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Design of Helical Array Antenna for generation of Positive Ramp and Stair Step patterns using Amplitude Distribution function

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ABSTRACT

For the generation of narrow beams and other desired beam shapes, the antenna arrays are widely used. The common problem which arises in antenna arrays is synthesis of the desired beam shapes. Normally, there is need of design antenna system to produce the required radiation characteristics. At least one type of beam shape is necessary for all communication and Radar systems. There is also a requirement in biomedical applications to produce various types of beams. In many applications one of the most important criteria is the beam shape. Positive ramp and stair-step are the typical desired Beam shapes. In point to point communication and also in high resolution radars positive ramp shaped beam is mostly used. Stair-step patterns are used to identify when there is more than one target is moving in different angular regions with different altitudes. For generating desired beam shapes, helical antenna is widely used. Normally beam shaping is done at expense. So the best option is employing of arrays and these are synthesized to produce the desired beam shapes. While producing any choice of beam shaped, high gains can be obtained from the array antenna. By employing Amplitude control technique the Fourier transform techniques are used to produce shaped beams. In this paper for generation of desired beam shapes using a helical antenna can be designed at 3.25GHz frequency.

Keywords: Helical antenna, Antenna Synthesis, Radar systems, Positive ramp, Stair-Step.

1. INTRODUCTION

Different antennas are used for various application in wireless communications.. In this paper for realization of positive ramp and the stair step patterns, helical antenna is used due to high directivity, circular polarization and wide bandwidth. Normally the helical antenna consists of conducting wire in the form of a spiral which may be either right handed (or) left handed. Based on the dimensions the helical antenna can radiate into modes namely axial mode and normal mode. In normal mode, the radiation pattern is perpendicular to the helical axis and radiation pattern observed is bidirectional. Whereas, in axial mode the radiation pattern is along the helical axis and radiation pattern observed in unidirectional. The axial mode is better the normal mode for point to point communication.

The desired radiation characteristics cannot be obtained by using single helical antenna so, we opt for arrays we can get the desired radiation characteristics and simultaneously high gain also by using helical antenna array. With the employment of Fourier transform techniques the desired shaped beams can be generated under the amplitude control method.By using WIPL-D the helical antenna is designed at 3.25GHz frequency. The coaxial cable is used as a feeding, for the purpose of input to the antenna. In space applications including weather, global positioning and radio telescope, ground stations for tracking satellite (or) space vehicles and data relay systems the helical antennas are commonly employed.

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2. GENERAL ANALYSIS

The helical antenna is one of the basic types of radiator, which is a simple antenna to provide circularly polarized waves. The antenna contains or leads by a coaxial transmission line in which, the center conductor is attached to the helical wire and the outer conductor is connected to the ground plane. Helical antennas are operated either in normal mode or axial mode. The common structure of the helix antenna is shown in Figure 1.

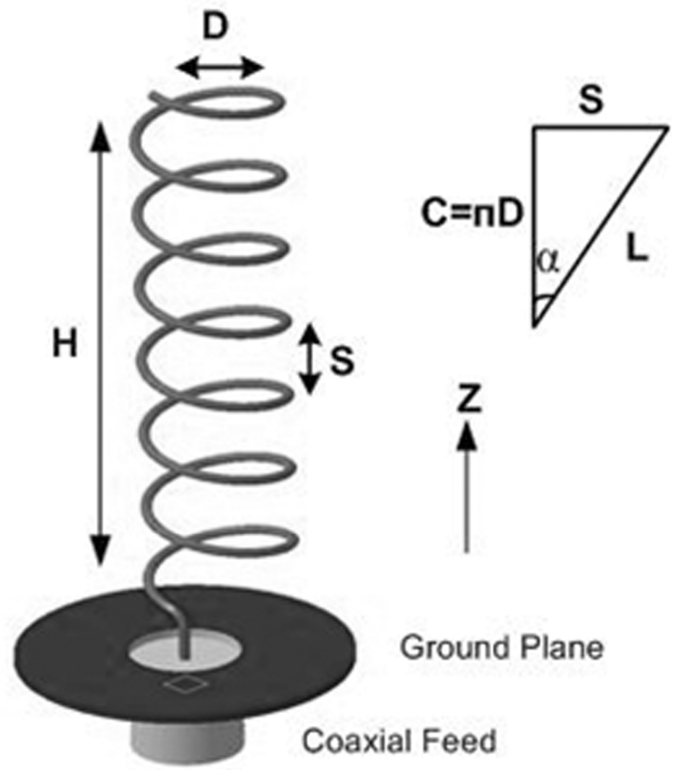

Figure 1: Geometry of the helix

From the Figure-1 shown above

'D' represents the helix antenna diameter of a turn.

'C' represents helix antenna circumference of a turn $C = \pi D$.

'S' represents vertical separation between turns of helical antenna.

'α' is the pitch angle, the extent of growth of the helix antenna parallel to the helix axis.

'*N* 'represents the total number of turns, present on helix.

'*H*' represents the total axial length of the helix, $H=NS$.

Figure-1show above is a left-handed helix antenna and the radiation pattern of the helical antenna will be maximum in axial direction .When the circumference *C* of the helix to be around a wavelength

$$\frac{3\lambda}{4} \leq C \leq \frac{4\lambda}{3} \tag{1}$$

In the axial mode operation the pitch angle α of the helical antenna is between 12 and 15 degrees, the helix antenna functions extremely well.

3. HELICAL ANTENNA DESIGN AND GEOMETRY

Generally, the helical antenna is assumed to be in a vacuum, if it is operated in the axial mode. Parameters of the helix are total axial length H, the radius of the imaged cylinder on which the helix is wound R. In this paper uniform helix are employed in which the pitch angle is constant, throughout the helical axis. Let us consider the following helical antenna data: axial length H=184.6mm, helix diameter 2a=29.3mm, and wire radius r=0.2mm. The number of turns is N=8 and total number of segments is 64. The antenna is designed for the frequency range from 3GHz to 3.5G Hz, with the central frequency of 3.25GHz.

The following are the design steps to determine the parameters of the helical antenna:

The wave length λ is $$\lambda = \frac{c}{f} \tag{2}$$

'S' is the spacing between two turns present on the helix, $$S = \frac{\lambda}{4} \tag{3}$$

The diameter D of the helix wire is $$D = \frac{\lambda}{3} \tag{4}$$

The circumference of one turn is $$C = \pi D \tag{5}$$

The helical antenna gain is calculated by

$$G = 10.8 + 10log\left(\frac{\mathrm{C}^2 NS}{\lambda^3}\right) \tag{6}$$

The Directivity D of the helical antenna is $$D = 15\mathrm{N}\frac{\mathrm{C}^2 S}{\lambda^3} \tag{7}$$

The Half Power beam width of the helical antenna is $$HPBW = \frac{52\lambda^{1.5}}{C\sqrt{NS}} \tag{8}$$

The Beam width between first nulls is $$FNBW = \frac{115\lambda^{1.5}}{C\sqrt{NS}} \tag{9}$$

The Axial Ratio (AR) is $$AR = \frac{2N+1}{2N} \tag{10}$$

The pitch angle of the helical antenna is $$\alpha = \tan^{-1}\frac{S}{C} \tag{11}$$

The normalized far-field pattern is $$E = \sin\left(\frac{\pi}{2N}\right)\cos\theta \frac{\sin\left(\frac{N}{2}\right)\psi}{\sin\left(\frac{\psi}{2}\right)} \tag{12}$$

$$\psi = k_0 S(\cos\theta - 1) - \pi(2 + \frac{1}{N}) \tag{13}$$

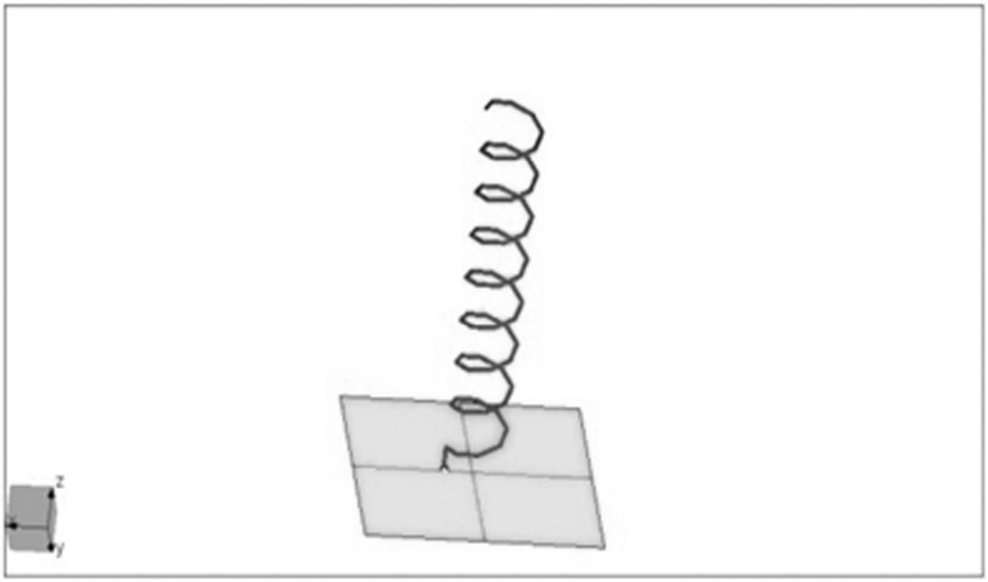

Figure 2: Model of Single element Helical antenna using WIPL-D

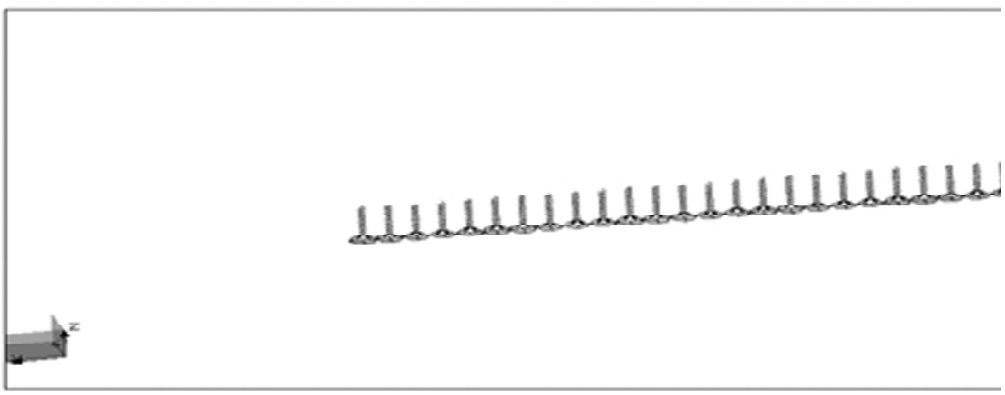

Figure 3: Helical antenna array using WIPL-D

Based on the above parameters we model the single helical antenna as well as 26 element helical array antennas using WIPL-D is shown in below Figure2 and Figure 3.

Generally, synthesis methods are used to obtain the required shaped beams. In this paper, we have used the amplitude distribution control method for the array synthesis. It is required to design an array with narrow beam width to produce radiation pattern along with low side lobes and decaying minor lobes. Here Fourier transform techniques are used under amplitude control method. Based on these techniques, we can generate the Ramp and Stair-step pattern using following equations

Ramp pattern is

$$r(u) = \left(\frac{u}{u_0}\right) e^{(-j\pi lqu)} \qquad 0 \le u \le u_0 \tag{14}$$

Stair-step pattern is

$$S_2 = \begin{cases} A_1 \; e^{(-j\pi lqu)} & -u_1 \le u \le -u_{21} \\ A_2 \; e^{(-j\pi lqu)} & -u_1 \le u \le +u_2 \\ A_1 \; e^{(-j\pi lqu)} & -u_2 \le u \le +u_1 \end{cases} \tag{15}$$

The amplitude distribution function is

$$A_m(x) = b_n e^{(-j\pi lqu)} \tag{16}$$

b_n = excitation coefficient

Based on these equations, we can generate the amplitude coefficients and these coefficients are placed in array of helical antenna.

4. RESULTS & CONCLUSION

The single element helical antenna is designed, modeled and fabricated. The radiation pattern obtained for the single element antenna by using WIPL-D software is shown in Figure-4. A gain of 13.43 dB and VSWR of 1.62 is noted from the radiation beam patterns. By observing the S-Parameter graph the return loss is -30.50dB. As due to return loss is small, so the maximum power will be transferred from input to the antenna. The Array antenna of 26 elements by using the above specified single element is realized to generate shaped beams using amplitude control method. In this paper, Ramp and Stir Step patterns are generated using Fourier series function and corresponding results are shown in Figure 8 and 9 respectively.

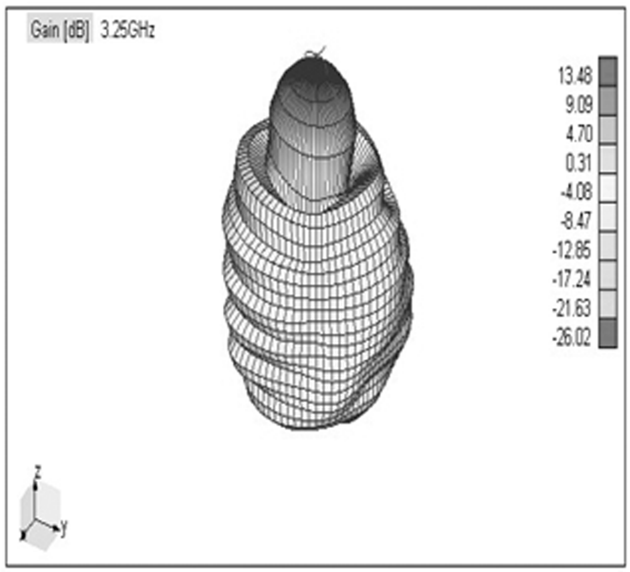

Figure 4: 3D Radiation pattern

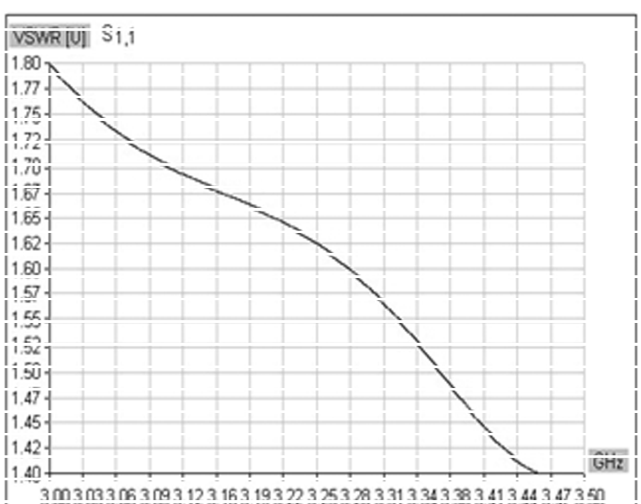

Figure 5: Simulation of VSWR

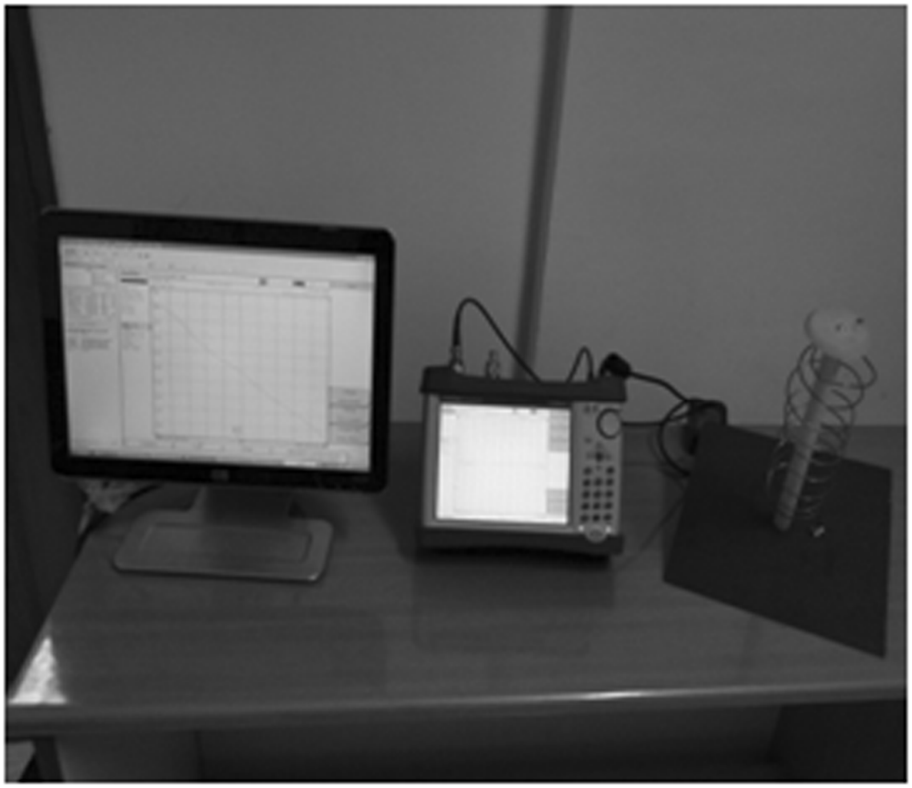

Figure 6: Experimental Setup to measure VSWR

Figure 7: Experimental measure VSWR

For various types of beams, the maximum amount of radiation is directly normal to the axis of the array. In arrays, ripples in the angular region are less and have a large number of elements. In the stair-step pattern, it is observed that the radiation pattern is symmetrical at the center of the array which reduces the area in the vertical direction with gradual steps. In ramp type beams the radiation pattern is non-symmetrical at the center of the array and also each exhibits a particular coverage on one side of the beam.

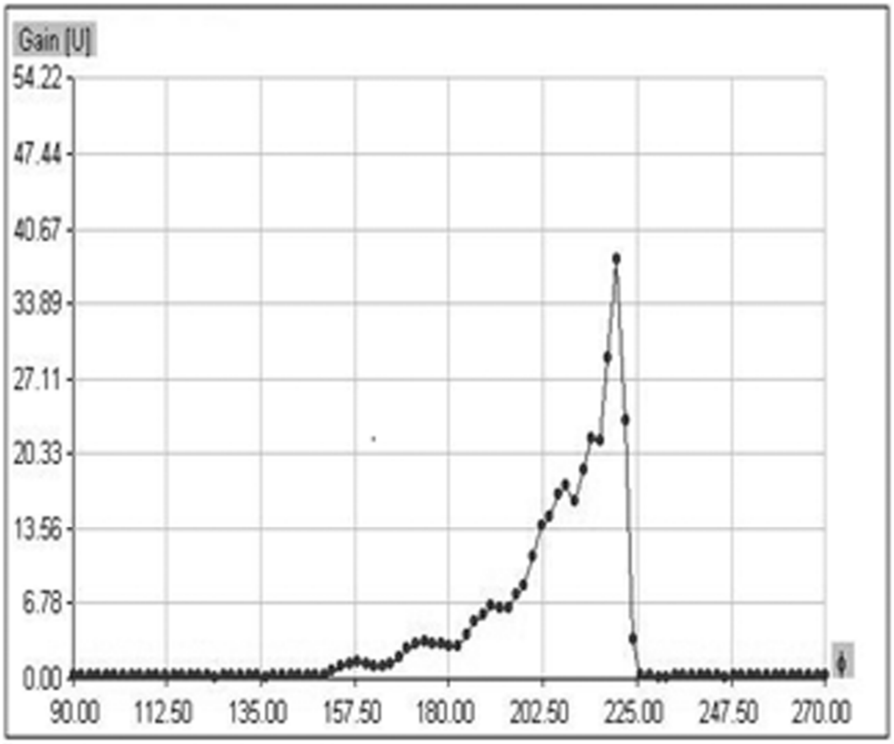

Figure 8: Positive ramp pattern

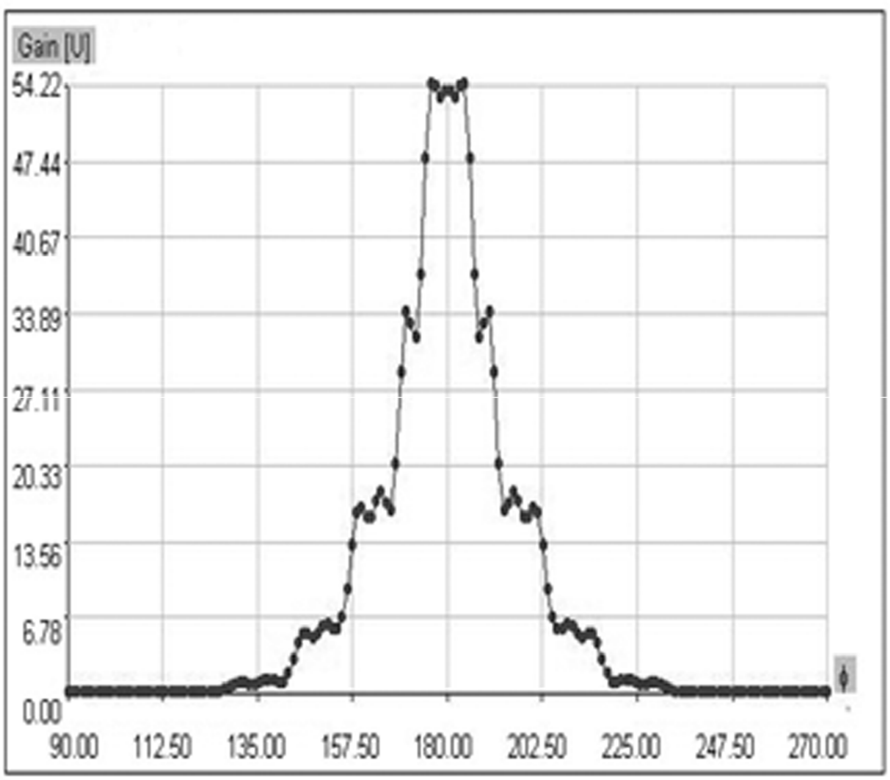

Figure 9: Stair-step pattern

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