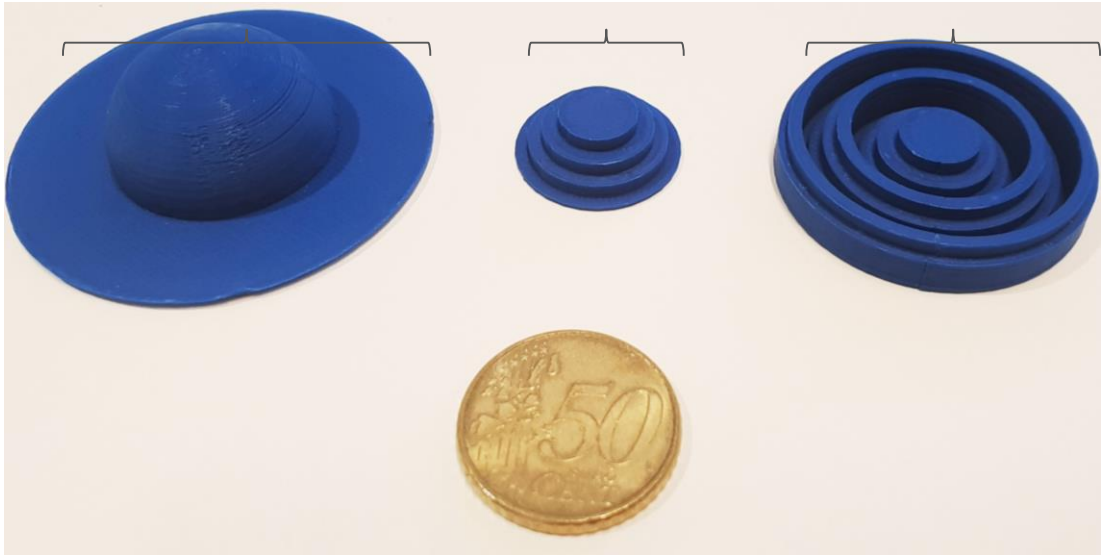
Explore the next sense

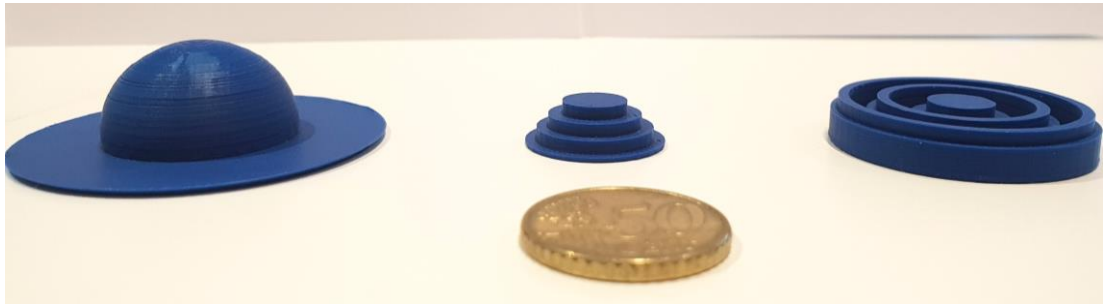
Comparison of far-field distributions using different lens designs

November 2018

Lens designs

Spherical lens	FZP[1] 1 zone	FZP[1] 3 zones





Lens Material: ABS plastic filament

Geometry

	Eps$_r$ (dielectric constant)	h (height)	d (diameter)	f (focal length)	F (aperture)
Free space	-	-	-	-	-
FZP 1 zone	2.7	7	22	~7	0.3
FZP 3 zone	2.7	7.2	40	~4	0.1
Spherical lens	2.7	16.3	30	6	0.2

Measured properties

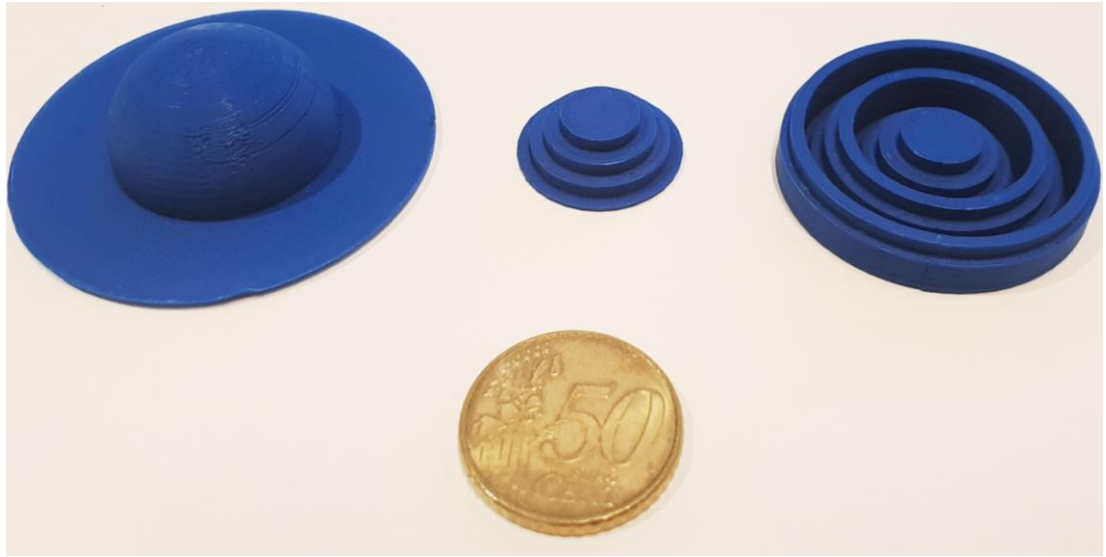
	HPBW[2] E-Plane	HPBW[2] H-Plane	Gain [dB]	Gain [linear]
Free space	**36°**	**61°**	**0**	1.0
FZP 1 zone	**12°**	**13°**	**7.5**	5.6
FZP 3 zone	**11°**	**8°**	**8**	6.3
Spherical lens	**10°**	**12°**	**9**	8.0

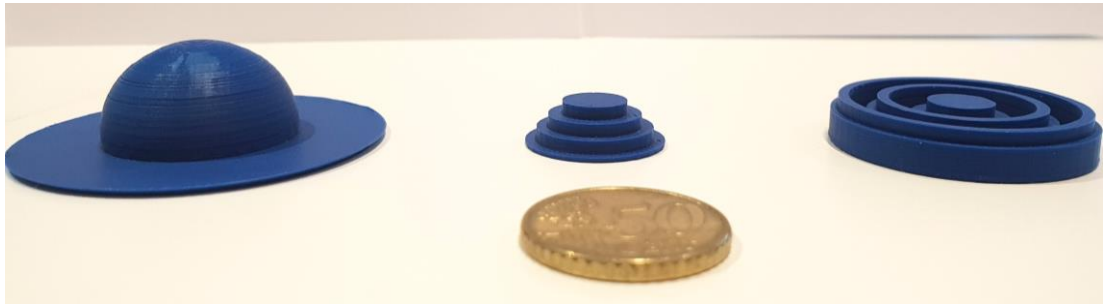
[1] phase correcting Fresnel zone plate with 4 steps

[2] HPBW = Beam width at half intensity for E- and H-plane, i.e., E^2 and H^2, respectively
Half intensity is 3dB below peak intensity

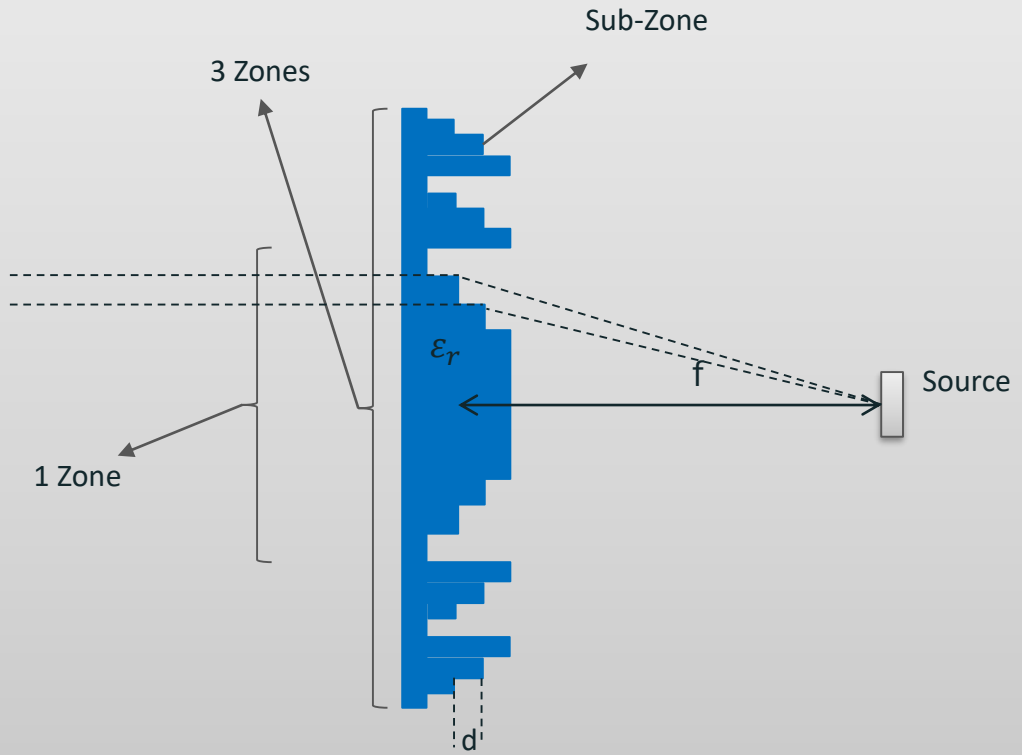
Lens designs

Spherical lens	FZP[1] 1 zone	FZP[1] 3 zones





The stepped-dielectric, phase-correcting Fresnel zone plate, collimates the beam originating from a source placed at a distance f (focal length)[2] from the zone plate:



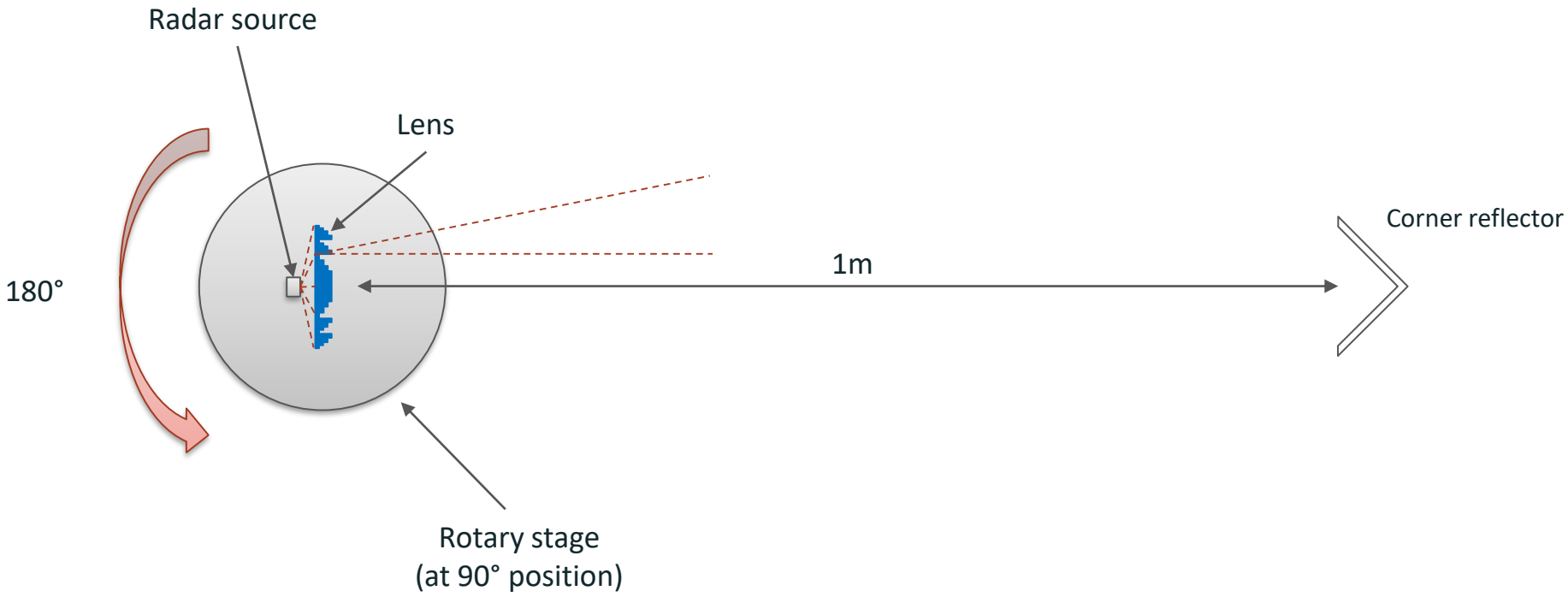
The radius of each subzone and its depths d, are chosen so that rays passing through the edges of neighboring subzones originating from the focal point f have the same phase shift.

[1] phase correcting Fresnel zone plate with 4 steps

[2] see Appendix A for details on focus of FZP

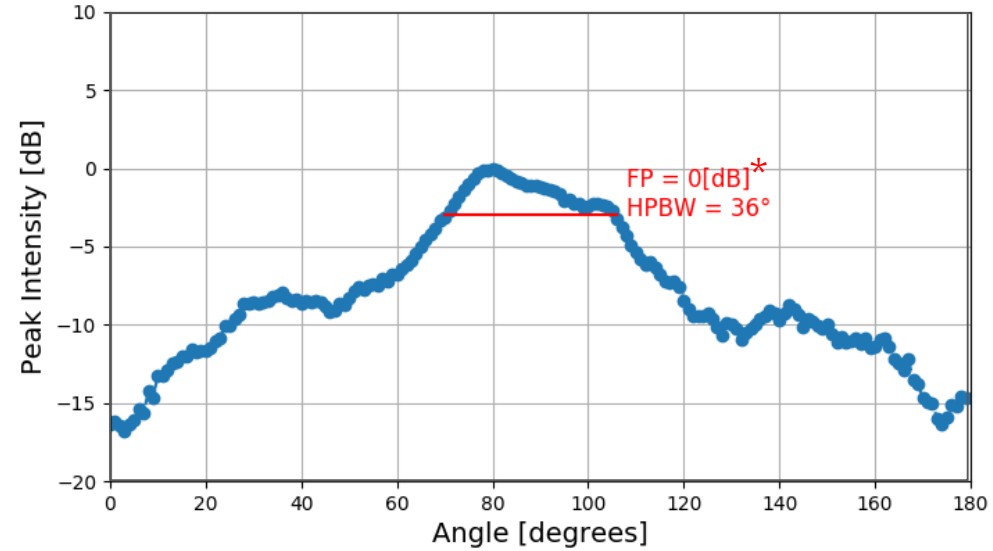
Measurement setup

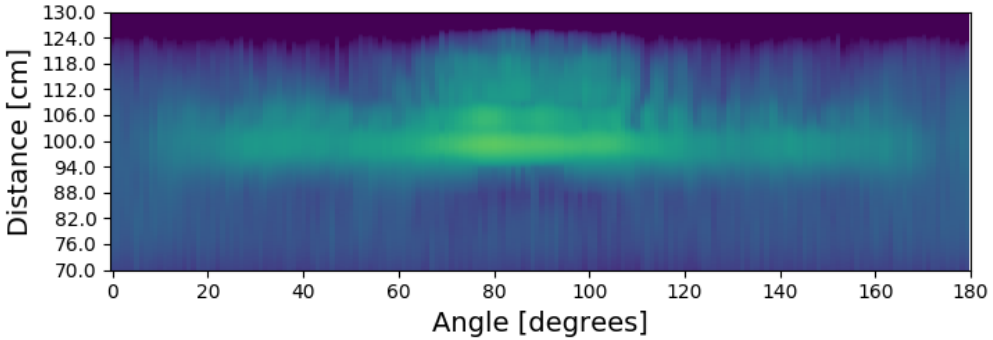
Radar and lens are placed on a standard Thorlabs rotary stage. Envelope of reflected signal from a corner reflector at 1m distance is measured in 1° steps.

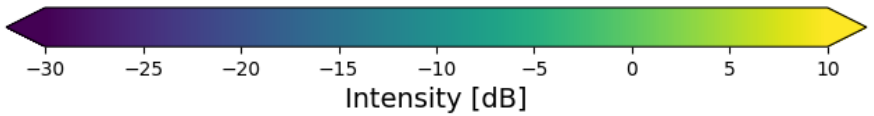


Free space

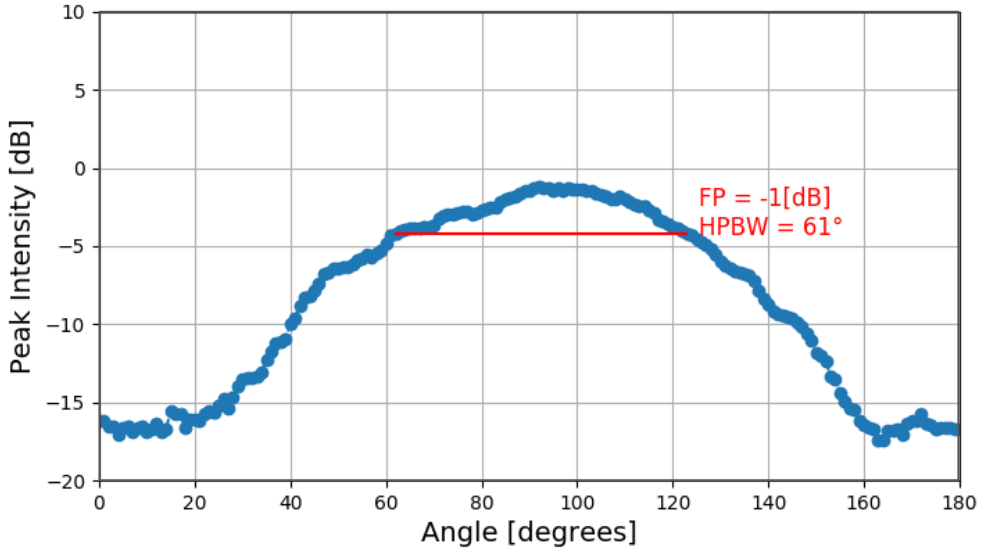
E-Plane

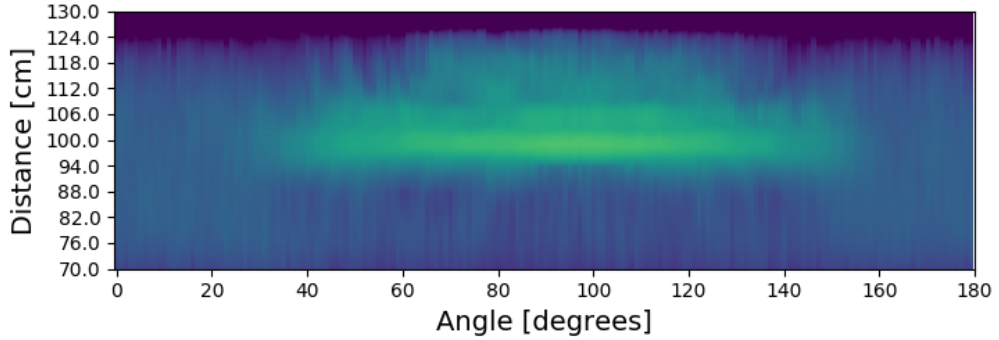


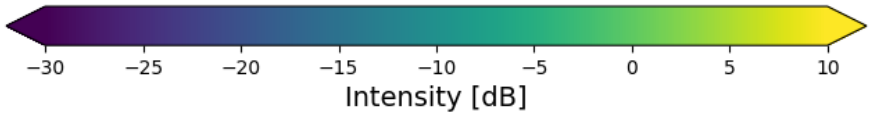




H-Plane



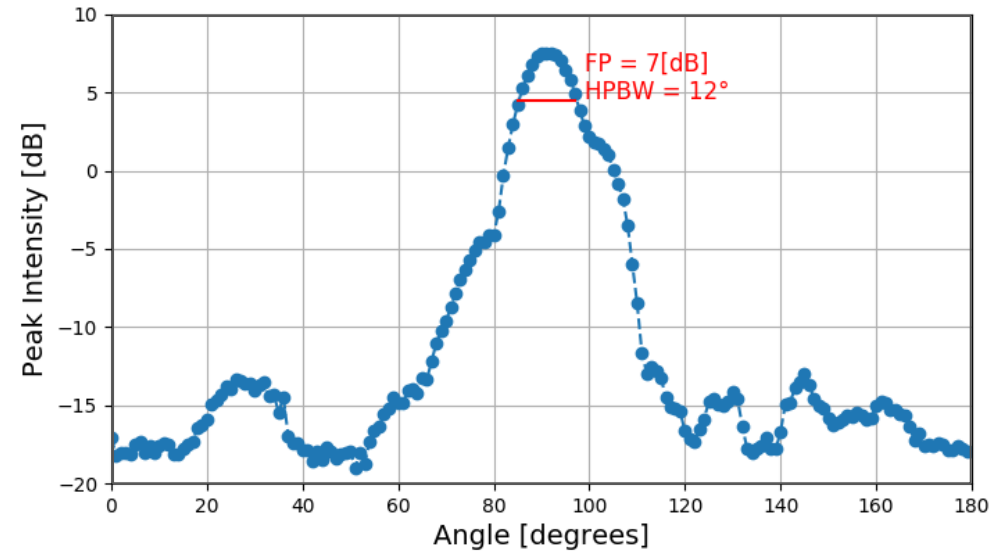


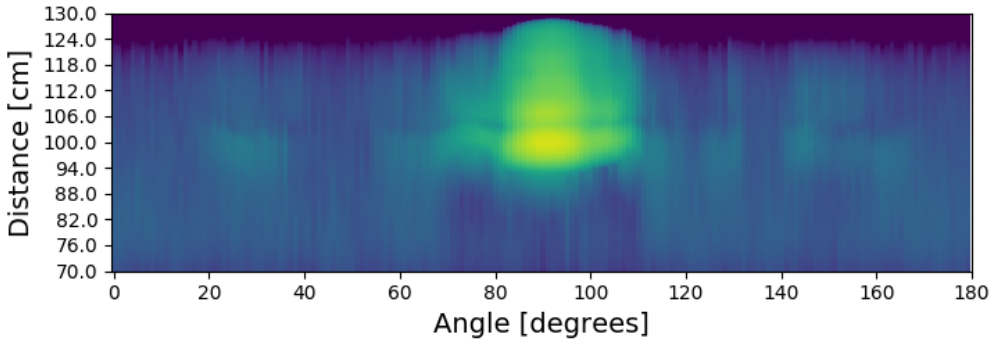


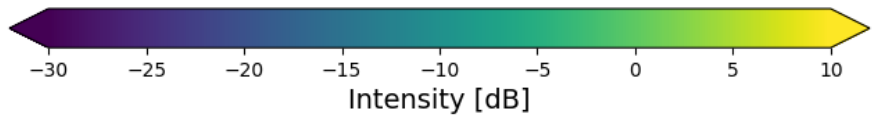
*Power at peak, measured from a corner reflector at 1m distance

FZP: 1 zone

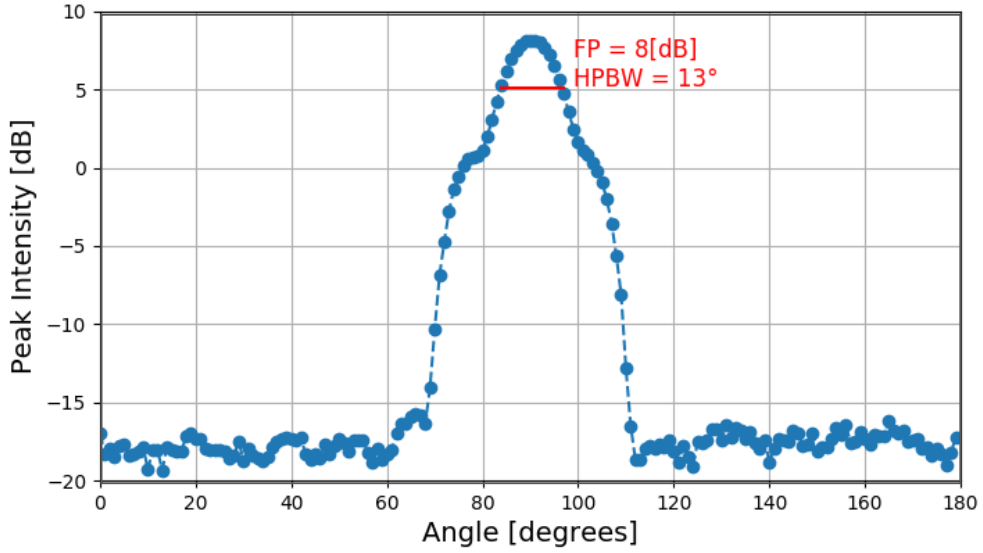
E-Plane

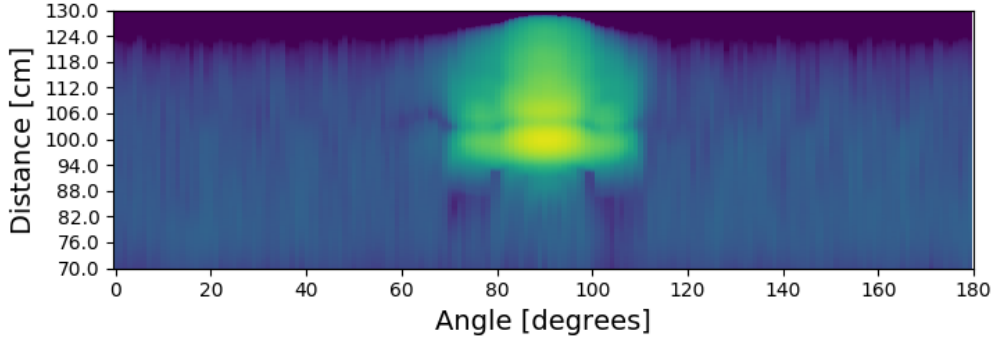


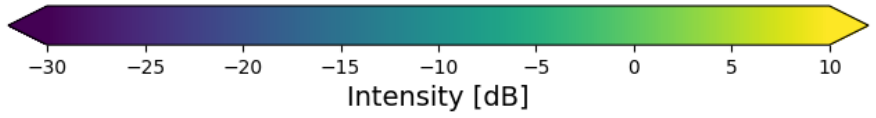




H-Plane

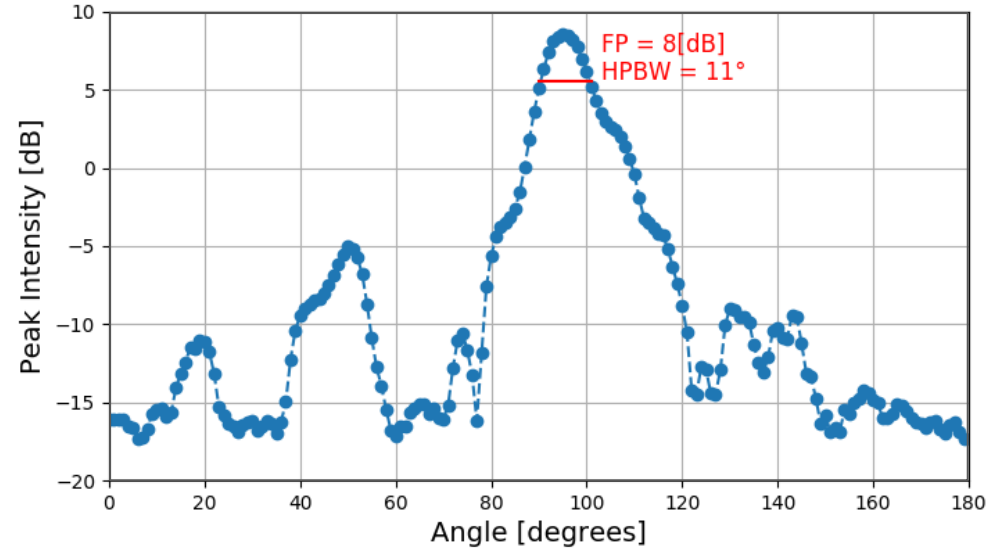


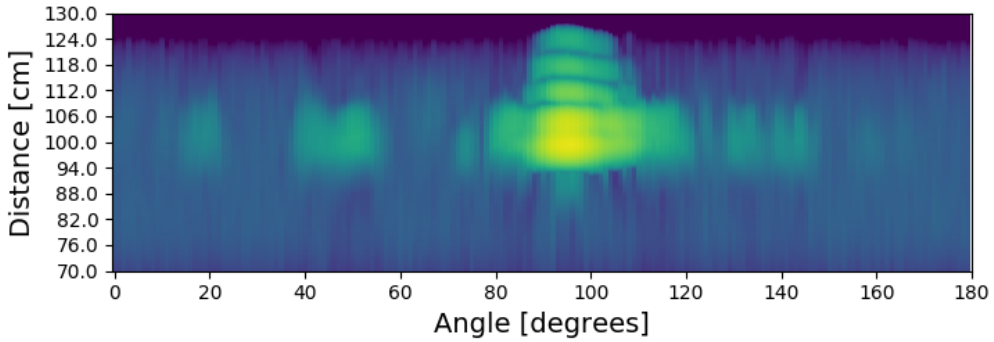


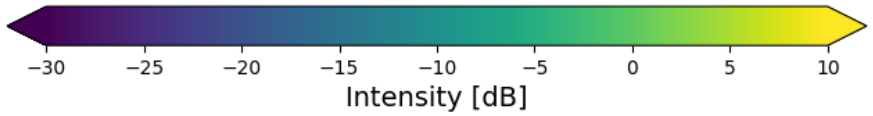


FZP: 3 zones

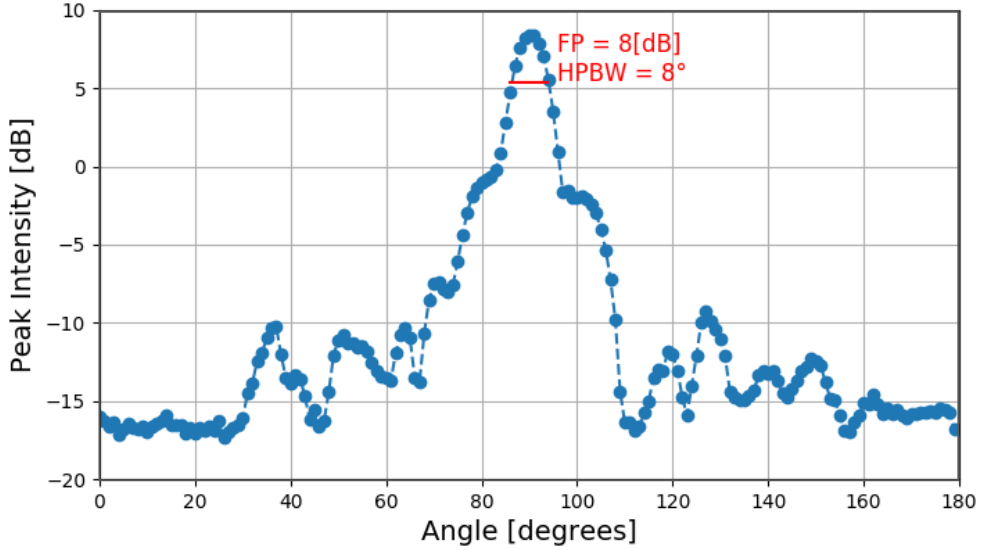
E-Plane

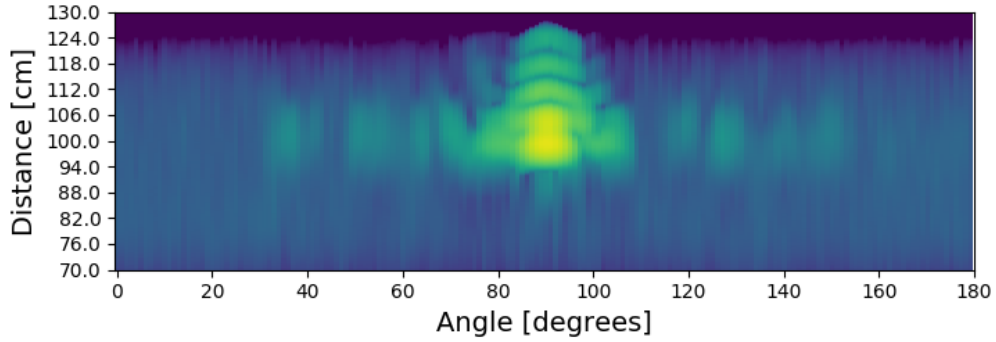


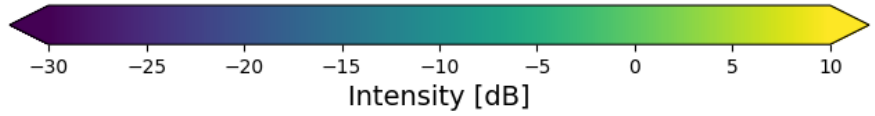




H-Plane

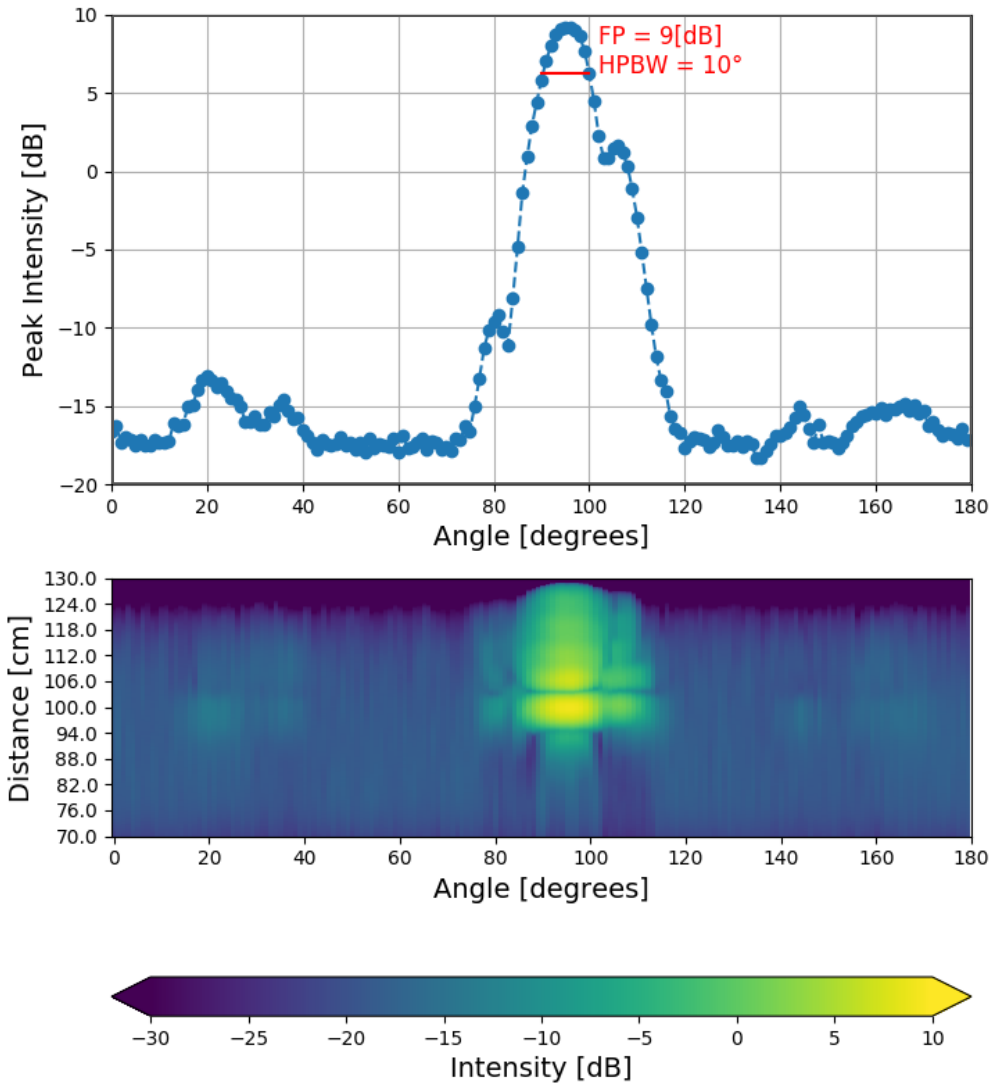




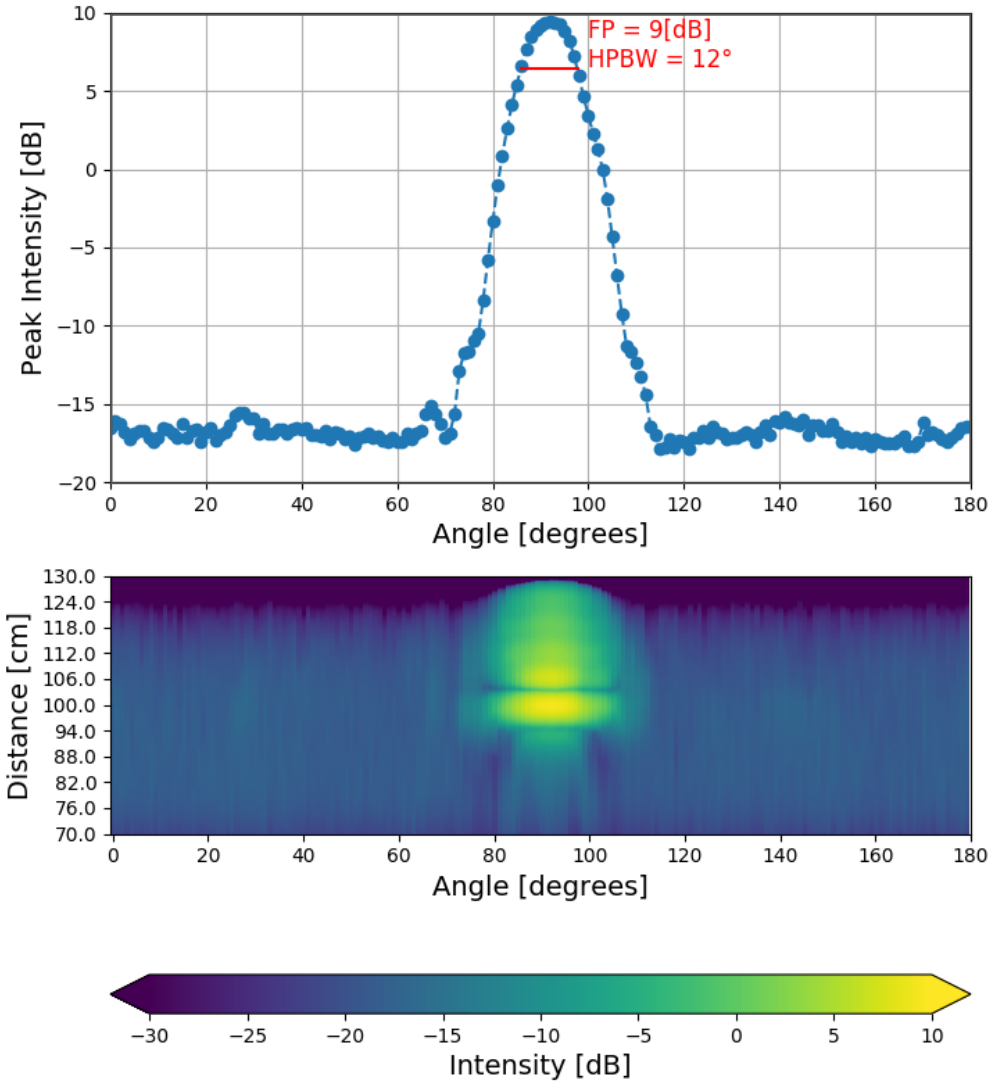


Spherical lens

E-Plane

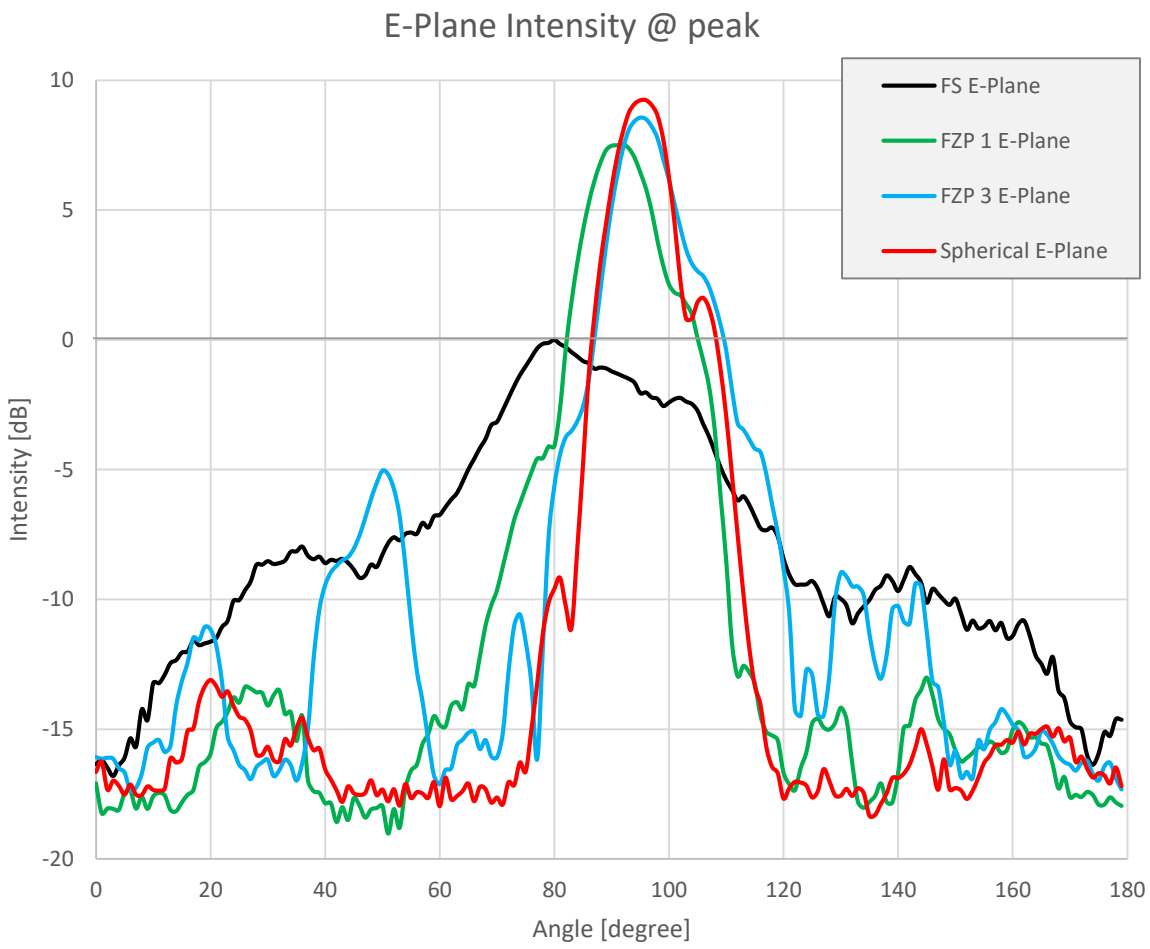


H-Plane

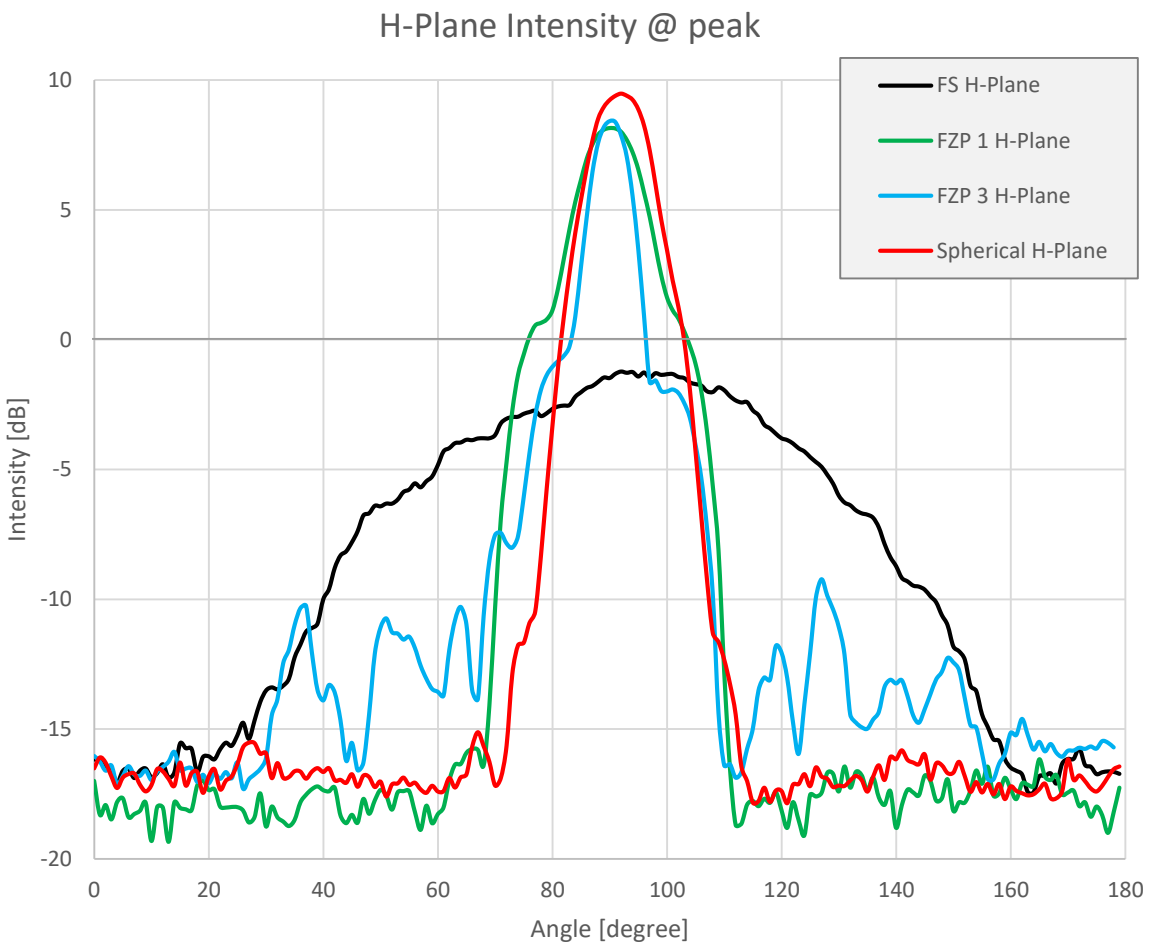


Direct comparison

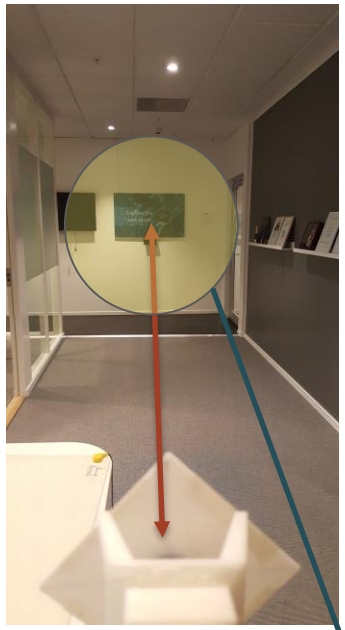
E-Plane



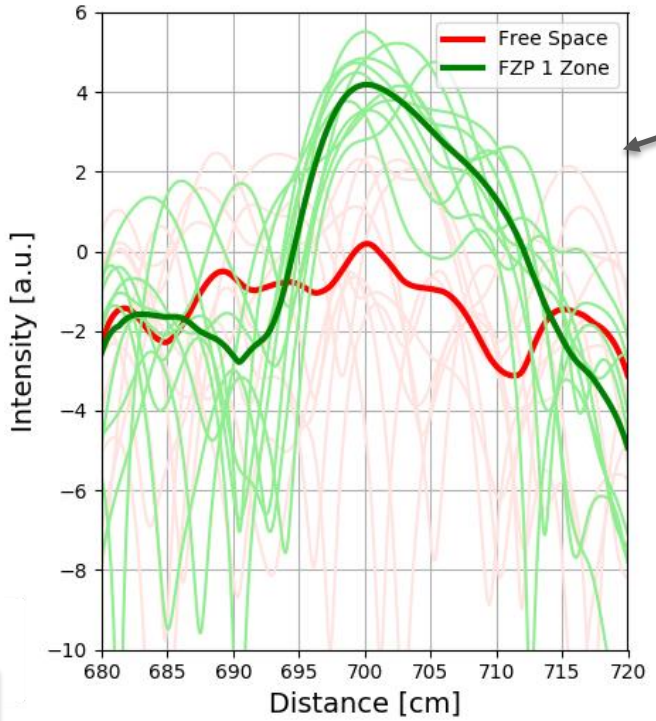
H-Plane



Performance comparison at 7m



Target: Acconeer sign made of plexiglass at 7m

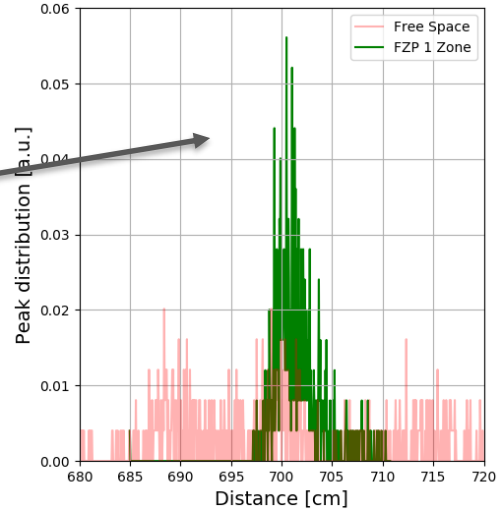


10 sweeps (light color) and average of 10 sweeps (bold), with amplitude normalized to free-space scenario.

With the FZP lens a clear peak is seen at 7 m.

Distribution of peak in single sweep envelope (for 500 sweeps)

FZP 1 Zone $\sigma = 2.4cm$
Free space $\sigma = 10.5cm$



Summary / Recommendation

The FZP with 1 zone offers seems to be best “in-between” option:

- Low material volume, i.e. low cost
- Simple design, can be made even flatter if material with higher dielectric constant is chosen
- Focal distance can be adjust easily by changing geometry of zones
- Reasonably high gain of ~7dB (could be further improved with curved step-design in subzones)
- Less energy in side-lobes compared to FZP with 3 zones
- Half power beam width (HPBW) of ~12°

Appendix A: Foci for FZP with 1 Zone

Fresnel zone plates have several foci, where constructive interference occurs. Here, we scan the received power from an object at a fixed distance and very the distance of the radar source to the FZP.