UWB Planar Antenna with Multi-slotted Ground Plane

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1. Introduction

Broadband and multiband antennas play strong roles in the wireless communication world because of the increasing demand of high data transmitting rate. Due to the attractive characteristics such as low cost, low complexity, low spectral power density, high precision ranging, very low interferences and extremely high data rates, ultra-wideband (UWB) technology has recently been widely used in communication systems. As a key component of the UWB systems, the antennas with ultra-wide bandwidth have been widely investigated by many researchers since the Federal Communications Commission (FCC) has allocated 7.5 GHz spectrum from 3.1 to 10.6 GHz for UWB radio applications [1]. The design of an efficient and compact size antenna for recent wideband applications is still a major challenge. Many microstrip-fed and coplanar waveguide-fed antennas have been reported for UWB applications. These antennas use the monopole configuration such as circular ring, elliptical, annual ring, triangle, pentagon and hexagonal antennas; the dipole configuration like bow-tie antennas [2-9]. Some of reported UWB antennas do not have a planar structure due to their ground planes perpendicular to the radiators and they are not suitable to be integrated with the printed circuit boards.

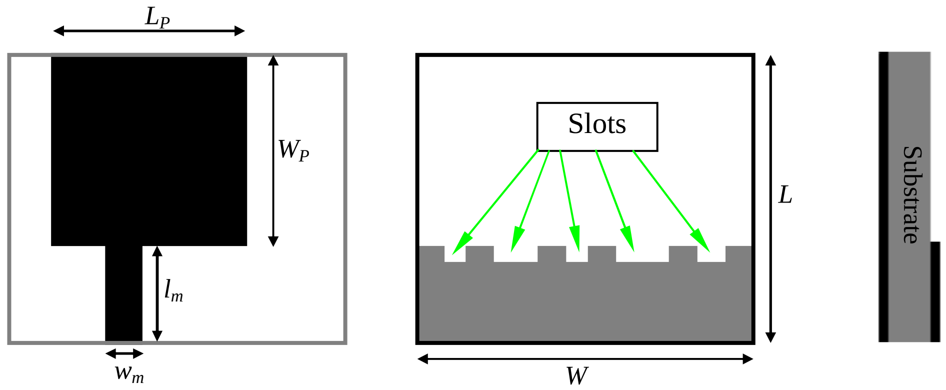
There are numerous and well-known methods to increase the bandwidth of UWB antennas, including increase of substrate thickness, use of a substrate with low dielectric constant, employment of various feeding techniques and the use of slot antenna geometry[10,11]. However, the bandwidth and the size of an antenna are generally mutually conflicting properties; improvement of one characteristic normally results in degradation of the other.

Recently, to increase the impedance bandwidth in circular and elliptical planar monopole antennas, techniques such as the insertion of additional stub to the one side of the circular patch [12], increasing the elliptically ratio of ellipse-shaped patch [4], addition of the slot on one side of the radiating element [13] and adding steps to the lower edge of the patch [14] have been reported. The square shaped antenna fed by a microstrip line, which has the planar configuration, is a good candidate in wideband applications.

In this paper, a wideband antenna that achieves a physically compact planar profile, sufficient impedance bandwidth and bi-directional radiation pattern is proposed. The proposed planar antenna consists of a square shaped radiating patch and partial ground plane with rectangular slots on its upper side to cause a wide bandwidth from 2 to 17 GHz for UWB applications.

2. Antenna Structure

The geometry of the proposed antenna is shown in figure 1. It consists of a square shaped patch and a partial ground plane with rectangular slots. The antenna is printed on a low cost FR4 substrate of thickness 1.6 mm, with relative permittivity 4.6 and has a total size of $W \times L$. The square shaped patch with a dimension of $W_P \times L_P$ and a microstrip feed line is printed on one side of the substrate. The width of the microstrip feed line is fixed at w_m to achieve 50Ω characteristics impedance. An SMA is connected to the port of the feeding microstrip line. The partial ground



(a) Top view (b) Bottom view (c) Side view

Figure 1: Geometry of the proposed antenna

plane having a length of l_m is printed on the other side of the substrate. Rectangular slots with dimensions 2× 1 and 6 × 1 are introduced on the top side of the finite ground plane to alter the input impedance characteristics. The antenna has the following parameters: W = 30 mm, L = 22 mm, w_m = 2.6 mm and l_m = 7.25 mm. The geometric parameters of this structure can be adjusted to tune the return loss and bandwidth over wide range of frequency. The square shaped radiator is capable of supporting multiple resonant modes providing a wider impedance bandwidth. The slots on the partial ground plane have an effect on matching as the gap between the radiating element and ground plane is increased. As a result the bandwidth is increased and the size of the ground plane is reduced.

3. Results and Discussion

The proposed antenna was optimized and analyzed by full-wave electromagnetic simulator Zeland IE3D [15]. The antenna was subsequently prototyped for experimental verification. The return losses were measured using an Agilent *E8362C PNA* series network analyzer. Figure 2 shows the measured and simulated return losses. The plot shows that the proposed antenna has an impedance bandwidth 2.81 to 16.60 GHz, which is equivalent to 142.24%. The discrepancy between simulation and measurement is mostly due to the small ground plane and inaccuracies during fabrication the process. It is also may be due to the effect of the feeding cable, which is used in the measurements but not considered in simulation as the antenna is small.

Figure 3 shows the gain of the proposed antenna in the frequency range of 3 to 11 GHz. It can be seen from the plot that the antenna has a maximum gain of 1.5 dBi at 5.2 GHz with an average of 0.94 dBi. The radiation efficiency of the proposed antenna is shown in figure 4. The antenna has a maximum of 70.64 % radiation efficiency. The low gain and low radiation efficiency of the proposed antenna might be due to the high losses in FR4 substrates and size of ground plane.

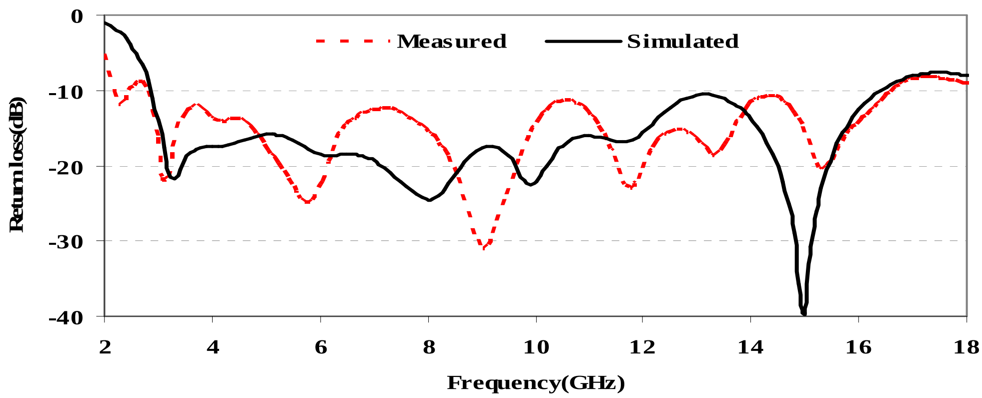


Figure 2 : Measured and simulated return losses of the proposed antenna

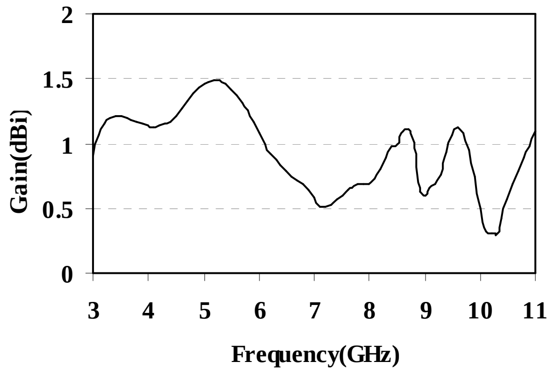


Figure 3 : Gain of the antenna

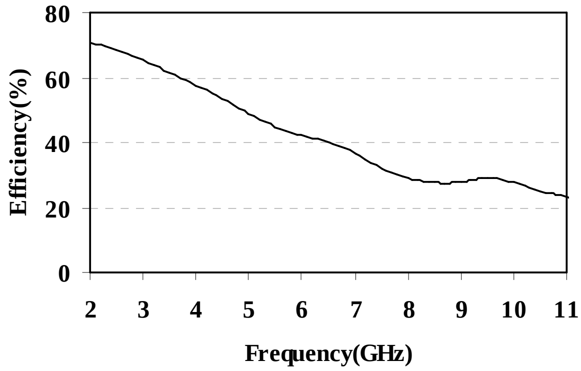


Figure 4 : Radiation efficiency of the Proposed antenna

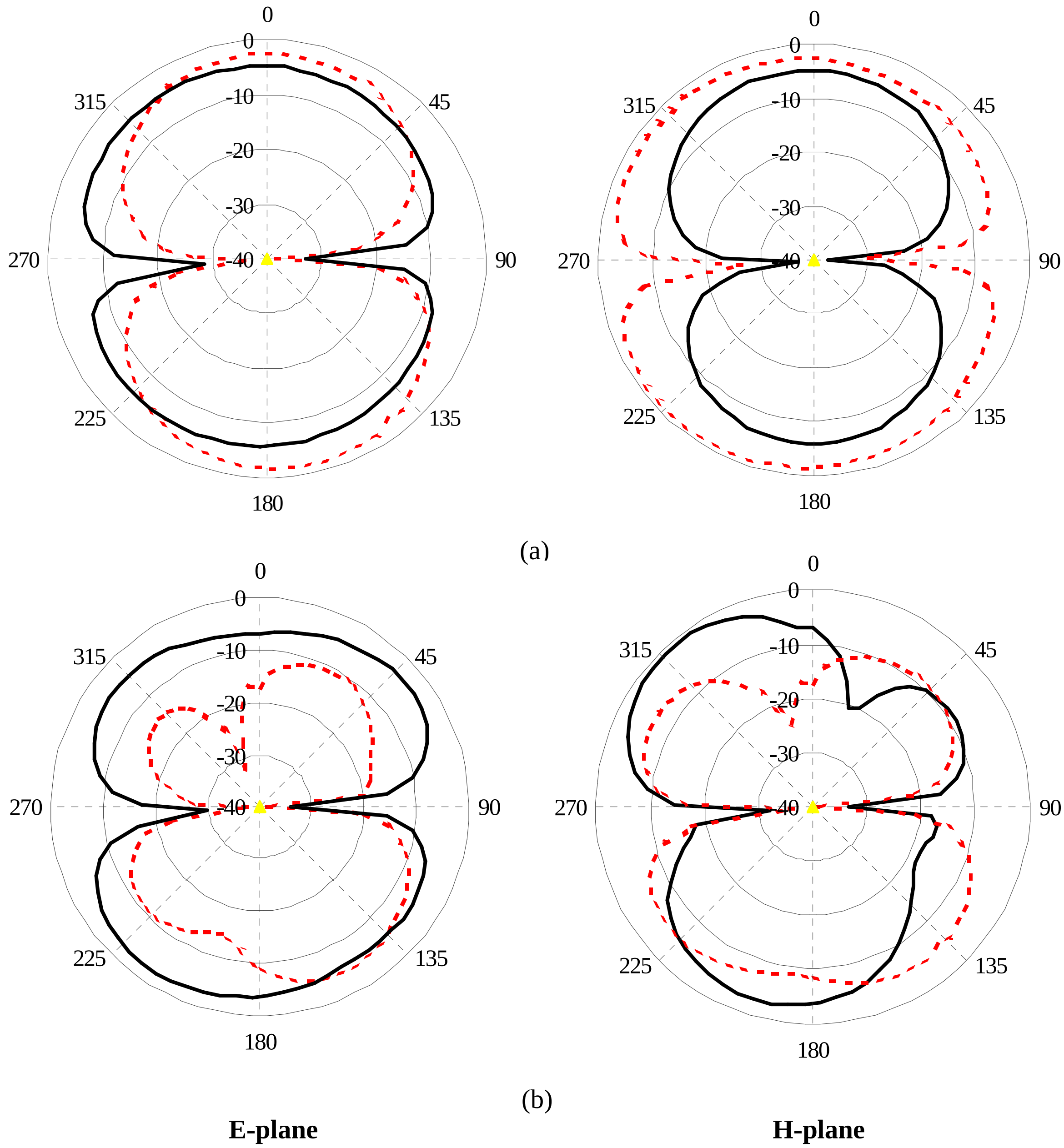


Figure 5: Radiation pattern at (a) 3.3 GHz and (b) 8 GHz.
[—— Co polarization, ... Cross polarization]

Figure 5 shows the radiation patterns of the proposed antenna at two resonance frequencies of 3.3 and 8.0 GHz. It can be observed that at low frequencies both the E- and H-plane radiation patterns are bidirectional and the antenna has a main beam in the broadside direction. At 3.3 GHz both the E- and H-plane radiation patterns are about the same as that of a dipole antenna. This may be due to the small ground plane. As the frequency increases, more higher order current modes are excited and the radiation patterns becomes more directional particularly in H-plane; with dips introduced to the pattern resulting in tilting the main beam away from the broadside direction. It can be seen that at 3.3 GHz, the 3-dB beamwidth (HPBW) in E- and H-planes are 154.64^0 and 85.49^0 respectively, while the planes have the values 144.45^0 and 73.16^0 respectively at 8.0 GHz.

4. Conclusion

A ground plane modified square shaped planar antenna has been proposed for UWB applications. The antenna having a compact size of 30 mm × 22 mm is simple and very easy to be integrated with microwave circuitry for low manufacturing cost. The use of rectangular slots on the top side of the partial ground plane not only improves the impedance matching in high frequency band but also the radiation characteristics at high frequencies. The proposed antenna achieved an impedance bandwidth of 142.42 % (from 2.81 to 16.60 GHz). The almost stable bidirectional radiation pattern with low cross polarization levels and flat gain makes the proposed antenna suitable for being used in UWB communication system.

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