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Modeling Beam forming in Circular Antenna Array with Directional Emitters

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ABSTRACT: The article discusses the functioning of the radio direction-finding and beamforming methods in the system of circular antenna arrays formed from the designed radiators, directional factor which is not equal to 1. Evaluation of forming of spatial pattern of cylindrical antenna array using phased method is fulfilled. Dolph-Chebyshev window is used to reduce the side lobe level.
Keywords : Antenna, Cylindrical antenna; Direction-Finding; Digital Processing; Dolph-Chebyshev; Phased array; Super resolution.

I. INTRODUCTION

Adaptive beamforming of antenna arrays (AR) can significantly increase the ratio of the transmitting signal power to interference and noise power. One way it is beamforming based on an assessment of the angular coordinates of radio sources. In such problems, the required number of primary modules processing the received signals and analog-to-digital converters can reach high values [1]. The different configurations are used today, but ones with the patch antennas which have the directive factor higher that one took great interest. One of the most famous configuration is cylindrical antenna arrays.

II. PROBLEM FORMULATION

Let an antenna array consist of *N* antenna elements (AE). Let's assume, that M radio signals arriving on the antenna array from distinct directions $\{\phi_m, \theta_m\}_{m=0}^{M-1}$. For an arbitrary geometry configuration antenna array a complex output signal vector can be written as: [1]:

$$\vec{\mathbf{x}}(t) = \mathbf{A} \cdot \vec{\mathbf{s}}(t) + \vec{\mathbf{n}}(t), \tag{1}$$

where $\vec{\mathbf{x}}(t)^T$ – *N*-dimensional vector describing output signals of each antenna element, $\vec{\mathbf{s}}(t)$ – *M*-dimensional signal vector; $\vec{\mathbf{n}}(t)$ – *N*-dimensional noise vector of spatial channel and receiver; $\mathbf{A}$ – *N*×*M* matrix of steering vectors, *m*th column of the matrix describes phase distribution of *m*th signal source inside antenna array. Assume that the antenna elements in the circular antenna array are identical and have a maximum radial direction from the center of the array, $g\left(\phi - \frac{2\pi n}{N}\right), n = 0,1,\ldots,N-1$. In this case, the steering vector is defined as [2]:

$$\mathbf{a}(\theta) = \left[g(\theta) e^{j\beta r \cos\theta} \quad \ldots \quad g\left(\theta - \frac{2(N-1)\pi}{N}\right) e^{j\beta r \cos\left(\theta - \frac{2(N-1)\pi}{N}\right)} \right]^T, \tag{2}$$

where $\beta = \frac{2\pi}{\lambda}$ - wave number (λ – wave length), $g(\cdot)$ - amplitude response of the antenna element (i.e., antenna gain) in the direction of θ.

It should be noted that since the direction vector (2) represents the amplitude and phase responses of the antennas in the composition of the lattice (1) from different incident waves, the gain g is the voltage gain (or current) relative to the values that could be taken hypothetical isotropic antenna . Antennas are typically defined in terms of their radiated (or received) power in a certain direction with respect to an isotropic antenna. If the radiation pattern of the antenna power to designate as a linear gain G (θ) relative to an isotropic antenna, then $g(\theta) = \sqrt{G(\theta)}$.

To investigate the effect of the directivity of the accuracy of the direction-finding is necessary to have a model of a hypothetical radiation pattern of the antenna. In this article the problems and limitations of the antennas of the development process are not considered, the purpose of the work to investigate the effect of NAM focus on the accuracy of radio direction finding. Model pattern of the antenna element in the far zone has

$(1+\cos(\theta))^m$ response in the azimuthal plane, where m directivity control. Such NAM has CPV, which increases with increasing m and has a maximum gain at θ = 0 °. This model is a close approximation of the antennas which have the radiation on the back side, such as a microstrip antenna with a finite ground. Furthermore, it is assumed that a symmetric Nam dimensional plane, then the normalized diagram for emitters arranged in a ring, looks like [4, 5]:

$$U_n(\varphi,\theta)=\frac{1}{2^{2m}}(1+\sin(\varphi))^m\left(1+\cos\left(\theta-\frac{2\pi n}{N}\right)\right)^m, n=0,1,\ldots,N-1 \quad (3)$$

It should be noted that the maximum of each element extends radially from the center of the ring are uniformly distributed AR. Using a mathematical model DN (3) directional coefficient of each antenna element in the composition calculated as the lattice [4, 5]:

$$D=\frac{2^{2m+2}\pi}{\int_0^{2\pi}\int_0^{\pi}(1+\sin(\varphi))^m(1+\cos(\theta))^m\sin(\varphi)d\varphi d\theta} \quad (4)$$

For an isotropic antenna, m = 0 and D = 1 in the expression (4), and by increasing the D m orientation also increases. For example, when m ≈ 2.7, D = 4 and when m ≈ 8,7, direction D = 10, etc.

From the expression (4) can be derived on a theoretical model DV power in the far field at plane φ = 90 ° relative to an isotropic antenna, assuming that the antennas are perfectly matched and lossless [4, 5]:

$$G(\theta)=\frac{D}{2^{2m}}\left(1+\cos\left(\theta-\frac{2\pi n}{N}\right)\right)^m, n=0,1,\ldots,N-1$$

Fig. 1 shows the theoretical Nam hypothetical antenna for φ = 90 ° from the directional coefficients D = 2, 4, 10, 25, 50 (i.e., from 3 dBi to 17 dBi) and isotropic AE NAM for comparison.

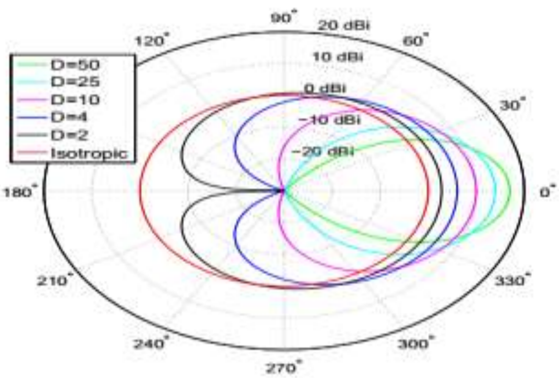


Fig. 1. Curves for different spatial patterns *D* = 1, 2, 4, 10, 25, 50, φ = 90°.

The research of beamforming method via composed of circular antenna arrays depending on the directivity of the antenna elements is fulfilled. Such antenna arrays composed of directed radiators, called conformal. Range the directive factor wipe from 1 (omnidirectional transmitter) up to 30. If the number of emitters equal to eight, and taking into account that the width of the substrate λ/2, take radius as $r=(1+\sqrt{2})\lambda/4$, then gap ("*Gap*") between the elements is empty (Fig. 2), also consider the configuration of radius λ.

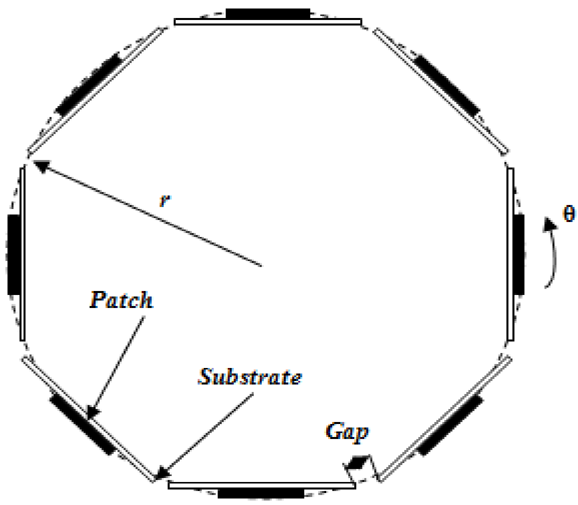


Fig. 2. The circuit array of eight designed radiators, consisting of a substrate ("Substrate") and the radiator ("Patch").

In telecommunication systems, when the output signal of time *k* is obtained as data by linear combination with *N* antenna elements [3]:

$$y(k) = \vec{\mathbf{w}}^H \vec{\mathbf{x}}(k) \,,$$

where $\vec{\mathbf{w}}$ – vector of weights. While changing $\vec{\mathbf{w}}$, the beam pattern can be positioned in any direction of the radiation pattern and adaptively control its shape to the total power of interference and additive noise was minimal with minimal distortion of the useful signal, i.e. .:

$$\min_{\vec{w}} E\{\vec{\mathbf{w}}^H \vec{\mathbf{x}}_{i+n}\} \text{, при } \vec{\mathbf{w}}^H \vec{\mathbf{a}}_1 = 1$$

where $\vec{\mathbf{x}}_{i+n}$ – signal from the antenna elements of the array, containing only interference and noise. In this beam shaper the weight vector is selected to be equal to the steering vector of the desired signal, i.e. [3]:

$$\vec{\mathbf{w}} = \vec{\mathbf{a}}(\theta_1) \,.$$

Here, the radiation pattern comprises a maximum in the direction θ_1. This usually has high side lobes, then weighting vector required (here we use the Chebyshev window to reduce the sidelobe level to -30 dB). The presence of sidelobes means that the array is radiating energy in untended directions. Additionally, due to reciprocity, the array is receiving energy from unintended directions. In a multipath environment, the sidelobes can receive the same signal from multiple angles. This is the basis for fading experienced in communications. The sidelobes can be suppressed by *weighting*, *shading*, or *windowing* the array elements [3]. Then the vector of weights:

$$\vec{\mathbf{w}} = \vec{\mathbf{a}}_0 \otimes \vec{\mathbf{t}} \,,$$

where $\vec{\mathbf{t}}$ – windowing vector.

Using Dolph-Chebyshev method of windowing for eight element antenna array allows computing the following coefficients: 1.0000, 0.6242, 0.2254, 0.0364, 0.0364, 0.2254, 0.6242, 1.0000. In this case, the radiating elements in the opposite direction from the signal source just ‘off’ (Fig. 3).

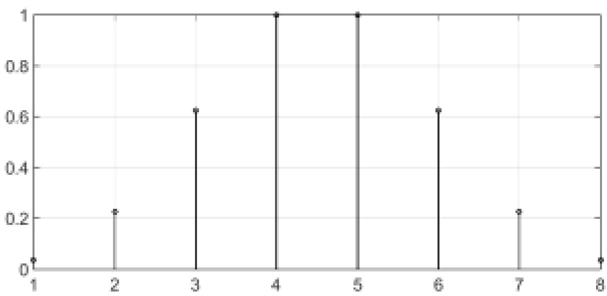
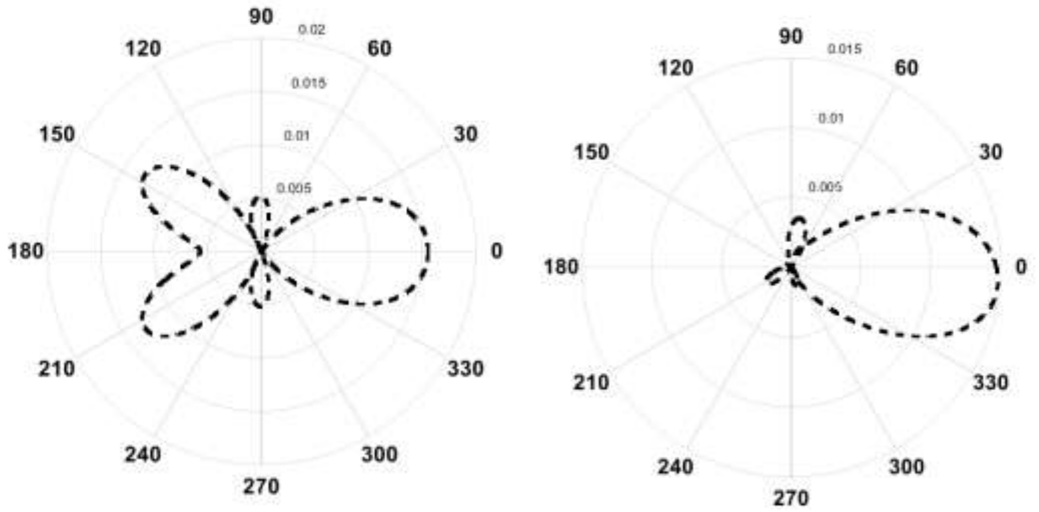


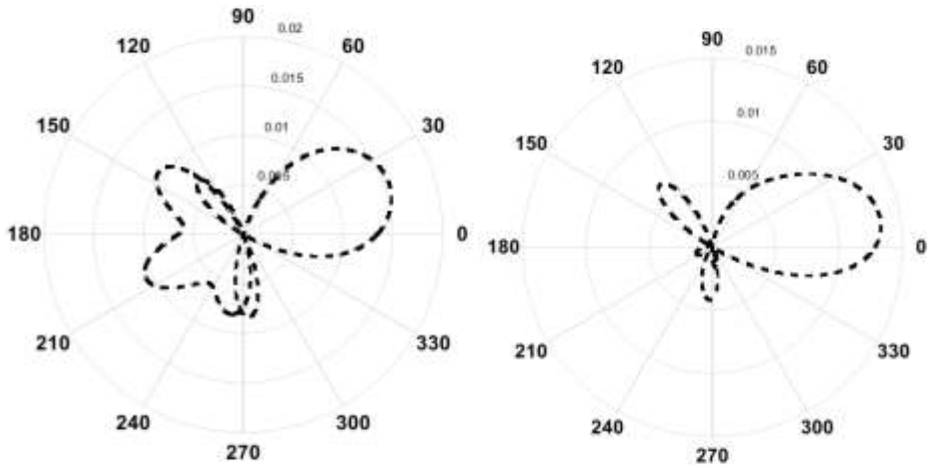
Fig. 3. Window of Dolph-Chebyshev



a) **b)**

Fig. 4. The radiation pattern a) without windowing
b) with window function of Dolph-Chebyshev

As can be seen from Fig. 4, beamforming without using the smoothing window function side-lobe level is several times higher than that with Dolph-Chebyshev window. Consider the radiation pattern of circular antenna arrays when you turn on the main beam of 20 °.



a) b)

Fig. 5. The radiation pattern a) without windowing
b) with window function of Dolph-Chebyshev

From Fig. 5 it seen that when you turn the main lobe of the radiation pattern using the Dolph-Chebyshev windows side-lobe level is also significantly reduced relative to conventional beamforming. The difference between the levels of the side lobes reaches 10dB and higher.

III. CONCLUSIONS

The paper analyzes the forming of the pattern of the circular antenna array composed of eight radiators with directional factor equal to ten. When using the method according to the smoothing window Dolph-Chebyshev the sidelobe level is greatly reduced as in the radiation azimuth 0 °, and in turn, in particular by 20 °.

REFERENCES

[1]. Krim H. Two decades of array signal processing research / H. Krim, M. Viberg // IEEE Signal Processing Magazine. – 1996. – Vol. 7. – P. 67-94.
[2]. Jackson B. R. Direction of Arrival Estimation Using Directive Antennas in Uniform Circular Arrays / Jackson Brad R., Rajan Sreeraman, Liao Bruce J., Wang Sichun // EEE Transactions on Antennas and Propagation. - vol. 63, issue 2. - pp. 736-747.
[3]. Gross F.B Smart antennas for wireless communications : with Matlab / F.B. Gross. – New York : McGraw-Hill Professional, 2005. – 288 p.
[4]. Jackson B. R. Direction of Arrival Estimation Using Directive Antennas in Uniform Circular Arrays / Jackson Brad R., Rajan Sreeraman, Liao Bruce J., Wang Sichun // EEE Transactions on Antennas and Propagation. - vol. 63, issue 2. - pp. 736-747.
[5]. J. D. Kraus, Antennas. McGraw-Hill, 1988.