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Research Article

Printed UWB Antenna with Coupled Slotted Element for Notch-Frequency Function

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A novel printed monopole antenna employing a slotted-plate, which is electromagnetically coupled to the microstrip-fed planar element, is proposed to provide notch-frequency function. This technique enables stopband characteristics with improved control, compared to placing the slot in the microstrip-fed element. A detailed investigation of the rejectband properties has been made for the UWB antenna. Measured data for the optimized case show the 10 dB return loss bandwidth to be 9.8 GHz (from 2.80 GHz to 12.60 GHz) with a notchband frequency from 5.15 GHz to 5.825 GHz. Propagation measurements indicate that the electromagnetically coupled slot provides a greater reduction in stopband gain for the three principal planes, compared to placing the slot in the fed element. This is desirable to mitigate interference from WLAN systems. A full parametric study of the antenna is presented.

1. INTRODUCTION

Ultrawideband (UWB) antennas have commanded increased interest in the last 4 years, due to the rapid development of wideband wireless communication systems. The planar monopole antenna is one of the candidate antennas proposed, due to low-cost, broad bandwidth, and attractive profile. These antennas have been reported with many various shaped planar elements, such as rectangular, disc, elliptical and triangular geometries [1–6]. Most UWB systems currently operate as Mode 1 devices, with an allocated spectrum from 3.1 GHz to 4.8 GHz. However, as demand increases, and the limitations in silicon technology are surpassed, the higher bands will become more populated. For these UWB systems, it may be necessary to provide rejection of interference from 802.11a WLAN or Unlicensed-National Information Infrastructure (U-NII), in the band from 5.15 GHz to 5.825 GHz. Thus, the provision of a narrow rejectband in the UWB allocated spectrum is desirable. Printed antennas with notch function have recently been reported [7–9], where various shaped narrow slots are embedded into the planar radiator to obtain the notch-frequency function. In [7–9], either U or H-shaped slots are embedded in the radiator element to obtain notchband frequencies. A different approach is to use parasitic elements which are coupled to the planar radiating element to provide the notch function [10]. An alternative method to provide the notch function is using a novel coplanar waveguide resonant cell in the CPW feedline as a narrow stopband filter [11]. In this technique, control of the notch bandwidth is more difficult due to the small dimensions involved. The proposed antenna differs from [7–9] because the H-slot is coupled to the planar radiator and is easier to tune. In comparison with [10], the proposed antenna provides better stopband rejection. Employing the filter into the antenna geometry can provide some stopband suppression with the advantages of low cost and zero passband insertion loss. This can be used alone or to complement additional filter circuitry where required.

In this paper, the notching function is provided by adding an extra slotted plate which is electromagnetically coupled to the microstrip-fed planar element, yielding greater stopband rejection. It is printed on the rear side of the substrate and provides the notch-reject function. The parameters of the slot and the coupled-plate are analysed in terms of the notch-frequency and bandwidth. A compact optimized UWB antenna with notch-frequency function was then fabricated

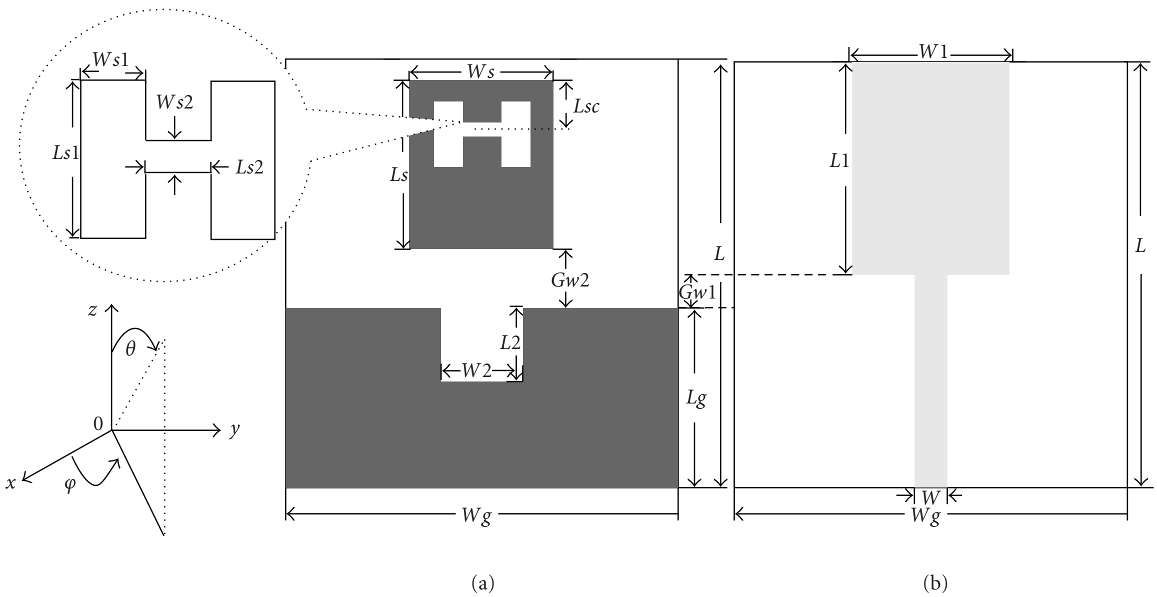


Figure 1: Geometry of the printed rectangular monopole antenna showing coupled element and coordinate system: (a) rear side showing groundplane and coupled element with H-slot, (b) front side showing microstrip-fed planar monopole.

and examined both experimentally and numerically. The measured results show that the proposed UWB antenna can achieve good impedance bandwidth characteristics, with improved control of bandnotch function.

2. NUMERICAL RESULTS FOR THE PRINTED MONOPOLE ANTENNA WITH SLOTTED-PLATE COUPLED TO RADIATOR-PLATE

The geometry and coordinate system for the proposed printed monopole antenna fed by a 50 ohm microstrip line is shown in Figure 1. It is printed on a Taconic RF35 substrate with a thickness of 1.52 mm, relative permittivity of 3.5, and a loss tangent of 0.0018. The width of microstrip feed line is fixed at 3.5 mm to achieve a 50 ohm impedance. A rectangular plate with a length $L1$ and width $W1$ is connected to the 50 ohm microstrip line. The substrate is of length L and width Wg. The ground plane has dimensions Lg and Wg. A section of groundplane of width $W2$ and length $L2$ is removed in order to improve the matching and also slightly reduces the lower-edge frequency [12]. The radiator plate is separated from the groundplane by a distance $Gw1$. The simulation was carried out using the Finite-Integration Time-Domain technique (CST MWS). The optimized printed monopole antenna dimensions are as follows: $L = 28$ mm, $Wg = 30$ mm, $L1 = 16.5$ mm, $W1 = 12$ mm, $L2 = 4$ mm, $W2 = 3$ mm, $Gw1 = 1.5$ mm, $Lg = 10$ mm.

To realise the proposed UWB antenna with the narrow rejectnotch band, a rectangular element is placed on the rear of the substrate and couples to the microstrip-fed plate. The H-shaped slot is removed from this rear plate as shown in Figure 1(a). The centre-frequency and width of rejected-frequency band are mainly determined by the size of H-shaped slot, its location in the coupled-plate, and the distance $Gw2$ between the coupled-plate and groundplane edge. The effects of various parameters of the H-shaped slot are discussed below. In this case, the rear plate size is selected at $Ls = 12$ mm and $Ws = 12$ mm, and an appropriate H-slot is removed from this plate to achieve the required function.

3. TUNING OF NOTCH FREQUENCY

A parametric study was made, and a set of design rules to tune the notch centre-frequency and control the notch bandwidth is presented.

3.1. *The effect of the separation between coupled-plate and groundplane Gw2*

The separation distance $Gw2$ between the coupled-plate and the groundplane was varied, and results show heavy dependence of the notch bandwidth on this parameter as shown in Figure 2. The dimensions of the H-shaped slot were $Ls1 = 4$ mm, $Ws1 = 1.4$ mm, $Ls2 = 3$ mm, $Ws2 = 0.6$ mm, and $Lsc = 3$ mm. It can be seen that as the separation $Gw2$ increases, the rejected-frequency band becomes much narrower. However, the improvement diminishes after a point and for this antenna requirement. In order to increase the bandwidth of the notch, the separation distance $Gw2$ should be reduced.

3.2. *The effect of the distance of slot from the plate edge*

The distance Lsc was varied from 3 mm to 9 mm for H-slot dimensions of $Ls1 = 4$ mm, $Ws1 = 1.4$ mm, $Ls2 = 3$ mm, $Ws2 = 0.6$ mm, and $Gw2 = 3$ mm. The simulated results show that only a small (0.5%) shift in notch frequency took place with no other significant changes.

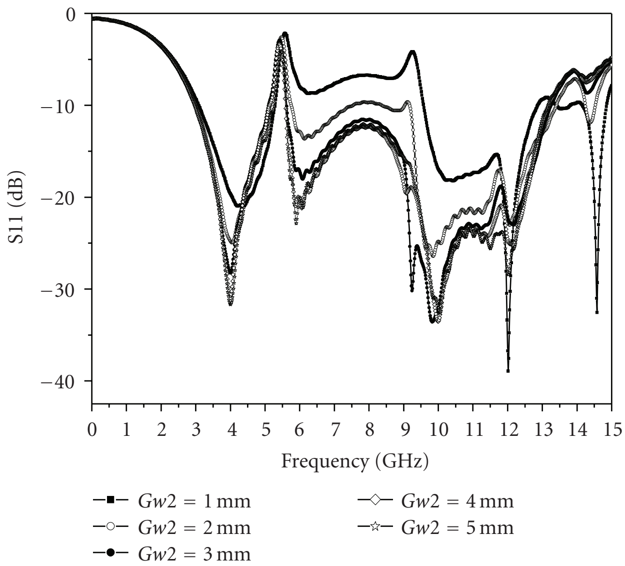


Figure 2: The simulated S11 for different values of *Gw*2.

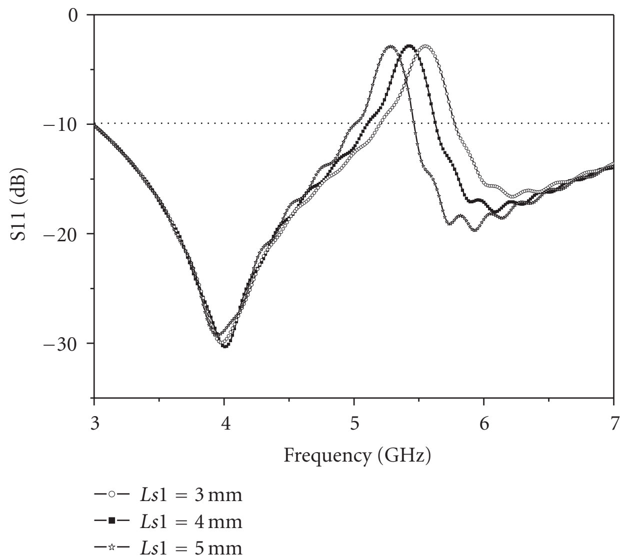


Figure 4: Simulated S11 showing notch dependence on *Ls*1.

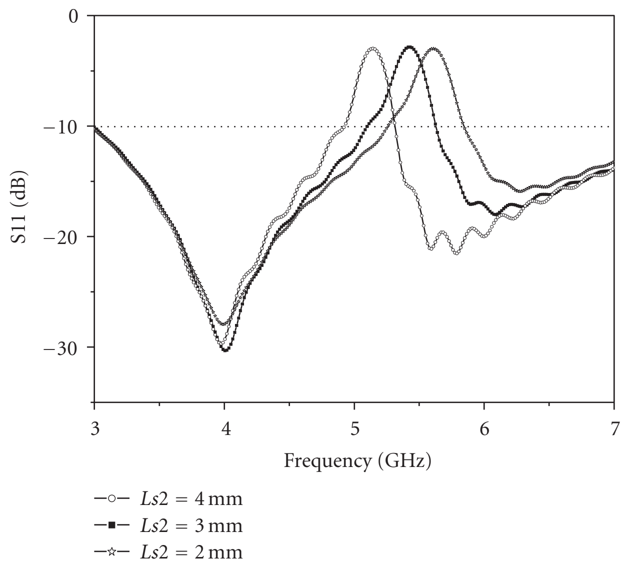


Figure 3: Simulated S11 showing notch dependence on *Ls*2.

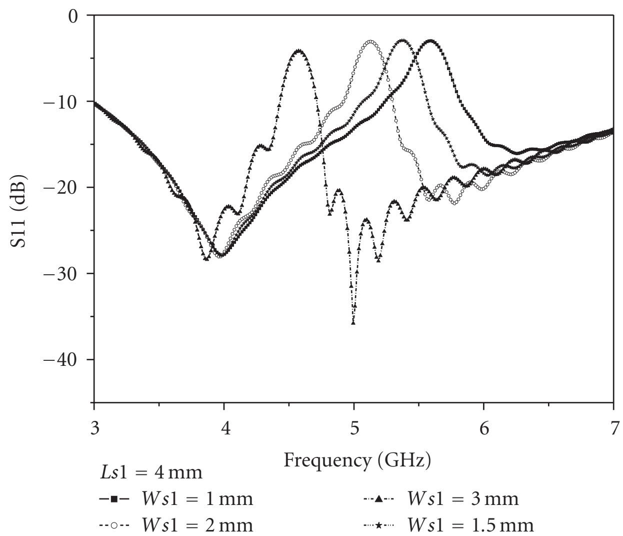


Figure 5: Simulated S11 showing notch dependence on *Ws*1.

3.3. The effect of slot dimensions Ws2 and Ls2

The slot dimensions *Ws*2 and *Ls*2, were varied, for *Ls*1 = 4 mm, *Ws*1 = 1.5 mm, *Gw*2 = 3 mm, *L*sc = 3 mm, and *Ls2* = 3 mm. It was observed that the bandwidth and notch-frequency show no dependence on *Ws*2, but that as *Ls*2 increases, the centre-frequency is reduced the reject bandwidth remaining constant.

Figure 3 illustrates the return loss for variation of the dimension *Ls*2 (*Ws*2 = 0.6 mm).

3.4. The effect of the slot length and width

The return loss curves in Figure 4 illustrate that the slot length *Ls*1 has a smaller effect on notch frequency than the parameter *Ls*2, (*Ws1* = 1.5 mm), and Figure 5 shows that the centre-frequency of the stopband shifts down as the slot width *Ws*1 increases. Here, *Ls*2 = 3 mm, *Ws*2 = 0.6 mm,

Table 1: The effects of H-slot parametric variation on stopband centre-frequency and bandwidth.

Parameters	Stopband centre-frequency	Stopband bandwidth
Ls1	Light dependence	Constant
Ls2	Light dependence	Constant
Ws1	Heavy dependence	Constant
Ws2	No dependence	Constant
*L*sc	Light dependence	Light dependence
Gw2	Light dependence	Heavy dependence

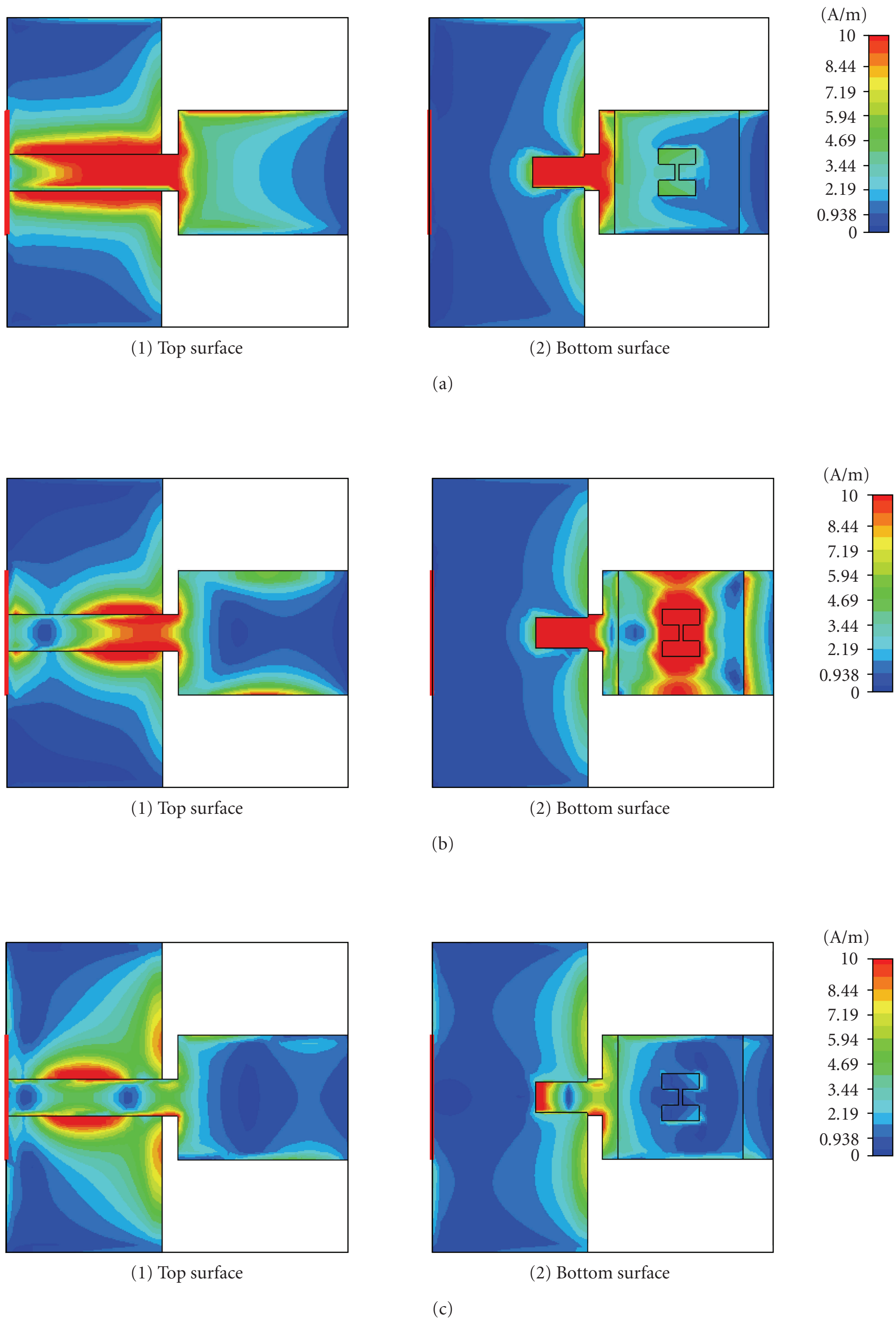
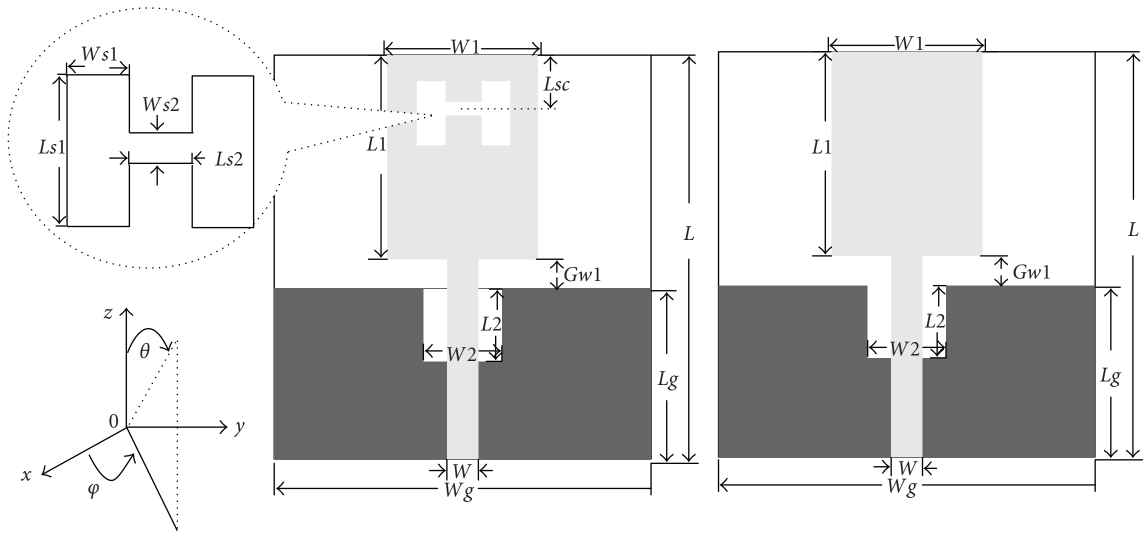


Figure 6: (a) The distribution of surface current at 3 GHz, (b) the distribution of surface current at 5.55 GHz, (c) the distribution of surface current at 8 GHz.

*Gw*2 = 3 mm, and *L*sc = 3 mm. The notch frequency is heavily dependent on this parameter. The effects of H-slot parametric variation on the reject centre-frequency and bandwidth are displayed in Table 1.

The distributions of surface current are simulated by using CST microwave studio software, as shown in Figures 6(a), 6(b), and 6(c). It is noted that surface current distributions on the edges of the rectangular plate and groundplane



(a) (b)

Figure 7: (a) Simple rectangular UWB monopole geometry, (b) rectangular monopole with H-slot in microstrip-fed element.

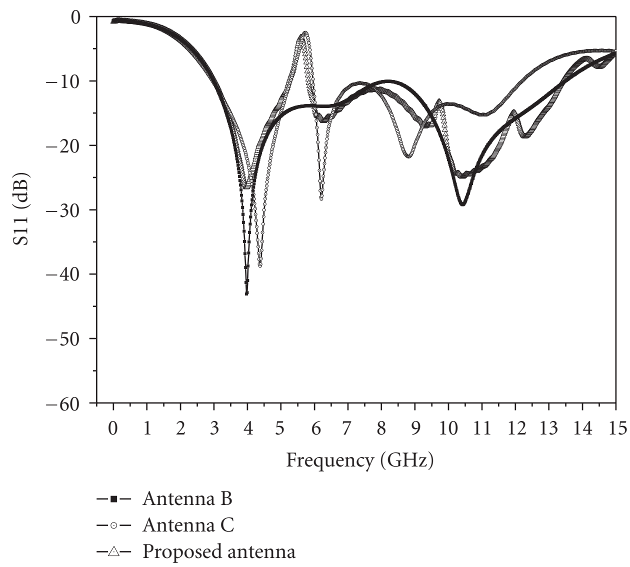


Figure 8: Comparison of simulated S11 for the three planar UWB antennas.

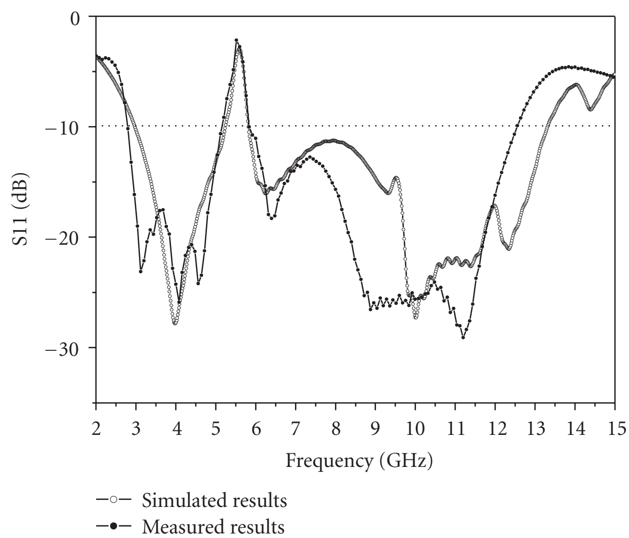


Figure 9: Comparison of the measured and simulated S11 for the proposed antenna.

are very strong. It was also observed that the surface current distributions at the edges of the H-slot are very strong at the notchband frequency of 5.55 GHz, but weak at other frequencies. This is because the H-slot shape is highly resonant at the notch frequency.

4. COMPARISON OF PROPOSED ANTENNA PERFORMANCE WITH OTHER RECTANGULAR PLANAR UWB ANTENNAS

The proposed antenna with coupled slotted plate (Figure 1, antenna A) is now compared to two other antennas, one with a simple microstrip-fed rectangular monopole (antenna B, without notch function) and the other with the slots in the microstrip-fed element (antenna C) as shown in Figures 7(a) and 7(b), respectively. The basic parameters were kept the same for all 3 antennas as follows: $L = 33$ mm, $Wg = 30$ mm, $L1 = 16.5$ mm, $W1 = 12$ mm, $L2 = 4$ mm, $W2 = 3$ mm, $Gw1 = 1.5$ mm, and $Lg = 15$ mm. The same substrate was used; Taconic RF35 with relative permittivity of 3.5 and thickness of 1.52 mm. For the antenna with the H-shape slot in the microstrip-fed element (Figure 7(b), antenna C), the other optimized dimensions are $L\mathrm{sc} = 2.25$ mm, $Ls1 = 4$ mm, $Ws1 = 2.5$ mm, $Ls = 4$ mm, and $Ws = 0.3$ mm. For the antenna with

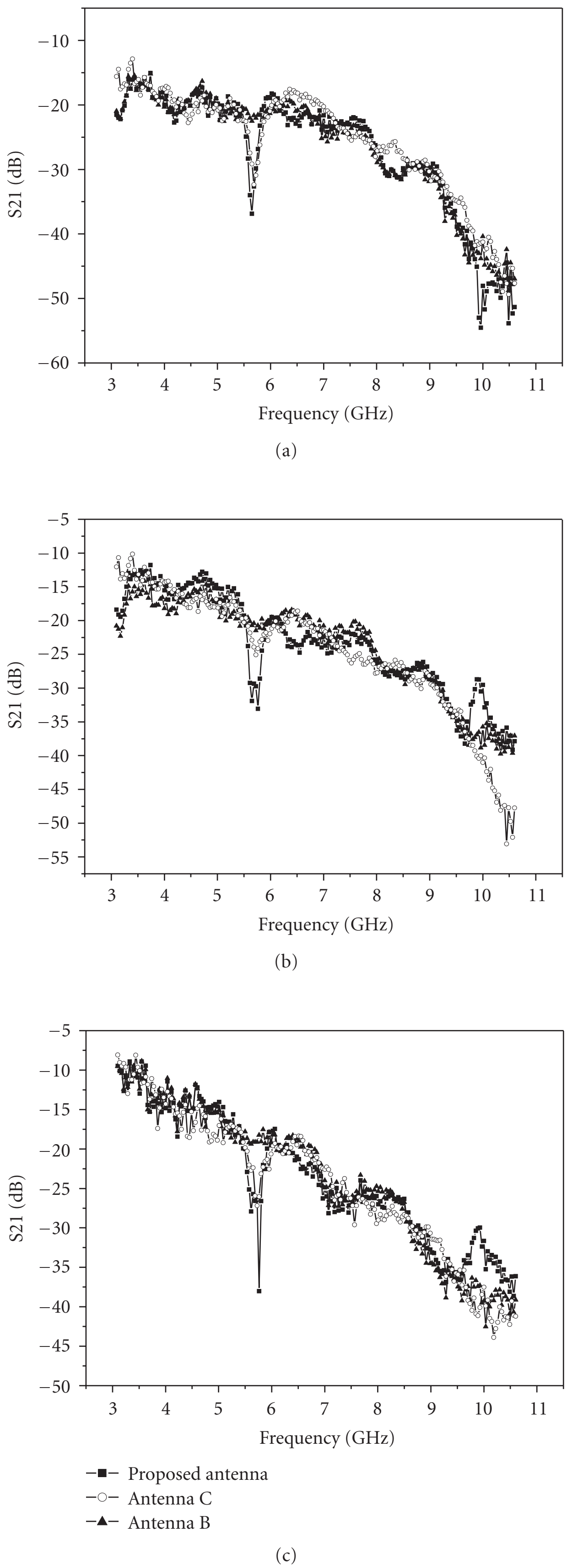


Figure 10: The measured S21 for the three antennas in the x, y, and z directions.

the coupled slotted plate (Figure 1, antenna A), the H-shape parameters are selected in $Ws = 12$ mm, $Ls = 12$ mm, $Gw2 = 3$ mm, $Lsc = 3$ mm, $Ls1 = 4$ mm, $Ws1 = 1$ mm, $Ls2 = 3$ mm, and $Ws2 = 0.6$ mm. The substrate had a width of 30 mm and length of 28 mm in each case. The simulated results of S11 for three antennas are shown in Figure 8. It is seen that both antenna A and antenna C show a notchband between 5.15 GHz and 5.825 GHz in the response.

Compared to the rectangular UWB, printed antenna with the H-shaped slot in the microstrip-fed element shown as Figure 7(b) (antenna C), this new proposed UWB antenna is much more convenient to tune the notch frequency and bandwidth by changing the H-slot dimensions, independent of the other antenna dimensions. This is in contrast to tuning the H-slot in the microstrip-fed planar element, which necessitates a change in the dimensions of the planar element, thus changing the overall S11 response, and requiring an iteration in the design.

Also, the proposed antenna can provide a deeper drop in notch gain.

5. MEASUREMENTS OF THE PROPOSED ANTENNA

Figure 9 presents the simulated and measured return losses for the proposed antenna, which are in good agreement. The measured 10 dB return loss impedance bandwidth is about 9.8 GHz from 2.80 GHz to 12.60 GHz with the narrow notch-frequency band from 5.15 GHz to 5.825 GHz.

The S21 was measured for the three antennas in the x, y, and z directions as illustrated in Figure 10. The illuminating antenna was a wideband horn antenna. It is observed that the proposed antenna has the greatest reduction in notchband gain, therefore providing better notch rejection.

The CW gain pattern is shown in Figure 11, which is determined from the directional measured transfer function. The plots in Figures 11(a) and 11(b) illustrate the measured patterns for the XoZ and XoY, planes for the UWB frequency range (from 3.1 GHz to 11 GHz), respectively. These results show the power distributions in the 3D space against frequency. The notch can be clearly seen. The measured group delay for the three UWB antennas is displayed in Figure 12, which show that the group delay is reasonably constant within about 1nanosecond except for the notchband. It shows that the antenna has low-impulse distortion and is suitable for UWB applications.

6. CONCLUSIONS

A notch-frequency band for an UWB antenna is obtained by employing a slotted coupled-plate. The effects of antenna parameters on the notch bandwidth and centre frequency are presented in detail. The measured results are in agreement with the simulated results. This parametric study is valuable in the design of wideband compact antennas with a narrow notched-band. The novel notchband UWB antenna provides easier tuning of the notch-frequency function and bandwidth with good stopband rejection. Group delay and radiation characteristics are appropriate for this application.

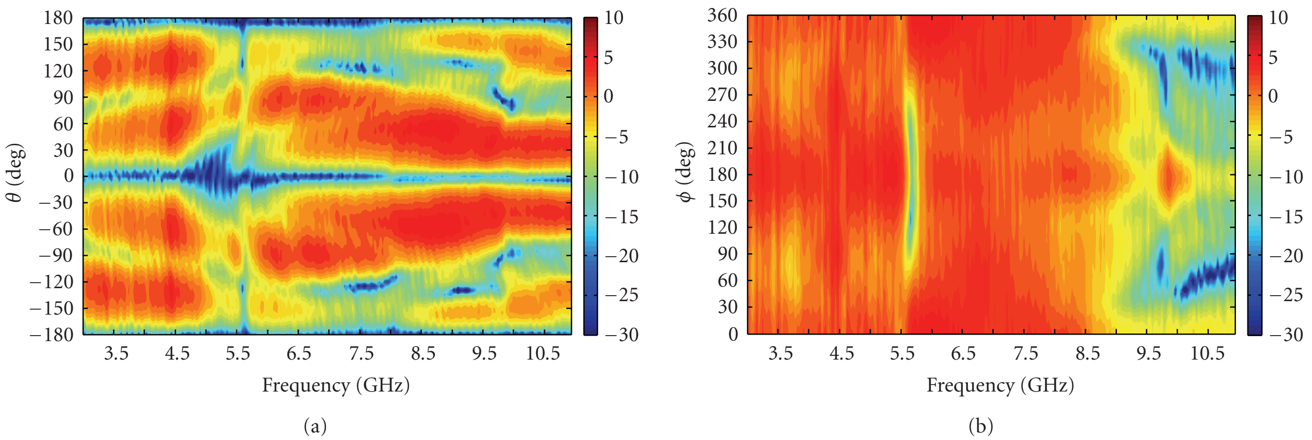


FIGURE 11: The measured copolar gain of the proposed antenna plotted against frequency for the principla planes: (a) *XoZ*, (b) *YoZ*.

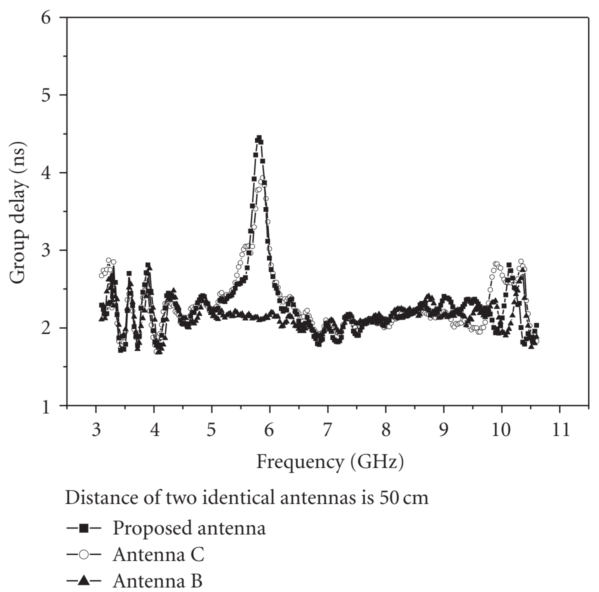


FIGURE 12: The measured group delay for the three UWB antennas.

ACKNOWLEDGMENT

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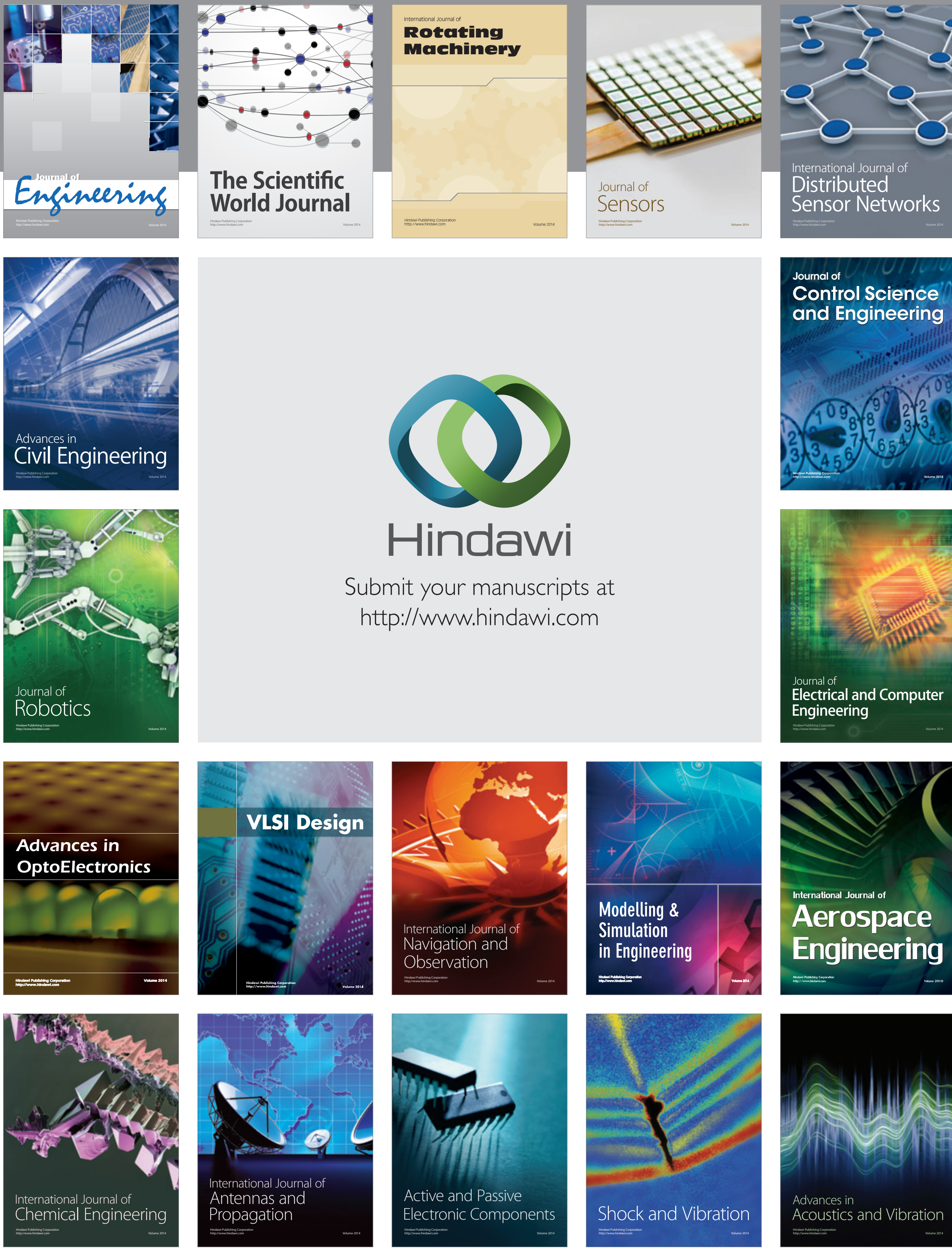
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