Compact Band-Notched Printed Monopole Antenna For Ultrawideband Communication

Ms. R. P. Labade Member, IEEE MTT'S
Research Scholar, Symbiosis Institute of Technology, SIU
Pune, India
rplabade@gmail.com

Dr. S. B. Deosarkar
Professor, BATU, Lonere, India

Dr. Narayan Pishoroty
Professor, Symbiosis Institute of Technology, SIU
Pune, India

Dr. Akshay Malahotra
Deputy Director, Symbiosis Institute of Technology, SIU
Pune, India

***Abstract*—A compact wideband printed monopole antenna with band notch characteristics is proposed and investigated. Introducing a two corner notches at the lower edges of radiating patch and notch in destructive ground surface (DGS) increased bandwidth from 3-11GHz. By inserting an inverted U-slot in the radiating plane 3.3-4.2GHz (Wi-Max and C-band satellite communication) band notch characteristics is obtained. Systematic parametric studies have been conducted by changing gap distance between radiating patch & defective ground surface (DGS), length and width of inverted U-notch. Antenna is simulated using CAD FEKO suite (6.2) using method of moment. A prototype of antenna is fabricated using a FR4 dielectric substrate with a dielectric constant of 4.4 and loss tangent of 0.02 having dimensions of 11 mm x 15 mm x 1.59 mm. Radiation pattern shows directional pattern along E-plane and nearly omnidirectional pattern along H-plane. Simulated and measured results of the proposed antenna are presented.**

Keywords*—band notch; DGS; inverted U-notch; method of moments; printed monopole; ultrawideband (UWB).

I. Introduction

In February 2002, FCC released an unlicensed frequency band from 3.1 to 10.6 GHz for commercial operation of ultra-wideband (UWB) technology. Since then the UWB has been considered as one of the most promising wireless technology for transmission of signal at very high data rate [1]. UWB antenna is the important part of ultra wideband system. Due to its fantabulous advantages such as small size, light weight, broad bandwidth, omnidirectional radiation pattern, easy of fabrication and integration with other MMIC's, Printed UWB antennas are becoming appraisingly popular.

Within the FCC's assign licensed free frequency band from 3.1 to 10.6GHz, few narrow band wireless communication systems are exist which cause interference to UWB wireless communication systems, These systems are 3.3 to 3.7GHz WiMAX (IEEE802.16), 3.7-4.2 GHz C-band satellite communication, 5.15-5.825GHz WLAN(IEEE 802.11a and HIPERLAN/2),7.25-7.75GHz X-band satellite communication, 8.025-8.4GHz ITU (International Telecommunication Union) band[2]. It is essential to reduce the potential inferences produced by aforementioned band in UWB frequency band. In some applications, UWB antenna uses filters to suppress interfernce bands. However, the uses of filters indeed increase the complexity of the UWB system and lead to increase in cost. In the world of miniaturization for PCS applications and other handheld devices size of system should be small, so it is desirable to design the UWB antenna with band notched function to minimize the potential interferences between UWB system and narrowband systems [3-4].

Great numbers of experiments have been conducted by researchers to obtain the wide bandwidth [5-7].Bandwidth enhancement achieved by exciting modes in vicinity of fundamental mode by inserting slots in the patch [8]. Integrating parasitic center patch in the rectangular slot improved impedance bandwidth [8]. Electromagnetic band gap structure is used for design of UWB antenna [9]. Theory of characteristics mode (TCM) analysis improved the bandwidth of square monopole antenna [10]. Printed UWB with band notch characteristics are presented recently. Antennas are designed with band notch function at single [11], two notch bands [12-13]. Band notch characteristics are obtained by embedding a half wavelength and quarter wavelength slots or parasitic elements either in patch, ground plane or in microstrip feed line. Working principle of band rejection with inserting half and quarter wavelength resonator is elaborated [14].

In this paper we proposed and demonstrated a compact UWB antenna with band notch function from 3.3-4.2GHz by embedding half wavelength inverted 'U' slot in the radiating patch. Corner notch at lower edge in radiating patch and notch in the DGS enhanced bandwidth from 3 to 11GHz for VSWR ≤ 2.

II. Antenna Design

The basic geometry of printed monopole antenna is shown in Fig. 1. Rectangular patch is fed by a microstrip line. Rectangular radiating patch and microstrip feed line are printed on same side of the substrate and destructive ground structure (DGS) is printed on the other side of the substrate. For simulation of antenna substrate FR4 with a dielectric

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constant (εr) of 4.4, loss tangent (tan δ) = 0.02, and 1.59mm substrate height is used.

Following formulae are used to design the monopole antenna. Lower edge frequency is considered for design [15].

$$L = \frac{\lambda}{4} - 2 * \Delta L \quad (1)$$

$$W = \frac{c}{4f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (2)$$

$$\lambda = \frac{C_0}{(f * \sqrt{\varepsilon_r})} \quad (3)$$

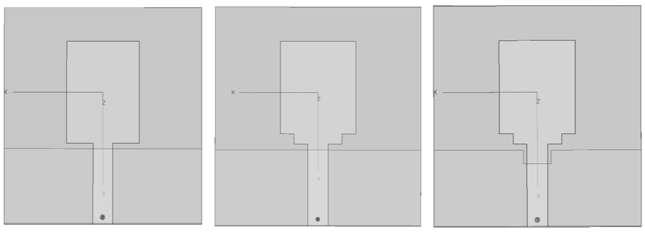
$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12 * \left(\frac{h}{w}\right)\right]^{\frac{-1}{2}} \quad (4)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon reff + 3)(\frac{W}{h} + 0.264)}{(\varepsilon reff - 0.258)\,(\frac{W}{h} + 0.8)} \quad (5)$$

Where L= length of patch, W= width of patch, λ = wavelength, ε_{eff} = effective dielectric constant, ε_r = dielectric constant of substrate, ΔL = extension along length, h = substrate height, w = width of substrate.

A. Evolution of printed rectangular monopole antenna

In this section we discussed evolution of printed rectangular monopole antenna which is depicted in fig.1 and effect of corner notches in radiating patch and ground notch in DGS are discussed.



(a)Simple rrectangular monopole (b) corner notch monopole (c) corner and ground notch monopole

Fig.1 Evolution of Rectangular Monopole antenna

B. Parametric study of Printed Rectangular Monopole Antenna

Parametric study of printed rectangular monopole antenna is conducted by varying the gap between the radiating patch and the ground plane. Fig.2 shows very poor VSWR when there is no gap between radiating patch and the DGS. Gap between the radiating patch and DGS produces a coupling capacitance and which balances the inductance produced by the patch and results in increased bandwidth [2].When 'g'=2mm good electromagnetic coupling is observed. Hence for further study 'g'=2mm is selected.

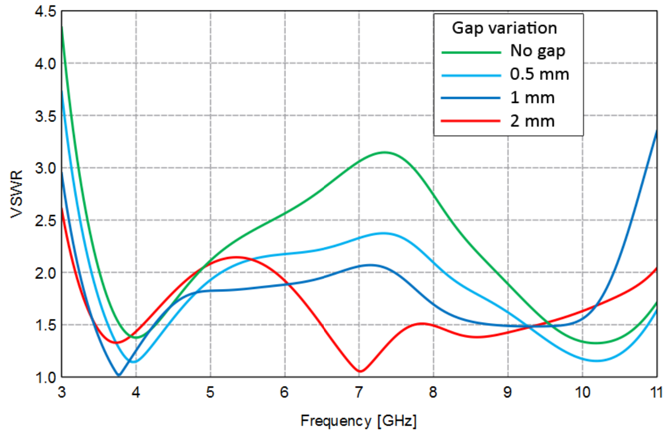


Fig.2 Simulated VSWR versus frequency for different gap distance 'g' for simple rectangular monopole antenna.

Graph of simulated VSWR versus frequency for simple patch antenna without corner and ground notches, with only corner notches and with corner notches & ground notch is shown in fig 3.For simple patch antenna without corner and ground notch VSWR ≤ 2 is obtained from 3.1GHz to 6.8GHz and 7.3GHz to 10.4GHz. When lower corners of the radiating patch are cut then impedance bandwidth is enhanced from 3.1GHz to 4.8GHZ and 6.4GHz to 11GHz for VSWR ≤ 2.Further notch is placed in DGS fig.3 shows ground notch produced additional resonance and obtained bandwidth from 3.1GHz to 11GHz.

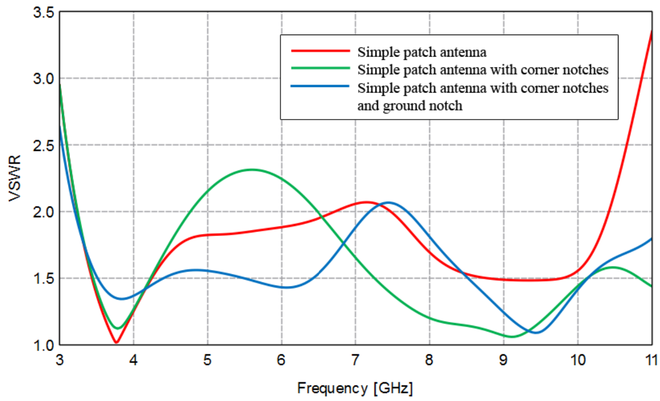


Fig.3 Simulated VSWR versus frequency of simple patch antenna without corner and ground notches, with corner notches and with corner notches & ground notch

C. Bandnotch printed rectangular monopole antenna

Geometry of proposed antenna is shown in fig 4 along with it's dimensions. Band notch is generated between 3.3 to 4.2GHz by inserting an inverted 'U' slot. The length of the inverted 'U' slot is calculated using equation (6) with 3.5GHz. center frequency

$$L_{notch} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (6)$$

UWB behavior of antenna is notice over entire band from 3GHz to 11GHz except aforementioned notch band.

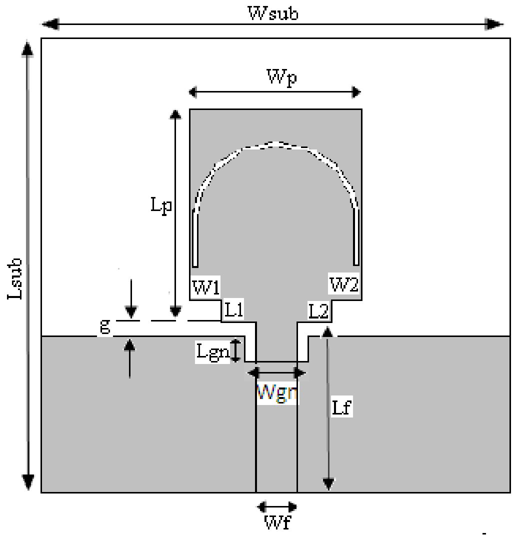


Fig.4 Geometry of band notch rrectangular monopole antenna with dimensions (in mm) Lp= 15,Wp =11, Lf =12,Wf =2.75,Lgn =2,Wgn =4,W1=1,W2=1,L1=1,L2=1,g =1,Lgnd =11,Wsub =30,Lsub =30

D. *Effect of slot lentgh*

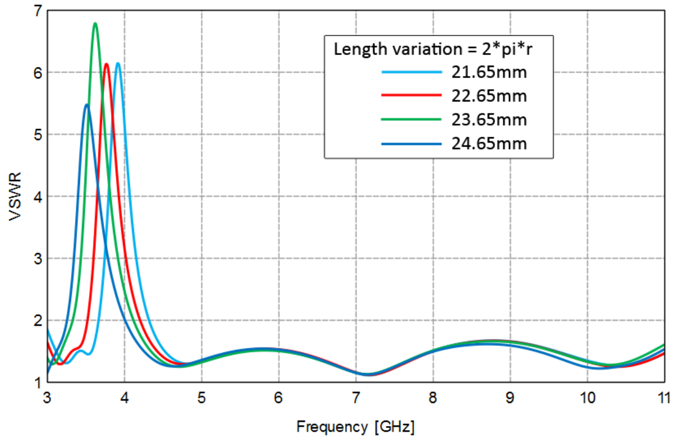


Fig.5 Simulated band rejection characteristics of band notch rectangular monopole antenna

Parametric study is carried out by changing one parameter at a time and other parameters are kept constant. In this study length of the inverted 'U' is changed from 21.65mm to 24.65mm.Incresae in the slot length results in shifting of resonance frequency towards lower side. For final design 23.65mm slot length is selected as highest notch amplitude with sharp selectivity is observed at this length.

E. *Effect of slot width*

Increase in width of inverted 'U' slot causes increase in rejection bandwidth. Large width increases current path for flow of current and increases the rejection bandwidth. At 0.3mm we observed the required band notching within aforementioned frequency band hence this slot width is consider for final antenna design.

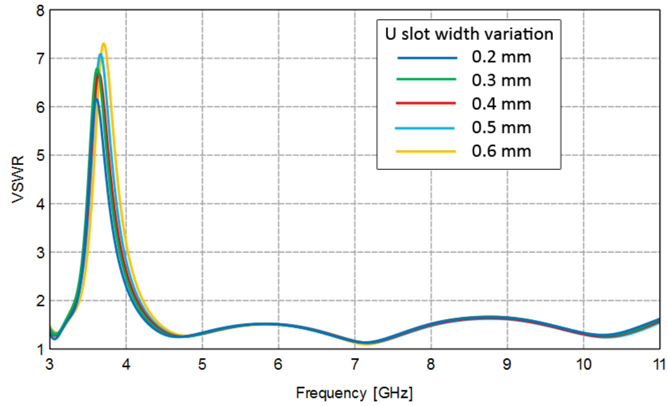
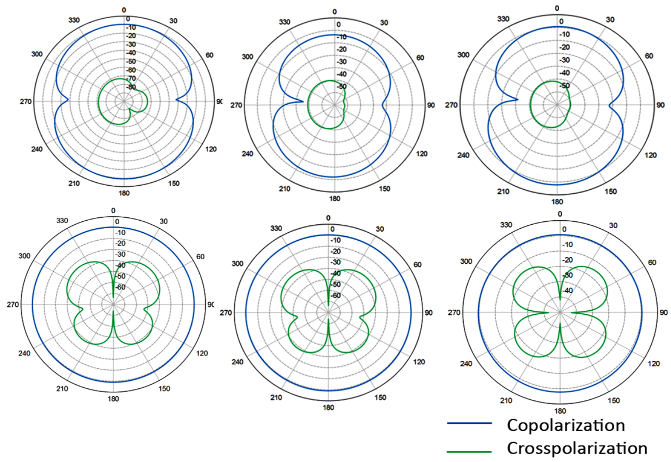


Fig.6 Simulated band rejection characteristics of band notch rectangular monopole antenna

F. *Radiation characteristics*

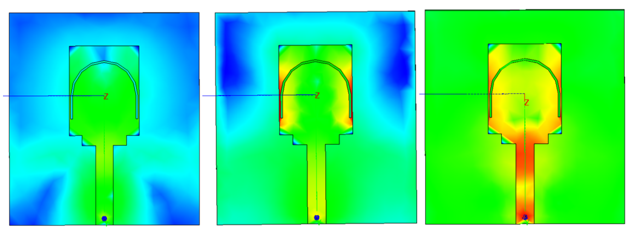
Radiation characteristics describe the energy directed by the antenna [6]. Fig.7 shows the radiation pattern for elevation plane (□=90^0) and azimuth plane (□=0^0) at f=3.1 GHz, f= 5.5 GHz and 7.5GHz. Radiation pattern of figure eight is observed in elevation plane and nearly omnidirectional in azimuth plane.



(a)3.1GHz (b) 5.5GHz (c) 7.5GHz

Fig. 7 Radiation pattern of band notch rectangular monopole antenna

At notch frequency band maximum current flows in inverted 'U' notch. While for all other frequency band patch radiates as depicted in Fig .8.



(a) 3GHz (b) 3.5 GHz (c) 7.5GHz

Fig. 8. Current distribution at different frequency of band notch rectangular monopole antenna.

G. *Efficency of bandnotch antenna*

Efficiency of antenna drops to 10% in aforementioned rejection band while about 70% at all other frequencies, which clearly indicates the antenna filter the frequency band from 3.3 to 4.2GHz as shown in Fig. 9.

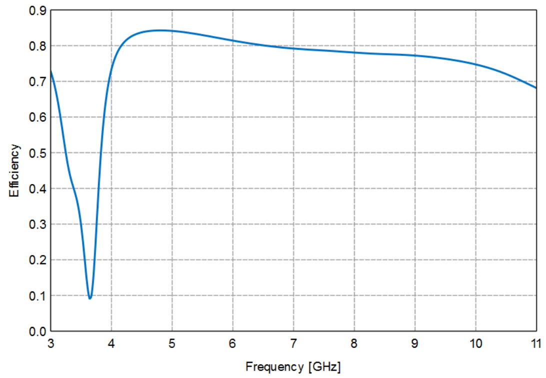


Fig. 9 Graph of Efficiency versus frequency of band notch rectangular monopole antenna

III. RESULTS AND DISCUSSION

Measured and simulated VSWR of rectangular band notch UWB is shown in Fig.10. Measurement was performed with an Agilent Field fox N9916A vector network analyzer. Measured results are in good agreement with the simulated results. Inverted 'U' notch successfully provided a band notching from 3.3 to 4.2 GHz frequency. While ultra wideband behavior is observed for remaining frequency band from 3GHz to 11GHz. Small variations in the measured VSWR are observed which may be due to solder SMA connector to patch and manufacturing tolerance, but it is with one to two VSWR range.

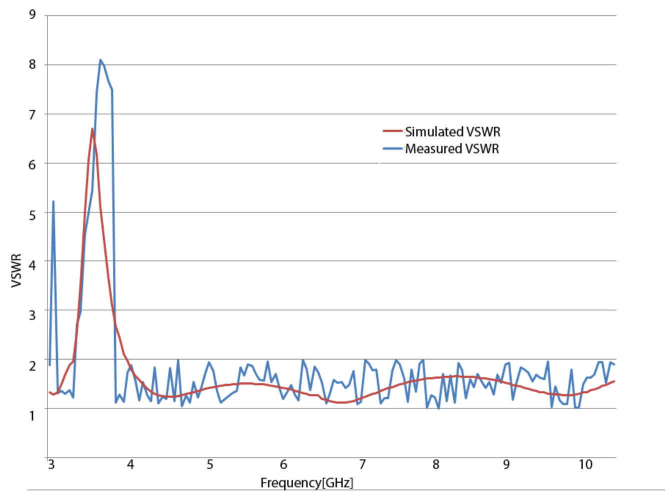


Fig. 10 Measured and simulated VSWR of band notch rectangular monopole antenna

Group delay of UWB antenna should be constant over the entire operating frequency band [16]. Above mention two port vector network analyzer is used for measurement of group delay. In this measurement two identical antennas are positioned face to face with 30cm apart from each other. Less variations in the group delay over UWB frequency band except notched band was noted.

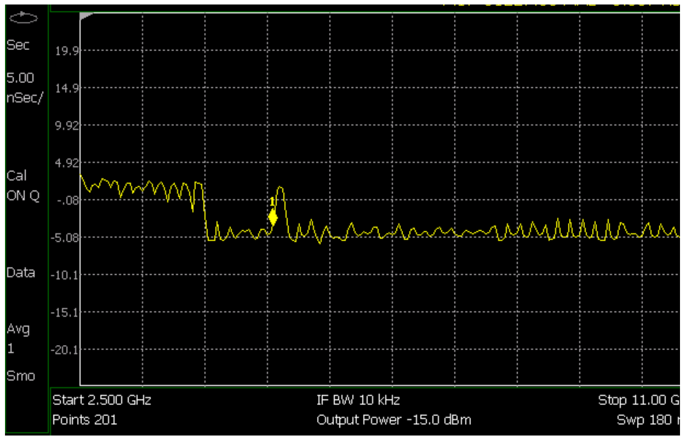


Fig. 11 Measured group delay (face to face) of band notch rectangular monopole antenna

Antenna was manufactured using photolithographic technique.Fig.12 shows photograph of fabricated prototype of band notch rectangular monopole antenna.

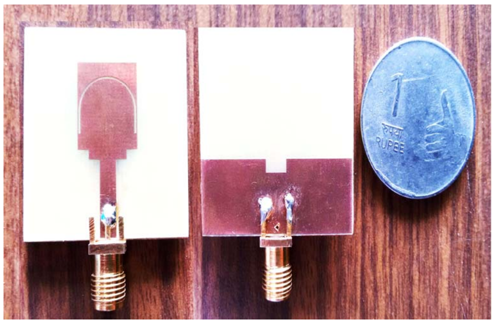


Fig. 12 Photograph of fabricated prototype of band notch rectangular monopole antenna

IV. CONCLUSION

A compact rectangular band notch UWB antenna has been designed, simulated, fabricated and measured. By inserting a two corner notches in patch and notch in DGS improved the impedance bandwidth from 3GHz to 11GHz. Inverted 'U' slot in the radiating patch produced the band notch characteristics from 3.3 to 4.2 GHz covering wimax (3.3-3.7 GHz) and C-band downlink (3.7-4.2 GHz) frequency bands. Good band rejection characteristics are obtained by optimizing the length and width of the slot. Increase in the length of slot shifts resonant frequency to lower side while increase in the slot width increases bandwidth of filter band. Except rejected band constant group delay has been observed over the entire operating frequency band.

V. RFEFERANCES

[1] "FCC Rules regarding UWB Transmission System", First report and order, (2002), 02-48.

[2] Sanjeev Kumar Mishra, Jayant Mukharjee, "Planar UWB Antennas, design, analysis and application", LAP Lambert Academic Publishing, Germany, 2012.

[3] Qing-Xin Chu, Member, IEEE, and Ying-Ying Yang, "A Compact Ultrawideband Antenna With 3.4/5.5GHz Dual Band-Notched Characteristics"IEEE Transactions On Antennas And Propagation, Vol. 56, NO. 12, DECEMBER 2008R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[4] K. P. Ray and Y. Ranga, "Ultrawideband Printed Elliptical Monopole Antennas ",IEEE Transaction on Antennas and propagation,vol. 55,NO.4,April 2007.

[5] M. J. Ammann and Zhi Ning Chen, "A Wide-Band Shorted Planar Monopole with Bevel", IEEE Trans. On Antennas and Propagation, Vol. 51, No. 4, AprilL 2003, 901-903.

[6] Kumar, G., and K. C. Gupta,''Broadband Microstrip Antennas Using Additional Resonators Gap-Coupled to the Radiating Edges,'' IEEE Trans. On Antennas Propagation, Vol. AP-32, December 1984, 1375-1379.

[7] Chao-Ming Wu, Wideband dual frequency CPW-fed triangular monopole antenna for DCS/WLAN application,Int. J. Electron. Commun. (AEÜ) 61 (2007) Pp 563 – 567.

[8] Y,Sung, " Bandwidth Enhancement of a Microstrip Line-Fed Printed Wide –Slot Antenna with a Parasetic Center Patch", IEEE Trans. On Antennas Propagation, Vol.60,NO.40,April 2012.,1712-1716.

[9] Lin Peng and Cheng- Li Runa, "UWB Band notch Monopole antenna design using Electromagnetic band gap structure", IEEE Transactions On Microwave Theory And Techniques, Vol. 59, No. 4, April 2011.

[10] Mari Komulainen,Pekka Salonen,Markku Kivikoski , "Dual frequency Microstrip patch antenna for WLAN Bluetooth & HiperLAN Application",Ieee-explorer(2001).

[11] T.G.Ma and S.J.Wu, "Ultrawideband band-notched folded strip Monopole Antenna", IEEE Trans. On Antennas Propagation, Vol.55,NO.9,September.2007, 2473-2479.

[12] Reza Zaker,Changiz Ghobadi and Javed Nourinia,"Bandwidth Enhancement of Novel Compact Single and Dual Band-Notched Printed IEEE Trans. On Antennas and propagation,Vol.57,No.12,December.2009, 3978-3983.

[13] Dang Trang Nguyen,Dong Hyun Lee and Hyun Chang Park, " Very Compact Printed Triple Band Notched UWB Antenna With Quarter Wavelength Slot", IEEE Antenna and Wireless Propagation Vol.11,2012 411-414 .

[14] Zhi-An Zheng,Qing-Xin Chu and Zhi-Hong Tu, " Compact Band-Rejected Ultrawideband Slot Antennas Inserting With λ/2 and λ/4 Resonators", IEEE Trans. On Antennas and Propagation ,Vol.59,No.2February 2011.

[15] C.A.Balanis "Antenna Theory and Design", second edition, John Wiley and Sons, New York, 1997.

[16] Jagath Kumara Halpe Gamage, Irene Anite Jensen, "Double-fed wideband printed monopole antenna", Second International ITG conference, Munich, DOI-10-1109/INICA. 4353936, 2007, 76-80.