A LINEAR FRACTAL IMPEDANCE MATCHING ARRAY ANTENNAFOR 5G SPECTRUM APPLICATIONS

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 ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KONIDENA CHANDUSWEETY (37130205)** who carried out the project entitled **"A LINEAR FRACTAL IMPEDANCE MATCHING ARRAY ANTENNAFOR 5G SPECTRUM APPLICATIONS .** under my supervision from Novemberber 2020 to march 2021.

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Head of the Department
Dr. T. RAVI, M.E., Ph.D.,

Submitted for Viva voce Examination held on ______________

Internal Examiner **External Examiner**

DECLARATION

I KONIDENA CHANDUSWEETY (37130205) hereby declare that the Project Report entitled," **LINEAR FRACTAL IMPEDANCE MATCHING ARRAY ANTENNAFOR 5G SPECTRUM APPLICATIONS**" done by me under the guidance of **Dr.T.RAVI, ME., Ph.D.,** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

1)

DATE :

SIGNATURE OF THE CANDIDATE

PLACE :

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ABSTRACT

Today, the two key access technologies that enable communication to the short upcoming 5G mobile communications. The 5G is expected to work at frequency 28 GHz as the candidate for its frequency band allocation. This technology would provide high data rates and high-quality multimedia applications, i.e., audio, video, and data services. These systems also demand highly efficient, compact, and wide bandwidth wireless antennas. 5G technology would provide high data rates and high-quality multimedia applications. This technology needs a broad bandwidth antenna. Among various antenna types, the linear fractal impedance matching array antenna has advantages of good design ,wide-bandwidth of frequency , and low-cost material for the antenna. A fractal is a recursively generated object having a fractional dimension. They have no characteristic size, and are constructed of many copies of themselves at different scales. Our Project focus on design of linear fractal impedance array antenna for matching even number of gain and bandwidth frequency of antenna . Arrays will be analyzed by fractal electrodynamics and also simulate the results by HFSS(High Frequency Structure Simulator) simulation software. The antenna will fabricated and analyzed.

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CHAPTER 1

INTRODUCTION TO ANTENNAS

Antennas are major part of any wireless communication system. In today's scenario, although, antenna as a device is not new to common man, but the level of understanding the background concept involved in the working of this device will certainly help in designing new types of antennas, in order to meet the necessary requirements in wireless domain.

Transmit antenna element is transferred to the other elements. Correspondingly, a portion of the energy in the incident field of a receive antenna element is transferred to the nearby elements. Another way of describing the effect of mutual coupling is that the electric field generated by one element alters the current distribution, as well as distorts the radiation/reception pattern of the other elements as compared to their isolated radiation/reception patterns. Moreover, the mutual coupling among array antennas depends on their radiation characteristics, relative separation and orientation. Hence, it is very important to investigate the impact of mutual coupling on the accuracy of measurements in a MPS system Antenna arrays are widely employed in both commercial and military applications. Consequently, there are many research topics devoted to enhance the performance of the various array configurations used. In particular, mutual coupling between the antenna elements in an antenna array is a potential source of performance degradation. Depending on the application, errors due to mutual coupling can be significant. Mutual coupling variations between the elements are a source of amplitude and phase errors.

The presence of mutual coupling distorts phase vectors of radiation sources. This can cause severe degradation of the performance in radar as well as increasing the bit error rate (BER) in communication antennas, if it is not properly compensated. The study of MIMO systems is more advantageous and also it is seen that the MIMO performances are linked to the mutual coupling and diversity of the systems. In order to incorporate the best advantages of MIMO systems, the element antennas need to be sufficiently spaced in the mobile systems. However, large sized antennas cannot be implemented in the mobile terminals. The existence of mutual coupling has to be taken in account in small size arrays and it affects the MIMO performances.

Mutual coupling increases with the reduced antenna spacing which causes problems in achieving high capacity of the system. Performance degradation in the MIMO systems due to the mutual coupling effect of antenna arrays is a well-known phenomenon.

1.1 ANTENNA BASICS

In any wireless communication system, after a radio frequency (rf) signal has been generated in a transmitter, some means must be used to radiate this signal through space to a receiver. The Rf energy is transmitted into space in the form of an electromagnetic field. As the travelling electromagnetic field arrives at the receiving antenna, a voltage is induced into the antenna.

The rf voltages induced into the receiving antenna are then passed into the receiver and converted back into the transmitted rf information. So, antennas can be thought of as a “transducer” that converts radio waves into electrical currents and voltages and vice versa.

1.2 TYPES OF ANTENNA

There are different types of antennas such as wire antenna, aperture antenna, reflector antenna, lens antenna, micro strip antenna,fractal antenna,etc…

1.2.1 Wire antennas

- Dipole, monopole, loop antenna, helix.
- Usually used in personal applications, automobiles, buildings, ships, aircrafts and spacecrafts.

1.2.2 Aperture Antennas

- Horn antennas, waveguide opening.
- Usually used in aircrafts and space crafts, because these antennas can be flush mounted.

1.2.3 Reflector Antennas

- Parabolic , corner reflectors
- Communication and Satellite Tracking.

1.2.4 Lens Antennas

- Convex plane, convex-convex, concave-convex and concave plane lenses.
- These antennas are usually used for very high frequency applications.

1.2.5 Microstrip Antennas

- Rectangular, Circular etc shaped metallic patch above a ground plane.
- Used in aircraft, spacecraft, satellites, cars, mobile phones etc.

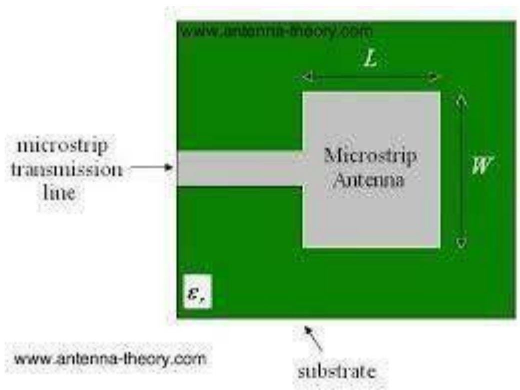


Fig:1.1: Microstrip antenna

1.2.5.1 Microstrip patch antenna

The microstrip patch antenna is a popular printed resonant antenna for narrow-band microwave wireless links. Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side as shown in Figure 1.1. The patch is generally made of a conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate

The microstrip antenna was first proposed by G.A. Deschamps in 1953, but didn't become practical until the 1970s when it was developed further by researchers such as Robert E. Munson and others using low-loss soft substrate materials that were just becoming available for good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.

1.2.5.2 Advantages and disadvantages of microstrip patch antenna

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure.Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc. The telemetry and communication antennas on missiles need to be thin and conformal and are often Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication. Some of their principal advantages are It is lightweight, low volume and thin profile configuration. These make them to be easily incorporated into any package. It has a low profile planar configuration that can be easily made conformal to host surface which fits the shape design and needs of modern communication equipment.

It can be made compact for use in personal mobile communication. The microstrip antenna shape flexibility enables mounting them on a rigid surface which makes them mechanically robust. Using printed-circuit technology leads to a low fabrication cost hence can be manufactured in large quantities. It supports both linear polarization and circular polarization. They accept for dual and triple frequency operations and can be easily integrated with microwave integrated circuits (MICs) on the same substrate.

Microstrip patch antennas also have a number of disadvantages as compared to conventional antennas. Some of their major disadvantages discussed are: It operates over narrow bandwidth, low efficiency and low gain while compared with conventional antennas. Extraneous radiation from feeds and junctions and relatively poor radiation efficiency as it radiates only in half-space. It also has low power handling capacity and high loss resulting from surface wave excitation.

1.3 Fractal Antenna

Antenna theory has become one of the latest fields where fractal geometry‟s use has made a significant impact. As a matter of fact, some of the antennas commercially used in the telecom sector have already been replaced by that using fractal geometry. Several improvements have already been observed in the case of antennas that make use of the aforementioned geometry. What‟s in fact missing is a direct connection between the usage of the properties of the underlying fractal geometry and the antenna features.

Some of the significant improvements attributed to fractals are size reduction of antennas and introduction of multi-band nature. They continue to remain the prime motivation, albeit more utilities have come into the scene. Using fractal gaskets (Sierpinski), for instance, reports of many dipole and monopole antennas have been made. Given that these qualitative links are not always fool-proof, design optimisation necessitates the existence of a quantitative connection. It‟s an area of continuous research to link to do the same, i.e. to establish a mathematical relation between the fractal dimensions and antenna behaviour.

1.3.1 Fractal theory

Self- similar geometrical shapes which repeat themselves are called fractals. This repetition is over different scales. The fact that length of the antenna increases without altering area is a major plus which makes the geometry an important fact of consideration. A mathematical process is used to arrive at the fractal‟s shape. This is called the IFS (Iterative Function Scheme). Analysis of all different types of fractals reveal the impossibility of knowing the level one is examining while doing so with fractals. This is so because at finer scales the same pattern tends to re-appear.

There are two stages of fractal generation: Initiator and Generator.

1) 0th stage (Initiator): It‟s the basis of the next step of design and any shape can be it ranging from rectangle to any other polygon.

2) Generator: This is the shape which scaling results. Subsequent stages of scaling of the initiator are required to be done to get the final design. Initiators generate generators.Owing to their features, fractals have numerous utilities

1. NO characteristic shape, shapes are very irregular Presence of infinite scaling results in repetition of the same shape at smaller scales with equal proportionality.

2. High Convolution

Associated with infinite complexity, fractals can be used for antennas with operational capabilities at multiple capabilities as the structure just keeps on repeating every time one zooms in. With respect to Euclidean geometry, its efficiency in filling the space available is much better. For a given volume this leads to more energy coupling. Virtually endless length is rendered owing to the presence of irregularities in enormous amounts and these are naturally broadband at higher frequencies.

Euclin Geometry Fractal GeometryDefined by formula Defined by iterative ruleApplicable for artificial objects Applicable for natural objectsScaling changes Shapes Self-similar, Invariant under scalingAnalytical equations define objects Recursive algorithms define object Differentiable Locally smooth, Not differentiable Locally rough, Elements: vertices, surfaces, edges Elements: functions‟ iteration.

1.3.6 Array Antennas

- Yagi-Uda antenna, Microstrip patch array, Aperture array, Slotted wave guide array.
- Used for high gain applications with added advantage such as controllable radiation.

1.4 ANTENNA PARAMETERS

An antenna is characterised by various performance parameters such as return loss, VSWR, gain, directivity, efficiency, band width, etc. These parameters are briefly discussed below.

1.4.1 Return Loss

The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. The relationship between SWR and return loss is the following.

Fig:1.2: Example for return loss

1.4.2 Band Width

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1. The bandwidth can also be described in terms of percentage of the center frequency of the band.

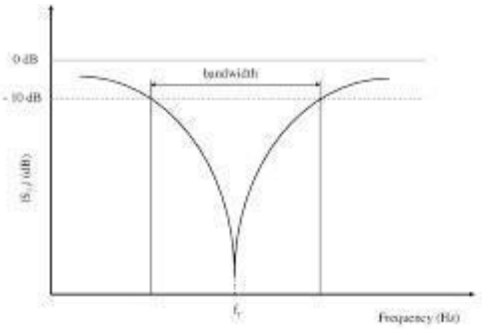


Fig:1.3: Example plot for bandwidth

1.4.3 Directivity

Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction when receiving. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the wanted direction. However in a dynamic system where the transceiver is not fixed, the antenna should radiate equally in all directions, and this is known as an omni-directional antenna.

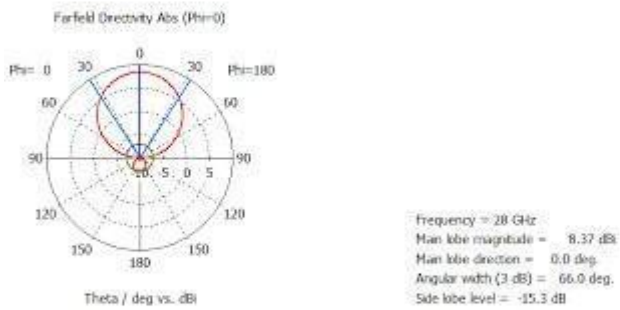


Fig:1.4: Example plot for directivity

1.4.4 Gain

Gain is not a quantity which can be defined in terms of a physical quantity such as the Watt or the Ohm, but it is a dimensionless ratio. Gain is given in reference to a standard antenna. The two most common reference antennas are the isotropic antenna and the resonant half-wave dipole antenna. The isotropic antenna radiates equally well in all directions. Real isotropic antennas do not exist, but they provide useful and simple theoretical antenna patterns with which to compare real antennas. Any real antenna will radiate more energy in some directions than in others. Since it cannot create energy, the total power radiated is the same as an isotropic antenna, so in other directions it must radiate less energy. The gain of an antenna in a given direction is the amount of energy radiated in that direction compared to the energy an isotropic antenna would radiate in the same direction when driven with the same input power. Usually we are only interested in the maximum gain, which is the gain in the direction in which the antenna is radiating most of the power. An antenna gain of 3 dB compared to an isotropic antenna would be written as 3 dBi. The resonant half-wave dipole can be a useful standard for comparing to other antennas at one frequency or over a very narrow band of frequencies. To compare the dipole to an antenna over a range of frequencies requires a number of dipoles of different lengths. An antenna gain of 3 dB compared to a dipole antenna would be written as 3 dBd. The method of measuring gain by comparing the antenna under test against a known standard antenna, which has a calibrated gain, is technically known as a gain transfer technique. Another method for measuring gain is the 3 antennas method. Where the transmitted and received power at the antenna terminals is measured between three arbitrary antennas at a known fixed distance.

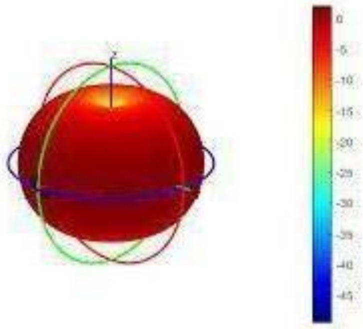


Fig:1.5: Example for gain pattern of an antenna

1.4.5 Radiation Pattern

The radiation or antenna pattern describes the relative strength of the radiated field in various directions from the antenna, at a constant distance.

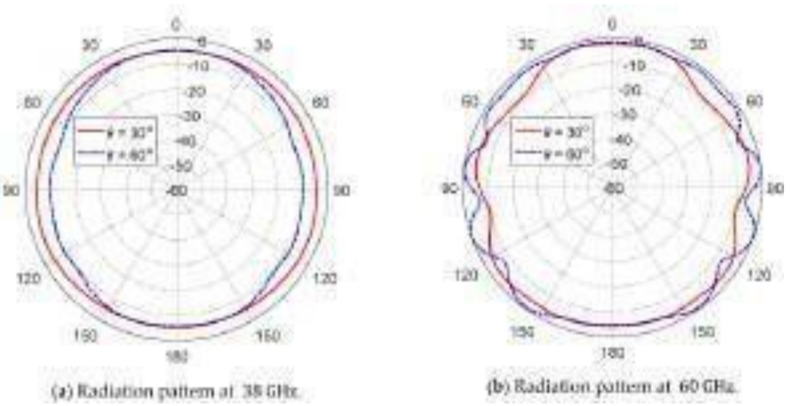


Fig:1.6: Example of Radiation Pattern

The radiation 8 pattern is a reception pattern as well, since it also describes the receiving properties of the antenna. The radiation pattern is three-dimensional, but usually the measured radiation patterns are a two dimensional slice of the threedimensional pattern, in the horizontal or vertical planes. These pattern measurements are presented in either a rectangular or a polar format.

1.5 NEEDS OF ANTENNAS

Wireless communications are impossible without antennas. An antenna is considered as a region of transition between a transmission line and space. The characteristic features of antenna are listed below:

- Light weight
- Small Size
- Effective and Efficient Operation
- Meeting Various Wireless Applications
- Broadband Frequency coverage
- Inexpensive
- Easy to design and manufacture
- Robust

1.6 SCOPE OF THE PROJECT

It compacts linear fractal array antenna developed on a FR4 substrate material to reduce the mutual coupling between two arrays patches. It enhances the performance characteristics of proposed antenna. Transmission line feed is used to feed the antenna in this case. Slotting techniques will be used on the radiating patch to reduce the impedance mismatching between the feed line and the patch. In this thesis work, various antenna array configurations has been modelled using HFSS to see the impact of coupling within the array and a MPS system is finally suggested which has low coupling effects. To design a miniaturized linear fractal impedance array antenna to reduce the cost and gives high frequency and band width .

CHAPTER 2

LITERATURE SURVEY

2.1 RELATED WORK

Lamine Sane et al. (2019), proposed a design of two elements pattern reconfigurable dual-band (2.6/3.6 GHz) and broadband Multiple Input Multiple Output (MIMO) antenna for excepted 5G wireless communication systems is proposed in this paper. The antenna structure is simple, compact and only occupied a small space of 18x5.5x4.5 mm^3. Pattern reconfigurability is achieved by using a dual band Branch-Line Coupler (BLC). BLCs are commonly used in balanced amplifiers and mixers for achieving good return loss, as well as spurious signal rejection. In antenna design area, couplers, particularly Ring Hybrid Couplers are used to get high isolation between ports. In this work, we propose the use of BLC for doing both decoupling antenna system and pattern reconfigurability. Simulated and measured Sparameters are presented in this paper. The measured results show that the proposed MIMO antenna system achieves in each band isolation between ports better than 25 dB, more than 80 percent efficiency and has a maximum gain of 2.74 dB.

Assane Ngom et al. (2019) proposed a design of dual-band pattern reconfigurable Multiple Input Multiple Output 2x2 antenna system design for 5G wireless communications systems. The proposed system operates at central frequencies of 2.6 GHz of 2.5-2.69 GHz band (Low Band (LB)) and 3.61 GHz of 3.4 – 3.8GHz band (High Band (HB)). The proposed technique of doing pattern reconfigurability in each band is the use of standard quadrature 3dB coupler. This method allows booth to make pattern reconfigurability and decoupling excitation ports of the antenna system. Simulated and measured scattering parameters are presented in this paper. The proposed MIMO antenna system has a return loss better than – 10 dB, more than 80 percent efficiency in each band and achieves a good gain.

Junho Park et al. (2019) proposed a design of novel hybrid antenna module concept at millimeter-waves to realize spherical beamsteering coverage that is structurally and systematically compatible with present day cellular devices. The hybrid antenna module concept coherently combines two existing concepts – the AiP (Antenna-in-Package) and AoD (Antenna-on-Display) tosteer the antenna main lobe in the end-fire and broadside direction. A compact end-fire antenna array (AiP) and a fully optically transparent antenna array (AoD) achieve impedance bandwidth (2:1 VSWR) of 1.67 GHz and 0.85 GHz respectively at28 GHz. Investigation in the farfield ascertains that the 4-elementend-fire AiP and the 16-element broadside AoD exhibit a realized gain of 9.2 dBi and 12.8 dBi in the $\theta = 90°$ and $\theta = 0°$ respectively.

Mohammad Ababil Hossain et al. (2017) presented a design, prototyping, and characterization of a radiation pattern reconfigurable antenna (RA) targeting 5Gcommunications are presented. The RA is based on a reconfigurable parasitic layer technique in which a driven dipole antenna is located along the central axis of a 3-D parasitic layer structure enclosing it. The reconfigurable parasitic structure is similar to a hexagonal prism, where the top/bottom bases are formed by a hexagonal domed structure. The surfaces of the parasitic structure house electrically small metallic pixels with various geometries. The adjacent pixels are connected by PIN diode switches to change the geometry of the parasitic surface, thus providing reconfigurability in the radiation pattern. This RA is designed to operate over a 4.8–5.2 GHz frequency band, producing various radiation patterns with a beam-steering capability in both the azimuth ($0° < \varphi < 360°$) and elevation planes ($-18° < \theta < 18°$). Small-cell access points equipped with RAs are used to investigate the system level performances for 5Gheterogeneous networks. The results show that using distributed mode optimization, RA equipped small-cell systems could provide up to 29% capacity gains and 13% coverage improvements as compared to legacy omni directional antenna equipped systems.

Walid Saad et al. (2019) has done the ongoing deployment of 5G cellular systems is continuously exposing the inherent limitations of this system, compared to its original premise as an enabler for Internet of Everything applications. These 5G drawbacks are spurring worldwide activities focused on defining the next-generation

6Gwireless system that can truly integrate far-reaching applications ranging from autonomous systems to extended reality. Despite recent 6G initiatives 1, the fundamental architectural and performance components of 6G remain largely undefined. In this paper, we present a holistic, forward-looking vision that defines the tenets of a 6G system. We opine that 6G will not be a mere exploration of more spectrum at high-frequency bands, but it will rather be a convergence of upcoming technological trends driven by exciting, underlying services. In this regard, we first identify the primary drivers of 6G systems, in terms of applications and accompanying technological trends. Then, we propose a new set of service classes and expose their target 6G performance requirements. We then identify the enabling technologies for the introduced 6G services and outline a comprehensive research agenda that leverages those technologies. We conclude by providing concrete recommendations for the roadmap toward 6G.Ultimately, the intent of this article is to serve as a basis for stimulating more out-of-the-box research around 6G.

Yogesh Tyagi et al. (2017) proposed a design of novel X-band high-efficiency broadband slotted waveguide array (SWA) antenna. Broadband nature of SWA has been achieved using differential feeding mechanism which bifurcates large resonating SWA into wideband sub-arrays by creating virtual short. The performance of such type of broadband SWA is also compared with conventionally designed edge fed SWA and coupling slot fed SWA. The proposed broadband SWA features high efficiency, high power handling capacity and low fabrication tolerances as compared with conventional SWA designs. The design and prototype development of tenelements linear SWA with differential feeding mechanism is presented. The developed prototype array antenna demonstrates measured return loss (RL) performance better than 17 dB with 90.2% antenna efficiency over 7.6% bandwidth. The realised gain of 16.32 dBi at 9.65 GHz is measured and the proposed antenna also shows significant improvement in gain flatness.

MohAmanta et al. (2017) discusses a design and simulation of the addition the number of slots on narrow wall waveguide antenna at X-band 9.4 GHz. The simulation results showed that the increment of slots number will narrow the bandwidth. However, compared to the broad wall slotted waveguide antenna, a narrow wall slotted waveguide antenna yield a wider bandwidth in the same number of slots and slot width. On the narrow wall slotted waveguide, the slot of waveguide interrupts the flow of current and the current around the slot that flows on the wall so that the power will be coupled from the waveguide field through the hole of the slotted waveguide to free space. For the excitation of linear slots to be well controlled, the rectangular waveguide is recommended operate only in single mode and preferably in small mode.

Pushkar B et al. (2016) presented a substrate integrated waveguide (SIW) cavity-backed slot antenna with 34% bandwidth at X-band. Dual differential feeding with a phase offset of 90◦ is employed to achieve circular polarization, resulting in an excellent isolation. The antenna achieves wide-band circularly polarized radiation with symmetric patterns in both principal planes, with average gain of 5.7 dB and simulated radiation efficiency greater than 96%. The antenna and its feeding structure are implemented on three dielectric layers, Upper, Lower and MSUB. The cavity is composed of Upper and Lower dielectric layers having low dielectric constant (εr = 2.2) and low loss (tan δ = 0.0009). MSUB is a dielectric layer that feeds the antenna with microstrip. It has high dielectric constant (εr = 6.15) and low loss (tan δ = 0.002) to keep the profile of the antenna low. The three dielectric layers are bonded together using a bonding film with electrical properties, εr = 2.28 and tan δ = 0.003. The conductor used for metallization is 1/2 oz. copper.

Indranil Acharya et al. (2017) provides a basic antenna structure in a circular patch which is modified by adding complementary circular split ring resonators and T strip connected to the top of the patch. The antenna is fed by a 50 ohm microstrip feed line. A slot of dimension 2 x 3.6mm2 is inserted in the ground plane which consists of a staircase structure having appropriate dimensions.The cicular patch antenna is designed in FR4 substrate having dielectric constant value 4.4 and thickness 1.5 mm. The circular patch has a radius of 11 mm. The 50 ohm microstrip feed has a width of 2.6 mm. The top portion of the patch is removed in order to achieve UWB characteristics.

Chandu DS et al. (2016) presents a novel approach to the design of substrate integrated waveguide (SIW) based slotted array antennas where wideband characteristics can be achieved when SIW is fed by a combination of longitudinal and transverse slots. 45° inclination of the transverse slots excites the orthogonal components of E-field to phase quadrature leading to circular polarization. To validate the design, a compact antenna of volume 29.72 x 37.92 x 1.6 mm3 is fabricated on a 1.6 mm thick FR4 substrate. Simulated and measured results show good return loss under 10dB from 10 GHz - 27 GHz covering X, Ku and K bands. The 3-dB axial ratio bandwidth (ARBW) is 1.90% (10.38 GHz - 10.58 GHz) in the X band, 10% (17 GHz - 18.7 GHz) in the Ku band, and 1.11% (19.58 GHz - 19.8 GHz) in the K band. It is also observed from the far field patterns that the main lobe can be discretely scanned from +22.5° to +67.5° in the X band.

ManikBhowmik et al. (Au2016) a modified Swastika slot on a Circular Patch antenna has been studied and proposed that operates in X, Ku, K, and Ka band. The proposed antenna is a novel design technique where the design of the modified swastika shaped slot is done in different iterations. High Frequency Structural Simulator (HFSS) version 13.0 which is based on finite element method is used for the simulation purpose. The proposed antenna is simulated and found to operate at five different resonant frequencies at 10.4 GHz, 16.5 GHz, 21.8 GHz, 26.9 GHz, and 29.9 GHz. The designed antenna shows better return loss, low VSWR, high antenna gain with good bandwidth and better radiation pattern characteristics where it can be used in satellite and RADAR applications.

Michael Civerolo (Apr 2015) provides a design of a rectangular WR62 waveguide fed fin-line (tapered slot) antenna. The antenna utilizes a tapered E-plane ridge within the rectangular waveguide to provide a smooth matched transition. This type of antenna is targeted for high power phased array applications where dielectric materials are prohibitive.Simulation shows wideband characteristics from covering the full WR62 bandwidth. The antenna is comprised of an all aluminum construction. This type of antenna is advantageous for millimeter-wave antenna arrays where simple feed structures are preferred. The dimensions of the WR62 waveguide is approximately 15.9mm × 7.9mm, which when configured in a H-plane linear array is approximately 0.67λo at 14 GHz.

Sungwu Park et al. (2010) presented a patch antenna with coplanar waveguide feed and dual spiral slots symmetrical to the feed point. Due to eccentric feed of the spiral arms the antenna produces circularly polarized wave with beam direction off-normal to the antenna plane. To eliminate the use of matching circuits like balun, etc., two spiral slots are fed by signals which are 180^o out of phase. The antenna covers UWB band from 2.7 to 12GHz and has peak resonance at 3.2GHz, 4.7 GHz and 6.5 GHz and 11.5GHz. The gain of the antenna varies from 3.4 to 6.1 dBi. [22].

Kai Fang Lee et al. (2010) analyzed the performance of an U slot antenna for different applications by making small variations to the standard U slotted patch. In the first design, a half U-slot is used to achieve wide bandwidth at reduced antenna dimensions. In the second design, Dual band resonance at 2.0GHz and 4.8GHz is achieved by suitably modifying width and length of the U slot. Triple band resonance is obtained at 1.94 GHz, 4.16 GHz, and S.44 GHz by adding an additional H-slot along with U-slot. Radiating patch with two U-slots is also used to create triple band resonance. To achieve circular polarization, the four corners of the U slotted rectangular patch is truncated. The exhibits an unidirectional radiation pattern.[23]

R.K Prasad et al. (2013) proposed a microstrip antenna with E-shaped radiating patch for dualband operation at 1.41GHz and 2.15GHz with a fractional bandwidth of 33.13% and 3.85%. The overall area of the antenna is 50x70mm2 with a thickness of 1.6mm. The design is analyzed using method of moments (MOM) based EM tool. The maximum gain and directivity of the antenna is found to be 3.6dB and 3.9dB respectively with 88% efficiency.[24]

Jaget Singh (2016) proposed an E-shaped microstrip antenna using flexible polyamide substrate with relative permittivity of 4.4. As poliamide substrate are much thinner than conventional dielectric substrates like FR4 and RTDuroid , they can be easily integrated with in the devices. The antenna is designed for single 2.4GHz ISM band wearable applications. The return loss of the antenna with inset feed is -32.5 dB and the gain is 5.2dBi. The impedance bandwidth of the antenna is 200MHz(2.44GHz to 2.46GHz) and fractional bandwidth is 12.25%. [25]

C. Y. D. Sim and Y. N. Lai (2013) proposed an inverted-F dual band patch antenna for WLAN and WiMAX applications. The dimensions of the antenna are 45mmx9mmx1.6mm and it is fabricated on a FR4 substrate. The design consists of a modified L shaped monopole patch on the top layer with two small notches to improve impedance matching. At the ground plane, a small C shaped parasitic is placed near the narrow strip of feedline. The end of this feed line is joined with the L patch on the top layer using vias. The antenna is suitable for wireless LAN devices operating at 2.4/5.2/5.8 GHz and WiMAX devices operating in 2.5/3.5/5.5 GHz frequency bands. The 10-dB fractional bandwidth is 45% and 31% for WLAN and WiMAX band respectively. The maximum gain and efficiency is 2.85dBi and 93% for 2.4GHz band and 2.9dBi and 84% for 5GHz band.[26]

Takuichi Hirano and Junichi Takada (2016) presented a dualband microstrip antenna for 2.45GHz and 5.5GHz frequency bands, The antenna is made on FR4 substrate with an inverted F-shaped patch on the top layer and half copper cladded ground at the bottom side. Two vias are used to connect the radiating and ground layer to provide better matching characteristics. The fractional bandwidth of the antenna is 4.7% at 2.45GHz and 9% at 5.5GHz. The gain and radiation efficiencies of the antenna are 1.07dBi and 92% at 2.45GHz and 3.36% and 88% at 5.5GHz respectively.

Sudhanshu Verma and Preetam Kumar (2014) proposed a pentaband monopole printed antenna for WLAN, WiMAX, ISM and UWB applications. The top patch layer consists of arc shaped narrow stripes of copper whose dimensions vary according to binomial arithmetic progression. The ground layer is half copper cladded and consists of a triangular parasitic copper patch.The overall length of the antenna is 32mm, width is 25mm and the thickness is 0.8mm. The antenna exhibits peak resonance at 2.5GHz with peak gain of 0.6dBi , 3.44GHz with peak gain of 2dBi, 4.41GHz with peak gain of 2.7dBi, 5.27GHz with peak gain of 3.8dB, 8.32 GHz with peak gain of 3.94dBi.[28]

Mukesh Kumar Khandelwal et al. (2015) proposed a stacked microstrip antenna for dual-band resonance at 2.55GHz and 5.25GHz. The antenna structure consists of a circular shaped defect at the bottom of the RT Duroid 5880 substrate and a 50 ohm microstrip feed line on top of it. A circular copper sheet of 17mm radius and 0.8mm thickness, which acts as the radiating patch, is placed at 1mm air gap from the substrate with the support of three 1mm diameter Teflon cylinders placed between copper patch and RT Duroid. The air gap between the RT Duroid substrate and copper sheet acts as a second substrate enhancing the bandwidth of the antenna. The antenna has a gain of 7.2dBi at both the bands.[29]

Jaswinder Kaur et al. [2013] has proposed a multistrip dualband monopole antenna for 2.4GHz and 5.4GHz frequency band. The radiating element on the top layer consists for three vertical strips of patch fed by crossed microstrip line and bottom layer has an I - shaped defected ground structure. The two horizontal stripes across the feed line improve the bandwidth of the antenna at 5.8GHz. The overall size of the antenna is 20x30mm^2 and the fractional bandwidth in the two operating bands is 10% (2.3–2.54 GHz) and 11% (5.26–5.85 GHz).

The radiation pattern of the antenna in both H plane and E plane is bidirectional and peak gain is 4dBi at 2.4GHz and 6dBi at 5.4GHz [30]

Dhirgham K. Naji (2016) proposed a coplanar waveguide fed fractal patch antenna for dual resonance at 3.5GHz and 5.5GHz bands. The size of antenna is 22mmx22mmx1.6mm and has a peak gain of 2.04dB and 3.44dB in the respective operating bands. The design consists of pentagonal fractal geometry of first order with ring shape. The antenna design is analyzed with CST and HFSS softwares and the performance parameters are compared. In CST software, gain of antenna is 2.04dB with 98% efficiency at 3.5GHz and 3.04dB with 91.4%.at 5.5GHz. In HFSS software, the gain is 1.58dB with 92% at 3.5GHz and 2.28dB with 93.3% at 5.5GHz. The slight difference in the two results is due to different numerical methods used by the softwares.

Yinting Liu et.al (2015) proposed a multiband antenna for satellite based navigational systems. It is fabricated with three dielectric substrate layers and three patch layers arranged one above the other. The top layer substrate is made of Rogers RT TMM 10i material with a relative permittivity of 9.85 and has a thickness of 3.18mm. The centre and bottom substrate layers are made of Taconic TLX-8 material with dielectric constant 2.55 and a thickness of 6mm and 3mm respectively. Broader impedance bandwidth is obtained because of larger substrate thickness. The antenna consists of three input ports. If the antenna is excited at Port-

1, it offers peak resonance in BDS B3 satellite communication band and for port-2 excitation it resonates in the GPS, BDS-1 L and GLONASS frequency bands. When excited at port-3, the antenna operates in BDS-1 S band. The measured scattering parameter S_{11} is below -10dB and the VSWR is below 2 for all the frequency bands.

Gaurav Varshney et al. (2018) proposed a multiband dielectric resonator (DR) antenna with dual band resonance and circular polarization(CP). This antenna is designed with an inverted-sigmoid shaped dielectric resonator to achieve circular polarization. Use of dual band CP response with single feeding mechanism provides a lower and upper band 3dB axial ratio (AR) bandwidth of 19.98% and 3.07% respectively. The dimension of the substrate is 50mm X 50mm X 0.8mm and a dielectric resonator of 11mm height is placed at the top of the substrate to achieve CP. The designed antenna structure provides circularly polarised radiation and allows tuning of the upper band axial ratio response.

Da Guo et.al (2016) investigated a dualband microstrip antenna that supports both horizontal and vertical polarization. This design uses separate port for horizontal polarisation (HP) and vertical polarization (VP). A diplexer is used to switch the polarisation mode. It uses printed dipole array for radiating horizontally polarised waves and a discone antenna to provide vertically polarised waves. In horizontal polarisation mode, the impedance bandwidth of the antenna is 690MHz–1.03GHz and 1.69GHz–3.21 GHz. In vertical polarisation mode, the impedance bandwidth is 770 MHz–980 MHz and 1.70GHz–3.75GHz. The antenna has omnidirectional radiation pattern, lower cross polarisation level of -15dB and provides a peak gain of 4.6dBi for HP and 5.2dBi for VP.

Vipul sharma et.al (2018) investigated a split ring resonator(SRR) based fractal antenna for multiband resonance. It uses a ring slotted circular radiating patch with small SRR connected at its periphery. The addition of SRR to the ring slotted circular patch results in a fractal structure and provides better matching characteristics and offers wider bandwidth. The dimension of the antenna is 45mmx45mmx1.6mm and is fabricated on a FR4 substrate. The resonates at 5.0GHz, 6.8GHz, 7.5GHz and 8.5GHz.The bandwidth of the antenna at 8.5GHz band increases from 200MHz to 350MHz with the use of edge coupled SRRs.

Yuehui1 Cui et.al (2016) proposed a multiband antenna that operates in the LTE 700MHz, GSM 850MHz/900MHz, GSM 1800MHz/1900MHz, Universal Mobile Telecommunications Systems (UMTS-2.1GHz), LTE 2.3GHz/2.6GHz and 2.4GHz wireless LAN. The antenna is fabricated on a TLY-5 substrate with relative permittivity of 2.2 and thickness of 20mils making it suitable for thin planar fabrications. This antenna uses a combination of quarter wavelength S-shaped narrow patch and inverted U-shaped monopole to cover LTE 700band and GSM band. To this structure, a C-shaped and an inverted C-shaped strip is added to cover UMTS, WiFi and WiMax. To increase the bandwidth at 3.5GHz and 2GHz band a small X-shaped monopole and a meander line is added to the antenna geometry.

The antenna uses coaxial probe feed, has a peak gain of 3-6dBi, efficiency of about 60%. The VSWR value of the antenna is less than 3 in all operating frequency bands and provides an omnidirectional radiation pattern in x-z plane[5].

Ashok kumar et.al (2018) proposed a low profile circular patch monopole antenna with patristic stubs for resonating at 2.5GHz, 4.5GHz, 5.7GHz, and 7.7GHz frequency bands. The antenna design consists of a line fed circular patch for the radiating layer and two inverted L-shaped and one double T-shaped parasitic stub in the ground layer. The inclusion of parasitic stubs induces multiple resonances. The impedance bandwidths for the four resonant bands are 290MHz (2.36–2.65GHz), 540MHz (4.28–4.82 GHz), 530 MHz (5.47–6.0 GHz), and 780 MHz (7.28–8.06 GHz).The simulated peak gains are 2.13dBi, 2.37dBi, 2.57dBi and 5.53dBi , and 5.66 dBi in four bands respectively. The antenna is fabricated on a RT-Duroid 5880 substrate with dimensions 30mm X 40mm X 0.79mm. The antenna exhibits doughnut shaped radiation pattern in yz plane and nearly omnidirectional pattern in xz plane[6].

Jahanzeb Sarwar Malik et.al (2016) proposed hexaband antenna operating at 790 MHz, 1.79GHz, 2.14GHz, 2.45GHz, 3.4GHz, and 5.3GHz suitable for GSM, DCS, IMT, Wi-MAX and WLAN with 10-dB impedance bandwidth of 42MHz, 25MHz, 25MHz, 32MHz, 29MHz, and 123MHz respectively. The gain of the antenna is 0.58dBi, 0.88dBi, 1.5dBi, 1.83dBi, 2.3dBi and 3.95dBi. The antenna uses a square patch with circular slot in the radiating layer and is fed by a coaxial probe. The ground layer consists of multiple square loop elements in the ground plane. The antenna is fabricated on a FR-4 substrate with overall dimension of 80mm × 80mm × 1.6mm.

Square loop elements used in the ground plane produces multiple resonance[7].

Abhishek K. Saroj et.al (2017) investigated a pentaband antenna resonating at 1.074GHz, 3.119GHz, 4.089GHz, 5.683GHz and 6.514GHz. The antenna comprises of a square patch at the centre with dimension 18x18mm^2 and four rectangular shaped patches with dimension 10mm x 12mm placed at the four corners. The overall dimension of the antenna is 50mm x 45mmx 1.6mm. The return loss and VSWR is -27.22dB and 1.958 at 1.074GHz,-22.60dB and 3.675 at 3.119GHz, -16.81dB and 2.014 at 4.089GHz, -17.95dB and 1.96 at 5.6GHz and -25.21dB and 2.014 at 6.514GHz respectively [8].

Waleed Tariq Sethi et.al (2017) presented a hexaband microstrip antenna comprising multiple L-shaped monopole elements in the radiating layer and a finite ground plane with a small rectangular slot. The antenna is designed to operate in GSM, CDMA, DCS, LTE, and WLAN frequency bands. The antenna resonates at 870–900MHz, 900–1000MHz, 1722–1880MHz, 1850–1900MHz, 2287–2837MHz and 5713–6386MHz with gain of 1.71dB, 1.83dB, 3.20dB, 3.23dB, and 5.82dB respectively. The antenna is fabricated with RTDuroid 5880 substrate and has an overall dimensions of 125mmx85mmx1.57mm[9].

CHAPTER 3

PROPOSED METHODLOGY

3.1 MICROSTRIP FRACTAL ANTENNA FEATURES

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. Consider the microstrip antenna fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length *L*, width *W*, and sitting on top of a substrate (some dielectric circuit board) of thickness *h* with permittivity. The thickness of the ground plane or of the microstrip is not critically important. Typically the height *h* is much 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.

3.2 CHARACTERISTICS OF 5G TECHNOLOGIES

The 5G network makes use of new technological solutions to meet the growing requirements of users. As a result, the new system will be able to handle an increasing number of devices, and to satisfy higher quality thresholds required by modern applications. It is an evolution of the 4G networks of today, which incorporates technologies capable of handling the rapidly increasing amount of transmitted data and facilitating data exchange between an ever-growing number of IoT devices. As is typical for the introduction of any next-generation network, it is expected that until its coverage and functionality can match or surpass existing 4G networks, the 5G network will need to coexist with such. In addition to the existing usage scenarios of mobile networks, three additional scenarios are planned for the emerging 5G network, all of which will be of particular importance to users and will distinguish the 5G network from previous generations. The first new usage scenario is an enhanced mobile broadband , which enables high-speed internet access (up to

1 Gbps) and will be the defining feature of this network as compared with existing networks, especially in the initial phase of its implementation. This advantage of the 5G system.

over legacy solutions will increase the efficiency and quality of communications in society. As an example, this will enable services base on the provision of high-resolution multimedia, attractive methods of communication (e.g., video, augmented and virtual reality), as well as smart city services (e.g., transmission of content from high-resolution cameras). The second use of 5G networks is based on massive machine type communications, where 5G will be able to support a very large number of connections from low-power devices, referred to as the Internet of Things (IoT), to the mobile network. These devices asynchronously exchange data, using the mobile network to communicate. This scenario assumes support for a large number of device types, with the reservation that these devices will use the mobile network in an occasional manner, exchanging small volumes of data. The third use is referred to as ultra-reliable low latency communications, which be a technology providing a minimum (1ms) latency for data exchange over a mobile network for critical applications (eg drone control). In previous generations of mobile networks, latency values were longer and amounted to about 100 milliseconds for 3G networks, with about 30 milliseconds in case of 4G (LTE—Long Term Evolution) network. According to the current state of standardization of the 5G network, it is intended to operate in three frequency bands, i.e., low, medium, and high. The use case of a particular band depends on its characteristics, which include two factors in particular, i.e., radio signal propagation and capacity of spectrum resources. The first factor is related to the physical properties of electromagnetic waves and determines the obtainable radio transmission range in changing weather conditions and radio signal coverage in hard-to-reach areas (eg interiors of buildings). The second factor is associated with the available amount of RF bands in a given frequency range, which can be used by 5G networks.

It should be noted that high bandwidths also require a wide radio band, which, being a limited resource, is subject to rationing, and its use must also take into account RF communication applications other than 5G networks, such as TV broadcasts, radio communication for home automation equipment, etc. In a 5G system, the following three frequency bands are assumed to be used From 694 to 790 MHz (700 MHz band); From 3400 to 3800 MHz (3.6 GHz band). From 27.50 to

28.35 GHz (28 GHz band). The 700 MHz band is characterized by good signal propagation and relatively low attenuation (absorption of signal by various obstacles), which helps cover large areas. Thanks to these characteristics, this band can be used for mMTC services. However, the Electronics 2021, 10, 1 3 of 19 700 MHz band alone would not be able to provide broadband internet access to mobile users (eMBB), as it does not allow the use of MIMO, which would increase the capacity of each cell site. However, it can be used together with the bands listed below, which have large spectral resources. This manner of operation improves signal transmission quality from the user to the base station (i.e., “upstream”) [7]. The 3.6 GHz band does allow the use of mMIMO (massive MIMO), while, at the same time, it constitutes a compromise between propagation and capacity in terms of spectral resources, especially when combined with the 700 MHz band, which would improve upward connectivity. This band would be used to build a coverage layer for eMBB services in several of the largest cities, including communication routes between these locations. This band can also be used to introduce services that requires reliable transmission and particularly low latency (URLLC) in applications requiring the transmission of particularly large amounts of data, such as highresolution images for medical or navigation purposes. The 28 GHz band is limited in its use, in particular, because of the requirements applied to transmission between the user and the base station (the “upstream” link). It can be used, for example, for broadband access points and picocell applications (cMTC/URLLC). This band, due to its large capacity and the possibility of allocating large spectrum resources, may also be considered for the provision of internet access via a fixed wireless access service.

3.3 BROADBAND FRACTAL ANTENNA DESIGNED FOR USE IN 5G SYSTEMS

The design process of a fractal antenna consists of multiple stages. The main steps of the project process are presented below. The procedure for designing a single-piece rectangular microstrip antenna are the following:

- Determine operational frequency;

- Determine operational bandwidth;

• Choose a substrate;

• Choose substrate height;

• Determine the dimensions of the patch;

• Determine the power supply;

• Determine the electrical parameters and characteristics of the antenna

; • Optimize the antenna to obtain the best possible parameters in the given frequency range. Before the development of a proper numerical model of the designed antenna could begin, it was necessary to perform preliminary calculations of its geometric parameters.

These calculations were done to work out an approximate shape of the antenna, which would ensure that the structure complied with the assumptions adopted for its design. The dimensions of the individual edges of the antenna depend primarily on the Electronics 2021, 10, 1 5 of 19 resonance frequency, fr , and the relative permittivity, εr , of the dielectric layer of the copper laminate, which are the foundation of the new antenna [24]. The antenna is designed to operate in a 5G system, on frequencies ranging from 27.50 GHz to 28.35 GHz (LMDS band) and the center frequency fr = 28.00 GHz. Choosing the thickness of the substrate is one of the most important stages in the antenna design process, as the thickness of the substrate directly affects the efficiency and bandwidth of the microstrip antenna. One of the assumptions for this antenna is to obtain the widest bandwidth possible. As the thickness of the substrate increases, the antenna's bandwidth increases, while its efficiency decreases.

3.4 LINEAR FRACTAL IMPEDANCE ANTENNA DESIGN AT 28 GHZ FOR 5G APPLICATIONS

5G will bring mobility to milimeter-wave communications as the next-generation wireless network attempts to serve more people and even things with a major expansion of mobile services. The emerging of 5G technology is demanding antennas with features previously unseen on a user terminal, such as beamforming capability of the radiation pattern to perform spatial scanning. This requirement raises numerous design challenges to achieve areasonable trade-off between technological design issues and commercial criteria-low profile or inexpensive manufacturing methods. Many existing and emerging wireless applications, as well as many radar application, operate over wide frequency bands and thus require broadband antennas.

Some researchers began to work to overcome the inherent disadvantage of the narrow bandwidth of impedance and produced interesting results based on the admired gain and bandwidth enhancement methods review previously. Table 2 and Table 3 displays the findings of various methods such as broadband designs, multiband designs, compact designs, circular polarization, increased directional design, reconfigurable designs, and array design, which are used to develop an antenna for mm-wave at 28/38/60 GHz band. Parameters including reflection coefficient, bandwidth, gain, materials used and techniques applied and for all the MPAs resonator models in addition to a few recently designed microstrip antennas were reported for the assessment. Also, the fabricates were segmented on the basis of the type of design for better perception of design for better perception.

3.5 ANTENNA DESIGN IN HFSS :

The following figure gives us a model of antenna designed in HFSS Simulation model.

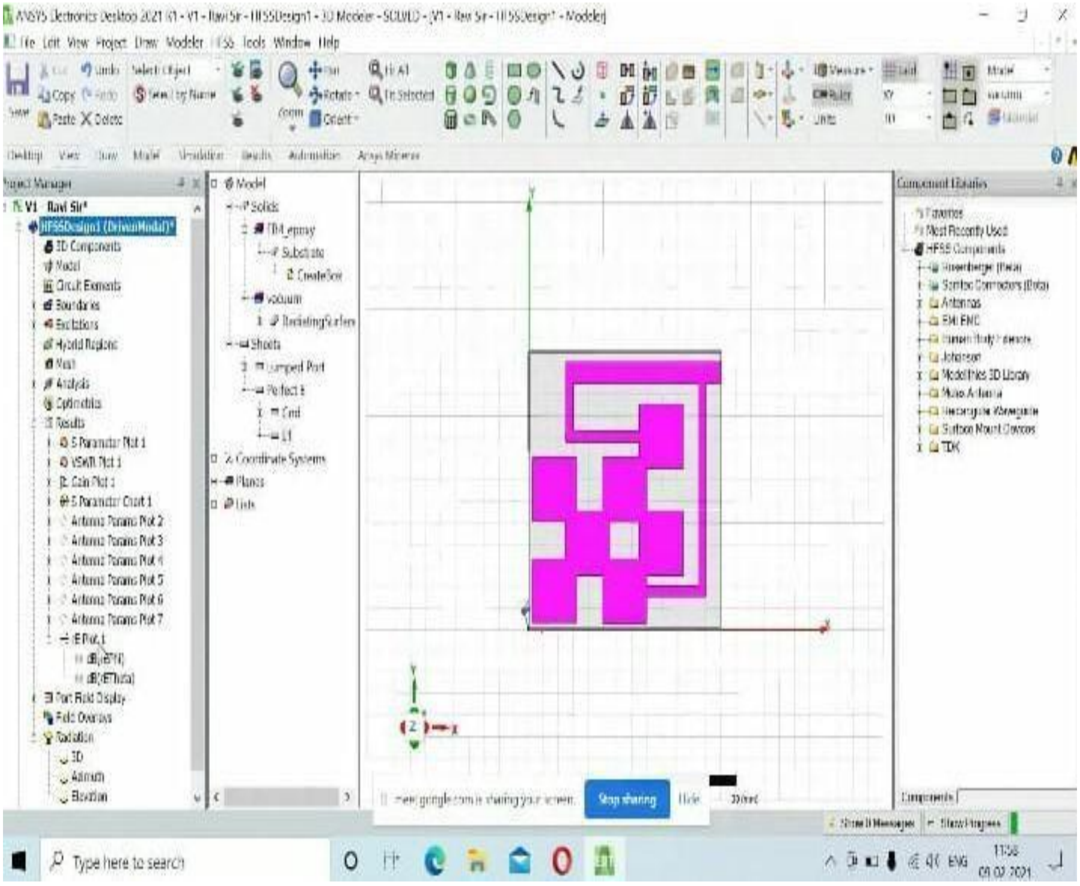


Fig: 3.1: Pattern Reconfiguration Antenna

3.6 DESIGN EQUATIONS OF FRACTAL ANTENNA

To design an antenna first the design calculations are carried out by using the following formulae.

3.6.1 Wave Length (λ)

The wavelength (λ) can be calculated using equation (3.1) as shown below,

$\lambda = \frac{c}{fo}$ (c = 3*10^8m/s) ,

where c is the velocity of light.

3.6.2 Dielectric Constant (□r)

The dielectric constant of the substrate can be varied according to the substrate material. For the FR 4 substrate the dielectric constant can be varied from 4.0 to 4.8. Here we choose the dielectric constant value as, $\varepsilon r = 4.4$.

3.6.3 Width (W)

The calculation of width(W) is given by equation ,

$$W = \frac{c}{2fo} * \sqrt{\frac{2}{\varepsilon_r + 1}}$$

3.6.4 Effective Dielectric Constant(□□□□□)

The Dielectric constant(ε_{reff}) is shown by equation ,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

Where h(Thickness of the antenna)=1.6mm

3.6.5 Effective Length (L_{eff})

The Effective length (L_{eff}) is given by equation ,

$$Leff = \frac{c}{2fo\sqrt{\varepsilon_{reff}}}$$

3.6.6 Length Extension (□□)

The extension length (ΔL) is calculated by equation as shown below,

$$\mathbf{\Delta} L = 0.412h * \frac{[(\varepsilon_{reff} + 0.3) * (W/h + 0.264)]}{[(\varepsilon_{reff} - 0.258) * (W/h + 0.8)]} ,$$

where h=1.

3.6.7 Actual Length of Patch (L)

The Length(L) can be calculated using the equation as shown below,

$L = Leff - 2\Delta L$

3.6.8 Directivity (D)

The directivity (D) of the antenna can be calculated as

$D = A_e 4\pi / \lambda^2$

where A_e (effective area) = 7.32

3.7 INTRODUCTION TO HFSS

The antennas can be designed and simulated using software. Various software available in market are Magus, Cosmol, IE3D, Sonnet, HFSS, FEKO, CST Microwave studio, SEMCAD, efield, XFdtd, EXPIRE, WIPL-ProGEMS. Here we have chosen HFSS where it is convenient for the user.

ANSOFT HFSS software is an industrial standard for simulating 3-D full-wave electromagnetic fields. It provides good-standard accuracy. The computer technology have made it an essential tool for engineers who are designing highfrequency and high-speed electronic components.

HFSS offers multiple state-of the-art solver technologies based on finite element, integral equation or advanced hybrid methods to solve a wide range of applications. Each HFSS solver incorporates a powerful, automated solution process, so designers need only to specify geometry, material properties and the desired output. The 3-D interface enables users to model complex 3-D geometry or import CAD geometry.

Typically, the 3-D mode is used to model and simulate high-frequency components, such as antennas, RF/microwave components and biomedical devices. Engineers can extract scattering matrix parameters (S, Y, Z parameters), and visualize 3-D electromagnetic fields (near- and far-field).

3.8 SOLUTION PROCESS

There are four variations to the solution process

- Single frequency solution
- Fast frequency solution
- Discrete frequency solution
- Interpolating frequency solution

3.8.1 Single Frequency Solution

A single frequency solution generates an adaptive or non-adaptive solution at a single frequency and is often the first step in performing a frequency sweep. An adaptive solution is one in which a finite element mesh is created and automatically refined in the areas of highest error thus increasing the accuracy of succeeding adaptive solutions.

3.8.2 Fast Frequency Solution

This type of solution uses an existing mesh to generate a solution over a range of frequencies. The system uses an Adaptive Lanczos-Pade Sweep (ALPS) – based solver to extrapolate an entire bandwidth of solution information. This solution is used to specify the starting and ending frequencies and the interval at which new solutions are generated. The same mesh is used for each solution, regardless of the frequency. While solutions can be computed and viewed at any frequency, the solution at the center frequency is most accurate.

3.8.3 Discrete Frequency Solution

To perform a discrete frequency sweep, the system uses an existing mesh to generate a solution over a range of frequencies. This solution is used to specify the starting and ending frequencies and the interval at which new solutions are generated. The same mesh is used for each solution, regardless of the frequency.

3.8.4 Interpolating Frequency Solution

To perform an interpolating frequency sweep, the system uses an existing mesh to interpolate solutions over a range of frequencies. The same mesh is used for each solution, regardless of the frequency. A uniform error tolerance exists throughout the entire solution.

3.9 ANSOFT HFSS EM SIMULATION

The performance of electronic devices depends on electromagnetic (EM) behavior. ANSYS □□□□□□ simulation results delivers the most accurate answer possible with the least amount of user involvement.

HFSS is essential for designing high frequency and/or high speed components used in modern electronics devices. Understanding the EM environment is critical to accurately predict how a component-or subsystem or end product performs in the field. HFSS address the entire range of EM problems, including losses due to reflection, attenuation, radiation and coupling.

The power behind HFSS occurs in the mathematics of the finite element method (FEM) and the integral, proven automatic adaptive meshing technique. This provides a mesh that is conformal to the 3D structure and appropriate for the electromagnetic problem solving. With HFSS, the physics defines the mesh; the mesh does not define the physics. As a result, designer can focus on design issues rather than to spend significant time determining and creating the best mesh.

HFSS results yield information critical to our engineering designs. Typical results include scattering parameters (S, Y, Z), visualization of 3D electromagnetic fields (transient or steady-state), transmission-path losses, reflection losses due to impedance mismatches, parasitic coupling, and near and fear-field antenna patterns.

3.10 HFSS IN RF AND MICROWAVE

HFSS has been used by RF and Microwave engineers to design high-frequency components found in communication systems, radar system, satellites, smart phones and tablet devices. The technology addresses a wide range of RF and microwave engineering challenges, and these applications benefit greatly from the automated meshing feature and results in high solution accuracy. The end result is the highest-fidelity solution with the best-in-class solution time.

3.11 ANSOFT HFSS FEATURES

ANSYS HFSS software contains the technology, solvers and capabilities needed to model RF and microwave as well as signal and power integrity issues.

- Automatic Adaptive Meshing
- Solver Technologies
- Advanced Finite Array Simulation Technology
- Mesh Element Technologies
- Leading Solution Technologies.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 SIMULATION RESULTS OF VARIOUS DESIGNS

5G will bring mobility to milimeter-wave communications as the next-generation wireless network attempts to serve more people and even things with a major expansion of mobile services. The emerging of 5G technology is demanding antennas with features previously unsee on a user terminal, such as beamforming capability of the radiation pattern to perform spatial scanning.This requirement raises numerous design challenges to achieve a reasonable trade-off between technological design issues and commercial criteria-low profile or inexpensive manufacturing methods.

4.2 REFLECTION COEFFICIENT

The base value of the reflection coefficient is assumed to be −10 dB, which means that 10% of the incident power is reflected, i.e., 90% of the power is received by the antenna, which is considered to be perfect for mobile communication. The proposed antenna has a resonance at 28.00 GHz with a reflection loss of −22.50 dB. The S11 parameter was obtained by powering the antenna using the edge port. The antenna has an operating bandwidth of 5.57 GHz, which gives a relative operating bandwidth of 19.89%. The bandwidth determined from the results of computer simulations is slightly smaller than the theoretical bandwidth determined on the basis of Relation (13), due to the inset feed used as a power supply. Nevertheless, this method of supplying power to a microstrip antenna provides us with better impedance matching (lower reflection factor value) for a resonance frequency.

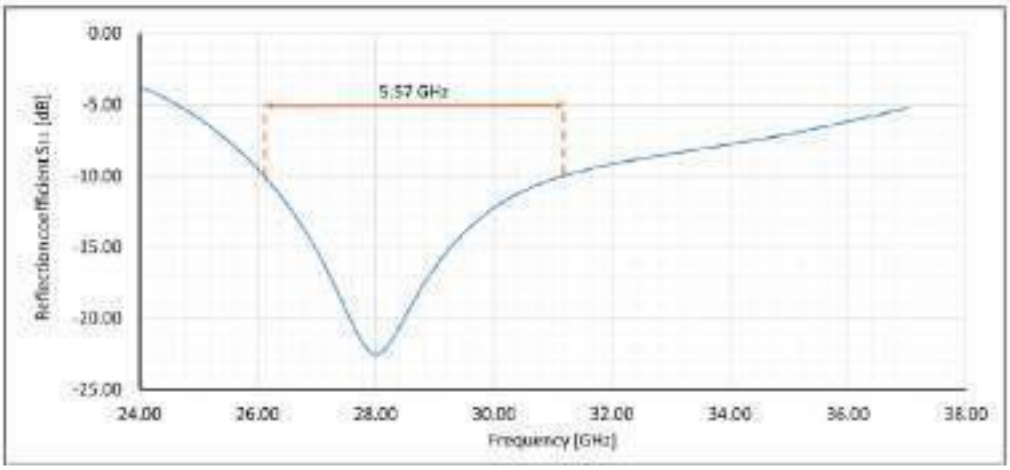
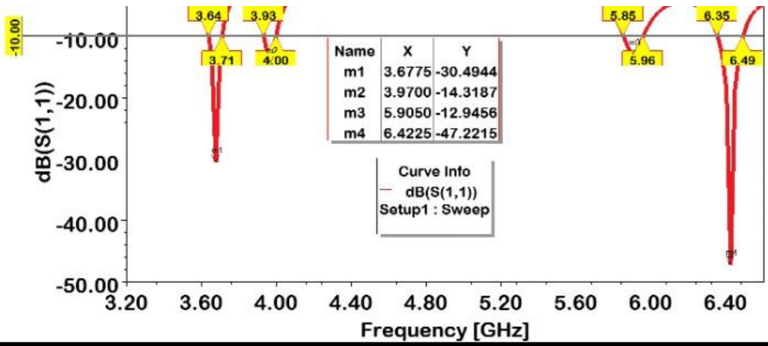


Fig: 4.1 : REFLECTION COEFFICIENT

4.2.1 VSWR Plot

The VSWR plot is given in figure 4.2.

Nowadays, wireless communication has undergone rapid evolutions from analog voice communication to the short upcoming 5G mobile communications. The 5G is expected to work at frequency 28 GHz as the candidate for its frequency band allocation. This technology would provide high data rates and high-quality multimedia applications, i.e., audio, video, and data services. These systems also demand highly efficient, compact, and wide bandwidth wireless antennas. 5G technology would provide high data rates and high-quality multimedia applications. This technology needs a broad bandwidth antenna. Among various antenna types, the linear fractal impedance matching array antenna has advantages of good design ,wide-bandwidth of frequency , and low-cost material for the antenna. A fractal is a recursively generated object having a fractional dimension. They have no characteristic size, and are constructed of many copies of themselves at different scales. Our Project focus on design of linear fractal impedance array antenna for matching even number of gain and bandwidth frequency of antenna . Arrays will be analyzed by fractal electrodynamics and also simulate the results by HFSS(High Frequency Structure Simulator) simulation software. The antenna will fabricated and analyzed.

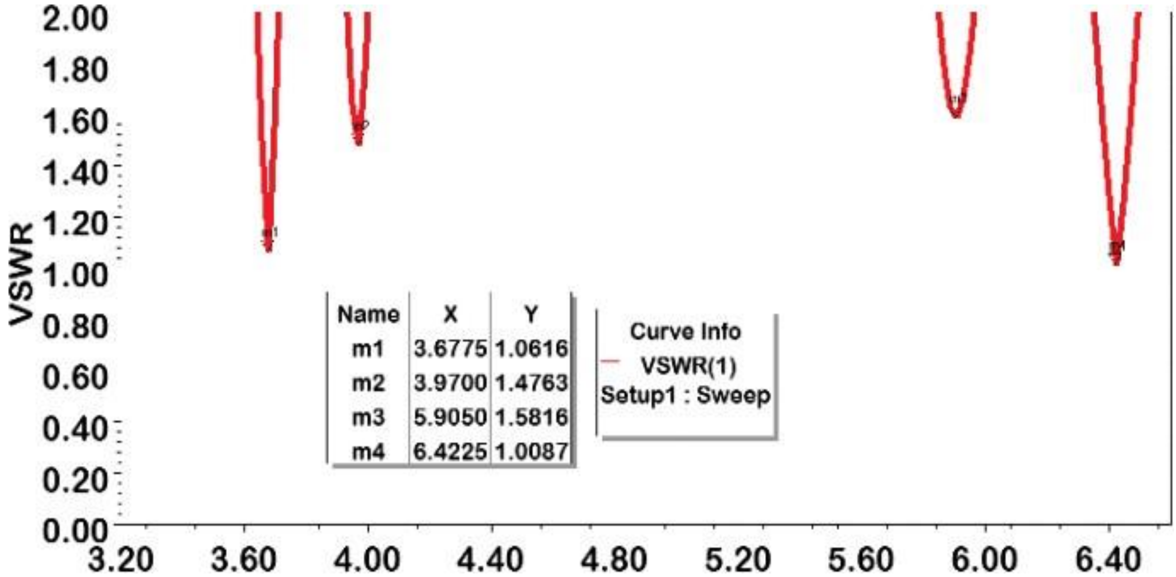


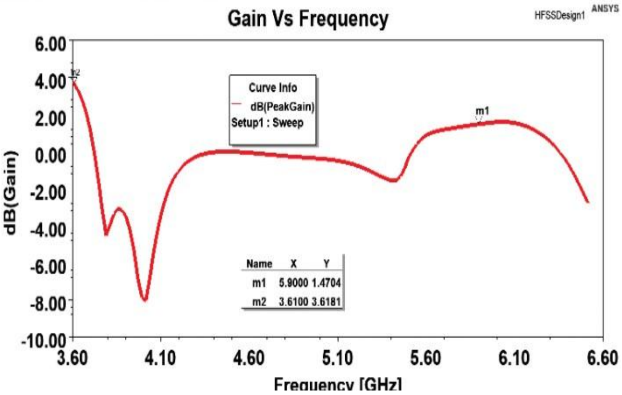
[redacted]

Fig:4.2 : VSWR Plot

4.2.2 S-Parameter Plot

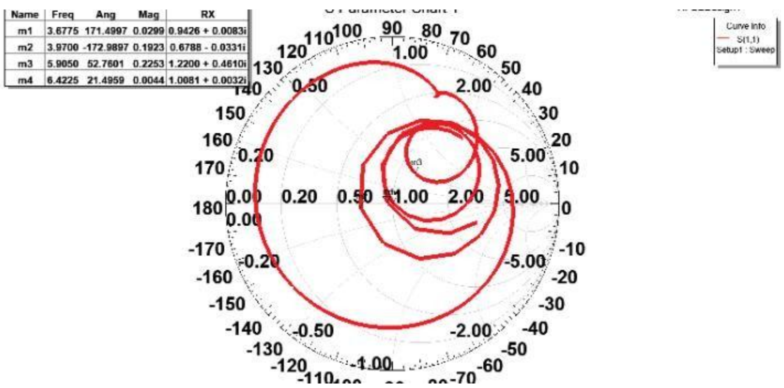
The S-Parameter plot is given in figure 4.2.





4.2.3 Smith Chart impedance plot

The impedance value shown by Smith chart is illustrated.



4.2.4 Gain plot

Usually, antenna gain is given in relation to an isotropic antenna and is expressed in dBi. In some cases, antenna gain is also given in relation to the dipole antenna and expressed in dBd. The energy gain of an antenna is dependent on its directivity and the energy loss of the antenna, which results from the material it is made of. The proposed antenna has a gain of 5.06 dBi at a resonance frequency of 28.00 GHz, which is considered to be high for compact microstrip antennas. Values of antenna gain as a function of frequency are shown.

4.3 RADIATION CHARACTERISTICS

The radiation characteristics show how the antenna radiates energy depending on direction. It represents a standardized distribution of the electric field, or the relative distribution of surface power density. The characteristics are determined in two planes, i.e., horizontal and vertical, and can also be presented in a three-dimensional (3D) format . The designed antenna should have directional radiation characteristics. A three-dimensional chart of the proposed antenna’s radiation characteristics for

27.51 GHz (a), 28.0 GHz (b), and 28.35 GHz (c) frequencies is the standardized radiation characteristics of the proposed antenna for 27.51 GHz (blue line), 28.0 GHz (green line), and 28.35 GHz (red line) frequencies in the polar coordinate system for vertical polarization. Figure 12 shows the standardized radiation characteristics of the proposed antenna for 27.51 GHz (blue line), 28.0 GHz (green line), and 28.35 GHz (red line) frequencies in the polar coordinate system for horizontal polarization. The presented drawings show that the beam width at the –3 dB level for vertical polarization is 115.04° with the back lobe being −6 dB, while the beam width at the –3dB level for horizontal polarization is
72.16° with the back lobe being −10 dB.

4.3.1 S-Parameter Graph

The S-Parameter plot obtained for milli-meter wave microstrip antenna is given in figure 4.8.

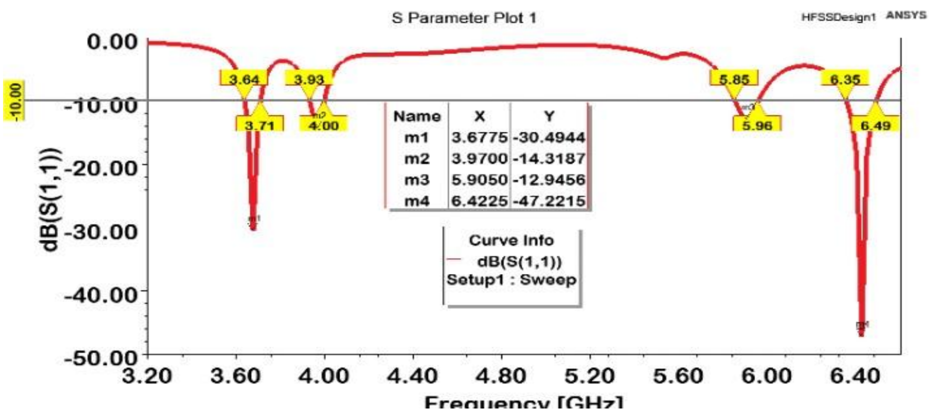
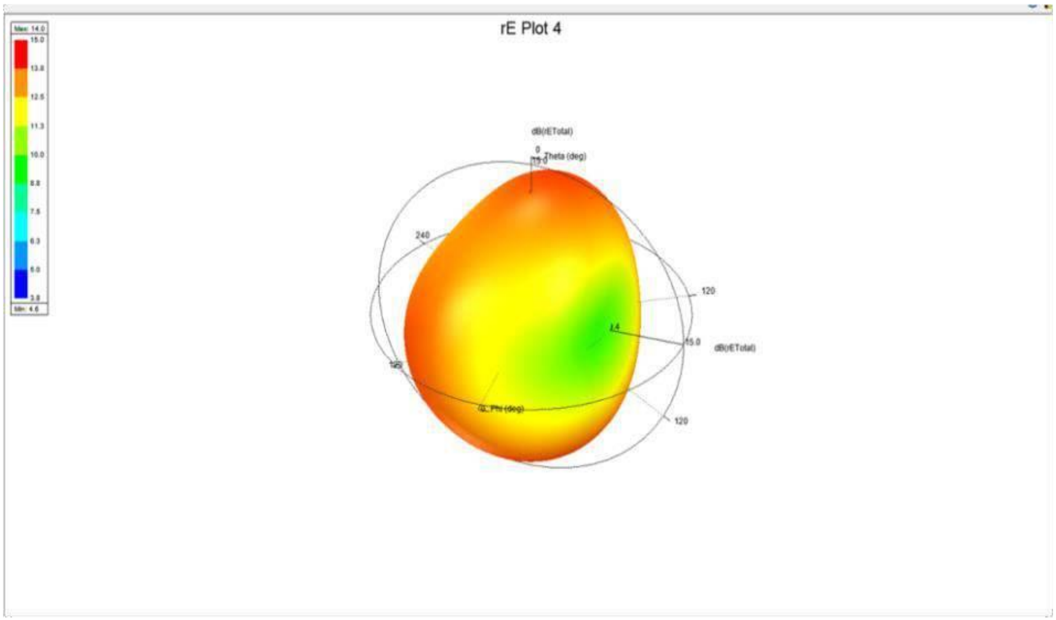


Fig:4.6: S-Parameter Graph

4.3.2 3D Radiation PATTERN



3D Radiation Pattern

4.3.3 REFLECTION COEFFICIENT

The base value of the reflection coefficient is assumed to be −10 dB, which means that 10% of the incident power is reflected, i.e., 90% of the power is received by the antenna, which is considered to be perfect for mobile communication. The proposed antenna has a resonance at 28.00 GHz with a reflection loss of −22.50 dB. The S11 parameter was obtained by powering the antenna using the edge port. The antenna has an operating bandwidth of 5.57 GHz, which gives a relative operating bandwidth of 19.89%. The bandwidth determined from the results of computer simulations is slightly smaller than the theoretical bandwidth determined on the basis of Relation (13), due to the inset feed used as a power supply. Nevertheless, this method of supplying power to a microstrip antenna provides us with better impedance matching (lower reflection factor value) for a resonance frequency.

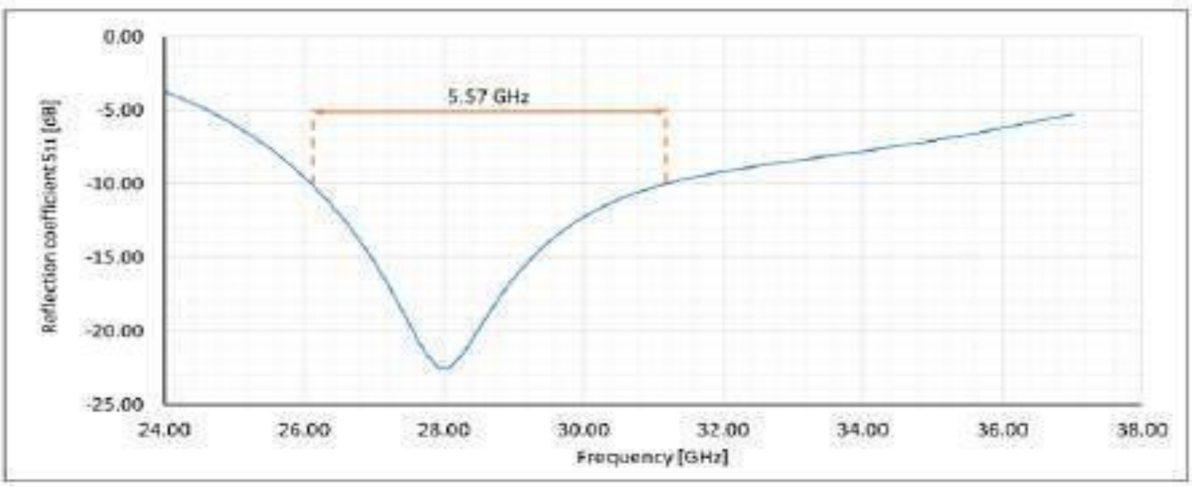


Fig:4.8: REFLECTION COEFFICIENT

4.4.1 INPUT IMPEDENCE

The voltage standing wave ratio obtained for dual phase shifting included in the SRR antenna

4.4.2 3D Radiation Pattern for mmv microstrip antenna

Below figure represents the 3D Radiation pattern for mmv microstrip antenna.

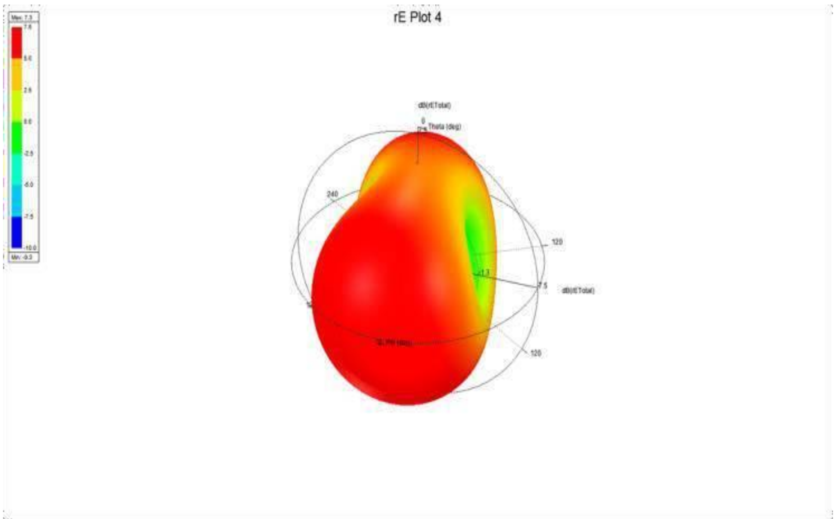


Fig:4.10:3D Radiation Pattern for mmw microstrip antenna

4.4.3 ANTENNA GAIN

Usually, antenna gain is given in relation to an isotropic antenna and is expressed in dBi. In some cases, antenna gain is also given in relation to the dipole antenna and expressed in dB. The energy gain of an antenna is dependent on its directivity and the energy loss of the antenna, which results from the material it is made. The proposed antenna has a gain of 5.06 dB at a resonance frequency of 28.00 GHz, which is considered to be high for compact microstrip antennas. Values of antenna gain as a function of frequency

The three-dimensional (3D) view of radiation pattern for the proposed 5G antenna model at different frequencies.

(a) 27.51 GHz;

(b) 28.0 GHz;

(c) 28.35 GHz.

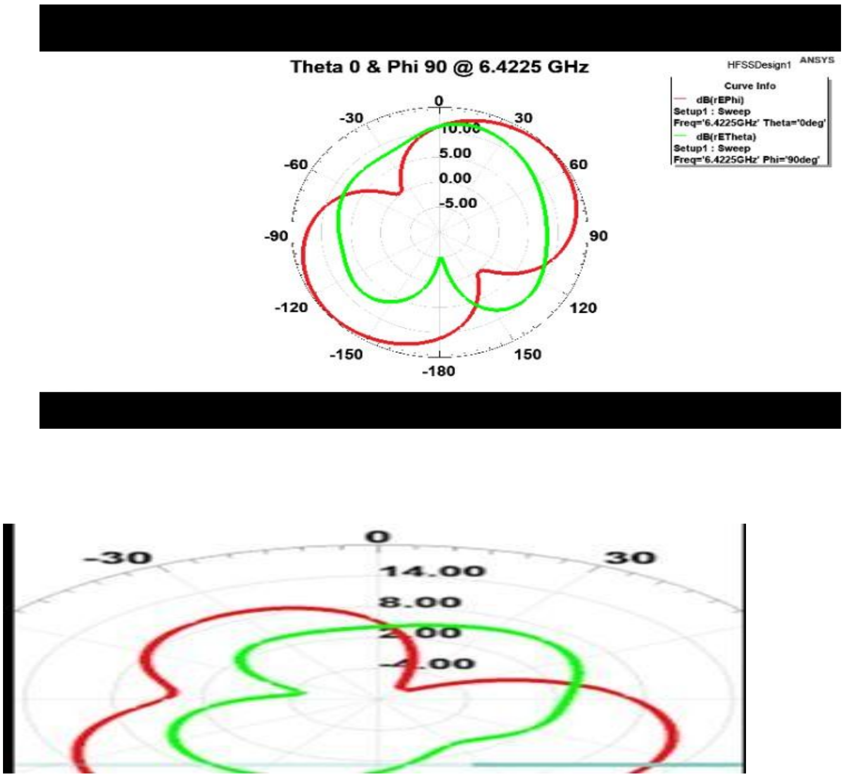
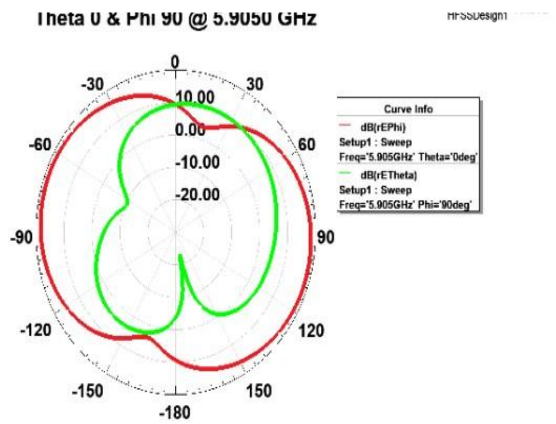
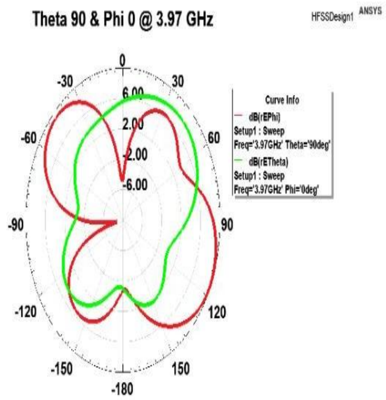


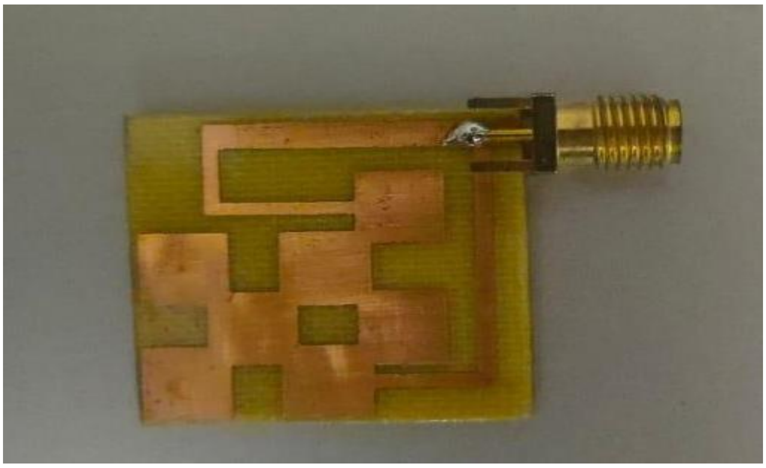
Fig: 4.13 2d View Of Normalized Radiation Pattern Simulation Results



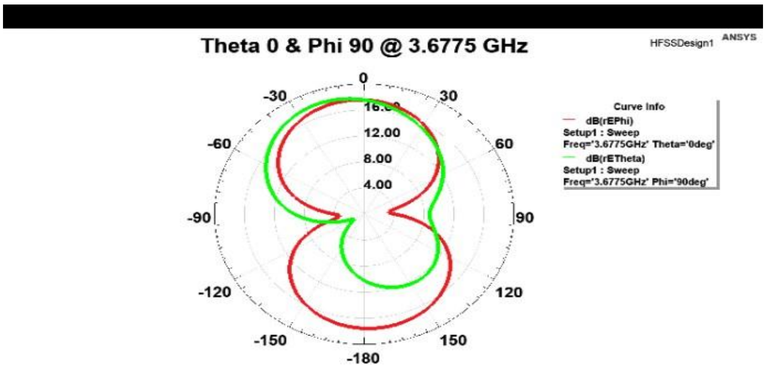


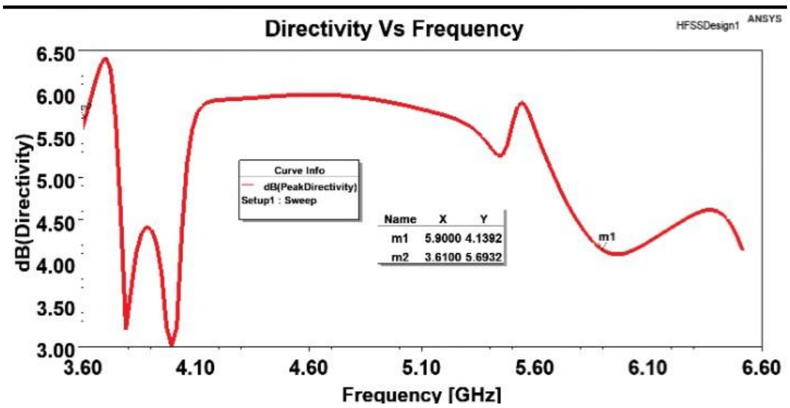
The normalized radiation patterns for the proposed antenna model operating in the 5G system for 27.51 GHz (blue line), 28.0 GHz (green line), and 28.35 GHz (red line) in polar coordinates for vertical polarization.

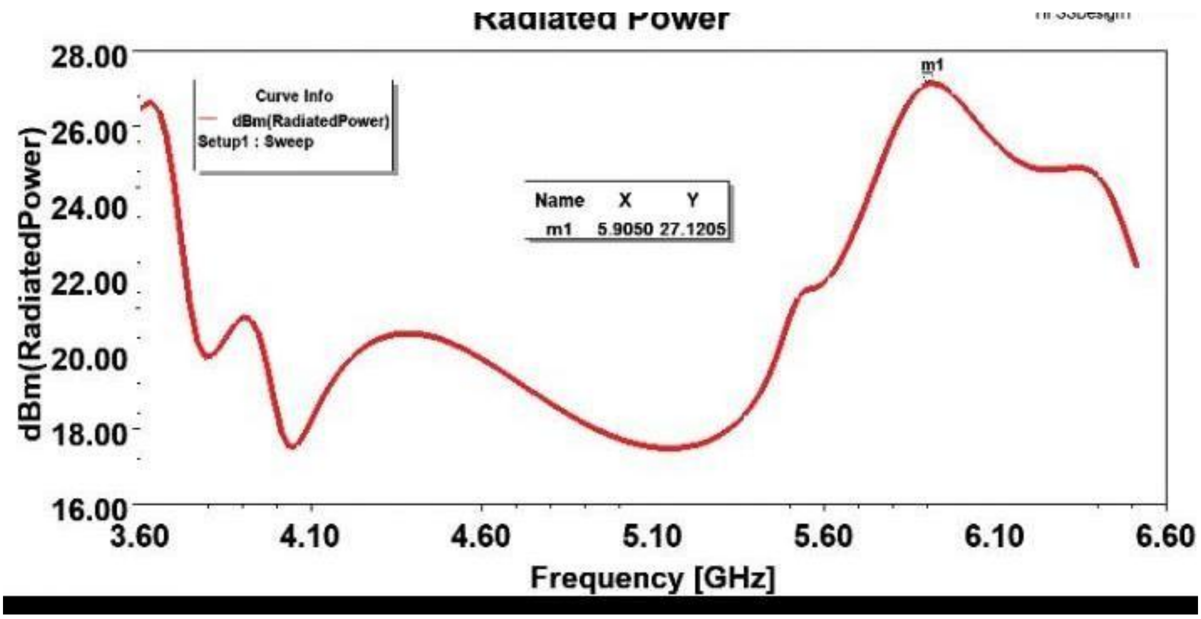
4.4.6 SIMULATION AND THETA RESULTS*:*

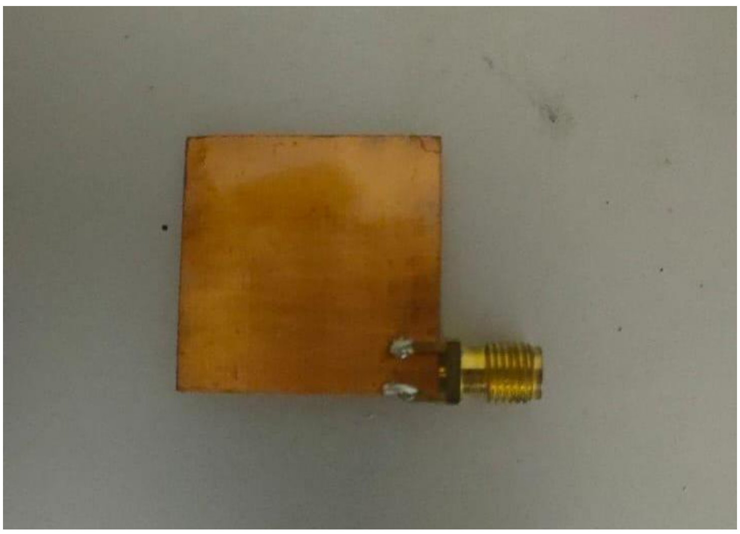


TOP VIEW OF AN ANTENNA









bottom view of an antenna

CHAPTER 5
CONCLUSION

5.1 SIMULATION RESULTS

To achieve better pattern reconfiguration, two phase shifters are included in the design as discussed in before chapter. The simulation results obtained for dual phase shifter network antenna is presented in the following sections.

A lineal fractal impedance array antenna is successfully designed and enhanced at a resonant frequency of 28 GHz. The antenna shows a healthy gain 7.64 dB and bandwidth is 1.009 GHz and can be increased to 1.5 GHz by increasing the substrate thickness. The VSWR of the antenna is 1.01. The effect of the antenna dimensions on millimeter antenna parameters is done and the results have been obtained and discussed. As the analysis results obtained, substrate thickness (h) is most significant parameter in microstrip patch antenna since it has significant effect on the antenna performance as well as it is a key factor in calculating antenna dimensions. The evaluation of various antenna elements used in millimeter microstrip patch antenna is simple and easy for fabrication, then it can either be used in 5 G applications. An array form of the design can also be designed to match a wide range of impedance values, thereby optimizing the antenna efficiency.

5.2 RESULT AND DISCUSSION

With the world eagerly waiting for 5G to come, the importance of 5G antennas has to be realized. The designed antenna is compact and can be adapted in mobile phones as a 5G communication antenna. As the antenna works in Extremely High

Frequency (EHF) range, it is also found suitable for applications in satellites. As the EHF range wavelength corresponds to millimeter waves, every object which is greater than or equal to millimeter range of dimensions poses an obstacle to the signal. Therefore, every man-made thing is an obstacle to the 5G signal. To avoid this problem, Massive MIMO antennas are used. The concept of Massive MIMO corresponds to use of a very large number of similar type of antennas for a single application so that the obstacles are covered by the Multiple Input Multiple Output (MIMO) antennas. The newer versions of 5G devices use massive MIMO antennas to increase the throughput of the device along with efficient beam steering. Further, small-cell cellular networks have to be adapted which include low powered mini base stations. This mini base station handles small cells of network and provide better signal strength in the area. The designed antenna can also be used in these mini stations due to their good radiation pattern with justified gain.

REFERENCES

[1] Ahmed, E. A. Abdallah, H. M. Elhennawy, “Design, Simulation, Fabrication, and Measurement of Antenna Array with Low Mutual Coupling for ISM Band Wireless Applications” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 3, Issue 10, Oct.2014

[2] Amat E., Martin F., Falcone F., Garcia-Garcia J., Bonache J., Baena J., Lopetegi T., Laso M., Iturmendi J., Sorolla M., and Marques R., “Microwave filters with improved stop band based on sub-wavelength resonators,” IEEE Trans. Microw. Theory Tech., vol. 53, no. 6, pp. 1997–2006, Jun. 2005.

[3] Bait, F. Siddiqui and M. Rahmani, “Mutual Coupling Reduction Between Microstrip Patch Antennas Using Slotted-Complementary Split-Ring Resonators,” IEEE Trans. Antennas Propag., vol. 9, pp.874-878, 2010.

[4] Bait-Suwailam M. M., Boybay M. S., and Ramahi O.M., “Mutual coupling reduction in MIMO antennas using artificial magnetic materias,” in Proc. 13th Int. Symp. on Antenna Technology and Applied Electromagnetics (ANTEM/URSI), pp. 1–4, Feb. 2009.

[5] Bait-Suwailam M. M., Siddiqui O. F., and Ramahi O. M., “Mutual Coupling Redction Between Microstrip Patch Antennas Using Slotted Complementary SplitRing Resonators”, IEEE Antennas And Wireless Propagation Letters, vol. 9, pp. 876-878, 2010.

[6] Chan Quanming, H. Lihao, , H. Zhang, Z. Huiling, “Reduction of Mutual Coupling between Closely-Packed Antenna Elements with Split Ring Resonator (SRR),” ICMMT, pp. 1873-1875, 2010.

[7] Falcone, T. Lopetegi, M. A. G. Laso, J. D. Baena, J. Bonache, M. Beruete, R.Marqués, F. Martín, and M. Sorolla, “Babinet principle applied to the design of metasurfaces and metamaterials,” Phys. Rev. Lett., vol. 93, no. 19, p.197401, Nov. 2004.

[8] Fathy, A. Hessel, H. J. Stalzer and J. Smoys, “Effect of lossy ground performance of planar and cylinder arrays,” Radio Sci., vol. 25, no. 2, pp.133-147, 1990. Antennas Propag., vol.55, no. 4, pp. 1074–1085, Apr. 2007.

[9] Ferrer J., Gonzalez-Arbesu J. M., and Romeu J., “Decorrelation of two closely spaced antennas with a metamaterial AMC surface,” Microw. Opt. Tech.Letts., vol. 50, no. 5, pp. 1414–1417, May 2008.

[10] Garcia, F. Martin, F. Falcone, J. Bonache, J. Baena, I. Gil, E. Amat, T.Lopetegi, M. Laso, J. Iturmendi, M. Sorolla, and R. Marques, “Microwave

filters with improved stopband based on sub-wavelength resonators," IEEE Trans. Micro Theory Tech., vol. 53, no. 6, pp. 1997– 2006, Jun. 2005.

[11] Grownald, "Calculation of Mutual Antenna Coupling With in Rectangular Enclosures," IEEE Trans. Electromagn. Compat. vol. 47, no. 4, Nov. 2005.

[12] Karnfelt, P. Hallbjorner, H. Zirath, A. Alping, "High gain active microstrip antenna for60-GHz WLAN/WPAN applications," IEEE Trans. Microwave Theory Tech, pp. 2593–2603, 2006.

[13] Kondori, M. A. Mansouri-Birjandi, S. Tavakoli,"Reducing Mutual Coupling in Microstrip Array Antenna Using Metamaterial Spiral Resonator", International Journal of Computer Science Issues, vol. 9, Issue 3, No 1,pp- 51-56, May 2012.

[14] Kondori, M. Mansouri-Birjandi and S. Tavakoli, "Reducing Mutual Coupling in Microstrip Array Antenna Using Metamaterial Spiral Resonator," IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 3, No 1, May 2012.

[15] Lee Y., Kim S. H., and Jang J. H., "Reduction of Mutual Coupling in Planar Multiple Antenna by Using 1-D EBG and SRR Structures" IEEE Trans. Antennas and Propagation, vol. 63, no. 9, pp 4194-4198, Sept 2015.

[16] Letaief B. and Murch R. D. "Antenna systems for broadband wireless access," IEEE Communication Mag., vol. 40, no. 4, pp. 76-83, Apr. 2002.

[17] Magnetic Metamaterials for MIMO Applications", IEEE Trans. on Antennas And Propagation, vol. 58, no. 9, pp. 2894- 2902, Sept 2010.

[18] McIlvenna F., Kernweis N. P. and Mailloux R. J., "Microstrip Array Technology," IEEE Trans. Antennas Propagate., No. 1, January 1981,pp. 25-27.

[19] Tang M., Xiao S., Deng T. and Wang B., "Novel Folded Single Split Ring Resonator and Its application to Eliminate Scan Blindness in Infinite Phased Array," Proceedings of International Symposium on Signals, Systems and Electronics, Nanjing, pp. 1-4, 2010.

[20] Yousef M., Shaalan A. A., Attia H., Awadalla K. H.,"Mutual Coupling.

[21] Reduction between Microstip Antennas Using complementary Split Spiral Resonators (CSSRS)", IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) , vol 10, Issue 5,pp. 38-44, Oct 2015.

[22] K. F. Lee, Microstrip antennas Basic properties and some recent advances, J. Atmosph. Terrestrial Phys.,vol.5,1, pp. 811–818, (1989).

[23] J.-F. Zurcher and F. E. Gardiol, Broadband Patch Antennas. Dedham, MA: Artech House, (1995).

[24] K. F. Lee and W. Chen, Eds., Advances in Microstrip and Printed Antennas. New York: Wiley Interscience, (1997).

[25] G. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook. Dedham, MA: Artech House.

[26] K. L. Wong, Compact and Broadband Microstrip Antennas. New York: Wiley Interscience, (2002).

[27] G. Kumar and K. P. Ray, Broadband Microstrip Antennas. Dedham, MA: Artech House, (2003).

[28] Z. N. Chen and M. Y. W. Chia, Broadband Planar Antennas. New York: Wiley, (2005).

[29] Z. N. Chen and M. Y. W. Chia, "Broadband Planar Antennas, Design and Applications,"John Wiley & Sons, Ltd.

[30] FCC 802 Standards Notes, "FCC First Report and Order on Ultra-Wideband Technology," (2002).

[31] H. Oraizi and S. Hedayati, "Miniaturized UWB Monopole Microstrip Antenna Design by the Combination of Giuseppe Peano and Sierpinski Carpet Fractals," IEEE Antennas and Wireless Propagation Letters, vol. 10, pp. 6770, (2011).

[32] R. Azim, M. T. Islam, "Compact TaperedShaped Slot Antenna for UWB Applications," IEEE Antennas and Wireless Propagation Letters, vol. 10, pp. 11901193, (2011).

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