http://www.jctjournals.com ISSN(ONLINE):2278 – 3814

Volume-6, Issue-8, August, 2017
JOURNAL OF COMPUTING TECHNOLOGIES (JCT)
International Journal
Page Number: 01-07

Comparative Analysis on Different U Shape Microstrip Patch with Defected Ground Structure

Arvind Sahu[1] *(Ph.D. Scholar)*, Dr. Kavita Burse[2] *(Professor)*
[1] Ph.D Scholar, [2]*Dean Research, TIT Group, Bhopal*
[1,2]*Department of Electronics and Communication Engineering*
[1]*Dr K N Modi University (DKNMU, Newai), Rajasthan*
[2]*Technocrats Institute of Technology (TIT), Bhopal, M.P.*
sahuarvind28@gmail.com[1]. Kavitaburse14@gmail.com[2]

ABSTRACT - In this paper demonstrated the investigation of various shape microstrip antenna. Microstrip antenna play a crucial part in WLAN correspondence, versatile communication 3G, 4G, and Wi-Fi, Wi-MAX gadgets in various range between 1 to 6 GHz. Distinctive shape microstrip fix radio wire is extremely fascinating and interesting issue for inquire about. There are diverse shape based reception apparatus exhibited in the most recent decade for WLAN and Wi-MAX gadgets like U shape, H shape, I shape, S shape and V shape. In this comparative analysis paper examined U-shape and other shape based patch antenna for wideband and narrowband application. In this overview paper likewise examined the study of various shape receiving wire and simulation tool.

Keywords**-- Microstrip Patch Antenna, Wi-MAX, WLAN, VSWR, Return Loss (RL), Wide band (WB), Narrow band**

I. INTRODUCTION

An antenna could be a particular emanating device that transforms radio waves (RW) fields into electrical energy and the other way around. There are two fundamental categories: the accepting radio waves antenna, that captures RF energy and conveys AC to different communication devices, and furthermore the transmittal receiving antenna, which is encouraged with from hardware and produces a RF field. Low profile antenna are basic for a few remote and media transmission frameworks and hand-held cell phones, where size, weight, cost, execution are constrained. They ordinarily contains a rectangular or square metal fix on a thin layer of protector or substrate on a ground plane. The transmission capacity determination of radio wires ought to be fulfilled for VSWR, radiation pattern and polarization properties. [11] The fundamental advantages of the microstrip antenna are low profile, simple fabrication, easily implement with PCB and microcircuit innovation. A superfluous features of microstrip antenna is that they will be essentially incorporated with RF devices. [12]

II. U SHAPE MICROSTRIP ANTENNA

In U-Slot patch antenna originally the U-slot patch antenna was developed as a wide band antenna, introduced by Huynh and Lee. They also are good choices for multiband applications and circular polarization operation. These antennas can provide impedance bandwidths of 20% to 30% for a patch with the thickness of about 0.08λ. Because of broad bandwidth slot patch antennas are very useful in commercial applications like 3G and 4G. U-slot antenna basic patch antenna with added slots is able to resonate in more operational bands. U-slot patch antennas with different dimensions can represent dual and triple band results. The ambition of presenting the U-shape on the quadrilateral patch is to crop four quality frequencies .Broadband operation is achieved when the second and third resonance frequencies are sufficiently close [14]. Wide band having a wideband antenna that is electrically large has always been a desired for different applications. Ideal broad-band performance is achieved when the loop of the impedance loci, such as in 1, 2 and 3, shrinks to the VSWR =1 point on the Smith Chart. For practical applications, the size and location of the loop of impedance loci is required to be such that VSWR ≤ 2, as in locus 4.VSWR ≤ 2 corresponds to a return loss of 10 db. The smith chart for four different impedance loci. Locus number 4 is the desired locus for the wideband design [14].

Today, the wireless system has become a part of human life. More electrical and electronic equipment around use the wireless system. An antenna is a vital a part of the wireless system. The Antenna is an device that transmits magnetic force waves into area by changing the given power at the input into the radio waves and at the receiver the antenna intercepts these radio waves and converts them into current. There are such a large amount of systems that use antennas like remote, cell phones, satellite communications, spacecraft, radars, conductor phones and wireless laptop networks. From day to day, new wireless devices introduce the growing demands of compact antennas. The rise in satellite communication and therefore the} use of antennas in craft and orbiter has also inflated the wants of an occasional profile antenna that may give reliable communication. A microstrip antenna is one that gives low profile and light-weight. It is a broad band narrowband antenna can be manufactured easily by printed circuit technology such that a metallic layer in a particular form is bonded to a permittivity value that made a radiating component and another constant metallic layer of on the opposite side of the substrate and other side as a ground.

III. LITERATURE SURVEY

In 1953 deacons first introduced the idea of MSA (micro-strip antenna) but the practical Antennas were developed by the Munson and Howell in 1970. Some of the advantages of micro-strip antenna is that its low volume, light weight and the easiness of method of fabrication using printed circuit Technology. There are different researchers working on research in the field of dipole antennas to increase antenna gain, bandwidth and directivity. The documents used as reference for the design of my work are the following:

Mahrukh Khan, et al, "Characteristic Mode Analysis of a Class of Empirical Design Techniques for Probe-Fed, U-Slot Microstrip Patch Antennas" **(2016)**

This paper is presented with three experimental design techniques based characteristic mode analysis to design a U slot micro-strip patch antenna. The antenna designed on single ground layer. It fed by probe fed in a symmetrical manner. The first method is defined as ResF that gives and utilizes four different resonance frequencies. The second method is based on the dimensional invariance (DI). In this above method optimization of the probe location is necessary to increase the return loss by 10db. Thus third method (DIResF) is defined as the combination of both the above two methods that contained the traits of both the above. It shows better bandwidth performance and less or no probe feed location optimization. Thus the third method is superior to the above two methods and can be used for Rapid prototype. Critical parameters like substrate electrical thickness, slot width, probe radius and feed location variation that can be analyzed by characteristic mode analysis. All these parameters shows the principal changes are on the characteristics of use slot micro strip patch antenna. [1]

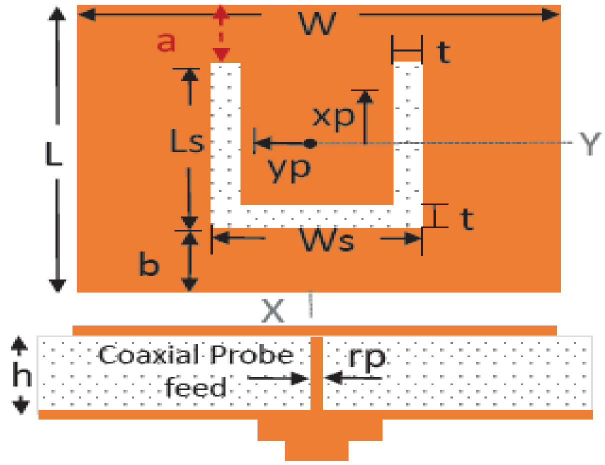

Fig. 1. U-slot loaded micro strip patch.

[2] Jeffrey Chalas et al, "Computation of the Q Limits for Arbitrary-Shaped Antennas using Characteristic Modes" **(2016)**

In this paper, they represented a fast and direct technique for computing the lower boundary on Q for randomly taken shape, absolutely conducting (PEC) antenna geometries. They start by deriving a new formula for Q supported the currents induced on the antenna and the methodology of moments (MoM) resistance matrix [Z]. They tend to then use this formula in conjunction with the idea of characteristic modes to search out lower bounds on arbitrary-shaped ESAs. Current distributions that yield the minimum possible Q also are given, providing for a strong insight into the physical factors that have an effect on Q, and provide tips for upgrading ESA designs constricted to any physical volumes. Many supporting examples are investigated, and appropriate comparisons to the literature are given to demonstrate the flexibleness and effectiveness of our approach. [2]

[3] A. A. Deshmukh, et al, "Analysis of Broadband Variations of U-Slot cut Rectangular Micro strip Antennas" **(2015)**

In this paper they use a powerful and a popular technique used to realize a very compact micro-strip antenna used in broadband communication. In this method a slot is cut inside the patch at a very well defined location. Today U lot including its designs variations and half u slot are used to increase the bandwidth range. In this paper they give a detailed explanation about the broadband response due to the U slot. In their work they studied the broadband behavior on U slot, half U slot and double slot on the rectangular micro-strip antenna(RMSA). With different aspect ratios of the patch and the variable dimensions of slot they studied the U slot configuration. During study, they observe that U slot and half U slot cuts on the patch doesn't introduce any new mode but on the other side it modified the resonant frequency of the original and the higher order mode to produce broadband response. Surface current distribution also improved by the slot and thus it also improve the broadside radiation pattern characteristics all over the required bandwidth without changing the direction of the principal planes. In the second method i.e. double slot cut on RMSA, when they introduced a second slot in the same patch the impedance and the frequency modified at higher mode also i.e. TM21 mode and it also improved available modes TM01 and TM20 moves resulting in the increased bandwidth.[03]

[4] S. Costanzo et al, "Compact MUSA: Modified U-Slot Patch Antenna with Reduced Cross-Polarization" [**2015**]

In this paper they also worked on reducing the dimensions of the U slot patch antenna and make it compact. They have introduce an extra feature in their antenna i.e. it also showed the reduced cross polarization effect as compared to other available U lot geometry by considering an enough bandwidth percentage between 15 to 20. A synthesis procedure is presented for proposed antenna configuration and it is evaluated both numerically and experimentally over the large range of frequency from 1 gigahertz to 10 gigahertz using different substrates.[04]

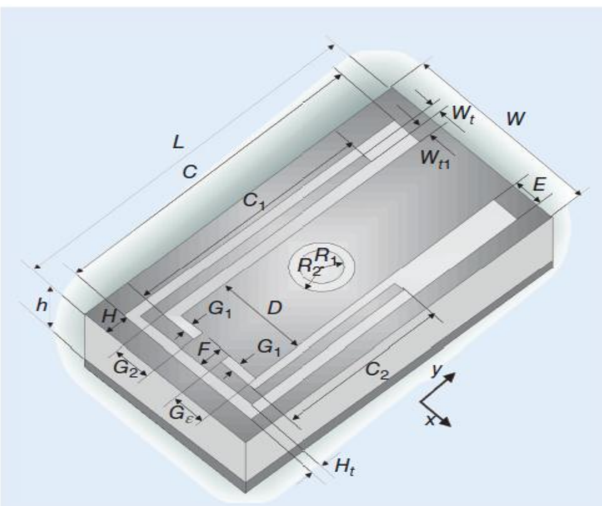

Fig. 2. MUSA Layout

[6] Q. I. Dai et al, "Combined Field Integral Equation Based on the Theory of Characteristic Mode" **(2015)**

When the characteristic modes of closed perfectly conducting objects are computed repeatedly on the conventional electric field integral equations based theory it is affected by false or unauthenticated internal resonance problem. Thus in this paper, they introduced a combined field integral equation based theory to remove spurious effect of internal resonance in CM analysis. Electrical and magnetic field integral operators share common set of significant characteristic pairs. This leaded to a General Eigen value problem that was now untouched by internal resonance spuriousness. Their proposed method was supported by numerical results.**[07]**

[7] M. Vogel at al, "Characteristic Mode Analysis: Putting Physics back into Simulation" **(2015)**

Characteristic mode analysis CMA enables the antenna designer to follow a systematic approach to design an antenna and carefully placing it. This method provide an approach to understand the fundamental resonance characteristics of antenna based on its geometry and the structure on which they are mounted. This help the designer to deeply understand and in choosing the locations of excitation of antenna. Also the understanding of the coupling between the excitation and the modes helps the designer to design the required antenna patterns by giving a linear combination of modal patterns as the excitation. It is only a deterministic approach that is based on the knowledge of Physics. It difference with an approach within which an optimization routine is employed to explore an oversized many-dimensional design space with few limitations. This paper offers a revision on the understanding of characteristic modes and contained sensible examples that each one use CMA within the design method and within the analysis of results.[08]

[8] J. Adams et al, "Broadband Equivalent Circuit Models for Antenna Impedances and Fields using Characteristics Modes" **(2013)**

In this paper they use fundamental Eigen modes for modeling antenna impedance and radiation patterns. They analysed the frequency behavior of characteristic mode and utilized it to develop the fundamental building block to create the total response by superimposition. In their work they studied the dipole on different modes but the method can also be applied to many complicated and complex structures as the modes did not change many of their characteristics. They showed the Eigen mode based approach results was far better as compared to a typical or R L C series resonant model for the same complexity. Higher order mode can also be accurately modeled with an extra added circuitry but it was not always necessary. As this method was based on the physical behaviour of the fundamental models thus the method also accurately connect circuit models to radiation patterns and other feed behavior. To validate this, they illustrated that far field patterns, gain, and beam width of a dipole could be accurately extrapolated over a decade of bandwidth using data at two different frequency points.**[10]**

[09] E. Safin et al, "Reconstruction of the characteristic modes on an antenna based on the radiated far field" (2013)

In this paper, we tend to present a way to reconstruct the modal current distribution on an antenna from the radiated far field and knowledge regarding the modes concerned. The tactic ends up in sensible results if the radiation mechanism of the antenna is approximated by the current distribution on a simplified structure. The current distribution of the simplified structure is decomposed into its characteristic modes and therefore the related modal far field is calculated. Assuming that the far field of the particular antenna contains a similar modes, their weighting coefficients are calculated by comparing the far field of the particular antenna to the modal far field of the simplified structure. It is shown that the weighting coefficients of all important modes can be reconstructed with sensible accuracy even for complicated real structures like mobile phones. A way to reconstruct the characteristic modes on an antenna from the radiated so much field has been given. the strategy relies on the radiated far field of the particular antenna and knowledge of the characteristic modes on a simplified structure. it's been shown that the reconstruction results in sensible results if the most radiation mechanism is described sufficiently by the simplified structure because it is typically the case for tiny terminal antennas. **[13]**

[10] Y. Chen and C. Wang, “Characteristic Mode Based Improvement of Circularly Polarized U-Slot and E-Shaped Patch Antennas” **(2012)**

U slot and E shaped coplanar patch antenna are the two popular circularly polarized micro-strip patch antenna. Characteristic mode analysis helps to understand the Physics of these Antennas for achieving the better performance. To achieve better performance of these Antennas the optimal feed positions and their dimensions to get compact size should be obtained. This can be obtained by examining the characteristic modes, model significance and the characteristic angle. Their proposed design shows better axial ratio and cross polarization performance without introducing any extra cost and complexity in their design compared to conventional designs. Here it was interesting to note two specific points. First, on providing offset probe feed in coplanar u-slot patch antenna produces excellent axial ratio performance. Second, on removing the redundant section from the coplanar E shaped patch antenna produce low cross polarization and gave highly compact dimensions.**[15]**

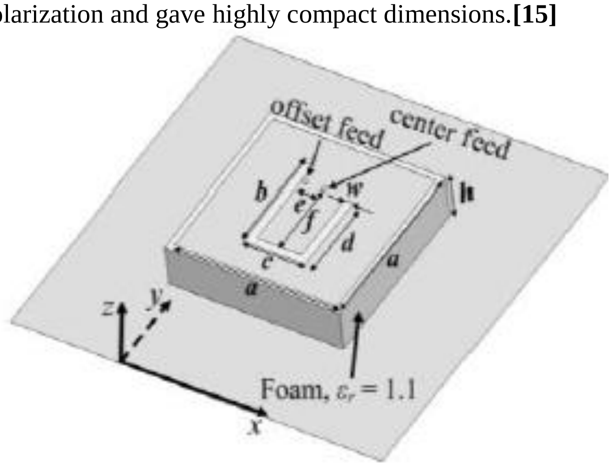

Fig.3 (a) circularly polarized U-slot antenna with offset feed.

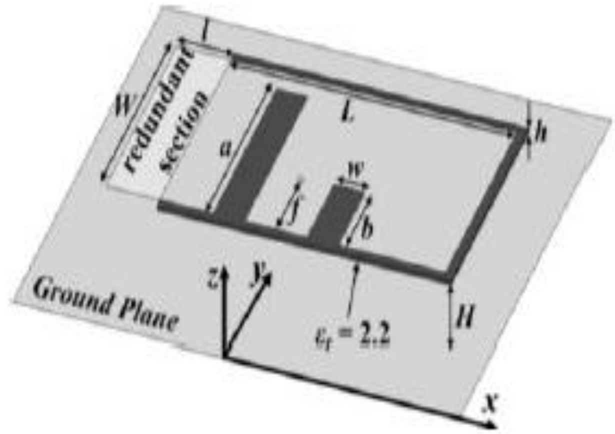

Fig.3 (b) circularly polarized E-shaped

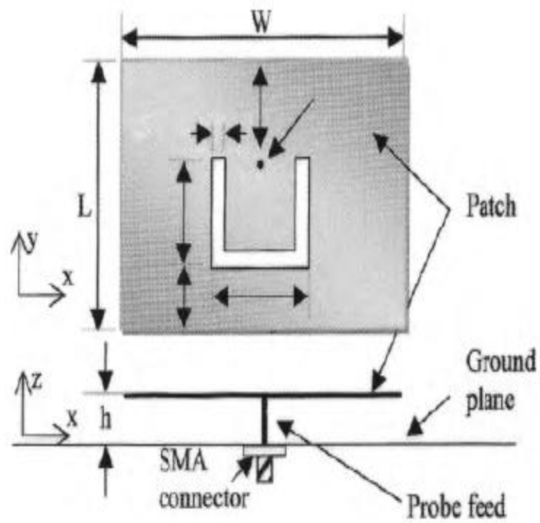

Fig.3 (c) U-slot patch antenna

[11] K. F. Lee, et al. “The Versatile U-Slot Patch Antenna,” **(2010)**

Initially the use slot patch antenna was developed on a single layer substrate and a single patch as a wideband antenna. In a recent work it has been showed that it can also be designed to perform a number of functions based on other practical applications. This paper totally focuses on the development of such type of antenna. This paper showed both the experimental and simulation result for various U-slot topologies demonstrating the antennas usefulness in various practical applications. This application may include wideband, dual band and triple band operations with small and large frequency ratios for the circularly polarized application also.**[20]**

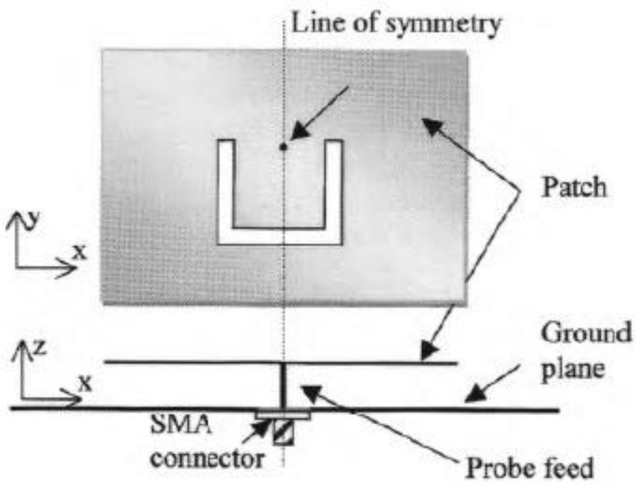

Fig.2.4 (a) U-slot patch antenna with a full U-slot.

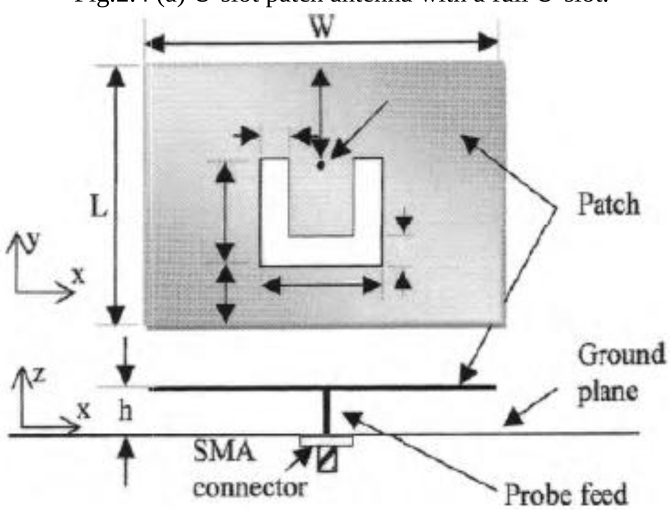

Fig. 2.4 (b) Dual-band U-slot patch antenna.

[12] G. F. Khodaei, J. Nourinia and C. Khobadi, "A Practical Miniaturized U-Slot Patch Antenna with Enhanced Bandwidth" **(2008)**

In this paper they represented an asymmetric U-slot patch antenna with low probe diameter. It had been also showed that reduction in the diameter of the probe causes in the reduction in the bandwidth. One of the interesting feature of this antenna to note here was that inspite of reducing the antenna size and smaller diameter of probe it maintains its bandwidth in 30% as compared to the work in past. In this paper they fabricated their antenna with PCB technique and tested the results. They have also represented the far field results based on simulation and 13 measurements. Even though the antenna has given high cross polarization level in case of using circular polarization, they still recommended for using their antenna because of its small size, high impedance bandwidth, high total gain in spite of low size and the easiness of fabrication.[23]

[13] H. Wang, X. B. Huang and D. Fang, "A Single Layer Wideband U-Slot Micro strip Patch Antenna Array **[2008]**

An array of U slot rectangular antenna was presented with 2 by 2 micro-strip feed line with design and the measured results. As the U slot patches and the feeding system were on the same plane it resulted in a very simple structure. The advantage of the microstrip feed line with u slot patch was that it could easily form array. It showed an impedance bandwidth of 80% ranging from 5.65 GHz to 6.78 GHz with a VSWR less than 2. Radiation pattern, cross polarization and the gain was also acceptable in this bandwidth. The highest measured gain shown in the result is 11.5 dBi. In array representation the similarity between the simulated result and the measured result is also good enough. The 2cross2 array can be extended to multiple array.**[25]**

[14] J. A. Ansari and B. R. Ram, "Analysis of Broad-Band U-Slot Micro strips Patch Antenna**" [2008]**

A micro strip U-slot patch antenna was presented on the basis of circuit theory concept that showed broadband characteristics. The antenna displayed two resonance frequencies that were very closely spaced but giving a Broadband characteristics. A frequency band of 186 MHz was achieved in this antenna with 36.4% impedance bandwidth. The theoretical results was also supported the simulated results. It is thus calculated that proposed antenna could be used for various communication systems that require the frequency band of around 186 megahertz.**[26]**

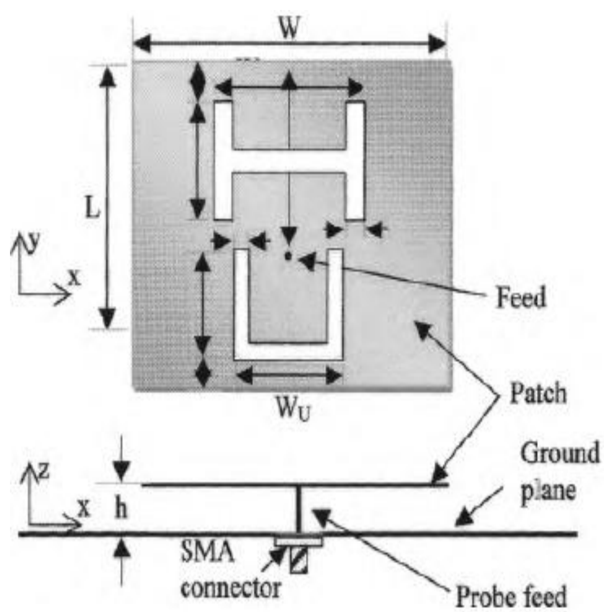

Figure 2.5 Tri-band U-slot patch antenna.

Table 1 Shows the Result Comparison of Different U Shape Antenna of Previous Researcch

Year	Title	Antenna Shape	Feed Technique	Range	S-11	Band Width	Number of Bands
2016	Characteristic Mode Analysis of a Class of Empirical Design Techniques for Probe-Fed, U-Slot Microstrip Patch Antennas	U-Slot Microstrip Patch Antennas	Probe Fed	1.7-2.55 GHz	2 GHz = -20dB 4 GHz = -15dB	0.85GHz	1 band
2015	Modified U-slot patch antennas with reduced cross-polarization.	U-slot patch antennas	Coaxially fed	1.7-1.95 GHz	1.8 GHz = -40dB	.25GHz	1 band
2015	Analysis of Broad band Variations of U-Slot Cut Rectangular Microstrip Antennas	U-Slot Cut Rectangular Microstrip Antennas	Coaxial connector	1241=1941 MHz	2 GHz = -20dB	700MHz	1 band
2012	Characteristic Mode Based Improvement of Circularly Polarized U-Slot and E-Shaped Patch Antennas	U-Slot and E-Shaped Patch Antennas	----------	2.35-2.55 GHz	2.45 GHz = -16dB	0.20GHz	1 band
2010	Versatile U-Slot Patch Antenna	U-Slot Patch Antenna	-----------	2.24-2.46 GHz	2.43 GHz = -17dB	0.22GHz	Multi band

TOOLS USED

Since the performance of electronic devices depends on electromagnetic behavior (EM), you need a quick and accurate account of how your design will behave in real world implementations - long before any prototype is built. The results of the CST ™ simulation give you the confidence you need: the technology offers the most accurate response possible with the least involvement of the user. As a reference simulation tool for 3-D electromagnetic wave simulation, HFSS is essential for the design of high-frequency and / or high-speed components used in modern electronic devices. Understanding the EM environment is essential to accurately predict how a component - or subsystem, system or end product - works in the field, or how it influences the performance of other components in the vicinity. CST addresses the full spectrum of EM problems, including losses due to reflection, attenuation, radiation and coupling. [18] [19].

IV CONCLUSIONS

This survey paper the basics of microstrip patch antenna also discussed the different shape based patch antenna which is used in 1 to 10 GHz for different wireless communication Devices, IEEE802.15 devices also discussed the comparison of different U-shape and different shape antenna with the help of table. In this table compared different microstrip patch antenna parameters ,they are antenna shape, antenna fed ,frequency range ,return loss ,gain voltage standing wave ration(VSWR),number of bands. On the above comparison we have conclude that coaxial probe fed shows netter result as compared to other fed for different S-shape antenna that is shown table in Design of S-shape multiband microstrip patch antenna[3].Apart from S-shape, L-shape and rectangular patch also shows better result. In future try to implement wide band antenna which is used for 4G and 5G communication. Also focus to design an antenna for TDLTE communication. [30]

REFERENCES

[1] Mahrukh Khan and Deb Chatterjee, "Characteristic Mode Analysis of a Class of Empirical Design Techniques for Probe-Fed, U-Slot Microstrip Patch Antennas", IEEE Transactions on Antennas and Propagation, pp 1-12, 2016.

[2] Jeffrey Chalas, Kubilay Sertel, and John L. Volakis, "Computation of the Q Limits for Arbitrary-Shaped

Antennas using Characteristic Modes" IEEE Transactions on Antennas and Propagation, 2016.

[3] A. A. Deshmukh and K. P. Ray, "Analysis of Broadband Variations of U-Slot cut Rectangular Micro strip Antennas", IEEE Antennas Propagation, Mag., vol. 57, no. 2, pp. 181–193, April 2015.

[4] S. Costanzo and A. Costanzo, "Compact MUSA: Modified U-Slot Patch Antenna with Reduced Cross-Polarization", IEEE Antennas Propagation, Mag., vol. 57, no. 3, pp. 71–80, June 2015.

[5] N. L. Bohannon and J. T. Bernhard, "Design Guidelines using Characteristic Mode Theory for Improving the Bandwidth of PIFAs," IEEE Transaction Antennas. Propagation. vol. 63, no. 2, pp. 459–465, February 2015.

[6] Y. Chen and C.-F. Wang, Characteristic Modes: Theory and Applications in Antenna Engineering. NJ, USA: John-Wiley & Sons, Inc., 2015.

[7] Q. I. Dai, Q. S. Liu, H. U. I. Gan and W. C. Chew, "Combined Field Integral Equation Based on the Theory of Characteristic Mode", IEEE Transaction Antennas. Propagation vol. 63, no. 9, pp. 3973–3980, 2015.

[8] M. Vogel, G. Gampala, D. Ludick, U. Jacobs and C. J. Reddy, "Characteristic Mode Analysis: Putting Physics back into Simulation," IEEE Antennas Propagation. Mag., vol. 57, no. 2, pp. 307–317, April 2015.

[9] A. Z. Elsherbeni, P. Nayeri and C. J. Reddy, Antenna Analysis and Design FEKO Electromagnetic Simulation Software. NJ, USA: SciTech Publications, 2014.

[10] J. Adams and J. Bernhard, "Broadband Equivalent Circuit Models for Antenna Impedances and Fields using Characteristics Modes," IEEE Transaction Antennas Propagation ., vol. 61, no. 8, pp. 3985–3994, 2013.

[11] M. Capek, P. Hamouz, P. Hazdra and J. Eichler, "Implementation of the Theory of Characteristic Modes in MATLAB,"IEEE Antennas Propagation. Mag., vol. 55, no. 2, pp. 176–189, April 2013.

[12] M. Gustafsson and S. Nordebo, "Optimal Antenna Currents for Q, Superdirectivity and Radiation Patterns Using Convex Optimization", IEEE Transaction Antennas. Propagation, vol. 61, no. 3, pp.1109-1118, 2013.

[13] E. Safin and D. Manteuffel, "Reconstruction of the characteristic modes on an antenna based on the radiated far field," IEEE Transaction Antennas Propagation., vol. 61, no. 6, pp. 2964–2971, June 2013.

[14] S. Bhardwaj and Y. Rahmat-Samii, "A Comparative Study of C-Shaped, E-Shaped and U-Slotted Patch Antennas," Micro Opt Techno Lett. , vol. 54, no. 7, pp.1746–1757, July 2012.

[15] Y. Chen and C. Wang, "Characteristic Mode Based Improvement of Circularly Polarized U-Slot and E-Shaped Patch Antennas", IEEE Antennas and Propagation action Letters, vol. 11, pp. 283–290, 2012.

[16] M. Gustafsson, M. Csimasu and B. L. G. Jonsson,"Physical Bounds and Optimal Currents on Antennas", IEEE Transaction Antennas Propagation., vol. 60, no. 6, pp. 2672–2681, June 2012.

[17] K. F. Lee and K. M. Luk, Micro strips Patch Antennas. London, UK: Imperial College Press, 2011.

[18] J. Chalas, K. Sertel, and J. L. Volakis, "Computation of Q limits for Arbitrary-Shaped Antennas using Characteristics Modes," Proc. IEEE Intl. Symp. Antennas Propagation. pp. 772–774, 2011.

[19] B. D. Raines, "Systematic Design of Multiple Antenna Systems Using Characteristic Modes," PhD dissertation, Electrical and Computer Engineering, Ohio State University, Columbus, Ohio, USA, 2011.

[20] K. F. Lee, S.Yang, A. Kishk, and K. M. Luk, "The Versatile U-Slot Patch Antenna," IEEE Antennas Proper. Mag., vol. 52, no. 1, pp. 71–88, Feb. 2010.

[21] M. Koohestani and M. Golpur, "U-Shaped Micro strip Patch Antenna with Novel Parasitic Tuning Stubs," IET Micro. Antennas Propagation, vol. 4, no. 7, pp. 938–946, 2010.

[22] E. A. Daviu and M. C. Fabres,"Modal Analysis and Design of Bandnotched UWB Planar Monopole Antennas", IEEE Transaction Antennas. Propagation. vol. 58, no. 5, pp. 1457–1467, May 2010.

[23] G. F. Khodaei, J. Nourinia and C. Khobadi, "A Practical Miniaturized U-Slot Patch Antenna with Enhanced Bandwidth, "PIERS, B, vol. 3, pp. 47–62, 2008.

[24] J. C´orcoles, M. A. Gonzalez, J. Rubio and J. Zapata, "Performance Characterization of Wideband, Wide-Angle Scan Arrays of Cavity backed U-Slot Micro strip Patch Antennas", Intl. Jour. RF and Microw. Comp.-Aided Engineering, pp. 389–396, December 2008.

[25] H. Wang, X. B. Huang and D. Fang, "A Single Layer Wideband U-Slot Micro strip Patch Antenna Array", IEEE AWPL, vol. 7, pp. 9–12, 2008.

[26] J. A. Ansari and B. R. Ram, "Analysis of Broad-Band U-Slot Micro strips Patch Antenna, "Microwave and Optical Technology Letters, vol. 50, no. 4, pp. 1069–1073, 2008.

[27] S. Lee, S. Ooi, A. Sambell, E. ,Korolkiewicz and S. Scott, "Application of Segmentation Analysis to a Matched U-Slot Patch Antenna," Micro Opt Techno Lett., vol. 50, no. 10, pp. 2608–2611, Oct. 2008.

[28] M. Fabres, E. Daviu, A. Nogueria, and M. Bataller, "The Theory of Characteristic Modes Revisited: A Contribution to the Design of Antennas for Modern Applications," IEEE Antennas and Propagation, vol. 49, no. 5, pp. 52–68, October 2007.

[29] A. Yaghjian and S. Best, "Impedance, Bandwidth and Q of Antennas," IEEE Transaction Antennas Propagation. vol. 53, no. 4, pp. 1298–1324, April 2005.

[30] Yadav P., Sharma S., Tiwari P., Dey N., Ashour A.S., Nguyen G.N. "A Modified Hybrid Structure for Next Generation Super High Speed Communication using TDLTE and Wi-Max"Big Data, Springer. 2017. https://link.springer.com/chapter/10.1007/978-3-319-60435-0_21#citeas

