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User Manual

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Contents

1 Introduction

This document provides information to use the ICARA (Induced Current Analysis of Reflector Antennas) software for the analysis and design of reflector antennas. It has been developed by the Antenna Group at the University of Vigo and it is based on the Physical Optics approximation of the induced currents on the reflector surfaces. Once these currents are determined the electromagnetic fields can be computed both in the far field region and in the aperture zone. The program is able to analyse multiple antenna configurations using single and dual reflector systems. It includes different feed models available whose location can be displaced to carry out a tolerance study.

The program also provides different graphical analysis results and a powerful post process module, including interactive design of excitation arrays, different kind of plotting and sampling methods for fast reconstruction of radiation patterns.

ICARA is composed by a main window and six different modules which will be described in this document. Furthermore, one tutorial example will be presented: a reflector antenna is defined and analysed in ICARA, guiding the user through the different modules needed to perform the analysis and to obtain and to post process the results. More information about the program can be found in [1].

2 Program description

2.1 Main window

By clicking the Icara1.2 icon, upon acceptance of the introductory disclaimer, the initial window is displayed, as shown in Figure 1. Click either the **New** button to start a new project or the **Open** button to load a previously saved project to access the main window, Figure 2.

In the following sections of this manual the different program modules, which can be accessed from this main window by using the corresponding buttons or pop-up menus, will be described.

In summary, the first is to specify the analysis options in the boxes on the left side of the window, selecting PO (Physical Optics) or PO+PTD (Physical Optics + Physical Theory of Diffraction) analysis. The second step is to define an antenna geometry by using the Geometry Configuration module. Then, the surface or the feed can be tilted or displaced by using the Tolerance module or an antenna feed can be directly defined in the Feed Configuration. Next, an electromagnetic analysis is performed by using the PO-Analysis module, obtaining graphic results that the user can post-process in the Post-Processing and saving to ASCII files. In main window the **Edit** buttons in Geometry Configuration or Feed Configuration modules are used in order to modify the configuration parameters.

The different modules of the program can be called not only from the main window but also from the menu bar at the top, where the **Help** menu is used for opening the program documentation and web site.

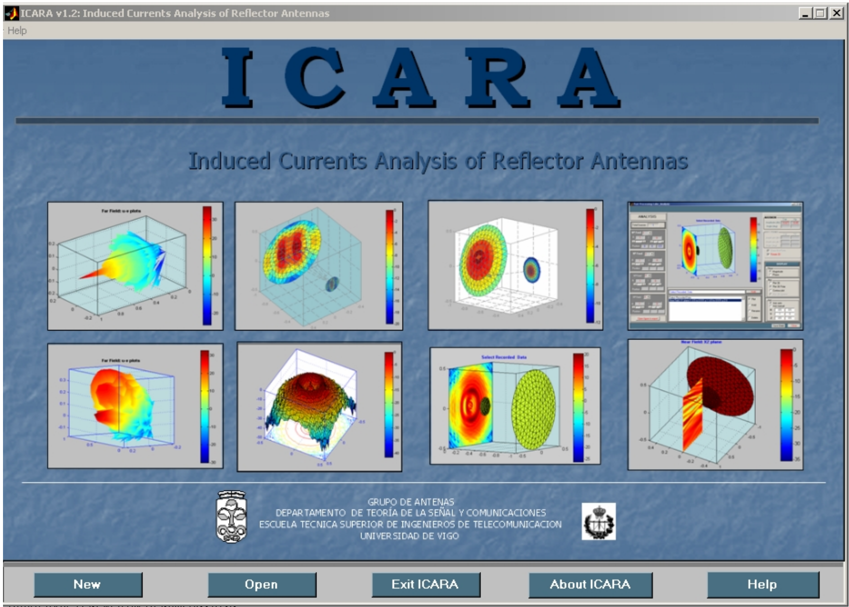


Figure 1: Icara Logo

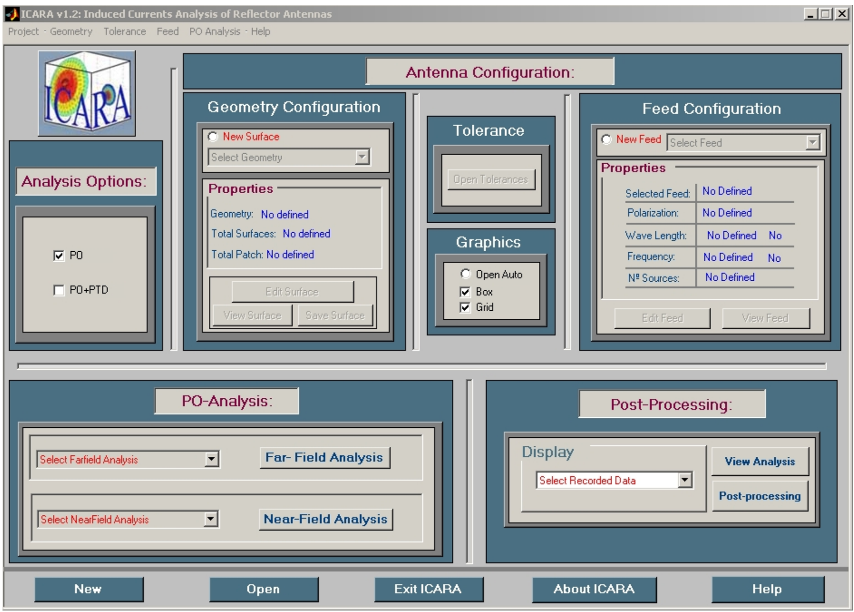


Figure 2: Icara main window

Geometry, feed and results can be saved as projects in order to further analysis perform.

2.2 Geometry Configuration

In Main window, click the **New surface** button and select the desired geometry from the pop-up menu shown in Figure 3. The geometry configuration window will be open.

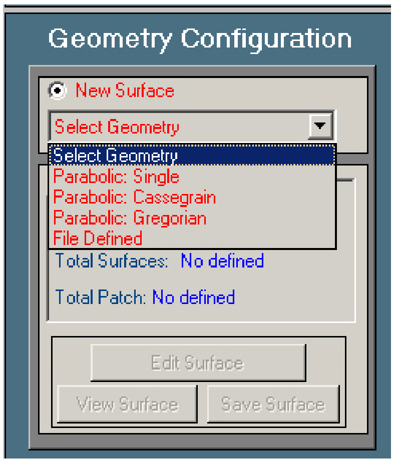


Figure 3: Selecting the geometry

By selecting a **Parabolic**, **Single**, **Gregorian** or **Cassegrain** configuration, the window in Figure 4 will appear. There are three differentiated menus: **Parabolic Main** on the left, **Hyperbolic or Ellyptic subreflector** on the right, and the **Offset plane antenna profile** and **Axis Control** in the middle.

In main reflector section, Figure 4(a), the parameters of the main reflector are configured. Parameters in textboxes can be modified by the user, by configuring **Focal length**, **Offset height** and **Aperture size** in the X and Y axis. Main reflector discretization is controlled with the **Rings** and **Patches** pop-up menus.

The Hyperbolic or Ellyptic subreflector part is only enabled if there are two reflector surfaces. In this section the type of subreflector configuration is selected among **Cassegrain**, **Gregorian**, **Inverse Cassegrain** or **Inverse Gregorian** by using the pop-up menu **Type** in Figure 4(c). It is also possible to configure the **Eccentricity**, **Magnification**, **Interfocal length** and the **Tilt** between the main reflector and subreflector axis, as well as the subreflector discretization, as we did in the **Parabolic Main** part.

The middle section, Figure 4(b), controls the figure axis. It is possible to adjust the representation by selecting **Axis automatic** or **Axis manual** and by modifying the values of Xmin, Zmin and Axis size. The geometry configuration can also be modified by dragging the Hotpoints into the plotted antenna profile.

By selecting **File Defined** in the geometry pop-up menu of Figure 3, window shown in Figure 5 is displayed. In this window and by using the corresponding buttons, a node and a triangle files (formats described in sections 3.1 and 3.2) are loaded. If a geometry with two surfaces is needed, the subreflector must be loaded first, then click the **Add Second Surface** button to load the main reflector. Furthermore, the feed position and the

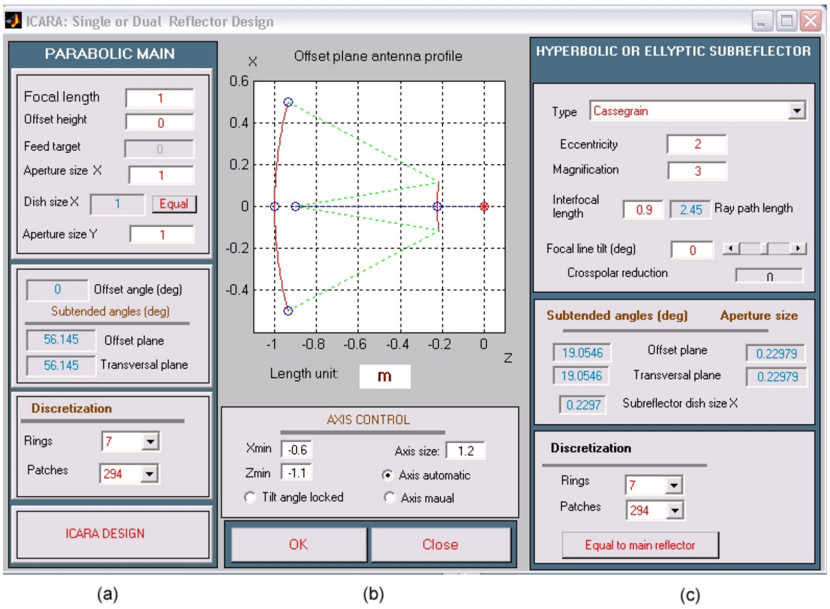


Figure 4: Geometry Configuration. (a) Main Reflector Configuration (b) Axis Configuration and Hotpoints (c) Subreflector Configuration

target point (any point selected by the user at feed axis) can be modified, bearing in mind that for two surface geometries this parameters must be adjusted before loading the main reflector.

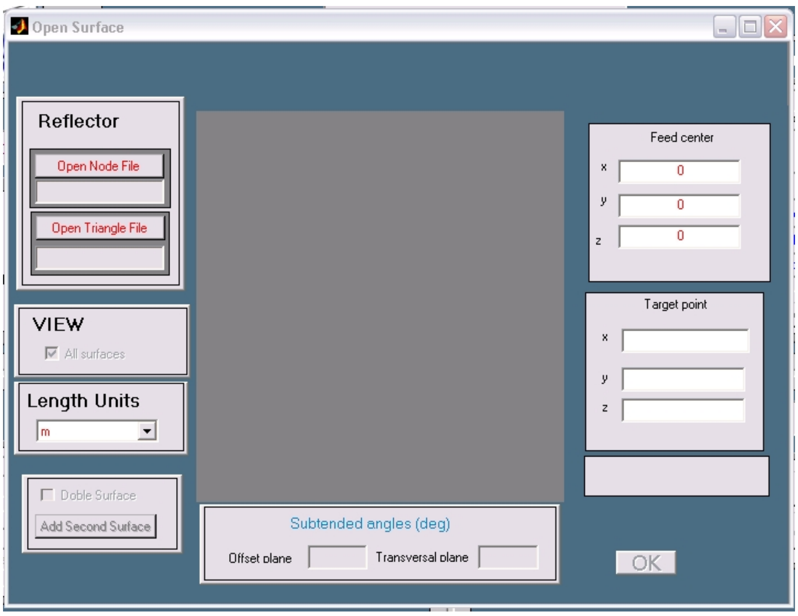


Figure 5: Open Surface

Once the geometry is configured, a summary of the current selection will be shown in main window, Figure 6. From this window it is possible to edit, view or save the defined surface by clicking the corresponding buttons.

The saved files will have the file structure defined in this document (Sections 3.1 and 3.2).

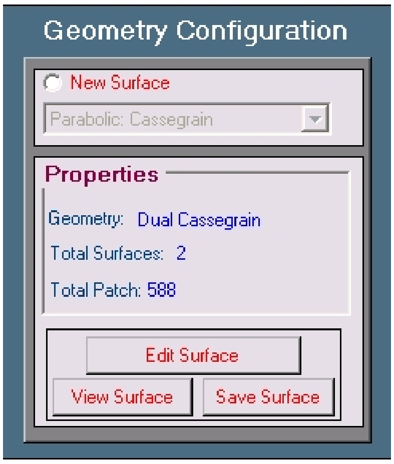


Figure 6: Geometry Summary

2.3 Tolerance

In this module, shown in Figure 7, the surfaces and feed positions are controlled and modified.

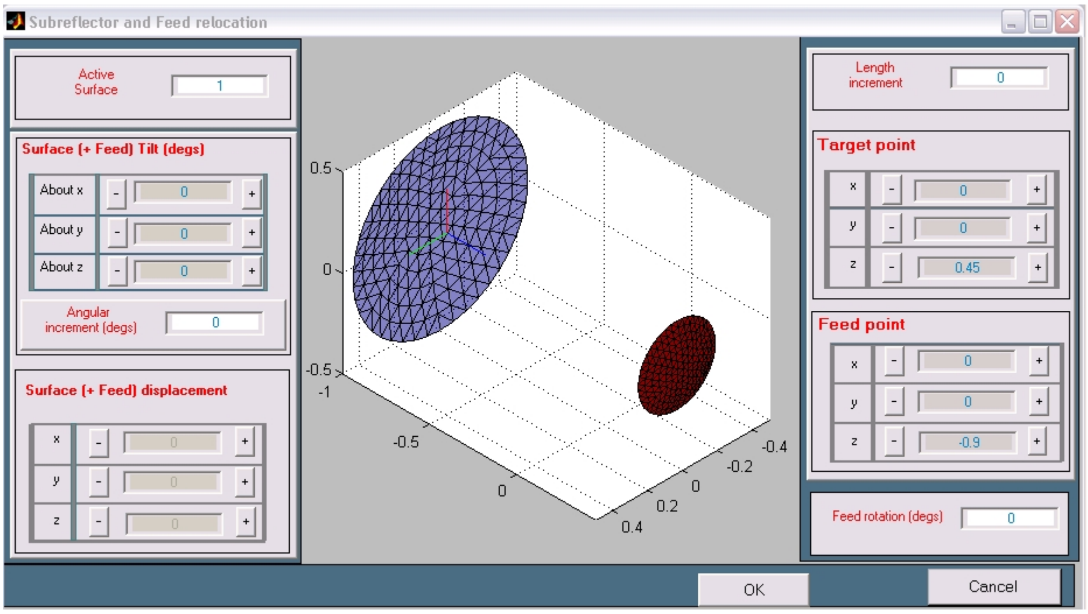


Figure 7: Tolerances Module.

In the **Active Surface** box, the surface to modify is selected if there is more than one. Then, in first place the length and angular increments must be set in their corresponding textboxes. Next, by using the **Surface (+Feed) Tilt** and the **Surface (+Feed) displacement** menus the active surface and feed can be displaced and rotated. Furthermore, by using the menus on the right, **Feed Point** and **Target Point** the feed position and the target point on the surface are modified. Finally, it is possible to rotate the feed axis by writing in the **Feed rotation** textbox the desired rotation angle in degrees. All the results of the displacements will be shown in the plotting. By clicking **Ok** button all data points are stored replacing the old values for further analysis.

2.4 Feed Configuration

By clicking **New Feed** radiobutton and by using the pop-up menu **Feed Configuration Module** in main window four different feed models can be chosen, with different associated windows:

1. Cos-q. This feed implements an ideal far field cos-q model with control parameters shown in Figure 8. In **Source** menu the electromagnetic properties of the feed, **Polarization** and **Wavelength / Frequency**, are adjusted. The **Feed** menu allows to relocate the feed and the target point previously defined on the reflector surface. Finally it is possible to adjust the cos-q taper parameters, seeing the resulting surface illumination in the plotting. For the taper and spillover calculations the corresponding subtended angles between the reflector and the feed of Figure 4 are taken into account.

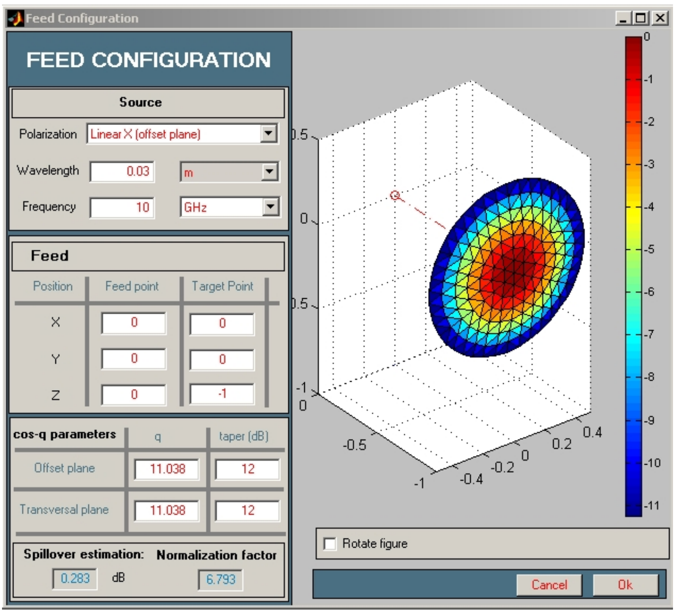


Figure 8: Cos-q Feed Module.

2. Cos-q Array. The control parameters are the same that in the cos-q feed, but now the **Add New** button shown in Figure 9 allows to obtain an array by adding new cos-q elements. The working frequency and polarization will be the same for every array element but their position and taper parameters can be different. It is possible to choose among the existing elements by writing their number in the textbox in the **Feed** menu.

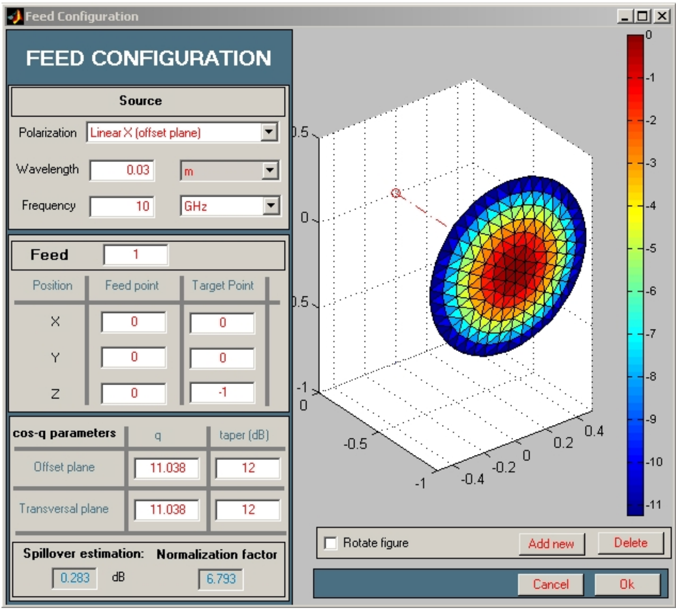


Figure 9: Cos-q Array Feed Module.

3. Feed File. This option allows to load a user defined feed into the program by using a file containing the feed radiation far field pattern, conforming to the file structure defined in this document (Section 3.3). To load the file click the **Open Feed File** button and then pick it. If the format is correct, the **Compute Gain** button will be activated and, by clicking it, the field distribution on the illuminated surface is calculated and plotted. Finally, select the feed polarization and frequency.

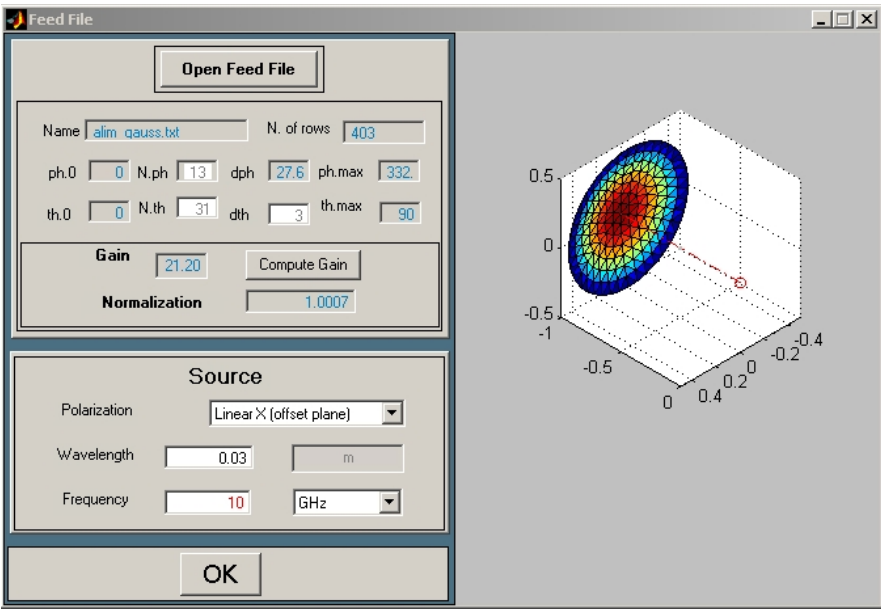


Figure 10: Feed File Module.

4. Aperture. With this option it is possible to configure a radiating aperture modeling, for example, a horn antenna. It is remarkable that this feed model is not restricted to far field assumptions.As a consequence this model should be selected if the first surface is not in the far field region of the feed. In Figure 11 the associated window is presented.

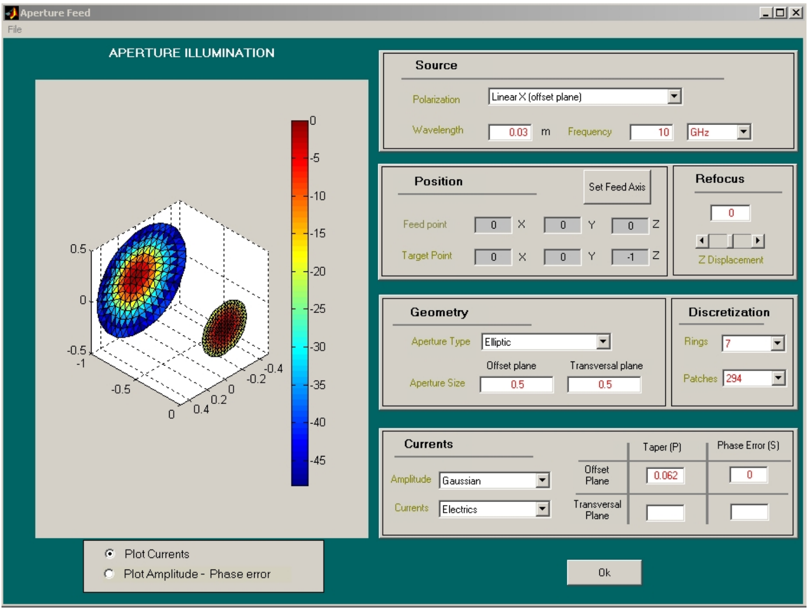


Figure 11: Aperture Feed Module.

At the top of the window the wave wavelength/frequency and polarization are configured. By using the **Refocus** button it is possible to displace the aperture along from the feed reference the pointing axis defined between the feed and the target points. With the **Geometry** menu the physical shape of the aperture is defined, setting whether it is elliptical or rectangular and its size in the offset and transversal planes. The **Discretization** menu is used in order to adjust the number of patches used for the aperture integration algorithm, which must be modified depending on the analysis frequency to ensure adequate analysis specially when first surface is not in the far field region.

The menu at the bottom of the figure adjusts the currents distribution on the radiating aperture following a Gaussian or Cosine function, as described in Appendix A. The Gaussian distribution is only available to the elliptical aperture. With the **Taper** and **Phase** Error the parameters of the selected distribution are controlled. For the PO approximation analysis it is possible to use electric currents, magnetic currents or both by means of **Currents** pop-up. Concerning the aperture illumination plotting, the available radiobutton is used to select between two different representations: the normalized fields on the reflector and the aperture or only the normalized field amplitude and phase on the reflector surface.

In order to offer a more realistic modeling, this feed model also allows repositioning and rotation of the feed by using the **Set Feed Axis** button, which is shown in n Figure 12. By assigning values to the control parameters in this window, it is possible to relocate the feed and target point, as well as to define the **Zf** axis, which is the pointing line between the aperture and the reflector surface. It is also possible to rotate the feed axis in order to correct the polarization vector. Then, the resulting feed and target points are shown in the Aperture main window.

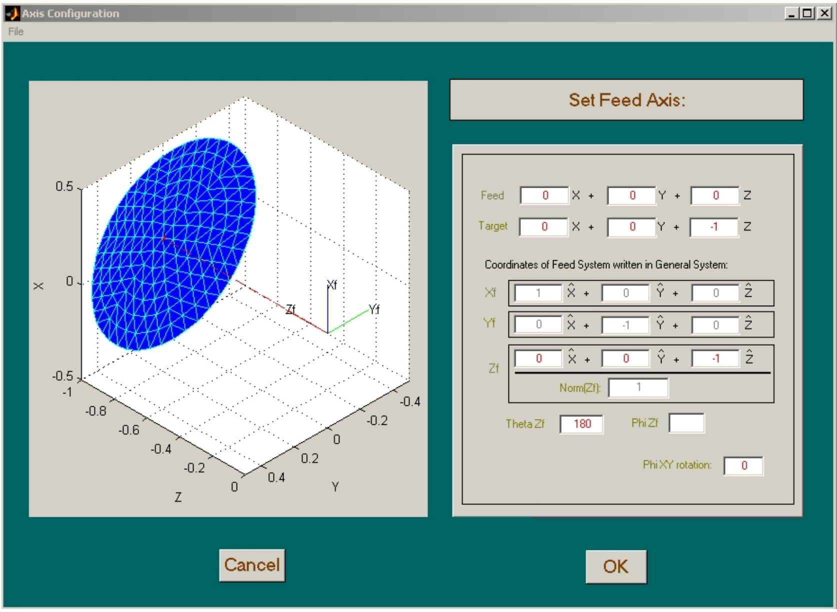


Figure 12: Axis Aperture.

2.5 PO-Analysis

In the corresponding main window menu, Figure 13, the type of PO (Optical Physics) Analysis is selected between two possibilities: far or near field.

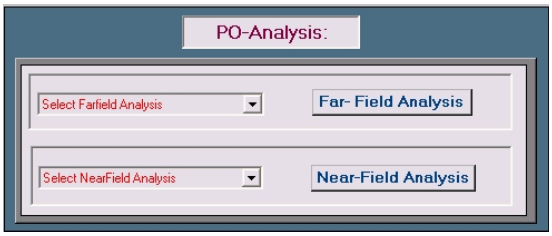
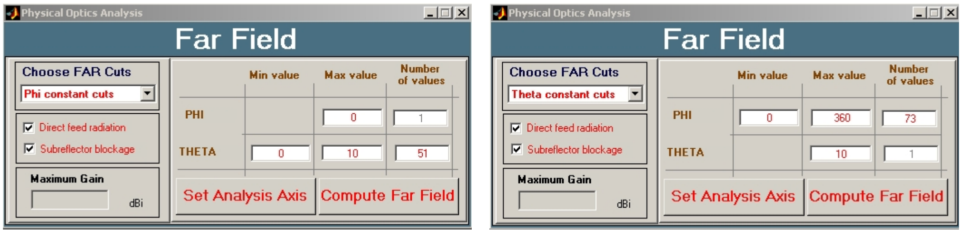


Figure 13: PO-Analysis Menu.

- For the **Far Field** option we can choose among the following type of cuts. Phi or Theta constant cut: this plotting shows a constant cut at theta or phi angles. The initial and final angles for the theta or phi cut are defined in the corresponding textboxes. In the other textbox only one angle value for all the cut points must be introduced. Finally, it is necessary to define the desired number of analysis points in the remaining textbox. If a double reflector configuration is defined, it is possible to compute or not the direct feed radiation and the subreflector blockage by using the corresponding checkboxes on the left, Figure 14.



(a) (b)

Figure 14: (a) Phi constant cut (b) Theta constant cut

- U-V plots: this plotting allows to calculate a U-V cut for the antenna far field, by defining $U = sin(\theta)\ cos(\phi)$ and $V = sin(\theta)\ sin(\phi)$.

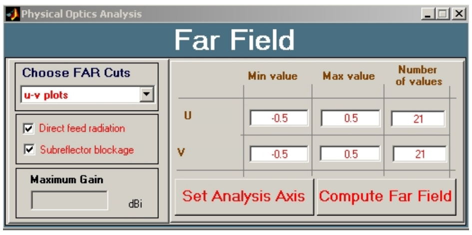


Figure 15: U-V cut.

The initial and final values of U and V for the cut are defined in the corresponding textboxes, Figure 15. For each direction the user must select the number of values to calculate. Like in the previous cut, the program allows to compute or not the direct feed radiation and the subreflector blockage when a double configuration is analysed.

After selecting the far field cut, the antenna farfield axis can be changed by using the **Set Analysis Axis** button which starts the window in Figure 16. This window allows to redefine the antenna coordinates system in general system by setting the antenna pointing vector and by rotating the system in phi and theta angles. Then, the system results are shown in the plotting, where the antenna is represented by a black dot in the space and it is possible to observe the axial displacements.

By selecting **Near-Field Analysis**, there are available two kind of plotting:

- Cut in an Axis: this plot shows the near field in X, Y or Z axis. The user must select in the pop-up menu, **Sample X axis**, **Sample Y axis** or **Sample Z axis**. Then, we can modify the minimum and maximum values for the corresponding analysis. Furthermore, we can adjust the values of the other two components in order to define the analysis line in the near field space. Parameters are shown in Figure 17.

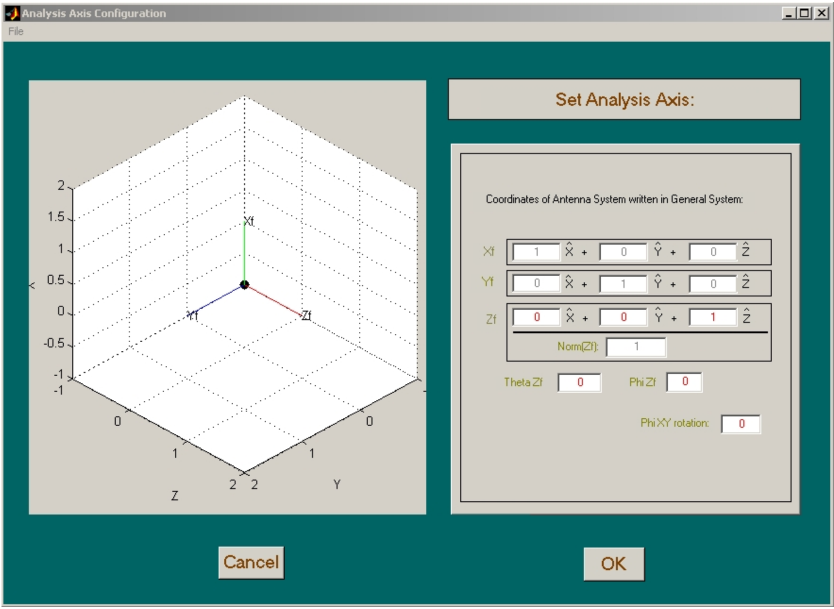


Figure 16: Farfield Axis.

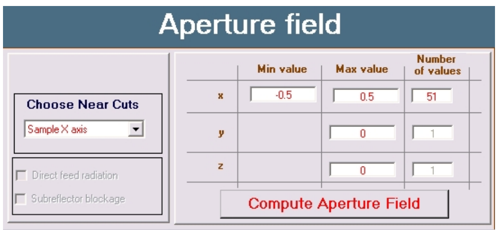


Figure 17: Aperture Field Analysis, Sample X axis.

- Cut in a Plane: this plot shows the near field in a constant plane. The user must select in the pop-up menu **XY plane**, **XZ plane** or **YZ plane**. Then, it is possible to modify the minimum and maximum values for the two plane components and to adjust the value of the other component in order to determine the selected plane, as seen in Figure 18.

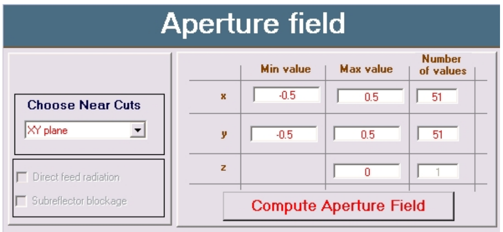


Figure 18: Aperture Field Analysis, XY plane.

Once the cut parameters are configured, and by clicking the **Compute Far Field** button or **Compute Aperture Field** button the analysis process is started. It can take several minutes depending on the surface and analysis parameters. Once the analysis is done, a window with the results will appear.

2.6 Post-Processing

After finishing the selected PO analysis, the program shows automatically the plotting window, allowing to plot the analysis result or the fed surface. To post process the results the user must click the **Hold** button in order to save the analysis and then to click the **Lobe Analysis** button to start the Post-Processing window shown in Figure 19.

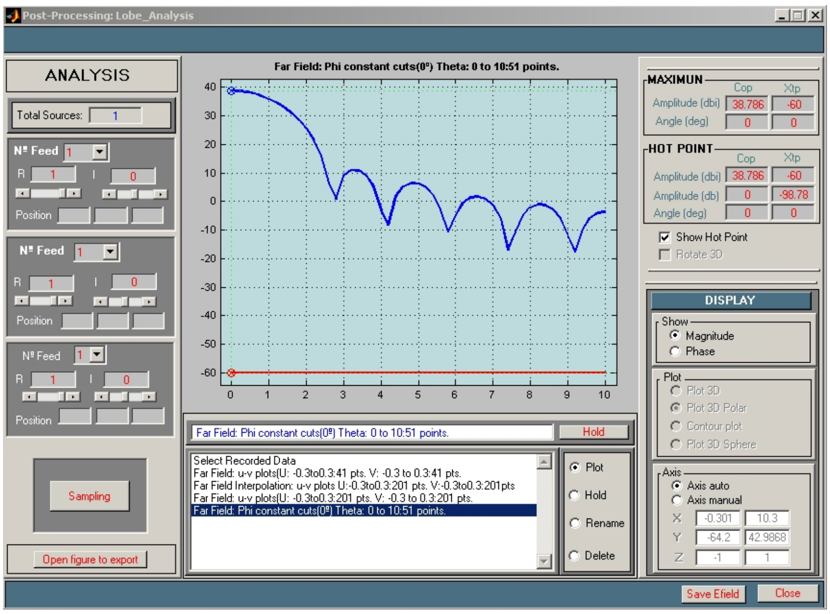


Figure 19: Post-Processing Window.

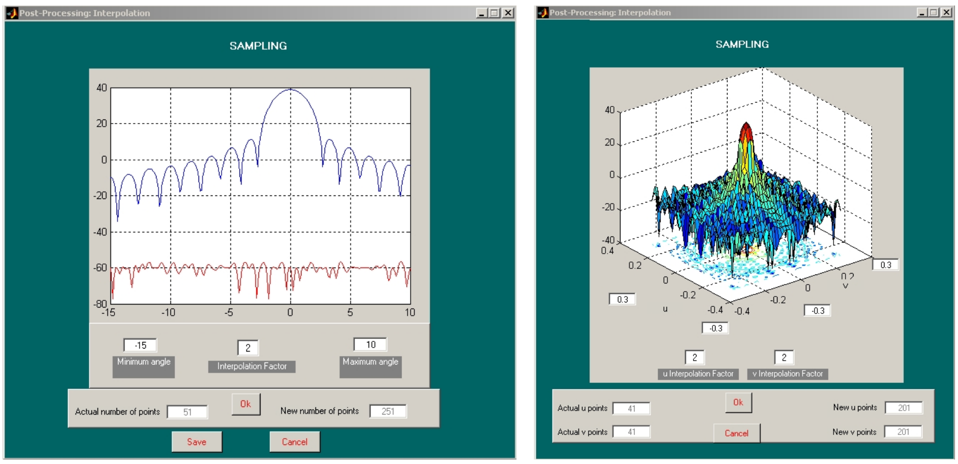
This module can also be started, if we already have a stored analysis result, by clicking the **Post-Processing** button in main window.

In window centre there is a listbox storing the saved analysis that can be administrated with the **Plot**, **Hold**, **Delete** and **Rename** commands. With the **Display** menu the plotted patterns are controlled, displaying magnitude or phase and allowing the selection between different kinds of plots. If the feed is a cos-q array, the **Analysis** menu on the left can be used to evaluate the pattern when the array amplitudes are changed. It is also possible to export and save the results as a figure with the **Open figure to export** button or as a text file with the format described in section 3.4 by using the **Save Efield** button on the right. Finally, with the **Sampling** button the interpolation module is started.

2.7 Sampling

The **Sampling** button in the **Post-Processing** window starts the **Sampling** module of the program, loading the selected analysis into one of the two windows shown in Figure 20, depending on the performed farfield analysis (1D or 2D). It is important to consider the next points:

- For using this sampling module a farfield PO analysis with an odd number of points is needed.
- It is strongly recommended to analyse the entire main lobe of the pattern before using the sampling option in order to achieve a result as accurate as possible.



(a) 1D sampling window (b) 2D sampling window

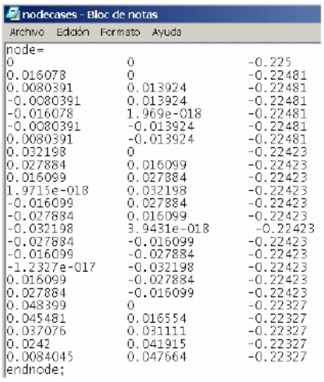
Figure 20: Sampling windows

The controls in the two windows have the same features: the textboxes around the figure control the margin for the interpolation and by using the **Interpolation factor** button the resulting number of points after the interpolation process is adjusted. With the **Ok** button the interpolated pattern is calculated. Then, for the 1D sampling the user must click the **Save** button to store the new pattern. However, for the 2D version, the result is directly transferred to the **Post-Processing** window, in order to save plotting time in the sampling module.

3 I/O file structure

3.1 Node Files (Input/Output)

In Figure 21 the node file structure is presented. The node file must start with the `node=` label. Then, it continues with three columns identifying the value of the XYZ coordinates for each point of the reflector surface. Each row represents a point. The end of the file is marked by the `endnode;` label.


nodecases - Bloc de notas

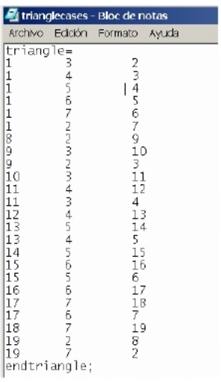
Archivo Edición Formato Ayuda

```
node=
0              0              -0.225
0.016078       0              -0.22481
0.0080391      0.013924       -0.22481
-0.0080391     0.013924       -0.22481
-0.016078      1.969e-018     -0.22481
-0.0080391     -0.013924      -0.22481
0.0080391      -0.013924      -0.22481
0.032198       0              -0.22423
0.027884       0.016099       -0.22423
0.016099       0.027884       -0.22423
1.9715e-018    0.032198       -0.22423
-0.016099      0.027884       -0.22423
-0.027884      0.016099       -0.22423
-0.032198      3.9431e-018    -0.22423
-0.027884      -0.016099      -0.22423
-0.016099      -0.027884      -0.22423
-1.2327e-017   -0.032198      -0.22423
0.016099       -0.027884      -0.22423
0.027884       -0.016099      -0.22423
0.048399       0              -0.22327
0.045481       0.016554       -0.22327
0.037076       0.031111       -0.22327
0.0242         0.041915       -0.22327
0.0084045      0.047664       -0.22327
endnode;
```

Figure 21: Nodes File

3.2 Triangle File (Input/Output)

Figure 22 shows the triangle file structure.


trianglecases - Bloc de notas

Archivo Edición Formato Ayuda

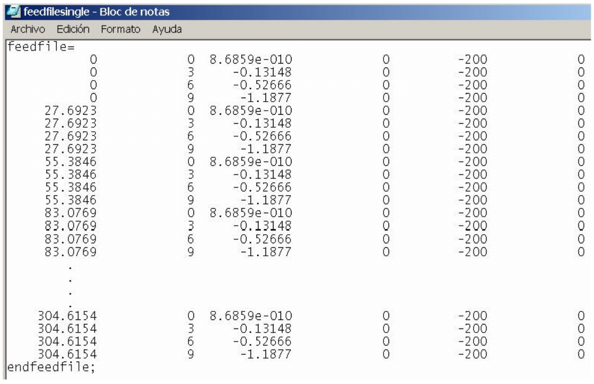
```
triangle=
1     3     2
1     4     3
1     5     4
1     6     5
1     7     6
1     2     7
8     2     9
9     3     10
9     2     3
10    3     11
11    4     12
11    3     4
12    4     13
13    5     14
13    4     5
14    5     15
15    6     16
15    5     6
16    6     17
17    7     18
17    6     7
18    7     19
19    2     8
19    7     2
endtriangle;
```

Figure 22: Triangles File

The file must start with the `triangle=` label. Then, it continues with the points composing each triangle, that is, each row has three integer values corresponding with the number of the points (defined in the node matrix) forming the triangle. The points composing a triangle are always written in the same way, either clockwise or anti-clockwise. The end of the file is marked by the `endtriangle;` label.

3.3 Feed File (Input)

Figure 23 shows the feed file structure. It starts with the `feedfile=` label. Then, it continues with six columns:




```
feedfile=
        0   0  8.6859e-010   0   -200   0
        0   3     -0.13148   0   -200   0
        0   6     -0.52666   0   -200   0
        0   9      -1.1877   0   -200   0
  27.6923   0  8.6859e-010   0   -200   0
  27.6923   3     -0.13148   0   -200   0
  27.6923   6     -0.52666   0   -200   0
  27.6923   9      -1.1877   0   -200   0
  55.3846   0  8.6859e-010   0   -200   0
  55.3846   3     -0.13148   0   -200   0
  55.3846   6     -0.52666   0   -200   0
  55.3846   9      -1.1877   0   -200   0
  83.0769   0  8.6859e-010   0   -200   0
  83.0769   3     -0.13148   0   -200   0
  83.0769   6     -0.52666   0   -200   0
  83.0769   9      -1.1877   0   -200   0
        .
        .
        .
        .
 304.6154   0  8.6859e-010   0   -200   0
 304.6154   3     -0.13148   0   -200   0
 304.6154   6     -0.52666   0   -200   0
 304.6154   9      -1.1877   0   -200   0
endfeedfile;
```

Figure 23: Feed File

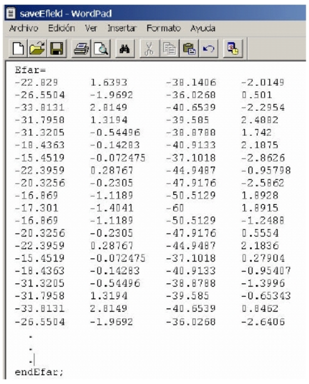
1. Phi angle in degrees.
2. Theta angle in degrees.
3. Module of copolar component in decibels.
4. Copolar phase in radians.
5. Module of contrapolar component in decibels.
6. Contrapolar phase in radians.

It is recommended to dispose of values of ϕ range from 0 to 360 degrees and the of values of θ from 0 to 90 degrees. Otherwise, the program will interpolate the data through the entire angular domain, so the interpolation result could be incorrect. The end of the file is marked by the `endfeedfile;` label.

3.4 Far Field File (Output)

In Figure 24 the far field file structure is presented. The output far field file starts with the `Efar=` label. Then, it continues with four columns:

1. Module of copolar component in decibels.
2. Phase of copolar component in degrees.




```
Efar=
-22.829     1.6393      -38.1406    -2.0149
-26.5504    -1.9692     -36.0268    0.501
-33.8131    2.8149      -40.6539    -2.2954
-31.7958    1.3194      -39.585     2.4882
-31.3205    -0.54496    -38.8788    1.742
-18.4363    -0.14283    -40.9133    2.1875
-15.4519    -0.072475   -37.1018    -2.8626
-22.3959    0.28767     -44.9487    -0.95798
-20.3256    -0.2305     -47.9176    -2.5862
-16.869     -1.1189     -50.5129    1.8928
-17.301     -1.4041     -60         1.8915
-16.869     -1.1189     -50.5129    -1.2488
-20.3256    -0.2305     -47.9176    0.5554
-22.3959    0.28767     -44.9487    2.1836
-15.4519    -0.072475   -37.1018    0.27904
-18.4363    -0.14283    -40.9133    -0.95407
-31.3205    -0.54496    -38.8788    -1.3996
-31.7958    1.3194      -39.585     -0.65343
-33.8131    2.8149      -40.6539    0.8462
-26.5504    -1.9692     -36.0268    -2.6406
  .
  .
  .
endEfar;
```

Figure 24: Far Field File

3. Module of contrapolar component in decibels.

4. Phase of contrapolar component in degrees.

There is a row for each analysed point. The end of file is marked whit the **`endEfar;`** label.

4 Application example

In this section, the user will be guided through the process of definition and analysis of an example configuration using the different modules of the ICARA program.

4.1 Example: Geometry

The analysed configuration will be a Gregorian antenna. Table 1 shows the geometry values.

Table 1: Geometric parameters of the selected configuration

Geometry Configuration	
Type	*Gregorian*
Focal lenght	$f_m = 1.3$ m
Offset height	$H_off = 0.7$ m
Aperture size X	$D_x = 1$ m
Aperture size Y	$D_y = 1$ m
Magnification	$M = 0.5$ m
Interfocal length	$f_s = 0.25$ m
Tilt	$\tau = 0.12$ m

Once the program is opened in main window (section 2.1), first step is to configure the geometry. By clicking the **New surface** button and by selecting **Parabolic: Gregorian** in the pop-up menu, the geometry window is presented. This window must be configured with the values from Table 1. In Figure 25 the final configuration is shown. Then, click the **OK** button to end the surface configuration.

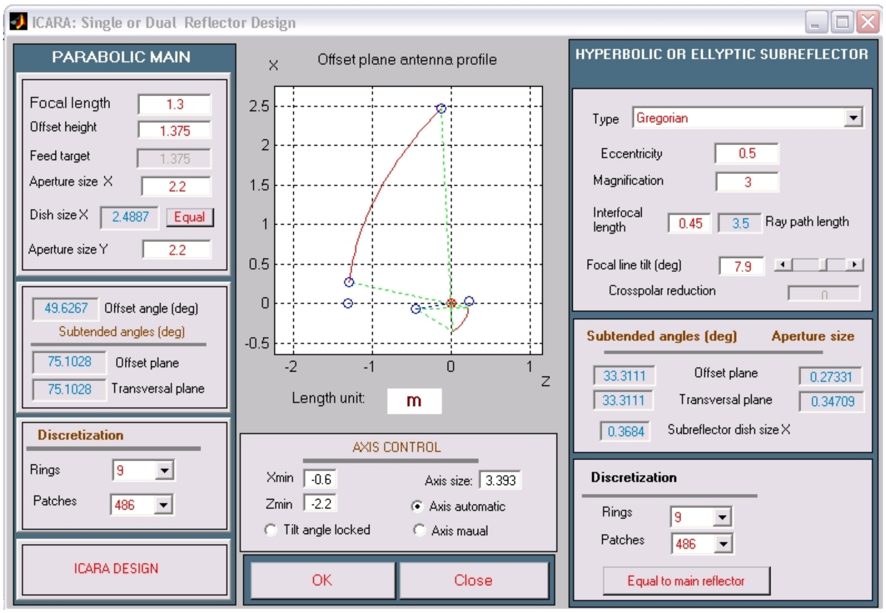


Figure 25: Geometry Configuration.

4.2 Example: Feed

In this example an aperture feed is used. Table 2 shows the feed parameters.

Table 2: Feed parameters of the selected configuration

Feed Configuration	
Type	*Aperture*
Target Point	$(-0.22829, 0, 0.15546)$
Feed Point	$(-0.06185, 0, -0.44573)$
Polarization	*LinearX*
Aperture type	*Elliptic*
Aperture size offset	0.15 m
Aperture size Transversal	0.15 m
Frequency	$f = 8.4$ Ghz
Amplitude currents	*Cosine* m
Currents type	*Electrics*

By clicking the **New Feed** button and by selecting **Aperture** in the pop-up menu, the aperture window is displayed. This window must be configured with the values from Table 2. The final configuration window should look like the one in Figure 26. Finally click the **OK** button. In main window a summary of our configuration is showed.

4.3 Example: PO-Analysis

Now a **Far Field** analysis is developed. It is necessary to click the **Far Field** button and to select the preferences in the new window. In this example a constant phi cut is selected: -35$\leq\theta\leq$5° and ϕ=0°. The Far Field window

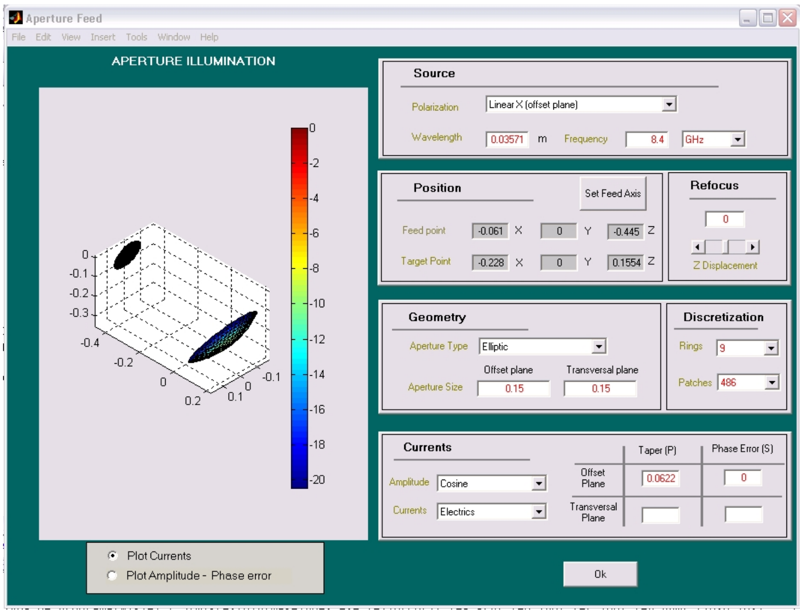


Figure 26: Feed Configuration

must be configured as shown in Figure 27. Then, by clicking the **Compute Far Field** button the results will appear in a new window, Figure 28.

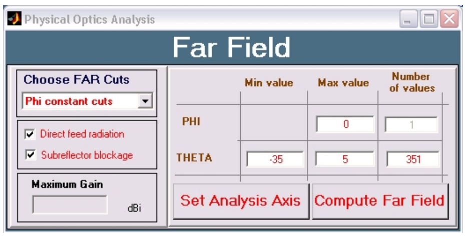


Figure 27: Cut example

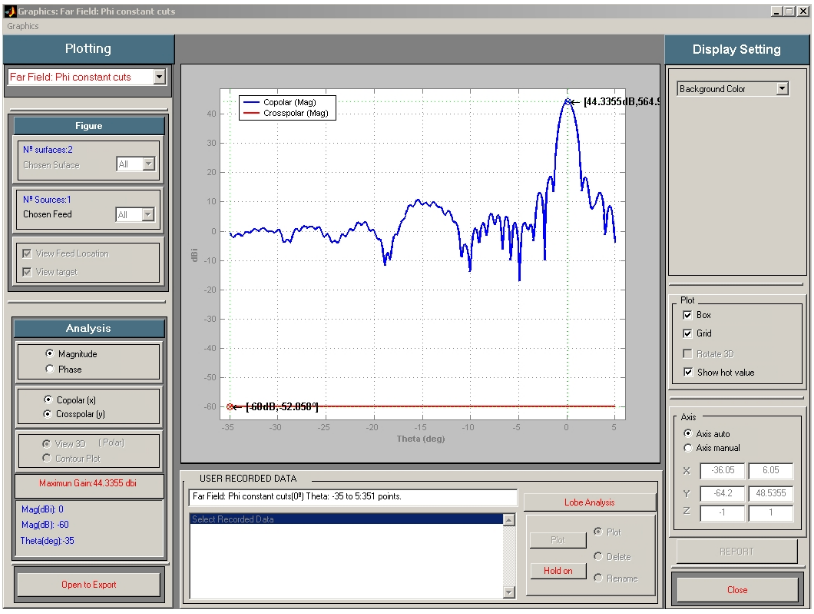


Figure 28: Example result

4.4 Example: Post-Processing

By clicking the **Hold** button the analysis is saved and it can be opened in the Post-Processing window with the **Lobe Analysis** button, Figure 29. Then the results can be analysed and post processed as it has been explained in previous sections.

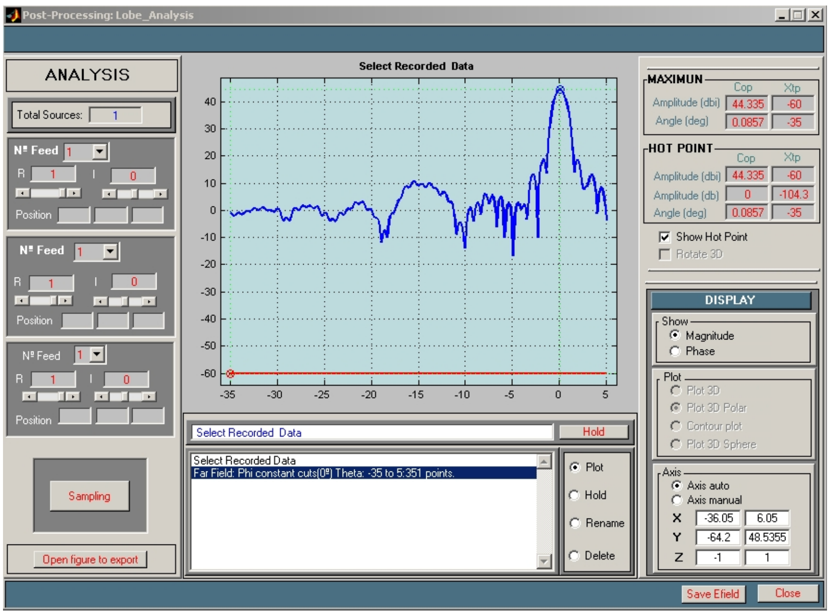


Figure 29: Example result

A Aperture current distributions

Cosine distribution

Ellipitic aperture

$$J(\tau) = p + (1-p)\ \cos\left(\frac{\pi\tau}{2}\right)\ \exp(-j2\pi s\tau^2)$$

Where:

$\tau = \left(\frac{2x}{A}\right)^2 + \left(\frac{2y}{B}\right)^2$

p : amplitude parameter

s : phase error parameter

A, B : aperture offset and transversal sizes

x, y : aperture cartesian coordinates

Rectangular aperture

$$J(x,y) = \left(p_x + (1-p_x)\ \cos\left(\frac{\pi x}{A}\right)\right) \cdot \left(p_y + (1-p_y)\ \cos\left(\frac{\pi y}{B}\right)\right)\ \cdot \exp(-j2\pi\ (s_x x^2 + s_y y^2))$$

Where:

p_x, p_y : amplitude parameters

s_x, s_y : phase error parameters

A, B : aperture offset and transversal sizes

x, y : aperture cartesian coordinates

Gaussian Distribution

$$J(\tau) = \exp(\alpha - j2\pi s)\tau^2$$

Where:

$\tau = \left(\frac{2x}{A}\right)^2 + \left(\frac{2y}{B}\right)^2$

$\alpha = \ln(p)$

p : amplitude parameter

s : phase error parameter

A, B : aperture offset and transversal sizes

x, y : aperture cartesian coordinates

References

[1] J. A. Martínez-Lorenzo, A. G. Pino, I. Vega, M. Arias, and O. Rubinos. Icara: Induced-current analysis of reflector antennas. *IEEE Antennas and Propagation Magazine*, 47(2):92–100, 2005.