Techniques for Supressing Grating Lobes

Introduction

Antennas are designed to radiate Electromagnetic energy. It is used for long-distance communication and/or transmitting of data [1]. In the simplest form, an antenna can be modelled as a point source radiating in all directions at a particular frequency. These point source antennas are known as omnidirectional antennas. The antennas can be arranged in a linear array (straight line) or a planar array (surface) with the distance between the antennas dependent on the application of the antenna array. Arranging the antennas in an array improves the overall power gain of the net radiation pattern which improves its directivity [1]. This is a result of the principle of superposition because each antenna contributes to the overall radiation pattern Figure 1. It means that the radiation energy is more concentrated in the target direction. This result makes the transmission of data over a larger distance possible.

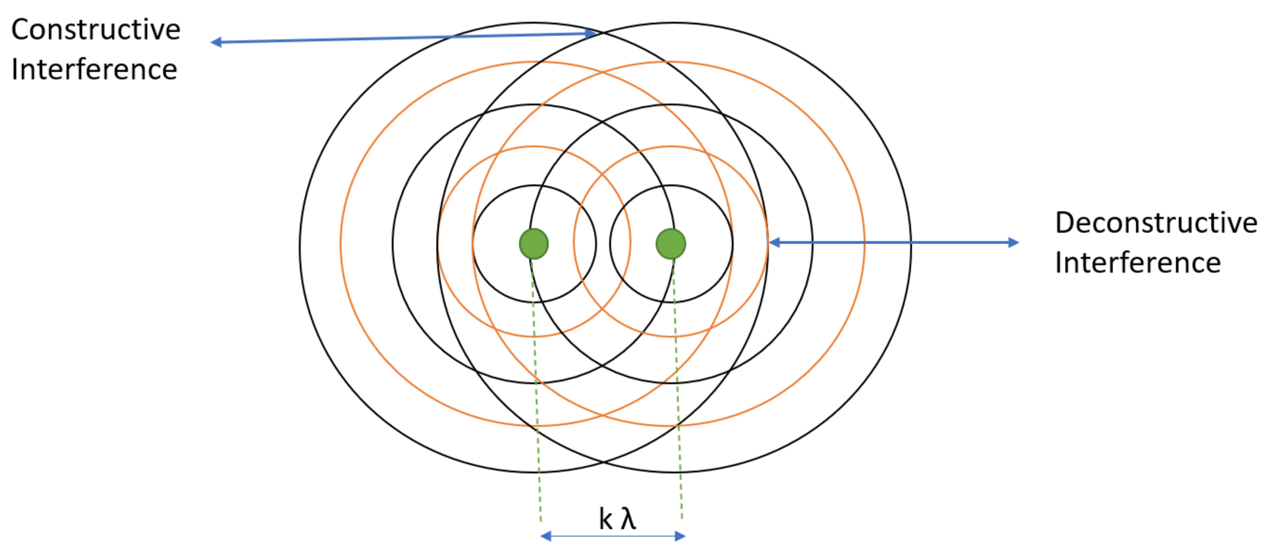

Figure 1. Two point source antennas.

Problem Statement

In this project, an investigation is made on how the **position**, **phase shift** and **amplitude distribution** of each antenna element affect grating lobes and how these parameters should be optimized to suppress the grating

Objective

The aim is to find a **fixed element spacing** and the resulting phase shift and amplitude distribution that allow for the suppression of grating lobes. This would result in a wider steering range and more efficient antenna. This must be achieved while keeping the half-power beamwidth (HPBW) as narrow as possible and maintaining a superior sidelobe level (SLL) compared to a uniformly spaced linear antenna array of half a wavelength.

Grating Lobes

Grating lobes are unwanted secondary main lobes that appear when the distance between antennas are wider than one wavelength or you steer the main beam beyond a critical angle (CA). The CA is determined by the array formation. These grating lobes are unwanted because they are wasted energy and cause interference from radiating stations in non-intended directions.

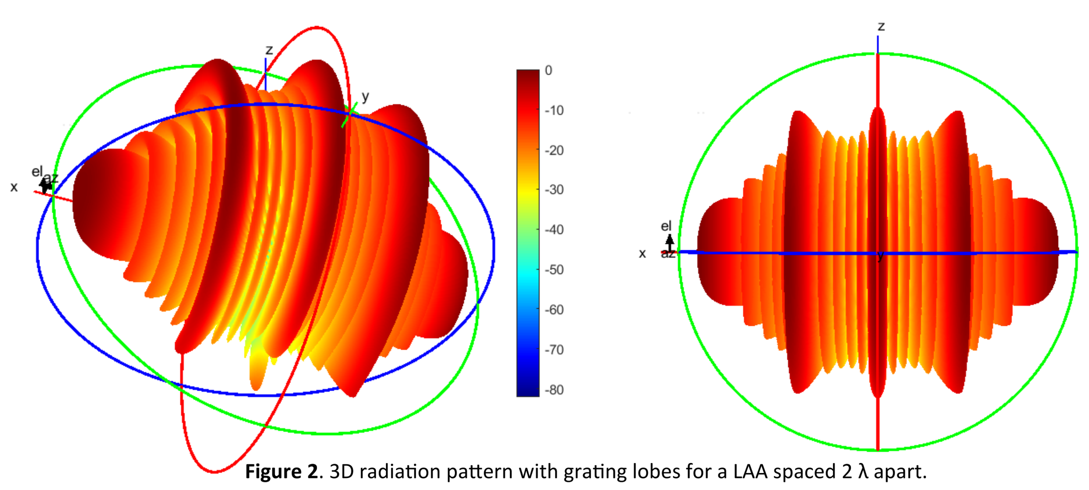

Figure 2. 3D radiation pattern with grating lobes for a LAA spaced 2 λ apart.

Array Factor

The Array Factor (AF) equation (1) describes the radiation pattern of the LAA of size N. Where each antenna is modelled as a point source with a particular amplitude, phase shift and fixed frequency.

The visible region is between $[0° \leq \theta \leq 180°]$.

$$AF = \sum_{m=0}^{N-1} I_m e^{j(kd_m \cos\theta + \alpha_m)} \quad (1) \qquad DFT = \sum_{n=0}^{N-1} x(n) e^{-j(\frac{2\pi kn}{N})} \quad (2)$$

The AF can be seen as the Discrete Fourier Transform (DFT) equation (2) [2]. The N antennas can be modelled as a rectangular window of size N sampled by a Dirac comb with interval *d.* The Fourier transform of a rectangular window function is a Sinc function [2]. The Sink function is then convolved with a Dirac comb function with interval λ/d. Only the Sinc functions that are within the visible region will be seen.

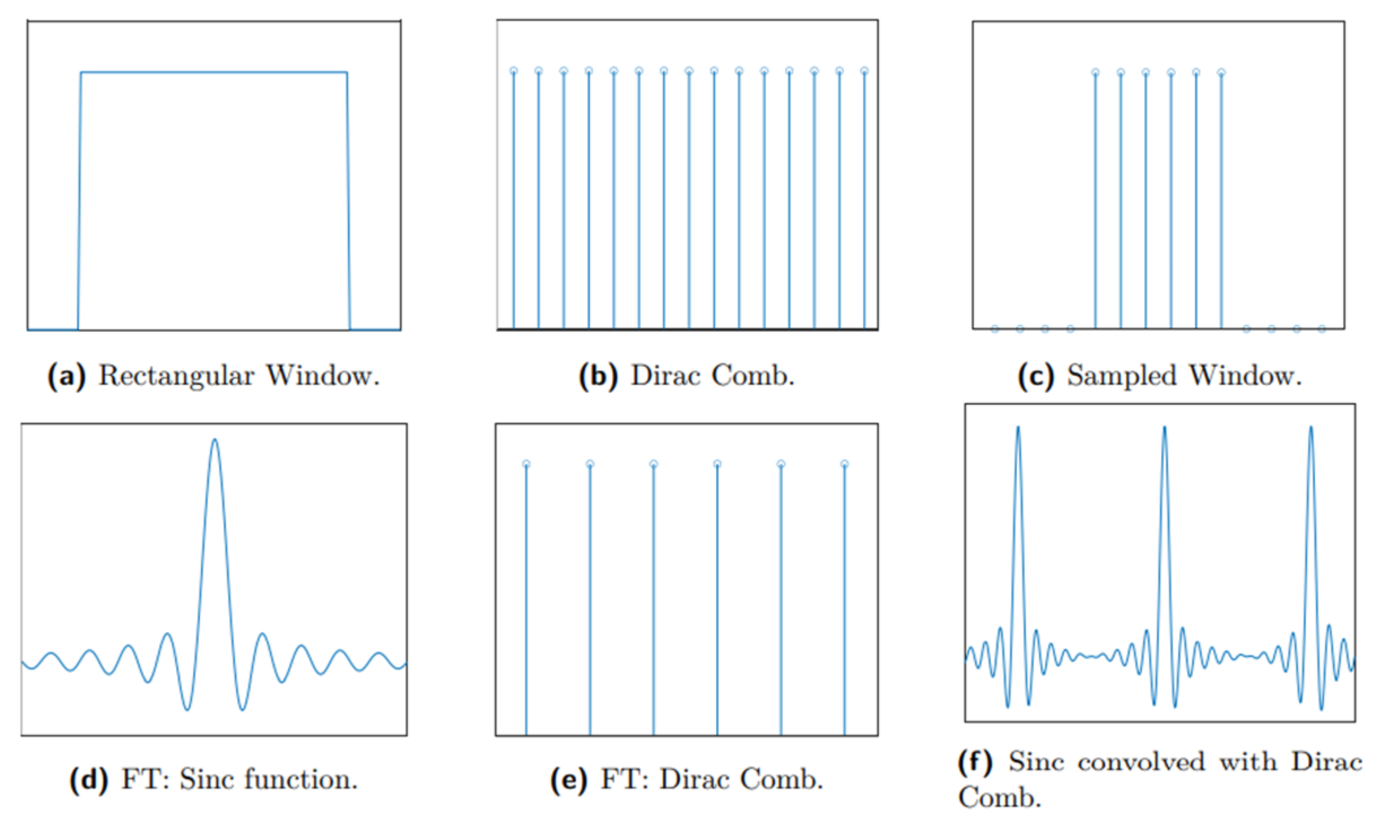

Figure 3.1: Visual representation of the Fourier transform of a LAA.

In Figure 3.1 (f) the middle Sinc function is known as the main beam and every other Sinc function is known as a grating lobe [4].

Results

Optimizing the amplitude distribution with the genetic algorithm (GA) is like changing the shape of the window function Figure **4**. This results in an improved a SLL but increased the width of the HPBW . The grating lobes however are not supressed.

From our Fourier transform knowledge it is clear that changing the window shape affects the width of the Sinc function and the ripples that comes with it [2]. The GA achieved a ***21.21 dB*** **(*159.59%*)** reduction in SLL compared to the uniform LAA.

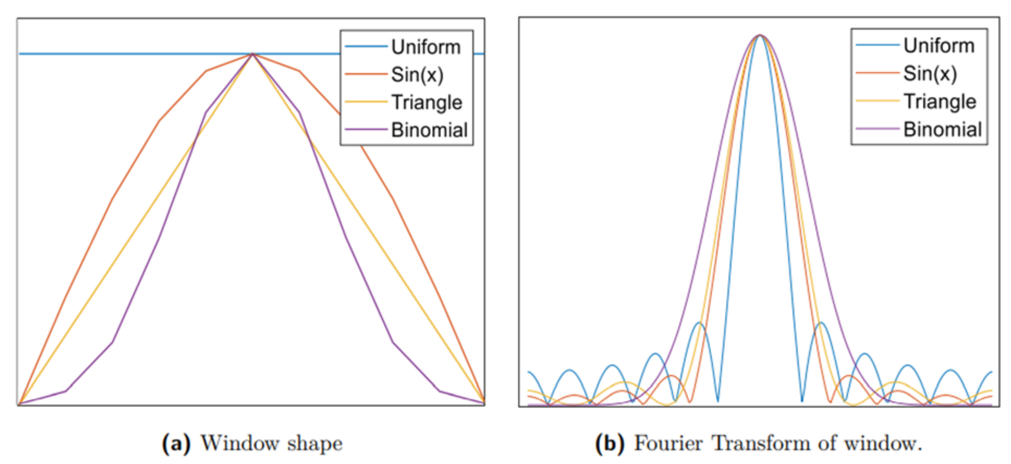

Figure 4. Different window functions and their corresponding Fourier transform.

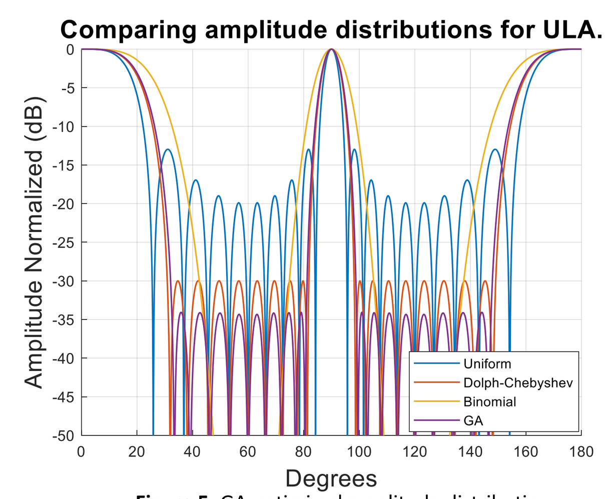

Figure 5. GA optimized amplitude distribution.

A Genetic Algorithm was deployed to optimize the LAA to be steered to the critical angle (CA) of 57 degrees from boresight. Three solutions were obtained that supress the grating lobe that appear in the uniform LAA that is spaced half a wavelength, Figure 6.

At the CA the HPBW ranges from *39.5* to *46* degrees which is *3.5* to *10* degrees (*9.72%* to *27.78%*) wider than the uniform LAA. The SLL of the uniform LAA is *−3.191 dB*. The GA solution with the worst SLL is *S3 = −8.236 dB*. This solution results in a ***5.045 dB*, (*158.1%*)** reduction in the growing grating lobe. With the superior SLL the overall directivity is only slightly improved for the GA solutions (S1 = +0.075, S2 = +0.215 and S3 = +0.133) due to the increase in the width of the HPBW. The GA solutions are S1 = +3.27%, S2 = +9.36% and S3 = +5.78% more directive than the uniform LAA.

When the beam is steered **beyond the CA** the uniform LAA officially has a grating lobe however, the solutions obtained by the GA steered 70 degrees from boresight do not have any grating lobes. The highest SLL at 20 degrees is S3 = *−6.846 dB*. This solution results in a ***5.846 dB*, (*584.6%*)** suppression of the grating lobe of the uniform LAA. With the superior SLL the overall directivity is improved for the GA solutions (*S1 = +0.320, S2 = +0.228 and S3 = +0.231*). The GA solutions are *S1 = +14.92%, S2 = +10.65% and S3 = +10.76%* more directive than the uniform LAA

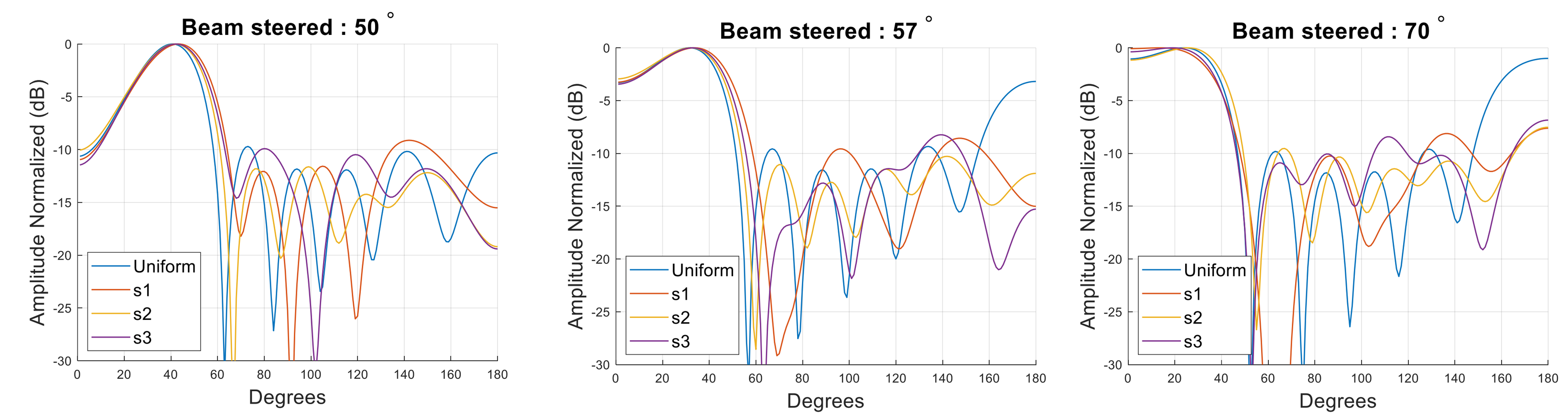

Figure 6. Non-uniform LAA with no grating lobes vs Uniform LAA with grating lobes.

Conclusion

A Genetic Algorithm was designed and deployed to optimize the amplitude distribution and phase shift independently. It was then combined to optimize the antenna spacing. Itis shown that the amplitude distribution has no effect on the grating lobes but instead affect the HPBW and SLL. The phase shift only steers the position of the main beam. Due to the grating lobe being a secondary main beam the phase shift affect the position of the grating lobe

The conclusion drawn from the investigation of techniques to suppress grating lobe formed by a LAA is that grating lobes are as a result of the periodic nature of the Array Factor. This periodicity is as a result of the inter element spacing of the antennas in a antenna array.

It is therefore concluded that a non-uniformly spaced LAA can suppress the grating lobes of the uniform LAA when steered to and beyond the CA. Depending on the specifications and intended use the steering range can vary between 114 to 180 degrees (63.33% to 100%) of the visible space. That is an increase of more than 36.67% in steering capabilities compared to the uniform LAA. The grating lobe is suppressed 158.1% at the CA but at the cost of a 9% to 27% increase of the HPBW.

References

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