Novel Small Form Factor Fresnel Zone Plates Lens Antenna

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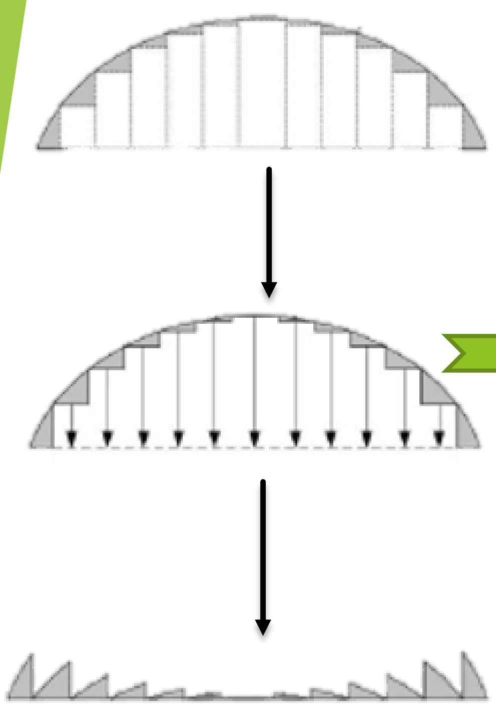
Outline

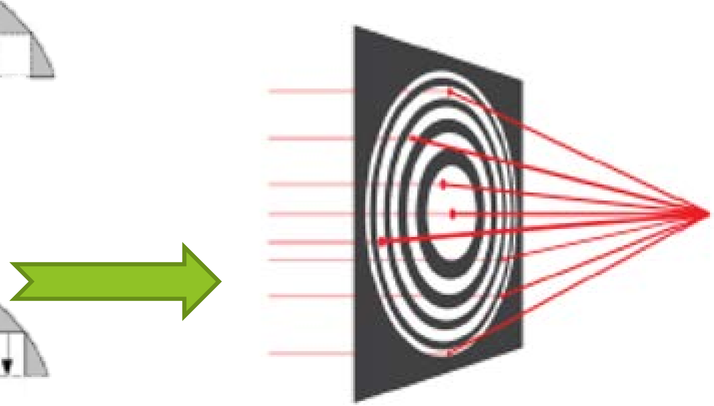
- Introduction
- Implementation of Fresnel Zone Plate Lens
- Implementation of slot patch antenna
- Configuration of proposed antenna
- Experimental and simulated results
- Conclusion

Fresnel zone plate lens(1/2)

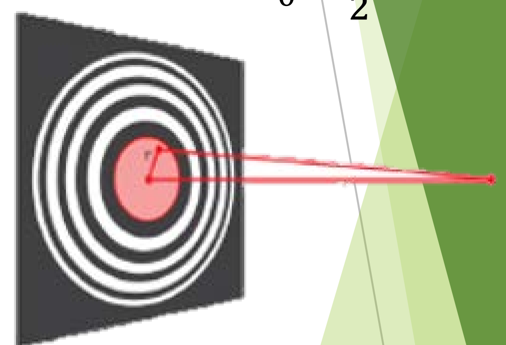
- Ordinary lens Compress to smaller lens for compactness and also save the characteristic of beam-forming.
- Another transformed is that using different planar material to focus beam instead of using Serrated one.



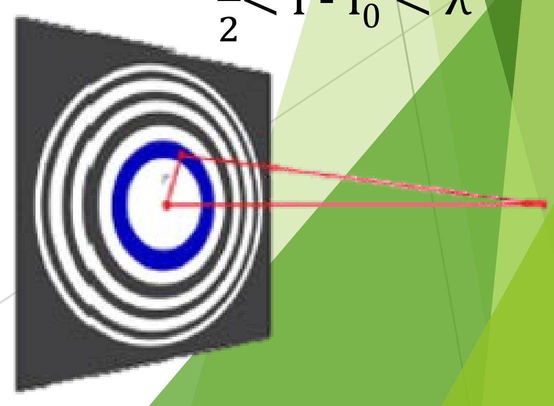
Fresnel Len



$l - l_0 < \frac{\lambda}{2}$



$\frac{\lambda}{2} < l - l_0 < \lambda$



General expression

$$r_n = \sqrt{\frac{2n\lambda F}{P} + \left(\frac{n\lambda}{P}\right)^2}$$

Fresnel zone plate lens(2/2)

- According to ray tracing formula, we can get the expression of every single layer of material

$$(\beta\sqrt{\epsilon_s}t + \beta r_s) - (\beta\sqrt{\epsilon_1}t + \beta r_1) = 2\pi$$

and

Constructive relationship:

$$r_n - r_1 = (n-1)(\lambda / P)$$

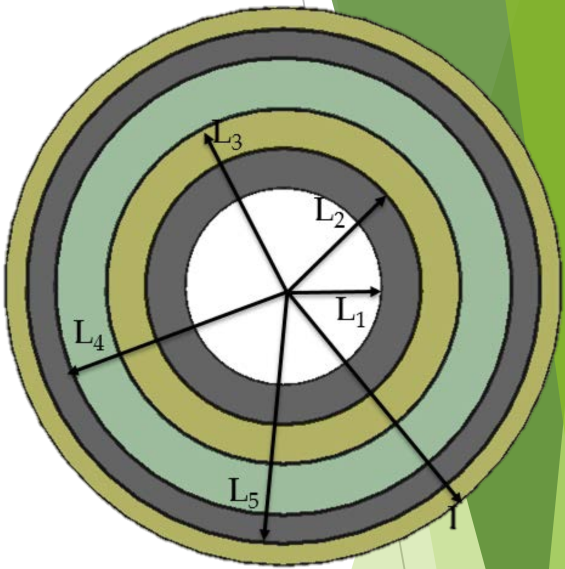
Thickness:

$$t = \frac{k\lambda}{2\sqrt{\epsilon_1}} = \frac{k\lambda}{2}$$

Then we can get

$$\epsilon_n = \epsilon_1 [\, 1 + \left(\frac{\lambda}{k}\right) (1 - \frac{(n-1)}{P})\,]^2$$

After we have these formula, we can design specified lens operate at 5G



L_1	L_2	L_3	L_4	L_5	L_6
8.75	12	15.5	20	22.5	24.5
ε_1	ε_2	ε_3	ε_4	ε_5	
2.4	1.8	1.4	2.4	1.8	

Unit:mm

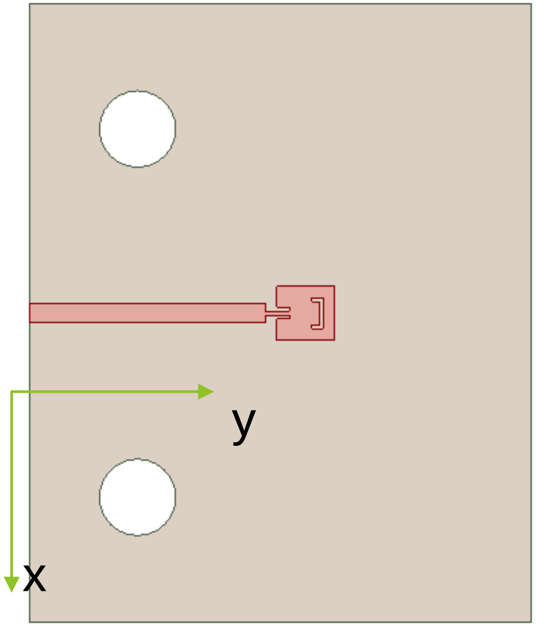
Effective Dielectric Constant Using 3D Printing

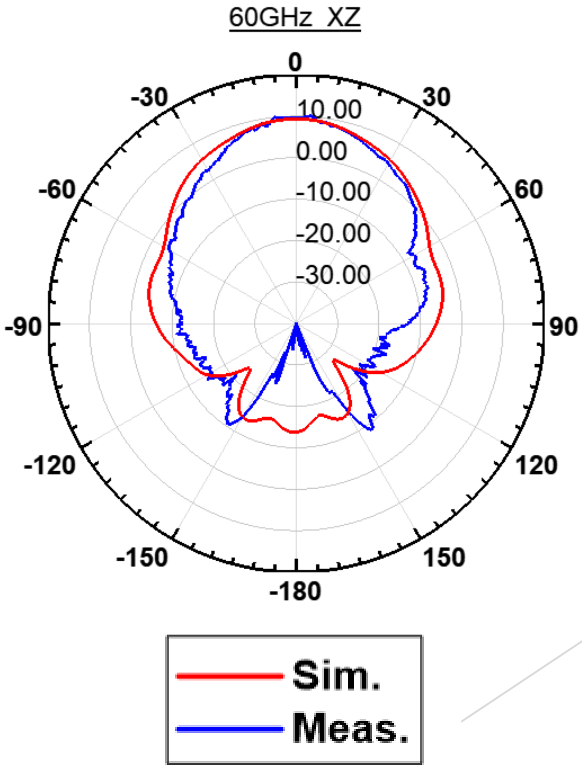
Polycarbonate Infill Percentage

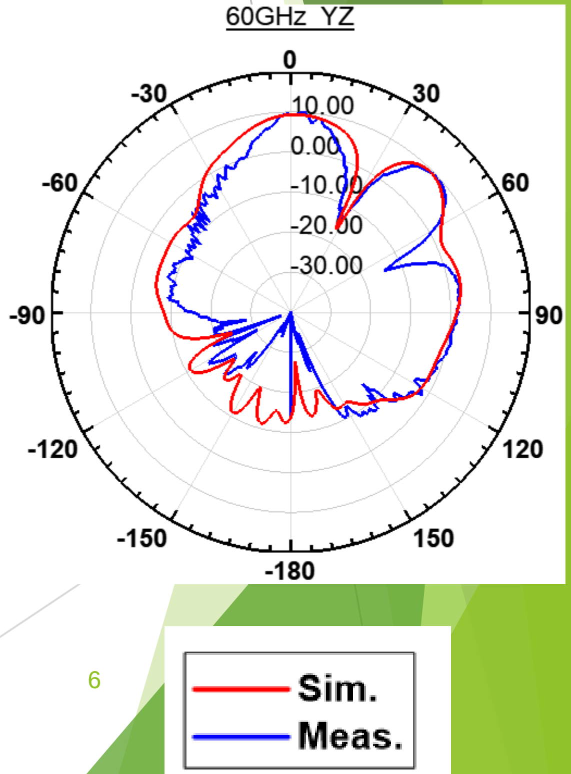
ε_1	ε_2	ε_3	ε_4	ε_5
2.4	1.8	1.4	2.4	1.8

Wide-band Slot Patch Antenna

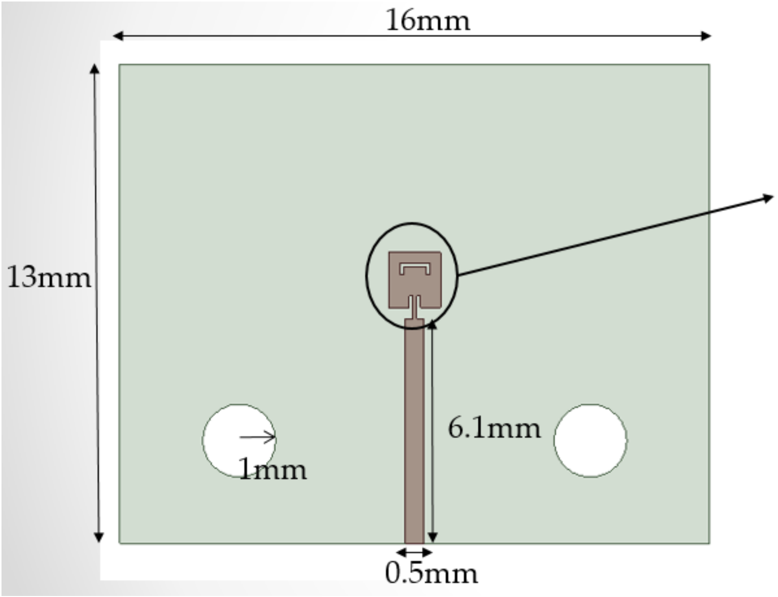
- By using slot on patch to create another resonance path, Making a wider bandwidth
- By reduce the width of feedline to create high order mode, increasing Peak gain of antenna

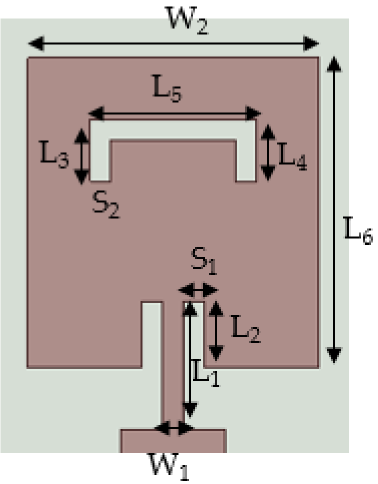






Physical Dimensions



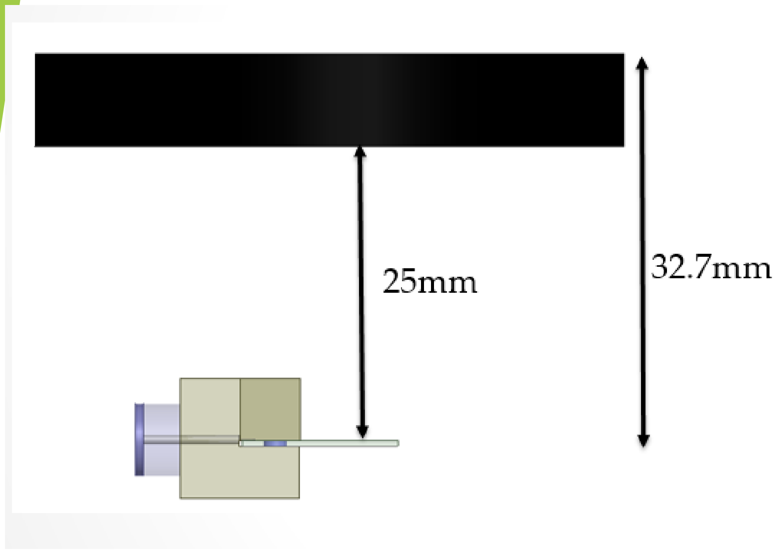


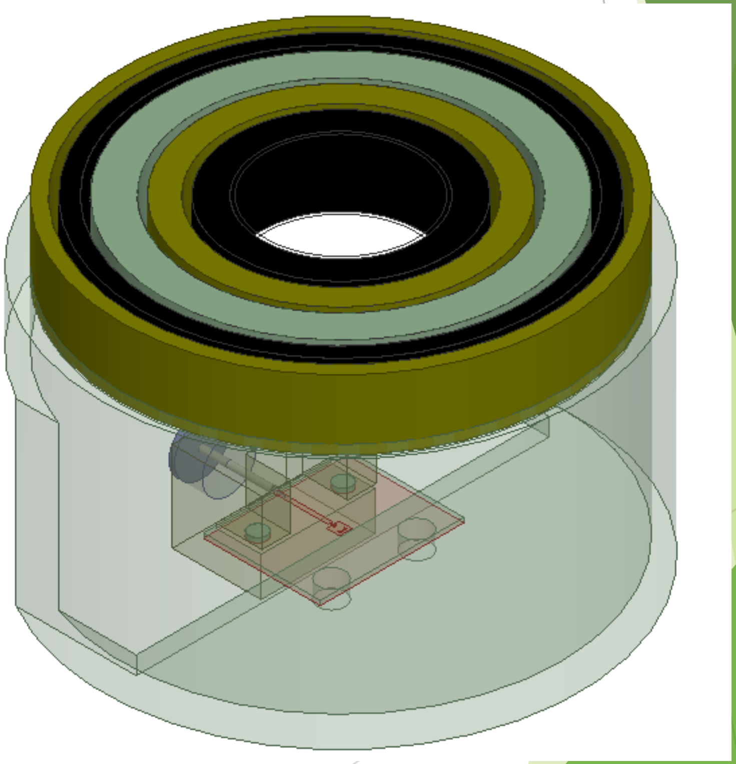
Antenna size: $2.6\lambda_0$ x $3.2\lambda_0$

L_1	L_2	L_3	L_4	L_5	L_6
0.62	0.32	0.3	0.3	0.8	1.5
W_1	W_2	S_1	S_2		
0.1	1.4	0.1	0.1		

Proposed SMF Antenna

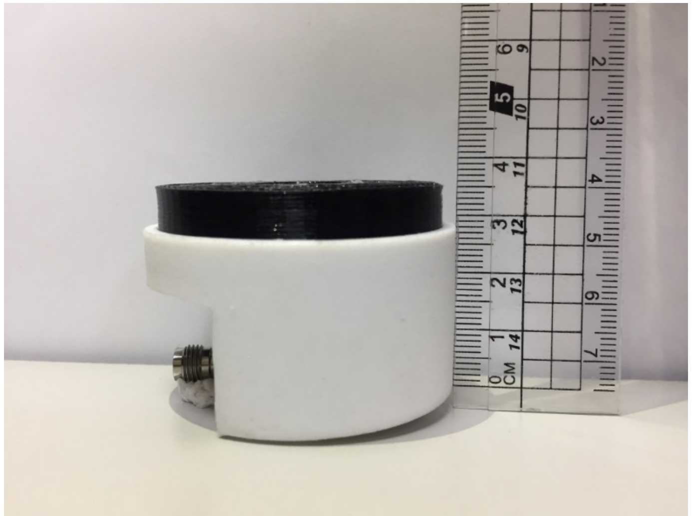
- Patch as an excitation element
- Frame is used to place Lens to hold the focal length





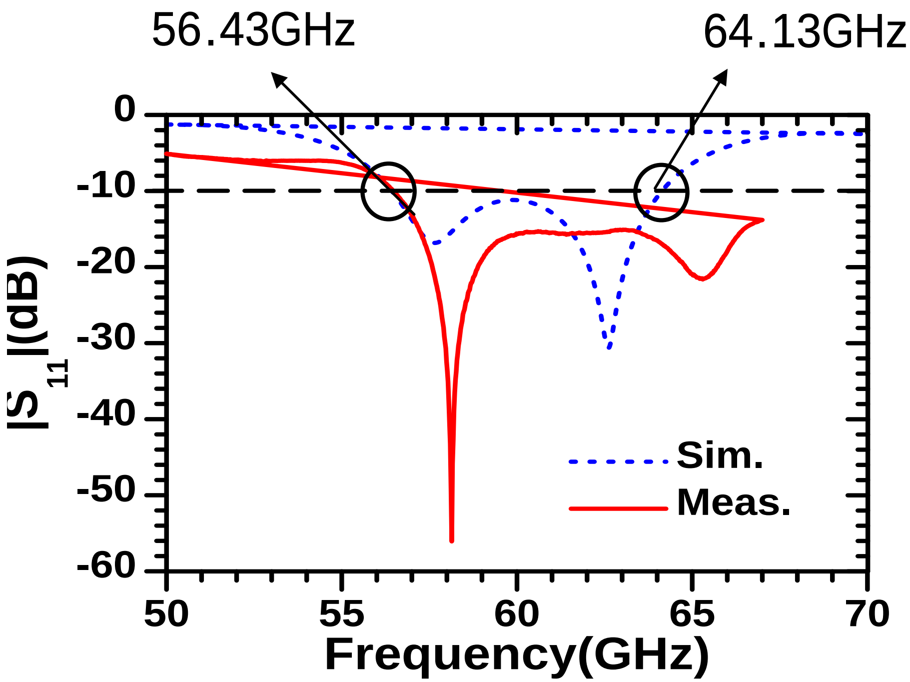
Antenna Prototype

- Proposed antenna was built on a Rogers RT/Duroid 5880 substrate of thickness 0.508 mm.
- Lens was fabricated by 3D tech.
- White shelf was made of Teflon

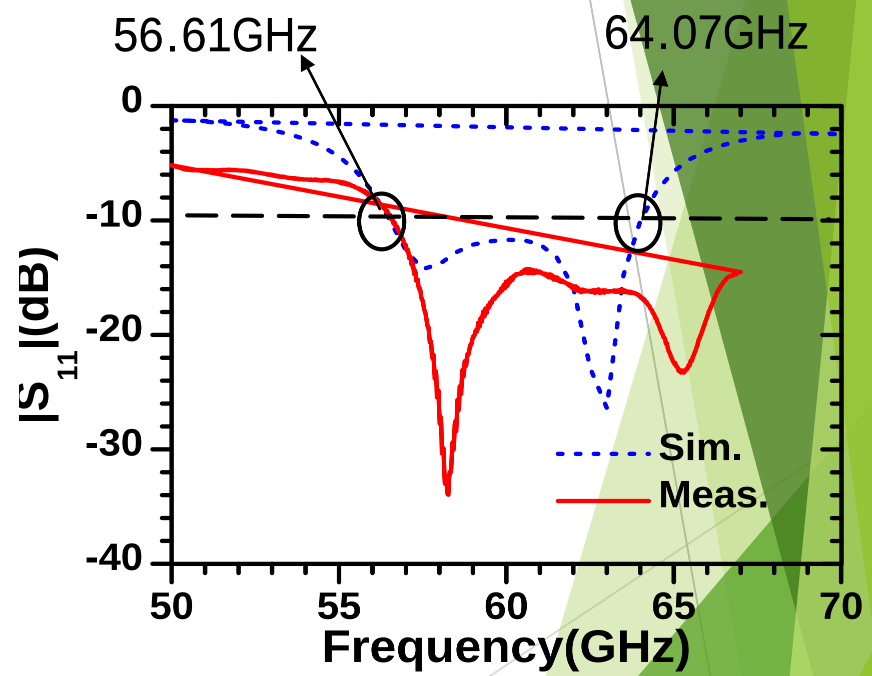


Reflection Coefficients

- The operational frequency is covered from 56.61GHz to 67GHz



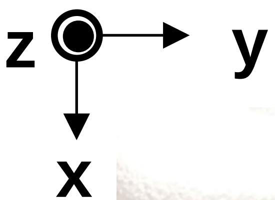
(Patch)

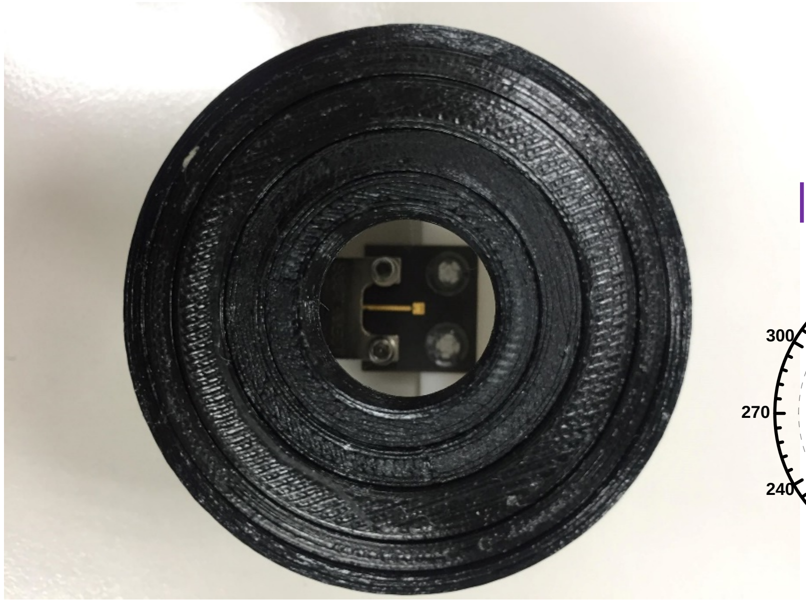


(Overall)

Radiation Patterns

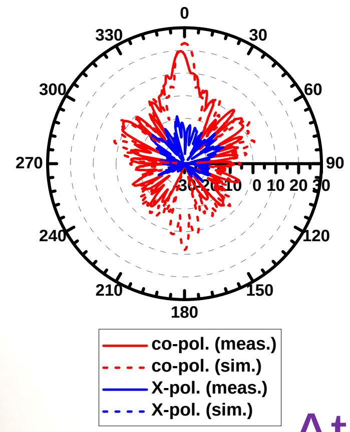
- The proposed antenna has broadside radiation properties in covered bands.
  - ✓ Peak gain: 19.74dBi at 57 GHz
  - ✓ Peak gain: 18.78dBi at 60 GHz



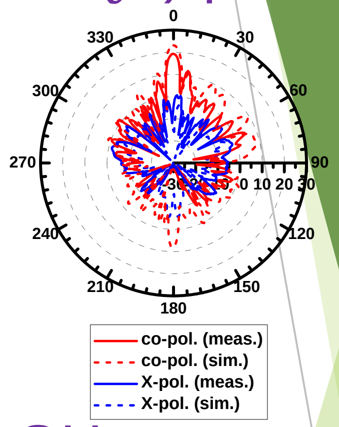


At 57 GHz

H(xz)-plane

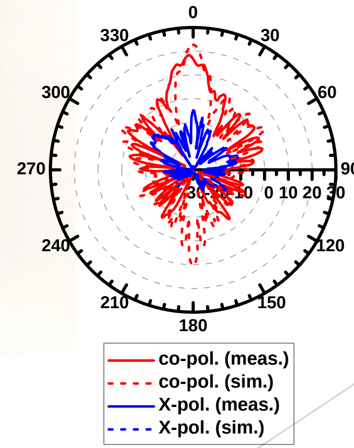


E(yz)-plane

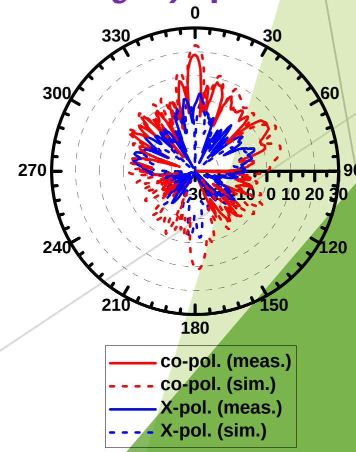


At 60 GHz

H(xz)-plane

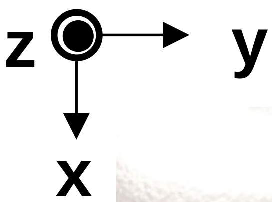


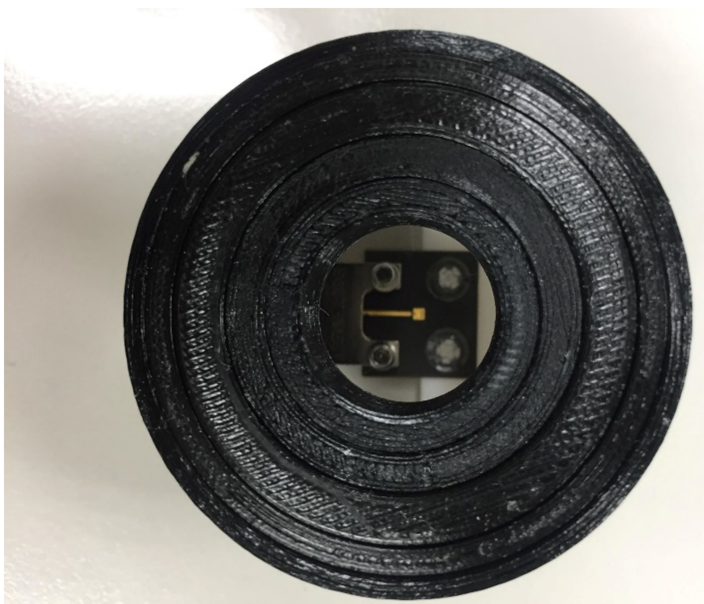
E(yz)-plane



Radiation Patterns

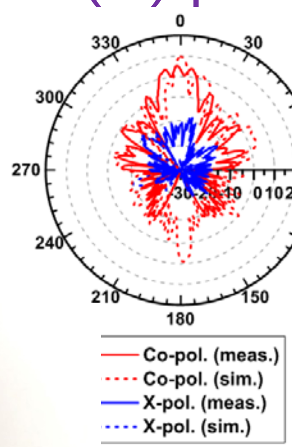
- The proposed antenna has broadside radiation properties in covered bands.
  - ✓ Peak gain: 16.7dBi at 63 GHz
  - ✓ Peak gain: 13.99dBi at 66 GHz



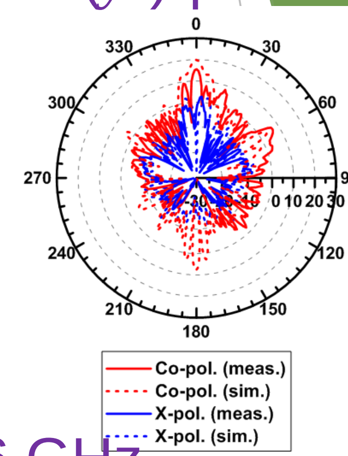


At 63 GHz

H(*xz*)-plane

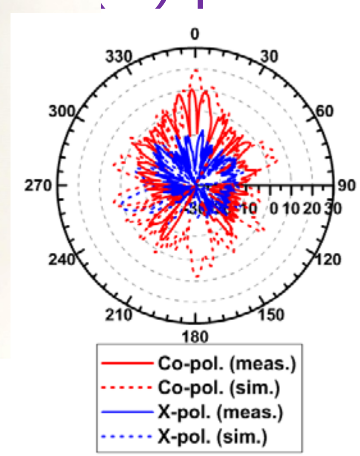


E(*yz*)-plane

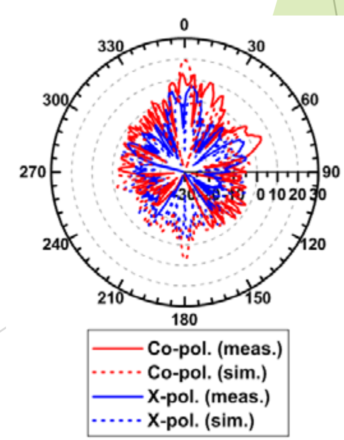


At 66 GHz

H(*xz*)-plane



E(*yz*)-plane



Performance Summary/Comparison

[1]	Multi-band	Yagi + Metamaterial	10dBi	Planar	
[2]	8GHz~12.2GHz	Patch+Lens	12.5dBi (gain enhancement)	Planar	65*65*0.762
[3]	8GHz~17GHz	Patch + reflecting surface	18.4dBi	Planar	110*110*
[4]	9.73GHz~9.91 GHz	slot+ Metameterial	8.6dBi	Planar	89*50*3
This work	57GHz~66GHz	Patch+Lens	19.74dBi	Flat	50*50*32.7

An easy interface with planar/active circuitry and can achieve a gain up to 20 dBi in the range of 57~66 GHz. .

[1]. Multiband High-Gain Printed Yagi Array Using Square Spiral Ring Metamaterial Structures for S-Band Applications, AWPL

[2]. High-Gain and High-Aperture-Efficiency Cavity Resonator Antenna Using Metamaterial Superstrate, AWPL

[3]. Low-RCS High-Gain Partially Reflecting Surface Antenna With Metamaterial Ground Plane, AP

[4]. A Low-Profile High-Gain Substrate-Integrated Waveguide-Slot Antenna With Suppressed Cross Polarization Using Metamaterial, AP

Conclusion

- A compact Fresnel plate len using 3-D printing technology is proposed for antenna application.

- A patch antenna is used to feed the Fresnel zone plate lens, and wide-band and high-gain performance is obtained for 60-GHz communications.