Aspects of Achieving 10 v/m Field Uniformity over 1-6GHz with Single, Multiple and Cassegrain Antennas

Tom Mullineaux

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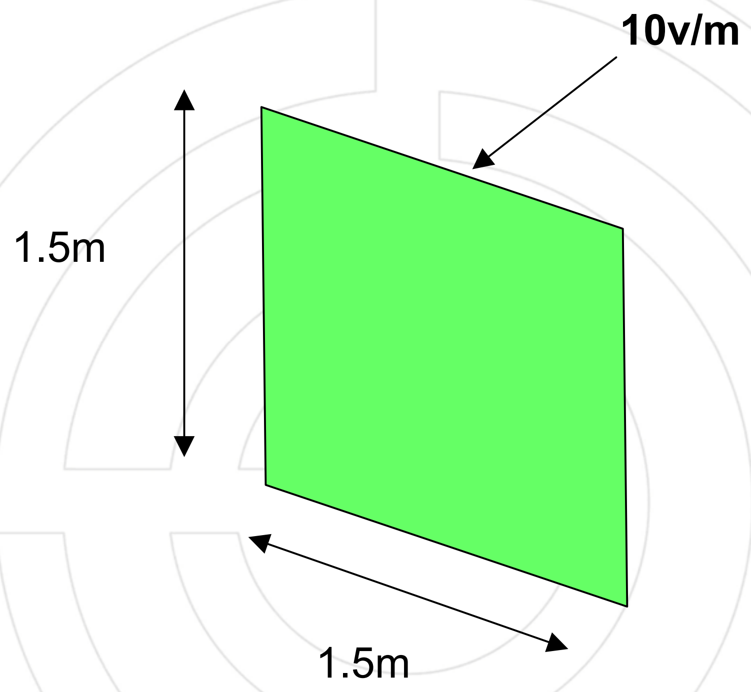
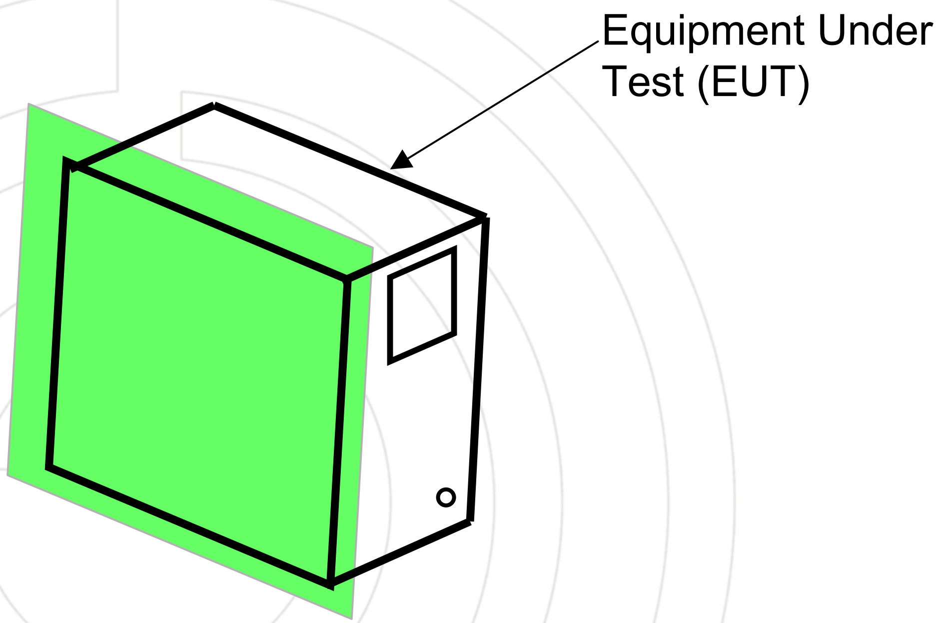
EN61000-4-3 Edition 3

1-6 GHz, 10 volts/meter @ 3 meters

Field Generation Fundamentals



Test Field of a Prescribed Field Strength Across a Defined Plane

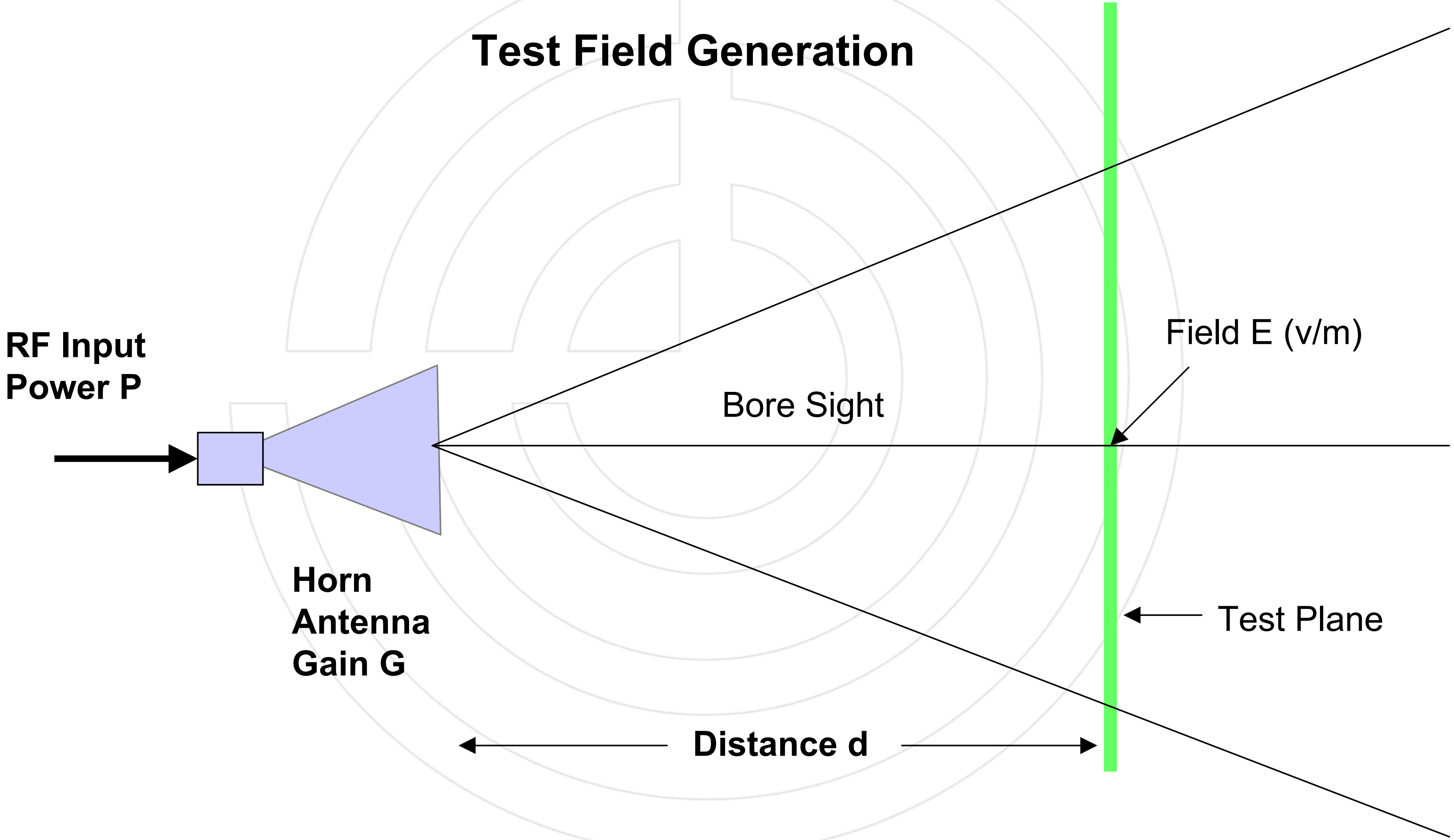


One Face of EUT is Placed at the Plane

EUT Is Monitored for Degradation in Performance when Exposed to Test Field

Repeat for All Faces

Test Field Generation

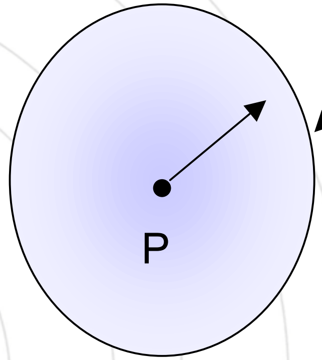


$$E = \sqrt{(30.P.G)} / d$$

- Field Strength in v/m
- Fiddle Factor?
- RF Power at Antenna Connector
- Gain of Antenna (Linear, not dB)
- Distance from Antenna

Area of Sphere

$4\pi R^2$



$$S = P/4\pi R^2$$

Power Density

$$S = E^2/Z_o$$

$$S = E^2/120\pi$$

Impedance of Free Space Z_o is 120π (377 Ohms)

$$P/4\pi R^2 = E^2/120\pi$$

$$E^2 = 120\pi.P / 4\pi R^2$$

$$E^2 = 30.P / R^2$$

$$E = \sqrt{(30.P)} / R$$

$$\boxed{E = \sqrt{(30.P.G)} / d}$$

IMPLICATIONS

$$P = d^2E^2 / 30G$$

RF Power Required at Antenna Connector

Implication #1: Two Times the Gain Means **HALF** the RF Power is Required

Implication #2: Double the Distance Means **FOUR** times the RF Power is Required

Implication #3: Two Times the Field Strength Means **FOUR** times the RF Power is Required

Characteristics of High Gain / Low Gain Antennas

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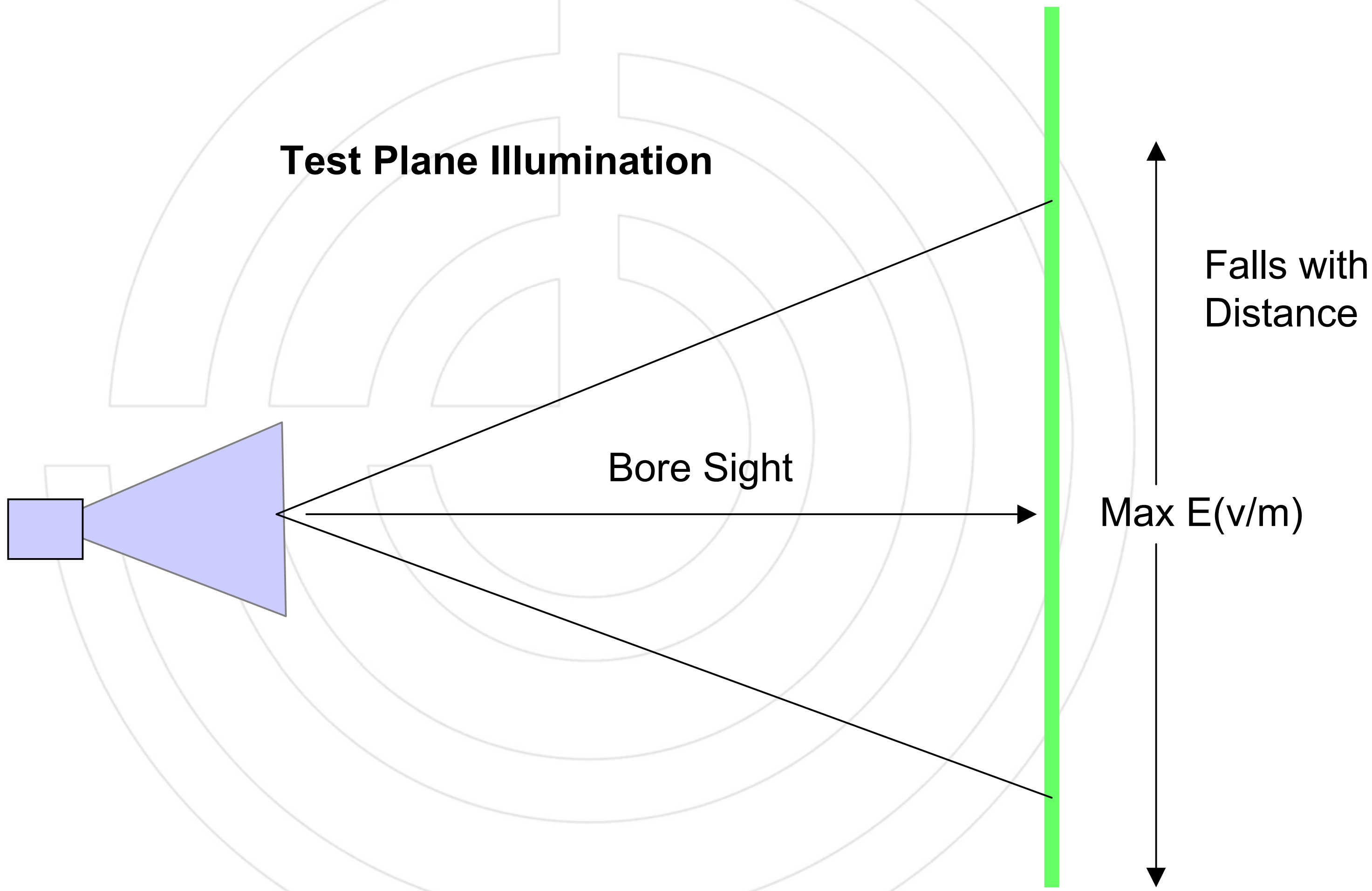
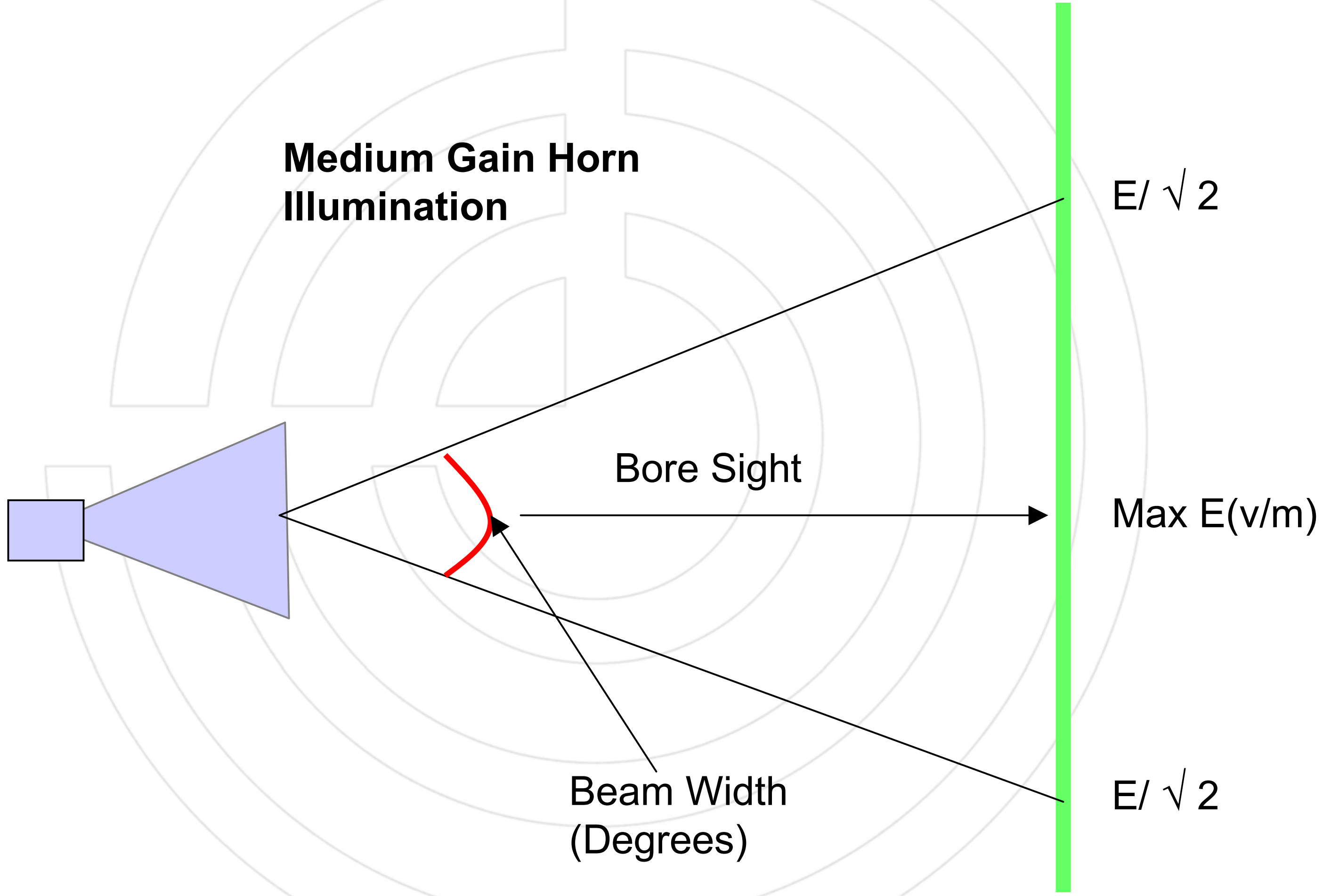
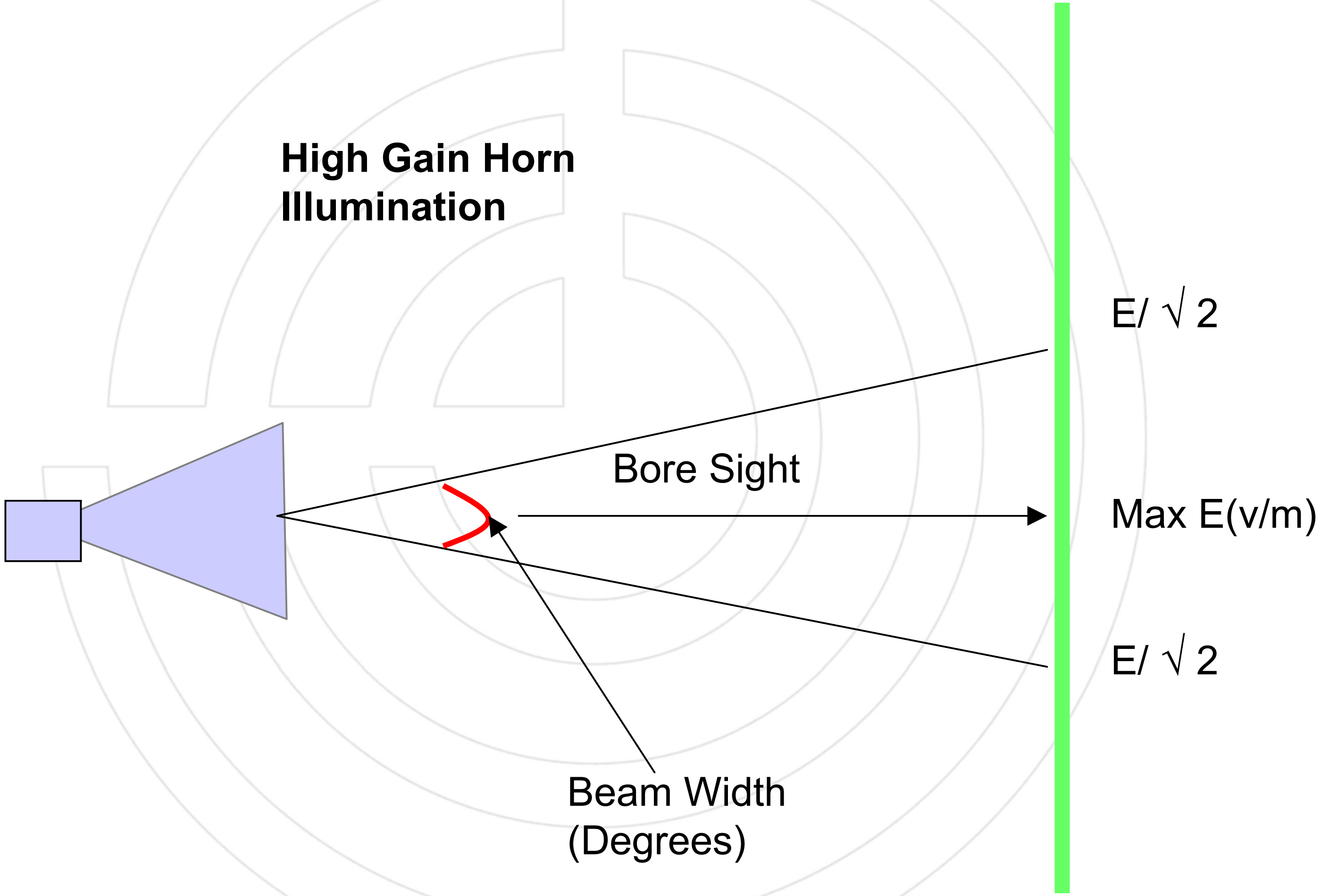
Test Plane Illumination



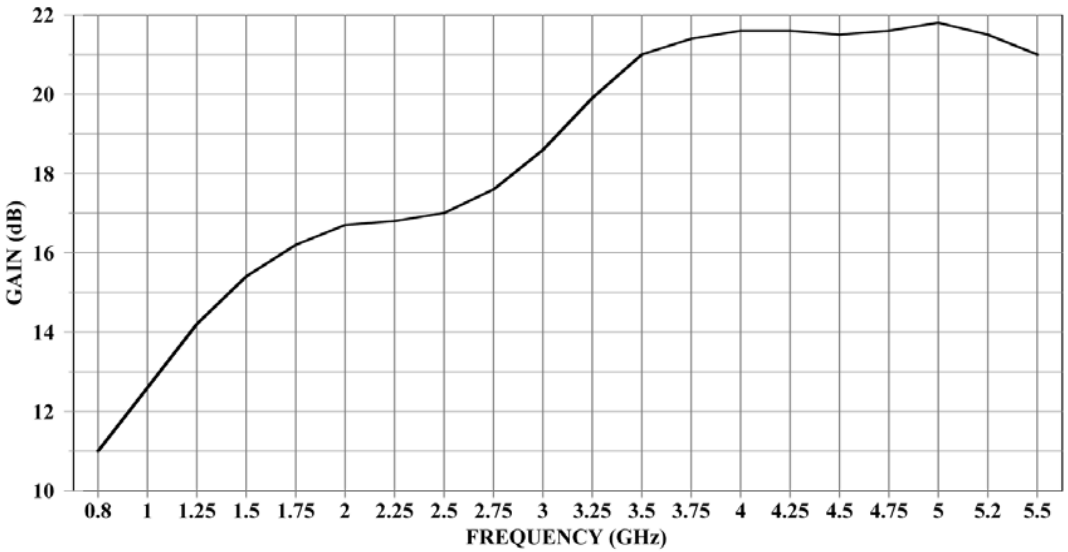
Medium Gain Horn Illumination



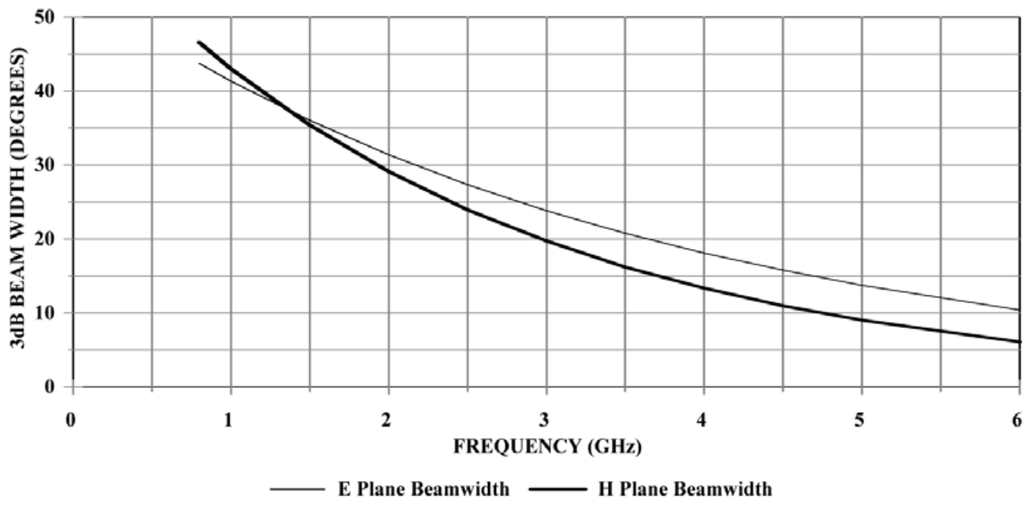
High Gain Horn Illumination

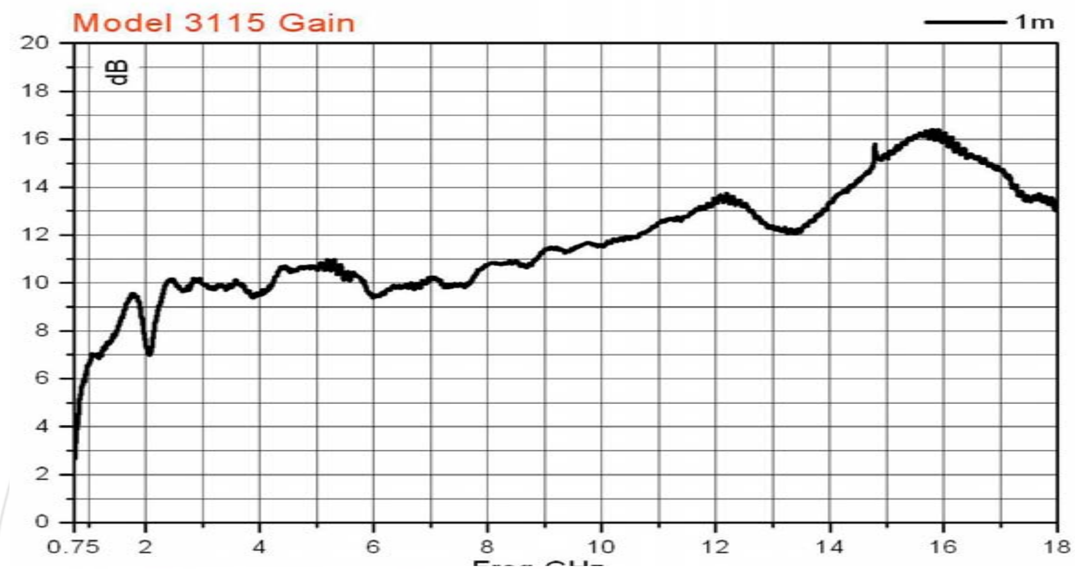


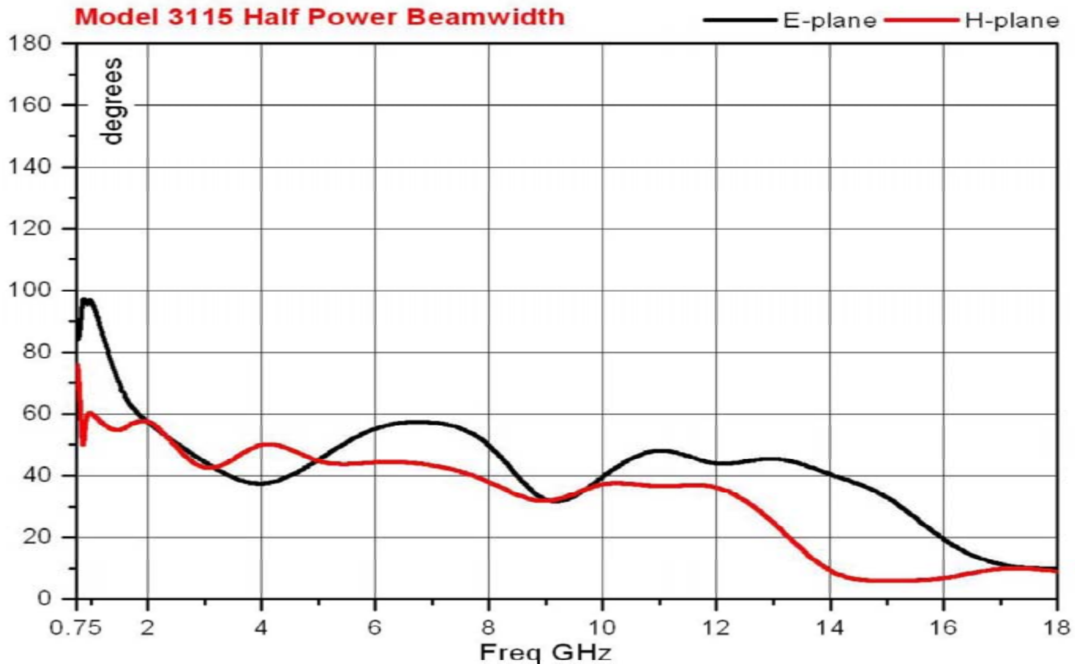
MODEL AT4002A GAIN VS FREQUENCY



Model AT4002A BEAMWIDTH VS FREQUENCY




Model 3115 Gain
1m
dB
20
18
16
14
12
10
8
6
4
2
0
0.75
2
4
6
8
10
12
14
16
18


Model 3115 Half Power Beamwidth
E-plane
H-plane
degrees
180
160
140
120
100
80
60
40
20
0
0.75
2
4
6
8
10
12
14
16
18
Freq GHz

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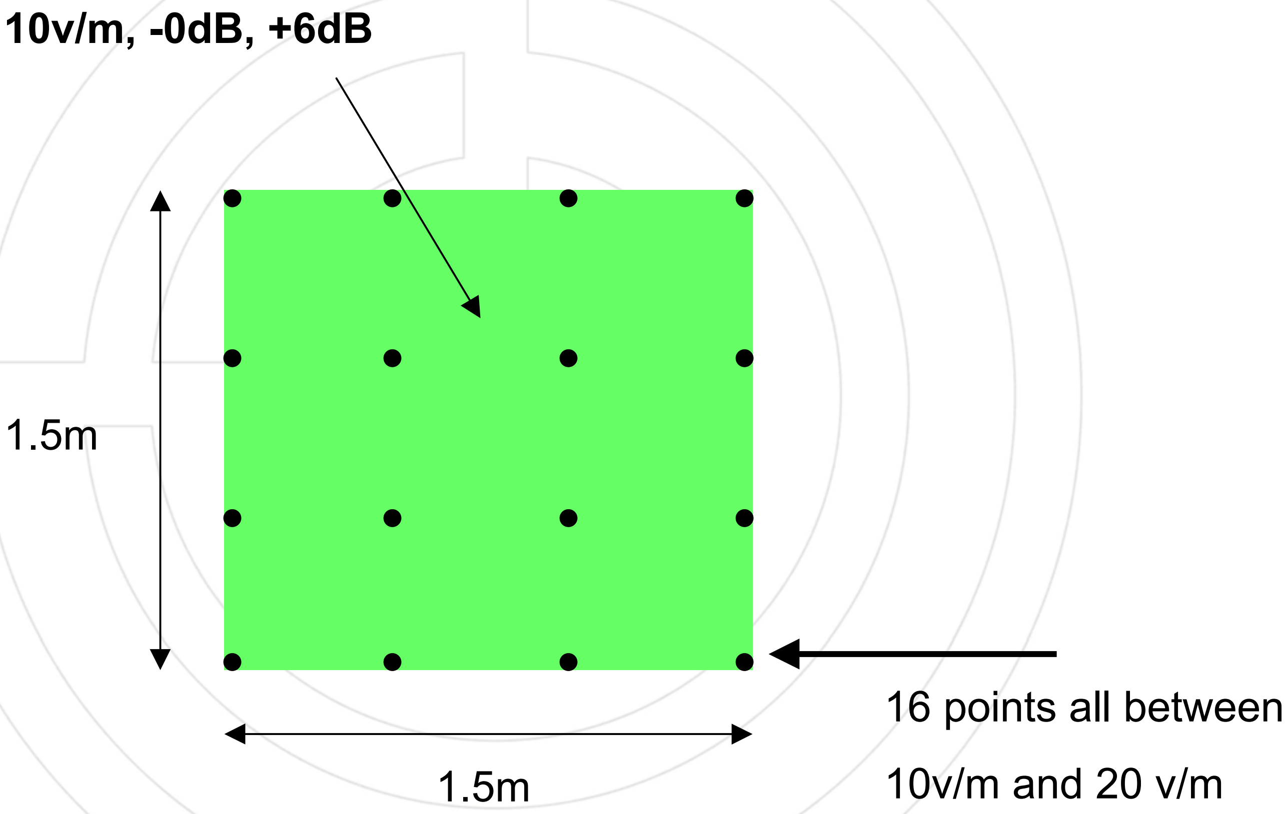
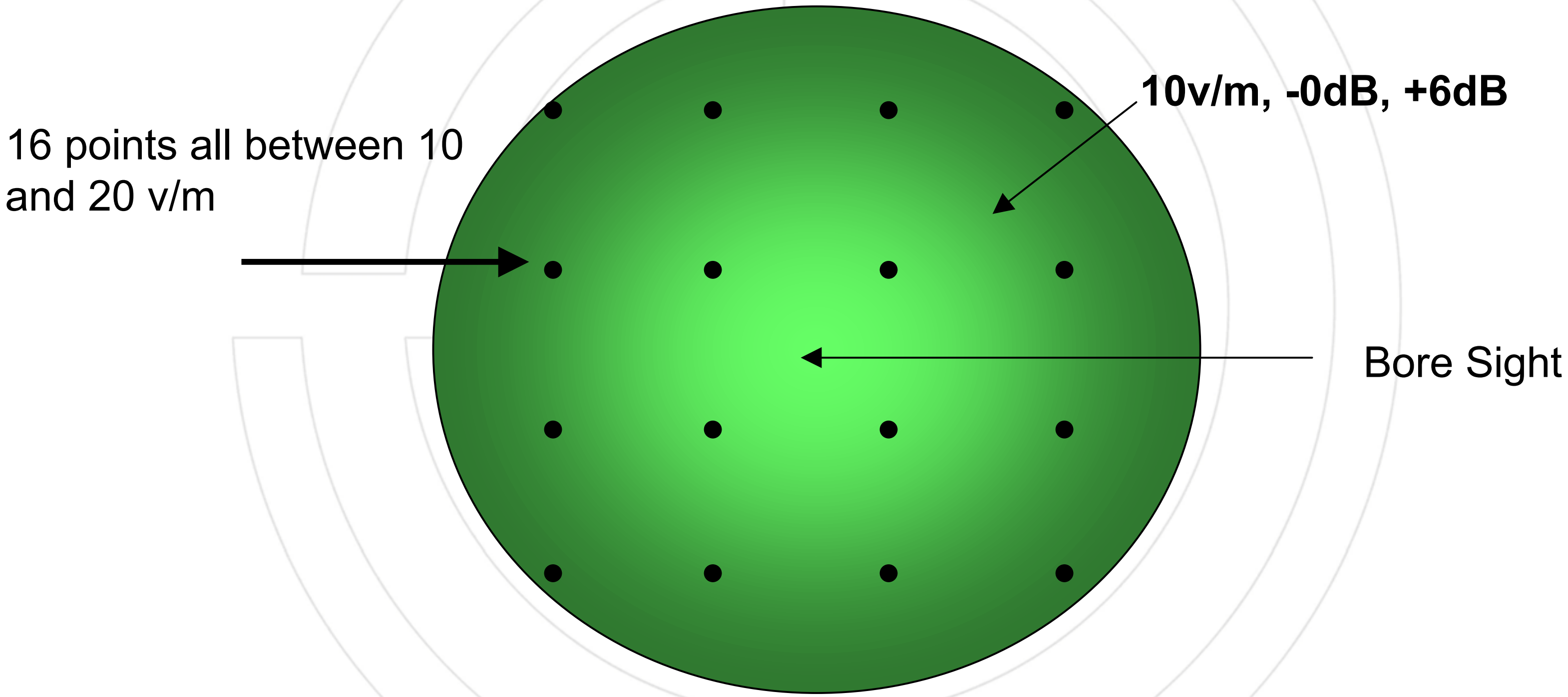
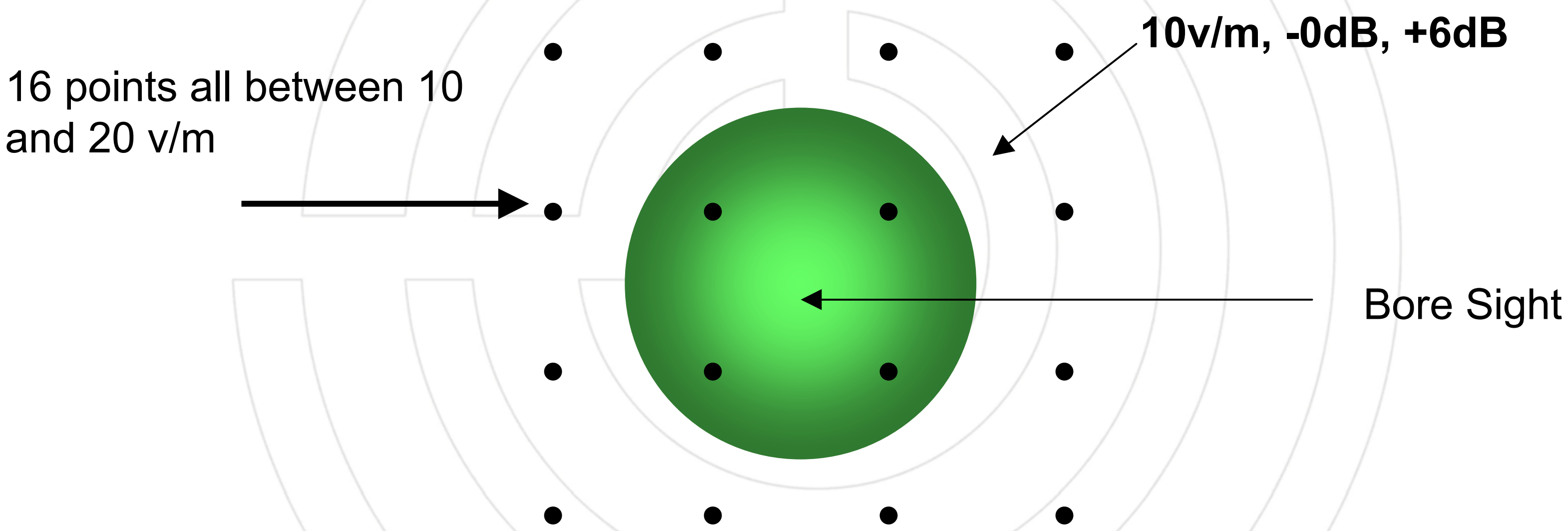
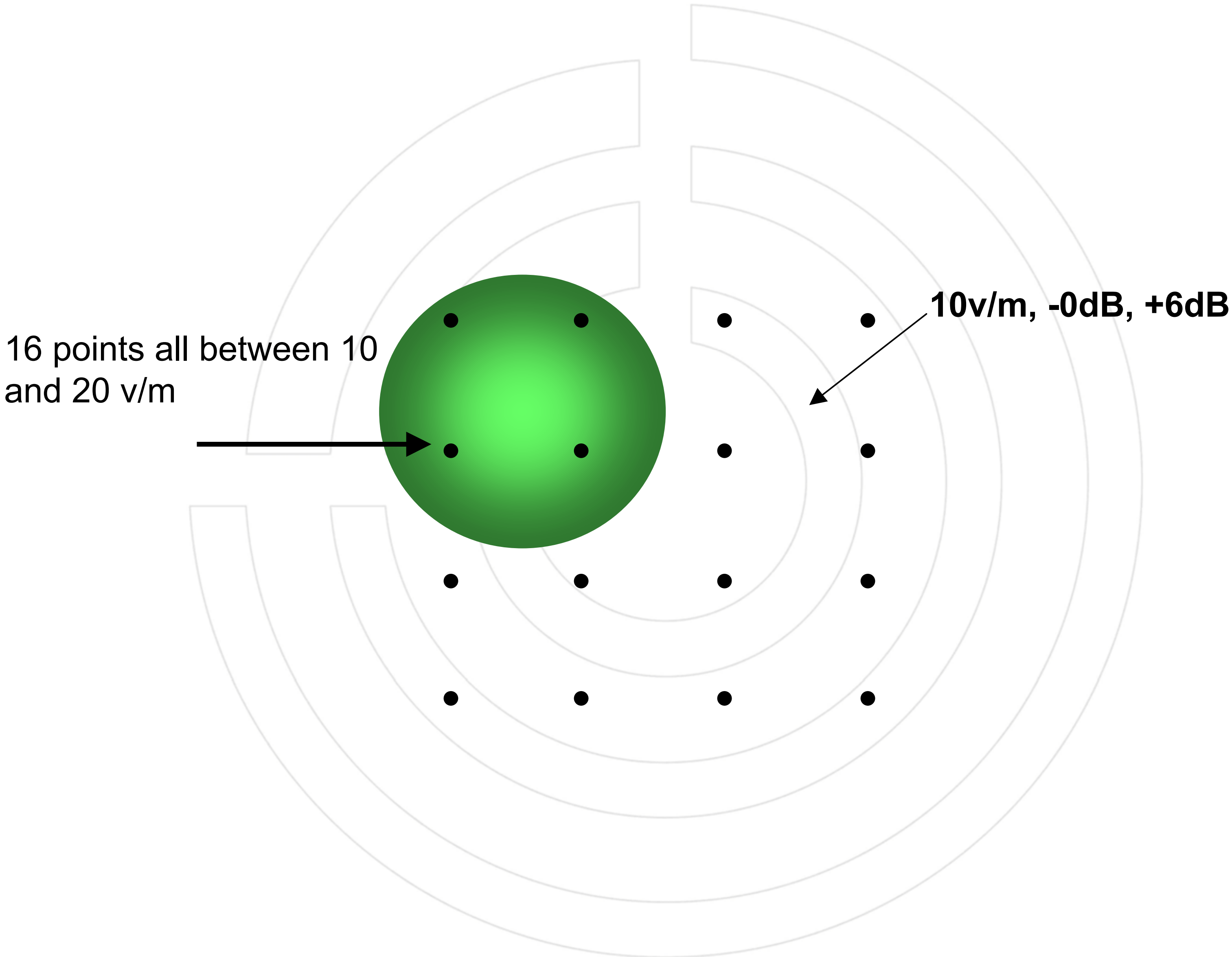

10v/m, -0dB, +6dB
1.5m
1.5m
16 points all between
10v/m and 20 v/m

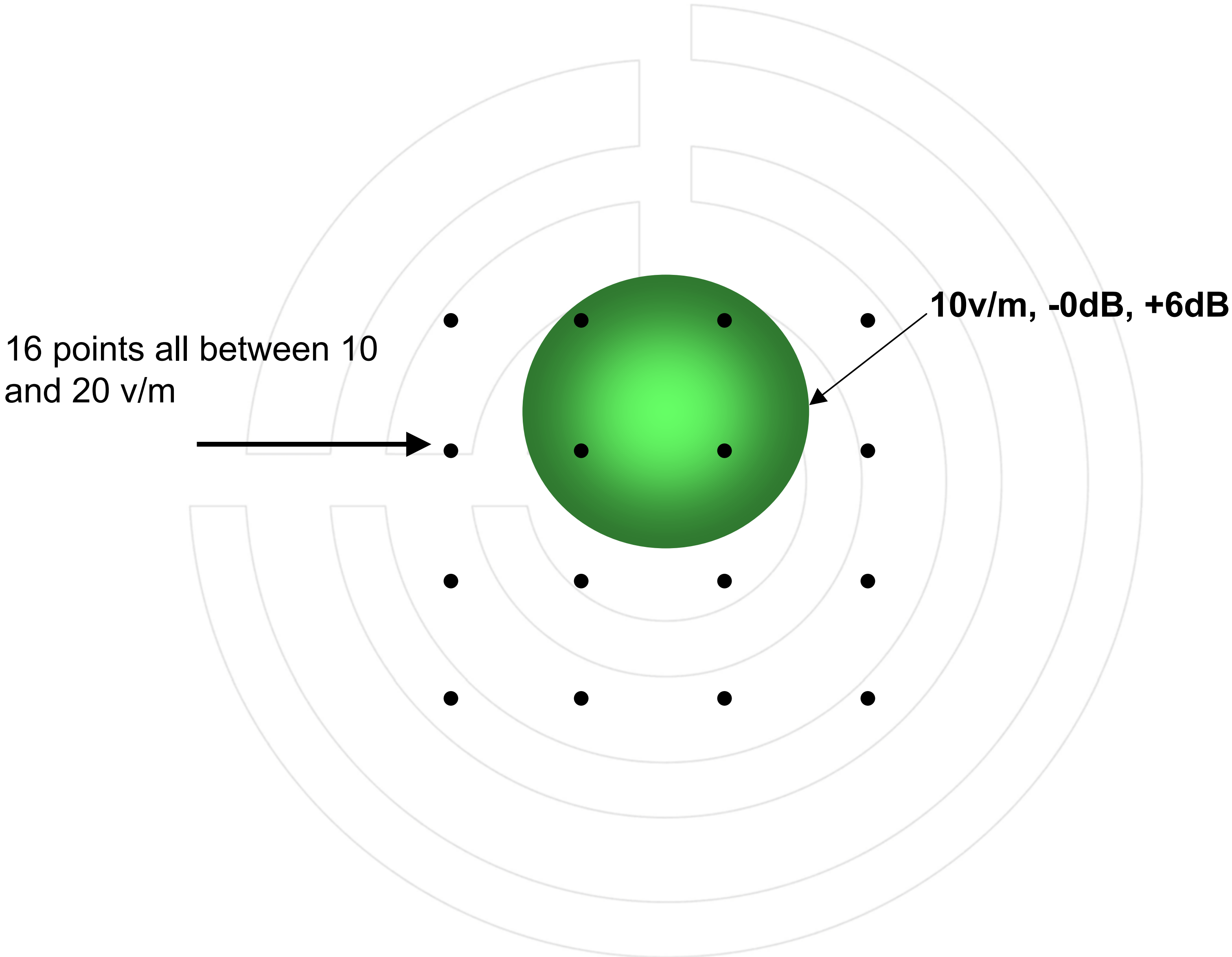
Test Plane Illumination

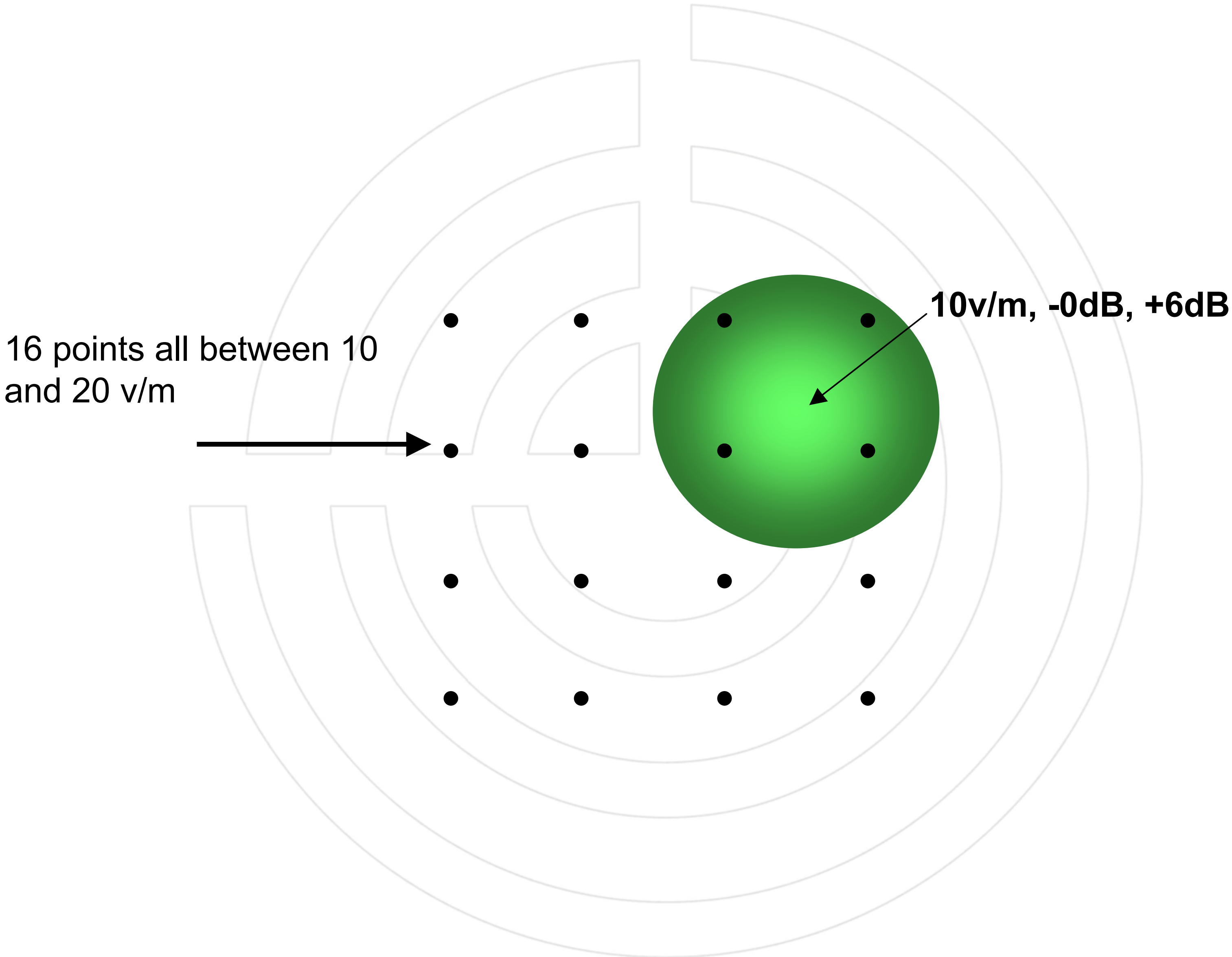


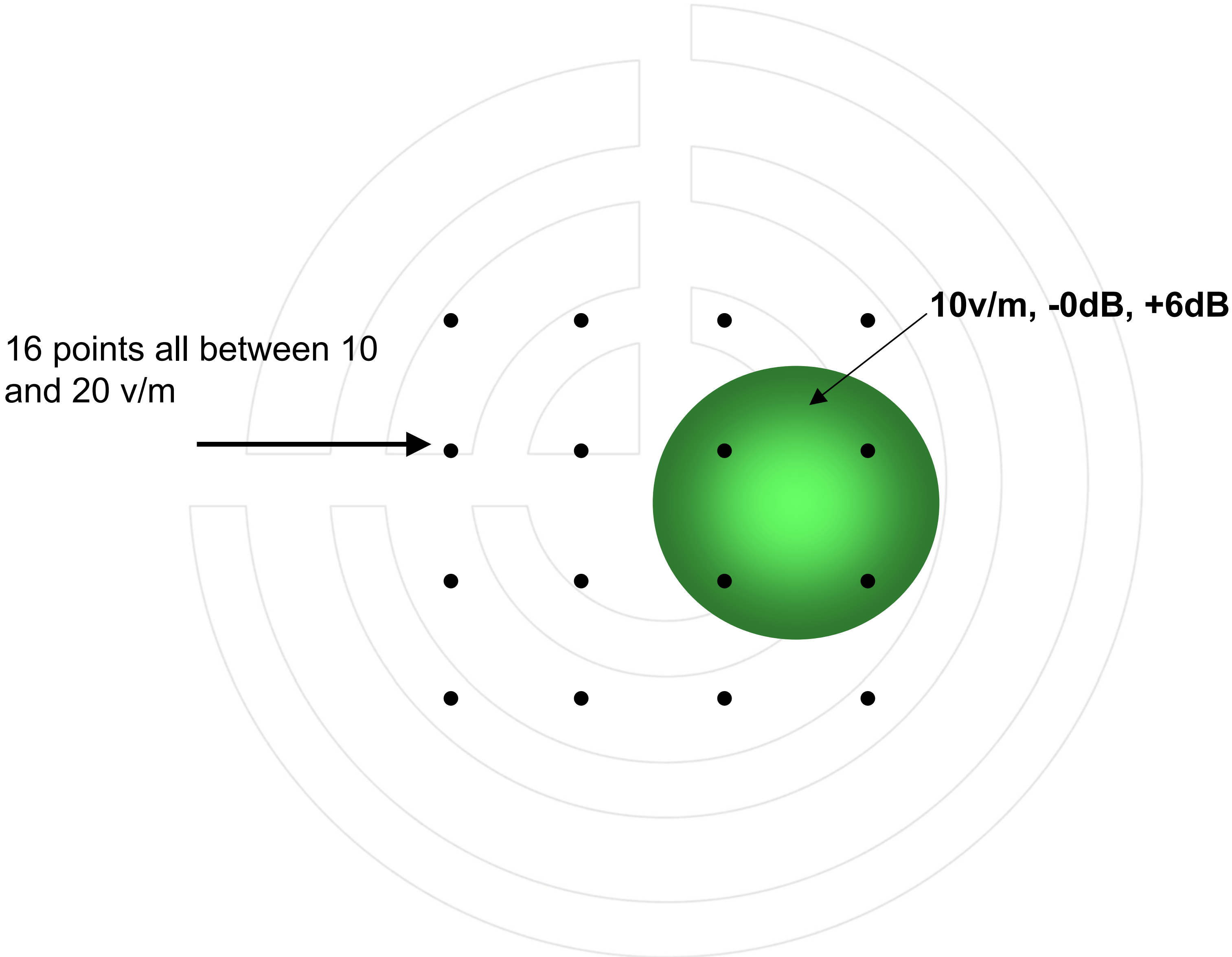
Effect of Higher Gain

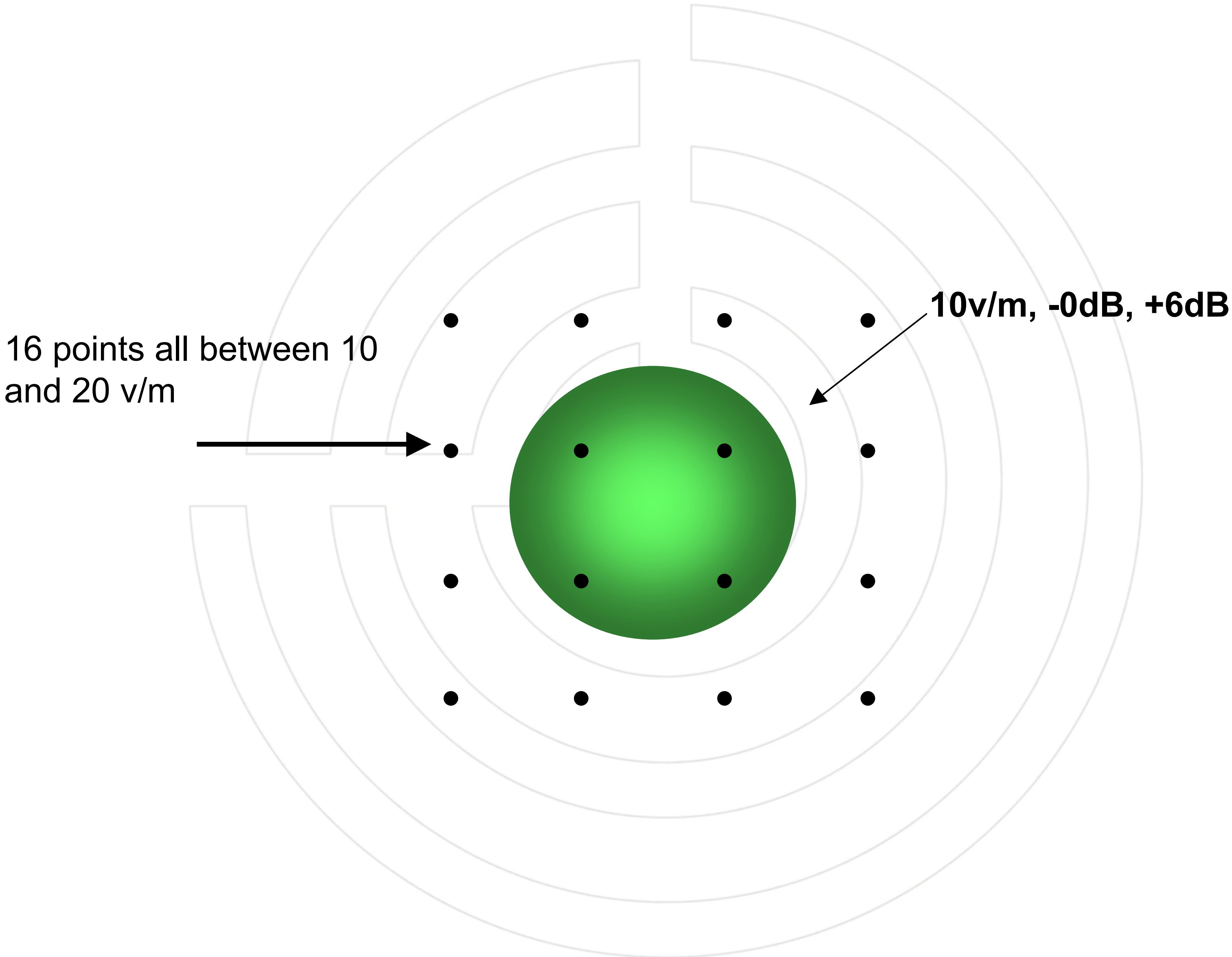


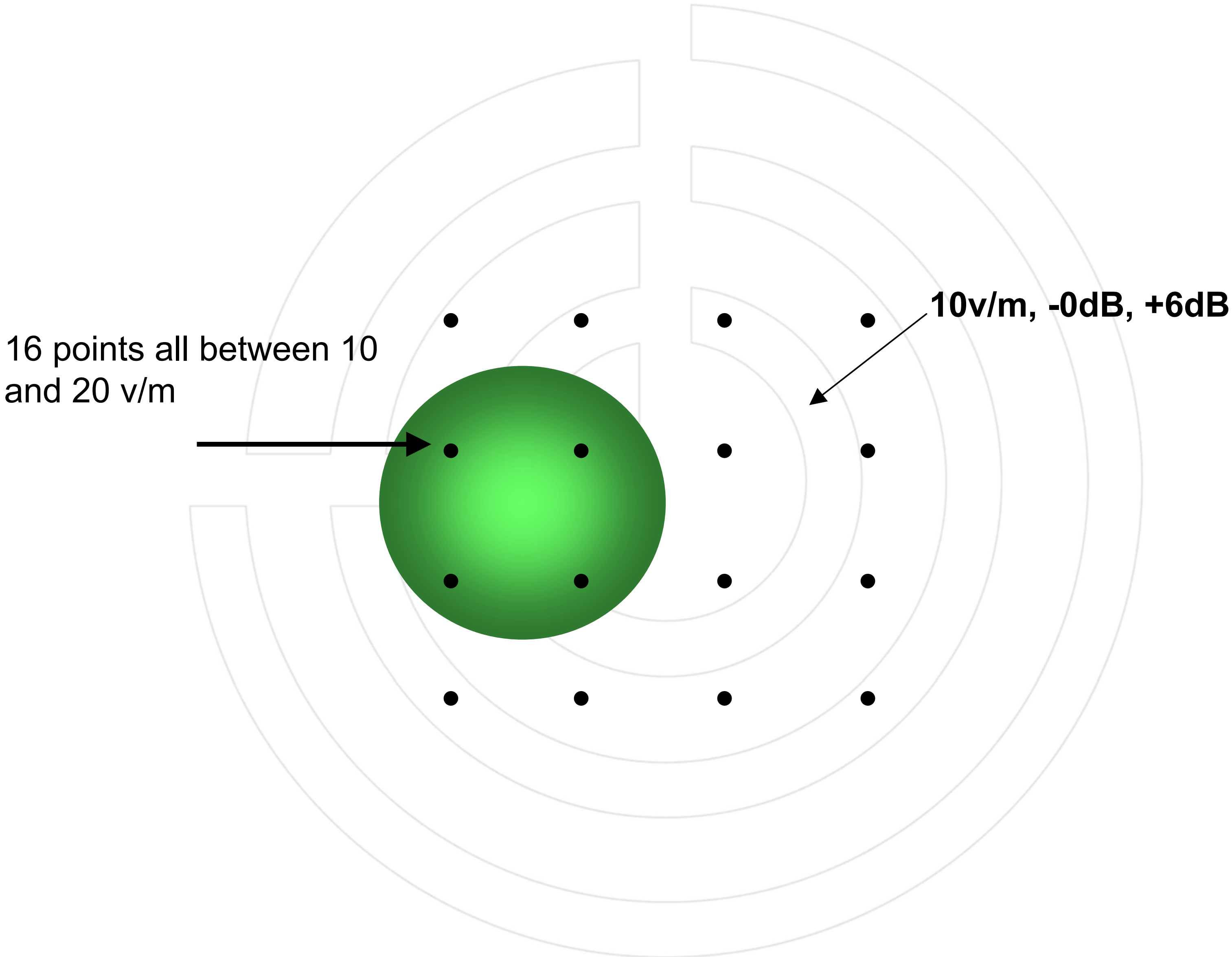

16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB


16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB

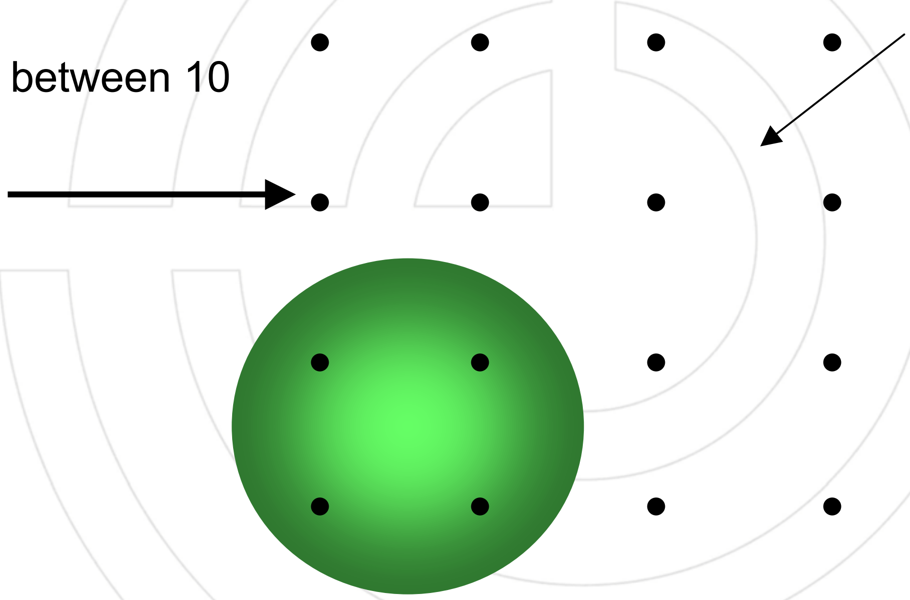

16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB

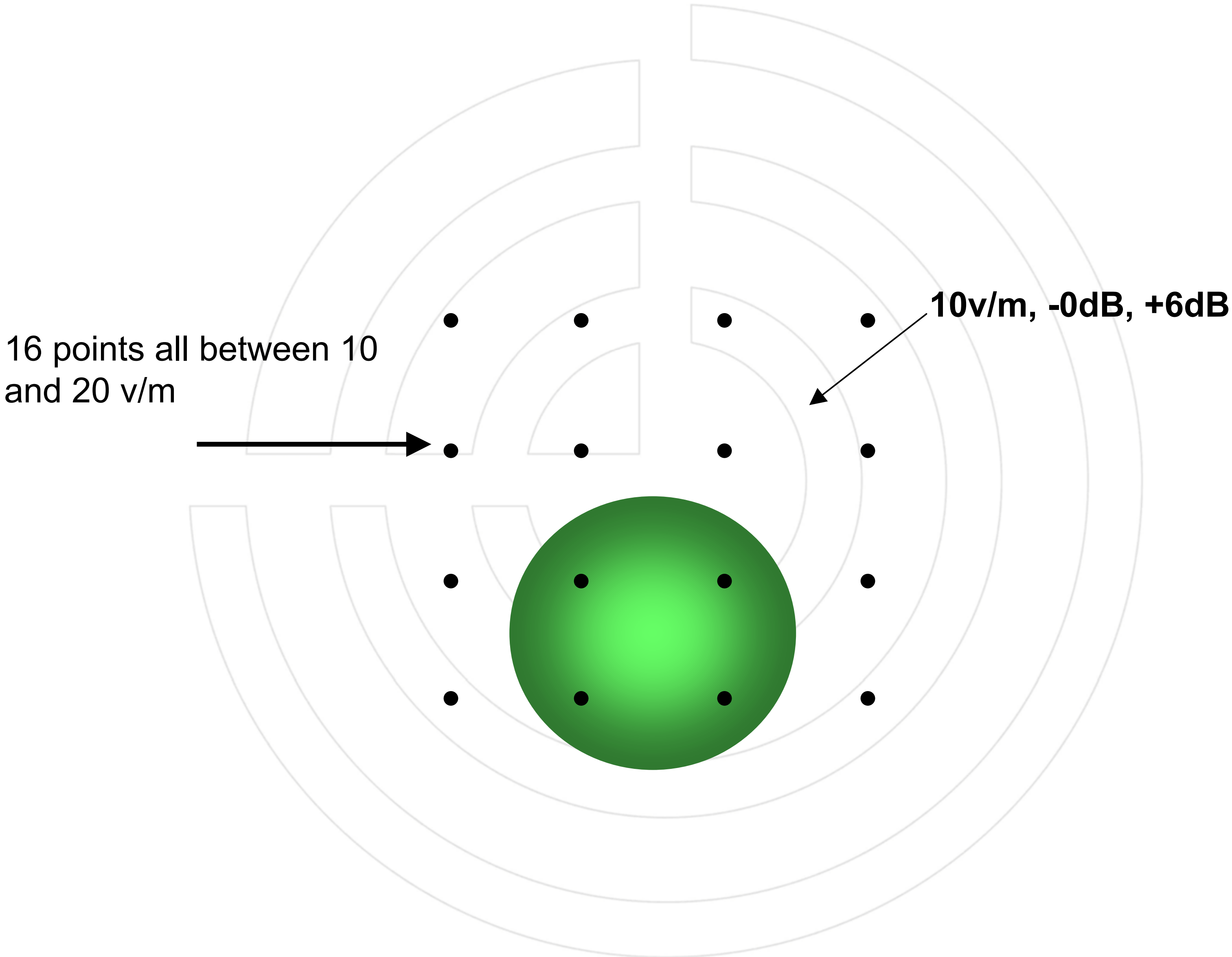

16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB

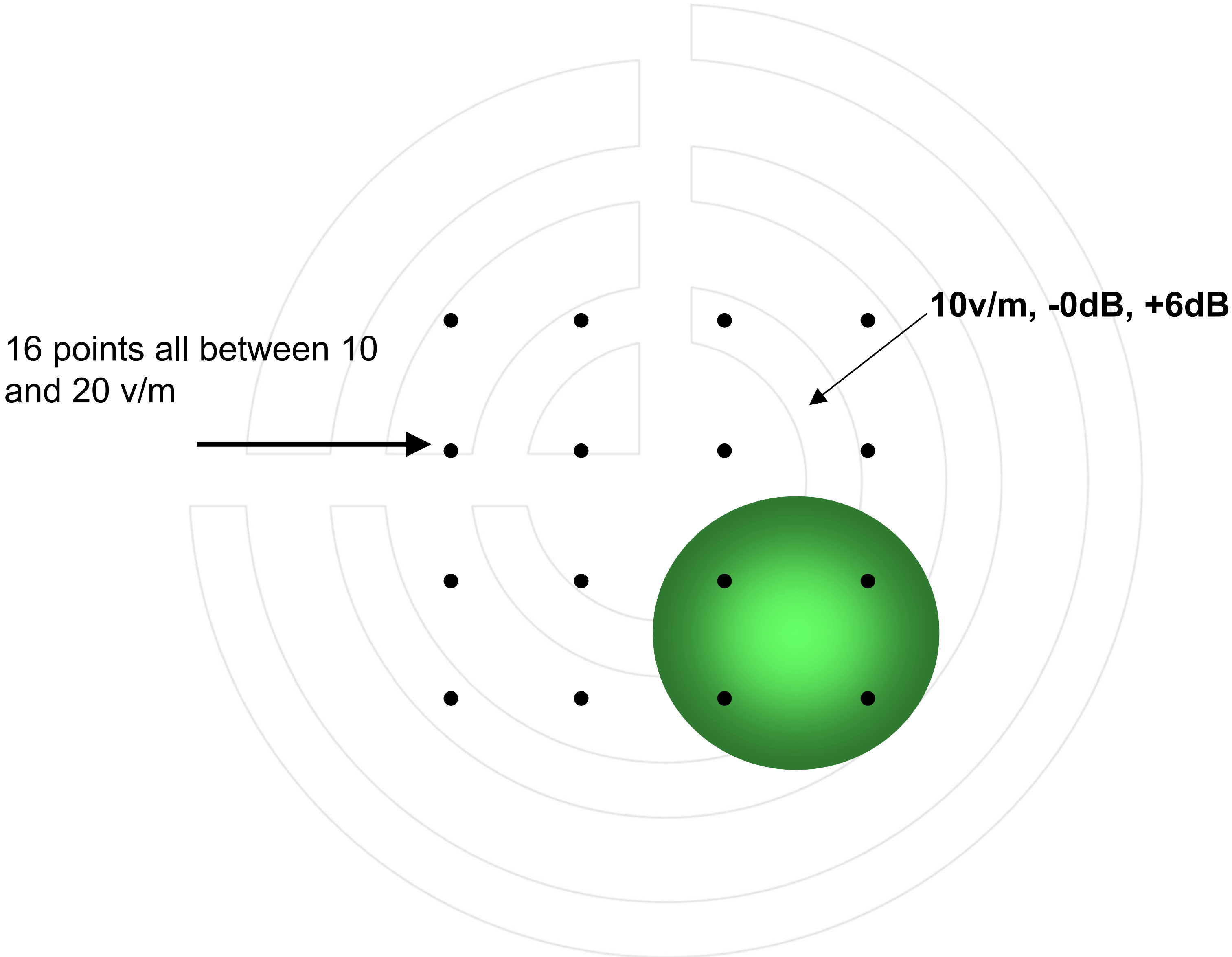

16 points all between 10
and 20 v/m
10v/m, -0dB, +6dB



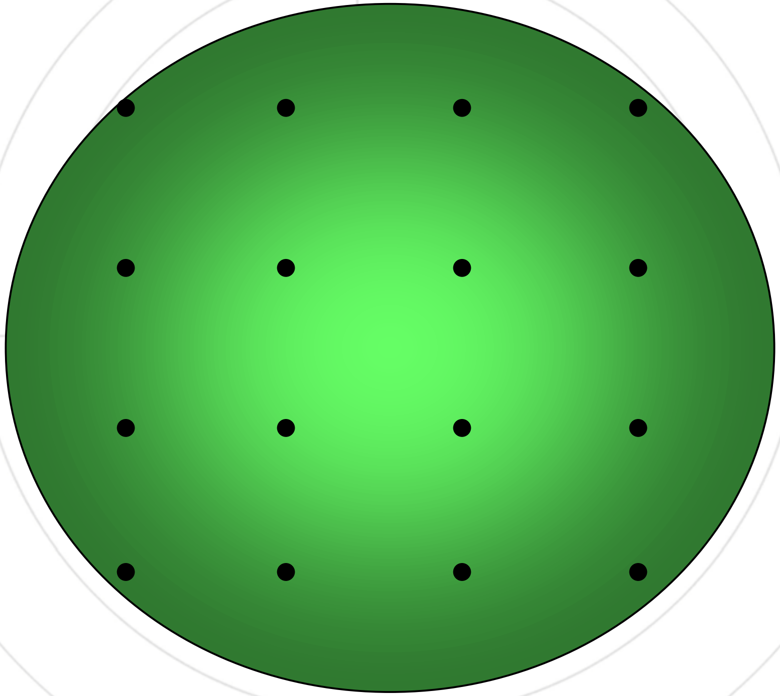
16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB


16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB

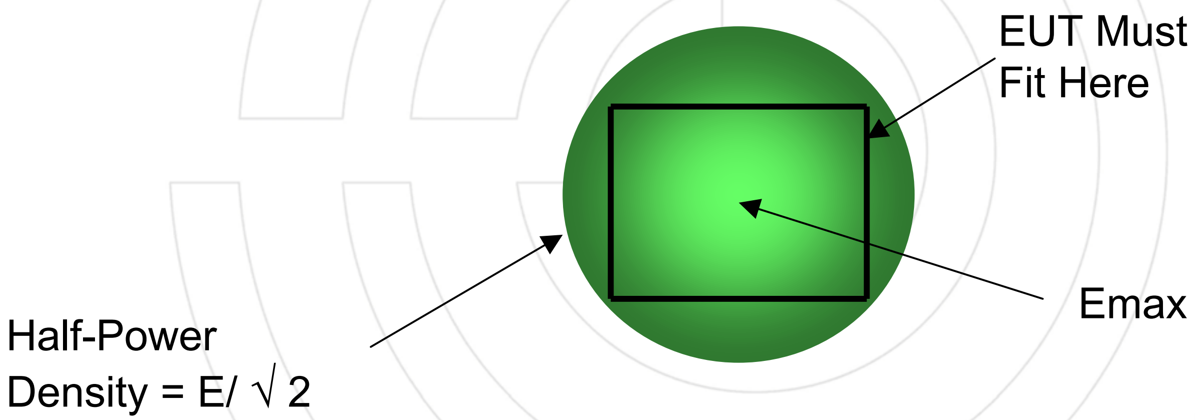

16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB


16 points all between 10 and 20 v/m
10v/m, -0dB, +6dB

EQUIVALENT TO??



Beam Width is Becoming Important - Some Standards Now Insist the EUT Fits Inside the Antenna Beam Width



Advantages / Disadvantages of Each Antenna Type

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

High Gain Horn Advantage

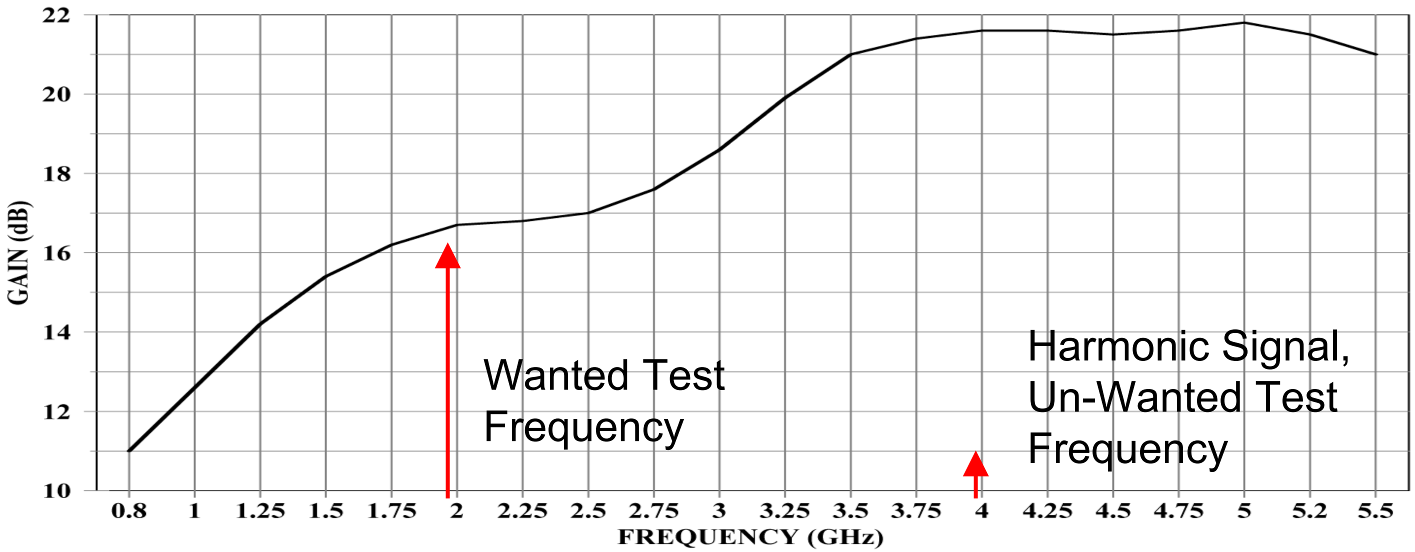
Reduced RF Power Requirement

High Gain Horn Disadvantage

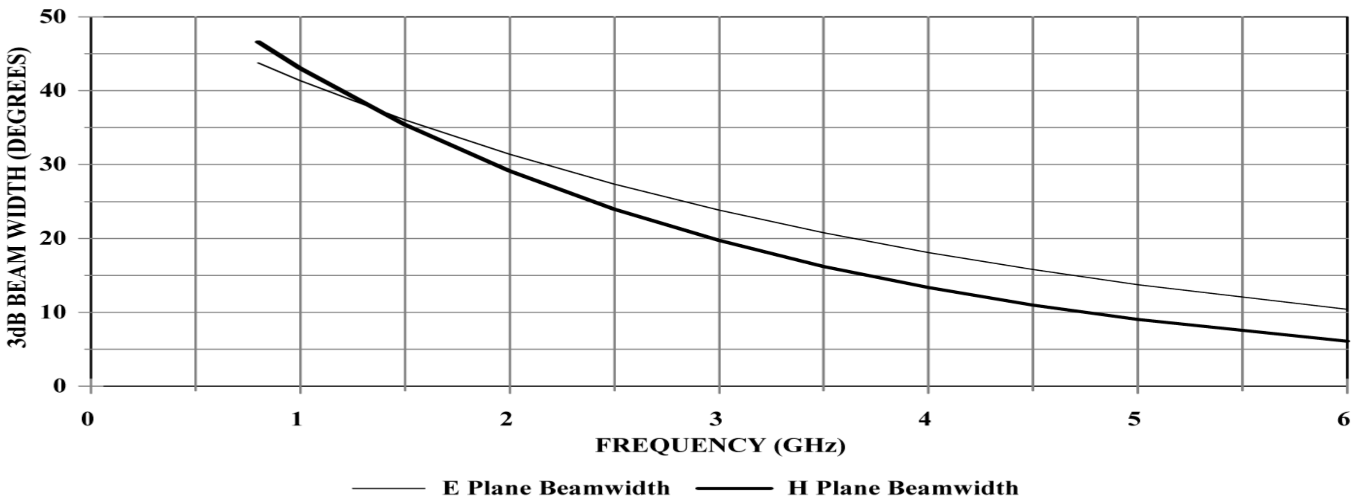
Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

MODEL AT4002A GAIN VS FREQUENCY



Model AT4002A BEAMWIDTH VS FREQUENCY



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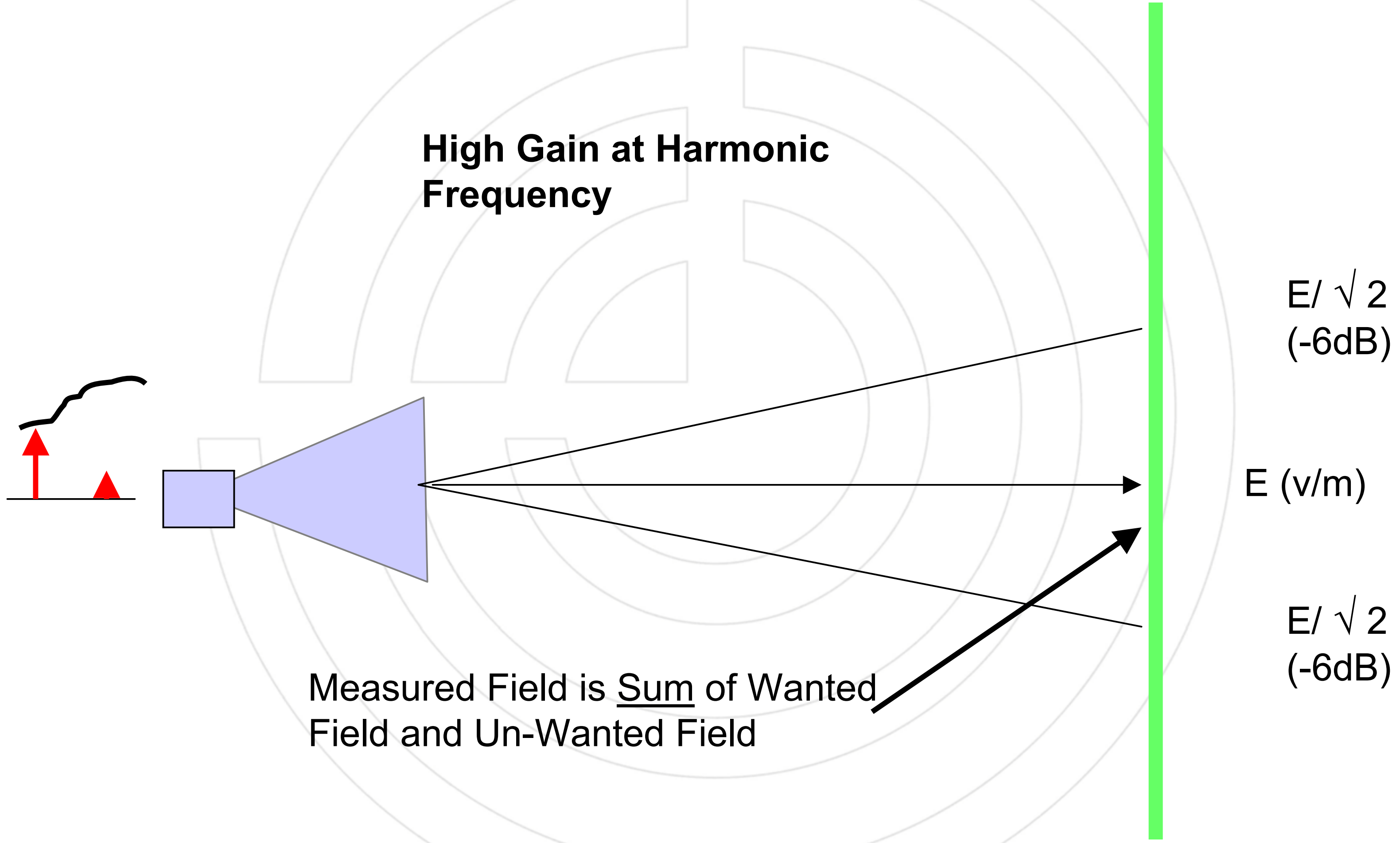
High Gain at Harmonic Frequency
E/ √ 2 (-6dB)
E (v/m)
E/ √ 2 (-6dB)
Measured Field is Sum of Wanted Field and Un-Wanted Field

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High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

Less Bandwidth so More Antennas Required

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

Less Bandwidth so More Antennas Required

Medium Gain Horn Advantage

Large Illumination Area

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

Less Bandwidth so More Antennas Required

Medium Gain Horn Advantage

Large Illumination Area

Less Field Contribution from Harmonic

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

Less Bandwidth so More Antennas Required

Medium Gain Horn Advantage

Large Illumination Area

Less Field Contribution from Harmonic

Wider Bandwidth, One Antenna Required

High Gain Horn Advantage

Reduced RF Power Requirement

High Gain Horn Disadvantage

Smaller Illumination Area (equivalent?)

Higher Field Contribution from Harmonic

Less Bandwidth so More Antennas Required

Medium Gain Horn Advantage

Large Illumination Area

Less Field Contribution from Harmonic

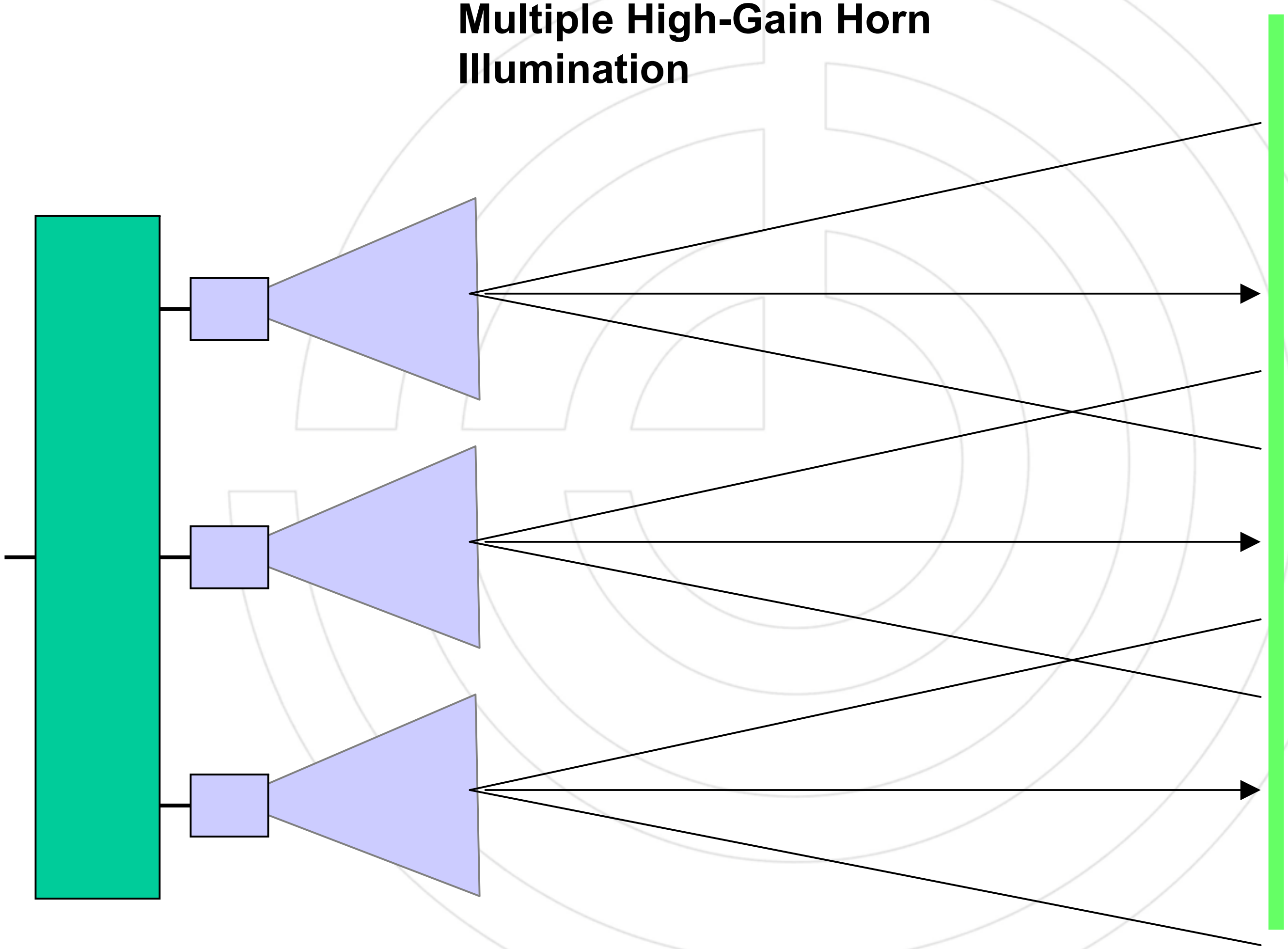
Wider Bandwidth, One Antenna Required

Medium Gain Horn Disadvantage

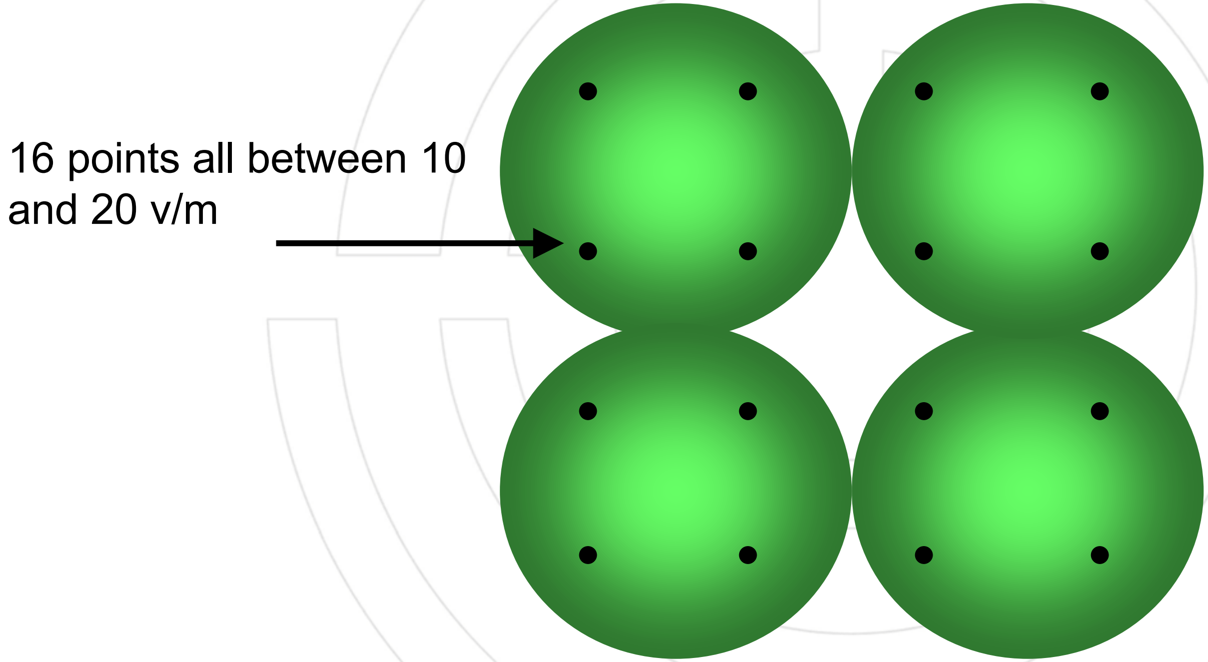
Higher RF Power Requirement

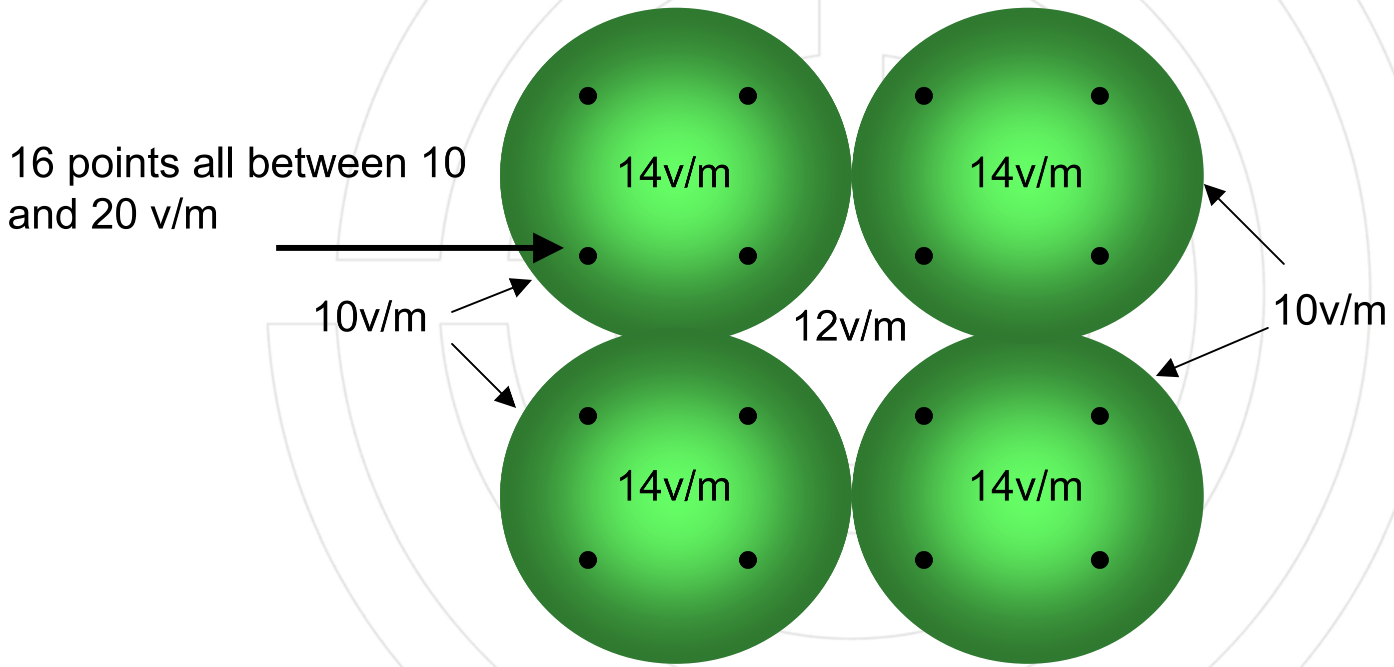
Field Uniformity Through Use of Multiple High-Gain Antennas

Multiple High-Gain Horn Illumination



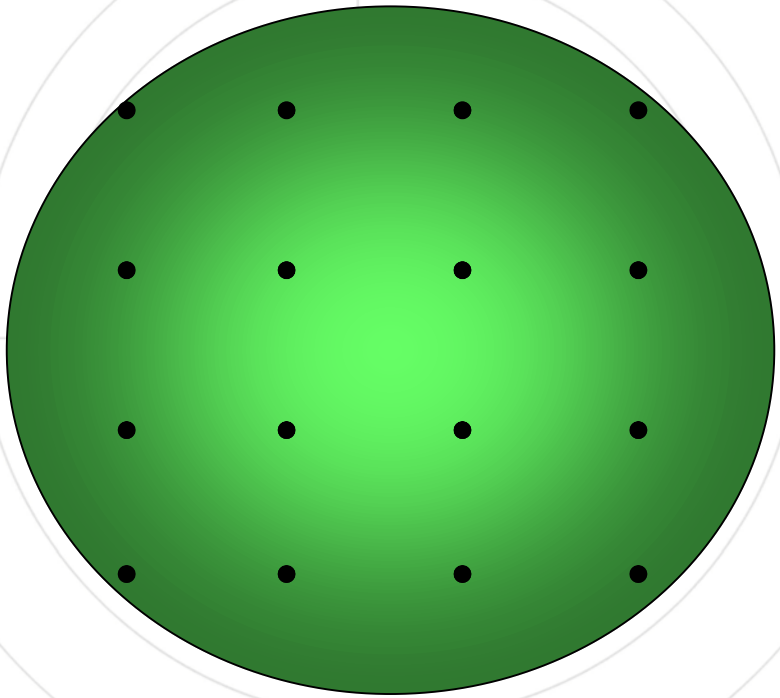
HIRF Multiple Horn
Illumination

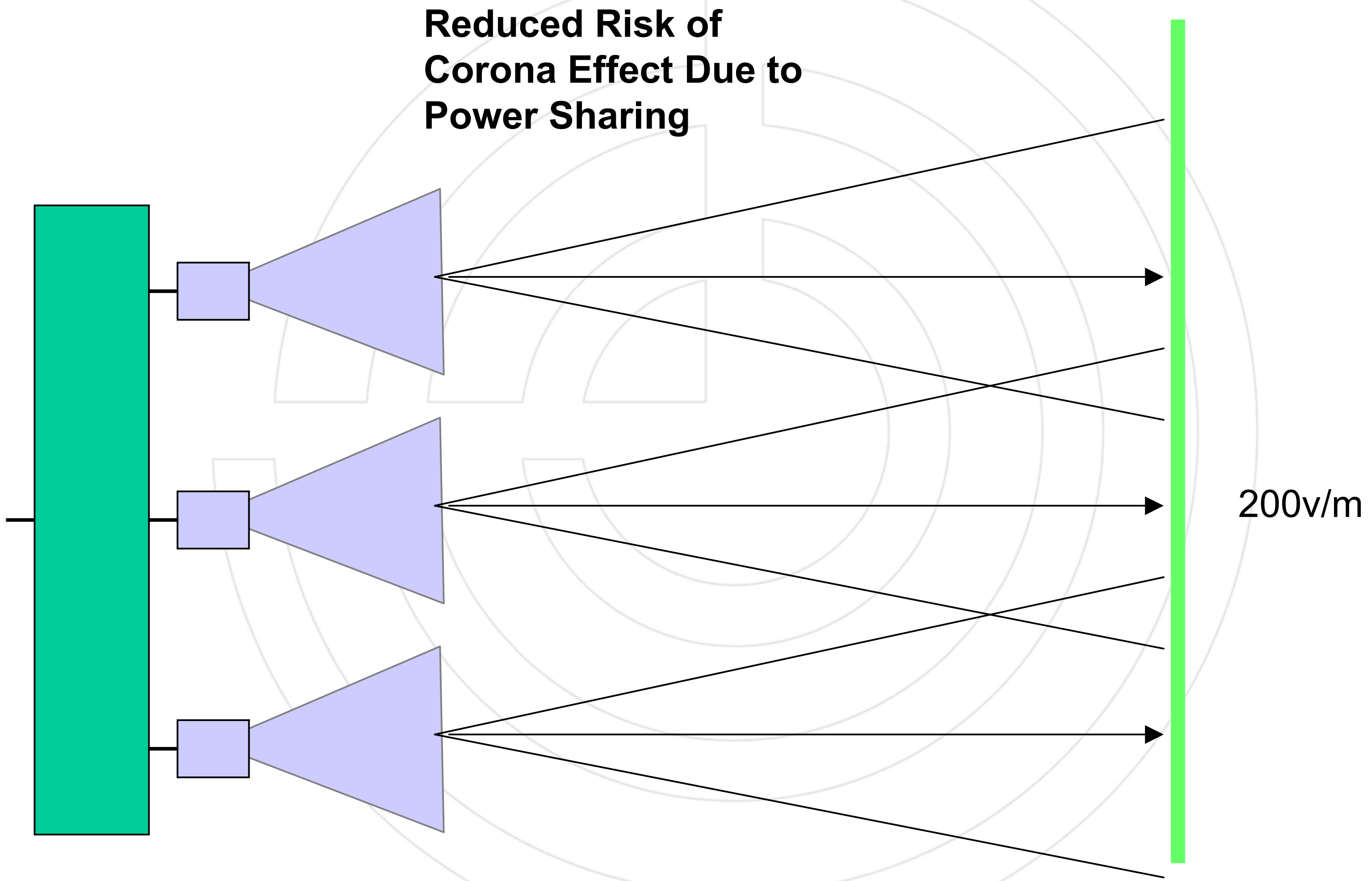

16 points all between 10
and 20 v/m



One Test Run Only

EQUIVALENT TO??





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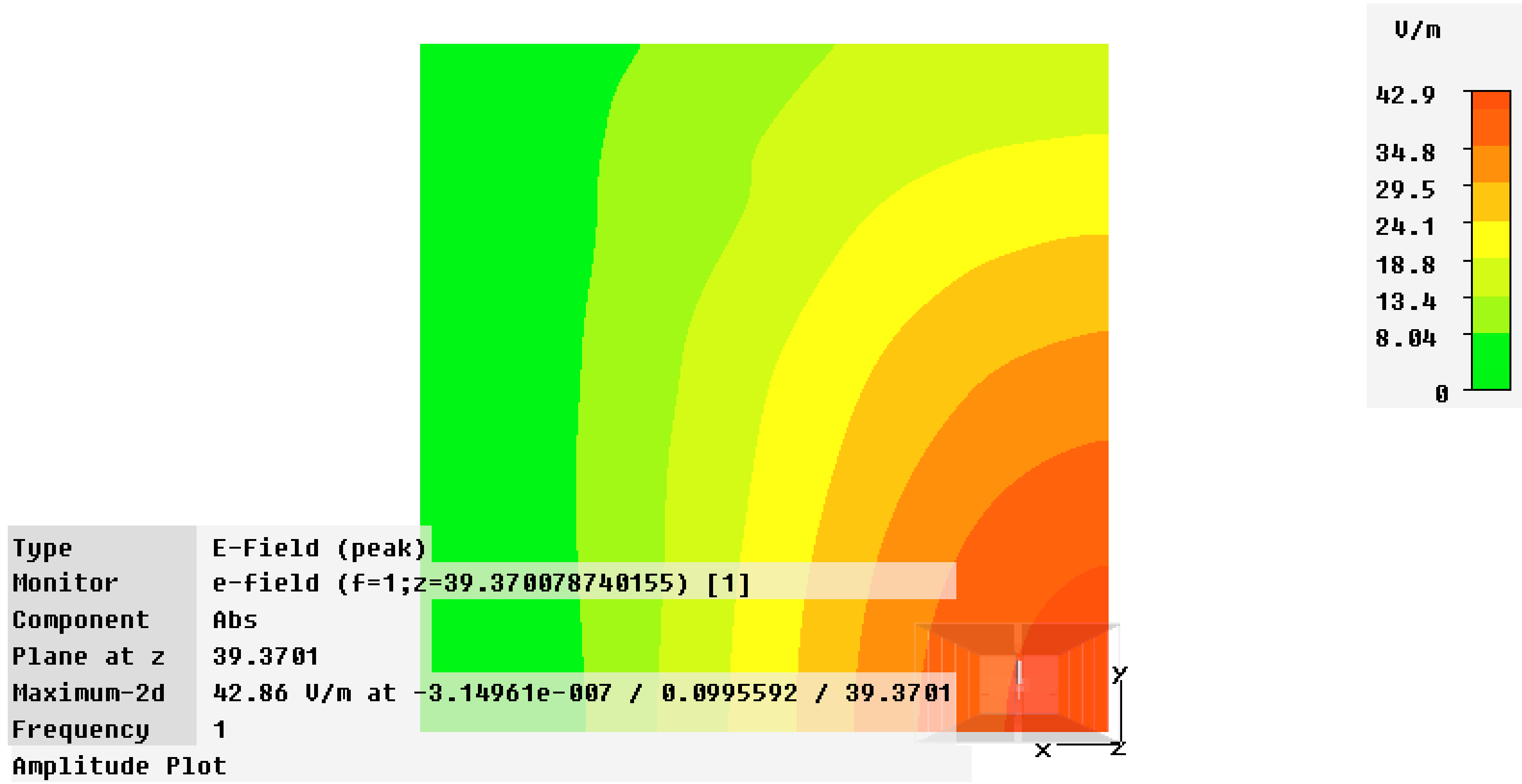
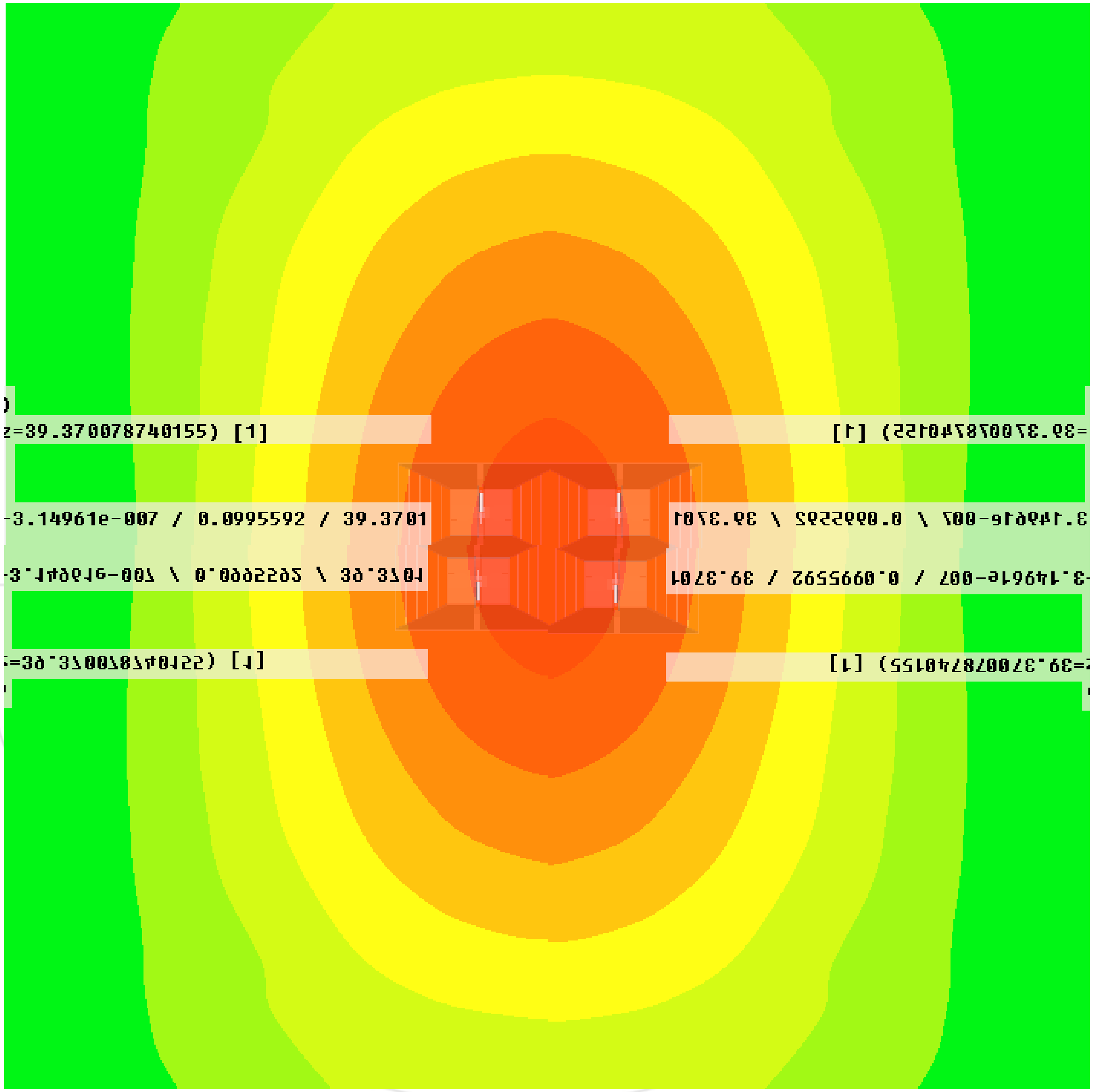
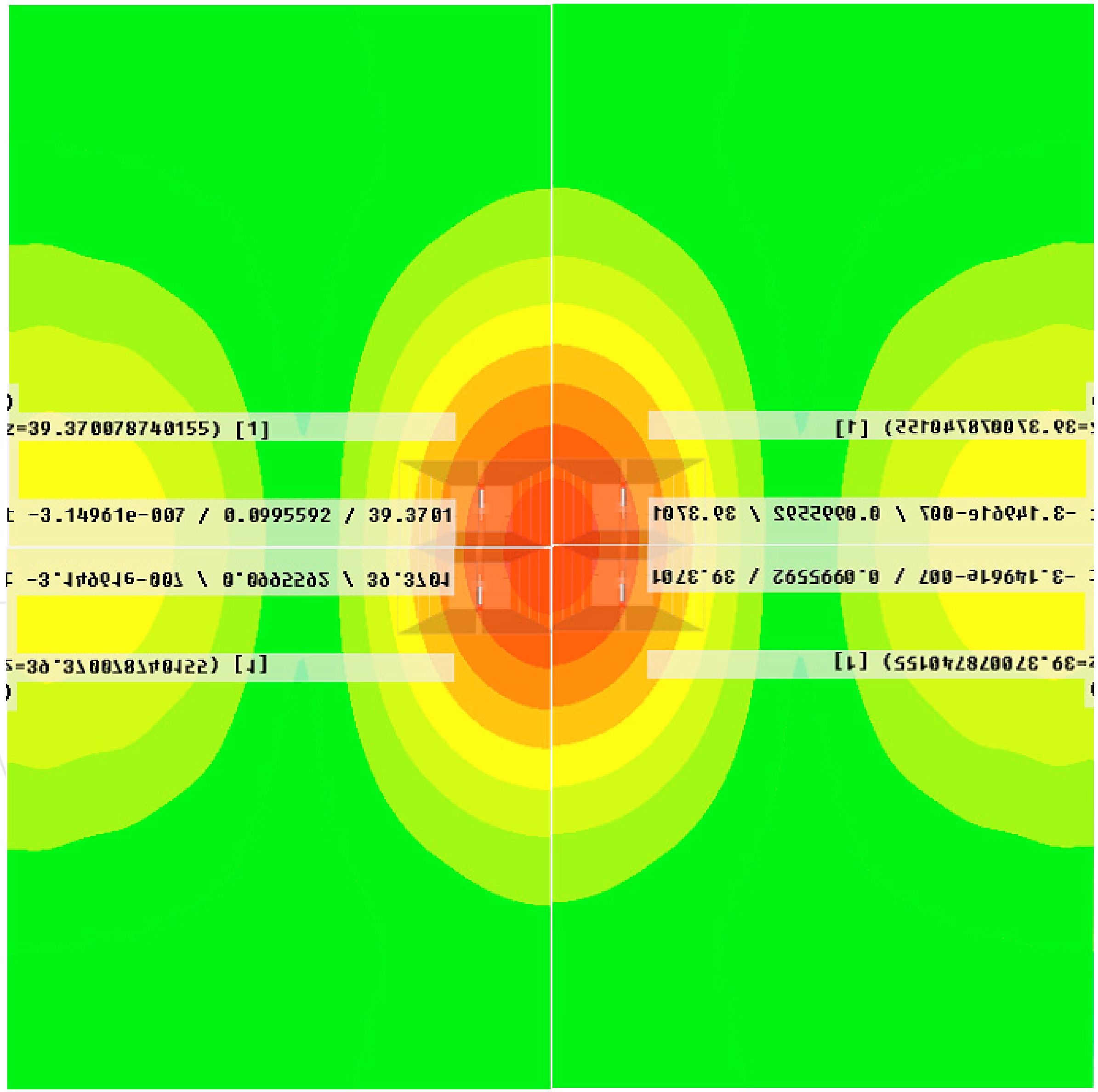
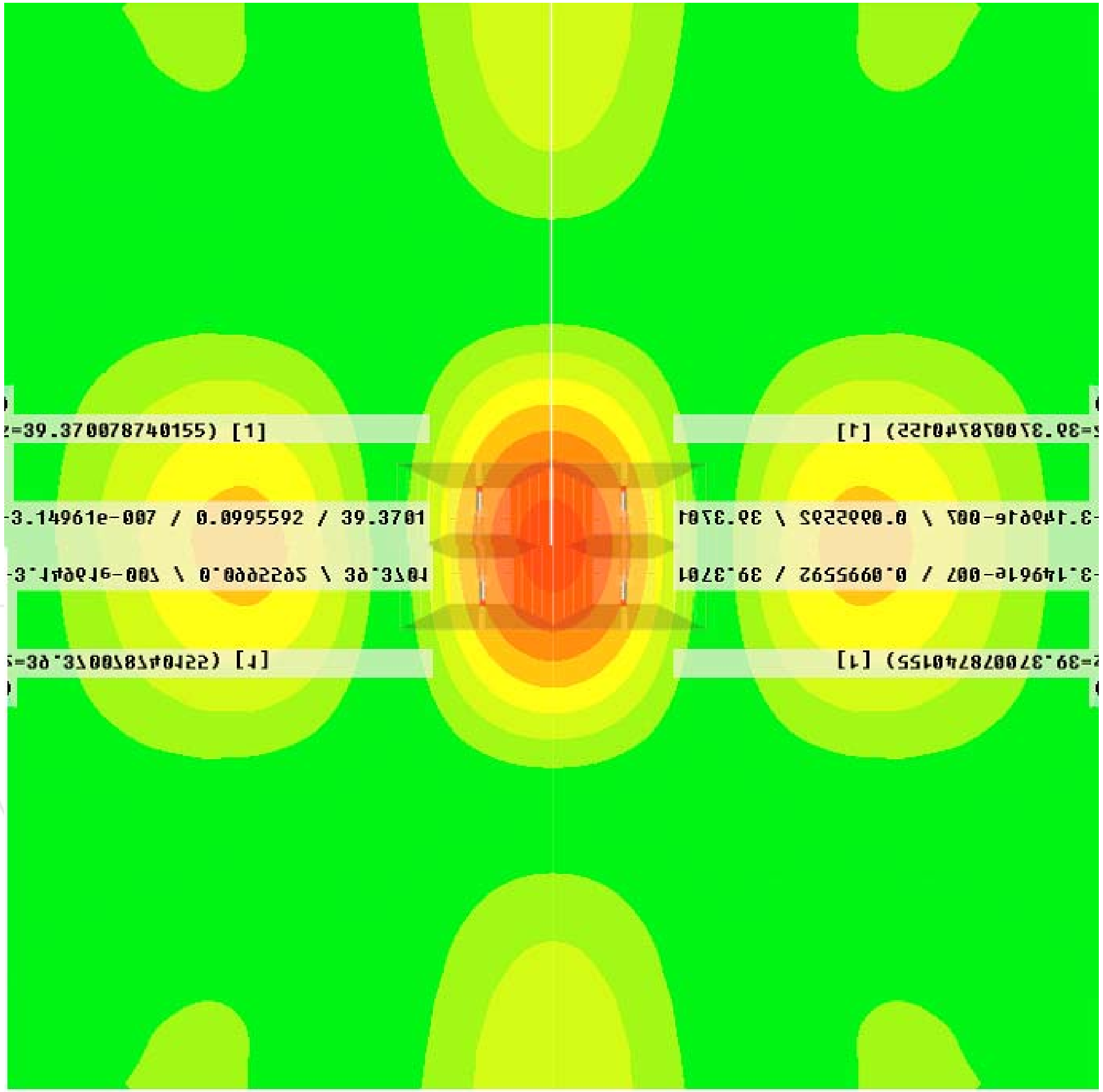
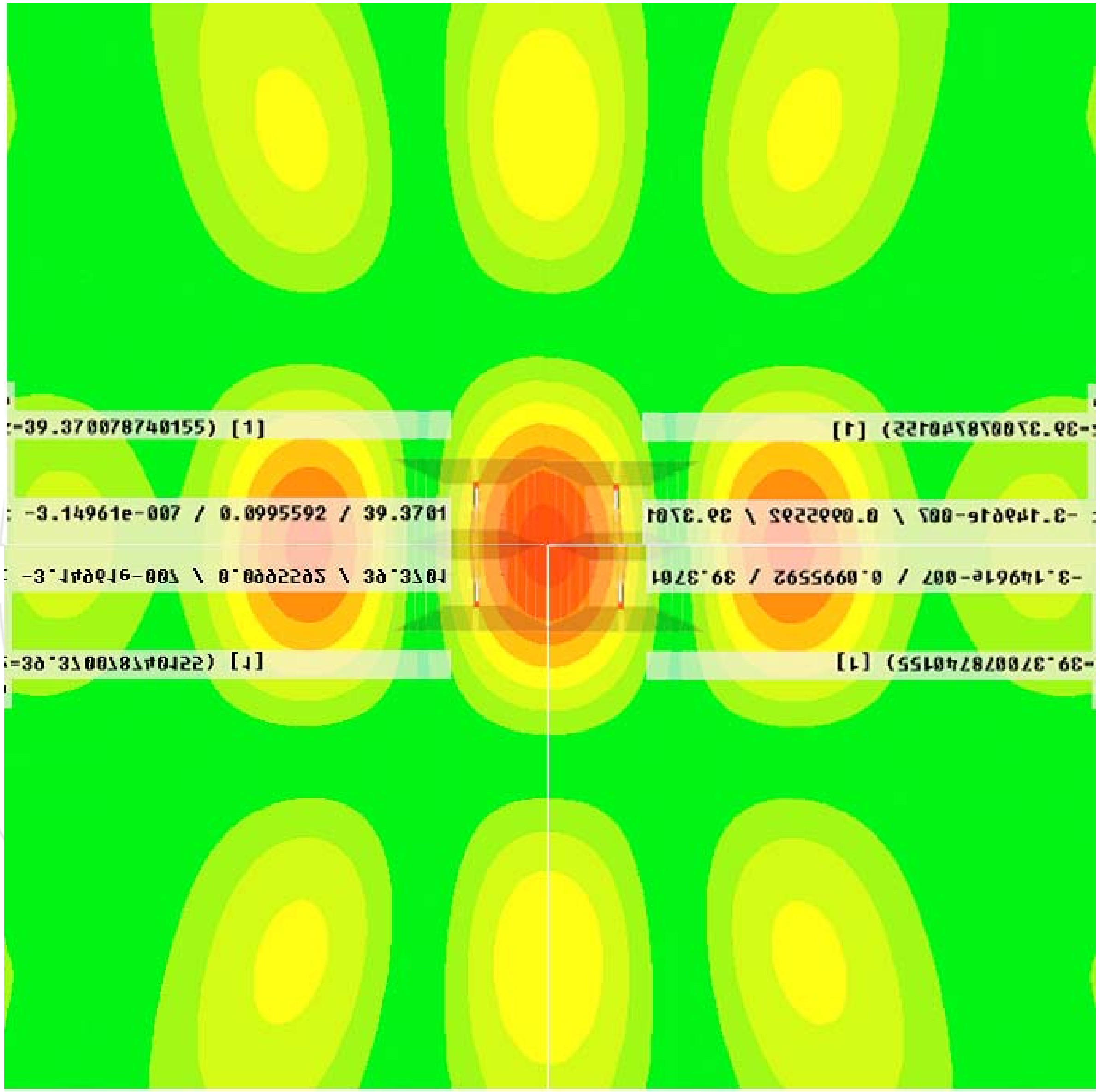
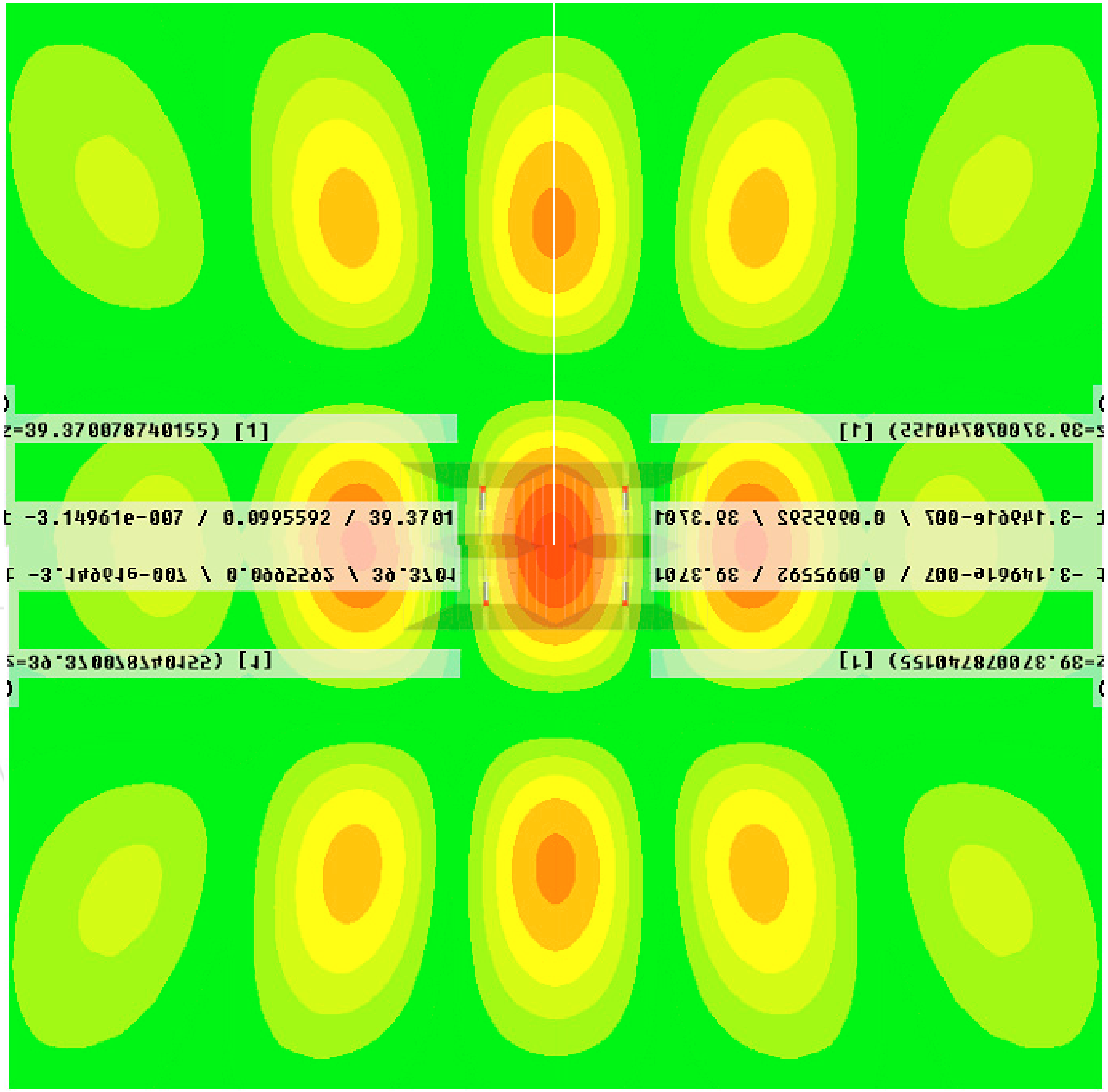

V/m
42.9
34.8
29.5
24.1
18.8
13.4
8.04
0
Type E-Field (peak)
Monitor e-field (f=1;z=39.370078740155) [1]
Component Abs
Plane at z 39.3701
Maximum-2d 42.86 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency 1
Amplitude Plot
y
x
z

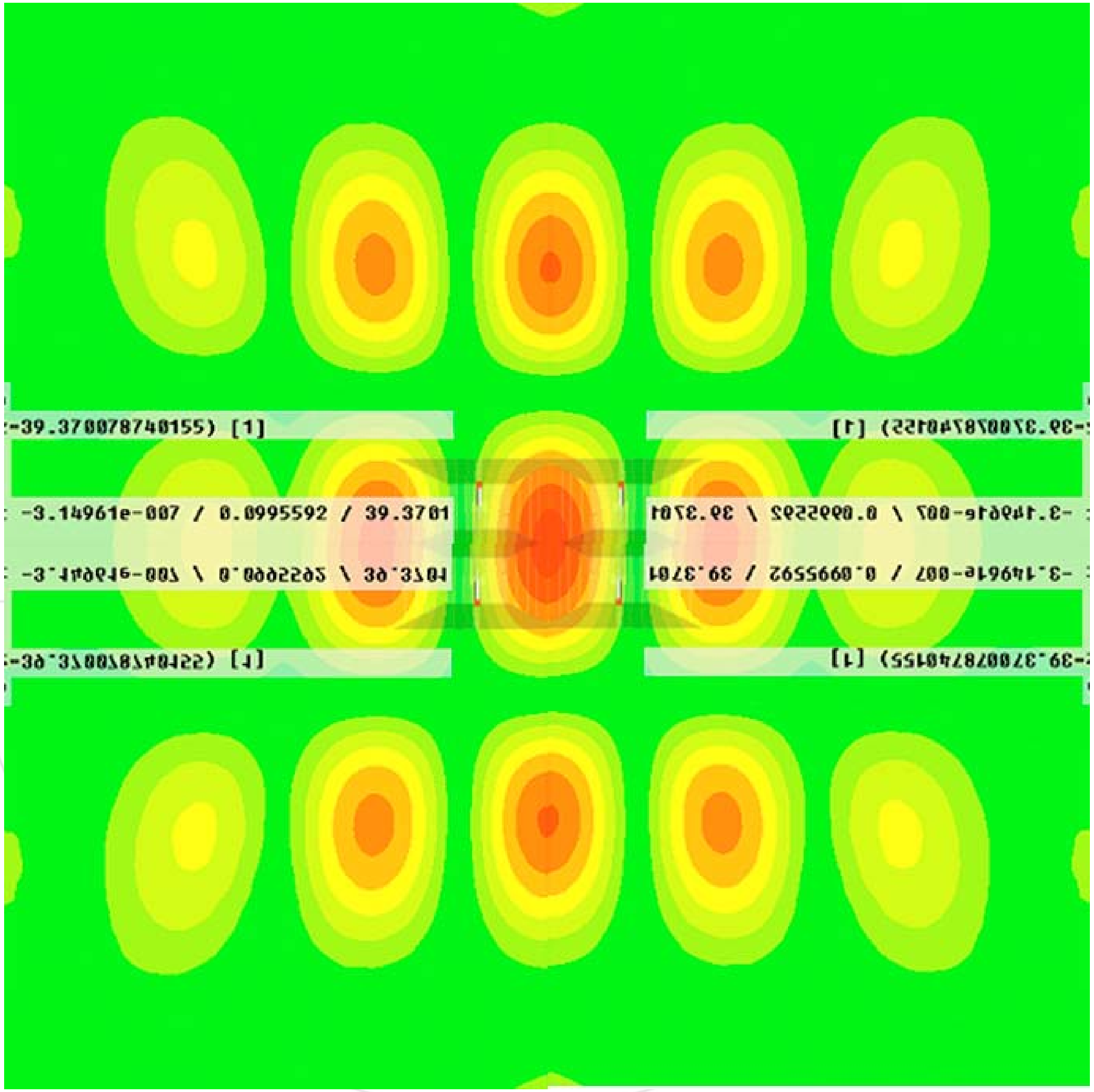

z=39.370078740155) [1]
-3.14961e-007 / 0.0995592 / 39.3701

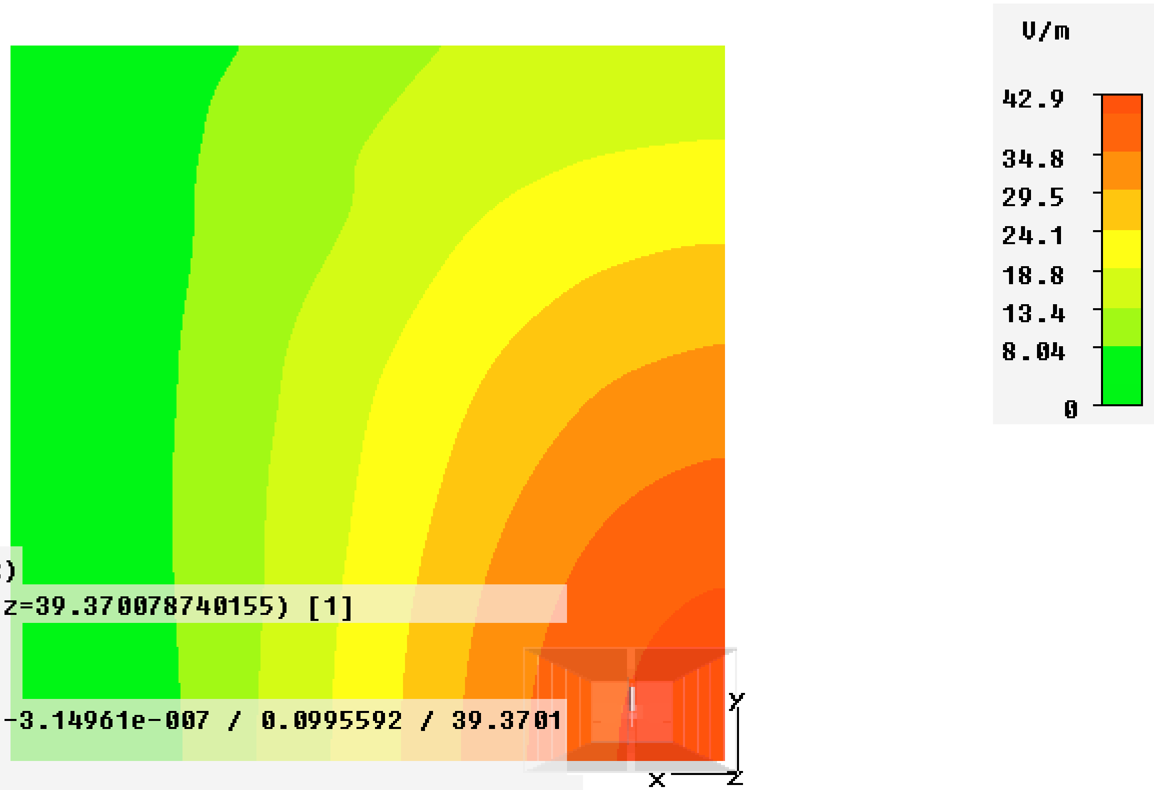

z=39.370078740155) [1]
t -3.14961e-007 / 0.0995592 / 39.3701


=39.370078740155) [1]
-3.14961e-007 / 0.0995592 / 39.3701

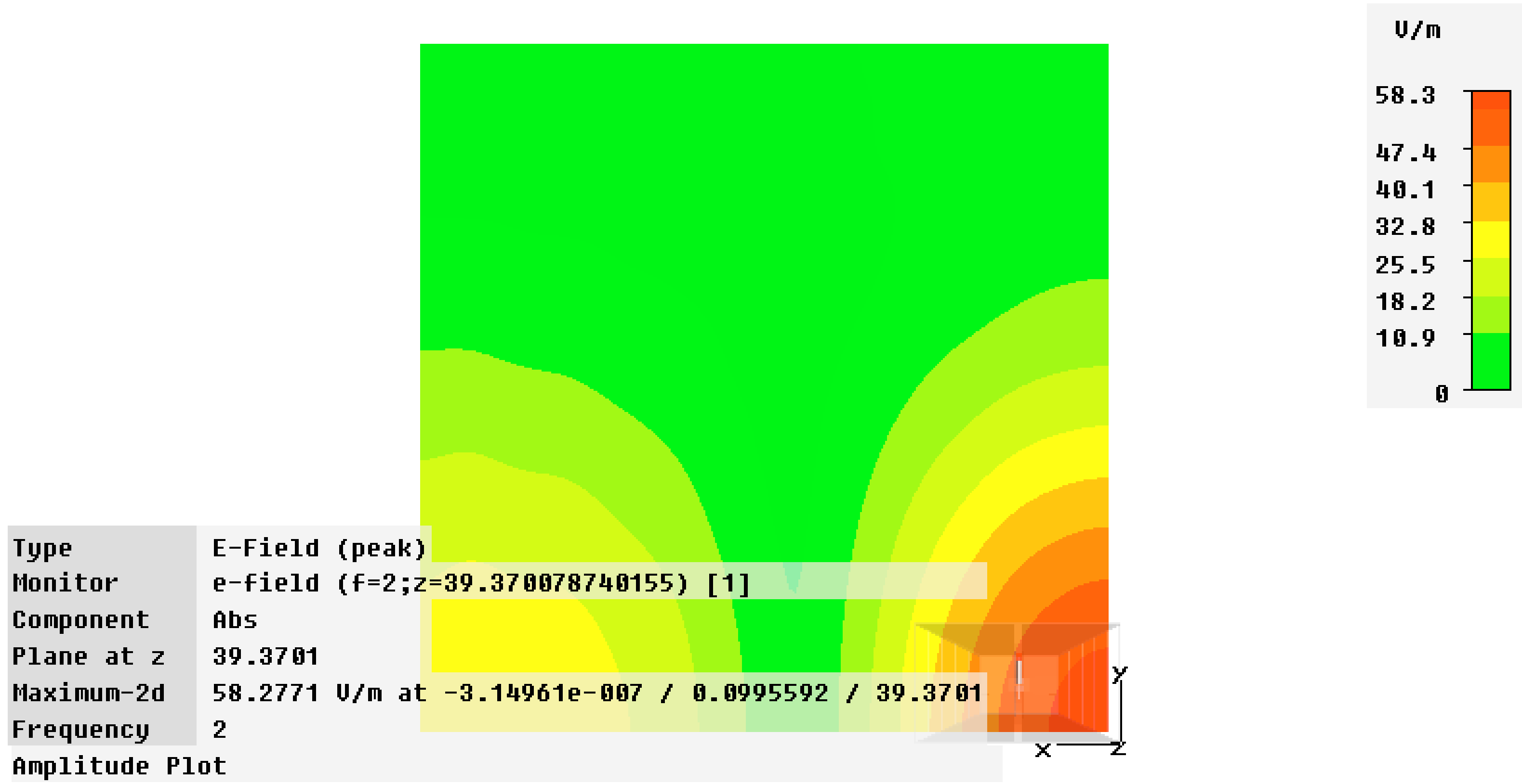

=-39.370078740155) [1]
: -3.14961e-007 / 0.0995592 / 39.3701

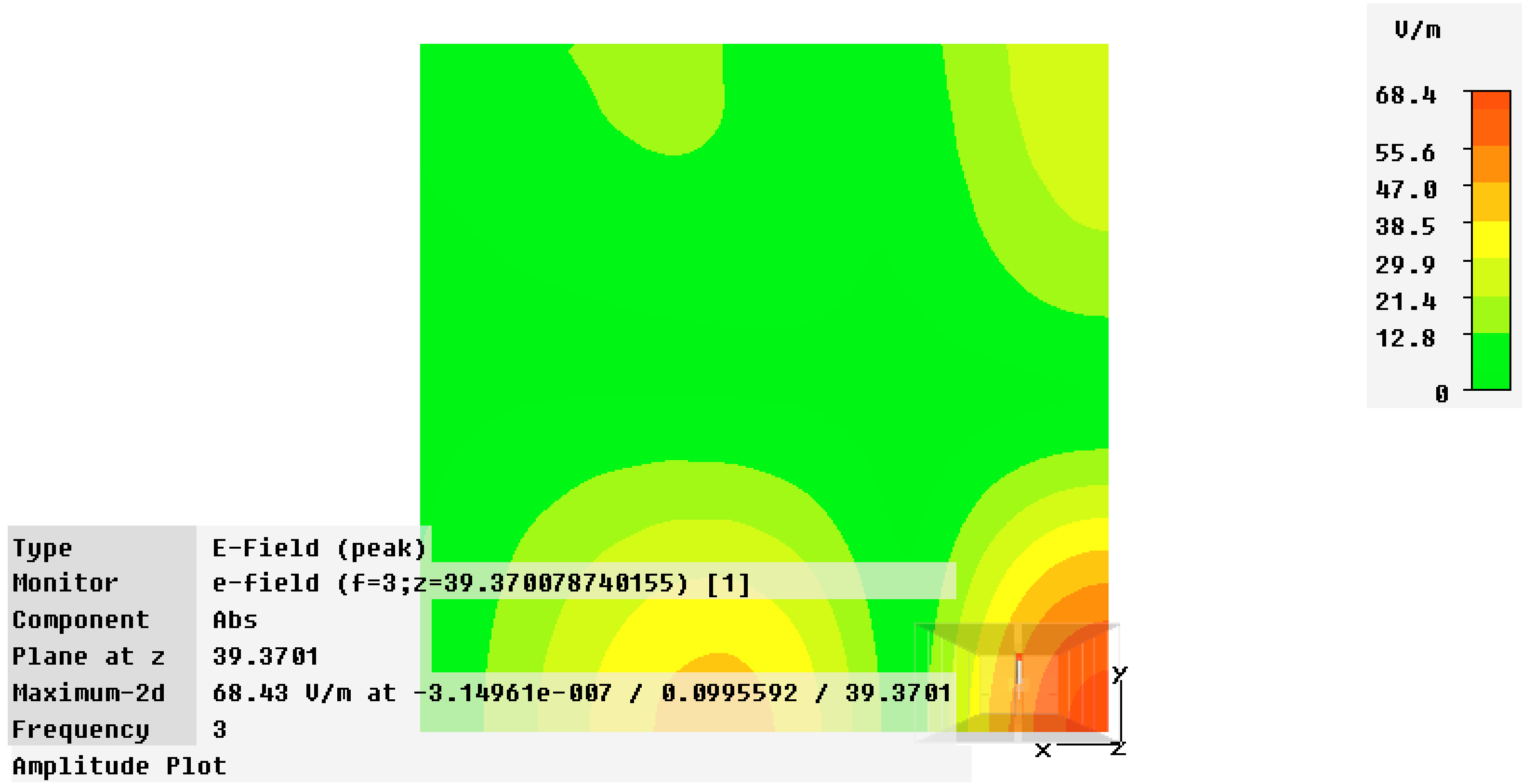

z=39.370078740155) [1]
t -3.14961e-007 / 0.0995592 / 39.3701


-39.370078740155) [1]
-3.14961e-007 / 0.0995592 / 39.3701



Type	E-Field (peak)
Monitor	e-field (f=1;z=39.370078740155) [1]
Component	Abs
Plane at z	39.3701
Maximum-2d	42.86 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency	1
Amplitude Plot	


V/m
58.3
47.4
40.1
32.8
25.5
18.2
10.9
0
Type E-Field (peak)
Monitor e-field (f=2;z=39.370078740155) [1]
Component Abs
Plane at z 39.3701
Maximum-2d 58.2771 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency 2
Amplitude Plot
Y
X
Z



V/m
68.4
55.6
47.0
38.5
29.9
21.4
12.8
0
Type E-Field (peak)
Monitor e-field (f=3;z=39.370078740155) [1]
Component Abs
Plane at z 39.3701
Maximum-2d 68.43 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency 3
Amplitude Plot
y
x
z

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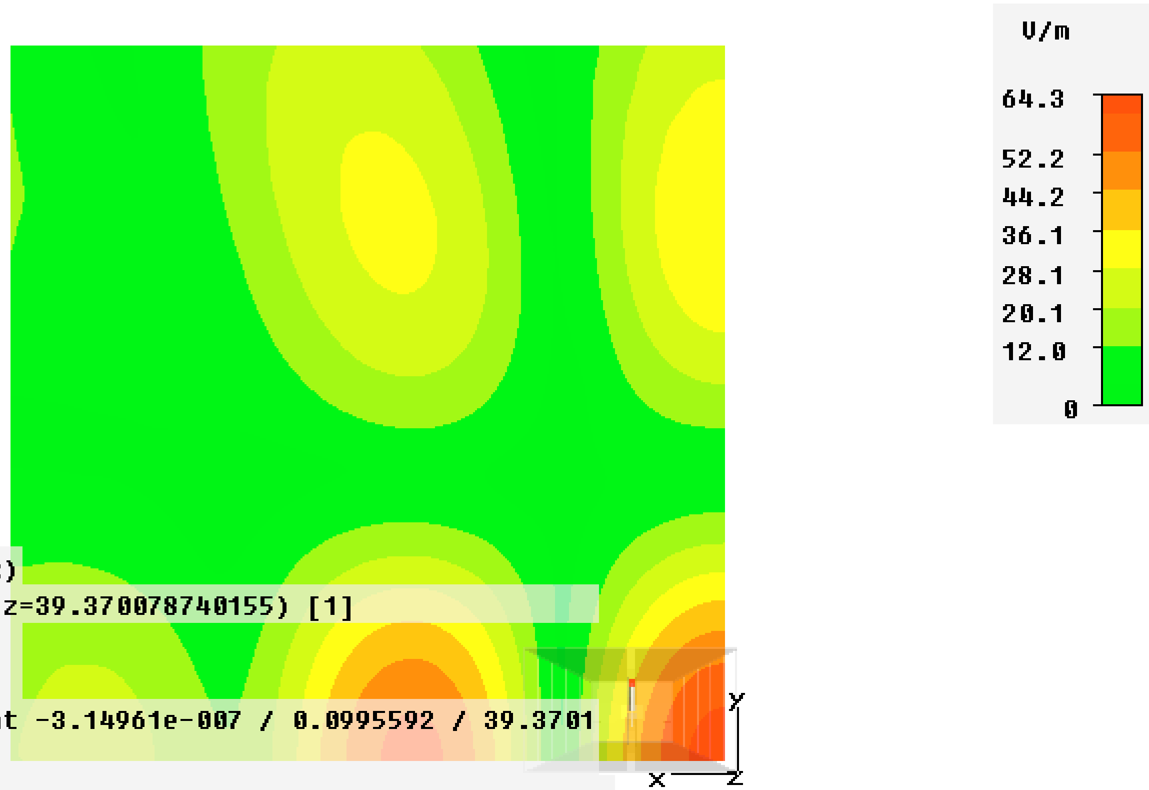
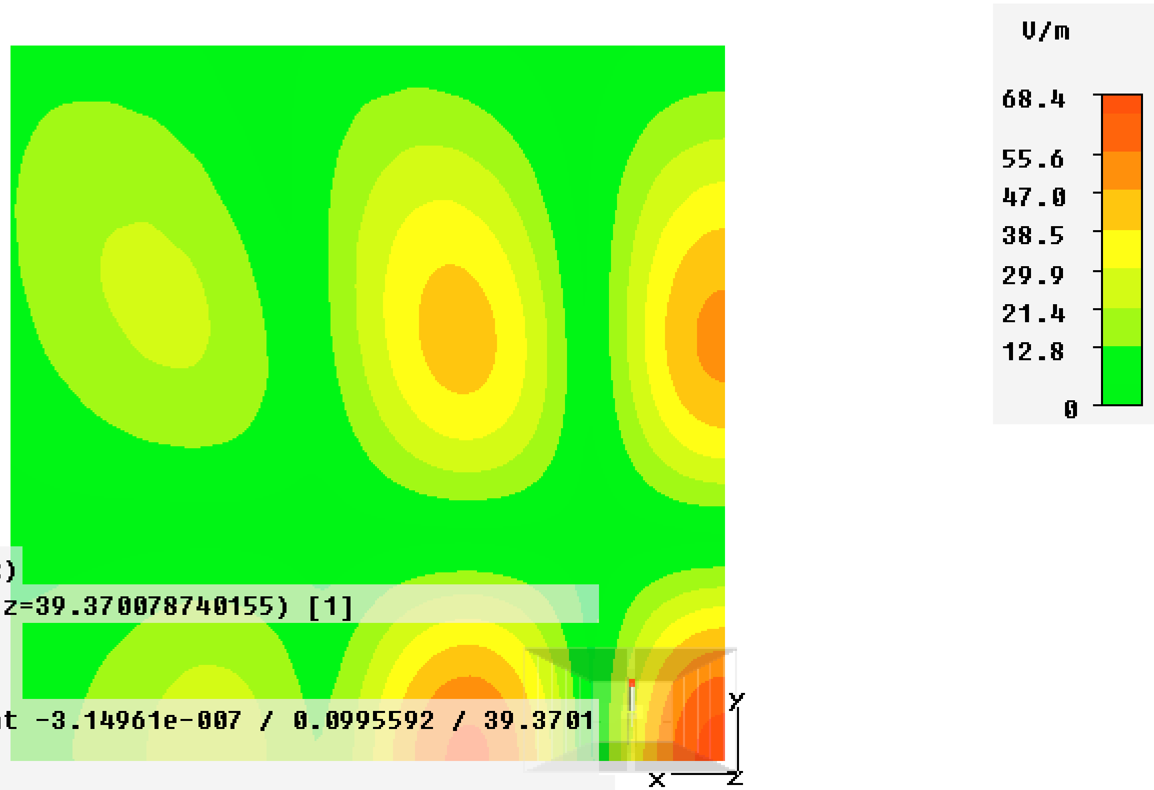
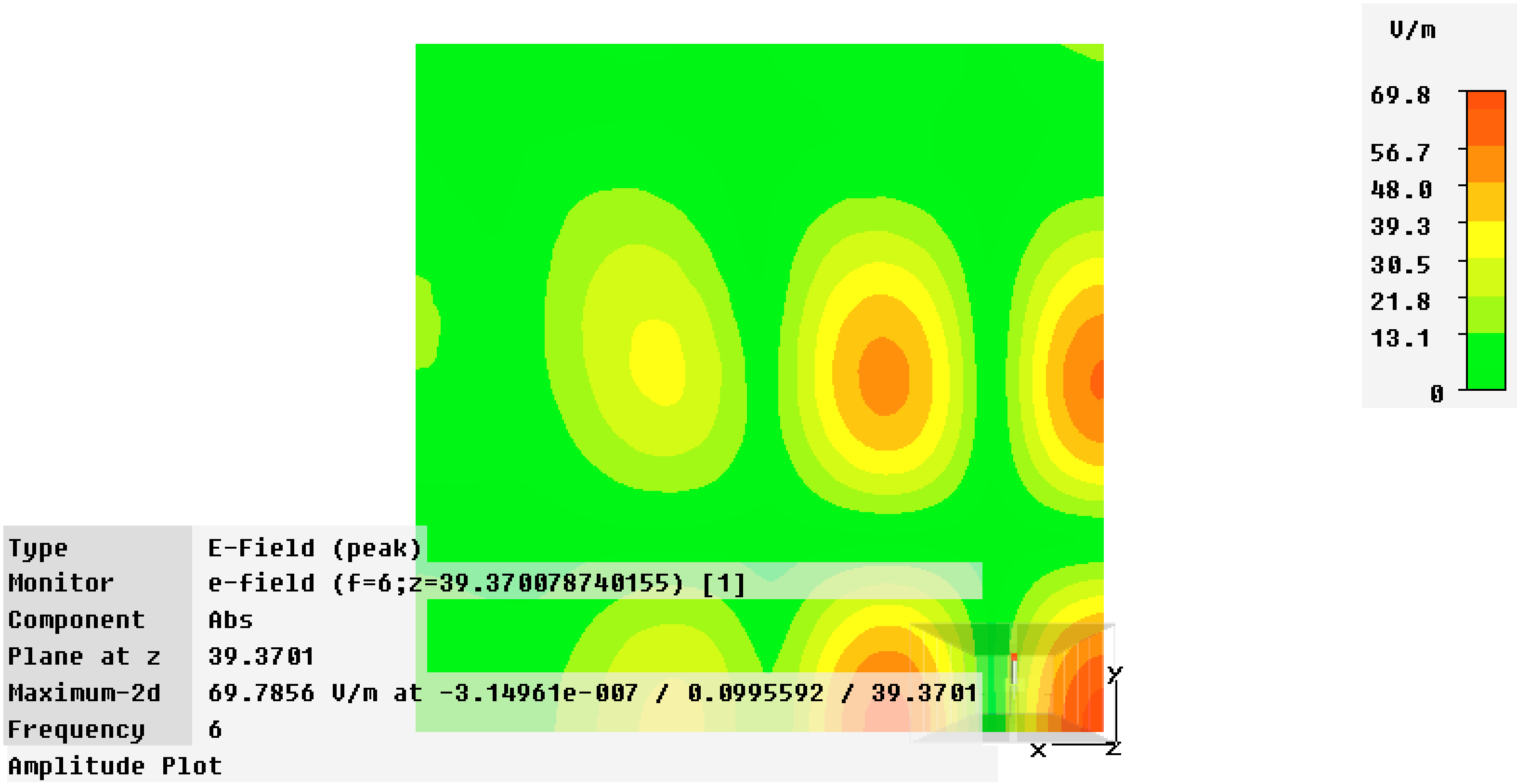


Type	E-Field (peak)
Monitor	e-field (f=4;z=39.370078740155) [1]
Component	Abs
Plane at z	39.3701
Maximum-2d	64.2603 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency	4

Amplitude Plot

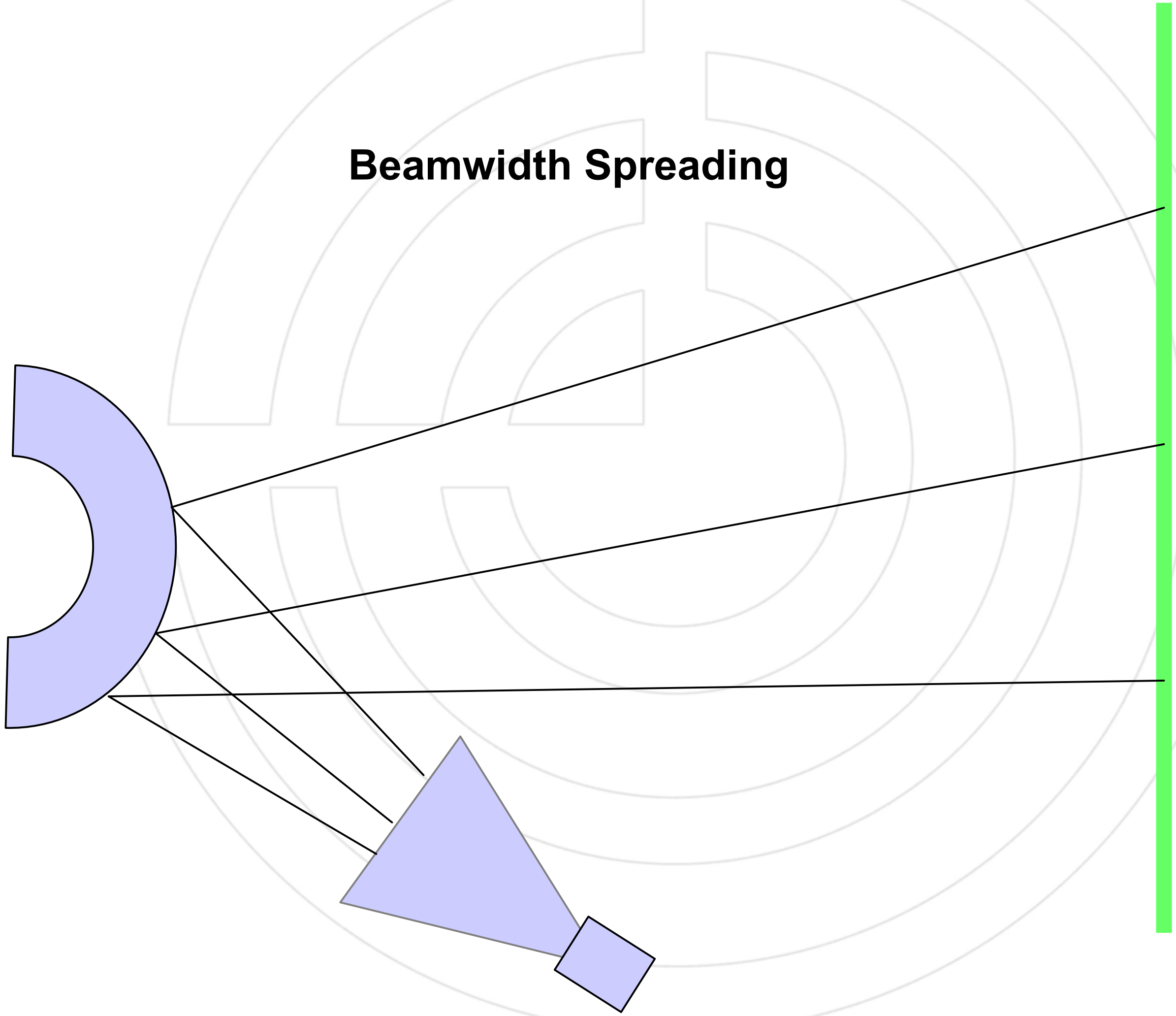


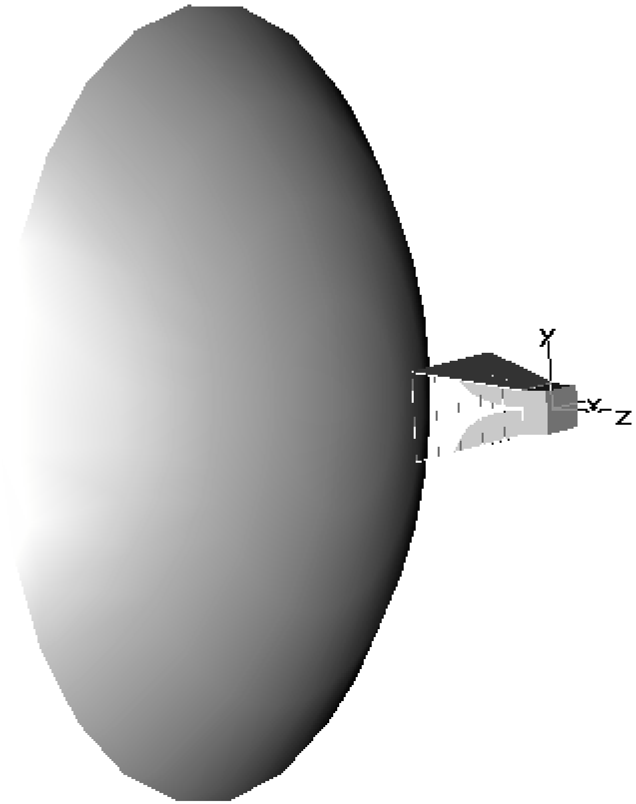
Type	E-Field (peak)
Monitor	e-field (f=5;z=39.370078740155) [1]
Component	Abs
Plane at z	39.3701
Maximum-2d	68.3953 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency	5
Amplitude Plot	


V/m
69.8
56.7
48.0
39.3
30.5
21.8
13.1
0
Type E-Field (peak)
Monitor e-field (f=6;z=39.370078740155) [1]
Component Abs
Plane at z 39.3701
Maximum-2d 69.7856 V/m at -3.14961e-007 / 0.0995592 / 39.3701
Frequency 6
Amplitude Plot
y
x
z

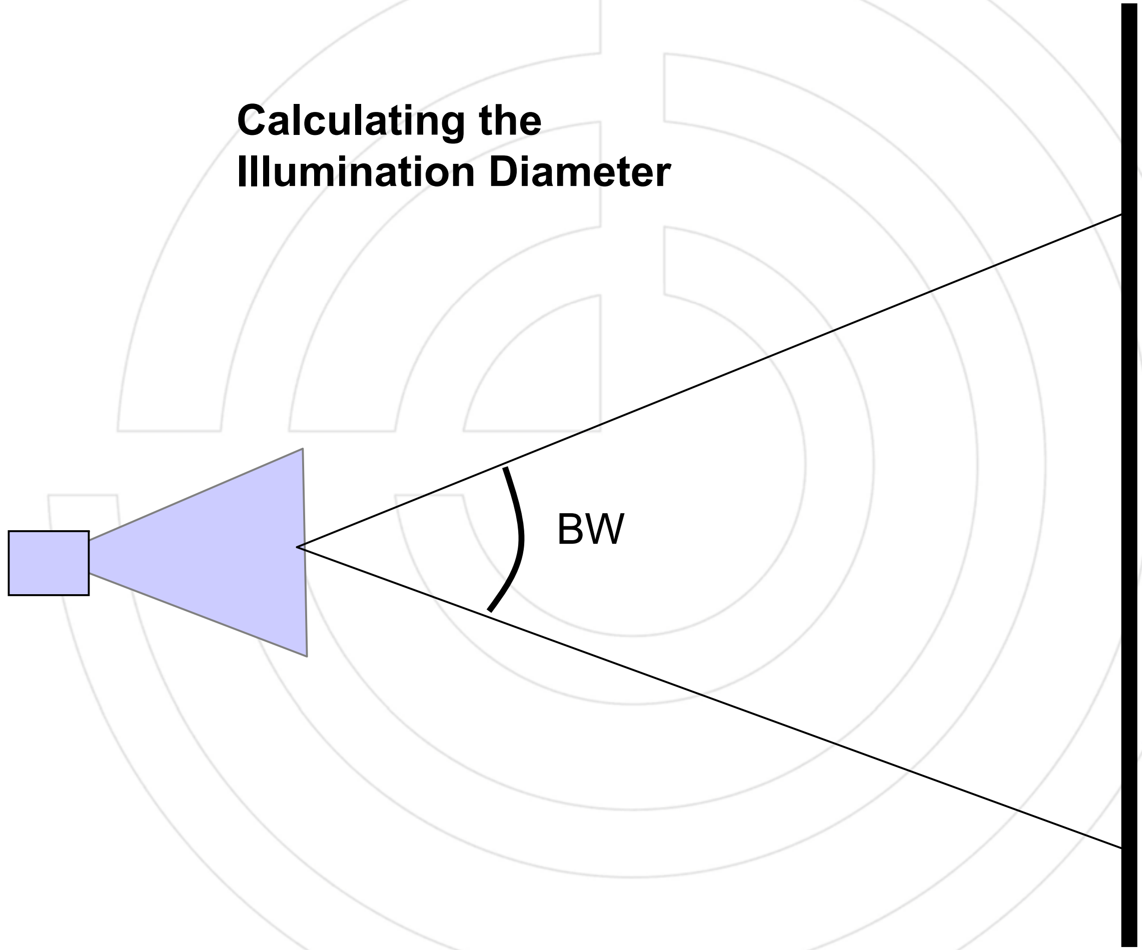
Use of Shaped Reflector Plate

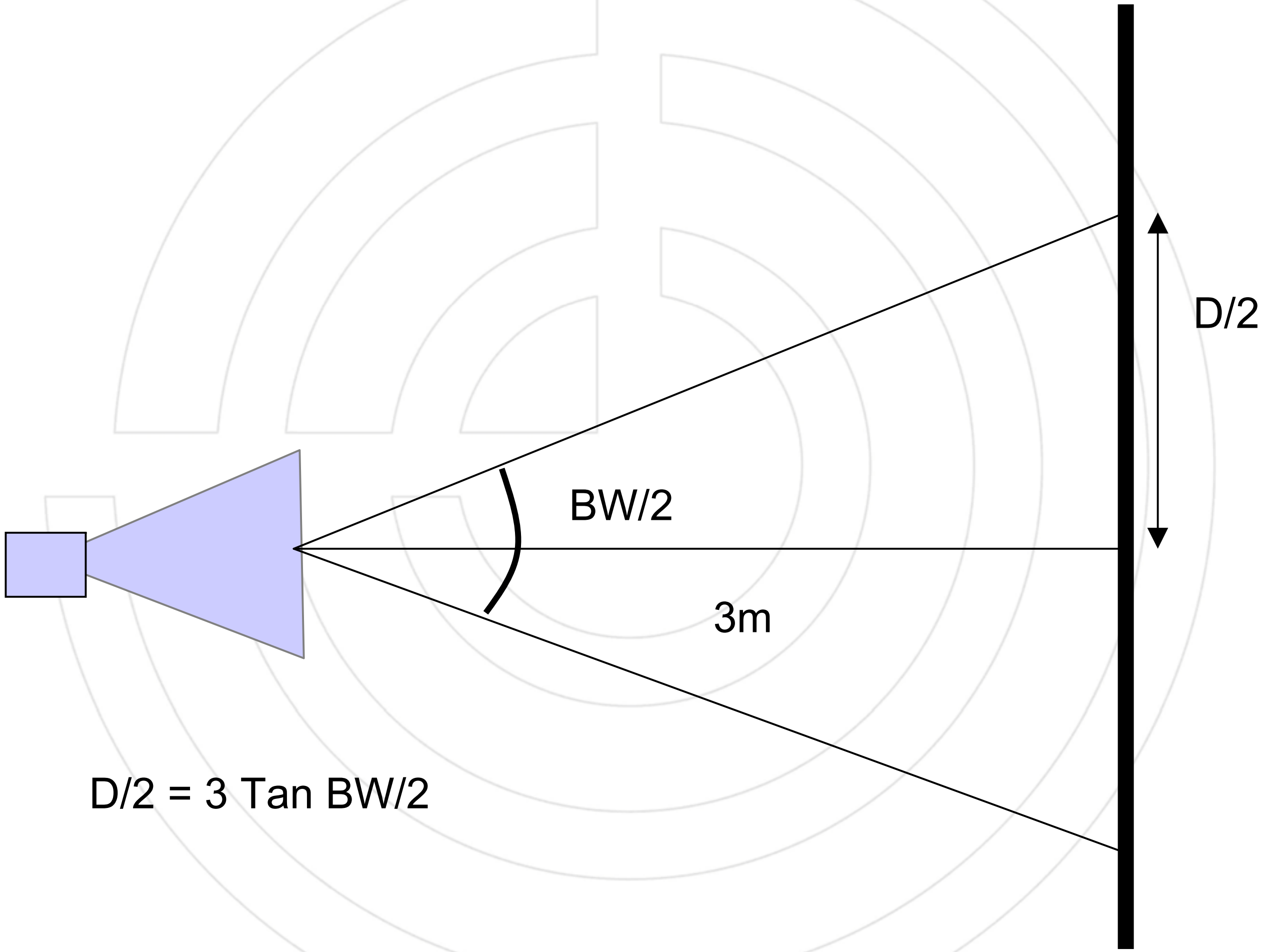
Beamwidth Spreading



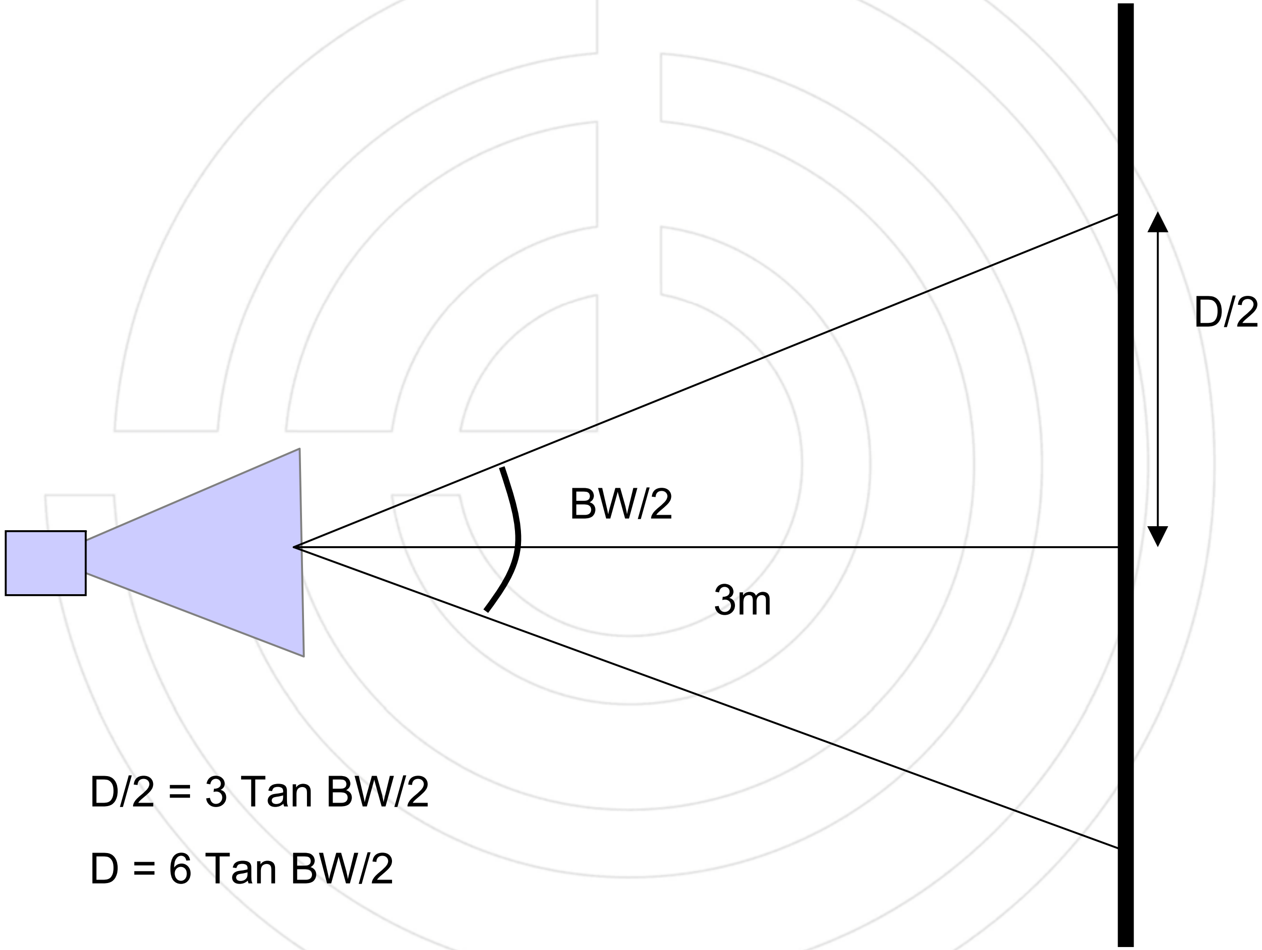

Y
X
Z

Calculating the Illumination Diameter





$$D/2 = 3 \tan BW/2$$



$$D/2 = 3 \tan BW/2$$

$$D = 6 \tan BW/2$$

At 3m Test Distance

Beam Width	*Diameter*
40 degrees	2.2m
30 degrees	1.6m
20 degrees	1.05m
10 degrees	0.5m

At 1m Test Distance

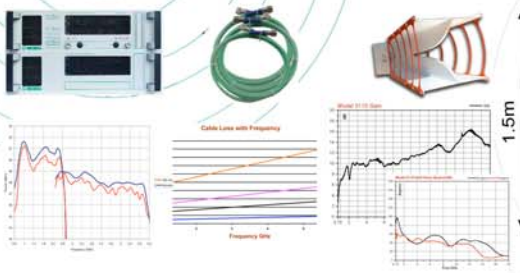
Beam Width	*Diameter*
40 degrees	1.8m
30 degrees	1.2m
20 degrees	0.8m
10 degrees	0.4m

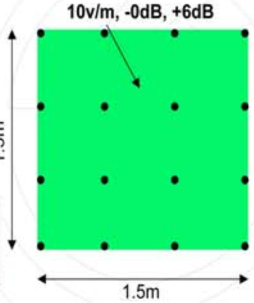
Worked Example Using 3115

61000-4-3 Field Generation 1.0-6.0 GHz 10v/m@3m

MILMEGA

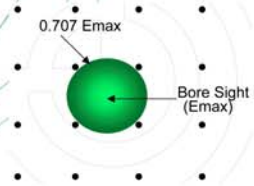
1 RF Field Generation Components



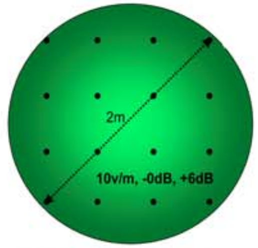


4 Impact of Antenna Beamwidth (BW)

At 3m test distance the -3dB Illumination Diameter is given by D = 6 Tan BW/2



10 Degrees BW
Gives 0.5m Diameter



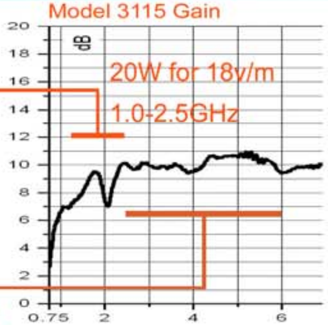
40 Degrees BW
Gives 2m Diameter

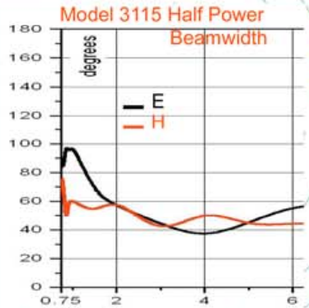
2 Power Required At Antenna Connector

$$E = \sqrt{(30.G.P)} / d$$

$$P = d^2E^2 / 30.G$$

10W for 18v/m 2.5-6.0GHz





The 3115 has a BW of 40 Degrees or better over most of the 1.0-6.0GHz Band

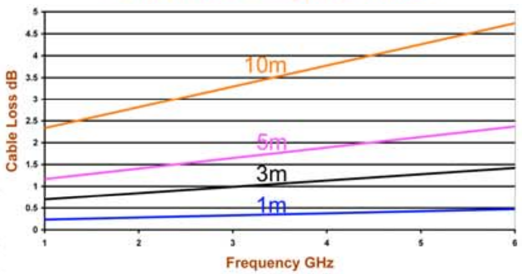
Outer Calibration Points at 18v/m imply a boresight field strength of 25v/m

This Equates to a 3dB increase in Amplifier Power

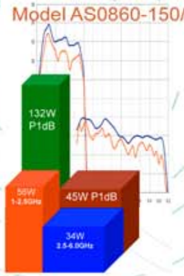
3 Impact of Cable Loss

	10m	5m	3m	1m
1.0-2.5GHz	40W	28W	25W	22W
2.5-6.0GHz	30W	17W	14W	11W

Amplifier Behind Antenna in Chamber



5 Power With Overhead in Each Band

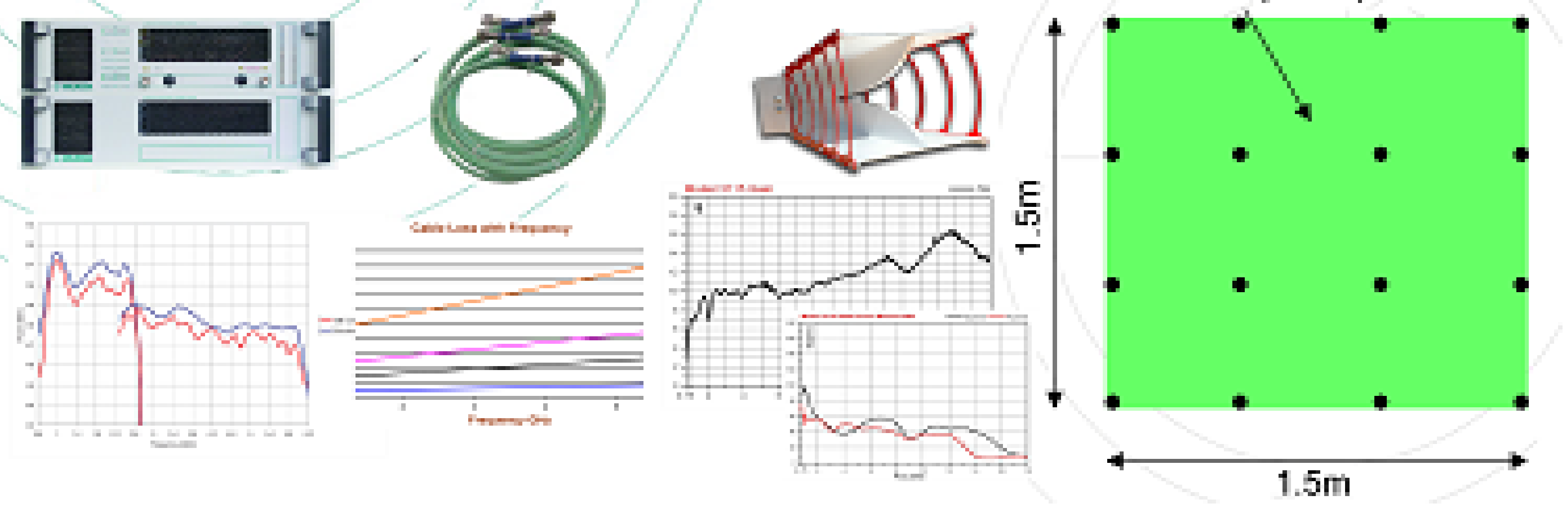


Cable 5m

Cable 1m

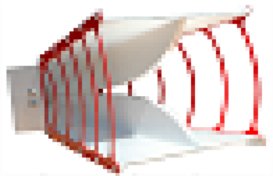
	Cable Length 5m	1m
1.0-2.5GHz	56W	44W
2.5-6.0GHz	34W	22W

1 RF Field Generation Components



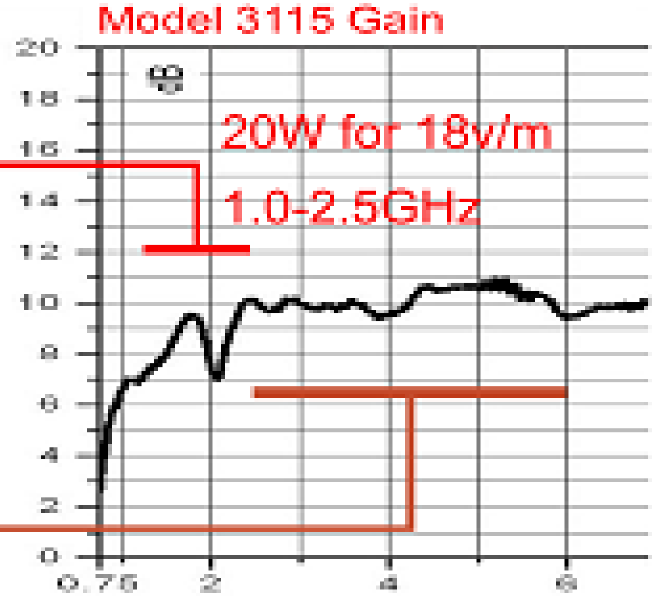
2

Power Required At Antenna Connector



$$E = \sqrt{(30.G.P)} / d$$

$$P = d^2E^2 / 30.G$$



10W for 18v/m 2.5-6.0GHz

3

Impact of Cable Loss

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1.0-2.5GHz	40W	28W	25W	22W
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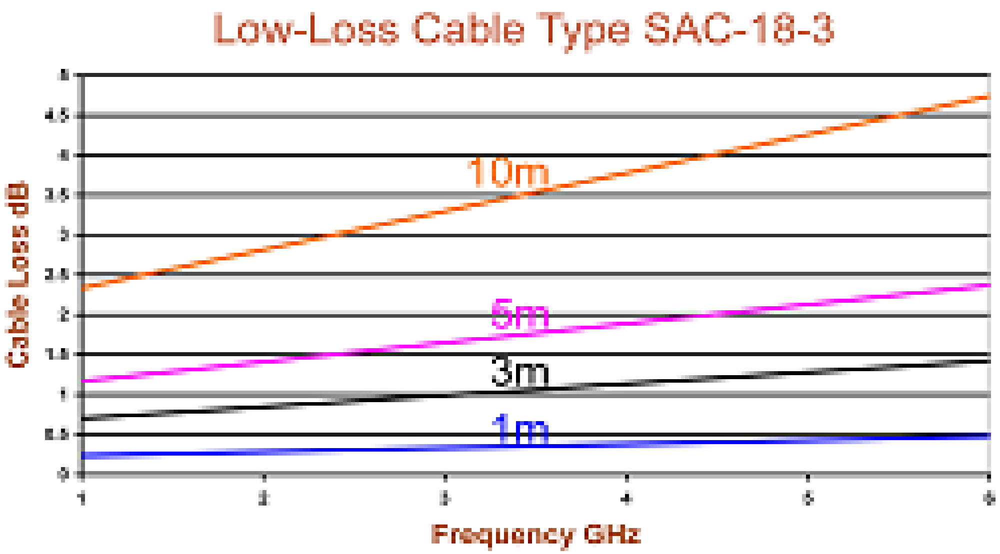
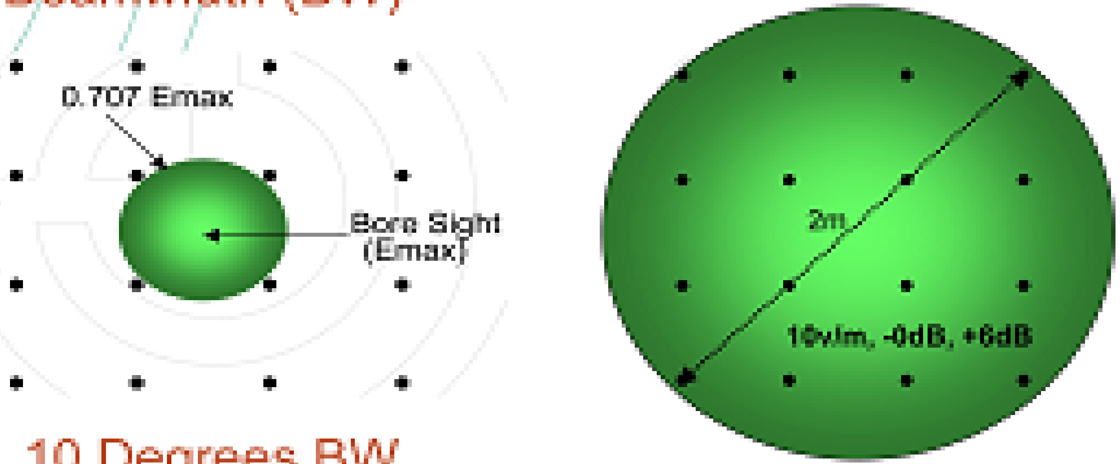


4 Impact of Antenna Beamwidth (BW)

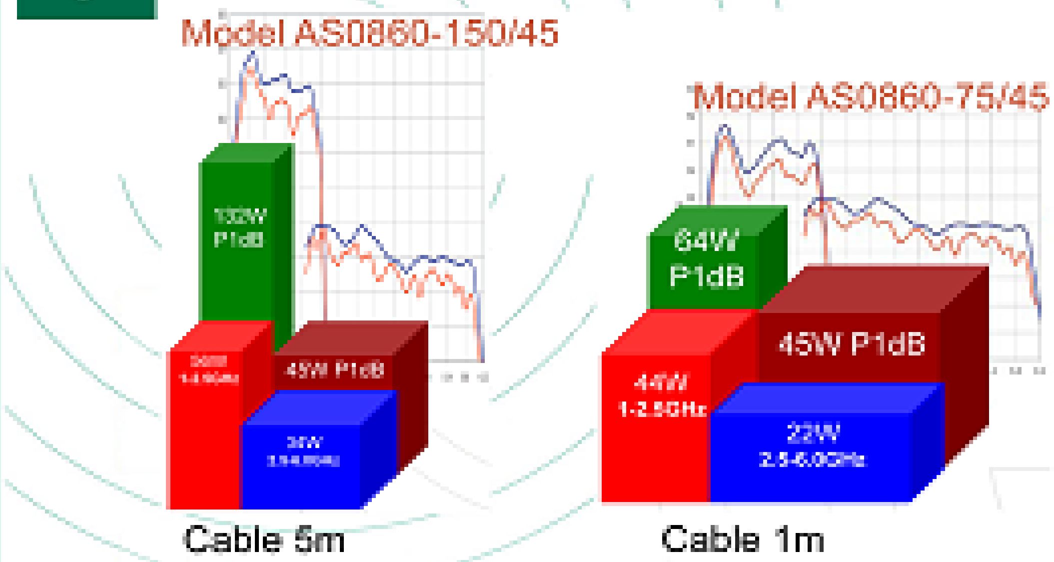
At 3m test distance the -3dB Illumination Diameter is given by D = 6 Tan BW/2



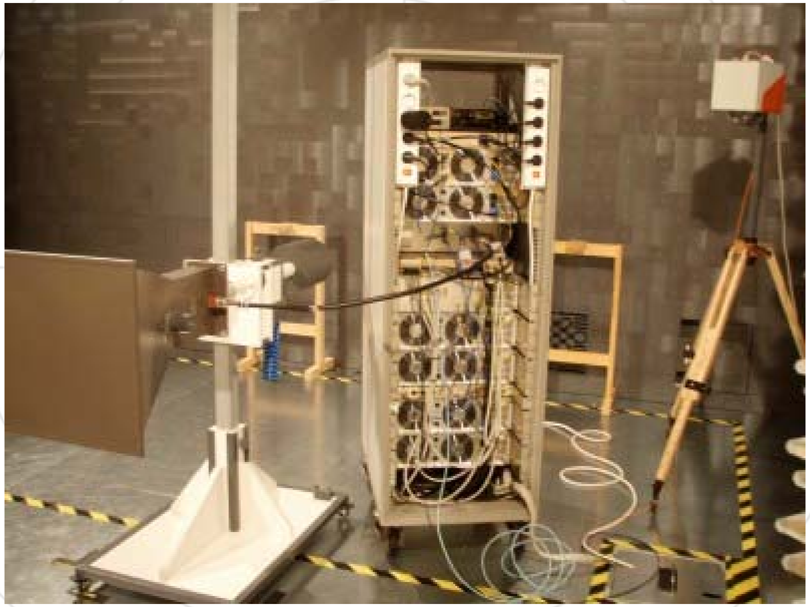
10 Degrees BW
Gives 0.5m Diameter

40 Degrees BW
Gives 2m Diameter

5 Power With Overhead in Each Band



	Cable Length 5m	Cable Length 1m
1.0-2.5GHz	56W	44W
2.5-6.0GHz	34W	22W



Aspects of Achieving 10 v/m Field Uniformity over 1-6GHz with Single, Multiple and Cassegrain Antennas

QUESTIONS?

Tom Mullineaux