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Conversion of Symmetrical Patterns to Asymmetrical Patterns using Amplitude and Phase Control

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Abstract**—*****An antenna is an essential device for wireless communication. Basically it is a transducer which converts electrical signals to electromagnetic waves during transmission and vice-versa during reception. Many applications require radiation characteristics that may not be achievable by a single element. However it is possible to obtain the desired characteristics, using an assembly of radiating elements in an electrical and geometrical configuration, referred to as an array. Different pattern synthesis techniques are reported in the literature. Symmetrical patterns can be generated using Taylor's distribution. With this method, it is possible to have a specified numbers of side lobes of equal level and other side lobes taper out from the main lobe. Suitable radiation patterns are required based on the application. In this work, symmetrical patterns are generated which are used for point-to-point communication. The asymmetrical patterns are very important for navigational purposes. Generation of symmetrical patterns is quite easy compared to asymmetrical patterns. In view of the importance of asymmetrical patterns, an attempt is made in this paper to convert symmetrical patterns into asymmetrical patterns using amplitude and phase control.***

Index Terms**— Amplitude, Asymmetrical Pattern, Phase, Radiation Pattern, Symmetrical Pattern, Taylor's method.**

I. INTRODUCTION

The symmetrical beams are used for point-to-point communications. The distance of communication depends on the values of the side lobe levels, the directivity and the beam width [1-3]. The lower the side lobe levels the more is the directivity and by decreasing the beam width of the antenna the directivity can be increased and by further decreasing the beam width pencil beams can be produced which are used for the tracking purposes. For good communication the side lobe levels need to be as low as possible.

II. GENERATION OF SYMMETRICAL PATTERNS

In this paper symmetrical patterns are generated using Taylor's synthesis [4-5] and the expression is given below

$$E(u) = \frac{\text{Sin}\pi u}{\pi u}\left[\frac{\prod_{n=1}^{\bar{n}-1}\left(1-\frac{u^2}{u_n^2}\right)}{\prod_{n=1}^{\bar{n}-1}\left(1-\frac{u^2}{n^2}\right)}\right] \quad (1)$$

in which $u = (2a/\lambda)\cos\theta$ with 2a/λ being the aperture extent in wave length, and theta referring to the angle measured from end fire. The roots u_n are given by

$$u_n = \pm\sigma\sqrt{A^2+\left(n-\frac{1}{2}\right)^2} \quad (2)$$

With A is measure of the side lobe level (SLL)

$$\sigma = \frac{\bar{n}}{\sqrt{A^2+\left(\bar{n}-\frac{1}{2}\right)}} \quad (3)$$

Where

$\bar{n}$ is the desired number of side lobes at equal levels

The aperture distribution required to produce Taylor patterns is given by

$$a(x) = E(0,A,\bar{n}) + 2\sum_{i=1}^{\bar{n}-1} E(i,A,\bar{n})\cos\left(\frac{\pi i x}{L}\right) \quad (4)$$

for $-L \le x \le L$

The amplitude distribution required to generate symmetrical patterns is presented in Fig.1 and the generated patterns in Figs. 2 to 4

III. CONVERSION OF SYMMETRICAL PATTERNS TO ASYMMETRICAL PATTERNS

The asymmetrical patterns [6-7] are used for navigation purposes. Depending on the depth off the sea or ocean, the crusts and thrusts the side lobe levels are to be varied. So depending on the side lobe levels the required pattern is to be generated. It has been possible to apply perturbation procedure [8] for continuous line sources to convert symmetric sum patterns into asymmetric sum patterns. However, this method is limited to patterns characterized by a sequence of lobes with deep nulls. When the desired pattern shapes are complicated, the aperture distribution to be designed also becomes complicated. For a given continuous aperture distribution and its corresponding pattern, the quality of approximation to this pattern by a discrete array is degraded when the sampling interval is increased, i.e., when the number of elements in the array is decreased. Taylor's method [6] of synthesis for producing symmetric sum pattern can be modified to produce unsymmetrical patterns. The Taylor's method is modified and is presented below. A generalization of equation (1) for asymmetrical patterns is

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$$E(u) = \frac{\sin\pi u}{\pi u}\left[\frac{\prod_{n=1}^{\bar{n}_r-1}\left(1-\frac{u}{r_n}\right)\prod_{n=1}^{\bar{n}_\ell-1}\left(1-\frac{u}{\ell_n}\right)}{\prod_{n=1}^{\bar{n}_r-1}\left(1-\frac{u}{n}\right)\prod_{n=1}^{\bar{n}_\ell-1}\left(1-\frac{u}{n}\right)}\right] \quad (5)$$

Here,

$$r_n = \sigma_r\sqrt{A_r^2+\left(n-\frac{1}{2}\right)^2} \quad (6)$$

$$\ell_n = -\sigma_\ell\sqrt{A_\ell^2+\left(n-\frac{1}{2}\right)^2} \quad (7)$$

With

$$\sigma_r = \frac{\bar{n}_r}{\sqrt{A_r^2+\left(\bar{n}_r-\frac{1}{2}\right)^2}} \quad (8)$$

and

$$\sigma_\ell = \frac{\bar{n}_\ell}{\sqrt{A_\ell^2+\left(n-\frac{1}{2}\right)^2}} \quad (9)$$

Where A_r and A_l represent right and left sidelobe level parameters.

The Taylor's pattern in more general form is given by

$$E(u) = \frac{\sin\pi u}{\pi u}D_0\left[\frac{\prod_{n=1}^{\bar{n}_r-1}\left(1-\frac{u}{r_n}\right)\prod_{n=1}^{\bar{n}_\ell-1}\left(1-\frac{u}{\ell_n}\right)}{\prod_{n=1}^{\bar{n}_r-1}\left(1-\frac{u}{n}\right)\prod_{n=1}^{\bar{n}_\ell-1}\left(1-\frac{u}{n}\right)}\right] \quad (10)$$

Here, D_o is a constant. When the subscripts r and ℓ are used to represent right and left side of the pattern, the null positions are given by

$$u_n' = \bar{n}_r\left[\frac{A_r^2+\left(n-\frac{1}{2}\right)^2}{A_r^2+\left(\bar{n}_r-\frac{1}{2}\right)^2}\right]^{\frac{1}{2}} \quad \text{For n=1, 2- - - -}(\bar{n}_r\text{-1}) \quad (11)$$

$$u_n' = -\bar{n}_\ell\left[\frac{A_\ell^2+\left(n+\frac{1}{2}\right)^2}{A_\ell^2+\left(\bar{n}_\ell-\frac{1}{2}\right)^2}\right]^{\frac{1}{2}} \quad (12)$$

Here, n= -1, -2, - - - $-(\bar{n}_\ell-1)$

Here $\bar{n}_r$ and $\bar{n}_l$ are positive integers and they represent the transition roots. A_r and A_l represent right and left side lobe level parameters.

Obviously that, if $\bar{n}_r = \bar{n}_\ell = \bar{n}$ and $\sigma_r = \sigma_\ell$ and $\bar{A}_r = \bar{A}_\ell$ =A then the above expression reduces to that of standard Taylor's pattern.

The aperture distribution corresponding to these modified Taylor patterns can be expressed from the Fourier Transform pair. That is,

$$A(x) = e^{-j\beta x}\sum_{m=-\infty}^{\infty} b_m e^{-jn\pi\frac{x}{a}} \quad (13)$$

Considering a continuous line source, the pattern [9-10] is represented by radiation integral. That is

$$E(\theta) = \int_{-L}^{L} A(x)e^{j\frac{2\pi L}{\lambda}xu}\,dx \quad (14)$$

Here,

L is length of the line source and $u = \sin(\theta)$.

Substitution of equation (13) in (14) gives

$$E(\theta) = \sum_{m=-\infty}^{\infty} b_m\int_{-L}^{L} e^{jn\pi\frac{x}{a}} e^{j\frac{2\pi L}{\lambda}x\left(\sin\theta-\beta\frac{\lambda}{2\pi L}\right)}dx \quad (15)$$

$$E(\theta) = \frac{a}{\pi}\sum_{m=-\infty}^{\infty} b_m\int_{-\pi}^{\pi} e^{jny}\,e^{juy}\,dy \quad (16)$$

Here,

$$y = \frac{\pi x}{a}$$

Simplifying the above integral we get

$$E_0(m) = 2xb_m$$

Finally, $$A(x) = \frac{1}{2a}\sum_{m=-(\bar{n}_\ell-1)}^{\bar{n}_r-1} E_o(m)e^{-jm\pi x/a} \quad (17)$$

This expression represents variation of amplitude distribution along with the phase to produce the Asymmetrical patterns. Amplitude and phase distribution required to convert symmetrical patterns into asymmetrical patterns are presented in figs. 5 & 6, and generated Asymmetrical patterns in fig 7 to 14, and their characteristics in Table. 1

IV. RESULTS

The amplitude distribution computed for generating symmetrical patterns using eq. (4) for $\bar{n} = 3$, SLL = -35dB is presented in fig. 1 and the symmetrical patterns generated using equation 1 from an array of 40 elements for $\bar{n} = 3$ SLL = -25 dB, -30 dB and -35dB are presented in Figs. 2 to 4 respectively. Amplitude and phase distribution required to convert symmetrical patterns into asymmetrical patterns are presented in figs. 5 & 6 for -15/-25 side lobe ratio.

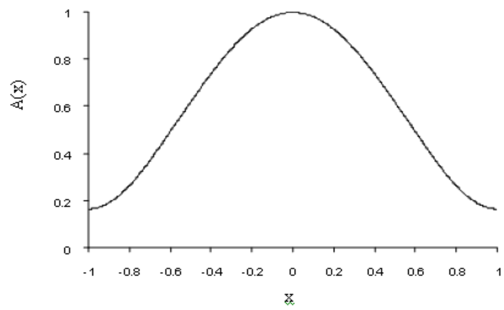

Fig. 1 Amplitude Distribution for Generating Symmetrical Pattern For $\bar{n} = 3$, SLL = - 35db

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Asymmetrical patterns for different side lobe ratios are presented in fig 7 to 14. Characteristics of generated asymmetrical patterns are presented in Table. 1

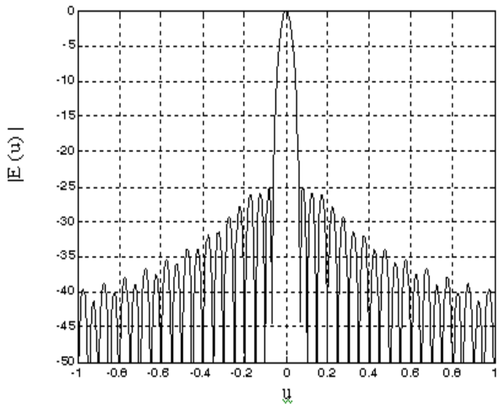

Fig. 2 Symmetrical pattern for $\bar{n} = 3$, SLL = -25 dB

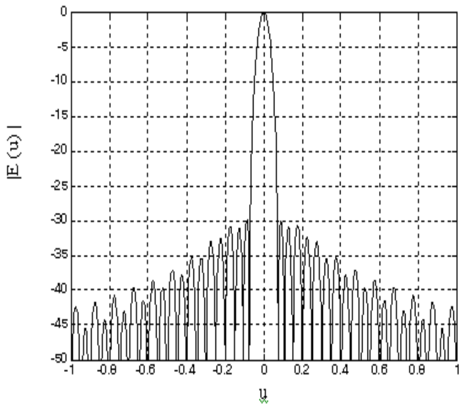

Fig. 3 Symmetrical pattern for $\bar{n} = 3$, SLL = -30 dB

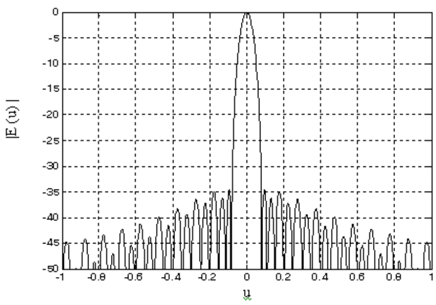

Fig. 4 Symmetrical pattern for $\bar{n} = 3$ SLL = -35 dB

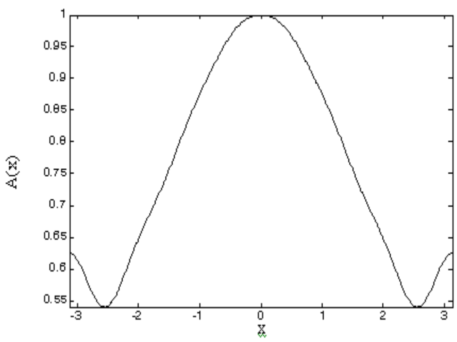

Fig. 5 Amplitude Pattern For Asymmetrical Beam Having -15/-25 Db Side Lobe Ratio

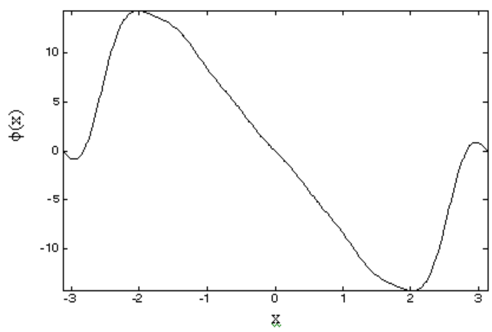

Fig 6. Phase Pattern For Asymmetrical Beam Having -15/-25 Db Side Lobe Ratio

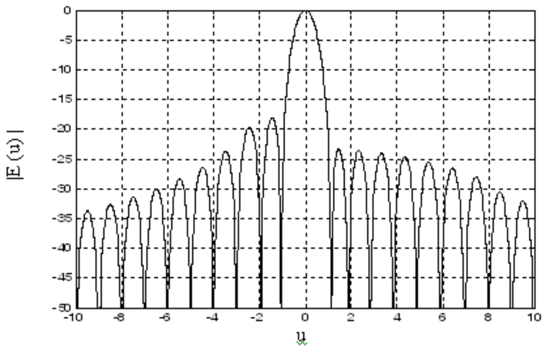

Fig 7. Asymmetrical Pattern for L_s= -15db and R_s= -20 Db

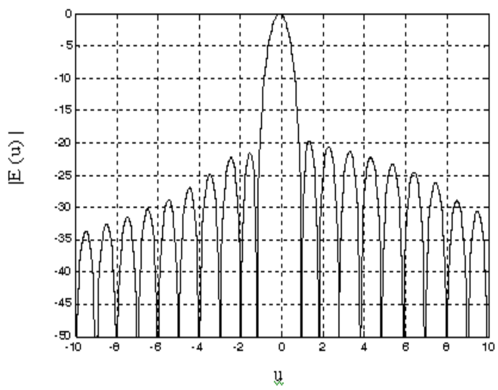

Fig. 8 Asymmetrical pattern for L_s=-20dB and R_s=-15 dB

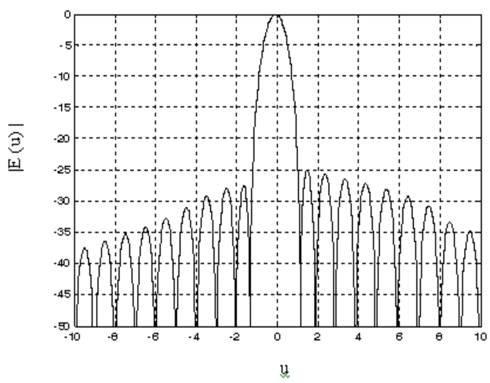

Fig. 9 Asymmetrical pattern for L_s=-25dB and R_s= -20 dB

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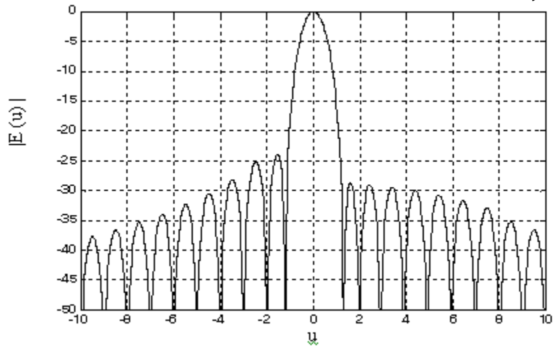

Fig. 10 Asymmetrical pattern for L_s=-20dB and R_s=-25 dB

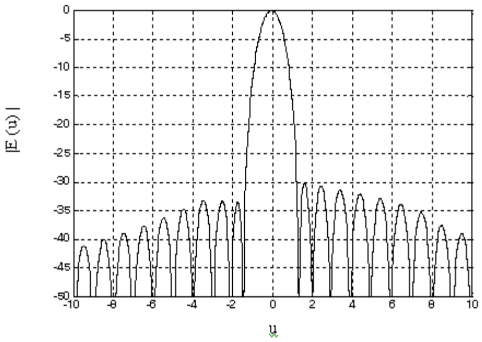

Fig. 11 Asymmetrical pattern for L_s= -30dB and R_s = -25 dB

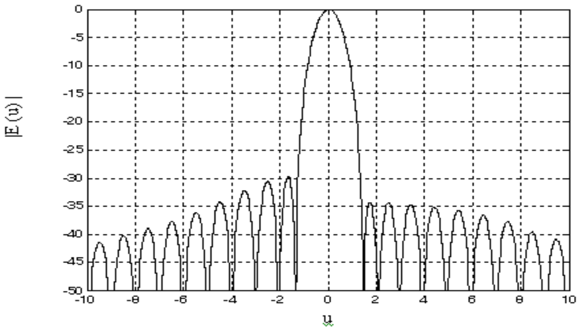

Fig. 12 Asymmetrical pattern for L_s= -25dB and R_s = -30 dB

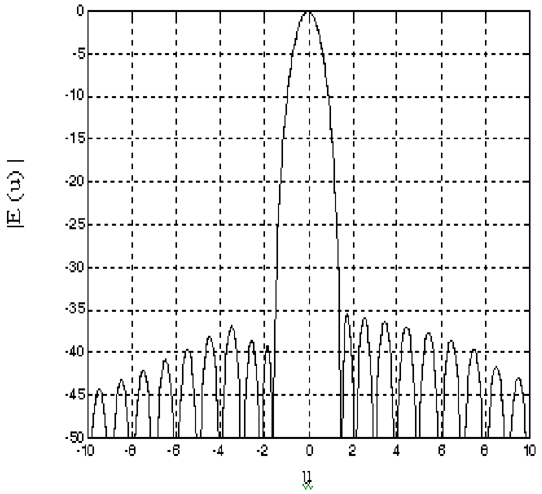

Fig. 13 Asymmetrical pattern for L_s= -35db And R_s = -30 Db

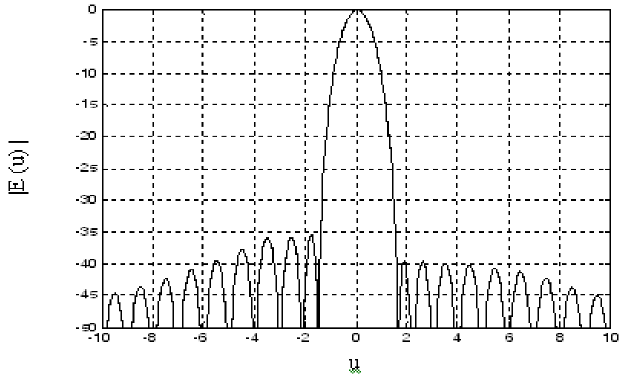

Fig. 14 Asymmetrical Pattern for L_s= -30db and R_s = -35 Db

Table 1 Characteristics of Modified Taylors Pattern

Designed Side lobe Levels (dB)	Computed Side lobe Levels (dB)	Main Beam Offset (Z_0)	Offset as percent of 3 dB Beam width	Main Beam Offset (Z_0)
15 / 25	16.7 / 24.3	0.06	6 %	0.062
15 / 30	17.5 / 28.3	0.12	12 %	0.115
15 / 35	18.2 / 32.3	0.175	17 %	0.165
15 / 40	19.0 / 35.7	0.23	22 %	0.211
20 / 30	21.8 / 28.4	0.095	9 %	0.098
20 / 35	22.5 / 32.2	0.15	15 %	0.150
20 / 40	23.4 / 35.9	0.25	19 %	0.199

V. CONCLUSION

Symmetrical beams are produced using Taylor's synthesis, as in this method there is flexibility to obtain the desired side lobe level and also to fix the number of side lobes having the same side lobe value. Symmetrical beams for side lobe levels -25 dB, -30dB and -35dB are presented. The generated symmetrical patterns are very useful in point to point communications. The reduction in side lobe levels reduces EMI problems. Different side lobe levels are required on either side of the main lobe depending on applications. So the symmetrical beams are converted into asymmetrical beams using amplitude and phase control. Using modified Taylor's synthesis method required amplitude and phase distribution is generated for converting symmetrical patterns to asymmetrical patterns of different side lobe ratios ranging from -15 dB to -40 dB. With this method Asymmetrical patterns of any side lobe ratios can be generated. Asymmetrical patterns generated are very useful in marine applications.

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