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Compact Multi-Band Flexible Antenna for ISM, WLAN, Wi-Fi, and 5G sub-6-GHz Applications

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Abstract

Design and analysis of a compact multi-band flexible antenna are presented here. The antenna is designed using the flexible substrate material Rogers 5880 and has a compact size of 18mm×18mm×0.254mm. The coplanar waveguide (CPW) fed radiator consists of a rectangular-shaped patch modified using a pair of rectangular slots to achieve the required bandwidth. Another smaller slot was etched in the radiator to achieve a lower resonance. The proposed design offers a multi-band functionality covering ISM, WLAN, Wi-Fi, and upper 5G sub-6-GHz bands.

1. Introduction

Industrial Scientific and Medical (ISM), Wireless LAN and Wi-Fi band spectra are well known and commonly used spectra. These applications usually work using one or several frequencies among 2.4, 2.45, 4.9, 5, 5.2, 5.8 GHz [1]. Due to the key importance of these band spectra in both wired and wireless communication systems, an extensive amount of work is dedicated to these applications in the literature. However, numerous designs proposed in the literature either use a thick substrate material or a thin stiff substrate material that cannot readily be used for flexible devices [2-3].

Thus, to meet the challenges arising due to the extensive use of flexible devices, a flexible antenna with high performance parameters is required. So far, only a limited number of publications can be found on the design of multiband flexible antenna for targeted band spectra [4-11]. For instance, in [4] a serpentine-based dual band antenna for flexible applications is presented. The serpentine structured stub was utilized to achieve compactness, while an additional capacitor is loaded to operation in lower frequency band. Due to its large physical size, this antenna is not suitable for modern day compact devices. A geometrically simple textile-material high gain and wideband antenna was presented in [5]. The antenna resonates at higher band of 5 GHz and X-band, but has the disadvantage of larger dimensions without a solution available for the lower frequency band of 2.4 GHz.

A meandered line monopole antenna for dual band flexible devices is proposed in [6]. The antenna offers wide bandwidth, but has disadvantages like bigger size and no information the gain of the presented design. A metasurface loaded high gain antenna was presented in [7]. Although high gain and broad bandwidth was achieved, the use of metasurfaces increases the structural complexity with high profile and increased physical dimensions. In [8], a relatively compact antenna for dual band application is presented. However, such a design is unable to cover the complete 5 GHz band and thus limits its application area.

A miniaturized dual band antenna is presented in [9] with physical size of 18 mm × 16mm. The antenna is designed using a complex geometrical configuration which creates major fabrication issues. Moreover, the results presented show that the measured results are not in good agreement with simulated results.

In this paper, a compact, dual band flexible antenna is presented. The rest of the paper is divided in two sections. Section-II presents the design methodology and various performance parameters of the proposed antenna, while section-III concludes the discussion.

2. Antenna Design and Results

The geometric top and side view of the proposed antenna is depicted in Figs. 1(a) and 1(b), respectively. The proposed antenna is embedded on the top side of a 0.254mm thick flexible Rogers RT/Duroid 5880 substrate. The Antenna design methodology consists of three major steps. In step-1, a conventional rectangular quarter wave monopole antenna to cover 5 GHz band is designed. The CPW feeding technique is utilized due to its advantage of a simple planar structure, which eases the impedance matching challenge with other RF components.

The resultant antenna offers a broad bandwidth of 1.4 GHz ranging between 4.2–5.6 GHz as depicted in Fig. 2(a). Although the antenna designed in step-1 offers a broad bandwidth, it still has a disadvantage of not covering the target band spectrum. Thus, to improve the bandwidth, two rectangular slots were etched from the rectangular radiator. This forces the surface current of the radiator to redistribute itself and causes the improvement in impedance matching, as shown in Fig. 2(a). Afterwards, to achieve a lower resonance at 2.4 GHz band spectrum, another rectangular slot is etched from the radiator. It behaves as a capacitor and provides a lower resonance at 2.4 GHz, which is explained briefly in [10]. The final antenna offers a multi-band operation having three resonances at 2.4, 4.5 and 7.2 GHz, as shown in Fig. 2(a).

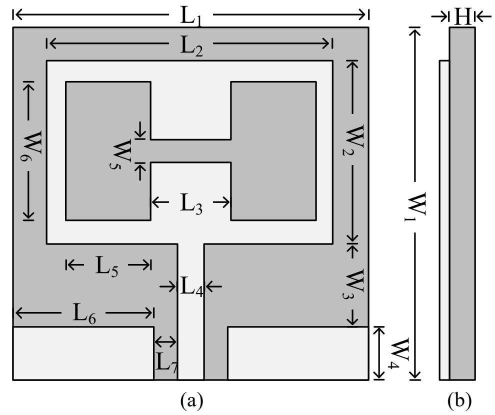

Fig. 1. Proposed multi-band antenna geometry (a) top-view (b) side-view. *L_1 = 18; L_2 = 16; L_3 = 4; L_4 = 2; L_5 = 5.5; L_6 = 7.5; L_7 = 0.5; W_1 = 18; W_2 = 13; W_3 = 2; W_4 = 2; W_5 = 0.5; W_6 = 7.5; H = 0.254. (Unit is mm)*

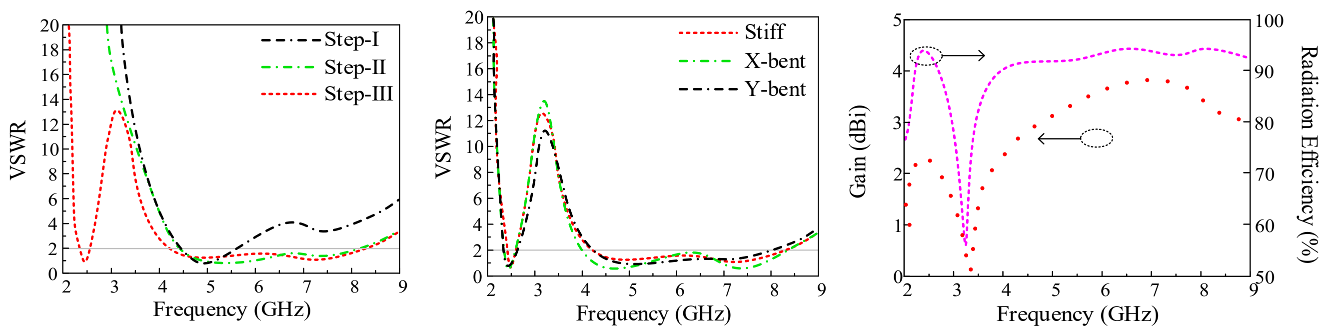

Fig. 2. (a) VSWR of various antenna design (b) Comparison among VSWR in stiff and conformal condition (c) Gain and radiation efficiency.

Fig. 2(b) presents the Voltage Standing Wave Ratio (VSWR) of the proposed antenna for stiff as well for conformal condition. The proposed antenna offers a strong agreement between both bent and unbent conditions, having VSWR 2:1 bandwidth of 2.29 – 2.57 GHz at the lower resonance of 2.45 GHz, as depicted in Fig. 3. while a bandwidth of 4 GHz ranging between 4.2 – 8.2 GHz is observed at higher frequency band, as shown in Fig. 2(b). Fig. 2(c) shows the gain and radiation efficiency versus frequency of the proposed antenna. It can be seen that the antenna offers a gain of > 2 dBi in the operational region having a peak value of 3.7 dBi at 7.4 GHz. Moreover, Fig. 4 shows that the antenna offers a high radiation efficiency of > 90% in both operational bands.

3. Conclusion

A compact size multi-band flexible antenna is presented in the present paper. The antenna consists of simple CPW fed rectangular quarter-wave monopole antenna, which is modified using a pair of rectangular slots to achieve a wide bandwidth of 4 GHz ranging 4.2 – 8.2 GHz. Afterwards, another rectangular slot of capacitive nature is etched from the center of the radiator to provide a lower frequency band between 2.29 – 2.57 GHz. The analysis of the proposed antenna in both the conformal and non-conformal scenario is carried out using HFSS. The proposed antenna performance is thereafter compared to other designs for similar applications. Thereby, it can be observed that our proposed design offers a good combination of performance parameters compared to other designs by providing a simple structure, wide bandwidth, relatively high gain, and compact size. It makes the presented design a potential good candidate for use in future wireless technologies.

Acknowledgements

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