World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:4, No:7, 2010

Compact Planar Antenna for UWB Applications

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Abstract—In this paper, a planar antenna for UWB applications has been proposed. The antenna consists of a square patch, a partial ground plane and a slot on the ground plane. The proposed antenna is easy to be integrated with microwave circuitry for low manufacturing cost. The flat type antenna has a compact structure and the total size is 14.5×14.5mm^2. The result shows that the impedance bandwidth (VSWR≤ 2) of the proposed antenna is 12.49 GHz (2.95 to 15.44 GHz), which is equivalent to 135.8%. Details of the proposed compact planar UWB antenna design is presented and discussed.

Keywords**—**Planar antenna, partial ground plane, ultrawideband (UWB) antenna.

I. INTRODUCTION

ULTRA-wideband (UWB) communication systems draw great attention in the wireless world because of their advantages, like high speed data rate, extremely low spectral power density, precision, high precision ranging, low complexity and low cost since the Federal Communications Commission(FCC) allowed 3.1 to 10.6 GHz unlicensed band for UWB communication[1]. UWB also have wide applications in short range and high speed wireless systems, such as ground penetrating radars, medical imaging system, high data rate wireless local area networks (WLAN), communication systems for military and short pulse radars for automotive even or robotics. The antenna is one of the crucial components which determine the performance of UWB system. The UWB antennas proposed in the open literature mainly focus on the slot and monopole antenna [2-5]. Printed wide slot antennas have an attractive property of providing a wide operating bandwidth, especially for those having a modified tuning stub, such as the fork-like stub [6–8], the rectangular stub [9], and the circular stub [10] inside the wide slot. Broadband planar monopole antennas have received considerable attention owing to their attractive merits, such as ultrawide frequency band, good radiation properties, simple structure and ease of fabrication. The typical shapes of these antennas are half-disc [11], circle, ellipse [12], and rectangle [13].

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One of the popular UWB antenna types requires a perpendicular ground plane, which resulted in increased antenna size and difficult to integration with microwave-integrated circuits. Compared with the three dimensional type of antenna, flat type UWB antenna printed onto a piece of printed circuit board (PCB) is a good option for many applications because it can be easily embedded into wireless devices or integrated with other microwave-integrated circuits. However, the antenna design for UWB applications faces many challenges.

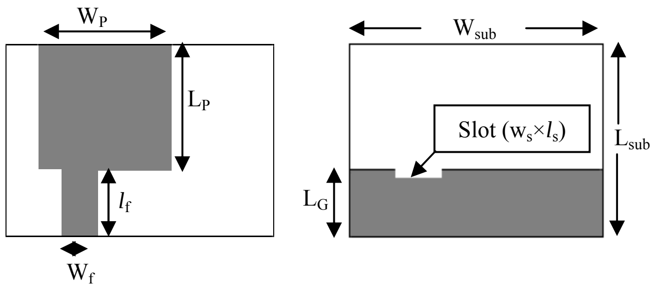
A low profile and embeddable unidirectional antenna is required for certain UWB communication, imaging, localization, and radar applications. The lower and upper UWB spectrums are 3.1–4.8 GHz (43%) and 6.0–10.6 GHz (55%), respectively. The existing broadband directional antennas, such as the Vivaldi, log-periodic, cavity-backed, waveguide, horn, and dish antennas, cover the entire 3.1–10.6 GHz band (109%). However, they are electrically large, and have a high profile in the direction of wave propagation. Omni- and bi-directional antennas, such as the planar monopoles [14, 15], disc cone [16], and slot antennas [17], have a low gain and back radiation pattern, therefore they are not suitable for sectorial or unidirectional communication. Also, it is a challenge to maintain a stable radiation pattern across the whole frequency band, since the radiation aperture is frequency dependent.

In this paper, a microstrip-fed antenna for the UWB applications that achieves a physically compact planar profile, sufficient impedance bandwidth and highly stable bi-directional radiation pattern is proposed. The planar antenna consists of a square shaped radiating patch and partial ground plane with a rectangular slot on the upper edge to cause a wide bandwidth from 3 to 10.6 GHz for UWB application. The antenna structure is flat, and its design is simple and straightforward.

II. ANTENNA GEOMETRY AND DESIGN

Antenna is the key element in UWB systems. The motivation of UWB antenna design is to design a small and simple antenna that introduces low distortions with large bandwidth. Fig. 1 illustrated the configuration of the proposed antenna, which consist of a squarer patch, a partial ground plane and a single rectangular slot on the ground plane. The antenna, which has a compact dimension of 14.5×14.5mm^2, is printed in the front of a FR4 PCB substrate of thickness 1.6 mm and relative permittivity 4.6. The dimension of partial ground plane which is printed in the back side of the substrate is chosen to be 29×7.5mm^2 in this study. The dimension of the slot is 5.5×0.9mm^2 and 5mm away from the left edge of the ground plane. The bottom of the square patch is connected by a microstrip line, which is fed by a 50Ω coaxial probe from the side of the antenna. The microstrip line was etched on the same side of the substrate as the radiator. The antenna has the following parameters: L_{sub} = 22mm, W_{sub} = 29mm, L_P =14.5mm, W_P = 14.5mm, L_G = 7.5mm, l_f = 7.5mm, W_f = 4mm, w_s = 5.5mm and l_s = 0.9mm. There is no gap between radiating patch and ground plane.

Three techniques: the use of (i) square radiating patch, (ii) a partial ground plane and (iii) a single slot on the ground plane applied to the proposed design lead to a good impedance matching. The geometric parameters of this structure can be adjusted to tune the return loss and bandwidth over wide range of frequency.



(a) front (b) back view

Fig. 1. Geometry of the proposed UWB antenna.

III. RESULTS

The performance of the proposed antenna has been analyzed and optimized by using commercially available method of moments based full-wave electromagnetic simulator IE3D[18]. The simulated return loss of the proposed antenna is depicted in fig.2.

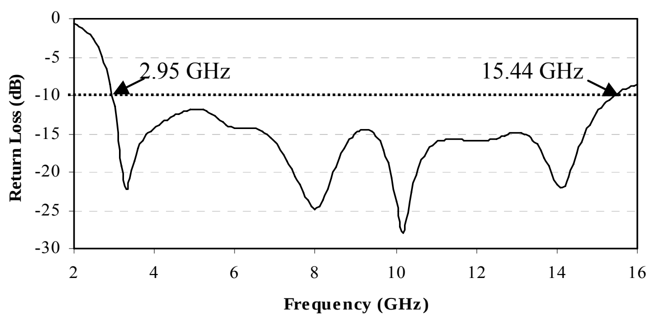


Fig. 2. Return loss of the proposed antenna.

The plot of the return loss shows that the impedance bandwidth of the proposed antenna is 12.49 GHz (from 2.95 GHz to 15.44 GHz which is equivalent to 135.8 %. Its covers the entire UWB frequencies mentioned earlier.

Fig. 3 shows the antenna gain in a frequency range (3-10 GHz) and the maximum gain is 1.15 dBi. The gain is affected by the size of the ground plane. The radiation efficiency of the antenna in the frequency range of 3-10 GHz is shown in fig. 4. The antenna has a maximum of 65% radiation efficiency. The use of a substrate with high dielectric constant and a direct microstrip feeder may be the cause for deterioration in the radiation efficiency.

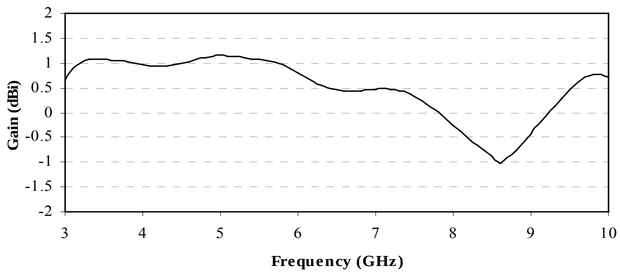


Fig. 3. Gain of the proposed antenna in 3-10 GHz.

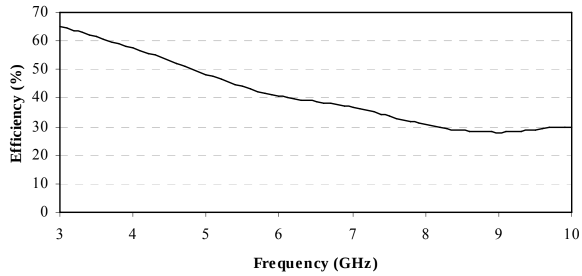


Fig. 4. Radiation efficiency of the antenna.

Fig. 5 shows the radiation patterns of the proposed antenna at 3.3, 8.0 and 10.1 GHz. It is seen that proposed antenna has a main beam in the broadside direction (0^0, 180^0) over all operating frequency. At 10.1 GHz although, the third harmonic radiation pattern (in cross-polarization) is observed, the antenna has a good stable radiation in the broadside direction without gain degradation unlike the existing UWB monopole antennas. At 10.1 GHz the difference of radiation level between copolarization ($\theta = 0^0$) and cross-polarization ($\theta = 90^0$) is approximately 8.96 dBi. The radiation pattern at 3.3 GHz shows that the difference in radiation level is relatively low compared to other frequency data. The differences of polarized radiation levels against the frequencies provide the advantage of minimizing fading effects by multicurrent paths in wireless communications [19]. In the E- plane, the 3 dB beam width is 85.2^0 at 3.3 GHz, 87.5^0 at 8.0 GHz and 43.3^0 at 10.1 GHz and the radiation patterns are almost similar. In the H- plane, the 3 dB beamwidth is 85.7^0 at 3.3 GHz, 65^0 at 8.0 GHz and 50^0 at 10.1 GHz.

Fig. 6 illustrates the current distributions of the proposed antenna at different frequencies. Through a numerical study of the vector current distributions on the antenna, four characteristics current modes are found to exist over the bandwidth from 3.0 to 16.0 GHz. Using fig. 3 as a reference, each current mode is dominant at each resonance, 3.3, 8.0, 10.1 and 14.1 GHz respectively. It is seen that for the antenna mode, the square patch is more like a resonance curved half-wave length dipole, rather than a low Q factor disc resonator. It is also seen that, the strongest currents are concentrated on the edges of the patch. At 3.3 GHz the current's polarity on the patch is upward (along + y-axis), at 8.0 GHz the polarity is downward while at 10.1 GHz the polarity on the left side of the patch (along x-direction) is opposite to that of right side and very little amount of current is found on the centre of the patch. However, the current is uniformly distributed elsewhere.

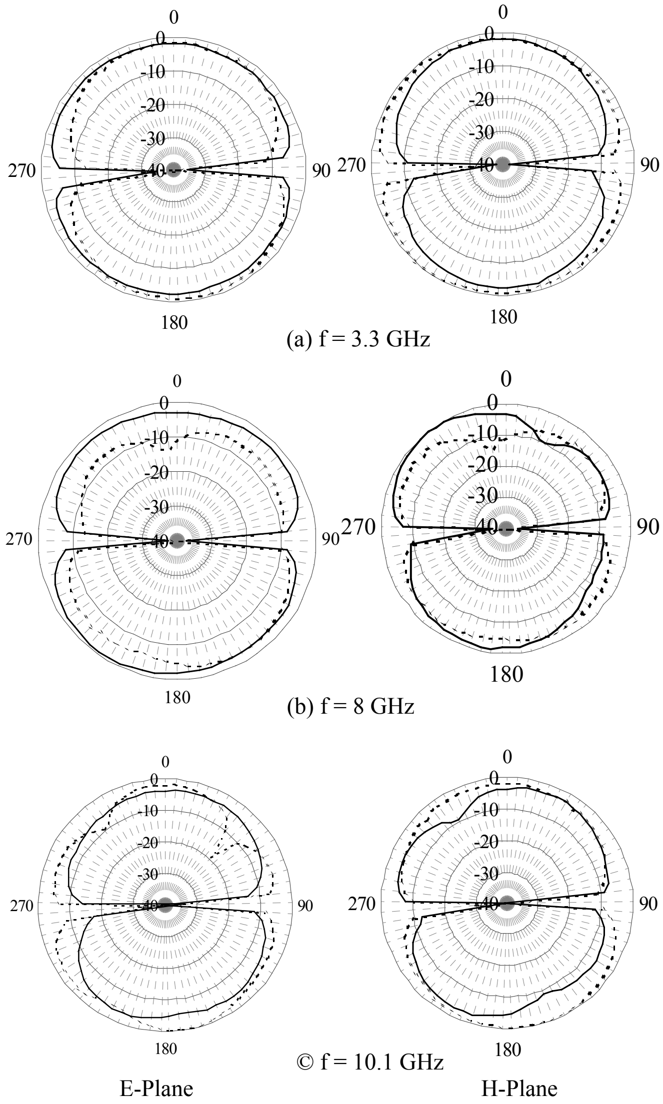


Fig. 5. Radiation patterns of the proposed antenna at different frequencies (—— Copolarization, ---- Crosspolarization).

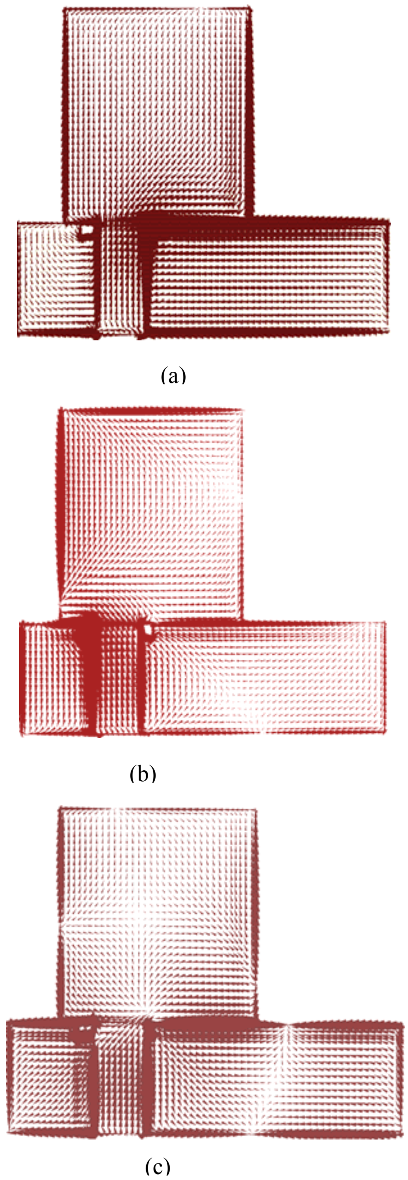


Fig. 6. Current distributions on the antenna at a) 3.3 GHz, b) 8.0 GHz and c) 10.1 GHz.

A low cost, compact microstrip-fed planar UWB antenna has been proposed and implemented. The antenna size is 14.5×14.5 mm^2. The use of rectangular slot on the upper side of the partial ground plane improves not only the impedance matching in high frequency band but also the radiation characteristics at high frequencies. The antenna structure is flat, and its design is simple and straightforward, so it is easy to fabricate. The proposed antenna achieved a bandwidth of 135.8% (2.95 -15.44 GHz) at -10 dB. The relatively constant bidirectional radiation patterns and rather flat gain throughout the whole bandwidth makes the proposed antenna suitable for UWB communication applications.

ACKNOWLEDGMENT

The authors would like to thank the Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia for sponsoring this work.

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