A TUNEABLE WAVEGUIDE ARRAY FOR RADIATION & SCATTERING EXPERIMENTS

Introduction

Waveguides

- Guide the propagation of electromagnetic waves [1]
- All-metal construction → low loss & high efficiency and high-power handling capacity [2,3]
- Planar waveguide array is compact, reduced manufacturing complexity compared to parabolic reflectors [4,5]

Reflectarray/Periodic Scatterer

- Reflecting elements in array introduce phase shifts or time-delays to steer beam via principle of superposition [6,7]
- Reconfigurable array with height adjustable reflecting elements
- Advantages: cheaper option than phased array with lossy & expensive parts [6,8-12]

Our Research

- Utilising additive manufacturing, fused filament fabrication for 8 heights corresponding to reflection phases of 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°
- Benefits: cheap, light, accurate high dimensions [10]

Methodology

Simulate unit cell on CST Microwave Studios to obtain S-curve (phase) → Model waveguide array in AutoCAD for each case → Simulate waveguide array on CST → Prepare materials, assemble prototype → Record data and compare to simulated results

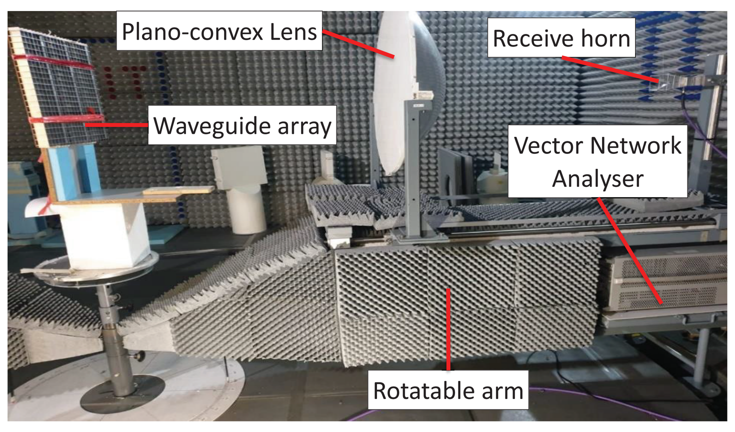


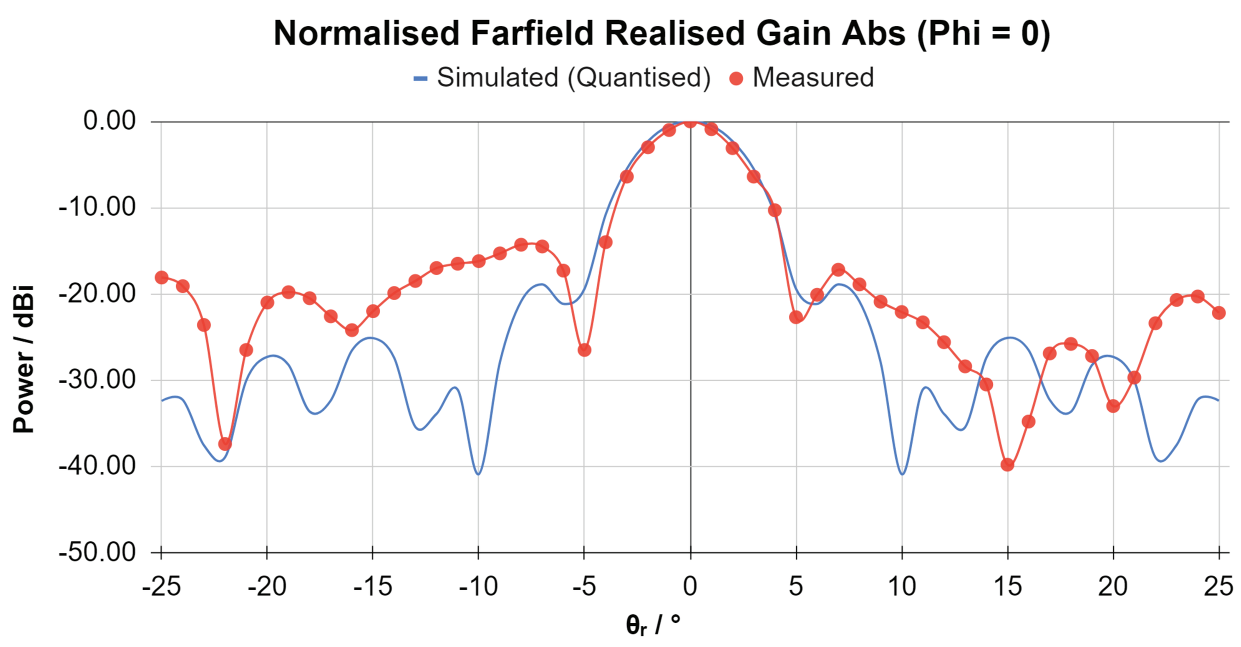
Figure 6: Experiment Set-up (w/o feedhorn)

Radiation Case

- Feedhorn placed 0.26 m away from waveguide array (F/D=1.22) for edge taper of -10dB to reduce edge diffractions [13]
- Phase-shift required by each cell of the array to steer beam is calculated via:

$$\varphi_r(x, y) = k[d_i - (x_n \cos\varphi_r + y_n \sin\varphi_r)\sin\theta_r]$$

- Shape of main beam in good agreement with simulated results
- Differences in sidelobes shape – coarse tuning of rotatable arm supporting the receiver
- Flat surface of lens slightly tilted by 2° from the vertical



Incident:
$\phi_i = 0°$
$\theta_i = 0°$

Radiated:
$\phi_r = 0°$
$\theta_r = 0°$

Figure 7: Simulated & Measured RCS

Design

- Plate support made from Acrylonitrile Butadiene Styrene
- Design frequency: 9.5GHz
- Within cut-off frequency of propagation mode TE_{10} and TE_{11}

$$f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

- a feedhorn is attached at the front for radiating cases

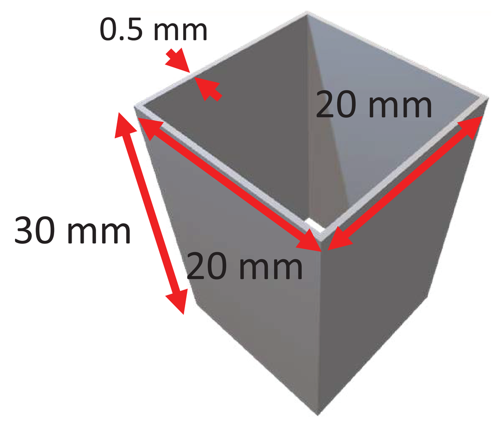


Figure 1: Unit Cell Wall

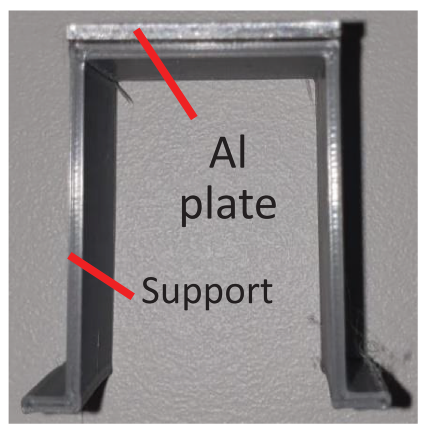


Figure 2: Plate Support

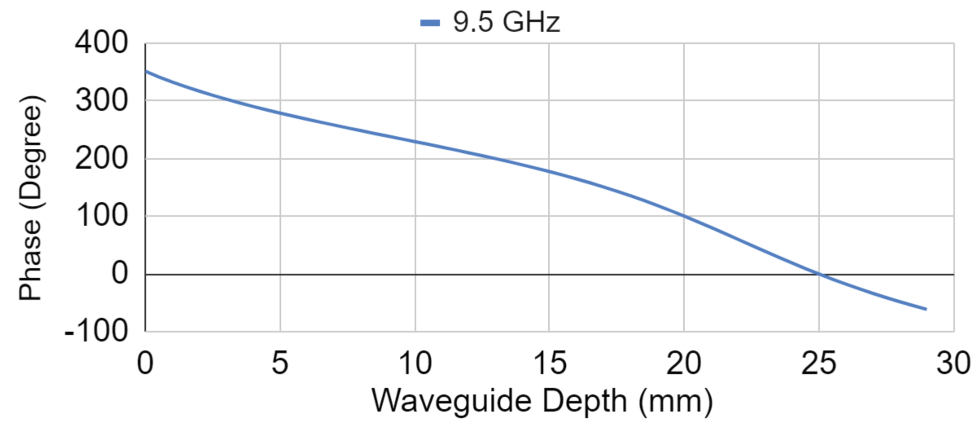


Figure 3: Phase vs depth of unit cell

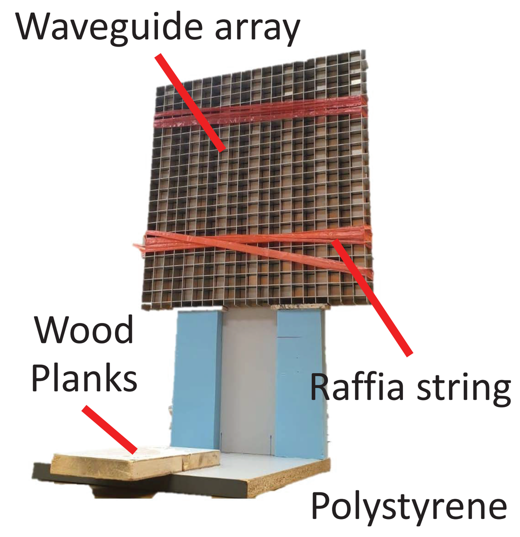


Figure 4: Waveguide Array and Stand

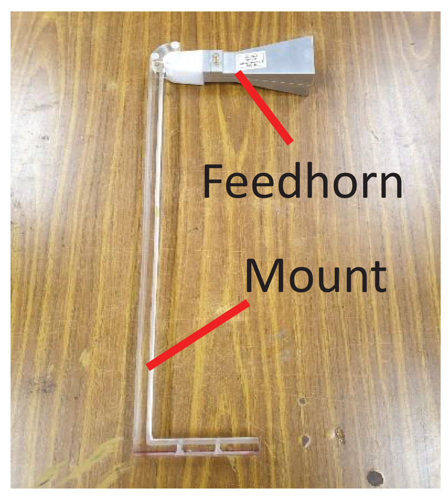


Figure 5: Feedhorn

Scattering Case

- Phase-shift required by each cell of the array is calculated via the following equation:

$$\varphi_r(x, y) = k[-(x_n \cos\varphi_i + y_n \sin\varphi_i)\sin\theta_i - (x_n \cos\varphi_s + y \sin\varphi_s)\sin\theta_s]$$

Due to facility limitations, a monostatic radar cross-section is captured.

- Major peaks agree fairly well with simulated peaks
- Angular offset – manual alignment of setup and rotation arm
  - difficult to capture positions of nulls accurately

Incident:
$\phi_i = 0°$
$\theta_i = -30°$

Scattered:
$\phi_s = 0°$
$\theta_s = 45°$

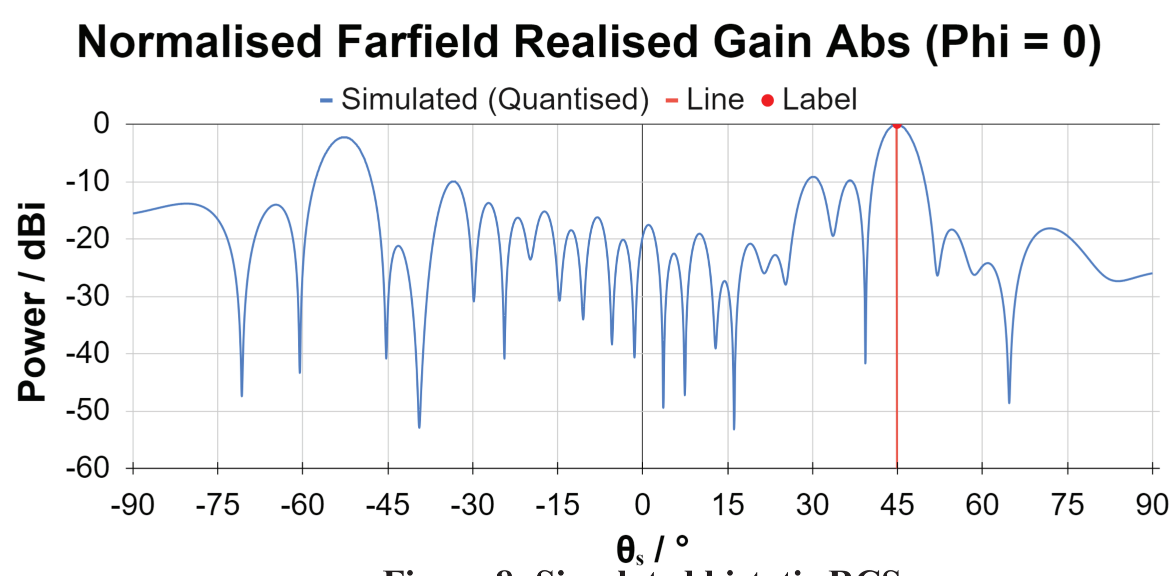


Figure 8: Simulated bistatic RCS

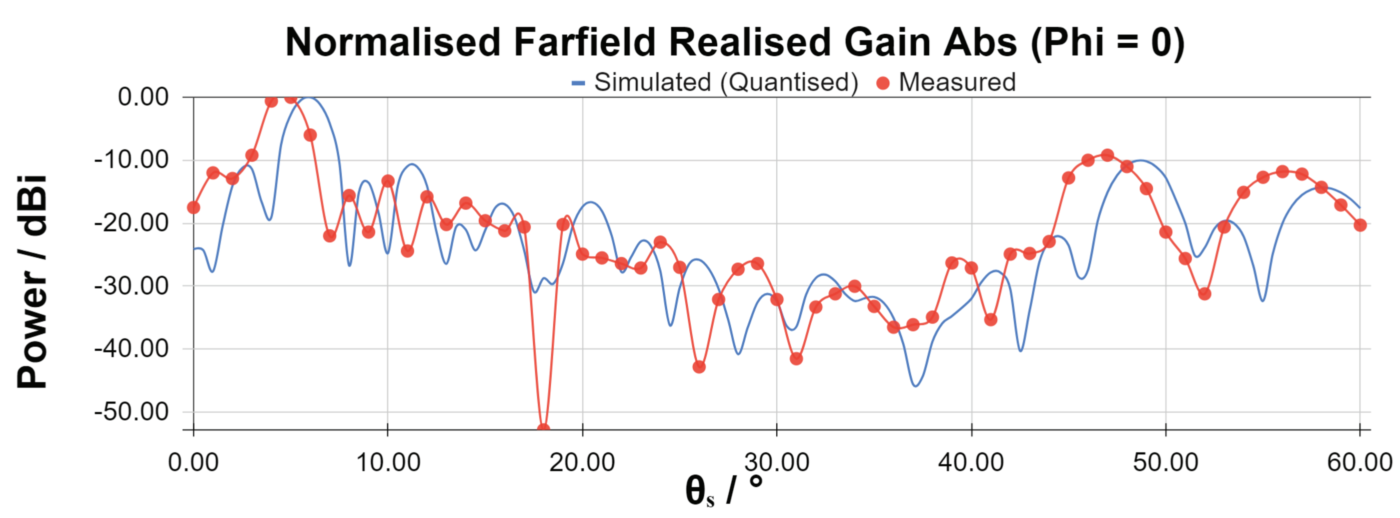


Figure 9: Simulated & Measured monostatic RCS

Conclusion

Reconfigurable waveguide array
✓ Light ✓Cost-effective ✗ Tedious

Suggested improvement

- Electro-mechanical system instead of manual reconfiguration

References

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YDSP Young Defence Scientists Programme
DSTA Defence Science & Technology Agency
DSO National Laboratories