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COMPACT OCTAGONAL UWB ANTENNA WITH ENHANCED BANDWIDTH USING W-SHAPED SLOTTED GROUND PLANE

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Abstract - This article presents a compact microstrip-fed monopole Antenna, which consists of an octagonal patch with W-shaped truncation on the ground plane. By cutting a novel W shaped slot at the lower edge of the ground plane with regular octagonal shaped Radiator, input impedance bandwidth and the high frequency radiation characteristics can be improved significantly. Therefore antenna can operates in extremely wide usable fractional bandwidth of more than 146% (3.1-20 GHz).The enhanced frequency band also makes antenna suitable for X band and Ku band application. Equivalent circuit model is adopted to analyze the ultra wide band (UWB) characteristics of the proposed antenna. Good omnidirectional radiation patterns and relatively flat gain over the entire UWB frequency has been obtained. The transient response also promises the suitability of the proposed design for future UWB system application.

Keywords—W shaped truncation, octagonal patch, Ultra wideband, X and Ku band.

I. Introduction

The ultra wideband (UWB) system becomes more popular in wireless communication since US-FCC has assigned the frequency band of 3.1-10.6 GHz [1]. Wide band Monopole antennas have received considerable attention in UWB communication system mainly due to their large impedance bandwidth. Several UWB monopole antenna design have been proposed in previous literatures [2-16]. Such as beveled rectangular [2-4], pentagonal [5], hexagonal [6], arrow-shaped [7], arc-shaped [8], U-shaped [9], stepped V-shaped [10], pincers-shaped [11] or slotted M-shaped antenna [12].another approach to obtain enhanced operating band for UWB antenna can be achieved by implementing L shaped parasitic element and L-shaped slot pair combination on ground plane [13] or by cutting a pair of rotating H shaped slot[14] or by using pair of rotating E shaped slot on the ground plane[15] or by embedding pair of rectangular ring slot[16] etc. In this letter an octagonal monopole UWB antenna is proposed. The main focus of this article is to introduce a novel W shaped slot to the upper side of the ground plane. The novel W shaped slot is designed by inserting two symmetrical rectangular notches inside the U shaped slotted part of the ground plane which play a significant role in impedance matching. By implement symmetrical notch pair additional resonances at the higher frequency band can be generated. Closely spaced multiple resonances resulting in extremely wide band width from 3.1-20 GHz.

II. Antenna Design and Configuration

Figure.1 shows the geometry of the proposed antenna which is fabricated on RT/DUROID 5870 with relative permittivity 2.33 and thickness 1.6 mm.

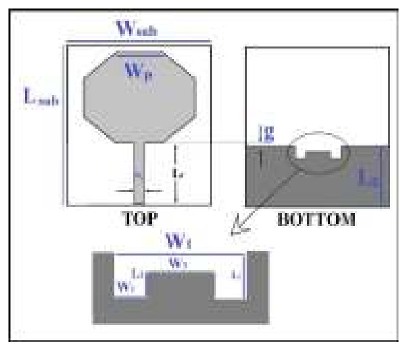

Fig. 1Configuration of the proposed antenna

The feed line microstrip width is 1.8 mm and it's length is 14 mm for 50-Ω impedance. Fig.2 illustrates the four different antenna geometry to clarify the phenomenon behind the development towards the proposed configuration. Antenna-1 consists of a simple rectangular radiating patch and the ground plane. The gap between the radiator and ground plane form an equivalent dipole antenna with fundamental resonance frequency which is mainly determined by the antenna length.

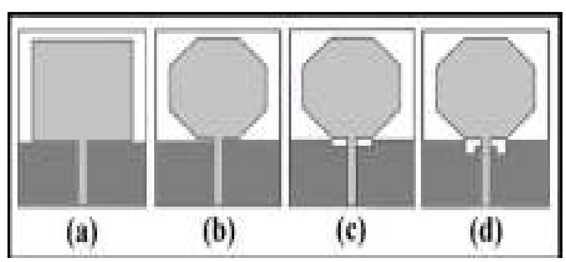

Fig. 2Geometry of (a) Antenna-1 (b) Antenna-2 (c) Antenna-3 (d) Proposed antenna

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In simple rectangular patch structure a sharp discontinuity in the connection point between the feed line and patch degrades the radiation performance of antenna .To obtain good impedance matching over a wide bandwidth, radiation patch is beveled , hence a regular octagonal patch geometry has been designed by placing four symmetrical bevel slot on the corners of rectangular patch referred as Antenna-2.octagonal shaped maintain a balance between the vertical and horizontal surface currents on the patch which affect the radiation characteristics of the antenna and broad impedance bandwidth can be achieved. Since ground plane is also a part of radiating configuration, hence an U shaped truncation on the upper edge of the ground plane introduces a coupling capacitance and plays a significant role in impedance matching in Antenna-3.The proposed antenna consist of a modified W shaped truncation on the upper edge of the ground plane. Inside the truncated part of the ground plane a symmetrical pair of U shaped notches has been introduced to obtain the W shaped truncation on the ground plane. It is found that additional notch pair inside the U shaped truncated part provides much better electromagnetic coupling between theoctagonal patch and the ground plane which further increases the surface current path and enhances travelling wave mode radiation which ultimately increases the sensitivity of the impedance bandwidth in the higher and lower frequencies of the band . Equivalent circuit model of the proposed geometry has also been carried out to comprehend the design mechanism. The conventional rectangular patch antenna can be considered as a parallel RLC equivalent circuit which displays the resonance effect with narrow bandwidth. The adjacent resonances which have been generated by the step by step design modifications yield extremely wide UWB frequency response of antenna. Each step of the modified geometry represents the parallel RLC equivalent circuit. Equivalent circuit representation of the proposed multiband UWB antenna is shown in Fig.3.

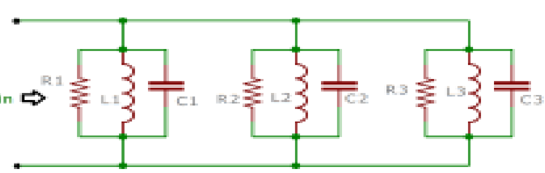

Fig. 3Equivalent Circuit Model of the proposed UWB antenna

The input admittance Y_{in} can be analyzed by [17].

$$Y_{in} = \sum_{k=1}^{3} \frac{j\omega L_k + R_k[1-\omega^2 L_k C_k]}{j\omega L_k R_k} \text{-------- (1)}$$

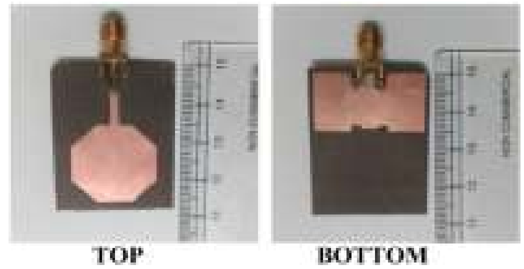

Fig. 4prototype of proposed antenna

The optimal dimension of the proposed antenna design is as follows. W_{sub}= 26 mm, L_{sub}= 36.6 mm, L_P = 8.42mm, L_f = 14mm, W_f =1.8mm L_g = 14mm, W_1= 9mm, L_2 = .8mm, W_2= 2.5mm,W_3= 4mm, L_1=1.6mm, g = .3mm The antenna is subsequently fabricated with optimal parameters as shown in Fig.4.

III. Results and Discussion

In this section various antenna structures are used for simulation studies as shown in Fig.5. The simulation results are obtained by using Finite element method (FEM) software HFSS [18].it can be observed that return loss characteristics are similar for different antennas at low frequencies, but high frequency impedance matching and higher resonance frequency changes significantly for different antenna structures. Though Resonance frequency of Antenna-1 at 6.3 GHz depends on patch length yet the return loss behavior is identical to narrowband dipole. For Antenna-2 the octagonal patch has been introduced by using four symmetrical bevels on rectangular patch which improves the higher band impedance matching by the generation of additional resonance at 14.2 GHz, which contributes to the widening of operating bandwidth. Since U shaped truncation in ground plane acts as an impedance matching element in Antenna-3, hence much enhanced impedance bandwidth can be achieved by using U shaped slot at the upper edge of the ground plane. However U shaped truncation on ground plane cannot form a good slot with the radiating patch to fully support travelling waves at higher frequencies. In proposed Antenna the modified W shaped truncation on ground plane significantly improves the

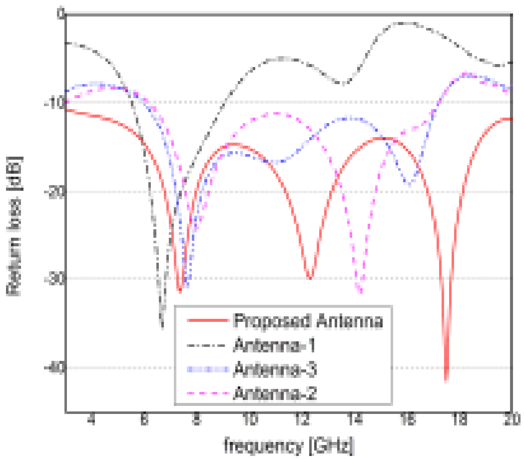

Fig. 5 Simulated return loss for various antenna

Geometry impedance matching condition where the usable upper frequency band extended from 17.23 GHz to 20 GHz. Return loss performance of the proposed antenna exhibits two additional resonances at 12.2 and 17.5 GHz along with lower resonance frequency at 7.3 GHz. The length (L_2) and width (W_2) of U shaped notch pair are most critical parameters. The simulated return loss characteristics with different values of L_2 is plotted at Fig.6, where W_2 is constant at 2 mm.it is observed that as L_2 increases, impedance mismatch between radiating patch and the ground plane improves which deteriorates the return loss performance, as a result of which 10dB impedance bandwidth decreases.

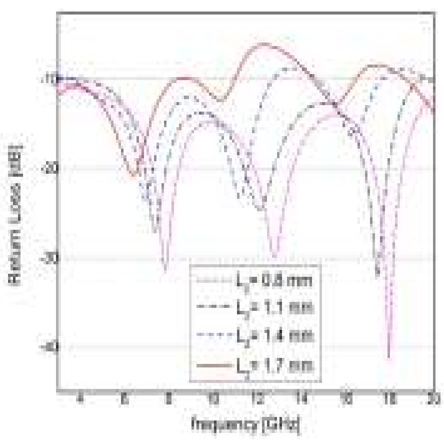

Fig. 6 Simulated return loss with different values of L_2

Fig.7 illustrates the return loss performance for various notch width W_2.it is seen that as W_2 increases the effective value of $W_3 = W_1 - 2W_2$ is gradually decreases and in the

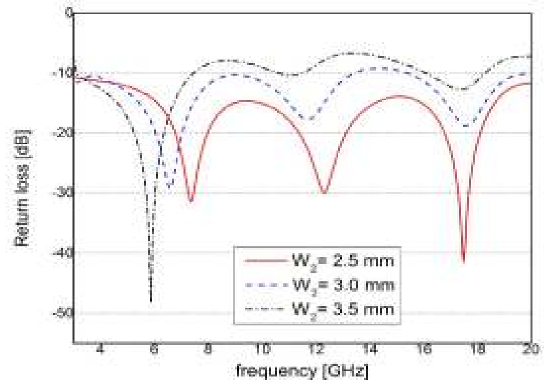

Fig. 7 Simulated return loss with different values of W_2

Simulated return loss curves the fundamental resonance frequency is lowered but return loss behavior for the higher frequency band become worse simultaneously due to the poor matching condition, consequently antenna behaves as narrow band dipole.

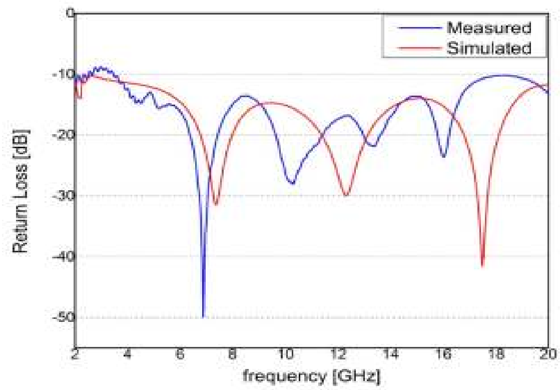

Fig. 8 Measured and simulated return loss

Fig.8 shows the measured and simulated return loss characteristics of the proposed antenna.

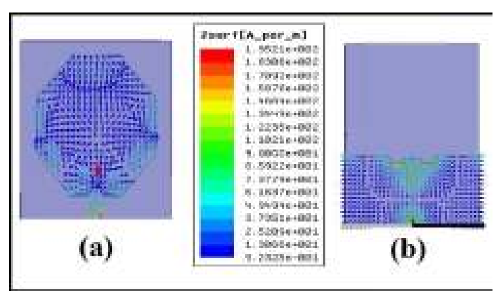

Fig.9 Simulated surface current distribution of the proposed antenna (a) at 12.2 GHz (b) at 17.35GHz

The fabricated antenna very well covers the intended return loss of < -10dB for 3.1-20 GHz. The phenomenon behind the additional resonance generation can be understood by the surface current distribution mechanism of the proposed antenna as shown in Fig.9.For the second resonance at 12.2 GHz the surface current mainlydistributed at the outer periphery of the octagonal patch which establish the utility of octagonal patch construction. At the third resonance frequency of 17.5 GHz the ground plane current mainly concentrated around the W shaped slotted portion of the ground plane.

Fig.10 shows measured radiation patterns at 7 and 12 GHz respectively. It can be observed that the radiation characteristics of x-z plane (H-plane) are all omnidirectional and stable, while the y-z plane(E-plane) patterns are bidirectional and it become worse with increasing frequency.

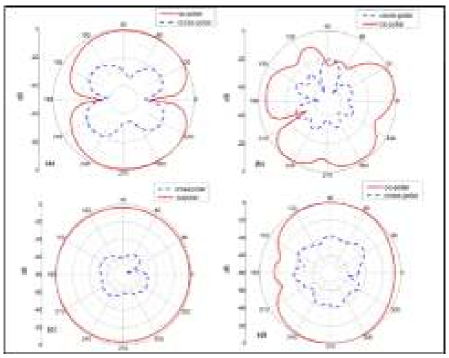

Fig.10 Measured radiation patterns (a) E-plane (b) H-plane

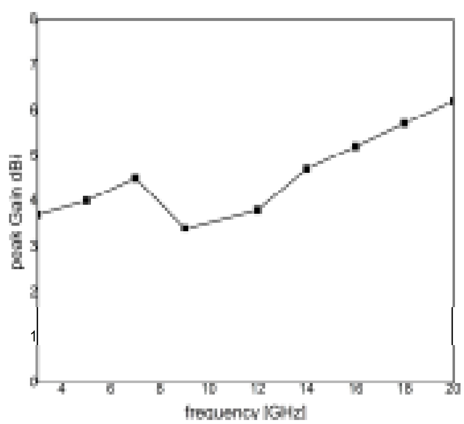

Fig.11 Measured peak Gain of the proposed antenna

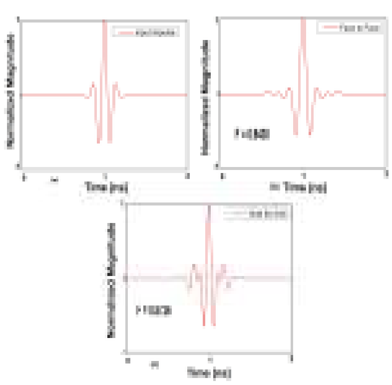

Fig.12 Transient response of the proposed antenna (a) Waveform of the transmitted pulse(b) Waveform of the received pulse (face to face) (c) Waveform of the received pulse (side by side)

Fig.11 shows the measured peak gain of the proposed antenna from 3.1 to 20 GHz. The maximum gain variation is less than 2.9 dB with peak gain at about 6.2 dBi. To observe the level of distortion imposed on the transmitted pulse by the proposed octagonal monopole antenna, the transmitted antenna is fed by a Gaussian excitation pulse .The received signal in face to face and side by side orientation in Fig.12 clearly shows the distortion and broadening of the received pulse. The fidelity factor between transmitted and received pulse in face to face to face is orientation is .9438 and for side by side orientation is .8726. Therefore the proposed antenna could satisfactorily retain the original waveform at the receiving end.

IV. Conclusion

A Regular octagonal monopole UWB antenna has been design and investigated. The distinctive feature of this design is the implementation of novel W shaped slot on the upper edge of the ground plane. Therefore bandwidth enhancement and matching improvement are noticeably obtained. Moreover the proposed Antenna can be demonstrated as a planer dipole or conversely as a planer monopole by adjusting the dimension of slot on the ground plane. The measured result illustrate that the bricated antenna offers extremely wide impedance bandwidth from 3.1-20 GHz. Proposed antenna also exhibit good radiation patterns and Gain performance throughout the operating band. Therefore the proposed antenna can be utilized in whole UWB frequency band as well as X band and Ku band applications. Besides satisfactory transient response ensure that the proposed antenna could be an attractive candidate for wireless system application.

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