A CPW-Fed Compact UWB Microstrip Antenna

Anil Kr Gautam, *Member, IEEE*, Swati Yadav, and Binod Kr Kanaujia, *Member, IEEE*

***Abstract*—A novel coplanar waveguide (CPW)-fed compact ultrawideband (UWB) microstrip antenna is proposed for ultrawideband applications. The proposed antenna posseses a method to minimize the monopole antenna by loading of inverted L-strip over the conventional monopole patch antenna to lower the height of the antenna. The ground was vertically extended toward two sides of the single radiator. Therefore, the large space around the radiator that is usually wasted can be effectively saved. The antenna is practically fabricated and simulated. Measured results show a good agreement with simulated results. The prototype with overall size of $25 \times 25 \times 1.6$ mm^3 achieves good impedance matching, constant gain, stable radiation patterns, and constant group delay over an operating bandwidth of 2.6-13.04 GHz (10.44 GHz).**

***Index Terms*—Monopole antenna, slot antenna, ultrawideband (UWB) microstrip antenna.**

I. Introduction

IN 2002, the Federal Communications Commission (FCC) [1] allocated the spectrum from 3.1 to 10.6 GHz for unlicensed ultrawideband (UWB) measurements and communication applications with EIRP less than -41.3 dBm/MHz. The microstrip UWB antennas have attracted much attention owing to their advantages such as simple structure, low profile, high data rate, easy integration with monolithic microwave integrated circuits (MMICs), and ease of fabrication. Thus, the UWB antenna has become the most promising solution for future short-range high-data wireless communication applications, UWB for short-range (10 m), peer-to-peer ultra-fast communications, and many more application. This has instigated researchers to dwell deep in the design of UWB antennas [2]–[9]. Various shapes of monopole antennas, such as a beveled rectangular patch [10] and a circular printed monopole with steps [11], and various shapes of slot antennas, such as inverted cone slot [12] and tapered slot with tuning patch [13], have been reported for a compact UWB antenna.

In this letter, a novel coplanar waveguide (CPW)-fed compact UWB microstrip antenna is proposed and designed. The antenna is mainly composed of a radiation patch with good radiation performance from 3.1 to 10.6 GHz. The proposed antenna posseses a method to minimize the monopole antenna by loading of inverted L-strip over the conventional radiator patch antenna to lower the height of the antenna. The ground was vertically extended toward two sides of the single radiator. Therefore, the large space around the radiator that is usually wasted can be effectively saved. The proposed structure is illustrated in Fig. 1.

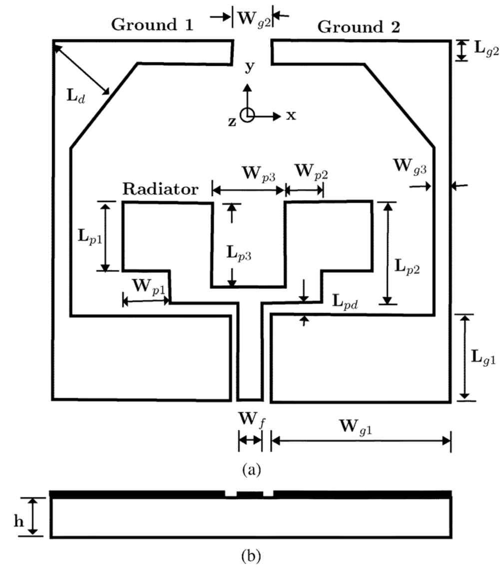

Fig. 1. Schematic configuration of the proposed compact UWB microstrip antenna.

II. Antenna Design

Normally, the bandwidth of a microstrip antenna is not very broad because it has only one resonance. Thus, to design a UWB antenna, two or more resonant parts with each one operating at its own resonance is required, and the overlapping of these multiple resonances may lead to multiband or broadband performance. Therefore, this design is chosen to generate two or more resonant bands for achieving ultrawide bandwidth. In addition, unlike the conventional UWB monopole antenna using a solid ground plane on the other side, in this design, the two grounds were etched on the same plane of the monopole as shown in Fig. 1. The above design skills are introduced to obtained ultrawideband accompanied with good impedance matching over the entire operating band. The basis of the monopole radiator is a rectangular patch, which has the dimensions of length L_{p2} and width W_{p3}, and is protruded with two inverted L-shaped strips from the patch's upper two sides. Each of the two strips comprises both the vertical and horizontal strips with dimensions of $L_{\mathrm{p2}} \times W_{\mathrm{p2}}$ and $L_{\mathrm{p1}} \times W_{\mathrm{p1}}$, respectively. As for the ground plane, unlike the general use of a solid rectangular plane for a microstrip-fed monopole antenna, ground planes are embedded from the patch's left and right sides on the same plane to provide the CPW feed. The overall size of the antenna is $25 \times 25 \times 1.6$ mm^3, and each of the embedded grounds has a vertical section of 25 mm as well as a horizontal section at the

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Fig. 2. Photograph of the fabricated compact UWB microstrip antenna.

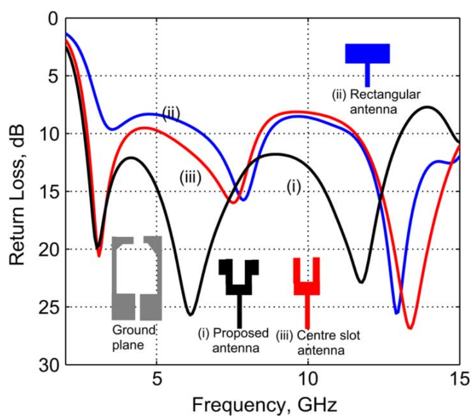

Fig. 3. Simulated return loss against frequency for the proposed UWB antenna, slot antenna without L-strips, and square antenna with same ground planes.

TABLE I
DESIGN PARAMETERS OF THE PROPOSED COMPACT INVERTED L-STRIP UWB MICROSTRIP ANTENNA SHOWN IN FIG. 1

Parameters	L_{p1}	L_{p2}	L_{p3}	L_{g1}	L_{g2}	L_{pd}	L_d
Unit(mm)	5	7	6.5	8	1	0.8	4
Parameters	W_{p1}	W_{p2}	W_{p3}	W_{g1}	W_{g2}	W_{g3}	W_f
Unit (mm)	2.5	2.5	5	10.6	4	1	3

upper and bottom face of 10.5 and 10.6 mm, respectively. The width of the CPW feedline is fixed at 3.0 mm to achieve 50 Ω characteristic impedance. Since the radiator is surrounded by a metal ground plane for reducing the antenna area, the small gap between the radiator and the ground plane is a major factor to cause overstrong capacitive coupling. The horizontal feed section (x-axis) is separated from the ground by a gap of 0.4 mm (see Fig. 1). The detailed dimensions of the proposed ultrawideband antenna are listed in Table I. A photograph of the fabricated antenna is shown in Fig. 2. This UWB antenna was fabricated and printed on a 1.6-mm-thick FR-4 substrate with permittivity of 4.4 and a loss tangent of 0.024.

The electromagnetic solver, Ansoft HFSS, is used to numerically investigate and optimize the proposed antenna configuration. Fig. 3, trace (i), shows the simulated return loss of the proposed antenna with the optimized parameters as listed in Table I. Obviously, the simulation results show ultrawide bandwidth from 2.6 to 13.04 GHz with three resonant bands at 3.03,

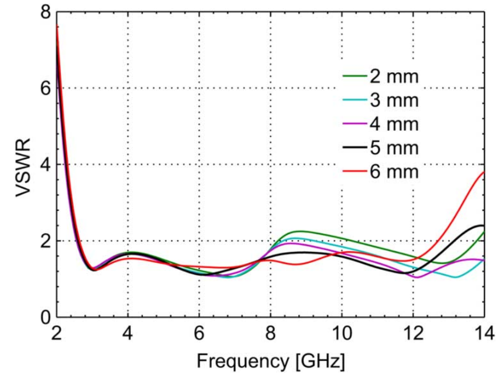

Fig. 4. Simulated VSWR against frequency for the proposed compact UWB microstrip antenna with various L_{p1}; other parameters are the same as listed in Table I.

6.11, and 11.78 GHz, respectively. Apparently, the above obtained bandwidth covers the entire UWB spectrum from 3.1 to 10.6 GHz. To further examine the appropriate impedance matching condition caused from addition of conventional rectangular patch or the center slot patch, the return loss for the proposed optimal design [case (i)] with same ground structures, which are denoted as curves (ii) and (iii), respectively, are also analyzed and presented in Fig. 3. Note that, in these cases, all the unmentioned dimensions are the same as listed in Table I. For the case of conventional rectangular monopole antenna, a worse matching condition appears over the frequency band, while two resonant modes seems to form at about 7.86 and 12.97 GHz, respectively. As for the case of the radiating monopole with center slot [curve (iii)], the matching condition is still poor across the full band. However, three modes are resonating at 3.1, 7.58, and 13.32 GHz, respectively. Finally, the inclusion of the two inverted L-shaped strips in the proposed design will significantly improve the impedance-matching conditions for the entire UWB and shows three resonant bands at 3.03, 6.11, and 11.78 GHz.

A. *Variation of Inverted L-Strip Parameters*

Fig. 4 shows the simulated results of the proposed antenna with inverted L-strip length L_{p1}, from 2 to 6 mm. It can be seen that the $\mathrm{VSWR} < 2$ bandwidth of the antenna increases greatly as L_{p1} increases from 2 to 5 mm and decreases as L_{p1} increases further. However, as L_{p1} increases from 2 to 5 mm, there is improvement in the UWB, but there is a mismatch of the impedance of the radiating patch and the input impedance at the middle frequencies of the UWB. Therefore, it is decided on $L_{p1} = 5$ mm as the optimum with the bandwidth from 2.6 to 13.04 GHz, covering the entire UWB.

Fig. 5 presents the simulated results of the proposed antenna with inverted L-strip width W_{p1}, from 2.5 to 6.5 mm. However, it can be observed that the $\mathrm{VSWR} < 2$ bandwidth for UWB band remains almost constant as W_{p1} increases from 2.5 to 6.5 mm, but a mismatch of the impedance of the radiating patch and the input impedance at the middle and lower frequencies of the UWB band increases. Furthermore, a single resonance is observed at upper frequencies of the UWB band when W_{p1} is 6.5 mm. Therefore, it is decided to take $W_{p1} = 2.5$ mm as the optimum, with minimum mismatch at middle frequency of UWB band.

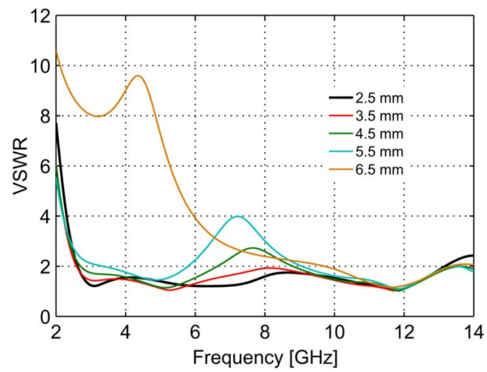

Fig. 5. Simulated VSWR against frequency for the proposed compact UWB microstrip antenna with various $W_{\rm p1}$; other parameters are the same as listed in Table I.

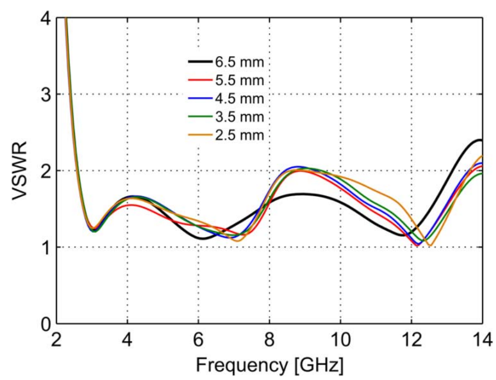

Fig. 6. Simulated VSWR against frequency for the proposed compact UWB microstrip antenna with various $L_{\rm p3}$; other parameters are the same as listed in Table I.

B. *Variation of Center Rectangular Slot Parameters*

The simulated results of the proposed antenna with centre rectangular slot length $L_{\rm p3}$, from 2.5 to 6.5 mm, are illustrated in Fig. 6. It can be seen that the $\rm VSWR < 2$ bandwidth at the upper band decreases greatly as $L_{\rm p3}$ increases from 2.5 to 6.5 mm. However, as $L_{\rm p3}$ increases from 2.5 to 6.5 mm, the impedance matching of the radiating patch and the input impedance at the lower and middle frequencies of the UWB band get improved. Therefore, it is decided to take $L_{\rm p3} = 6.5$ mm as the optimum, resulting in the bandwidth from 2.6 to 13.04 GHz.

Furthermore, the width of center rectangular slot $W_{\rm p3}$ also affects the characteristics of the antenna. Fig. 7 shows the simulated VSWR as $W_{\rm p3}$ varies from 3 to 6 mm. It can be seen that the $\rm VSWR < 2$ bandwidth of the antenna decreases as $W_{\rm p3}$ increases from 3 to 6 mm. It is also observed that impedance mismatch at the middle frequencies of the UWB band reduces as $W_{\rm p3}$ increases from 3 to 5 mm. Therefore, we decided on $W_{\rm p3} = 5$ mm as the optimum with the bandwidth from 2.6 to 13.04 GHz, covering the entire UWB band.

C. *Variation of Overall-Size Ground Plane*

Fig. 8 presents the simulated results of the proposed antenna with overall size of ground structure, from 21×21 to 25×25 mm^2. It can be observed, as the size is reduced from 25×25 mm^2, the $\rm VSWR < 2$ bandwidth for UWB band shifted toward the upper side and also a mismatch of the impedance of the radiating patch and the input impedance at

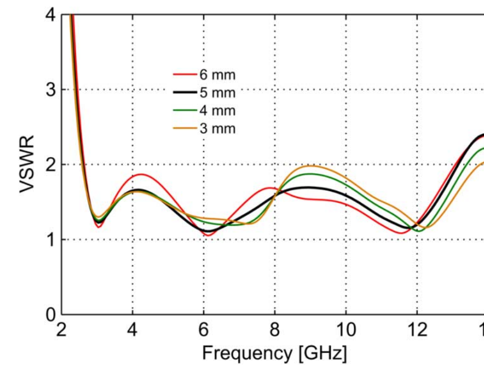

Fig. 7. Simulated VSWR against frequency for the proposed compact UWB microstrip antenna with various $W_{\rm p3}$; other parameters are the same as listed in Table I.

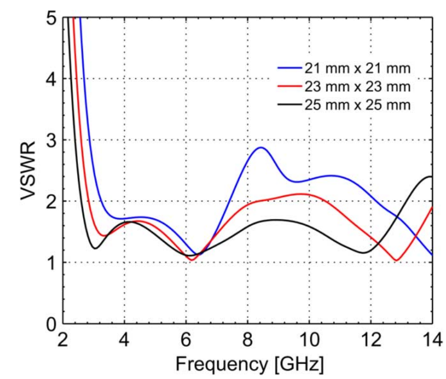

Fig. 8. Simulated VSWR against frequency for the proposed compact UWB microstrip antenna with various ground size.

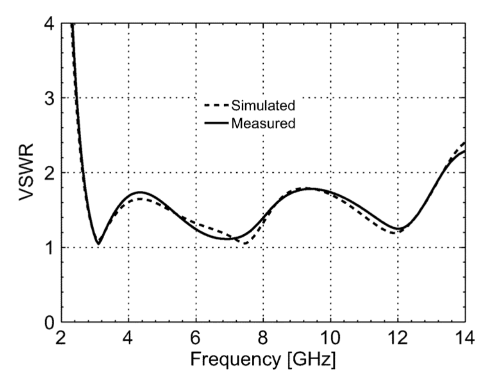

Fig. 9. VSWR for the proposed compact UWB microstrip antenna.

the middle frequencies of the UWB band greatly increased. Therefore, it is decided to take overall size of ground plane 25×25 mm^2 as the optimum, with minimum mismatch at the entire frequency of UWB band.

III. Experimental Results and Discussion

An Agilent N5230A vector network analyzer was used to measure the electrical performance of the proposed antenna such as impedance bandwidth, VSWR, and gain. Fig. 9 shows the measured and simulated VSWR curves of the compact inverted L-strip UWB antenna. As shown in Fig. 9, a good agreement between the simulated and measured results is observed. The small difference between the measured and

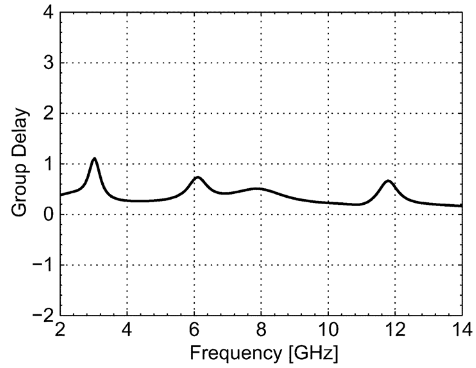

Fig. 10. Group delay for the proposed compact UWB microstrip antenna.

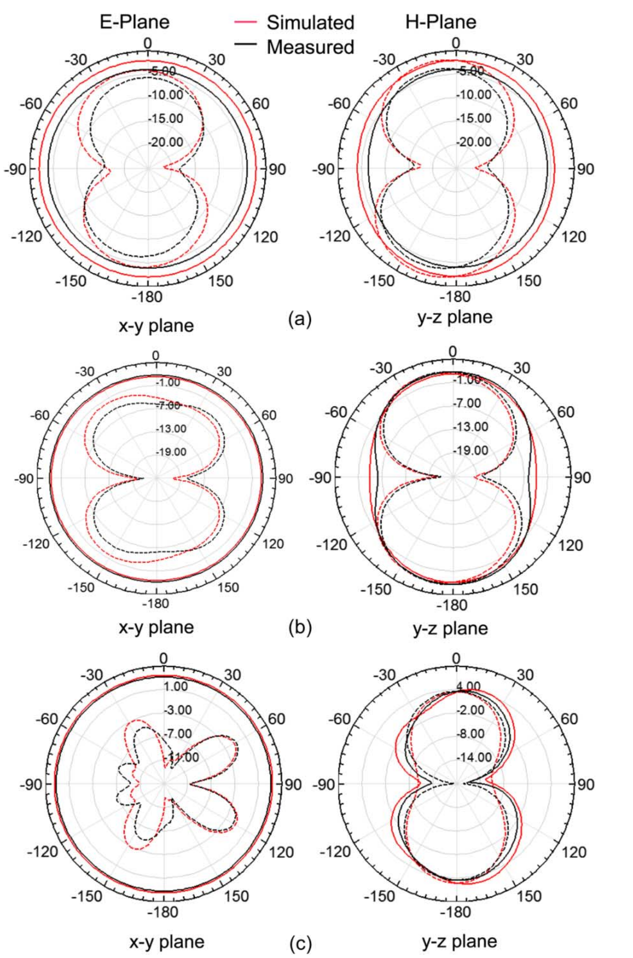

Fig. 11. Radiation pattern for various resonance frequency for the proposed compact UWB microstrip antenna with ——— copolar and - - - cross-polar (a) 3.03, (b) 6.11, and (c) 11.78 GHz.

simulated results is due to the effect of SMA connector soldering and fabrication tolerance. The designed antenna has an ultrawideband performance of 2.6–13.04 GHz.

Group delay is an important parameter in the design of the UWB antenna since it gives the distortion of the transmitted pulses in the UWB communication. For a good pulse transmission, group delay should be almost constant in the UWB band. The simulated group delay of the proposed antenna is shown in Fig. 10. As it can be seen, the variation of the group delay for the proposed antenna is almost constant (remains nearly 1 ns) for the entire UWB band. This confirms that the proposed UWB antenna is suitable for UWB communication. Fig. 11(a)–(c) shows the measured and simulated 2-D far-field radiation patterns in the H- and E-planes at sampling frequencies of 3.03, 6.11, and 11.78 GHz resonance frequencies, respectively. It is found that the antenna has nearly good omnidirectional radiation patterns at all frequencies in the E-plane (xy-plane) and the H-plane (yz-plane). This pattern is suitable for application in most wireless communication equipment, as expected. The antenna exhibits directional orientation in H-plane at 11.78 GHz. It is also observed that simulated results shows a good agreement with measured results.

IV. Conclusion

A novel CPW-fed compact UWB microstrip antenna is proposed. The measured results of the fabricated antenna show stable radiation patterns over the whole of the UWB band as well as the extra bands. Also, almost constant group delay is achieved. The good impedance-matching characteristic, constant gain, and omnidirectional radiation patterns over the entire operating bandwidth of 2.6–13.04 GHz (10.44 GHz) make this antenna a good candidate for UWB applications and systems.

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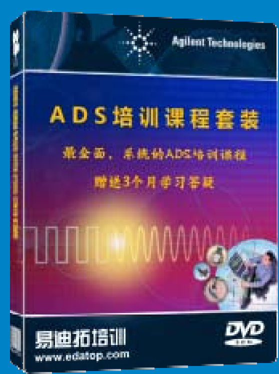

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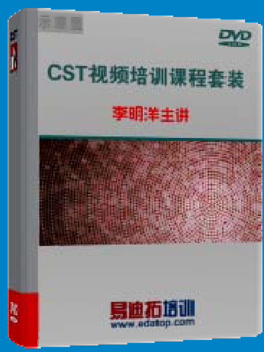

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