COMPARISON OF REFLECTARRAY ANTENNAE WITH DIFFERENT LATTICES USING ELEMENTS WITH TWO-AXIAL SYMMETRY

Choo Ze Xian[1], Ian **Tay** Rongde[1], Samuel **Tan** Ming Ying[1], **Chia** Tse Tong[2]

[1]Raffles Institution, One Raffles Institution Lane, Singapore 575954
[2]DSO National Laboratories, 12 Science Park Dr, Singapore 118225

1. Introduction

Combining the concepts of a reflector and an antenna array, a reflectarray antenna comprises a planar reflecting surface of elements of different electrical phases, which radiate the incident field from a feed antenna such that a planar wavefront is formed in the far-field distance. Due to their flat aperture, reflectarray antennas have advantages in terms of foldability and conformality. However, a conventional reflectarray antenna using a rectangular lattice with element separation exceeding λ/2 may result in undesired large grating lobes and high sidelobes [1]. One method to achieve a sparser element distribution on the reflectarray aperture while maintaining low sidelobe levels is the use of an aperiodic lattice arrangement. While research has been conducted into aperiodic lattice arrangements in phased arrays [1],[2], there has been little research conducted on the use of aperiodic lattice arrangements in reflectarray antennas [3]. In addition, there has been little research done comparing radiation patterns of aperiodic lattice arrays with a rectangular lattice.

2. Research Methods

A two-axial symmetrical unit element (Fig. 1) was designed to allow for dual polarisation use and low cross-polarisation performance.

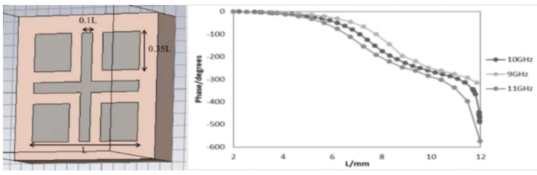

Figure 1: Element design and its S-Curve.

The logarithmic spiral, circular uniform concentric rings and periodic rectangular lattices of the reflectarray elements as shown in Fig. 2 were investigated.

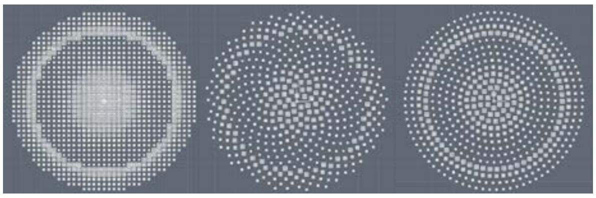

Figure 2 - (L-R) Rectangular, logarithmic spiral and circular lattice arrangements for a circular reflectarray.

The required phase of each element in a reflectarray is given by [4] $\Phi = k_0[d_i - (x_i \cos\phi_B + y_i sin\phi_B)\sin\theta_B]$ where θ_B and ϕ_b specify the desired direction of the radiation beam in spherical coordinates, x_i and y_i are the coordinates of the reflectarray element, d_i is the distance between the feed and the reflectarray, and $k_0 = \frac{2\pi}{\lambda}$. Using the required element phases and the S-curve, which gives the relation between electrical phase and element dimensions, the dimensions of the elements can be determined for simulation.

3. Results

From Table 1, it can be seen that the sparse logarithmic spiral and circular lattices can still provide comparable gain and efficiency compared to a rectangular lattice, which has a denser element distribution. The logarithmic spiral and circular lattice arrangement exhibit similar sidelobe levels to the rectangular lattice despite having a much sparser element distribution. Spiral lattice arrangements have been shown to be able to suppress grating lobe formation and thus reduce sidelobe levels [1]. Similarly, the concentric ring arrangement with angular offset eliminates periodicity along the axes of the reflectarray aperture and reduces the formation of grating lobes. The greater element density of the circular lattice as compared to the logarithmic spiral lattice could result in a greater reduction in the formation of grating lobes, leading to comparably lower sidelobe levels.

Table 1: Performance comparison of reflectarrays with different lattice arrangements at 10GHz.

	Rectangular Lattice	**Circular Lattice**	**Log Spiral Lattice**
# of elements	1085	566	478
Realised gain (dB)	30.2	30.5	30.3
E-plane peak sidelobe level (dB)	-21.2	-22.6	-21.7
Cross-pol level at boresight (dB)	-224.0	-53.6	-44.9
Aperture eff (%)	45.9	49.2	47.0

The rectangular lattice distribution of elements allows for much reduced cross-polarisation levels compared to the circular and logarithmic spiral lattices because of the symmetry of the element arrangements in the rectangular lattice, which results in symmetry in current direction on the reflectarray surface, allowing for cancellation of cross-polarisation vectors.

4. Conclusion

The results of this study show that aperiodic circular and logarithmic spiral lattices exhibit similar realised gain, aperture efficiency and sidelobe levels compared to a rectangular lattice despite having much sparser element distribution. However, the aperiodic lattices have much higher cross-polarisation levels. Future study can involve the fabrication and testing of reflectarrays constructed using the lattices and unit element detailed in this study to allow for experimental confirmation of simulation results.

5. References

[1] Viganó, M. C., Toso, G., Caille, G., Mangenot, C., & Lager, I. E. (2009). Sunflower Array Antenna with Adjustable Density Taper. Int. J. Ant. Propagat., 2009, 1-10.
[2] Haupt, R. L. (2008). Optimized Element Spacing for Low Sidelobe Concentric Ring Arrays. IEEE Trans. Ant. Propagat., 56(1), 266-268.
[3] Niaz, M. W., Ahmed, Z., & Ihsan, M. B. (2016). Reflectarray with logarithmic spiral lattice of elementary antennas on its aperture. AEU – Int. J. Elect. and Comm., 70(8), 1050-1054.
[4] Huang, J., & Encinar, J. A. (2008). Reflectarray antennas. Piscataway, N.J: IEEE Press.