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Compact Monopole Ultra-wideband Antenna with Band Notched Characteristics

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Abstract: This paper presents design of monopole band notched ultra wideband antenna. A coupling strip gap introduced in the square patch helps to notch certain frequency bands. This is a compact, low power ultra wide band (UWB) antenna which mitigates the saturation of spectrum. Its low power characteristic make it invisible for the radio systems sharing the same spectrum hence minimizes interference due to other licensed bands. This proposed band notched UWB antenna is used for several frequency bands such as Wi-Max(3.3 GHz to 3.6 GHz), WLAN (5.15 GHz to 5.35 GHz and 5.725 GHz to 5.825 GHz) and HIPERLAN/ 2(5.15 to 5.35 GHz and 5.47GHz to 5.725 GHz).

Keywords: Ultra-wideband antenna, VSWR, Partial ground plane, rectangular metallic strip, U-slot rectangular patch antenna, coupling strip, industrial, scientific, and medical radio band(ISM).

I. INTRODUCTION

Worldwide interest in Ultra-Wide-Band (UWB) wireless has increased greatly with the release in Feb 2002 by the FCC of their first authorization for UWB. It is usually considered to be wireless communication or remote sensing using non-sinusoidal carriers, or sinusoidal carriers of only a few cycles duration. The U.S. Federal Communication Commission (FCC) authorized the licensed use of the Ultra Wide Band (UWB 3.1-10.6 GHz).The frequency range for UWB systems approved by the FCC between 3.1 to 10.6 GHz will cause interference to the existing wireless communication systems, such as the IEEE 802.16 Wi-MAX system at 3.5 GHz (3.3-3.7 GHz) and the IEEE 802.11a wireless local area network (WLAN) system at 5.2/5.8 GHz (5.15-5.825 GHz) [2]. Various techniques are used to create a single monopole antenna which works for all frequency bands. The designed antenna should have high speed, low power and high data rate. It tries to mitigate the saturation of the spectrum, transmitting at very low power over a frequency band that is already occupied. Its low power characteristics make it invisible for the radio systems sharing the same spectrum. Its ultra-wideband spectrum allows transmitting information at high data rates, increasing with this the amount of information transmitted per second.

Band notched filters show different characteristics and frequency responses than UWB antennas without band notched filters. Interference due to licensed bands such as WLAN, WiMAX, HIPERLAN etc is much less in band notched antennas. There are several methods with which one can achieve a band-notched UWB antenna. The most popular approach is to embed different shaped slots in the radiating element or in its ground plane. Examples include multiple shaped slots. However, most UWB antennas have been designed with only one or two notched-frequency bands. Details of the antenna design are discussed in section II. Fabrication and results of the proposed antenna is discussed in section III and finally a brief summary is given in section IV.

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in fig.1. It is fabricated on 1.6mm thick FR4 substrate with dielectric constant of ε_r = 4.4 and loss tangent tan δ= 0.02. A 50 Ω microstrip line with a width of 3.4mm is used to fed this antenna. A square slot patch with coupling strip inside is used to implement monopole antenna.

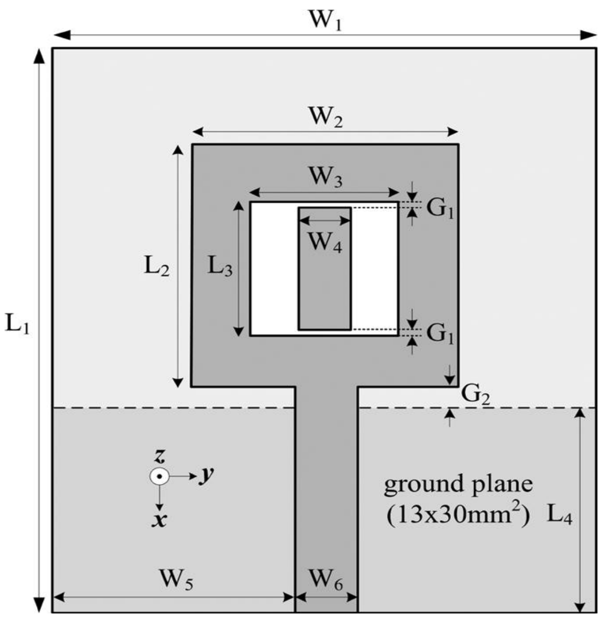

Fig.1 Geometry of proposed UWB antenna

The design parameters optimized for the antenna were calculated as L_1=35mm, L_2=15mm, L3=8.3mm, L_4=13mm, W_1=30mm, W_2=15mm, W_3=8.3mm, W_4=3mm, W_5=13.3mm, W_6=3.4mm, G_1=0.2mm, G_2=1mm.
Photograph of the proposed UWB antenna is shown in below fig 2.As shown in figure 2, coupling strip placed at the center of the slot is used to achieve particular band notch frequency. Band rejection frequency is determined from the derived equation as follows.

$$f_r \approx \frac{c}{4\sqrt{\frac{\varepsilon_r+1}{2}}\cdot(\mathrm{L}_3-2\mathrm{G}_1)}$$

Where c= speed of light in air=3*10^8 m/s
f_r = rejection frequency
ε_r = dielectric constant=4.4
L_3=length of square slot
G_1= gap between coupling strip and slot

Using above formula various band rejection frequencies can be selected by varying length of gap G_1 between coupling strip and square slot. Various values of gap are G_1=0.1mm, G_1=0.2 mm, G_1=0.3 mm.

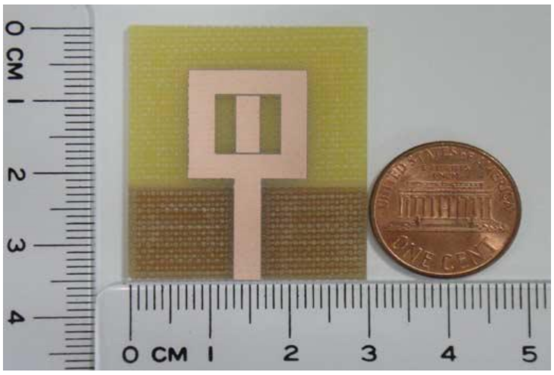

Figure2. Photograph of the proposed UWB band-notched antenna

Since the center-rejected frequency is expected about 5.6 GHz, the strip length of the antenna can be calculated to be 7.9 mm, suitable for those optimum design parameters as listed above. Besides, to overcome the effects due to the frequency shifting for practical applications, the stop band property of the antenna can be controlled by flexibly tuning either the width (W_4) or the gap (G_1) for the strip.

III. RESULTS AND DISCUSSIONS

The proposed UWB antenna was constructed and tested using vector network analyzer (Agilent PNA 8362B) of 14 GHz frequency range. VSWR and return loss are the performance parameters of UWB antenna. Here simulated and experimental return losses are listed in below figure 3.Fairly good matches are achieved between simulated and experimental results. Bandwidth for UWB antenna is chosen in between 3.05 to 12 GHz rejecting the frequency band of about 5.12 -6.08 GHz. By changing different parameters of UWB antenna such as strip width and strip gap we can further analyse performance of antenna at different rejection frequencies. Coupling strip gaps are selected between 0.1mm to 0.3 mm. The simulation results for varying strip gaps are shown in figure 4.Strip gap of 0.2mm is suggested for proposed UWB antenna. Strip widths are varied in the range of 1 to 5 mm with equal intervals of 1mm. The simulation results are shown in figure 5. Corresponding to the strip widths of 4mm and 5mm nearly same stop band features are achieved. So a strip width of3mm is chosen for proposed UWB antenna.

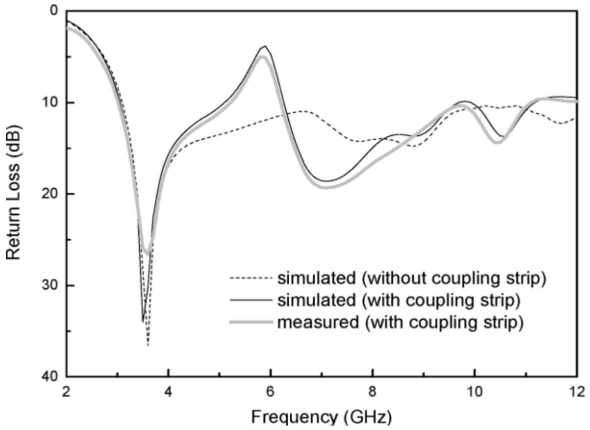

Figure.3 Graph between frequency & return loss of antenna

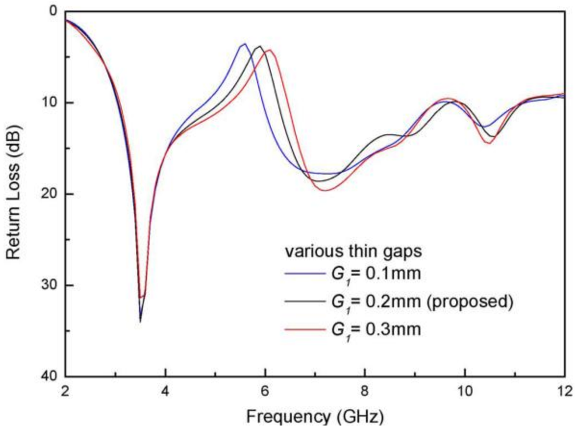

Figure 4.Simulated Return losses for different strip gaps

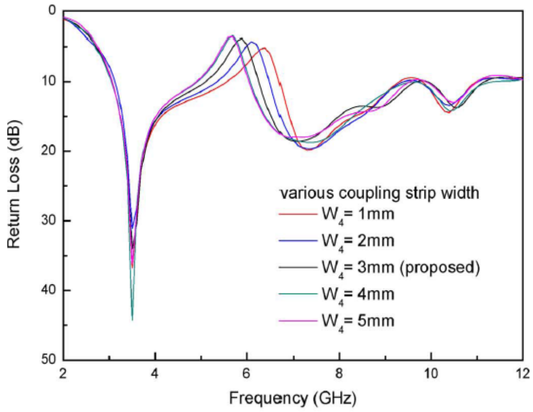

Figure 5.Simulated Return losses for different strip widths

To further analyse band notched property of UWB antenna surface current distribution is explained. Choosing the centre rejected frequency as 5.6 GHz the surface current distribution has been simulated in below figure 6.

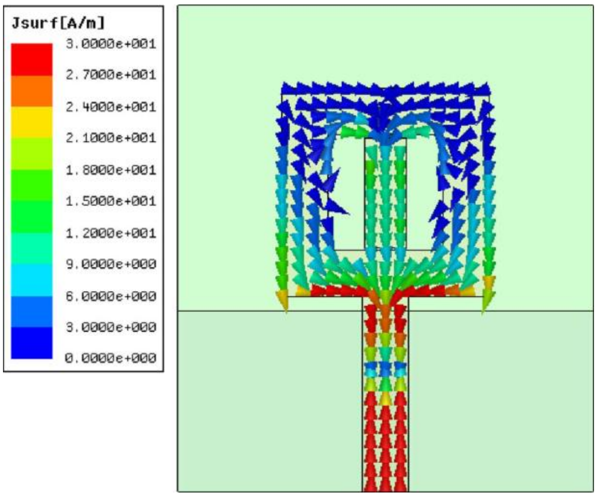

Figure 6 Simulated surface current distribution at the center-rejected frequency of 5.6 GHz for the proposed antenna

From above figure, we can see that a stronger resonance pattern is observed at coupling strip rather than square slot. This will help in achieving good rejection frequency. More the current distribution more will be the resonance achieved. Far-field radiation patterns in the xy, yz and xy are measured for the frequencies at 4 GHz and 8GHz. In the yz plane nearly good omnidirectional patterns are observed and bidirectional patterns are observed in the xy plane. It shows that implemented UWB antenna gives large and uniform coverage over range of frequencies. Radiation patterns are shown in figure 7.

The other parameter for performance measurement of antenna is its gain and radiation efficiency. Figure 8 shows measured antenna gain and radiation efficiency versus the frequency. It is observed that radiation efficiency is greater than 82% at passband. Over the stopband i.e. from 5.12-6.08 GHz the gain and efficiency is lower. Use of low loss substrate gives better performance for practical applications. From above all results, the proposed compact antenna is capable of offering good performance as demanded by modern UWB communication systems.

IV. CONCLUSION

The stop band properties of proposed antenna and previous antennas are compared. It is observed that proposed UWB antenna shows better radiation performance and its stop band can be easily adjusted. ISM band frequency interference issues are better resolved in proposed UWB antenna. This antenna shows good omnidirectional coverage, stable transmission characteristics which are required for practical implementation of antenna in UWB portable devices.

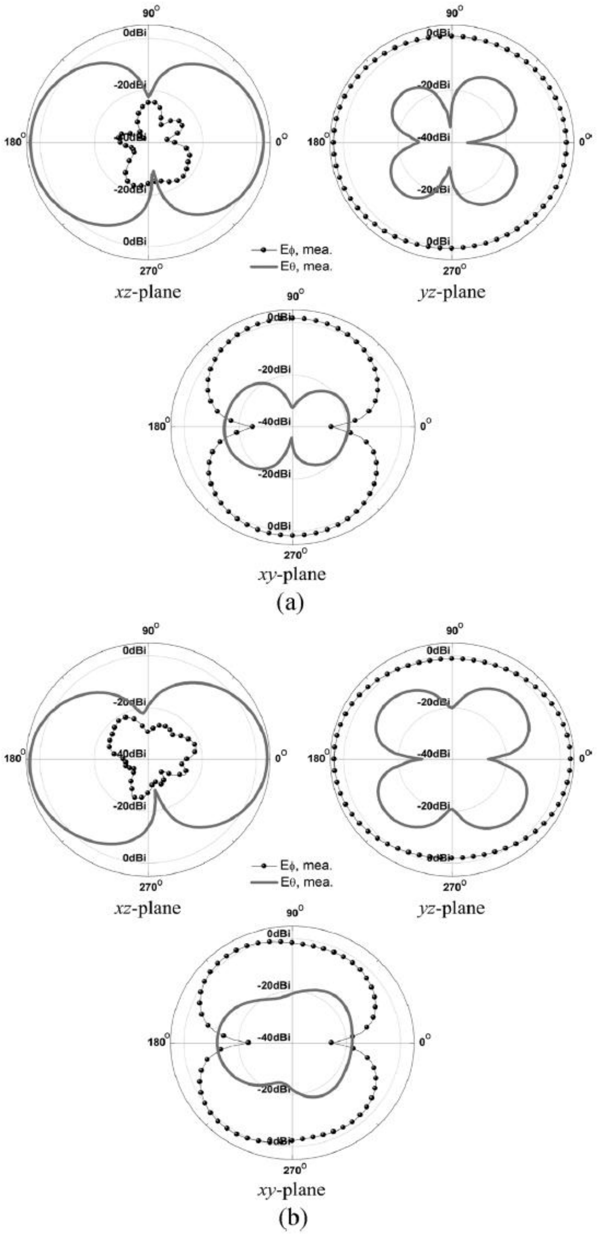

Figure.7 Measured radiation patterns of the proposed antenna. (a) 4 GHz. (b) 8 GHz.

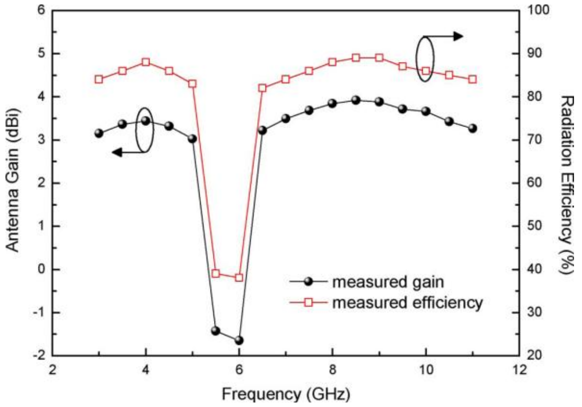

Fig.8. Measured antenna gain and radiation efficiency of antenna

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BIOGRAPHY

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