GTD

User Manual

V4.9.4

Legal Aspects

Use of the software and of the present software manual is submitted to a license agreement to be accepted before the software installation on a computer.

All suggestion or error concerning the software or this software manual can be sent to:

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FRANCE

GTD USER MANUAL

This Manual describes the GTD application and its integration into the SYSTEMA v4 framework.

For the general usage of SYSTEMA, please refer to the SYSTEMA User Manual

Contents

Introduction

1 Overview

GTD

The **GTD** applications deal with electromagnetism problems:

The **GTD** tool consists of a complete radio-frequency prediction tool for large structure. It is used to propagate the electromagnetism field from the antenna sources to different points of interests such as:

- **other antennas:** to compute the decoupling between them
- **targets:** to evaluate the incoming field and decoupling at a specific location
- **far sphere:** to evaluate the antenna pattern

The propagation of the field is made by a ray-tracing method and uses the Geometrical Theory of Diffraction.

SYSTEMA Interface

GTD is based on the **SYSTEMA** framework allowing building or importing the geometry in a very powerful 3D multidisciplinary framework.

The *Modeler* and *Processing* tabs of **SYSTEMA** are used by **GTD**. The others (trajectory, Kinematics and Mission) are not.

2 Process

General Process

In order to perform an analysis, all the required inputs shall be properly set within the **SYSTEMA** environment.

To execute a **GTD** pre-processor module, a **SYSTEMA** v4 geometry associated with a meshing structure shall exist.

The geometry contains the geometrical description of the model plus its physical properties. The geometrical description can be imported from different format (SYSTEMA v3: *SYSEXP* or *SYSBAS* – Mechanical tool: Nastran *bdf* – CAD tool: *Step* AP203 – Other graphical tool: *WRML*) or may be built entirely within the geometrical modeler. This modeler is explained details in the “SYSTEMA User’s Manual”.

The meshing structure converts the geometry to calculation elements called mesh. In the case of **GTD**, it is not necessary to sub-mesh the geometry except in the case of GTD target for which a mapping of results is required (several computation elements are then required on the geometrical element). However, even if no sub-mesh is required, the identification of the shapes by a numbering is always required by the computation. Then the meshing structure is always mandatory for the computation.

Besides the meshing and numbering aspects, the meshing tree contains also additional elements which may be required by the computation. Those “specific items” are used to complete the description given by the geometry or meshing and may also specialize elements. The specific items of **GTD** indicate the antennas and targets properties.

Once the model and meshing have been correctly set, the process can be created in the Processing tab of **SYSTEMA**. The options dedicated to the computation are editable from the process placed on the diagram. It is also possible to modify the location of the outputs from the “Edit” button beside the current specified path, just below the diagram.

3 GTD Introduction

What is GTD

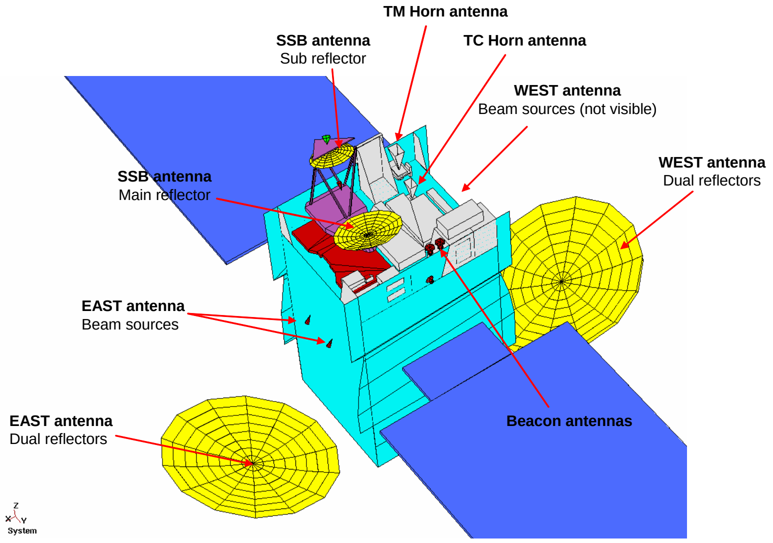
The radio frequency (RF) analysis of satellites is one of many important steps required to ensure a successful mission. For directive antennae, the satellite structure and nearby payloads may often be neglected, but for low-gain antennae and omnidirectional antennae, the structure may influence the radiation characteristics substantially.

Therefore it is of a great interest for these types of antennae, to have the capability to compute the interfered antenna pattern, for an antenna mounted on a satellite structure.

In addition to the antenna pattern, this software enables the calculation of antenna to antenna coupling due to the structure, which is very important for the positioning of antennae, and the study of the electromagnetic compatibility between them. The field computation on surfaces of the structure or on virtual surfaces is also available in this new version.

The RF analysis is based on the Geometrical Theory of Diffraction (GTD) which assumes high frequency. The ray-tracing may be carried out in two essentially different ways. The traditional backward ray tracing determines the ray paths when the source position, the scattering objects and the far field direction are given. Alternatively, the forward ray tracing principles of CAD applications may be applied. A large number of rays are then emitted from the source in all directions and each ray is followed to its final destination. The **GTD** software makes use of this latter efficient and powerful technique.

In this version of the software, multiple reflected rays, as well as multiple diffracted rays are handled for all planed and curved **SYSTEMA** surfaces. The number of reflections and diffractions for a single ray is limited to 2, creeping rays on plane surfaces are also taken into account.



Example of a mechanical model used for the GTD computation

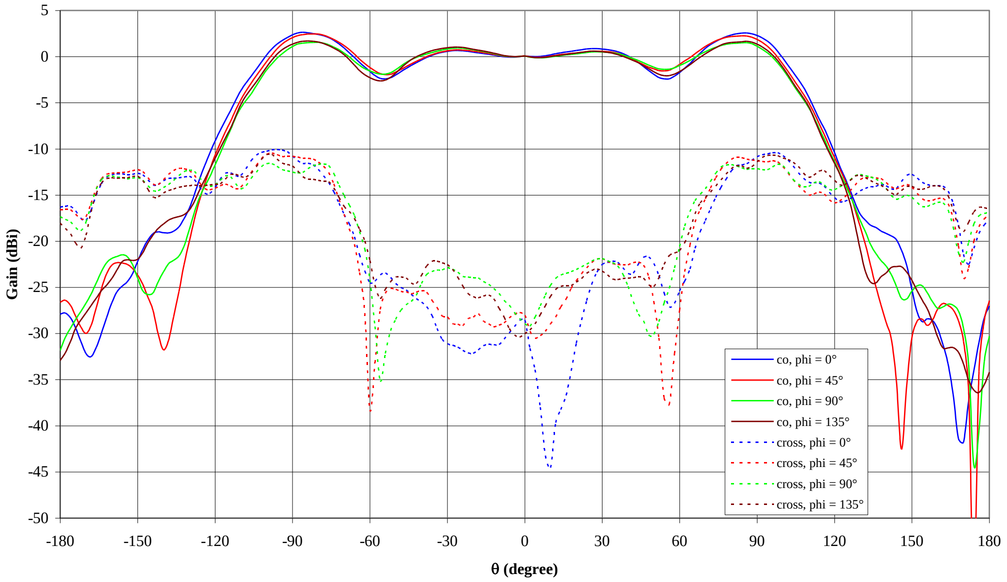
The antenna to antenna coupling allows computing the coupling coefficient between two antennas. In a first step, the “ray tracing” determines the coupling ray paths. In a second step, the coupling value is calculated by field propagation along the rays using a complex or RSS field summation.

GTD offers a great help to the engineer for the RF System analysis like the positioning of antennae on the structure, the detection of interaction problems very early in the program and the prediction of the antenna pattern.

Antennas modelling

The GTD tool is able to model all main antennas currently used on satellites by several means.

It is able to load the measured (or simulated gain) provided by Antenna Supplier under φ cuts format (typically φ = 0°, 45°, 90° & 135° with θ within [-180°; 180°]), or under Spherical Wave Expansion files (SWE). This is particularly well fitted to TCR antennas, Horns and Payload Feeds.



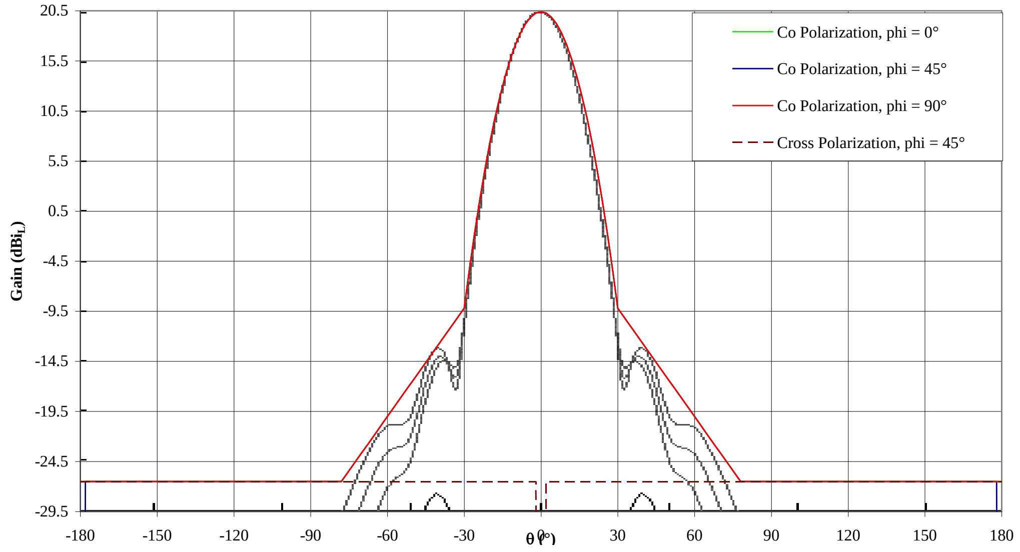
Example of measured gain corresponding to GTD input

It can simulate Reflector Antennas using the parabolic reflectors combined with the measured gain for the Feed. The three classical Reflector Antennas can be modeled under GTD:

- **centered parabolic antennas**
- **Single offset antennas**
- **Gregorian Antennas (hyperbolic sub-reflector approximated by Best Fit Parabola)**

It offers a database of theoretical antennas (half wave dipole, helix antenna, circular & rectangular apertures, standard feeds, cardioids).

For Decoupling Analysis, it integrates Feed envelop modeler, for Main Lobe (Gaussian Part) & back radiation optimization. It also calculates the integrated gain over 4π steradians in view to avoid unrealistic antennas.



Ku-Band Feed gain (measured & envelop)

Overview of the Method

This software is based on the Unified Geometrical Theory of Diffraction (UTD). The GTD is a generalization of the classical geometrical optics theory which enables to convey the phenomena of diffraction by introducing a new kind of rays, the « diffracted » rays. The theoretical aspects of GTD are explained to a great extent in the "Theoretical Background" chapter. The ray tracing from the diffracting elements is performed by applying Keller's diffraction laws. The value of the diffracted field is determined in terms of the initial value of the field on the diffracting element by means of the optical principles of phase variation and energy conservation. This value can be obtained by multiplying the incident field by the diffraction coefficient as derived by Kouyoumjian and Pathak in their Unified GTD.

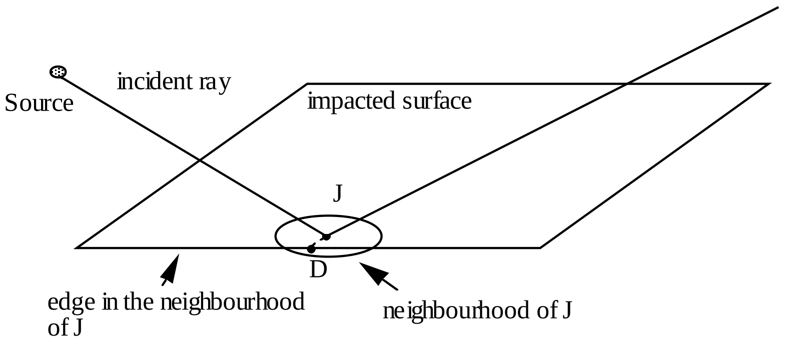
The use of the software consists of three main parts:

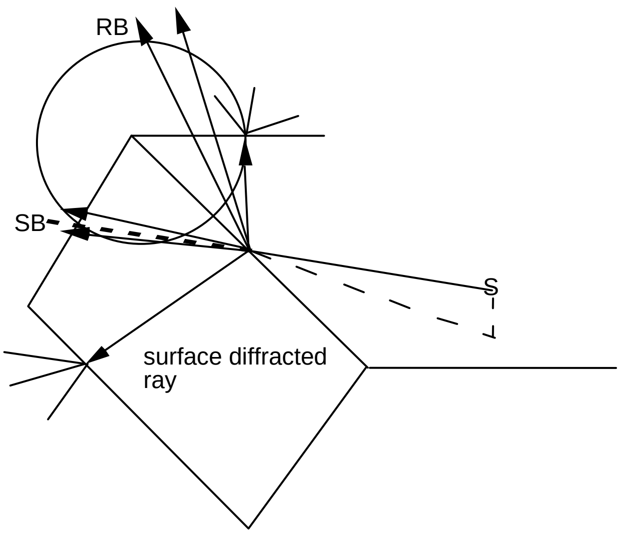
- **The path pre-determination** estimate by a forward ray-tracing the potential paths from the source either to the far field sphere (for far field pattern), to receiving antennas (for antenna to antenna coupling) and to target surfaces (for target field calculations).
- **The path correction** solves the exact interaction positions and ray path from the source to their destinations. This part has been optimized to handle single targets (as antennas or not meshed targets) or multiple targets (meshed targets).
- **The E-Field propagation** computes either the field in the chosen directions (far field calculations), or the coupling between antennae (antenna to antenna coupling), or the field on surfaces (near field calculations) using the ray paths**.**

The GTD Ray-Tracing

The conventional ray tracing used in connection with GTD calculations is based on a backward ray tracing, which is an analytical method by which the possible ray types are checked for existence and when existing the precise ray path to the given far field direction is determined. The main problem of this technique is to have automatically determined all possible ray types without a need for checking an immense number of unrealistic ray types. However, the ray-tracing used in this software is based on a forward ray-tracing where a large number of uniformly distributed rays are emitted from the antenna, which is modeled as a point source. The rays may undergo single or multiple interactions (reflection, diffraction) before they finally reach their final destination. In this version of the software a maximum of 2 interactions can be processed.

The handling of diffraction requires a geometrical analysis to determine when diffraction occurs, and on which edge. Since rays have nearly no chance to hit directly an edge, the software constructs diffracted rays, starting from reflected rays. So each time a surface is hit, starting from the impact point on the surface, the software searches edges. Diffraction may be possible if the impact point is near one or several edges.





A secondary source is created at the diffraction point, from which several rays are re-emitted on the Keller's diffraction cone, propagating in free space. These rays will be close to the reflection and shadow boundaries. Diffracted rays are also cast along the possible plane surfaces common to the edge. These creeping rays, will follow the surface to an opposite edge where a new diffraction occurs. The surface rays are thus only cast when multiple diffractions are specified.

4 GTD Input Model & Meshing

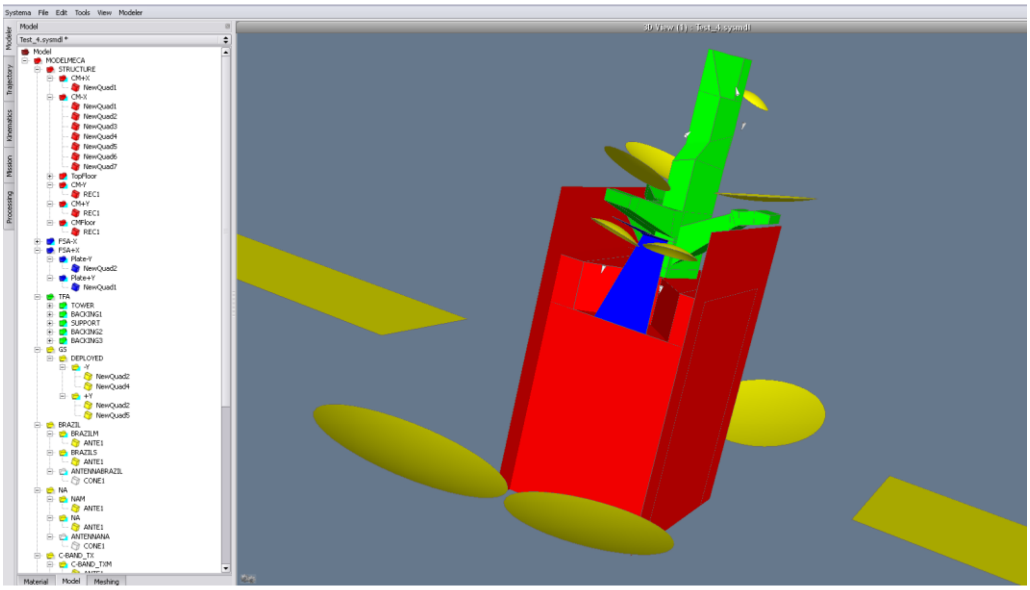
4.1 The GTD Model

Geometry

A **GTD** model is composed of the satellite geometry including the antennas orientations and positioning given by small cones (the origin is the sharp corner of the cone the Z axis gives the main direction and the X axis the 0° cut of the antenna pattern) and/or the target surfaces on which the E-Field or Decoupling is required.

For the construction of the geometry and the geometry interfaces please refer to the **SYSTEMA** User's Manual.

All the shapes proposed by **SYSTEMA** may be used in a **GTD** model except the boolean cuts for which the diffraction on the cutter's edge can be taken into account.



SYSTEMA Model

Applicative Properties

The properties attached to the geometry are the following:

- **Surface property:**

  This property defines if the surface reflects perfectly the electromagnetism waves (*Conductive*), stops the waves (*Absorbent*) or let the wave go through (*Transparent*).

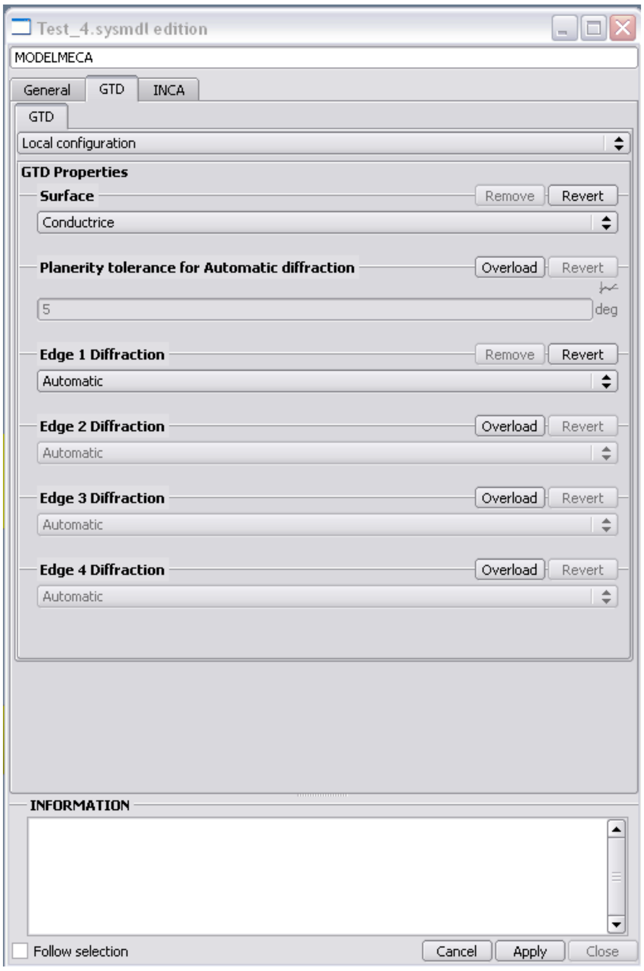
➢ **Planarity tolerance for Automatic diffraction:**

When the *Edge Diffraction* is set to *Automatic*, the edge will not diffract where it has a contact defining a flat angle. The planarity tolerance may be used in that case in order to set the angular tolerance on flat contacts.

➢ **Edge Diffraction:**

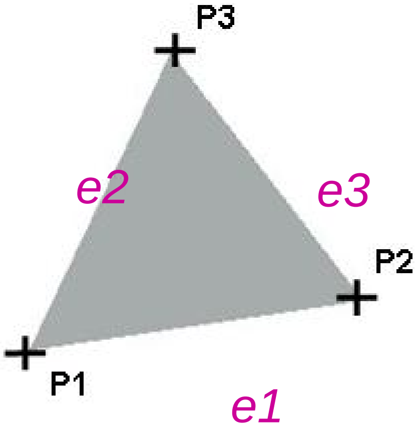
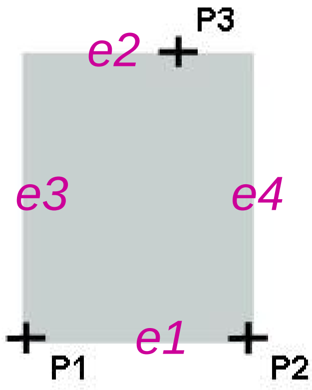
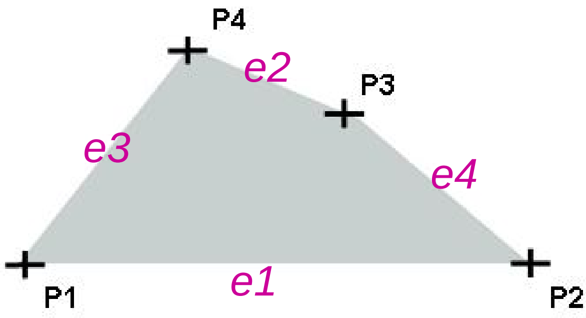
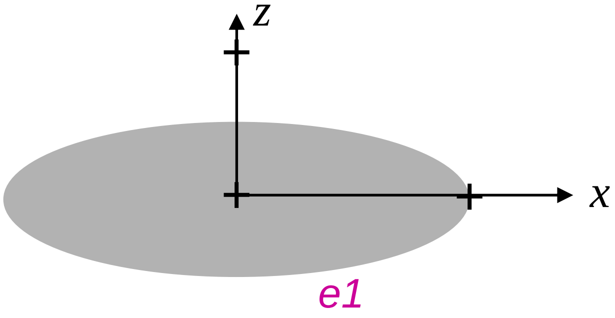
This property sets if an edge is diffracting (*Diffract*) or not (*None*). It is also possible to leave this option to *Automatic* that de-activates diffraction if the edge defines a flat angle between 2 shapes or if the shape has an *Absorbent* or *Transparent* surface property.

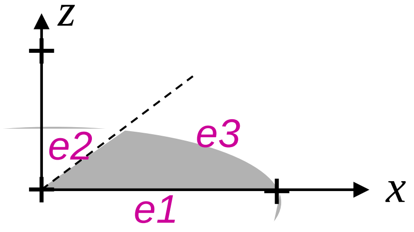
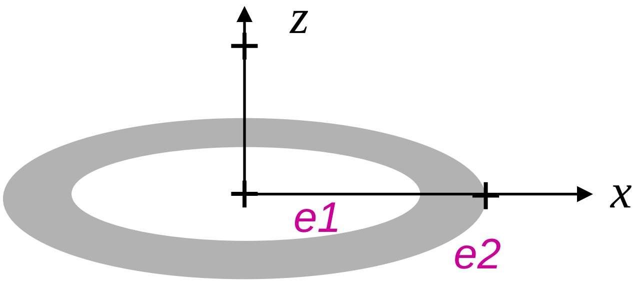
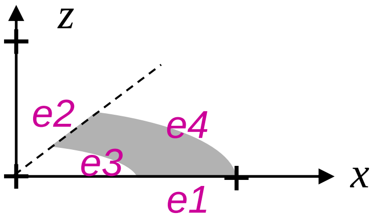
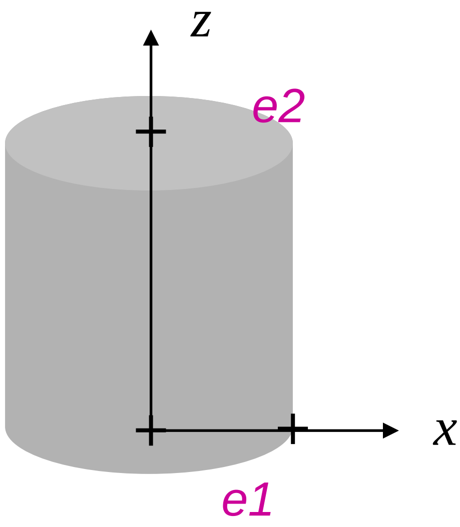
Edges are numbered 1 to 4. In case it is required to set edge diffraction other than *Automatic*, the correspondence between edge numbers and surface definitions is given in the following table.

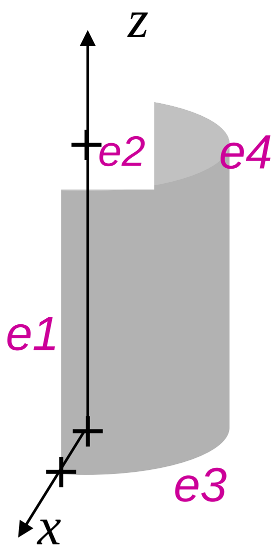
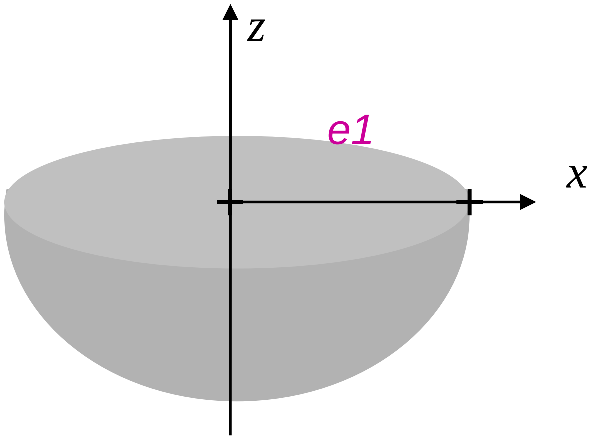


GTD Properties

The properties set at an object level are automatically propagated to all its sub-tree unless "*Local configuration*" is set bellow. It is also possible to overload inherited properties. In that case the overloaded properties will be propagated bellow the object on which the overload has been made.

Triangle	
Rectangle	
Quadrangle	
Full disc	

Truncated Disc 1 And similar truncated Cone / Sphere (similar to triangle)	
Truncated Disc 2 (full ring)	
Truncated Disc 3 (similar to quadrangle)	
Cylinder And similar Truncated Cone / Sphere / Parabola	

Truncated Cylinder And similar Truncated Cone / Sphere / Parabola (similar to rectan	
Parabola / Antenna And similar Cone / Truncated Sphere	

Edge / Surface correspondence table

4.2 The GTD Meshing

Geometric Meshing

By default the geometry is meshed 1x1 leading to one mesh per shape is numbered by hundreds. This default structure is suitable for the **GTD** computation and the mesh shall not be extended except for target surfaces. The numbering may be left with default values.

The surface that will be defined as a target may be meshed in order to get several results, leading to a mapping E-Field into the surface.

GTD Specific Items

If antennas and targets geometries have been defined in the model they are not yet referenced as being such elements (they are only geometrical elements of the model). Indeed it is required to indicate that the geometrical shape represents a specific element of the computation. This operation is performed using the "*Specific Items*" of the meshing structure.

Specific items may include properties and links to the geometry.

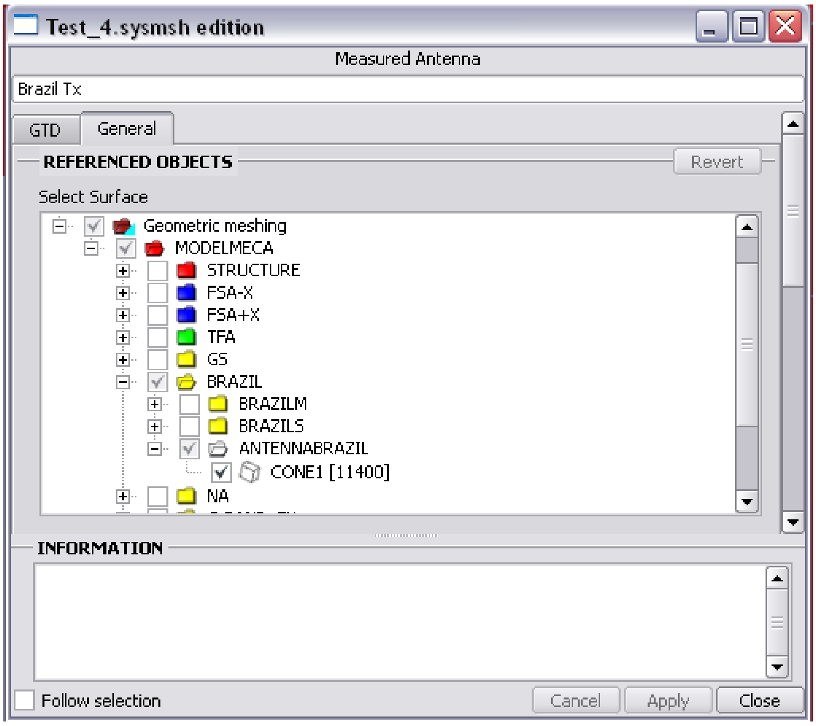
4.3 Antennas Definition

The **GTD** antennas may be of the following kind:

- **Cardioid**
- **Standard feed**
- **Measured**
- **Envelop**
- **Spherical wave expansion**

For each antenna, it is required to link the definition to a cone shape that gives the origin of the feed (corner of the cone) and its orientation: the Z axis of the cone, in its opening direction, gives the main orientation of the feed (theta=0°); the X axis gives the cut reference (phi=0°).

The link is done by selecting the shape from the "General" Tab of the Antenna Specific Item.



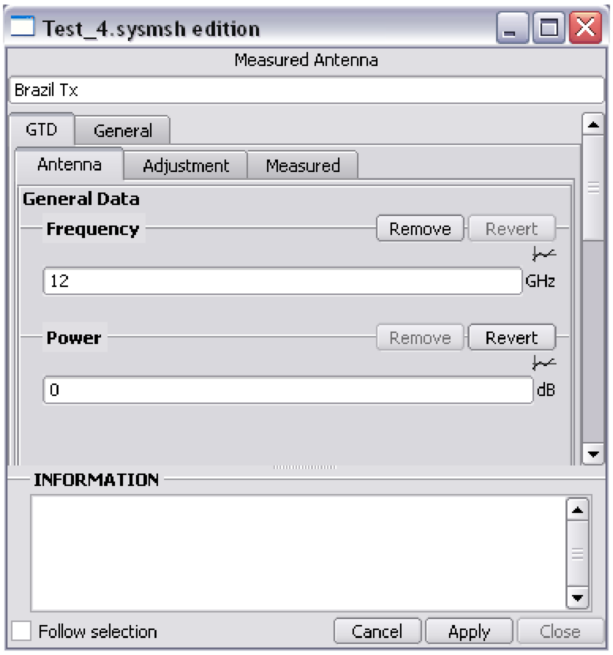
Antenna Geometrical Reference

Common Properties

Bellow the **GTD** tab of the Antenna Specific Item, the properties of the antenna shall be set. The first category of properties, called “Antenna” contains general properties common to all the antenna feeds.

The common properties are:

- **Frequency:** defines the frequency of the antenna in GHz.
- **Power:** defines the power emitted by the antenna in dBW. This property is only used to compute the E-Field on targets.



Antenna Common Properties

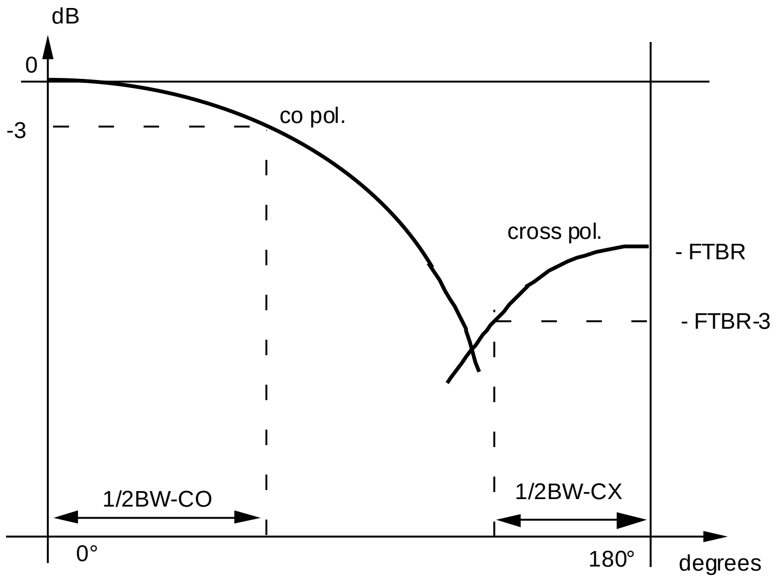
Cardioid Shaped

This model approximates a cardioid shaped, circularly polarised satellite telemetry and telecommand antenna pattern. The sense of the polarisation and the relative level of the back radiation in the opposite polarisation may be specified. The halfpower beamwidth is specified by the user for each sense of polarisation assuming a pattern function of the shape:

$$f(\theta) = K\left[\frac{(1 + \cos(\theta))}{2}\right]^n$$

where the power *n* depends upon the beamwidth specified. The constant K normalises the pattern to isotropic level.

The following figure illustrates the pattern. The half power half beam widths for co- and cross-polar main lobes are illustrated (it is the full beam width which shall be specified) and the level of the cross polar back lobe is given by the front-to-back ratio.

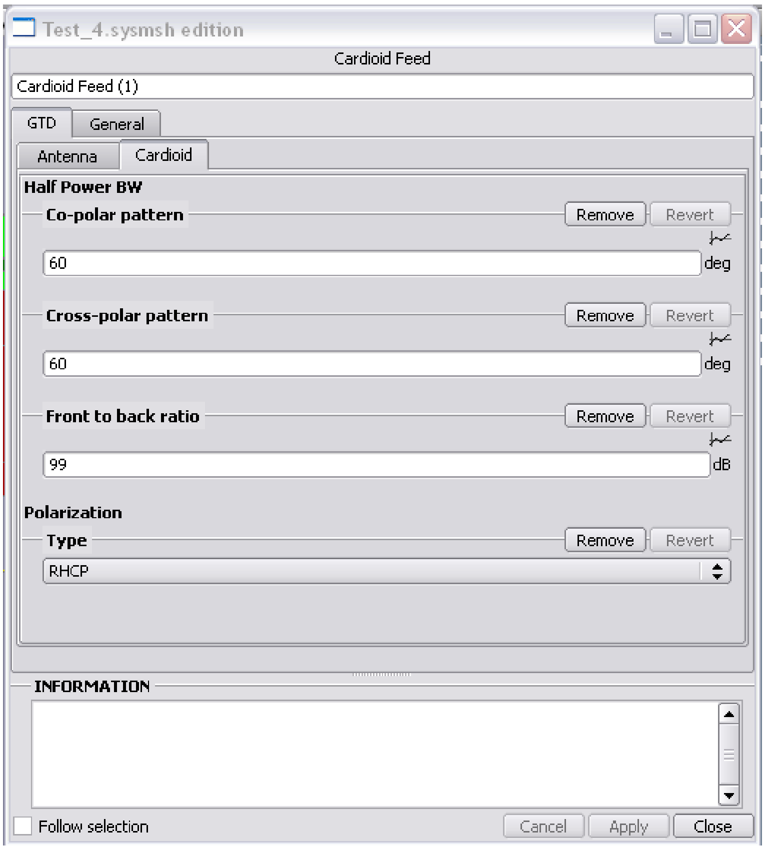


Cardioid shaped antenna pattern

The half power co-polar beamwidth is BW-CO and the half power beamwidth of the backward radiating cross-polar lobe is BW-CX. The front-to-back ratio of the pattern is FTBR. FTBR is usually positive.

The Cardioid properties are:

- **Half power beamwidth of co-polar pattern:** in degrees.
- **Half power beamwidth of cross-polar pattern:** in degrees.
- **Front to back ratio:** in dB.
- **Polarization type:** defines the co-polar polarization type that may be either RHCP (right hand circular polarized) or LHCP (left hand circular polarized), in dB.



Cardioid Properties

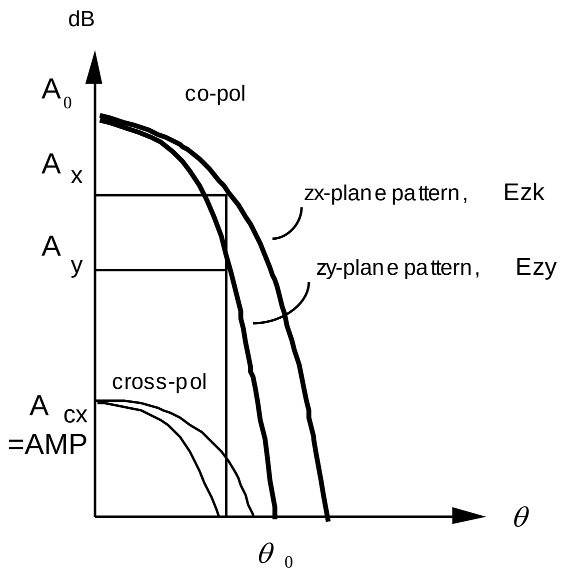
Standard Feed

This antenna model generates a pattern with user-specified tapers in the xz- and yz-planes. The amplitude function referred to isotropic level in the xz-plane is $E_{zx}(\theta)$

$$E_{zx}(\theta) = A_0.10^{(A_X/20).(\theta/\theta_0)^2}$$

where Ax is the amplitude level in dB at $\theta = \theta_O$ relative to maximum level A_0. A similar pattern $E_{zx}(\theta)$ defined by the relative amplitude level Ay at $\theta = \theta_O$ is assumed for the yz-plane (see next figure). A_0 is a gain normalisation constant found by a pattern integration. In the normal case where both A_X and A_Y are negative, the integration is carried out down to 40 dB below the maximum level. If either Ax or Ay is positive or zero, the integration is carried out to θ_O. It is possible also to generate a feed with constant amplitude or one can specify an inverse taper in order to simulate an approximately constant amplitude of a reflector aperture illumination. The user specifies the polarisation which can be linear along the x- or the y-axis, or right or left hand circular.

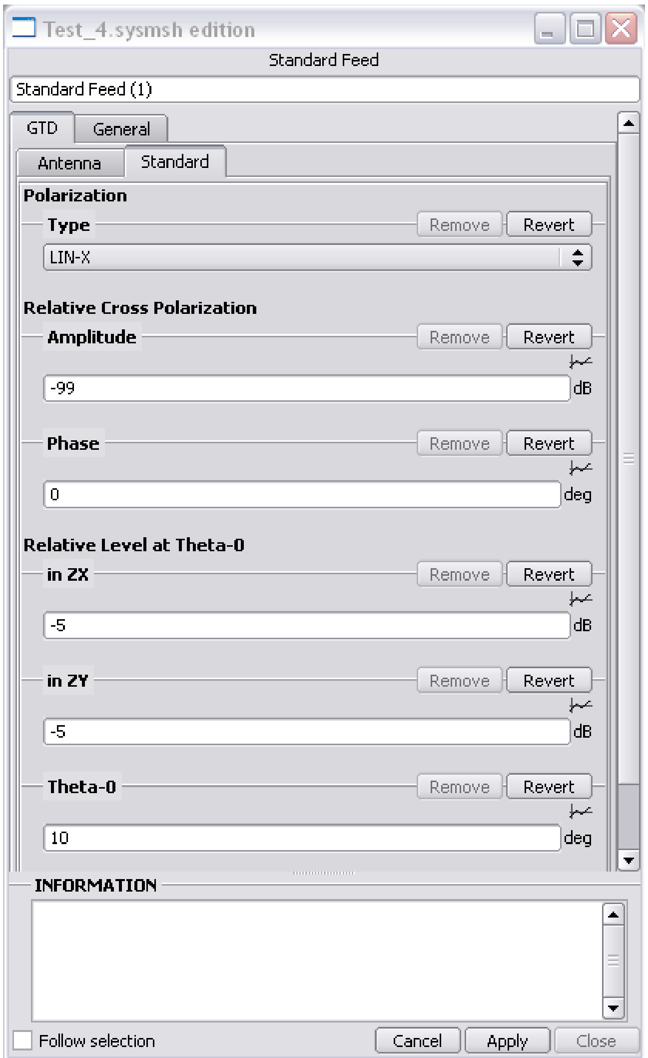
A cross polar level may be specified. The cross-polarised pattern will be identical to the co-polar pattern with a relative amplitude and phase as specified by the user.



Standard feed antenna pattern

The Standard Feed properties are:

- **Polarization type:** defines the co-polar polarization which may be LIN-X (linear polarization along x for theta=0°), LIN-Y (linear polarization along y for theta=0°), RHCP (right hand circular polarization) or LHCP (left hand circular polarization).
- **Relative level at Theta-0:**
  - **Theta-0:** value of the angle in degree
  - **In ZX:** relative level in dB at theta-0 in zx plane (phi=0°)
  - **In ZY:** relative level in dB at theta-0 in zy plane (phi=90°)
- **Relative cross polarization:**
  - **Amplitude:** relative amplitude of cross-polarization in dB
  - **Phase:** relative phase of cross-polarization in degree



Standard Feed Properties

Measured Pattern

By this antenna specification the horn is described by pattern data in polar θ-cuts, for instance from a measurement or from a horn aperture or array element radiator analysis program. The same data must be input either as full cuts, $-\theta_{max} \leq \theta \leq \theta_{max}$, or as half cuts, $0 \leq \theta \leq \theta_{max}$ The time factor can be either exp(-i.ω.t) or exp(+j.ω.t). No restrictions are imposed on the number of pattern cuts on the spacing between pattern cuts apart from the number of half cuts must be even and not less than four. However, in each cut data must be provided in equispaced θ-points.When the program execution is initiated, the input data are converted to azimuthal modes, i.e. the pattern is expressed as a summation of modes, $A(\theta)\exp(-jm\phi)$. For each θ value, the modes are calculated by a Fourier transformation. Later, the program calculates the field in the specified direction by interpolation.

The number of modes is automatically set to N_{full}-1, where N_{full} is the number of full polar cuts (or the half of the number of half cuts).

It is possible to adjust the phase reference point as the phase reference point in the measured input data may be different from the optimum phase centre position.

The input data can be normalised to dBi and scaled in phase, or, alternatively, scaled by a complex factor.

If the pattern cuts on input have different field values for θ = 0 (i.e. the cuts are inconsistent at the pole in amplitude, phase or polarisation) it is possible to impose an equalisation of the values in this direction (cut adjustment). The equalisation adjusts each cut to have identical complex amplitude for the principal polarisation at θ = 0. The cross polarisation in this main direction is assumed low and not used for the adjustment.

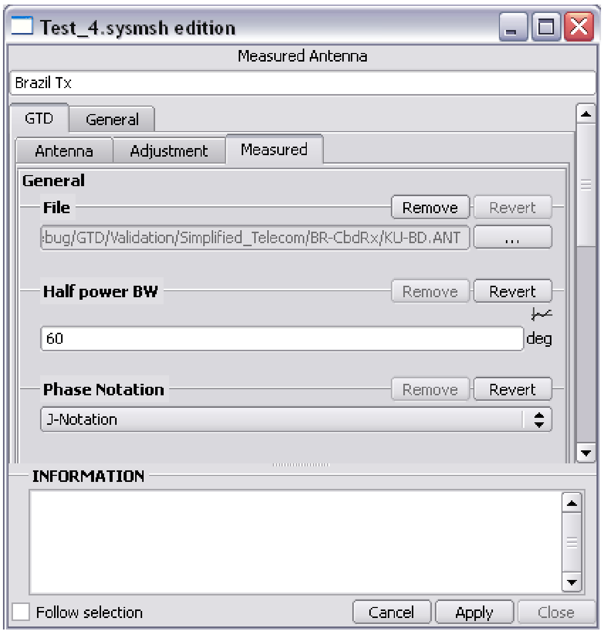
The program assumes that a typical lobe in the pattern has a half power beam of $60°/N_{full}$ and suggests this as a default value. If this value is far from correct a better may be specified.

The pattern input routine is designed to read complex pattern field data represented by real and imaginary values. The format of this file is the GRASP format.

The Measured properties are split into 2 main categories: Adjustment and Measured.

The Measured properties are:

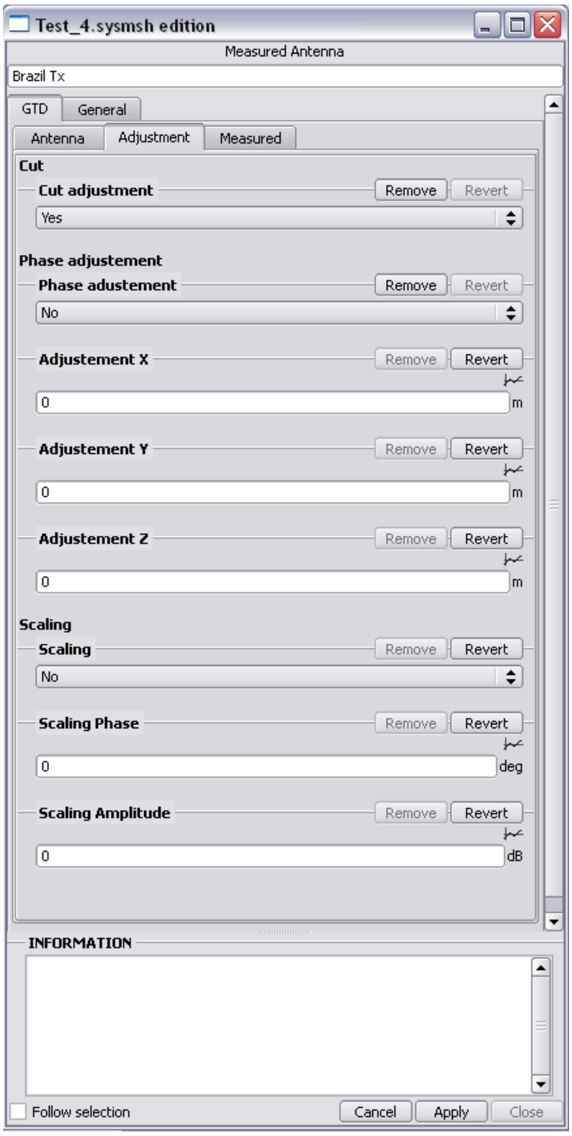
- **File:** name of the file where the measured pattern is stored.
- **Half power beamwidth:** half power half beamwidth of typical lobes of the pattern, in degree.
- **Phase notation:** i-notation or j-notation indicates wheter the measured phase increase (i-notation) or decrease (j-notation) when the measuring probe moves away from the measured antenna. The i-notation corresponds to a time factor exp(-i.ω.t), j-notation corresponds to a time factor exp(j.ω t). Most measurements equipment output results are in j-notation.



Measured Antenna Properties

The Adjustment Measured properties are :

- **Cut adjustment:** pattern cuts may be adjusted in amplitude to have identical principal polarization component at theta=0°. The polarization of the input field is used. This option is by default to "Yes".
- **Phase adjustment:** the phase reference point is adjsued to a position (x,y,z) in the measurement coordinate system (meter).
- **Scaling:** The measured pattern can be scaled by a complex factor of amplitude in dB and a factor of phase in degree.



Measured Adjustment Properties

Envelop Pattern

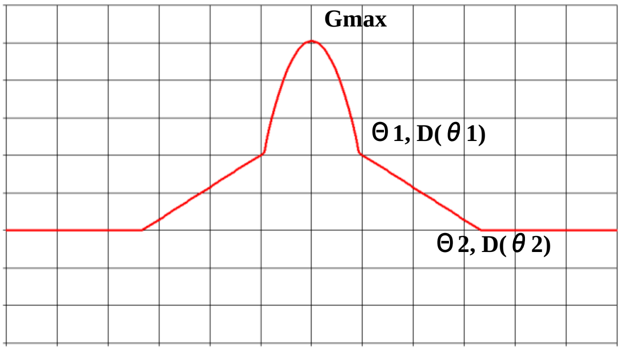
The envelop Pattern is useful to define a profile of antenna pattern by its envelop.

Patterns are defined with their Co polarization and cross polarization.

Polarizations are either linear or circular.

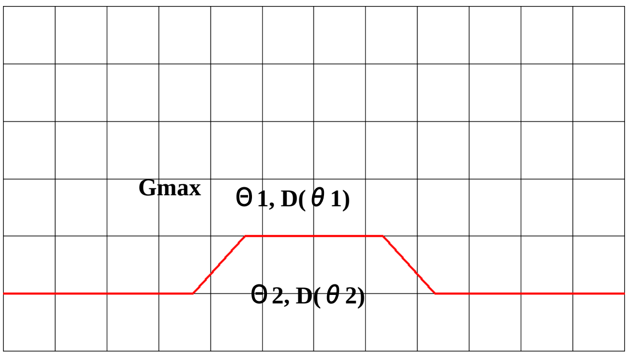
Co Polarization is defined in three parts: Gaussian, Linear and Flat from 0 to 180° (the pattern is symmetric).

The gains and angles to be defined are:



Cross Polarization is defined in three parts: flat, linear and flat from 0 to 180° (the pattern is symmetric).

The gains and angles to be defined are:



Envelop Properties

Spherical Wave Expansion

Spherical Wave Expansion is a format (SWE) describing the pattern of the antenna which is widely used as input or output of RF simulation tools. The **GTD** software is compatible with this self content definition for which no other option than the file reference is required.

4.4 Targets Definition

A target is a surface on which the incoming E-Field from an antenna and its power decoupling are computed.

A target shall be linked to a rectangle or a full disc for which its surface properties (conductive, transparent or absorbent) will still be taken into account for the ray propagation.

If a target is meshed, then the E-Field and Power decoupling will be computed for each individual mesh, leading to the possibility of mapping those results onto the surface and of searching extreme values.

Uniform Target

A uniform target may be used to get results on a surface considering the sum of all contributions regardless to their direction. A uniform target behaves like an omnidirectional antenna.

The E-Field on the surface is computed with the following formulae:

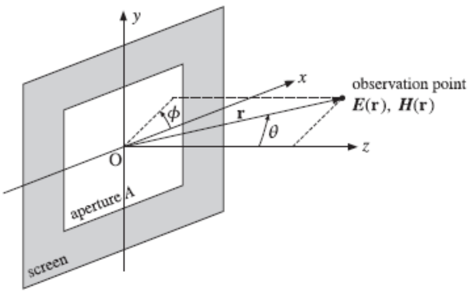
$$E = \frac{4\pi}{\lambda}\sqrt{30.P}$$

Where the received power P is computed from the power emitted by the antenna source $P_{antenna}$ and the decoupling value obtained on the target D :

$$P = \frac{P_{antenna}}{D}$$

Aperture Target

A target aperture may be used to represent a rectangular or circular aperture. Indeed the E-Field and Power decoupling take into account its radiation pattern. The figure here below shows the polar angle convention.



Radiation fields from an aperture

The decoupling computed from the antenna to the target is then corrected on each ray by the following gain normalization coefficient:

$$D = \frac{|E(\theta,\varphi)|}{|E|_{\max}} = \sqrt{g(\theta,\varphi)} = \left(\frac{1+\cos\theta}{2}\right).|f(\theta,\phi)|$$

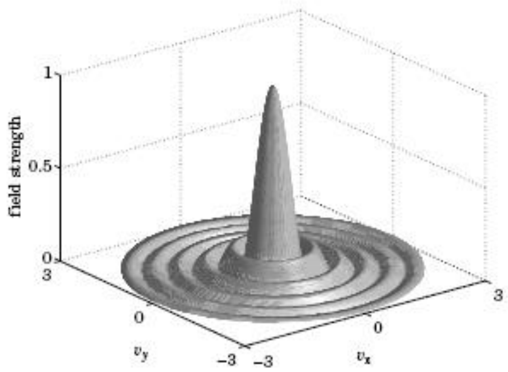
Where the function $f(\theta,\phi)$ depends on the aperture geometry.

For a circular aperture of radius *a*, the cylindrical symmetry implies that the function $f(\theta,\phi)$ is independent of ϕ. Then:

$$f(\theta) = 2\frac{J_1(ka\sin\theta)}{ka\sin\theta} = 2\frac{J_1(2\pi u)}{2\pi u}$$

Where $J_1(x)$ is the Bessel function and $u = \frac{1}{2\pi}ka\sin\theta = \frac{a}{\lambda}\sin\theta$.

The figure here below presents an example of the radiation pattern of a circular aperture with $a = 3.\lambda$:



Radiation pattern of circular aperture

For a rectangular aperture of sides *a* and *b*, the function $f(\theta,\phi)$ is equal to:

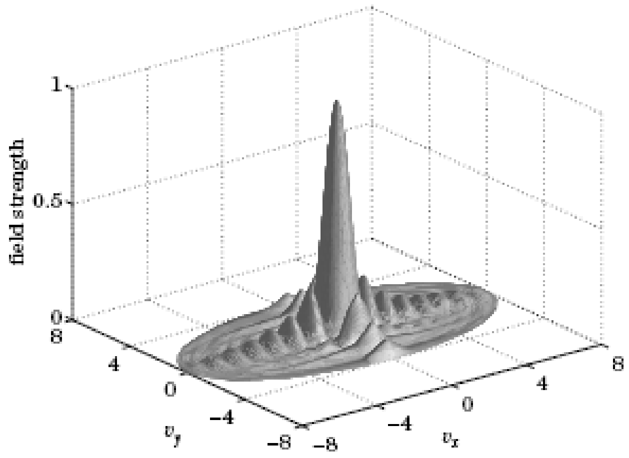
$$f(\theta,\phi) = \frac{\sin(ka/2)}{ka/2}\frac{\sin(kb/2)}{kb/2} = \frac{\sin(\pi\nu_x)}{\pi\nu_x}\frac{\sin(\pi\nu_y)}{\pi\nu_y}$$

Where

$$\nu_x = \frac{1}{2\pi}ka\sin\theta\cos\phi = \frac{a}{\lambda}\sin\theta\cos\phi$$

$$\nu_y = \frac{1}{2\pi}kb\sin\theta\sin\phi = \frac{b}{\lambda}\sin\theta\sin\phi$$

The figure here below presents an example of the radiation pattern of a rectangular aperture with $a = 8.\lambda$ and $b = 4.\lambda$:



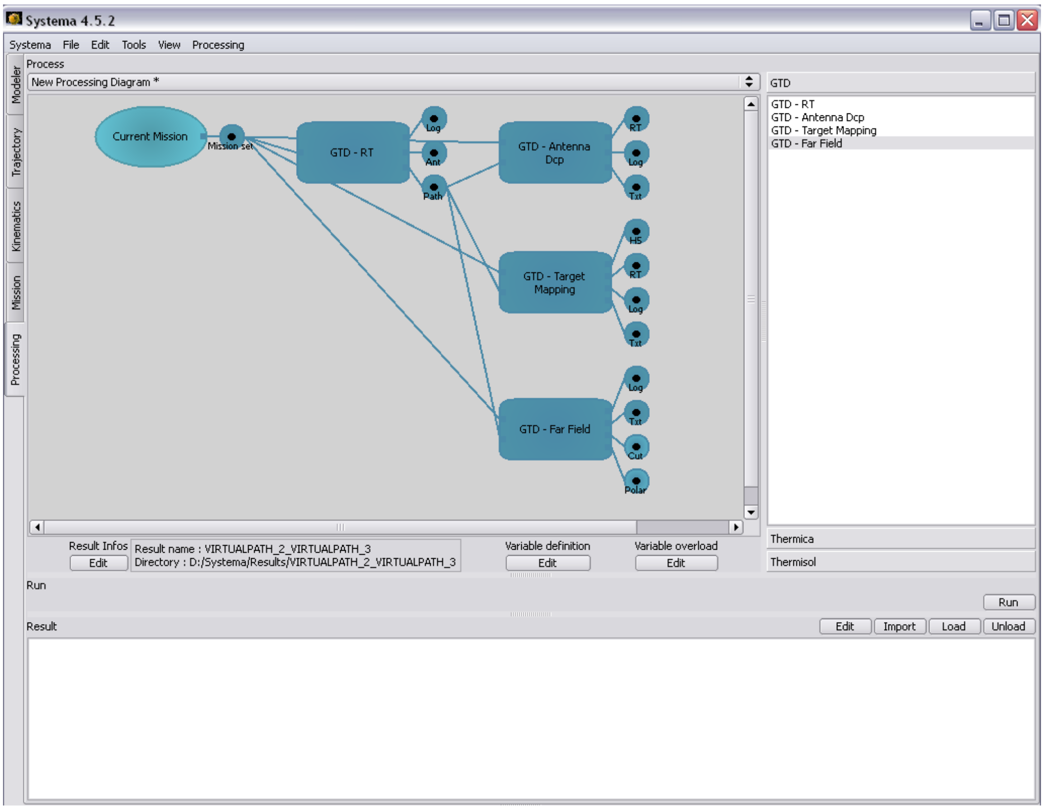
Radiation pattern of a rectangular aperture

The E-Field is then computed as for a uniform target but using the computed decoupling which has taken into accounts the radiation pattern of the aperture.

5 GTD Analysis

5.1 Process Overview

Once the input model has been correctly set with its properties and its meshing, the computation process can be set and executed from the *Processing* tab of **SYSTEMA**.



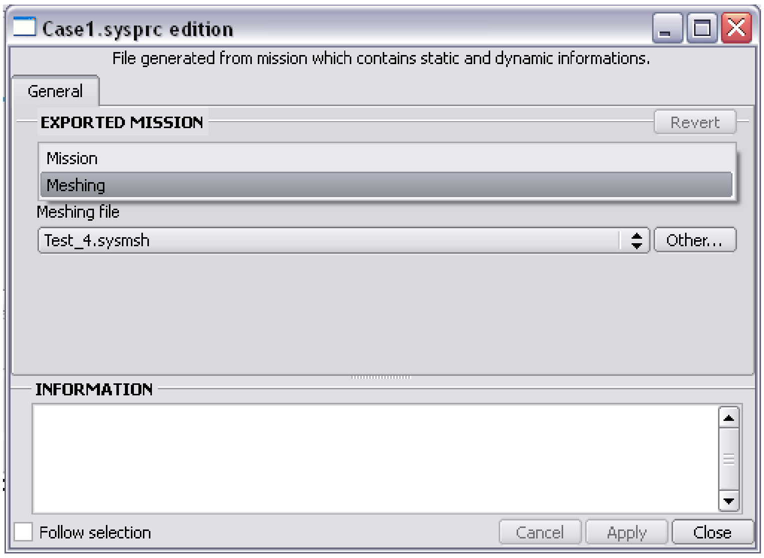
GTD Process Diagram

The GTD Ray-Tracing module pre-determines the possible path to the far sphere directions, antennas and targets. The three other modules (Antenna Dcp / Target Mapping / Far Field) are dedicated to the correction and the E field progation to the computations points or directions.

A process can be added to the process diagram by double clicking on it from the list of processes on the right side of the windows or by a drag-and-drop from this list to the diagram. The input called “Current Mission” will be automatically added if it is not already set in the diagram.

The ellipsoid called “Current Mission” is the input of the computation. This input will be pre-processed for the computation module, creating an intermediate file called *Mission Set* (sysset file).

The current mission can be edited to select the kind and path of the input. In the case of a **GTD** computation, the input may be a single meshing (rather than a mission which may contain also trajectory and kinematics elements not handled by the GTD program).



Input setting of the GTD process

By default, all created files will be named using the input process name. The results will be stored in a folder named from the input and process names. This folder is by default located in the input file directory. It is possible to modify those default options from the *Result Infos* edition button.

The GTD – RT process produces a file (called *Path*) which is required for any other GTD module. Indeed, it has to be connected has an input to the modules requiring this input (or a previously computed *Path* file may be selected from the hard-drive).

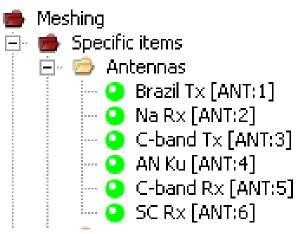
The modules may be also edited in order to set the properties of the computation. Those properties are split into module dependent parameters (specific to each module instance of the process diagram) and *Common* properties which are shared by all GTD modules.

In the *Common* parameters, the user can set the Beam maximum diameter, i.e. all cylinders with a diameter bellow the specified value will be considered as a beam.

5.2 GTD Ray-Tracing Module

The Ray-Tracing process pre-determines the possible path from a source to all destinations (antennas, targets and far sphere) using a forward ray-tracing technic. This module produces a *Pah* file (binary) that shall then be used by the other modules.

The *Emitting Antenna* parameters allow selecting the source. To select a specific antenna, its number has to be given as it appears in the antennas list of the meshing between brackets.

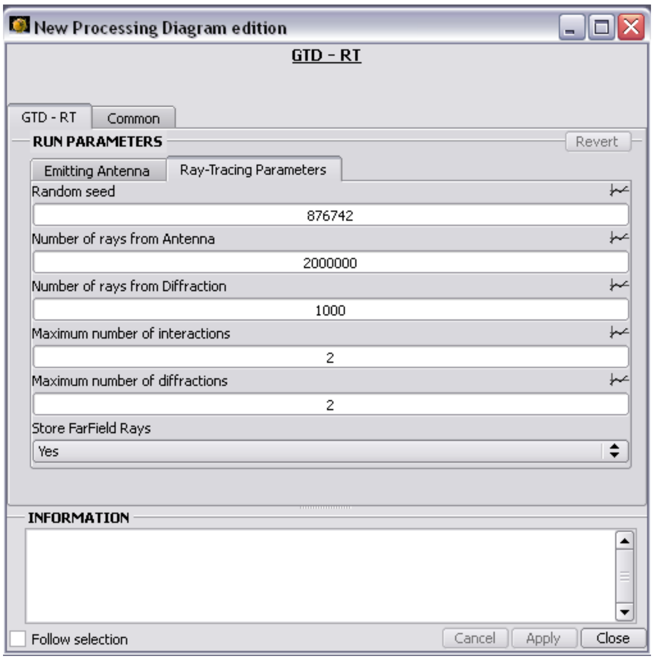


Antennas list From the Meshing structure

The *Ray-Tracing Parameters* contains all the options required for the ray-tracing and path determination. The ray-tracing being based on a random ray direction approach, it is possible to select a random seed that will affect the random series used and consequently the ray emitted from the source. Modifying this value may be useful if the results of a previous computation may be incomplete because of an insufficient number of rays used. In that case, re-running the process with a different random seed will lead to a new computation with different rays.

The numbers of rays used are by default 2.000.000 from the antenna (primary source) and 1.800 from each diffraction point (secondary source). If the model has many diffractive edges, this may result of a total number of rays up to 6.480 billion (but also many possible paths between sources and destinations that need to be tested). The number of rays used shall then be a good compromise between good accuracy (all path are determined) and execution time. The default values are set to provide a good level of accuracy for an execution time not generally exceeding 10 minutes.

The total number of interactions and especially the number of diffractions for each path may also be modified. The maximum, and default value, of interactions is 2 including 2 possible diffractions.



GTD Ray-Tracing Parameters

A final option called “Store FarField Rays” may be set to the value “No” in case the *Path* file will not be used for any Far Field Pattern computation. In that case, the CPU time is decreased since much less pre-defined path are to be managed.

GTD-RT Outputs

There are three output files from the GTD computation:

- **Log file:** execution summary of the process.
- **Antennas & Targets diagram:** curves of input antenna patterns and target radiation pattern – PS format (post-script)*.
- **Path:** Contains all pre-determined path details for further path correction.

*Note: If a ps2pdf executable is defined in environment variable GTD_PS2PDF, GTD will automatically convert the generated PS files to PDF.

5.3 GTD Antenna Decoupling Module

The Antenna Decoupling module computes the decoupling between two antennas (or eventually a self-decoupling).

The module options are mainly the selection of the receiving antenna, specified as for the emitting antenna – i.e. using the antenna's index visible on the meshing – but with the possibility to select all antennas (by setting a value of 0) allowing to perform all decoupling computations at once.

The second option of this module is the *Ray output Filter*, set to -30 dB by default which enables to remove from the output all rays having a contribution less than 30 dB compared to the maximum one.

GTD- Antenna Dcp Outputs

There are three output files from the GTD computation:

- **RT results:** ray-tracing paths and properties for displaying rays in the SYSTEMA modeler – HDF5 format.
- **Log file:** execution summary and extended results dedicated to results checking.
- **Txt results:** textual results presenting all rays contributions sorted by decoupling decreasing order.

The Decoupling results are given by summation of all rays contributors. The complex, amplitude and root square sums are all specified.

The complex sum is the smallest one, the phases of each contributors being different. This is also the closest result to the physics but since a small variation or approximation on the geometry may lead to a greater variation of the total decoupling value, a worst case value is generally preferred.

The amplitude sum is the greatest one, all amplitude being summed independently of their phase. This value is worst case but is generally too over-estimated.

The root square sum corresponds to a power sum of all contributors. Its value is in between the complex and amplitude sum and is generally kept as the final results of the antenna's decoupling.


```
Antenna  1 :
------------

  -> To Antenna 2

    |----------------------------------------------------------|
    |          Antenna  1 to Antenna  2   (220 rays)          |
    |----------------------------------------------------------|
    |  Ray  | Type |      Complex decoupling      | Decoupling  |
    |--------------|-----------------------------|-------------|
    |    1  | D    |   -6.0250e-06  -3.3699e-05 |    -89.31   |       D (surf 1800 - edge 1)                                           ( -62.48, -55.48, -57.10)  ( -78.34, -78.36, -58.93)
    |    2  | RD   |    1.4055e-06   2.5686e-05 |    -91.79   |       R (surf 2300)   /   D (surf 1800 - edge 1)                   ( -63.03, -53.00, -57.29)  ( -65.41, -60.29, -61.31)  ( -8
    |    3  | DR   |   -1.6831e-05  -1.3058e-05 |    -93.43   |       D (surf 1800 - edge 1)   /   R (surf 2300)                   ( -62.28, -55.16, -56.93)  ( -72.38, -67.59, -43.12)  ( -8
    |    4  | DR   |    1.0255e-05   1.6827e-05 |    -94.11   |       D (surf 1800 - edge 2)   /   R (surf 2300)                   ( -62.65, -55.90, -57.09)  ( -73.73, -67.67, -33.42)  ( -8
    |    5  | DR   |    6.8856e-06   1.5529e-05 |    -95.40   |       D (surf 12400 - edge 1)   /   R (surf 1400)                  ( -69.39, -73.96, -68.09)  ( -88.71, -87.70, -76.14)  ( -8
    |    6  | RD   |   -1.4305e-05   6.8931e-06 |    -95.98   |       R (surf 2300)   /   D (surf 11300 - edge 1)                  ( -62.85, -47.78, -53.77)  ( -67.52, -59.26, -62.38)  ( -8
    |    7  | DR   |   -1.0526e-05   1.7742e-06 |    -99.43   |       D (surf 1900 - edge 2)   /   R (surf 2300)                   ( -63.08, -57.12, -57.01)  ( -80.29, -83.55, -58.82)  ( -8
    |    8  | D    |   -2.0693e-06   8.5764e-06 |   -101.09   |       D (surf 11600 - edge 1)                                          ( -63.20, -60.51, -53.35)  ( -91.68, -85.71,-104.65)
    |    9  | D    |    6.6980e-06  -4.5113e-06 |   -101.86   |       D (surf 11300 - edge 1)                                          ( -58.98, -54.69, -47.96)  ( -89.86, -87.61, -96.63)
    |   10  | D    |   -5.1555e-06   3.3808e-06 |   -104.20   |       D (surf 2100 - edge 4)                                           ( -66.88, -61.14, -62.18)  ( -93.23, -98.01, -83.90)
    |   11  | DD   |   -1.5575e-07   5.2253e-06 |   -105.63   |       D (surf 11300 - edge 1)   /   D (surf 11600 - edge 1)        ( -59.03, -55.92, -47.90)  ( -78.58, -85.77, -63.92)  ( -9
    |   12  | R    |    7.9153e-07  -4.8557e-06 |   -106.16   |       R (surf 700)                                                     ( -79.39, -74.31, -76.78)  ( -81.29, -78.08, -80.77)
    |   13  | DD   |    4.6807e-06  -1.0105e-06 |   -106.40   |       D (surf 2100 - edge 3)   /   D (surf 11600 - edge 1)         ( -63.09, -56.44, -57.63)  ( -76.95, -75.48, -51.69)  ( -9
    |   14  | Dir  |   -1.8266e-06   4.3868e-06 |   -106.46   |                                                                        ( -79.28, -74.73, -74.72)
    |   15  | DR   |    9.9391e-07   4.4142e-06 |   -106.89   |       D (surf 500 - edge 1)   /   R (surf 700)                     ( -70.62, -79.42, -58.80)  ( -80.36, -93.14, -52.62)  ( -8
    |   16  | DR   |   -5.8208e-07  -4.4286e-06 |   -107.00   |       D (surf 2300 - edge 2)   /   R (surf 1800)                   ( -61.19, -48.53, -55.23)  ( -83.66, -71.90, -59.48)  ( -9
    |   17  | R    |   -3.5748e-06   2.5177e-06 |   -107.19   |       R (surf 2300)                                                    ( -75.10, -76.79, -64.44)  ( -80.90, -88.80, -75.92)
   ...
   ...
   ...
    |  218  | DD   |    7.9063e-12  -6.9260e-12 |   -219.57   |       D (surf 1500 - edge 4)   /   D (surf 11200 - edge 1)         ( -79.97, -72.63, -73.44)  (-122.50,-138.33,-121.33)  (-17
    |----------------------------------------------------------|

         Total Decoupling :
                             Complex sum     4.1767e-05  or   -87.58 dB   (Total)
                           Amplitude sum     2.4797e-04  or   -72.11 dB   (Worst case)
                                 RSS sum     6.1267e-05  or   -84.26 dB   (Power sum)
```

Textual GTD Results

5.4 GTD Target Module

The Target module is very similar to the decoupling value, considering each target mesh as an antenna (with either a uniform pattern – worst case – or considering the aperture's pattern).

The target module options are also identical to the antenna's decoupling module, i.e. the selection of the receiving target (0 for all or using the target index from the meshing tree list) and the output ray filter.

GTD- Target Mapping Outputs

There are four output files from the GTD computation:

- **H5 results:** contains the results on the target mesh for being mapped and displayed onto the geometry – HDF5 format.
- **RT results:** ray-tracing paths and properties for displaying rays in the SYSTEMA modeler – HDF5 format.
- **Log file:** execution summary and extended results dedicated to results checking.
- **Txt results:** textual results presenting all rays contributions sorted by decoupling decreasing order.

For sub-meshed target minimum, maximum and average values of power decoupling:

```
|****************************************************************************************************|
|*                                       TARGET  2 Decoupling                                       *|
|****************************************************************************************************|
|*                                 Min                        Max                        Ave        *|
|* Coupling :                                                                                       *|
|*     -   Complex sum      5.844e-006 (-104.67 dB)    5.898e-005 ( -84.59 dB)    2.253e-005 ( -92.95 dB) *|
|*     - Amplitude sum      1.848e-005 ( -94.67 dB)    6.805e-005 ( -83.34 dB)    2.938e-005 ( -90.64 dB) *|
|*     -       RSS sum      1.026e-005 ( -99.78 dB)    3.391e-005 ( -89.39 dB)    1.621e-005 ( -95.81 dB) *|
|****************************************************************************************************|
```

Target Decoupling Summary

5.5 GTD Far Field Module

The Far Field module computes the pattern of the field seen from a long distance. The results are given in phi and theta cuts, and polar diagrams.

In the *Computation Mode* parameters, it is possible to choose the reference axis which corresponds to the theta reference (0°). A local frame is then built around this axis, the second angle – phi – being the angle in the direction, depending on the theta reference axis:

+Z reference axis: +X to +Y

+Y reference axis: +Y to +Z

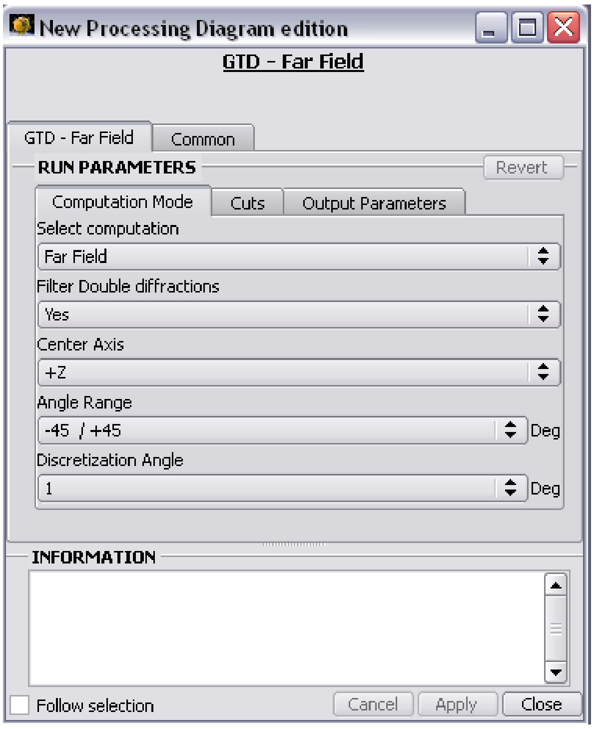
+X reference axis: +Z to +X

-Z reference axis: -X to -Y

-Y reference axis: -Y to -Z

-X reference axis: -Z to -X

The other *Computation Mode* parameters allow choosing the theta amplitude (“Angle Range”), the “discretization Angle” of the output plus an option to filter the double-diffractions from the pre-determined path file.



GTD far Field Parameters

A second option category named *Cuts* allows selecting the theta and phi values of the cuts.

Remark: To deactivate the computation of the polar diagram, which requires much more computations and many directions, the output file "Polar" may be directly deactivated from the processing diagram (with a right click on the file icon).

GTD- Far Field Outputs

There are four output files from the GTD computation:

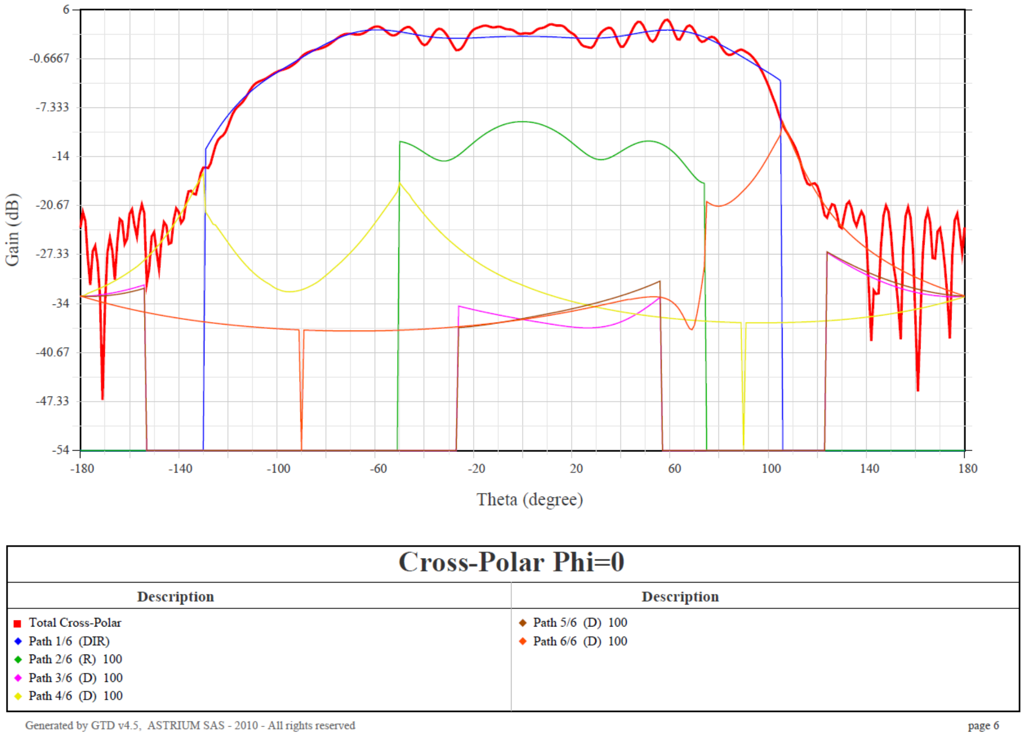
- **Log file:** execution summary and extended results dedicated to results checking.
- **Txt results:** textual results presenting all rays contributions sorted by decoupling decreasing order.
- **Cuts diagram:** curves of output patterns in the selected theta and phi – PS format (post-script)*.
- **Polar diagram:** display of far field pattern in theta-phi polar graphs – PS format (post-script)*.

*Note: If a ps2pdf executable is defined in environment variable GTD_PS2PDF, GTD will automatically convert the generated PS files to PDF.

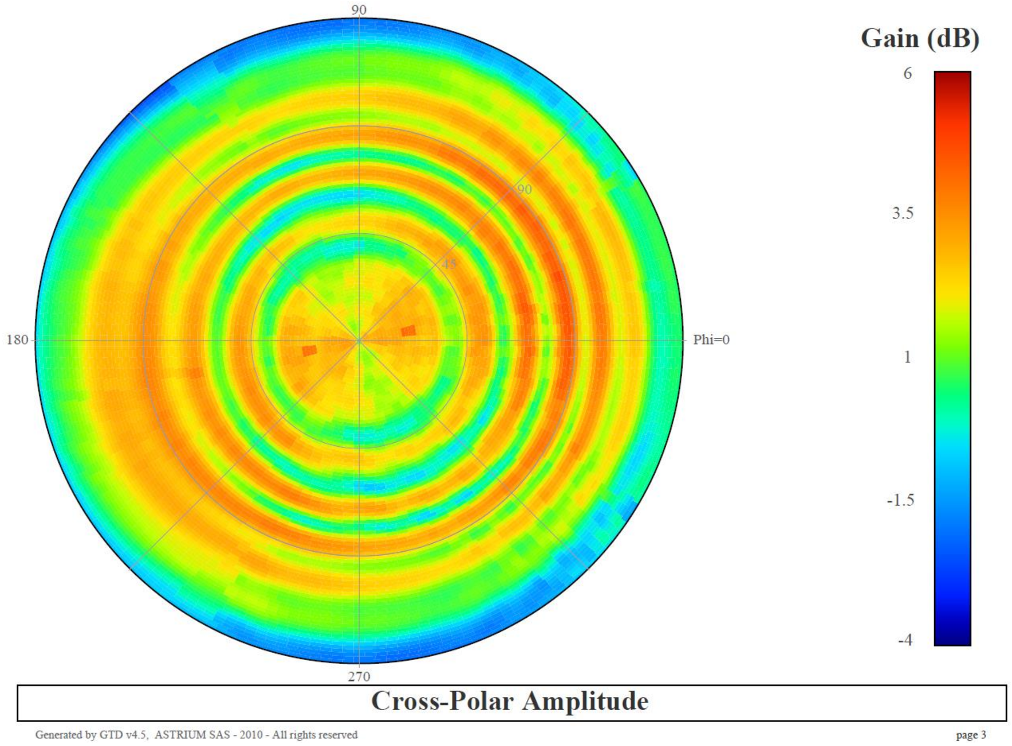
The cuts diagram is composed of the following graphs:

- Co-Polar Gain in Phi cuts
- Co-Polar Phase in Phi cuts
- Cross-Polar Gain in Theta cuts
- Cross-Polar Phase in Theta cuts
- For each cut:
    - Amplitude of the major contributors to the total field (Co-Polar)
    - Amplitude of the major contributors to the total field (Cross-Polar)

The polar diagram presents the Co-Polar and Cross-Polar amplitudes and phases in four graphs (the amplitude of theta is restricted to 90° on this output).



GTD Far Field Cut



GTD Far Field Polar Diagram

6 Results Display in SYSTEMA

Applies to Antenna’s Decoupling and Target Mapping results (hdf5 output files).

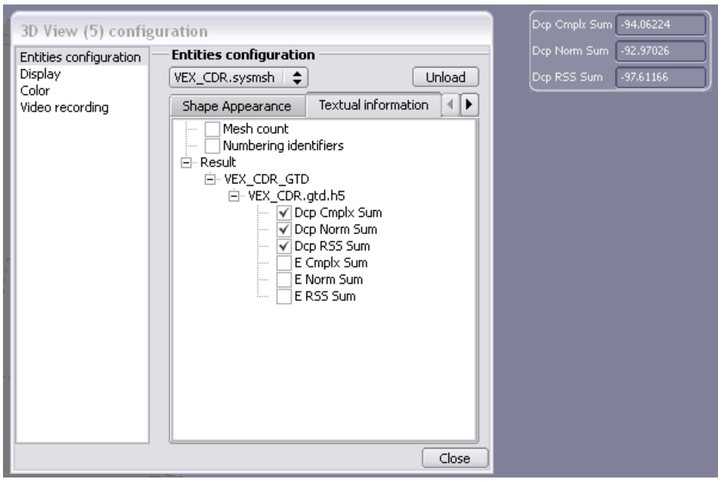
At the end of an execution, the list of outputs appears automatically in the result window of the *Processing* tab. To load or unload results, it is possible to use the corresponding button at the top right of this windows. The set of results are then available through the *sysres* file generated by the execution of the diagram.

Whenever results are loaded (manually or automatically after the execution of a run case), they are available in other tabs in order to graphically post-process the results.

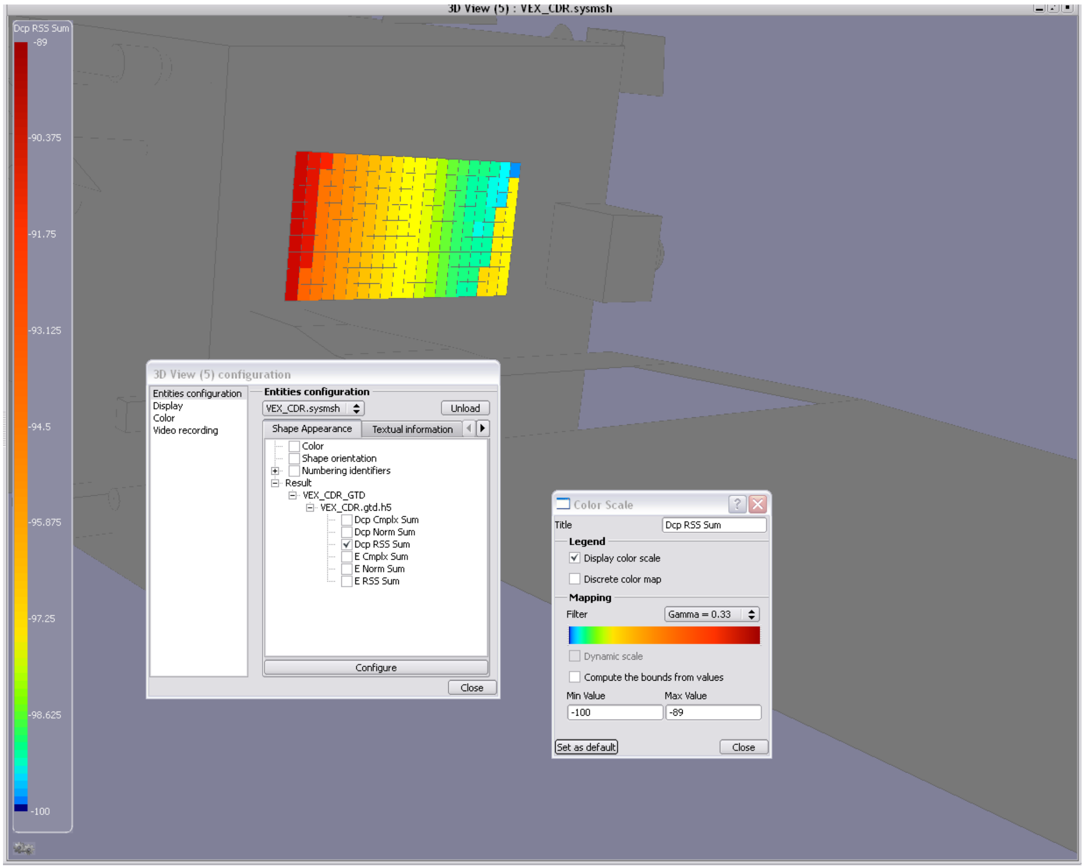
Target Mapping

From a 3D View of the meshing in the *Modeler* tab, it is possible to set the shape appearance to a result. The configure button from the shape appearance selection allows to adjust the scale of the mapping.

Besides the shape appearance, it is possible to select Textual information. Then textual results will appear on a text window for the selected mesh.



Textual Information



Target Results Mapping

Ray Display

From the 3D configuration view of the meshing, a third category (besides Shape appearance and Textual information) called Ray display is available when a ray display result is loaded in the *Processing* tab.

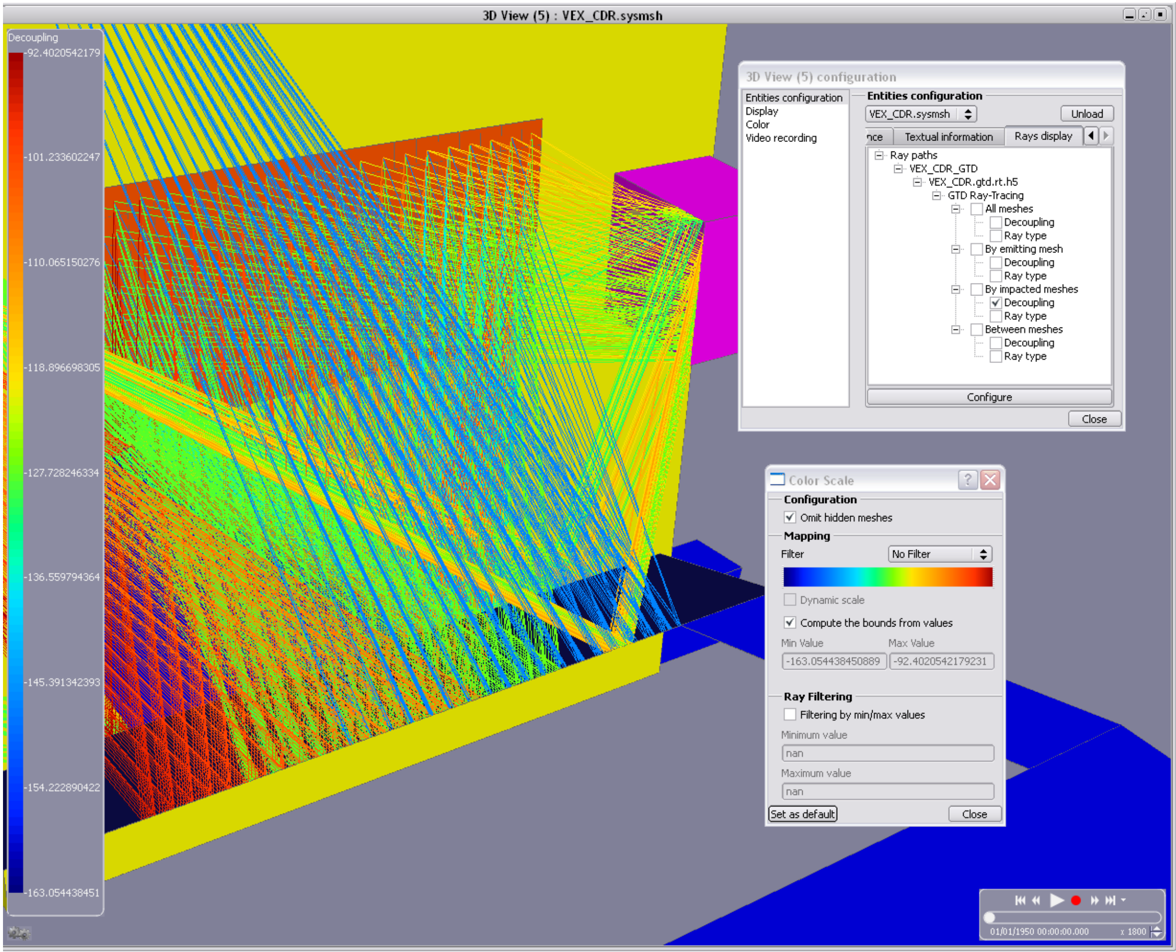
It is possible to select the rays to display and their properties.

The rays may be display with the following options:

- **All meshes:** Display all rays from the result file
- **By emitting mesh:** Once a mesh is selected, only the rays coming from this mesh are displayed
- **By impacted meshes:** Only rays impacting the selected mesh are displayed. If two or more meshes are selected, the rays displayed are the one going by all of them
- **Between meshes:** produces the same behavior than “by impacted meshes” on GTD ray display

The legend of the rays may also be defined with:

- **No Legend:** In case one of the previous options is directly checked.
- **Decoupling:** The rays are colored depending on their final decoupling contributions. The *Configure* option allows setting the bounds of the scale.
- **Ray Type:** The rays are sorted by ray types (D – diffrated, DD – double diffracted, DR – diffracted and reflected, Dir – direct, R – reflected, RD – reflected and diffracted, RR – double reflected). The *Configure* option allows filtering the ray type to be displayed.



GTD Ray Display

