A Printed Monopole Antenna with DGS for Multiband Wireless Communication

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***Abstract*—In this paper, a multiband antenna having a variety of application in portable wireless communication devices is presented. The proposed multiband antenna resonates at five different frequencies including the wireless portable devices band and an X- band. The type of antenna is having truncated T-Shaped having FR4 material used as a substrate with dimension of ($56 \times 44 \times 0.8 mm^3$). The truncated T-Shaped multiband antenna operates at five different frequencies such as (1.525-1.599), (2.334-2.445), (3.136-3.854), (7.131-7.545) and (10.013-11.301) GHz. These bands cover (GPS at 1.56 GHz, Wi-Fi at 2.402 GHz, WIMAX at 3.32 GHz, 7.3 GHz and X bands 10.7 GHz). The simulation result shows good agreement with measured result and the simulated results of Return loss, Gain, directivity and radiation pattern are within the acceptable range. The antenna designing and simulation is performed in CST MWS 2015 solely.**

Keywords*—*Multiband antenna, T shaped, Slot, penta-Bands, Wireless applications

I. Introduction

With the advancement of different wireless communications systems, it is needed to assimilate as many applications such as the global positioning system (GPS), worldwide interoperability for microwave access (WiMAX), and wireless local area network (WLAN) as possible into a single wireless device. For this purpose, various multiband antennas have been proposed. A dual-band antenna is proposed in [1] for the WiMAX applications, a multiband planar Inverted F antenna (PIFA) is designed in [2] for WWAN applications, a multiband micro-strip patch antenna having diverse polarization states in [3] and a multiband loop antenna is presented in [4] which 2.4/5.2/5.8 GHz bands. Slot antenna is good nominee for multiband antennas design, because of its wide bandwidth, compact size, and easy integration with other devices. In past year, a lot of work have been done on multiband antenna design for portable devices applications. In [5] an antenna was presented for mobile applications focus UMT/GSM/LTE bands the total size of antenna is $40 \times 115 \times 10\, mm3$. But its size and weight was quit large for portable devices. $40 \times 115 \times 5\, mm3$ size of multiband antenna design in [6] for GSM and UMTS but still its size was large and only dual band. In [7] an antenna was presented for C and X band but did not cover the lower bands as GPS, WLAN, and WiMAX bands. For WiMAX and WLAN application an antenna in [8] is designed. It covers entire bands of WLAN and WiMAX design was sample and compact size but it covers only these two application. In addition, fork type [9], M-shaped tri/dual-band is proposed in [10]. In [11] rectangular slot for triple-band and trapezoid slot for dual-band, L-strips with square-slot [12] are presented. To attain multiband task low height (PIFA) antenna has been considered in [13]. A monopole planer T-shaped Antenna in [14] for WLAN and other wireless application is also designed and four band antenna was designed in [15] for GPS, WLAN and WiMAX. Though all these Antenna design for C/X band or GPS/WLAN bands and even only for triple band or dual band. In this article, a multiband antenna design is suggested and designed for portable devices wireless communication than can work and operate for GPS (1.525-1.599) GHz, Wi-Fi (2.334-2.445) GHz, WiMAX (3.136-3.854) GHZ, X Band (7.131-7.545) GHz and X band (10.013-11.301) GHz. The overall dimension of suggested design antenna is $44 \times 56 \times 0.8\, mm3$. Which is suitable for portable devices, multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. Antenna Design EVALUATION

Initially the antenna is design for single band. The design is like T shaped with over tuned stub at both edge of T-shape with full ground having length and width 48 mm and 56 mm respectively. The antenna resonates on 5.94 GHz. the design and result are shown in Fig. 1 and Fig. 2. By introducing a rectangular slot in ground plane having dimension 48 18 mm2, the antenna resonates on three frequencies which are 1.8 GHz, 3.7 GHz and 10.7 GHz. By inserting an inverted T-shaped stub in rectangular slot the antenna start resonates on 1.56 GHz, 3.2GHz, 4.7GHz and 9.9 GHz. Furthermore, inserting two E-shaped stub in rectangular slot the antenna resonates on five frequencies which are 1.56 GHz, 2.34 GHz, 3.17 GHz, 5 GHz and 10 GHz. Fig. 3 show the return losses for different design structure.

III. PROPOSED ANTENNA STRUCTURE

The overall structure of proposed penta-band antenna is shown if the Fig. 4. The elementary structure of antenna refers to planar monopole hence design formulas based on transmission line model [16] that has been used to regulate the parameters of

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Multiband Frequency Antenna. Antenna is design using 0.8 mm thicker FR4 substrate.

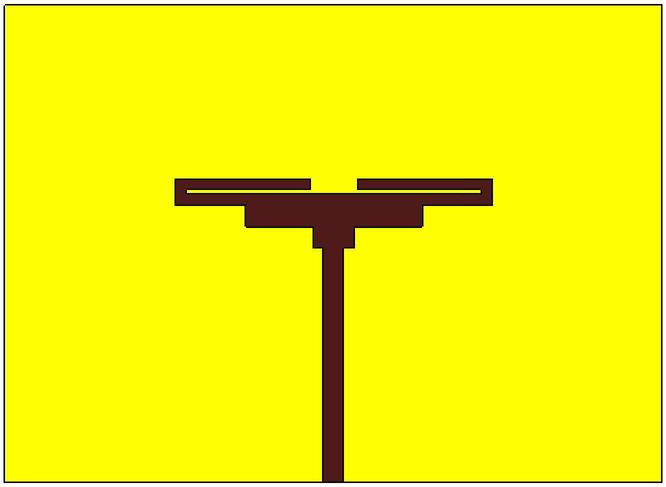

Fig. 1. Single band Antenna Design

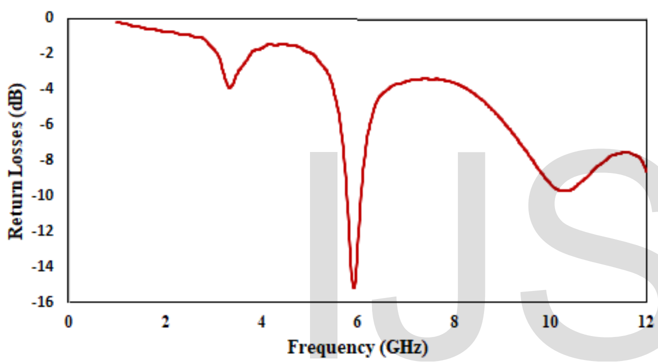

Fig. 2. Return Loss vs Frequency for Single Band Antenna

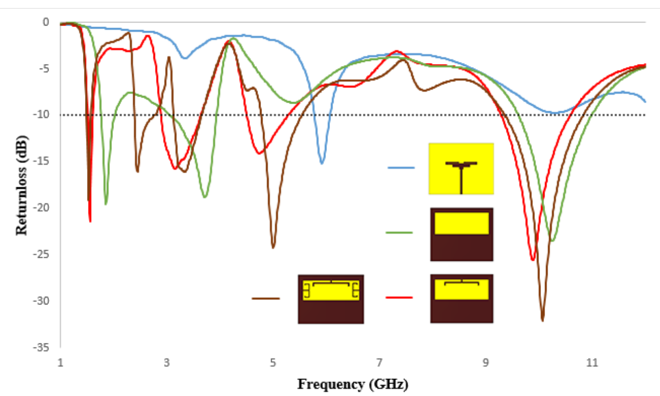

Fig. 3. Return Loss vs Frequency for Different Design Structure

In order to obtain the better radiation pattern, optimum efficiency, directivity and gain, a metallic slot able ground is used in design**.** Structure of the Antenna is T shaped feed with a slot in the ground side having a length of L1 × W1= 48 × 18 mm^2 on one side way of substrate. The four-sided slot has an overturned T-shaped stub at the higher upper hand of the rectangle slot and two E-shape stub on the Left- Hand (LH) and Right-Hand (RH) sides of the slot. To gain compact size, straight stripe has folded on both sides of T-shaped stub. On the other side of substrate, a T shaped patch, feed with microstrip feed line of width W_f is used. To achieve 50 Ω impudence the width of feed line is kept 1.76mm. to attain a squeeze dimension the T-shaped patch is prolonged and then bent twice the upper sides. For best matching impudence a stair is used on both sides of T-shaped Patch.

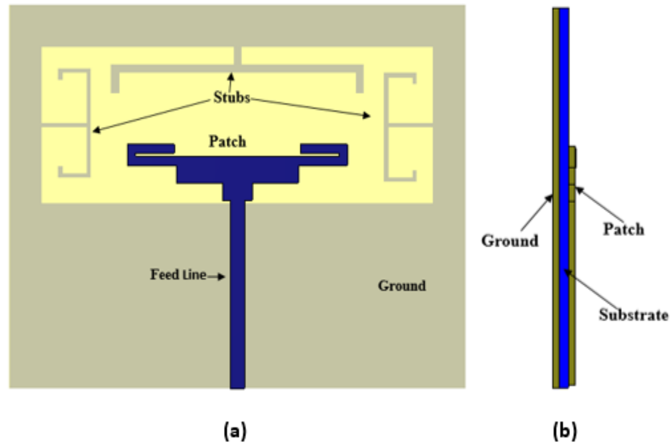

Fig. 4. Antenna Design (a) Front and Back (b) Side view

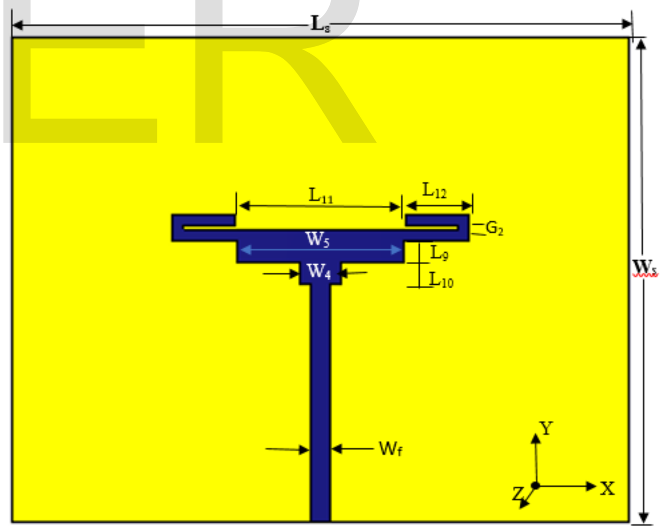

Fig. 5. Parametric Top view

The parametric view of the proposed antenna design is shown in Fig. 5-6. For optimization and analysis of proposed antenna a commercial software CST MWS 2015 is used. The entire dimension is listed in the Table 1.

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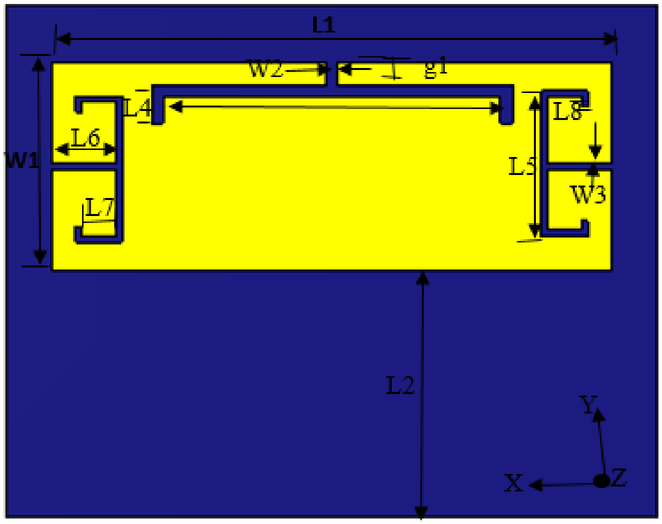


Fig. 6. Parametric Bottom view

Table 1
DIMENSION OF ANTENNA STRUCTURE

Parameter	Value (mm)	parameter	Value (mm)
W1	18	L1	48
W2	1	L2	21.6
W3	0.5	L3	29
W4	3.3	L4	3.3
W5	12	L5	12
Wf	1.76	L6	5.1
Ws	44	L7	4
Hs	0.8	Ls	56
L8	1.3	L11	15.5
L9	2	L12	5.75
L10	2	g1	2
g2	0.4		

IV. PARAMETRIC STUDY OF ANTENNA

S_{11} Simulation is carried out to study the frequency bands effect on radiating elements. Here only two elements parametric study is carried out, all other parameter is kept constant. As from transmission line model [16] when length is increased frequency is decrease. In Fig. 12, the current distribution for 7.3 GHz and 10.7 GHz is shown. For these frequencies band current is mainly distributed along T-shaped

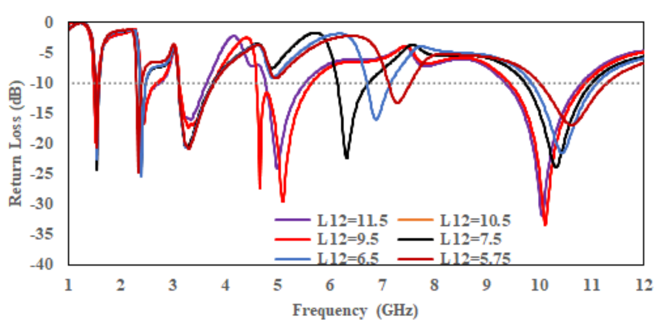


Fig. 7. S11 for different values of L12

upper folded side. By changing the length of L12 as shown in Fig. 7, it gives different results, as the length of L12 is decreased to 5.75 mm the required higher frequencies is achieved as shown in S_{11} plot in Fig. 8. Similarly, for getting 2.40 GHz frequency band the length of middle arm of E-stub L6 is varied the required band is achieved.

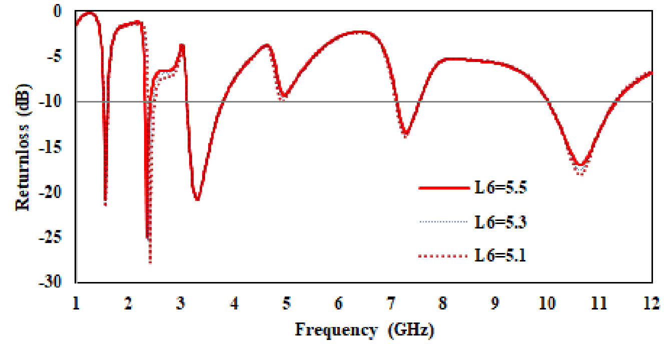


Fig. 8. S11 for different values of L6

V. RESULTS AND DISCUSSION

All the optimization and analysis is carried out in CST MWS. In this proposed design penta-band microstrip slot antenna is achieved. The resonance frequency of first band is 1.56 GHz its bandwidth is 74MHz with return loss of -20.9 dB. The second resonance frequency is 2.402 GHz, Bandwidth is 111 MHz and return loss is -25dB. The resonance frequency of 3rd band is 3.48 with return loss of -20.98 dB and bandwidth is 686 MHz. The 4th resonance frequency is 7.3, return loss of -13.47 dB and bandwidth of 414 MHz, and the resonance frequency of 5th band is 10.7 having bandwidth of 288 MHz and return loss is -16.93. Fig. 9 shows the plot of return loss vs frequency of the design antenna.

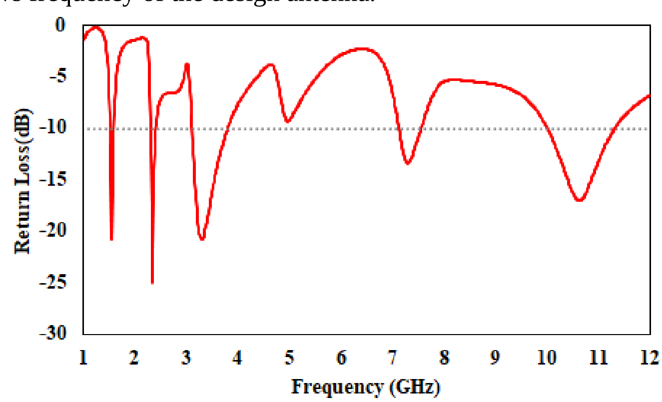
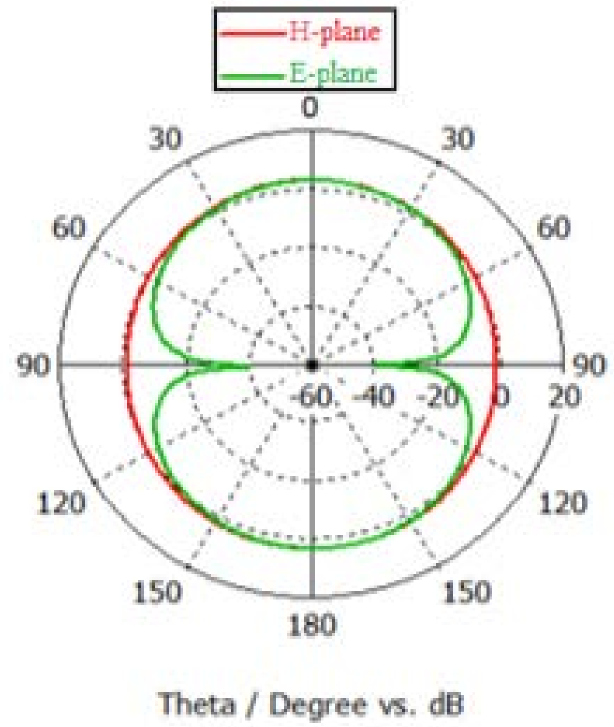


Fig. 9. Frequency vs Return Loss Plot

For the antenna the radiation pattern is also examined Fig. 10 shows the 2-D directivity and radiation patterns antenna operate in five bands with directivity values of 3.47, 3.91, 4.80, 6.33 and 4.24 dBi at 1.56 GHz, 2.4 GHz, 3.32 GHz, 7.3 GHz and 10.71 GHz respectively. The directivity is maximum at the angle of 0 and 180 degrees so forming a shape of 8 as shown.


H-plane
E-plane
0
30
30
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90
-60
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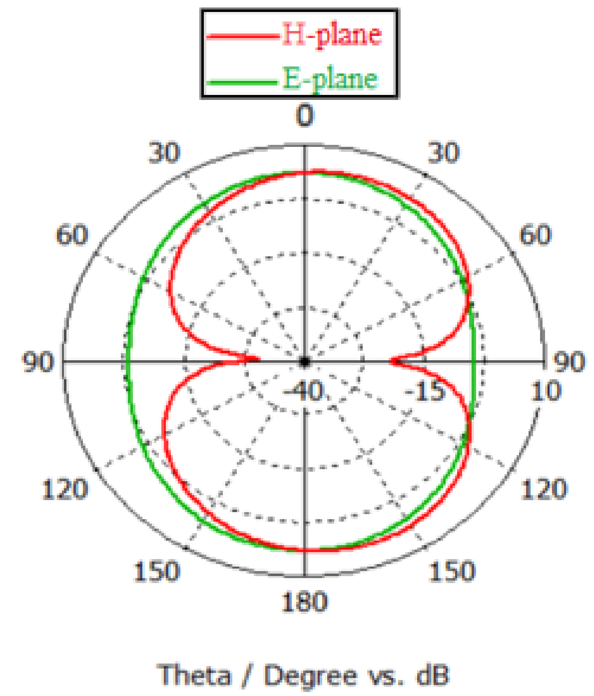
20
120
120
150
150
180
Theta / Degree vs. dB

(a)


H-plane
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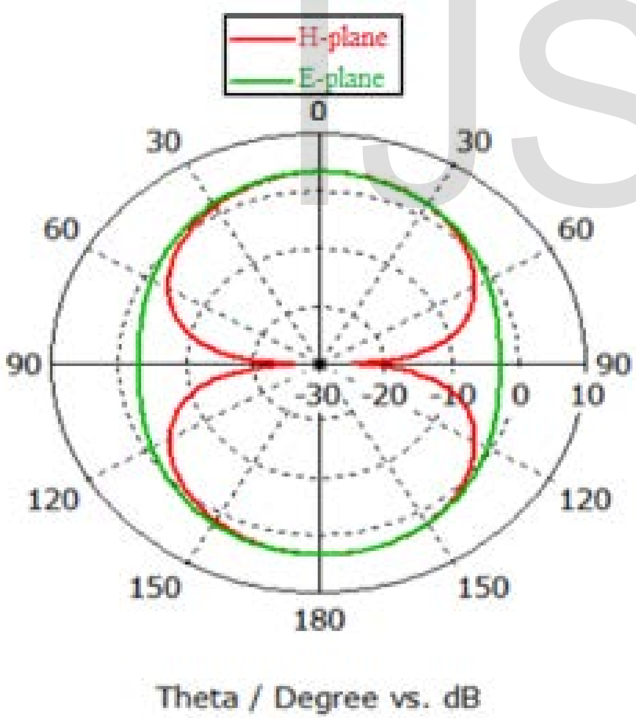
Theta / Degree vs. dB

(c)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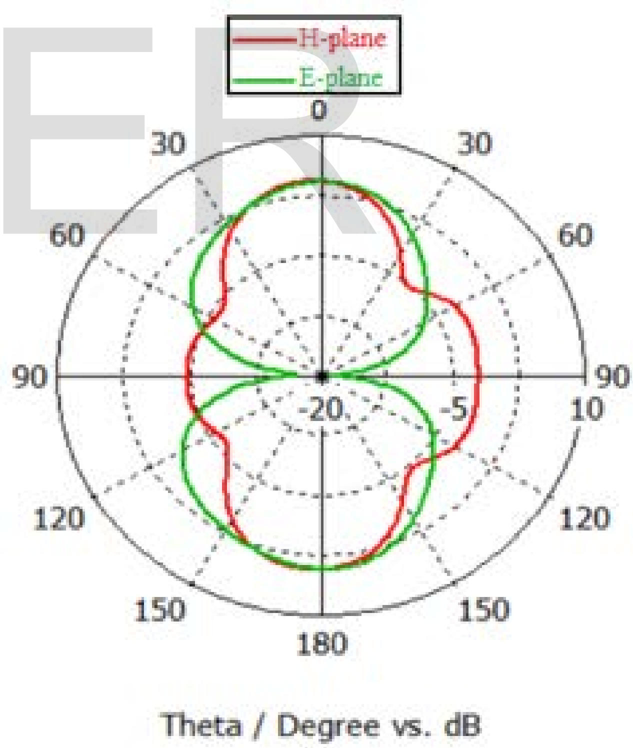
Theta / Degree vs. dB

(b)


H-plane
E-plane
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Theta / Degree vs. dB

(d)

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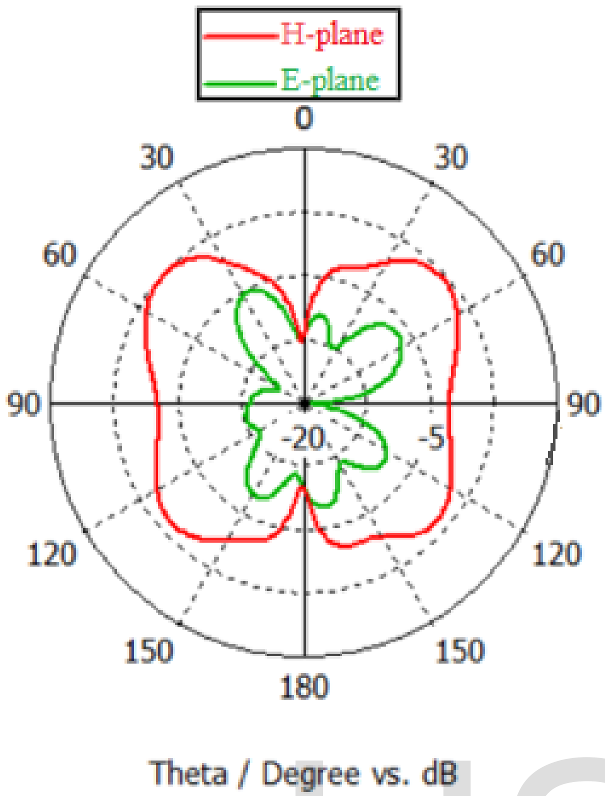
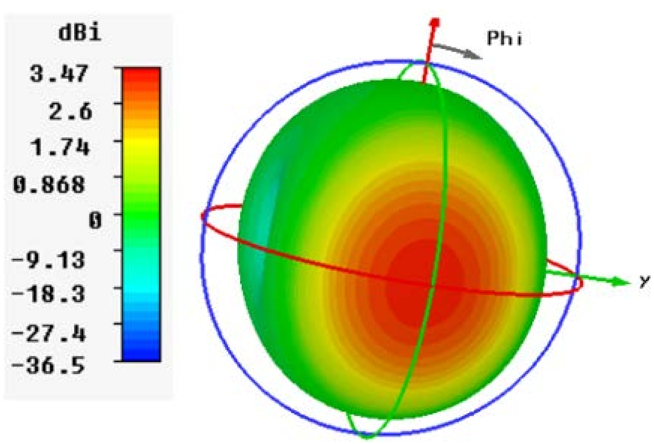


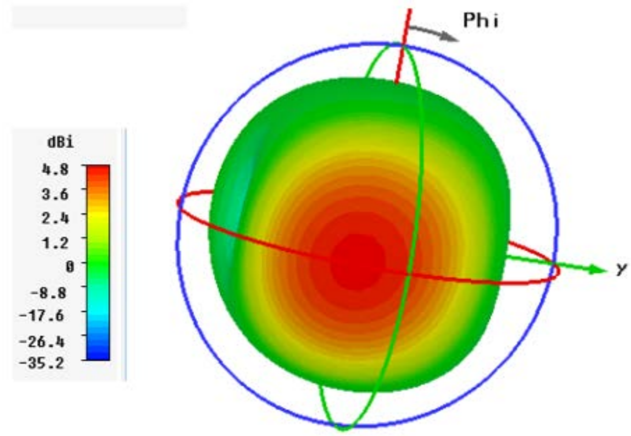
(e)

Fig. 10. 2D radiation plot for (a) 1.56GHz (b) 2.4 GHz (c) 3.32 GHz (d) 7.3GHz (e) 10.7 GHz

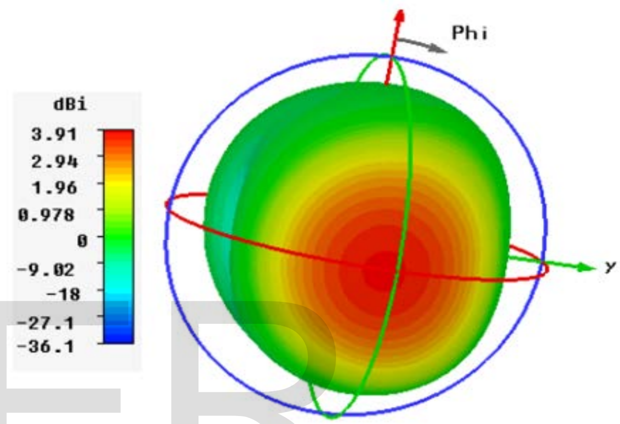
The designed panta-band antenna radiates Omni directionally forming donut shape at all frequencies (1.56, 2.40, 3.32, 7.3, 10.71 and 5.59 GHz). 3-D directivity patterns at corresponding frequencies are given in Fig. 11. The red color indicates direction in which radiation is strong (main beam). It is actually the measurement of directivity and gain in desired direction.



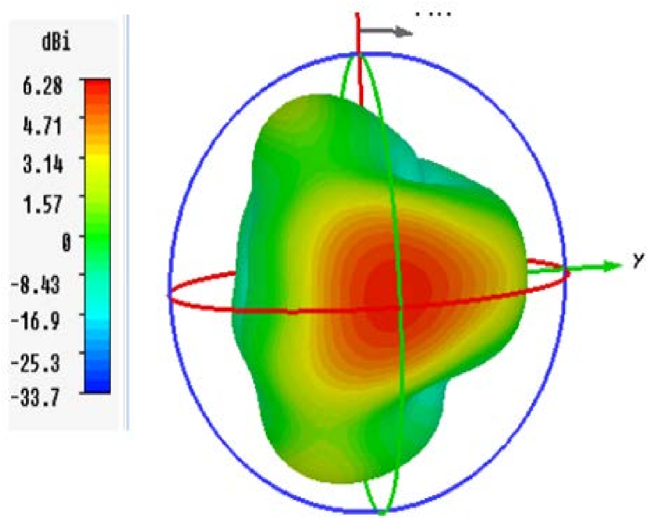
(a)



(b)



(c)



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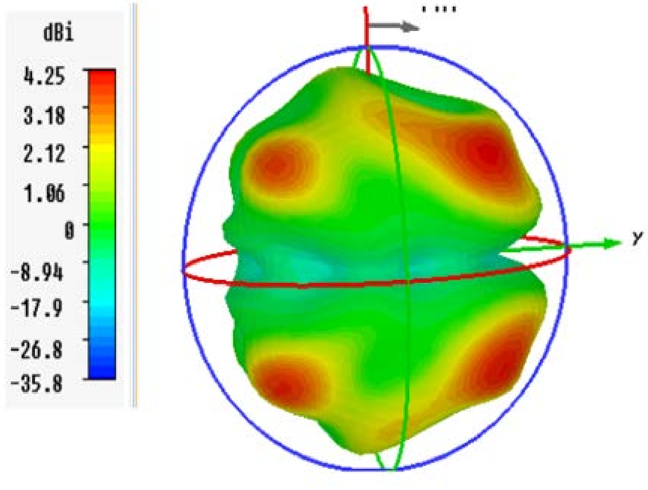
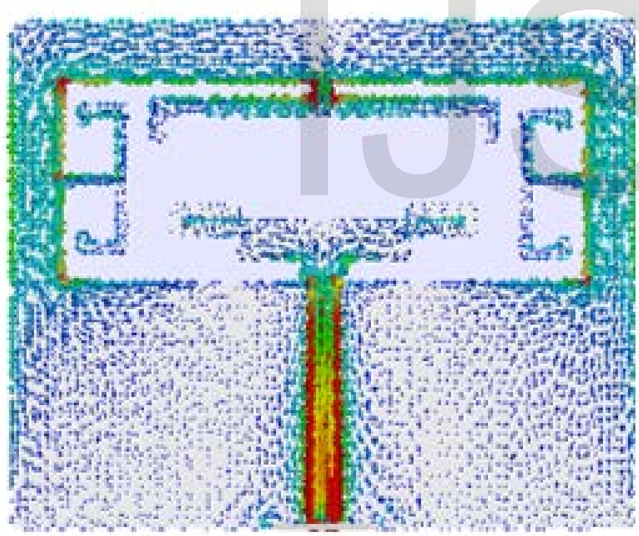


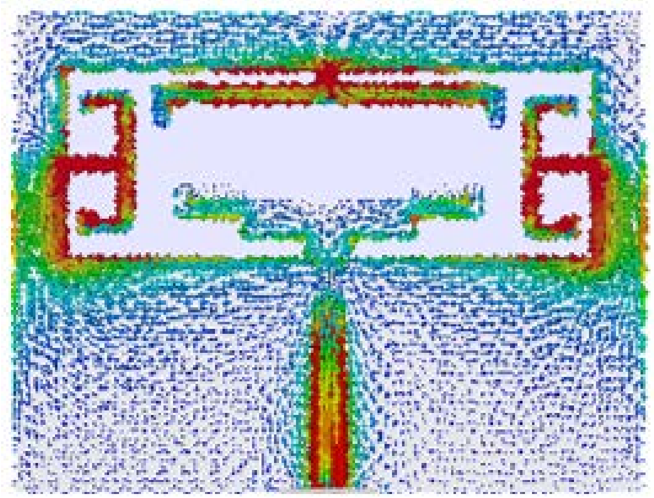
(e)

Fig. 11. 3D far field pattern 2D radiation plot for (a) 1.56GHz (b) 2.4 GHz (c) 3.32 GHz (d) 7.3GHz (e) 10.7 GHz

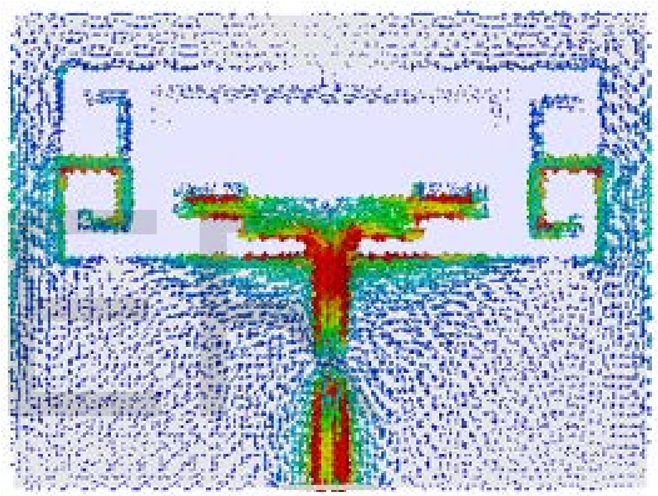
The surface current of electric field for each frequency of operation is shown in the Fig. 12 This indicates parts of the antenna being resonate for a given frequency of operation. These plots show the resonant lengths for different frequency bands. At 1.56 GHz the current is mainly distributed along both side of feed line. For 2.4 GHz current is dense at the bottom of feed line, middle arm of both E-shape stub and trunk of T-shape stub. Current is distributed at bottom and top of feed line and arm of T-shape patch for 3.48 GHz. For 7.3 GHz resonance frequency the current is contracted at top, middle and bottom of feed line, folded arm of T-shape patch and lower arm of both E-stub. At 10.7 GHz band the current is spread along edge of feed line and patch.



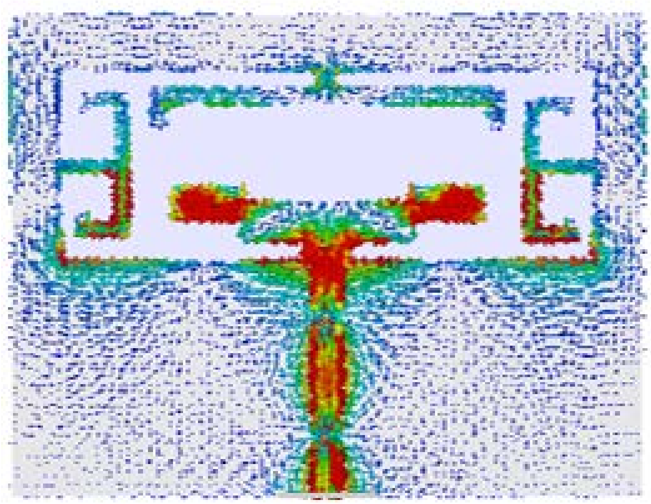
(a)



(b)



(c)



(d)

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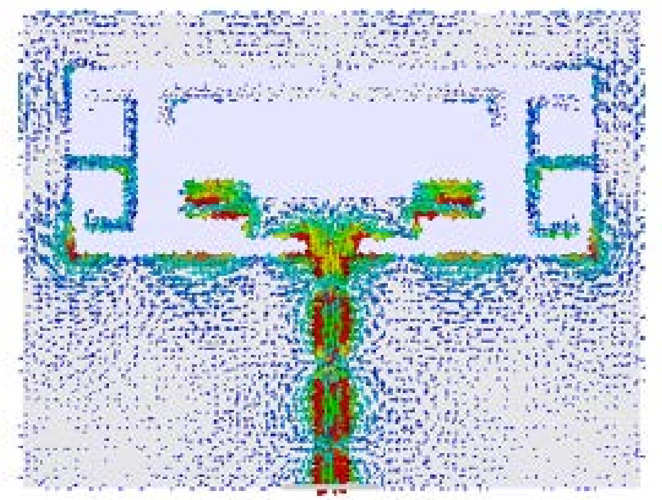

(e)

Fig. 12. Surface Current distribution for (a) 1.56GHz (b) 2.4 GHz (c) 3.32 GHz (d) 7.3GHz (e) 10.7 GHz

The designed mono pole antenna has satisfactory gain values at all operating frequencies. The antenna is more efficient and has outstanding efficiency values i.e. 89 %, 88.15 %, 64.81 %, 67 %, and 71.45 %, and at 1.56, 2.4, 3.32, 7.1, 10.71 and GHz respectively.

VI. FABRICATION AND MEASURED RESULTS

For real time measuring the proposed penta-band antenna is fabricated and measured its results with the help of network analyzer. For feeding fabricated antenna SMA female connector is used. Fig. 13 shows the fabricated prototype. As we have low frequency network analyzer can measured result up to 8 GHz that why high frequency 10.7 GHz is skipped by analyzer. Measured result is shown in Fig. 14 and Fig. 15, Fig. 14 show return losses S_{11} for four frequencies band. These band are at 1.50GHz, 2.38GHz, 3.17 GHz and 3.17 GHz having return losses -12.99 dB, -13.67 dB, -14.02 dB and 18.62 respectively. VSWR are 2, 1.97, 1.90 and 1.46 for 1.50GHz, 2.38GHz, 3.17 GHz and 3.17 GHz bands respectively.

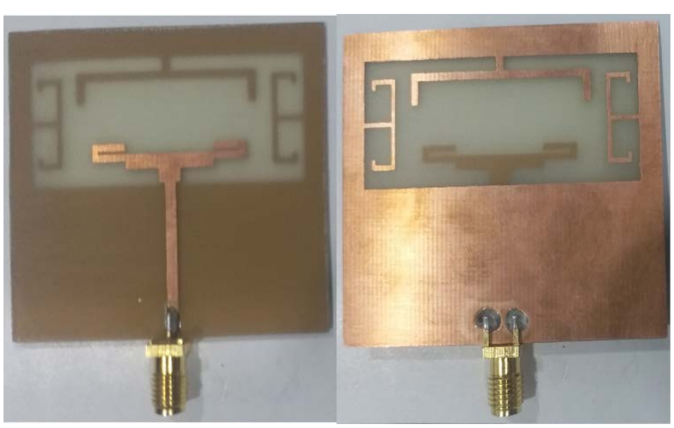

Fig. 13. Fabricated Prototype

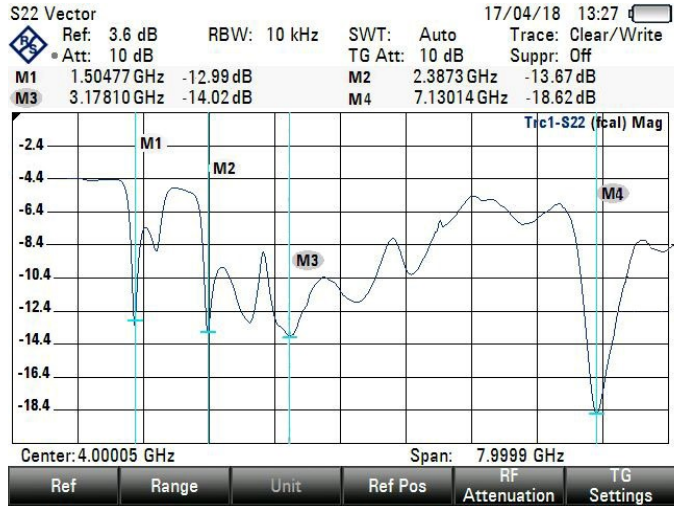

Fig. 14. Return Losses of Fabricated Antenna

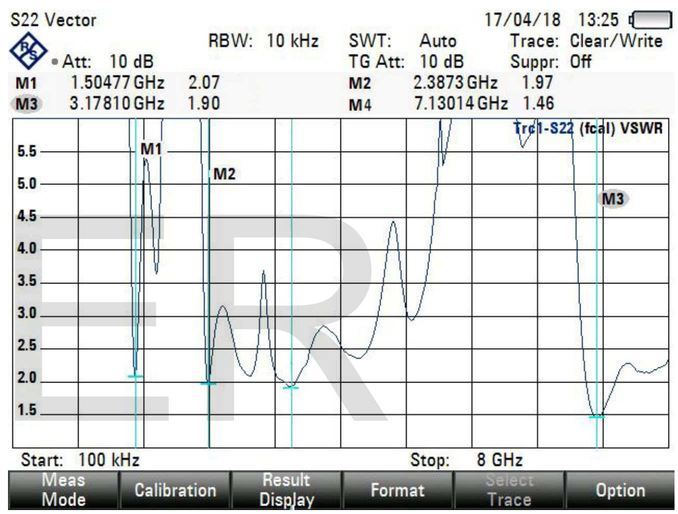

Fig. 15. VSWR of Fabricated Antenna

VII. MEASURED RESULTS AND SIMULATED RESULT COMPARISON

Return loss and VSWR of simulated and measured results are compared and shown in Fig. 16 and Fig. 17.

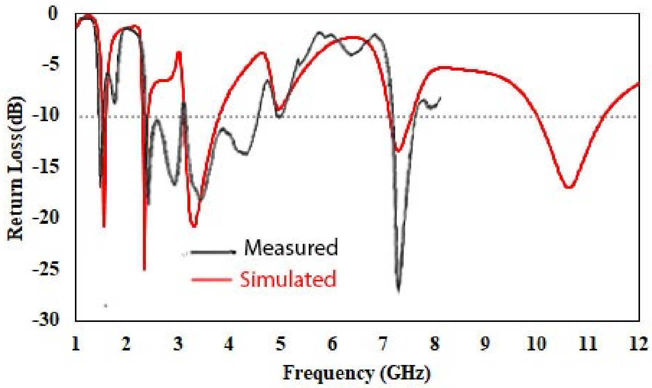

Fig. 16. Return Loss Comparison of Measured result and Simulation

From Fig. 16 it can be seen the measured result resonance is slightly moved toward higher or lower frequencies. The return loss is good for 7.3 GHz and less for other frequencies and VSWR is quite good for 7.3 GHz and compered to other frequencies.

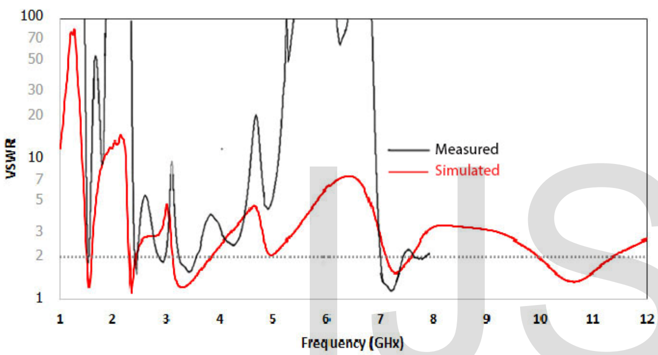

Fig. 17. VSWR Comparison of Measured result and Simulation

VIII. CONCLUSION

The penta-bands for GPS/WLAN/WiMAX and X bands, microstrip multiband antenna design is proposed in this paper, which is the main aim of this work. Microstrip is used for feeding of antenna. Design consist of T-shaped feed patch, two E-shape and inverted T-shaped stub with rectangular slot in ground plan. Overall dimension of proposed design is 56 × 44 × 0.8 mm3. From the parametric study which is carried out on L12, the desire goal is achieved. To study the performance of antenna simulation is done. Design resulting five bands at 1.56 GHz use for GPS, 2.40 GHz for WLAN, 3.32 for WiMAX, 7.3 GHz and 10.7 GHz X-bands which is suitable radar communication and military communication. The proposed design has good efficiency, return loss and Gain at different frequencies.

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