A COMPACT TRI-BAND MONOPOLE ANTENNA FOR HANDHELD DEVICES

Ashwini Anil kadam[1], Prof. A.S.deshpande[2]

[1]PG student, Department of Electronics and Telecommunication, ICOER wagholi, pune, Maharashtra, India
[2] Assistant Professor, Department of Electronics and Telecommunication, ICOER wagholi pune, Maharashtra, India

ABSTRACT

*This paper depicts a work on the tri-band monopole antenna with parasitic elements suggested for LTE, Wi-Max and WLAN applications. The Proposed antenna is used for small handheld gadgets, such as, cell phone, tablet, portable PCs and so on. The L shaped slots are used in antenna design having different widths. The proposed monopole patch antenna resonates at frequencies LTE 2.5GHz, Wi-Max 3.2GHz and WLAN 5GHz.The monopole antenna has many points of interest, for example, small size, good radiation pattern, better antenna efficiency, less input impedance etc. Monopole antenna is used in countries where coverage is limited. The overall size of proposed antenna is 23*20 mm² which makes this antenna suitable to embed in mobile phones. The antenna is simulated on IE3D software for gain, bandwidth, efficiency, VSWR, directivity etc. parameters. The proposed antenna is tested on vector network analyzer.*

Keyword: - *Long term evolution, Wireless Local Area Network, Monopole antenna, worldwide interoperability for microwave access etc.*

1. INTRODUCTION

The advances in the Wireless communications had been begun from the so-called second generation (2G) systems of the early 1990s, in this year digital cellular technology was introducing. For 4G framework fewer models are being proposed than in past eras. Only two 4G candidates being actively developed today: 3GPP LTE-Advanced and IEEE 802.16m, which is evolution of the Wi-MAX standard known as Mobile Wi-MAX [2]. The long-term evolution (LTE) framework with LTE700 (698-787 MHz), LTE2300 (2300-2400 MHz), and LTE2500 (2500-2690 MHz) operating bands are greatly used in 4G wireless wide area network (WWAN) [1]. Due to the rapid growth in communication technology, many Portable devices such as smart cell phones, tablets and laptops will have both the WWAN and the LTE functions. For this antenna application a multiband antenna design will be a suitable technique [3]. There are a few guidelines for the WLAN application, the lower band ranges from 2.4–2.485 GHz for IEEE 802.11b/g and the upper band covers frequency range from 5.15–5.825 GHz for IEEE 802.11a [8]. Consequently, there are more components that need to be integrated inside a smaller device in order to meet the expectations of the end user. To make the device more compact and stylish, cell phone's external antenna has been replaced with an internal antenna. Designing an internal antenna for mobile device is very challenging because of the limited space available inside mobile devices [1], [11]. The monopole antenna has many preferences, for example, the size of monopole is half of the dipole; the directivity of monopole antenna doubles that of corresponding dipole antenna; the monopole's input impedance is half of dipole antenna etc[16]. The paper is divided in four sections In this paper section 2 is literature survey of various antennas designed for LTE,Wi-MAX and WLAN applications. Section 3 is actual design of monopole antenna, section 4 presents the simulation and testing results and discussion of antenna and finnally section 5 is the conclusion.

2. LITERATURE SURVEY

In literature, many multiband antennas for mobile phone have been proposed. In [1] small size printed monopole with C shaped system ground antenna is propoesd to enhance the bandwidth, A novel loop shorted strip as parasitic element to resonate antenna at LTE 700MHz. Where as in [3] a planar coupled-fed eight-band monopole antenna is planned utilizing the T-molded strip and coupled emanating structure for LTE band. Planar monopole with a coupling feed and an inductive shorting strip in [4] has been intended for LTE application. The size of antenna is 40*120 mm^2. In [5]antenna designer proposed a printed circle type antenna coordinated with two stacked coupled-fed shorted strip monopole for LTE operation to build the data transmission of antenna. Another coupled fed antenna with slotted ground structure have been proposed in [6] to widening the bandwidth. From [1], [3], [4], [5] & [6] the average gain for LTE band varies between 1.19-3.8dBi. The average efficiency for LTE band varies between 50-80%. The bandwidth is greater than 1000MHz.The over size of antenna is greater.

In [7] the outline of a smaller scale strip based compact double band monopole antenna for Wireless Local Area Network (WLAN) and Wi-MAX (Wi-Fi) applications have been exhibited. It is simulated for 2.4 and 5.2 GHz. The 28*23 mm^2 is over all size of antenna. A dual band monopole antenna is proposed in [8] for (WLAN) application. The antenna comprises of rectangular ring with two slots and abandoned ground plane, because of which two resonant modes are created to cover 2.7 and 5.5 GHz WLAN groups. A compact, low profile planar monopole antenna is proposed in [9] to operate in Wi-Max and WLAN application. The span of antenna is 28*45 mm^2. In [10] an uneven smaller scale strip-nourished tri-band monopole antenna with a C-formed ground stub stacked is examined. Two strips and a screwy stub associated with the ground through a via-hole are use to acquire the frequency ranges of 2.4–2.52 GHz, 3.4–3.65 GHz, and 5.16–6.2GHz, which is met the particulars of WLAN 2.4/5.2/5.8 GHz and Wi-MAX 3.5/5.5 GHz. In [11] author introduces a minimized multiband planar monopole micro strip antenna for current cell phone applications. Another system of utilizing a slits and slots in the emanating patch and the ground plane has been utilized to accomplish the multiband execution of the antenna. The size of antenna is 50*19 mm^2.

A minimal, novel O-formed ACS fed double band monopole antenna for 2.4 GHz Bluetooth/WLAN, 4.9 GHz US open security band and 5.0 GHz WLAN/Wi-MAX applications have been exhibited and researched in [12]. A triple-frequency smaller monopole antenna with coplanar waveguide (CPW)-encouraged structure has been expressed in [13]. It comprises of a rectangular radiation patch with L-molded slot and a modified L-shaped stub reaching out starting from the ground plane. By engraving an L-shaped slot on the rectangular radiation patch, the antenna can excite two resonant modes (Wi-MAX and WLAN). A compact size ($20 \times 38.5 \times 0.8$ mm^3) CPW fed monopole antenna design with triple band operation for WLAN and Wi-MAX applications is proposed in [16]. From paper [8-15] it is observed that the gain for Wi-Max band is very less than WLAN. The gain reduces if size of antenna is reduced. Antenna design in [12] is compact antenna among all antennas stated above. Bandwidth is less for Wi-max than WLAN application except [7] & [14].

In this paper a minimized monopole antenna with parasitic components for LTE, Wi-MAX and WLAN applications is exhibited. The detail plan of proposed antenna will be discussed, and typical measurement results are also presented.

3. ANTENNA DESIGN

The simulated design of monopole patch antenna with parasitic elements is shown in figure below: All dimensions of the fig are in millimeter (mm). The fig.1demonstrates the design of monopole patch antenna. A microstrip line feeding is provided at port 1 to excite the antenna. The proposed antenna estimate is $23\times20\times1.6$ mm^3. The antenna is excited by microstrip line feeding provided to 2 mm width horizontal main strip. The antenna is composed of L and inverted L shaped radiating elements. The main five parasitic strips shown in fig. 1 plays crucial role in getting the desired bands of LTE 2500 MHz, Wi-MAX 3.2GHz and WLAN 5GHz etc. The main vertical and horizontal long strip having 2mm width and 1mm width of vertical strip 5 are responsible for getting the LTE2.5GHz band then, after introducing strip 4 in the design the 3.2 GHz Wi-MAX &5GHz WLAN band shown below -10dB but, the efficiency and gain are very low for the desired bands hence, strip 2 is added in the design to increase the efficiency of antenna.

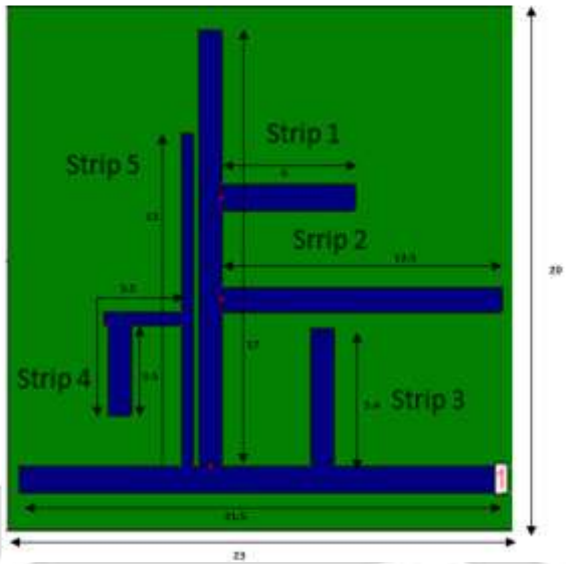


Fig.1.The geometry of monopole antenna

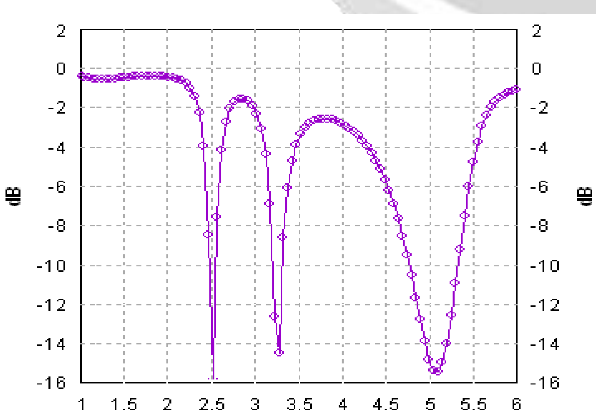
The problem arrives due to strip 4, 5 & 2 is the new additional 3GHz and 5.9 GHz bands are introduced. To remove these additional bands the strip 3 is linked to the main horizontal radiator. The strip 1 is used to improve the gain of the antenna.

4. RESULTS AND DISCUSSION

The various parameters of antenna such as VSWR, return loss, radiation pattern, gain, efficiency and directivity of antenna etc. are simulated on IE3D software

4.1 Simulation Results of Antenna

The simulated return loss graph is shown in fig.2. The return loss is used for impedance matching. The return loss values for LTE2.5/Wi-MAX 3.2/WLAN 5GHz bands of projected antenna are -15.03/-13.97/-15.37dB. The bandwidth is calculated from the above graph for the bands below -10dB. The three bands shown below -10dB are 2.5GHz is the upper LTE band. 3.2GHz is the Wi-MAX band and 5GHz is the WLAN upper band. The corresponding bandwidths for these bands are 100MHz, 140MHz and 600MHz etc. The bandwidth is greater for WLAN band.



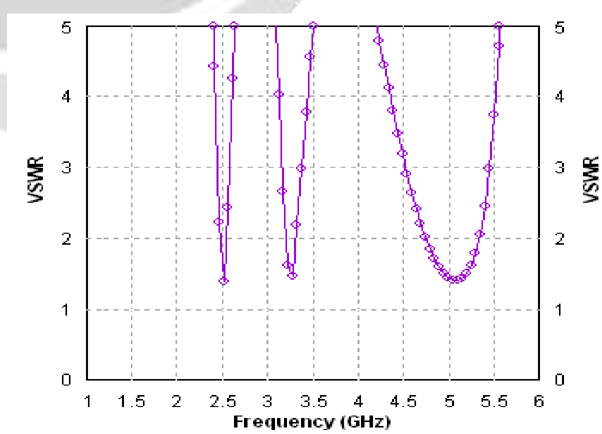


Fig. 2 The return loss of proposed antenna.

Fig. 3 VSWR of antenna.

The simulated voltage standing ratio graph of antenna in fig. 3 shows VSWR values below 2. The voltage standing wave ratio is the way to measure the transmission line imperfection. It describes the power reflected from the antenna. The designed antenna shows the values of VSWR for LTE/Wi-MAX/WLAN application. 1.38, 1.46, 1.41 are simulated VSWR values of antenna.

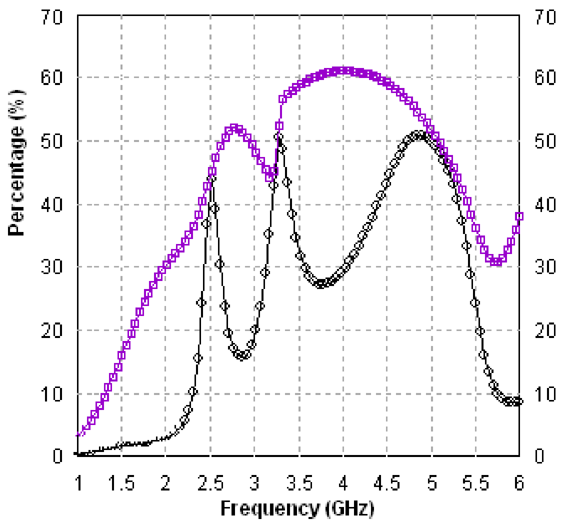


Fig. 4 Efficiency of proposed antenna.

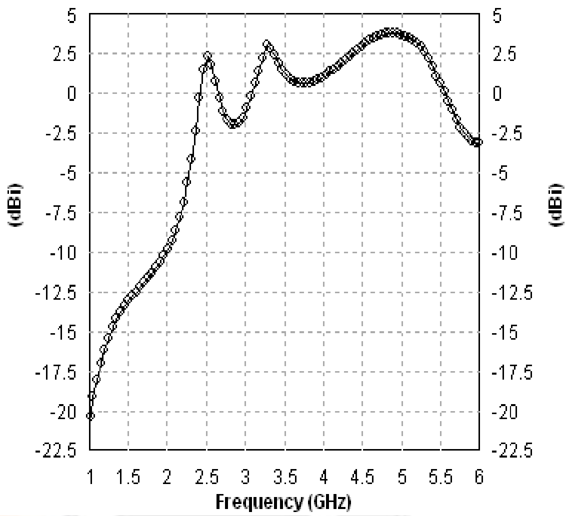


Fig. 5 Gain of proposed antenna.

The efficiency is the product of gain and directivity. From fig. 4 the efficiency for LTE band is 45%, for Wi-MAX 46% and for WLAN 51.79% etc. The gain of antenna is depicted in fig. 5 the gain is specifically relative to the efficiency of antenna. The gain diminishes as the measure of antenna decreased. It is shown from fig 5. The gain for the proposed bands are 2.4dBi, 2.95dBi and 3.6dBi etc. The gain is improved in the proposed antenna because of radiating strip 1 having 2mm width connected to main vertical parasitic element.

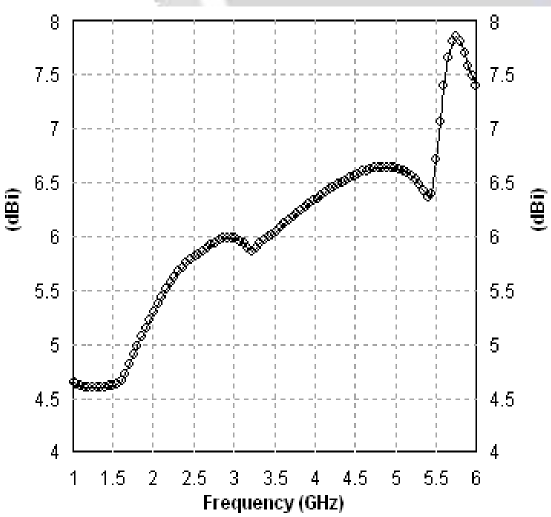


Fig. 6 Directivity of proposed antenna.

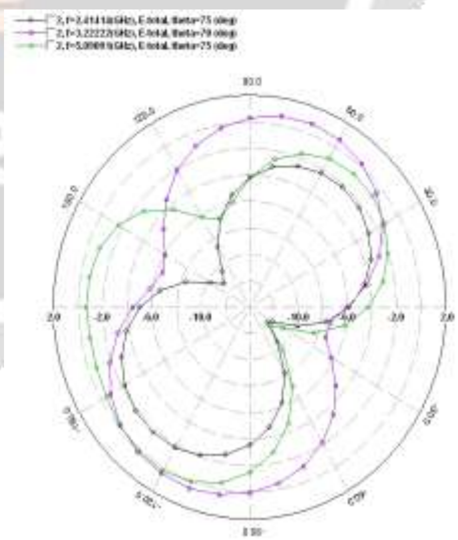
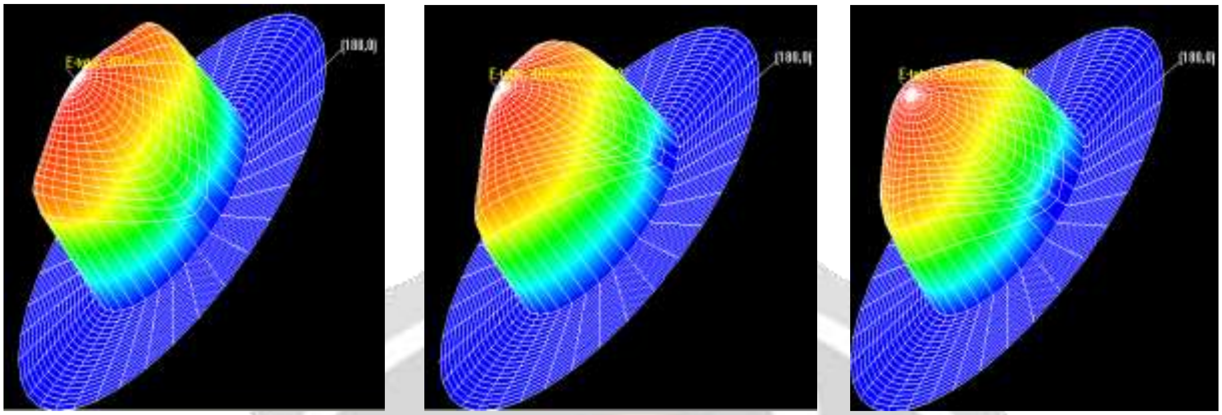


Fig. 7 The2-D radiation pattern of proposed antenna.

In fig. 7 the 2-D radiation patterns for LTE, -MAX and WLAN are shown. The values of θ for proposed bands are shown in figure.

When current is passed through antenna, it radiates more in one direction and less in other directions. This is termed as radiation property of antenna. Isotropic antenna radiates uniformly in all directions where non-isotropic antenna radiates in one direction. The monopole antenna is non-isotropic antenna. The radiation pattern of antenna for LTE band is presented in fig 8(a). The radiation pattern of proposed antenna for Wi-MAX band is appeared in fig. 8 (b) and the radiation pattern of monopole antenna for WLAN band is shown in fig. 8 (c) etc.



a) 3-D radiation pattern for 2.5GHz **b)** 3-D radiation pattern for 3.2GHz **c)** 3-D radiation pattern for 5GHz

Fig. 8 The 3-D Radiation patterns of antenna.

4.2 Testing Results of Antenna

The following fig. 9 (a) shows the top view of antenna design and fig. 9 (b) shows the system ground of antenna design.

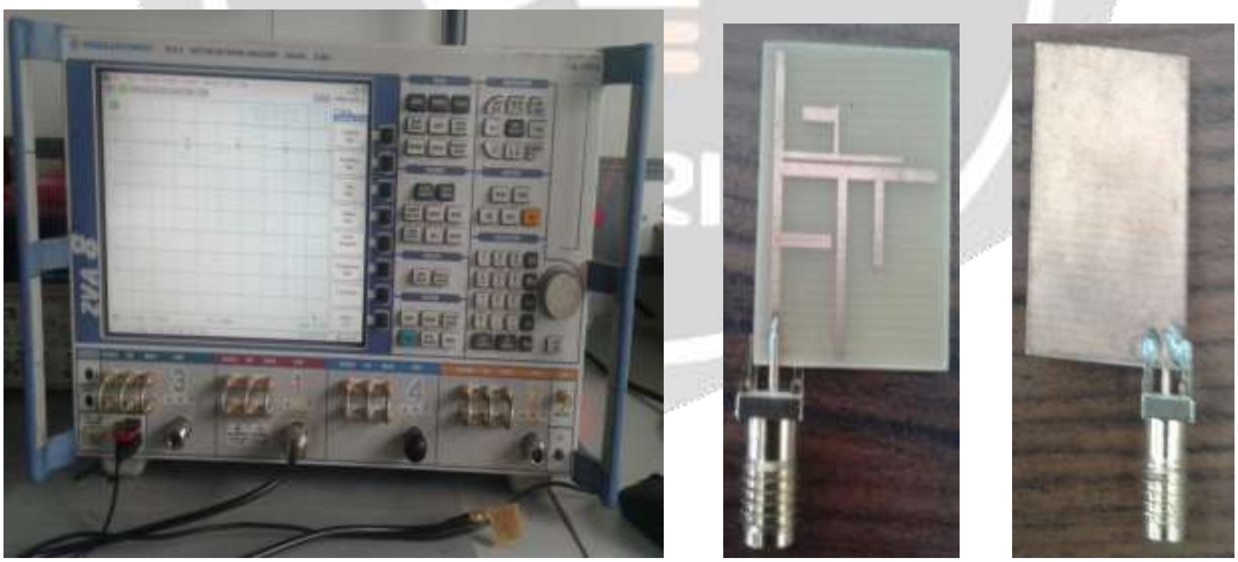


Fig. 9 Photograph of fabricated antenna and testing setup. a) Top view of antenna b) Ground plane of antenna.

The photographs of fabricated antenna in fig.9 is printed on a cheap FR4 substrate with a thickness of 1.6 mm, relative permittivity εr = 4.4, and loss tangent, tan δ = 0.02. A 50Ω coaxial cable is connected to antenna through SMA connector.

The fig.10 depicts the testing result of return loss for antenna. The antenna is tested on vector network analyzer for LTE, Wi-MAX and WLAN bands. The marker M1, M2 and M3 are placed on the tips of the wave below -10dB showing the return loss values of -25.33dB for LTE, -14.37 dB for Wi-MAX and -14.37dB for WLAN etc. The fig.11 depicts the measured result of VSWR for antenna.

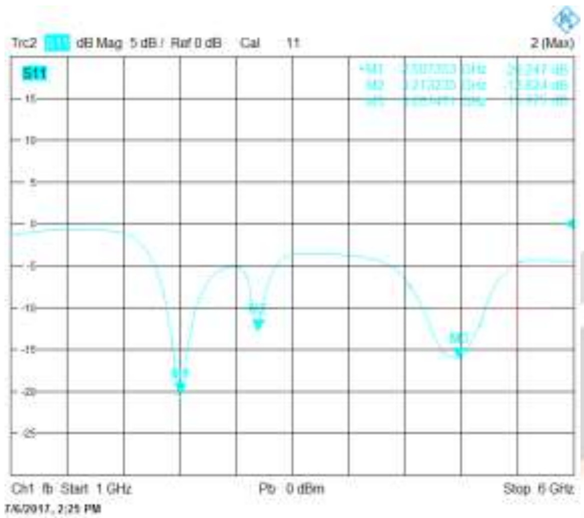


Fig. 10 The measured Return loss of antenna

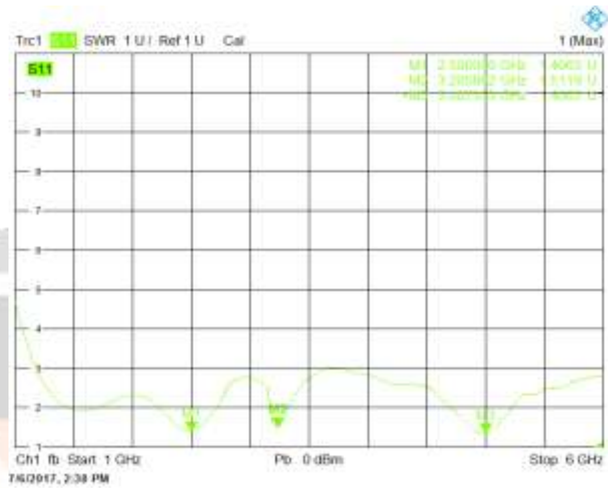


Fig. 11 The measured VSWR of antenna.

The antenna is tested on vector network analyzer for LTE, Wi-MAX and WLAN bands. The marker M1, M2 and M3 are placed on the tips of the wave between 1-2 showing the VSWR values of 1.40 for LTE 2.5 GHz, 1.51 for Wi-MAX 3.2 GHz and 1.40 for WLAN 5GHz etc.

4.3 Comparison of results of proposed antenna

Table 1: Comparison of simulated and tested results of antenna design

Parameters	LTE		Wi-MAX		WLAN	
	Simulation results	Testing results	Simulation results	Testing results	Simulation results	Testing results
Frequency	2.5GHz	2.50 GHz	3.2GHz	3.20GHz	5GHz	5.00GHz
Return loss	-15.03dB	-25.33dB	-13.97dB	-14.37dB	-15.37dB	-14.37dB
VSWR	1.38	1.40	1.46	1.51	1.41	1.40

From the above table it is clear that the measured values of VSWR, reflection coefficient and frequency bands on vector network analyzer are approximately matched with the simulation results.

5. CONCLUSIONS

In this paper we present the tri-band monopole antenna using L and inverted L shaped elements resonates at frequencies 2.5GHz, 3.2GHz and 5GHz etc. covers LTE, Wi-Max and WLAN bands. It is simple and the size of antenna is 23*20mm², which is very small. This antenna is suitable to embed into small handheld devices like mobile phones. The operating bandwidth usually decreases when the antenna size is reduced. The directivity of given antenna is grater which is 5.8/5.85/6.62dBi for the LTE2.5/Wi-MAX3.2/WLAN 5GHz bands.

6. REFERENCES

[1] Jui-Han Lu and Jia-Ling Guo, "Small-Size Octa-band Monopole Antenna in an LTE/WWAN Mobile Phone," *IEEE Trans. Antennas and wireless Propag.lett.*,vol. 13, 2014.

[2] The 3rd Generation Partnership Project, ", LTE Advanced" 2011 [Online]. Available: http://www.3gpp.org/LTE-Advanced

[3] C. H. Ku, H. W. Liu, and Y. X. Ding, "Design of planar coupled-fed monopole antenna for eight-band LTE/WWAN mobile handset application," *Prog.Electromagn. Res. C,* vol. 33, pp. 185–198, Oct. 2012.

[4] C. T. Lee and K. L. Wong, "Planar monopole with a coupling feed and an inductive shorting strip for LTE/GSM/UMTS operation in the mobile phone," *IEEE Trans. Antennas Propag.*, vol. 58, no. 7, pp. 2479–2483, Jul. 2010.

[5] K. L. Wong and W. Y. Chen, "Small size printed loop type antenna integrated with two stacked coupled-fed shorted strip monopoles for eight-band LTE/GSM/UMTS operation the mobile phone," *Microw.Opt. Technol. Lett.*, vol. 52, pp. 1471–1476, Jul. 2010.

[6] [8] Z. Chen, Y. L. Ban, J. H. Chen, J. L.-W. Li, and Y. J. Wu,"Bandwidth enhancement of LTE/WWAN printed mobile phone antenna using slotted ground structure," *Prog. Electromagn. Res. , vol*. 129, pp.469–483, Jul. 2012.

[7] S. Venkatrami Reddy, Aditya Singh, Yadu Nath. K and M. Jaleel Akhtar, "Design of a Practical Dual-band Planar Monopole Antenna for WLAN and Wi-MAX Applications," IEEE, 2013.

[8] Missi K. Bhasker, Chandan and R.K. Prasad, "Design of Monopole Antenna with Defected Ground for WLAN Application," *International Conference on Emerging Trends in Electrical, Electronics and Sustainable Energy Systems (ICETEESES–16) pp 91-94 2016.*

[9] Suvadeep Choudhury and Santasri Koley, "A compact quad-band planar monopole antenna for Bluetooth/Wi-MAX/WLAN applications," IEEE 2013.

[10] Junyu Guo and Ziqiang Xu, "Design of Miniature Tri-band Monopole Antenna for WLAN and Wi-MAX Applications," 15th international conference on electronic packaging technology, pp. 1397-1399, 2014.

[11] Muhammad R. Khan, Mohamed M. Morsy, Muhammad Z.Khan and Frances J. Harackiewicz, "Miniaturized Multiband Planar Antenna for GSM, UMTS, WLAN, and Wi-MAX bands," AP-S/URSI pp 1387-89, 2011.

[12] Arvind Kumar and Praveen V. Naidu, "A Compact O-shaped Printed ACS Fed Monopole Dual-band Antenna for 2.4GHz Bluetooth and 5GHz WLAN/Wi-MAX Applications," Progress In Electromagnetic Research Symposium (PIERS), Shanghai, China, pp. 2004-2008, 8–11 August, 2016.

[13] Ahmed Zakaria Manouare, Abdelaziz El Idrissi, Saida Ibnyaich and Abdelilah Ghammaz, "A Compact Triple-Frequency CPW-fed Planar Monopole Antenna for PCS/Wi-MAX/WLAN Applications," IEEE, 2014.

[14] S. A. A. Shah, M. F. Khan, S. Ullah and J. A. Flint, "Design of a Multi-Band Frequency Reconfigurable Planar Monopole Antenna Using Truncated Ground Plane for Wi-Fi, WLAN and Wi MAX Applications," International Conference on Open Source Systems and Technologies (ICOSST), pp 151-155, 2014.

[15] Chow-Yen-Desmond Sim, Chih-Husan Yeh, and Hen-Lun Lin, “Compact Size Triple-band Monopole Antenna with Parasitic Element for WLAN/Wi-MAX Applications,” Proceedings of ISAP 2014, Kaohsiung, Taiwan, pp. 469-470, Dec. 2-5, 2014.

[16] Y. Huang and K. Boyle, *Antennas from theory to practice*. Hoboken, NJ, USA: Wiley, 2008, p. 124.