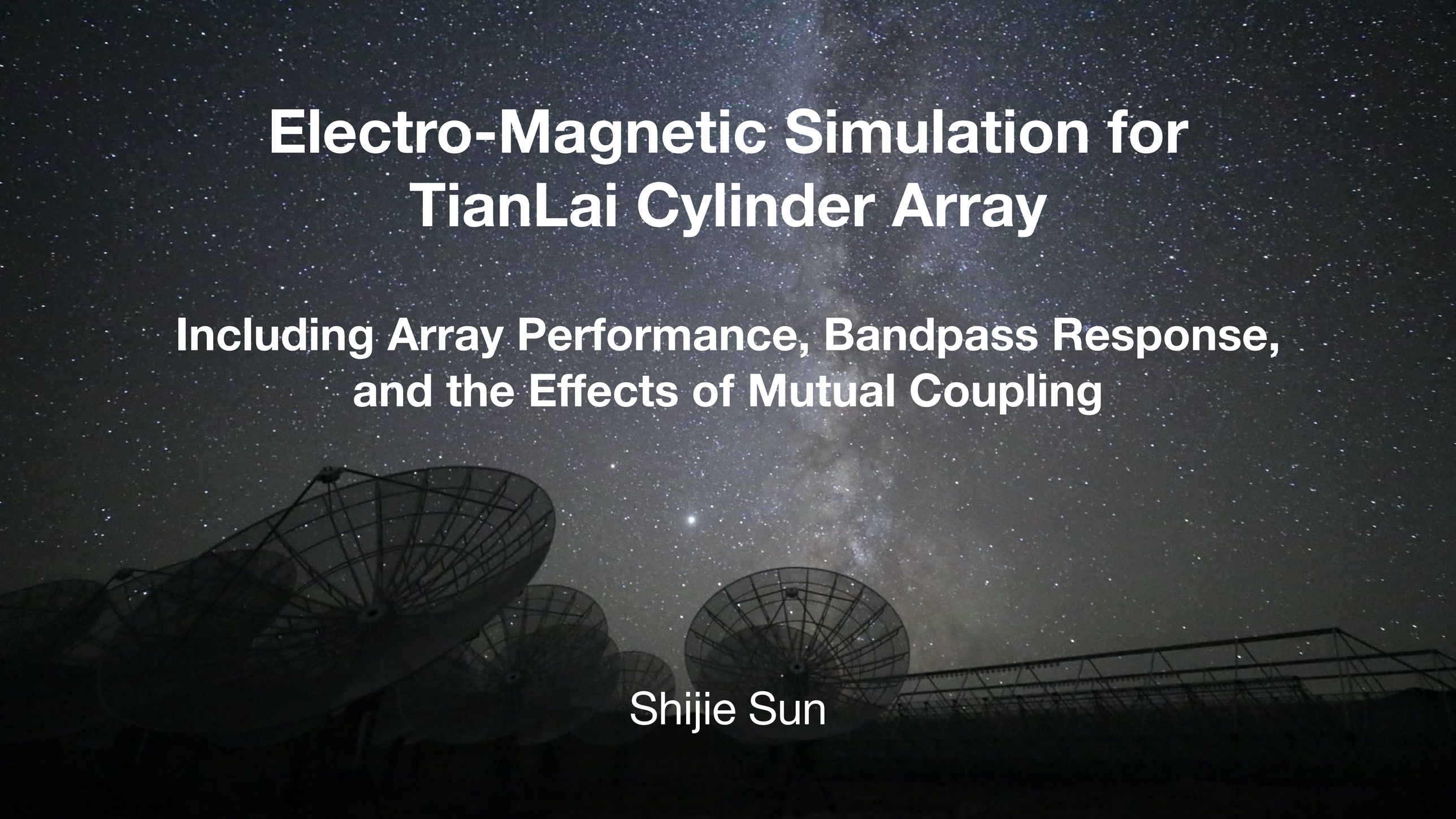


Electro-Magnetic Simulation for TianLai Cylinder Array

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

Shijie Sun

Outlines

1. Simulation method
2. One feed simulation and measurement
3. One feed + reflector simulation
4. Feed array simulation
5. Feed array + reflector simulation
6. Summary

1. Simulation method

- model size

feed: ~21cm $\longrightarrow \sim 1 \times \lambda(1.4GHz)$

feed array: ~13✖0.21m $\longrightarrow \sim 62 \times \lambda(1.4GHz)$

cylinder reflector: 40✖15m $\longrightarrow \sim 200 \times \lambda(1.4GHz)$

- simulation software — Ansys EM 2020R2(HFSS)

- simulation method

feed → Finite Element Method

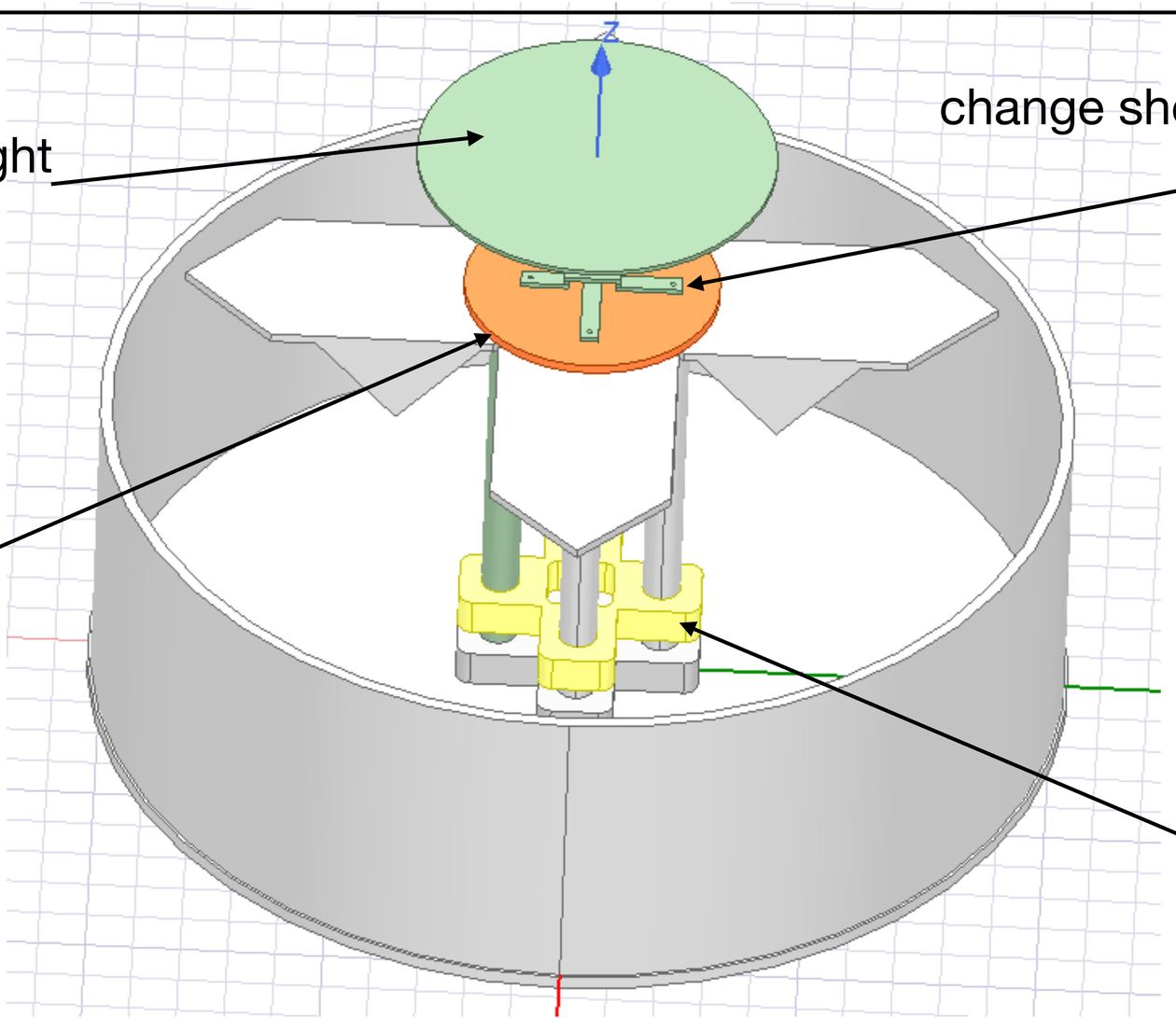
feed array → FEBI: Finite Element + Integral Equation

one feed + reflector → Hybrid: FEBI + PO(Physical Optics)

feed array + reflector → Hybrid: FEBI + PO(Physical Optic)

2. Feed simulation and measurement

- Previously designed and optimized by CETC54 institute and Tao Liu;
- Update feed model based on real feed and S11,S22 measurement result；



change match plate height

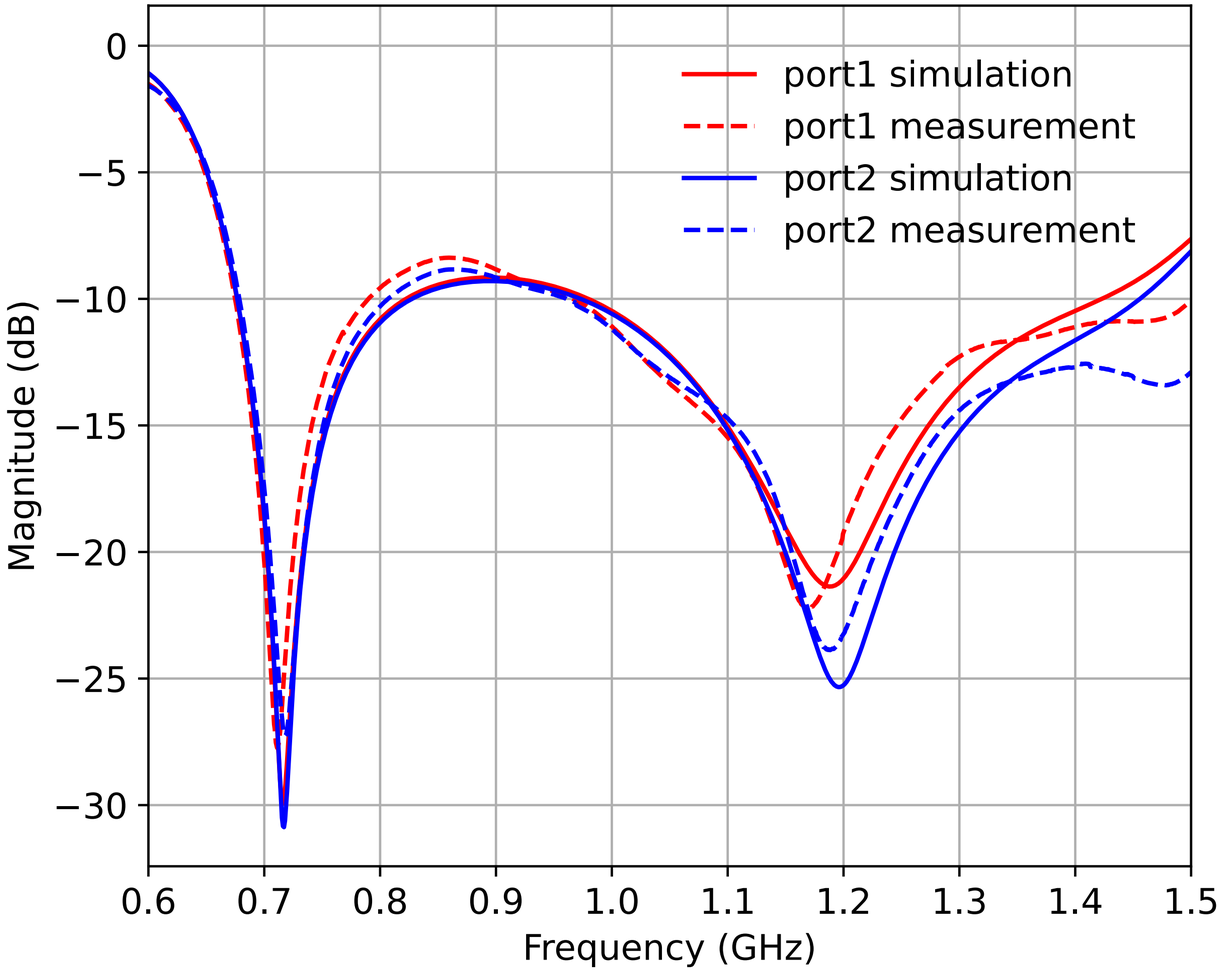
change short bridge width and length

add dielectric

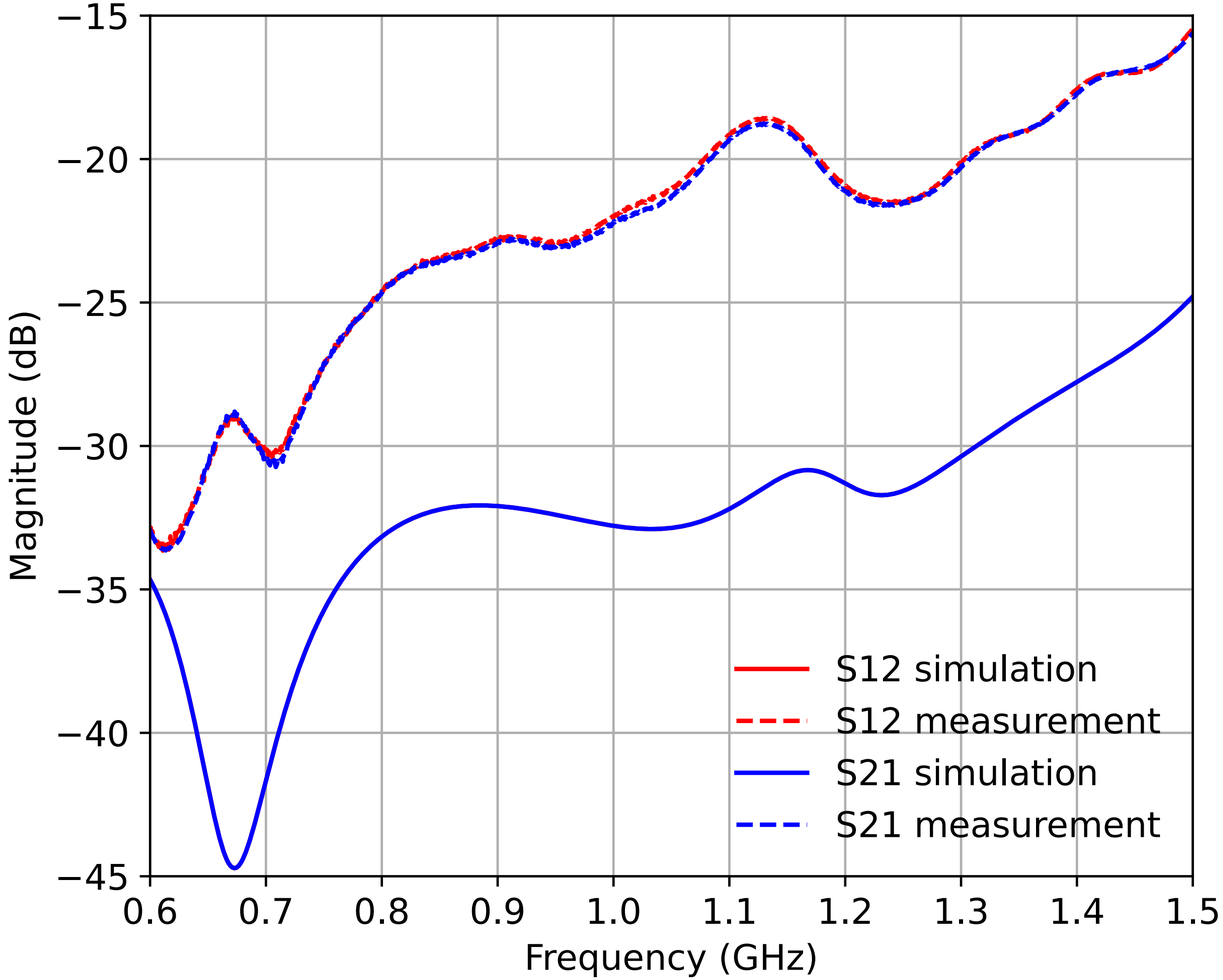
add short connector

2. Feed simulation and measurement

- A more precision model after modification



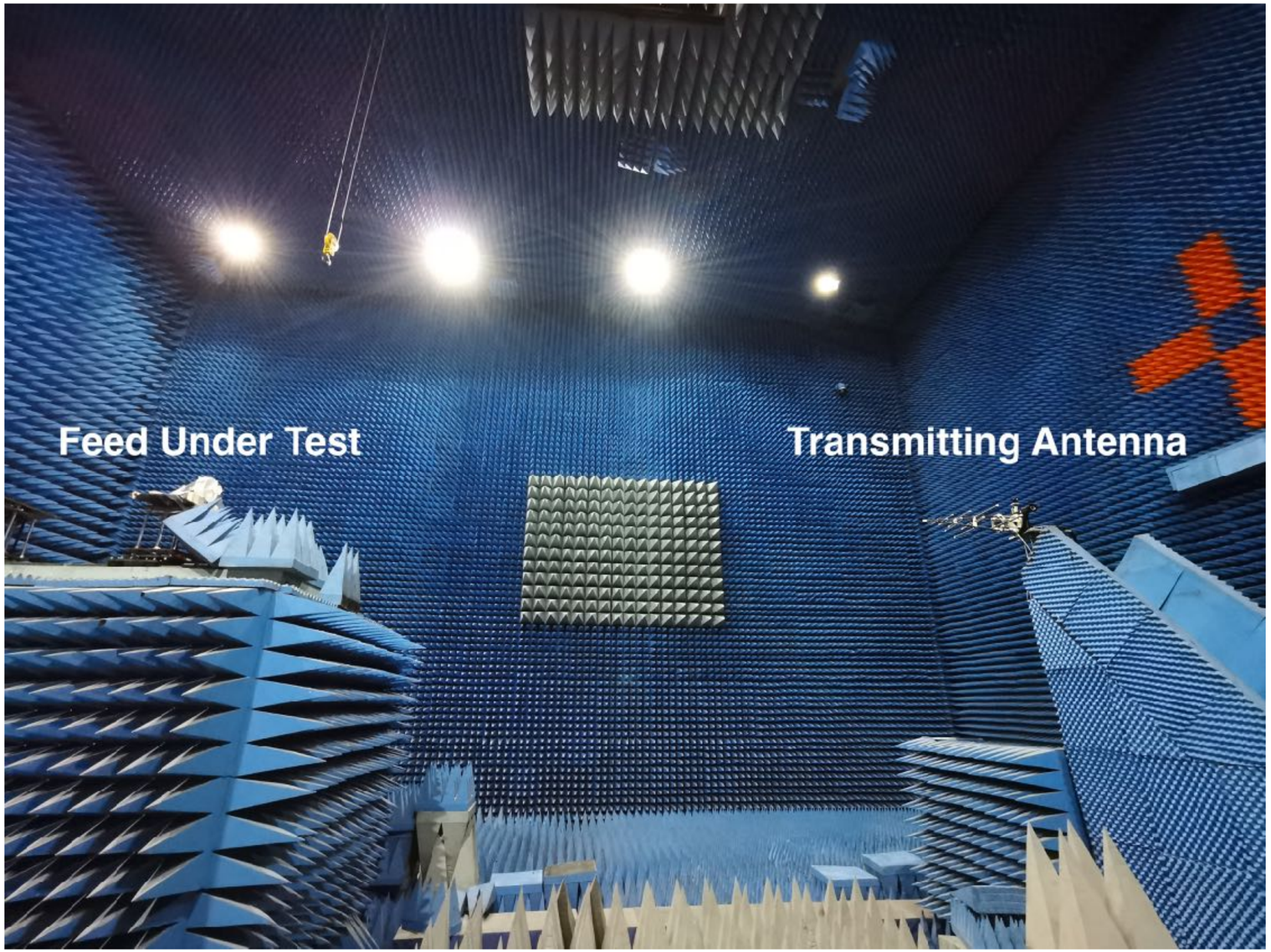
S11,S22, Self coupling coefficient



S21,S12, Mutual coupling coefficient

2. Feed simulation and measurement

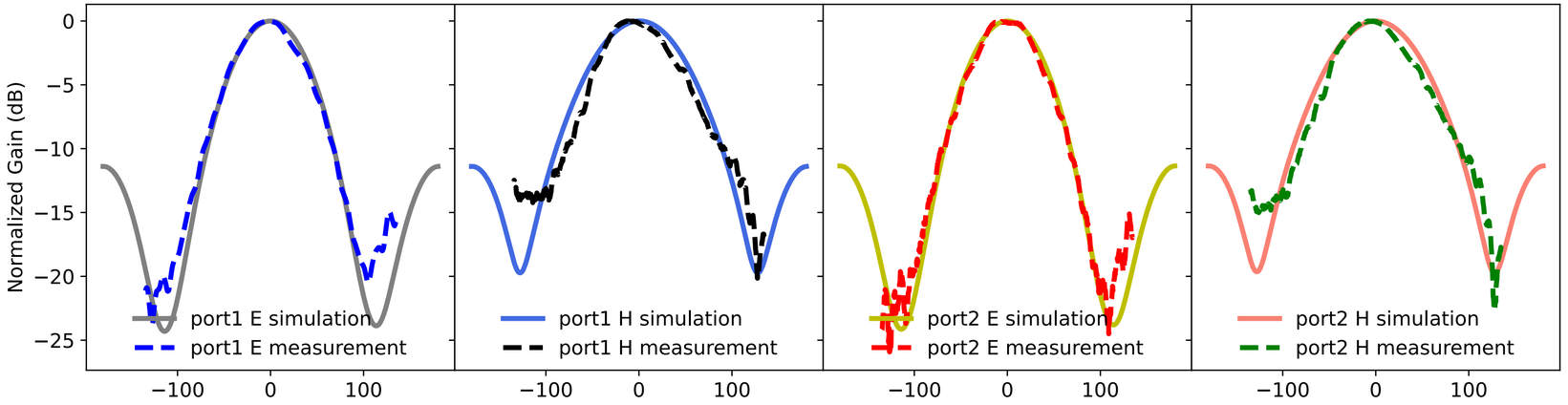
Feed radiation pattern measurement in microwave chamber



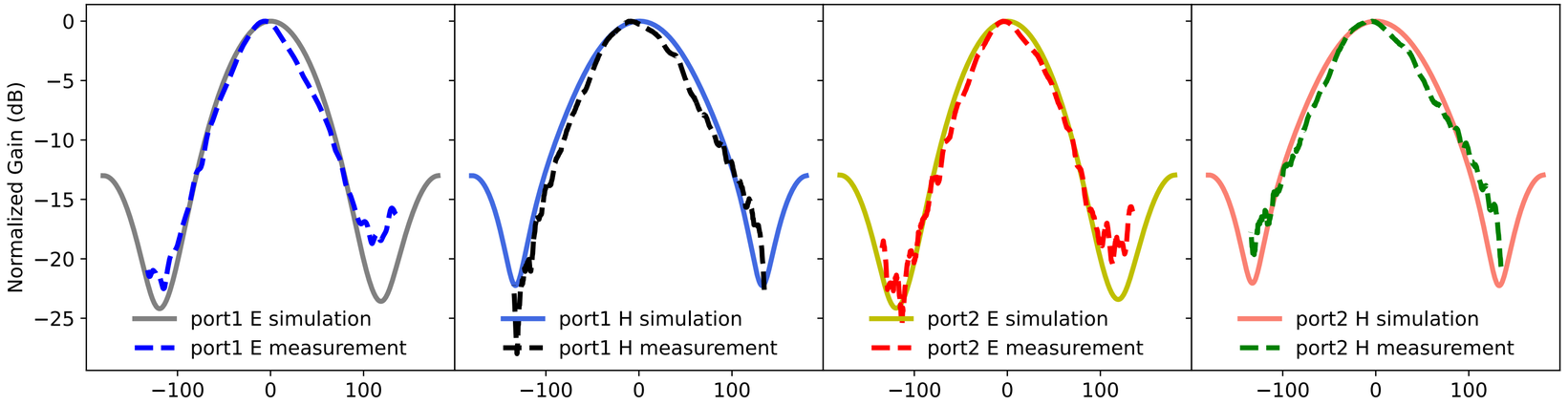
In CETC54 Lab

2. Feed simulation and measurement

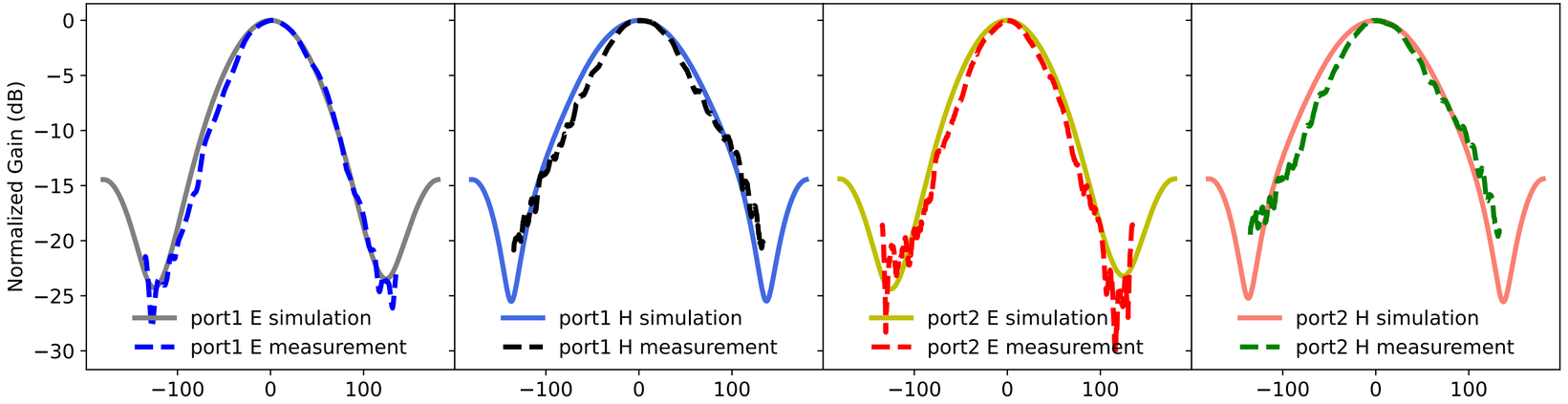
0.70GHz



0.75GHz

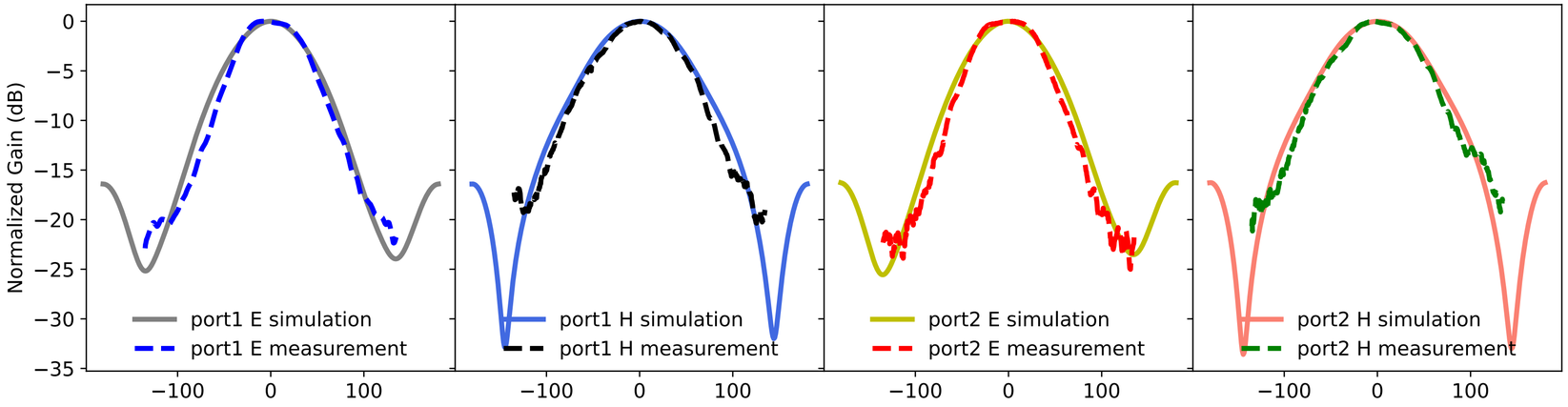


0.80GHz

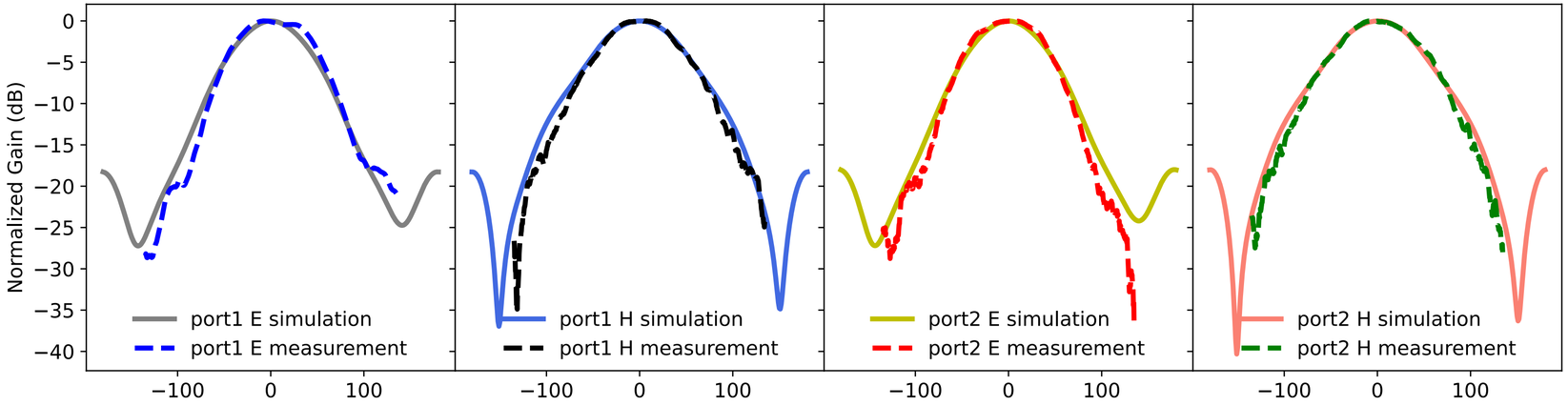


2. Feed simulation and measurement

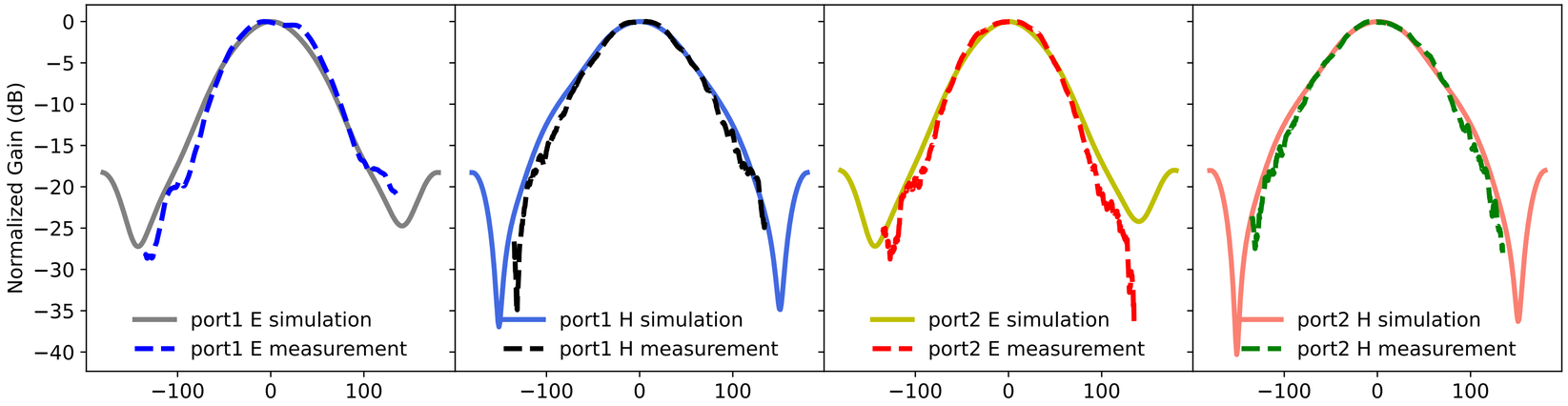
0.90GHz



1.00GHz

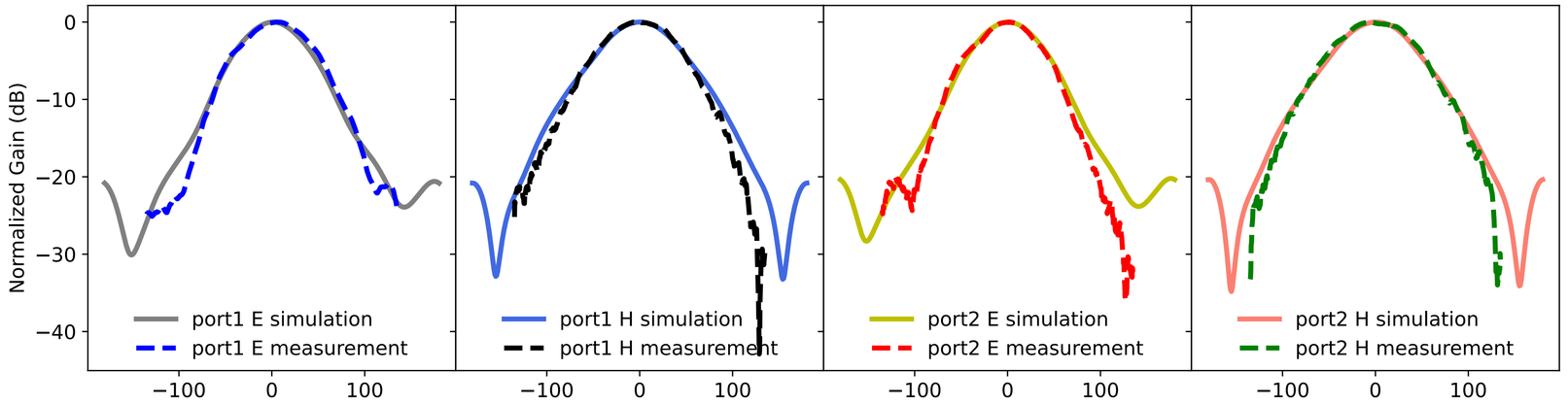


1.10GHz

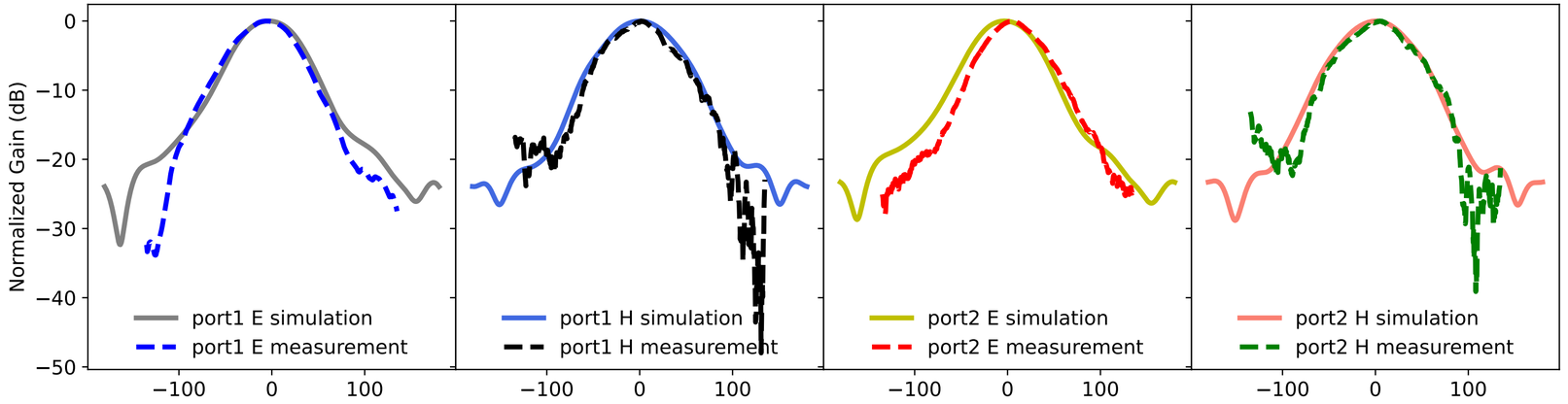


2. Feed simulation and measurement

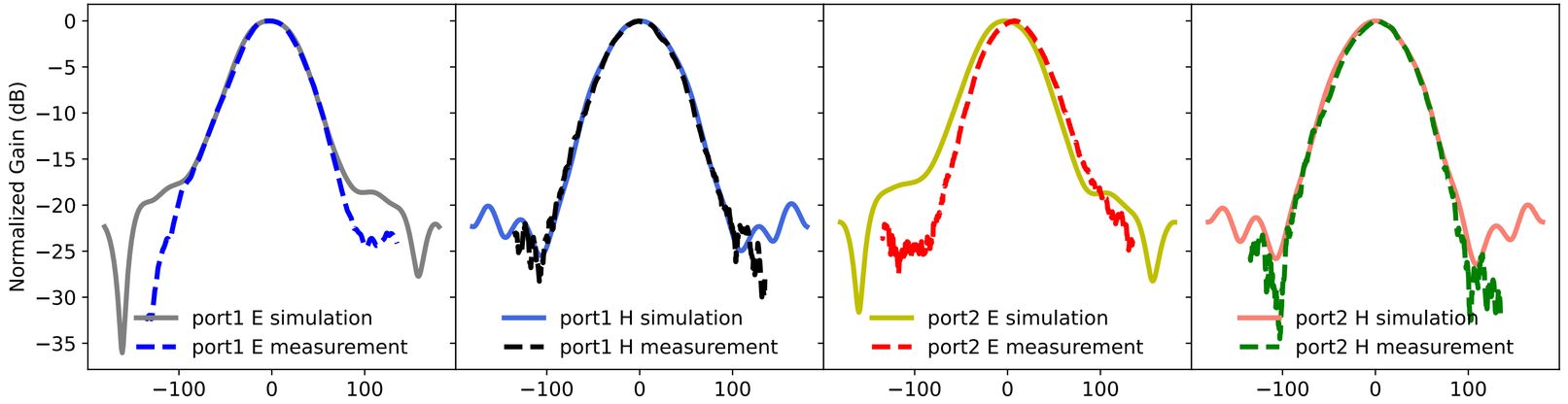
- Simulation results and measurement results are consistent with each other from 0.7GHz~1.4GHz
- Lack of side lobe measurement data;
- Measurement ranges from theta $-135^{\circ} \sim +135^{\circ}$ due to limitation of rotating platform



1.20GHz



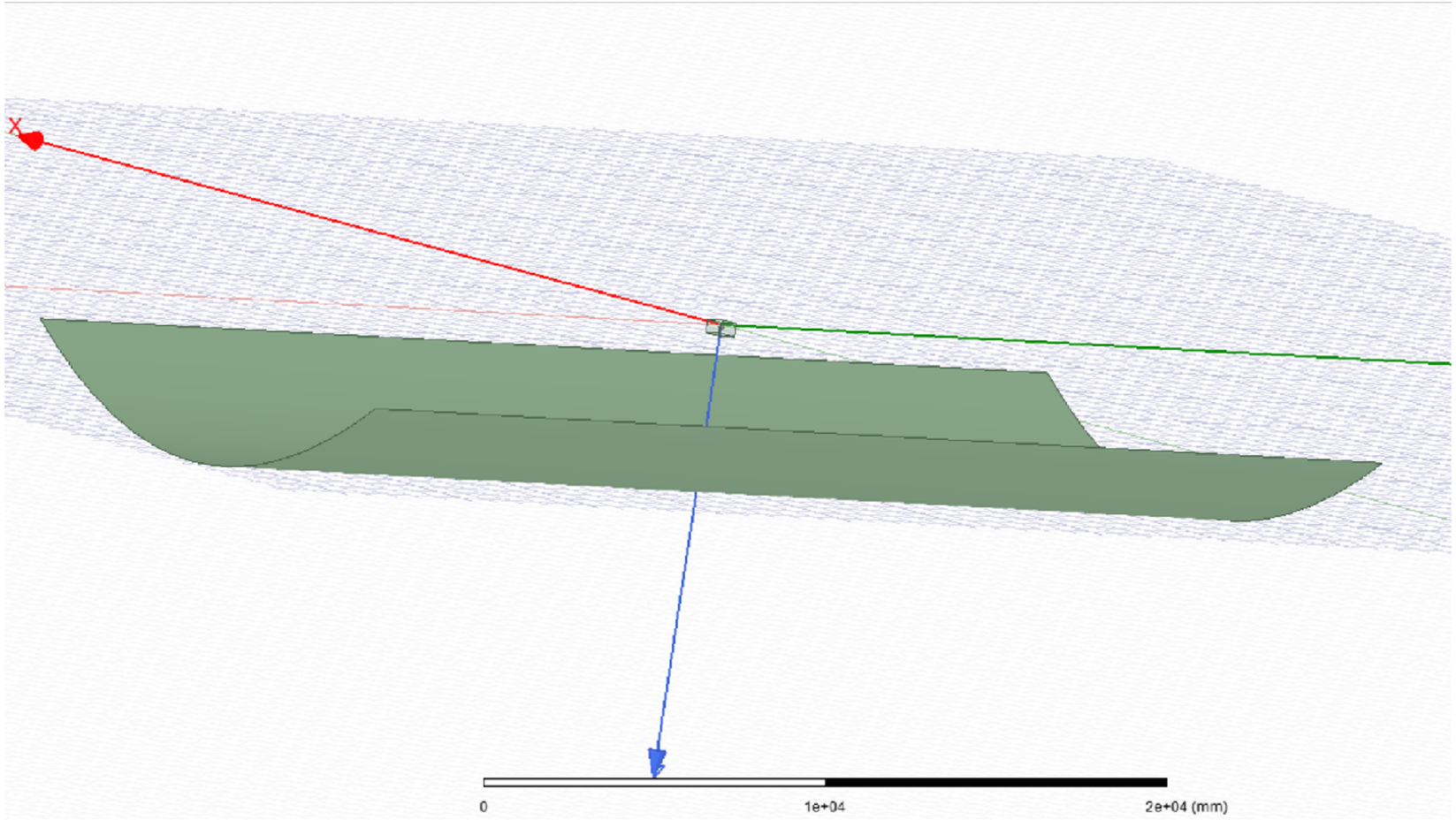
1.30GHz

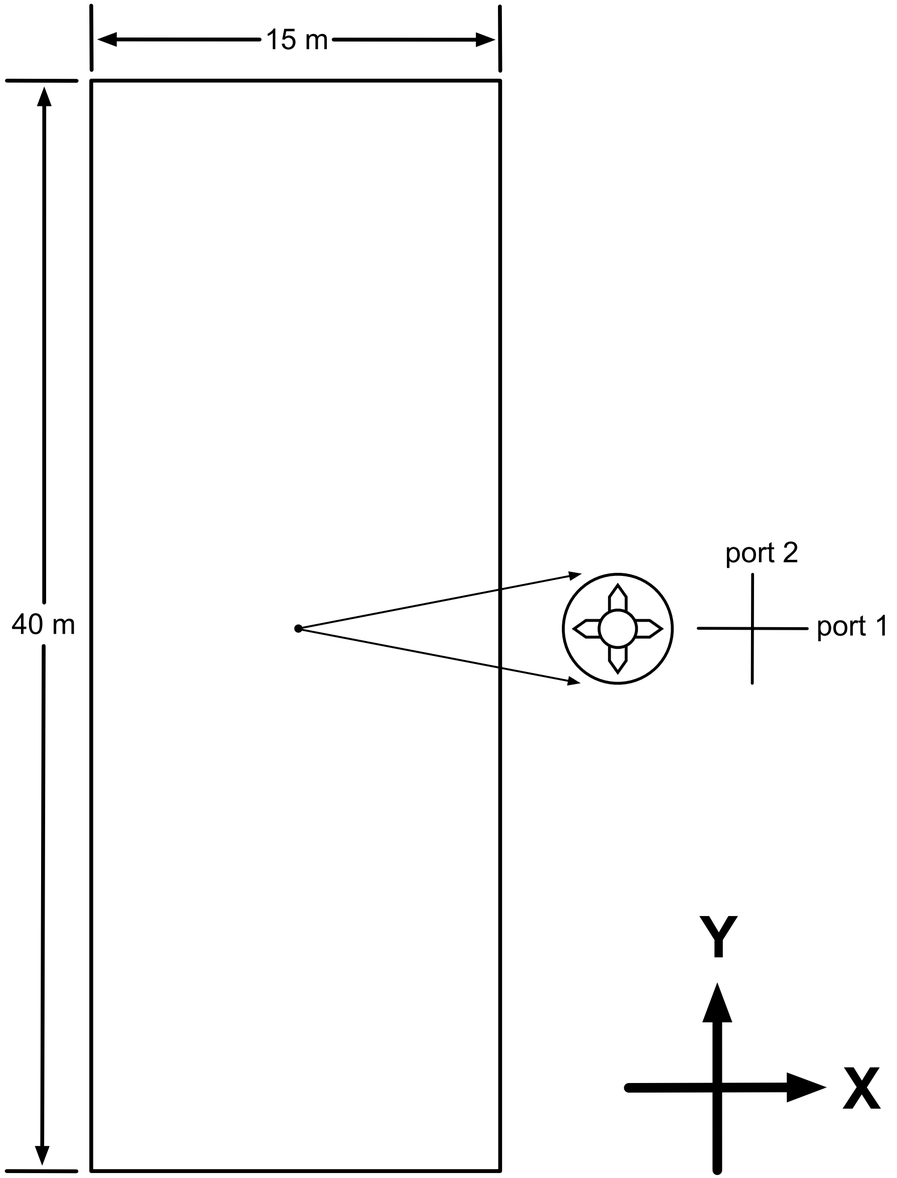


1.40GHz

3. One feed + reflector simulation

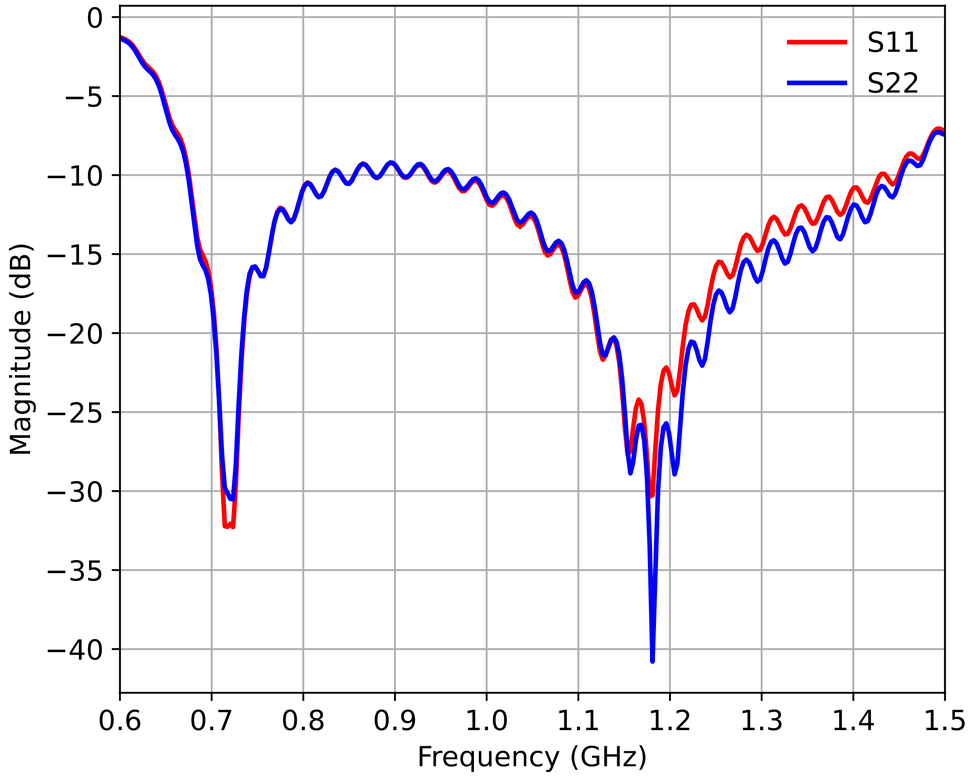
- Simulation model: one feed in center position

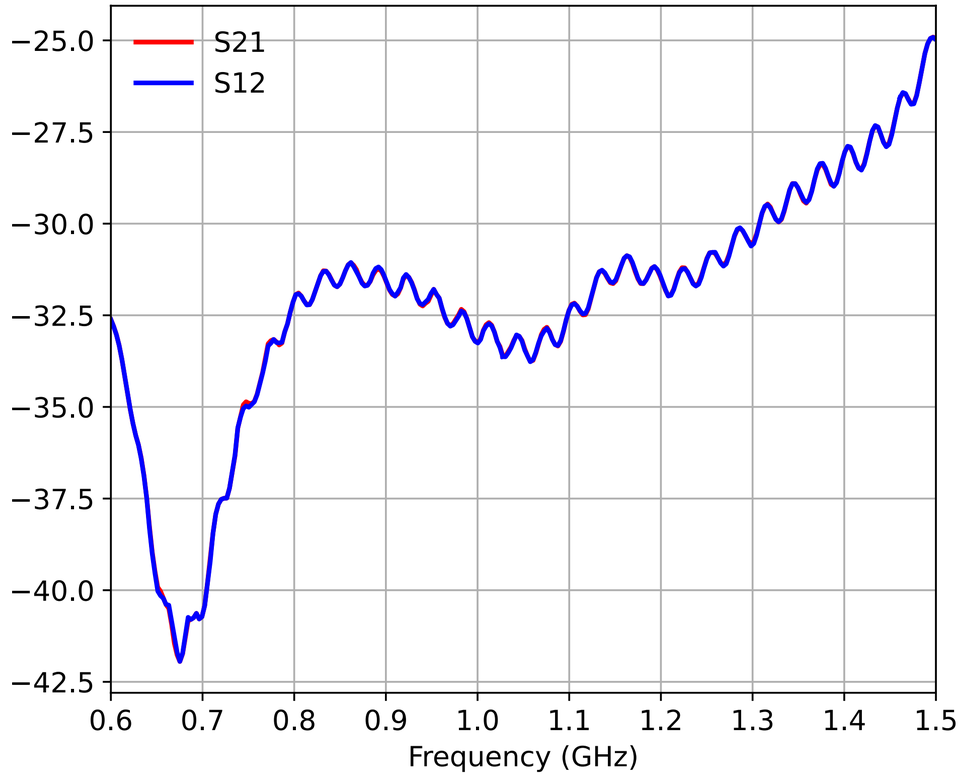




3. One feed + reflector simulation

- S parameters have similar characteristics compared with feed results

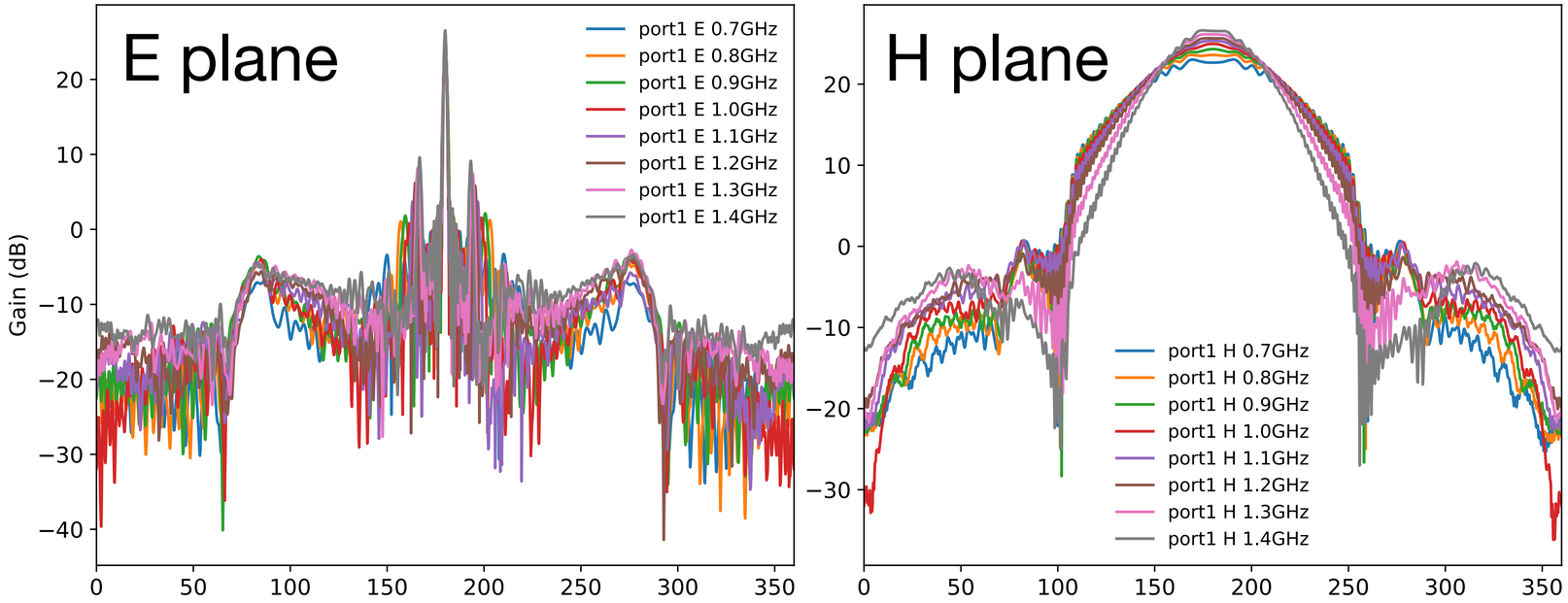




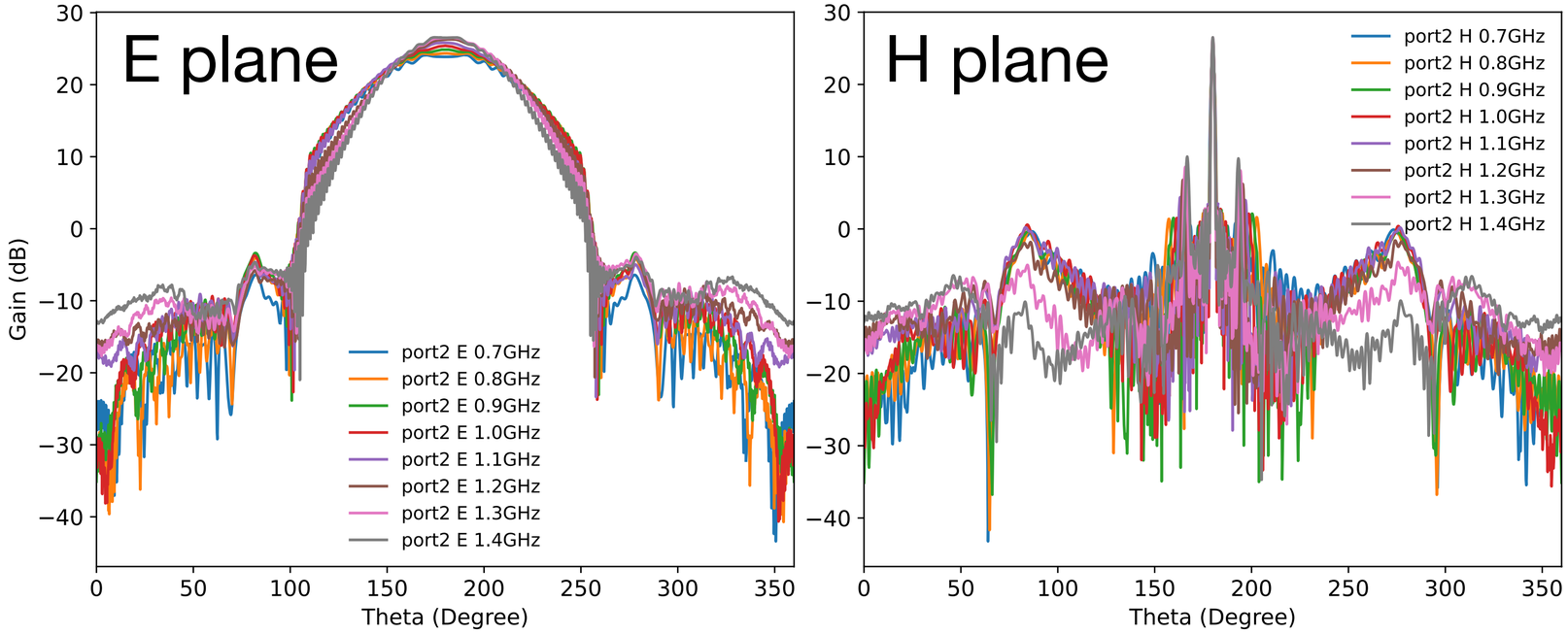
- appear standing wave structure in frequency domain;
- standing wave in 31MHz, corresponding to 9.68meters distance in free space;
- distance between radiation plate in feed and reflector is 4.8meters.

3. One feed + reflector simulation

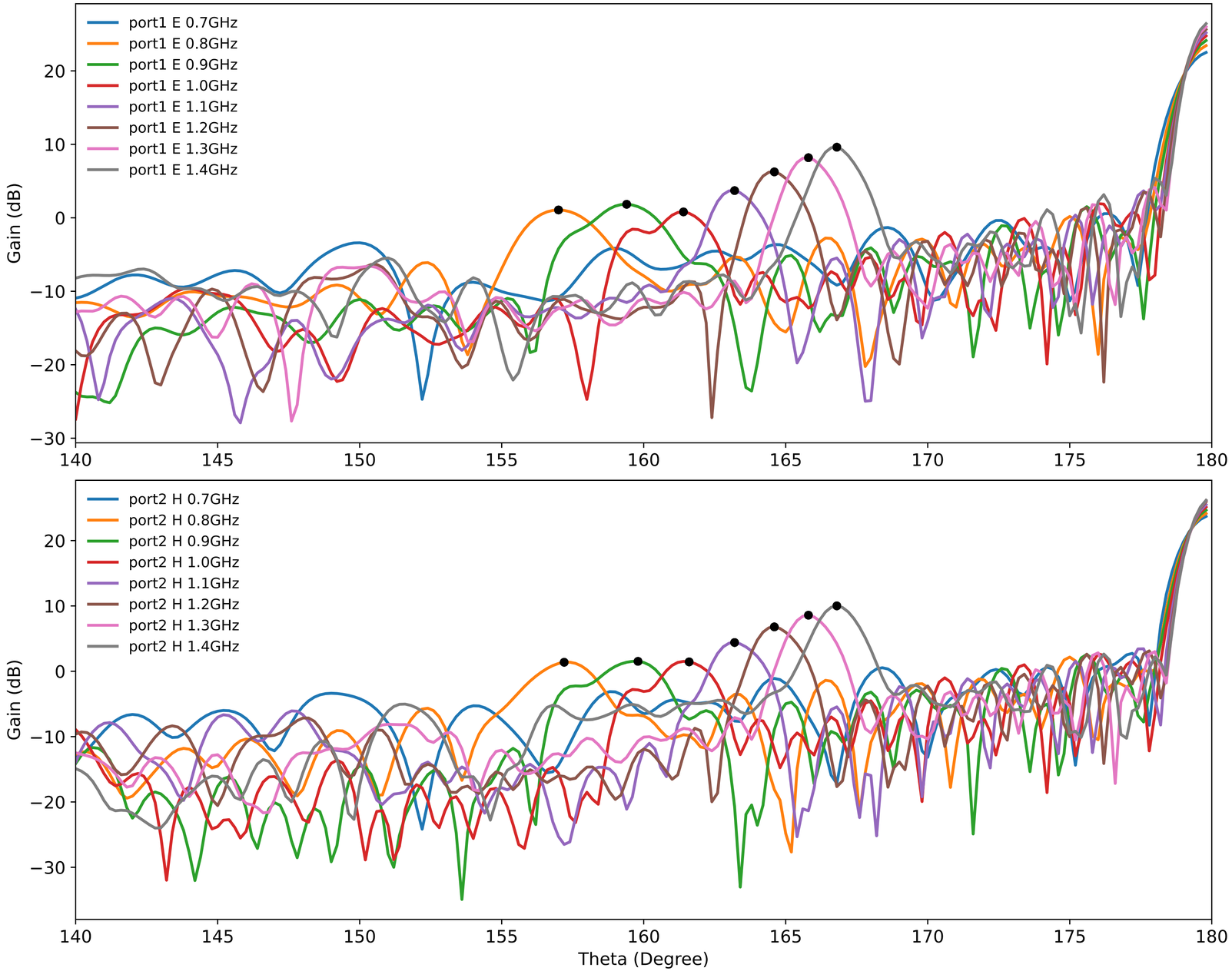
Port1



Port2



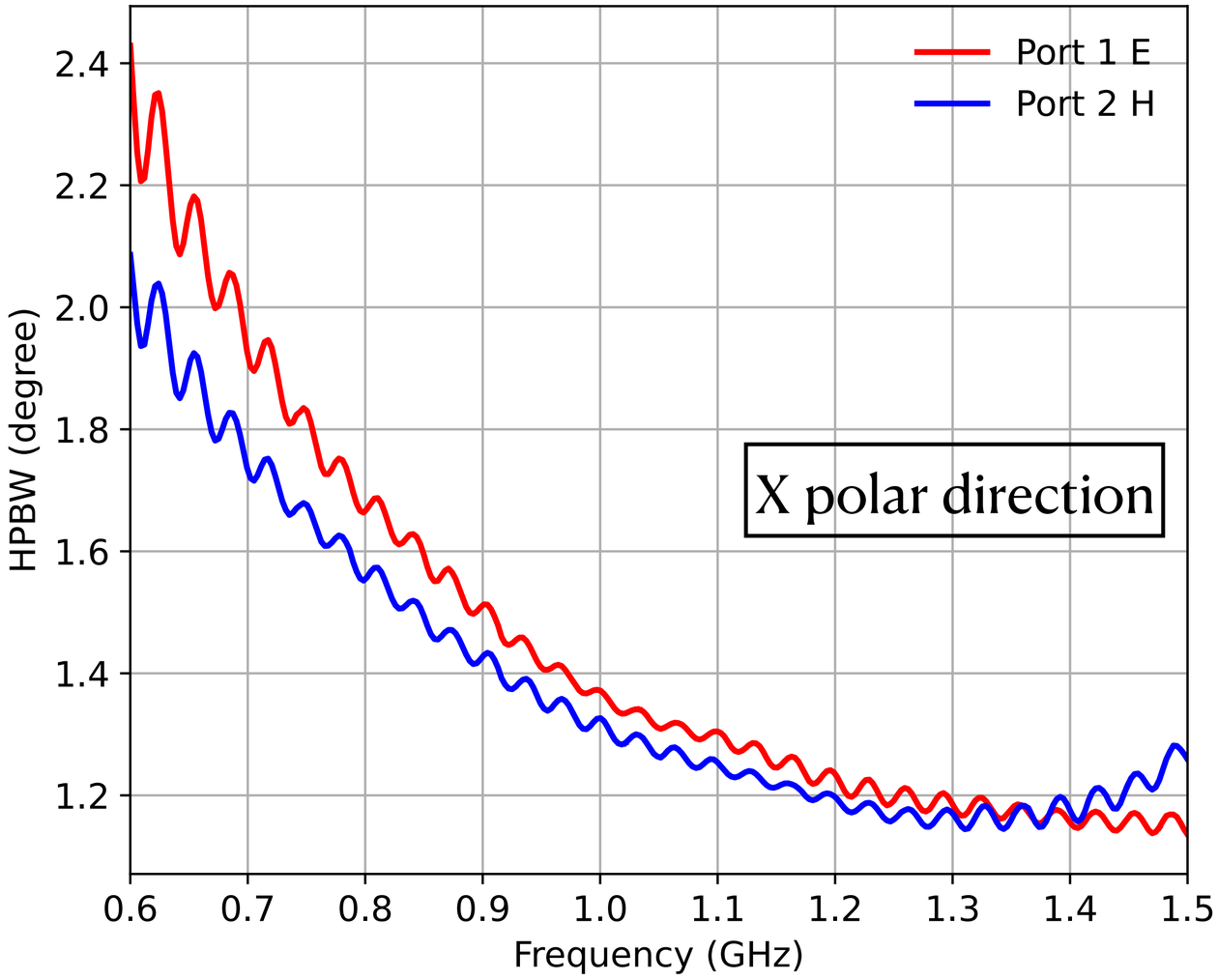
3. One feed + reflector simulation

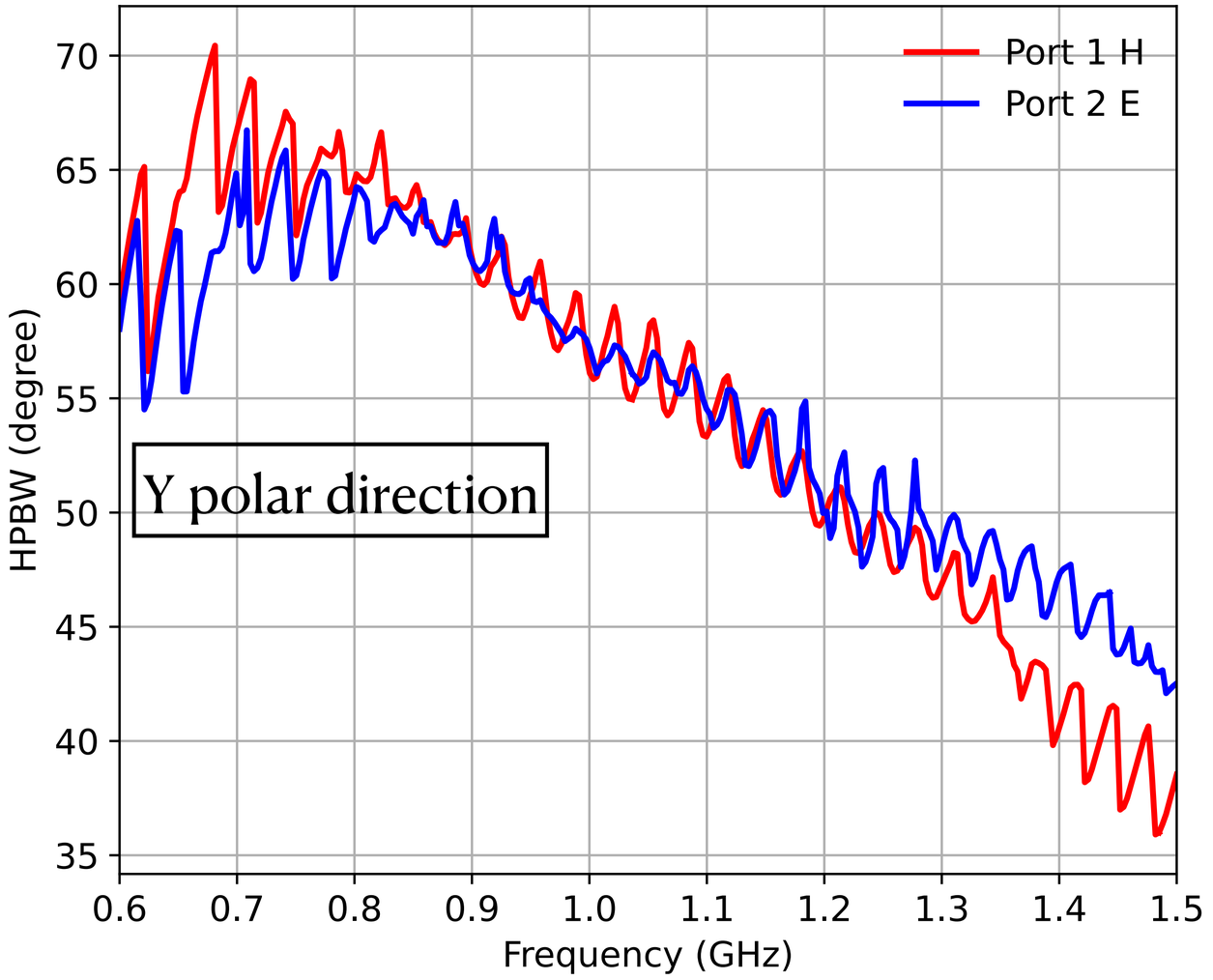


- With higher frequency, the maximum side lobe becomes larger, and closer to main lobe.

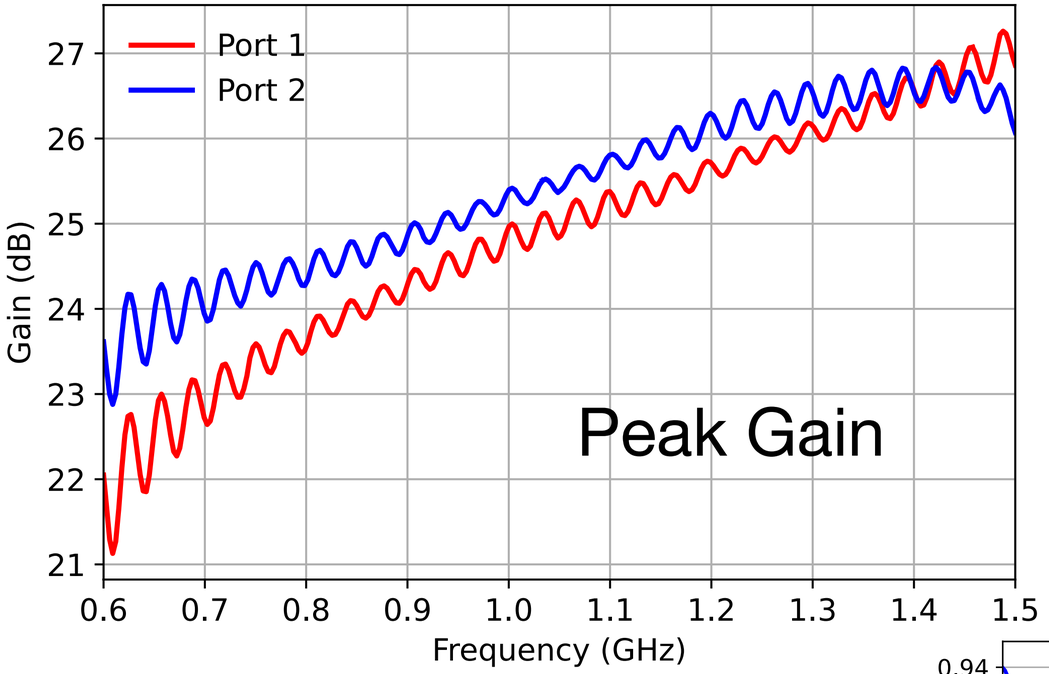
3. One feed + reflector simulation

- HPBW (half power beamwidth, or -3dB width) decrease along frequency





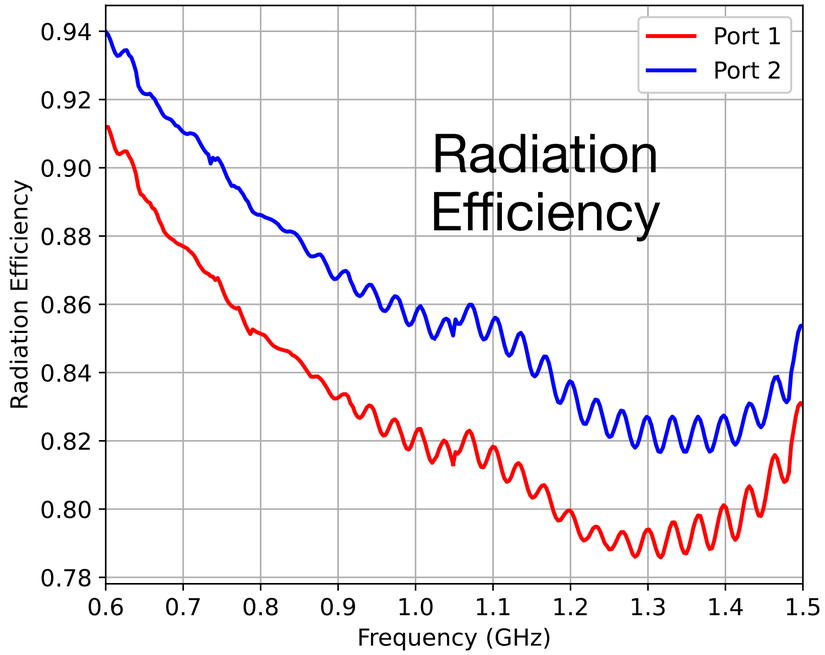
3. One feed + reflector simulation

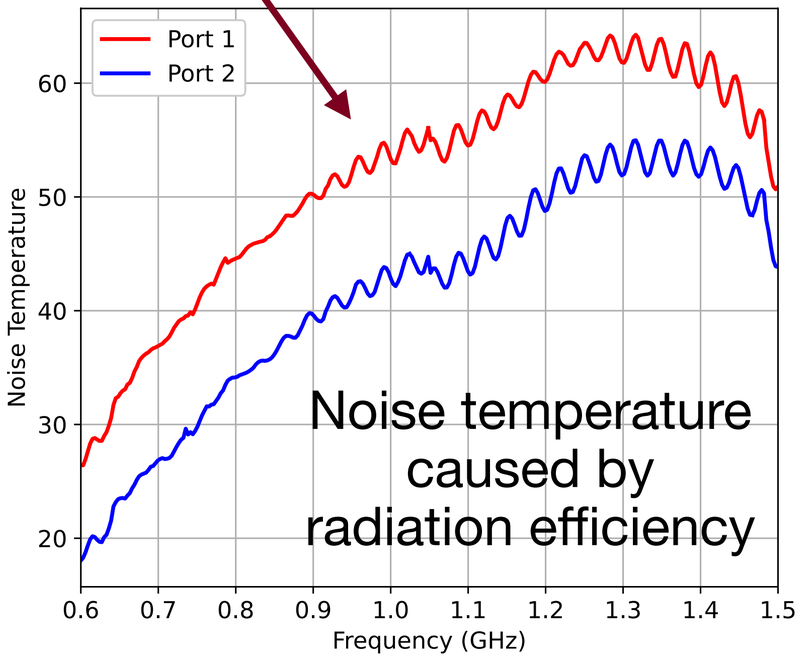


- Peak gain increases with frequency increases;
- Radiation efficiency decreases with frequency increases;

$$T_{sys} = \eta_{rad} T_{ant} + (1 - \eta_{rad}) T_{phy} + T_{rec}$$

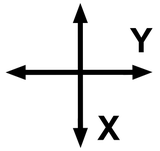
$$\eta_{rad} = \frac{P_{radiation}}{P_{input}}$$

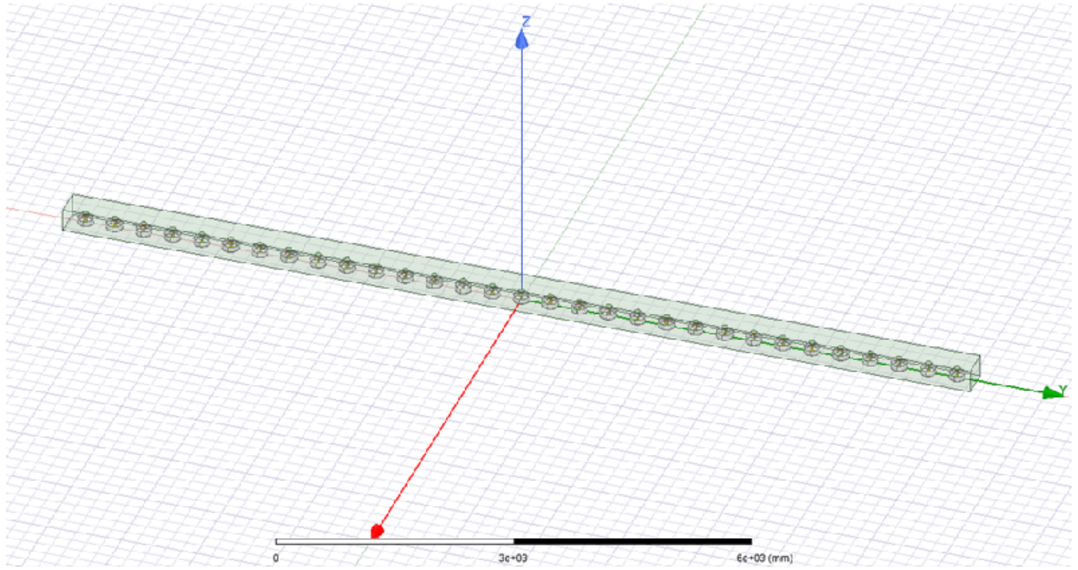


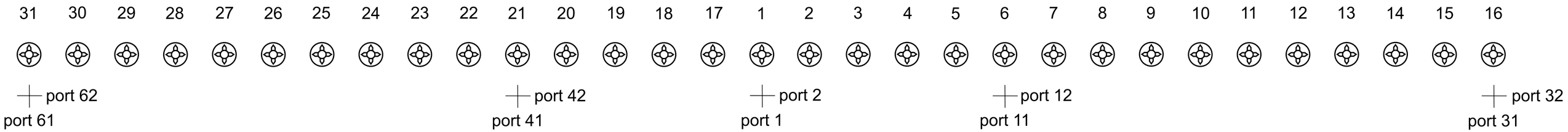


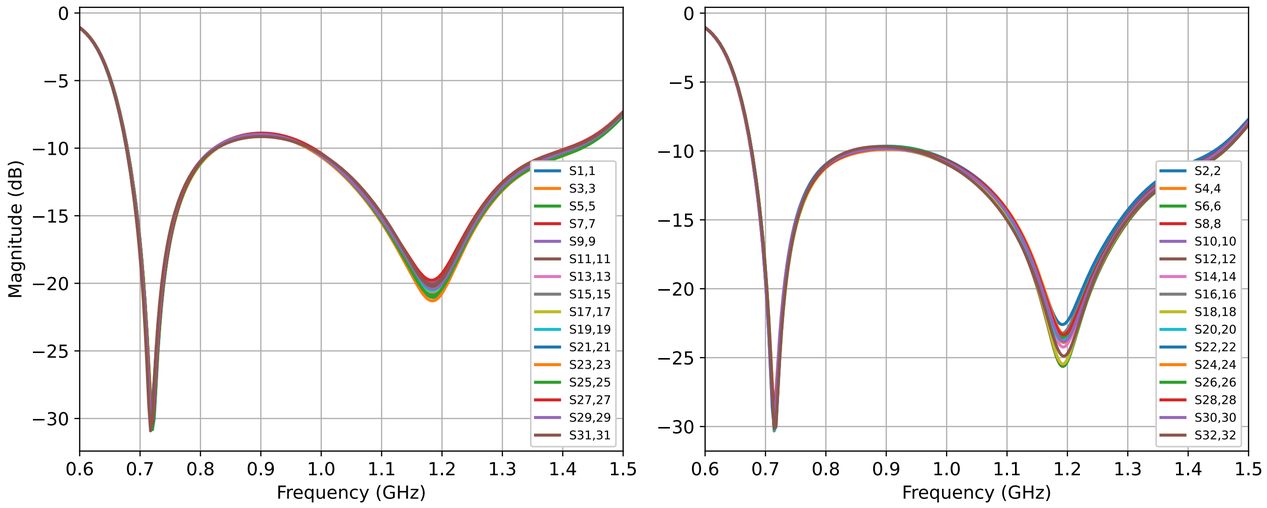
4. Feed array simulation

- 31 feeds;
- No.1 feed in center position;
- two feeds distance: 38.75cm;
- Two sides of No.1 feed are symmetrical;
- Odd ports along X polar direction;
- Even ports along Y polar direction;





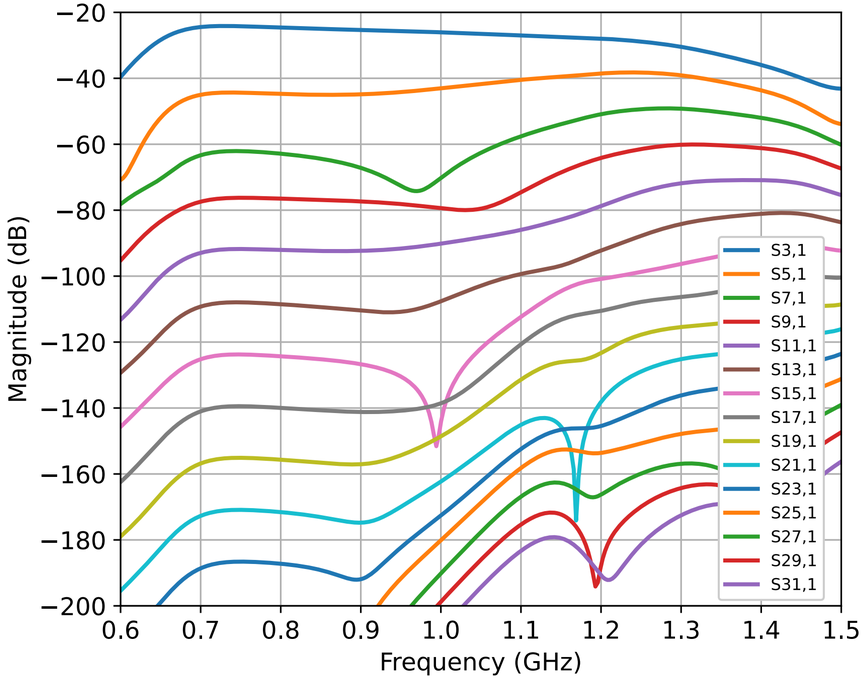


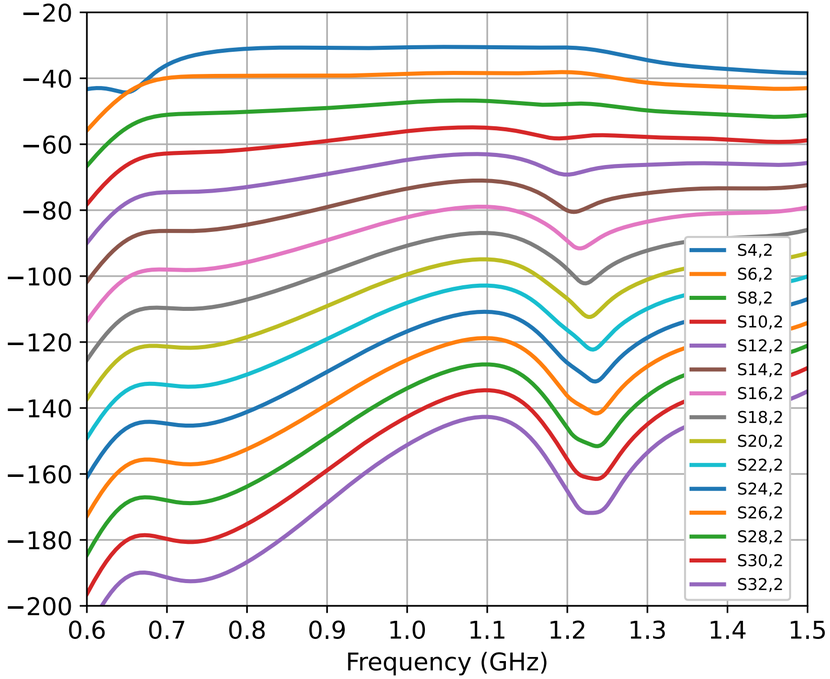


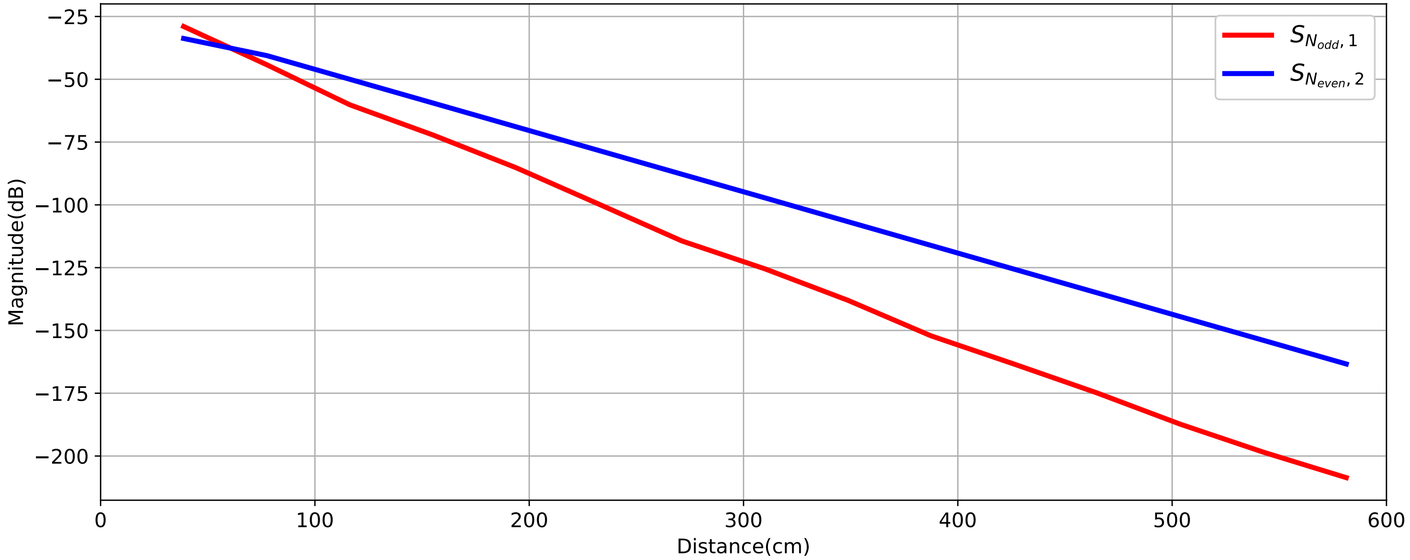
- Self reflection coefficients of all ports are consistent with one feed simulation result

4. Feed array simulation

- $S_{N1,N2}$ indicates transmission coefficient between two ports;
- $S_{N_{odd},1}$ indicates transmission coefficient between other ports in X polar direction and port1;
- $S_{N_{odd},2}$ indicates transmission coefficient between other ports in Y polar direction and port2;





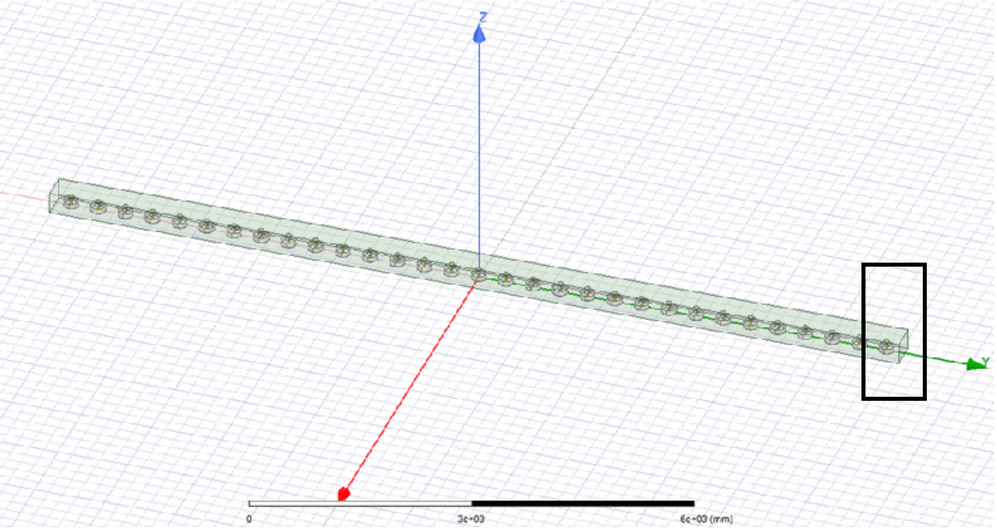


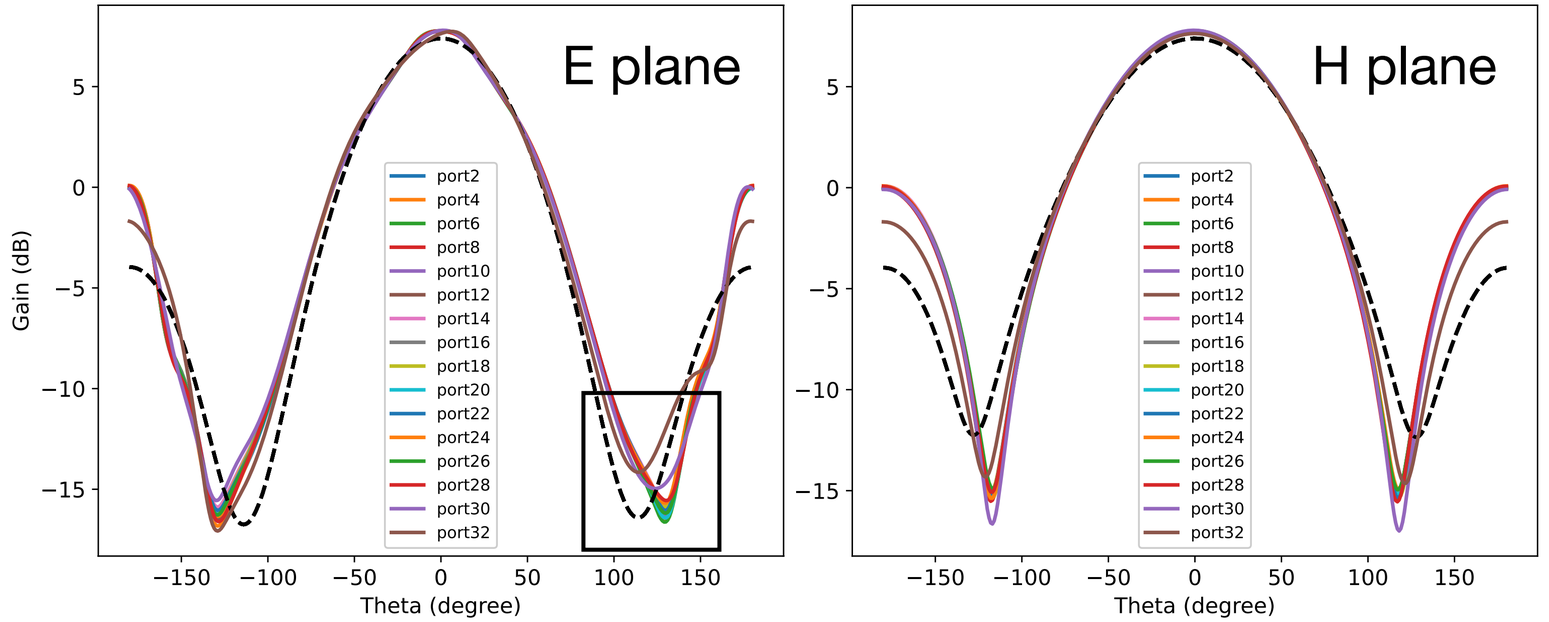
- As the distance increases, the transmission coefficient decreases linearly

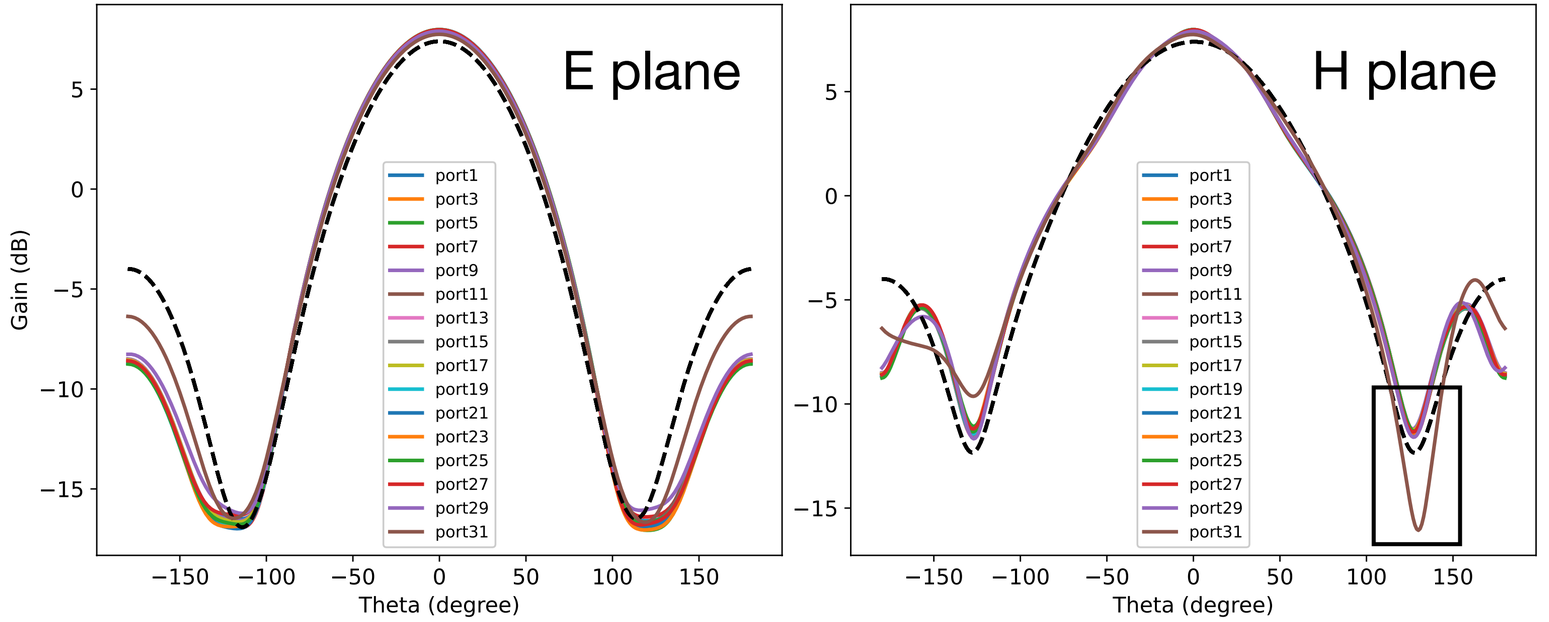
4. Feed array simulation

- Radiation pattern of port31 H plane and port32 E plane become asymmetry due to No.16 feed is in edge position

0.7GHz

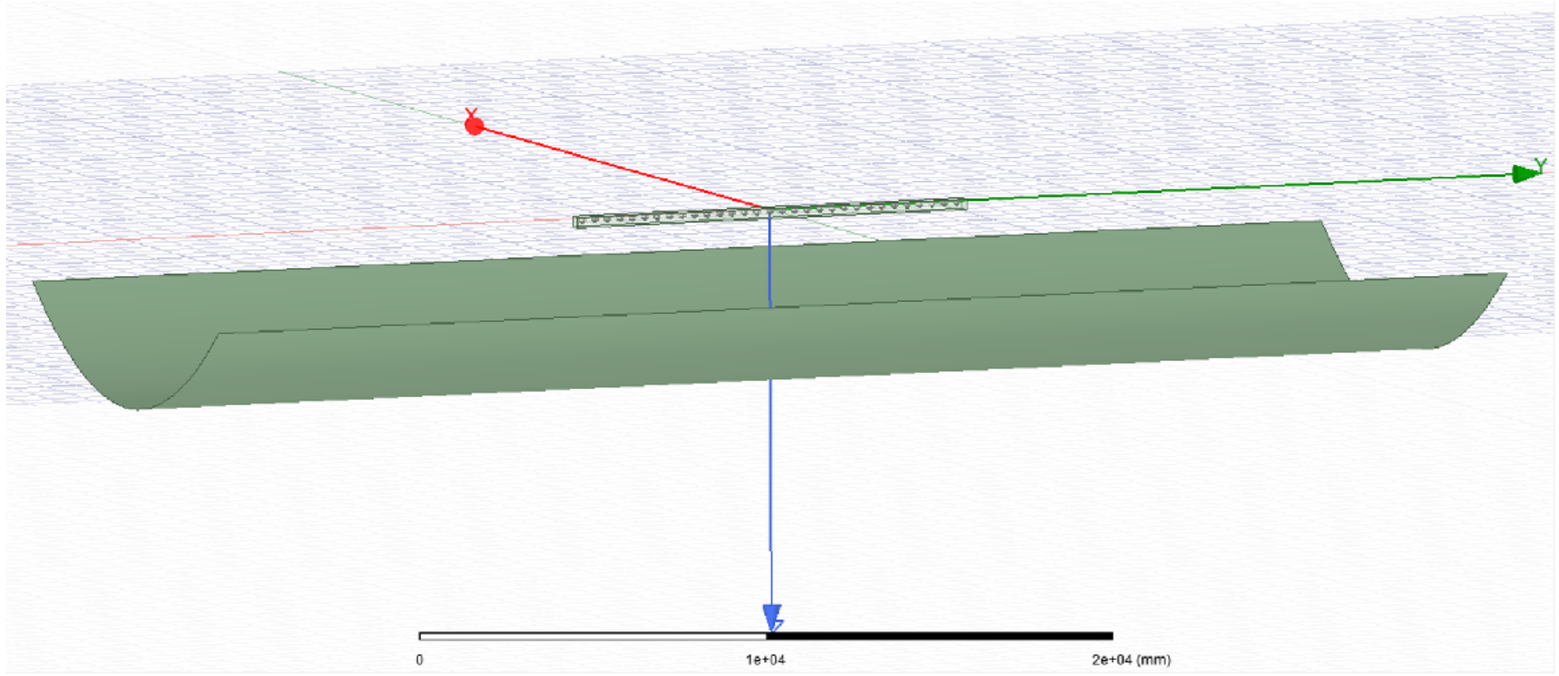


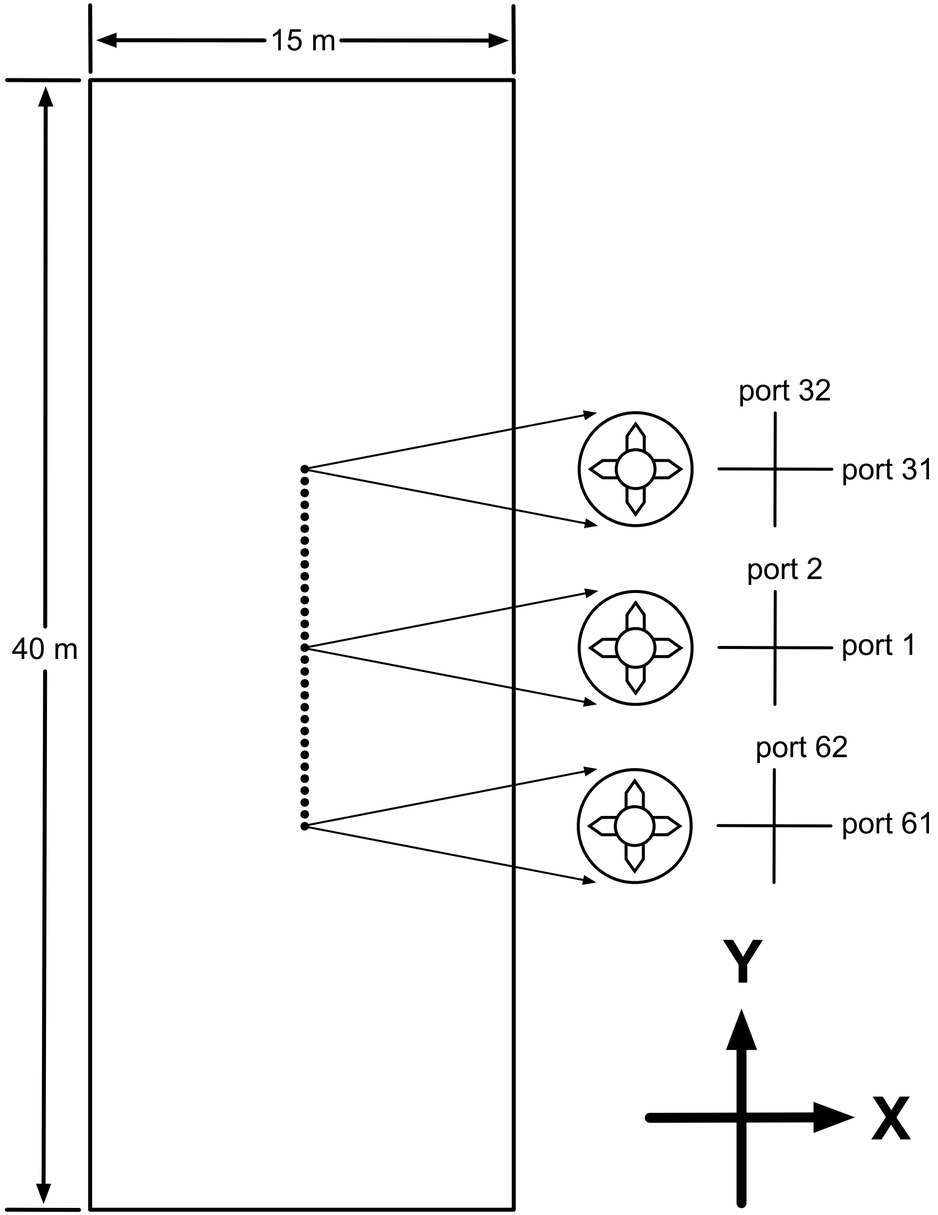




5. Feed array + reflector simulation

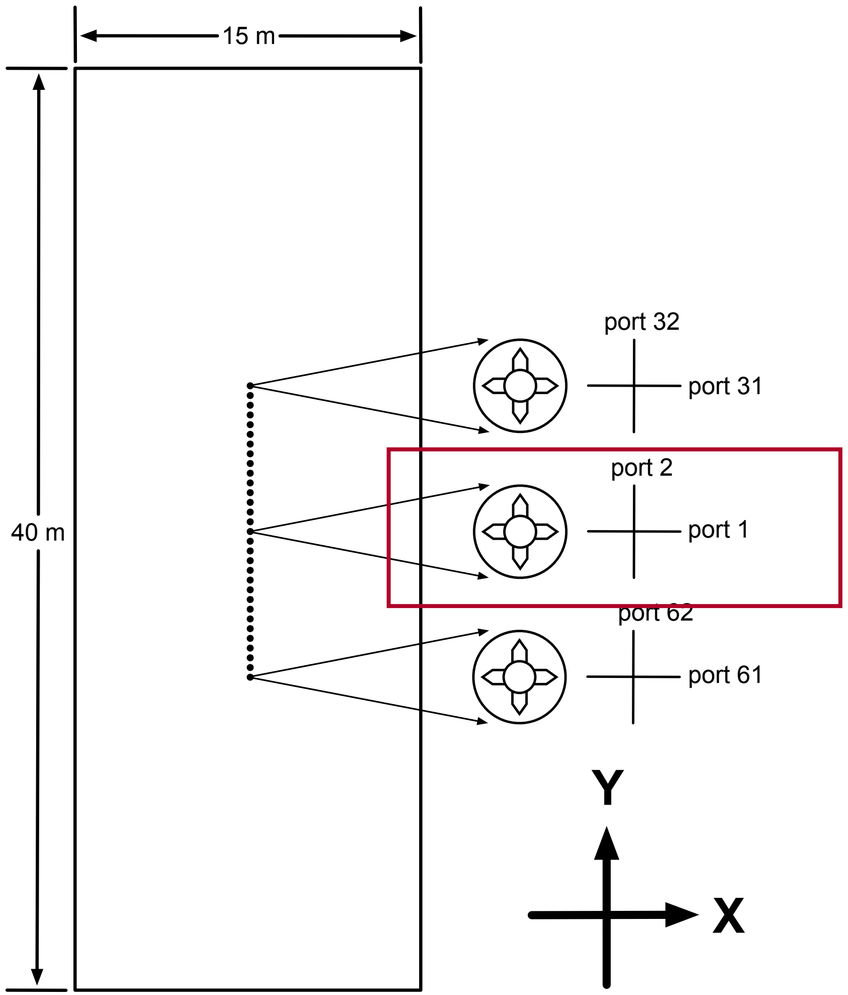
- Simulation model: feed array in center position

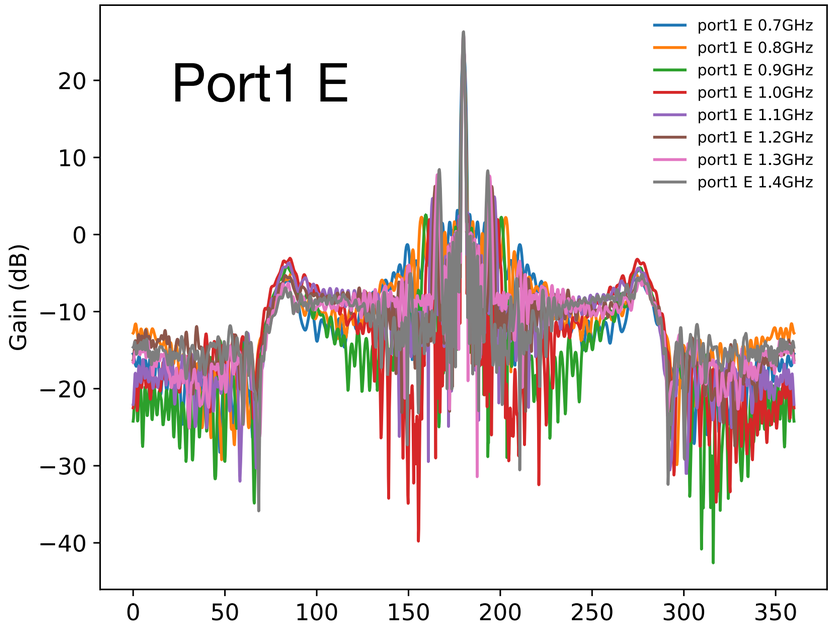


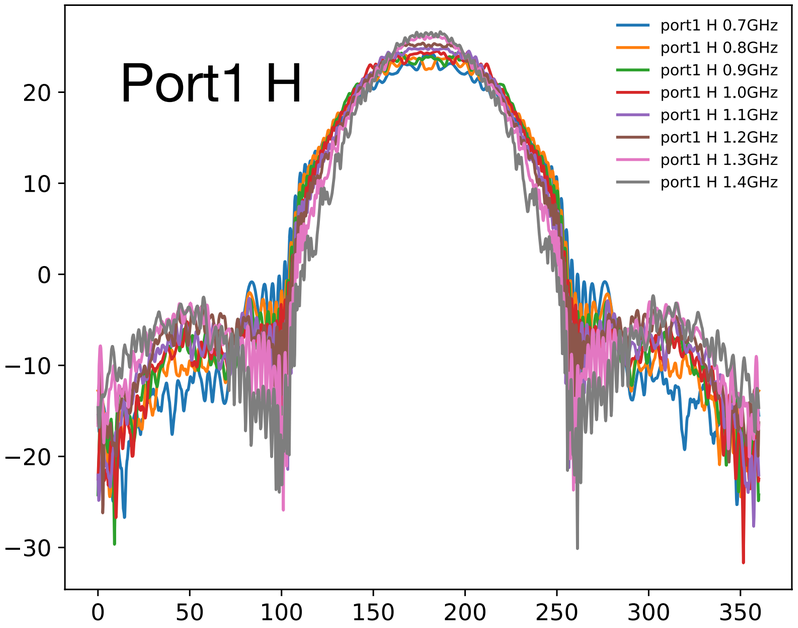


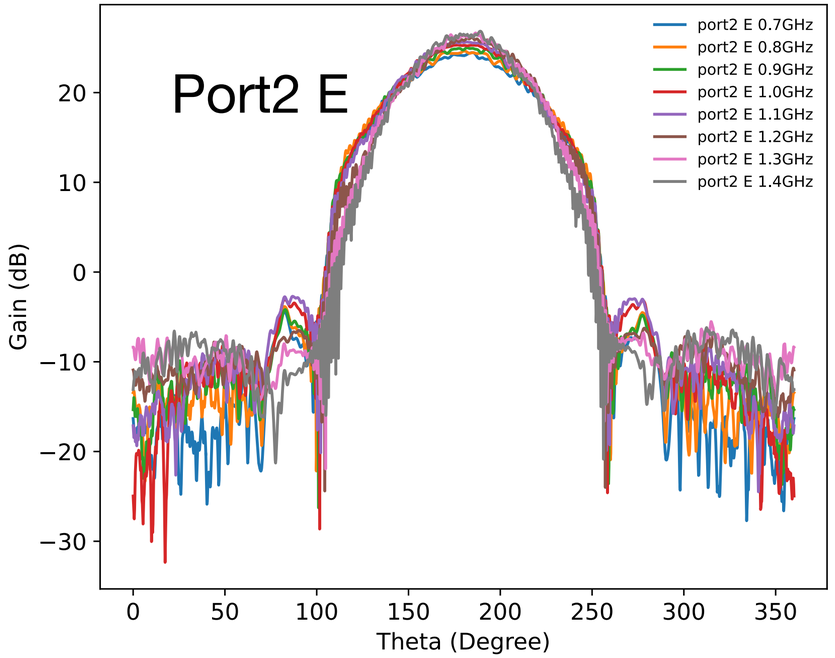
5. Feed array + reflector simulation

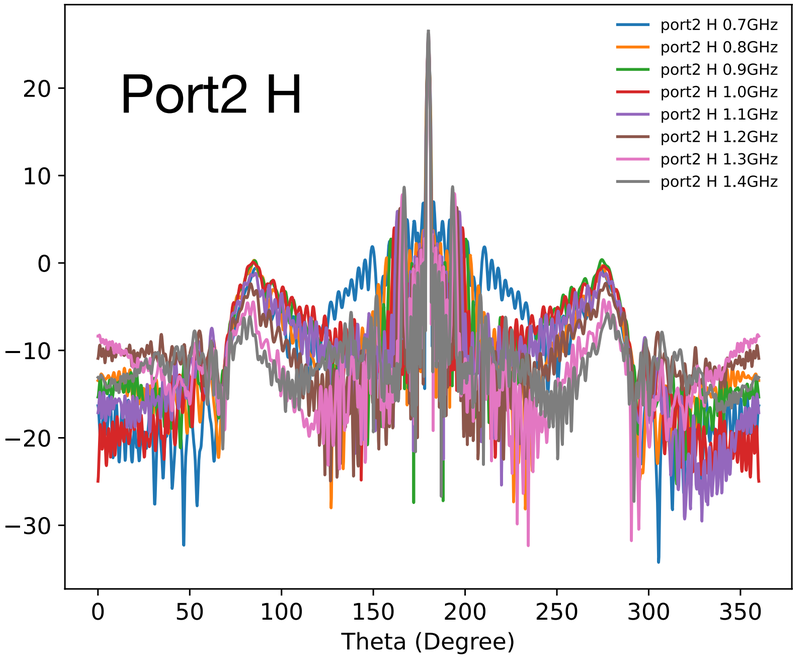
- Radiation pattern of port1 and port2 are consistent with one feed + reflector simulation results.





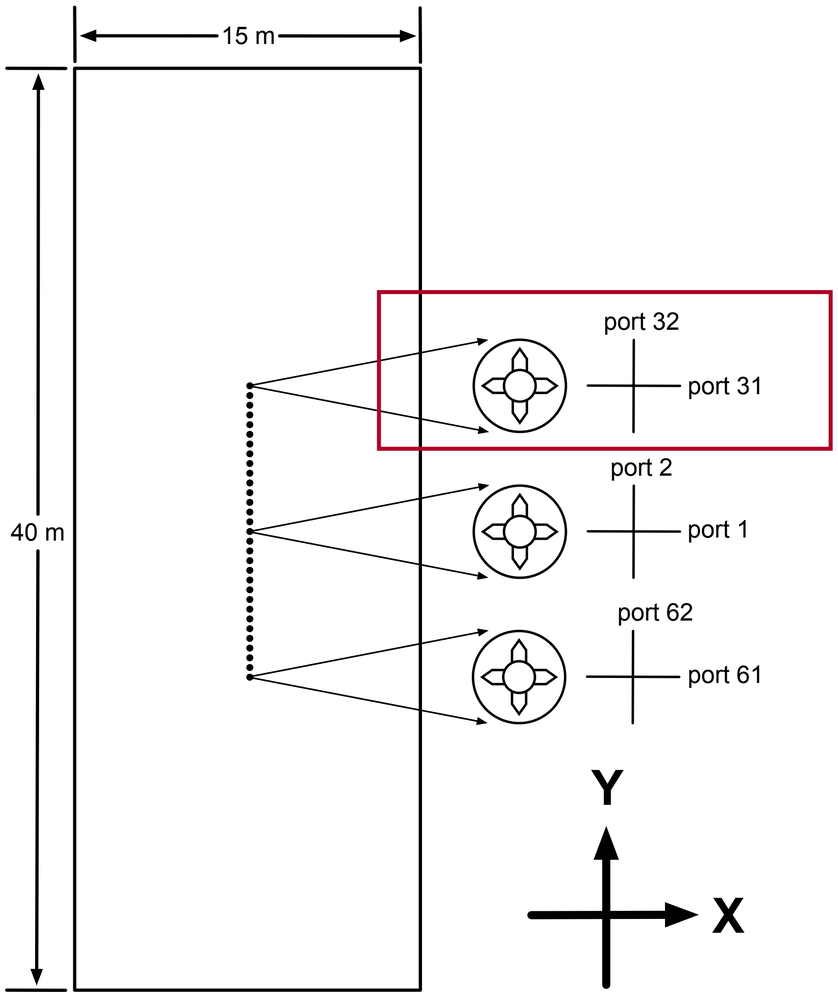


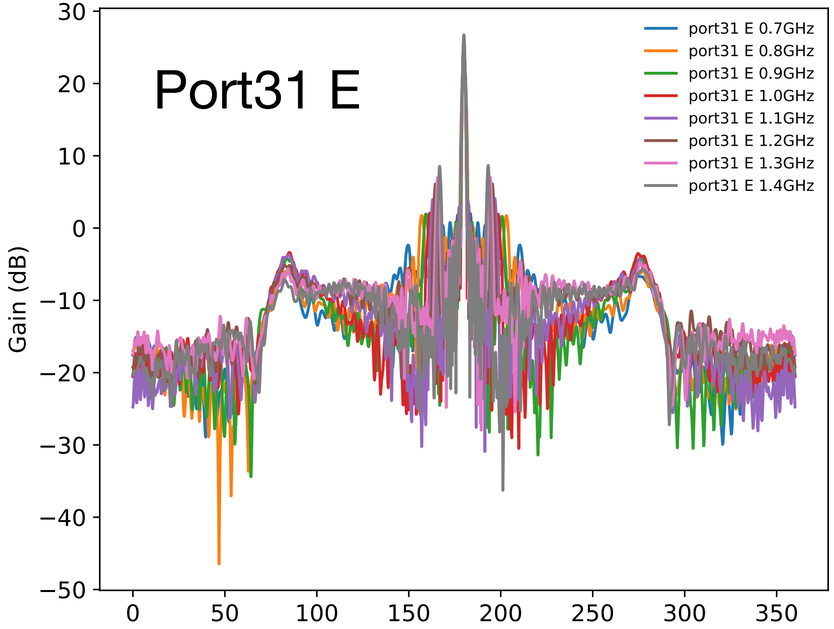


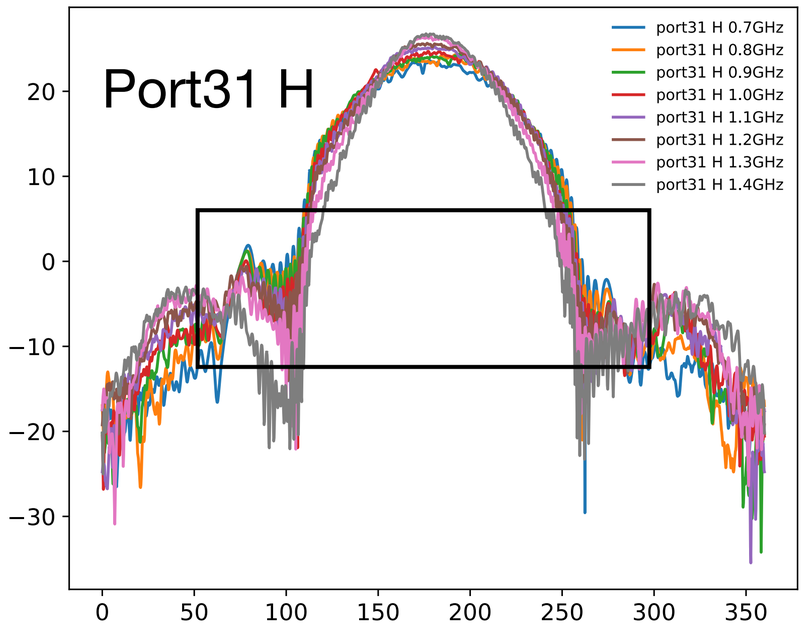


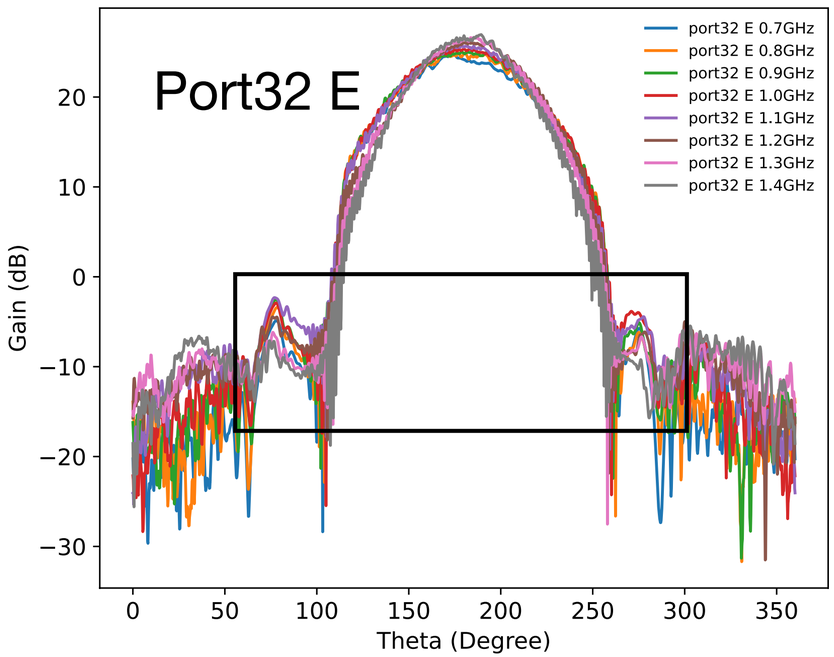
5. Feed array + reflector simulation

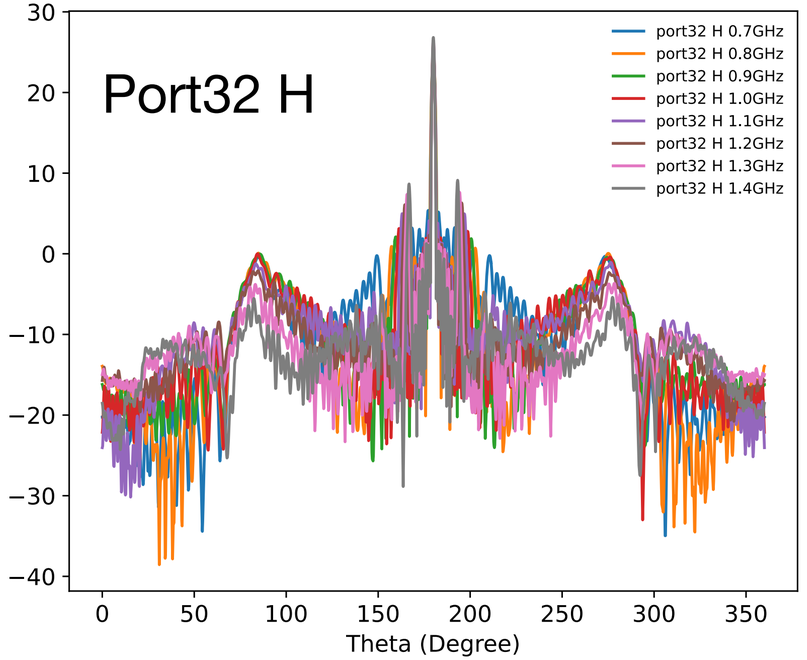
- Radiation pattern of port31 H plane and port32 E plane become asymmetry due to No.16 feed in edge position



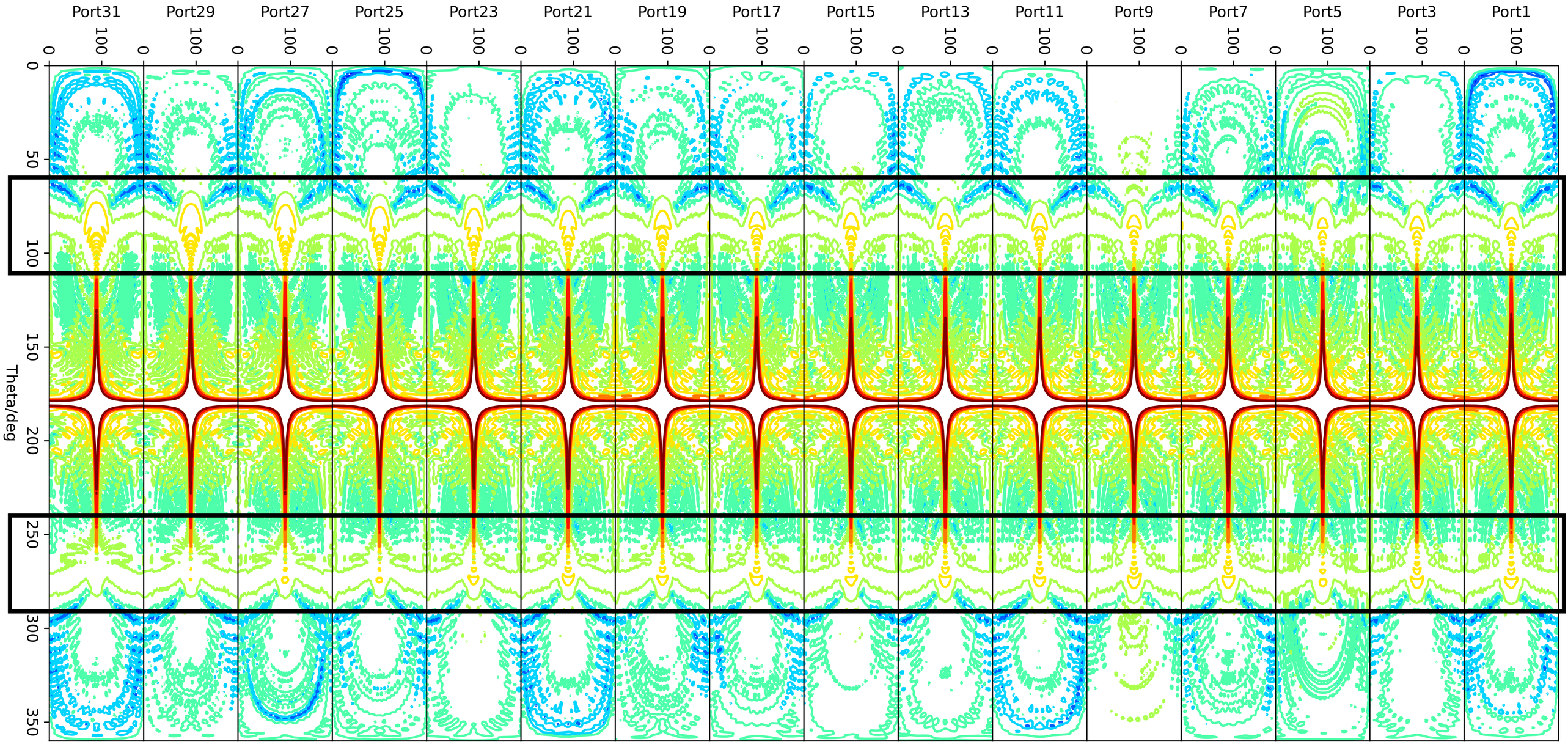




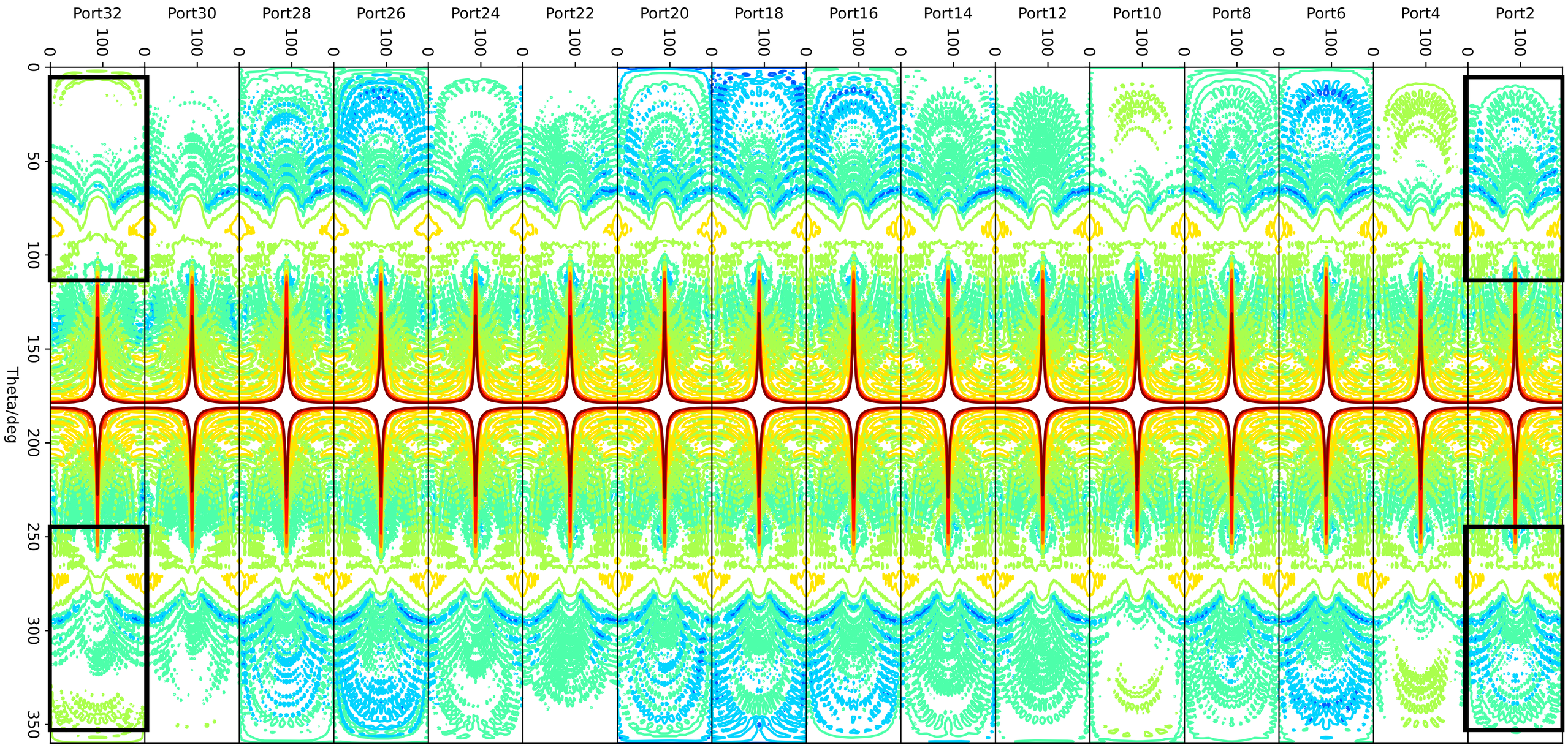




- 750MHz; odd ports; theta, phi, gain in rectangular coordinate;
- With port number increases, asymmetry of side lobe increases;

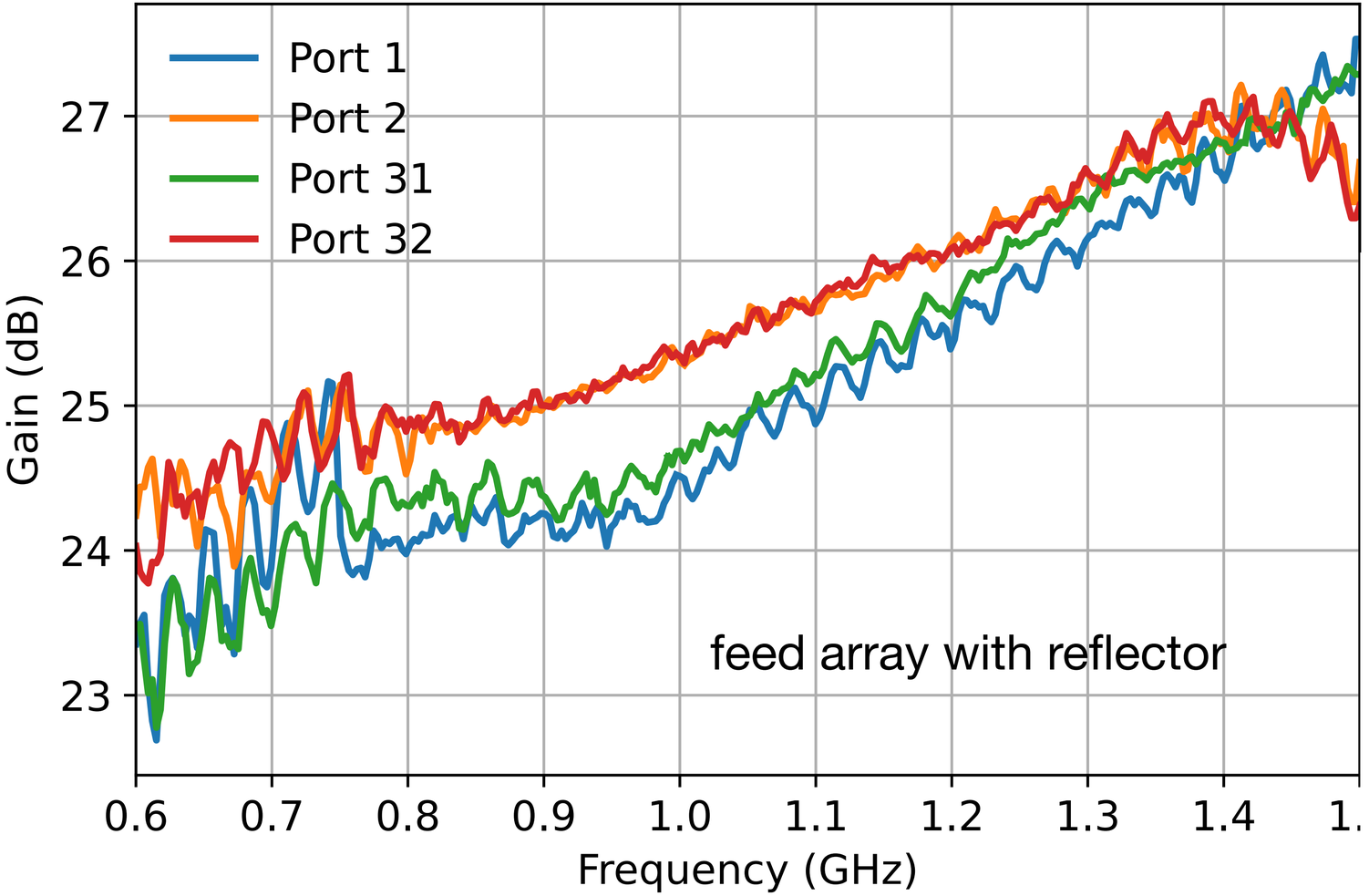


- 0.75GHz; even ports; theta, phi, gain in rectangular coordinate;
- With port number increases, asymmetry of side lobe increases;

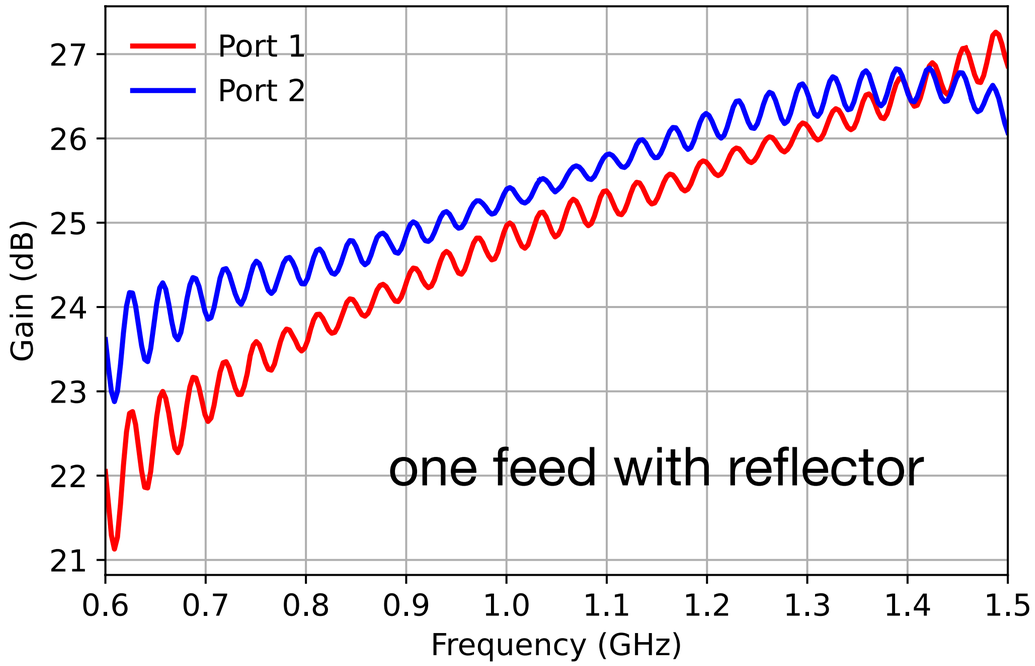


5. Feed array + reflector simulation

- Peak gain increases with frequency increases;
- Seems complex in narrow frequency band compare with one feed+cylinder result;

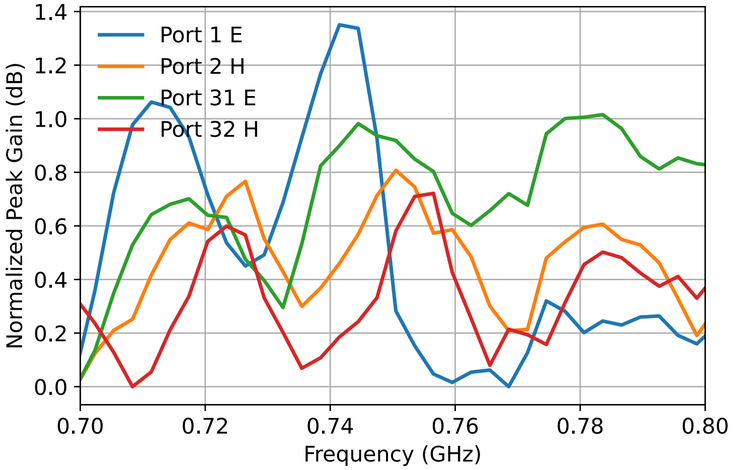


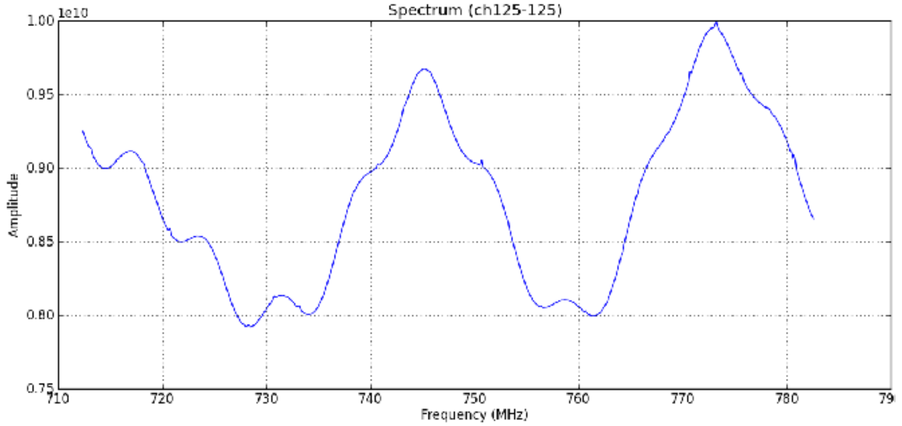
Same frequency sweep points(300);
Same solver accuracy;



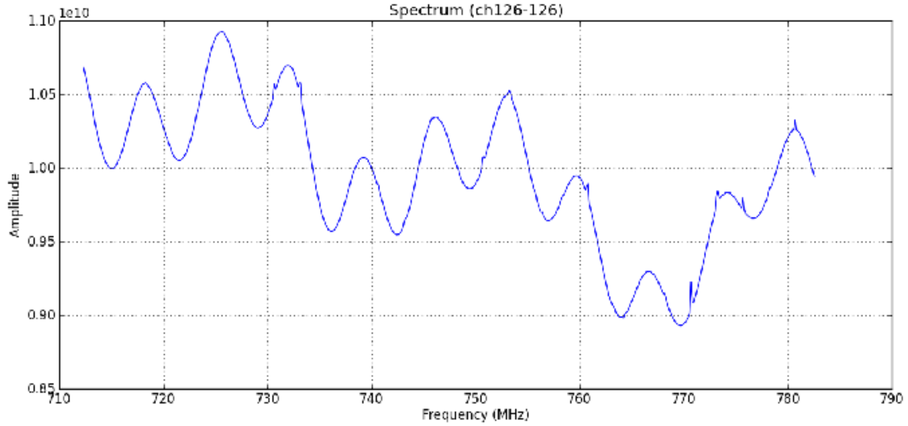
5. Feed array + reflector simulation

- Normalized peak gain in 0.7GHz-0.8GHz;
- Compare simulation results with auto correlation observation results;
- Data of B32 feed, in edge of Center cylinder; and A16 feed, in center of East cylinder;
- Higher frequency standing wave in data due to 15 meters feed cable (Jixia et al.2020).

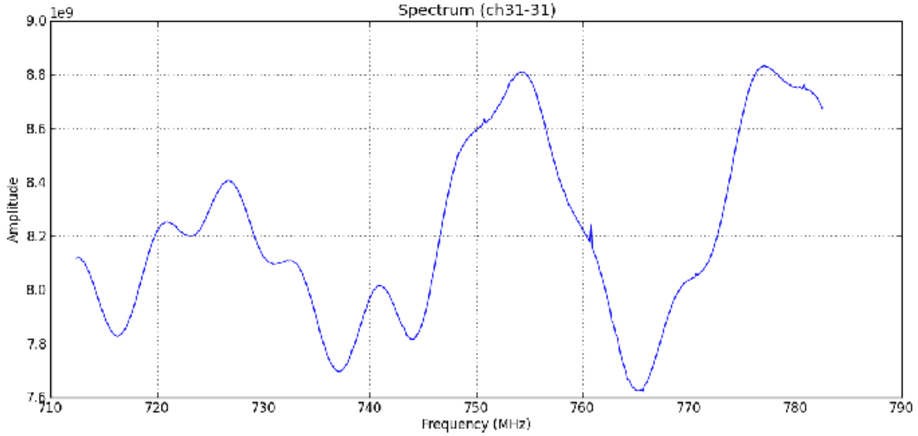




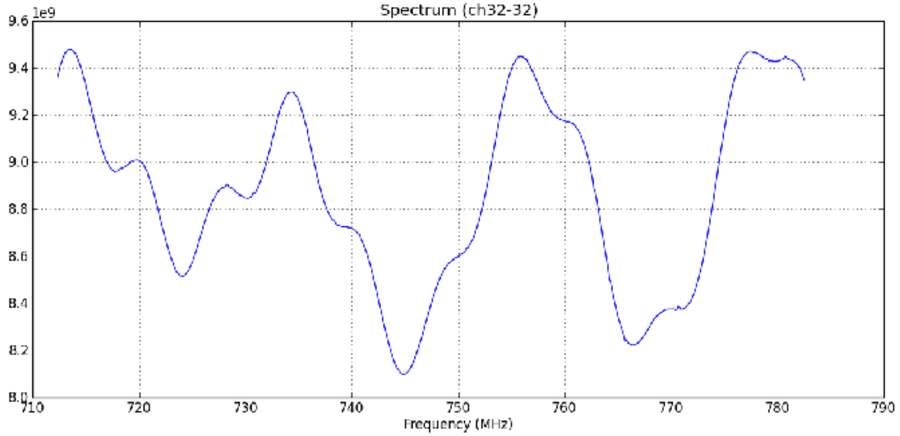
Feed B32, in edge, X polar



Feed B32, in edge, Y polar



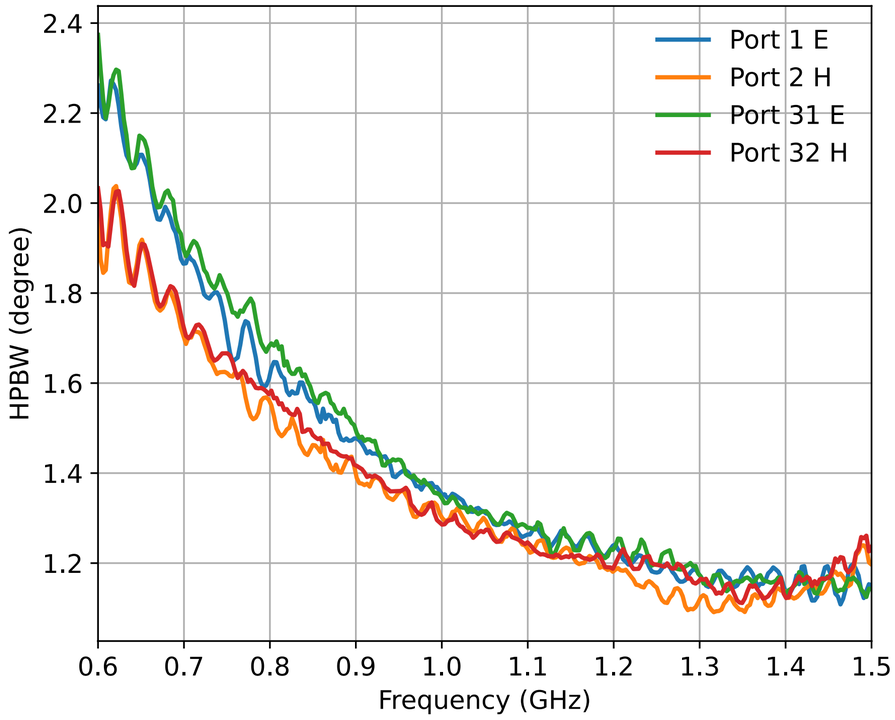
Feed A16, in center, X polar

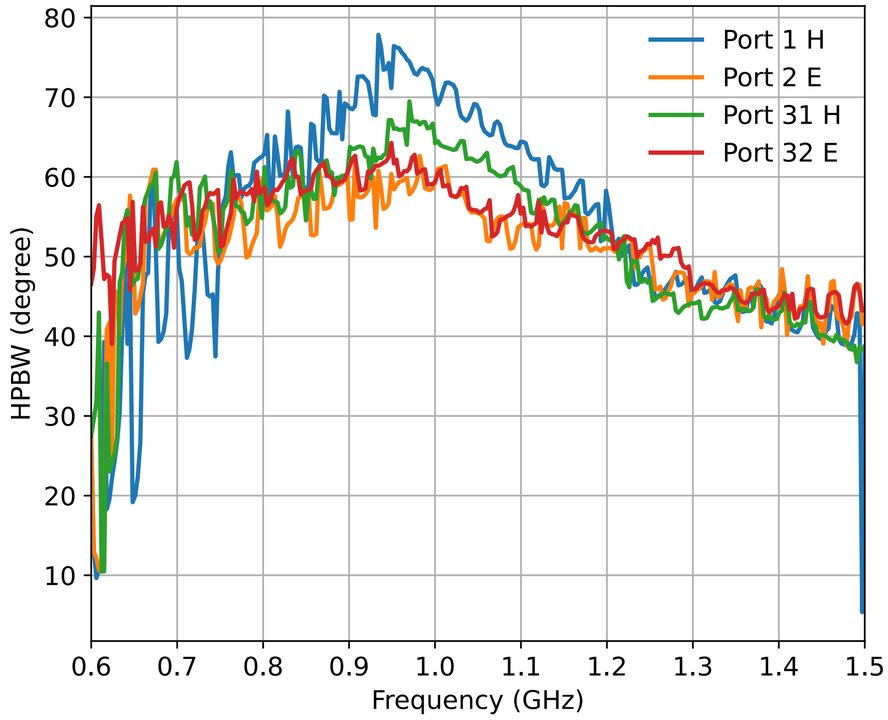


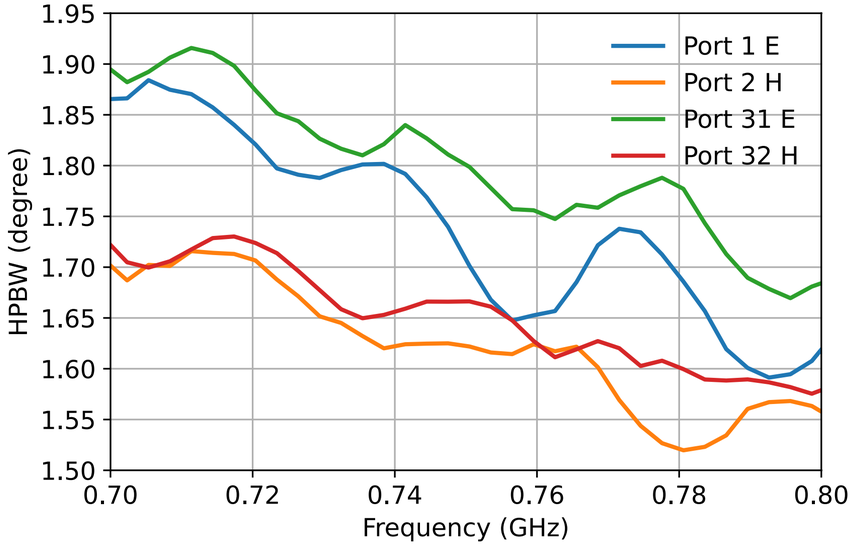
Feed A16, in center, Y polar

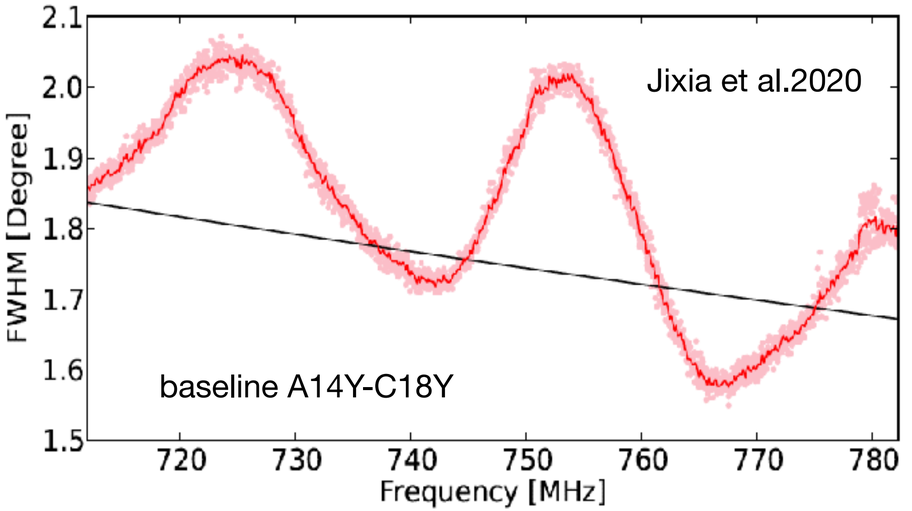
5. Feed array + reflector simulation

- HPBW in X polar direction decreases exponentially with frequency;
- HPBW of odd ports are wider than even ports;
- Standing waves in frequency response;
- Consistent with observation result in 0.7GHz~0.8GHz;



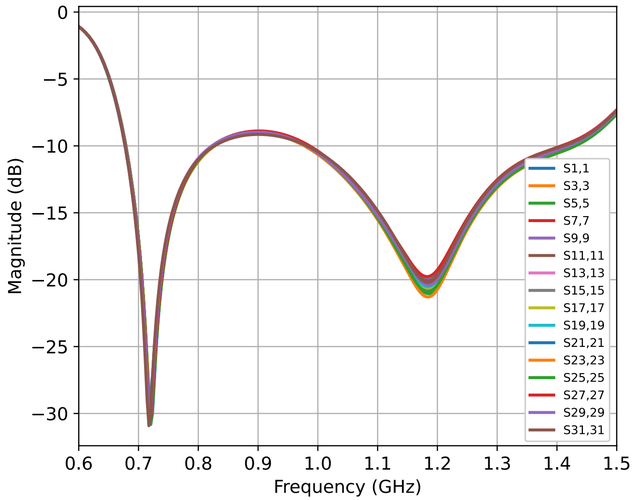


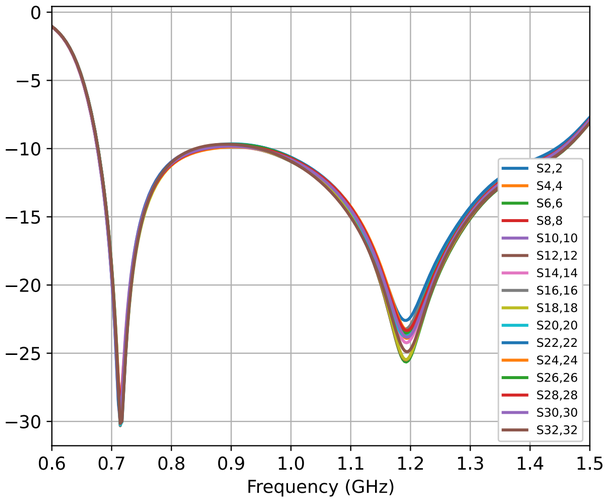




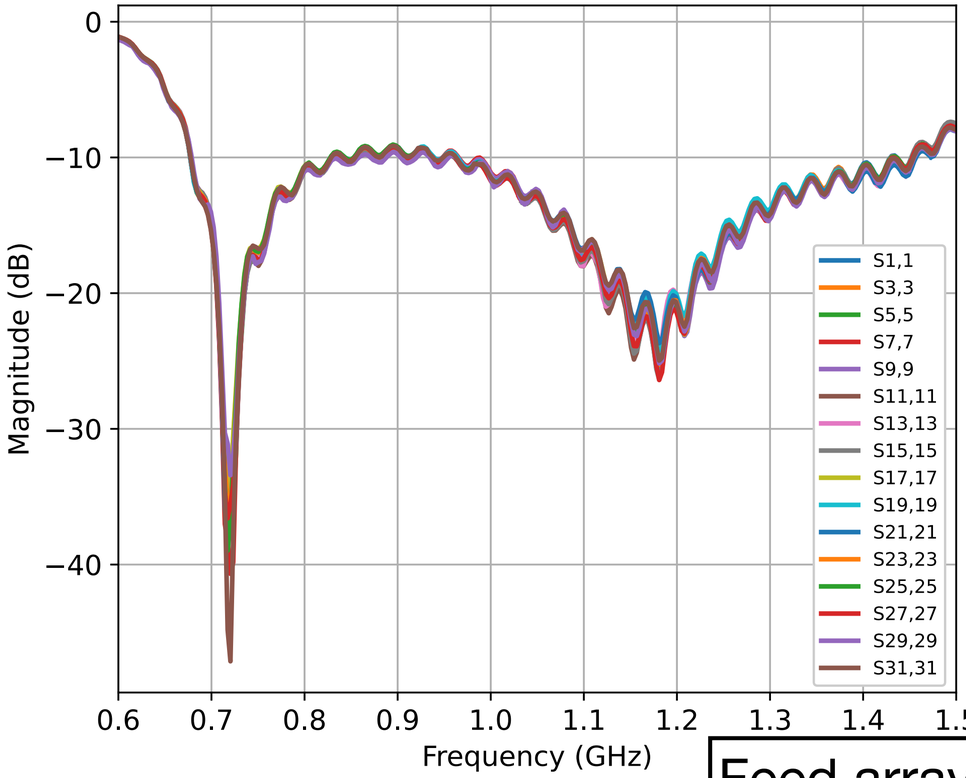
5. Feed array + reflector simulation

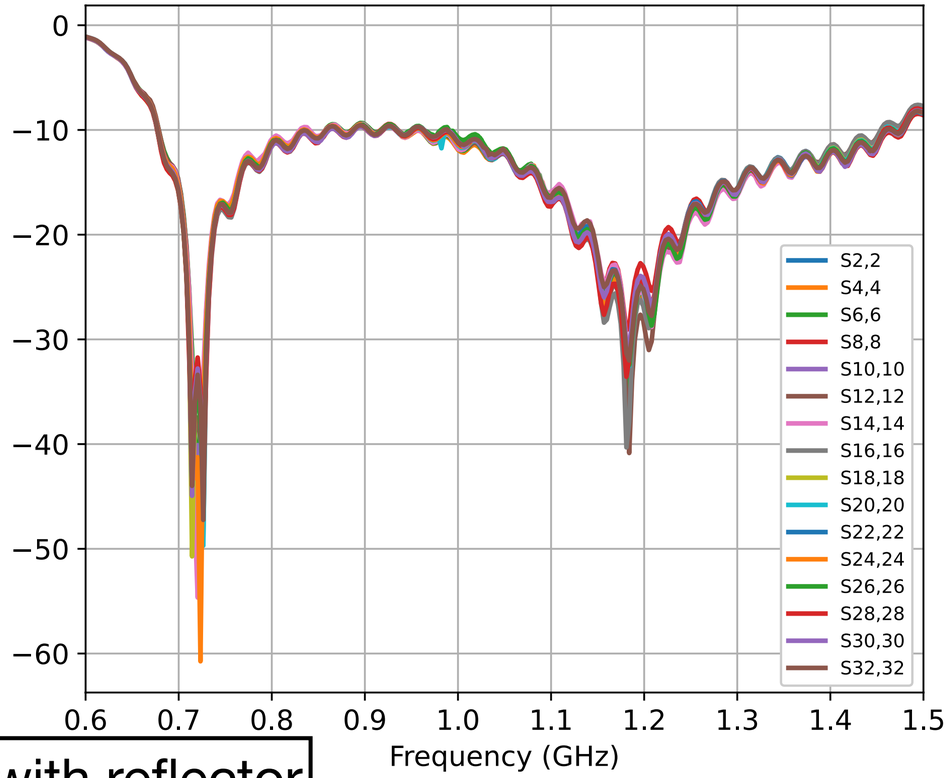
- General characteristics of self reflection coefficients are consistent with one feed and feed array results;
- Standing waves appear, due to reflection;



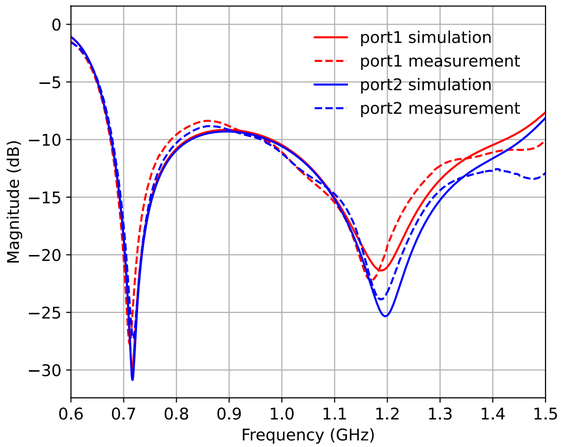


Feed array



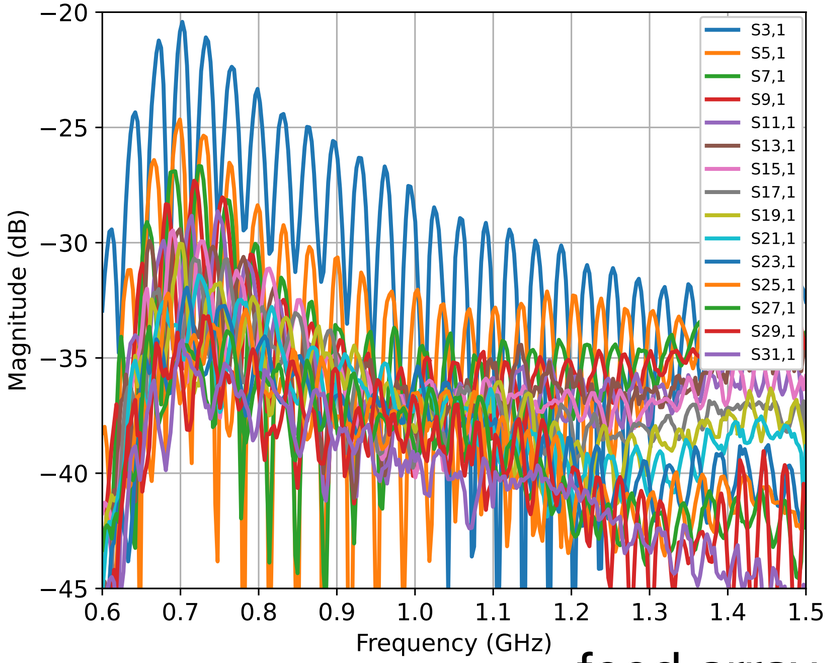


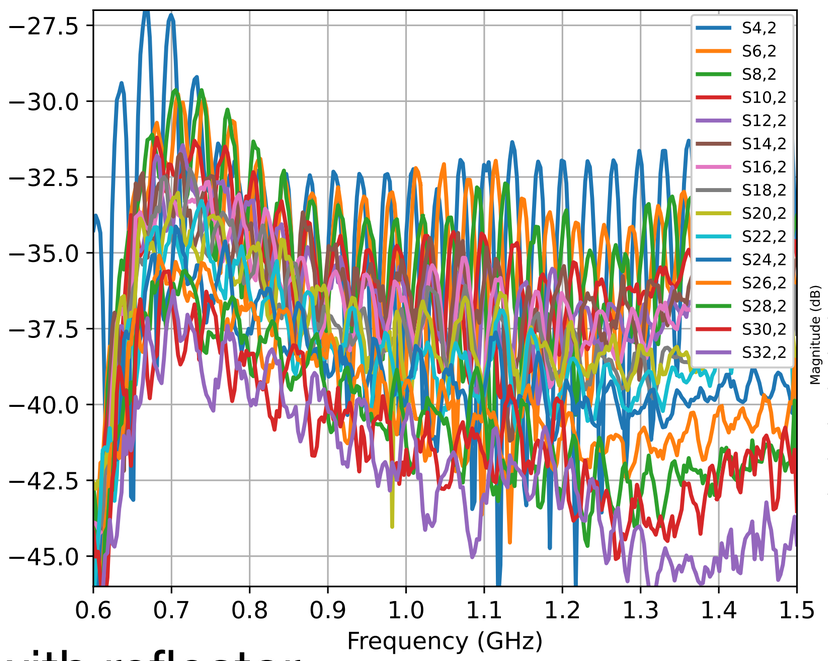
Feed array with reflector



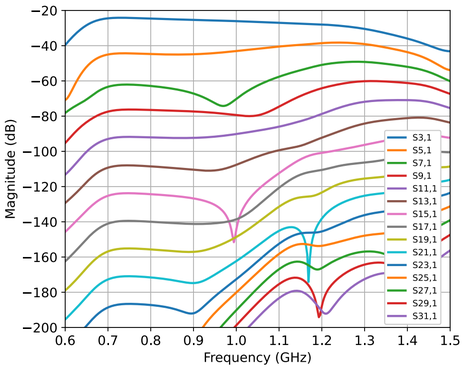
One feed

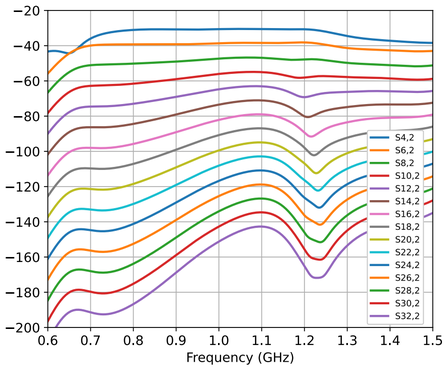
5. Feed array + reflector simulation



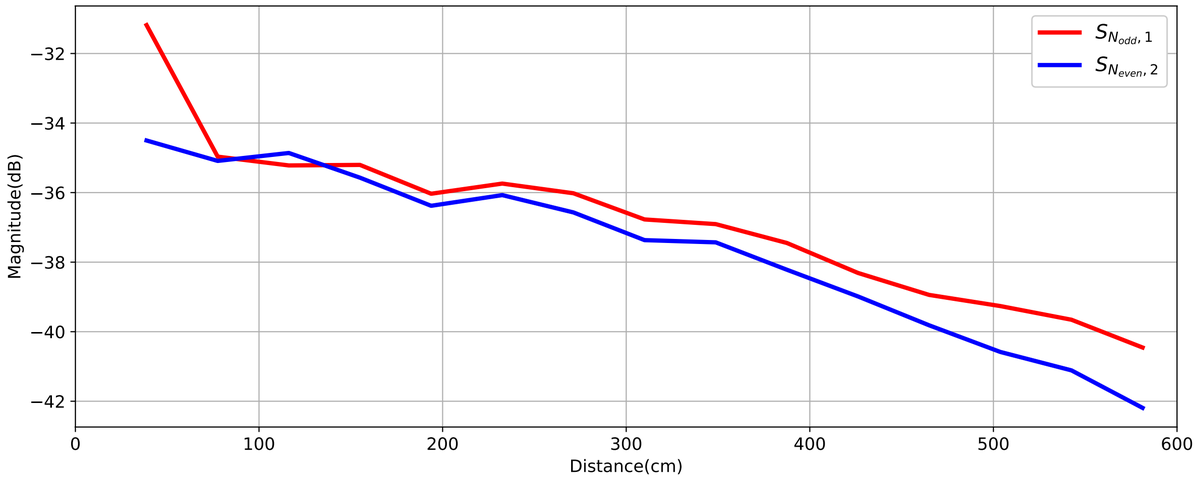


feed array with reflector





feed array



- Standing wave exists in mutual coupling coefficients;
- As the distance increases, the transmission coefficient decreases ~linearly;
- Compared with feed array simulation results, all ports' mutual coupling coefficients increase.

6. Summary

1. A more precision feed model is constructed;
2. Standing wave in bandpass is due to reflection of cylinder reflector;
3. Adjacent feeds have a coupling coefficient of ~20dB；
4. Cylinder reflector increases mutual coupling effects;
5. Closer to the edge, the more asymmetry of side lobe pattern;
6. Simulated bandpass characteristics are in agreement with observation results.


Thanks