



PATCH ANTENNA DESIGN ANALYSIS FOR WIRELESS COMMUNICATION

J. Salai Thillai Thilagam¹, Dr. P. K. Jawahar²

Part Time Research Scholar, Dept. of ECE, B. S. Abdur Rahman University, Chennai, India¹

Professor, Dept. of ECE, B. S. Abdur Rahman University, Chennai, India²

ABSTRACT: A simulation of sixteen (hexadeci) faced microstrip patch antenna design using slit on the edge is discussed here. This antenna is fed using probe feed model. It is simulated using IE3D electromagnetic simulator. The simulated results of the antenna achieve the radiation parameters such as scattering parameter (S-parameter), radiation pattern and voltage standing wave ratio (VSWR). In S-parameter, the S_{11} parameter value is reached < -10 dB for the resonant frequencies 0.9 GHz, 0.87 GHz to 0.90 GHz and VSWR value is obtained < 2 for that same frequencies. The proposed antennas will be useful for 900 MHz band in wireless communication applications.

Keywords: Microstrip Antenna, Patch Antennas, Probe Feed, Wireless Communication.

I. INTRODUCTION

An antenna converts an electromagnetic signal to an electrical signal at a receiver or electrical signal to an electromagnetic signal at a transmitter. It is also the interface between transmitter lines and space. The importance of wireless communication systems increase efforts devoted to the design and implementation of novel microstrip structures from miniaturized electronic circuits to the antenna arrays [19].

One major application is design of microstrip antenna arrays which are attractive candidates for adaptive systems in the present and future communication systems. Their main advantages are light weight, low cost, planar or conformal layout, and ability of integration with electronic or signal processing circuitry [23, 24].

A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate [25]. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape [4].

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation [26]. However, such a configuration leads to a larger antenna size. In order to design a compact microstrip patch antenna, a compromise must be reached between its dimensions and performance to get efficient antenna [7]. Cutting slits on the edge of the excited patch surface make fractal design for the microstrip antenna [9].

In this paper, the hexadeci faced patch antenna with slit on edge is introduced to simulate them and get good radiation properties. The remainder of the paper is organized as follows. Section II provides the literature survey of the proposed hexadeci faced patch antenna [5]. Section III provides the analysis and design of the proposed hexadeci faced patch antenna [6]. Section IV gives experimental results for the conventional patch antenna with probe feed and proposed meandered line patch. The results demonstrate that an enhancement of the gain significantly the matching of the patch antenna. Finally, concluding remarks are given in Section V.

II. LITERATURE SURVEY

In this section, the microstrip antenna literature survey is discussed. Tae-Hyun Kim, Dong-Chul Park (2005) presents a compact dual-band antenna with double L-slits for wireless local area network (WLAN) applications in IEEE 802.11a/b/g. The proposed antenna effectively covers both 2.4/5-GHz bands with three resonances that are caused by the double L-slits. The proposed antenna has compact size of 15 mm×9 mm×7 mm, which is only half size of the antenna using double U-slits [11].

A.Al-Zoubi et al (2009) presented a broadband center-fed circular patch-ring antenna with a monopole like radiation pattern [17]. R. Kumar et al (2010) designed a CPW–Fed Ultra wideband Fractal Antenna and Backscattering Reduction [18]. Garima et al (2011) proposed antenna with improved bandwidth in hexadeci faced patch antenna [21].



The circular microstrip antenna offers a number of radiation pattern options not readily implemented using a rectangular patch. The fundamental mode of the circular microstrip patch antenna is the TM_{11} . This mode produces a radiation pattern that is very similar to the lowest order mode of a rectangular microstrip antenna. The next higher order mode is the TM_{21} , which can be driven to produce circularly polarized radiation with a monopole-type pattern [8, 10]. This is followed in frequency by the TM_{02} mode, which radiates a monopole pattern with linear polarization. In the late 1970s, liquid crystals were used to experimentally map the electric field of the driven modes surrounding a circular microstrip antenna and optimize them [1].

In Figure 1, the geometry of a circular microstrip antenna is defined. The circular metallic patch has a radius ‘a’ and a driving point located at ‘r’ at an angle ‘ ϕ ’ measured from the x- axis. As with the rectangular microstrip antenna, the radiating patch is spaced at a distance ‘h’ from a ground plane. A substrate of ϵ_r separates the patch and the ground plane.

An analysis of the circular microstrip antenna, which is very useful for engineering purposes, has been undertaken by Derneryd and is utilized here[2]. The electric field under the circular microstrip antenna is described by:

$$E_z = E_0 J_n(kr) \cos(n\phi) \quad (1)$$

The magnetic field components are described as H_r and H_ϕ in eq.(2) and (3)

$$H_r = -\frac{j\omega\epsilon n}{k^2 r} E_0 J_n(kr) \sin n\phi$$

$$H_\phi = -\frac{j\omega\epsilon}{k} E_0 J'_n(kr) \cos n\phi$$

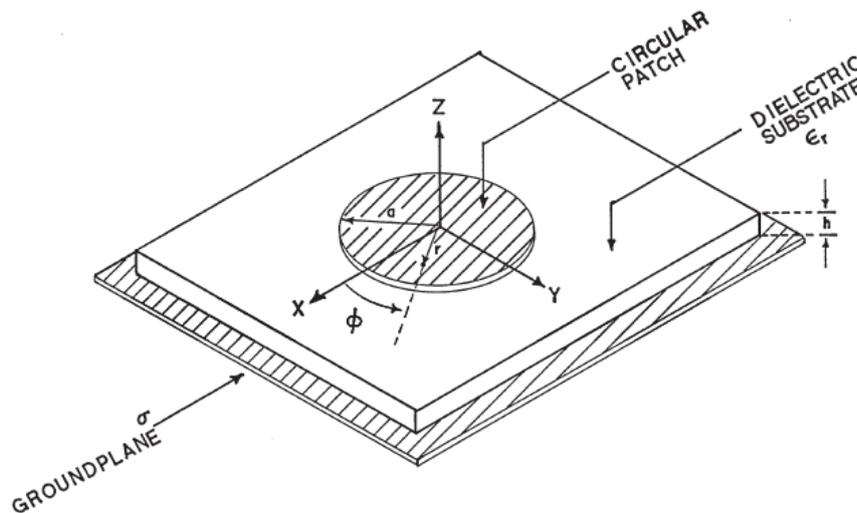


Fig.1 Geometry of a Circular Microstrip Antenna

Where ‘k’ is the propagation constant of the dielectric substrate. J_n is the Bessel function of the first kind of order n. J'_n is the derivative of the Bessel function with respect to its argument, ω is the angular frequency ($=2\pi f$). The TM_{21} mode has the next highest frequency of operation (after TM_{11}). This particular mode is useful in creating a monopole radiation pattern that has circular polarization, as described by Huang [3]. It is possible to drive a patch in the TM_{21} mode with a single feed which will produce circular polarization [10].

VSWR is the ratio between the maximum voltage and the minimum voltage along the transmission line. The VSWR and reflection coefficient is given by the equation shown eq. (4), (5).

$$VSWR = (1 + \Gamma) / (1 - \Gamma) \quad (4)$$

Where Γ is the reflection coefficient,

$$\Gamma = (Z_L - Z_0) / (Z_L + Z_0) \quad (5)$$

The VSWR indicate that how closely or efficiently an antenna’s terminal input impedance is matched to the characteristic impedance of the transmission line. The larger the number of VSWR provides, the greater the mismatch between the antenna and the transmission line.

An antenna’s radiation pattern is the characteristics that most affect system coverage and performance. All antennas do not radiate more total energy than is delivered to their input connector. Antenna radiation pattern are typically



presented in the form of a polar plot for a 360° angular pattern in one of two sweep planes and it is presented on a relative power dB scale [13]-[16].

Relative permittivity of the substrate is an important parameter to consider. It is because relative permittivity will enhance the fringing fields that account for radiation. This type of antenna is characterized by its length L, width w, and thickness.

The other radiation pattern properties of significance are the antenna’s side lobes, back lobes and front to back ratio (f/b). In practice, it is impossible to eliminate antenna side lobes and back lobes completely.

Antenna side and back lobes affect antenna and system performance in several ways. First, energy delivered to or received by side and back lobes is from a direction other than the intended region of coverage and is therefore wasted.

At a transmitter, energy delivered to side and back lobes maybe directed towards other receive systems causing interference. Then at a receiver, energy from other transmit sites may be received through the side and back lobes causing interference within the system.

Main lobe is the radiation lobe containing the direction of the maximum radiation. For side lobe, it is a radiation lobe in any direction other than the intended lobe direction. It is usually adjacent to the main lobe and occupies the hemisphere in the direction of the main beam. A radiation lobe in which axis is at 180° with respect to the main beam. It usually refers to a small lobe that occupies the hemisphere in a direction opposite to a main lobe are the definition for back lobe.

Looking at the current (magnetic field) and voltage (electrical field) for a single circular patch, the current is maximum at the centre and minimum near the left and right edges, while the electrical field is zero at the centre and maximum near the left and minimum near the right edges, as in Fig.2

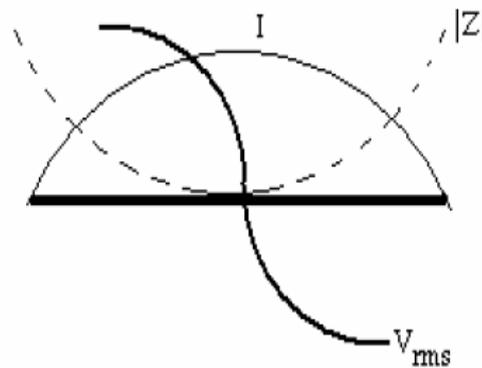


Fig.2 Voltage, Current, Impedance distribution in CPA

From the magnitude of the current and voltage, we can conclude that the impedance is minimum at the middle of the patch and maximum (around 200 Ω, but depend on the Q of the leaky cavity) near the edges. Hence, there is a point where the impedance is 50Ω along the “resonant length” at x-axis of the element. I, Z expressions are given in eq. (6) and (7) below.

$$I = \int_s \bar{J} \cdot d\bar{s}$$

$$Z = \frac{1}{2} \frac{P_{tot}}{|I|^2}$$

Where J = current density
 Z = impedance
 P_{tot} = total power received

Mathematically speaking, impedance can be computed if the current distribution is known [15].

III. ANALYSIS AND DESIGN

In this section, the microstrip antenna analysis, design methodology is discussed. The first design step is to select a suitable dielectric substrate material. The major electrical properties considered here are relative dielectric constant ϵ_r and loss tangent $\tan(\delta)$. Generally it is best to select a substrate with the lowest possible dielectric constant consistent with the space available for the antenna. Substrate thickness should be chosen as large as possible to maximize



bandwidth and efficiency, but not so large as to risk surface-wave excitation [22]. The analysis is carried out by calculating the radius ‘a’, from the given data such as dielectric constant, height, resonant frequency, etc.

Theoretically the radius of circular patch antenna is calculated from the expression as in eq.(8) given below by

$$a = \frac{F}{\left\{ 1 + \frac{2h}{\pi\epsilon F} \left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726 \right] \right\}^{\frac{1}{2}}}$$

$$\text{Where } F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon}}$$

f_r is resonant frequency. The circular microstrip patch antenna geometry [28] is shown in Fig. 1. We proposed a hexadeci faced microstrip antenna with a radius of 46 mm on a dielectric substrate that is 3.2 mm thick and has a relative dielectric constant of $\epsilon_r = 4.4$ and $\tan \delta = 0.0009$ to illustrate the properties of the TM_{11} mode. Conventional antenna details are shown in Table I.

TABLE I
 CONVENTIONAL ANTENNA DETAILS

Symbol	Parameter	Values
a	Hexadeci faced patch Radius	46 mm
ϵ_r	Substrate Dielectric constant	4.4
h	height of the substrate	3.2
r	probe radius	1 mm

mm= millimeter

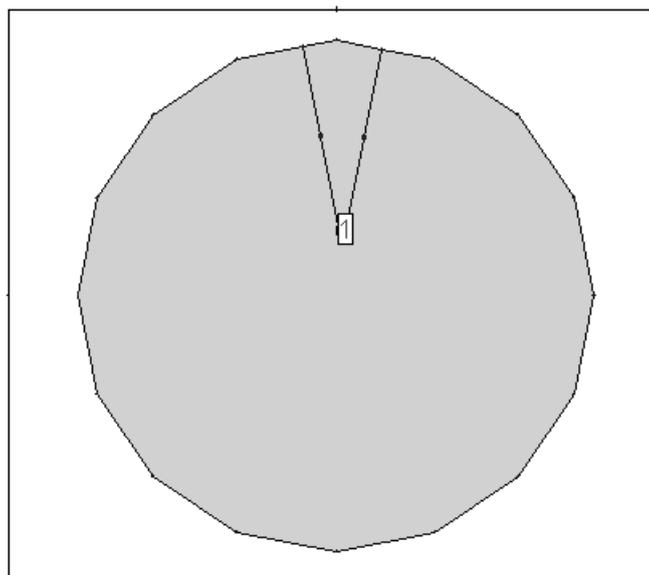


Fig.3 Geometry of Conventional Hexadeci faced Patch Antenna

A. Hexadeci faced microstrip patch antenna iteration1

This antenna designed for the resonant frequency 0.9 GHz is shown in Fig. 4. The patch antenna is hexadeci faced with a radius of a = 46 mm with 8 rectangular slits of each 8mm x 1mm on the edge surface and is printed on a



substrate with a relative permittivity of $\epsilon_r = 4.4$ and a thickness of $h = 3.2$ mm. The patch is fed by a probe with a radius of 1 mm placed at feed point (1.185, 11.8) of the patch. The feed location was optimized to give good impedance matching. The size of the substrate is 200 mm X 200 mm. The antenna resonates at 0.89 GHz.

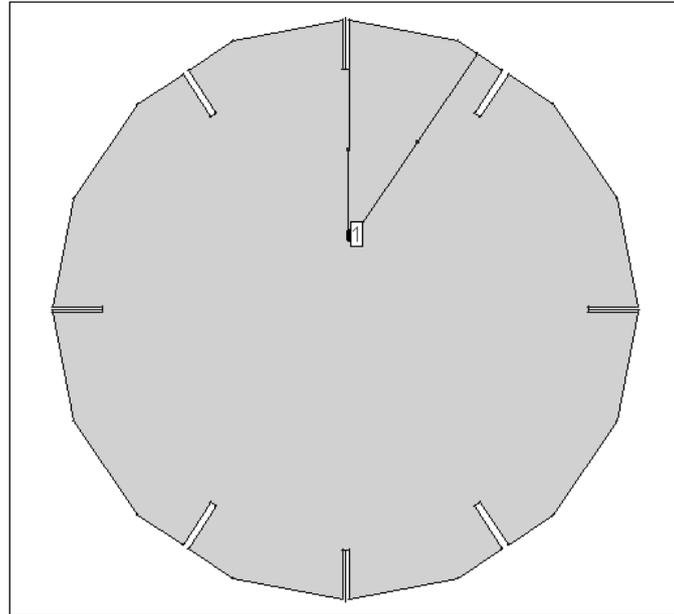


Fig.4 Geometry of iteration1

B. Hexadeci faced microstrip patch antenna iteration2

The patch antenna is hexadeci faced with a radius of $a = 46$ mm with 16 rectangular slits of each 8mm x 1mm on the edge surface and is printed on a substrate with a relative permittivity of $\epsilon_r = 4.4$ and a thickness of $h = 3.2$ mm. The patch is fed by a probe with a radius of 1 mm placed at feed point (1.185, 11.8) of the patch. The feed location was optimized to give good impedance matching. The size of the substrate is 200 mm X 200 mm. This iteration2 is shown in fig.5

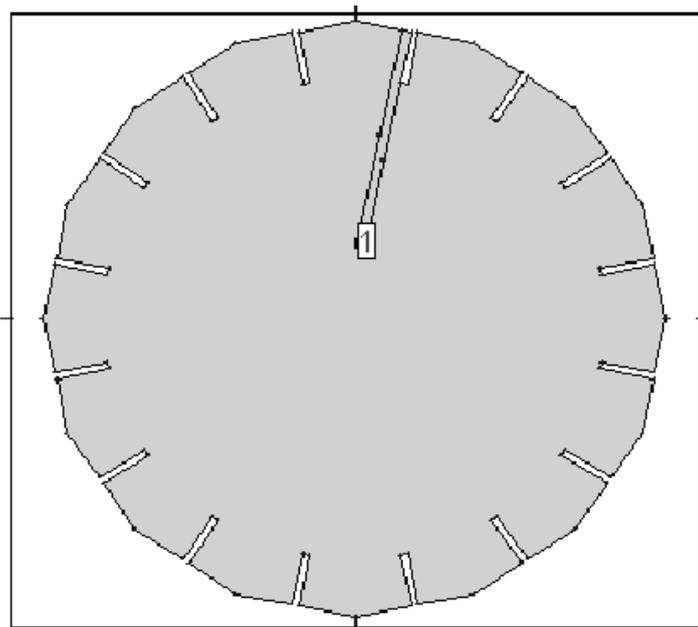


Fig.5 Geometry of iteration2

C. Hexadeci faced microstrip patch antenna iteration3



This patch antenna is hexadeci faced with a radius of $a = 46$ mm with 48 rectangular slits of each 8mm x 1mm on the edge surface and is printed on a substrate with a relative permittivity of $\epsilon_r = 4.4$ and a thickness of $h = 3.2$ mm. The patch is fed by a probe with a radius of 1 mm placed at feed point (1.185, 11.8) of the patch. The feed location was optimized to give good impedance matching. The size of the substrate is 200 mm X 200 mm. this iteration3 is shown in fig.6

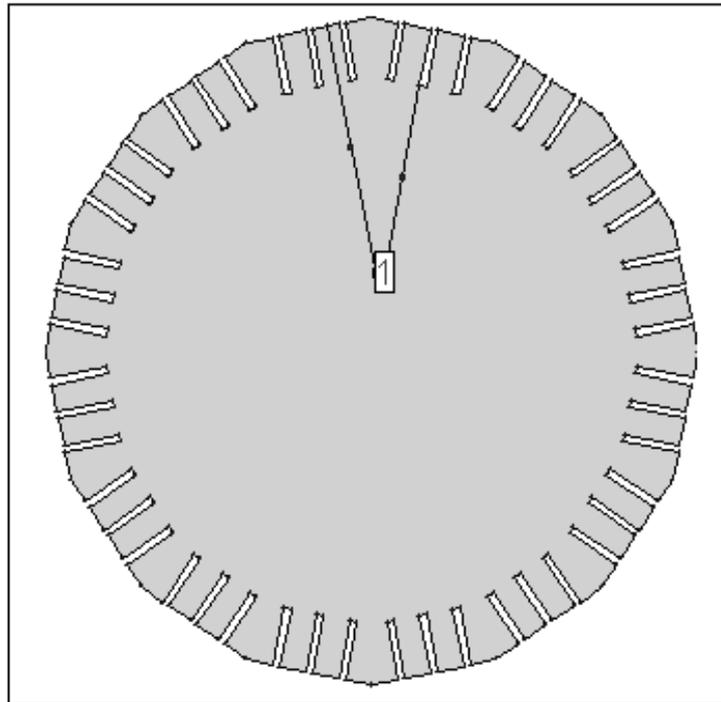


Fig.6 Geometry of iteration3

IV. RESULT AND DISCUSSION

The proposed hexadeci faced patch antennas using probe feed are designed. They are simulated in IE3D electromagnetic simulator software [27]. The results are given in following figures 7-8 and it is compared in the table II.

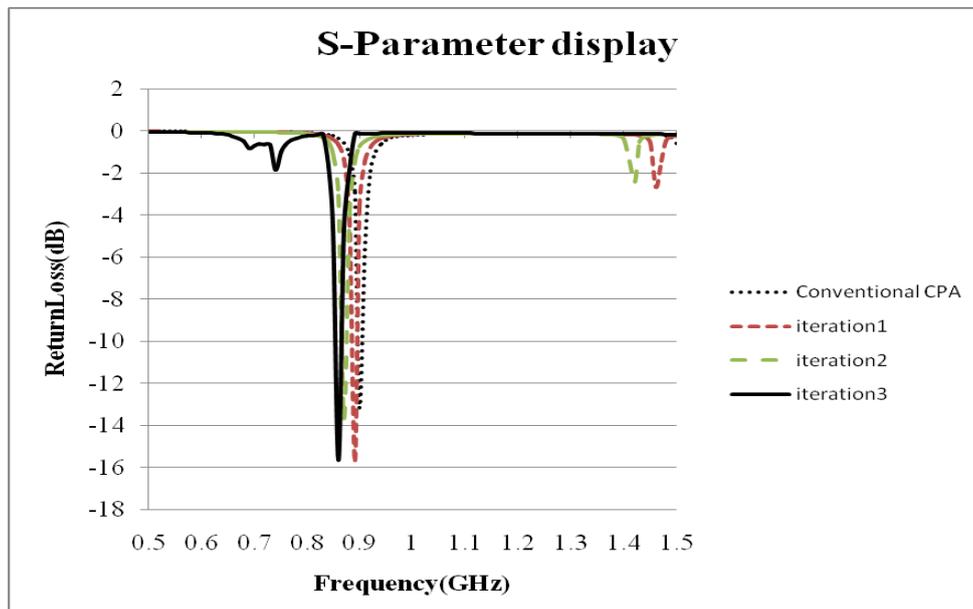




Fig.7 Return Loss versus Frequency of conventional, iteration1-3 antennas

From the iteration1 graph it is understood that the resonant occurs at the frequency 0.89 GHz for the return loss -15.67 dB. From the S-parameter display of iteration2 graph it is understood that the resonant occurs at the frequency 0.87 GHz for the return loss -13.64 dB. The simulated VSWR value is 1.5 for the same frequency and it is recorded in the table II. The S-parameter display of conventional, iteration1-3 is shown in Fig.7. From this graph it is understood that the resonant occurs at the frequency around 0.9 GHz for the return loss -15.63 dB.

From this figure 8, it is noted that how the radiation pattern distribution takes place in the patch. The antenna impedance parameter for the proposed hexadeci faced patch antenna is close to 50 ohms for the resonant frequencies. During the simulation the total field gain, directivity, Radiation Efficiency, antenna efficiency of antennas is noted and shown in Table II. The dielectric constant, ϵ_r primarily affects the bandwidth and radiation efficiency of the antenna.

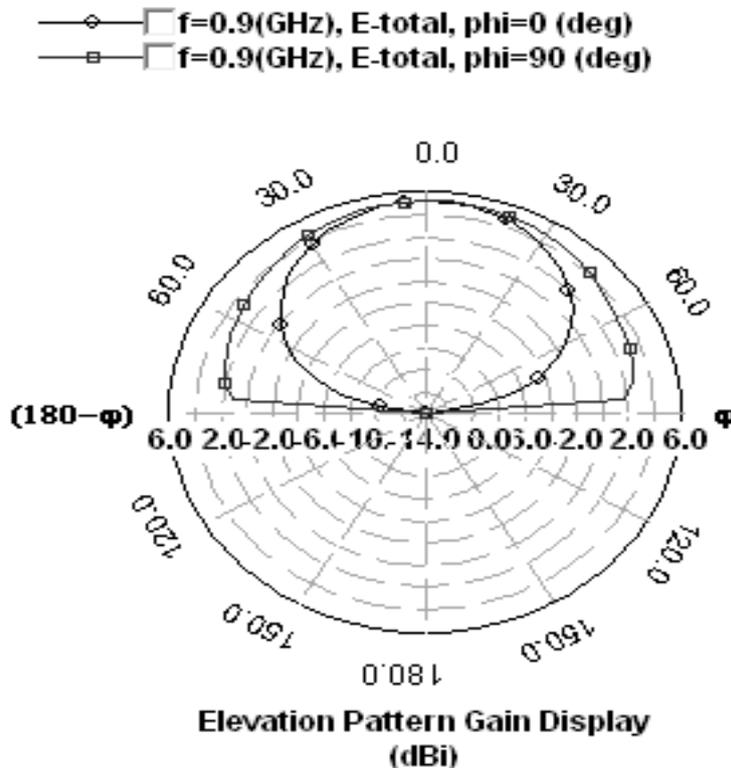


Fig.8 Elevation pattern gain display for f=0.9 GHz

The antenna with lower permittivity will give a wider impedance bandwidth and reduce the surface wave excitation. The comparison of antennas [12] is furnished in the table II.

TABLE II
 COMPARISON OF PROPOSED ANTENNAS WITH CONVENTIONAL CPA

Characteristics of Antennas	Conventional CPA	Proposed iteration1	Proposed iteration2	Proposed iteration3
Resonant Frequency (GHz)	0.90	0.89	0.87	0.85
Return Loss(dB)	-13.158	-15.670	-13.640	-15.630
VSWR	1.6	1.4	1.5	1.46



Radiation Efficiency (%) η_{rad}	80.60	79.15	77.59	78.05
Antenna Efficiency (%) η_{ant}	76.70	77.01	74.24	76.10
Gain (dBi)	5.147	5.155	4.966	5.150
Directivity (%)	6.298	6.289	6.260	6.280
% Reduction in area	-	0.96	1.92	5.77

CPA=Circular Patch Antenna

From these comparison results, it is understood that iteration of antenna makes the reduction in frequency with the reduction of area.

V. CONCLUSION

In this paper, we have analyzed a hexadeci faced microstrip antenna with slits on the edge. It is simulated in IE3D software. Simulations have been carried out to investigate the antenna's performance and characteristics. The simulation result shows good agreement with theoretical values. The antennas proposed can be built and measured to compare the real results with those obtained from the simulations as a future work. Possible applications of this antenna include RFID, UHF applications.

ACKNOWLEDGMENT

The author is thankful to the Dean and Head of the Department, Electronics and Communication Engineering, B. S. Abdur Rahman University, Chennai for providing research facility and valuable suggestions for this work.

REFERENCES

- [1] Kernweis, N. P., and McIlvenna, J. F., "Liquid crystal diagnostic techniques an antenna design aid," *Microwave Journal*, Vol. 20, pp. 47–58, October 1977.
- [2] Derneryd, A. G., "Analysis of the microstrip disk antenna element," *IEEE Transactions on Antennas and Propagation*, Vol. AP-27, No. 5, pp. 660–664, September 1979.
- [3] Huang, J., "Circularly polarized conical patterns from circular Microstrip antennas," *IEEE Transactions on Antennas and Propagation*, Vol. AP-32, No. 9, pp. 991–994, September 1984.
- [4] D. M. Pozar, "Microstrip antennas", Dept. of Electrical & Computer Engineering, Massachusetts University, Proceedings of the IEEE, Amherst, MA Jan 1992.
- [5] Suprlyo Day, C. K. Aanandan, P. Mohanan, and K. G. Nair, "A New Broadband Circular Patch Antenna", *Microwave and Optical Technology Letters*, Vol. 7, No. 13, pp.604-606, September 1994.
- [6] D. M. Pozar and D. H. Schaubert, "Microstrip Antennas: The analysis and design of microstrip antennas and arrays", IEEE press, New York, 1995.
- [7] K. L. Wong, C. L. Tang, and H. T. Chen, "A compact meandered circular microstrip antenna with a shorting pin," *Microwave and Optical Technology Letters*, 15, 147–149, June 20, 1997.
- [8] Du, B., and Yung, E., "A single-feed TM_{21} -mode circular patch antenna with circular polarization," *Microwave and Optical Technology Letters*, Vol. 33, No. 3, pp.154–156, May 2002.
- [9] Werner, D. H., Ganguly, S., "An overview of fractal antenna engineering research", *IEEE Antennas and Propagation Magazine*, Vol. 45, pp. 38 – 57, Feb 2003.
- [10] K. L. Lau and K.M. Luk, "A wideband circularly polarized coupled patch antenna for dual band operation", *IEEE Transaction on Antennas and Propagation*, vol.53, no. 8, pp.2636-2644, August 2005.
- [11] Tae-Hyun Kim, Dong-Chul Park, "Compact dual-band antenna with double L-slits for WLAN operations", *IEEE Antennas and Wireless Propagation Letters*, Vol. 4, Page(s): 249 – 252, 2005.
- [12] V. R. Gupta and Nisha Gupta, "Two compact Microstrip patch antennas for 2.4.GHz band-A comparison," *Microwave and Optical Technology letters*, pp29-31, November 2006.
- [13] Tong K.F., Wong T.P., "Circularly polarized U-slot antenna", *IEEE Transactions on Antennas and Propagation*, vol.55, no.8, pp. 2382–2385, 2007.
- [14] A. S. N. Khan, J. Hu, J. Xiong, and S. He, "Circular fractal monopole antenna for low VSWR UWB applications", *Progress in Electromagnetics Research Letters*, Vol. 1, pp. 19–25, 2008.
- [15] T.F.Lai, Wan Nor Liza Mahadi, Norhayati Soin, "Circular Patch Microstrip Array Antenna for KU-band", *Proc. of World Academy of Science, Engineering and Technology* 48, 2008.



- [16] S.L.S. Yang and K.M. Luk, "A Wideband L-probes fed circularly-polarized Reconfigurable Microstrip Patch antenna", IEEE Transactions on Antennas and Propagation, AP-56, pp. 581-584, February 2008.
- [17] A.Al-Zoubi, F. Yang, and A. Kishk, "A broadband center-fed circular patch-ring antenna with a monopole like radiation pattern," IEEE Transactions on Antennas and Propagation, vol. 57, pp. 789–792, 2009.
- [18] R. Kumar and P. Malathi, "Design of CPW–Fed Ultra wideband Fractal Antenna and Backscattering Reduction", Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol. 9, No. 1, pp. 10-19, June 2010.
- [19] B.J.Kwaha, O.N.Inyang, & P.Amalu, "The circular Microstrip patch antenna design and implementation", IJRRAS, Vol.8, Issue 1, pp.86-95, July 2011.
- [20] Ali Daliri, Amir Galehdar, Sabu John, Wayne S. T. Rowe and Kamran Ghorbani, "Slotted Circular Microstrip Patch Antenna Application in Strain Based Structural Health Monitoring", AIAC14 Fourteenth Australian International Aerospace Congress, HUMS 2011.
- [21] Garima, D.Bhatnagar, J.S.Saini, V.K.Saxena, & L.M.Joshi, "Design of broadband circular patch Microstrip antenna with diamond shape slot", Indian Journal of Radio & Space physics, Vol.40, pp.275-281, October 2011.
- [22] S. S. Gultekin, D. Uzer, and O. Dundar, "Calculation of Circular Microstrip Antenna Parameters with a Single Artificial Neural Network Model", Progress in Electromagnetics Research Symposium Proceedings, KL, MALAYSIA, pp.545-548, March 27-30, 2012.
- [23] J. Bahl and P. Bhartia, "Microstrip Antennas", Dedham, Ma, Artech House, 1981.
- [24] Handbook of microstrip antennas, Volume 2, By James R. James, Jim R. James, Institution of Electrical Engineers.
- [25] D. Orban and G.J.K. Moernaut, The Basics of Patch Antennas, Orban Microwave Products, www.orbanmicrowave.com
- [26] Wong K.L., Compact and broadband Microstrip antennas, John Wiley, New York, 2003.
- [27] IE3D Software, 2008.

BIOGRAPHY



Salai Thillai Thilagam. J received his Diploma in Electronics and Communication Engineering from Department of Technical Education, Government of Tamilnadu, India, in 1989, the AMIE degree in Electronics and Communication Engineering from The Institution of Engineers, India, in 2000, and the M.Tech degree in Applied Electronics from Dr. MGR University, Chennai, India in 2007. He was a teaching assistant, lecturer, with Department of Electronics and Communication Engineering, Madras University and Anna University affiliated institutions, in 2000, and 2006 respectively. He was a senior lecturer, assistant professor in 2009 and 2010 respectively and now is an associate professor, Aarupadai Veedu Institute of Technology, Vinayaka Missions University, India. His research interests include RF, Microwave applications and Antennas. At present, He is pursuing the Ph.D. degree in wireless communication from B. S. Abdur Rahman University, Chennai, India. He is a Member (M) of IEEE from 2010.



Dr. P. K. Jawahar completed his B.E. degree in Electronics & Communication Engineering from Coimbatore Institute of Technology in 1989, M. Tech degree in Electronics & Communication Engineering from Pondicherry Engineering College in 1998 and the Ph.D. degree in Information and Communication Engineering from Anna University, Chennai in February, 2010. He has 21 years of teaching experience and now he is working as Professor in Department of Electronics and Communication Engineering, B. S. Abdur Rahman University, Chennai handling courses for under graduate and graduate students in the area of wired and wireless networks, VLSI, microprocessor and microcontrollers. He has published many papers in international journals and conferences in the area of VoIP and reconfigurable architectures. He is a Fellow of IE and IETE.