

A MULTI-BAND INTEGRATED SUBSTRATE WAVEGUIDE ANTENNA FOR WIRELESS APPLICATION

A Project Report Phase – II

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Electronics and Communication Engineering
by

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade “A” by NAAC

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APRIL 2023



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **REVATHI. M (39130372)** and **SANTHIYA J (39130400)** who carried out the project entitled **"A MULTI-BAND INTEGRATED SUBSTRATE WAVEGUIDE ANTENNA FOR WIRELESS APPLICATION"** under our supervision from November 2022 to April 2023.

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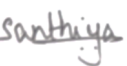
DECLARATION

We **REVATHI. M (39130372)** and **SANTHIYA J (39130400)** hereby declare that the project report entitled “**A MULTIBAND INTEGRATED SUBSTRATE WAVEGUIDE ANTENNA FOR WIRELESS APPLICATION**” done by us under the guidance of **Dr. S. LAKSHMI M.E., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

DATE: 24.04.2023

PLACE: CHENNAI

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ABSTRACT

An antenna is designed using multi-band in substrate integrated waveguide (SIW) technique for wireless applications. This antenna is has been developed by multi band ISW antenna for wireless application. A multiband antenna is designed to operate in multiple bands of frequencies. Multiband antennas use a design in which one part of the antenna is active for one band, while another part is active for a different band. The proposed antenna possesses square patch cavity, inverted U-shaped slot and innermost inverted U-shaped slot, which are governed by an inset micro strip feed line. The square patch SIW cavity-backed antenna offers cavity modes TM_{110} and TM_{210} . Two inverted U-shaped slots are introduced on the top metallic surface of the cavity to drive the lower resonant modes for acquiring antenna miniaturization. These lower resonance frequencies are formed by hybrid mode and coupling of hybrid mode. The wireless application method has been performed to enhance the performance of the antenna using HFSS software. The designed antenna has a compact size, which is fabricated on a low-cost FR-4 substrate. To validate the simulated equivalence, the fabricated antenna has been measured.

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LIST OF ABBREVIATIONS

SIW Antenna	Substrate Integrated Waveguide Antenna
ANSYS HFSS	ANSYS High Frequency Structure Simulator
VSWR	Voltage Standing Wave Ratio
ISW	Integrated Substrate Waveguide
ISM	Industrial Scientific Medical Frequency band
RFID	Radio Frequency Identification
Wi-Max	Worldwide Interoperability for Microwave Access
ANN	Artificial Neural Network
MSE	Mean Square Error
GCPW	Grounded Coplanar Waveguide
WLAN	Wireless Local Area Network
SRR Antenna	Split Ring Resonator Antenna
LWA	Leaky Wave Antenna
GSM	Global System for Mobile Communication
DCS	Distributed Control System
MMIC	Monolithic Microwave Integrated Circuit
E Field	Electric Field
H Field	Magnetic Field
SAR	Specific Absorption Rate

CHAPTER 1

INTRODUCTION

Due to its low profile, affordability, and ease of integration utilizing printed circuit boards, planar antennas have been thriving in the electronic/digital transceiver system in the current environment. Multiband, compact dimensions, and consistent radiation properties are now required as antenna technology develops. For achieving multiband along with adequate radiation properties, a variety of planar topologies have been suggested, such as loading slots in the patch, fractal structures, meta materials, and efficient feeding methods. Due to its excellent isolation, shorter wavelength, high power capabilities, and planar topologies, SIW methods are becoming increasingly important in microwave devices.

A substrate-integrated waveguide (SIW) is formed in a dielectric substrate by densely arraying metallized posts or via holes that connect the upper and lower metal plates of the substrate. It is also referred to as a post-wall waveguide or laminated waveguide. Through-hole fabrication processes, including via fences for the post walls, make it simple and inexpensive to mass produce the waveguide. With an equivalent guide wavelength, SIW is known to have guided wave and mode properties that are identical to those of a traditional rectangular waveguide. High-performance millimeter-wave systems have become more necessary with the development of new communication technologies in the 1990s. They need to be dependable, affordable, portable, and high-frequency compatible. Sadly, the well-known microstrip and coplanar lines technologies cannot operate over 10 GHz. Due to magnetic wall shielding, SIW applications with circular polarization, high gain, phase correction, reduced side lobe levels, and bandwidth enhancement are more appealing antenna for SIW. A Microstrip patch antenna is an antenna that is created by etching away an area of conductive material from a dielectric surface. The ground plane, which serves as the foundation for the entire construction, is where

the dielectric material is installed. Feed wires connecting through the patch are also used to excite the antenna. It is also referred to as a microstrip antenna or a printed antenna since it is constructed on a printed circuit board using a microstrip technology. Patch antennas are typically utilized for microwave frequency applications with frequency more than 100 MHz and are regarded as low-profile antennas.

Using the integrated substrate waveguide (ISW) technology, a multiband antenna is created for wireless applications. Slots have been incorporated onto a square patch cavity to create this antenna for quad band radiation. The innermost and square patch cavity inverted U-shaped slots of the proposed antenna are controlled by an inset microstrip feed line. Cavity modes are available with the square patch ISW cavity supported antenna. Using HFSS software, the optimization method has been used to improve the performance of the antenna. The planned antenna, which is constructed on a cheap FR-4 substrate, has a small dimension of 25251.6mm³. The manufactured antenna has been measured to verify the simulated equivalent.

1.1 ANTENNA

An Antenna is a transducer, which converts electrical power into electromagnetic waves and vice versa.

An Antenna can be used either as a transmitting antenna or a receiving antenna.

- A transmitting antenna is one, which converts electrical signals into electromagnetic waves and radiates them.
- A receiving antenna is one, which converts electromagnetic waves from the received beam into electrical signals.
- In two-way communication, the same antenna can be used for both transmission and reception.

Antenna can also be termed as an Aerial. Plural of it is, antennae or antennas. Nowadays, antennas have undergone many changes, in accordance with their size and

shape. There are many types of antennas depending upon their wide variety of applications.

In the field of communication systems, whenever the need for wireless communication arises, there occurs the necessity of an antenna. Antenna has the capability of sending or receiving the electromagnetic waves for the sake of communication, where you cannot expect to lay down a wiring system. The following scenario explains this. In order to contact a remote area, the wiring has to be laid down throughout the whole route along the valleys, the mountains, the tedious paths, the tunnels etc., to reach the remote location. As shown in the fig 1.1 The evolution of wireless technology has made this whole process very simple. Antenna is the key element of this wireless technology.

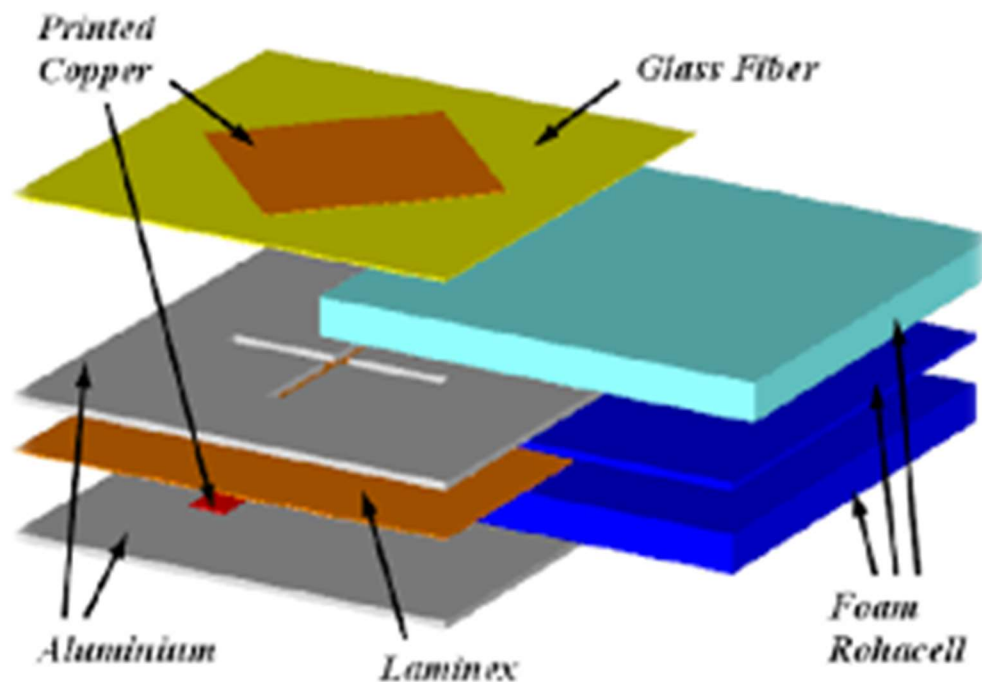


Fig: 1.1 Antenna Structure

1.1.1 BASIC TYPES OF ANTENNAS

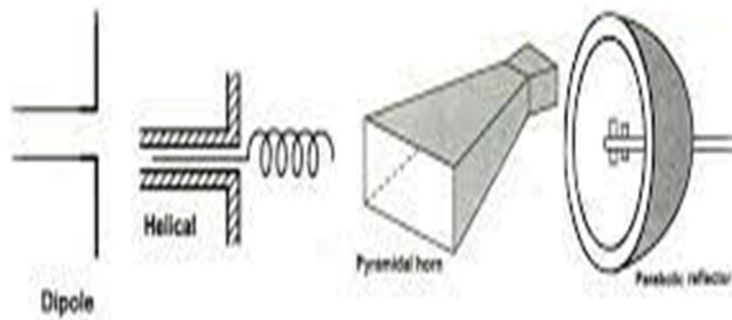


Fig: 1.2 Antenna types

As shown in the fig 1.2 Antennas may be divided into various types depending upon

- The physical structure of the antenna.
- The frequency ranges of operation.
- The mode of applications etc.

Physical structure

Following are the types of antennas according to the physical structure. You will learn about these antennas in later chapters.

- Wire antennas
- Aperture antennas
- Reflector antennas
- Lens antennas
- Micro strip antennas
- Array antennas

Frequency of operation

Following are the types of antennas according to the frequency of operation.

- Very Low Frequency (VLF)
- Low Frequency (LF)
- Medium Frequency (MF)

- High Frequency (HF)
- Very High Frequency (VHF)
- Ultra High Frequency (UHF)
- Super High Frequency (SHF)
- Micro wave
- Radio wave

1.1.2 APPLICATIONS OF ANTENNA

- Vehicular
- Airborne
- Communications
- SIGINT (signal intelligence)
- ISR (Intelligence, Surveillance, and reconnaissance)

1.2 PROBLEM STATEMENT

For ISM, WiMAX, C-band, and RFID applications, a miniature cavity-backed antenna loaded with slots is created utilizing the substrate integrated waveguide (SIW) technology. This antenna's hexagonal cavity for quad band radiation has slots built into it. An inset microstrip feedline controls the proposed antenna's hexagonal cavity, innermost inverted U-shaped slot, and outermost inverted U-shaped slot. We are using the integrated substrate waveguide (ISW) technology, a multiband antenna is created for wireless applications.

Slots have been incorporated onto a square patch cavity to create this antenna for quad band radiation. The innermost and square patch cavity inverted U-shaped slots of the proposed antenna are controlled by an inset microstrip feed line. Cavity modes are available with the square patch ISW cavity supported antenna. Using HFSS software, the optimization method has been used to improve the performance of the antenna, which is constructed on a cheap FR-4 substrate. The manufactured antenna has been measured to verify the simulated equivalent.

1.3 OBJECTIVE

This antenna has been developed by embedding slots onto a square patch cavity for quad band radiation. The proposed antenna possesses square patch cavity inverted U-shaped slot and innermost inverted U-shaped slot, which are governed by an inset microstrip feedline. The square patch ISW cavity backed antenna offers cavity modes. The optimization method has been performed to enhance the performance of the antenna using HFSS software. The designed antenna has a compact size, which is fabricated on a low-cost FR-4 substrate. To validate the simulated equivalence, the fabricated antenna has been measured.

1.4 SUMMARY

The project aims to design and analyze microstrip patch antennas for a specific application or frequency band, such as Wi-Fi, cellular communication, or satellite communication.

Design and Simulation: The project involves using software tools like computer-aided design (CAD) software or electromagnetic simulation software to design and simulate the microstrip patch antenna. The design parameters may include the shape, size, substrate material, feeding technique, and impedance matching network.

Fabrication: Once the antenna design is finalized, the project may involve the fabrication of the microstrip patch antenna on a PCB or other suitable substrate material using standard PCB manufacturing techniques, such as etching or printing.

Testing and Performance Evaluation: After fabrication, the microstrip patch antenna is tested and evaluated for its performance characteristics, such as return loss, bandwidth, radiation pattern, gain, and efficiency. The project may involve using specialized equipment like network analyzers, spectrum analyzers, and anechoic chambers for testing and measurement.

Analysis and Optimization: Based on the test results, the project may involve analyzing the performance of the microstrip patch antenna and optimizing its design

to meet the desired specifications or requirements. This may include fine-tuning the antenna parameters, adjusting the feeding technique, or improving the impedance matching network to enhance the antenna's performance.

The summary of the microstrip patch antenna project may conclude with a summary of the design, fabrication, testing, and performance evaluation results. It may also highlight the significance of the project's findings, potential applications, and future work, such as further optimization or integration with other systems.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Many people done projects on antenna different ways. Here we have collected some references. And we came up with a project which implements the Multi-band integrated substrate antenna for wireless application. Here we listed some of the references related to waveguide antenna for wireless application.

Samson Danial. R (2021), et al., proposed by using a miniaturized cavity-backed antenna loaded with slots is designed using substrate integrated waveguide (SIW) technique for ISM/ Wi-MAX /C-band/RFID applications. This antenna has been developed by embedding slots onto a hexagonal cavity for quad band radiation. The proposed antenna possesses hexagonal cavity, inverted U-shaped slot and innermost inverted U-shaped slot, which are governed by an inset micro strip feed line. The hexagonal SIW cavity-backed antenna offers cavity modes TM₁₁₀ at 4.16 GHz and TM₂₁₀ at 5.8 GHz. To validate the simulated equivalence, the fabricated antenna has been measured. Artificial neural network (ANN) is a synthesis and analysis tool for computing mean square error (MSE) to support optimal results, which has been performed using MATLAB. This network model has input layer, hidden layer and output layer. The number of neurons in the hidden layer estimates the data samples from input layer and the evaluated samples are shifted to the output layer for generating MSE as described. After reaching data samples in the hidden layer, each neuron calculates the data samples and its result has been examined by non-linear function to obtain the desired Mean Square Error (MSE). The algorithms of MATLAB for artificial neural network have been studied to calculate MSE such as Leven berg–Marquardt, Bayesian Regularization and Scaled Conjugate Gradient. In this work, the Leven berg– Marquardt algorithm has been utilized for better optimization performance. The designed antenna offers quad band resonance at 2.4, 3.33, 4.16, and 5.8 GHz, respectively. The lower resonance frequencies (at 2.4 and at 3.33 GHz) are created due to slots and other

two resonances (at 4.16 and at 5.8 GHz) are created due to conventional cavity. Therefore, the different parameters of the physical values such as inverted U-shaped slot (L1), Length of the innermost inverted U-shaped slot (L2) and feed width (Wf) have been optimized by the artificial neural network, which is illustrated. By amending the parameters of the physical values L1, L2, W f & P, the collection of 3000 samples have been synthesized by A soft High Frequency Structure Simulator (HFSS) software. The comparison between the various training algorithms is exposed, which represents the Leven berg–Marquardt algorithm yields the minimum mean square error compared with other training algorithms. Therefore, it is chosen as best performer for better optimization performance. The experimental results of the fabricated antenna have been vindicated by simulated results. Both results are endorsed in good agreement. The tested planar antenna provides multiband, reduced cross-polarization, suitable far-field patterns and gain for 2.38 GHz ISM, 3.33 GHz, Wi MAX, 4.22 GHz C-band and 5.8 GHz RFID applications with compact size.

Muddineni Raveendra (2021), et al., proposed an ultimate goal of this work is to design a suitable SIW antenna for Ku band and K band applications. A copper has been used between the ground and patch surface to improve the number of resonating frequency bands of the investigated antenna. The working effectiveness of the antenna is analyzed with the help of the properties of return loss, VSWR, bandwidth and its radiation patterns. The proposed parametric analysis offers resonance frequencies. In recent year's substrate integrated waveguide antennas are becoming more popular due to their outstanding feature such low loss, high bandwidth with good radiation properties at high frequency bands. A segue squared structure slot has been employed on the patch surface with different dimensions of the slot to achieve the good return loss characteristics performance. It has been observed that during the change in slot width on patch surface the proposed antenna offers at least five resonating frequency bands at each parametric analysis without Compromising its other features. And copper has been inserted to achieve multiband performance. The length and width of the feeding structure were adjusted

to match antenna impedance. Micro strip line has been considered for designing power feeding structure since it is easy to tune its dimensions to match the impedance characteristics. As the requirement of the high data rate in wireless communication systems compel the scientists and industries to the exploration of lower wavelength to defeat the boundaries of frictional bandwidth of the existing bands. It is easy to realize antennas for good bandwidth at desired frequency using SIW structures. The general hitch of the feed set up needs a comparatively convoluted that increases the dimension of the structure. To overcome this drawback substrate integrated waveguides techniques can be used. Seventeen resonating bands at K band Ku band wavelengths on the electromagnetic spectrum has been analyzed including with their radiation performances. The ultimate goal of this antenna is used for different applications of Ku-band & K band wavelength applications.

Jin-ping Zhang and (2011), et al., proposed a substrate integrated waveguide (SIW) slot antenna for 79GHz applications is proposed. In order to get the high gain and lower losses, the antenna is designed as a sub-array composed with eight slots, which fabricated in the wide side plane of the SIW, and placed along the central axis with the equal interval of half waveguide wavelength. The slots can radiate the electromagnetic energy through the field disturbance caused by the plated-through hole (PTH) positioned beside the slots. The antenna is fed by the 50 coaxial-fed structure located from the bottom of SIW. This bottom-fed method is different from the traditional micro strip feeding method, it has more convenience to extend the 2- dimensional phased array through multiple independent sub arrays in the 79-GHz applications. The simulated results of the sub array indicate that the frequency band with $|S_{11}| < -10\text{dB}$ is from 78GHz to 80GHz, and the cross-polarization is lower than -50dB. An array model with sub arrays is also fabricated and simulated, it is found that the array radiation efficiency can be evaluated larger than 80%, and the patterns are also extremely well qualified. The performances confirm that the proposed SIW slot antenna is suitable for the millimeter-wave electronic systems with the requirement of array antenna.

Shibu Ghosh and (2019), et al., proposed to create a substrate integrated waveguide by using Horn Antenna (Design of H-Plane X-Band Horn Antenna). A 'Substrate Integrated Waveguide H Plane Horn Antenna' is designed for operating specifically in X Band i.e. from major 8.2 GHz-12.4 GHz. The antenna is designed and simulated by using the ANSYS-HFSS Software with FR-4 or typically 'Flame Retardant-4' as the substrate. The authors have done analysis where it obtained a bandwidth of 250 MHz with an ideal antenna size & showed out the classical behavioral as a front of a 'perfect antenna'. All the simulations are carried out by using the Full Wave Simulator termed ANSYS-HFSS as known to be High Frequency Structure Simulator. As a virtue of it, the main implementation is shifted on the Wireless Communication Domain. The microwave antennas are designed using micro strip circuits which has ideal features like low cost, smaller size and can be easily integrated. But these micro strip circuits when operated at higher frequencies shows some undesirable radiation loss. In order to avoid such conditions waveguide circuits are used which shows minimum radiation loss but it has got its own demerit of not being easily integrated as compared to micro strip circuits. So an emerging type of technology called Substrate Integrated Waveguide is introduced which extracts the merits from both the waveguide and the micro strip circuit. It has the advantage of micro strip which has compact size and easy integration and the waveguide which gives low radiation loss. SIW implements a waveguide on a printed circuit board by using two rows of metallic posts. The disadvantages of horn antenna like big size and three-dimensional structure can be overcome by using SIW technology to design the horn. The authors had first designed the Rectangular Substrate Integrated Waveguide where it achieved the classic behavioral of a waveguide on which the Horn Antenna is taken to design by using 'appropriate flare angle' with preferred out 'aperture length'. On the account of it, a simple H-Plane Horn Antenna is designed out satisfying the fundamental needs of Wireless Communication Domain. An "H-plane Horn Antenna" using Substrate Integrated Waveguide (SIW) technology is being successfully designed using the prolific 'HFSS Software' which shows all the desired parameters as discussed above as that of an 'ideal antenna' and works in the X-band. The

characteristics of the antenna can be further enhanced by using the concept dielectric loading for the horn which is one of the future applications the authors are trying to incorporate and after achieving them the fabricated prototype would be revealed out. In all, the major concerns are addressed for Wireless Communication Domain.

Soumava Mukherje (2018), et al., proposed a novel design technique for broadband substrate integrated waveguide cavity-backed slot antenna is demonstrated in this letter. Instead of using a conventional narrow rectangular slot, a bow-tie-shaped slot is implemented to get broader bandwidth performance. The modification of the slot shape helps to induce strong loading effect in the cavity and generates two closely spaced hybrid modes that help to get a broadband response. The slot antenna incorporates thin cavity backing in a single substrate and thus retains low-profile planar configuration while showing unidirectional radiation characteristics with moderate gain. A fabricated prototype is also presented that shows a bandwidth of 1.03 GHz (9.4%), a gain of 3.7 dB over the bandwidth, 15 dB front-to-back ratio, and cross-polarization level below 18 dB. Several techniques to improve the bandwidth of the SIW cavity backed slot antenna are reported in recent years. In, a via hole is placed above the slot to modify its electrical length and thus to add a second resonance to improve the bandwidth. Another method of enhancing bandwidth and efficiency is proposed, where the dielectric substrate is removed under the slot to change the effective and to increase the bandwidth. However, all these techniques lead to a fractional bandwidth up to 2.16%, which is still narrowband. Finally, in, a rectangular slot of much higher length is used in a rectangular-shaped cavity to generate hybrid modes, which helps to increase the operational bandwidth of the antenna up to 6.3%. Studies on this type of antenna reveal that it has potential to exhibit 20%–36% bandwidth with proper design of feeding network. A broadband substrate integrated cavity-backed bow-tie slot antenna is implemented in this letter. The proposed antenna replaces a conventional narrow rectangular slot with a bow-tie shaped slot and is excited by a simple GCPW feeding technique. The loading effect due to placement of the bow-

tie-shaped slot on the top of the cavity can be adjusted by optimizing the dimensions of the slot to generate two closely spaced hybrid modes. These two resonances lead to a broadband response of 9.4%, which is much higher than that of the conventional SIW cavity backed slot antenna (1.7%). The proposed antenna is fabricated in a single substrate using standard PCB technologies and thus maintains its low profile while retaining the advantages of unidirectional radiation pattern of conventional cavity backed antenna.

Elavarasi. C (2018), et al., proposed a study and design the antenna is printed on the Flame Retardant- grade 4 dielectric substrate of 12 mm x 20 mm by Relative-Permittivity of 4.4 with a thickness of 1.6 mm. To endorse multiband quality, mixture of fractal geometries is placed on the face side of the rectangular patch resonator, Split ring Meta material resonator is fixed back side of the FR4, outstanding to this the additional resonances be attained. The antenna scheme at Multi vends, layer at 2.55 GHz, 3.17 GHz on S band, 5.46 GHz, 6.51 GHz on C band with 10.37 GHz on X band covering WLAN IEEE802.11/ Radio Frequency Identification/ satellite/ microwave relay/ HYPER-LAN 2/ Radar band. All constraints of the planned antenna be simulated and measured result shows with the intention of highflying performance, high desirable S11, and supreme radiation pattern along with fair gain across the functioning band. Contrasting category of the design part to a variety of client needs to be evidence. These invent contain versatile formation which craft them difficult on the way to mix with WLAN scheme. A countless variety of planar multiple band antenna has been reported in reviews. The pro t via fractal antenna is to facilitate the large elective length along with the contour of its contour container produce a capacitance and inductance to be assisted, to fit the antenna. In the center of value to the geometry, fractals cover geometrical figure which are self-similar in addition to replicate themselves at the original set of scales. Meta materials are artificial matter with the intention of increasing the radiation primacy of the antenna. The proposition and revision of a multiple band KC and MC fractal antenna cover subsist recognized. The KC plus MC patch among ACS-fed SRR antenna meant for numerous frequencies.

Wenlei Wang (2017), et al., proposed a multi-mode resonator featuring low loss and low profile, is suitable for the implementation of circularly polarized (CP) antennas. By embedding CP patches into SIW cavities, radiation nulls can be generated by the modes of SIW cavity and the mixed electric and magnetic coupling between the patch and SIW cavity, simultaneously, to form filtering responses. By adopting these filtering mechanisms, three examples of SIW cavity-backed filtennas are proposed and studied. A wideband single-layer dual-CP SIW cavity-backed patch filtenna with an out-of-band rejection level over 13 dB is achieved. The radiation nulls are realized by the TE₁₁₀ mode of the SIW cavity and the mixed coupling between the patch and the cavity. Then modified perturbations are used in our second work to reduce the frequency of TE₂₂₀ mode of the SIW cavity to improve the high band side roll-off characteristics. The dual-CP SIW cavity-backed filtenna is implemented by employing a corner-excited square SIW cavity operating at the degenerated TE₁₂₀/TE₂₁₀ modes. with the slot perturbation, these two SIW cavity modes can be split to generated CP radiation. By embedding a square CP patch, the AR bandwidth can be significantly improved. Using SIW cavity-backed patch antennas and the multi modes of the SIW cavities to achieve CP filtennas with wide bandwidth and good filtering performance is an effective approach. A comparison of the proposed three filtennas with other published CP filtennas is given in Table I. As compared, Antenna I is a single-fed dual-CP filtenna, which has an edge in wideband, single-layer structure, and compact size. Antenna is a 2 × 2 CP filtenna array. As no extra filtering circuits are required, Antenna II features simple design with high antenna gain, wide operating band and good filtering performance.

Zhen Peng (2017), et al., proposed a multi-object detecting and tracking without blindness exhibits potential applications in wireless communication and radar systems. The beam scanning rate is a key indicator to measure the scanning performance of LWA. However, the high scanning rate dual-beam LWA with continuous scanning is sel-dom considered in the published literatures. Defined first as the sum of the scanning rate of each beam in this article, a novel asymmetrical

dual-beam LWA with a high scanning rate of 12.9 is then proposed based on the combination of half-mode substrate integrated waveguide (HMSIW)-surface plasmon polaritons (SPP) structure and sinusoidally modulated reactance superposing surface (SMRSS) technique. The high scanning rate is attributed to the dispersion enhancement of the slotted HMSIW-SPP unit, while periodic modulation superposed and uniform slots etched on the top and bottom layer respectively contribute to the asymmetrical dual-beam continuous scanning. Planar leaky wave antenna (LWA) is an excellent candidate for radar and wireless communication systems due to the merits of frequency-dependent beam scanning, attractive directivity, low cost, and simple feeding. In this article, based on the combination of HMSIW-SPP unit and SMRSS technique, a compact dual-beam LWA with merits of high scanning rate and asymmetrical dual-beam scanning without blindness is proposed. By enhancing the dispersion response of the HMSIW-SPP unit, the scanning rate performance is improved. According to SMRSS principle, a series of slots etched on the top layer of HMSIW is modulated for the realization of two asymmetrical beam radiation, while a series of slots is etched on the bottom layer with an offset against the top ones to mitigate the OSB effect, leading to a seamless beam scanning from backward to forward along with bore sight. As a result, the proposed LWA radiates two beams with a wide scanning range from -65° to -2° and from -6° to $+51^\circ$ within the operating band of 8.65 GHz - 9.5 GHz.

Ashutosh Srivastava (2017), et al., proposed a C-shaped structure is constructed using slot region oriented along the longitudinal as well as the transversal directions to feed line. A C-shaped circular slot SIW antenna is designed and fabricated to achieve larger bandwidth, higher gain and low cross polarization level. The designed C-shaped circular slot SIW antenna produces dual band measured response in the frequency range of 11.05 GHz to 11.30 GHz and 12.80 GHz to 13.30 GHz, with the center frequencies of 11.19 GHz, and 13.06 GHz, respectively. At these center frequencies measured gain is 8.81 dB and 8.70 dB, respectively. To design a C-shaped circular slot SIW antenna to achieve higher

gain, larger bandwidth and low cross polarization level. The C-shaped circular slot SIW antenna designed for X band and Ku-band applications. The Designed SIW slot antenna is applicable for narrow band and high gain applications. The C-shaped circular slot SIW antenna shows dual-band response at 11.19 GHz and 13.06 with bandwidth of 2.45% and 3.01% respectively. The gain at 11.19 GHz is 8.81 dBi, while at 13.06 GHz gain is 8.70 d. The response of the C-shaped circular slot SIW antenna is better than that of the L-shaped slot SIW antenna.

Issam Zahraoui (2018), et al., proposed a CPW-Fed multi bands planar antenna. The design takes into account that this structure can be integrated with circuits behind, that why the Fed is a CPW one. The antenna validated is suitable for GSM, DCS and ISM band. The entire area of the antenna is 36x72.5 mm² and it is printed on an FR4 substrate. The printed V-shaped antenna is formed from two horizontal arms of different lengths and an L-shaped shorted strip which is connected between the vertical arm and the ground plane. The antenna is designed, optimized, and miniaturized by using ADS" Advanced Design System" and the results are compared with CST Microwave Studio. Global system for mobile communication (GSM), digital cellular system (DCS) and industrial scientific and medical (ISM), there is an increasing requirement for antennas having low profile, small size and multi-bands. The antennas having small size are required for mobile phone applications and wireless integrated systems. For such applications, coplanar waveguide CPW-fed planar structures have many attractive features, such as having a single metallic layer for the feed network and the antenna element and easy integration with passive and active elements.

2.2 SUMMARY

A study on the conception and design of a novel CPW-Fed planar multi bands antenna structure for mobile phone applications. The antenna is validated into simulation by using two electromagnetic software ADS and CST Microwave studio. An inset microstrip feedline controls the proposed antenna's hexagonal cavity, innermost inverted U-shaped slot, and outermost inverted U-shaped slot.

CHAPTER 3

EXISTING METHODOLOGY

3.1 INTRODUCTION

For ISM, WiMAX, C-band, and RFID applications, a miniature cavity-backed antenna loaded with slots is created utilizing the substrate integrated waveguide (SIW) technology. This antenna's hexagonal cavity for quad band radiation has slots built into it. An inset microstrip feedline controls the proposed antenna's hexagonal cavity, innermost inverted U-shaped slot, and outermost inverted U-shaped slot as shown in the fig 3.1. The cavity modes available from the hexagonal SIW cavity-backed antenna are TM_{110} at 4.16 GHz and TM_{210} at 5.8 GHz. For the purpose of gaining antenna miniaturization, two inverted U-shaped slots are added to the cavity's upper metallic surface. These lower resonance frequencies are created by the coupling of hybrid modes at 3.33 GHz and hybrid mode at 2.4 GHz. Optimization of ANN method has been performed to enhance the performance of the antenna using MATLAB. The designed antenna has a compact, which is fabricated on a low-cost FR-4 substrate. To validate the simulated equivalence, the fabricated antenna has been measured. It yields a fractional bandwidth of 5.04% (2.31– 2.43 GHz) in the hybrid mode at 2.38 GHz, 6% (3.22– 3.42 GHz) in the coupling of hybrid mode at 3.33 GHz, 19.19% (3.97– 4.78 GHz) in the cavity mode TM_{110} at 4.22 GHz and 7.2% (5.69–6.11 GHz) in the cavity mode TM_{210} at 5.8 GHz with stable radiation pattern.

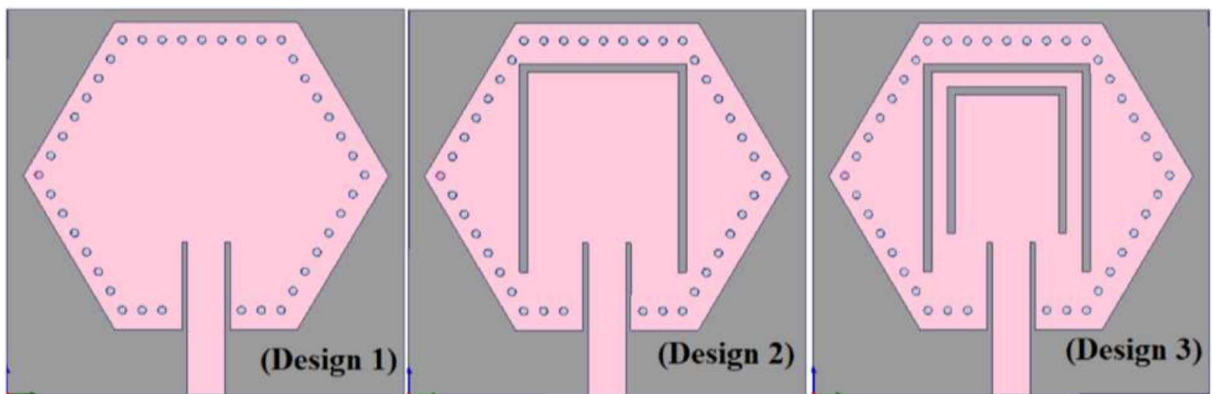


Fig: 3.1 Existing Antenna Design

3.1.1 DRAWBACKS OF EXISTING METHODOLOGY:

- In existing work, the antenna would have less power consume because of impedance mismatch.
- The antenna loss was very maximum
- Antenna efficiency less than 90%.

3.2 SUMMARY

The project focuses on the design and fabrication of a miniature cavity-backed antenna that is loaded with slots using the substrate integrated waveguide (SIW) technology. The antenna design is based on the concept of a cavity-backed structure, where the antenna is placed within a cavity formed by the substrate and a metallic backplane. The antenna is loaded with slots, which are strategically placed to enhance its performance. The SIW technology, which involves integrating waveguides into a printed circuit board (PCB) substrate, is used to realize the antenna structure. The project may involve theoretical analysis, simulation, fabrication, and testing of the antenna to evaluate its performance characteristics, such as bandwidth, radiation pattern, gain, and efficiency. The goal of the project is to create a miniature cavity-backed antenna with improved performance using the SIW technology and slots, which could have potential applications in wireless communication, radar systems, and other microwave or millimeter-wave systems. The summary of the project may highlight the key aspects of the antenna design, fabrication, and testing, as well as the significance of the findings and potential future work in this area.

CHAPTER 4

PROPOSED METHODOLOGY

4.1 INTRODUCTION

An antenna is designed using multi-band in substrate integrated waveguide (SIW) technique for wireless applications. This antenna is has been developed by multi band ISW antenna for wireless application. A multiband antenna is designed to operate in multiple bands of frequencies. Multiband antennas use a design in which one part of the antenna is active for one band, while another part is active for a different band. Using the integrated substrate waveguide (ISW) technology, a multiband antenna is created for wireless applications. Slots have been incorporated onto a square batch cavity to create this antenna for quad band radiation. The innermost and square patch cavity inverted U-shaped slots of the proposed antenna are controlled by an inset microstrip feed line. Cavity modes are available with the square patch ISW cavity supported antenna. Using HFSS software, the optimization method has been used to improve the performance of the antenna, which is constructed on a cheap FR-4 substrate. The manufactured antenna has been measured to verify the simulated equivalent.

4.1.1 PROPOSED ANTENNA DESIGN MODEL:

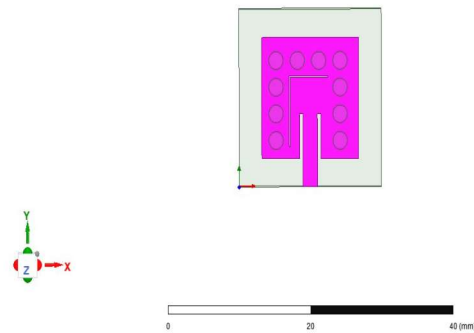


Fig: 4.1 Proposed antenna design model-front side

As shown in the fig 4.1 known as proposed square patch U shaped antenna design model-front side. We will apply SIW technology for wireless purposes in this project.

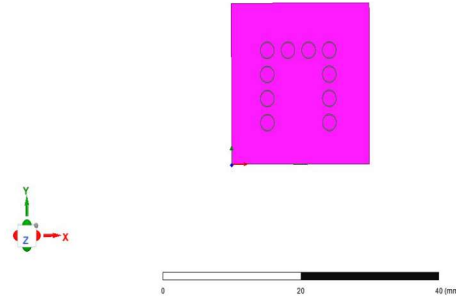


Fig: 4.2 Proposed antenna design model-back side

As shown in the fig 4.1 known as proposed square patch U shaped antenna design model-back side. We will apply SIW technology for wireless purposes in this project.

4.2 AIM OF PROPOSED METHODOLOGY

An antenna is designed using multi-band in substrate integrated waveguide (SIW) technique for wireless applications. This antenna is has been developed by multi band ISW antenna for wireless application. A multiband antenna is designed to operate in multiple bands of frequencies. Multiband antennas use a design in which one part of the antenna is active for one band, while another part is active for a different band. The wireless application method has been performed to enhance the performance of the antenna using HFSS software. The designed antenna has a compact size which is fabricated on a low-cost FR-4 substrate. To validate the simulated equivalence, the fabricated antenna has been measured.

4.3 SCOPE OF PROPOSED METHODOLOGY

- In Proposed work, the antenna would have less power consume because of impedance match.
- The antenna loss was very minimum
- Antenna efficiency more than 90%.
- The substrate waveguide antenna could be integrated with other wireless technologies, such as Bluetooth, Wi-Fi, or 5G, to provide a more comprehensive wireless communication system. This would require developing the necessary hardware and software interfaces to enable seamless integration.

4.4 SUMMARY

Integrated substrate waveguide antennas are a type of antenna that is commonly used in wireless communication systems. They are designed to operate at high frequencies and are typically used in applications such as radar systems, satellite communication, and microwave systems. These antennas are constructed by embedding a waveguide structure into a substrate material such as silicon or printed circuit board (PCB). The waveguide structure guides the electromagnetic waves along the substrate, and the radiating element is usually located at the end of the waveguide. This design provides a compact and efficient antenna solution for high-frequency wireless applications.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 INTRODUCTION

A substrate-integrated waveguide (SIW) is formed in a dielectric substrate by densely arraying metallized posts or via holes that connect the upper and lower metal plates of the substrate. It is also referred to as a post-wall waveguide or laminated waveguide. Through-hole fabrication processes, including via fences for the post walls, make it simple and inexpensive to mass produce the waveguide. With an equivalent guide wavelength, SIW is known to have guided wave and mode properties that are identical to those of a traditional rectangular waveguide. High-performance millimeter-wave systems have become more necessary with the development of new communication technologies in the 1990s. They need to be dependable, affordable, portable, and high-frequency compatible.

5.1.1 MICROSTRIP PATCH ANTENNA

The ability to print microstrip or patch antennas directly onto a circuit board makes them more and more practical. The use of microstrip antennas in mobile phones is expanding rapidly. Patch antennas are inexpensive, have a small profile, and are simple to make. A microstrip transmission line feeds the microstrip antenna in Figure 5.1 as an example. High conductivity metal is used to make the patch antenna, microstrip transmission line, and ground plane (typically copper). The patch has the following dimensions: L , W , and is supported by a substrate (a dielectric circuit board) with the following thickness, h , and permittivity, or dielectric constant. It is not crucially significant how thick the ground plane or microstrip is. The height h is typically significantly smaller than the wavelength of operation, but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded.

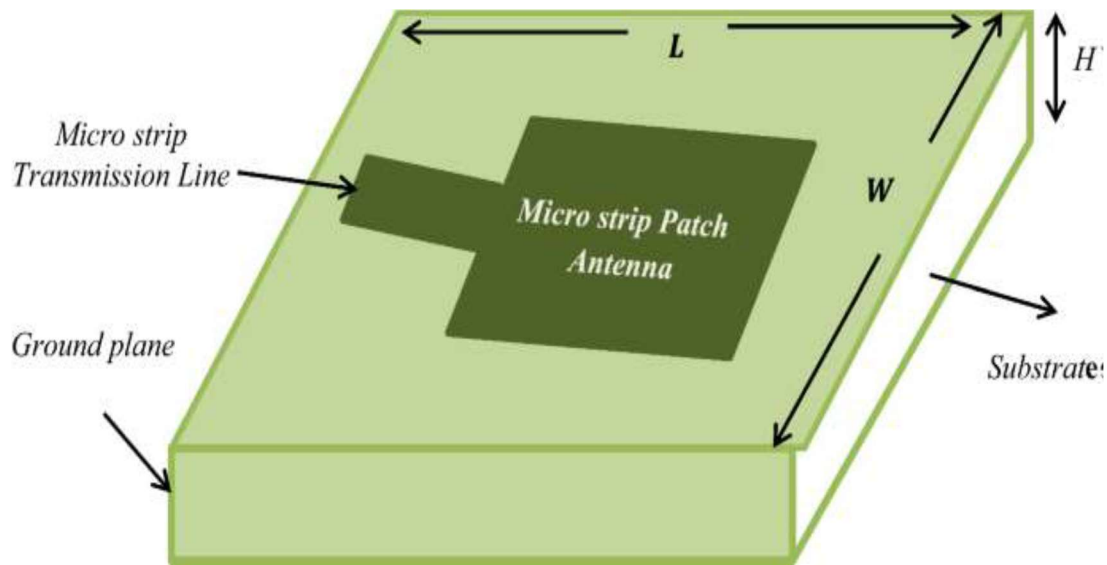


Fig: 5.1 Microstrip Patch Antenna

Patch antenna has 2D geometry. These antennas come in various shapes where its shape is defined by the shape of the metallic patch placed on the dielectric material. The patches can be rectangular, square, circular, triangular, annular or elliptical in shape. Suppose we have a rectangular patch antenna, which is formed by fabricating a rectangular metallic patch on a dielectric coated ground plane. This can be said in simple terms that a dielectric material having a conducting patch is supported by a ground plane. The figure here represents the top view of the microstrip antenna:

Here we have shown the simplest form of patch antenna where the patch etched on the substrate is half-wavelength long while the thickness of the same is extremely less than λ . Also, excitation to the antenna is provided through feed lines connected to the patch. Here the substrate which is nothing but the dielectric material is used to separate the strip from the ground plane. Basically, the patch or strip and the feed lines are photo-etched on the surface of the substrate. As we have already discussed that patches can be formed in multiple shapes, however, due to easy rectangular, circular or square-shaped patches are generally used.

Till now we have discussed a single patch etched on a substrate. But patch antennas can also be formed with a collection of multiple patches on a dielectric substrate. Either single or multiple feed lines are used to provide excitation to the antenna. The presence of arrays of microstrip elements provides greater directivity, higher gain, increased transmission range with less interference.

A microstrip or patch antenna operates in a way that when current through a feed line reaches the strip of the antenna, then electromagnetic waves are generated. The waves from the patch start getting radiated from the width side. But as the thickness of the strip is extremely small thus the waves that are produced within the substrate get reflected by the edge of the strip. The continuous structure of the strip along the length does not permit the emission of radiation. Furthermore, on experiencing a sudden discontinuity in the structure of the patch, radiations are again emitted from the second width side of the patch. As this discontinuous structure favors reflections, thus the patch antenna radiates only a small fraction of supplied incident energy. This makes the antenna inefficient, that rather displaying the characteristics of a good radiator, it somewhat acts as a cavity.

The low radiating ability of microstrip antenna allows it to cover the only small distances of wave transmissions like local offices, stores or any indoor locations. As such inefficient transmission is not supportable at a centralized location in an extremely large area.

5.1.1.1 CHARACTERISTICS OF MICROSTRIP PATCH ANTENNA

- The patch of the antenna must be a very thin conductive region, $t \ll \lambda_0$ (λ_0 free space wavelength).
- The ground plane must have comparatively very large dimensions than the patch.
- Photo-etching is done to fabricate the radiating element and feed lines on the substrate.

- A thick dielectric substrate with dielectric constant within the range of 2.2 to 12 provides good antenna performance.
- Arrays of microstrip elements in the antenna configuration provide greater directivity.
- Microstrip antennas provide high beamwidth.
- A very high-quality factor is offered by a patch antenna. A large Q results in a narrow bandwidth and low efficiency. However, this can be compensated by increasing the thickness of the substrate. However, the increase in thickness beyond a certain limit will cause an unwanted loss of power.

5.1.1.2 FEEDING METHOD OF PATCH ANTENNA

There are various methods through which the microstrip antenna is fed.

However, the classification of feeding methods is done in two ways:

- **Contacting feed:** In this method, the power is directly given to the radiating element. This is done using a microstrip or coaxial line. Thus there are two types of contacting feed:
- **Microstrip feed:** It is a conducting strip having width extremely smaller than the width of the radiating element. Due to thinner dimensions of the strip, the feed line offers easy etching on the substrate. The feed line to the structure can be provided either at the center, inset or offset.
- **Coaxial feed:** It is one of the commonly used methods for feeding the antenna. Coaxial feeding is provided to the antenna in such a way that the inner conductor is connected to the patch. While the outer conductor is attached to the ground plane.

With the variation in the position of the coaxial feed, the impedance also varies. However, connecting the feed line with the ground plane is a bit difficult as this will require drilling a hole in the substrate.

- **Non-contacting feed:** The power from the feed line is provided to the radiating element using electromagnetic coupling. The two types of non-contacting feed are:

Aperture: It is a type of electromagnetic coupling, that permits providing excitation to the radiating element without forming direct contact with it. In this method, two dielectric substrates are considered which are separated by a ground plane. The feed line is provided through the ground plane. The patch is present at the upper dielectric substrate. As the feed does not form direct contact with the radiating patch. The ground plane isolates the feedline from the radiating element. The length of the slot and the width of the feedline permits controlling. It is the most difficult method to feed the antenna. This is so because the two dielectric substrates cause difficulty in fabricating the microstrip in the structure.

Proximity: It is also known as indirect feed in which the ground plane is absent. A slot is present on the conductive surface of the antenna and coupling is provided using a microstrip line. It is easy to manufacture in comparison to an aperture coupled feed antenna. It offers low spurious radiation and the largest bandwidth.

5.1.1.3 APPLICATIONS OF MICROSTRIP PATCH ANTENNA

APPLICATIONS BASED ON COMMUNICATION:

- There are several uses for microstrip patch antenna in wireless communication. For instance, circularly polarized radiation patterns are needed for satellite communication and can be achieved using either a square patch microstrip antenna or a circular patch microstrip antenna. Circularly polarized microstrip antennae are utilized in GPS (global positioning satellite) systems. Due to their placement, they are highly pricey and quite small in size.
- Mobile communications, healthcare, and RFID (radio frequency identification) are other industries that utilize microstrip antennas. A tag and a reader are the basic components of an RFID system. It typically operates between 30 Hz and 5.8 GHz.

- Microstrip antennae operate at a frequency of 2.45 GHz in telemedicine applications. Microstrip antennae that can be worn are appropriate for wireless body area networks. A 6.7 dB gain antenna with a front-to-back ratio of 11.7 dB, and resonating at 2.45 GHz is suitable for telemedicine applications.

5.1.1.4 ADVANTAGES OF MICROSTRIP PATCH ANTENNA

- They operate at microwave frequencies where traditional antennas are not feasible to be designed.
- This antenna type has smaller size and hence will provide small size end devices.
- The microstrip based antennas are easily etched on any PCB and will also provide easy access for troubleshooting during design and development. This is due to the fact that microstrip pattern is visible and accessible from top. Hence they are easy to fabricate and comfortable on curved parts of the device. Hence it is easy to integrate them with MICs or MMICs.
- As the patch antennas are fed along centerline to symmetry, it minimizes excitation of other undesired modes.
- The microstrip patches of various shapes e.g. rectangular, square, triangular etc. are easily etched.
- They have lower fabrication cost and hence they can be mass manufactured.
- They are capable of supporting multiple frequency bands (dual, triple).
- They support dual polarization types viz. linear and circular both.
- They are light in weight.
- They are robust when mounted on rigid surfaces of the devices.

5.1.1.5 DISADVANTAGES OF MICROSTRIP PATCH ANTENNA

- The spurious radiation exists in various microstrip based antennas such as microstrip patch antenna, microstrip slot antenna and printed dipole antenna.
- It offers low efficiency due to dielectric losses and conductor losses.

- It offers lower gain.
- It has higher level of cross polarization radiation.
- It has lower power handling capability.
- It has inherently lower impedance bandwidth.
- The microstrip antenna structure radiates from feeds and other junction points.

5.1.2 SIW ANTENNA

A substrate-integrated waveguide (SIW) is formed in a dielectric substrate by densely arraying metallized posts or via holes that connect the upper and lower metal plates of the substrate. It is also referred to as a post-wall waveguide or laminated waveguide. Through-hole fabrication processes, including via fences for the post walls, make it simple and inexpensive to mass produce the waveguide. With an equivalent guide wavelength, SIW is known to have guided wave and mode properties that are identical to those of a traditional rectangular waveguide.

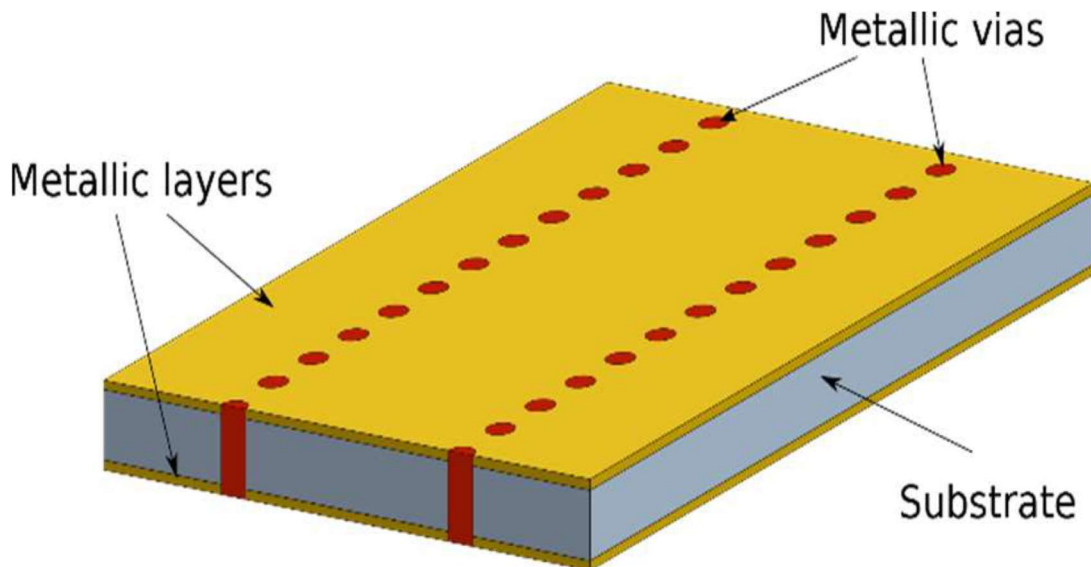


Fig: 5.2 SIW Antenna

As shown in the Fig 5.2 A thin dielectric substrate coated on both faces by a metallic layer makes up a SIW. The wave propagation area is defined by two parallel rows

of metallic through holes embedded in the substrate. The attached figure describes the geometric parameters and how the vias are organized. The distance a between a SIW's two through rows, measured from centre to centre, determines the SIW's width. To describe the wave propagation more precisely, utilize the effective width a_e . Two consecutive vias in the same row are separated by s , and d represents the diameter of the vias.

The waveguide can be easily fabricated with low-cost mass-production using through-hole techniques where the post walls consist of via fences. SIW is known to have similar guided wave and mode characteristics to conventional rectangular waveguide with equivalent guide wavelength.

Since the emergence of new communication technologies in the 1990s, there has been an increasing need for high-performance millimeter-wave systems. These need to be reliable, low-cost, compact, and compatible with high-frequencies. Unfortunately, above 10 GHz, the well-known microstrip and coplanar lines technologies cannot be used because they have high insertion and radiation losses at these frequencies. The rectangular waveguide topology can overcome these issues, as it offers an excellent immunity against radiation losses and presents low insertion losses. But in their classical form, rectangular waveguide is not compatible with the miniaturization required by modern applications

The concept of SIW was developed in the early 2000s by Ke. Wu to reconcile those requirements. The authors presented a platform for integrating all the components of a microwave circuit inside a single substrate, with a rectangular cross-section. Using a single substrate guarantees a limited volume and a simplicity of manufacture, while the rectangular cross-section of the line provides the advantages of the waveguide topology in terms of losses.

5.1.2.1 PRINCIPLE OF SIW ANTENNA

A SIW is composed of a thin dielectric substrate covered on both faces by a metallic layer. The substrate embeds two parallel rows of metallic via holes delimiting the wave propagation area. The organization of the vias and the geometric parameters are described in the attached figure.

The width of a SIW is the distance between its two vias rows a , which is defined from center to center. An effective width a_e may be used to characterize more precisely the wave propagation. The distance between two successive vias of the same row is s , and the vias diameter is denoted by d .

5.1.2.2 ADVANTAGES OF SIW ANTENNA

- Power handling capabilities are higher.
- Radiation losses are lower.
- Fabrication cost of various rf components using SIW structure is lower.
- High density integration can be achieved in mountation of discrete components on SIW structures.
- Due to use of metal, conductor loss is lower.

5.1.2.3 DISADVANTAGES OF SIW ANTENNA

- Leakage losses are substantial which depends on separation of via holes placed on the top planes.
- Due to use of dielectric into the waveguide structure, dielectric losses will occur compare to air used in normal rectangular waveguide. Moreover, it depends on frequency and hence mm wave (millimeter wave) applications of SIW need to be carefully considered.
- Due to its waveguide structure, SIW exhibits cutoff frequency of lower values.

5.2 SOFTWARE USED

Two software found in this field one of them is the high frequency structure simulator (HFSS) is a 3D electromagnetic simulation software for the purpose of designing and simulating antennas or any other high frequency electronic. Researchers and engineering use the HFSS to design and simulate those electronics to build various communication systems, internet of things (IoT) products, digital devices, and other high-speed RF systems.

This software can give unparalleled performance and deep insight to all the 3D electromagnetic problems, providing a complete analysis of the electronics products with accuracy and reliability challenges by its automatic adaptive meshing technique and precise solvers.

A set of solvers to tackle electromagnetic problems starting from passive components to analyses with large-scale. The automatic adaptive mesh designed with the software is reliable and makes the design process easier by focusing only on the design rather than spending time finding the best mesh. Another software used for antenna design is the CST Studio Suite, which is a high-performance 3D EM analysis software package for designing, analyzing and optimizing electromagnetic (EM) components and systems.

This software gives the engineers more flexibility in order to be able to analyze multiple components in an efficient and direct way. Because it can do multiple simulations, analyzation of performance and efficiency of antennas and other electromagnetics structures can be made software also the exposure of human body to the electromagnetic fields can be analyzed, which a great technology to be used to for easy simulation.

The CST MWS is based on FIT which finite integration technique. It gives the user the choice of using frequency domain approach, and the time domain approach. Hexahedral mesh type is used to have a transient analysis of the

proposed structured antenna; the user has a full control over the mesh size in CST, which make it a good competitor for the HFSS. In this work, the CST Microwave studio will be used for designing and simulating the antenna.

5.2.1 ABOUT SOFTWARE

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS software to design high-frequency, high-speed electronics found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) products.

Ansys HFSS mainly used in,

- Component-to-System EM Workflow
- Coupled EM System Solver
- Encrypted 3D Design Share
- Automatic Adaptive Meshing

Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing the strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys simulation gives engineers the ability to explore and predict how products will work or won't work in the real world. With industry-leading capabilities, Ansys enables our clients to rapidly innovate and easily validate their design ideas, empowering them to develop transformational products.

Ansys Parametric Design Language (APDL) is a powerful structured scripting language used to interact with the Ansys Mechanical solver. PyAnsys is a family of

Python packages that enable users to interact with Ansys products, including MAPDL, AEDT, and others, in an unprecedented manner. Ansys delivers the expertise, capabilities and tools to transform the design and production processes of industries ranging from automotive to energy to healthcare.



Fig: 5.3 Ansys Software logo

Ansys was founded in 1970 by John Swanson, who sold his interest in the company to venture capitalists in 1993. Ansys went public on NASDAQ in 1996. In the 2000s, the company acquired other engineering design companies, obtaining additional technology for fluid dynamics, electronics design, and physics analysis. Ansys became a component of the NASDAQ-100 index on December 23, 2019.

The idea for Ansys was first conceived by John Swanson while working at the Westinghouse Astronuclear Laboratory in the 1960s. At the time, engineers performed finite element analysis (FEA) by hand. Westinghouse rejected Swanson's idea to automate FEA by developing general purpose engineering software, so Swanson left the company in 1969 to develop the software on his own. He founded Ansys under the name Swanson Analysis Systems Inc. (SASI) the next year, working out of his farmhouse in Pittsburgh.

Swanson developed the initial Ansys software on punch-cards and used a mainframe computer that was rented by the hour as shown in the fig 5.3. Westinghouse hired Swanson as a consultant, under the condition that any code he developed for Westinghouse could also be included in the Ansys product line. Westinghouse also became the first Ansys user.

Ansys develops and markets engineering simulation software for use across the product life cycle. Ansys Mechanical finite element analysis software is used to

simulate computer models of structures, electronics, or machine components for analyzing the strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

5.3 RESULTS:

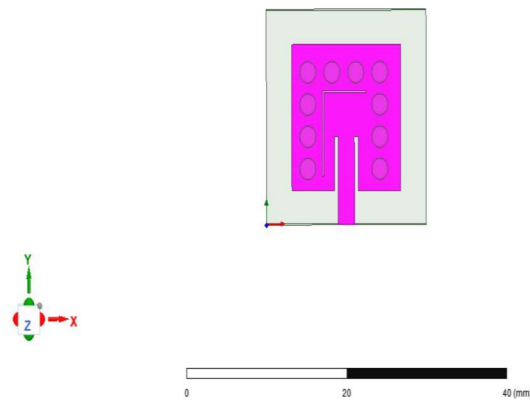


Fig: 5.4 Final multiband antenna design-front side

As shown in the fig 5.4 known as final proposed square patch U shaped multiband antenna design- front side. This is the simulated antenna design by using HFSS software.

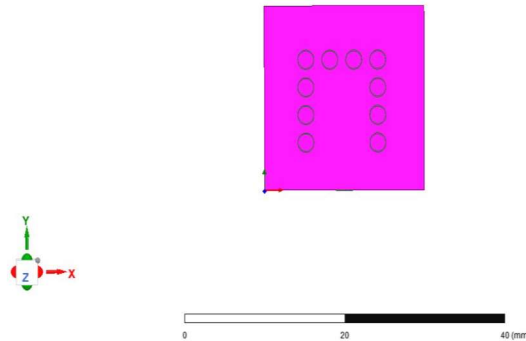


Fig: 5.5 Final multiband antenna design-back side

As shown in the fig 5.5 known as final proposed square patch U shaped multiband antenna design- back side. This is the simulated antenna design by using HFSS software.

5.3.1 S PPARAMETER PLOT:

As shown in the Fig 5.6 The input-output relationship between ports (or terminals) in an electrical system is described by S-parameters. S12, for instance, denotes the power transferred from Port 2 to Port 1 in the case of two ports (intelligently referred to as Port 1 and Port 2). Power was transported from Port 1 to Port 2 as shown by S21. In a multi-port network, SNM typically denotes the power that was transmitted from Port M to Port N. Each location where we can deliver voltage and current can be considered a port. So, the radio terminals which supply power to the two antennas would be the two ports if we had a communication system with two radios (radio 1 and radio 2). S11 would then be the radio 1's reflected power attempt. The reflected power that radio 2 is attempting to send to antenna 2 is represented by S22. And S12 is the power that radio 2 transmits to radio 1 via antenna 1.

The expression used to calculate the Active S-Parameter is

$$(S_{11} * a_1 + S_{12} * a_2)/a_1 \dots \dots \dots (5.1)$$

where a1 is the complex excitation in volts incident on Port 1 and a2 is the complex excitation in volts incident on Port 2.

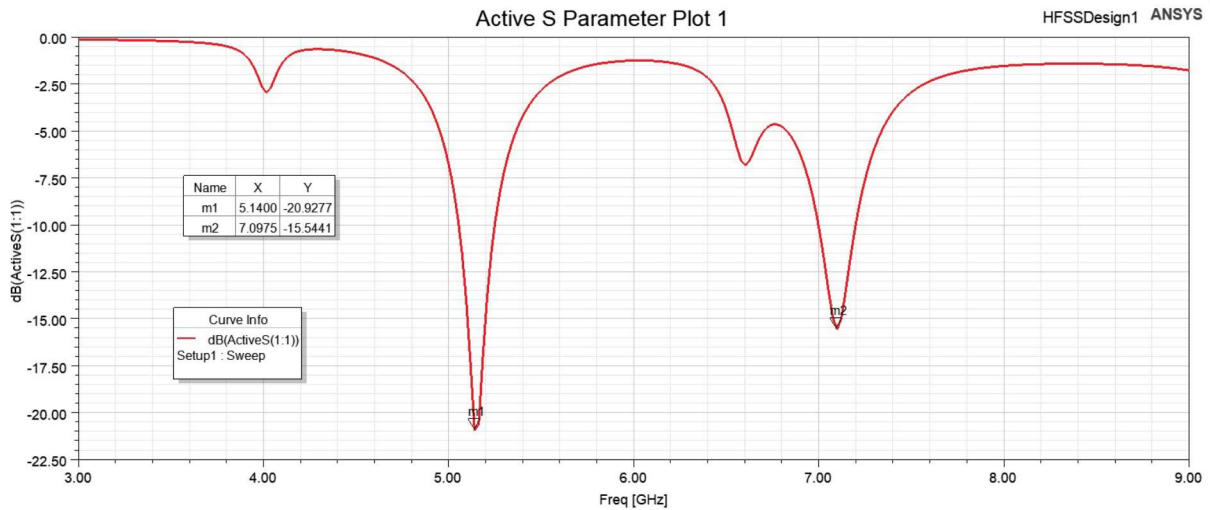


Fig: 5.6 Active S Parameter Plot

As shown in the fig 5.6 Known as an active s parameter plot, this graph. Using this active s parameter plot, we measured a variety of multiband waves and also obtained the s11 and s22 values.

5.3.2 VSWR PLOT:

The impedance of the radio and transmission line must be properly matched to the impedance of the antenna for a radio (transmitter or receiver) to supply power to an antenna. The impedance matching performance of the antenna with respect to the radio or transmission line it is linked to is quantified by the VSWR parameter. As shown in the Fig 5.7 The Voltage Standing Wave Ratio, commonly known as Standing Wave Ratio, is the abbreviation for this measurement (SWR). The reflection coefficient, which specifies the power reflected from the antenna, is a function of VSWR. The VSWR is described by the following formula.

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \dots\dots\dots(5.2)$$

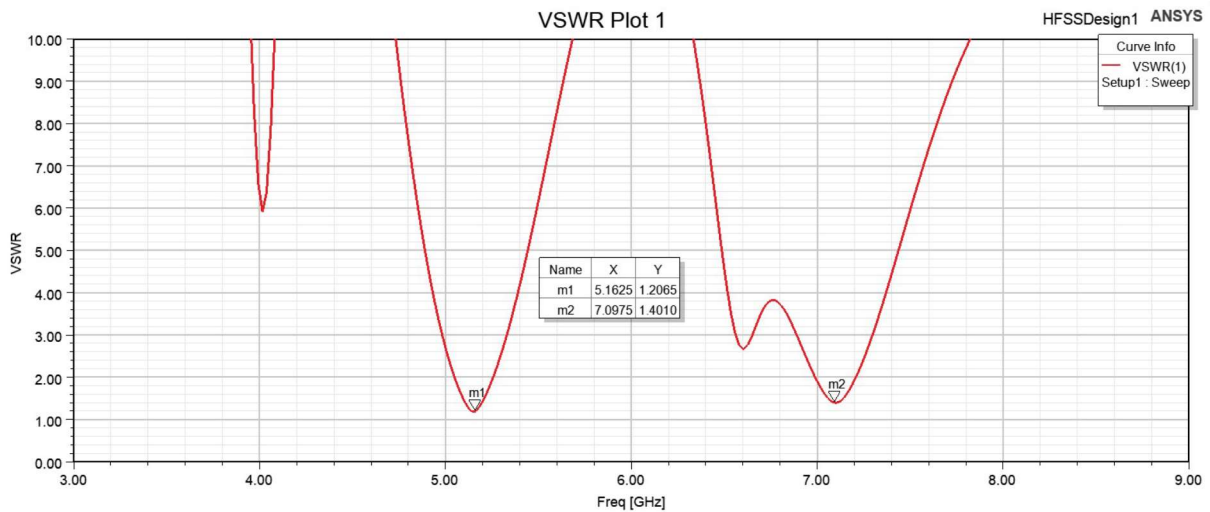


Fig: 5.7 VSWR Plot

As shown in the fig 5.7 known as Voltage Standing Wave Ratio. S11 is essentially a recommended direction to VSWR. Thus, the S11 value and frequency of the VSWR waves are shown in this graph.

5.3.3 GAIN PLOT:

The ability of an antenna to focus the power that a transmitter provides to it in the direction of a target is measured as antenna gain. Antenna gain, which is sometimes represented by the sign G, is the antenna's ability to emit radiation at a higher intensity than a lossless, isotropic radiator using the same amount of power. An isotropic radiator would broadcast half as much effective power at a target as would an antenna with a gain of 2 (3 dB), which is equivalent to double the transmitter's output power in that direction. A ship's radar antenna will normally have a gain of 30 dB. (1000).

$$G_{dB} = 10 \log_{10} (4\pi\eta A/\lambda^2) \dots \dots \dots (5.3)$$

GdB is the antenna gain,

η is the efficiency,

A is the physical aperture area,

λ is the wavelength of the signal

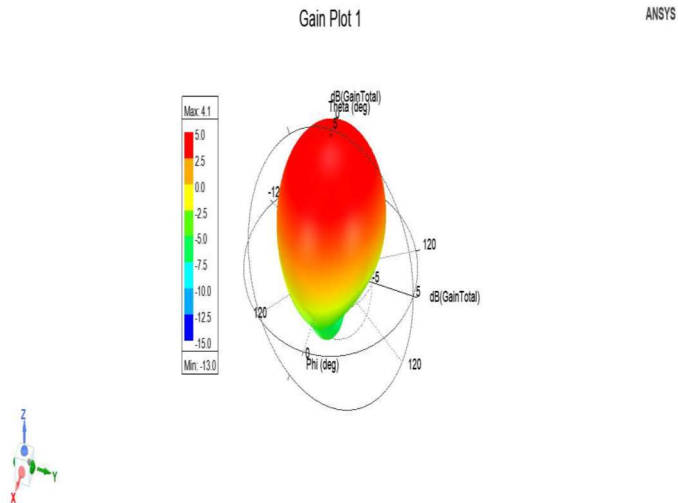


Fig: 5.8 Gain Plot1

As shown in the fig 5.8 known as gain plot of multiband antenna. The maximum antenna value in this gain plot is 4.1, while the minimum antenna value is -13.3.

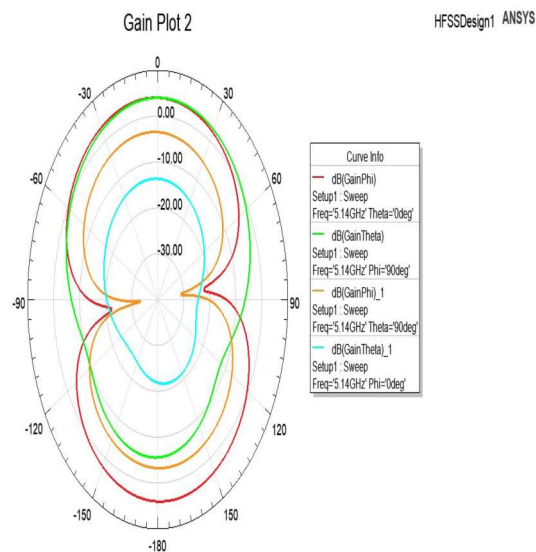


Fig: 5.9 Gain plot2

As shown in the fig 5.9 known as gain plot2 chart of square patch U shaped multiband antenna for wireless applications.

5.3.4 DIRECTIVITY PLOT:

A fundamental antenna parameter is directivity. It gauges how "directional" the radiation pattern is from an antenna. As shown in the fig 5.10 The directionality of an antenna that radiates evenly in all directions would be essentially zero, and its directivity would be 1. (or 0 Db). The only difference between a radiation pattern and a normalized radiation pattern is a scaling of the magnitude so that the maximum value of the radiation pattern's magnitude is equal to 1. The directivity (D) formula is represented mathematically as follows:

$$D = \frac{1}{\frac{1}{4\pi} \int_0^{2\pi} \int_0^\pi |F(\theta, \phi)|^2 \sin\theta d\theta d\phi} \dots\dots\dots (5.4)$$

Although the denominator of this equation for directivity simply denotes the "average power emitted over all directions," the numerator of this equation for directivity is the greatest value of F. In order to determine the directivity of the antenna, this equation simply divides the peak amount of radiated power by its average.

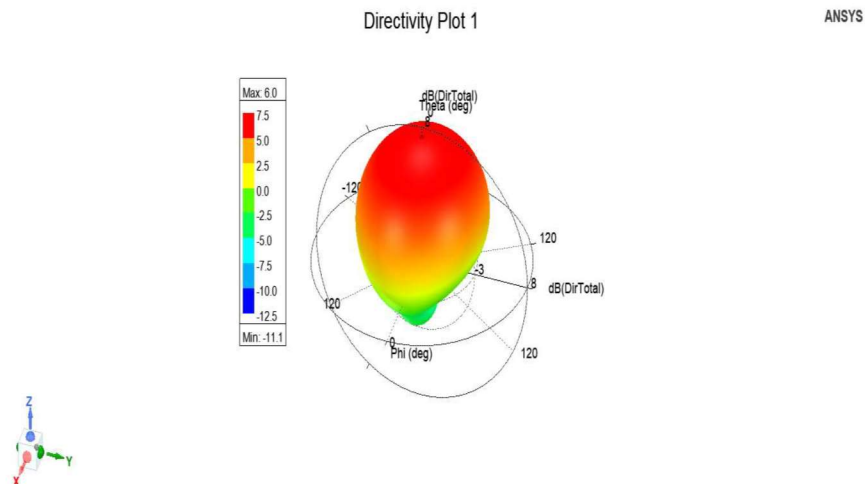


Fig: 5.10 Directivity Plot

As shown in the fig 5.10 known as directivity plot of multiband antenna. The maximum antenna value in this directivity plot is 6.0, while the minimum antenna value is -11.1.

5.3.5 S PARAMETER CHART:

An electrical system's ports (or terminals) and their input-output relationships are described by S-parameters. For example, if there are two ports (intelligently referred to as Port 1 and Port 2), S12 stands for the electricity that was transferred from Port 2 to Port 1. Power moved from Port 1 to Port 2 is shown by the signal S21. The electricity that is transported from Port M to Port N in a multi-port network is typically represented as SNM. Any location where we can deliver current and voltage can be broadly referred to as a port. As a result, if a communication system has two radios (radios 1 and 2), the radio terminals which supply power to the two antennas would be the two ports. S11 would therefore be the radio 1's attempt to represent its power.

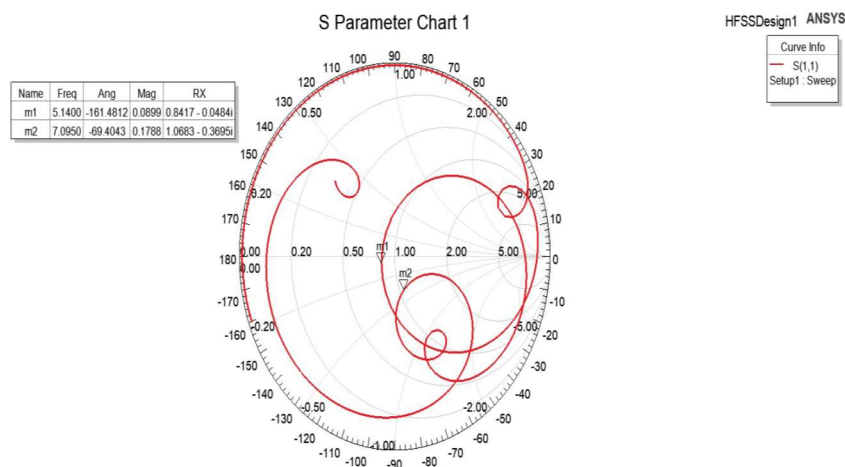


Fig: 5.11 S Parameter Chart

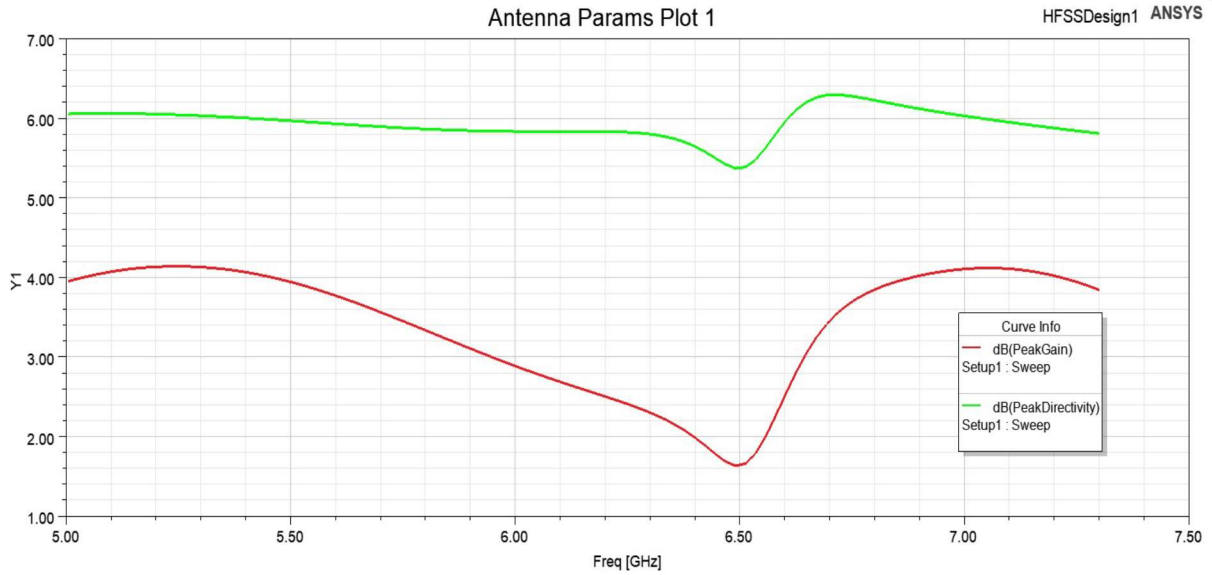


Fig: 5.12 Antenna Params Plot

As shown in the fig 6.9 known as antenna params plot. In this graph, peak directivity is indicated by the green color, and peak gain is indicated by the red color.

5.3.6 PROPOSED ANTENNA DESIGNS:

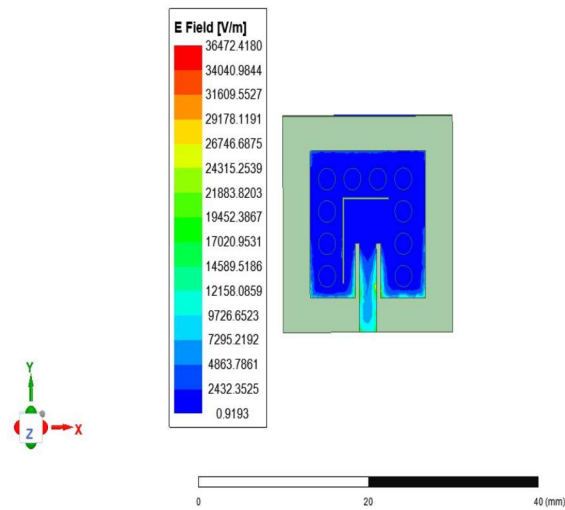


Fig: 5.13 E field design

As shown in the fig 5.13 known as Electric field design of multiband antenna. This Electric field design Charges on each part of the antenna produce a field into space between the two halves of the antenna.

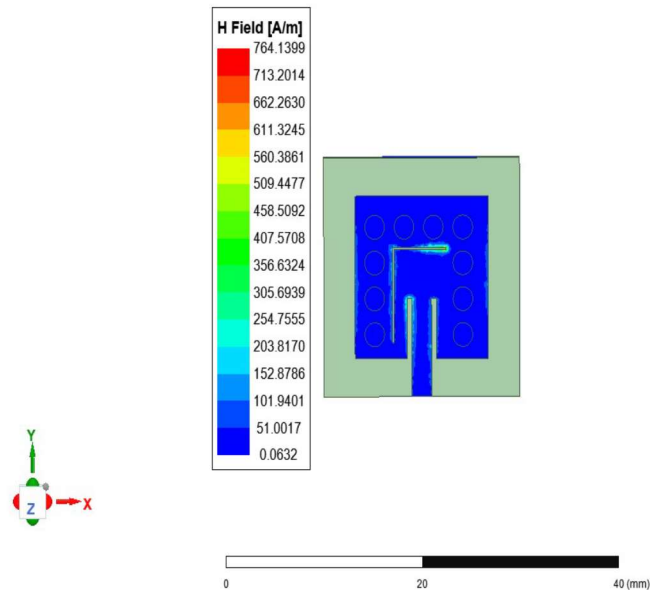


Fig: 5.14 H field design

As shown in the fig 5.14 known as Magnetic field design of multiband antenna. This antenna is called the magnetic field or magnetic loop antenna. The magnetic loop antenna measures the magnetic field (H-field) emanating from the EUT. Measurement of the H-field is often specified when RE testing below the normal 30 MHz lower frequency point is required by the product standard.

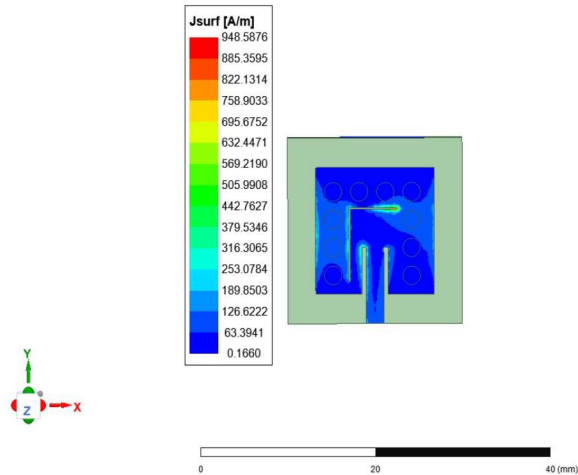


Fig: 5.15 Jsurf design

As shown in the fig 5.15 known as Jsurf design of multiband antenna. In comparison to the previous antenna, this one is stronger.

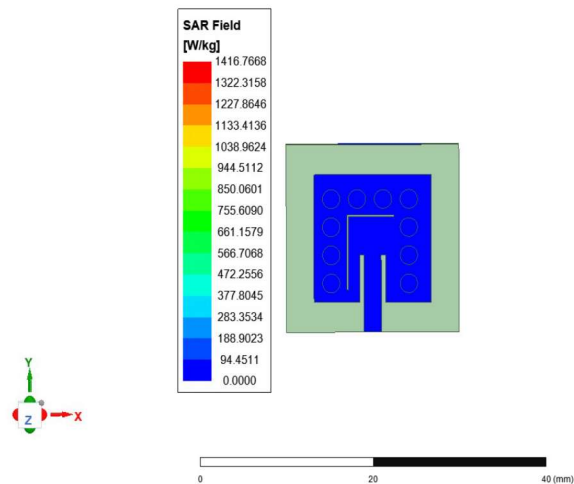


Fig: 5.16 SAR field design

As shown in the fig 5.16 known as Specific Absorption Rate. SAR is the measure of the allowable level of EM radiation to be produced by communication antenna in wireless devices. SPA and half-wave dipole antennas are used to address the SAR level. In comparison to the previous antenna, this one is stronger.

5.4 MAXIMUM AND MINIMUM VALUES OF SIMULATED ANTENNA DESIGNS

Table: 6.1 Maximum and Minimum values of simulated antenna designs

Parameters	Maximum value	Minimum value
Gain	5.0 dB	-13.0 dB
Directivity	6.0 dB	-11.1 dB
Standing wave ratio	7.1GHz frequency bandwidth	5.2GHz frequency bandwidth
Reflection coefficient	5.3 frequency	6.4 Frequency

5.5 FABRICATION WORK

The antenna design which is fabricated using the inkjet printing technology covers the ISM 2.45 GHz and fed by a CPW feed. Moreover, the performance of the antenna is evaluated under bending effects in terms of impedance matching and shift in resonant frequency.

5.5.1 FABRICATION STEPS OF ANTENNA

Design and fabrication processes of the prototype antenna. As shown in Figure 1, there are five main stages in the proposed approach, namely,

- simulation,
- antenna printing,
- antenna curing,
- conductivity measurement,
- antenna parameters measurements.

5.5.2 MATERIALS USED IN ANTENNA FABRICATION

Manufacturing cost and the weight of the material should be as minimum as possible.

- Copper,
- brass (copper-zinc alloy),
- bronze (copper-tin alloy)
- Aluminium

are among widely used conducting materials to build antennas.

5.5.3 FABRICATION PROCESS IN MICROSTRIP PATCH ANTENNA

The designed microstrip patch antenna is fabricated by photo-lithographic method. Photo-lithographic method is a chemical etching process which removes the unwanted metal regions of the metallic layer. Photo-lithographic method produces highly accurate etched pattern for the microstrip patch.

5.5.4 FABRICATION RESULT

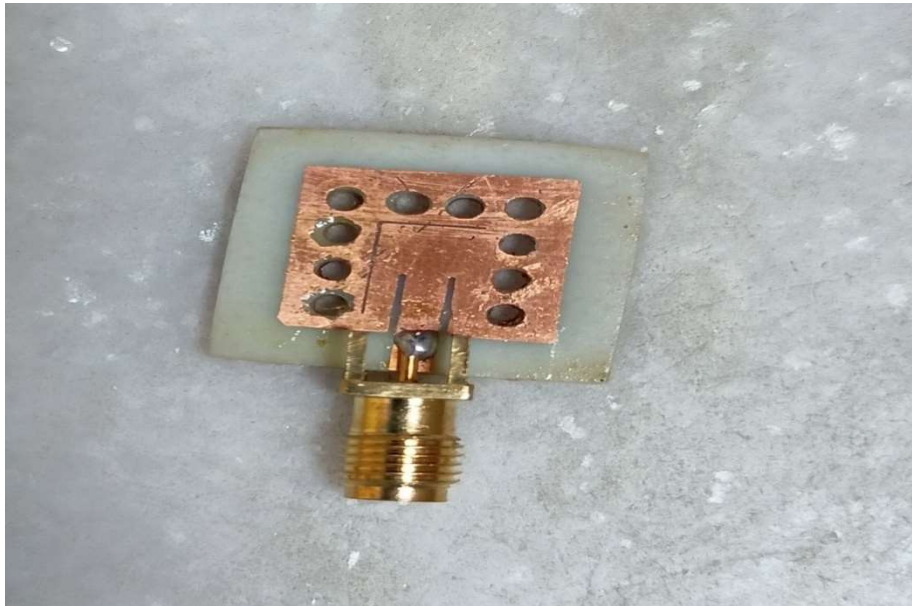


Fig: 5.17 Fabricated antenna-front side

As shown in the fig 5.17 known as fabricated u shaped square patch antenna- front side. To validate the simulated equivalence, this fabricated antenna has been measured.



Fig: 5.18 Fabricated antenna-back side

As shown in the fig 5.18 known as fabricated u shaped square patch antenna- front side. To validate the simulated equivalence, this fabricated antenna has been measured.

5.6 ANTENNA TESTING

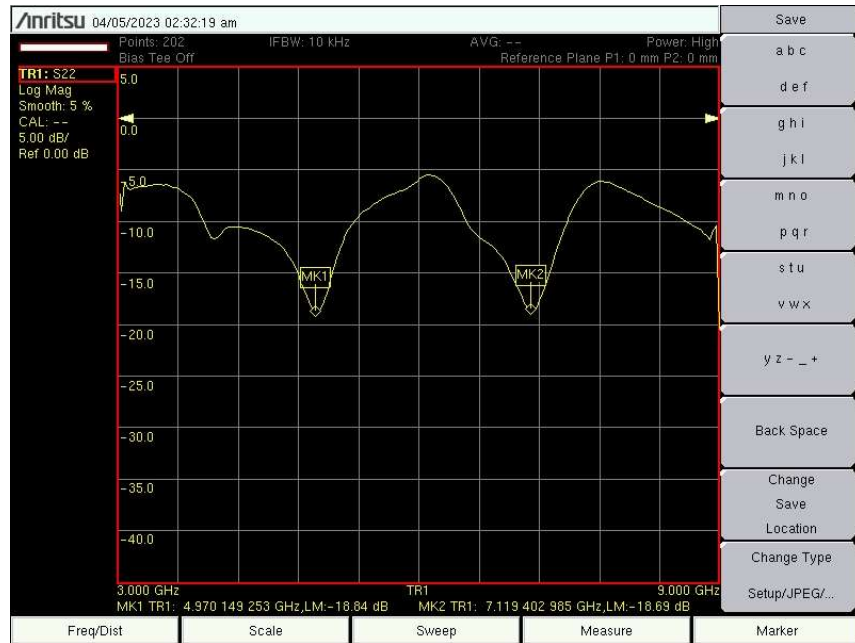


Fig: 5.19 s11

As shown in the fig 5.19 known as S11, which is a S11 graph made-up antenna testing by using fabricated antenna design for multiband.

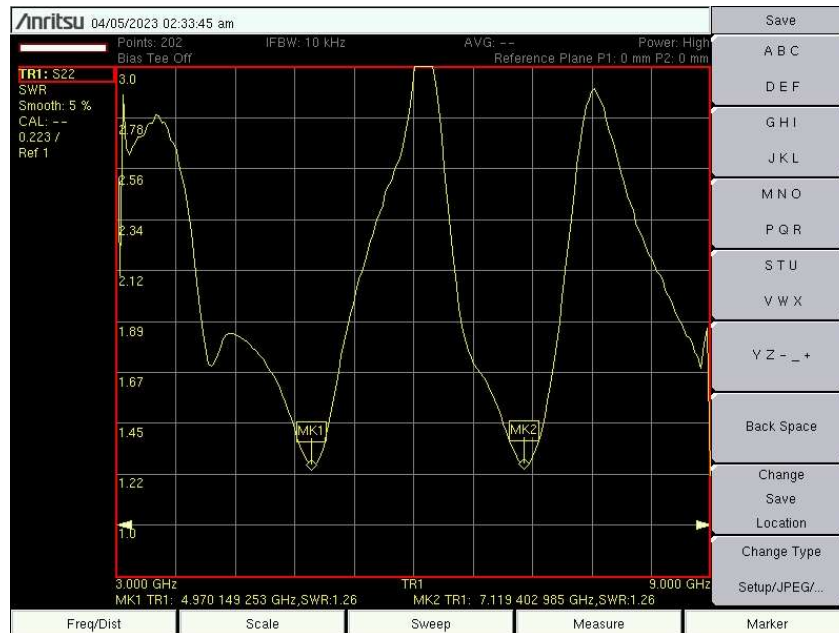


Fig: 5.20 VSWR

As shown in the fig 5.20 known as Voltage Standing Wave Ratio(VSWR), which is a VSWR graph made-up antenna testing by using fabricated antenna design for multiband.

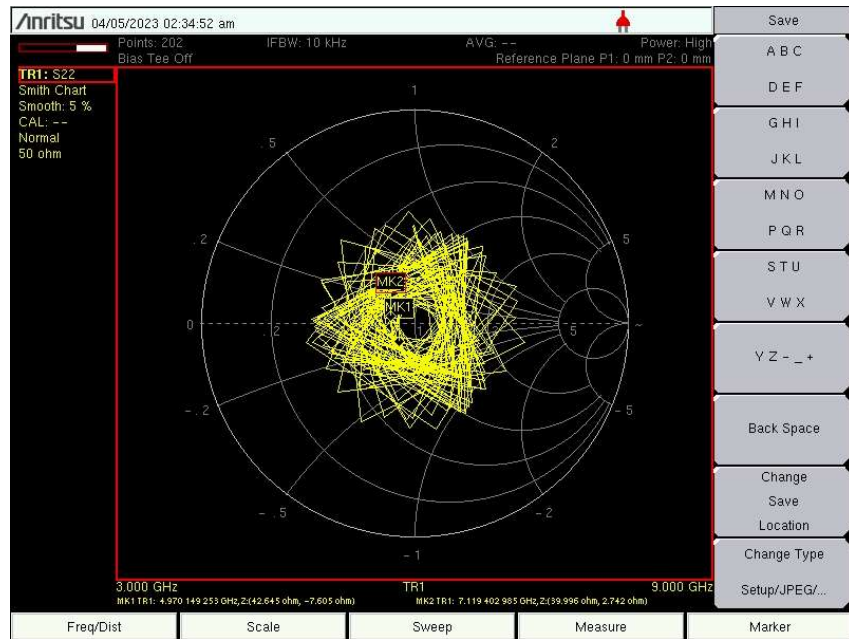


Fig: 5.21 SMITH CHART

As shown in the fig 5.21 known as SMITH chart, which is a SMITH chart graph made-up antenna testing by using fabricated antenna design for multiband.

5.6.1 DIFFERENCE BETWEEN SIMULATED DESIGN AND FABRICATED DESIGN

Table: 5.2 Difference between simulated design and fabricated design

	SIMULATED DESIGN RESULT	FABRICATED DESIGN RESULT
VSWR	5.17 – 7.15 GHz	5.36 – 7.89 GHz
S11	5.18– 7.16 GHz	5.24 – 7.96 GHz

5.7 SUMMARY

Integrated substrate waveguide antennas are a type of antenna that is commonly used in wireless communication systems. They are designed to operate at high frequencies and are typically used in applications such as radar systems, satellite communication, and microwave systems. These antennas are constructed by embedding a waveguide structure into a substrate material such as silicon or printed circuit board (PCB). The waveguide structure guides the electromagnetic waves along the substrate, and the radiating element is usually located at the end of the waveguide. This design provides a compact and efficient antenna solution for high-frequency wireless applications.

CHAPTER 6

CONCLUSIONS AND FUTURE SCOPE

6.1 CONCLUSIONS

An antenna is designed using multi-band in substrate integrated waveguide (SIW) technique for wireless applications. This antenna is has been developed by multi band ISW antenna for wireless application. A multiband antenna is designed to operate in multiple bands of frequencies. Multiband antennas use a design in which one part of the antenna is active for one band, while another part is active for a different band. The proposed antenna possesses square patch cavity , inverted U-shaped slot and innermost inverted U-shaped slot, which are governed by an inset micro strip feed line. Two inverted U-shaped slots are introduced on the top metallic surface of the cavity to drive the lower resonant modes for acquiring antenna miniaturization. By using ISW technology the multiband antenna has been created for wireless applications. The optimization method has been performed to enhance the performance of the antenna using HFSS software. To validate the simulated equivalence, the fabricated antenna has been measured.

6.2 FUTURE SCOPE

- **Optimization of antenna performance:** The project could be further developed by optimizing the performance of the substrate waveguide antenna, such as by increasing the bandwidth, gain, and radiation efficiency of the antenna. This could involve using advanced simulation and optimization tools to fine-tune the antenna design.
- **Integration with other wireless technologies:** The substrate waveguide antenna could be integrated with other wireless technologies, such as Bluetooth, Wi-Fi, or 5G, to provide a more comprehensive wireless

communication system. This would require developing the necessary hardware and software interfaces to enable seamless integration.

- ***Miniaturization of the antenna:*** The substrate waveguide antenna could be further miniaturized to enable its use in smaller devices, such as wearables or Internet of Things (IoT) devices. This would require developing new fabrication techniques and optimizing the antenna design for smaller form factors.
- ***Power efficiency:*** Power efficiency is an important consideration for wireless applications, particularly for battery-powered devices. Future research could focus on improving the power efficiency of the substrate waveguide antenna, such as by reducing the antenna's power consumption or optimizing the antenna's impedance matching.
- ***Real-world testing:*** The performance of the substrate waveguide antenna could be tested in real-world environments to determine how it performs in various conditions, such as indoors, outdoors, or in the presence of obstacles. This would require developing testing methodologies and conducting field trials.

Overall, there are many potential areas for future research and development of the substrate waveguide antenna for wireless applications. Further optimization of the antenna's performance, integration with other wireless technologies, miniaturization, power efficiency, and real-world testing are all areas that could be explored to improve the antenna's functionality and usability.

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