

# Spherical Antenna Plotting. Visual Gain & Beamwidth measurements. Compare antennas.

**INTRODUCTION** This application note shows how to make 3-d spherical measurements and determine the gain and associated Az or EL beam width of your antenna. Actual measurements are made with two identical patch antennas. The method also applies to substitution using a known standard.

If you take enough measurements around an antenna at a fixed radius you can establish the radiation pattern in spherical coordinates. The DAMs provides an easy to use Scan function. The scan function can provide the data for the spherical plot.

The figure below shows the scan concept. A receive horn is used to measure the Tx power at a radius R from the phase center of the AUT(antenna under test).

Rotating the platform performs the same result as moving the horn at radius R in the OPPOSITE direction

Tilting the platform performs the same result as changing the horn elevation at radius R in the OPPOSITE direction. It is only necessary to move from -90 to +90 degrees to scan the entire antenna provided an Az= 0 to 360 is done for each EL movement.



## Scan Top Hemisphere

1. First Perform SIDE Scan from EI 0 to -45 deg with Az 0 to 360 deg. Save to REG1 in the Data Processing section.



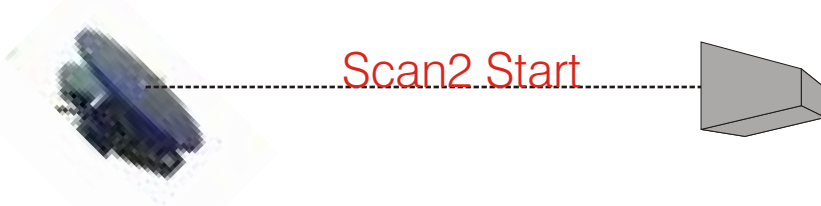
2. Re-position Tripod to AzEL (0,0)



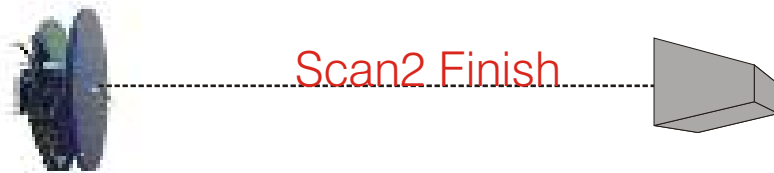
3. Rotate Platform 90 deg. Double jointed tripod is required



4. Position platform EL to +45 to begin where step 2 stopped.



5. Perform scan to EL 0 deg. Save to REG2 This completes the top hemisphere scan.

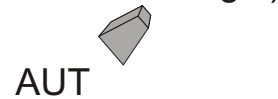


# Generate a spherical gain plot

Assume the previous measurements were made on a high gain beam antenna pointing at Az=+90 EL=+45. The data is resident in REG1 and REG2 as shown below AND is also saved to disc..



← Az 0 360 EL 0 -45 (+45 Antenna angle)  
Top quadrant



← Az 0 360 EL 45 0 (-45 Antenna angle)  
Bottom quadrant



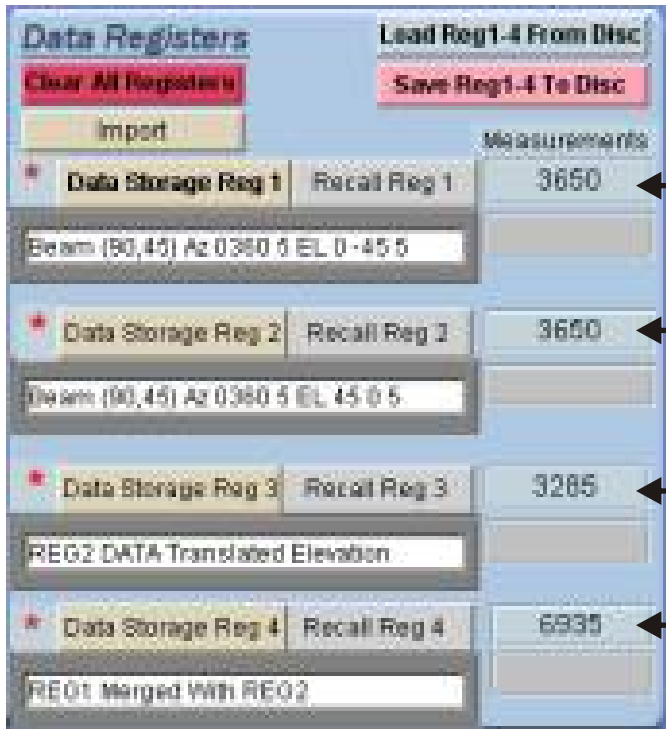
Next invoke the MergeScans module. This module will merge two measurements into a single measurement provided they have been created using pg. 2 instructions.

Note that the measurements at EL=-45 and EL=+45(platform at -90) are repeat measurements. You may want to check your vna display recall to be sure they agree.



# Generate a spherical gain plot

The merged data is sent to REG4. REG3 contains REG2 data with elevation angle translated by -90 degrees.



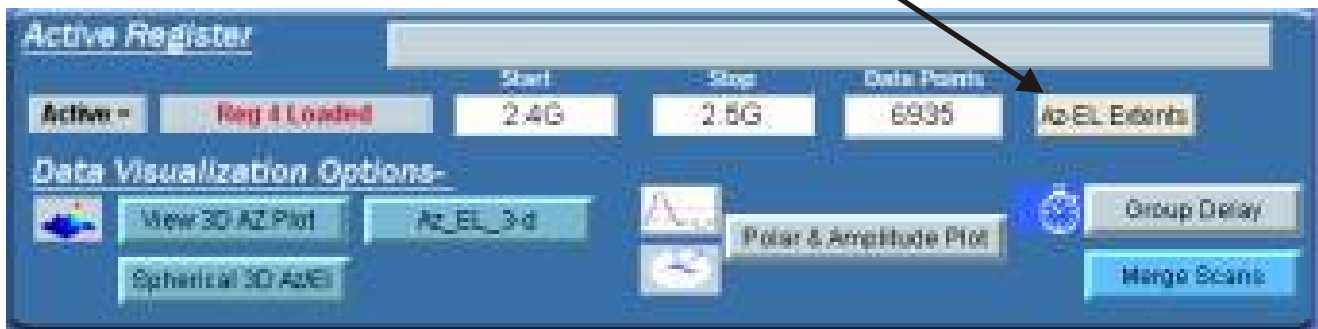
Az 0 360 EL 0 -45 (+45 Antenna angle)  
Top quadrant

Az 0 360 EL 45 0 (-45 Antenna angle)  
Bottom quadrant

Az 0 360 EL -45 -90  
Bottom quadrant

Az 0 360 EL 0 -90  
Bottom quadrant

Recall REG4 data and check the movement extents

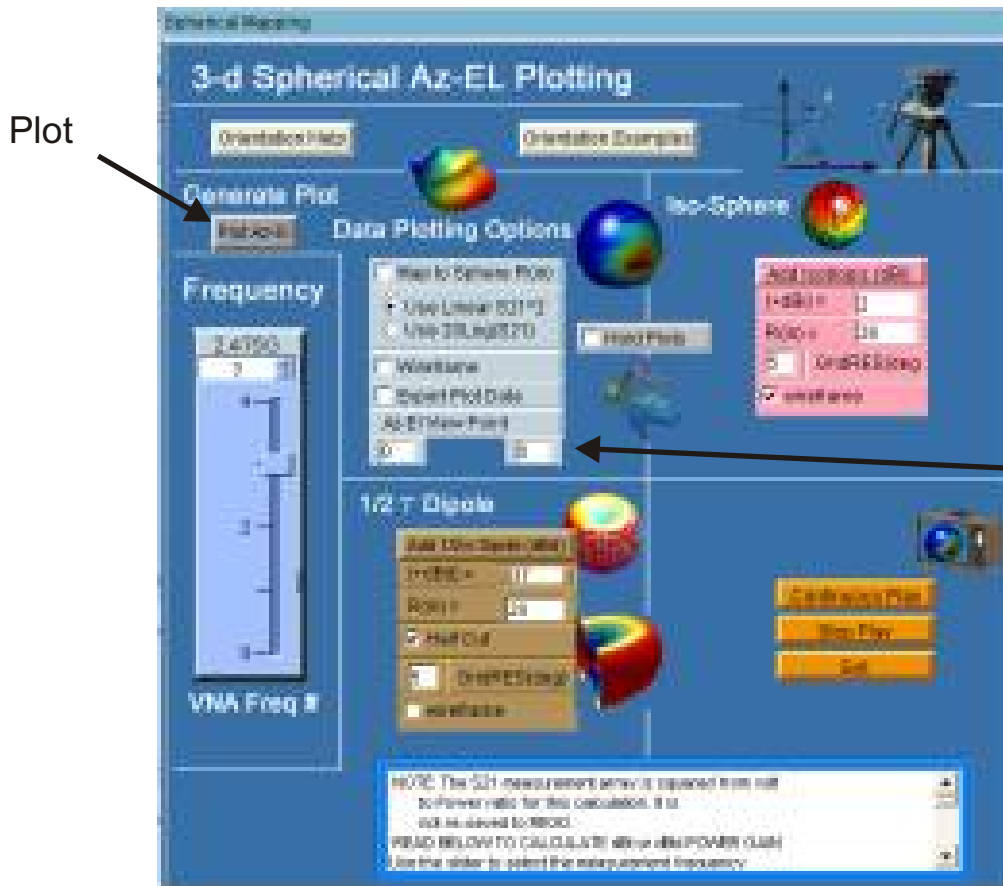


You should observe the following:

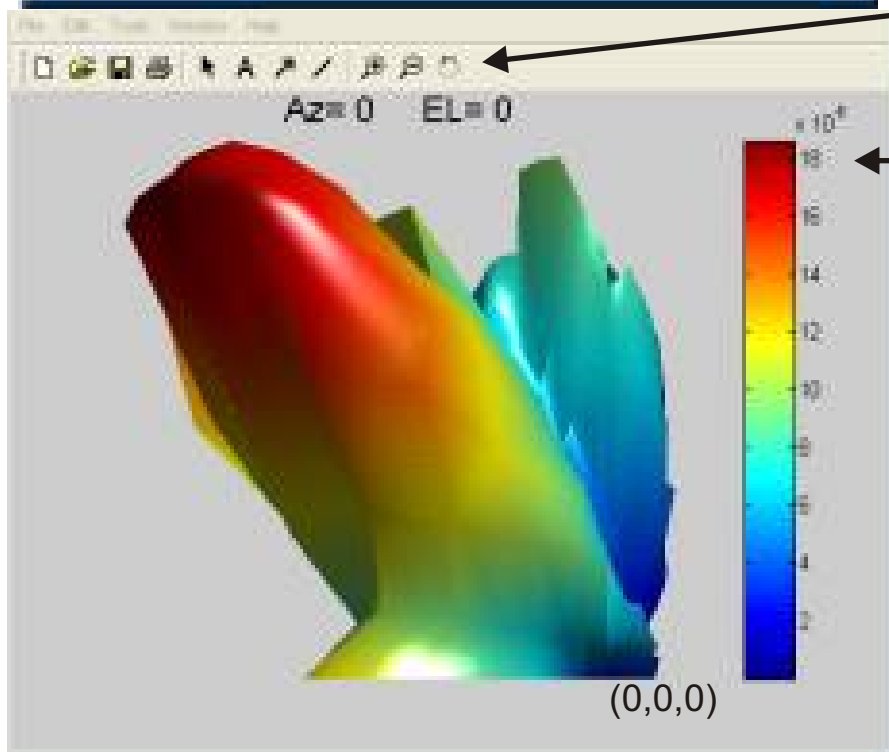
Az Start	Az Step	Az Stop
0	5	360
EL Start	EL Step	EL Stop
0	5	-90
OK		

# Generate a spherical gain plot

Recall the merged data REG4 and verify it is a beam located at Az=35 and EL=20 deg with the default spherical settings.



Observation point is set at Az = 0 EL = 0



Local object tools

$|S_{21}|^2$

Note that the beam is pointed at Az<360 deg. When observing at Az=0 deg the beam is seen from the left quadrant.

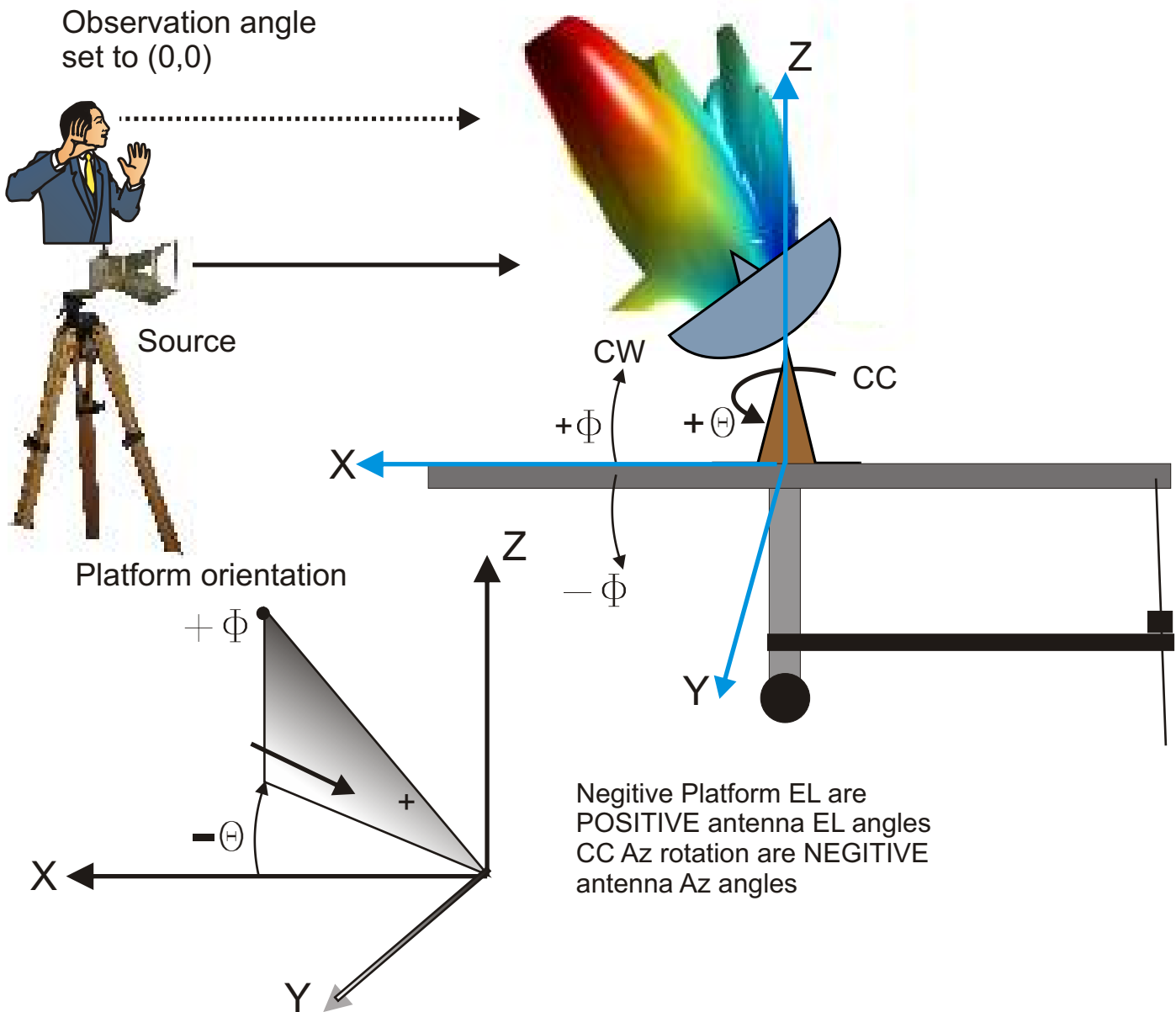
# Generate a spherical gain plot Understanding Orientation

Viewing from the same view point as the source



Observation angle set to (0,0) (Observation from source)

This Beam located at Az=-35 deg EL = 20 deg

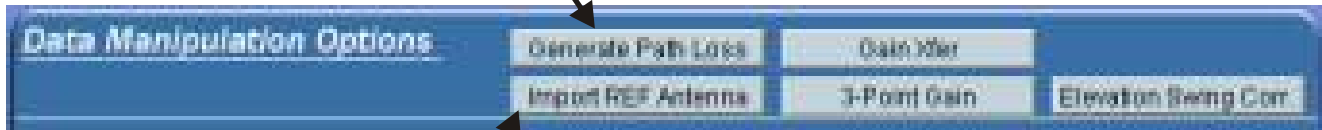


# Generate a spherical gain plot

## Calculate Gain

Next generate a path loss matrix with same size and shape as the measurement matrix. Save the path loss matrix to REG2 (overwrite Bottom Quadrant data).

Follow Path Loss Module instructions



Follow Module instructions

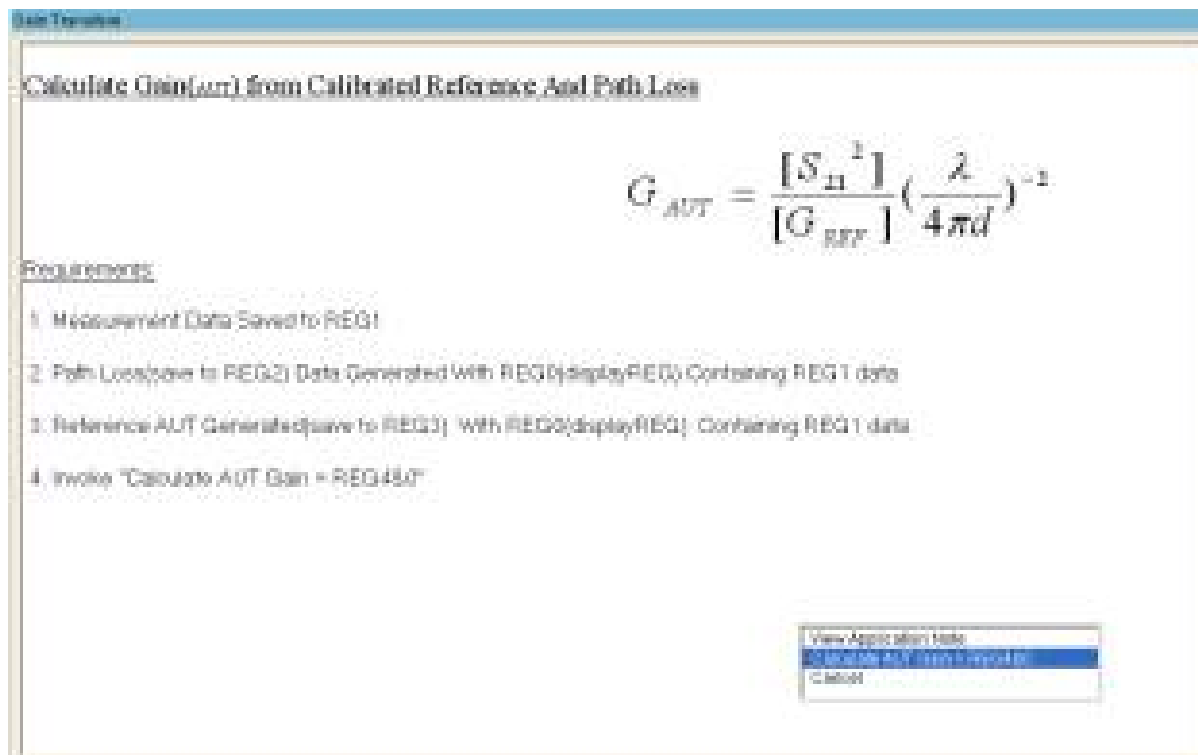
Now generate reference horn matrix with same size and shape as the measurement matrix. Save to REG3.

The Gain Xfer module may be used to solve for the AUT gain. The module utilizes REG1, REG2 and REG3 to calculate:

$$G_{AUT} = \frac{[S_{21}]^2}{[G_{REF}]} \left( \frac{\lambda}{4\pi d} \right)^{-2}$$

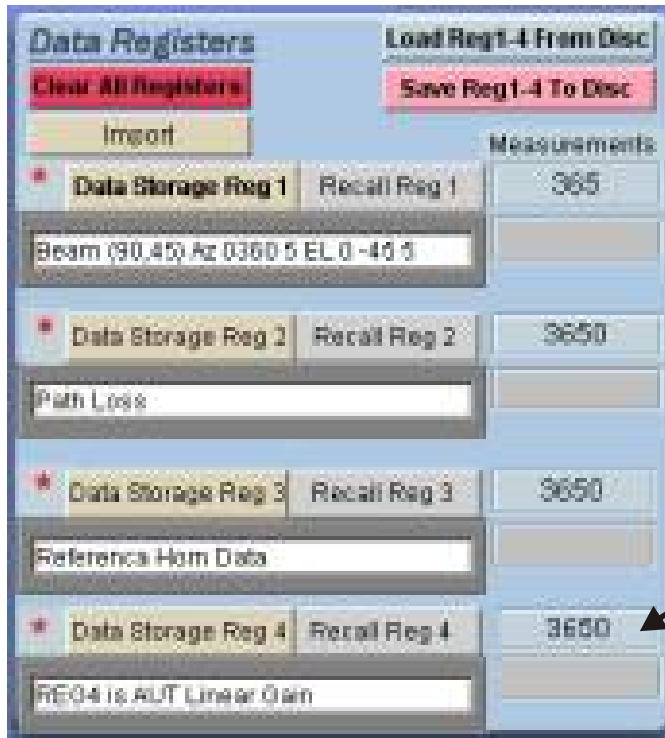
Invoke the Gain Xfer module.

### Gain Transfer Module



# Generate a spherical gain plot Calculate Gain

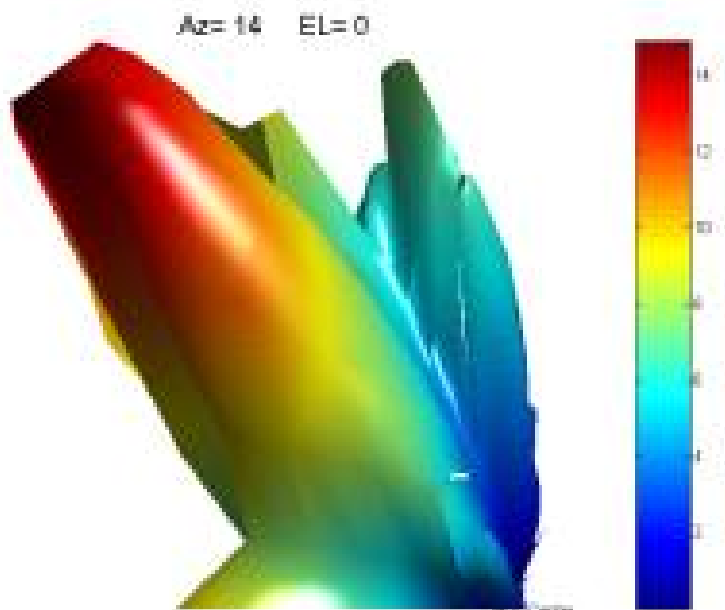
Execution of the Gain Xfer module results in the gain save to REG4



Save this data set and repeat the process with the bottom quadrant data originally in REG2.

GainXfer module saves Gain matrix to REG4 and inserts note

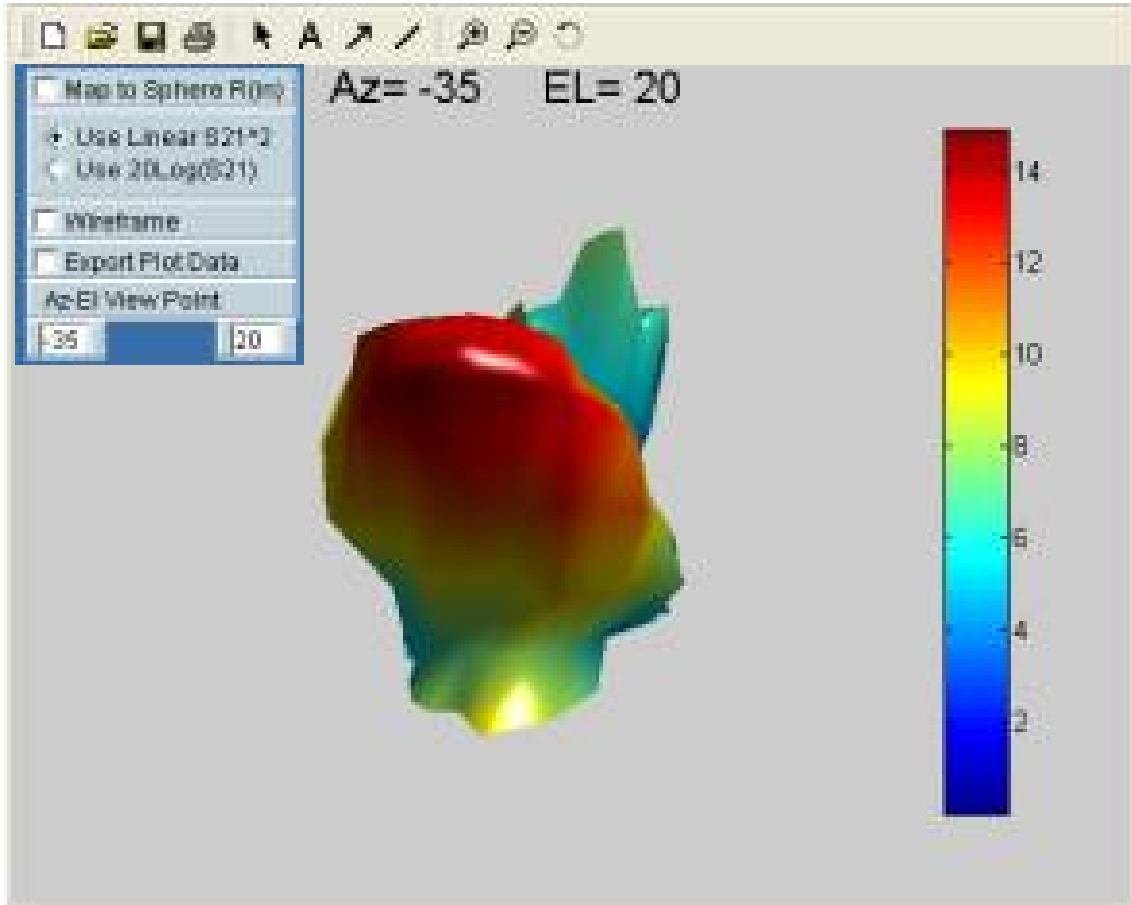
Recall REG4 and plot the spherical profile



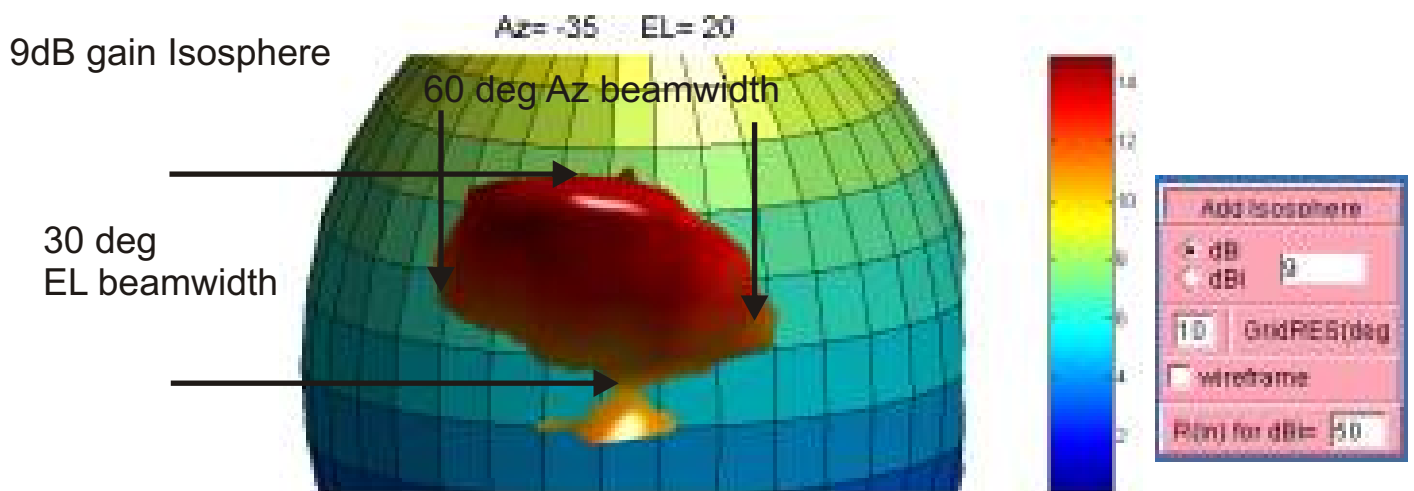
The linear power gain is 12-14 corresponding to about 11dBdB beam gain.

# Generate a spherical gain plot Looking down the beam

Since the beam is pointing at Az=-35 EL=20 change the view point to these coordinates.



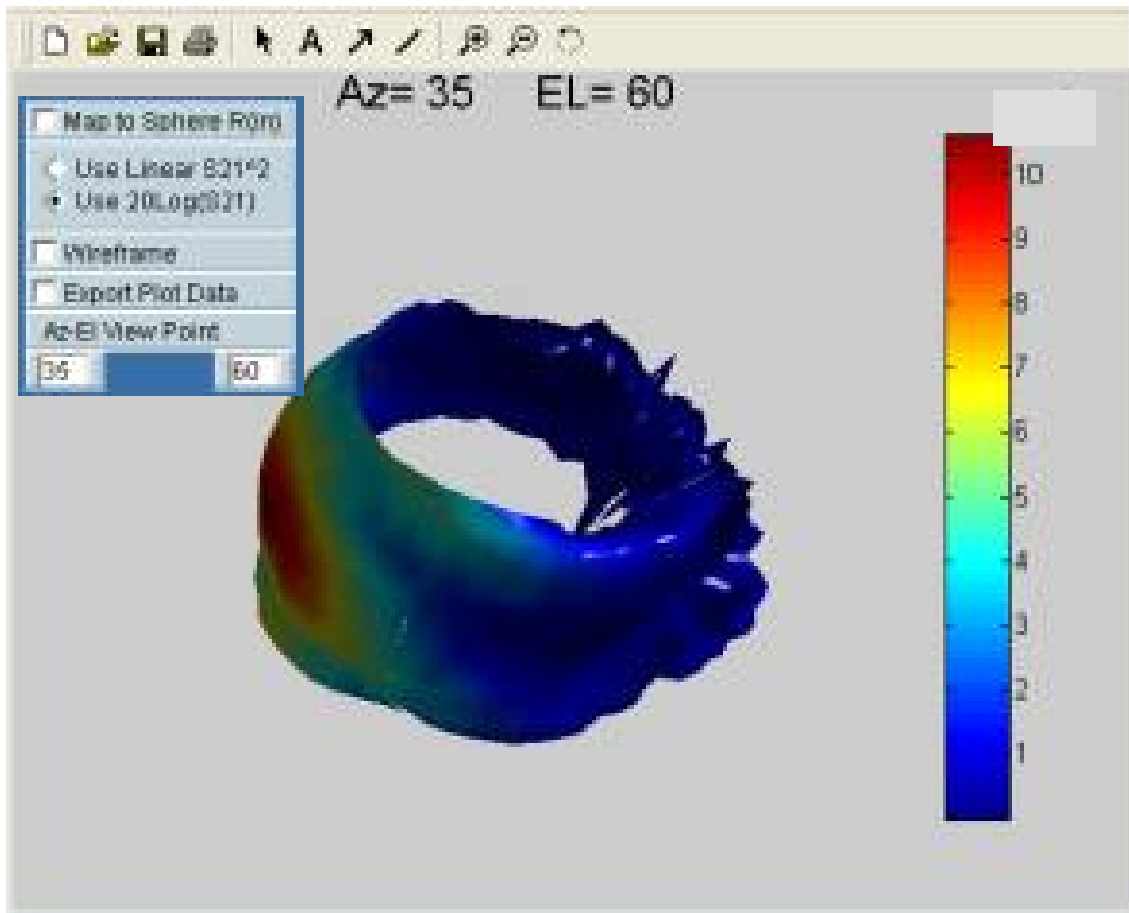
Next determine the 3dB beam width using the isospheres. Set the Isosphere dB gain profile to 3dB less than the maximum gain. You can use the Isosphere to determine the maximum gain of you can use the Polar plot. Set the AzEL grid to 10 deg.



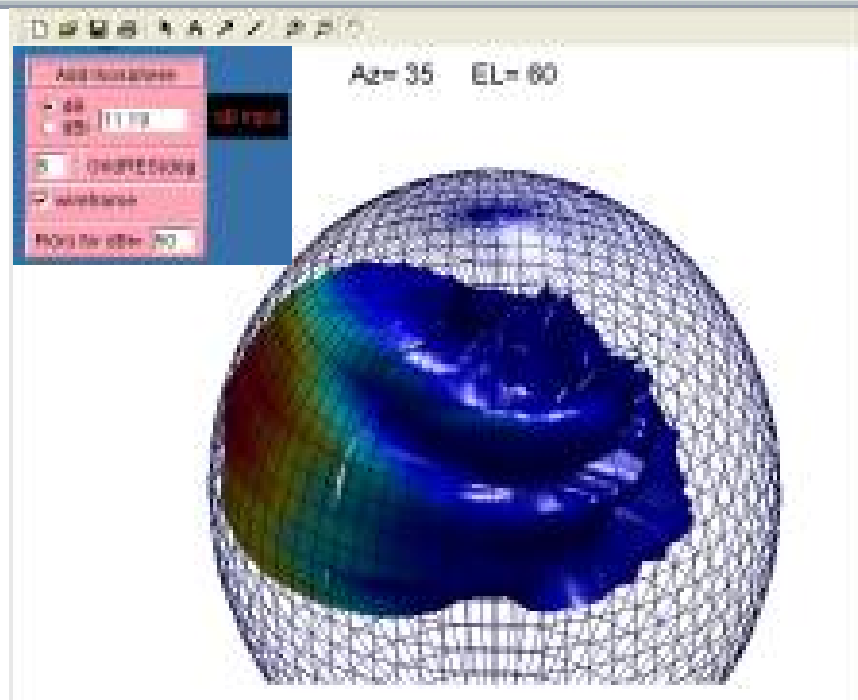
# Generate a spherical gain plot

**Diamond  
Engineering**

Release the isospheres and check the Use 20 LOG(S21) to plot the dB gain



Add a Gmax(default) Isosphere to the dB Gain plot with 5 deg grid resolution.



# Spherical Software Special Utilities

When the spherical module is invoked it is possible to perform many tasks. Here are just a few:

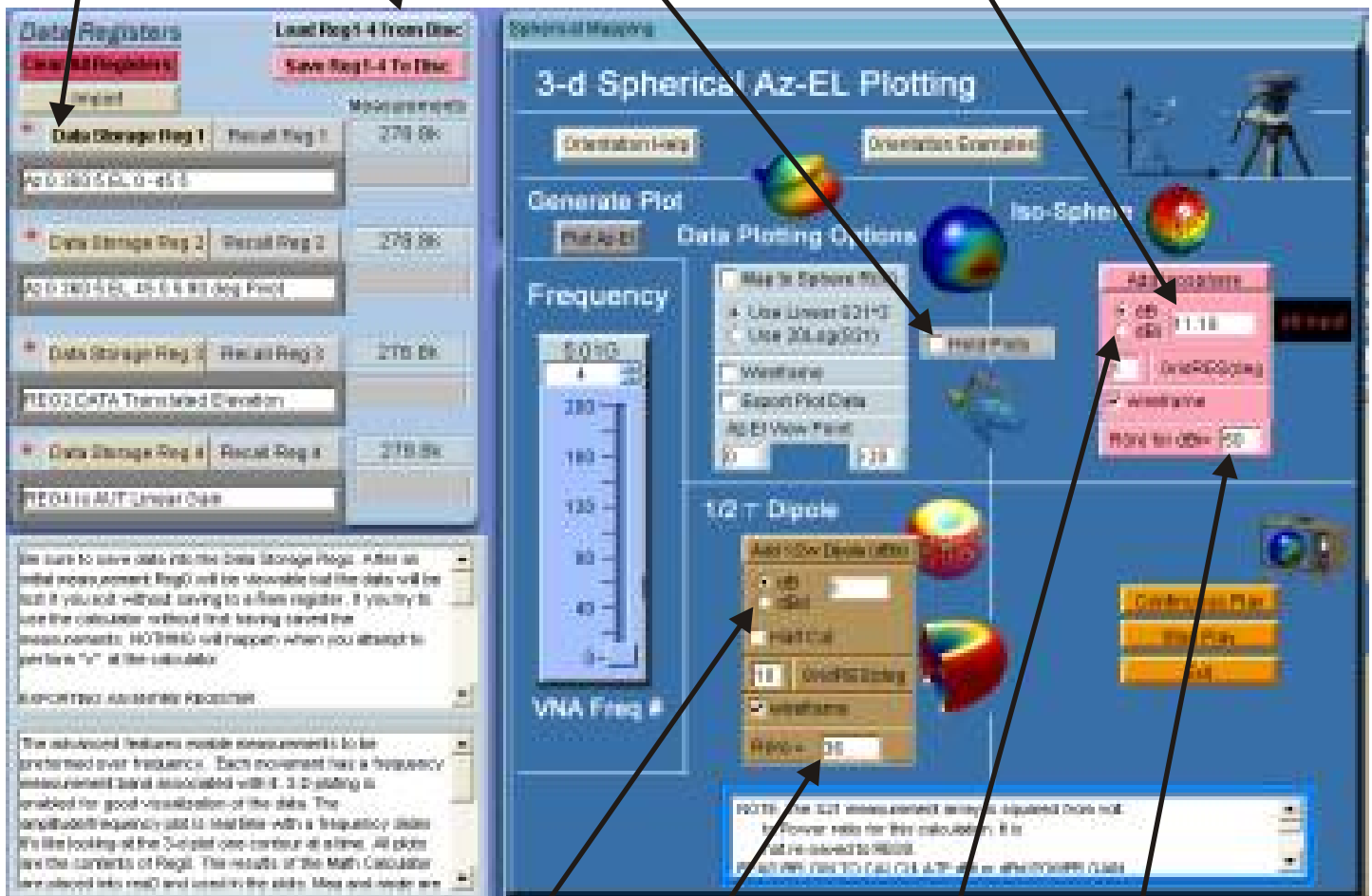
1. Plot gain or Link power in linear or dB.
2. Compare gain plots or links to Isotropic or dipole links.
3. Compare plots to other measurement files.

Any file may be loaded while the spherical module is running

When REG data is plotted in either linear or log mode the Isosphere window defaults to the MAX dB value for the data. This makes it easy to determine any gain-beamwidth.

Any REG may be loaded into the spherical module

Hold Plots may be used to compare files or REGs

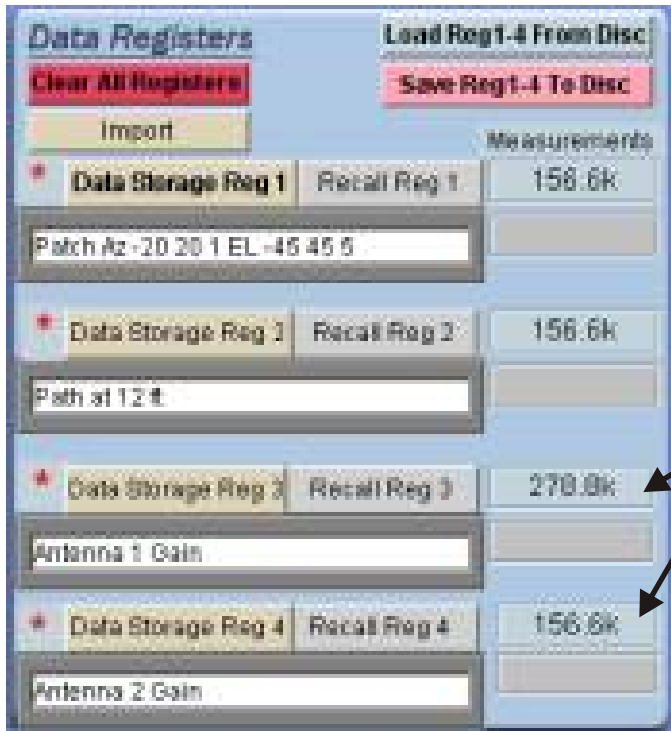


To include path loss such as original measurements use dBd and enter separation distance

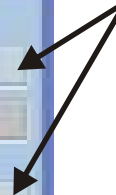
To include path loss such as original measurements use dBi and enter separation distance

# Compare Two Antennas

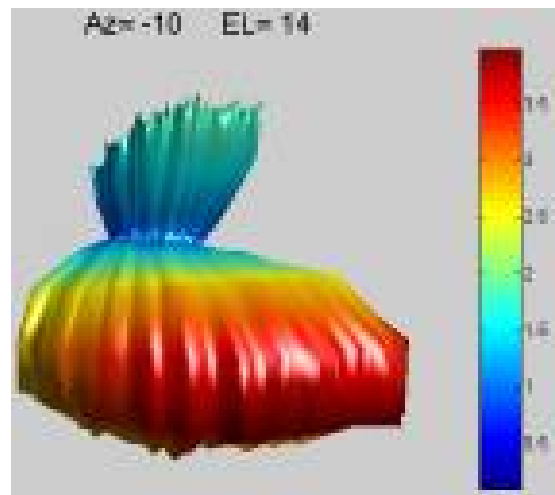
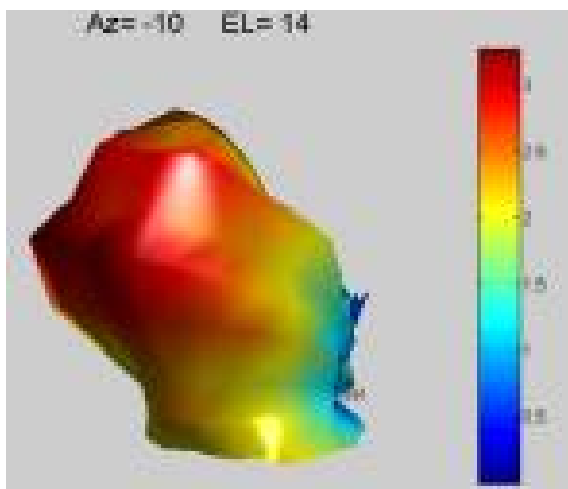
The spherical plot can accommodate different data file sets.  
The data may be of different size and shape.



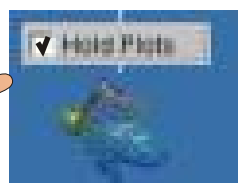
Two different antenna Gain measurements



Recall and plot the first antenna (REG3) gain, then recall the second and plot

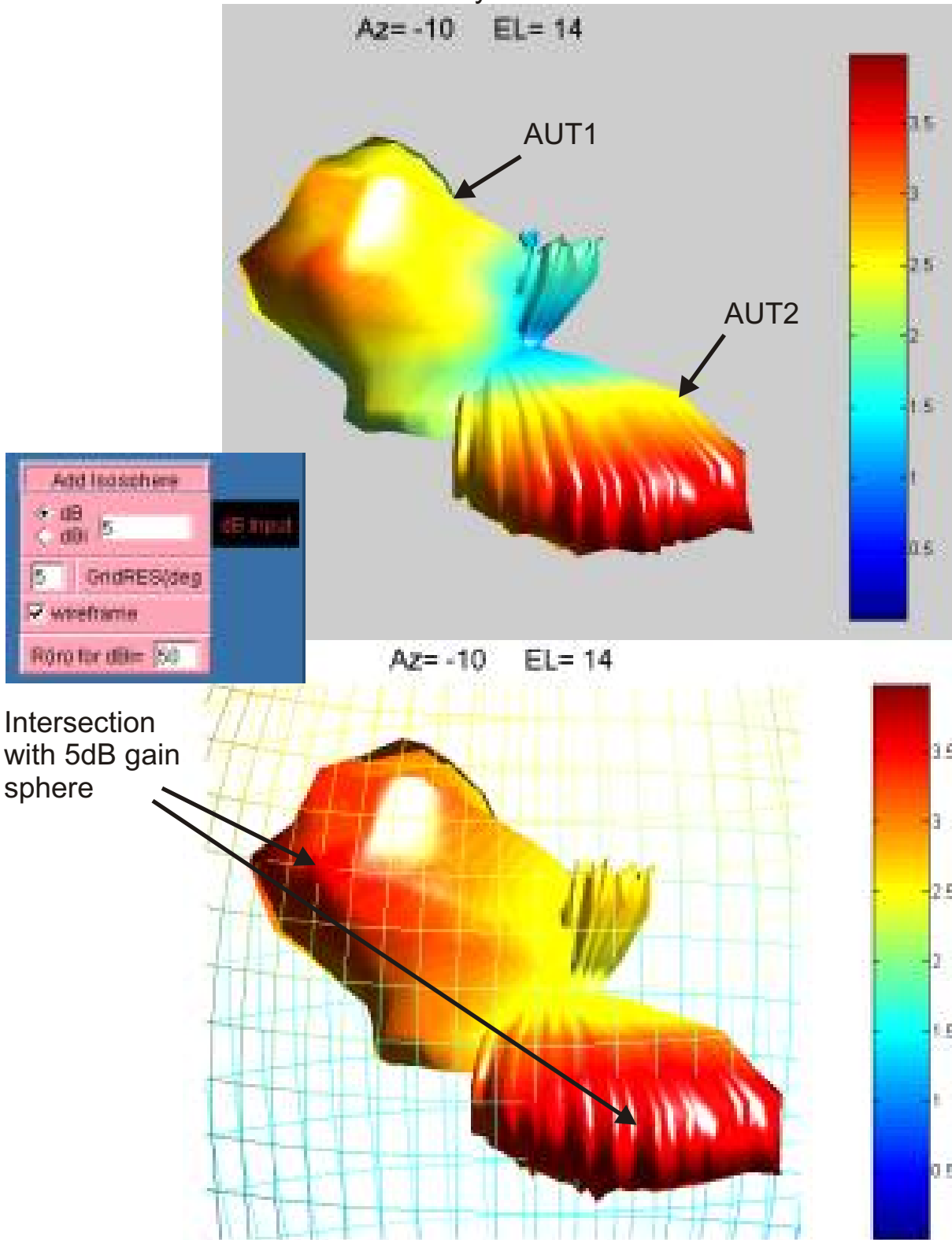


Retain the second and all subsequent plots by checking Hold Plots.



## Compare Two Antennas

Both AUTs are plot spherically. Now add a 5dB gain sphere with 5 deg grid resolution by re-plotting with the Add Isosphere invoked. These are linear gain plots (could also have been 10Log) the intersection of the 5dB sphere establishes an intersection boundary.



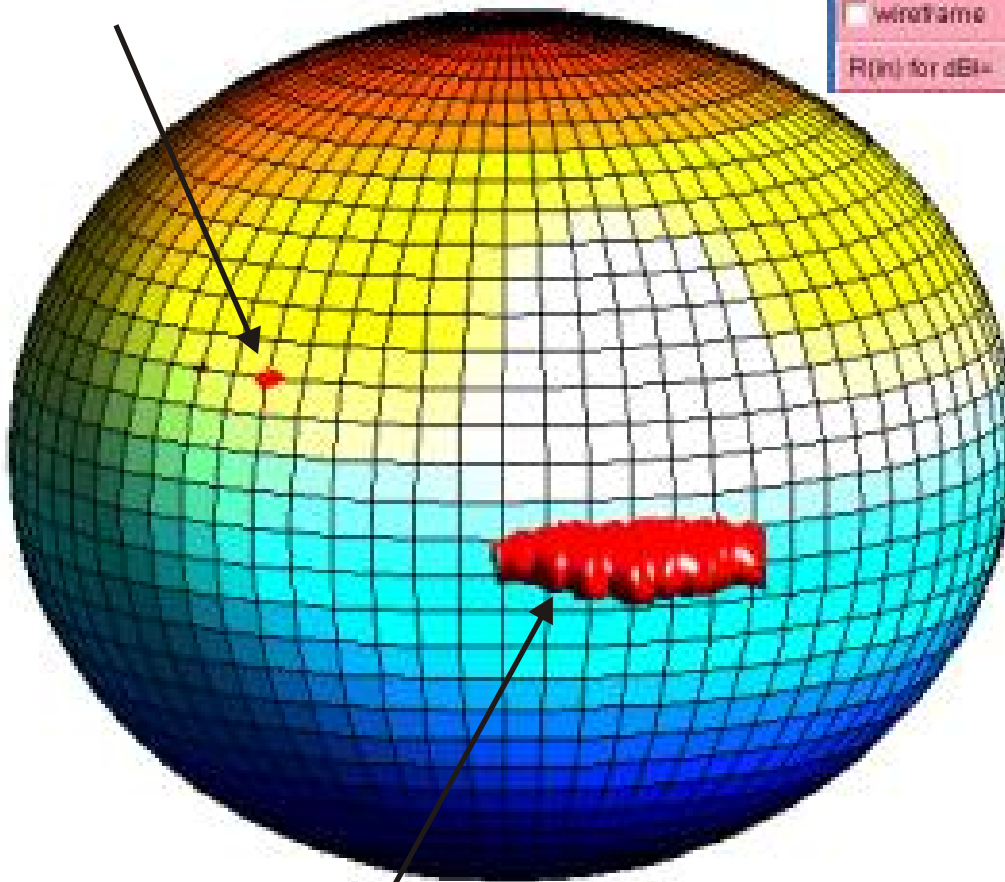
# Compare Two Antennas

To see the 5dB gain-Beamwidth uncheck wireframe and re-plot.

Az= -10    EL= 14

AUT1 5dB beamwidth (3 deg)

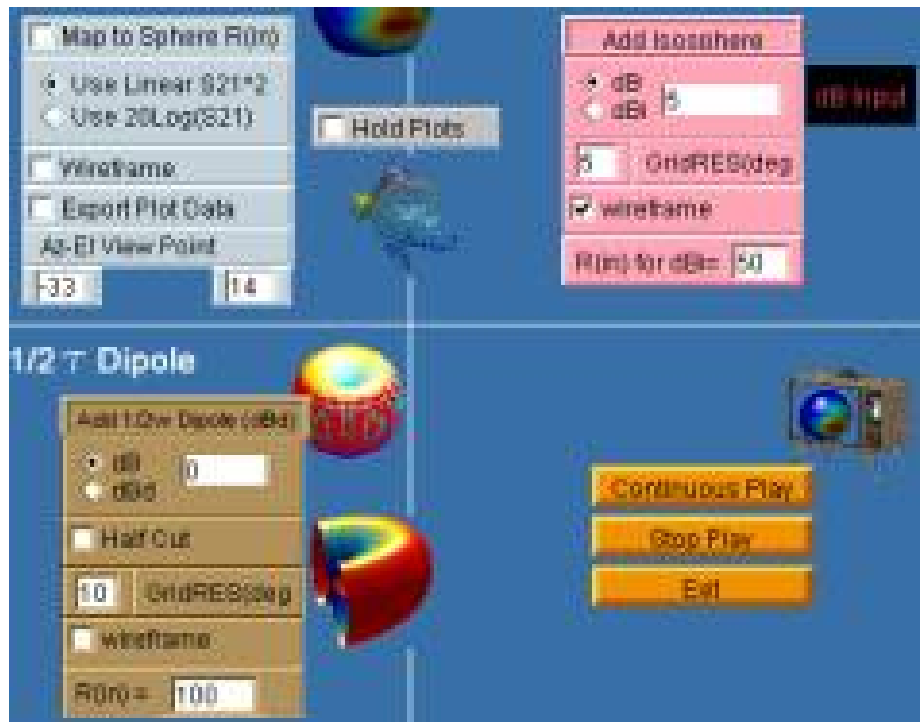
Add Isosphere	
dB	dB Input
5	dB
5	Grid RES (deg)
<input type="checkbox"/>	Wireframe
R (in) for dBi =	50



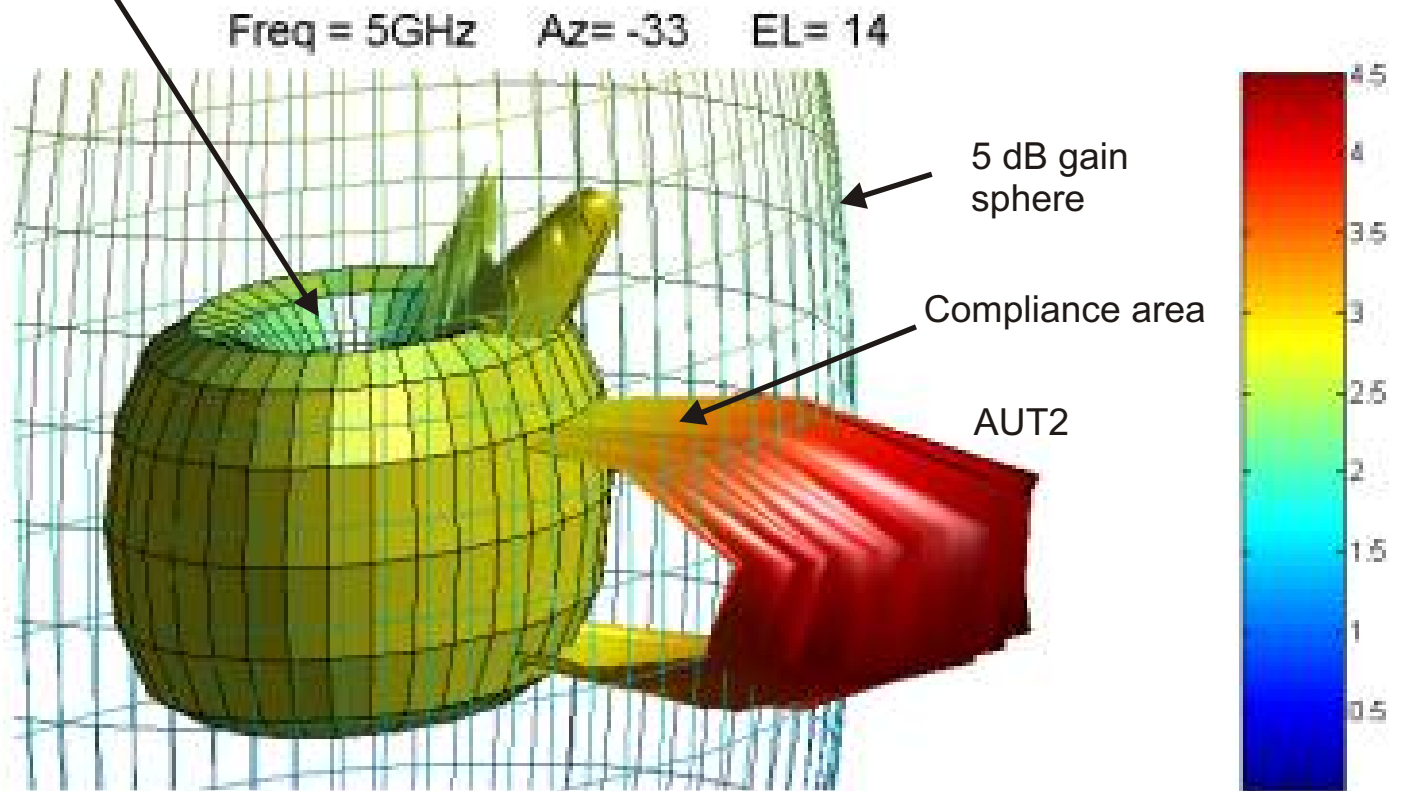
AUT2 5 dB beamwidth ( 30 deg)

# Determine the Beamwidth between AUT2 and a single 1/2 wave dipole and 5dB gain sphere

Enter 0 dB for a single dipole and uncheck Wireframe. Enter 5dB for dB Isosphere and check Wireframe.



Single dipole gain



# Determine the Cross-Pol ratio



The cross-pol measurement may be made using a highly linear calibrated reference. This is made with the reference horn in one orientation and the results saved to REG usually REG(1). The reference is rotated 90 degrees and the antenna remeasured. The results are saved to REG2.

Save data to REG1



Vertical polarization

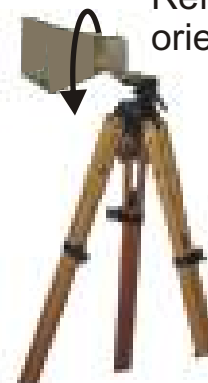


Reference vertical orientation

Save data to REG2



Horizontal polarization



Reference horizontal orientation

Data Registers		Load Reg1-4 From Disc
Clear All Registers		Save Reg1-4 To Disc
Import		Measurements
* Data Storage Reg 1	Recall Reg 1	175.4k
H-patch 5.2GHz at 30 in. Az-90 90 1 EL		
* Data Storage Reg 2	Recall Reg 2	175.4k
Y-patch 5.2GHz at 30 in. Az-90 90 1 EL		

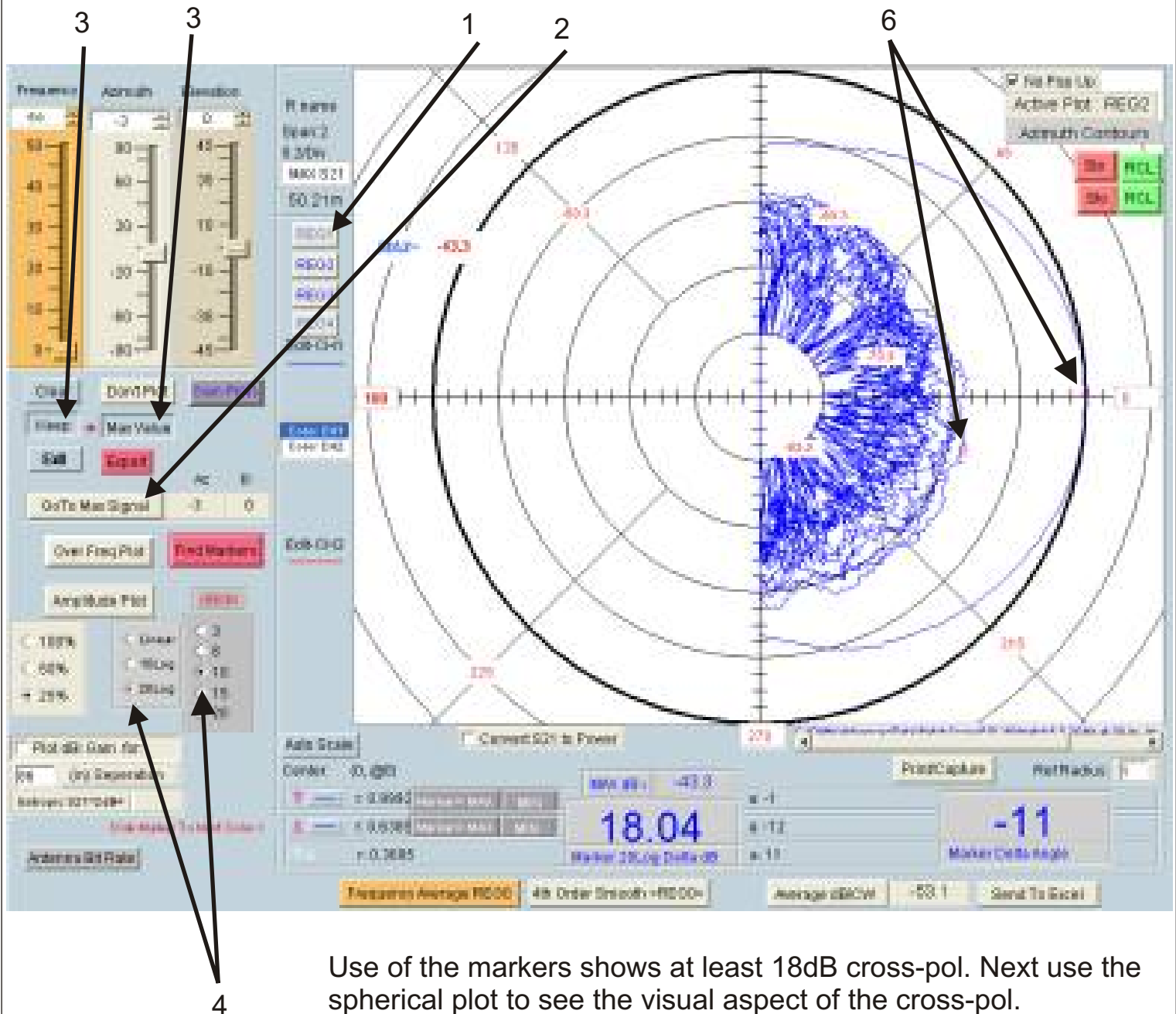
Measurement results are saved into REGs 1 and 2.

# Determine the Cross-Pol ratio

**Diamond  
Engineering**

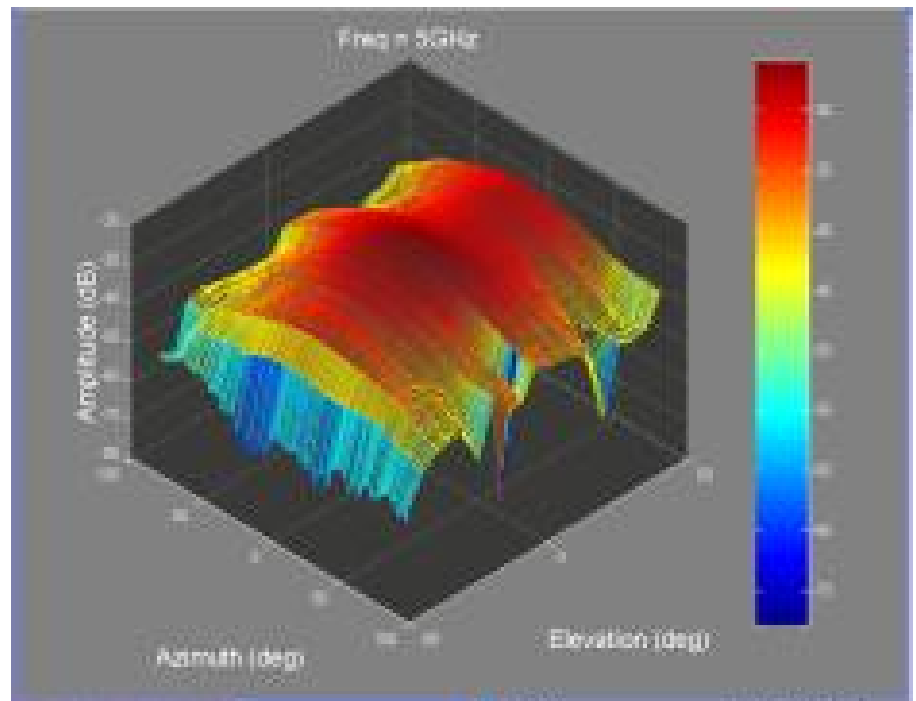
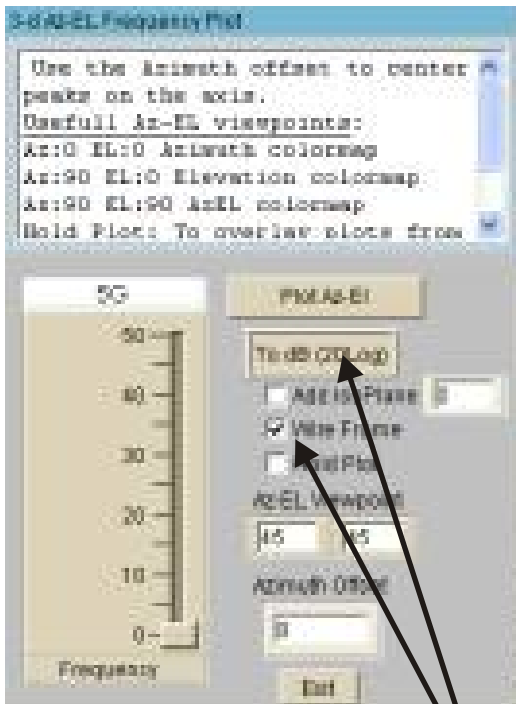
Use the polar plot to establish a polar visualization of the cross-pol.

1. Recall REG1
2. Invoke "go to max signal"
3. Depress "Keep" and "Max value"
4. Check 20Log and 10dB/div
5. Recall REG2
6. Use the markers to measure the dB difference.



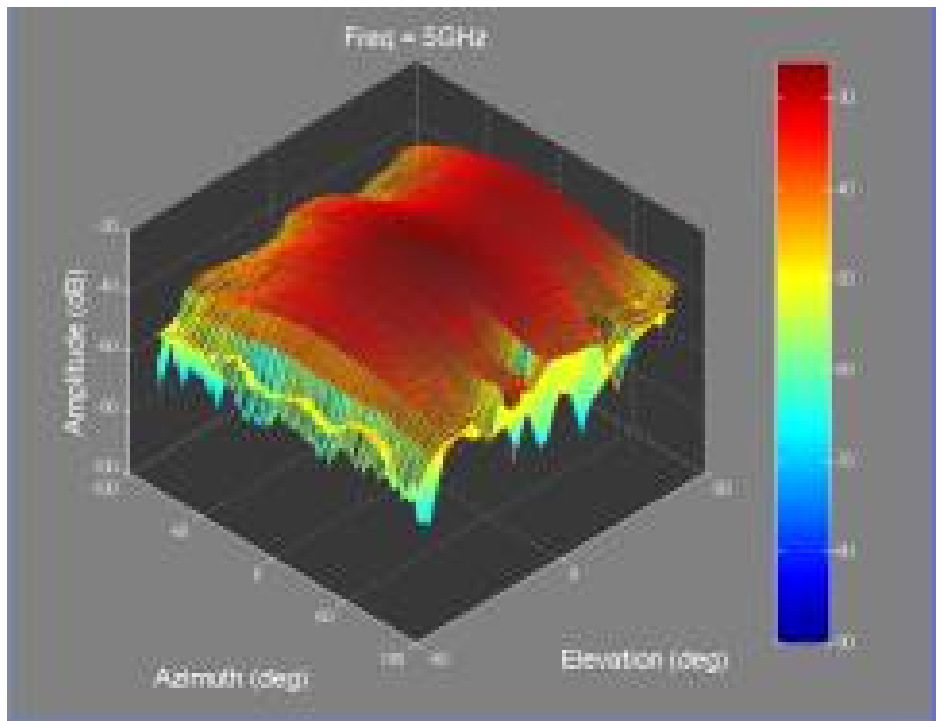
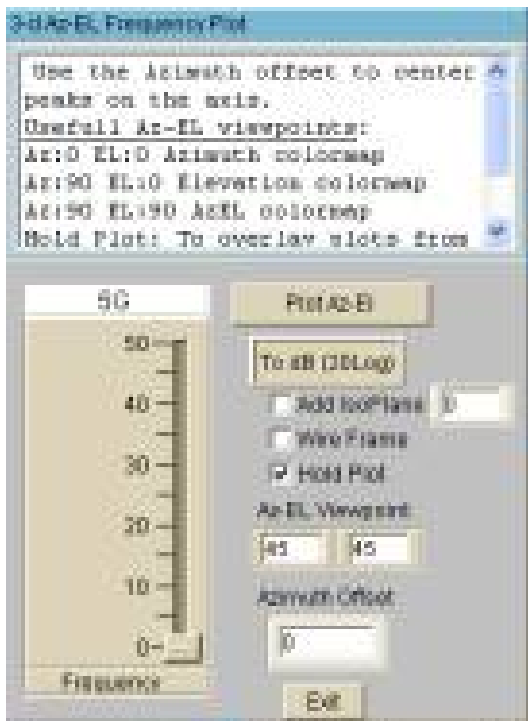
# Determine the Cross-Pol ratio Using the Az-EL Plot

Since both vertical and horizontal data are saved to REG1 and REG2 invoke the Az-EL plot function, recall plot REG1 in dB.



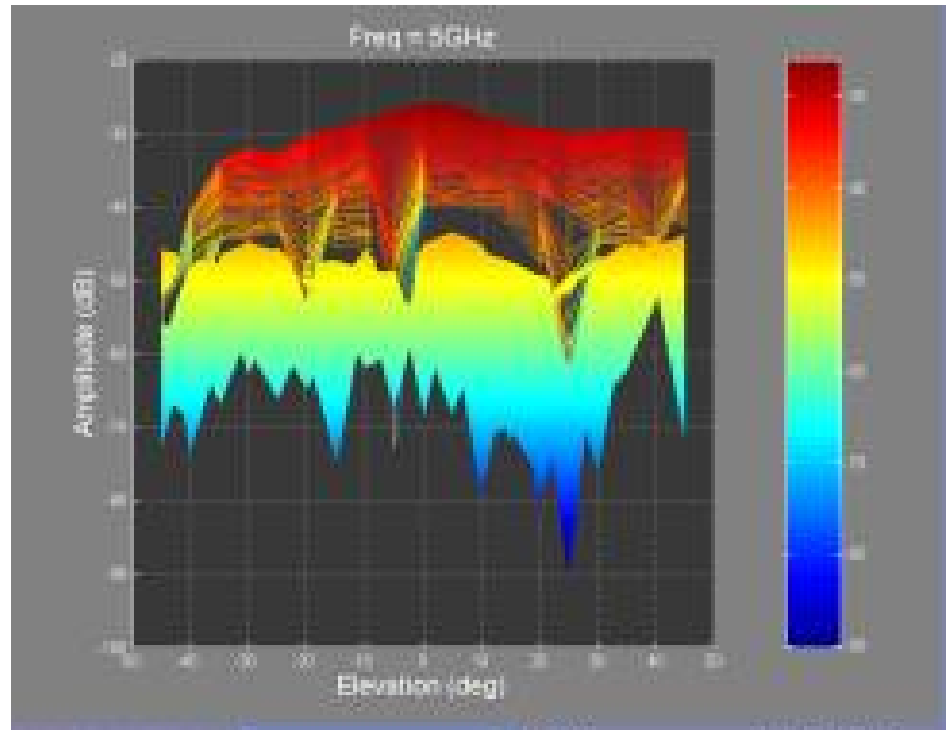
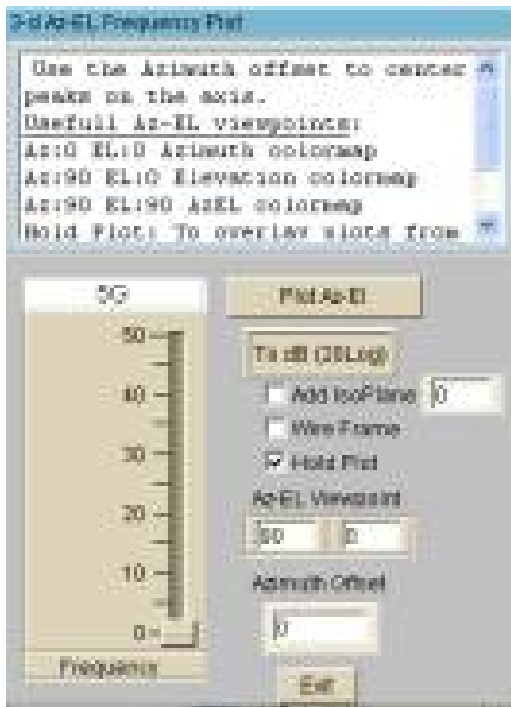
Invoke dB and Wireframe

To add REG2 data invoke "Hold Plot", recall REG2, uncheck wireframe.



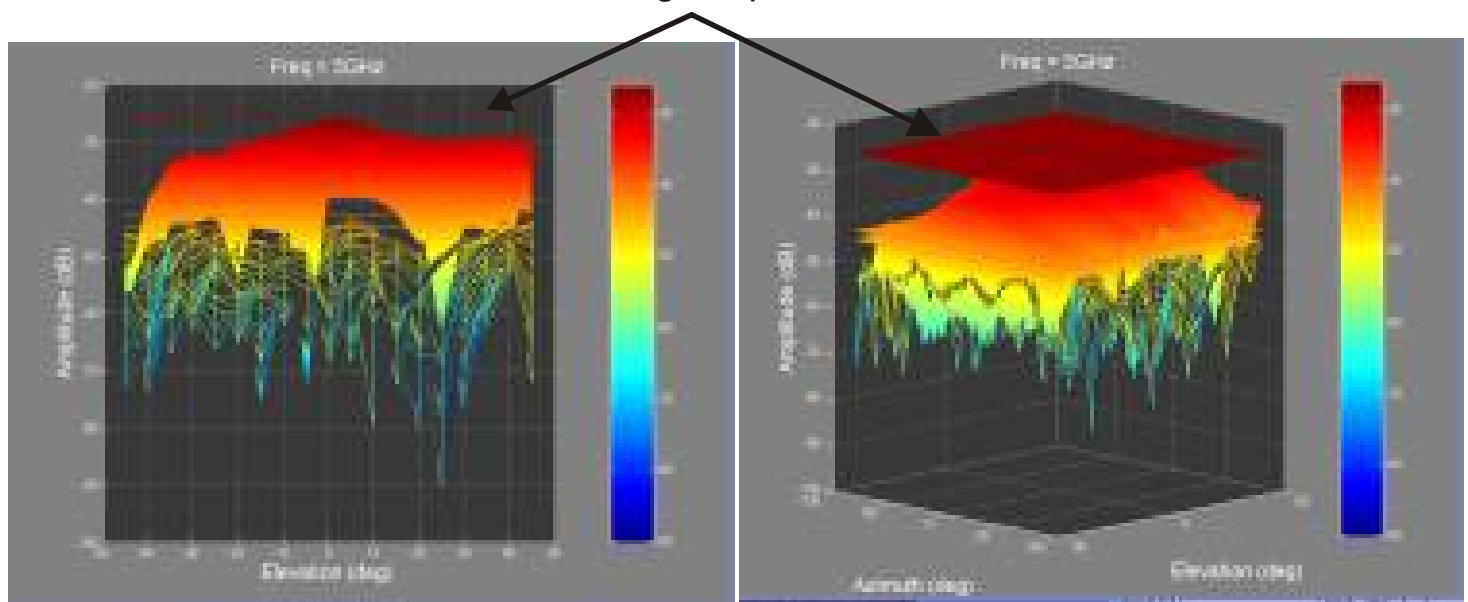
# Determine the Cross-Pol ratio Using the Az-EL Plot

Rotate the plot to Az=90 EL=0 to create a one dimensional plot



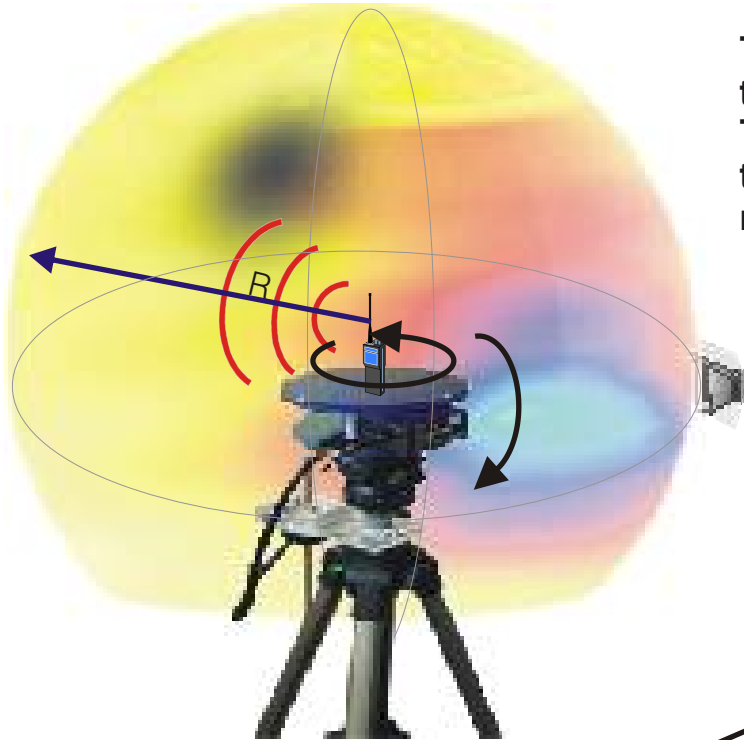
The plot shows about 18dB min. cross-pol isolation between horz and vert. You can construct isoplanes to determine cross-pol limits. In this case a -26db and -43dB iso plane was added.

Adding Iso-planes



# Projecting The Scan Array on To The Measurement Sphere

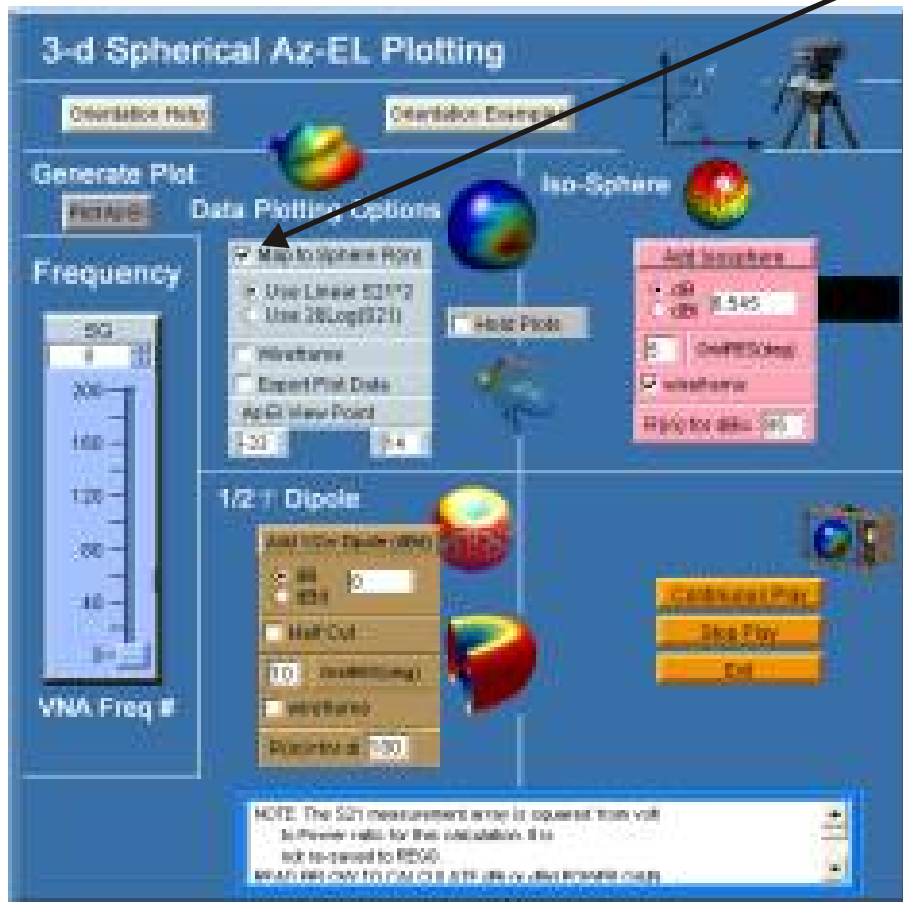
Perform a complete scan



The Map To Sphere feature projects the response on to the unit sphere. This is useful for determining the beam width for any level relative to the maximum.

Measurement Antenna

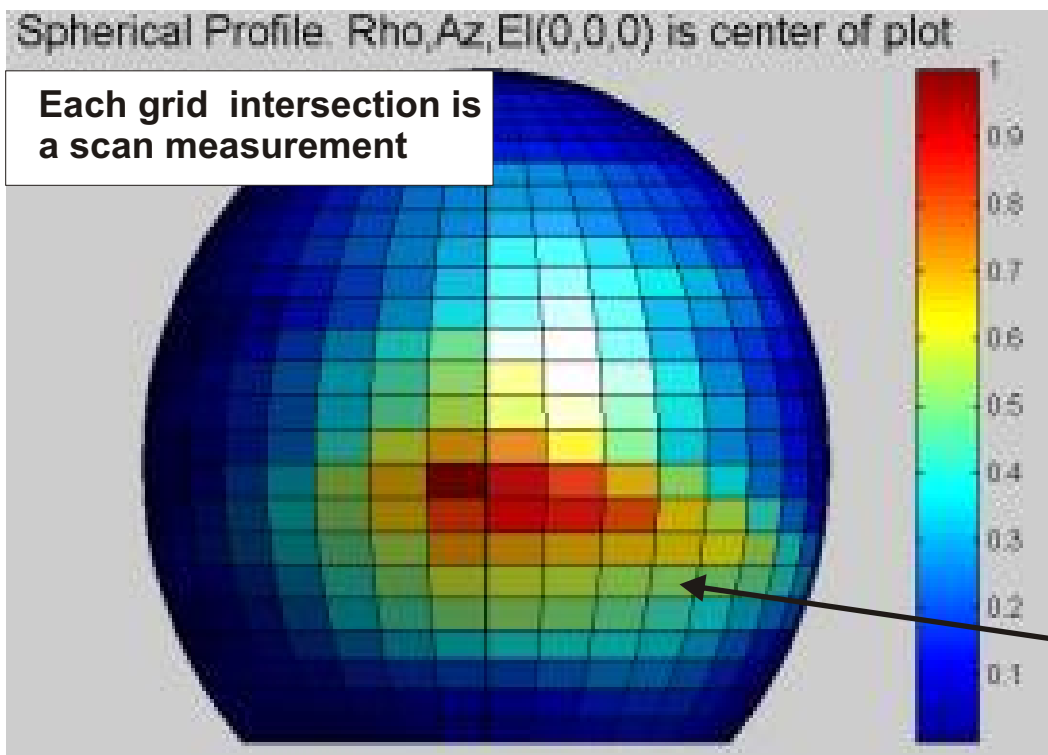
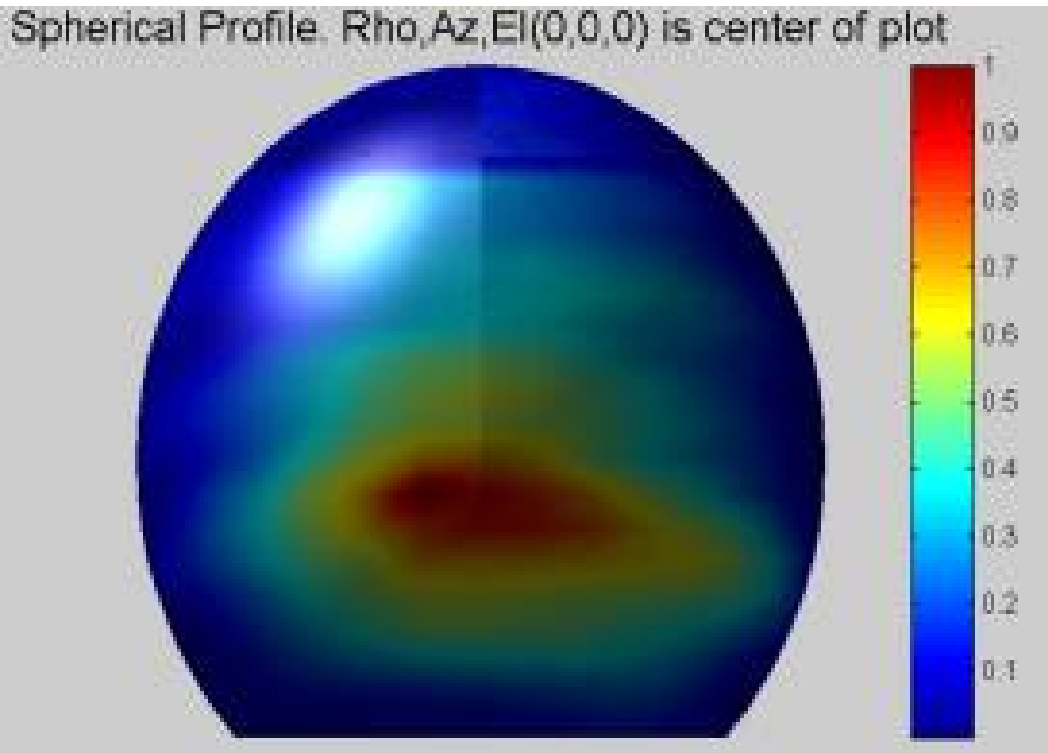
Be sure you have scan data in REG0.  
Check the Map to Sphere



Set the Az El viewing to 0 and 90 deg to view head-on

# Projecting The Scan Array on To The Measurement Sphere

Linear(or Log) data array projection on to the unit sphere



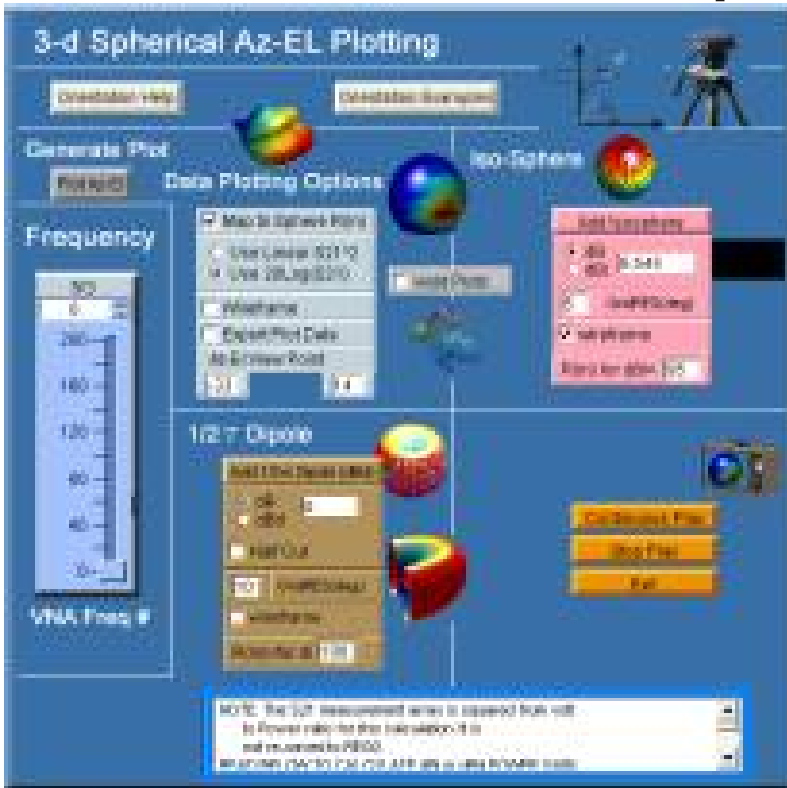
Check the Wireframe option to view the response against the measurement profile.

**NOTE:** The Latitude grid = Az resolution

The Longitude grid = EI resolution

The green area represents the 3dB beamwidth

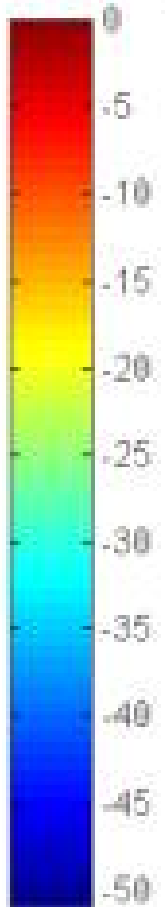
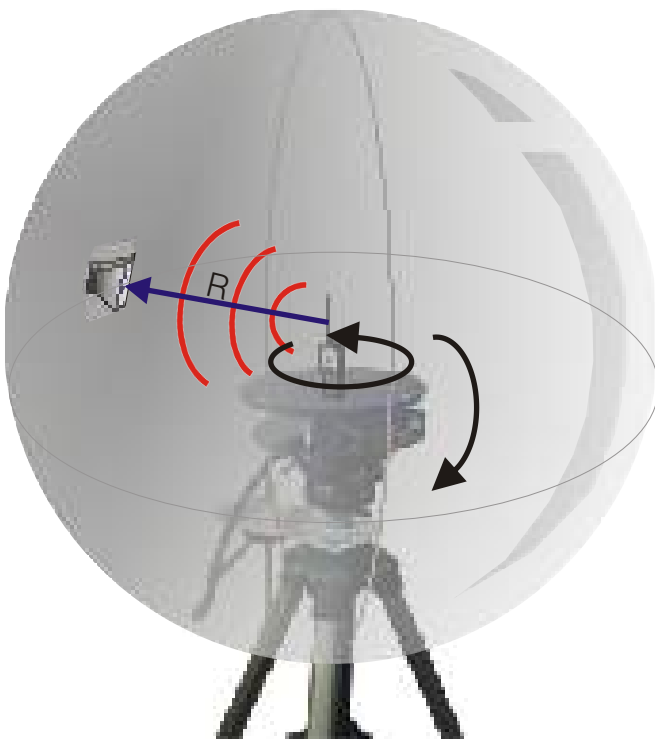
# Projecting The Scan Array on To The Measurement Sphere



You can project the Log response by checking the Use 20Log(S21). It is actually 20Log(S21/S21max)

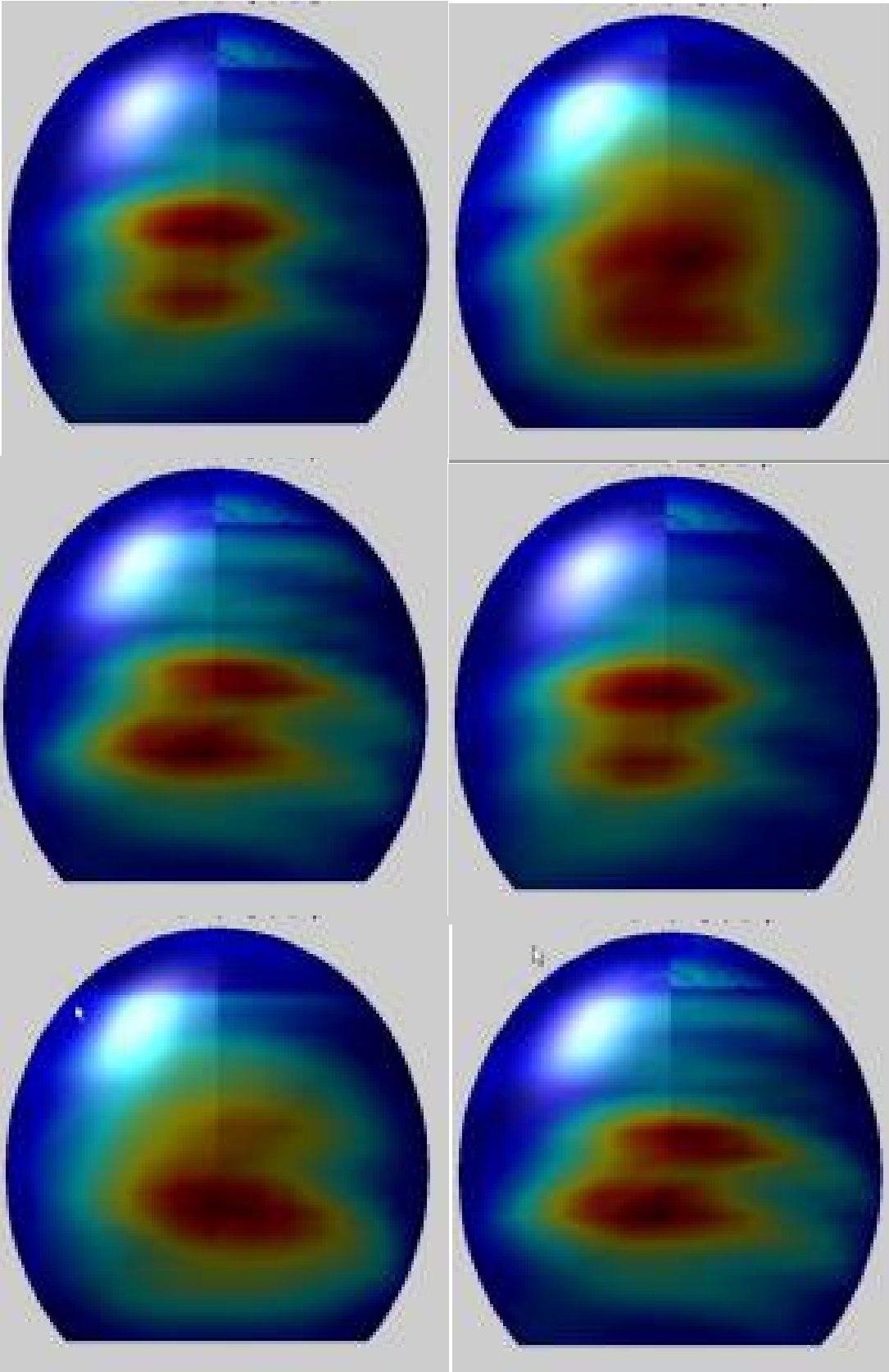
20Log(S21/S21max)

The figure below shows the equivalence of the projection and the measurement. The color bar is 20Log(S21). The projection sphere has been rotated up to view the adjacent side and show the platform orientation.



# Projecting The Scan Array on To The Measurement Sphere

**Diamond  
Engineering**



You can play any plot through the frequency array and view the highest gain or best beam width

Actual measurements of a patch antenna made by combining a top scan and a side scan and processed using the Merge Scan feature

