Phased array antenna simulations

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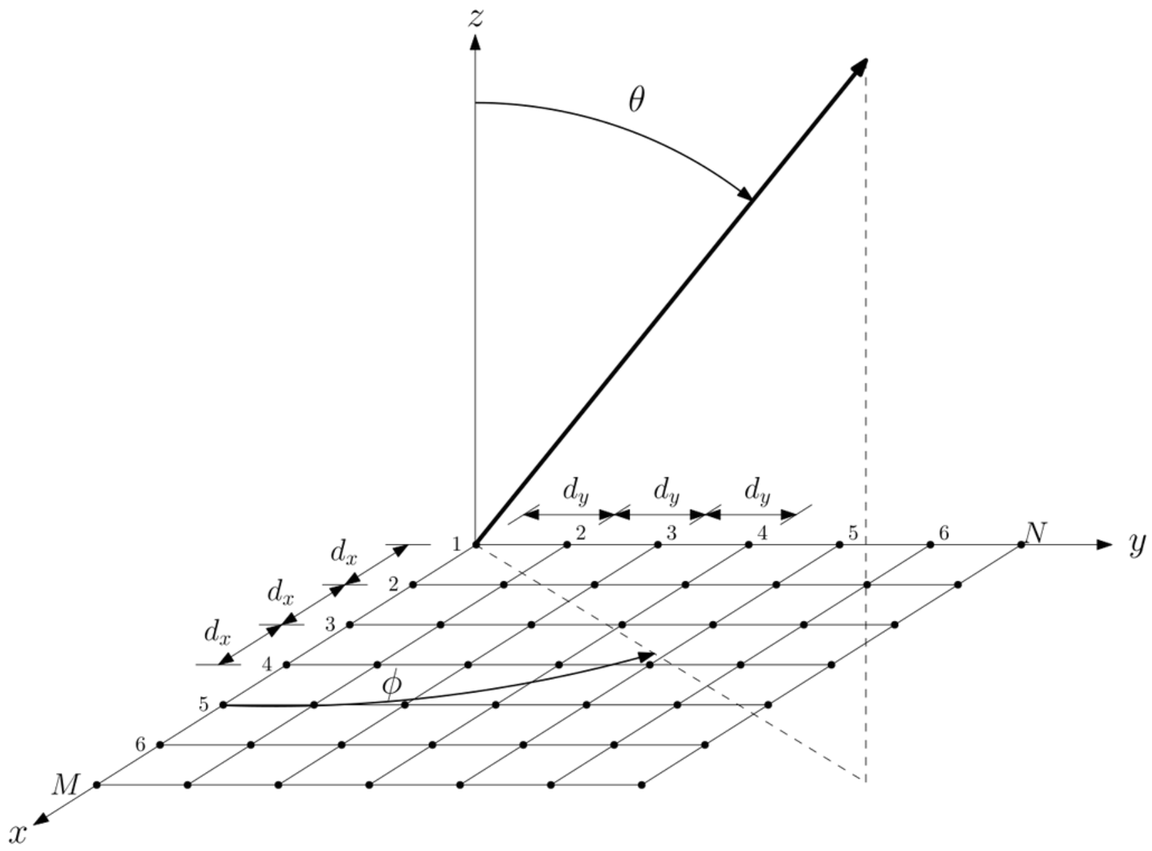
Phased aray antennas



Array factors

$$\mathbf{E}_{array}(\theta,\phi) = AF(\theta,\phi)\,\mathbf{E}_{element}(\theta,\phi)$$

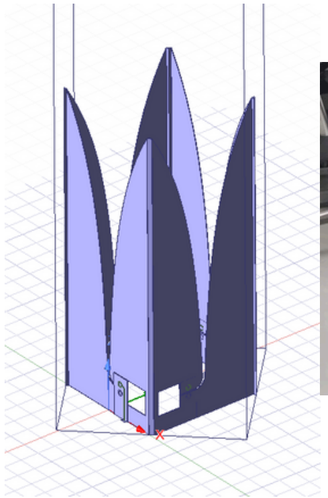
$$AF(\theta,\phi) = \sum_{n}^{N} e^{jk\mathbf{r}_n\cdot\left(\hat{r}(\theta,\phi)-\hat{r}_S\right)}$$

Phase shift

$$\psi_n = -k\mathbf{r}_n\cdot\hat{r}_S$$

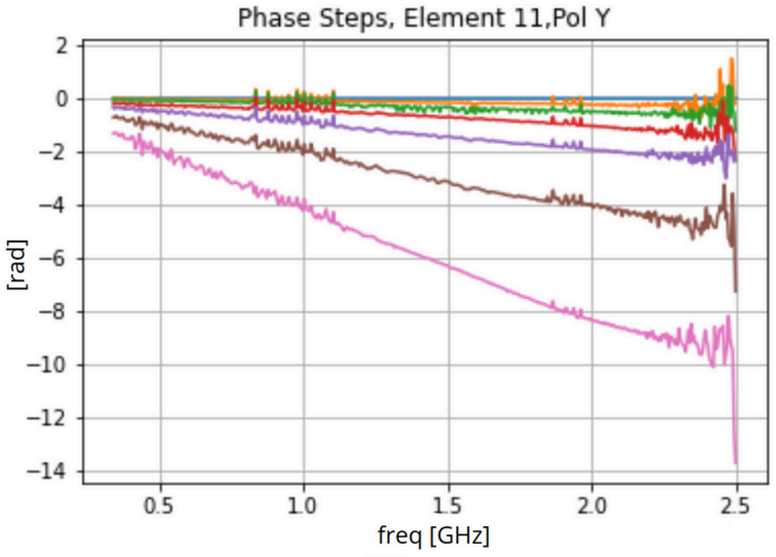
The technology

- **Vivaldi antenna:** This tapering design helps provide a wide bandwidth and directional radiation pattern.
- **Beamforming:** performed in two steps: the first is analog on the tile and the second is digital. The digital step form multiple directed beams at the same time.
- **True-time delay:** exhibit constant phase slope over frequency. $\psi_n = -k\mathbf{r}_n \cdot \hat{r}_S$



Vivaldi antenna

Tile

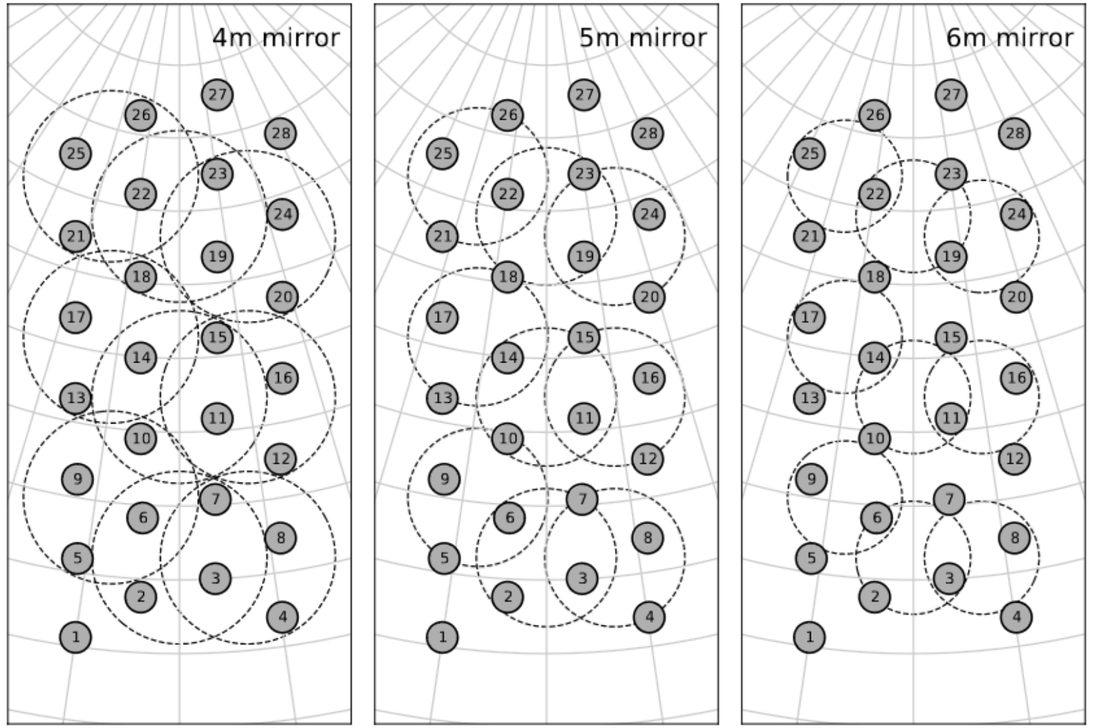


Science case: FRB

- BINGO IX paper (Santos et al) proposes **single-dished outriggers** for the BINGO Interformetry System (BIS).
- However, one **phased-array (PA) outrigger** can cover the entire instantanous area of the BINGO main telescope.
- We explore PA stations with similar effective area as in Santos et al.
- The minimal flux density of the sources will also depend the system temperature (*to be measured*) by

$$S_{\min}^{\mathrm{intf}} = \frac{1}{\sqrt{2 n_p \Delta\nu\, \tau}} \left[\sum_{\substack{i,\,j,\\ i<j}} \frac{G_i \mathrm{P}_{\mathrm{n,i}}(\mathbf{n})}{K_i T_{\mathrm{sys,i}}} \frac{G_j \mathrm{P}_{\mathrm{n,j}}(\mathbf{n})}{K_j T_{\mathrm{sys,j}}} \right]^{-1/2} .$$

- Preliminary results points that BIS detection with one PA outrigger of 6m of diameter is 10 times higher than with nine sigle-dished outriggers of 6m.

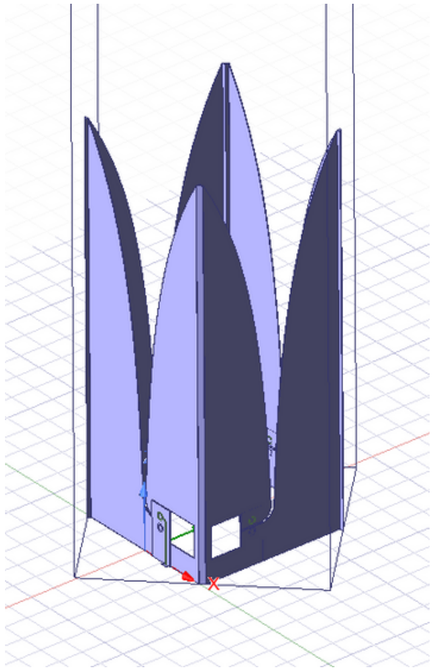


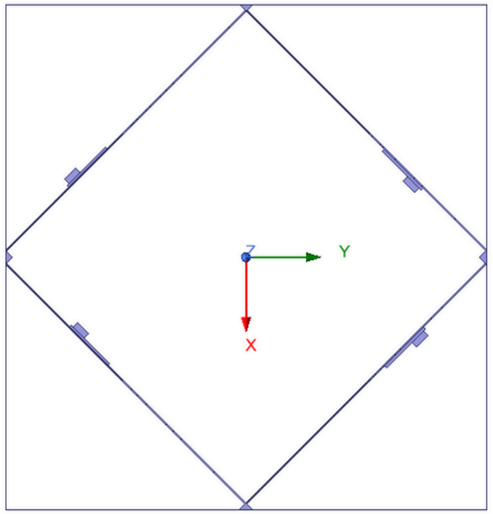
Santos et al

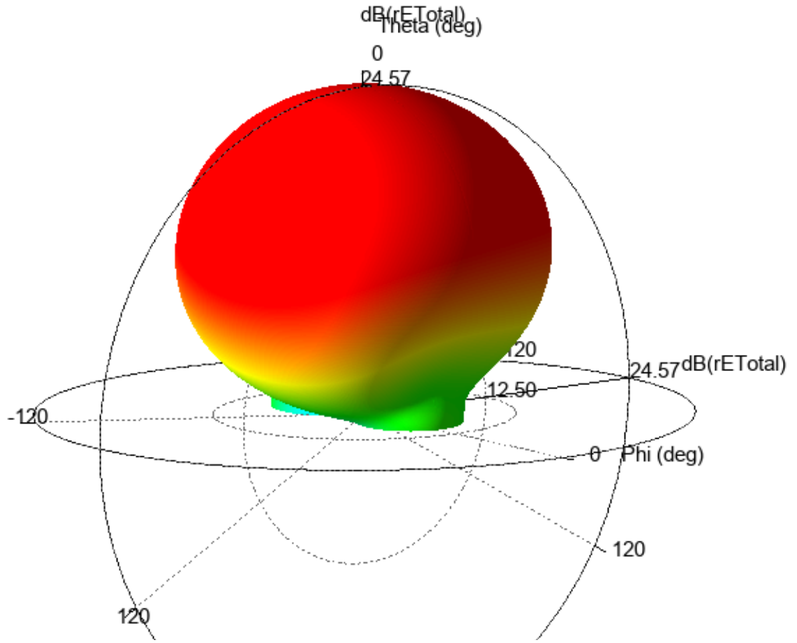
Results

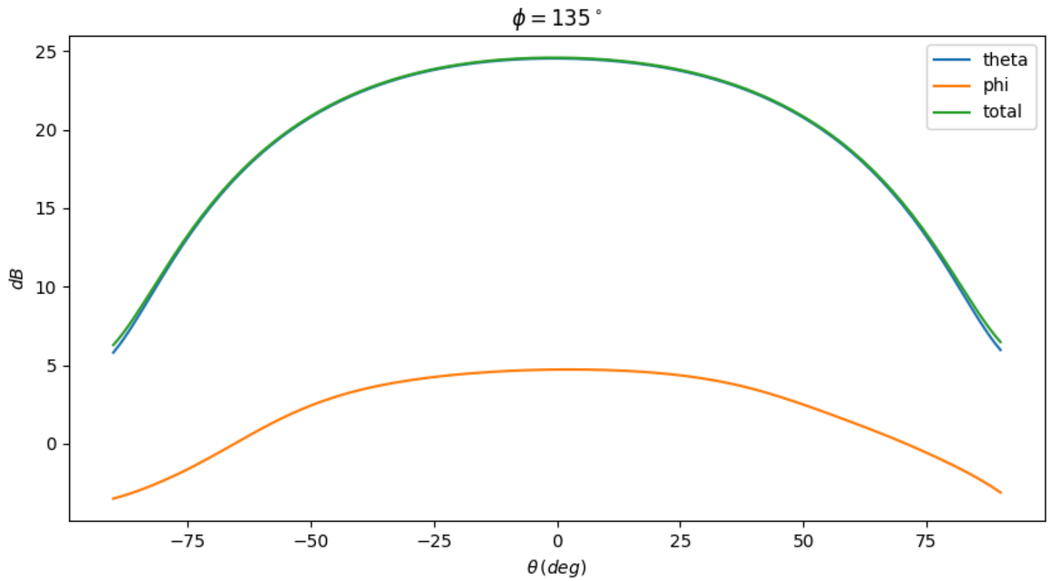
Unit Cell simulation

- One unit cell is assumed with four antenna elements, two for each polarization.
- We excite two elements of same polarization and run EM simulations on HFSS sofware.



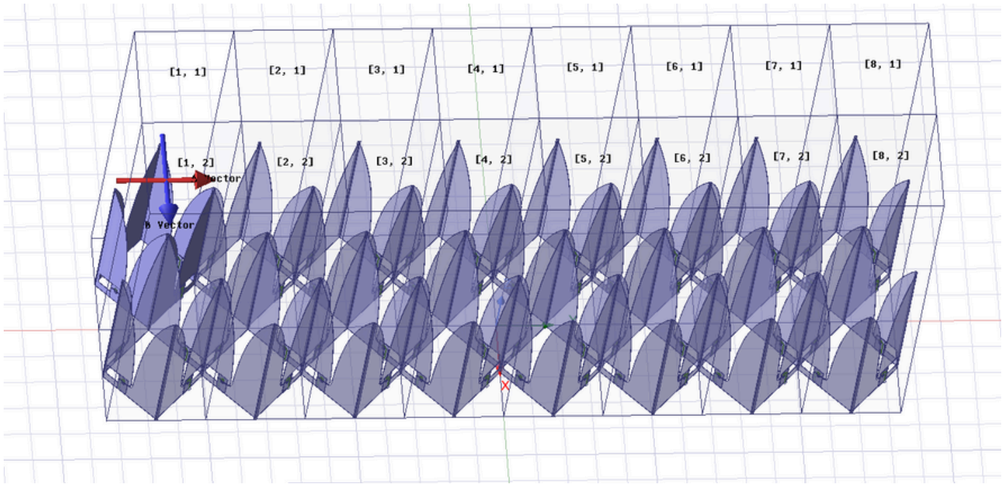


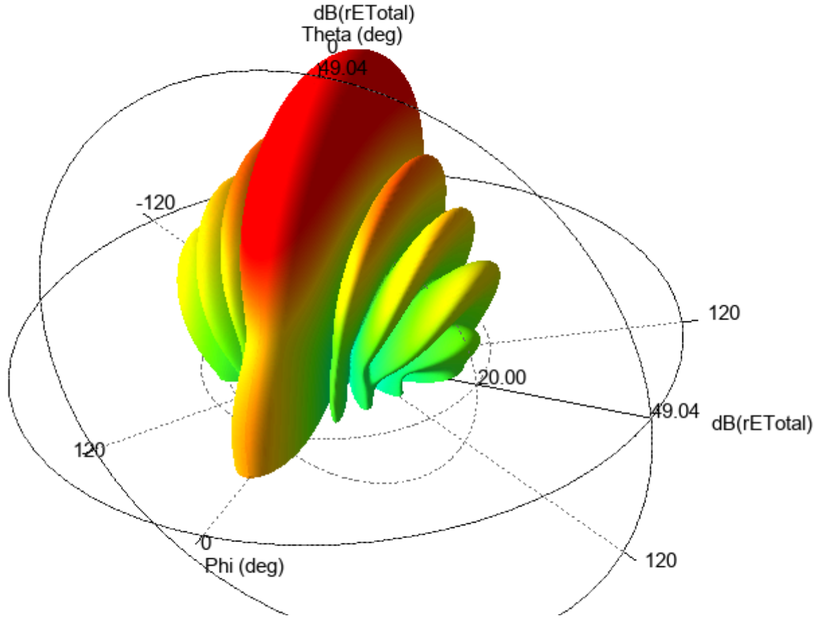


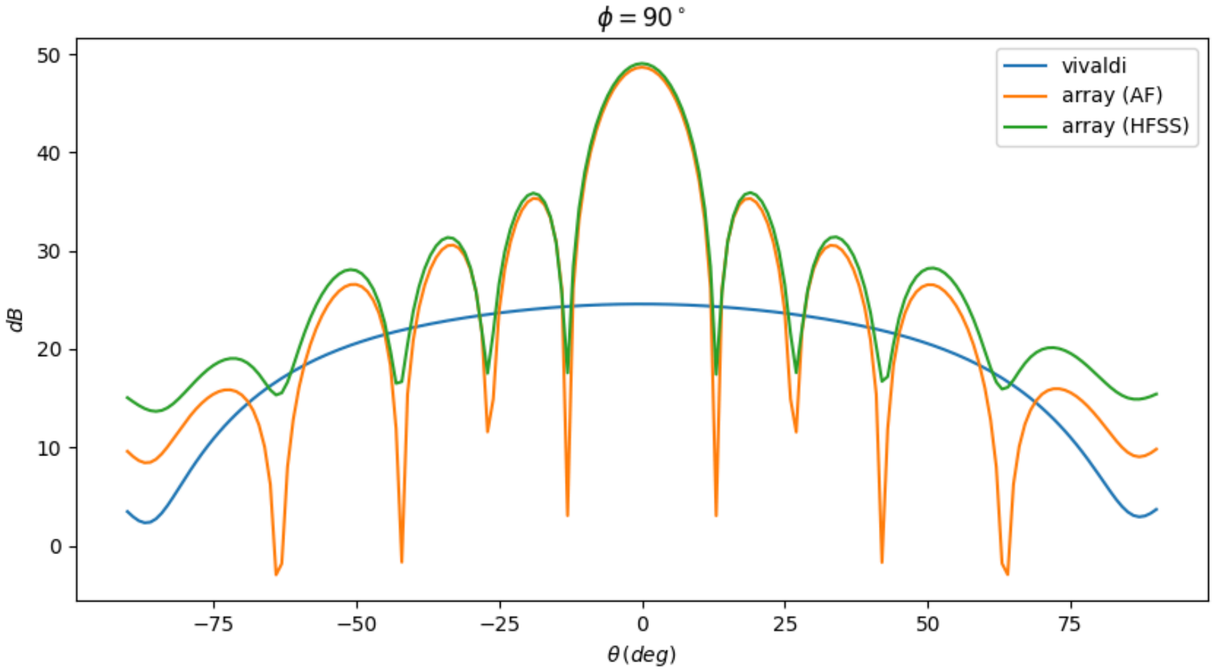


Vivaldi Tile simulation

- We simulated a 2x8 array. It correspond to a 35cm x 134 cm tile that will be used on ABDUS project.

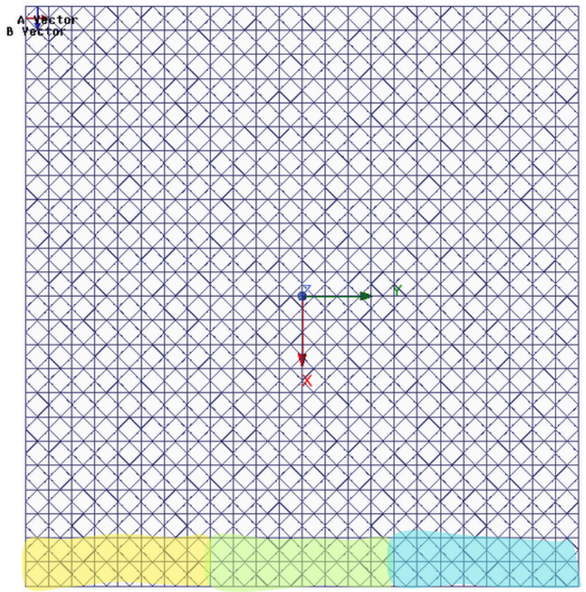




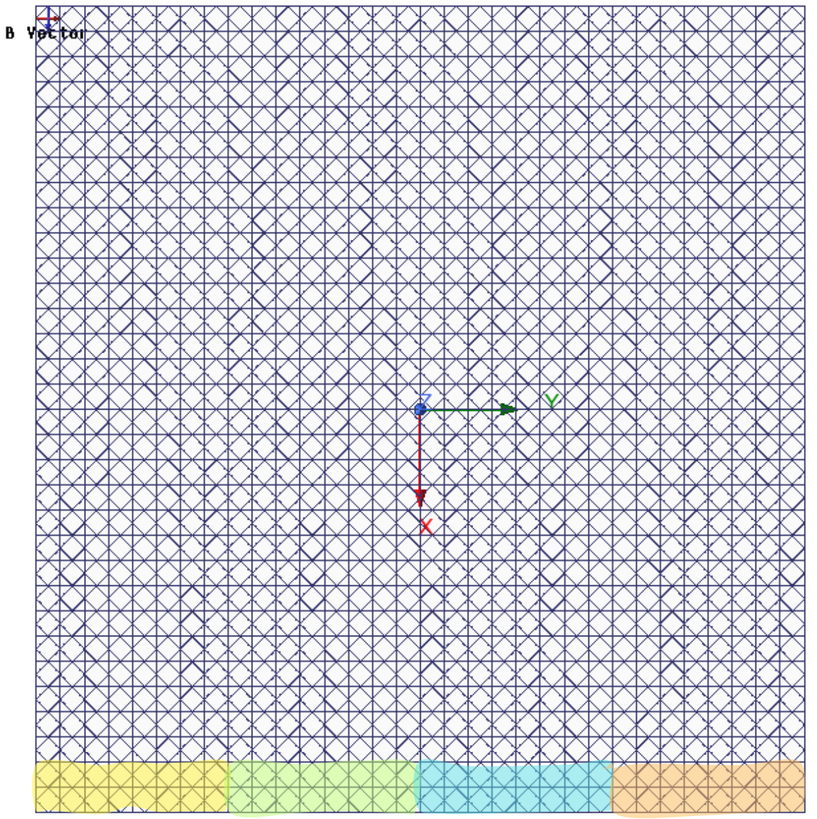


Simulating stations

Stations comparison

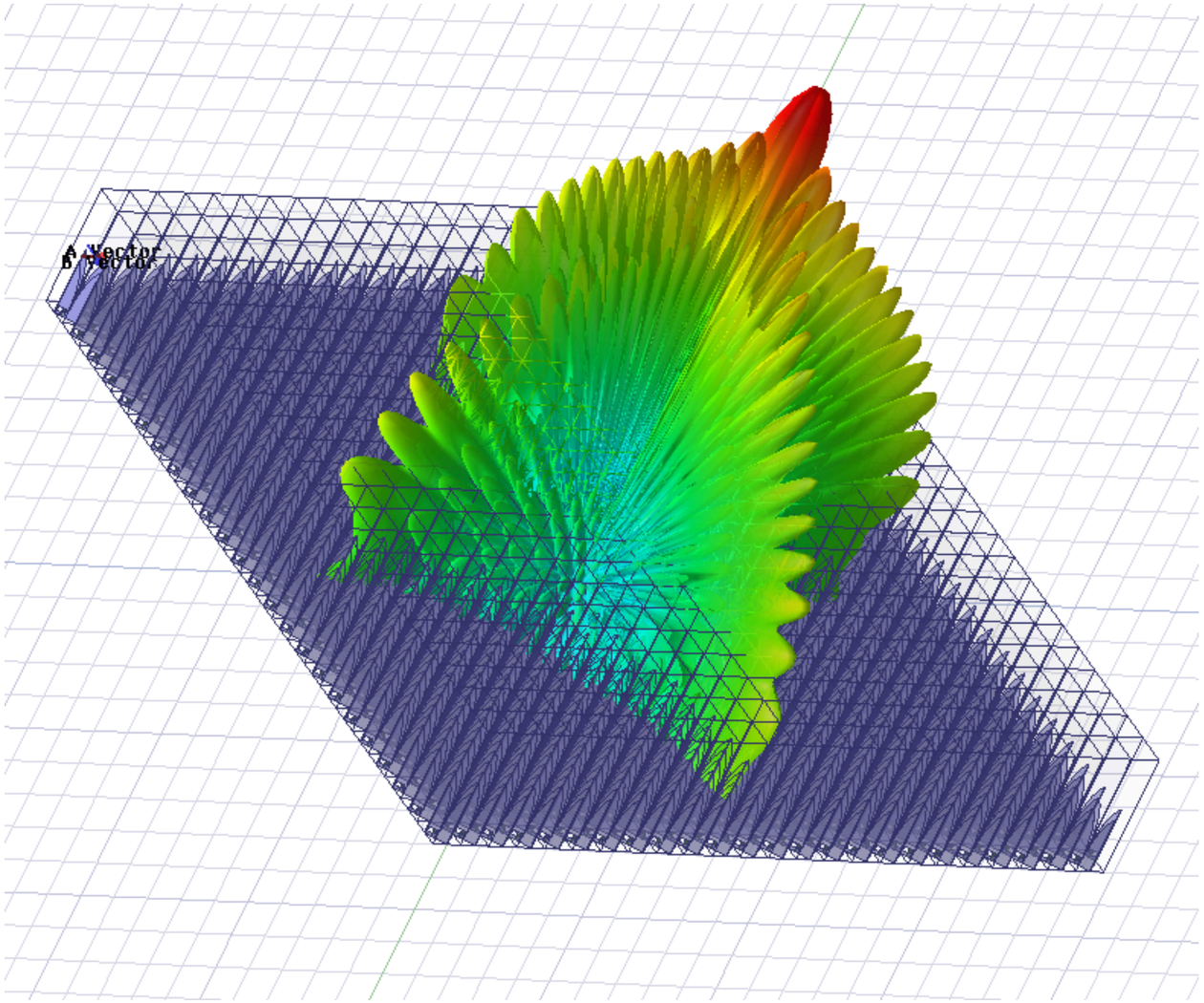


- 24x24 unit cells
- 36 tiles
- 422cm x 402cm
- Physical area: 17m2
- Effective area: 16.24m2



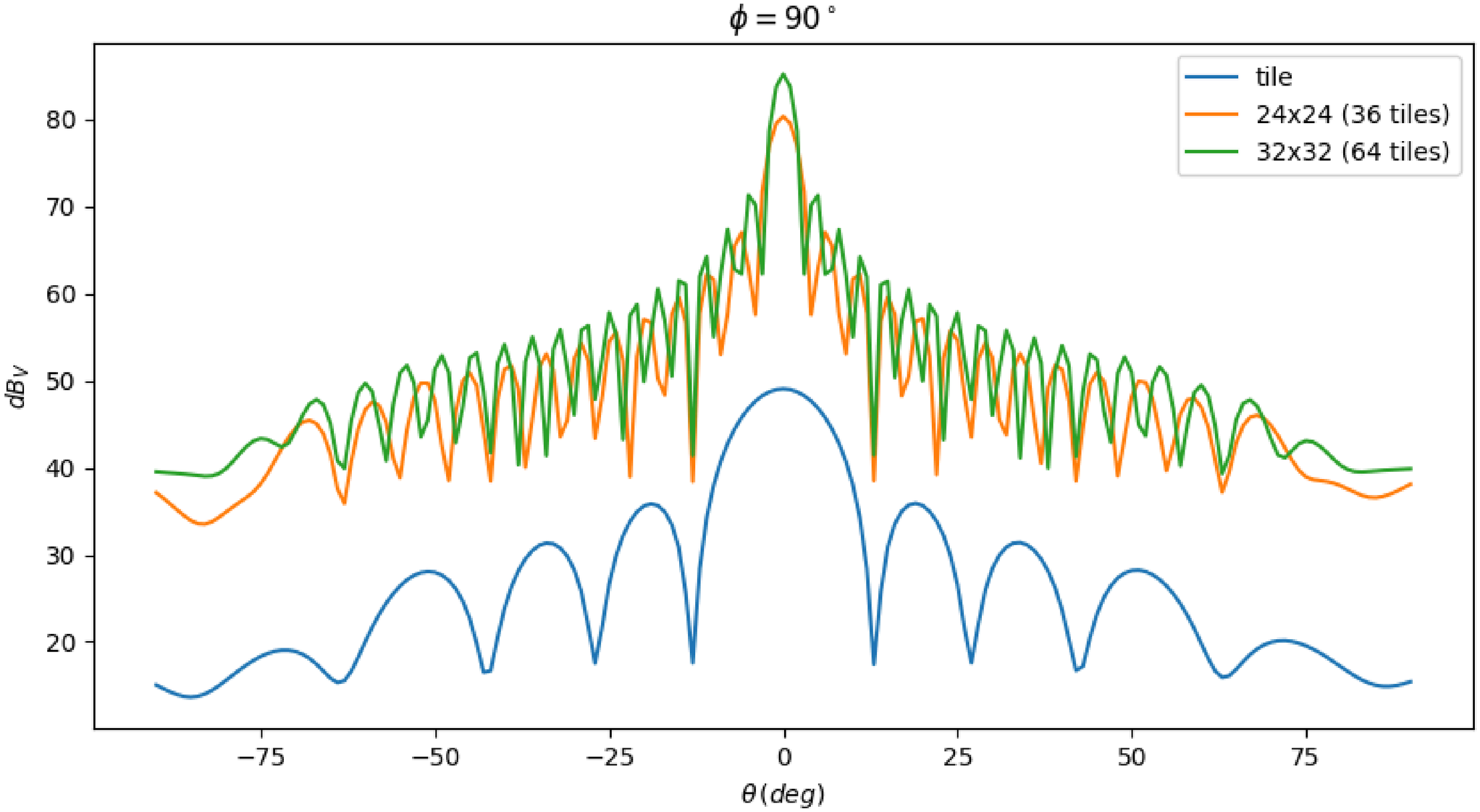
- 32x32 unit cells
- 64 tiles
- 563cm x 536cm
- Physical area: 30.21m2
- Effective area: 28.84m2

Simulated station - 3d

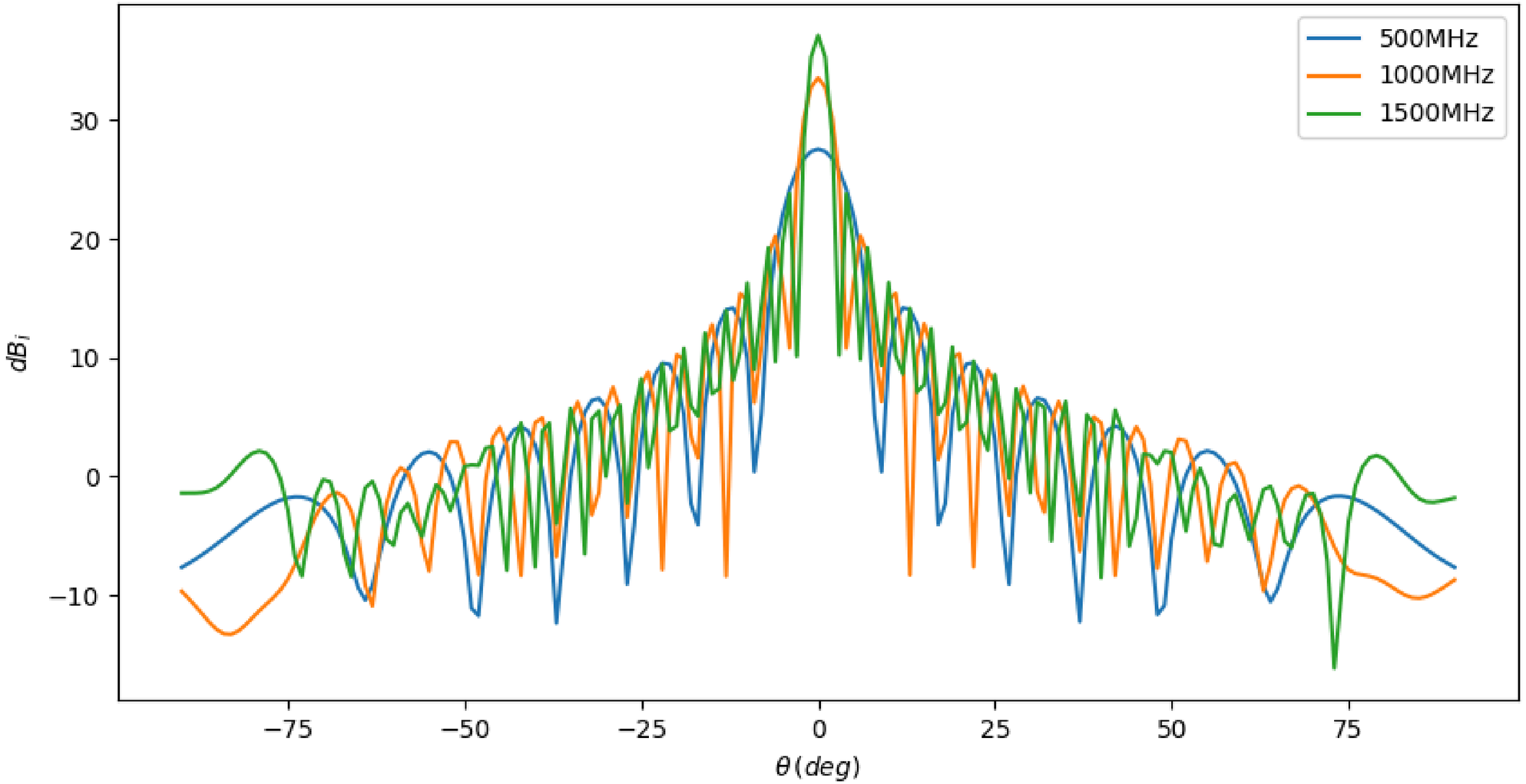


dB

Simulated station - 36 vs 64 tiles



Simulated station - Frequencies

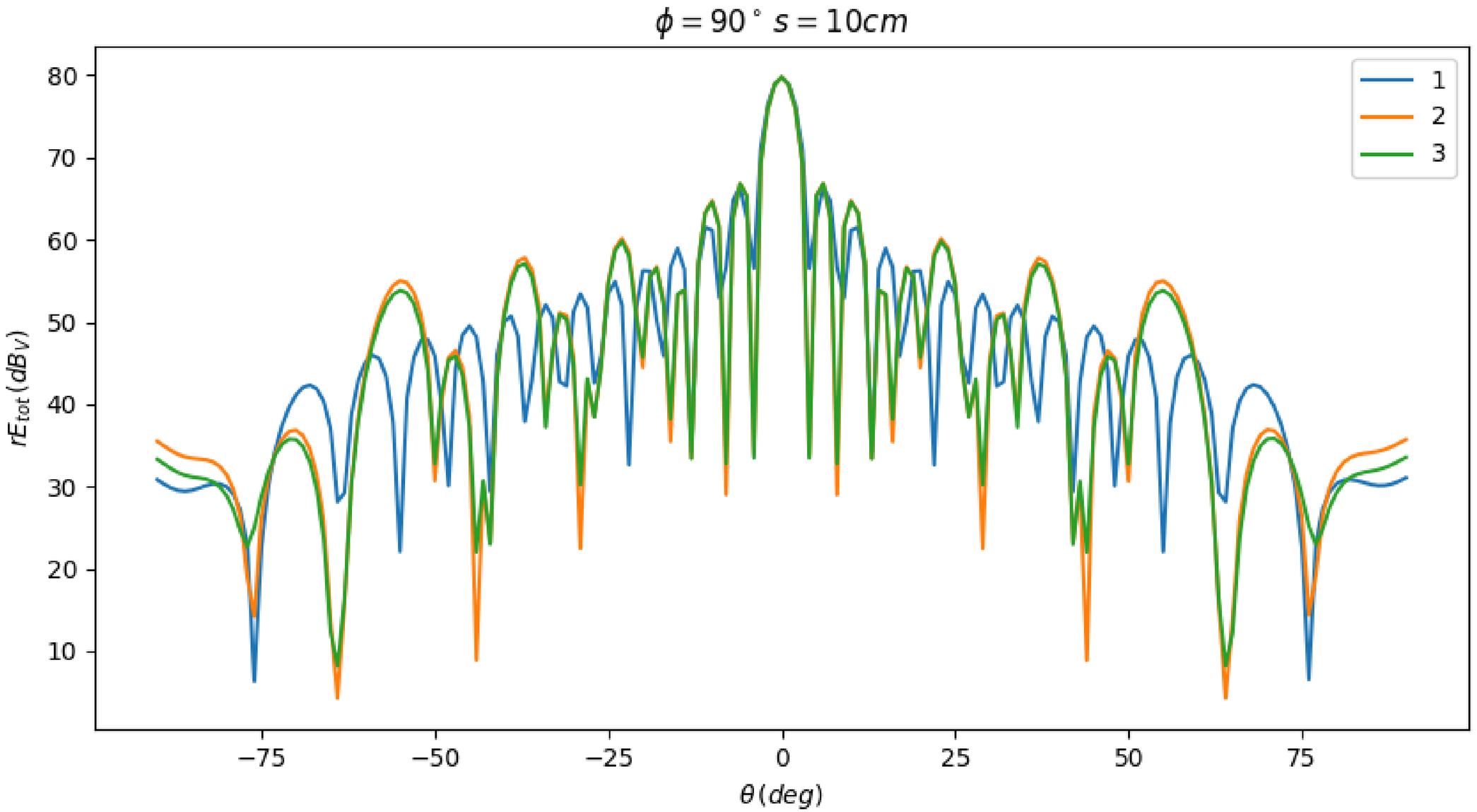


	01 tile	36 tiles	64 tiles
Size (m x m)	0.35 x 1.34	4.22 x 4.02	5.63 x 5.36
Gain (dBi)	5.02	33.6	36.1
Phis. area (m2)	0.47	17	30.2
Eff. area (m2)	0.45	16.2	28.8
FWHM (deg)	10 (42)	4	2
First side lobe (deg)	-13.3	-13.3	-13.9

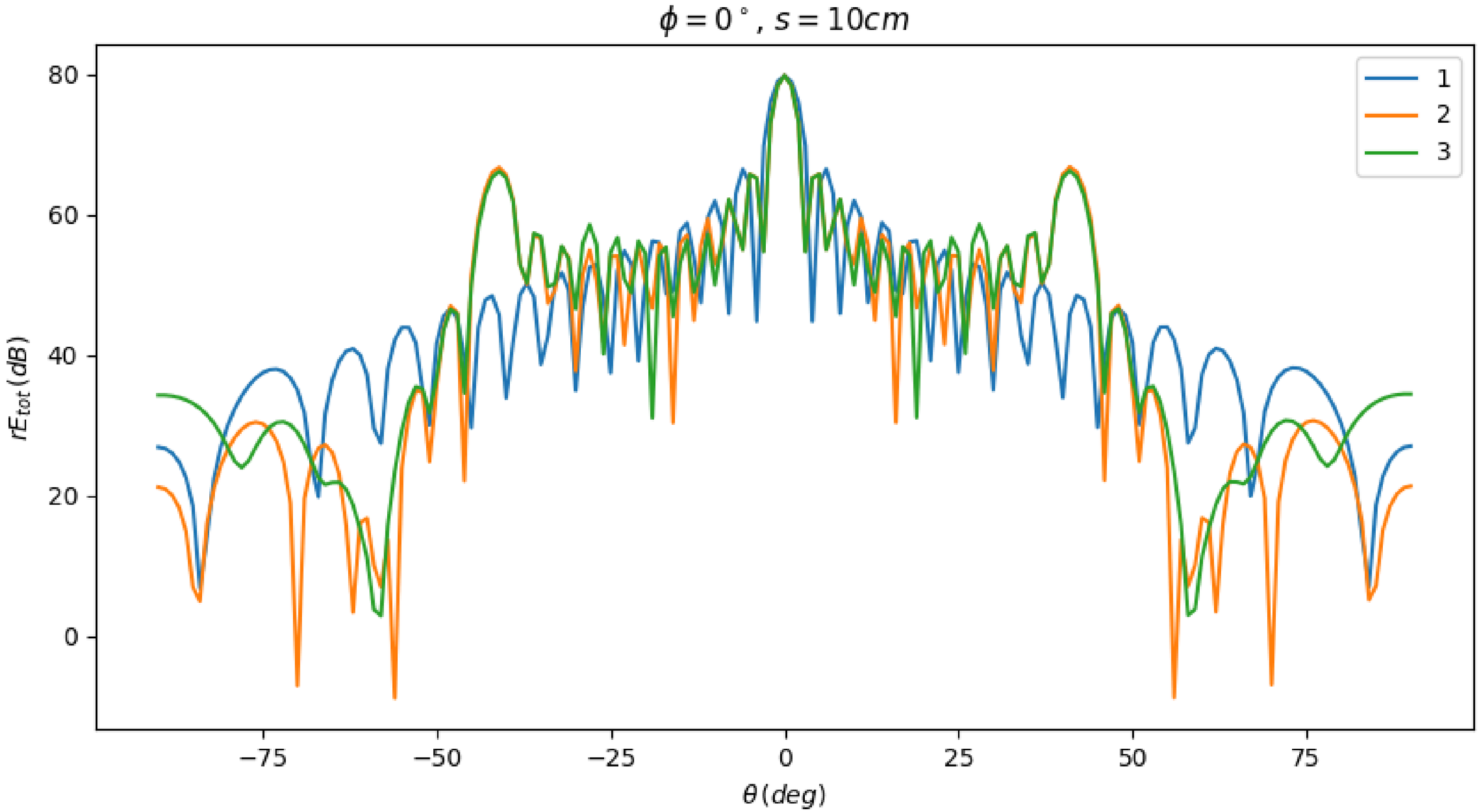
Table 1. Technical data for the tile and for the 36-tile and 64-tile station. All the quantities except the size and physical area were computed from the HFSS simulations.

Stations with randomly spaced tiles

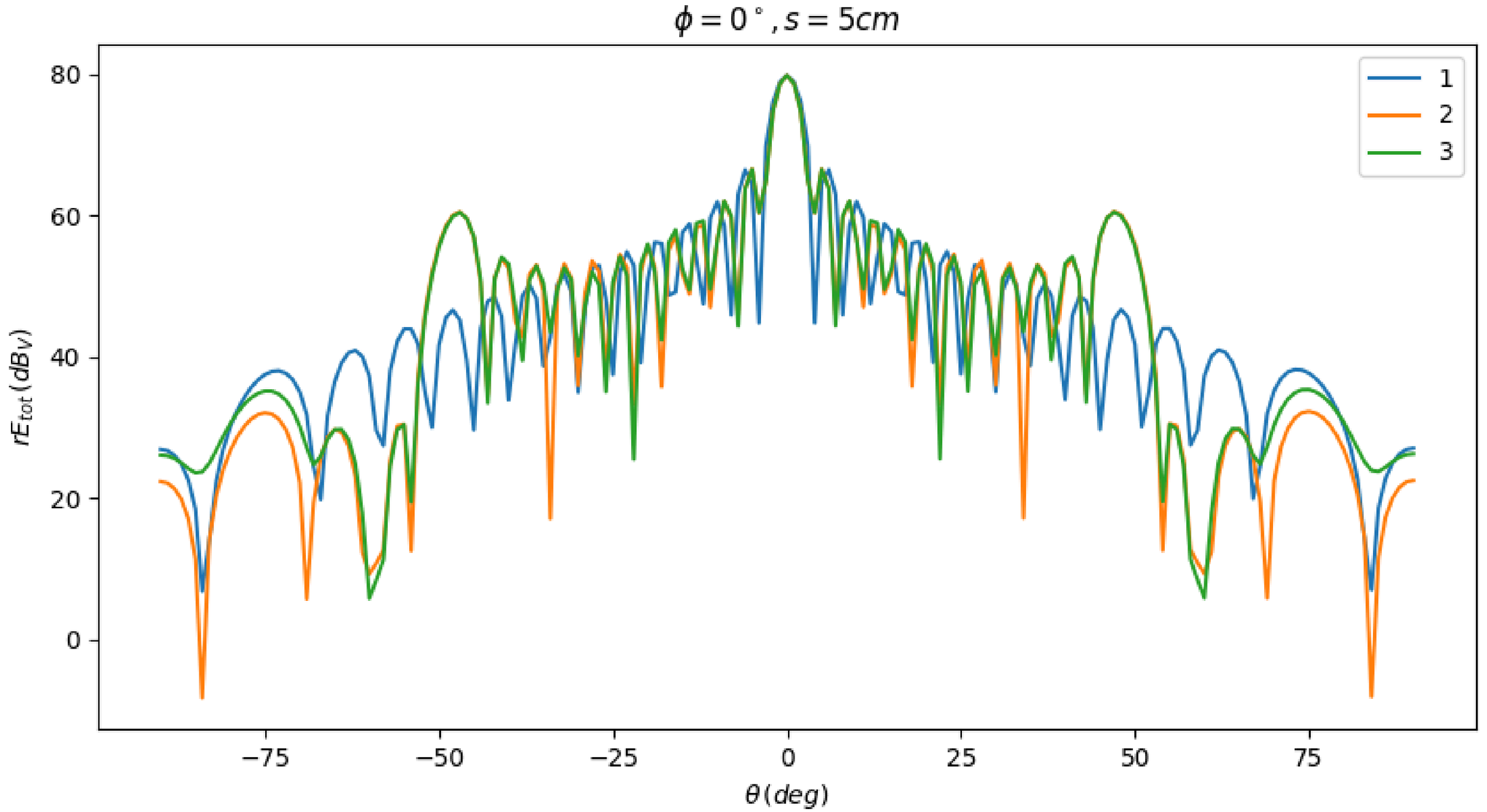
10cm spaced station



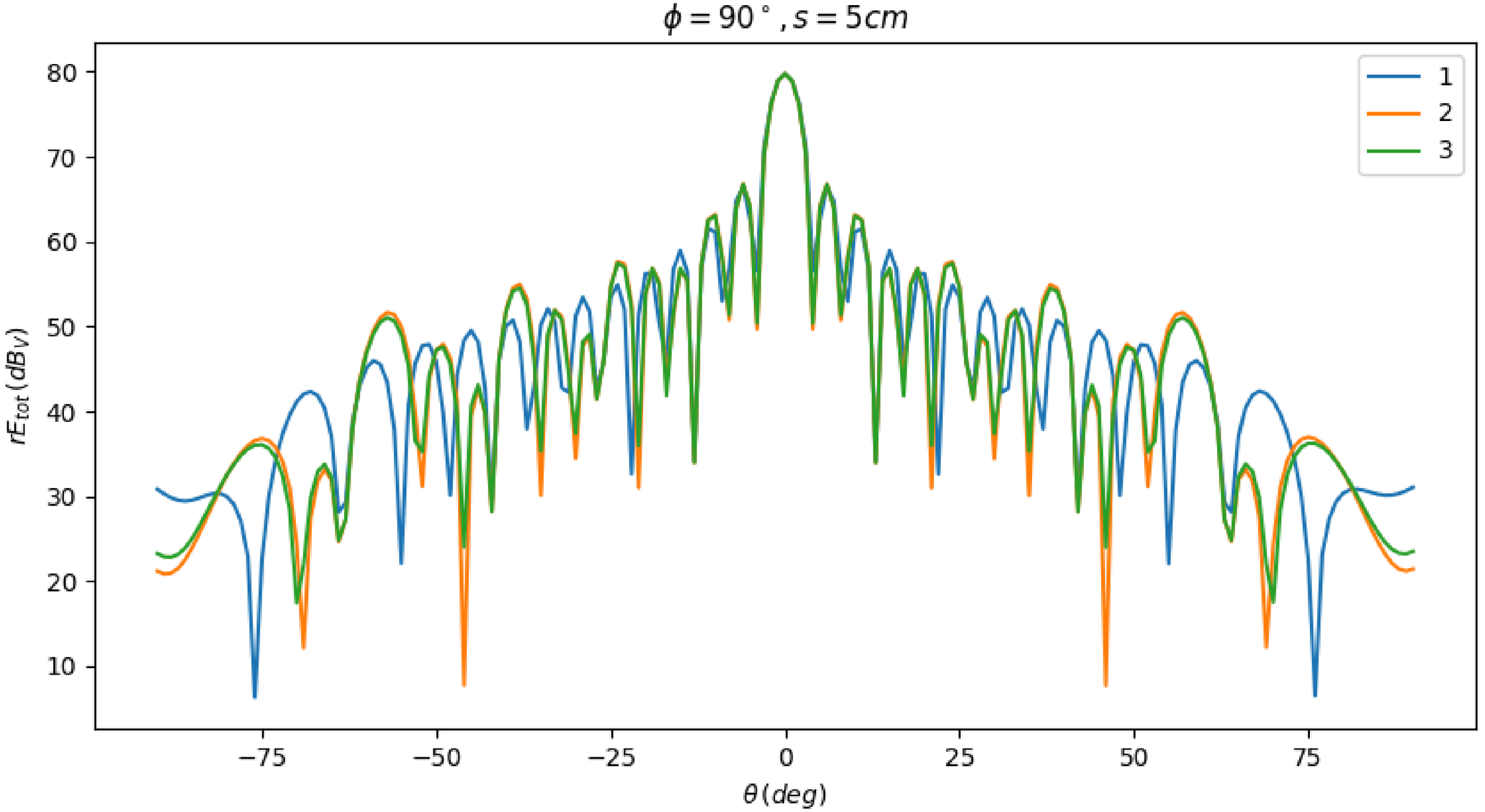
10cm spaced station



5cm spaced station

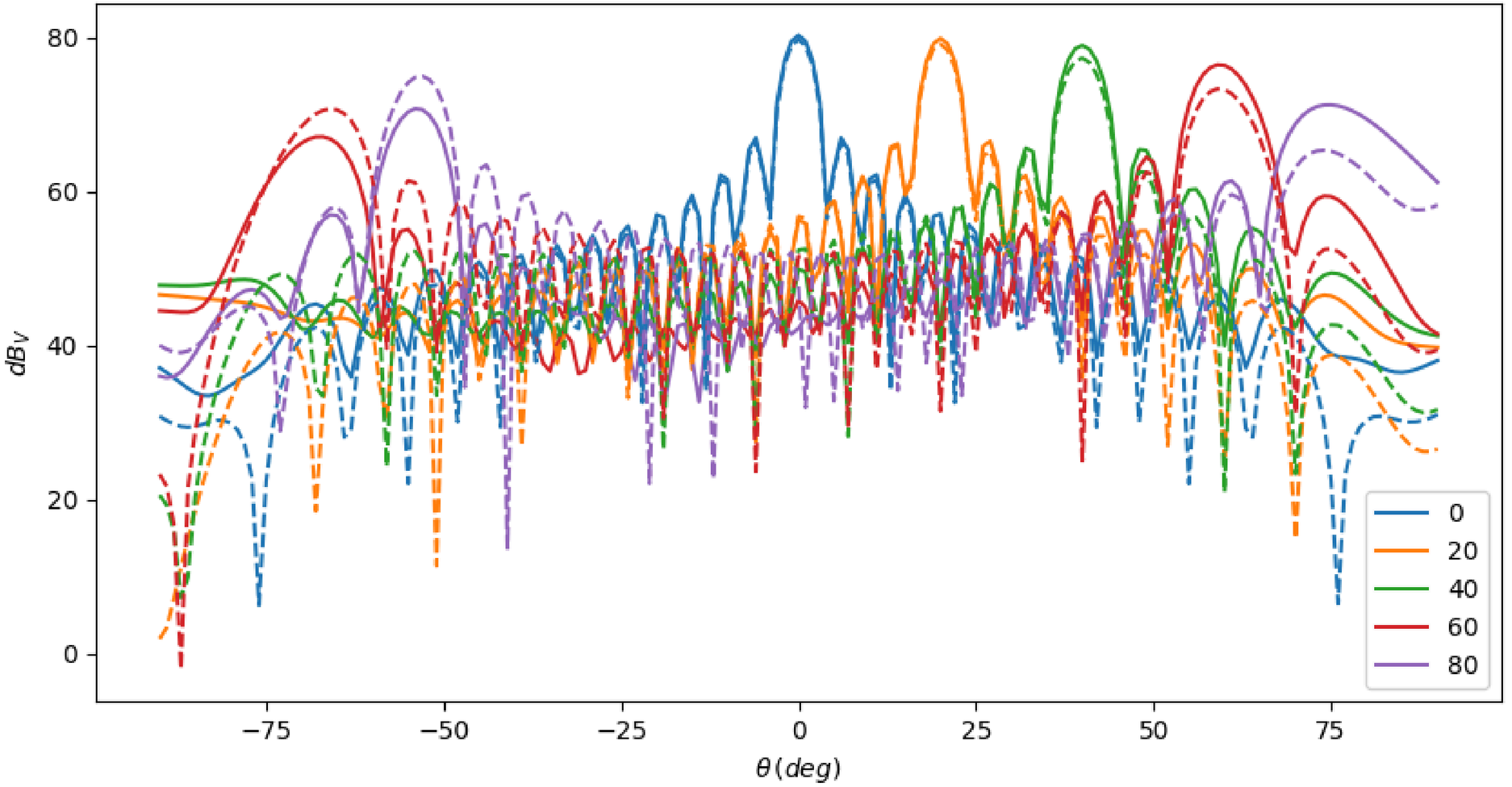


5cm spaced station

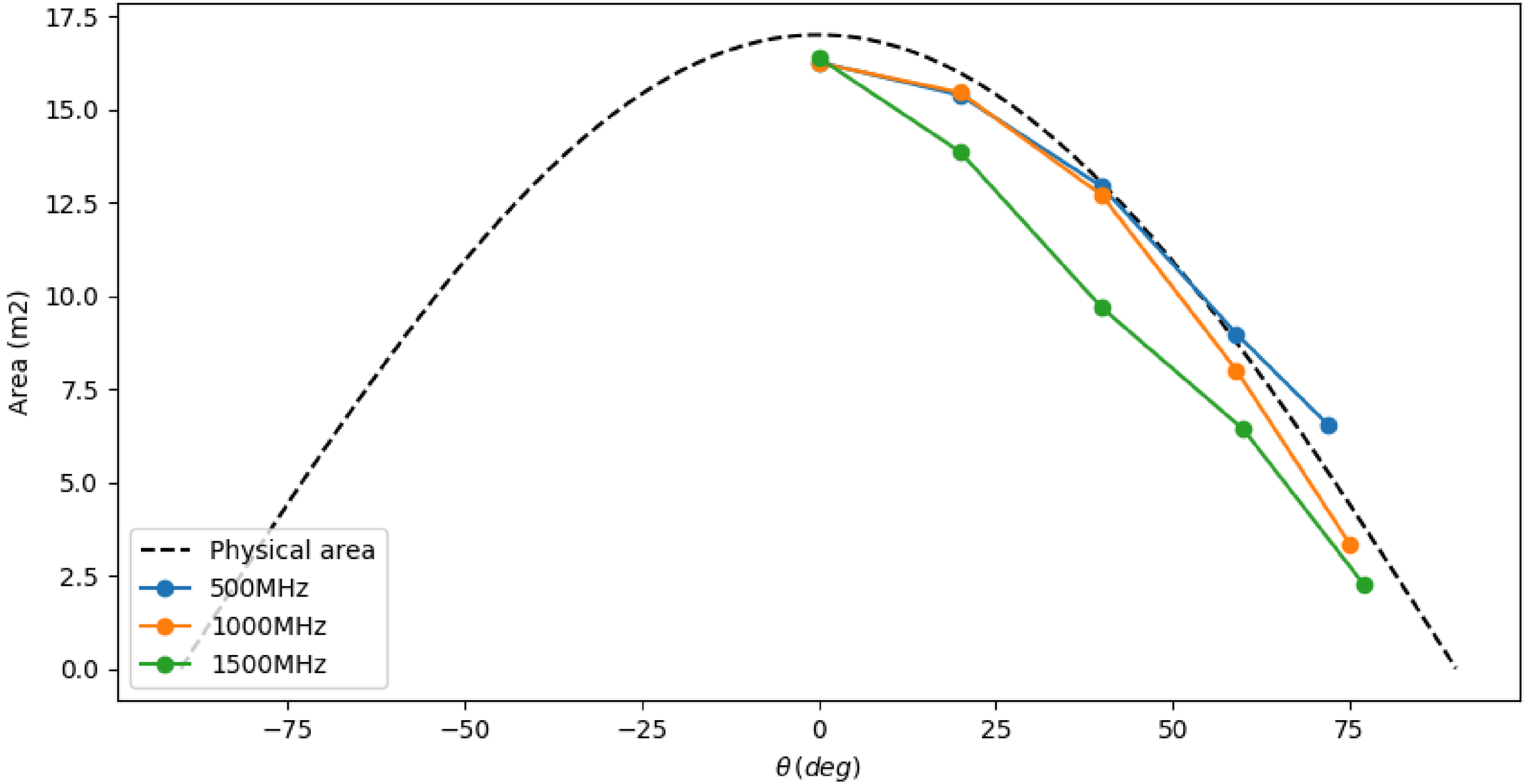


Scan angle and effective area

Beam steering

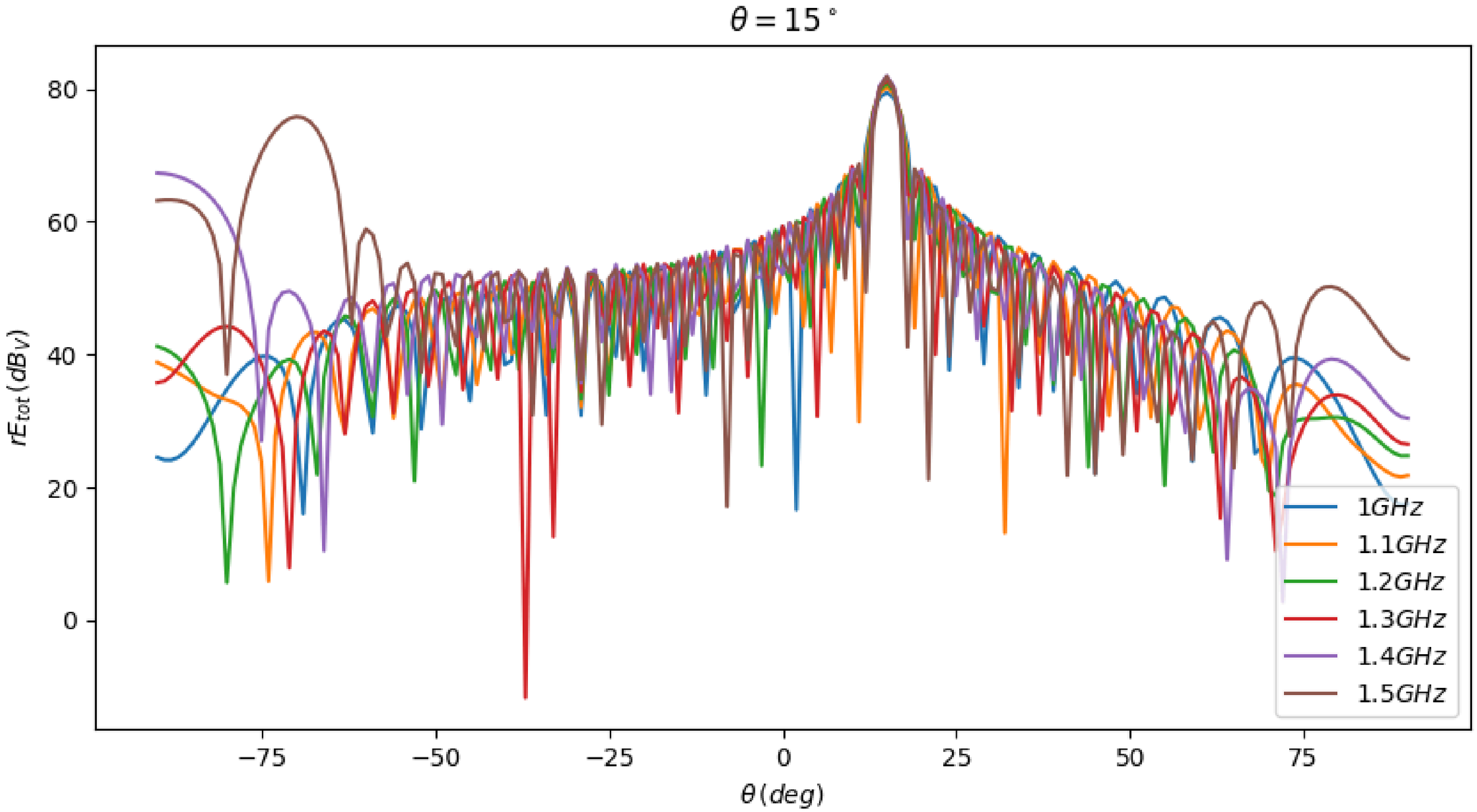


Effective area

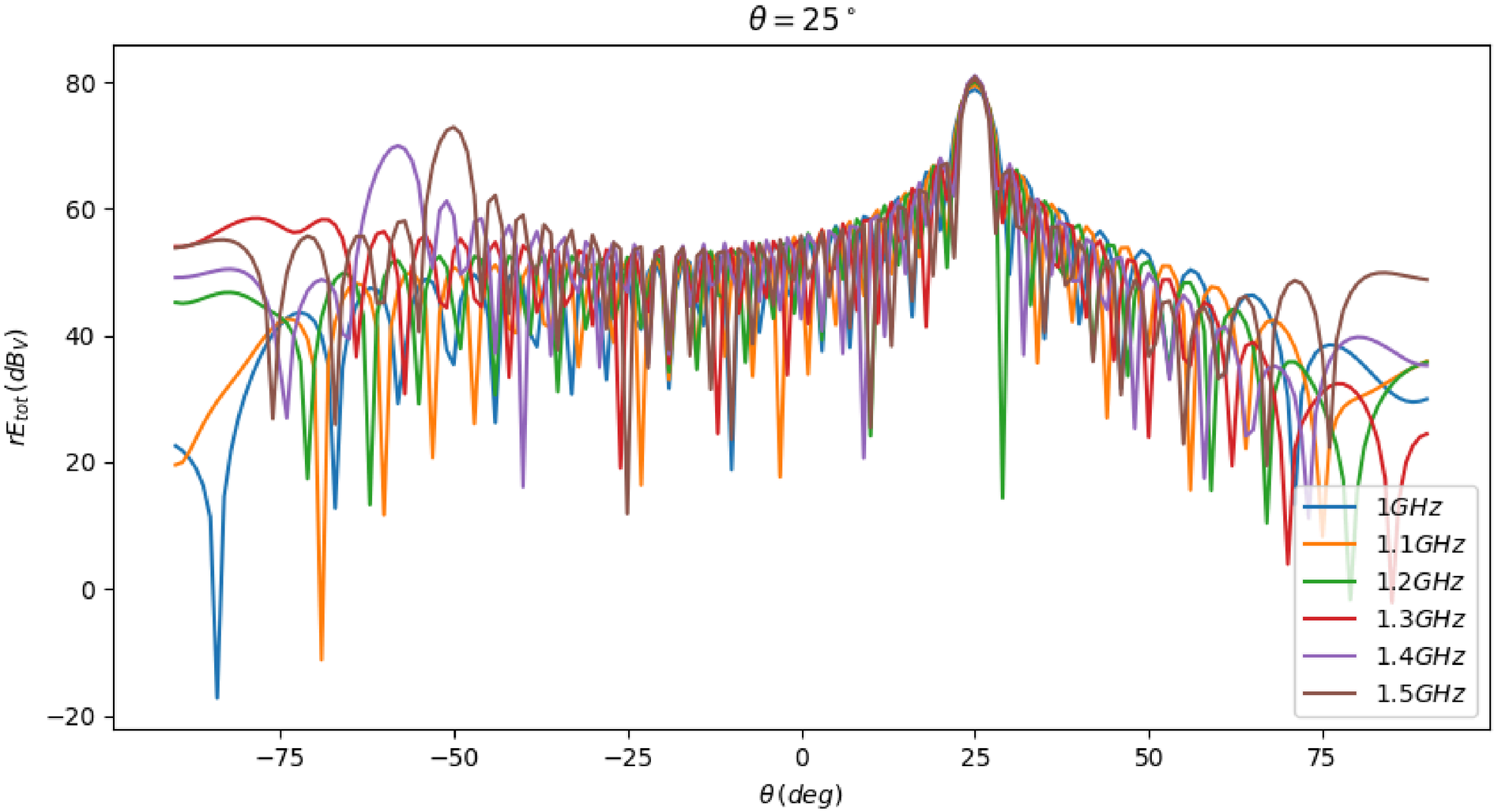


Scan angle and grating lobes

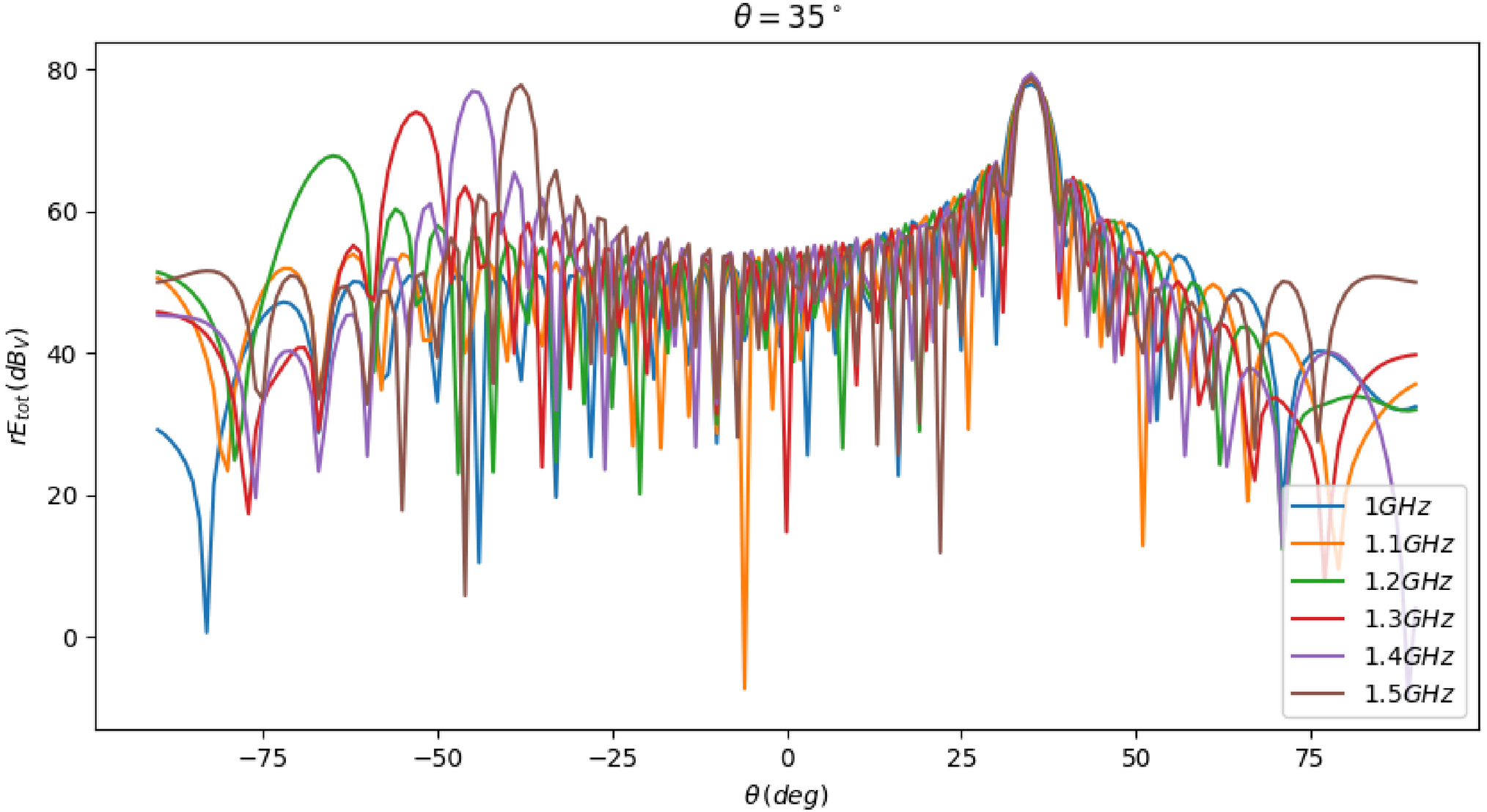
Sweeping frequency at 15°



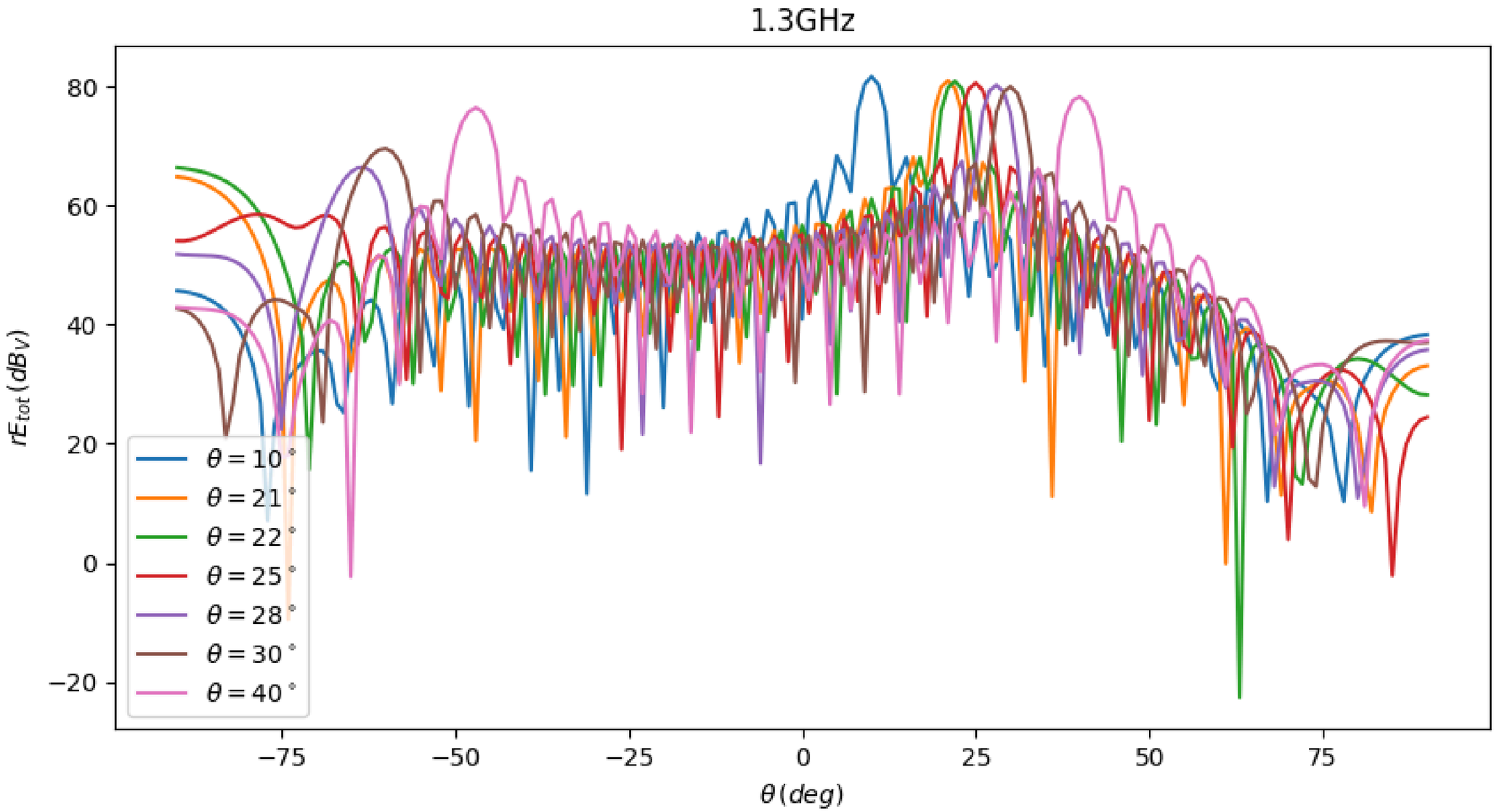
Sweeping frequency at 25°



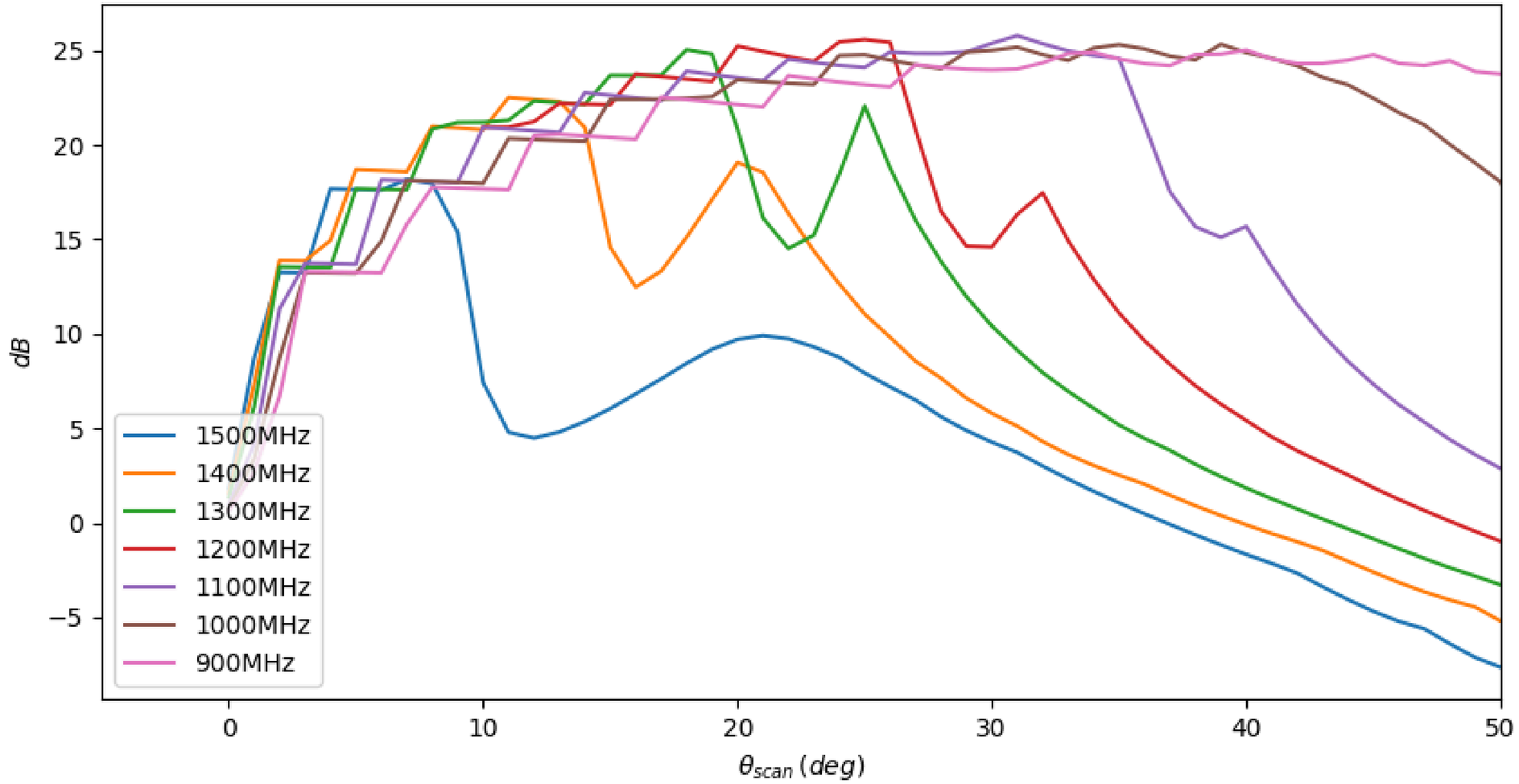
Sweeping frequency at 35°



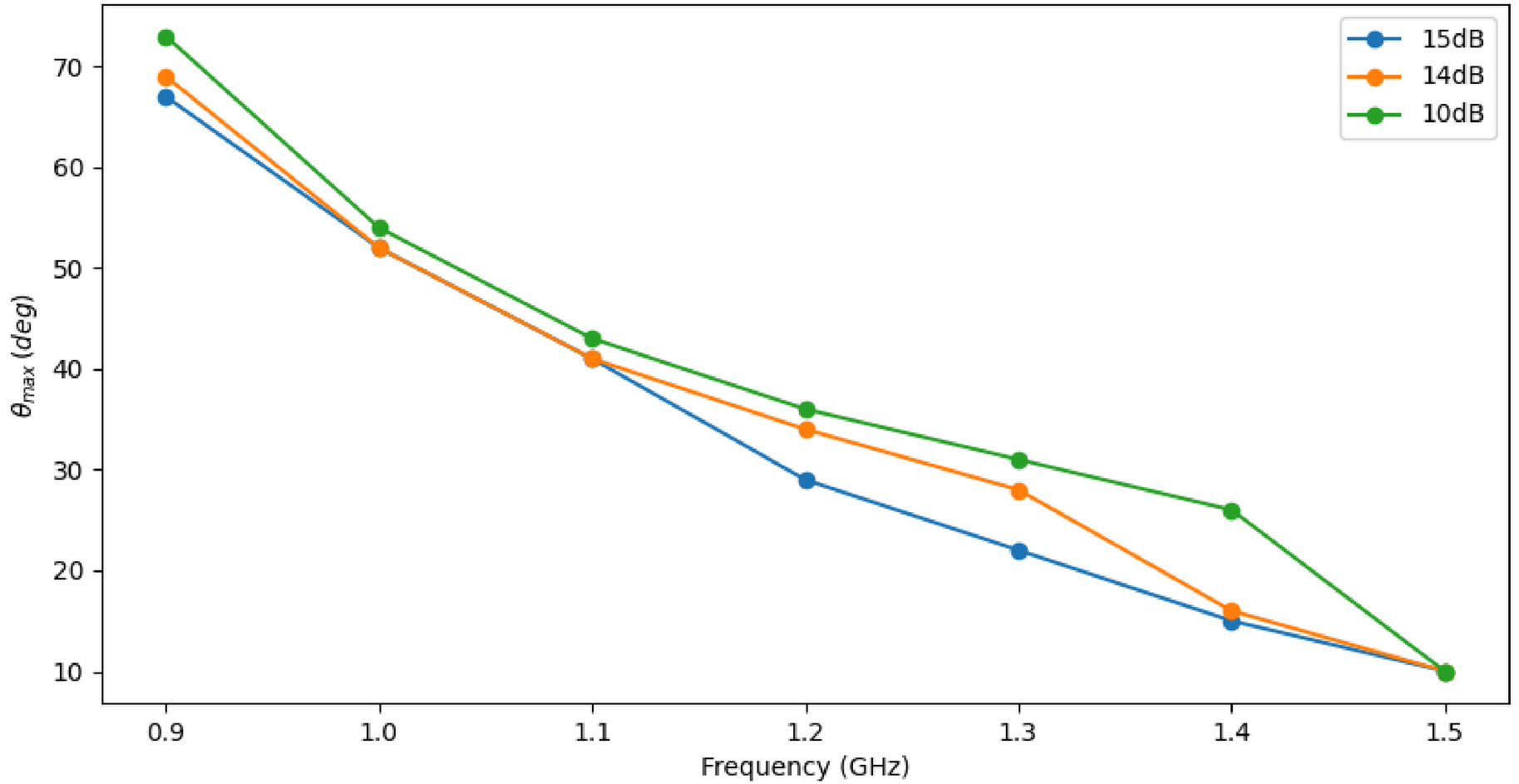
Sweeping theta at 1.3GHz



Difference between main lobe and maximum value at negative theta



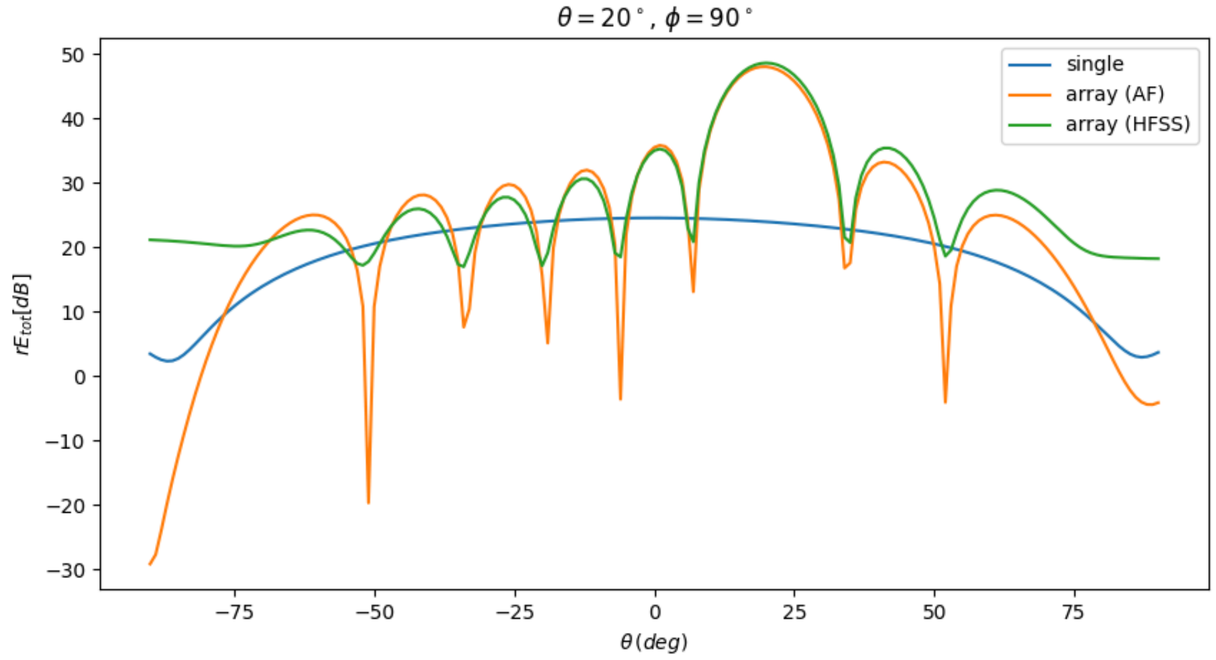
Maximum scan angle

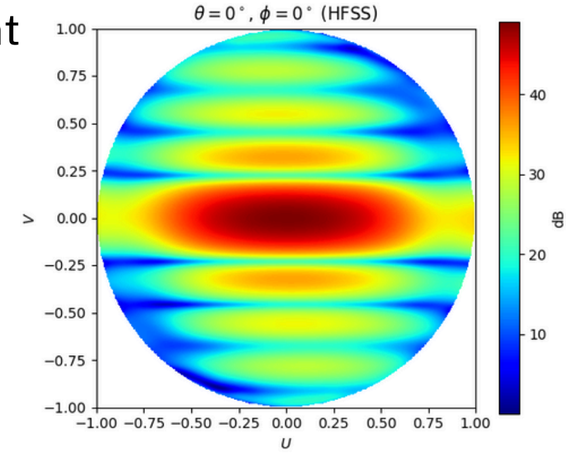


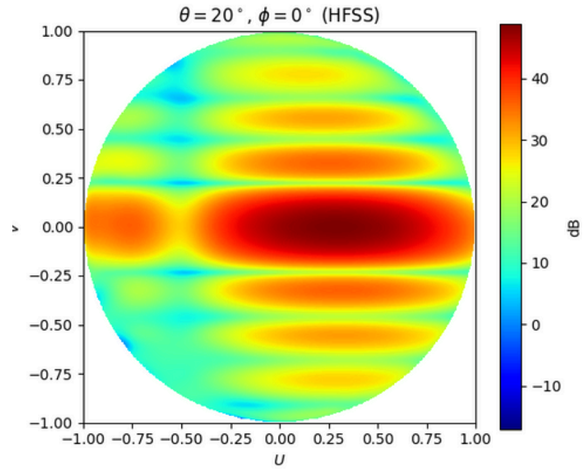
End

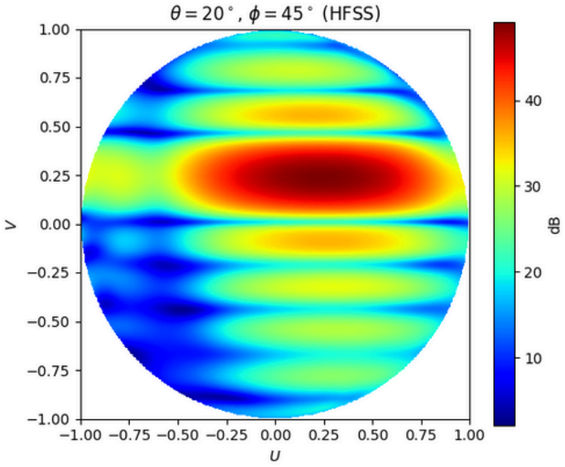
Vivaldi Tile simulation: scanning

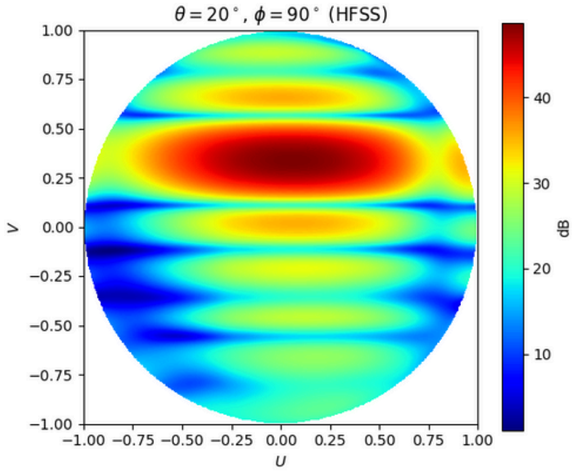
- We then present simulations steering in some different directions.





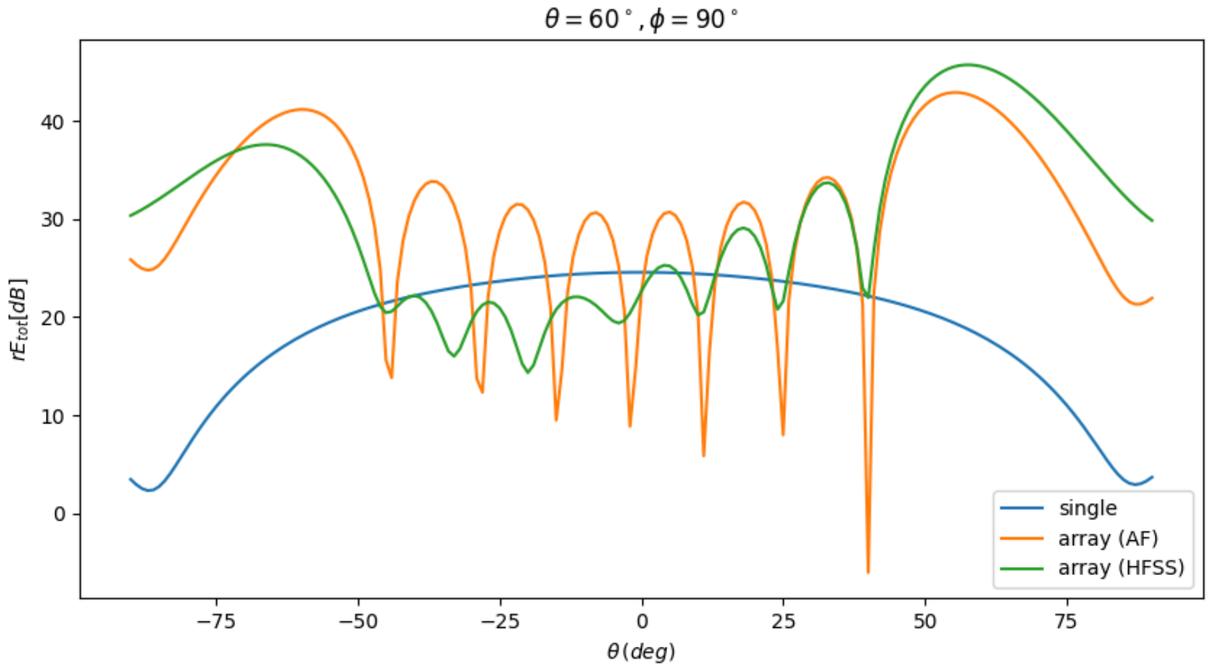


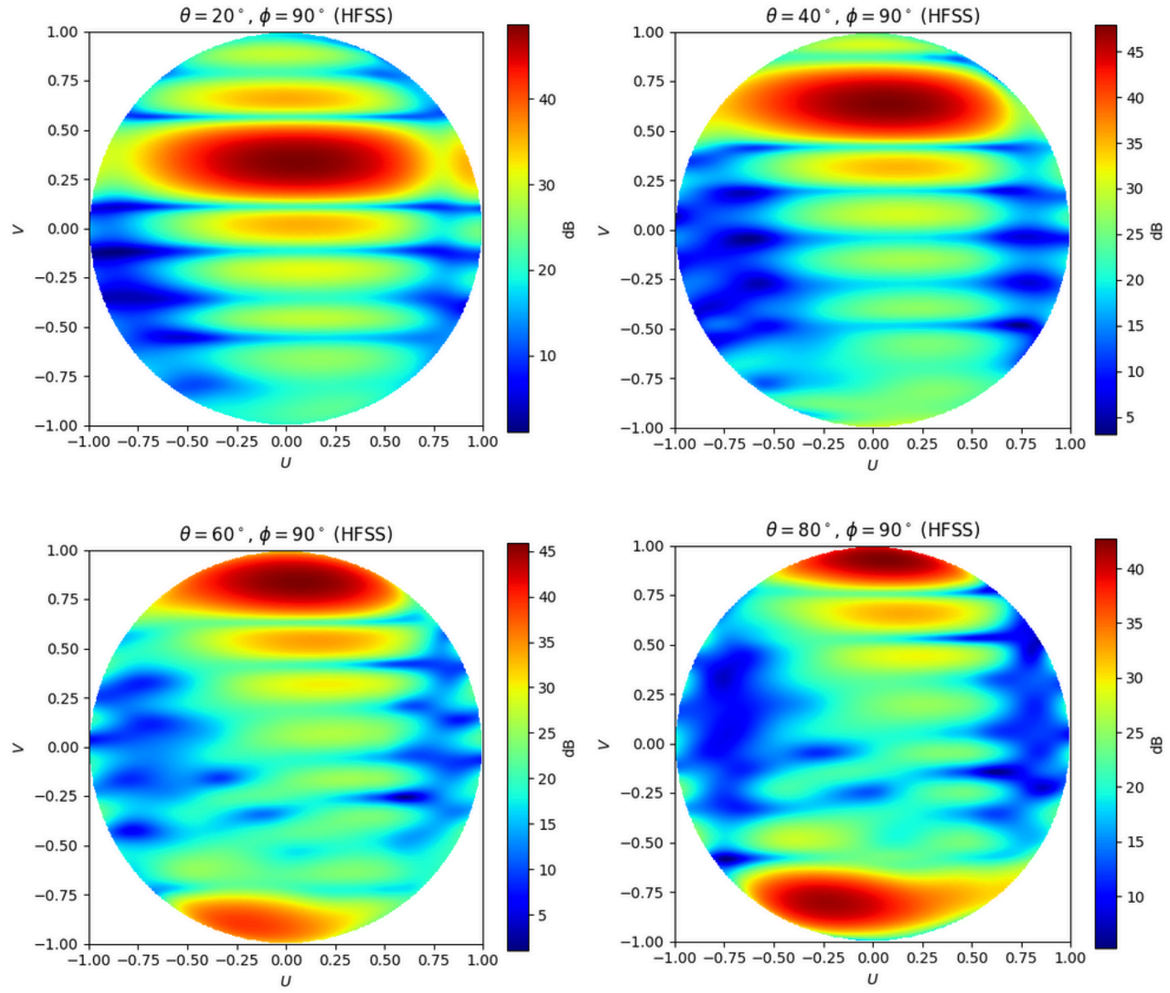




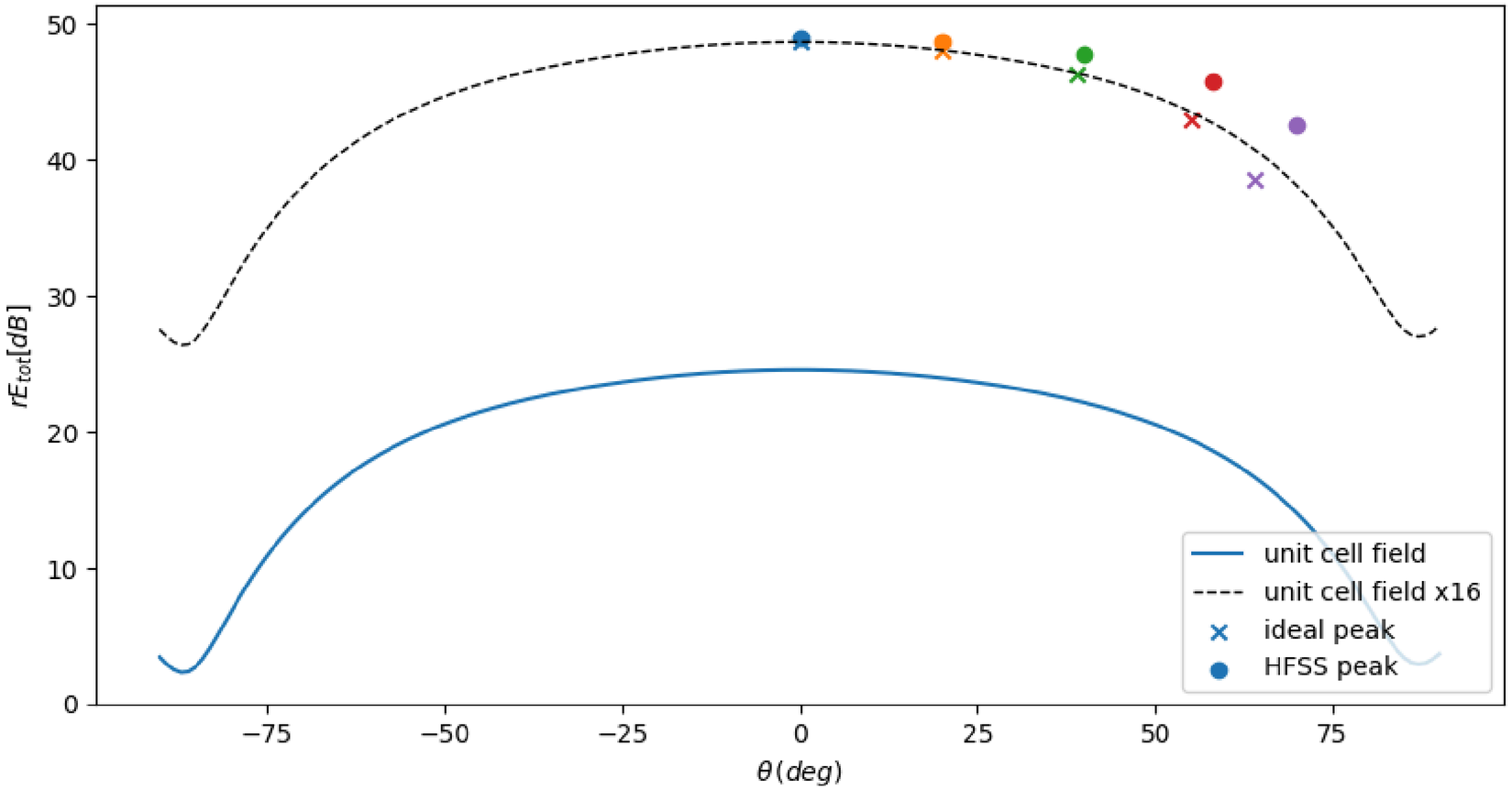
Vivaldi Tile simulation: scanning II

- Now we scan the theta angle and keep the phi fixed (90 deg).
- We found grating lobes for large theta



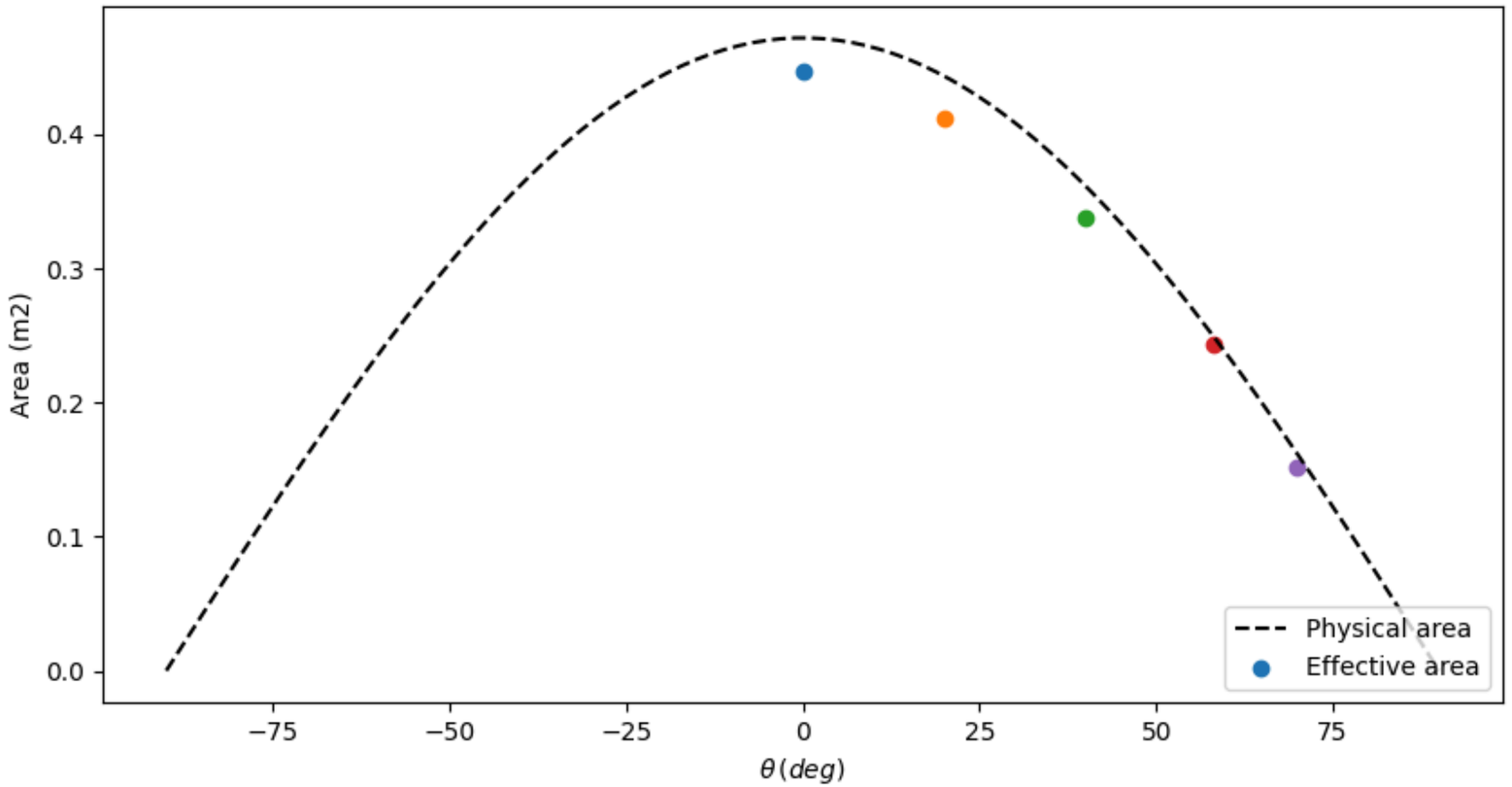


Maximum value of the field



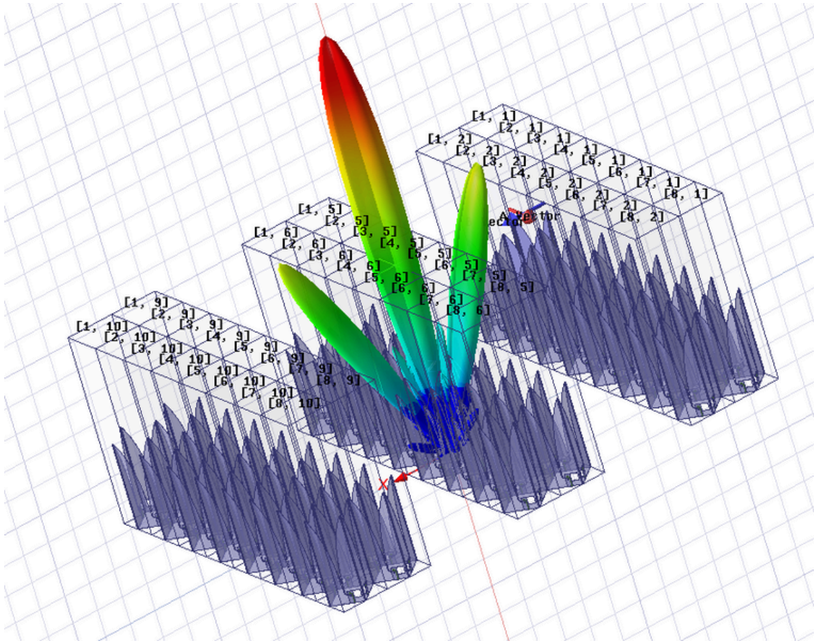
Effective area

$$A_{\text{eff}} = \frac{\lambda^2}{4\pi} G$$

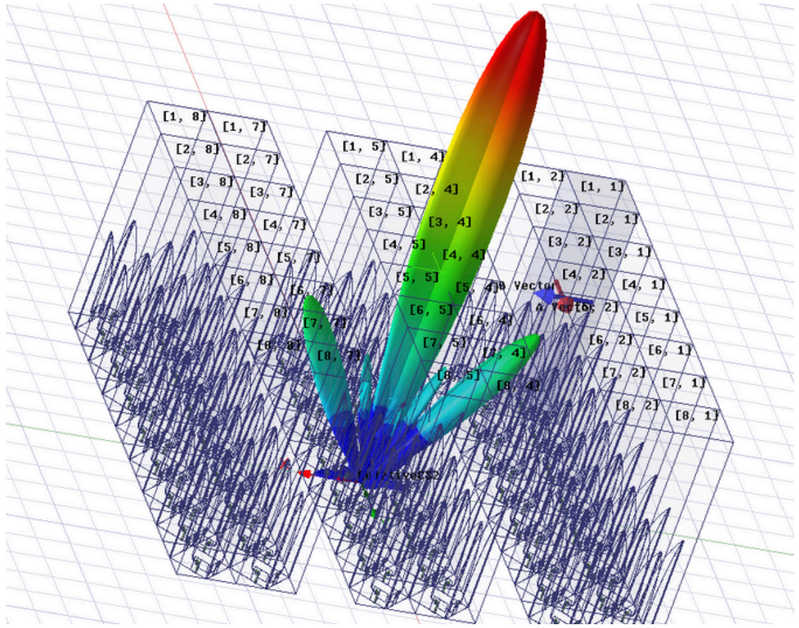


Array of 3 tiles

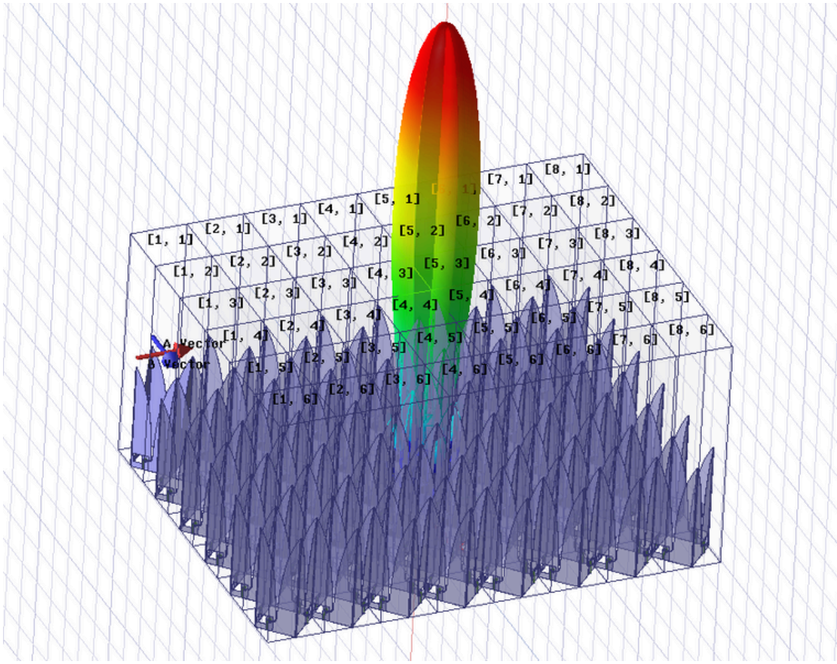
Array of 3 tiles



Model 1

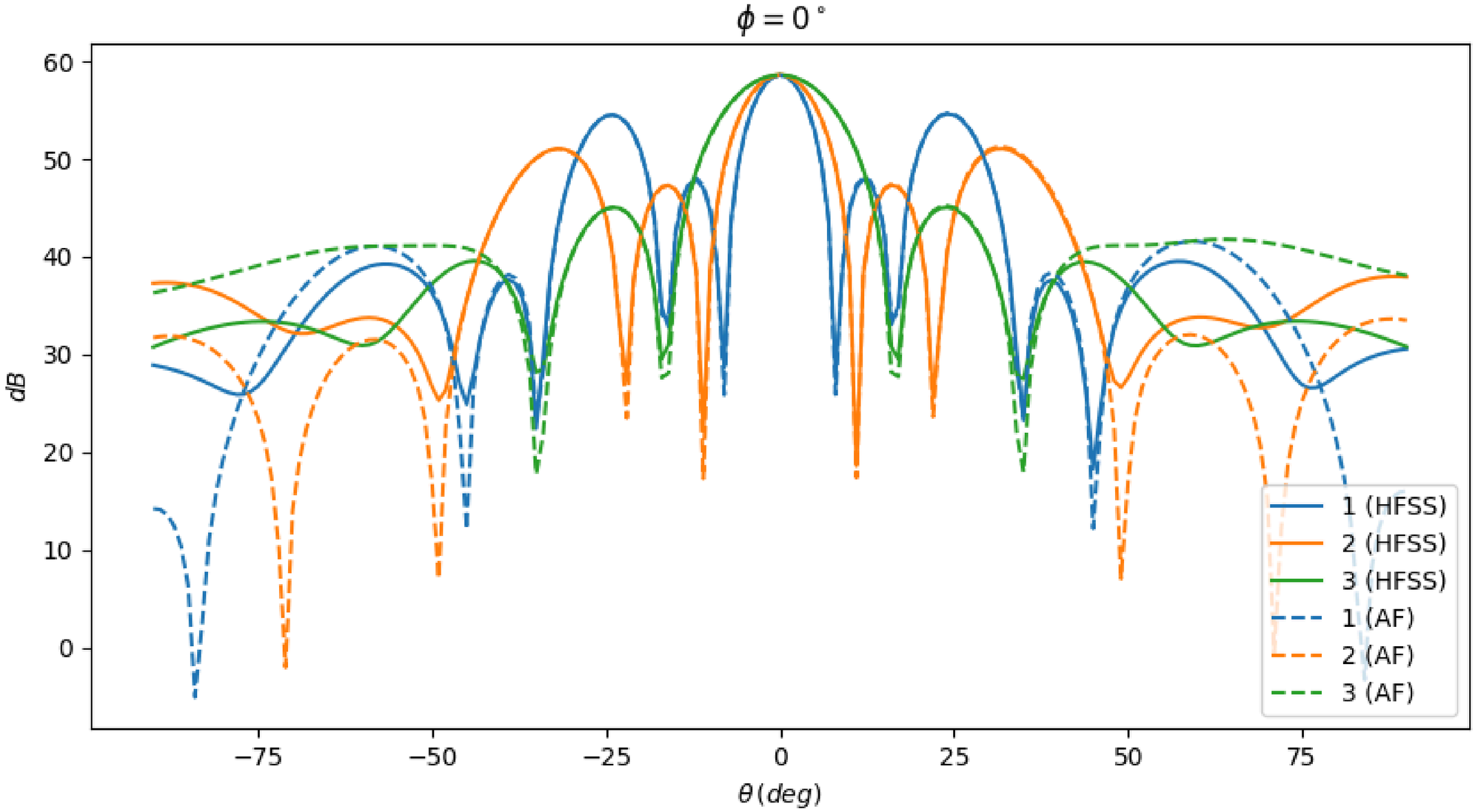


Model 2

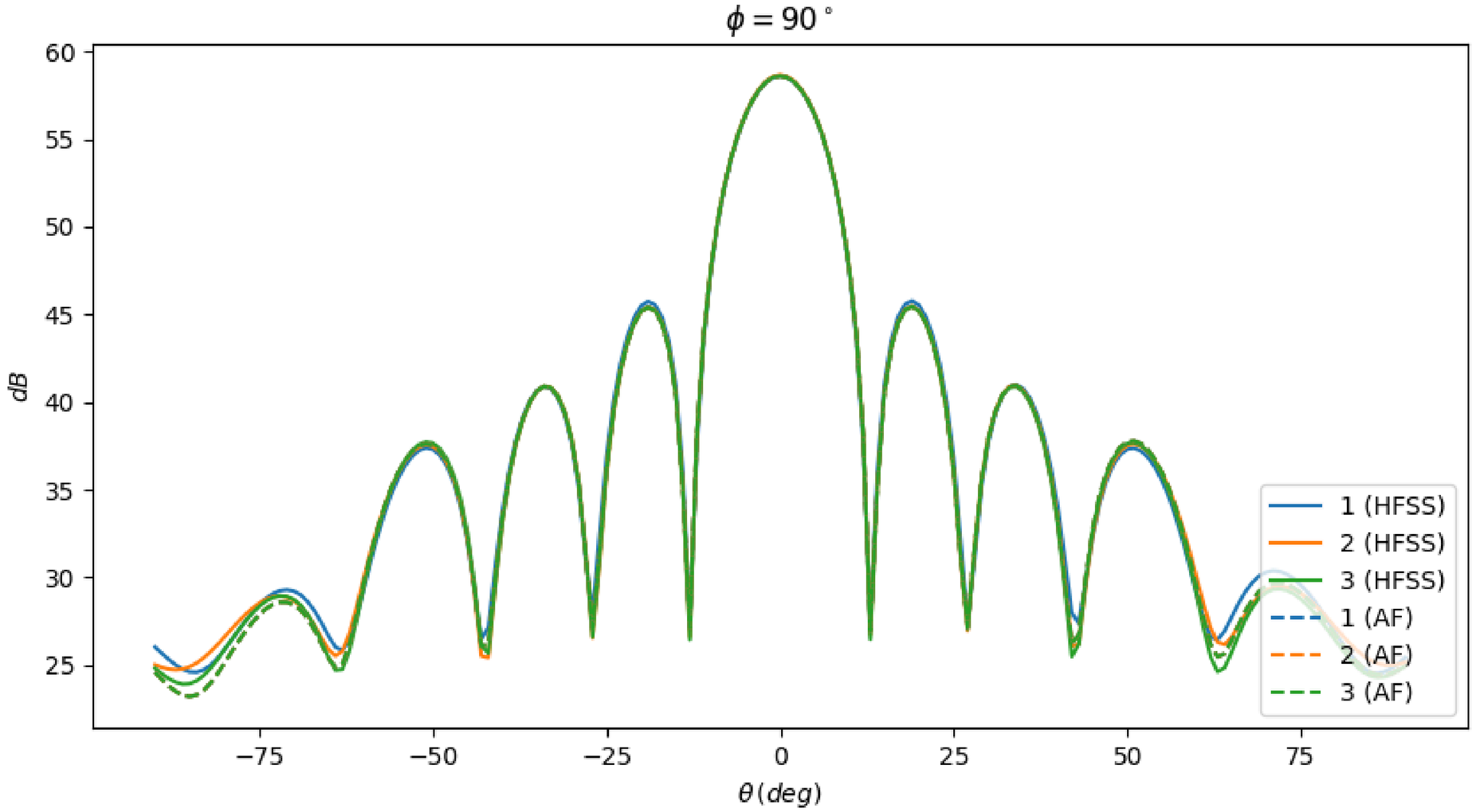


Model 3

Simulation of the 3 tiles array

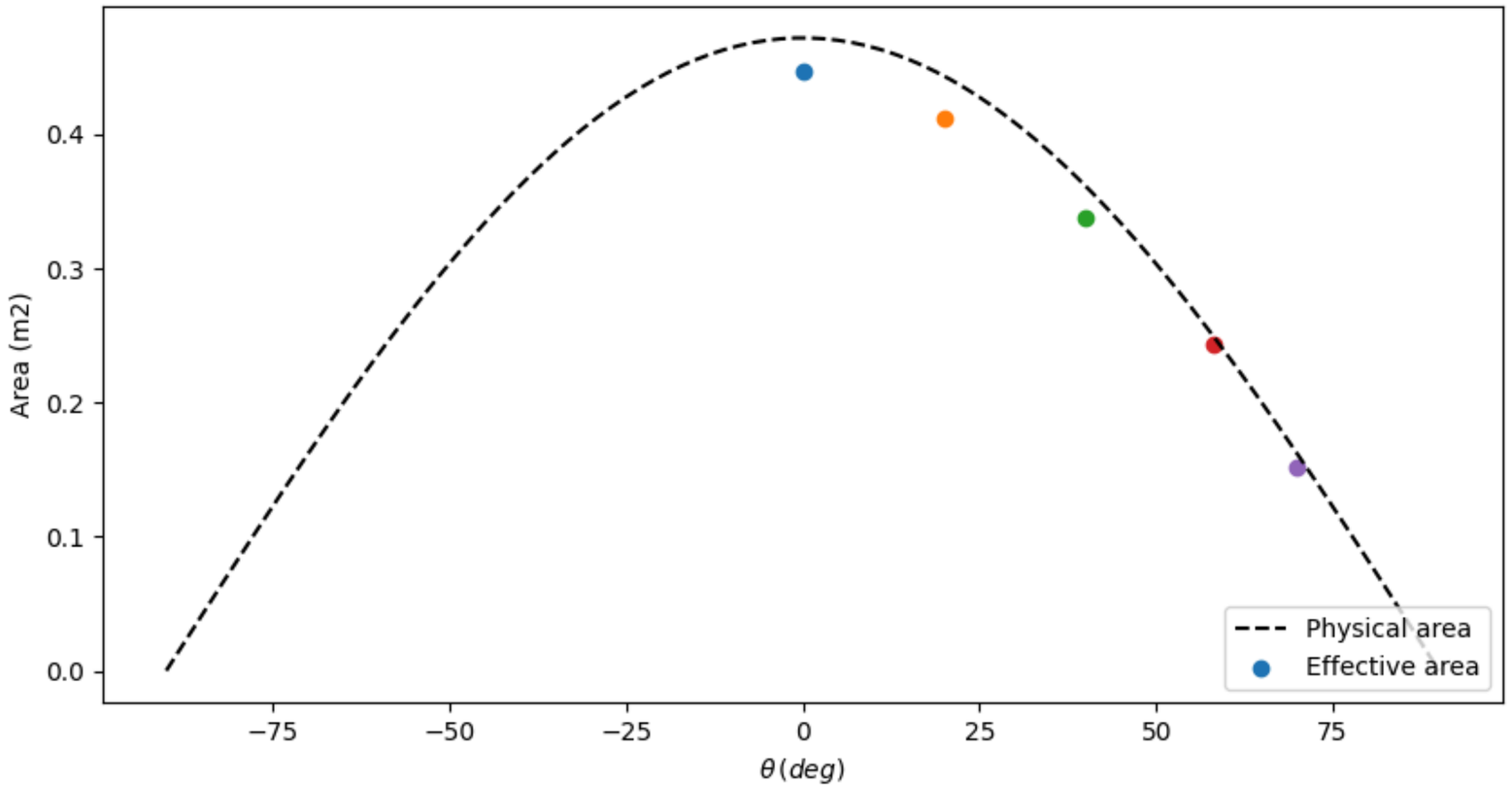


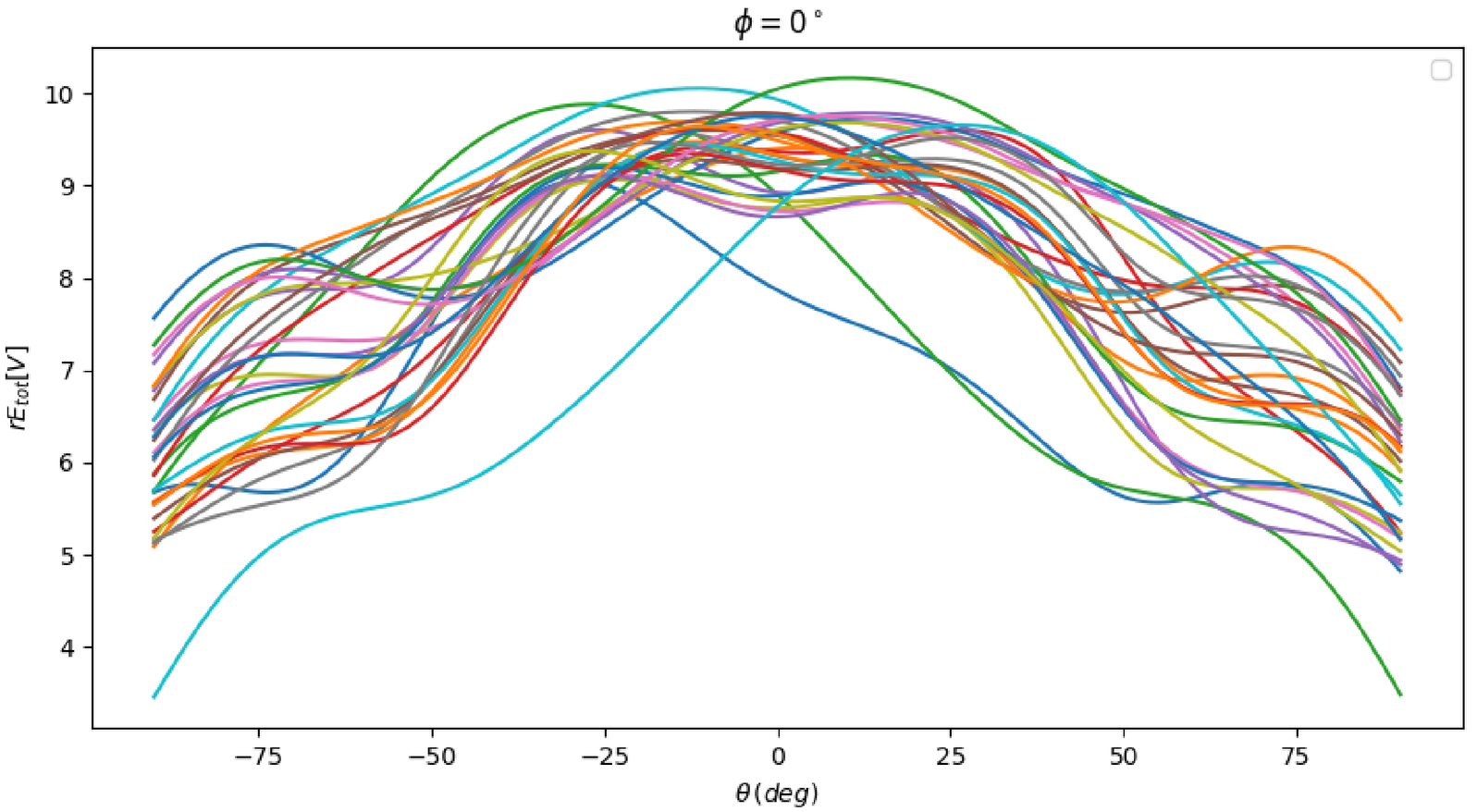
Simulation of the 3 tiles array

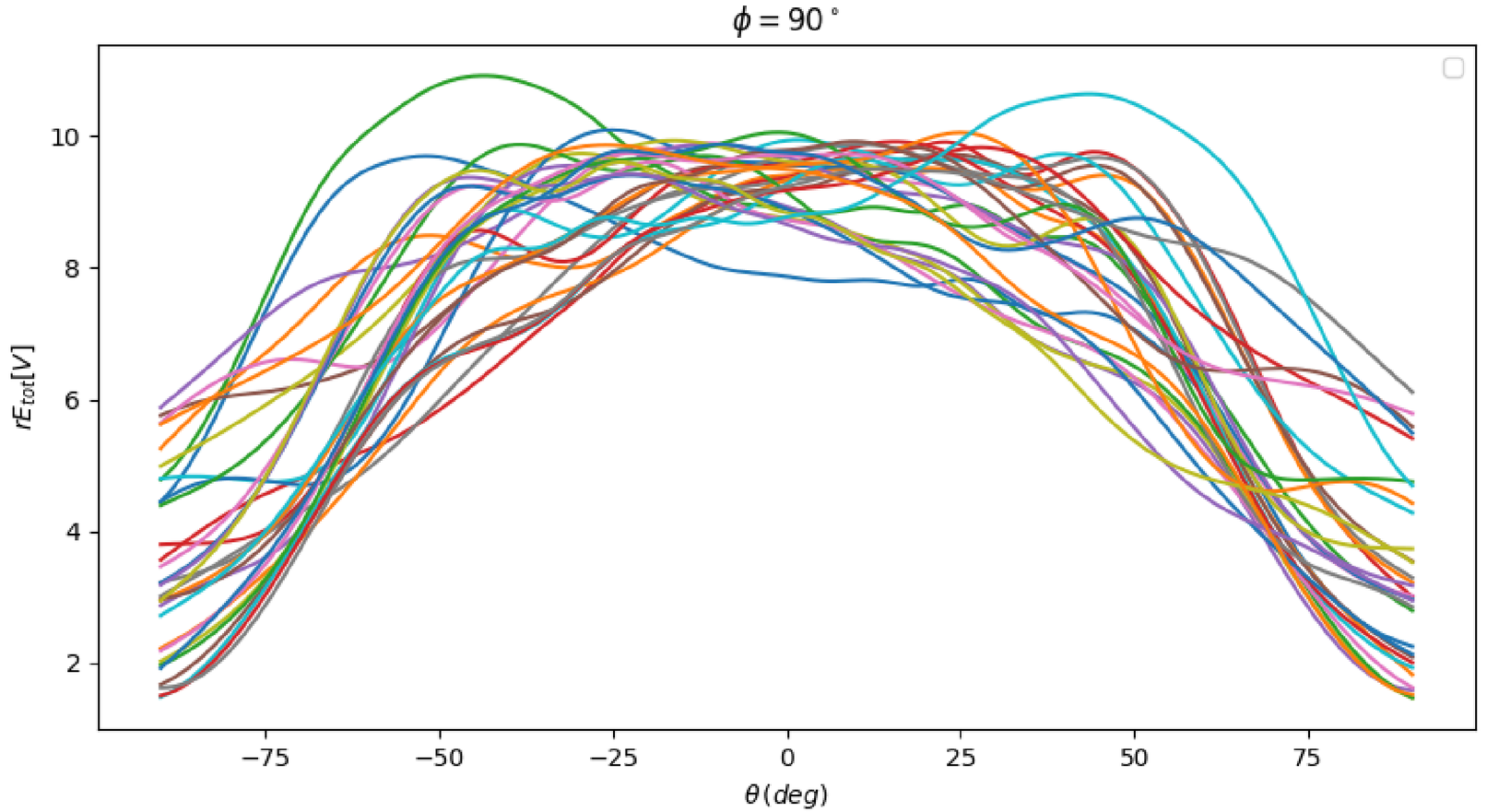


Effective area

$$A_{\text{eff}} = \frac{\lambda^2}{4\pi} G$$




$\phi = 0^\circ$
10
9
8
7
6
5
4
$rE_{tot}[V]$
−75
−50
−25
0
25
50
75
$\theta(deg)$


$\phi = 90^\circ$
$rE_{tot}[V]$
10
8
6
4
2
−75
−50
−25
0
25
50
75
$\theta(deg)$

Simulated station - 36 vs 64 tiles