Compact Printed Ultra-wideband Antenna with Band-Notch for WLAN

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Abstract

A compact printed antenna with band-notch characteristics for WLAN is proposed. The proposed compact antenna consists of a partial ground plane and an annular ring patch with a partial annular slot. By properly designing the annular slot placed at the lower side of the ring radiator, good frequency rejection of 5.1- 5.9 GHz with a wide operating band from 3 to 10.6 GHz can be obtained. Furthermore, a symmetric radiation pattern and stable gain except in the notched band makes the proposed antenna suitable for being used in UWB applications.

Keywords : Annular slot Band-notch Ultra-wideband (UWB) WLAN.

1. Introduction

After the declaration of ultra-wide frequency band of 3.1 to 10.6 GHz for unlicensed radio communication by Federal Communications Commission (FCC), the demand for antennas that are capable of operating at an extremely wide frequency band is increasing. Many coplanar waveguide-fed and microstrip-fed antennas have been proposed for UWB applications. Due to the attractive features, such as low cost, low profile, wide bandwidth and omnidirectional radiation pattern, printed planar antennas in which the antenna can be printed onto a piece of printed circuit board (PCB) received much attention for use in UWB systems. Many coplanar waveguide-fed and microstrip-fed antennas have been proposed for UWB applications [1].Circular and elliptical planar antennas are widely investigated by many researchers both in academia and industry since they exhibits the basic characteristics of planar UWB antennas.

Over the designated UWB frequency band there are existing bands used by wireless local area network (WLAN) operating in the 5.15 to 5.825 GHz band. As a result, there is potential risk that the UWB systems will interfere with these existing bands. One effective way to suppress the interfering signals is to use a spatial filter such as a frequency selective surface above the antenna. However, this approach will increase the cost and system complexity and requires more space when integrated with other microwave circuitry. Another method is to employ an UWB antenna with notched band function. So, it is desirable to design antennas that are capable of filtering the frequency band from 5.15 -5.825 GHz in UWB systems to avoid possible interference between UWB and existing WLAN systems i.e., antennas with band-rejection characteristics.

There are various methods to achieve the band-notched characteristics. The conventional methods are embedding a quarter wavelength tuning stub within a large slot on the patch [2], U-slot [3], square slot [4], pi-slot [5] and inserting a slit on the patch [6-7]. Alternate way is putting parasitic elements near the printed monopole as filters to reject the limited band [8], or embedded semi-circular annular parasitic strip [9]. However, some of the proposed designs have complex band notch structures with large size which cannot fulfil the requirement of integrated with planar printed circuits nowadays. Furthermore, among the designs of band notched antennas rejecting the WLAN bands to date, the entire 5-6 GHz frequency band has been completely rejected. However, the needed band notch is from 5.15 to 5.825 GHz for the WLAN band.

In this paper, a simple and compact microstrip-fed planar antenna covering the UWB band with band notch for WLAN is proposed. The rectangular shape slot on the ground plane causes a wider impedance bandwidth. The notched band characteristic is achieved by etching a partial annular ring slot in the radiating element which is connected to inner periphery of the ring radiator by a rectangular slot.

2. Antenna structure

The geometry and configuration of proposed antenna is shown in Fig.1. The proposed antenna consists of an annular ring radiating patch with an inner radius of 3 *mm* and outer radius of 8 *mm* and a partial ground plane. The ring radiator fed by a microstrip feed-line is printed on one side of an inexpensive FR4 dielectric substrate of thickness 1.6 and dielectric constant 4.6 while the partial ground plane of side length 7.5 *mm* is printed on the other side of the substrate. The length and width of the microstrip feed line are fixed at 3 *mm* and 7.5 *mm* respectively to achieve a 50 Ω characteristics impedance. An SMA is connected to the port of the feeding microstrip line. A rectangular slot with dimensions 4 *mm* × 1 *mm* is inserted on the top side of the partial ground plane to alter the input impedance characteristics. The gap between the radiating patch and ground plane is 0.5 *mm*. The overall dimension of the proposed antenna is $W \times L$.

To achieve band-notch characteristic, a partial annular slot of width t_1 has been inserted at the lower portion of ring radiator which leads to high impedance at the notch frequency. A rectangular slot of width t_2 connects the partial annular slot to the inner periphery the ring radiator. The length and position of the partial annular slot is bound by the flare angle θ and distance d. The effective length of the semicircular partial annular slot is nearly equivalent to half a wavelength for the frequency around 5.5 GHz. This means that the notched band can be generated around 5.5 GHz. However, the actual notch frequency of the microstrip-fed antenna can be above or below this approximate frequency depending on the location of the slot.

A parametric study was been conducted to investigate the effects of slots on band-notched characteristics. Fig. 2 and Fig. 3 show the simulated results on the effects of t_1 and θ which are the more susceptible parameters for band-notched function. It can be observed that t_1 and θ determine the centre frequency of the notched band. As the values of t_1 increases from 0 to 1.5 mm, the centre frequency of the first notched band shifted towards higher frequency. From Fig. 3 it is observed that, the centre frequency of the notched band is strongly affected by θ. As the value of θ increases from 80^0 to 100^0, the centre frequency of the second notched band is varied from 5.35 to 6.2 GHz. From these results, it can be concluded that the notched band for WLAN is controlled by the partial annular slot that is connected to the inner periphery by the rectangular slot. It is also observed that the centre frequency as well as the bandwidth of the notched band can be adjusted by properly selecting the values of $t_1$and θ. It is also revealed from the figure that when the values of t_1 and θ are changed, the return loss over the entire UWB band almost remains unchanged except at the notched band. The optimized parameters of the proposed antenna are as follows: t_1 = 1 *mm*, $\theta = 92^0$, t_2 = 1 *mm*, d = 6 *mm*, W = 26 *mm* and L = 24 *mm*.

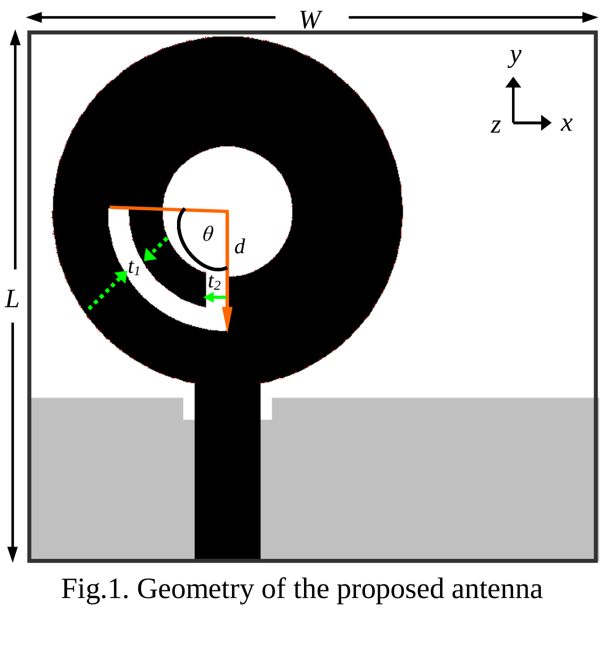

Fig.1. Geometry of the proposed antenna

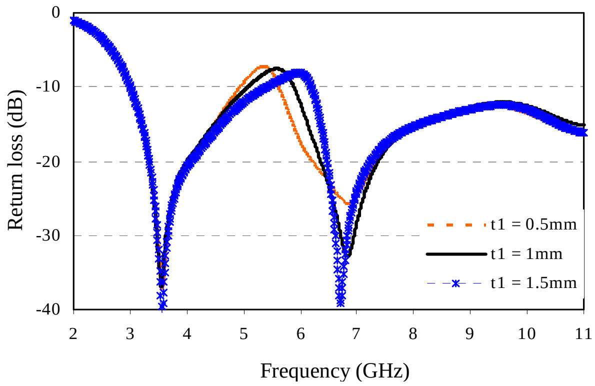

Fig.2. Variation of return loss with t_1

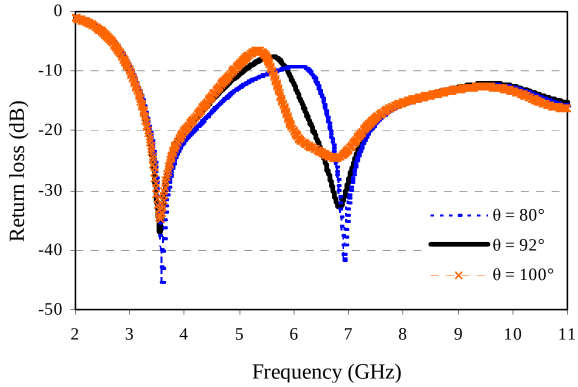

Fig.3. Variation of return loss with θ

3. Results and discussion

The performance of the proposed antenna was analyzed and optimized using full-wave electromagnetic simulator IE3D which is based on method of moments. The antenna was subsequently fabricated for experimental verification. The antenna performance was measured in an anechoic chamber using far field antenna measurement system and Agilent E8362C vector network analyzer. Fig. 4 illustrates the simulated and experimental return losses against the frequency of the antenna. Fairly good agreements between the simulations and measurements have been achieved. It is observed from the figure that the measured impedance bandwidth with -10 dB return loss for the proposed antenna is 3 to 10.6 GHz. It is also seen that the designed antenna exhibits notch band of 5.1- 5.9 GHz, so that effects due to the interference can be avoided well.

The gain versus the frequency is plotted in Fig. 5. As depicted in the graphs, the gain decreases significantly at the notched frequency bands. However, at the frequency of 9-10 GHz the antenna gain slightly decreases because of the low matching of that antenna in that frequency. Other than the notched frequency band, for other frequencies the antenna gain is about the same for the proposed antenna without band notched design.

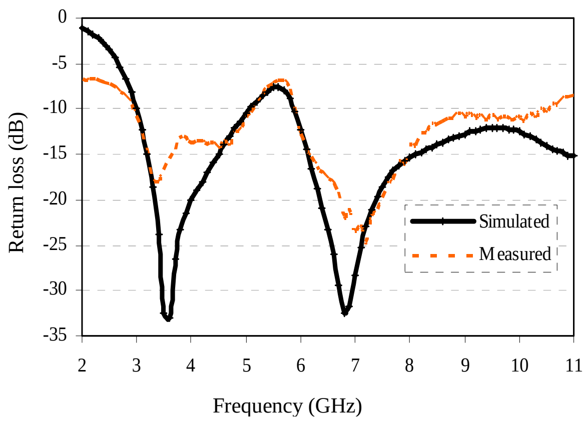

Fig.4. Simulated and measured return losses

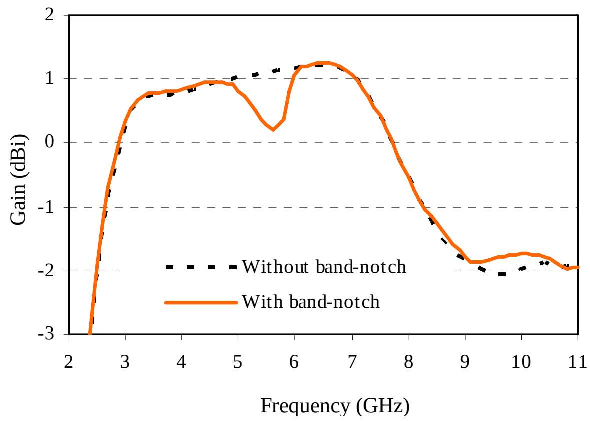

Fig.5. Gain vs. frequency response

Fig. 6 shows the E-plane and H-plane radiation patterns of the proposed band notch antenna at three resonance frequencies of 3.5, 6.8 and 9 GHz respectively. It can be observed that at low frequencies both the E- and H-plane radiation patterns are approximately bidirectional and the antenna has a main beam in the broadside direction. At lower frequencies both the E- and H-plane radiation patterns are about the same as that of a monopole antenna. As frequency increases, higher order current modes are excited and the radiation patterns becomes slight directional. However a stable and symmetric radiation patterns are observed over the operating band of the proposed antenna.

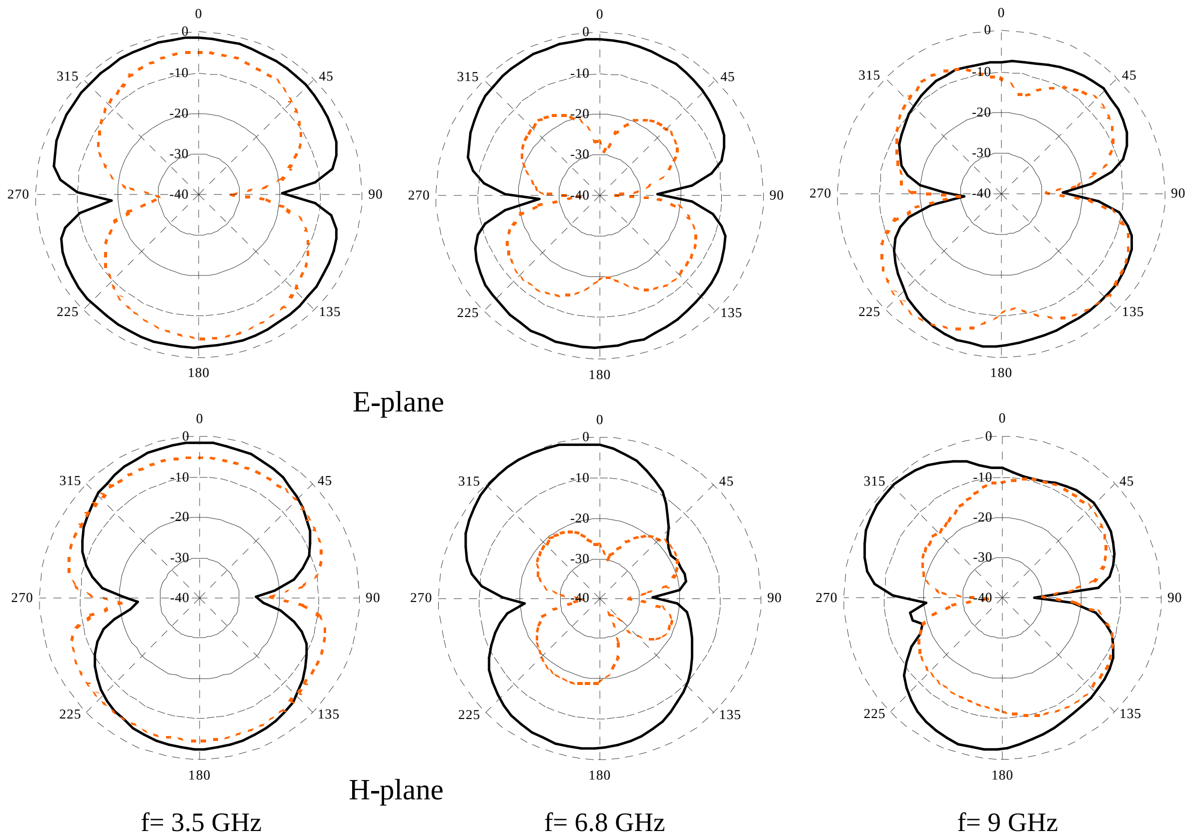

Fig.6. Radiation patterns at different frequencies [Copolarization ▬▬, Cross-polarization ······]

4. Conclusion

A compact microstrip line-fed printed planar antenna with the band-notched characteristics around 5.5 GHz has been proposed and discussed. Several design parameters have been investigated for optimal design. A partial annular slot at the lower portion of the ring radiator is realized to obtain the band-notched function. The proposed antenna revealed good UWB performance, accompanied with band-rejection characteristics to avoid interference caused from WLAN. The characteristics of low profile with stable radiation patterns make the proposed antenna suitable for being used in UWB applications.

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