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A Survey on Microstrip Antenna Array Design for 5G Communication

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Abstract: With the development of telecommunication, antenna are designed with miniature size with high performance. Microstrip patch antenna is playing an essential role. It is very demanded and significant thing in the 5G communication because of itsseveral advantages over usual antennas like reduction cost, light weight, conventional to feed and antenna characteristics. It should be noted that researchers are working for the improvement of the antenna system for 5G communication for achieving high gain and bandwidth. 5G communication system provides higher frequency range with larger bandwidth. The objective of this paper is to discuss the overview study of microstrip patch antenna in 5G Communication for past few years. The measurements of antenna parameters are also discussed in this paper.

Keywords: Microstrip Patch Antenna array, Design parameter, 5G Communication, mm-wave, Bandwidth and Gain Enhancement.

I. INTRODUCTION

Wireless communication having huge requirement of antennas system, antennadesign becomes additional confront and required. Microstrip patch antennas have been substantially utilized in radars, satellite communications, military, aerospace communication, biomedical and for mobile communication because of its structural characteristics. Currently these antenna are generally employed in 5G communication.

PIFA antennas are used for mobile communication in olden days because it has less interaction with hand –held environment. The major drawback of PIFA antenna is that use narrow bandwidth. Microstrip antennas replace this problem and it is mostly used in mobile communication nowadays. Microstrip antenna are considered to be the most suitable design for wireless communication due to their evident advantages of light weight, low cost, planar configuration and also it has noticeable precedence of easy of conformal, suitable for arrays, superior portability and easy for fabrication. It is applied in various applications such as mobile communication, satellite communication, television, and multiple-input multiple-output (MIMO) system is specially relayed in civilian and military applications and so on. The updation is still carry on the microstrip antennas for finding new applications of it by having more innovations.

A) Microstrip Patch Antenna:

Generally, antennas are in a metallic structure, used for transmit and receive the signal in the form of electromagnetic waves. Microstrip antennas take important role in communication system because of its several advantages and characteristics. It consists of simplest design.

A microstrip patch antenna design consists of a three layers. Two conducting materials are in the top and bottom of the antenna and the middle layer is made of dielectric substrate with a particular dielectric constant (εr). It covers a narrow-band microwave which is a imprinted resonant antenna. Due to its compact, it is applicable for small area such as in switch box. The basic microstrip antennas are in the shapes of rectangular and circular patches and most widely utilized in the most of the applications.

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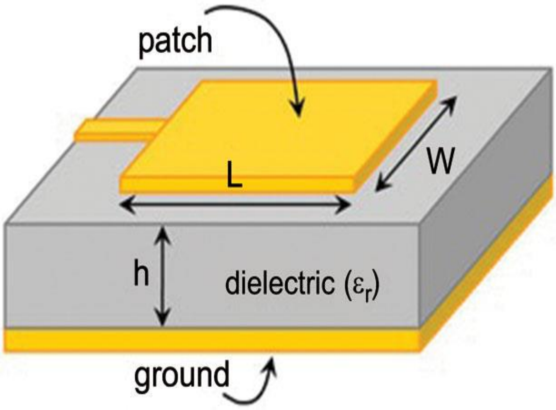

Figure 1: Microstrip antenna with substrate and ground

B) Microstrip Patch Antenna Array Design:

Antenna array is exerted to increase the total gain in antenna, remove interference and increase the Signal to Interference plus Noise Ratio. Microstrip patch antenna is fabricated by using a very thin metallic strip and which is positioned on ground plane with the thickness of h. It has many advantages such as reduced feed length, reduced losses, equal power to all element and supports for larger bandwidth.

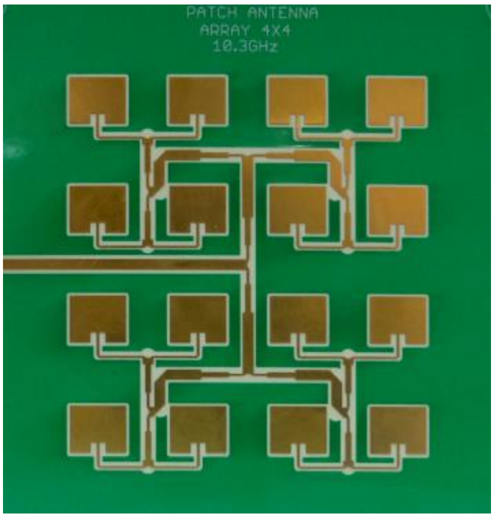

Figure 2: Microstrip Patch Antenna Array

Antenna array characteristics depend on various parameters which are pre-calculated for designing antenna array element based on the applications. Voltage Standing Wave Ratio, Substrate width, Actual Length of the Patch, Patch Length Extension, Return Loss Curve, Gain, Directivity, Effective Dielectric Constant, and Bandwidth etc. are the elemental parameters which decide the performance of antenna.

Radiation Power:

$$\mathrm{Prad} = \frac{1}{2\eta}\iint(|E_\theta|^2 \times |E_\theta{}^*|^2) r^2 \sin\theta \, d\theta \, d\phi$$

Gain and Directivity:

$$D = \frac{\frac{1}{2}\mathrm{Re}(E_\theta H'_\varphi - E_\varphi H'_\theta)(\theta=0)}{P_{rad}/4\Pi}$$

$$G = \eta \text{ x } D$$

Width of the microstrip line:

$$W = \frac{1}{2fr\sqrt{\mu_0 \varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{\upsilon_0}{2fr}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Impedence of the microstrip line:

$$Z_0 = \frac{120\Pi}{\sqrt{\varepsilon reff}(1.393+\frac{W}{h}+\frac{2}{3}\ln(\frac{W}{h}+1.444))}$$

Extension of Length of the patch:

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$$\frac{\Delta L_{eff}}{h} = 0.412 \frac{(\mathcal{E}_{reff}+0.3)(\frac{W}{h}+0.264)}{(\mathcal{E}_{reff}-0.258)(\frac{W}{h}+0.8)}$$

Actual Length of the patch:

$$L = \frac{1}{2fr\sqrt{\mathcal{E}reff}\sqrt{\mu_0 \mathcal{E}_0}} - 2\Delta L$$

Effective Length of the patch:

$$L_{eff} = (L + 2\Delta L_{eff})$$

Resonant frequency:

$$f_r = \frac{1}{2L\sqrt{\mathcal{E}_r \mu_0 \mathcal{E}_0}} \frac{\upsilon_0}{2L\sqrt{\mathcal{E}_r}}$$

Effective dielectric constant:

$$\mathcal{E}reff = \frac{\mathcal{E}r + 1}{2} + \frac{\mathcal{E}r - 1}{2\sqrt{1 + \frac{12h}{W}}}$$

Return Loss:

$$RL = 20\log_{10} \left| \frac{z_1 + z_2}{z_1 + z_2} \right|$$

Voltage Standing Wave Ratio:

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1+S_{11}}{1-S_{11}}$$

Return Loss:

$$S_{11} = -20\log\left[\frac{V_r}{V_i}\right] = -20\log\left[\frac{VSWR-1}{VSWR+1}\right]$$

II. MICROSTRIP ANTENNA DESIGN IN 5G COMMUNICATION

The 5G network provides the crucial solutions that fulfil the users' requirements. As a result of it, we have to make input handling capacity as more. The plethora of requirements needed for specific applications with higher data rate and in compact size also. The design of microstrip antenna for 5G application should be aimed to achieve compact size and higher gain by widely increasing the usage of radiation elements. For the desired structure antenna parameter calculations have to be done by using corresponding equations. The enhanced sizes are needed to meet the requirements in the sense of 5G wireless communication network applications. Depending upon the requirements number of radiation elements are getting increased and so we can able to increase size optimization of substrate. Ground is defected with a square shape slot in order to improvise the bandwidth and return loss of an antenna. The line feeding can be designed as rectangular shaped and which is placed on the substrate. At the resonant frequency if antenna is excited, a strong field is created inside the cavity and it create the current on the surface of the patch and the current is more strengthen on the surface of the patch. The power accomplished with the radiation resistance actually radiated by the antenna due to dielectric and conducting losses power dissipated as heat loss in the microstrip antenna itself.

III. LITERATURE SURVEY

In this section, literature survey of microstrip patch antenna is rooted on the previous research and analysis made on microstrip antenna. The previous study shows that microstrip antenna design is the best antenna for 5G Wireless Communication. It reveals many advantages including light weight, low price, low profile, easy of conformal, planar configuration, suitable arrays, easy fabrication, and easy integration with external circuitries. Some of the following papers demonstrated the work on antenna design.

Colaco J, et al.,[1] This work is deployed on the design of antenna for 5G applications. This antenna is designed with millimeter wave bands at resonant frequency of 26 GHz. In this system, they have employed in rectangular microstrip antenna with the dielectric constant of 2.2. The simulated design achieves better return loss of -33.4dB in the bandwidth of 3.56 GHz to 99.5% antenna radiation efficiency.

Murugan S [2] The purpose of this idea is to design and analyze a compact MIMO antenna. It is a 4 element MIMO antenna and it is simulated in HFSS software. This antenna operates at sub 6 GHz band. The measurement of the antenna is mentioned as 25.3 x 26.8 x 1.6 mm^3. The antenna is fabricated with a FR4 substrate with a dielectric constant of 4.4 and the thickness of 1.6 mm. It achieves gain between -0.52 dB to 4.2 dB

Sokunbi O, et al.,[3] This paper demonstrated a novel slotted-ring electromagnetic band gap structure. It operates under the frequency band of 26.5 GHz to 27.6 GHz. The distance between two antennas is 3.07 mm which is equivalent to 0.28λ. It achieves the improved impedance matching and the mutual coupling between two antennas is decreased by 30 dB for 5G wireless applications.

Outerelo DA, et al.,[4] This practical demonstrated antenna works under 28 GHz (LMDS band) to 60 GHz frequency band. This paper detailed the design issues of the rectangular microstrip antenna for 5G broadband communications. It figure out the issues in antenna design such as inaccurate value of relative dielectric permittivity, connector – feed line soldering and fabrication mechanical inaccuracies and errors. It is simulated and analysed in CST software.

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Imran D, et al.,[5] This project illustrated a single patch antenna. It is fabricated with the measurement of 2 x 2 mm^2. The substrate of the antenna framed of the dielectric constant of 2.2 with the thickness 0.508 mm. It is operated under the bandwidth of 3.5GHz, 2.5GHz and 1.3GHz with tapered line feeding. It attains high gain of 12dB for mobile applications. It has the return loss of -15.5dB for 38GHz and -12dB for 54GHz. The 5G antenna array achieves the return loss of -13.6dB for 38.6GHz, -22.5dB for 47,7GHz and -18dB for 54GHz. The antenna array achieves high gain of 12.2dB for 38.6GHz, 11.6dB for 47.7GHz and 12.1dB for 54GHz.

Kumawat P, et al.,[6] This work displays a noval dual-band orthogonally polarized elliptical microstrip antenna array. It employed under the millimeter wave spectrum. It has the return loss of -22.2dB for 28GHz and -15.56dB for 38GHz. It uses the substrate length of 10 mm and width of 10 mm. It achieves efficiency of 80.38% and 76.68% at 28GHz and 38GHz. The VSWR value lies between 1 and 2 for 5G bands. The acquired gain for antenna array for 28GHz is 11.9dB and for 38GHz is 12.2dB.

Raviteja GV [7] In this paper, a 2x2 microstrip antenna array is proposed and simulated for 5G applications. It is designed with rogers substrate of dielectric constant of 2.94 with loss tangent 0.0012. It is employed with corporate feeding. This antenna designed in 2x1 and 2x2 array. It operates in the frequency range of 24.25GHz to 27.5GHz. The S11 value is calculated as -31.94dB at 26.78GHz frequency. It obtained the gain of 11.02dB and directivity to be 11.12 dB. It is deployed as a conventional antenna with three antenna configurations with good reflection co-efficient values of -38.1dB, -35.11dB and -31.94dB.

Hakim ML, et al.,[8] Multiband Millimeter wave Microstrip antenna array for 5G wireless communication is exhibited in this paper. It is 2x2 antenna array with high efficient, because of their lowest cost of fabrication and light weight. It operates in the microwave frequency. It provides gain ranges between 15.63dB and 9.23dB at the frequencies of 26.82GHz and 34.60GHz. The volume the substrate is designed of 20.66 x 22.56 x 5.357 mm^3. The measurement of the patch is 5.10 x 4.44 x 0.248 mm^3. It has return loss less than -10dB for all resonant frequency. The peak directivity 15.7dB is obtained at 26.82 GHz.

Rahayu Y, et al.,[9] This paper deals with antenna fifth generation wireless cellular communication networks. It uses broad bandwidth with microstrip antenna array single, two, four and six elements. This antennas are printed on Rogers substrate of dielectric value of 2.2 with thickness 1.575 mm. It made of fed line with a 50Ω microstrip line. It accomplished with a maximum gain 7.47 dB with return loss of -30.70 dB at 28 GHz and 12.1 dB gain with return loss of -34.5 dB at 38 GHz frequencies.

Faisal MM, et al.,[10] The objective of this project is to design a high gain microstrip patch antenna. It is designed with broad bandwidth, high gain and low cost using air substrate. It is designed and simulated using IE3D software and operates at 28 GHz frequency. It is executed with bandwidth of 1.29 GHz, return loss of 42 dB and provides high efficiency.

Table 1: Comparison of various parameters discussed

S.NO	TITLE	TECHNOLOGY
1	Design and Implementation of Microstrip Patch Antenna for 5G applications	Operating frequency - mm wave Dielectric constant 2.2 VSWR>2, return loss - 33.5dB
2	Compact MIMO Shorted Microstrip Antenna for 5G Applications	Operating frequency - 6 GHZ and Dielectric constant thickness of 1.6 mm. Two shorting pins are employed for getting better impedance matching.
3	Microstrip Antenna Array with Reduced Mutual Coupling Using Slotted-Ring EBG Structure for 5G Applications	Two rows of slotted-ring EBG structures are positioned between these two closely-spaced microstrip antennas and Operating frequency is dual band of 26.5 and 27.6 GHZ

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4	Microstrip Antenna for 5G Broadband Communications: Overview of Design Issues	Operating Frequency is 27.5 and 28.35 GHZ and discussed three categories of design issues.
5	Millimeter Wave MicroStrip Patch Antenna for 5G Mobile Communication	Operating Frequency is mm wave, Rogers Substrate thickness is 0.508 mm and loss tangent is 0.0013.
6	A Novel Dual-Band Orthogonal Polarized Elliptical Patch Antenna Array for 5G Applications	Operating frequency - mm wave, Substrate thickness - 0.25 mm and loss tangent - 0.003
7	A 2x2 Millimeter-Wave Microstrip Antenna Array for 5G Applications	Operating frequency is mm wave of 27 GHz, Dielectric constant is 2.94, loss tangent is 0.0012 and S11 is -31.94dB
8	Design and Simulation of a Multiband Millimeter Wave Microstrip Patch Antenna Array for 5G Wireless Communication	Multiband mm wave frequency is used and maximum and minimum gains of 15.63dB and 9.23dB at various operating frequency.
9	Design of 28/38 GHz Dual-Band Triangular-Shaped Slot Microstrip Antenna Array for 5G Applications	Dual band frequency is used(28 and 38 GHz), Substrate thickness is 1.575 mm, loss tangent and achieves gain ranging from 7.47 to 12.1 dB
10	Design and Simulation of a Single Element High Gain Microstrip Patch Antenna for 5G Wireless Communication	It is synthesized at 28 GHz band and achieves 100% efficiency

IV. CONCLUSION

Various techniques have briefly discussed for the design of microstrip antenna in this survey paper. In all-exclusive techniques the right most objective is to increase the gain and and compensating it with bandwidth of the antenna. The huge number of researches are going on microstrip antenna design regarding that compensation. As day by day results there is possible to get different kind of patch antennas with several features for peculiar applications in 5G communnication. By these performance analysis we can use these dielectric substrate parameters for 5G mobile communication. These microstrip antennas have been suggested to meet the demand in growing mobile data and mobile devices. Microstrip antenna plays extended role with plethora of applications in advanced communication systems. Even as of now microstrip antenna has a tremendous potential applications in Personal Communication System, Direct Broadcast Satellite, Mobile Satellite Communication, Global Positioning System, WLAN, Intelligent Vehicle Highway System and also it is getting attention for Microwave Therapy. Microstrip antenna gets attention to do achievement in patch antenna array design especially in satellite communication systems for designing a thin, light weight and compact size. The extension of patch antennas are going to be an array in design and for this several models have to be designed. For the need of dual frequency in many applications including radar and satellite communication the design of array can be extended in future.

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