REFLECTARRAY ANTENNAS: ANALYSIS, DESIGN AND APPLICATIONS

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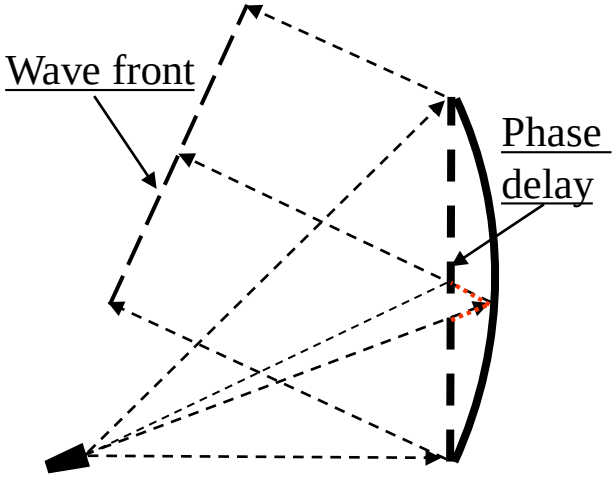
INTRODUCTION

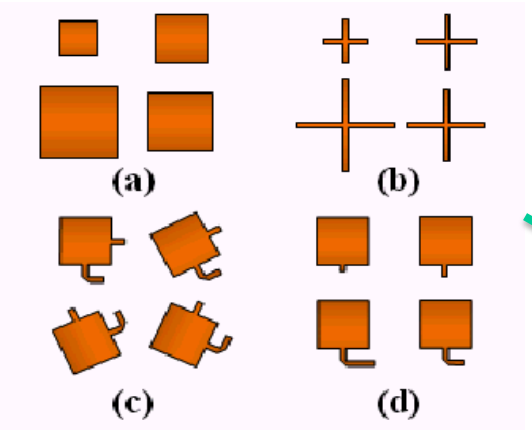
REFLECTARRAY:

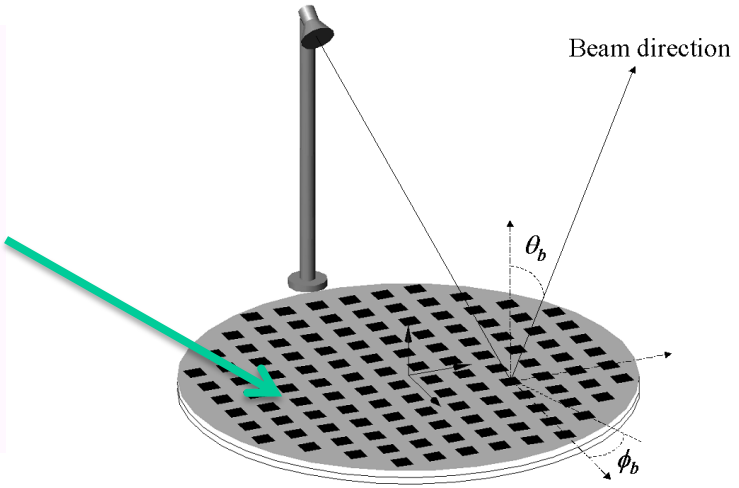
A planar array of microstrip patches on a grounded substrate with a certain tuning to produce a phase sift



Phase Control (at each element):

- Stubs of different length
- Varying the patch size
- Sequential rotation

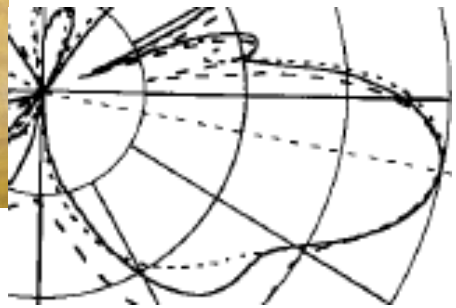


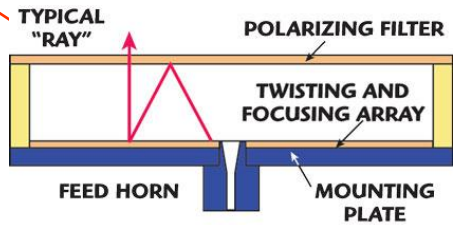


APPLICATIONS

Reflectarrays for base stations

Space Applications, Radar





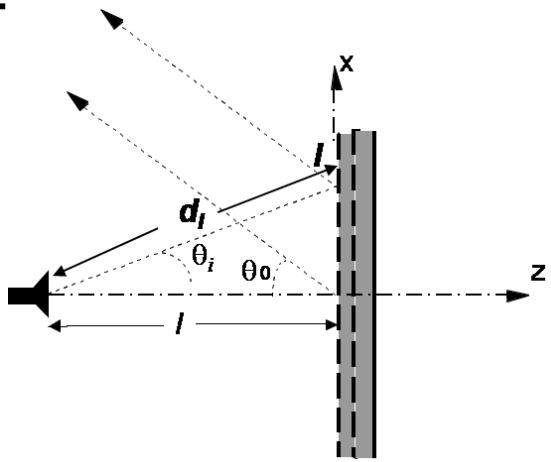
APPLICATIONS

- Contoured-beam reflectarrays for Direct Broadcast Satellite applications
- Dual reflector with grid subreflector (folded reflectarrays):
  - Point-to-Multipoint applications
  - Automotive radar
- Multi-beam reflectarrays:
  - Synthetic Aperture Radar (SAR)
  - Point-to-Multipoint antennas
- Millimeter-wave applications.
- Dual reflector configuration:
  - Tx-Rx space antennas in Ku-band (low cross-pol., beam shaping, beam reconfiguration)

REQUIRED PHASE-SHIFT

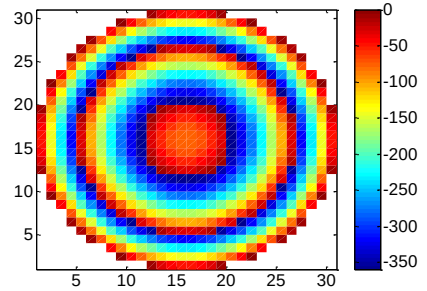
- To radiate a focused beam in the direction (θ_0 ϕ_0), the reflected field must have a progressive phase distribution:

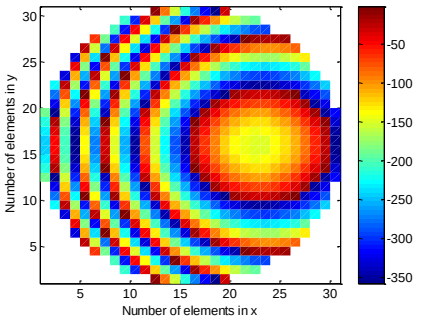
$$Phase(x,y) = -K_0 \sin\theta_0 (x\cos\varphi_0 + y\sin\varphi_0)$$



- The phase-shift to be implemented on each reflectarray element:
  (any value from 0º to –360º)

$$\varphi(x_l, y_l) = K_0 \left[d_l - sin\theta_0 (x_l \cos\varphi_0 + y_l \, sin\varphi_0) \right]$$

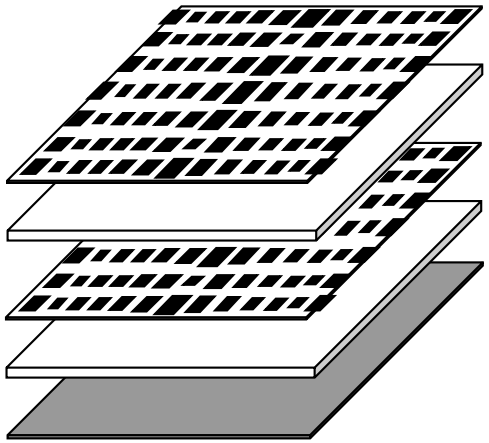


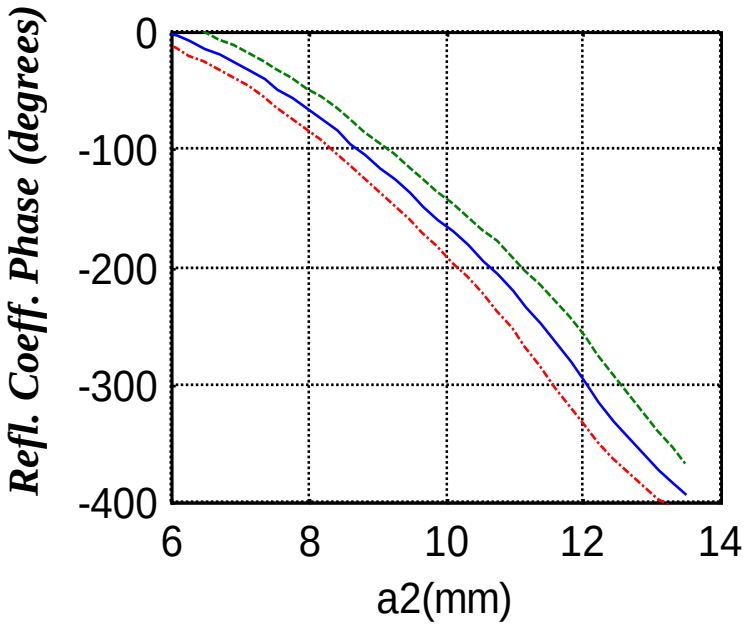


- To scan the beam, the phase-shift must be changed in a range of 360º

PHASE CONTROL BY ADJUSTING PATCH SIZE

(2-stacked array)





Advantages:

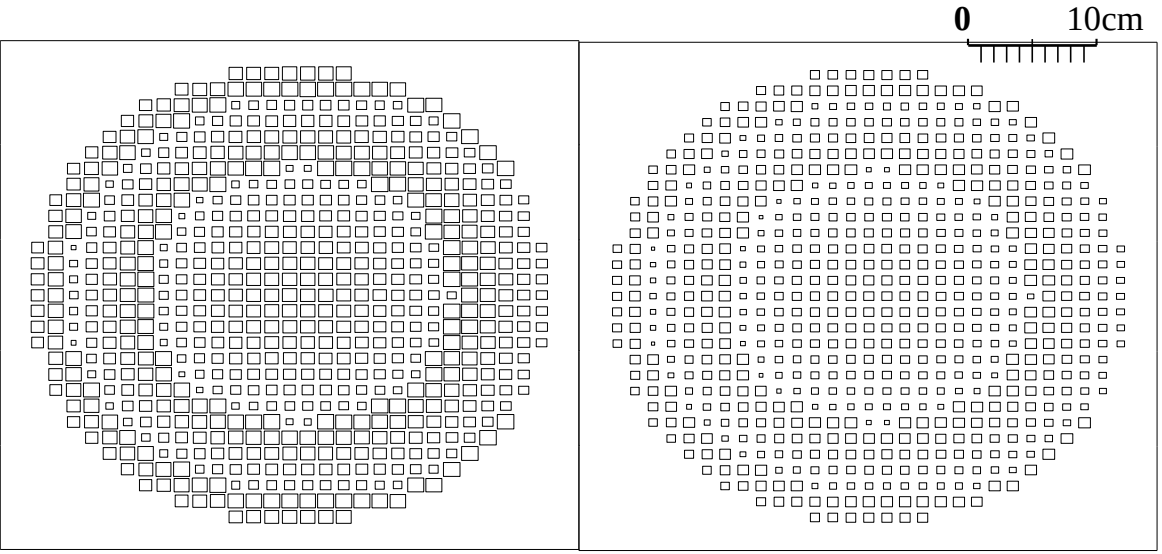
- **Large element bandwidth**
- **More linear**
- **Range: > 360º**

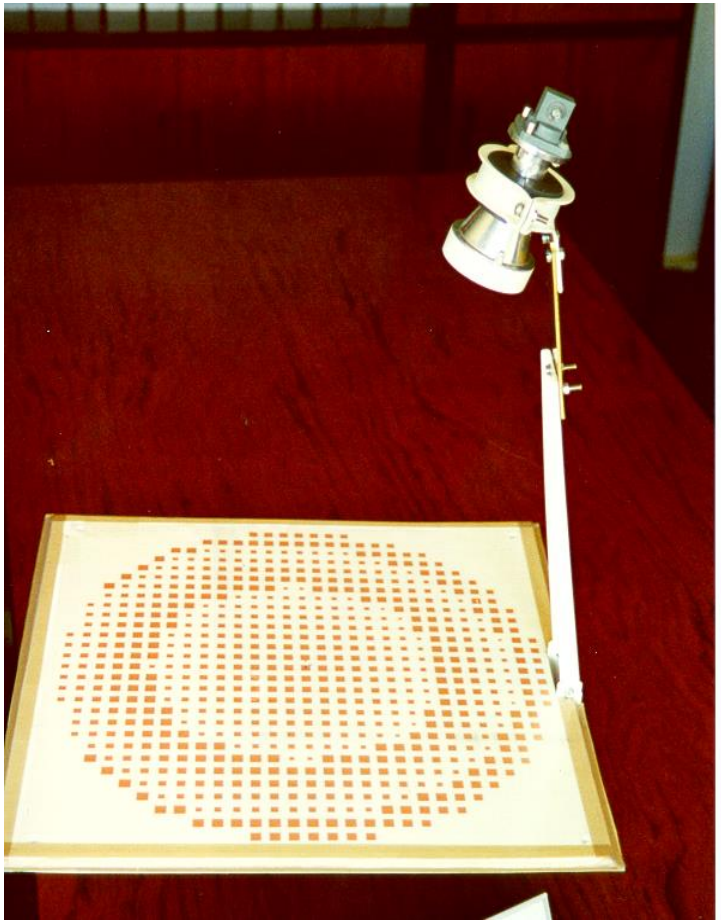
Infinite array, **a**=14mm., εr = 1,05, **h**=3mm.

11,5 (-----), 12 (——) 12,5 (-·-·-) GHz.

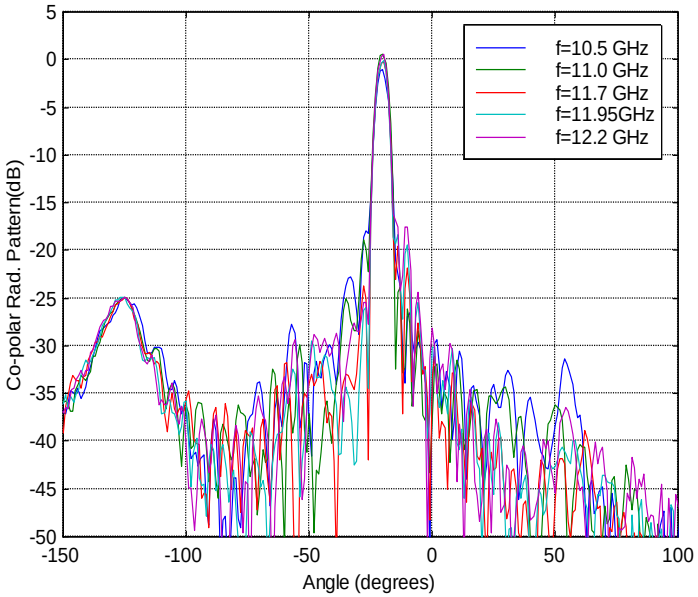
40-cm REFLECTARRAY USING 2 LAYERS OF VARYING-SIZED PATCHES

- Frequency: 11.95GHz
- Polarization: dual linear
- Feed position:
  $x_f = -116$, $y_f = 0$, $z_f = 340$mm
- Separator: 3mm thick Rohacell
- Periodic cell: 14x14mm

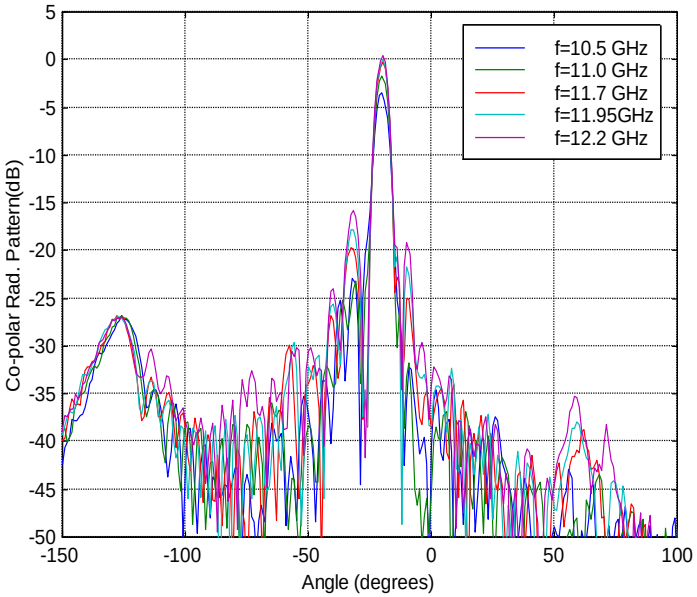




MEASURED RADIATION PATTERNS VS. FREQUENCY



E (theta) Ex

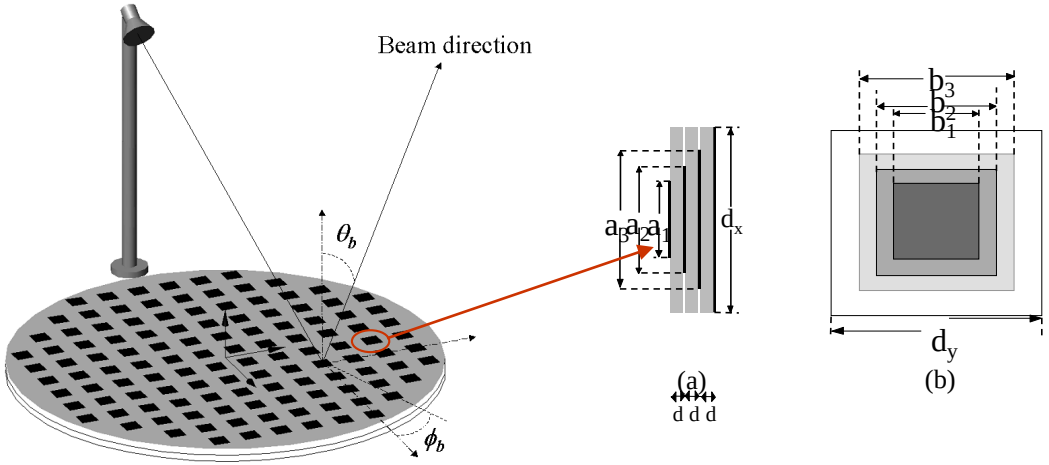


E (phi) Ey

Gain: 31±0.15dB in the 11.5 - 12.4GHz. band

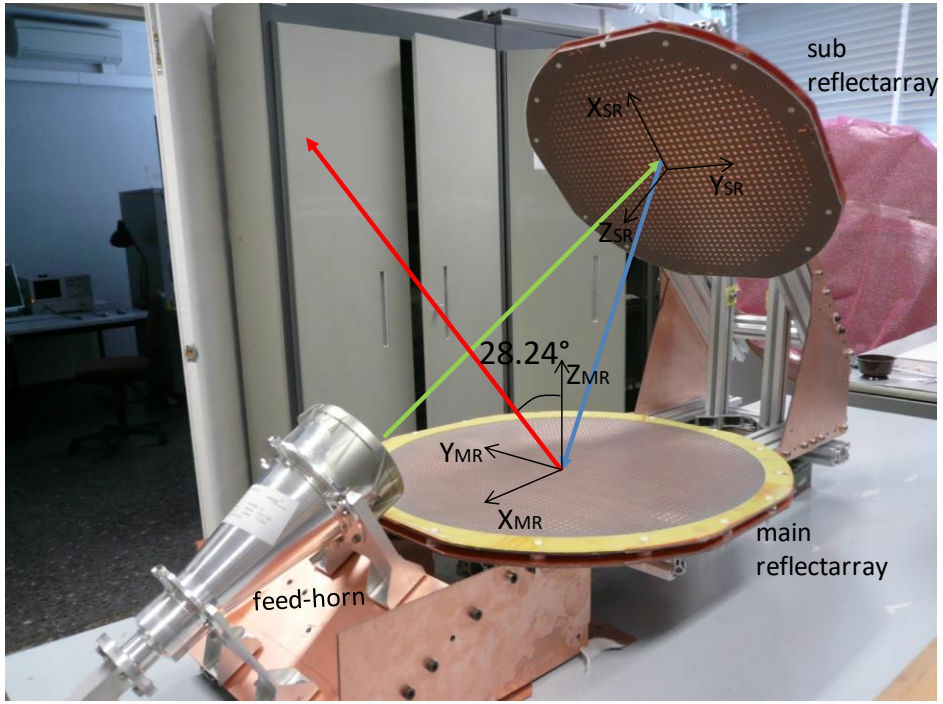
REFLECTARRAY ANTENNAS FOR DBS

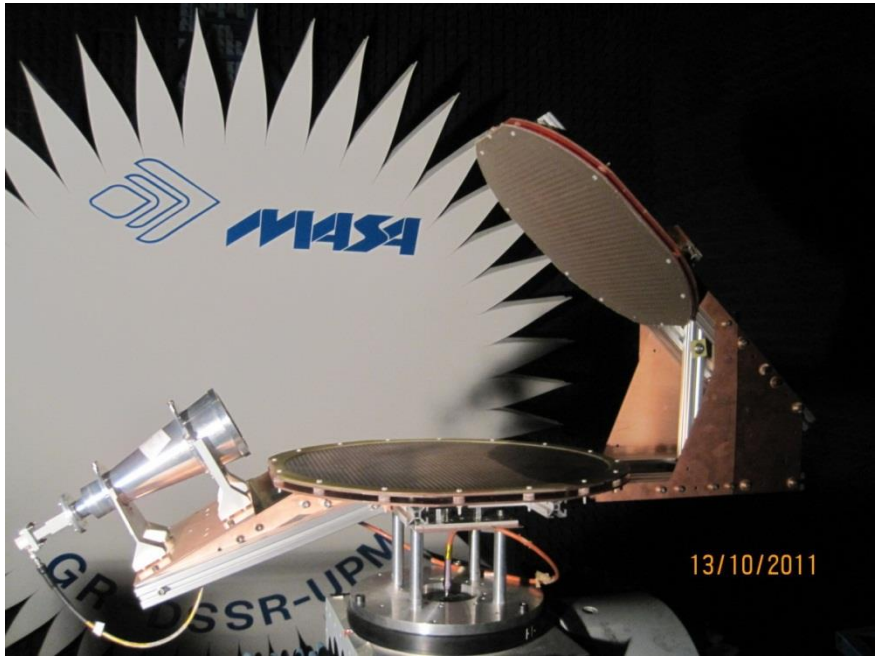
- Reflectarrays can easily generate contoured beams
  - by the appropriated phase-shift on the reflectarray
  - A phase-only pattern synthesis[1] is used
- A possible application for reflectarrays is in space antennas for DBS (as alternative to shaped reflectors)
- Bandwidth can be improved by using stacked varying-sized patches as reflectarray elements

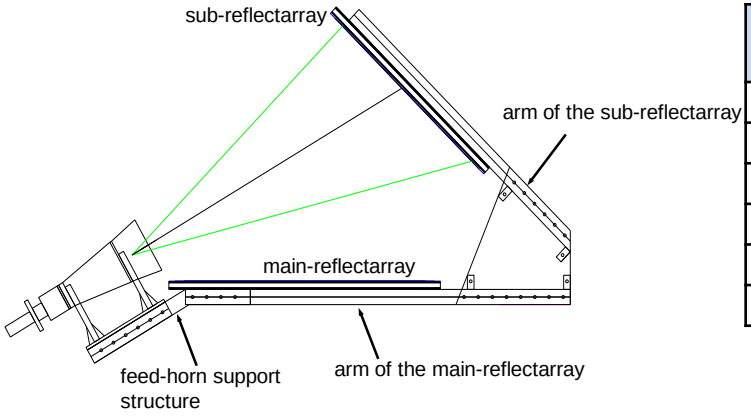


[1] O. M. Bucci, G. Franceschetti, G. Mazzarella, and G. Panariello, "Intersection approach to array pattern synthesis," *IEE Proceedings*, vol. 137, pt. H, no. 6, pp. 349-357, Dec. 1990.

DUAL-REFLECTARRAY ANTENNA







Frequency(GHz)	Sim. Gain (dBi)	Mea.Gain (dBi)	Sim.XPD min(dB)	Mea.XPD min (dB)
12.2	32.99	32.12	33.84	30.01
13.75	34.44	33.94	36.58	32.43
14.0	34.65	34.56	35.77	37.12
14.25	34.78	-	35.17	-
14.5	-	34.53	-	34.89
15	-	34.51	-	33.39

0.09 dB

>30 dB

gea Grupo de Electromagnetismo Aplicado

UPM

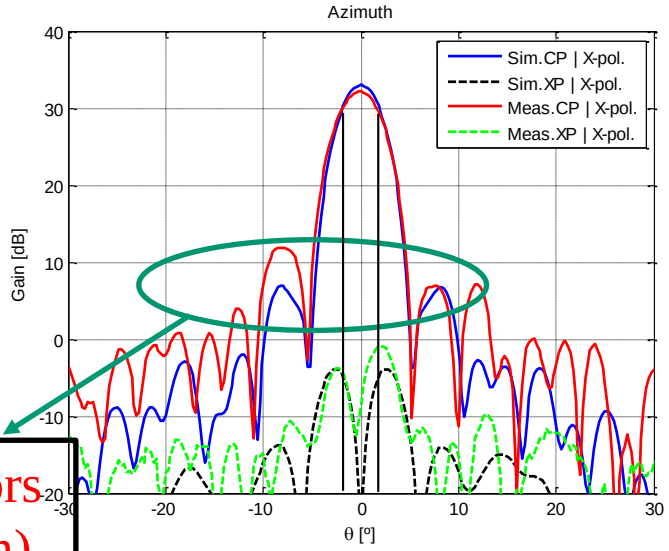
DUAL-REFLECTARRAY ANTENNA

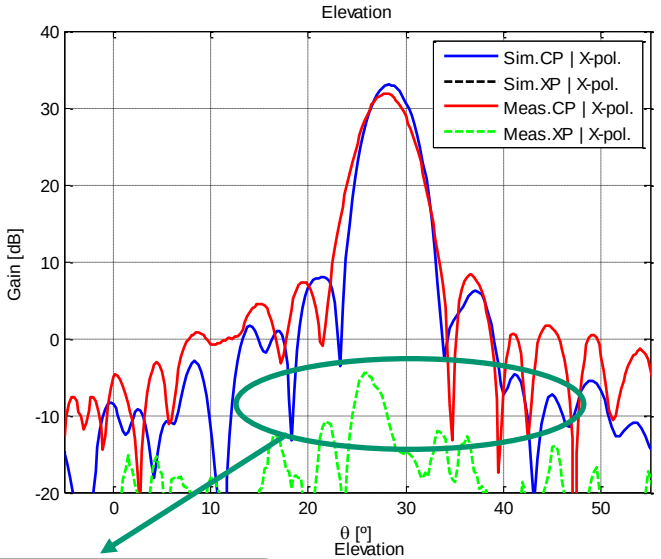
12.2 GHz

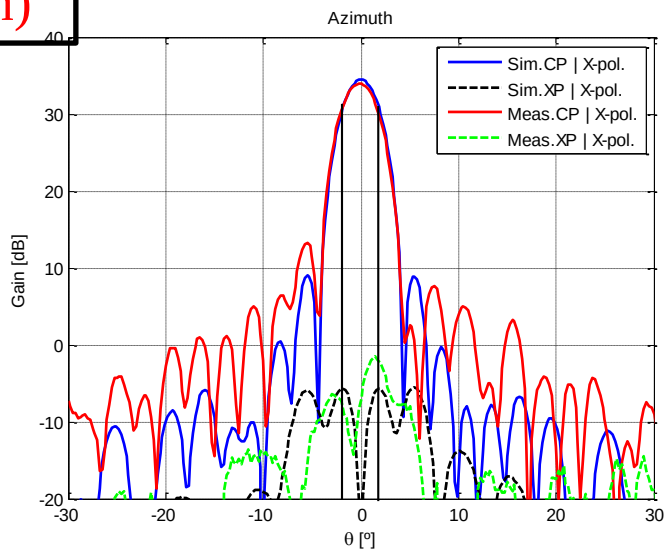
Tolerance Errors (-10 μm,-60μm)

13.75 GHz

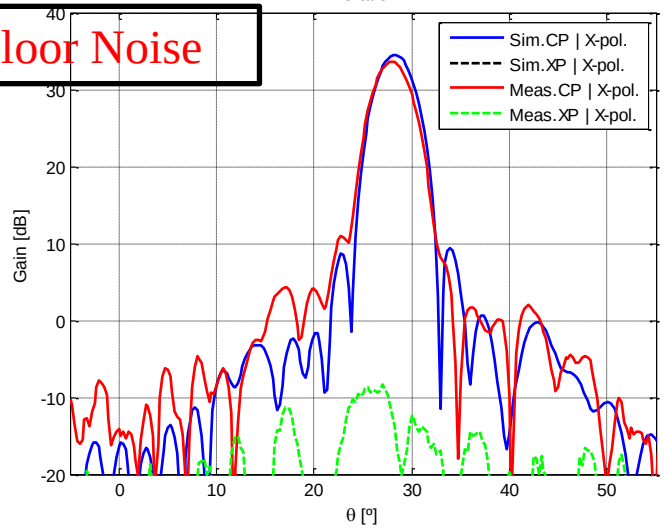
20% Bandwidth Tx/Rx in Ku-band







Floor Noise

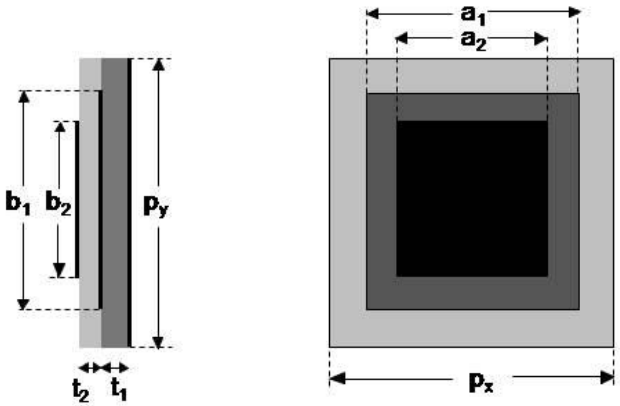


BIBLIOGRAPHY (Capabilities & Analysis)

1. John Huang, Jose A. Encinar, Reflectarray Antennas, IEEE Press, John Wiley, 2008.
2. C. Wan, J.A. Encinar, “Efficient computation of generalized scattering matrix for analyzing multilayered periodic structures”, IEEE Trans. on AP., 43(11), 1995, pp. 1233-1242.
3. J.A. Encinar, “Design of two-layer printed reflectarrays using patches of variable size”, IEEE Trans. on AP. Vol. 49, Oct. 2001, pp. 1403-1410.
4. J. A. Encinar, J. A. Zornoza, “Broadband design of three–layer printed reflectarrays”, IEEE Transactions on Antennas and Propagation, 51(7), 2003, 1662– 1664.
5. E. Carrasco, J. A. Encinar, M. Barba, “Bandwidth Improvement in Large Reflectarrays by Using True-Time Delay”, IEEE Trans. on Antennas and Propagat., Vol. 56, pp. 2496-2503, Aug. 2008.
6. O. M. Bucci, G. Franceschetti, G. Mazzarella, and G. Panariello, “Intersection approach to array pattern synthesis,” *IEE Proceedings*, vol. 137, pt. H, no. 6, pp. 349-357, Dec. 1990.
7. J. A. Zornoza, J. A. Encinar, “Efficient Phase-Only Synthesis of Contoured Beam Patterns for Very Large Reflectarrays”, Intl. J. RF & Microwave Computer-Aided Eng. Sept. 2004.
8. J.A. Encinar, J.A. Zornoza, “Three–Layer Printed Reflectarrays for Contoured Beam Space Applications”, IEEE Trans. on Antennas and Propagation, 52(5), 2004, 1138–1148.

Reflectarray Antenna Design Tool (RAD_UPM)

- This is a software tool to design multilayer reflectarray antennas, i.e. to define the antenna geometry, feed position, period, reflectarray size and finally to adjust all the patch dimensions in order to produce the required focused or shaped beam. From the dimensions of the metallizations in each layer, the photo-etching masks are also obtained.
- Once the reflectarray antenna has been fully designed, the program evaluates the radiation patterns, including co- and cross-polar components. The feed-horn is modeled as a cosq(θ) function. The radiation patterns are computed in gain (dBi), by taking into account the total power radiated by the feed-horn.
- The reflectarray elements are stacked patches of variable size

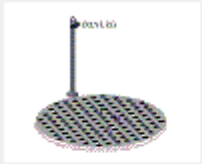


INPUT DATA

Reflectarray Antenna Design Manager - Design Parameters

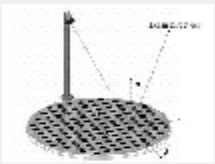
ANTENNA DEFINITION

Feed Definition



xf	-120
yf	0
zf	300
QF	10

Angle of Radiation



THETA0X	20
PHI0X	0
THETA0Y	30
PHI0Y	0

Number of Elements

NEX	20
NEY	18
RASHAPE	Elliptical

Cell Dimensions

PX	16
PY	16

Frequencies

F0	10
DF	1
NF	3

REFLECTARRAY ELEMENT

Sandwich Definition

Layers { NL = 2

	ALPHA	TS	ER Real	ER Imag
1	1	3	1.1	-0.001
2	0.7	3	1.1	-0.001

Substrate/superstrate of Printed Patches

Layers { Layers { Layers {

Tsub	Ersub Real	Ersub Imag
0.1	2	-0.001

Tsup	Ersup Real	Ersup Imag
0	2	-0.001

Patch Size Range

ANMIN	4
ANMAX	15.5
NPOINTS	40

Computation Parameters

NH	300	NBF	30
NS	20	CTE1	0

Cancel | Reset to default values | OK

ANTENNA DESIGN

Radiation Pattern

UMIN	-0.7
UMAX	0.9
VMIN	-0.8
VMAX	0.8
SRP	2
MINRP	0.001

Design Parameters

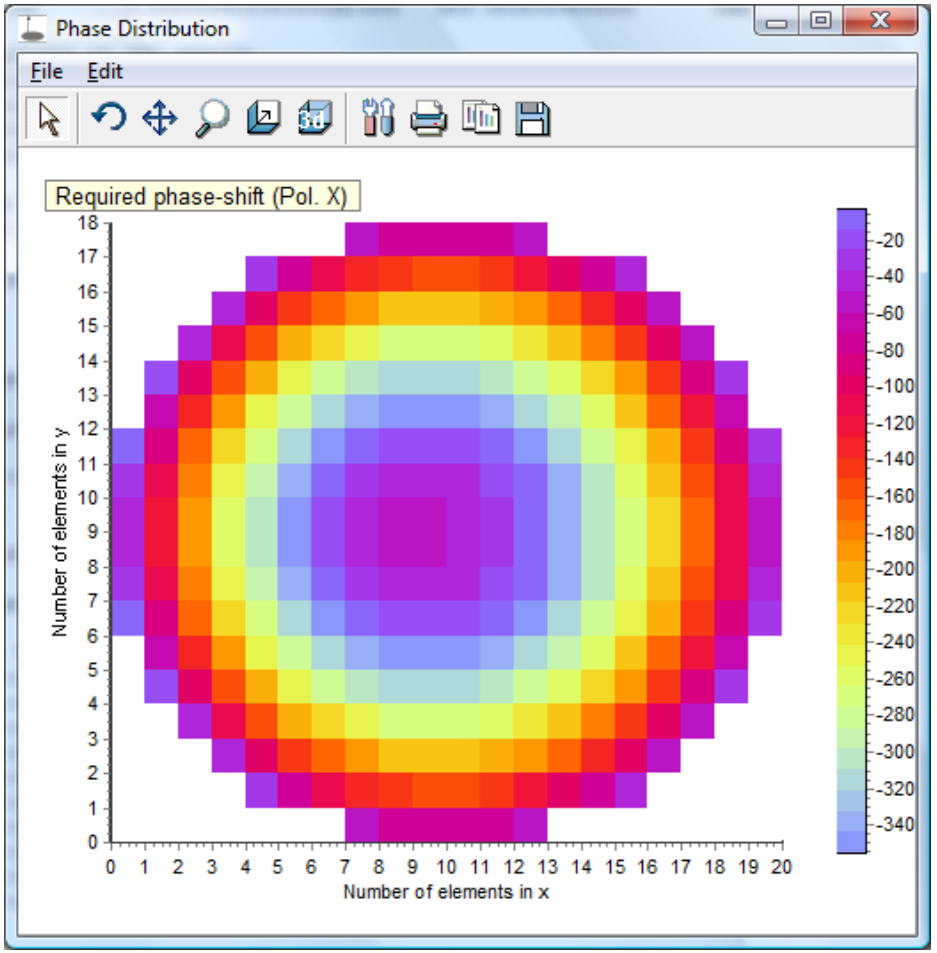
PHCTEX	0
PHCTEY	0
DFMIN	-15
DFMAX	-100
CAJ	0.5
CFMAX	0.8
EPS	50
PHERR	1
NIT	4

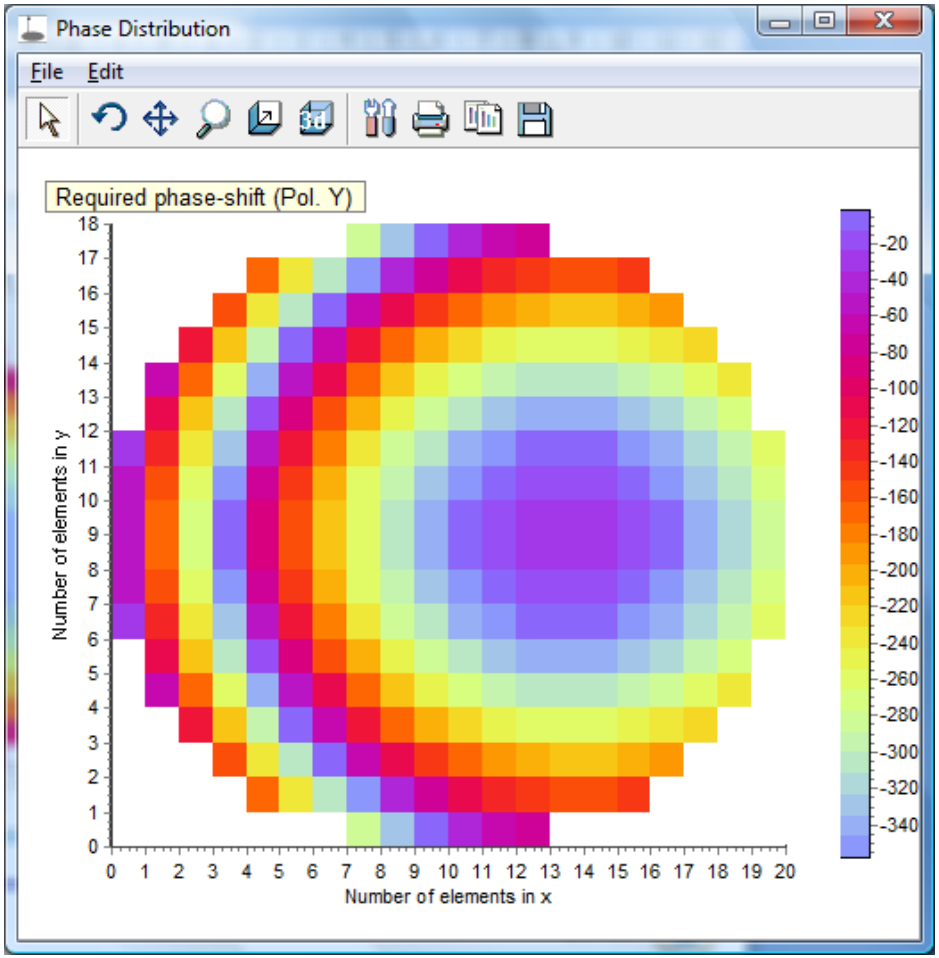
Other Parameters

EFF	0.65
NF0	1
CNTE	0.2
C2	1.1
STEP	40

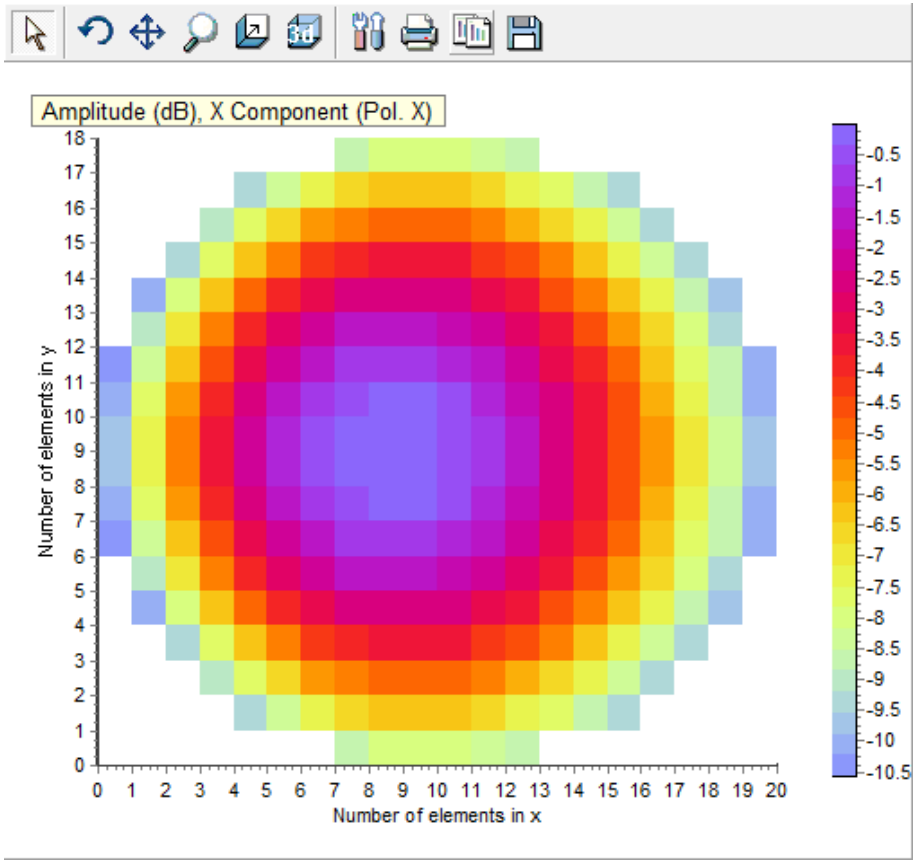
REQUIRED PHASE DISTRIBUTION

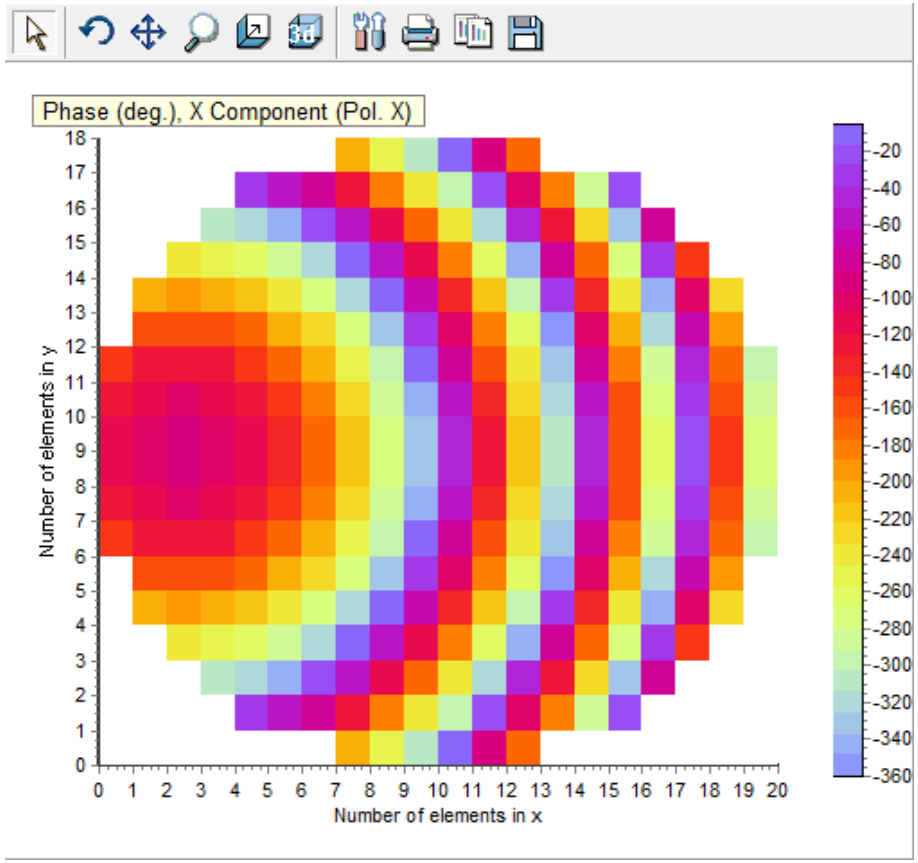
- To produce a beam at 20º in X-pol and 30º in Y-pol



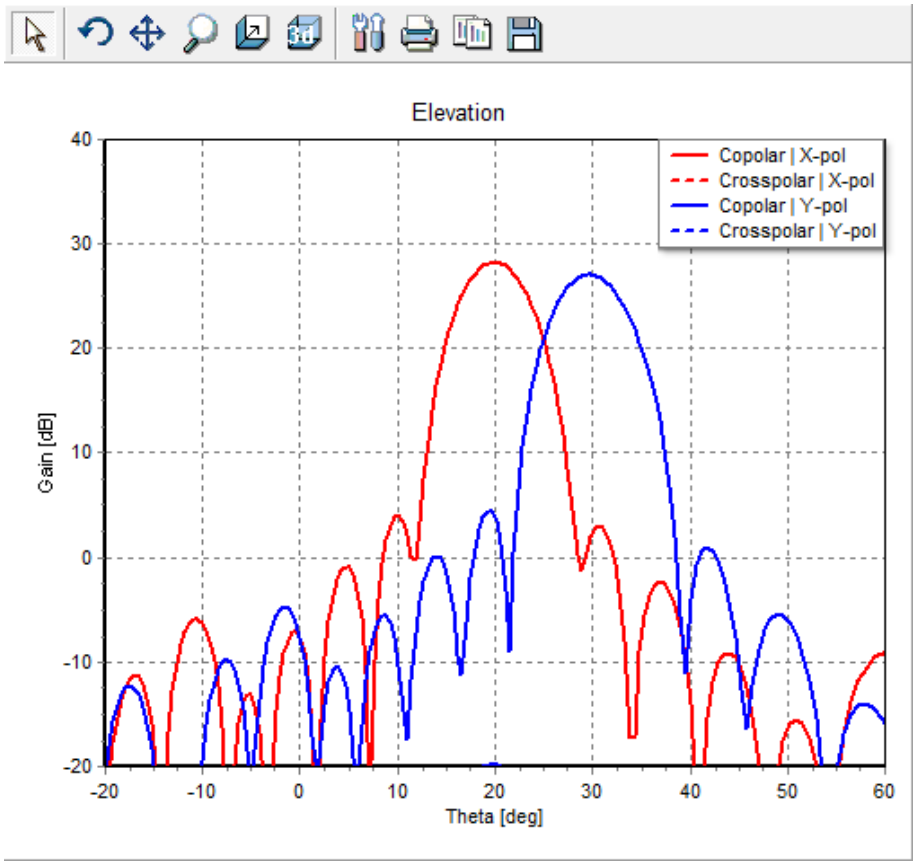


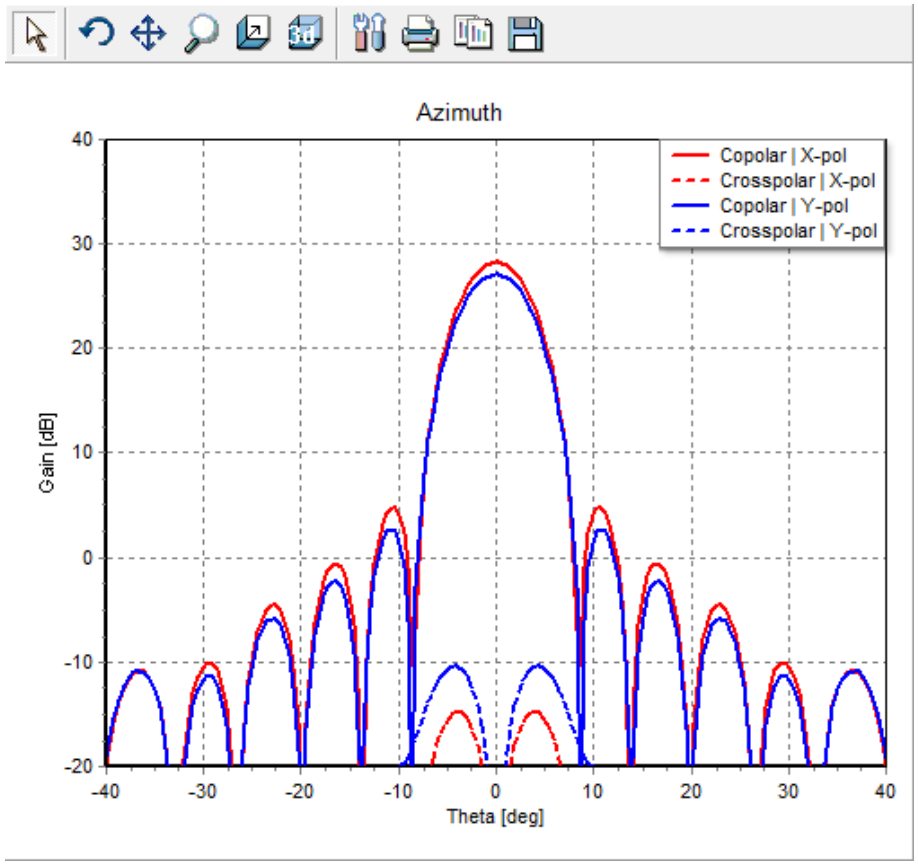
INCIDENT FIELD



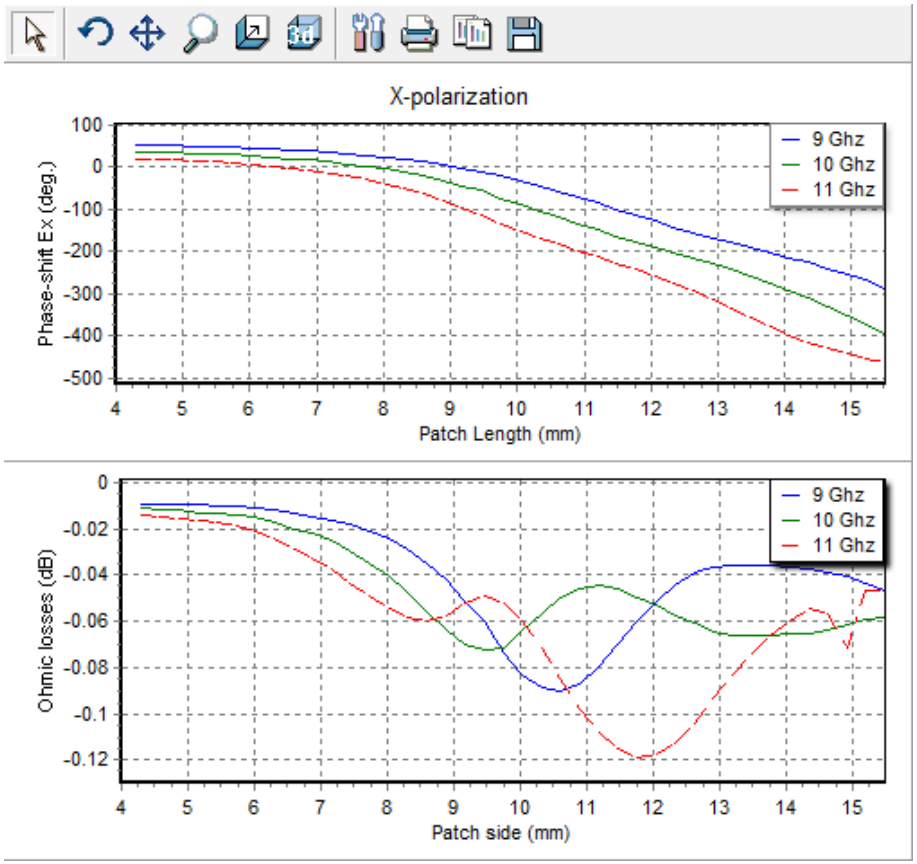


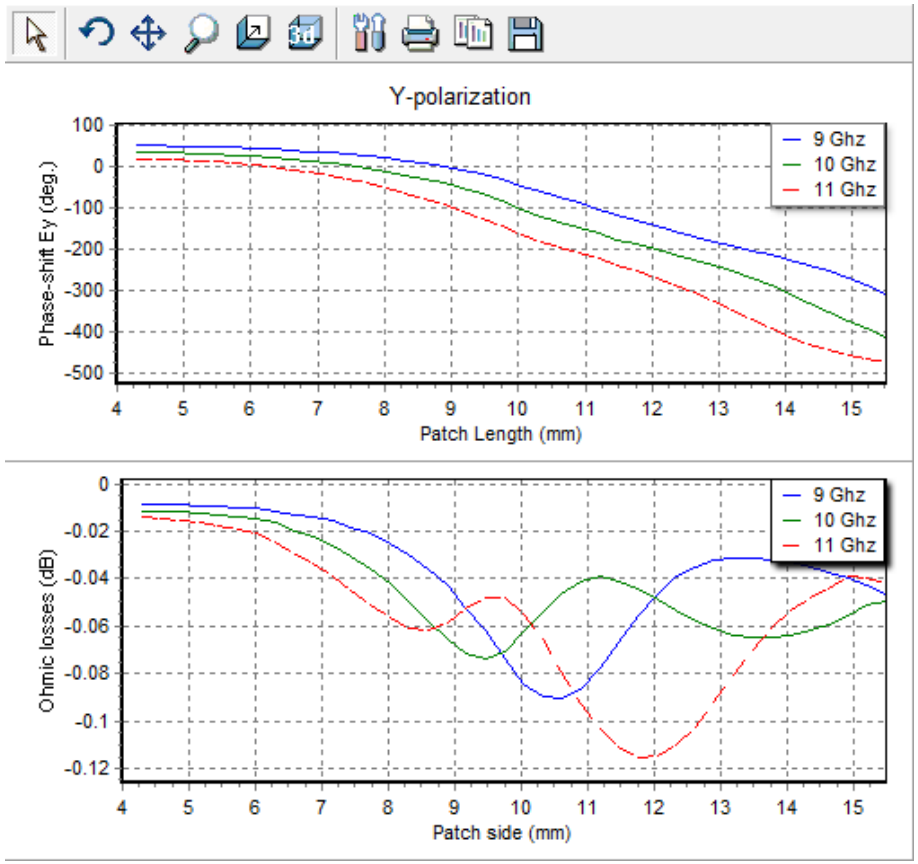
IDEAL RADIATION PATTERNS



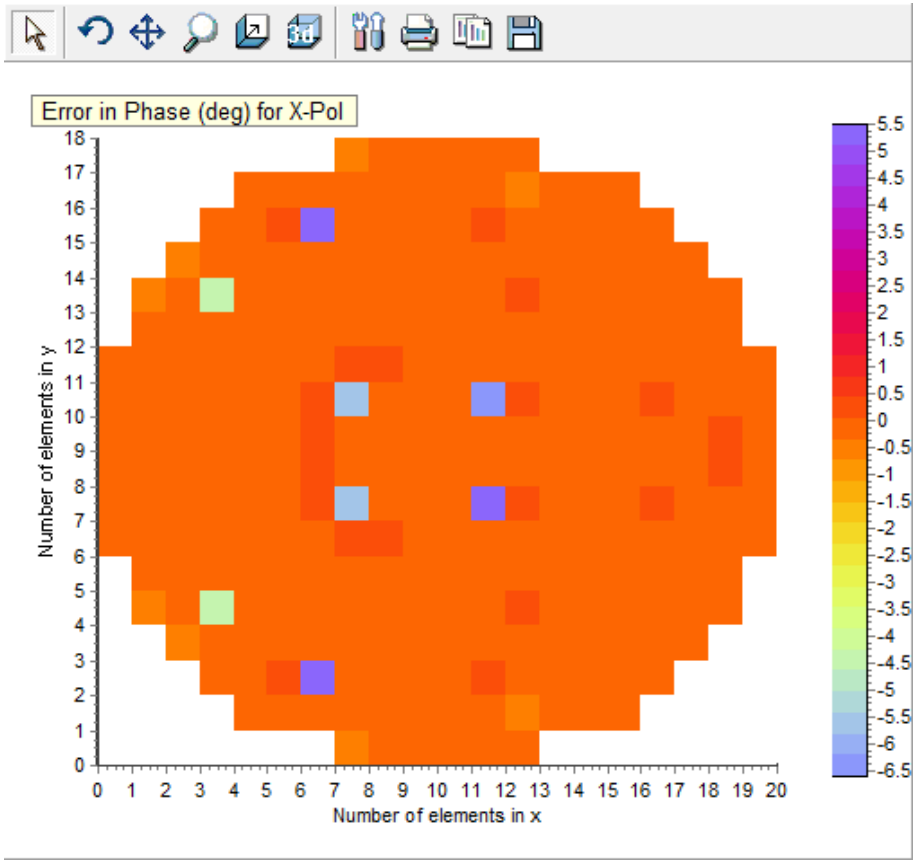


PHASE CURVES AND LOSSES (THETA=30, Phi=30º)





PHASE ERRORS



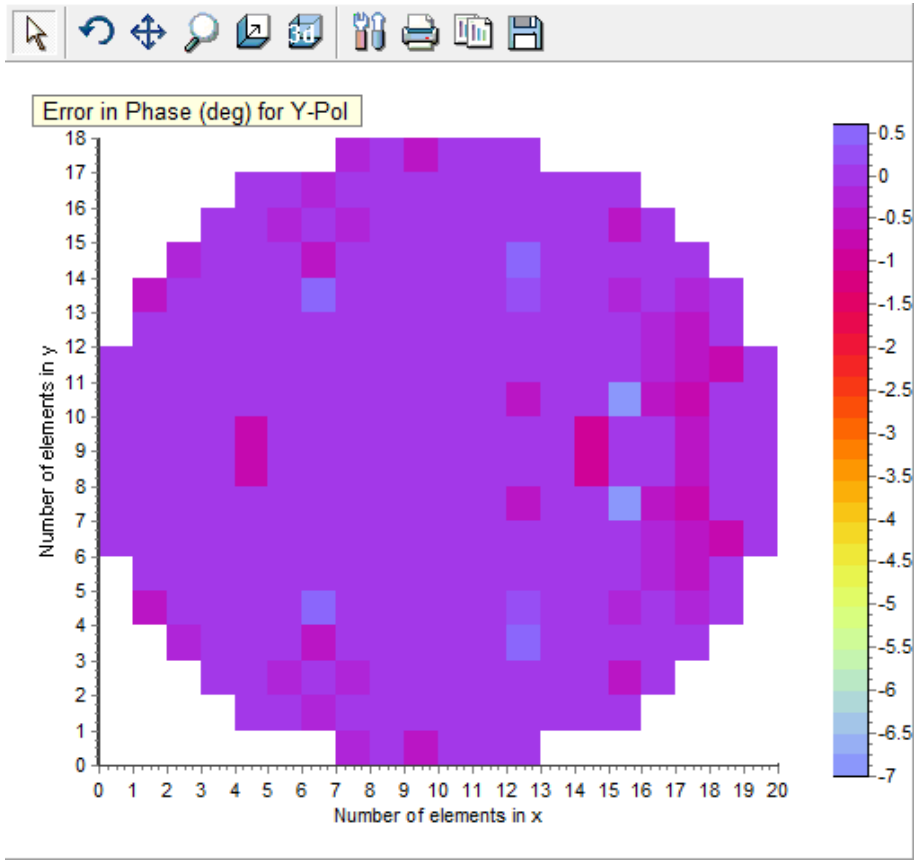
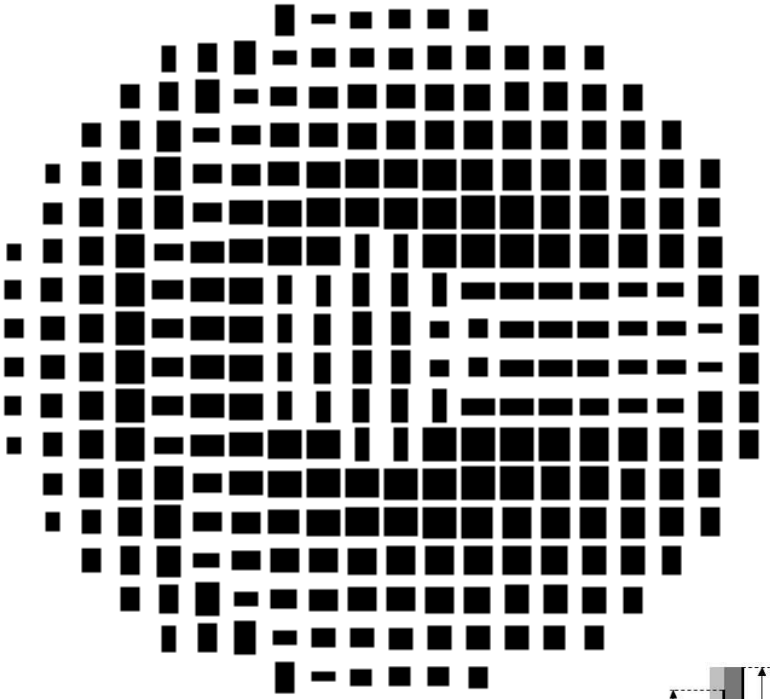
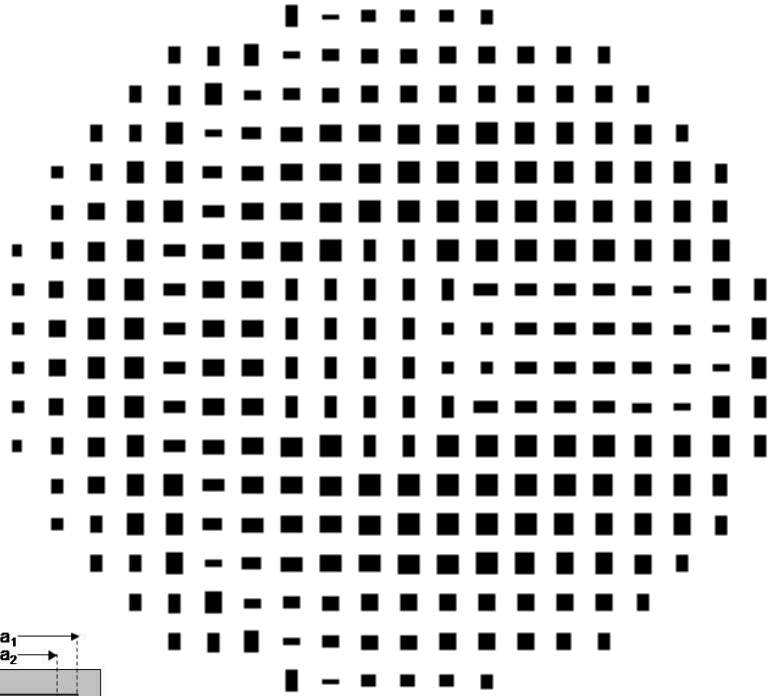


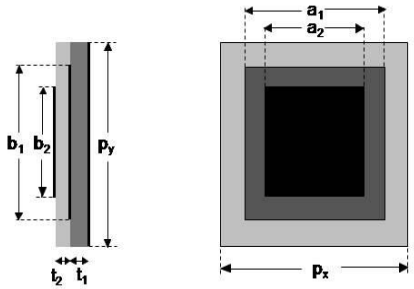
PHOTO-ETCHING MASKS

Layer 1

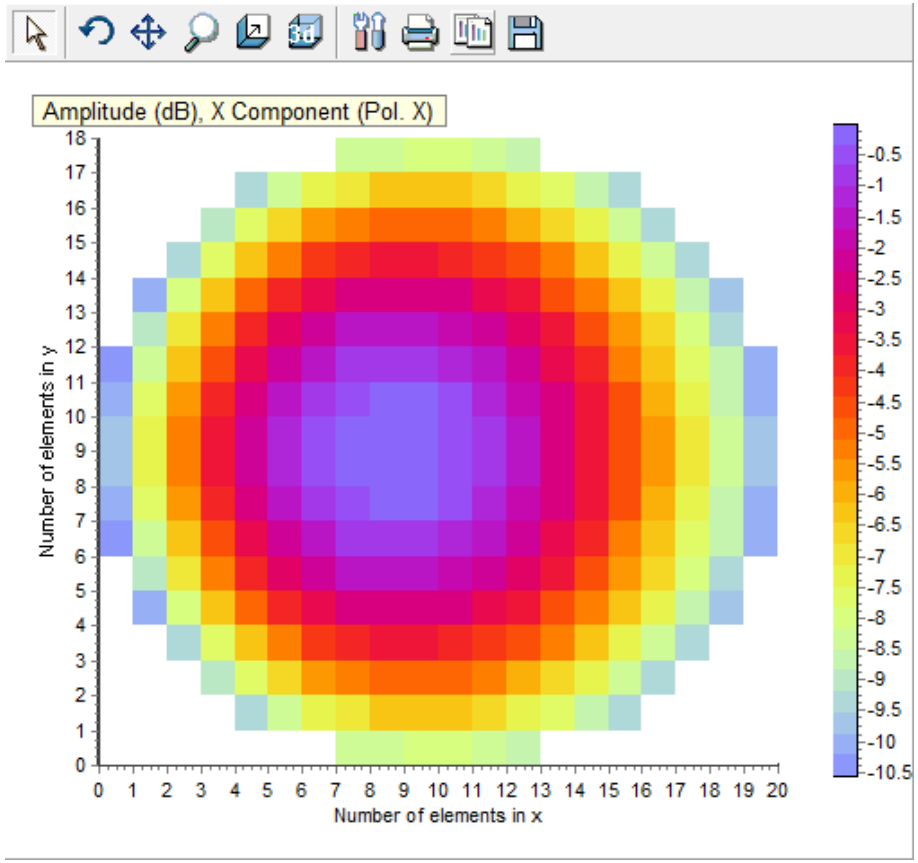


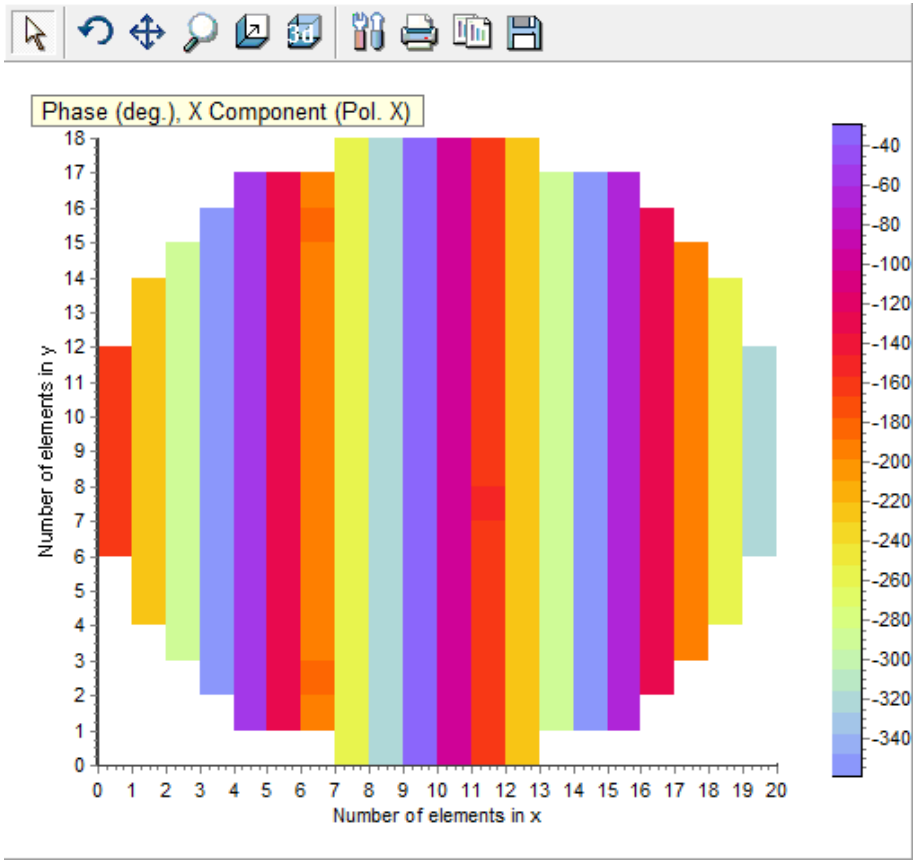
Layer 2



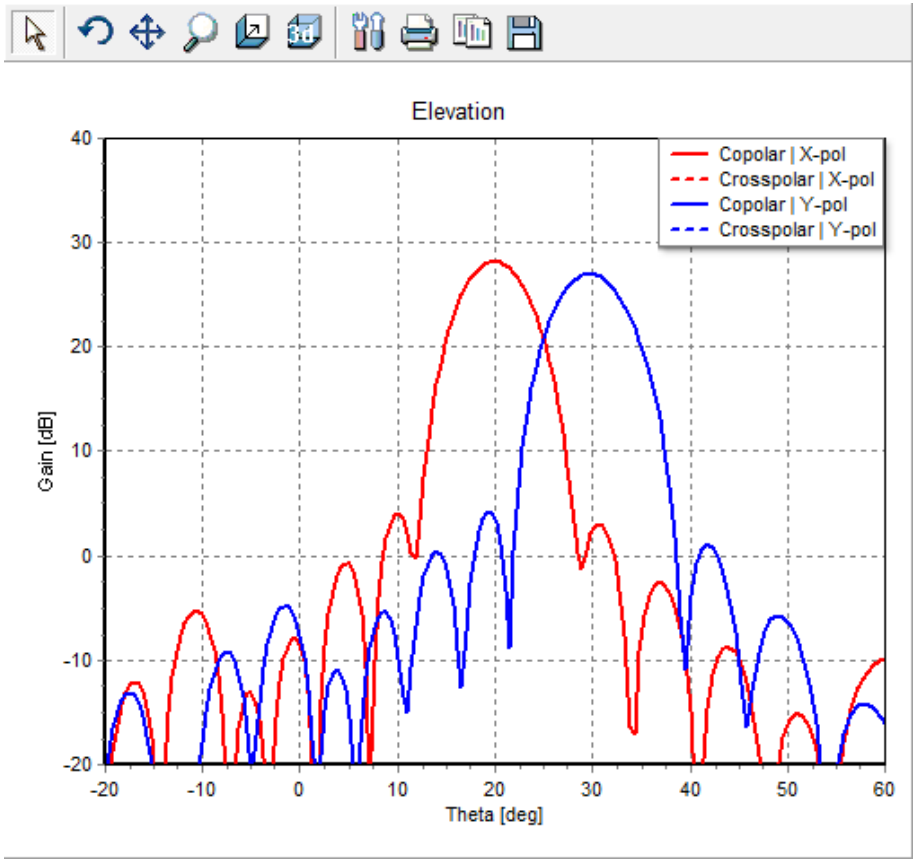


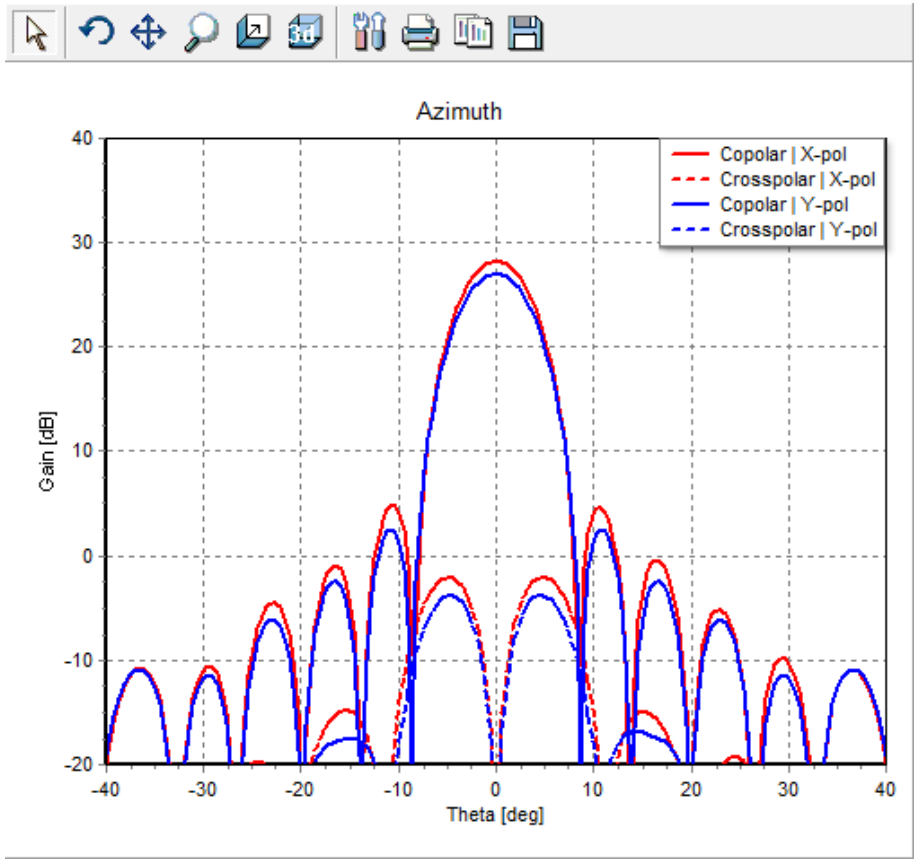
REFLECTED FIELD





SIMULATTED RADIATION PATTERNS (SD-MoM)





SIMULATED RADIATION PATTERNS (SD-MoM)