A BIRD EYEVIEW ON AMC BASED DIPOLE COMPACT FLEXIBLE ANTENNA FOR RADIATION DOSIMETER TAGS

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***Abstract*: In the current generation there are many medical devices are updated and working based on smart wireless system. In this dissertation work proposed a robust flexible artificial magnetic conductor (AMC) structure based dipole antenna for wireless tags in the specific frequency of 2.1 and 2.44GHz for wireless biomedical applications. In the current generation there are many research work presented in the area of flexible antenna that is discussed in the literature survey.The proposed work show multiple resonating frequency bands 2.1 ,2.44 and 3.15 GHz. There are three bands obtain in which proposed design shows optimum result in terms of refection coefficient, VSWR and number of bands. The proposed design low-profile design without via wave-guide port together with the flexible characteristic, low cost, easy to fabrication, and integration, makes it very attractive for applications involving antennas in RFID tags, wearable systems, and RCS reduction. Also it could be used as part of Microwave Integrated Circuits (MICs).The main motive of this research work to design antenna for medical application based RF id tags. The presented design shows better result as compare to other previous design in terms of refection coefficient and number of bands.**

***Keywords*: flexible antenna, refection coefficient, artificial magnetic conductor , RFID tags,Microwave Integrated Circuits (MICs), wearable systems, kapton polyimide, rubber and dipole, etc...**

1. INTRODUCTION

In radio engineering, an antenna is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver. In transmission, a radio transmitter supplies an electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of a radio wave in order to produce an electric current at its terminals, that is applied to a receiver to be amplified. Antennas are essential components of all radio equipment.

An antenna is an array of conductors (elements), electrically connected to the receiver or transmitter. Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional, or high-gain, or "beam" antennas). An antenna may include components not connected to the transmitter, parabolic reflectors, horns, or parasitic elements, which serve to direct the radio waves into a beam or other desired radiation pattern.

The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of waves predicted by the electromagnetic theory of James Clerk Maxwell. Hertz placed dipole antennas at the focal point of parabolic reflectors for both transmitting and receiving. Starting in 1895, Guglielmo Marconi began development of antennas practical for long-distance, wireless telegraphy, for which he received a Nobel Prize.

1.1 TERMINOLOGY

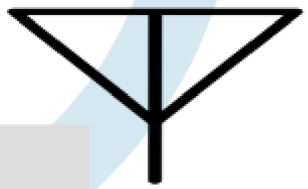


Fig 1.1 Electronic symbol for an antenna

The words antenna and aerial are used interchangeably. Occasionally the equivalent term "aerial" is used to specifically mean an elevated horizontal wire antenna. The origin of the word antenna relative to wireless apparatus is attributed to Italian radio pioneer Guglielmo Marconi. In the summer of 1895, Marconi began testing his wireless system outdoors on his father's estate near Bologna and soon began to experiment with long wire "aerials" suspended from a pole. In Italian a tent pole is known as l'antenna centrale, and the pole with the wire was simply called l'antenna. Until then wireless radiating transmitting and receiving elements were known simply as "terminals". Because of his prominence, Marconi's use of the word antenna spread among wireless researchers and enthusiasts, and later to the general public.

1.2 RESONANT ANTENNAS

The majority of antenna designs are based on the resonance principle. This relies on the behavior of moving electrons, which reflect off surfaces where the dielectric constant changes, in a fashion similar to the way light reflects when optical properties change. In these designs, the reflective surface is created by the end of a conductor, normally a thin metal wire or rod, which in the simplest case has a feed point at one end where it is connected to a transmission line. The conductor, or element, is aligned with the electrical field of the desired signal, normally meaning it is perpendicular to the line from the antenna to the source (or receiver in the case of a broadcast antenna).

The standing wave forms with this desired pattern at the design operating frequency, fo, and antennas are normally designed to be this size. However, feeding that element with 3 f0 (whose wavelength is 1⁄3 that of fo) will also lead to a standing wave pattern. Thus, an antenna element is also resonant when its length is 3⁄4 of a wavelength. This is true for all odd multiples of 1⁄4 wavelength. This allows some flexibility of design in terms of antenna lengths and feed points. Antennas used in such a fashion are known to be harmonically operated. Resonant antennas usually use a linear conductor (or element), or pair of such elements, each of which is about a quarter of the wavelength in length (an odd multiple of quarter wavelengths will also be resonant). Antennas that are required to be small compared to the wavelength sacrifice efficiency and cannot be very directional. Since wavelengths are so small at higher frequencies (UHF, microwaves) trading off performance to obtain a smaller physical size is usually not required.

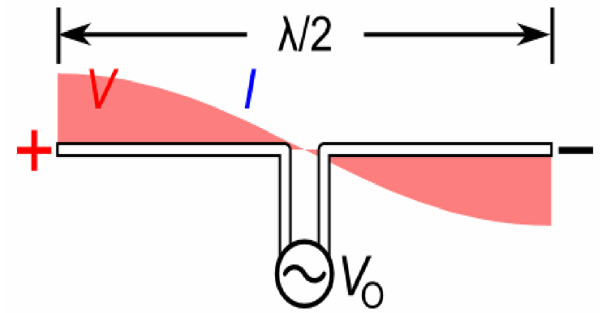


Fig 1.2 Standing waves on a half wave dipole driven at its resonant frequency.

1.3 BANDWIDTH

The frequency range or bandwidth over which an antenna functions well can be very wide (as in a log-periodic antenna) or narrow (as in a small loop antenna); outside this range the antenna impedance becomes a poor match to the transmission line and transmitter (or receiver). Use of the antenna well away from its design frequency affects its radiation pattern, reducing its directive gain.

Generally an antenna will not have a feed-point impedance that matches that of a transmission line; a matching network between antenna terminals and the transmission line will improve power transfer to the antenna. The matching network may also limit the usable bandwidth of the antenna system. It may be desirable to use tubular elements, instead of thin wires, to make an antenna; these will allow a greater bandwidth. Or, several thin wires can be grouped in a cage to simulate a thicker element. This widens the bandwidth of the resonance.

1.4 EFFECT OF GROUND

The radiation pattern and even the driving point impedance of an antenna can be influenced by the dielectric constant and especially conductivity of nearby objects. For a terrestrial antenna, the ground is usually one such object of importance. The antenna's height above the ground, as well as the electrical properties (permittivity and conductivity) of the ground, can then be important. Also, in the particular case of a monopole antenna, the ground (or an artificial ground plane) serves as the return connection for the antenna current thus having an additional effect, particularly on the impedance seen by the feed line.

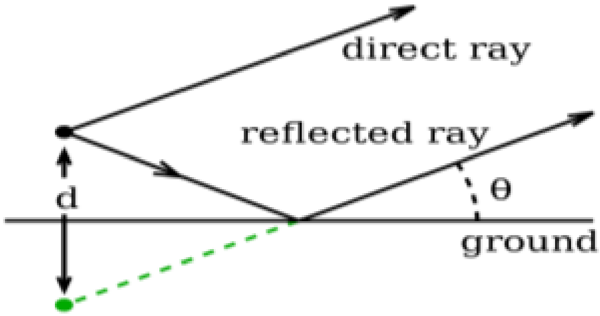


Fig 1.3 The wave reflected by earth can be considered as emitted by the image antenna.

At VHF and above (> 30 MHz) the ground becomes a poorer reflector. However it remains a good reflector especially for horizontal polarization and grazing angles of incidence. That is important as these higher frequencies usually depend on horizontal line-of-sight propagation (except for satellite communications), the ground then behaving almost as a mirror.

The net quality of a ground reflection depends on the topography of the surface. When the irregularities of the surface are much smaller than the wavelength, the dominant regime is that of secular reflection, and the receiver sees both the real antenna and an image of the antenna under the ground due to reflection. But if the ground has irregularities not small compared to the wavelength, reflections will not be coherent but shifted by random phases. With shorter wavelengths (higher frequencies), this is generally the case.

II. LITERATURE SURVEY

Chandiea, L., & Anusudha, K. (2017, January) - From **Alemaryeen, A., & Noghanian, S. (2019) -** In this paper, we have proposed a compact conformal textile AMC antenna for wearable applications. The antenna design methodology and fabrication process were summarized and presented. In order to verify the simulation results, prototypes of the antennas were fabricated and measured in different conditions. In free-space, the realized AMC antenna showed an impedance bandwidth of 34% (4.30 GHz – 5.90 GHz), with a gain value of 6.12 dBi. Numerical simulations and experimental measurements have further revealed that the proposed AMC antenna is robust in respect to impedance resonance frequency, showing minimal changes due to structural deformation such as bending and crumpling, as well as loading effects of human body. In addition, the inclusion of the AMC reflector considerably reduces the SAR values and the back radiation, making the AMC antenna far superior to a single monopole antenna.**[01]**

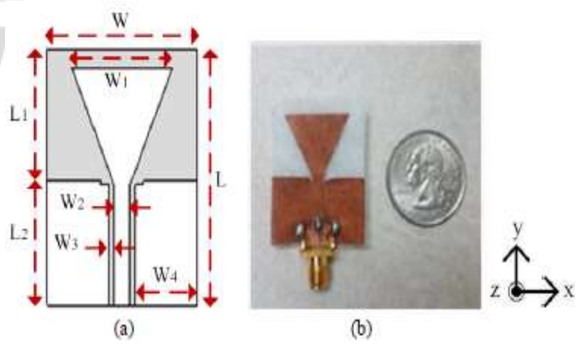


Fig.2.1. (a) Configuration of CPW-fed monopole antenna and (b) a photograph of the fabricated monopole prototype. The optimized dimensions in mm are W = 27, L = 34, L1 = 15.5, L2 = 16.5, W1 = 19, W2 = 3, W3 = 0.4, and W4 = 11.6.

Wang, B., Yang, S., Chen, Y., & Qu, S. W. (2019, May) - A wideband long slot antenna based on a novel AMC reflector is proposed in this paper. By carefully design of the structure and size of the AMC reflector, the whole profile is significantly reduced down to 0.22λ height at 2.4GHz. Simulation result shows the proposed antenna achieves a wide bandwidth of 0.9-2.4GHz and E-Plane scanning angle up to ±45°. Due to the attractive characteristics such as compact size and low profile, the proposed antenna has potential to be applied to radar and communication systems.**[02]**

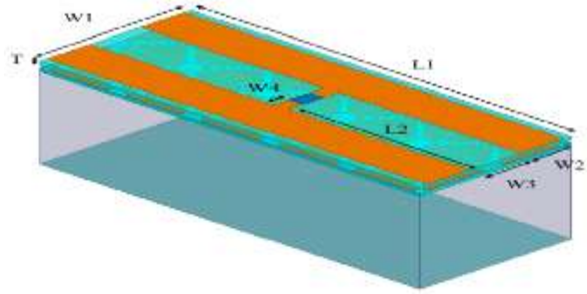


Fig. 2.2. Long Slot Antenna element with AMC substrate

Jin, J., & Xu, F. (2019, May) - A 1:4 power divider based on T-shaped junction with AMC packaging has been fabricated and simulated. The structure and design have been described in detailed, and the power divider operates at 30GHz, which is employed for millimeterwave application. Comparison between the primitive MS power divider and the proposed MS power divider with AMC packaging has demonstrated that the aid of AMC packaging show overall, system-level performance enhancement in minimizing the spurious radiation loss which is suitable for millimeter-wave biomedical applications.**[03]**

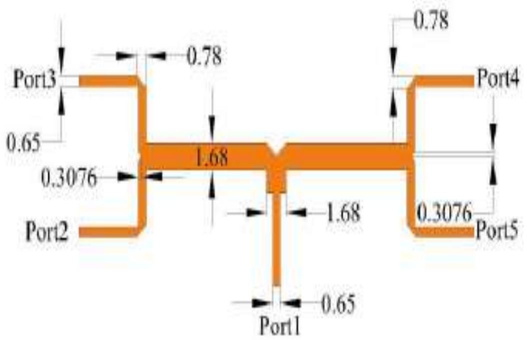


Fig.2.3. Schematics of the primitive power divider

Rahim, M. K. A., Hamid, M. R., Samsuri, N. A., Murad, N. A., Zubir, F., Ayop, O., ... & Majid, H. A. (2019, November) - The paper explained two application of AMC with antenna. The first application is for RFID antenna Tag with metal object and the second application is the enhancement of transmission between two antennas. From the experimental result both application can enhance the propagation of electromagnetic signal when the antenna is attached to the AMC.**[04]**

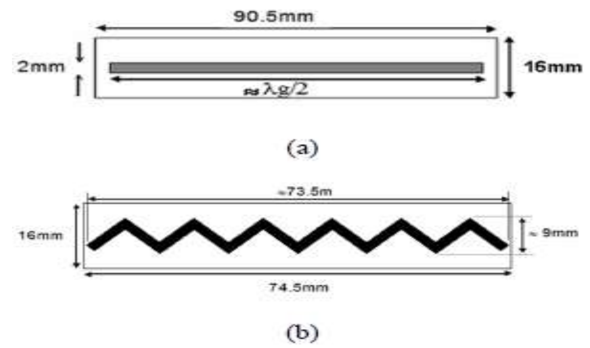


Fig.2.4. A unit cell of (a) straight dipole and (b) zigzag dipole AMC design at 920MHz

Sanusi, O. M., Ghaffar, F. A., Shamim, A., Vaseem, M., Wang, Y., & Roy, L. (2019) - In this paper, the design and performance of a dipole antenna over the AMC structure are described in a proposed dosimeter tag. The design and optimal configuration of an AMC structure to achieve best gain and beamwidth performance are also presented. The designed dipole-AMC structure operates at 2.45 GHz with a bandwidth from 2.32 GHz to 2.56 GHz. The proposed antenna structure occupies an area of 20 mm 100 mm with an overall thickness of 9.24 mm. The antenna uses a 1 4 AMC surface to significantly improve its broadside gain and reduce its back lobe at its operating frequency. Studies show that increasing the number of AMC unit cells could create high gain antennas with narrow beamwidth. It was also noted that increasing the AMC bandwidth has major implications on the antenna bandwidth. The measured results show that the antenna reflection coefficient remains relatively the same from 2 GHz to 3 GHz regardless of the bending condition or presence of a lossy host structure. The measured far field radiation pattern results show that the antenna maintains a broadside radiation under bending and on a filled blood bag with a gain variation of about 0.7 dBi. When integrated with a 2.45 GHz rectifier, the performance and suitability of the antenna as part of a wireless power unit is demonstrated. The rectenna is capable of providing the nominal voltage level needed by the proposed dosimeter tag. It attains output dc voltages of up to 1.7 V over a 25 k resistor. In addition, the rectenna achieves a range of up to 1m. This antenna design is appropriate for wearable designs, mounting on lossy host structures and for direct integration with wireless power units, biomedical sensing and signal processing chips.**[05]**

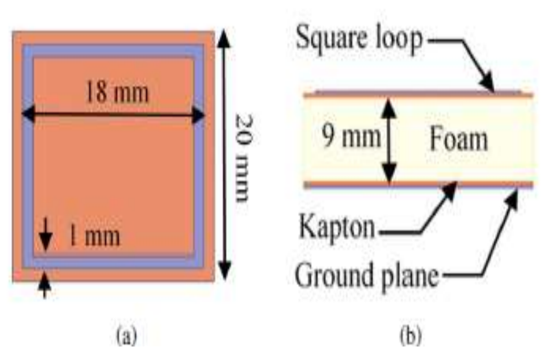


Fig. 2.5. 2.45 GHz square loop unit cell with dimensions (a) top view and (b) side view.

Cosker, M., Lizzi, L., Ferrero, F., Staraj, R., & Ribero, J. M. (2016) – In this paper, an approach for the realization of 3D flexible antenna based on the use of liquid metal and additive printing technologies has been proposed. The effectiveness of the approach has been validated by designing an IFA for wearable applications. An antenna prototype has been realized using Galinstan liquid metal and NinjaFlex plastic material. The obtained experimental results confirm the possibility of realizing flexible miniature antennas with good impedance matching and fair total efficiency. These performance are maintained when the antenna is bent and placed over a human body phantom.**[06]**

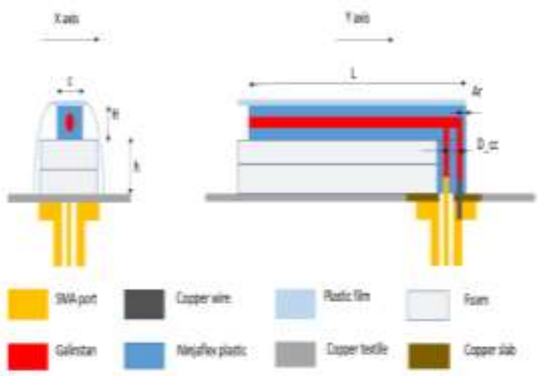


Fig.2.6.Antenna structure.

Ashyap, A. Y., Abidin, Z. Z., Dahlan, S. H., Majid, H. A., Shah, S. M., Kamarudin, M. R., & Alomainy, A. (2017) - A novel compact wearable antenna with a miniaturized EBG structure for medical applications is successfully designed, simulated and measured. The EBG structure is used to eliminate the mismatch and frequency shifting caused by the human body. In addition, the presence of the EBG structure reduces the unwanted radiation towards the human body. The bending do not affect the resonant frequency and bandwidth of the antenna. The proposed design exhibits an operating bandwidth of 27% and a gain of 7.8 dBi at 2.4 GHz. The front-to-back ratio improves by 15.5 dB. Furthermore, the calculated SAR values are low and obey the limit stipulated in the FCC and CNIRP regulations. Thus, the proposed antenna with EBG structure is a strong potential candidate for wearable medical applications.**[07]**

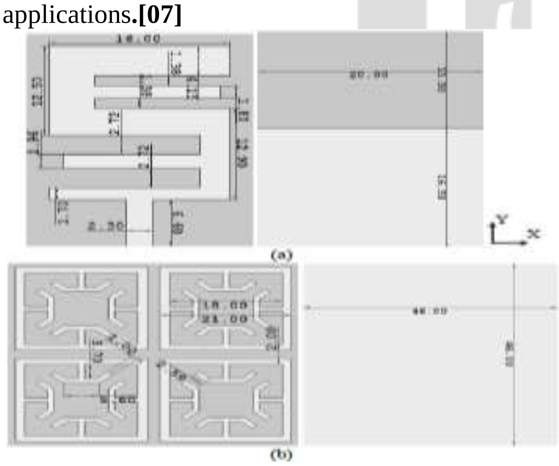


Fig.2.7. Antenna and EBG structure: (a) Top and bottom view of antenna. (b) Top and bottom view of EBG structure. (Unit: mm).

III. PROPOSED METHODOLOGY

3.1 Microstrip Patch Antenna for Wireless Range

The proposed work shows the micro-strip patch antenna (MSA) design. In this research method design robust MSP antenna with the help of different parameters analysis such length of patch, ground length, feed line. It can also be used to enhance the return loss and VSWR. The micro-strip patch antenna has become popular day to day, the reason behind this is an ease of analysis and fabrications. The proposed micro-strip dipole antenna is designed for Giga hertz frequency range from 4.7 GHz to 9.6 GHz. The various bands of operation for proposed design are 4.4 GHz to 5.9 GHz ranges and 7.8 GHz to 9.9 GHz for all are used in different applications such as Wi-Fi, fourth and fifth generation communication. For the proof of proposed research methodology require a simulator in which validate and simulate of proposal. Computer simulated technology (CST) software has use for the simulation and validation of proposed methodology.

3.2 Steps of Design

In the conventional procedure design of rectangular micro-strip patch antenna.There are three essential parameters:

Frequency of operation (f_0): The antenna resonance frequency must be chosen appropriately. The communication systems using frequency range from 4.4 to 9.67 GHz at different wireless frequencies. The antenna design for Wi-Fi and Wi-Max devices. The communication system must be able to operate in from 1to 10 GHz frequency range.

Di-electric constant of substrate (εr): The di-electric constant of substrate material plays an important role for design of patch antenna. A substrate having a high di-electric constant reduces the dimension of antenna, but also affects the performance of antenna. The dielectric constant of substrate is use to a compromise between size and performance of patch antenna. In this presented work use FR-4 substrate with di-electric constant (εr=4.4) is used.

Height of di-electric substrate (*h*): The micro-strip patch antenna use in communication systems, it is essential that antenna is small size. Therefore, height ofdi-electric substrate must be less. In this proposed work substrate height is taken as 1.6 mm.

3.3 Proposed Solution of Z Shape Patch Antenna with DGS

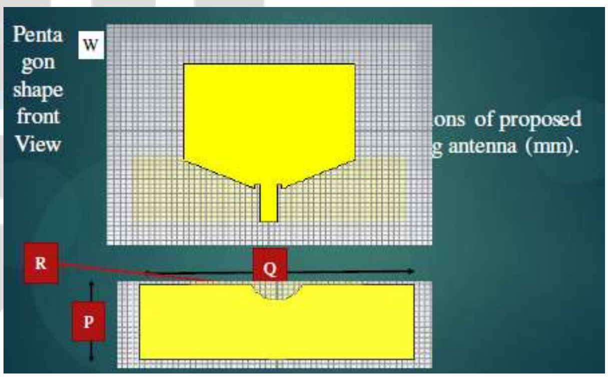


Fig 8 Design of back end view of -MSA with DGS

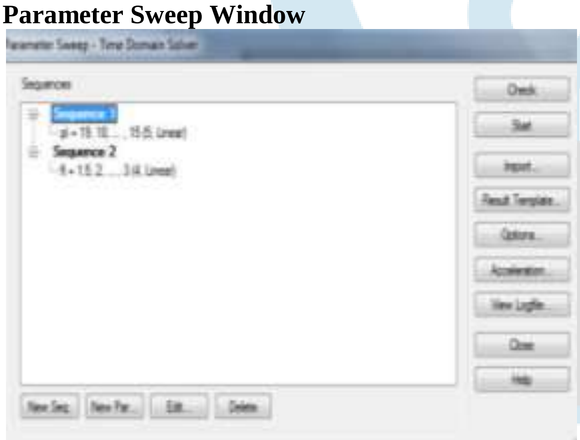
3.2 PARAMET ERS TABLE

S. No.	Parameter	Dimension (mm.)
1	Substrate(Sl x Sw x Sh)	52×38.32×1
2	Ground(Sl x Sw x Sh)	44×14.16×0.635
3	Patch(Sl x Sw x Sh)	{13 to 19 }×26.32×0.035
4	Feed type - Micro strip(Sl x Sw x Sh)	10.16×7×0.035
5.	T- Cuts square Patch (Ptb x Ptp x Pth)	Patch - [L{4×3×0.035}+R{4×3×0.035}]

FR-4 –EPOXY AS SUBSTRATE –

FR-4 or (FR4) is a grade designation assigned to glass reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing). FR-4 glass epoxy is a popular and versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength.

Parameter Sweep Window



IV. SIMULATION AND EXPERIMENTAL RESULT

4.1 Introduction

In this chapter discussion simulation and result of the proposed research of octagon. The presented work on different shapes of antenna. The presented pentagon with DGS antenna is design for Giga hertz (GHz) frequency range 4.7 to 9.4 GHz. This frequency range accommodate in various bands, it covers Wi-Fi, WI-Max range. The pentagon patch based MSA is gaining importance due to its versatile applications. The important applications are wireless local area networks (WLAN), Wi-Fi and Wi-Max. The simulated results are return loss (S_{11}), VSWR, size of antenna, bandwidth and number of bands discussed in this chapter.

The optimize dimensions of geometric parameters are listed in previous which is test on parametric study shown in results. The impedance bandwidth of measured return loss (S-11) reaches up to -36.286 dB. The range of proposed work cover from 4.4 GHz to 9.9 GHz. CST microwave studio is use for simulation of proposed design. The results of proposed antenna such as S-11 and VSWR shows good outcome as compare to the previous results.

4.2 CST Design environment

The figure 4.1 shows basic view of CST. The proposed design is simulate on CST 2016 version. The main parts of proposed design are substrate (S), patch (P), ground (G) and feeding system (Waveguide feed). This design uses a wave guide port for feeding system. In general there are two type of feeding systems first is circular wave guide port and second is wave guide port. Figure 5.1(a) and 5.2(b) shows the CST Design environment. Figure 5.1(a) shows front side (patch side) of proposed antenna in 3D view of CST window. Figure 5.1(b) shows back view of proposed design in 3D view of CST window. This windows shows in divided into two or three part, above part shows menu. Proposed antenna shows in particular area this area is work plane and left hand side the corner list is shown that is called a navigator window.

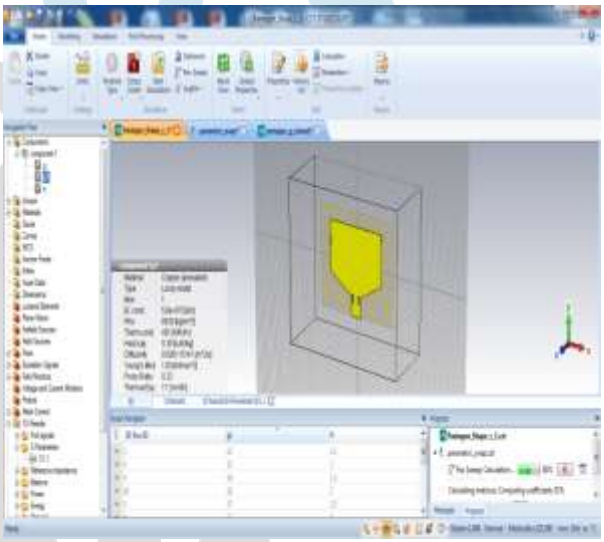


Fig 4.1 (a) Shows the front view of proposed design

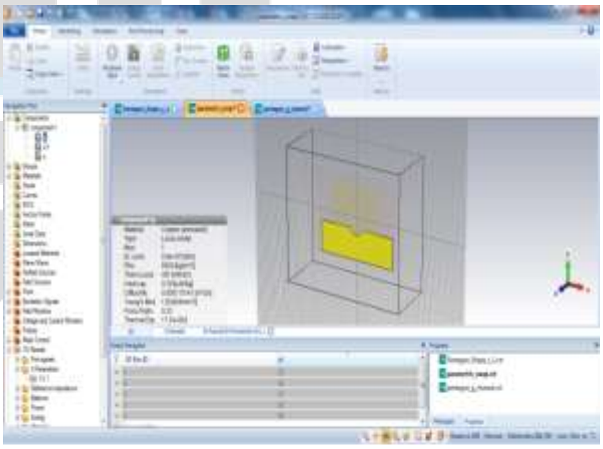
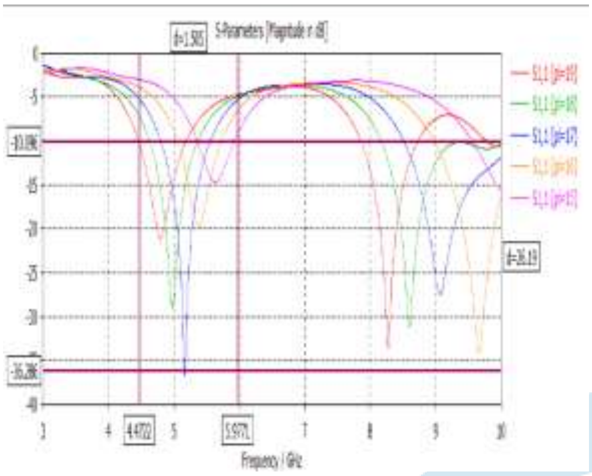
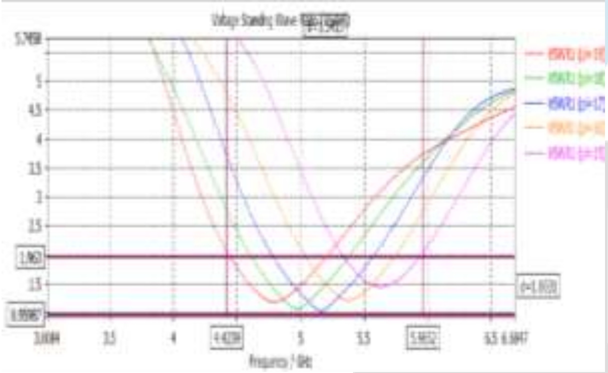


Fig 4.1 (b) Shows the Back view of proposed design (Ground)



Parametric Sweep Results

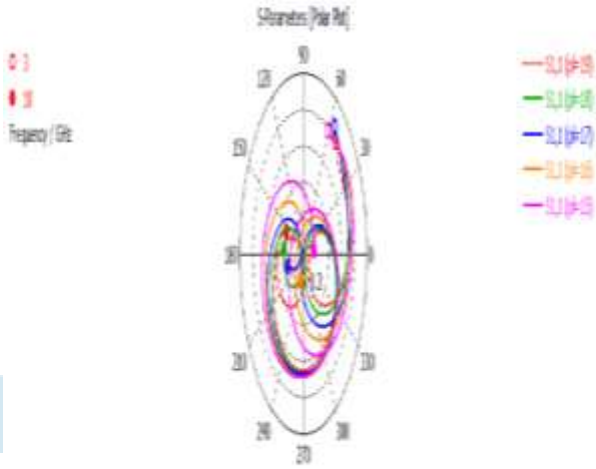
S. No.	Parameter Patch Width	Return Loss (S11) db	Bandwidth (B.W.)	Number of bands
1	19 mm	33.56 at 8.2747 GHz	0.74 GHz	2
		21.112 at 4.79 GHz	0.82 GHz	
2	18mm	28.814 at 4.97 GHz	0.77 GHz	2
		30.889 at 8.601 GHz	1.1446 GHz	
3	17 mm	36.698 at 5.16 GHz	0.7518 GHz	2
		27.846 at 9.6 GHz	1.4878 GHz	
4	16 mm	20.378 at 5.7317	0.7112GHz	2
		34.85 at 9.4652 GHz	1.5368 GHz	
5	15 mm	14.658 at 5.665 GHz	0.59 GHz	1
		at 10GHz	[illegible] GHz	



VSWR Table

s.no	Frequency (GHz)	VSWR
1	4.7854	1.1691
2	4.9705	1.074
3	5.1	0.99
4	5.3849	1.8
5	5.66	1.4

The VSWR is always in between 1 to 2 the presented design VSWR touch 1, again it's a good sign of presented Pentagon.



4.2 Result Comparison with different previous Methods

Year Ref	Shape	Range	S–Parameter (dB)	VSWR	Band Width	No. of Band
2020 Proposed	Modified Pentagon	4.4 to 9.9 GHz	5.16 GHz = -36.698 dB 9.6GHz = -27.846 dB	0.99 1.1123	0.75 1.48	2
	Simple Pentagon	4.6 to 9.9above	9.04GHz = -38.812 dB	0.9	0.89	1
2017 [01] Base	Performance Analysis of Pentagon Shaped Microstrip Patch Antenna	1.45-1.75	7.2GHz = -15.82 dB 7.7 GHz = -20.98 dB 7.7 GHz - 32.5 dB	1.05	0.30	2

V. CONCLUSION

In this discuss on A Bird Eyeview On Pentagon Shaped Microstrip Patch Antenna. The important outcomes of this paper are shown in the section of comparative analysis.

In this paper observe that the A Bird Eyeview On Pentagon Shaped Microstrip Patch Antenna.Also most of the Pentagon Shaped Microstrip Patch Antenna.

In future design a better A Bird Eyeview On Pentagon Shaped Microstrip Patch Antenna. That can improve all these problems in this communication area. In future try to A Bird Eyeview On Pentagon Shaped Microstrip Patch Antenna.

REFERENCES

[1] Alemaryeen, Ala, and Sima Noghanian. "On-body low-profile textile antenna with artificial magnetic conductor." IEEE Transactions on Antennas and Propagation 67.6 (2019): 3649-3656.
[2] Wang, Bingjun, et al. "Low-profile wideband long slot phased arrays based on novel amc reflectors." 2019 IEEE MTT-S International Wireless Symposium (IWS). IEEE, 2019.
[3] Jin, Jun, and Feng Xu. "Design of 1: 4 Power Divider Using Artificial Magnetic Conductor Packaging for Millimeter-wave Application." 2019 IEEE MTT-S International Microwave Biomedical Conference (IMBioC). Vol. 1. IEEE, 2019.
[4] Rahim, M. K. A., et al. "Antenna with Artificial Magnetic Conductor for Wireless Application." 2019 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE). IEEE, 2019.
[5] Sanusi, Ololade M., et al. "Development of a 2.45 GHz Antenna for Flexible Compact Radiation Dosimeter Tags." IEEE Transactions on Antennas and Propagation 67.8 (2019): 5063-5072.
[6] Cosker, Mathieu, et al. "Realization of 3-D flexible antennas using liquid metal and additive printing technologies." IEEE Antennas and Wireless Propagation Letters 16 (2017): 971-974.
[7] Ashyap, A. Y., Abidin, Z. Z., Dahlan, S. H., Majid, H. A., Shah, S. M., Kamarudin, M. R., & Alomainy, A. (2017). Compact and low-profile textile EBG-based antenna for wearable medical applications. IEEE Antennas and Wireless Propagation Letters, 16, 2550-2553.
[8] Saeed, S. M., Balanis, C. A., Birtcher, C. R., Durgun, A. C., & Shaman, H. N. (2017). Wearable flexible reconfigurable antenna integrated with artificial magnetic conductor. IEEE Antennas and Wireless Propagation Letters, 16, 2396-2399.
[9] Elobaid, H. A. E., Rahim, S. K. A., Himdi, M., Castel, X., & Kasgari, M. A. (2016). A transparent and flexible polymer-fabric tissue UWB antenna for future wireless networks. IEEE Antennas and Wireless Propagation Letters, 16, 1333-1336.
[10] Agarwal, Kush, Yong-Xin Guo, and Budiman Salam. "Wearable AMC backed near-endfire antenna for on-body communications on latex substrate." IEEE Transactions on components, packaging and manufacturing technology 6.3 (2016): 346-358.
[11] Dewan, Raimi, and Mohamad Kamal A. Rahim. "Antenna performance enhancement with artificial magnetic conductor (AMC)." 2015 IEEE Conference on Antenna Measurements & Applications (CAMA). IEEE, 2015.
[12] Kim, S., Le, T., Tentzeris, M. M., Harrabi, A., Collado, A., & Georgiadis, A. (2014, November). An RFID-enabled inkjet-printed soil moisture sensor on paper for “smart” agricultural applications. In SENSORS, 2014 IEEE (pp. 1507-1510). IEEE.
[13] Farooqui, M. F., Claudel, C., & Shamim, A. (2014). An inkjet-printed buoyant 3-D Lagrangian sensor for real-time flood monitoring. IEEE transactions on antennas and propagation, 62(6), 3354-3359.
[14] Yang, Chin-Lung, Chi-Lin Tsai, and Sheng-Hao Chen. "Implantable high-gain dental antennas for minimally invasive biomedical devices." IEEE transactions on antennas and propagation 61.5 (2013): 2380-2387.
[15] Cook, Benjamin Stassen, and Atif Shamim. "Utilizing wideband AMC structures for high-gain inkjet-printed antennas on lossy paper substrate." IEEE Antennas and Wireless Propagation Letters 12 (2013): 76-79.
[16] Raad, Haider R., et al. "Flexible and compact AMC based antenna for telemedicine applications." IEEE Transactions on antennas and propagation 61.2 (2012): 524-531.
[17] Hadarig, Ramona Cosmina, et al. "Novel bow-tie–AMC combination for 5.8-GHz RFID tags usable with metallic objects." IEEE Antennas and Wireless Propagation Letters 9 (2010): 1217-1220.
[18] Kim, S., Ren, Y. J., Lee, H., Rida, A., Nikolaou, S., & Tentzeris, M. M. (2012). Monopole antenna with inkjet-printed EBG array on paper substrate for wearable applications. IEEE Antennas and wireless propagation letters, 11, 663-666.
[19] Foroozesh, A., & Shafai, L. (2008). Effects of artificial magnetic conductors in the design of low-profile high-gain planar antennas with high-permittivity dielectric superstrate. IEEE Antennas and Wireless Propagation Letters, 8, 10-13.
[20] Hosseini, Mehdi, and Mohammad Hakkak. "Characteristics estimation for Jerusalem cross-based artificial magnetic conductors." IEEE Antennas and wireless propagation letters 7 (2008): 58-61.
[21] Karacolak, Tutku, Aaron Z. Hood, and Erdem Topsakal. "Design of a dual-band implantable antenna and development of skin mimicking gels for continuous glucose monitoring." IEEE Transactions on Microwave Theory and Techniques 56.4 (2008): 1001-1008.
[22] Yousefi, Leila, Baharak Mohajer-Iravani, and Omar M. Ramahi. "Enhanced bandwidth artificial magnetic ground plane for low-profile antennas." IEEE Antennas and Wireless Propagation Letters 6 (2007): 289-292.
[23] Goussetis, George, Alexandros P. Feresidis, and John C. Vardaxoglou. "Tailoring the AMC and EBG characteristics of periodic metallic arrays printed on grounded dielectric substrate." IEEE Transactions on Antennas and Propagation 54.1 (2006): 82-89.
[24] Erentok, Aycan, Paul L. Luljak, and Richard W. Ziolkowski. "Characterization of a volumetric metamaterial realization of an artificial magnetic conductor for antenna applications." IEEE Transactions on Antennas and Propagation 53.1 (2005): 160-172.
[25] Yan, Dunbao, et al. "A novel polarization convert surface based on artificial magnetic conductor." 2005 Asia-Pacific Microwave Conference Proceedings. Vol. 3. IEEE, 2005.
[26] Kern, D. J., Werner, D. H., Monorchio, A., Lanuzza, L., & Wilhelm, M. J. (2005). The design synthesis of multiband artificial magnetic conductors using high impedance frequency selective surfaces. IEEE Transactions on antennas and propagation, 53(1), 8-17.
[27] Feresidis, Alexandros P., et al. "Artificial magnetic conductor surfaces and their application to low-profile high-gain planar antennas." IEEE Transactions on Antennas and Propagation 53.1 (2005): 209-215.
[28] Kretly, L. C., and A. M. P. A. Silva. "The influence of the height variation on the frequency bandgap in an amc, artificial magnetic conductor, for wireless applications: an em experimental design approach." Proceedings of the 2003 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference-IMOC 2003.(Cat. No. 03TH8678). Vol. 1. IEEE, 2003.
[29] Diaz, Rodolfo. "Magnetic loading of artificial magnetic conductors for bandwidth enhancement." IEEE Antennas and Propagation Society International Symposium. Digest. Held in conjunction with: USNC/CNC/URSI North American Radio Sci. Meeting (Cat. No. 03CH37450). Vol. 2. IEEE, 2003.

[30] Sievenpiper, D., Zhang, L., Broas, R. F., Alexopolous, N. G., & Yablonovitch, E. (1999). High-impedance electromagnetic surfaces with a forbidden frequency band. IEEE Transactions on Microwave Theory and techniques, 47(11), 2059-2074.