USERS MANUAL FOR FEMA-PRISM (VERSION 2)

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Changes from the previous version:

1. Mesher and the analysis code has been separated. Mesher is called "mesh.f" and the code is called "FEMA-PRISM.f".
2. Boundary integral option has been added to the analysis code.
3. Log-periodic geometry has been added to the list of the geometries that the meshers can tessellate.
4. Non-planar sunstrate option has been added where the layers are described by families of linear segments.
5. Compressed-row-storage has been implemented in the BI version for memory savings.
6. Dimension allocation problem has been reduced to minimum (i.e., specifying surface triangles, edges and nodes before running the meshers. Rest is taken care of by the code itself).
7. Improved MatLab interface.

For the rest, the previous manual holds true.

Running FEMA-PRISM:

Mesher:

1. Adjust the dimension parameters "NdmTri", "NdmSED", and "NdmSNo" in the file called "fema.dm1".
2. Compile the meshers "Mesh.f"
3. Create the input file "MeshIn"
4. Run the meshers
5. User the MatLab interface to view the mesh, identify feed locations, etc.

Code:

1. Create the input file "MainIn" for the code.
2. Compile "dm.f"
3. Run "dm.f" (reads in the mesh data already created and creates a decent fema.dm1" file).
4. Compile "FEMA-PRISM.f"
5. Run the code for memory allocation (see the description of "MainIn")
6. Compile "FEMA-PRISM.f" again
7. Run the code for analysis.

Currently only BI option is working.
MainIn

- I
  -  = Boundary Integral termination, 2 = Artificial Absorber termination
- I
  -  = Adaptive frequency sweep, 2 = Uniform frequency sweep
- R
  - Desired amount of increment in the input impedace (in Ohms)
- I I
  -  = Printed, 0 = Slot, 1 = Compute memory allocation, 0 = Analysis
- I I I I
  - # of substrate layers
  -  = all substrate layers are identical and planar, 0 = non-uniform but planar, 2 = Non-uniform and non-planar
  - = number of superstrate layers (enter zero for no superstrate)
  -  = all superstrate layers have the same thickness and material parameters, 0 = otherwise

- R C C C C C
  - Ordered from the bottom of the cavity up, each row corresponds to a substrate layer. Only one row is needed if all layers are identical (row has the info for a single layer).
  - Thickness of the layer
  - Relative permittivity of the layer
  - Relative permeability of the layer

- I C C
  - Number of linear segments
  - Relative permittivity of the layer
  - Relative permeability of the layer

- R R R R R R
  - z- r coordinates of the segments (number of pairs is one more than the first entry on the previous line)

- I C C
  - R R R R R R
  - I C C
  - R R R R R R

- R C C C C C
  - Same as above but for the superstrate. Ordered from the antenna surface up (first row corresponds to the layer just above the antenna surface).

- I
  - # of probe feeds

- I I I C
  - Each row corresponds to a probe feed
  - Surface node number #1
  - Surface node number #2
  - Layer # (layer within which the normally oriented probe is located, or the layer at the top of which the laterally oriented probe is located). Entry can be positive or negative and increase away from the surface of the antenna with zero corresponding to the layer immediately below the antenna
  - Complex amplitude of the probe current

- R R R I I I I
  - Starting frequency in GHz
  - Final frequency in GHz
  - Increment frequency in GHz
  - Frequency run to save (1 = save the first freq. run, 2 = next frequency, etc.)
  - Tolerance ( < 0.01 )
  - 1 = monitor convergence (dump residual error at each iter.), 0 = otherwise
  - 1 = compute element matrices assuming distorted prism (must for doubly-curved or non-planar substrates), 0 = read in element matrices, 2 = compute assuming right prism (excellent for B1 case)
  - Maximum number of iterations

- I
  -  = Read in user specified termination parameters (given in the following row), 0 = code will figure out the optimum parameters (this is the safe course if one is not familiar with the artificial absorber termination).

- R I I C
  - Thickness of one layer (all layers have the same thickness)
  - Total number of layers from the top of the outer-most superstrate layer to the termination boundary
  - Number of Absorber Layers
  - Relative permittivity of the absorbing layers. Unity for B1
Mesh.f

Three types of configurations:  1) Log-periodic
2) Circular
3) Rectangular

The antenna could be printed or slot

Reads in input file "MeshIn" which contains geometry info and creates the following files:

SurfMesh → For FEMA-PRISM
MeshDs
Attr
AngInt
AntEdg → For mesh display on MatLab
CavEdg
SrfEdg
Setup.m

Before running "Mesh.f", one must have two files in the same directory:

Plot.aux Contains the statement "axis('equal')" in its first line.
fema.dm1 Contains the parameter statement for memory allocation. An example is given below

PARAMETER(NdmPri= 12321,NdmTri= 3081,NdmSED= 4713,NdmSNo= 1634,
  &NdmVED= 30093,NdmVNo= 8166,NdmNZE= 19629,NdmLay= 5,
  &NdmRow= 243569,NdmNZS= 249)

This statement is also used by the FEMA-PRISM code, and for the mesher, only three parameter
are needed to be specified:

NdmTri:  Maximum number of triangles expected in the final mesh.
NdmSED: Maximum number of edges
NdmSNo: Maximum number of nodes

The file "Mesh.f" must be compiled after the dimension allocations are specified.
MeshIn - 1

Line #1:  I I I
- 1 = Boundary Integral (BI), 0 = Artificial Absorber (AA)
- 1 = Log-periodic, 2 = Circular, 3 = Rectangular
- 1 = Printed, 0 = Slot

Lines #2-4 depend on the entries on Line #1 (see the following pages).

Modeling of the above two configurations with Bi and AA terminations:
(Computation space is circled with dashed lines)

<table>
<thead>
<tr>
<th>Termination Technique Configuration</th>
<th>Boundary Integral (BI)</th>
<th>Artificial Absorber (AA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavity-backed</td>
<td></td>
<td>Absrober</td>
</tr>
<tr>
<td>Microstrip</td>
<td>Does not apply</td>
<td>Absrober</td>
</tr>
</tbody>
</table>
MeshIn - 2

BI termination / Log-periodic - 1 (Only "cavity-backed" configuration is available)

Line #1: 111 or 110

Line #2: R R I I R R R R

- \( \alpha \) (deg.)
- \( \beta \) (deg.)
- \( N_a \) (# of arms)
- \( N_s \) (# of sections)
- \( R_0 \)
- \( R_1 \)
- \( \tau \)
- \( \kappa \)
- \( \Delta R \) (suggested radial discretization length for the mesh)

Line #3: R

- \( \Delta R_c \) (distance from the antenna boundary to the cavity wall)

**Definition of the parameters**

\[ \beta \]

~

\[ \alpha \]

\[ R_1, R_2, R_3, r_1, r_2, r_3 \]

\[ \Delta R_c \]

~

\[ \alpha \]

\[ \beta \]

\[ R_0 \]

\[ R_1 \]

\[ \tau \]

\[ \kappa \]

\[ \Delta R \]

\[ \Delta R_c \]

\[ \text{Arm #1} \]

\[ \text{Arm #2} \]

\[ \text{Section #1} \]

\[ \text{Section #2} \]

\[ \text{Section #3} \]

\[ \tau = \frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{R_3}{R_4} = \ldots \]

\[ \kappa = \frac{R_1}{r_1} = \frac{R_2}{r_2} = \frac{R_3}{r_3} = \ldots \]

Note: \( \kappa = \sqrt{\tau} \) for equal metal and air teeth width

\( \Delta R \leq R_0 / 3 \) for decent mesh quality around the center of the antenna
MeshIn - 3

BI termination / Log-periodic - 2

Example run - 1

Line #1:   1    1    1
Line #2:   45   35   2    2    .66  1.   .6   .775    .22
Line #3:   .72

After running the mesher, one can view the mesh, number the nodes and assess the mesh quality using MatLab as shown below:

**MATLAB INTERFACE**

1. Display the mesh

2. Number the nodes and zoom in
3. Distribution of internal angles for the mesh just created

This is very useful for assessing the quality of the mesh. The ideal distribution is a delta function located at 60 degrees and represents a perfect surface mesh. The more concentrated the distribution is around 60 degrees the better. One can conclude that the mesh created is a decent one. In fact, same behavior should be expected each time one uses the mesher to tessellate a log-periodic geometry.
**MeshIn - 5**

**BI termination / Circular - 1**

(Only "cavity-backed" configuration is available)

Line #1:  1 2 1 or  1 2 0

Line #2:  R I

- $\Delta R$ (radial thickness of the rings)
- $Na$ (# of antenna rings)

Line #3:  I

- $Nc$ (# of rings between the antenna and the cavity wall)

**Definition of the parameters**

- Cavity wall
- Antenna
- $\Delta R$

**Warning:** $Nc > 1$

For the above example: $Na = 5$, $Nc = 2$
MeshIn - 6

BI termination / Circular - 2

Example run - 1

Line #1: 1 2 0 (slot antenna)
Line #2: 1 5
Line #3: 2

After running the mesher, one can view the mesh, number the nodes and assess the mesh quality using MatLab as shown below:

MATLAB INTERFACE

1. Display the mesh

2. Number the nodes and zoom in
3. Distribution of internal angles for the mesh just created

![Figure No. 1: Distribution of Angles](image)

Version 4.2c
Nov 28 1994

Dst
Commands to get started: intro, demo, help help
Commands for more information: help, whatsnew, info, subscribe

>> AngDst

>> □
MeshIn - 8

BI termination / Rectangular - 1

Line #1: 1 3 1 or 1 3 0

Line #2: R R I I

- Δx (sampling cell size in x-direction)
- Δy (sampling cell size in y-direction)
- NxA (number of antenna cells in x-direction)
- NyA (number of antenna cells in y-direction)

Line #3: I I

- NxC (# of cells between the antenna and the cavity wall in x-direction)
- NyC (# of cells between the antenna and the cavity wall in y-direction)

Definition of the parameters

For the above example: NxA = 12, NyA = 2, NxC = 3, NyC = 4

Warning: NxC, NyC > 2
MeshIn - 9

BI termination / Rectangular - 2

Example run - 1

Line #1:  1 3 1 (printed)
Line #2:  1 1 12  2
Line #3:  3 4

After running the mesher, one can view the mesh, number the nodes and assess the mesh quality using MatLab as shown below:

MATLAB INTERFACE

1. Display the mesh:

2. Number the nodes and zoom in

Figure No. 1
MeshIn - 10

BI termination / Rectangular - 3

Example run - 2

3. Distribution of internal angles for the mesh just created

AngDst
Commands to get started: intro, demo, help help
Commands for more information: help, whatsnew, info, subscribe

>> AngDst
>>

Figure No. 1
Distribution of Angles
MeshIn - 11

AA termination / Log-periodic

Line #1: 0 1 1 or 0 1 0 (printed or slot)

Line #2: R R I I R R R R R
   ▶ α (deg.)
   ▶ β (deg.)
   ▶ Na (# of arms)
   ▶ Ns (# of sections)
   ▶ Ro
   ▶ R1
   ▶ τ
   ▶ κ
   ▶ ΔR (suggested radial discretization length for the mesh)

Line #3: I
   ▶ 1 = Cavity-backed, 0 = Microstrip

Line #4: R R R
   ▶ ΔRc (distance from the antenna boundary to the cavity wall)
   ▶ ΔRair (thickness of the air gap)
   ▶ ΔRabs (thickness of the absorber)

Definition of the parameters

Definitions of Line #2 parameters are the same as before
MeshIn - 12

AA termination / Log-periodic / Cavity-backed

Line #1: 0 1 0 (slot antenna)
Line #2: 45 35 2 2 0.66 1. 0.6 0.775 0.22
Line #3: 1
Line #4: 0.72 0.66 0.44

Commands to get
Commands for mesh
>> Setup
>> Mesh

AA termination / Log-periodic / Microstrip

Line #1: 0 1 0 (slot antenna)
Line #2: 45 35 2 2 0.66 1. 0.6 0.775 0.22
Line #3: 0
Line #4: 0.66 0.44

Commands to get
Commands for mesh
>> Setup
>> Mesh
MeshIn - 13

AA termination / Circular

Line #1: 0 2 1 or 0 2 0 (printed or slot)

Line #2: R I
   ▶ ΔR (radial thickness of the rings)
   ▶ Na (# of antenna rings)

Line #3: I
   ▶ I = Cavity-backed, 0 = Microstrip

Line #4: I I I
   ▶ Nc (# of rings between the antenna and the cavity wall)
   ▶ Nair (# of air gap rings)
   ▶ Nabs (# of absorber rings)

Line #4: I I
   ▶ Nair (# of air gap rings)
   ▶ Nabs (# of absorber rings)

Definition of the parameters:

Line #2 parameters have the same definitions as before.

For the above example:
Na = 5, Nc = 2, Nair = 3, Nabs = 2

For the above example:
Na = 5, Nair = 5, Nabs = 2

Warning: Nair > 1
MeshIn - 14

AA termination / Circular / Cavity-backed

Line #1:  0 2 1 (printed)
Line #2:  1 5
Line #3:  1
Line #4:  2 3 2

AA termination / Circular / Microstrip

Line #1:  0 2 1 (printed)
Line #2:  1 5
Line #3:  0
Line #4:  5 2
MeshIn - 15

AA termination / Rectangular

Line #1: 031 or 030 (printed or slot)
Line #2: RRII
  - $\Delta x$ (sampling cell size in x-direction)
  - $\Delta y$ (sampling cell size in y-direction)
  - $N_{xA}$ (number of antenna cells in x-direction)
  - $N_{yA}$ (number of antenna cells in y-direction)

Line #3: I
  - I = cavity-backed, 0 = microstrip

Line #4: I II II II
  - $N_{xC}$ (# of cells between the antenna and the cavity wall in x-direction)
  - $N_{yC}$ (# of cells between the antenna and the cavity wall in y-direction)
  - $N_{xAir}$ (# of air gap cells in x-direction)
  - $N_{yAir}$ (# of air gap cells in y-direction)
  - $N_{xAbs}$ (# of absorber cells in x-direction)
  - $N_{yAbs}$ (# of absorber cells in y-direction)

Line #4: I II I
  - $N_{xAir}$ (# of air gap cells in x-direction)
  - $N_{yAir}$ (# of air gap cells in y-direction)
  - $N_{xAbs}$ (# of absorber cells in x-direction)
  - $N_{yAbs}$ (# of absorber cells in y-direction)

**Definition of the parameters**

![Diagram of cavity-backed and microstrip configurations]

For the above example:
- $N_{xA} = 24$, $N_{yA} = 4$
- $N_{xC} = 2$, $N_{yC} = 3$
- $N_{xAir} = 2$, $N_{yAir} = 3$
- $N_{xAbs} = 2$, $N_{yAbs} = 2$

Warning: $N_{xAir}, N_{yAir} > 0$

For the above example:
- $N_{xA} = 12$, $N_{yA} = 2$
- $N_{xAir} = 2$, $N_{yAir} = 3$
- $N_{xAbs} = 1$, $N_{yAbs} = 1$

Warning: $N_{xAir}, N_{yAir} > 1$
AA termination / Rectangular / Cavity-backed

Line #1: 0 3 0 (slot)
Line #2: 1 1 24 4
Line #3: 1
Line #4: 2 3 2 3 2 2

AA termination / Rectangular / microstrip

Line #1: 0 3 0 (slot)
Line #2: 1 1 12 2
Line #3: 0
Line #4: 2 3 1 1

Commands to get started: intro, demo, help help
Commands for more information: help, whatsnew, info, subscribe

>> Setup
>> Mesh
>> 0