IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 10, Issue 6, Ver. III (Nov - Dec .2015), PP 16-21
www.iosrjournals.org

Generation of Asymmetrical Difference Patterns from Continuous Line Source to Reduce Electro Magnetic Interference for Marine Applications

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Abstract: *It is well known that narrow beams are produced for maximum directivity, small beam width from a line source of specified length meeting desired side-lobe levels. However, side-lobe suppression may not be required in all the directions for certain applications. The generated patterns are useful for point to point communication and high resolution radars, but they have limited use in the marine radars where pitch and roll of the ship exists. There are some situations where the array associated with the radar operating from a ship requires asymmetric Sum and Difference patterns to take care of pitch and roll of the ship in turbulent seas. This particular application demands the generation of patterns with asymmetrical side-lobes adjacent to the main lobe. These patterns are characterized by one main lobe and with low side-lobes on one side and high side-lobes on the other side of the main beam. In order to meet the EMI standards the side-lobe levels of the radiation beams are made smaller and smaller. The side-lobe levels of the order -25 dB are acceptable in general. If further lower side-lobes are required, it is practically very difficult to design appropriate tapered excitations.*

In view of the above facts some investigations are carried out in the present work on the design of line sources, to generate asymmetrical patterns to make them suitable in marine radars applications. The antennas associated with the marine radars are required to produce patterns with asymmetric side-lobes. In particular the side-lobes in one side are lower than those of the other side. The amplitude and phase distributions are designed for small and large arrays. The radiation patterns are numerically computed

and they are presented in u- domain.

Key Words: *Radiation Patterns, Asymmetrical Patterns, EMI, Side-lobes, Beam Patterns*

I. Introduction

Array synthesis is carried out by several researchers [1-5]. In the classic paper of Dolph [1], array weights for a uniformly spaced linear array are derived to obtain minimum beam width for a given side-lobe level. In his work, isotropic elements in the array are considered. Taylor [2] reported an excellent method on the design of line source. Villeneuve [3] extended Taylors method to linear arrays. Elliot et. al. [4] reported a few typical pattern synthesis techniques for arrays. All these methods are applied for arrays of isotropic elements with uniform spacing. The equi-spaced linear arrays have been investigated with analytical and

numerical approaches. For the design Dolph-Chebeshev [1], Woodward Lawson"s Method [12] is used for several years to produce some specified patterns. Fourier series method and Fourier Transform method [13] are useful to design different beam shapes. Elliot [14] extended results of continuous line source for the synthesis of the array. But it does not provide any control in the trade-in region of the patterns. There are several methods for antenna pattern synthesis, however it might appear that many of these methods are alike as of there is no difference or no distinction. Actually, this is not the case. Each method of the design is developed to a given class of problems. For instance, Chebyshev method provides an array with the smallest possible beamwidth for a given sidelobe level and hence it is found to be useful for reduced sidelobe design. The use of communication and radar systems specify the type of radiation pattern to be radiated from the antenna. Among different types of patterns, for point to point communication and also for high angular resolution radars narrow beams are best opted by the users. Such patterns are conveniently generated from the array antennas with appropriate amplitude distributions. These distributions are designed using standard functional variations. Schelkunoff polynomial method, Fourier Transform, Dolph-Chebyshev and Taylor"s methods etc are also useful to same extent. In radar applications the sum patterns are produced by the vectorial sum of all the fields produced by the discrete radiating elements in the array.

It is well known that narrow beams are produced for maximum directivity (small beamwidth) from a line source of specified length meeting desired sidelobe levels. However, sidelobe suppression may not be required in all the directions for certain applications. In this connection, it may be pointed out that the Taylor"s pattern is not optimum in some applications as each sidelobe is suppressed at the cost of beamwidth. In view of this, Elliot [189] considered a method of design which leads to the presence of high sidelobes in the unwanted regions while maintaining low sidelobes in the required regions.

Formulation

A symmetric broadside array of 2N+1 isotropic elements is shown in fig 1,

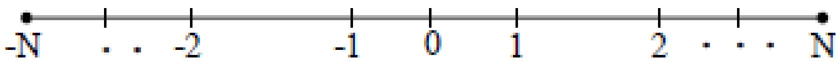

Fig. 1 Symmetric array

The difference pattern from a continuous line source is also obtained from

$$E_d(u) = \left[\int_{-1}^{0} A(x) e^{j\frac{2\pi L}{\lambda}[ux+\alpha]} dx + \int_{0}^{1} A(x) e^{j\frac{2\pi L}{\lambda}[ux+\alpha]} dx\right] \tag{1}$$

Here A (x) is excitation function. To generate a null in the boresight directions 1800phase shift is introduced to one half of the array i.e.

$$\left.\begin{array}{ll} \alpha = 0 \text{ for} & -1 \le x \le 0 \\ \alpha = \pi \text{ for} & 0 \le x \le 1 \end{array}\right\} \tag{2}$$

Substituting equation (2) in equation (1), then radiation pattern is now given by

$$E(u) = \int_{-1}^{0} A(x) e^{j\frac{2\pi L}{\lambda}ux} dx + \int_{0}^{1} A(x) e^{j\frac{2\pi L}{\lambda}(ux+\pi)} dx \tag{3}$$

Let $a = \frac{2\pi L}{\lambda}$ then

$$E(u) = \int_{-1}^{0} A(x) e^{jaux} dx + \int_{0}^{1} A(x) e^{ja(ux+\pi)} dx \tag{4}$$

$$E(\theta) = A(x)\left\{\int_{-1}^{0} \cos(aux) + j\sin(aux) dx\right\} + A(x)\left\{\int_{0}^{1} \cos(aux+\pi) + j\sin(aux+\pi) dx\right\} \tag{5}$$

In the boresight direction, u = 0
By substituting this value in the above equation, we get

$$E(u) = A(x)(1) + A(x)(-1) \quad (6)$$

Therefore E (u) = 0.
This means a null is generated corresponding to the boresight direction.

II. Results

The results on the far field variation as a function of u for discrete array and continuous line sources are presented in figures (1 - 6). The radiation patterns are computed for the following arrays. For

$$\frac{2L}{\lambda} = 15, \; N = 30$$

$$\frac{2L}{\lambda} = 30, \; N = 60$$

$$\frac{2L}{\lambda} = 45, \; N = 90$$

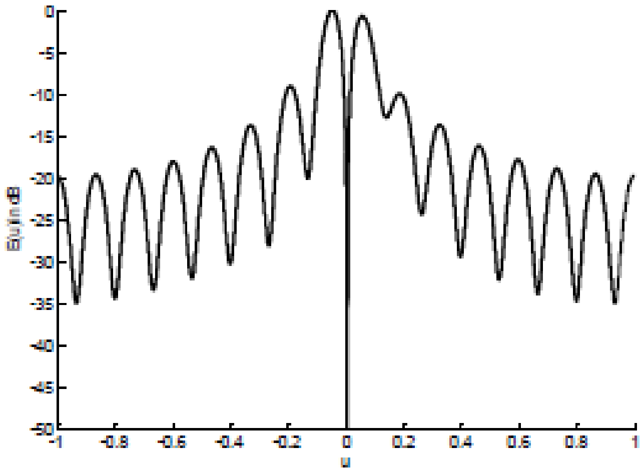

Fig. 1 Asymmetric Difference Pattern for array of discrete elements for N=30

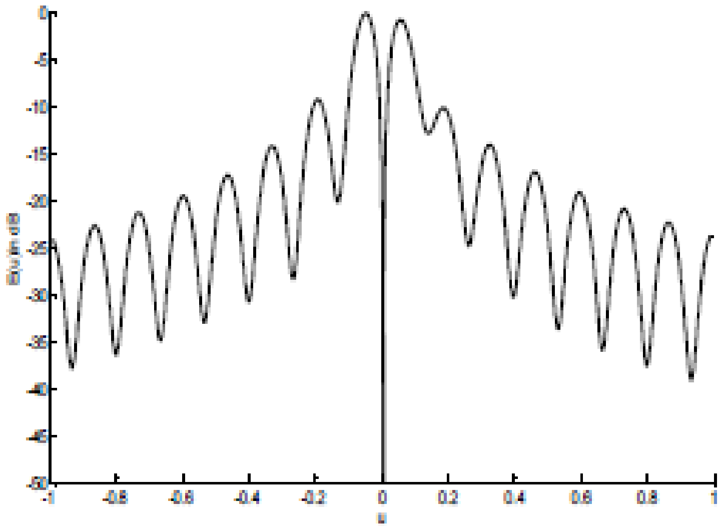

Fig. 2 Asymmetric Difference Pattern of a continuous line source for 2L/λ = 15

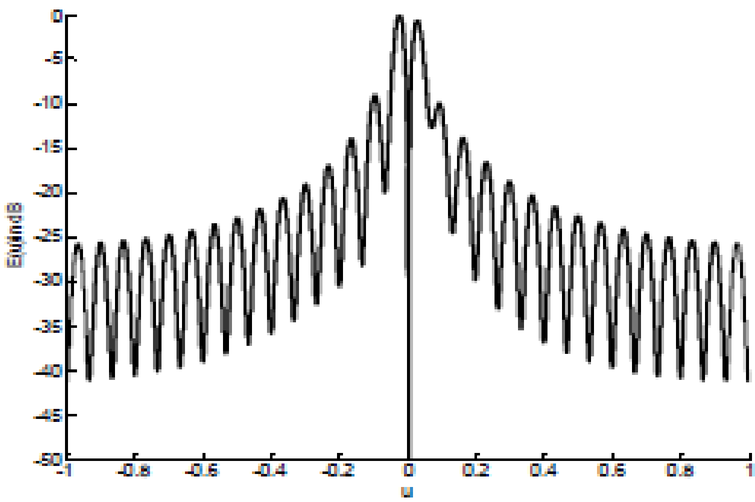

Fig. 3. Asymmetric Difference Pattern for array of discrete elements for N=60

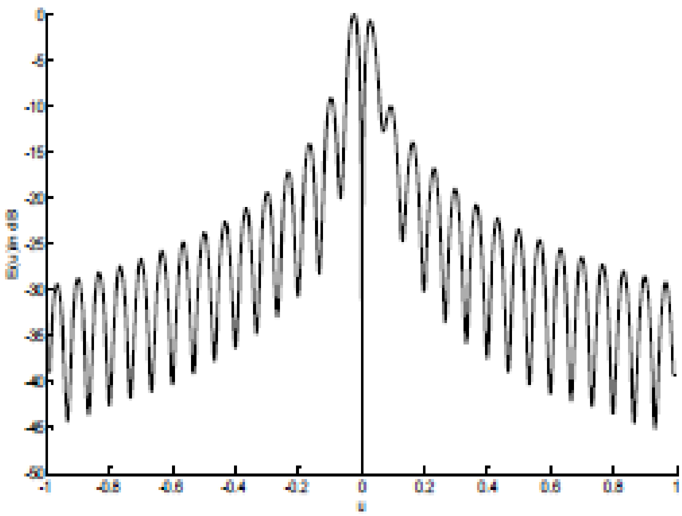

Fig. 4. Asymmetric Difference Pattern of a continuous line source for 2L/λ =30

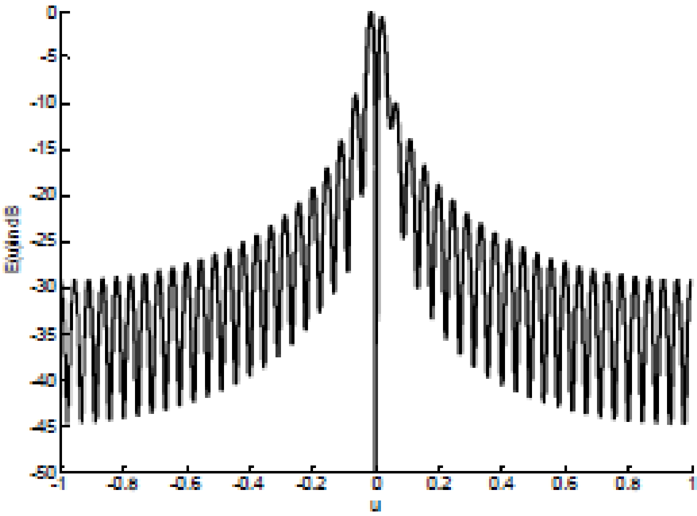

Fig. 5 Asymmetric Difference Pattern for array of discrete elements for N=90

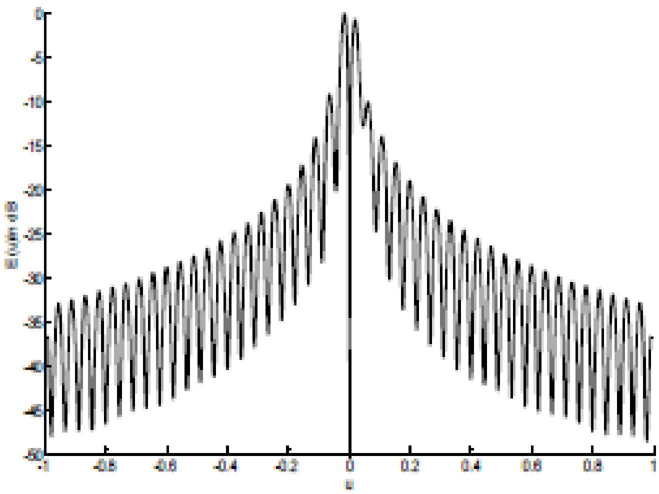

Fig. 6 Asymmetric Difference Pattern of a continuous line source for $2L/\lambda = 45$

III. Conclusions

The difference patterns computed with the above data on spacing, amplitude and phase distribution is found to have deep null in the boresight. The patterns are not symmetric as the introduced phase is not symmetric. The patterns are found to exhibit high difference lobes in the boresight which is an essential requirement in Radar applications. The number of lobes including minor one is found to increase with the increasing number of elements. The width of the difference slopes is small for large and vice-versa for small arrays. Asymmetric difference patterns are generated by introducing additional phase of 0 180 to one half of the discrete array as mentioned above. It is found from the results, useful asymmetrical difference patterns are generated.

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