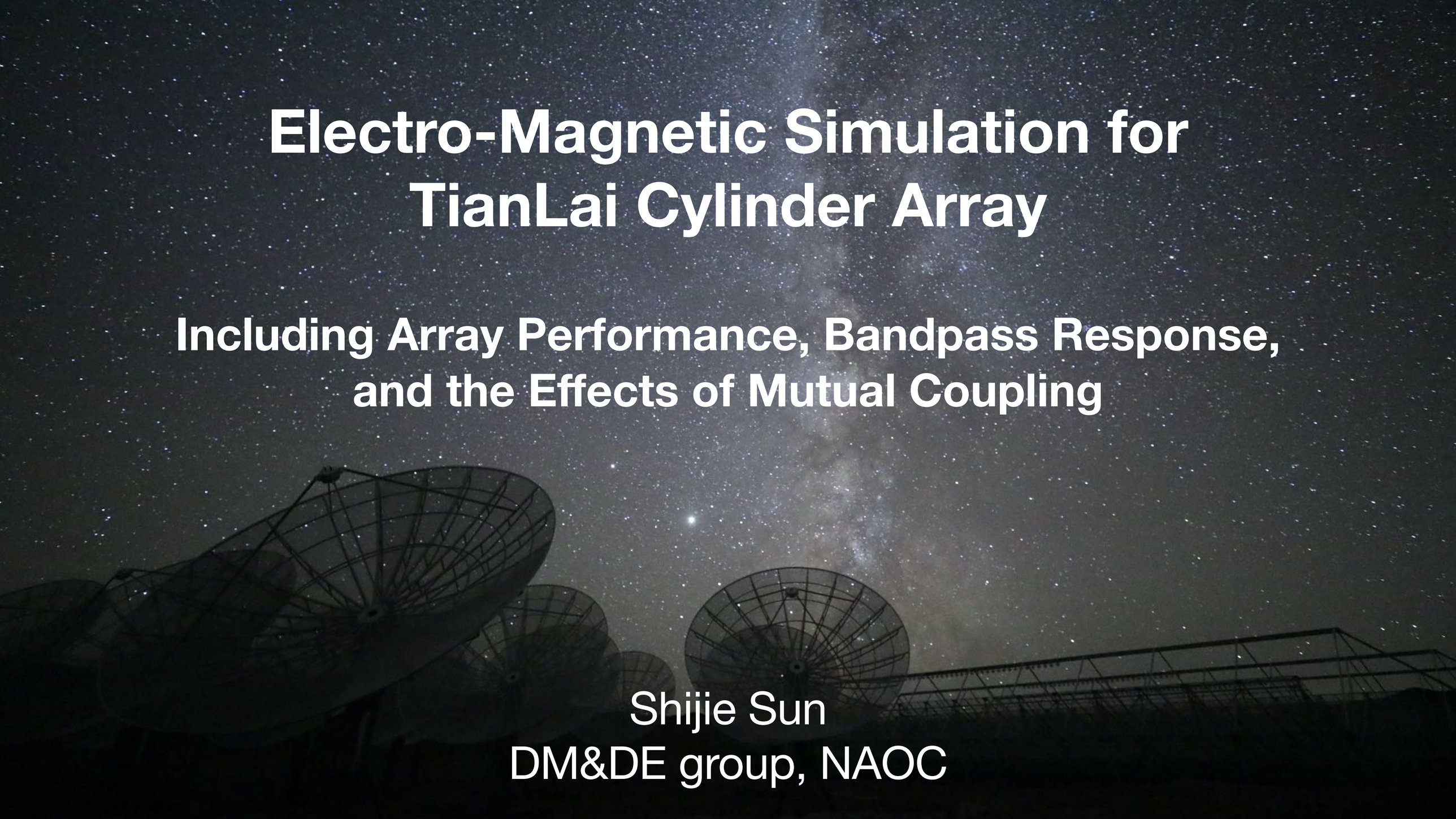
Electro-Magnetic Simulation for TianLai Cylinder Array

Including Array Performance, Bandpass Response, and the Effects of Mutual Coupling



Shijie Sun
DM&DE group, NAOC

Outline

I. Method
II. Simulation results
III. Experiment results
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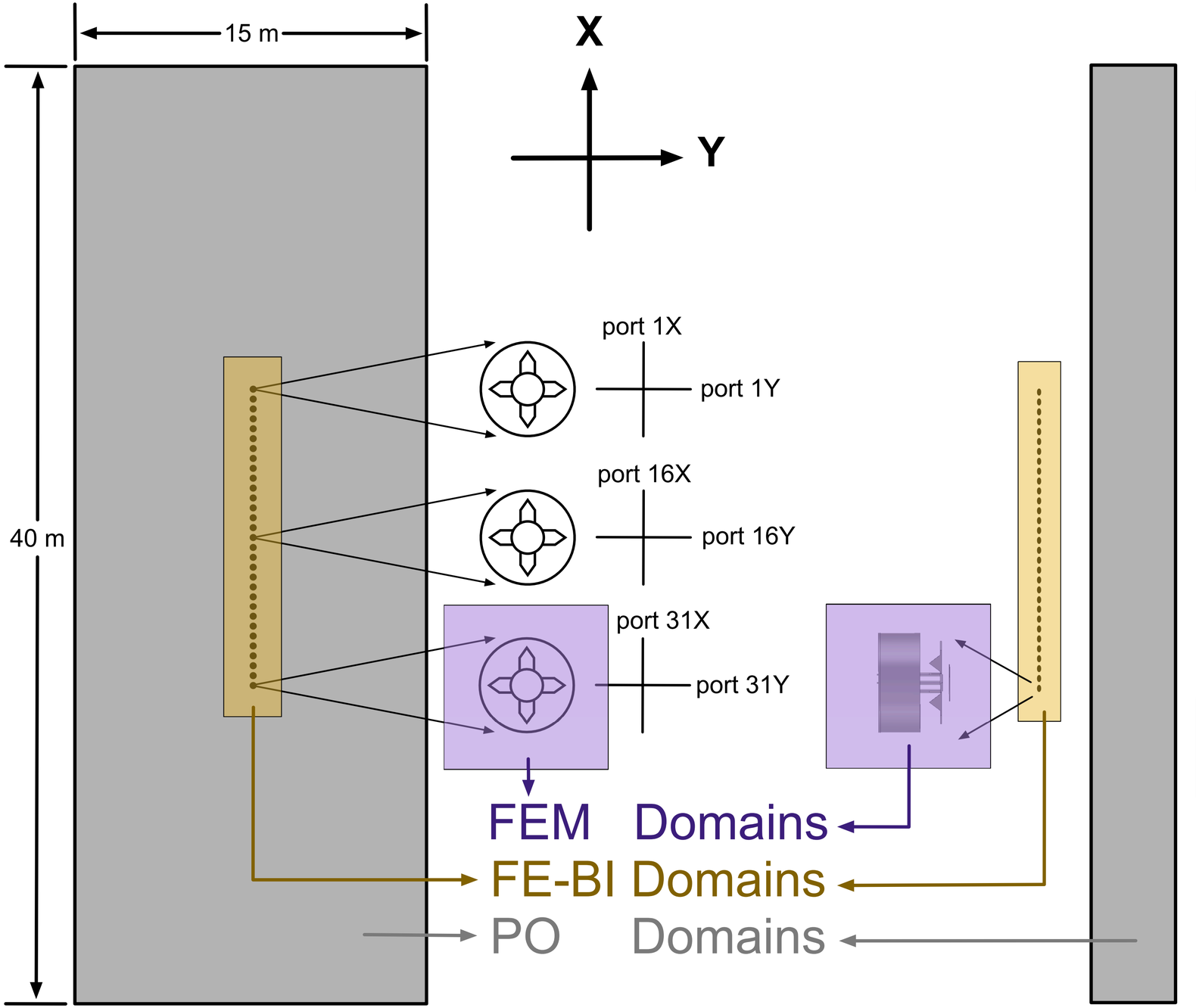
Simulation method



Model size

radiation blade:

$\sim 3cm = \sim 0.15 \times \lambda(1.4GHz)$

feed array:

$\sim 13 \times 0.21m = \sim 62 \times \lambda(1.4GHz)$

one cylinder reflector:

$\sim 15 \times 40m = \sim 200 \times \lambda(1.4GHz)$

Software

Ansys EM 2020R2 (HFSS)

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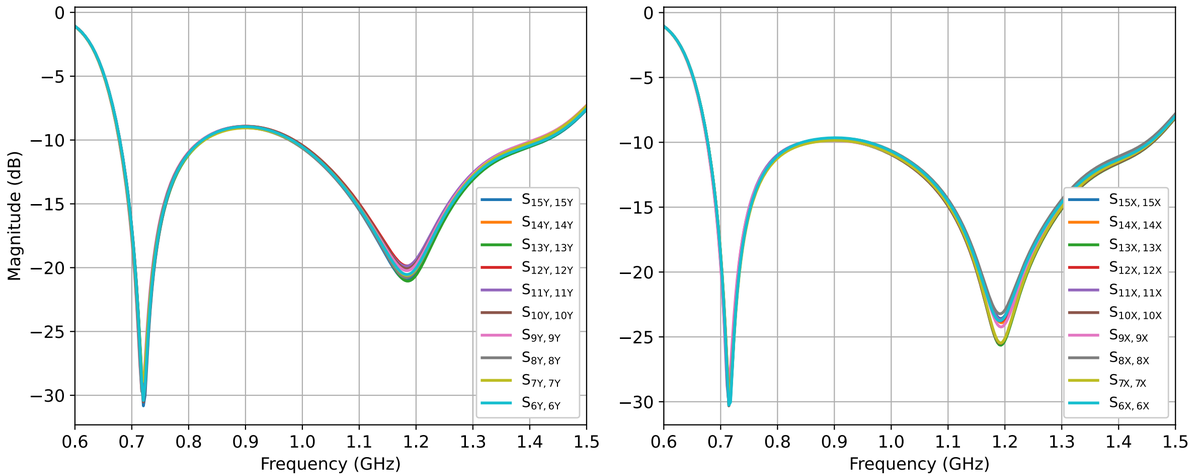
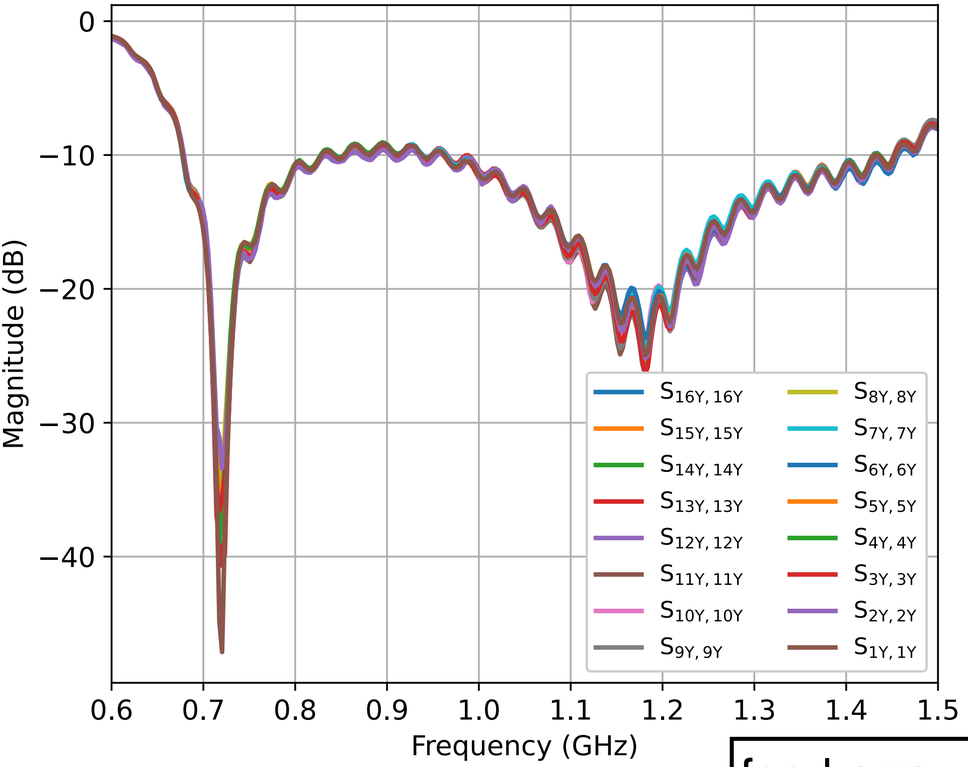
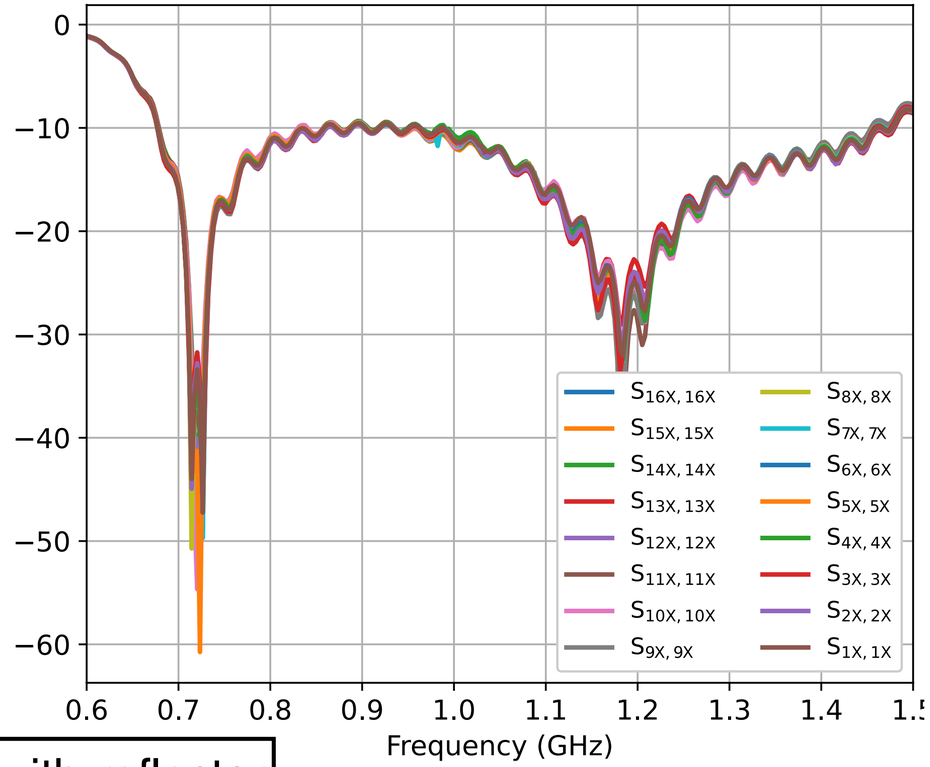
Simulation results——reflection coefficient

- standing wave structure appear in frequency domain;
- standing wave in 31MHz, corresponding to 9.68 meters distance in free space;
- distance between radiation blade and reflector is 4.8 meters.

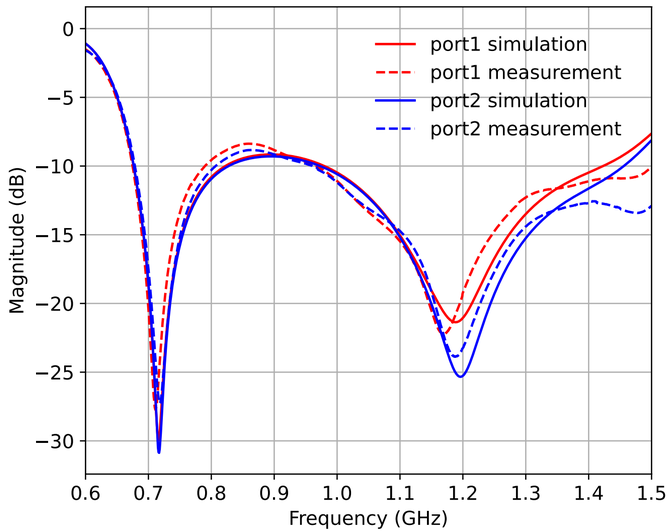


feed array



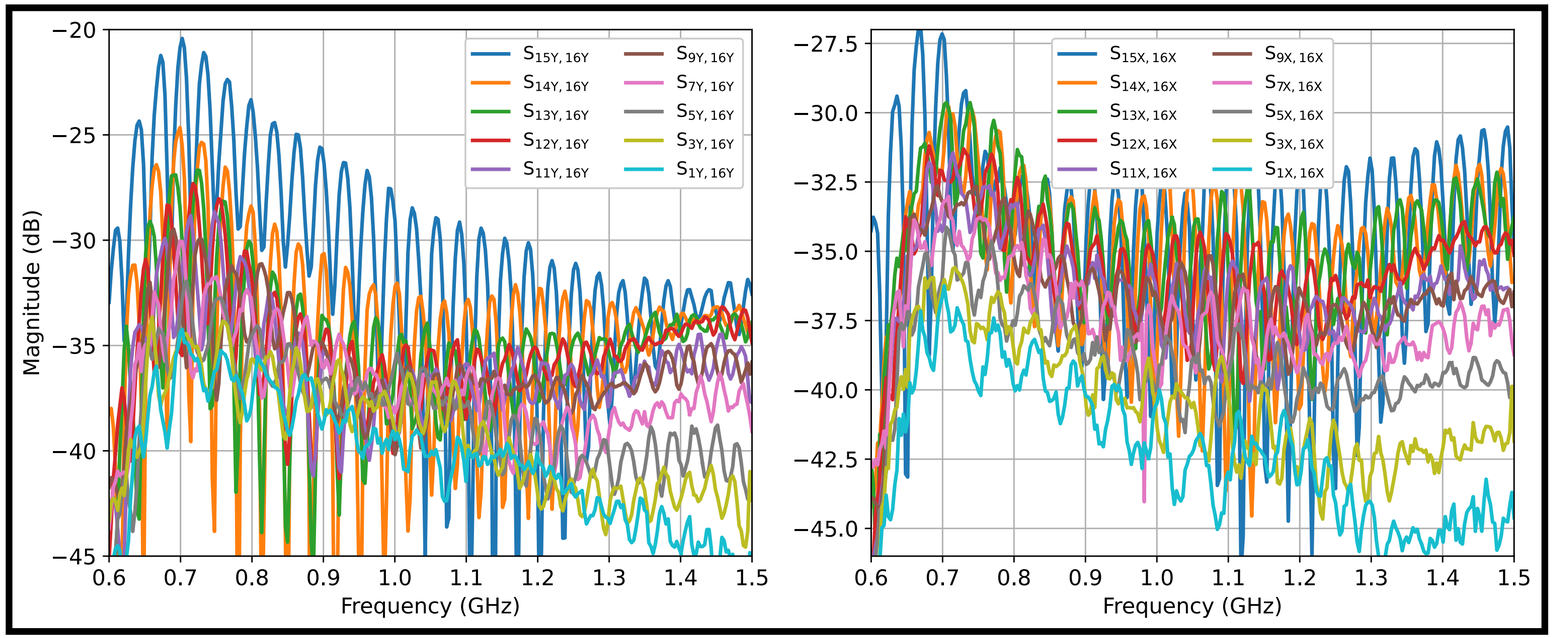


feed array with reflector

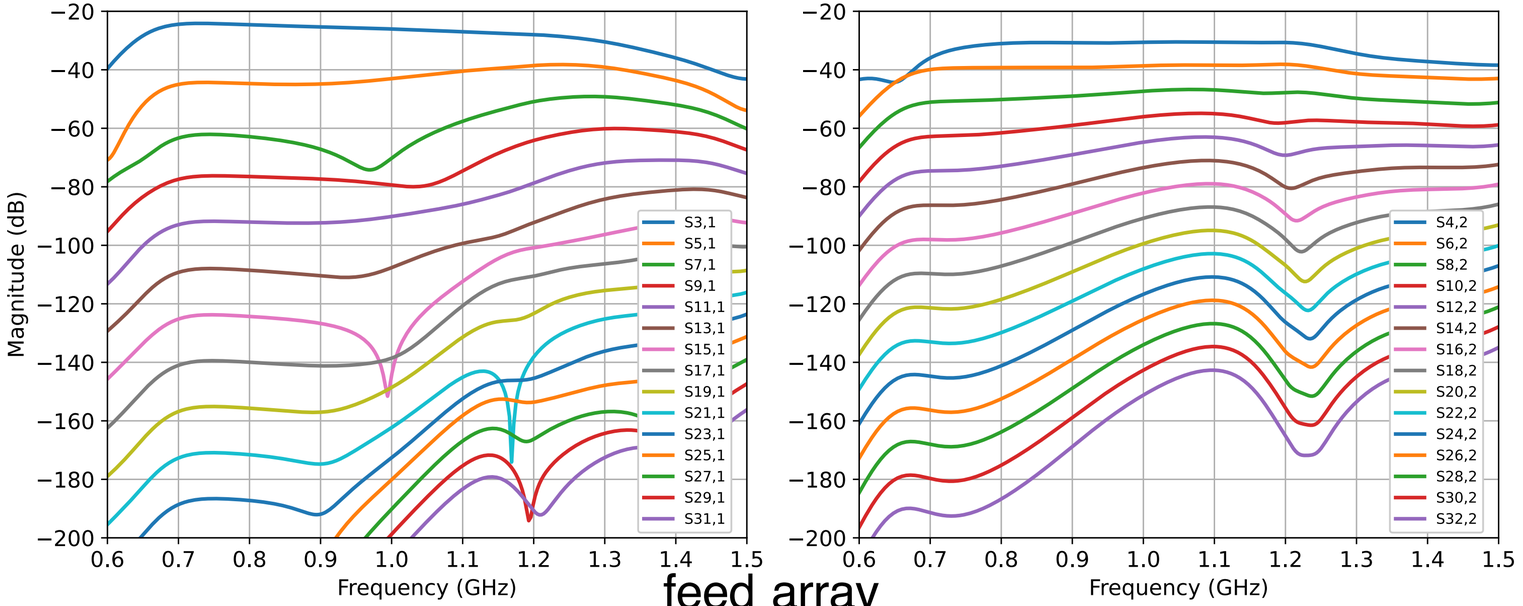


single feed

Simulation results——transmission coefficient

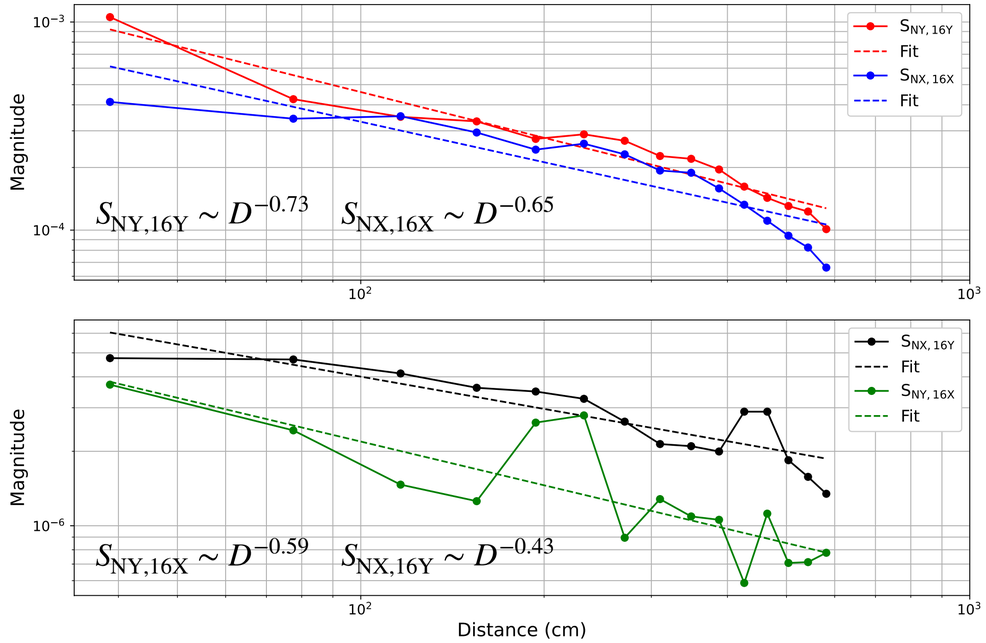


Y polarized X polarized

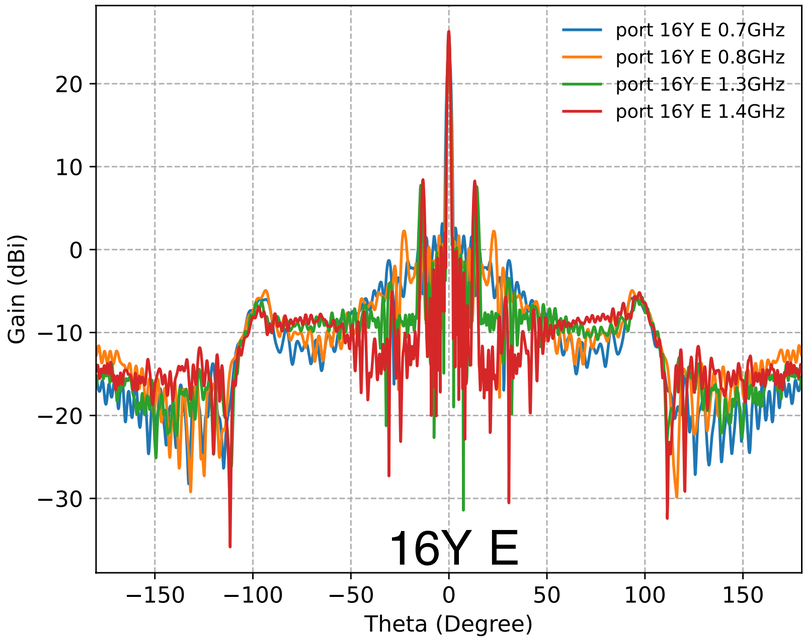


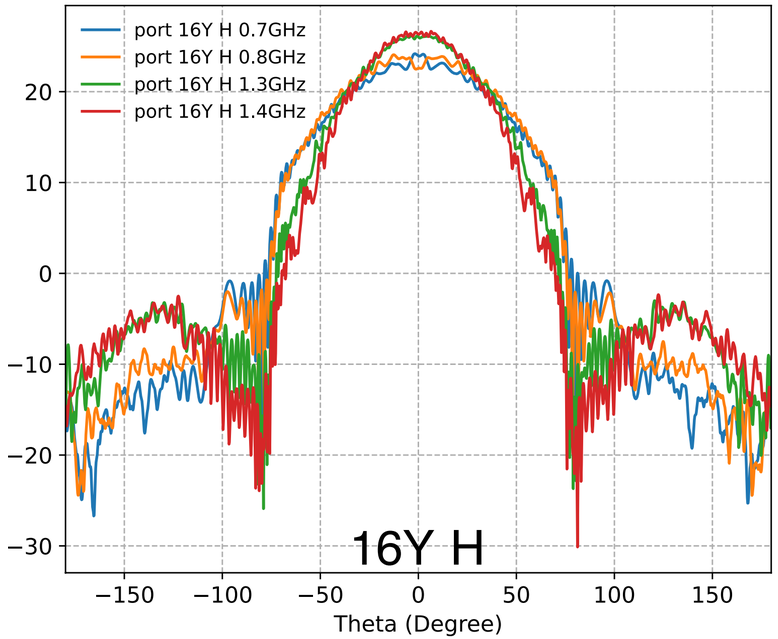
feed array

- Standing wave exists in mutual coupling coefficients;
- As the distance increases, the transmission coefficient decreases logarithmic;
- All ports' mutual coupling magnitude increase compared with feed array model simulation results.

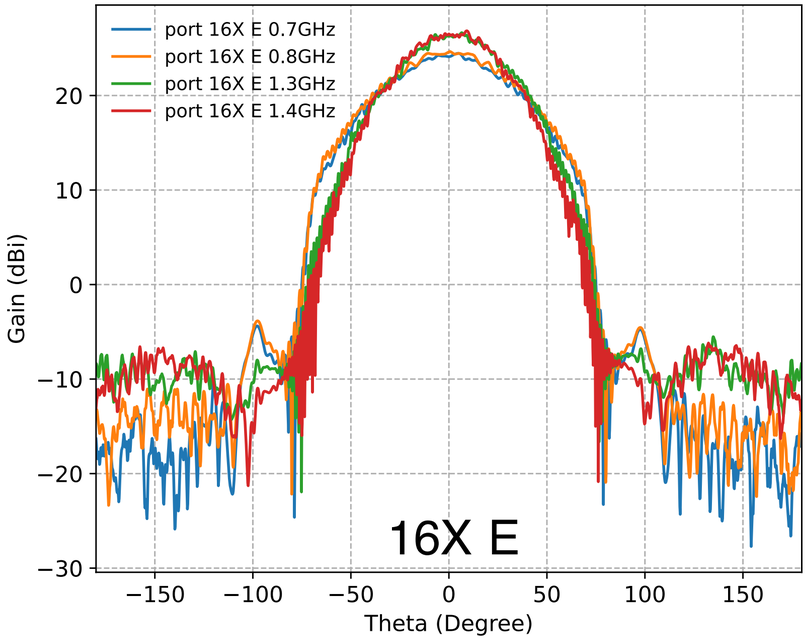


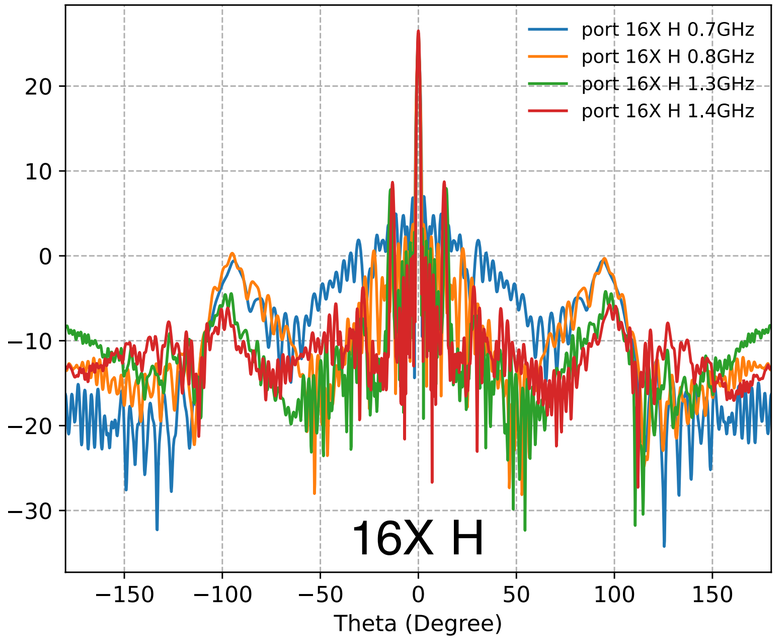
Simulation results——radiation pattern

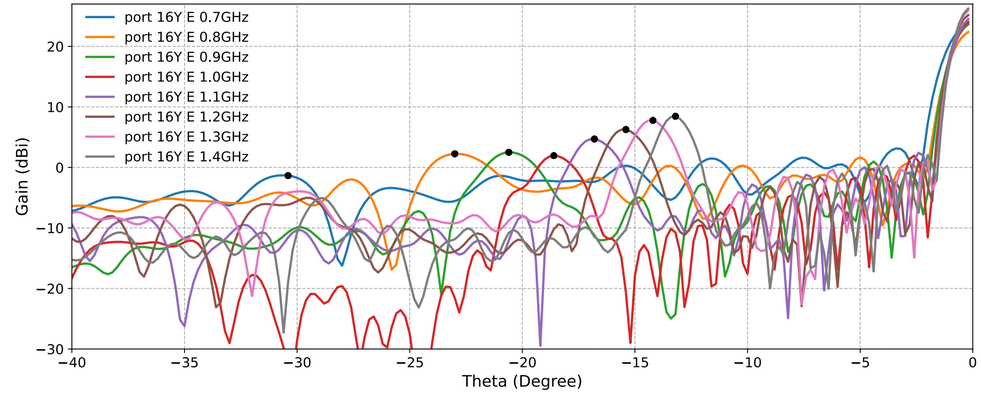




- NO.16 feed, in the center position;
- Radiation pattern is symmetry about $\theta = 0°$.

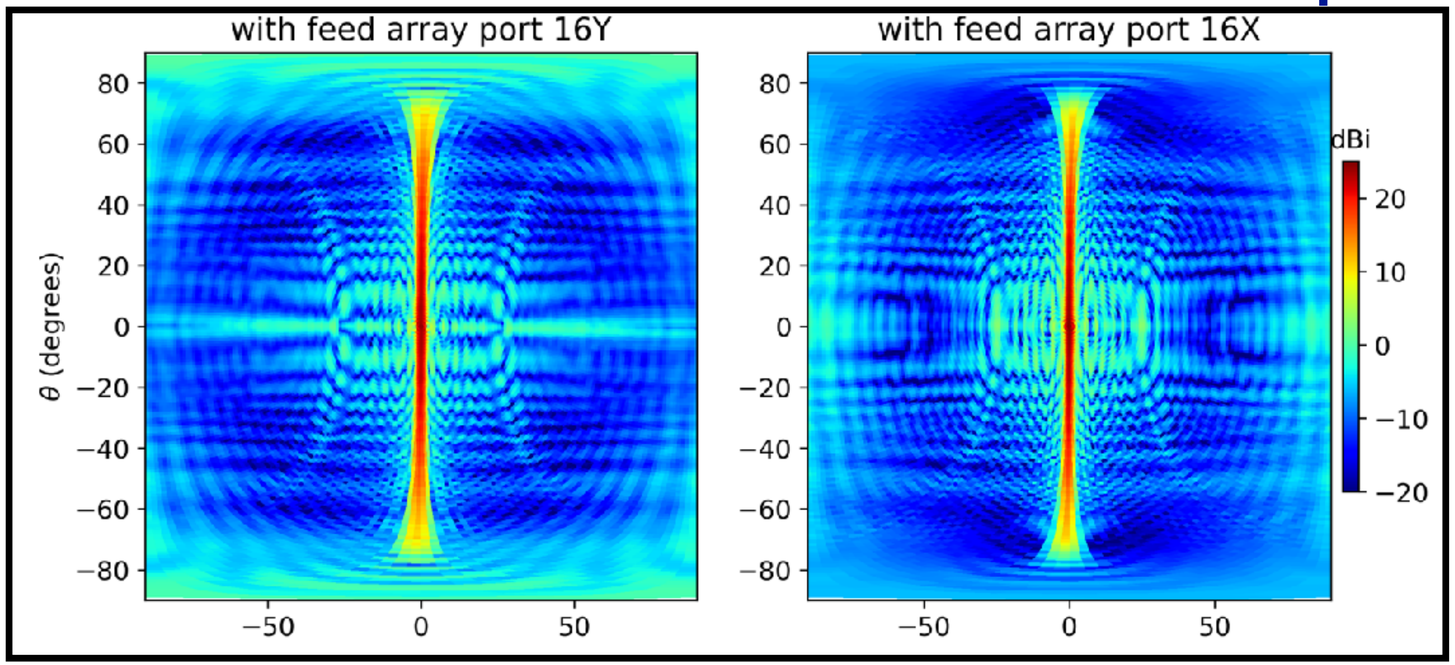




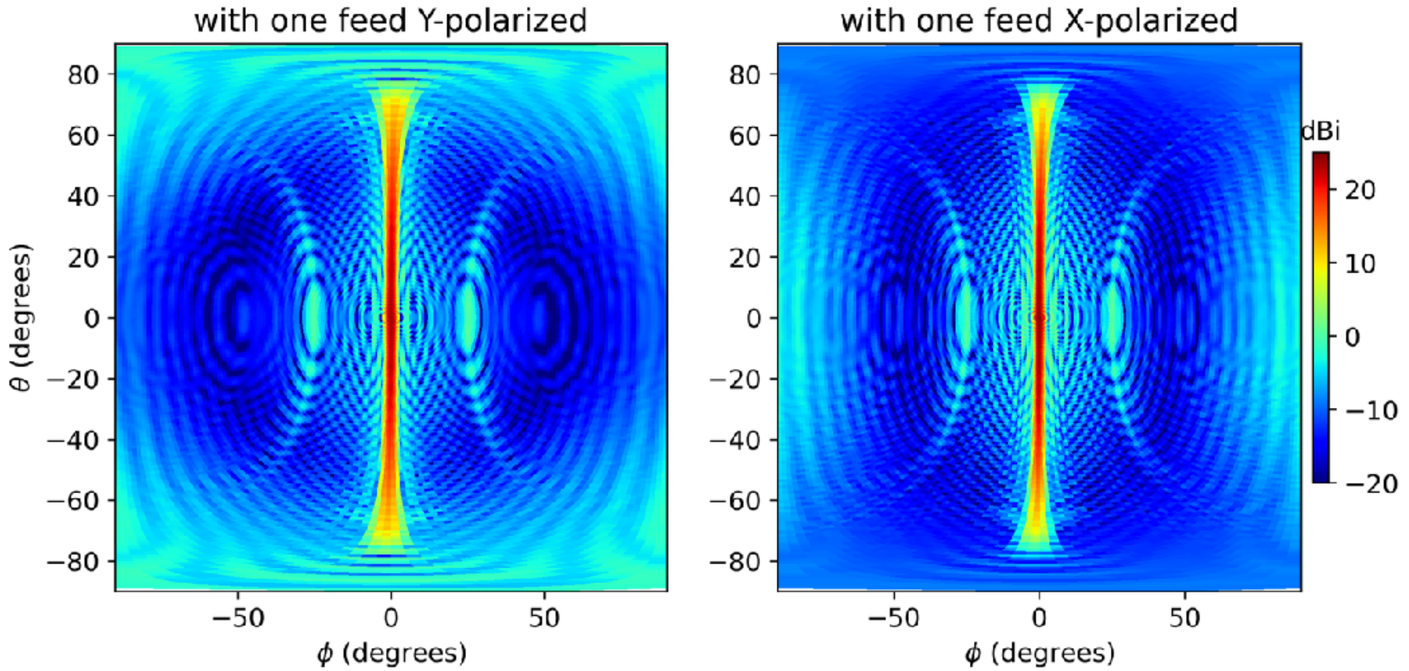


sidelobes

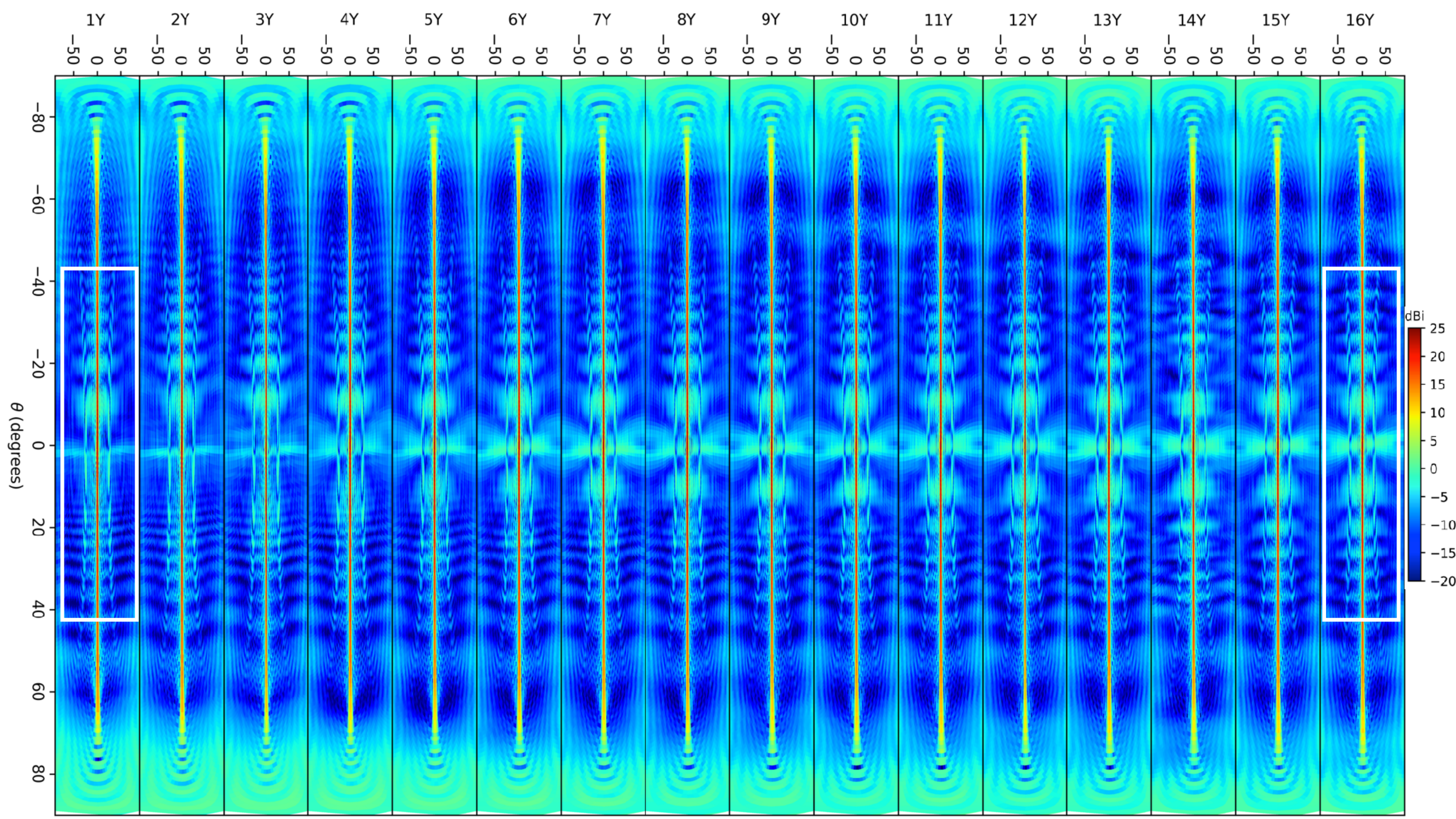
Simulation results——radiation pattern (0.75GHz)

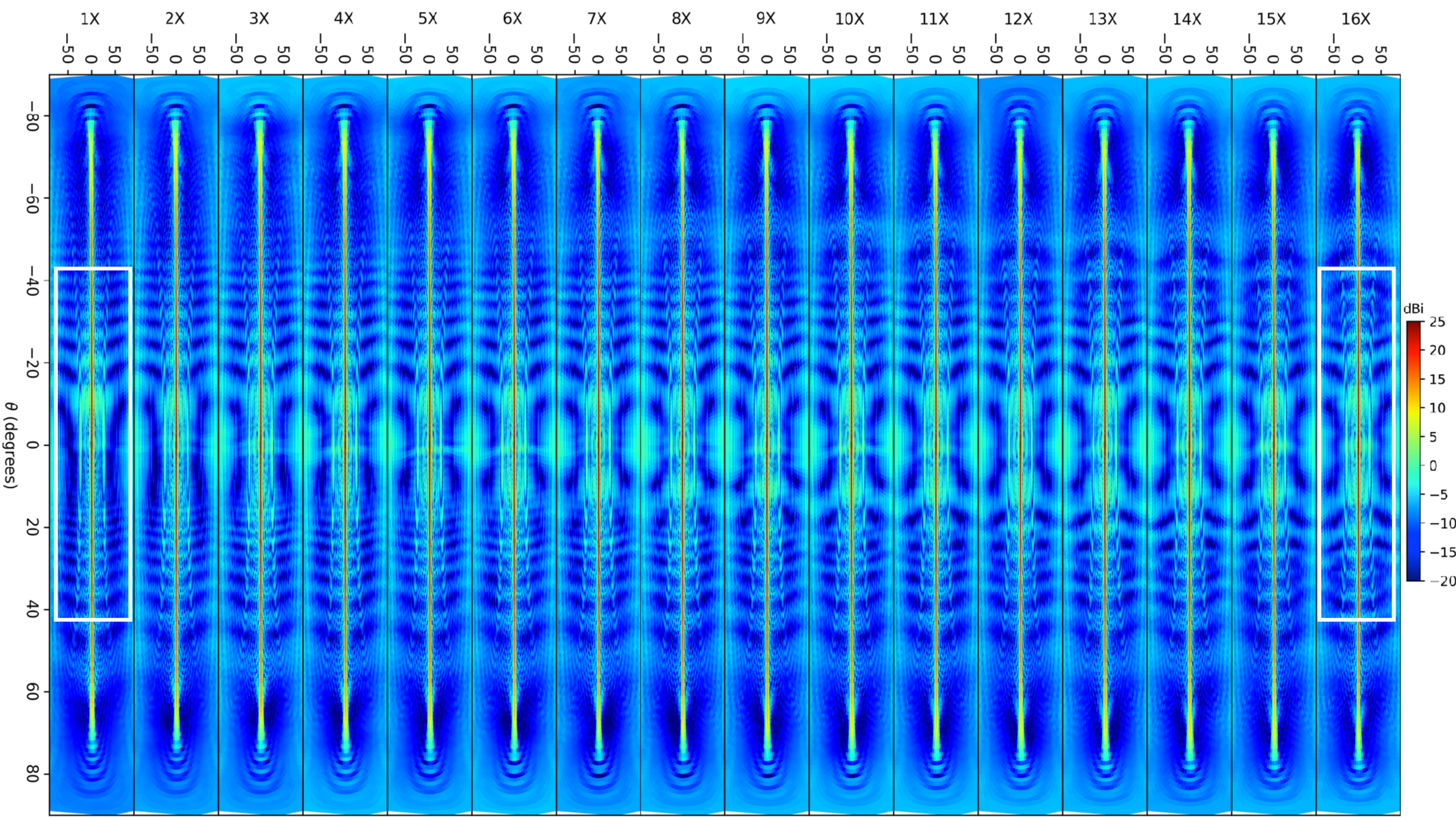


feed array with reflector



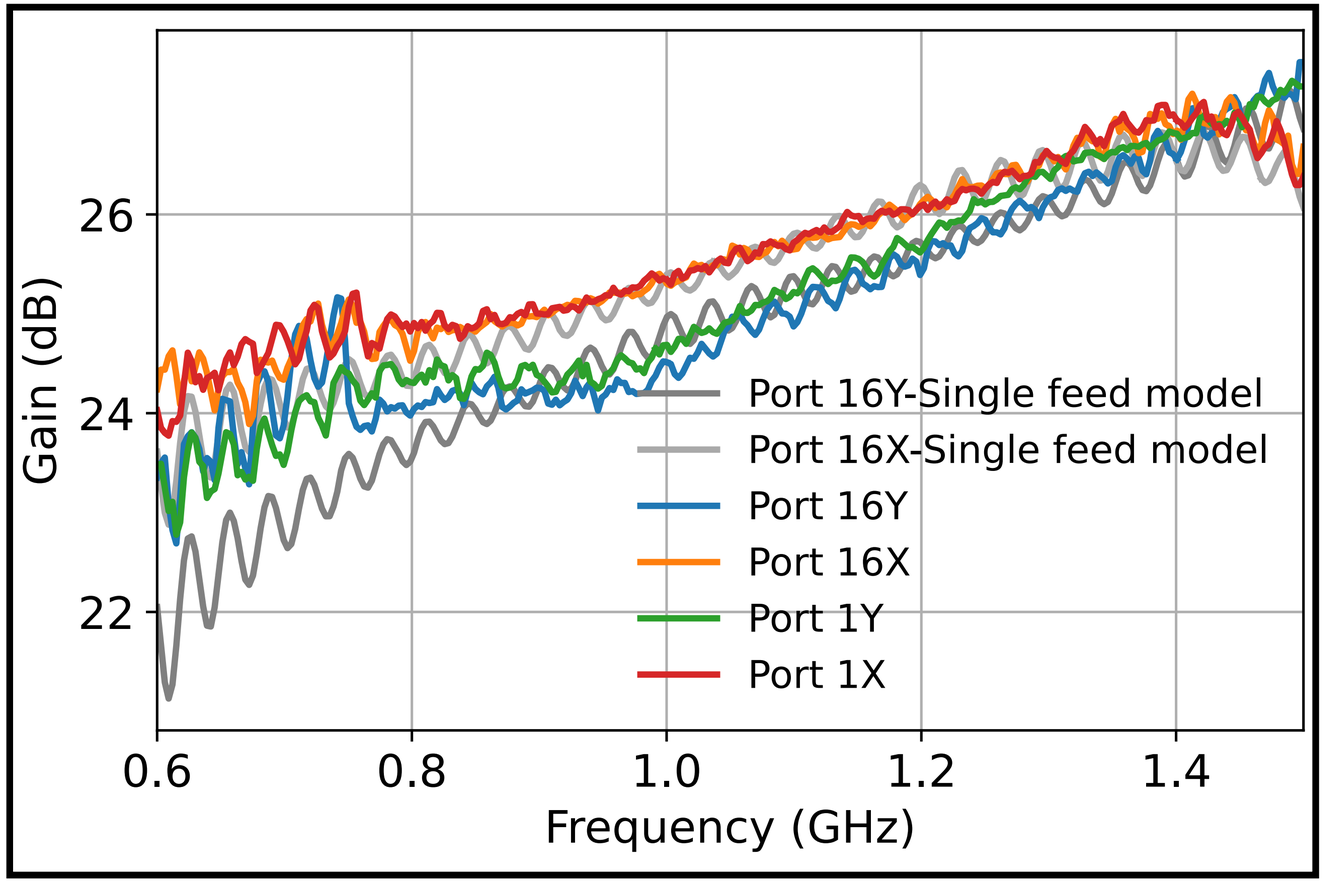
single feed with reflector


1Y
2Y
3Y
4Y
5Y
6Y
7Y
8Y
9Y
10Y
11Y
12Y
13Y
14Y
15Y
16Y
−50
0
50
−80
−60
−40
−20
0
20
40
60
80
θ (degrees)
dBi
25
20
15
10
5
0
−5
−10
−15
−20

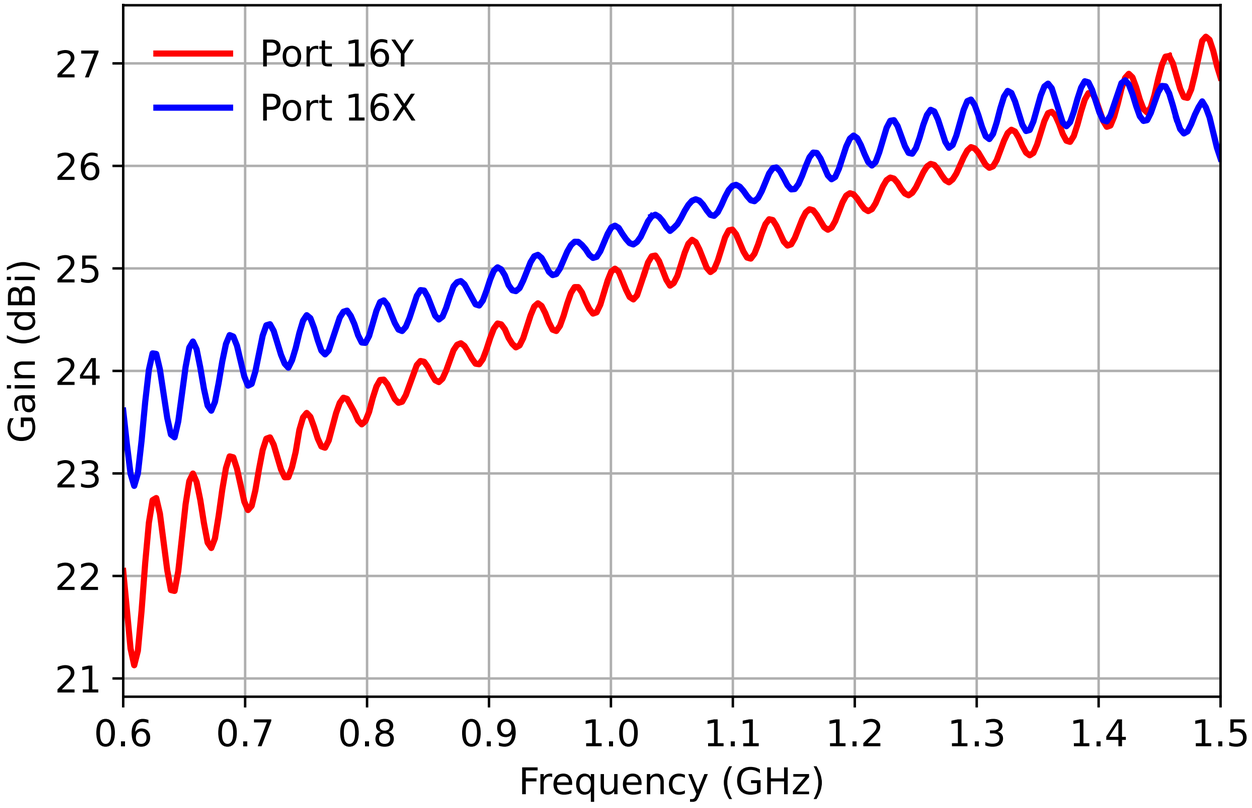

1X
2X
3X
4X
5X
6X
7X
8X
9X
10X
11X
12X
13X
14X
15X
16X
−50
0
50
−80
−60
−40
−20
0
20
40
60
80
θ (degrees)
dBi
25
20
15
10
5
0
−5
−10
−15
−20

Simulation results——peak gain

- Peak gain increases as frequency increases;
- Some complex structures in narrow frequency band comparing with single feed+reflector simulation result.

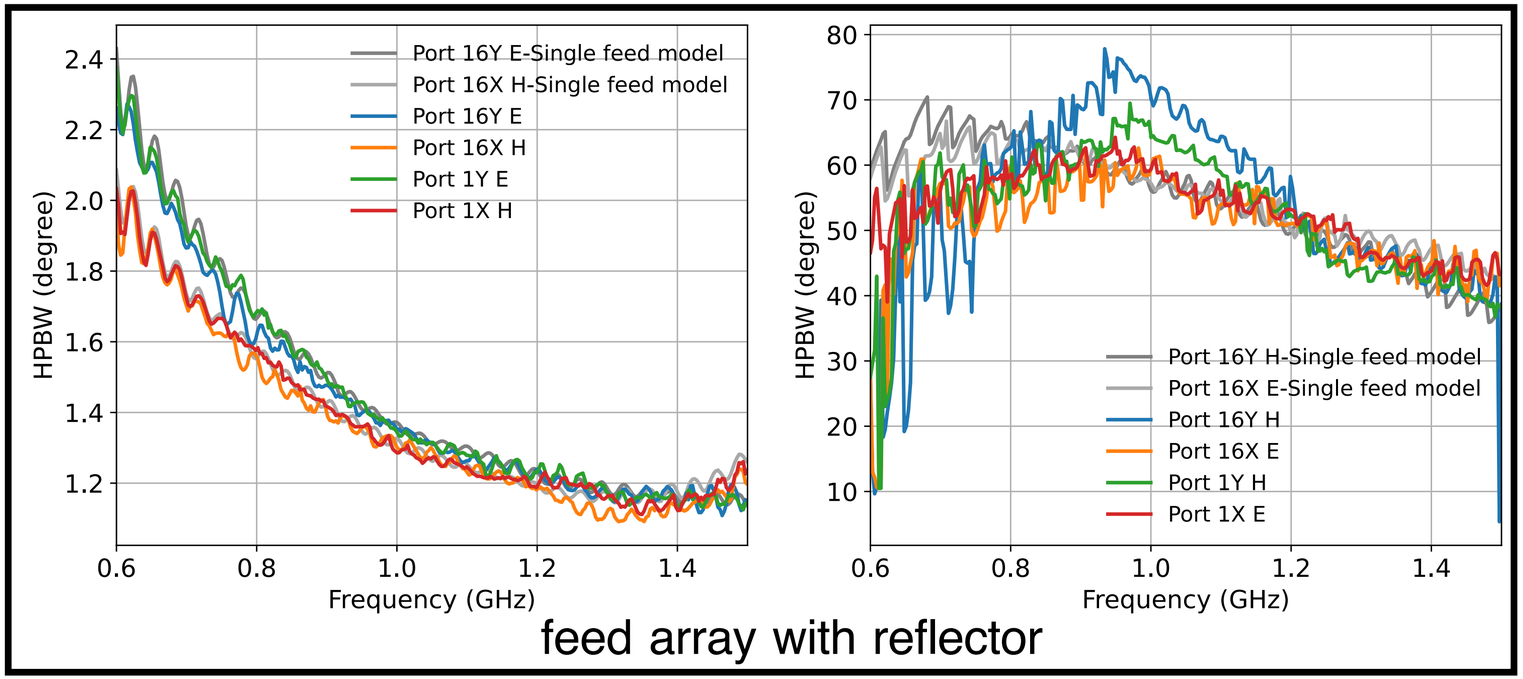


feed array with reflector

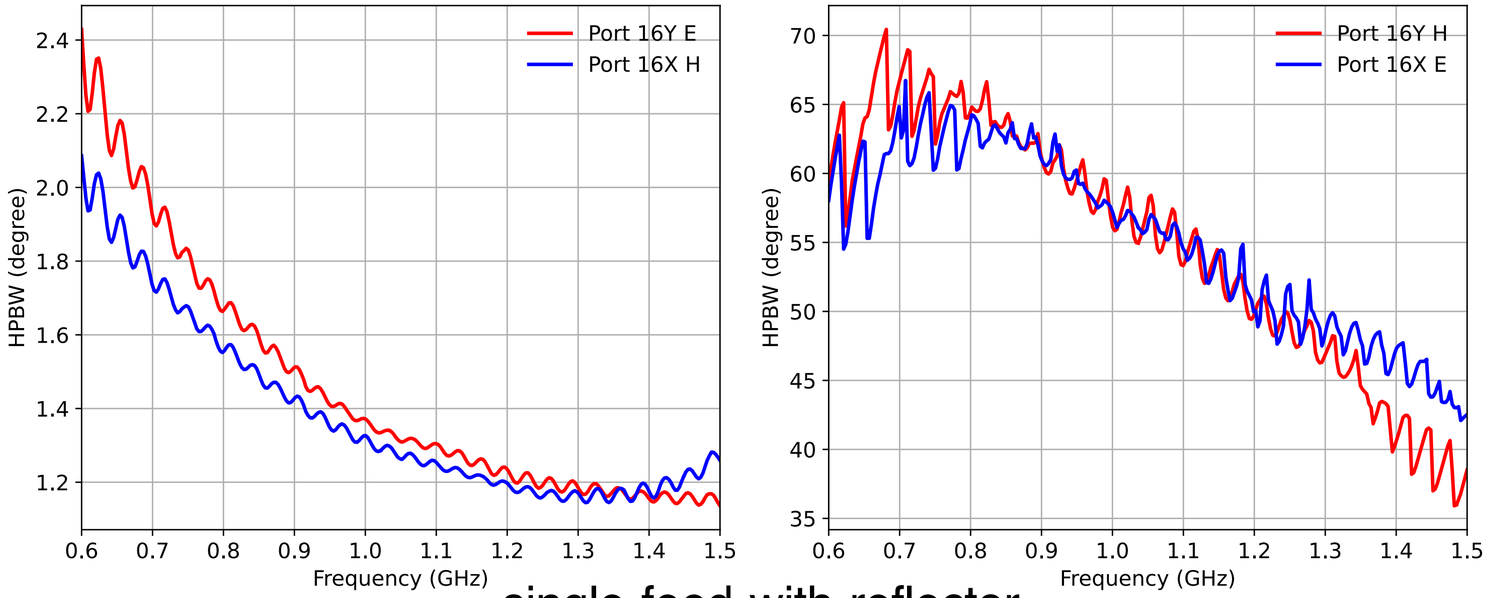


single feed with reflector

Simulation results——HPBW



feed array with reflector



single feed with reflector

- HPBW in both polarizations decrease as frequency increases;
- HPBW of Y-polarized ports are wider than X-polarized ports;
- Standing waves in bandpass.

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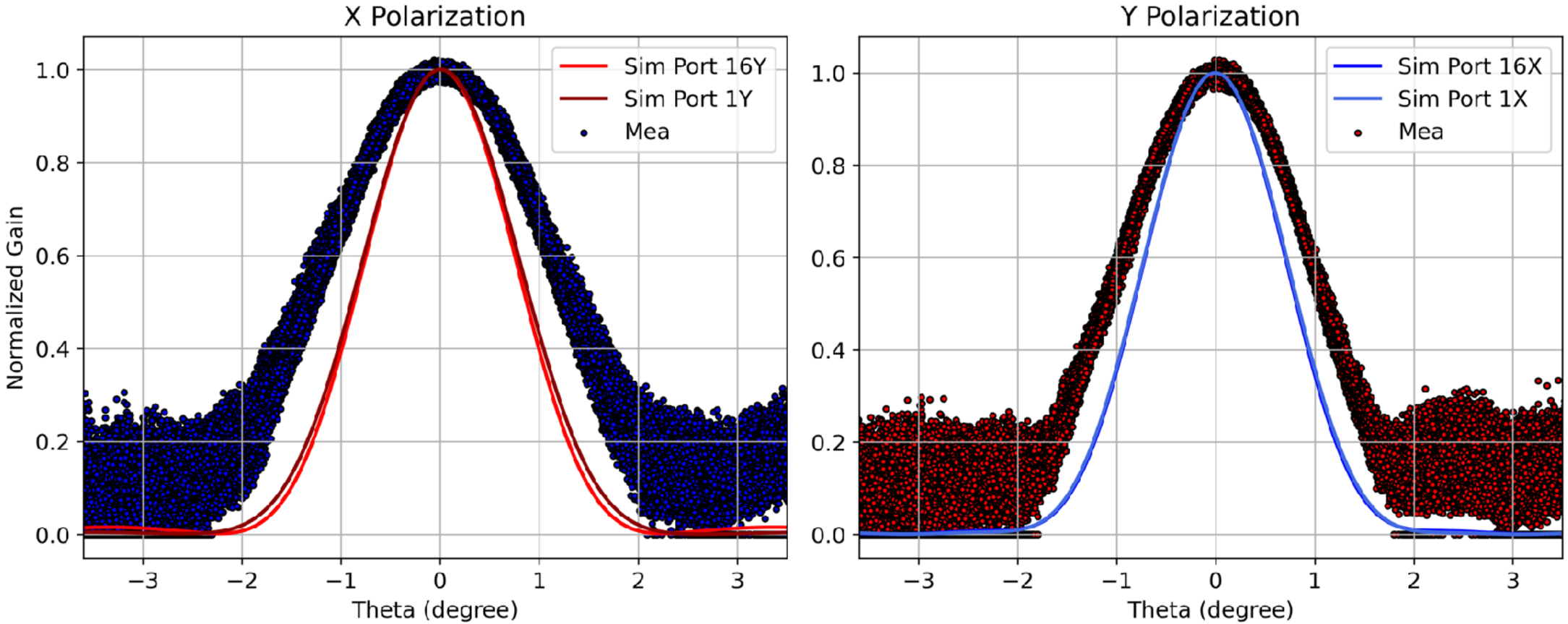
Experiment vs. Simulation——primary beam

$$\theta = \Omega_{Earth}\Delta_t cos\delta_{src}$$

- Cyg A $(19^h59^m28.3566^s, 40°44'02.096'')$
- drift scan by all 96 feeds
- 0.75 GHz

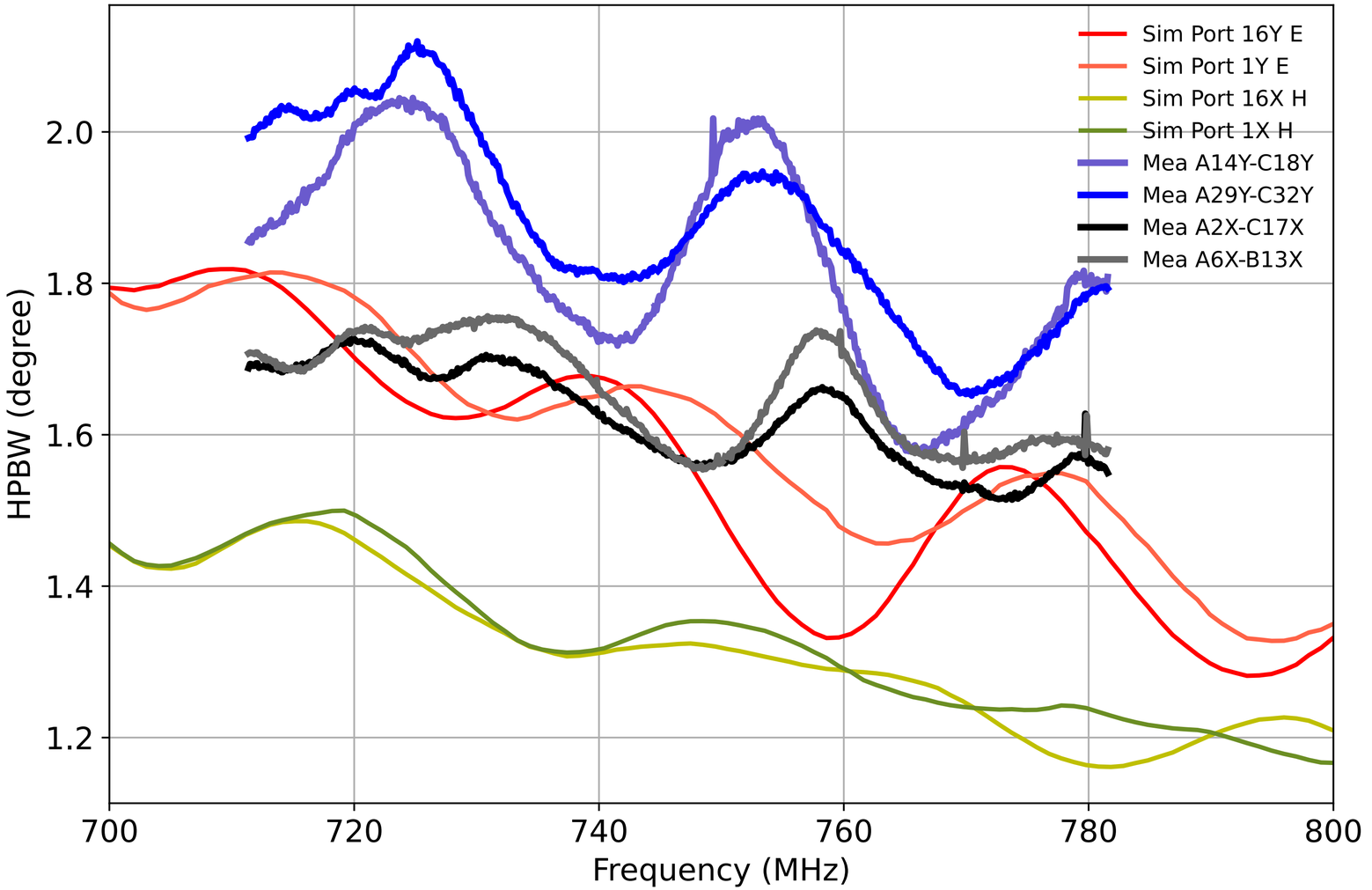


Y polarized: measured $2.54°$, simulated $1.60°$

X polarized: measured $2.10°$, simulated $1.40°$

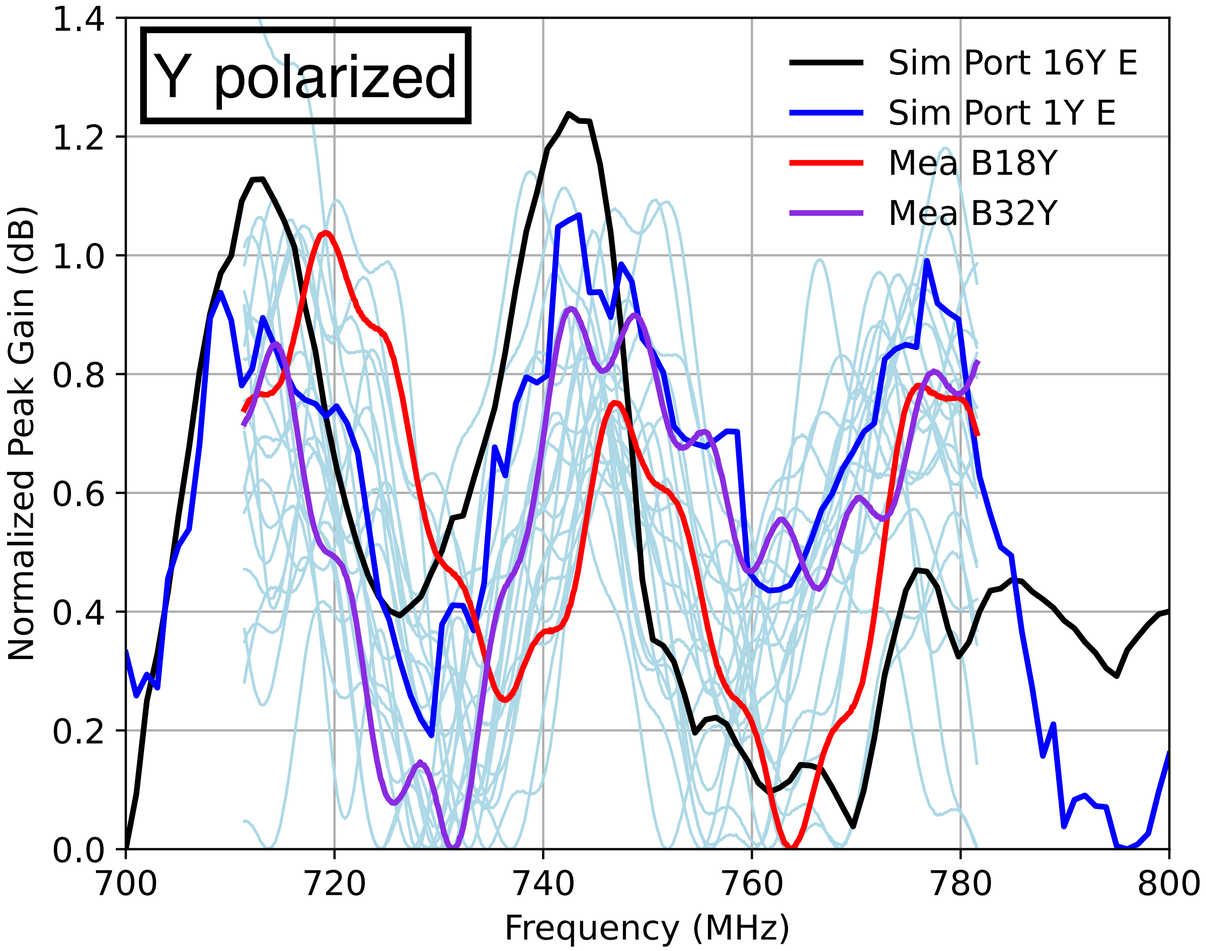
Experiment vs. Simulation——HPBW

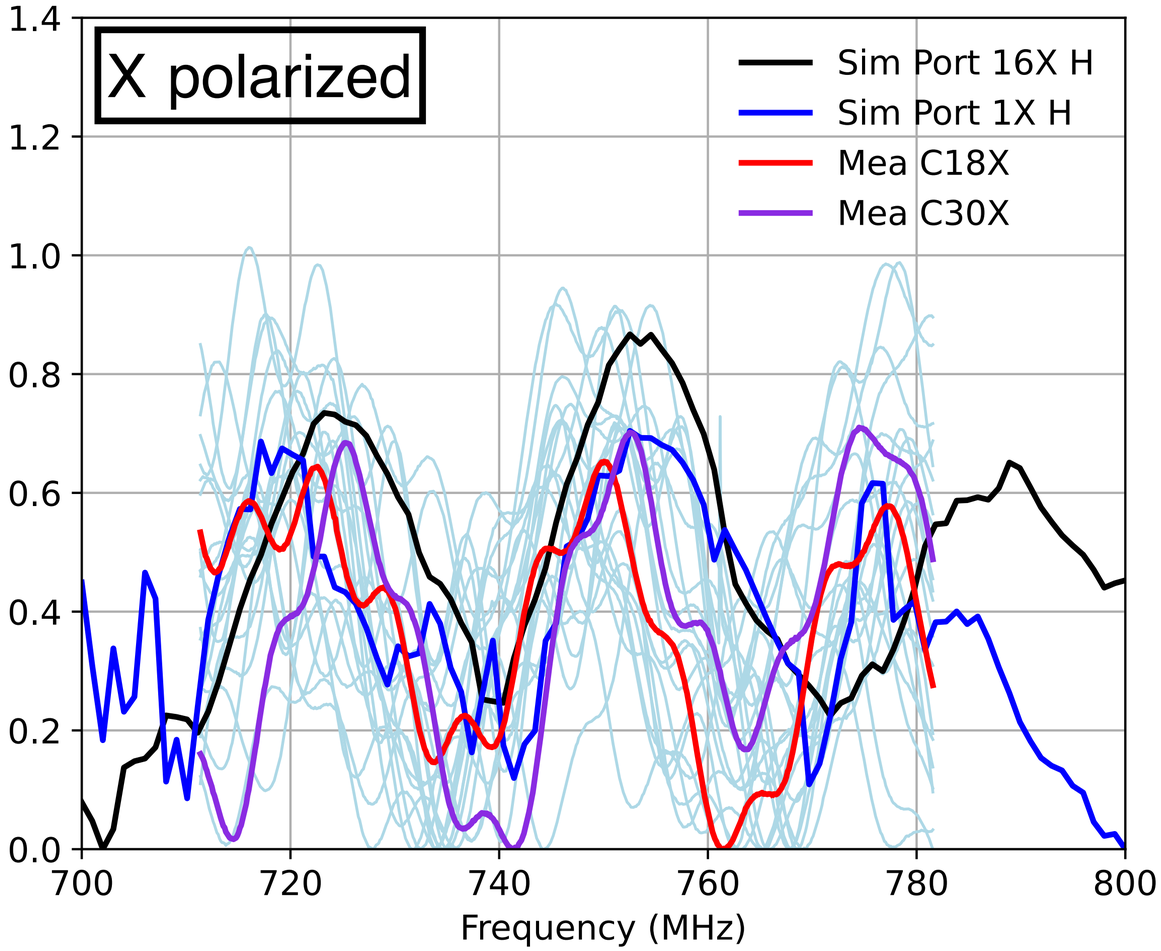
1. Experiment result is from cross correlation result;
2. HPBW of Y-polarized ports are wider than X-polarized ports.



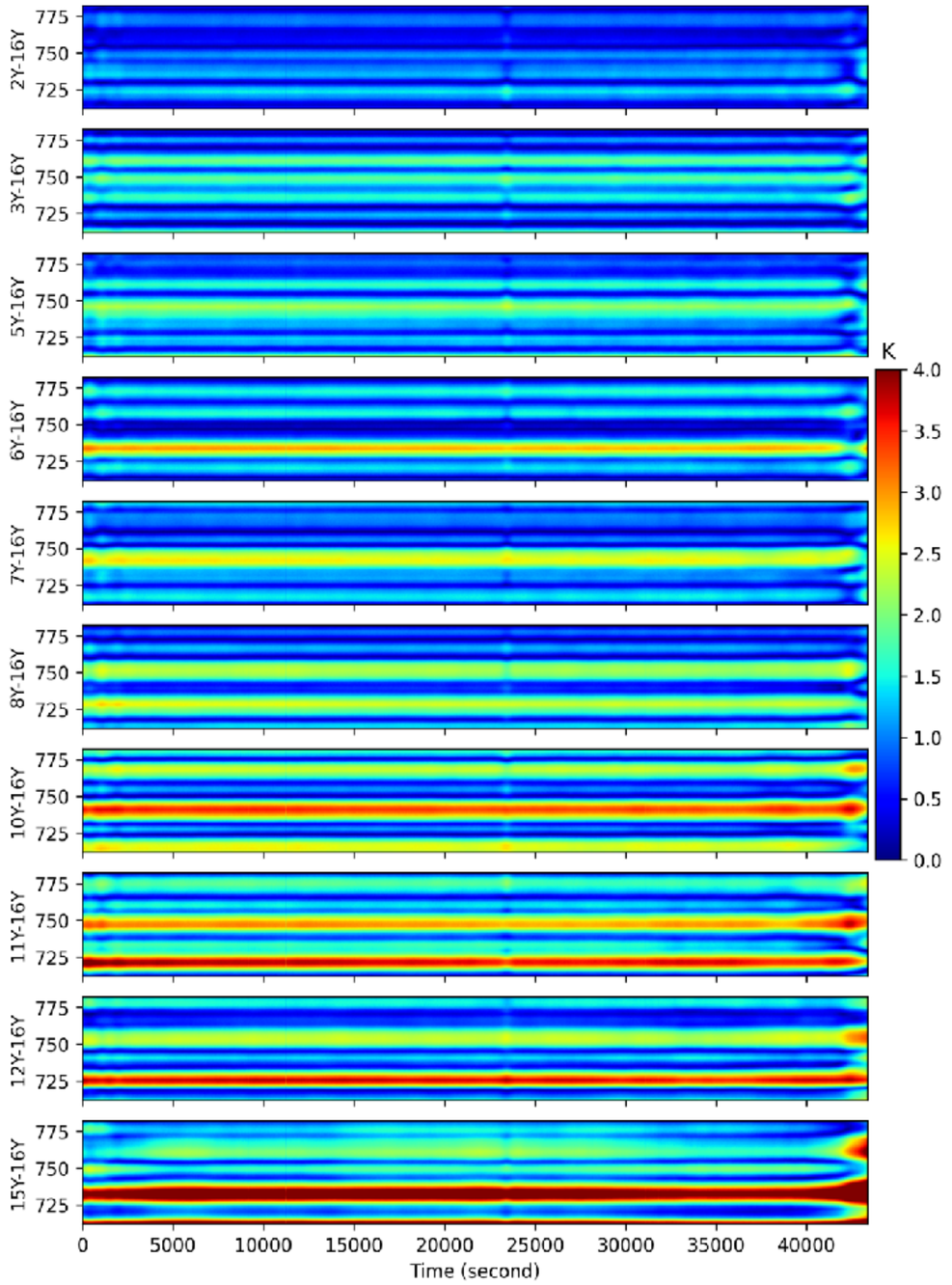
Experiment vs. Simulation——peak gain

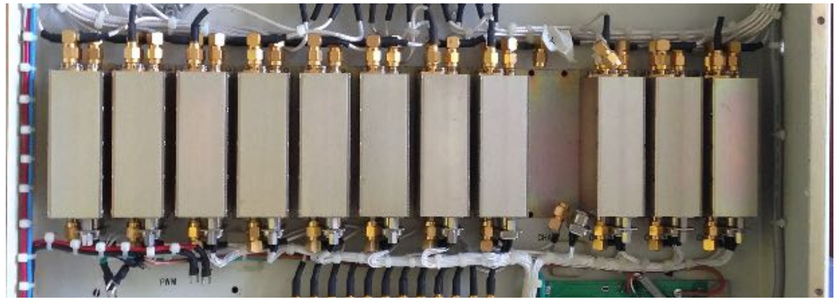
- Normalized peak gain in 0.7GHz-0.8GHz;
- Compare simulation results with auto correlation observation results;
- Higher frequency standing wave in data due to 15 meters feed cable.





Experiment vs. Simulation——mutual coupling





Shielding efficiency is better than 60 dB

coupling path: 1. Feed array

2. Ground Pickup

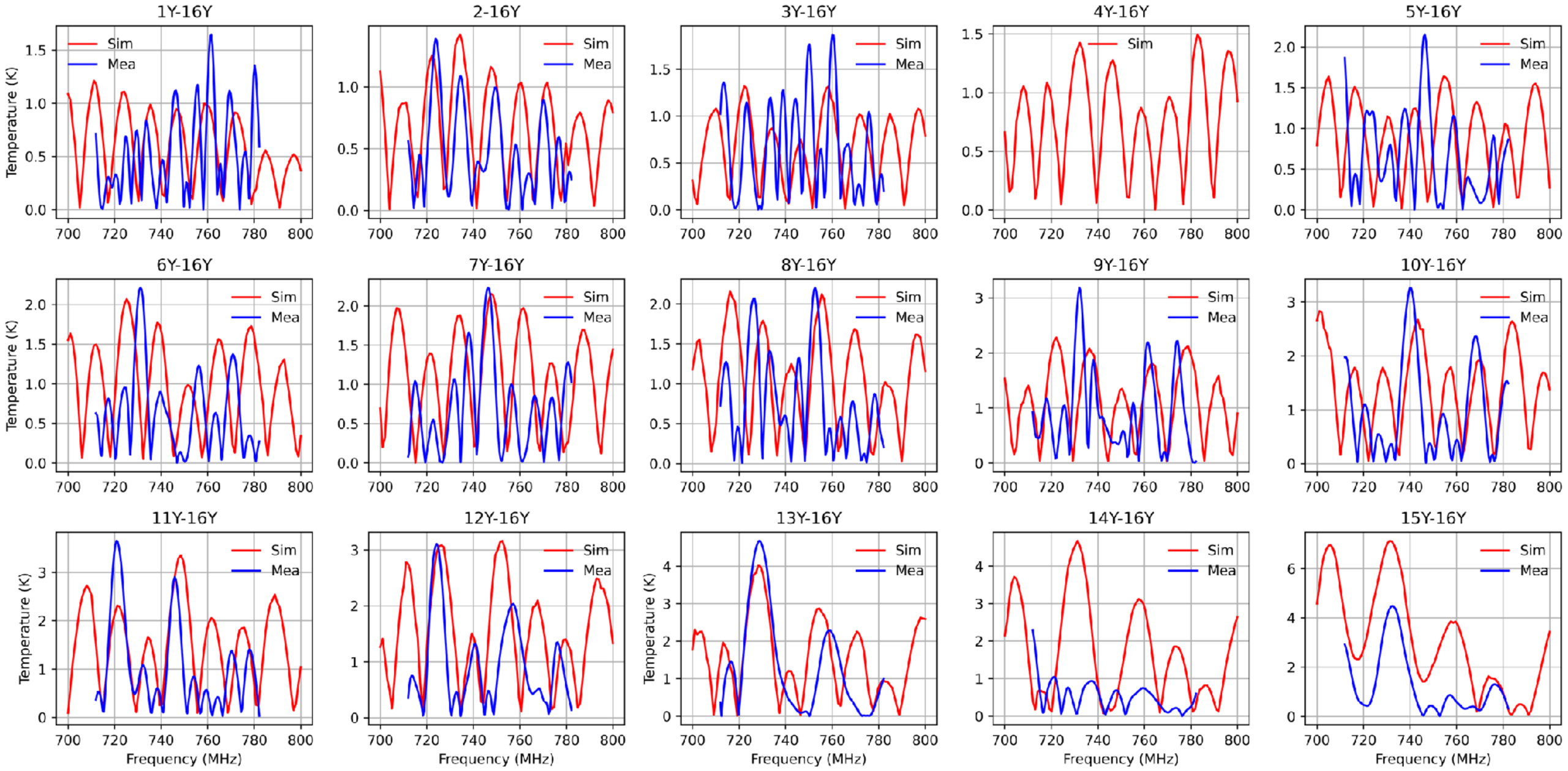
$$
\begin{aligned}
V_{ij} &= \langle \tilde{U}_i^* \tilde{U}_j \rangle \\
&= \langle (U_i + S_{ij} U_j)^* (U_j + S_{ji} U_i) \rangle \\
&= (1 + S_{ij}{}^* S_{ji}) \langle U_i^* U_j \rangle + S_{ij}{}^* \langle |U_j|^2 \rangle + S_{ji} \langle |U_i|^2 \rangle
\end{aligned}
$$

$$
S_{ij} = S_{ji}, \text{ and } S_{ij}^* + S_{ji} = 2\mathrm{Re}(\dot{S}_{ij})
$$

$$
\boxed{V_{ij} = \langle U_i^* U_j \rangle + 2\mathrm{Re}[S_{ij}] \langle |U_i|^2 \rangle} \qquad \langle |U_i|^2 \rangle = CT_{\mathrm{ant}}
$$

Experiment vs. Simulation——mutual coupling

System temperature = 90 K, LNA noise = 48 K, so antenna temperature = 42 K.



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Summary

1. Standing wave in bandpass is due to reflection between reflector and radiation blade;
2. Cylinder reflector increases mutual coupling effects;
3. Closer to the edge, the more asymmetry of radiation pattern;
4. Simulated bandpass characteristics are in good agreement with observation results in 700MHz-800MHz;
5. For an antenna temperature of 42 K, the maximum coupling temperature is ~4 K.

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Thanks

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