

Advantages of 5G Antenna and its Design

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Abstract— In recent years, wireless communication made people lives very comfortable by rapid response and contactless interaction. 5th Generation of wireless communication will further aid in providing larger bandwidth, lower latency and improved data rate. For this purpose, 3 GHz onwards the frequency band is available to be deployed. Mobile communication happening in the recent past is done via Microstrip patch antenna. In this paper, an analysis is presented on 5G system of technology and different parameters related to Microstrip Patch Antenna (MPA).

Keywords— 5th Generation of mobile communication, Microstrip Patch Antenna (MPA), Feeding Techniques, Designing an MPA.

I. INTRODUCTION

Communication has two major forms. The wired and wireless communication. The wireless communication has evolved very rapidly in the near future because of many users because it is low cost and large coverage area without physical medium [1]. 5th Generation of mobile communication is aimed to have larger bandwidth and faster data rate. Some of the new features introduced are enhanced Mobile Broadband (eMBB), massive Machine Type Communication (mMTC), Ultra-Reliable Low-Latency Communication (URLLC) and fixed fiber like radio communication. The technology can provide users from 100 Mbps to 20 Gbps and for this minimum of required bandwidth is 800 MHz [2].

Antenna is considered the most important aspect of Aerial communication. For signals to get radiated an antenna should be having immaculate efficiency and optimized design [3]. The antenna coordinates between the devices, radio energy systems and free space or guided mediums [4]. For 5G, Millimeter wave (MM-wave i.e., 30-300 Ghz) is recommended because of its massive bandwidth and availability. There is an increase of 50% in data users each year and because of IoT devices in the near future it is expected to increase many folds [5],[6].

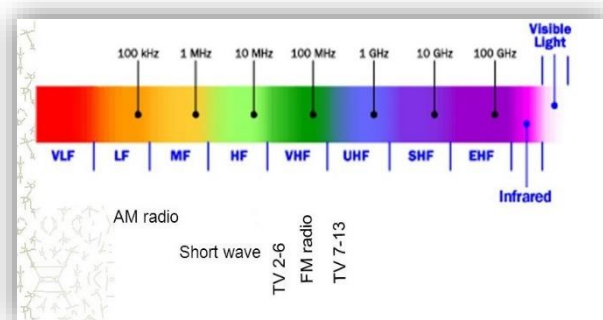


Figure 1: Radio Frequency Spectrum

For 5G to be implemented, it should satisfy the following standards mentioned by The Next Generation Mobile Network (NGMN):

- 10s of MB/s of data rate should be allotted to all the consumers.
- 100s of MB/s of data rate should be allotted to all the consumers in metropolitan areas.
- 1 GB/s speed should be provided to the commercial connections.
- Multiple connections for massive number of users.
- Should be having better spectral efficiency as compared to 4G.
- Enhanced coverage.
- Better signal strength.
- Considerably lower latency as compared to 4G.

The problems related to the propagation at higher frequencies need to be unstated and addressed before getting the optimum results of 5G system [7].

Cellular communication technology has evolved very swiftly. The first 1G system of communication started in 1981 as an analogue communication, with major emphasis on rapid communication through voice channel. Then came 2G in 1991

with an already feature of voice call and a new one as SMS. This technology not only was digital in nature but it was much clearer because of higher bandwidth and frequency. Internet was also introduced to cellular devices. 3G was introduced in 2001 with a stress on enhancing bandwidth. While 4G came in 2012 having a clear vision of providing more faster speed data communication and large channel capacity [8]. 4G has the restraint of limited bandwidth and speed for upcoming technology, as to resolve this issue, 5G is inevitable. To reduce path-loss it is essential to improve the bandwidth and increase gain, which will make the data rate increased at briefer distances [9]. Though 5G is launched in 2021 with extra smart features added. Faster data rate, IoT and Smart communication are some of the key improvements in this area [10]. Through 5G many areas like Artificial Intelligence, Blockchain Technology and services for IoT such as Smart Grids, Smart Cities and Smart Transportation will be greatly benefited [11].

II. LITERATURE REVIEW

a) Designing a MPA

Antenna can be designed using various materials to get desired results. Now a days in cellular communication Microstrip patch antenna is used in almost all devices. To design a Microstrip Patch Antenna there are four main parts. A patch, a feed line, a ground plane and a substrate that is used as a dielectric between patch and ground plane [12], [13]. Mostly the ground plane and patch are made up of highly conducting material as shown in Figure 2, whereas the substrates, due to having different relative permittivity are made up of different materials.

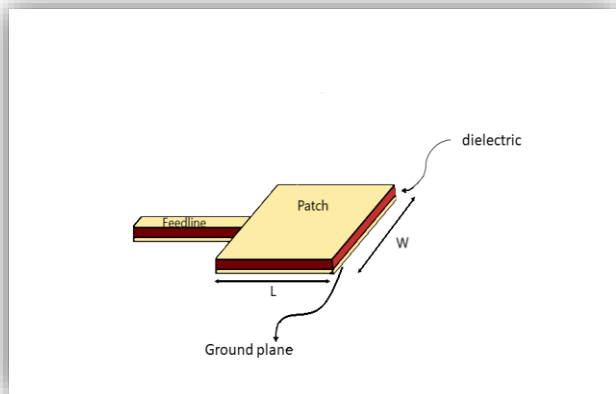


Figure 2: Microstrip Patch Antenna (MPA)

b) The Substrate

In a MPA the permittivity of the substrate ranges from $2.2 \leq \epsilon_r \leq 12$. To accomplish a higher bandwidth and more efficient design, the permittivity of the dielectric substrate should be reduced but the size increases. The ϵ_r effects the microwave and radio frequencies [14], [15]. Below is the Table 1 showing different attributes associated with materials [16].

Table 1: Attributes of different material

Material	Relative permittivity (ϵ_r)	Gain (dBi)	Loss tangent	Resonant Frequency (GHz)
Benzocyclo Butane	2.6	5.5	0	2
Roger 4350	3.66	4.62	.004	2.5
FR4_epoxy	4.4	9.8	.018	5.8
Bakelite	4.8	5.64	.028	3.8
RT/duroid 5880	2.2	6.04	0.0009	3.32

There are many simulation softwares that can help in designing the antenna virtually without physically going through the full process. CST and HFSS are the most renown simulation softwares. These softwares can help in getting the results accurately without wasting time and money. All the important parameters like (S1,1), VSWR, efficiencies, impedance matching, gain, directivity, etc., are assessed [17].

c) The Patch

To design the patch that radiates RF signals, careful considerations should be taken into account. It can be designed in any profile that are shown in the figure below. These can also be named as microstrip patch antenna or just a printed antenna. Some designs are shown below in Figure 3.

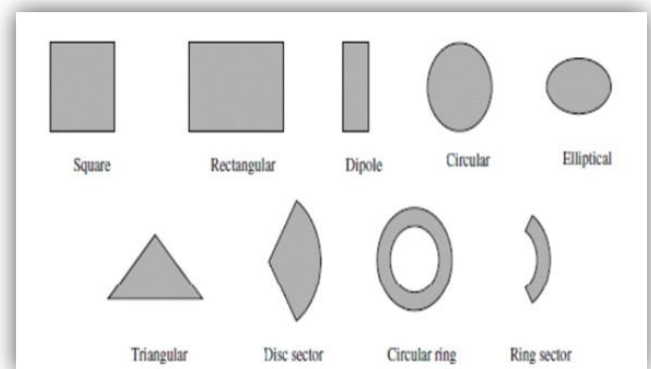


Figure 3: Patch Antenna's Designable Shapes

The range of the frequency for antenna is restricted from 300 MHz to 300 GHz [18]. Firstly, the patch should be calculated according to the known formulas given below [19], [20]:

Width of the patch:

$$Wp = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (2.1)$$

Length of the patch:

$$L = L_{eff} - 2 \cdot \Delta L \quad (2.2)$$

Effective length of patch:

$$L_{eff} = \frac{c}{2f_0\sqrt{\epsilon_{reff}}} \quad (2.3)$$

Change in length of the patch:

$$\Delta L = 0.412h \frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (2.4)$$

Effective dielectric constant of the patch:

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \times \frac{1}{\sqrt{(1+12\frac{h}{W})}} \quad (2.5)$$

Where:

- c = 3×10^8 m/s = Speed of light
- ϵ_r = Dielectric constant
- f_0 = Resonant frequency
- h = Thickness of substrate
- ϵ_{reff} = Effective dielectric constant

Besides that, slots in the patch antenna have an important role in steering the frequency and return losses [21]. Slot or slits needs to be introduced into the radiating patch to achieve the desired efficiency, bandwidth, solidity, number of bands and broadband properties to radiates electromagnetic energy efficiently [22]. T, L, Y and U shaped slots are most often used in the research [23]. Usually the material used in the antenna for patch and ground is copper and the substrate is insulator [24]. Two or more patch antennas can be combined to get multiple frequency bands in a single antenna design. The signals fed to the antennas must be considered carefully, i.e., if the first antenna is line fed, the other antennas should be coupled accordingly [25], [26]. In order to reduce unwanted interference significantly between array antennas, a row of fractal uniplanar compact electromagnetic bandgap (UC-EBG) construction and slots as the decoupling structures. One of the variants of Hilbert curve, i-e, the More curve is used in the basic unit of UC-EBG [27]. To enhance the impedance bandwidth of the antenna the unit is adopted. Though, to decrease the mutual coupling in the antenna, the stop-band feature of UC-EBG is used. There are two radiating patches with Fractal UC-EBG which is shown in the Figure 4 [28].

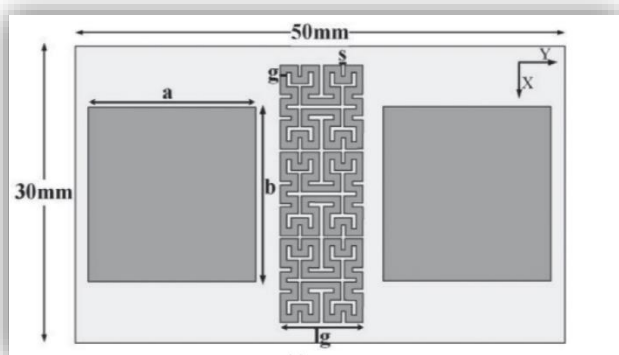


Figure 4: UC-EBG Structure Based Antenna Design

d) The Feed

To provide signals to antenna is called feeding. These techniques are mainly of four different types, i.e., Line feed, Coaxial feed, Aperture coupled feed and Proximity coupled feed. In most of the cases line feed is preferred because it is easily fabricated and used for impedance matching. In coaxial feed the radiating patch is soldered to the coaxial connector's inner side which is passed through the dielectric substrate, whereas the ground plane is soldered to the outer side of the connector [29]. An aperture-coupled feed has a common ground plane but two different dielectric substrates are used. So, a high permittivity material can be used with a low permittivity material together [30]. Proximity coupled feed can enhance the effectiveness of the antenna, i-e, increase more bandwidth, have low spurious radiation without making it difficult [31].

III. PARAMETTERS AFFECTING

Different parameters of antenna are very important for efficient transmission. Some of the parameters are VSWR, (S1,1), bandwidth, gain, directivity, radiation efficiency, total efficiency, impedance matching etc. Voltage Standing Wave Ratio (VSWR) represent the power transmitted from the source through transmission line to antenna [32]. Return loss is the ratio of incident power to the reflected power which is also called reflection coefficient and is generally represented by (S1,1). Usually, at return loss of -10 dB or -15 dB the performance of the antenna is assessed [33]. One of the most vital parameters in communication is bandwidth. Because of the growing new users in communication sector and many applications in our daily lives, the bandwidth needs to be increased rapidly [34]. Adding to the fact that the high-gain antennas are also critical for the path losses and the power constraints. Antenna's directivity is the ratio of maximum power to the average power radiated or concentration of power radiated in the maximum radiation's direction. The radiation efficiency is the ratio of radiated power to the accepted power or input power of an antenna. [35].

$$\eta_r = \frac{P_{rad}}{P_{in}} \quad (2.6)$$

Where:

- η_r = Radiation efficiency
- P_{rad} = Power radiated
- P_{in} = Input power

The ratio between the radiated power and the incident power to the network is known as total efficiency. Losses in the system is basically due to the dissipation of radiated power in conductor and dielectric. It also includes both reflection losses as well as the losses in the antenna impedance miss-matching [36].

Impedance matching is very important parameter in designing and fabricating the antenna. 50 Ω is considered usually as the

impedance of the system, i.e., impedance of the antenna, impedance of the transmission line and impedance of the signal generator with proper termination. Without impedance matching signals cannot be transmitted efficiently and power losses will occur [37].

For multipath transmission and receiving of signals by multiple antennas to maximize the data transmission Multi-Input-Multi-Output (MIMO) is a technique that can be incorporated [38],[39]. Also in order to accommodate increasing number of devices and larger number connections MIMO can be applied [40].

As 5G in IoT based applications are increasing, through low power wide area network (LPWAN) the unlicensed spectrum band can be used [41]. The co-occurrence of alternative waveforms and OFDM to achieve a better data rate through Machine type communication (MTC) in device to device (D2D) communication [42], [43].

IV. OPTIMIZATION

There are many ways to optimize an antenna to get its full potential. Pre-specified dielectric properties of a substrate can make is discussed. Different patterns in the volume of substrate can be made artificially. To achieve the desired results that are required different material should be created by the formal design optimization algorithm, i.e., the solid isotropic material with penalization (SIMP) method. The dielectric constant ϵ_r is changed in comparison with the patch's resonant frequency. This method is a mathematically well-posed topology optimization algorithm because the actual material properties can be related to the cell's variables as the continuous density function is used [44]. In different areas of electromagnetics, Genetic algorithm (GA) is an authoritative means for optimization. This algorithm is based on natural selection and evaluation of Darwinian concepts. The directivity, size, bandwidth, gain, multi-band, etc., can be optimized of patch antenna by GA [45]. Particle swarm optimization (PSO) is a technique that was established using curve fitting using equations. Through this program the bandwidth was increased by 15% of an inverted E-shaped microstrip patch antenna [46], [47].

Low permittivity substrates can increase the bandwidth at the cost of large dimensions and higher permittivity substrate will improve the quality factor hence the bandwidth reduces. The bandwidth is improved by micro-machining process in the high index substrates as explained in the above sections. Further improvement in the bandwidth can be achieved by using the concept of composite substrate of an antenna [48]. By making slits into the rectangular patch, multi-band operations can be attained. By using the optimization methods like Coyote Optimization algorithm and a powerful high-frequency electromagnetic solver the desired results are accomplished [49], [50]. Through different simulation software the diverse shape of slots can be created in the microstrip patch surface and ground plane that can optimize

gain and bandwidth. Genetic algorithm is used in this optimization technique which can greatly increase the results, i.e., 100% in the bandwidth and 18.6% in gain of the antenna [51].

The use of artificial magnetic conductor (AMC) substrate may be recommended for bandwidth improvement. By implementing high impedance surface (HIS), the impedance matching gets easier due to the reduction of mutual coupling between the antenna and its image giving a wide bandwidth and total power reflection. The invasive weed optimization (IWO) is a tool used to develop AMC in order to improve the radiation characteristics of resonant frequency as well as to enhance the bandwidth [52]. Gain and directivity can also be increased by replicating the patch several times [53].

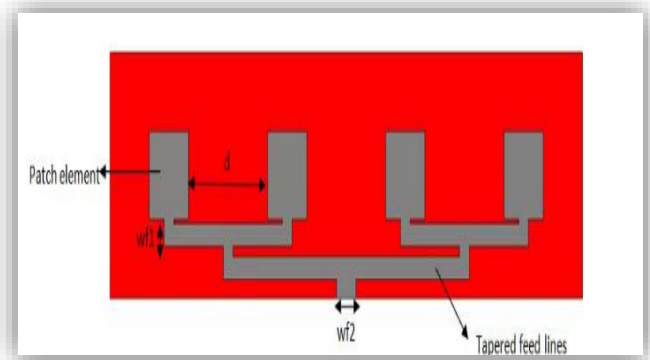


Figure 5: 1 × 4 Antenna Array

The antenna design using Metasurface (MTS) and a ground plane, which consist of modified patch, sandwiched between a 4 × 4 array. Primarily, a diagonal rectangular slot is made in the patch of the antenna to enhance the narrow bandwidth [54]. Performance degradation is expected when using thicker and higher permittivity substrate due to surface waves, where as if the substrate is thinner and lower permittivity the antenna may expect copper losses [55]. The antenna's performance for single element, linear array 1 × 4, 4 × 4 and planar array 1 × 8 are explored. Moreover, high-gain beams with low back lobes and sufficient radiation behaviors have been achieved for the designed planar array [56], [57].

For 5G MM-Wave parasitic patch shown in the Figure 6 can improve bandwidth. This method can greatly enhance the bandwidth due to coupling between the driven and the parasitic patch over a wide range of frequency band. This antenna is having a VSWR bandwidth of 16 GBs, which is appropriate for all the high data rate applications, related to upcoming demand. For an antenna like this the impedance matching should be prioritized and the rectangular part should be designed accordingly [58], [59].



Figure 6: Different parasitic coupled antennas

V. APPLICATIONS

5G has a massive impact on technological development. Some of which are mentioned below:

1. Low latency for faster communication
2. Augment reality
3. Real time monitoring
4. Massive wireless bandwidth
5. Automation control
6. Virtual reality
7. High speed internet
8. Crystal clear voice quality for mobile communication
9. Used in satellite communication

Presently, 5G wireless communication technology is in its development phase and it is going to achieve more milestones in the recent future. The network is gradually improving capability to reduce the space between the technology and demand [60].

VI. CONCLUSION

It can be concluded that 5G is going to bring incredible changes in revolutionary technology. This paper is survey for 5G Microstrip patch antenna experimental and theoretical. Designing and formulation of the patch antenna is discussed extensively. Different shapes of patch, slits and slots are mentioned, in addition its impact on the results is deliberated. The materials used for fabrication of antenna, i.e., patch and substrate are mentioned, as well as the comparison of different material that can enhance the performance of antenna related to bandwidth, losses, resonant frequency and gain. After designing optimization is another task which is addressed with detail, that can enhance the performance of different parameters. Also, the applications related to 5G are revealed which can make great change in the coming future.

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