IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 12, Issue 4, Ver. III (Jul.-Aug. 2017), PP 56-61
www.iosrjournals.org

Comparison of Various Regular Shaped Co-axial fed Conventional and Single-Shorted Microstrip Antenna for Ultra-compactness

*Amar D. Chaudhari, Vilas K. Dhavane, Priyanka V. Jinde, Amutha Jeyakumar, R. N. Awale
(Department of Electrical Engineering, Veermata Jijabai Technology Institute, Matunga-India)
Corresponding Author: Amar D. Chaudhari

Abstract: *In this paper, design, analysis and comparison of various regularly shaped co-axial probe-fed microstrip antenna (MSA) configurations, such as rectangular, circular, triangular and hexagonal shape is carried out. The low-cost FR4 glass epoxy substrate with ε_r = 4.3 and substrate height h = 1.6 mm is taken to realize all these configurations. The MSA dimensions are chosen in such a way that the resonance frequency of all these antennas operating in their fundamental mode is around 1.8 GHz. Later on, analysis of single shorted configuration of same MSA is carried out for the compactness. To achieve further compactness investigation of edge shorted MSA's is carried. All the simulation for the various configurations has been performed using the method of moment based IE3D Software. Different parameters such as return loss, % bandwidth (BW), and frequency reduction has been compared, through simulation for basic as well as shorted configuration. Depending on the BW, gain requirement, and space available choice of a various compact MSAs has been suggested.*

Keywords: *Microstrip Antenna (MSA), Rectangular MSA (RMSA), Circular MSA (CMSA), Triangular MSA (TMSA), Hexagonal MSA (HMSA), Shorting post, Center Shorted MSA, Edge Shorted MSA, Compact.*

I. Introduction

The demand of small antennas for personal communication is increasing in the field of practical application. The miniaturization of the microstrip antenna is a considerably most important factor. Many techniques have been used to reduce the size of MSA such as by introduction of shorting post/wall patch [1-3], [6], [8-9], meandered patch, and folded patch or by inserting different geometry of slot on the patch [1-4]. Of all the mentioned method shorting post is easy to realize. Apart from the reduction in the size of MSA [1-4],[7], shorting post are effective in enhancing the BW, input impedance matching [10], multi-frequency operation, change of polarization, harmonic suppression, field perturbation. Depending on the application, the shorting post may be located at the center or at the edge of the patch [8-9]. However, the effect of the shorting post depends on different parameters like the number of the posts, the radius of each post and the thickness of the MSA which determines the length of the posts. It has been inferred that position of shorting post, its dimension, its position with respect to feed position plays a major role in deciding the resonance frequency [2-4]. Also, it has been observed that MSA resonates and gives results only when the feed is given in close proximity with the shorting post position [4]. Further, it has been proved that maximum reduction in resonance frequency is observed when the shorting post is near the edge of the MSA [5-6].

Much work has been done previously on shorting post on different patch geometry for different resonance frequency. To the best of author's knowledge complete modal analysis of different conventional configuration for same fundamental mode frequency using shorting post has not been reported till date. This paper presents the study of effects of various configurations of compact and shorted MSAs. The concept of shorting has been studied in detail and its postulation has been proved and supported with the simulated results. In this paper, all the conventional MSA's have been designed at the same resonance frequency and the effect of the introduction of shorting post at the edge as well as the center of the patch has been explained briefly with simulated results using IE3D software to support it [15].

II. Design of Conventional Regular Shaped MSA

In this section, the basic design of conventional MSA's such as rectangular, triangular, circular and hexagonal is presented. These configurations are designed at fundamental resonance frequency 1.8 GHz on FR-4 substrate having dielectric constant ε_r=4.3 with a substrate thickness of h =1.6 mm and loss tangent of tan δ =0.02.The patch has been excited through coaxial probe with feed point optimized at 50Ω for impedance matching as shown in Fig. 1. The simulation of all the antenna design has been carried out in the method of moments based IE3D software on the infinite ground plane [15]. The fringing of the fields at the edges of the patch occurs as the patch dimensions are finite. This fringing effect depends on the width of the patch (Refer Equation 1) and height of the substrate. For accounting fringing field, effective dielectric constant which is calculated by equation (2) is considered. The value of effective dielectric constant must lie in the range of $1 < \varepsilon_{eff} < \varepsilon_r$.

$$W = \frac{c}{2 f_0}\left(\frac{2}{\varepsilon_r + 1}\right)^{1/2} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times \left[1 + 12 \times \frac{h}{w}\right]^{-1/2} \tag{2}$$

The following sub section demonstrates the equations taken into account for calculating the fundamental resonance frequency for all conventional antenna configurations. The important point to consider is that the fundamental mode for RMSA and TMSA are TM_{10}, whereas TM_{11} is the fundamental mode for CMSA. Now if we compare HMSA with RMSA and then if the feed is given along the X-axis the dominant mode is TM_{10} and if the feed is given along the Y-axis then the dominant mode is TM_{01}.

2.1 Rectangular Microstrip Antenna (RMSA) [3, 10]

The design formulae for RMSA using transmission-line model are as follows [3]:
Width (W):- Width of the patch can be calculated by using equation (1).

Length Extension (ΔL):-

$$\Delta L = 0.412 \times h \times \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{3}$$

Effective Length (L_{eff}):-

$$L_{eff} = \frac{\lambda}{2} = \frac{\lambda_0}{2\left[\varepsilon_{eff}\right]^{1/2}} = \frac{c}{2 f_0 \left[\varepsilon_{eff}\right]^{1/2}} \tag{4}$$

Actual Length of Patch (L):-

$$L - L_{eff} - 2\Delta L \tag{5}$$

2.2 Circular Microstrip Antenna (CMSA) [6, 11]

The radius a of CMSA can be calculated using equation (6),

$$F_{mn} = \frac{K_{mn} c}{2\pi a_{eff} \left(\varepsilon_{eff}\right)^{1/2}} \tag{6}$$

Where,

$$a_{eff} = \left[a + \frac{h}{(\varepsilon_r)^{1/2}}\right] \tag{7}$$

Where, c is the velocity of light and K_{11} is the n^{th} root of the derivative of the Bessel function of order m . For CSMA the fundamental mode is TM_{11}, so the value of K_{11} is 1.8412.

2.3 Triangular Microstrip Antenna (TMSA) [3]

The resonance frequency obtained from the cavity model can be calculated by,

$$F_{mn} = \frac{K_{mn} c}{2\pi \left(\varepsilon_{eff}\right)^{1/2}} \tag{8}$$

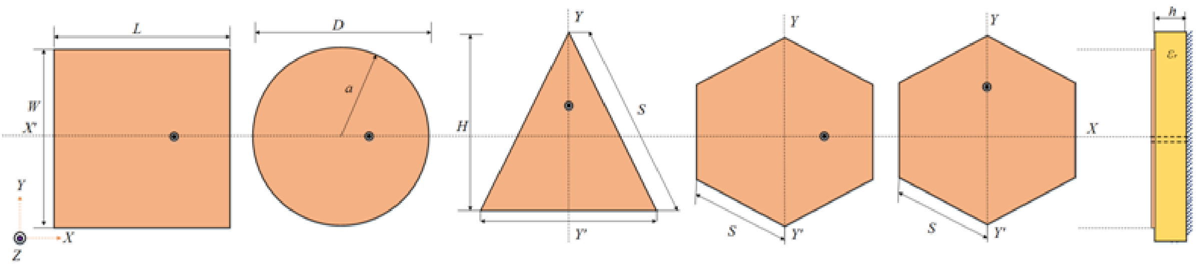


Fig. 1: Conventional MSA configuration

Here, value of K_{mn} is given as,

$$K_{mn} = \frac{4\pi}{3S_{eff}}\left(m^2 + mn + n^2\right)^{1/2} \quad \text{and} \quad S_{eff} = \left[S + \frac{4h}{(\varepsilon_r)^{1/2}}\right] \tag{9}$$

Where, ε_{eff} is obtained from equation (2) by replacing W with S/2.

2.4 Hexagonal Microstrip Antenna (HMSA) [12-14]

The resonance frequency of HMSA can be obtained by equating the area of HMSA to that of CMSA [9]. And then the resonance frequency of HMSA can be calculated using CMSA equation (6). The determination of a_{eff} and ε_{eff} of equivalent CMSA for equation (6) is done by equating the area of HMSA to that of RMSA while doing so the resonance length *L* of RMSA is kept same as that of HMSA. For calculating width *W* of RMSA, its area is equated to that of HMSA. Thus, for x-axis feed HMSA with side length *S*, the equivalent RMSA has $L = \sqrt{3}S$ and $W = 3S/2$. Similarly, for the configuration with Y-axis feed HMSA, the equivalent RMSA dimensions calculated has $L = 2S$ and $W = 3\sqrt{3}S/8$. Using this L and W , equation (2) can be used for the calculation of ε_{eff} . This ε_{eff} is then used for calculating edge extensions ΔL and ΔW of RMSA from all sides using equation (3). This gives the effective length and width of RMSA as,

$$L_{eff} = L + 2\Delta L \quad \text{and} \quad W_{eff} = W + 2\Delta W \tag{11}$$

Then the area of expanded RMSA is equated back with the area of CMSA for obtaining a_{eff} of equivalent CMSA. Therefore,

$$a_{eff} = \left(L_{eff} \times W_{eff}/\pi\right)^{1/2} \tag{12}$$

2.5 Dimension of Ground Plane

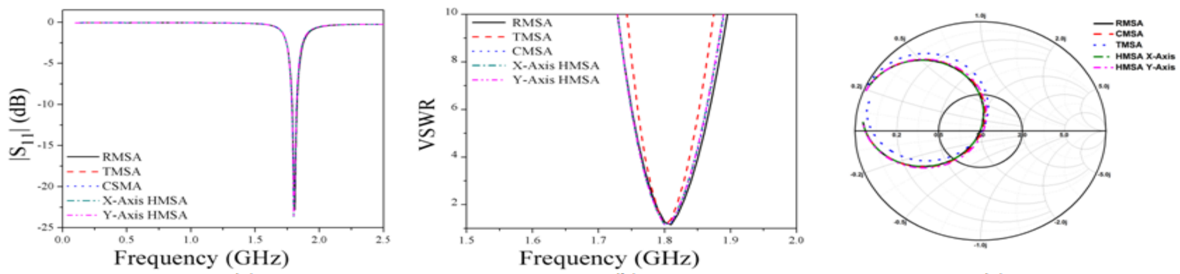
The design of ground plane for all the above configuration is explained here. The transmission line model can only be used for infinite ground planes. However, if we take practical consideration into account, the finite ground plane becomes mandatory. The study has shown that infinite and finite ground plane can give similar results if the ground plane is extended approximately six times the substrate thickness across all peripheries of the patch dimensions.

$$L_g = L + 6h + 6h \quad \text{and} \quad W_g = W + 6h + 6h \tag{13}$$

The simulation results for return loss (S_{11}), VSWR and Smith chart are plotted for all the configurations, the results for the same are summarized in Table 1. Fig. 2(a) depicts the return loss (S_{11}) plot of the all conventional MSA. We can see all the basic antenna configuration are resonating at 1.8 GHz frequency. VSWR for all the above conventional MSA configuration is plotted in Fig. 2(b) which shows that minimum value of VSWR is obtained at 1.8 GHz. Fig. 2(c) depicts the impedance variation within the simulated range through Smith chart. On the basis of Smith chart information, impedance matching can be easily obtained. Percentage bandwidth (%BW) shown in Table 1 is calculated as follows:

$$\%BW = \frac{f_2 - f_1}{f_0}$$

Where, f_2 =Higher frequency, f_1 = Lower frequency, and f_0 =Fundamental resonance frequency.



(a) (b) (c)

Fig. 2: Comparison of result for conventional regular shaped MSA (a) Return loss (b) VSWR and (c) Smith chart

Table 1: Comparison of result of Conventional MSA

Sr. No.	Type of MSA	Dimension (mm)	Resonance Frequency (GHz)	Feed Point (mm)	RL (dB)	% BW	Area $(mm)^2$
1	RMSA	L=39.07, W=51.19	1.8	10.4	-43.57	2.18	1999
2	CMSA	A=23.47	1.8	8.7	-37.03	2.10	1729
3	TMSA	S=53.58	1.805	4.5	-30.75	1.65	1243
4	HMSA X-Axis	S=25	1.807	8.4	-54.69	2.06	1623
5	HMSA Y-Axis	S=25	1.816	8.4	-39.21	2.01	1623

From Table 1, it follows that for the same fundamental resonance frequency of 1.8 GHz, TMSA has the smallest area.

III. Design of Center Shorted Regular Shaped MSA Configuration

According to the transmission line theory, shorting post is modeled as the addition of the parallel inductance. The inductance can be added by making virtual ground on the patch. This is done by connecting ground plane to the patch by copper wire. The current density at the point of shorting post gets strengthen. Larger the added inductance, smaller will be the resonance frequency. The added inductance can be changed by changing the radius of the shorting post and number of shorting post. As mentioned earlier, the location of shorting post plays a key role in changing the fundamental frequency and other basic parameters of MSA. Also, the number of shorting post or single shorting post improvise the basic parameters of patch antenna like impedance, directivity and cross polarization. At the center of the patch antenna there always exists zero potential and the addition of shorting post at the center does change the field distribution. But it does not disturb the fundamental resonating frequency of the antenna and the shorting post at center excite the lower order mode towards the low frequency. By properly adjusting the parameter of lower mode it can be used as dual band antenna. Different modes can be excited and controlled by the shorting post.

The Single center shorted MSA configuration depicted in Fig. 4 is investigated keeping the dimension of MSA's and substrate parameters same as the previous case. The shorting post radius 0.5 mm. Shorting post location plays very important role in determining the field distribution. When shorting post is inserted on the patch to create a virtual ground at the center of the patch the field perturbation happens. It makes electric field zero at the center of the patch which means that voltage is minimum and current is maximum at that point where shorting post is placed. Fig. 3 depicts S_{11} plots center shorted MSA configuration of all basic patches. Along with fundamental mode, the lower order mode is generated by introducing shorting post at the center of the patch. For CMSA, RMSA, X-axis, and Y –axis MSA, we can see that lower mode is generated at the same frequency which is approximately equal to 0.81 GHz but for TMSA the lower mode is generated at 0.925 GHz which is quite higher as compared to the other center shorted MSA configuration depicted in the Fig. 4. Frequency reduction factor shown in Table 2 is calculated as follows: Frequency reduction = F_L/F_F, Where, F_L = Lower order resonance frequency; F_F = Fundamental resonance frequency.

IV. Design Of Edge Shorted Regular Shaped MSA Configuration

In previous section, compactness is achieved by placing a shorting post at the center of the patch. Now if more compactness is desired then it can be obtained by introducing a single shorting post at the edge of the patch [6], [8]. Fig. 5 depicts MSA configuration for the edge shorting post which is investigated keeping the dimension of MSA's, shorting post and substrate parameters same as the previous case. And by placing the shorting post at one of the edges of the patch, the field distribution of these patches gets altered. The impedance variation, in this case, has been found to be much larger as compared to the Conventional MSA's (without shorting post). Comparison of edge shorted MSA with regular shaped MSA configuration is tabulated in Table. 3.

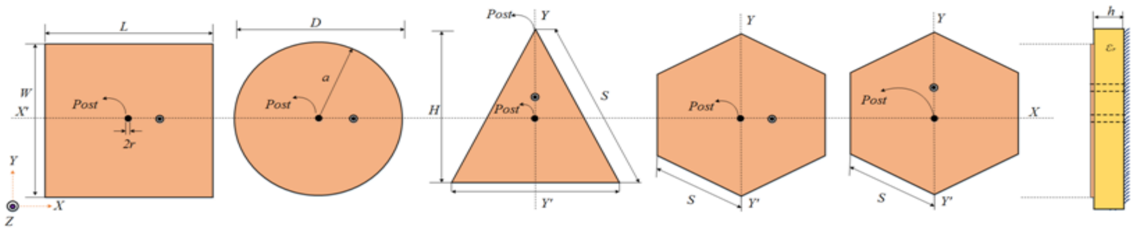


Fig. 4: Single Center shorted regular shaped MSA configuration

Table 2: Comparison of result of Center shorted regular shaped MSA configuration

Sr. No	Type of MSA	Resonance Frequency (GHz)	Resonance Frequency of conventional MSA (GHz)	Frequency Reduction
1	RMSA	0.819	1.8	2.1
2	CMSA	0.811	1.8	2.2
3	TMSA	0.925	1.805	1.95
4	HMSA X-Axis	0.819	1.807	2.2
5	HMSA Y-Axis	0.819	1.816	2.2

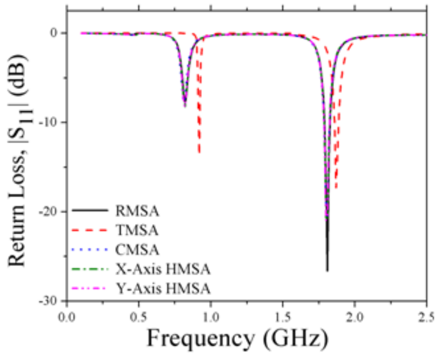


Fig. 3: Comparison of return loss for Center shorted regular shaped MSA

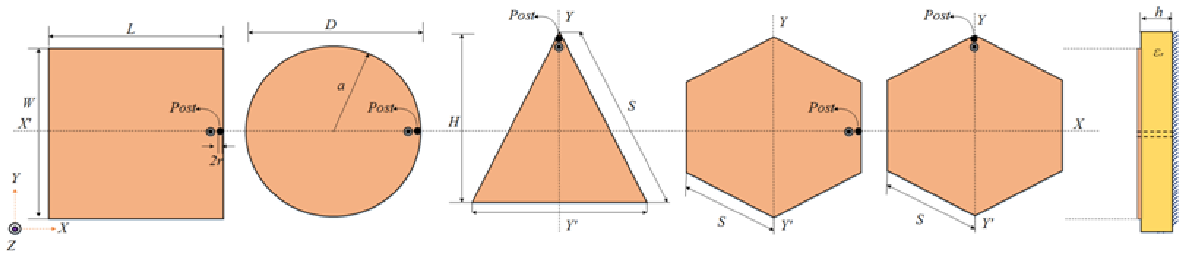


Fig. 5: Single Edge shorted regular shaped MSA configuration

Fig. 6 depicts an S_{11} plot of all edge shorted MSA which shows only the lower order mode. The lowest frequency of lower order mode is obtained for TMSA at 0.478 GHz which means that maximum size reduction is obtained for TMSA by placing the shorting post at one of the vertexes of the triangle. Although TMSA has a more compact frequency (i.e. maximum frequency reduction) compare to another antenna, but HMSA has the advantage of straight edges which helps for parasitic coupling in array application [12-14], [9] and also, the gain is more in the case of HMSA. So, HMSA is one of the good choice over another antenna when gain and compact size is a key element for antenna design consideration. HMSA also offers two different combinations depending on feed position i.e. HMSA X-axis feed and HMSA Y-axis feed. Maximum size reduction can be obtained for a square MSA by placing the shorting post at one of the corners of the patch.

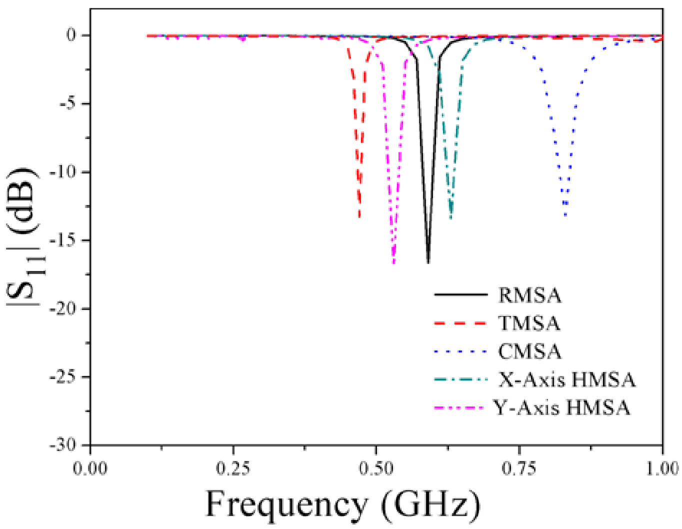


Fig. 6: Comparison of return loss for Edge shorted regular shaped MSA

Table 3: Comparison of result of Edge shorted configuration

Sr. No	Type of MSA	Resonance Frequency, F_L (GHz)	% BW	Resonance Frequency of conventional MSA, F_F(GHz)	% BW	Frequency Reduction
1	RMSA (Shorting at center of width)	0.582	1.3	1.8	2.1	3.0
2	CMSA	0.567	1.9	1.8	2.1	3.1
3	TMSA	0.4787	1.3	1.805	1.6	3.77
4	HMSA X-Axis	0.607	2.0	1.807	2.0	2.9
5	HMSA Y-Axis	0.513	1.9	1.816	2.0	3.5

V. Conclusion

In this paper, detailed investigation of conventional MSA's is carried out with fundamental mode frequency 1.8 GHz. The same conventional MSA's is investigated by placing a shorting post at the center as well as the edge of the patch to obtained Ultra- compactness. On comparing all the conventional MSA's, it can be observed that TMSA has the smallest area for the same fundamental frequency of 1.8 GHz. On introducing shorting post at the edge more compactness is achieved for TMSA. But TMSA has high cross polarization as compared to other shorted MSA configuration. Thus, depending on the application i.e. available space, reduction in antenna size etc. the shorted MSA configuration mentioned in this paper can be used accordingly.

Acknowledgements

The authors would like to thank Dr. K. P. Ray from DIAT, Pune, S. M. Rathod from VJTI, Mumbai for their kind help and valuable input during the simulation. Also, we would like to thanks, Shri. S. S. Kakatkar and Shri. Jagdish Prajapatee from SAMEER, Mumbai.

References

[1] K. L. Wong, Compact and Broadband Microstrip Antennas, New York, John Wiley & Sons, Inc., 2002.
[2] R. Waterhouse, "Small microstrip patch antenna," Electronics Letters, vol. 31, no. 8, pp. 604-605, 1995.
[3] G. Kumar and K. P. Ray, Broadband Microstrip Antennas, Norwood, MA, Artech House, USA, 2003.
[4] K. L. Wong and W. S. Chen, "Compact microstrip antenna with dual-frequency operation," Electronics Letters, vol. 33, no. 8, pp. 646-647, 1997.
[5] C. L. Tang, H. T. Chen and K. L. Wong, "Small circular microstrip antenna with dual-frequency operation," Electronics Letters, vol. 33, no. 13, pp. 1112-1113, 1997.
[6] K. P. Ray, "Broadband, dual frequency and compact microstrip antennas", Ph.D. Thesis, Department of electrical engineering, Indian Institute of Technology, Bombay, India, 1999.
[7] S. M. Rathod, M. Dhakane, P. Deosarkar, "Design of compact rectangular MSA with partial grounding for enhancing bandwidth," Proceeding of International Conference on Electronics and Communication Engineering (ICECE), pp.4-7, 2012.
[8] S. M. Rathod, " Design and develepment of compact microstrip antenna," RSAS-2014, vol. 1, pp. 62, IIT-Bombay, 2014.
[9] S. M. Rathod, "Compact and shorted hexagonal microstrip antenna," RESCON-2015, IIT-Bombay, 2015.
[10] S. M. Rathod, R. N. Awale and K. P. Ray, "Analysis of shorted rectangular microstrip antenna with 50Ω microstrip line feed," International Antenna and Propagation Symposium (APSYM), pp. 1-4, CUSAT-Cochin, 2016.
[11] S. M. Rathod, A. Achugatla, R. N. Awale, K. P. Ray and S. S. Kakatkar, "Analysis of Directivity Enhance Circular Microstrip Antenna with Shorting Post," Proceeding of 3rd International Union of Radio Science- Regional Conference on Radio Science (URSI-RCRS), pp.24, NARL-Tirupati, 2017.
[12] K. P. Ray, M. D. Pandey, S. Krishnan, "Determination of resonance frequency of hexagonal and half-hexagonal microstrip antenna," Microwave Opt Technol Lett, vol. 49, pp. 2876-2879, 2007.
[13] K. P. Ray and M. D. Pandey, "Resonance frequency of hexagonal and half hexagonal microstrip antennas," Microwave Opt Technol Lett, vol.51, pp. 448-452, 2009.
[14] K. P. Ray , M. D. Pandey,R. Rashmi and S.P. Duttagupta, "Compact configurations of hexagonal microstrip antennas," Microwave and Optical Technology Letters, vol. 55, Issue 3, pp. 604–608, March 2013.
[15] HyperLynx 3D EM Design System, Mentor Graphics Corp, Ver. 15.2, Wilsonville, USA, 201

IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) is UGC approved Journal with Sl. No. 5016, Journal no. 49082.

*Amar D. Chaudhari " Comparison of Various Regular Shaped Co-axial fed Conventional and Single-Shorted Microstrip Antenna for Ultra-compactness" IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) 12.4 (2017): 56-61.