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Research Article

Elevated CPW-Fed Slotted Microstrip Antenna for Ultra-Wideband Application

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Elevated-coplanar-waveguide- (ECPW-) fed microstrip antenna with inverted "G" slots in the back conductor is presented. It is modeled and analyzed for the application of multiple frequency bands. The changes in radiation and the transmission characteristics are investigated by the introduction of the slots in two different positions at the ground plane (back conductor). The proposed antenna without slots exhibits a stop band from 2.55 GHz to 4.25 GHz while introducing two slots on the back conductor, two adjacent poles appear at central frequencies of 3.0 GHz and 3.9 GHz, respectively, and the antenna shows the ultra-wideband (UWB) characteristics. The first pole appears at the central frequency of 3.0 GHz and covers the band width of 950 MHz, and the second pole exists at a central frequency of 3.90 GHz covering a bandwidth of 750 MHz. Experimental result shows that impedance bandwidth of 129% ($S_{11} < -10$ dB) is well achieved when the antenna is excited with both slots. Compared to most of the previously reported ECPW structures, the impedance bandwidth of this antenna is increased and also the size of the antenna becomes smaller and more suitable for many wireless applications like PCS (1850–1990 MHz), WLAN (2.4–2.484 GHz), WiMAX (2.5–2.69 GHz and 5.15–5.85 GHz), and also X-band communication.

1. Introduction

Recently, a considerable amount of researches have been devoted to the development of UWB antenna for its enabling high data transmission rates, low power consumption, and simple hardware configuration in wireless applications like radio frequency identification devices, sensor networks, radar, location tracking system, and so forth. The UWB antennas of such systems are also required for small size, nondispersive [1], and wideband properties. Its commercial applications of the frequency band from 3.1 GHz to 10.6 GHz were approved by the Federal Communications Commission (FCC) in America in 2002 [2, 3]. As a result, many new UWB antennas [4–12] have been proposed; among them, the printed monopole antennas [13–18] have received much attention due to their wideband characteristic, omnidirectional radiation patterns, high radiation efficiency, and compact size. Recent technological advances and the size reduction of electronic circuits have changed the wireless communications and sensor network design specifications. In particular, they have exposed the need for electrically small antennas that are efficient and have significant bandwidths. The standard electrically small antenna designs are known to be inefficient due to the large reactance and small resistance, which leads to the poor match to a given source. However, to compensate the impedance mismatch and additional bandwidth the researchers have already been introduced the concept of defected ground structure (DGS), defected microstrip structure (DMS), and so forth.

The research in the area of design of compact broadband antenna design for the application of WLAN compatible devices is growing exponentially. For these modern communication applications, size reduction of microstrip patch antenna with wide bandwidth and multiband operation

Table 1: Geometrical parameters of Figure 2.

Parameters	L_0	L	L_1	L_2	L_3	L_5	W_0	W	W_1	W_2	W_3	W_4	g
mm	8	85	65	28	4	10	16	30	10	12	5	15	1

Table 2: Geometrical parameters of Figure 3.

Parameters	W_3	W_4	W_5	W_7	L_6	L_7	L_8	d_1	$d_2 = W_1$	d_3	d_4
mm	5	15	0.75	3	4	3	1.5	7	10	5	7

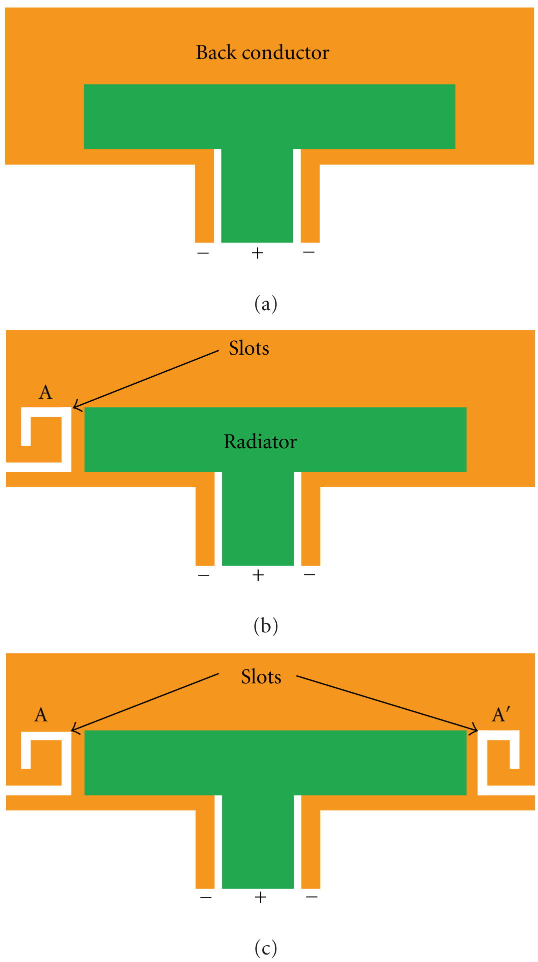

Figure 1: Geometry of the proposed antenna with (a) no slot, (b) slot (A), and (c) slot (A′).

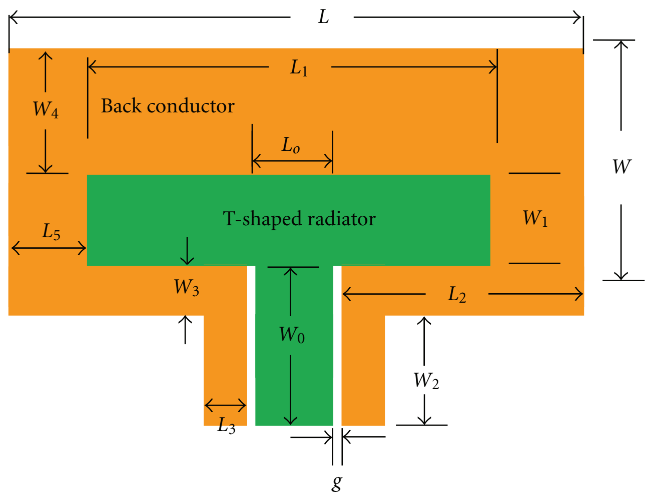

Figure 2: Geometry of the proposed antenna without slots at the ground plane.

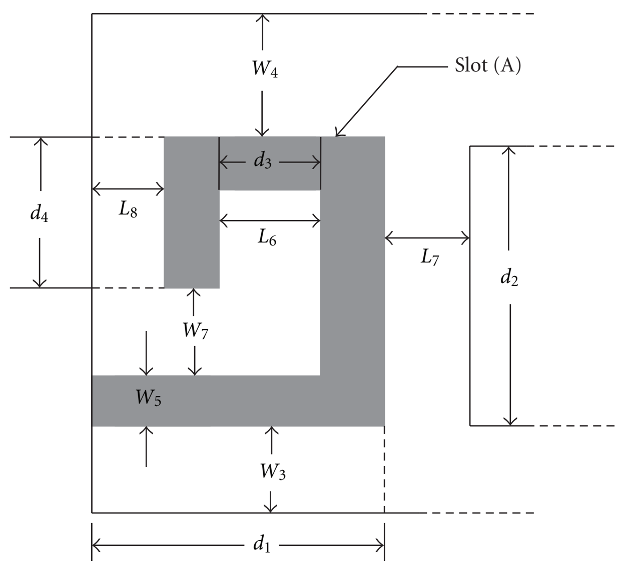

Figure 3: Schematic diagram of inverted "G" slot (A).

are becoming important design considerations for practical applications. Many authors have presented antenna that designs suitable for WLAN operations are in the 2.4 GHz band (2.4–2.484 GHz) and 5.2/5.8 GHz bands (5.15–5.35 GHz/5.725–5.825 GHz) [19–22]. Because of the increased demand in wireless communication system, microstrip patch antennas have attracted much interest due to their various attractive feathers. Microstrip antennas with ECPW exhibit attractive performances including significantly wider impedance bandwidth that is not achieved by conventional microstrip configuration.

In this paper, a simple and compact ECPW-fed microstrip antenna for UWB application is proposed. Few papers have been published in this area [23–31] based on ECPW, but all have insufficient bandwidth or design complicacy. In this design, the proposed antenna offers a bandwidth of 8.74 GHz (1.85 GHz to 10.54 GHz) covering

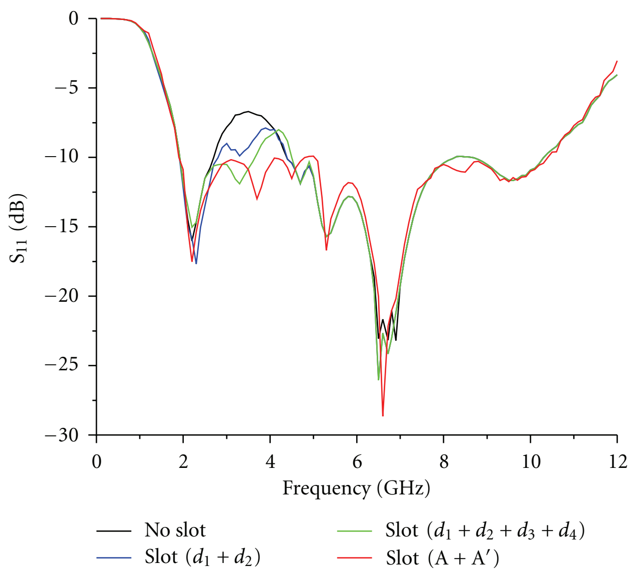

Figure 4: Simulated results of the proposed antenna with and without slots.

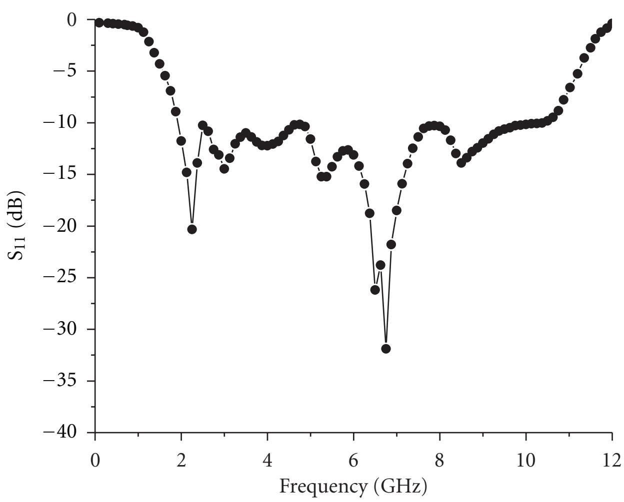

Figure 5: Simulated result of S_{11} with slots (A + A′).

FCC regulated band and also PCS (1.85–1.99 GHz) band. The antenna is slotted at the edges of the back conductor (shown in Figure 1) and the effects are studied. This antenna structure has been constructed with less number of design parameters compared with the existing UWB antennas in the literature. The bandwidth, gain, directivity, and other antenna parameters are at acceptable level. IE3D method of moment-based simulation software is used for the analysis. The antenna presented can be easily fabricated and integrated in portable devices. The measured frequency bandwidth with VSWR below 2 of the antenna covers 1.85 GHz–10.54 GHz, which satisfies the UWB system requirement.

The UWB characteristic is achieved by introducing two inverted G-shaped slots on the back conductor as shown in Figure 1. The addition of the slots produces two adjacent

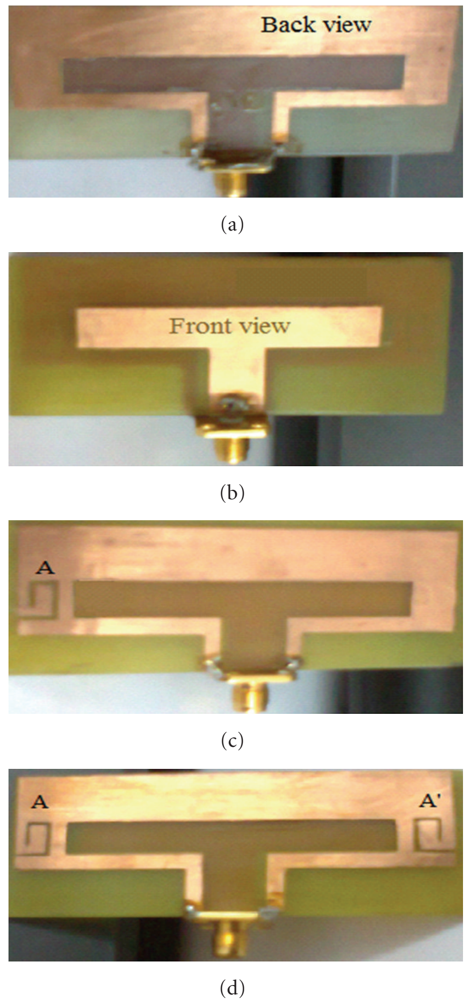

Figure 6: Photograph of the proposed antenna. (a) Back view without slot, (b) front view, (c) back view with slot (A), (d) back view with slot (A) and (A′).

poles that remove the notch band covering the frequency band ranges from 2.5 GHz to 4.3 GHz.

2. Antenna Design

In this section, the antenna covering the UWB band is first described. Then the new pass band from 2.5 GHz to 4.3 GHz has been investigated by introducing properly designed two inverted G-slots. The effects of changing the geometric parameters of the proposed antenna on impedance matching and bandwidth are discussed. The UWB antenna design features the gap (g) in both the feed line of the radiator between the radiator and the back conductor which introduces a coupling capacitance and plays an important role in obtaining UWB behavior. Compact UWB antenna and the feeding technique [32, 33] are the motivations of this study. The design of the proposed antenna and its experimental results are presented and discussed. Figure 2 shows the geometrical structure without slots and the corresponding dimensions of the proposed antenna are shown in the

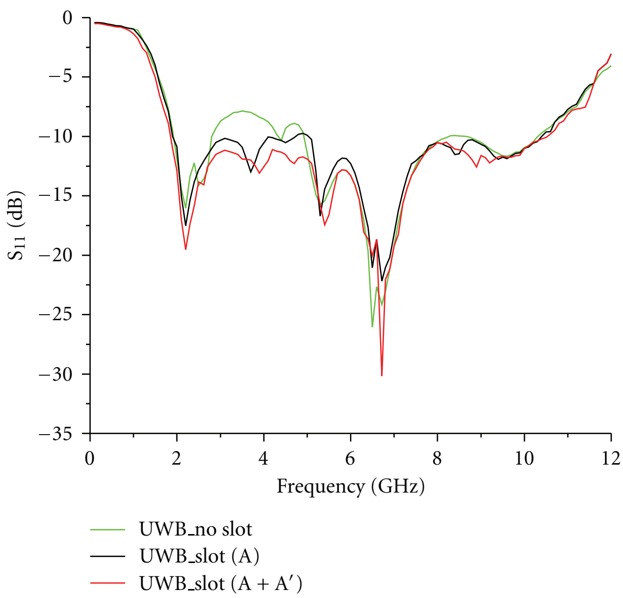

FIGURE 7: Measured results of S_{11} of the proposed antenna.

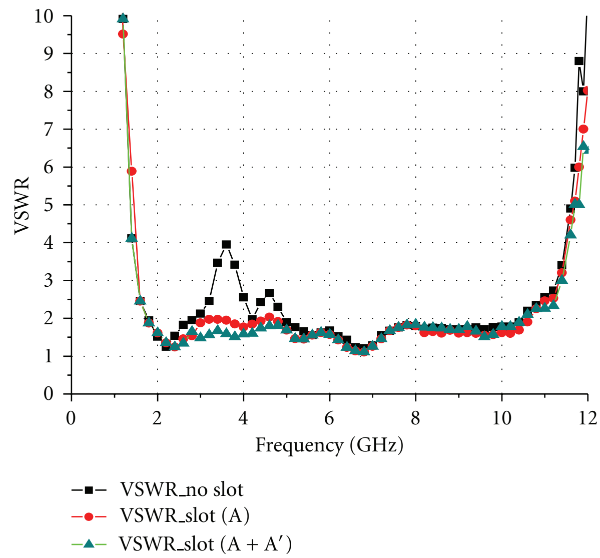

FIGURE 8: Measured results of the variation of VSWR of the proposed antenna.

Table 1. The antenna is fed by a 50Ω SMA which is connected to the vertical arm of the T-shaped radiator surrounded by back conductor and guided by two identical gaps (g) of 1.0 mm width. The antenna is printed on FR4 substrate with the dielectric constant of $\varepsilon r = 4.4$, loss tangent of $\delta = .001$, and the substrate thickness of $h = 1.587$ mm. The slot geometry of the antenna is shown in Figure 3 and its detail dimensions are shown in the Table 2.

The second slot (A′) is identical to the first one in terms of dimension, and it is placed just to the opposite edge of the back conductor with the similar geometrical position (not shown in the Figure). The introduction of one inverted "G-" shaped slot could not cover the whole FCC-defined UWB

FIGURE 9: Gain versus frequency of the proposed antenna with both slots (A) and (A′).

frequency band. The addition of second slot (A′) covers the entire UWB range and it also covers an additional band like PCS (1850–1990 MHz). In fact, the parameters of the tuning arms of slots play an important role for achieving the broadband operation of the proposed antenna. By carefully adjusting the width W5 and length parameters of the slots (A and A′), the resonance frequency, the lower cutoff, and the higher cut-off frequencies are adjusted. A study of S_{11} versus frequency has been performed by introducing arms (d_1, d_2, d_3, and d_4) of the slot (A) one by one and the effect is studied.

3. Simulated Results

To understand the effects of geometric parameters on the frequency responses of the proposed antenna, this study conducts parametric analysis using a MoM-based electromagnetic simulator. This study investigates the effect of dimensions on the antenna characteristics. The important parameters that have optimized in this design are d_1, d_2, d_3, d_4, W_3, L_3, W_5, W_7, L_6, L_7, L_8, and g. Figure 4 shows the effects of varying the arms of the slot (A) and slot (A′) on S_{11} parameter.

The simulated result of S_{11} versus frequency of the proposed antenna by introducing the slots (A) and (A′) are shown separately in Figure 5. From VSWR curve, it is observed that VSWR $\leq$ 2 for entire UWB range of frequencies when both slots are introduced. The gain versus frequency of the proposed antenna is shown in Figure 7.

From Figure 5, it is observed that the combination of the feed line, the T-shaped radiator, and the slots at the back conductor leads to achieve a large BW. In the antenna structure presented in Figure 1, during several tests and simulations, it was observed that the BW, RL, and the radiation performances of the antenna are principally interrelated to the design of the slots, back conductor, and the shape of the radiator.

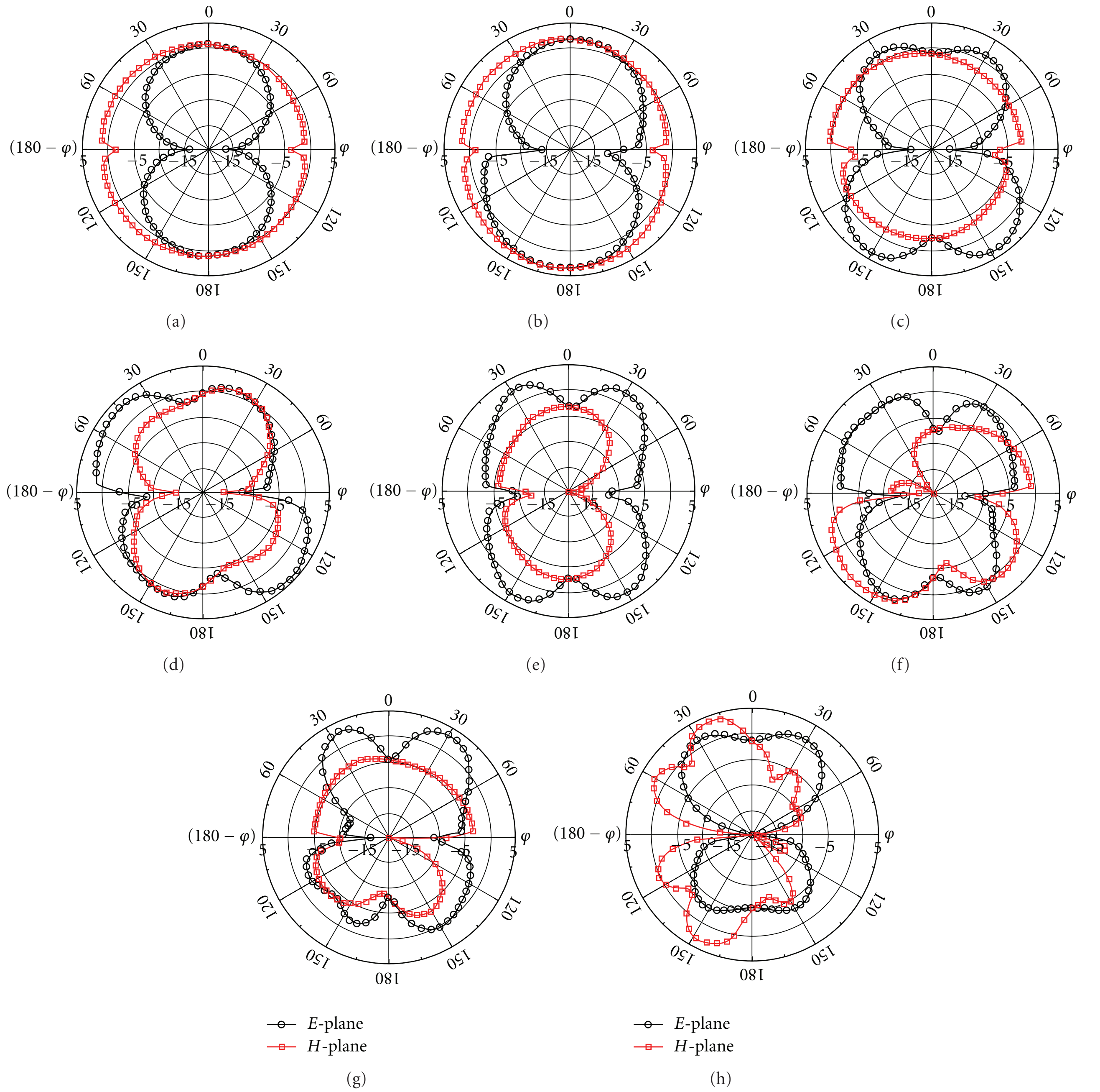

Figure 10: Simulated radiation patterns of the proposed antenna—(a) $f = 1.95$ GHz, (b) $f = 2.5$ GHz, (c) $f = 3.8$ GHz, (d) $f = 5.0$ GHz, (e) $f = 6.5$ GHz, (f) $f = 8.0$ GHz, (g) $f = 9.8$ GHz, and (h) $f = 10.4$ GHz.

4. Antenna Fabrication and Measurement

The antenna has been fabricated by the following process and the fabricated antenna is shown in Figures 6(a)–6(d).

4.1. Fabrication Process. For the fabrication process, see Figure 13.

4.2. Return Loss and Other Characteristics. The measured return loss as shown in Figure 7 is −31 dB at 6.45 GHz and from RL curve, the bandwidth obtained for RL ≤ −10 dB is 8.74 GHz. The results obtained from the measurement has a VSWR (Figure 8) lower than 2 ($S_{11} \leq -10$ dB) for the entire frequency range from 1.85 GHz to 10.54 GHz, and the maximum impedance bandwidth of 129% is obtained centered at 6.45 GHz. A good agreement is observed between the measured and simulated data.

One can observe a small difference between measured and simulated data at different frequencies. This might be due to other unknown parasitic effects which are not

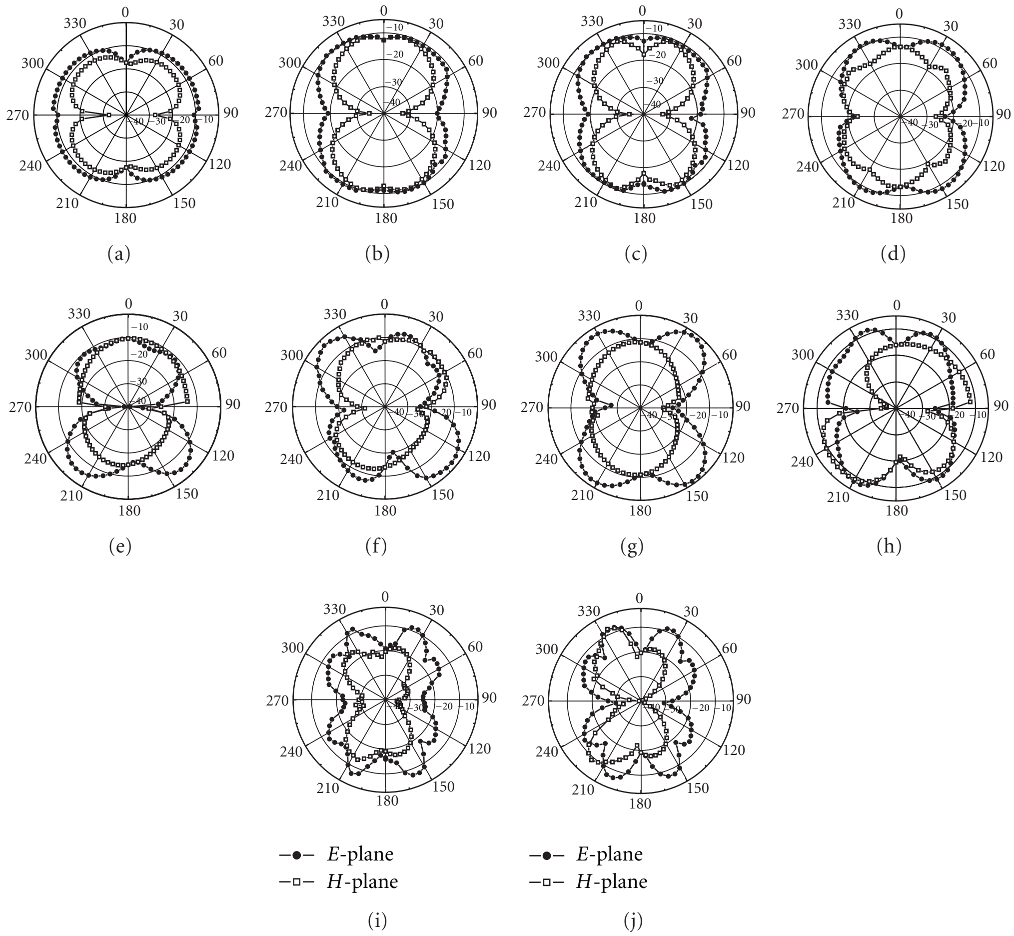

FIGURE 11: Measured radiation patterns of the proposed antenna—(a) $f = 1.95$ GHz, (b) $f = 2.4$ GHz, (c) $f = 3.5$ GHz, (d) $f = 4.5$ GHz, (e) $f = 5.5$ GHz, (f) $f = 6.5$ GHz, (g) $f = 7.5$ GHz, (h) $f = 8.8$ GHz, (i) $f = 9.5$ GHz, and (j) $f = 10.4$ GHz.

considered in the simulation. Since the soldering is not done with a machine on the PCB, positional errors might give rise to the discrepancy.

Measurements of antenna gain for UWB band across frequencies from 1 GHz to 11.4 GHz are investigated. The measured peak gain in the *y-z* (*E*-plane) plane across the frequency bands of interest is shown in Figure 9. A small difference between measured and simulated data of curve at different frequencies is observed. This difference may be due to the error occurred as a result of fabrication.

4.3. Radiation Pattern. The microstrip patch antenna radiates normally to its patch surface. So the elevation pattern gain for $\varphi = 0$ and $\varphi = 90$ degrees is important for the measurement. Figures 10 and 11 show the simulated and measured *E*-plane and *H*-plane patterns at different frequencies. The maximum gain is obtained in broadside direction and the peak gain at design frequencies varies from 0.8 dBi to 3.9 dBi.

From measured and simulated radiation pattern (shown in Figures 10 and 11), it is observed that the ripples become more prominent at higher frequencies since the antenna operates in higher order modes instead of the typical monopole mode.

The simulated results of current distribution (front and back view) on the patch surface with and without slots are illustrated stepwise in Figure 12.

5. Conclusion

A new approach of slotted antenna fed by a 50Ω ECPW for UWB applications was presented. Wide bandwidth of 129% was achieved by using inverted G'-shaped tuning slots placed at the back conductor. The proposed slotted ECPW microstrip antenna is electrically small and suitable to be handled easily. From the results, it is observed that the maximum gain obtained in the broadside direction. The measured value of RL and VSWR fairly tallied with the simulated results. In this work, the B.W of 8.74 GHz has been achieved by the proposed antenna structure. The impedance bandwidth of VSWR lower than 2 ($S_{11} \leq -10$ dB) for the entire UWB range (3.1 GHz to 10.6 GHz) has been achieved with simple ECPW antenna structure. A prototype antenna has been designed, simulated, optimized, and measured for

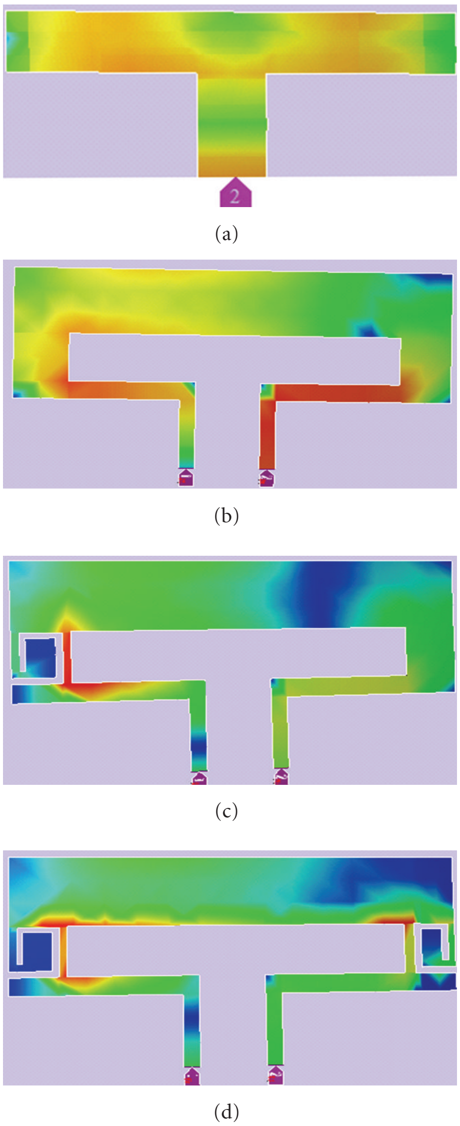

FIGURE 12: Current distribution. (a) Front view and back, (b) without slot, (c) with slot A, (d) with slot (A and A′).

UWB operation. The novel antenna promotes impedance bandwidth and radiation which offers good radiation pattern and has a favorable field gain across the matching band as a desirable feature for UWB applications. The proposed antenna has a simple and effective feeding structure which is suitable for use in UWB applications. The fabrication process is simple and has a low cost. The antennas have demonstrated good performance in terms of VSWR, input impedance, current distribution, radiation pattern, gain, and efficiency.

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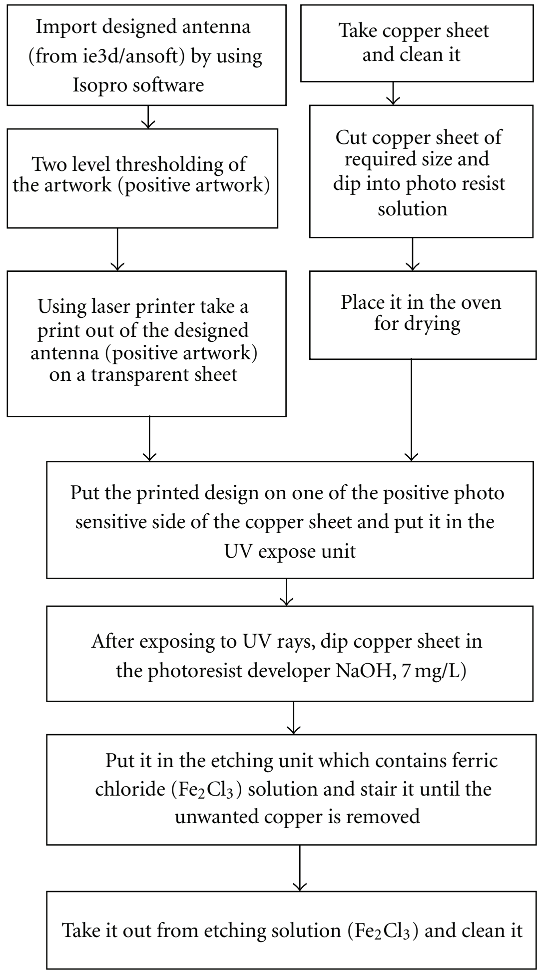

FIGURE 13

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