Conformal Reflectarray Metasurface

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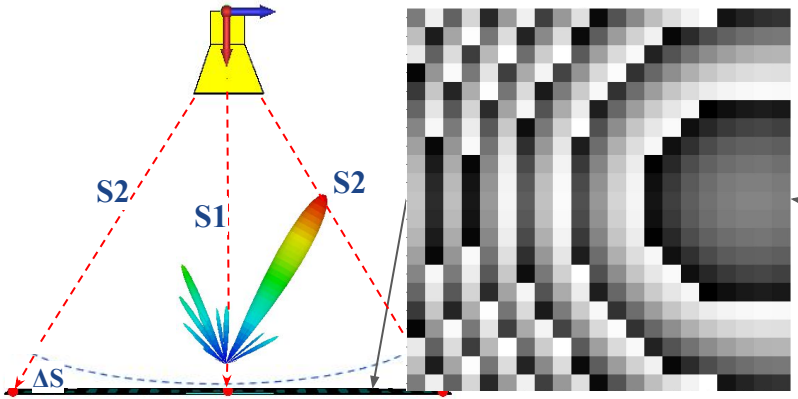
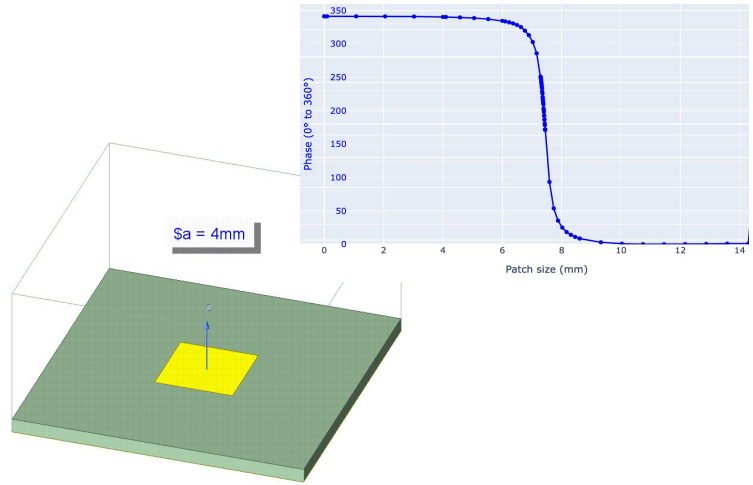
Reflectarray Design Workflow

1) System design

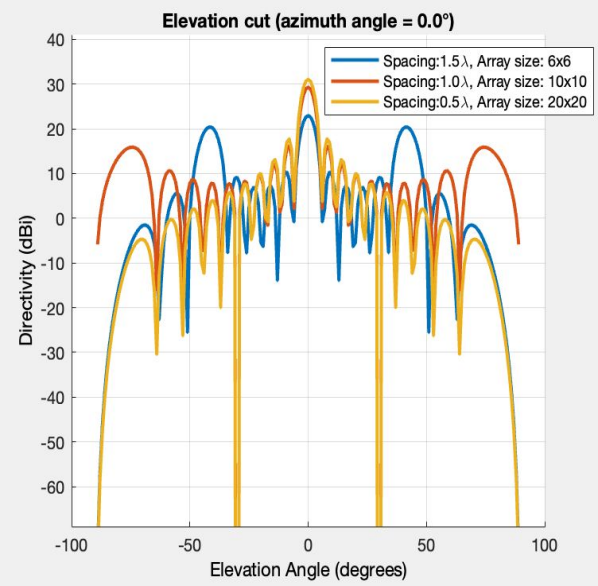
2) Element design

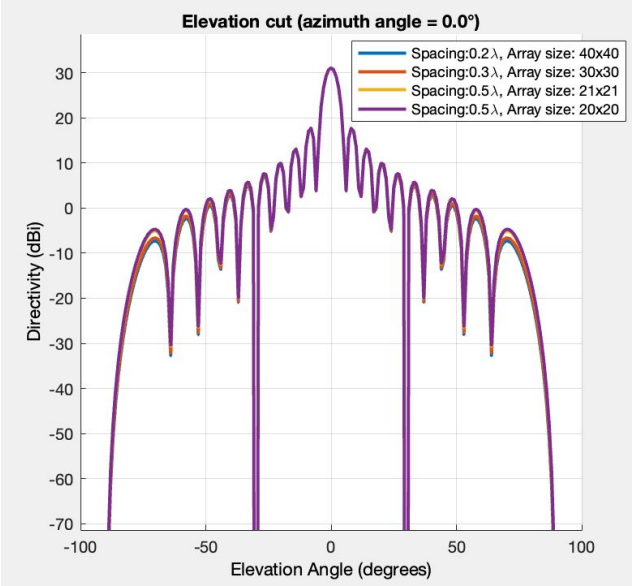




1) MATLAB

1) Element Spacing for 30 cm Antenna



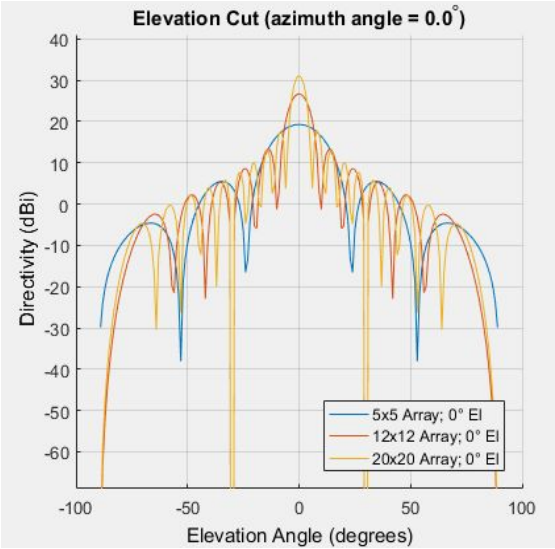


$\geq \lambda/2$

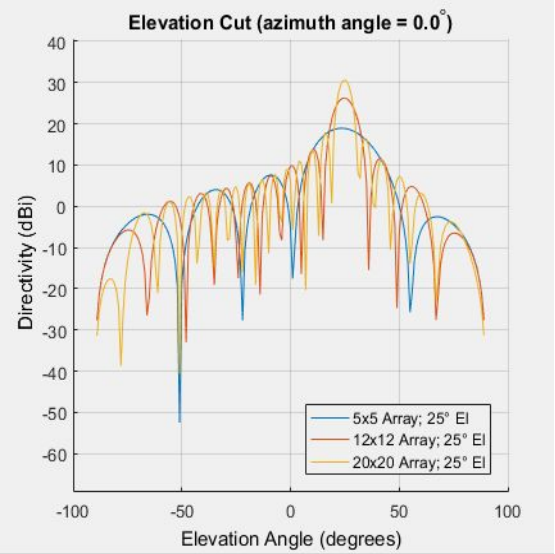
$\leq \lambda/2$

MATLAB 9.1 and Phased Array System Toolbox 3.3

1) Array Configuration and Beam Steering



Array creates the beam pattern

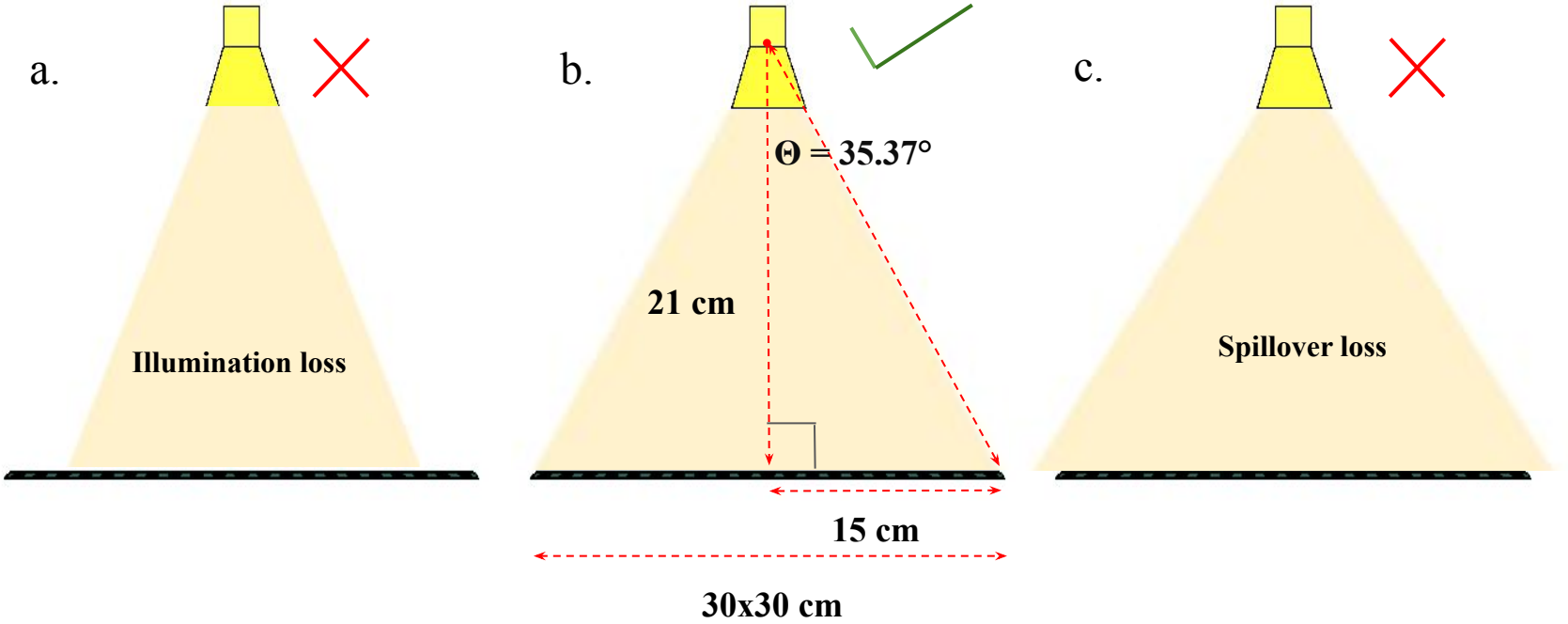


Phase shift steers the beam

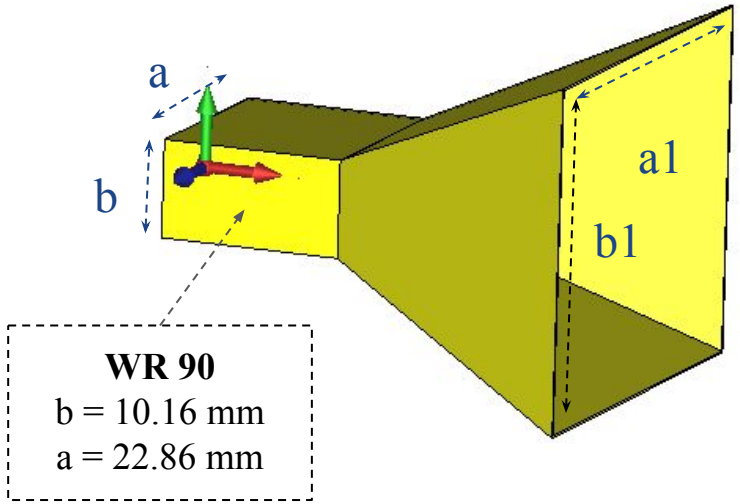
MATLAB 9.1 and Phased Array System Toolbox 3.3

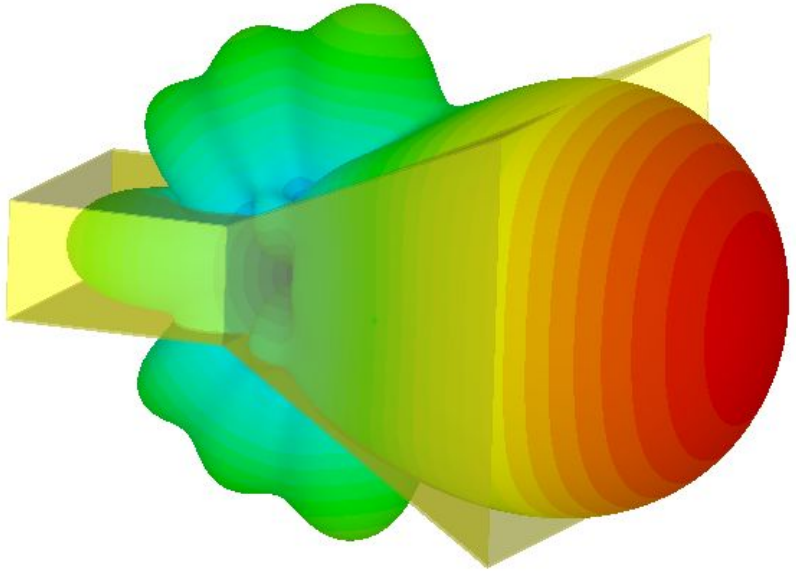
2) Horn Antenna

2) Feed to Reflectarray Distance



2) Pyramidal Horn Antenna

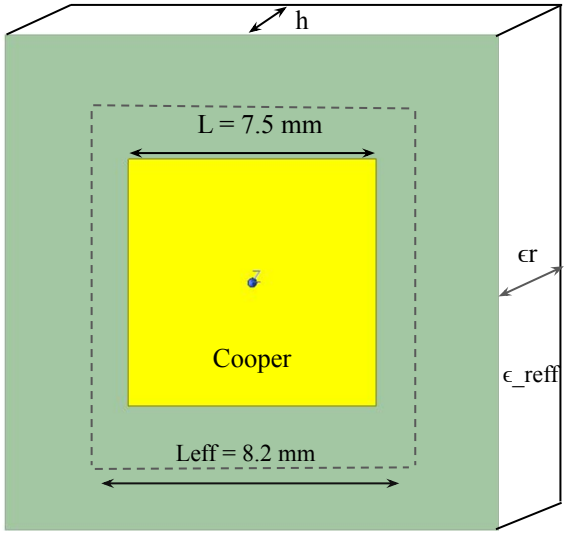




Directivity: 13 dBi

3) Unit Cell

3) Unit Cell Design



Parameter	Value
fr	10 GHz
λ	3 cm
ϵr	3.48 *(Rogers RO4350B)*
h	0.762 mm
t	0.0035 mm *(cooper)*
L=W	7.5 mm (λ/4)
ϵ_reff	3.072
Leff	8.2 mm

$$0.003\lambda_0 \le h \le 0.05\lambda_0 \qquad t \ll \lambda_0$$

$$W/h > 1$$

Effective Dielectric Constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \qquad 1 < \epsilon_{reff} < \epsilon_r$$

$$2.2 \le \epsilon_r \le 12$$

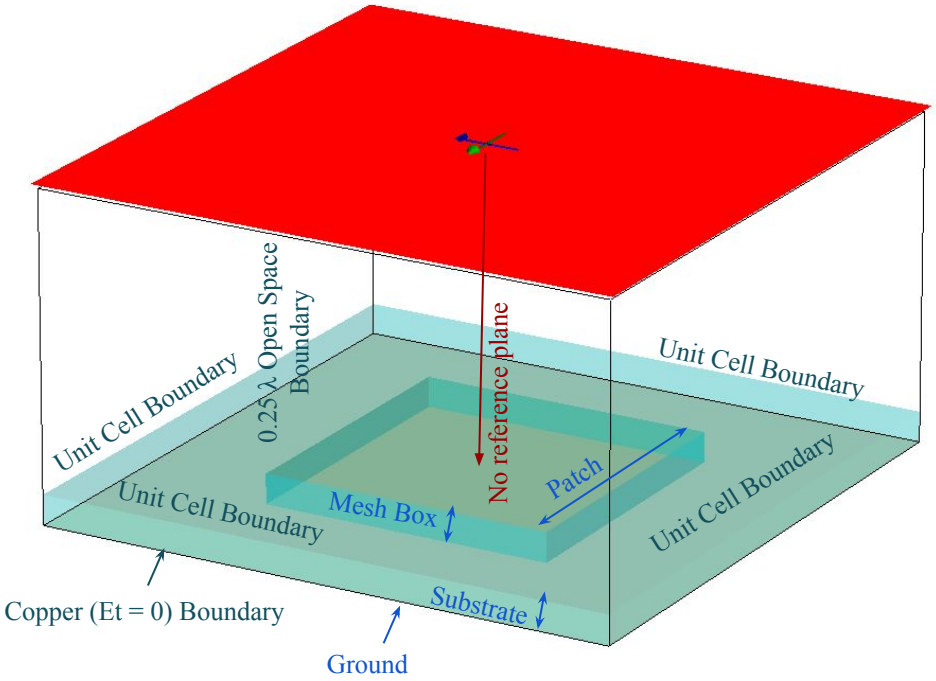
Effective Length Extension

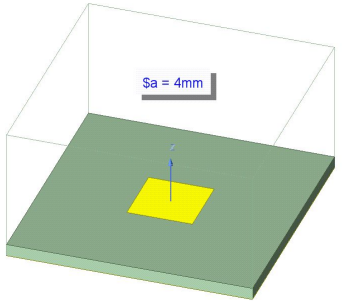
$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

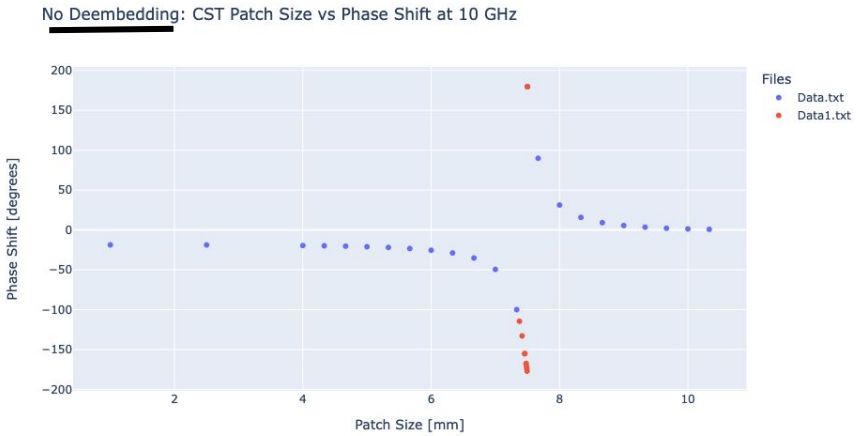
$$L_{eff} = L + 2\Delta L$$

Constantine A. Balanis, Antenna Theory Analysis and Design, Third Edition, Chapter 14

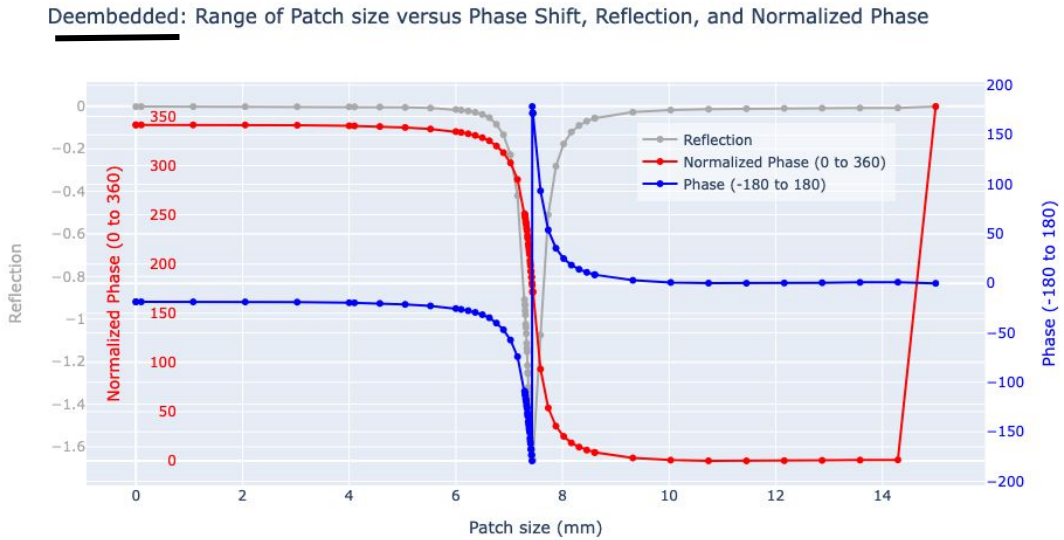
3.1) Unit Cell Simulation with mesh box (Case 1)







3.2) Unit Cell Simulation with no mesh box (Case 2)

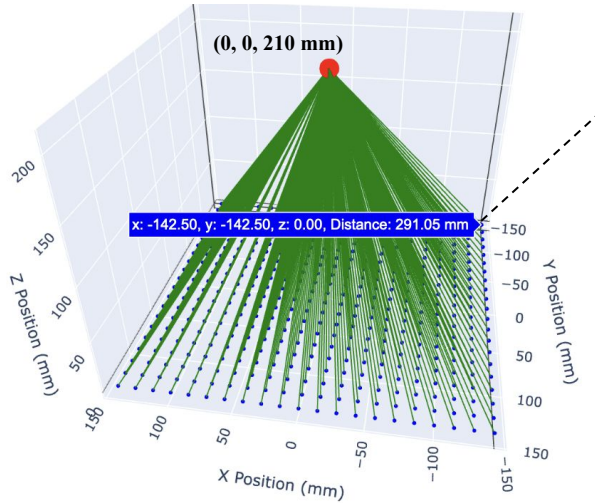


4) Reflectarray Design

4.1) Case 1

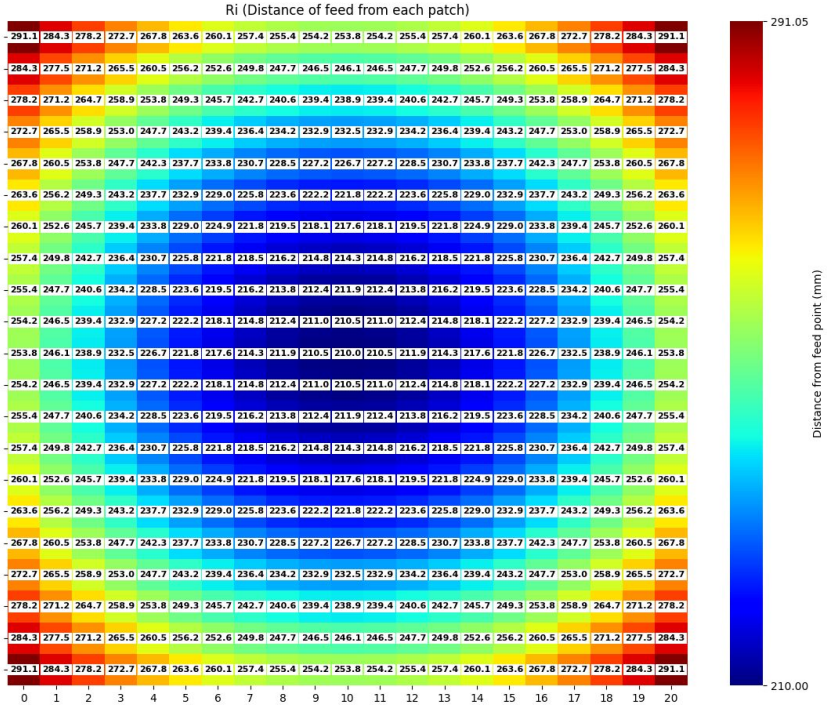
- Element Spacing: λ/2.12
- Unit Cell: No De-embedding
- Unit Cell Tuning Range: 0 - 10.7 mm
- Waveguide Input to Reflectarray: 230 mm

4.1) Reflectarray element position from feed

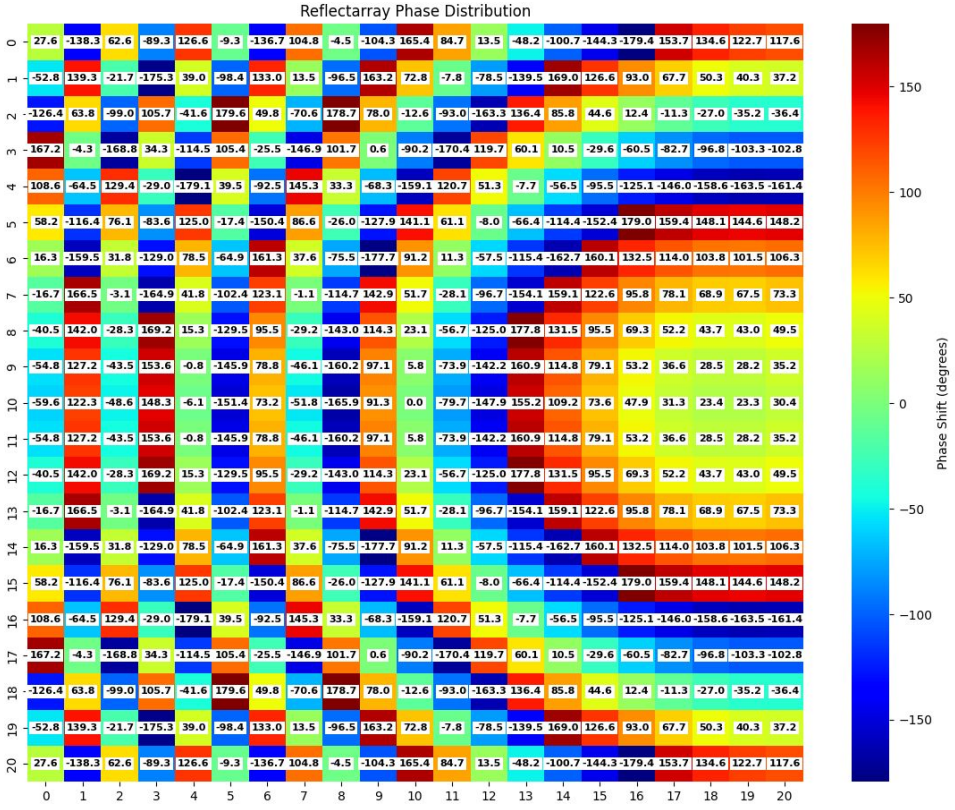


$$d = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2}$$

distance

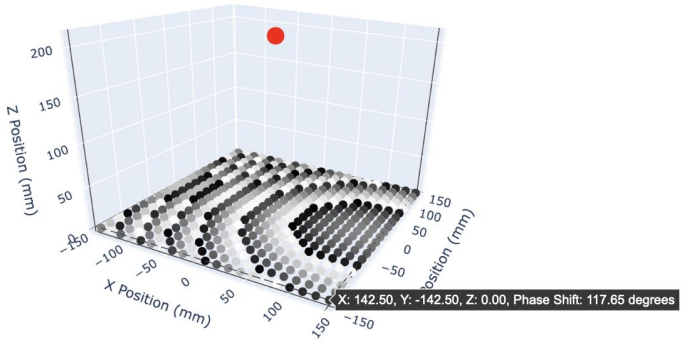


4.1) Reflectarray Phase Distribution

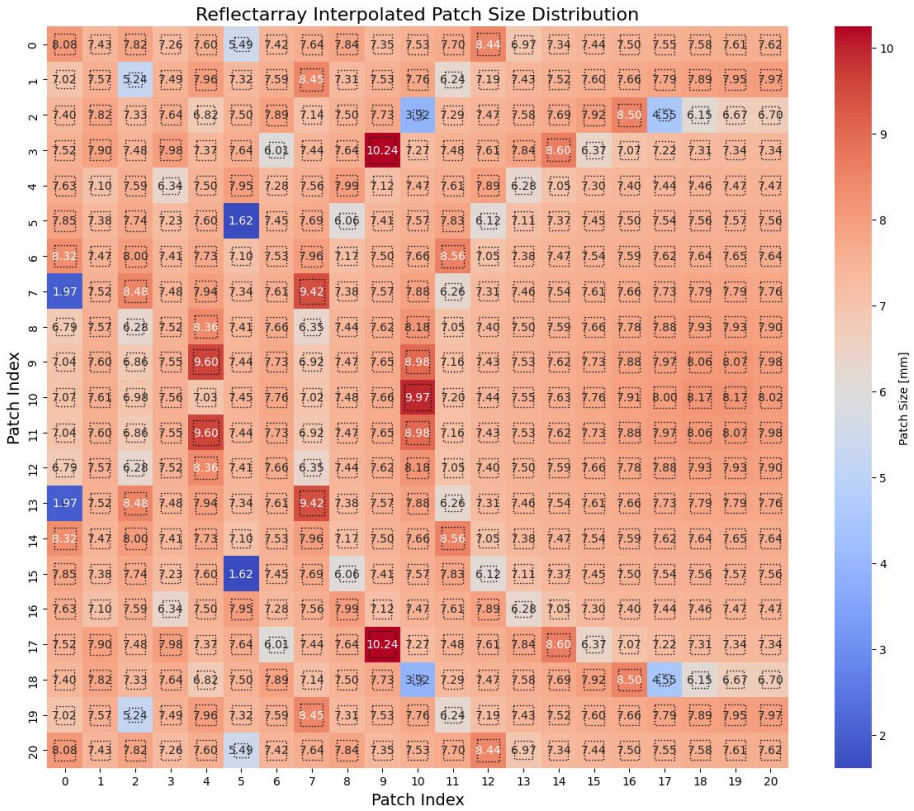


Highest Phase Value: 179.63°

Lowest Phase Value: -179.41°



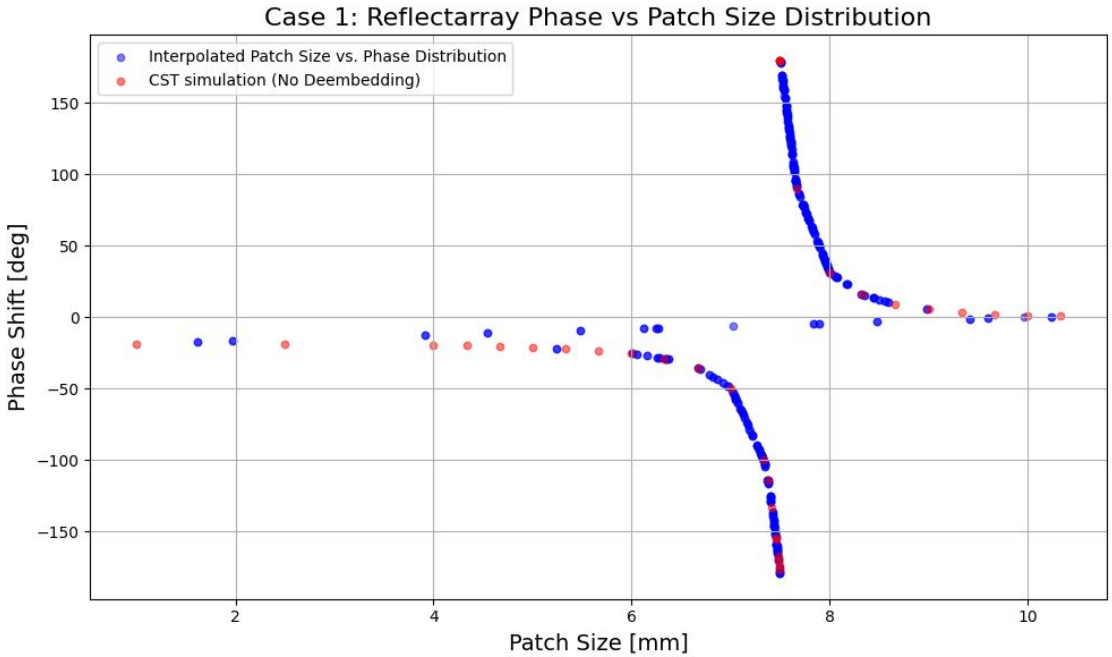
4.1) Reflectarray Patch Size Distribution



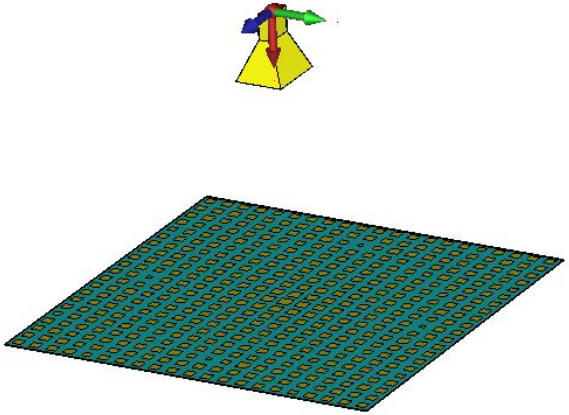
Highest Patch Value: 10.24 mm

Lowest Patch Value: 1.62 mm

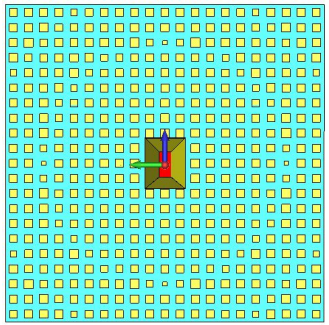
4.1) Linear Interpolation



4.1) Reflectarray Design (0°, 0°)

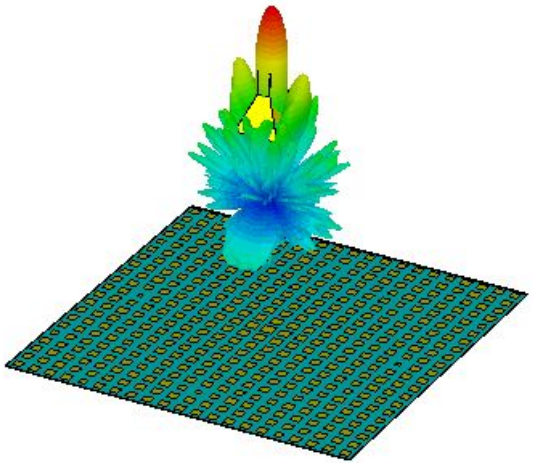


Top view



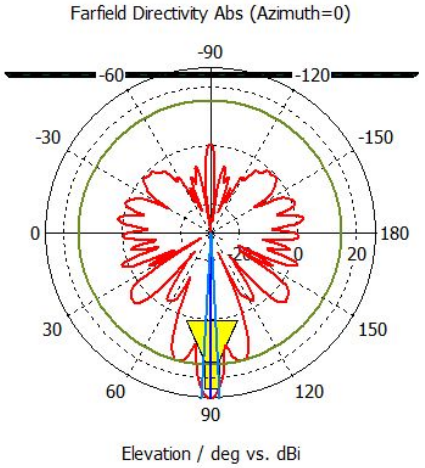
Side view

4.1) Reflectarray Design (0°, 0°) Results



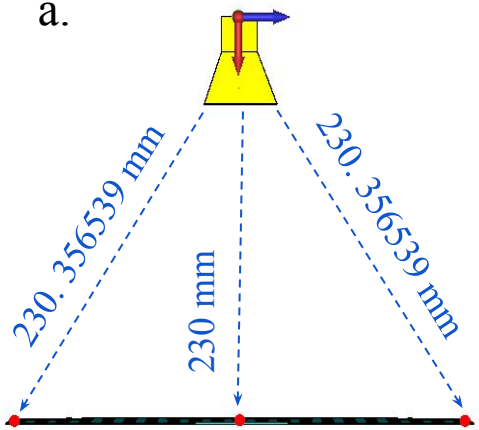
Directivity: 26.62 dBi

Side-lobe: -11.4 dB



4.1) Conformal Reflectarray (0°, 0°) Design

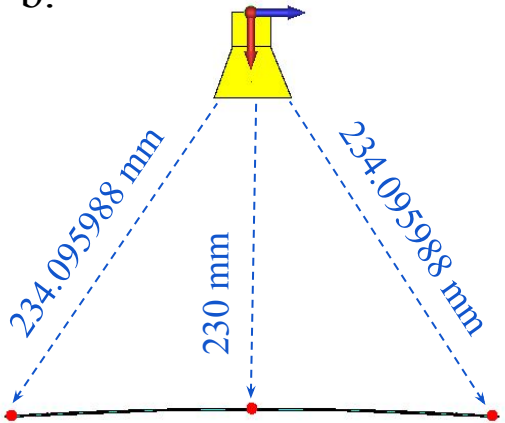
a.



$\Delta = 0.012\lambda = 0.36$ mm

R= 1000λ = 30000 mm

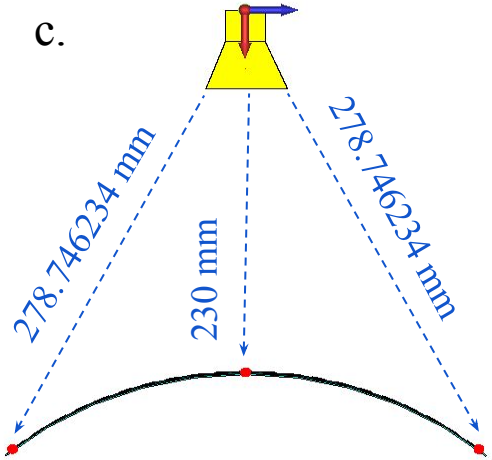
b.



$\Delta = 0.14\lambda = 4.2$ mm

R = 87λ = 2610 mm

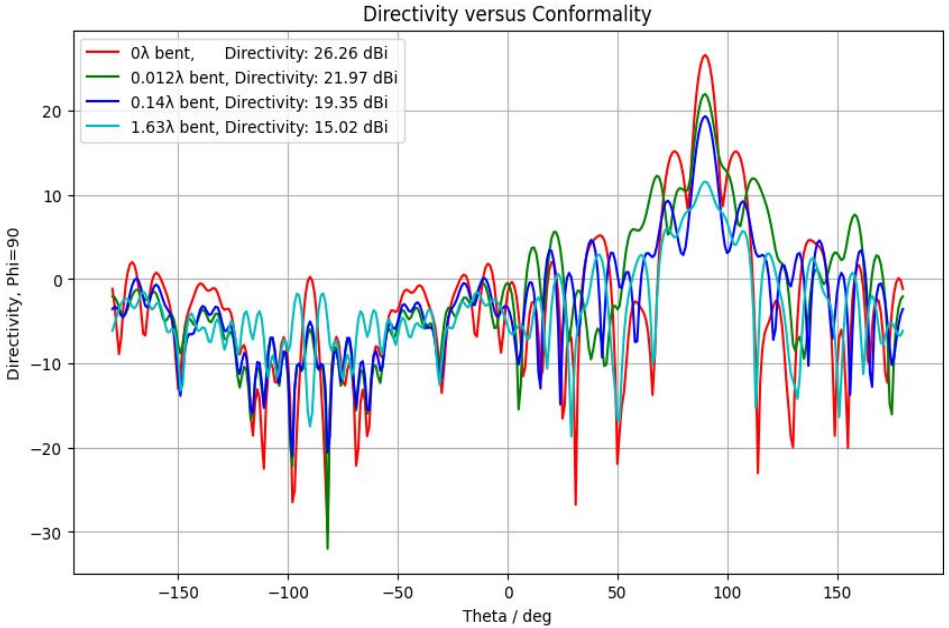
c.

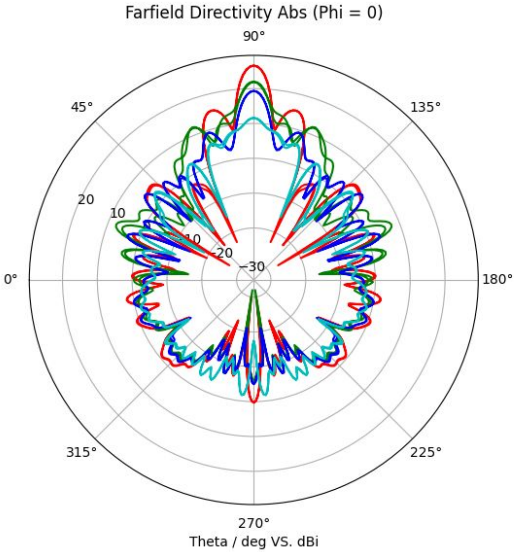


$\Delta = 1.62\lambda = 49$ mm

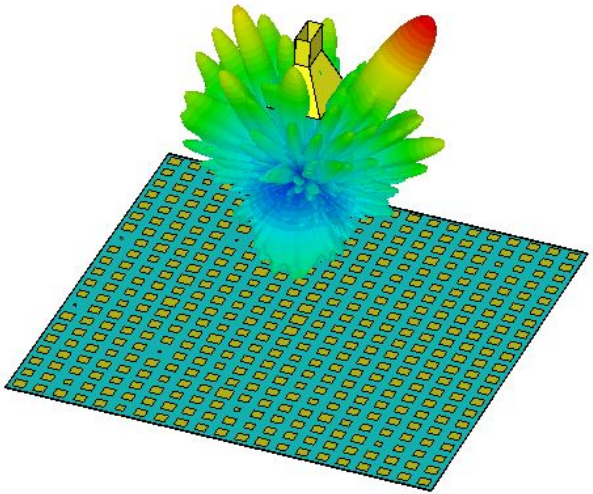
R = 7λ = 210 mm

4.1) Conformal Reflectarray (0°, 30°) Design Results



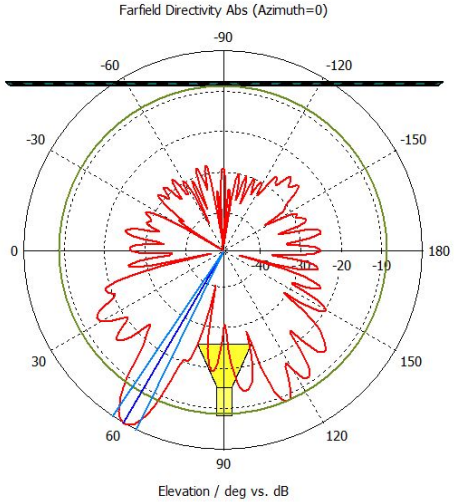


4.1) Reflectarray Results (0°, 30°)



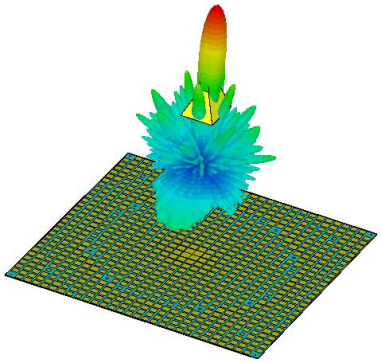
Directivity: 24.6 dBi

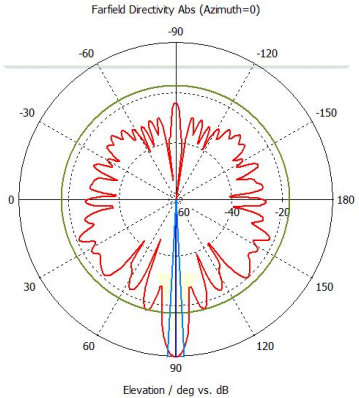
Side-lobe: -8.8 dB



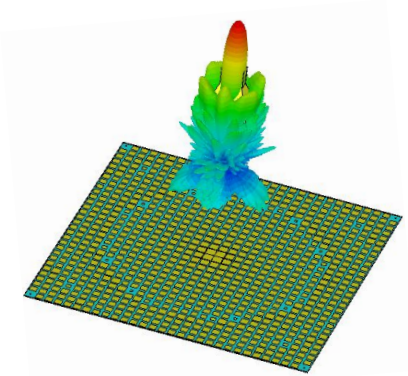
4.1) Element spacing λ/3

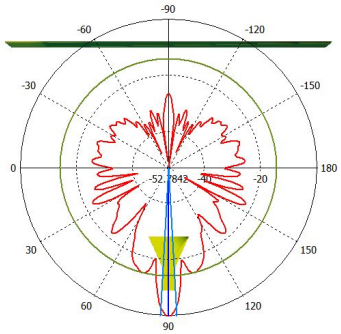
- **9.5 GHz**
- Dir: 27.32 dBi,
- Side-lobe: -17.2 dBi





- **10 GHz**
- Dir: 26.21 dBi,
- Side-lobe: -14.2 dBi

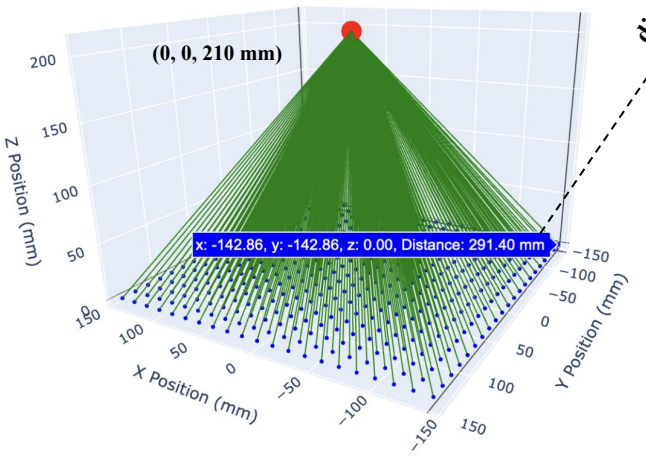




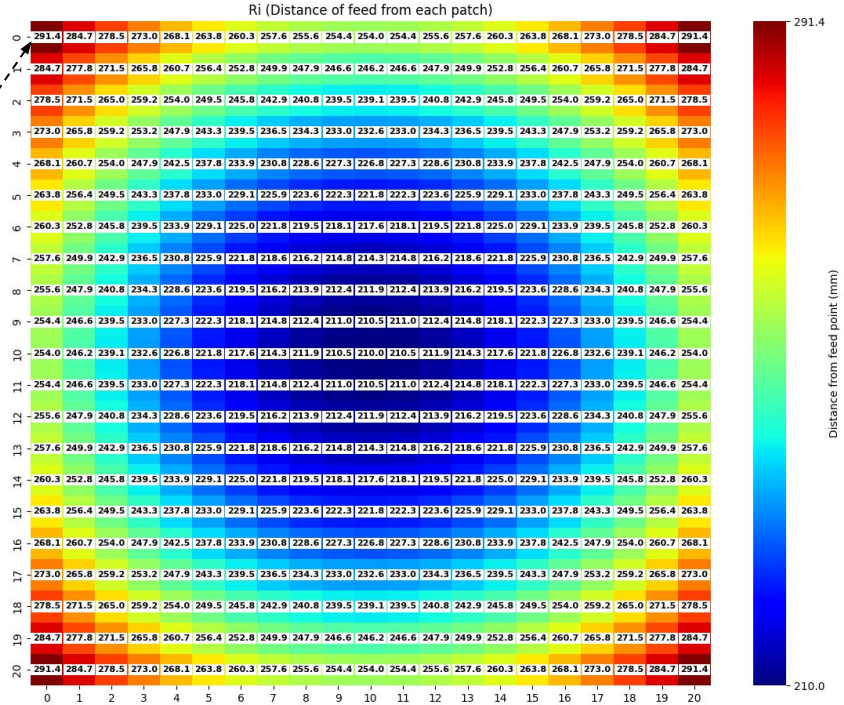
4.2) Case 2

- Element Spacing: λ/2.1
- Unit Cell: De-embedding
- Unit Cell Tuning Range: 0 - 15 mm
- Waveguide Input to Reflectarray: 260 mm

4.2) Reflectarray element position from feed

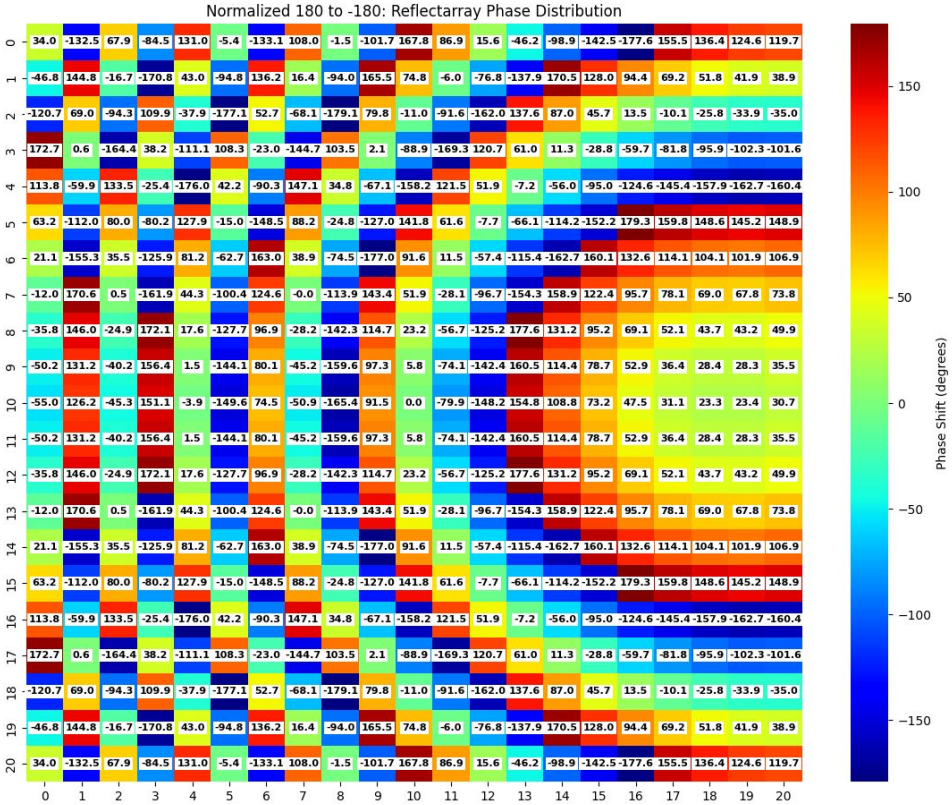


distance



$$d = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2}$$

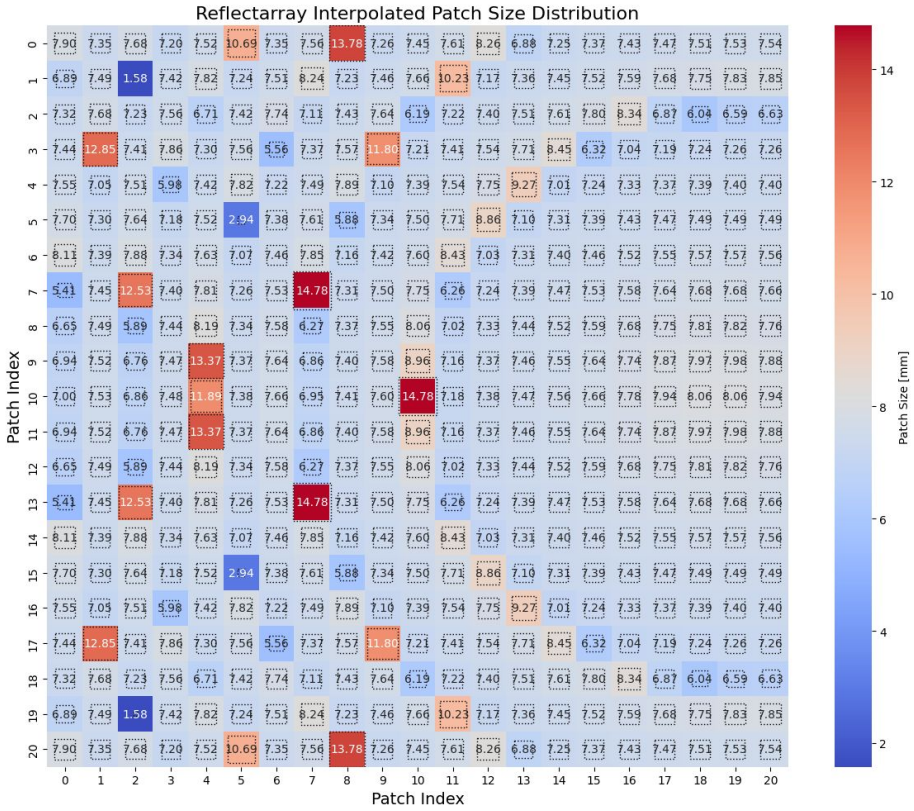
4.2) Reflectarray Phase Distribution



Highest Phase Value: 179.32°

Lowest Phase Value: -179.15°

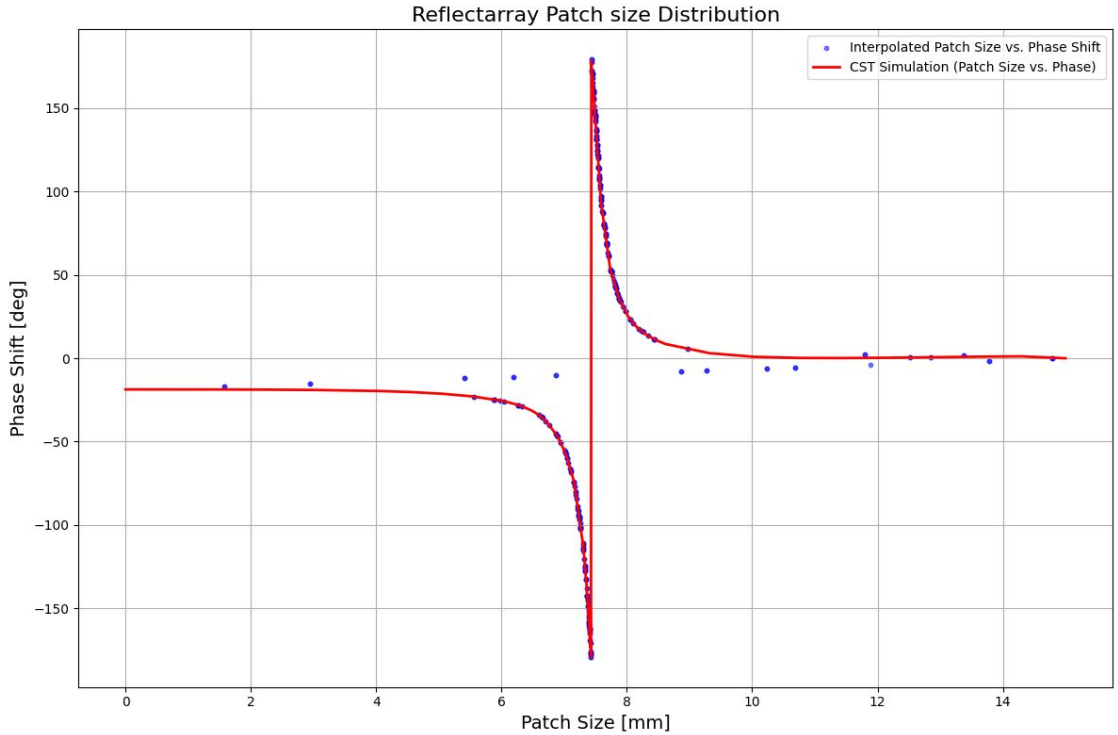
4.2) Reflectarray Patch Size Distribution



Highest Patch Value: 14.78 mm

Lowest Patch Value: 1.58 mm

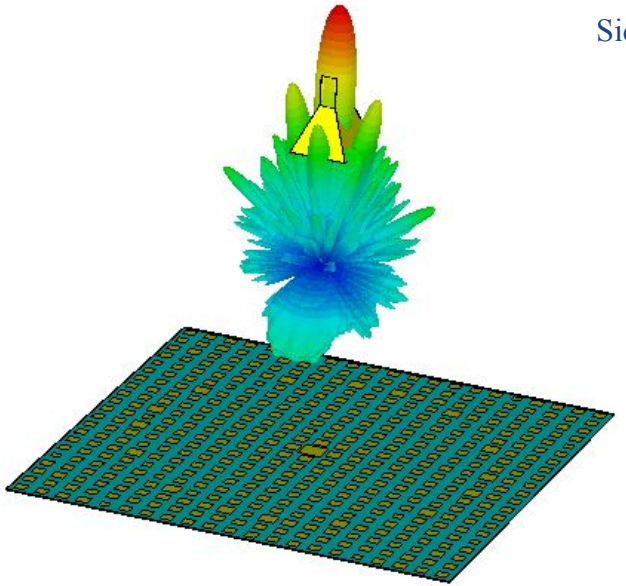
4.2) Linear Interpolation

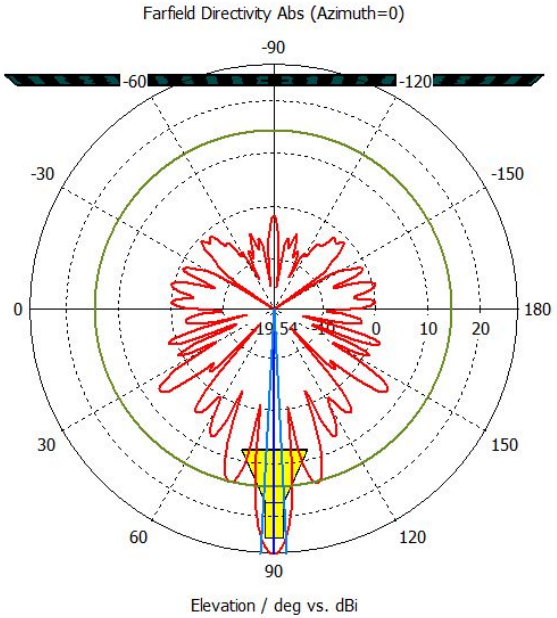


4.2) Reflectarray Design (0°, 0°) Results

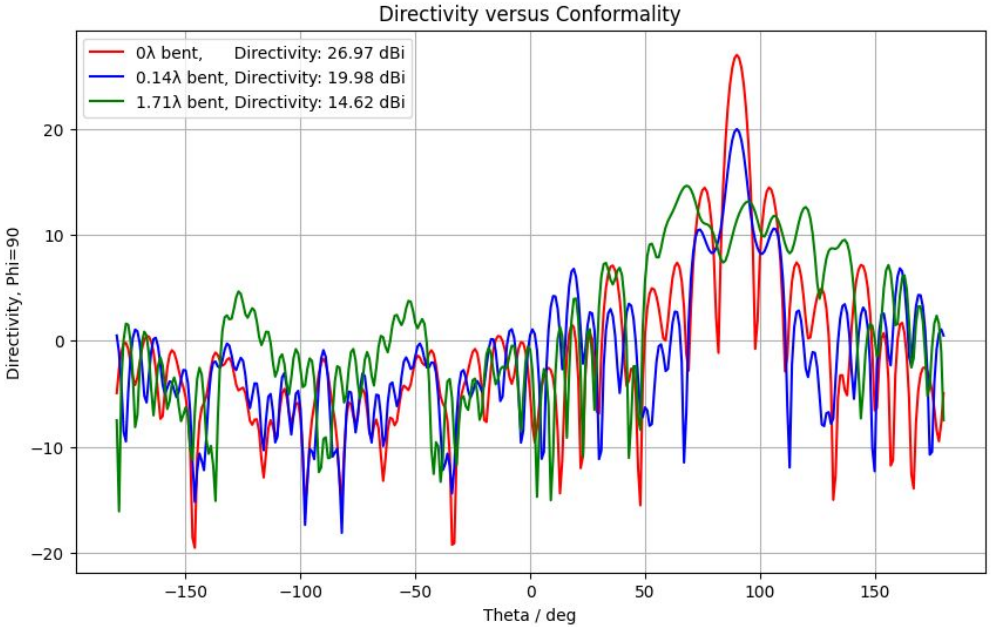
Directivity: 26.97 dBi

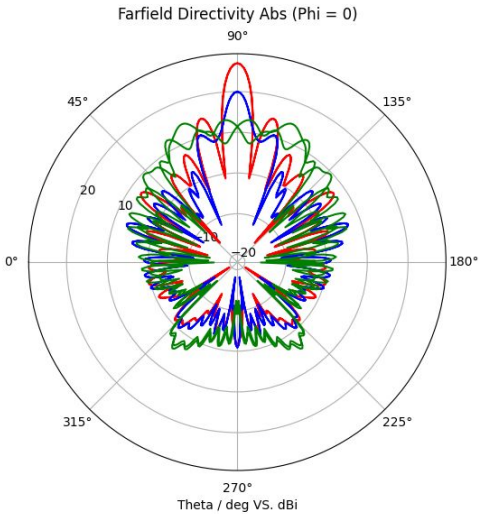
Side-lobe: ***-12.5 dB***



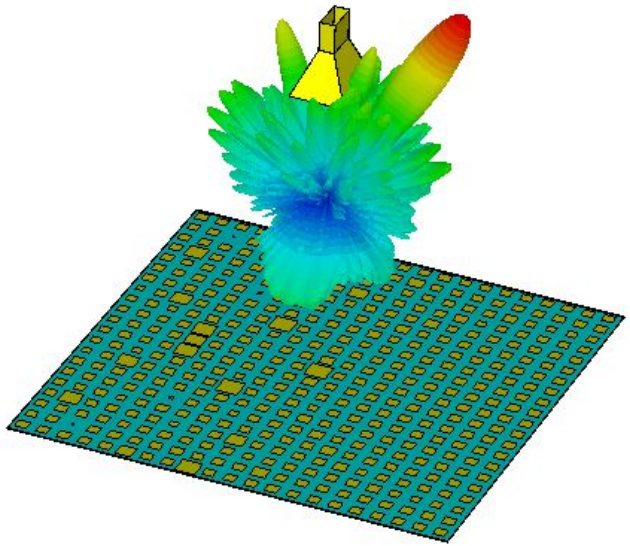


4.2) Conformal Reflectarray Design (0°, 0°) Results



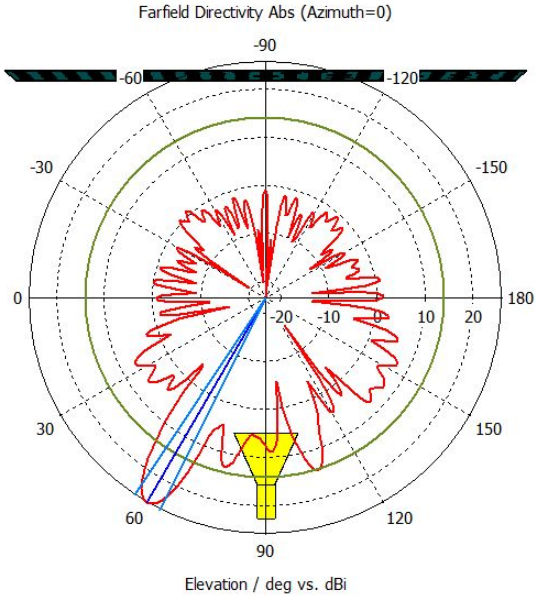


4.1) Reflectarray Design (0°, 30°) Results



Directivity: 25.8 dBi

Side-lobe: ***-11.8 dB***



Thank you!