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Maple Leaf Shaped UWB Monopole Antenna with Dual Band Notch Functionality

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Abstract—A sharply rejected dual notch band UWB monopole antenna is presented in this paper. The proposed antenna consists of maple leaf shaped radiating element, a $50\,\Omega$ microstrip feed line and truncated ground plane. The proposed antenna shows the UWB operation in the frequency range (1.7 GHz–11.1 GHz) with VSWR < 2 except the notch bands and two band notches centered at 4.3 GHz and 7.7 GHz. The band notches are achieved by introducing a meandered slot in the radiating element and U-shaped slot in feed line. The substrate used for designing of UWB antenna is low loss Rogers 5880 having relative permittivity of 2.2. The novelty of the proposed antenna is its shape and ability to support UWB bandwidth requirements, and it also rejects two bands to avoid possible interference with existing communication system. Good agreement between the simulated and measured results is observed. The proposed antenna has good gain and efficiency at pass bands.

1. INTRODUCTION

Since the Federal Communications Commission (FCC)'s choice to allow unlicensed operation band from 3.1 to 10.6 GHz in 2002, the ultra-wideband (UWB) has been getting progressively well known in scholarly and industry fields. As an important part of UWB wireless communication system, the UWB antenna has drawn expanding consideration [1–4]. The possible UWB antenna ought to be designed with small size, good impedance matching, level group delay and omnidirectional radiation pattern [5]. In any case, a perpetual test is that there is interference between the composed UWB framework and some overlapping frequency bands. In order to avoid the interference, it is important to sift through the covering frequency bands. A common way to address this need is to connect filters to the UWB RF front end to block unnecessary frequency bands. However, this approach may consume an excessive amount of room and prompts huge increment in the outline intricacy. A feasible way is to implement band notching in UWB antenna to mitigate the interference. However designing and placement of these notch creating structures are challenging as compared to the traditional RF filtering technique [6, 7]. In spite of the fact that different UWB printed antennas with band-notched functionality have been as of late displayed, a large portion of which were composed with one notched band [8], two notched bands [9], or three notched bands [10] at their mentioned frequency bands. In [11], a quadrilateral slot patch and ring resonators are designed on multilayered planes to produce notches at desired frequency bands. For instance, in [12] a single notch is created in UWB antenna by utilizing an open loop resonator on the back side of the substrate. A couple of nested C-shaped stubs are used in [13] to generate multiple notch bands. In [14] crescent-shaped resonators are designed on the ground plane of the antenna and shorted with radiation element through via holes to generate multiple notches. Further, utilizing more minimal resonators for band-notch printed antennas is additionally worth concentrating on.

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This paper presents a low cost microstrip fed compact and sharply rejected dual band notch UWB monopole antenna. In this paper, a novel structure for the UWB antenna is proposed and analyzed in term of reflection coefficient, VSWR, gain and radiation pattern. The notch bands in the proposed antenna are achieved using U-slot and meandered lines in the feeding line and radiating patches respectively.

2. ANTENNA DESIGN

The geometry and configuration of the proposed antenna is given in Fig. 1. The antenna is designed on low loss substrate of Rogers 5880 having dielectric constant $\varepsilon_r = 2.2$ and height $h_s = 1.575$ mm. The length of the feed line is $\lambda g/2$ and the width of the microstrip line is chosen as 4.78 mm to achieve line characteristic impedance of 50 Ω. The radiating element and the feed line are designed on the top of the substrate and the ground plane is designed on the bottom of the substrate. The patch is a modified rectangular radiator with a double step cut in the lower edge of the radiator. The steps cut in the radiating patch always play a vital role in achieving wide bandwidth.

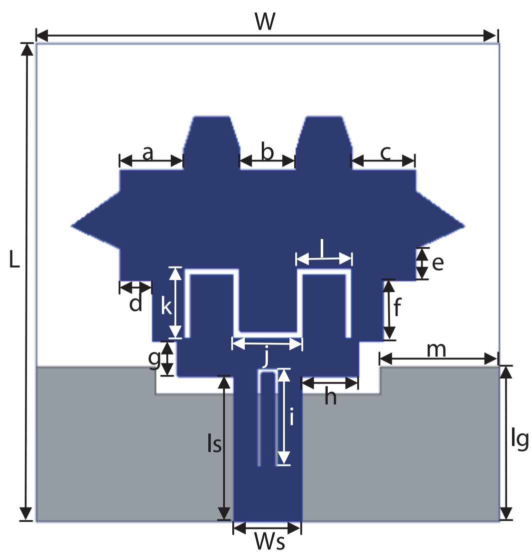

Figure 1. Top view of the proposed UWB antenna.

The optimized parameters of the proposed antenna are given in Table 1.

Table 1. Summary of the dimensions of the proposed antenna.

Parameter	Dimensions (mm)	Parameter	Dimensions (mm)
a	4.5	g	2.54
b	4.0	h	4.04
c	4.5	i	7
d	2.275	j	5
e	2.24	k	4.5
f	4.31	l	4
Ws	4.78	Lg	11.11
ls	10.3	m	8.5
L	34	W	33

The fundamental challenge in the implementation of band notching is proper placement of notching structures in the feed line, radiating patch or ground plane to effectively filter out the band of interest. The proposed notching structures are designed on the position where maximum current density can be achieved. HFSS software is used to conduct Finite Element Method (FEM) based simulations for this design. The antenna is analyzed with and without band notching functions. Firstly a maple leaf shape UWB antenna is designed and results showed that the proposed antenna covers a wide range of frequencies without having single notch. Meandered slots are made in radiating patch and feed line in the same design to achieve band notch functionality. The proposed design with band notch functionality is shown in Fig. 1. The band notch is implemented by using the 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 = resonant frequency and L = length of the slot.

2.1. Notching Structure for 4.3 GHz

The first structure is designed to produce a notch at 4.3 GHz. The structure consists of meander lines on the main radiating element. Calculated length to produce a notch at 4.3 GHz is 27 mm. The surface current density of the proposed structure is presented in Fig. 2.

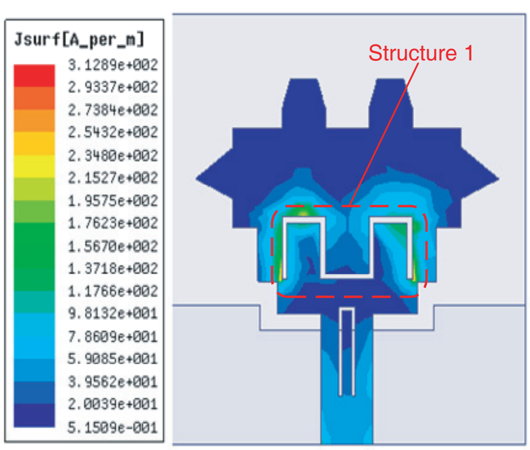

Figure 2. Surface current density at 4.3 GHz.

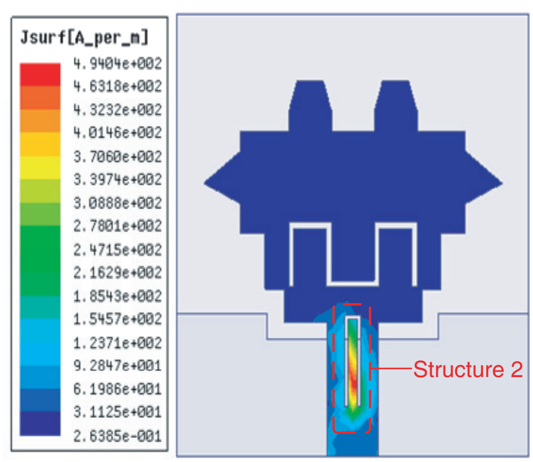

Figure 3. Surface current density at 7.7 GHz.

2.2. Notching Structure for 7.7 GHz

The second structure is designed to produce a notch at 7.7 GHz. Notch is produced in the designed antenna because of the U-shape slot on the feeding line to filter out the unwanted frequencies centered at 7.7 GHz. Calculated length to produce a notch at 7.7 GHz is 15.4 mm. The surface current density of the proposed structure is presented in Fig. 3.

3. RESULTS AND DISCUSSION

The results of the proposed UWB antenna design are presented here. The reflection coefficient (S_{11}), Voltage Standing Wave Ratio (VSWR) and gain of the proposed antenna are analyzed in the following sections.

3.1. Reflection Coefficient

Reflection coefficient (S_{11}) shows the fraction of power being reflected backwards from the antenna input to the excitation port. It is measured in decibel (dB) and is given by:

$$S_{11} = -20\log_{10}\left|\frac{Z_{in} - Z_0}{Z_{in} + Z_0}\right| \tag{3}$$

where, Z_{in} is the driving point impedance of the proposed antenna, and Z is the characteristic impedance of the $50\,\Omega$ SMA port. The simulated result of the proposed UWB antenna with and without notches is shown in Fig. 4.

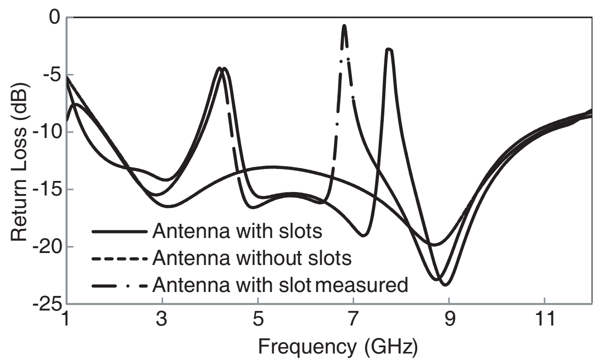

Figure 4. S_{11} of the proposed antenna with and without notches.

It is obvious from Fig. 4 that the operating frequency of the proposed antenna without notches is from 1.7 GHz to 11.1 GHz. Meandered line is made on the radiating element to produce notch at 4.3 and U-shape slot on the feeding line to produce notch at 7.7 GHz.

3.2. Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio of the maximum to minimum voltage (or electric fields) along the transmission feed line of the proposed antenna. Fig. 5 compares the simulated results of the proposed UWB antenna with and without notches. The proposed antennas without notches have VSWR < 2 for all frequencies from 1.7 GHz to 11.1 GHz.

As obvious from Fig. 2 and Fig. 3, the two notches in the pass band of the UWB antenna are created by the two structures in the radiating patch and feeding. The effect of varying U-slot length (i) on the antenna is shown in Fig. 6. It is noticeable that changing the U-slot length (i) value only

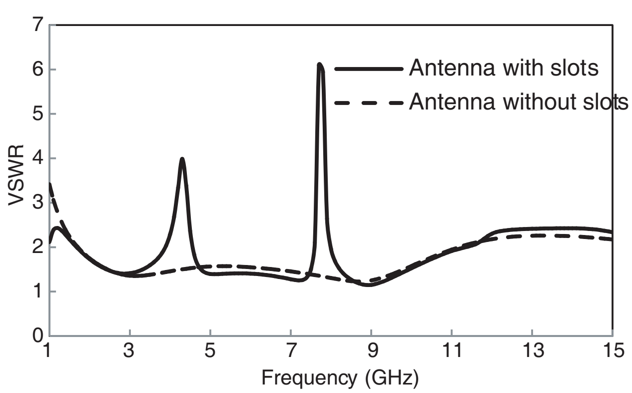

Figure 5. VSWR of the proposed antenna with and without notches.

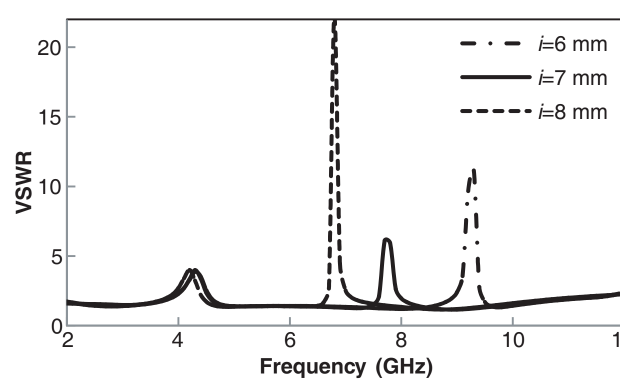

Figure 6. VSWR for varying values of i.

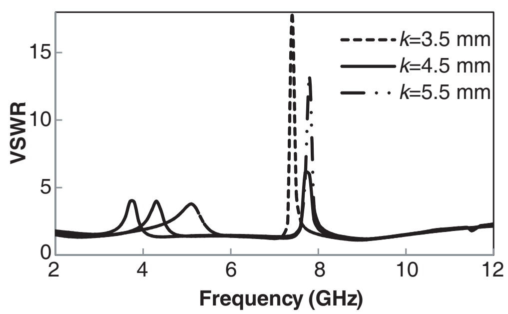

Figure 7. VSWR for varying values of k.

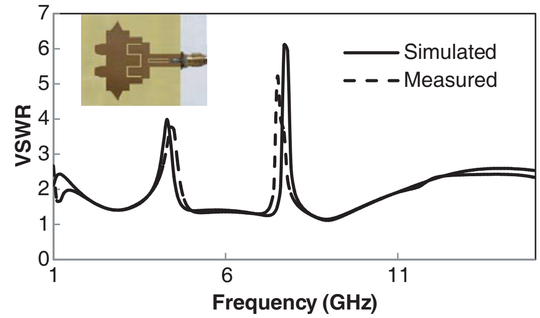

Figure 8. Simulated and measured values of proposed UWB antenna.

shifts the higher notch band while the lower notch band remains the same. Varying the parameter k has only effect on the lower notch band while higher notch band remains the same. The effect of varying parameter k is shown in Fig. 7.

Figure 8 shows the simulated and measured VSWRs of the proposed UWB antenna. A good agreement between the simulated and measured results is observed.

3.3. Surface Current Density (Jsurf)

The effect of the notching structure is analyzed in terms of surface current density as shown in Fig. 2 and Fig. 3. High surface current density is observed around the notching structure at relevant resonant frequencies.

3.4. Radiation Characteristics

The radiation characteristics of the dual band notch UWB antenna are analyzed at 2.6 GHz and 8.9 GHz. Simulated and measured Radiation Pattern for phi = 0 and phi = 90 are shown in Fig. 9 and Fig. 10. It is clear from Fig. 9 and Fig. 10 that the radiation pattern at lower frequency is omnidirectional while a little distortion at higher frequency is observed. The gain of the antenna is found to be 3.96 dB at 2.6 GHz and 1.30 dB at 8.89 GHz.

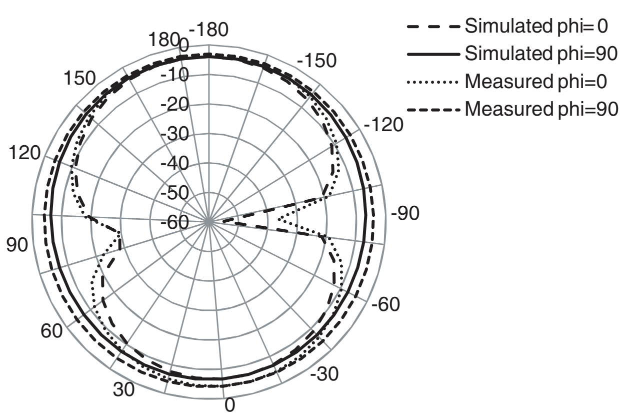

Figure 9. Radiation pattern at 2.6 GHz.

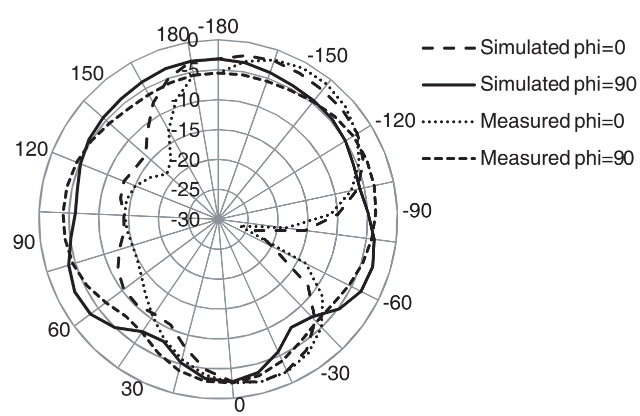

Figure 10. Radiation pattern at 8.9 GHz.

3.5. Gain

The simulated maximum gain of the proposed UWB antenna is shown for the dual band notches and without notches in Fig. 11 and Fig. 12, respectively. It is very clear from Fig. 11 that antenna without

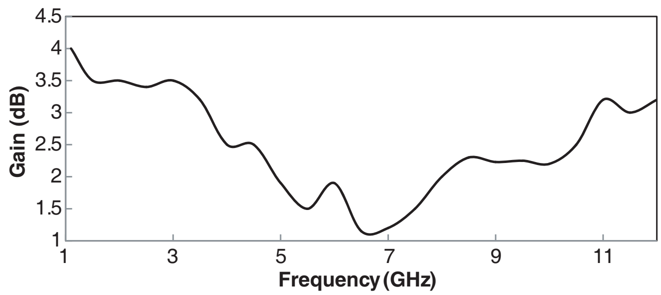

Figure 11. Simulated gain of the proposed antenna without notches.

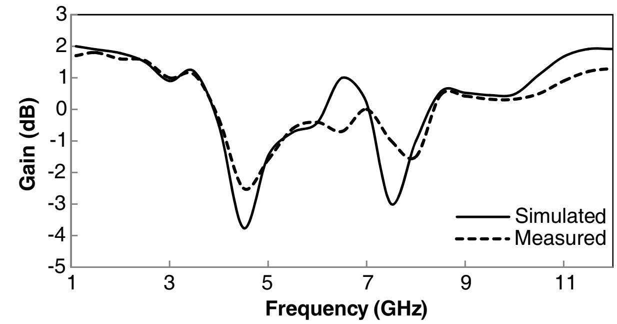

Figure 12. Simulated gain of the proposed antennas with dual notches.

notches has somewhat flat gain for all pass band without having much more reduction in any specific band. In case of notched antenna two sharp reductions in the gain can be observed as shown in Fig. 12. The reduction in the gain is because of the two sharply notched bands.

4. CONCLUSION

This paper proposes a maple leaf shape UWB antenna with dual band notch functionality. The antenna is simulated and fabricated on the low loss material of a Rogers 5880 substrate. The antenna system has compact dimensions of $33 \times 34 \times 1.575$ mm. Notches in the proposed antenna are created by optimally placing notching structures in the radiation element and feeding line. The antenna system is analyzed in term of return loss, VSWR, surface current density and radiation characteristics and gain. A good agreement is observed between the simulated and measured results.

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