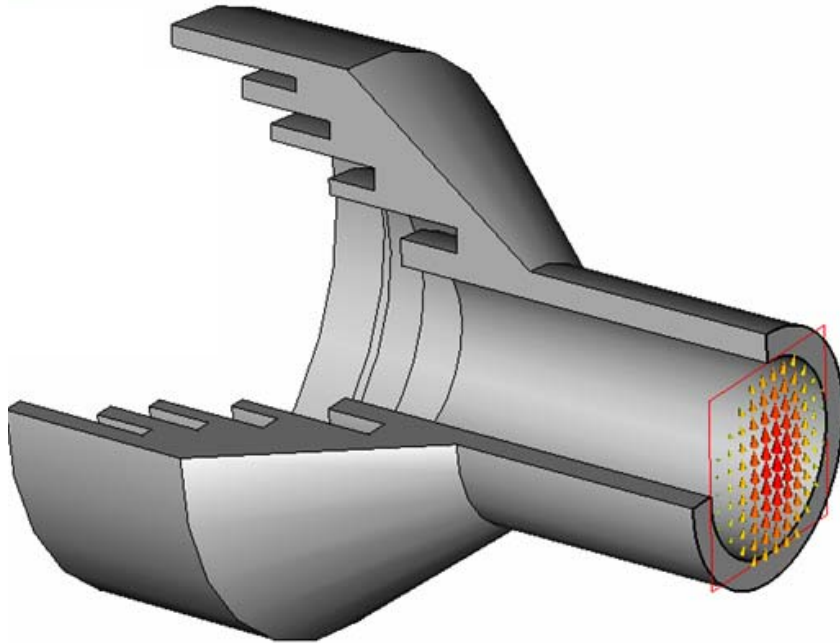


CST STUDIO SUITE™ 2006B

Application Note

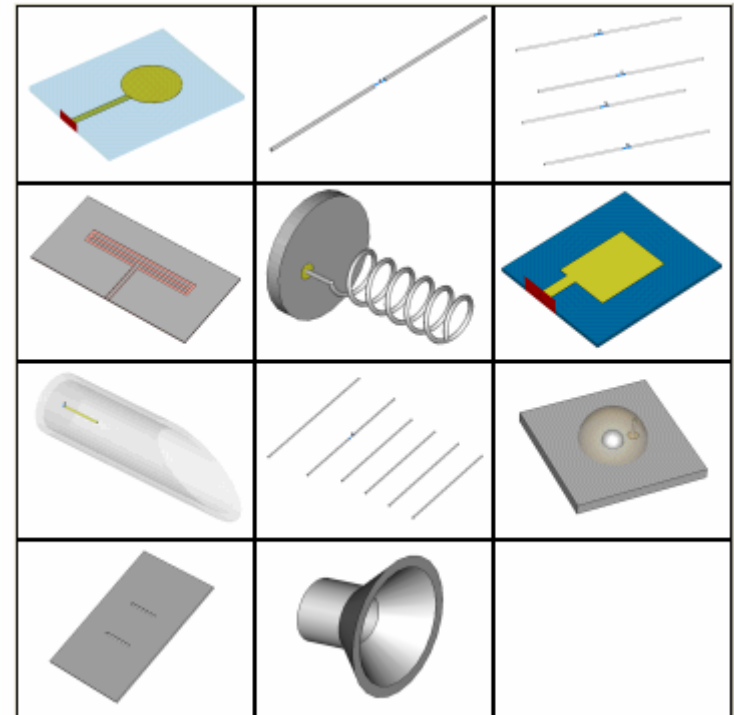
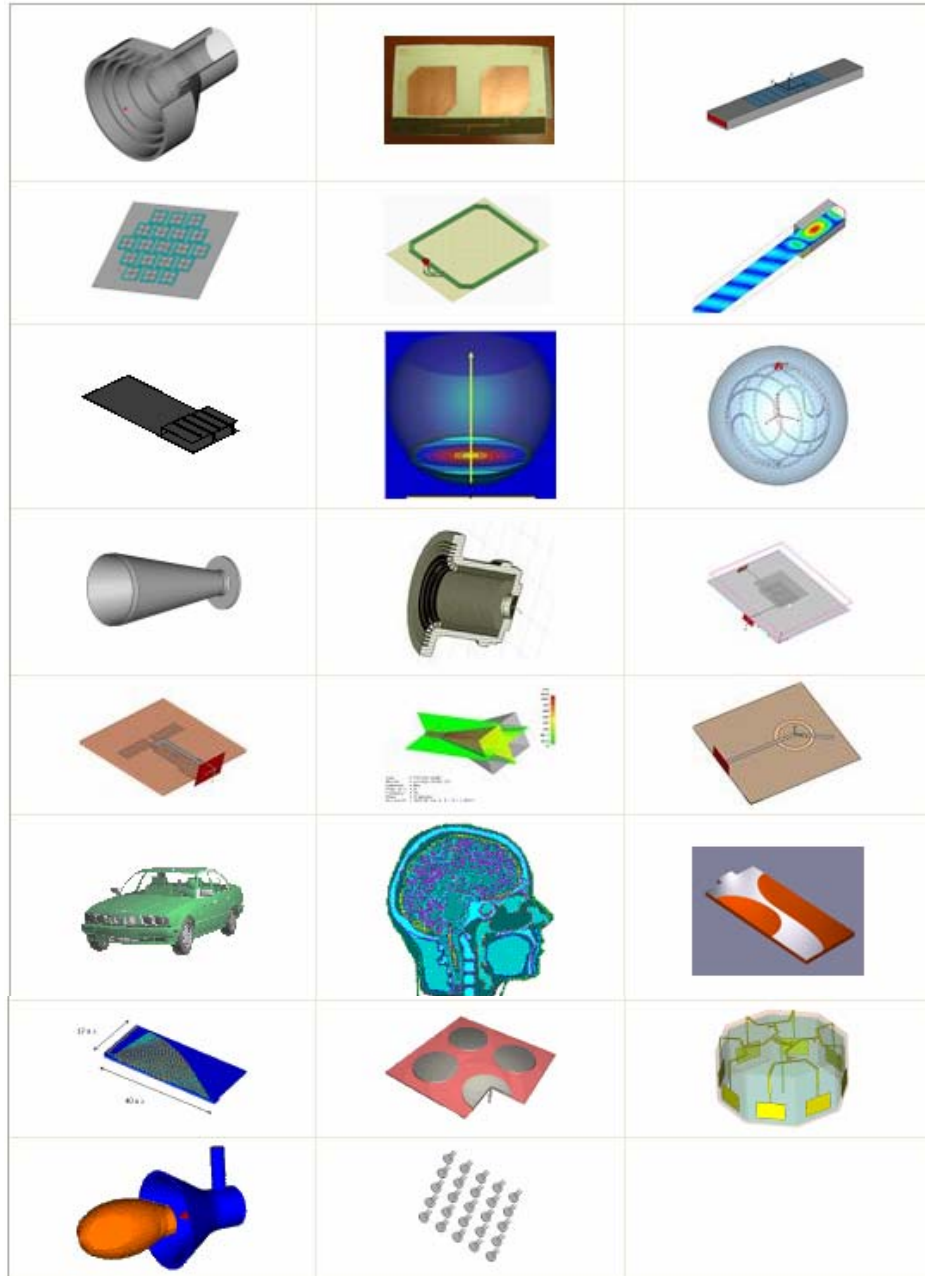
Antenna Simulation



Farfield Terminology
Broadband Farfield
Farfield Optimization
Co & Cross Polarization
Phase Center / Grasp Export
Circular Polarized Antennas

Antenna Examples

pre-installed examples in
CST STUDIO SUITE 2006

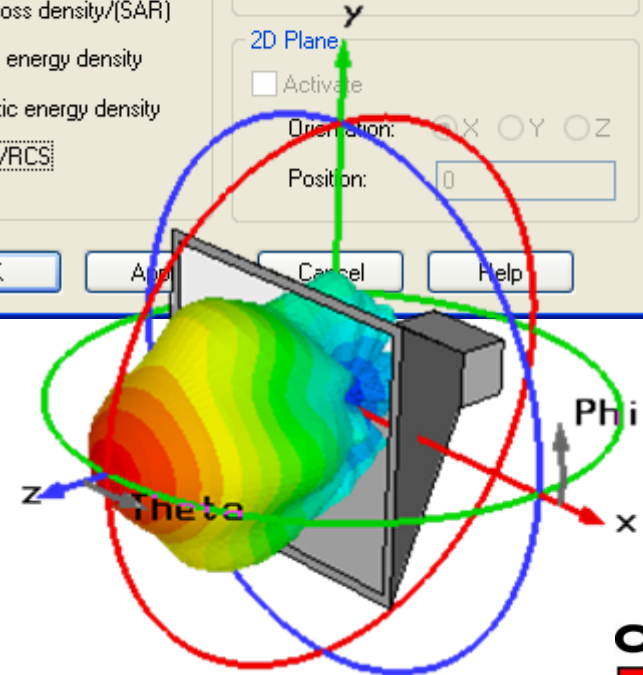
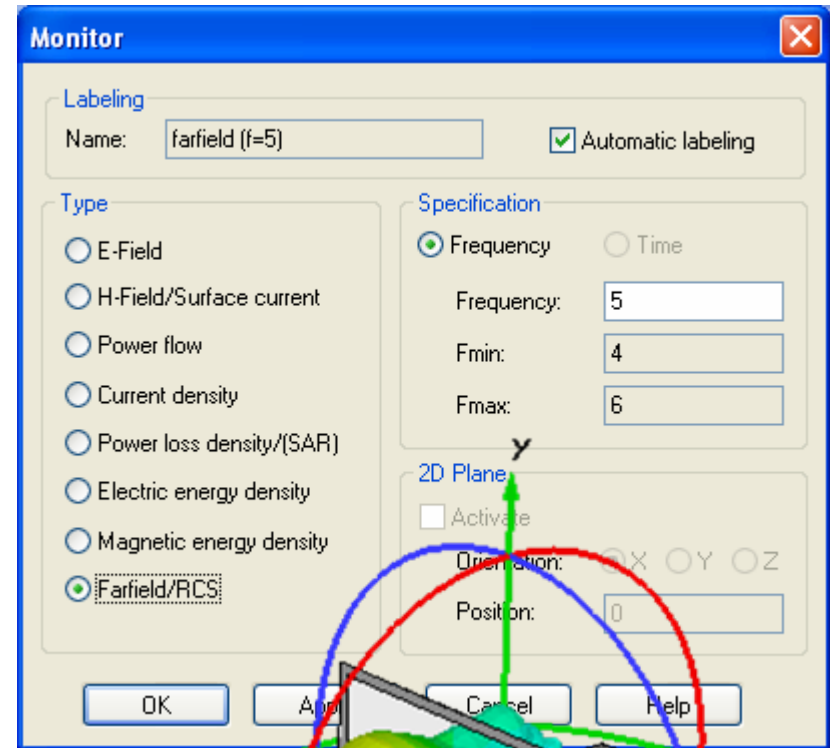
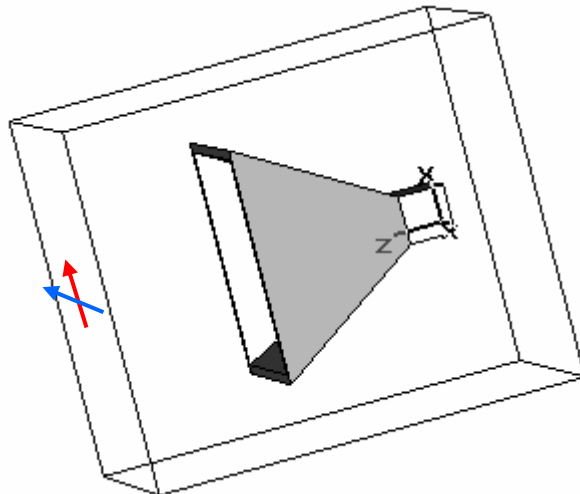


C:\Program Files\CST STUDIO SUITE 2006\
Examples\CST MICROWAVE STUDIO\
Transient Analysis\Antennas

How to generate the Farfield Info

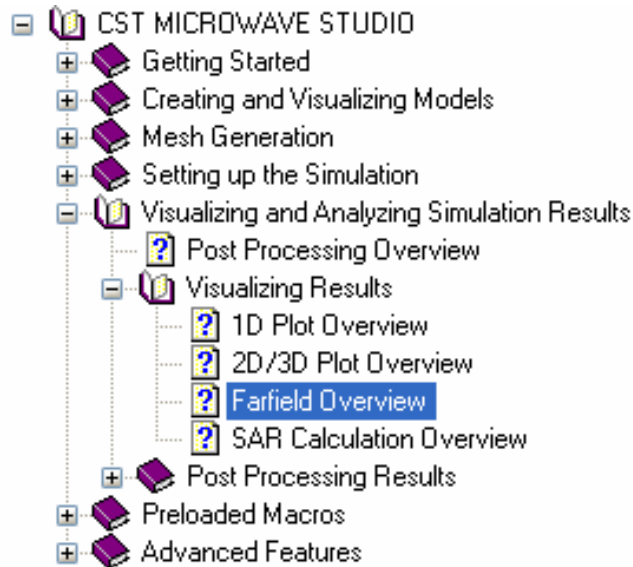
- define farfield monitor at one or more specified frequencies
- box surface fields (E+H) are recorded, from which in the postprocessing the farfield is calculated.

E, H



Farfield Terminology

Online Help



CST MICROWAVE STUDIO

Farfield Overview

In CST MWS the used reference for gain/directivity is an ideal spherical radiator (=isotropic antenna -> dBi), a $\lambda/2$ -Dipole has a gain of 2.2dB(i).

Some Farfield Terms

Directivity: The directivity of an antenna is officially defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions". At this the radiation intensity is given by the total power radiated by the antenna divided by 4π :

$$D(\theta, \varphi) = 4\pi \cdot \frac{\text{power radiated per unit solid angle}}{\text{total radiated power}}$$

Gain: Accordingly the gain is defined quite similar but related to the input or accepted power of the antenna. In case of a loss free antenna (no conductional or dielectric losses) the gain is equal to the directivity.

$$G(\theta, \varphi) = 4\pi \cdot \frac{\text{power radiated per unit solid angle}}{\text{input (accepted) power}}$$

Radiation efficiency: The antenna radiation efficiency is defined as the ratio of gain to directivity or equally the ratio between the radiated to accepted (input) power of the antenna:

$$G(\theta, \varphi) = e_{rad} \cdot D(\theta, \varphi) \quad \text{or} \quad P_{rad} = e_{rad} \cdot P_{in}$$

Total efficiency: The total efficiency is defined as the ratio of radiated to stimulated power of the antenna:

$$P_{rad} = e_{total} \cdot P_{stim}$$

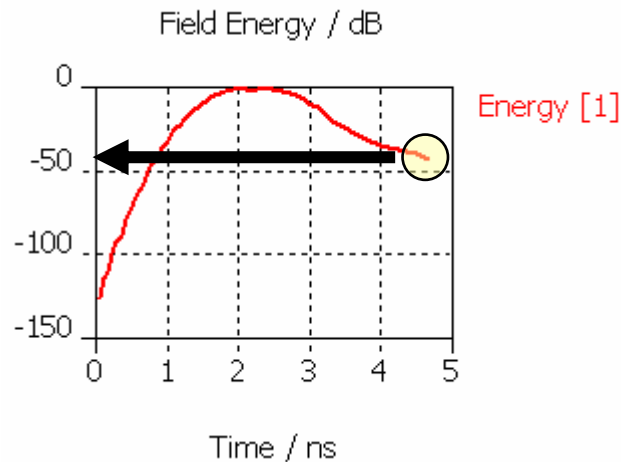
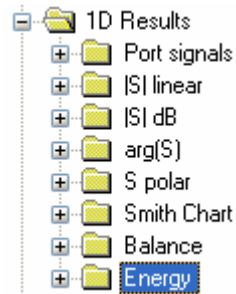
Compared to the input power the stimulated power consider any occurring reflections at the feeding location.

Reflection efficiency: The reflection efficiency is defined as the ratio of input to stimulated power. In CST MICROWAVE STUDIO® this value can also be determined from the reflection factor:

$$e_{refl} = \frac{P_{in}}{P_{stim}} = \frac{e_{total}}{e_{rad}} = 1 - S_{11}^2$$

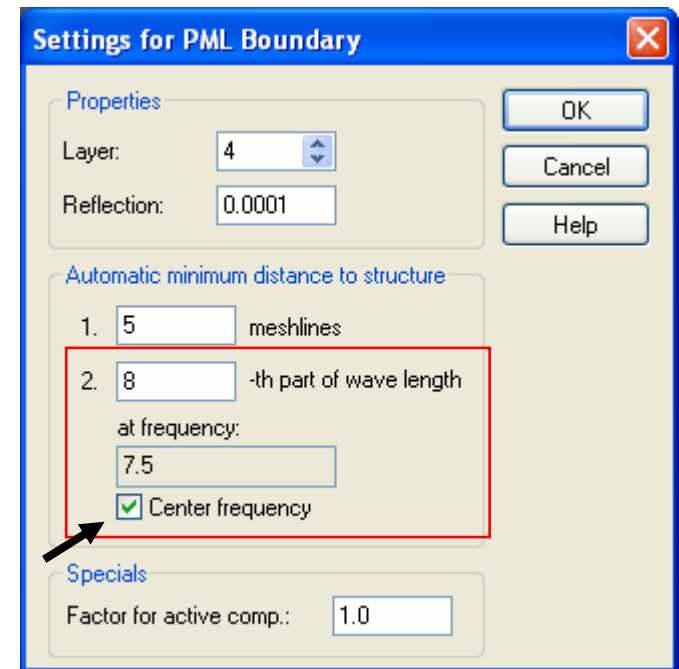
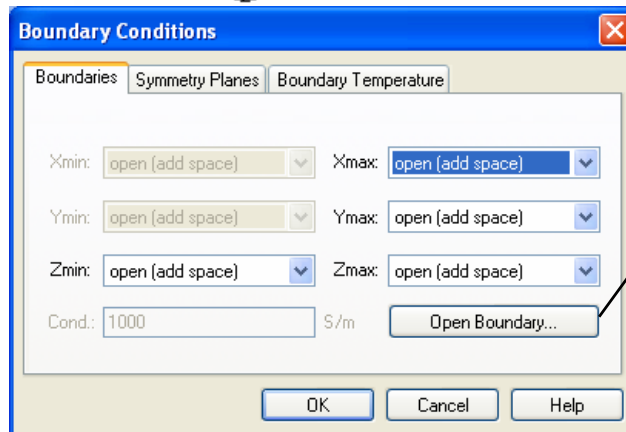
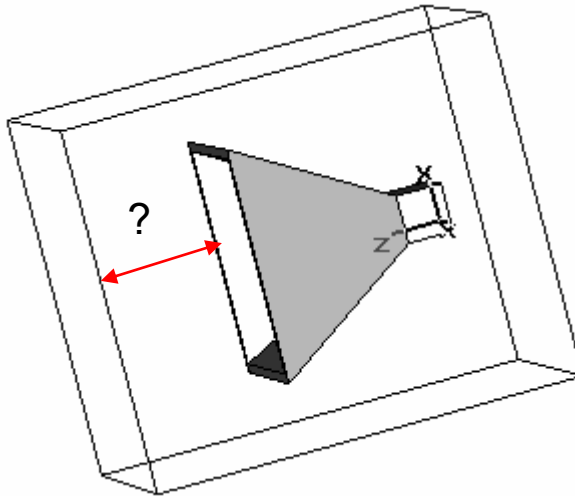
Tips & Tricks to obtain accurate farfield results

Tip 1/3 : Check Energy



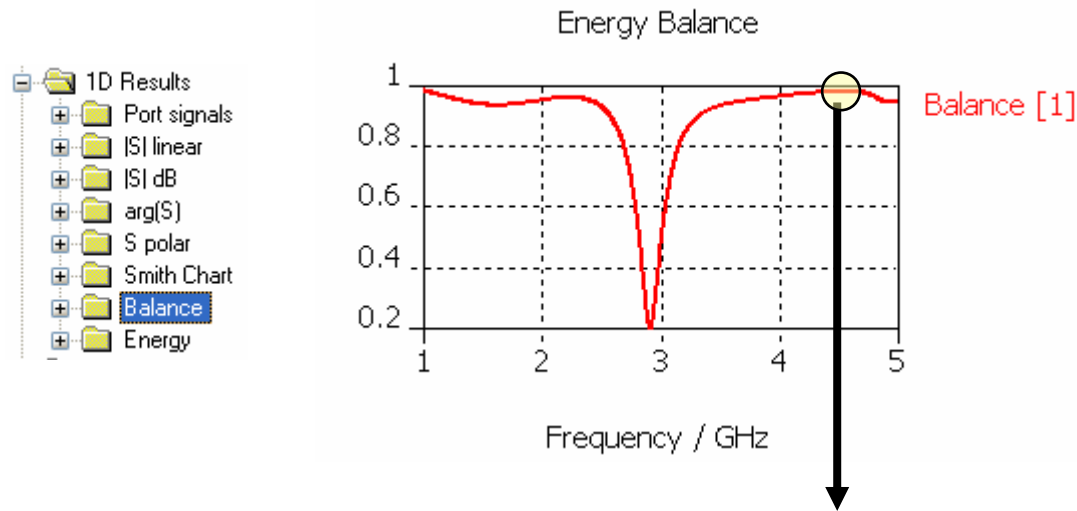
- The accuracy level in the T-solver should be **-40dB**.
For larger frequency bands (eg 0-3 GHz) or bad radiation better use -60dB, so that E+H on the bounding box do not suffer from FFT/DFT truncation error.

Tip 2/3 : Check ,add. space‘



„**open (add space)**“ **boundary** ensures $\lambda/8$ space at the center frequency, for lower frequencies (bigger λ) the space needs to be increased accordingly.

Tip 3/3 : Check Balance

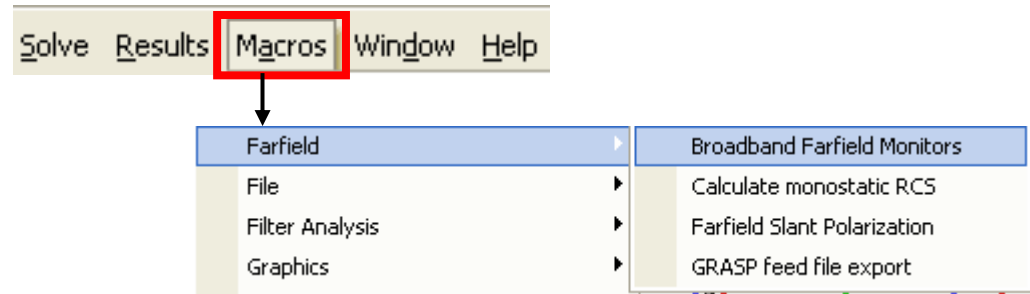


at 4.5 GHz farfield can be critical

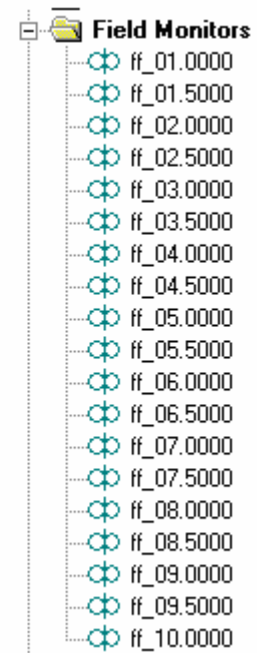
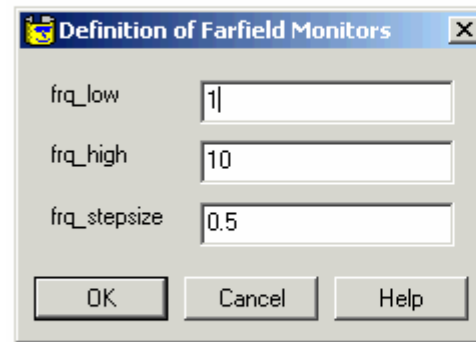
- Farfield values become critical, **if *S-Parameter balance*=1** (no power is radiated). In this case directivity and gain are calculated from dividing 0/0, which is numerically critical.
A good measure for total radiated power is: (1-balance).

How to calculate farfield Broadband at many frequencies

Definition of Broadband Farfield Monitors



- macro can be applied **multiple times** without overwriting the previous definitions, so that different frequency resolutions can be combined.



Evaluation of Broadband Farfield Monitors

Template Based Postprocessing

1D Results | 3D Results

- ADS Component Export
- Mix 3D Fields
- Power Flow - 3D Mode
- SAR Calculation
- + 1D Result from 1D Result (Rescale xy, FFT, Derivation, ...)
- + Load 1D Data File (project and external)
- + Mix 1D Results
- Coil parameters (1- or 2-port)
- Evaluate Field along arbitrary Coordinates (1D Plot)
- Evaluate Field on predefined Curve
- Exchange Excitation
- Farfield (broadband)**
- Farfield (single freq)
- Farfield probes
- Group Delay Time
- S Parameter
- TDR
- VSWR
- Wrap - Unwrap Phase
- Y Parameter
- Z Parameter

Broadband Farfield Result

Excitation String: [1]

Plot Range: 3D Plot | Result Value: Max. Value

Cutplane: Varying Angle (Theta selected) | Fixed Angle (Theta: 90, Phi: 0)

Stepsize: 15 deg

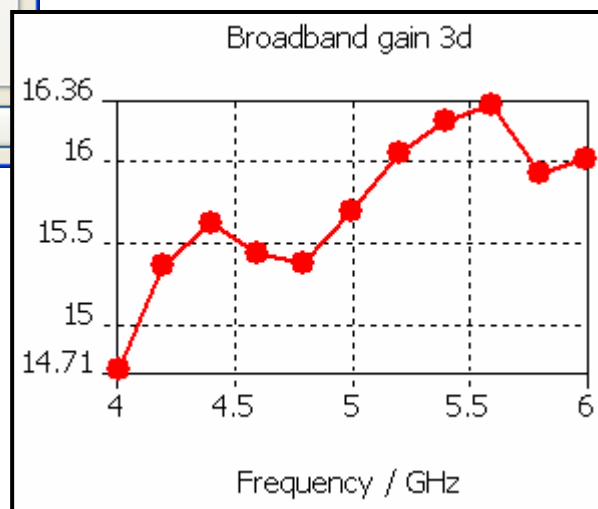
Plot Mode and Scaling: Gain (IEEE), Component: Abs, Pol.Vector (x/y/z): 0/1/0, Reference Distance: 1 m

log (dB) selected, dB Units: dBV/m, dBA/m, dBW/m2

Buttons: OK, Cancel, Help, Phase Center Options

Tables

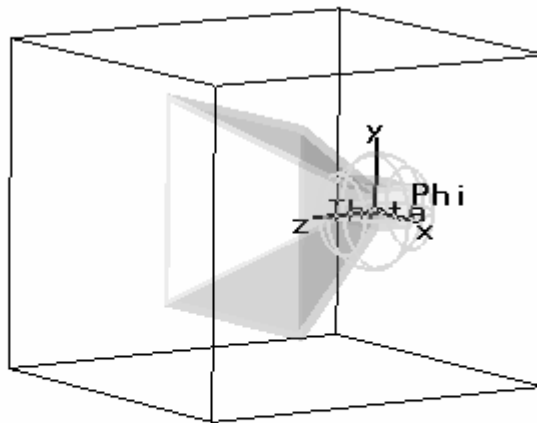
- 1D Results
- Broadband gain 3d**



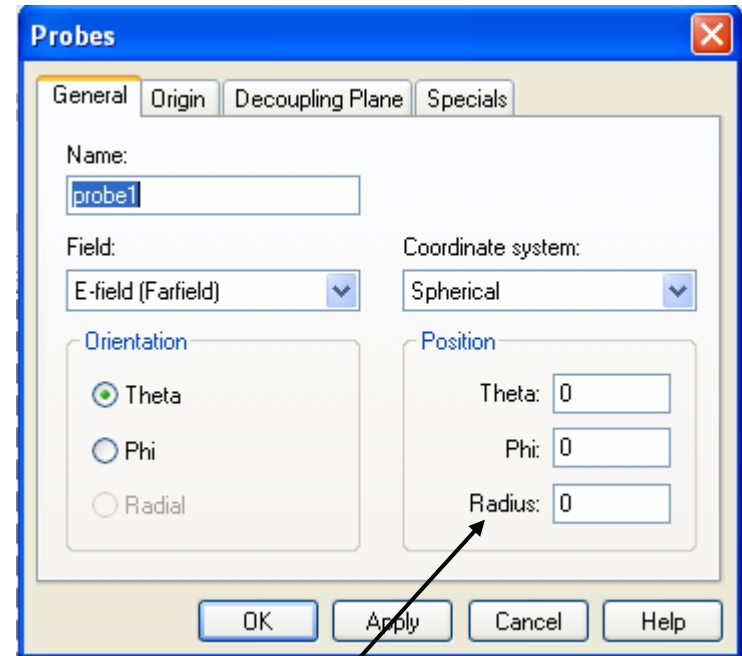
Definition of Farfield Probes

Farfield *monitors* record the radiation in ALL directions for ONE frequency.

Farfield *probes* record the radiation in ONE direction for ALL frequencies. (recording a time signal)

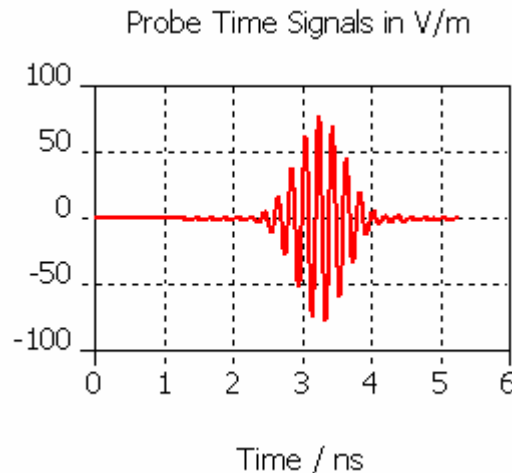
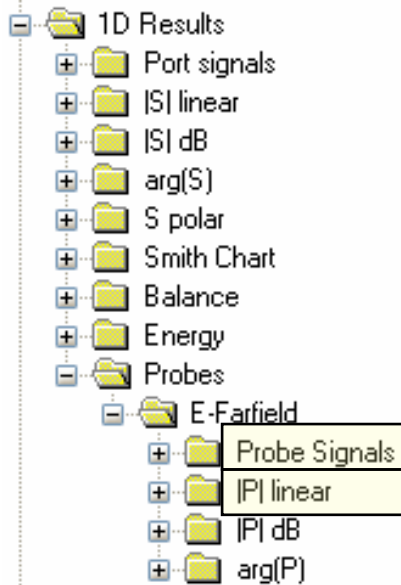
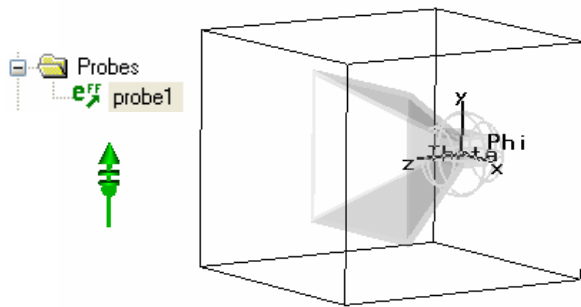


Probe	=	probe1
Type	=	Efield (farfield)
Theta	=	0
Phi	=	90
Radius	=	40

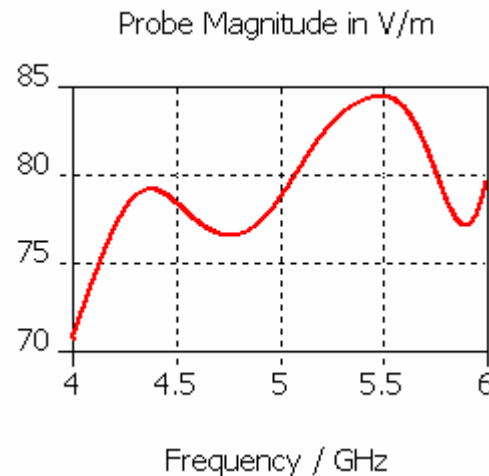


Attn: this radius is entered in the design-units (e.g. cm) and not automatically in Meter

Results from Farfield Probes



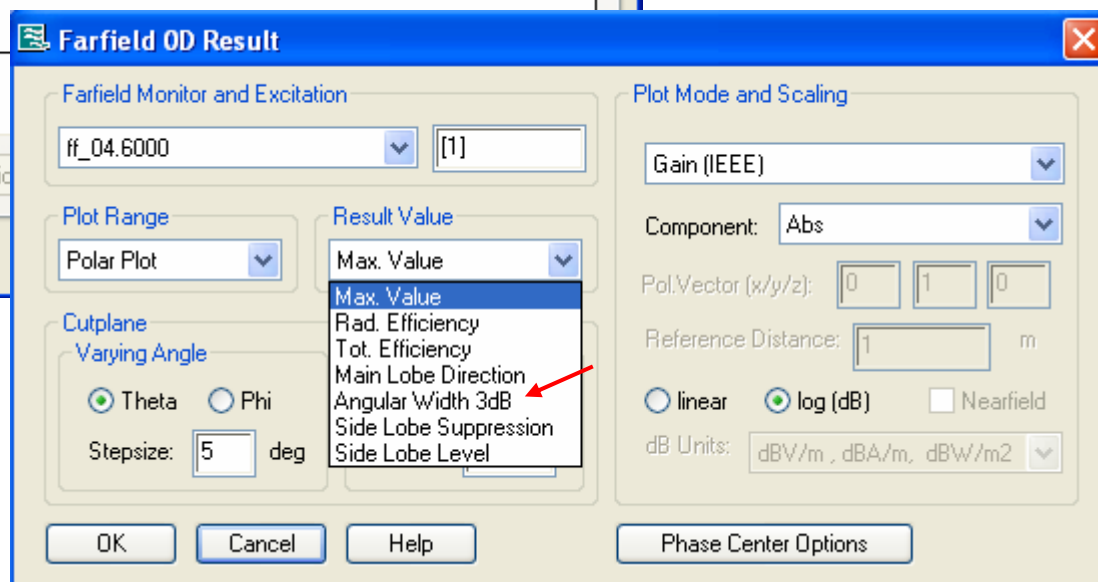
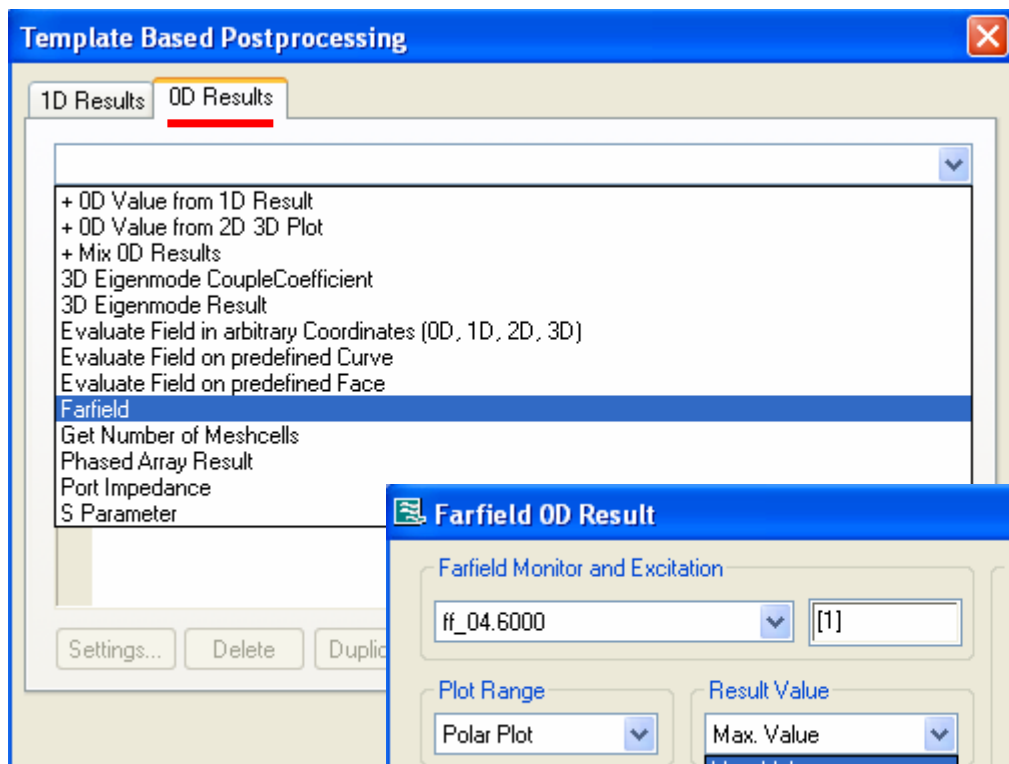
Farfield
Time Signal



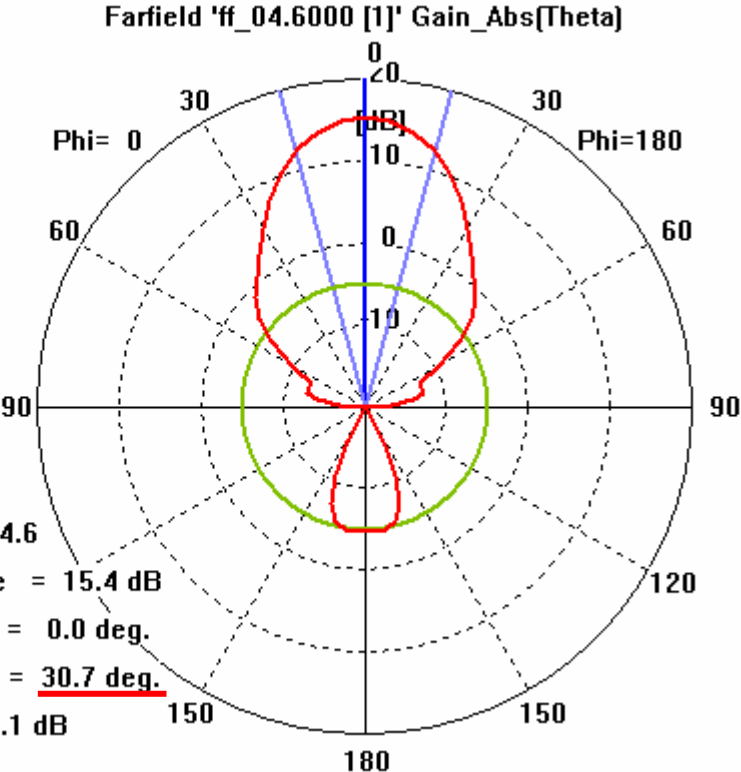
Highly resolved
Farfield
Frequency Spectrum
(1000 samples)

Optimizing Farfield Results

Optimizing Farfield Results

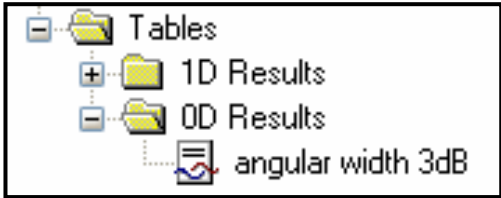


Example: 3dB Angular Width

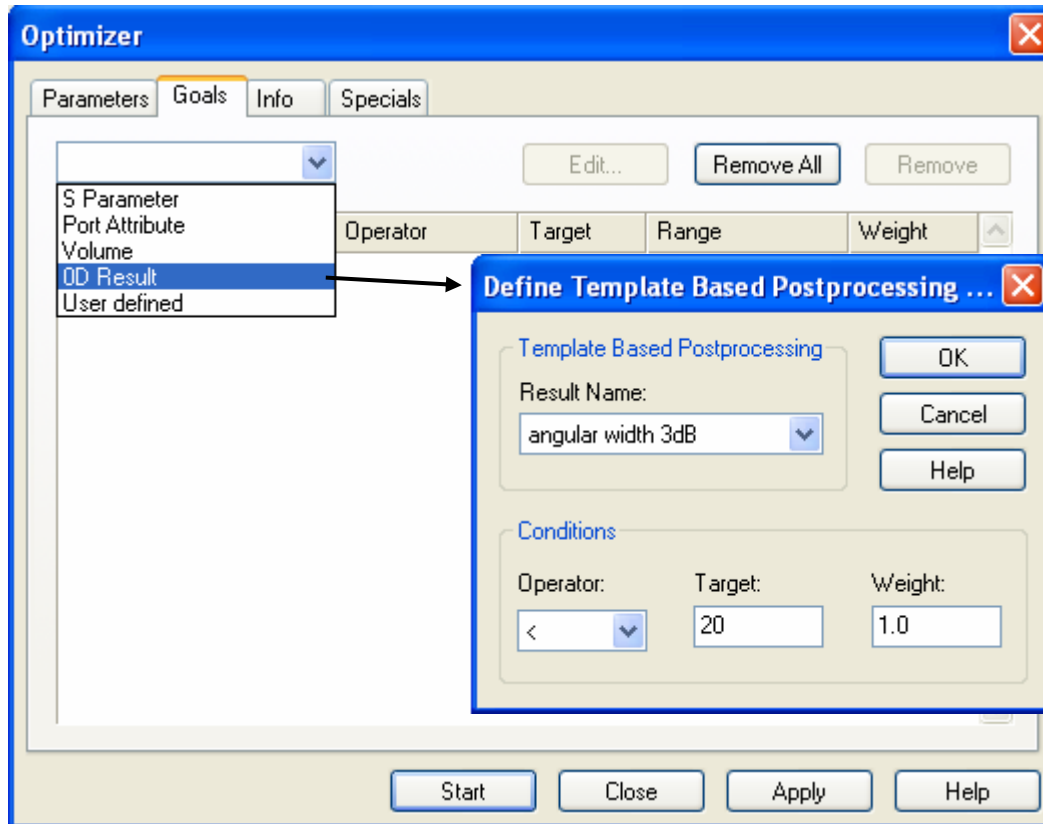


Frequency = 4.6
Main lobe magnitude = 15.4 dB
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 30.7 deg.
Side lobe level = -20.1 dB

value also displayed here:



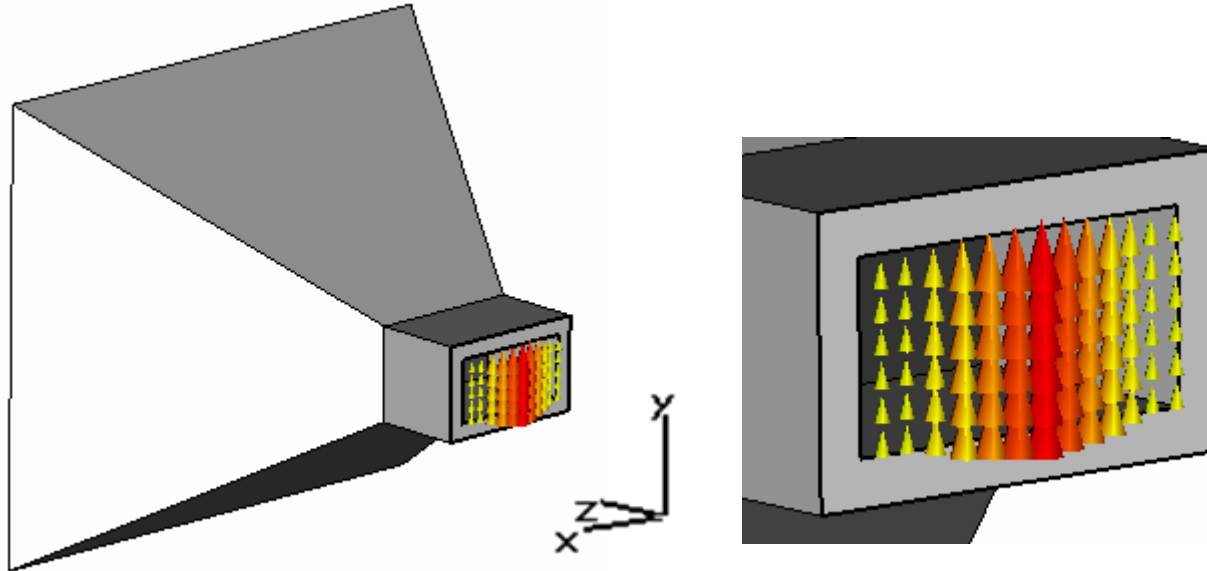
Define Goal from 0D Template



all existing
0D Result Templates
can be used
to define goals
for optimization runs.

Co & Cross Polarization

Co & Cross Polarization



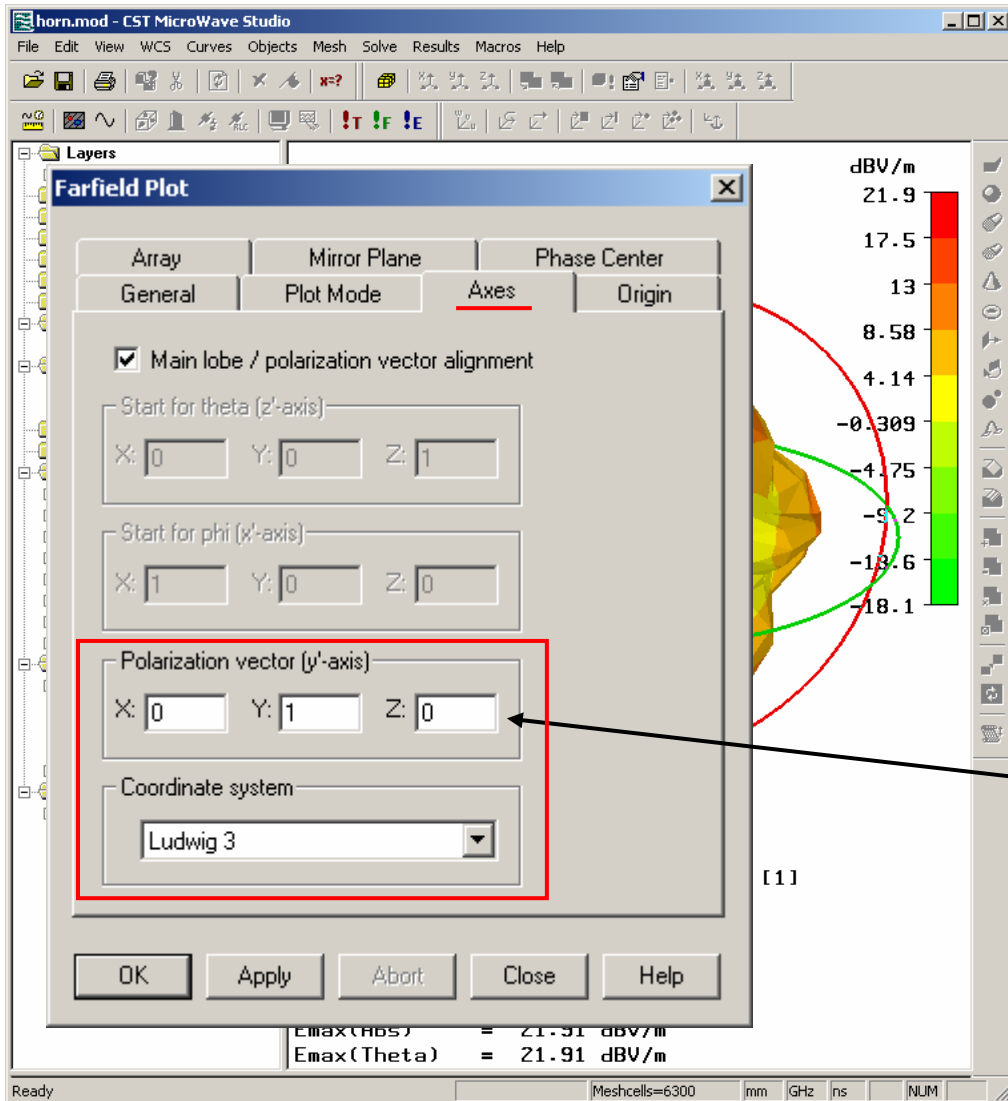
The ***Co-polarized*** farfield component has the same polarization as the excitation (y-oriented in our case).

The ***Cross-polarized*** farfield component is orthogonal to Co-pol component and mainlobe direction.

In order to use different polarizations for transmitting/receiving, an antenna design goal might be to maximize the Co-pol and minimize the cross-pol component.

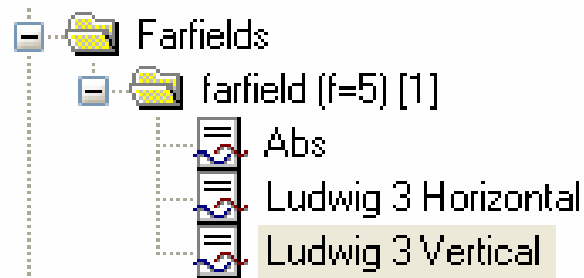
Co & Cross Polarization

Adjust the Axes / coord. system

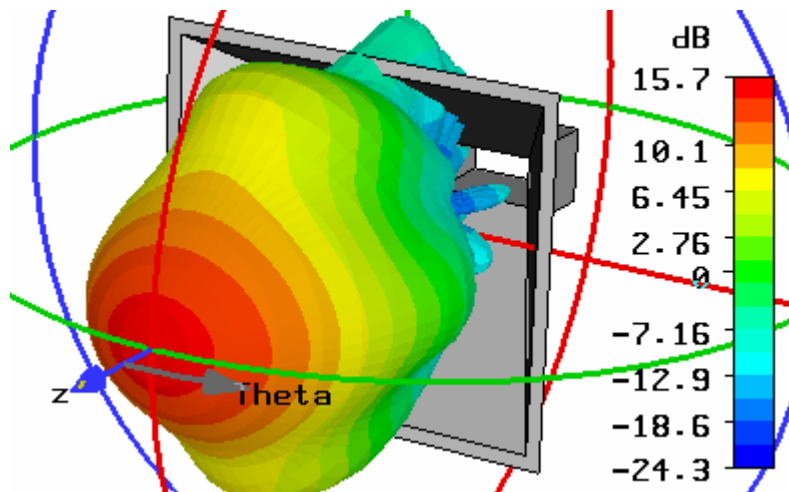


Polarization vector default direction
(the right one for our example;
arbitrary user input possible)

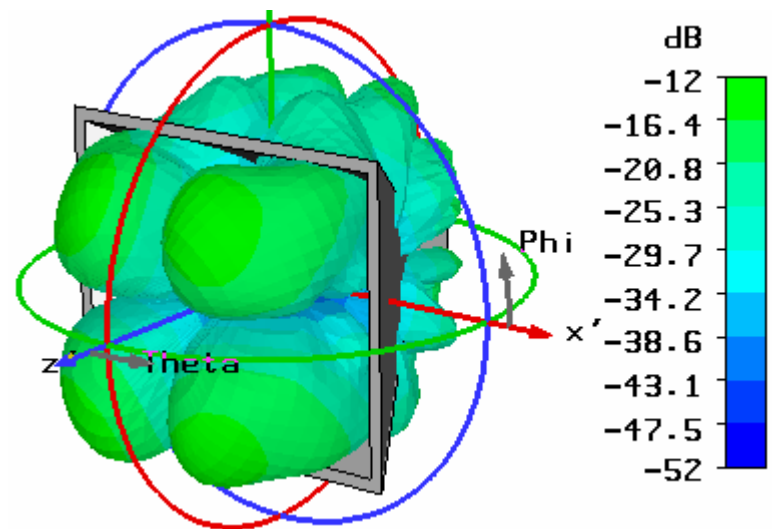
Co & Cross Polarization



Co pol = Ludwig 3 Vertical



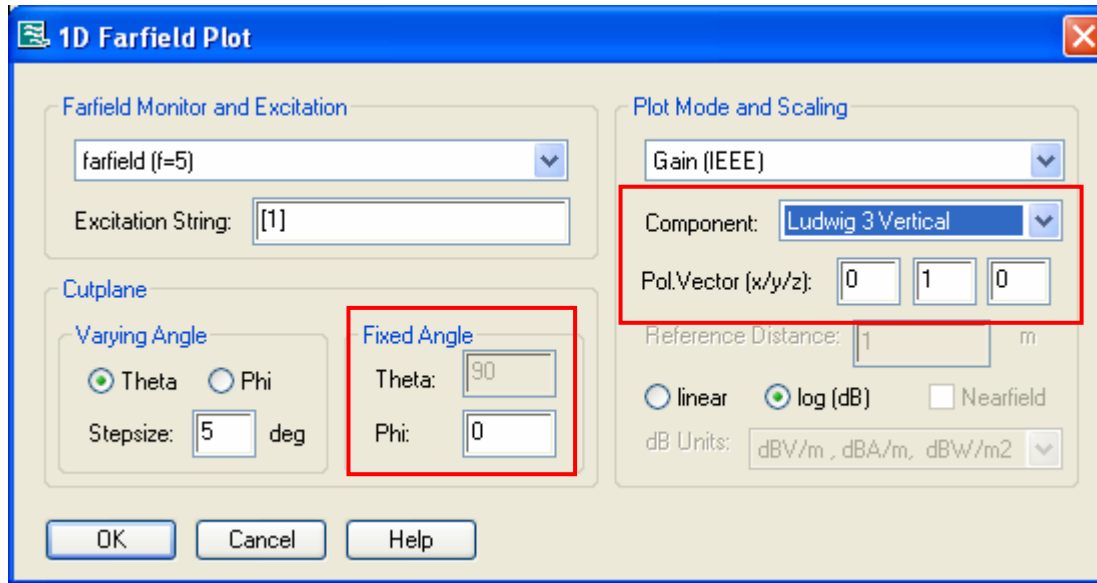
Cross pol = Ludwig 3 Horizontal



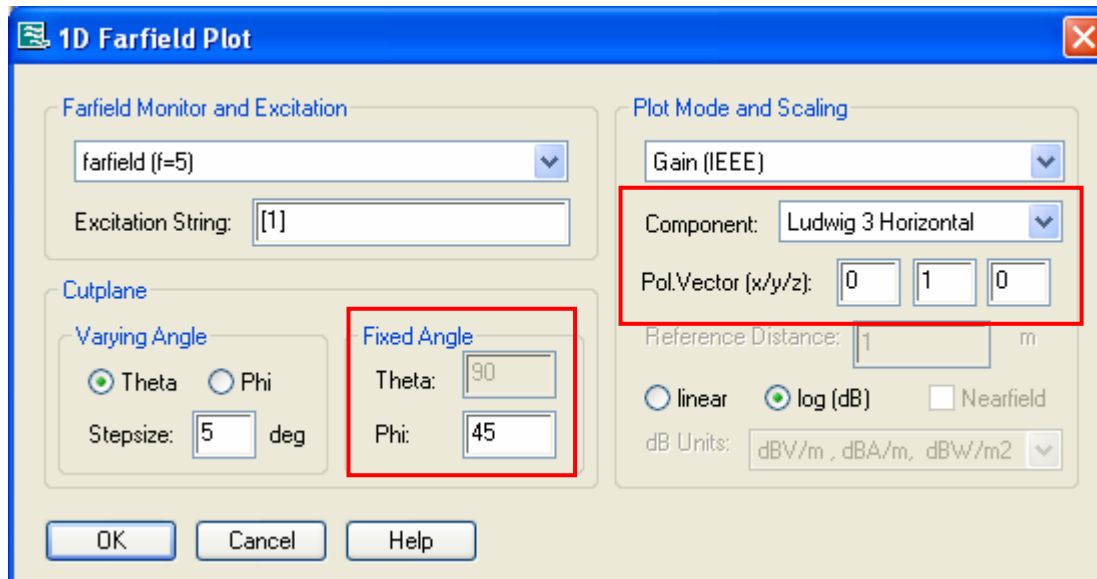
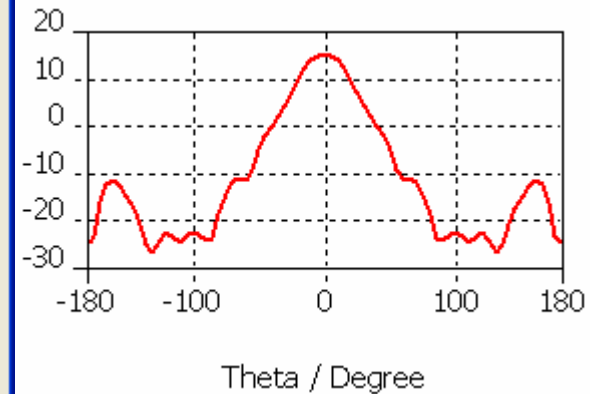
Cross polarized component is typically worse for the angles $\phi=45$ and $\phi=225$

Co & Cross Polarization

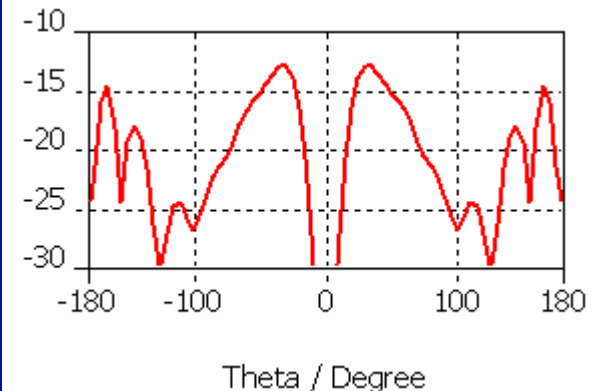
Result Templ. for Param-Sweep & Optimization



Co pol = Ludwig 3 Vertical



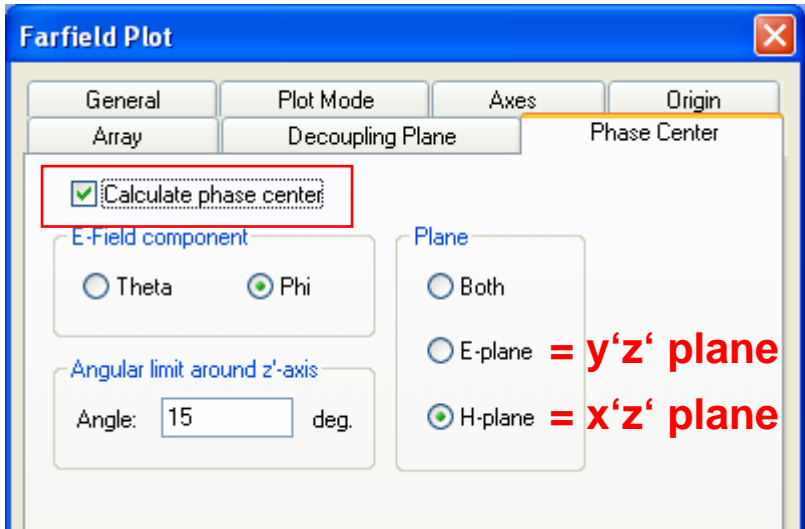
Cross pol = Ludwig 3 Horizontal



Phase Center / Grasp Export

Phase Center Calculation

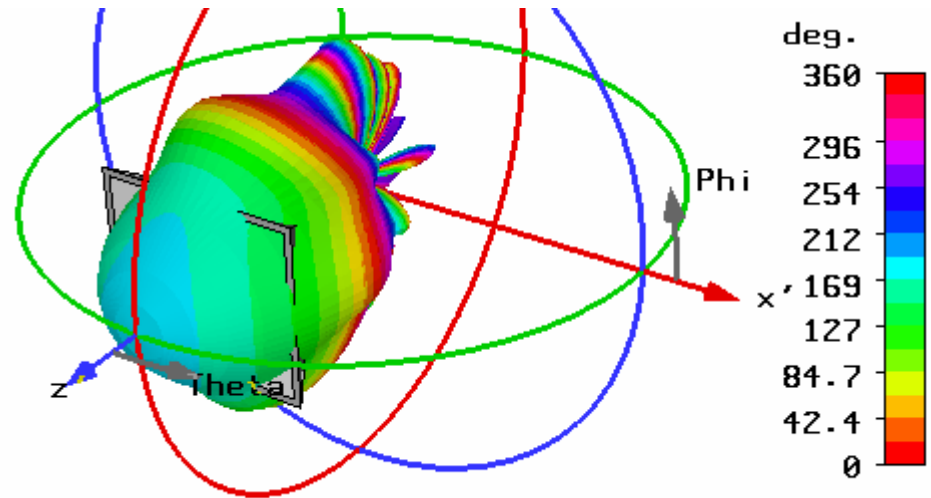
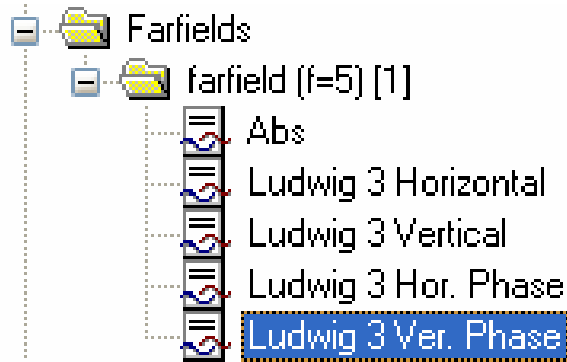
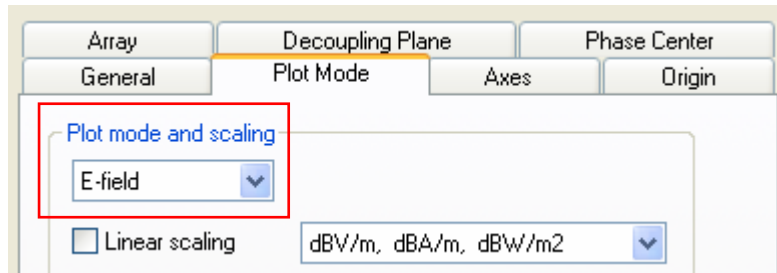
Finding the best location to place the horn inside a dish antenna. The best position is to match the **focal point of the dish** with the **phase center of the horn**.



```
Type = Farfield
Approximation = enabled (kR >> 1)
Monitor = farfield (f=5) [1]
Component = Ludwig 3 Ver. Phase
Output = E-Field(r=1m)
Frequency = 5
Eray(Theta) = 20.41 dBu/m
Phase center = (2, 1, 5.29659) Sigma 0.0829187 (H-Plane)
```

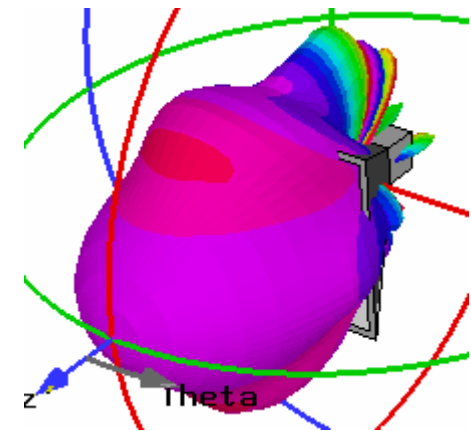
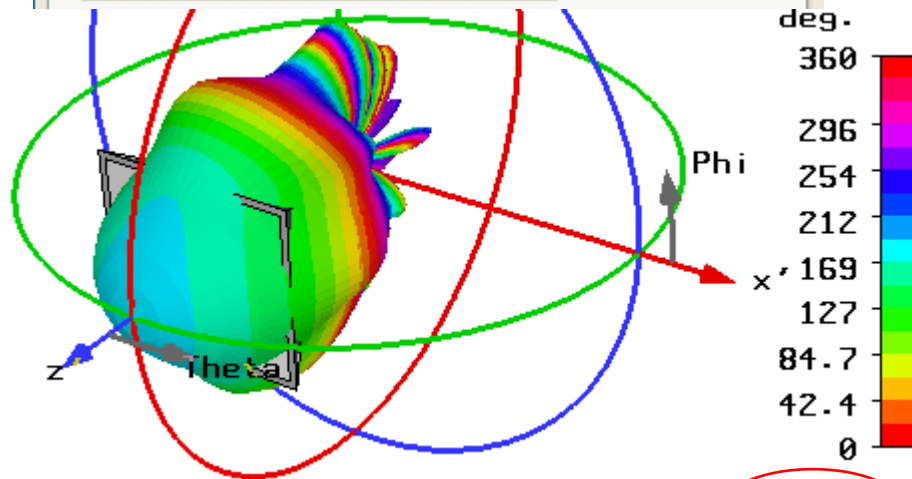
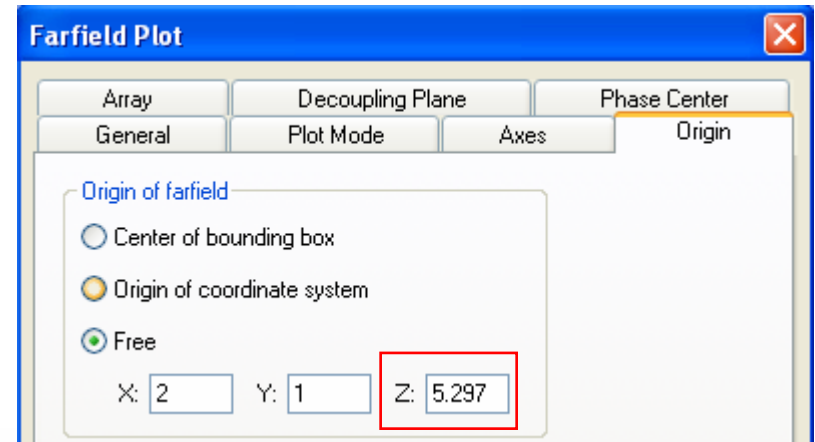
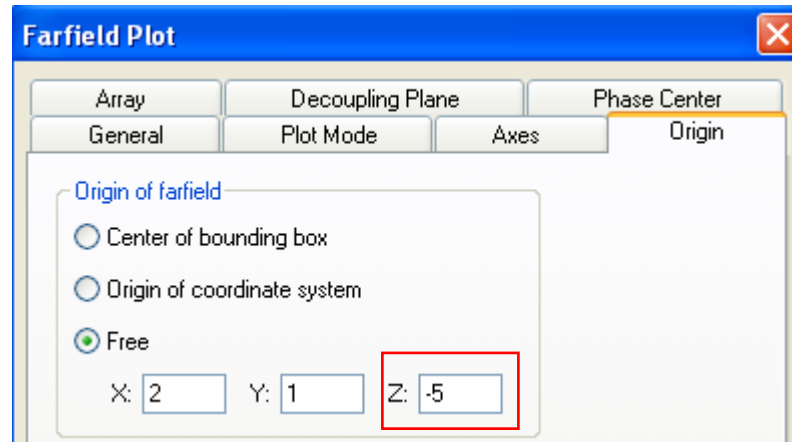


Check Phase Center by plotting Ludwig3-Ver.Phase



Plotting the Phase of Ludwig 3 Vertical
(=dominant component co-pol) does not result
in a phase 180 deg jump (=colour jump) at theta=0

Check Phase Center by moving Origin into Phase Center



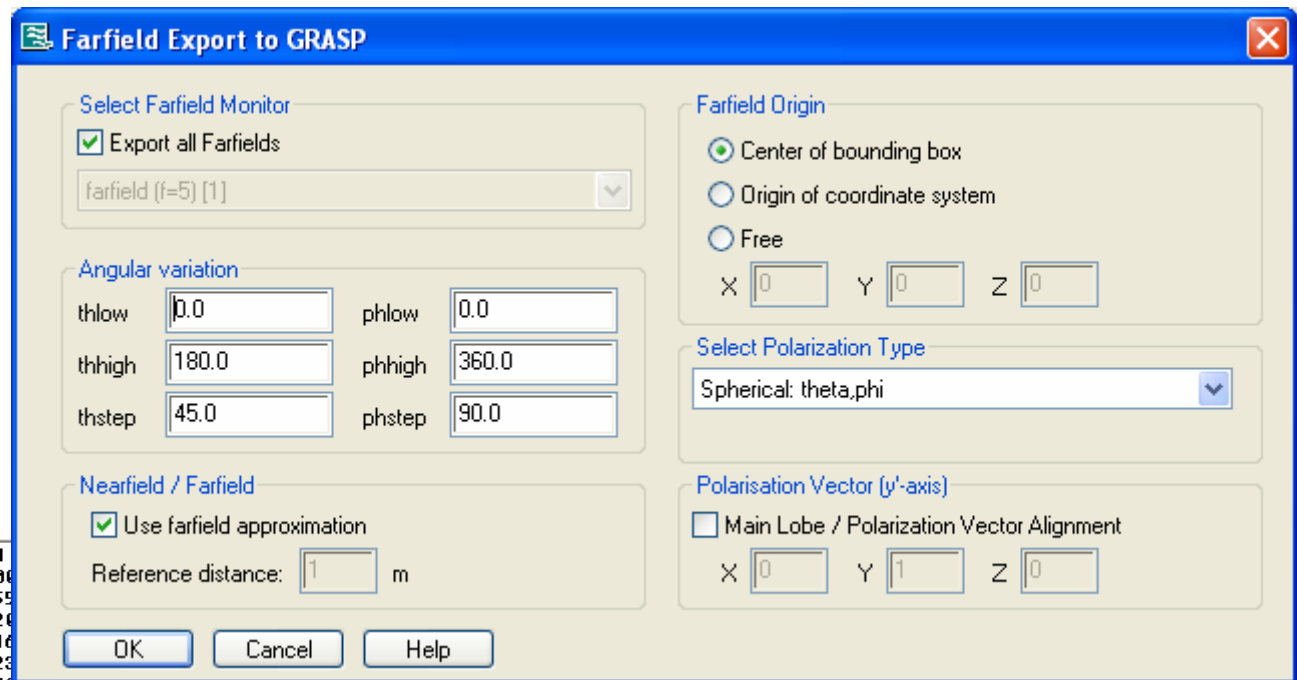
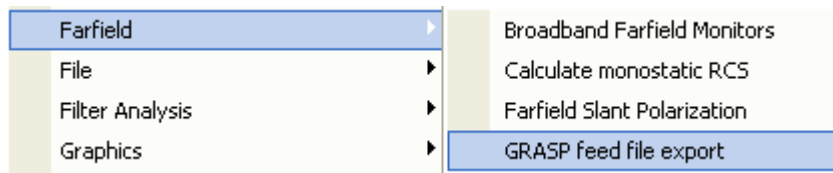
Phase center = (2, 1, 5.29651) Sigma 0.0830522 (H-Plane)

see also article (phase center comparison with measurement)
on www.cst.com -> Application Article ID=256

Farfield Data Export in Grasp Format

Solve Results **Macros** Window Help

Grasp is a software, based on physical optics, analyzing Reflector Antennas and Scatterers

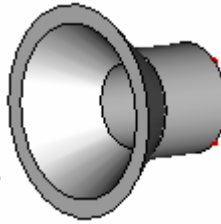


```
CST MWS Results: horn, Farfield
0.000000000E+00 4.500000000E+00
-4.896464690E-18 -3.040153825E-17
-2.345405218E-16 -4.359065422E-15
-1.061475095E-17 -2.308382231E-16
-4.210674381E-18 3.675252842E-17
4.044248651E-18 -4.246160207E-16
5.002700000E-02 2.771051000E-02
```

```
CST MWS Results: horn, Farfield (f=5) [1], Polarization: theta,phi, FF Origin: center of bounding box
0.000000000E+00 4.500000000E+01 5 9.000000000E+01 1 1 2
5.055888490E+00 3.488068378E+00 3.144700993E-16 2.166156807E-16
-6.340192298E-01 1.211314137E+00 -2.950881635E-18 5.226171028E-17
-5.080989801E-02 5.289432604E-01 2.305563380E-17 1.186077381E-17
-3.277271306E-01 1.024174811E-01 -2.931822156E-18 3.077404893E-17
5.632703081E-02 -2.771651863E-02 -5.887909918E-18 5.706071305E-18
```

Circular Polarized Antennas

Circular Polarized Antennas

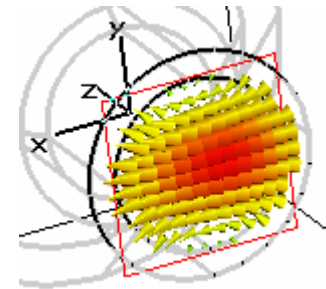


Waveguide port Settings

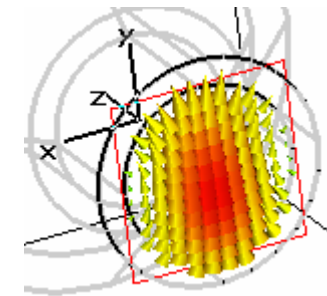
Number of modes:
2

Polarization angle
0.0

Mode 1



Mode 2

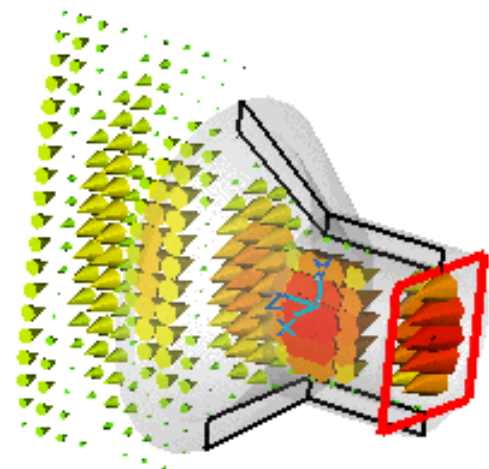


Transient Solver Parameters

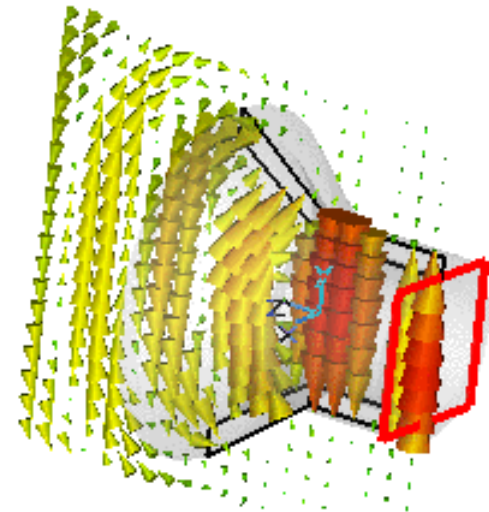
Solver settings
Accuracy: -50 dB

Stimulation settings
Source type: All Ports
Mode: All

only mode 1 active



only mode 2 active

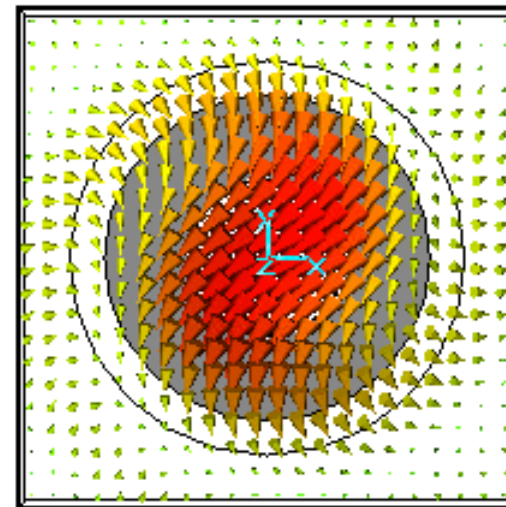
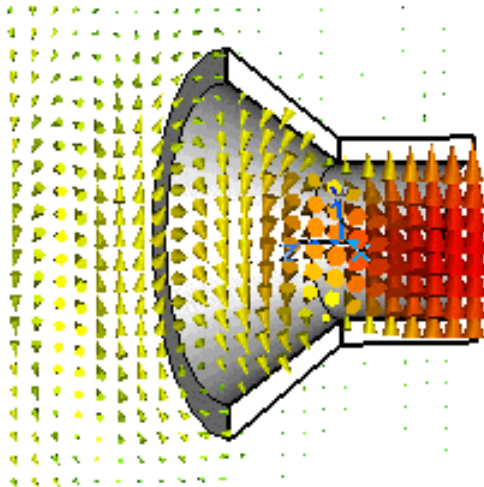
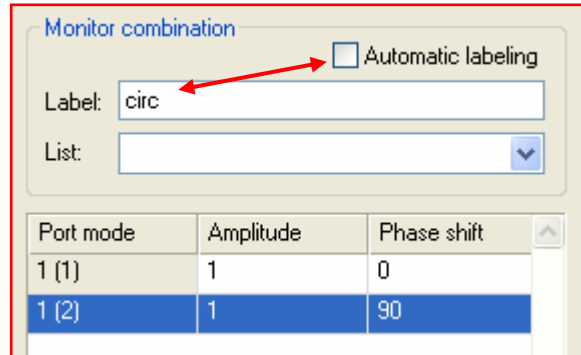


-> Distributed Port Runs



Combining the Results

Results -> Combine Results...



view in $-z$ direction

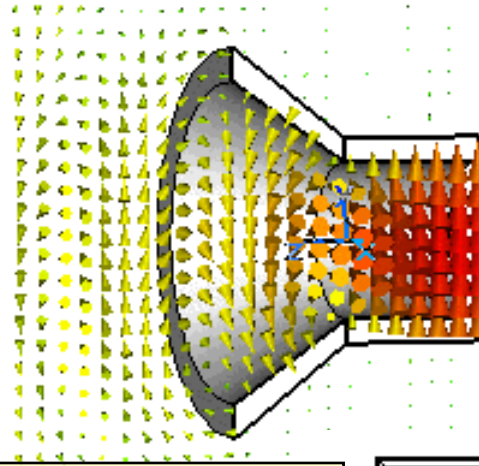
Combining the Results

Monitor combination Automatic labeling

Label:

List:

Port mode	Amplitude	Phase shift
1 (1)	1	0
1 (2)	1	90

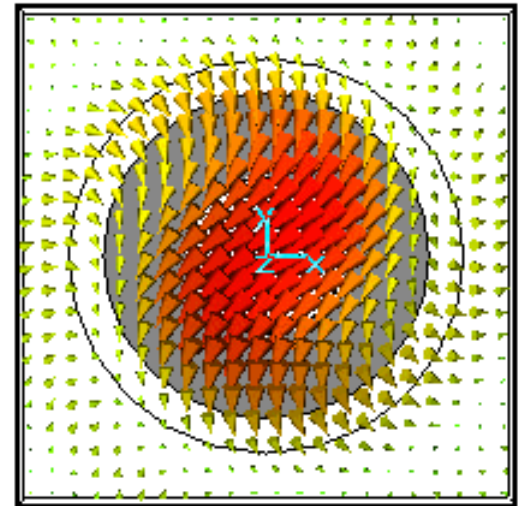


Ports=ALL/Modes=All + Combine Results

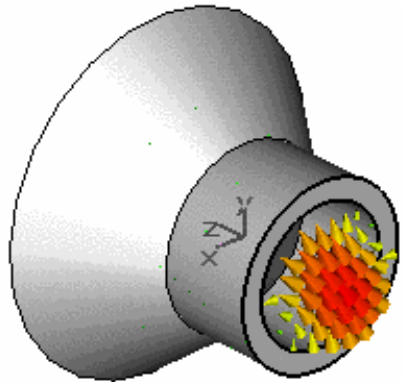
- requires several T-runs (-> use Distributed Computing!)
- + produces S-Parameters
- + **broadband** constant phase shift of 90 deg.
- + flexibility to get results for arbitrary am/ph combination in postprocessing

Simultaneous Excitation

- + only one run required
- produces F-Parameters (no S-Parameters)
- constant phase shift only valid for one frequency
- different am/ph combination requires new run



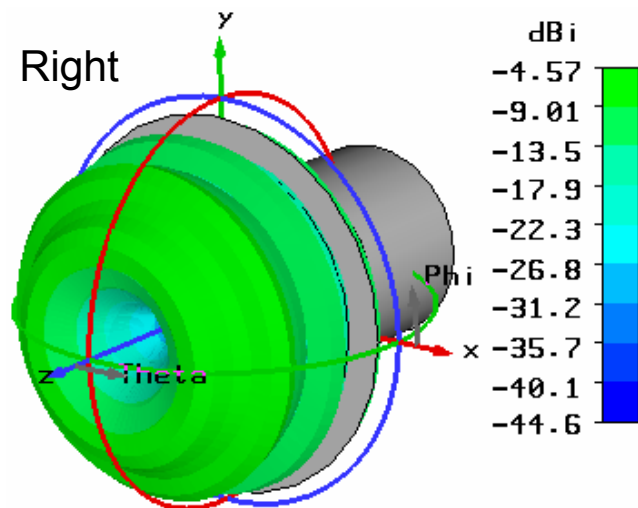
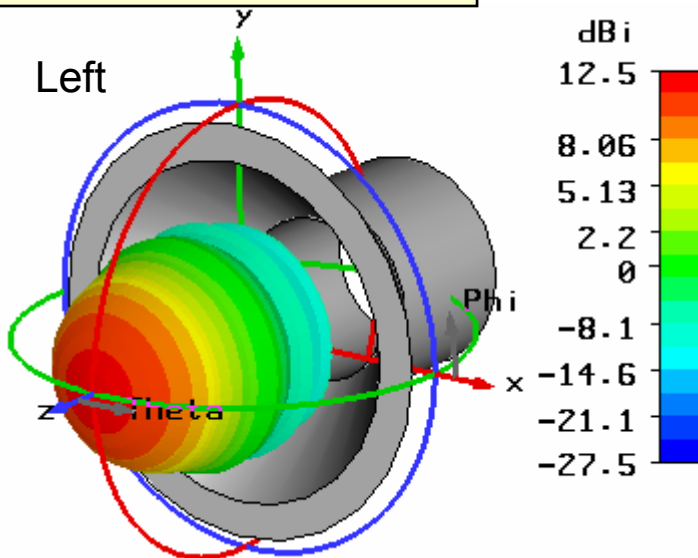
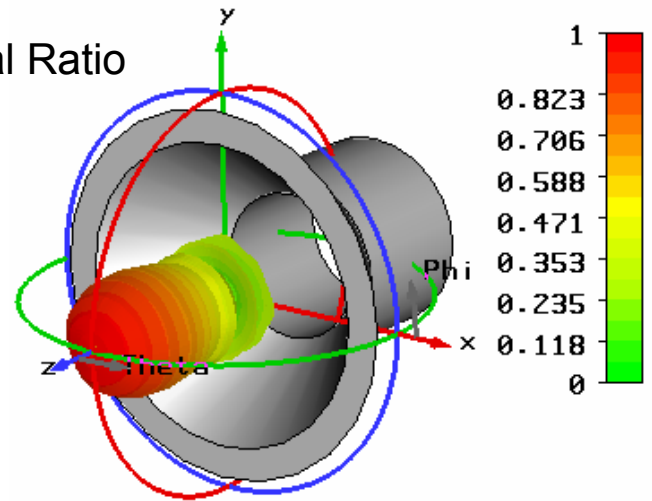
Farfield Capabilities for circular polarized Antennas



- farfield (f=80) [circ]
- Abs
- Theta
- Phi
- Axial Ratio
- Left Polarisation
- Right Polarisation

Note: Left / Right is seen from the transmitting antenna port.

Axial Ratio



Result Template for Combined Monitor 1[1.0,0.0]+2[1.0,90],[80]

Farfield 'farfield (f=60) [1[1.0,0.0]+2[1.0,90],[80]]' Gain_Abs(Theta)

Solver Parameters

Solver settings
Accuracy: -30 dB Store result data in cache

Stimulation settings
Source type: Selected Ports Full deembedded Calculate mo

S-parameter settings
 Normalize to fixed impedance S-parameter s
50 Ohms Adaptive mesh refinement Network computing

Port Mode Excitation Selection

	Port mode	Ampli.	Phase shift	Signal
<input checked="" type="checkbox"/>	1	1.0	0.0	default
<input checked="" type="checkbox"/>	2	1.0	90	default

Note: In all farfield result templates the Excitation string has to be set manually !! It is recommended to use a shorter userdefined labelling instead of the automatic number- labelling.

Simultaneous excitation
 Activate
Label: 1[1.0,0.0]+2[1.0,90],[80]
List:
Excitation of
 Time delay Phase shift

„circ“

Farfield 0D Result

Farfield Monitor and Excitation
farfield (f=60) +2[1.0,90],[80]

Plot Range
Polar Plot

Result Value
Max. Value „circ“

Cutplane
Varying Angle
 Theta Phi
Stepsize: 5 deg

Fixed Angle
Theta: 90
Phi: 0

Plot Mode and Scaling
Gain (IEEE)
Component: Abs
Pol.Vector (x/y/z): 0 1 0
Reference Distance: 1 m
 linear log (dB) Nearfield
dB Units: dBV/m, dBA/m, dBW/m2

Frequency = 60
Main lobe magnitude = 15.5 dB
Main lobe direction = 5.0 deg.
Angular width (3 dB) = 12.2 deg.
Side lobe level = -5.0 dB



Summary

- Antenna Farfield can be recorded in time and frequency domain (Probe / Monitor)
- Postprocessing templates automate result extraction (e.g. broadband farfield)
- checklist for accurate farfield:
 - energy decayed to -40dB [-60dB] ?
 - enough surrounding space ($\lambda/8$) – open (add space)?
 - Is antenna radiating at this frequency? (S-balance < 1 ?)
- Advanced capabilities to extract:
co+cross-pol / phase center / Grasp input data
RL pol / axial ratio