SIDELOBE REJECTION IN A UNIFORM LINEAR ARRAY ANTENNA USING WINDOWING TECHNIQUES

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Abstract

In this paper the radiation pattern of Uniform linear arrays like Broad Side Array and End Fire Array with reduced side lobes is generated. For some applications, single element antennas are unable to meet the gain or radiation pattern requirements. So combining several single antenna elements in an array can be a possible solution. Array is a system of similar antennas oriented similarly to get greater directivity in a desired direction. Various techniques can be used to reduce the side lobes in the radiation pattern. Here, we employ windowing techniques for the reduction of side lobes. MATLAB (7.12) is the Simulation Platform. Various Windows used are Rectangular, Hamming, Hanning, Gaussian, Blackmann, Bartlett, Tukey, Parzen, Kaiser Windows

Keywords— *radiation pattern, Directivity, Hamming, Hanning, Gaussian Bartlett*

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1. INTRODUCTION

Antenna is a transducer designed to transmit or receive electromagnetic waves. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. high frequency AC) to the antenna's terminals, and the antenna radiates the energy as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified.

Antenna array (electromagnetic) is a group of isotropic radiators such that the currents running through them are of different amplitudes and phases. For some applications, single element antennas are unable to meet the gain or radiation pattern requirements. So combining several single antenna elements in an array can be a possible solution. These can be classified into two types.

1.1 Uniform Linear Array

A uniform array is defined by uniformly-spaced identical elements of equal magnitude with a linearly progressive phase from element to element.

1.2 Non-Uniform Linear Array

Arrays that have dissimilar sources and are unequally spaced is known as Non- Uniform Linear Array.

2. TYPES

The phasing of the uniform linear array elements may be chosen such that the main lobe of the array pattern lies along the array axis (end-fire array) or normal to the array axis (broadside array).

End-fire array mainlobe at theta= 0degrees or 180 degrees

Broadside array main lobe at theta = 90degrees

2.1 End-Fire Array

A linear array whose direction of maximum radiation is along the axis of the array; It may be either unidirectional or bidirectional; the elements of the array are parallel.

2.2 Broad-Side Array

The maximum radiation intensity is in the direction perpendicular to the plane of the array because the fields of all the radiators are in phase in that direction

3. RADIATION PATTERN

It is the Graphical Representation of the Radiation properties as a function of space. This can be explained in two patterns FIELD STRENGTH PATTERN, POWER PATTERN. The following diagram represents the Radiation pattern of Uniform Linear Array in Rectangular and Polar co-ordinate systems. In the field of antenna design, the term **radiation pattern** (or

antenna pattern or **far-field pattern**) refers to the *directional* (angular) dependence of the strength of the radio waves from the antenna or other source.

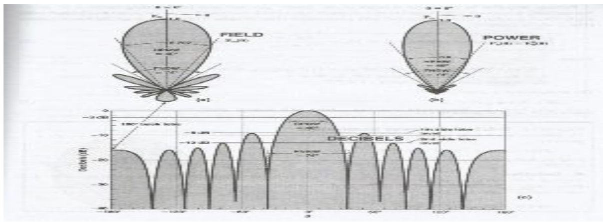


Fig 1: Radiation pattern of Uniform Linear Array

3.1 Broad Side Array:

The Radiation pattern of Broad Side Array is as follows:

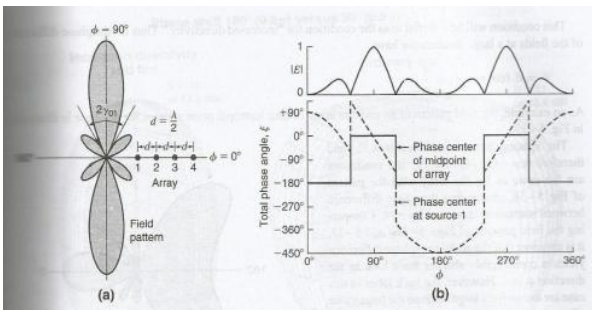


Fig2: Radiation pattern of Broad Side Array

3.2 End Fire Array

The Radiation pattern of End Fire Array is as follows

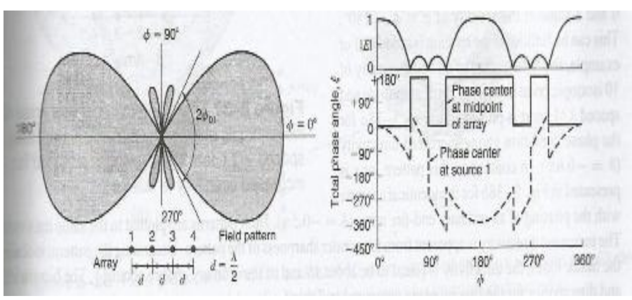


Fig3: Radiation pattern of End fire Array

3.3 Array Factor

The overall radiation pattern changes when several antenna elements are combined in an array. This is due to the so called **array factor.** This factor quantifies the effect of combining radiating elements in an array without the element specific radiation pattern taken into account. The overall radiation pattern of an array is determined by this array factor. combined with the radiation pattern of the antenna element.

Array factor depends on the excitation of currents both Amplitude and phase and position of elements.

$$AF = \sum_{i=1}^{N} w_i e^{-j\mathbf{k}\,\mathbf{r}_i}$$

3.4 Pattern of Multiplication:

It states that the Radiation Pattern of an array is the product of the pattern of the individual antenna with the array pattern. It helps to sketch the Radiation pattern of an Array Antenna rapidly from the simple product of Element pattern and Array Pattern. If we assume that all the polar radiation patterns of the elements taken individually are identical (within a certain tolerance) and that the patterns are all aligned in the same direction in azimuth and elevation, then the total array antenna pattern is got by multiplying the array pattern by the element pattern.

PATTERN MULTIPLICATION THEOREM

Array pattern=Array element pattern*Array Factor

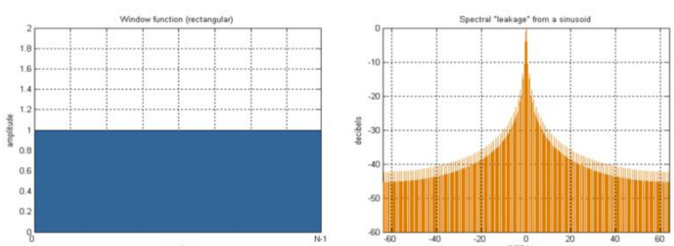
One of the major drawback of a Uniform linear Array is the presence of Side lobes. This can be overcome by using several techniques.

4. WINDOWING TECHNIQUES

A Window function also known as apodization or tapering function. It is a mathematical Function that is zero value outside of some chosen interval. An ideal window shape will taper off at the ends of the input record, but still have a reasonable compact and narrow spectrum.

4.1 Different Windowing Techniques:

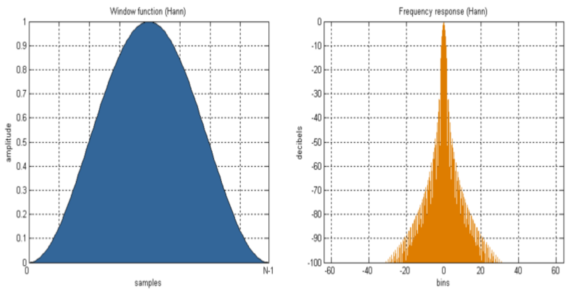
4.1.1 Rectangular Window:



$$w(n) = 1$$

The rectangular window is sometimes known as a Dirichlet window. It is the simplest window, equivalent to replacing all but N values of a data sequence by zeros, making it appear as though the waveform suddenly turns on and off.

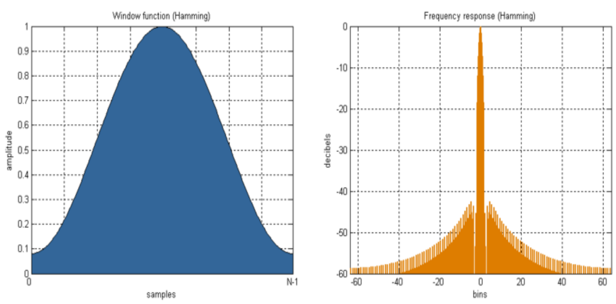
4.1.2 Hanning Window



$$w(n) = 0.5\ \left(1 - \cos\left(\frac{2\pi n}{N-1}\right)\right)$$

'The ends of the cosine just touch zero, so the side-lobes roll off at about 18 dB per octave. The Hann and Hamming windows, both of which are in the family known as "raised cosine" or "generalized Hamming" windows, are respectively named after Julius_von Hann and Richard Hamming. The term "Hanning window" is sometimes (erroneously) used to refer to the Hann window.

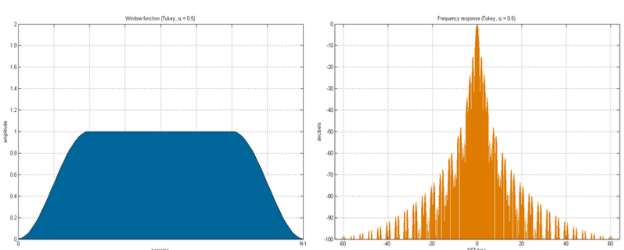
4.1.3 Hamming Window



The "raised cosine" with these particular coefficients was proposed by Richard W. Hamming. The window is optimized to minimize the maximum (nearest) side lobe, giving it a height of about one-fifth that of the Hann window, a raised cosine with simpler coefficients.

$$w(n) = 0.54 - 0.46\ \cos\left(\frac{2\pi n}{N-1}\right)$$

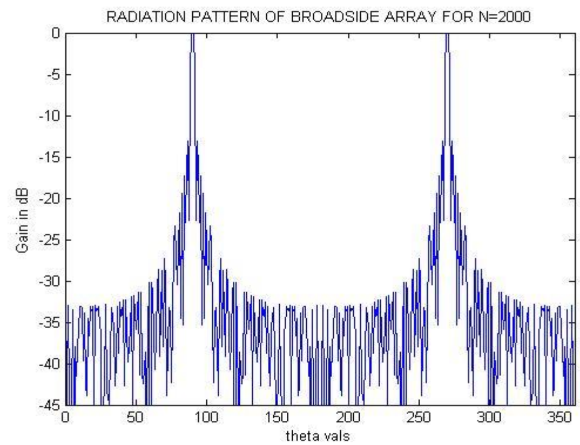
4.1.4 Tukey Window



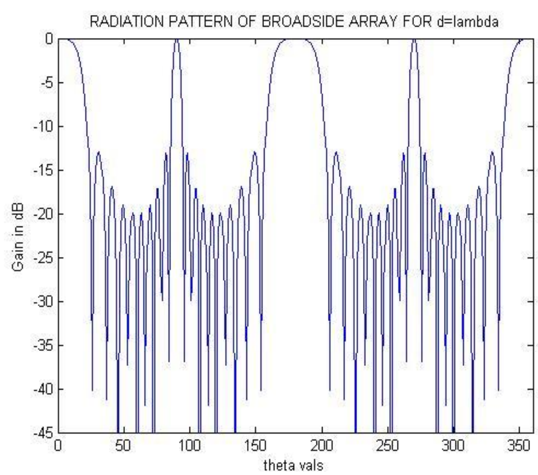
$$w(n) = \begin{cases} \frac{1}{2}\left[1+\cos\left(\pi\left(\frac{2n}{\alpha(N-1)}-1\right)\right)\right] & \text{when} 0 \leqslant n \leqslant \frac{\alpha(N-1)}{2} \\ 1 & \text{when} \frac{\alpha(N-1)}{2} \leqslant n \leqslant (N-1)(1-\frac{\alpha}{2}) \\ \frac{1}{2}\left[1+\cos\left(\pi\left(\frac{2n}{\alpha(N-1)}-\frac{2}{\alpha}+1\right)\right)\right] & \text{when} (N-1)(1-\frac{\alpha}{2}) \leqslant n \leqslant (N-1) \end{cases}$$

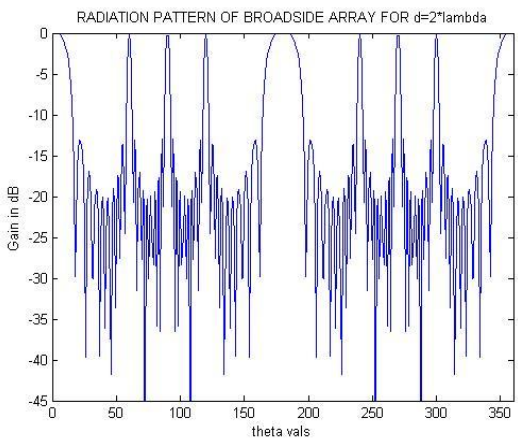
4.2 Advantages of Windowing Techniques

1. For obtaining a narrow beam width of broadside and end fire array we have some possibilities:
-increasing number of elements in the array or decreasing wavelength. These two possibilities lead to high cost.



2. Using windowing techniques with less number of elements side lobe levels can be reduced and reducing cost.
-increasing spacing. But it leads to grating lobe. Windowing techniques does not result in grating lobes.





3. Using binomial array:
The disadvantage in binomial array is the large beam width of the main lobe which is undesirable.

4. Taylor's Distribution:
It has disadvantage in case of very large arrays, as all the radiation elements in the array require independent sources leading to a number of sources equal to that of radiating elements.

WINDOWING TECHNIQUE	SIDE LOBE LEVEL (ENDFIRE	SIDE LOBE LEVEL(BROADSIDE ARRAY)
Uniform Array(INPUT)	-13	-12.6
Kaiser window	-14	-13.6
Hanning window	-32	-30
Tukey window	-15	-16
Hamming window	-36	-36
Parzen and Blackman window	No side lobes	No side lobes

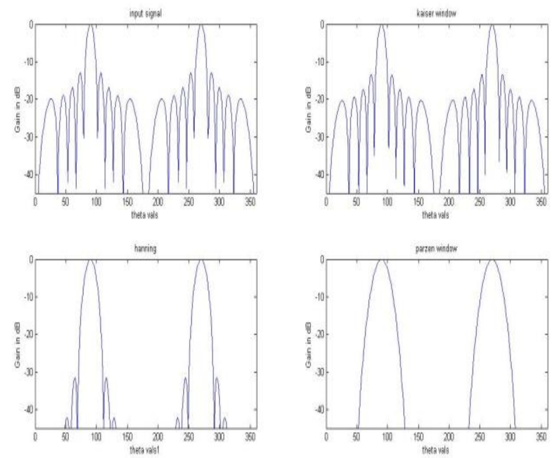
4.3 Applications

The patterns with small beam widths and low side lobes are widely used for
-point to point communication
-high resolution radar
-long range detection

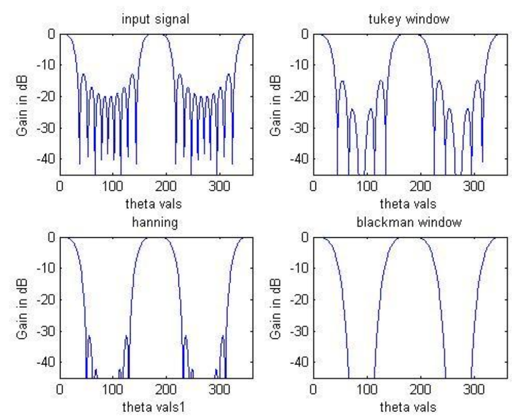
Major problem in uniform linear arrays is that the main lobes are associated with number of side lobes around them. The presence of high side lobes causes electromagnetic interference in radar receiver due to nearby objects. Sometimes this interference is so high that it leads to abnormal echoes.

Moreover, with the presence of high side lobes the system is susceptible for jamming.

5. RESULTS



Radiation pattern of broad side array with reduced side lobes



Radiation Pattern of Endfire Array with Reduced Side Lobes

6. CONCLUSIONS

Hence, the above results are the graphs that are simulated after the rejection of side lobes. Using windowing techniques with less number of elements side lobe levels can be reduced But it leads to grating lobe. Windowing techniques does not result grating lobes. Different windowing techniques leads to various results having reduced side lobes but a trade off hast to be made on side lobe level and directivity.

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