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Analysis Of Linear And Planarantenna Arrays

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Abstract
This paper describes the theories and techniques for designing linear and planar Antenna arrays and compares their radiation pattern with conventional arrays. The results of this work are among others, a software that includes the design of linear and planar arrays. Linear arrays cover uniform and non-uniform cases for broadside, endfire, scanning, and Hansen-woodyard radiation patterns.

In linear arrays the amplitude and separation can be chosen for any distribution and triangular. Planar uniform arrays have been incorporated in the software for rectangular and circulargeometries and today we are developing non-uniform arrays for them

Index Terms – Uniform, linear, planar, cantor, Antenna array, Scanning, Broadside, Endfire, Radiation pattern, Hansen-Woodyard,Binomial.

I. Introduction

There has been an ever growing demand, in both the military as well as the commercial sectors, for antenna design that possesses the following highly desirable attributes:

i) Compact size
ii) Low profile
iii) Conformal
iv) Multi- band or broadband

There are a variety of approaches that have been developed over that year, which can be utilized to achieve one or more of these design objectives. The term fractal, which means broken or irregular fragments, was originally coined by Mandelbrot to describe a family of complex shapes that possess an inherent self similarity in their geometrical structure. The original inspiration for the development of fractal geometry came largely from in depth study of the patterns of nature. This geometry, which has been used to model complex objects found in nature such as clouds and coastlines, has space-filling properties that can be utilized to miniaturize antennas. One such area is fractal electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problems. Modern telecommunication systems require antennas with wider bandwidths and Smaller Dimensions than conventionally possible. The design and development of radar systems with arrays is complex and costly. To reduce costs and risks, and to improve the performance of the arrays, we use simulations. These simulations must meet certain criteria they have to be fast and determine the parameters of performance accurately. Because of the need to design antenna arrays and the current reliance on expensive programs, it was decided to create an own tool to obtain reliable results and access the program code to modify the design variables and made optimization.

One of the main advantages of antenna arrays respect to other types of antennas is the ability to direct its beam electronically through the excitement phase between the elements [1-3].

The purpose of the study is to develop a computer program by modifying an existing computer code which can be utilized as an educational method to develop insight into radiating structures by the beginning student of electro-magnetic theory.

The MATLAB tool for analysis and design of linear and planar antenna arrays is directed toward the advanced student who has the expertise necessary to manipulate the input data for proper execution of the larger more comprehensive analysis program. Even though this tool is small in core requirements and

is fast in run time, it is capable of analyzing structures to assist the engineer with design problems.[4-6]

II. Literature Survey On Analysis Of Linear Antenna Arrays

The linear arrays of antennas allow the generation of radiation patterns whichcannot be obtained with simple antennas. In the available literature, there is the analysis of a variety oftypical linear arrays. Some authors provide computer software to support the analysis, however, all themare limited versions respect to the functions it performs. This paper presents the analysis of linear arraysof antennas supported by a program developed specifically for this purpose.

The developed program is a tool to analyze the field of antenna arrays. The antenna arrays are used in radar, guidance systems for navigation and astronomy, among others. The program was developed in the most actual version of MatLab language, and is managed through a menu. Some data that can provide are the number of elements, location and orientation of them and the type of excitation (uniform, binomial, triangular, etc.). [7-9]The program will output graphics array factor or radiation pattern, as the case, indicating the beam width, directivity, lobe ratio and other characteristics of the patterns.

The program also has features which allow performing the analysis of arrangements and phasing separation even with variableamplitude. In this case the program calculates excitation amplitude ratios for different types of distribution such as binomial

$$(AF)_{2M}(\text{even}) = \sum_{n=1}^{M} a_n \cos[(2n-1)u]$$

$$(AF)_{2M+1}(\text{odd}) = \sum_{n=1}^{M+1} a_n \cos[(2n-1)u]$$

$$u = \frac{\pi d}{\lambda}\cos\theta$$

III. Two-Element Array

The total field radiated by two elements, assuming no coupling between the elements, is equal to the sum of the two and in the x-y plane it is given by

$$E_t = E_1 + E_2 = \hat{a}_0 j\eta \frac{kI_0 l}{4\pi}\left\{\frac{e^{-j[kr_1-(\beta/2)]}}{r_1}\cos\theta_1 + \frac{e^{-j[kr_2-(\beta/2)]}}{r_2}\cos\theta_2\right\}$$

Where β is the difference in phase excitation between elements. The magnitude excitation of the radiators is identical. Assuming far-field observations and referring to the Fig. 1

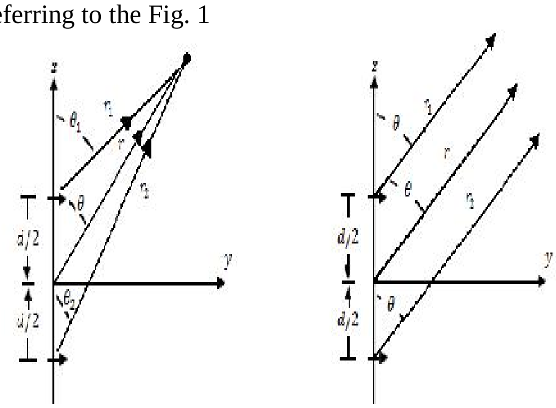


Fig:1- Geometry of a two-element array positioned along the z-axis.Two infinitesimal dipoles (left), Far-field observations (right)

$$\left.\begin{aligned} r_1 &\cong r - \frac{d}{2}\cos\theta \\ r_2 &\cong r + \frac{d}{2}\cos\theta \end{aligned}\right\}, \text{For phase variations}$$

$$r_2 \cong r + \frac{d}{2}\cos\theta, \text{ For amplitude variations}$$

$$E_t = \hat{a}_\theta j\eta \frac{kI_0 l e^{-jkr}}{4\pi r}\cos\theta\left[e^{+j(kd\cos\theta+\beta)/2} + e^{-j(kd\cos\theta+\beta)/2}\right]$$

$$E_t = \hat{a}_\theta j\eta \frac{kI_0 l e^{-jkr}}{4\pi r}\cos\theta\, 2\cos\left[\frac{1}{2}(kd\cos\theta+\beta)\right]$$

Each array has its own array factor. The array factor, in general, is a function of the number of elements, their geometrical arrangement, their relative magnitudes, their relative phases, and their spacing.

The array factor will be of simpler form if the elements have identical amplitudes, phases, and spacing. Since the array factor does not depend on the directional characteristics of the radiating elements themselves, it can be formulated by replacing the actual elements with isotropic (point) sources. Once the array factor has been derived using the point-source array, the total field of the actual array is obtained Each point-source is assumed to have the amplitude, phase, and location of the corresponding element it is replacing.

In order to synthesize the total pattern of an array, the designer is not only required to select the properradiating elements but the geometry (positioning) and excitation of the individual elements. To illustratethe principles, in Fig. 2 an example of pattern multiplication is shown

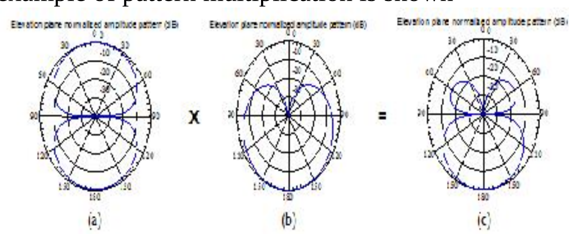


Figure 2. Pattern multiplication of element (a), array factor (b) and total array patterns (c) of a two-element array of infinitesimal horizontal dipoles with β = 90°, d = λ/4.

The null at θ= 90° is attributed to the patterns of the individual elements of the array while the remaining ones are due to the formation of the array. For no phase difference between the elements, the separation d must be equal or greater than half a wavelength (d ≥ λ /2) in order for at least one null, due to the formation of the array to occur.

IV-N-Element Linear Array: Uniform Amplitude And Spacing

Now that the arraying of elements has been introduced and it was illustrated by the two-element array, let us generalize the method to include N elements [11]. Referring to the geometry of the Fig.3, let us assume that all the elements have identical amplitudes but each succeeding element has a β progressive phase lead current excitation relative to the preceding one (β represents the phase by which the current in each element leads the current of the preceding element).\

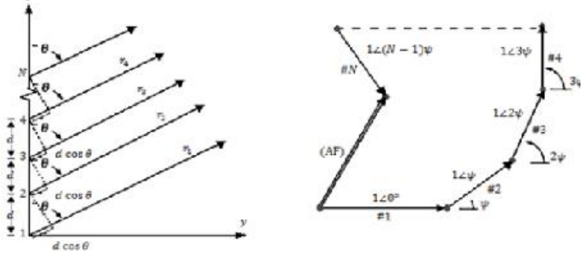


Figure 3. Far-field geometry (left) and phasor diagram (right) of N-elements array of isotropic source positioned along the z-axis.

An array of identical elements all of identical magnitude and each with a progressive phase is referred to as an uniform array. The array factor can be obtained by considering the elements to be point sources.[7-9]

Since the total array factor for the uniform array is a summation of exponentials, it can be represented by the vector sum of β phasor each of unit amplitude and progressive phase relative to the previous one.[10-13]

Graphically this is illustrated by the phasor diagram in Fig. 3. It is apparent from the phasor diagram that the amplitude and phase of the AF can be controlled in uniform arrays by properly selecting the relativephase between the elements; in non uniform arrays, the amplitude as well as the phase can be used to control the formation and distribution of the total array factor

Results

The Broadside Array

In many applications it is desirable to have the maximum radiation of an array directed normal to the axis of the array (broadside: θ = 90°). To optimize the design, the maxima of the single element and of the array factor should both be directed toward θ = 90°.

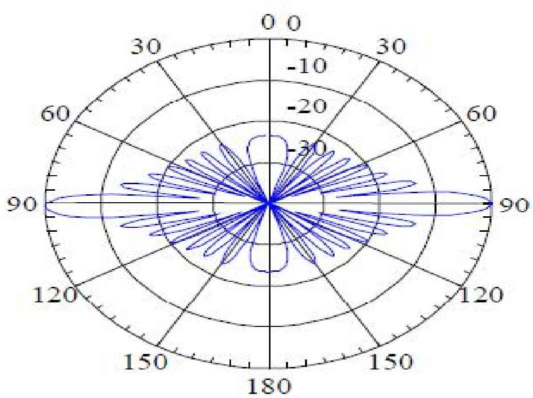


Fig 4.Broadside array factor with N = 15,d = λ/2.

The End-fire Array

Instead of having the maximum radiation broadside to the axis, it may be desirable to direct it along the axis of the array (end-fire).[10-13]

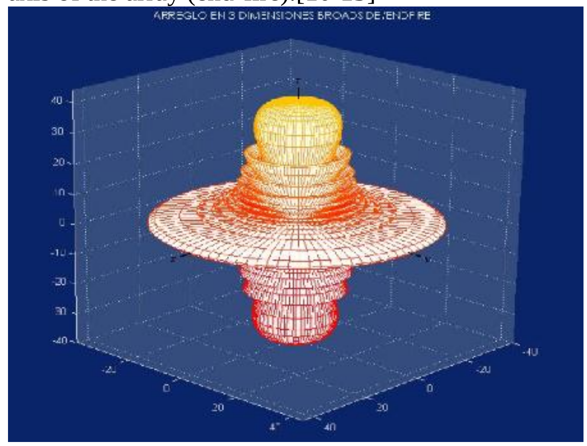


Figure 5. Three-dimensional amplitude patterns for broadside/end-fire array of a 10-element whit uniform amplitude: N = 10, β = 0, and d = λ.

Phased (Scanning) Array

In the previous two sections it was shown how to direct the major radiation from an array, by controlling the phase excitation between the elements, in directions normal (broadside) and along the axis (end-fire) of the array. It is then logical to assume that the maximum radiation can be oriented in any direction to form a scanning array. Let us assume that the maximum radiation of the array is required to be oriented at an angle θ

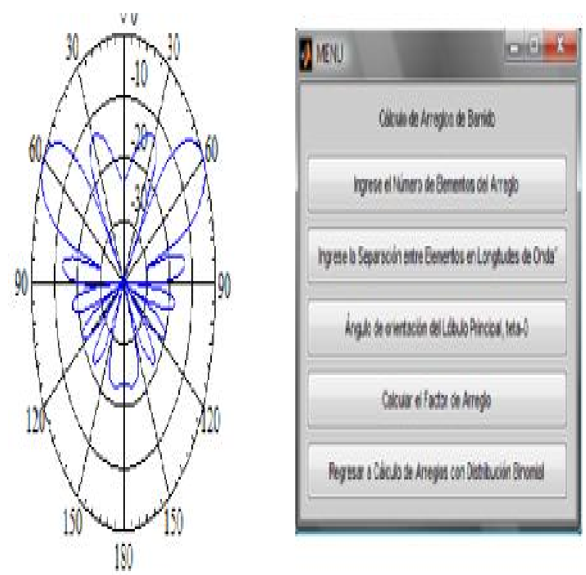


Fig6. Scanning array pattern with N = 15,d = λ/4,θ = 60° (left); Respective menu forScanning patterns included in the software (right).

Planar Array

Planar arrays are those in which the array elements are located on a plane, there are several settings that can be obtained, for example, rectangular arrays, circular or cross.

Planar arrays are much more versatile than linear arrays [14,15] as they have larger number of control parameters, allowing the obtainment of more symmetrical patterns with smaller side lobes and facilitating the movement of the main beam toward any point in space. These characteristics make the arrangements to be flat, ideal for applications such as radar, smart antennas applied to modern communications, radio astronomy, telemetry, etc.

$$AF = \sum_{n=1}^{N} I_{1n}\left[\sum_{m=1}^{M} I_{m1} e^{j(m-1)(kd_x sen\theta\cos\varphi+\beta_x)}\right]\cdot e^{j(n-1)(kd_y sen\theta\cos\varphi+\beta_y)}$$

3D (Dimensionless)

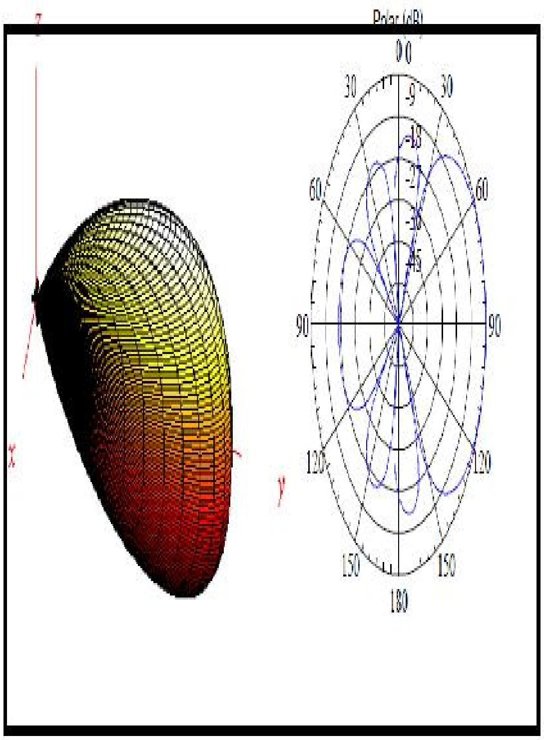


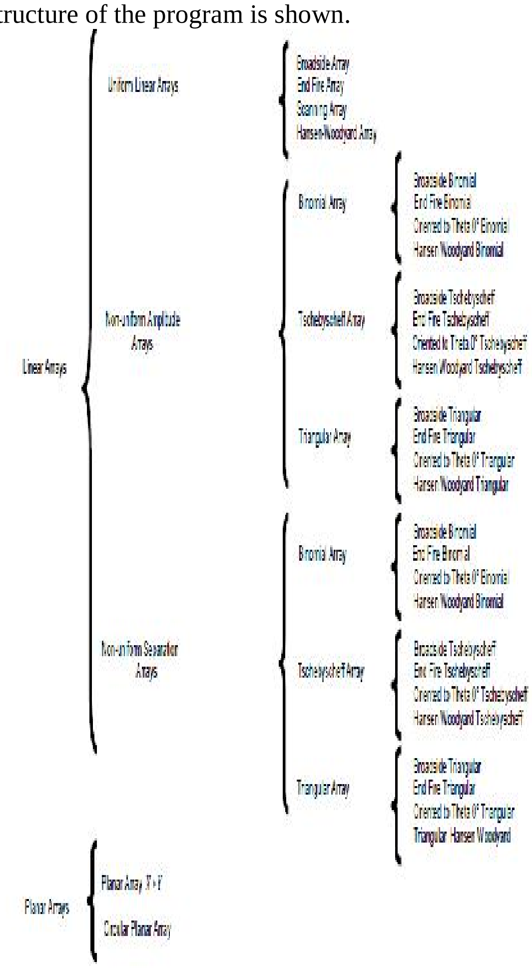
Fig 7(Left) Rectangular Array Factor 3D (dimensionless)

The array that produces the array factor radiation shown in Fig. 7 is one of the simplest cases becausethe amplitude excitation is uniform and phase of excitation in each element is equal. However, theseparameters and even the separation between elements can be established according to specificdistributions (binomial, Tschebyscheff, triangular, sinusoidal, etc.) factor leading to the desired array.

V.Software Structure

The software was created as a versatile and powerful tool to generate the most patterns known and with an open code to improve and add more subroutines inside it, and to expand its limits, that why actually there is a lot of interest and work to do about this issue, developing the last part (planar arrays) and trying to get new patterns and analyzing new distributions in amplitude and separation.

A schematic diagram is presented where a completely structure of the program is shown.



VI.Conclusion

The programs developed greatly facilitate the design of almost any type of antenna array, in the case of flat rectangular arrays, it has been developed a general algorithm that can be extended to consider arrays with different excitations in both: amplitude and phase as well as non-uniform separation between elements. It is currently working to improve the design of flat rectangular and circular arrays.

For calculating the mutual coupling between elements, especially with micro-strip antennas modeling them and making much more investigation in this line of knowledge.

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