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Sidelobes Reduction Method in Circular Antenna Array

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Abstract*—Circular antenna array posses good directivity and low sidelobes level as compared with the antenna of a single element. The sidelobes level of the array still high and need to be reduced to overcome the interference from unwanted signals. Many methods were used in obtaining the suitable excitation for the elements of the array for low side lobes level. Modification in the weights of certain specified elements of an existing uniform excitation circular antenna array is presented her for lower sidelobes. The idea of modification in the current weights was developed for two and four elements. Computer simulations showed better results in reduction of the sidelobes level as compared to that of a uniform circular antenna array.

***Index Terms*—circular antenna array, side lobes reduction.**

I. INTRODUCTION

The elements of the array lies in two dimensions. Its applications include space navigation, underground propagation, radar, sonar, radio direction finding, mobile and commercial satellite communications systems [2-5]. The advantage of circular antenna array is its ability to steering the main beam electronically through all azimuth angles without any change in the beamwidth and sidelobes level [2]. The radiation pattern of a circular array depends on the radius of the circular antenna array, number of elements in the array, excitation and phase of each element that constitute the array.

In the uniform antenna array, all the elements have identical magnitudes and each succeeding element has a progressive phase lead current excitation relative to the preceding one.

II. ARRAY FACTOR OF CIRCULAR ANTENNA ARRAY

Consider N isotropic radiators distributed in circular ring of radius ***a*** placed in x-y plane. The origin of the coordinate system is located at the center of the array. The array factor can be obtained by considering the elements to be isotropic sources. If the actual elements are not isotropic sources, the total field can be found by multiplying the array factor of the isotropic sources by the field of the single element. This is known as the pattern multiplication rule, and it applies only for arrays of identical elements. The array factor of N-element array shown in Fig.1 can be given by [1]:

$$E_n = \sum_{n=1}^{N} a_n \frac{e^{-jkR_n}}{R_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$R_n = r - a\sin(\theta)\cos(\phi - \phi_n)$$

Where R_n is the distance from the nth element to the observation point (θ, ϕ), elevation and azimuth angle respectively?

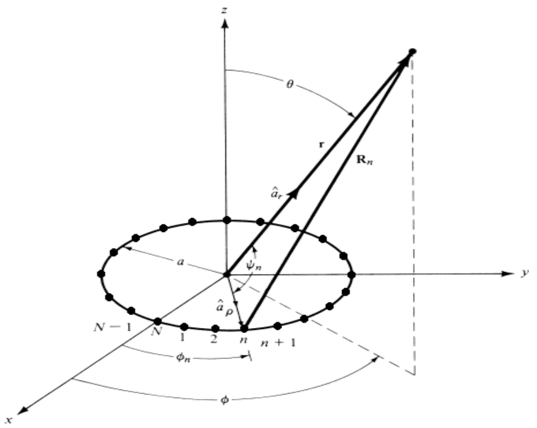

Fig.1: Geometry of circular antenna array of N elements positioned in x-y plane.

a_n is the excitation coefficient of the nth element, I_n amplitude excitation of the nth element, α_n phase excitation (relative to the array center) of the nth element.

$$a_n = I_n e^{j\alpha_n}$$

The angular position of the nth element ϕ_n on the resting plane is given by:

$$\phi_n = \frac{2\pi n}{N}, \quad n = (1,2,3,\ldots,N)$$

In amplitude variations $R_n = r$ then equation (1) can be written as:

$$E_n(r,\theta,\phi) = \frac{e^{-jkr}}{r} \sum_{n=1}^{N} I_n e^{j(ka\sin\theta\cos(\phi-\phi_n)+\alpha_n)} \quad \ldots\ldots\ldots(2)$$

$$E_n(r,\theta,\phi) = \frac{e^{-jkr}}{r}\left[AF(\theta,\phi)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

From equations (2,3), the array factor can be written as:

$$AF(\theta,\phi) = \sum_{n=1}^{N} I_n e^{j(ka\sin\theta\cos(\phi-\phi n)+\alpha_n)} \quad \ldots\ldots\ldots\ldots (4)$$

$$\alpha_n = -ka\sin\theta_0\cos(\phi_0 - \phi_n), \quad n = 1,2,\ldots N$$

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Equation (4) represents the array factor of a circular array of N equally spaced elements in z-x plane[1]. To direct the peak of the main beam in the (θ_0, ϕ_0) direction, the phase excitation of the nth element can be chosen to be then; the array factor can be written as.

$$AF(\theta,\phi) = \sum_{n=1}^{N} I_n e^{jka[\sin\theta\cos(\phi-\phi_n)-\sin\theta_0\cos(\phi_0-\phi_n)]} \quad \text{........ (5)}$$

III. SIDELOBES LEVEL REDUCTION WITH MODIFIED EXCITATION FOR THE SELECTED ELEMENTS OF THE UNIFORM CIRCULAR ANTENNA ARRAY

Modifying the uniform circular antenna array can be done for the existing uniform circular array to enhance its performance. The modification is to change the excitations of two or more opposed elements at specified angular positions**.**

Here we used a modification in the amplitude excitation for certain selected elements of the circular antenna array. Choosing suitable amplitude excitations for 2 or more opposed elements selected at specified ϕ_n angle in the uniform array, will contribute in reducing the sidelobes level of the array pattern.

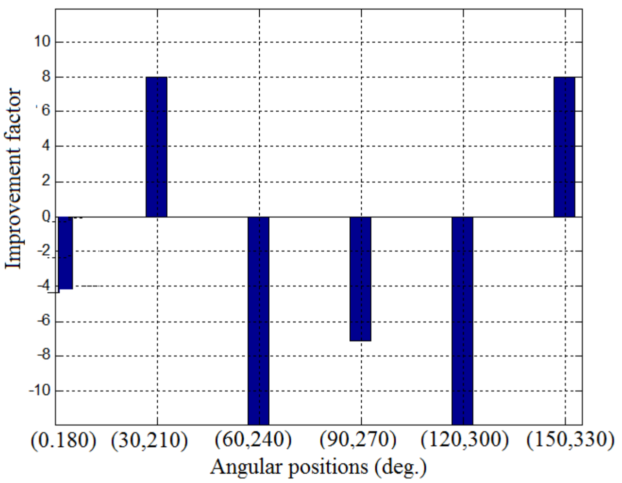


Fig.2: Improvement factor versus angular positions for each pair of elements locations in the resting plane for 12 elements uniform circular array.

Fig.2 shows the improvement factor in the sidelobes reduction versus angular positions for changing the excitation of each opposed pair of elements in the uniform circular array. The more positive values in the improvement factor indicate a more reduction in the sidelobes whereas negative values are for unwanted increasing in the sidelobe structure.

Consider an array of N isotropic radiators separated by d meters and positioned on the x-y plane, as shown in Fig.3. Modification in the excitation elements involves selection of certain opposed pair of elements from the circular array at certain specified angular positions ϕ_n that gives a reduction in the sidelobe structure by altering their excitations. From equation (5) assuming the selected elements is two as shown in Fig.3.In broadside array $(\theta_0 = 0, \phi_0 = 0)$, the separation between any two opposed selected elements is equal to $2a$ .The array factor for these selected elements in z-x plane can be written as:

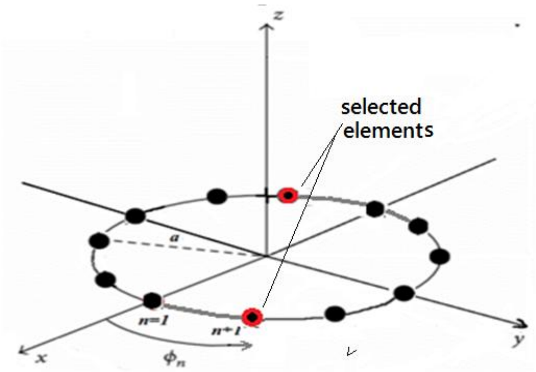


Fig.3: Geometry of modified excitation circular antenna array in x-y plane

$$AF_{N=2} = 2I_r \cos(ka\sin\theta\cos\phi_{rn}) \qquad \phi = 0 \qquad \text{....(6)}$$

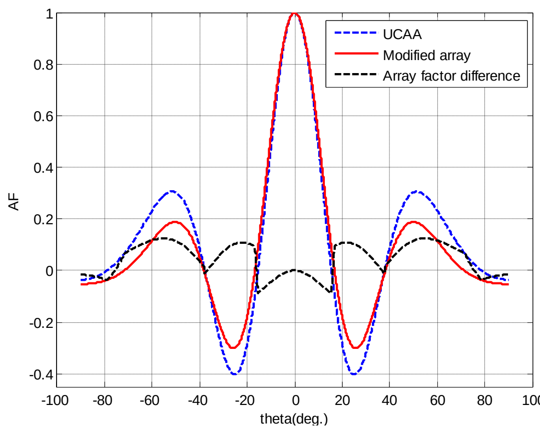
Where I_r is the excitation current of these two elements and ϕ_{rn} is its angular positions. The total array factor for this circular array is obtained by superimposing the array factor of the 2 elements with the array factor of the N-element circular array. The superimposed array factor is given by:

$$AF_{mod}(\theta,\phi) = \sum_{n=1}^{N} I_n \exp(jka\sin\theta\cos\phi_n) \pm 2I_r \cos(ka\sin\theta\cos\phi_{rn})$$

---------(7)

The sign plus or minus in the equation above represent the increasing or decreasing in the value of amplitude excitation for the selected elements.

We select two opposed elements from 12-element uniform circular antenna array as an example. Fig.2 shows that there are two opposed pairs of element that can be selected to modify their excitations by tray and error for reducing the sidelobes. These pairs are at $(30^0, 210^0)$ or $(150^0, 330^0)$ .The value of I_r obtained from try and error is equal to (0.1) of its original value in the normalized uniform array, gives us good reduction in the sidelobes level as shown in Fig.4.



(a)

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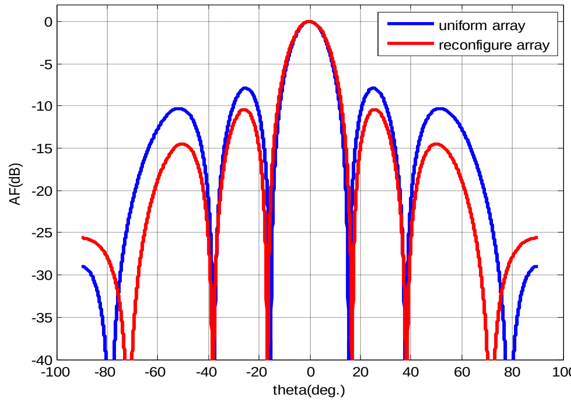
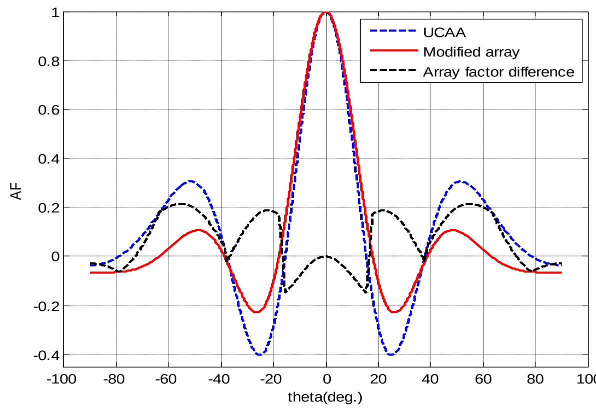


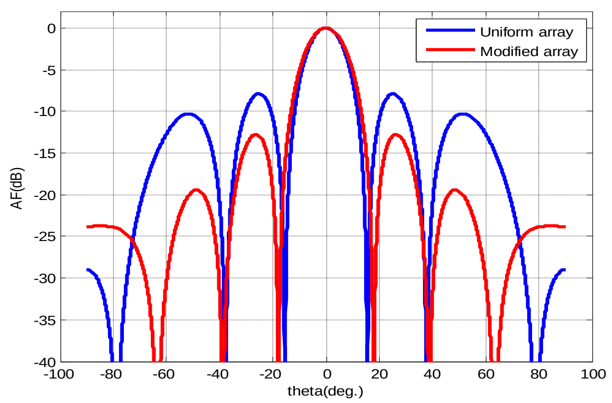
(b)

Fig.4 (a & b): Radiation pattern of 12-element circular array with unity excitation of all elements except two opposed elements with 0.1 positioned at angles 30^0, 210^0

The idea of using 2 elements modified in their amplitude excitation can be extended to 4 elements. Making use of Fig.2 the angular positions of the selected pairs of elements are $(30^0,210^0)$ and $(150^0,330^0)$. When the amplitude excitation for each selected elements is 0.3 of its original value in the uniform circular array, good reduction in the sidelobe structure can be obtained. Fig.5 shows the array pattern of 12-element uniform array together with pattern of the modified excitation circular array.



(a)



(b)

Fig. 5(a &b): Radiation pattern of 12-element circular array with unity excitation of all elements except 4 elements with excitation 0.3 positioned at angles 300,2100,1500,3300

Fig.6 shows the plot of the first and second sidelobes level in the modified excitation in certain specified pair of elements for a circular antenna array N=12 versus the excitation of the modified elements. The figure shows that, reduction of the sidelobes level for the modified array increases as the excitation value decreases in its specified range.

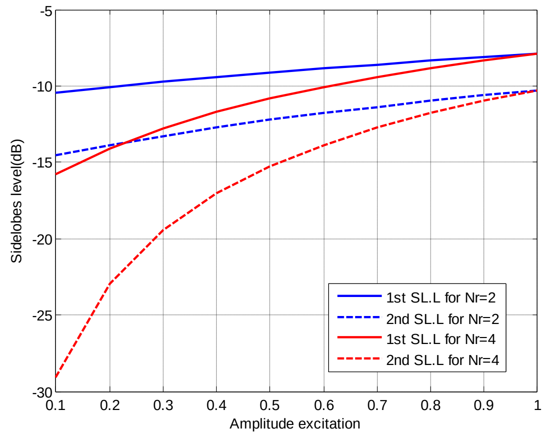


Fig.6: Plot of first and second Sidelobes level for modified excitation circular antenna array with N=12 &*d*=0.75λ versus amplitude excitation for selected elements, Nr=2 at $(\phi_1 = 30^0, \phi_7 = 210^0)$ **and Nr=4 at** $(\phi_1 = 30^0, \phi_5 = 150^0, \phi_7 = 210^0, \phi_{11} = 330^0)$

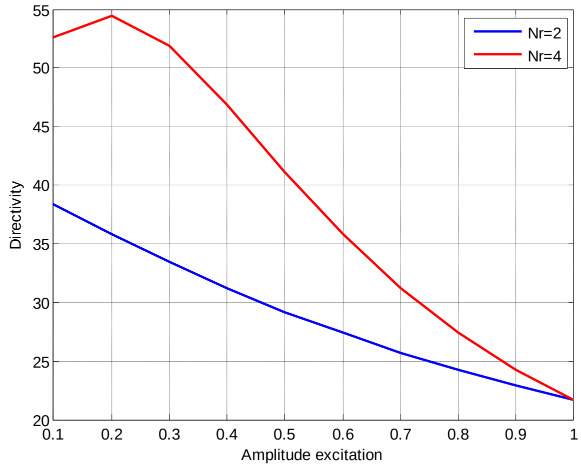


Fig.7:Plot of directivity for modified excitation circular antenna array with N=12 &*d*=0.75λ versus amplitude Excitation for selected elements, Nr=2 at $(\phi = 30^0, 210^0)$ **and Nr=4 at** $(\phi = 30^0, 150^0 \text{ and } \phi = 210^0, 330^0)$

Fig.7 shows the plot of the directivity for 12-element circular antenna array versus the excitation of the modified elements. The plot reveals good directivity for 4 elements modified excitation.

Fig.8 shows a plot of the beamwidth for the modified excitation circular array versus amplitude excitation for different number of the modified elements. From the plot it is obvious that the beam width is inversely proportional with the excitation of the modified elements. Fig.9 shows plot of the ratio of area under the sidelobes for the modified N-element array, to that of N-element uniform circular array, versus

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amplitude excitation. It is clear from the plot that, the area ratio increases as amplitude excitation increases. Minimum value of this ratio gives good reduction in sidelobes structure and good directivity. The plot shows good curve for area ratio when number of the modified elements equal to 4 in the case when the total number of the array elements is equal to 12

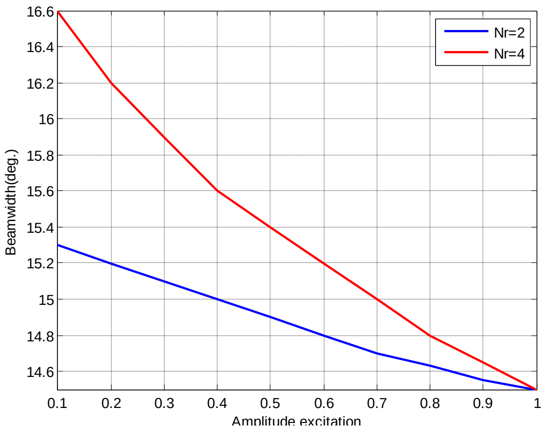

Fig.8: Plot of beam width for modified excitation circular antenna array with N=12&*d*=0.75λ versus amplitude excitation for selected elements, Nr=2 at $(\phi = 30^0, 210^0)$ **and Nr=4 at** $(\phi = 30^0, 150^0$ and $\phi = 210^0, 330^0)$

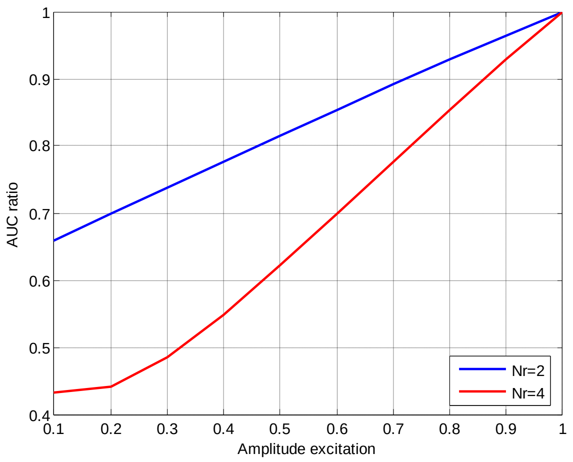

Fig.9: Plot of AUC ratio for modified excitation circular antenna array with N=12 &*d*=0.75λ versus amplitude excitation for selected elements, Nr=2 at $(\phi = 30^0, 210^0)$ **and Nr=4 at** $(\phi - 30^0, 150^0$ and $\phi_7 = 210^0, 330^0)$

It is clear from the plots and the results given in Fig.4 and Fig.5 that, there is a reduction in the value of the sidelobes level. There is also an appreciable unwanted change in the beamwidth values. The plots also show the array factor difference between the absolute values of the array factor of the original array and that of a reduced side lobes level **[6].** The positive value of the array factor difference indicates the local reduction of the original sidelobes. The area under the array factor difference gives us an improvement factor shown in Fig.2.

IV. CONCLUSION

Adjustments were made in the excitations for certain selected pair of elements in the uniform circular antenna array. These adjustment leads in good reduction in the values of the sidelobes level. For instance, in 12-element circular antenna array, modifying the amplitude excitation for only 2 opposed elements of a uniformly excited array at specified angular positions, gives sidelobe reduction level by -2.5dB and -4.5 dB for the first and second side lobes respectively.

Selecting 4 elements in modified excitation array gives sidelobe reduction level by -4.2dB and -13 dB for the first and second side lobes respectively.

Using 2 elements with modified excitations in the uniform circular array leads to the following conclusions

a –Reducing the amplitude excitation of the selected elements in the uniform circular antenna array to 0.1 of its value uniform value, it is possible to reduce the sidelobes level of the uniform circular antenna array.

b – There is a maximum reduction in the value of the sidelobes level for the modified arrays at certain excitation value of the selected elements in the array.

c – Ratio of the area under the sidelobes of the modified excitation array to that of the uniform array, reaches minimum value at certain excitation value of the selected elements for each size of the main array.

d – Directivity of the modified antenna array reaches a maximum value when the area ratio reaches minimum at certain excitation of the selected elements for each size of the main array.

Using 4 elements with modified excitations in the uniform circular array leads to the following conclusions:

a – With suitable excitations for 4 specified angular positions of the selected elements in circular antenna array gives better reduction in the sidelobes level as compared with that obtained using 2 elements modified excitations.

b – Ratio of area under sidelobes of the modified excitations circular array to that of the uniform circular array, reaches minimum value at certain excitations of the modified selected elements

c – Directivity of the modified excitation circular array reaches maximum at certain excitations value for the selected elements.

REFERENCES

[1] Ballanis, C.A., "Antenna theory analysis and design", 3nedition, JohnWilley and Son's Inc. New York, 2005.

[2] Davies, D. E. N. "Circular arrays." The handbook of antenna design 2, pp. 299-329, 1983, chapter 12.

[3] Elliott, R. S., "Antenna Theory and Design", Revised Edition, John Wiley, New Jersey, 2003.

[4] Collin, R. E., "Antenna and Radio-wave Propagation", McGraw- Hill, New York, 1985.

[5] Bogdan, L. and C. Comsa, "Analysis of circular arrays as smart antennas for cellular networks", Proc. IEEE Int. Symp. Signals, Circuits and Systems.03, Vol. 2, pp. 525-528, 2003.

ISSN: 2277-3754
ISO 9001:2008 Certified
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[6] Sayidmarie, K. H., and Aboud H.A. "Improvement of array radiation pattern by element position perturbation." Systems, Signals and Devices, IEEE SSD. 5th International Multi-Conference on. IEEE, 2008.