirange] -(EphiregoyITES = SphiregoyITES) = Sin[phirange] - 2+ ([EthreegyITES = KoncegoyITES) = Sin[phirange] = (BphiregoyITES + EphiregoyITES = CoscegoyITES = CoscegoyITES = EregoyITES + SintergoyITES = Teampose[Interase, SolEAlITMplurTES]];

(\*RCS Solution\*  $\begin{array}{l} (*KCS solution*) \\ RCSSolErregcy1MplusTE = \left( 4 * Pi * \left( \rho^2 \right) \right) * \\ \left( \left( (\lambda bs [Exregcy1TE + Exregcy1TKI + Construction (Integration (I$ 

$$\begin{split} & \texttt{RCSSOlErhoregcylTMplusTE} = \\ & \left(4 + pi * \left(p^{-2}\right)\right) + \left(\left((\text{Abs[EchoregcylTES} + \text{EchoregcylTMS})\right)^{-2}\right) / \\ & \left((\text{Abs[EchoregcylTES + EchoregcylTME]}^{-2}\right)\right); \\ & \texttt{RCSdataEchoregcylTMplusTE} = \texttt{Transpose}(\{\text{phirange, RCSSolEchoregcylTM}) + (\text{RCSSolEchoregcylTM}) + \text{RCSSolEchoregcylTM}) \\ & \texttt{RCSdataEchoregcylTMplusTE} = \texttt{Transpose}(\{\text{phirange, RCSSolEchoregcylTM}) + \text{RCSSolEchoregcylTM}) \\ & \texttt{RCSSOLEchoregcylTMplusTE} = \texttt{Transpose}(\{\text{phirange, RCSSolEchoregcylTM}) + \text{RCSSolEchoregcylTM}) \\ & \texttt{RCSSOLEchoregcylTMplusTE} = \texttt{Transpose}(\{\text{phirange, RCSSolEchoregcylTM}) \\ & \texttt{RCSSOLEchoregcylTMplusTE} = \texttt{Transpose}(\{\text{phirange, RCSSolEchoregcylTM}) \\ & \texttt{RCSSOLEchoregcylTMplusTE} = \texttt{Transpose}(\{\text{phirange, RCSSolEchoregcylTM}) \\ & \texttt{RCSSOLEchoregcylTM}) \\ & \texttt{RCSSOLEchoregcylTM} \\ &$$

pe, RCSSolErhoregcylTMplusTE}];

$$\begin{split} & \texttt{RCSSolBphiregcylTMS} : \\ & \left( 4 \cdot t + \left( \rho \cdot 2 \right) \right) + \left( \left( (\texttt{MscSphiregcylTMS} + \texttt{RphiregcylTMS}) \right)^2 \right) \big/ \\ & \left( (\texttt{MscSphiregcylTMS} + \texttt{RphiregcylTMS}) \right)^2 ) \\ & \texttt{RCSdataEphiregcylTMSphiregcy$$

ECSSIDIEsegry(TMP)=httPAILS - Egr( (Ethorsegry(TMS)-terminal) - Cos[phirange] - (Phirange)(TMS) + Ephirage)(TMS) + Sin[phirange]) - 2 - ((Fintersegr)(TMS) - Cos[phirange]) -(Eqhirage)(TMS - Escreg)(TMS) - (cos[phirange]) -2 + (Escreg)(TMS - Escreg)(TMS) - (cos[phirange]) -(Eqhirage)(TMS - Escreg)(TMS) - (and (cos)) - (cos[phirange] -(Ephirage)(TMS - Escreg)(TMS) - (and (cos)) - (cos[phirange] -(Ephirage)(TMS - Escreg)(TMS) - (cos[phirange]) - 2 - (Escreg)(TMS - Escreg)(TMS) - (cos[phirange]) - 2 - ((Escreg)(TMS - Escreg)(TMS) - (cos[phirange]) - 2 - ((Escreg)(TMS - Escreg)(TMS) - (cos[phirange]) -2 + ((Escreg)(TMS - Escreg)(TMS) - (cos[phirange]) -2 + (Escreg)(TMS - Escreg)(TMS) - (cos[phirange]) -

# ch Garcia\_Final\_v4.1.nb | 65 66 PhD Research Garcia\_Final\_v4.1.nb PhD Res $\begin{array}{l} & \texttt{SSolEregcylTMplusTEAll = (4 + Pi + (\rho^2)) + \\ & \left((\texttt{Abs}(\texttt{RCSSolEregcylTMplusTEAll))^2) / ((\texttt{Abs}(\texttt{RCSSolEregcylTMplusTEAll))^2) \right); \\ & \texttt{SdataEregcylTMplusTEAll = Transpose(\{\texttt{phirange, RCSSolEregcylTMplusTEAll}); \\ \end{array}$ Changing Phi Polar Plots Table of Parameters (\*RCS Solution - in dB\*) (+ACE Solution - in dB+) REdataErsegry[Thp[uaTEd] = Transpore([phirange, 10 \* Log10[RCES0Erregcy]Thp[uaTE]]]; REdataEhrongey[Thp[uaTEd] = Transpore([phirange, 10 \* Log10[RCES0ERbiregcy]Thp[uaTE]]]; REdataEphiregcy]Thp[uaTEd] = Transpore([phirange, 10 \* Log10[RCES0ERbiregcy]Thp[uaTEA]]); Export Data [Changing Rho Data] data2 = (a, b, p2, p1, Ettemp5, Ettemp1, Ethotemp5, Ethotemp1, Ephitemp5, Ephitemp5, Exreqoy1785, Exreqoy1785, Exreqoy1785, Ethotemp3, Ethotemp31785, Ethotemp31785, Ethotemp31781, Ethotemp31784, Exploragey1785, Ethotemp31785, Ethotemp31781, Ethotemp31784, Ephitemp31785, Ephitemp31787, Ephitemp321785, Honosaya, a, lambda0, ai, a, E0, B0, f0, shonin, shomax, rhoddla, spoint, jgty, ai, main, mass, negly, lami, lamax, lgty, main, mass, ledy, mancheck, lamacheck, boundarydheck, Ettemp, Sphitemp, Ethotemp, 64, 41va1097 - ChangingPhiTable = Grid[ArrayFlatten]((((" ")), (tablecolheading)), [List/#tablerowheading, ArrayFlatten[tablevalues])], ItemStyle + (Bold, 20), Frame + All, Background + ([LightGray), [LightGray])] 0)- Export[ToString[StringForm["``.mx", Rhofilename]], data2] Export[ToString[StringForm["``.jpg", PhiTableName]], ChangingPhiTable] Corrugated Cylinder Plots Plot Ez (Scattered) EzCorrS = ListPolarPlot(dataEzS, Joined → True, PolarGridLines → Automatic, corr = introduzer/sequence.bs/ Joint's Triby relationship (New York) Delations - (New York) (New York) (New York) BaseStyle → AbsoluteFildbaren[2], Fildbarkers → Non, Flotbale → 70, BaseStyle (New York) (New York) Delatker → Tro, BaseStyle (New York) (New York) Delatker = Trop, PointAseStyle (New York) Delatker = Trop, PointAseStyle (New York) (New York) (New York) (New York) Delatker = Trop, PointAseStyle (New York) (New York)) PhD Research Garcia\_Final\_v4.1.nb | 67 68 | PhD Research Garcia\_Final\_v4.1.nb Plot Ez (Inc + Scattered) Plot Ephi (Inc + Scattered) Recordand: Listolariolc(dathr, Joined + True, Polardridlines + Automatic, Polardrids - ("Begress", Automatic), Piolathyla -> (Bed, Bashad), RaseStyle -> Monoluth(Linear(], Piolathyra -> None, Pioltabel -> "E, Corrupted Cylinder (Incident + Scattered Field)", Dangofiz -> 'TG, BaseStyle -> (Toncils -> 1, FossWeight -> "Bold"), Polarkee + True, PolarkeeGrigis + (9, Max[SolEs]); For the second secon Plot EAII (Scattered) Plot Erho (Scattered) ErhoGorrf = ListFolarFlot[datErhoS, Joined + Trum, PolarCridLines + Automatic, PolarTinks ("Degrees", Automatic), FlotStyle >> [ned, Deahed], BaseStyle - NelosteThinkoss[1], PlotInters -> Noo, PlotLabel -> "E, Corrugated Cylinder [SastIared Field]", ImageDime -> TOD, DaseStyle >> [TerdSime >> 14, FertMight >> "Bold"), PlotAmes + Trum, PolarAmeStrigin = (0, Mam[SolErho]]); MAXMEDE EALLCORTS = ListPolarPlot[dataEALLS, Joined -> True, PolarGridLines -> Automatic, Liors = introduction(clatical); Fourthins ("Organes", Automatic, Fistery(") - (Red, Talhes) Basety() -> AbsoluteThickness[], PictMarkers >> Noos, PictLabel >> Text, Corrupted Cylinder (claticaed Field)", ImageDiss >> 700, Basety(s >> (Fontiles >> 14, FontWeight >> Pictrace = Text, Picture, Picture, PictWeight >> (PictWeight >> 14, FontWeight >> (PictWeight >> -> "Bold"}, Plot EAll (Inc + Scattered) Plot Erho (Inc + Scattered) EncloseStand: = ListDiarGid(ataEnho, Joined + True, PolarGridLines + Automatic, PolarTicks = ("Degrees", Automatic), PlatEkyle >> [Bed, Bashed], BaseStyle >> MoniteThinkens[], PlatEkyle >> [Bed, Bashed], PlatEksel >> TE, Groupsted Gylinder (Incident - Scattered Field)", ImageDis >> TGO, BaseStyle >> [PolarKes = True, FolarKes[]; PlatEkse = True, FolarKeeOrigin = (6, Mag(SolEhol)]; EMilOurSeadI = ListOurSeadI = Polarticles ("Degrees", Automatic), FlotHtyle -> (Red, Dashed), BasdStyle -> AbscluteThickness[2], FlotHstyle -> (Red, Dashed), BasdStyle -> AbscluteThickness[2], FlotHstyler -> Boon, FlotLabel -> "Bool, Carrysed Gylinder (Inclaimt = fostlered Field)", Basettyle -> (FontElse -> 14, FontHeight -> "Bod"), Folarkees -> Too, Basettyle -> (FontElse -> 14, FontHeight -> "Bod"), Plot Ephi (Scattered) inc upro (control of a starbalar)cs(dataRphiS, Joined + True, Polardridines + Automat Polarticka + ("segress" Automatic), PlotSkyle -> [Med, Dashed), BaseSyle -> AbsoluteThicherss[2], PlotSkyters -> None, PlotLabel -> "%, Corrupated Cylinder (Scattered Field)", ImageDise -> 700, BaseSyle -> (PontSize -> 14, FontWeight -> "Bold"), Polarkses = True, FolarKeedFigin = (0, Mag(Defphil)]; Summary Corrugated Cylinder Plots raphicadrid[ {{ExCorr5, ExCorr5andI}, {ErhoCorr5, ErhoCorr5andI}, {EphiCorr5, EphiCorr5a {EhilCorr5, EkilCorr5andI}}, Spacings -> {Scalad[0], Scalad[0]};

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### Smooth Cylinder Plots - TM Plots

### Ez (TM Scattered)

ERRegCyITHS = ListPolarPlot(dataErregcyITHG, Joined + True, PolarGridhines + Automatic), PolarTicks = ("Degrees", Automatic), PlotStyle -> Blue, BaseStyle -> AbsoluteThickness[2], FlotMarkers -> None, PlotLabel -> "&\_ Booth Cylinder (TM Gottarend Field)", ImageDime -> 700, BaseStyle -> (Fontline -> 14, FontWeight -> "Bold"), PolarKers = Frue, FlotAErsectigint (0, MarchioEnteregcyITHE)];

### Ez (TM Inc + Scattered)

prove Extend()/INMEANT = ListOinFlot(dataExregoryITMEANT, Joined + True, DolarGridLines + Automatic, PolarTicits = ("Degrees", Automatic), Plottyle > Niom, BasedVyla - Nahoulexethichness[2], PlotBackress - None, PlotLabel >> True, BasedVyla -> Arolutexethichness[2], PlotBackress -> None, PlotLabel >> True, FolszkassOrigin = (0, Max[SolErregoryITMEandI])];

### Erho (TM Scattered)

BindespQyITMS = ListPolarDiof(datEthoregoyITMS, Joined + True, PolarGridLines = Automatic, PolarDiok = ("Degrees", Automatic), PlotStyle > Blue, Basebyle > Absoluterinkonses[2], PlotBuckars > Nome, PlotLabsd >> %, Basebi Cylinder (TM Seatared Field)\*, ImageSime > 700, BaseBirgi >> (If Seatared Field)\*, PolarAsses = True, PolarAssofrigin = (0, Max[SolEthoregoyITMS]));

### Erho (TM Inc + Scattered)

Biology (Fillmant - Listolar) be[datathorsegy] HHLand; Joined - True, PolarGridLines - Automatic, PolarTicks + ("Degrees", Automatic), PolarGridLines - Nion, BaselSyla -> Monitarichichese[], PolarBathara -> Non Plotabal -> "E, Emoch Cylinder ("M Incident + Scattered Tield)", PolarXees - True, PolarBatheroTigin + ("M Kalcilithroegy], PolarBath] -> "Bold"), PolarXees - True, PolarBatheroTigin + ("M Kalcilithroegy), PolarBather, True, PolarBatheroTigin + ("MarkGolithroegy), PolarBathero, True, PolarBathero, PolarBath

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### Smooth Cylinder Plots - TE Plots

### Ez (TE Scattered)

DERegCyITES = ListPolsrPlot[distErregcyITES, Joined - True, PolsrCridices - Automatic, PolsrIcks - ("Degrees", Automatic), PlotEtyc: = Niue, Basefyi e> Absoluterinithness(2), PlotEtyces - None, PlotLabel -> "E. mooth Cylinder (TE Soattered Field)", ImageSize > 700, BaseSity => (Infilter > Li, FontEtyck) -> "Bold"), PolsrAsse - True, PolsrAssOrigin - (0, Max[SolErregcyITES])];

### Ez (TE Inc + Scattered)

FileSopyIEEEndL ListPolsFlot(datAircepyIEEEndL, Joined + True, PolarGridLines - Automatic, PolarTicks ( "Degrees", Automatic), PlotStyle -> Nies, BaseStyle -> ManuletAThinkons2(), PlotAirkers -> None, PlotLabal -> "Ex Bmooth Cylinder (TE Incident + Scattered Field", ImageDits -> TOO, BaseStyle -> (FondDits -> 14, FontBeight -> "Bold"), PolarKes - Too, PlotRedGrin = (0, Max[Schterey]TEEEnd[));

### Erho (TE Scattered)

process for content of the state of the

### Erho (TE Inc + Scattered)

LinkegetyTestant = ListPoissPois(distExtborggyITEEsadI, Joined + True, PoisTeridLine + Automatic, Polaritek + ("Degrees", Automatic), Ploiftyte > Blue, Basetyte > Absolution(Loness[2], FloitExters > None, Ploitabel > "E. Boosch Cylinder (ET Incident + Sostered Wind)", ImageSize > 700, BaseStyle > (FontSize > 14, FontNeight > "Bold"), Polarkes = True, PolarkesScript + (0, Mar[501ErborgeyFiEsadI]);

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### Ephi (TM Scattered)

publicacy/INE = ListPolarDict(dataRphireopyINM, Joined + True, PolardridLines - Automatic, PolarTicks + ("Degrees", Automatic), PiolStyle - Show, BaseStyle -> AbsoluteThickness[2], PiolMarker -> None, PiolLabel -> "E\_ Booch Cylinder (DM Rostiered Field)", Polarkses True, PolarkseStyle -> (FortLine -> 14, FortWeight -> "Bold"), Polarkses True, PolarkseStrigin + (0, Mas[ShuRphireopyINM]]);

### Ephi (TM Inc + Scattered)

provide the second s

### EAII(TM Scattered)

EAILBagCyITMS = ListPolarPlot[dataEAIlTMS], Joined - True, PolarCridLines - Automatic, PolarTicks + ("Degrees", Automatic), PlotStyle - Blue, BaseStyle -> MaoluteThickness[2], PlotRarker -> None, PlotLabel -> Thur, Booch Cylinder (TM Gosteres Flaid)", ImageNies -> 300, BaseStyle -> (TentLine >> 14, FortHarker -> "Bold"), Polarkers + True, PolarkerStrigin + (0, Mas[SolEA1ITMS]);

### EAll (TM Inc + Scattered)

BilBagGylTMEandT = ListPolarFlot[distRilTMEandT, Joined + True, PolarGridLines - Automatic, Polaricks + ("Degrees", Automatic), PlotStyle - Nice, NaesGyle - > MoolutAthones(2), FlotBackers -> None, PlotLabal -> "E<sub>buil</sub> mooth Cylinder (TH Incident = Notatered Field", Imageline - > > Non, EansChuid -> (Tentine -> "Ind"), PolarAxes + True, PolarAxesOrigin + (0, Max[SolEAllTMEandT]));

### Summary TM Plots

GraphicsGrid[{{ErRegCylTHS, ErRegCylTHSandl}, {ErhoRegCylTHS, ErhoRegCylTHSindl}, {phikegCylTHS, EphiRegCylTHSandl}, {EAllRegCylTHS, EAllRegCylTHSandl}, Spacings -> (Scaled[0], Scaled[0]);

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### Ephi (TE Scattered)

print() Community print() Community Polardridines - Antomatic, Polaritiks - ("Degrees", Antomatic), Polardrida - Nuce, Maeskity - AbsoluteRhichans2[2], Polarkers -> None, Polatikabal -> Te, Banoch Cylinder (TE Scattered Field)", Polarkers - True, PolarkerSteigin + (0, Mae[SolRphirego;ITE])];

### Ephi (TE Inc + Scattered)

- bph3kegcylTESandI = ListPolarPlot[distAtphiregcylTESandI, Joined + True, PolarovidLine - Automatic, Polaritake + ("Depress", Automatic), Plottyle - Bies, Baseflyle -> AbsoluttAtionses[2], Flottakers -> None, Plottabel -> "E, Basch Sylic -> Monitationses[2], Flottakers -> None, Plottabel -> "E, Basch Sylic -> (Fantiser -> 14, Fontisejde -> "Bold"), Polarkes + True, PolarkasStrigin + (0, Max[SolEphiregoylTESandI]];;

### EAII (TE Scattered)

Dillogogitte SittPolarPiot[dataEkl1TE5, Voined + True, PolarGridlines - Automatic, PolarTicks + ("Degress", Automatic), Flottfyle > Bine, BassHyle > MaolutFolichness[2], FlottBackers > None, Flottabal > Tenuis Booch Cylinder (TE Sontiered Trid)", ImageSize > 700, BassBacker (TE Sontiered Trid)", FolarSwes - True, FolarSwesSorigin + (0, Mas[olEKl1TE5]]);

### EAII (TE Inc + Scattered)

Def() = M. - Contected) Enling()(Theor - ListPole(dataEllTEEnd(, Joined + True, PolatridLees - Automatic, Polaticks + (Teogrees", Automatic), PlotStyle - Nuo, Basstyle - MobuleThionse(2), PlotEnters - Nuo PlotLabel -> "B<sub>mail</sub> Smooth Cylinder (TE Incident + Scattered Field)", ImageLise - 700, BaseTyle -> (Fontlise -> 14, Fontlinght -> "Bold"), Polarkes = Fune, FolarKeesChigin + (D. Ka(ChillTEBadd)));

### Summary TE Plots

GraphiceGrid[{{ExRegCylTES, ExRegCylTESandI},
 {ErhoRegCylTES, ErhoRegCylTESandI}, {EphiRegCylTES, EphiRegCylTESandI},
 {EAllRegCylTES, EAllRegCylTESandI}}, Spacings -> {Scaled(0), Scaled(0}};

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### ooth Cylinder Plots - TM + TE Plots

### Ez (TM+TE Scattered)

ExkeqCylTMpLisTK5 - ListFolarPiot(dat&TregcyLTMpLisTK5, Joined + True, PolarGridLines + Automatic, PolarTicks + ("Degrees", Automatic), PlotTkyls -> Blue, BaseKyls -> AbsolutEThicknes(2), FlotMarkers -> None, PlotTkals -> "& Booch Cylinder (M + TE Sectemed Field)", ImageSize -> 700, BaseKyls -> (FontLike -> 14, FontKelght -> "Bold"), PlotExes -> PlotExesCrime (M & TE Sectemed Field)", PolarAxes -> True, PolarAxesOrigin -> (0, Max[SolEzregcylTMplusTES])];

### Ez (TM+TE Inc + Scattered)

### Erho (TM+TE Scattered)

EthologylTMplusTES = ListPolsFlot[dstafrhoreggylTMplusTES, Joined + True, PolsFdridLines - Automatic, PolsFlotk + ("Degrees", Automatic), PlotStyle - Nius, NaesShip - NaholitAthones[2], PlotBarkers - None, PlotLabal - "K. Boosh Cylinds: (DN + TE Scatterse Fleid)", ImageSize - NOG, BaseStyle - (Entitser - 14, FontKeysh -> "Bold"), PolsFkes + True, FolsFkesGrigin + (0, Max[SolEthoregoylTMplusTES])};

### Erho (TM+TE Inc + Scattered)

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### Summary TM+TE Plots

GraphicsGrid[{{ErRegCylTMplusTES, ErRegCylTMplusT {ErhoRegCylTMplusTES, ErhoRegCylTMplusTESand1} {EphiRegCylTMplusTES, EphiRegCylTMplusTESand1} sTESandT) {EAllRegCylTMplusTES, EAllRegCylTMplusTESandI}}, Spacings -> (Scaled[0], Scaled[0])];

### Compare (Regular vs Corrugated) Plots

### TM Compare

individ((ListPolarPlot[ (datBreggy1MB(datBr), Joind - True, PolarCridines - Automatic, PolarIcka ('Degreen', Automatic), FlotBries -> (Blue, (Bed, Dashed)), BaseStyle -> AbsolutFlickesse[2], FlotBries -> (Blue, FlotBalles', \*5, FM Scattered Booch Cyclinder (Blau ey Corrugated Cyclinder (Bed, --)\*, Imagelize -> 100, BaseStyle -> (Contize -> 14, FortBaight -> 'Bolf'), FolarMes - True, FolarKeesCripin +0, Mac(BiolReregy1MB, SolBiel)],

ListPolarPlot[(dataErregcylTMEsnd1, dataEr), Joined + True, PolarGitAlines - Automatic, PolarTicke + (Degrees\*, Automatic), PiotHyle -> (Blue, [Red, Dashed)), BaseStyle -> AbsoluteThickness[2], PiotHarkers -> None, PiotLabel -> F. Th Incident - Scattered Boosth Cylinder (Blue) vs Corrupted Cylinder (Red, -->", NampSis -> 700, BaseStyle -> (Fontime -> 14, FontWeight -> "Bold"), Polarkes + True, PolarkesStrigin - (0, Max[SolkTentycy]TMEsnd1, Solk1)])],

ListFolarFict[dataEthoregeyITME, dataEthol], Joinset + Trum, FolarFittelines + Actomatic, FolarTides - (Dergeret', Actomatic), JicEthyls → (Blum, FolarBate), BandTyls → DataDiscriptiones[2], FitteRetAres → Data, PittEable), JangaDise → Jones - (Construction + Construction + Construction + Construction), TampATise → Doll.BastRyls → (Construct + 0.1), FontSchutt → Thele), DataBates → True, FolarSkeeDrigin + (0, Max[SolEchoregorDS, SolEthol]),

ListFolarFlot[(dataErhoregeylTMSandI, dataErho), Joined + True, PolarGirdLines = Automatic, PolarIicks + (Tegerses +, Automatic), PolarIicks + (Tegerses +, Automatic), PolarStyle -> {Riue, (Red, Dashed)}, BaseStyle -> AbscluteThickness[2], PlotMarkers => None,

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### Ephi (TM+TE Scattered)

philosopylTopHurtEs = ListPolarSiot[dataBphirosopylTopLurtEs, Joined + True, PolarGridLines - Automatic, PolarTicks + ("Degrees", Automatic), PiotStyle - Shue, BaseStyle - AlkeoluteThickness[2], PiotMarkers -> None, PiotLabel -> "E\_ Bonch Cylinder (D4 + TE Seattered Field)", ImageDias -> 700, BaseStyle -> {FortLine -> 14, FortWeight -> "Bold"), Polarkees = Tome, FolarAsseStrigin + (0, Mas[SubphirosopylTopLurE5]);

### Ephi (TM+TE Inc + Scattered)

philosofyllopiartEsand1 + LisPolarPice(detaSphiregoylTbpluartEsand1, Joined+ PolardridLines + Antomatic, PolarTicks + (Pagress', Antomatic), PlotStyla - Nike, Rassfyld - AlkohiteThickness[1, PlotMarkers -> None, PlotLabel -> Te, Bosch Cylinder (NH + TE Incident = Eastaned Field\*, PlotLabel -> Te, Bosch Cylinder (NH + TE Incident = Eastaned Field\*, TampeSite.> 700, BaseStyle - (FontLis => 1) A rostNajbt -> Teold\*, PolarAses + True, PolarAseSrigin + (0, Mas[SolEphiregoylTbplusTESand1]);

### EAII (TM+TE Scattered)

EAllRegCylTMplusTES = ListFolarFlor[dstaEAllTMplusTES, Joined + True, PolarCridLines - Automatic, Polaricks + ("Degrees", Automatic), PlotStyle = Niee, BaseStyle > AbsolutEntiones[2], FlorBackers -> None, PlotLabal -> Te<sub>max</sub> Booch Cylinder (TM + TE Satterest Flaid)", Imagelies = NG0, BaseStyle > (Fontline > 14, Fontleight -> "Bold"), Polarkes + True, PolarkesGrigin = (0, Max[SolEAllTMplusTES])];

### EAII (TM+TE Inc + Scattered)

BilBagdylTMplusTEEandT = ListDhlarPlot[dstaElliTMplusTEEandT, Jnimed = Trum, PolarGridLines = Automatic, Polaritoka = ("Degrees", Automatic), PlotStyle = Nime, NaesStyle = Naholitäthkonses[2], FlotBackers = None, PlotLabal => "Enuil Smooth Cylinder (TH = TE Incident = Scattared Fuid]", ImageSize = NoO, BaseStyle >: (FortEins = 14, Fortsteight => "Bold"), PolarAmes = Trum, PolarAmesOrigin = (0, Max[SolEAllTMplusTEEandT])];

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PlotLabel -> "E, TM Incident + Scattered Emoth Cylinder (Blue) vs Corrugated Cylinder (Red, --)", TangeEite -> 700, BasStyla-> (Fontine > 14, FontHeight >> Told'), PolatAxes = True, PolarAxesOrigin - (G. Max[SolErhoregcylTMEandI, SolErho]]],

{ListPolarPlot[(dstaTphirespy)TME, dstaTphiS), Joined + True, PolarGridLines + Automatic, PolarTicks + ("Regrees", Automatic), PlotStyle -> (Blue, [Red, Dashed)}, BaseStyle >> AbsolutArThicherse]}, PlotHarkers -> None, PlotLabel -> "Ms TM Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Bed, --)", ImagoSize -> 700, BaseStyle -> (FontSize -> 4.1, FontKeight -> Thold\*), PolarAxes + True, PolarAxesOrigin + (0, Max[SolEphiregoy1TME, SolEphirS])},

ListPointPiot{(dataBphiregcylTMEnndf, dataBphi}, Joinset + Fram, PointPiotLinse + Automatio, PointFiota + "Opergers", Automatio), PointSpiel → (Alue, (Red. Dashed)), BaseStyla → NewsluteThioInnes[2], PiotHarkner → Nose, PiotLabai) → "g, UT Dicidant + Restread Booch (Aylinder (Alue) we Corrupted Cylinder (Red. --)", ImageSize → 700, BaseStyla → (Nosizise → 14, FontSwigth → "Hold"), Polatkaes + True, PolarkaesOrigin + (6, Mas[SolEphiregcylTMEnndf, SolEphi])],

[ListPolarPlot[[dstEAllTMS; dstEAll5], Joined + True, PolarFridLines - Automatic, PolarTicks + ("Pegrees", Automatic), PictEtyle >> Mone, PictEabel), Basetyle >> AkeoluteThidness[2], PictErkes -> Mone, PictEabel >> Texas; PK features faceth Cyliador (Sulav 40 Corrupted Cyliador (Med. --)\*, ImageSize -> To0, BaseEtyle >> (FontBise >> 14, FontWeight -> \*Bold\*), Polarkes = True, PictEabedSign = (5, Mag(StallIME, SolEall5])],

ListPointFlot[(dstaEkliTMEsnd], dstaEkliBend]), Joinsei + True, Folardisiilinse - Automatio, Polarticia + "Obspress", Automatio, Polstyles -> (Blue, (Red, Dashed)), BassEyle -> XhoolutsThickness[2], FolstWarkers -> None, Poltabel -> "Omaint Winddam + Sontteed Booch Oylinder (Blue) we Corrupted Oylinder (Red, --)", ImageSize -> 700, meedSyle -> (Dockize -> 14, FonsWeight -> "Onle'), Folarkes = True, PolarkesOrigin - (O, Mas[SolEAllTMEnd], SolEAllSmed])})} 11;

### TE Compare

GraphicsGrid[{{ListPolarPlot[ {dataErregcylTES, dataErS}, Joined → True, PolarGridLines → Automatic,

# {ListPolarPlot { { dataEAllTMplusTES, dataEAllS } , $$\label{eq:listeriary} \begin{split} & Listeriary(d(atabl)) points, databl), \\ & Johnd - Tune, Pointrichlanes + Automatic, \\ & Pointricke + (Degrees', hatomatic), \\ & Pointricke + (Degrees', hatomatic), \\ & Bastiyi \rightarrow Shealtrithinkassel[], \\ & Pointricke - None, \\$$

ListPolarPlot[(distBphiregoy1706)LosTESandf, datAEphi), Joinsd + True, FolardistLinss - Automatic, Polarticle - (Pogeree', Automatic, ) Foldtyles -> (Blue, [Red, Dashed]), BassDigt -> AbsoluteThichese(2], Foldtarkars -> None, Polatabal -> "M Hort Encident = teastered Booch (Vylinder (Blue) ve Corrugated Cylinder (Med, --)", Izagolise -> 700, BassDigt -> (Politis -> 14, FortKight -> "Bold", Polarkase True, PolarkaesOrigin + (0, Mas(SolEphiregoy1706)usTESandf, SolEphi])),

ListPolarPlot{{dataErhoregcylTMplusTESandI, dataErho}, Joined → True, PolarGridLines → Automatic, 
$$\label{eq:constraints} \begin{split} & Joined - True, Polardirditions - Automatic, \\ & Polardicks + ("bogrees", Automatic, ) Flottypics -> (Blue, [Bed, Dashed]), \\ & Baesitypic -> MaroluteThickness[2], FlottAnicare -> None, \\ & FlottAnic -> T, Thort T noidest - B castered Booch (bylinder (Blue) \\ & vs Corrupated Cylinder (Bed, --)^*, ImageSize -> 700, \\ & Baesitypic -> (TentSize -> 14, FontWeight -> Tbolt'), Polarkaes = True, \\ & Polarkaesitypin = (0, Has[SaiKoneegy/TbigutTSacd, SaiKoh]]), \end{split}$$

{ListPolarPlot[ {dataErhoregcylTMplusTES, dataErhoS}, Joined → True, PolarGridLines → Automatic,  $\label{eq:constraints} Joind - True, PolarGridlinns - Automatic. \\ Delaritics ( "toppeses", Automatic.) = FlotTyle -> (Blue, [Red, Dashed]), \\ BaseStyle -> NanoluteFhichesse[2], FlotEathers -> Nane, \\ FlotTabal -> T, Hoffer Ecattered Booch (Sylinds (Blue) ve Corrupts) = (Red, --)^*, ImageSize -> 700, \\ BaseStyle -> (Collise -> 14, -Contelght -> "fold"), PolarKes + True, \\ PolarKesStrigin + (0, Kas [SolEchoregoy170gluatES, SolEchol]]), \\ \end{cases}$ 

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ListPolarPlot[{dataEphiregcylTESandI, dataEphi}, Joined - True, PolarGridLines - Automatic, PolarTicks - { "Degrees", Automatic}, PlotStyle -> {Blue, {Red, Dashed}},

ListPolstPlot[(dataEthorsgo;)TESendI, dataEtho), Juinsei + Trum, FolardFicHinse - Automatio, Polarticles - ("Operares", Automatio, P. Rottyles -> (Blue, (Bed, Dashed)), BaseDigt -> XhooluteThichese(2], PlotEthairer -> None, PlotElabi -> "R. Tarifacte - Rottreed Booch (Vinder (Blue) vs Corrupted Cylinder (Bed, --)", LangeDise -> 700, BaseDigt -> ("Onitise >> 14, Fortikight -> "Bold", PlotEkes -> Tru, PolarAseSOrigin - (0, Mas[SolEchorego;)TESendI, SolEtho])]);

ListDiarPiot[(diatEregry)ITEEndI, disEe), Joind + True, PolarGridines - Automatic, PolarTicks + ("Operase", Automatic, Polotlyks → (Blue, [Bed, Dashed]), RaseStyle → AbsoluteThichese(2], Piottarkars → None, PiotLabel → ", Tr Trindent + Sontreed Booth Oylinder (Blue) vs Corrupted Cylinder (Bed, --)", ImageLize → 700, RaseStyle → (Politis - > 14, Contaight + ~ %Ind!", PolarKass = True, PolarKaseStrigin + (0, Mas[SolEregry]TEEndI, SolEx]]),

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11:

TM+TE Compare

BaseStyle  $\rightarrow$  AbsoluteThickness[2], PlotMarkers  $\rightarrow$  Nose, PlotLabel  $\rightarrow$  "My TK Incident + Scattered Bmoth Cylinder (Blue)  $\nu$ s Corrupted Cylinder (Bd.,  $\rightarrow$ )", InageLine  $\rightarrow$  700, BaseStyle  $\rightarrow$  (FontElse  $\rightarrow$  14, FontWeight  $\rightarrow$  "Bold", Foliatkees+True, PlotArkeeStrigt.e (D. Mag(ES)ENtregol/TESdd(; ES)ERD[1]),

(ListPolarPlot[(dstEAllTES, dstEAllS), Joined + True, PolarCridLines - Antomatio, PolarTicke + ("Degrees", Antomatic), FlotExyle -> Mone, FlotLabel >> Wen, TE Scattered Mooth Oplinder (Buo) w Gorourgated Oplinder (Med, -->', Imagedise -> Too, BaseExyle -> (Fontline -> 14, FontWeight -> "Bold"), PolarAses Toue, PolarExplore (DstEalling), Schlill[]),

ListPolarPlot[{dataEAllTESandI, dataEAllSandI},

ListClarPlot[(detaBllTEador], detaBllBadd], Soled Tem, Polarridkins + Morentic), FlotRyle  $\rightarrow$  (Bise, (Bed, Dashed)), BaskYid  $\rightarrow$  Maolucthickseq[), FlotRyle  $\rightarrow$  (Bose, FlotBad  $\rightarrow$  Te<sub>max</sub> TE fucient + Seattened Smooth Oylindor (Bise)  $\rightarrow$  Corrupted Oylindor (Bed,  $\rightarrow$  "Journal of the order (Bise)  $\rightarrow$  Corrupted (FlotEin  $\rightarrow$  14, FoutNeight  $\rightarrow$  "Bolf", Folkews True, FolkewScript, ed. (Bas(SML)), Status, (Basky), (Basky

GraphicsGrid((LitF9LarF2)ot[ (dstAffreqcyTMPbiarFE3, dstAffS), Joined + True, PolarGridLines + Automatic, PolarTick + ("Sepress", Automatic), PlotBryle -> (Blue, (Red, Dashed)), BaseStyle -> AbsoluteThichness[2], PlotBrackers -> Nose, PlotLabel -> "E. PolarEstered Booth Cyclinder (Blue) vs Corrupted Cylinder (Red, --)", ImageLice -> 706, BaseStyle -> (Fondlise -> Alt, FondKeight -> ToLd\*), DiarAsse + True, PolarAseStrigin + (0, Mas[SolEeregogiTMPblusTEE, BolEsE])),

ListPolarPlot[(dstaBsregoylTMplusTESand], dstaBs), Joined + Trum, PolarCritikinse - Automatic, PolarTiciet - (Mergeres\*, Automatic), Polstyles -> (Blue, (Med, Dashed)), BaseStyle -> AbsoluteThickness[2], PolstArkers -> Nose, PoltLabsi. -> "E. MCHT Encients + Genttered Booch Oylinder (Blue) vs Corrugated Cylinder (Med, --)", Imagalize -> 700, BaseStyle -> (Mosilse -> 14, Forskight -> "Pols/14", Polarkees + rcvs, PolarkaseOrigin + (0, Mas[GolErregoylTMplusTESand], Soliki])),

ListPolarPlot[{dataEAllTMplusTESandI, dataEAllSandI}, ListCoinFold (distAllished), statistical, distAllished), Solied Tem, PalakiTopiarTEsend, distAllished), PolarTicks ('Degrees', Antomito), Pictifytis  $\rightarrow$  (Bios, (Bed, Dashed)), Basetytis  $\rightarrow$  Moholorith(closed)), Pictification  $\rightarrow$  Mono, FlotLabel  $\rightarrow$  Te<sub>max</sub> THAT Rollder : Southered Bmoth Qilder (Bios)  $\rightarrow$  (Computed Qilder (Bed,  $-1^{-1}$ , Inspitts  $\rightarrow$  MO, Basetytis  $\rightarrow$  (Fortilis  $\rightarrow$  14, Fortikight  $\rightarrow$  Table1, Follarkee Tem, FlotLabel (-), Mac(SELE)(DistFlot  $\rightarrow$  Table1), Follarkee Tem, FlotLakeesCript (-), (Mac(SELE)(DistFlot  $\rightarrow$  Table1), Sollarkees Tem, FlotLakees Tem, Flot (-), Sollarkees Tem, Flot (-), Sollarkees Tem, FlotLakees Tem, Flot (-), Sollarkees Tem 31;

TM, TE, and TM+TE Compare

PhiPolarPlots =

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PhiPelasPlots= Grephicodid((ListPolarPlot[(dataErsegcyITMS, dataErs), Joined + True, FolarGidLines+ Automatic, PolarTicks = ("Degrees", Automatic), PlotBx2es > (Bies, (Red, Dashed)), BaseSU2(a >> AbsoluteThickness[2), PlotBx2es > None, PioLabal> > "E, Mi Scattered (Vym) Bmoth Cylinder (Bies) vs Corrupted Cylinder (Bed, --)", Tangedise > 1000, BaseSU2(a >> (TentSize >> 1.4), FontWeight >> "hold"), PolarAses = True, PolarAseSorigin = (0, Mar(SolErregcyITMS, SolEd)]), "E, TL Gos NE Exize", ListPolarPlot[(dataErregcyITMS]INTES, dataEr3), Oxined - True, PolarGidLinder = Automatic, PolarTicks + ("Degrees", Automatic), PlotEtyls -> (Bius, (Bed, Dashed)), BaseStyls -> (EntT (V/M) Scatteres -> None, PlotLabal -> "E, TheT (V/M) Scatteres -> None, PlotLabal -> (E, DetT (V/M) Scatteres -> None, PlotExbend -> (E, Max(SolExeregr)ITMpionTES, SolExbend))),).

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"E, TE Does Not Exist", "E, TE Dors Not Exist", Joined - True, Folardirditars - Automatic, Diardirds - True, Folardirditars - Automatic, Folarticks ("Opperson", Automatic, Plotityis -> (Blue, [Med, Dashed]), BaseStyle -> AbsoluteThickness[2], Plotitarer -> None, Plotabal -> "A, ThorT Incident - Esstered ("Was Smooth Cylinder (Blue) ve Corrugated Cylinder (Med, --)", Enseptise -> 700. BaseStyle -> (Dottise -> 14, Contleight -> "Bold", Polarkees True, PelackeeScigin + (0, Mas[SolErregoylThglusTESendI, SolEs)]),

[ListPolarPlot[(dstErhoregoy1TMEand], dstErho), Joined = True, PolarCitAlines = Automatic, PolarCitAr = (Degress\*, Automatic), PlotSkyls => (Blue, (Ked, Dashed)), BaseStyls => AbmoluteThichnes[2], PlotSkerkers => Nome, PlotLabl => "%, TM Incident = Kosttered (Voi Booch Gylinder (Blue) vo Corrupted Cylinder (Med, ...)\*, ImageSite >> 700. BaseStyls => (Fontise >> 14, FontMed)t => Told\*1, FolarAmes = True, PolarAmesOrigin + (0, Mas[SolErhoregoy1TMEand], SolErho]}];

(ListDiArPlot[(distSphiregcylTMSand], distSphi), Joined - True, FolsGirdiLines - Automatic, PolsTicks - ("Degrees", Automatic), PlotStyle -> (Size, [Red, Dashed]), RassSyle -> NassiutsThioness[], FolsKayes -> Nose, PiotLabel -> "5, MT Incident + Scattered (VM) Smooth Cylinder (Riue) vs Corrupted Cylinder (de. .)-", TangeSites -> 700. RassSyle -> (ProtSize -> 14, FontSkipt -> Thold'), PolarAssen=True, PolarAssGirigin => (NassGirightregcylTMSand], dashshi), Joined - True, PolarKisGirigin => (NassGirightregcylTMSand], dashshi), Joined - True, PolarGirightregcylTMSand], dashShi), Soined - True, PolarGirightregcylTMSand], dashShi), SizedSyle -> (Ruis, Tanident + Scattered (VM) Smooth Cylinder (Riue) vs Corrupted Cylinder (de. .)-", TangeStize -> Nose, PolarLassGirightregcylTMShartSfand], datSphi), JiiterlarBic([diatSphiregcylTMShartSfand], datSphi), JiiterlarBic([diatSphiregcylTMShartSfand], datSphi), JiiterlarBic(Calabel -> "%, MTCHTICH = NassBill -> NassBill PolarTicke= ("Degrees", Automatic), PlotStyle -> (Bick, (Red, Dashed)), BassBill -> Nasolut#Thichmsel]), PlotStyle -> (Bick, (Red, Dashed)), BassBill -> Nasolut#Thichmsel]), PlotStyle -> (Bick, (Red, Dashed)), BassBill -> Corrupted Cylinder (Red, -)->, TangeBill -> 706, BassBill -> (TontEise -> 14, FontSkipt -> Thold'), PolarAsses=True, PlotLabel -> "%, MTCHT Incident + & Scattered (VM) Booth Cylinder (Biu) vs Corrupted Cylinder (Red, -)->, TangeBill -> 706, BassBill -> (TontEise -> 14, FontSkipt -> Thold'), PolarAsses=True, PlotAssesTrue, -> (PontEise -> 14, FontSkipt -> Thold'), PolarAsses=True, PlotAssesTrue, -> (PontEise -> 14, FontSkipt -> Thold'), PolarAsses=True, PlotAssesTrue, -> (PontEise -> 14, FontSkipt -> Thold'), PolarAsses=True, PlotAssesTrue, -> (PontEise -> 14, FontSkipt -> Thold'), PolarAsses=True, PlotAssesTrue, -> (Red CalabahergeyT

(listPolacFlot[(dataEAllTMS, dataEAllS), Joined-True, PolarGridLines - Actomatic, PolarTick - ("Segrees", Actomatic), PiotStyle -> (Biue, (Bed, Dashed)), BaseStyle -> AboutseThichness[], PiotStyle -> Snos, PiotLands -> Thous, Machiness[], Displayles -> Snos, PiotLands -> Thous, Machiness[], Displayles -> Thou, PaletakeeOrigie - (h.Mac(balkAllTMS, SolEAllE)], DistPolarPiot(dataEAllTMS, dataEAllS), Joined -True, PolarGridLines - Actomatic, PolarTick + ("Segrees", Actomatic), PiotStyle -> Snos, PiotLands -> (Thous, Takatakee), PiotStyle -> Snos, PiotLands), BaseStyle -> AboutChickness[], PiotStyle -> Snos, PiotLands -> (Thous, Takatakee), PiotStyle -> Snos, PiotLands -> (Thous, Takatakee, ->>, PiotStyle -> Snos, PiotLands -> (Thous, Takatakee, ->>, PiotLands -> Snos, PiotLands -> (Thous, Takatakee, ->>, PiotLands -> Tho, BaseStyle -> (Thous, ->>, PiotLands -> Thou, PiotLandsThis, Joins -> Thou Opioder((dataEAllTMS, Joins -> (Thous, ->>, PiotLands -> Actomatic, PiolarTick =("Segrees", Actomatic), PiotStyle -> (Riue, (Red, Dashed)), BaseStyle -> AbouturThickness[], PiotStyle -> (Riue, (Red, Dashed)), BaseStyle -> AbouturThickness[], PiotStyle -> (Riue, (Red, Dashed)), BaseStyle -> AbouturThickness[],

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$$\begin{split} & \mbox{PlotMarkers} \rightarrow \mbox{None, PlotLabel} \rightarrow \mbox{*E}_{PlotA1} \mbox{TM-TE} \mbox{Scattered} \mbox{(V/m)} \\ & \mbox{Booth Cylinder (Bus) vs Corrugated Cylinder (Med, --)", \\ & \mbox{ImageSlin} \rightarrow \mbox{TOO, BaseSyles} \rightarrow \mbox{(PlotA182)} \$$
(listPolarPlet(dstaBAllTMEandt, dstaBalldandt), Joined + Tram, PolarZidLines + Automatic, Polarticset (Degress\*, Automatic, PletStyle >> (Bins, (Bad, Dashed)), BaseBtyle -> AbsoluteThickness[2], PletMarkers -> Nos, PletLabel -> "Branz BH Incident + Geattered (VM) Basch Cylinder (Bins) vs Corrupted Cylinder (Bed, --)\*, Tampedie -> 706, (Blaw) vs Corrugated Gylinder (Med. -)\*, Imagedise -> 700, BaseStyle -> (TootSize >14, FortKaight -> TootKaight -> TootKaight

ListPolarPlot((dataHallTMplusTEBandf, dataHalfandf), Joinde + Trum, FolarCitikines + Antomatic, Polarticka - ("Operase", Antomatic), PiolStyle -> (Blue, (Bed, Dashed)), BaseStyle -> AbsolutStickness[2], PiolHarkers -> Nom, PiolLabel -> "Bong, DHTE Locket + Scattered (You Smooth Sylinder (Blum) vt Corrugated Sylinder (Bed, --)", Imageliae >> 700, BaseStyle -> (MonSites >14, Forskight -> "BiolA"), Polarkees = True, PolarkeesOrigin + (0, Mas(SolMallStglusTESandf, SolEAllBand[))]

Changing Phi RCS Polar Plots

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ListPolarPlot[(datAEthoregoylTESandI, datAEtho), Joined + True, PolarGridLines + Antomatic, PolarTicks + ("begrees", Automatic), FlotBryls - (Liue, (Red, Dasked)), BaseBryls - AlmoluteThichness[2], FlotTarkers - Nnee, FlotLabel - \* Truchident + Souttered (Vie) month Cylinder (Blue) PlotLabel -> \*\*, TE Troilent + Seattered (Vm) Booch Gylinder (Riue) we Corrupated Cylinder (Rud, --)\*, Tangelise -> 706, BaseStyle -> (Fondlise >> 14, FontReight -> \*Bold'), Folarkases+True, Folarkasestrigt= (>, Mas(ElstereggylTEsdad, dataRho), Goind = True, FolarGidlisse = Antomatic; Polarticks+'(Forgeres', Atomatic; ) FoldStyle -> (Blee, (Red, Dashed)), BaseStyle -> (ResoluteThickness[2], FoldStyle -> (Blee, (Red, Dashed)), Folatiles' +\*, Burti Troident + Scattered (Vm) Booch Gylinder (Diale) ve Corrupated Cylinder (Red, ->\*, Tangelise >> 700, BaseStyle -> (Routise >> 14, FontSeight ->\* Fold-1, PolarKase True, Folarkasestrigin = (0, Mas(BolkHoregeylTMplueTHEadd, Solithe))]),

(ListPolarPlot [(dstBphiregoylTH5, dstBphi5), Obiesd + True, PolarGridLines + Automatic, PolarTicks = ('Degress', Automatic, PolarTicks = ('Degress', Automatic), PolarStabel, -> Tay TE Scattered ('Wa) Booch ('Jinder (Buo) ve Corrugated Ojlinds ('Bed, -)', Taggdies >> Too, PolarStabel, -> Tay TE Scattered ('Wa) Booch ('Jinder (Buo) ve Corrugated Ojlinds ('Bed, -)', Taggdies >> Too, PolarStabel, -> Tay TE Scattered ('Wa) Booch ('Jinder (Buo) ve Corrugate -> 14, PoutStaiphisy, -> Told'), PolarAsses True, PolarStabel, -> (Base, [Med, Dashed)), BaseStyle -> AbouttFThickress[2], PolarStabel, -> Atomatic, PolarTiks (-Yoggere', Automatic), PolarStyle -> (Blase, [Med, Dashed)), BaseStyle -> AbouttFThickress[2], PolarStabes -> Atomatic, PolarTiks (-> Corgenee', Automatic), PolarStabes -> Tone, PolarStabesOrigin (O, Mas[SolBphiregoylTE, SolBphiT]), IstabelarStel((Lischphiregoy)TE, Mas[SolBphiregoylTE, SolBphiT], PolarStabes -> Automatic, PolarTiks (-Yoggere', Automatic), PolarStabelard (LischphiregoylT), PolarStabelard ('Dashers), PolarDiarDiarStabelard), PolarTiks (-Yoggere', Automatic), PolarDiarDiarDiarDiarDiarDiard, SolBphiregoylTE, SolBphiT], PolarAsses -> Namo, PolarDiarDiarDiarDiard, -> TangStabes -> Nam, PolarAssesTrue, PolarStabesOrigin -> Nam, PolarAsseoTrue, YogolTiks -> 14, PontNagith -> "SolA'), PolarAsses = True, PolarAsseoTrue, PolarStabesOrigin -> (Nam, Folar), PolarAsses = True, PolarAsseoTrue, PolarStabesOrigin -> (Nam, Folar), PolarAsses = True, PolarAsseoTrue, PolarStabesOrigin -> (Nam, Folar), PolarAsses = True, PolarAsseoTrue, PolarStabesOrigin -> (Assacting), PolarStabes -> Nam, PolarAsseoTrue, PolarStabesOrigin -> (Nam, Folar), PolarAsses = True, PolarAsseoTrue, PolarStabesOrigin -> (Nam, Folar), PolarAsses = True, PolarAsseoTrue, Polar, Bastersed, (Nam, Polar), PolarAsses = True, PolarAsseoTrue, Polar, PolarStabesOrigin -> (Nam, Folar), PolarAsses = True, PolarAsseoTrue, Polar, Bastersed, (Nam, Folar), PolarAsses = True, PolarAsseoTrue, -> (Nam, Folar), Polar, PolarAsses = True, PolarAsseoTr

// Export[ToString[StringForm["``.jpg", PhiPolarPlotsName]], PhiPolarPlots]

### Corrugated Cylinder Plots

Plot Ez

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### Smooth Cylinder Plots - TM Plots

### Ez (TM RCS)

- ElseRseqSyIM = ListPolsFlot[RCSdstatErregcyITM, Joined + True, Folardridines Automatic, Polarticis = (Tegress", Automatic), FlotEtyle Nue, Basselyte X hebuterMitkesse[1], FlotBackars Nue, Rosselyte X hebuterMitkesse[1], FlotBackars Non, FlotLabel -> "4, Month Cylinder (M HCS m<sup>3</sup>)", Tampedise -> 700, BassEtyle -> (FontSize -> 14, FontMeight -> "Rold"), Folarkars = True, FolarKessOrigin = (0, mag(Ecollersegc)TM)];

### Erho (TM RCS)

### Ephi (TM RCS)

$$\label{eq:constraints} \begin{split} & \text{CSSphiRegCyIIM} \times \text{ListFolesPlot} \left[ \texttt{ACdataEpliregcyIIM}, \text{Joined} + \texttt{True}, \\ & \text{PolarGridLines} + \text{Automatic}, \text{PolarTicks} + (\texttt{Togress}^*, \text{Automatic}), \\ & \text{Plot(Sylaw)} = \text{Nise}, \texttt{BaseSylaw} > \text{Mosel} \texttt{Mosel} \times \texttt{Mosel}, \\ & \text{Plot(Markars} > \text{None, PlotLabel} > \texttt{True}, \texttt{fasoch}(\texttt{CM} \texttt{RCS}), \\ & \text{Plot(Markars} > \text{None, PlotLabel} > \texttt{fasoch} \times \texttt{L}, \texttt{Mosel} \times \texttt{Mosel}, \\ & \text{Imageline} > \texttt{True}, \texttt{PolarKars} > \texttt{True}, \texttt{PlotRabel} > \texttt{Mosel}, \\ & \text{PlotRabel} > \texttt{True}, \texttt{PolarKars} > \texttt{True}$$

### EAII (TM RCS)

control (rinco) press: Recalling of the statution of the state of

### Summary TM Plots

SMD\_ GraphicsGrid[{(RCSEzRegCylTM), {RCSEzhoRegCylTM), {RCSEphiRegCylTM), {RCSEAllRegCylTM)}, Spacings -> {Scaled[0], Scaled[0]};

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### Smooth Cylinder Plots - TM + TE Plots

### Ez (TM + TE RCS)

HEBERBRGVITMplusTE = ListDolarTiot [KCddataEzregyITMplusTE, Joined + True, PolarGridLines + Automatio, PolarTick + ("Degrees", Automatio), PolatGridLines + Automatio, PolarTick + ("Degrees", Automatio), PolatArckers - Nome, PolatAbal - TE, Booch Gylinder (TM - II RGS m<sup>3</sup>)<sup>+</sup>, ImageGrine - 700, BaseDrijs - (Tentins - 14. FortKimpt - "Toold"), PolarAres - True, PolarAresGrigin + (0, Max[RCBolEzregoyITMplerTE)];

No (nov + c x < ) Rechnegy(TH)main f : LitPolarPlot [RCBdstaRthoregy(THpluSTE, Joined + True, Polardridinas Antonatic, Polarticks + ("Degress", Antonatic), PlotNigi => Nike, Rashiya >> Nabulathikikanse(]), PlotNatkers -> Nike, PlotLabel -> %, Smooth Cylindes (M = TE RCS #)", Imagelize -> 700, Rashiyi=> (FontEise -> 14, FontWaight -> "Bold"); PlotAsster -> Nike, PlotRashiyi=> (N Ass[CSChrosogriMpiurT]];

### Ephi (TM + TE RCS)

### EAII (TM + TE RCS)

List(") - ListPolas?lot[PCSdataErespy170plusTEAll, Joinsd - True, PolardridLines - Automatic, Polarilots + ("Degrees", Automatic), PloStyle - Blue, BaseStyle -> AbsoluteThickness[2], PloTakeker -> None, PlotLabel -> "Boult Smooth Gylinder (TM + TE ECE #")", ImsgeDise -> TOO, BaseStyle -> (FontBlue -> 14, FontWeight -> "Bold"), Polarkees + True, FolarkaeStigin + (0, Mag(ESSD)Erespy170plusTEAll)]];

# RCSEzCorr = ListPolarPlot RCSdataEz, Joined - True $$\begin{split} & \texttt{BECORT} - \texttt{ListFolarTice}(\texttt{FORMARE}, \texttt{Solided} - \texttt{True}, \texttt{PointGridlines} - \texttt{ListFolarTice}(\texttt{I}), \texttt{PointGridlines} - \texttt{Solider}(\texttt{I}), \texttt{PointGridlines}, \texttt{Solident}(\texttt{I}), \texttt{PointGridlines}, \texttt{Solide}(\texttt{I}), \texttt{PointGridlines} - \texttt{Solides}(\texttt{I}), \texttt{PointGridlines} - \texttt{Solides}(\texttt{I}), \texttt{Solids}(\texttt{I}), \texttt{Solides}(\texttt{I}), \texttt{Solides}(\texttt{I}), \texttt{Solides}(\texttt{I}),$$

### Plot Erho

$$\label{eq:constraints} \begin{split} & \text{Refstation}, \ \text{Joined + True}, \\ & \text{PolarGidines - Automatic, Polarticis = ("Degrees", Automatic), \\ & \text{PolarGidines - Automatic, Polarticis = ("Degrees", Automatic), \\ & \text{PolarGidines - Automatic, Polarticis - ("Degrees", Automatic), \\ & \text{PolarGidines - None, Polarded - >> "M_o Corrupted Cyliness (CGS m<sup>2</sup>)" \\ & \text{PolarGidines ->> Too, BaseStyle -> (FontSize ->> 14, FontMeight -> "Bold Polarded Cyliness (CGS m<sup>2</sup>)" \\ & \text{PolarKes - True, PolardeedCristin = (0, Kar(Refsolth))]}; \end{split}$$
-) ,

### Plot Ephi

Noteppilor = ListPolarPiot[StSdstaRphi, Joined + True, PolarGridLines - Automatic, PolarTicke + ("Degrees", Automatic), PiotStyle -> (Red. Dashd), ImasStyle -> MolarUnterMickose[2], PiotMarkers -> Nome, PiotLabel -> "KG Corrupted Cylinter (RCS m<sup>3</sup>)", Daspdiss -> 700, Basedtyle -> (PontSize -> 14, FontWeight -> "Bold"), Polarkee True, PolarKeeScrigin - (5, Mas(RCSolRphi)];

### Plot FAII

REEMILOOR + ListPolarPlot[RESdataKl], Joined + True, Polardridhines + Automatic, PolarTicke + ("Degrees", Automatic), PlotStyle - (Med. Dashed), ImaseStyle - Machinethickness[2], PlotBarkare -> Nose, PlotLahel -> "Engl Corrupated Gylinter (RES #]", ImagoSize -> ToO, BaseStyle - (Machinethickness[2], PolarAxes + True, PolarAxesOrigin + (0, Max[RESoLEAL])];

### Summary Corrugated Cylinder Plots

GraphicsGrid[{{RCSExCorr}, {RCSErhoCorr}, {RCSEphiCorr}, {RCSEAllCorr}}, Spacings -> {Scaled[0], Scaled[0]};

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### Smooth Cylinder Plots - TE Plots

### Ez (TE RCS) - DOES NOT EXIST

### Erho (TE RCS)

### Ephi (TE RCS)

upin (i: rcus) CECEPAilEqcy(IT = ListFolarFlot[EddataSphireqcyITE, Joined + True, PolartridLess + Automatic, FolarTicks + ('Degrees', Automatic), PlotStyle - Blue, BaseStyle - N BolutEditoses[2], PlotMarkers -> Mone, PlotLabel -> 'fe fmooth Cylinder (TE RCE m)', ImageDise -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> 'Bold'), Polarkers = True, FolarResOrigin - (0, Bas(FoldEd)EdploreqcyTE]];

### EAII (TE RCS)

DETAILBOYCHTE - ListPolarPlot[SCSdatEregoylTEAL], Joined + True, PolarGridLines - Automatic, PolarTicks + ("Degrees", Automatic), PlotStyle - Blue, BaseStyle - Machulethochess[1], PlotBarkers -> None, PlotLabel -> "Equal Baocht Cylloder (TE RCS m"), Imagelize -> "DO, BaseStyle -> (Tendizer -> 14, FortHaylethochess"), Polarkes + True, FolarkesOrigin + (0, Mar[RCSDolEregoylTEAL])];

### Summary TE Plots

P(EIND)- GraphicsGrid[{{RCSErhoRegCylTE}, {RCSEphiRegCylTE}, {RCSEAllRegCylTE}}, Spacings -> {Scaled[0], Scaled[0]};

### Erho (TM + TE RCS)

Summary TM + TE Plots

GraphicsGrid[ {{RCSERsegCylTMplusTE}, {RCSErhoRegCylTMplusTE}, {RCSEphIRegCylTMplus {RCSEAllRegCylTMplusTE}}, Spacings -> {scaled(0}, scaled(0)};

### Compare (Regular vs Corrugated) Plots

### TM. TE, and TM+TE Compare

BRAGSPLOLEFLOCE = Graphicapril([ListFlot[(RCSdstaffreqor)TM, RCSdstaffr), Joined + True, Polardidiane + Automatic, Polarticks + ("Pagress", Automatic), Flottryis -> (Blue, (Med, Dashed)). Baseftyis -> (Blue, Med, Dashed). Baseftyis -> Monoltefflichense[1], Flottarkars -> None, FlotLabel -> "K. TH RCS (m<sup>2</sup>) Boosch Cylinder (Hue) vs Corrupated Cylinder (Hed, ->)", Imagelises -> 706, Baseftyis -> (Tentifers -> 14, FouNted)th -> Tenlif). PolarAmes + True, PolarAmedorigin + (0, Mas[RCSSolEregory1M, RCSSolEs)]]

### "Ez TE Does Not Exist"

, ListPolarPiol[(RC5dstaEregoylTMplusTE, RC5dstaEr), Joined + True, FolardFicLines + Automatic, PolarTiclet + "Operare", Automatic, PiolStyles → (Blue, [Red, Dashed)), BassBiyle → AbsoluteThichese(2], PiotEnterare → None, Jointales) → "R MPTE RGL (0<sup>2</sup>), Booch Schlader (Blue) vs Corrupted Cylinder (Red, →)", Imagelise → 700, BassBiyle → (Rofiles → 4), FortBight → Thick", Polarkes → True, PolarkeseOrigin + (0, Mas[RC550]EregoylTMplusTE, RC550]Er])],

$$\begin{split} & \label{eq:loss} \label{eq:loss} \\ & \mbox{ListPolarPlot} \left[ (\mbox{RidstaRthoregoy17K} \ \mbox{RCdstaRtho}) , \\ & \mbox{Jointed + True, PolarFlicks + ("Degrees", Automatic), PlotBarkers > None, PlotLabel -> \\ & \mbox{RidstaRthoregoy1} , PlotBarkers > None, PlotLabel -> \\ & \mbox{R}, M \mbox{Rid} (ad) & \mbox{BoolterPlotAnses} \left[ 1 \right], PlotBarkers > None, PlotLabel -> \\ & \mbox{R}, M \mbox{Rid} (ad) & \mbox{BoolterPlotAnses} \left[ 1 \right], PlotBarkers > None, PlotLabel -> \\ & \mbox{RidstaRthoregoy1} & \mbox{Rid} (ad) & \mbox{RidstaRthoregoy1} & \mbox{RidstaR$$

, istPolarPloE[[RCSdstaErhoregcylTE, RCSdstaErho], Joined + True, PolarGidLines + Automatic, Polarficks + ("Degrees", Automatic), PlotStyle -> (Blue, (Red, Dashed)), BaesStyle -> AbsoluteThickness[2], PlotMarkers -> None, PlotLabel ->

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# $$\begin{split} & \text{BaseStyle} \to \text{AbsoluteThickness}[2], \text{FlotMarkers} \to \text{None}, \\ & \text{FlotLabel} \to \mathcal{T}_{\text{Even}} \to \text{MGC}(p^{0}), \text{Smooth} \circ \text{Spillaber} (\text{Blue}) \, \text{vs} \\ & \text{Corrupted Cylinder} (\text{Bd}_{-1}, \text{vs})^{-1}, \text{Empellies} \to 700, \\ & \text{BaseStyle} \to (\text{FlotLaber} \to \text{H}_{1}, \text{FlotMarker}) \to \text{FlotCharl}), \\ & \text{FlotRessTright} \to (\text{MarkEnderger}) \, \text{TMI}, \text{ReforesCharl}), \\ & \text{FlotRessTright} \to (\text{MarkEnderger}) \, \text{TMI}, \text{Reformation}, \\ & \text{FlotRessTright} \to (\text{MarkEnderger}) \, \text{TMI}, \text{Reformation}, \\ & \text{FlotRessTright} \to (\text{MarkEnderger}) \, \text{TMI}, \text{Reformation}, \\ & \text{Corrupted} \, \text{FlotRessTright}, \\ & \text{FlotRessTr$$

, ListPolarPiot[(RCSdateStreegey1TAll, RCSdateSAll), Joined + True, FolarGriddines - Antomatic, FolarTicka + ("Degrees", knownic, ) Folstyla → (Blue, (Red, Dashed)), BaseStyla → Rheen, TR RCS ("A), Booth Cylinder (Slue) va Corrupted Cylinder (Red, -1", TasgeSise → 700, BaseStyla → (Rostise > 14, Forskight → "Shol", FolarAses + True, FolarAse="True", Red, Coll., RCSdolfreegey1TAll, RCSdolfAll)]]

ListPolarPiot[[RCMdsaEcegoylThglusTEAl], RCMdstaEAl]), Joined + True, FolarGridines - Automatic, Polarticle + ("Operare", Automatic, Picityla >> (Bius, [Red, Dashed)), EaseDigta >> AbsolutThichese(2], Picitkariar >> None, Picitabal -> "Picitabal -> "Picitaba -> "P

} }] r(sss7)- Export[ToString[StringForm["``.jpg", PhiRCSPolarPlotsName]], PhiRCSPolarPlots];

### Changing Phi RCS dB Polar Plots

### Corrugated Cylinder Plots

### Plot Ez

# REEECord = ListPolstPlot[RCSdstaEsdB, Joinsd = Trus, PolsGridlines - Automatic, PolarTicks = (Togrees", Automatic), PlotStyle > (Med. Dashb), BasStyle > MoniteThinChess[2], PlotHarkers > None, PlotLabel > "E, Corrupated Cylinder (RCS dimp) Tampélies > 700, BassEtyle > [Fontise > 14, Rontheight >> "Bold"] PolstAkes = Trus, FloatAessOrigin = (0, Naclabil for LogiO(RCSdSIE])]])]

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"Eg TE RCS  $(m^2)$  Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)", ImageSime -> 700, BaseStyle -> [FontSime -> 14, FontWeight -> "Bold"), FolarAxee + True, FolarAxeeOrigin + (0, Max[RCISolEthoregoylTE, RCSSolErho]}]

, ListPolarPloE[ {REddataErhoregoylTMplusTE, REddataErho), Dolmed + True, PolarEited + Tompsee', Automatic, PolarEides 4 ("Degress", Automatic), PictEtyle → (Blue, (Bed, Dashed)), BaseEyle → AbsoluteThickness[2], PictEtaEl → Sone, PictEaEl → T. Thref ESC ("Soneth Qilance (Blue) ye Corrugated Qilander (Bed, -...)\*, ImageSize → 700, BaseESyle → FiceTize → Chold', PolarAnses + True, PolarAnseoTrigin + (0, Max[RCSSD1ErhoregoylTMplusTE, RCSSolErhol)]]

$$\label{eq:constraint} \begin{split} & \{ \texttt{ListrolarPlot}[\texttt{RC5dataRphirepoylTW, RC5dataRphi}), \\ & \texttt{Joint True, PolarTisLines + Automatic, \\ PolarTiscks + ("Begrees", Automatic, ) PolstByls -> (Blue, (Bed, Dashed)), \\ & \texttt{BaseStyls >> AbsoluteThisChesses[2], PlotMarkers -> Nose, PlotLabel -> "E, TW RC5 (m<sup>2</sup>), \\ & \texttt{BaseStyls >> CO, BaseStyls >> (PlotMarkers -> Nose, PlotLabel -> "E, TW RC5 (m<sup>2</sup>), \\ & \texttt{PolarTiscks -> True, PolarAuesOrigin + (0, Max[RC5SolEphiregcyLTW, RC5SolEphily]) } \end{split}$$

, ListPolarPlot[(MCHdataEphiregoyIT, MCHdatEphi), Obised + True, PolarGriniLinse + Antomatio, PolarTicks + ("Degrees", Antomatic), PlotByle -> (Blue, (Bed, Dashed)), BaseStyle -> NeosulterLinseas(J], FlotBarkers -> None, FlotLabel -> "W, TH RCH (w<sup>1</sup>) month Cylinder (Blue) vs Corrupted Cylinder (Bed, --)", ImageSite >> 700, BaseStyle -> (Forsties -1 4, FortKeight -> "Bold"), PolarAxee + True, PolarAxesOrigin + (0, Max[KCS01BphiregoyITK, KCE01Bphir)])

, ListPolarPlot[ {REddataRphiregcylTMplusTE, REddataRphi), Dolardia+ crew, PolarGridLines - Automatic, Polardia+ cremerted - Automatic, BaseSyla → AmeoluteRic, PiotKarkers → Nose, PiotLabel → Tr, Hiver EGC (19) Ameol (Bluey ye Corrugated Cyllonder (Bad, --)\*, LangaSize → 780; BaseSyla → Chortia → S. J. FortKarket → Touch1\*, PolarAres+ True, PolarAresOrigin + (0, Mas[RCSSOLBphiregcylTMplusTE, RCSSoLBphi])]

{ListPolarPlot[{RCSdataEreqcylTMAll, RCSdataEAll}, Joined + True, PolarGridLines + Automatic, PolarTicks + ("Degrees", Automatic], PlotStyle -> {Blue, {Red, Dashed}},

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### Plot Erho

REERACOPER = ListPolarNot(RESSataErhod), Joined + True, Folardridhises - Automatic, PolarTicke + ("Degrees", Automatic), FlodRyle - (Med. Dankd), ImaStyle - AbsoluteThichese3[2], FlodRyckers -> Nose, FlotLabel -> Tre, Corregated Cylinder (RES dBms)\*, ImageSise -> Toos, PlotLabel -> (Trotises -> Tool.\*), FolarAses - True, PolarAsesOrigin + (0, Max[Abe[10+Log10[RESSolErho]])]);

### Plot Ephi

RCERphiCorrdB = ListPolarPlot[RCEdataRphidB, Joined + True, FolarCridLines - Antematic, PolarTicks + ("Pagress", Antematic), FlotStyle - (Red, Dankol), InseStyle - AlsociuteThichness[2], FlotMarkers - Nice, FlotLahel -> Tr, Corregated Cylinder (RCE dimm), Imagediras -> Too, BaseStyle -> (Pontiss -> Al, PontNeight -> Tol.47), FlotArker = True, PelarAssOrigin + (0, Mar[Abs[10:Log10[RCE6.Hzphi]])];

### Plot EAII

REEMILCORED = ListFolarPlot [RCEdstathliß, Joined + True, PolardridLines - Antomatic, PolarTicke + ("Degrees", Antomatic), FlotTypla - (Med. Dathoh), LessTyle - Albenturthichese[2], PlotBarkers -> None, PlotLabel -> Thema: Corrupted ("plotder (CCE dates"), TampeEise -> 700, BaseBryle -> (FontSize -> 14, PontMeight -> Tao[4"), PolarExes -True, PolarZeedrigin - (0, Mar[Ades[10.Log10[RCEGDIAL1]])]);

### Summary Corrugated Cylinder Plots

GraphicsGrid[{{RCSExCorrdB}, {RCSErhoCorrdB}, {RCSEphiCorrdB}, {RCSEAllCo Spacings -> {Scaled[0], Scaled[0]}; rdB}),

### Smooth Cylinder Plots - TM Plots

### Ez (TM RCS)

REEREmp()1948 = ListPlatPlo([RCSdstEiregry1948], Joined - True, Polatoridines - Antomatic, Polaricka ( 'Degrees', Antomatic), Plottyle - Nie, Nasstyle - AbsoluteThickes(2), FlotBarkers - None, Plottabel - "E, Month Cylinder (M NGC dbms)', Taegelia -> 700, Eastyle - (Profile -> 14, Ponthsgit -> "Plot"), PlotAreas - True, PolarAxesOrigin -> (0, Max[Abs[10 + Log10[RCSSolEzregcy17M]]])];

### Erho (TM RCS)

Districtions and the state of the state o

### Ephi (TM RCS)

HUND, RCERbinegCyTNMB - LietPolarIot[RCSdatEpbiregcyTNMB, Joined + True, PolarGridLines Automatic, PolarTicks = (Thepress', Automatic), PolarGridLines - Automatic, PolarTicks = (Thepress', Automatic), Polatical > Te, Booch Cylinder (DN RCE diem)', Imageline > 700; BaseStyles > (FonSite > 14, Pontheight > 70al/), PolarAnses True, PolarAnsesGrigin = (0, Max[Abs[10:Log10[RCSSolEphiregcy130]]]);

### EAII (TM RCS)

HUNDER REIBLINGSCHTMEN + ListPolarPlot[REISdatEresge/INRAlldR, Joined + True, PolarGridLines + Antomatic, PolarPlote, ("Degrees", Antomatic), PolarGridLines + Antomatic, PolarPlote, Antomatica, Polar PlotImbel -> "Bown: Booth Cylinder ("M RCS diss)", ImageSize -> None, PlotImbel -> "Bown: Booth Cylinder ("M RCS diss)", ImageSize -> 700, Resettyle -> (TontSize -> 14, Fontheight -> "Bold"), Folarkees + True, PolarkeeScigns (-0, NackBallo 10-200[CheSoltregot/ThUE])])];

### Summary TM Plots

HEALTHY GRAPHICSGrid[{RCSErRegCylTMdB}, (RCSErhoRegCylTMdB), (RCSEphiRegCylTMdB), (RCSEAllRegCylTMdB), Spacings -> (Scaled[0], Scaled[0])];

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### Smooth Cylinder Plots - TM + TE Plots

### Ez (TM + TE RCS)

NEEKERgCyTMpLuTEdB = ListDiarPlot[NCEdstatrengcyITMplusTEdB, Joined + True, PolaGridLines -Astomatic, Polaritoks + ("Degrees", Astomatic), PlotStyle > Blue, Basely as > Monot Artichtesse[], PlotEntarar >> None, PlotLabel >> TE, Monoth Cylinder (TM : TL RCE dBms)", Tangelise >> TO0, BaseStyle > (TenSiles >> Al, FontNeights >> ToldT, PlotLabest = True, PolarAmesGrigin + (0, Mas(Abs[10 = Log10[RCSFolErengcyITMplusTE]]));

### Erho (TM + TE RCS)

Distributery(TMP)LurWEdM + ListPolarPict(ECSdataErhoregcyLTMpLurTEdM, Joined + True, PolarticLines - Antenatic, PolarTicks + ("Degrees", Antonatic), PictSyle - Blue, Baselyle - AlkoniterFiltenses(], PicHarkers -> None, PictLabel -> "K, Bmooth Cylinder (TM - TH RCS dBan)", ImageEise -> 700, BaseStyle -> (FormEise -> 14, FontWeight -> "Bold"), FolarAses True, PolarAsesCrigin + (), Mark(Bas) (10 - LogiC)(EcSdatheregc)(TMplexiD)[]));

### Ephi (TM + TE RCS)

CTRBMARGCylTMBLusTERD = ListFolarPlot[ScEdstatphiregcylTMBLusTERD, Jolned + True, PolarcidLines + Automatic, PolarTicks = ("Degrees", Automatic), JlotStyle > Diue, BassSyle > DabeluteThickness[], FlotMarkers -> Nese, FlotLabel -> "Es Bonch CylLinder (H + TE SCE diss) +, ImageSize >> 700, BassStyle -> (FontSize -> 14, FontWeight -> "Bold", Jonzkase + True, Folarkeestrijke = (6, Mas(Hell's Logid)(MCSOLphiregylTMB/usTE)]]);

### FAIL (TM + TE BCS)

Control Terrerow RESLIPScy(TybplerTEM = ListPolarPict(RCSdstaTergcylDbplurTEAldB, Joined + True, Polatdridins = Antomatic, PolarTicke + ("Pagres", Antomatic), Flottyle > Blos, BaseStyle > AbsolutEAtholesses[], FlotUmkran = > None, FlotLabel >> Thomation => AbsolutEAtholesses[], FlotUmkran => None, FlotUmkrangen == (None) AbsolutEAtholesses => None, FlotUmkrangen => None,

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### Smooth Cylinder Plots - TE Plots

### Ez (TE RCS) - DOES NOT EXIST

### Erho (TE RCS)

RCSErhoRegCylTEGB = ListFolstPlot[RCSdstatrhoregcylTEGB, Joined + True, PolarCridLines + Automatic, Polaricks + ("Degrees", Automatic), PlotStyle = Niue, RaseStyle > Nakolitethones(2), FlotBarkers -> None, PlotLabal -> TE, Booth Cylinder (TE RCS dBm)", LangeSize -> 700, RaseStyle > (PontSize -> Al, PontHeight -> "Bold", Polarkase + True, PolarkesOrigin + (0, Max[Abs[10+Log10[RCSSolEhorescylTE]]]));

### Ephi (TE RCS)

RCSEphiRegCylTEdB = ListPolarPlot[RCSdataEphiregcylTEdB, Joined -> True, District Action and Actional Society (Constraints) (Constr

### EAII (TE RCS)

EMB(1: record) EMB(1: record) EMB(1: record) Polarizidiane Automatic, Polarizida ("Degrees", Automatic), Polarizidiane Automatic, Polarizida ("E Polarizida", Automatic), Polarizida - Nime, Basefyla - Akoolateristichanes(1), Polarizida Polarizati - (Foncilia - 1), Fontietida ("E RG dism", ImageSize - 70 Basefyla - (Foncilia - 1), Fontietida - "Deld", Fontanes - Tr Polarizaterizida - (0, Max(Abs(10+Log10[RCS0LErepy1TEA11]))));

### Summary TE Plots

- GraphicsGrid[({RCSErhoRegCylTEdB}, {RCSEphiRegCylTEdB}, {RCSEAllRegCylTEdB}}, Spacings -> {Scaled[0], Scaled[0]}};

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### Summary TM + TE Plots

- GranhicsGrid

### ({RCSERRegCylTMplusTEdB}, {RCSErhoRegCylTMplusTEdB}, {RCSEphiRegCylTMplusTEdB}, {RCSEAllRegCylTMplusTEdB}}, Spacings -> {Scaled[0], Scaled[0]};

### Compare (Regular vs Corrugated) Plots

### TM. TE. and TM+TE Compare

PhiRCSdBPolarPlots : bildCdBrolarblots = GrephiaGrid(LittPlatFlot[(RC5dstaErregcylTM6B, RC5dstaErd8), Joined + True, PolarGridLines - Automatic, PolarTicks + ("Degrees", Automatic), PictStyle - Qilas, (Mc, Joshad)), ResetVie -> AbsolutAthichness[2], PictStyle -> Qilas, (Mc, Joshad)), ResetVie -> AbsolutAthichness[2], PictStyle -> Qilas, (Mc, Joshad), ResetVie -> AbsolutAthichness[2], PictStyle -> Qilas, (Mc, Joshad), ResetVie -> AbsolutAthichness[2], PictStyle -> Too, ResetVie -> (TentSize -> 14, FontWeight -> "Rold"), PolarAses + True, PolarAsedOrigin -> (0, Max[Abs[10 - Log10[RC5SolErregv]TM]], Abs[10 + Log10[RC5SolEr]]]))

### "E, TE Does Not Exist"

, ListPolsflot[(hC5dstaErcegoylTh0jusTh3b, RC5dstaEsdb), Joined + True, Polsfcfidines - Antomatic, Polsflot(- ("Segress", Automatic), Plot5tyles - (Hus, (Bed, Dashb)), Bastyles - Automatic), Plot5tyles - (Hus, (Bed, Dashb), Bastyles - Automatic), Plotbacer -> None, Plottabel -> 'B, DHOTE RC5 (dBes) Booth Cylinder (Hus) vs Corrupted Cylinder (Hed, ->', Tamgedist -> 700, Bastyle -> (Pontline -> 14, FontWeight -> "Bold"), PlotArcses +Two, PlotArsbor(Hgi= (D, Max[Abs[10 ± Log10[RC56clKreegoylTh0]usTR], Abs[10 ± Log10[RC56clRe]])])),

[ListNolarPlet[(RCEdetatherego;ITME, RCEdetathodf), Joined + True, FolarCidLine + Antonatic, PolarTick + (Togres\*, Antonatic), FoltSyle - Miss, (Red.Daubel), RassCyle - AbcolteThickness[2], FoltBackers - None, FlotLabel -> "E, MI CC (dem) Bmooth Cylinds (Lime) ve Corrugated Cylinds (Red. ->", ImageSite -> TO, BaseStyle -> (FontSite -> 14, FontWeight -> "Bold"), FolsArkes T-res, PolarAsedCigin + (), Has(Abs[10+Log10]RCESoLEthorego;ITG], Abe(10+Log10[RCESoLEtho]])])

, ListPolarPlot[{RCSdataErhoregcylTEdB, RCSdataErhodB}, Joined  $\rightarrow$  True, PolarGridLines  $\rightarrow$  Automatic, PolarTicks  $\rightarrow$  {"Degrees", Automatic},

# Garcia\_Final\_v4.1.nb 97 98 | PhD Research Garcia\_Final\_v4.1.nb $$\begin{split} \label{eq:loss_states} & \mbox{PictRive} \rightarrow (Bive, (End, Dashed)), BaseStyle \rightarrow AbsoluteThickness[2], \\ & \mbox{PictRiver} \rightarrow None, PictLabel \rightarrow "K_F TK ACS (dBmm) Bmoch \\ & \mbox{Oylinder (Bas, -0)"}, \\ & \mbox{DistRive and Transformed Oylinder (Bas, -0)"}, \\ & \mbox{DistRive and Transformed or DistRive and States} \rightarrow 10, \mbox{PictRiver} \rightarrow "Bold", \\ & \mbox{DistRive and Transformed or DistRive and States} \rightarrow 14, \mbox{PictRiver} \rightarrow "Bold", \\ & \mbox{DistRive and Transformed or DistRiver and States} \rightarrow 14, \mbox{PictRiver} \rightarrow "Bold", \\ & \mbox{DistRiver and Transformed or DistRiver and States} \rightarrow 14, \mbox{PictRiver} \rightarrow "Bold", \\ & \mbox{DistRiver and Transformed or DistRiver and States} \rightarrow 14, \mbox{PictRiver and States} \rightarrow "Bold", \\ & \mbox{DistRiver and Transformed or DistRiver and States} \rightarrow 14, \mbox{PictRiver and States} \rightarrow \mbox{Time} \rightarrow \mbox{Time$$ (listPolarPlot[NC5detaRrepcylTMAlldB, NC5detaEAlldB), Joined + True, PolarGridLines + Automatic, PolarTicks = ("Degrees", Automatic), FlotTkyis -> Siles, [ted, Leaked), RaestYis -> AbcliteThickness[2], FlotTkrkers -> None, FlotLabel -> "Bo<sub>nul</sub> TM RCG (dBms Booth Oylinder (law) vs Corrupcies Oylinder (Hed, ->)", Tangedise -> NOn, BasedSyla -> [Fontlise -> 14, FontWeight -> "Boild"), Folarkes -Toxe, PolarkeeGrigin + (0, Max[Abs[10+Log10[RC550LErepcylTMAll]), Abs[10+Log10[RC550LEAL]])])) (0, Max[Abs[10 \* Log10[RCSSolErhoregcylTE]], Abs[10 \* Log10[RCSSolErho]]])] , ListolarPlot[(RC5dataErhorsegcylTMpluwTEGB, RC5dataErhodB), Joined + True, PolarGridLines - Antonatic, PolarTicks + ("Pagress", Automatic), FlotStyle - (Mue, (Red, Tabatel)), Resstyle -> AbsolutAFilchorses[2], FlotStackers -> None, FlotLabel -> 'B, TheTE RC5 (dBes) Booth (ylinder (Ruis) +> Gorzyated (ylinder (Red, ->)\*, TangoBite -> 700, BaseStyle -> (PontEine -> 14, FontWeight -> "Bold"), Folakemes + True, Polarkasofighte (0, Mar] Abs[10 + Log10[RC5501Erhorsegct]TMplusTE]], Abs[10 + Log10[RC5501Erhorseg1]])] , ListPolarPlot[(RCSdataEzegcylTEAlIdB, RCSdataEAlIdB), Joined - True, Polardridines + Automatic, PolarTicks - ("Degrees", Automatic), Pioletsyles - (bine, (Bed, Databel), BassCyles - Abscitetinkenses[2], Piolstarkers -> None, Piolabel -> "B<sub>2014</sub> IT RCE (dBms Booth Cylindes (Humo) vs Corrugated Cylindes (Hed, --)", ImageSime -> T00. BassCyle -> (PontEise -> 14, FontWeight -> "Bold"), Polarkees -True, PolarkeeStyle -> (TontEise -> 14, FontWeight -> "Bold"), Polarkees -True, PolarkeeStyle -> (TontEise -> 14, FontWeight -> "Bold"), Polarkees -True, PolarkeeStyle -> (TontEise -> 14, FontWeight -> "Bold"), Polarkees -True, PolarkeeStyle -> (TontEise -> 14, FontWeight -> "Bold"), Polarkees -True, PolarkeeStyle -> (TontEise -> 14, FontWeight -> "Bold"), Polarkees -True, PolarkeeStyle -> (TontEise -> 14, FontWeight -> "Bold"), Polarkees -TontWeight -> (Bold (RCSSolEregcylTEALI]), Abe(10+Logi0(RCSSolEALI)])))) istPolarPlot[(RCdstaBphiregcy1766B, RCdstaBphidB), Joined + True, PolarFridLines + Actomatic, PolarTicks + ("begrees", Automatic); PiotStyle > (Biue, (Red, Bashd)), BasStyle > AbsolutAFhichness[2], PiotBarkers -> None, PiotLabel >> "B, TM ECI (dBms) Smooth Cylinder (Biue) ve Corrugated Cylinder (Red, ->)", Tangodisc >> 700, BasStyle >> (PontBise >> 14, FontWeight -> "Bold"), FolarMaes True, PioLarMaesCiglin +> (0, Mas(Abs[10 + Log10[RCS01Bphi]]))] , ListPolarPlot[(RCHdstaEregoylTMplusTEALIdB, RCHdstaEALIdB), Joined → True, PolarGridLines + Automatic, FolarTicks + ("Degrees", Automatic), FlotStyles (> Ulsus, (Red, Dasho), Isastyles → AutoiutofLicheses[2], FlotHarkers → News, FlotLakel → "E<sub>Nucl</sub> The TE RCB (dees) Smooth Cylindes (Ulsus ∨ Scrutymate Oylinder (Red, -)", Tamsgeline → TOD, Resettyle → (Fontiler → 14, FontWeight → "Rold"), FlotAres + True, FolarAssoftyle = (Resettyle → Ulsus), Nel(10 + Log10[RCESolEregoylTMplusTEALI]], Abe(10 + Log10[RCESoLEALI]])])] , ListPolstPlot[[RC5dstaSphiregry1TKdB, RC5dstaSphidB], Joined + True, PolarGidLines - Antonatic, PolarTicks + ("Degrees", Antonutch), PlotStyle → Club, (Red, Dabed), RaseStyle → AncolutchLiness[2], PlotSterkers → None, PlotLabel → "M, TR CS (dHem) Emoth Gylinder (Rule) va Corrugated Gylinder (Red, --)\*, TangeStar → 700, BaseStyle → (PentEine → 14, FontWeight -> "Bol4", PlotExtes + True, PlotLabedCigin + (0, Mas(Abs[10 + Log10[RC5501Ephilegoy1TE]], Abs[10 + Log10[RC5501Ephil]])] Export[ToString[StringForm["``.jpg", PhiRCSdBPolarPlotsName]], PhiRCSdBPolarPlots] Changing Phi RCS dB XY Plots , istobarPlot([RCMatsRphiregoylTMpileTRdM, RCMatsRphidB), Joined + True, PolarGridiane + Antonatic, PolarGridiane + Antonatic, PolarSteide + (Tbegrees", Antonatic), PiotsRyse + (Rive, (Red, Daheb), BaseSkyle + NacoluteThiotoms[2], PiotsRase + Norm, PiotLabal - "K, MTR RCM (dHen) Moorth (Rivers), Cylinder (Red, - "), ImageDise -> 700, BaseSkyle -> (FortElse > 14, FortWeight -> "Bol4"), Red (Red, -> 14), Red (Red, -> 14), Red (Red, -> 14), Red Corrugated Cylinder Plots Plot Ez

PolarAxes + True, PolarAxesOrigin + {0, Max[ Abs{10 + Log10[RCSSolEphiregcylTMplusTE]], Abs[10 + Log10[RCSSolEphi]]])]

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RCERCOrrdBay = ListLinePlct[RCEdstaKedH. PlotBange -> {{0, 2 Pk}, {Min[10:Log10[RCESOLKe]], Max[10:Log10[RCESOLE]]}}, PlotBayle -> (Med, Dashd), DassetPla -> XBooltwaThichess[2], PlotBaylers -> Nose, PlotLabel -> %. Corrupted Cylindser (RCE dBan)\*, Frame -> True, Franciabel -> (\*\*, "RCS (dBan)"), GridLines -> ([0, { (Thick ), Gray, Dashed])), Notesatic), Background -> White, ImageSize -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> "Bold")];

### Plot Erho

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(ListPol

RCEErboCorrdBay = ListLineFlot[RCEdstatErboCB, PlotRange ->
 ((5.2 PJ), (Man[04-Logi0[RCESbiErbo1], Max[04-Logi0[RCESbiErbo1])),
 PlotStyle -> (Med. Dashod) = seeStyle -> AbsociutATLiconaes[2],
 PlotEstarkers -> Nome, PlotEsbal -> '%, Corrupted Cylindes (RCE dBam)',
 reinLines -> Nome, PlotEsbal -> '%, Corrupted Cylindes (RCE dBam)',
 reinLines -> (Plet, Teshod), Associute(), Backgroud -> White,
 ImageDize -> 760, BaceDtyle -> (Fortize -> 14, FortHeight -> "Bold")];

### Plot Ephi

RCHRphiCorrdHxy + ListLineFlot[RCSdatABphid], PlotRange → ((6, 7±), (Man(10-Logid[RCSDatBphi]), Max[10-Logid[RCSDatBphi]])), PlotEtyle> (Med, Dahad), masdryle> AbadisuteThickness[2], PlotEtyle> (Med, Dahad), masdryle> AbadisuteThickness[2], PlotEtyle> (Med, Dahad), Medsata (Med), Medsata (Med), Prasm > True, Francibal > ('4', 'EC (Med)), Atlontic), Background > 1 GaidLines → (((PL, (Thick, Fey, Dahad))), Atlontic), Background > 1 ImageDize > (10, BaseRyle> (PlotLine > 1, FortBeight > "Salf")); nd -> White,

### Plot EAII

$$\label{eq:constraints} \begin{split} & \texttt{RCEdataEAllds, PlotRange} \rightarrow \\ & (0, 2P3), (Ma(10+logi0)RCESsLEML)), Ma(10+logi0|RCESsLEML])), \\ & \texttt{PlotEty10-}, (Ma, Daheda, Basetyia > AbsolutionThickness[2], \\ & \texttt{PlotEty10-}, (Ma, Daheda), Basetyia > AbsolutionThickness[2], \\ & \texttt{PlotEty10-}, (Ma, Daheda), Basetyia > AbsolutionThickness[2], \\ & \texttt{PlotEty10-}, (Ma, Daheda), Basetyia > Main (Main ($$

### Summary Corrugated Cylinder Plots

GraphicsGrid[{{RCSEzCorrdBxy}, {RCSErhoCorrdBxy}, {RCSEphiC {RCSEAllCorrdBxy}}, Spacings -> {Scaled[0], Scaled[0]}};

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### Smooth Cylinder Plots - TM Plots

### Ez (TM RCS)

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NCERsbegCyITMEMsy = ListLineFlot(RCdataErsegcyITMEM, PlotRange -> ((0, 2P1), (Hin(10+top)(CRCSOLErcepcyITM[), Na(10+top)(PRCSOLErcepcyITM[)), FlotRyle=> Nice, Baselyle=> NaceLyETLineEnse[], FlotRyle=> None, FlotLabel -> TL, Booch GyLinder (TM RC dBas)\*, Frame-> Track, FrankLabl -> ((V\*, \*RC(dBas)\*), GridLines -> (((R. (Thick, Gray, Dashed))), Axtentic), Background -> White, Imagelize >> TOB, Baselyle=> (FortLines -> (R. (Taubhyd) -> Tole]);

### Erho (TM RCS)

Linking:/linkiny=ListLinePlot[RCIdataExhoregcy15MEN, PlotEanops -> ((0, 2 FL), (Min[10+Log10[RCSBolExhoregcy15M]], Max[10+Log10[RCSBolExhoregcy15M]])), PlotEytig=> Blue, BaseStyle >> AbsoluteThickness[2], PlotEarkers >> Nres, PlotEabel >> "%, SnottO-fyloader (TM RCS dBmn)", Prame -> True, Franziabel >> (%, "RCG (dBmn)"), GridLines >> ([(Pi, (Thick, Gray, Bashed)), Aktomatic), Background -> White, ImageSize -> 700, BaseStyle >> (FontSize -> 14, FontWeight -> "Bold")];

### Ephi (TM RCS)

spin(rives)
RSEEphileg(7)INERsy = ListLinePlot[RSEdstaEphiregoryINEE, PlotEange -> ((),
(Min[10+Log10[RSE501EphiregoryINE]], Max[10+Log10[RSE501EphiregoryINE]]
PlotEtyle -> Biue, BaseStyle -> AbsolutaThickness[2],
PlotEtheckers, Nome, PlotEthel -> '%, South Cylinder (TM RSC dBms)',
Frame -> True, Francialel -> '%, South Cylinder (TM RSC dBms)',
GridLines -> ((Pi, (Thick), Grey, Dateshi)), Antomatio), Background -> M
ImageSize -> 700, BaseStyle -> (PontEize -> 14, FontWaight -> "Bold")]; -> {{0, 2 Pi},

### EAII (TM RCS)

ECELLINES/CJTMEMERY = ListLinePlot(RCEdstaTregoyISGLIdB, FlotEange > ((0, 2Fi), (Min[10+16040[RCEGOLEmegoyISGLI], Mar[10+Logi0[RCENbulkregoyISGLI]))), PlotByle > Elso, BaseStyle > MassloteThicknes[2], FlotBarkars >> Bos, PlotBabl > "Bound Booth Cylinder (TM RCE dams", Frame > Tree, Francishel > ("4", "RCE (dams"), GridLines > ([Fi, (Thick ), Gray, Babed))), Notesnic), Background >> White, ImageSize > 700, BaseStyle > (FontEize >> 14, FontWeight >> "Bold")];

### Summary TM Plots

GraphicsGrid[{{RCSEzRegCylTMdBxy}, {RCSErhoRegCylTMdBxy}, {RCSEphiRegCylTMdBxy}, {RCSEAllRegCylTMdBxy}}, Spacings -> {Scaled[0], Scaled[0]};

Smooth Cylinder Plots - TE Plots

### Ez (TE RCS) - DOES NOT EXIST

### Erho (TE RCS)

Ephi (TE RCS)

Stepshines(v)TREMBy = ListlineFlot(RCMdstaBphiregcylTEdB, FlotRange -> {(0, 2 Fl), (Min(10=Logi0[CCCMDERphiregcylTE]], Max(10=Logi0[CCCMDERphiregcylTE]])}, PlotStyle -> Blue, BaseStyle -> AbsoluteThicknes(2), PlotStarkera -> Nome, FlotLabel -> "4, Booth Cylinder (TE RCG dBms)", Frame -> True, Franciabel -> (4°, "RCG (dBms"), CridLines -> ([Pl, (Thick, Gray, DashedDi)), Natosatio), Background -> White, ImageSize -> 700, BaseStyle -> (FontEise -> 14, FontWeight -> "Bold"));

### EAII (TE RCS)

Letu (ic.co) RCSAllmeyCyTTEMBy = ListLinePlot(hCEdataErepsylTEAllds, PlotEneps -> ([0, 2Pi), (Min[10 \* Log10[RCSSolErepsylTEAll]], Max[10 \* Log10[RCSSolErepsylTEAll]])), PlotEyle -> Rise, BaseStyle -> AksoluteThickness[2], PlotMarkers -> None, PlotEale -> True, Francischel -> ("4", "RCS (dHum"), CridLines -> True, Francischel -> ("4", "RCS (dHum"), Breader -> True, Francischel -> ("4", "RCS (dHum"), Breidlines -> TO, BaseStyle -> (FontSize -> 14, FontWeight -> "Bold")];

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### EAII (TM + TE RCS)

Reliikey/ITBplosTERBey = ListLinePlot[RCBdstaFrego/ITbplosTEAlldB, PlotRange -> ((0, 2F4), (Min[10.Logi(RCBdstaFrego/ITbplosTEAlldB, Nam(10.Logi(RCBdstaFrego/IbplosTEAll]), NetEstyle -> Blue, Basstyle -> AbsoluteTLicknes(2], FlotRarkers -> Bone, PlotLabl-> "Evani Booth Crylinder (THT REG dBmg)", Frame -> True, Franchabl -> ("\$", "RCG (dBmg)", Arcidines -> ([C4, (Thick ergs, Dashed]), Antomatio), Background -> White, ImageSize -> 700, BaseStyle -> (FootSize -> 14, FootHaight -> "Bold")];

### Summary TM + TE Plots

resess. GraphicsGrid[(RCSErRegCylTMplusTEdBxy), (RCSErhoRegCylTMplusTEdBxy), (RCSEphiRegCylTMplusTEdBxy), (RCSEAllRegCylTMplusTEdBxy)), Spacings -> (Scaled[0], Scaled[0]);

### Compare (Regular vs Corrugated) Plots

TM, TE, and TM+TE Compare

hiRCHGHXTPlots =
GraphicsGrid([(Rhow[(RCEEsBegCylTMGHey, RCEEsCoredHey], FlotHange ->
((0, 2FL), Unin(10+Log10[RCES0lEregcylTM], 10+Log10[RCES0lER]),
Max[10+Log10[RCES0LEregcylTM], 10+Log10[RCES0LER])])), FlotLabei-"K. TM RC (GHam) Monot CylInder (Blau), accorrugated Gylinder (Blau),
ImageEize -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> "Bld")] --) ", "Ez TE RCS dB Does Not Exist"

, how(1KCERsheg(y)1%plusTbdBay, RCHEsCoredBay), FlotRange → {(0, 2+1), (Nk1|0 + iq01)RCH50LErregcy/TbplusTb, 10 + log01[RCH50LE]] Nk1[0 + log10[RCH50LErregcy/TbplusTb, 10 + log01[RCH50LE]]}, PlotEabel → Tc, ThVTE RCI (dBms] Smooth Cylinder (Blus) vs Corrupted Cylinder (RAC - -)<sup>\*</sup>, ImageSize → 700, BaseStyle → {PostBize → 14, FostNeight → \*Bold\*}] SSolEz]],

), (Mov[RGERhoBegCylTMdBwy,RCEExhoCorrdBwy), FlotHange → ((0, P1), (Mar[10 + Logit[RGEShiThoregcylTM], 16 + Logit[RGEShiThol]), Mar[10 + Logit[RGEShiThoregcylTM], 16 + Logit[RGEShiThol])), FlotLabel → "R, TM RG (dBms)Smooth Gylinder (Blau) wa Corrugeted Gylinder (Bad. → )", Rapefiles → 700, BaseNtyl → (Cortains → 14, RowNight) → Rold']]

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### Summary TE Plots

# GraphicsGrid[{{RCSErhoRegCylTEdBxy}, {RCSEphiRegCylTEdBxy}, {RCSEAllRegCylTEdBxy}}, Spacings -> {Scaled[0], Scaled[0]}];

### Smooth Cylinder Plots - TM + TE Plots

### Ez (TM + TE RCS)

CERtRegcyID%plusTEdBay = ListLine#lot[ECSdstaHzregcyID%plusTEdB, PlotEnage -> (0, 2 PL), (Min[10 + Log(01)CRESoLExregcyID%plusTEdB, Mas(10 + Cog(01)CRESoLErregcyID%plusTEJ]), PlotBytle -> also, BaseStyle -> AbsoluteMickness[2], PlotBytlers -> None, PlotEabel -> 7%, EmontCyIDmicr(THT RECGMen)\*, Frame -> True, Franciabel -> (\*\*, TCE (dBam)\*), Griddines -> (TO, BaseStyle -> (FontSise -> 14, FontBwight -> "Bold\*)]) -> White,

### Erbo (TM + TE RCS)

SEchoRegCylThplusTkdRay = ListLineFlot[RCSdataFkhoregoylThplusTkdR, FlotRange -> ([6. 21]), (Hin[16 + LogiO[RCSdoLEnheregoylThplusTE]), Kan[10 + LogiO[RCSdoLEnheregoyThplusTE])), FlotRyle -> Blue, BaseStyle -> AbsoluteThickness[2], FlotRatkers -> Hone, FlotLabel. -> "E, Smooth Cylinder (Hurf: RCG Homm)", Frame -> True, FrancLabel.-> (\*4", "RCG (Homm)", Gridlines -> ((Fet, (Thick, Gray, Dabed)), Automatio), Rackground -> White, ImageSize -> 700, BaseStyle -> (FontSize -> 14, FontNeight -> "Bold"));

### Ephi (TM + TE RCS)

RCERphikegcyIthplusTEdBay = ListLisedIot[RCEdataBphikegcyIthplusTEdB, PlotEnangs -> [(0, 21), [Min[14:LogO](RCEDatBphikegcyThplusTE]], Man[14:LogO](RCEDatBphikegcyThplusTE]), PlotByLes BaseStyle -> AbsoluteThicknes[2], PlotBetLes -> Nuce, PlotEabl-', "& RoottO, PlotBetLes -> Nuce, PlotEabl-', "& RoottO, PlotBetLes -> Nuce, Prame -> True, Franciabel -> (\*\*, "RCE (dBms)", GridLines -> (16), [Thick -> (Rey, Dahedb)], Antomito], Background -> ImageSize -> 700, BaseStyle -> (PortSize -> 14, FontMeight -> "Bold")]; -> White,

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, how [RACSRthoRegCylThplusThdHay, RCBSrhoCorrdHay], PlotLange  $\rightarrow$  ((0, 2 Pl), (Min[10+log10[RCBSRthoregylThplusTR], 10-log10[RCBSRLhrohr], Max[10+log10[RCBSRLhrohr], Nav[10+log10[RCBSRLhrohr]]]]] PlotLabel  $\rightarrow$  "G, THCFR RCS (dBam; Booch CylInder (Blue) we Corrupated CylInder (Rod  $\leftarrow - - ^{+}$ , ZamgeSize  $\rightarrow$  700, BaseStyle  $\rightarrow$  (FontSize  $\rightarrow$  14, FontWeight  $\rightarrow$  "Bold")]

(BorW(RCEBphlBegCylTMdBwy,RCEBphlCorefBwy),FlotHange → ((0, Pl), (Mar[10-log2(REESbiphleegy:TMQ, 10-log3(RCESbiphl]), Mar[10-log2(RCESbiphleegy:TMQ, 10-log3(RCESbiphl)])),FlotLabel → "% YM RCE (dBws) Bmoch CylInder (Bluw) vs Corrupated GylInder (Red, →" ImageSites → "On LaedFyle → (Cortiate → 14, ForeWaght → "Balled")

, Bow[[ACERphiRegCylTEdBay, BCEEphiCorrdBay], FlotRange ->
 [(0, 2 Pi), (Min[10 + Log10[RcESolEphiregcylTE], 10 + Log10[RcESolEphiregcylTE], 10 + Log10[RcESolEphiregcylTE], 10 + Log10[RcESolEphi]])], FlotEabel
 "5, TR ECG dems Booch CylInder (Bale v= ) transfer (Bed. --)
 TangeSize -> 700, BaseStyle -> (FontSize -> 14, FontBeight -> "Bold")]

, nov({RCERphiRegCylTMplusTEdHay, RCERphiCorrdHay), FlotRange → ((0, 2 Pi), (Min(10 + Logi010RCEStphirespylTMplusTE, 10 + Logi0[RCESolEghi]), Kas(10 + Logi0[RCESolEghirespylTMplusTE, 10 + Logi0[RCESolEghi]))), FlotLabat → "& THCTE RCE (dHam; Booth Cylinder (Blue) 'w Corrugate Cylinder (Had, -..)", ImmgeSize → 700, BaseStyle → (FontSize → 14, FontWeight → "Bold")]

(Blow([RCERAILBegCylTMCBky, RCERAILCorrdBky), Plothange → {(0, 2Pi), (His[10+Log10]RCSSolEreoylTMR1], 10+Log10[RCSSolEA1]], Max(10+Log10[RCSSolEreoylTMR1], 10+Log10[RCESSIEA1]]), PlotLabel → Texa: TR RCE (dBme) Bmooth Cylinder (Blue) v= Corrupated Cylinder (Add, ~)<sup>2</sup>, ImageSize → 700, BareStyle → (FontSize → 14, FontSwight → "Bold")]

/
Show[{RCSEAllRegCylTEdExy, RCSEAllCorrdExy}, PlotRange ->




# Changing Rho Plot Calculations

### Solution for Plots - Corrugated Cylinder

 $\phi = \phi \mathbf{a}; \, (* \texttt{scattered field } \phi, \text{ possibly incident } \phi \text{ as well}*)$  $(*\phi!=\phi;*)$   $\phi!=\phi!value; (*Only if considered unique and distinct from scattered field*)$ (\*Incident + Scattered Solution\*)
SolEx = N[Abs[Estemp]];
dataEx = Transpose[{rhorange/lambda0, SolEx}];

SolEphi = N[Abs[Ephitemp]]; dataEphi = Transpose[{rhorange/lambda0, SolEphi}];

# SolErho = N[Abs[Erhotemp]]; dataErho = Transpose[{rhorange/lambda0, SolErho}];

SolEAllSandI = N{Abs[Sqrt[((Erhotemp) + Cos[\$] - (Ephitemp) + Sin[\$])^2 + ((Erhotemp) + Sin[\$] + (Ephitemp) + Cos[\$])^2 + (Extemp)^2]]; dataEAllSandI = Transpose[{rhorange/lambda0, SolEAllSandI}];

(+Scattered Only Solution+) SolErS = N[Abs[Ertemp5]]; dataErS = Transpose[{rhorange/lambda0, SolErS}];

SolEphiS = N[Abs[EphitempS]]; dataEphiS = Transpose[{rhorange/lambda0, SolEphiS}];

SolErhoS = N[Abs[ErhotempS]]; dataErhoS = Transpose[{rhorange/lambda0, SolErhoS}];

$$\label{eq:solar_solar} \begin{split} & \text{SolEAllS} = N\{\text{Abs}[\text{Sqrt}[ \{\text{ErhotempS} * \text{Cos}[\phi] - \text{EphitempS} * \text{Sin}[\phi] \}^2 + \\ & (\text{ErhotempS} * \text{Sin}[\phi] * \text{EphitempS} * \text{Cos}[\phi] )^2 + (\text{ExtempS})^2]]]; \\ & \text{dataEAllS} = \text{Transpose}[\{\text{rhorange} / \text{lambda0}, \text{ SolEAllS}\}]; \end{split}$$

#### Solution for Plots - Regular "Smooth" Cylinder

TE Mode Solutions

SulEALITESandI -

 $\phi = \phi a$ ; (\*scattered field  $\phi$ , possibly incident  $\phi$  as well\*)  $(*\phi i = \phi; *)$   $\phi i = \phi i value; (*Only if considered unique and distinct from scattered field*)$ 

(+Incident + Scattered Solution+)
SolErregcylTESandI = N{Abs[ErregcylTESandI]];
dataErregcylTESandI = Transpose[{rhorange/lambda0, SolErregcylTESandI}];

SolErhoregcylTESandI = M[Abs[ErhoregcylTESandI]]; dataErhoregcylTESandI = Transpose[{rhorange/lambda0, SolErhoregcylTESandI}];

SolEphiregcylTESandI = M{Abs[EphiregcylTESandI]; dataEphiregcylTESandI = Transpose[{thorange/lambda0, SolEphiregcylTESandI}];

3ulBALITERson1 = NulBas[Sqt[{[(ErboregcylTESand]) + Cos[6] - (BphiregcylTESand]) + Sin[6])^2 + ((ErboregcylTESand]) + Sin[6] + (BphiregcylTESand]) + Cos[6])^2 + (EresqcylTESand] + Sin[6] + (BphiregcylTESand]) dataEAllTESand] = Transpose[{rhorange/lambda0, SolEAllTESand]];

(\*Scattared Only Solution\*) SolEzregcylTES = N[Abs[EzregcylTES]]; dataEzregcylTES = Transpose[{thorange/lambda0, SolEzregcylTES}]; SolErhoregcylTES = N{Abs{ErhoregcylTES}}; dataErhoregcylTES = Transpose[{rhorange/lambda0, SolErhoregcylTES}];

SolEphiregcylTES = N[Abs[EphiregcylTES]]; dataEphiregcylTES = Transpose[{rhorange/lambda0, SolEphiregcylTES}];

SolEAllTES = N{Abs[Sqrt[(ErhoregcylTES + Cos(\$) - EphiregcylTES + Sin(\$)] ^2 + (ErhoregcylTES + Sin(\$) = EphiregcylTES + Cos(\$) ^2 + (ErregcylTES) ^2]]]; dataEAllTES = Transpose[{rhorange/lambda0, SolEAllTES];

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## TM Mode Solutions

(\*Incident + Scattered Solution\*) SolErregcylTMSandI = N[Abs[ErregcylTMSandI]]; dataErregcylTMSandI = Transpose[{rhorange/lambda0, SolErregcylTMSandI}];

SolErhoregcylTMSandI = N[Abs[ErhoregcylTMSand]]; dataErhoregcylTMSandI = Transpose[{rhorange/lambda0, SolErhoregcylTMSandI}];

SolRphiregcylTMSandI = N[Abs[EphiregcylTMSandI]]; dataEphiregcylTMSandI = Transpose[{rhorange/lambda0, SolEphiregcylTMSandI}];

SolDAll'MHIANT = W(Rb/Egrt1((Exhoregoyl'MHIANG) = Cos(#) - (Sphiregoyl'MHIANG) + \$in(#)) ^2 + ((Exhoregoyl'MHIANG) = sin(#) + (Sphiregoyl'MHIANG) + Cos(#)) ^2 + (Exregoyl'MHIANG) = 1211); dataEAll'MHIANG1 = Transpose[{horizong/lambda0, SolEAll'MHIANG1]};

(\*Scattered Only Solution\*) SolErregcy1TMS = N[Abs[Erregcy1TMS]]; dataErregcy1TMS = Transpose[{rhorange/lambda0, SolErregcy1TMS]};

SolErhoregcylTMS = N{Abs{ErhoregcylTMS]}; dataErhoregcylTMS = Transpose[{rhorange/lambda0, SolErhoregcylTMS}];

SolEphiregcylTMS = N[Abs[EphiregcylTMS]]; dataEphiregcylTMS = Transpose[{rhorange/lambda0, SolEphiregcylTMS}];

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#### TM + TE Mode Solutions

(\*Incident + Scattered Solution\*) SolEzregcylTMplusTESandI = N[Abs[EzregcylTESandI+EzregcylTMSandI]]; dataEzregcylTMplusTESandI = Transpose[{rhorange/lambda0, SolEzregcylTMplusTESandI}];

SolExhoregcylTMplusTESandI = N{Abs[ErhoregcylTESandI = ErhoregcylTMSandI]]; dataErhoregcylTMplusTESandI = Transpose[{thorange/lambds0, SolErhoregcylTMplusTESandI}];

SolEphiregcylTMplusTESandI = N[Abs[EphiregcylTESandI+EphiregcylTMSandI]]; dataEphiregcylTMplusTESandI = Transpose[{rhorange/lambda0, SolEphiregcylTMplusTESandI}];

SolEAllTMplusTESandI - H[Abs[Sqrt[{(EnborageylTESandI + EnborageylTESandI) + Cos[0] -(EphirageylTESandI + EphirageylTESandI + Sol(0] + ((Enboragy)TESandI + EnboragylTESandI + Sol(0] + (EphirageylTESandI + EnginageylTESandI + Cos[0]) + 2 + (EtraceylTESandI + Transpose][(chorange/lambda0, SolEAllTMplusTESand]];

(\*Scattered Only Solution\* SolErregcylTMplusTES = N[Abs[ErregcylTES + ErregcylTMS]]; dataErregcylTMplusTES = Transpose[[rhorange/lambda0, SolErregcylTMplusTES]];

SolErhoregcylTMplusTES = N[Abs[ErhoregcylTES + ErhoregcylTMS]]; dataErhoregcylTMplusTES = Transpose[{rhorange/lambda0, SolErhor regcylTMplusTES}];

SolEphiregcylTMplusTES = N{Abs{EphiregcylTES\*EphiregcylTMS}]; dataEphiregcylTMplusTES = Transpose[{rhorange/lambda0, SolEphiregcylTMplusTES}];

SoIEALITHplusTES = N{Abs(Sgrt[(Efchoregoy)TES = Echoregoy)THS) + Cos(\$) -(Ephinegoy)TES = EnhoregoyITHS + Esi(\$)) \* 2 + ((EchoregoyITHS = EchoregoyITHS) + Esi(\$) + (SphinegoyITHS = EphinegoyITHS) + Cos(\$) \* 2 + (ExerceptITE = ExerceptITE) \* 21]]; distAllThplusTES = Texnograd [(EncargoyITHS) + SoIEALITHplusTES]];

# Changing Rho XY Plots

## Table of Parameters

- $$\begin{split} \textbf{Table of Parameters} \\ & \quad \\$$
- w(10)- Export[ToString[StringForm["``.jpg", RhoTableName]], ChangingRhoTable]
- Corrugated Cylinder Plots

## Plot Ez (Scattered)

wprop- ExCorrS = ListLinePlot[dataEzS, PlotRange -> {{rhomin/lambda0, rhomax/lambda0}, (0, Max[SolEzS])}, 
$$\label{eq:constraint} \begin{split} & \operatorname{Corri} : \operatorname{Listline?}(\operatorname{classify}, \\ & \operatorname{Ploting} \sim : [\operatorname{Ploting} | \operatorname{Listline}), \\ & \operatorname{Ploting} \sim : [\operatorname{Ploting} | \operatorname{Listline}), \\ & \operatorname{Ploting} \sim : [\operatorname{Ploting} | \operatorname{Listline}), \\ & \operatorname{Ploting} \sim : \operatorname{Ploting} : \operatorname{Ploting} : \\ & \operatorname{Ploting} : \operatorname{Ploting} : \\ & \operatorname{Ploting} : \operatorname{Ploting} : \\ & \operatorname{Ploting} : \\ & \operatorname{Ploting} : \\ & \operatorname{Ploting} : : \\ & \operatorname{Ploting} : : \\ & \operatorname{Ploting} : \\ & \operatorname{Ploting} : : \\ & \operatorname{Ploting} :$$

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#### Plot Ephi (Inc + Scattered)

FightCortSoft = ListLinePlot[detaRph, PlotRange -> {[thomin/lambda0], thomas/lambda0], (0, Max(SolEphi])}, PlotExple->, (Mad, Dahed), LameStyle -> AbsoluteThichnes[2], PlotExple->, None, PlotExple->, Mad, Dahed), LameStyle -> AbsoluteThichnes[2], PlotExple->, None, PlotExple->, Sandtyle-Content -> Sandtyle-Trame -> True, Franctale1->, "(r/A,", "V=1), GridLines -> [[(s21ianded), (Thick, Texy, Dashed)], Automatic], BaseStyle -> (FontSize -> 16, FontWeight -> "Bold")];

#### Plot EAII (Scattered)

WHE-EAllOard = ListLingTot[dataEAll5, FlotEnge >> {[ichomin/lambda0], thoman/lambda0], (0, Mas[loIEAll5])}, FlotEnge >> {Red, Eahadd), BasedFyle >> AbsoluteThichness[2], FlotEnkerse >> Bone, FlotEahel -> Th<sub>Datal</sub> Corrupted Cylinder (Scattared Field)\*, Frame -> Fram, FrameMatel >> ("o/A", "Var), GridLines >> {[[of]lambda0, (Thick, Gray, Dashed]}, Automatic], BaseBryue -> (FontSize -> 14, FontWeight -> "Bold")];

#### Plot EAll (Inc + Scattered)

EAllCorrSandI = ListLinePlot[dataEAllSandI ilicortend: = ListLinePle([statAlliand; FlotRamps - {[Chimbi/Lahdad, Fhoma/Lahdad], {0, Max(SolZAlliandI]}}, FlotRayle -> {Red, Dashed}, EaseStyle -> AbsoluteThickness[2], FlotMarkers -> None, FlotLabel -> "Benu: Corrupted Cylinder (Incident + Scattered Field)", Frame -> True, FrameLabel -> {[ColAr', "VM"], GridLines -> {[[(z]/Lahdad), (Thick, Gray, Dashed]]}, Automatic], Background -> Winel, Emageliae -> 700, BaseStyle -> {FontBise -> 14, PontBisight -> "Bold"];

### Summary TM Plots

BUDD: GraphicsGrid[[[ExCorrS, ExCorrSandI], (ErhoCorrS, ErhoCorrSandI], (EphiCorrS, EphiCorrSandI], (EhilCorrS, EAilCorrSandI)), Spacings -> {Scaled[0], Scaled[0]]};

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## Plot Ez (Inc + Scattered)

#### Plot Erho (Scattered)

- NVP. EthoCord = listLinePlot[dstaErhod, PlotEkage -> [(fontn/lambdd, homax/lambdd)], (0, Hax[GlErhoB])], PlotEkage -> [dst, Dambdd, Baseftyla -> AksoluteThickness[1], PlotEkages -> Hone, FlotLabel -> "%, Corrugated Gylinder (Scattered Field)", Frame -> Tree, Franzbabs -> "%, Orrugated Gylinder (Scattered Field)", Griddines -> [[(d2/lambds), (Thick, Gray, Dashed)]], Automatic], Background -> White. Tangefice -> 706, BaseStyle -> (FontSize -> 14, FontWeight -> "Bold"]];
- Plot Erho (Inc + Scattered)
- semp. EnhoCorrfandI + ListLineTot[dstEtho, PlotEnspe → [(Homain / LimbdeG, Thomas / LimbdeG), (0, Max[SolEho]), PlotEntype > Red, Dashed), BaseRtyla → MasoluteThickness[2], PlotEntkers None, PlotLabels → Tm, Corrupted Cylinder (Encident + Scattered Field)\*, Frame → True, Framabalo = \{"plot", "V"a"), GridLines → {[[(g]/LimbdeG), [Thick, Gray, Dashed]]}, Automatic], Background → White, Background → Wite, Scattered → 10, []; Background → White, Scattered → 14, PontWeight → "Bold"]];

#### Plot Ephi (Scattered)

RphiCorr# = ListLinePlot[dataRphi5, PlotEnarge -> [[[homin/Lambda0, homas/lambda0], (0, Mas[SolRphi5])], PlotEtyle -> (Sed, Dahedd, EaseStyle -> AbsoluteThichnes[2]), PlotEtyle -> Stons, PlotLabbl -> Ts, Corrugsted Cylinder (Sostered Field)\*, Frame -> True, FrameLabl -> ("c)/1\*, "Va",", GridHines -> [[[of/lambda0, (Thick, Grey, Dashed]]], Automatic], Background -> Mule, ImageSine -> 700, BacsStyle -> (FontBise -> 14, FontBeight -> "Bold")];

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#### Smooth Cylinder Plots - TM Plots

## Ez (TM Scattered)

static listinePlot[dstafreqoy1785, FlotTange -> {[(homin/lambdo), thomas/lambdo], (0, Max[dolEreqoy1785])}, FlotTayle -> Blue, Resettyl= > MaolutSThichnes[2], FlotTachers >> None, FlotTabel -> True, Translatel >> ("0/A", "Var), Griddines -> {[[ds/lambdo], (Thick, Grey, Dashed])}, Astomatic}, Background -> Mile, Emgdises -> 700, Background -> Mile, Emgdises -> 700, Background -> Mile, Emgdises -> 700, Background -> Mile, Emgdises -> 700,

#### Ez (TM Inc + Scattered)

Entry()TMEsadf \* ListLineFlot[distArregcyTDHEndf, FlotRange ->
 [{homin/lambds/.homas/lambds/.lo. Mat[GolErescyTDHEndf]]}.
 FlotEtyle -> Nhos. hassific and -> AbsoluteFlotEntescy[.> THOMESACE -> None.
 FlotEtabel -> The month Cylinder (M Incident = Gattered Field)\*,
 Frame -> Two, Franchab -> (\*(0/1\*, "VM"),
 distLines -> [[(o/1.4mbds/, (Thick, Gray, Dashed)]), Automatic],
 Background -> Nhis. Inaggita -> 710,
 BaseStyle -> (FontEise -> 14, FontHeight -> "Bold")];

#### Erho (TM Scattered)

EndowsylTBE = ListinsPlot[dstaRthoregoyITB6, FlotBangs -> {{holmin\_lambds, honsex,lambds}, (0, Kas[SolEthoregoyITB6]]}, FlotBigles - Blue, EastPlue - AkeolutFhichkense[], FlotBarkers -> None, FlotEibal -> "K, Booth Cylinds (TM Sotterse Flatd)", Frame -> True, FrameNabl -> ("(r)/", "(u")], Gridlines -> {[(n/1 : Monthol ( Thick, Grey, Dashed)]}, Automatic], Readymoud -> Mukis, Imagdines -> 700, BaseStyple -> (FontSize -> 14, FontWeight -> "Bold")];

#### Erho (TM Inc + Scattered)

SthoRepCylTMEandf = ListLinePlot[distRthoregcylTMEandf, PlotRange → {{thomin/lambdad, rhomax/lambdad}, {0, Nax(SolEnbreegcylTMEandf]}}, PlotStyle > Niou, BasedYile > Niooliuterinkense2[], PlotBackers → None, PlotLabel → "K, Monoth CylLoder (TM Incident = Sottered Field)", Frame → "Twa, Framathad > ("pl/A", "W"), ditLines → {[(a7] lambdad, (Thick, Gray, Dashed)]}, Automatic), BaseGryune → Nike, Rangedise → 700, BaseGryune → Nike, Rangedise → 780,

## Ephi (TM Scattered)

philascy/ITME = ListLineFlot[distRphiregryITME, PlotEnge -> [[rhomin/lambda0, rhomsy/lambda0], (0, Haw[SolEphiregryITME]]}, PlotEngle -> Nuo, Hassetty- > AbsoluteThiomese[]]. PlotEngle -> Nose, PlotLabel -> T\*, Honoth Cylloder (TM Esattered Teid]\*. Frame >> Tree, Franklad -> (\*/).\* (\*\*). Cridine -> [[[a7] lambda0, (Thick, Gray, Dashed]], Automatie]. HasseStyle -> (FontSize -> 14, FontWeight -> "Bold"]]:

## Ephi (TM Inc + Scattered)

projection to the set of the

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#### Ez (TE Inc + Scattered)

[ (int limiting)] ExBog()TEAD(I = ListingFlot[dstAtragcy)TEEAndI, FlotRange -> {[rhomin/lambdd, rhoms/lambdd], (0, Kar(3blfreegoy)TEEAndI]], PlotStyle -> blos, BaseStyle -> Abnoltethickess[2], FlotRatkers -> Sone, PlotLabel -> Ts, Basoth Cylinder (TE Incident + Southered Flaid)", Frame -> Tour, Franchabel -> (C/A', "V"), GridLinee -> [[[62]lambddo. (Thick, Gray, Dashed]]), Automatie], BaseStyle -> (FlotSize -> 14, FootHeight -> "Bold"]];

#### Erho (TE Scattered)

NUND- Erholog()ITES = litLinePlct[dstaFrhoregcyITES, PlotEnego >> {[{fchmin}] sabds0, hence/lambda0}, (0, Max[SclEthoregcyITE3])}, PlotEyle >> Blue, BaseNyle >> Absolutinkiness[2], PlotEnthere >> None, PlotEnbel >> Twu, Framaballo >> (rcl/v, 'Vm'), GridLines >> {[[/c/]sabds0, 'Thick, Grey, Dashed]}, Automatic], Background >> Minte, ImageNine >> O(0, BaseBryle >> {FontSize >> 14, FontNeight >> "Nol4"]};

#### Erho (TE Inc + Scattered)

Enchologe\_VITESendf = ListLinePlot[dataTheregcyITESendf, PlotRange ->
{{ (fromin/lambd8, rhoms/lambd8), (0, Max[50:EhroregcyITESendf]} ),
PlotEtyle - Nike, BaseStyle -> AbsoluteThickess[2], PlotEtheregcyITESendf] ),
PlotEtyle - Nike, BaseStyle -> MonoListLineSens[2], PlotEtheregcyITESendf] ),
Frame>True, Francabel -> (fo/A<sup>+</sup>, "V<sup>m2</sup>),
GridLinee -> ([[G2]lambd80, (Thick, Gray, Dashed])), Astomatic),
BaseStyle -> (FortSize -> 14, PontWaight -> "Bold\*)];

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## EAII (TM Scattered)

MILIBACY/INE + ListinoPlot[dataEX1ITM6, PlotEange -> {{thomin/lambdo,thomax/lambdo], (0. Mac[dolEA1ITM5]}}. PlotEyles Also, Baselyles -> AbsoluteThichnese[1], PlotMarkers -> None, PlotEalso -> Tayla, Mooth Cylinder (TH Sottered Field)\*, Frame -> "true, FrameLatel -> ("pl/A", "Wr), GritLines -> ([[da7]imsddo, (Thick, Gray, Dashed)]), Astomatic), Background -> Nhiks, Tangedises -> 70, Baseltyle -> (FontSize -> 14, FontNeight -> "Bold\*)];

- EAII (TM Inc + Scattered)

- EAllRegCylTMSandI = ListLinePlot[dataEAllTMSand 
  $$\begin{split} & lime_Q^{-1}(Redardf = ListineFlot[detabllHemardf, \\ & Foltamops = \{[chims]/lambda, branax/lambda], (0, Max[dolBallHemard]]\}, \\ & FlotIstyle \rightarrow Blue, BaseStyle \rightarrow AbsoluteThickness[2], FlotMarkers \rightarrow Hone, \\ & FlotIstel \rightarrow "Brana; Bosonb Gylinder (M Encident = Scattered Field)", \\ & Fram \rightarrow Tree, Francishes \rightarrow ("Grid', "Grid"), \\ & GridLines \rightarrow [[(z]/lambda0, (Thick, Gray, Bashed])], Automatic], \\ & Background \rightarrow Vhite, ImageSize \rightarrow 700, \\ & BaseStyle \rightarrow (FontSize \rightarrow 14. FontWeight \rightarrow "Bold")]; \end{split}$$

## Summary TM Plots

## Smooth Cylinder Plots - TE Plots

## Ez (TE Scattered)

ta (i bacterou) mp: Electrony of the statistical (datafreepoylTES) plottings => {[themin]/lambds, themas/lambds], (0, Hax[SolEcrepoylTES]]}, Plottings => hiles, Electrical => hiles/lambds], Plottingter => None, Plottingter >> hiles, Taesethylic => hiles/lambds], Prame >> True, Frandbalo >> (Thick, Gray, Dashed]}, Antomatic], Background >> hile, Tangethies >> No, BaseStyle >> (PlotSize >> 14, FontWeight >> "blot\*)];

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#### Ephi (TE Scattered)

 $\label{eq:control of the set of$ 

### Ephi (TE Inc + Scattered)

uprn (in the 'security field is a security of the securit

## EAII (TE Scattered)

Exilency:/Test = ListinePlot[dstaRAlITES, FlotBange -> {[rhemin/lambda0, rhemay, lambda0], (b, Max[SoIRAlITES]], FlotEtyle -> Almo, Bassetyle -> AksoluteThickness[2], FlotBarkers -> Non FlotItabel -> Thus, Bassetyle -> AksoluteThickness[2], FlotBarkers -> Non FlotItabel -> Thus, Bassetyle -> ((rstartered Field)\*, Frame -> True, Frankelat -> (r(r)/\*, "V#], GridLines -> {[(s/2] imbda0, (Thick, rey, Dashed]], Automatic], BassEtyle -> (FontSize -> 14, FontWeight -> "Bold")];

#### EAII (TE Inc + Scattered)

 $\begin{array}{l} = 1 \left( \left( 2 + 1 \right) \left( 1 + 1 \right) \left( 1 + 1 \right) \left( 2 + 1 \right) \left( 1 + 1 \right) \left( 2 + 1 \right) \left( 1 + 1 \right) \left( 2 + 1 \right) \left( 1 + 1 \right) \left( 2 + 1 \right) \left($ 

## Summary TE Plots

#### Smooth Cylinder Plots - TM + TE Plots

### Ez (TM+TE Scattered)

## Ez (TM+TE Inc + Scattered)

La ("If" I is " Scherberg)
Lambdal, homax/lambdal, (o. Mas(Tollzeragoy/TMplusTEEsadI), FlotEange ->
[[(homin/lambdal, homax/lambdal), (o. Mas(Tollzeragoy/TMplusTEEsadI)],
FlotEtyle -> Nion, Banestyle -> Abaloutefhichess2[], Hichtersen -> Nion,
FlotEtabal -> Ta, Donoth Sylloder (M + W I no and Soutered)",
Frame -> True, Framidabl -> ("Golt", "UM"),
GritHinse -> [[(of/lambdal, (Thick, Gray, Dashed)], Automatic),
Background -> Nile, Imagdia -> 700,
Background -> (Tollis -> 14, YontWeight -> "Bold")];

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#### Ephi (TM+TE Inc + Scattered)

philes(y)THENU TELLINETIC [dstabplicecyc)THEDisTESandf, PictRang [[homin/lambdd, homax/lambdd], (0, Max[SolBplicecyc]THEDisTESandf, PictExplo-2 Nako, BaseStyle - MakolteRhickness[], PictExplo-2 Nako, BaseStyle - MaxBordeRhickers - Nako, PictExplo-2 Nako, BaseStyle - MacDisTESandf, PictRang, TESandI])},

### EAII (TM+TE Scattered)

ExilegeCylTMplueTES = Listinnello[dstaEkliTMplueTES, FlotExage >> {[{chemin}/ismbds, nemes/ismbds], (d. Mar[SciEkliTMplueTES])}, FlotExplus > Blue, HaseKyla => Absolutinkiness[2], FlotExhares => None, FlotExbel >> Texa, Famoshab >> (rol\*, "vm\*), GridLares >> {[[/ds/lambds, Thick, Grey, Dashed]}, Automatic], Background >> Minte, ImageNine >> O(), BaseExple >> (FontSize >> 14, FontWeight -> "hold"]};

#### EAII (TM+TE Inc + Scattered)

BallRegCyTepBlustESandT + ListinsPlot[dstatAllTMplustESandT, PlotRange ->
{{rhomin/lambda0.rhoms/lambda0, (0. Nex(SolRalTMplusTESandT])}
rlotStyle - Sules BaseStyle -> AbsolutEntickess[2], PlotRikers -> Sone,
PlotLabel -> "Enux Bmooth CyLinder (M + WE The and SoltBergd)',
results -> Tenux Francabel -> ((C/2) / Imbda0. (Thick, Gray, Dashed))}, Automatie),
BaseStyle -> (FlotEsse -> 14, FortBergd -> "Bold")];

## Summary TM+TE Plots

NULL: GraphicsGrid[(ExBegCylTMplusTES, ExBegCylTMplusTESand]), (ErhoRegCylTMplusTES, ErhoRegCylTMplusTESand], (EphiRegCylTMplusTES, ErhoRegCylTMplusTESand], (ExliRegCylTMplusTES, EphiRegCylTMplusTESand]), (ExliRegCylTMplusTES, ExliRegCylTMplusTESand]), Spacings -> (Scaled[0], Scaled[0]);

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## Erho (TM+TE Scattered)

- $$\label{eq:states} \begin{split} & \text{hologoly}(10) \text{holo$$

## Erho (TM+TE Inc + Scattered)

- $$\label{eq:constraint} \begin{split} & \text{constraint} \left[ \text{detathergylTMplusTEsadI}, \text{PletRage} \left\{ \left( \text{detathergylTMplusTEsadI}, \text{PletRage} \left\{ \left( \text{detathergylTMplusTEsadI} \right) \right\}, \text{PletRage} \left\{ \left( \text{detathergylTMplusTEsadI} \right) \right\}, \text{PletRage} \left\{ \text{detathergylTMplusTEsadI} \right\}, \text{PletRage} \left\{ \text{lock}, \text{RaseRight} \right\} \\ \text{PletRage} \text{True, resultable} \rightarrow \left( \text{True, resultable}, \text{resultable}, \text{resultable},$$
- Ephi (TM+TE Scattered)
- $$\label{eq:product} \begin{split} & = print(v) + 1 = trained of [detalphiregory]ThglueTES, PlotBange &> \\ & \left\{ \{homin / lambda \}, homas / lambda \}, (o. Mac(Bollphiregory)ThglueTES) \}, \\ & PlotEtyle > Blow, BaseRyte > AbmoltetThinkows(2), PlotBackers > None, \\ & PlotEtabal > Slow, BaseRyte > AbmoltetThinkows(2), PlotBackers > None, \\ & PlotEtabal > Slow, BaseRyte > AbmoltetThinkows(2), PlotBackers > None, \\ & PlotEtabal > Slow, BaseRyte > AbmoltetThinkows(2), PlotBackers > None, \\ & PlotEtabal > Slow, BaseRyte > (PlotEtabal > Slow, BaseRyte > (PlotEtabal > Slow, BaseRyte > (PlotEtabal > Slow, Slow, PlotEtabal > Slow, PlotEtabal > Slow, BaseRyte > (PlotEtabal > Slow, PlotEtabal > Sl$$

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#### Compare (Smooth vs Corrugated) Plots

#### TM Compare

v Corrupted Cylinder [Ref, ->']; Biol [Ethology(TBEand], FubCubage >> {[{homin/lambdo, rionax/lambdo], (0. Nas[Solfrieresyo]TBEand], Solfrol]}, BaseNyie of (Prestime >> 14, FortMingthr >> Nolf"). Frame >> True, Framalabel >( Tp/A\*, "Vyrs), Distabel > True, Framalabel >( Tp/A\*, "Vyrs), Biologian > True, Framalabel >( Tp/A\*, "Vyrs), Biologian >( True, Framalabel >( Tp/A\*, "Vyrs), Biolabel >( Turue, Framalabel >( Turue, Turue, Framalabel >( Turue, Frama) >( Turue, Framalabel >( Turue, Framalabel >( Turue, Frama) >

(Blue) vs Corrupated Cylinder (Med, -,)<sup>2</sup>), file/Ellinge/SIMEndT, KillOresandT, FlotAnega > {{rhomin/lambda0, rhomas/lambda0}. (0. Mes[sclmlHTMendT, SolEalIsendT]), Resoftyle > (FortKize > 1/k, rontkeigth > "Role"), Frame > Tree, Franclabel > {"o/A", "V(m), PlotLabel > "Doubl HT are Socitaterd Bmooth Cylinder (Blue) vs Corrupated Cylinder (Med, -,)\*]}

# }]; TE Compare

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#### TM, TE, TM+TE Compare

11;

# IPi, [L, ITT+L Compare Short2fots: ecglishedical[[Blow[Eshedy:]186, EsCort5, FlotHange-> {chemin/lambdo.themay/lambdo], 0, Mos(IolExreey:ITME, BolEs)]}, Basettyle-(TentEise-al, FortKeisch-> Tblot3), Prame >> True, FramLabi-> (\*/A/L, "V/w"), FlotLabi-> "E, TH Gostreed Booot (yolInder (Blus) vs Corrugated (yiInder (Bad. - )\*], "A Ti Does Not Extar", Bhow[Eshedy:ITME]urtES, EcCort5, FlotEnage >> {[rhoni/lambdo], rhomas/lambdo], 0, Mos(SolErego;ITME]urtES, SolEmB]}, Basettyle => (FortSize >> 14, FortWeight >> "Bold"),

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$$\begin{split} & \mbox{PlotLabel $> "E_0 TE Seattered Bmosth Cylinder (Bius) \\ & v Corrupted Cylinder (Bad, -.)"], \\ & \mbox{Bmbladge}() Constraint, Fictures, and Cylinder (Bius) \\ & \mbox{histopic}() Constraint, ScielSinghiergey/Tittanst, ScielBill), \\ & \mbox{Baselyie} > (Fontistic > 14, FontWeight > "Bold"), \\ & \mbox{Baselyie} > (Fontistic > 14, FontWeight > "Bold"), \\ & \mbox{Fittures, France is a constraint of Cylinder (Bad, -)"], \\ & \mbox{Baselyie} > Constraint of Cylinder (Bad, -)"], \\ & \mbox{Baselyie} > (Baselyinder (Bad, -)"], \\ & \mbox{Baselyie} > (Baselyinder (Bad, -)"], \\ & \mbox{Baselyie} > (Baselyinder (Bad, -)"), \\ & \mbo$$
}]; TM+TE Compare

TM-TE Compare
GraphicaGrid[
{[thow[ExtBudge]ChTBulseTES, EnCorrd, FlotMange → {{rhomin/lambda0, rhoms/
lambda0}, (0, Max[JolErregor/TBulseTES, Bolzel]},
BaseStyle > {Total provide a start of the control of the

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Frame -> True, FrameLabel -> {"p/\", "V/m"},
PlotLabel -> "E: TM\*TE Scattered Smooth Cylinder
(Blue) vs Corrugated Cylinder (Red, --)"]}; (Bise) vs Corrupted Oplinder (Red, --,)"]; { dfor [Energy:HEMand, ErCorefand, FiokBang= > { [themin/lateds, themar/lateds], (d, Res [GERreepy:HEMand, SolEs])}, BaseStyla > (FordEise > 14, FortNeigher > "Bold"), Frame > Trees, Frandhald > ("yd/x", "yd"), PletLabel > "g, "H for a Sontreed Smooth Cylinder (Mise) vs corrupted Oplinder (Red, --)"]. "5. TE Does Not Exist". Now[Elsnöy:Theoremy:DetEnding, Teorem (Red, --)"], "6. TE Does Not Exist", Now[Elsnöy:Theoremy:DetEnding, Teorem (Red, --)"], BaseStyla >> (FortEise >> 14, FortNeight > "Bold"), FrameStrage:Theorem (Red, Red, --)"], BletLabel >> "First Theorem Scattered Smooth Cylinder (Blue) vs Corrupted Oplinder (Red, --)"],

[Show]ErhoRegCy17MiandI, ErhoCorrEandJ, FlotRange → {{rhomin/lambda, rhomax/lambda], {0, Mar[SolEhoregcy17MiandI, SolEhol]}, RamStyla + {[ColEise → 14, ForMispht → Table17], Prems → True, PramaEndel → {Table17, Var<sup>3</sup>, FlotLabel → <sup>\*</sup> (M Then + Sources Honoth Cylinder

(Bius) vs Corrugated Cylinder (Hed. --)\*], Show Erholms(y):TERandi, ErhoCorrEndi, YielKange -> [{rhomin/lambda0, rhomax/lambda0], (0, Max[Solirhorequy):Tentin, Solirho)}}, Erms -> True, Framilabel >> ('n/A<sup>\*</sup>, 'Wrm'), Frame -> True, Framilabel >> ('n/A<sup>\*</sup>, 'Wrm'), Foltabel >> 's, TI he + Scattered Smooth Oylinder (Bius) vs Corrugated Oylinder (Hed. --)'], How[Erholms(y):TheylarKishni, ErhoCorrEndi, Flotaheys -> ([framin/lambda0], (0, Max[SolIrhorequy]:TheylarKishni, homax/lambda0], (0, Max[SolIrhorequy]:TheylarKishni, SolIrho)]}, Frame >> True, Framilabel >> ('n/A<sup>\*</sup>, 'Wrm'), Frame >> True, Framilabel >> ('n/A<sup>\*</sup>, 'Wrm'), Frame >> True, Term Erholms(), SolIrho)],

b(200). ErhoregcylTMSa = dataa[[16]];

HEND- ErhoregcylTEIa = dataa[[17]];

H(227)- ErhoregcylTMIs = datas[[18]];

w200. EphiregcylTESa = dataa[[19]];

H(220)- EphiregcylTMSa = datas[[20]];

#### PhD Research Garcia\_Boundary a\_plus\_b.nb | 27 28 | PhD Research Garcia\_Boundary a\_plus\_b.nb $$\label{eq:rame-strue} \begin{split} & \mbox{FrameLabel} \rightarrow \ \{ "\rho/\lambda", "V/m" \}, \\ & \mbox{PlotLabel} \rightarrow \ "E_{Potal} \ TM+TE \ Inc + \ Scattered \ Smooth \\ & \ Cylinder \ (Blue) \ vs \ Corrugated \ Cylinder \ (Red, \ --)" ] \} \end{split}$$ HEALT EphiregcylTMIa = dataa[[22]]; }] H(202). phirange = datas[[23]]; Report[ToString[StringForm["``.jpg", RhoXYPlotsName]], RhoXYPlots]; speak["The rho plots are done"] H[H1]= 01 = dataa[[26]]; Import Data [Changing Phi Data] H(2H)- phidelta = dataa[[27]]; Boundary 'b' Data Boundary 'a' Data were- dataa = Import["phi\_outa.mx"]; H(220)- a = datas[[1]] Home b = dataa[[2]]: $\mu_{(222)} = \rho^2 = dataa[[3]];$ emp- p1 = dataa[[4]]; H[224]. EztempSa = dataa[[5]]; H(225)- Estempla = dataa[[6]]; i(204). ErhotempSb = datab[[7]]; ErhotempSa = dataa[[7]]; will be a state [8]; w(228)- EphitempSa = dataa[[9]]; b(229)- EphitempIa = dataa[[10]]; H(2H)- EzregcylTESb = datab[[11]]; H(220)- EzregcylTESa = dataa[[11]]; H221)- EzregcylTMSa = dataa[[12]]; H(200)- EzregcylTEIa = dataa[[13]]; H(223)- EzregcylTMIa = dataa[[14]]; H224)- ErhoregcylTESa = dataa[[15]];

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$$\begin{split} & \text{Plotlabel} \rightarrow ``E_n TE Inc + Scattered Smooth Cylinder (Bius) vs Cc \\ & \text{Cylinder (Bed, --)^{+}], Bnve[Ephiles/CyTEM_intTEStandI, \\ & \text{EphiCorrEndI, CicteRang } \rightarrow \{[fentin], lambded, Nemas/Lambded], \\ & (0, max[ColEphiles/CyTEMplatTEStandI, SclEphil]]. \\ & Basetyl > Crossitis \rightarrow 34, rontwight ~ > Tolo(3^{+}), \\ & \text{Frame -> True, Translabel } \rightarrow (?p/A^{+}, V^{en}), \\ & \text{PlotLabel} \rightarrow ``E, BritET fine + Schwaresd Bmooth Cylinder \\ & (Blue) vs Corrugated Cylinder (Bed, --)^{+}]], \end{split}$$
(Blue) vs Corrugated

(Nino) vs Corrugated Cylinder (Red, -,)^]; {flow[LinkeyCylINE, Enlicer£, FlotEmage → {[chomain]nube6, thomas/instable], (0, Max[SciEall5, SoiEAllTME])}, BaseStyle → [FontSine → 34, FontWeight → Thold"), Frame → True, Franklahl → (Fo/A', "V/M'), FlotEabel → Te<sub>main</sub> TH Eastered Smooth Cylinder (Nino) vs Corrugated Cylinder (Red, -,)^], Show[EallBacyCylINE, EallCore£, FlotEmage → {[thomain].imstable], Prame → True, Franklahl → (SoiEall1, SoiEall1, SoiEall1, Temmor, Franklahl → (Fo/A', "V/M'), FlotEabel → Temax TH Eastered Smooth Cylinder (Nino) vs Corrugated Cylinder (Red, -,)"], BaseStyle → [FontSine → 34, FontWeight → Thold"), Frame → True, TH Eastered Smooth Cylinder (Nino) vs Corrugated Cylinder (Red, -,)"], BaseStyle → [FontSine → 34, FontWeight → Thold"), Frame → True, Thereat FontSine → Shid"), Frame → True, The TH Eastered Smooth Cylinder (Inhouni, Inholef, rhomay, Linkshoh), (0, Max (SoiEall1, SoiEall1Re, SoiEall1Re[soiEall1Re])}, BaseStyle → [FontSine → 34, FontWeight → Thold"), Frame → True, Thereat FontSine (Red, -,)"], Butabel → Te<sub>Maxi</sub> The TH Eastered Rooth Cylinder (Mino) vs Corrugated Cylinder (Red, -,)"], Chon(Minov (2)VSEADL CylineriaedT ElectRone → {[fromin], flambdab]

(Nise) vs Corrupated Cylinds: (Rad, --)^]], {{morphilicallsegCyliNBandf, EXILCorrEandf, FlotRange -> {{(rhomin/lambda), rhomax/lambda), (0, MagdiolExILTBandf, SolEXILEandf),), BaseStyle -> (Fontline -> 14, FontWeight -> "mold"), Frame-> True, Franchabel - (P/A<sup>+</sup>, "Vo"), PlotLabel -> "E<sub>post</sub> Thino : Ecsttered Smooth Cylinder (Bluey Corrugated Cylinder (Rad, --)\*], mongf Labladed), (0, MagdiolElablaTBegioseffendf, SolEXILEandf)), BaseStyle -> (Fontline -> 14, FontWeight -> "mold"), Frame-> True, Franchabel - (P/A<sup>+</sup>, "Vo"), PlotLabel -> (PostIne -> 14, FontWeight -> "mold"), Frame-> True, Franchabel - (P/A<sup>+</sup>, "Vo"), PlotLabel -> "E<sub>post</sub> HortE Inc = Scattered Smooth Cylinder (Rules Vo Corregated Cylinder (Red, --)"], Boof[ExilsegCyliNBelorEXIsed], RailColEXIDBejourSmod, SolEXISEndf]), BaseStyle -> (FontSize -> 14, FontWeight -> "Bold"), BaseStyle -> (FontSize -> 14, FontWeight -> "Bold"),

EphiregcylTEIa = dataa[[21]];

- u(204)- lambda0 = dataa[[25]];

an- datab = Import["phi\_outb.mx"]; Hom. a = datab[[1]]; H2H2- b = datab[[2]]; wmm. o2 = datab[[3]]: H(20)- p1 = datab[[4]]; H(212). ExtempSb = datab[[5]]; HESH- EztempIb = datab[[6]];

- HENR- ErhotempIb = datab[[8]];
- w(200) EphitempSb = datab[[9]];
- HENDIE = datab[[10]];
- HENH- EzregcylTMSb = datab[[12]];
- H(200)- EzregcylTEIb = datab[[13]];
- h(211)- EzregcylTMIb = datab[[14]];
- H(202)- ErhoregcylTESb = datab[[15]]; H(203)- ErhoregcylTMSb = datab[[16]];
- H(204)- ErhoregcylTEIb = datab[[17]];
- HAME- ErhoregcylTMIb = datab[[18]];
- scale EphiregcylTESb = datab[[19]];
- H(NT). EphiregcylTMSb = datab[[20]]; HEAD = datab[[21]];

# PhD Research Garcia\_Boundary a\_plus\_b.nb | 29 30 PhD Research Garcia\_Boundary a\_plus\_b.nb b(NO)\* EphiregcylTMIb = datab[[22]]; Equations [Changing Phi Data] sers. (\*Combining of Boundar 's' and Boundar 'b' fields\*) Extempls Extempls, Extempls; Extempls a ExtocageDs (Extempls); ExtocageD & ExtocageDs (ExtocageDs); ExtocageD & ExtocageDs; ExtocageD & ExtocageD; ExtocageD; ExtocageD & ExtocageD; Comparison Paper - A. Freni Comparison rape: -x.rean proc. CrossPolarTEMEENTPict = ListLimsPlot[CrossPolarTEME, PlotRange -> ((0, F1), (Min[CrossPolarTEME](L1), 51], Sma[CrossPolarTEMEB[[A11, 2]]]), PlotExtyLe -> (Green, Dotted, Thinkness[0, Cl3]), BaseStyLe -> MesoluteThickness[2], PlotMacker -> None, PlotLabel -> °q\_u/AO (BD) Corrupted Cylinder (RCS Bime)\*, Frame.-> (Tray, FrameLabel -> (\*\*, °q\_u/AO (BD')), GridLines -> ((E00, fmick, Gray, Dashed)), Natomatic), Reckground -> Mhite, ImageBirs -> 700, BaseStyle -> (FORSIRE -> 14, FORSMelty); } whitempi = sphitempis: trenspyIMs = trenspyITms = trenspyITms; trenspyIMs = trenspyITms; trenspyITms = trenspyITms; trenspyITms = trenspyITms; trenspyITms = trenspyITms; trenspyITms = trenspyITms; CrossPolarMoMdB = Import["CrossPolarMoM.csv"]; casPCiarMoMED = Taport["CrossPClarMoM.cs"); cosPCiarMoMETTINE = ListLineDic[CrossPClarMoMED, PlotBange → ((0, Pl). (Min[CrossPlatHoMED[[All.2]]), Mar[CrossPlatHoMED[[All.2]]])); FlotEtyle → AlkoLuteThickness[2], PlotBarker → None, FlotEtyle → AlkoLuteThickness[2], PlotBarker → None, FlotEtable → "qr./Al (dB) Corregated Cylinder (CES dBm)', Frame → True, FrameLable → ("qr', "qr./AD (dB)"), Gridlines → ((Pl, (Thick, Gray, Deshed)), Nutematic), Background → Mhite, ImageSize → 700, BacsStyle → (FontSize → 14, FontWeight → "Bold")]; CrossPolarMoMdBM (\*Additional changing phi plot equations\*) ExregcylTMSandI = ExregcylTMI + ExregcylTMS; ErhoregcylTMSandI = ErhoregcylTMI + ErhoregcylTMS EphiregcylTMSandI = EphiregcylTMI + EphiregcylTMS EzregcylTESandI = EzregcylTEI + EzregcylTES ErhoregcylTESandI = ErhoregcylTEI + ErhoregcylTES; EphiregcylTESandI = EphiregcylTEI + EphiregcylTES; Extemp = ExtempI + ExtempS; Erhotemp = ErhotempI + ErhotempS Ephitemp = EphitempI + EphitempS Changing Phi Plot Calculations Solution for Plots - Corrugated Cylinder sil= (\*Incident + Scattered Solution\*) SolEz = N[Abs[Eztemp]]; PhD Research Garcia\_Boundary a\_plus\_b.nb | 31 32 | PhD Research Garcia\_Boundary a\_plus\_b.nb dataEz = Transpose[{phirange, SolEz}]; (+RCS Solution - in dB+) RCSdataErdB + Transpose[(phirange, 10 + Log10[RCSSolEx])]; RCSdataEhodB + Transpose[(phirange, 10 + Log10[RCSSolEhol]]]; RCSdataEhidB = Transpose[(phirange, 10 + Log10[RCSSolEAh1])]; SolEphi = N[Abs[Ephitemp]]; dataEphi = Transpose[{phirange, SolEphi}]; SolErho = N[Abs[Erhotemp]]; dataErho = Transpose[(phirange, SolErho)]; $\label{eq:cscs} \begin{array}{l} (\mbox{scsl} * \mbox{cscsl} * \mbox{cscsl}$ SolEAllSandI -SolMalisand: \* N[Abs[Sqrt[((Erhotemp) + Cos[phirange] - (Ephitemp) + Sin[phirange]) ^2 + ((Erhotemp) + Sin[phirange] + (Ephitemp) + Cos[phirange]) ^2 + (Extemp) ^2]]]; dataEAllSandI = Transpose[(phirange, SolEAllSandI]); $\begin{array}{l} & \text{RCSSolErho} = \left(4 * \text{Pi} * \left(\rho^2\right)\right) * \left(\left[\left(\text{Abs}\left[\text{ErhotempS}\right]\right)^2\right] / \left(\left(\text{Abs}\left[\text{ErhotempI}\right]\right)^2\right)\right); \\ & \text{RCSdataErho} = \text{Transpose}\left[\left\{\text{phirange, RCSSolErho}\right\}\right]; \\ \end{array}$ (\*Scattered Only Solution\*) SolErS = N[Abs[ExtempS]]; dataErS = Transpose[{phirange, SolErS}]; $\text{RCSSolEphi} = \left(4 * \text{Pi} * \left(\rho^2\right)\right) * \left(\left(\text{(Abs[Ephitemp5])}^2\right) / \left(\left(\text{Abs[Ephitemp1]}\right)^2\right)\right); \\ \text{RCSdataEphi} = \text{Transpose}\left(\text{(phitemp1)}\right)^2 \\$ $$\begin{split} & \mathsf{RCSDIERLS} = \mathsf{Sqrt} \left( [\mathsf{Rchotseps} - \mathsf{Cos}[\mathsf{phirangs}] - \mathsf{Rphirseps} + \mathsf{Sin}[\mathsf{phirangs}] \cdot ^2 + \\ & (\mathsf{Rchotseps} - \mathsf{Sin}[\mathsf{phirangs}] - \mathsf{Rphirseps} - \mathsf{Cos}[\mathsf{phirangs}] - \mathsf{Rphirseps}] \cdot ^2 + \\ & (\mathsf{Rchotseps} - \mathsf{Sin}[\mathsf{phirangs}] - \mathsf{Rphirseps}] - \mathsf{Rphirseps}] \cdot ^2 + \\ & (\mathsf{Rchotseps} - \mathsf{Sin}[\mathsf{phirangs}] - \mathsf{Rphirseps}] - \mathsf{Cos}[\mathsf{phirangs}] + \mathsf{Rphirseps}] \cdot ^2 + \\ & (\mathsf{Rchotseps} - \mathsf{Sin}[\mathsf{phirangs}] - \mathsf{Rphirseps}] - \mathsf{Cos}[\mathsf{phirangs}] + \mathsf{Rphirseps}] \cdot ^2 + \\ & (\mathsf{Rchotseps} - \mathsf{Sin}[\mathsf{phirangs}] - \mathsf{Rphirseps}] - \mathsf{Cos}[\mathsf{phirangs}] \cdot ^2 + \\ & (\mathsf{Rchotseps}) - \mathsf{Sin}[\mathsf{phirangs}] \cdot \mathsf{Rphiraseps}] \cdot ^2 \right) (\mathsf{RcShotsel} + \mathsf{Sin} \mathsf{phiraseps}) - \mathsf{Sin}[\mathsf{RcShotsel} + \mathsf{Sin} \mathsf{sphiraseps}] \cdot \mathsf{Sin}[\mathsf{RcShotsel} + \mathsf{Sin} \mathsf{sphiraseps}] \cdot \mathsf{Sin}[\mathsf{RcShotsel} + \mathsf{Sin} \mathsf{sphiraseps}] \cdot \mathsf{RcShotsel} + \mathsf{Sin} \mathsf{sphiraseps}) \cdot \mathsf{RcShotsel} + \mathsf{Sin} \mathsf{sphiraseps}) \cdot \mathsf{RcShotsel} + \\ & \mathsf{RcShotsel} + \mathsf{Ros} \mathsf{sphiraseps} \cdot \mathsf{RcShotsel} \mathsf{Sin}[\mathsf{RnShotsel} + \mathsf{RcShotsel} + \mathsf{Ros} \mathsf{Sin}[\mathsf{RnShotsel} + \mathsf{Ros} \mathsf{RcShotsel} + \mathsf{Ros} \mathsf{Ros} \mathsf{RcShotsel} + \mathsf{Ros} \mathsf{RcShotsel} + \mathsf{Ros} \mathsf{Ro$$ SolEphiS = N[Abs[EphitempS]]; dataEphiS = Transpose[{phirange, SolEphiS}]; SolErhoS = N[Abs[ErhotempS]]; dataErhoS = Transpose[{phirange, SolErhoS}]; SolEAl1S = N{Abs[Sqrt[(Erhotemp5+Cos[phirange] - Ephitemp5 + Sin[phirange]) ^2 + (Erhotemp5 + Sin[phirange] + Ephitemp5 + Cos[phirange]) ^2 + (Extemp5) ^2]]]; dataEAl1S = Transpose[{phirange, SolEAl1S}]; (+RCS Solution - in dB+) RCSdataErdB = Transpose[(phirange, 10 + Log10[RCSSolEx])]; RCSdataErhodB = Transpose[(phirange, 10 + Log10[RCSSolExh])]; RCSdataErhodB = Transpose[(phirange, 10 + Log10[RCSSolExh1])];

 $\begin{array}{l} (*RCS \ \mbox{Solution}*) \\ RCSSolEz = & \left(4 * \mbox{Pi} + \left(\rho^{2}\right)\right) * \left(\left(\mbox{Abs}\left[\mbox{Extemp5}\right]\right)^{2}\right) / \left(\mbox{Abs}\left[\mbox{Extemp1}\right]\right)^{2}\right); \\ RCSdtaEz = & \mbox{Transpose}\left(\mbox{[phirange, RCSSolEz]}\right); \end{array}$ 

 $\label{eq:RCSSolErho} \begin{array}{l} \texttt{RCSSolErho} = \left( \texttt{4} * \texttt{Pi} * \left( \rho^2 \right) \right) * \left( \left( (\texttt{Abs[Erhotemp5]} \ ^2 \right) \middle/ \left( (\texttt{Abs[Erhotemp5]} \ ^2 \right) \right); \\ \texttt{RCSdataErho} = Transpose[\{\texttt{phirange}, \texttt{RCSSolErho}]; \\ \end{array}$ 

$$\begin{split} & \texttt{RCSSolEphi} = \left(4*\texttt{Pi} * \left(\rho \cap 2\right)\right) * \left(\left(\left(\texttt{Abs}[\texttt{EphitempS}]\right) \cap 2\right) \middle/ \left(\left(\texttt{Abs}[\texttt{EphitempI}]\right) \cap 2\right)\right); \\ & \texttt{RCSdataEphi} = \texttt{Transpose}[\{\texttt{phirange}, \texttt{RCSSolEphi}\}]; \end{split}$$

$$\begin{split} & \texttt{RCSSolEALIS} = \texttt{Gqrt}\left(\texttt{Rthotemp6} + \texttt{Cos}[\texttt{phirange}] - \texttt{Ephitemp6} + \texttt{sin}[\texttt{phirange}] \right)^{2} + \\ & \texttt{(Rthotemp6} + \texttt{sin}[\texttt{phirange}] - \texttt{Rphitemp6} - \texttt{Cos}[\texttt{phirange}] \right)^{2} + (\texttt{Statemp6} - \texttt{2}]; \\ & \texttt{RCSolEALI} = \\ & \texttt{gqrt}\left(\texttt{Rhotemp6} - \texttt{Cos}[\texttt{phirange}] - \texttt{Cos}[\texttt{phirange}] \right)^{2} + \\ & \texttt{(Rthotemp6} + \texttt{sin}[\texttt{phirange}] - \texttt{Rphitemp6} + \texttt{Cos}[\texttt{phirange}] \right)^{2} + \\ & \texttt{(Rthotemp6} + \texttt{sin}[\texttt{phirange}] - \texttt{Rphitemp6} + \texttt{Cos}[\texttt{phirange}] \right)^{2} + \\ & \texttt{(Rthotemp6} + \texttt{sin}[\texttt{phirange}] - \texttt{Rphitemp6} + \texttt{Cos}[\texttt{phirange}] \right)^{2} + \\ & \texttt{(Rthotemp6} + \texttt{Sin}[\texttt{phirange}] - \texttt{Rphitemp6} + \\ & \texttt{RCSolEALI} \right)^{2} \\ & \texttt{RCSolEALI} + \texttt{Trangeos}\left(\texttt{phirange} - \texttt{RCSolEALI}\right); \end{split}$$

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SolRphilspherical = Ephitempi; (+ Convert to Co-Polar and Cross-Polar +) Ecopolars = SolEthetaSepherical + Cos[phirange] ; SolEphiSepherical + Sin[phirange];

SolEphiSspherical = EphitempS;

SolEthetaSspherical = ErhotempS \* Cos[0i] - EztempS \* Sin[0i]; SolEthetaIspherical = ErhotempI \* Cos[0i] - EztempI \* Sin[0i];

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EcopolarI = SolEthetaIspherical + Cos[phirange] - SolEphiIspherical + Sin[phirange];

SolEthetaSs nerical \* Sin[phirange] + Sol%phiSspherical \* Cos[phirange]; = Sol%thetaIspherical \* Sin[phirange] + opolarI = SolEthetaIs SolEphiIspherical \* Cos[phirange];

(\* convert to DCE and DCE db - Co-Polar and Cross-Polar +) RC5000 \* (2 \* Pi r, p) \* Abs[\$0]EthetaEmphorical/SolEthetaEmphorical]\*2; (~Co-Polar according to A. Frank, 1954; Soltaring from a dialectic originider axially loaded with periodic metallic rings;) RC5000 4; [\* 1: p] \* Abs[\$0]EtheEmpirical/SolEthetaEmphorical]\*2; (~Cross-Polar according to A. Frank, 1954; Soltaring from a dialectic originider axially loaded with periodic metallic rings;) RC50000 4; Francesong([phirangs, 10 + Log10[RC5000 / lambda0]]]; RC50000 4; Francesong([phirangs, 10 + Log10[RC5000 / lambda0]]];

ossopolarI]^2;

$$\begin{split} & \texttt{RCSCopolar2} = \begin{pmatrix} 2 * \texttt{Pi} * \rho \end{pmatrix} * \texttt{Abs} \{\texttt{Ecopolars} / \texttt{RCSSoleAll1} \}^2; \\ & \texttt{RCSCrosspolar2} = \begin{pmatrix} 2 * \texttt{Pi} * \rho \end{pmatrix} * \texttt{Abs} \{\texttt{Ecrossopolars} / \texttt{RCSSoleAll1} \}^2; \end{split}$$

 $\label{eq:cscoplardB} = \texttt{Transpose}[\{\texttt{phirange, 10*Log10[\texttt{RCSCopolar/lambda0}]}\}; \\ \texttt{RCSCrosspolardB} = \texttt{Transpose}[\{\texttt{phirange, 10*Log10[\texttt{RCSCrosspolar/lambda0}]}\}]; \\ \end{cases}$ 

RCSCopolardB2 = Transpose[{phirange, 10 \* Log10[RCSCopolar2/lambda0]}]; RCSCrosspolardB2 = Transpose[{phirange, 10 \* Log10[RCSCrosspolar2/lambda0]}];

## Solution for Plots - Regular "Smooth" Cylinder

TM Mode Solutions

(+Incident + Scattered Solution+)
SolExregcylTMSandI];
dataExregcylTMSandI = N(Abs[ExregcylTMSandI]];

SolErhoregcylTMSandI = N{Abs[ErhoregcylTMSandI]]; dataErhoregcylTMSandI = Transpose[{phirange, SolErhoregcylTMSandI}];

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(Ethorsegy1HH: <Cor[phirange] - Ephiregy1HH: <Ein[phirange]) \*2+ (Ethorsegy1HH: <in[phirange] + Ephiregy1HH: <Cor[phirange]) \*2+ (Exrego1HH: \*2]; RCSDaltesgy1HH: = (+ \*1\* (p<sup>\*</sup>)]) + ({(Aba: RCSDaltesgy1HHH!) \*2) / (Aba: RCSDaltesgy1HHL!); RCSDataEregy1HHL! \* Transpose[(phirange, RCSDaltesgy1HHL!);

(+RCS Solution - in dbs) RCSdealarrogry1MME = Transpose[{phirange, 10 + Log10[RCSSolExregry1M(]]; RCSdealarbrogry1MME = Transpose[{phirange, 10 + Log10[RCSSolExregry1M(]]; RCSdealarbrogry1MME = Transpose[{phirange, 10 + Log10[RCSSolExregry1M(]]; RCSdealarbrogry1MMII = Transpose[{phirange, 10 + Log10[RCSSolExregry1MMI]];

**TE Mode Solutions** 

(+Incident + Scattered Solution\*)
SolExregcylTESandI = N[Abs[ExregcylTESandI]];
dataExregcylTESandI = Transpose[{phirange, SolEzregcylTESandI}];

SolErhoregcylTESandI = N{Abs[ErhoregcylTESandI]]; dataErhoregcylTESandI = Transpose[{phirange, SolErhoregcylTESandI}];

SolEphiregcylTESandI = N[Abs[EphiregcylTESandI]]; dataEphiregcylTESandI = Transpose[{phirange, SolEphiregcylTESandI}];

SolExlITESand1 = W[Abs[Sptt[ ((EthoregoyITESand1 = Cos[phirange] - (SphiragoyITESand1) = Sin[phirange]) ^2 + ((EthoregoyITESand1 = Cos[phirange] + (SphiragoyITESand1) = Cos[phirange]) ^2 + (EthoregoyITESand1 = 2]]]) dataXlITESand1 = Transport[(phirange, SolExlITESand1)];

(+Scattered Only Solution+) SolEzregcylTES = N[Abs[EzregcylTES]]; dataEzregcylTES = Transpose[{phirange, SolEzregcylTES}];

SolErhoregcylTES = N[Abs[ErhoregcylTES]]; dataErhoregcylTES = Transpose[{phirange, SolErhoregcylTES]];

SolEphiregcylTES = N[Abs[EphiregcylTES]]; dataEphiregcylTES = Transpose[(phirange, SolEphiregcylTES)];

# SolEAllTES = N[Abs[Sqrt[[ErhoregcylTES + Cos[phirange] - EphiregcylTES + Sin[phirange]) ^2 +

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SolEphiregcylTMSandI = N{Abs{EphiregcylTMSandI};; dataEphiregcylTMSandI = Transpose[{phirage, SolEphiregcylTMSa ndI}];

SolEAllTMS =

BolEAlINE =
 (Rhos[sqt](EthoregoyITMS + Cos[phirange] - EphiragoyITMS + Ein[phirange]) ^2 +
 (EthoregoyITMS + Sin[phirange] - EphiragoyITMS + Cos[phirange]) ^2 +
 (EtsogoyITMS > 2]];
 dataEAlITMS = Transpose[[phirange, SolEAlITMS]];

(+Scattered Only Solution+) SolErregcylTMS = N[Abs[ErregcylTMS]]; dataErregcylTMS = Transpose[{phirange, SolErregcylTMS}];

SolErhoregcylTMS = N[Abs[ErhoregcylTMS]]; dataErhoregcylTMS = Transpose[(phirange, SolErhoregcylTMS)];

SolEphiregcylTMS = N[Abs[EphiregcylTMS]]; dataEphiregcylTMS = Transpose[(phirange, SolEphiregcylTMS)];

SolDAll'MEardI = N[Abe[Sqrt[ ((Ethorego;UMSandI) = Cas[phirango] - (Ephirango]UMSandI) = Sin[phirango]) \* 2 + ((Ethorego;UMSandI) = Sin[phirango] + (Ephirango;UMSandI) + Cos[phirango]) \* 2 (Errego;UMSandI '21]]) dickLill'MEandI = Transport[(phirango, SolDAll'HEandI)];

(\*RCS Solution\*) (Host Stollarser) CGSolErregcylTM = (4 \* Pi \* (p^2)) \* ((iAbs[ErregcylTMS])^2) / (iAbs[ErregcylTMI])^2)); RCSdataErregcylTM = Transpose[(phirange, RCSSolErregcylTM)];

CYITM  $(4 * Pi * (\rho \land 2)) * (((Abs[ErhoregcylTMS]) \land 2) / ((Abs[ErhoregcylTMI]) \land 2));$ CSdataErhoregcylTM = Transpose[(phirange, RCSSolErhoregcylTM]; RCSd

$$\begin{split} & \texttt{RCSSolEphiregcylTM} = \\ & \left( 4 * \texttt{Pi} * \left( \left ( \texttt{Abs[EphiregcylTMS]} \right) ^2 \right) / \left( (\texttt{Abs[EphiregcylTMI]} ^2 \right) \right); \\ & \texttt{RCSdataEphiregcylTM} = \texttt{Transpose[{phirange, RCSSolEphiregcylTM}]; } \end{split}$$

RCBHolEregry1MMills -Eget (Exhonogry1MH + Cos[phirange] - Ephiragry1MH + Ein[phirange])'2 + (Exhonogry1MH = Sin[phirange] - Ephiragry1MH + Cos[phirange])'2 + (Excepty1MH) = 2];

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(ErhoregoylTES \* Sin[phirange] + EphiregoylTES \* Cos[phirange]) ^2 + (ErregoylTES) ^2]]]; dataEAllTES = Transpose[{phirange, SolEAllTES}];

 $\begin{aligned} & (+RCE Solution) \\ & (+RCE Solution) \\ & (+RCESLErregcyTE + DNE; +) \\ & (+RCEsLErregcyTE + DNE; +) \\ & RCESLERregcyTE + \\ & (+1+i(Abs(ExcoregcyTEE)) ^2) / ((Abs(ExcoregcyTEE)) ^2) ); \\ & RCESLERregcyTE + Transpose((phreage, RCESolErcoregcyTEE)); \\ \end{aligned}$ 

 $\begin{aligned} & \texttt{RCSSolEphiregcylTE} = \\ & \left( 4 \times \texttt{Pi} \star \left( \rho^2 2 \right) \right) \star \left( \left( \texttt{Abs[EphiregcylTES]} \right)^2 \right) / \left( \texttt{(Abs[EphiregcylTEI]} \right)^2 \right) \right) ; \\ & \texttt{RCSdataEphiregcylTE} = \texttt{Transpose[(phirage, \texttt{RCSSolEphiregcylTE)}); \end{aligned}$ 

(+RCS Solution - in dB+) RCSdatAlthoregcyITEMS = Transpose[[phirange, 10 \* Log10[RCSSolEthoregcyITE]]]; RCSdataBltregcyITEMS = Transpose[[phirange, 10 \* Log10[RCSSolEthoregcyITEM]]]; RCSdataBltregcyITEM1HS = Transpose[[phirange, 10 \* Log10[RCSSolEtegcyITEM1]]];

## TM + TE Mode Solutions

(+Incident + Scattered Solution+) SolErregcylTMSplusTESandI = N[Abs[ErregcylTESandI+ErregcylTMSandI]]; dataErregcylTMplusTESandI = Transpose[[phirange, SolErregcylTMplusTES SandI}];

SolErhoregcylTMplusTESandI = N[Abs[ErhoregcylTESandI + ErhoregcylTMfandI]]; dataErhoregcylTMplusTESandI = Transpose[{plirange, SolErhoregcylTMplusTESan

SolEphiregcylTMplusTESandI = N{Abs[EphiregcylTESandI + EphiregcylTMSandI]]; dataEphiregcylTMplusTESandI = Transpose[{phirenge, SolEphiregcylTMplusTESandI];

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- SolEAllTMplusTESandf = N[Abs[Sqrt[[Eshoregoy]TESandf = Eshoregoy]TMSandf] = Son[phirange] 2 = (Ephiregoy]TESandf = Ephiregoy]TMSandf] = Sin[phirange] 2 = (Eshoregoy]TESandf = Eshiregoy]TMSandf] = Son[phirange] 2 + (Espiregoy]TESandf = Ergoy[TMSandf] + Cos[phirange] 2 + (Esregoy]TESandf = Ergoy[TMSandf] + Cos[phirange] 2 + (Esregoy]TESandf = Transpose[(phirange, SolEAllTMplusTESandf]);

(\*Scattered Only Solution\*)
SolErregcylTMplusTES = N[Abs[ErregcylTES \* ErregcylTMS]];
dataErregcylTMplusTES = Transpose[[phirange, SolErregcylTMplusTES]];

SolErhoregcylTMplusTES = N[Abs[ErhoregcylTES + ErhoregcylTMS]]; dataErhoregcylTMplusTES = Transpose[{phirange, SolErhoregcylTMplusTES]];

SolRphiregcylTMplusTES = N[Abs[EphiregcylTES + EphiregcylTM5]]; dataEphiregcylTMplusTES = Transpose[{phirange, SolEphiregcylTMplusTES]};

SolEAlThqLusTES = N(Abs(Sqrt[((Ethoregor)ITES - Ethoregor)ITES) - Cos[phirange] -(Ephiragor)ITES = Thoiragor)ITES = sin(phirange) - (Thoiragor)ITE = (Cethoregor)ITES = thoragor)ITES = filteragor)ITES = filteragor)ITES = filteragor)ITES = filteragor) - (2 + (Etaregor)ITES = filteragor) - 2 + (Etaregor)ITES = filteragor) - 2

(+RCS Solution+)
RCSSolErragoy17Mb[usTE + (4+Fi+(c^2))+
(((Abs[Erragoy17E5+Erragoy17M5])'2)/((Abs[Erragoy17E1+Erragoy17M1])'2));
RCSdst&Erragoy17Mb[usTE + Transpose((phirange, RCSdolErragoy17Mb[usTE));

$$\begin{split} & (\texttt{A} \times \texttt{Pi} + (p^*2)) * ((\texttt{Abs}(\texttt{EthoregoylTES} + \texttt{EthoregoylTES})^2) / \\ & (\texttt{Abs}(\texttt{EthoregoylTES} + \texttt{EthoregoylTES})^2); \\ & (\texttt{Abs}(\texttt{EthoregoylTES} + \texttt{EthoregoylTES})^2); \\ & \texttt{RCSdataEthoregoylTMplusTE} = \texttt{Transpose}(\texttt{phirange}, \texttt{RCSSolEthoregoylTMplusTE}); \end{split}$$

$$\begin{split} & \texttt{RCSSolBphiregoylTMSplusTE } \ast \\ & \texttt{(4 r} r + (n^2)) + ((\texttt{(bal(gbalregoy)TEE + \texttt{RphiregoylTME}) ^2) / \\ & \texttt{(bal(gbalregoylTEE + \texttt{Rphiregoy})TEE + \texttt{)}); \\ & \texttt{RCSdataBphiregoylTME plusTE + Transpose((phirange, \texttt{RCSSolBphiregoylTMplusTE)); } \end{split}$$

RCSSolEragcylTMplusTEAllS = Sqrt[ ((ErhoregcylTES + ErhoregcylTMS) \* Cos[phirange] - (EphiregcylTES + EphiregcylTMS) \* Sin[phirange]) ^2 + ((ErhoregcylTES + ErhoregcylTMS) \* Sin[phirange] +

wass- Export[ToString[StringForm["``.jpg", PhiTableName]], ChangingPhiTable]

N(499)- EzCorrS = ListPolarPlot[dataEzS, Joined → True, PolarGridLines → Automatic,

Corr : LitPointruct("Frequent, Automatics, Pointructumes Automatic, Fointruct, "Frequent, Automatics, Picktyls-> (Mod, Dashed) Baseltyls-> MacluteThickes(2), Picktyls-> Moo, Picklast-> TO, Baseltyls-(Frequent, Picktyls-> 14, FontWeight>> Teld", Fointructumes -> 100, Baseltyls-(Fontfuer, >> 14, FontWeight>> Teld", Fointructumes -> 100, Baseltyls-(Fontfuer, -> 14, FontWeight>> Teld",

# (BphirsgcylTES = RphirsgcylTME) = Cos[phirsgs]) \* 2 \* (ErsegcylTEE = KresgcylTME) \* 2); (ExclaresgcylTEE = KresgcylTME) = Entphirsgs] \* 2 (BphirsgcylTEE = RphirsgcylTME) = Sniphirsgs] \* 2 ((EntorsgcylTME = KresgcylTME) = Sniphirsgs]) \* 2 \* (ErsegcylTME = KresgcylTME) \* Cos[phirsgs]) \* 2 \* (ErsegcylTME = KresgcylTME) \* Cos[phirsgs]) \* 2 \* (ErsegcylTME = KresgcylTME) \* (Ass[phirsgs]) \* 2 \* (ErsegcylTME = KresgcylTME) \* (Ass[phirsgs]) \* 2 \* (ErsegcylTME = KresgcylTME) \* (Ass[phirsgs]) \* 2 \* (CostagciesgcylTME) \* 2 \* \* (\*RCS Solution - in dB\*) RCSdataErregoylTMplusTME = Transpose[[phirange, 10 + Log10[RCSS0IErregcylTMplusTE]]; RCSdataErchoregylTMplusTME = RCGdatEnforgeylTMpluuTEdB + Transpose[[birange, 10 + Log10]RCEGBSIErhoregeylTMplusTE]]]; RCGdatEnEgylTMplusTEdB + Transpose[[birange, 10 + Log10]RCESBIEphiregeylTMplusTE]]]; RCGdatEnEgeylTMpluuTEALB + Transpose[[birange, 10 + Log10]RCESBIEregeylTMplusTEAL]]);

Changing Phi Polar Plots

Table of Parameters

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## Plot Erho (Scattered)

Performer Communications (Communication) (C

#### Plot Erho (Inc + Scattered)

W000 EthoCorfand1 = ListDialPlot[dtaltho, Joined + True, PolarGidLines + Automatic, PolarGide = ("Degrees", Automatic), Plottsyle >> (Red, Dached), Basstyle >> Absoluttichtomes[2], Plottaltexes >> None, PlotLahel >> 'Tc, Corrupted Cylinder (Incident + Scattered Field)\*, ImageSize >> 700, BassRyle >> (PontBires >> 14, FontHeight >> "Bold\*), Polarkes = True, PolarkesCorigis < {0, Max[SolEhc]];</pre>

## Plot Ephi (Scattered)

## Plot Ephi (Inc + Scattered)

For pair (in Sources) Philorenand: Listoclarid(dataRphi, Joined + True, PolarGridLines + Aut Philarticks ("Degrees", Automatic), PLotKyle -> (Red, Dashed), BaseStyle -> NahoutenThickes[], PLotKylerz -> None, PlotLabel -> "E, Corrugated Cylinder (Incident + Scattared Field)", ImageLise -> Tob, BaseStyle -> (EnotLise -> L4, FontHeight -> "Bold"), Polarkees + True, Polarkees(Jini + (0, KatSchhill)); dLines - Automatic,

## Plot Ez (Inc + Scattered)

Corrugated Cylinder Plots Plot Ez (Scattered)

smss=EscoreSandf = ListPolsTol(datEs, Joined + True, PolarGidines + Automatic, PolarGides = (Degrees\*, Automatic), PictByle >> [Red, Dashed], BaseStyle >> AbsoluteDinkses[2], PictBackers >> Nom, PictLabel >> %, Corrupted Cylinder (Incidnt + Ecattered Field)\*, ImageDisc >> 700, BaseStyle >> [AroSteice >> 14, FontWeight >> "Bold"), FolarAses + True, FolarAsesOrigin + (0, Max[SolEz])];

## Plot EAII (Scattered)

Fict on (Contextury)
Exilors's ListOlarPlot(dataBAlls, Joined - True, PolarGridLines + Automat
Exilors's ListOlarPlot(dataBAlls, Joined - True, PolarGridLines + Automat
Exitopic - MeoniteThiones(]). FlotRates -> None,
FlotLabel -> Thous, Corrupted Cylinder (Sottered Teisd)\*,
Polarkee - 700, ReseByla -> (FontBins -> 14, FontMeight -> "Rold"),
Polarkee True, PolarkeeStripin = (0, Me(SolMall))]);

## Plot EAII (Inc + Scattered)

EkilCorrSand = ListFolarile([statklisnd], Voined - True, FolarGridlines + Automatic, Folaritets - (Tedgress\*, Automatic), FlotEsyle -> (Bed, Dashed), Isottabel -> AbsoluteThicknes[2], FlotEsyle -> Kost, FlotEabel -> Too, Teoroyated Cylinder (Incident + Ecattered Field)\*, ImageEise >> Too. BaseStyle >> (FontEse -> No.4), FontSeylet -> Toold\*), FolarAxes + True, FolarAxesOrigin + (0, Max[SolEAlEand1])};

#### Summary Corrugated Cylinder Plots

#### squb. GraphicsGrid[ ([RECORF, EECorfSand]), (ErhoCorrS, ErhoCorrSand]), (EphiCorrS, EphiCorrSand]), (ELiCorrS, EAliCorrSand]), Spacings -> (Scaled[0], Scaled[0]);

#### Smooth Cylinder Plots - TM Plots

## Ez (TM Scattered)

wmm.HzBegCy1700 + LittPolarFlot[dstalkreegoy1706], Joined + True, PolarGridLines + Automatic, PolarTicks = ("Degrees", Automatic), FlotExplot > Slus, ResetVia - Shoolinethickness[2], FlotExplore > None, FlotExbel > VTC, ResetVia- Visionic (WE Excited Field)\*, TangeDisc > VTC, ResetVia- (TomSter > 14, FontWeight -> %sld\*), Folzekkes = True, Folzekkeedrigin = (0, Max[SolErregoy1706])];

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#### Ephi (TM Inc + Scattered)

pp. (first visual visual

#### EAII(TM Scattered)

WHVP. EXIEngCylTHS = ListPolarPlot[dstaEklITHS, Joined + True, PolarC+IdLine: Automatic, PolarEtuke : (Pospress', Automatic), FoldTyle > Slue, BaceStyle - Sheoltenickness[2], FoldEtacker > None, FlotLabel >> Too, Face, BaceStyle - Sheoltenet Fladd ', ImageStee > 700, BaceStyle > (FondStee > 14, FondSteight > Toold', FoldEtakes = True, PolarAceStrigin = (0, Max[SolEklITHS]]);

#### EAII (TM Inc + Scattered)

ELileg(y)HEand: = ListPlatPlot[dstsElilMEand;, Joined = Trus, PlatGridLines = Automatic, PlatFick= ("Degrees", Automatic), PlatEquip = Slau, BaseTyle = SheelineThickness[2], PloMackers = She PlatEabel >> "Equal Booth Cylinder (W Incident : Scattered Field)", ImageEine >> Too, BaseEtyle >> [PottEine >> 14, FontHeight >> "Bold"), PlatEabes = True, PlatEaberOrigin = (0, Max[SolELINESAct]);

## Summary TM Plots

%cmp.GraphicsGrid[[[SERegCylTMS, ExEegCylTMSand]], [ErhöRegCylTMS, ErhöRegCylTMSand]], [EphiRegCylTMS, EphiRegCylTMSand]], [EAllRegCylTMS, EAllRegCylTMSand]], Spacings -> {Scaled[0], Scaled[0]};

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## Ez (TM Inc + Scattered)

#### Erho (TM Scattered)

EnhesgcyTest ListPlatFlat(dataEchoregoyITES, Joined + True,
PolarGridLase + Antomatic, PolarTicks + ("Degress", Antomatic),
PlacEtyles - Blue, BaseWite - Maholitethichass[], PlacItarkers - None,
PlacEthabel -> Tag, Boosth (yilnder (TW Scattered Field)\*,
Imageliae - 700, Basetyles - (TomSizes - 14, FacHMeight -> "Bold"),
PolarAxes + True, PolarAxesOrigin + (0, Max[SolEchoregoyITMS]);

#### Erho (TM Inc + Scattered)

b. EchologcylifBlandi = Listolarlot(dataErhoregcylIfBlandI, Joined - True, PolarGridLines - Automatic, Polarlicks + ("Degrees", Automatic), Plottyle - Blae, Baseflyic - AbsoluteFinitones[2], Flottakers -> None, Plottakel -> Te, Booch Cylindsr ("M Incident + Sostared Field", ImagoDise -> 760, BaseGlyin -> (Tontime -> 14, FoutHeight -> "Bold"), Polarkess = True, PolarkesGrigin -> (0, Max[SolEchoregcylTHEandI]};;

#### Ephi (TM Scattered)

TyhiRmy()1785 = LisiDolar#Disk(data#phiregy)1785, Johned+Trome, PolarGridLines+Automatic, PolarTicks+(Tbegrees\*, Automatic), PlotStyle=> Disk, BaseStyle=> AbsoluteThickness[], PlotInkers=> None, PlotLabal -> Tw, Boosh Cylinds: (Wf Scattered Field)\*, Imageline -> TOD, BaseStyle=> (FortEine > 14, FortHacht=> "Bold\*), FolarAmes+True, PolarAmesOrigin+(0, Max(SolEphiregry1785]);

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#### Smooth Cylinder Plots - TE Plots

## Ez (TE Scattered)

segry: Efect/yITES = ListPolarFlot[dataExrempcyITES, Joined + True, PolarGridLines + Automatic, PolarItiks = ("Degrees", Automatic); FlotTayles > Size, EsserStyle - Desoluterinthemses[2], FlotDatacter > None, FlotLabel >> TE, Booth Gylinder (TE Scattered Field", TangeDise >> Non. Sentypics >> (Non-Statered Field", PolarAmes + True, PolarAmesGrigin = (0, Max[SolExrempcyITES]];

#### Ez (TE Inc + Scattered)

Li (1 mit > Lattorov)
sump. EnlegyTitEand; Joined + True,
Polardriddines Automatic, Polardridts ( Toegress', Automatic),
PlotStyle > Jice, HaceNyle > AbsoluteThickness[2], PlotMarkers > None,
PlotEabel > "%, Hmooth Oplinder (TH Incident + Scattered Field)",
ImageSize > Too, Resettyle >> (Pontize >> 14, FontWeight >> Toold'),
Polardsee = True, Polardsencign = (0, Mark GolfsreegyTiedGil)]);

#### Erho (TE Scattered)

Erhöhegy/THT + ListPolarPlot[distAthorsegy]TEE, Joined + True, PolarCidLines + Automatic, PolarTicks - ("Degrees", Automatic), PlotEyle - Niuw, ImselPipt - Nahoulterinkonsej(2), PlotEwiczer - None, PlotLabel -> TM, Bonoth Cylinder (TE Scattered Field)", ImageSime -> TRO, BaseEyle -> (FortSime -> 14, FortHeight -> "Bold"), Polarkee = True, Polarkeer(jain - (0, Mari Sclichnergey2)TES]]];

## Erho (TE Inc + Scattered)

Endodecyliadad = ListOclasPlet(dataEchoregylIEEandI, Joined + True, PolarGridlines - Automatic, PolarItck + ("Degress", Automatic), Plottyle > Blue, Basellyle > AbsolutPolichionsa[], PlotRackers > None, PlotLabel -> "E. Smooth Cylindsr (TE Inziden: + Socktared Field", Imagelise -> TGO, BaseByle -> (FontSize -> 14, FontWeight -> "Bold"), Folszkes = True, PolarAsseCrigis + (0, Mac[OlEhoregoyTHEandI])];

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## Ephi (TE Scattered)

putcerimits 1; point of the statematic point (dataBphiregoy1755, Joined + Tree, pointGridhies + Automatic, Polaritoka + ("Degrees", Automatic), PointGrid > Niue, BaseSpile - Nakoultaritokesse[1], Polarkacks -> None, PointAmbi -> "M, Honoth Cylinder (TM Sonthered Field)", Imagedise -> TKO, BaseStyle -> (FontSise -> 14, FontWeight -> "Bold"), Polarkacks = True, Polarkackofrigin = (0, Mar[Solfphiregoy1755]);

## Ephi (TE Inc + Scattered)

cpHm()(int not - subscretcy) ppHm()(int not - subscretcy) polardridines - Automatic, Polaricker ("Degrees", Automatic), PletEtyle - Nius, Bassity - AkoniteThiotess(]), PletKers -> None, PletEtabai -> Niu, Bioshty -> AkoniteThiotess(]), PletKers -> None, PletEtabai -> Niu, Bioshty -> Conditions -> None, PletEtabai -> Non, Bioshty -> Conditions -> None, PletEtabai -> Non, Bioshty -> Conditions -> None, PletEtabai -> None, PletEtabai -> N

#### EAII (TE Scattered)

WillingCylIfEs = ListPolarFlot[dstaEilITES, Joined + True, FolarGriddines + Automatic, PolarTidis = ("Degress", Automatic), FoldTyle - Slues, Basedbyle - Sheolusethickess2[], FoldTakers - None, FlotLabel -> Tieux, Basedb CylInder (TE Esattered Floid)\*, Tangedise >> 700, BaseStyle >> [forStifts -> 34, FontSeight >> "Bold"), PolarAmes = True, FolarAmesGrigin = (0, Max[SolEAlITES])];

#### EAII (TE Inc + Scattered)

# unio. EliBapty/PEEnoff = tisPolarDid[detafAllPEEnoff, Joinsd = Trum, PolarGridLines = Automatic, PolarTick= ("Degress", Automatic), PolafBridLines = Automatic, PolarTick= ("Degress", Automatic), PolafBrid= > Sue, Basoth Cylinder (TE Incident = Scattered Field); ImageSize > 700, Basoth Sylinder (TE Incident = Scattered Field); PolarAxes + True, PolarAxesOrigin = (0, Max[SolEAllTEEand]]);

#### Summary TE Plots

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#### Ephi (TM+TE Scattered)

performance and the second secon

## Ephi (TM+TE Inc + Scattered)

WHM-EphilegCylTMplusTESandI = ListPolarPlot(dataSphiregoylTMplusTESandI, Joined + True, PolarC+LikLines - Automatic, PolarTiche ("Despress", Antomatic), PioLityle - Silon, BacedTyle - Marolithickness[2], PioLithicknes - None, PioLianel -> Tru, BacedTyle -> (Ternistics - Santared Field)", ImagedIse -> 700, BacedTyle -> (Ternistics -> 14, FontWeyler -> "Bold"), PolarAckes = True, PolarAcedTrigin + (0, Mar[SolEphiregrylTMplusTESandI)];

#### EAII (TM+TE Scattered)

ELIMO()106/UNTEF = ListPole[distall106/UNTEF, Joined + True, PolerCidlines + Automatic, PolerTicks ("Degrees", Automatic), Flottfyle > Nion, Bestyle > NionPolerCiness(2) FlotTickers > None, Flottabel -> Te<sub>full</sub> Bmoth Cylinder (TM + TE Scattered Field)", ImageSize -> TGO, BaseStyle -> (Fortiste -> 14, FortSeight -> "Bold"), Polarkees True, Polarkeercigin -(O, Mas(SciUl1076)urtET)]);

## EAII (TM+TE Inc + Scattered)

E. M. Hillscy/TMPUsvTEadt - ListPlasTole[detaEAllTmpUsvTEsch], Joined + True, W. Eallacy/TMPUsvTEsch - ListPlasTole(detaEAllTmpUsvTEsch], Joined + True, PlasTyle > Blue, Baselyle - Neoulertichesse[2], PlasTolekters - None PlotLabel -> TM\_main Emotyle -> Mentioness[2], PlasTolekters -> None PlotLabel -> TM\_main Emotyle -> (FontSize -> 14, FontWeight -> Tbold'), Polarkees = True, PlasTakeofigin = (0, Margi DoLLint[burgUtFamil])];

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#### ooth Cylinder Plots - TM + TE Plots Sm

#### Ez (TM+TE Scattered)

[10] Holaridi E. ListPolarPiot(dataErregcylTMplusTE, Joined + True, PolardridLines - Antonic, PolarTicks ( "Degrees", Antonetic), PlotByle - Blue, BaseRyte - AbsoluteThickness(), PlotBackers - None, PlotEabal -> "Le Bonch Sylinder (M + TE Instreed Find)", ImageBiss -> 700, BaseByle -> (FormElss -> 14, FortWeight -> "Bold"), Polarkes True, PolarkesCrigin + (0, Mas(SolkreegylTMplusTES)])

#### Ez (TM+TE Inc + Scattered)

Elseksycjimpikustkändi = Listolarbick[datäEregsylThplustKändi, Joined + True, PolardridLines + Automatic, Polarticks = ("Degrees", Automatic), Plottyle - Blue, Baseltyle - Maolustkhinkoss[2], Flottakres -> None, Plottabel -> "E. Boosth GylInder ("M + TE Incident = Acattered Field)", Imageliae - 700. Basettyle -> (FortSize -> 11, FortNeight -> "Bodd"), Polarkes + True, PelarkesOrigin - (0, Mas[SolEregsylThplustEšand]));

#### Erho (TM+TE Scattered)

semp. EthologOylDMplusTES + ListPelasFlot[dataEthoregoylDMplusTES, Joined + True, PolarGridLines + Automatic, PolarTicks = ("Degrees", Automatic), PolatFlot - Nies, HaesDiyls - Naboulterhichess2[], PlotBarkers - Nies, PlotLabel -> Tie, Booth OylInder (DH + TE Soattered Field)", ImageDire > 700. BaseNiej -> (FonStier - Mir Order Field)", PolarAses + True, PolarAsesOrigin = (0, Max[SolEthoregoylDMplusTES])];

#### Erho (TM+TE Inc + Scattered)

Minimum control = ListPolarDot(dstaTrhoregor)TheListTisandI, Joined = True, PolarCidLines = Automatic, PolarDicks = ("Degrees", Automatic), Polarty = Degrees = Automatic, PolarDicks, Polardstate = (Degrees), Polarksker => None, Plottabel => Tr\_\_Smooth Cylinder (TM + TE Incident + Scattared Field)", ImageSize => 700, BaseStyle >> (PontSize >> 14, FontHeight >> Told"), Polarkses = True, PolarksesCigute = (D. New (Scittoregy)The[umFisch]);

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#### Summary TM+TE Plots

set. Graphicsdid[[ExRegCylTMplusTES, ExRegCylTMplusTES [ErhoRegCylTMplusTES, ErhoRegCylTMplusTESand], [EphiRegCylTMplusTES, EphiRegCylTMplusTESand], [ExlinegCylTMplusTES, EnliNegCylTMplusTESand]], Spacings -> [Soaled[0], Scaled[0]]; The

#### Compare (Regular vs Corrugated) Plots

#### TM Compare

cmc. Grephice@rid(([ListbolarPlot] (dataEiregoyTME, dataEi), Joined + True, PolarGridLines + Automatic, PolarTicka + ("Degrees", Automatic), PictuRyte → (Biue, (Bed, Dashed), BaseStyle → MicroluteTHickness[]). PictURatkers → None, PictLabel → "5, TM Statisterd Booch (Fylinder (Biue) vs Corrugeder Cylinder (Bed, --)", TangeBirs → 700, BaseStyle → (PontSize → 14, PontSeight → Fold\*), Polarkers + True, PolarkerSorfigin = (N Mat(SoitregoyThe, SoitR\*)],

ListPolarPlot[{dataEzregcylTMSandI, dataEz},  $\label{eq:listbold} Tree, platfield (datafreego:TMBand, datafr, Joned Tree, platfield lists - Attornation, Flottigt () > Slattigt () > Slatt$ 

## {ListPolarPlot[{dataErhoregcylTMS, dataErhoS},

ListPlarPlot[ditatArbreyspi196, detaIfho8), Joinda Trum, PularTidiinas - Mattomatic, PolarTicka = ("Regrees", Automatic). FlotRiyla -> (Biuse, [Red. Bashed]), Resetyla -> AbsoluteThickoscegi (]. FlotRiytera -> None, FlotLabel -> "E, TM Scattered Booch Cylinder (Biau) w2 Corrupted Cylinder (Red. ->" RogeNise -> Tous, PolarAresorigin = (0, Max[SolErhoregoy1965, SolErho5])], PolarAreso + True, PolarAresorigin = (0, Max[SolErhoregoy1965, SolErho5])],

ListPolafPlot[(dataEthoregoylTMEandI, dataEtho), Joined + True, PolafOidLinne + Automatic, PolafTiche + (Degreef, Automatic), PiotFiyle -> [Blue, [Red, Dashed]), BaedSyle -> AbsolutAThichomes[2], FlotMathere -> Bone, PiotLabel -> Te, TM Toicide + Sonttared Booch Kylinder (blue)

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$$\begin{split} & \text{Polarticks} \rightarrow (\text{Tegress}^*, \text{Automatic}), \text{ PlotByle} \rightarrow (\text{Blue}, (\text{Red, Dashed})), \\ & \text{BassByle} \rightarrow \text{ AbsoluteThickness[2], PlotBarkers \rightarrow \text{ None, PlotLabel} \rightarrow \\ & \text{'s, TF Southerd Booch Cylinder (Blue) vs Corrupted Cylinder (eds, --)', \\ & \text{ImageDisc} \rightarrow \text{TOO, BaseByle} \rightarrow (\text{ToutEins} \rightarrow 14, \text{ ForeWeight} \rightarrow \text{ Thole'}), \\ & \text{Polarkees True, PlotReedSright } (6, \text{ Max[Solutergy]TES, Solute])], \end{split}$$

ListPointPiot((dataEuropsylTESandI, dataEu), Joinde + frum, PointFichines - Antomatio, PointFicks - (Poperes\*, Antomatio), PointSylte -> (Alue, (Red, Dashed)), BaseSyle -> NacointFichicnes(2), PiotHarkers -> Nose, PiotLabai -> ", Et Toinden + Scattered Booth Oylinder (Alue) 'es Corrugated Cylinder (Med, --)", ImageNise -> 700, BaseSyle -> (Woilise >> 15, FontWayehts -> 700, PointAeseSorigin + (0, Mas[GolExregoy]TESandI, SolEs]))),

ListPointflot[(dstafthoregcylTfSandf, dstaftho), Joinsi + True, Folardicilius - Automatio, Pointricia + ("Operare", Automatio, Pointflyich >> (Blue, [Red, Bashed]), BassEyl => Absolutefliciense(2). Foltstarkers -> None, Pointakel >> "R T Enclident + Eachtreed Booth (Yulnder (Blue) ve Corrupted Cylinder (Red, --)", Tampélise -> 700, BassEyl => (Toristis -> 14, Fortskipt -> "Point/", Folardstas + True, PolarkessOrigin + (0, Mas(BolEthoregcylTfSandf, BolIrho)])},

 $\label{eq:listPolarFlot[(dataSphiregcylTES, dataSphiS), \\ Joined + True, PolarFlotd= + Automatic, \\ PolarFlotk= ("Degrees", Automatic), PlotBarkers <math>\rightarrow$  (Biue, (Bed, Dashed)), \\ BaseStyle  $\rightarrow$  MasslutdThichones[2], FlotBarkers  $\rightarrow$  Nose, FlotLabel  $\rightarrow$  "5, TE Scattered Smooth Cylinder (Biue) vs Corrupted Cylinder (Bied, =-)", \\ ImageSize  $\rightarrow$  700, BaseStyle  $\rightarrow$  (FortSize  $\rightarrow$  4.4, FortKeight  $\rightarrow$  Thold", PolarAses0rigin + (0, Max[SclEphiregcylTES, SolBphiS]), \\ \\ PolarAses  $\rightarrow$  True, PolarAses0rigin + (0, Max[SclEphiregcylTES, SolBphiS]), \\ \end{cases}

ListPolarPlot[{data&phiregcylTESandI, data&phi}, Joined → True, PolarGridLines → Automatic, PolarTicks → {"Degrees", Automatic], PlotStyle -> {Blue, {Red, Dashed}},

{ListPolarPlot[(dstErkoregoy170plusTES, dstaErhof), Joinnd True, PolarZider ("Urgeres", Automatic, PiotStyle -> (Blue, (Bed, Dashed)), BaesStyle -> AbsoluteThichness[2], PiotMarkers -> None, PiotLablo -> "G, MrHE Gaetareed Month Cylinder (Blue) vs Corrupated (yiInder (Bed, --)", ImageSize -> 760, BaesStyle -> (Fontile -> 14, FontMeight -> 760, PolarAmesOrigin + (0, Mar[SolErhoregy170plusTES, SolErhof)]),

$$\label{eq:constraints} \begin{split} & Joinds - Artosatio, \\ & Dolaridka + ("operasi', Automatio, " Jointy -> (Blue, (Bed, Dashed)), \\ & BaseStyla > XheolateFhickness(2), Flottikarer -> None, \\ & Plotikale -> T, Hofti Thiodist - Scattered Booch (Sylinder (Blue) \\ & vs Corrupated Cylinder (Bed, --)^*, ImageSize -> 700, \\ & BaseStyls -> (Flottikare -> 14, FontHeight -> Tbld'), Polatkees = True, \\ & PolatkeesCript => (Mostile -> 14, FontHeight -> Tbld'), Folatkees = True, \\ & PolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), FolatkeesCript => (Theol => 100 ), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> Tbld'), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> 100 ), \\ & FolatkeesCript => (Bost -> 14, FontHeight -> 100 ), \\ & FontHeight -> (Bost -> 100 ), \\ & FontHeight -> (Bost -> 100 ), \\ & FontHeight -> (Bost -> 100 ), \\ & FontHeight -> 100 ), \\ & FontHeight -> (Bost -> 100 ), \\ & FontHeight -> 100 ), \\ & FontHei$$

{listPolarPlot[[dstRphiregcylTMplusTES, dstRphiB], Joinda True, PolarZid+r ("Degrees", Automatic, PolarZid+r ("Degrees", Automatic), PioStyla -> [Biue, [Bed, Dashed]}, BaseStyla -> AbsoluteThickness[2], PiotMarkers -> Nome, PlotLabl-> -> Tm.FTE Gatered Month Cylinder (Dalay va Corrupated Cylinder (Bed, --)\*, DamapEire -> 760, BaseStyla -> (Fontise -> 14, FontHeight -> Tod(-), PolarAnses - True, PolarAnsesOrigin + (0, Mas[SolEphiregcylTMplusTES, SolEphiS])],

ListPolarPlot[(dstaBphiregcylTMplusTESandf, dstaBphi), Joinsei + True, FolardFicilinse - Automatic, PolarTicket - ("Degreen", Automatic, ) FoldStyle -> (Blue, [Red, Dashed]), BassStyle -> AlsoSubsThickness[2], FoldBarksen -> Home, Polatabel -> "E uHTT Encident - Scattered Booch Cylinder (Blue) vm Corrupted Cylinder (Red, --)", ImageDize -> 700, BassStyle -> (TonElize -> 14, FontStejht -> Told/, PolarAsse = True, PolarAssoSrigin + (0, Mas[SolEphiregcylTMplusTESandf, SolEphi])],

 $\label{eq:listfold} Listfold (datability), Joined Trans, Pointford (datability), Joined Trans, Pointfold (datability), Point$ 

{ListPolarPlot[{dataEAllTMplusTES, dataEAllS},

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ListPolarPlot[{dataErhoregcylTMplusTESandI, dataErho} Joined → True, PolarGridLines → Automatic,

Corrugated Cylinder (Red, --)", ImageSire -> 700, tyle -> {FontSire -> 14, FontWeight -> "Bold"), FolarAxes → Tr AxesOrigin → (0, Max[SolErhoregcylTMSandI, SolErho])]}, BaseStyle -PolarAxesOr

[ListPolarPlot[(dataSphiregoyITME, dataSphiS), Joinset + True, PolarSridLines + Automatic, PolarTicks + ("Degrees", Automatic), PlotStyle -> (Blue, (Red, Dashed)), BaseStyle >> AbsoluteThicKnees[2]. Elottarkers -> None, PlotLabel -> "%, TM Eastteed Smooth Cylinder (Blue) vs Corrupted Cylinder (Red, --)", ImageSiae >> Corol. BaseStyle -> (Contision > 14, FontKingt -> "Biol"), Polarkess + True, PolarkesOrigin + (0, Max[SolEphiregoyITME, SolEphiS])),

$$\begin{split} & ListblarPlot[(dataSphiregeyITMSandI, dataSphi), \\ & Joinds + True, FolarGridines - Actomatic, \\ & FolarTicks + ("Operses", Actomatic, ) Folstyla: <math>\rightarrow$$
 (Blue, [Red, Dashed]), \\ & BasdTyla  $\rightarrow$  (NaclustFilckesse][2], FildMarkers  $\rightarrow$  None, \\ & Foltabel  $\rightarrow$  "Fu Thichtes + Cattered Monoh (yinder (Blue) vs Corrupted Cylinder (Red,  $\rightarrow$ )", Tamgedise  $\rightarrow$  700, \\ & BasdTyla  $\rightarrow$  (Totlise  $\rightarrow$  34, Fontheyich  $\rightarrow$  "Boil", FolarAsea + True, FolarkesoFrigin + (0, Mas(SolEphiregeyITMSandI, SolEphi)])), \\ \end{split}

{ListPolarPlot[{dataEAllTMS, dataEAllS}, Joined → True ListPolarRot([datAllINg, datAllIN], Joined = True, PolarGidlines Antomatic, PolarTick = ("Degrees", Antomatic), PlotStyle → (Blue, (Bed, Dashed)), BaseStyle → AbsoluteRickense[2], PlotBarkers → None, PlotLabel → Tenair IM Seattased Bmooth Cylinder (Blue) +0 Corrupted Cylinder (Bed, --)\*, ImapPiles → 700, BaseStyle → ("Contine > 14, Fortbarkhet > "Buld"), PolarAses → True, PolarAseStrigin → (0, Max[SolEAlINE, SolEAlIF]]),

ListPolarFiof[(distAllTMSandf, distAllSandf), Joind + True, PolarGridlines - Automatic, PolarTicke - (Pogeres\*, Automatic, ) Flottyle -> (Blue, [Red, Dashed]), Basetyle -> KhacluteThickness[2], Flottkarter -> None, Polataki -> "Fomar M Thicdant + softward Booch Oylindar (Blue) ve Occupated Cylindar (Red, -->", Langdise -> 700, Rasetyle -> (Toifise -> 21, ForWhight -> "Bold"), Polarkaes = True, PolarkaesGrigin = (0, Mes[BolEAllTMSandf, SolEAllBandf])])

 $\label{eq:GraphicsGrid} $$ GraphicsGrid[ \{ListPolarPlot[ \\ \{dataErregcylTES, dataErS}, Joined \to True, PolarGridLines \to Automatic, \\ $$ Output the set of the set of$ 

$$\begin{split} BaseStyle \rightarrow AbsoluteThickness[2], FlotMarkers \rightarrow Hoke,\\ FlotEabel \rightarrow "E" TT Incident + Scattered Bmoch Cylinder (Biss)$$
 $vs Corrupted Cylinder (Bc.) -> InageEine > 780,\\ BaseStyle \rightarrow (FontEine > 14, FontWeigher > "Roid"), Foliakee + True,$ Foliakeestrigue (C. Mag EinBurgeryTHEndl, EinBahu)]),

[ListPolarFlot](dstaEkl1FS, dstaEkl1S), Joined + True, PolatGridines + Automatic, PolarTicks + ("Degrees", Automatic), PlotEtyle -> (Blue, [Red, Dashed]), BassEtyle -> AksoluteThickness[2], PlotEnterkers -> Nene, PlotEable -> Nene: TE Scattered Booth Cylinder (Blue) vs Corrupted Cylinder (Red, --)", Tampešies -> Toolkasetyle -> ("Contiles -> 14, NortHeight -> "Bold"), PolarAxes + True, PolarAxeoGrigin + (0, Max(SolEAlITES, SolEAlIS)]),

ListPolneflot[(dtatAllTESndf, dtatAllSndf), Joind + True, FolarGridines - Automatic, Polneficiat - (Degrese\*, Automatic, ). FoldStyle -> (Blue, (Bed, Dashed)), BaseStyle -> XheolutFinicheme(2]. FoldStarkars -> None, Polniable -> "PolnaT Hinddant + Scattered Booch (Sylinder (Blue) ye Corrugated Cylinder (Med, --)", Imagdize -> 700, BaseStyle -> (Trofise -> 18, Fortwight -> "Bold"). FolarKas -> True, Polnatesorigin + (0, Mas(SolEAllTEEndf, SolEAllSadI)]])

hicds:rid((LintPolarPtot[ (LintFeqop(NeburtS, dataES), Joined + True, PolarGridLines + Automatic, PolarIcks + (Tegress", Automatic), FlotBarkers -> None, Polabel -> AbsoluteThickness[2], FlotBarkers -> None, Dictabel -> Tr, TH-TE Scattered Bmoch Sylinder (Blue) vs Corrugated QiLinder (Bed, --)", Imagdise -> 700, BaseStyl=> (FundSise -> 14, FonKeight -> Tokatkes = True, PolackesOrigin + (0, Mas(SolErregoy1DMplusTES, SolErS])),

ListDiarDio[(ditairango/ThplusTEInnd, datAE), Joinds True, PolaTrioLins + Automatic, PolaTicks + ("Depress", Automatic), PiotKyls -> (Biue, (Bed, Dashed)), BaseStyle -> AbsolutaThickness[2], PiotMarkers -> None, PiotLabel -> To Thor Incident - Scattered Monoth Oylinder (Blue) vs Corrupted Oylinder (Red, --)\*, Tamgešis -> 700, BaseStyle -> (Potsis -> 14, Fortikejt -> Thol?", PolatArkes + True, PolazAmesOrigin + (0, Mas[SolEregoylThglusTESandI, SolE])]),

ListFolarFlot[{dataEzregcylTMplusTESandI, dataEz},

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11 TE Compare

}]; TM+TE Compare ||417]- GraphicsGrid[{{ListPolarPlot]

BaseStyle -> {FontSize -> 14, FontWeight -> "Bold"}, PolarAxes → True, PolarAxesOrigin → {0, Max[SolEAl1TMplusTES, SolEAl1S])1.

ListPolarPlot[{dataEAllTMplusTESandI, dataEAllSandI}, Joined → True, PolarGridLines → Automatic,

Joined rTww, PolarGridhine - Automatic, DolarTicka + (Poperes\*, Automatic,). Flottyle → (Blue, [Red, Dashed]), BaseStyle → ZhenlutFhickness[2], FlottAnkers → None, FlottAhel → "Swam. HVT: Encident = feattered featorh (yiloder (Blue) ve Corrupated (yiloder (Red, --)\*, Tampedise → 700, BaseStyle → (Ponlise → 34, F-ortkeight → "Bold", PolarZhese True, PolarZhesGrigin + (0, Mas[SolEAllThplusTESand], SolEAllSand]))))

#### TM, TE, and TM+TE Compare

iPolarPlots

- hitelarflotes -GraphicoGrafid ([LintPolarPlot[[dataEregoy]TMS, dataEx3], Joined + True, PolarGridLines + Automatic, PolarTicks + ("Degrees", Automatic), PlotStyla -> (Blue, [Msd, Dashed)), BaseStyla -> AbsoluceThickness[2], PlotBackress None, PlotLands -> "&: TM Gattreed (VM) Month Cylinder (Blue) vs Corrugated Cylinder (Bnd, --)", ImageElae -> 700. BaseStyla -> (TentElae -> 14, FontWeight -> "Bold"), Polarkness + True, PolarAssoCrigin + (0, Max [SolErregoy]TMS, SolEs5]],
  - "E. TE Does Not Exist",
- "E. TE Doce Not Exist", Literizario (idiatereopy) ThplueTES, dataEcs), Joined + True, PolarGridines Antomatic, PolarTicks + (Pogress", Antomatic), Polstypis →> (Blue, (Bed, Dashed)), Rasstypis → AbsolutThichness[2], PiotHarkers →> Non, PiotLabal → "E. Morti (Wa) Schured Schuler, Clusker, (Blue) vs Corrupted Cylinder (Bed, --)", Raspitz →> 700, Rasstypis → (Ronline → 14, Ronling), Polarkers + True, PolarkersGrigin + (0, Mas[SolErrogrylThplueTES, BolEx5]))),

ListPolarPlot[(dataErsegoylTMEand1, dataEs), Joinds - frum, PolarCiddinss - Antomatic, PolarTicks - ("Degrees", Antomatic, PlotEtyle -> (Blue, (Bed, Dashed)), BaseStyle -> XocilottFinickness(2), FlotMarkars -> Noce, PlotEabel -> Tc. TM Incident - Scattered (V(m) Smooth Cylinder (Blue) vs Corrupated Cylinder (Bed. -)\*, LangeSter > 700, BaseStyle -> (FootSize -> 14, FootNeight -> "Bold"), PolarAmes - True, PolarAmedrig = (0, Mag(SliErregoylTMEand1, SolEz])), "M, TE Does Not Exist",

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# PolarGridLines → Automatic, PolarTicks → {"Degrees", Automatic},

Polarizidines - Natomatic, Polaritika - ("Begnes", Natomatic), Filostyla - (Nashint filosienes(2), Filosikara -> Nane, Filosikasi -> T, T londeri -> Backress ('W), Booch Gylinder (Riw) we Corrupted Gylinder (Red, -->, Tampdise -> 700, Rassityla -> (Tonlise -> 14, Polaritandt, Boltho)), Joind + True, Polaritikasi, -> None, Statho), Joind + True, Polaritikasi, -> None, Statho), Joint + True, Polaritikase, Attomatic, Polaritikas - (Tonlise -> 14, Polaritikase, Nano, Polaritikas - (Tonlise -> 14, Polaritikase, Tau, Polaritikas - (Tonlise -> 14, Polaritikase, Tau, Polaritikas - (Tonlise -> 14, Polaritikase, Tau, Polaritikas - (Nano, Solitho)), polaritikas - Tau, Polaritikas - (Nano, Solitho), Polaritikas - Tau, Polaritikas - (Nano, Solitho), Polaritikas - Tau, Polaritikas - (Nano, Solitho), Polaritikas, Tau, Polaritikas - (Nano, Solitho), Polaritikas - Tau, Polaritikas - (Nano, Solitho), Polaritikas, Tau, Polaritikas - (Nano, Solitho), Polaritikas - Tau, Polaritikas - (Nano, Solitho), Polaritikas, Tau, Polaritikas - (Nano, Solitho), Polaritikas - Tau, Polaritikas - (Nano, Solitho), Polaritikas, Tau, Polaritikas - (Nano, Solitho), Polaritikas - Tau, Polaritikas - (Nano, Polaritikas), Polaritikas - Tau, Polaritikas - (Nano, Polaritikas, Polaritik

{ListPolarPlot[{dataEphiregcylTMSandI, dataEphi}}

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ListFolarPiot[(dataEregrylTMplurTEEndI, dataEr), Joind a True, FolarGridlinss - Astomatic, FolarTicks - ("Ogneses", Automatic, ) FolsTyls -> (Blue, [Med, Dashed]), BaseStyls -> AbsolutFhickness[2], Flottmarer -> Hone, FlotLabel ->", TheTT Indiaden - Folattend ("My) Booch Gylinder (Blue) ve Corrugsted Cylinder (Med, -->', TaugeSis -> 700. BaseStyls -> (Toufise -> 14, FortKeight -> "Folar", FolarSes True, PolarAesOrigin + (0, Mas[SolEregrylTMplusTEEndI, SolEs)]),

(ListPolarPlot[(dat&EnhoregoylTMsanH, dat&Enho), Joined \* Trues PolarGridLines \* Automatic, PolarTicks + ("Regress", Automatic), BlotHyls -> (Blue, [Red, Dashed)), BaseStyls -> AubolutAThichness[2], FlotHarkers -> None. PlotLabel -> "E, TM Incident + Scattered (V/m) Bmooth Gylinder (Blue) vs Corrugated Gylinder (Bud, --)>", TangeStime >> 700. BaseStyls -> (FontSize -> 14, FontHeight -> "Biold"), PolarAses + True, PolarAseGrigin + (0. Mag(SintChoregoylTEEIndI, dolThe)]), ListPolarPlot((dat&EnhoregoylTEEIndI, dat&Enho), Joined + True,

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Joined + True, PolardZidLines + Automatic, PolarZicks - (Tbegrees\*, Automatic), Flottyje >> (Biue, (Red, Dashed)), BasedSyie >> MeoinstPhickness[], FlottArises -> None, PietLabel -> Te, TH Incident + Scattsered (Yrd) Bmooth Cylinder (Biue) vs Corrupated Cylinder (Red, ->)\*, ImageDisco >> Non, PolarAssofington = (0, Mass(Salphreegy/IMBendt, Sollphi)]), ListPolarZiel((dataRphiregy/IMBendt, dataRphi), Joined + True, PolarZiellen = Automatic, PolarZicks + ("Degrees", Automatic), PietStyla -> (Biae, (Back, Dashed)), BaseStyla -> (Biae, (Back, Dashed)), BaseStyla -> (Biae, (Back, Dashed)), BaseStyla -> (BabolterRhickness[2], FlottArkers -> None, PietLabel -> Te, TE Incident + Scattsered (Yrd) Smooth Cylinder (Biue) vs Corrupated Cylinder (Red, ->)\*, TangStime -> Tool, BaseStyla -> (PolarZielen -> 14, FontWeight -> "Bold"), PolarAsses + True, PolarAssofingen (0, Mas(Salphireegy/IMBendt, Sollphi))], Joined + True, PolarGidlinnes + Automatic, PolarZietk - ("Degrees", Automatic], PolatStyla -> (Biae, (Bach, Bashed)), BaseStyla -> Monitor (BasolterRhickness -> None, PietLabel -> Te, Th Incident + Scattsred (Yrd) Bmooth Cylinder (Buu ys Corrupated Cylinder (Back ->) Tong, BaseStyla -> Monitor (Back ->) Shothyla -> (Back, Bashed)), BaseStyla -> Shothyla Thicknes (J), PolarAsses -> Too, PietLabel -> Te, Th Incident + Scattsred (Yrd) Bmooth Cylinder (Buu ys Corrupated Cylinder (Back ->) Tong, BmaesTyla -> Too, BaseStyla -> (FontTime -> 14, FontWeight -> "Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> (Tottime -> 14, FontWeight ->"Bold"), PolarAsses +True, PolarAssofies(1) -> Joined → True, PolarGridLines → Automatic

[ListPolarFlot[(dataEAllTMS, dataEAllS), Joined + Trum, PolarGridLines - Automatic, PolarTicke + ("Degrees", Automatic), PlotBarkers - Nome, PlotLabel -> "Ensum M Scattered (WM) Smooth Cylinder (Blue) vs Corrupted Cylinder (Bed, --)", Imagolize -> Nome, PlotLabel -> (Tensum, FL & Fouthershipt -> "Bold"), PolarAcess - Trum, PolarAcessOrigin = (0, Max[dolBAllTMS, BolEAllB]), ListPolarFlot(BatABALTMS, dolBAllTMS, BolEAllB]), DistPolarFlot(BatABALTMS, dolBAllTMS, BolEAllB]), DistPolarFlot(BatABALTMS, dolBAllTMS, BolEAllB]), PlotExyla -> Nome, PlotLabel -> "Ensum TH Scattered (VM) Smooth Cylinder (Buo) vs Corrupted Cylinder (Bud, --)", TangBits -> NOD, BaceStyle -> (Tensing The Scattered (VM) Smooth Cylinder (Buo) vs Corrupted Cylinder (BudMINTS, SolEAllB])], ListPolarFlot(IdataEAllTMS, Joined - Trum, PolarCest -> Trum, FlotAcessOrigin = (0, Max[dolBAllTMS, dolBallTB]), ListPolarFlot(IdataEAllTMS, DolEntic -> 14, TentWsight -> "Bold"), PolarCest -= Natomatic, PolarTick -> (Tegrees", Automatic), PlotExyls -> (Blue, (Bad, Bashed)), BaseStyle -> AbeolutThichness[2], PlotMarkers -> None, PlotLabel -> "Ensu; TH E Scattered (V/m)

 $\label{eq:smooth cylinder (Blue) vs Corrugated Cylinder (Red, ---)", \\ ImageSize \rightarrow 700, BaseStyle \rightarrow (PontSize <math display="inline">>$  14, PontWeight >> "Bold"}, \\ PolarAxes \rightarrow True, PolarAxesOrigin  $\rightarrow$  (0, Max[SolEAllTMplusTES, SolEAllS])}), \\

## {ListPolarPlot[{dataEAllTMSandI, dataEAllSandI}

ListPolarFlot[(dataEll]PHEandT, dataEll]EandT], Joinsflot = (Degrees\*, Automatic); PolarTicks = (Degrees\*, Automatic); PolarTicks = (Degrees\*, Automatic); PolarTicks = (Degrees\*, Automatic); PolarEndes = Automatic; PolarTicks = None; PolarEndes = Theose (2); PolarEndes = None; (Biow) we Corrugated Cylinder (Bed. -)\*, ImageSize - 700; BeaeStyle > (Destis = > 14; PontMeight > "Doid"); PolarEndes = Theo; PolarEndes\*Theose = Theose = Theose = Theose; PolarEndes\*Theose = Theose = Theose = Theo; PolarEndes\*Theose = Theose = Theose = Theose; PolarEndes\*Theose = Theose = Theo

ListPolsFlot[(dstafAllTMplesTESsndT, dstafAllfandT), Joinnd = Trus, FolafCidLines = Astonasic, PolafLine + ("Degrees", Astonatic), PiceHys -> (Bius, (Red, Dashed)), Resettyle -> AbsoluteTLichnes[2], FicHMsrkers -> None, PictLabl -> "Emic:HTVET Incident = fostItered (V/m) Mmoch (yilinder (Blus) vs Corrupted (Yilinder (Red, --)\*, ImageSize -> 700, Resettyle -> (Fondise -> 11, rolkingt, -> TRold-1, FolafArse = Trus, PolarkmesOrigin + (0, Max[SolBAllTMplusTESsndT, SolExalISndT])];

Export[ToString[StringForm["``.jpg", PhiPolarPlotsName]], PhiPolarPlots]

## Changing Phi RCS Polar Plots

## Corrugated Cylinder Plots

Plot Ez

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#### Smooth Cylinder Plots - TM Plots

## Ez (TM RCS)

RCHERkegCyIH = ListPolarPlot[RCSdstaHzregcyIH, Joined - True, PolarGridLines - Automatic, PolarTick= ("Degrees", Automatic), PolatFyle - Slue, BaserSyle - JAseolterBickness[2], PiolMarkers - None, PioltAnel - TE, Hmooth Cylinder (TM RCE M)\*, Imagedies - 700, BaserSyle - (Tontiker - )44, FontWeight - "Bold"), Polarkers + True, PolarkerOrigin = (0, Max[RCSSolErregryIH]]];

## Erho (TM RCS)

Int (rink c) Exchange()TH = ListPlat[RCBataEthorage()TM, Joined + True, FoldStillines = Automatic, Polaritisk e ("Degrees", Automatic), FoldStyle = Num, Bardyle - NahoultSThickens(]), FoldStates = Nione, Fleitabel -> 7%, Booth Cylinder (TH NEL 0"), DistAtes = Nione, Fleitabel -> 7%, Booth Cylinder (TH NEL 0"), FolstAtes = True, FolstAtesCitic = (), Ast(RCBiolithorage()TH)]; Bold=)

## Ephi (TM RCS)

mminimetry = ListPolarPlot[ECSdataSphiregryITM, Joined + True, PolarScidLines + Automatic, PolarTicks + ("Degress", Automatic), Polatkyla + Bious, Basekyla -> NonlottFnicknesses[], PlotBarkers -> None, Plotabel -> Ts, Booth Cyllnder (HR ES M<sup>1</sup> +, Imagelise -> True, PolarAmeSrigis - (("Destine -> 14, ForMishipt -> "Beld"), PlotBarkers = True, PolarAmeSrigis - (0, Mas[RCS01BphiregryITG)]];

## EAII (TM RCS)

#### Summary TM Plots

SECTION: GROUND CONTROL (RCSErhoRegCylTM), (RCSEphiRegCylTM), (RCSEAllRegCylTM), Spacings -> (Scaled[0], Scaled[0]));

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NCHECOrr = ListDarPlot[RCSdataE, Joind - True, PolarGridLame + Antomatic, PolarTick = ("Degrees", Antomatic), PolarDridLame - (Red, Dashed), BaseStyle -> MacDulaThichness[2], PlotMarker -> None, PlotLabel -> "%. Corrupted Cylinter (RCS m<sup>3</sup>)", ImageDire -> 700. BaseStyle -> (NonSite -> 14, FontHeight -> "Bold"), PolarAses -> True, PolarAseSCrigin - (0, Max[RCSSolXr])];

### Plot Erho

Detriot = ListPolarPlot[RCEdstaTcho, Joined = True, PolarGridLines = Antonatic, PolarTicks = ("Degrees", Antonatic), FlotStyla = (Sed, Bashed), BaseStyla = AbsoluteThichnes(2), FlotEnckers => Non, FlotLabel => 7%, Corrupted Cylinter (RCE w) = InageEirs => 700, BaseStyle >> (FontEirs => 14, FontMeight => "Bolc FlotRes = True, FolarDesoFin = (0, Max[RESolEtho]]]; 1d"},

## Plot Ephi

NREEphiCorr = ListPolarPiot[RC5dstaRphi, Joined - True, PolarGridLines - Automatic, PolarTick= - ("Degrees", Automatic), PolatField: -> (Ned. Danhol, RaseStyle -> NaholiteThickess[2], PiotMarkers -> None, PiotLabel -> "To Corrupted Gylister (RC5 ")", ImageDise -> 700, BaseStyle -> To (PontSise -> 14, PontMeight -> "Bold"), FolarAses = True, PolarAseOrigin -> (0, Mas(RC50c)Rphi])];

#### Plot EAII

NOLD: RESALLCorr = ListPolsrPict[RCSdataEll], Joined = True, Polardridines = Automatic, Polarticks = ("Degrees", Automatic), PloStpl4= (Red. Dashed), EaseSyla = > MacDistEntichese[2], PloBackers => Nose, PlotLabel >> "Equal Corrugated Gylinker (ACE m")", ImageSize >> ToO, Resetyla = > (Rest), Al, FontMeight >> "Bold"), PolarAsse = True, PolarAssorrigin = (0, Max[ACSSolEAll])];

#### Summary Corrugated Cylinder Plots

SelphicsGrid[{{RCSExCorr}, {RCSErhoCorr}, {RCSEphiCorr}, {RCSEAllCorr}}, Spacings -> {Scaled[0], Scaled[0]};

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#### Smooth Cylinder Plots - TE Plots

#### Ez (TE RCS) - DOES NOT EXIST

#### Erho (TE RCS)

- MCHRINGRQC/IT = ListPolarPloT[RCBdstaRthoregoyIT, Joined + True, PolardFidLines + Automatic, PolarIcks + ("Degrees", Automatic), PolardFidLines Blue, BaselPlot -> MassLinethiones(1), PolardFiders -> Hous, PolardFid -> MassLinethiones(1), PolardFiders -> Too, BaseRtyle -> (FontBise -> 14, FontMaight -> "Bold"), FolardFieles + True, FolardFider(14 = (0, Max(CSB01EhroergoyITM))];

#### Ephi (TE RCS)

cps:(r:rcs) CEGEphileg(y)(T# +ListPile(RCHdstaRphileg(y)(T#, Joined + True, FolatricHiles - Antensic, Folarikk + (Tegress", Automatic), FlotStyle - Blue, BaseStyle - MonitorHiles(2), FlotMarkers -> None, FlotIabal -> T#, Baoth Cylinder (T# RCE ")", ImageLise -> TKO, BaseStyle -> (ForMiss -> 14, FoutMadpt -> "Bold Folarkes = True, FolarkeeOrigin + (0, Mar(RCHSTR))]; -> "Bold"},

#### EAII (TE RCS)

RCSEAllRegCylTE = ListPolarPlot RCSdataEregcylTEAll, Joined → Tr 
$$\begin{split} & \texttt{SRAIIBopy}(\texttt{T} \texttt{T} + \texttt{istPolarize}[\texttt{RCStatkForgy}(\texttt{TRAII}, \texttt{Joind} = \texttt{Tree}, \texttt{Polarcidilize} = \texttt{Atomatic, Polarcitike} = \{\texttt{Degree}, \texttt{Atomatic}, \texttt{Polarcitike} = \texttt{Note}, \texttt{Atomatic}, \texttt{Polarcitike} = \texttt{Note} \texttt{State} = \texttt{N$$

## Summary TE Plots

H[SS]- GraphicsGrid[{{RCSErhoRegCylTE}, {RCSEphiRegCylTE}, {RCSEAllRegCylTE}}, Spacings -> {Scaled[0], Scaled[0]});

## Smooth Cylinder Plots - TM + TE Plots

#### Ez (TM + TE RCS)

Control C

#### Erho (TM + TE RCS)

District True True, REScholegy(C)(TbplustE = ListPolarPiol[StSdstafthoregoy)ISQuerg, Joined + True, PolarCridLines + Automatic, PolarTicks + ("Degrees", Automatic), FlotStple+ = Nuo, massety = - NabolterHickness[1], FlotShckres = Nuo, Basstyle - NabolterHickness[2], FlotShckres - Nuo, B. FlotLabel -> "E, Smooth Cylinder (TH + TE SCH ") \*, ImageSize >> Too, Basstyle -> (FonSize -> 11, ForNAgith -> "Sch1"); FlotAnces + True, PolarAcesOrigin + (0, Mar[RCSSolEthoregoy]TbplustE]]];

#### Ephi (TM + TE RCS)

RESphilegCyITeplusT + ListPolarPiol [RCSdstARphiregcyITMplusTE, Joined + True, PolardridLines + Automatic, PolarTicks = ("Degrees", Automatic), FlotEtple + Nuo, BassEtyle - MooliterKinese[2], FlotMackers - Nuos, ElotLabel -> "E, Boooth Cylinder (TM + TE RCE m<sup>2</sup>)", ImageDiare -> Too, BassEtyle -> [ConSise -> 11, ForNispit -> "Bold"), FlotAkees + True, PolarAkeeOrigin + (0, Max[RCSSolEphiregcyITMplusTE])];

#### EAII (TM + TE RCS)

$$\begin{split} & \text{Railing(y): TMplumT + iistPolarilot[RCIdstaRrespy:)TMplusTLAll, Joined + Trus, \\ & \text{PolarGidines - Automatic, Polarilot + (Vappress', Automatic), \\ & \text{Polatyle} - Biom, Baselyle > - Nonoluttin(holemat[], Polatikars > None, \\ & \text{Polatyle - Sinos, Boselyle > - Nonoluttin(holemat[], Polatikars > None, \\ & \text{Polatyle - Sinos, Baselyle > - (FontSize >> 14, FontMeight > 'Bold'), \\ & \text{FolarMes True, PolarMesSingle - (Smaller - (Massel)TMpluTLAL])]} \end{split}$$

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, ListVolsflot[[dtCddstAtkhorsegeylTMglusTE, RcSdatatkrko], Joined = True, Polardinikinse = Astomatic, Polarticke + ("agnese", Antonacic, ) JocStyle → (Blue, (Red, Dashed) RassDiyle → AbsclutzDickness[2], Polatkrkers → None, Polarkale → "", "DHCS RCS ("d), "Socch / Julae (Rus) ys corrugated (Jilder (Red, -)", Daspiss → 700, RassDiyle → (FontSite → 14, FontWeight → "Roid"), Polatkree = True, PolarkaeoTuja → (R. Mat[RCSDithorseyc]TMplusTe, RCSDithrol)]

[istPolarPict[(RCHdstaEphiregcyIM, RCHdstaEphi), Joinsd + True, PolarGridLines + Automatic, PolarTicks = ("Degrees", Automatic), FlotBiyle -> (Blue, (Med, Bashed)), BaseStyle >> NociuleThichness[2]. ElotBarkers -> None, FlotLabel -> "%, TM HCS (m<sup>2</sup>) Bacotto Pylinder (Blue) vs Corrugated Cylinder (Med, --)", ImageSise >> Tou, BaseStyle -> ("Contistes -> 14, FortKapt -> "Seld"), PolarAnses + True, PolarAnseOrgin+ (0, Max(RCHSolEphiregcyIM, RCHSolEphir))]

, ListPolarFiot[(RCSdstatphiregeylTE, RCSdstatphi), Joined + True, PolarGridLines + Automatic, PolarFickes + (Teogrees\*, Automatic), PiotStyle -> (Blue, (Bed, Dashed)), BaseStyle -> XheolutThickenes[2], PiotStathent -> None, PiotLabel -> "K, TE KCS (m<sup>2</sup>) Smooth Cylinder (Blue) vs Corrupated Cylinder (Bed, --)\*, TageSites -> ToolkaeStyle -> (Postize -> 14, Fortkeight -> Shol'), Polarkees + True, PolarkeeStrigin + (0, Max(RCSSolEphiregeylTE, RCSSolEphir))]

, ListPolsPiol[[RC5dstaBphiregoy1706/usTE, RC5dstaBphi], Joinds True, Polardridines - Attomatic, Polarticks - (Pogerses<sup>2</sup>, Attomatic, ) Flottyle → (Blue, [Red, Dashed]), BaseStyle → AbsoluteThickness[2], FlottRiver → None, Poltabal → <sup>2</sup>, Mort RC (2], <sup>2</sup>, Month (Polled), Bostyle → (Pollise → At, FortRight, → "Add"), FolatAses → True, PolarAsesOrigin → (0, Mas[RC501Bphiregoy170plosT, RC501Bphi])]

[ListPolarPlot[(RCSdataEregcylTHAll, RCSdataEAll), Joined → True, PolarGridLines → Automatic, PolarTicks → ("Degrees", Automatic], PlotStyle -> (Blue, (Red, Dash

id)},

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## Summary TM + TE Plots

raphicsGrid[
{
{
{RCSEzRegCylTMplusTE}, {RCSEzhoRegCylTMplusTE}, {RCSEphiRegCylTMplusTE},
{RCSEAllRegCylTMplusTE}}, Spacings -> {Scaled[0], Scaled[0]};

### Compare (Regular vs Corrugated) Plots

## TM, TE, and TM+TE Compare

PRECEPTIONS\* GraphicsFields\* GraphicsGrid[(ListFold:[RCGdstaErregor)TM, RCGdstaEr, Joined + True, Polarditises - Automatic, Polarticks + ("Regrees", Automatic), Plotttyle -> (Bion, (Red, Dashed)). Basettyle -> Mosuitefficiences[2], PlotBarkers -> Mone, PlotLabel -> "E. TW RCG (R<sup>0</sup>) Booch Cylindsr (Dias) vs Corrugeted Cylindsr (Back, --)", Tangobises -> 700, Basettyle -> (Tontime -> 14, Tontsights -> Tbold\*). Polarkess + True, PolarkesOrigin + (9, Max[RCSDolExregor)TK, RCSDolEs)]

"Ez TE Does Not Exist"

, ListPolarPlot[(RCSdataErregcylTMpluwTE, RCSdataEr), Joinsd + True, PolarGidLines - Axtomatic, PolarTicke + (Degreen', Axtomatic), PiotStyle → (Blue, (Red, Dashed)), BaseStyle → AbsoluteThickness[7], FlotMarkers → None, PlotLabel → Tex ThruE RCG (Magnetic Red, -)\*, DetLabel → Tex ThruE RCG (Magnetic Red, -)\*, DetLabel → Tex ThruE RCG (Magnetic Red, -)\*, BaseStyle → TortLine - 1, TortLing(La → Told), PolarAxes - True, PolarAxesOrigin - (0, Mas(RCSSolErregcylTMplusTE, RCSSolEs)]],

$$\begin{split} & \left\{ \text{ListPolarPice} \left[ (\text{REdutathoregoy}(2M, \text{REdataErko)}, \\ & \text{Joined - True, PolarFieldLines + Automatic,} \\ & \text{PolarFicks + ("Degrees", Automatic,} ) PolsField -> \\ & \text{ReseRyis >> None, Flottander, PolarPicks + (Red, Bashed)}, \\ & \text{ReseRyis >> None, Flottander, PolarAutomatic, PolarAu$$

, istrolarPloE[[RCSdataErhoregcylTE, RCSdataErho), Joined + Trme, PolarGidLines + Automatic, PolarTicks + ("Degrees", Automatic), PlotStyle -> (Riue, (Red, Dashed)}, BaesStyle -> XbsoluteThickness[2], PlotMarkers -> None, PlotLabel ->

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# $$\begin{split} & \texttt{Basedtyle} \rightarrow \texttt{AbsoluteThickness[2], FlotMarkers \rightarrow Bone,} \\ & \texttt{FlotLabel} \rightarrow \texttt{Tbous}, \texttt{M} \texttt{HO}(\texttt{uk}) \texttt{ Booth oplicate} (\texttt{Bluey ve} \\ & \texttt{Corrupted}(\texttt{cluster}(\texttt{Bbe}, -\texttt{vl})^*, \texttt{Engelies} \rightarrow \texttt{Tbol}, \texttt{Bluekser} + \texttt{True}, \\ & \texttt{Basettyle} \rightarrow \texttt{(FlotLase} \rightarrow \texttt{14}, \texttt{FlotMarker} \rightarrow \texttt{Tbol}, \texttt{Cluster} + \texttt{True}, \\ & \texttt{PlotLasettyle} \rightarrow \texttt{(Boothies} \rightarrow \texttt{Tbol}, \texttt{Cluster} \rightarrow \texttt{True}, \\ & \texttt{PlotLasettyle} \rightarrow \texttt{(Boothies} \rightarrow \texttt{Tbol}, \texttt{Cluster} \rightarrow \texttt{True}, \\ & \texttt{PlotLasettyle} \rightarrow \texttt{(Boothies} \rightarrow \texttt{True}, \\ & \texttt{PlotLasettyle} \rightarrow \texttt{(Boothies} \rightarrow \texttt{Tbol}, \\ & \texttt{Cluster} \rightarrow \texttt{(Boothies} \rightarrow \texttt{Tbol}, \\ & \texttt{(Boothies} \rightarrow \texttt{Tbol}, \\ & \texttt{(Boothies} \rightarrow \texttt{Cluster}, \\ & \texttt{(Boothies} \rightarrow \texttt{Tbol}, \\ & \texttt{(Boothies}$$

ListPolarTio[[DCGdstaFregcyJTEA1], RCGdstaFA11); Joinds + Trus, PolarCiclines - Automatic, Polartics + (Tegrese\*, Automatic), Polstypt → (Alue, (Red, Dashed)), BassStyl → Xheolutriticnes[2], Piotharkers → Bose, PiotLabsi → "Bosnit RCE (Mg, Bosnit Qrilder (Ries) vs Corrupted Gylinder (Red, --)", Inagelise → 700, BassStyl → (Rotits → 31, Fortkight → "Bosnit", Polarkes + True, Polarkesorrigi = (0, Mas[RCE0]EregcyITEA11, RCE0]EN11}]]

ListPoistPiot[[RCSdstafregoylTMpiusTEAl], RCSdstafral), Joinsd+True, PolardizidLines - Antomatic, Polartizet < ("Degress", Automatic,") PiotStyle -> (Blue, (Red, Dashed)), BaseStyle -> AbsoluteThickness[2], FlotMarkers -> None, PiotLabel -> Format Thurk RCG (a") Booch (yinder (Blue) vs Corrupted Cylinder (Red, --)\*, ImageSite -> 700, BaseStyle -> (Fontlis -> 14, FontWalth -> Toid(3\*), Foltarkes - True, Polarkesorigin = (6, Mas[RCSslEregoylTmpiusTEAl], RCSSlEAL])]

}] HSSN- Export[ToString[StringForm["``.jpg", PhiRCSPolarPlotsName]], PhiRCSPolarPlots];

# Changing Phi RCS dB Polar Plots

# Corrugated Cylinder Plots

Plot Ez

NOTECOURS + ListPolstPlot[RCSdstaTedB, Joined + True, POLSGFLEDimes - Automatic, PolstFlock + ("Degrees", Automatic), PlotStyle - (Med. Dathol), BasStyle - NahoulteThichness[2], PlotBarkers -> (Med. Dathol), BasStyle -> NahoulteThichness[2], PlotBarkers -> TOD, BasStyle -> ("Mathol -> NahoulteThichness[2], PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PolstRess = True, PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PlotTackeeOrigin = (D. Mathol = NahoulteThichness], "Dathol PlotTackeeOrigin = (D. Mathol = NahoulteThichness[2], "Dathol PlotTackeeOrigin = (D. Ma

#### Plot Erho

RESERACOATER = ListPolarPict(RCSdataErhodB, Joined + True, PolarGridLines + Automatic, PolarTicks = ("Degrees", Automatic), PiolStyle > (Red, Dasho), BaseStyle >> NeolutErhichcoss(2), PiolNackers >> Neose, PiolLabel. >> "E, Corrupated Cylindsc (REG Hems)", ImageDime >> 700, BaseStyle >> (Fortilare >> 14, FortKabet >> "Bole", Polarkaes = True, PolarkaesOrigin = (0, Mar(Abs[10.Log10[RCSD0Erho]]));;

## Plot Ephi

NCSERphiCorrelB = ListPolarPice[RCSdataRphidB, Joined + True, PolardridLine + Automatic, PolarTicks + ("Degrees", Automatic), PictStyle > (Red, Dashed), EasStyle > AbsoluteThichenses[2], PictStarker >> None, PictLabel > Tg, Corrugated Cylinder (ACC dimas", Tangedine > 700, TansKright >> (TentStrue >> 14, ForstWark) +> 7mle17, PolarAnces + True, PolarAncedrigin + (0, Mar[Abe[10 + Logi0[RCSGolTphi]])]))

#### Plot EAII

spine. RCEKAllCorrdB = ListPolarFlot[RCEdstaKAlldB, Joined - True, PolarGrEdines - Automatic, PolarTicks = ("Degrees", Automatic), Flottyle-> (Red, Dankel), BaseTyle-> NonlottFinkConses[]; FlotMarkers -> Rose, FlotLabel -> Te<sub>mati</sub> Corrupted Cylinder (RCE dhem)\*, ImageDies -> 700, BaseTyle> (Tentister -> 14, ForsWinght -> %holf+ PolarAses = True, PolarAsesOrigin = (0, Mar[Abs[10-Log10[RCESoLEAL]]])};

Summary Corrugated Cylinder Plots

square GraphicsGrid[((RCSExCorrdB), (RCSErhoCorrdB), (RCSEphiCorrdB), (RCSEallCorrdB)), Spacings -> (Scaled[0], Scaled[0])];

## Smooth Cylinder Plots - TM Plots

## Ez (TM RCS)

HUN-RCHERRegCylTMGB - ListPolarPlot[RCSdataErregcylTMGB, Joined + True, FolarGridLines 4 Automatic, PolarTicks = ("Degress", Automatic), FoldTkyle - Slus, BaseStyle - Shollterichtenses [2], FoldTkyler - None, FoldTabel -> Tru, BaseStyle -> Monitor (MR RCS dBam) +, TamgeStime -> 760, BaseStyle -> (Fontline -> 14, FontWindth -> "Sold"), FoldThates +> True, FolsrAmesDrigin + (0, Max[Abs[10.sol0](RCSSolErregcylTM[])]);

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#### Smooth Cylinder Plots - TE Plots

#### Ez (TE RCS) - DOES NOT EXIST

#### Erho (TE RCS)

NUL RCEERhoRegCyITES + listPolarPlot[RCEdstaErhoregcyITES, Joined + True, PolarGridLines + Automatic, PolarTick= ("Degrees", Automatic), PolarEyel= N Bun, BaselPut => Absoluterinthoness(2), PolarKares -> None, Pictabel -> "#, Smooth Cylinder (TR RCE dime) \*, Tampelise -> 780, BaseTyle -> (TonEise -> 14, FontWeight -> "Bold"), PolarKares + True, PolarKaresorigin = (0, Nau[Abs106 + Log0[RCES]Cherosogry[Th]])];

#### Ephi (TE RCS)

pinit(in:NCB)
wime: RottphilespCylTEdB + ListPolarDis(RottphilespCylTEdB, Joined + True,
PolarDiddines - Automatic, PolarTicks ( Degrees', Automatic),
PiolsTyle > Jbo, BasedTyle > Abouthchess2[], PiolStyler > None,
Piotabel > 'To Booth CylInder (TR ECE dBmm)', ImageSime >> 700,
BaseStyle > (Prolim >> 14, Crosheight >> 'Bold'), Polarkers -> True,
PiotabeeTrigin = (0, Max[Aba[16 is ogo](RotSchaphracgyrI]])];

## EAII (TE RCS)

RCHAllBegCyITedB = ListPolarPlot(RCBdataErepcyITEAlldB, Joined + True, PolarCridLines - Antonatic, PolarTicks - ("Degrees", Antonatic), PlotStyle - Slue, BaseStyle - AkeoluteThickness[2], PlotKarker -> None, PlotLabel -> "Enco. Booch Cylinder (TE RC dBam)", ImageSize -> 700, BaseStyle -> ("Confiles -> 14, PontHight -> "Bold"), PlotRakes FlotArkesOrigin + (D, Max[Abs[10 + Log10[RCSDaIregcyITEAll]]])];

#### Summary TE Plots

NEINE: GraphicsGrid[{RCSErhoRegCylTEdB}, {RCSEphiRegCylTEdB}, {RCSEAllRegCylTEdB}}, Spacings -> {Scaled[0], Scaled[0])};

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# Erho (TM RCS)

Chickenberge/JMEMB = ListPolarPiot/RCGdataErborege/IMEM, Joined + True, PolarCridLines - Antomatic, PolarTicke + (Pegress', Antomatic), PiotEtyle - Nue, RessFitz - AbsolutEfhickens[1], PiotEkrkers -> Neue, PiotEtabel -> "E, Smoth Cylinder (DM HCH dBmd", Inagedise -> 700; RessEtyle -> (FontSize -> 14, FontBigHs) -> "Boil", Polarkees - True, PolarkeeS(Tige + (), Neu/Aug 10 = Log10[RCHS0LThthreegey2H0]]));

#### Ephi (TM RCS)

processing and the state of the state o

## EAII (TM RCS)

NUMP. RCHAILBAGYITHES = ListbolarSic [RCHdstalregoyITHALIdS, Joined - True, PolarGriddine + Automatic, PolarItiks = ("Degress", Automatic), PolarGriddine > Size, HaseStyle - Sheolarethichness(2), FlotBackers - None, Piotabel >> Touri, Hanoth Gylinder (TH RCG dBms)', ImageLime >> Ton, BaseStyles >> (Touline >> 14, FortHauft, >> Touri, Touri, Teury, PolarAmesDrigin = (0, Max[Abs[10 = Log10]RCHSolTempyITHALI]]));

#### Summary TM Plots

SUL\_ GraphicsGrid[({RCSExRegCylTMdB), {RCSErhoRegCylTMdB), {RCSEphiRegCylTMdB}, {RCSEAllRegCylTMdB}), Spacings -> {Scaled[0], Scaled[0]}];

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#### Smooth Cylinder Plots - TM + TE Plots

## Ez (TM + TE RCS)

CEEERegCyITMplusTEdB = ListPolarPiot[NC5dstaEregcyITMplusTEdB, Joined + True, PolarCridLines + Automatic, PolarTicks = ("Degrees", Automatic), PlotEtyle + Blue, BaseStyle - MeolureThickness[2], PlotEtharker > None, PlotEabai -> "E, Boosth Cylinder (WH - 11 RCG dBmm) -, ImageSis -> T00, BaseStyle -> (FonElse -> 1A, FonEdayLin -> Tolo]; Polackees = True, PolarAsesOrigin + (0, Max[Abs[10 + Logi0[RC5SolEregcyITMplusTE]]])];

## Erho (TM + TE RCS)

Stochegy:THyDusTEDS + ListPolarFlot (RCSdstaTchoregcyITMplusTEDS, Joined + True, PolarGotAlines - Automatic, PolarTicks + ("Degrees", Automatic), PlotByle > Disue, EasEtyle = AbholuteThichness[2], FlotMarkers > None, PlotLabel -> "E, Smooth Cylindse (TM + TI RCS dBms)", ImageSize >> TGO, BassHyle -> (FontSize >> 14, FontSeigHt -> Thol?), FolarAsesrig => Tree, FolarAsesrigute (0, Max[Abs]() = cogl0(ECSG)(ECSG)(ECSG)(T)]]]];

## Ephi (TM + TE RCS)

RCERphInegryITMplusTMB + ListFolarilet[RCEdstatphiregryITMplusTMB, Joined + True, PolardridLines - Antomatic, Polarilet + ("Pagrees", Auromatic) FlotStyle -> Blue, BaseStyle -> AbsolutEfhickense[], FlotBarkers -> None, FlotLabel -> "E, Smooth Cylinder (TM : TE RCE dBmm)", BaseStyle -> (FontSize -> 14, FontBeight -> "Bold"), Polarkees+True, FlotLabel -> [fontSize -> 14, FontBeight -> "Bold"), Polarkees+True, FlotLabel -> [in -] (RoutEgol 10 - Legi0[RCES]bhireegryITMplusTT]]]);

## EAII (TM + TE RCS)

Destilation().thereas is a static product and a static product product and a static product prod

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Summary TM + TE Plots

GraphicsGrid[ {{DCSExBagCylTMplusTEdB}, {RCSEchoRegCylTMplusTEdB}, {RCSEphiRegCylTMplusTEdB}, {RCSEAlRegCylTMplusTEdB}}, Spacings -> {Scaled{0}, Scaled{0}};;

## Compare (Regular vs Corrugated) Plots

## TM, TE, and TM+TE Compare

iACIdBP0larFlots: rephicsOf([ListPolarFlot([ACIdstaErrepcyITM6B, RCSdstaErd8), Joind - Trem, PolarDridLines - Actomatic PolarDrive, PolarDridLines, Actomatic PolarDrive, The Distribution of the State State - Distribution (Bed, Deshed)), Tr TH RCS (Moss Desch Dylines (Edla) vs. Corrupted Cylinder (Bed, --)\*, Trum PolarDess - Trum, PolarDessOf(Bin - 14, PontMsight -> "Bold"), PolarDess - Trum, PolarDessOf(Bin - 14, PontMsight -> "Bold"), (0, Mes(Nbs[10-Log10]BCSS0IErrepcyITM]), Abs[10+Log10[RCSS0IE]])))

"E, TE Does Not Exist"

, ListPolneflot[(RCSdataErropsylTMplusTEMB, RCSdataEx80), Joined → True, Polneflidines = Antomatic, Polneflicks → ("begrease", Antomatic), Poletityia → Giues, (Rad, Dankel)), RessNyla → AnholteThickness[1], Pletitykers → Nene, Pletikabl → "E, TWIET RCE (dBas) Gauchi → Statistica → The TWIET RCE (dBas) Cylinder (Ruis) ∨ Gorrugated Cylinder (Rad, →)", TamapeEine → 700, BaseBryla → (TentEine → 14, TentBaight → "Bold"), Pletikaes + Two, PlatkaesOrljan + (D. Max(Abs[10+Logi0[RCSSolErropsylTMplusTE]], Abs[10+Logi0[RCSSolEr]])))),

## {ListPolarPlot[{RCSdataErhoregcvlTMdB, RCSdataErhodB},

. ListPolarPlot[{RCSdataErhoregcylTEdB, RCSdataErhodB}, Joined → True, PolarGridLines → Automatic,

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1.

{ListPolarPlot[{RCSdataEregcylTMAlldB, RCSdataEAlldB}, Joined -> True, LittleFortOot[(ECGataLErgoryITMALIS, ECGataLERIS), Joinsed = True, PointGridlines = Actionatic, PointerChes = ("Segreget", Automatic), PictErgits  $\rightarrow$  (Eise, [Red, Dashed)), ResetTyle  $\rightarrow$  AnsoluteThickness[2], PictErgits  $\rightarrow$  Sense, PictBable  $\rightarrow$  "Final, TM RCG (Geme) Smooth Cylinder (Eisa) vs Corrupted Cylinder (Red,  $\rightarrow$ )", RangeSise  $\rightarrow$  Too, ResetTyle  $\rightarrow$  "(Dettilies  $\rightarrow$  14, Toottesight  $\rightarrow$  "Bold"), Polarkes = True, PolarkesGrigin = (Creation of the Contemport of Content of the Cylinder (Schollerang)]))

, Littolarflot[(RCSdstaEregcylTEAlldB, RCSdstaEAlldB), Joined - True, Polarficialines - Automatic, PolarTicks - ("begrees", Automatic), Pictityies - (Bue, (Bed, Baselby), BaseTsyles - AutointeThickness[1], Pictityies - Since, Pictubal - Te<sub>nail</sub> TE RCS (dBms) Bmooth Cylinds: RLue) ve Goruguted Cylinds: RBad, --)". Dampediate - 700, BaseTsyle -> (PontDise -> 14, PontWeight -> Teol"), Polarkes = True, PichakesCrigin -(0. Max[Abs[10 + Log10[RCSSolEregcvlTEA11]]. Abs[10 + Log10[RCSSolEA11]]])]

, ListPolarFlot[(RCEdataEregoyIThplusTEAlldB, RCEdataExlldB), Joined → True, PolarGridLines - Automatic, PolarTicts - ("Degrees", Automatic), PloEntryla - (Uine, (Bed, Dashod), BaseStyla - AbaolteThickness[], PloEntrylares - None, PolataBel -> "Enux TH/TE RCE (dams) Baooth Cylinder (Bun) vs Corrugated Cylinder (Bed, ->)", TampeEtax -> TOD, BaseStyla -> (FuncEise -> 14, FontHeight -> "Bold"), PolarDase = True, PolarDaseOrigin = (0, Max[des[10 + coj0[RCESolEAll]]))]

Fi
Export[ToString[StringForm["``.jpg", PhiRCSdBPolarPlotsName]], PhiRCSdBPolarPlots]

## Changing Phi RCS dB XY Plots

#### Corrugated Cylinder Plots

Plot Fz

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$$\begin{split} & \text{PolarTicks} + (^{\text{Degrees}^*}, \text{Automatic}), \ \text{PolarTicks} + (\text{Blue}, (&d, Dashed)), \\ & \text{BassStyle} \to & \text{AbsoluteFhickessel2}, \ \text{PolarKiers} \to & \text{Nose}, \ \text{PolarBick} \to & \text{``soluteFhickessel2}, \\ & \text{``sourcessel2}, \ \text{Comparison} \to & \text{Compa$$
{0, Max[Abs[10 \* Log10[RCSSolErhoregcylTE]], Abs[10 \* Log10[RCSSolErho]]])]

, ListFolsFlot[RCSdstaErhoregcylTMplusTEdB, RCSdstaErhodB), Joined + True, PolstStyle - (Mise, Red, Dabel), BasStyle - NabelsteThickness(2), PlotStyle - (Mise, Red, Dabels), BasStyle - NabelsteThickness(2), PlotBarkers - Neos, PlotLabel -> "E, MVIE RCG (dBms) Smooth Cylindm (Eduar v Corrugated Cylindm (Hed, ->)", ImageDira -> 700, Bassetyle -> (FontDiras -> 14, FontWeight -> "Eold"), PlotErkmes + True, PlotAnsed(Time (), Abs(10 + Logio[RCSSolErho]])]

١.

[ListPolarFlot[[RCHdstaRphiregcy1766], RCHdstaRphidB), Joined - True, PolarCick - Attoastic, PolarCick - ("Degreen", Attoastic), PiotStyle -> (Biue, (Red, Dashed)), BaedStyle -> AbsoluteThicknes(2), PiotMarkers -> Bone, PiotLabel -> "Ag TH RG (Gimes) month Orjinder (Biue) was Courrayated Oylindes (Red, --)", ImagoEixe -> 700, BaedStyle -> (FontBis -> 14, FontWeight -> "Bold"), Polarkes - True, PiotArkesOrigin -(0, Mas(Abs[10 + Logio]RCHSolEphiregcy176]], Abs[10 + Logio[RCHSolEphir]])]]

ListPolstPiot[[RC564saBphiregoy1TH58, RC564saBphi08), Joined arrue, PolarGridLines - Artomatic, PolarTicket - (Pogereen\*, Antomatic, ) PiotTytie -> (Blue, (Bed, Dashed)), BaseStyle -> AbsoluteThickness[2], PiotEnterer -> None, PiotLabel -> "% TR EEC (and) Booch Cylinder (Blue) vs Corrupted Cylinder (Bed, --)\*, TamagoEire -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> \*Bold\*), PioLatwes + True, PioLatAwesDig (=) + (0, MasgiAbs[10 + Logi0]RC5501Ephiregoy1TE]], Abs[10 + Logi0]RC5501Ephi1]]]]

, ListPolstPlot[(RCHdataEphiregoylThglusTEM, RCHdataEphirM), Joined - True, PolarTidLines - Automatic, PolarTicks ( (Tengrees", Automatic), PlotStyles - 2 (Bace, (Bac, Jackabad)), BaseStyles - AbsciteThichesses[2], PlotHackars -> None, PlotLabel -> "Es TMCTE RCS (dBms) Booch Cylinder (Limo) ve Corrupated Cylinder (Back, --)", TampeStim -> TOD, BaseStyle -> (FonStist -> 14, FontWeight -> "Rolf"), PolarAmes - True, FolarAmeoTign + (0, Max(Absc10+Log10[RCSSolEphiregoylThglusTE]], Abs[10+Log10[RCSSolEphi]])])

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RCSEcCorrdRey = ListLinePlot[RCSdstaErdB, PlotBasge -> ({0, 2F}), (Min[10: Logi0[RCSSolEr]], Max[10:Logi0[RCSSolEr]]), FlotBytz -> (Red, Dashed], EnsetyL => AbsoluteThickness[2], FlotBarkers -> Snoe, FlotLabel -> "E. Corrugated Cylinder (RCS dBms)", Frame -> True, FrameLabel -> ("0", "RCS (dBms)"), GridLime -> ((FL, (Thick Care, Dashed)), Natomatic), Background -> White, ImageSize -> 700, BaseStyle -> (PontSize -> 14, FontHeight -> "Bold")];

#### Plot Erho

RCEErhoCorrdBay = ListLineFlot[RCEdstaEthodB, FlotRange ->
 ((6, 291), [Min[10-Logid[RCESolEthol], Man[10-Logid[RCESolEthol]]),
 FlotBiyle-> (Eds. Dashol) = seeStyle -> AbsolutaThiothems[2],
 FlotBarkers -> Nome, FlotLabel -> 'R, Corraysed Cylinder (RCE dBam)',
 for the set of the set of

## Plot Ephi

sext- RCHEphiCorrdBxy + ListinePlot[RCHdstaBphid], PlotRange -> (6, 2\*1), (thu:[b\*Logit[RCH0stght]], Mac[10+Logit[RCH0slpht]])), PlotBxyLes -> (Mad\_Dshada), EastRyLes -> MaolutArthichemas[2], PlotBarRers -> Rome, PlotLabd -> "#, Corrugeted Cylinder (RCH GMm)", Frame -> True, Francharth -> "#, "Arthic (GMm)", GridLines -> (T(2): (Thick, Gray, EastHol)), Actomatic), Background -> White, ImageDire -> ToO, BackGriget -> (In Critics -> I, ForcWhight -> "Bold"));

#### Plot EAII

RCERLICorrollary = ListLinePlot[RCEdstatAlldB, PlotRange ->
 ((0, 2Pi), (Min[10+Log10[RCESolEAll]], Max[10+Log10[RCESolEAll]])),
PlotBityle -> (Red, Dathed), ExestPlot -> AkmoituteThichemse[2],
PlotBiteCres -> None, PlotLabel -> "Simit Corrugated Oplander (RCE dHem)",
Frame -> True, Franctabel -> ("0", "RCE (dBam)"),
Gridlines -> ((0\*, "RCE), (drog, Dathed)), Antomatic), Enckground -> Mhite,
ImageSize -> 700, HaseStyle -> (PontSize -> 14, FontWeight -> "Bold")];

#### Summary Corrugated Cylinder Plots

si- GraphicsGrid[{{RCSEzCorrdBxy}, {RCSErhoCorrdBxy}, {RCSEphiC {RCSEAllCorrdBxy}}, Spacings -> {Scaled[0], Scaled[0]}};

## Smooth Cylinder Plots - TM Plots

#### Ez (TM RCS)

#### Erho (TM RCS)

## Ephi (TM RCS)

$$\label{eq:constraints} \begin{split} & \mbox{Minkey} \times \mbox{ListLineFlot}(RCSdetaBplicegeyIMdB, FlotBange \rightarrow \{\{0,2Pi\}\}, \\ & \mbox{(Min(10-LogiO(RCS0s)BplicegeyIMd]), } \\ & \mbox{FlotBy}(a \rightarrow \mbox{Subs}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Rest}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Rest}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Rest}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Resty}(a \rightarrow \mbox{Subs}, \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Rest}, \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Rest}, \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Rest}, \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Rest}, \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty}), \mbox{Resty}(a \rightarrow \mbox{Resty}), \mbox{Resty})$$

#### EAIL (TM RCS)

$$\begin{split} & \text{IEEEIInegGy/IMMENy} = \text{ListinsFlot[RCidataEregy/IMAII]0, PlotRange <math>\rightarrow$$
 ((0, 2 Pi), (Barl[16+Log10[RCidataEregy/IMAII])), PlotEyle  $\rightarrow$  ShoulterHinkmes[2], PlotRater  $\rightarrow$  None, PlotRater  $\rightarrow$  None, PlotRater  $\rightarrow$  None, PlotRater  $\rightarrow$  None, PlotRater  $\rightarrow$  ShoulterHinkmes[2], PlotRater  $\rightarrow$  None, PlotRater  $\rightarrow$ 

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#### Summary TE Plots

GraphicsGrid[{{RCSErhoRegCylTEdBxy}, {RCSEphiRegCylTEdBxy},
{RCSEAllRegCylTEdBxy}}, Spacings -> (Scaled[0], Scaled[0]);

#### Smooth Cylinder Plots - TM + TE Plots

## Ez (TM + TE RCS)

LotStabegOylDelusTEdBay = ListLine03c1/EC5dstaEsreegoylTMplesTEdB. Plethangs -> (0. 24), OHin[10 + Exg0]OES5olEsreegoylTMplesTE]. Ma(10 + Cool)OES5olEsreegoylTMplesTE]]. PletStyle -> Rise, BaseStyle -> AsoluteThicknes[2], PlotBackets -> Rose, PletLabel -> XE.soluteThicknes[2], PlotBackets -> Rose, Fieltabel -> XE.soluteThicknes[2], NotEstle -> Rose, Gasdianes -> (124, CHink -> (24\*, CHE (dHms)\*), GeidLames -> (124, CHink -> (24\*, CHE (dHms)\*), Background -> White, ImageDime -> T60, BaseStyle -> (PontSise -> 14, FontMsight -> "Bold")];

#### Erho (TM + TE RCS)

SHrholtegCylTMplusTKdHxy \* ListlinsPlot[hCSdstaHrhoregcylTMplusTKdH, FlotEnage >> ([0. 21), (Min[10:LogD(hCSdstHrhoregcylTMplusTW]), Mss[10:LogD(hCSdsEHrhoregylTMplusTW]), PlotExyle >> Blue, EaseEtyle >> AbeoluteThickness[2], PlotEnkler >> None, PlotLabel >> "E, Booth Qiuter (MrtH ECG Kame) \*, Frame >> Tram, FramLabel >> (\*4", "ACG (diam)\*), Griddiane >> ([04], (fhick, Gray, Dashed]), Natomatic), Background >> 1 Imagediae >> 700, BaseStyle >> (FontSize >> 14, FontWeight >> "Bold\*); nd -> White.

## Ephi (TM + TE RCS)

Fphilepty1PhplueTEGBey = ListLinePlot[NC5dstaBphirepcy1PhplueTEGB, PlotBarge >> (10, 2Fi), NBa[10 + Log10[RC505LPhirepcy1PhplueTE]], Mac[10 + Log10[RC551Dphirepcy1PhplueTE]]), PlotBarge >> Nese, PlotBarl >> Are (RC551Dphirepcy1PhplueTE)], PlotBarl >> Kr BarsStyle >> AbsoluteThickness[2], PlotBarlsers >> Nese, PlotBarl >> True, Francishal >> (\*\*, "RC5 (GGBes)', Frame >> True, Francishal >> (\*\*, "RC5 (GGBes)', Cristianes >> (Te), (Thick, Grav, Dashed)), Antomatic), Background >> Imagedize >> Too, BaseStyle >> (PontSize >> 14, FontMaipht >> "Bold\*)]; -> White,

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## Summary TM Plots

HOR:- GraphicsGrid[({RCSExRegCylTMdExy}, {RCSErhoRegCylTMdExy}, {RCSEphiRegCylTMdExy}, {RCSEhIRegCylTMdExy}, spacing -> {Scaled[0], Scaled[0]};

## Smooth Cylinder Plots - TE Plots

## Ez (TE RCS) - DOES NOT EXIST

#### Erho (TE RCS)

#### Ephi (TE RCS)

MRTEphiRegCyTEEdBay + ListLinsFlot[RCEdataEphiregcyTEEDB, FlotEange -> ((0, 2 Fi), (Man[10:Log1(RCEBaEphiregcyTE]], Max[10:Log1(RCEBaEphiregcyTE]])), FlotEtyle -> Blue, EaseEtyle -> AbsoluteThickness[2], FlotEtxletera -> None, FlotEabel-> "Ex\_ Bmoch Cylinder (TH RCE dBam)", Frame -> True, FrameLabel -> ("4", "RCE (dBam)", GridLinee -> (([14", (Thick, Gray, DashedD)), Automatic), Background -> White, ImageSize -> 700, BaseStyle -> [FortSize -> 14, FontMeight -> "Bold"]);

### EAII (TE RCS)

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#### EAII (TM + TE RCS)

RCEBLIReqCyTMpletTRdBay = ListLinePlot[RCEdetAFreqcyTMpletTRAILdB, FlotEnage -> ([0, FF1, [Min1]0 + Logi(RCEDelTreqcyTMpletTRAIL]], Har(10 + Logi(RCEDelTreqcyTMpletTRAIL]), NetExt[4 -> Blue, EaseTtyle -> AbsoluteTLicEneg(]), FlotEntaFare -> Blue, FlotEale1 -> Thron: Bmoth Coulding (Inter Red Sma) +, Frame -> True, FrameLatel -> ("4", "Red Sma) +, Antomica(), Antomica(), Antomica(), Background -> White, ImageEise -> T00, BaceEtyle -> (FootEise -> 14, FootMaight -> "Bold");

## Summary TM + TE Plots

HENRI- GraphicsGrid{{(RCSExRegCylTMplusTEdBxy}, {RCSErhoRegCylTMplusTEdBxy}, {RCSEphiRegCylTMplusTEdBxy}, {RCSEAllRegCylTMplusTEdBxy}}, Spacings -> {Scaled[0], Scaled[0]}};

### Compare (Regular vs Corrugated) Plots

## TM, TE, and TM+TE Compare

SHLCSHKTPlots -GraphicsGrid[(thew[[RCBERGcy]]MBHey, RCBECorrdHey], FlotHange -> ([0, 21]). [Min(10\*Log10[RCBEnlErergey]MM]. 10\*Log10[RCBEnlEr]]. Mac[10\*Log10[RCBENLErergey]MM]. 10\*Log10[RCBENLER]]). PlotLabel -> "K. FM RCE (ddms) Booth Spilader (Hubo) ve Corrugated Cylinder (Red. ImageSize -> 700, RaseStyle -> (FontSize -> 14, FontWeight -> "Bold")] 

## "Ez TE RCS dB Does Not Exist"

- , mar(162BithegCylTHB/usTEdHey, HCHErCoredHey), PlotRange  $\rightarrow$  ((0, 24), (km:[10 + copi0[NGENGITE\_regeryHHplustT], 10 + copi0[NGENT], 10 + copi0[NGENT], 10 + copi0[NGENT], 10 + copi0[NGENT], 10 +

), (Mov[RCERthoBegCylTMEMmy, RCERthoGorefMmy), FlotHange -> ((0, Pls), (Mai[10-Logit[RCESsLEhroegy:TM], 10-Logit[RCESsLEho]], Mai[10-Logit[RCESsLEhroegy:TM], 10-Logit[RCESsLEho]])), FlotLabal -> "R, TM RCE (dems/Smooth Cylinder (Blaw) we Corruspield[Jinder (Red. -)", Tampédia= > "On BaseKyle -> (Postlas -) 44, ForeKaipti -> "RcE[1]

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bev(iK:Etshokeg/sittdHzy, RCEErhoCorrdHzy), PlotHaoge → ((0, 2+1), (Mts110 + LegdD(RCESolErhoregyz(TE), 10 + Legd(RCESolErhol]), Max(10 + Legd(RCESolErhoregyz(TE), 10 + Legd(RCESolErhol])), PlotLabel → "Kg TE RCE mooth Cylinder (Slum) vs Corrugated Cylinder (Red, --)", Tangelice → 70 RasHz(1+a ~ (RCE1Ea + 34, FortMaght) ~ "Rod(1)]

, bev([RCERchRegCylTMplusTEdBxy.RCEEchoCoredBxy], PlotEange → {(0, 2 Pl}, (Mai)10 - Logi0[RCE50LEncregcylTMplusTE, 10 - Logi0[RCE50LEncb]], Max[10 - Logi0[RCE50LEncregcylTMplusTE, 10 - Logi0[RCE50LEncb]]), PlotLabel → "E, TM-TE RCE (dBam) Smooth Cylinder (Blue) vs Gorrupated Cylinder (Bed, ---)", Imagelica → "On BaseStyla → [Contains → 14, FontWeight → "Bold"}]

(Bhew(IRCBRbHRegCyIHMENg, NCBRbHCorrdNay), FlotNange → ((0, 2rk), (bs1(2) + Logi0[NCBS61kphrtregryIH0, 10 + Logi0[NCBS61kphr]], Max[2] + Logi0[NCBS61kphrtregryIH0, 10 + Logi0[NCBS61kphr]]]), FlotLabel → "%, TM NCE (oBas) Boosth Cylinder (Niou) vo Corrupted Cylinder (Med. --)", ImageSize → 'Dol, BaseStyle → (Tontlise → 14, Tonthishte → "Sold")]

, hew([NCERphiRegCyITEdBay, NCEEphiCoredBay), PlotRange → ((0, 291), (NL10 = log01)RCE00EphicegyITE], 10 = log01(RCE00Ephi]), Max[10 = log(RCE0EEphicegyITE], 10 = log01(RCE0Ephi)]), PlotEabel → Max[10 = log(RCE0EEphicegyITE], 10 = log01(RCE0Ephi)]), PlotEabel → Tep TE ACD (dBam) Bmooth Cylinder (Blaw) w Corrupted Cylinder (Bad, →17) EageSize → 300, MastRyla → C(RCE1ias → 14, Fortkagtd → "ShortKagt])

, het ([RGERphlRepty]TbplusTEdBay, RGERphlCorrdBay), PlotEnage  $\rightarrow$  ((0, 2 Pl), (Mn[10+Log1(RGESblRphlergy]TbplusTP, 10+Log1(RGESblRphl]), Max[10+Log1(RGESblRphl2); Max[10+Log1(RGESblRphl])]), PlotEnbel  $\rightarrow$  "4, MH-TE KGI (dBam) Smooth cylinder (Blue) vs Corrupted Cylinder (RLue) ImageSize -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> "Bold"}]

, Show[{RCSEAllRegCylTEdBxy, RCSEAllCorrdBxy}, PlotRange ->

NUMP: Exocred views.intervi

Ricormand: ListinaPlot[dataEx, FlotEange -> {{0, 2 \* F}, 6, Max[SolEx]}}, FlotEstyle -> {Red, Dashed}, BaseStyle -> AbsoluteThickness[], FlotEanler -> None, FlotEanle -> True, FremeLabel -> {\*4, "vwr/>, GridLime -> Yrue, FremeLabel -> {\*4," vwr/>, EridLime -> ([24, thick - Gary, Dashed]), Automatic), Background -> White, ImageSize -> 700, BaseStyle -> {FontSize -> 14, FontWeight -> "Bold");;

bdocr5 = listinsPip(dataErho5, FlotRange -> ((0, 2\*Pi), {0, Max[SolErho5]}), FlotByle -> (Med, Dashed), BeseByle -> MaroluteThickness[2], FlotByle -> None, FlotLabel -> "%, Corrupated Oylindsr (Sottered Fleid)", Frame -> True, FramaLabi -> ("4", "Vu"), distinses -> ((Pi), (Thick, Gary, Dashed)), Astonstio, Background -> White, ImageSize -> TRO, BaseStyle -> (FontSize -> 14, FontWeight -> "Rold")];

Changing Phi XY Plots

Corrugated Cylinder Plots Plot Ez (Scattered)

Plot Ez (Inc + Scattered)

Plot Erho (Scattered) ErhoCorrS =

{(0, 2 Pi), (Hin[10+Log10]RCHSolEregryITEAl], 10+Log10[RCHSolEAl]], Mac[10-Log10[RCHSolEregryITEAl], 10-Log10[RCHSolEAl]]], Plotlabel -> "weather the second s

, move(InCSEALIRegCyIMOplusTEMBay, RCSEALICORYEMBY), FlotEange  $\rightarrow$  ((0, 2 Pl), (Hin(10 ± logi0)(RCSEALRegCyIMOplusTEALI), 10 ± logi0(RCSEALREGU), House (RCSEALEALI)), Max(10 ± logi0(RCSEALREGU), Theolarteali), 10 ± logi0(RCSEALREGU), Theolarteali), 10 ± logi0(RCSEALREGU), Theorem (RCSEALEALI))), PlotLabel  $\rightarrow$  Sec. (The TR ECS (dem) Smooth Cylinder (Alue) we Correspect Cylinder (RCSEAL), Sec. (RCSEALEALI), 10 ± RCSEALEALI), 10 ± RCSEALI), 1

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HMMIP- Export[ToString[StringForm["``.jpg", PhiRCSdBXYPlotsName]], PhiRCSdBXYPlots]

owner- PhiRCSdBXYPlotsName.jpg

## RCS dBsm Data Export

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- ablevalues = (10 + Log10[RCSSolEr], 10 + Log10[RCSSolErregoy1TMplusTE], 10 + Log10[RCSSolErb], 10 + Log10[RCSSolErboregoy1TMplusTE], 10 + Log10[RCSSolErbl], 10 + Log10[RCSSolErboregoy1TMplusTE], 10 + Log10[RCSSolErbl], 10 + Log10[RCSSolEregoy1TMplusTE]]; (004) - tablecolheading =
- ablecolheading = {{"ExtoGrungCyl RMS dBem", "ExEmoothCyl RMS dBem", "ErhoGorrugCyl RMS dBem", "ErhoBmoothCyl RMS dBem", "EphiCorrugCyl RMS dBem", "EphiEmoothCyl RMS dBem", "EtotCorrugCyl RMS dBem", "EtotSmoothCyl RMS dBem")};
- Emport[ToString[StringForm["``.mlsm", RCSdBdataSheetName]], Join[tablecolheading, Transpose[tablevalues]]]
- (NN)- Speak["The polar plots are done"]

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#### Plot Erho (Inc + Scattered)

hoCorriandI = ListLinePot(dataErko, FlotEnces -> (No., 2+1). (0. Max[solErko])), FlotEncyla -> (Nod, Dashed), BaseStyle -> AbnoluteThickness[2], FlotMarkers -> None, FlotEabel -> "S\_Corrugated Cylinds: (Incident + Ecattered Field)", Frame -> True, FrameLabel -> ("s', "VA"), GridLines -> ([To), (Thick, Graz, Dashed)), Automatic), Background -> Mhite, ImageSize -> 700, BaseStyle -> (FontSize -> 14, FontMeight -> "Bold")];

## Plot Ephi (Scattered)

EphiCorr8 -
$$\label{eq:losses} \begin{split} & = \\ &$$

Plot Ephi (Inc + Scattered)

$$\label{eq:constraints} \begin{split} & \text{ListianFor}(\texttt{dataByh}, \texttt{FotImperp}) (\texttt{d}, \texttt{srh})(\texttt{d}, \texttt{dataByh}, \texttt{fotImperp})(\texttt{d}, \texttt{srh})(\texttt{d}, \texttt{dataByh}, \texttt{fotImperp})(\texttt{d}, \texttt{srh})(\texttt{d}, \texttt{srh})(\texttt{srh})(\texttt{d}, \texttt{srh})(\texttt{srh})(\texttt{d}, \texttt{srh})(\texttt{srh}$$
Plot EAll (Scattered)

FIGUE as (seturity) RailCords = ListLinsDot(dateBalls, BaseStyle > Xhoult Emichanes(2), FlotBalls()), PlotStyle >> (Red, Dashed), BaseStyle > Xhoult Emichanes(2), FlotBalls()), PlotStyle >> (Red, Dashed), BaseStyle >> Tm<sub>tol</sub> Corrupted Cylinder (Scattered Field)\*, Frame >> Tree, FrameLabel >> (\*\*, "Var"), GridLines >> ([Fi, (Thick Gray, Dashed)), Automatic), Background >> Mhite, ImageStime >> 700, BaseStyle >> (FontSime >> 14, FontMeight >> "Bold\*));

## Plot EAII (Inc + Scattered)

#### Summary TM Plots

#prop. GraphicsGrid[{(ErCorrS, ErCorrSandI), (ErhoCorrS, ErhoCorrSandI (EphiCorrS, EphiCorrSandI), (EAllCorrS, EAllCorrSandI)), Spacings -> (Scaled[0], Scaled[0])];

#### Smooth Cylinder Plots - TM Plots

#### Ez (TM Scattered)

with Esse()/1HW - ListLinePlot[datAfreqoy1DH. PlotBarge -> {(0, 2\*Pl), (0, Max[dolErreqoy1DH]), PlotStyle -> Blue, BassStyle -> MacolutThichess[], PlotBarkers -> None, PlotLabel -> 'K, Smoth Vojinde ('H Gattered Field)', Frame -> True, FrameLabel -> ('e', ''('a'), GridLines -> (([24, fib.( erg. Tabeled)), Automatic), Background -> White, ImageSize -> 700, BaseStyle -> (PotSize -> 14, FontWeight -> "Bold"));

## Ez (TM Inc + Scattered)

LERBeyCylHHiandI = ListLinaPlot[dstaKreegojIHHiandI, PlottAuge >> ((0, 2+F), (0, Mar[GolErregcylHHiandI])), PlottAubel >> Hiw, Baselly => Nabellaretildness[2], PlotMarkers -> None, PlotLabel >> Him, Baselly => Nabelly (H Incidence # Seattered Field)\*, Freme >> True, FrameLabel >> (d\*, "Ywe'), Automatic), Background -> Whit ImageEine >> TOD, BaseRyie >> (Horigo, Fielder), Automatic), Hockground -> Whit ImageEine >> TOD, BaseRyie >> (Horigo, Fielder);

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#### EAII (TM Scattered)

#### (SIZ)- EAllRegCylTMS =

$$\begin{split} & \text{like}_{\mathcal{O}}(\gamma)\text{He} = \\ & \text{like}_{\mathcal{O}}(\gamma)\text{He} = \lambda \text{ boolurthickes}(1), \ (0, \ \text{Max[folEAllTME]}), \\ & \text{PlotExpla } > \text{ Blue, BaseStyle } > \lambda \text{Boolurthickes}(1), \ \text{PlotExpla } > \lambda \text{ Boolurthickes}(1), \\ & \text{PlotEab}(-)^{-\varphi} \frac{\text{Nexplane}}{\text{Nexplane}} (1), \\ & \text{Prase } > \text{Tree, Franclabel} > (^{\varphi}, ^{-\varphi}, ^{-\varphi}), \\ & \text{GridLase } > (^{\varphi}, \text{ Ready, Dashed}), \ \lambda \text{Monstel}(), \\ & \text{Baseground } > \text{Mole, } \\ & \text{ImageSize } > \text{Too, BaseStyle } > (\text{FontSize } > 14, \ \text{FontWeight } \rightarrow \text{"Boold"}); \\ \end{split}$$

## EAII (TM Inc + Scattered)

## Summary TM Plots

GraphicsGi[(ExRegCylTMS, ExRegCylTMSandl), (ErhoRegCylTMS, ErhoRegCylTMSandl), (EphiRegCylTMS, EphiRegCylTMSandl), (EAllRegCylTMS, EAllRegCylTMSandl), Spacings -> (Scaled[0], Scaled[0]));

### Smooth Cylinder Plots - TE Plots

## Ez (TE Scattered)

Ef [[sourcewoy] ERRepQ1ES = (iniliarDic[datErrepy1ES], PiotRange -> {(0, 2 \* Pi), (0, Max[SolErrepy1ES])), PiotStyle -> Blue, BaseStyle -> MacNuteRhichnes[2], PiotBarkers -> None, PiotEabel-> 76, Sourch Qinder (TE Sottered Field)\*, Press -> True, Pressible! -> (Ye\*, "Vwr"), Gridiname >> ([D4, (Thick Gwr, Dashed))), Automatic), Background -> White, ImageSize -> T00, BaseStyle -> (FontBire -> 14, PontMeight -> "Bold");;

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## Erho (TM Scattered)

Echolog()INS = ListinePlot(dataEchoregoyING, PlotBarge -> {(0, 2\*Pi}, (0, Mar(SolEntoregoyING))), PlotStyle -> Elue, BaseStyle -> AbsoluteFinichems[], PlotBarkers -> Nome, PlotEabl -> "S\_\_Smooth()ylinder (TM Soutcased Field)", Frama -> True, FramaLabl -> ("0", "Var), GridLimes -> ([CH, (Thick, Gray, Dashed])), Antomatic), Background -> White, ImageSize -> 700, BaseStyle -> (PontSize -> 14, FontHeight -> "Bold")];

#### Erho (TM Inc + Scattered)

$$\begin{split} & EnhologOylHMEand] * ListLingFlow[datadirosgoylHMEand]; \\ & PlotEange \rightarrow \{(f_0, 2 \times 1), (f_0, 4 \times \{[bl]EnhoregoylHMEand]]\}\}, \\ & PlotEand > The second second$$

#### Ephi (TM Scattered)

TphiRegCylTHE = listLineflot(dataSphiregoylTHE, FlotRange >> {(0, 2 + 3), (o, Macf[oliphiregoylTHE,])}, PlotStyle -> Blue, BaseStyle >> AbsoluteFinitemers[], FlotRatextes >> Kome, FlotLabel -> "K, Smooth Cylinder (TM Scattered Field)", Frame -> True, TransLabel -> ("Y, "V","), GridLines >> (([24, flotK, Grey, Dashed)), Automatic), Reckground -> White, ImageSize -> 700, ReseStyle -> (PontSize -> 14, FontWeight -> "Bold"));

## Ephi (TM Inc + Scattered)

pre('1') = definition = listinoFlot(dstaRphiregcylTMEandI, FlotEange -> ((0, 2 + Fi), (0, Mex[SolEphiregcylTMEandI])), FlotEabel -> Kase BaseSyste -> AboleteThickess[2], FlotEahel -> Kone, FlotEabel -> Kg. Smoth Cylinder ('M Encident - Scattered Floid)', Frame -> Trame\_FlotEabel -> ('0', 'V'm'), GridLines -> (CHS, (Thick, Carg, Dashed)), Automatic), Background -> Mhite, ImageSize -> 700, BaseStyle -> (FontSize -> 14, FontMeight -> 'Bold\*)];

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#### Ez (TE Inc + Scattered)

temperature of the set of th

## Erho (TE Scattered)

Enhology(FEG - ListicarDiv[dataEnhorequy(TEG, FlotRage > ([0, 2+P]), (0, Ma(FolkInorequy(TEG))), FlotByle > Blue, BaseByle > AboliutFiliates[2], FlotBackers > None, FlotElasi > "k, Month Cylindes (TE Soutzersel Field", Frame > Frame, FrameLable > (( $P^{+}, "V^{+})$ ), GidElase > (( $P^{-}, (Folk), Grey, Dashed)$ ), Automatic), Background > White, TangeEirs > TOG, BaseByle > (Pentlise > (A (FoutHeight > Tho[d^{+})));

#### Erho (TE Inc + Scattered)

KinobecylTEEsand1 = ListLinsFlot[dstaRthoregoylTEEsand1, FlotEnage > ((0, 2 + 91), (0, Kes[dslthoregoylTEEsand1))), FlotEtyle > Slee, BaseStyle > AbsoluteTh(Lonses[2], FlotEsaters -> None, FlotEsabel -> Te, Bonoth Cylinder (TE Incident + Scattered Field)\*, Frame > True, FrameLabel -> ("(\*\* "\\*\*)", GridLines -> (((P1, (Thick, Gray, Dashed))), Automatic), Background -> Mhite, ImageSize -> ToO, BaseStyle -> (FontEise -> 14, FontMeight -> Teold)];

## Ephi (TE Scattered)

philosofylTEs = ListLinePlot[dstaRphiregoylTES; PiotMange -> ([0, 2 + Pi], (0, Max[dolRphiregoylTES])), PlotStyle -> Biue, BaseStyle -> MacoluteThickness[2], PlotMarkers -> None, PlotLabel -> "A, Mooth Cylinder (TE Sottered Field", Frame -> True, FrameLabel -> ("0", "Vwr), Gridlines -> ([0], (Thick | Gwr, Dashed])), Antomatic), Background -> Mhite, ImageSize -> 700, BaseStyle -> (PontBize -> 14, PontMaight -> "Bold");;

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#### Ephi (TE Inc + Scattered)

provide further function of the set of

EAII (TE Scattered)

## - EAllRegCylTES

limecylime = limecylime = sintinamologidarakilitze, PlotRange -> {(0, 2+Pl), (0, Max[SolEAlITEE]}}, PlotEtyle -> Blue, Basedyle -> AbsoluteThichese]2, PlotBatchers -> Nose, PlotLabel -> <sup>Texan</sup>, Imoch Cylinder (TE factured Field)\*, Frame -> True, Franklabel -> (\*\*, "V\*). Gridlines -> ([Ch; (Thich, Gray, Dashed]), Antonatic), Background -> Whi ImageSize -> 700, BaseStyle -> (FontSize -> 14, FontWeight -> "Bold");

-> White,

## EAII (TE Inc + Scattered)

HIND- EAllRegCylTESandI = ListLinePlot[dataEAllTESandI] 
$$\begin{split} & (likeg)(TRindf + ListLine) to (datAll(TRindf, PlotArg) = (0, 2+N), (0, And(Slill(TRindf, C))), PlotTyle <math>\rightarrow$$
 Blue, BaseStyle  $\rightarrow$  AlmoluteThiokness[2], PlotArkers  $\rightarrow$  Nome, FlotAbal  $\rightarrow = Nexa,$  Broch Sylander (TR Incident  $\rightarrow$  Sacksteed birld)<sup>n</sup>, Frame  $\rightarrow$  True, FrameLabel  $\rightarrow (4^n, -Vm^n),$  Gridines  $\rightarrow \{(10, (Thick, Gray, Dashed))), Antomatic), Background <math>\rightarrow$  White, InageSize  $\rightarrow$  700, BaseStyle  $\rightarrow$  (FontSize  $\rightarrow$  14, FontWeight  $\rightarrow$  "Bol4")];

## Summary TE Plots

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#### Ephi (TM+TE Scattered)

uprov(r) \* for the second second

## Ephi (TM+TE Inc + Scattered)

BylikegdylftýluvTfándí - Listlineľist (ástafphiregoylftýluvTfándí), PiotBage -> ((C, 2+2), (D. Ma(EdBAjtiregoylftýluvTfándí))), PiotByle -> Slun, Barstyle -> AksolutFinistensel), PiotBatters -> Non PiotEibal -> %g. Bonch Cylinde (TM - TT for and Bontsread), Prama -> frum, Franklad -> ((\*\*. 'V'n'), Goidines -> (((PL, (Tolch, Ger, Dasho))), Automatic), Background -> W DangOlizes -> T(G. BassTyle -> (Pentlines >- 14, FontMeight -> "Bold"));

## EAII (TM+TE Scattered)

Elikaeg():ThpluwTES = Listinaeloi[dsisElilThpluwTES, PlotEnage -> ([0, 2 + 05), [0, Mas(EsleLilThpluwTES])), PlotEtyle -> Blue, BaseEtyle -> MoniutFhickeres(], PlotEtaters -> None, PlotEabel -> Tenag Booch Cylinder (M\* TE Scattered)\*, Prama -> True, Frankabba -> ((\*\*, "Vrm"), GridLanse -> (([%), (Thick, Gray, Dashed])), Automatic), Background -> Whi Dampdise -> Too, BaseCylar on (Fontise -> 14, FontMaight -> Wes(d\*)]; and -> White,

#### EAII (TM+TE Inc + Scattered)

BilkecyclTMplusTESandT = ListLinePlot[dstaEAllTMplusTESandT, PlotEkange >> ([0.2 rsl); (0. Mss[GolkAllTMplusTESandT]); PlotEkange >> ([0.2 rsl); (0. Mss[GolkAllTMplusTESandT]); PlotEabel >> Tmpici Booth Cylinder (TM = TM Inc and Scattered)\*, Frame >> True, FrameLabel >> ("4", "VM="); GridEnses >> ([0.2, (Thick Gray, Dashed)); Automatic), Background >> Whit ImageNize -> 700, NaseStyle -> (PontSize -> 14, PontWeight -> "Bold"); -> White,

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#### ooth Cylinder Plots - TM + TE Plots Sm

#### Ez (TM+TE Scattered)

(c) Transfer (c) Transfer

## Ez (TM+TE Inc + Scattered)

EzRegCvlTMplusTESandI = ListLinePlot(dataEzregcvlTMplusTESandI. RegCylTeplurffandt = ListLinePlot(dataErregcylTeplurffandt, FlotRanges - (U. 2 + Pl.), (0. Mus(loikregcylTeplurffandt))), FlotRytel -> Blam, Easettyle -> MascluteThichnes(2), FlotRatkers -> None, FlotRatel ->" (F. Booth Cyllender (PH + TE Ion and Goutared)", Frame -> True, FrameLahel -> ("4", ""\""), Gridlines -> (Te), 'Hinki, Tagen, Dashed)), Astronatic), Bedground -> Whi ImageSize -> 700, BaseStyle -> (FontBize -> 14, FontWeight -> "Bold")]; White,

## Erho (TM+TE Scattered)

$$\label{eq:starting} \begin{split} & \text{Modegly:HighurtE:::} itstl:neFlot(dataRthoregy:HighurtE), \\ & \text{PlotRayer } ((0, 2 \times N), (0, Mas(SolEchoregy:HighurtE)), \\ & \text{PlotRy::} = Niem, Mas(Ny) = Niemierinthanker(), \\ & \text{PlotRy:} = Niemiakabi > (^n_{i}, 'Wa'), \\ & \text{Prand > True, Frankabi > (^n_{i}, 'Wa'), \\ & \text{Prand > True, Frankabi > (^n_{i}, 'Wa'), \\ & \text{PlotRay > (} Niemiakabi > (^n_{i}, 'Wa'), \\ & \text{PlotRay > (} Niem$$

## Erho (TM+TE Inc + Scattered)

$$\label{eq:constraint} \begin{split} & \text{holigylithplustEinnel}: \texttt{ListlinePlot[dataEthoregoylithplustEinnel]}, \\ & \text{PlotEnge} \rightarrow \{(0, 2 + 7 1), (0, Mar(SolEhoregoylithplustEinnel]), \\ & \text{PlotExple } = \texttt{Salessine} \rightarrow \texttt{Salessi$$

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#### Summary TM+TE Plots

GraphicsGrid[([ERegCylTMplusTES, ErBegCylTMplusTES [ErboRegCylTMplusTES, ErboRegCylTMplusTESand], [EphiRegCylTMplusTES, ErbiRegCylTMplusTESand], [EhiRegCylTMplusTES, EhiRegCylTMplusTESand], EhiRegCylTMplusTES, EhiRegCylTMplusTESand]], Spacings -> (Scaled[0], Scaled[0])];

#### Compare (Smooth vs Corrugated) Plots

## TM Compare

TM Compare
mass desphicadia(((Bow(EslagOy1766, EsCors6,
 Pottmaps → ((0, 2 + Fi), (0, Mas[TolErregoy1766, SolEt])),
 BaseStyle → (Fontlise → 14, FontWeight → "Bold"),
 Fram → True, FrameLabel → ("p/3," "Vi"), PlotLabel → \*
 "%, TM Eosttaread Booch Oylinder (Blue) vs Corrupated Cylinder (Med, --)"),
 Bhow(Eslegy1708And, EsCorrEnd, PlotLabel → \*
 ((0, 2 + Fi), (0, Mas[SolErregoy1785And, SolEt])),
 BaseStyle → (Fontlise → 14, FontWeight → "Bold"),
 Fram → True, FrameLabel → ("p/3," "Vi"),
 PlotLabel → "L, TH the V Esctared Booch Oylinder
 (Blue) vs Corrupated Cylinder (Bed, --)"),
 (dow(Eshohegy1786, And, FontWeight → "Bold"),
 Fram → True, FrameLabel → ("p/3," "Cu"),
 (dow(Eshohegy1786, And, FontWeight → "Bold"),
 FrameLabel → ("p/3," "Tu"),
 BaseStyle → (FontSise → 4, FontWeight → "Bold"),
 FrameLabel → ("p/3," "Tu"),
 Torbised → (1, Torbise),
 True,
 FrameLabel → ("p/3," "Torbise),
 The Corrupated Soch Oylinder
 (Blue) = (Sochegy1786, And, FontWeight → "Bold"),
 FrameLabel → ("p/3," "Turbise),
 (0, Mas[SolErregoy1786, And, FontWeight → "Bold"),
 FrameLabel → ("p/3," "Turbise),
 The Corrupated Soche Oylinder
 (Blue) = (Sochegy1786, And, FontWeight → Torbel,
 True,
 FrameLabel → ("p/3," "Turbise),
 "R, TM Sochegy1786, And, FontWeight → Torbel,
 True,
 Show[ErhoRegCylTMSandI, ErhoCorrSandI, PlotRange -> 
$$\begin{split} & line(Erbolage)/ITHEANSI, ErhColorHand, PictRang \rightarrow \\ & ((G, 2+8), (G, Mar(SolfChrossy)/ITHEANS, Solfchol)), \\ & Basstyla \rightarrow (FontLiss \rightarrow 14, FontHealpt \rightarrow "Bald"), \\ & Frame \rightarrow Trans, Frankladb \rightarrow ((\gamma)/2, "\nu"), \\ & PictLabel \rightarrow "E, "H Ton + Sonttered Boosth Cylinder \\ & (Blas) \forall orcrupated Qilnder (Bed, \neg)"), \\ & (Bbor(EghlassyC)/ITHS, EghloartS, PictRange \rightarrow ((G, 2+81)), \\ & (0, Mar(SolFahresyOrIHS, SolFahris)), \\ & Basstyla \rightarrow (FontLiss \rightarrow 11, FontHealpt \rightarrow "Bold"), Frameward - ((G, 2+81), Colfahres), \\ & "E, Mt Eastteved Boosth Cylinder (Bus) vs Corrupated Cylinder (Bed, ~-)"), \\ & Boost(Pirelamid, EghloartSond, FictRange \rightarrow \\ & ((G, 2+81), (G, Mar(SolEphiregy)/ItHS, SolEphireg), \\ & ((G, 2+81), (G, Mar(SolEphiregy)/ItHS, SolEphireg), \\ \end{array}$$

BaseStyle → (FontSize → 14, FontWeight → "Bold"), Frame → Frue, FrameLabel → ("p/X", "V/m"), FlotLabel → "& TM Ine + Easttered Bmoch Cylinder (Blue) vs Corrugated Cylinder (Red, --)"), (Boiv[KallkeqCylTHG, EastCyl=> (TouTsize → 14, FontWeight → "Bold"), Frame → True, FrameLabel → ("p/X", "V/m"), FlotLabel → "Bound The State Booch Cylinder (Blue) vs Corrugated Cylinder (Red, --)"), con(Ellinder)(Themail, EkloTermadi, FlotLangs → ((0, 2 + N), (0, Mac(SolNLHTHEmail, FlotLangs → ((0, 2 + N), (0, Mac(SolNLHTHEmail, FlotLangs → ((0, 2 + N), (0, Mac(SolNLHTHEmail, FlotLangs → Frame → True, FrameLabel → ("p/X", "V"), FlotLabel → "Bound The Cattered Bmoch Cylinder (Blue) vs Corrugated Cylinder (Red, --)"])

# )]

## TE Compare

# Carchards #. SetSensetSid (((Mov/Enders/YTHS, ECOTH)); #. SetSensetSid (((Mov/Enders/YTHS, ECOTH)); BaseStyla > (Fontlin > 1(, Max[GallErs/Py17HS, GalLES])); BaseStyla > (Fontlin > 1(, Mov/Enders/Py17HS, GalLES]); BaseStyla > (Fontlin > 1(, Mov/Enders/Py17HS, GalLES]); BaseStyla > (Fontlin > 1(, Mov/Enders/Py17HS, GalLES)); BaseStyla > (Fontlin > 1(, Fontling); BaseStyla > (Fontlin > 1(, Fontlin > (Fontlin > (Fontlin > (Fontlin )); BaseStyla > (Fontlin > 1(, Fontlin > (Fontlin > (Fontlin )); BaseStyla > (Fontlin > (Fontlin > (Fontlin )); BaseStyla > (Fontlin > (Fontlin )); BaseStyla > (Fontlin > (Fontlin )); BaseS

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(Bise) we Corrupted Oylinder (Med. --)\*], Move[EnchempCytThe]iurTESand]. EnchoOrstRand]. DirEktags --((0, 2+1), (0, Mas[ColtAnoregy/ThgNumTESAL], SolIRAD])), BaseStyles - (Fontiss -- 14, FontWaingt -- Theid\*), Frame -- To - The The The (FyAL, "YeV), (10, 0, 0, Mas[ColtAnoregy/ThgNumTESAL], SolIRAD])), (3, Massing -- (Fontiss -- 14, FontWaingt -- Theid\*), Font -- (Finder -- Theid\*), Massing -- (Fontiss -- 14, FontWaingt -- Theid\*), Massing -- (Fontiss -- 14, FontWaingt -- Theid\*), Font -- True, Franchabl -- (Font', "YeV), Intelsels - True, Franchabl -- (Font', "YeV), Intelsels - True, Franchabl -- (Font', "YeV), Massing -- True, Franchabl -- (Font', "YeV), Intelsels -- (Fontiss -- 14, FontWaingt -- Theid\*), Resetyles - (Fontiss -- 14, FontWaingt -- Theid\*), Resetyles - (Fontiss -- 14, FontWaingt -- Theid\*), Resetyles - (Fontiss -- 14, FontWaingt -- Theid\*), Intelsels - (Fontiss -- 14, FontWaingt -- Theid\*), Resetyles - (Fontiss -- 14, FontWaingt -- Theid\*), Resetyles

#### TM, TE, TM+TE Compare

The Le Compare
 RhotYPlets • GraphicsCrid[(Elsov[ExReg/y1786, ExCord, Plotkang -> {(0, 2 \* Pl), (0, Max[SolExreg/y1786, SolEx5])}, Basedtyla -> [TontExls +> 14, FontWeight -> "Bold"), Frame -> True, Framework -> (0, 2 \* Pl), Plotkable -> "K, TM fontered Booth Cylinder (Blue) vs Corrugsted Cylinder (Bed, --)", "%, TF Gostress Rot Exist".
 Bhov[ERReg/y178]utFES, ExCord, (0, Max[SolExregoy1786]utFES, SolEx5])}, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> True, BaseStyla -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> Frame -> FontWeight -> "Bold"), Frame -> Frame -> FontWeight -> "Bold"), Frame -> Frame -> FontWeight -> (FontSize -> 14, FontWeight -> "Bold"), Frame -> Frame -> FontWeight -> (FontWeight -> FontWeight -> FontWeight ->

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(0, Max[SolEphiregcylTES, SolEphiS])), BaseStyle -> (Fontime -> 14, FontWeight -> "Bold"), Frame -> True, FrameLabel -> (<sup>\*</sup>ρ/λ<sup>\*</sup>, "V/m"), PlotLabel -> "E<sub>0</sub> TE Scattered Bmooth Cylinder (Blue) vs Corrugated Cylinder (Red, --)"], 

}];

## TM+TE Compare

 $\label{eq:constraint} TOH-TE Compare$ GraphicalCid(((Bhow(ExDepCylThplusTES, ExCloreS,PictEanger (0, 2+Fi), (0, Max[SolErregsylThplusTES, SolES))),haseStyle ~ ([0, 2+Fi), (0, Max[SolErregsylThplusTES, SolES))),haseStyle ~ ([0, 2+Fi), (0, Max[SolErregsylThplusTES, SolES))),Picture of the constraint of the constra

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FrameLabel -> {"\$"", "V/m"}, PlotLabel -> "E, TM\*TE Scattered Smooth Cylinder (Blue) vs Corrugated Cylinder (Red, ---)"]),

(Belege)(Hesand, Escoretand, PlotHauge ~ ([0, 2 + Pl), [0, Mas(SolErrege)(INSiand, SolE])), BaseBayla ~ ([0, 2 + Pl), [0, Mas(SolErrege)(INSiand, SolE])), Prame ~ True, Franchable > ("4", "V/m"), PlotLabel ~ "K, PM Inc + Scattered Booth Cylinder (Blow) vs. Corrupted Cylinder (Bed, --)"), "K, TE Does Not Doith", Bhou[Esheg)(PhylauTESand, EsCorefand, PlotLabel ~ ([0, 2 + Pl), [0, Mas(SolErrege)INplusTESand, SolE])), BaseStyle ~ [FontLise ~ 1, FontWeight ~ Bold"), Frame ~ True, Franchabel ~ ("4", "V/m"), PlotLabel ~ "K, TMTE Inc + Solatered Booth Cylinder (Blow) vs. Corrupated Cylinder (Bed, --)"]).

(Blue) vs Corrupted Cylinder (Red. --)")).
(Show[Exchosecy[196], EchoCore5, [Io (Bac(SolEchorescy(196], SolEchos])), Baseltyla -> (PostEines -> 14, FontWaight -> Theid"), Frame -> True, FrameLabla -> (Ve, Var), PostEahla -> True, BostEanted EchoCore, SolEchosecy(196, SolEchosecw(196, SolEchosecw(196,

(fhow[Etholegy]iHEandf, EthoCorrfandf, PlotRang→ (0, 2+E), (0, Mas[SolEthorego]iHEandf, SolEtho])), BaneSiyla→ (TontLine → 14, FontMaight → "Bold"), Frame → True, FramtLabl → ('\$', "V'n"), PlotLabl → "C, TH fao + Scattered Booth SylInder (Blue) vs Corrugated SylInder (Bad, --)"]. Bow(Etholegy/IETHand, EtholocetSmalf, PlotLange → ((0, 2+Pi), (0, Max[SolEthoregoyIEEEandI, SolEtho])),

# 

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## Changing Phi RCS dB XY Plots - Compare with Reference [Cross-Polar]

## Corrugated Cylinder Plots

Plot Cross-Polar [RCSod@ According to A. Fern]
(\*Cross-Polar according to A. Frank, 1996,
Bosttering from a dislectic cylinder snislly leaded
"Uth you'do' on a dislectic cylinder snislly leaded
"Uth you'do' on a dislectic (BECSddd, BLotRange ->
{(0, Fi), (4tn[10 + coj0[RCSddd, BLotRange ->
{(0, Fi), (4tn[10 + coj0[RCSddd, BLotRange ->
{(10, Fi), (4tn[10 + coj0[RCSddd, BLotRange ->
{(10, Fi), (4tn[10 + coj0] RCSddd, SLORAGE(ABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, SLORAGE(ABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI), Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI, Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI, Tordense, ->
{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT)CI, Tordense, ->
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{(10, Fi), (4tn[10 + coj0] RCSddd, Landed], RCSddTABMINT, RCSddTABMINT)CI, RCSddTABMINT, RCSddTABMINT,

# APPENDIX B

Derivation for Fundamental Equations of Guided Waves from Maxwell's Equations Start with Maxwell's equations in differential form,  $\nabla \times \vec{E}$  and  $\nabla \times \vec{H}$  [12, p. 2], and expand into cylindrical coordinates [12, p. 925]

$$\nabla \times \vec{E} = -j\omega\mu\vec{H} = \hat{\rho}\left(\frac{1}{\rho}\frac{\partial E_z}{\partial \phi} - \frac{\partial E_{\phi}}{\partial z}\right) + \hat{\phi}\left(\frac{\partial E_{\rho}}{\partial z} - \frac{\partial E_z}{\partial \rho}\right) + \hat{z}\left(\frac{1}{\rho}\frac{\partial(\rho E_{\phi})}{\partial \rho} - \frac{1}{\rho}\frac{\partial E_{\rho}}{\partial \phi}\right)$$

$$\nabla \times \vec{H} = j\omega\varepsilon\vec{E} = \hat{\rho}\left(\frac{1}{\rho}\frac{\partial H_z}{\partial \phi} - \frac{\partial H_{\phi}}{\partial z}\right) + \hat{\phi}\left(\frac{\partial H_{\rho}}{\partial z} - \frac{\partial H_z}{\partial \rho}\right) + \hat{z}\left(\frac{1}{\rho}\frac{\partial(\rho H_{\phi})}{\partial \rho} - \frac{1}{\rho}\frac{\partial H_{\rho}}{\partial \phi}\right)$$
Replace,  $\frac{\partial}{\partial z} = -j\beta$  based on the relationship the relationship  $\frac{\partial}{\partial z}\left(e^{-j\beta z}\right) = -j\beta e^{-j\beta z}$ 
and separate into cylindrical components
$$-j\omega\mu H_{\rho} = \frac{1}{\rho}\frac{\partial E_z}{\partial \phi} - \frac{\partial E_{\phi}}{\partial z} = \frac{1}{\rho}\frac{\partial E_z}{\partial \phi} + j\beta E_{\phi}$$

$$j\omega\varepsilon E_{\rho} = \frac{1}{\rho}\frac{\partial H_z}{\partial \phi} - \frac{\partial H_{\phi}}{\partial z} = -j\beta E_{\rho} - \frac{\partial E_z}{\partial \rho}$$

$$j\omega\varepsilon E_{\phi} = \frac{\partial H_{\rho}}{\partial z} - \frac{\partial E_{z}}{\partial \rho} = -j\beta H_{\rho} - \frac{\partial H_{z}}{\partial \rho}$$

$$-j\omega\mu H_{z} = \frac{1}{\rho} \frac{\partial(\rho E_{\phi})}{\partial\rho} - \frac{1}{\rho} \frac{\partial E_{\rho}}{\partial\phi}$$
$$j\omega\varepsilon E_{z} = \frac{1}{\rho} \frac{\partial(\rho H_{\phi})}{\partial\rho} - \frac{1}{\rho} \frac{\partial H_{\rho}}{\partial\phi}$$

Also,

$$k = \frac{2\pi}{\lambda} = \omega \sqrt{\mu\varepsilon}$$
$$k_c^2 = k^2 - \beta^2 = \omega^2 \mu\varepsilon - \beta^2$$

Solving for  $E_{\rho}$ 

$$E_{\rho} = \frac{1}{j\omega\varepsilon} \left( \frac{1}{\rho} \frac{\partial H_z}{\partial \phi} + j\beta H_{\phi} \right)$$

Substitute

$$\begin{split} H_{\phi} &= \frac{1}{j\omega\mu} \left( j\beta E_{\rho} + \frac{\partial E_{z}}{\partial \rho} \right) \\ E_{\rho} &= \frac{1}{j\omega\varepsilon} \left( \frac{1}{\rho} \frac{\partial H_{z}}{\partial \phi} + \frac{j\beta}{j\omega\mu} \left( j\beta E_{\rho} + \frac{\partial E_{z}}{\partial \rho} \right) \right) = \frac{1}{j\omega\varepsilon} \left( \frac{1}{\rho} \frac{\partial H_{z}}{\partial \phi} - \frac{\beta^{2} E_{\rho}}{j\omega\mu} + \frac{j\beta}{j\omega\mu} \frac{\partial E_{z}}{\partial \rho} \right) \\ E_{\rho} &= \frac{1}{j\omega\varepsilon\rho} \frac{\partial H_{z}}{\partial \phi} + \frac{\beta^{2} E_{\rho}}{\omega^{2}\mu\varepsilon} - \frac{j\beta}{\omega^{2}\mu\varepsilon} \frac{\partial E_{z}}{\partial \rho} \\ E_{\rho} &- \frac{\beta^{2} E_{\rho}}{\omega^{2}\mu\varepsilon} = \frac{1}{j\omega\varepsilon\rho} \frac{\partial H_{z}}{\partial \phi} - \frac{j\beta}{\omega^{2}\mu\varepsilon} \frac{\partial E_{z}}{\partial \rho} \\ E_{\rho} &\left( 1 - \frac{\beta^{2}}{\omega^{2}\mu\varepsilon} \right) = \frac{1}{j\omega\varepsilon\rho} \frac{\partial H_{z}}{\partial \phi} - \frac{j\beta}{\omega^{2}\mu\varepsilon} \frac{\partial E_{z}}{\partial \rho} \end{split}$$

Multiply both sides by  $\omega^2 \mu \varepsilon$ 

$$E_{\rho}(\omega^{2}\mu\varepsilon-\beta^{2})=\frac{\omega\mu}{j\rho}\frac{\partial H_{z}}{\partial\phi}-j\beta\frac{\partial E_{z}}{\partial\rho}$$

Replace  $k_c^2 = \omega^2 \mu \varepsilon - \beta^2$  and solve for  $E_{\rho}$ 

$$E_{\rho} = \frac{-j}{k_c^2} \left( \frac{\omega \mu}{\rho} \frac{\partial H_z}{\partial \phi} + \beta \frac{\partial E_z}{\partial \rho} \right)$$

Solving for  $H_{\phi}$ 

$$\begin{split} H_{\phi} &= \frac{1}{j\omega\mu} \Big( j\beta E_{\rho} + \frac{\partial E_{z}}{\partial \rho} \Big) = \frac{1}{j\omega\mu} \Big( j\beta \left( \frac{1}{j\omega\varepsilon} \Big( \frac{1}{\rho} \frac{\partial H_{z}}{\partial \phi} + j\beta H_{\phi} \Big) \Big) + \frac{\partial E_{z}}{\partial \rho} \Big) \\ H_{\phi} &= \frac{1}{j\omega\mu} \Big( \frac{j\beta}{j\omega\varepsilon\rho} \frac{\partial H_{z}}{\partial \phi} - \frac{\beta^{2}}{j\omega\varepsilon} H_{\phi} + \frac{\partial E_{z}}{\partial \rho} \Big) = -\frac{j\beta}{\omega^{2}\mu\varepsilon\rho} \frac{\partial H_{z}}{\partial \phi} + \frac{\beta^{2}}{\omega^{2}\mu\varepsilon} H_{\phi} + \frac{1}{j\omega\mu} \frac{\partial E_{z}}{\partial \rho} \\ H_{\phi} \Big( 1 - \frac{\beta^{2}}{\omega^{2}\mu\varepsilon} \Big) = -\frac{j\beta}{\omega^{2}\mu\varepsilon\rho} \frac{\partial H_{z}}{\partial \phi} + \frac{1}{j\omega\mu} \frac{\partial E_{z}}{\partial \rho} \end{split}$$

Multiply both sides by  $\omega^2 \mu \varepsilon$ 

$$H_{\phi}(\omega^{2}\mu\varepsilon - \beta^{2}) = -\frac{j\beta}{\rho}\frac{\delta H_{z}}{\delta\phi} + \frac{\omega\varepsilon}{j}\frac{\partial E_{z}}{\partial\rho} = -j\left(\frac{\beta}{\rho}\frac{\partial H_{z}}{\partial\phi} + \omega\varepsilon\frac{\partial E_{z}}{\partial\rho}\right)$$

$$H_{\phi} = \frac{-j}{k_c^2} \left( \frac{\beta}{\rho} \frac{\partial H_z}{\partial \phi} + \omega \varepsilon \frac{\partial E_z}{\partial \rho} \right)$$

Solving for  $E_{\phi}$ 

$$E_{\phi} = \frac{1}{j\omega\varepsilon} \left( -j\beta H_{\rho} - \frac{\partial H_z}{\partial \rho} \right)$$

Substitute,

$$\begin{split} H_{\rho} &= -\frac{1}{j\omega\mu} \left( \frac{1}{\rho} \frac{\partial E_z}{\partial \phi} + j\beta E_{\phi} \right) \\ E_{\phi} &= \frac{1}{j\omega\varepsilon} \left( \frac{j\beta}{j\omega\mu\rho} \frac{\partial E_z}{\partial \phi} - \frac{\beta^2}{j\omega\mu} E_{\phi} - \frac{\partial H_z}{\partial \rho} \right) = \frac{-j\beta}{\omega^2 \mu\varepsilon\rho} \frac{\partial E_z}{\partial \phi} + \frac{\beta^2}{\omega^2 \mu\varepsilon} E_{\phi} - \frac{1}{j\omega\varepsilon} \frac{\partial H_z}{\partial \rho} \\ E_{\phi} \left( 1 - \frac{\beta^2}{\omega^2 \mu\varepsilon} \right) = \frac{-j\beta}{\omega^2 \mu\varepsilon\rho} \frac{\partial E_z}{\partial \phi} - \frac{1}{j\omega\varepsilon} \frac{\partial H_z}{\partial \rho} \end{split}$$

Multiply both sides by  $\omega^2 \mu \varepsilon$ 

$$E_{\phi}(\omega^{2}\mu\varepsilon - \beta^{2}) = \frac{-j\beta}{\rho}\frac{\partial E_{z}}{\partial\phi} - \frac{\omega\mu}{j}\frac{\partial H_{z}}{\partial\rho} = -j\left(\frac{\beta}{\rho}\frac{\partial E_{z}}{\partial\phi} - \omega\mu\frac{\partial H_{z}}{\partial\rho}\right)$$

$$E_{\phi} = \frac{-j}{k_c^2} \left( \frac{\beta}{\rho} \frac{\delta E_z}{\delta \phi} - \omega \mu \frac{\delta H_z}{\delta \rho} \right)$$

Solving for  $H_{\rho}$ 

$$H_{\rho} = \frac{-1}{j\omega\mu} \left( \frac{1}{\rho} \frac{\partial E_z}{\partial \phi} + j\beta E_{\phi} \right)$$

Substitute,

$$\begin{split} E_{\phi} &= \frac{1}{j\omega\varepsilon} \Big( j\beta H_{\rho} - \frac{\partial H_{z}}{\partial \rho} \Big) \\ H_{\rho} &= \frac{-1}{j\omega\mu} \left( \frac{1}{\rho} \frac{\partial E_{z}}{\partial \phi} + j\beta \left( \frac{1}{j\omega\varepsilon} \Big( j\beta H_{\rho} - \frac{\partial H_{z}}{\partial \rho} \Big) \right) \right) = \frac{-1}{j\omega\mu} \Big( \frac{1}{\rho} \frac{\partial E_{z}}{\partial \phi} + \frac{\beta^{2}}{j\omega\varepsilon} H_{\rho} - \frac{j\beta}{j\omega\varepsilon} \frac{\partial H_{z}}{\partial \rho} \Big) \\ H_{\rho} &= \frac{-1}{j\omega\mu\rho} \frac{\partial E_{z}}{\partial \phi} + \frac{\beta^{2}}{\omega^{2}\mu\varepsilon} H_{\rho} - \frac{j\beta}{\omega^{2}\mu\varepsilon} \frac{\partial H_{z}}{\partial \rho} \\ H_{\rho} \left( 1 - \frac{\beta^{2}}{\omega^{2}\mu\varepsilon} \right) = \frac{-1}{j\omega\mu\rho} \frac{\partial E_{z}}{\partial \phi} - \frac{j\beta}{\omega^{2}\mu\varepsilon} \frac{\partial H_{z}}{\partial \rho} \end{split}$$

Multiply both sides by  $\omega^2 \mu \varepsilon$ 

$$H_{\rho}(\omega^{2}\mu\varepsilon - \beta^{2}) = \frac{-\omega\varepsilon}{j\rho}\frac{\partial E_{z}}{\partial\phi} - j\beta\frac{\partial H_{z}}{\partial\rho} = -j\left(\frac{-\omega\varepsilon}{\rho}\frac{\partial E_{z}}{\partial\phi} + \beta\frac{\partial H_{z}}{\partial\rho}\right)$$
$$H_{\rho} = \frac{-j}{k_{c}^{2}}\left(\frac{-\omega\varepsilon}{\rho}\frac{\partial E_{z}}{\partial\phi} + \beta\frac{\partial H_{z}}{\partial\rho}\right)$$

Note that in paper  $k_c$  is substituted with  $k_\rho$  and  $\beta$  is substituted with  $k_z$ .

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