Compact and Planar Monopole Antenna for WLAN and WiMAX Applications

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Abstract **—** A novel compact dual-band monopole antenna for WLAN and WiMAX applications is presented. The antenna is fed by a microstrip feed line and consists of two side-by-side split-ring structure as the radiating element. The proposed antenna is compact in size and provides 25.5% and 11.8% dual band performance covering 2.4/5.2 GHz WLAN and 2.5/2.7 GHz WiMAX bands, respectively. Also, the antenna exhibits uniform radiation patterns at each frequency band in both *E*- and *H*-planes. Comparison of simulated and measured results of return losses, radiation patterns and gains of the antenna are provided.

Index Terms **—** Dual-band antenna, monopole antenna, split-ring elements, WiMAX, WLAN.

I. INTRODUCTION

The explosive growth in the number and variety of mobile communication devices, such as cell phones, laptops, and wireless modems, necessitates design of adaptable, miniature, multi-functional antennas. In this context, several frequency bands and signaling standards are typically exploited by means of a single antenna that must either support multiband or wideband operation. Conventional microstrip antennas have been the preferred choice for mobile devices due to their low-profile and high efficiency; however, they are inherently narrowband. It is, thus, necessary to tailor either the feed structure or the antenna element or both to achieve acceptable performance. Moreover, due to limited RF real-estate on mobile devices, antenna sizes must be kept to a minimum. In an effort to address the aforementioned requirements, monopole type printed antennas have played an increasingly important role. As they exhibit wide impedance bandwidth, compact and simple structure and ease-of-fabrication. Also, the omni-directional radiation pattern characteristics of monopole antenna make them very suitable for indoor applications such as airplane, shopping center, hospital, etc. Thus, the monopole structure has received much attention in the design of small antennas having wideband or multiband operation in recent years, as reported in literature.

For example, a monopole antenna can be designed to generate multiple resonant modes for size reduction and bandwidth improvement. In [1], an antenna with an L-shaped strip is designed for this purpose. There are many reported antenna designs for wireless systems such as coplanar waveguide (CPW)-fed monopole antenna with embedded slots [2], meandered split-ring (SR) slot [3], and slot monopole antenna with rectangular parasitic elements [4]. A dual-band back-to-back printed monopole antenna operating at UMTS and 2.4 GHz WLAN is reported in [5]. In [6], a dual-band orthogonal C-shaped printed monopole antenna with protruding T-shaped ground plane for 2.4 and 5.2 GHz WLAN operation is reported. In addition, miniature dual-band or multiband monopole antennas based on SR elements [7] and complementary-SR elements are reported in [8,9]. The antenna presented in [7] using concentric split-ring elements and metallic loadings appropriately placed between the rings provides dual-wideband performance. The dual-band antenna in [8] is formed by concentric complementary-SR resonators and slot elements inserted between the rings, and the antenna in [9] consists of two side-by-side complementary SR elements generating multiband performance.

In this paper, a novel SR antenna fed by a microstrip feed line is proposed. Unlike the designs in [7-9], two side-by-side split-ring elements are used as the main radiator in the new design as shown in Fig. 1. Furthermore, in order to achieve desired antenna performance, several ground plane geometrics were investigated and compared (also depicted in Fig. 1). In addition, dimensions of the microstrip feed line were optimized to obtain a very wide bandwidth. Based on this analysis, a dual-wideband antenna was fabricated and

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characterized. The measurement results are in good agreement with the simulations (carried out using Ansoft HFSS v.14). The proposed antenna provides dual-band operation covering an impedance bandwidth of 25.5% at 2.75 GHz and 11.8% at 5.27 GHz, with a compact size of 28 mm by 32 mm. We also demonstrate that this antenna exhibits well-behaved radiation patterns in the respective bands.

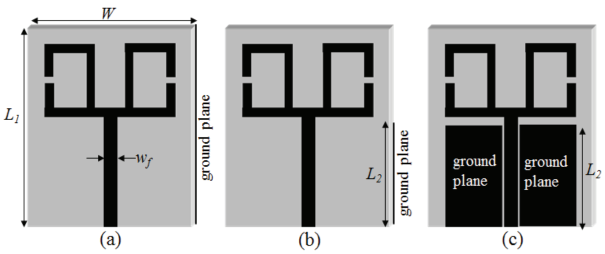


Fig. 1. Geometry of the printed SR-antenna: (a) full-covered ground plane, (b) half-covered ground plane, and (c) CPW-type ground plane. L_1=32, L_2=16, W=28, w_f=2.5.

II. NUMERICAL DESIGN OF THE ANTENNA

Figures 1 (a)-(c) shows three versions of the proposed antenna with two side-by-side SR elements and microstrip feed line. All antennas shown in Fig. 1 have same geometric dimensions apart from the difference in the ground plane metallization. In Fig. 1, while L_1 and L_2 are the lengths of ground planes, w_f is the width of microstrip feed line for three cases. The analysis of the three configurations shown in Fig. 1 reveals that the antenna with full-covered ground plane doesn't exhibit any resonances (as shown in Fig. 2). While the antenna with CPW-type ground plane provides single band performance at 3 GHz, a dual-band performance at 2.9 GHz and 5.2 GHz can be achieved using half-covered ground plane.

On the other hand, in order to enhance the bandwidths of the design with half-covered ground plane and achieve desired dual-wideband operation, the width of microstrip feed line are varied and compared as shown in Fig. 3. When width of the microstrip feed line is 1.5 mm, the antenna provides a single band operation about 3 GHz. When it is 3.5 mm, a single band operation about 5 GHz is observed. When the width of the feed line is 2.5 mm, a dual band operation about 2.9 and 5.2 GHz is obtained. Finally, in order to obtain broader bandwidth, two stage microstrip feed line is introduced as shown in the inset of Fig. 3. As seen, when the first stage of the feed line (W_1) is 3.5 mm and the second stage (W_2) is 1.5 mm, the antenna provides dual-wide band performance at 2 and 5 GHz bands.

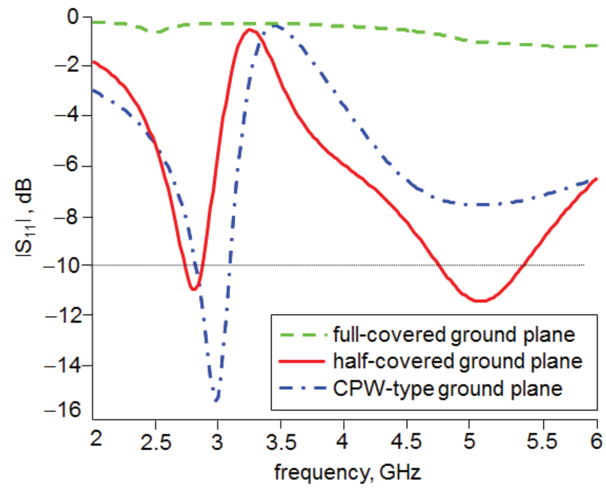


Fig. 2. Simulated return loss characteristics for different geometrical ground planes.

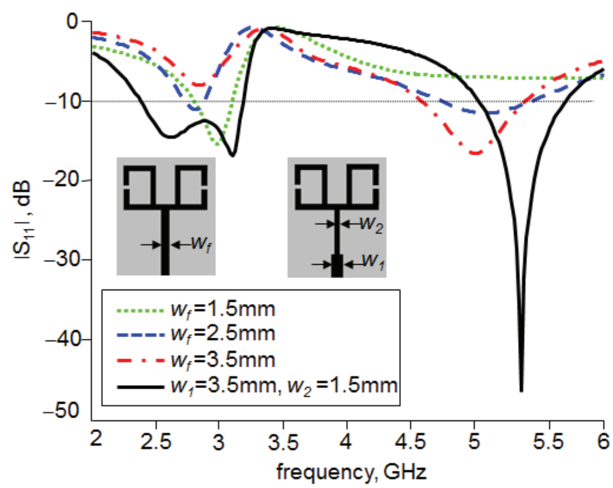
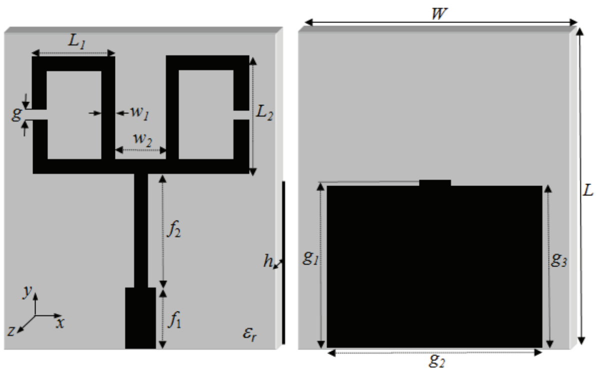


Fig. 3. Simulated return loss characteristics for different widths of microstrip feed line.

The optimum split-ring antenna (SRA) configuration with its design parameters is shown in Fig. 4. Here, the compact SRA is composed of two side-by-side split-ring elements fed by a two-stage microstrip feed line. The first stage of the feed line is 6 mm in length and 3.5 mm in width, while the second stage has a size of 12×1.5 mm^2. The split-ring resonators with microstrip feed-line are placed on a half grounded Rogers TMM4 substrate with 0.76 mm thickness and dielectric constant of ε_r=4.4. On the back side of the dielectric substrate, a half ground plane is printed below the microstrip feed-line. In order to tune first frequency band, a small patch (3.5×1 mm) is implemented into the top of the ground plane as shown in Fig. 4 (b). The design of the proposed antenna was carried out by means of Ansoft HFSS v.14, and the final dimensions of the antenna are recorded as follows (in millimeters): W=28, L=32, L_1=8.5, L_2=12, w_1=1.5, w_2=5, f_1=6, f_2=12, g=1, g_1=17, g_2=22, g_3=16.5, h=0.76.



(a) (b)

Fig. 4. Configuration of proposed SRA with its design parameters: (a) top view, and (b) bottom view.

III. SIMULATION AND MEASURMENT RESULTS AND DISCUSSION

Based on the design parameters shown in Fig. 4, a prototype antenna was fabricated, and the return loss, radiation pattern and gain measurements were carried out at The Ohio State University ElectroScience Laboratory. The return loss characteristics of the simulated as well as measured designs are shown in Fig. 5. As seen, for the simulated design dual-band coverage is achieved at 2.75 GHz and 5.27 GHz with corresponding 25.5% and 11.8% bandwidths, respectively. This modular design achieves coverage of WLAN bands in 2.4 (2.4–2.84 GHz), 5.2 (5.15–5.35 GHz) and WiMAX band in 2.6 GHz (2.5–2.7 GHz) and 2.8 GHZ (2.7–2.9 GHz).

The radiation patterns and gain of the proposed antenna were also measured. The simulated and measured radiation patterns on the y–z plane and x–y plane for 2.4, 2.6 and 5.3 GHz are shown in Fig. 6 (a), (b) and (c), respectively. As seen, the simulation and measurement results are in excellent agreement, and show that the proposed antenna exhibits omnidirectional radiation pattern in the H-plane (y–z plane) and dipole-like radiation pattern in the E-plane (x–y plane) at the respective bands. In addition, simulated and measured gains of the antenna are shown in Fig. 7 for the H-plane.

The measured gain at the frequencies 2.4 GHz, 2.6 GHz and 5.25 GHz are approximately 1.5, 1 and 2 dBi, respectively.

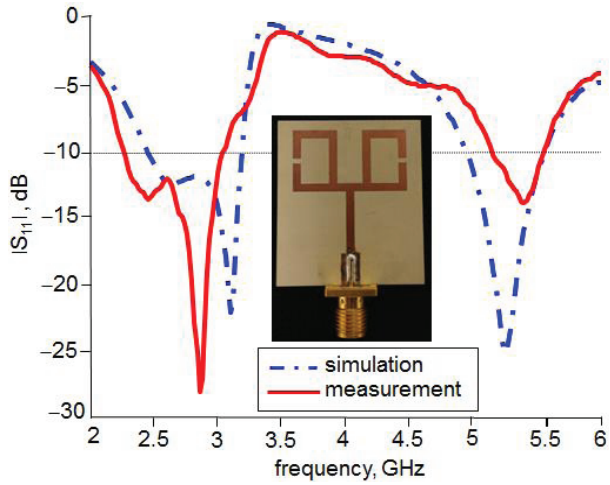


Fig. 5. Simulated and measured return loss (S_{11}) characteristics for the proposed SRA and the prototype of the antenna.

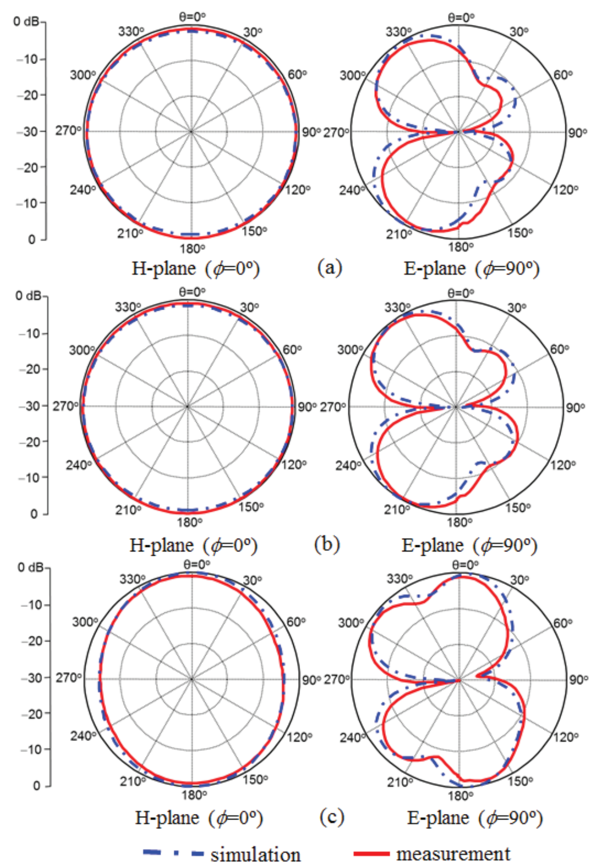


Fig. 6. Measured and simulated radiation patterns of proposed antenna at: (a) 2.4, (b) 2.6, and (c) 5.3 GHz.

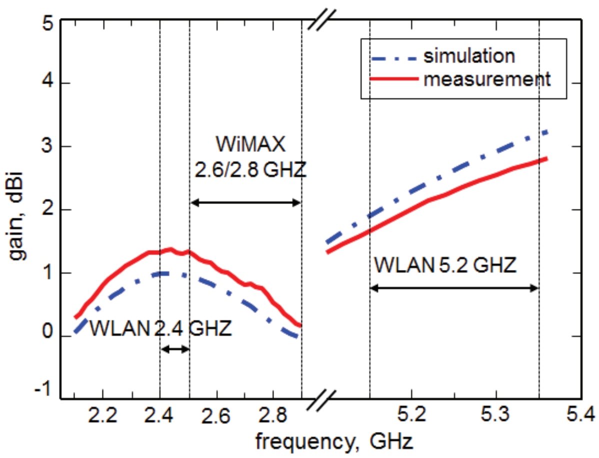


Fig. 7. Simulated and measured gain of the proposed antenna for the 2 GHz and 5 GHz band.

IV. CONCLUSION

A new dual-band monopole antenna for 2.4/5.2 GHz band WLAN and 2.6/2.8 GHz band WiMAX applications was presented. In order to keep the antenna size small, side-by-side split-ring elements are used as the main radiator of the antenna. The two-stage microstrip feed line and a partial ground plane provides to enhance bandwidth of the antenna at the dual respective bands. In addition, a good radiation pattern as well as gain performance is achieved for the frequency bands considered.

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