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REGULAR ARTICLE

Dual Notched Miniaturized Super Wideband Antenna Using Parasitic Strip and Slot

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In this proposed article authors present the design and analysis of a miniaturized dual-notched super wideband (SWB) monopole microstrip antenna for various wireless communication applications. Initially a monopole reference SWB antenna is designed by semi-circular shaped radiating patch and perfectly positioned notch loaded reduced ground plane. Final proposed antenna structure incorporates properly positioned 'U' shaped slot on the radiating patch and a 'U' shaped parasitic strip resonator on the modified ground plane to eliminate mainly 5 GHz WLAN frequency band and 7.2 GHz satellite downlink frequency bands, respectively. The suggested antenna accomplishes two notch bands without the need of two separate filters. Thus, the suggested antenna is likewise smaller one also. Having a footprint of 26 × 27 × 1.588 mm^3 the proposed antenna exhibits large impedance bandwidth of 22.64 GHz (2.48 to 25.12 GHz), fractional bandwidth of 164% and Bandwidth Dimension Ratio (BDR) of 3374. Mathematical analysis and modification processes that were included into the original reference antenna to meet the required design objectives have been presented. The proposed antenna has been designed and simulated. The suggested antenna is designed on a Rogers RT/Duroid® 5880 substrate (h = 1.588 mm, ε_r = 2.2, and tan δ = 0.0009) and simulated by using CST Microwave Studio Suite Software.

Keywords: Band notched, Miniaturized, Super wideband, Wireless communication.

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1. INTRODUCTION

Antennas seldom possess a wide bandwidth and a high gain simultaneously. In case of scarcity of space, an antenna with a wide frequency range and moderate gain is a better compromise. The unprecedented advantages that include higher data rates, low power consumption, less cost, especially compared to conventional narrow-band antennas, make wideband counterparts more appealing. Various potent methods like intrinsic techniques, proximity coupled and aperture-coupled patches, applying horizontally coupled patches to driven patch on a single layer and stacked patches can enhance bandwidth [1-2]. Technical challenges in design and analysis of Super Wide Band antennas for wireless application have been discussed in [3]. J. S. Abdaljabar et al. in [4] proposed hybrid shape multiband microstrip patch antenna for wireless application. T. Tewary et al. [5-7] proposed various shaped miniaturized wideband antenna by loading suitable size slots on radiating patch, ground plane and feedline. S. Maity et al. [8-9] proposed hybrid shape super wideband (SWB) antenna for wireless communication application. Hybrid shape of the patch enables to achieve better impedance matching. But to avoid the electromagnetic interference between the wideband antenna system and the existing wireless system, band notch functionality is also necessary. P. P. Shome et al. [10] reviewed most recent techniques to achieve notch band characteristics in wideband system. These includes U/L/H/C/G shaped slot loading on radiating patch, parasitic segments in the bottom of substrate, loading of capacitive loop resonators, T shape, Arc shape, open ended suitable length slot or stub loading in feedline, Electromagnetic Band Gap (EBG) coupling etc. In [11] P. Mayuri et al. proposed compact dual notch Ultra Wideband (UWB) monopole antenna. Two double split ring resonators (DSRRs), one on each side of the feed, and an inverted pi-slot in the patch element are used to provide the band notch characteristics. M. Shi et al. [12] proposed coplanar waveguide fed ultra-wideband antenna with band notched characteristic. One pair of half-wave-length stubs and slits is placed inside the tapered slot and circular patch, respectively, on the basis of a UWB antenna, to obtain a crisp and controlled notch-band feature. F. Guichi et al. [13] rejected two frequency bands from UWB monopole antenna by using 2 parasitic stubs that are inserted on the patch, and an inverted U-shaped slot that is etched on the transmission line, respectively. V. K. R.

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Devana and A. M. Rao modified elliptically slotted antenna by etching S-shaped slot in the microstrip feed line and an asymmetrical C- shaped parasitic stub above the DGS, respectively to achieve two notch band characteristics.[14].S. Mukherjee et al. [15-16] presented analysis of dual notch band antenna by using parasitic strip and slot. N. Jaglan et al. [17] presented defected ground compact electromagnetic band gap (DG-CEBG) designs to accomplish notch band phenomenon. O. P. Kumar et al. [18] introduced an inverted-U-shaped and conductor-shaped resonator to achieve dual-band notch characteristics. In [19] S. Mukherjee et al. presented detailed design and analysis of a triple notch band UWB antenna by using strip, slot and EBG.

In this article, a planar microstrip monopole SWB antenna with a dual band-notch attribute has been demonstrated. A 'U' shaped slot has been incorporated into the radiating patch to eradicate the 5 GHz WLAN band. Furthermore, by introducing a 'U' shaped ground plane, a notch band at 7.2 GHz downlink frequency for satellite communication has also been achieved. In the proposed design, two different techniques have been applied to attain two notch bands. Detailed calculations are also included for the two different techniques. The proposed antenna is also a miniaturized one with high BDR value of 3374.

2. REFERENCE ANTENNA

Fig. 1 illustrates the radiating patch and ground plane configuration and dimensions (mm) of the initial reference antenna. Initially a substrate of dimension (26 mm × 27 mm × 1.6 mm) is taken as reference. On top of the substrate a semicircular shape radiating patch having radius of 13 mm is designed. The ground plane length is reduced to 11.5 mm and a rectangular notch is loaded just under the feed-line for better impedance matching throughout the band of interest.

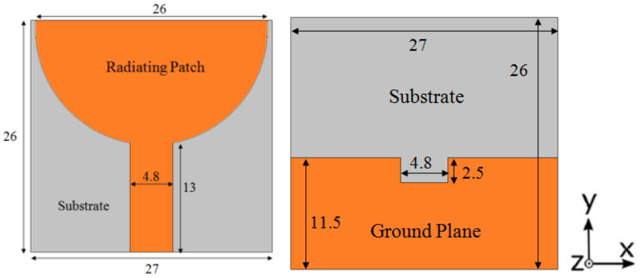

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Fig. 1 – Referenceantennaand dimensions of parameters (mm) (a) Radiating plane (b) Ground plane

3. DESIGN STEPS AND ANALYSIS OF PROPOSED ANTENA AND SIMULATED RESULTS

Fig. 2 illustrates evolution of the proposed antenna through four steps and Fig. 3 illustrates corresponding reflection coefficient for all design steps.

Step 1: This step shows the initial reference antenna. The geometrical configuration and dimensions of all parameters are already given in detail in previous section. With resonance behavior at 3, 5.8, 14.4, and 20.4 GHz, the simulation result of the designed antenna shows a SWB (2.5 – 25.25 GHz) phenomenon as can be seen from Fig. 3.

Step 2: Along with notch loaded reduced ground plane, a U-shaped parasitic strip is added to the ground plane. This serves as a parasitic resonator that can reject frequencies at 7.2 GHz. As a result, the downlink frequency for X-band satellite communication has been effectively removed. Fig. 4 (a) illustrates 'U' shaped Parasitic Strip loaded bottom of the substrate and Fig. 4 (b) shows surface current length along the parasitic strip. Fig. 3 illustrates simulated Reflection Coefficient (S_{11}) for only 'U' shape parasitic strip loaded reference antenna. The modified antenna exhibits SWB (2.5 – 25 GHz) characteristics with notch band characteristics from 6.9 – 7.32 GHz.

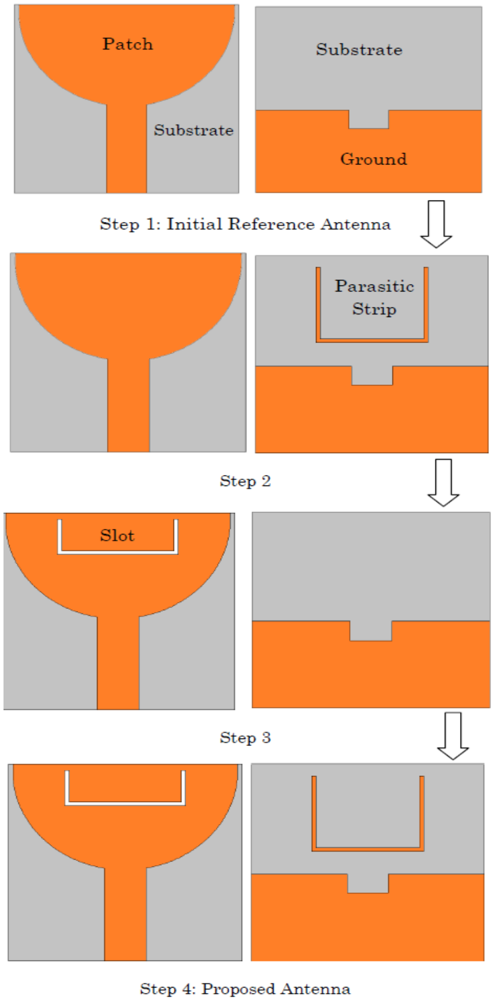

Fig. 2 – Evolution steps of the proposed antenna

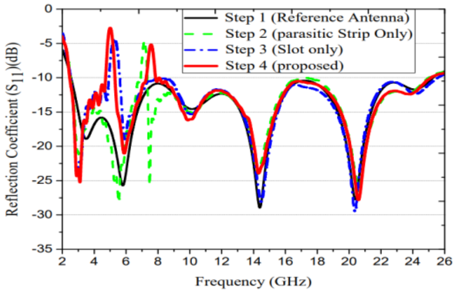

Fig. 3 – Simulated Reflection Coefficient for all the designed steps

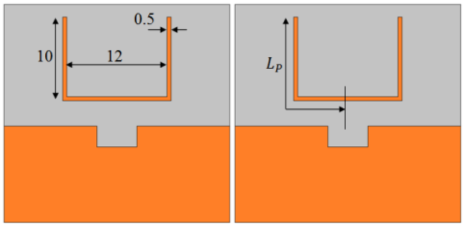

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Fig. 4 – (a) Proposed 'U' shape Parasitic Strip loaded ground, (b) Effective surface current path along strip

From the value of the effective current path length L_P for the center frequency of the notch band at 7.2 GHz can be calculated using the equation given below [20].

$f_{notch} = \frac{C}{2L_P\sqrt{\frac{\varepsilon_r+1}{2}}} = 7.18$ GHz; C = velocity of light; L_P = 16.5 mm; ε_r = relative dielectric constant of the substrate = 2.2

Step 3: Another band-rejection characteristic for the WLAN band is accomplished by engraving a 'U'-shaped slot on the metallic radiating patch. Fig. 5 (a) illustrates 'U' shape slot loaded radiating patch and Fig. 5 (b) shows surface current length around the slot. Fig. 3 illustrates simulated Reflection Coefficient (S_{11}) for only 'U' shape slot loaded patch of the reference antenna. The modified antenna exhibits SWB (2.5 – 25.53 GHz) characteristics with notch band characteristics from 4.9 – 5.6 GHz. from The value of the effective current path length L_{slot} for the center frequency of the notch band at 5 GHz can be calculated using the equation given below.

$f_{notch} = \frac{C}{2L_{slot}\sqrt{\frac{\varepsilon_r+1}{2}}} = 5$ GHz; $L_{slot} = 23.5$ mm;

Step 4:

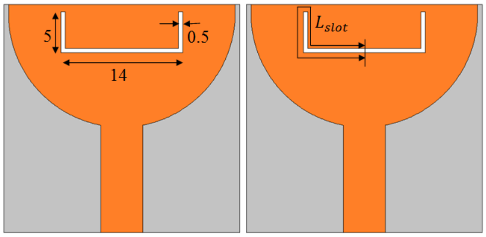

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Fig. 5 – (a) Proposed 'U' shape slot loaded radiating patch, (b) Effective surface current path around slot

This step illustrates simulated Reflection Coefficient (S_{11}) of the proposed antenna when both 'U' shape slot and 'U' shape parasitic strip are loaded simultaneously. It can be observed that the proposed antenna exhibits SWB characteristics from 2.48 to 25.12 GHz, with an impedance bandwidth of 22.64 GHz, percentage bandwidth of 164%, Bandwidth Dimension Ratio (BDR) of 3374 along with two notch band characteristics from 4.75 to 5.3 GHz (WLAN) and 7.1 to 7.5 GHz (satellite downlink).

Fractional bandwidth (% FBR), Bandwidth Dimension Ratio (BDR) are calculated by using the following relations. High BDR value confirms miniaturization.

$$FBR\ (\%) = \frac{F_H - F_L}{F_C} \times 100\ \% = 164\ \%$$

Where $F_L = 2.48\ GHz,\ F_H = 25.12\ GHz$

$$BDR = \frac{FBR(\%)}{\lambda_{antennalength} \times \lambda_{antennawidth}} = \frac{164}{0.216 \times 0.225} = 3374$$

Where λ corresponds to wavelength of 2.48 GHz.

Fig. 6 and Fig. 7 display peak gain and radiation efficiency comparison for initial reference antenna and proposed antenna. It can be noticed that at notch band frequencies (5 GHz, 7.2 GHz) efficiency and gain decreases significantly.

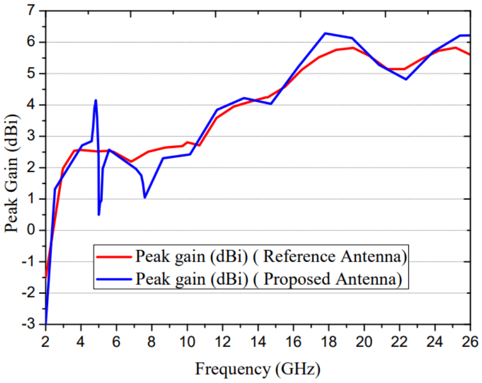


Fig. 6 – Peak Gain (dBi) comparison of reference antenna and proposed antenna

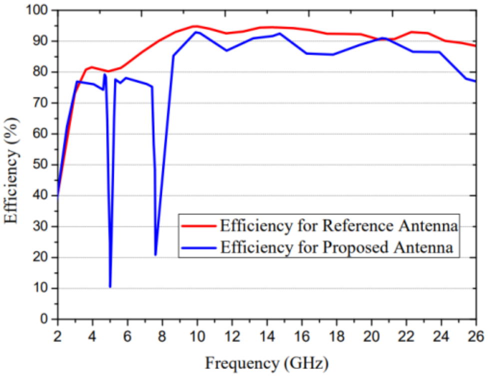
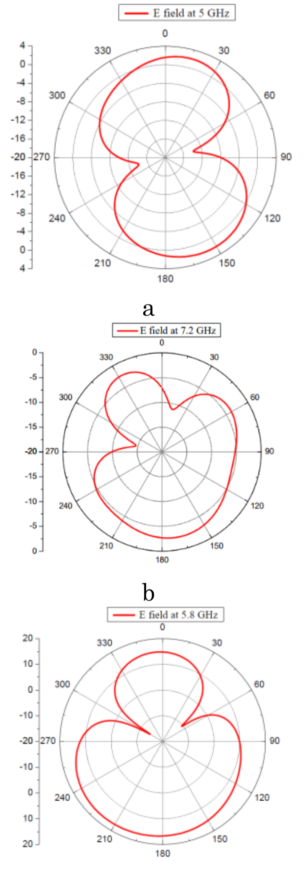


Fig. 7 – Efficiency (%) comparison of reference antenna and proposed antenna

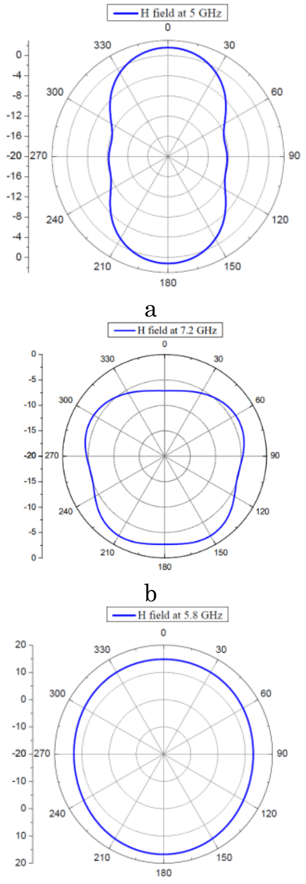


a

b

c

Fig. 8 – RadiationPatterns at (a) 5, (b) 7.2, (c) 5.8 GHz in E plane



a

b

c

Fig. 9 – Radiation Patterns at (a) 5, (b) 7.2, (c) 5.8 GHz in H plane

Figs. 8 and 9 show absolute simulated radiation pattern for the proposed antenna for the YZ-plane (E plane) and XZ-plane (H plane) respectively for two notched frequencies (5 GHz, 7.2 GHz) and one resonant frequency (5.8 GHz). It can be seen that gain at notch frequencies is very much less than gain at resonant frequency.

4. CONCLUSION

This literature has presented a design and analysis of a SWB antenna having dual band-notched properties. In the proposed design, two different techniques, namely, slot and strip, for getting notch band, are used. The simulated data for notched frequencies are explained with detailed mathematical formulation. Optimum values of important design parameters were taken to achieve desired elimination bands (WLAN and satellite communication downlink frequency of X-band).

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Мініатюрна супершироксмугова антена з подвійним пазом із використанням паразитної стрічки та слота

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У цій статті автори представляють проект та аналіз мініатюрної монопольної мікросмужкової антени з подвійним вирізом надширокосмугової (SWB) для різних програм бездротового зв'язку. Монопольна еталонна SWB антена розроблена за допомогою випромінюючої ділянки напівкруглої форми та ідеально розташованої зменшеної площини заземлення з виїмкою. Запропонована структура антени включає належним чином розміщений «U»-подібний проріз на випромінювальній ділянці та «U»-подібний резонатор із паразитною смугою на модифікованій площині заземлення, щоб усунути переважно смугу частот WLAN 5 ГГц і смуги частот супутникової лінії зв'язку 7,2 ГГц відповідно. Антена забезпечує два діапазони ріжків без необхідності використання двох окремих фільтрів. Таким чином, запропонована антена також є меншою. Маючи площу 26 × 27 × 1,588 мм^3, запропонована антена має широку смугу пропускання 22,64 ГГц (від 2,48 до 25,12 ГГц), часткову смугу пропускання 164 % і коефіцієнт розмірності смуги пропускання (BDR) 3374. Математичний аналіз і процеси модифікації, які були включені в оригінальну еталонну антену, щоб відповідати необхідним цілям дизайну. Запропонована антена розроблена на підкладці Rogers RT/Duroid® 5880 (h = 1,588 мм, ε_r = 2,2 і tan δ = 0,0009) і змодельована за допомогою програмного забезпечення CST Microwave Studio Suite.

Ключові слова: Смуга з насічкою, Мініатюризація, Супершироксмуга, Бездротовий зв'язок.