Dual-Band and Tri-Band Parasitic Dipole Antennas for Wearable Applications

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***Abstract*—Dual-band and triple-band(Tri-band) T-shaped dipole antennas with two couples of parasitic dipoles are proposed. Two or three resonances are realized by T-shaped printed dipoles and parasitic dipoles, respectively. The frequency of resonance depends on the width and length of parasitic dipoles. The proposed structure can achieve multiband operation. Both of the middle and upper operating frequencies can be easily controlled independently. Simulation results show that the maximum realized gains for tri-band antenna are 2.69 dBi, 1.65 dBi and 2.76 dBi at the resonant frequencies of 2.5 GHz, 4.6 GHz and 5.6 GHz, and the maximum realized gains for dual-band antenna are 3.11 dBi and 2.78 dBi at the operating frequencies of 2.5 GHz and 5.6 GHz. The proposed antennas are suitable for wearable applications.**

***Index Terms*—Dual-band, Tri-bnad, Dipole antenna, Parasitic dipoles.**

I. INTRODUCTION

Antenna bandwidth is vital for wireless communication systems. In order to meet wireless communication systems demand, multi-band antennas are investigated. A pair of parasitic dipole was placed beside printed dipole to enhance lower bandwidth of base stations antenna [1]. By embedding uniform slot on patch, the higher resonant mode was obtained [2]. A single printed dipole was proposed in [3]. After adding one or two parasitic dipoles, dual-band or tri-band antennas were realized, however the radiation patterns were relatively asymmetric. Parasitic dipoles were mounted near T-shaped printed dipoles to meet multiband requirement while different size of parasitic dipoles have a great influent on resonant frequency [4]. Broad-band and dual-band antennas were realized in [5], where two strip dipoles were mounted on the front side and the back side of substrate, respectively. The different length of parasitic dipoles makes it possible to achieve broadband or multiband characteristics. A dual-band antenna with two parasitic dipoles for harmonic transponders application was proposed in [6], where the first resonant frequency is fixed and the second resonant frequency can be tuned very conveniently. Due to single layer of dipole in [6], its gain was not enough. In this paper, dual-band and triple-band antennas with two layers of dipoles are presented.

II. ANTENNA STRUCTURE

The structures of the proposed dual-band antenna and tri-band antenna are illustrated in Fig. 1. The proposed antennas are composed of a T-shaped dipole and two pairs of parasitic dipoles. T-shaped dipole is mounted on the front side and back side of substrate, respectively. T-shaped dipole is connected to inner and outer conductor of 50 Ohm coaxial cable, respectively. The lower band mainly depends on T-shaped dipole. T-shaped dipole size in dual-band antenna is the same as that in tri-band antenna, thus some characteristics for dual-band antenna have no difference with that for tri-band antenna in lower band. Higher band of dual-band antenna is realized, where two parasitic dipoles are mounted on the front side and the other parasitic dipoles are mounted on the back side with the same size of L_2, d_4. The structure of dual-band antenna is shown in Fig. 1(a), Fig. 1(b) and Fig. 1(c). In order to obtain tri-band characteristics, two pairs of parasitic dipoles with different length and width are placed on both side of the substrate, respectively. The resonant frequency is influenced by the size of parasitic dipoles, especially the length of parasitic dipoles. The structure of tri-band antenna is shown in Fig. 1(a), Fig. 1(d) and Fig. 1(e). Although the length of parasitic dipoles on the same side is different, the radiation patterns of the antenna are symmetric which is the reason why the parasitic dipoles with the same size are placed near T-shaped dipole on two sides to modify radiation patterns. The thickness of the FR-4 substrate is 1.6 mm while the relative permittivity is 4.4, and the loss tangent is 0.02. Two couples of parasitic dipoles are mounted on both sides of the substrate. The geometry parameters of the proposed antenna are shown in Fig. 1. The detailed parameter values are listed in Table I. During the design process, all of our work has been analyzed by the Electromagnetics Suit 18.1.

TABLE I
GEOMETRICAL PARAMETERS FOR THE PROPOSED ANTENNAS

Parameter	H	d_1	W_{r1}	W_{r2}	W
Value(mm)	0.8	1.1	2.83	2.35	18
Parameter	d_2	d_3	L_2	L_3	d_4
Value(mm)	13.5	12.5	2.39	2	13

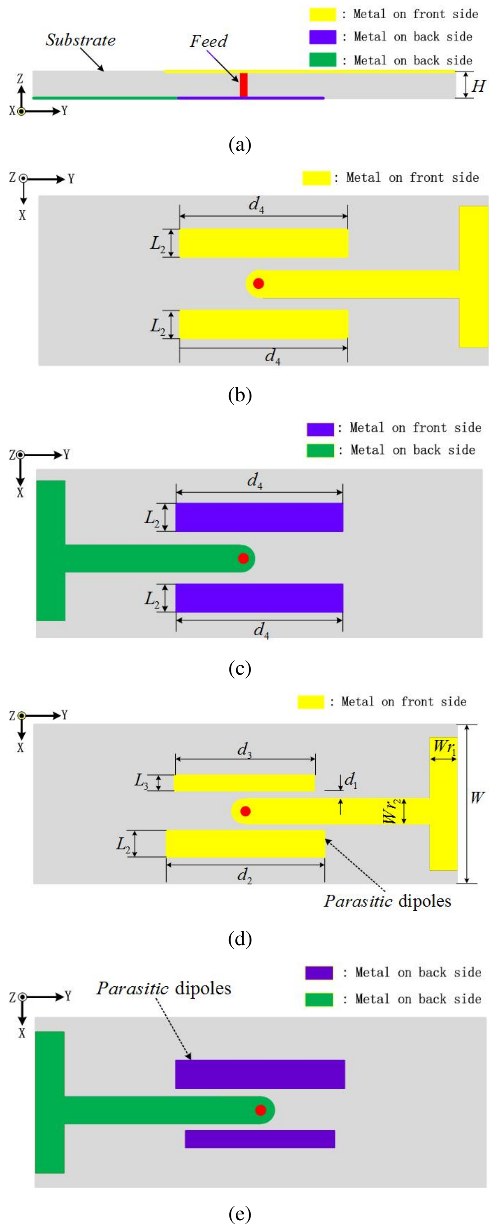


Fig. 1. Structures of the proposed antennas. (a) Side view for dual-band and tri-band antennas; (b) Top view for dual-band antenna; (c) Bottom view for dual-band antenna; (d) Top view for tri-band antenna; (e) Bottom view for tri-band antenna

III. Simulation Results and Analysis

Simulation results of the proposed antennas are obtained in this section. Fig. 2 shows the return loss for dual-band and tri-band antennas. The center frequencies of the tri-band antenna are 2.5 GHz, 4.6 GHz and 5.6 GHz, and the center frequencies for the dual-band antenna are 2.5 GHz and 5.6 GHz. For tri-band antenna, the bandwidth (S_{11}<-10 dB) of 11.2% (2.34-2.62 GHz) at the lower band, 3.9% (4.52-4.7 GHz) at middle band and 8.3% (5.37-5.84 GHz) at the upper band are achieved. For dual-band antenna, the bandwidths for two bands are 11.2% (2.35-2.63 GHz) and 13% (5.23-5.96 GHz). Fig. 3(a) and Fig.3(b) demonstrate the simulated S_{11} with different values of d_2, d_3 and d_4. Different resonant frequencies can be realized if different lengths of parasitic dipoles are used. A wide bandwidth can be covered by changing the length of parasitic dipoles, which makes dual-band antenna and tri-band antenna more suitable for wearable applications.

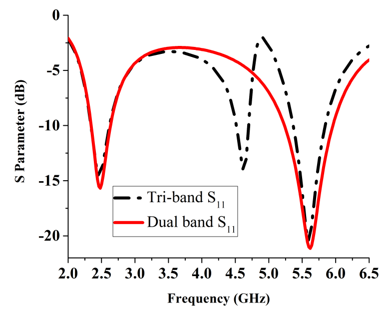


Fig. 2. Simulated S_{11} for the proposed dual-band and tri-band antennas

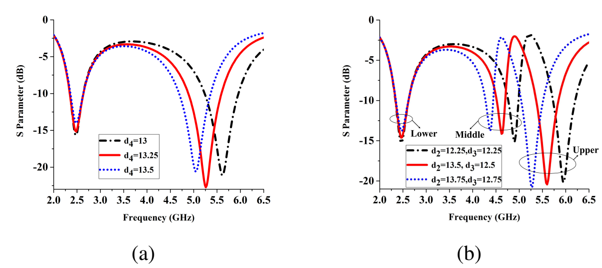


Fig. 3. (a) Simulated S_{11} with different values of d_4 for dual-band antenna; (b) Simulated S_{11} with different values of d_2 and d_3 for tri-band antenna

Apart from the S-parameters, radiation patterns for the proposed antennas are shown in Fig. 4, Fig. 5 and Fig. 6. The simulated realized gain for dual-band and tri-band antennas varied with theta are shown in Fig. 7 (a) and Fig. 7 (b). The maximum realized gain values are 2.69 dBi, 1.65 dBi and 2.76 dBi for triple-band antenna, and 3.11 dBi and 2.78 dBi for dual-band antenna. Comparison of the realized gain between dual-band and tri-band antennas is shown in Fig. 8, where there is a sharp decrease of the realized gain at 4.88 GHz, which is probably caused by poor return loss at corresponding frequency. The proposed antennas can cover the 2.5 and 5.6 GHz band, which makes the proposed antennas suitable for wearable applications. The middle resonant frequency of 4.6 GHz can be applied into many scenarios in the wireless communications, such as the digital microwave relay communication system and so on.

IV. Conclusion

Dual-band and triple-band T-shaped dipole antennas with two pairs of additional parasitically coupled dipoles are presented and studied in this paper. Dual-band or tri-band operation can be realized by changing the size of parasitic dipoles. The proposed antenna can be used for wearable applications. A

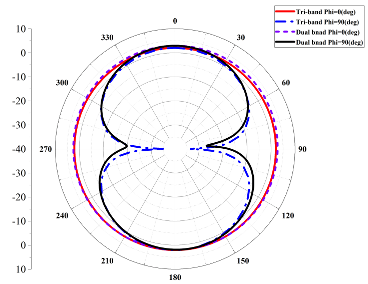


Fig. 4. Radiation patterns for the proposed dual-band and tri-band antennas at 2.5 GHz

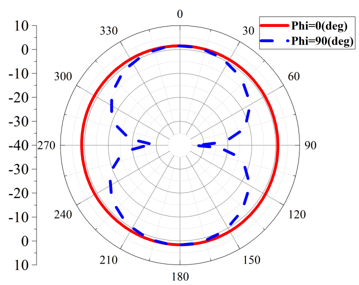


Fig. 5. Radiation patterns for the proposed tri-band antenna at 4.6 GHz

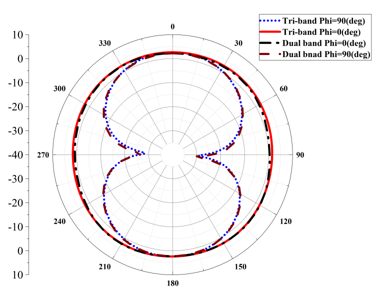
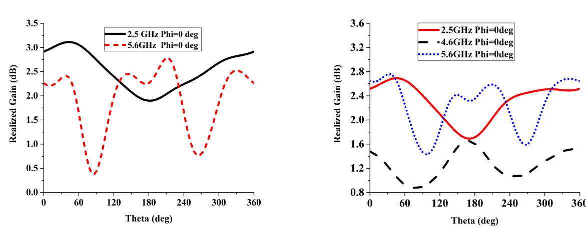


Fig. 6. Radiation patterns for the proposed dual-band and tri-band antennas at 5.6 GHz



(a) (b)

Fig. 7. (a) Realized gain for the proposed dual-band antenna vs theta; (b)Realized gain for the proposed tri-band antenna vs theta

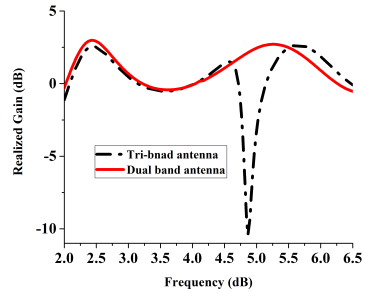


Fig. 8. Comparison of realized gain between dual-band antenna and tri-band antenna vs frequency

series of simulation parameters are listed to verify the excellent performance of this design. The maximum realized gain values for tri-band antenna are 2.69 dBi, 1.65 dBi and 2.76 dBi, while those of the dual-band antenna are 3.11 dBi and 2.78 dBi. The radiation patterns are relatively symmetric at their resonant frequencies so that the proposed antennas can radiate electromagnetic waves evenly. The proposed antennas are very simple in structure and can operate in multiband.

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