Reflectarray Antenna Design Manager

User's Manual

1 Introduction

A printed reflectarray consists of a planar array of printed radiating elements which incorporates a certain phase-shift to produce a collimated or a shaped beam when it is illuminated by a feed. The operating principle can be explained by considering the reflectarray in transmitting mode with a horn antenna located in a centered or offset position, and assuming that the reflectarray elements are in the far field region of the horn. In this case, the electromagnetic field incident on each reflectarray element at a certain angle can be locally considered as a plane wave with a phase proportional to the distance from the phase center of the feed-horn to each element. In order to convert the spherical wave radiated by the horn into a focused or shaped beam, the field must be reflected from each element with an appropriate phase shift, which is independently adjusted at each element.
The necessary phase shift at each element is obtained by varying one or several geometrical parameters in the reflectarray element. The variation of the dimensions in rectangular printed patches has been widely used because of the advantages of low losses and low cross-polarization, but this technique suffers from a narrow-band behavior and a limitation of the maximum range of phase variation (in the order of 330º). All these drawbacks are solved by using two or three stacked array layers, as used in this software tool.

One of the most important parts of the reflectarray analysis and design is the accurate characterization of the reflective elements, i.e. for a given geometry of the reflectarray element, to accurately predict the phase-shift and dissipative losses for each polarization of the field. The element performance is obtained in the present software tool, by a full-wave electromagnetic analysis technique implemented for multilayer reflectarrays based in MoM (Method of Moments), considering local periodicity and the angle of incidence of the wave coming from the feed to each periodic cell. The incident and reflected fields on each reflectarray cell are related through a reflection matrix, which depends on the incidence angle. The software tool consider reflectarray elements made of one or more layers of varying-sized patches printed on different dielectric layers, where the number of dielectric layers and printed patches are defined in the input data file. The software takes into account the dielectric losses and it is suitable to analyze very thin dielectric layers, in order to accurately model the different bonding layers used in space manufacturing sandwiches.

The main object of this software tool is the design of multilayer reflectarray antennas, i.e. to define the antenna geometry, feed position and pattern, period, reflectarray size, and finally to adjust all the patch dimensions in order to produce

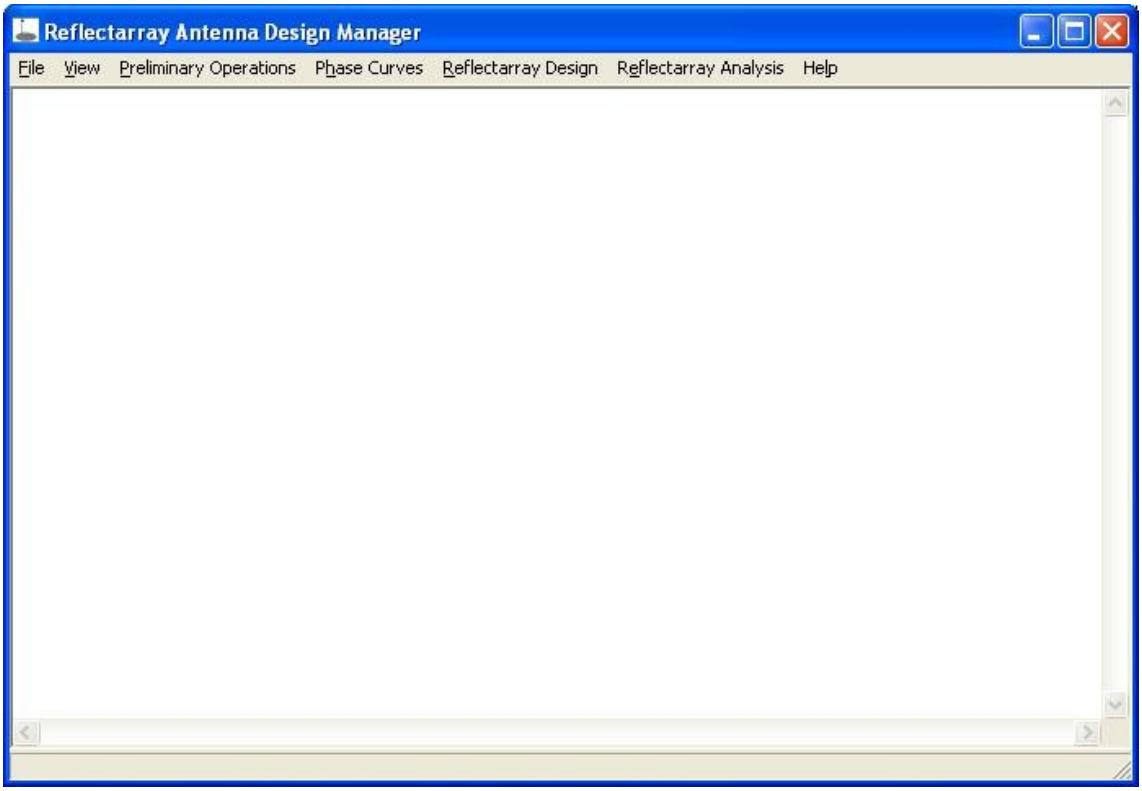
the required focused or shaped beam. From the dimensions of the metalisations in each layer, the photo-etching masks are also obtained in CAD files.

Once the reflectarray antenna has been fully designed, an important aspect is the accurate evaluation of the radiation patterns, including co- and cross-polar components. For the evaluation of the radiation patterns, the feed-horn is modeled as a $\cos^q(\theta)$ function. The radiation patterns are computed in gain (dBi), by taking into account the total power radiated by the feed-horn.

Graphic User's Interface will be explained step by step in the following text.

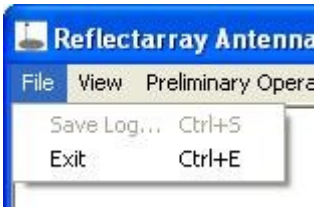
2 Main Window

Available options of the menu bar:



3 File

This option provides another two options:



3.1 Save Log

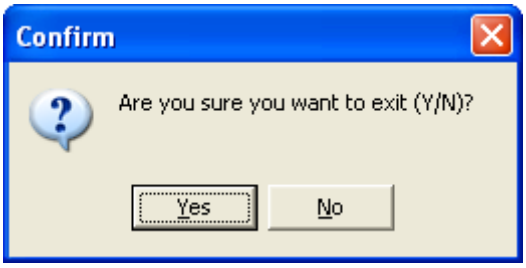
By the use of this utility you can save in a file the content of the current client area in the main window. This area keeps a log with all operations done, and brief views of the content of every file generated with all those operations done.

A form will be shown asking for the route and the name of the file to be saved within the system files.

This option will be enabled since the moment there is any content in the log.

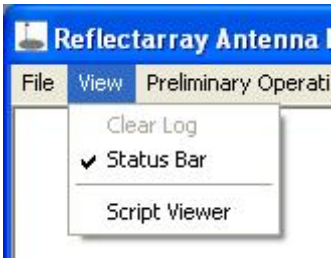
3.2 Exit

This option allows closing the tool. You'll be prompted to confirm you want to close it completely.



4 View

This option provides another three options:

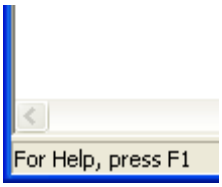


4.1 Clear Log

This option deletes all the log information shown in the client area.

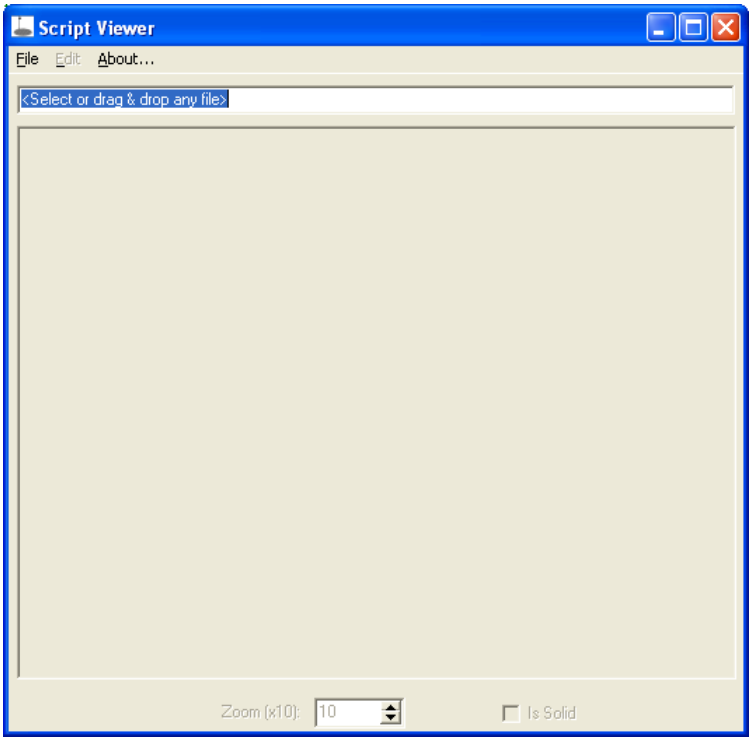
4.2 Status Bar

Show/hide the status bar.



4.3 Script Viewer

Opens a tool designed to view graphically the script files generated by the FORTRAN programs used by AppsFort.dll.

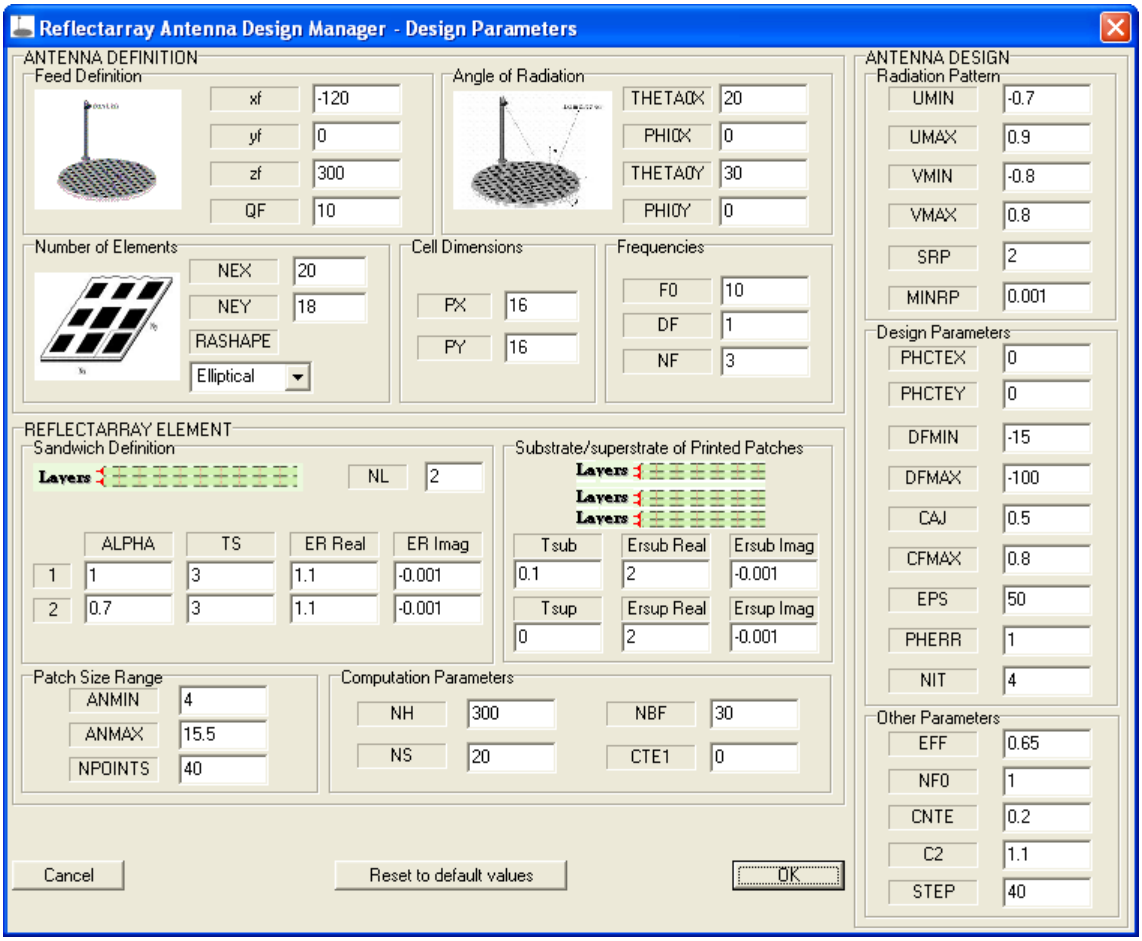


5 Preliminary Operations

This option provides several options:

5.1 Preliminary Design

This is the most important option in the tool. It opens a form where you can provide all the parameters to be used in the former operations.



When you open it by the first time, it appers filled with default values. You can modify any of them as desired. This parameters come from the file **refltnc.in**, or if it does not exist, from **refltnc.default**. If none of them exist, you can either choose it from your system files, or use the default values hardcoded in the tool. At any time you can get these parameters by the use of button "*Reset to default values*".

Once you have pushed the *OK* button, **PreDesign** external utility will be run, then some files will be generated. One of them is **refltnc.in**.

This file contains all the parameters chosen in this form, and it will be used by many of the functionalities of this tool.

Another files generated by PreDesign, all needed for the next options of the tool are:

angles.dat, **faseob.dat**, **faseobml.dat**, **nelem.dat**, **reflnc.dat**.

By using *Cancel* button you will exit this form and no file will be updated.

This form is composed of several sections, they will be analyzed step by step.

5.1.1 Antenna definition

This section contains the following groups:

5.1.1.1 Feed definition

xf, **yf**, **zf**: Coordinates of Feed position. Unities in mm.

QF: q-factor. Range from 0 to 40. It is modelled as $\cos^q(\theta)$.

5.1.1.2 Angle of radiation

Theta0X, **Phi0X**: Angle of the radiated beam for X polarization. Range from -60 to 60, range de -90 to 90.

Theta0Y, **Phi0Y**: Angle of the radiated beam for Y polarization. Range from -60 to 60, range de -90 to 90.

Spheric coordinates, in degrees, of the coordinates system of the reflectarray.

5.1.1.3 Number of elements

NEX, **NEY**: Number of elements of the reflectarray in the X and Y axis, respectively. Range from 10 to 60.

5.1.1.4 Cell dimensions

PX, **PY**: X and Y dimensions of the periodic cell. Maximum value preferibly less than 0.8 lambda to prevent grating lobes. Unities in mm.

5.1.1.5 Frequencies

Fo: Central frequency. Unities in GHz.

Df: Increment of frequency. Unities in GHz.

Nf: Number of frequencies. Maximum value: 5.

Limit frequencies are Fo+-Nf*Df

5.1.2 Reflectarray Element

This section contains the following groups:

5.1.2.1 Sandwich definition

NL: Number of layers. Range from 1 to 3.

Alpha: Relative dimension to the first layer. Value 1 for the first layer. Range for the other layers, from 0.1 to 11.

Ts: Thickness of separator. Unities in mm.

ER Real, **ER Imag**.: Real and imaginary complex components, respectively, of the permitivity of the separator.

5.1.2.2 Substrate/supestrate of printed patches

Tsub, **Tsup**: Thickness of the substrate and superstrate, respectively. Unities in mm.

Ersub Real, **ERsub Imag**: Real and imaginary complex components, respectively, of the permitivity of the sustrate.

Ersup Real, **ERsup Imag**: Real and imaginary complex components, respectively, of the permitivity of the superstrate.

5.1.2.3 Patch size range

ANMIN, **ANMAX**: Minimum and maximum dimensions of patches, respectively. Range from 0.1* PX to 0.99*PX. ANMIN < ANMAX, and ANMAX < PX. Unities in mm.

NPOINTS: Number of points for the phase curve.

5.1.2.4 Computation Parameters

NH: Number of Floquet harmonics for MoM (Method of Moments). Range from 100 to 400.

NS: Number of Floquet harmonics for cascade of stacked layers. Range de 10 to 40.

NBF: Maximum number of base functions of complete domain for rectangular patches, used in the SD-MoM. Range from 20 to 60.

CTE1: Constant added to the phase-shift of the reflectarray element. Unities in degrees.

5.1.3 Antenna design

This section contains the following groups:

5.1.3.1 Radiation Pattern

UMIN, **UMAX**, **VMIN**, **VMAX**: Extreme values of the u and v angular coordinates for the radiation patterns. Range from -1 to 1.

SRP: Intervales to represent radiation patterns.

MINRP: Minimum value for the radiation pattern level. Natural unities.

5.1.3.2 Design Parameters

PHCTEX: Constant to be added to the required phase distribution, X polarization.

PHCTEY: Constant to be added to the required phase distribution, Y polarization.

DFMIN: Minimum value of the phase difference in the file faseob.dat. Range from -600 to 0.

DFMAX: Maximum value of the phase difference in the file faseob.dat. Range from -600 to 0.

CAJ: Coefficient to accomplish the minimum dimensions of the patch in the central area. Range from 0 to 1. In the central part, A1 > CAJ*PX, B1 > CAJ*PY

CFMAX: Coefficient to define the central area. Range from 0.1 to 1. For the default value 1, a1min and b1min grow linearly from the edge to the center.

EPS: Increment of the patch dimensión to compute the derivative. Unities in micras (μm).

PHERR: Phase error used as condition to stop Newton Raphson. Range from 0.1 to 1. Unities en degrees.

NIT: Maximum number of iterations t stop Newton Raphson. Range from 1 to 10. A small number of iterations is enough to achieve convergence.

5.1.3.3 Other parameters

EFF: Estimated antenna efficiency to evaluate the directivity. Range from 0 to 1.

NF0: Index to initiate thephase distribution. Values 1 or 2. If it is equal to 1 the phase distribution with value 0 starts at the end of the negative coordinate x, if it is equal to 2 the phase distribution with value 0 starts at the end of the positive coordinate x.

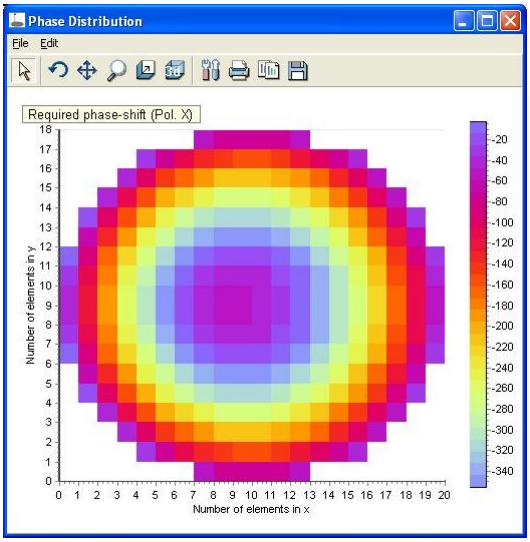
CNTE: Constant to compute the number of base functions of complete domain for the rectangular patches. Range from 0.1 to 0.3. A high value increments the number of base functions and the CPU time.

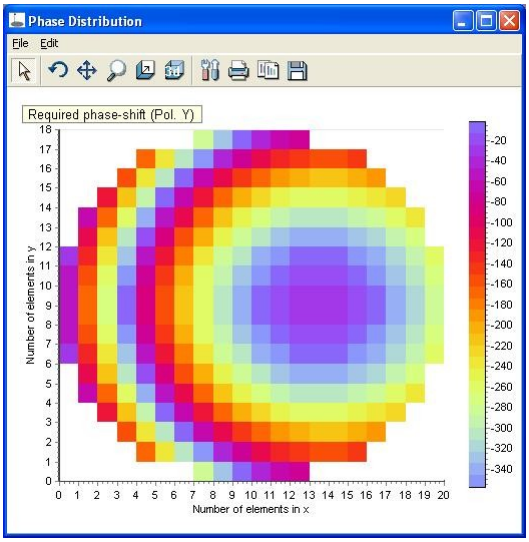
C2: Constant to adjust the necessary value of the phase difference at extreme frequencies. Range from 0.8 to 1.5. Unities in degrees.

STEP: Interval allowed for the decreasing phase curve. Range from 10 to 100. Unities in degrees.

6 Phase Distribution

This option opens two windows that show graphically the phase distribution for X and Y polarizations, respectively.





Each one of them consist of the following options in the menú bar:

6.1 File

This option provides another options:

6.1.1 Save

It allows to save the client area in a file with a bitmap or jpeg format.

6.1.2 Close

It closes the window.

6.2 Edit

This option provides another options:

6.2.1 Copy

Copy the client area in the clipboard.

6.2.2 Fonts

It allows modifying the fonts shown in the graphic.

This option provides another options:

6.2.2.1 Default values

It resets the fonts shown in the graphic as default.

6.2.2.2 Set all to...

It allows modifying all of the fonts shown in the graphic with a single form to give them the same configuration.

6.2.2.3 Title

It allows modifying the fonts of the title.

6.2.2.4 Left Axis Title

It allows modifying the fonts of the left axis title.

6.2.2.5 Left Axis Labels

It allows modifying the fonts of the left axis labels.

6.2.2.6 Bottom Axis Title

It allows modifying the fonts of the bottom axis title.

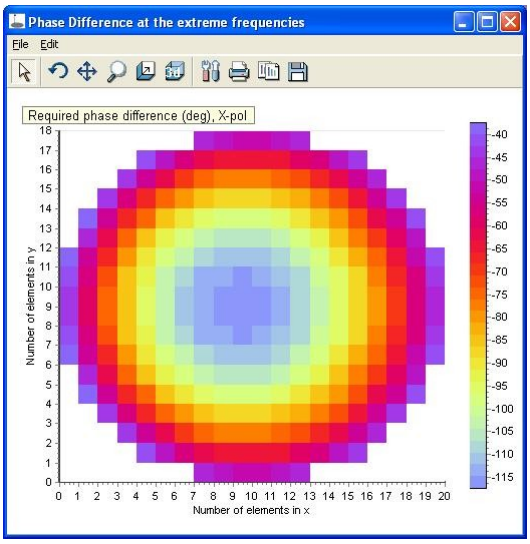
6.2.2.7 Bottom Axis Labels

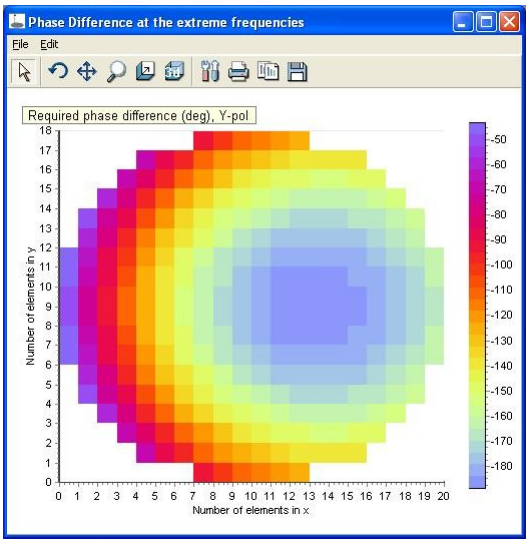
It allows modifying the fonts of the bottom axis labels.

Also, a toolbar is provided to perform multiple operations on the graphics.

6.3 Phase Difference at the extreme Frequencies

This option opens two windows that show graphically the required phase shift for X and Y polarizations, respectively.

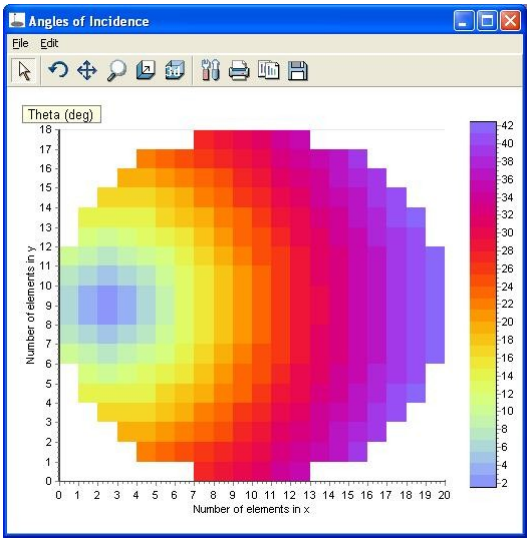


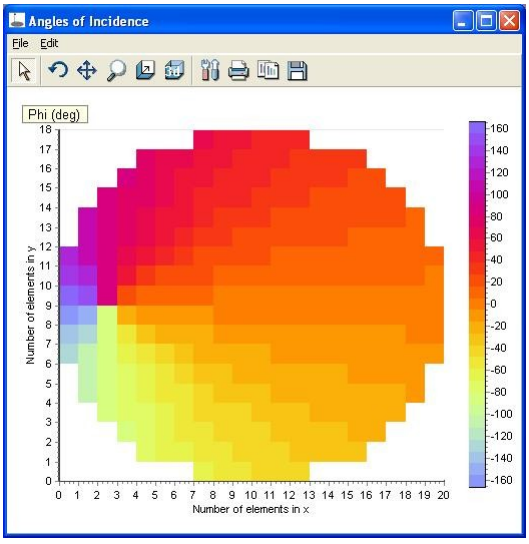


All available options in this window are identical to this.

6.4 Angles of Incidence

This option opens two windows that show graphically the incidence angles for the Theta and Phi angles, respectively.



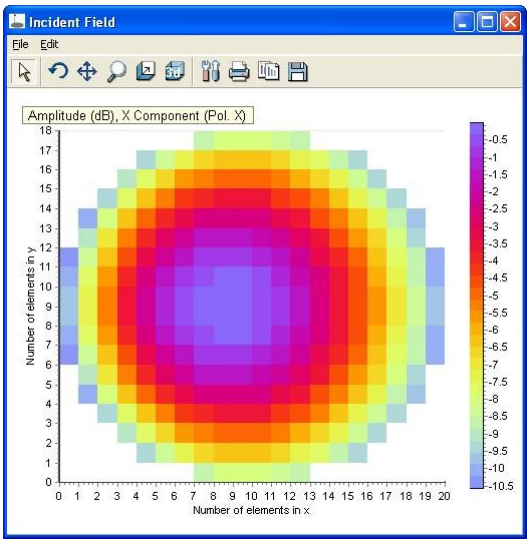


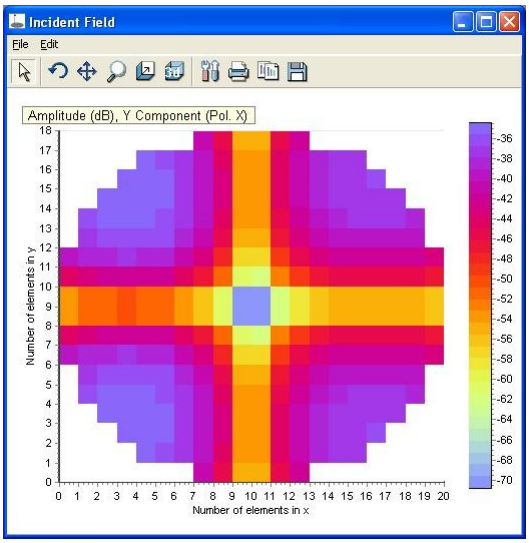
All available options in this windows are identical to this.

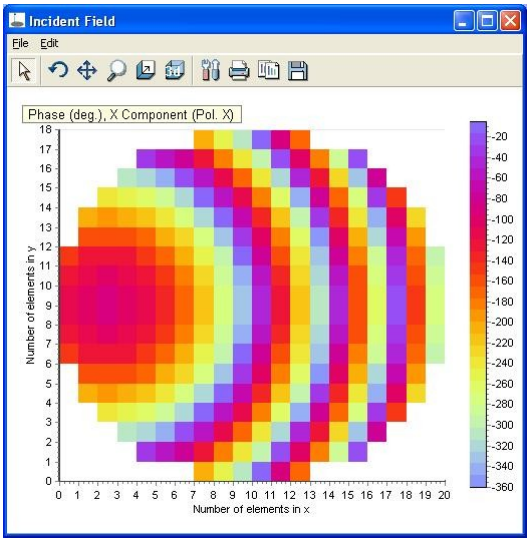
6.5 Incident Field

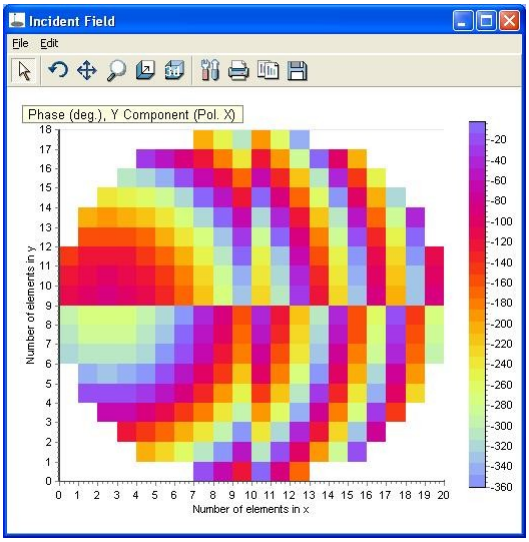
This option opens a form where you can choose the frequency and the polarization required to compute the incident field.

By pushing OK, the external application **FeedCosQ** will be run; it generates the file **eelem.dat**, and then four windows are opened to show graphically the X and Y components of amplitude and phase for X and Y polarization, repectively.





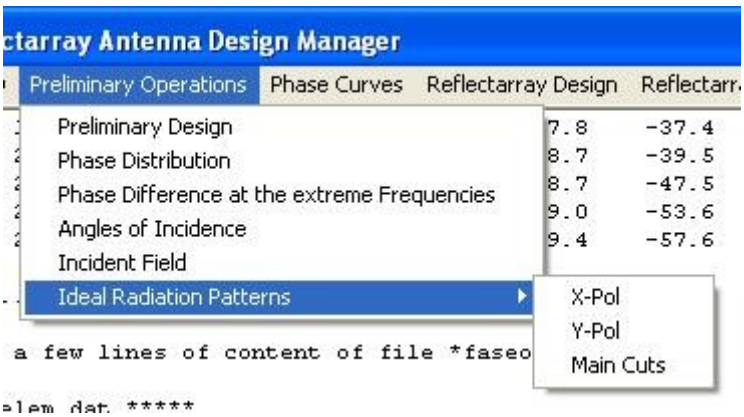




All available options in this windows are identical to this.

6.6 Ideal Radiation Patterns

This option provides another options:

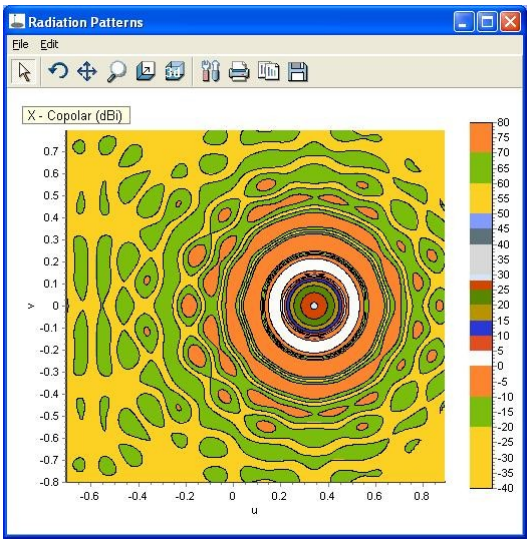


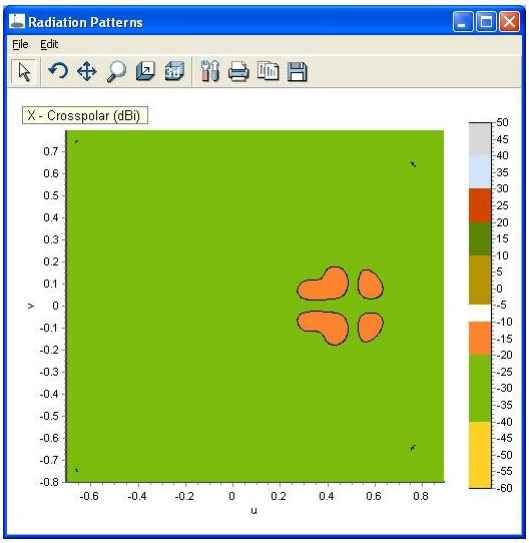
6.6.1 X-Pol

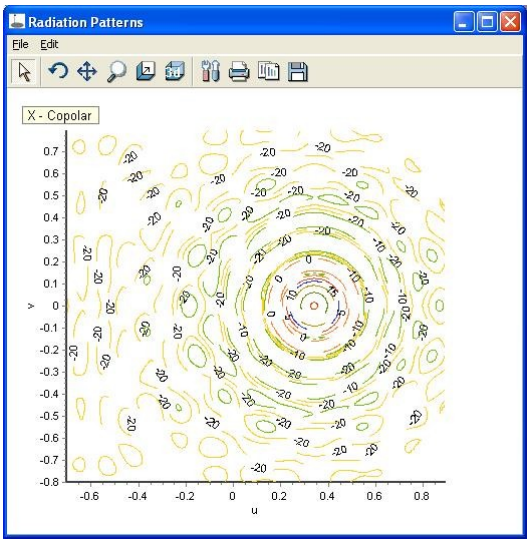
This option runs the external application **RadPattern**, and it generates the following files:

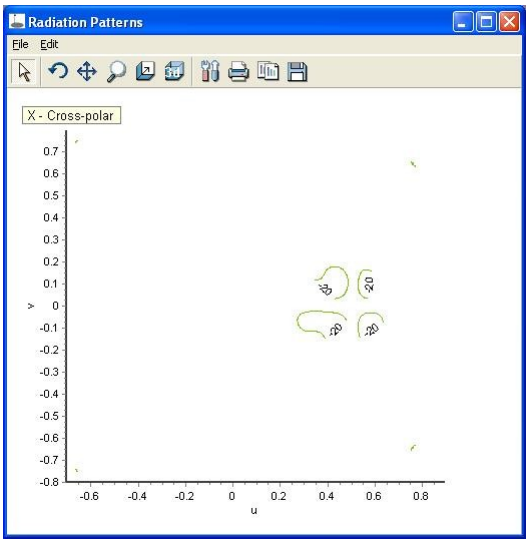
eelem_refl.dat, **ganx.dat**, **gany.dat**, **Refl_E_field_Xpol.grd**, **Refl_E_field_Ypol.grd**, **result2.dat**, **u.dat**, **v.dat**.

Then, four windows are opened, two of them to show graphically the amplitude in dBi of the Copolar and Crosspolar components for X polarization, and the other two show with isobaras the amplitude in dBi the Copolar and Crosspolar components for X polarization.









All available options in this windows are identical to this.

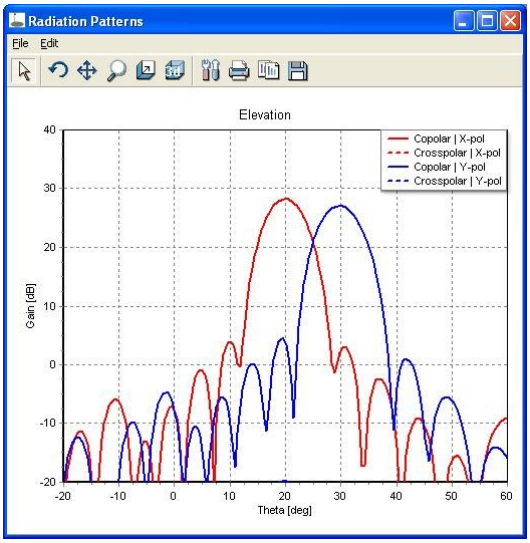
6.6.2 Y-Pol

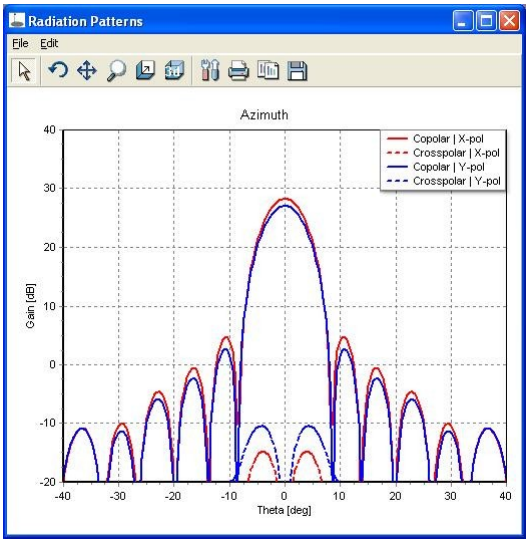
This option opens four windows, two of them to show graphically the amplitude in dBi of the Copolar and Crosspolar components for Y polarization, and the other two show with isobaras the amplitude in dBi the Copolar and Crosspolar components for Y polarization.

All available options in this windows are identical to this.

6.6.3 Main Cuts

This option opens two Windows to show graphically the elevation (dB) and the azimuth (dB) of the Copolar and Crosspolar components for the chosen polarization of the incident field.

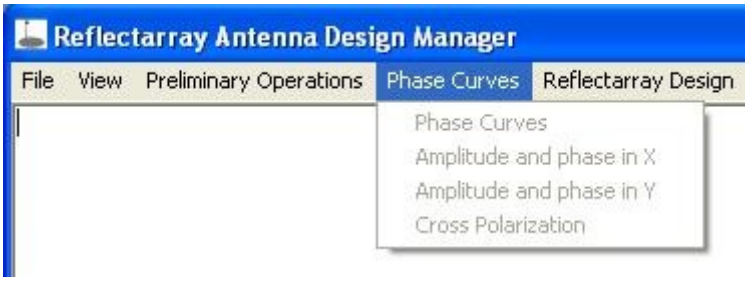




All available options in this windows are identical to this.

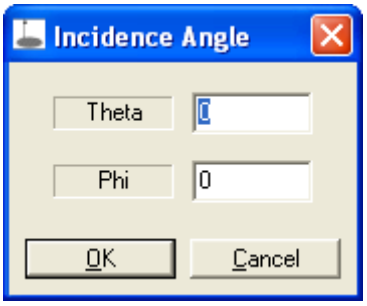
7 Phase Curves

This option provides another options:

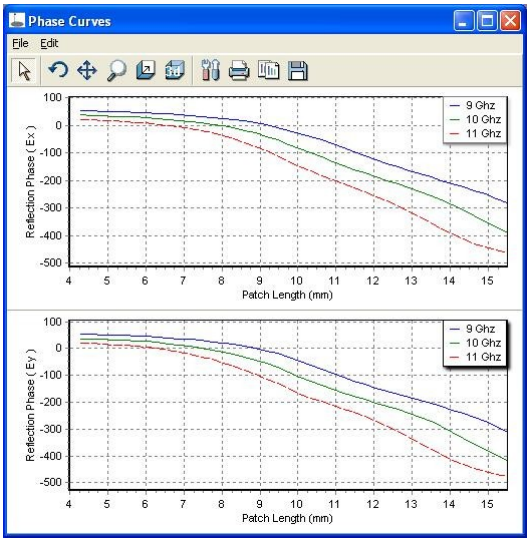


7.1 Phase Curves

This option opens a form where you can choose the incidence angles Theta and Phi to compute the phase curves.



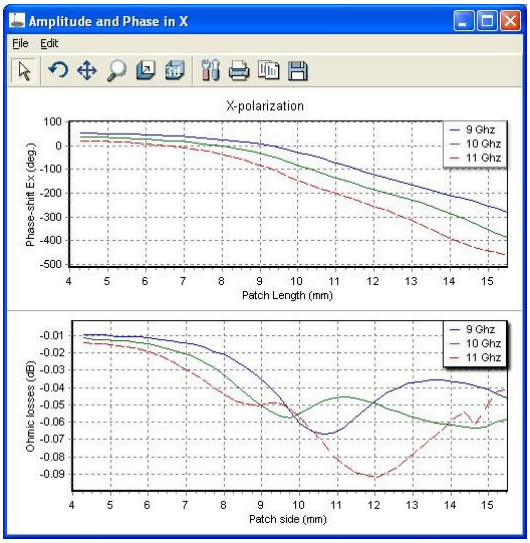
When you push OK, the external application **Fase3Fmc** will be run, and it generates **fase0.dat**, **fase1.dat** and **fase2.dat** files; then it opens Windows to show graphically the phase curves Ex and Ey for the length of the patch, for three frequencies.



All available options in this window are identical to this.

7.2 Amplitude and phase in X

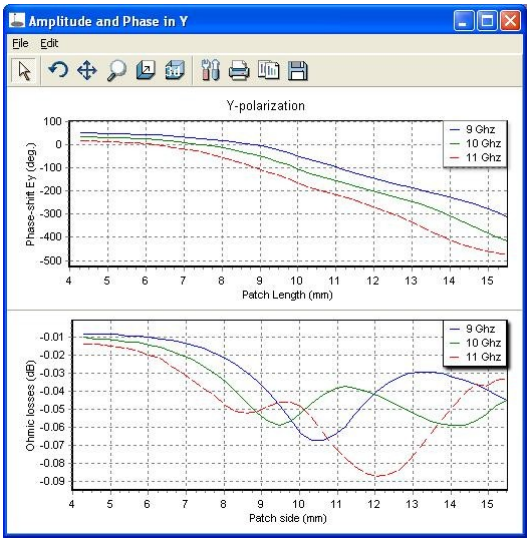
This option opens a window to show graphically the phase-shift in Ex and the ohmic losses for X polarization, for three frequencies.



All available options in this window are identical to this.

7.3 Amplitude and phase in Y

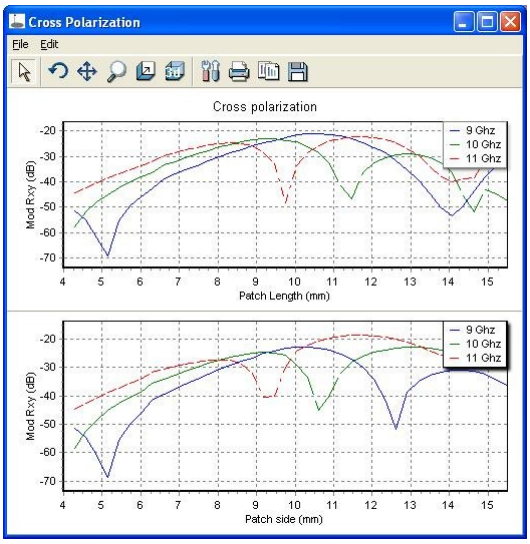
This option opens a window to show graphically the phase-shift in Ey and the ohmic losses for Y polarization, for three frequencies.



All available options in this window are identical to this.

7.4 Cross Polarization

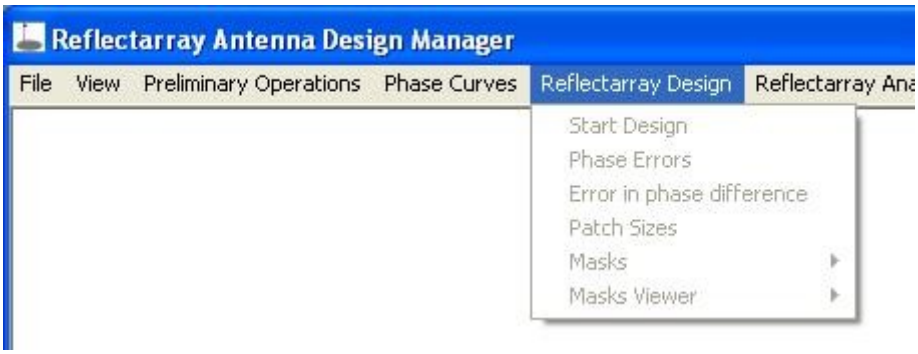
This option opens a window to show graphically the Rxy amplitude (dB) and the length of the patch and width of the patch respectively, for three frequencies.



All available options in this window are identical to this.

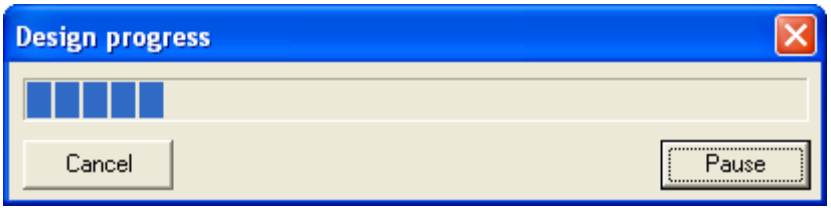
8 Reflectarray Design

This option provides another options:



8.1 Start Design

This option starts the design of the reflectarray by running the external application **Designf0**, and shows a progress bar about the current status of the operation. This could take a few minutes, depending on your machine's performance.



The available buttons allow either to cancel or to pause the operation, respectively. By using ESC key you will cancel also the operation.

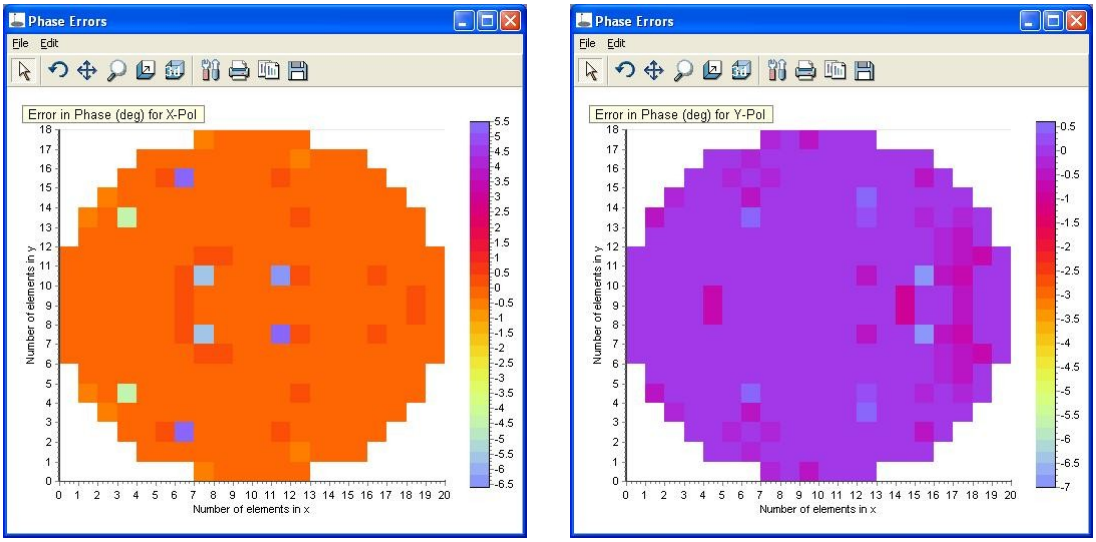
When finished correctly, some menu options will be enabled.

It will generate also the following files:

ajuste.out, **refl.dat** y **result.dat**.

8.2 Phase Errors

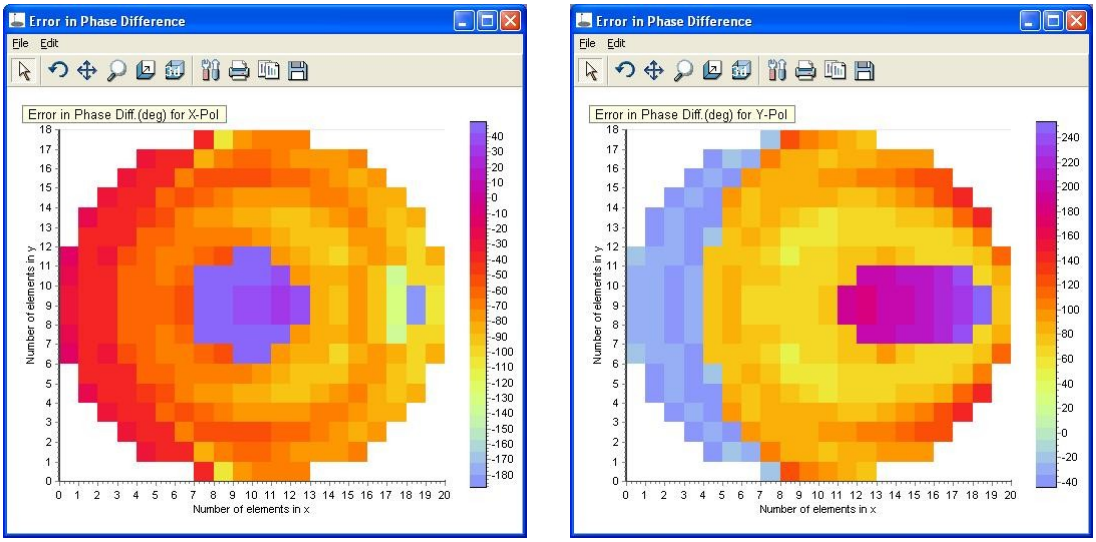
This option runs the external application **FasErr**, and the **faserr.dat** file will be generated when finished. Then two windows will be opened to show graphically the phase error in degrees, for X and Y polarization, repectively.



All available options in these windows are identical to [this].

8.3 Error in phase difference

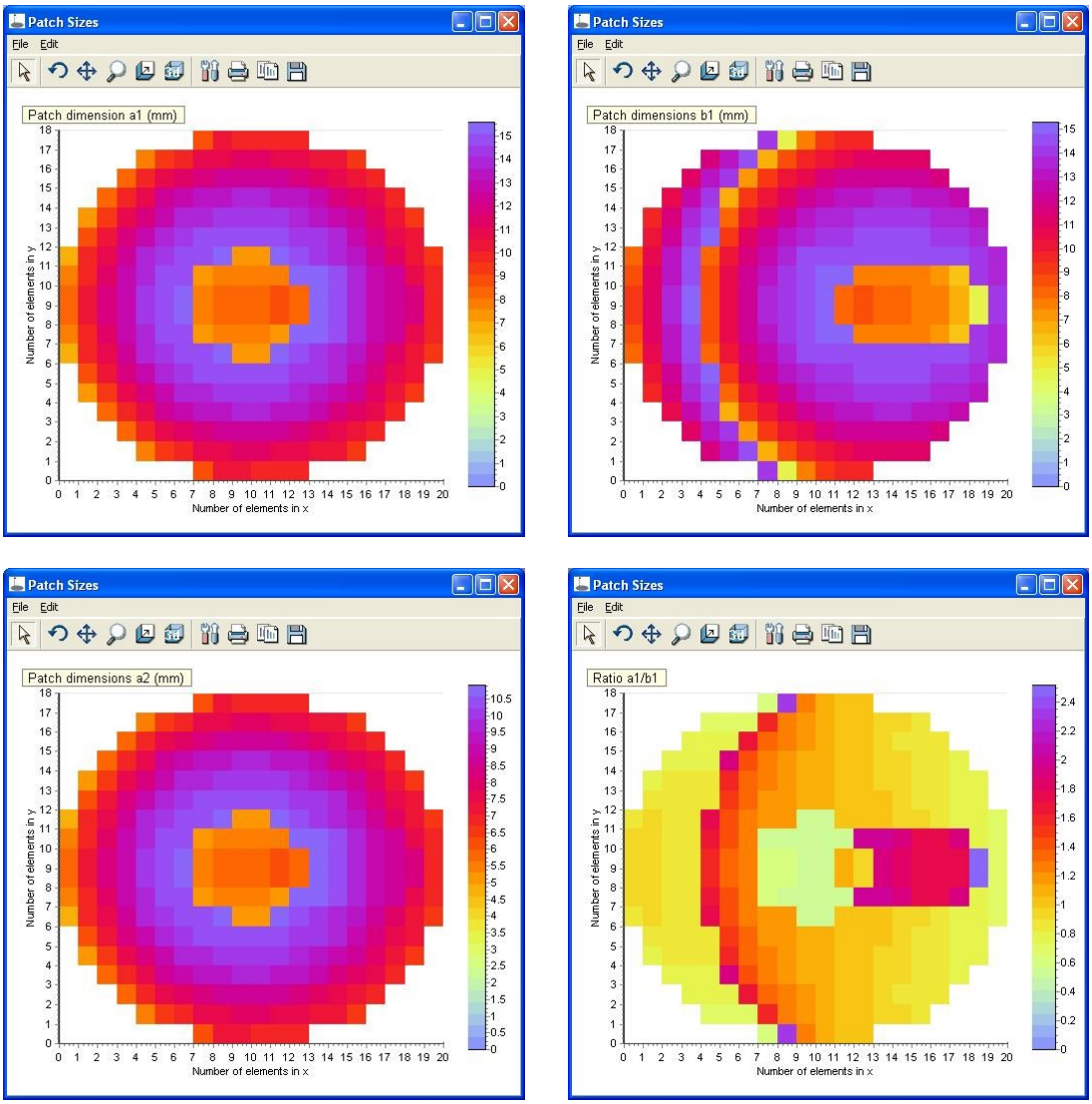
This option opens two windows to show graphically the error in phase difference in degrees, for X and Y polarization, repectively.



All available options in these windows are identical to this.

8.4 Patch Sizes

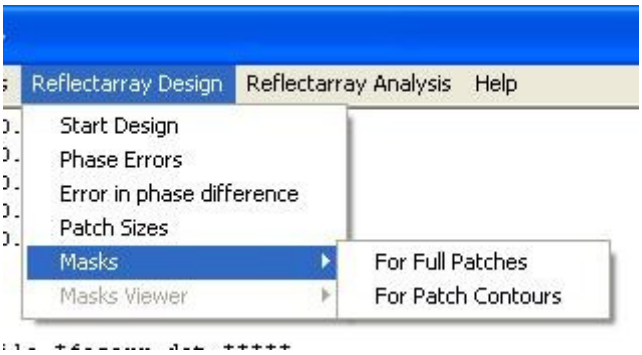
This option runs the external application **PatchSizes**, and the **patch_sizes.dat** file will be generated when finished. Then, two Windows will be opened to show graphically the dimensions of patches in milimeters: a1, b1 and a2, and also the relative dimension a1/b1.



All available options in these windows are identical to this.

8.5 Masks

This option provides another options:



Both of them run the external application **Masks**, this generates the **layer1.scr**, **layer2.scr** y **layer3.scr** files, depending on the number of layers selected in the Preliminary Design form.

8.5.1 For Full Patches

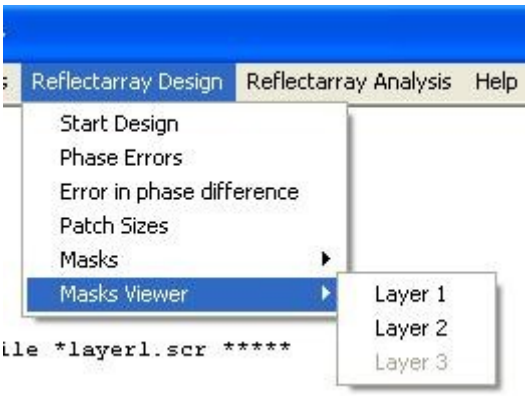
This option generates an autocad script with information about filled patches, in every one of the generated files.

8.5.2 For Patch Contours

This option generates an autocad script with information about contour of patches, in every one of the generated files.

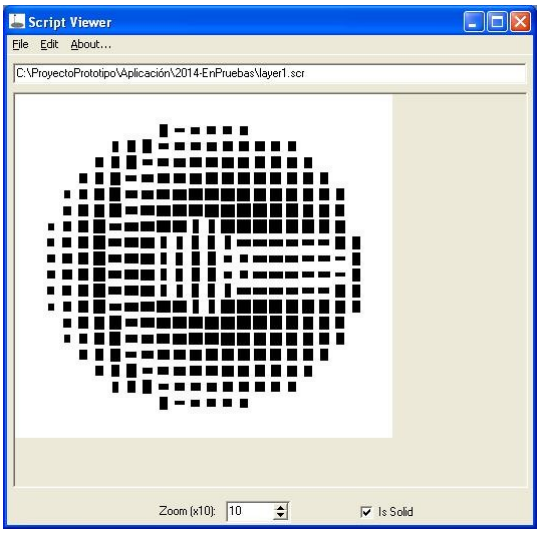
8.6 Masks Viewer

This option provides another options:



8.6.1 Layer 1

This option allows the graphical visualization of all patches for layer 1, their sort of information depends on the Masks option previously chosen.



8.6.2 Layer 2

This option allows the graphical visualization of all patches for layer 2, their sort of information depends on the Masks option previously chosen.

All available options in this window are identical to Layer 1 ones.

8.6.3 Layer 3

This option allows the graphical visualization of all patches for layer 3, their sort of information depends on the Masks option previously chosen.

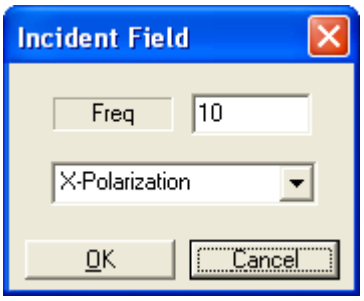
All available options in this window are identical to Layer 1 ones.

9 Reflectarray Analysis

This option provides another options:

9.1 Incident Field

This option opens a form where you can choose the frequency and the polarization required to compute the incident field.

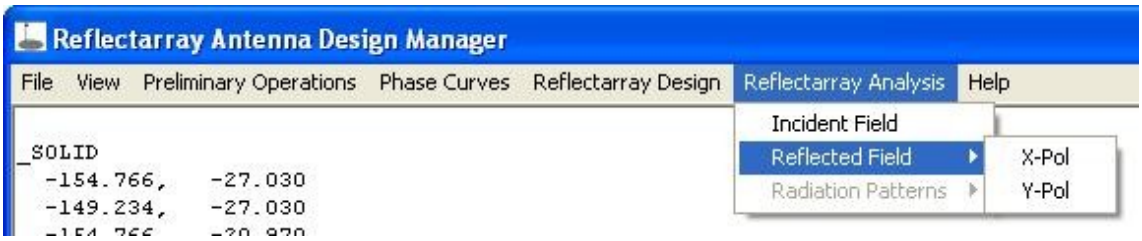


By pushing OK, the external application **FeedCosQ** will be run; it generates the file **eelem.dat**, and then four windows are opened to show graphically the X and Y components of amplitude and phase for X and Y polarization, repectively.

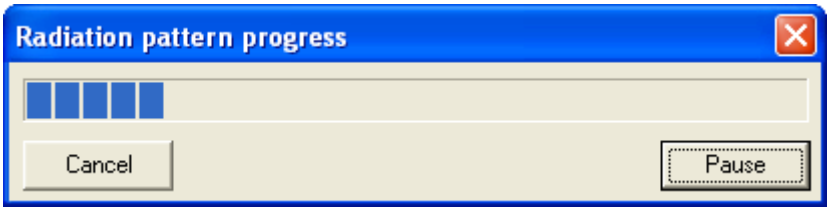
The windows opened are similar to the ones displayed with the option Incident Field mentioned here.

9.2 Reflected Field

This option provides another options:



The first time you use any of this features, the external application **RadPattern** will be run, showing a progress bar about the current status of the operation.

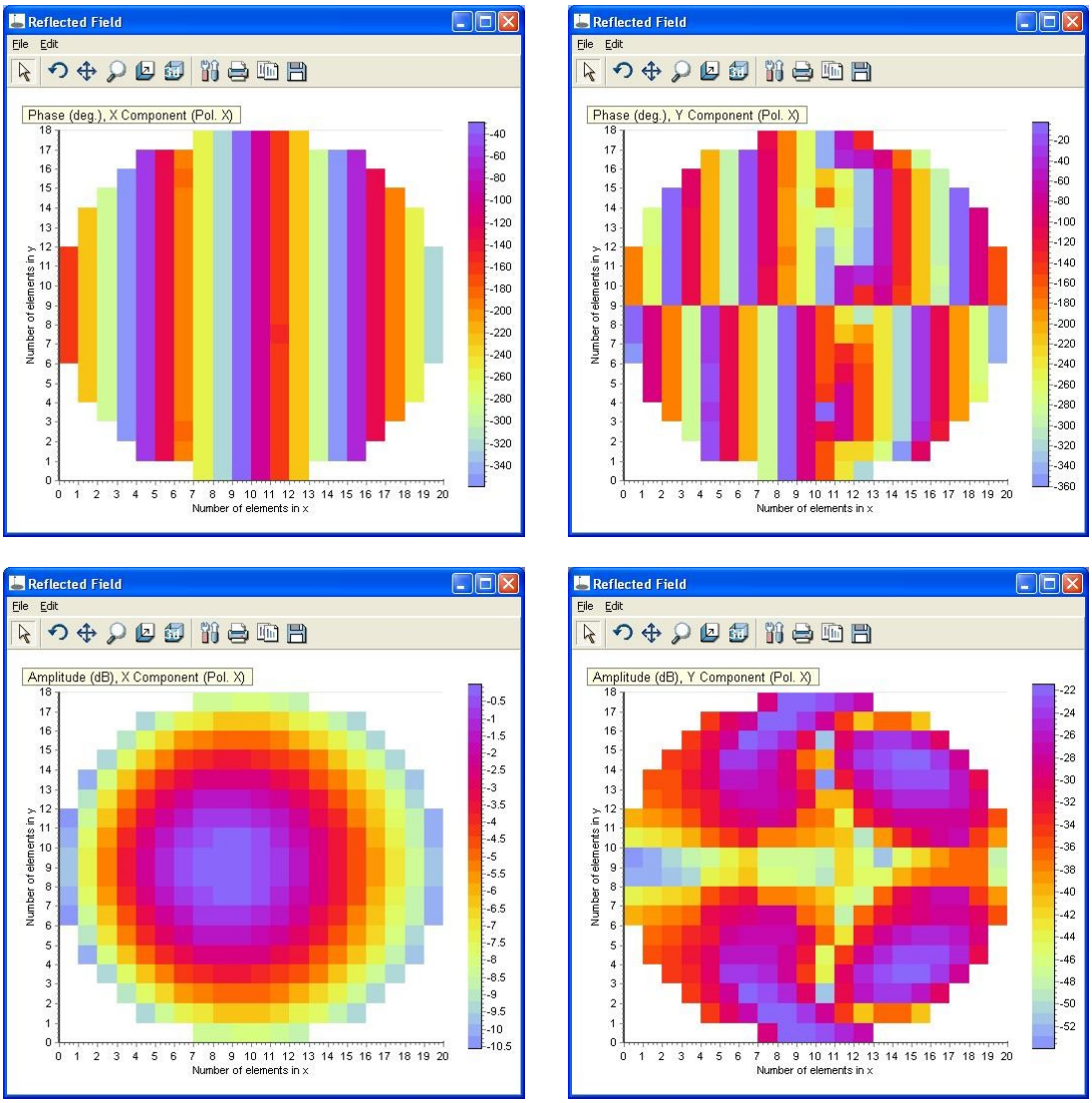


Once the operation has finished, the following files will be generated:

eelem_refl.dat, **ganx.dat**, **gany.dat**, **Refl_E_field_Xpol.grd**, **Refl_E_field_Ypol.grd**, **result2.dat**, **u.dat**, **v.dat**.

9.2.1 X-Pol

This option opens two windows to show graphically the X and Y reflected field components of amplitude and phase for X polarization, respectively.



All available options in these windows are identical to this.

9.2.2 Y-Pol

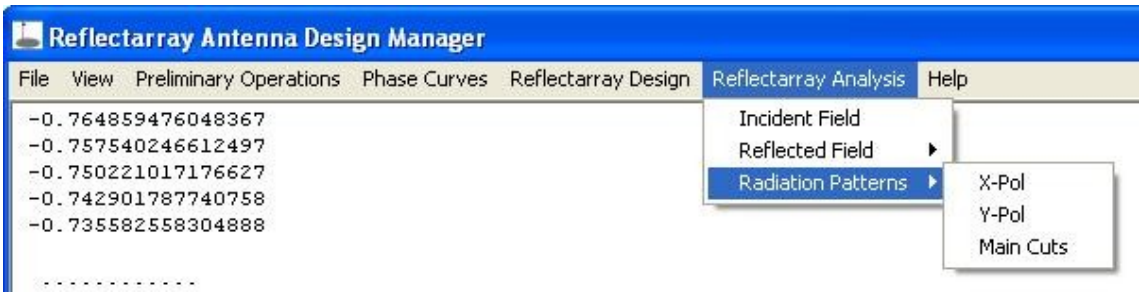
This option opens two windows to show graphically the X and Y reflected field components of amplitude and phase for y polarization, respectively.

Graphics are similar to the ones of the X-Pol option.

All available options in these windows are identical to this.

9.3 Radiation Patterns

This option provides another options:



9.3.1 X-Pol

This option opens four windows, two of them to show graphically the amplitude in dBi of the Copolar and Crosspolar components for X polarization, and the other two show with isobaras the amplitude in dBi the Copolar and Crosspolar components for X polarization.

They are similar to the ones in the option Ideal Radiation patterns.

All available options in these windows are identical to this.

9.3.2 Y-Pol

This option opens four windows, two of them to show graphically the amplitude in dBi of the Copolar and Crosspolar components for Y polarization, and the other two show with isobaras the amplitude in dBi the Copolar and Crosspolar components for Y polarization.

They are similar to the ones in the option Ideal Radiation patterns.

All available options in these windows are identical to this.

9.3.3 Main Cuts

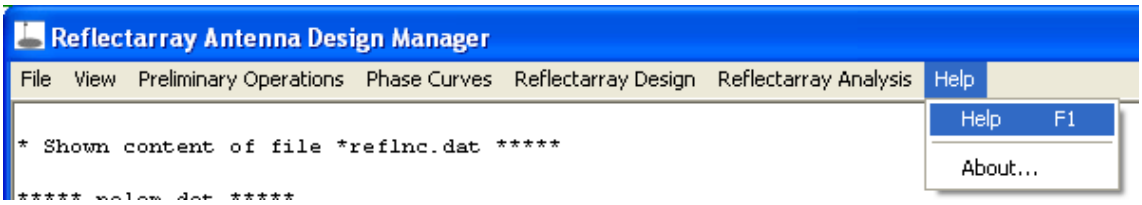
This option opens two Windows to show graphically the elevation (dB) and the azimuth (dB) of the Copolar and Crosspolar components for the chosen polarization of the incident field.

They are similar to the ones in the option Main Cuts.

All available options in these windows are identical to this.

9.4 Help

This option provides several options:



9.4.1 Help

This option opens a pdf file to show a user's manual.

9.4.2 About...

This option opens a form showing the application information.