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Side Lobe Suppression of Concentric Circular Arrays Using Non Conventional Beam Forming Technique

[1]P. Rama Krishna, [2]S. Sri Jaya Lakshmi, [3]I.Sreedevi, [4]Habibulla Khan, [5]M.P.K.Aditya , [6]V. Vamsi Krishna, [7]J.Lavanya

1, 3, 5, 6, 7 B Tech students, Department of ECE, K L University
2 Women scientist, Department of ECE, K L University
3 Professors , Department of ECE, K L University
K L University, Vaddeswaram, Guntur-522502, India.

ABSTRACT

Circular antenna array design is one of the most important electromagnetic optimization problems of current interest. The antenna must generate a pencil beam pattern in the vertical plane along with minimized side lobe level. In this paper we present non conventional method based on improved parameter of hyper beam exponent x. The circular array when implemented using hyper beam technique, there is a considerable reduction of side lobe levels and half power beam width compared to conventional beam forming. The design of circular array is with uniform inter-element spacing. Simulation results of the effect of the hyper beam exponent on the beam patterns are shown.

Keywords: *Hyper beam; circular array; side lobe level; half power beam width.*

1 INTRODUCTION

Circular antenna array, in which antenna elements are placed in a circular ring, is an array configuration of very practical use among all other antenna arrays present in modern day. It consists of a number of elements arranged on a circle [1] with uniform spacing between them. It possesses various applications in sonar, radar, mobile and commercial satellite communications systems [1-5]. They can be used for beam forming in the azimuth plane for example at the base stations of the mobile radio communications system [2-5]. Circular array has several advantages over other types of array antenna configurations such as all azimuth scan capability, invariant beam pattern in every ϕ-cut, i.e., ϕ symmetric pattern, flexibility in array pattern synthesis [2-5] etc. For those advantages, design of circular antennas by different methods is being encouraged in present days. There are several kinds of circular arrays. Concentric Circular Antenna Array (CCAA), one of the most important circular arrays, contains many concentric circular rings of different radii and number of elements proportional to the ring radii. The main feature of CCAA is observed in Direction of Arrival (DOA) applications providing almost invariant azimuth angle coverage.

2. METHODOLOGY

Noise reduction and improvement of detecting the target are a successful design of a high performance system. While the classic way is to increase the array's size, constraints as integration, size and cost require new technical approaches like non-classical beam forming techniques. A new beam forming technique, called hyper beam is presented. As a result of the hyper beam offers high detection performance like beam width reduction, the target bearing estimation and reduces false alarm i.e., side lobe suppression.

1 Hyper Beam

The hyper beam formed by means of two half beams, beam one is the right half beam and the second beam is the left half beam. The process of formation of the hyper beam is illustrated by a series of directivity patterns for a linear, planar and circular transducer. Moreover the influence of isotropic noise and non- isotropic noise sources as well as the separation of multiple targets are examined. The two-dimensional Hyper beam focusing in one plane which contain the main beam direction, in order to achieve even greater reduction of beam width and the side lobes around the main beam in all directions.

The hyper beam technique yields a very narrow beam width with suppressed side lobe levels. The narrowness of beam width and side lobe suppression level depends on the variation of exponent value, which also leads to the suppression of grating lobe and also reduction of received noise level. With conventional beam forming the smallest possible beam width depends on the geometric dimensions of the receiving array. Using shading coefficients for beam forming side lobe suppression can be achieved, but at the cost of a broadened beam width.

2 Generation of Hyper Beam

In principle of hyper beam generation a simple concentric circular transducer used is shown in Fig.1. The element spacing is half the wave length ($\lambda/2$) in order to allow beam steering in that particular direction without steering, i.e. all elements have the same phase or all elements are arranged in a ring, conventionally beam forming is done by summing up all the transducer elements.

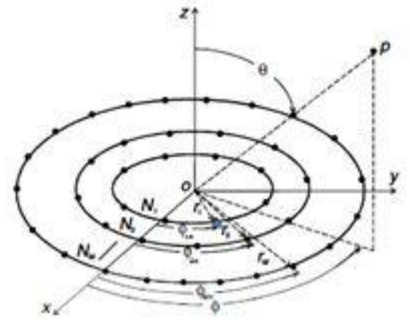

Figure 1 multiple concentric circular ring arrays of isotropic antennas in XY plane

3 Forming of hyper beam for circular array

The circular array shown in the Fig.1 is first split into two equal half parts right and left. The beams produced by each half is taken individually where beam1 is the left half beam and beam2 is the right half beam. The forming of the hyper beam, which resembles to some extent the above mentioned ideal beam, shall now be illustrated by means of the sum beam pattern which is the sum of both half beams i.e. beam1 and beam2 of Fig.2. Applicable to the proposed circular transducer in the Fig.1

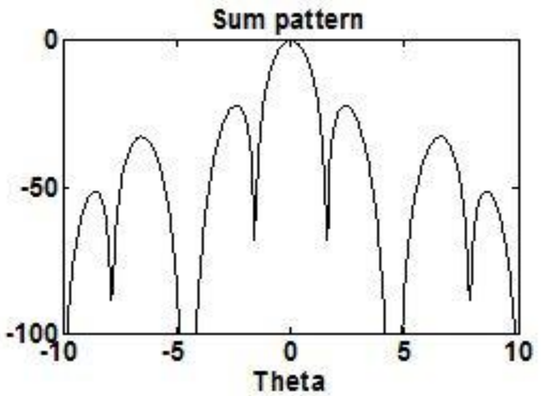

Figure 2 2D sum pattern for 10 element circular array

The sum beam pattern is now generated by the summation of beam1 and beam2 which are the left half beam and right half beam respectively. The beam magnitude is plotted in the normalized plot Fig.2.We can see that the Fig.2 beam pattern shows that the magnitude of both left and right half beams are identical.

The Difference beam generated is the magnitude of the difference of beam2 signal subtracted from the beam1 signal taking phases of the signals in to consideration.

By observing the difference beam pattern it can be easily seen that the values of the difference beam at each given direction is found to be always lower than or equal to those of the half beams. Furthermore the difference beam has a minimum point in the direction of the sum beam at 0^o as shown in Fig.3.

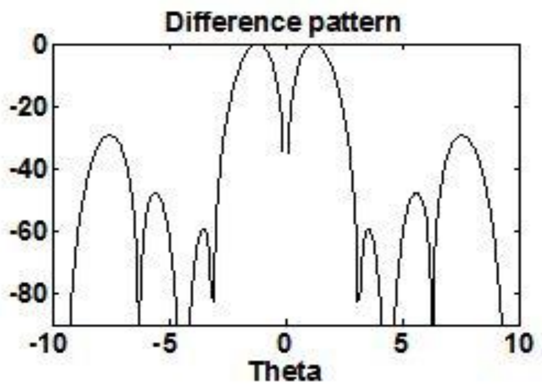

Figure 3 2D difference pattern for 10 element circular array

On proper study of both the sum and difference patterns in Fig.2 and Fig.3 we can recognize an interrelation between them. Having recognized this interrelation it is obvious to get the idea of subtracting the magnitude of the difference beam pattern from the sum beam pattern. The subtraction operation has to be performed rather on the magnitude numbers themselves, and not on the magnitude levels. The resulted simple hyper beam in 2D simulated for a 10element circular array with exponent value x=1 is formed as shown in Fig.4.

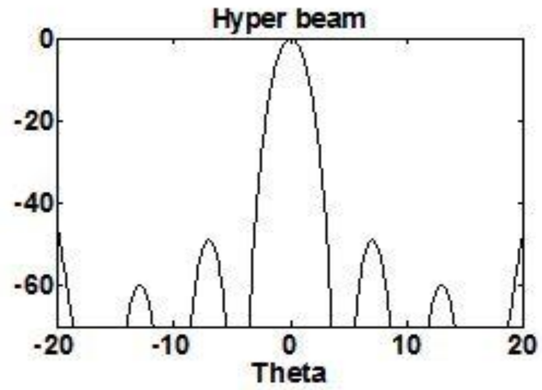

Figure 4 2D simple hyper beam pattern for 10 element circular array with x=1

3 MATHEMATICAL FORMULAS

The equations for the creation of sum, difference and simple hyper beam are as follows:

The array factor equation for simple circular array is

$$AF(\theta,\phi) = \sum_{m=1}^{M} \sum_{n=1}^{N} I_{mn} e^{j(2\Pi r)[\sin(\theta)\cos(\phi-\phi_n)+\alpha_n]}$$

The sum pattern is calculated from two half beams is given by

$$S(\theta,\phi) = |E_L|+|E_R|$$

The difference pattern is calculated from below equation

$$D(\theta,\phi) = |E_L-E_R|$$

Then the equation to obtain simple Hyper beam is

$$E_{hyp} = |E_L|+|E_R|-|E_L-E_R|$$

The equation of the general hyper beam is a function of the hyper beam exponent x:

$$E_{hyp}= \{(|E_L|+|E_R|)^x - (|E_L-E_R|)^x\}^{1/x}$$

where

$$E_L= \sum_{m=1}^{M} \sum_{n=1}^{N/2} I_{mn} e^{j(2\Pi r)[\sin(\theta)\cos(\phi-\phi_n)+\alpha_n]}$$

$$E_R= \sum_{m=1}^{M} \sum_{n=N/2}^{N} I_{mn} e^{j(2\Pi r)[\sin(\theta)\cos(\phi-\phi_n)+\alpha_n]}$$

$K = 2\Pi/\lambda$ = Wave number
M = number of rings
N = number of elements present on m^{th} ring
r = radius of the m^{th} ring
I_{mn}= amplitude excitation of the n^{th} element
α_n= phase excitation of the n^{th} element
$\phi_n= 2\Pi(n/N)$= angular position of the n^{th} element

To steer the main lobe in the (θ_0,ϕ_0) direction, the phase excitation of the n^{th} element can be chosen to be
$\alpha_n= -kr \sin(\theta_0) \cos(\phi_0-\phi_n)$

And 'x' ranges from 0.1 to 1.

4 RESULTS

With the hyper beam effect, reduction of beam width and side lobe levels can be amplified and controlled by varying the exponent value u, different hyper beam patterns are obtained. As from the results the side lobe level and half power beam width is decreasing as the exponent value is decreased. For x=1 the half power beam width for 10 element linear array is 4 degrees where as for x=0.1 the half power beam width is reduced to 0.6 degrees as shown in Fig.6. The resulted simple hyper beam in 2D simulated for a 10 element circular array with exponent value x=0.5 is also shown in Fig.5. Where the half power beam width is observed as 2 degrees.

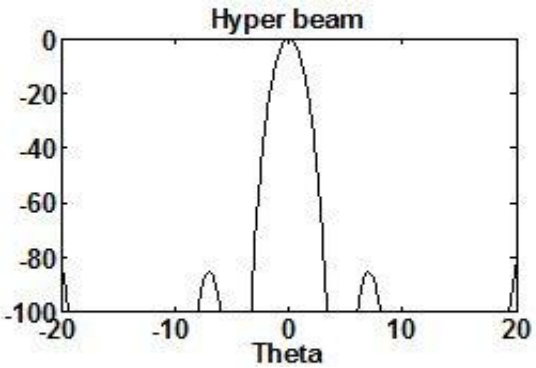

Figure 5 2D hyper beam pattern for 10 element circular array with x=0.5

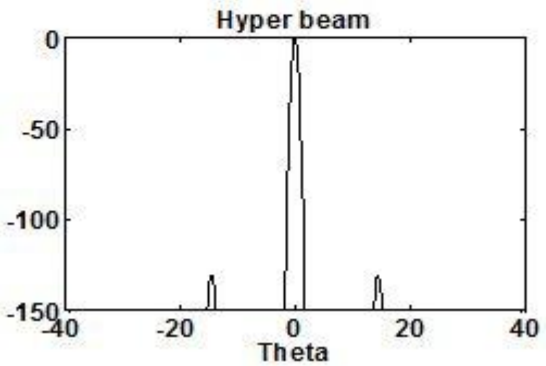

Figure 6 2D hyper beam pattern for 10 element circular array with x=0.1

From Fig.6 and Fig.7, for a 10 element circular array, conventional beam forming has the side lobe level and half power beam width -17dB and 10 degrees where as for Hyper beam forming technique, the side lobe level and the half power beam width is reduced to -140dB and 0.6 degrees respectively. Therefore, in comparison to conventional beam forming Hyper beam technique allows simultaneous reduction of beam width and side lobes.

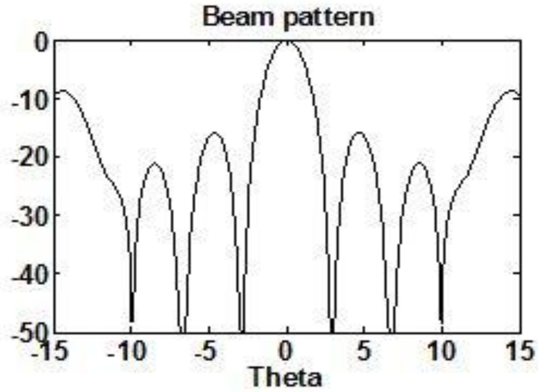

Figure 7 2D conventional beam pattern for 10 element circular array

To achieve point-to-point communication at higher frequencies, a single narrow beam of the radiation pattern is required which is usually obtained by concentric circular array, the side lobe level and half power beam width is reduced as from the results. For a 10 element circular array with exponent value x=0.1, the side lobe level is -140dB where as for a 15 element circular array with the same exponent value, the side lobe level is -190dB as shown in Fig.8. The resulted simple hyper beam in 2D simulated for a 20 element circular array with exponent value x=0.1 is also shown in Fig.9 where the side lobe level is observed as -240dB.

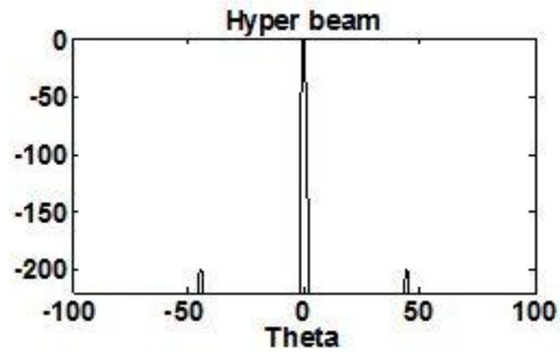

Figure 8 2D hyper beam pattern for 15 element circular array with x=0.1

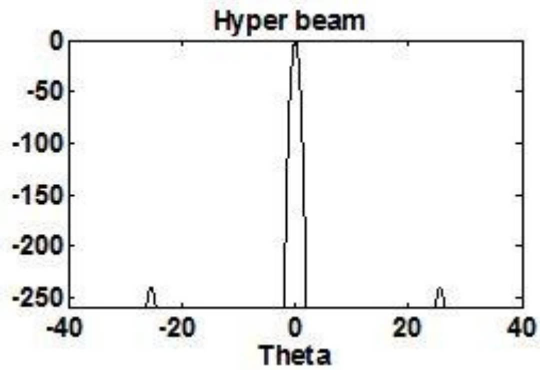

Figure 9 2D hyper beam pattern for 20 element circular array with x=0.1

5. CONCLUSIONS

This paper proposes a new technique for designing a concentric circular array antenna of isotropic elements to generate a pencil beam in the vertical plane with reduced side lobe level, suppression of grating lobe and also reduction of received noise level along with chance for increasing number of elements based on exponent value for certain array configurations. Results clearly show a very good resemblance between the desired and synthesized specifications for all the cases. This method is very effective and put into practice for array antennas of other shapes like planar array, liner array etc..

It has been proved that the hyper beam technique is much more effective than the conventional beam forming techniques in practice, where the high quality reception of data is allowed with an increased dynamic range and accurate target detection. This is not only applicable for high frequency surface wave radar systems but also for the other communication systems.

So our method can also be used to design antenna with any desired side lobe level while maintaining the number of elements to a reasonable value. Results for concentric circular ring antenna arrays have illustrated the performance of this proposed technique. Our further work will be focused on the design of more complex practical antenna problems.

6. ACKNOWLEDGMENT

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