PRINTED TRI - BAND MONOPOLE ANTENNA STRUCTURES FOR WIRELESS APPLICATIONS

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ABSTRACT: ***This paper proposes a novel tri-band printed monopole antenna structure for Wireless applications in GSM, DCS and WLAN, IEEE 802.11 ISM band. The proposed antenna consists of a rectangular patch monopole printed antenna in which a slot is cut and dual band E shape patch is placed. The three arms in monopole antenna generates three resonate frequencies to cover 890 - 960 MHz GSM band, 1710-1880 MHz DCS band and 2.4 – 2.5 GHz ISM band. Slots are removed to coincide with central arm to obtain the second structure. Central arm of antenna resonate at GSM while the other two side arms resonate at DCS and ISM band, therefore three bands can be optimized easily. The proposed antennas can easily be fed by using a 50 ohm probe feed. The simulated VSWR is < 2 over 890-960 MHz, 1710 – 1880 MHz and 2.4 - 2.5 GHz The radiation patterns indicate the suitability of these antennas for wireless applications.***

Key words***: Tri band, ISM band, IEEE 802.11, GSM, DCS, WLAN, Printed antenna.***

1. INTRODUCTION

Dual and multi-frequency band operation of antennas has increasingly become common, mainly because of the tremendous growth in modern wireless communication systems. Most of them are antennas with linear polarization in multiple frequency bands for mobile phones and wireless Local Area Network applications (WLAN). WLAN is one of the most important applications of the wireless communication technology that takes advantage of license free frequency bands, industrial, scientific and medical (ISM) bands. In order to integrate these bands for use in one device, it is essential to develop efficient dual-band or tri-band antennas. Dual band monopole antennas have been reported [1-5] but these however offer narrow impedance bandwidth characteristics. Rectangular planar monopole antennas (RMA) on the other hand have been shown to exhibit a relatively wide impedance bandwidth and good radiation pattern characteristics [6]. The planar monopole antenna is a good candidate for wireless communication

because of its simple structure, omni-directional radiation characteristic, low profile, and lightweight internal antenna [7]. It is significant that the designed dual or multi band antenna maintained good radiation efficiency value and constant gain at both bands [8]. U slot dual band patch antennas are discussed [9-11]. Compact multi-band antennas for wireless communication are reported [12-14].

In this paper novel tri band antenna structures for GSM, DCS and WLAN are proposed. The proposed antennas are simple to design and offer an effective control of three operating bands by controlling the dimensions of three arms. The proposed antennas can easily be fed by using a 50 ohm probe feed. The simulated VSWR is < 2 over the 890-960 MHz, 1710 -1880 MHz and 2.4 - 2.5 GHz. The radiation patterns indicate the suitability of these antennas for wireless applications.

The antenna geometry and design theory are described in the following sections. The impedance variation, current distribution, radiation pattern and gain variation versus frequency in three bands are also discussed in the following sections.

2. ANTENNA DESIGN THEORY

In planar monopoles, most of the current is concentrated on the outside edge of the radiating element [6] and therefore the centre section of a rectangular monopole can be removed with negligible effect on antenna impedance or radiation characteristics. This leads to the formation of a U-shaped monopole antenna. The impedance bandwidth of this U-shaped monopole antenna is wide enough to cover ISM (2.4-2.5 GHz) band. A planar rectangular monopole is placed in the central portion of U – shaped monopole antenna to resonate at 1.8 GHz band to cover the DCS (1710-1880 MHZ) leading to E shaped dual band antenna [10 - 11] and based on similar principal another slot is cut in the central arm of the E shaped antenna and a rectangular arm is placed to cover 890-960 MHz GSM band leading to an extended E shape tri band monopole antenna (EESMA).

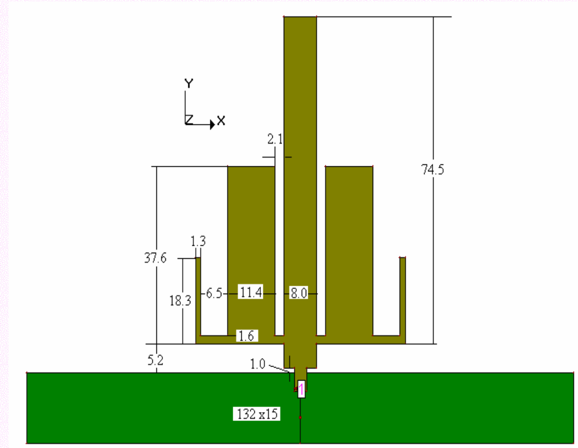
Since different arms of monopole antenna resonate at different frequencies, therefore three bands can be optimized easily.

Theoretical current path length of an arm of monopole antenna structures to resonate at a frequency should be equal to λ / 4 in free space which is 81.1, 41.7 and 30.6 at 925 MHz, 1.8 GHz and 2.45 GHz respectively. The width of the corresponding arms determines impedance bandwidth at respective bands

If the slots are removed or the arms resonating at 2.4 and 1.8 GHz are allowed to coincide with central arm it gives rise to an extended E shape monopole antenna without slots (EESMAWS). This antenna can also be treated as one with the width discontinuity. The antenna offers a reduction in size without any degradation in radiation pattern. The antennas provide nearly omnidirectional radiation pattern in all the bands

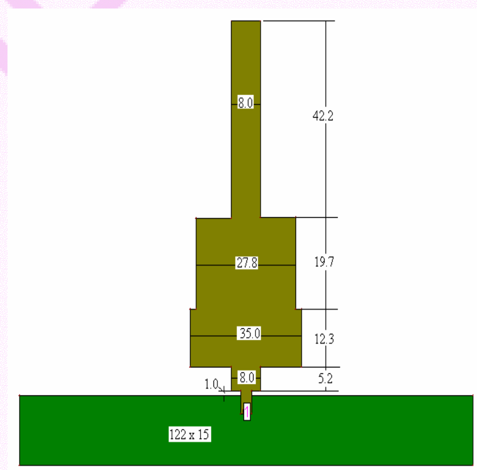
2. ANTENNA GEOMETRY AND SIMULATION RESULTS

The geometry of the proposed antenna structures are shown in Figure 1. The antenna structures are designed and simulated using FR4 substrate. The relative permittivity and loss tangent thickness of 1.59 mm thick substrate are 4.4 and 0.02 respectively. The structure is fabricated on the one side of the substrate and ground is on the other side of the substrate. The antenna is fed through a 50 Ω probe feed at the centre of a 50 Ω microstrip line of width 3 mm and a length of 4 mm.



(a) Extended E shape monopole antenna

To achieve the desired tri-band characteristics for GSM / DCS and WLAN operations in the 900 MHz, 1.8 GHz and 2.4 GHz bands respectively, the dimensions of the longer arm of rectangular monopole is optimized to resonate at 900MHz while dimensions of



(b) Extended E shape monopole antenna without slots

Figure 1 Geometry of the proposed Dual band antennas

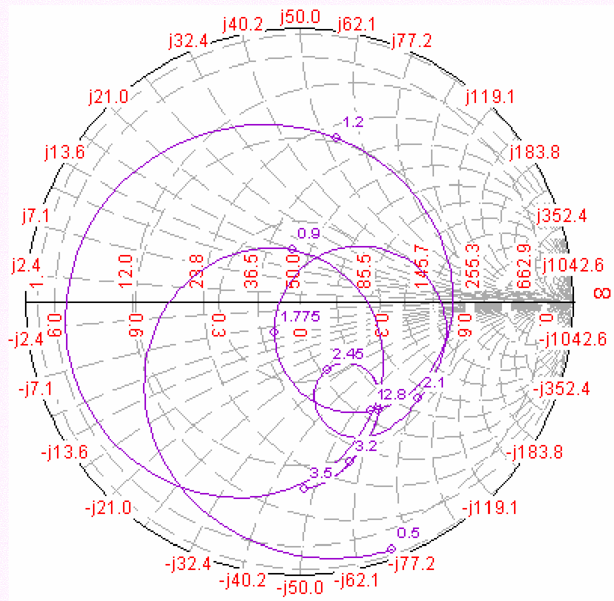
(All dimensions mentioned here are in mm only)

the middle and shorter arm of monopole is optimized to resonate at 1.8 and 2.45 GHz respectively. Hence the proposed antennas provide effective control of the three operating bands. In addition, Ground plane dimensions are also optimized to achieve the desired tri-band operation as it affects the resonant frequencies and operating bandwidths in three bands. An overall substrate dimensions in extended E shaped monopole antenna is 150 x 105 mm^2 while substrate dimensions reduces to 125 x105 mm^2 in case of extended E shape monopole antenna without slots.. A dipole or monopole like radiation pattern can be obtained by varying the ground-plane dimensions. The antenna structures are simulated using IE3D software [15].

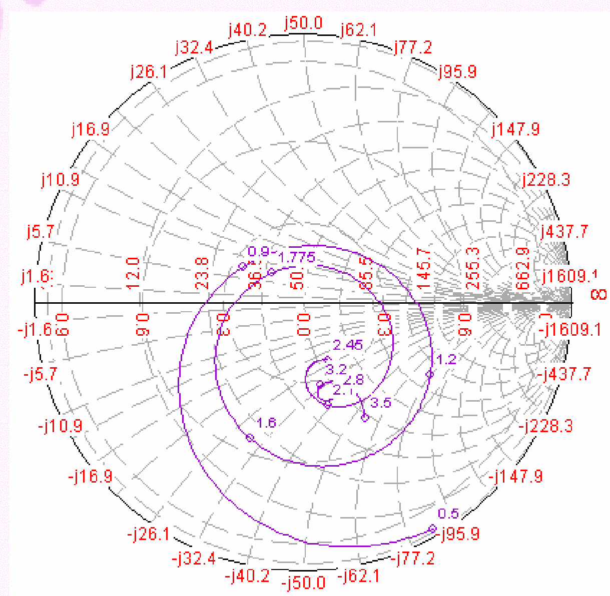
The simulated impedance variations of the antenna structures are shown in Figure 2. Tri - band with wide bandwidths are observed. The frequency range for VSWR ≤ 2 in GSM, DCS and ISM band is tabulated in Table 1. The lower band covers 890 -960 MHz GSM band, central band covers 1.710 – 1.880 DCS band and the upper band covers 2.4 -2.5 GHz (IEEE 802.11b and IEEE 802.11g) ISM band. The current distribution at 925 MHz, 1.8 GHz and 2.45 GHz is shown in Figure 3. The normalized radiation patterns at 925 MHz, 1.8 GHz and 2.45 GHz are shown in Figure 4. The radiation pattern are observed to be nearly omnidirectional in φ = 0˚ plane in both structures. Cross polar component is observed to be more in EESMAWS as compared to EESMA antenna. Also EESMA provides better isolation between two nearby bands as compared to EESMAWS. Cross polarization component also increases with frequency. The pattern variation over the frequency band is small. The gain variation vs. frequency is shown in Figure 5 which is less than 1 dB over the three frequency bands.

Table 1 Frequency band for VSWR ≤ 2.

Antenna structure	GSM Band MHz	DCS Band GHz	ISM Band GHz
E ESMA	862-962	1.705-1.882	2.394-2.562
EESMAWS	871-1040	1.710-1.890	2.217-2.637

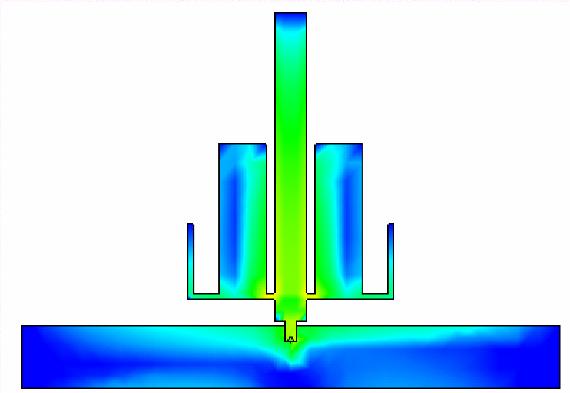


(a) Extended E shape monopole antenna

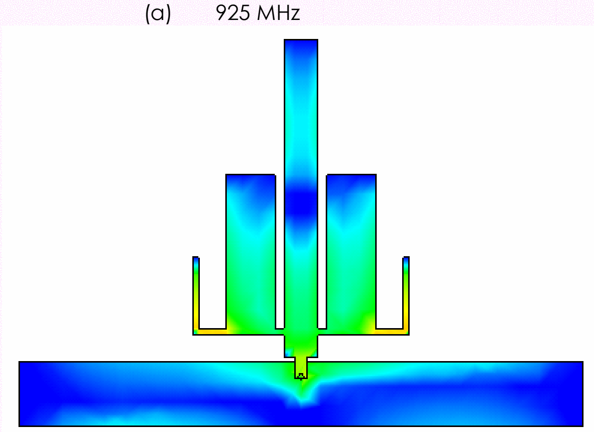


(b) Extended E shape antenna without slots

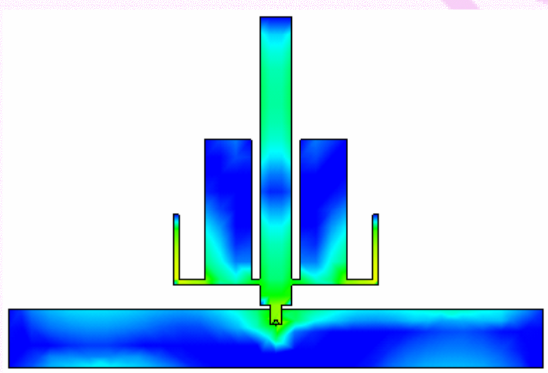
Figure 2 Impedance variations vs. frequency



(a) 925 MHz

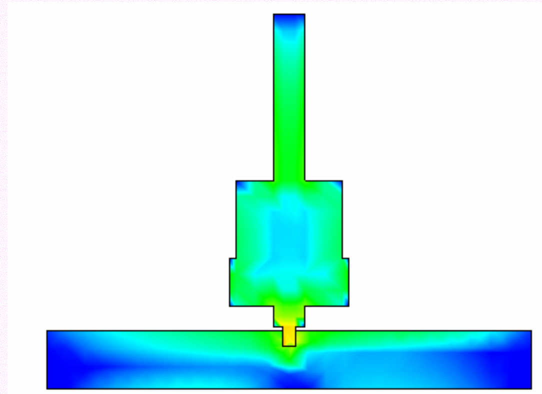


(b) 1.8 GHz

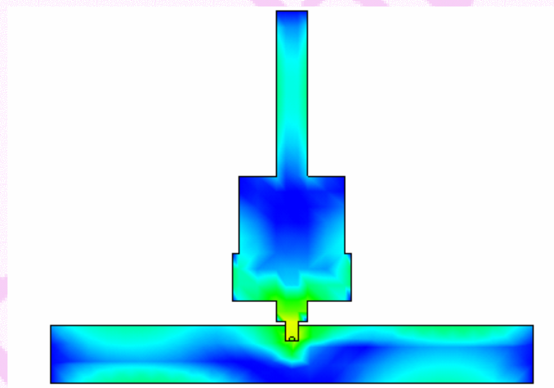


(c) 2.45 GHz

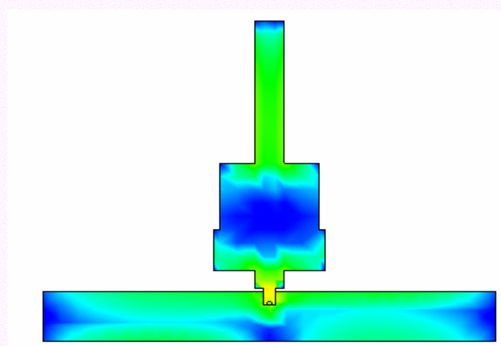
Figure 3 (a) Current distributions in EESMA structure



(a) 925 MHz

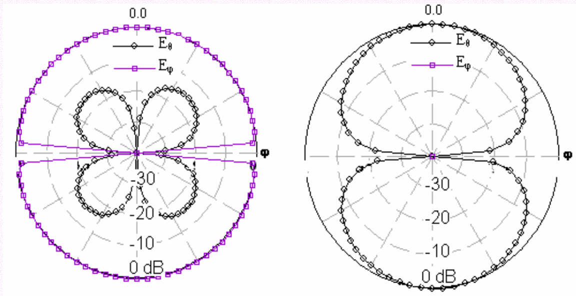


(b) 1.8 GHz

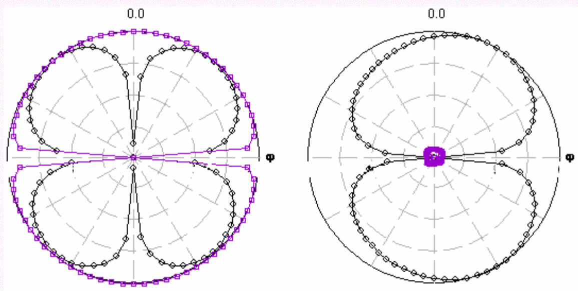


(c) 2.45 GHz

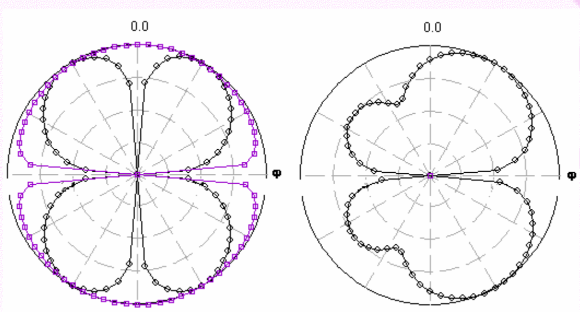
Figure 3 (b) Current distributions in EESMAWS structure



(a) 900 MHz



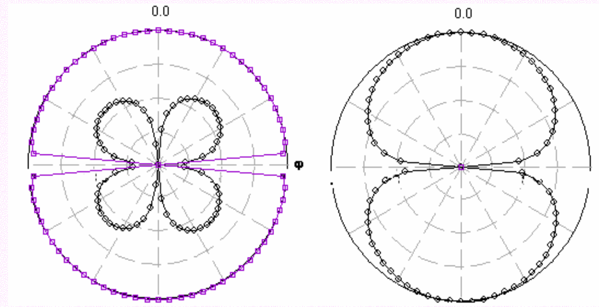
(b) 1.8 GHz



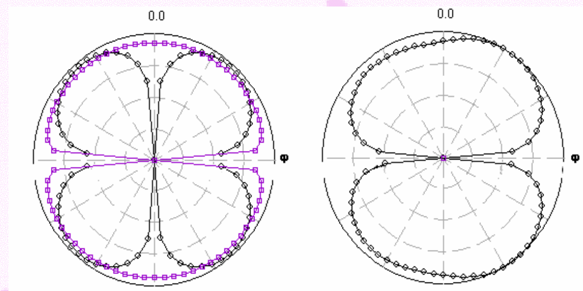
(c) 2.45 GHz

(i) φ = 0˚ (ii) φ = 90˚

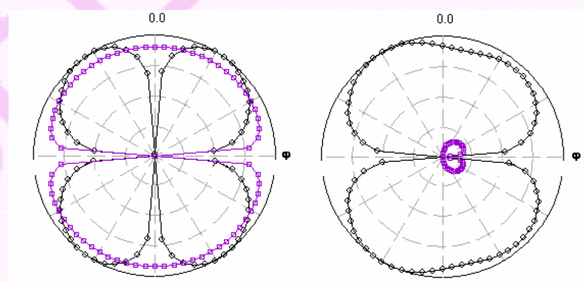
Figure 4 (a) Radiation pattern of Extended E shaped monopole antenna



(a) 900MHz



(b) 1.8 GHz



(c) 2.45 GHz

(i) φ = 0˚ (ii) φ = 90˚

Figure 4 (b) Radiation pattern of Extended E shape monopole antenna without slots

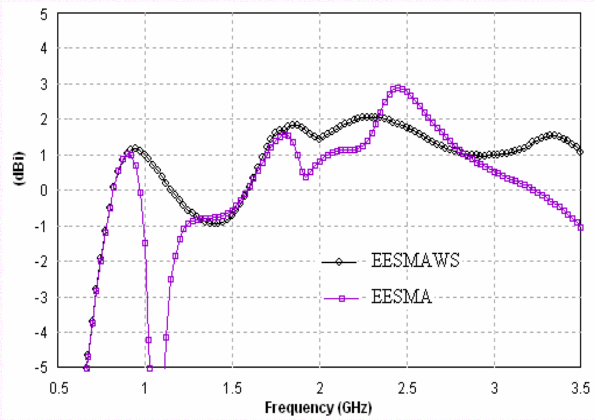


Figure 5 Gain vs. Frequency of tri- band antenna structures

3. FABRIACATION AND MEASURED RESULTS

The antenna structures are fabricated and tested. The measured results are in close agreement with simulated results. The measured and simulated VSWR plots of extended E shape monopole antenna (EESMA) and extended E shape monopole antenna without slots (EESMAWS) are shown in Figure 6 and Figure 7 respectively.

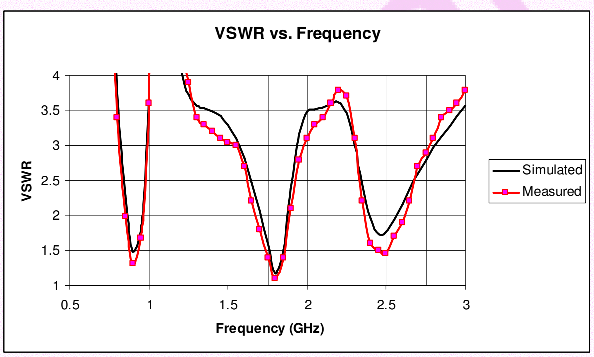


Figure 6 Measured and simulated VSWR of Extended E Shape monopole (EESMA) antenna

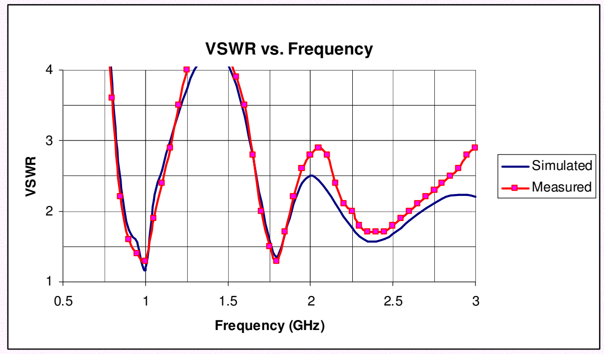


Figure 7 Measured and simulated VSWR of Extended E Shape monopole without slots (EESMAWS) antenna

6. CONCLUSION

Printed tri-band monopole antenna structures for GSM / DCS / WLAN applications are analyzed. A triple band with wide bandwidth characteristics is observed in each structure which covers 890 - 960 MHz, 1.710 – 1.880 GHz and 2.4 – 2.5 GHz bands. The proposed antennas are designed on low cost easily available FR4 substrate. The results obtained clearly indicate that the antennas are capable of generating nearly omnidirectional radiation pattern in all the three frequency bands. These antenna structures provide flexibility of shape and also space availability on substrate beside satisfactory and comparative performance for wireless applications.

REFERENCES

1. Tae-Hyun Kim and Dong-Chul Park, Compact Dual-Band Antenna With Double L-Slits for WLAN Operation, IEEE Antennas And Wireless Propagation Letters, VOL. 4, 2005

2. D. Nashaat, H.A.Elsadek and H Ghali, Dual-band reduced size PIFA antenna with U-slot for Bluetooth and WLAN applications, Proc. IEEE Antennas and Propagation Society Int. Symp, vol 2 USA,2003, pp 962-965.

3. C.C.Lin, G.Y.Lee and K.Y.Wong, Surface-mount dual-loop antenna for 2.4/5 GHz WLAN operations, Electron. Lett. , vol 39, pp. 1302-1304, Sept. 2003.

4. Y.L.Kuo and K.L.Wong, Printed double-T monopole antenna for 2.4/5.2 GHz dual-band WLAN operations, IEEE Transaction Antennas and Propagation, vol. 51, no 9, pp 2187-2192, Sept. 2003.

5. Y.H.Suh and K.Chang, Low cost microstrip-fed dual frequency printed dipole antenna for wireless communications, Electron. Lett. , vol. 36, pp. 1177-1179, Jul 6 2000.

6. M.J. Ammann, Square planar monopole antenna, IEEE National Conf.Antennas and propagation, UK, no.461, pp. 37-40, 1999.

7. K.P. Ray, P.V. Anob, R. Kapur and G. Kumar, Broadband planar rectangular monopole antennas, Microwave and Optical Technology letters, vol.28, no.1, pp.55-58, Jan.2001.

8. G. Kumar and K.P. Ray, Broadband Microstrip Antennas, Norwood, MA Artech house, 2003.

9. A.J. Kerkhoff, R.L. Rogers and H. Ling, Design and analysis of planar monopole antennas using a genetic algorithm approach,, IEEE Transactions Antennas and Propagation, vol. 52, no.10, pp 2709 – 2718, Oct. 2004

10. S.K.Das, R.K.Gupta and G.Kumar, Planar Dual Band antenna, IEEE Antennas and Propagation Society International Symposium, Albuquerque, New Mexico, USA, pp. 1706- 1709, July 2006.

11. Ryan D'Souza and R. K.Gupta, Printed Dual Band WLAN antenna, International conference on Electro - Information Technology, U.S.A. , pp 539-543, May 2006.

12. Qinjiang Rao and Tayeb A. Denidni, New Broadband Dual- Printed Inverted L – Shaped Monopole Antenna for Tri-band Wireless Applications, Microwave and Optical Technology letters, vol.49, no.2, pp.278-280, Feb. 2007

13. Li-Na Zhang, Shun-Shi Zhong, Xian-Ling Liang and Chun-Hui Li, Compact Meander Monopole Antenna for Tri-band WLAN Applications, Microwave and Optical Technology letters, vol.49, no.4, pp.986-988, April 2007.

14. Yue Song, Yong-Chang Jiao, Hui Zhao, Zheng Zhang, Zi-Bin Weng, and Fu-Shun Zhang, Compact Printed Monopole Antenna for Multiband WLAN Applications, Microwave and Optical Technology letters, vol.50, no.2, pp.365-367, Feb. 2008.

15. IE3D release 12.0, Zeland software Inc., Fremont, CA., USA, 2002.