Analysis of Directional Patterns from Linear Ring Arrays for DF Applications

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Abstract **- Linear arrays are widely reported in literature. However, linear arrays are not suitable in direction finding and 360 degrees scanning. To overcome the problem, the ring arrays are found to be suitable, however ring arrays produce first-sidelobe level is about - 8 dB, which creates a lot of EMI. In this paper, to reduce these problems linear ring arrays used. Using the optimized linear ring arrays, the radiations patterns are numerically evaluated for linear ring arrays of different radius. The data is presented in results. It is very much useful in the applications where direction finding is required in radars and satellite communications.**

Index Terms**—linear arrays, direction finding, Electromagnetic Interference, radiations patterns**

I. INTRODUCTION

In the last few decades, the linear array, that has been investigated thoroughly in the literature. But few researchers has attempted on ring arrays. The ring arrays are more useful than linear arrays for many practical applications, such as radar, acoustics, sonar, communications, biomedical, imaging. Compared with linear arrays, ring arrays have the advantages that steering of the radiation pattern, over any desired range of directions. Ring array is a planar array. It contains uniformly spaced radiating elements on a circle [1-4].

Kundsen [5] has proposed homogeneous ring arrays. The properties of ring arrays are discussed by Royer [6], and also found the antenna impedance and mean directive gain of the ring array. Redlich [7] has designed a ring arrays for aircraft navigation.

Vu [8-9] proposed a new field synthesis technique for minimizing sidelobe levels of circular ring array. Longstaff et al. [10] carried out on a single ring array of monopoles for communication. Fenby [11] studies carried out on directional patterns for circular arrays. Linear array synthesis is reported by Ng et al. [12] to controlled nulls. Linear concentric ring array synthesis is reported in [13] for wireless applications.

In this paper, the analysis is carried out on ring arrays. It's considered as single radiating element, such elements are separated by $\lambda/2$, and it is formed as linear ring array. The directional patterns are presented in the results these are useful for directional applications.

II. GENERAL ANALYSIS

The ring array of present interest consists of M identical and identically oriented isotropic antennas placed equidistantly along a circle with radius r as shown in Figure 1. A spherical coordinate system (r, θ, ϕ) placed with its origin at the center of the circle is considered. Assume that it lies in the xy-plane and considered distance between two elements is $\lambda/2$.

A. *Proposed technique*

A ring array is considered as single radiating element. The arrangement these elements in a linear fashion constitutes a linear ring array. The radiation pattern of linear ring array depends upon radiator. A linear ring array is shown in Figure 2 along z-axis. Here, considered radiating element is isotropic radiator.

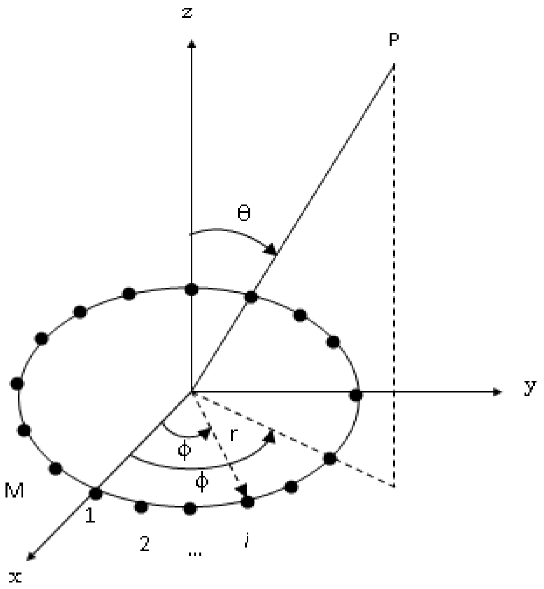

Figure 1. Typical geometry of isotropic ring array

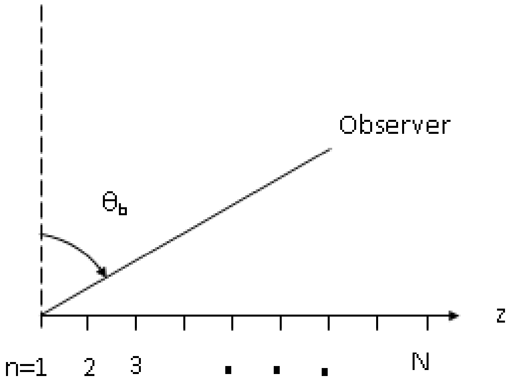

Figure 2 A linear ring array

The far-field radiation pattern is given for ring array by [2]

$$E_1 = f(\theta,\phi)\times\sum_{i=1}^{M} A_i \exp\left[j\,k\,\sin\theta\,r\cos(\phi-\phi_i)+j\alpha_i\right] \quad (1)$$

Here,

$f(\theta,\phi)$ = Far-field function associated with the isotropic radiators, $f(\theta,\phi)=1$,

A_i = Current excitation of the i^{th} element,

M= Number of elements on the ring,

$k=\frac{2\pi}{\lambda}$, λ = Free space wavelength,

r = Radius of the ring array,

θ = Elevation angle, ϕ = Azimuth angle,

ϕ_i = Angular location of i^{th} element

a phase function is given by

$$\alpha_i = \exp\left[j\,k\,r\,\sin\theta_s\,\cos(\phi_s-\phi_i)\right] \quad (2)$$

Here, (θ_s,ϕ_s) = steering angle

In the above expression (1), amplitude with same weight, phase, and M is large ring array. The far-field radiation pattern of ring array is given by [13],

$$E_1 = \left[A_t\,J_0(k\,r\sin\theta)\right] \quad (3)$$

If M is large there is no possibility for the presence of grating lobes with an increment of *kr*.

The radiation patterns of discrete linear array is given by [3]

$$E_2 = \sum_{n=1}^{N} A(x_n)\exp\left[j\frac{2\pi L}{\lambda}x_n\sin\theta + j\alpha(x_n)\right] \quad (4)$$

Here,

$A(x_n)$=Amplitude excitation function,

$\frac{2L}{\lambda}$ = Array length, N= Number of elements,

$\alpha(x_n)$ = Phase excitation function,

$x_n = \frac{2n-1-N}{N}$ = Spacing function,

B. Patterns of linear ring array

The far-field radiation pattern of linear ring array of isotropic elements is obtained from the product of patterns of the ring array and patterns of linear array.

i.e. $E_c = E_1\times E_2$ (5)

$$E_c = f(\theta,\phi)\times\left[A_t\,J_0(k\,r\sin\theta)\right]\times \sum_{n=1}^{N} A(x_n)\exp\left[j\frac{2\pi L}{\lambda}x_n\sin\theta + j\,\alpha(x_n)\right] \quad (6)$$

Here,

$f(\theta,\phi)$=Far-field function of isotropic radiators, $f(\theta,\phi)=1$

The resultant radiation pattern for linear isotropic ring array is given by

$$E_c = \left[A_t\,J_0(k\,r\sin\theta)\right]\times \sum_{n=1}^{N} A(x_n)\exp\left[j\frac{2\pi L}{\lambda}x_n\sin\theta + j\alpha(x_n)\right] \quad (7)$$

C. Directivity of linear ring array

The directivity of linear isotropic ring arrays is given by [1].

$$D = \frac{4\pi\left|E_c(\theta_s,\phi_s)\right|^2}{\int_0^{2\pi}\int_0^{\pi}\left|E_c(\theta,\phi)\right|^2\sin\theta\,d\theta\,d\phi} \quad (8)$$

(8

The directivity is computed for linear ring array with isotropic radiator using (7).

III. RESULTS AND DISCUSSIONS

Eq. (1) and (7), the radiation patterns are numerically evaluated for the ring arrays and linear ring arrays using isotropic radiators. The resultant radiation patterns of the ring arrays and linear ring array of isotropic radiators with different radius are presented in Figures 2–9.

From the Figure 3, the sidelobe level is -7.9 dB, null to null beamwidth is 44.9 degrees for a single ring array of isotropic radiator with ring radius is 1 λ . A ring array is considered as a single radiating element, such two elements (N=2) are placed on uniform linear array and the sidelobe level -12.25dB is noted, null to null beamwidth is 44.9 degrees. The patterns of single ring array and linear ring arrays with two elements are compared in that figure. Similarly, single ring array is compared with linear ring arrays for N=3 elements and N=5 elements, these patterns are shown in Figures 4 and 5 respectively. The comparative data is tabulated in table 1.

Similarly, ring radius is considered 5 λ and the patterns of ring arrays and linear ring arrays are shown in Figures 6–9, varied N is 2, 8, 12, and 17. The comparison data is tabulated in table 2.The directivity is evaluated for ring radius 1 λ and 5 λ, using (8) for linear ring arrays data is tabulated in tables 1-2.

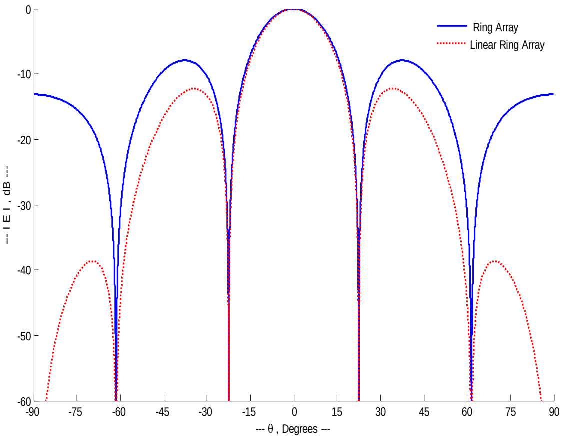

Figure 3. Patterns of a ring array of radius 1 λ and linear ring array with N=2

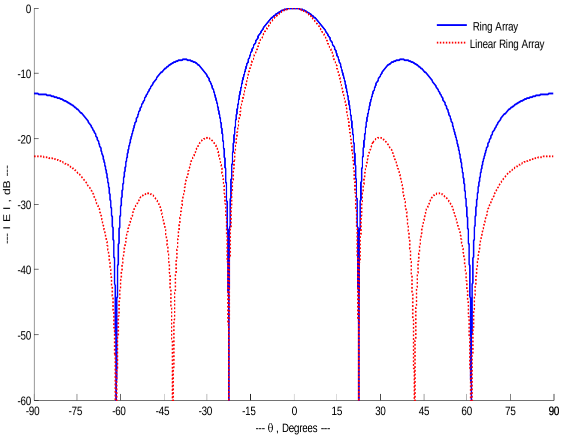

Figure 4. Patterns of a ring array of radius 1 λ and linear ring array with N=3

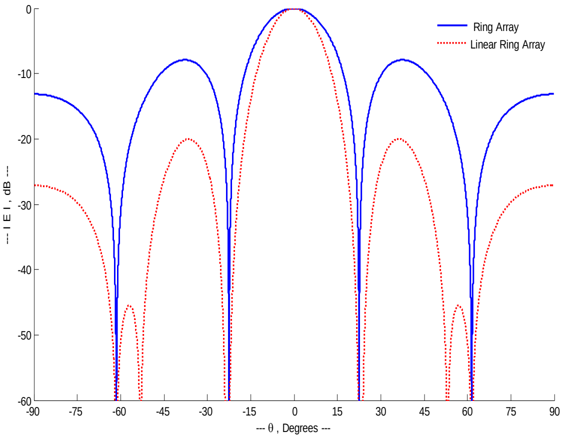

Figure 5. Patterns of a ring array of radius 1 λ and linear ring array with N=5

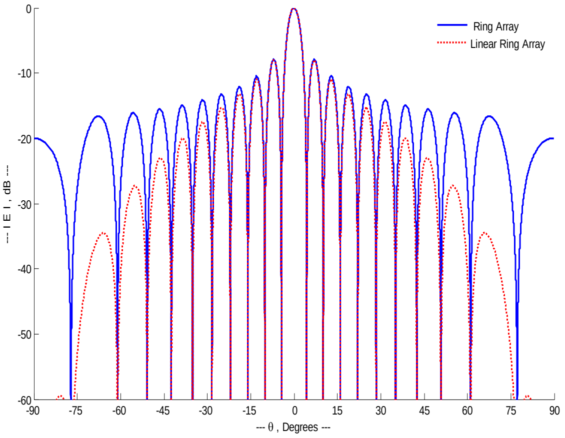

Figure 6. Patterns of a ring array of radius 5 λ with N=2

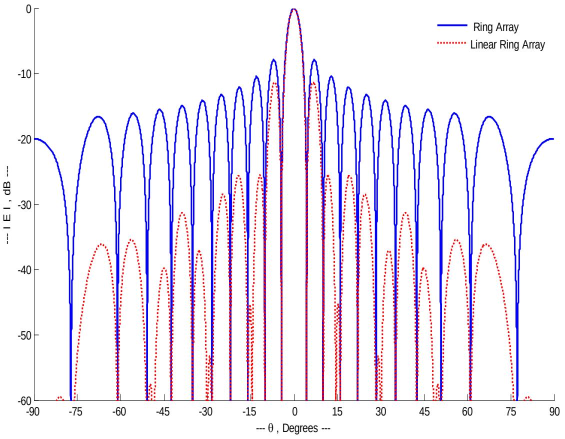

Figure 7. Patterns of a ring array of radius 5 λ with N=8

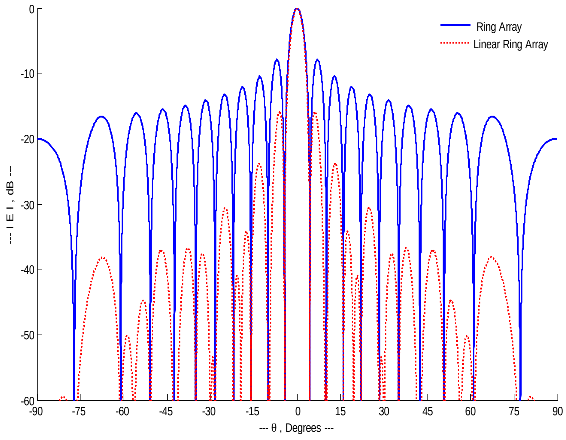

Figure 8. Patterns of a ring array of radius 5 λ with N=12

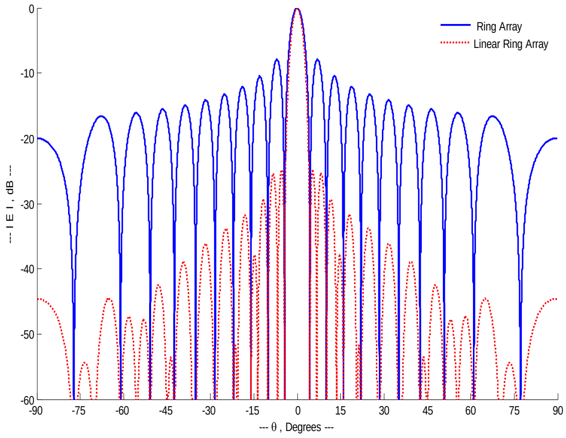

Figure 9. Patterns of a ring array of radius 5 λ with N=17

TABLE 1

Directional pattern characteristics with radius 1 λ of linear isotropic ring array

Number of elements on linear (N)	First sidelobe level in dB	Second sidelobe level in dB	Null-to-null beamwidth in degrees	Directivity in dB
1	-7.90	-13.15	44.90	0.00
2	-12.25	-38.67	44.90	6.02
3	-19.89	-28.37	44.90	9.54
5	-20.08	-44.88	44.90	13.98

TABLE 2

Directional pattern characteristics with radius 5 λ of linear isotropic ring array

Number of elements on linear (N)	First sidelobe level in dB	Second sidelobe level in dB	Null-to-null beamwidth in degrees	Directivity in dB
1	-7.90	-10.47	8.76	0.00
2	-8.07	-11.00	8.76	6.02
8	-11.39	-25.50	8.76	18.06
12	-15.89	-23.91	8.76	21.47
17	-25.12	-25.44	8.76	24.58

IV. CONCLUSIONS

It is evident from Figures 3–9, that the sidelobes of linear ring array of isotropic radiators are less than to that of the ring arrays of isotropic radiators. The null-to-null beamwidth is decreased and sidelobe level is same with increasing the ring radius. Hence, the pencil beams are generated and these are used for directional applications. The sidelobes are reduced upto - 25.12 dB for 5 λ using the linear array concept of ring arrays. Therefore, the EMI problems to be reduced. The patterns and directivity characteristics of linear ring arrays of isotropic radiators are very much evident from the results presented in tables 1–2. The null-to-null beamwidth, first sidelobe level, second sidelobe level, and directivity are found to be the function of ring radius in linear ring arrays. The results are useful for direction finding in radars and communication applications.

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