

Design of a wideband strip helical antenna for 5G applications

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ABSTRACT

This paper presents the design of wideband strip helical antenna for 5G application. The strip helical antenna is designed for 5G and wideband applications that provide a wide bandwidth and circular polarization. The helical antenna is planned on at 5.8 GHz frequency by using teflon material. The new designed 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 wireless communication. A wideband bandwidth of 2.41 GHz with a resonant frequency at 5.8 GHz is achieved by the helical antenna on the teflon substrate. The presented antenna on teflon substrate has achieved a gain of 11.2 dB. The antenna design parameters and the simulated results are achieved using the commercial software CST. The proposed antenna can be used for various wireless applications such as wideband, ultra wideband, 5G and wireless applications.

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1. 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 end-fire) [2]. The radiation behavior of the helix antenna varies 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 [6-15].

Recently, the circular polarization [16-22] on the wideband and 5G 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 [23-27]. The dielectric resonator of the Helical antenna helps to provide wide bandwidth with low cost and a small size of antenna [28]. On the other hand, the reflector is used to enhance the antenna's performances. Nevertheless, in [29], 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 5.8 GHz proposed in [30-37]. 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.

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 5.8 GHz by using teflon 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 5G, wideband and ultra-wideband wireless communication. The antenna design parameters and the simulated results are achieved using the commercial software CST.

2. DESIGN OF HELICAL ANTENNA AND SPECIFICATIONS

The geometry of the strip helical antenna design is depicted in Figure 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 teflon substrate with a uniform width (w). Furthermore, the substrate is rolled into 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. Table 1 shows Helical antenna parameters.

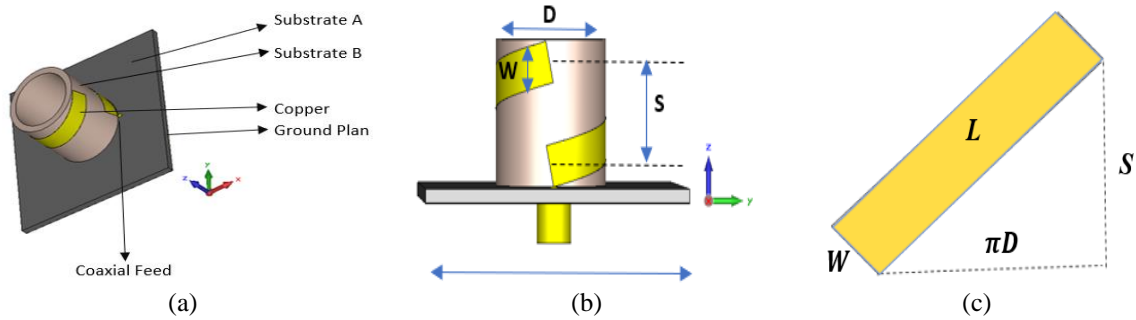


Figure 1. The structure of the proposed antenna: (a) 3D view, (b) Side view, and (c) Unrolled strip helix of one turn

Table 1. Antenna parameters

Parameters	Short form
Width	w
Diameter	D
Spacing (center-to-center)	S
Length of one turn	L
Number of turns	N

The empirical formulas used to calculate the helical antenna parameters

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

Where D_o 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.

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

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

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

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

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

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:

$$p = \frac{\frac{L_o}{\lambda_o}}{\frac{s}{\lambda_o} + 1} \quad (7)$$

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

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

To obtain the axial-mode for helical antenna, the C should be ranging from $\frac{3}{4}\lambda < C < \frac{4}{3}\lambda$ [7].

Figure 2 demonstrates the design of the proposed helix antenna which targeted to operate at 5.8 GHz. This helix antenna has a specification with 10 turns, wavelength of 51.72mm, length of 53mm, height of 120mm, spacing of 12mm, diameter of 16.46mm.

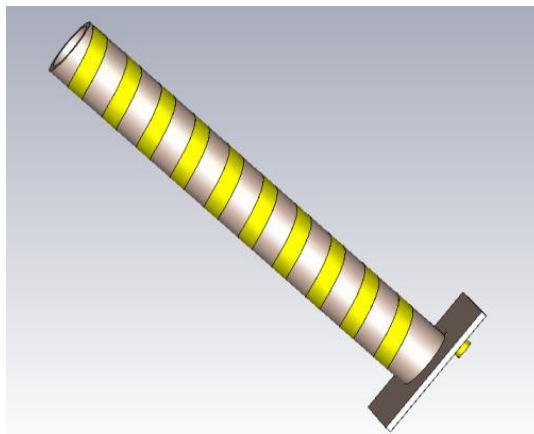


Figure 2. Design structure of 5.8 GHz helical antenna using teflon material

However, by using teflon material, with square shape ground, Table 2 shows the design specifications for helical antenna at 5.8 GHz operating frequency by using teflon material.

Table 2. The design specifications of 5.8 GHz helical antenna using teflon material

Parameters	Values
Dielectric constant (ϵ_r)	2.1
Substrate thickness (h)	1.5mm
Pitch angle (α)	13°
Wavelength (λ)	51.72mm
Circumference (C)	51.72mm
Number of turns (N)	10
Spacing between turns (S)	12mm
Cylindrical diameter (d)	16.46mm
Length of 1 turn strip (L_0)	53mm
Total length of helical antenna (L)	530mm
Height of helical antenna (H)	120mm
Ground Plane (0.75λ)	38.80mm

3. RESULTS AND DISCUSSION

Figure 3 demonstrates the simulation results for the designed helical antenna at 5.8 GHz operating frequency by using the teflon substrate. The magnitude of the S_{11} parameter was recorded at operating frequency of 5.8 GHz as illustrated in Figure 3(a). The simulated results showed wideband width at frequency range from 4 GHz to 8 GHz and achieved less than -10 dB at 5.8 GHz operating frequency. It achieved -13.66 dB at 5.8 GHz operating frequency with ultra-wide bandwidth of about 2.4 GHz which make it suitable for many applications.

The voltage standing wave ratio (VSWR) which was obtained from the simulation is about 1.52 and achieved the bandwidth of 2.4 GHz. Figure 3(b) demonstrates the (VSWR) for the 5.8 GHz helical antenna using teflon material with square ground shape. For further investigation Figure 3(c) shows good impedance frequency at 5.8 GHz. The gain of the designed antenna is demonstrated in Figure 4(a) for 5.8 GHz helical antenna as well as at 5.9 GHz in Figure 4(b). It is clearly showing that the maximum gain is achieved by the proposed antenna is 11.21 dB at 5.8 GHz and 12.6 dB at 5.9 GHz as shown in Figure 4(a) and Figure 4(b) respectively. 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 [31].

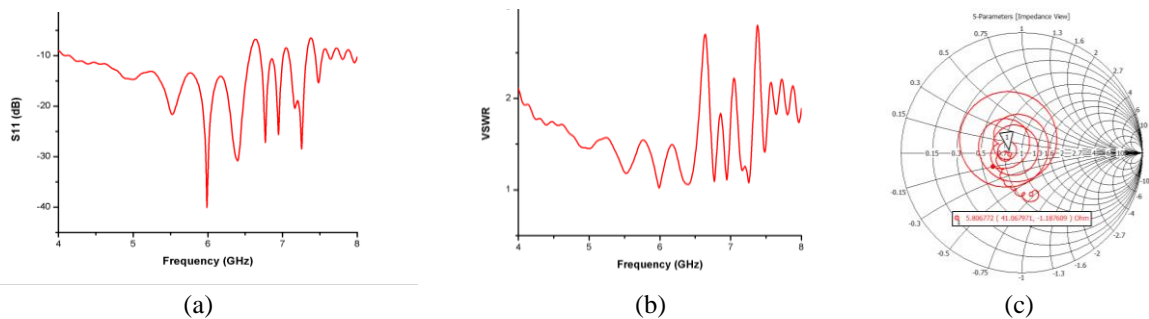


Figure 3. Simulated (a) S_{11} results, (b) VSWR and (c) Impedance of 5.8 GHz of helical antenna using teflon material with square shape in the ground

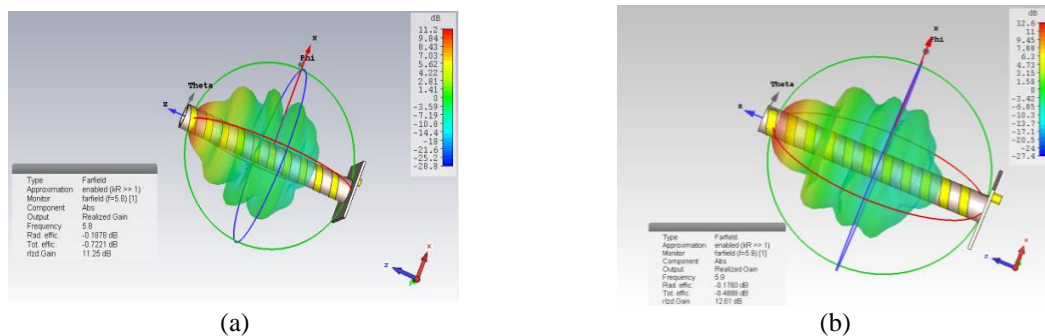


Figure 4. Simulated farfield results of helical antenna, (a) Antenna gain at 5.8 GHz and, (b) At 5.9 GHz

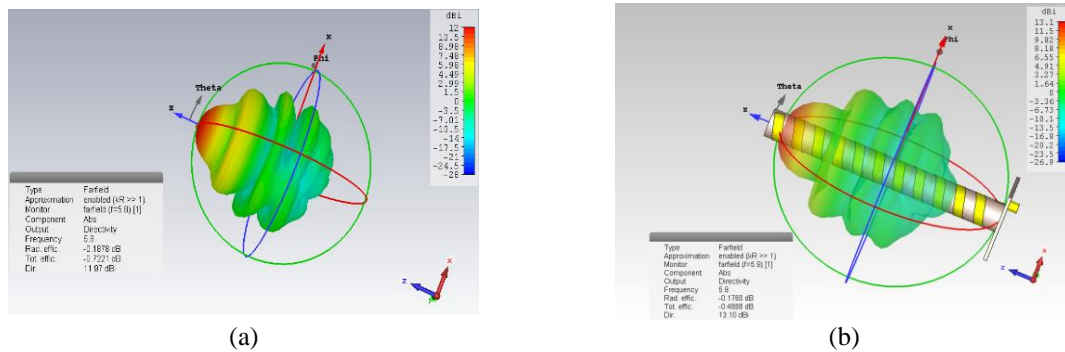


Figure 5. Simulated farfield results of helical antenna, (a) Directivity at 5.8 GHz and, (b) At 5.9 GHz

While the directivity of the designed antenna patterns is achieved a value of 12.2 dB for the same operating frequency as indicated in Figure 5(a). The directivity at 5.9 GHz is 13.1 dB as shown in Figure 5(b). Furthermore, it is clearly indicated that most of the energy radiates in the positive of z directions with the side-lobes more than 5.7 dB below main lobe.

4. 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 5.8 and 5.9 GHz by using teflon material has been successfully simulated. The designed helical antenna based on strip-line structure with a desired frequency at 5.8 and 5.9 GHz has been realized using teflon as the substrate with thickness of 1.5 mm. This structure achieves high directivity which peaked up to 12.2 dB and 13.1 dB at 5.8 GHz and 5.9 GHz respectively. With a maximum gain of 11.25 dB and 12.6 dB at 5.8 GHz and 5.9 GHz respectively. The design could be used for different applications such as 5G, wide bandwidth, Ultra-wide bandwidth wireless communication.

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