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Compact Dual Band Antenna for GSM1800/1900/ UMTS/ LTE/ UWB

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Abstract

In this paper, a UWB antenna with added lower band is presented. The proposed antenna is planar and its low profile makes it suitable for wireless applications. The design achieves good input impedance match from 1.8 - 11 GHz making it suitable for Global System for Mobile communication (GSM 1800/1900 : 1.71- 1.88 GHz /1.85-1.99 GHz), Universal Mobile Telecommunication System (UMTS : 1.92 - 2.17 GHz) , Long Term Evolution (LTE : 1.71 - 2.61 GHz) and Ultra Wide Band (UWB : 3.1 - 10.6 GHz) applications. The antenna is simulated using Ansys HFSS and CST microwave studio; fabrication is done using commercially available FR4 epoxy substrate of relative permittivity 4.4 and loss tangent 0.02.The overall antenna dimensions are 65 mm x 50 mm x 1.6 mm.

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*Keywords:*Dual band;UWB;LTE;GSM;Folded stub

1. Introduction

Current advances in wireless communication have increased the demand for antennas with compact size and low cost, that can work at various frequencies with sufficient bandwidth. The US Federal Communications Commission

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(FCC) has released the unlicensed frequency band of 3.1 GHz to 10.6 GHz for ultra wideband applications with an absolute bandwidth of 7.5 GHz or 110% fractional bandwidth of the center frequency[1, 2]. UWB uses extremely low energy pulses and it is suitable for short range wireless communication and high bandwidth applications. UWB communication has the advantages of large channel capacity, high data rate and immunity to multipath fading.

LTE is a high speed data communication standard for wireless communication in mobile phones and data terminals. The standard was developed by 3GPP (3rd Generation Partnership Project) as an improvement for GSM and UMTS network technologies[3]. LTE facilitates increase in capacity and speed of wireless data networks using improved digital signal processing and modulation techniques and supports both frequency division duplexing (FDD) and time division duplexing (TDD).

The paper is organized as follows: Section 2 describes the antenna design and simulation studies are discussed in Section 3. Measured results are presented in Section 4 followed by the conclusion in Section 5.

2. Antenna Design

A UWB antenna with added LTE band is initially developed4 in which it is shown that a rectangular patch with two stepped impedance sections and a coupled folded stub results in wide band operation. The design of the dual-band antenna, enables independent control in both bands with good matching and radiation properties while using a simple geometry and feeding technique. The antenna consists of a rectangular patch (PL x PW) etched on substrate of (SL x SW). A microstrip line feed with size (FL x FW) is used to feed the patch. However, measurement results show poor impedance matching in the upper UWB range from 4.75-6.25 GHz and 8.5-9.5 GHz.

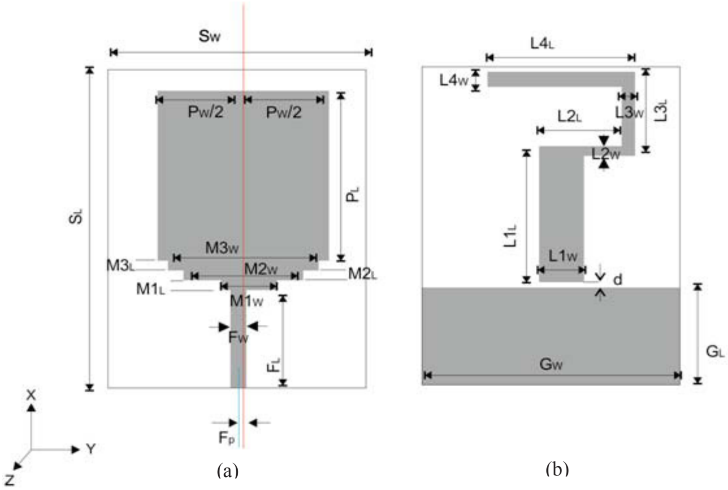


Fig. 1. Antenna Geometry (a) Front View (b) Back View

Table 1. Dimensions (mm) of the antenna fabricated on FR4 substrate (65 mm x 50 mm x 1.6 mm)

S_L	S_W	P_L	P_W	F_L	F_W	G_L	G_W	$M1_L$	$M1_W$	$M2_L$	$M2_W$
65	50	34.7	33.2	20	3	19.9	50	10.8	2	23.2	2
$M3_L$	$M3_W$	$L1_L$	$L1_W$	$L2_L$	$L2_W$	$L3_L$	$L3_W$	$L4_L$	$L4_W$	F_P	d
29.2	2	25.8	8.7	18.6	2	12.2	2.6	28.6	3.2	0.96	1

The dual band proposed in this paper introduces three modifications to achieve improved impedance matching in the entire UWB band. First, three stepped impedance sections of size M1 ($M1_L$ x $M1_W$) , M2 ($M2_L$ x $M2_W$) and M3 ($M3_L$ x $M3_W$) are used. Next, the feed position is offset by F_P along the -y-axis from the centre of the patch and finally, the width of the L1 segment of the coupled folded stub is increased[4] to $L1_W$. The folded stub consists of four elements of lengths L1, L2, L3 and L4. The ground plane has dimensions (G_L x G_W) and it is separated from the coupled element by a gap d. This antenna design has a compact length of 65 mm with broad bandwidth of 9.1 GHz. The antenna geometry is shown in Fig. 1. and its detailed dimensions are listed in Table 1.

3. Simulation Results

3.1. Optimetric analysis

Optimetric analysis is carried out for the width of stepped impedance section M1, feed position and width of folded stub section L1. Fig. 2. shows the reflection characteristics of the antenna for various widths of the stepped impedance section M1. It is seen that step feed width M1w =10.8 mm optimizes the returns loss for the frequency range 1.8 GHz to 3.8 GHz (lower frequency band). As width is further increased or decreased impedance matching deteriorates at higher frequencies. Fig. 3. shows the reflection characteristics of the antenna for different positions of feed line.

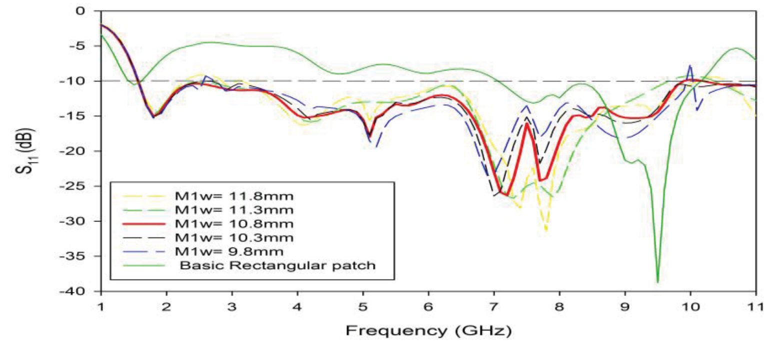


Fig. 2. Optimetric analysis for different width of stepped impedance section M1

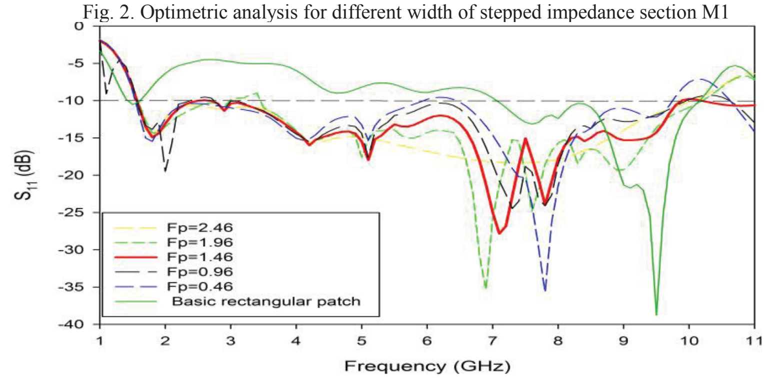


Fig. 3. Optimetric analysis for different feed position

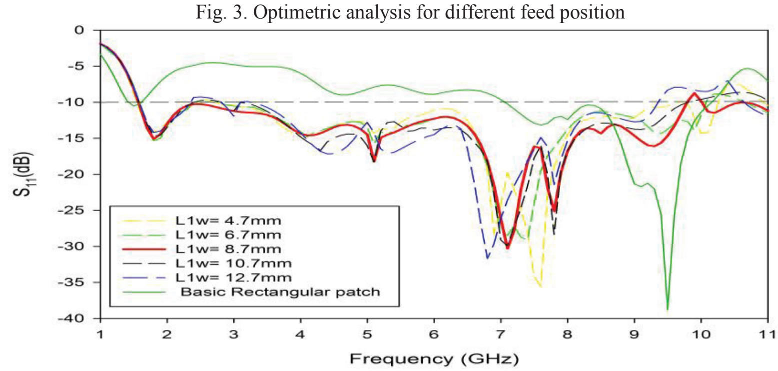


Fig. 4. Optimetric analysis for different width of L1 element

When feed offset is 0.96 mm, optimum impedance matching results are obtained in the desired frequency band. The reflection characteristics of the antenna for different widths $L1_w$, of the element L1 of folded stub is shown in Fig. 4. On varying width of L1, the lower frequency bands are not affected much but impedance matching at upper UWB frequencies in the range 9-10.6 GHz vary significantly. For $L1_w$= 8.7 mm impedance matching in the upper frequency range is optimum. The optimetric analysis is carried out with all other antenna dimensions fixed at the values given in Table. 1.

3.2 Surface Current Distributions

Fig. 5. shows the simulated surface current of the proposed antenna at different frequencies (1.8 GHz, 3.1 GHz, and 10.6 GHz). It is observed that the folded stub has significant current at upper UWB bands than at lower bands. Prefabrication studies of these antennas are done using HFSS and CST Microwave studio.

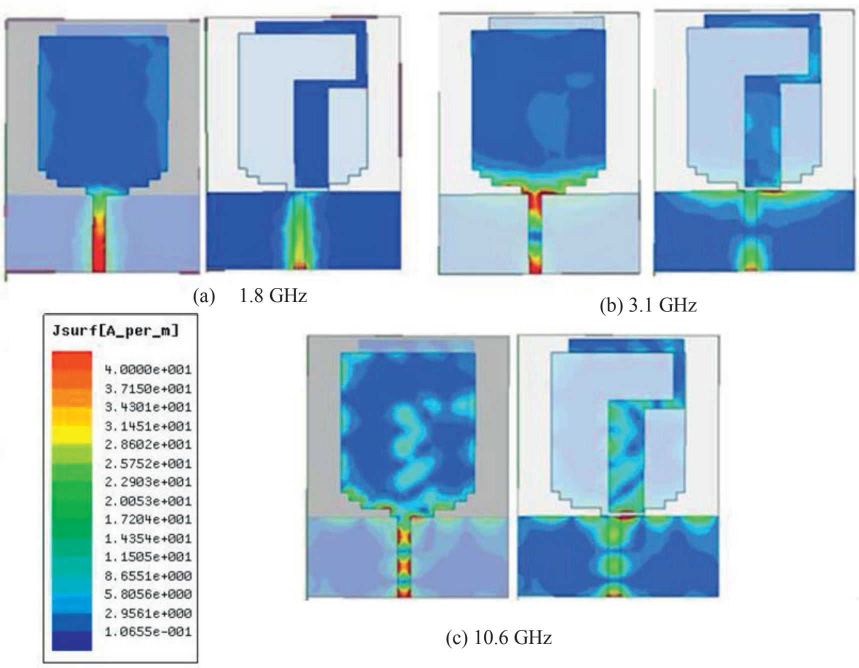


Fig. 5. Simulated surface current of the proposed antenna at different frequencies

4. Radiation Characteristics

Measurement of the radiation characteristics of the antenna in frequency domain and time domain is carried out using E8362B PNA network analyzer.

4.1. Reflection Characteristics

The antenna offers broad -10 dB impedance band from 1.8 GHz-11 GHz. Fig. 6. shows the comparison of the measured simulated S_{11} vs frequency in HFSS and CST Microwave studio respectively. The simulated results in HFSS and CST are in reasonably good agreement with measured results. Though the lower cut off frequency, which is determined by the rectangular patch dimension, is showing a deviation from the simulated outcome, it is suitable for the GSM/UMTS/LTE/UWB applications.

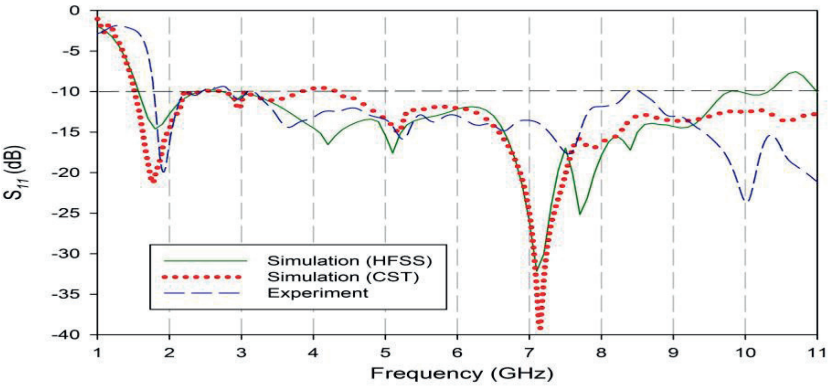
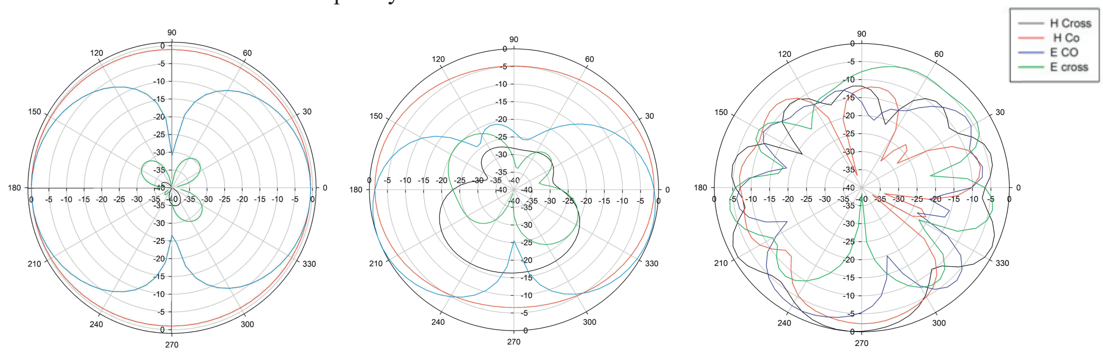


Fig. 6. Comparison of simulated and measured S_{11}

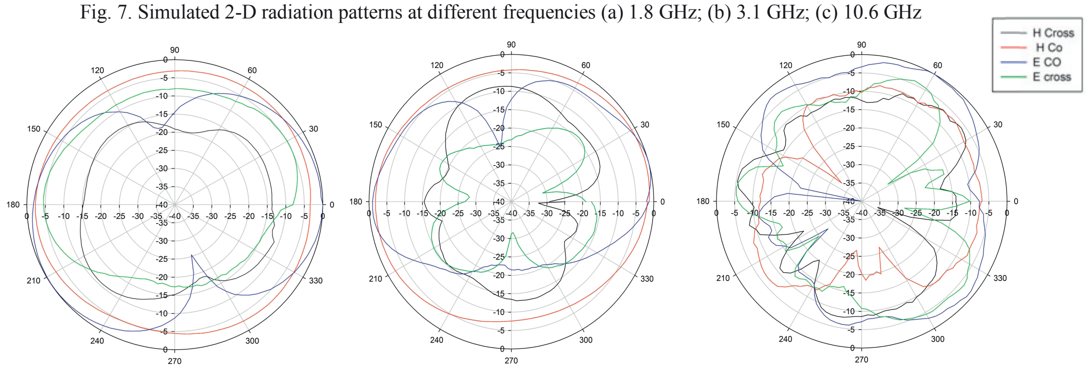
4.2 Radiation Patterns

The radiation pattern in the E-plane (X-Y) and H-plane (Y-Z) demonstrates that the antenna radiates with typical dipole-like characteristics at lower frequency bands.



(a) (b) (c)

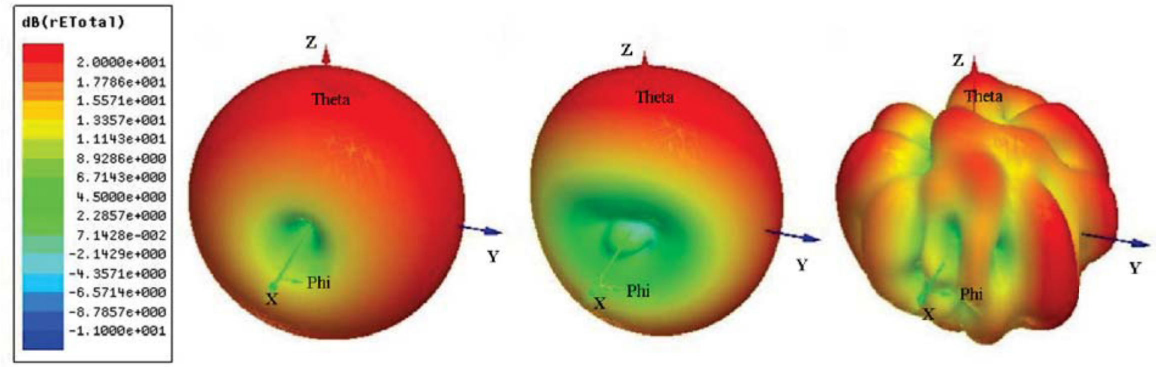
Fig. 7. Simulated 2-D radiation patterns at different frequencies (a) 1.8 GHz; (b) 3.1 GHz; (c) 10.6 GHz



(a) (b) (c)

Fig. 8. Measured 2-D radiation patterns at different frequencies (a) 1.8 GHz; (b) 3.1 GHz; (c) 10.6 GHz

The radiation pattern varies with frequency[5] and the main beam of antenna squints slightly at higher frequencies. Fig. 7.a-c and Fig. 8.a-c show the simulated and measured 2-D radiation patterns at different frequencies of 1.8 GHz, 3.1 GHz and 10.6 GHz respectively. Fig. 9.a-c shows simulated 3-D radiation pattern at different frequencies. The patterns are nearly omni directional at lower frequencies though there is slight distortion in the shape of the pattern at upper end of the band. The antenna offers linear polarization in the lower spectra and nearly linear behavior in the UWB spectrum.



(a) (b) (c)

Fig. 9. Simulated 3-D radiation patterns at different frequencies (a) 1.8 GHz; (b) 3.1 GHz; (c) 10.6 GHz

4.3. Group Delay

So far the proposed antenna has been investigated with an emphasis on its frequency domain performance. UWB systems transmit information using narrow pulses rather than a continuous carrier wave used in conventional narrowband systems. Hence if the UWB antenna introduces considerable group delay, the received signal will be distorted and information is lost[6]. To analyze the time-domain characteristics of the UWB antenna, two identical antennas are placed opposite to each other in different orientations 10 cm apart. One antenna is excited with a time domain pulse and acts as the transmitter while the other acts as the receiver[7]. The measured results are shown in Fig. 10., 11. and 12.

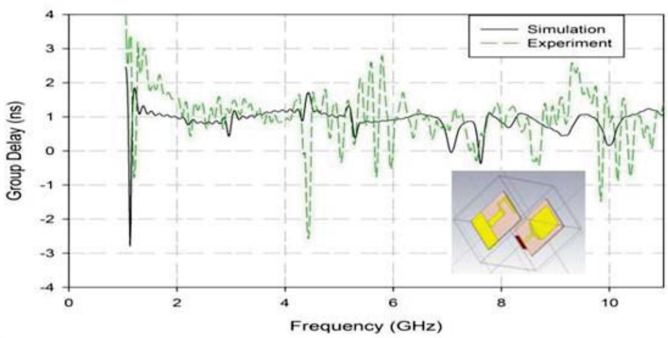


Fig. 10. Group delay characteristics (face to face)

Group delay is simulated and measured with the antenna in face to face, side by side and face to side orientations as illustrated in Fig. 10., 11. and 12. respectively. In all the cases, the measured group delay is within an acceptable 2 ns range suggesting the suitability in the UWB spectrum.

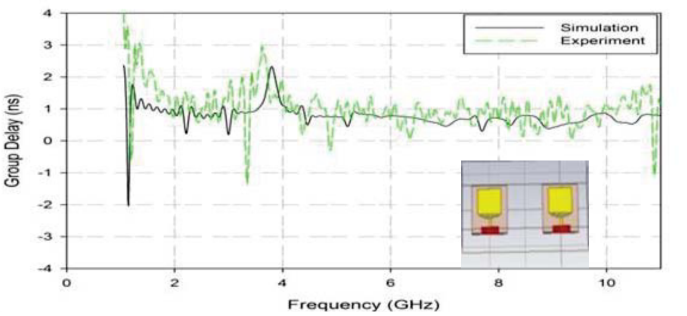


Fig. 11. Group delay characteristics (side to side)

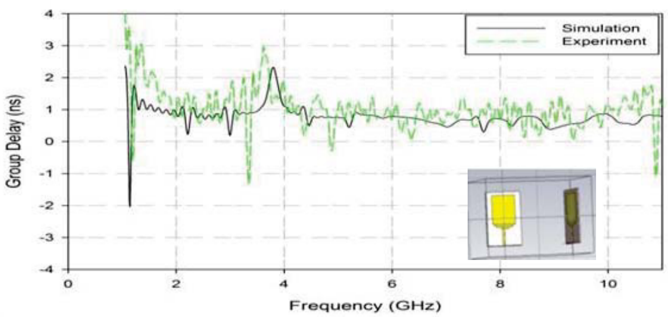


Fig. 12. Group delay characteristics (face to side)

A photograph of the fabricated antenna is shown in Fig. 13.

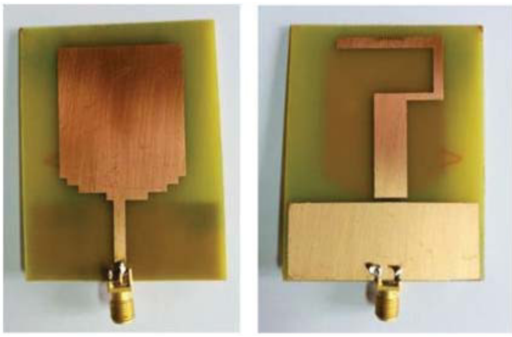


Fig. 13. Antenna fabricated on a FR4 substrate

5. Conclusion

A compact printed dual band antenna with coupled elements, for UWB and LTE has been proposed, simulated, fabricated, and characterized. Using a coupled folded stub and stepped feed to improve the desired impedance bandwidths, a single wide operating band from 1.8-11 GHz is obtained. The proposed antenna is a good candidate for integrated GSM1800 (1.7 -1.88 GHz), GSM1900 (1.85 – 1.99 GHz), UMTS (1.92 – 2.17 GHz), LTE Band 1, 2, 3, 4, 5, 9 and 25 (1.710 – 2.69 GHz) and UWB (3.1 -10.6 GHz) and its moderate size makes it suitable for future GSM-Bluetooth-UWB integrated wireless devices.

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