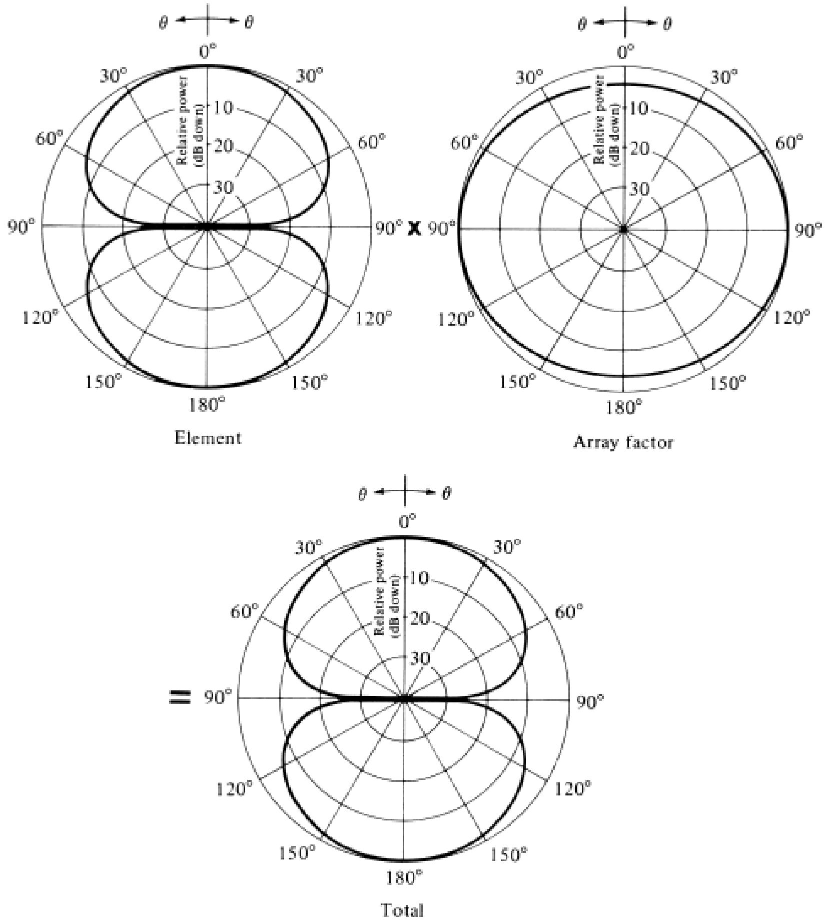



**Figure 6.3** Element, array factor, and total field patterns of a two-element array of infinitesimal horizontal dipoles with identical phase excitation ($\beta = 0^\circ, d = \lambda/4$).

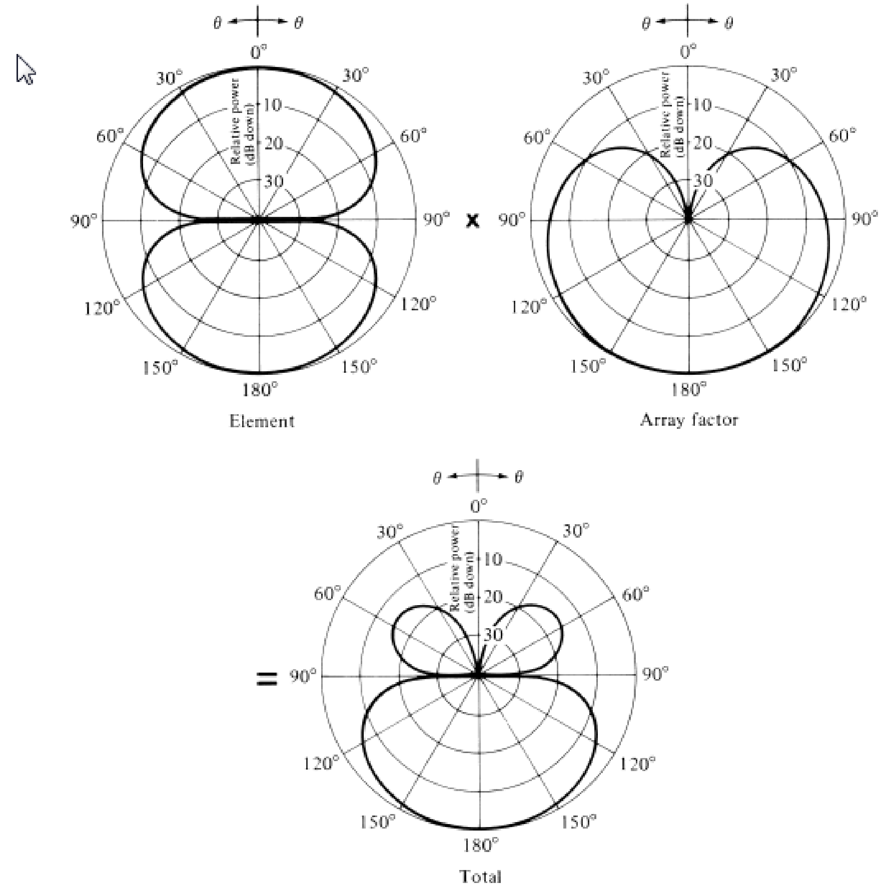
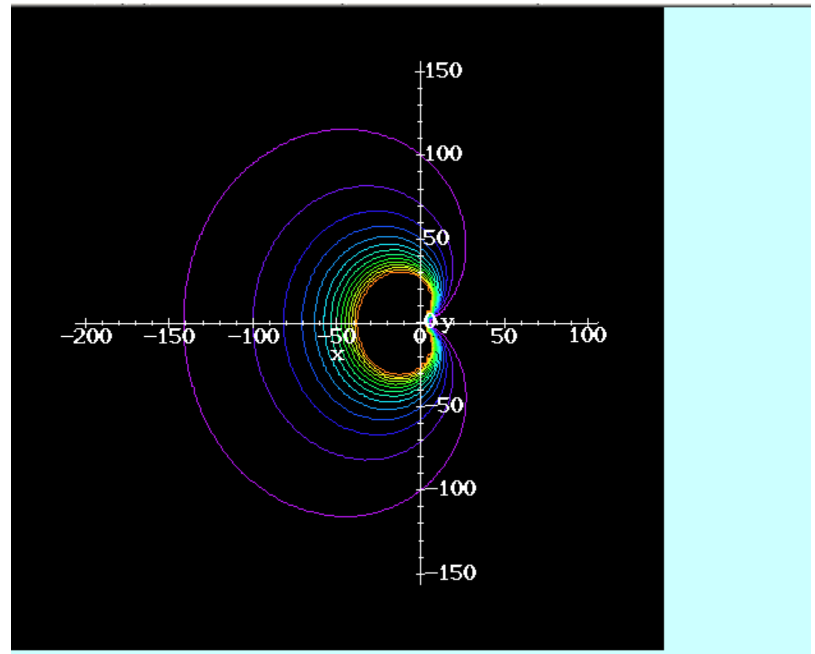


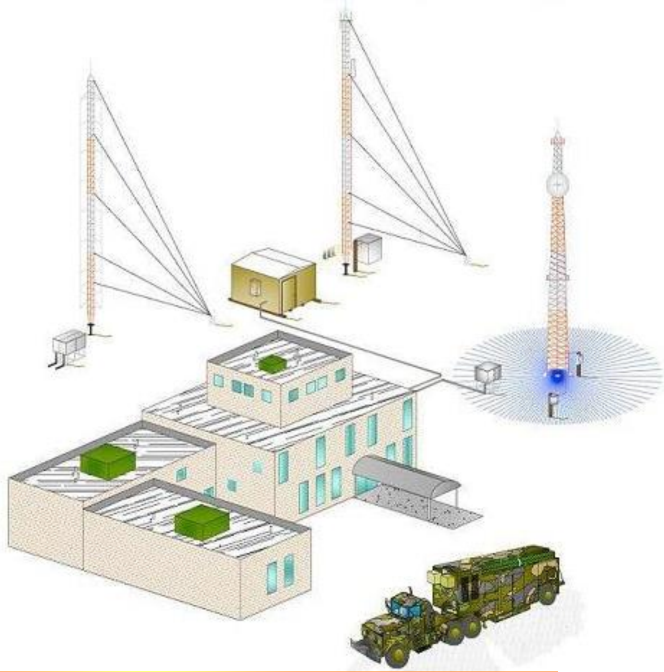

**Figure 6.4** Pattern multiplication of element, array factor, and total array patterns of a two-element array of infinitesimal horizontal dipoles with (a) $\beta = +90^\circ$, $d = \lambda/4$.

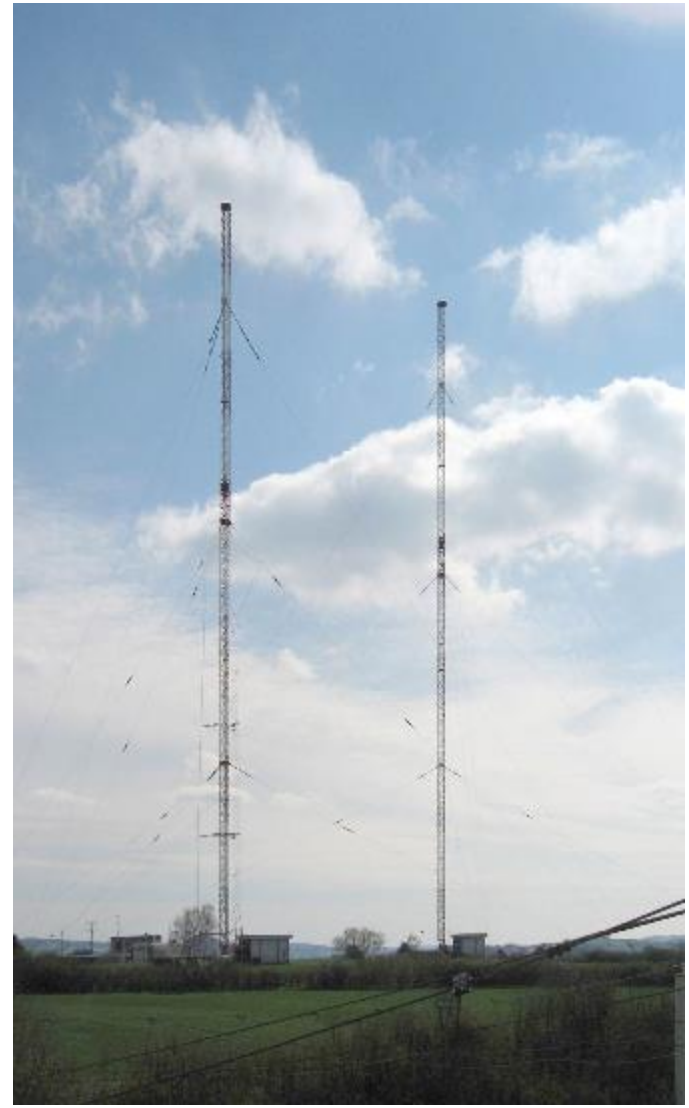
# Redes de Antenas – para que servem?

TWO ISOTROPES 1/4 WAVELENGTH APART 90 DEGREES PHASE SHIFT

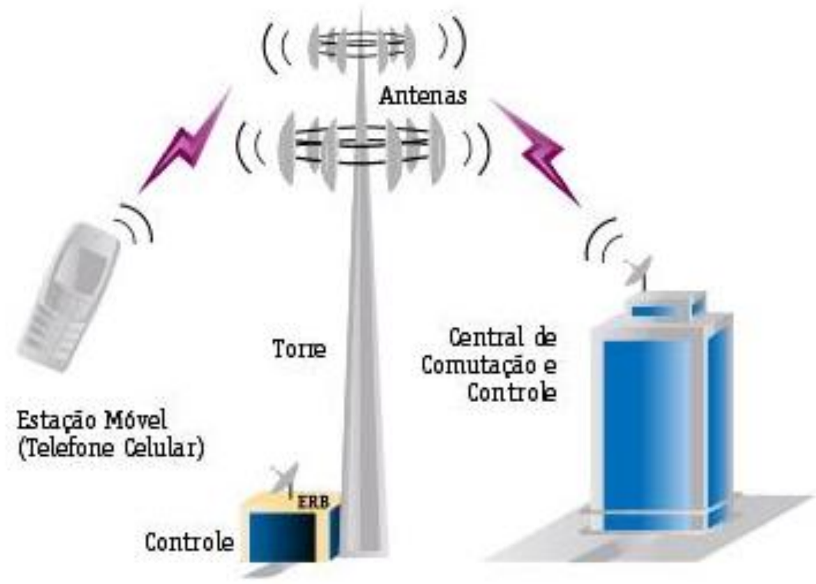
Antenas de radio, localizada em Fortaleza, nao precisa iluminar o oceano. Assim coloca outro elemento e joga a onda para o interior e zona metropolitana do Ceara.

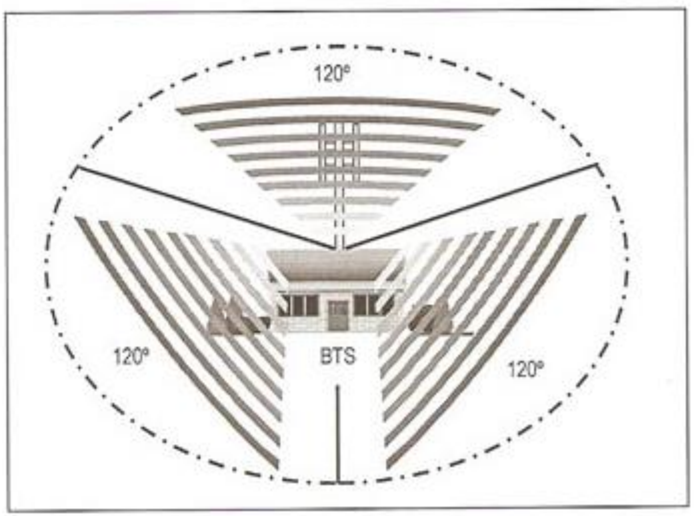




# Redes de Antenas – para que servem?

Em comunicacao movel, em ERBs de celular, fornecem uma cobertura desejada numa regiao.



# Redes de Antenas – para que servem?

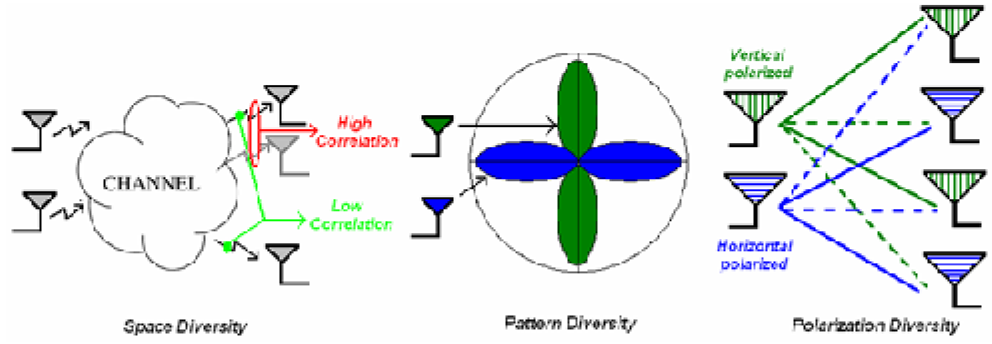
Ja no receptor, podem formar complexas redes para implementar sistemas MIMO.

Perceba o jargao: Nao correlacionado significa, em RF, com baixo acoplamento S21!!

## Introduction to MIMO Antenna Design

Multiple-input multiple-output (MIMO) wireless technology uses multiple antennas at the transmitter and receiver to produce significant capacity gains over single-input single-output (SISO) systems using the same bandwidth and transmit power. It has been shown that the capacity of a MIMO system increases linearly with the number of antennas in the presence of a scattering-rich environment. This will ensure that the signals at the antennas in the array are sufficiently uncorrelated with each other. This is where antenna design comes in for MIMO systems.

The primary aim of MIMO antenna design is to reduce correlation between received signals by exploiting various forms of diversity that arise due to the presence of multiple antennas, like space diversity (spacing antennas far apart), pattern diversity (using antennas with different or orthogonal radiation patterns), polarization diversity (using antennas with different polarizations) etc. These 3 forms of diversity are pictorially represented as shown.




http://users.ece.utexas.edu/~rheath/research/mimo/antenna/

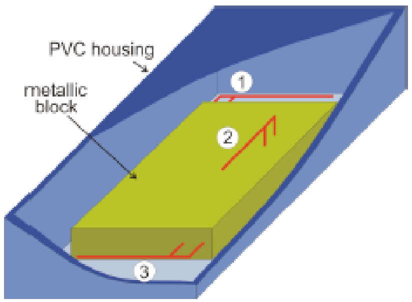



Figure 1: Model of a MIMO handset with three Inverted-F antennas

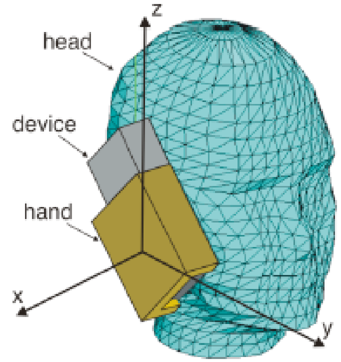
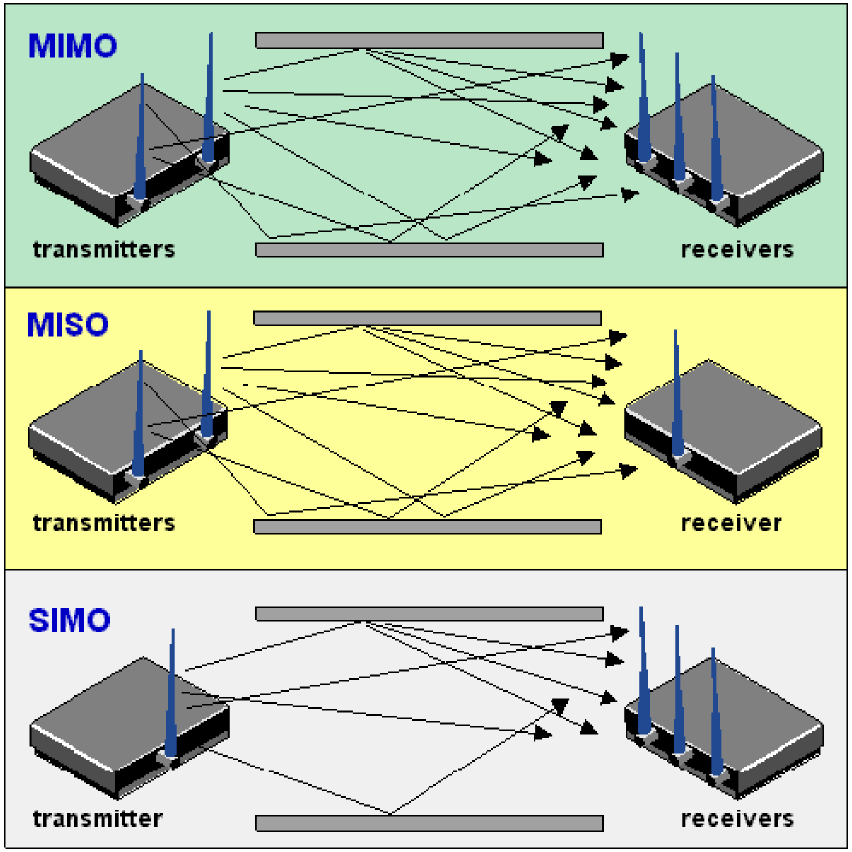



Figure 2: Small MIMO hand-held device attached to a human head and hand

A ideia seria estudar a geometria e colocacao de um conjunto de 3 antenas F-invertidas em um celular para obter a melhor resposta (nao correlacionadas).




Diferentes configuracoes de multiplas antenas. MIMO apresenta a maior complexidade.

Lembrando: SMART Antenas dependem fortemente de processamento; RF torna-se um detalhe.

# Redes de Antenas – para que servem?

Phased array – conjunto de antenas tem as correntes dos elementos variadas inteligentemente de forma a fazer o feixe principal "varrer" (beam steering) o espaco a procura de alvos.

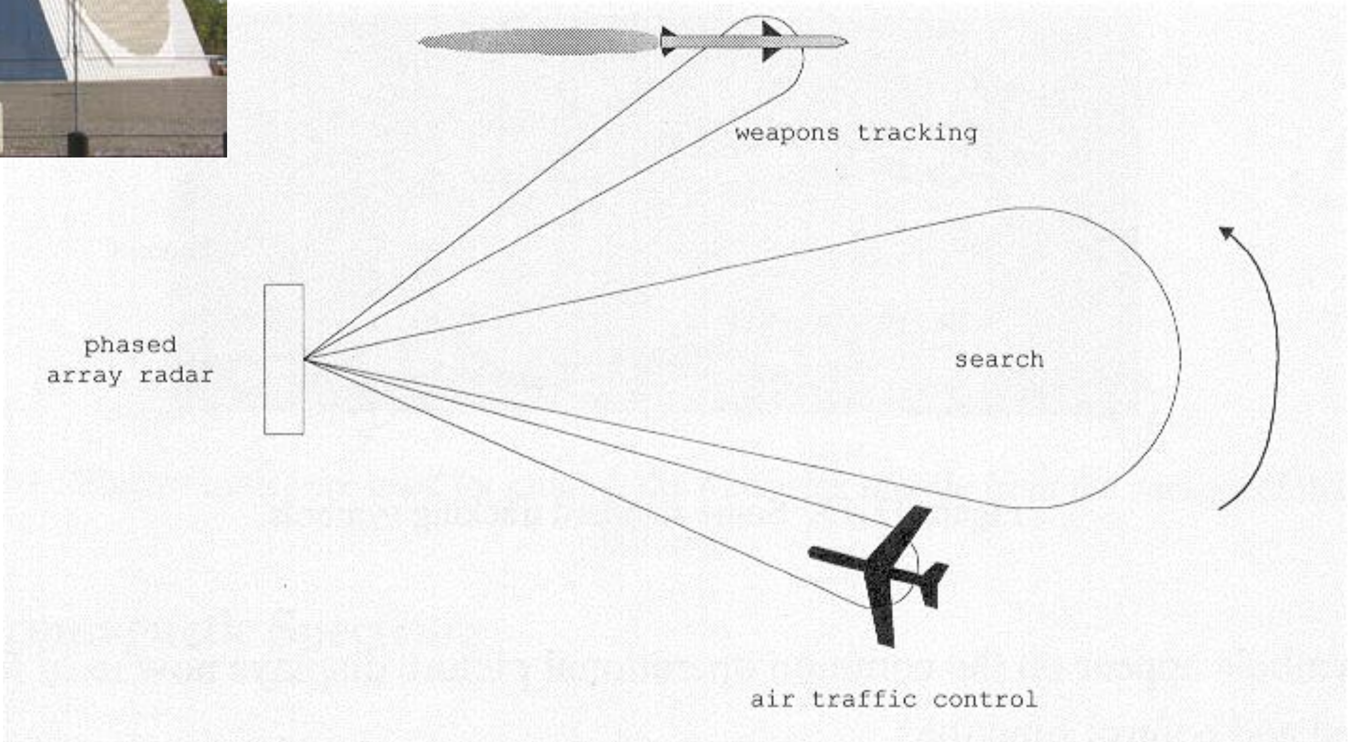



Figure 11-14. Multiple beams of phased array radar.

Uma rede de antenas excitada por um conjunto de phase shifters eletronicamente controladas, para varrer o feixe.

Alternativa: varredura mecanica, onde a antena movimenta-se em torno de um eixo (veja em aeroportos)

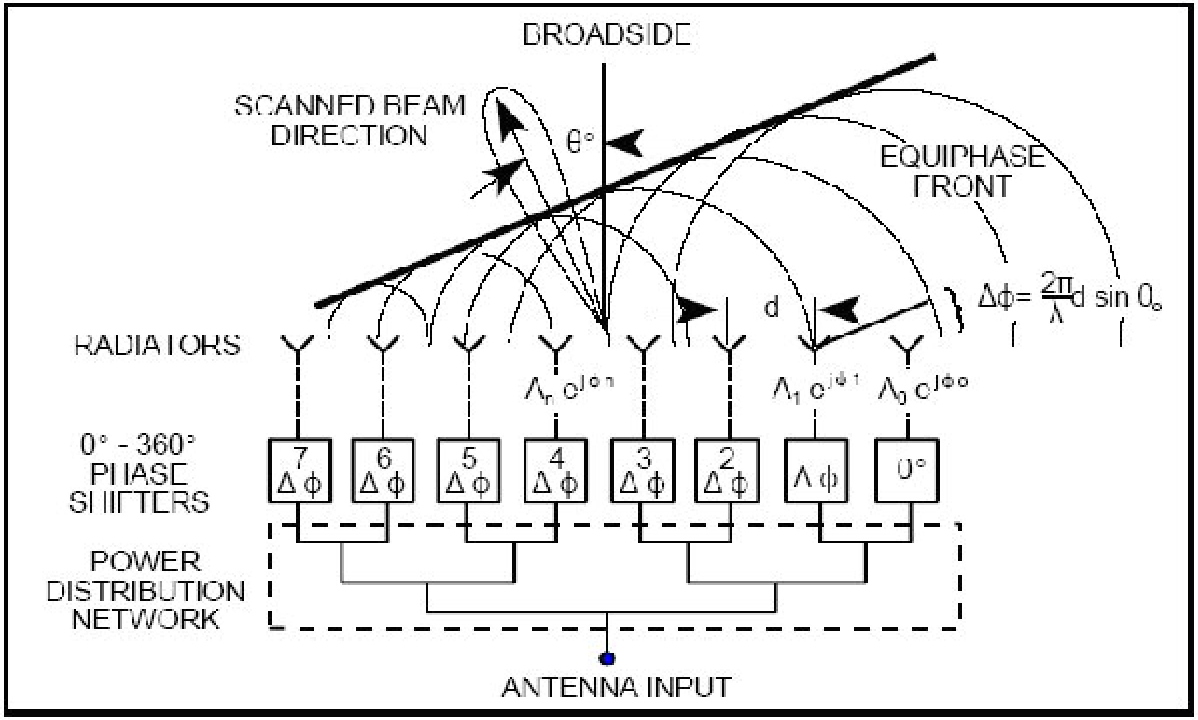
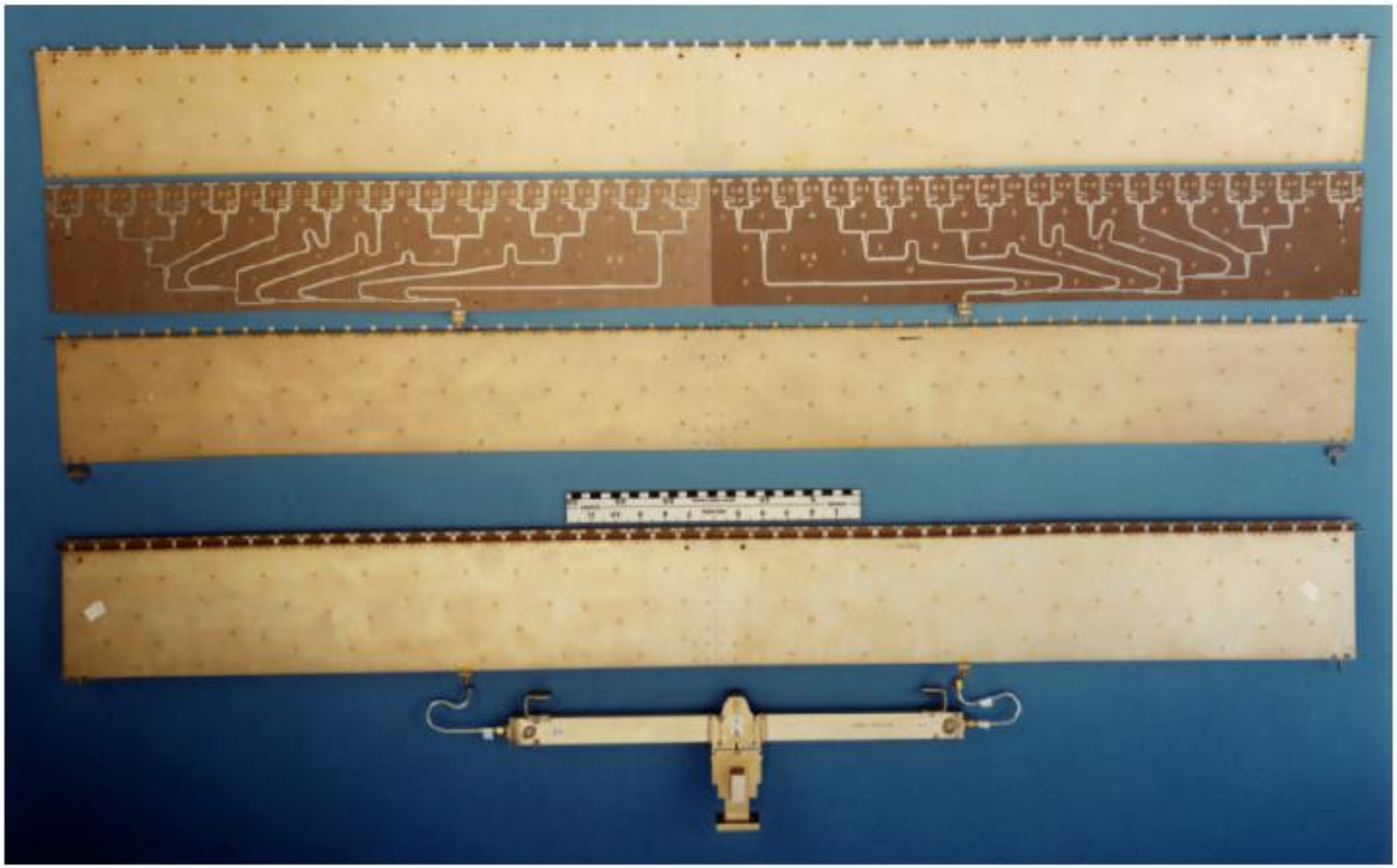


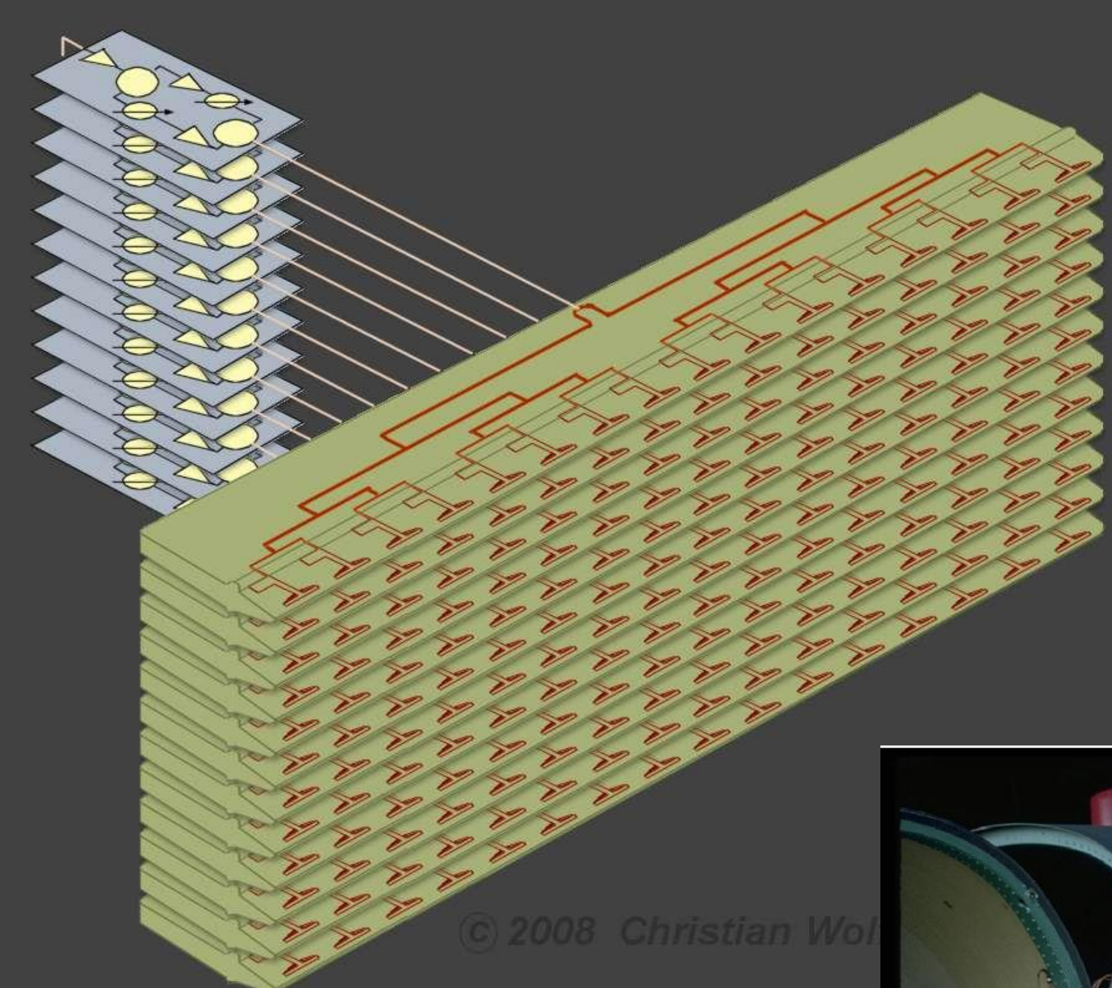

Figure 3. Corporate fed phased array

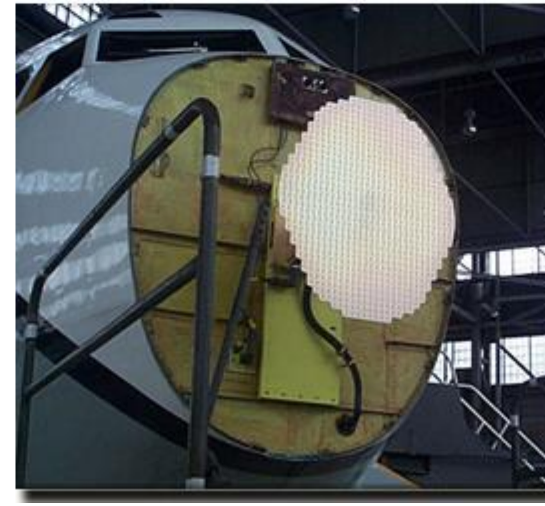
# Printed Circuit Dipole Array



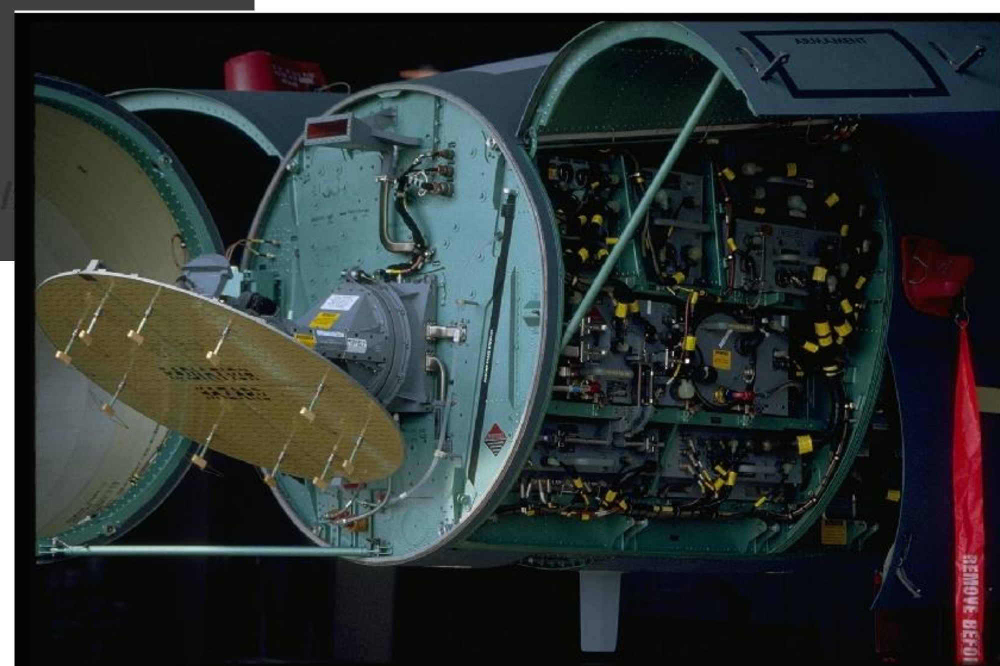
# Corporate Fed Waveguide Array

# Series Fed Waveguide Slot Arrays



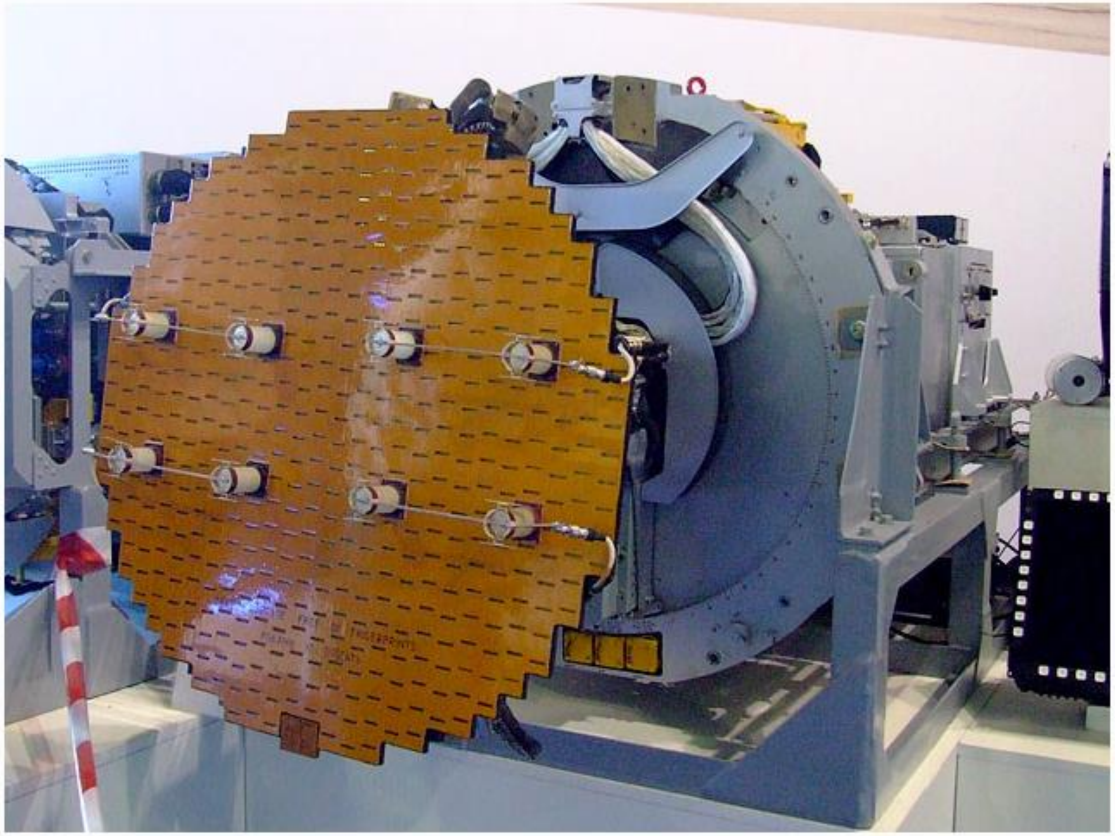


Radar
meteorologico



F-106

**Zhuk-A**



Peak power 2W, 6W dependendo do modelo

Radar air surface (MIG29) detection range of up to 120 km vs a 5 m^2 RCS target for the export variant, and up to 10 targets tracked and up to 4 attacked at once in air to air mode.
In air to surface mode the radar can detect a tank from up to 25 km away and a bridge from 120 km away, a naval destroyer could be detected up to 300 km away and up to two surface targets can be tracked at once. The radar has a weight of 220 kg and a scanning area of +/- 85 degrees in azimuth and +56/-40 in elevation. The antenna is an electronically scanned slotted planar array and has a diameter of 624 mm.

# Redes de Antenas – projeto

Projeto de redes de antenas envolvem conhecimentos complexos, infelizmente nao se trata apenas de agrupar elementos proximos uns dos outros para obtermos ganhos/diretividades maiores.

Exemplo:

1. Lobulos secundarios

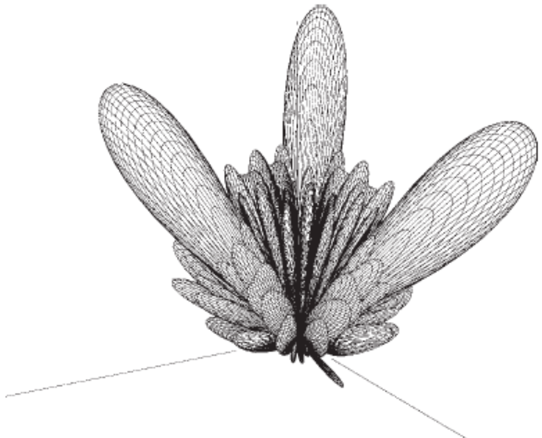


FIGURE 3-21 Spherical radiation pattern of hexagon-array grating lobes.

2. Efeitos de acoplamento mutuo

3. Blind spots – existem angulos de incidencia particulares que fazem com que o coeficiente de reflexao atinja valores proximo a 1- a antena nao entrega energia para o resto do circuito.

# Acoplamento mutuo

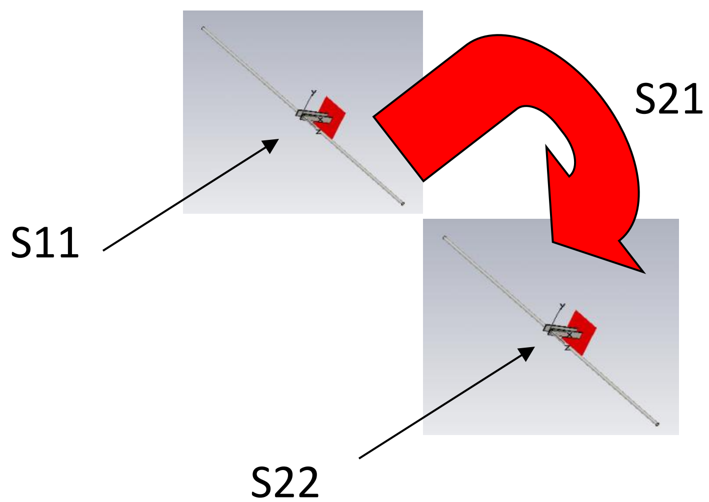
Uma antena que irradie bem, tambem recebe bem.

i.e. <u>desempenho da antena operando como RX deve ser igual a antena operando como TX.</u>

**Principio da RECIPROCIDADE**

Ps. Nao vale para antenas UWB

ASSIM ANTENAS PROXIMAS “CONVERSAM” – ACOPLAMENTO MUTUO




Como mede? S21, Sij

Lembrando que NO MELHOR CASO (antena casada perfeitamente, em termos de impedancia, polarizacao, etc) uma antena RETRANSMITE exatamente a mesma potencia que recebe da fonte.

Assim, se 1W incidir na antena, 0.5W sera entregue para a carga e 0.5W sera reirradiado.

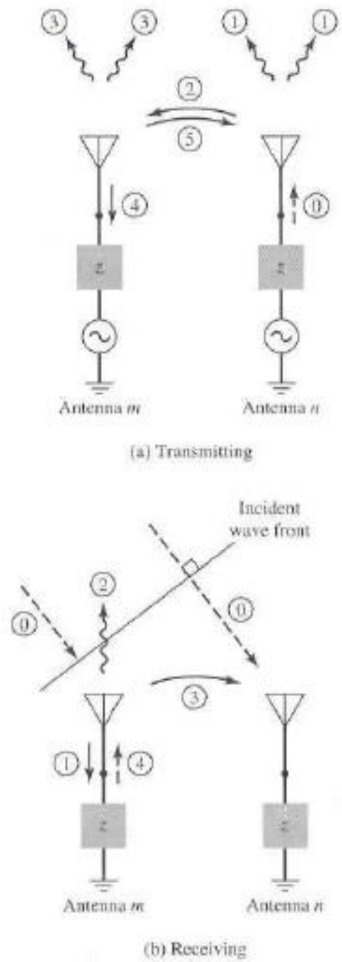
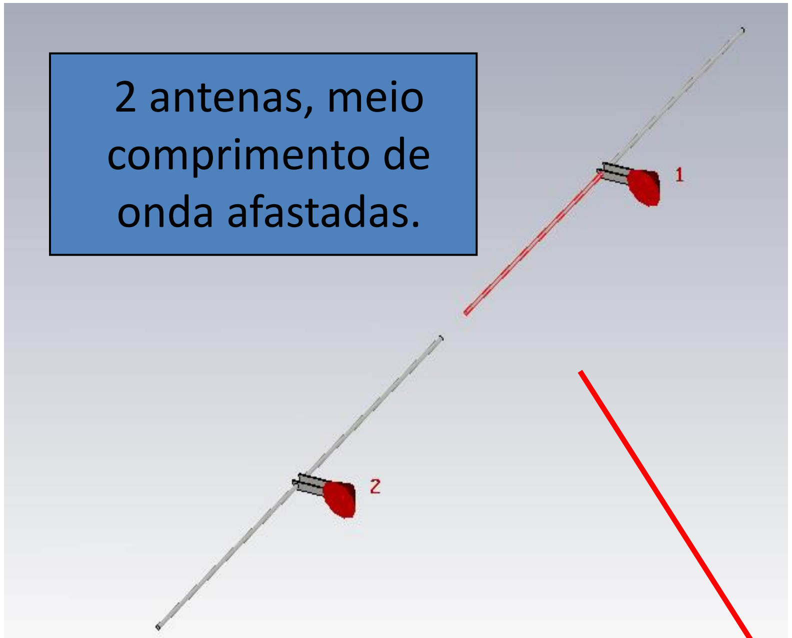


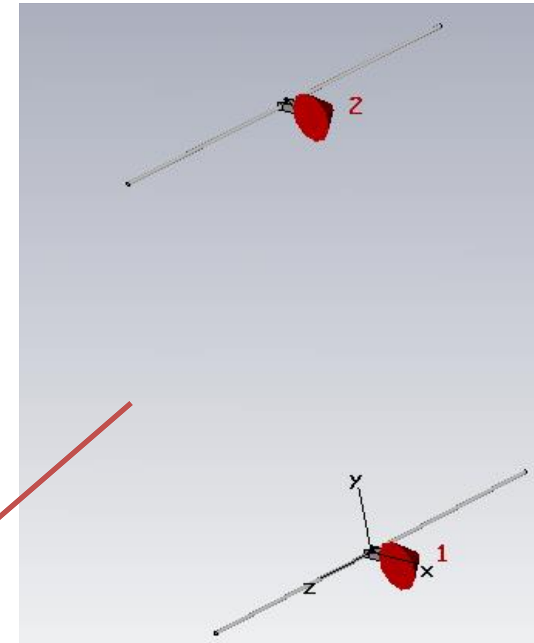

**Figure 8.25** Transmitting mode coupling paths between antennas m and n (Reprinted with permission of MIT Lincoln Laboratory, Lexington, MA).

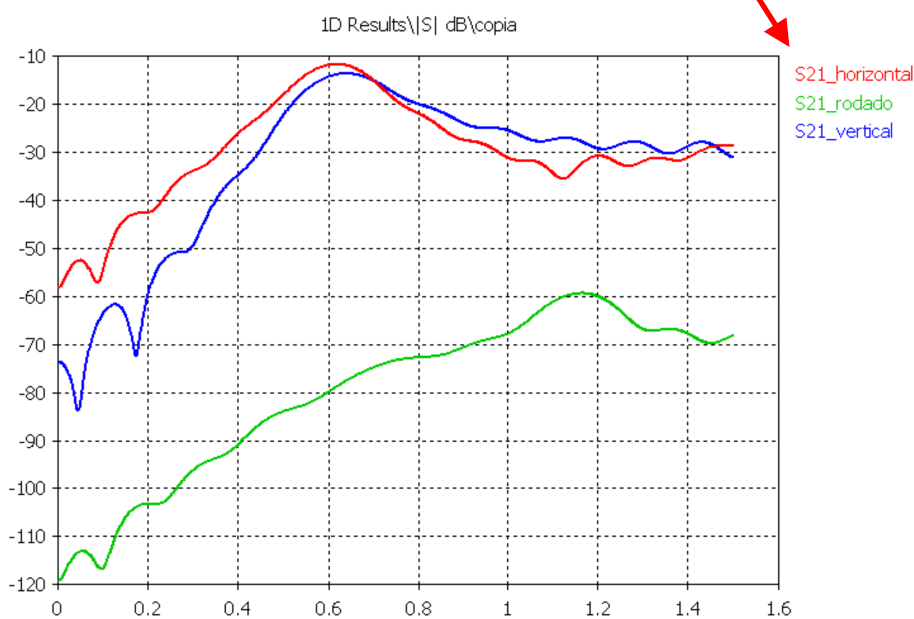
Mecanismo do acoplamento, para os casos TX e RX

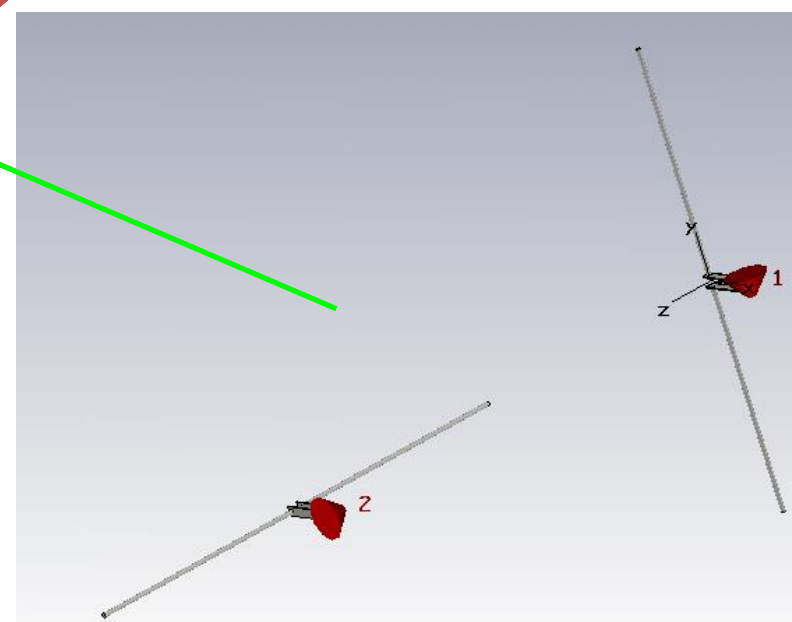
# Acoplamento mutuo

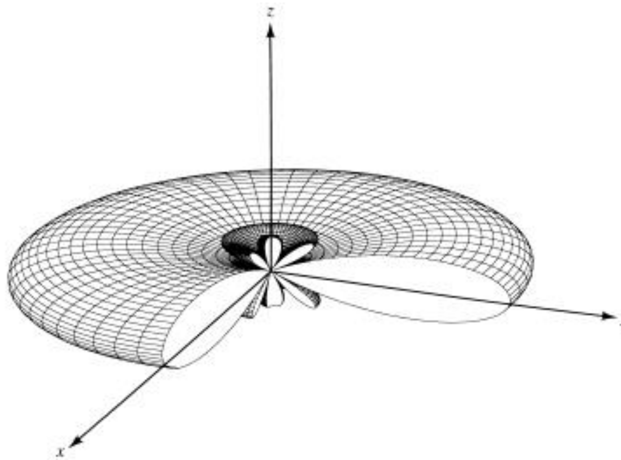
2 antenas, meio comprimento de onda afastadas.



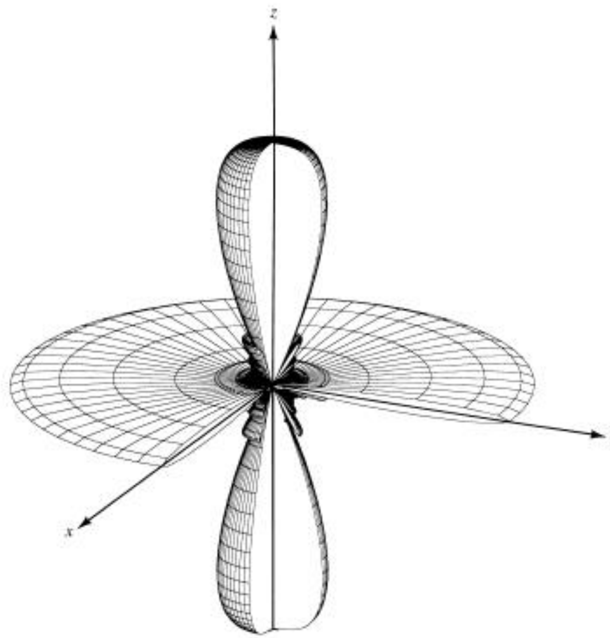



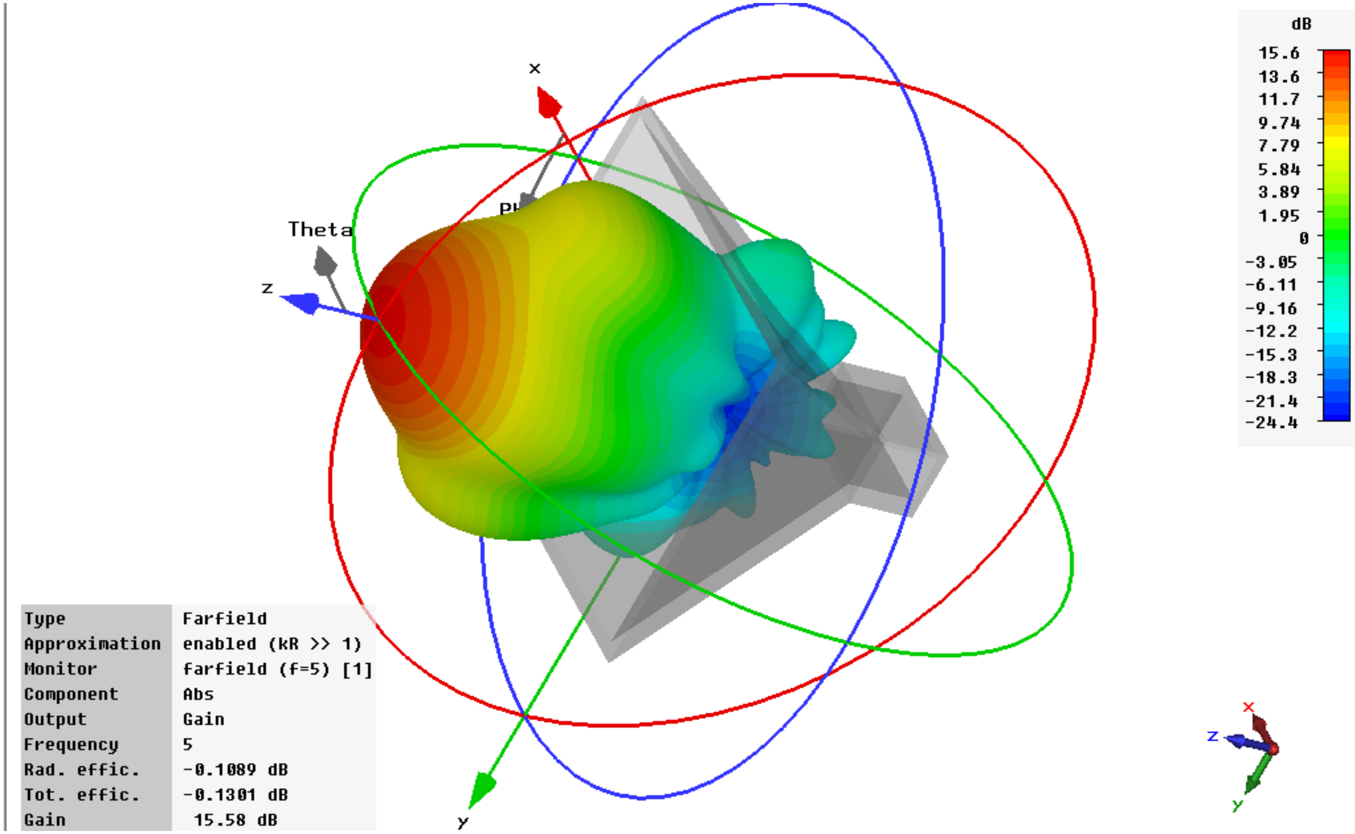



(a) Broadside ($\beta = 0$, $d = \lambda/4$)




(b) Broadside/end-fire ($\beta = 0$, $d = \lambda$)

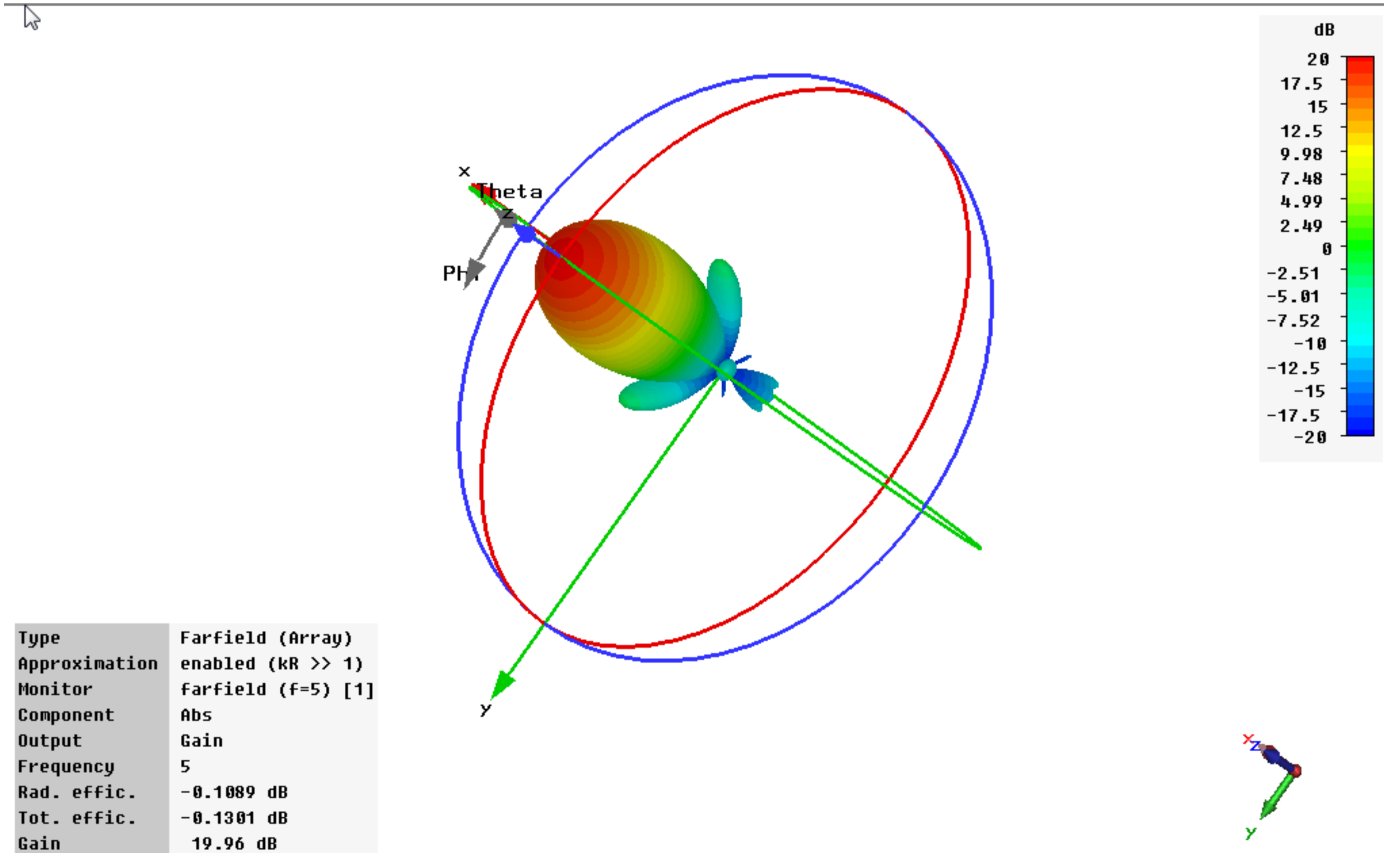
**Figure 6.6** Three-dimensional amplitude patterns for broadside, and broadside/end-fire arrays ($N = 10$).

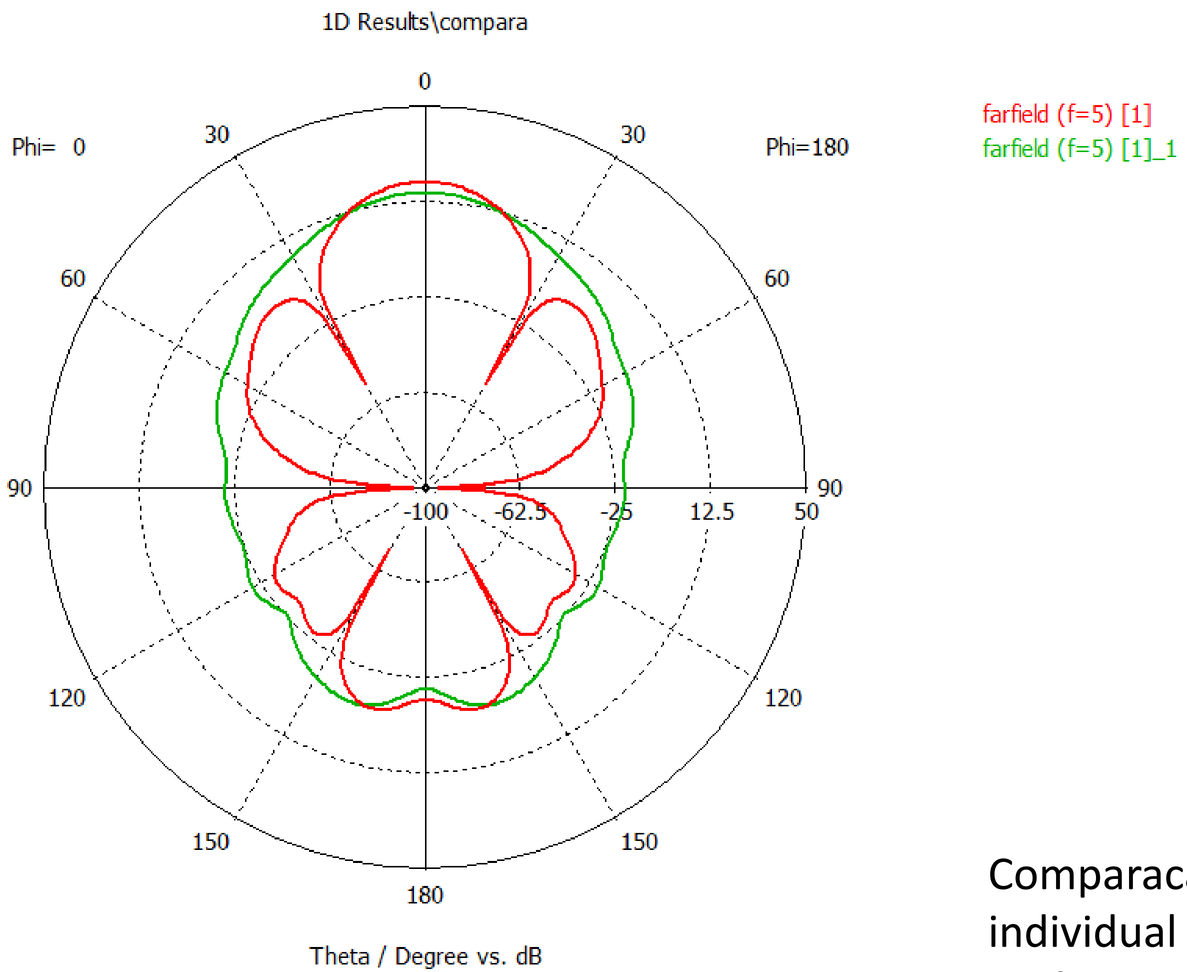



Corneta Individual

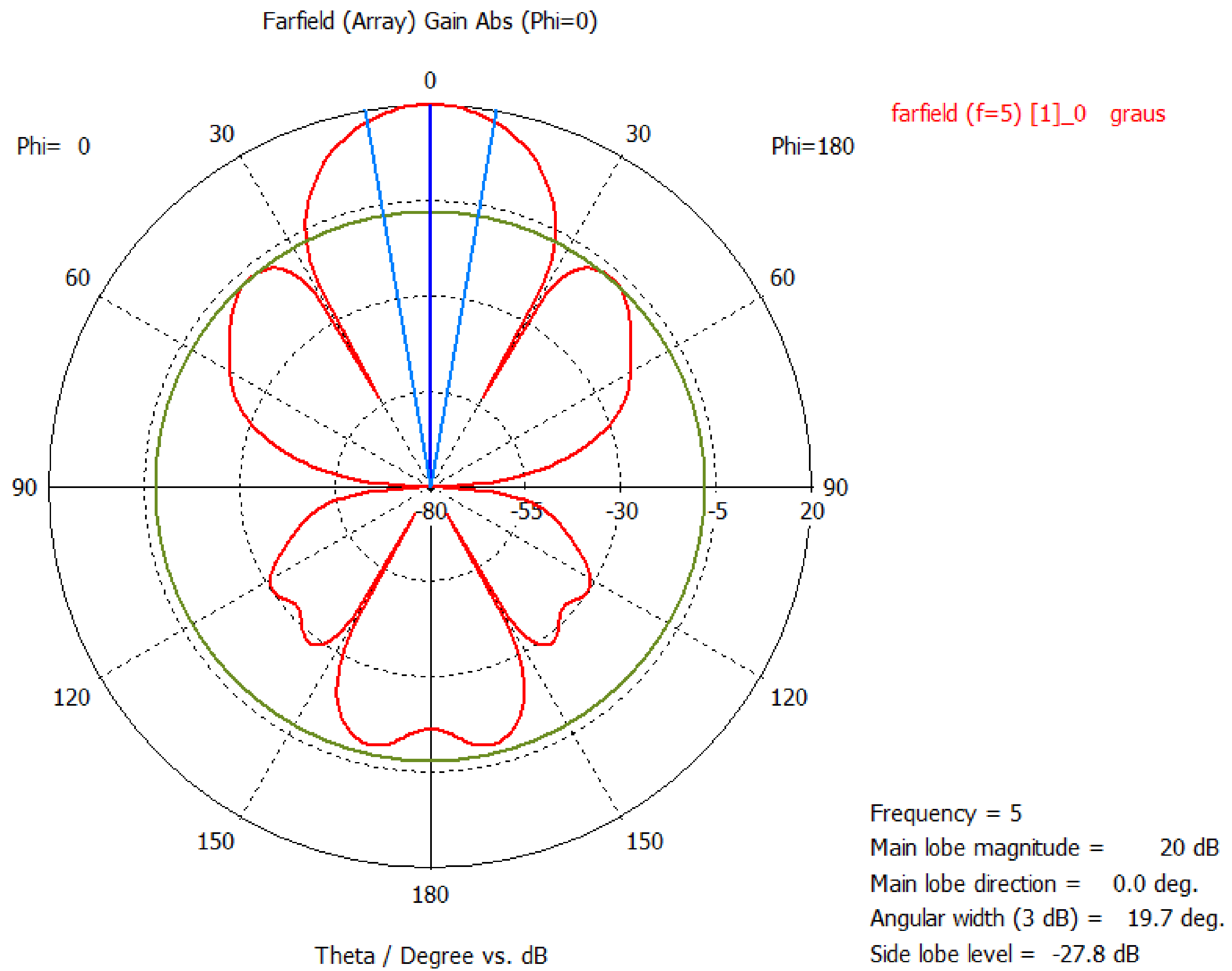
Rede 4 x 4

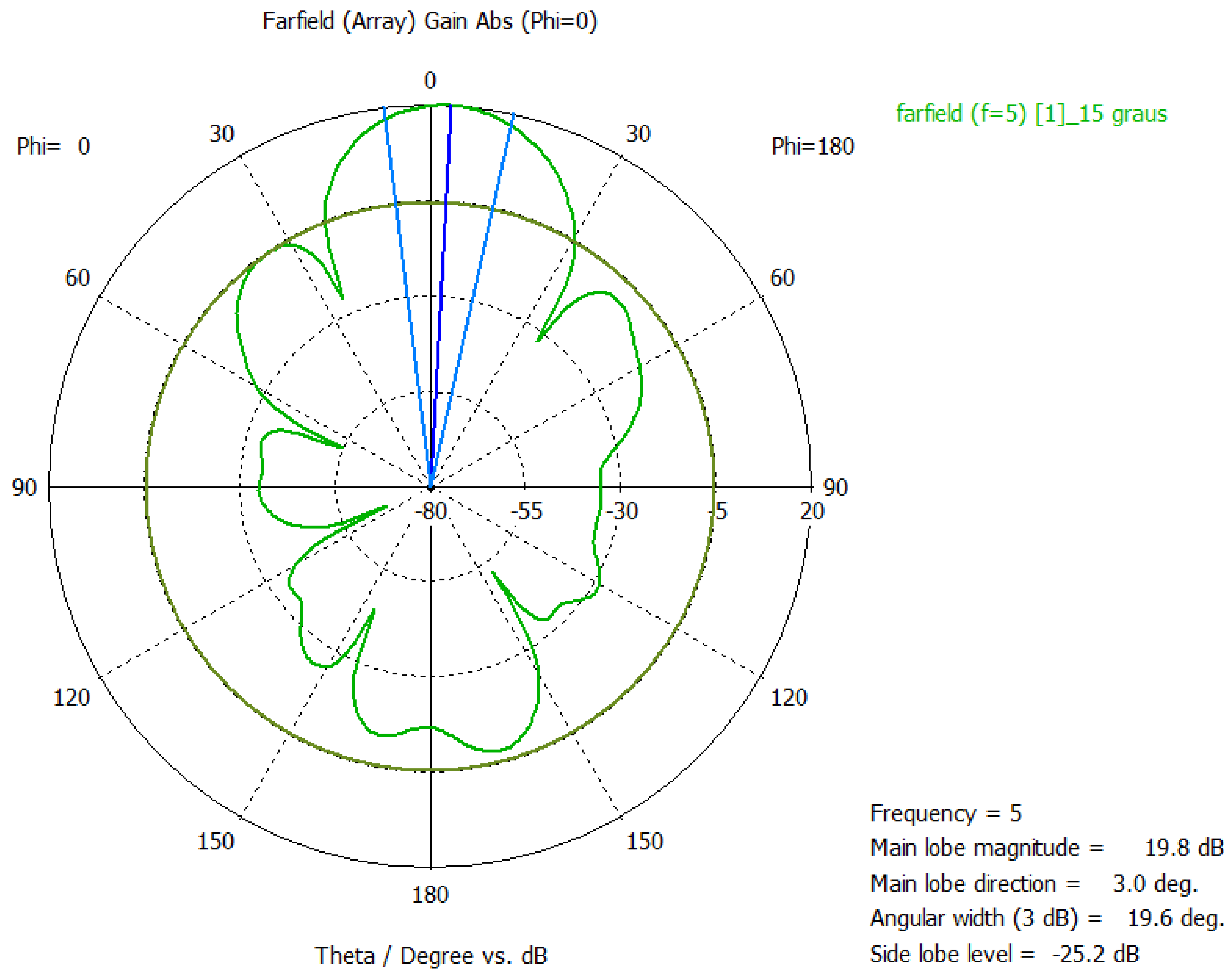
Distancia entre elementos lambda/2 @ 5 GHz  = 6/2 cm



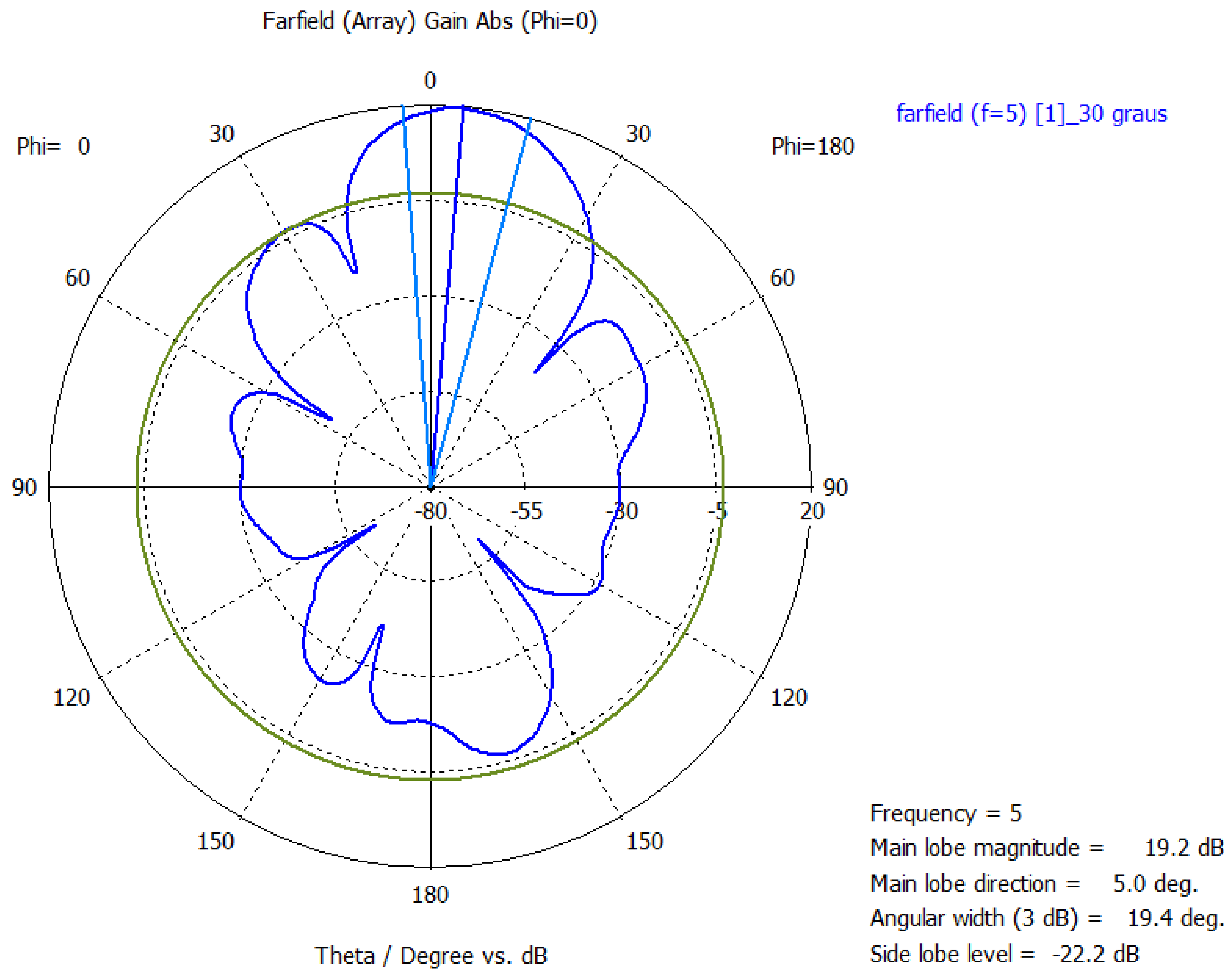



Comparacao antena individual + array 4x4 uniforme

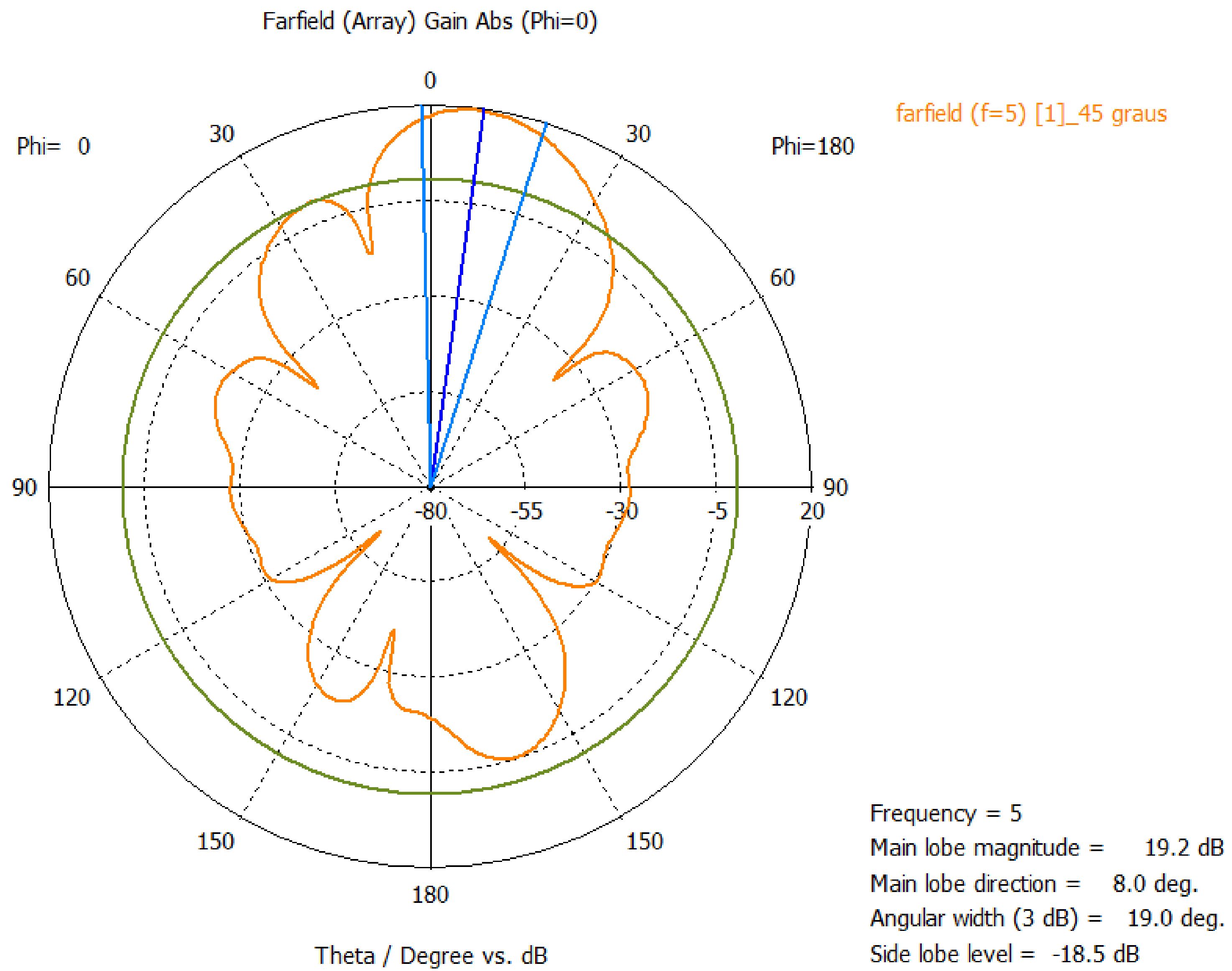

Farfield (Array) Gain Abs (Phi=0)
0
30
30
Phi= 0
Phi=180
farfield (f=5) [1]_0 graus
60
60
90
90
-80
-55
-30
-5
20
120
120
150
150
180
Theta / Degree vs. dB
Frequency = 5
Main lobe magnitude = 20 dB
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 19.7 deg.
Side lobe level = -27.8 dB



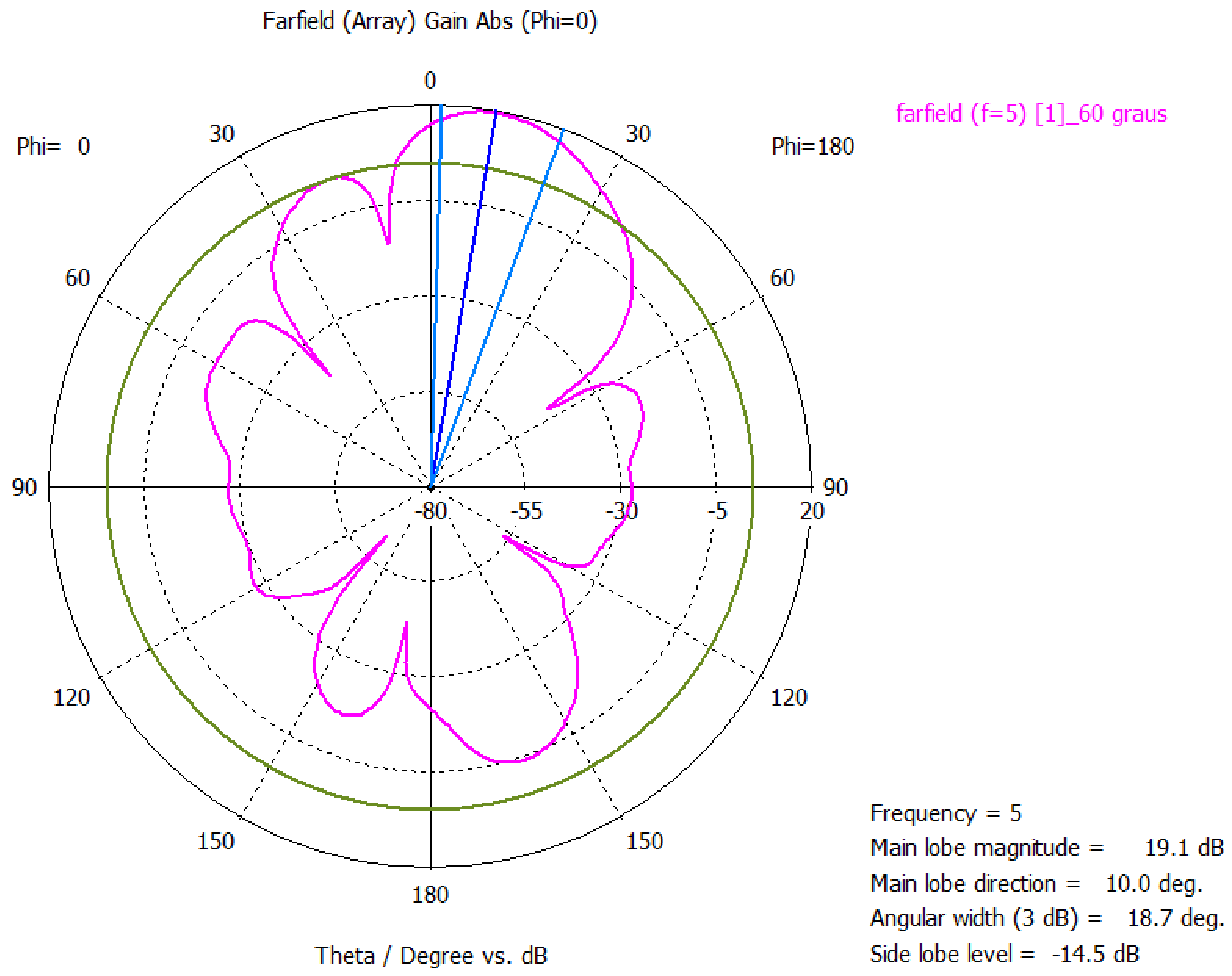
Farfield (Array) Gain Abs (Phi=0)
0
Phi= 0
30
30
Phi=180
farfield (f=5) [1]_15 graus
60
60
90
90
-80
-55
-30
-5
20
120
120
150
150
180
Theta / Degree vs. dB
Frequency = 5
Main lobe magnitude = 19.8 dB
Main lobe direction = 3.0 deg.
Angular width (3 dB) = 19.6 deg.
Side lobe level = -25.2 dB

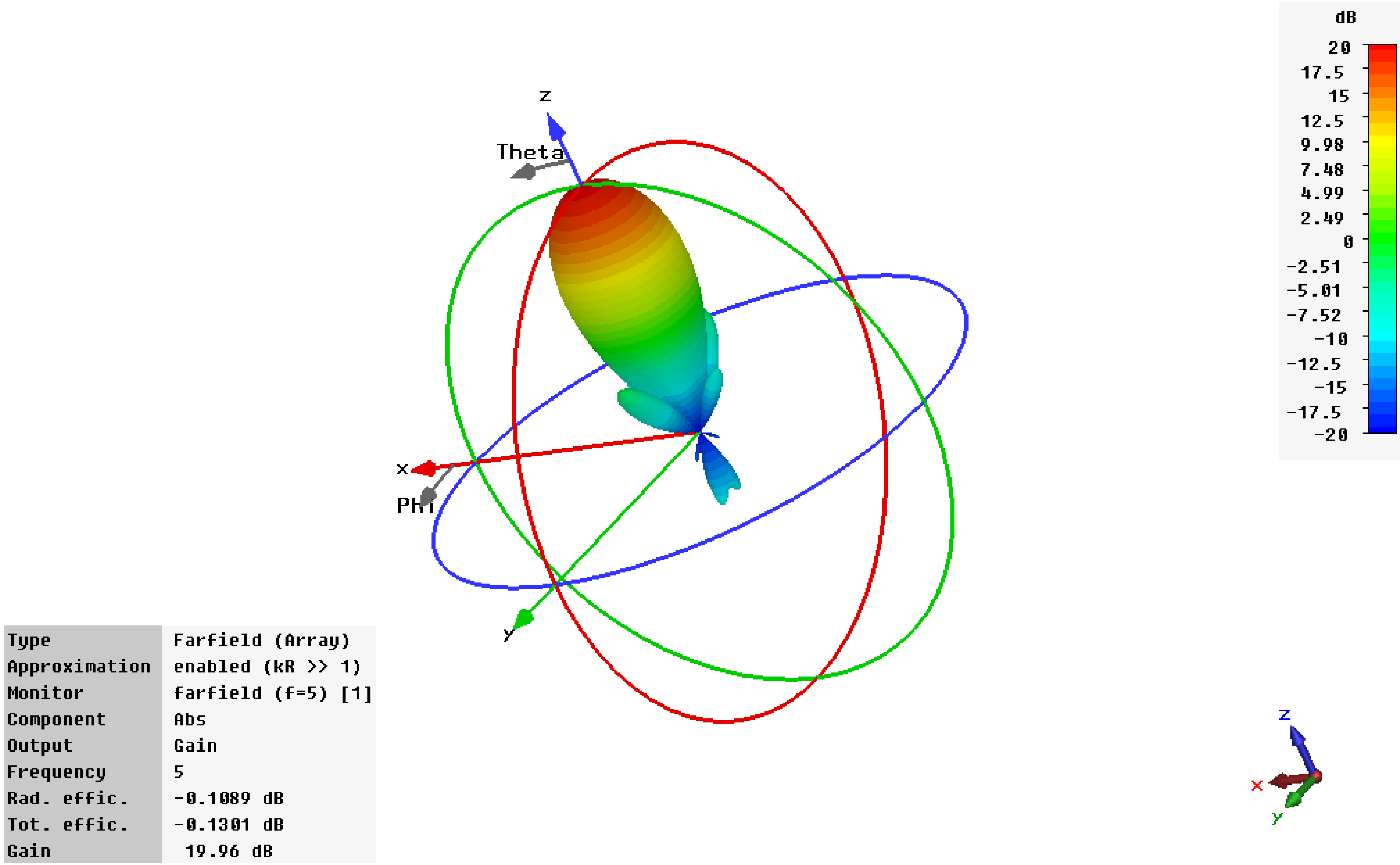


Farfield (Array) Gain Abs (Phi=0)
0
30
30
Phi= 0
Phi=180
farfield (f=5) [1]_30 graus
60
60
90
90
-80
-55
-30
-5
20
120
120
150
150
180
Theta / Degree vs. dB
Frequency = 5
Main lobe magnitude = 19.2 dB
Main lobe direction = 5.0 deg.
Angular width (3 dB) = 19.4 deg.
Side lobe level = -22.2 dB

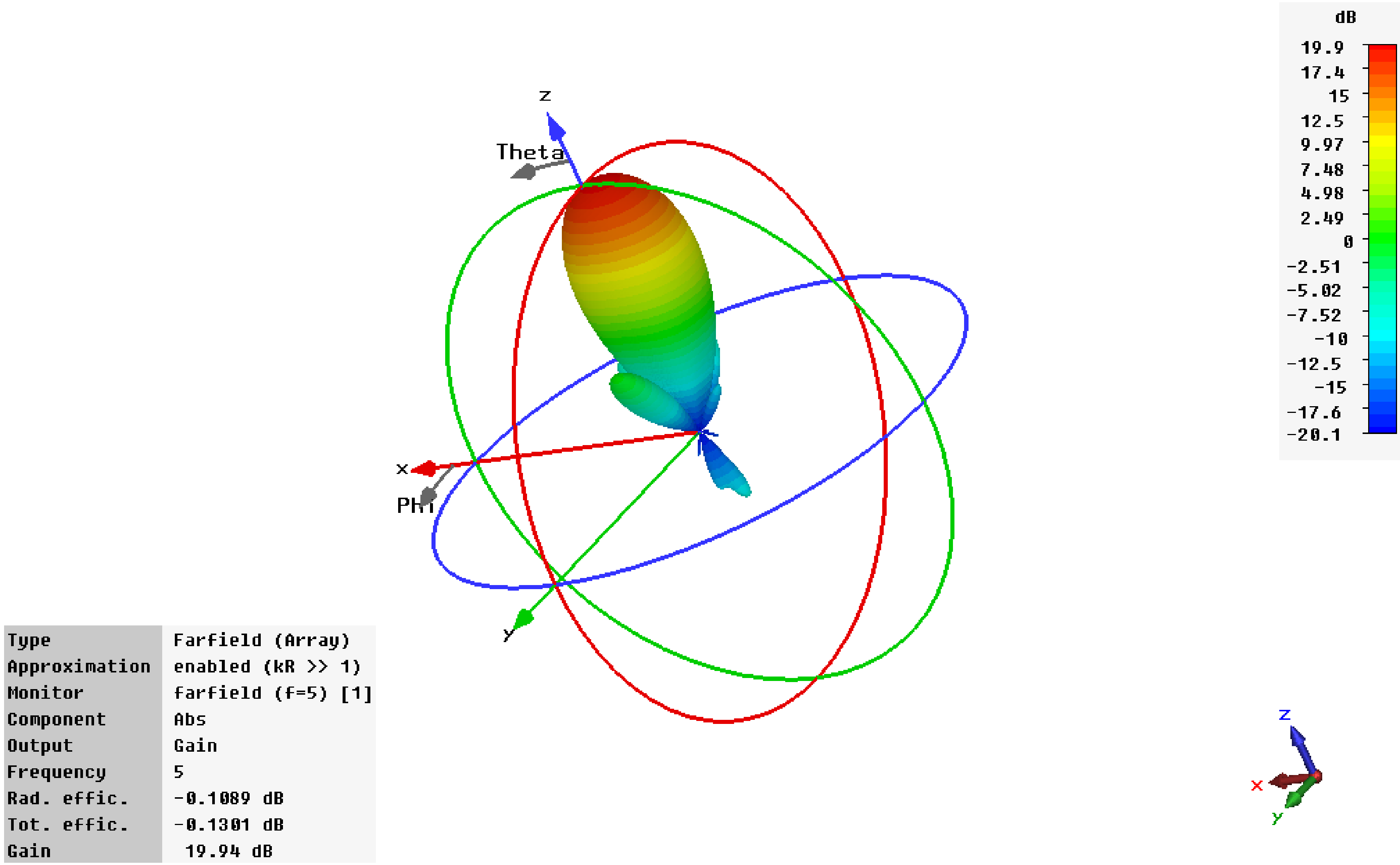


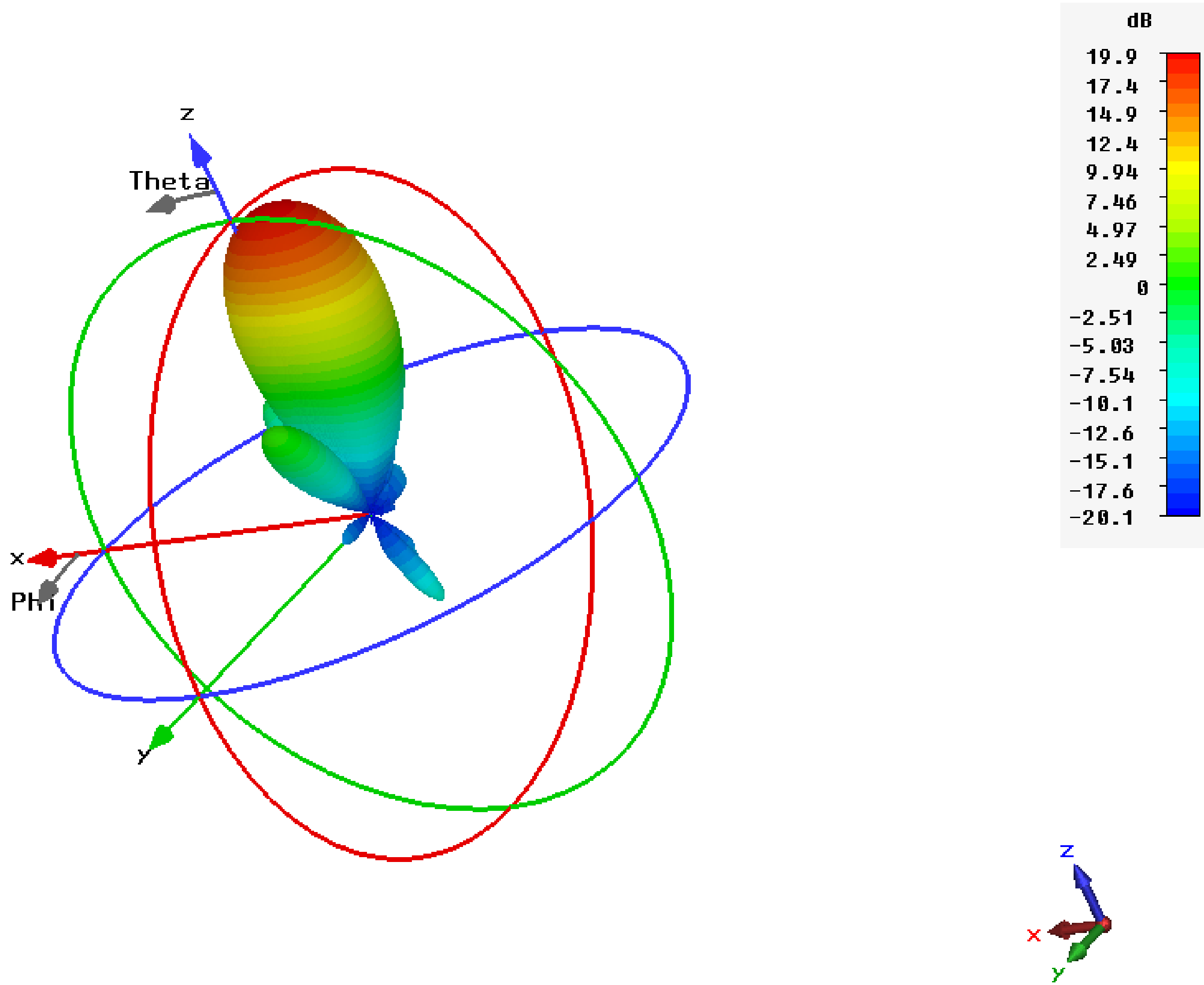
Farfield (Array) Gain Abs (Phi=0)
0
farfield (f=5) [1]_45 graus
Phi= 0
30
30
Phi=180
60
60
90
90
-80
-55
-30
-5
20
120
120
150
150
180
Theta / Degree vs. dB
Frequency = 5
Main lobe magnitude = 19.2 dB
Main lobe direction = 8.0 deg.
Angular width (3 dB) = 19.0 deg.
Side lobe level = -18.5 dB


Farfield (Array) Gain Abs (Phi=0)
0
30
Phi= 0
farfield (f=5) [1]_60 graus
30
Phi=180
60
60
90
90
-80
-55
-30
-5
20
120
120
150
150
180
Theta / Degree vs. dB
Frequency = 5
Main lobe magnitude = 19.1 dB
Main lobe direction = 10.0 deg.
Angular width (3 dB) = 18.7 deg.
Side lobe level = -14.5 dB

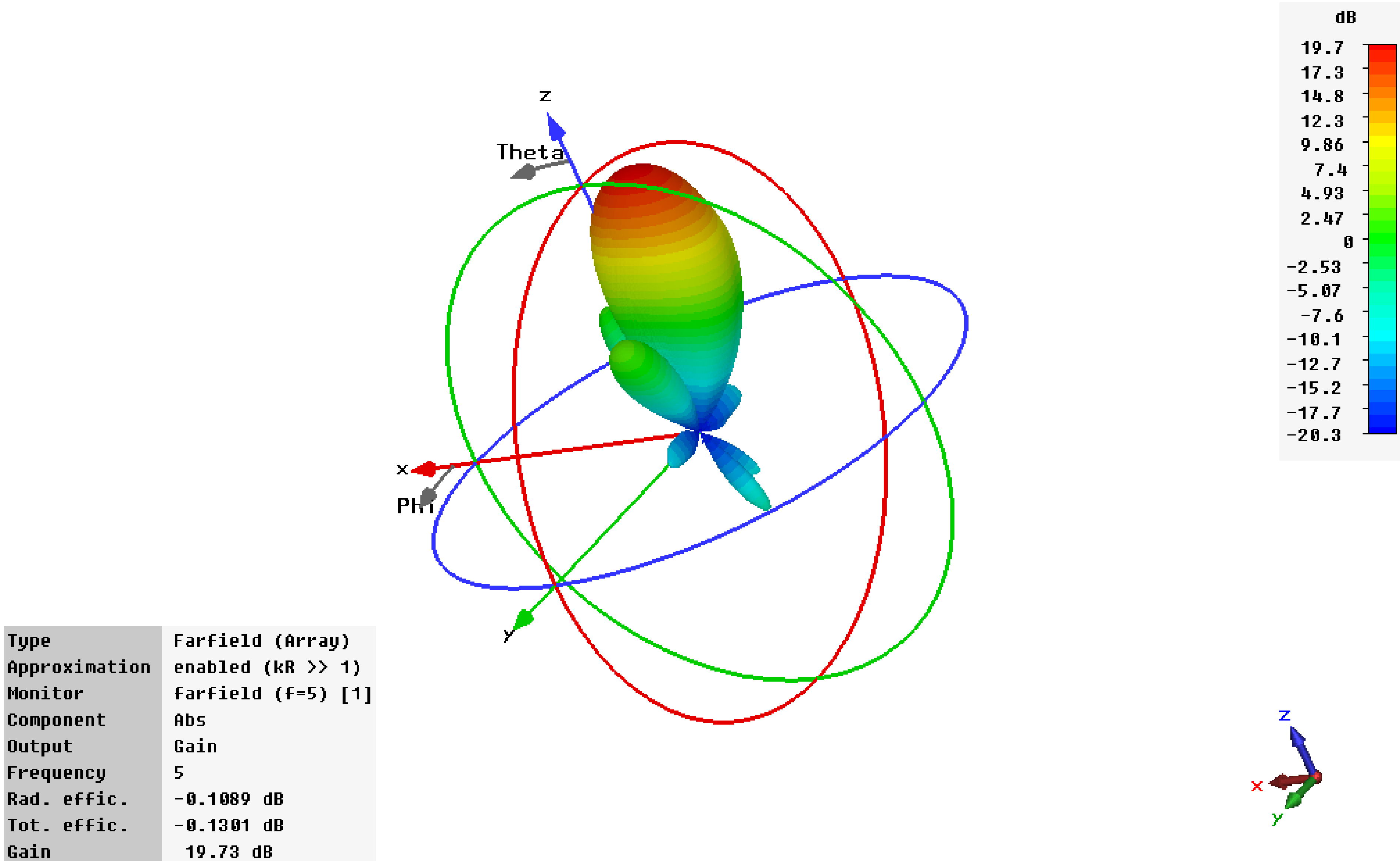


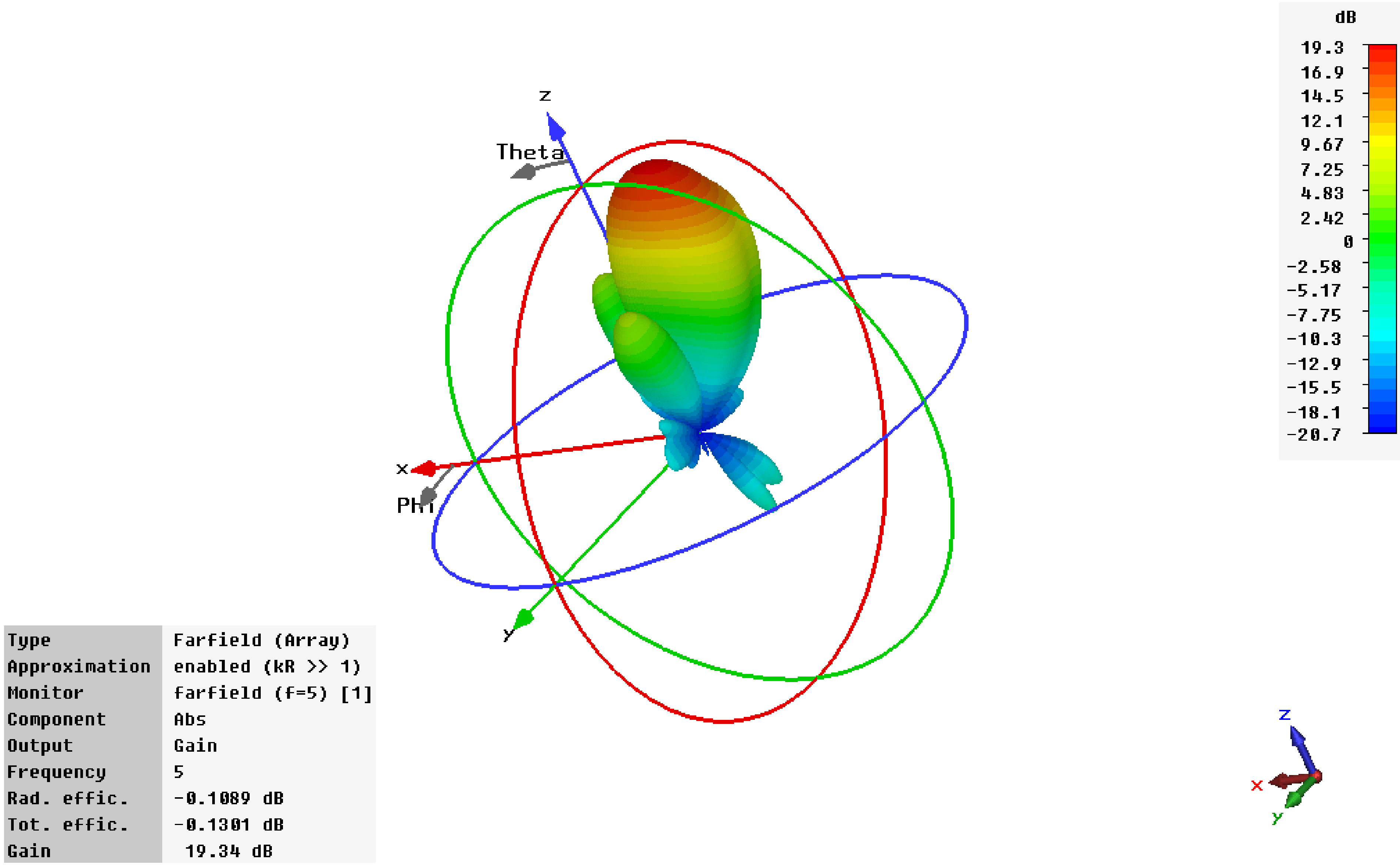
dB
20
17.5
15
12.5
9.98
7.48
4.99
2.49
0
-2.51
-5.01
-7.52
-10
-12.5
-15
-17.5
-20
z
Theta
x
Phi
y
Type Farfield (Array)
Approximation enabled (kR >> 1)
Monitor farfield (f=5) [1]
Component Abs
Output Gain
Frequency 5
Rad. effic. -0.1089 dB
Tot. effic. -0.1301 dB
Gain 19.96 dB


dB
19.9
17.4
15
12.5
9.97
7.48
4.98
2.49
0
-2.51
-5.02
-7.52
-10
-12.5
-15
-17.6
-20.1
z
Theta
x
Phi
y
Type Farfield (Array)
Approximation enabled (kR >> 1)
Monitor farfield (f=5) [1]
Component Abs
Output Gain
Frequency 5
Rad. effic. -0.1089 dB
Tot. effic. -0.1301 dB
Gain 19.94 dB
z
x
y




| | |
|---|---|
| Type | Farfield (Array) |
| Approximation | enabled (kR >> 1) |
| Monitor | farfield (f=5) [1] |
| Component | Abs |
| Output | Gain |
| Frequency | 5 |
| Rad. effic. | -0.1089 dB |
| Tot. effic. | -0.1301 dB |
| Gain | 19.89 dB |


z
Theta
x
Phi
y
dB
19.7
17.3
14.8
12.3
9.86
7.4
4.93
2.47
0
-2.53
-5.07
-7.6
-10.1
-12.7
-15.2
-17.7
-20.3
Type Farfield (Array)
Approximation enabled (kR >> 1)
Monitor farfield (f=5) [1]
Component Abs
Output Gain
Frequency 5
Rad. effic. -0.1089 dB
Tot. effic. -0.1301 dB
Gain 19.73 dB
z
x
y


z
Theta
x
Phi
y
dB
19.3
16.9
14.5
12.1
9.67
7.25
4.83
2.42
0
-2.58
-5.17
-7.75
-10.3
-12.9
-15.5
-18.1
-20.7
Type Farfield (Array)
Approximation enabled (kR >> 1)
Monitor farfield (f=5) [1]
Component Abs
Output Gain
Frequency 5
Rad. effic. -0.1089 dB
Tot. effic. -0.1301 dB
Gain 19.34 dB
z
x
y