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A CPW FED COMPACT PLANAR MONOPOLE ANTENNA FOR UWB APPLICATIONS

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ABSTRACT

This article proposes the design of a compact beveled rectangular planar monopole antenna for Ultra wideband (UWB) applications. The radiating element is printed on a low- cost FR-4 epoxy substrate with relative permittivity of 4.4 and thickness of 1.6mm. It has overall dimensions of 18×15×1.6 mm^3. A 50-ohm coplanar waveguide (CPW) transmission line is used to excite the proposed antenna. The simulated impedance bandwidth of the proposed antenna for -10dB reflection coefficient is from 2.9GHz to more than 12GHz. Radiation efficiency better than 90% and group delay variation less than 1ns are obtained throughout the UWB. Furthermore, a stable omnidirectional radiation and a peak gain of 3.91dB are observed. A prototype of the proposed antenna is fabricated. The measured reflection coefficient of the proposed antenna covers a wide impedance bandwidth from 2GHz to over 12GHz with S11 better than -10dB.

Keywords: CPW, UWB, compact, planar monopole antenna.

1. INTRODUCTION

In recent years, due to the advancements in wireless technology, the numbers of users opting for high data rate wireless communication are increasing rapidly. A high data rate wireless communication link can be set up by increasing the channel bandwidth according to Shannon's Theorem. In 2002, a huge channel bandwidth of 7.5GHz from 3.1GHz to 10.6GHz was allocated for license-free usage by the Federal Communications Commission (FCC) [1]. Therefore, Ultra-wideband technology offers data rates in the order of 100MBps to 500MBps. The advantages of UWB technology are low-power transmission, immunity to multi-path fading and very high data rates. The low power transmission of the UWB system enables it to coexist with other wireless networking standards such as Wi-Fi/WLAN/WMAX, etc. UWB systems could be used for indoor short-range communications, radar, imaging, remote sensing, and body area network (BAN) applications. Antenna plays a vital role in the UWB system by transmitting and receiving information. Printed monopole antennas are widely used over the conventional antennas in UWB systems due to their advantages such as small footprint, lightweight, low fabrication cost; conform to any surface, and easy fabrication [2]. In the literature, different patch structures like rectangular, circular, triangular, square, flower and leaf, etc. are mentioned. Feeding techniques such as strip feed, CPW feed, aperture feed, probe feed, and proximity coupled feed are available to excite the given patch antenna. Nowadays microstrip line feed and coplanar waveguide feed are gaining a lot of attention. The benefits of using CPW feed line over microstrip line are wide bandwidth, simple planar structure, easy integration, low radiation loss, and low dispersion loss. Therefore, in this work a CPW feed line is selected to excite the proposed antenna. Some of the antenna designs implemented for UWB antenna systems are listed in [4-15].

In this paper, a beveled rectangular patch antenna excited by a CPW feed line is proposed for the UWB communication systems. Design and analysis of the proposed antenna are performed in HFSS software [16]. The remaining of the paper is organized as follows. In the section II, the proposed antenna design is described. Section III explains the simulated and experimental results and discussions. Finally, Section IV concludes the paper.

2. PROPOSED UWB ANTENNA GEOMETRY

The proposed UWB antenna configuration is illustrated in Figure-1.

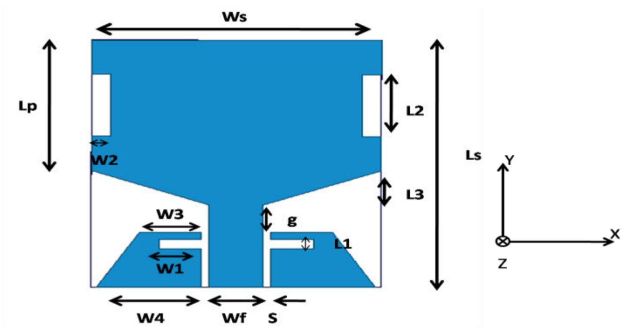

Figure-1. Proposed UWB antenna geometry.

The UWB antenna and the CPW transmission line are etched on the top layer of the FR-4 substrate. This allows easy integration of the proposed antenna with RF-front end. The optimized dimensions of the proposed antenna are listed in Table-1.

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Table-1. Optimal dimensions of the proposed UWB antenna in mm.

Ls=18	Lp=9.5	L1=0.7	L2=4.5	L3=2.5
W3=3.2	Ws=15	Wf=2.8	W1=2.2	W2=1
W4=5.42	s=0.4	g=2.0		

The characteristic impedance of the CPW transmission line is taken as 50 ohms. For this purpose, center strip line width and slot gap width dimensions are selected as 2.8mm and 0.4mm respectively. The proposed antenna structure is etched on a cheaply available FR4 substrate with dielectric constant of 4.4, dielectric loss tangent of 0.002.

The Overall dimensions of the proposed antenna are 18*15*1.6mm^3. The bottom corners of the rectangular radiating patch are beveled to allow smooth transmission of current from the CPW feed line to the radiating patch. Thus, a large impedance bandwidth is obtained. The geometrical parameters of the antenna are optimized to obtain the desired UWB bandwidth. The optimized parameters of the proposed antenna are listed in Table-1.

A comparative study on the impedance bandwidth and overall dimensions of the proposed antenna with the existing UWB antennas is presented in Table-2.

Table-2. Dimensions and bandwidths of the antennas from [4] to [15].

Reference antenna	Substrate dimensions (mm^3)	UWB range (GHz)
[4]	30 x 30 x 1.6	2.72 - 12.68
[5]	25 x 25x 1.6	2.6- 13.04
[6]	34.2 x 34.2 x 1.6	3.6- 12
[7]	25 x 25 x 1.0	2.6- 11.12
[8]	26 x30 x1.6	3.1- 10.6
[9]	19 x 16 x 1.6	3 to above 12
[10]	18.7 x 17.6 x 1.5	2.9–13.7
[11]	24x 19x1.2	2.45 -10.65
[12]	30.2x 25*0.762	2.7 t-12.3
[13]	30 x 26 x1.6	3.1- 10.6
[14]	31x 28 x 1.6	3.0 -12.8
[15]	26 x 32 x 1.6	2.8–11
Proposed antenna	18x15x1.6	2.5 to more than 12 GHz

3. SIMULATED AND MEASURED RESULTS

A simple rectangular patch antenna with CPW feeding could not produce desired UWB bandwidth. Therefore, to improve the impedance bandwidth bevel edges and rectangular open slots are incorporated on the antenna geometry. The final geometry of the proposed antenna is shown in Figure-1. The proposed antenna geometry is modeled and simulated in the HFSS EM simulator.

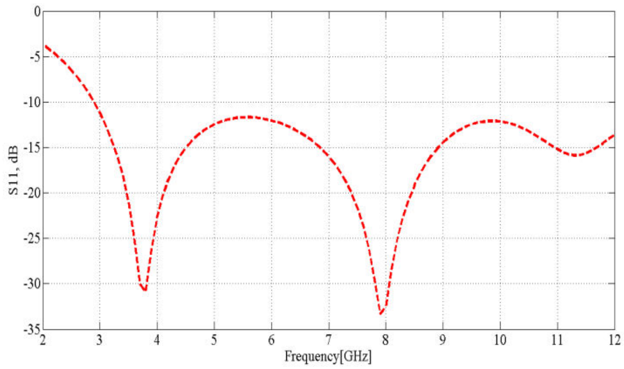

Figure-2. The simulated reflection coefficient curve of the proposed antenna.

Figure-2 illustrates the simulated reflection coefficient of the proposed antenna. From Figure-2 it is noted that the simulated bandwidth of the proposed UWB antenna is from 2.9GHz to more than 12GHz for reflection coefficient less than -10dB.

A parametric study has been carried out to understand the influence of geometrical parameter variation on the reflection coefficient. In the parametric study, the parameter under study is varied, while other parameters are kept unchanged. In this paper, the geometrical parameters L1, L2, and W2 are chosen for the parametric study.

Figure-3 shows the simulated reflection coefficient curves for L3=0.5mm, 2.5mm and 4.5mm. It can be seen that the impedance bandwidth degrades at higher frequencies, when L3 is varied from 2.5mm to 0.5mm. Incremental change in L3 causes the Lower frequencies of UWB shift to the right. Hence, the optimized value of L3 is taken as 2.5mm.

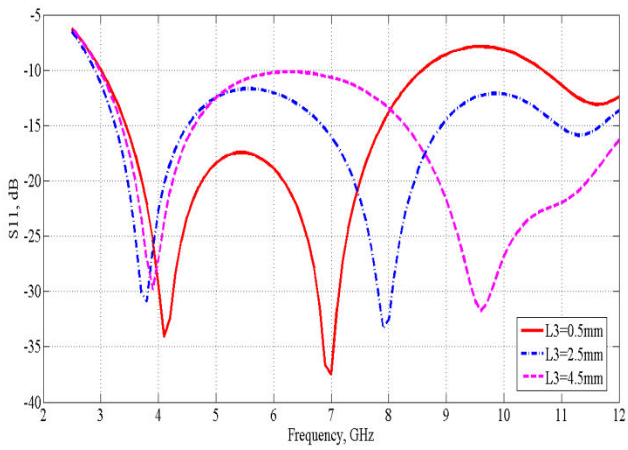

Figure-3. Simulated reflection coefficient curves of the proposed antenna for different values of L3.

Two symmetrical rectangular slots are introduced on the two ground planes of CPW transmission line. These slots will further improve the impedance bandwidth of the

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antenna at lower frequencies. The slots are introduced at the top portion of the ground planes to make sure that they do not impose difficulty during the fabrication process.

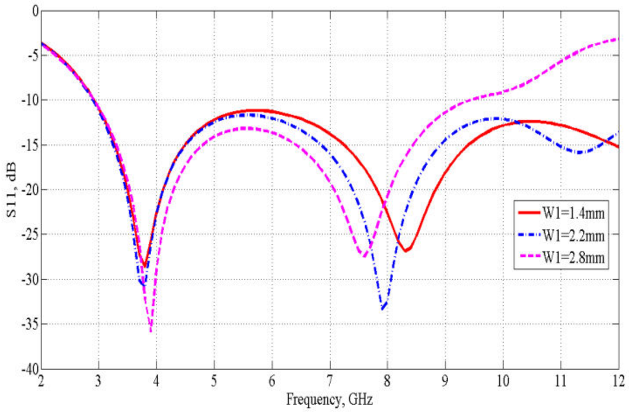


Figure-4. Simulated reflection coefficient curves of the given antenna for different values of W1.

Simulated reflection coefficient curves of the given antenna for different values of W1 are illustrated in Figure-4. It can be observed that as the width of the slot W1 increases from 2.2mm to 2.8mm, the reflection coefficient curve at higher frequencies deteriorates. An overall good reflection coefficient is observed when W1 is 2.2mm rather than 1.6mm. So the optimal value of W1 is taken as 2.2mm.

The effect of slot length L1 on the simulated reflection coefficient of the proposed antenna is illustrated in Figure-5. From the figure, it is clear that the proposed antenna produces a better return loss when L1=0.7mm.

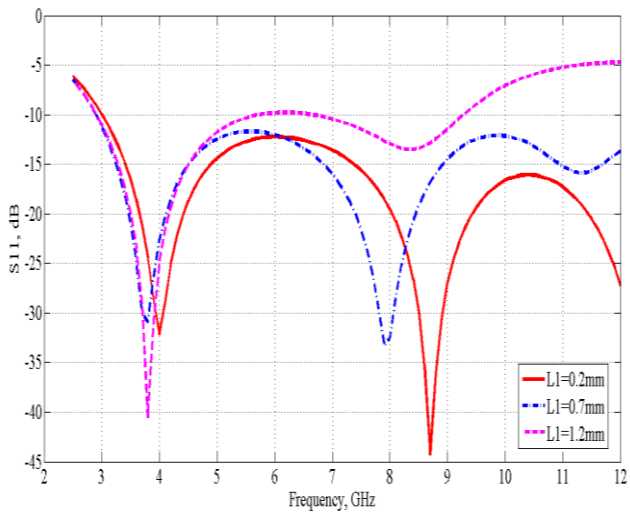


Figure-5. Simulated reflection coefficient curves of the proposed antenna for different values of L1.

The radiation efficiency vs. frequency plot of the proposed antenna is depicted in Figure-6. From the figure, we can observe that the radiation efficiency of the antenna varies from 98.2% to 92%.

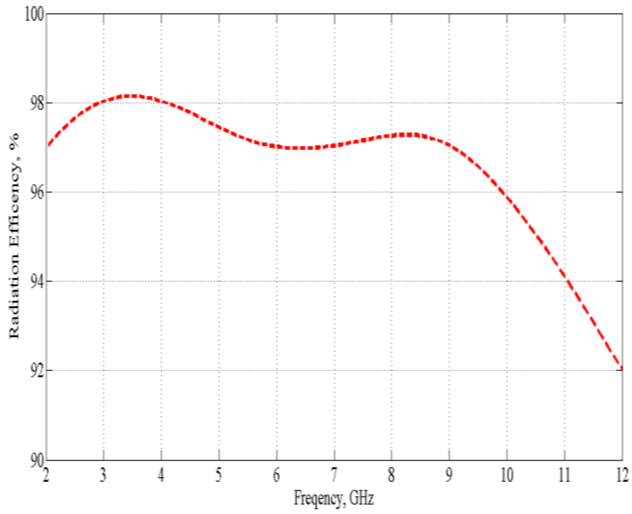
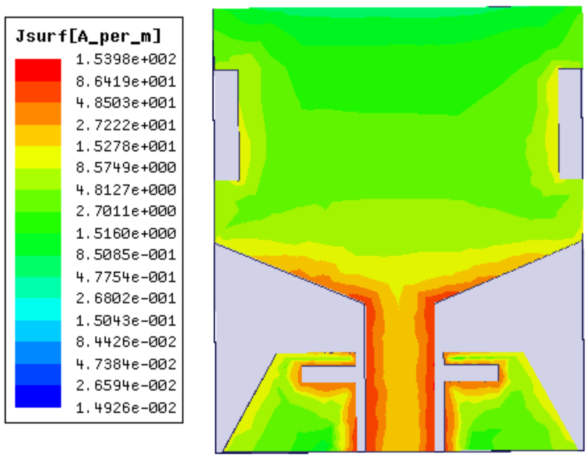
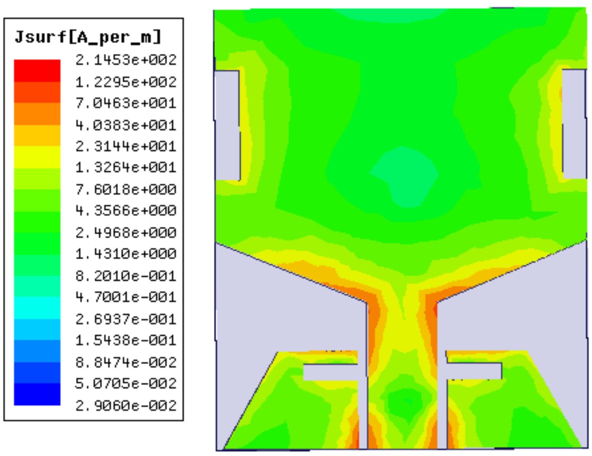


Figure-6. Simulated antenna radiation efficiency vs. frequency plot of the proposed antenna.

The simulated current distribution on the antenna geometry at frequencies 3.5 GHz and 10.5 GHz is illustrated in Figure-7.



(a)



(b)

Figure-7. Surface current distribution on the antenna structure at (a) 3.5GHz and (b) 10.5GHz.

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From the Figure-7 (a) it can be observed that the surface current density is mostly concentrated on the feed line, on the beveled section and along two rectangular slots inserted in the ground plane. Figure-7 (b) shows that most of the surface current density is distributed along the perimeter of radiating patch.

Figure-8 represents the simulated realized peak gain plot of the proposed UWB antenna. It is observed that a maximum realized peak gain of 3.91dBi is obtained at 10.3GHz.

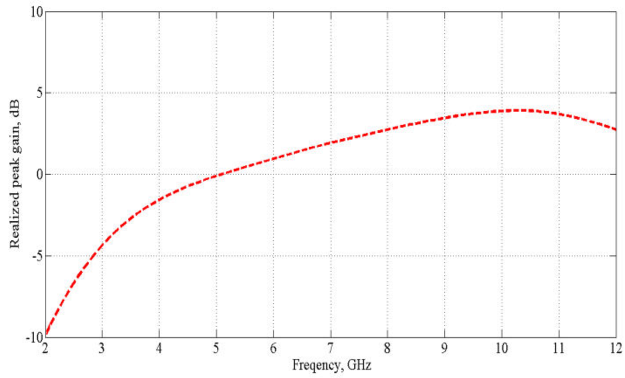
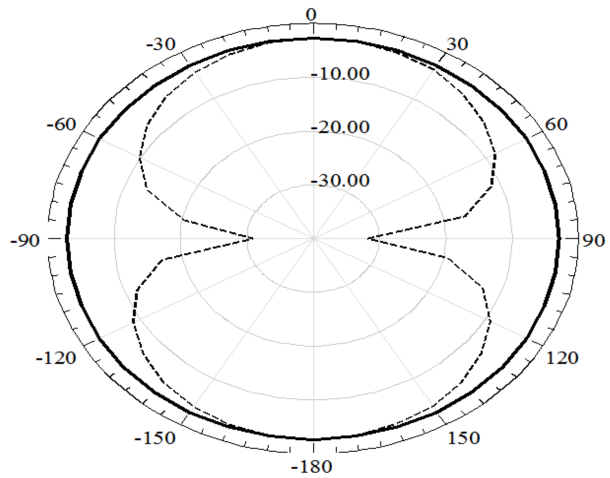
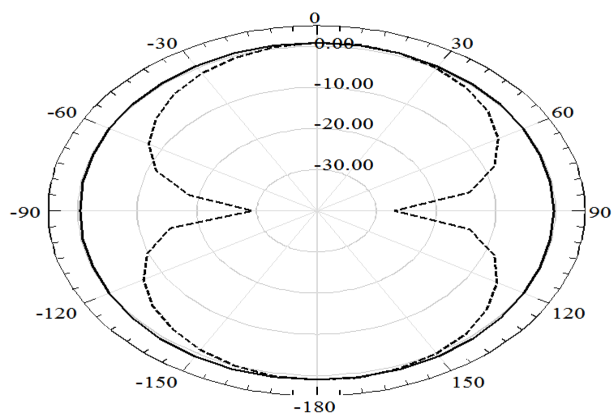


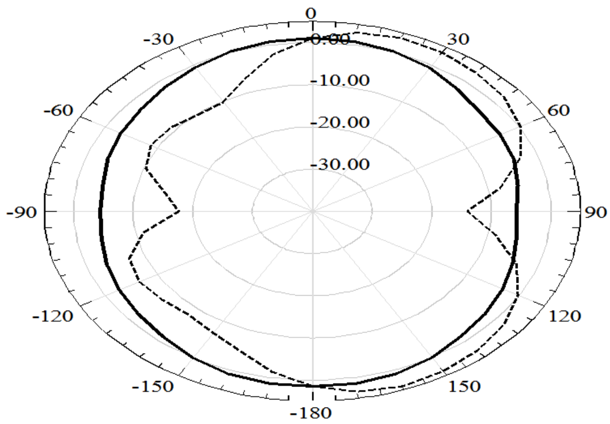
Figure-8. Simulated realized peak gain of the proposed UWB antenna.



(a)



(b)



(c)

--------YZ-plane (Theta=0^0, Phi=90^0)

——— XZ-plane (Theta=0^0, Phi=0^0)

Figure-9. Simulated YZ-plane and XZ-plane radiation patterns of the proposed antenna at (a) 3.5GHz, (b) 6.0GHz and (c) 10.5GHz.

The simulated YZ-plane and XZ-plane radiation patterns are plotted at selected frequencies 3.5GHz, 5GHz, 8GHz, and 10.5GHz in Figure-8. It is noticed that YZ - plane pattern represents dipole-like radiation pattern at lower frequencies and as the frequency increases it starts to become a directional pattern. The antenna produces a good omnidirectional radiation pattern in XZ-plane radiation at selected frequencies. Therefore, the proposed antenna is suitable for the Personal wireless area network applications.

Two identical antennas are arranged in face to face and side by side orientations to find out the group delay response.

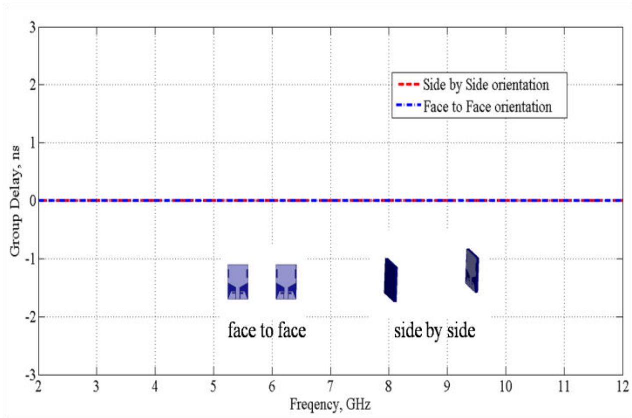


Figure-10. Simulated group delay of the antenna in side by orientation and face to face orientation.

The distance of separation between the two antennas is taken as 1.5m. An UWB antenna uses pulse signals to transmit the information. The pulse duration of these pulses is kept less than 1ns to ensure the minimum distortion. From the Figure-9 it can be noted that the simulated group delay variation of the proposed antenna is

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less than 1ns in both orientations. Therefore, the given antenna has good phase linearity over UWB band.

A prototype of the proposed UWB antenna is fabricated to validate the obtained simulated results. Figure-11 illustrates the geometry of the fabricated prototype antenna.

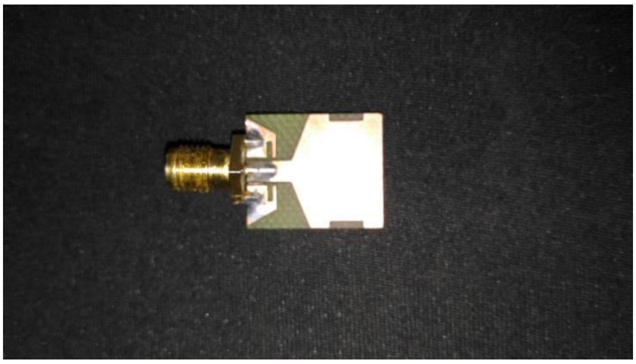

Figure-11. Fabricated prototype antenna.

The reflection coefficient measurement was carried out with the Anritsu combinational analyzer. Figure-12 illustrates the measured and simulated reflection coefficient curves of the proposed UWB antenna structure. It is observed that measured and simulated reflection coefficient results are in good agreement.

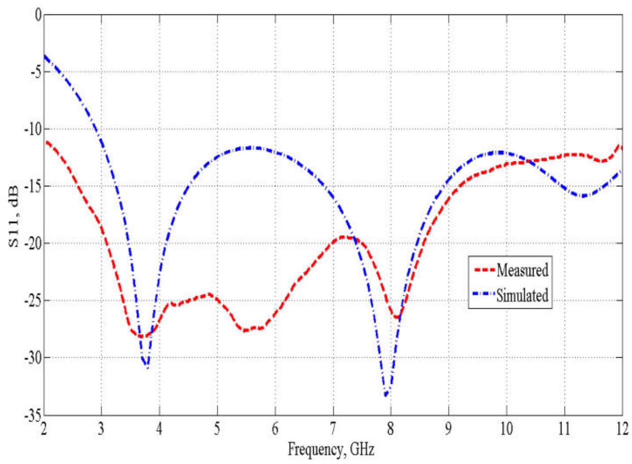

Figure-12. Simulated and measured reflection coefficient curves.

The measured impedance bandwidth of the antenna ranges from 2 GHz to over 12 GHz. Therefore, the proposed antenna is useful for UWB applications. The discrepancies between measured and simulated reflection coefficient results are due to fabrication tolerance and cable losses.

4. CONCLUSIONS

In this paper, a compact planar antenna for UWB applications is proposed. The measured reflection coefficient covers a very wide bandwidth from 2 to more than 12 GHz. The simulated radiation pattern shows a good omnidirectional radiation pattern. The simulated group delay response is flat over the UWB frequency spectrum. The simulated radiation efficiency of the antenna is better than 90% throughout the UWB band. Therefore, the proposed antenna can be used for the UWB applications.

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