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New design method for derivation of the amplitude distributions of an uniformly spaced n-element linear antenna array

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Abstract

In this work, a linear array that is formed by placing elements along a straight line is considered to shape the beam and control the level of the side lobes by adjusting the amplitudes of the current in the array. The total radiated field, |E| is produced by using the N^{th} Bernstein polynomial, $B_N(f;x)$. So that the well-known linear arrays and rest unrealized ones that uses the current distribution excitations for the required radiation, can be obtained as special cases from an unified analytical procedure by changing f_k coefficients in the Bernstein polynomial. The connection between arrays and Bernstein polynomial is established by considering current excitation symmetrical for obtaining real-valued array function, and by choosing an appropriate transformation between x and Ψ to make the array function and polynomial identical. By this new method, both broadside (maximum radiation at $\theta = \pi/2$) and end-fire (maximum radiation at $\theta = 0$) type arrays can obtain by adjusting the current excitations. Also, to control and change the directivity function at a given Ψ point is possible and one can set the maximum lobe amplitude for a given N and by the time can change the other lobes position and amplitude.

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Keywords: Linear array; antennas; bernstein Polynomial; propagation.

1. Introduction

By using very directive characteristics antenna, one can obtain long distance communication in many applications. According to some references, this can be obtain by the electrical size increased antenna. However, to enlarge the dimensions of the antenna by increasing the size of the individual elements, one can form an assembly of radiating

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elements. This new antenna which can be formed by multi-elements, is named as an array. In an array of identical elements, one can control (i) the geometrical configuration of the overall array, (ii) the relative displacement between the elements, (iii) the excitation amplitude or phase of the individual elements and (iv) the relative pattern of the individual elements, to shape the overall pattern of the antenna.

According to the references, by the vector addition of the individual fields, the total field of the array can be determined. Here the current in each individual element is assumed to be the same. This is usually not the case and it depends on the separation between the elements. To provide very directive patterns, the fields from the elements of the array interfere constructively in the desired directions and interfere destructively in the remaining space. It is proposed that it can be accomplished ideally but it is only approach practically.

In this work, a linear array that is formed by placing N-elements uniformly along a straight line is considered to shape the beam. Also by adjusting the amplitudes of the current in the array, it is proposed to control the level of the side lobes.

For a linear array of equally spaced elements (Fig. 1-2), the relative amplitude of the radiated field strength can be expressed as,

$$|E| = \left|a_p\, e^{-j.(p.\Psi-\alpha_p)} + \cdots + a_n\, e^{-j.(n.\Psi-\alpha_n)} + \cdots + a_p\, e^{j.(p.\Psi-\alpha_p)}\right|$$

where $\Psi = 2.\,(\pi/\lambda).\mathrm{d}.\cos(\theta)$ and (d) is the spacing between elements. The coefficients (a_n) are proportional to the current amplitudes in the respective elements and (α_n) is the progressive phase shift. In this work, the total length of the array (L), the spacing between the array elements (d) is maintained constant. Phase shift is taken as ($\alpha = 0$) for all elements to be able to show the unique of the proposed method. The total field of an array is considered as follows;

E (total) = E (single element at reference point) x AF (Array Factor)

First the point-source array derived. Then by using this array the array factor can be derived and the total field of the actual array can be obtained. (Balanis, 1997; Dolph, 1943; Jordan, 1997)

1.1 Array Factor

1.1.1 Linear Array with Even Number of Elements

In Figure 1 it is shown that an even number of isotropic elements, (N_e) is assumed to be positioned symmetrically along the z-axis. Here N_e / 2 elements are placed on each side of the origin. It is assumed that the amplitude excitation is symmetrical about the origin. With this respect, the array factor of a non-uniform amplitude array can be given as,

$$AF_e = 2.\sum_{n=1}^{N_e/2} a_n \cos\left(\frac{2.n-1}{2}.\mathrm{k.d}.\cos\theta\right) \tag{1}$$

Here, the excitation coefficients of the array elements are defined as (a_n).

1.1.2 Linear Array with Odd Number of Elements

The array factor is defined below for the N_0 odd total number of elements of the array, which is given in Figure 2.

$$AF_o = 2.\sum_{n=1}^{(N_o+1)/2} a_n \cos((n-1).\mathrm{k.d}.\cos\theta) \tag{2}$$

Here, ($2.a_1$) is the amplitude excitation of the center element. The equations can be written as;

$$AF_e = 2.\sum_{n=1}^{N_e/2} a_n \cos\big((2.n-1).\Psi.\big) \tag{3}$$

$$AF_o = 2.\sum_{n=1}^{(N_o+1)/2} a_n \cos((n-1).\Psi) \tag{4}$$

$$\Psi = \frac{\pi.d}{\lambda}.\cos\theta \tag{5}$$

1.2 Broadside Array

To extend the effect of the new design method here it is assumed that one can desire to have maximum radiation in θ = 90° direction. This can be obtain by optimizing the design. In this case the maxima of the single element and of the array factor should both be directed toward θ = 90°. By judicious choice of the radiators the requirements of the single elements can be