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Design of Helical Antenna for Wideband Frequency

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Abstract

A design of helical antenna for wideband frequency is proposed. The strip helical antenna is designed for wideband applications that provide a wide bandwidth and circular polarization. The helical antenna is planned on at 10 GHz frequency by using Paper material. The copper strip is printed on a substrate then rolled into a helix shape with a specific radius to realize the circular polarization. A wideband bandwidth of 1.37GHz with a resonant frequency at 10 GHz is achieved by the helical antenna on the Paper substrate. The presented antenna on paper substrate has achieved a gain of 11.61dB. The antenna parameters have been simulated and analyzed by using the commercial CST software. The proposed antenna can be used for various wireless applications especially for wideband applications.

Keywords - Helical Antenna, wideband, Paper material, Wireless applications.

I. INTRODUCTION

Helical antenna or helix has a long history and have attracted various study and development for more than 60 years since its first invention [1]. Helical antennas have two popular modes of operation which is normal mode (electrically small broadside) and axial mode (electrically large endfire) [2]. The radiation behavior of the helix antenna vary according to the design structure. As a result, the antenna performances can be different in terms of polarizations and radiation pattern [3],[4].

A helical antenna consists of a conductor wound into a helical shape and connected to a ground plane [5]. Based on the helical antenna structure, it can provide a wide bandwidth with circular polarization characteristics as presented in [6]-[11]. Recently, the circular polarization on the wideband antennas have received significant attention among the researcher due to its capabilities in fulfilling the requirement of the high gain, high data rate transmission and high efficiency [12]-[13].

The dielectric resonator of the Helical antenna helps to provide wide bandwidth with low cost and a small size of antenna [14]. On the other hand, the reflector is used to enhance the antenna's performances. Nevertheless, in [15], the gain obtained by the antenna is not adequate although the design was similar to the classical helical antenna. A helical antenna with dielectric resonator with cylindrical ground plane mounted with the helical antenna with operating frequency of 5.8GHz proposed in [16-17]. Through the dielectric resonator and cylindrical ground plane, the antenna capable to realize the high gain and wide bandwidth but with narrow radiation pattern. Moreover, the Axial Ratio (AR) bandwidth is still low and cannot be used for high data rate transmission.

Therefore, an effective alternative proposed in [8] is the hemispherical helical antenna. By replacing the wire with a tapered metallic strip, the AR bandwidth of the hemispherical helical antenna is enhanced to 24% with antenna height of 0.28 λ_0 but it requires an impedance matching section which complicates its structure and makes it hard to fabricate. When the number of helical elements increases, the helical antenna can radiate in circular polarization because the helical elements are fed with a certain phase difference and their length is less than one wavelength. As a result, these helical antennas which are called the multifilar helix antenna play an essential role in mobile satellite communication and global positioning systems.

In this paper, a detailed analysis of the strip-helical antenna is carried out at 10 GHz by using Paper material. The strip is printed on a substrate then rolled into a helix shape to achieve circular polarization without an impedance matching and that the proposed antenna can be used for potential applications in wideband and ultra-wideband wireless communication. The antenna design parameters and the simulated results are achieved using the commercial software CST.

II. DESIGN OF HELICAL ANTENNA AND SPECIFICATIONS

The geometry of the strip helical antenna design is depicted in Fig. 1. Which is comprises of a cylindrical helix and square shape ground plane. The metallic strip which contains the cylindrical helix is patched on the paper substrate with a uniform width (*w*). Furthermore, the substrate is rolled in to hollow cylinder in order to form the strip helix with the diameter (D), spacing (center-to-center) between turns (S), length of one turn (L), and number of turns (N). To obtain the axial-mode operation, substrate B is used as a square shape ground plane below the helix.

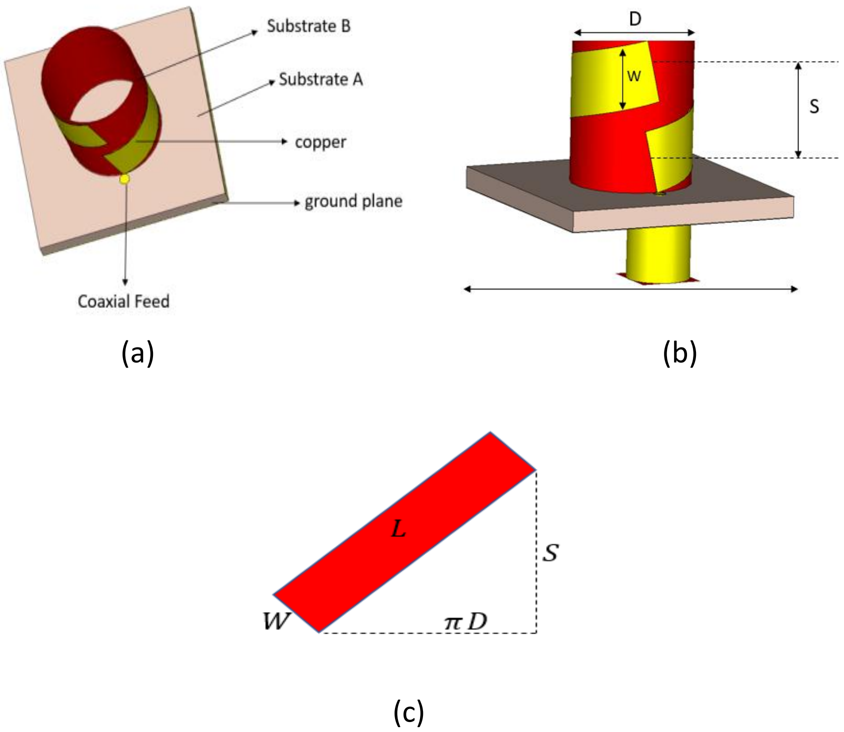

Figure 1: The structure of the proposed antenna: (a) 3D view, (b) Side view, and (c) unrolled strip helix of one turn.

The empirical formulas used to calculate the helical antenna parameters.

$$D_o = \frac{15NSC^2}{\lambda_o^{\ 3}} (\,dimensionless\,) \qquad (1)$$

Where D_0 is the directivity, N is the number of turns, S is the spacing between the turns, C is the helix circumference, and λ is the wavelength.

$$HPBW = \frac{52}{C}\sqrt{\frac{\lambda^2}{NS}}(degrees) \qquad (2)$$

$$FNBW = \frac{115}{C}\sqrt{\frac{\lambda^a}{NS}}(\,degrees\,) \qquad (3)$$

$$A_{eff} = \frac{C\lambda^2}{4\pi} meters^2 \qquad (4)$$

$$Impedance\ at\ terminal\ = \frac{140C}{\lambda}\Omega \qquad (5)$$

$$AR = \frac{2N+1}{2N} \qquad (6)$$

Where the HPBW is the Half-Power band width, FNBW is the First Nulls Beamwidth, A_{eff} is the effective aperture, and AR is the axial ratio.

The ratio of the wave velocity travelled along the helix to that in free space:

$$p = \frac{\frac{L_o}{\lambda_o}}{\frac{s}{\lambda_o} + 1} \tag{7}$$

This is for ordinary end-fire radiation. However, for the Hansen-woodyard end-fire radiation, the following expression can be used:

$$p = \frac{\frac{L_o}{\lambda_o}}{\frac{s}{\lambda_o} + \left(\frac{2N+1}{2N}\right)} \tag{8}$$

To obtain the axial-mode for helical antenna, the C should be ranging from ¾ λ < C < ⁴⁄₃ λ [7].

Fig. 2 demonstrates the design of the proposed helix antenna which targeted to operate at 10 GHz. This helix antenna has a specification with 10 turns, wavelength of 30 *mm*, length of 310 *mm*, height of 70 *mm*, spacing of 7 *mm*, diameter of 9.55 *mm*, and a calculated strip width of 4.84 *mm*.

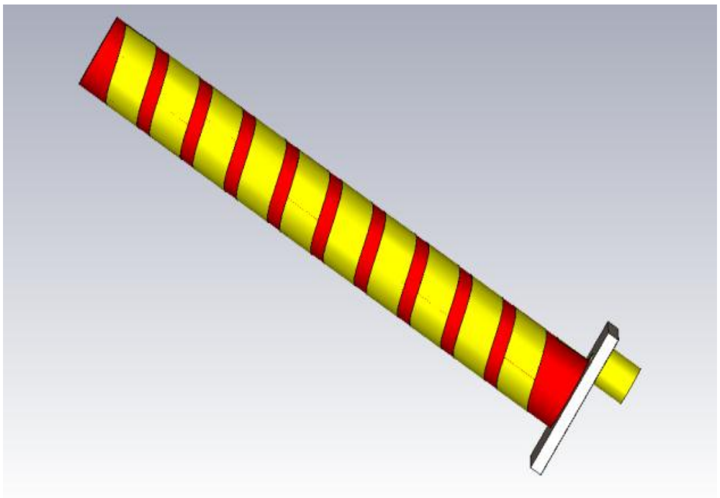

Figure 2: Design structure of 10 GHz Helical Antenna using Paper material.

However, by using Paper material, with square shape ground, Table 1 shows the design specifications for helical antenna at 10 GHz operating frequency by using Paper material.

Table 1

The design specifications of 10 GHz helical antenna using Paper material

Parameters	Value
Dielectric constant (εr)	2.31
Substrate thickness (h)	0.1 mm
Pitch angle (∝)	13°
Wavelength (λ)	30 mm
Circumference (C)	30 mm
Number of turns (N)	10
Spacing between turns (S)	7 mm
Cylindrical diameter (d)	9.55 mm
Length of 1 turn strip (Lo)	31.0 mm
Total length of helical antenna (L)	310 mm
Height of helical antenna (H)	70 mm
Ground Plane (0.75 λ)	22.5 mm

III. RESULTS AND DISCUSSIONS

Fig. 3 demonstrates the simulation results for the designed helical antenna at 10 GHz operating frequency by using the Paper substrate. The magnitude of the S_{11} parameter was recorded at operating frequency of 10 GHz as illustrated in Fig. 3. The simulated results showed wideband width at frequency range from 8 GHz to 12 GHz and achieved less than -10 dB at 10 GHz operating frequency. It achieved -11.52 dB at 10 GHz operating frequency with a bandwidth of 1.37 GHz which make it suitable for wideband applications.

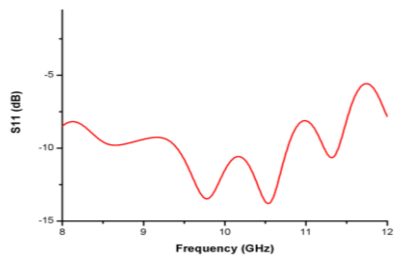

Figure 3: Simulated S_{11} results of 10 GHz of helical antenna using Paper material

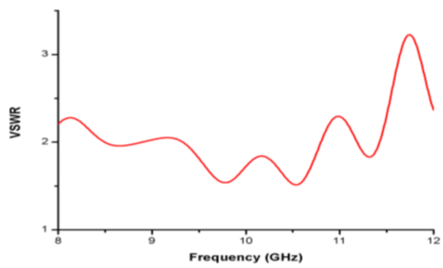

Figure 4: Simulated VSWR of 10 GHz helical antenna using paper material with square shape in the ground

The voltage standing wave ratio (VSWR) which was obtained from the simulation is about 1.72 and achieved the bandwidth of 1.37 GHz. Fig 4 demonstrates the (VSWR) for the 10 GHz helical antenna using paper material with square ground shape.

The gain of the designed antenna is demonstrated in Fig 5 for 10 GHz helical antenna. It is clearly shows that the maximum gain is achieved by the proposed antenna is 11.61 dB at 10 GHz. The gain could be affected by the input impedance matching and it could be due to the crucial design parameter towards maximizing the gain of helical antenna such as its length [18].

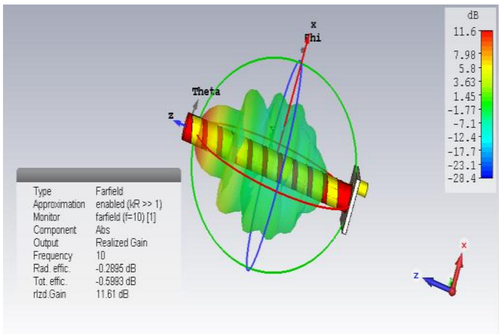

Figure 5: Simulated Gain antenna at 10 GHz

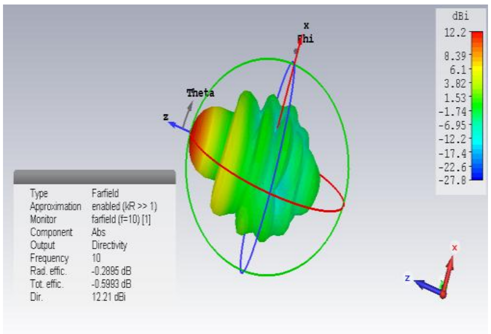

Figure 6: Directivity profile of helical antenna at10GHz

While the directivity of the designed antenna patterns is achieved a value of 12.2 dB for the same operating frequency as indicated in Fig 6. Furthermore, it is clearly indicate that most of the energy radiates in the positive of z directions with the side-lobes more than 6.4dB below main lobe. However, the polar form is shown in Fig 7 which the simulation also yields a directivity of 12.2 dB with a beamwidth of 32.3 degrees for 10 turns antenna.

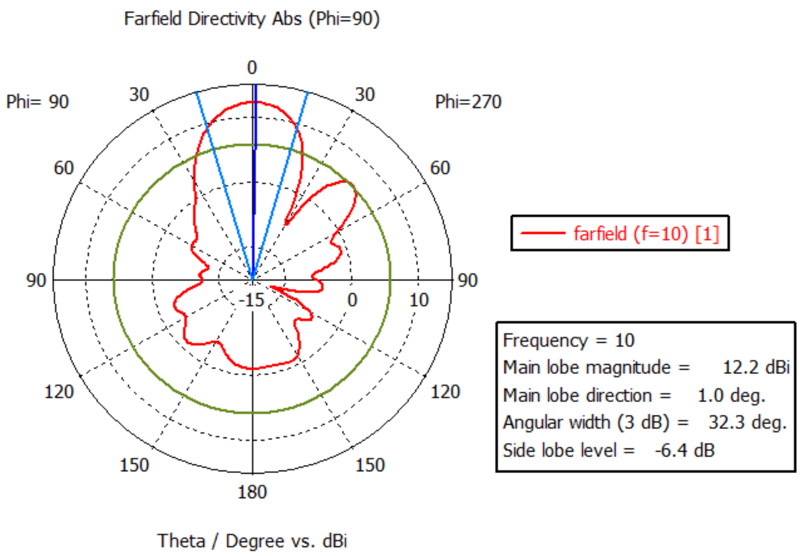

Figure 7: Directivity profile in polar form of helical antenna at 10 GHz

Fig 8 shows the fabricated design of helix antenna at 10 GHz operating frequency by using paper material because of the flexibility with square grounded shape.

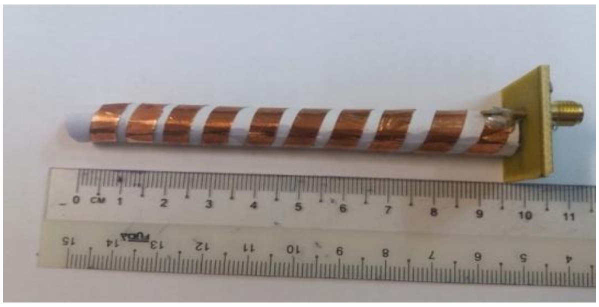

Figure 8: Fabricated design of 10 GHz helical antenna using Paper material

The magnitude of the S_{11} parameter was measured at operating frequency of 9.31 GHz as illustrated in Fig 9. It can be observed that there is a shifting in frequency response to lower frequency. This is due to manually fabrication and soldering. Not only this but also measured the dimensions manually which it will not be precise as the simulation structures. The recorded return loss is about -15.28 dB at 9.31 GHz which means it is operating at that point because the return loss is below than -10 dB for reflected power.

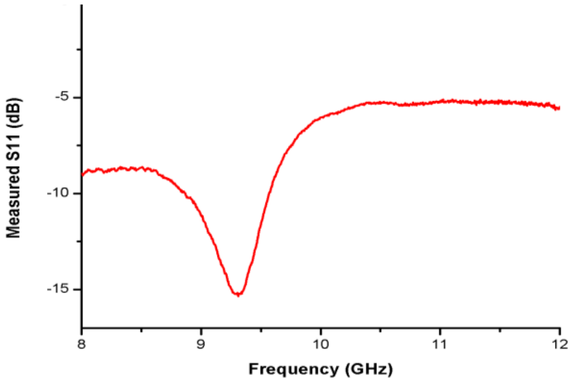

Figure 9: Measured S_{11} result of 10 GHz helical antenna using Paper material

From the simulated and measured results for 10 GHz helical antenna using paper materials. As stated above, there is shifting of frequency due to the manually fabrication which has many losses. Furthermore, dimensions are not exact as the simulated structure because of manually cutting which is not precise.

IV. CONCLUSION

The work presented in this paper is mainly focused towards the development of helical antenna for industrial applications. The design of helical antennas at 10 GHz by using Paper material has been successfully simulated and fabricated.

The designed helical antenna based on strip-line structure with a desired frequency at 10 GHz has been realized using Paper as the substrate with thickness of 0.1 mm. The range frequency is from 8 GHz to 12 GHz. This structure achieves high directivity which peaked up to 12.21 dB and with a maximum gain of 11.61 dB at 10 GHz. The magnitude of the S_{11} parameter is -15.28 dB has been measured at operating frequency of 9.31 GHz which means It can be observed that there is a shifting in frequency response to lower frequency. This is due to manually fabrication and soldering.

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