Design of Microstrip Patch Antenna for 5G Mobile Communication

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Abstract- **The development of 5G Technology is aimed at increasing the current data rates existing in mobile communication. The existing 4G technology operates in the 2-8 GHz band and supports data rates of more than 20 Mbps while 3G, operating in the 1.8-2.5 GHz band supports data rates up to 2 Mbps. The developing 5G technology utilizes the sub 6 GHz band and millimeter wave bands of which are specified by FCC and is capable of supporting data rates up to 1 Gbps. With increasing demand for high data rates, 5G antenna proves to exhibit itself as potential candidate to meet the requirements of the subscribers. The project discusses the design of microstrip based antenna for operation in the S-band. A novel design comprising 1x2 microstrip array antenna is presented for 5G mobile communications. The proposed antenna is placed on a compact Rogers RT duroid 5880 lossy dielectric substrate with a relative permittivity of 2.2. A gain of 9.44 dB was achieved for a 1x2 microstrip array antenna with good return loss of -24 dB; VSWR is under 2 and radiation efficiency 81.52%. The antenna is designed and optimized using CST Microwave Studio Suite.**

Index terms- **Microstrip patch antenna, 5G, VSWR, ReturnLoss, different patch materials, CST design**

I.INTRODUCTION

Micro-strip patch antenna plays a vital role in the fastest growing wireless communications industry and today we cannot think of any development in wireless communication without changes in micro-strip patch antenna technology. To establish the communication between the wireless devices on higher frequency band such as millimeter wave band, we need the antennas which are conformal, small and compact , cheap and easy to fabrication. So printed antennas have been preferred due to their advantages over other radiating antennas. The recent trends shows that the wireless communication has evolved at a fast rate. 5G wireless standard has evolved to be the most recent technology now- a-days. The stupendous increase in mobile data, technologies are approaching from 4G i.e., fourth generation to 5G, fifth generation. Various different fields have already adopted the 5G technology such as Internet of Things (IOT), advance MIMO structure, advance small cell technology etc.

5th generation (5G) mobile technology greatly increases the communication capacity. This innovation brings the need for advanced antenna design. Performing an antenna with high gain, low loss, low cost, high bandwidth, and high radiation efficiency leads to various design consideration. Modern wireless communication systems require low-profile, lightweight, high-gain and simple-built antennas to ensure reliability, mobility and high efficiency. Therefore, microstrip antennas are highly preferred due to their low profile, simple to manufacture, and ease of feeding. In recent years, there are quite a few microstrip antenna designs in different structures in the literature. Islam et. al. designed a microstrip patch antenna for the WiMAX communication system operating in the 5.8 GHz frequency band and they evaluated the performance for different dielectric material. The best performance was observed for FR4 and dupont-951 dielectric materials. Yoon and Seo, 2017 proposed a 2x2 U-slotted array antenna operating at 28 GHz for the broadband communication system. In their studies, they achieved about 3.35 GHz bandwidth and about 13 dBi gain in this operating frequency. A small microstrip patch antenna was implemented for the 5G wireless standard using High- Frequency Structure Simulator (HFSS) in Verma et. al. From the measured results, it was observed that the designed antenna resonates at 10.11 GHz with a bandwidth of 380 MHz. In Khalily et. al., the modified serial-feed patch antenna array is designed and implemented for 28 GHz millimeter wave applications. The proposed designs are predicted to be applicable for future 5G. Kiran et. al. investigated a compact elliptical microstrip patch antenna operating at 28 GHz by using a simulation program and obtained good results. Ahmed et. al. performed on the sloped substrate of the mm-wave microstrip patch array. The convex slope of the substrate was observed to be highly effective on performance, while the concave slope was observed to have a minimal effect. Sethi et. al. achieved an average gain of approximately 23 dBi in the broadband range (25-40 GHz) operating at 28 GHz and 38 GHz, by designing Aguni et.al. designed a microstrip patch antenna for 2.45 GHz Industrial, Scientific and Medical (ISM) band applications using artificial neural network and obtained a good reflection coefficient value at desired frequency band. Mondal and Sarkar recommended a high-gain wide-band microstrip patch antenna applicable for various applications such as satellite communication, WiMAX, scientific and medical band, etc. In their studies, it was achieved a peak gain of 9 dBi at 5.5-7.5 GHz frequency range through recommended antenna. The main objective of this paper is to design, analyse and optimize the narrowband antenna for 5G mobile communications. The two-element microstrip patch antenna is designed and optimized for required frequency range to achieve needs as per the required applications.

II. LITERATURE SURVEY

Quite a few studies is going at the destiny generation of mobile conversation. Many proposals in terms of architecture and generation have been given by means of one-of-a-kind authors and research groups around the sector alongside addressing the issues, troubles that may occur in implementing those proposals. Brief overview of some of these studies work associated with this design had been offered here contributing closer to the numerous antenna designs, with admire to the technologies that are without a doubt the key promising technology related to this new technology 5g.

The microstrip antennas had been studied appreciably for the duration of the beyond three many years. These antennas preferentially consists of a metallic patch revealed on a dielectric substrate over a ground plane, gives many blessings which includes ease of layout and fabrication, low profile. In current years, with the dynamic changes of new standards and sophisticated Wi-Fi gadgets, there is a need developed to reduce the appearance of these types of microstrip patch antennas. These miniaturization strategies involves changing the shape of antenna, material inserting, folding, inserting slots and defects inside the ground plane. The foremost characteristics and downsides of these techniques are highlighted in this paper [1].

The defects of different sizes and shapes in the ground plane of patch antenna improves the technical parameters like VSWR, return loss, performance and so on. This has been carried out by using analyzing and experimenting by means of slicing different shapes of defects within the ground of antenna. Authors are recommending the micro strip patch antenna for Wi-Fi frequency in this paper. The performance and features of micro strip antenna includes cost price is low, short profile, less in weight made them best desire for communication systems engineers [2].

A unique layout of mm-wave micro strip patch antenna in broadband for gadgets like mobile has brought various changes in the 5G communication system. In this paper, the author proposes an antenna detail that operates around 40 GHz. 9 percent of bandwidth can be obtained by using more than one resonance patch structure.In this paper, the author says that parasitic patches are carried out to lessen the antenna's directivity, and thus develops the microstrip patch antenna appropriate for targeted cell features [3].

While compared with 4g/3g/2g communication technologies, the close to destiny 5g wireless verbal exchange mechanisms can also develop 60GHz mm-wave band as certainly one of the essential resonating frequencies for the benefits of high possible rate of transmission and broad bandwidth. In this article, the writer proposed a unique shape in designing an antenna array which is operated at the crucial frequency of 60GHz. The complete antenna is adopted by means of 4 similar branches in which each one among is developed by using three rectangular patches which are linearly serialized. As a end result, the optimized microstrip antenna array can attain the gain of 8.4 dBi at a frequency range of 60 GHz [4].

This article reveals that there is a technique for fabrication of mm-wave patch antennas which is totally depends on the Printed Circuit Boards (PCB). The design of this technique had been authenticated for more than one layer printed patch antennas, displaying in all cases an accurate level appropriate for the manufacturing of mmwave printed patch antennas [5].

There is sophisticated study in the area of micro-strip patch antennas within the latest years. This assessment gives the details of the task completed on printed antennas from the past ten years. Exclusive microstip patch antenna designs had been revealed with the point of interest in developing the microstrip patch antenna parameters like gain, efficiency, directivity, and bandwidth and return loss. More research had done to fabricate these printed antennas highly compactable and occasional profile [6].

The layout of this rectangular printed patch antenna is resonated at 1.7 GHz of frequency. These printed antennas are having very minimum profile and very simple to design. With the assist of defected shape mechanism, the given antenna has a medium return loss of -33db, better gain of 10db with suitable bandwidth of 109.4 MHz, the directivity is mentioned as 4.442 and overall high performance of 90.95%. Moreover, This antenna is reasonably-priced, low in size, simple to manufacture and compact [7].

This article represents about a microstrip patch antenna in rectangular shape using the defected ground plane method. The antenna is designed at broad bandwidth of 5GHz. The defected ground plane mechanism is used to increase the bandwidth of the antenna. In this, the duroid substrate is used which has dielectric constant of 2.2. The vswr value which is obtained in this antenna is less than 2 [8].

There are various shapes for the design of patch antenna. The traditional shapes such as circle, rectangle, triangle patch antenna represented in this paper. The x-band range lies between 8GHz to 12GHz and has wide applications in radar. FR-4 is used as substrate in this paper [9].

A round disc shaped antenna which has a miniaturized layout has explored in this noval for wireless communications. Revealed on a dielectric substance and supplied via 50ohms microstrip line, the represented antenna has an capability to offer a very high extensive return loss of 10db bandwidth with better characteristics. The unique design decreases the occupied volume and it's far used to determine the parameters of the antenna [10].

III. ANTENNA DESIGN

There is increasing demand for higher data rates to accommodate new services in fifth-generation mobile communications (5G). The seamless coverage for 5G wireless network has boost the demand of 5G base station antenna with favorable properties such as wide impedance bandwidth with high gain and stable radiation pattern. Microstrip antenna is a good candidate for 5G base station antenna design due to its attractive features of low profile, light weight, easy fabrication, and conformability to mounting hosts. These features highlight the necessity and significance of the design of 5G antennas. The layout design of the basic microstrip antenna is given below. This design can be done by using the design parameters which are explained below with the design equations.

Generally, the patch antenna consists of many components in it. Among them, the top layer which is patch, the middle layer that is the substrate and the bottom one which is ground layer are the most important.

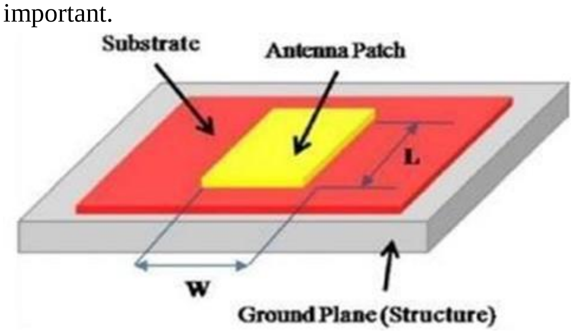

Figure.1 Perspective View

A. FR-4 Substrate:

FR-4 is a glass reinforced and epoxy laminated material. FR-4 glass epoxy is a versatile material which contains a fiber glass cloth (along with an epoxy resin binder) which is self-extinguishing. With nearly very low (approximately zero) water absorption, this substrate is highly popular as an electric insulator owning widespread physical strength. It has a dielectric value of 4.2 and a loss tangent of 0.008 respectively.

B. RT Duroid

RT Duroid is an Glass Microfiber (Reinforced PolyTetraFluoroEthylene material) which showcase very high chemical resistance, along with some solvents that are utilized in printing mechanisms as well as fabrication processes such as slicing, machining. It has a dielectric value of 2.2 and loss tangent value of 0.0013 respectively.

C. Cuflon

Cuflon consist of high composite of Teflon which is electroplated along with a copper material using a method evolved by means of polyflon. The device existence is predicted while extracting cuflon than glass laminates (reinforced). It has a dielectric value of 2.1 and loss tangent value of 0.0004 respectively.

D. Fused quartz

Fused quartz also called as Fused silica is a glass together with silica which is not in crystalline shape. This property of substrate is an advanced one compared to some other variety of glass. The thermal expansion of this substrate is very low. It has a dielectric value of 3.78 and loss tangent value of 0.0001 respectively.

E. DESIGN PARAMETERS

Design parameters of a patch antenna are Relative permittivity $\varepsilon r = 2.2$

Height of the substrate =1.6mmm Loss Tangent = 0.0009

F. DESIGN EQUATIONS

Following steps are taken to design a rectangular micro strip patch antenna.

Step1: Calculation of width (W):

The width of the micro strip patch antenna is given by the equation as

$$\text{width of the patch}(W) = \frac{c}{2f_o\sqrt{\frac{(1+\varepsilon_r)}{2}}} \quad (1)$$

W- Width of the patch.

C - Free space velocity of light, 3 x 108 m/s.

fo-The resonance frequency

εr - The relative permittivity of the dielectric substrate

Step 2: Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna.

$$\text{Effective dielectric constant}(\varepsilon_{reff}) = \left(\frac{\varepsilon_r + 1}{2}\right) + \frac{\varepsilon_r - 1}{2\sqrt{\left(1 + \frac{10h}{W}\right)}} \quad (2)$$

Step 3: Calculation of the Effective length

$$\text{Length of the patch } (L_{eff}) = L + 2\Delta L = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (3)$$

Step 4: Calculation of the length extension

The following equation gives the length extension as

$$\frac{\Delta L}{h} = 0.412 * \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

h – Thickness

Step 5: Calculation of actual length of the patch

$$L = L_{eff} - 2\Delta L \quad (5)$$

L – The length of patch.

IV. SIMULATED RESULTS

A two array element antenna is designed for 5G mobile communications using a standard 0.787mm thickness Rogers RT duroid 5880 lossy dielectric substrate with a permittivity of 2.2. From the formulas the length and width of the patch is calculated. The length of the patch is 71.10 mm and the width of the patch is

27.45 mm and the thickness of patch is 0.0354 mm. A corporate feed network acts as a power divider used to connect the array elements. The antenna is simulated in CST microwave studio and the same is studied for impedance characteristics such as return loss, VSWR and radiation characteristic such as gain, bandwidth and directivity. The proposed patch yields desirable results throughout the operating frequency range

A. DESIGN OF 1x2 ARRAY ANTENNA

Fig.2 shows the layout structure of two-element antenna array with each patch is fed with an inset feed and connected by using a corporate feed in it. An Elliptical slot is incorporated in the center of each radiating patch.

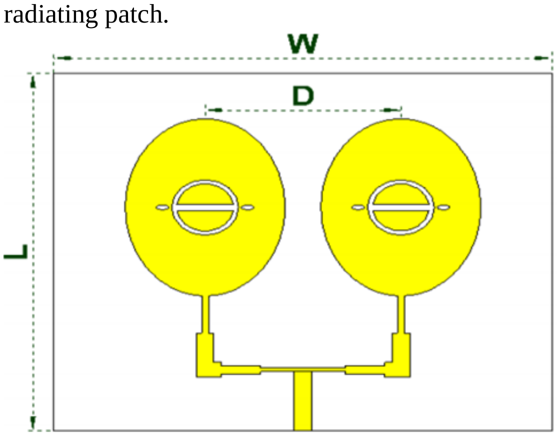

Figure.2 Proposed array antenna design

B. RETURN LOSS

The return loss of the proposed design is -24.043 dB at a center frequency of 3.486 GHz. Lowest values of return loss which represents the maximum coupling of the antenna.

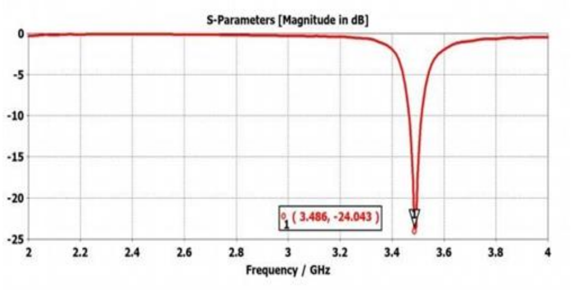

Figure.3 Simulated response of S-Parameter

C. VSWR

The VSWR value in the existing microstrip antenna is 1.1362 at a resonant frequency of 3.486 GHz. In this case the feed line has no loss, and matches both the transmitter output impedance and the antenna input impedance, so the maximum power is delivered to the antenna. The proposed antenna performs well and satisfies the required the conditions as VSWR < 2 as shown in Fig 4

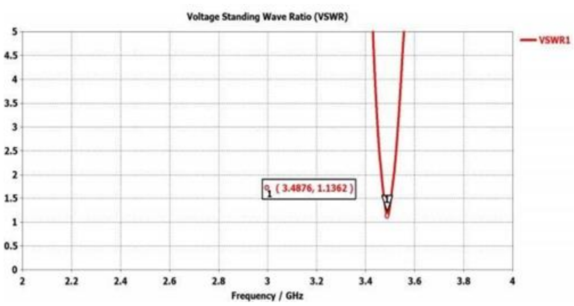

Figure.4 VSWR plot of array antenna

D. FARFIELD GAIN

The 2-dimensional Far-field gain is shown in Fig.9. The angular width of the main lobe at 3 dB is 86.1 degrees and the main lobe direction at the center frequency is 46.0 degrees.

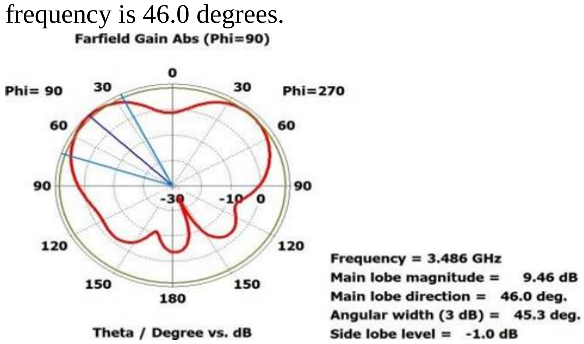

Figure.5 Far-field gain of array antenna

E. GAIN

Gain of an antenna is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically, gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. This proposed array antenna achieves high gain of 9.448 dB as shown in fig.6

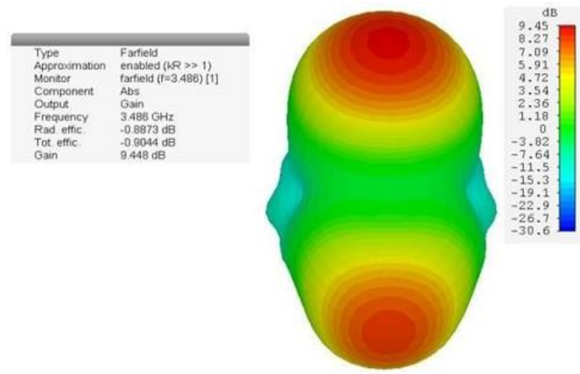

Figure.6 Gain plot of array antenna

F. DIRECTIVITY

The ratio of maximum radiation intensity of the subject antenna to the radiation intensity of an isotropic or reference antenna, radiating the same total power is called the directivity. The directivity of the array antenna is shown in Fig.7. The directivity value in the existing antenna is 6.759 dBi.

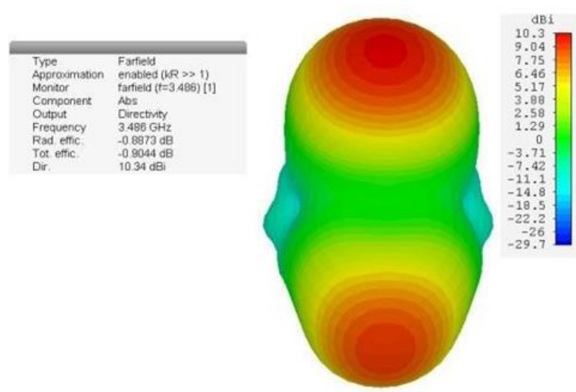

Figure.7 Directivity plot of array antenna

G. RADIATION EFFICIENCY

The Figure 8 shows proposed array antenna yields good radiation efficiency value of 81.52%

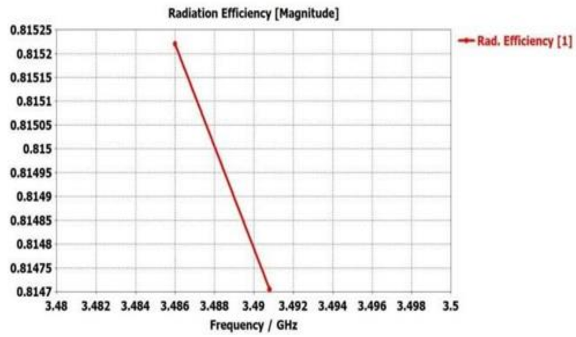

Figure.8 Radiation Efficiency

V. CONCLUSION

As a conclusion, the aim of this project was to design and study a microstrip patch antenna for 5G applications and to study the array of a two-element array antenna. Microstrip antenna has lead to many applications in the real world due to its low-profile feature. The elliptical antenna has been designed and simulated by using the electromagnetic software CST Microwave Studio Suite. The proposed patch yields desirable results throughout the operating frequency range. The proposed elliptical array antenna achieves a good return loss (-24 dB), VSWR (1.13), good gain (9.44 dB), good directivity (10.34 dBi) and narrow band-width at 3.485 GHz that determine a long range of operability. This proposed elliptical design is well suited for 5G mobile applications respectively. The future scope of work revolves around increasing the efficiency and decreasing the substrate dimensions and applies new techniques to reduce the patch size and enhance the antenna characteristics for 5G applications. Many other applications are under research like multiband antenna, circular polarised antenna, array antenna etc.

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