

Modified Slots Loaded with Four E Shaped Patch Antenna for Multiband Application

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Abstract— Wireless communication has been growing exponentially over the last decade, where multimedia application, satellite and radar communication have developing with it, as well as demand for multitask features in same device has drawn attention to the consumers. Integration of Microstrip Patch Antenna in wireless equipments helps to fulfill requirement due to its miniature dimension, robustness and inexpensive attributes. In this paper, a modified slots loaded with E shaped patch antenna with dielectric substrate layer on the top has been illustrated. The proposed antenna has the capability to operate in eight different multiple frequencies having single radiator. The antenna has been design on the top of the dielectric substrate of permittivity 4.3 and thickness of 1.6mm. The proposed antenna resonates at 5.54 GHz, 6.51 GHz, 7.75 GHz, 8.15 GHz, 10.49 GHz, 11.98 GHz, 12.96 GHz and 16.11 GHz with impedance bandwidth of 44.51 MHz, 33.28 MHz, 330 MHz, 102 MHz, 1.101 GHz, 483 MHz and 4.532 respectively that covers C, X and Ku band. The design scheme and simulation results of proposed antenna are presented.

Index Terms— C band, X band, Ku band, Slot, Electromagnetic (EM), IE3D Software and Rectangular Microstrip Patch Antenna (RMPA).

1 INTRODUCTION

It was idea of Maxwell who predicted the existence of electromagnetic waves [1]. After getting the knowledge of Hertz earth observed the invention of radio by Marconi in 1895. Later he gives the demonstration of wireless communication through ships over sea. During the battle of Jutland British Navy uses wireless equipments. After few years US police started to use mobile communications. So we can say mobile communication has history of more than hundred years. It is becoming very popular over last two decades. Communication with fixed lines has been used since late 19th century. Communication with fixed telephone line has been practical since 1940s. Satellite links started to roll out in 1960s. It developed rapidly from 1980s [1]. As a result of various researches Advanced Mobile Phone System (AMPS), Global System for Mobile Communication (GSM), Digital Cellular System (DCS), Code Division Multiple Access (CDMA) were introduced [1].

Wireless communication is the basic needs of modern days. A single day without mobile communication is unbelievable. Most important device of this technology is antenna which is nothing but a transceiver. It works as transmitter at transmitting end and as receiver at receiving end. There are various types of antenna such as monopole, dipole, helical, reflector, planar etc [2]. They have several functions; researchers are trying to fit an antenna within a compact casing.

In present era there are so much necessity of smart phones, tablets, phablets etc. These devices needs compact antenna. Moreover it requires some performances like radiation pattern, input impedance, efficiency, restructurability and size [3]. Planar antenna is using for these gadgets. Types of planar antennas are inverted planar antenna, planar inverted F-antenna or PIFA [4]. But for small size another antenna is used for mobile communication which is patch antenna. These are generally used in mobile communication, aircraft, spacecraft, satellite, missile applications because of various alterative features. Moreover patch antennas are used in GPS communication, Wireless Local Area Network (WLAN),

Synthetic Aperture Radar (SAR), MMIC design and modern printed circuit technology. Scientists and researchers are trying to develop and improve the bandwidth, return loss and reduction sizes [5-15].

There are various types of patch antennas, but in general they are called micro-strip patch antenna (MPA) [16]. Patch antenna has many advantages such as low cost, small size, manufacturing cost is low. Main disadvantages of MPA are low bandwidth, low efficiency and low gain. Due to this there are research going on to improve the bandwidth ranges, efficiency and gain of the antenna. As a result several patches have been introduced such as rectangular, circular, square, elliptical etc. Other types of patches also introduced like U, H, E, F etc. Not only patch but also by varying the thickness of dielectric material with various dielectric materials improves the bandwidth and gain. Further researches are going on to enhance the bandwidth and gain of the antennas.

The frequency bands from 500 MHz to 40 GHz is broken into several groups such as 500-1000 MHz for VHF, 1-2 GHz for L band, 2-4GHz for S band, 4-8 GHz for C band, 8-12.4 GHz for X band, 12.4-18 GHz for Ku band, 18-26 GHz for K band and 26.5-40 GHz for Ka band [17]. Among these bands all wireless communication devices developed. Radio communication takes place between 3 kHz to 300 GHz [1]. From the above literature authors are motivated to design an antenna that operates in C, X and Ku band.

2 ANTENNA DESIGN

The proposed antenna design has been configured on the top of the Rectangular Microstrip Patch Antenna (RMPA). The RMPA consists of a rectangular conducting patch on one side of a dielectric substrate with a ground plane on the other side. The antenna has been excited by coaxial feeding technique which provides RMPA to penetrate in multiple frequencies. The parameters of RMPA are calculated mathematically and simulated through designing software. The initial dimensions of the patch are determined from the following equation [18].

$$W = \frac{v_o}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2} \quad (2)$$

$$\Delta L = 0.421h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)} \quad (3)$$

$$L = \frac{1}{2f_r \sqrt{\epsilon_{eff}} \sqrt{\mu_o \epsilon_o}} - 2\Delta L \quad (4)$$

Here W is the width of the patch, v_o is the speed of light in a vacuum, ϵ_r is the dielectric constant of the substrate, f_r is the target frequency, ϵ_{eff} is the effective dielectric constant of the substrate, ΔL represents the extension in length caused by the fringing effect, h is the thickness of the substrate and L is the length of the patch.

The proposed antenna has same patch and ground plane with dimensions of $(L \times W)$ 16mm \times 22mm and $(L_g \times W_g)$ 26mm \times 32mm respectively as RMPA. The geometry of the proposed antenna has been shown in the figure 1. Four rectangular modified slots are trimmed off from the patch such that two pair of 0 and 180 degree phase shift "E" shaped, total four individual patches can be loaded into the slots shown in figure 2.

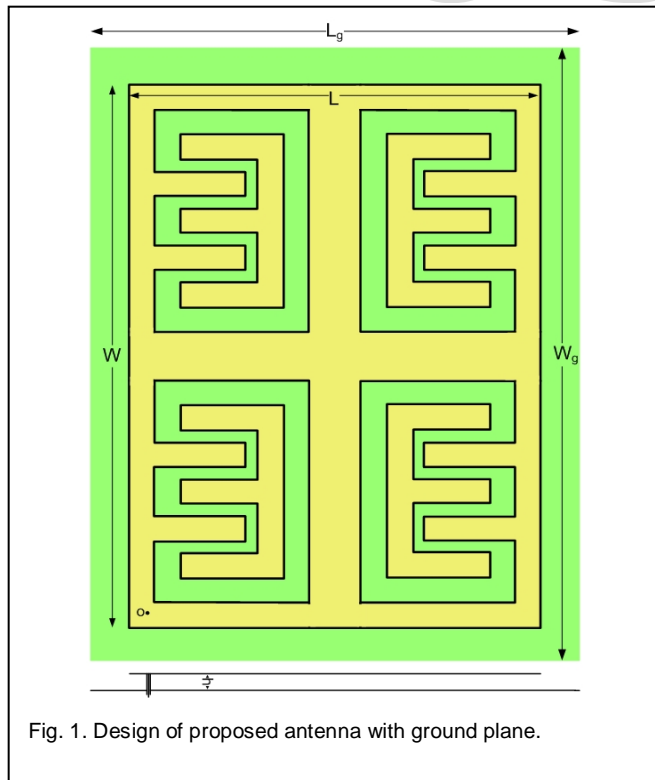


Fig. 1. Design of proposed antenna with ground plane.

The slots and loaded patches are separated by distance so that they cannot be attaching to each other. The slots structure on the rectangular patch interrupts the surface current on the patch and creates local inductive effect that provides proposed antenna to operate in multiband. This antenna is design and simulated on the FR4 epoxy substrate of thickness of $h = 1.6\text{mm}$ and dielectric constant of 4.3. The antenna is coaxially fed at $x = 0.6\text{mm}$ and $y = 0.6\text{mm}$. For better antenna performance improvement another dielectric substrate layer has been attached on the top of the main patch of same height of 1.6mm and permittivity of 4.3 as proposed antenna.

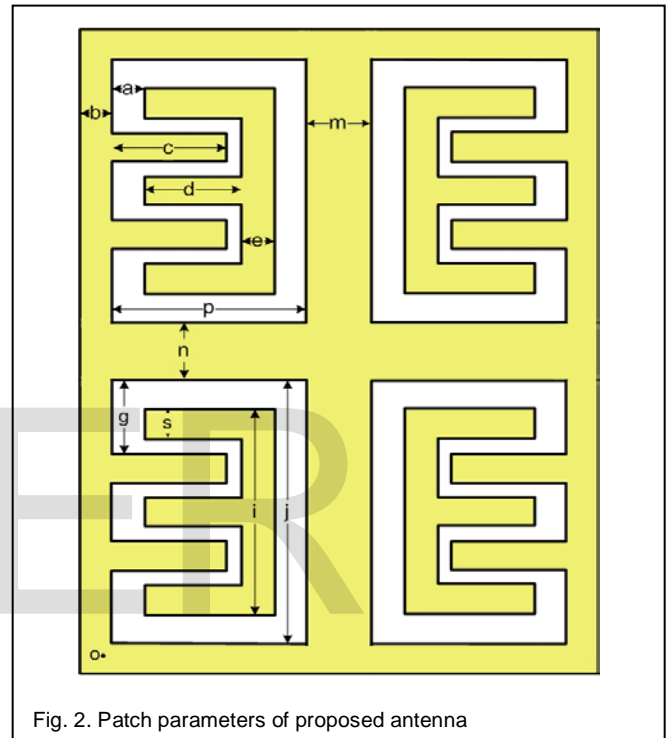


Fig. 2. Patch parameters of proposed antenna

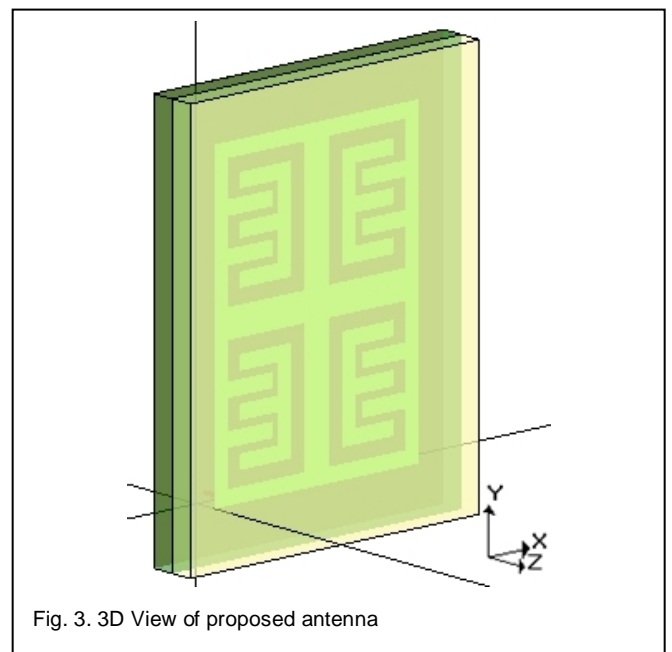


Fig. 3. 3D View of proposed antenna

TABLE 1
 DIMENSIONS OF PROPOSED ANTENNA

| Parameters | Dimensions (mm) |
|------------|-----------------|
| a, b, e | 1 |
| c | 3.5 |
| d | 3 |
| p | 6 |
| m, n | 2 |
| g | 2.5 |
| i | 7 |
| j | 9 |
| L | 16 |
| W | 22 |
| L_g | 26 |
| W_g | 32 |

3 SIMULATION AND RESULT

All the antennas have been designed and simulated in IE3D software. It is one of the most advance software in electromagnetic (EM) simulation and antenna designing. IE3D is a full wave, method of moments (MOM) based electromagnetic simulator for analyzing and optimizing planar and 3D structures in a multi-layer dielectric environment. It solves Maxwell's equation in integral form and its solutions include the wave effects, discontinuity effects, coupling effects and radiation effects. The simulated result includes S,Y, and Z-parameters, VSWR, RLC equivalent circuits, current field distribution, near and far field estimation, radiation pattern etc [19].

Dimension parameters of both RMPA and proposed antenna are transfer in this software. All the simulations are done in between 4 GHz to 18 GHz range. Figure 4 represent return loss versus frequency graph of basic RMPA. The feeding position and technique helps the antenna to operate in multiband. It has been noted that return losses at all centre frequencies are less than -10dB. The antenna resonates at 6.44 GHz, 10.93 GHz and 15.62 GHz means antenna has the ability to operate in C, X and Ku band. At the centre frequencies the return losses are -13.46 dB, -18.6 dB and -11.67 dB under the bandwidth of 153 MHz, 167 MHz, and 35 MHz respectively. The antenna directivities at operating frequencies are 8.41 dBi, 7.24 dBi, and 8.13 dBi.

Figure 5 shows the variation of return loss versus frequency of proposed antenna. From this figure it is seen that, the antenna resonates for three band of frequencies C, X, and Ku band. The patch and slots structure provides the proposed antenna to operate in eight different frequencies. The desired antenna resonates at 5.54 GHz, 6.51 GHz, 7.75 GHz, 8.15 GHz, 10.49 GHz, 11.98 GHz, 12.96 GHz and 16.11 GHz having return losses of -21.63 dB, -15.84 dB, -30.52 dB, -15.8 dB, -24.35 dB, -15.46 dB, -35.93 dB, and -16.31 dB respectively. The

corresponding -10 dB return loss bandwidth at the operating frequencies are 44.51 MHz, 33.28 MHz, 330 MHz, 102 MHz, 1.101 GHz, 483 MHz and 4.532 GHz for last two centre frequencies. Figure 6 illustrates the Voltage Standing Wave Ratio (VSWR) of proposed antenna. It is an indication of the quality of the impedance match. A high VSWR is an indication the signal is reflected prior to being radiated by the antenna. VSWR and reflected power are different ways of measuring and expressing the same thing. Here the ratio of the maximum voltage of a standing wave pattern on a transmission line to the minimum voltage on the line is less than 2 at operating frequencies.

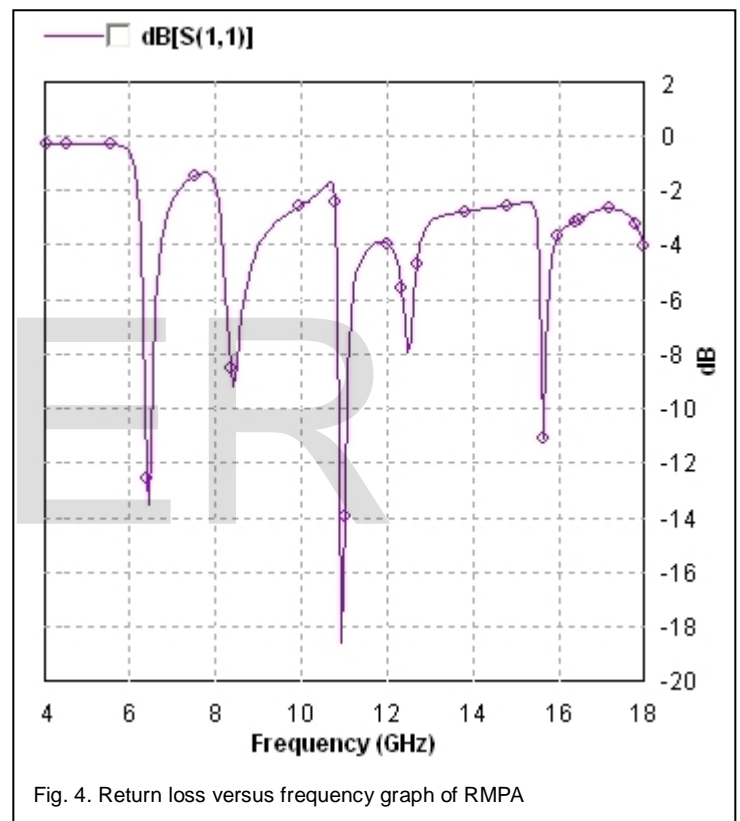
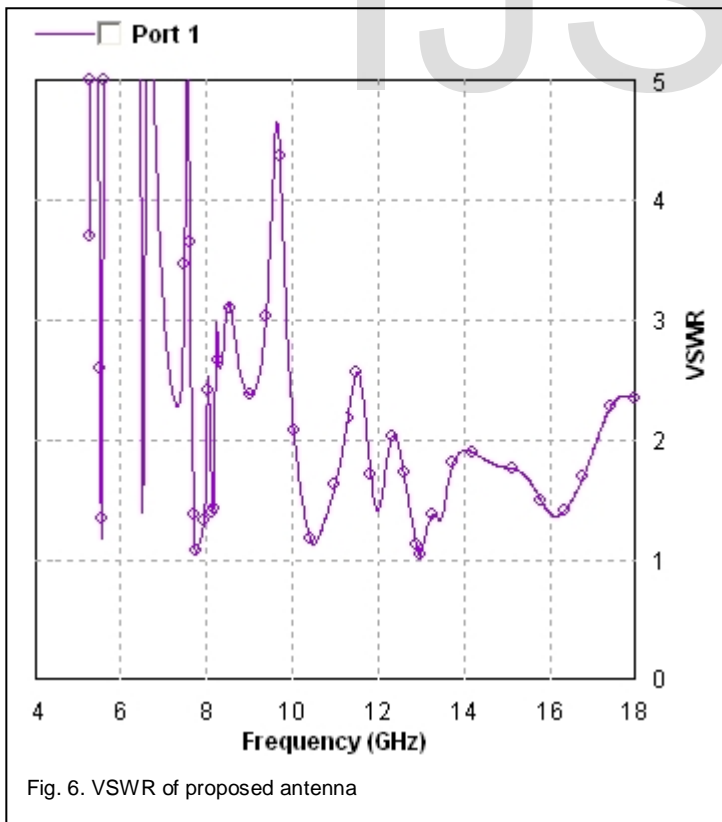
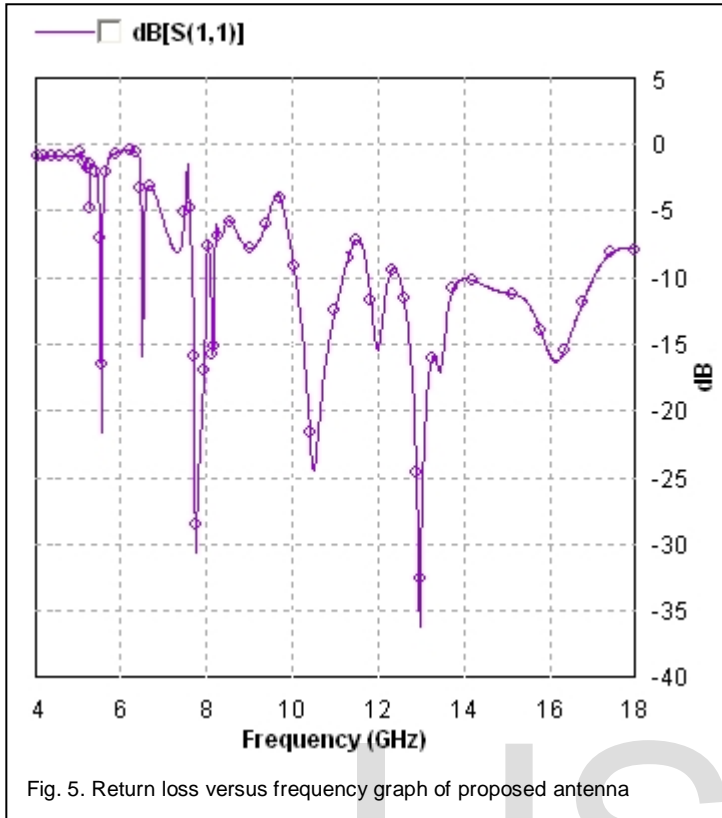


Fig. 4. Return loss versus frequency graph of RMPA



under same frequency range. It is convenient that proposed antenna shows better antenna performances than the RMPA. The proposed antenna operates in three different band frequencies range where it covers 10% of C, 42% of X and 76% of Ku band.

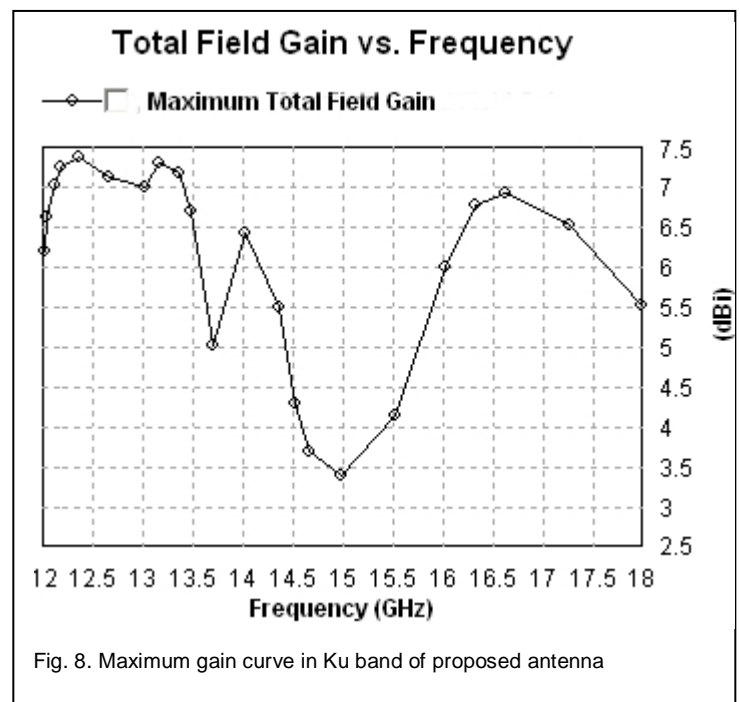
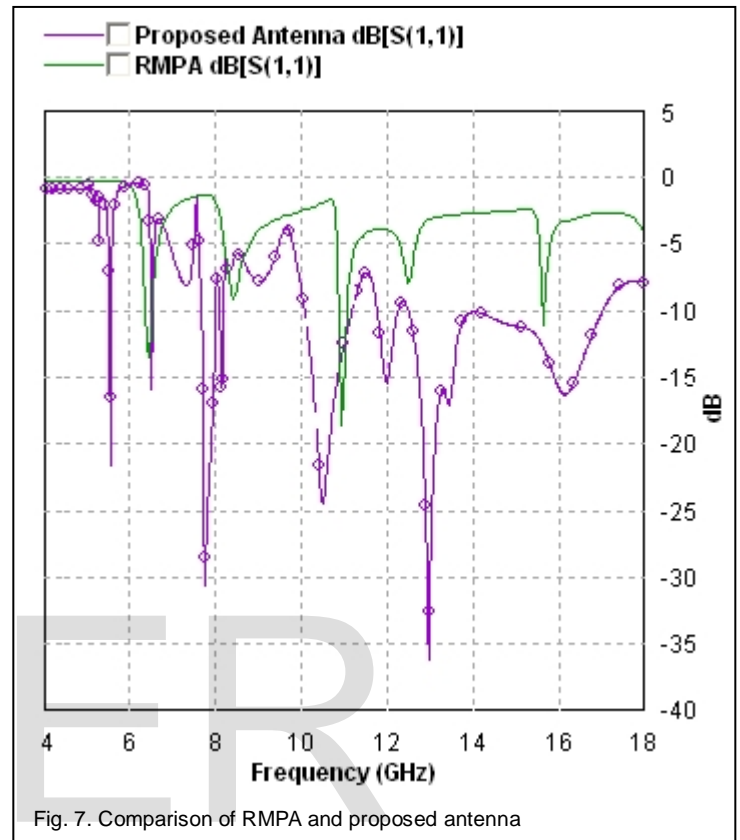
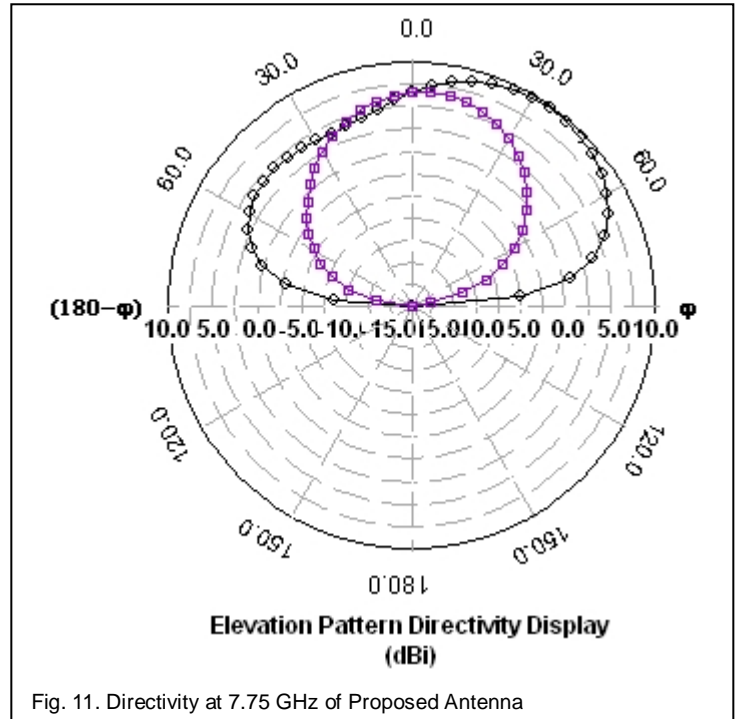
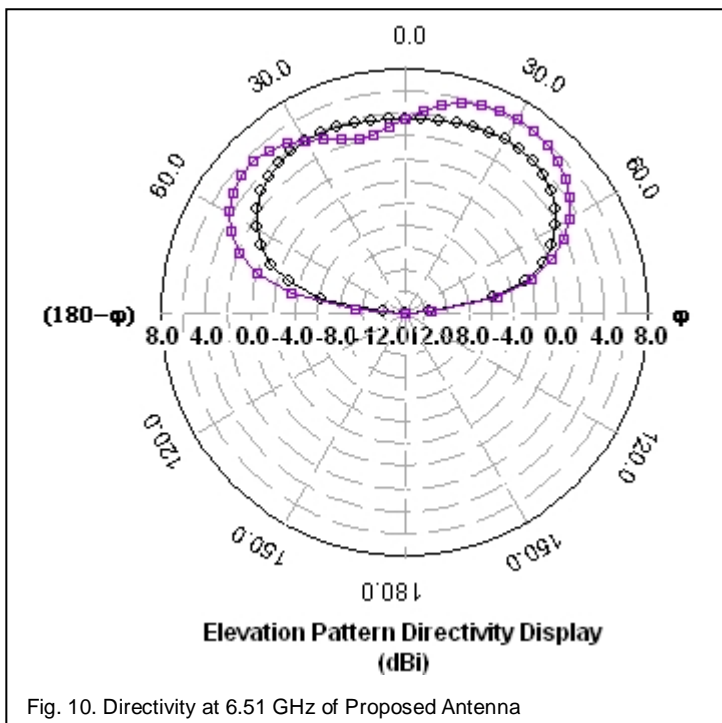
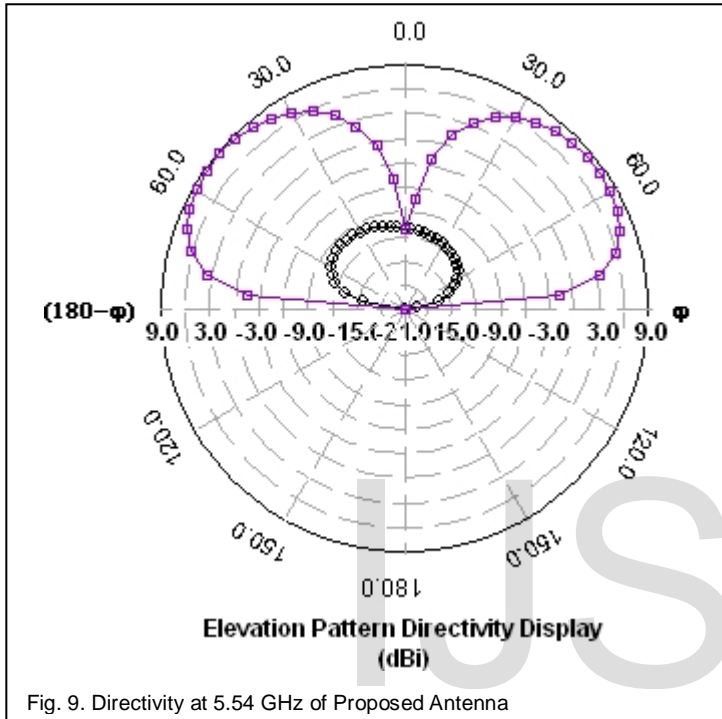


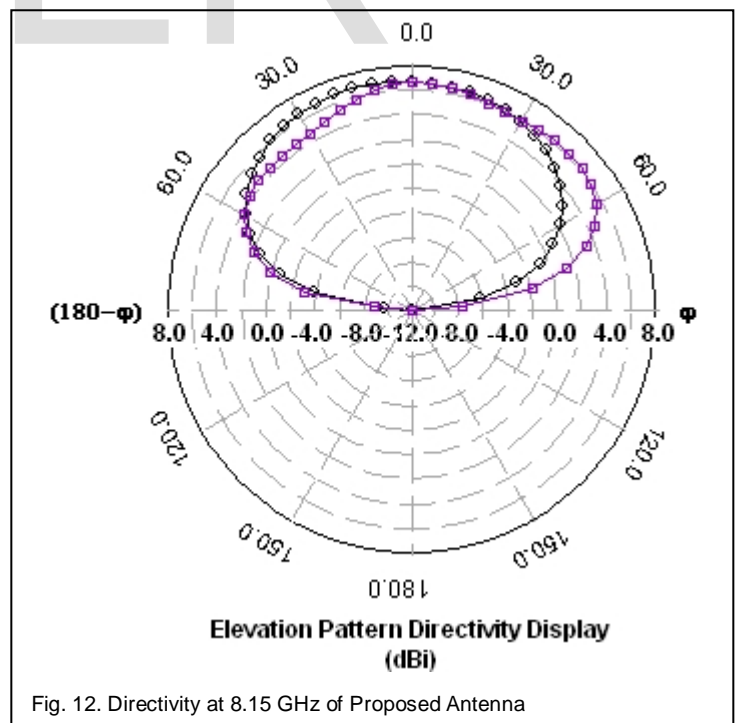
Figure 7 is a combine graph of RMPA and proposed antenna

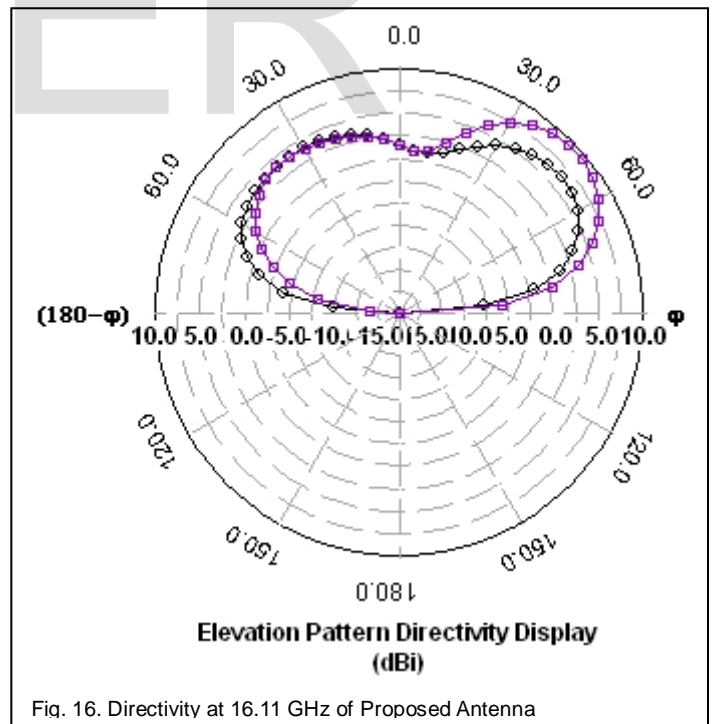
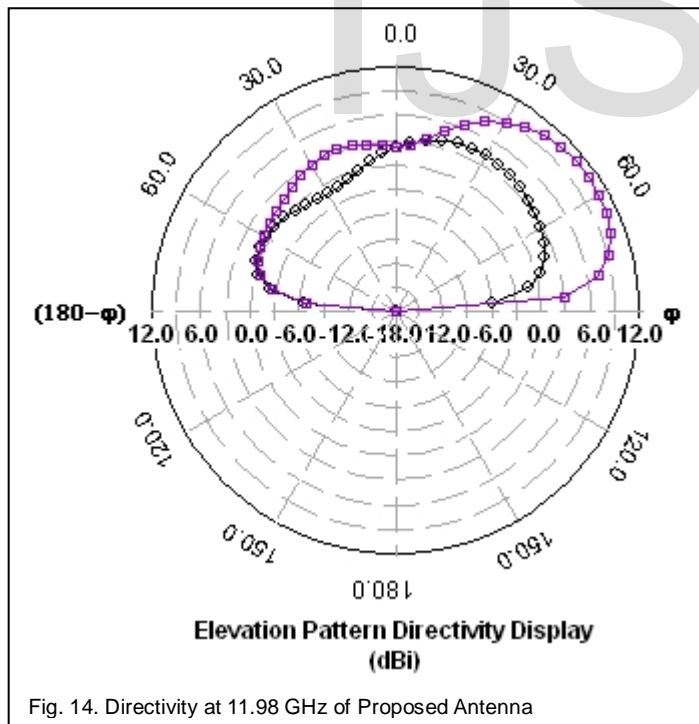
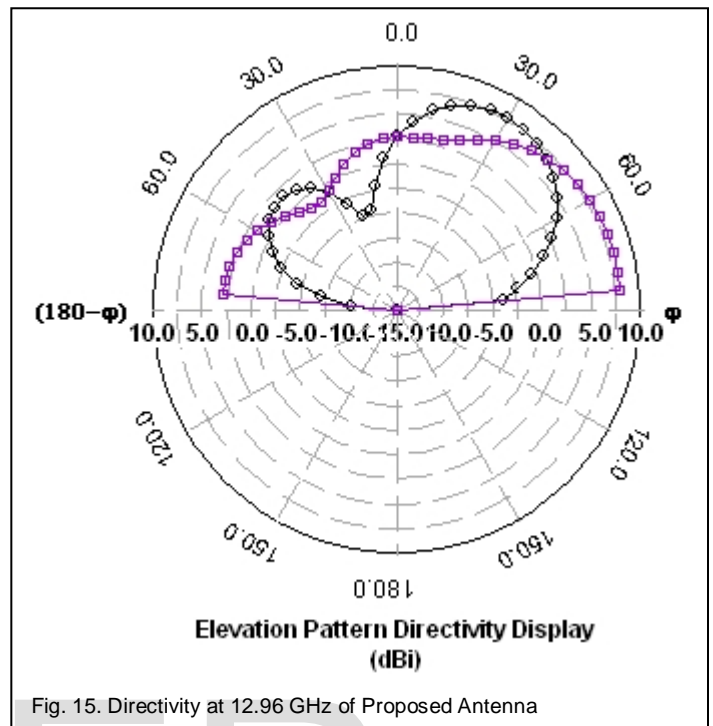
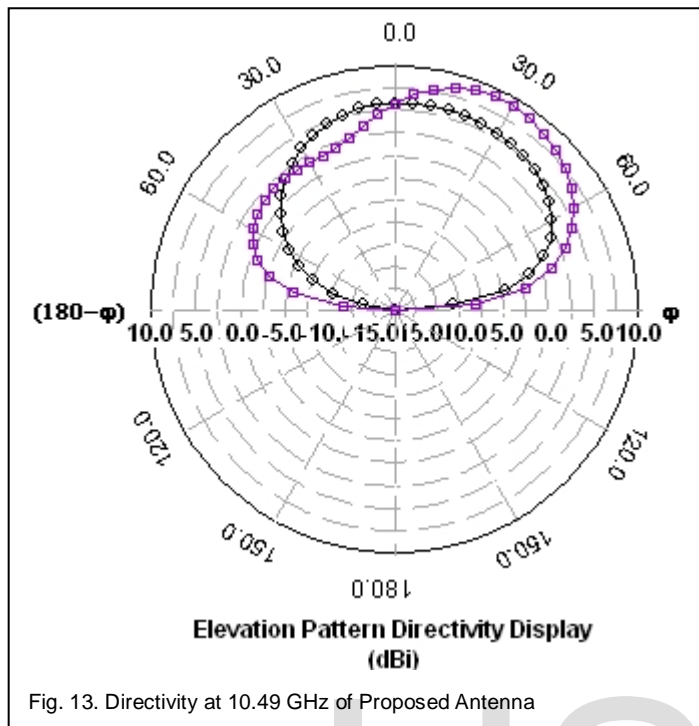
Directivity is the ability of an antenna to focus energy in a

particular direction when transmitting or to receive energy better from a particular direction when receiving. Here figure 8 represents the gain versus frequency graph under Ku band domain where it has been observed that maximum gain is 7.26 dBi at 13.18 GHz and minimum gain is 3.92 dBi at 15 GHz frequencies. The antenna gains at centre frequencies are 3.82 dBi, 2.01 dBi, 2.82 dBi, -0.22 dBi, 1.36 dBi, 6.02dBi, 6.79 dBi and 6.32 dBi. Figure 9-16 shows 2D directional radiation pattern of proposed antenna.



At operating frequencies the directivities are 8.65 dBi, 6.27 dBi, 9.61 dBi, 7.09 dBi, 9.12 dBi, 10.71 dBi, 8.20 dBi and 9.58 dBi respectively. The figure shown below for the elevation pattern from $\phi = 0$ and $\phi = 90$ degrees





It can be clearly seen that the designed antenna produce broadside or omni-directional radiation pattern and almost symmetrical radiation pattern has been observed.

4 CONCLUSION

A modified slots loaded with four E shaped patch antenna has been designed and analyzed in this paper. The proposed antenna designed such that it worked at C, X and Ku band. The resonant frequencies are 6.44 GHz, 10.93 GHz and 15.62 GHz which indicates this antenna has the ability to operate in C, X and Ku band respectively. It covers 10% of C, 42% of X and 76% of Ku band. The patch and slots structure provides the proposed antenna to operate in eight different frequencies. The desired antenna resonates at 5.54 GHz, 6.51 GHz, 7.75 GHz, 8.15 GHz, 10.49 GHz, 11.98 GHz, 12.96 GHz and 16.11 GHz. The antenna directivities at operating frequencies are 8.65 dBi, 6.27 dBi, 9.61 dBi, 7.09 dBi, 9.12 dBi, 10.71 dBi, 8.20 dBi and 9.58 dBi respectively. The proposed antenna can be easily fabricated and place on the small devices because of its dimension and availability of materials.

REFERENCES

- [1] Simon R. Saunders, Alejandro Aragon Zavala, "Antennas and Propagation for Wireless Communication Systems", 2nd Edition, John Wiley & Sons, Ltd, England, 2007 pp.5-6, Ch-1
- [2] Constantine A. Balanis, "Antenna Theory Analysis and Design", 2nd Edition, John Wiley & Sons Inc. UK, Ch-14, pp. 723-724
- [3] Simon R. Saunders, Alejandro Aragon Zavala, "Antennas and Propagation for Wireless Communication Systems", 2nd Edition, John Wiley & Sons, Ltd, England, 2007 pp.361-362, Ch-15
- [4] Simon R. Saunders, Alejandro Aragon Zavala, "Antennas and Propagation for Wireless Communication Systems", 2nd Edition, John Wiley & Sons, Ltd, England, 2007 pp.366-368, Ch-15
- [5] S.C.Gao and J.Li. "FDTD analysis of a size- reduced, dual-frequency patch antenna", progr. Electromagn. Res., Vol.PIER 23, pp.59-77, 1999.
- [6] S.C.Gao, L.W.Li, "Small dual-frequency microstrip antenna", IEEE Transaction on vehicular Technology.vol.51.No.1. Jan.2002
- [7] K.Gosalia, G.Lazzi. "Reduced size, Dual-polarized microstrip patch antenna for wireless communications", IEEE Trans. Antenna prop., vol.51, No.9, Sept.2003.
- [8] X.L.Bao and M.J.Ammann, "Compact annular-ring embedded circular patch antenna with a cross-slot ground plane for Circular Polarization", Electron. Lett., Vol.42. No.4, Feb. 2006.
- [9] S.Bhunia, S.Biswas, D.Sarkar, P.P.Sarkar, "Experimental investigation on dual-frequency broad band microstrip antenna with swastika Slot", Indian Journal physics, Vol-81.No.4, pp- 497-499, April 2007.
- [10] S.Bhunia, D.Sarkar, S.Biswas, P.P.sarkar, B.Gupta,K.Yasumoto "Reduced Size Small Dual-Frequency Microstrip Antenna" Microwave & optical Technology Letters. Vol. 50, No.4, pp.961-965, April 2008.
- [11] S.Bhunia, P.P.Sarkar, "Reduced Sized Dual Frequency Microstrip Antenna" Indian J. Phys Vol.83, No.10, pp- 1457- 1461 October 2009.

- [12] L. Guo, S. Wang, X. Chen, and C.G. Parini, Study of compact antenna for UWB applications, Electron Lett 46 (2010), 115– 116.
- [13] K.G. Thomas and M. Sreenivasan, Compact CPW-fed dual-band antenna, Electron Lett 46 (2010), 13–14.
- [14] C.Y.D. Sim, W.T. Chung, and C.H. Lee, Compact slot antenna for UWB applications, IEEE AntennaWireless Propag Lett 9 (2010), 63– 66.
- [15] S. Sarkar, D. Sarkar, A. Das Majumdar, P. P. Sarkar, S. Mondal, S. Biswas, "Miniaturization of Rectangular Microstrip Patch Antenna Using Optimized Single -Slotted ground plane" Microwave & optical Technology Letters. Vol. 53, No.1, pp.111- 115, January, 2011.
- [16] Kin-Lu Wong, Compact and Broadband Microstrip Antennas, Jon Wiley & Sons, Inc., 2002
- [17] Robert E. Collin, "Antennas and Radiowave Propagation", McGraw-Hill, 1st Edition, 1985, Singapore, Ch-1, pp. 12
- [18] Razin Ahmed, Md. Fokrul Islam, "E shaped Microstrip Patch Antenna for Ku band" Published in International Journal of Computer Applications Volume 80, No.6, October 2013
- [19] V. Harsha Ram Keerthi, Dr. Habibullah Khan, Dr. P. Srinivasulu "Design of C-Band Microstrip Patch Antenna for Radar Applications Using IE3D" IOSR Journal of Electronics and Communication Engineering, Volume 5, Issue 3, PP 49-58, 2013.

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