DESIGN OF HELICAL FEED FOR PARABOLIC REFLECTOR ANTENNA AT 2.45 GHZ

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Abstract *Helical antennas have long been popular in applications from VHF to microwaves requiring circular polarization, since they have the unique property of naturally providing circularly polarized radiation. One area that takes advantage of this property is satellite communications. Where more gain is required than can be provided by a helical antenna alone, a helical antenna can also be used as a feed for a parabolic dish for higher gains. As we shall see, the helical antenna can be an excellent feed for a dish, with the advantage of circular polarization. One limitation is that the usefulness of the circular polarization is limited since it cannot be easily reversed to the other sense, left-handed to right-handed or vice-versa*

Keywords: Helical Antenna, Parabolic Dish feed, Right Hand Circular Polarization

1. INTRODUCTION

The helix is only a small fraction of wavelength in diameter and acts as a guiding structure [01].it consists of a single conductor or multiple conductors wound in to a helical shape. The main purpose of the paper is to point out low cost and high gain feed design for parabolic dish of 600mm diameter. Designed feed is very small of only 2.5 turns and provides RH circular polarization. This is considering in wire antenna category which is familiar because they are seen virtually everywhere on automobiles, building, ships, aircrafts, spacecraft and so on [02], the helix is a basic three-dimensional geometric form. A helical wire on a uniform cylinder becomes a straight wire when unwound by rolling the cylinder on a flat surface. Viewed end-on, a helix projects as a circle. Thus, a helix combines the geometric forms of a straight line, a circle and a cylinder. In addition a helix has handedness [08]; it can be either left or right handed. Helical antenna consists of helical loops made of a thick conductor, which have the appearance of a screw thread. It is associated with a ground plane made of the conductor. The ground plane is often made of screen or sheet or of radial and concentric conductors. The antenna is fed by a coaxial cable. The energy in the circularly polarized wave is divided equally between the horizontal and vertical components; the two are 90º out of phase, with either one leading, depending on construction [09]. The transmission from a circularly polarized antenna will be acceptable to vertical or horizontal antennas, and similarly a helical antenna will accept either vertical or horizontal polarization. Experimental techniques in shaping reflector surfaces and optimizing illumination over their apertures so as to maximize the gain. The use of reflector antennas for deep space communication [02]. It is widely used to modify the radiation pattern of a radiating element, the backward radiation from an antenna may be eliminated radiates from an antenna may be eliminated with a plane sheet reflectors of large enough dimensions [01]. Research found that helix pitches much smaller than the recommended optimum pitch of 12 to 14 degrees seemed to work well, so I expanded the range to include pitches from 7.5 to 15 degrees and lengths from 2 to 5 turns. The helix dimensions were targeted for a center frequency of 2.4 GHz, and patterns calculated over 1.8 to 3.0 GHz. The results, rather than finding any optimum, suggest that the helical antenna is a very forgiving feed – near the center design frequency, almost any dimensions will work to some degree [04]. The success in the exploration of outer space has resulted in the advancement of antenna theory.

Because of the need to communicate over great distances, sophisticated forms of antennas had to be used in order to transmit and receive signals that had to travel million of mile [15].

2. DESIGN & CALCULATIONS

Helical antennas are relatively broadband, typically useful over a range of frequencies relative to the helix circumference of 3/4λ to 4/3λ, or roughly a 60% bandwidth [04]. The radiation patterns are much more useful near the center of the range. Thus, the main advantage of the broadband characteristic of the helical antenna is that the dimension is not critical. The ratio f/D (focal length/diameter of dish) is the fundamental factor governing the design of the feed for a dish. The ratio is directly related to the beam width of the feed necessary to illuminate the dish effectively [03].

R= Diameter of Ground Plane
D = Diameter of Helix
S = Axial Linear Distance (Spacing) Between Two Windings
d = Wire (coil) Thickness
C = Circumference of Winding
α = Pitch Angle

See in the Figure 1, the sketch of helical antenna.

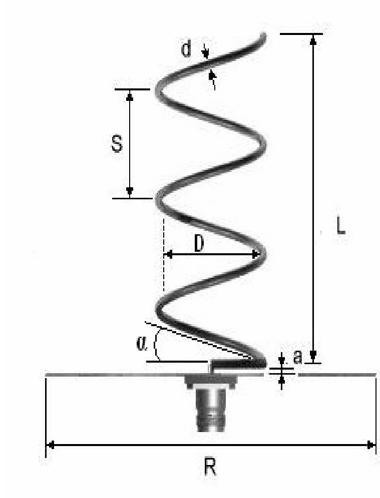

Fig (1) Helical antenna

The input information required to start the design procedure consists of the frequency range and the central frequency, f_c the required maximum antenna gain, the allowed variations in the gain, the axial ratio, and the required relative bandwidth. To illustrate the design procedure we have designed a helical feed for the parabolic reflector having diameter (D) of 600mm, focal length (f) of 270mm and depth of dish (d) is 83mm. From the dimension of the dish the f/D ratio turns out to be 0.45 see in Figure 2.

As discussed above f/D ratio is the key factor in the design of the feed for the dish [07]. Feed design is carried out for the frequency range of 2.4 GHz to 2.5 GHz with center frequency equal to 2.45 GHz. All helical dimension equations are in terms of wavelength. For 2.45 GHz center frequency value of λ is 0.1224 m i.e. λ = 122.4 mm.

Fig (2) 2.5 Turns RHCP helical antenna at 2.4 GHz

All the parameter mentioned in the above figure can be calculated. The coil or wire thickness is about λ/100 = 1.22mm. Now for the required turns spacing of 20mm and directivity of about 4 db, circumference and the diameter of the coil is obtained as 99.74mm and 31.74mm respectively. Pitch angle α = 11.33 ° and gain of helical without reflector is 9.03 db.From the conventional approach the theoretical value of all required parameters are calculated [13]. The experimental set up included reference antenna that works at the same operating frequency at which helical feed had to operate. A patch antenna having gain of 7 db and operating frequency of 2.45 GHz has been employed for the purpose. The results of the experiments with reflector are provided in the Table 1.

Frequency of operation: 2.4GHz – 2.5 GHz
Center Frequency f_c: 2.45 GHz

$$\therefore \ \lambda_c = c / f_c \qquad (1)$$

$$\lambda_c = c / f_c$$

Helical winding (coil) thickness (d):

$$d = \frac{\lambda}{100} \qquad (2)$$

d = 1.22 mm

Required spacing (s) = 20 mm

Required Directivity = 4.069 db

Directivity (D)

$$D = \frac{15C^2 NS}{\lambda^3} \quad (3)$$

$$C^2 = \frac{D\lambda^3}{15NS}$$

$$\therefore C^2 = \frac{4.069\times (122.4)^3}{15\times 2.5\times 20}$$

$$\therefore C = 99.74 \text{ mm}$$

But $C = \pi D$

$$\therefore D = 31.74 \text{ mm}$$

A very common antenna form for such an application is a parabolic reflector. Antennas of this type have been built with diameters as large as 305 m. Such large dimensions are needed to achieve high gain required transmit or receive signals after millions of miles of travel. Some of the AMSAT satellites and others require more than 15 dB gain with circular polarization for good reception [05]. Until someone finds an optimization that yields higher gain from a long helix, some other antenna type is needed; a parabolic dish is often a good choice see proposed design in Figure 2. While a large dish can provide gains upward of 30 dB, a small dish can easily provide the 20 to 25 dB gain needed for many satellite applications [11]. The beam width of a small dish is broader than the beam of a large dish, making tracking less difficult. Of course, the dish needs a feed antenna, and a short helix is a good choice for circular polarization.Asmalloffsetdishisvery attractive, since the feed blockage, which degrades small dish performance is greatly reduced [10].

3. RESULTS AND DISCUSSIONS

Parabolic dish antenna is the most commonly and widely used antenna in communication field mainly in satellite and radar communication. The feed designs for the parabolic dishes are having their own advantages over conventional feed. From a practical point of view, the antenna's length, L, is an important design parameter. Hence, we set a goal to maximize the gain for a given normalized length. The gain of the parabolic dish with center feed of helical has been measured for the different shape and size of the helix ground plane [12] see in Figure (3).it shows a reasonably clean pattern with relatively small sidelobes adjacent shades of gray have a difference in amplitude of 2dB.the backlobes of most helical antennas. Like a twisted asymmetric shape. Figure (4) shows a VSWR measurement set up.

Requirement of the helical feed arises from the need of circular polarization. It’s having Right Hand Circular Polarization operating at center frequency of 2.45 GHz [14]. Helical feed with reflector dish having maximum gain of 23 dB (circular ground plane of 110 mm diameter) and 22 dB (octagon ground plane) observed on spectrum analyzer see in Figure 5.

Not only gain but we got excellent result for VSWR i.e. 1.19 & return loss 21 dB with just only 2.5 turns of coil. Its design is simplest of all antennas with coil wound on core [09]. We have measured a Return Loss = 21 dB, VSWR = 1.19 for this proposed design that will justifies a value by comparing the results with parabolic reflector calculator.

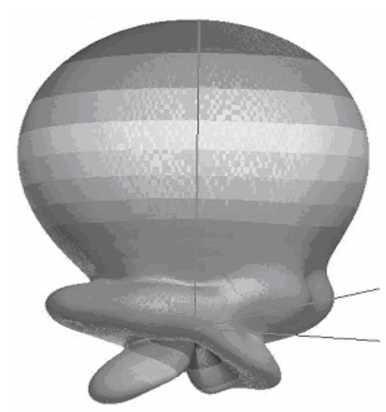

Fig (3) Gain of helical antenna with circular ground plane courtesy by [3] & [14] for four turn helix a 2.4 GHz.

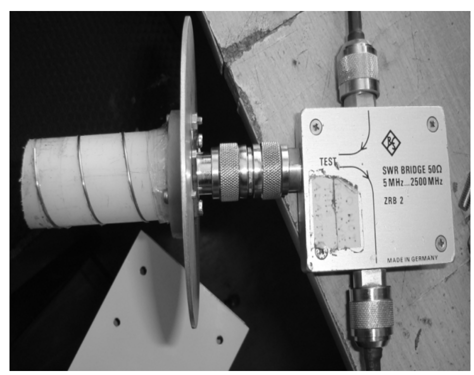

Fig (4) VSWR Measurement set up

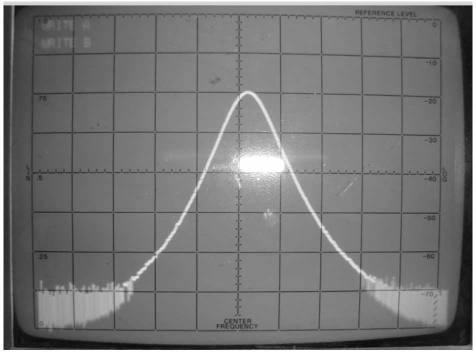

Fig (5) Gain of Parabolic Dish with helix on Spectrum analyzer

See in below table we have analysis at three different frequencies and Free Space Loss (FSL).

FSL= $4 \pi R/\lambda$,

Gain = FSL + Cable Loss-Transmitter level-Receiver Level-transmitter antenna Gain

Table 1. Result of Helical Antenna at different frequency

Freq (GHz)	FSL (dB)	FSL - 7+2.14 (dB)	Reading (dB)	Gain (dB)
2.40	46.066	41.20	18	23.20
2.45	46.245	41.38	18	23.38
2.50	46.421	41.56	20	21.56

4. CONCLUSION

Requirement of the helical feed arises from the need of circular polarization. It's having Right Hand Circular Polarization operating at center frequency of 2.45 GHz. Helical feed with reflector dish having maximum gain of 23.38 dB. With the good gain we got excellent result for VSWR is 1.19 & return loss 21 dB with just only 2.5 turns of coil set up is explained. Its design is simplest of all antennas with coil wound on core.

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