BEYOND OMNIDIRECTIONALITY: INVESTIGATING THE DESIGN AND USE OF CIRCULAR ANTENNA ARRAYS

INTRODUCTION

- Conventional monopole antennas are omnidirectional which causes it to suffer in long-distance radio transmission
- An intelligent antenna has an array of individual radiation elements which are placed in a particular configuration (linear, circular or matrix)
- By changing the characteristics of the applied signals without employing mechanical changes in the structure, the array can present different gains in desired directions [1]
- This manipulation involves changes in the phase excitation of the elements [2]

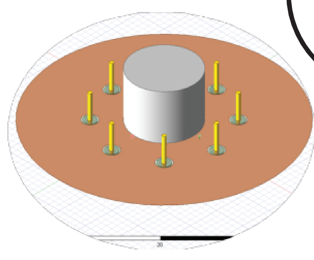
METHODOLOGY

1

Simulation

Parametric sweeps using HFSS on design parameters

- Simple monopole
- Circular array (omnidirectional/ directional)



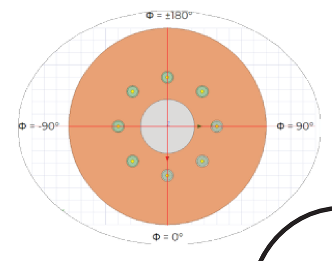
2

Simulation (cont'd)

Implementation of phase changes for

- Maximised gain
- Beamsteering

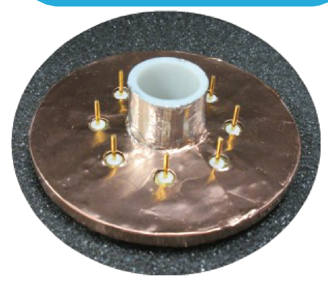
Derivation of general formula



3

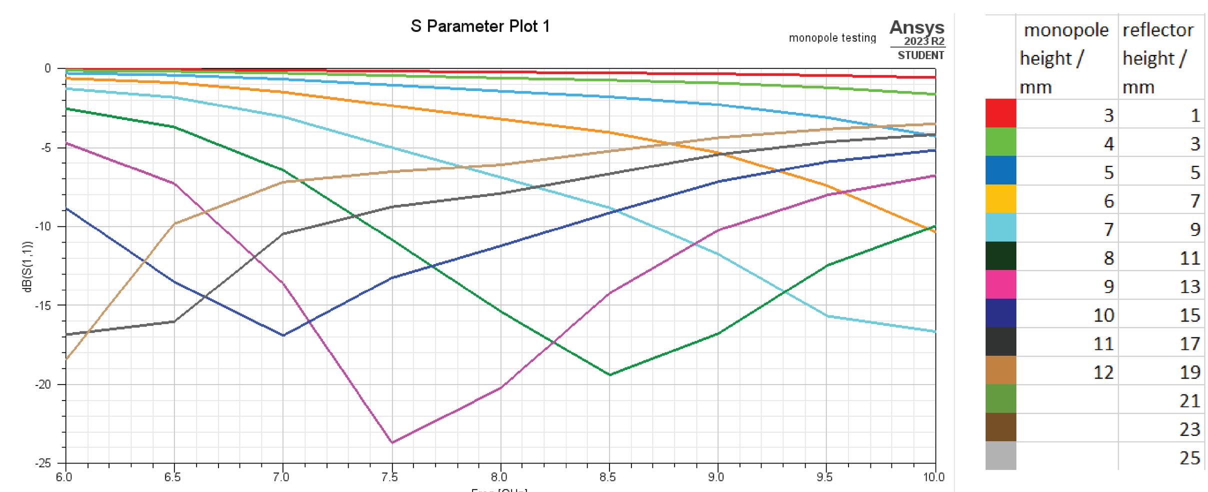
Fabrication & Testing

- Metallised 3D-printed PLA with 8 SMA connectors adhered
- S11 performance tested with VNA

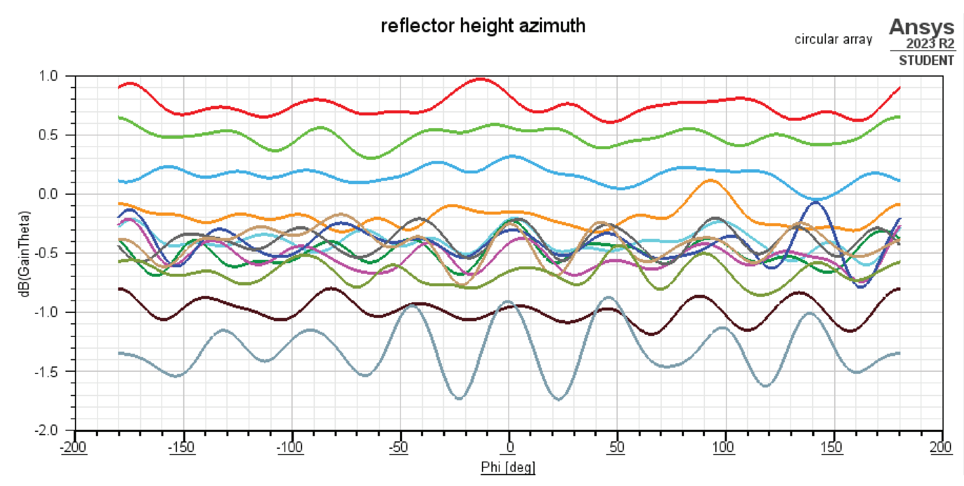


RESULTS - DESIGN PROCESS

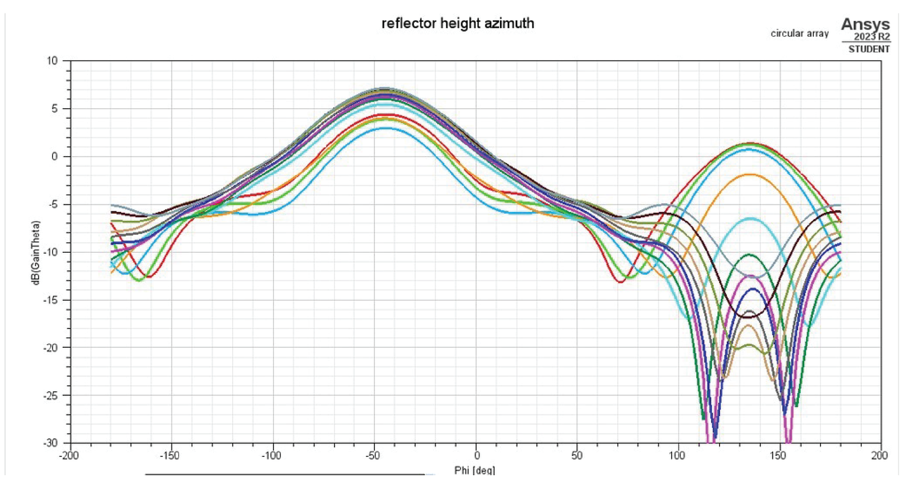
How do the reflector height and array radius affect the performance of the antenna?



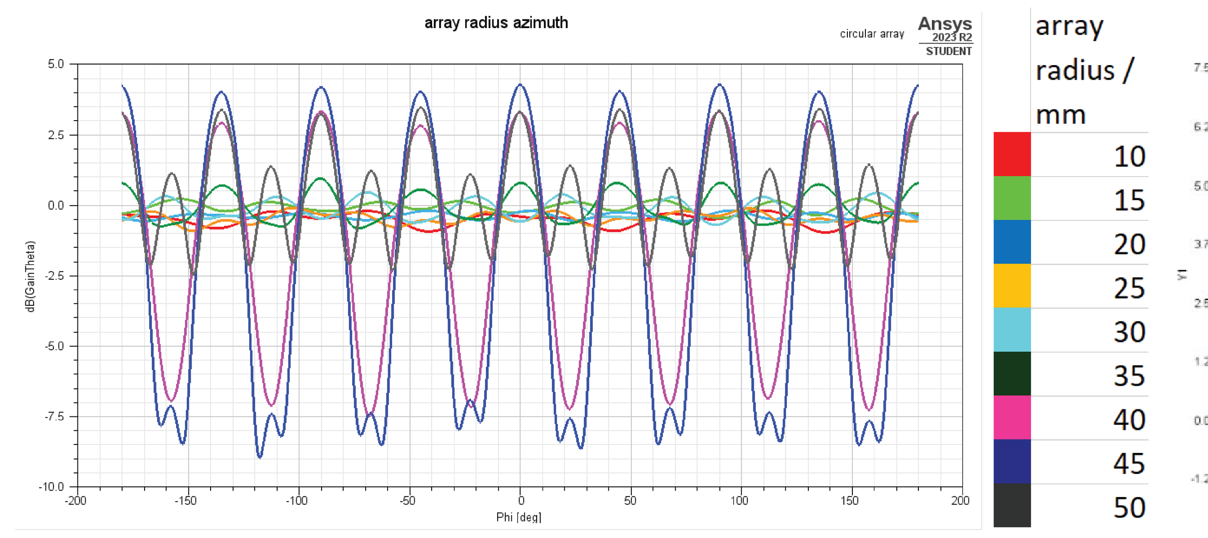
Monopole height of 9mm gives a return loss better than -10dB from 6.7GHz-9GHz.



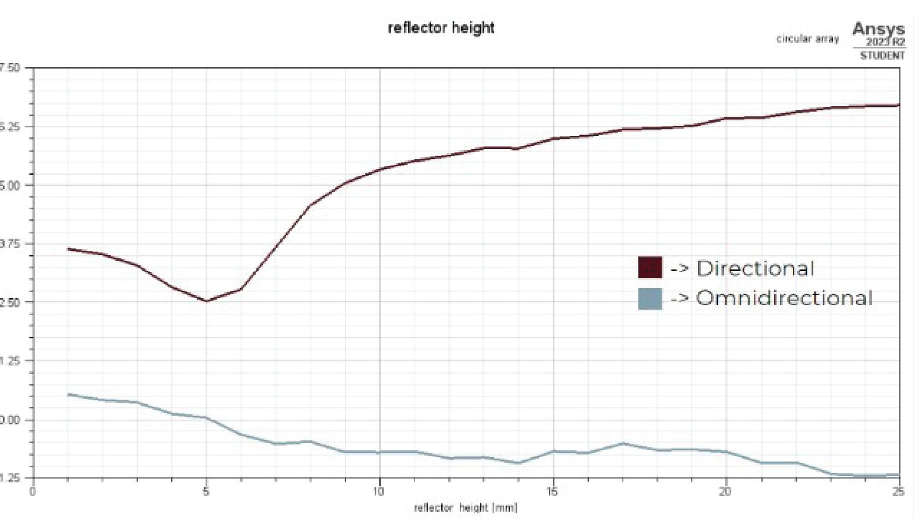
Omnidirectional mode - lower reflector height gives more gain



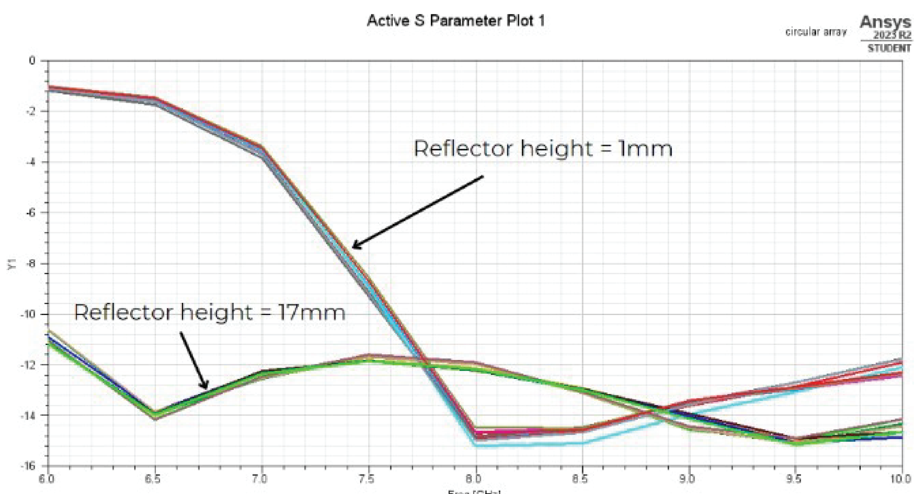
Directional mode - higher reflector height gives more gain



As array radius increases, ripple magnitude increases. A smaller array radius provides more consistent omnidirectional coverage.



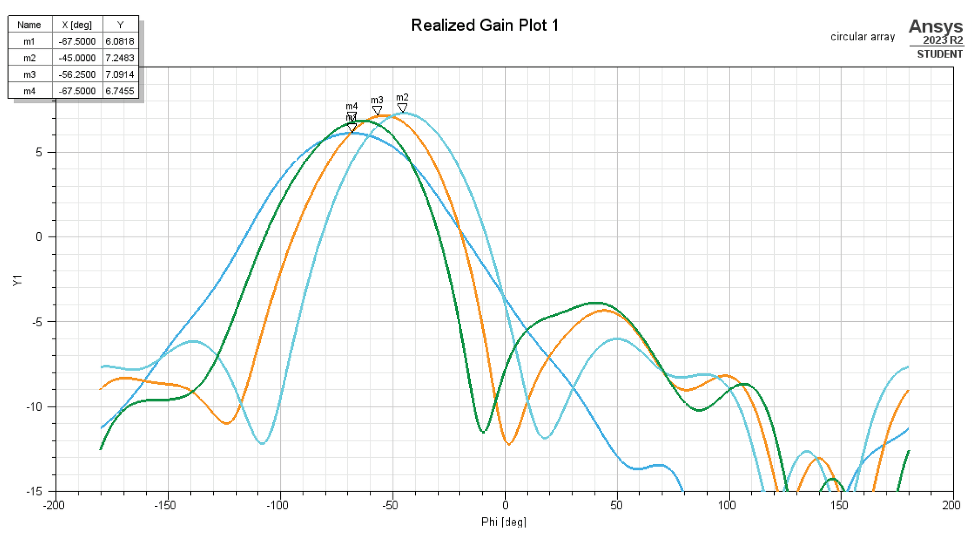
Compromise: 17mm reflector height gives 1dB less average omnidirectional gain than 1mm reflector height, but would provide 2.2dB more of directional gain.

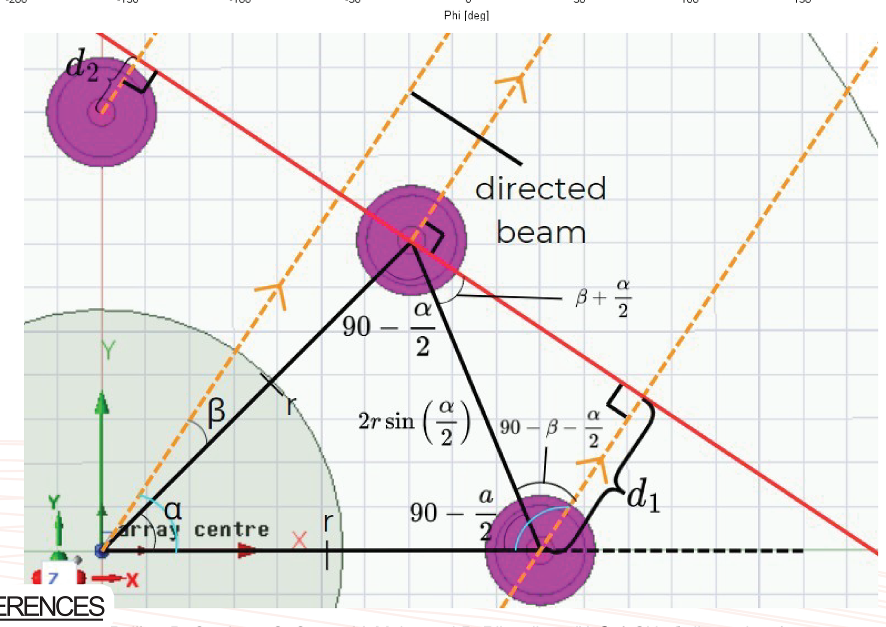


A low reflector height impacts active S11 performance, hence a higher reflector height is favourable.

RESULTS - PHASE CHANGE

Dimensions: 17mm reflector height, 20mm array radius

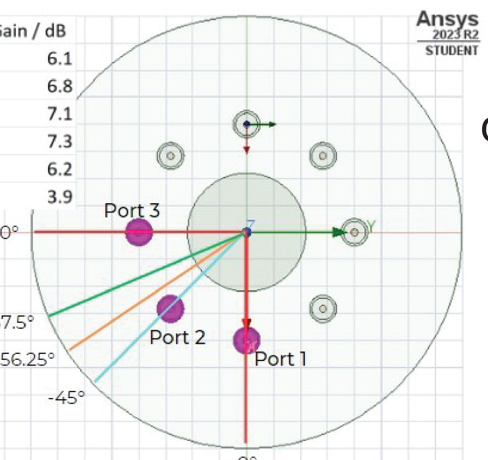




To electronically "align" the radiating ports, maximising constructive interference.

	ϕ / deg	Gain / dB
m1 (ports 2&3 no phase)	-67.50	6.1
m2 (3 ports β=-22.5 deg)	-67.50	6.8
m3 (3 ports β=-11.25deg)	-56.25	7.1
m4 (3 ports phased)	-45.00	7.3
m5 (3 ports no phase)	-45.00	6.2
m6 (1 port)	-45.00	3.9

Beamsteering at different azimuthal angles



General formula: phase change $= \frac{d}{\frac{\lambda}{360}}$

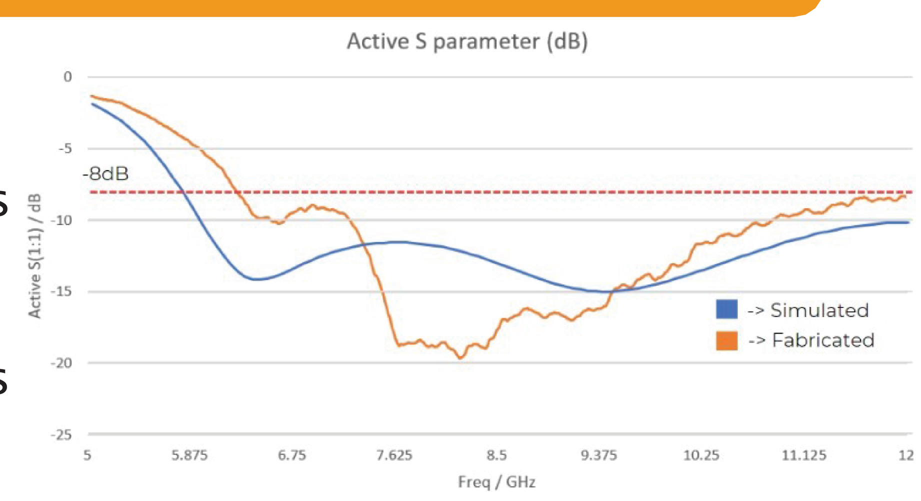
$$\lambda = \frac{3.0 \times 10^8}{f}, \quad d = 2r\sin(\frac{\alpha}{2})\sin(\beta + \frac{\alpha}{2})$$

where d = distance from element to wavefront, r = array radius, f = centre frequency

β = deviation of directed gain from port 2,

$\alpha = \frac{360°}{\text{no. of elements}}$

DISCUSSION & CONCLUSION



Measured result shows correspondence with simulated result, displaying a return loss better than -8dB from 6-12GHz

- Small discrepancies can be due to human error in fabrication, e.g. the crumpling of metal tape
- Gain of fabricated array was not measured due to logistical constraints
- More complex element shapes can also be arrayed in further work
- -0.6dB average omnidirectional gain and 6.8-7.3dB phased directional gain on azimuth plane
- Array has met our performance criteria, provides an adaptable alternative to the conventional monopole

REFERENCES

1 N. Tonme, J. -M. Paillot, D. Cordeau, S. Cauet, Y. Mahe and P. Ribardiere, "A 2.4 GHz 1-dimensional array antenna driven by vector modulators," 2008 IEEE MTT-S International Microwave Symposium Digest, Atlanta, GA, USA, 2008, pp. 803-806.
2 N. H. Noordin, V. Zuniga, A. O. El-Rayis, N. Haridas, A. T. Erdogan and T. Arslan, "Uniform circular arrays for phased array antenna," 2011 Loughborough Antennas & Propagation Conference, Loughborough, UK, 2011, pp. 1-4.

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