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DESIGN OF HORN ANTENNA ARRAYSFOR THE GENERATION OF LOW SIDELOBES

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ABSTRACT

The source of electromagnetic waves is antenna. Antenna is a device which radiates electromagnetic energy into free space in all directions single antenna characteristics like high beam width, low gain and low bandwidth are not sufficient in radar communication system for beam steering array antennas are designed for improving the parameters of beam width, gain and bandwidth.

In the conventional arrays side lobe level -13.5 dB is the obstacle to find the object in the radar system since main beam to first side lobe level is -13.5 dB. In the first side lobe level the most of the power is diverted from main beam, to overcome this and reduce the side lobe level is the array system. Standard amplitude distribution is used to reduce side lobe level. In this work triangular amplitude distribution is used to reduce the side lobe level up to -26.8dB. The standard Horn antenna is used in this work to produce narrow beams and high gain. By neglecting inter element interference the desired Horn arrays for N=10, 20, 40, 60 are designed. By adopting standard amplitude distribution to these arrays side lobe level are also reduced and are compared with the isotropic arrays. The results come up with good agreement.

KEYWORDS: Antenna Arrays, Horn Antenna, Side Lobe Level, Pattern Multiplication, Amplitude Distribution

INTRODUCTION

An antenna is a conductor that can transmit, send and receive signals such as microwave, radio or satellite signals. A high-gain antenna increases signal strength, where a low-gain antenna receives or transmits over a wide angle. In transmission, a radio transmitter supplies an electric current oscillating at frequency. In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified. A horn antenna or microwave horn is an antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies. [1][7].

The horn antenna is the simplest and probably the most widely used microwave radiator. It is used as the feed for large reflector and lens antennas in communication systems throughout the world. It is also a high gain element in phased arrays. Because horn antennas are highly accurate radiating devices, they are often used as standard-gain devices for the calibration of other antennas. The application of electromagnetic horns has been explored for nearly a century. Extensive investigations ofhorn antennas have been of increasing interest during the past three decades. A suitable developments of the fields at the transition of the conical/corrugated horn to free space using the mode-matching technique is reported by Ralf R. Collmannet. Al [2]. But the finite-difference time-domain (FDTD) method is used to accurately analyze TEM horn antennas for pulse radiation [4]. The transition from the feeding waveguide to the radiating aperture is analyzed by using the mode matching technique employing a stepped-waveguide approach [5]. As a result they are relatively easy to construct. By the very nature of their shape, these antennas are very easy to interface to waveguide. Horn antennas have very little loss, so the directivity of a horn is roughly equal to its gain.[3]

Formulation

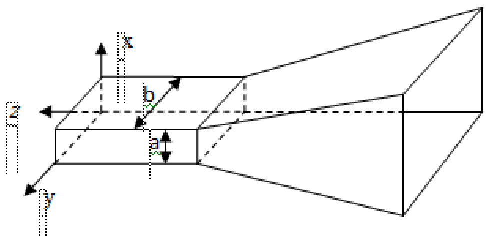

Figure 1: Pyramidal Horn Antenna

The radiation pattern for horns can be given by the following equations

$$x = \frac{a}{\lambda}\sin\theta\cos\phi \qquad y = \frac{b}{\lambda}\sin\theta\sin\phi \tag{1}$$

$$X = \frac{\cos(\pi x)}{\pi^2 - 4(\pi x)^2} \tag{2}$$

$$Y = \frac{\sin(\pi y)}{\pi y} \tag{3}$$

The overall radiation pattern changes when several antenna elements are combined in an array. This is due to the so called array factor: this factor quantifies the effect of combining radiating elements in an array without the element specific radiation pattern taken into account. The plot for the rectangular of horn antenna for the equation 4 is

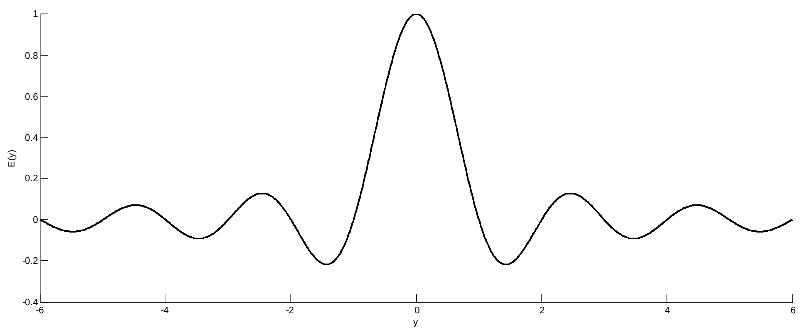

Figure 2: Rectangular Plot of Horn Antenna (Element Pattern)

Triangle Amplitude Distribution

The normalised amplitude distribution function [5] is given by

$$A(x)=\left(1+\frac{2x}{l}\right) \qquad \text{for } -\frac{l}{2}\leq x\leq 0$$
$$=\left(1-\frac{2x}{l}\right) \qquad \text{for } 0\leq x\leq \frac{l}{2} \qquad (4)$$

Using the above equation the triangular amplitude distribution pattern is ploted and is represented below figure.

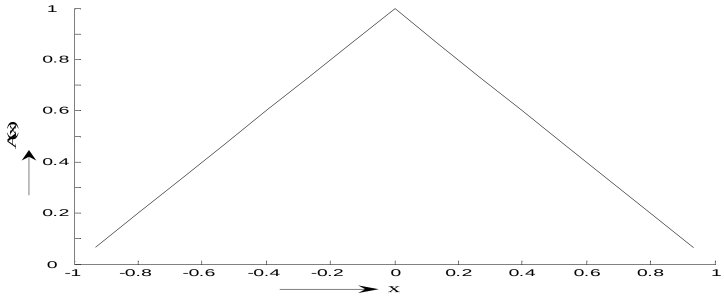

Figure 3: Triangular Amplitude Distribution along the Line Source

Pattern Multiplication

Principle of pattern multiplication states that the radiation pattern of an array is the product of the pattern of the individual antenna with the array pattern. Individual element pattern is the pattern of the individual array element. Array factor is a function dependent only on the geometry of the array and the excitation (amplitude, phase) of the elements. [4]

For horn antenna array the total field pattern is given by

E = element pattern × Array Factor

E = X * AF

X= the pattern factor of a single point source radiator for a horn antenna

AF=the array factor for the radiators for a linear antenna array

Where $$X = \frac{\cos(\pi X)}{\pi^2 - 4(\pi X)^2} \qquad (5)$$

$$AF = \sum_{n=1}^{N} A(x) e^{j\frac{2\pi l}{\lambda} u X_n} \qquad (6)$$

From the above equation (5)

X_n=location of the N^{th} element in the array

A (x_n) =excitation weight of x_n

N=no of elements in the array

$$x_n = \frac{2n-1-N}{N} \qquad (7)$$

u = sin θ

RESULTS

The amplitude distribution is used to reduce the side lobe level to the required level. Many applications where interference/jamming concerns are important require low side lobes. As the beam width increases it results in the reduced directivity which is the drawback. The rectangular form for the practical horn antenna is plotted in the figure 1. The resultant radiation pattern of horn antenna is multiplied with the amplitude distribution function using the pattern multiplication. The tabular forms for the specific location and amplitude are noted from table 1-4 .The plots of the uniform isotropic array with the triangular amplitude distribution array are compared and are plotted from the figure 2 to 7 for N=10, 20,40 elements.

Table 1: Triangular Amplitude Distribution with Specific Locations of N=10 Elements

S. No.	Element Location x_n	Amplitude $A(x_n)$
1	-0.9	0.1
2	-0.7	0.3
3	-0.5	0.5
4	-0.3	0.7
5	-0.1	0.9
6	0.0	1.0
7	0.1	0.9
8	0.3	0.7
9	0.5	0.5
10	0.7	0.3
11	0.9	0.1

Table 2: Triangular Amplitude Distribution with Specific Locations of N=20 Element

S. No	Element Location(X_n)	Amplitude $a(X_n)$
1	-0.9750	0.02
2	-0.9250	0.07
3	-0.8750	0.12
4	-0.8250	0.17
5	-0.7750	0.22
6	-0.7250	0.27
7	-0.6750	0.32
8	-0.6250	0.37
9	-0.5750	0.42
10	-0.5250	0.47
11	-0.4750	0.52
12	-0.4250	0.57
13	-0.3750	0.62
14	-0.3250	0.67
15	-0.2750	0.72
16	-0.2250	0.77
17	-0.1750	0.82
18	-0.1250	0.87
19	-0.0750	0.92
20	-0.0250	0.97
21	0.0000	1.00

Table 3: Triangular Amplitude Distribution with Specific Locations of N=40 Elements

S. No	Element Location(Xn)	Amplitude A(Xn)
1	-0.9750	0.02
2	-0.9250	0.07
3	-0.8750	0.12
4	-0.8250	0.17
5	-0.7750	0.22
6	-0.7250	0.27
7	-0.6750	0.32
8	-0.6250	0.37
9	-0.5750	0.42
10	-0.5250	0.47
11	-0.4750	0.52
12	-0.4250	0.57
13	-0.3750	0.62
14	-0.3250	0.67
15	-0.2750	0.72
16	-0.2250	0.77
17	-0.1750	0.82
18	-0.1250	0.87
19	-0.0750	0.92
20	-0.0250	0.97
21	0.0000	1.00
22	0.0250	0.97
23	0.0750	0.92
24	0.1250	0.87
25	0.2750	0.82
26	0.2250	0.77
27	0.2750	0.72
28	0.3250	0.67
29	0.3750	0.62
30	0.4250	0.57
31	0.4750	0.52
32	0.5250	0.47
33	0.5750	0.42
34	0.6250	0.37
35	0.6750	0.32
36	0.7250	0.27
37	0.7750	0.22
38	0.8250	0.17
39	0.8750	0.12
40	0.9250	0.07
41	0.9750	0.02

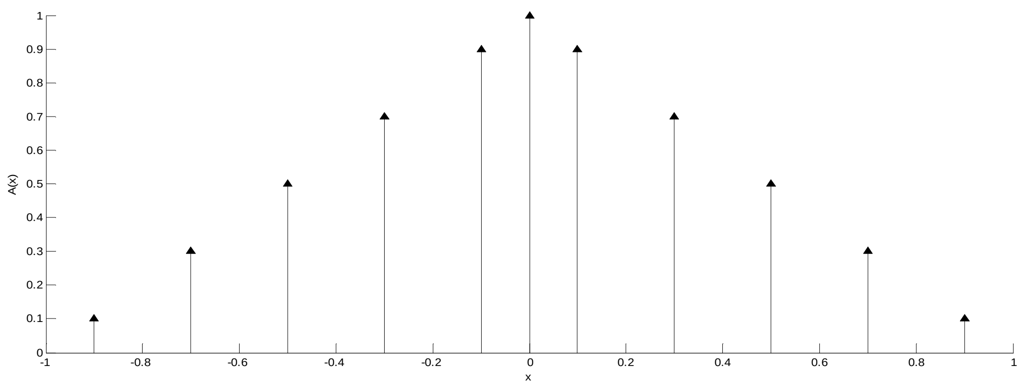

Figure 4: Triangular Amplitude Distribution with Discrete Locations of N=10

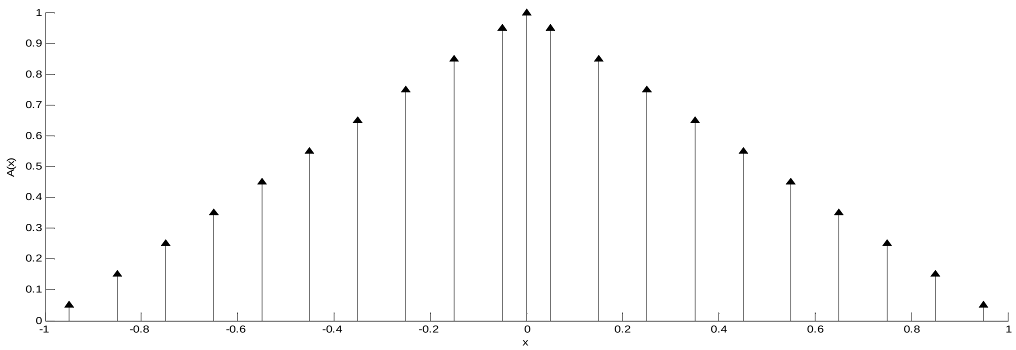

Figure 5: Triangular Amplitude Distribution with Discrete Locations of N=20

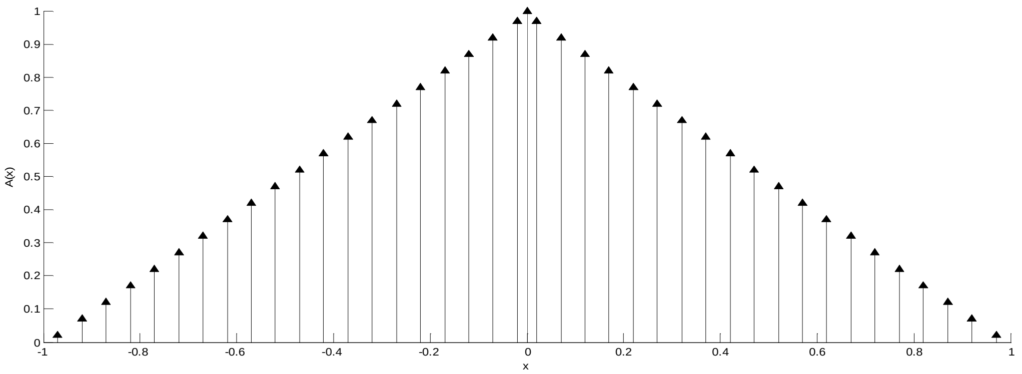

Figure 6: Triangular Amplitude Distribution with Discrete Locations of N=40

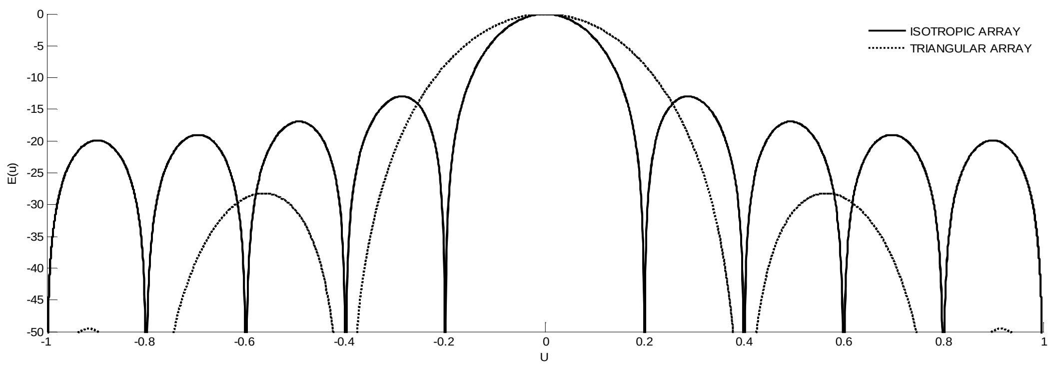

Figure 7: Triangular Amplitude Distribution with Isotropic Array for N=10

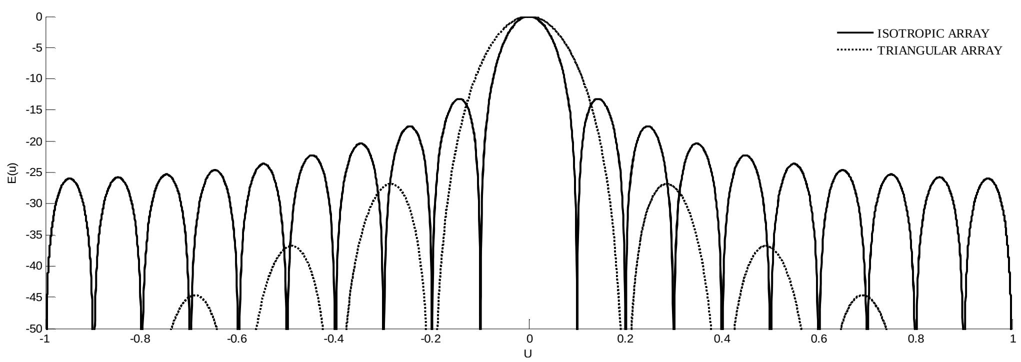

Figure 8: Triangular Amplitude Distribution with Isotropic Array for N=20

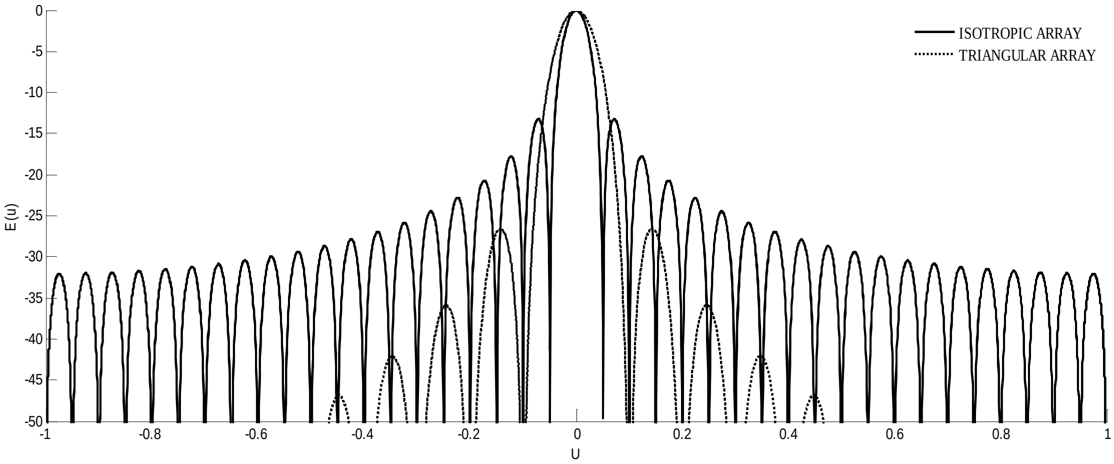

Figure 9: Triangular Amplitude Distribution with Isotropic Array for N=40

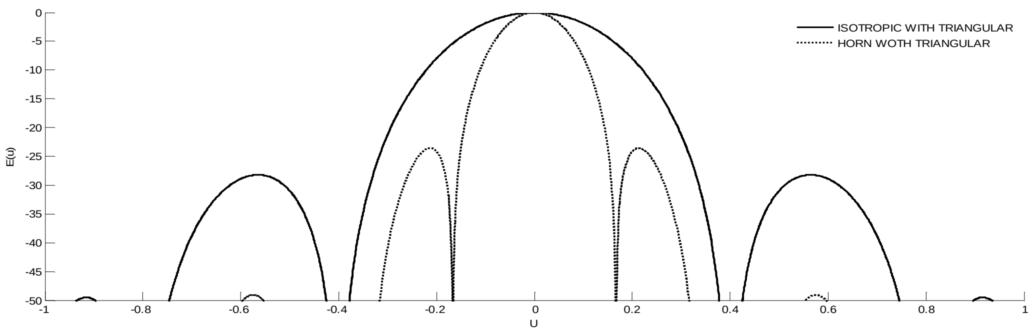

Figure 10: Synthesized Isotropic Arrays with and Without Horn Antenna for N=10

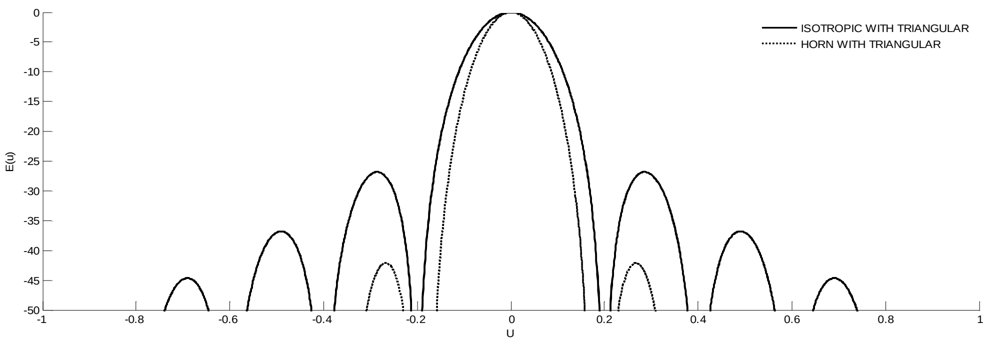

Figure 11: Synthesized Isotropic Arrays with and Without Waveguide for N=20

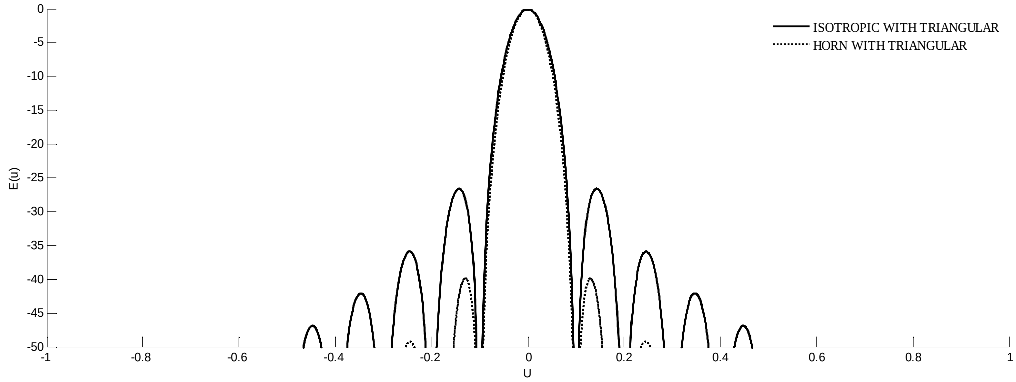

Figure 12: Synthesized Isotropic Arrays with and Without Waveguide for N=40

CONCLUSIONS

Many applications where interference/jamming concerns are important require low side lobes as the beam width increases it results in the reduced directivity which is the drawback. The trade-off between beam width and side lobe level is a principle encountered in antenna design that applies to both arrays and continuous distributions. Hence we are using the standard amplitude distribution techniques. Here we are using the triangular amplitude distribution. The plots for the amplitude distribution function are obtained using the equation. The side lobe level is reduced from -13.5 dB to -26.8 dB. The resultant pattern is multiplied with the horn antenna radiation pattern using the pattern multiplication.

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