Multiband Planar Antenna for Cellular and Wireless Applications

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***Abstract*—A multiband planar antenna design is presented for cellular and wireless communications. The presented antenna realizes an overall size of 40×40×1.6 mm^3. It consists of a G-shaped and inverted L-shaped radiator. The G-shaped radiator is responsible to offer 1800 MHz, 2.45 GHz, and 3.5 GHz frequency bands, while the inverted L-shaped radiator can provide resonance at 900 MHz and 5 GHz frequency bands. Moreover, the proposed multiband antenna offers good radiation characteristics and gain for desired frequency bands. The proposed antenna design is also fabricated and measured to validate the simulation results.**

***Index Terms*—Multiband; Planar antenna; Cellular communication; Wireless communication; G-shape; Inverted L-shape.**

I. Introduction

Over the past few years, wireless communication systems have been developed with an astonishing rate. With these developments, future applications need to provide diverse services for wireless terminals. On the other hand, this rising demand in wireless systems prompts the need for antennas, which can cover multiple bandwidths. At the same time, a compact antenna is highly desired due to the integration requirements of every system. For this purpose, several researchers proposed compact and multiband antenna designs for wireless communication systems.

In the early literature, researchers presented planar antenna configurations for dual and tri-band frequency response. In [1], a dual-band planar antenna was designed for Wireless Local Area Network (WLAN) applications. The antenna design was simple, and it can easily be embedded onboard for indoor wireless communication. The results showed that the antenna was not able to operate well for the 2.45 GHz frequency band. But, it provides good gain for both frequency bands. A defected ground structure (DGS) with fractal patch geometry was presented for bandwidth enhancement for dual-band Worldwide Interoperability for Microwave Access (WiMAX) communication [2]. According to the authors, DGS was able to increase the bandwidth of an antenna with relatively good gain. Veeravalli et al. [3] proposed a meandered planar antenna design for dual-band GSM 900 MHz and 1800 MHz communication. The presented antenna design followed the design principle of Planar Inverted F-Antenna (PIFA). One of the reconfigurable antenna configurations was also presented in the literature for tri-band frequency response [4]. In this technique, slots were designed on a rectangular patch, which accommodates passive radio frequency (RF) switches. The antenna somehow was not a good candidate for wireless communication because the passive RF switches need proper tuning to respond perfectly to the desired band.

A T-shaped planar antenna having two inverted L-shaped strips was presented in Ref. [5]. The presented antenna was able to provide resonance for 2.55 GHz, 3.5 GHz, and 6.19 GHz frequency bands. In [6], a planar antenna design was presented for cellular, WiMAX and WLAN applications. The authors used a T-shaped radiator with a rectangular loop structure to achieve a dual-band response. A G-shaped antenna was designed and presented in Ref. [7]. By using a simple structure, a dual-band response for Radio Frequency Identification (RFID) and WLAN applications was achieved. In [8], authors presented dual-band antenna design for WLAN/WiMAX communications. To achieve dual-band characteristics, they employed a key-shaped slot in a rectangular patch.

A compact co-planar waveguide (CPW) fed planar antenna was presented for tri-band wireless applications [9]. The authors utilized two inverted L-strips and a circular parasitic element for tri-band characteristics. It was also described that the designed antenna offers a good gain with stable radiation properties. In [10], a paw-shaped printed antenna was presented for WiMAX and WLAN communication systems. The presented antenna provided a wide impedance bandwidth for the desired frequency bands. A simple and compact antenna design for WLAN applications was presented in Ref. [11]. The presented antenna design consists of an L-shaped element and a meandered strip line. The L-shaped element was fed using a 50Ω microstrip feed line. It is described that only L-shaped element was resonating above 6 GHz. To achieve dual-band response, authors employed meandered strip with a ground plane.

Recently, some compact and novel printed antenna designs are also presented for dual and triple-band wireless applications. In [12], a split ring resonator (SRR) based monopole antenna was presented for dual-band wireless communications.

Ratnaraton et al. [13] presented Hilbert fractal slot antenna for multiband cellular and WLAN applications. In [14], a single layer slot antenna was presented for multiband applications. The authors' used a Q-shaped slot with an open mouth ended radiator to achieve a multiband response. In [15], a patch antenna design was presented for multiband cellular, WiMAX and WLAN applications. The authors' utilized square-loop elements with a rectangular patch to achieve multiband response. But the presented design was large and cannot be easily integrated into hand-held devices.

In this paper, G-shaped and inverted L-shaped based planar antenna is presented for multiband cellular and wireless communication applications. It is demonstrated that the proposed antenna design can resonate well for 900 MHz, 1800 MHz, 2.45 GHz, 3.5 GHz, and 5 GHz frequency bands. Furthermore, the proposed planar antenna is compact than the designs presented in [6, 13–15].

II. Proposed Antenna Design

The design of the proposed planar multiband antenna is illustrated in Fig. 1 along with its design parameters. A low cost FR-4 substrate having h = 1.6 mm and ε_r = 4.4 is used to design the antenna. From Fig. 1, it is observed that the proposed antenna consists of G-shaped and inverted L-shaped radiators. First of all, a G-shaped radiator is designed and simulated, and it is observed that the G-shaped radiator is responsible to provide resonance at 1800 MHz, 2.45 GHz, and 3.5 GHz, respectively. After that, an inverted L-shaped radiator is designed with G-shaped radiator to achieve resonance at 900 MHz and 5 GHz. Therefore, a multiband planar antenna is realized as shown in Fig. 1. The width of both the radiators is equal to 0.5 mm, and their lengths are equal to $\lambda_g/4$, where λ_g is the guided wavelength and can be calculated as:

$$\lambda_g = \frac{c}{f_r\sqrt{\varepsilon_{eff}}} \tag{1}$$

where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \tag{2}$$

A 50Ω microstrip feed line is used to feed the antenna whose width is calculated according to the expression given in [16].

III. Results and Discussion

The proposed antenna design is simulated in Ansys HFSS, a commercially available electromagnetic software, and the return loss result is shown in Fig. 2. It is observed that the proposed antenna design can provide resonance for 900 MHz, 1800 MHz, 2.45 GHz, 3.5 GHz, and 5.16 GHz frequency bands, respectively. The proposed antenna is also fabricated to validate the simulation results and the prototype is shown in Fig. 3. Agilent Technologies Vector Network Analyzer (VNA) N5242A is used to measure the return loss characteristics. The comparison between simulated and measured return loss results is also depicted in Fig. 2. It is observed from Fig. 2 that both simulated and measured results are well in agreement.

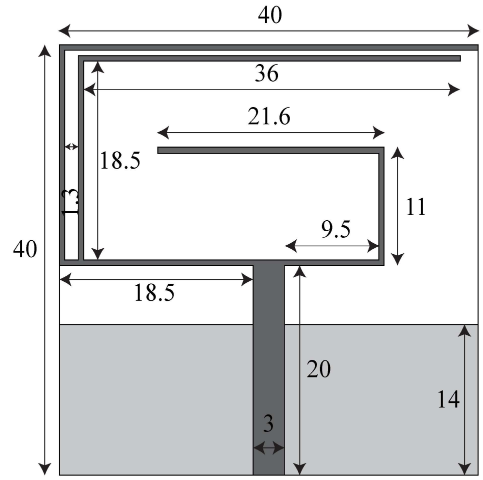

Fig. 1. Geometry and parameters of the proposed planar multiband antenna (all dimensions in mm).

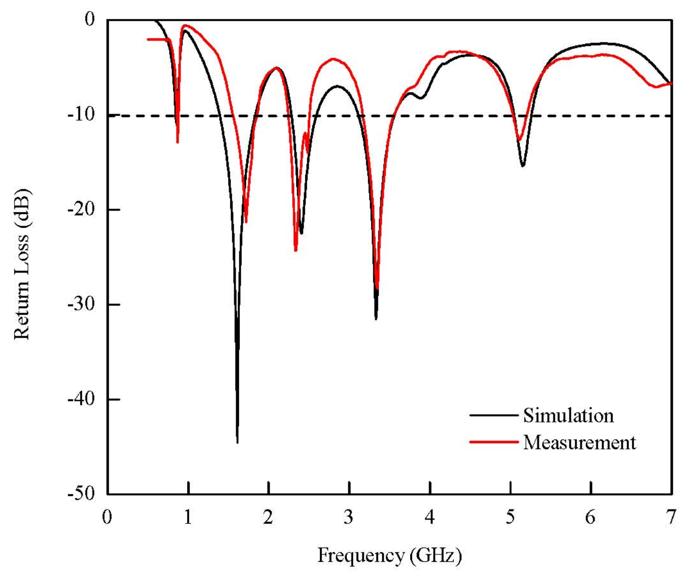

Fig. 2. Comparison between simulated and measured return loss results.

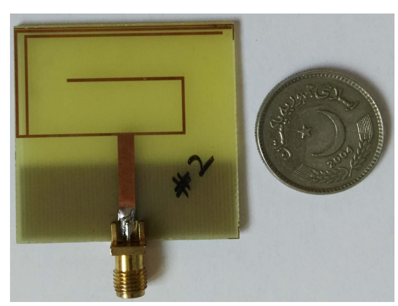

Fig. 3. Prototype of the proposed planar multiband antenna.

The discrepancies between the results are due to fabrication intolerance and SMA connector losses.

Figure 4 presents the results of input impedance for desired frequency bands in terms of its real and imaginary parts. It

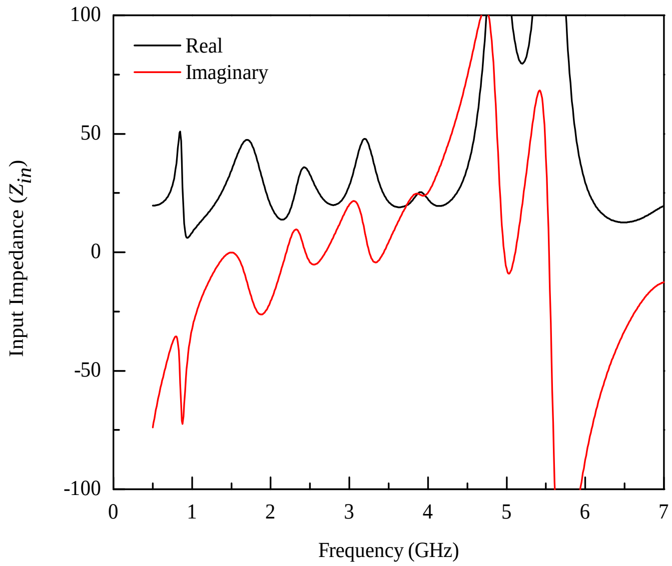

Fig. 4. Input impedance (Z_{in}) of the proposed planar multiband antenna.

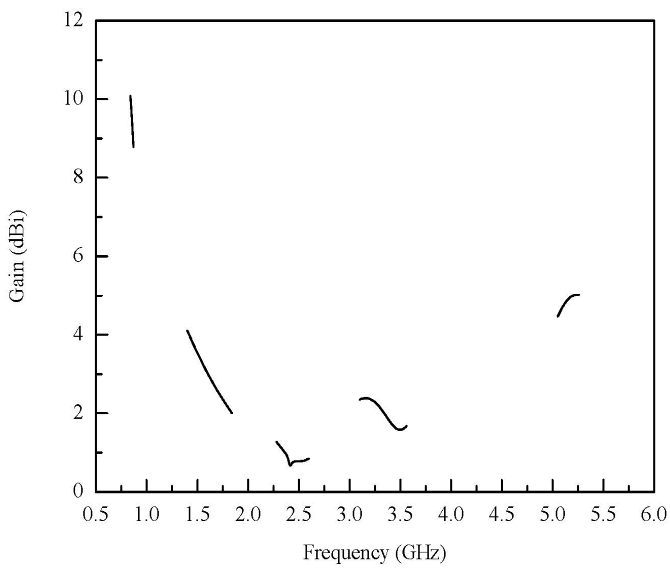

Fig. 5. Simulated gain of the proposed planar multiband antenna.

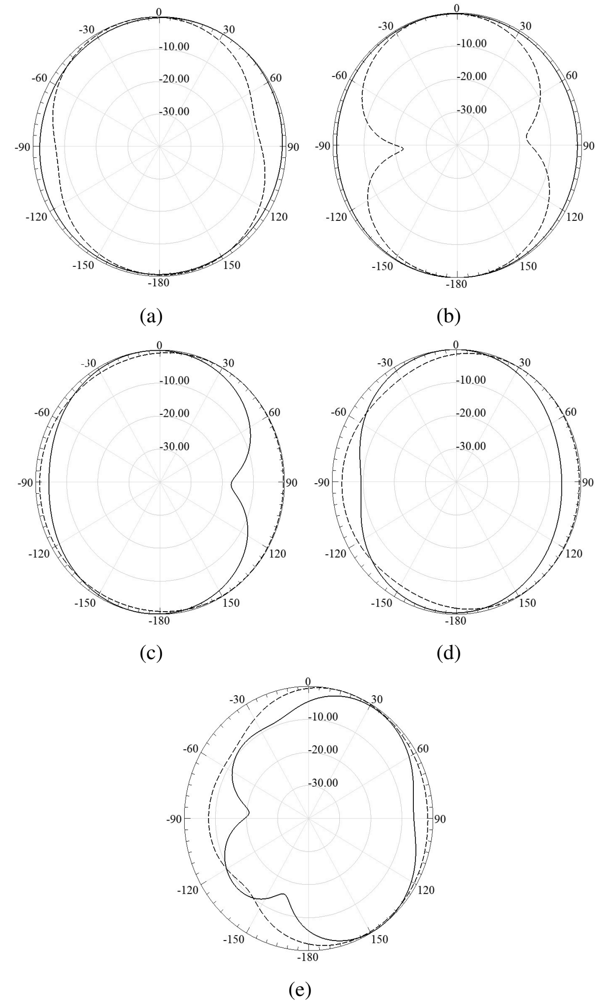

Fig. 6. Radiation patterns of the proposed planar multiband antenna for (a) 900 MHz (b) 1800 MHz (c) 2.45 GHz (d) 3.5 GHz and (e) 5.16 GHz (Dashed line: E-plane, Solid line: H-plane).

is observed that for desired frequency bands, the real part is fluctuating around 50Ω. On the other hand, the imaginary part of input impedance is fluctuating around 0Ω. The simulated gain of the proposed multiband antenna is depicted in Fig. 5. The gain values noted for resonant frequency 900 MHz, 1800 MHz, 2.45 GHz, 3.5 GHz, and 5.16 GHz are 9.67 dBi, 2.15 dBi, 1 dBi, 2 dBi and 5 dBi, respectively. It is also observed that the gain at 900 MHz frequency band is high as compared to other bands. This effect can be occurred due to the mutual coupling between both the radiators.

The simulated radiation properties for E- and H-plane at different frequencies are shown in Fig. 6. For resonant frequencies 900 MHz, 1800 MHz, 2.45 GHz, and 3.5 GHz, shown in Fig. 6 (a, b, c, d), a typical monopole like patterns are observed for E-plane, while omni-directional radiation characteristics are observed for H-plane. For resonant frequency 5.16 GHz, the directional radiation pattern is realized for both E- and H-plane as shown in Fig. 6(e).

The simulated current distribution results of the proposed antenna are shown in Fig. 7. For 900 MHz, the field is distributed on both the radiators and both are equally playing their role in generating 900 MHz frequency band. The same behavior is observed for 2.45 GHz and 5.16 GHz frequency bands. For 1800 MHz and 3.5 GHz, a dense current is distributed on G-shaped radiator.

IV. Conclusion

A compact planar antenna design is presented for multiband cellular and wireless communications. The proposed antenna design consists of a G-shaped and inverted L-shaped radiators connected to a 50Ω microstrip feed line. It is observed from results that the proposed antenna is able to provide resonance at 900 MHz, 1800 MHz, 2.45 GHz, 3.5 GHz and 5.3 GHz

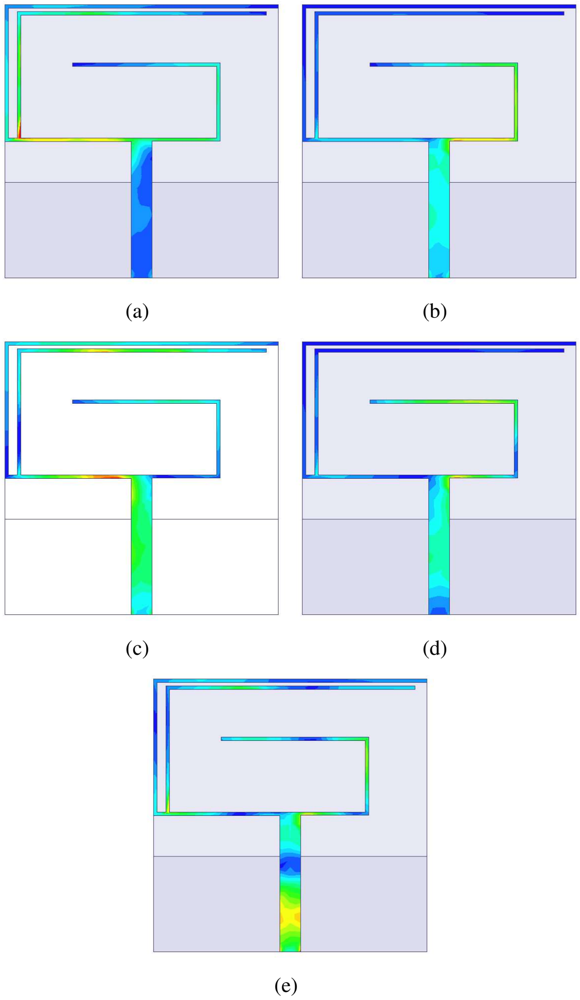

Fig. 7. Current distribution of the proposed planar multiband antenna for (a) 900 MHz (b) 1800 MHz (c) 2.45 GHz (d) 3.5 GHz and (e) 5.16 GHz.

frequency bands. Furthermore, the designed antenna provides good gain and stable radiation properties for desired bands. The designed antenna occupies an overall size of $40\times40\times1.6$ mm^3 so that it can easily be integrated with hand-held devices.

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