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Design of Helical Antenna for Next Generation Wireless Communication

***Abstract**. This study proposes a novel helical antenna design for next generation applications. The strip helical antenna is prescribed for next generation wireless communication and wideband applications that offer circular polarization and a wide bandwidth. In fact, the proposed helical antenna suits 5.8 GHz frequency by using Teflon material. The newly-designed strip was printed on a substrate and rolled into a helix shape to achieve circular polarization without impedance matching. This antenna is meant for wideband wireless communication applications. A wide bandwidth of 2.7 GHz with 5.8 GHz resonant frequency was attained through the use of helical antenna on Teflon substrate. The proposed antenna on Teflon substrate recorded a gain of 8.97 dB and 92% efficiency. The antenna design parameters and the simulated results were retrieved using Computer Simulation Technology software (CST). The measurement result of return loss displayed mismatch at 5.22 GHz due to manual fabrication. This developed antenna may be applied for a number of wireless applications, including Wideband, Ultra-wideband, and 5G.*

***Streszczenie.** Zaprezentowano projekt nowej anteny śrubowej o polaryzacji kołowej i szerokim paśmie. Antena umożliwia pracę przy częstotliwości 5.8 GHz. I pasmo 2.7 GHz, przy wzmocnieniu 8.97 dB I sprawności 92%. Symulację przeprowadzono przy pomocy oprogramowania CST. **(Projekt anteny śrubowej do bezprzewodowej komunikacji 5G)**.*

Keywords: Helical Antenna; Teflon Material; 5G Antenna; Wideband.
Słowa kluczowe: antena śrubowa, komunikacja bezprzewodowa, komunikacja 5G.

Introduction

Wireless communication systems have been evolving at an astonishing rate, hence promoting wireless terminals to offer various services for future applications [1]. The 5G wireless technology networks applied for audio communication and videos are the next huge projection for mobile telecommunication [2]. Helical antenna or helix has a long history and has attracted numerous studies and development for more than six decades since its advent [3]. Helical antennas have two popular modes of operation, namely normal mode (electrically small broadside) and axial mode (electrically large end-fire) [4]. The radiation behaviour of the helix antenna varies based on the design structure. As a result, the antenna performances can differ in terms of polarization and radiation pattern [5]-[6].

The helical antenna is composed of a helical-shaped conductor that is connected to ground plane [7]. The structure of the helical antenna offers a wide bandwidth with circular polarization characteristics [8]-[17]. Helical antenna is commonly found in wired helix form, although the more recent printed antenna is preferred due to cost efficiency, small volume, and good consistency, when compared to the wired form that demands intricate machining process. Strip helical antenna gives more advantages than wire helical antenna does, such as the generation of more operation bandwidths [18]-[19].

Recently, the circular polarization on wideband and 5G antennas has garnered much attention among researchers due to its capabilities in fulfilling the requirements of high gain, high data rate transmission, and high efficiency [20]-[29]. Antenna array with circular polarization is proposed in this study for 5G communication system. The performance exerted by the phased antenna array prescribed in this study was verified by determining the axial ratio (AR) beamwidth and bandwidth [30]. The dielectric resonator of the helical antenna offers a wide bandwidth at a low cost and a small-sized antenna [31]. A reflector is used to enhance the performance of the antenna.

Nevertheless, in [32], the gain obtained by the antenna was inadequate although the design was similar to the classical helical antenna. A helical antenna with dielectric resonator and cylindrical ground plane mounted on the helical antenna with an operating frequency of 5.8 GHz had been proposed in [33]-[36]. The implementation of dielectric resonator and cylindrical ground plane enabled the antenna to achieve high gain and wide bandwidth, but narrow radiation pattern. The AR bandwidth was still low and insufficient for high data rate transmission. When the number of helical elements increased, the helical antenna radiated in circular polarization, as the helical elements were fed with a certain phase difference and their length was less than a wavelength. As a result, these helical antennas, also known as ‘multifilar helix antenna’, have a vital role in mobile satellite communication and global positioning systems.

This study presents the detailed analysis of strip-helical antenna tested at 5.8 GHz by using Teflon material. The strip was printed on a substrate and rolled into a helix shape to achieve circular polarization without impedance matching. This proposed antenna may be applied for 5G, wideband, and ultra-wideband wireless communication systems. The antenna design parameters and the simulated results were determined using the commercial software CST. The measurement of return loss had shifted to lower frequency due to manual fabrication.

Design of Helical Antenna and Its Specifications

Figure 1 displays the geometry of strip helical antenna that comprises of a cylindrical helix and a square ground plane. The metallic strip that contained the cylindrical helix was patched on the Teflon substrate with a uniform width (***w***). The substrate was rolled into a hollow cylinder to form the strip helix with diameter (**D**), spacing (centre-to-centre) between turns (**S**), length of a turn (**L**), and number of turns (**N**). In order to obtain the axial mode operation, substrate B was used as the square ground plane below the helix. Table 1 shows the parameters of the helical antenna.

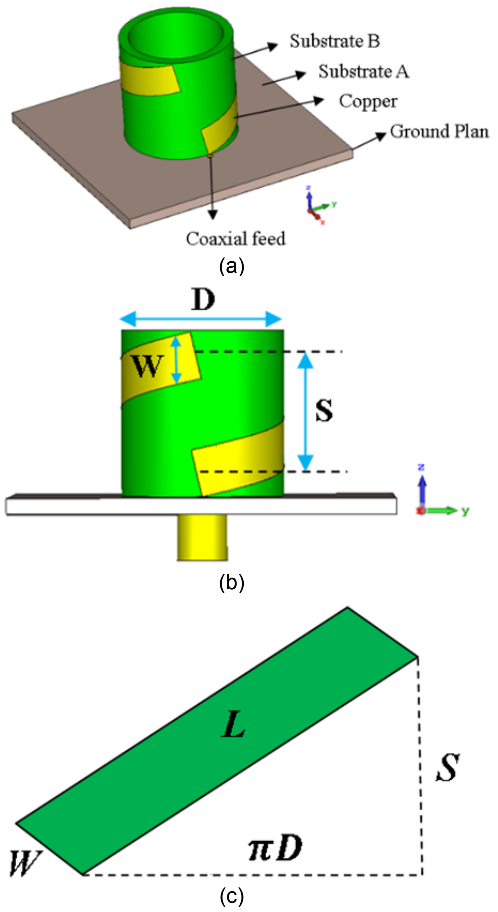


Fig 1. The structure of the proposed antenna: (a) 3D view, (b) Side view, and (c) unrolled strip helix of one turn.

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 are given as follows:

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

where D_O refers to directivity, N denotes the number of turns, S signifies the spacing between the turns, C reflects the circumference of helix, and λ represent wavelength.

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

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

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

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

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

where HPBW stands for half-power band width, FNBW is defined as the first nulls beamwidth, A_{eff} refers to effective aperture, and AR denotes the AR. The ratio of wave velocity that travelled along the helix to that in free space is expressed below:

(7) $$p = \frac{\frac{L_O}{\lambda_O}}{\frac{S}{\lambda_O}+1}$$

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

(8) $$p = \frac{\frac{L_O}{\lambda_O}}{\frac{S}{\lambda_O}+\left(\frac{2N+1}{2N}\right)}$$

In order to obtain the axial mode for helical antenna, C should range at ¾ λ < C < ⁴⁄₃ λ [9]-[37]-[40-42].

Figure 2 illustrates the design of the proposed helix antenna that was operated at 5.8 GHz. The helix antenna had the following specifications: 10 turns, a wavelength of 51.72 *mm*, a length of 53 *mm*, a height of 120 *mm,* spacing of 12 *mm*, and a diameter of 16.46 *mm*.

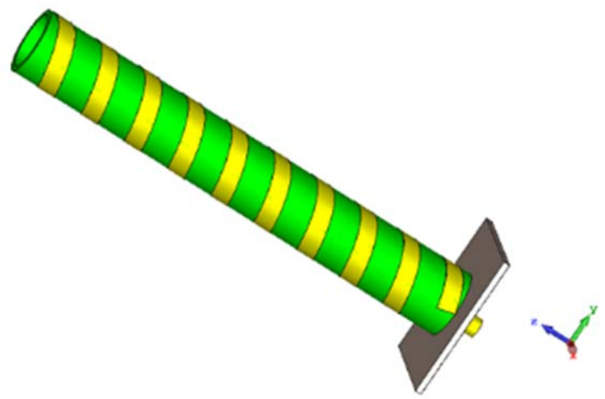


Fig 2. Design structure of 5.8 GHz Helical Antenna using Teflon material.

Table 2 presents the design specifications for helical antenna operated at 5.8 GHz using Teflon material and a square ground.

Table 2. The Design Specifications of Helical antenna

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

Results and Discussion

Figure 3 illustrates the simulation results for the proposed helical antenna operated at 5.8 GHz frequency using Teflon substrate. The magnitude of S_{11} parameter had been recorded at 5.8 GHz (see Figure 3). The simulated results showed that the wideband width ranged between 4 and 8 GHz, apart from achieving below -10 dB when operated at 5.8 GHz. Besides, it recorded -34 dB at 5.8 GHz operating frequency with 2.7 GHz ultra-wide bandwidth, hence suitable for many applications.

Figure 4 (a) displays the outcomes of the proposed helical antenna operated at 5.8 GHz, whereby the maximum gain achieved was 8.97 dB. This result could have been influenced by input impedance matching stemming from the design parameters (e.g., length) that maximised the gain [35]-[36].

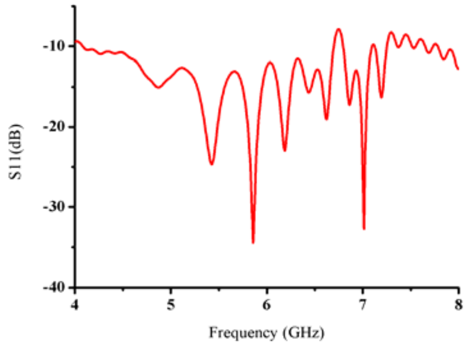
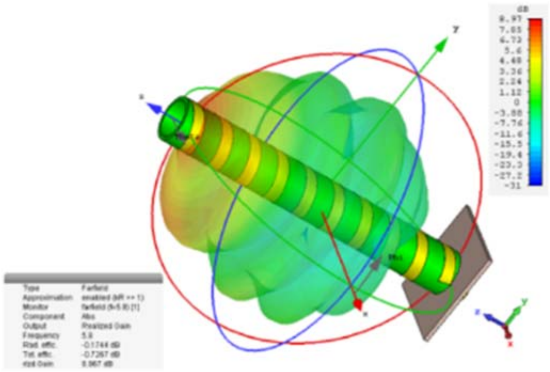
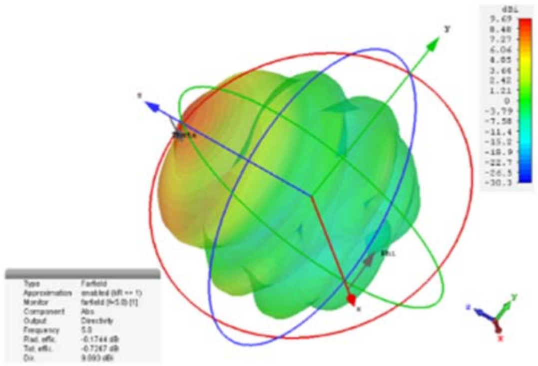


Fig 3. Simulated S11 results at 5.8 GHz for helical antenna using Teflon material and square ground.



(a)



(b)

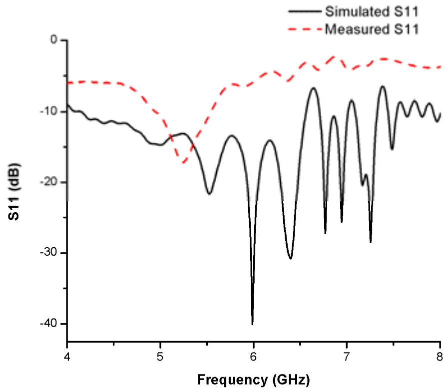
Fig 4. (a) Simulated Gain antenna and (b) directivity profile of helical antenna at 5.8 GHz.

Figure 4 (b) shows the directivity of the proposed antenna that achieved 9.69 dBi for 5.8 GHz operating frequency. This clearly indicated that most of the energy radiated in the positive of z directions with side-lobes exceeded 5.7 dB below the main lobe. The proposed antenna achieved high efficiency at 92%. Figure 5 (a) presents the fabricated helix antenna design operated at 5.8 GHz using Teflon material and a square ground. The magnitude of S_{11} parameter was measured at 5.22 GHz operating frequency, as portrayed in Figure 5 (b) that exhibits the variances between the measured and simulated outcomes. A shift to lower frequency response was noted due to manual fabrication and soldering. The manually measured dimensions were not as precise as the simulation structures. The recorded return loss at -17.30 dB for 5.22 GHz signified its operation, mainly because the return loss is below -10 dB for reflected power.

Conclusion

This study mainly focused on the development of helical antenna for industrial applications. The design of helical antennas at 5.8 GHz using Teflon material was successfully simulated and analysed. The designed helical antenna based on strip-line structure with a desired frequency at 5.8 GHz was realised using Teflon as the substrate with 1.5 mm thickness. The proposed structure attained high directivity that peaked up to 9.69 dB and a maximum gain of 8.97 dB when operated at 5.8 GHz. This proposed design is suitable for various applications, such as 5G, wide bandwidth, and ultra-wide bandwidth wireless communication. The fabrication was performed in the laboratory and the Vector Network Analyzer was used for measurement. The shift to lower response frequency was due to manual fabrication and soldering, which seemed to be not as precise as the simulation structures.

(a)



(b)

Fig 5: (a) Fabricated design (b) Comparison of measured and simulated S11 results at 5.8GHz.

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