Multiband Dual Spiral Stripline-Loaded Monopole Antenna

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***Abstract*—We propose a multiband antenna that exhibits a dual coupling characteristic and dual frequency operation using a dual spiral stripline-loaded monopole in conjunction with L-shaped slots in a ground plane. The slots allow the upper part of the ground plane to function as an additional monopole that resonates in concordance with the existing resonances of the upper and lower spiral stripline monopoles. As a result, the impedance bandwidths are greatly enhanced while maintaining relatively good omnidirectional radiation characteristics. The proposed antenna occupies a volume of $36 \times 7 \times 102$ mm^3 including the ground plane, and the measured impedance bandwidths with VSWR ≤ 2 simultaneously cover CDMA, GSM900, DCS1800, PCS1900, UMTS, IMT-2000, and WiMAX2350 bands. We describe the detailed antenna structure and present measurement results.**

***Index Terms*—Electromagnetic (EM) coupling, monopole antennas, multiband antennas, small antennas.**

I. Introduction

INCREASING consumer demand for handsets that can operate across several communication standards has spurred considerable interest in multiband antenna designs. Although multiband planar and printed antennas benefit from low profile and low cost, such antennas feature narrow bandwidths and deteriorated radiation characteristic at high operating frequencies [1]–[4]. Recently, by using mutual coupling between two spiral stripline radiators located in very close proximity, the bandwidth of the antenna could be improved and the size of the antenna markedly reduced [5], [6]. Moreover, by properly embedding slots in the ground plane, an improvement in antenna gain and bandwidth, as well as radiation characteristics, was obtained [7], [8].

In this letter, we present a dual spiral stripline-loaded monopole antenna with L-shaped slots in the ground plane for multiple broadband applications. The proposed antenna has physical dimensions of $36 \times 7 \times 102$ mm^3, including a ground plane and dual-frequency operation with broad impedance bandwidths of about 26.3% and 35.9% based on VSWR $\leq$ 2 at the first and second frequency bands, respectively. The operating frequency of the antenna extends from 773 to 1007 MHz and from 1703 to 2450 MHz, simultaneously covering CDMA (824–894 MHz), GSM900 (880–960 MHz), DCS1800 (1710–1880 MHz), PCS1900 (1850–1990 MHz), UMTS (1920–2170 MHz), IMT-2000 (1885–2200 MHz), and WiMAX2350 (2300–2400 MHz) bands. A full-wave electromagnetic (EM) simulator, CST Microwave Studio, was used to validate the measured results of the fabricated antenna.

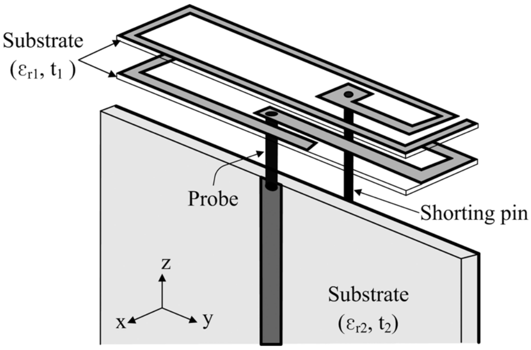

Fig. 1. The 3-D prospective view of the designed antenna.

II. Antenna Characteristics and Results

The 3-dimensional view and the detailed design of the antenna are shown in Figs. 1 and 2, respectively. Two almost identical spiral striplines are stacked together and placed on the top side of the ground plane. These two spirals are printed on a RO4003 substrate with a dielectric constant of 3.38 and a thickness of 0.203 mm. The antenna is fed by a 50-Ω microstrip line that is located along the center of the ground plane with a size of 40×90 mm and connected to the lower spiral stripline via a probe pin with a diameter of 1.0 mm. The upper spiral stripline is attached to the ground plane by a shorting pin with a diameter of 0.7 mm. The substrate for the ground plane has a dielectric constant of 3.38 and a thickness of 0.508 mm.

An electromagnetic simulation using CST Microwave Studio showed that the shorting pin with the upper spiral stripline monopole controls the lower resonance frequency, while the probe pin with the lower spiral stripline monopole controls the upper resonance frequency at both the first and second frequency bands. The total lengths of these two monopoles were chosen to approximately equal a quarter-wavelength at the resonance frequencies. We found in simulation that the changes in the widths of these two spiral striplines made the resonance frequency shift. For instance, decreasing their widths resulted in reductions of the total length of these two monopoles, causing the resonance frequencies to increase. In addition, the distance between the feeding probe and shorting

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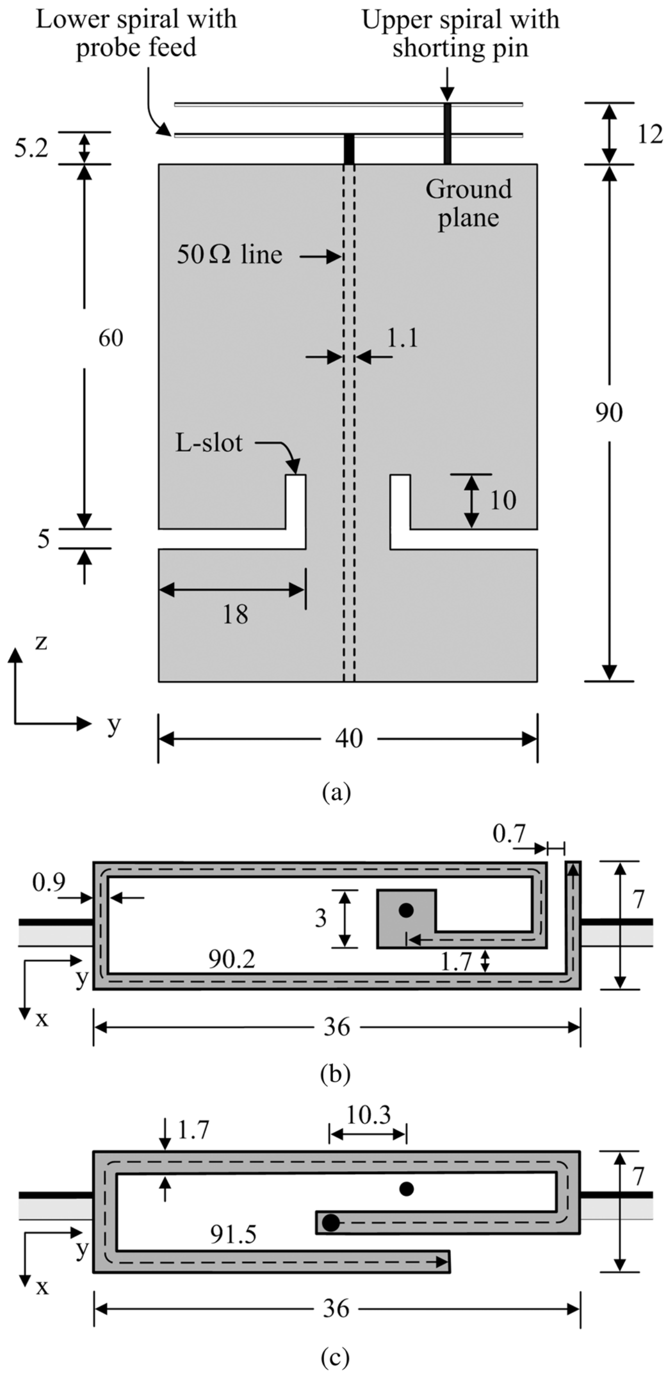

Fig. 2. Detailed geometry of the multiband antenna: (a) front view, (b) top view of the upper spiral stripline, and (c) top view of the lower spiral stripline (all dimensions in millimeters).

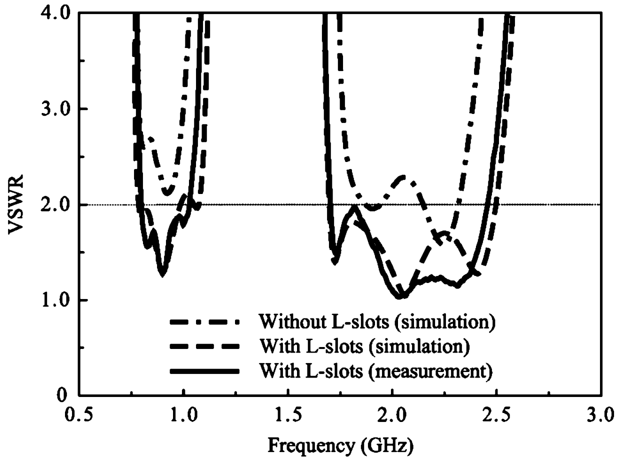

Fig. 3. Measured and simulated VSWR of the antenna with and without L-shaped slots in the ground plane.

pin was found not to affect the change in the resonances due to the remains in the total lengths of these monopoles. However, the change in distance greatly affects the EM coupling between these two monopoles, viz., a closer distance, a higher coupling, and vice versa. Therefore, these spiral stripline dimensions are carefully tuned to achieve the mutual coupling and small impedance variation over a wide frequency range.

To broaden the impedance bandwidths and improve the radiation characteristics of the antenna, two open-ended L-shaped slots, located symmetrically with respect to the microstrip line, are inserted into the ground plane. Fig. 3 shows the VSWR of the antenna with and without slots in the ground plane. Two additional resonances are produced at 1070 and 2413 MHz in the first and second frequency bands, respectively. These resonances are then electromagnetically coupled with the center resonances, which are controlled by the probe pin and the lower spiral stripline monopole, in the first and second frequency bands. A dual coupling characteristic has thereby been achieved, and the impedance bandwidths of both frequency bands are significantly broadened. We found in simulations that the sizes and locations in the ground plane of these L-shaped slots should be carefully adjusted to fine-tune the second frequency band to cover the DCS, PCS, UMTS, IMT-2000, and WiMAX2350 bands. The simulation results also showed that the radiation patterns with the slots resonances were significantly improved in comparison to the antenna without slots in the ground plane, especially the copolarized components of the electric field at the higher frequency.

We performed the antenna measurement with an Agilent E5071B network analyzer. The measured VSWR of the proposed antenna is close to the simulated VSWR as shown in Fig. 3. The measured bandwidths, based on VSWR ≤ 2, are 234 MHz (773–1007 MHz) at the first frequency band and 747 MHz (1703–2450 MHz) at the second frequency band. We observed slight discrepancies between the simulation and measurement at the highest resonance frequencies of the first and second frequency bands, which was predicted from the slight misalignment of the upper and lower spiral striplines. Fig. 4(a)–(c) shows the measured and simulated far-field radiation patterns of the antenna at 920, 1920, and 2350 MHz, respectively. It can be seen that the good omnidirectional radiation characteristics are obtained for both the first and second frequency bands. The peak gains at the frequencies of 920, 1920, and 2350 MHz are approximately 0.1, 2.11, and 3.06 dBi, respectively. We found a relatively good agreement between the measured and simulated ones, especially the copolarized components of the electric field.

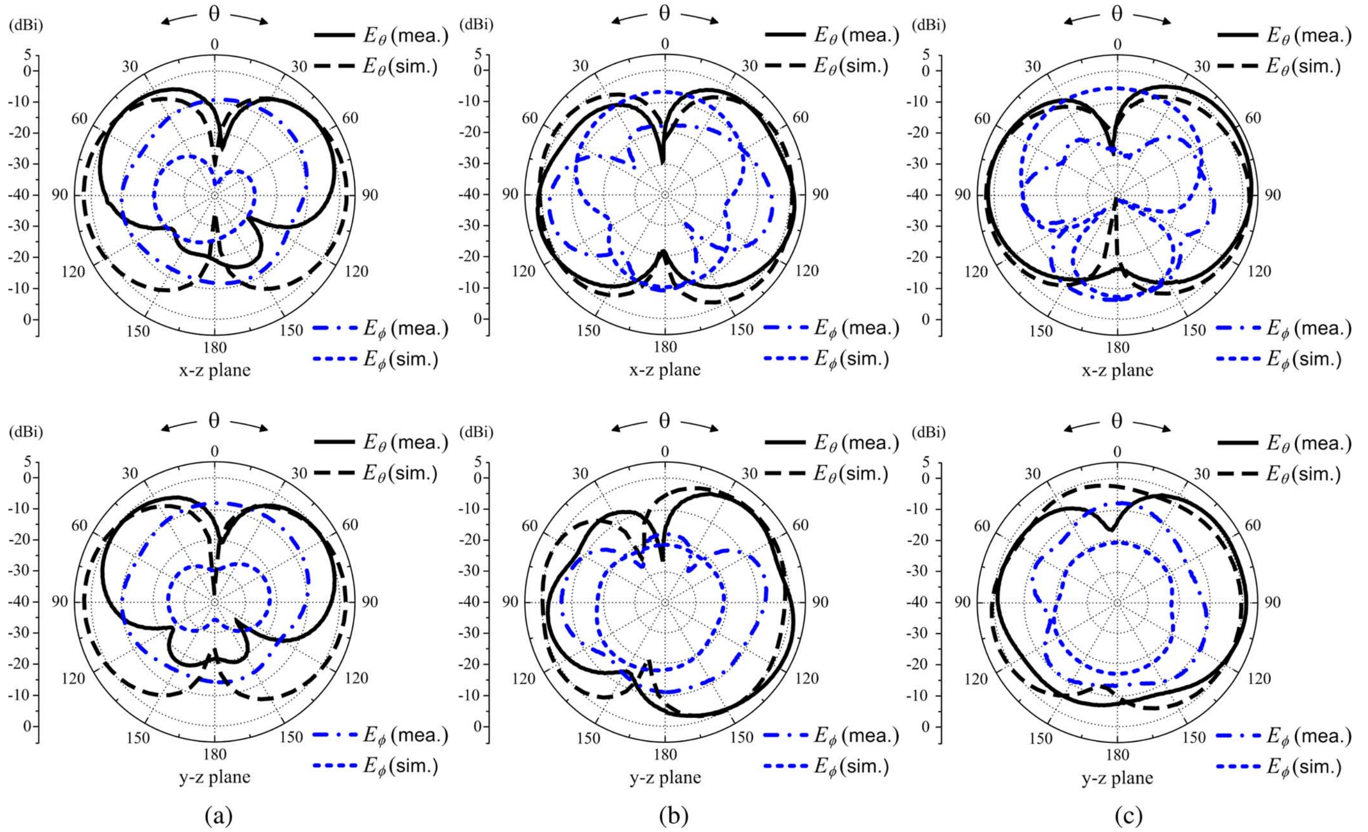

Fig. 4. Measured and simulated radiation gain patterns at (a) 920 MHz, (b) 1920 MHz, and (c) 2350 MHz for the proposed multiband antenna. Antenna orientation is given in Fig. 1.

III. CONCLUSION

We designed and successfully implemented a multiband dual spiral stripline-loaded monopole antenna with L-shaped slots in the ground plane to cover seven communication bands: CDMA, GSM900, DCS1800, PCS1900, UMTS, IMT-2000, and WiMAX2350. A dual-frequency operation with broad impedance bandwidths is achieved by the dual mutual-coupling characteristic. We observed a good agreement between simulated and measured results, as well as the relatively good radiation characteristics. The proposed antenna is very well suited to use as an internal multiband antenna for wireless communication terminals.

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