

Investigations on Millimeter Wave (mmW) Antenna for 5G Technology: Design Considerations and Applications

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Abstract: The millimeter wave technology has made its way to the 5G technology as the system of 5G requires larger bandwidth, higher frequency and system capacity. In order to achieve these parameters, the millimeter wave antenna research becomes necessary. The current wireless technologies require huge bandwidth which makes the spectrum of millimeter wave a potential candidate. Microstrip antennas have always been in an increasing demand due to their exceptional performance in the applications of wireless communication. The advantages of microstrip patch antenna led to its popularity among the researchers. The technologies such as MIMO, CMOS and beam forming are used with millimeter wave antenna for improving the mobile phone performance. There are various designs of microstrip patch antenna related to 5G technology and applications in the millimeter wave band which are discussed in the paper.

Keywords —Microstrip Patch Antenna, 5G technology, Millimeter Wave, Wireless Applications, Bandwidth;

I. INTRODUCTION

5G stands for fifth generation in telecommunication. In cellular networks, 5G technology is a standard which has been deployed by various companies of cellular phone in 2019 worldwide. 5G technology is a successor to the networks of 4G through which the connectivity to most of the current cellphones is provided. There is division of the service area in 5G cellular networks into small cells. These cells are the geographical areas inside the cellular network. A single cell contains large number of 5G wireless devices which are connected to the cellular network and internet by radio waves via antenna present in the cell. This new network has various advantages such as larger bandwidth and higher data rates [1-2]. Because of the larger bandwidth, the new networks can be used as internet service providers to desktop computers and laptops. The new applications in M2M and IoT areas would also be possible. The NR (New Radio) air interface for 5G is divided into frequency bands. First one is FR1 which has the frequency range below 6 GHz and other is FR2 for millimeter wave frequency. Each frequency band has different capabilities. The maximum bandwidth of the channel for FR1 is 100 MHz because the frequency range is highly crowded which further lacks the continuous spectrum [3]. The channel bandwidth for FR2 is 50 MHz- 400 MHz high speed data transfer is supported by higher frequency. Various applications of 5G technology include automobiles, public safety, fixed wireless and broadcast applications as the wireless video transmission would be possible. The services of the wireless communication are increasing in demand day by day due and have possessed a great challenge to the current wireless communication system due to lack of bandwidth requirement [4-5]. The millimeter wave technology has made its way to the 5G technology as the system of 5G requires larger bandwidth, higher frequency and system capacity. In order to achieve these parameters, the millimeter wave antenna research becomes necessary. The large transmission gain and high bandwidth are the two main utmost important factors of millimeter wave antenna

[6]. The frequency of 28 GHz and 72 GHz are introduced in the MMB (millimeter-wave mobile broadband) system. In comparison to the microwave, the propagation loss and the penetration loss of millimeter wave is much less which relatively leads to long links and higher antenna gain. The capacity and the spectrum requirements are the prominent factors owing to increased data traffic the current wireless communication system [7]. The 5G mobile network can use the millimeter wave band of high bandwidth to provide various communication services such as HDTV (high definition television) and UHDV (ultra-high definition video). The electronic products used in the millimeter wave band such as CMOS (Complementary metal-oxide Semiconductor) and RF (Radio Frequency) integrated circuits have been in rapid progress. There are many factors on which the applications dependent on the 5G operations are enabled [8-9]. These factors include spectrum selection, antenna technology, digital signal processing, and transceiver integration along with propagation characteristics. The current wireless technologies require huge bandwidth which makes the spectrum of millimeter wave a potential candidate of such technologies. Therefore, a significant amount of work is done in collecting the substantial knowledge about the millimeter wave spectrum as the 5G technology is evolving at a fast pace in industrial and commercial applications. In wireless systems, antenna is the most important component as it affects the sensitivity of the receiver, transceiver designs, link budget and the schemes made in the choice of digital modulation [10]. There are improved characteristics in the design of millimeter wave antenna such as size of the antenna, bandwidth, high data rate, traffic demand and the antenna gain. The basic ground for the 5G technology is provided by the radio frequency at millimeter wave. The spectrum of the millimeter wave is 30GHz-300GHz as shown in figure 1. The spectrum required for the 5G application is 20GHz-90GHz. The antenna for the 5G technology is designed at various frequencies of 28 GHz, 38 GHz and 72 GHz. They have the bandwidths of 500MHz, 1 GHz and 2 GHz. These bandwidths are suitable for low latency system and high

data rates. Such type of antenna design can be used in the 5G cellular applications because of their high directivity and sensitivity to the obstacles having narrow width.

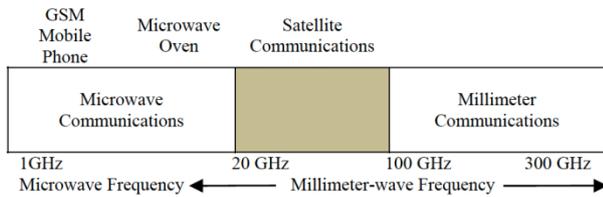


Fig. 1. Millimeter wave spectrum

II. MILLIMETER WAVE ANTENNA FOR 5G TECHNOLOGY

As the demand of the mobile traffic is increasing significantly, there is prominent shortage of the spectrum and capacity requirements. 5G wireless networks require large bandwidth. Therefore, the millimeter wave band having huge bandwidth of 30 GHz – 300 GHz prove to be an integral part of the 5G wireless system. The current research is mostly focused on 28 GHz, 38 GHz and 60 GHz frequency. Due to the rapid and fast progress in CMOS (Complementary Metal Oxide Semiconductor) and RF (Radio Frequency) integrated circuits, the electronic components and devices can easily compliment the millimeter wave communication [11-12]. There are various standards defined for WLAN and WPAN such as IEEE 802.11, ECMA-387 which helps in extending the millimeter wave band network in cellular system. There are various challenges faced by the millimeter wave communication in the physical layer and the routing layer because it varies significantly with the current microwave band communication. This leads to the great impact on 5G wireless communication system [13]. New insights and thoughts in the protocols and architecture of the millimeter wave communication is required in terms of directivity, propagation loss and sensitivity caused by the mobility of the communication.

A. 5G Related Millimeter Wave (mmW) Microstrip Patch Antenna

To develop a mobile network in 5G, the designing of a suitable antenna become very critical. The proper measurement of various antenna parameters is required to check on the suitability in 5G network and technology. The technologies such as MIMO, CMOS and beam forming are used with millimeter wave antenna for improving the mobile phone performance. There are various designs of microstrip patch antenna related to 5G technology. An antenna for 5G technology with circular polarization was designed which focused on the miniaturization of patch and enhancing the beam width. Consideration of various parameters is necessary to design an antenna for 5G cellular network which include bandwidth, antenna size, operating frequency, manufacturing cost and polarization. The size of the antenna is reduced by introducing folded type antenna of circular shape. The antenna beam width is enhanced by surrounding the patch antenna with dielectric substrate and adding the metallic block at the rear side of

the antenna [14]. 5G directional antenna was designed using the technology of millimeter wave spectrum to face the challenges of rapid increase in the growth of mobile users. This required large bandwidth for efficient communication [15]. 5G wideband rectangular shaped antenna is used at 6 GHz frequency which satisfied the requirements of 5G technology. The design technology of far field radiation pattern is used in the antenna which significantly analyzed the environmental parameters of atmospheric absorption [16]. 5G directional antenna is designed at the operating frequency of 28GHz and 38 GHz in the mobile communication of millimeter wave spectrum. This design followed some effective approaches such as impedance matching optimization, multiple resonance and increasing the substrate thickness which results in the reduced substrate permittivity. The substrate of high dielectric constant is used which reduced the radiation losses [17]. A CPW fed design microstrip patch antenna is designed for 5G technology with operating frequency of 8.4 GHz WSN, WLAN, Hyper LAN and Wi-Fi technology. These designs use fractal technology for multiple band spectrum operation and better impedance matching [18]. 5G array patch antenna is designed at the operating frequency of 18GHz-28GHz. The wide area is covered using the modified antenna array design. The radiation pattern of Omni direction is used with this design to avoid the traffic rate. High gain is achieved by placing the identical sub arrays with coaxial probe feed [19]. 5G wideband patch antenna is designed at the operating frequency of 6 GHz using MIMO (Multiple input Multiple output) technology which increases the gain and quality of service [20]. Table 1 shows the complete comparison of antenna designs used at 5G cellular network and communication technology.

TABLE 1. COMPARISON OF ANTENNAS FOR 5G.

S.No	Type of Antenna	Technology	Features/Advantages
1	Circular Polarized Antenna	Technique of miniaturization	Beam width enhancement
2	Directional Antenna	Millimeter wave spectrum	Bandwidth improvement
3	5G Wideband Antenna	Design of far field radiation pattern	Analysis of environmental parameters
4	5G Directional Antenna	Millimeter wave spectrum	Multiple resonance and impedance matching
5	Microstrip Patch antenna with CPW feed design	Fractal Technology	Multiple band spectrum and good impedance matching
6	5G Array Patch Antenna	MIMO Technology	Improved space coverage
7	5G wideband patch Antenna	MIMO Technology	Gain improvement

III. MILLIMETER WAVE (MMW) ANTENNA DESIGN CONSIDERATIONS

The design of the communication system in 5G need to support high data rates and high speed with maximum frequency band coverage. The spectrum allocation and coverage depend on various applications such as smart buildings and sensor networks. High gain of the antenna

is one of the most essential and desirable requirements to balance the path loss created at millimeter wave frequency and system cost reduction. The other desirable properties of designing such an antenna include high efficiency, compact size and technology of multi-antenna. The radiation patterns should be stable over the entire frequency band. The antenna should be low profile and can be easily integrated with various electronic devices. Higher levels of received signals are desirable which can be achieved by increased antenna efficiency and gain [21]. The technology of multi-antenna increases the quality of received signal by maintaining the link through the production of high gain beams. The high frequency antenna design is achieved by miniaturizing the front end of RF and on-chip system integration without comprising on bandwidth, radiation efficiency and gain. The capacity of the system design can be increased by using the techniques of multiplexing that relies on baseband signal processing. The feeding structure is also one of the significant design considerations in the antenna array design at millimeter wave frequency band. Radiation and conduction losses are experienced by traditional feeding techniques such as coplanar waveguides and microstrip lines at millimeter wave frequencies. This restricts the gain reduces the efficiency of antenna arrays [22]. To design the millimeter wave antenna at high gain, waveguide structure is preferred over the microstrip line because of lower losses. This kind of design is not suitable for production at large scale due to bulky volume and huge production costs. SIW (Substrate Integrated Waveguide) is an alternate option for applications in millimeter wave communication as it has the characteristic of low fabrication cost, low loss and planer structure [23].

IV. APPLICATIONS OF MILLIMETER WAVE BAND IN WIRELESS COMMUNICATION

The investigations on millimeter wave technology has been explored intensively in 1965 on radio communication, atmospheric sensing, radars and satellite imagery [24]. The low-cost transceiver design is made possible with the millimeter wave technology. These transceivers have components of small size and which are specially for wireless communication having high speed and short range with applications of high resolution and accuracy. There are three frequency bands in the millimeter wave spectrum which are V-band, E-band and W-band. The applications used in all the three bands are discussed.

A. V-Band: Wireless Communications with High-Speed and Short-Range

V-band is the 60 GHz band that is unlicensed allocated by FCC (Federal Communication Commission) in which the spectral band of 5 GHz is utilized by the researchers. The advantages include interference immunity, frequency reuse and high security [25-27]. The losses in the atmospheric oxygen is very high in the V-band millimeter wave spectrum due to which the attractive resources in the wireless industry are exploited which include radar sensors of high resolution with short distance and indoor communications of high speed. Therefore, short range communication is suitable for atmospheric losses of 10-15

dB/km. Some of the V-band applications include video transmission at high definition, wireless ethernet, high speed file transfer and short-range communications.

B. E-Band: Radar Detectors

The sensors and radars are required for traffic detail monitoring very precisely around the vehicle. The system of driver assistance is one of the major applications which uses the most important technology of millimeter wave radar. The vehicle radar detectors have two frequency bands of 24 GHz and 77 GHz. A critical role is played by the size of the sensor related to the antenna as all the sensors are integrated in the vehicle. The antenna size is smaller for larger frequencies which in return require large apertures. The absolute bandwidth of 4 GHz is required by the radars of short range to attain high resolution [28-29]. The high distance and long-range abilities and operations are ensured by combining high bandwidth and high transmit power. 77 GHz frequency band allows this combination.

C. W-band: Radiometric Imaging Systems in Millimeter Wave

The recent and challenging technology in the domain of wireless communication is imagery. The W-band has the frequency band of 85GHz – 94GHz [30-31]. The most important application of W-band is indoor and outdoor imaging. The active imaging radars have high resolution and are low range and therefore more suitable than infrared and optical sensors. A fixed atmospheric attenuation is allocated in the wavelength of 3 mm and 9 mm. so, the movement through fog, dust, rain and smoke is easily allowed while avoiding the obstacles. The useful information of aircraft landing can be provided by the imaging radars so that the dependence on the instrument present at the ground plane is reduced. The transparent dielectrics are present in the W-band spectrum of millimeter wave. So, a millimeter wave sensor can be used to detect the weapons while scanning a group of people. Surveillance and security confirm their needs of millimeter wave imaging. The early cancer detection in the diagnostic medicine field can also be done by millimeter wave imagery [32]. As compared to X-Ray imagery, the interaction of the target with the microwave radiation is based on the dielectric rather than on the density.

V. CONCLUSION

The millimeter wave technology has made its way to the 5G technology as the system of 5G requires larger bandwidth, higher frequency and system capacity. In order to achieve these parameters, the millimeter wave antenna research becomes necessary. The current wireless technologies require huge bandwidth which makes the spectrum of millimeter wave a potential candidate. The millimeter wave technology has made its way to the 5G technology as the system of 5G requires larger bandwidth, higher frequency and system capacity. In order to achieve these parameters, the millimeter wave antenna research becomes necessary. There are improved characteristics in the design of millimeter wave antenna such as size of the

antenna, bandwidth, high data rate, traffic demand and the antenna gain. The basic ground for the 5G technology is provided by the radio frequency at millimeter wave. To develop a mobile network in 5G, the designing of a suitable antenna become very critical. The proper measurement of various antenna parameters is required to check on the suitability in 5G network and technology. The complete comparison of antenna designs used at 5G cellular network and communication technology is discussed. The design considerations of the millimeter wave band antenna and the applications used in all the three bands of millimeter wave band in wireless communication is discussed in detail

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