DESIGN OF COMPACT PRINTED RECTANGULAR MONOPOLE ANTENNA AND U- SHAPED MONOPOLE ANTENNA FOR L-BAND AND S-BAND APPLICATIONS

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Abstract: - In this paper we have investigated printed monopole antennas, which is basically a printed micro strip antenna with etched ground plane for multi-band applications. In particular we have fabricated and tested printed monopole antennas for L-band and S-band applications. Printed rectangular monopole antennas are studied first for L-band applications. In high performance aircraft, spacecraft, satellite, missile and consumer electronics applications, where weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications that have similar specification. To meet these requirements, micro strip patch antennas can be used. These antennas are low profile, conformable to planar and non planar surfaces, simple and inexpensive to manufacture. In this thesis mainly we have designed Rectangular printed monopole antenna and U-shape Printed monopole antennas for L-band and S-bands applications. The final structures are presented in this report after doing an extensive simulation study and analysis and presented relevant results.

I. INTRODUCTION

Antennas, which can work properly in more than one frequency region either for transmitting or receiving electromagnetic (EM) waves, are termed as Multi-band antennas [1]. Such antennas are usually tri-band, penta-band etc. Multi-band antennas are much more complex than the single band antennas in their design, structures and operations. In this paper we will investigate printed monopole antenna (PMA), which is basically a printed micro strip antenna and U-shape Printed monopole antennas with etched ground plane [2]-[3] as shown in Figure 1 and 2 respectively for L-band and S-band applications**.** The Multiband Antenna Technology has many significant developments as well as several applications in wireless and mobile communications, some commercial application (mentioned above) as well as L-band (from 1GHz to 2GHz) and S-bands (from 2GHz to 4GHz). We can use single Multiband antenna instead of using several antennas for different frequency bands, this type of antennas are called as "Multiband Antennas" (i.e. single antenna works in more than one frequency band), for example WLAN integrated antennas (IEEE 802.11b/g), operate at 2.4GHz as well as 5GHz frequency bands respectively [4]- [5].

II. GEOMETRY OF MULTI-BAND ANTENNAS AND EXPERIMENTAL RESULTS

Printed Rectangular monopole antenna and Printed U- Shaped Monopole Antennas for L-band and S-bands Applications (Simulation as well as Experimental Results):

Model 1:
The printed rectangular monopole antenna with partially etched ground plane designed for 2.4 GHz frequency of operation and fabricated on FR4 substrate with 4.4 relative permittivity and 1.6 mm thickness. Antenna impedance is exactly 50 Ω. The final dimensions of the entire monopole antenna after extensive simulation study are [6] - [8].

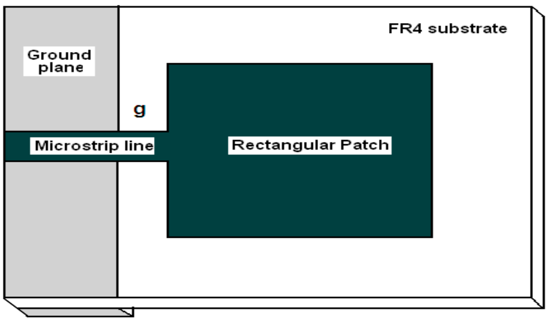

Fig1 (a) Printed Rectangular Monopole antenna with etched ground plane

1. Dimensions of Patch: W = 38.01mm and L = 30mm& t =0.035mm
2. Dimensions of Substrate: W = 38.01mm and L = 30mm & t =1.6mm
3. Dimensions of Micro strip line: W=3.12mm, L = 14.5mm & t =0.035mm
4. Dimensions of Ground: W = 42.01mm and L = (14.5-g) mm & t =0.5mm
   where g values = 3mm,4mm

In this antenna structure, some portion of ground plane was etched and some gap (g) was existed

W of GND plane(mm)	g value in mm	F_{low} (GHz)	F_{high} (GHz)	Antenna Impedance in Ω s	Band of Frequencies. (GHz)	Radiation Efficiency. %
11.5	3	1.55	2.9	60	1.35	97.2
10.5	4	1.4	3	50	1.6	97.2

between the radiating patch and ground plane below the substrate. This gap (i.e "g") was played vital role in order to get broad bandwidth as well as impedance matching. Here we have simulated the antenna with two different values, at both the cases, how the antenna frequency band width is varying with respect to the changes of values of "g", the values are tabulated in the Table. At beginning, we have chosen then value of "g" is 3mm and simulated the antenna, the resultant Frequency bandwidth is starting from 1.55 GHz to 2.9 GHz, which includes both the L-band and s-band applications. But, according to frequency regulations for L-band, the frequency bandwidth is fixed from 1GHz to 2GHz, then again, we have simulated the antenna at "g" value is 4mm, at this point, the antenna is having huge bandwidth, Lower cutoff frequency is shifted from 1.55 GHz to 1.4 GHz and higher cutoff frequency has shifted from 2.9 GHz to 3 GHz, we can say as this is one kind of Bandwidth enhancement techniques (i.e. Broadband techniques) in the design and analysis of printed antennas. After extensive simulation study, the final antenna dimensions were fixed. At particular values of gap (i.e. g = 3mm and 4mm), the antenna is having maximum radiation efficiency and % Bandwidth, the values of "g" are increased step by step then the antenna impedance, Band of Frequencies and antenna radiation efficiency is increasing proportionally [9]-[10].

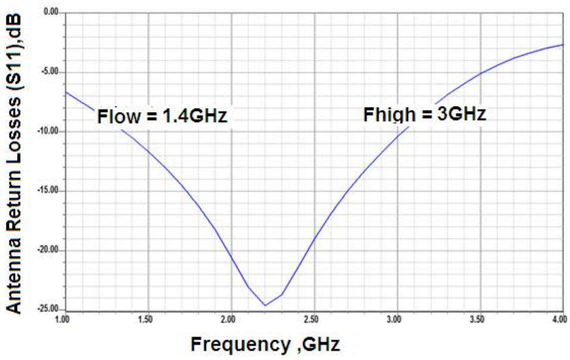

Fig 1(b) Experimental results of printed rectangular monopole (s_{11} vs frequency) at g=4mm

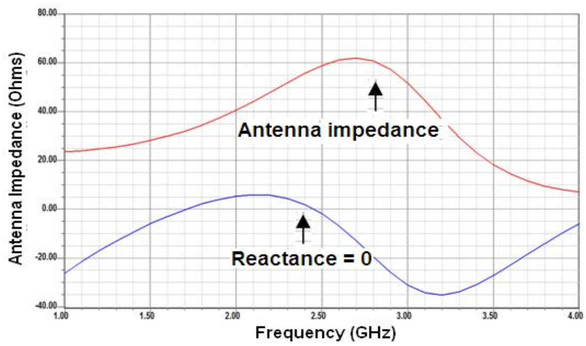

Fig 1(c) Antenna impedance vs frequency (real part and imaginary part of antenna impedance) at g=4mm

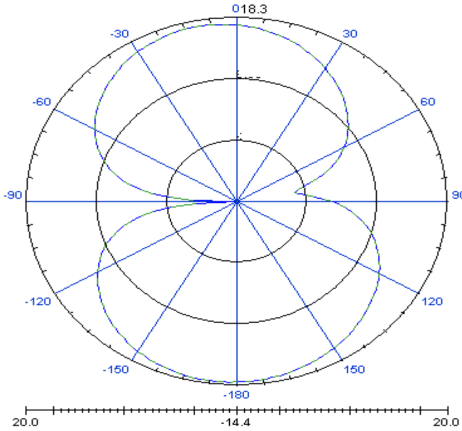

Fig1 (d) E-plane radiation patterns at 3GHz

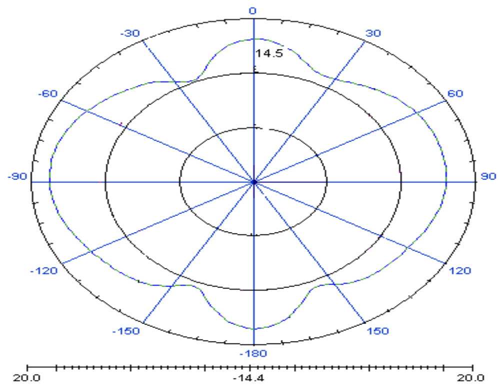

Fig 1(e) H-plane radiation patterns at 3GHz

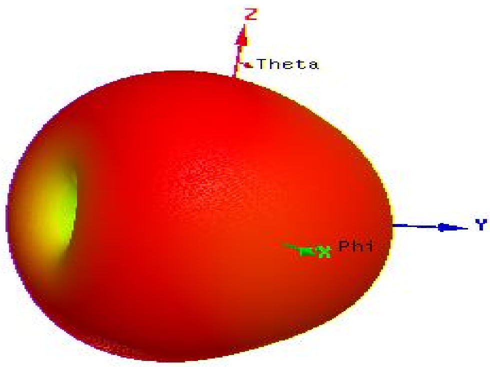

Fig 1(f) 3D pattern at 3GHz

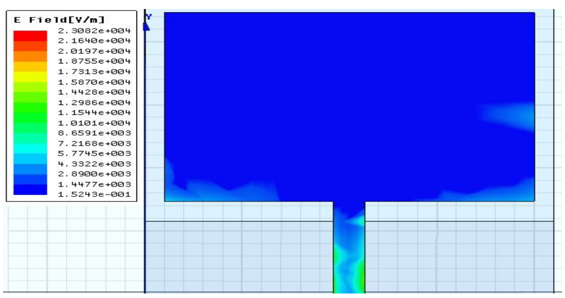

Fig 1(g) Current distribution at 3GHz

Figure 1 Geometry of printed rectangular monopole antenna (a) 3-D (b) Experimental results of printed rectangular monopole (s_{11} vs frequency) at g=4mm (c) Antenna impedance vs frequency (real part and imaginary part of antenna impedance) at g=4mm. (d) E-plane radiation patterns (simulation) of printed rectangular monopole antenna at 3GHz (e) H-plane Radiation patterns (simulation) of printed rectangular monopole antenna at 3GHz (f) 3D patterns at 3GHz (g) Current distribution at 3GHz .

The dimensions of the printed rectangular monopole antenna illustrated in Fig. 1 (a) using FR4 substrate after doing an extensive simulation study were calculated as patch and substrate W=38.01mm, L=30mm, ground width chosen are W=42.01mm, L=(14.5-g)mm, gap between the ground plane and patch antenna g=4mm.The scattering parameters s11 in dB versus frequency in MHz from 1.4GHz to 3GHz for the compact PRMA, which can be fitted in a cellular mobile phone, is obtained using Network Analyzer and is plotted in Figure 1(b). The PRMA bandwidth is from 1.4GHz to 3GHz at the mid frequency of 2.4GHz . Note that the present L band (1-2GHz) PRMA can work well for penta-band applications, viz. digital communication system (DCS, 1710-1880MHz), personal communication system (PCS, 1850-1990MHz), universal mobile telecommunication system (UMTS, 1920-2170MHz), global positioning system (GPS, 1575.42MHz, 1227.60MHz, 1371.913 MHz, 1381.05MHz) and digital audio broadcasting (DAB L Band, 1452 MHz to 1490 MHz). The radiation pattern of the rectangular monopole antenna is depicted in Fig. 1(d)and Fig1(e). The real part of the impedance of antenna at the point (frequency) where the imaginary part of impedance is zero i.e. reactance = 0 and resistance is equal to antenna impedance. Here antenna is fed with 50 Ohms characteristic impedance. The radiation pattern looks like a doughnut, similar to that of a dipole pattern, at the cut off frequency i.e. 1.4GHz. At the mid frequency i.e. at 2.4GHz and the Upper cut off frequency i.e. at 3GHz, the radiation pattern is somewhat like pinched doughnut (i.e. omni directional). As the frequency moves toward the upper end of the bandwidth the radiation pattern is somewhat slightly distorted as it reaches higher frequencies (i.e.3 GHz.). As frequency increases the current distribution becomes more complicated indicating to a third order harmonic at 3 GHz.

Model 2:

The U-shaped printed monopole antenna with partially etched ground plane designed for 2.4 GHz frequency of operation and fabricated on FR4 substrate with 4.4 relative permittivity and 1.6 mm thickness. Antenna impedance is exactly 50 Ω. This U-Shape Printed monopole antenna can work for both L-band and S-band applications and the final dimensions of the entire monopole antenna after extensive simulation study are [11]- [14].

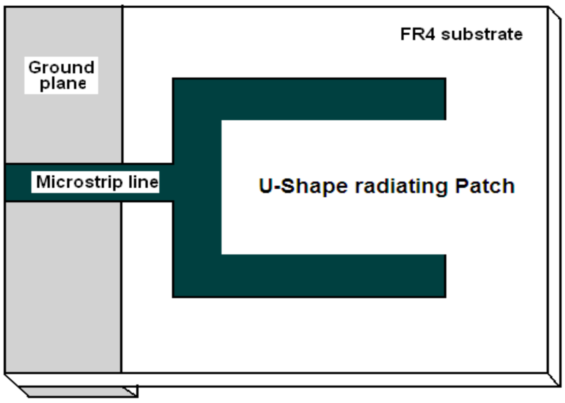

Fig 2 U-Shape monopole antenna with etched ground plane

1. Dimensions of Patch: W = 38.01mm and L = 30mm& t =0.035mm
2. Dimensions of Substrate: W = 38.01mm and L = 30mm & t =1.6mm
3. Dimensions of Microstrip line: W=3.12mm, L = 14.5mm & t =0.035mm
4. Dimensions of Ground: W = 42.01mm and L = (14.5-g) mm & t =0.5mm
   Where g value = 4mm

In this antenna structure, some portion of ground

W of GND plane (mm)	g value in mm	F_{low} (GHz)	F_{high} (GHz)	Antenna Impedance in Ω s	Band of Frequencies. (GHz)	Radiation Efficiency. %
10.5	4	1.35	3.4	50	2.05	97

plane was etched and some gap (g) was existed between the U-Shape radiating patch and ground plane below the substrate. This gap was played vital role in order to get broad bandwidth as well as impedance matching. After extensive simulation study, the final antenna dimensions were fixed. At particular value of gap (i.e. g = 4mm), the antenna is having maximum radiation efficiency and %Bandwidth, the values of “g” are increased step by step then the antenna impedance, Band of Frequencies and antenna radiation efficiency is increasing proportionally [15]. The values of g are increased step by step then the antenna impedance, % bandwidth and antenna radiation efficiency are increasing proportionally. These two models (monopole antenna) can be fabricated; here model 2 is the compact one due to its dimensions as well as in terms of its performance.

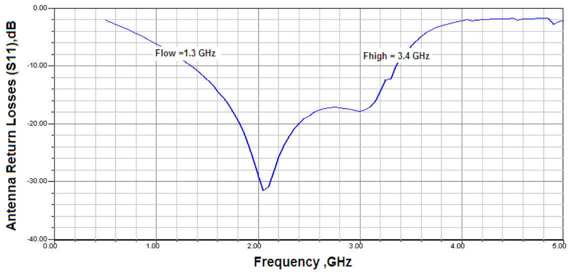

Fig 2(b) Simulated results of printed rectangular monopole (s_{11} vs frequency) at g=4mm

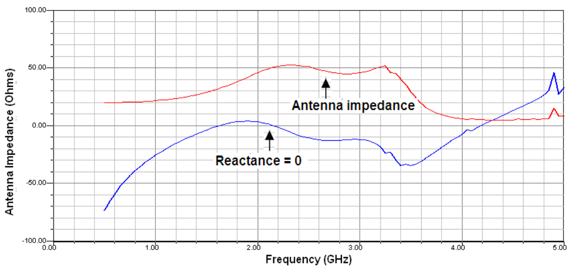

Fig 2(c) Antenna impedance vs frequency (real part and imaginary part of antenna impedance)

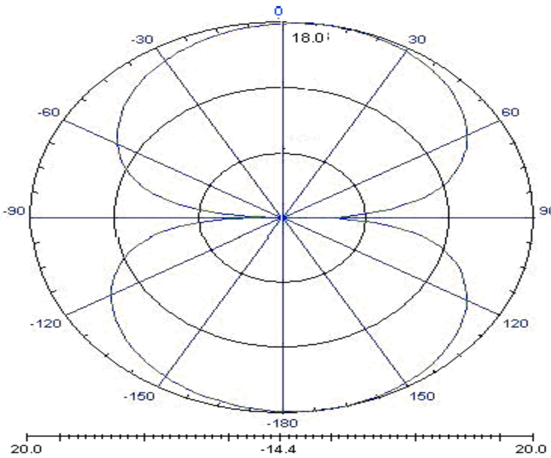

Fig 2(d) E-plane radiation patterns at 3.4GHz

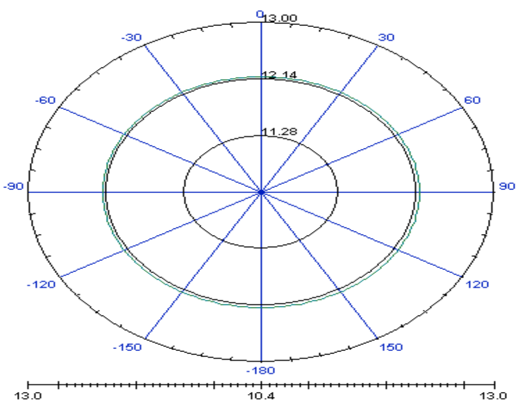

Fig 2(e) H-plane radiation patterns at 3.4GHz

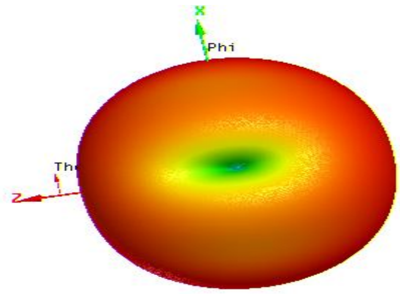

Fig 2(f) 3D patterns at 3.4GHz

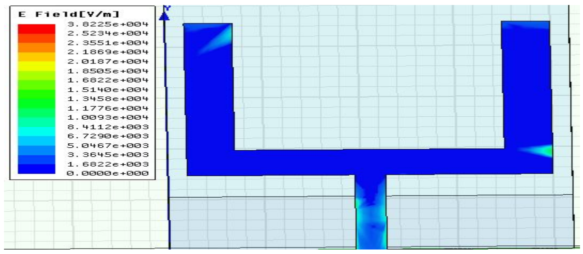

Fig 2(f) Current distribution plots at 3.4GHz

Figure 2 Geometry of printed U shaped monopole antenna (a) 3-D (b) Experimental results of printed Ushaped monopole (s_{11} vs frequency) at g=4mm (c) Antenna impedance vs frequency (real part and imaginary part of antenna impedance) at g=4mm. (d) E-plane radiation patterns (simulation) of printed U shaped monopole antenna at 3GHz (e) H-plane Radiation patterns (simulation) of printed U shaped monopole antenna at 3.4GHz (f) 3D patterns at 3.4GHz (g) Current distribution at 3.4GHz .

The dimensions of the printed U Shaped monopole antenna illustrated in Fig 2 (a) using FR4 substrate after doing an extensive simulation study were calculated as patch and substrate W=38.01mm, L=30mm, ground width chosen are W=42.01mm, L=(14.5-g)mm, gap between the ground plane and patch antenna g=4mm.The scattering parameters s11 in dB versus frequency in MHz from 1.3GHz to 3.4GHz for the compact printed U Shaped monopole antenna , which can be fitted in a cellular mobile phone. The printed U Shaped monopole antenna bandwidth is from 1.3GHz to 3.4GHz at the mid frequency of 2.4GHz. U-Shape Printed monopole antenna can work well for both L-band and S-band applications than conventional rectangular printed monopole antennas in frequency bandwidth. Note that the present L band (1-2GHz), this antenna can work well for S-band (2-4 GHz) applications, viz. Digital Communication System (DCS, 1710-1880MHz), Personal Communication System (PCS, 1850-1990MHz), Universal Mobile Telecommunication System (UMTS, 1920-2170MHz), Global Positioning System (GPS, 1575.42MHz, 1227.60MHz, 1371.913 MHz, 1381.05MHz) and Digital Audio Broadcasting (DAB

L Band, 1452 MHz to 1490 MHz.. The radiation pattern of the rectangular monopole antenna is depicted in Fig. 2(d) and Fig2(e). The real part of the impedance of antenna at the point (frequency) where the imaginary part of impedance is zero i.e. reactance = 0 and resistance is equal to antenna impedance. Here antenna is fed with 50 Ohms characteristic impedance. The radiation pattern looks like a doughnut, similar to that of a dipole pattern, at the lower cut off frequency i.e. 1.3GHz. At the mid frequency i.e. at 2.4GHz and the Higher cut off frequency i.e. at 3.4 GHz the radiation pattern is slightly distorted somewhat like pinched doughnut (i.e. omni directional). As the frequency moves toward the upper end of the bandwidth the radiation pattern is slightly distorted as it reaches higher frequencies (i.e. 3.4GHz.).. As frequency increases the current distribution becomes more complicated indicating to a third order harmonic at 3 GHz.

CONCLUSION

In this paper we have investigated printed monopole antennas and U-Shaped printed monopole antenna which is basically a printed micro strip antenna with etched ground plane for multi-band antennas for both L-band (i.e. from 1GHz to 2 GHz) and S-band (i.e. from 2GHz to 4 GHz) applications . Printed monopole antennas are less fragile, planar and can be integrated with the integrated circuits unlike monopole antennas which have non-planar or protruded structures above the ground plane. In particular we have fabricated and tested printed monopole antennas for L-band and S-band applications. Printed rectangular monopole antennas are studied first for such application and secondly U-Shaped printed monopole antenna was Analyzed and designed directly from the simple rectangular printed micro strip patch antenna with some modifications on the radiating patch (i.e. etching some part of the rectangular patch) and the remaining structure is kept the same, eventually the Rectangular patch became U-Shape radiating patch. The value of “g” is fixed at 4mm for this monopole antenna. After doing an extensive simulation study only, the final dimensions are fixed and designed as per the frequency regulations for both L-band and S-band applications.

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