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Study on Shortwave Circular Adaptive Anti-Interference

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Abstract. Adaptive antenna array combines array antenna and adaptive signal processing technology together, and has the capacity of effectively restraining strong interference in airspace. The paper starts from the analysis on formation and array parameters, adopts the electromagnetic calculation software FEKO to make Circular array modeling and simulation, and optimizes the phase values of various array elements via genetic algorithm in the circumstances of taking SIR (signal to interference plus power ratio) and of not taking SIR into consideration separately to achieve the purpose of anti-interference, and the result shows that the optimization taking SIR into consideration results in more powerful anti-interference capacity of Circular array, and conforms to the needs of practical engineering more.

Introduction

Currently, the electromagnetic environment for shortwave frequency band is poor, various frequency equipment and industrial interferences cause great influences in the communication, and shortwave communication needs to rely on the ionized later for propagation because its frequency band is very narrow, it will easily influenced by weather noise and man-made noise[1]. Thus, how to rapidly and effectively restrain various interferences and improve the reception effect of antenna has become an important objective for shortwave antenna system design. Adaptive antenna array combines array antenna technology with adaptive signal processing technology together, and realizes spatial filtering via aligning null steering of directional diagram at the interference as the phased array antenna beam is controllable, thus, effectively restraining interference not from the direction of incoming wave. Therefore, it is the development trend for shortwave anti-interference communication [2].

Circular array has superior advantages, and it can provide estimation of the angle of pitch; can realize omni-directional scanning, can easily and flexibly operate the position of beam via moving array motivation in circulation, thus, even circular array has a wide application prospect. Of array antennas, when compared with linear array, circular array antenna has the advantages of good symmetry and strong omnibearing scanning capacity, thus, it is applicable to be used as shortwave adaptive anti-interference antenna array [3].

To effectively improve anti-interference effect of shortwave circular array antenna, by combining FEKO and Matlab software and applying genetic algorithm, the paper realizes SIR optimization via changing the phase values of various array elements under the frequency of 5MHZ-20MHZ, and then obtains the directional diagram of circular array in the horizontal direction. Thus, it is proved that in the shortwave frequency band, circular array has a good anti-interference capacity and can satisfy the demands of engineering application when SIR circumstance is fully considered.

Formation selection Section Headings

The formation of array antenna mainly includes linear array, planar array, and circular array, etc. Linear array is consisted of N array elements that are distributed at a straight line, it has the

characteristics of concentrated energy of main lobe, small sidelobe level, however, it is very difficult to achieve 360° omnibearing scanning [4]. Planar array is consisted of N array elements that are distributed at a horizontal plane irregularly, and it has the characteristics of high directivity, low sidelobe, however, its data size is large, there are a lot of antenna units and it covers a large area of land [5]. Circular array is consisted of N array elements that are distributed at a circumference, it has circumference rotation symmetry, can make all-round operation on its null point. In spatial filtering technology, the number of null point formed via circular array is controlled by the quantity of array elements, N-1 null steering can be formed at most, however. There is no great difference between the main lobe and sidelobe of circular array. When compared with linear array and planar array, circular array can adaptively adjust the angle of null steering, and realize the omnibearing scanning of the horizontal plane, what's more, there is little influence of cross coupling between antennas, with small size, low cost and good mobile capacity, and it can make up the problem of small difference between the main lobe and sidelobe via algorithm. Thus, for the problem of anti-interference, circular array has the advantages that the linear array and planar array can not match. So, in the paper, circular array is chosen to make simulation.

Selection of circular array parameters

Influences of the interval between array elements This paper selection the middle frequency range 5MHZ-20MHZ, The wavelength is from 300 meters to 15 meters, array element number is 8, According to the The literature [6] when array element spacing is less than 0.25 of a wavelength, beam pattern formation is too large, when the array element spacing of 1 wavelengths, the sidelobe too much. Considering the short wave range and covers an area of and other reasons, The ring array with the radius of 10 meters.

Influence of the number of array elements In spatial filtering technology, the more the quantity of array elements of adaptive antenna array is, the more the null steering will be formed in directional diagram, and generally N element array can have N-1 null steering at most, however, the more the quantity of array element is, the larger the cross coupling influence between array elements will be, the more the noise receiving external influences will be, and the higher the cost will be. In case the quantity of array element is too less, the main lobe width of the directional diagram formed will be too narrow. By taking overall considerations on the objectives of study of the paper, quantity of anti-interference sources, and complexity of hardware, 8-element circular array is chosen in the paper. Antenna model is shown in figure 1.

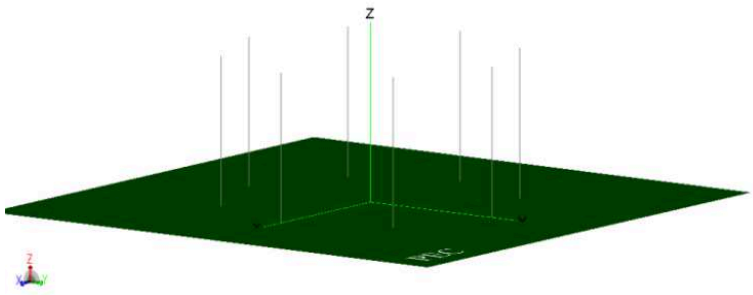


Fig. 1 Eight element antenna array

Beam optimization criterion

Adaptive array determines its excellence via adaptive algorithm, and there are four common criteria to determine their adaptive weight, namely: (1) minimum mean square error (MSE) criterion; (2) maximum signal to interference plus noise ratio (SINR) criterion; (3) maximum likelihood ratio (LH) criterion; (4) minimum noise variance (VN) criterion. In the paper, the beam optimization adopts SINR, as the paper is mainly focused on the influence of interference, external noise is regarded as the ideal external environment. Data accepted by array is:

$$X(t)=x_s(t)+x_i(t)$$

In the formula, $x_s(t)$ is the part of signal at time t, $x_i(t)$ is the part of interference at time 5. When the beam is formed, the output of array is:

$$y(t)=W^H X(t)=W^H x_s(t)+W^H x_i(t)$$

In the formula, W^H is adaptive array weight vector. When the beam in formed, the signal power is:

$$S=E\left\{W^H x_s(t) x_s{}^H(t) w\right\}=w^H R_s w$$

In the formula, $R_s=E\left\{x_s(t)x_s{}^H(t)\right\}$. Interference power is: $I=E\left\{W^H x_i(t)x_i{}^H(t)w\right\}=w^H R_i w$

In the formula, $R_i=E\left\{x_i(t)x_i{}^H(t)\right\}$. Thus, SIR is: $\frac{S}{I}=\frac{w^H R_s w}{w^H R_i w}$

The weight vector w_{opt} that makes SIR in the above formula to have the maximum output is the eigenvector corresponding to the most generalized eigenvalue of matrix to (R_s, R_i).

Performance analysis of circular array

Suppose N isotropic radiation elements arrange along the circumference with radius of a and constitute the circular array as shown. The circular array is located on xy plane. Far-field pattern function of the circular array can be obtained via overlaying the every unit's contributions to far field:

$$E(\theta,\varphi)=\sum_{n=1}^{N} I_n \exp[jka\sin\theta\cos(\varphi-\varphi_n)+j\alpha_n]$$

In the formula, In is the excitation current in the n unit where $\varphi=\varphi_n$ is located, α_n is corresponding excitation phase (with array center as the reference point). N is the number of array elementAs long as a, N, I_n, φ_n, θ_0 and φ_0 are given, the above three formulas can be adopted to calculate the field strength pattern of single circular array.

Field–strength distribution formula of circular array in the ideal situation is given in the above description, however, what we really need to consider in the practical application is directional income level of circular array, that is, gain factor of antenna（*Gain*）. Calculation formula of directional diagram gain of array will be discusses below.

$$F(\theta_0)=W^H a(\theta_0) \qquad W=[w_1,w_2,\cdots w_N]^T \qquad a(\theta_0)=\left[1, e^{j\frac{2\pi}{\lambda}d\sin\theta_0},\cdots e^{j\frac{2\pi}{\lambda}(N-1)d\sin\theta_0}\right]^T$$

In the formula, θ_0 is corresponding angle of the directional diagram, $F(\theta_0)$ is normalized field strength directional function. W is adaptive weight vector. Here, it is supposed that various array elements are isotropic array elements, and take the first array element in the direction of 3 o'clock on the horizontal plane as the reference array element. Generally, take the square of the mould and make normalization, then, de-logarithm, namely, the gain of the normalized pattern in the θ_0 direction is:

$$G(\theta_0)=\frac{\left|F(\theta_0)\right|^2}{\max\left|F(\theta_0)\right|^2} \qquad G(\theta_0)(dB)=10\log\left(\frac{\left|F(\theta_0)\right|^2}{\max\left|F(\theta_0)\right|^2}\right)$$

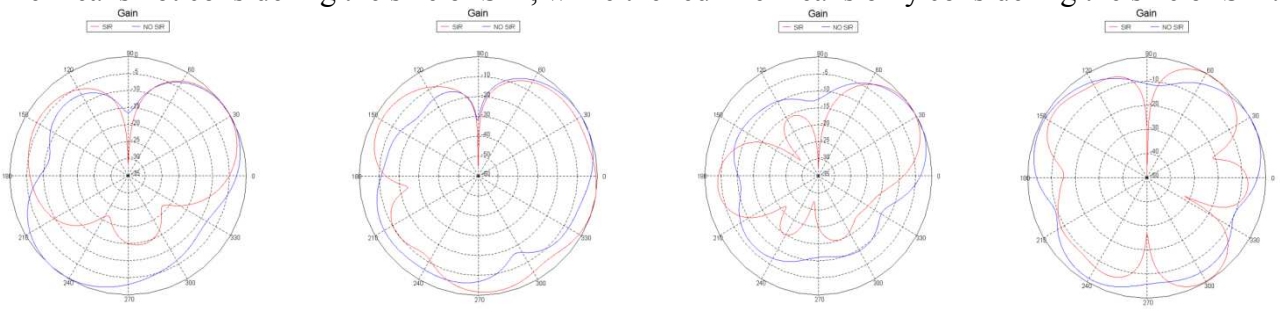
So the SIR is $SIR=\frac{G(\theta_0)}{G(\theta_1)}$

Analysis of simulation result

To analyze the directional diagram of loop array in the horizontal direction, the paper adopts commercial software FEKO to make directional diagram simulation in the 5MHZ-20MHZ frequency

range for incoming wave 30°and interference direction 90°, as well as incoming wave 30°and interference direction 45°respectively. In the simulation, a loop array is set with its array element of 10m whip antenna, number of array element is 8 and radius is 10m. Amplitude of various array elements is 1.

30°90°Directional diagram comparison It respectively calculates the horizontal directional diagram comparison between the two situations that loop array only considers the size of SIR and ignores the size of SIR at the frequency points of 8MHZ, 12MHZ, 16MHZ and 20MHZ, it only requires the interference direction to realize null steering of directional diagram and the maximum gain in the direction of incoming wave, and lists out the specific parameter values, as shown in Fig.2 and Sheet 1. Note: 30°is the direction of incoming wave, and 90°is the interference direction. Blue line means not considering the size of SIR, while the red line means only considering the size of SIR.



8MHZ 12MHZ 16MHZ 20MHZ

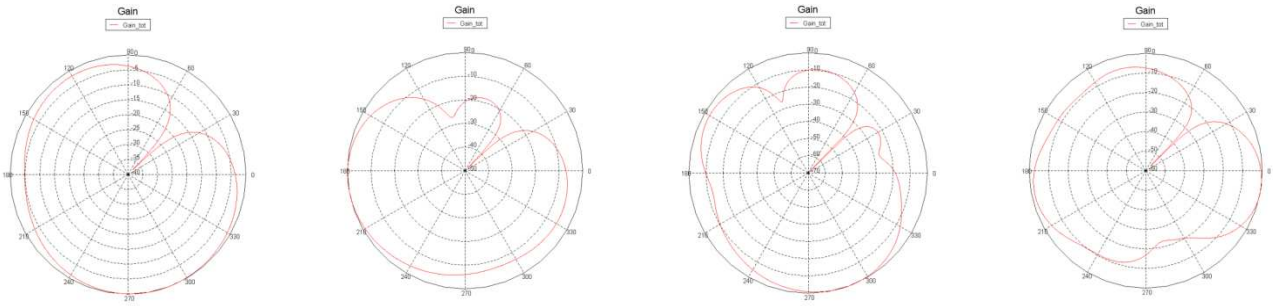
Fig.2 Horizontal directional diagram comparison in the two situations

	ignores the size of SIR			considers the size of SIR		
Frequency（MHZ）	30°Gain（dB）	90° Gain（dB）	SIR（dB）	30°Gain（dB）	90°Gain（dB）	SIR（dB）
8	4.85	-11.62	16.47	5.4	-25.74	31.14
12	6.24	-25.7	31.94	5.07	-47.11	52.18
16	9.14	-3.27	12.41	8.7	-23.43	32.13
20	5.82	-5.2	11.02	-0.3	-41.9	41.6

Sheet 1 Eigenvalue of directional diagram

It can be seen from Fig.2 and Sheet 1 that although the interference signal is avoided by only considering whether the null steering and incoming wave of directional diagram fall to the main lobe, however, the gain factor obtained is far behind the actual engineering requirements. While the directional diagram obtained via only optimizing SIR value not only realizes null steering in the interference direction, the gain of input signal is far greater than the gain of interference signal, thus, it restrains the interference signal preferably, and is more aligned with the actual engineering requirements, with stronger anti-interference capacity.

30°45°Directional diagram As the great difference between 90°and 30°direction angles is insufficient to prove the loop array has good anti-interference capacity in the short wave frequency range, the paper calculates the directional diagram formed as the loop array optimizes SIR at the frequency points of 5MHZ, 10MHZ, 14MHZ and 18MHZ, and lists out the specific parameter value, as shown in Fig.2 and Sheet 2. Note: Note: 30°is the direction of incoming wave, and 45°is the interference direction.



5MHZ 8MHZ 14MHZ 18MHZ

Fig.3 Horizontal directional diagram loop array

Frequency（MHZ）	5	10	14	18
30° Gain（dB）	10.27	4.35	14.67	16.85
45° Gain（dB）	-30.29	-44.72	-55.3	-42.9
SIR（dB）	40.56	49.07	69.97	58.75

Sheet 2 Eigenvalue of directional diagram

It can be seen from Fig.3 and Sheet 2 that the loop array can also achieve good interference restraining effect when there is only little difference between the30°and 45°direction angles.

Conclusion

From the simulation comparison in the above two cases, we can see that directional diagram null steering can be formed perfectly in the direction of interference via the optimization of signal to interference plus suppression ratio of circular adaptive array receiving antenna at various frequencies of shortwave, and the value of gain factor satisfy the needs of practical engineering, thus, verifying that a good anti-interference effect can be obtained when there is single interference source for circular adaptive array antenna at shortwave frequency range. But it is only limited to single interference source. In case there are multi-interference sources, how to optimize the directional diagram of circular adaptive array antenna will become the focus of the following study.

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