THE ANTENNA ARRAY

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Abstract

The presented program is devoted to the analysis of general ekvidistant antenna arrays. "The Antenna Array" computes gain, radiation resistance and directivity patterns of antenna systems.

1. Introduction

At the present time, antenna arrays are systems of the great importance. They are used for synthesis of directivity patterns, for construction of superdirective antennas and electronically steerable antennas, for adaptive beamforming, etc. Designers of such systems are interested in gain, directivity pattern and radiation resistance of antenna arrays. Computations of these parameters are not difficult but they consume a lot of time. That is the reason why the program "The Antenna Array" has been written.

2. Description of the program

In Fig.1, you can see the shape of an antenna array, which can be analyzed by the presented program. An antenna system may consist of "row of elements", "rectangle of elements" or "cube of elements" which are or are not completed by a reflector in the plane xy. Elements are spaced d_x, d_y, d_z and linearly phased by the phase steps Φ_x, Φ_y, Φ_z in respective directions.

In the presented version of the program, only dipoles may be elements of the array but the library of elements is expected to become more rich.

Directivity pattern of an array is computed according to the relation

$$F(\varphi,\theta) = F_0(\varphi,\theta) \,.\, F_A(\varphi,\theta) \,.\, F_R(\theta) \qquad (1)$$

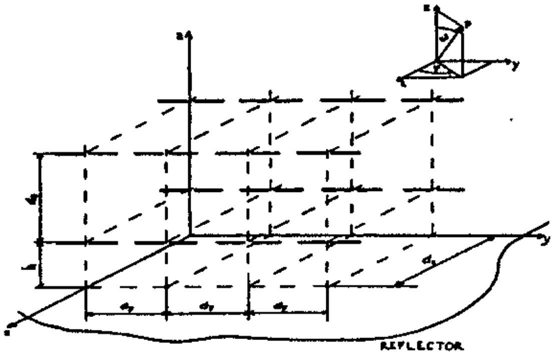

Fig.1
Structure of tested antenna arrays

where $F_0(\varphi,\theta)$ is directivity pattern of an antenna element; in the case of dipole

$$F_0(\varphi,\theta) = \frac{\cos(kl \,.\, \sin\theta \,.\, \sin\varphi) - \cos(kl)}{\sqrt{1 - (\sin\theta \,.\, \sin\varphi)^2}} \qquad (1a)$$

$F_A(\varphi,\theta)$ is the array factor

$$F_A(\varphi,\theta) = \frac{\sin\alpha \,.\, \sin\beta \,.\, \sin\left[\frac{n_z}{2}(kd_z\cos\theta - \Phi_z\right]}{\sin\left[\frac{1}{2}(kd_z\cos\theta - \Phi_z)\right]}$$

$$\alpha = \left[\frac{n_x}{2}(kd_x\sin\theta \,.\, \cos\varphi - \Phi_x)\right] \qquad (1b)$$

$$\beta = \left[\frac{n_y}{2}(kd_y\sin\theta \,.\, \sin\varphi - \Phi_y)\right]$$

$F_R(\theta)$ describes influence of reflector

$$F_R(\theta) = 2\sin(kh\cos\theta) \qquad (1c)$$

In relations (1) respective symbols denote :

φ, θ coordinates of spherical system,
n_x, n_y, n_z number of elements in respective directions, d_x, d_y, d_z spacing in respective directions,
Φ_x, Φ_y, Φ_z phasing in respective directions,
$2l$ length of dipole,
$k = \frac{2\pi}{\lambda}$, where λ is wavelength,
h distance of reflector.

Radiation resistance related to the maximum of current of one element is computed according to the relation

$$R_{\sum_m} = \frac{30}{\pi}\int_0^{2\pi}\int_0^{\pi} |F(\varphi,\theta)|^2 \sin\theta \, d\varphi \, d\theta \qquad (2)$$

Gain of an array is computed according to the relation

$$G = 10\log\left(\frac{120}{R_{\sum_m}} . F_{max}^{2}\right) \qquad (3)$$

3. Examples

Assume two dipoles $\frac{l}{\lambda} = 0.25$ situated in x-direction of coordinate system. They are spaced $dx = 0.25\,\lambda$ and phased $\Phi_x = 90\,°$. Directivity pattern in plane xz (in polar coordina tes) is drawn in Fig.2, G = 5.16 dB, $R_{\sum_m} = 146\,\Omega$.

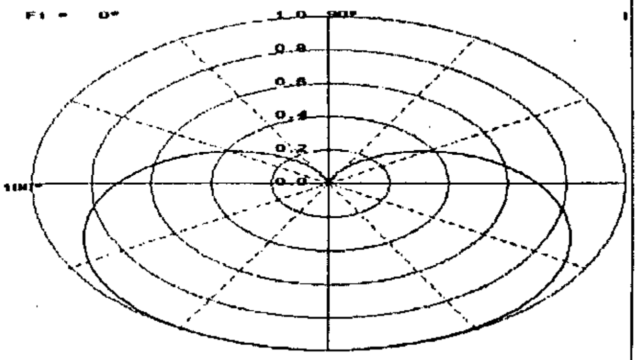

Fig.2
Example of directivity pattern in polar coordinates

Assume four dipoles $\frac{l}{\lambda} = 0.25$ situated in y-direction of coordinate system. They are spaced $dy = 0.5\,\lambda$ and phased $\Phi_y = 135°$. Directivity pattern in plane yz (in carthesian coordinates) is drawn in Fig.3, G = 6.42 dB, $R_{\sum_m} = 182\,\Omega$.

Assume rectangle of dipoles $\frac{l}{\lambda} = 0.25$ - four dipoles in x-direction and two in y-direction. They are spaced in both directions $dx = dy = 0.5\,\lambda$ and there is a reflector in the distance $h = 0.25\,\lambda$ from dipoles. There is no phasing $\Phi_x = \Phi_y = 0\,°$ in the case of Fig.4a and phasing $\Phi_x = 60°$, $\Phi_y = 0°$ in the case of Fig.4b.

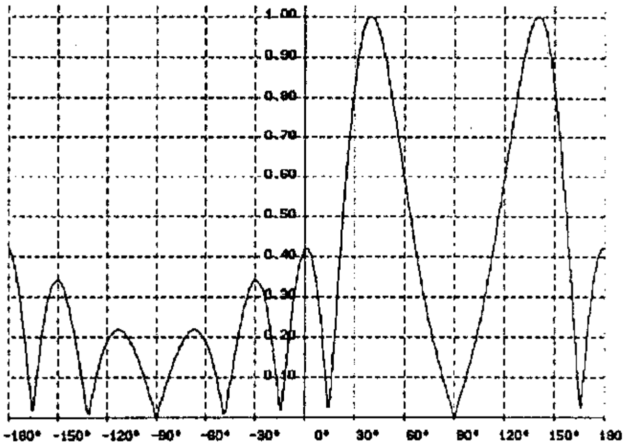

Fig.3
Example of directivity pattern in carthesian coordinates

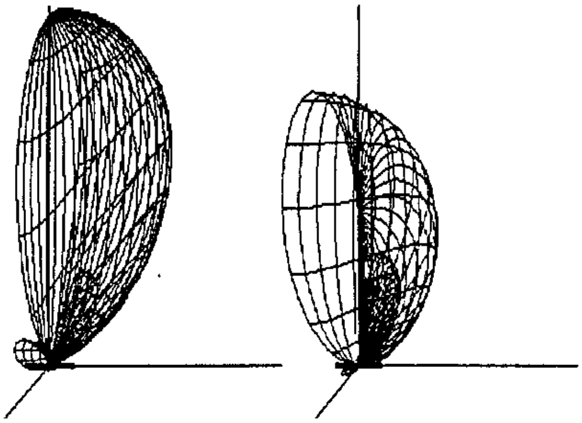

Fig.4.
Example of 3D directivity patterns. [a) left, b) right]

4. Conclusion

"The Antenna Array" is a useful tool for both antenna array designers and students. From the educational point of view, this program makes easier understanding the basic pro perties of antenna arrays because students can change configuration, spacing and phasing of antenna and observe effect of these actions to properties of an array.

"The Antenna Array" is tested in teaching at dpt. of Radioelectronics at TU Brno.

References

[1] Černohorský,D. - Nováček,Z.: Antény a šíření elektromagnetických vln, ES VUT, Brno, 1989.

About author

See Radioengineering Vol. 1, No. 2, 1992, p. 17