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Band Notched Elliptical Slot Antenna as EMI Sensor

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ABSTRACT: This paper presents the parametric analysis of novel band notched elliptical slot antenna as electromagnetic interference sensor over the ultra-wideband frequency range (3.1 GHz-10.6 GHz). The antenna is comprised of FR4 lossy ($\mathcal{E}_r$=4.3) dielectric substrate, rectangular patch and U-shaped tuning stubs fed by micro strip line. The antenna is nearly omnidirectional over the UWB frequency range. Design and simulation of proposed slot antenna as electromagnetic interference sensor is done using CST Microwave studio software. The performance characteristics of the antenna as EMI sensor is analysed in terms of radiation characteristics and antenna factor. Simulated Return losses (RL), Antenna factor (AF), Gain, Input impedance results are obtained. These results show that the proposed slot antenna is found to be more suitable and efficient electromagnetic interference (EMI) sensor for electromagnetic compatibility (EMC) measurements over the UWB frequency range.

KEYWORDS: Elliptical slot antenna, antenna factor (AF), EMI sensor, EMC, Ultra wideband.

I.INTRODUCTION

Electromagnetic interference (EMI) is caused due to electromagnetic emissions form a device or system that interfere with the normal operation of another device or system. It is also referred to as Radio Frequency Interference (RFI). The ability of device or system to function satisfactorily in its electromagnetic environment (EME) without introducing intolerable electromagnetic disturbance to anything in that environment is known as electromagnetic compatibility (EMC) of the system.

In this modern era electromagnetic interference has become crucial problem for most of the high speed and highly efficient systems which are designed for better performance against noise. Therefore electromagnetic interference measurement is a major concern in the design of efficient systems. In order to measure the electromagnetic interference generated from a system EMI sensors play a vital role in conforming system design so as to mitigate the interference effect. For this purpose antennas are widely used as EMI sensors [2-4]. Micro strip circular, rectangular and circular patch antennas are studied as EMI sensors [7-9].

In this paper compact UWB printed elliptical slot antenna of dimensions 38 mm×36 mm is proposed as EMI sensor. It is observed that UWB printed antennas with elliptical slot has good impedance bandwidth and radiation characteristics when compared to circular, square, rectangle shaped slots [1],[11]. The antenna is designed and simulated in CST Microwave studio [6].

II.BAND NOTCHED ELLIPTICAL SLOT ANTENNA GEOMETRY

The geometry of proposed band notched elliptical slot antenna is shown in Fig. 1. The slot antenna is fed by a micro strip line of characteristic impedance 50Ω. The elliptical slot, feed line and tuning stub and rectangular patch are etched on substrate. FR4 dielectric substrate (ε_r=4.3) with thickness t=1mm is used in the design of slot antenna. The separation between the bottom of the U-shaped tuning stub and the lower edge of the elliptical slot which is 0.35 mm determines better impedance matching between slot and feed line. A rectangular patch of length (a=1.5 mm) and breadth (b= 0.35 mm) introduced in between arms of the tuning stub reduces the return losses of the antenna.

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In the proposed antenna design, a U-shaped slot is cut in the U-shaped tuning stub. The dimensions of the cut are adjusted so that antenna offers high return losses at frequency range of 5.15 to 5.825 GHz. There are several existing NB communication systems operating in FCC bandwidth range which leads to interference with the UWB systems such as IEEE 802.11a WLAN systems. These systems operate in the range 5.15-5.825 GHz which may cause interference with existing UWB systems. Therefore a filter with band stop characteristics is introduced in the antenna to achieve a notch function at the interfering frequency band.

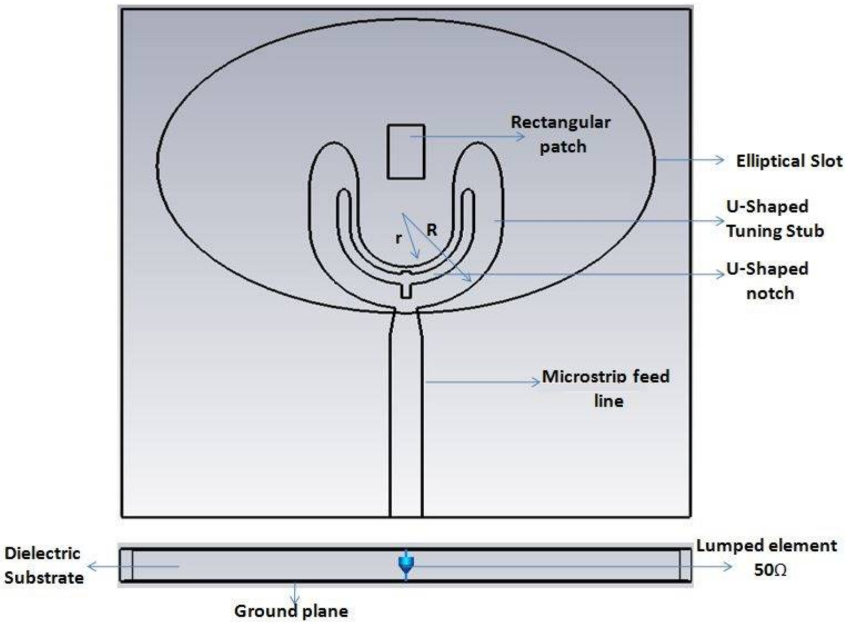

Fig. 1 Antenna Geometry

The above Fig. 1 represents antenna geometry of proposed antenna. The antenna size is 35 mm ×35 mm with dielectric substrate FR4 Lossy ($\mathcal{E}_r$=4.3). Elliptical slot with major axis 31.5 mm and minor axis 22 mm is made on one surface of dielectric substrate and rectangular patch (0.35 mm × 1.5 mm) and U-shaped tuning stub containing inner radius (r)=3 mm and outer radius (R)= 6.1 mm are printed on the other side of the substrate. The U-shaped notch has radius of 3.55mm and width 0.75 mm and the vertical notch in addition to U-shaped notch has length and width given by 2mm × 0.6 mm. The separation between the elliptical slot and the U-shaped tuning stub has an optimal value of 0.35 mm is responsible for better impedance matching between slot and the tuning stub.

III.RESULTS AND DISCUSSION

ANTENNA FACTOR: Antenna factor (AF) is most widely used performance descriptor of a device in EMC area. The ratio of incident electric or magnetic field on the surface of the sensor to the received voltage (equation (1)) at the antenna terminal which is terminated by 50Ω load impedance is known as antenna factor [10]. By using this antenna factor one would multiply the received voltage at the receiving antenna to obtain or recover the incident electric or magnetic field [10] as shown in equation (2).

$$|AF^{electric}| = |(E_{incident})| / |(V_{recieved})| \ 1/m \qquad (1)$$

$$|(E_{incident})| = |AF^{electric}|.|(V_{recieved})| \ V/m \qquad (2)$$

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For the proposed antenna as EMI sensor, antenna factor is obtained for co-polarized (vertical) and cross-polarized (horizontal) electric field strength of 1V/m incident on the surface of the slot antenna is shown in the Fig. 2.
Gain of the antenna is found to inversely proportional to the Antenna factor from the simulated result shown in Fig. 2 which is obtained for co polarized E-field. Gain is nearly constant from 2.8 GHz to 10 GHz because of very less return losses and it decreases above 10 GHz. The antenna factor sharply increases in the frequency range 5.15 GHz to5.85 GHz due to band stop filtering function implemented in the design of antenna.

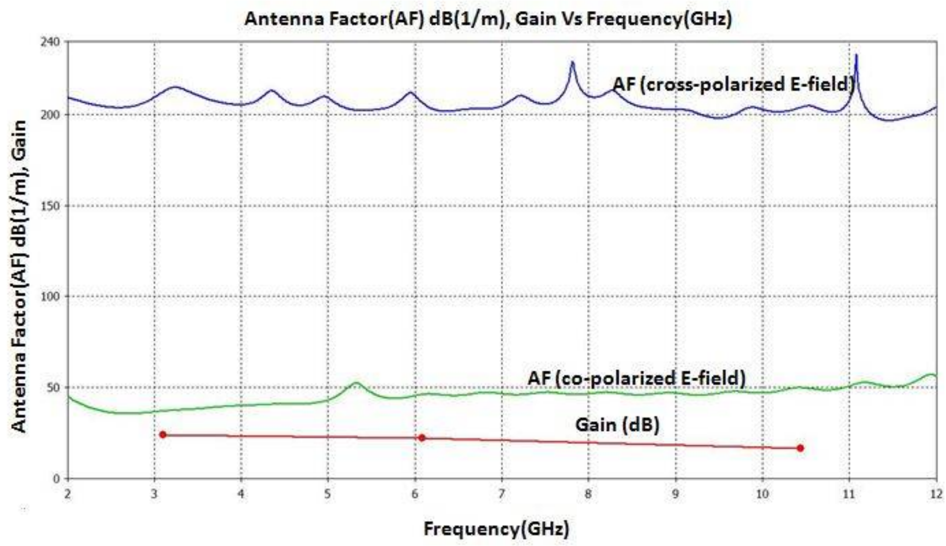

Fig.2Antenna Factor and Gain (dB) of the antenna Vs. Frequency for incident Co-polarized E-field and cross Polarized E-field.

RETURN LOSSES:Simulated return loss curve is shown in the Fig. 3. It is observed that there are three resonant frequencies- f_o=3.18 GHz (fundamental frequency), f_1=6.62 GHz and f_3=10.4 GHz (harmonics of f_o) which indicates the proposed antenna has wide bandwidth of 2.6 GHz to 13 GHz (-10 dB bandwidth) and impedance bandwidth ratio 5:1. Antenna factor (AF) decreases with decrease in return losses (RL) as received voltage ($V_{recieved}$) increases and vice versa. At frequency band 5.2-5.8 GHz the return losses is high which indicates the antenna operates very poorly in this frequency range which implies that there exists no interference with other NB systems.

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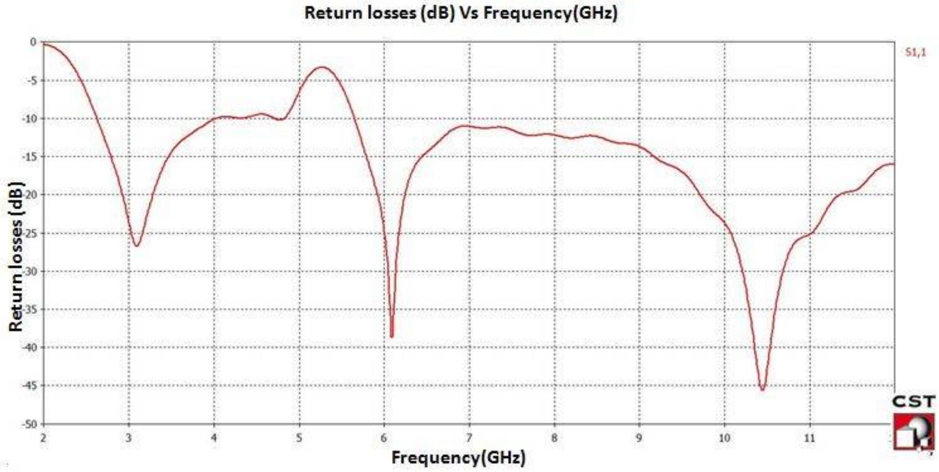

Fig. 3 Return losses (dB) Vs frequency (GHz)

INPUT IMPEDANCE:The input impedance is responsible for proper matching of EMI sensor with the transmission line [9]. Simulated input resistance R (Ω) and reactance X are shown in Fig. 4. Input impedance is resistive at resonant frequencies (f_o, f_1, f_2) and complex for other frequencies.

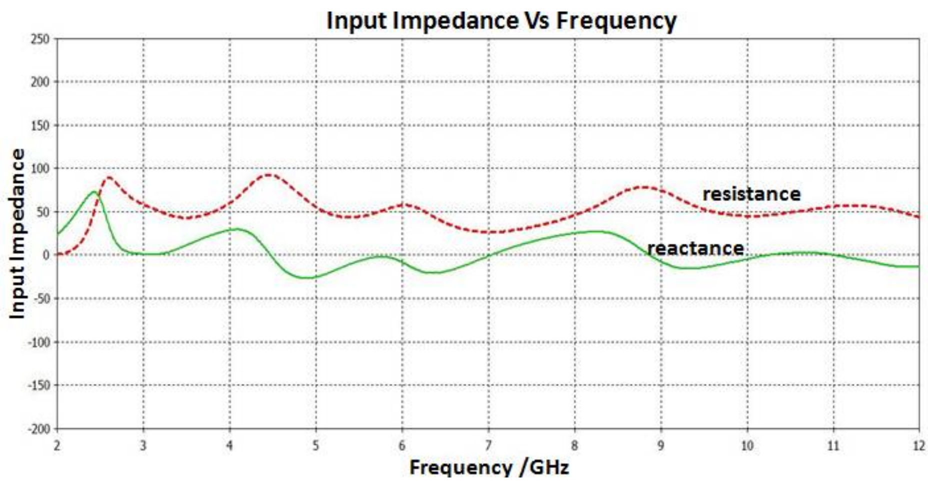

Fig .4 Input impedance Vs Frequency (GHz)

IV.CONCLUSION

Band notched printed elliptical slot antenna is presented with a very interesting and significant application as EMI sensor. The characteristics and performance of EMI sensor is presented in terms of antenna factor to measure the strength of radiated field in the antenna environment. This simulated work on the band notched elliptical slot antenna as an EMI sensor encourages the application of UWB antennas as EMI sensors. The study may be extended for the consideration of mutual coupling between the source and the antenna as EMI sensor.

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