

High Gain Broadband Antenna/Array for Ku Band Satellite Communication

PROJECT REPORT

*Submitted in partial fulfillment of the requirements for the award of the
Degree of Master of Technology in Electronics and Communication
Engineering with Specilisation in Communication Systems by the A P J Abdul
Kalam Kerala Technological University*

by

JUBILY V REJI

TKM20ECCS07



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ENGINEERING

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CERTIFICATE

Certified that this thesis titled “**High Gain Broadband Antenna/Array for Ku Band Satellite Communication** ” is a bonafide record of the work done by **JUBILY V REJI** (Reg. No. TKM20ECCS07) under my supervision, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Electronics and Communication Engineering with specialization in Communication Systems by the A P J Abdul Kalam Technological University.

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ABSTRACT

A novel type of transmission line that has gained popularity recently is the substrate integrated waveguide (SIW). A rectangular waveguide is created inside a substrate by putting a top metal over the ground plane and encircling either side of the structure with plated vias arranged in rows. Four rows of metallic vias and two metallic plates on the top and bottom of the substrate combine to create the square SIW cavity. Additionally, the ground coplanar waveguide feeding structure ignites the high-order resonant modes inside the subcavity, and by placing the high-order modes close to one another, the broadband impedance bandwidth may be accomplished. The interaction of the slot, SIW structure and feeding structure in the high gain broadband antenna array for ku band satellite communication helps to excite high-order modes. The first phase of project results investigates a 2x1 antenna array which shows a high bandwidth and gain. It was realized using the slot geometry at the backed substrate. The simulated results show that the antenna array radiates at the following three frequencies of 11.6GHz, 12.95GHz and 13.9GHz. A peak gain of 9.5 dBi was observed at 20.4 GHz. Second phase of project deals with the design of high gain broadband SIW antenna for KU band satellite communications. The design was realized using a SIW modified flower slot dumbbell shaped antenna. The proposed design demonstrated a gain of 9dBi and impedance bandwidth of 16.36%.

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Abbreviations

SIW Substrate Integrated Waveguide

CBS Cavity Backed Slot

TM Transverse Magnetic

TE Transverse Electric

DFW Dielectric Filled Waveguide

TCSRS Triangular Complementary Split Ring Slot

MMIC Monolithic Microwave Integrated Circuit

Chapter 1

Introduction

Substrate integrated waveguide (SIW) is a new form of transmission line that has been popularized in the past few years. By encircling the structure with rows of plated vias on either side and covering the ground plane with a top metal, a rectangular guide is produced within a substrate. Microstrip devices are ineffective in high frequency applications due to the small wavelengths at these frequencies, and their manufacturing demands for extremely tight tolerances. Waveguide devices are favoured at high frequencies, but their production is challenging. Consequently, substrate integrated waveguide evolved as a novel idea. Microstrip and dielectric-filled waveguide are separated by SIW (DFW). Vias for the waveguide's side walls assist transform a dielectric-filled waveguide into a substrate integrated waveguide (SIW). Transverse magnetic (TM) modes are absent due to the presence of vias at the sidewalls, making TE₁₀ the predominant mode.

1.1 Transmission waveguides

MICROSTRIP LINES

Using microstrip lines with metallic waveguides is the preferred method for achieving guided wave propagation in the microwave frequency. Metallic waveguides are not planar, although microstrip lines are planar. Microstrip lines are small and lightweight, and they are inexpensive to manufacture, but they suffer from significant losses and crosstalk. Low losses and perfect shielding are features of the metallic waveguides. But it is heavy and expensive. To overcome these restrictions and to use the new

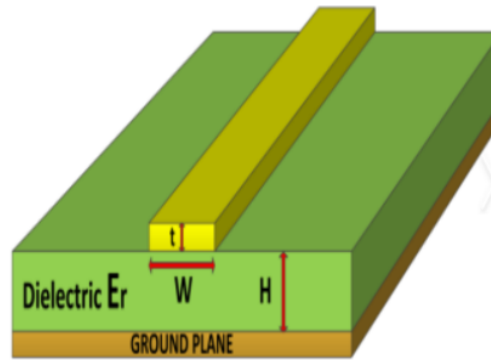


Figure 1.1: Microstrip lines

Substrate Integrated Waveguide technology.

Due of their attractive characteristics, cavity backed antennas, particularly cavity-backed slot antennas, have been utilised extensively in wireless communication systems. However, due of their large profiles, conventional cavity-backed slot antennas are challenging to connect with other planar circuits. Recently, the substrate integrated waveguide (SIW) structure was introduced to the planer cavity-backed slot antenna to alleviate the aforementioned issue. The impedance bandwidth (BW) of the SIW cavity-backed slot antenna is however limited by the high-Q property of the SIW cavity. Several methods have been suggested to increase the SIW cavity supported slot antenna's impedance bandwidth. Yun et al. By removing the substrate from beneath or adjacent to the slot, Yun et al. increased the bandwidth, however it was only 5 percent [1]. In [2], the antenna is able to attain an impedance bandwidth of 8.5% by linking the slots of various lengths and using hybrid modes to increase the broadband. The generation of a hybrid mode in a rectangular slot allows the antenna to achieve an operational bandwidth of 6.%. The enhanced bow-tie slot antenna achieves a larger impedance bandwidth of 9.4% [3] when compared to the rectangular slot. The perturbative TM₁₁ mode helps a dual resonant slotpatch antenna reach an impedance bandwidth of 17.32 percent; impedance bandwidths of 15.2 percent and 17.5 percent are achieved by coupling the lower modes with higher modes. In [5], a triangular complementary split ring slot (TCSRS) antenna with a broadband dual-mode (TE₁₀₂ and TE₂₀₁ modes) obtains an impedance bandwidth of 16.7 percent at 28 GHz; The antenna, however, has a low gain at lower frequencies and a high level of crosspolarization. The coupled feeding element and multilayer structure

make it possible to increase the impedance bandwidth. The coupled feeding structure and the meta-mushroom structure aid in the bow-tie slot antenna's achievement of a 21.8 percent impedance bandwidth. The slot-coupled feeding mechanism of [7] excites four successively enlarged SIW cavities, enabling the antenna to reach an impedance bandwidth more than 30%. The large profiles and layered constructions, however, limited their use.

A conductor constructed on a dielectric substrate with a grounded plane creates a microstrip, a form of transmission line. It is a popular option of transmission line since it is simple to miniaturise and can be integrated with microwave equipment. Electro-Magnetic Waves (EM waves) or microwave frequency signals are transmitted by microstrip lines. Conducting strip, dielectric, and ground plane make up its three layers. It is used to create and develop RF and microwave parts including directional couplers, power divider/combiners, filters, antennas, MMICs, etc.

METALLIC WAVEGUIDE

In comparison to conventional transmission lines, a metallic waveguide has reduced loss and can send out more power. Additionally, the signal leaks much less. Compared to other waveguiding devices or transmission lines, a dielectric waveguide like an optical fibre can transfer a lot more data. Typically, any metal with a low bulk resistivity—brass, copper, silver, aluminum—is used to make waveguides. If the internal walls are suitably coated, it is possible to employ metals with weak conductivity properties. Even plastic waveguide can be created.

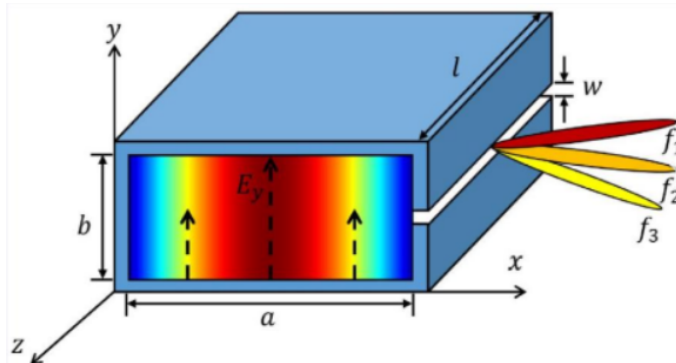


Figure 1.2: Metallic Waveguide

CAVITY BACKED SLOT ANTENNA

The antenna is made of a ground plane slot that has been shorted on both sides to create a backing cavity. Figure 1 depicts the fundamental cavity-backed slot antenna as a rectangular cube of sizes $A*B*C$. The interior is hollow, and the walls are metallic (electrically conductive). One end has a slot carved out of it. A probe antenna inside the cavity typically modelled as a monopole antenna is usually what excites the cavity.

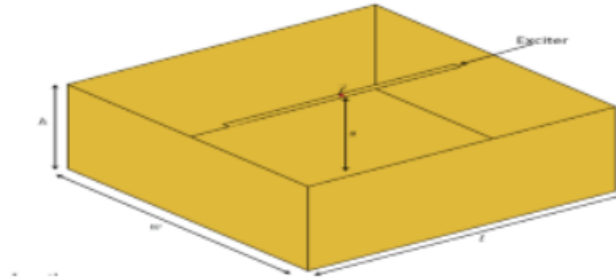


Figure 1.3: Cavity Backed Slot Antenna

The cavity's capacity usually has an impact on the bandwidth; a greater volume frequently results in a higher bandwidth. A dielectric medium may be used in place of the material that now fills the cavity. This shortens the slot's resonance length, enabling a smaller antenna. The trade-off is that a dielectric cavity medium often results in a decrease in bandwidth and efficiency.

SUBSTRATE INTEGRATED WAVEGUIDE

Metallized posts or via-holes that connect the upper and bottom metal plates of the substrate are densely arrayed to create a synthetic rectangular electromagnetic waveguide called a substrate integrated waveguide (SIW). Through-hole fabrication methods, including via barriers for the post wall, make it simple and inexpensive to mass produce the waveguide. It is well known that SIW has guided wave and mode properties that are comparable to those of a traditional rectangular waveguide with an analogous guide wavelength. High-performance millimeter-wave systems have become more necessary with the development of new communication technologies in the 1990s. These need to be dependable, affordable, portable, and high-frequency compatible. Unfortunately, the well-known microstrip and coplanar lines technologies cannot be used at frequencies beyond 10 GHz due to their significant insertion and radiation losses. These problems can be resolved by the rectangular waveguide topology since

it has minimal insertion losses and great resilience to radiation losses. However, the downsizing required by contemporary applications does not work with rectangular waveguide in their traditional shape. To balance these demands, Ke Wu created the SIW idea in the early 2000s. The authors proposed a platform for integrating all components of a microwave circuit onto a single substrate with a rectangular cross-section. The rectangular cross-section of the line contributes to the waveguide topology's advantages in terms of losses, while having a single substrate assures a small volume and simplicity in fabrication. A SIW is made comprised of a thin dielectric substrate that is covered on both faces by a metallic layer. Two parallel rows of metallic via-holes put into the substrate served as the boundary for the wave propagation region. The width of a SIW is defined as the distance between its two through rows, measured from centre to centre. An effective width can be used to more accurately depict wave propagation. S stands for the separation of two objects., and d represents the diameter of the vias.

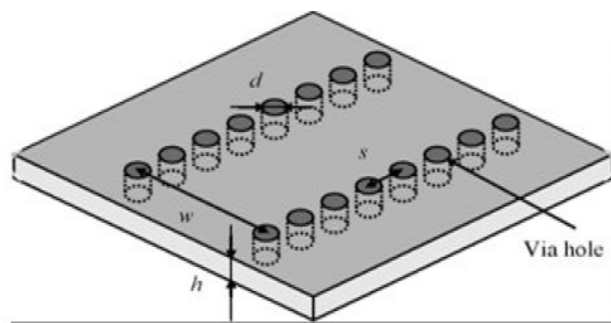


Figure 1.4: SIW Antenna

Objectives

- Design and simulate high gain broadband SIW Antenna Array and verify its performance parameters.
- Design and simulate SIW antenna for KU band satellite communication and verify its performance parameters.

Organization of the thesis

The first chapter of the thesis introduces the concept of SIW Antenna and the advantages of SIW Antenna over cavity backed slot antenna and traditional transmission lines. The second chapter includes a comprehensive review of the literature covering the SIW Antennas. The third chapter of the thesis discuss the design and simulation of various kind of antenna and antenna array. The fourth chapter focuses on the results of the SIW antenna and antenna array for communication. The last chapter deals with the conclusion finally the references.

Chapter 2

Literature Review

Qi Wu, et.al [1] proposed two different kinds of cavity-backed slot (CBS) antennas with substrate integrated waveguide (SIW) to increase bandwidth. In this design firstly, a loaded imbalanced shorting via and a cross-shaped slot are suggested for a quad-resonance SIW CBS antenna. Three further independent modes, including half-TE₁₁₀, odd and even TE₂₁₀ modes, and an additional half-TE₁₂₀ mode are also successfully aroused. Then, a penta-resonance SIW CBS antenna is suggested with a slot that is cross-shaped and loaded with two pairs of shorting vias. Three new independent modes, including half-TE₁₁₀ and the odd and even TE₃₁₀ modes, as well as two more hybrid versions of the half-TE₂₁₀ and half-TE₁₂₀ modes are also introduced.

A low side-lobe substrate-integrated-waveguide (SIW), a millimeter-wave (mm-wave) antenna array is displayed at the 28-GHz band using a broadband uneven feeding network by Seong-jin park, et.al [2]. The suggested antenna has a fixed ground-plane size that is half the size of the Samsung Galaxy Note 4. Three substrates and a copper plate were stacked to produce a multilayer framework for the antenna array. To achieve broadband performance, an 8-way SIW feeding network with broadband 4-stage T-junction dividers and a cavity-backed antenna is examined. We introduce and design the proposed uneven T-junction dividers with phase compensation for different output ratios. Low side-lobe performance is attained via Taylor beam-pattern synthesis in the 8-way SIW feeding network. The manufactured antenna's measured result shows a 2.3 GHz bandwidth with an S₁₁ 10 dB tolerance. With low cross-polarization and symmetrical fan beam radiation patterns with low side-lobe levels, the constructed

antenna can operate with a gain of up to 13.97 dBi. Additionally, across the operating frequency band, the radiation performance exhibits symmetrical fan beam patterns with low side-lobe values of less than 20 dB in the azimuth plane. The majority of measured data are validated using results from simulations. The antenna array offers mm-wave handset devices and other applications a low-cost, broadband performance, good radiation performances, and low side-lobe levels. This innovative active antenna array will be a desirable contender for beam forming mm-wave handset devices once phase shifters are integrated into the SIW feeding network.

To achieve greater bandwidth performance, a bow-tie-shaped slot is used in place of the more common narrow rectangular slot by Soumava Mukherjee, et.al [3]. A high loading effect is induced in the cavity according to the alteration of the slot form, which also produces two closely spaced hybrid modes that aid in obtaining a broadband response. The slot antenna maintains low-profile planar structure and exhibits unidirectional radiation characteristics with modest gain by using thin cavity backing in a single substrate. A constructed prototype is also shown; it has a cross-polarization level below -18 dB, a bandwidth of 1.03 GHz (9.4 percent), a gain of 3.7 dBi over the bandwidth, and a front-to-back ratio of 15 dB.

A single substrate is used to produce the entire antenna, including the backing cavity and feeding element, utilising the substrate integrated waveguide technology and grounded coplanar waveguide by Guo Qing Luo, et.al [4]. A 1.7 percent bandwidth example with 5.4 dBi gain, 16.1 dB front-to-back ratio, and a maximum cross polarised radiation intensity of -19 dB with its whole thickness has been provided. The antenna has the low profile, light weight, simple production at cheap cost, and facile integration with planar circuitry of traditional planar antennas while maintaining the good radiation performance of conventional cavity supported antennas. Instead of the more typical narrow rectangular slot, a bow-tie-shaped slot is employed to achieve better bandwidth performance. The modification of the slot form results in two closely spaced hybrid modes that help create a broadband response and induces a significant loading effect in the cavity. By employing a narrow cavity backing in a single substrate, the slot antenna maintains a low-profile planar structure and offers unidirectional radiation characteristics with a modest gain. A built-in prototype is also displayed; it has a front-to-back ratio of 15 dB, a gain of 3.7 dBi over the bandwidth,

a bandwidth of 1.03 GHz (9.4 percent), and a cross-polarization level below -18 dB. Using substrate integrated waveguide technology and grounded coplanar waveguide, the complete antenna—including the backing cavity and feeding element—is produced on a single substrate by Guo Qing Luo, et.al [5]. We've given an example with a 1.7 percent bandwidth, 5.4 dBi gain, 16.1 dB front-to-back ratio, and a maximum cross polarised radiation intensity of -19 dB over the entire thickness. The antenna maintains the good radiation performance of traditional cavity supported antennas while having the low profile, light weight, simple production at a low cost, and simple integration with planar circuit advantages of conventional planar antennas.

A substrate integrated waveguide-based cavity-backed triangular complementary split ring slot (TCSRS) antenna (SIW), with an antenna element developed and implemented for fifth-generation (5G) wireless communications at 28 GHz and 45 GHz by Prem Narayan Choubey, et.al [6]. Prior to designing two- and four-element arrays for high gain operation, the suggested antenna element's basic operation is examined. At both frequencies, 28 GHz and 45 GHz, antenna prototypes and their arrays are created using the common printed circuit board (PCB) technology. According to measurements, it is possible to reach impedance bandwidths of 16.67 percent at 28 GHz and 22.2 percent at 45 GHz while keeping the substrate height constant in both cases. The 2 x 2 antenna array's observed peak gains at 30GHz or 50GHz are 13.5dBi or 14.4dBi, respectively.

An L-shaped cavity-backed ground plane is employed in a wideband proximity-coupled dual-polarized microstrip antenna to improve the feeding coupling and hence increase the bandwidth of the antenna by Liu, et.al [7]. To demonstrate the guidelines for designing this antenna, a detailed parameter study has been completed. Design and construction of a prototype antenna with optimum specifications. The suggested design achieves S11dB bandwidth of more than 30% (8.2-11.4GHz) according to simulation and measurement data, and the port isolation is greater than 20dB over the band. This antenna can be installed directly on the metal body surface because of its very straightforward structure.

Bilateral Compared to traditional antennas, which use unilateral slots to broaden the bandwidth of low-profile substrate integrated waveguide (SIW) cavity antennas, the novel design employs slots as radiating elements by S. Yun, et.al [8]. By etching an

additional slot at the bottom plane, a new resonant mode is created and the quality factors of the two preceding modes are dramatically reduced. The antenna's bandwidth can be considerably expanded by integrating all three operating modes inside a single operational band. creating a prototype and measuring it. The measured 10-dB bandwidth is 410 MHz (3.24-3.65 GHz), or 11.9 percent fractional bandwidth, with a height of 0.018 λ . The measured gain is higher than 4.3 dBi within the operating band, and the measured efficiency is close to 75%. The proposed antenna is suited for upcoming 5G systems due to its appealing properties, such as low profile, increased bandwidth, and moderate radiation performances.

The bandwidth of a cavity-backed slot antenna is enhanced by a triangular slot on a half-mode substrate integrated waveguide structure antenna by S.Yun,et.al [9]. Hybrid modes, which boosted bandwidth, were made by combining the stationary TE₁₀₁ and the downward sliding TE₁₀₂ modes. As the slot antenna changed from a half-non-resonating rectangular slot to a triangular slot antenna, its fractional bandwidth increased. The simulation showed an increase in fractional bandwidth from 6.27 to 9.1 percent. The 350 MHz bandwidth with a 3.84 GHz centre frequency translates to the fractional bandwidth of 9.87 percent., was validated by measurement. At the central frequency, 4.2dBi of gain was measured. It is demonstrated that both measurement and modelling findings yield very good radiation characteristics.

Chapter 3

Design and simulation

3.1 Design of SIW Antenna

The designed SIW slot antenna is entirely constructed out of fr4 material, which has a thickness of 0.787 mm and a dielectric constant of 2.2. Four rows of metallic vias and two metallic plates on the top and bottom of the substrate combine to create the square SIW cavity. To ensure minimal energy leakage, the diameter and spacing of the vias can be optimised to ensure minimum leakage of energy.

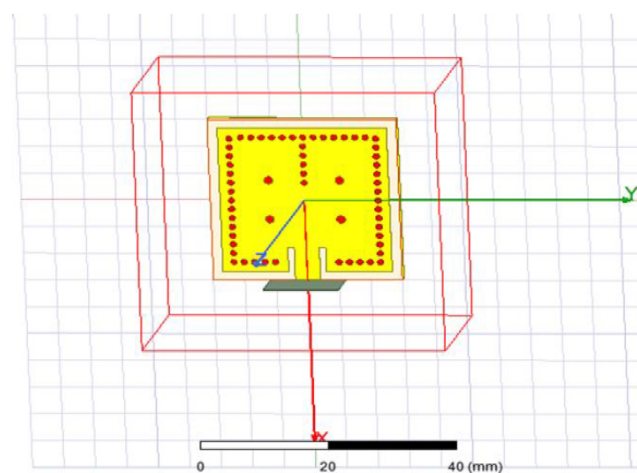


Figure 3.1: Schematic diagram of SIW Antenna

The slot's shape and the cavity's modes work together to establish the impedance bandwidth for SIW cavity-backed slot antenna. To further understand the proposed antenna's suggested broadband operating principle, the slot and modes are investigated separately. A dielectric substrate with metalized top and bottom edges serves as the substrate for the SIW structure. 2 rows of closely spaced metalized cylindrical holes (often known as metal vias or posts) that form the waveguide's side walls connect the top and bottom metal layers electrically. SIW structures can be built using dielectric substrates, which are frequently utilised in microstrip and coplanar waveguide circuits. The dielectric layer's thickness, which can range from 0.2 to 1 mm, is often not as great as the waveguide's width. Typically, the relative dielectric constant, ϵ_r , falls between 2 and 10. The SIW's geometry is entirely determined by three factors: the longitudinal separation s between the holes, the waveguide's width w , and the diameter d of the holes. Due to the SIW structure's resemblance to a rectangular waveguide, its width w is primarily correlated with the fundamental SIW mode's cutoff frequency and, consequently, with the operational frequency band, as will be covered below. The holes' diameter d is normally a modest percentage of their width; To prevent potential band-gap effects brought on by the periodic modulation of the waveguide width, the longitudinal spacing (s) has an impact on how the electromagnetic field is contained.

3.1.1 S Parameter Plot

S parameter plot which shows the high radiation because graph lies in below -10dB, this refers 3dB of power is delivered to antenna and -7dB is reflected power. Measured results shows that impedance bandwidth of 12.93% which gives a maximum bandwidth and gain also. So this SIW antenna is used for making antenna array for communication.

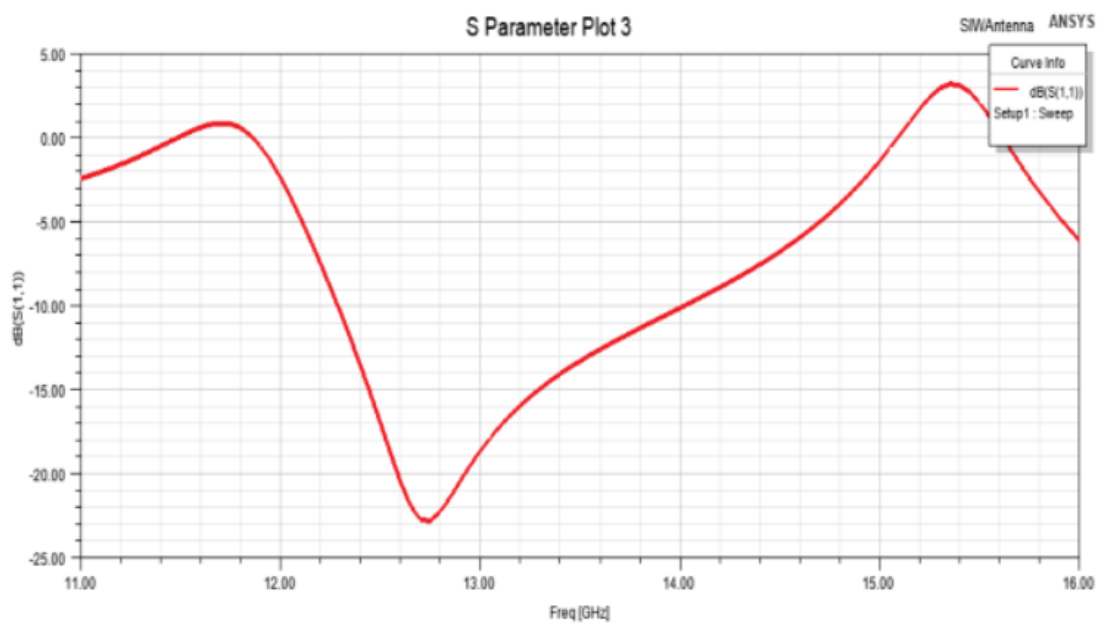


Figure 3.2: S Parameter of SIW Slot Antenna

3.1.2 SIW Transition Design

The SIW transition has a very straightforward design that is also extremely easy to produce. Its dimensions are also small, and its insertion loss is also relatively low. To calculate the taper's length and width, full-wave simulations are typically needed while designing this transition. Without requiring full-wave simulations, analytical equations derived from curve fitting have been proposed to assess the ideal taper dimensions. It is typically achievable to get an input reflection coefficient lower than -20 dB over the whole normal single-mode bandwidth of the SIW by using these tapered transitions (conventionally defined as the frequency range from $1.25 f_0$ to $1.9 f_0$). The connection of the microstrip to the top wall of the SIW can be made through a via hole if the substrate thickness of the microstrip line differs from the thickness of the SIW structure.

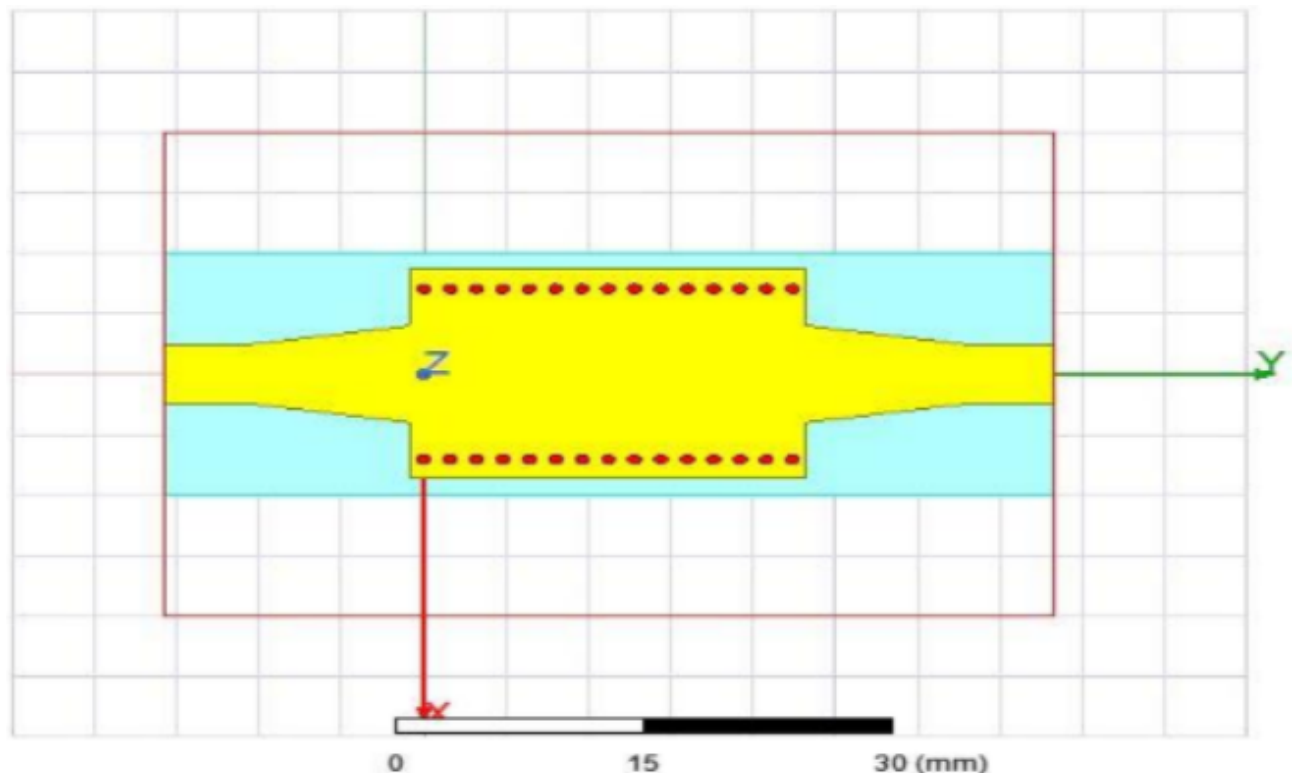


Figure 3.3: Schematic diagram of SIW Transition Design

3.1.3 Y Junction Divider

The SIW power dividers and microstrip transitions are integrated on the same substrate using arrays of vias. At -18.5 dB, the Y junction displays a bandwidth of 25.2%. Many integrated circuits and systems for microwave and millimeter-wave frequencies are constructed using waveguide power dividers. A few examples include antenna feeders, couplers, and multiplexers. High-Q components can be designed thanks to the rectangular waveguide's low power dissipation. However, it is quite expensive to produce rectangular waveguide structures. Furthermore, complex transitions are needed for the integration of rectangular waveguide components with planar circuits. At millimeter-wave frequency, the transitions typically need a mechanical assembly, which is highly expensive to implement. Substrate Integrated Waveguide (SIW), a new strategy, has been put up to address these issues. In a planar substrate with metallic through arrays, the SIW is created. Since the transitions are created on the same substrate, mechanical assembly is not necessary. Using this technology, planar circuitry and high Q rectangular waveguide components can be combined at a low cost using conventional PCB procedures.

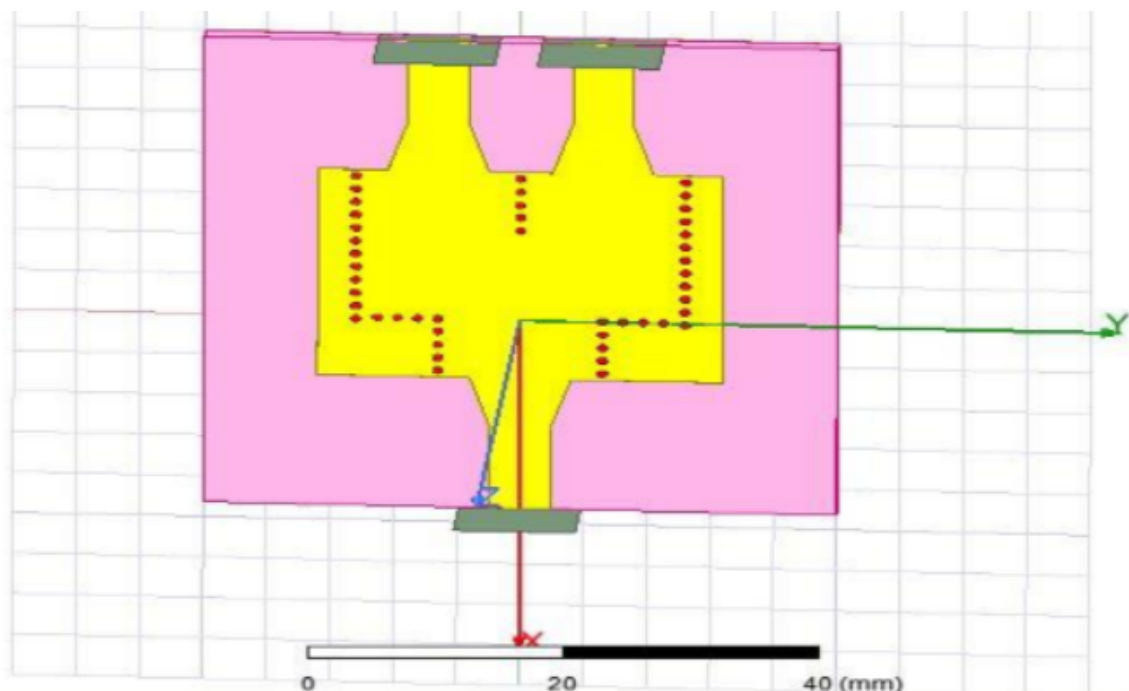


Figure 3.4: Schematic diagram of Y Junction Divider

3.2 Design of 2*1 SIW Antenna Array

An antenna array, also known as an array antenna, is a collection of interconnected antennas that operate as one antenna to broadcast or receive radio waves. Typically, feedlines that deliver power to the individual antennas in a predetermined phase relationship are used to connect the individual antennas, also known as elements, to a single receiver or transmitter. Each individual antenna's radio waves mix and su-

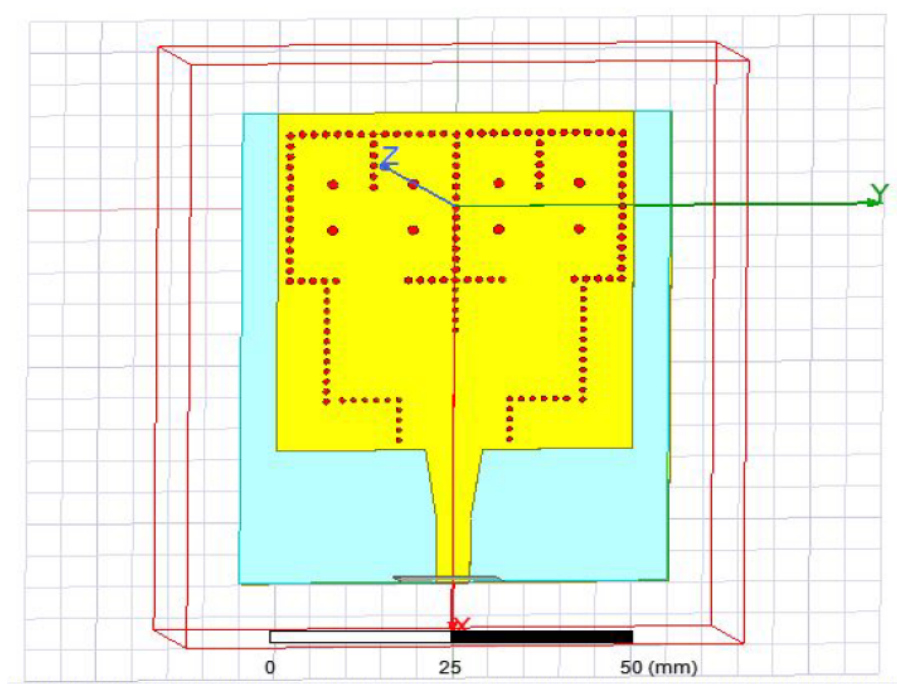


Figure 3.5: Schematic diagram of 2*1 SIW Antenna Array

perpose with one another, adding together (interfering constructively) to increase the power emitted in desired directions and cancelling (interfering destructively) to decrease the power radiated in undesirable ones. Similar to sending, during receiving, the various radio frequency currents from the various antennas combine in the receiver with the appropriate phase relationship to increase signals received from the desirable directions and negate signals from undesired directions. Multiple transmitter or receiver modules that are each coupled to a different antenna element or group of elements may be present in more complex array antennas.

3.2.1 Slot Geometry OF 2*1 SIW Antenna Array

Microwave radar systems employ a slotted antenna as its antenna. These antennas are made of metal and have a surface that resembles a flat plate with slots. Circular or rectangular holes make up these slots.

The driving frequency, slot dimensions, and slot shape all affect the antenna's radiating pattern. These antennas, which are used for broadband applications, are half a wavelength long and have a breadth that is only a small portion of the wavelength. Slot antennas are used for DBS reception as well. Radar antennas are the slot array antenna's most popular use. When they are supplied by an array, slotted antennas are occasionally used in cell phone stations.

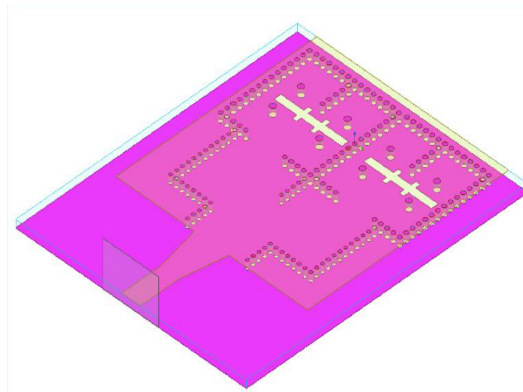


Figure 3.6: Slot Geometry of 2*1 SIW Antenna Array in 3D View

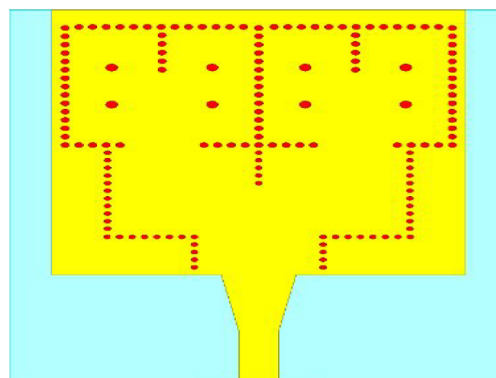


Figure 3.7: Slot Geometry of 2*1 SIW Antenna Array in front View

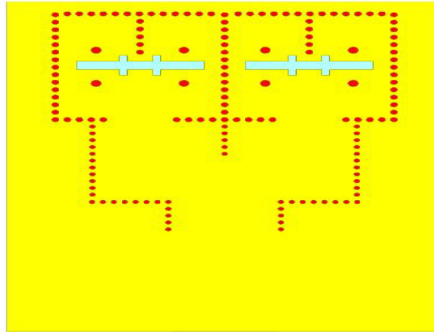


Figure 3.8: Slot Geometry of 2*1 SIW Antenna Array in back View

3.3 Design of SIW Cavity-Backed Bow-Tie Slot Antenna

In order to improve the performance over a wider bandwidth a technology for SIW Cavity-Backed Bow-Tie Slot Antenna is developed and put into practice. This design is originated from the paper. A high loading effect is induced in the cavity thanks to the alteration of the slot form, which also produces two closely spaced hybrid modes that aid in obtaining a broadband response. The slot antenna maintains low-profile planar structure and exhibits unidirectional radiation characteristics with modest gain by using thin cavity backing in a single substrate. The SIW cavity supported slot antenna has a cross-polarization level below -18 dB, a bandwidth of 1.03 GHz (9.4 percent), gain of 3.7 dBi throughout the band-width, and 15 dB front-to-back ratio[1].

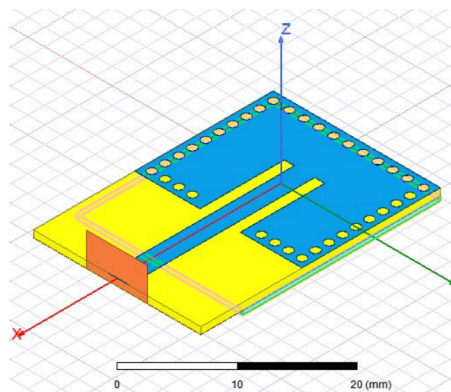


Figure 3.9: Schematic diagram of SIW Bow-Tie shaped Antenna

3.4 Design of SIW Cavity-Backed Bow-Tie with Planar Slot Backed Antenna

With an aim to improve the gain a new design was implemented by using Substrate Integrated Waveguide cavity backed Bow-Tie and four planar slots at the backed cavity. Schematic diagram of SIW Bow-Tie with planar slot backed Antenna in front view and back view as in figure 3.11 and 3.12 respectively.

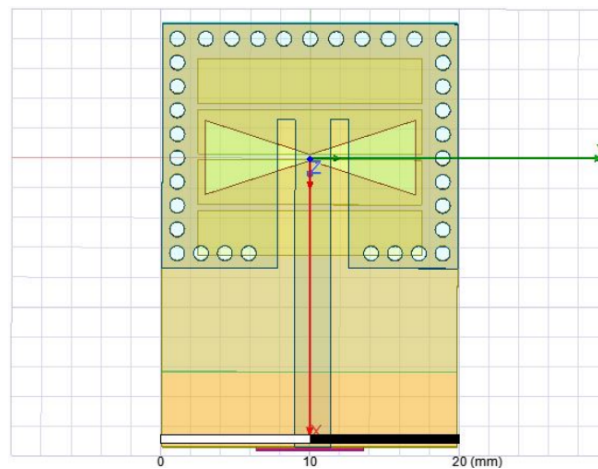


Figure 3.10: Schematic diagram of SIW Bow-Tie with planar slot backed Antenna

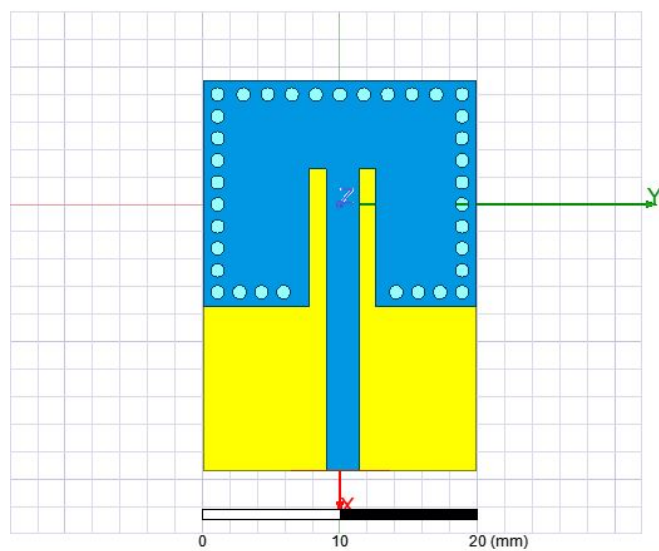


Figure 3.11: Schematic diagram of SIW Bow-Tie with planar slot backed Antenna in front view

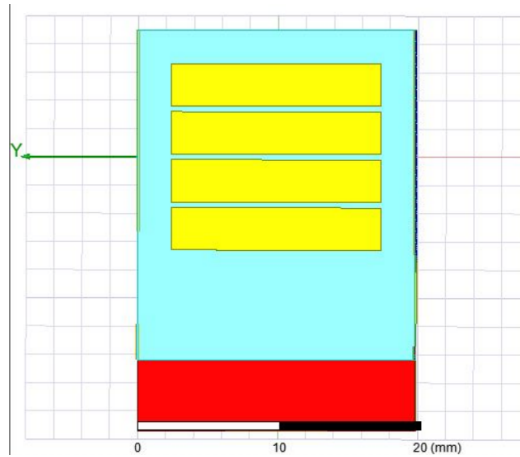


Figure 3.12: Schematic diagram of SIW Bow-Tie with planar slot backed Antenna in back view

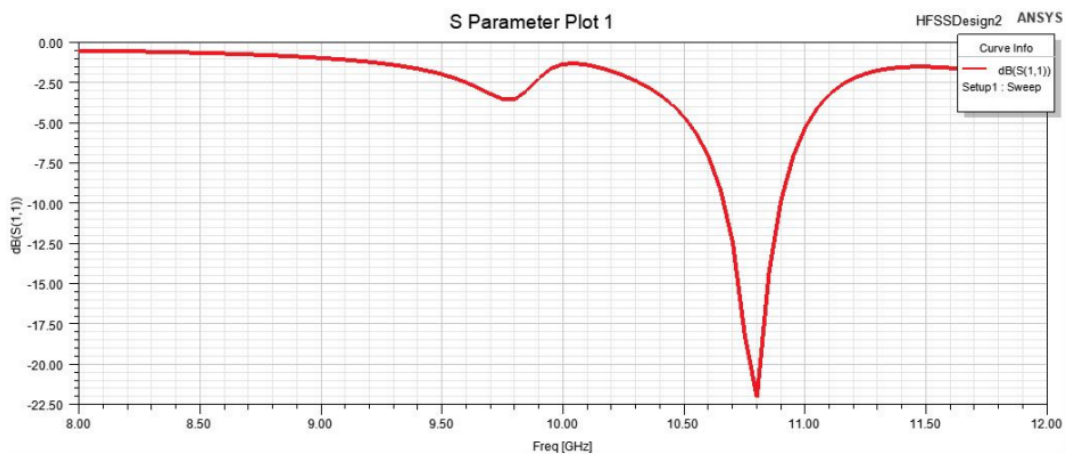


Figure 3.13: S Parameter plot of SIW Bow-Tie with planar slot backed Antenna

Measured result shows in figure 3.13 that, the design have a bandwidth impedance of 9.4% and achieves gain of 3.7dBi at 10.8 GHz frequency range.

3.5 New Design of SIW Cavity-Backed Bow-Tie Antenna

This is a new design of SIW cavity backed slot Antenna with more number of vias on it to increase the bandwidth impedance as well as gain shown in figure 3.14.

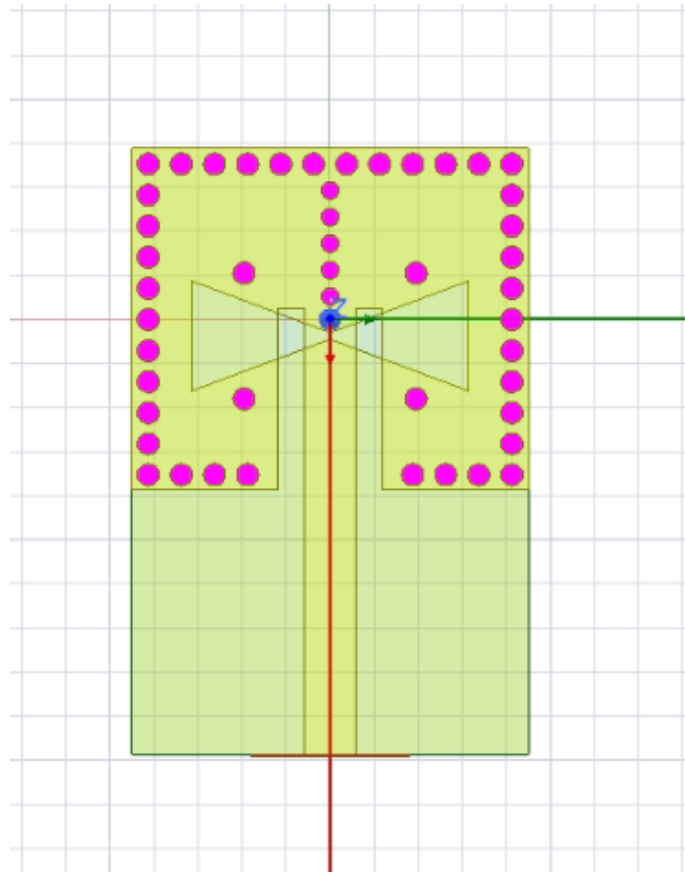


Figure 3.14: Schematic diagram of Bow Tie Slot Antenna

The new design of SIW cavity backed slot antenna shows bandwidth of 13.17 and 14.99 with a impedance bandwidth of 12.93%.

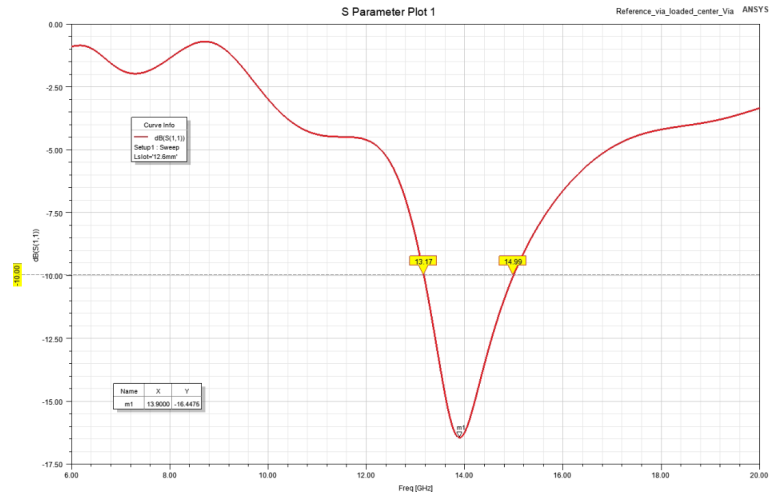


Figure 3.15: S parameter of Bow Tie Slot Antenna

3.6 Design of SIW Cavity-Backed Flower Slot Antenna

Flower slot is used in this design instead of bow tie design. The design and testing of a compact flower slot antenna suitable for Ku band satellite communication. The antenna consists of a flower shaped slot which is fed with a line terminated with a planar backed cavity.

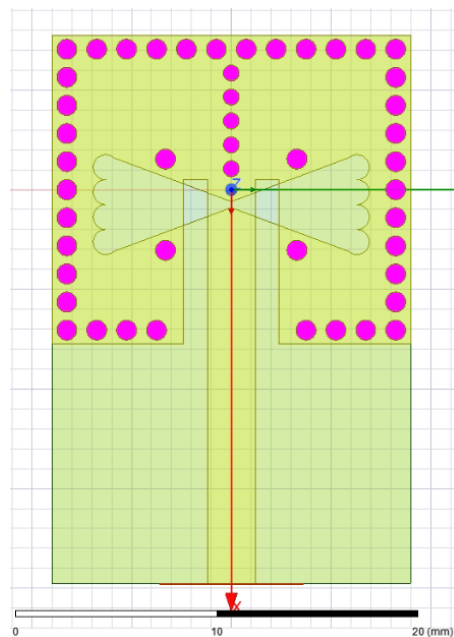


Figure 3.16: Schematic diagram of Flower Slot Antenna

The simulated results show that it offers impedance bandwidth of 17.04% fractional bandwidth (from 14.01 to 16.62 GHz) and a gain of 6.1dBi. Moreover, desirable radiation performance characteristics, including relatively stable and high performance of radiation patterns are obtained over this range. So this flower shaped antenna is more preferable.

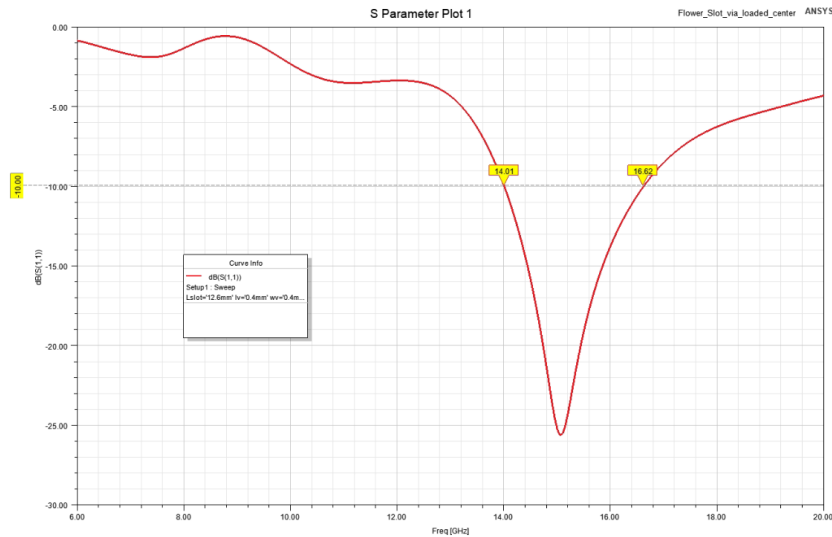


Figure 3.17: S parameter of Flower Slot Antenna

3.7 Design of SIW Flower Slot- Dumbbell shaped Antenna

The antenna consists of a flower shaped slot which is fed with dumbbell shaped antenna and vias are less in this design compared to previous one.

The simulated results show that it offers impedance bandwidth of 17.56% fractional bandwidth (from 13.87 to 16.54GHz) and a gain of 6dBi. Moreover, desirable radiation performance characteristics with high gain and achieving to start broadband at 15GHz and 16GHz frequency range.

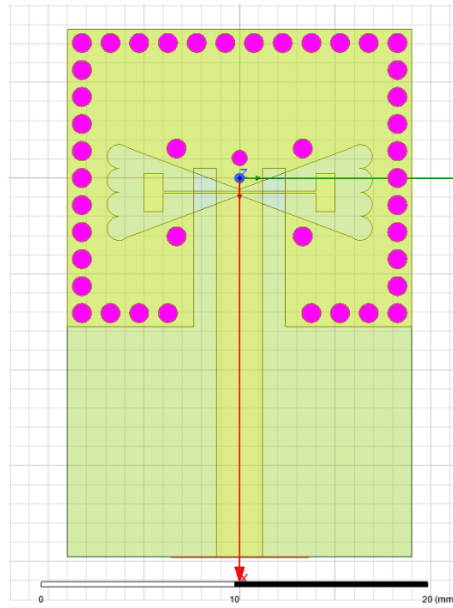


Figure 3.18: Schematic diagram of SIW Flower Slot- Dumbbell shaped Antenna

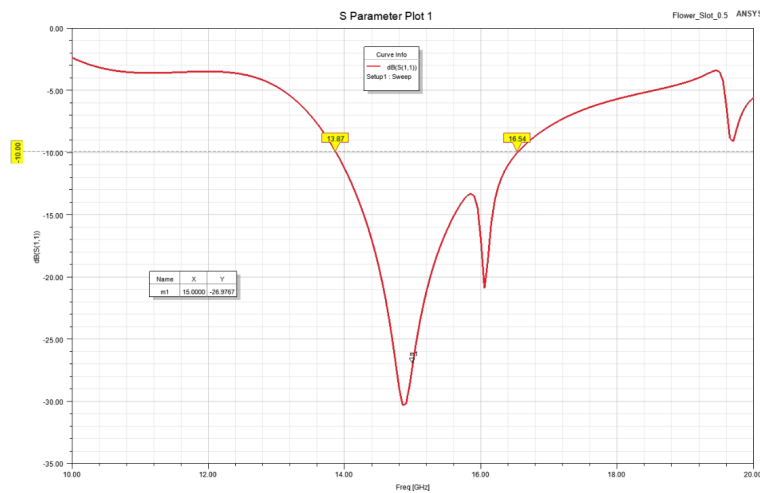


Figure 3.19: S parameter of SIW Flower Slot- Dumbbell shaped Antenna

3.8 Design of SIW Flower Cut Slot Antenna

Here corresponding design of flower-cut shaped antenna parameters is shown in the Fig. 6.5. Therefore a compact and miniaturize of and it has a design is simple. Their flower shape antenna is a simulation of HFSS. Flower slot is cut by a inverted L at both of the side of flower antenna.

The simulated results shows that it offers impedance bandwidth of 14.836% fractional bandwidth (from 14.54 to 16.87GHz) and 1.897% fractional bandwidth (from 10.96

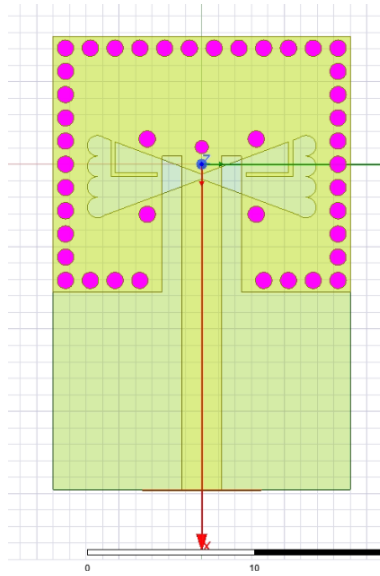


Figure 3.20: Schematic diagram of SIW Flower Cut Slot Antenna

to 11.17GHz). It achieves a gain of 5.9dBi. Moreover, desirable radiation performance characteristics with high gain and achieving to start broadband at 15GHz and 16GHz frequency range. Simulation results verified that the broadband dual-frequency antenna can achieve the double broadband performance, and it can completely cover frequency band of 10.96 to 11.17GHz and 14.54 to 16.87GHz

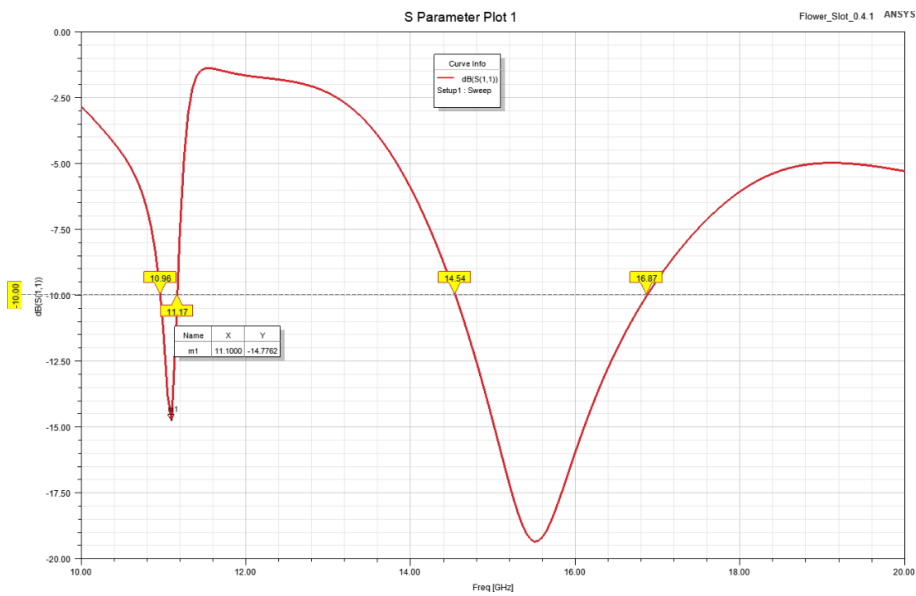


Figure 3.21: S parameter of SIW Flower Cut Slot Antenna

3.9 Design of SIW Modified Flower Slot- Dumbbell Shaped Antenna

The latest version of the design consists of a Flower shape antenna which is modified with dumbbell slot above the flower shape antenna, a cut slot is introduced at the top side of the substrate with 2 corners bent over to the bottom. This shape helps to achieve a broadband dual-frequency performance. The schematic diagram of SIW Modified Flower Slot- Dumbbell Shaped Antenna in front view and back view as in figure 3.23 and 3.24 respectively.

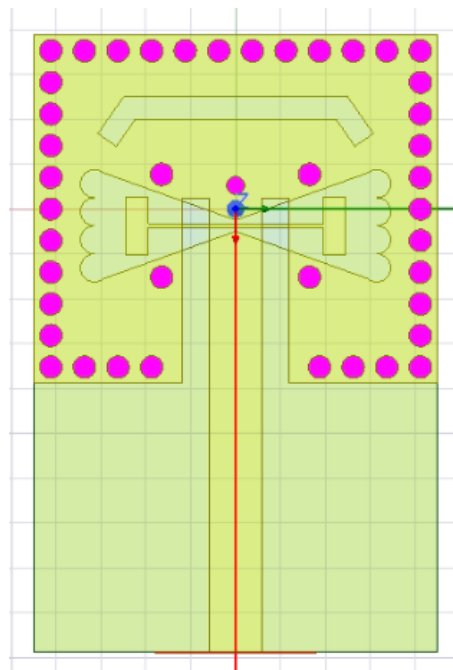


Figure 3.22: Schematic diagram of SIW Modified Flower Slot- Dumbbell Shaped Antenna

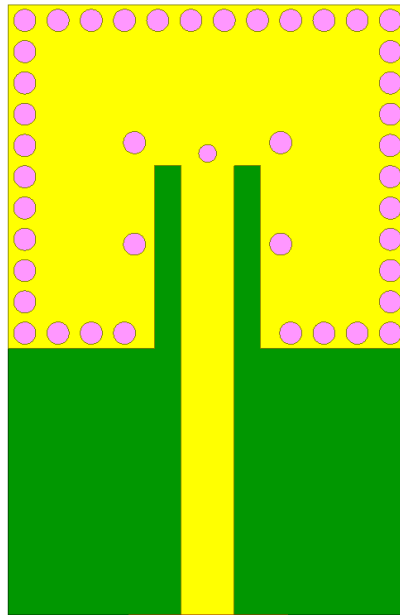


Figure 3.23: SIW Modified Flower Slot- Dumbbell Shaped Antenna front view

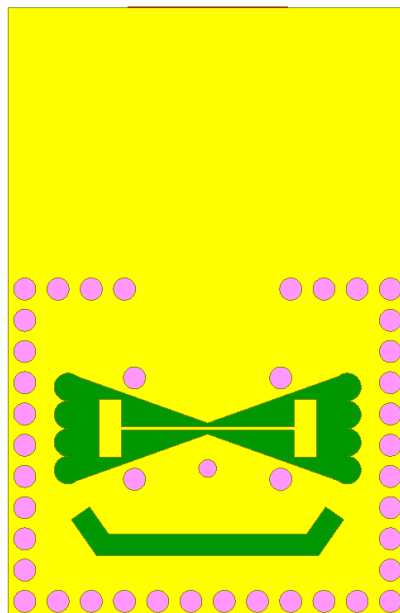


Figure 3.24: SIW Modified Flower Slot- Dumbbell Shaped Antenna back view

Chapter 4

Results and Discussion

4.1 Results of 2*1 SIW Antenna Array

S11 PARAMETER RESULTS

To demonstrate the simulated performance of the antenna, photograph of the sample is included in Figure which shows an excellent agreement with between them. The measured and simulated impedance bandwidth is 16%. Antenna array which is radiated at 3 frequencies m1,m2 and m3 11.6, 12.95 and 13.9 GHz respectively.

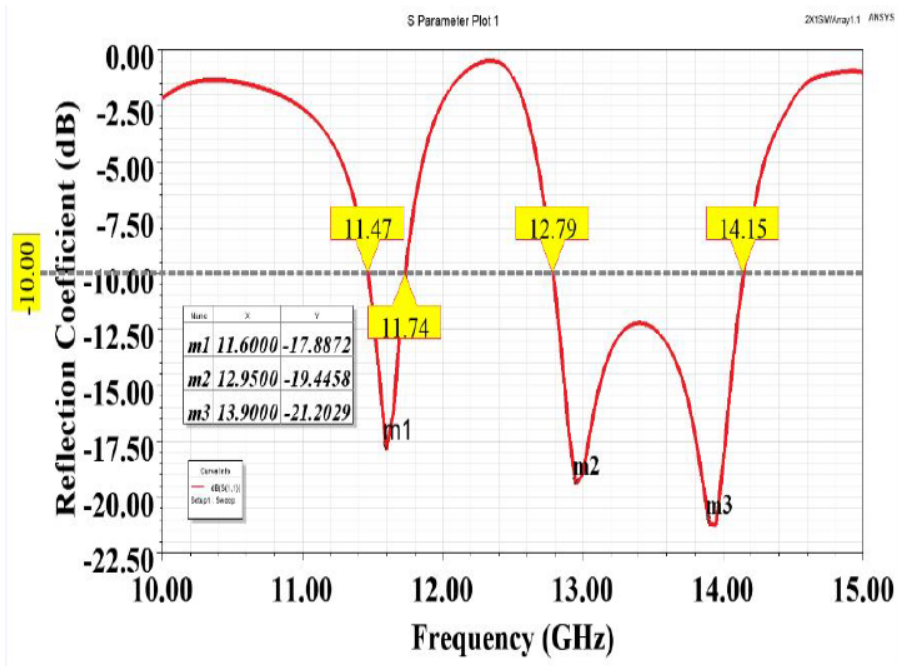


Figure 4.1: Simulated —S11— of the antenna array

RADIATION PERFORMANCE

The azimuth plane (x-z plane) and elevation plane (y-z plane) normalised radiation patterns at 11.6, 12.95, and 13.9 GHz are depicted in Figure 4.2, 4.3 and 4.4 respectively. The results from simulation and measurement are in good agreement. In comparison to the simulated gain of 14.9 dBi, the tests show that the antenna array's highest gain is 13.97 dBi. The fabrication defects and the air-gap issue when stacking each of the layers are to blame for the differences between the measurement and simulation. The proposed antenna array has good polarisation qualities because its cross-polarization values are less than 20 dB across the full operational frequency band.

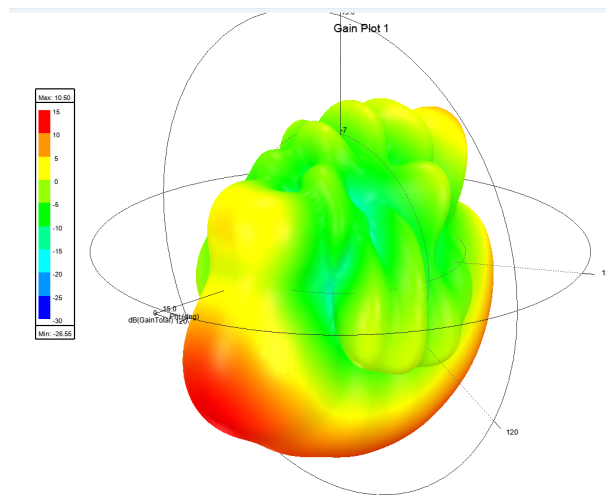


Figure 4.2: Radiation pattern at 11.6GHz

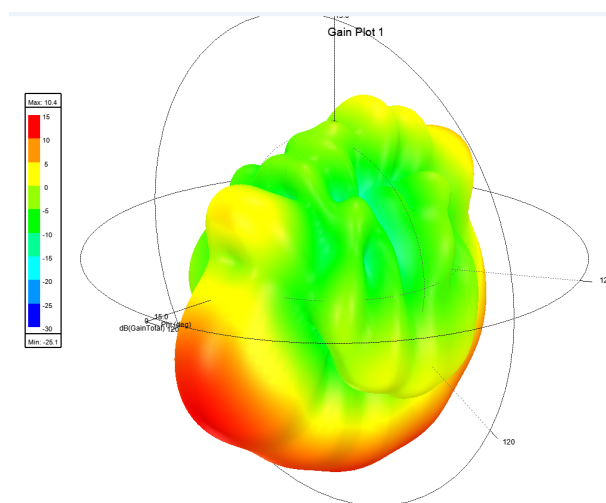


Figure 4.3: Radiation pattern at 12.95GHz

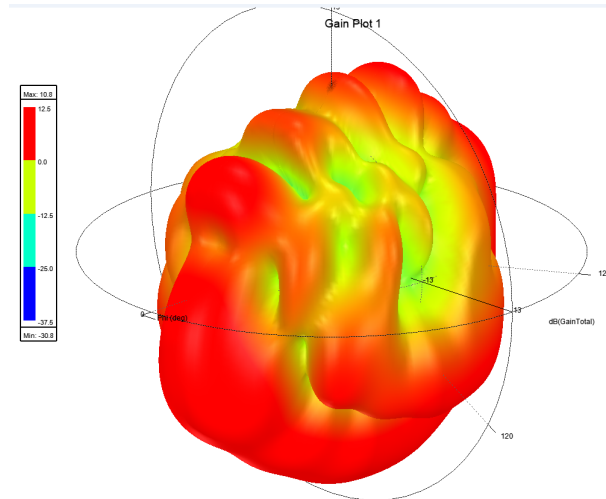


Figure 4.4: Radiation pattern at 13.5GHz

4.2 Results of SIW Modified Flower Slot- Dumbbell Shaped Antenna

The simulated results show that it offers impedance bandwidth of 16.362% fractional bandwidth (from 13.58 to 16GHz). It achieves a gain of 9dBi. Figure 4.5 depicts the s parameter of SIW Modified Flower Slot- Dumbbell Shaped Antenna. Simulation results verified that the broadband dual-frequency antenna can achieve the double broadband performance, and it can completely cover frequency band of 13.58 to 16GHz and 16.08 to 17.58GHz. It has impedance matching at 16.05GHz frequency. In figure 4.7, shows that antenna achieves 100% of efficiency and z parameter of SIW Modified Flower Slot- Dumbbell Shaped Antenna as in figure 4.6. This design achieves high impedance bandwidth and high broadband performance, So this design is used for the high gain broadband SIW antenna array for KU band satellite communications. Figure 4.8-4.11 shows the simulated radiation patterns of the proposed antenna in two principal planes E and H. The SIW Modified Flower Slot- Dumbbell Shaped Antenna exhibits good unidirectional radiation at three resonance frequencies 13.95GHz, 14.95GHz and 16.3GHz.

The table 4.1 shows the comparison of different antenna design. To improve the impedance bandwidth and gain, proposed SIW cavity backed bow tie slot antenna is diverted to flower slot antenna with dumbbell shaped antenna which improves the gain

3.7dBi to 9dBi.

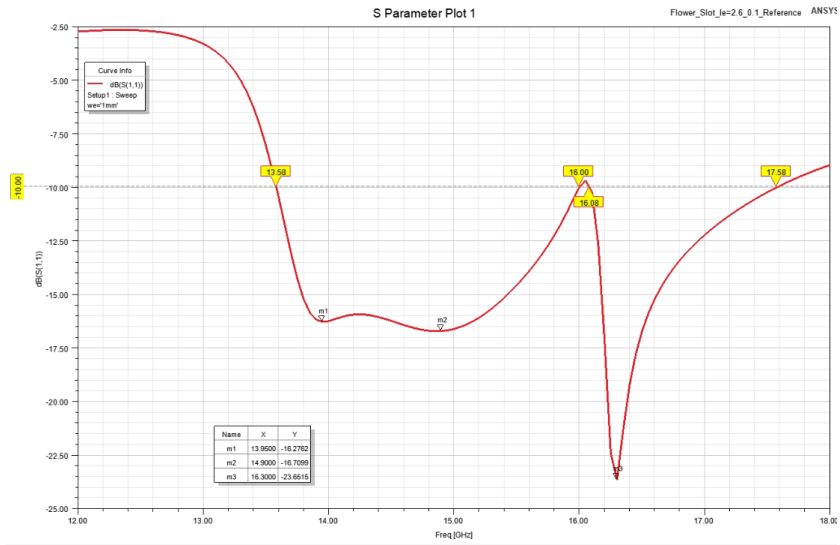


Figure 4.5: S parameter of SIW Modified Flower Slot- Dumbbell Shaped Antenna

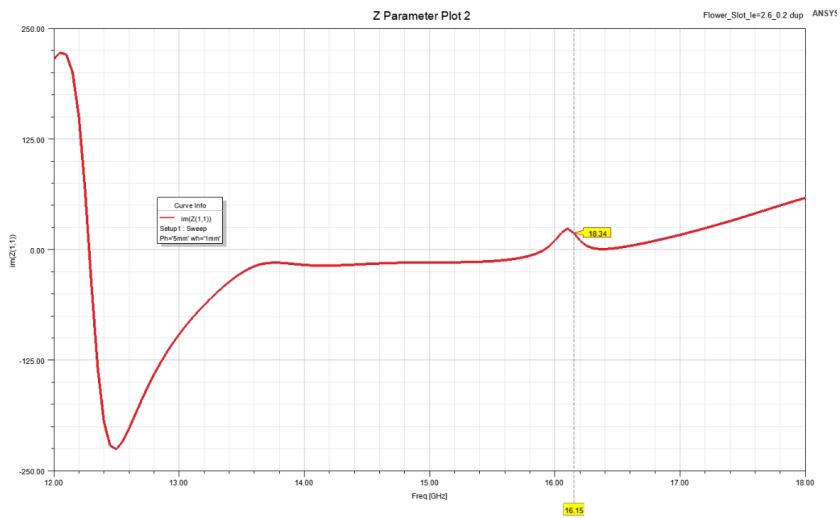


Figure 4.6: Z parameter of SIW Modified Flower Slot- Dumbbell Shaped Antenna

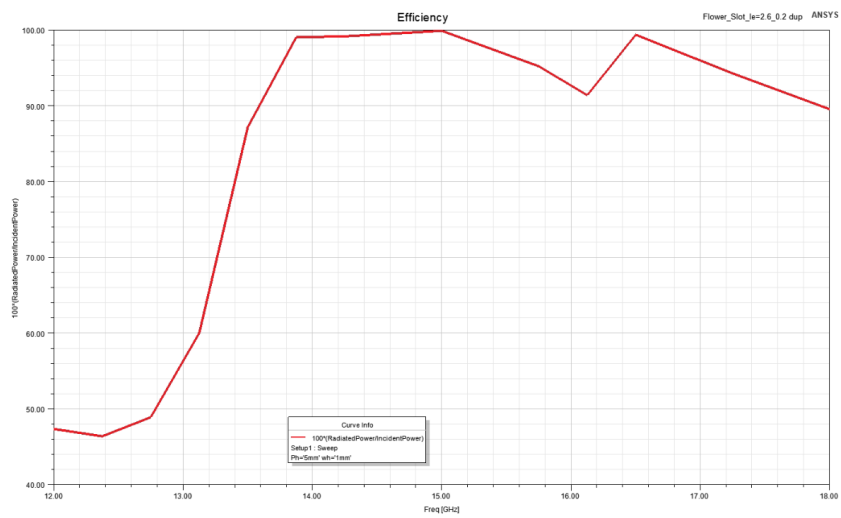


Figure 4.7: Efficiency of SIW Modified Flower Slot- Dumbbell Shaped Antenna

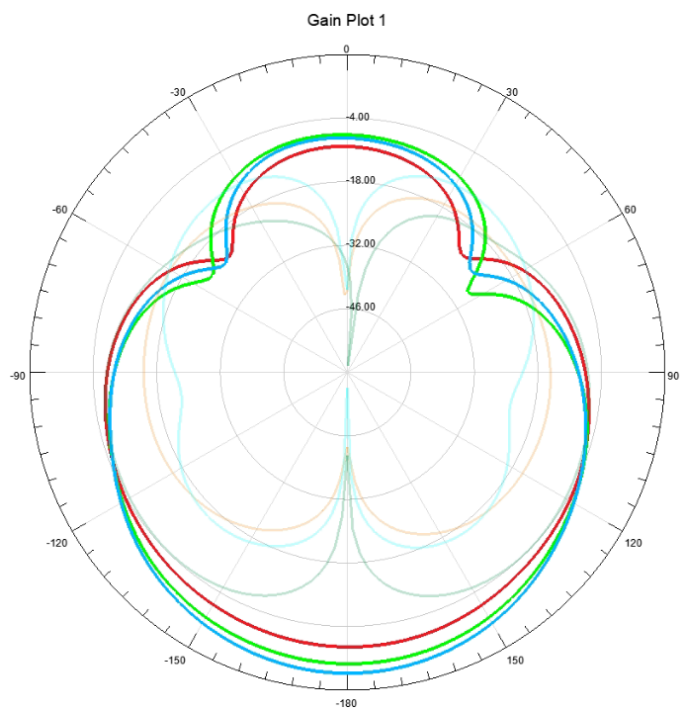


Figure 4.8: Gain plot (Phi) of SIW Modified Flower Slot- Dumbbell Shaped Antenna

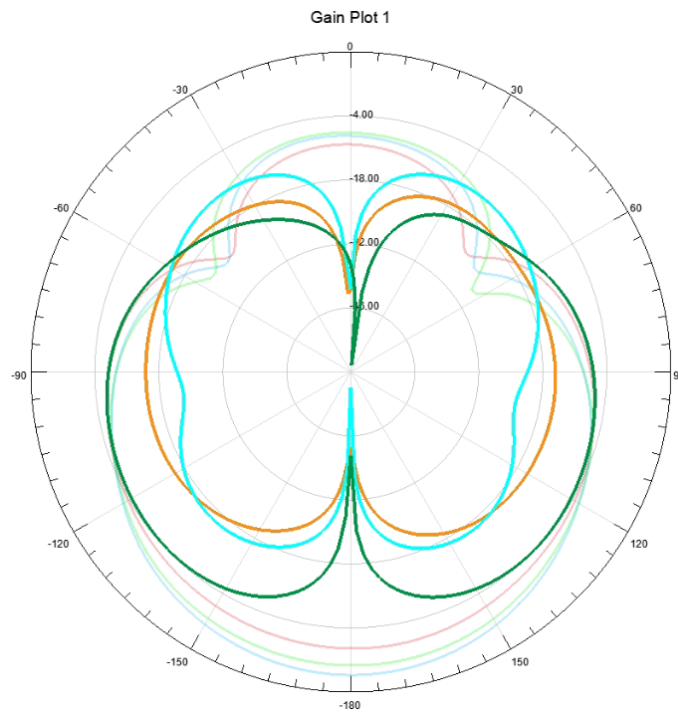


Figure 4.9: Gain plot (Theta) of SIW Modified Flower Slot- Dumbbell Shaped Antenna

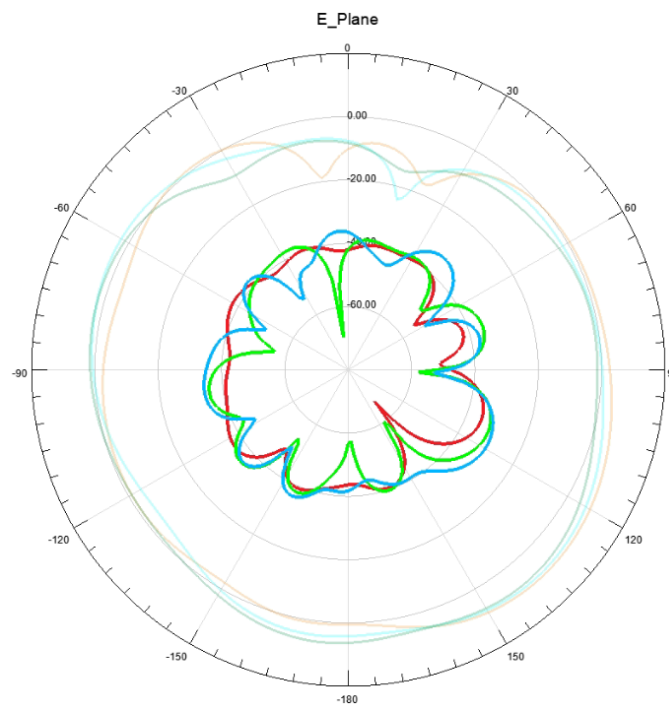


Figure 4.10: E Plane plot (Phi) of SIW Modified Flower Slot- Dumbbell Shaped Antenna

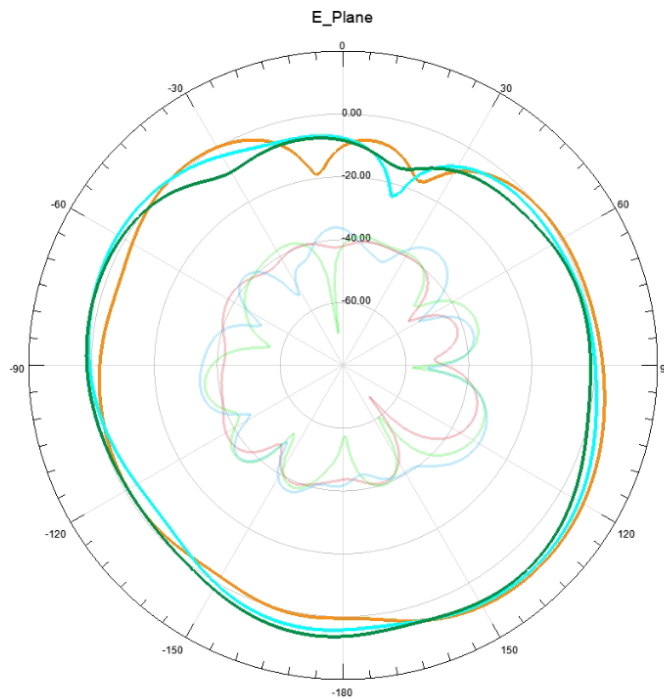


Figure 4.11: E Plane plot (Theta) of SIW Modified Flower Slot- Dumbbell Shaped Antenna

Table 4.1: Comparison of different antenna design

Design	Impedance Bandwidth	Gain
SIW Cavity-Backed Bow-Tie Slot Antenna	9.4%	3.7dBi
New Design of SIW Cavity-Backed Bow-Tie Antenna	12.93%.	4dBi
SIW Cavity-Backed Flower Slot Antenna	17.04%	6.1dBi
SIW Flower Slot- Dumbbell shaped Antenna	17.56%	6dBi
SIW Flower Cut Slot Antenna	14.836%	5.9dBi
SIW Modified Flower Slot- Dumbbell Shaped Antenna	16.362%	9dBi

Chapter 5

Conclusion

High Gain Broadband Antenna Array for Ku Band Satellite Communication in which, the High-order modes are stimulated by the combination between the slot and the feeding structure. better performances and simulated radiation patterns. The broadband impedance bandwidth can be obtained by making the high-order modes close to each other. Project aims at two phases, one is high gain broadband 2X1 antenna array for communications which achieves impedance bandwidth of 10.09% and gain of 10.8dBi. Moreover, the modified slot geometry of 2*1 antenna array enhances the better performances and radiation performances. Next phase of project part is high gain broadband SIW antenna for KU band satellite communications. Here achieves gain of 9dBi and impedance bandwidth of 16.36% and achieves 100% of efficiency. With the proper placement of flower and dumbbell slots on the backside of the cavity, the hybrid modes are generate in the frequency band, therefore the simulated impedance bandwidth is substantially enhanced to 16.362%, with a gain of 3.7 to 9 dBi. The The mentioned advantages make the antenna array more suitable for high-gain, low cross-polarized and broadband Ku band satellite communications applications. The ultimate goal of this antenna is used for different applications of Ku-band wavelength applications. The growing and demanding need of high speed communication along with improved performance will lead to explore new ways of transmission/reception. The proposed and designed antenna can be used for communication purpose in ku band communication and further if the gain is improved in antenna array made in future to meet the ku band satellite applications.

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