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A Compact UWB Stacked Circular Monopole Antenna with Band Dispensation

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ABSTRACT— A printed low profile monopole antenna with stacked structure for UWB applications is proposed. The antenna system has a circular radiating element coupled to a square patch by a via hole. The antenna is fabricated on a FR4 substrate and is fed by a 50Ω microstripeline feed. The operation bandwidth of antenna ranges from 3.2 GHz to 11 GHz with band dispensation from 5GHz to 6.3 GHz to provide interference elimination from WLAN bands. The ground plane dimensions are optimized for an improved antenna performance. The via holes facilitate stacked structure and hence achieves wide operation bandwidth. The impedance bandwidth (VSWR <2) of the antenna is 107 % and the gain of the proposed antenna is stable in the entire operation band with a peak value of 2.9 dB. The antenna provides a consistent radiation pattern. The designed antenna system has the smallest dimensions among many existing footprints with improved impedance bandwidth performances.

INDEX TERMS — UWB, monopole, microstripeline, VSWR.

I. INTRODUCTION

Evolution in high speed wireless communication technology triggers the necessity for wideband antennas in portable devices. Federal communication commission (FCC) has authorized 3.1 GHz to 10.6 GHz for ultrawideband applications and is considered as eminent solution for emerging wireless technology due to its enticing merits like high data rate, jamming resistance and improved throughput capabilities. Design of antennas for this promising technology has thrown daunting challenges to the antenna design engineers. The antenna design for most wireless applications should render consistent radiation pattern, low group delay and better radiation efficiency [1].

The interference elimination in certain frequency bands like 5.15-5.35 GHz & 5.725- 5.825 GHz (WLAN) and at 5.8 GHz (WIMAX) is facilitated by design enhancements. The antennas reported in literatures for UWB applications include geometries like loop, dipole, slot and monopole[2]-[5]. Monopole antennas are established as class of antennas for UWB applications due to striking advantages like low fabrication cost, compact geometry and simple integration with the feed network [6].Widely pronounced geometries of monopole antennas include square, rectangle, triangle [7]-[9].

Coplanar waveguide (CPW) fed antennas are largely hampered due to backflow of current [10]. Certain antennas equipped with flat reflectors result in proximity effects and eventually cause hazardous reflections [11]. Circular monopole antennas are considered as fitting candidates for UWB applications as their frequency characteristics are predominantly function of disk radius [12].

This article unveils a circular radiating element shorted to a square patch with via holes for UWB operating frequency. The proposed antenna is fed by a conventional 50 Ω microstripe feed. The antenna parameters are enhanced by better ground plane design. The antenna renders appreciable gain and impedance bandwidth performance across the operating frequency. The antenna system miniaturization is achieved via stacked structure. Via holes are used to achieve shorting of radiating elements. The antenna is designed to have least thickness justifying its suitability for compact and portable applications.

The organization of the article is asfollows. Section II deals with articles related to the literature and section III focuses on antenna configuration with the focus of section IV directed towards antenna design principles and effects of designparameters on the antenna system are analyzed. In Section V, the simulation results are depictedfor antenna performance verification. Finally the paper is concluded in section VI.

II. RELATED WORK

Innumerable research articles are focused towards monopole antennasfor UWB applications [1]-[12]. The notable advantages of monopole antenna compared to other antennas include compactness in geometry, less complex design. However these antennas are deteriorated by features like large radiator area, complex geometry and limited bandwidth etc., these features can be overcome by design enhancements such as beveling, stacked structure and shorting via holes. Beveling and stacked structure aids in surface area reduction and via holes facilitate largeroperation bandwidth. The discussed literatures emphasis on utility of monopole antenna for UWB applications based on geometries, feeding methods, design enhancements etc.

Ojaroudi et al.[13] designed a novel printed monopole antenna for monopole UWB applications. The antenna is equipped with inverted T slot and a conductor supported ground plane. The antenna has an operating frequency of 2.91 GHz to 14.1 GHz. The antenna has a compact dimensions of $12 \times 18\ mm^2$. The antenna is fabricated on a FR4 substrate and it is fed by a microstripeline feed of length 2 mm. The antenna has an optimized ground plane to stabilize antenna performances. The slots also improve the gain performance of the antenna. The performance of the antenna is measured with and without slots. The antenna enabled with slots excites additional resonances and the simplicity in fabrication is the notorious feature. The antenna has an omnidirectional radiation pattern.

Tang et al.[14] proposed a compact antenna with concentric circular slots to enable band rejection in WLAN and WIMAX bands with operating frequency ranging from 3.03 to 11.4 GHz. The transfer function of the antenna is analyzed and the transfer gains remain flat on the entire frequency band. Time domain finite integration is performed using CST microwave studio. As the inner ring gets close to the feeding strip, the peak rejection gets higher and rejection band gets wider. The antenna is fabricated on a FR4 substrate with suitable dimensions for an omnidirectional radiation performance.The antenna performance is measured by transforming it into frequency domain. The antenna response is linear and ripples are observed.

Thomas et al. [15] designed a rectangular monopole antenna with a modified rectangular patch on the rear side of the substrate.The antenna operates in UWB with band dispensation from 5 GHz to 6 GHz. The radiating elements and the ground plane are tapered to obtain better antenna performances in the operating frequency.Theeffects of geometry modifications in the antenna performance are analyzed with emphasis on an empirical relation for antenna design. The band dispensation is enabled by locating the patch on rear side. The antenna performance with the beveling process is studied and the results are depicted for various height and width of bevels.The notorious merit of the antenna is simpler construction with a wider operation bandwidth. Thecomparison of the related articles is briefed in table I.

TABLE I

COMPARISON OF RELATED LITERATURES

Antenna	**Operation bandwidth**	**Notched frequencies**	**Mechanism**
Ojarudi et al	2.9 -14.1 GHz	-	T slot
Tang et al.	3.03 -11.4 GHz	3.3–3.6 GHz, 5.15–5.35 GHz, 5.72–5.82 GHz.	Circular slot
Thomas et al.	3.1-10.6 GHz	5 - 6 GHz	Rectangular patch

III. ANTENNA CONFIGURATION

The geometry of the proposed low profile circular monopole antenna is depicted in fig 1.The design of antenna is facilitated for wideband frequencies. The dimensions of the antenna and the associated ground plane and feed aredepicted in the figure 2. The diameter of the circular disc radiator designed for UWB applications is D = 17 mm. The antenna system is designed on a FR4 substrate with ε_r= 4.4 and loss tangent and its dimensions are $30\ mm \times 35\ mm \times 0.9mm$. The antenna system is fed by a microstripeline feed of 50 Ω impedance located and its dimensions are $W_f = 0.85\ mm$ and $L_f = 16.5mm$.

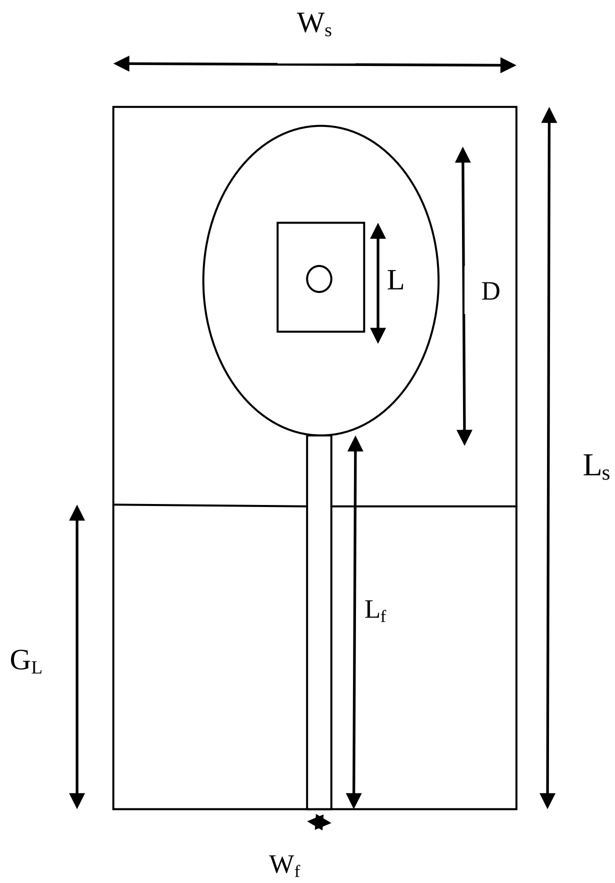

Fig. 1. Geometry of the proposed low profile antenna

The circular disc shaped radiating element and feed are printed on front side of the substrate and the patch and ground plane combination is located on the substrate's rear side. The patch on the back side of the substrate enables band dispensation and it is shorted to the circular element by using via holes. The ground plane of the proposed system is subjected to bevel near the feed line to enhance antenna performance. The location of the patch on the rear side effects antenna performance to a larger extend and the results are simulated using ANSOFT HFSS Ver.13 which involves finite element method for solving design problems utilizing the mesh techniques.

The antenna design is optimized for enhanced performance in the UWB frequencies by the following design features: 1) Via holesprovide band elimination by shorting the patch to circular disc. 2) Beveling the ground plane with optimized dimensions results in better impedance matching resulting in minimization of the return loss effects which is evaluated from return loss co efficient.3) Optimization of the feed location results in improved operating frequency.

IV. ANTENNA DESIGN

In this section the antenna design for UWB band is analyzed and the design effect of design features are discussed.

A. Circular antenna design considerations

The circular monopole antenna is considered advantageous than many other configurations as the operating frequency of the antenna is a function of the disk radius predominantly. The ground plane of the antenna system is also an element of the radiating configuration and the current distribution. The modified ground plane has a dominant consequence on the antenna characteristics. For circular monopole, the ground plane functions as animpedance matching circuit and inputimpedance, return loss and bandwidth are functions of feed gap [16], [17]. The location of feed relative to the radiating element affects the antenna parameters such as operating frequency and impedance bandwidth. The impedance matching of the antenna affects the impedance bandwidth. The design of disc antenna for UWB frequencies is obtained with the help of CST Microwave studio and the lower resonant frequency of the proposed antenna is verified using (1).

$$f_L(GHz) = \frac{300}{\pi \times D \times \sqrt{\varepsilon_{eff}}} \quad (1)$$

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

B. Stacked structure

The stacked structure of the antenna system largely results in enhancing the operation frequency and reduction of lateral dimensions of the antenna system [18]. The proposed antenna system equipped with disc shaped radiator operates in the UWB operating frequency and band dispensation at WLAN and WIMAX frequencies are facilitated by the square patch present on the rear side. The miniaturization of the antenna results in portable communication devices. The proposed antenna system houses the combination of disc and patch by using the shorting via holes.

C. Ground plane

The ground plane acts as a part of the radiating system and the modifications in the ground plane results in reasonable antenna performance. The modifications in the ground plane include insertion of slit [19], beveling the ground plane [20]. The proposed system involves tapering the ground plane and it results in enhancement of capacitive coupling between the radiating element and ground plane [21].The ground plane optimization enhances antenna return loss performance. The effect of ground plane design on antenna performance is depicted in results section. Ground plane dimensions ensure better matching by elimination of reflections. The tapered ground plane near the field point ensures optimal performance.

V. RESULTS

To characterize the excitation of the resonance modes the current paths at 4 GHz and 8 GHz is analyzed and the current concentration is predominant at the contact point of the feed.

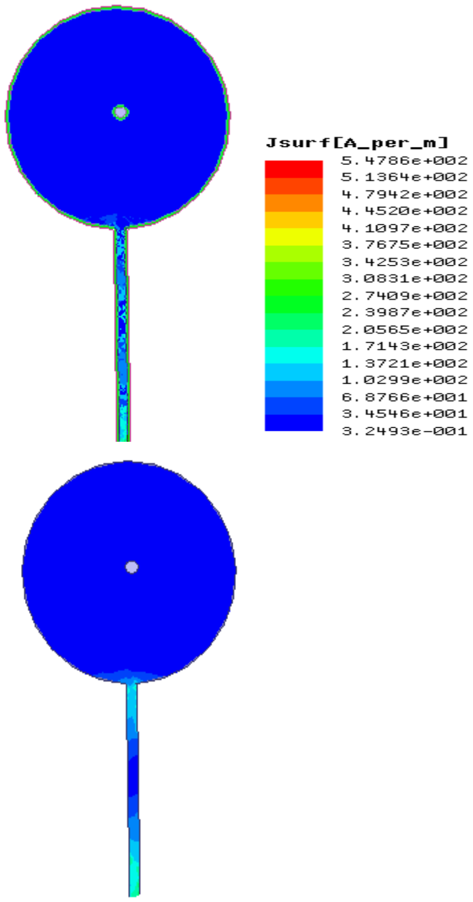

Fig. 2. Current paths for 4.2 GHz and 8.2 GHz

A. Effects of Disc radius`

The simulated return loss of the antenna for various disc radius is shown in fig. 2. The return loss performance of the antenna is enhanced for different frequencies by tuning the disc radius. It is inferred that a marked shift in frequency characteristics of the antenna is observed due to disc radius. The resonance frequencies of the antenna are centered at 4.2 GHz and 8.2 GHz with band rejection achieved from 5 GHz to 6 GHz for a radius of 8.5 mm. The resonance frequency locations fluctuates for a disc radius of 8 mm resulting in a truncated operation frequency with resonances observed at 4 GHz and 8 GHz and a disc radius of 9 mm shifts the resonance to 6 GHz with band dispensation.

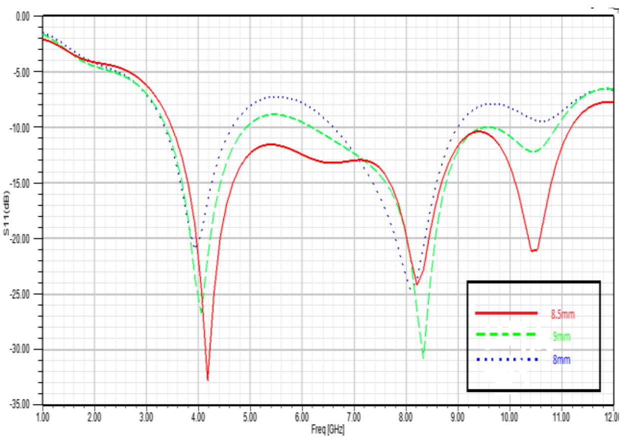

Fig. 3 .Return loss performance for varying disc radius

B. Effect of Ground plane design

The effect of ground dimensions on return loss performance is studied and depicted in Fig. 4.The ground plane facilitates elimination of ground plane effects by proper design and optimization. Ground plane greatly minimizes reflections and promotes antenna performance by elimination of higher order modes. A ground plane length of 13 mm results in operation bandwidth of 1 GHz with resonant frequency at 3.8 GHz. Similarly the performance for varying ground plane dimensions are studied with optimized dimensions of ground plane being 30 mm × 15 mm for UWB performance. The best trade off between ground plane width and length are achieved by optimization procedure and it enables a stabilized performance. Further the distance between the ground plane and the patch also predominantly affectsthe impedance matching because of strong coupling [22].

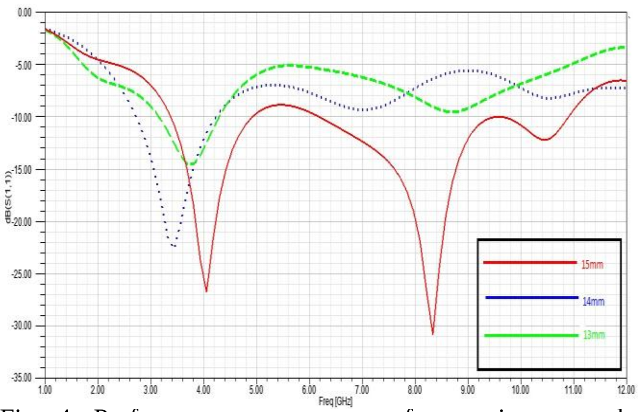

Fig. 4. Performance measurement for varying ground plane dimensions

Similarly the VSWR plot of the antenna shows the impedance bandwidth (VSWR ≤ 2) which justifies the optimal operation bandwidth of the antenna. The VSWR plot is depicted in Fig. 5. The VSWR plot shows that impedance bandwidth criteria is overridden only at the notched frequencies. The matching of feedline to the antenna system is shown by VSWR graph and it is largely affected by feed dimensions and feed location.

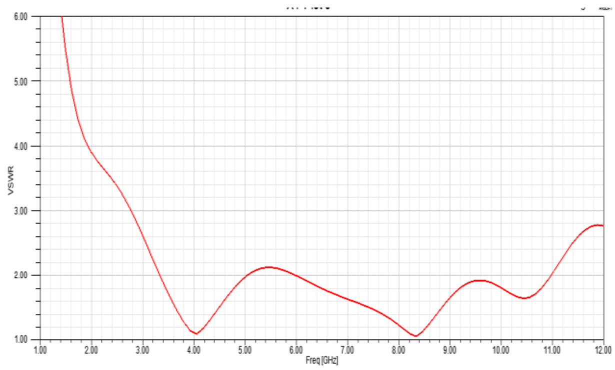

Fig. 5. VSWR plot.

The impedance parameter of the antenna shows that the feed is matched well at resonant frequencies of 4 GHz and 8 GHz and the imaginary part of the impedance is 0 Ω implying that the antenna is purely inductive as depicted in Fig. 6.

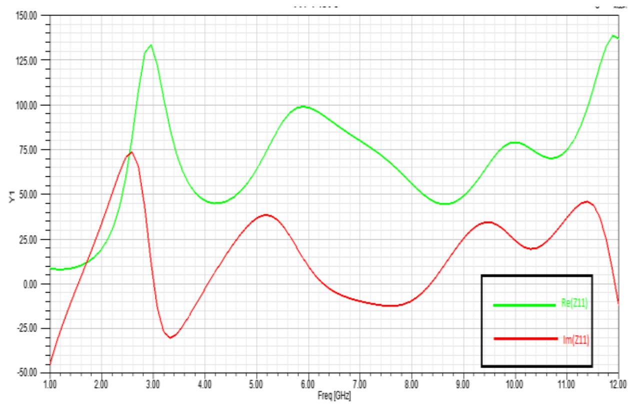

Fig. 6. Plot for Impedance parameter of the antenna.

The gain of an antenna is another important parameter in gauging antenna performance. The proposed antenna has an appreciable gain in its operating frequency with a peak value of 2.92 dB at 6 GHz and the gain values are almost stable in the entire frequency band.

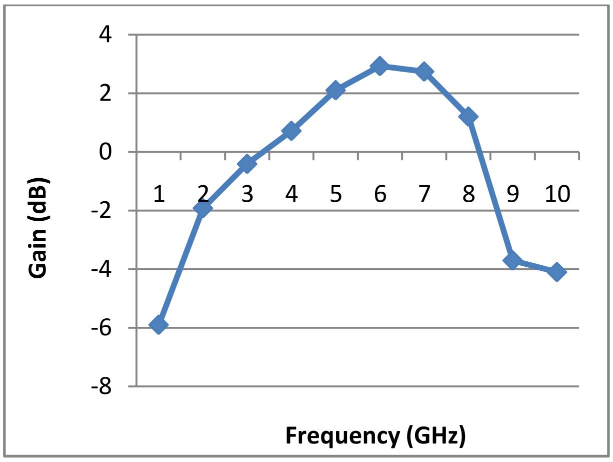

Fig. 7. Gain plot at various frequencies

The radiation pattern of the proposed antenna along xy,yz and zx planes are depicted in Fig. 8.The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. The radiation pattern of the antenna is omnidirectional and it is consistent in the entire band of operation. The deteriorations in the radiation pattern are controlled by patch radiator thus improving the peak gain. In common, planar monopoles reveal elevation plane patterns analogous to that of wire monopoles though presenting some directionality in the azimuth plane. Planar monopole radiation patterns exhibit an extremely lobed structure with condensed radiation towards the horizon at greater frequencies, which may limit their useful bandwidth [23].

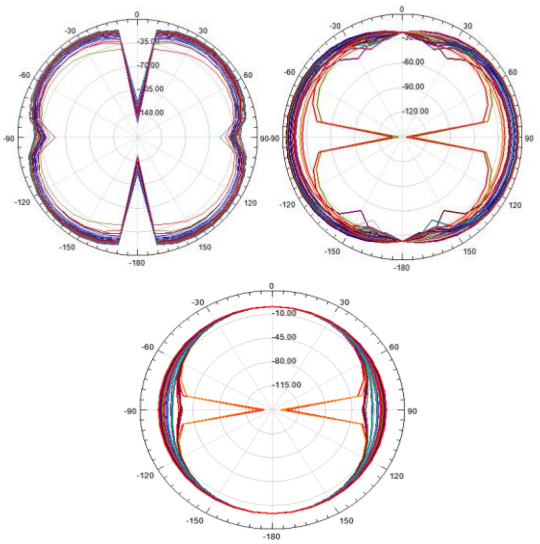

Fig. 8. Radiation pattern along xy- yz- zx- planes

VI. CONCLUSION

A disc shaped radiating element with a square shaped patch facilitated by a stacked structure is presented in this paper. The antenna operates in entire UWB band of operation and a band dispensation characteristics are observed from 5 GHz to 6 GHz. The proposed band rejection from the pass band of antenna results in interference elimination and enhancement of antenna performance in the operation band. The peak gain of the antenna is 2.9 dB and the gain response is appreciably flat in the operation band. The antenna comprises of a patch on rear side of antenna substrate and a disc shaped radiator complemented by shorting via holes. The simulated performance measuresof antenna substantiate the fitting aspects of antenna for UWB applications. The parametric study has stressed the importance of ground plane and disc radius inthe antenna design, and help antenna engineers with useful design attributes.

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