Analysis and Design of Antenna Arrays for Microwave Links

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Abstract: - In this paper, the design of some antenna arrays for microwave links are carried out. The main performance parameters used are the gain and radiation patterns. The antenna arrays were designed for uniform, binomial and Dolph-Tschebyscheff excitations. Theoretical and simulation results are given.

Key-words: - Antenna, Antenna Array, Microwave links, EMC, Radiation pattern, Binomial Array.

1 Introduction
A lot of communications systems that provide mobility use antenna array, because it is possible to obtain a versatile radiation pattern [5], [6] and [7].
In this paper, the elements of antenna array are linear or planar, see Figure 1.

This kind of array is employed in both terrestrial and satellite mobile systems. The implementation of this antenna can be included in the terminal equipment by microstrip techniques.
The structure of this paper is the following: the section two is dedicated to show the procedure to design antenna arrays, the results of this work are presented in the sections three; and, the section four shows the conclusions.

2 Antenna Array Design
The antenna array is a set of single antennas normally oriented in the same direction. The elements of the array are separated by a short distance. These elements are uniformly separated in one, two or three dimensions. The final radiation pattern can be directed in one or more desired destinations [4] and [6].
There are many applications that require an irregular radiation pattern, this may be solved by antenna arrays. The terrestrial cellular system is one of the most known examples of this problem [3].
The array factor is the result of the elements combination. In the first case the amplitude and spacing are uniform, see equations (1) and (2).

\[ AF = \sum_{n=1}^{N} \left\{ e^{j(n-1)\omega} \right\} \] (1)
\[ \psi = kd \cos \theta + \beta \quad (2) \]
\[ k = \frac{2\pi}{\lambda} \quad (3) \]

Where \( N \) is the number of elements; \( \beta \) is the difference in phase excitation between the elements, rad; \( \theta \) is the angle to the destination, rad; and, \( d/2 \) is the separation between the elements, m.

Figure 2 shows an example of binomial arrays.

![Binomial two-element array](image1)

**Fig. 2 Binomial two-element array.**

If the magnitude of each element is different, the array factor is determined by equations (4), (5) and (6).

\[
AF_{2M} = \sum_{n=1}^{M} \left\{ a_n \cos \left( (2n-1)\frac{u}{\lambda} \right) \right\} \quad (4)
\]

\[
AF_{2M+1} = \sum_{n=1}^{M+1} \left\{ a_n \cos \left[ 2(n-1)\frac{u}{\lambda} \right] \right\} \quad (5)
\]

\[
u = \frac{\pi d}{\lambda} \cos \theta \quad (6)
\]

Equation 4 is for even-arrays with \( 2M \) elements and, equation 5 is for odd-arrays with \( 2M+1 \) elements; where \( M \) is an integer. There are two main techniques to excite the elements for non-uniform magnitude antenna arrays: Binomial and Dolph-Tschebyscheff. Binomial arrays excite the elements according to the Pascal’s triangle, see Figure 3.

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**Fig. 3 Pascal’s triangle.**

In Binomial arrays, the excitation of the elements is symmetrical in the array. In Figure 4 an example of binomial array is illustrated.

![Binomial four-element array](image2)

**Fig. 4 Binomial four-element array.**

In comparison to this, Dolph-Tschebyscheff uses a polynomial distribution \[2\], where each polynomial can be computing using (7), (8) and (9).

\[
T_m(z) = 2zT_{m-1}(z) - T_{m-2}(z) \quad (7)
\]

\[
T_m(z) = \cos \left[ m \cos^{-1}(z) \right], \quad -1 \leq z \leq 1 \quad (8)
\]

\[
T_m(z) = \cosh \left[ m \cosh^{-1}(z) \right], \quad z < -1, \ z > 1 \quad (9)
\]

In this work, the arrays designed are uniform, binomial and Dolph-Tschebyshev, for two or three elements in linear arrays.

![Dolph-Tschebyscheff array](image3)

**Fig. 5 Dolph-Tschebyscheff array.**
In Figure 5 an 8-element Dolph-Tschebyscheff array is shown.

3 Results
The arrays simulated use the dipole shown in the Figure 6, instead the infinitesimal isotropic antenna assumed in the equations (1) to (9).

![Single element of the arrays.](image)

The single element has the antenna pattern illustrated in Figure 7. In this plot, both horizontal and vertical patterns are shown in red and green respectively.

![Antenna pattern of a single element.](image)

The results presented here were obtained with HFSS.

In Figure 8 is possible to see the excitation of a single element in the array.

The color table displayed in Figure 8 indicates the excitation level, blue color the lowest level and, the red color the highest level.

Note that these colors are in the two sides of the dipole.

![Single element simulation.](image)

In figure 9, the two-element binomial array and its simulation can be shown.

![Two-element array.](image)
The antenna pattern corresponding to two-element array is illustrated in Figure 11. Finally, the three-element array simulation and its radiation pattern are illustrated in Figures 12 and 13.

4 Conclusions
This paper shows the performance of some antenna arrays designed for microwave applications [1]. The theoretical analysis and their simulations are carried out. Theoretical results were obtained using Matlab and, simulations were computed employing HFSS. The antenna patterns are quite similar, but in the simulations some real dipoles were modeled.

The arrays designed and simulated were excited by uniform, binomial and Dolph-Tschebyscheff techniques. These arrays can modify significantly their antenna patterns in order to cover irregular areas in terrestrial and satellite mobile communication systems [2].

Now, the results of this paper are used in smart antennas for mobile systems.

References:


