Elliptical UWB Antenna with Quad Band Notch Functionality

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***ABSTRACT*—In this paper, a quad-band-notch Ultra Wideband (UWB) antenna is presented. The band-notch is achieved by introducing two meander-line slots in elliptical radiation element, a defected ground plane L-shape slot and an inverted U-slot in feed line. Four notches are achieved centered at frequencies WiMAX 3.5 GHz, IEEE 802.11a/n 5.2 GHz and 5.8 GHz and downlink X-band 7.4 GHz. The substrate employed is low-loss Rogers 5880. Measured results indicate that the proposed design not only supports UWB bandwidth requirements but also rejects four narrow bands to avoid possible interference with existing communication systems. Moreover, the proposed antenna has relatively omni directional radiation patterns in passbands.**

***Keywords* - Ultra Wideband (UWB), Band Notching.**

I. Introduction

In general, wireless technologies have gained significant focus over last few decades. A number of wireless standards are ubiquitous and some are in testing and deployment phase. The main aim of these wireless standards is to utilize minimum resources, achieve high data rate and cause minimum interference to other services. With wideband wireless domain growing rapidly, interference to other narrow band and wide band services is inevitable. The interferences, narrow band and wide band, impede the performance of wireless links [1–4].

The US Federal Communication Commission (FCC) has assigned license free frequency band of 3.1 to 10.6 GHz for Ultra Wideband (UWB) technology. A bandwidth of 7.5 GHz is attractive for attaining high data rates. However, the FCC has imposed power level restriction of -41 dBm/ MHz. The restriction on transmitting power is mainly because of interference concerns. The UWB spectra allowed for UWB communication overlaps other wireless standards. These wireless standards contain but are not limited to IEEE 802.16 WiMAX operating at 3.3-3.6 GHz ; IEEE 802.11a/n operating at 5.15-5.35 and 5.725-5.825 GHz and the downlink X-band satellite communication systems operating at 7.25-7.75 GHz. The presence of narrow and wide band standards create interference to and from the UWB radio [5–7]

RF filtering helps to mitigate the interference signals. However, the wireless hand held devices are compact and traditional filtering fails mainly due to cost and complexity.

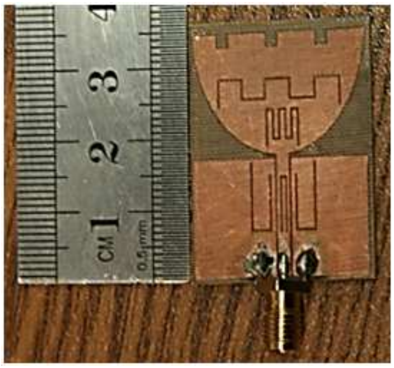


Fig. 1 Fabricated Antenna

A feasible way is to implement band notching in Ultra Wideband antenna to mitigate the interference. However, designing and placement of these structures is challenging as compared to the traditional RF filtering techniques [8]. The layout of the rest of the paper is as follows: the antenna element and notching structure layout is given in Section II, in Section III simulation and measured results are discussed and finally Section IV concludes the paper.

II. Antenna Element and Notching Structure Design

The fundamental challenge in the implementation of band notching is proper placement of notching structure in the feed line, ground plane and radiating element to effectively filter out the band of interest. The proposed notching structures are etched on the position where maximum current density can be achieved. Firstly, semi-elliptical antenna is designed for incorporating band-notch. HFSS software is utilized to conduct Finite Element Method (FEM) based simulations for this design. The antenna system is analyzed with and without the notching structures. The proposed design, with band notching structures is shown in the Figs. 1 and 2. The band notch is implemented by using following formula

$$f_r = \frac{C}{2L\sqrt{\varepsilon_{eff}}}, \tag{1}$$

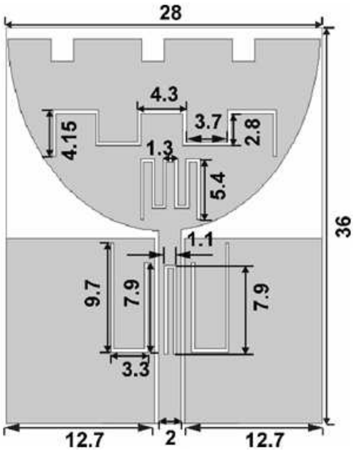
and

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2}, \tag{2}$$

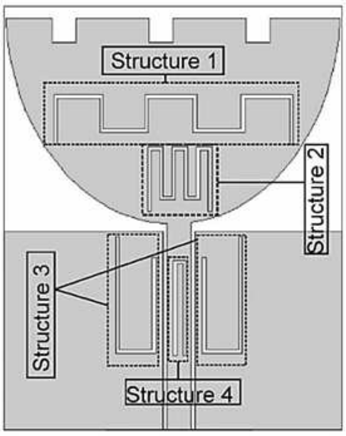
where f_r = Resonance frequency and L = Length of notching slot.

A. Notching structure for WiMAX

The structure 1 is designed for notching the WiMAX standard centered at 3.5 GHz. The structure consist of meander-lines. Calculated length to notch the WiMAX band is L = 32.5 mm placed in the main radiating element. The VSWR and surface current density result of the proposed structure is shown in Figs. 3a and 4.



(a) Antenna element dimensions (mm)



(b) Antenna element with four notching structures

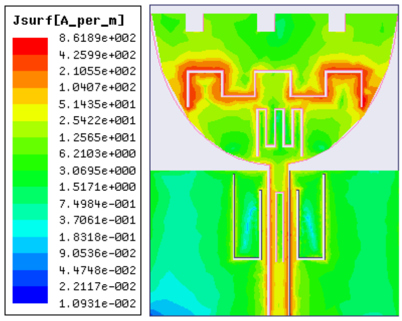
Fig. 2 Antenna element dimensions and notching structures

B. Notching structure for Lower WLAN

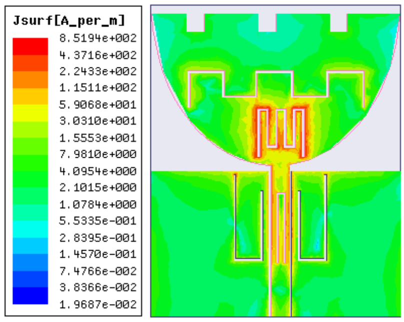
The structure 2 is proposed to notch Lower WLAN, centered at 5.25 GHz. The structure again consists of meander lines. The calculated length to notch the Lower WLAN band is L = 22.5 mm and is placed in the radiating element, close to feed line end. The surface current density and VSWR are shown in Figs. 3b and 4 respectively.

C. Notching structure for Upper WLAN

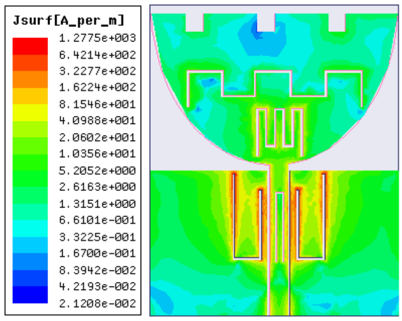
The structure 3 is suggested to notch the upper WLAN, centered at 5.75 GHz. It consists of U-shape slot etched in the ground plane. The slot length L = 20.5 mm is used to filter out the upper WLAN. The surface current density and VSWR graphs are shown in Figs. 3c and 4 respectively.



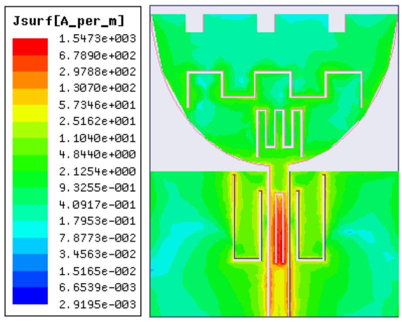
(a) WiMax 3.5 GHz



(b) Lower WLAN 5.25 GHz



(c) Upper WLAN 5.75 GHz



(d) Downlink of X-band satellite 7.4 GHz

Fig. 3 Surface current density

D. Notching structure for Downlink of X-band satellite

The downlink X-band satellite communication is centered at 7.4 GHz, this band is notched with structure 4 which consists of inverted U-shape slot having length L = 16 mm, etched in the feed line of the antenna. The surface current density and VSWR graphs are shown in Figs. 3d and 4

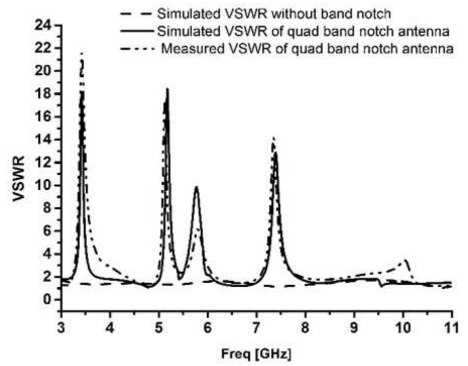
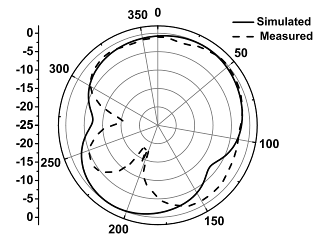
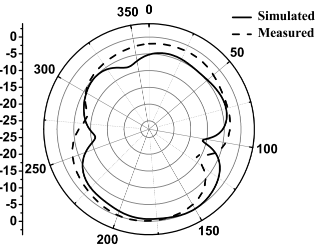


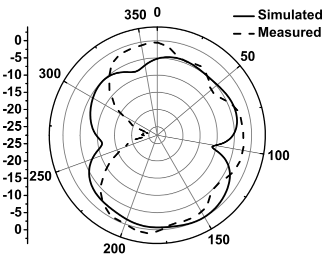
Fig. 4 VSWR of Elliptical UWB Quad Band Notch antenna



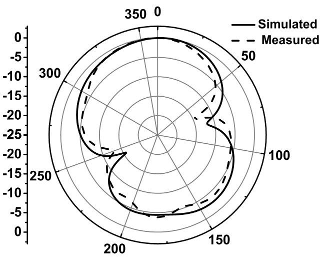
(a) E-Plane at 4 GHz



(b) H-Plane at 4 GHz



(c) E-Plane at 8 GHz



(d) E-Plane at 8 GHz

Fig. 5 E-Plane and H-Plane Radiation [dB]

respectively.

III. Simulation and Measurement Results

The results of the proposed antenna design have been presented here. Primarily the performance has been gauged in terms of VSWR and Surface current density. In addition to this, the *radiation characteristics* of the proposed design have also been highlighted.

A. VSWR Performance

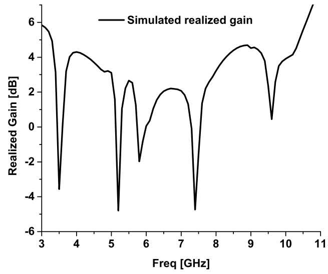
The simulated and measured VSWR of the proposed design at WiMAX, Lower WLAN, Upper WLAN and downlink X-band is shown in Fig. 4.

B. Surface Current Density (Jsurf)

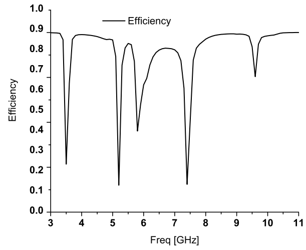
The effect of notching structure is analyzed with the help of surface current density as shown in Fig. 3. High surface current density is observed around the notching structures at relevant resonant frequencies.

C. Radiation Characteristics

The radiation characteristics of proposed quad-band notch antenna are analyzed at 4 GHz and 8 GHz. Radiation patterns for E-field and H-field are shown in Fig. 5, which are omni directional at lower frequency. Little distortion at higher frequency is observed within allowable limit.



(a) Gain



(b) Efficiency

Fig. 6 Gain and Efficiency Plots

D. Gain and Efficiency

Lower values of gain and efficiency has been observed at the notch bands as shown in Figs. 6a and 6b respectively.

IV. Conclusion

This paper proposes an elliptical UWB antenna with quad-band notch functionality. The antenna is implemented on 1 mm thick low-loss Rogers 5880 substrate. The antenna system has compact dimensions of 28 mm x 36 mm. The notching structures are optimally placed in the main radiation element, ground plane and feed line. Meander-line slot, L-shape slot, and inverted U-slots are etched to filter out WiMAX, lower and upper WLAN as well as downlink X-band. Antenna system is analyzed with help of VSWR, surface current density and radiation characteristics. More important to that is the measured results are in good agreement with the simulated results.

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