Copper Cladding CPW Fed Single Layer Antenna for UWB Applications

S. Suganthi and P. Thiruvalar Selvan

Abstract--- *A CPW-fed has been designed fro multiband application which includes ultra wide and Ku band. The antenna was etched on a single-layer copper-cladding substrate, of which the material was FR4 with relative permittivity of 4.4, and the magnitude was 40.0 mm × 50.0 mm × 1.6 mm. The parameters of the antenna are simulated and optimized with HFSS. This paper proposes a new CPW-fed UWB antenna operates at the bandwidth covers 2.4 – 6.2 GHz range for UWB band and 10.2 to 15.1 for Ku band applications with return loss ≤ −10 dB. The relative bandwidth of 110% has been achieved in addition of good radiation patterns and gain. Simulated and measured results for return loss, radiation pattern and gain were presented. A good agreement has been obtained between the simulation and experiment and the proposed antenna meets the requirements of the ultra-wideband antenna.*

Keywords--- *Ultra-Wideband (UWB) Antenna, Coplanar Waveguide (CPW), HFSS Simulation, Return Loss.*

I. INTRODUCTION

Traditional Ultra-wideband (UWB) antennas have been unable to combine with the modern integrated system for their complex structures and large volumes, miniaturized ultra-wideband printed antennas being good candidates for their low profile. Recently CPW-fed printed antennas have received considerable attention owing to their attractive merits, such as ultra-wide frequency band, good radiation properties and easy integration with system circuits. However, most previously reported CPW-fed antenna designs are complex [1-3], with poor radiation patterns, unsuitable for practical applications. In this paper, a new tapered CPW-fed isosceles trapezoid disk printed mono- pole UWB antenna is proposed. A prototype antenna was fabricated and measured. It demonstrates that the com- pact design can achieve an ultra wide bandwidth, the operation bandwidth being 2.7 - 9.3 GHz, covering WLAN operating band, with satisfactory radiation pat- terns and 9.6 dB peak gain.

When the antenna is fed by microstrip line, misalignment can result because etching is required on both sides of the dielectric substrate. Using CPW feeding technique alignment error can be eliminated. In CPW the conductor formed a center strip separated by a narrow gap from two ground planes on either side. Slot antenna results into wideband characteristic with CPW fed line having square slot [4] and CPW-fed hexagonal patch antennas [5] are demonstrated in the literature. In CPW-fed slot antenna by varying the dimensions of the slot and keeping it to the optimum value for wide bandwidth and proper impedance matching. In slot antenna geometries different tuning techniques has been carried out like circular slot [6], bow-tie slot [7], and wide rectangular slot [8].

S. Suganthi, Professor, Department of Electronics and Communication Engineering, K. Ramakrishnan College of Technology, Tiruchirappalli, Tamilnadu, India. Email: suganthis.ece@krct.ac.in
P. Thiruvalar Selvan, Professor, Department of Electronics and Communication Engineering, SRM-TRP Engineering College. E-mail: thiruvalar@gmail.com

DOI: 10.37200/IJPR/V24I5/PR201752
Received: 09 Feb 2020 | Revised: 03 Mar 2020 | Accepted: 18 Mar 2020

Research involving electromagnetic absorbers (EMAs) has been widely conducted for various applications such as anechoic chambers, electromagnetic interference/ electromagnetic compatibility (EMI/ EMC) control systems, and concealment applications [9]–[10]. EMAs are primarily classified into three types. The most widely used absorber type is the wedge tapered absorber [11]. It usually has a pyramidal-shaped array to absorb and scatter electromagnetic waves in the broadband and is commonly used in anechoic chambers. However, this absorber is bulky and fragile and therefore, is not suitable for portable applications. Another type of EMAs is the lossy absorber, which uses high-permeability or permittivity-composite materials [12]. It also has high absorptivity in the broadband. However, it is quite expensive because of the scarcity of the materials. Generally, in FSS absorber design, a periodic resonator patch is located on the top side of a lossy substrate and the ground is placed on the back side of the substrate [13].

UWB technology or concept was used in the first spark based radio invented by Marconi in 1895. The modern UWB for wireless communications started with the study of time domain electromagnetic in 1960s and was developed for wireless communications in 1970s and 1980s. A lot of pioneering work has established the basis of the impulse radio systems for military communication applications. Meanwhile, academia and industry are exciting to the release of extremely wide spectrum for commercial UWB application but facing many technical challenges for practical applications. Among the UWB wireless connection systems, the high data rate wireless USB may be the most promising applications. Therefore, the antenna designers especially from industry have long paid attention on small and embeddable UWB antennas. Both academic and industry have proposed many types of small UWB antennas especially on PCB or ceramic. The antennas with low profile are easy to be integrated into other RF circuits on the PCB or embedded into small and portable devices. Proposed antenna design model is studied at multiband [14-16],[19] and is applicable for UWB technology.

In this paper, a UWB antenna which can operate in the allowable return loss than _10 dB in the frequency range from 3.1 GHz to 10.6 GHz has been designed using finite element method solver for electromagnetic structures called high frequency structural simulator. HFSS offers state-of the-art solver technologies based on finite element, integral equation, asymptotic and advanced hybrid methods to solve a wide range of microwave, RF and high-speed digital applications.

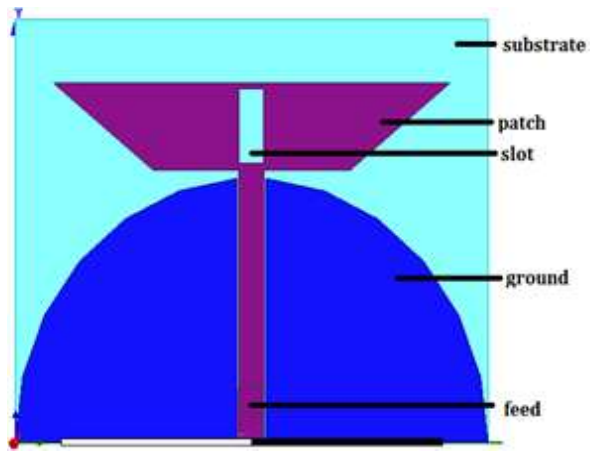
II. ANTENNA CONFIGURATION AND ANALYSIS

In order to achieve the broadband performance of the micro-strip antenna, some scholars have proposed a variety of antenna structures [21-23], such as U-slot patch antenna, bow-shaped antenna, monopole antenna, etc. [1]. The design of antenna used the symmetrical structure of coplanar waveguide bandwidth up from 3.5 to 11.0 GHz (VSWR < 2), but these antennas are large in size. The radiating patch generally used unit of area of regular shape, such as rectangular, circular or circular ring sheet micro-strip patch. With the same working frequency, the rectangular patch is available to slight higher efficiency, gain and wider bandwidth than the circular patch. The method of increasing the antenna bandwidth [2-3,24]: Multipatch, gap loading, lumped element loading (including short-circuit pin) and the feed point. These methods have advantages and disadvantages, such as multi-patches and

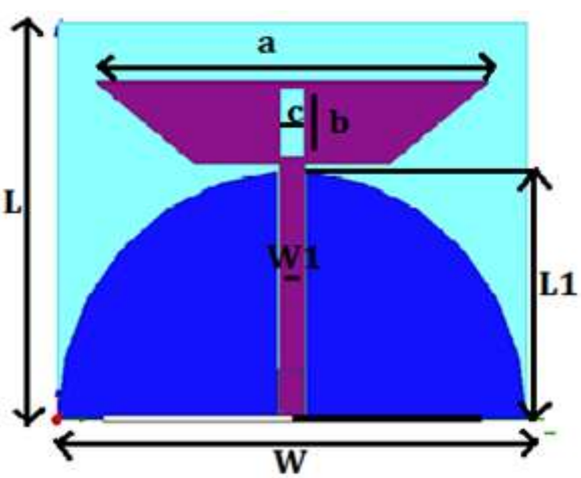
DOI: 10.37200/IJPR/V24I5/PR201752
Received: 09 Feb 2020 | Revised: 03 Mar 2020 | Accepted: 18 Mar 2020

lumped element loading will make the structure of the antenna complicated [25,26,27 & 28] , doubly fed point resonant frequency tuning range is subject to certain restrictions, slotting may change the resonant frequency points.

In order to calculate the full three-dimensional electromagnetic field inside a structure and the corresponding S-parameters, HFSS employs the finite element method (FEM) [29,30] . The basic approach of this method is to divide a complex structure into smaller sections of finite dimensions known as elements [31,32]. These elements are connected to each other via joints called nodes. After the optimization, the geometric dimensions of the proposed antenna are as follows in Table I. The basic approach of this method is to divide a complex structure into smaller sections of finite dimensions known as elements. These elements are connected to each other via joints called nodes. Each unique element is then solved independently of the others thereby drastically reducing the solution complexity. The final solution is then computed by reconnecting all the elements and combining their solutions. These processes are named assembly and solution respectively in the FEM. In order to design the high performance broadband CP square patch antenna [33] , a detailed parametric study of the antenna is made.



(a)



(b)

Fig. 1: Proposed antenna (a) Structure (b) Dimensions

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 05, 2020
ISSN: 1475-7192

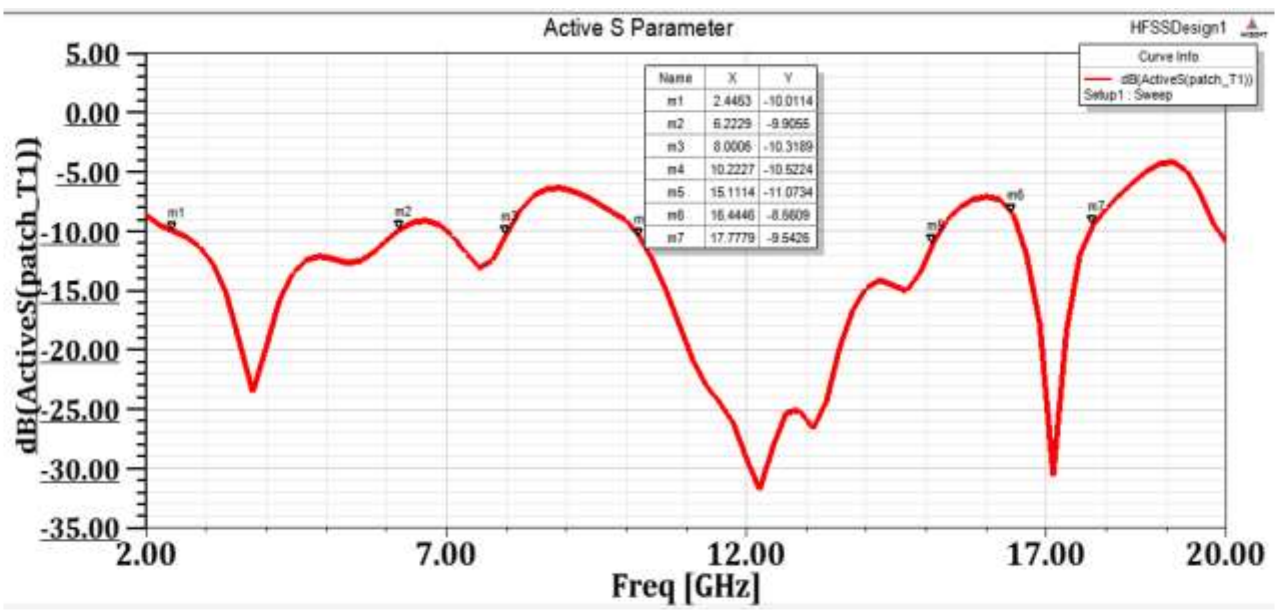
The optimized sizes are: W = 50 mm, W1 = 2.6 mm, L = 40 mm, L1 = 25 mm, S = 0.28 mm, a = 42 mm, b = 8.2 mm, g = 0.8 mm. According to the optimization done by using several trail simulation in software simulation the above given different dimension of the structure of antenna has been chosen. The impedance frequency characteristics of disc cone antenna are significantly superior to the ordinary dipole antenna. Based on the idea of applying planar printed structure to replace the traditional 3D disk cone antenna, the geometry structure of the proposed antenna is shown in Figure 1. Coplanar waveguide feed structure consists of the feed-forward signal band and the feed-forward signal with both sides of the slit. The magnitude of antenna was 40.0 mm × 50.0 mm × 1.6 mm, of which the material was FR4 with relative permittivity of 4.4. The parameters of the antenna were simulated and optimized with HFSS, The result shows that the band-width is from 2.4 to 17.7 GHz which means the compact design can achieve an ultra wide bandwidth.

III. ANALYSIS AND SIMULATION

To ensure the effectiveness and practicality of the designing, we must consider the dielectric substrate thickness and finite coplanar waveguide structure. The antenna feed structure is calculated in Equations (1)-(7). A Lumped Port excitation will be used for the CPW feed. The simulation process and platform are as the following [25-28]:

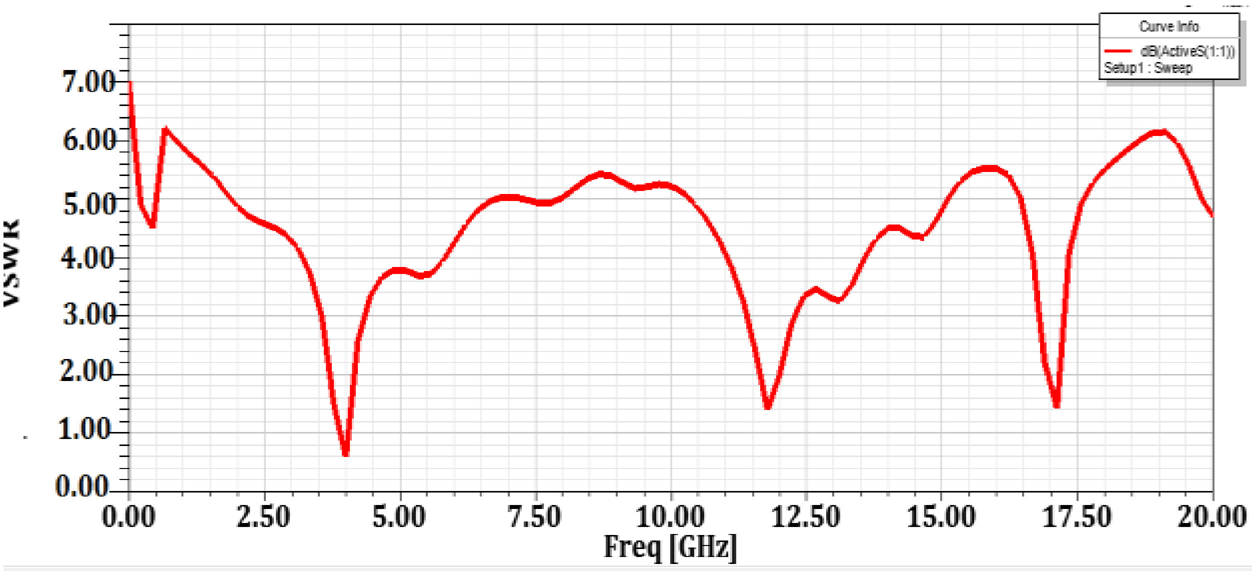
- Launching Ansoft HFSS13.0 and create the model Save Project;
- Model Validation;
- Analyze to start the solution process;
- Solution Data Create Reports;
- Validation & Simulation

The characteristics of the proposed CP antenna have been simulated by Ansoft High Frequency Structure Simulator (HFSS) software and measured by Agilent N5230A network analyzer.



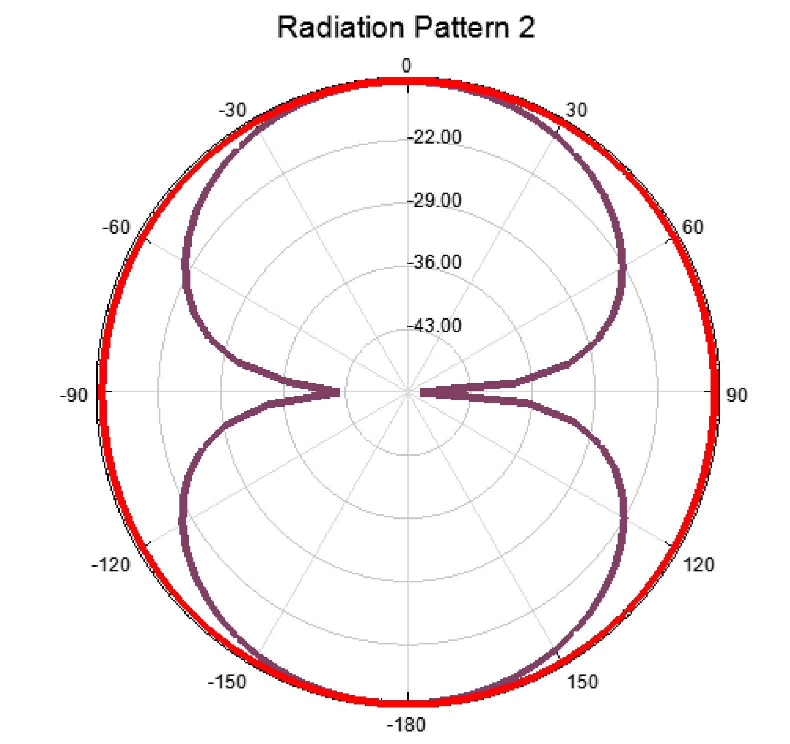
(a)

DOI: 10.37200/IJPR/V24I5/PR201752
Received: 09 Feb 2020 | Revised: 03 Mar 2020 | Accepted: 18 Mar 2020



(b)

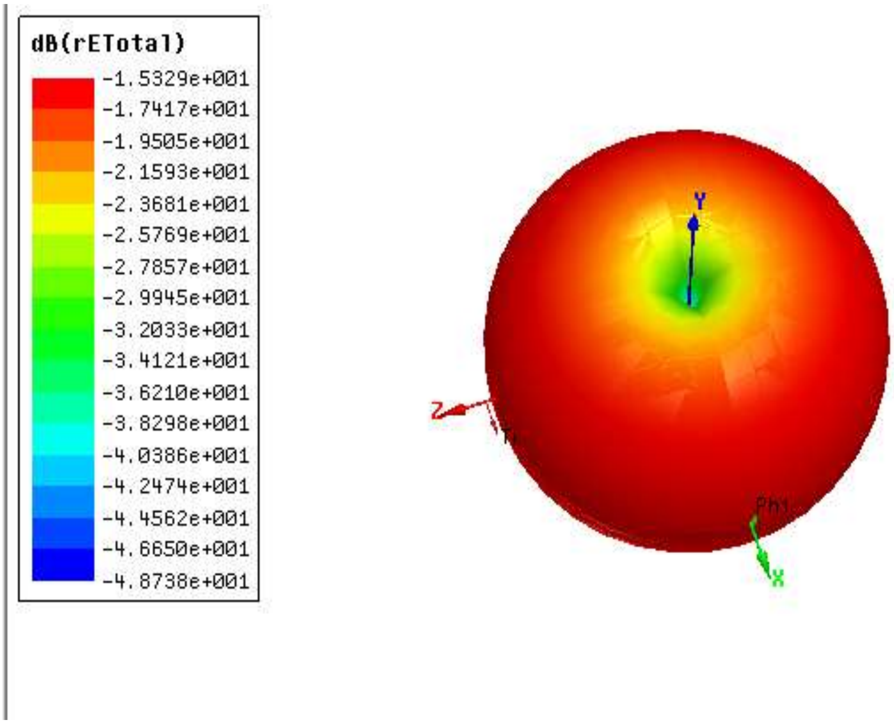
It was fabricated on a 40.0 mm × 50.0 mm × 1.6 mm FR4 epoxy substrate with dielectric constant ε_r=4.4 and loss tangent tanδ=0.02. Two symmetrical E-shaped slits embedded in the center of square patch are constructed, which can introduce more resonant branches. Moreover, the antenna can be easily fabricated on PCB. Simulated results are illustrating that the optimum 3-dB bandwidth can be completely covered by the VSWR < 2 impedance bandwidth.



(a)

DOI: 10.37200/IJPR/V24I5/PR201752
Received: 09 Feb 2020 | Revised: 03 Mar 2020 | Accepted: 18 Mar 2020

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 05, 2020
ISSN: 1475-7192



(b)

Fig.4.(a) 2D Radiation pattern graph of the antenna (b) 3D pattern

The patch with the feed gap “g” between the patch and coplanar waveguide decreasing, the bandwidth of the antenna decreases, it is mainly because of the de crease of the gap that makes the coupling capacitance which between the antenna radiating patch and the co- planar waveguide ground changed, therefore, caused the becoming narrowed. While the antenna achieved the ultra-wideband performance, it has a good pattern and gain indicators**.** Another important parameter to understand the antenna characteristics is its 2D radiation pattern which is shown in figure 4 for the proposed antenna. The E plane is the plane containing the electric field vector which is perpendicular to the direction of propagation and the H plane is the plane containing the magnetic field vector which is perpendicular to the direction of propagation. Radiation pattern shown presents the graphical representation of radiation properties of antenna as a function of space co- ordinates taken in xy plane. The proposed antenna has bi-directional radiation patterns in E-plane at 9.5 GHz resonant frequency.

H-plane pattern of the antenna in the low-frequency was Omni directional radiation in working band, radiation is strongest in the $\varphi = 0$ and $\varphi = \pi$, the main lobe of the E plane pattern at $\theta = 0$ and $\theta = \pi$; in a relatively high-frequency point of the main wave direction is slightly changed, the H-surface radiation is zero at $\varphi = -\pi/2$. It is also observed that the radiation patterns are nearly Omnidirectional over the entire operating bandwidth. The results have proved that the design stands out as a potential candidate for future UWB applications.

DOI: 10.37200/IJPR/V24I5/PR201752
Received: 09 Feb 2020 | Revised: 03 Mar 2020 | Accepted: 18 Mar 2020

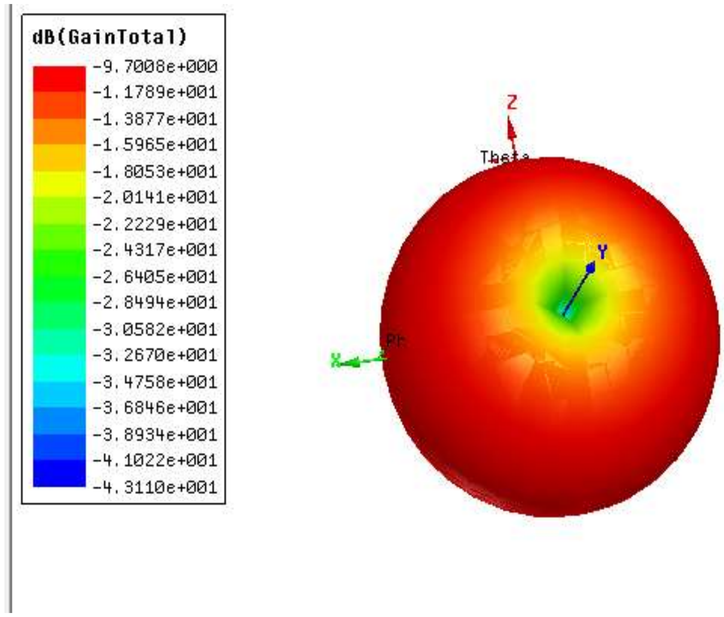


Fig. 5: 3D Gain graph of the antenna

Figure 5.shows the graph for 3D Gain of RHCP helical antenna at Ku-band which gives the peak gain of 11.39dB at operating frequency 18GHz.

Table 1: Antenna parameter comparison

parameters	***Proposed antenna***	***1***	***2***	***3***
Bandwidth (GHz)	2.4-17.7	2.7 - 9.3	3.5 - 11.0	2.8 - 12.3
Maximum size (mm)	50	50	28	44

Table 1 provides the parameters of the study and the literature [1-4, 8] antennas. It is not hard to find that our research in antenna has obvious advantages in bandwidth, gain and antenna size compared to the literature antennas, which demonstrates that a coplanar waveguide technology and defected ground structure can effectively widen impedance bandwidth of the antenna.

IV. Conclusion

The ground plane, serving as an impedance matching circuit, tunes the input impedance. The fabricated antenna is compact with dimensions of 40 × 50 × 1.6 mm3 suitable for integration with electrical circuits. Both simulation and measurement have demonstrated that the trapezoidal CPW-fed printed antenna can achieve an ultra wide bandwidth. It is also observed that the radiation patterns are nearly Omnidirectional over the en- tire operating bandwidth. The results have proved that the design stands out as a potential candidate for future UWB applications.

References

[1] Design of a CPW-Fed Ultra Wide Band Antenna* Shaowen Hu, Yiqiang Wu, Ye Zhang, Huilin Zhou *Antennas and Propagation*, 2013, 1, 18-22

[2] Rohit kumar saini, santanu dwari, mrinal kanti, mandal "CPW –Fed dual-band dual-sense circularly polarized monopole antenna" *IEEE Antennas Wireless Propagation Letters*, Vol. 16, No. 1, 2017, pp. 2497-2500.

[3] Lin peng, bao-jain wen xiao-feng li, xing-jiang "CPW fed antenna UWB antenna by EBGs with wide rectangular notched band" *IEEE Access,* Vol. 4, No. 1, 2016, pp. 9545-9552.

[4] Lin, Y.-C., and Hung, K.-J, "Compact ultra wideband rectangular aperture antenna and band-notched designs", *IEEE Trans. Antennas Propag,* 54, (11), pp. 3075–3081, 2006.

[5] F. Consoli, F. Maimone, and S. Barbarino, "Study of a CPW-fed circular Slot antenna for UWB communications," *Microwave and Optical Technology Letters,* vol. 48, pp. 2272-2277, 2006.

[6] B. K. Kormanyos, W. Harokopus, L. Katehi, and G. Rebeiz, "CPW-fed active slot antennas," *IEEE Trans. Microwave Theory Tech.*, vol. 42, pp. 541–545, Apr. 1994.

[7] J.-Y. Sze, C.-I. G. Hsu, and S.-C. Hsu, "Design of a compact dual-band annular-ring slot antenna," *IEEE Antennas Wireless Propag. Lett.*, vol.6, pp. 423–426, 2007.

[8] H. L. Lee, H. J. Lee, J. G. Yook, and H. K. Park, "Broadband planar antenna having round corner rectangular wide slot," *in Proc. IEEE Antennas and Propagation Society Int. Symp.,*vol. 2, pp. 460–463, Jun. 16–21, 2002.

[9] U. Bhobe, C. L. Holloway, and M. Piket-May, "CPW fed wide-band hybrid slot antenna," *in Proc. IEEE Antennas Propag. Soc. Int. Symp. Dig,* vol. 2, pp. 636–639.Jul. 2000.

[10] F. Bahret, "The beginnings of stealth technology", *IEEE Transactions on Aerospace and Electronic Systems*, vol. 29, no.4, pp. 1377-1385, 1993.

[11] K. Matsumoto, "Wave absorber based on rubber sheet with circular lattice for installing between ETC lanes", *Proceedings of the 9th European Conference on Wireless Technology,* pp. 261-264, 2006.

[12] B. DeWitt andW. Burnside, "Electromagnetic scattering by pyramidal and wedge absorber," *IEEE Transactions on Antennas and Propagation*, vol. 36, no. 7, pp. 971–984, 1988.

[13] C. P. Neo, "Optimization of carbon fiber composite for microwave absorber", *IEEE Transactions on Electromagnetic Compatibility*, vol. 46, no. 1, pp.102-106, 2004

[14] J. Tak, Y. Lee, and J. Choi, "Design of a metamaterial absorber for ISM applications," *KIEES Journal of Electromagnetic Engineering and Science,* vol. 13, no. 1, pp. 1-7, Mar. 2013.

[15] J. Deepa, S. Suganthi, G. Shenbaga Ranjani. J.Candice Freeda & M. Jayaprabha, "Multiband Planar MIMO Antenna for GSM1800/LTE2300/WiMAX/WLAN Applications", *International Journal of Engineering Research & Technology (IJERT),* Vol. 4, No.19, pp: 38-43, 2016.

[16] ANSYS High Frequency Structure Simulator HFSS), Ver. 15, *ANSYS Inc.*

[17] S. Suganthi, S. Iswaryalakshmi & D. Sriadhavi, "Double Folded Multiband Slot Antenna with Dual E Stub", *International Journal of Engineering Research & Technology (IJERT),* Vol. 4, No.19, pp: 49-54, 2016.

[18] S. Suganthi, "Compact MIMO antenna for portable devices in UWB applications" *Proc. Indian Antenna Week 2016, Thiagarajar College of Engineering, Madurai,* 6th June, 2016.

[19] ABBOSH, A. Planar ultra wideband antennas with rejected sub bands. *In IEEE Proceedings of Asia-Pacific Microwave Conference. Bangkok (Thailand),* 2007.

[20] S.Suganthi, "Double folded multiband slot antenna with dual E shaped stub", *Proc. ICEEET'16, Indira Ganesan College of Engineering, 19th* March, 2016.

[21] Mai O.Sallam, sara M.Kandil Valdimir volsik Guy A.E. Vandenbosch "Wideband CPW Fed flexible bow-tie slot antenna forWLAN/WiMax systems". *IEEE Transactions on An- tennas and Propagation*, Vol. 65, No. 8, 2017, pp. 4274-4277.

[22] Hi-Liu Ying Liu, Shuix Gong "Broad band microstrip CPW fed ZOR antenna for Bluetooth applications" IET Microwaves *Antennas Propagation* Vol. 11, No. 6, 2017, pp. 880-885.

[23] A.Subbarao and S. Raghavan, "A Novel Pot Shaped CPW-Fed Slot Antenna for Ultra Wideband Applications," *Emerging Trends in Electrical and Computer Technology*, Vol. 23, No. 24, 2011, pp. 1119-1122.

[24] S. J. Shi and H. P. Guo, "A New Type of Ultra-Wideband Planar Monopole Antenna Design," *Communication Technology*, Vol. 42, No. 1, 2009, pp. 112-114.

[25] Y. S. Jia, I. G. Chung and W. C. Zhi, "Broadband CPW- Fed Circularly Polarized Square Slot Antenna with Lightening-Shaped Feedline and Inverted-L Grounded Strips," *IEEE Transactions on Antennas and Propagation,* Vol. 3, No. 58, 2010, pp. 973-977.

[26] M. A. Habib, A. Bostani and A. Djaiz, "Ultra Wideband CPW-Fed Aperture Antenna with WLAN Band Rejection," *Progress in Electromagnetics Research*, Vol. 106, 2010, pp. 17-31.

[27] M. S. Yuan and Y. L. Chung, "CPW-Fed Dual Folded Symmetry Planar Antenna for Multiband Operation," *International Conference on Electromagnetics*, *Applications and Student Innovation* (iWEM), Taipei, 2011, pp. 43-47.

[28] P. Pongsoon and D. Bunnjaweht, "CPW-Fed Disc Patch Antennas with an Annular Ground Plane for UWB Applications," *International Symposium on Intelligent Signal Processing and Communications Systems* (*ISPACS*), Chiang Mai, 2011, pp.1-4.

[29] **S**. Suganthi, "CPW fed square patch antenna for biomedical applications" *Proc. First International Conference on Innovations in Electrical, Information and Communication Engineering, (ICIEICE'17)*, 24th-25th March, 2017.

[30] S. Suganthi, M.Noorjahan and P.Thiruvalar slevan "Miniaturized Implantable Loop Antenna for Biomedical Applications" *International Journal of Engineering Research & Technology (IJERT),* ISSN: 2278-0181, Vol: 05, No: 13, pp. 455-458, 2017.

[31] S. Suganthi, "Bandstop Filter Design Having Thin Film Capacitors In Open Loop Resonators", *TEQIP-II Sponsored International Conference on Electrical, Electronics & Communication (ICEEC'16),* March 31st, 201

[32] S. Suganthi, S. Iswaryalakshmi & D. Sriadhavi, "Double Folded Multiband Slot Antenna with Dual E Stub", *International Journal of Engineering Research & Technology (IJERT),* Vol. 4, No.19, pp: 49-54, 2016.

[33] S. Suganthi U. Jagadish Praveen & R. Gunaseelan, "Millimeter-Wave High-Gain SIW End- Fire Bow-Tie Antenna", *International Journal of Engineering Research & Technology (IJERT),* Vol. 4, No.19, pp: 103-108, 2016.