Triple-Band Dual-Polarized Dipole Antenna for 5G Sub-6 GHz Communications

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Triple-band Dual-polarized dipole antenna for 5G Sub-6 GHz Communications

Lixia Yang, Hafiz Usman Tahseen, Syed Shah Irfan Hussain and Wang Hongjin

Abstract—A triple-band $\pm 45^\circ$ dual-polarized dipole antenna is presented in this paper. The proposed antenna covers two bands from n77 and one from n79 5G NR frequency spectrums. The profile antenna exhibits the measured impedance bandwidths 3.6-3.85 GHz, 4.05-4.2 GHz and 4.8- 5.15 GHz with S11, S22 < -15dB return loss. Antenna is fabricated with four substrates; one radiator, one reflector and two feeding baluns. Antenna is designed and optimized with HFSS simulator and fabricated for experimental verification. Antenna gives a stable radiation pattern with 8.55dBi high gain and 70° half power beam width (HPBW) that makes it a good candidate for wireless 5G sub-6 GHz and multiband base station applications. Finally, antenna is tested in a realistic application environment to show the utility of the proposed antenna for wireless sub-6 GHz IoT applications.

Index Terms— Sub-6 GHz, IoT, 5G.

I. INTRODUCTION

INTERNET of things (IoT) is expected to be adopted for most of the electronic communication applications in near future. The polarization diversities and frequencies will work at several bands in future. IoT is bringing an advanced digital revolution to our daily life. As a result, there is a huge production of sensors and integrated antennas associated with IoT age. The IoT technology associated with integrated antennas is expected to make our future communications a very sophisticated and simple. The concept of internet of things (IoT) is known as extension of internet now. It is a worldwide interconnected emerging network of different objects associated with sensors, input/output devices, actuators and communication systems. The efficiency of internet of things (IoT) and wireless internet connection are improved with the wireless sensor technology [1].

In fact, antennas are playing a vital role in the wireless sensor technology that leads to an emerging future with the development of IoT techniques. The compact and low profile integrated antennas have drawn a large attention in last few years due to multi-band and multi-function features in communication systems [2]. A loop antenna is presented in [3] for an IoT application with the antenna placement at different places. A multi-standard MIMO antenna is proposed in [4] for IoT applications. A loop antenna is proposed in [5] for a biotelemetry application to operate in GSM900, GSM1800 and Bluetooth Low Energy. In the recent years, different antenna modules and antennas are being designed for upcoming multimedia high speed and large data volume challenges. The technological development in different cellular and wireless applications has generated a high speed data rate requirement that leads to a fifth generation (5G) communication system. In present communication systems, dual-polarized antenna has attained a large attraction to reduce multi-path fading. For dual-polarized antennas, a significant research is present [6]-[14]. Many countries are using (IMT- 2020) standard 5G networks and services for research and services. The sub-6GHz frequency spectrum i.e. 3.3-3.6 GHz and 4.8-5.0 GHz in China and 3.4 GHz to 3.8 GHz in Europe has been licensed. The N78 (3.3-3.8 GHz) 5G band has been assigned in many countries. The broadband MIMO antennas with high impedance bandwidths have become a good solution for 5G demands. A dual-polarized printed dipole antenna with 52% impedance bandwidth is presented in [15]. The base station broadband antennas for 2G, 3G and 4G networks are proposed in [16]-[22]. The comparison of the proposed work with the related ones [23]-[30] is presented in Table I.

A low cost, low profile triple band $\pm 45^\circ$ dual-polarized dipole antenna is proposed for wireless 5G applications. In the first step, an un-slotted printed dipole with $\pm 45^\circ$ cross pair arrangement antenna is designed. In the next steps, slots are added in the center of each quadrant patch and then at corners. Radiation patterns and return loss are noted at each stage of electromagnetic analysis to get optimum antenna structure.

The paper is organized as follows: design of the profile antenna with EM analysis lies in section II. Simulated and experimental results are discussed in section III. The final summary lies in section IV.

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Table I
COMPARISON WITH RELATED WORKS

Ref	Height (mm)	Gain (dB)	Bandwidth S11,S22<10dB	HPBW
23	19.2	8.7	2.45-3.7 GHz	NA
24	13.8	3.91-10.2dBi	2.96-11 GHz	57°
25	3.2	10.2dBi	3.65-3.81 GHz	52°
26	33	9dBi	3.4-3.8 GHz	11°, 44°
27	12.8	8.1dBi	3.14-3.81 GHz	64°
28	5.3	8.5dBi	3.3-3.6 GHz	69.7°
29	6.81	8.2dBi	3.17-3.77 GHz	65°
30	7.2	9.5	3.15-4.05	72°
This work	24.3	8.55dBi	3.6-3.85, 4.05-4.2 4.8-5.15 GHz (S11,S22<15dB)	70°

II. TRIPLE-BAND DUAL-POLARIZED ANTENNA

A. Antenna design

The antenna geometry is shown in Figure (1). The profile antenna consists of one reflector, one radiator and two baluns. The radiator has a 0.8 mm thick RT5880 substrate printed on the top. The RT5880 substrate has dielectric constant and loss tangent 2.2 and 0.0004 respectively. The reflector has RT5880 substrate with 0.8 mm thickness printed at bottom. Baluns are erected perpendicularly between radiator and reflectors.

The main radiator of the proposed antenna has two dipoles with $\pm 45^\circ$ cross pair arrangement as shown in Figure 1(a). Radiator is a 32×36 mm printed substrate mounted on both baluns at 23.8 mm height. The patch is divided into four equal quadrants on the substrate. Each quadrant has 15.5×17.5 mm dimension and is connected with the other in a $\pm 45^\circ$ cross pair dipole arrangement. Balun shorts each dipole with ground separately. The two center lines slots divide the main radiator patch into four equal quadrants. The quarter circle slot is placed at each corner of the main radiator. The quarter circle has 2.8 mm radius. Each quadrant has an E-shaped slot at the center. The whole radiator arrangement demonstrates $\pm 45^\circ$ dual-polarized cross pair dipoles that are shorted with the ground via baluns.

Geometric configuration of baluns is shown in Figure 1(c) and (d). Each balun has a micro strip patch at one side and feed line on the other side on a FR4 dielectric substrate. Both baluns are erected perpendicularly in a $\pm 45^\circ$ cross arrangement. Radiator is mounted on the upper bumps of the baluns and the lower bumps are inserted in the reflector bores. Micro strip patches on both baluns short radiator to the ground through balun bumps. The feed line on the other side of each balun is shorted with the inner conductor of port/coaxial cable.

Fig. 1. Geometric configuration of the proposed antenna; (a) Top view, (b) Side view, (c) & (d) Baluns.

The outer conductor of coaxial cable/port is connected to the ground. The feed lines on both baluns have different dimensions but the micro strip patches and relevant bumps have same dimensions as shown in Figure 1(c) and (d). The reflector is a 120×120 mm RT5880 dielectric substrate with ground patch at bottom. This ground is connected with the outer conductors of both ports port1 and port2 as shown in Figure 1(b). Hence a $\pm 45^\circ$ dual-polarized cross pair dipole antenna structure is developed by connecting each feed line to a separate port and each dipole to the ground.

B. EM analysis

The numerical simulations and optimization of the profile antenna are done on HFSS. The slotted radiator develops a dual band s-parameter while the L-probe feed line achieves a better 50 ohm matching with a wide band feature. Based on the cited work and literature review, an un-slotted radiator with cross pair dipoles mounted on feeding baluns is designed for a dual-polarized radiation pattern in the first step. It exhibits 8.55 dBi gain and impedance bandwidth 3.6-4.1 GHz with $S_{11}, S_{22} < -15$ dB as shown in Figure (3). In the 2nd step E-shaped and corner circle slots are added to get dual band feature. The antenna exhibits 8.55dBi gain with impedance bandwidth 3.6-3.85 GHz, 4.05-4.20 GHz and 4.8-5.1GHz with $S_{11}, S_{22} < -15$ dB as shown in Figures (2) and (3). So, a triple band dual-polarized feature is achieved with a $\pm 45^\circ$ dual-polarized cross pair dipole arrangement along with feeding baluns and reflector. A uniform stable radiation pattern is observed with no evident drop when slots are added to get triple band feature as shown in Figure (2). Figure (3) shows the return loss of the profile antenna with slotted and un-slotted radiator. It is observed that the un-slotted radiator structure gives a single while the antenna with slotted radiator configuration exhibits triple band feature with the same uniform radiation pattern.

III. SIMULATION AND EXPERIMENTAL RESULTS

Based on optimization and above EM analysis with both dipole configurations, a dual band dual-polarized dipole antenna is proposed for 5G wireless applications. The profile antenna is fabricated and measured as shown in Figure (4). Experimental results were taken in anechoic chamber using vector network analyzer. The reflection coefficient of the proposed antenna is shown in Figure (5). It is observed that the antenna gives impedance bandwidth 3.6-3.85 GHz, 4.05-4.20 GHz and 4.8-5.1 GHz. The simulated and measured radiation patterns of the proposed antenna at 3.6 GHz center frequency in E and H planes are shown in Figures (6) and (7). The -45° polarized radiation pattern is omitted due to the similarity in results. The simulated and measured radiation patterns are very consistent and uniform in E and H planes. The radiation patterns at various frequencies within the proposed bands are shown in Figure (8). It is observed that the profile antenna gives a uniform and stable radiation pattern over the entire band. The profile antenna gives 8.55 ± 0.6 dBi gains over the entire band.

Fig. 2. Simulated antenna radiation patterns.

Fig. 3. Simulated antenna reflection coefficients.

Fig. 4. Proposed fabricated antenna.

Both simulated and measured results are in a good agreement and small discrepancy is due to the fabrication and insertion loss. The half power beam width (HPBW) of the proposed antenna is 70° . Furthermore, the comparison of the proposed antenna with reference papers of related works is presented in Table I. For IoT applications, the profile antenna was tested in a realistic environment. The port1 was connected to a 5GHz supported core I5 DELL laptop through a USB port connector as shown in Figure (9). It was observed that the profile antenna got connected with Wi-Fi WLAN (Wi-Fi 4(802.11n)) and supporting browsing as shown in Figure (9).

Fig. 5. Reflection coefficient of the proposed antenna.

Fig. 6. Antenna radiation pattern at 3.6 GHz in E-plane

Fig. 7. Antenna radiation pattern at 3.6 GHz in H-plane.

Fig. 8. Measured antenna radiation patterns in E and H planes; (a) at 3.8 GHz, (b) at 4.0 GHz, (c) at 4.8 GHz, (d) at 5.0 GHz.

Fig. 9. Antenna integrated with WLAN (Wi-Fi 4(802.11n)) at 5GHz.

IV. CONCLUSION

In IoT applications, there is an advantage of applying an antenna as a wireless sensor technology. In this paper, a dual band $\pm 45^\circ$ dual-polarized dipole antenna is proposed for 5G wireless applications. Antenna covers 3.6-3.85 GHz, 4.05-4.20GHz and 4.8-5.1 GHz measured bands and exhibits 8.55dBi high gain with 70° half power beam width (HPBW). Antenna supports WLAN (Wi-Fi 4(802.11n)) when tested for an IoT application in a realistic environment. The measured results confirm the validity of the proposed antenna design that makes it a good candidate for 5G sub-6 GHz wireless applications. The antenna performance and comparison with related works makes it eligible for massive MIMO antenna array for multiband 5G base station applications.

DECLARATIONS

Conflict of interest: All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version. This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

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Figure 1

Geometric configuration of the proposed antenna; (a) Top view, (b) Side view, (c) & (d) Baluns.

Figure 2

Simulated antenna radiation patterns.

Figure 3

Simulated antenna reflection coefficients.

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