Half Power Beamwidth Measurements of Radiated Emission Antennas for EMC

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An ESCO Technologies Company

IEEE EMC SOCIETY

Outline I

- Radiation pattern
  - What is it
  - E and H plane
  - Far and near field
  - Omnidirectional/Directional
  - Main, side and back lobes.
  - Half power and 3dB beamwidth

Outline II

- Half Power Beamwidth
  - Biconicals
  - LPDA
  - Hybrid Antennas
  - DRGH Antennas
  - Caveats
  - Conclusion

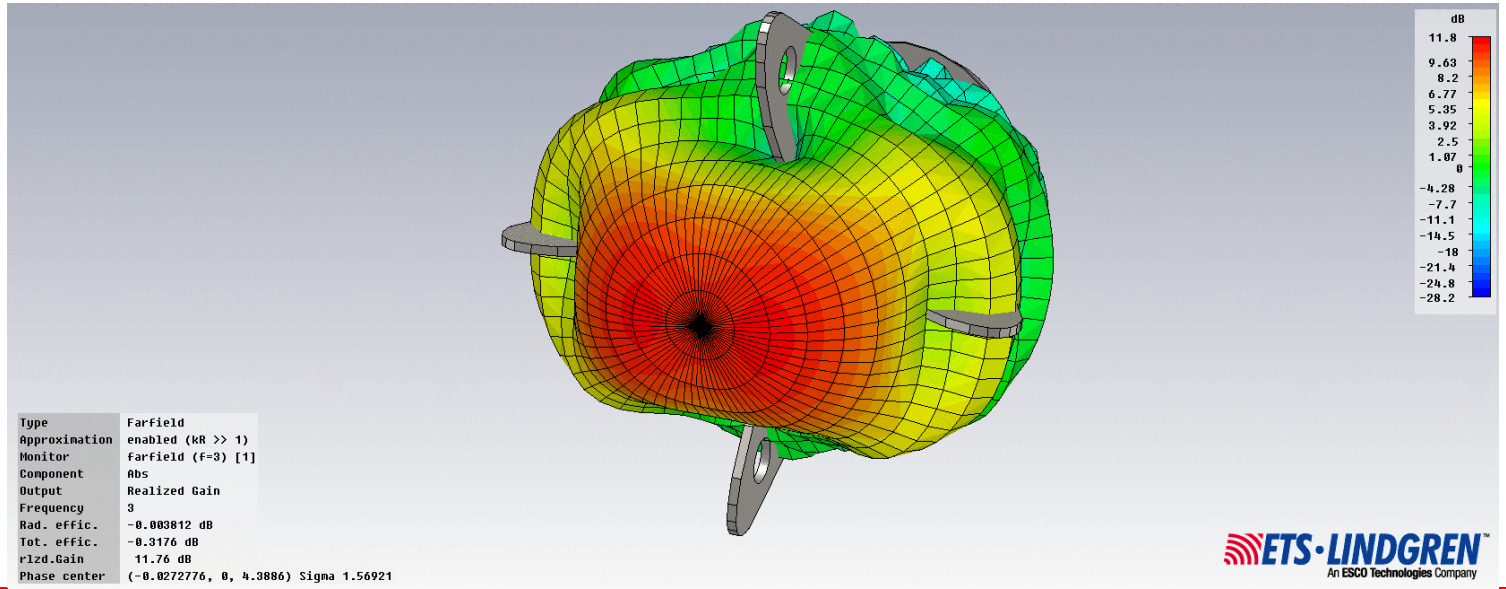
Radiation Pattern

Book definition

"a 3D plot that displays the strength of the radiated fields or power density as a function of direction"

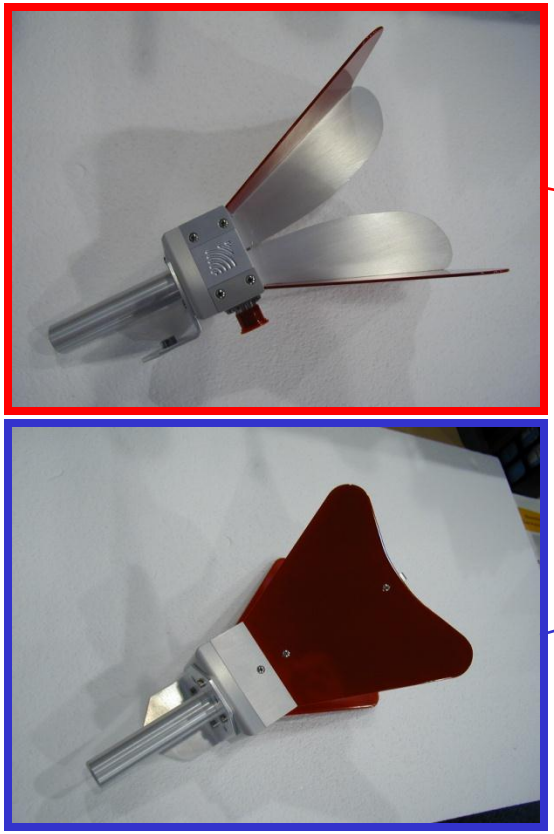
Radiation Pattern

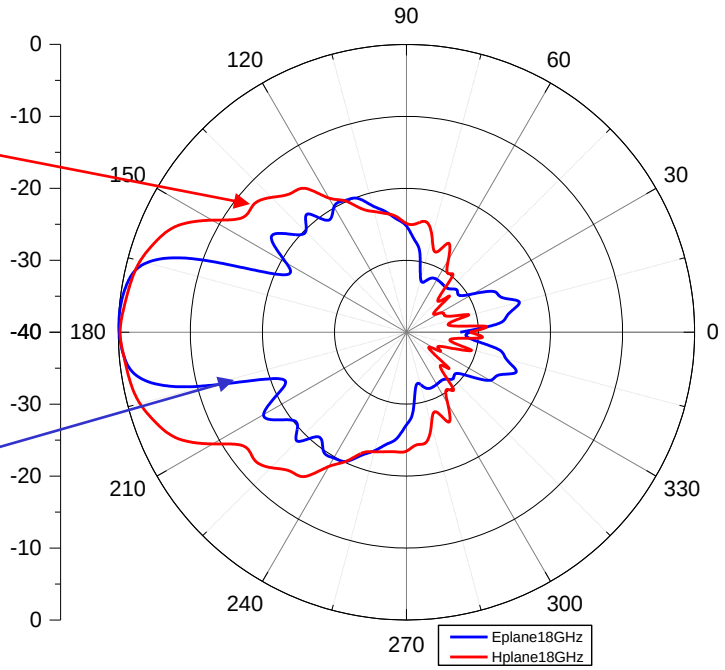
The radiation is then a representation of how much Electromagnetic energy is concentrated in each direction around the antenna



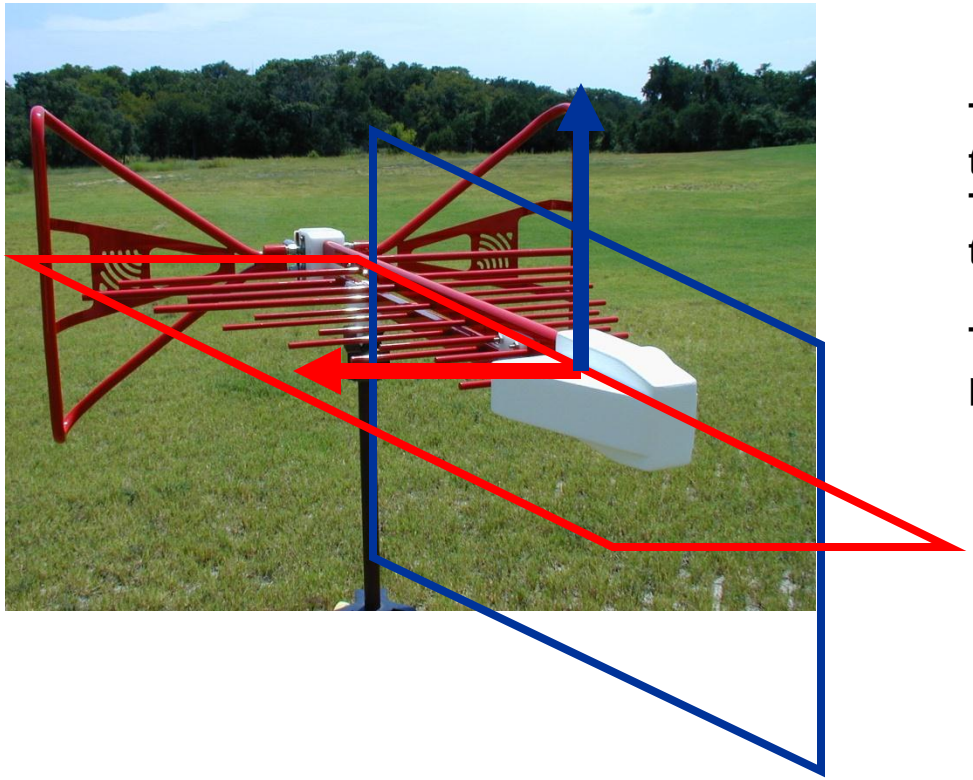
Radiation Pattern

Because of the difficulty of plotting a 3D plot usually the patterns are shown as E and H planes





Radiation Pattern: E and H Plane



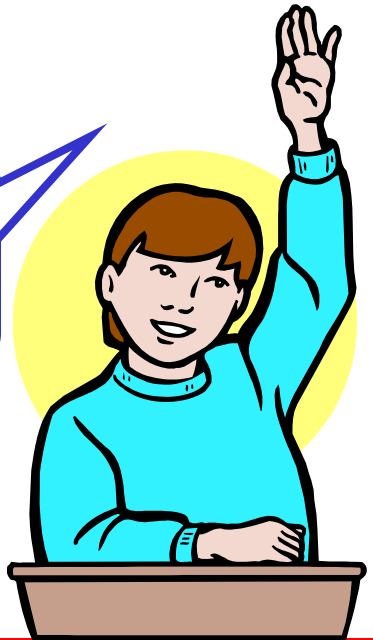
The E plane is the plane that is parallel to the Electric field
The H plane is the plane that is parallel to the Magnetic field

The Electric and Magnetic fields are perpendicular to each other

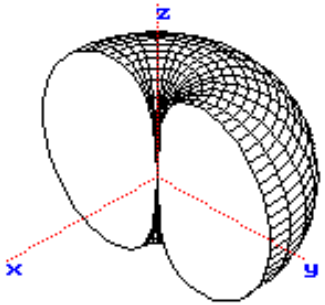
Radiation Pattern: Omnidirectional and Directional

OMNI = Latin for Every or All

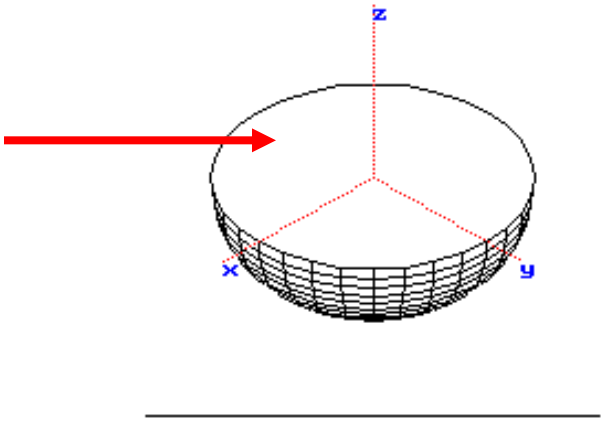
So, Omnidirectional radiates in "every" direction?

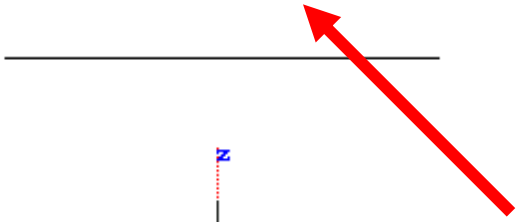


Radiation Pattern: Omnidirectional and Directional

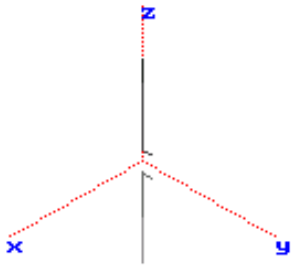


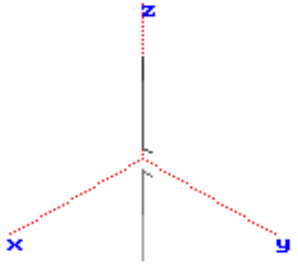
Omni directional on the H plane. It radiates equally on all directions on this plane

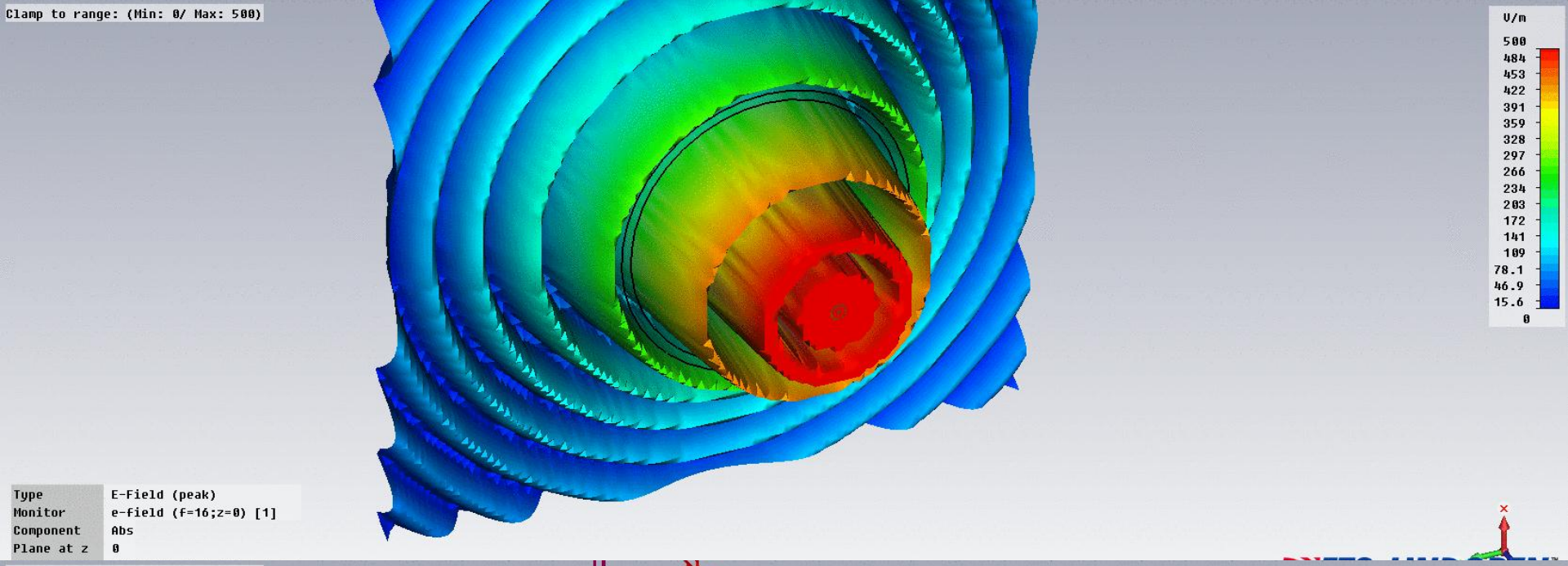


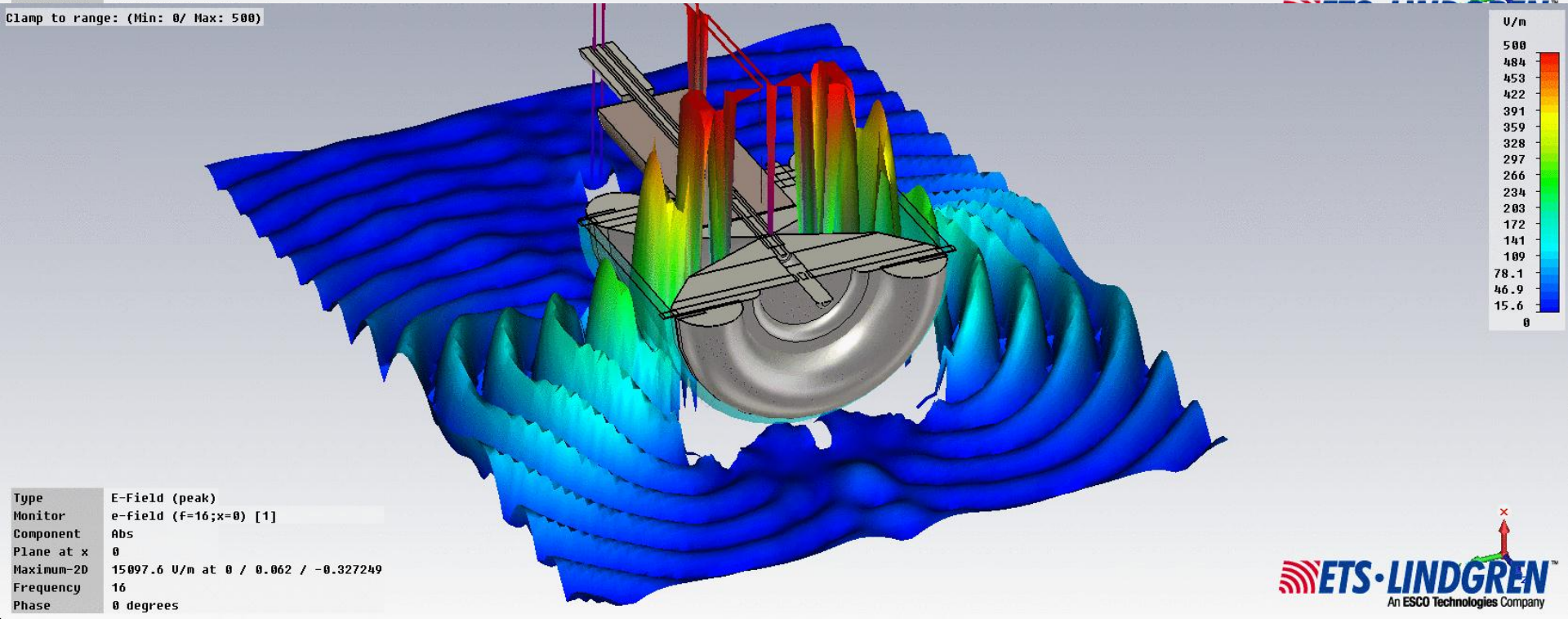


But not on this plane






Clamp to range: (Min: 0/ Max: 500)
V/m
500
484
453
422
391
359
328
297
266
234
203
172
141
109
78.1
46.9
15.6
0
Type E-Field (peak)
Monitor e-field (f=16;z=0) [1]
Component Abs
Plane at z 0


Clamp to range: (Min: 0/ Max: 500)
V/m
500
484
453
422
391
359
328
297
266
234
203
172
141
109
78.1
46.9
15.6
0
Type E-Field (peak)
Monitor e-field (f=16;x=0) [1]
Component Abs
Plane at x 0
Maximum-2D 15097.6 V/m at 0 / 0.062 / -0.327249
Frequency 16
Phase 0 degrees
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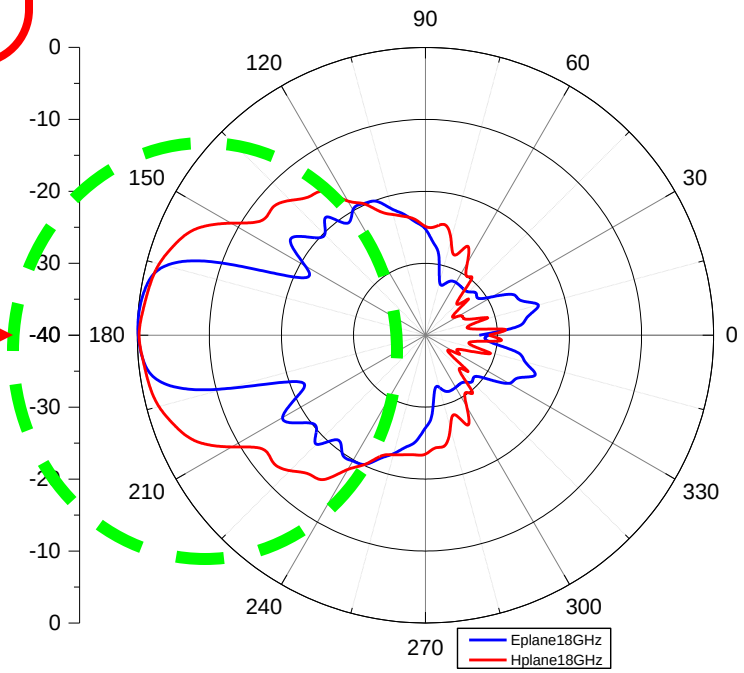
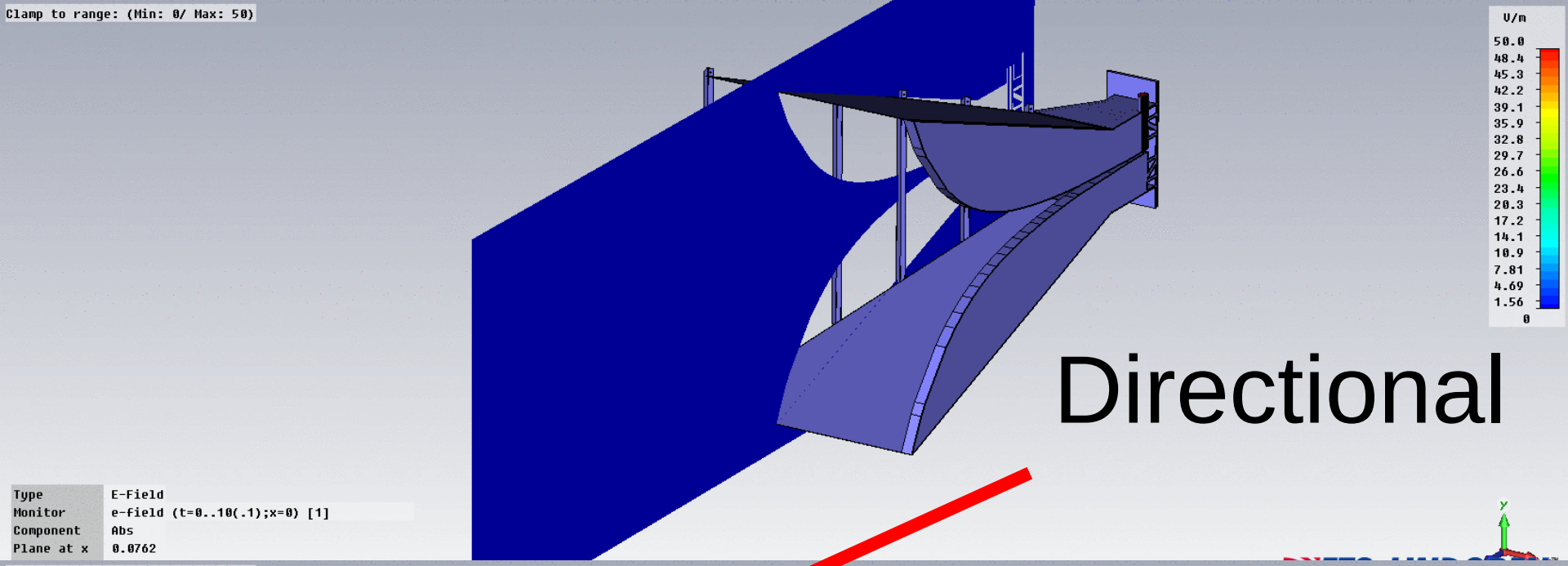
Omnidirectional and Directional

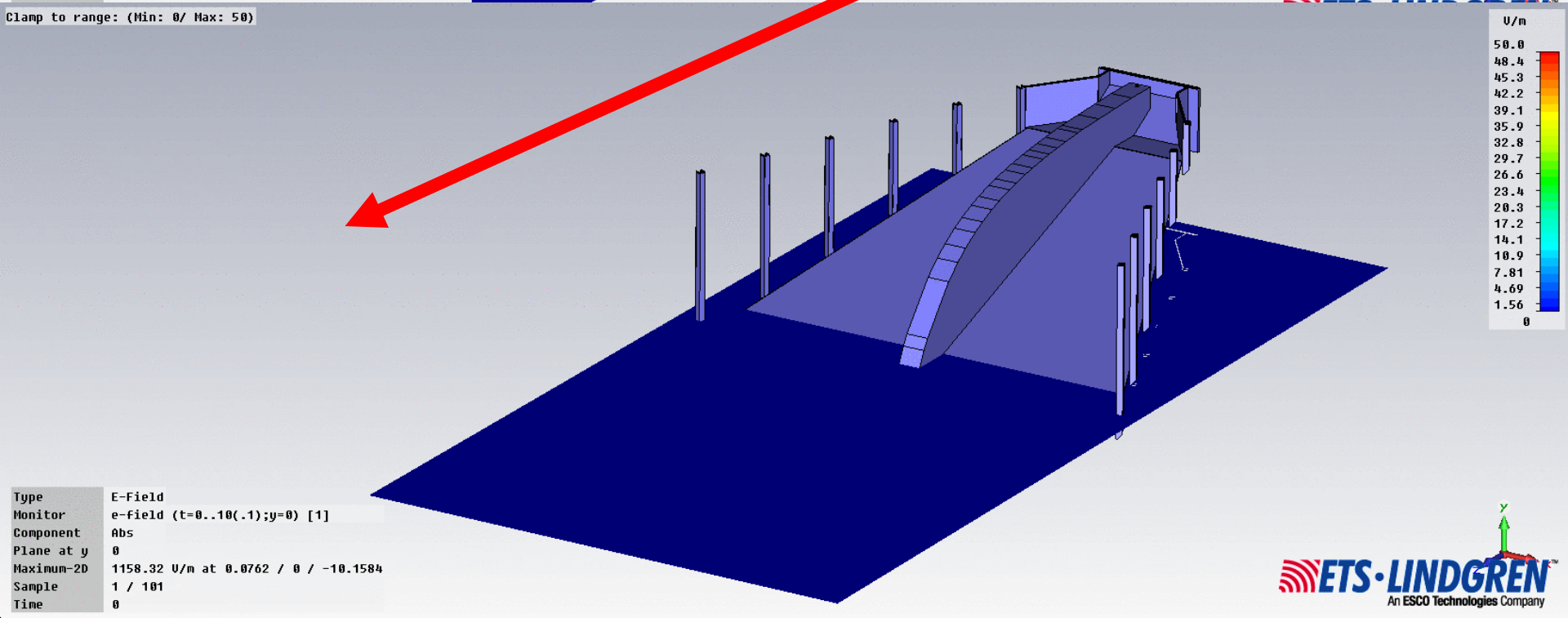
Directional?, well that is plain English, The antenna radiates mainly in one direction. Lets look again at a horn antenna

Radiation is mainly in this direction

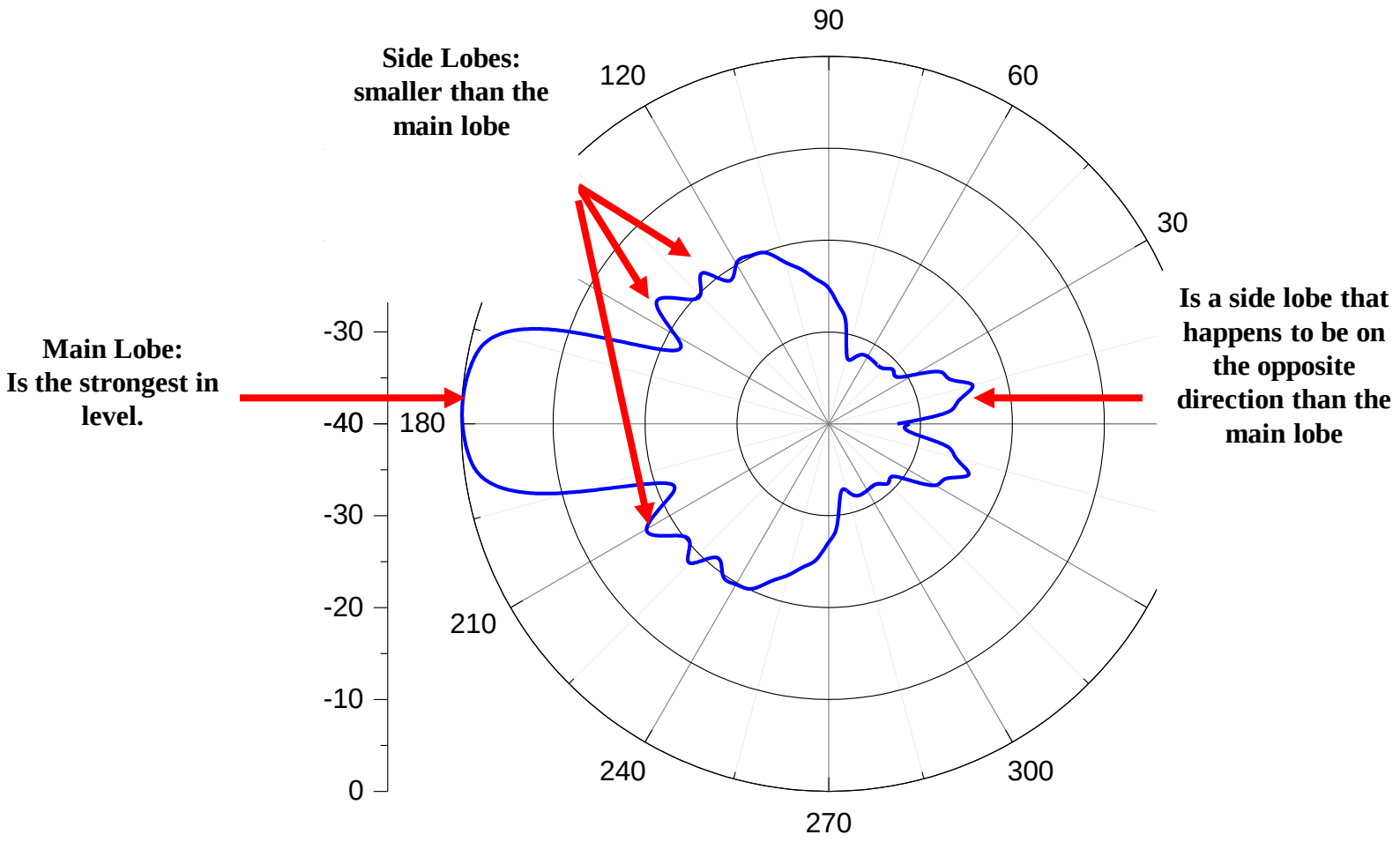




Directional



Radiation Pattern: Main, Side and Back



Radiation Pattern: Half Power Beamwidth

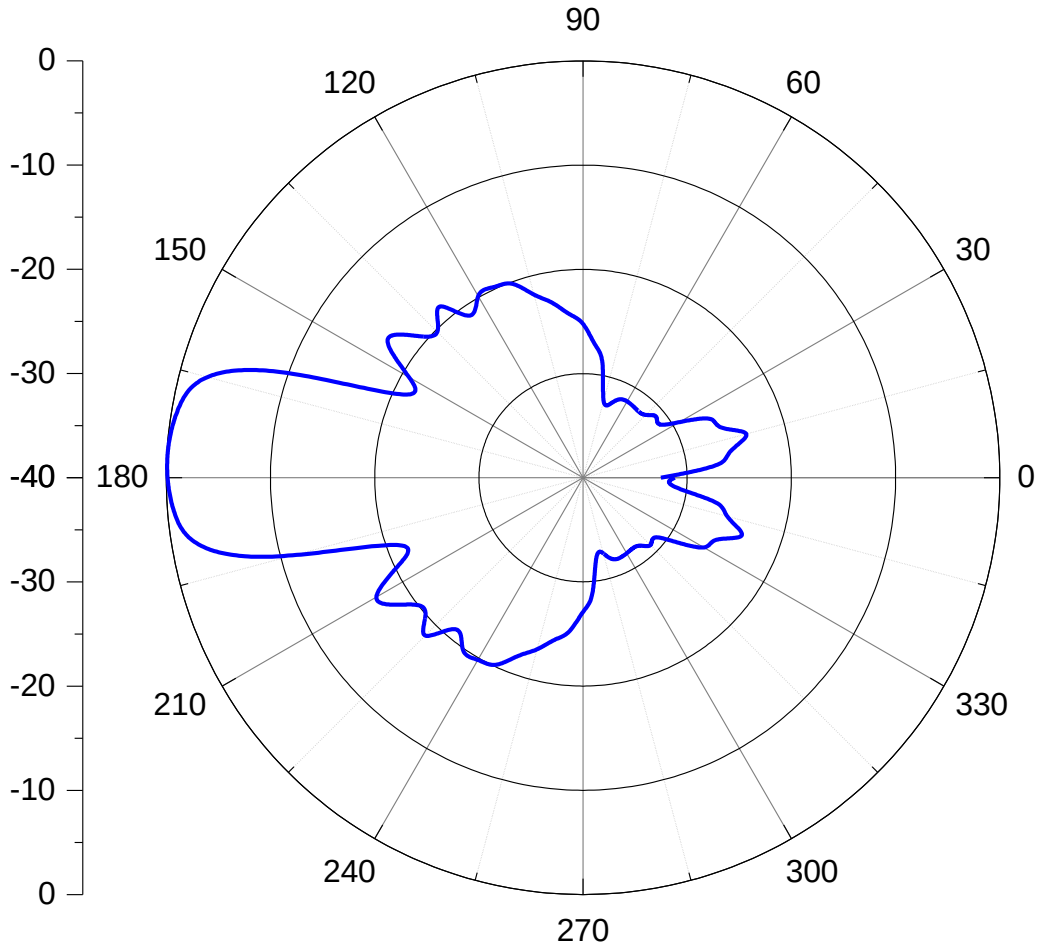
Half power

Half = $\frac{1}{2} = 0.5$

In decibels

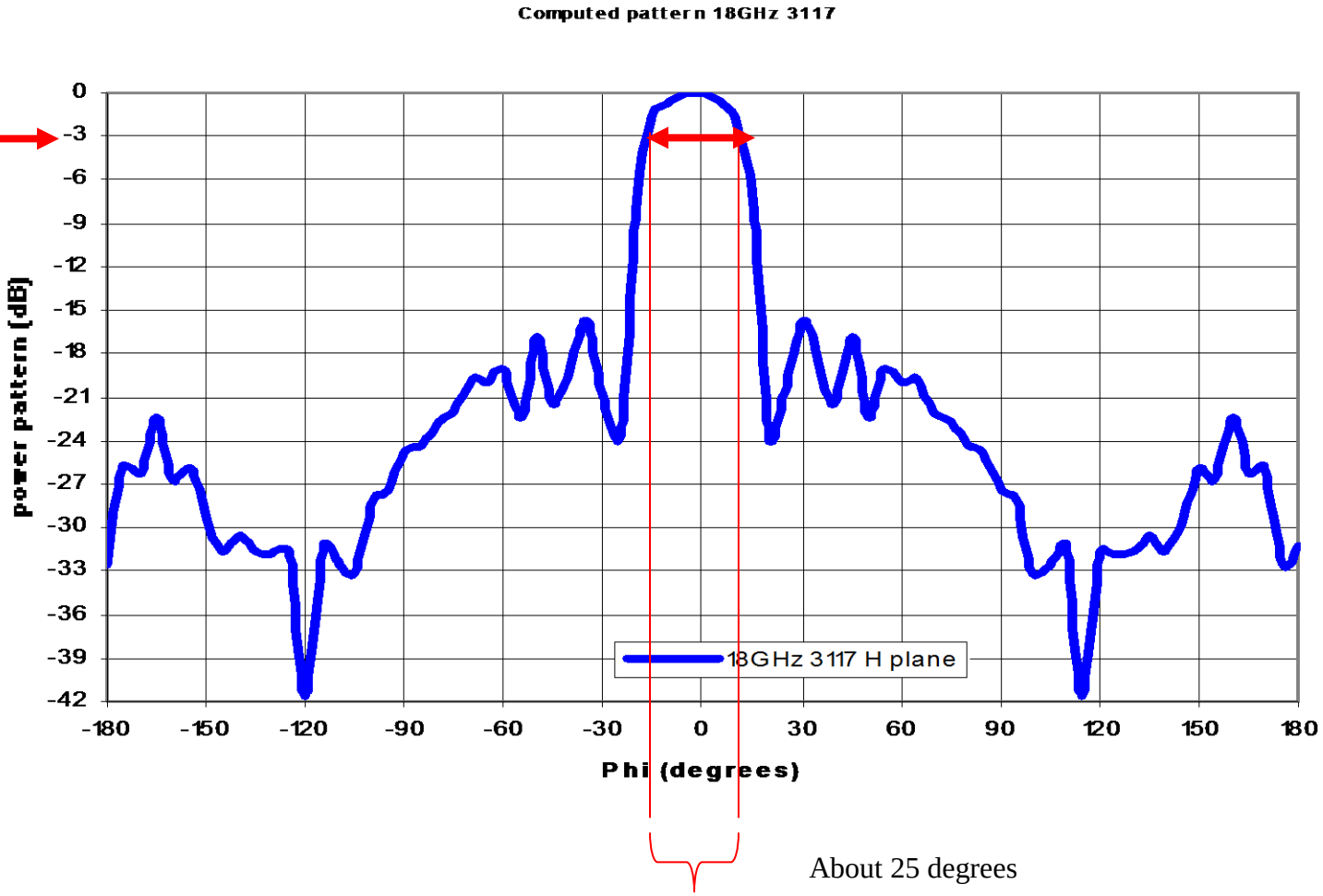
-3dB= half power

$$10 \times \log_{10}\left(\frac{1}{2}\right) = -3.02 \approx -3dB$$



Radiation Pattern: Half Power Beamwidth

-3dB Half power

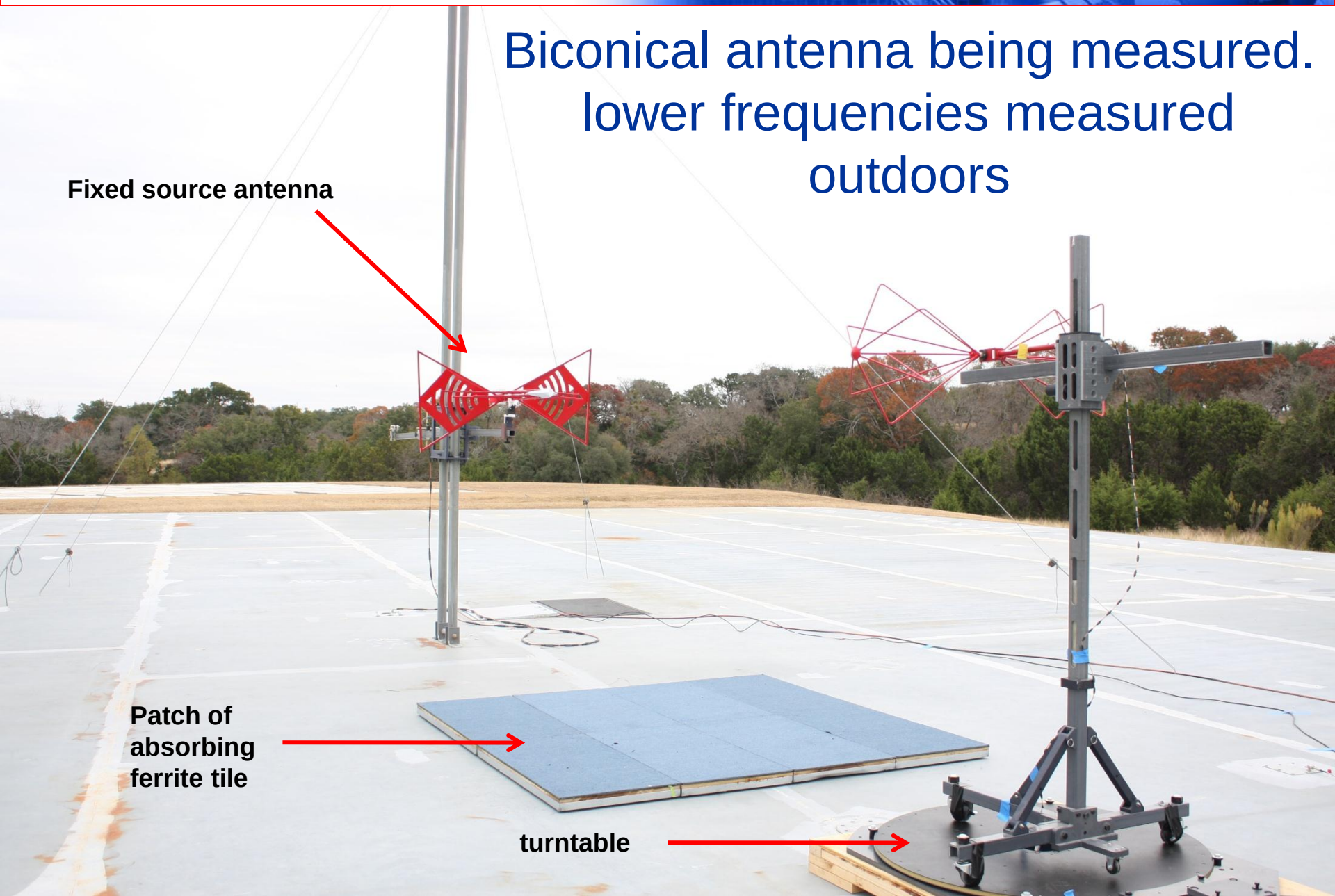


PATTERN MEASUREMENT OF TYPICAL EMC ANTENNAS

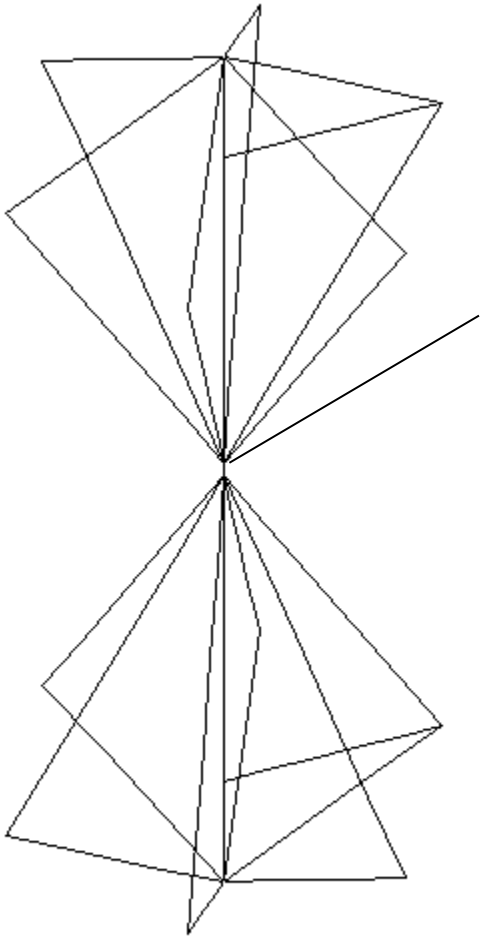
Biconical

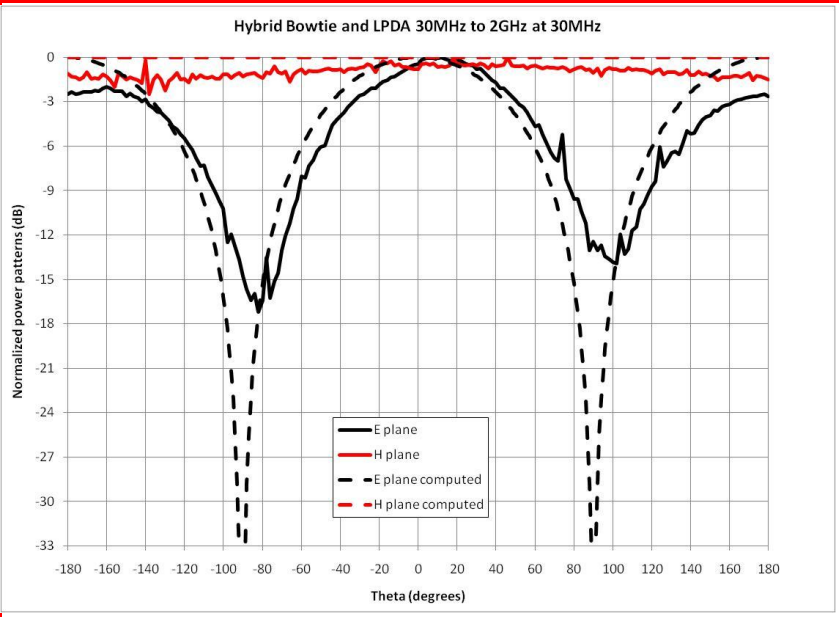
- Workhorse of the EMC antennas for low frequency
- Electrically Small so high VSWR
- Balun determines the frequency range
- Broad banded and omnidirectional

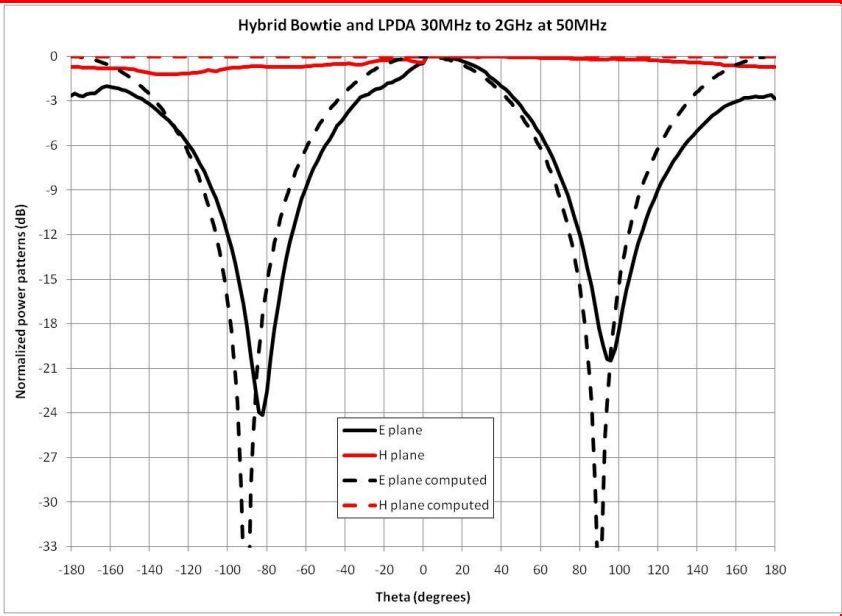
Biconical antenna being measured. lower frequencies measured outdoors

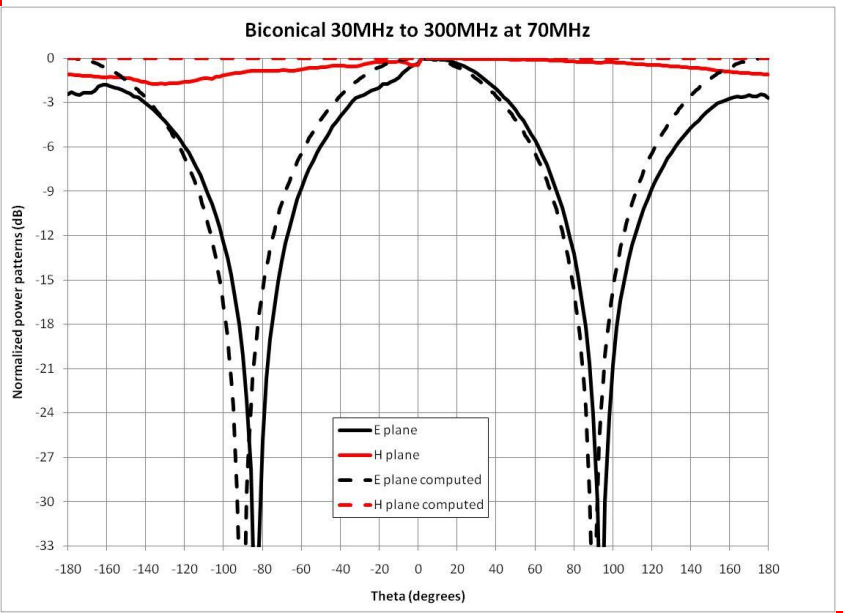


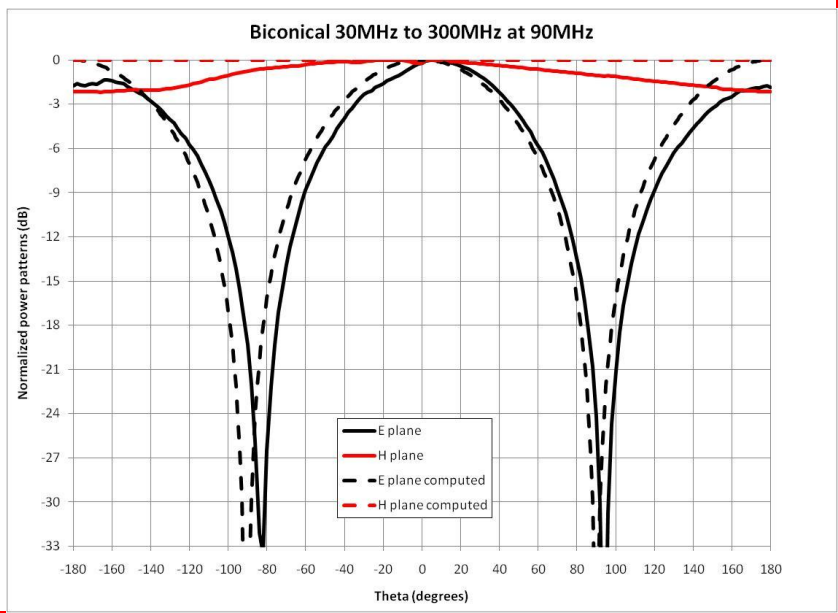
Simplified model of the typical 30MHz to 300MHz biconical antenna.

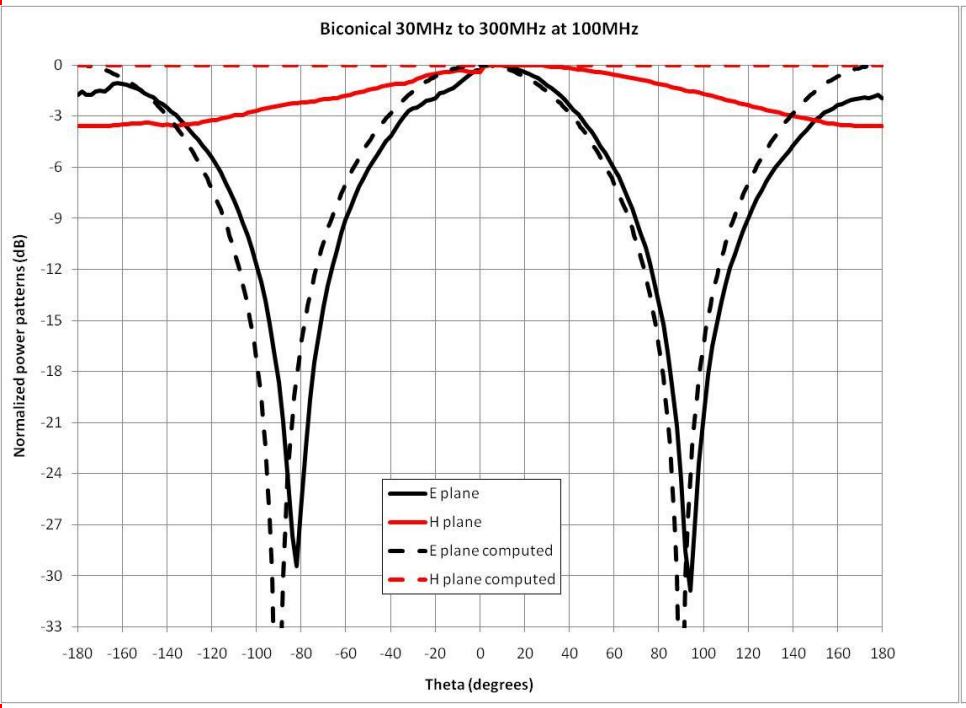


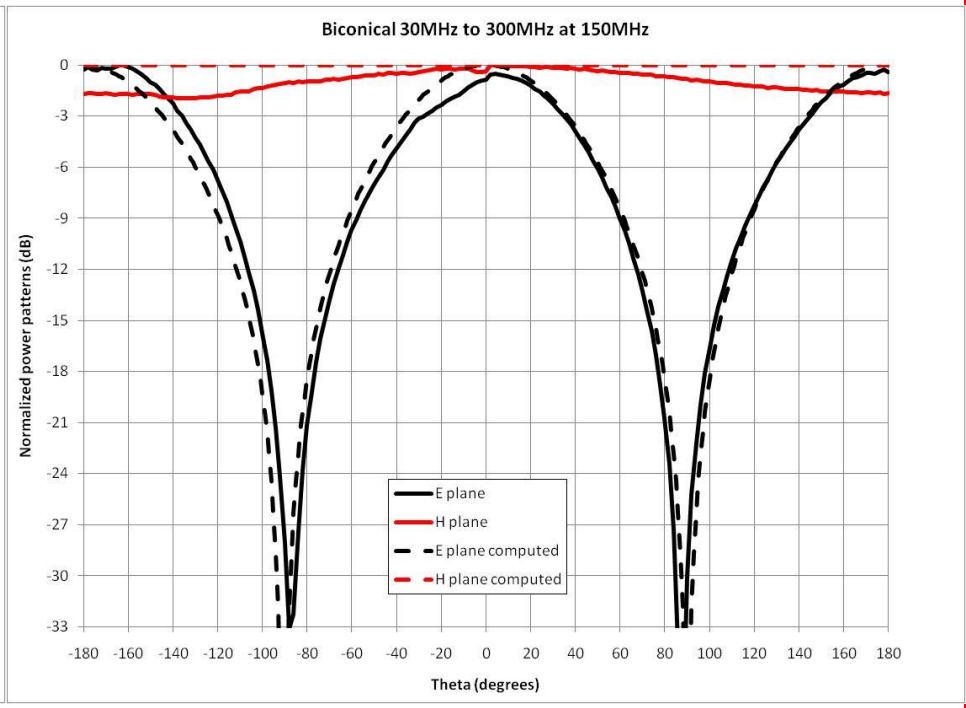

Hybrid Bowtie and LPDA 30MHz to 2GHz at 30MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

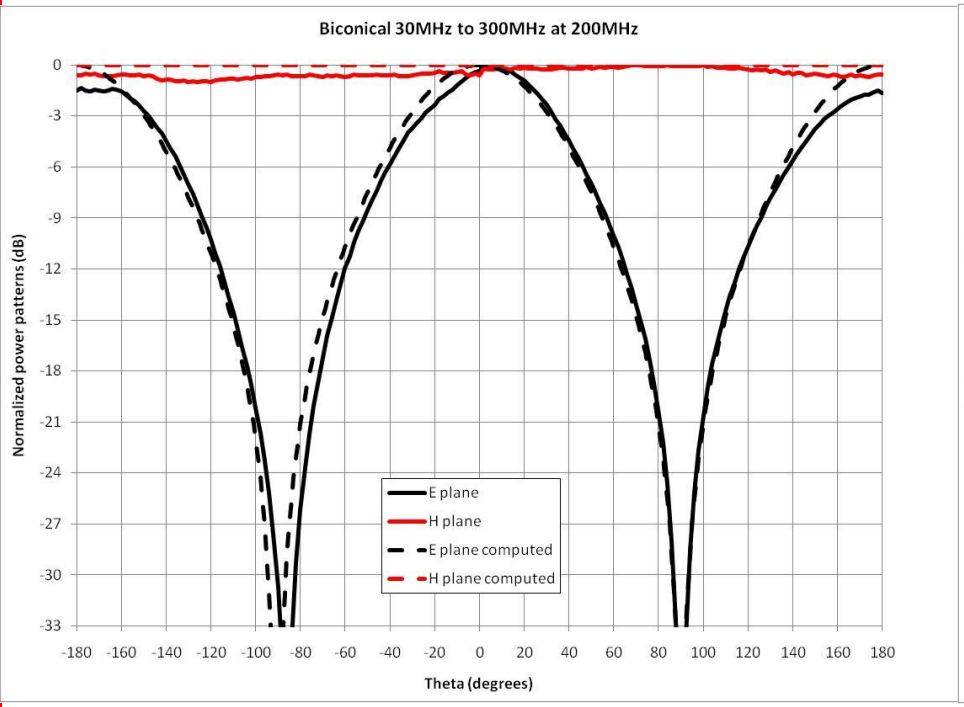

Hybrid Bowtie and LPDA 30MHz to 2GHz at 50MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

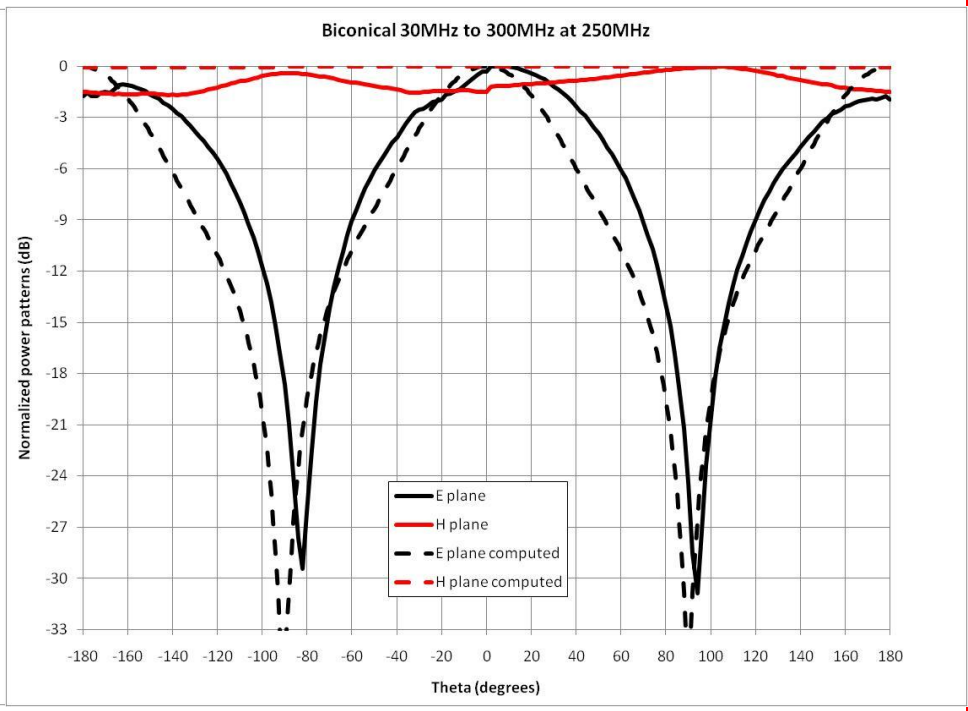

Biconical 30MHz to 300MHz at 70MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

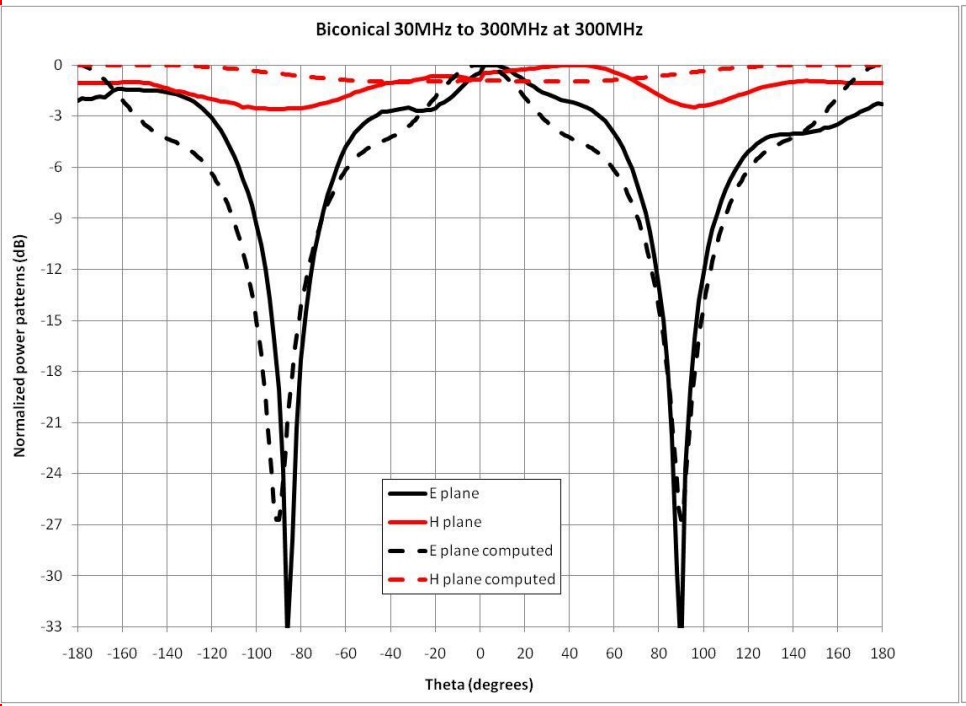

Biconical 30MHz to 300MHz at 90MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

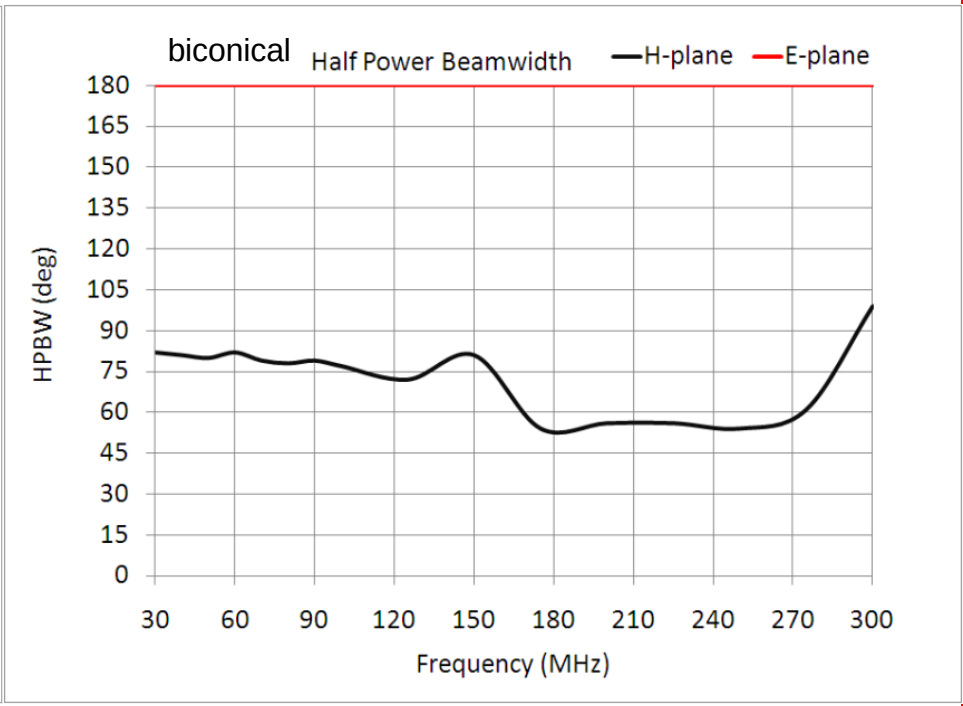

Biconical 30MHz to 300MHz at 100MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed


Biconical 30MHz to 300MHz at 150MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed


Biconical 30MHz to 300MHz at 200MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed


Biconical 30MHz to 300MHz at 250MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed


Biconical 30MHz to 300MHz at 300MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

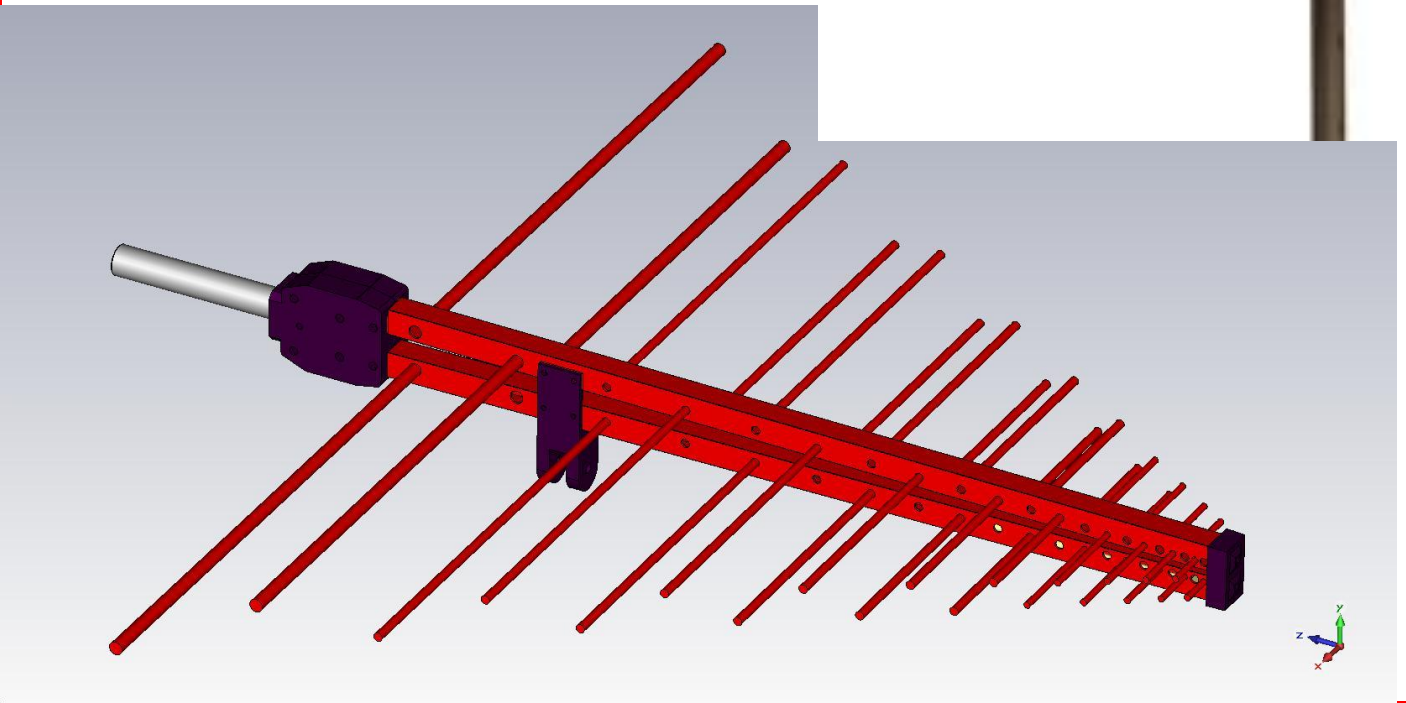

biconical
Half Power Beamwidth
H-plane
E-plane
HPBW (deg)
180
165
150
135
120
105
90
75
60
45
30
15
0
30 60 90 120 150 180 210 240 270 300
Frequency (MHz)

Logarithmic Periodic Dipole Array

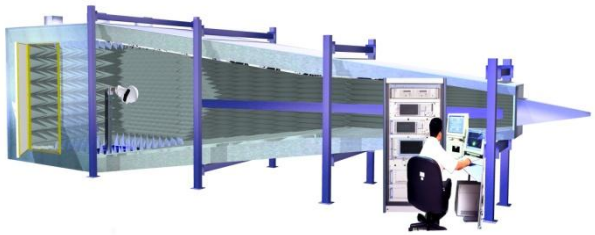
- Log P. Log Per. LPDA, etc
- Efficient antennas
- In order not to make them extremely long usually gain is capped at 6dBi
- Some units can handle high power
- Usually used between 200MHz and 2GHz
- Broad banded and directional

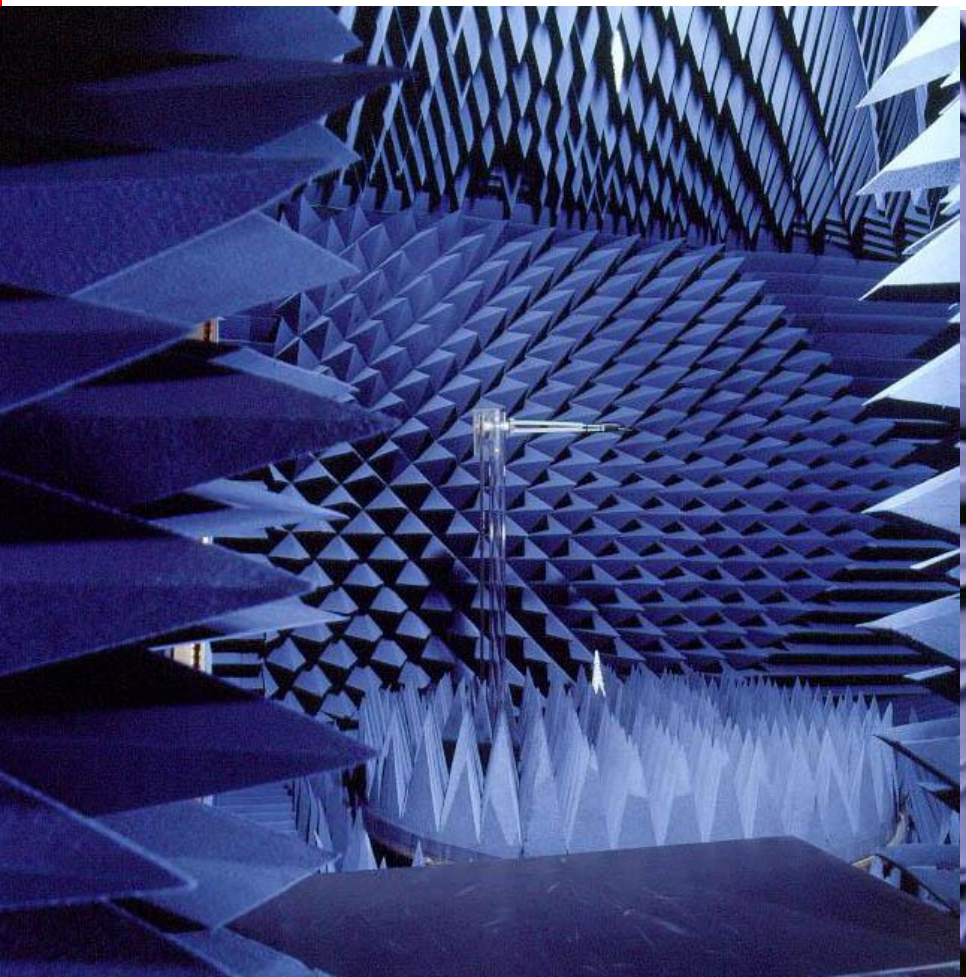

80MHz to 2GHz
LPDA on the OATS

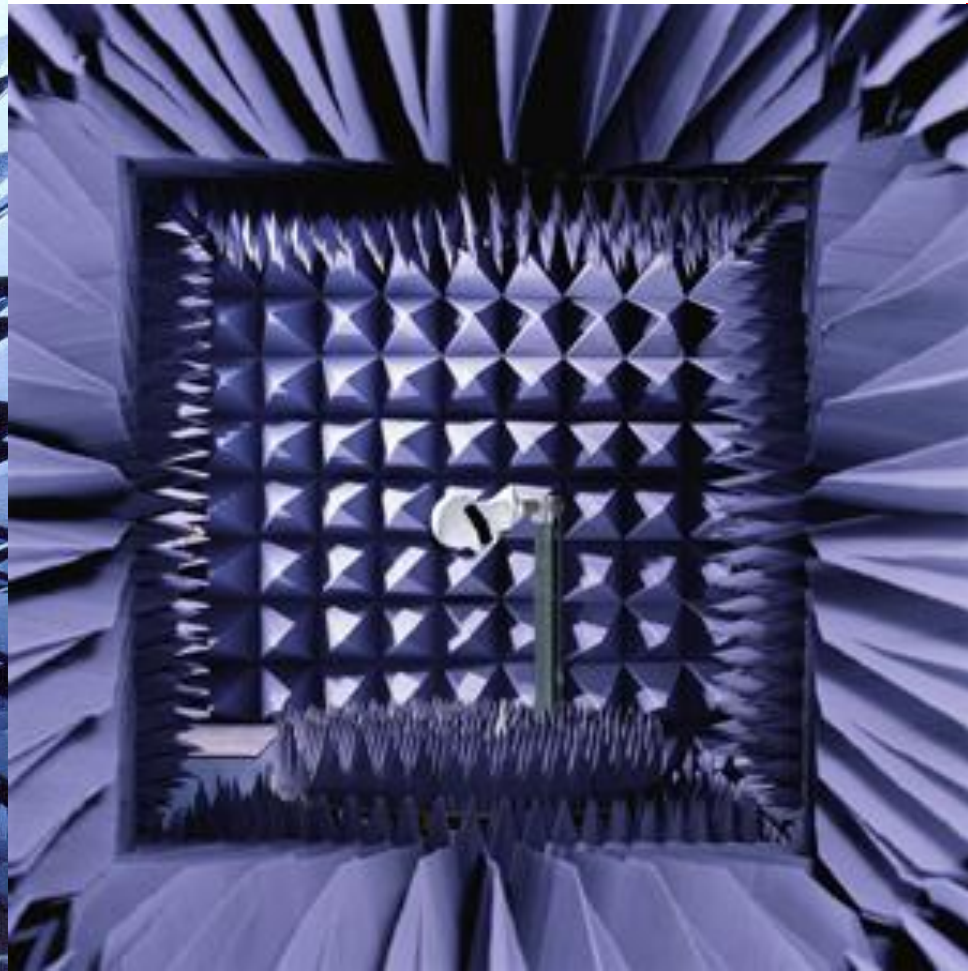
Numerical Model and Picture of the 200MHz to 2GHz log Periodic This one was measured in the taper anechoic antenna pattern measurement chamber



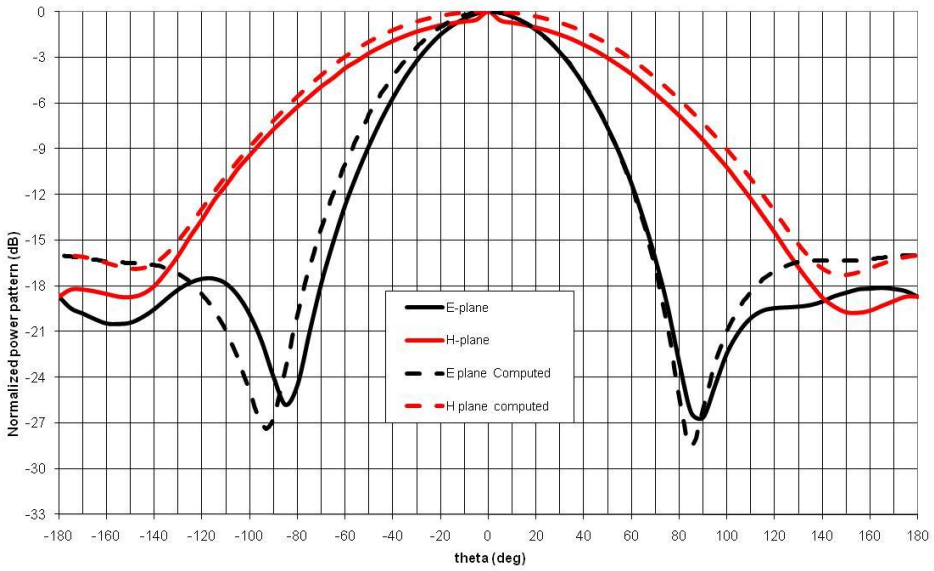
The Taper anechoic chamber has a range of 400MHz to 18GHz it was used from 400MHz to 2GHz



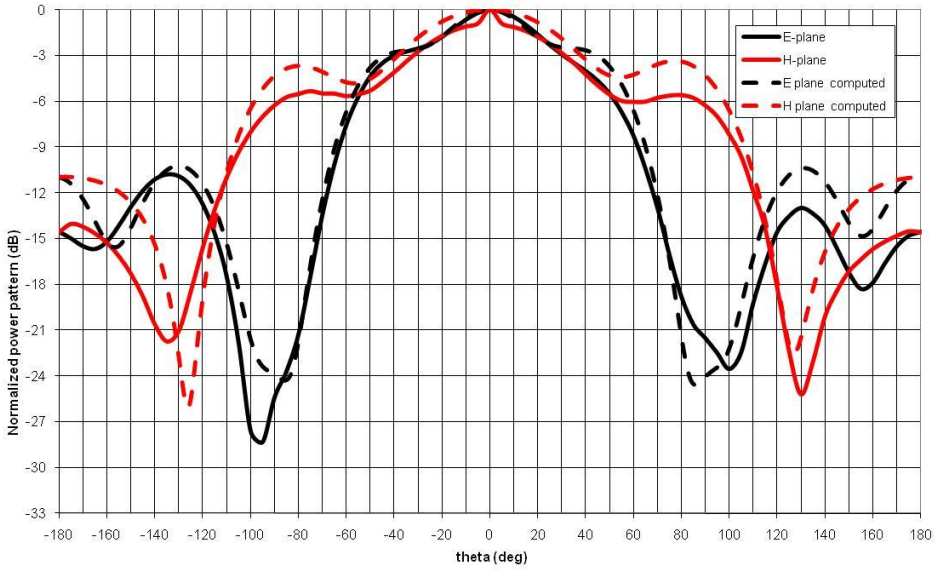




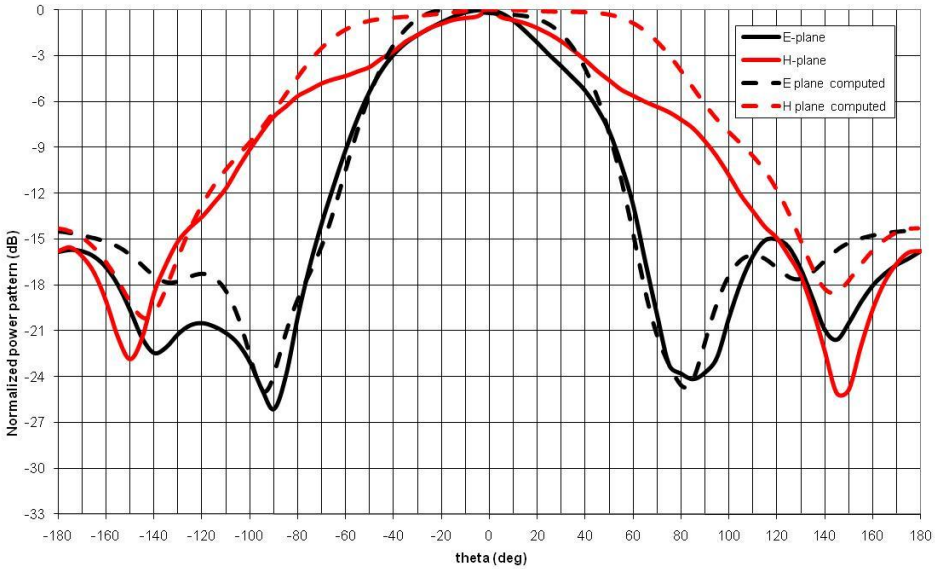
200MHz to 2GHz EMC Log Periodic Pattern at 400MHz



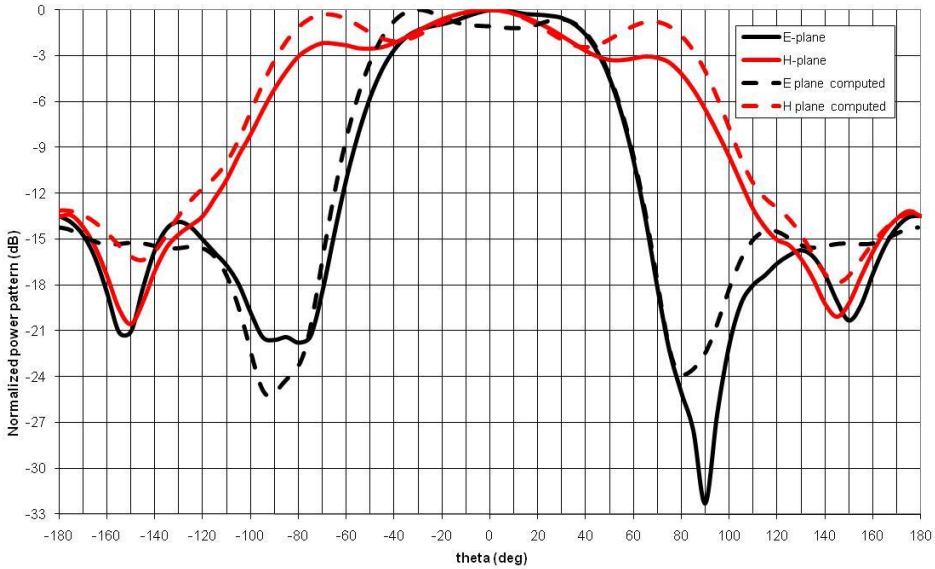
200MHz to 2GHz EMC Log Periodic Pattern at 500MHz

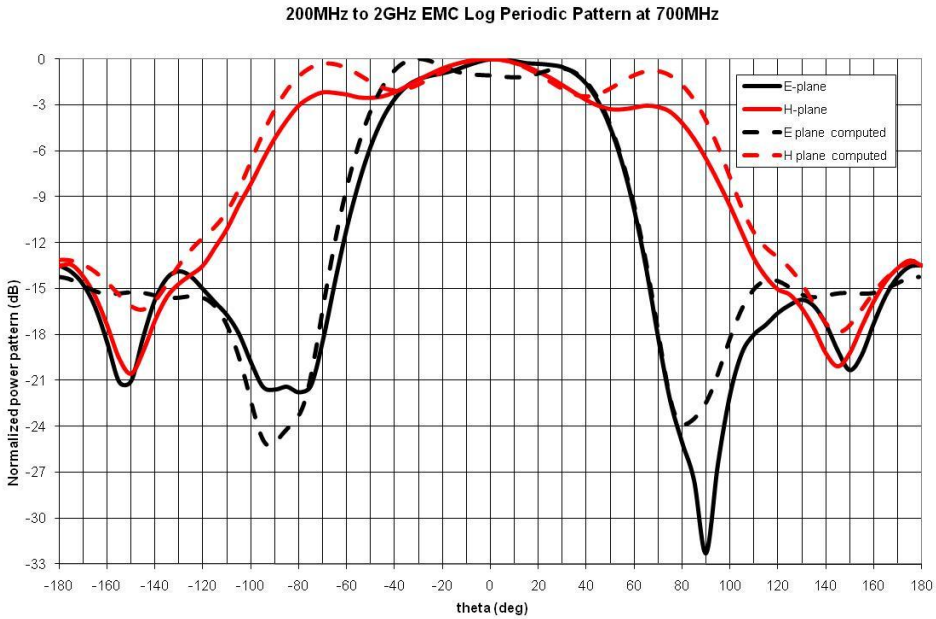


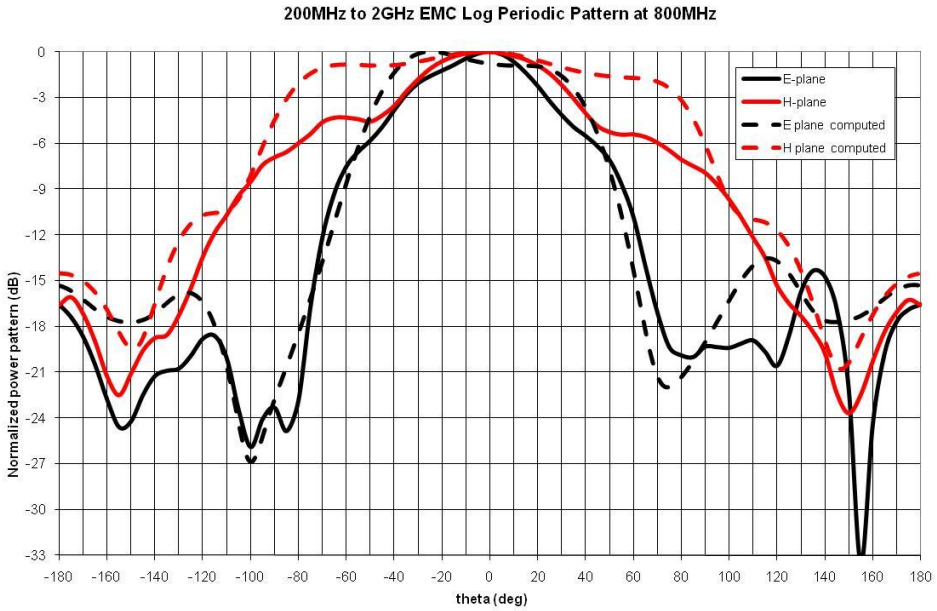
200MHz to 2GHz EMC Log Periodic Pattern at 600MHz

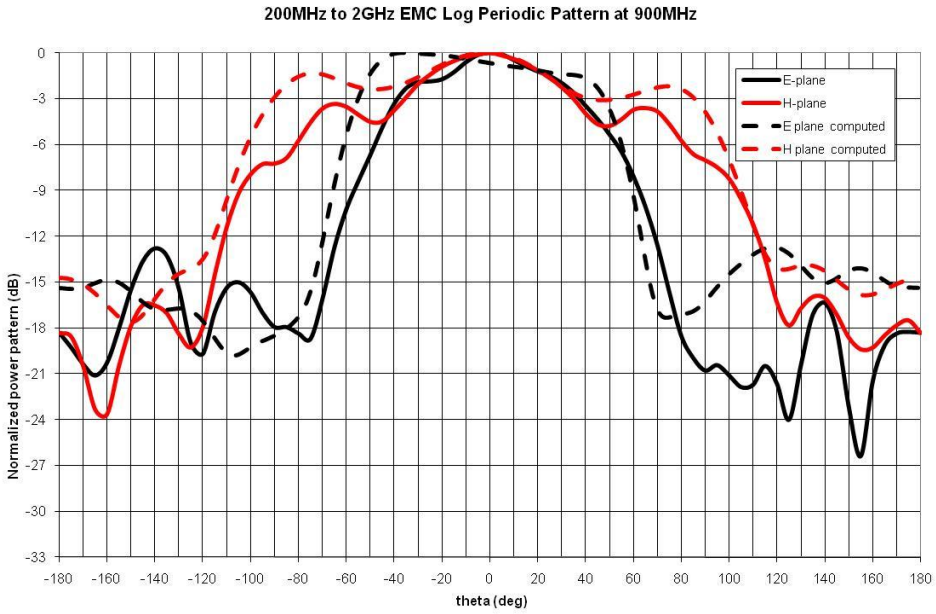


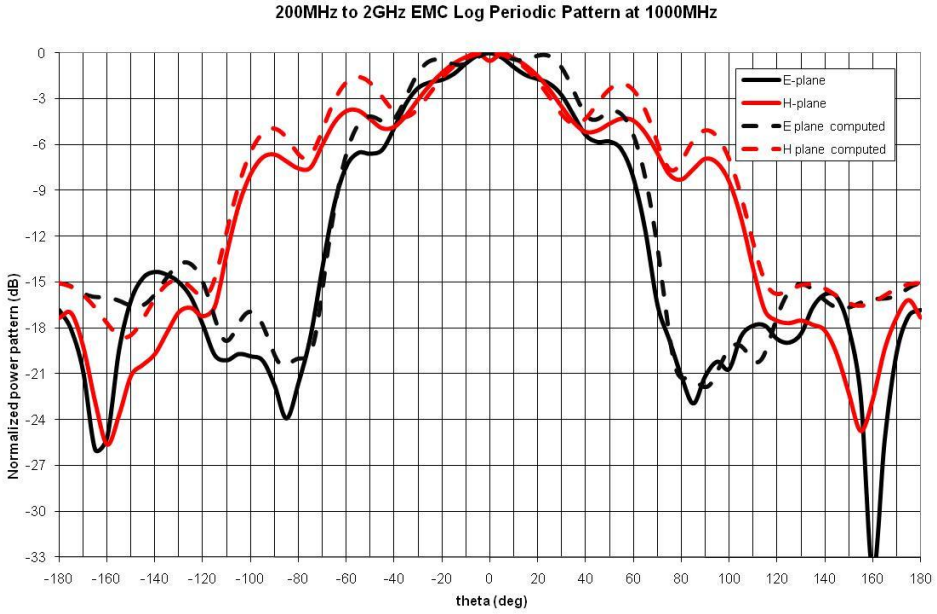
200MHz to 2GHz EMC Log Periodic Pattern at 700MHz



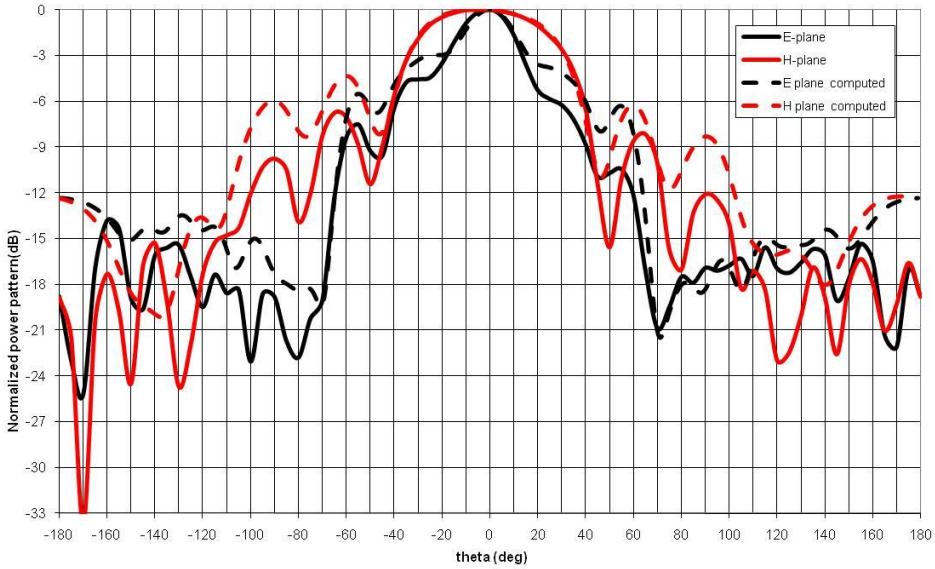

200MHz to 2GHz EMC Log Periodic Pattern at 700MHz
E-plane
H-plane
E plane computed
H plane computed
Normalized power pattern (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
theta (deg)


200MHz to 2GHz EMC Log Periodic Pattern at 800MHz
E-plane
H-plane
E plane computed
H plane computed
Normalized power pattern (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
theta (deg)

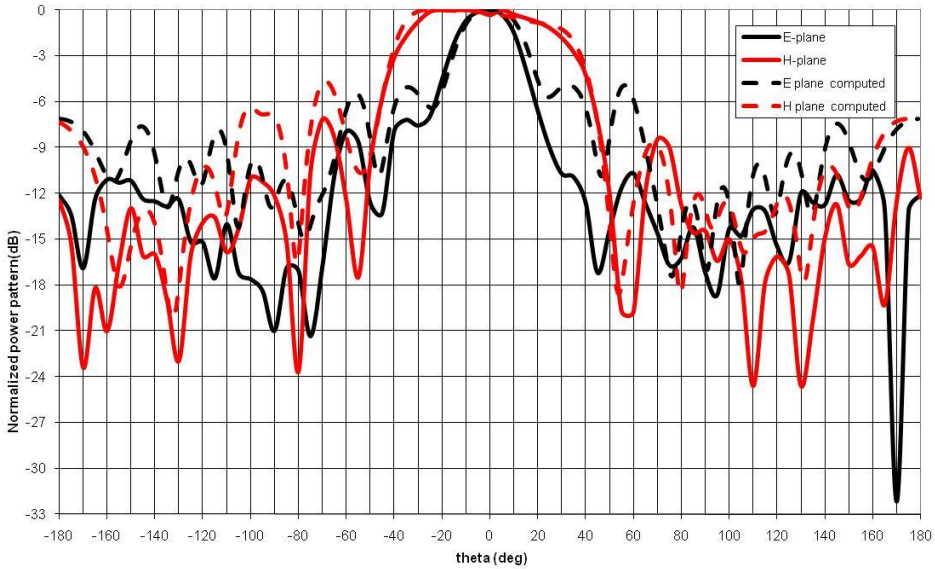

200MHz to 2GHz EMC Log Periodic Pattern at 900MHz
E-plane
H-plane
E plane computed
H plane computed
Normalized power pattern (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
theta (deg)

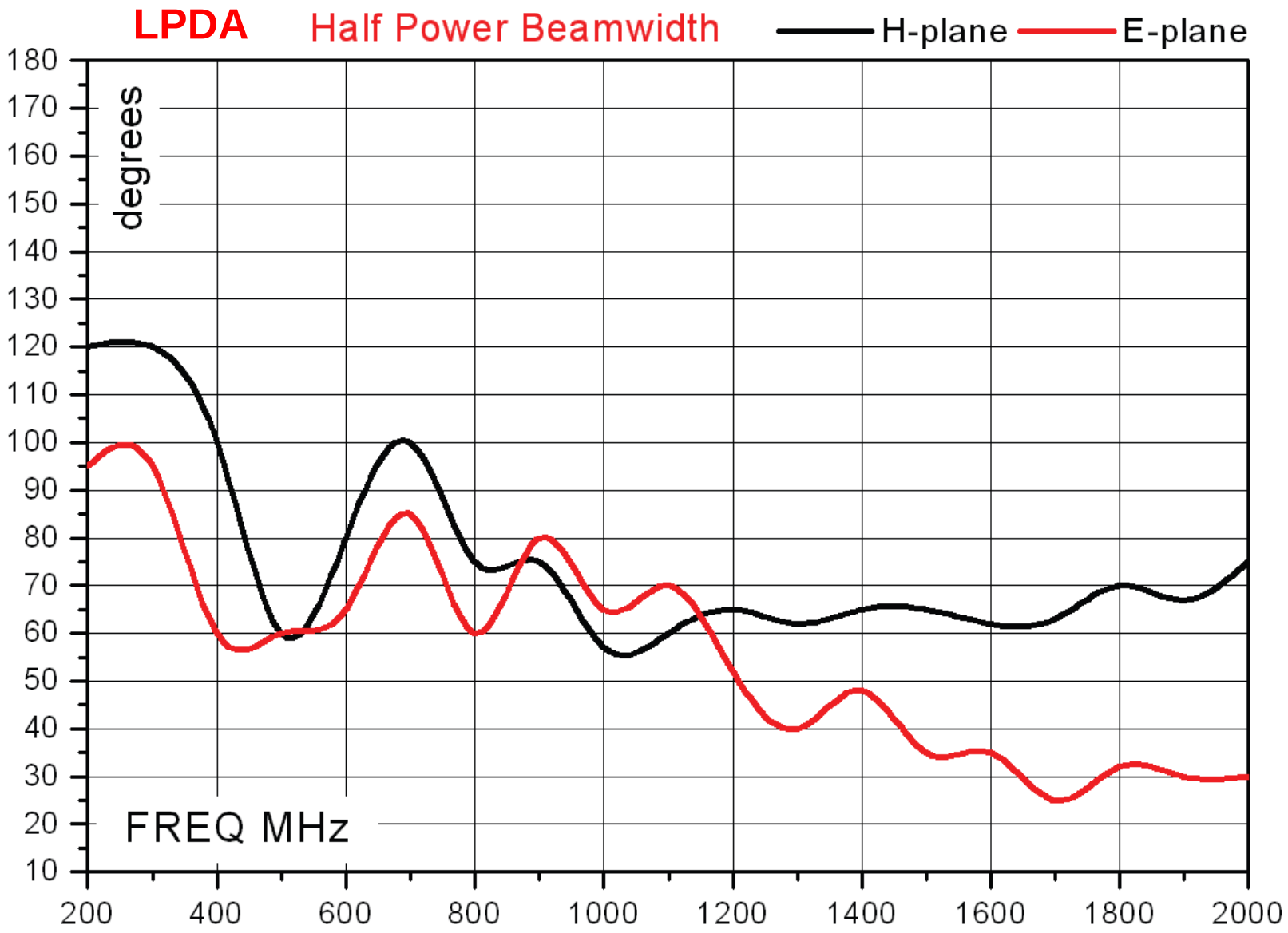

200MHz to 2GHz EMC Log Periodic Pattern at 1000MHz
E-plane
H-plane
E plane computed
H plane computed
Normalized power pattern (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
theta (deg)

200MHz to 2GHz EMC Log Periodic Pattern at 1500MHz



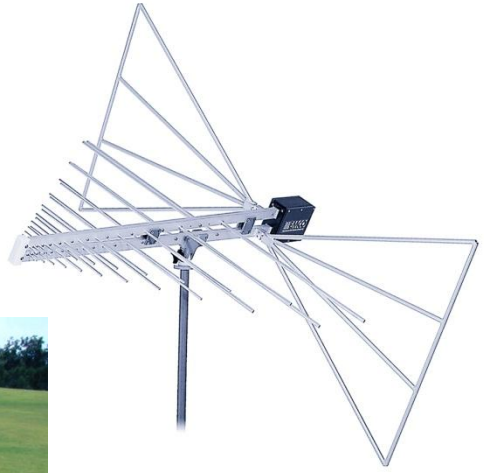
200MHz to 2GHz EMC Log Periodic Pattern at 2000MHz



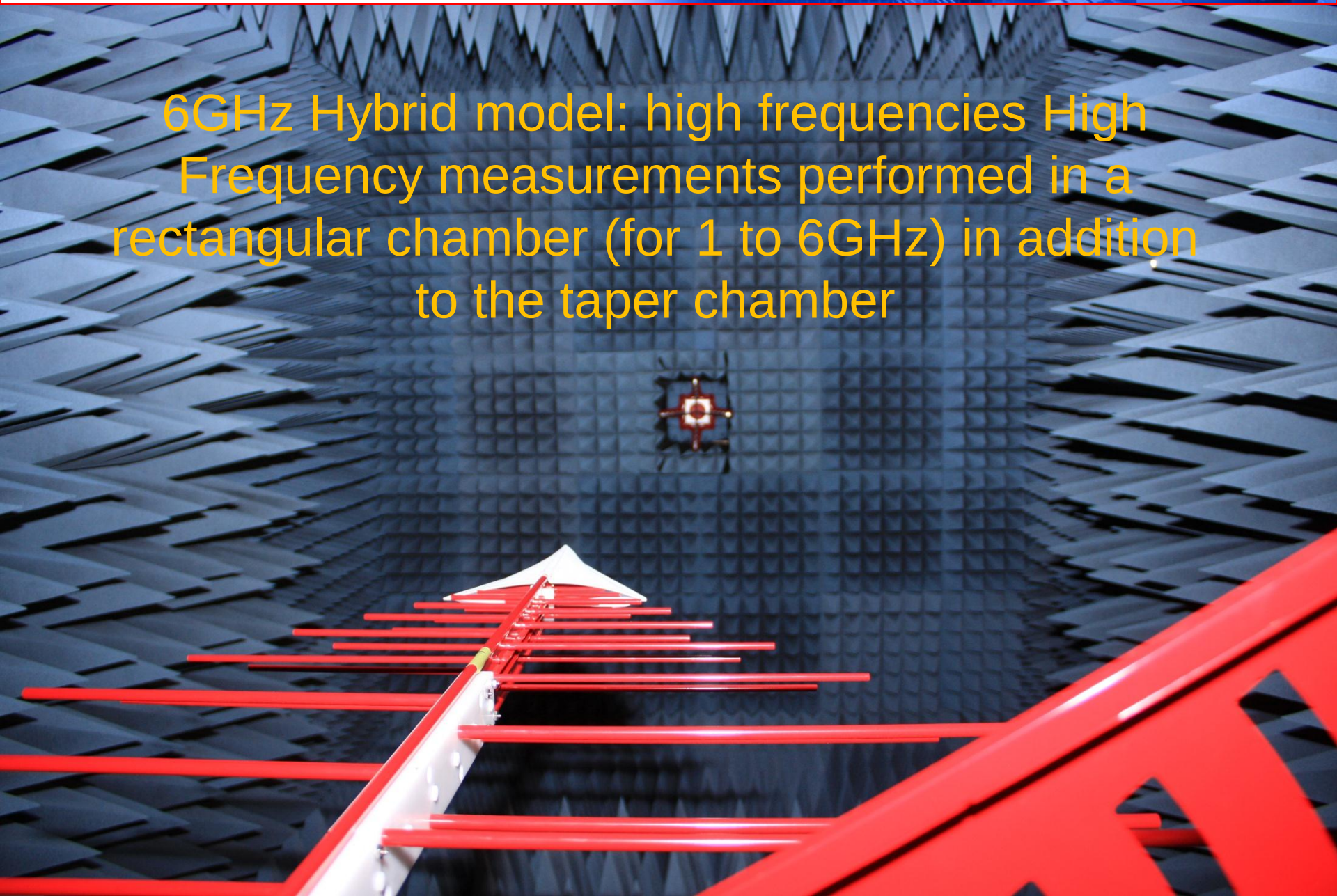

LPDA
Half Power Beamwidth
H-plane
E-plane
degrees
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
FREQ MHz
200
400
600
800
1000
1200
1400
1600
1800
2000

Biconical/Bowtie Log Periodic Hybrid

- Extremely broadband antennas mixing the advantages of the biconicals (electrically small) and LPDA (high gain and broadband)
- Some standards do not approve
- Incredible broadband one single antenna covering from 30MHz to 6GHz

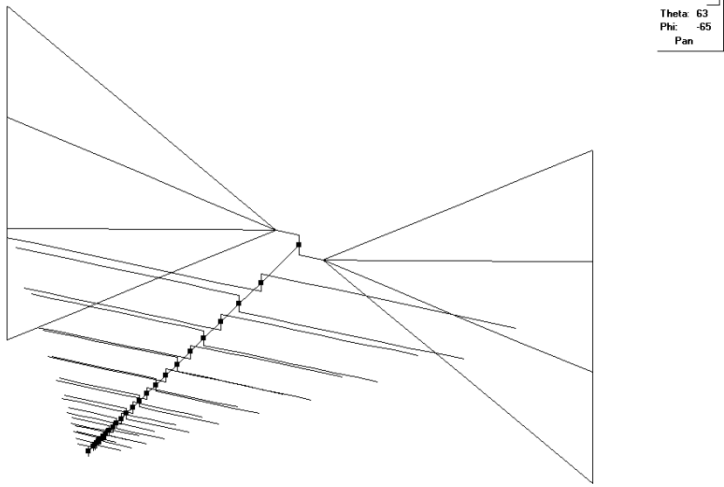


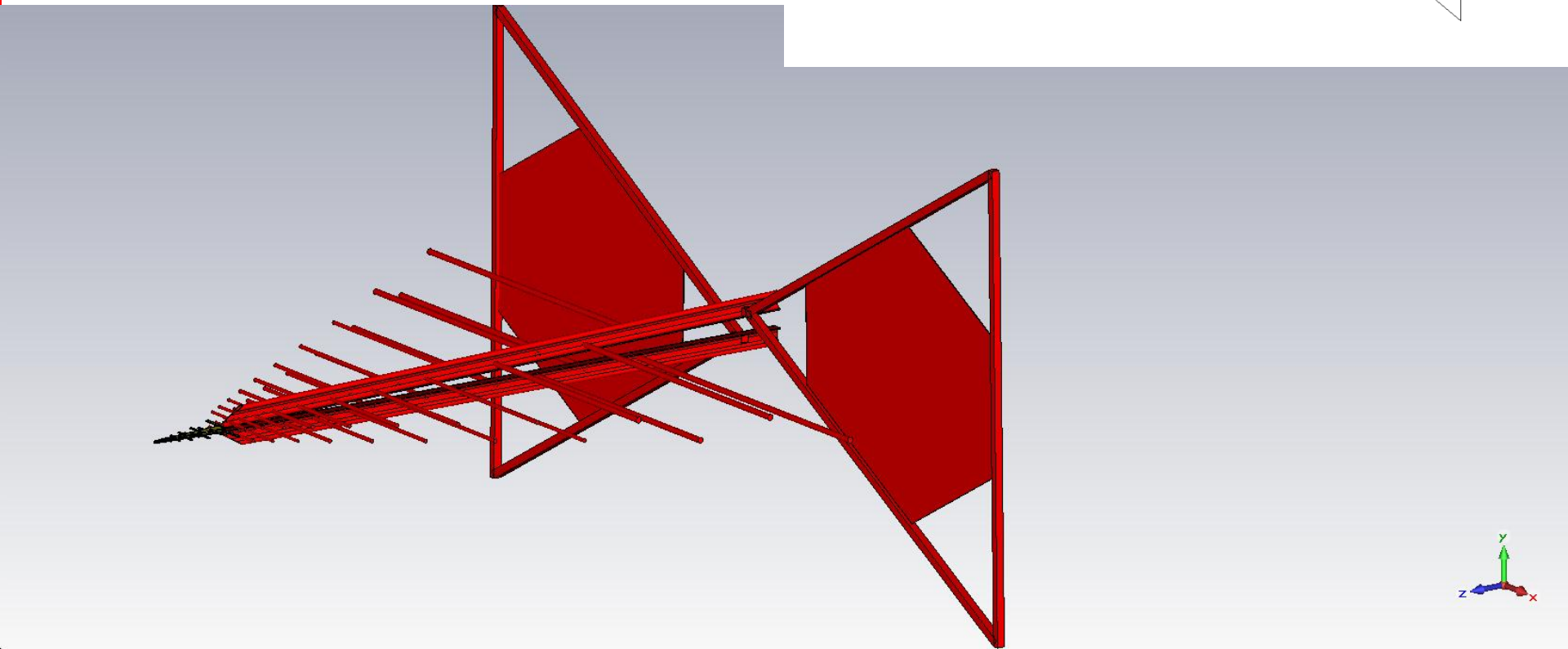
6GHz Hybrid model: high frequencies High Frequency measurements performed in a rectangular chamber (for 1 to 6GHz) in addition to the taper chamber

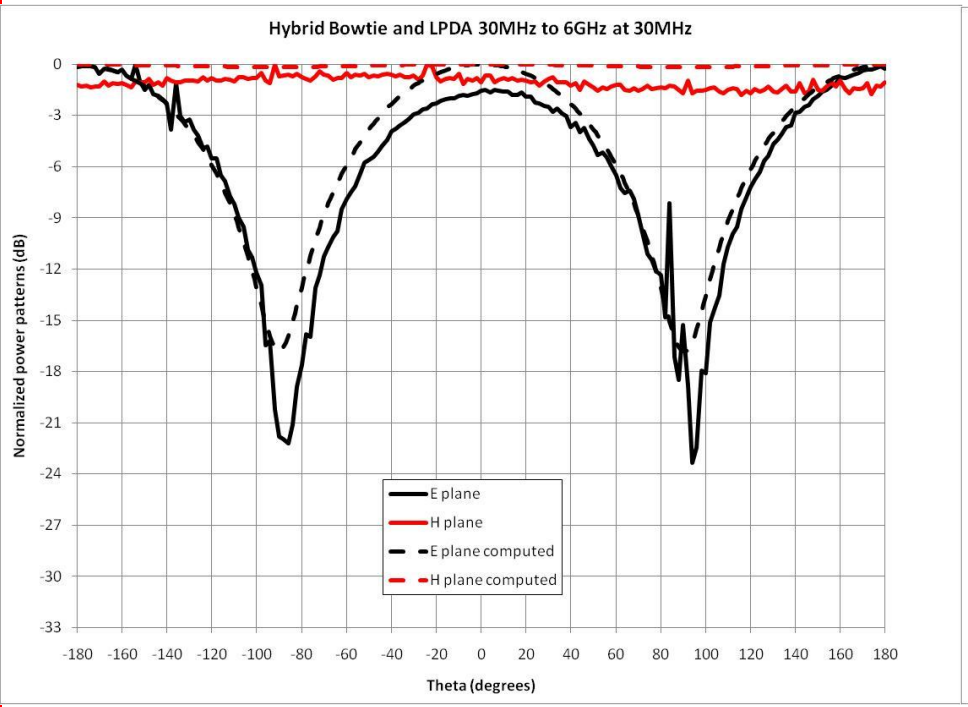


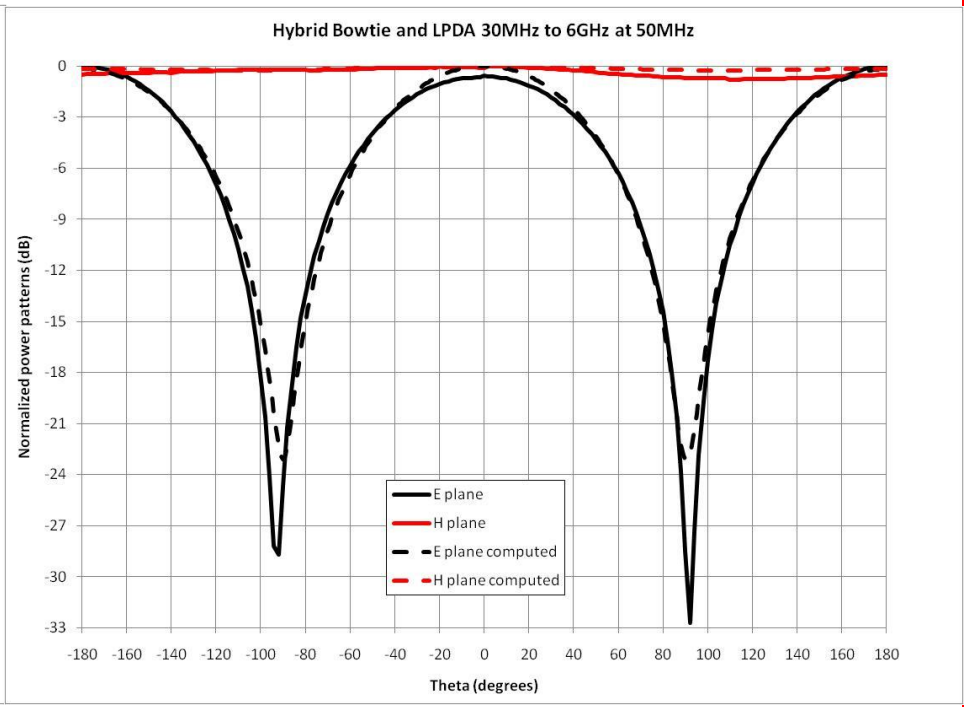
6GHz Hybrid model: lower frequencies measured on the OATS

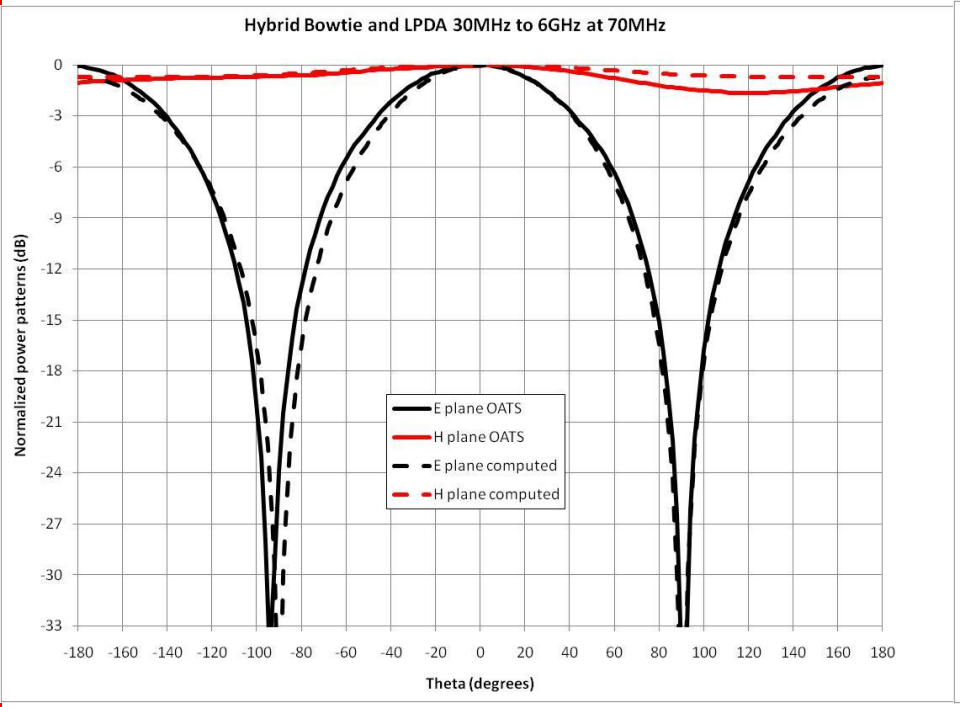
Numerical Model for NEC and a commercial package for the 30MHz to 6GHz Hybrid antenna

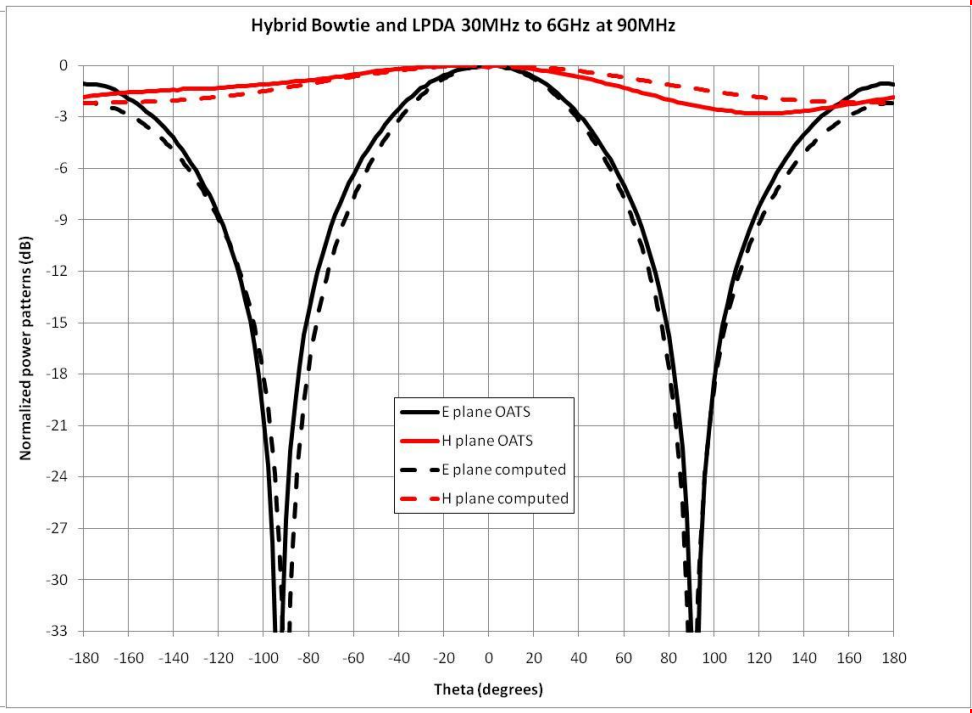


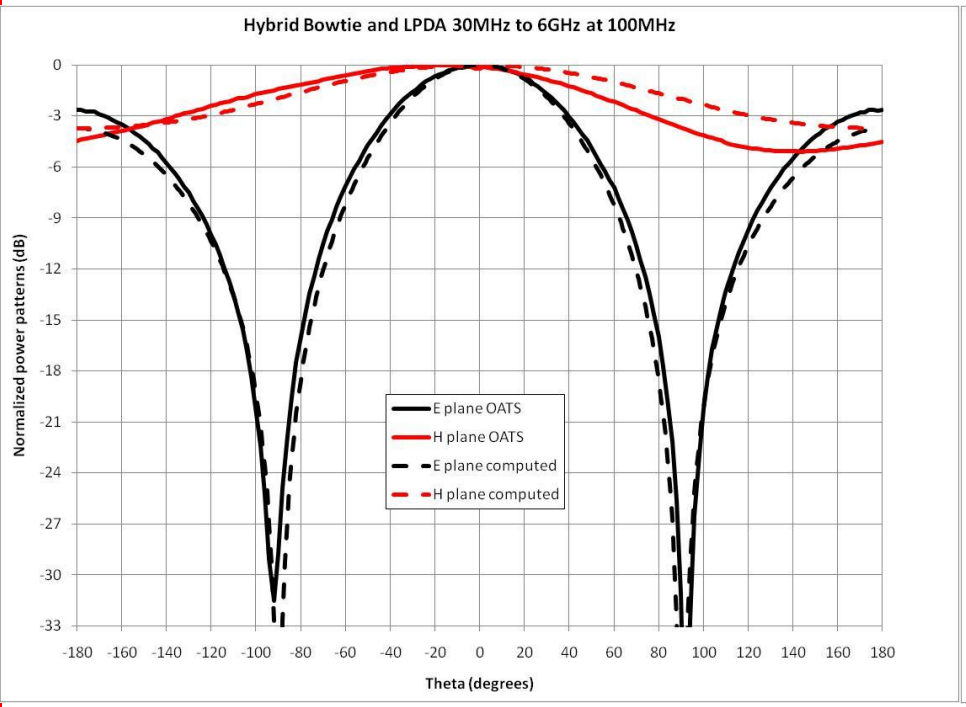


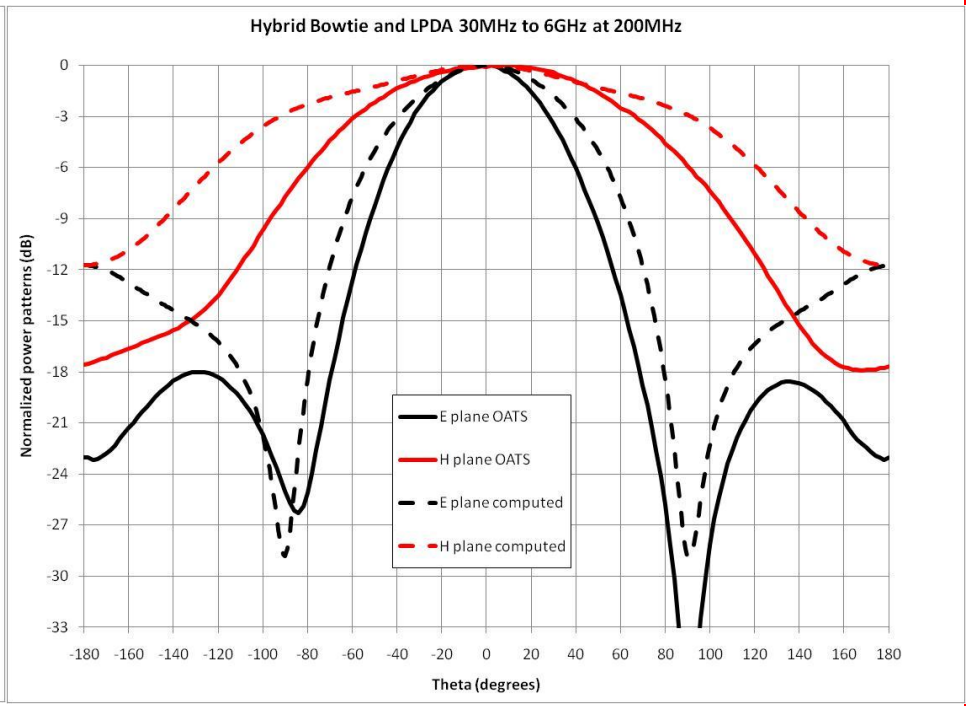

Hybrid Bowtie and LPDA 30MHz to 6GHz at 30MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

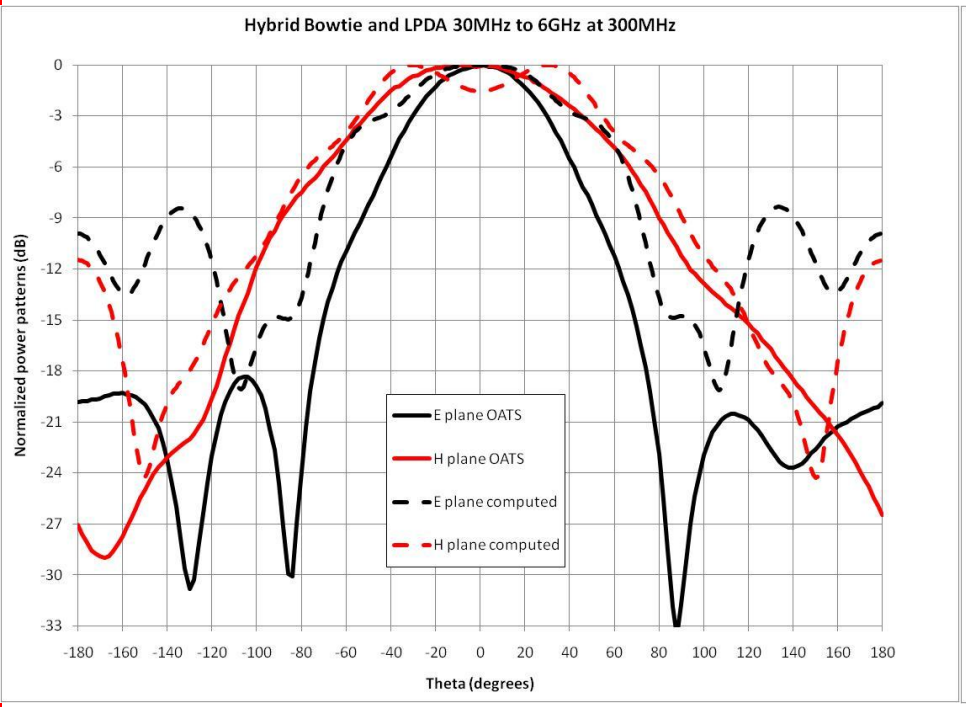

Hybrid Bowtie and LPDA 30MHz to 6GHz at 50MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane
H plane
E plane computed
H plane computed

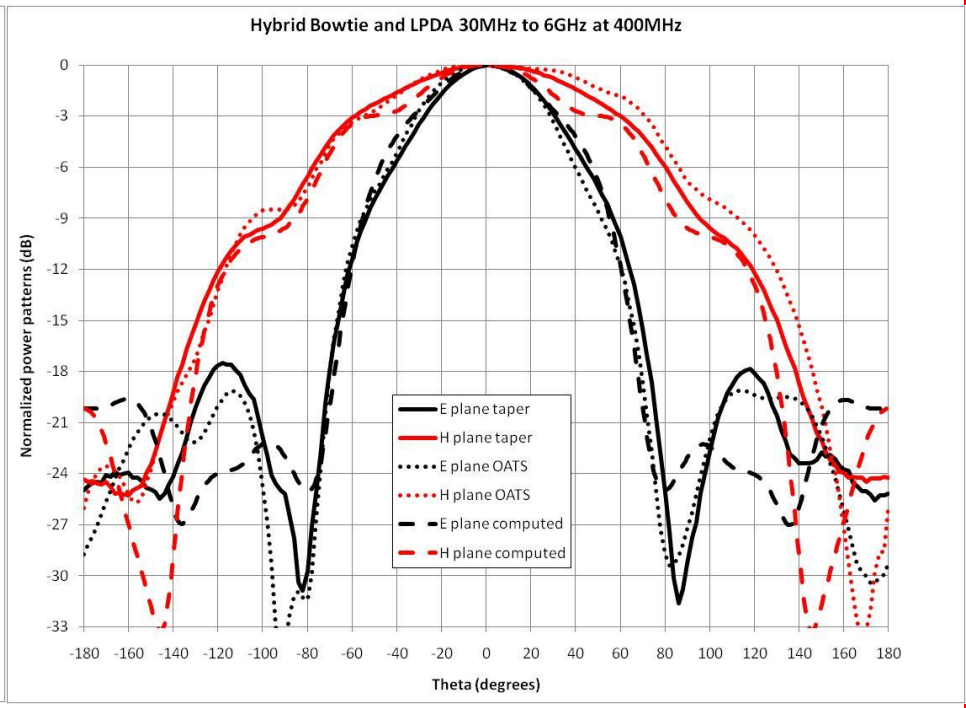

Hybrid Bowtie and LPDA 30MHz to 6GHz at 70MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane OATS
H plane OATS
E plane computed
H plane computed

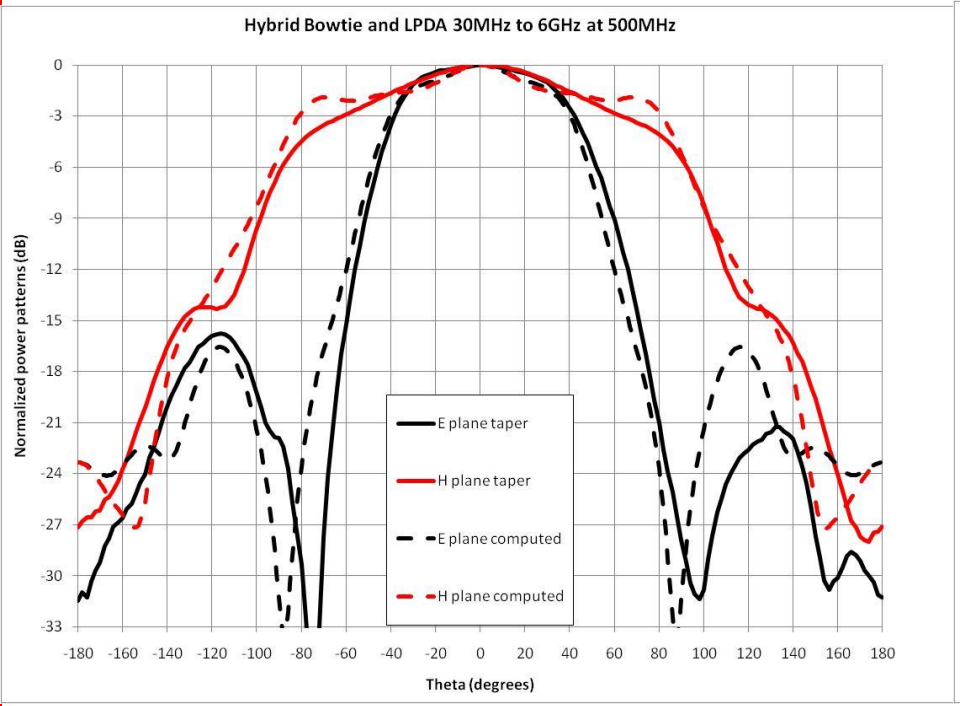

Hybrid Bowtie and LPDA 30MHz to 6GHz at 90MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane OATS
H plane OATS
E plane computed
H plane computed

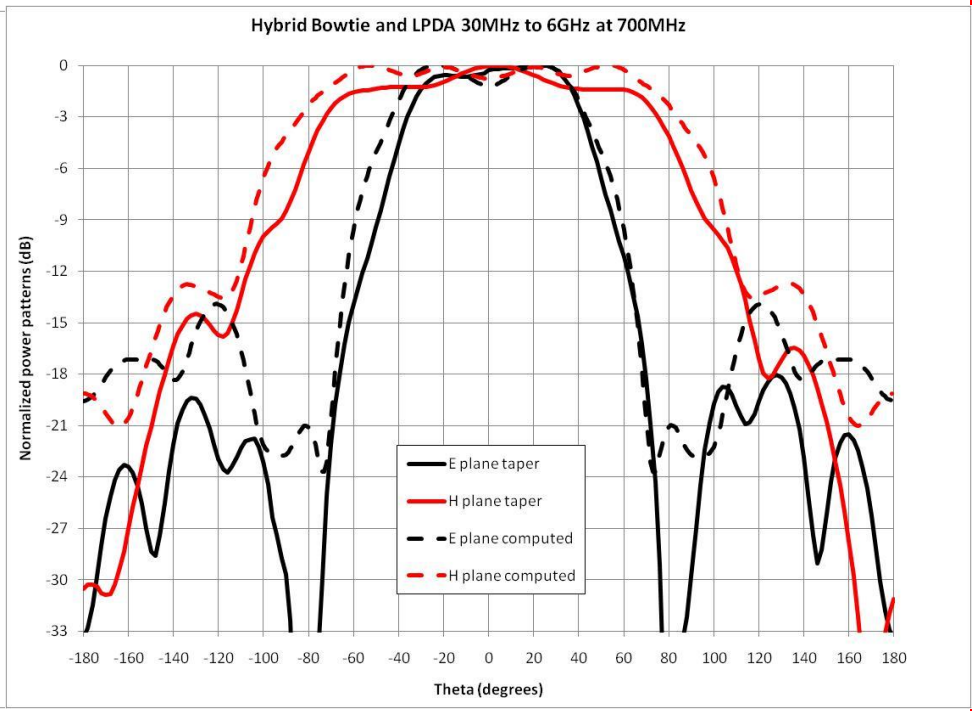

Hybrid Bowtie and LPDA 30MHz to 6GHz at 100MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane OATS
H plane OATS
E plane computed
H plane computed

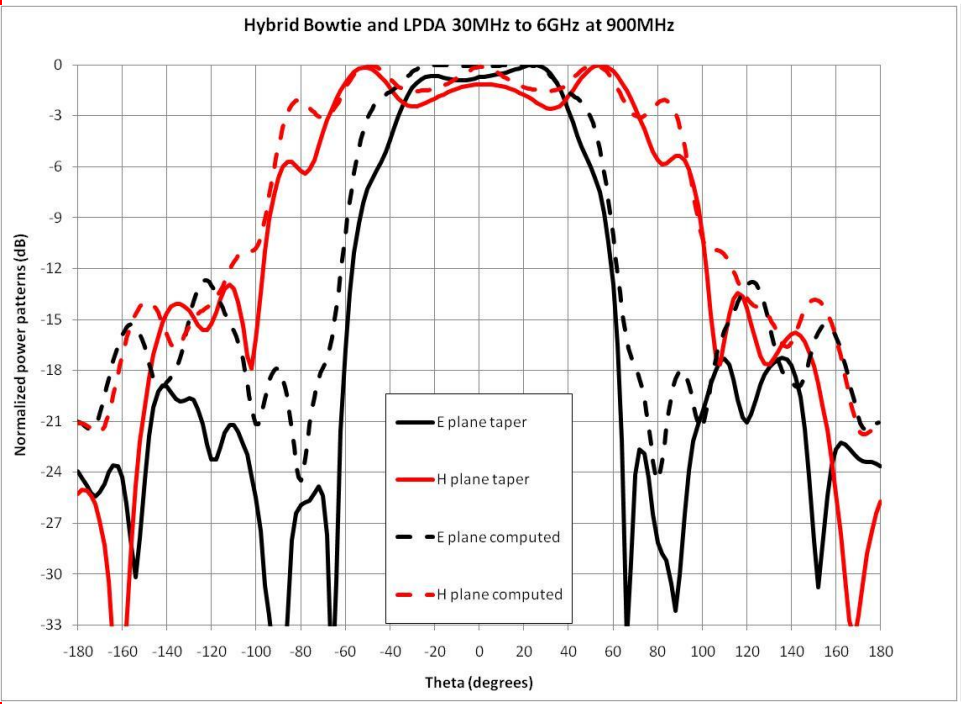

Hybrid Bowtie and LPDA 30MHz to 6GHz at 200MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane OATS
H plane OATS
E plane computed
H plane computed

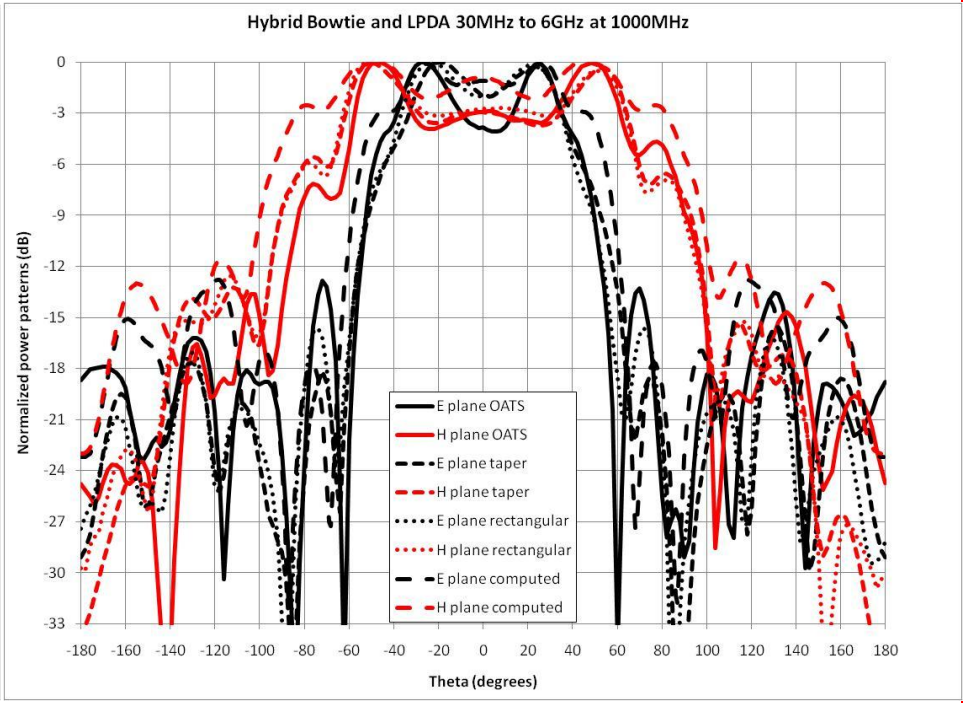

Hybrid Bowtie and LPDA 30MHz to 6GHz at 300MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane OATS
H plane OATS
E plane computed
H plane computed

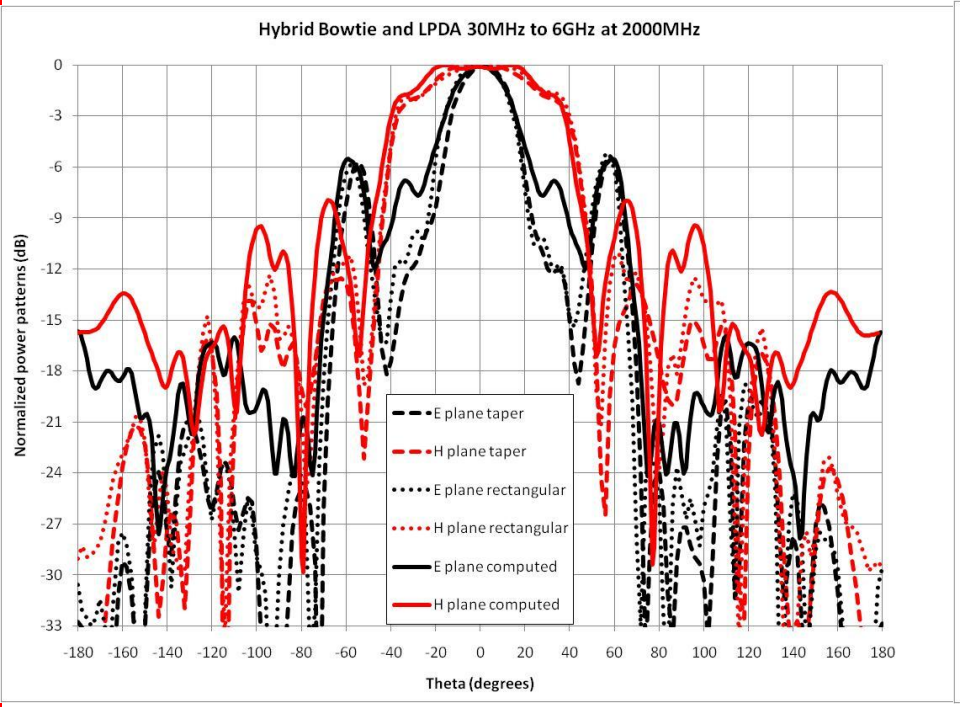

Hybrid Bowtie and LPDA 30MHz to 6GHz at 400MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane taper
H plane taper
E plane OATS
H plane OATS
E plane computed
H plane computed

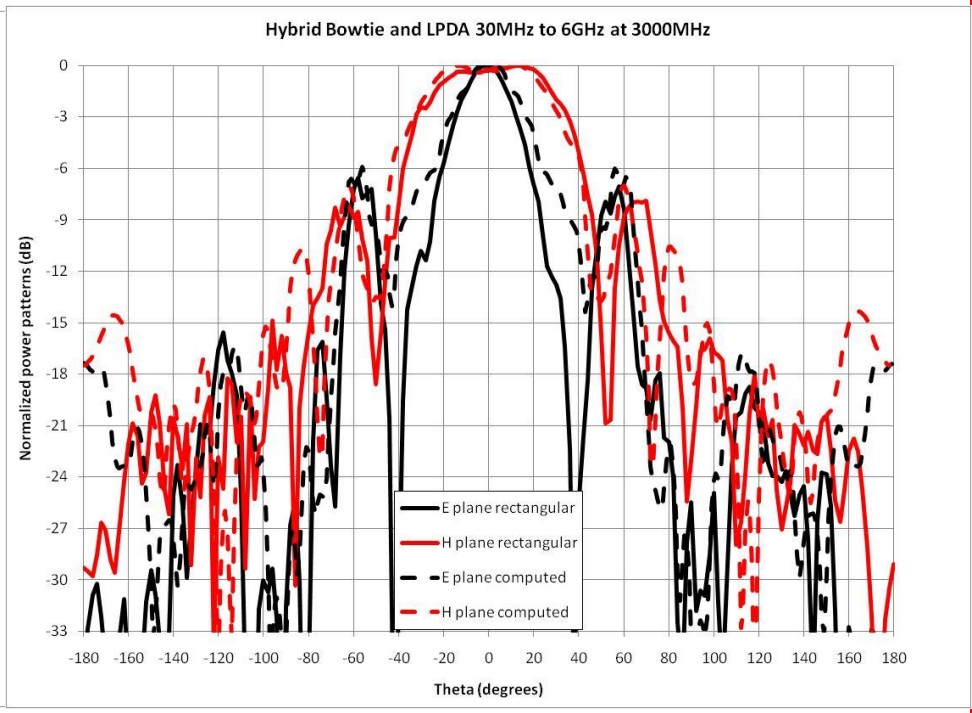

Hybrid Bowtie and LPDA 30MHz to 6GHz at 500MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane taper
H plane taper
E plane computed
H plane computed

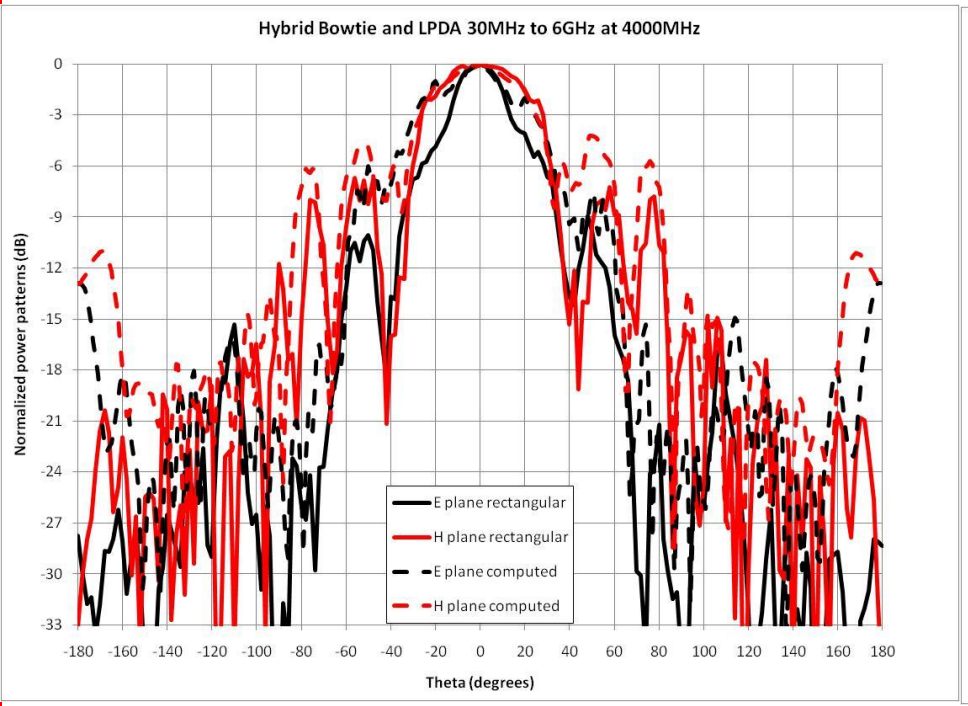

Hybrid Bowtie and LPDA 30MHz to 6GHz at 700MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane taper
H plane taper
E plane computed
H plane computed

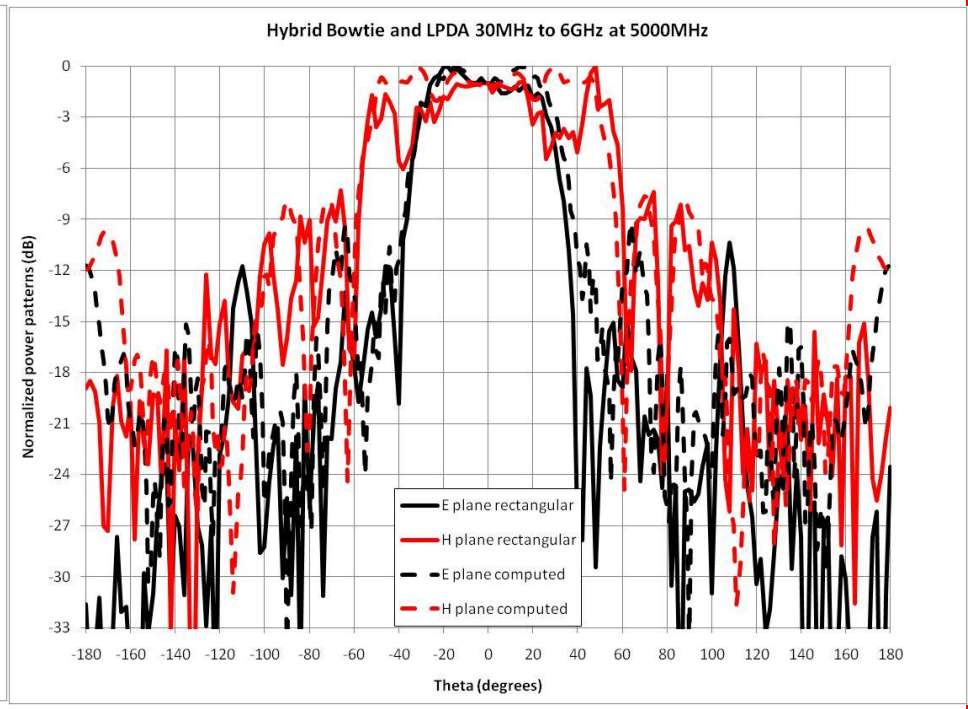

Hybrid Bowtie and LPDA 30MHz to 6GHz at 900MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane taper
H plane taper
E plane computed
H plane computed

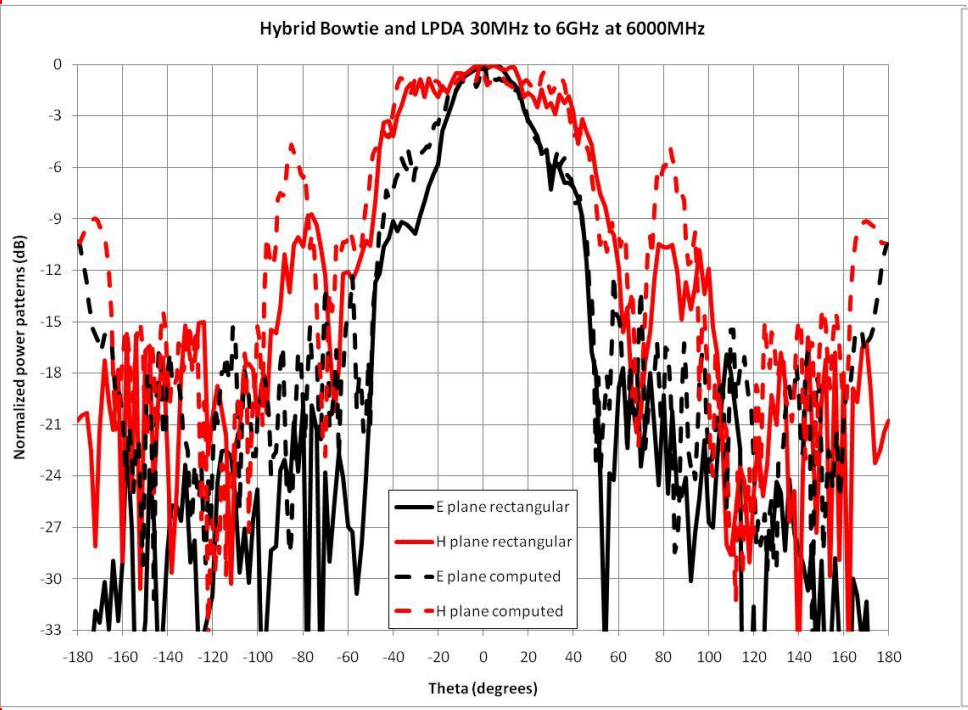

Hybrid Bowtie and LPDA 30MHz to 6GHz at 1000MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane OATS
H plane OATS
E plane taper
H plane taper
E plane rectangular
H plane rectangular
E plane computed
H plane computed

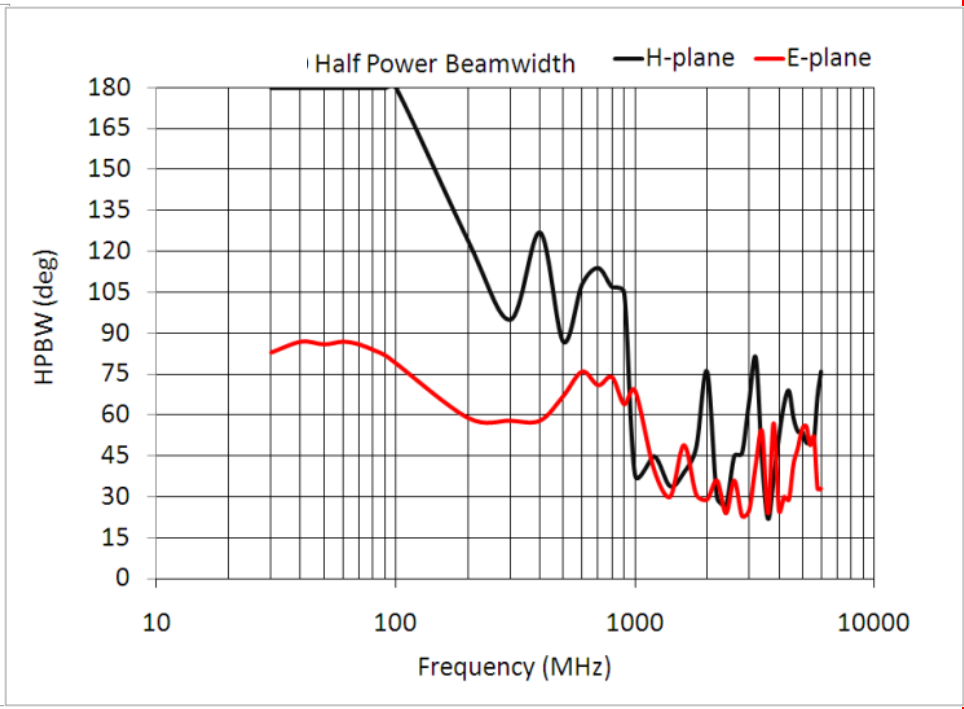

Hybrid Bowtie and LPDA 30MHz to 6GHz at 2000MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane taper
H plane taper
E plane rectangular
H plane rectangular
E plane computed
H plane computed


Hybrid Bowtie and LPDA 30MHz to 6GHz at 3000MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane rectangular
H plane rectangular
E plane computed
H plane computed


Hybrid Bowtie and LPDA 30MHz to 6GHz at 4000MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane rectangular
H plane rectangular
E plane computed
H plane computed

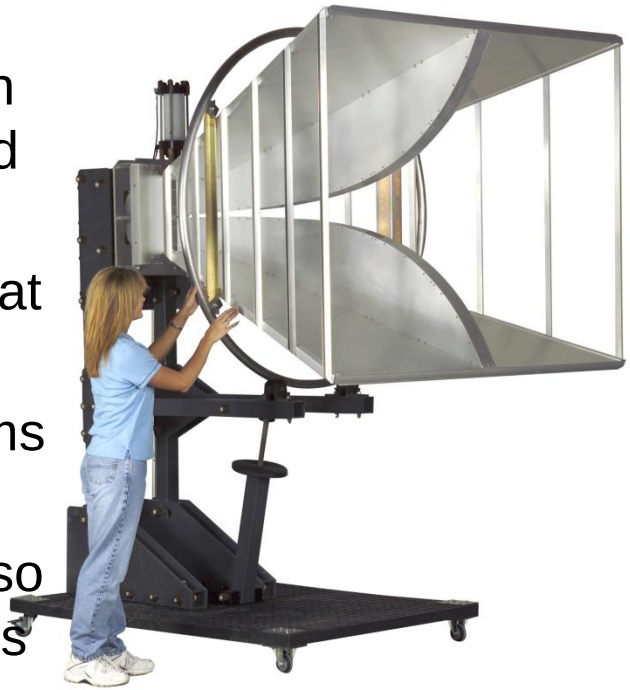

Hybrid Bowtie and LPDA 30MHz to 6GHz at 5000MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane rectangular
H plane rectangular
E plane computed
H plane computed

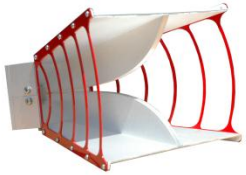

Hybrid Bowtie and LPDA 30MHz to 6GHz at 6000MHz
Normalized power patterns (dB)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Theta (degrees)
E plane rectangular
H plane rectangular
E plane computed
H plane computed

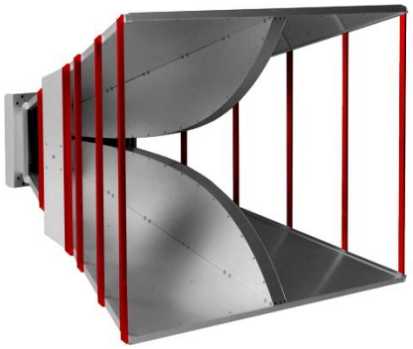

Half Power Beamwidth
H-plane
E-plane
HPBW (deg)
180
165
150
135
120
105
90
75
60
45
30
15
0
10
100
1000
10000
Frequency (MHz)

Dual Ridge Guide Horns

- Extremely broadband antennas with higher gain than any other broadband antennas 8 to 10dB
- Can have pattern issues at the upper band
- Recently, pattern problems have been solved.
- Ideal for immunity, but also can be used for emissions



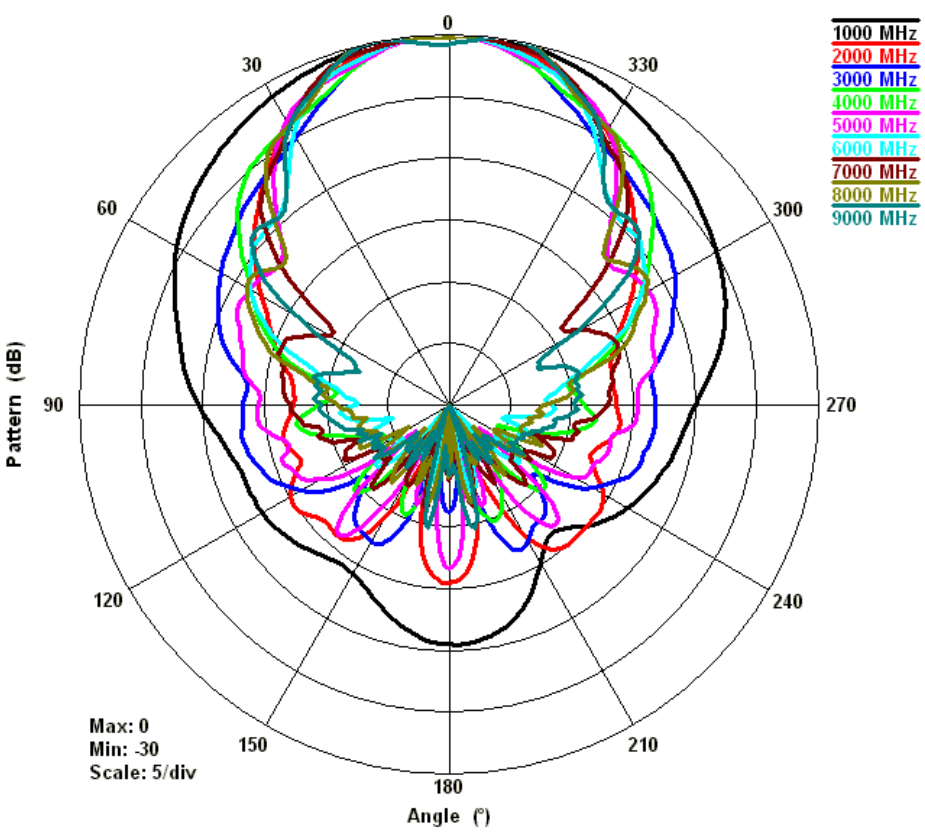


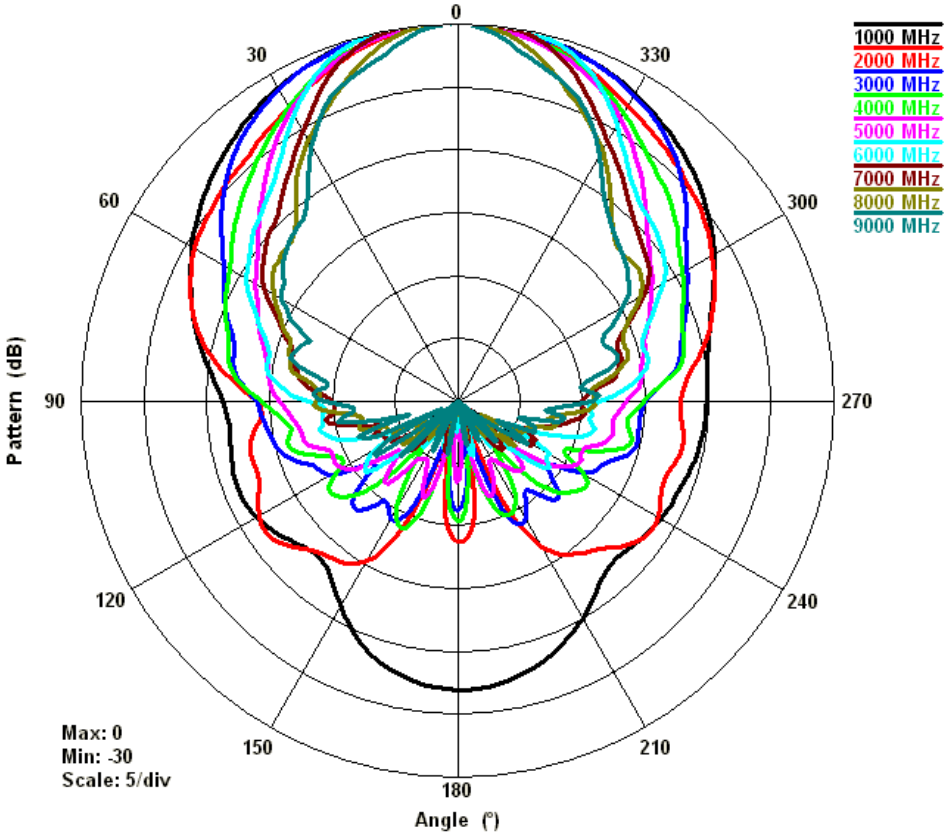


Discussed frequently in the literature

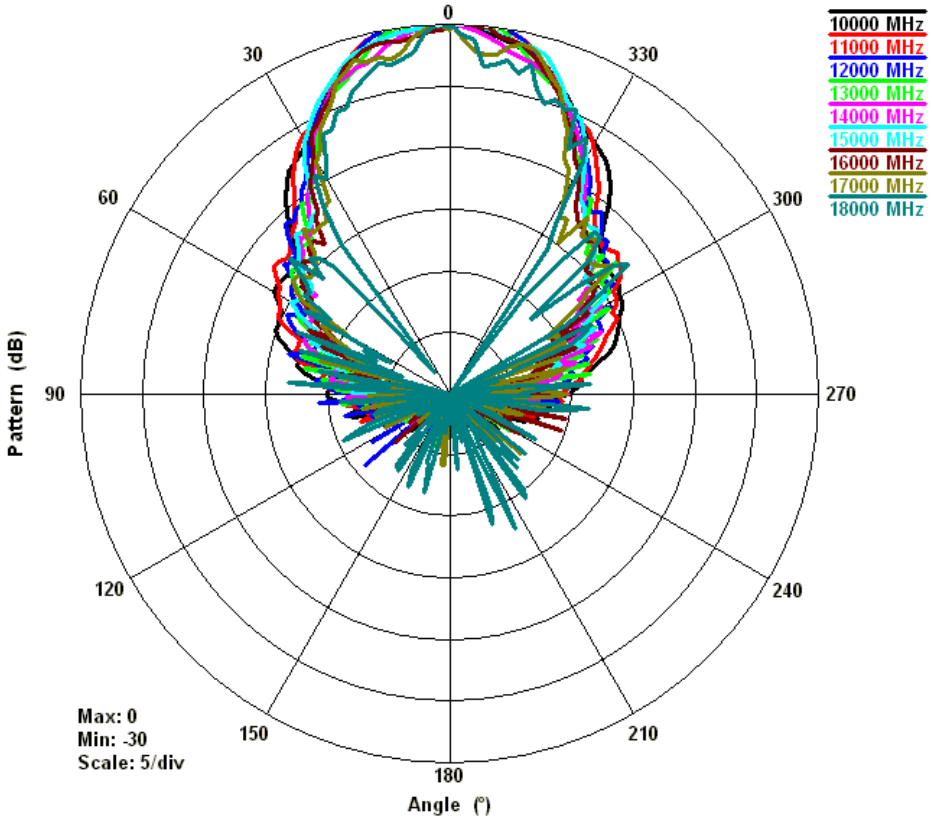
- C. Bruns, P. Leuchtmann, and R. Vahldieck “Analysis of a 1-18GHz Broadband Double-Ridge Antenna,” *IEEE Transactions of Electromagnetic Compatibility*, Vol 45, No. 1, pp.55-60, February 2003
- V. Rodriguez “New Broadband EMC double-ridge guide horn antenna” *RF Design.* May 2004, pp. 44-50.
- V. Rodriguez, “A new broadband Double Ridge guide Horn with improved Radiation Pattern for Electromagnetic Compatibility Testing”,*16th international Zurich symposium on Electromagnetic compatibility*, Zurich, Switzerland, February 2005.
- V. Rodriguez “Improvements to Broadband Dual Ridge Waveguide Horn Antennas” *2009 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting.* Charleston SC June 1-5 2009.
- V. Rodriguez “Recent Improvements to Dual Ridge Horn Antennas: The 200MHz to 2GHz and 18GHz to 40GHz Models” *2009 IEEE International Symposium on EMC*. Austin, TX Aug 17-21 2009

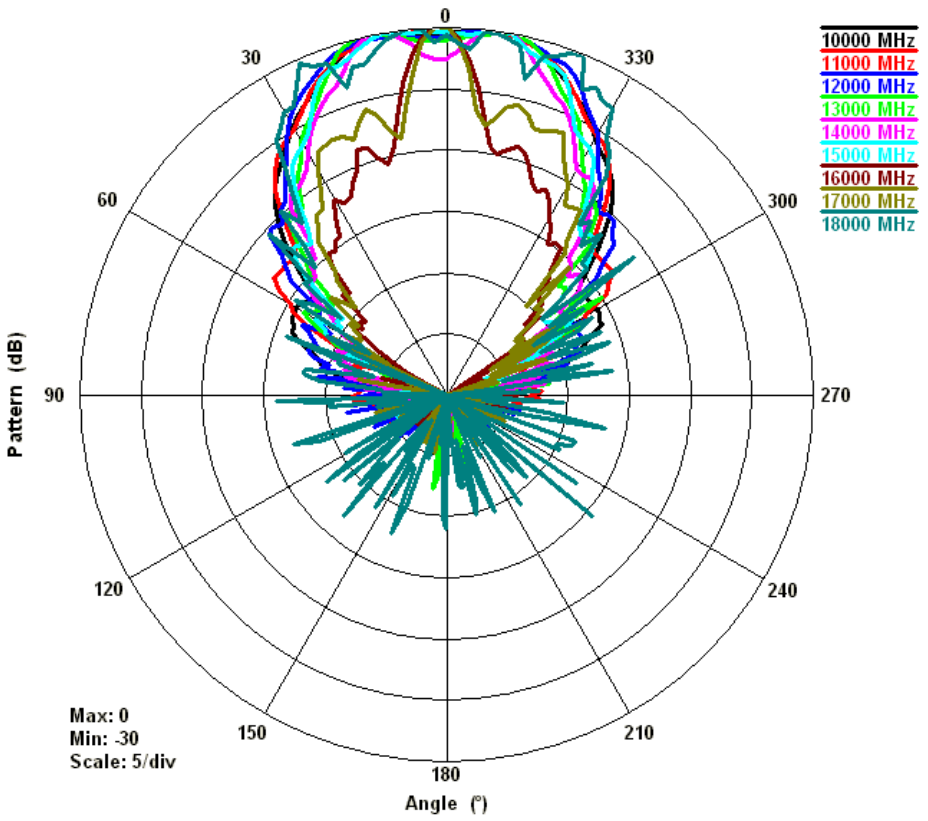
1 to 18GHz models
E plane



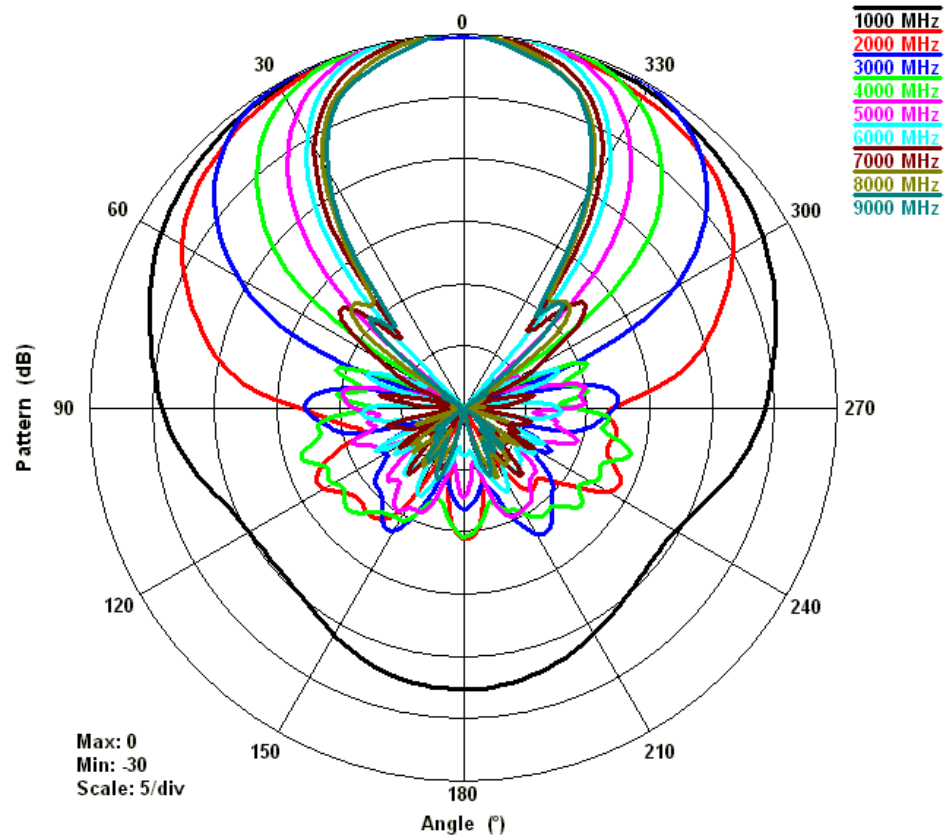


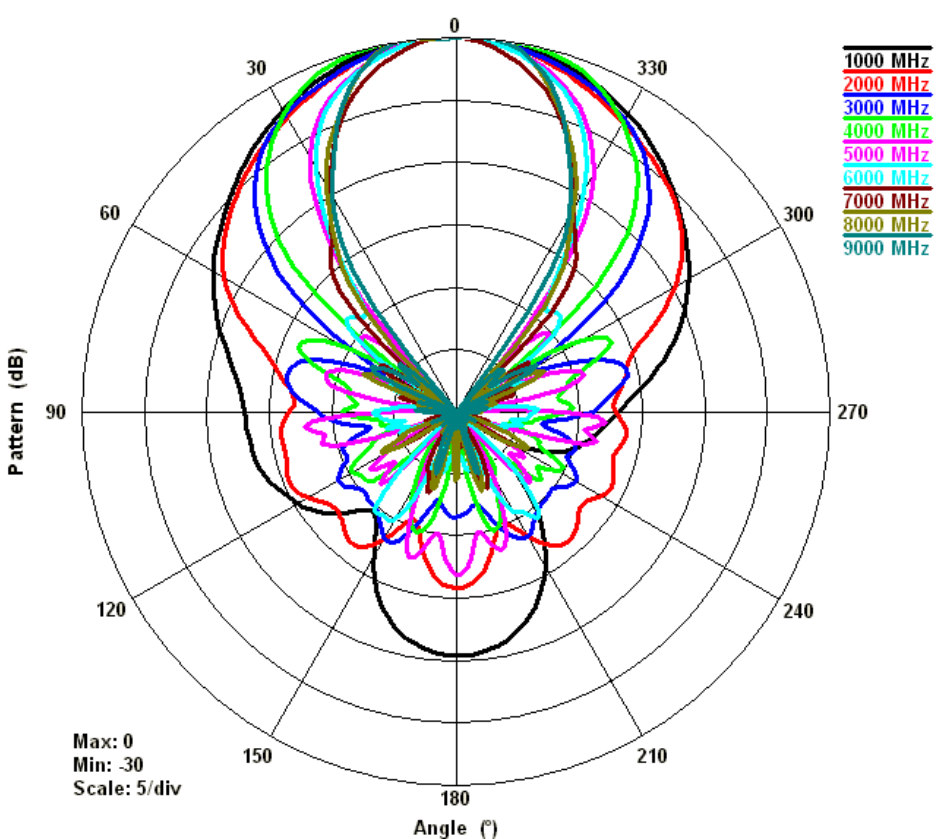
1 to 18GHz models
E plane



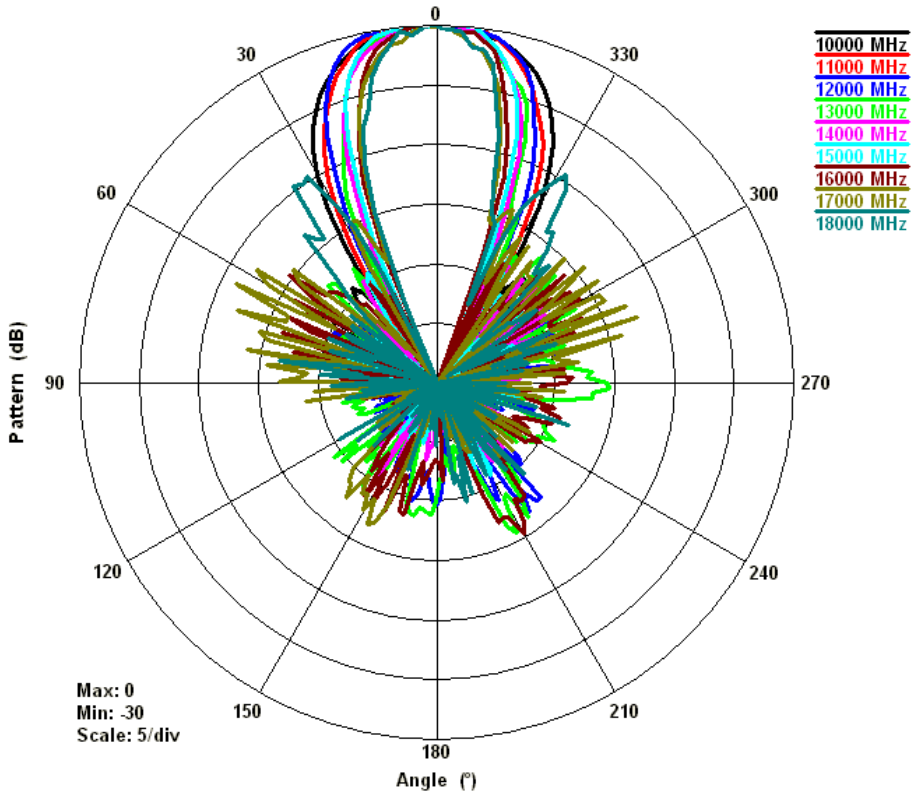


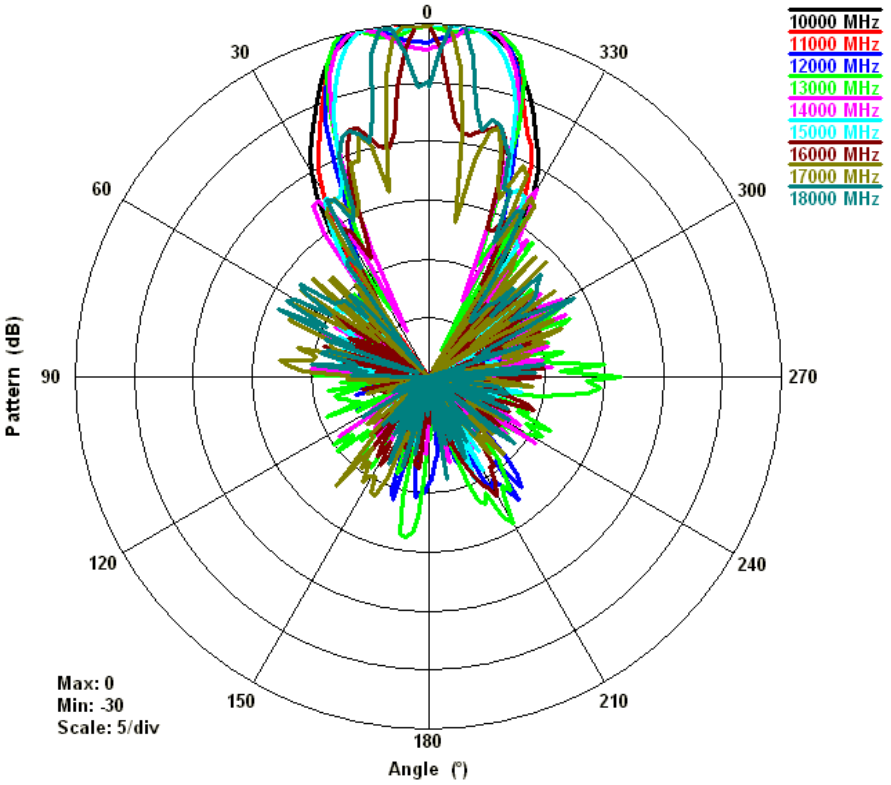
1 to 18GHz models
H plane



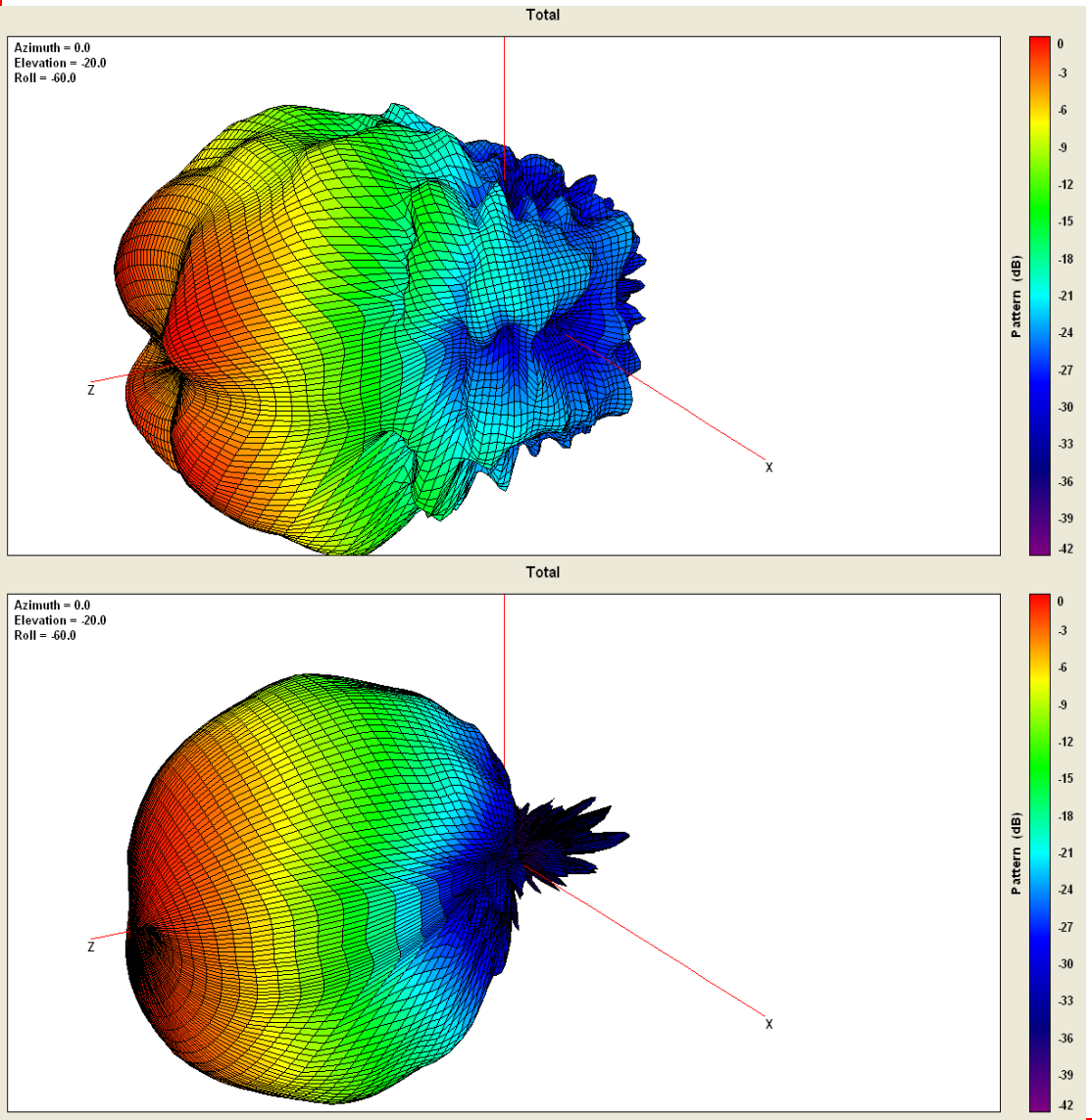


1 to 18GHz models
H plane

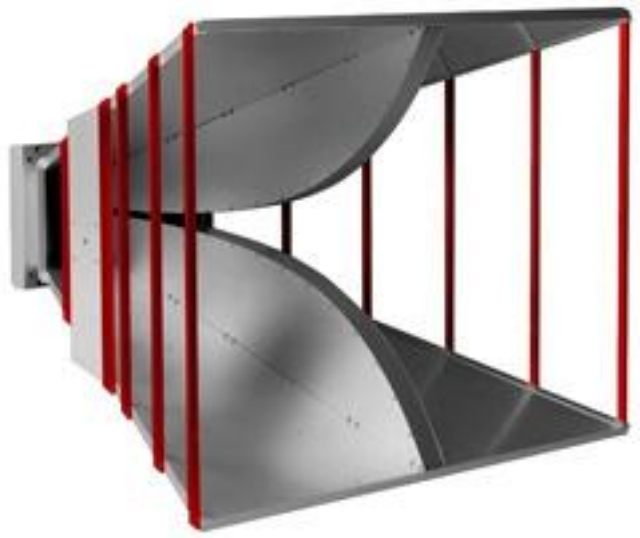




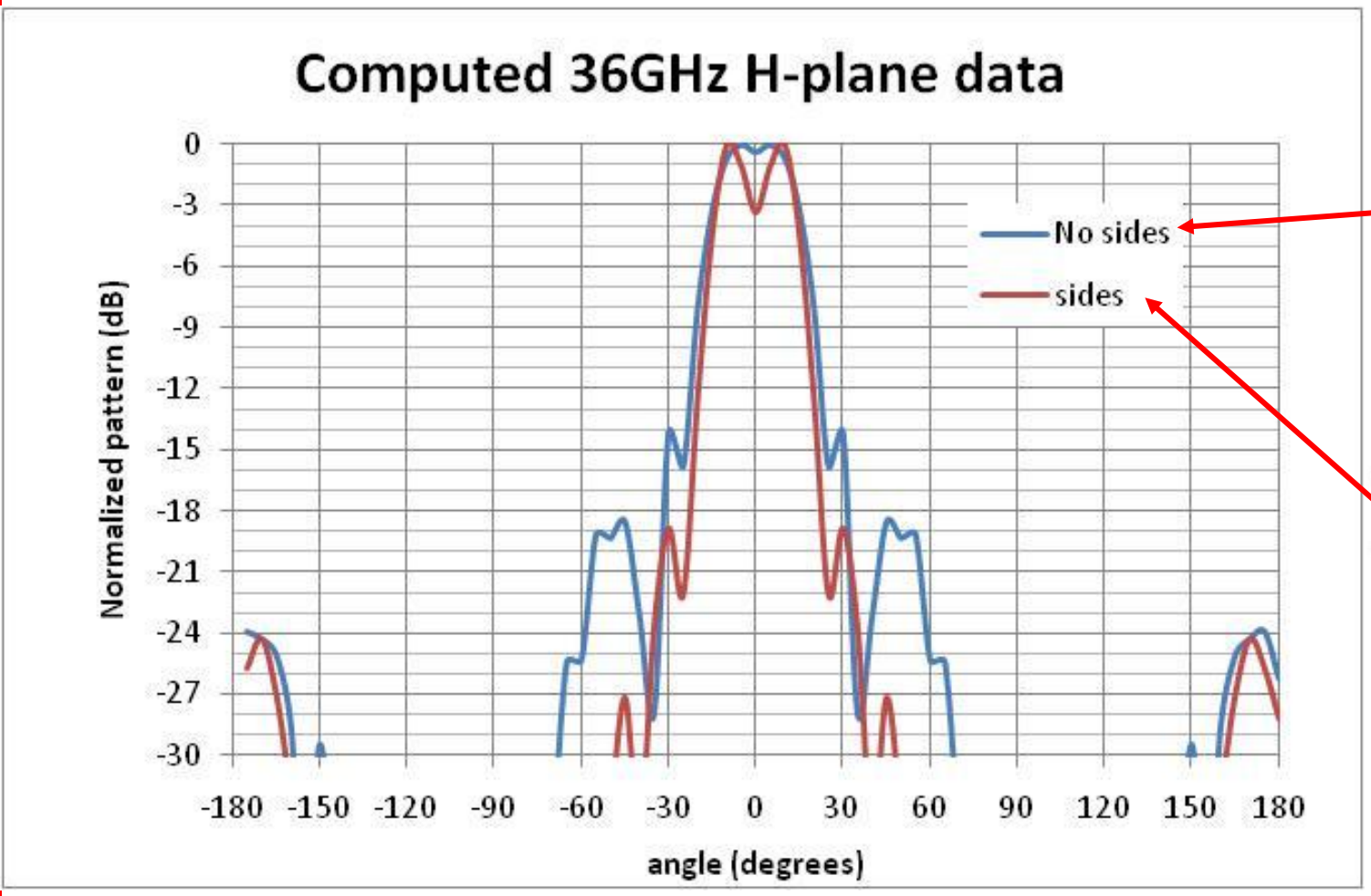
200MHz to 2000MHz model at 2GHz

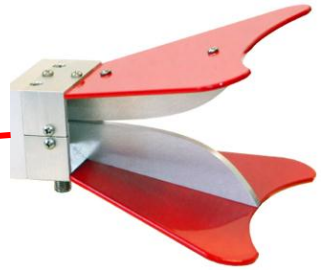


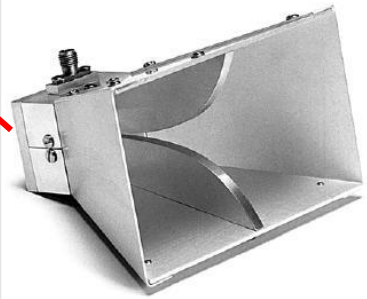
The common design for the 200-2000MHz design has a pattern that splits into four beams.
Improved designs introduced 3 years ago avoid this problem by improving the feed cavity.
The boresight gain increases by 6dB gain



18 to 40GHz designs.





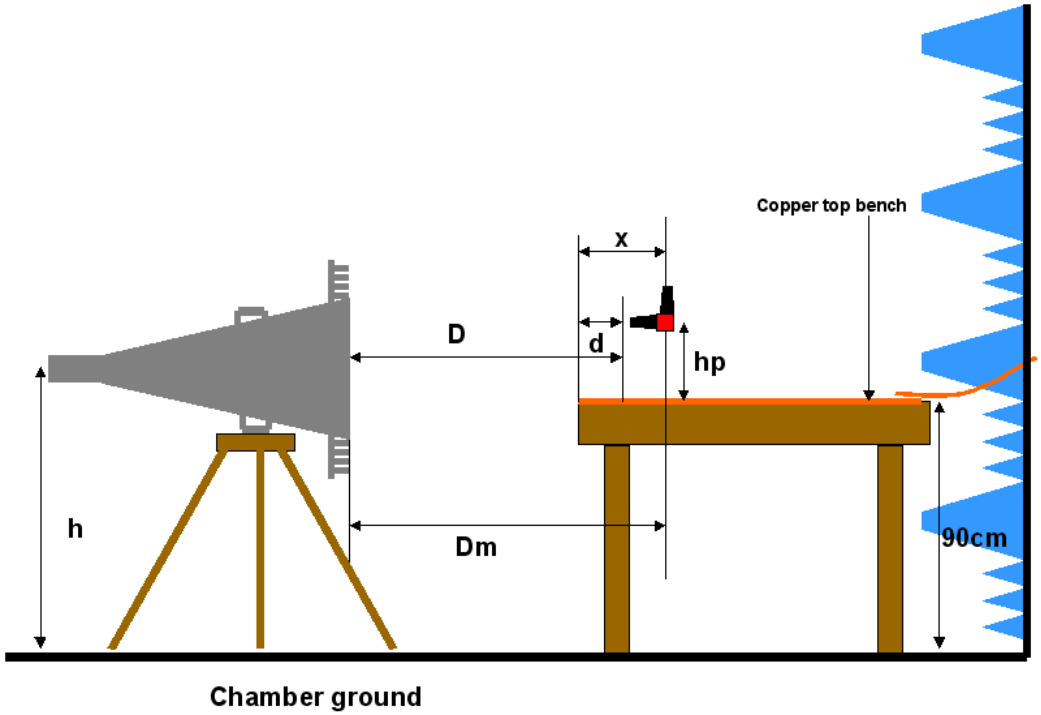


Regarding pattern Information

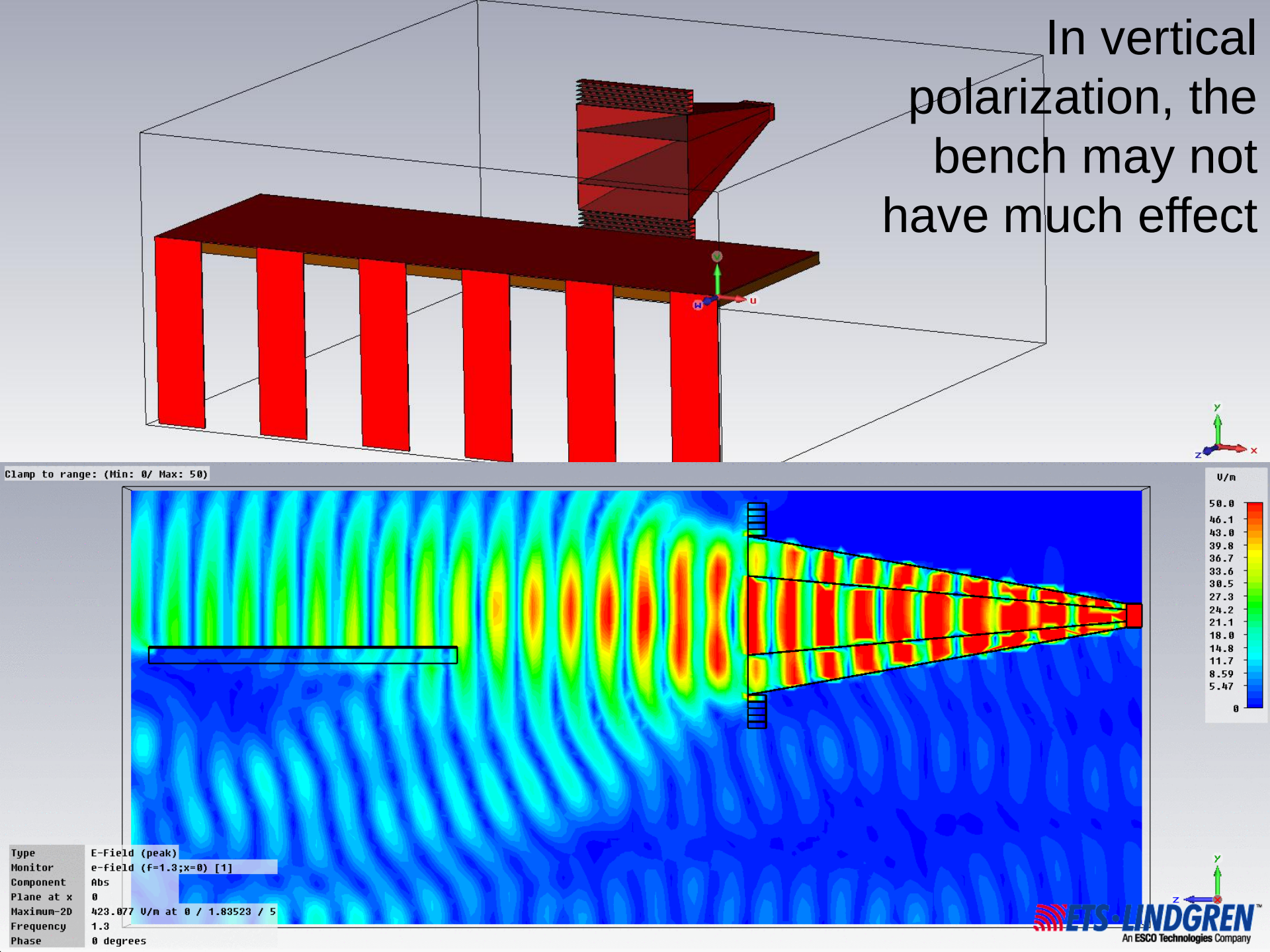
- Pattern Data is Free Space and Far Field
- Sometimes neither condition is met in an EMC test layout
- Use as guidelines

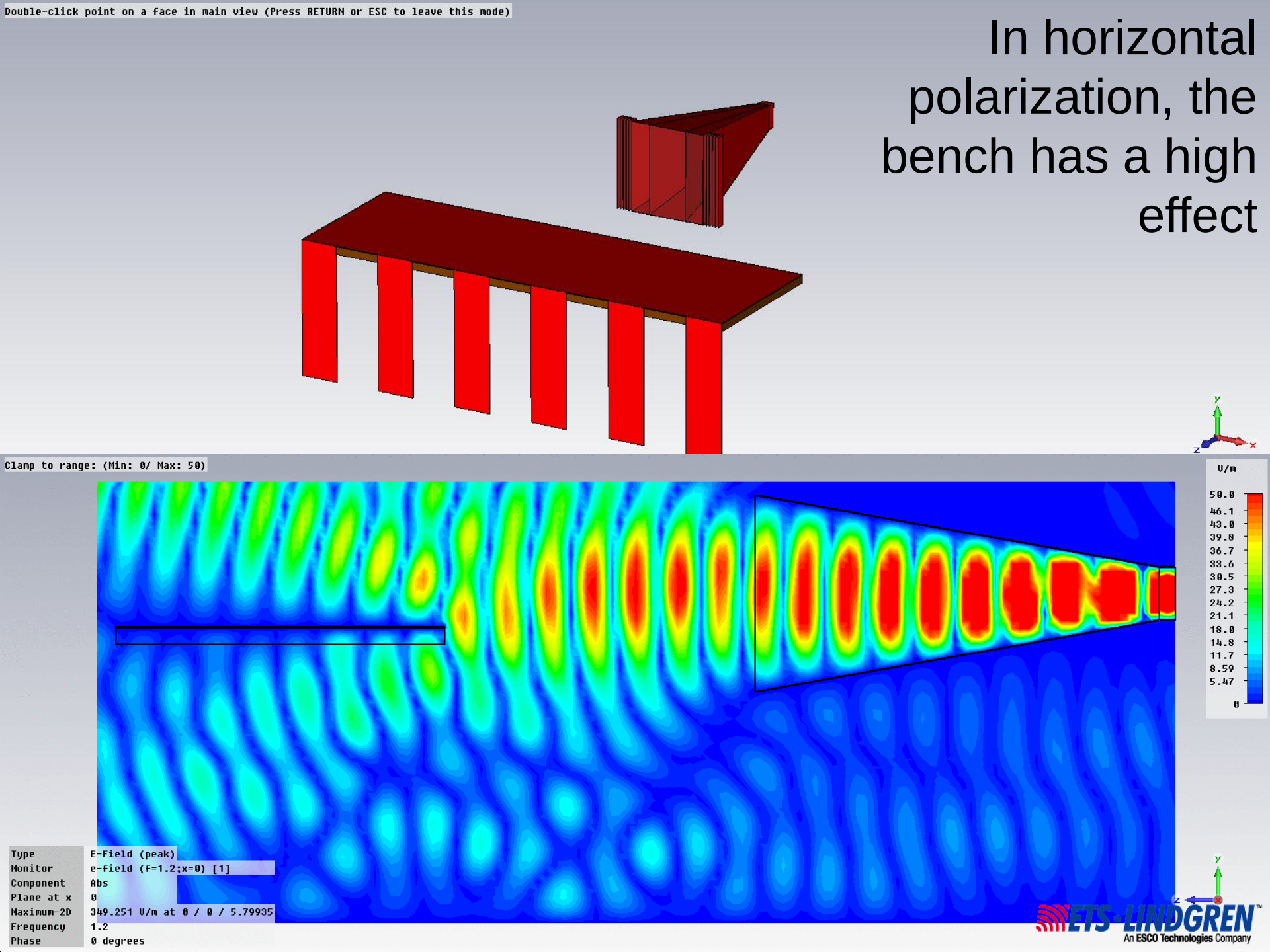
There is no far field, there is no free space

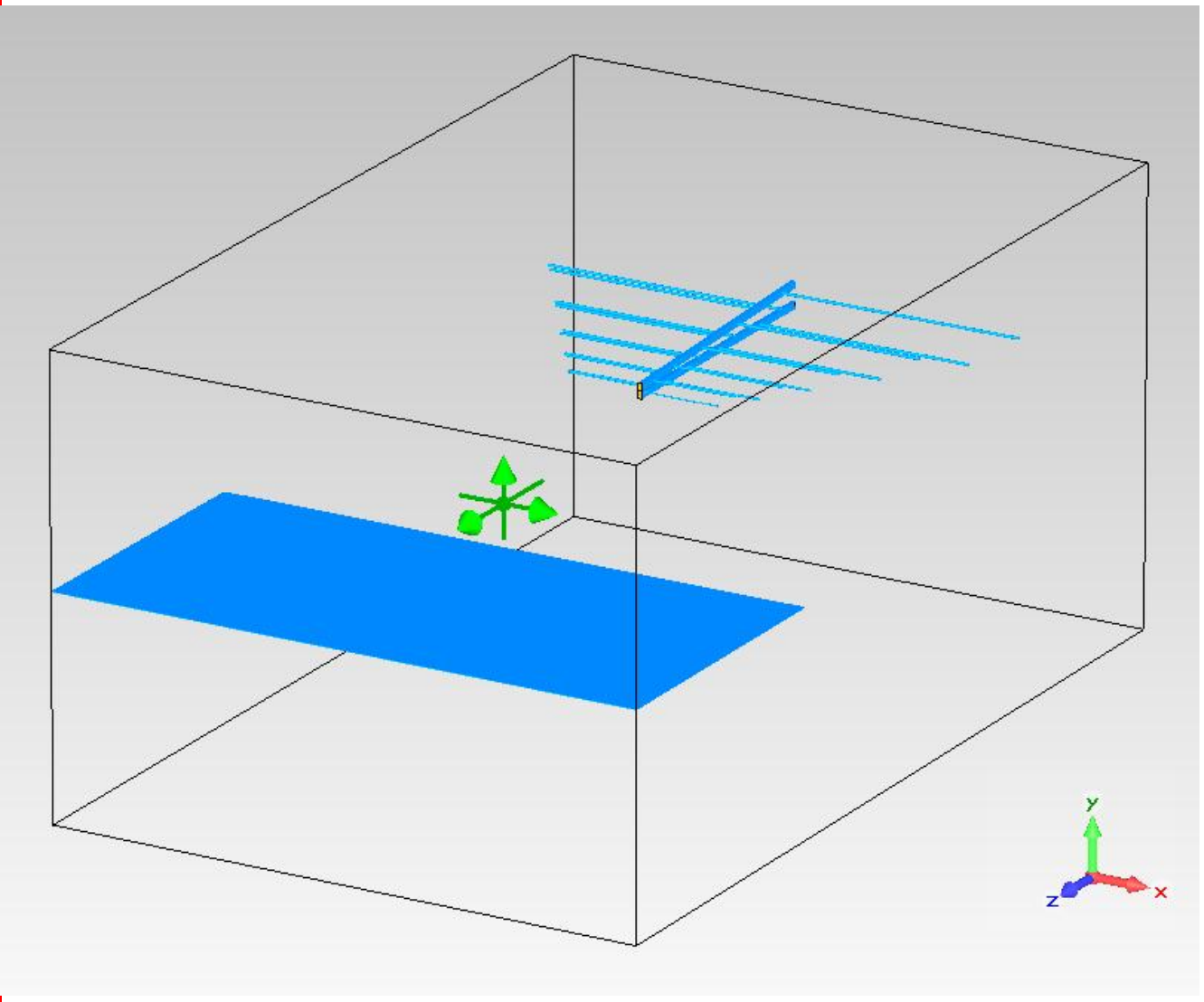
As the field is incident onto the metallic top bench both polarizations are affected very differently.



In vertical polarization, the bench may not have much effect

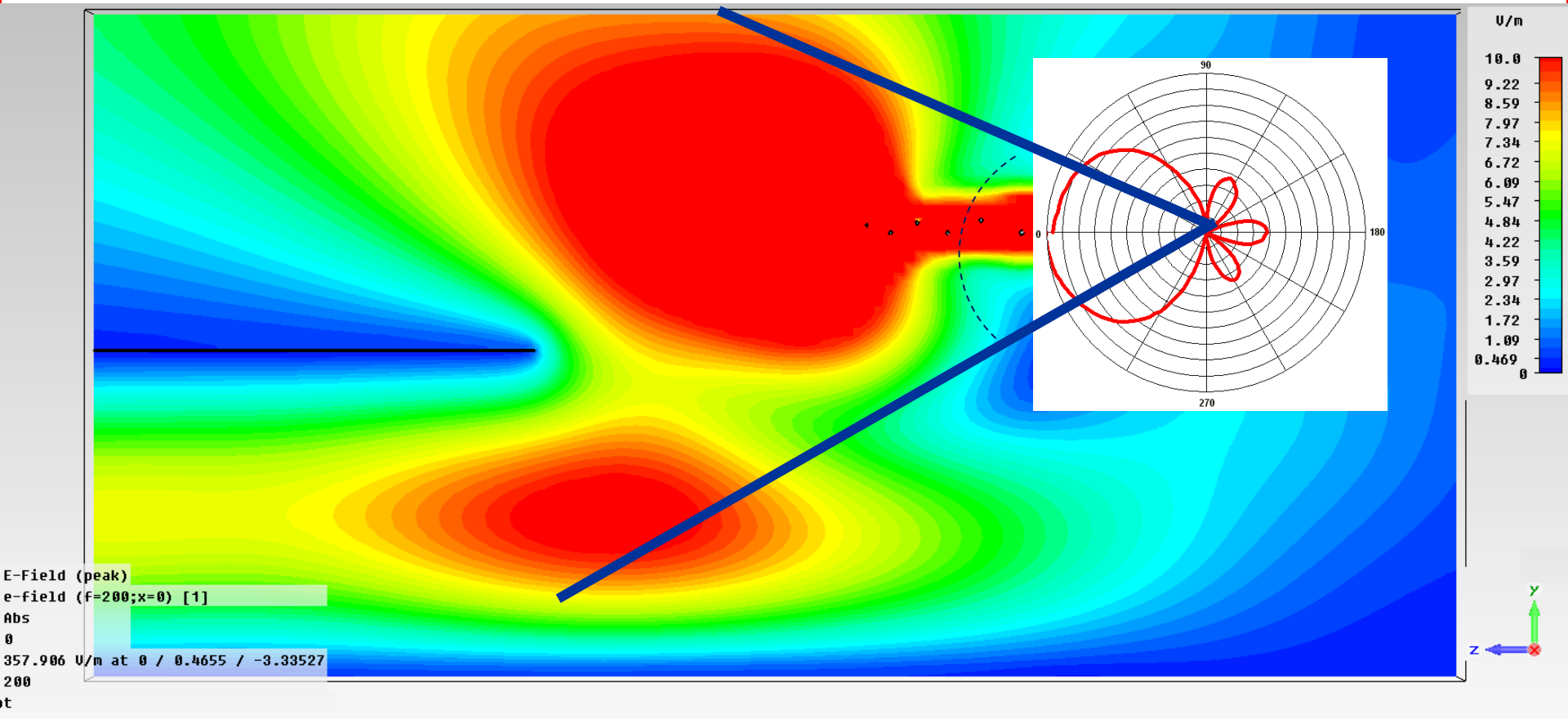



Double-click point on a face in main view (Press RETURN or ESC to leave this mode)
In horizontal polarization, the bench has a high effect
Clamp to range: (Min: 0/ Max: 50)
V/m
50.0
46.1
43.0
39.8
36.7
33.6
30.5
27.3
24.2
21.1
18.0
14.8
11.7
8.59
5.47
0
Type E-Field (peak)
Monitor e-field (f=1.2;x=0) [1]
Component Abs
Plane at x 0
Maximum-2D 349.251 V/m at 0 / 0 / 5.79935
Frequency 1.2
Phase 0 degrees
ETS-LINDGREN
An ESCO Technologies Company



This effect is present even at low frequencies. Let us consider a Log periodic operating in the 200MHz range

The bench splits the beam and the half power beamwidth at 200MHz does not longer have any meaning



Conclusions

- A brief introduction to antenna patterns has been given
- Analysis of measured and computed data has been introduced for the most common EMC antennas
- Biconical, LPDA, Hybrid antennas have been shown

Conclusions

- A survey of Dual Ridge Horn antenna patterns has been shown
- DRHA have been previously described in the literature
- Limitations of the pattern knowledge have been show through simulations.