Radiation Analysis of Phased Antenna Arrays with Differentially Feeding Networks towards Better Directivity

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Abstract - *The design of phased antenna arrays for the better enhancements in the controlling over side lobe level (SLL) of radiation, directivity with antenna mode scattering i.e., when is radiating. In this paper, the differentially fed phased antenna arrays and the challenges faced during the radiation performance analysis and the feeding networks for the excitation are presented. The antenna feed can be depends on array size, frequency of operation and permittivity of substrate [1]. There is a development towards the reduction in the scattering of a phased antenna arrays. The operating frequency and the resonance frequency depend on the dimensions of the patch in the antenna array.*

*Key Words***:** Phased antenna array, differentially fed, radiation, antenna mode RCS, SLL control

1. INTRODUCTION

The phased antenna arrays are designed towards the growth in the structural development monitoring systems by using various techniques. The differentially fed phased antenna arrays are designed with plane arrays which comprises of patch elements (array), a substrate, and a ground plane with feeding networks. The feeding of phased arrays from the ground plane to patch elements with two transmission feed lines of 50 ohms impedance which can be used to achieve better control over SLL. The taper optimization for pattern synthesis of antenna arrays having the each antenna element i.e., $\lambda/4$ or $\lambda/2$-transmission line of the patch in an array can be performed. The series array width tapering is the solution for the radiation control over SLL which nearly keeps the element patterns persistent with the broad amplitude range [2].

The phased antenna arrays are deliberated for the applications in satellite communication systems, aerospace platforms etc., which are low profile and light weight. As the development is still in progress for observing the circumstances of complex operational aerospace structure, this can be done through phased antenna arrays. This enhances the methods to develop wireless sensors which are reliable and efficient enough to be used in complex environments and applications. The antennas can be of dipole, microstrip, horn, yagi-uda elements etc. In this paper, the design of phased arrays are designed with the different feeding networks that gives better improvement in the radiation characteristics as the number of antenna elements increases are presented. The array design can includes the frequency of operation, dielectric constant of the substrate and height of the dielectric substrate.

2. THERETICAL BACKGROUND

The phased antenna arrays for the better control over the array performance with antenna mode RCS which can be solved by using different feed networks, tapering of antennas, element and amplitude excitation etc. The amplitude and the phase of excitation control helps to predict the radiation parameters of antenna arrays with the help of frequency of operation [3].

The SLL reduction in antenna array performance used in the applications of digital beam forming which can lead to the reduction in the effect of interference arriving outside the main lobe and suppression of grating lobes. The SLL reduction in the phased arrays can be done by having non-uniform spacing between the antenna elements of amplitude excitation is assumed to be constant. This method may fails to SLL reduction for maximum, this problem can be solved by half power beam width (HPBW) broadening.

To address the extortions in the phased arrays, the array antennas have to operate over large bandwidths with the improved sensitivity, stability, higher radiated power levels etc. which reduces target radar cross-section. The performance limitations of phased antenna arrays of transmission beam former losses and large amount of power required to overcome losses. The side lobe levels in the radiations decides the amplitude and phase of excitation characteristics of the T/R modules and its beam formers.

The development in the phased arrays can include operating frequency, bandwidth, scan coverage, effective isotropic radiated power, beam widths, side lobe levels, stability and phase noise, reliability, availability, maintainability, manufacturing and life-cycle costs, prime power requirements.

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3. PHASED ARRAY PRINCIPLE

The block diagram of an N×N element phased array is shown in figure 1. "N" identical antennas are equally spaced by a distance "d" along an axis. A plane-wave beam is assumed to be incident upon the antenna array at an angle of θ to the normal direction. Because of the spacing between the array antennas, the beams will experience a time delay while reaching successive antennas. The structure of N×N elements having the dimensions of each element of width W, length b and substrate height is h as shown in the figure 1.
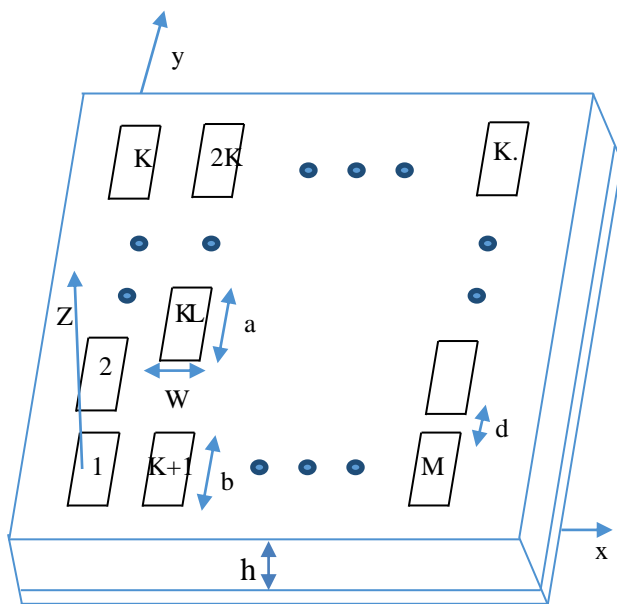

Fig-1: Structure of N element phased array

The incidence angle of a plane wave upon the phased arrays will have a linear delay progression at every successive antenna elements. So, the variable delays must be set to similar but with reverse delay progression to get compensation in the delay of the signal arrived at the antenna elements. In linear phased arrays, the design of variable time delays in order to provide uniform phase progressions across the array elements. In order to enhance the spatial discrimination of phased arrays, the beam width of the arrays can be reduced by increasing the number of array elements.

An advantage of including phased arrays into the communication systems is its spatial filtering capability. Phased arrays can suppress the signals arising from undesired directions, even if one directional elements are used. In general, the final radiation pattern of a phased arrays are determined by adding the received patterns of a each of the single antenna elements by the array factor, by assuming identical antenna elements across the entire array.

4. PHASED ANTENNA ARRAYS BASED ON FEED NETWORK DESIGN

Phased antenna arrays are usually consists of a feed network and a number of phase shifters for coupling. Feed networks used to distribute the output signals from the transmitter to the radiation elements and phase shifters which controls the phase of the signals at each radiating element to form a beam at the vital direction. There are many ways to feed the antenna arrays in existence. In general, array feed networks can be classified into three basic categories space feed, constrained feed and semi constrained feed which is a hybrid of the constrained and the space feeds. The figure 2 shows the power divider network such that the feeding can be done.
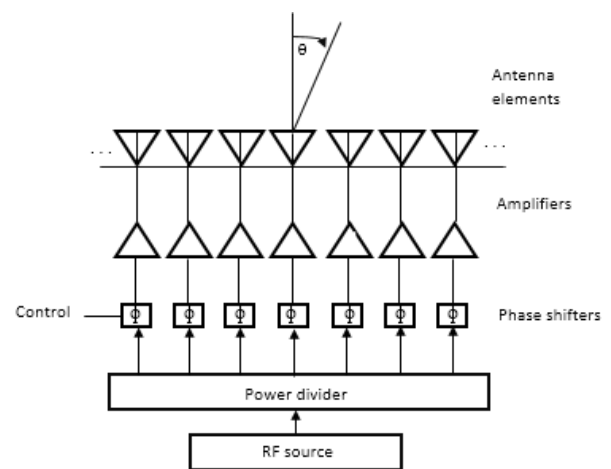
Fig-2: Power divider network

The free space existence between the feeding and radiating elements which can causes the feeding networks not to be a possible planar arrays. Frequently, the method of feeding an antenna array is with constrained feed and generally takes the power from a source and distributes it to the antenna elements with a feed line and passive devices. The feeding methods in the constrained feed are parallel feeds and series feeds [4].

4.1 Parallel-fed Arrays

The parallel feeding networks are commonly called as corporate feeds. In this, the input signals are divided in a corporate network (tree) to all the antenna elements in an array. These networks normally employs power dividers [5]. The array performance analytically depends on the structure of the power splitter/combiner used.

4.2 Series-fed Arrays

In the series-fed antenna array networks, the input signals fed from one end of the antenna and coupled serially to the antenna elements on the other end. The feed improvement nature and phase shifts in the series antenna arrays can relax the design controls on the phase tuning

range of the phase shifters. In an N×N element series-fed antenna array, the number of phased shifts required will be smaller than parallel fed antenna arrays by a factor of N-1. This enables phase shifts through the feeding networks which can results into an increased beam squint which is a main limitation in the series-fed designs. The loss occurs through the phase shifters ban also helps in the growing of series fed arrays which makes an issue in the design of arrays with a large number of array elements.

5. RADIATION OF THE ANTENNA ARRAY

The choice of antenna element can be depends on power, polarization i.e., angle of rotation, feeding arrangement, bandwidth and environmental conditions etc. The antennas can be of microstrip patch, dipole and horn etc. which are generally have narrower bandwidth. The dielectric constant of the substrate can be in the range of $2<\varepsilon_r<12$. The resonant frequency of the phased arrays will decreases linearly with increase in length of the radiation direction [5]. To eliminate all the problems of the objects associated on the axis in a radar system, the phased arrays can be used. The phased antenna arrays are feasible due to their flexibility in speed and multiple beams. In this, the main lobes and grating lobes that mainly confine the radiation performance of arrays from the antenna parameters is between array elements. The side lobes are a moment of the periodicity of the array patterns and depend on the arrangement of the elements in an array.

Phased antenna arrays based on the multiple antenna elements that are used for desired high antenna gain in an authentic direction and interference suppression in undesired directions. The techniques used to reduce the cost of phased antenna arrays can be array thinning and sub-arraying.

Apart from radiation behavior, scattering from antenna array is an important issue. The design of phased arrays are to improve the radiation performance efficiently as per the user requirement.

The main focus of array designs to have suitable antenna gain with optimum beam width, low SLL and reduced radar cross section. The development in the stealth technologies aim at decreasing to the least extent in order to get rid from the enemy radars. With this, low observable platform has a moment of surrendering array performance in terms of gain and radiation characteristics. As far as scattering is concerned it is not only antenna elements in phased array but the entire phased array system comprising of array aperture, and feed network is important [6]. The reflections can takes place at the level of antenna element, phase shifter, coupler, terminating load etc.

The tapering of the antennas with their uniform dimensions on both the sides other than centre element

which can be a possible configuration towards control of SLL in the radiation pattern. The array scattering can be improved by the design parameters and the feed network. It may be series, parallel, or corporate feed network. Thus an optimal design of phased array is required for reducing the impedance divergences and hence the scattering reduces. The space in the phased array can be grouped by many radiating elements those are being controlled phase and amplitude individually. The radiation patterns and the beam pointing directions can be achieved accurately. In order to avoid the generation of multiple beams (side lobes) in the radiation pattern of the elements are spaced by X/2, where X is wavelength, the number of radiating elements N is given by

$$N = \frac{10000}{(\theta_B)^2}$$

$$\theta_B = \frac{100}{\sqrt{N}}$$

Where θ_B is the 3dB beam width in degrees.

Out of all feeding networks like series fed, corporate fed and series-corporate fed, the series-corporate fed is more appropriate possible configuration for the surface current distribution and radiation characteristics in the case of taper antenna array. The tapered antennas with X-band can be used in radar applications, satellite communication and other wireless systems.

The pattern synthesis of rectangular antenna arrays has various current distributions namely uniform, cosine, cosine-squared, Taylor and Dolph-Chebyshev distributions. For uniform distribution, the amplitude of the excitation is constant. The space sector is given by rectangular array on a grounded dielectric substrate [7]. The antenna array RCS versus frequency or angle consists of a number of large peaks which are identified as impedance or pattern factor resonance peaks. The antenna surface is of metallic patch and having the grounded dielectric slab with perfect electric conductor. Over the span, phased antenna arrays are found to be proliferation in the applications due to they are lightweight, essentially flat, moderately ease.

The transformation among the polynomial and isotropic patterns will have the side lobes lower than isotropic pattern. The radiation pattern of the phased antenna array with N=64 is presented in the figure 3.
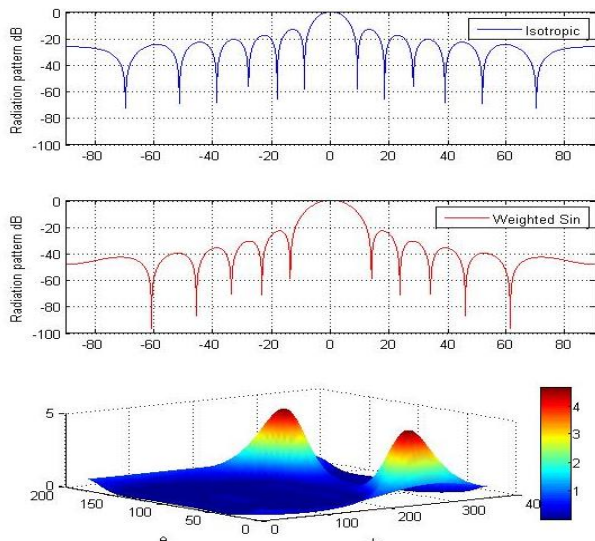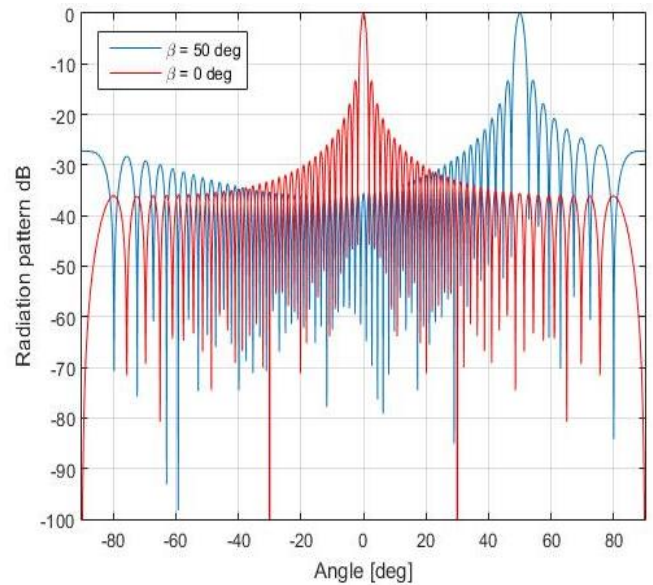
Fig-3: Radiation pattern of the phased antenna array with N=64
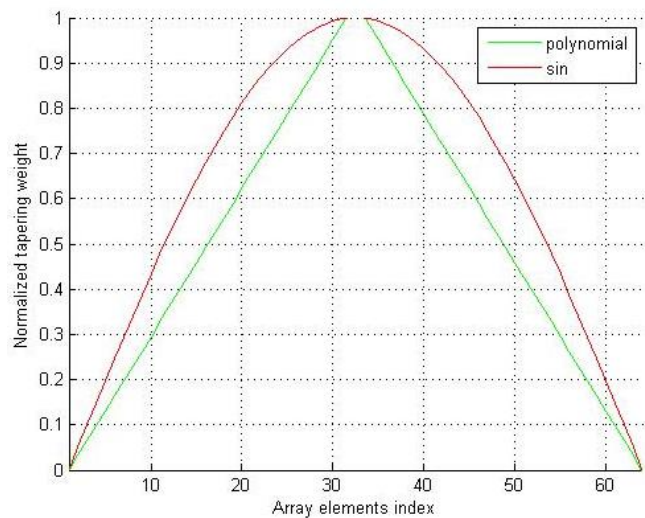
increases with the increase in the gain of an antenna.
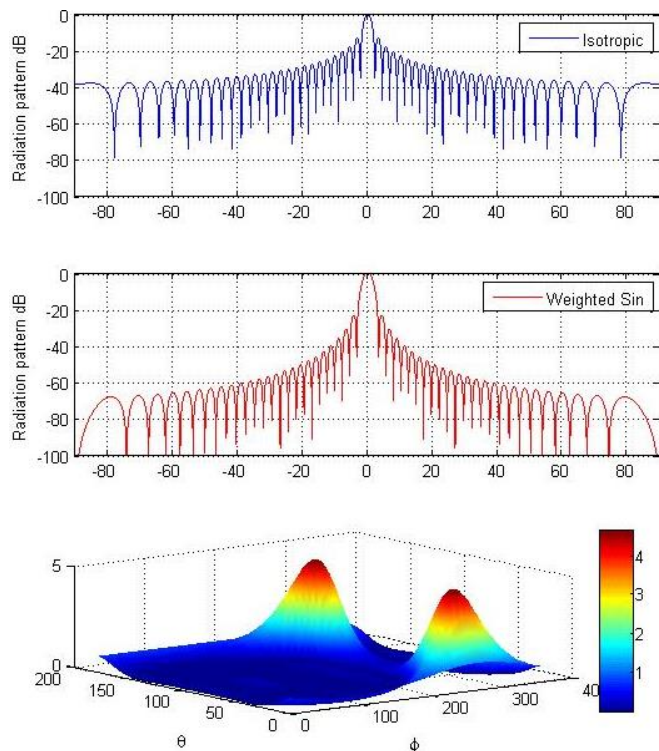
Fig-4: Radiation pattern of the phased antenna array with N=256

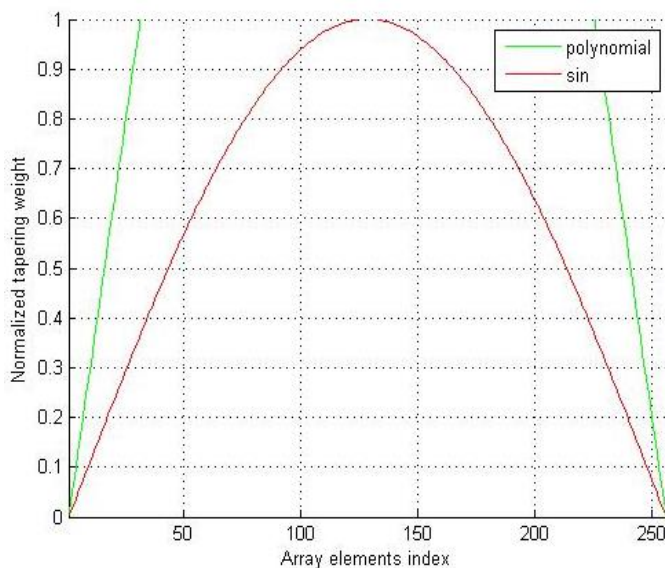The radiation pattern i.e., directivity of the phased antenna array with N=256 is presented in the figure 4.

Fig-5: Radiation pattern of the phased antenna array with Beta=50°

Fig-6: Normalized tapering weight of the phased array with N=64

The angle shift in the isotropic and the polynomial array patterns is shown in the figure 5. In this, the shift is 50°. The normalized tapering weight of the phased array with N=64 elements is shown in the figure 6 and normalized tapering weight of the phased array with N=256 elements is shown in the figure 7.

Fig-7: Normalized tapering weight of the phased array with N=64

6. CONCLUSION

The radiation and scattering of the phased antenna arrays are presented. As the number of elements increases, the directivity increases according to feed design and radiation. To reduce the SLL, the tapering can be more effective without hampering its radiation pattern with the compact.

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