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Millimeter Wave Antenna Using Microstrip Patch

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Abstract— This paper is propose to design a MM-Wave antenna using Microstrip patch for 5G communication. The proposed antenna is design by using CST Studio. This simulation tool enables us to anlyze and record different parameters of the antenna in ral time simulation like the gain, effieciency, bandwidth, return losses directivity and many other parameters as well. The 5th Generation of communication technology is most probable being implemented in 2020 around the globe. The work done in this field of communication is so far up to smaller, compact, efficient and less coastly antennas whicn can provide high bandwidth with high gain. The goal of this work is to design an antenna with more greater bandwidth which can be utilize for 5th generation communication in the futurea and by varying the design of the patch it is seen that different parameters of the antenna also improved.

Keywords— MM-Wave Antennna using Microstrip patch, high bandwidth, CST Studio, 5G Communication, High frequency

I. Introduction

Modern age is the age of communication especially wireless communication. With the beginning of 21st century wireless communication has seen unexpected modifications. If we study mobile phone services of last fifteen years we will come to know that there is a tremendous change in their services regarding data rate, size, graphics and other quality services without compromising on the performance of the wireless communication. The rapid increase of smart phones and high data rate with high bandwidth is creating unprecedented challenges for wireless services providing companies to overcome the bandwidth issue and also other security issues. As we know that now a day's wireless communication companies are trying their best to provide high quality services regarding bandwidth and data rate with the minimum possible cost.

Wireless services provider's needs to tackle the ever growing exponential rate of data rate to the consumer and also the increase in traffic predicted. As we know that first generation cellular networks were the basic analogue system only design to provide the voice communication services. The digital modulation, time division and code division multiple access and the importance of efficient spectral efficiency is realized in the second generation of cellular network system.

High speed packet access (HSPA) and wideband code division multiple access (W-CDMA) is introduced in the third generation of cellular communication in which high internet speed with multimedia functions like video calling and online streaming is required. In third generation wireless communication system frequency spectrum ranges from 700MHz to 2.6GHz. High speed download packet access (HSDPA) and high speed upload packet access (HSUPA) both are also a feature of 3G cellular communication which helps and improves the protocols utilization of WCDMA and provide us a better telecommunication system [3].

There is a lot of engineering efforts to develop more power efficient RFIC's upto 60GHz and industrial standards is also develop such as Wireless HD technology, ECMA-387 etc, integrated circuit transceivers are also available for some of the standards to achieve their targets of high gain and efficiency. Many of these technologies were also use for millimeter wave (MM-Wave) spectrum [2].

II. LITERATURE REVIEW

An antenna is the interference among radio waves propagating through space and electric currents moving in a conductor used with a transmitter and receiver. In the transmitter side transmitter a radio transmitter supplies an electric current to the antenna terminal and that antenna converts that electric current into and electromagnetic wave and radiates it while at receiver ends an antenna catches some of that radiated power of the electromagnetic wave in order to produce an electric current at its terminal which is feed to the receiver for amplification. Antennas are fundamental device for radio communication, cell phones, television broad casting, satellite communication, and so many other communication systems [1].

An antenna is an array of elements that is connected electrically to the transmitter and receiver. In the process of transmission an oscillating current is applied to the antenna by a transmitter in result it generates oscillating electric and magnetic field around the elements of antenna. As we know that these fields are time-varying and it radiates energy away from the antenna into the space as a transverse electromagnetic field wave.

At receiver end oscillating electric and magnetic field of an incoming radio wave exerts force on the electron of antenna elements causing them to move back and forth as a result creates an oscillating current in the antenna.

There are mainly two types of antenna i.e. Omni-directional antenna and directional antenna [4]. Omni-directional antenna transmits and receives waves in all horizontal directions equally while in directional antenna it mostly transmits waves in a specified direction. One of the best features of antenna is that if an antenna is design for transmission it will be the same for receiving.

A typical micro-strip patch antenna is usually rectangular or square. For certain reasons, such a design has advantages but the shape of the patch is not limited to a these shapes and may differ according to the application it is used for. Some of the paper present circular antennas with coaxial feed and show good results for a specific frequency range. In [6], a tri-band patch antenna for Wi-Max applications has been proposed. The three operating frequencies of the antenna are 2.4, 5.2 and 5.8 GHz and have a very large impedance bandwidth ranging from 3.1 to 9.0 GHz. This shows that the typical monopole antennas used for wideband applications have some drawbacks. Figure 2 shows a typical rectangular micro-strip patch antenna for a single band.

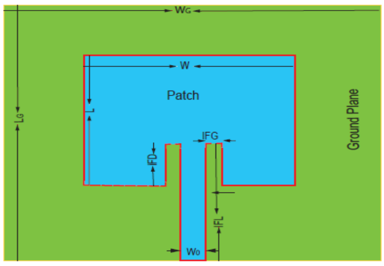

Figure 1: A typical Rectangular Micro-strip patch antenna

In figure 1, the blue region shows the patch. This square patch antenna has a feed line at the bottom and the width and length of the antenna is mentioned as 'w' and 'l' in the figure. Some other important parameters such as Wg, Lg IFL, IFG, IFD and W0 represent the dimensions that are important for the antenna to acquire maximum radiation. Wg and Lg however represent the width and length of the entire antenna respectively. Keeping in mind these parameters, the center frequency, bandwidth, and gain etc can be adjusted.

In a micro-strip patch antenna, the width of the antenna is given by

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (1)$$

Given the center frequency, we can calculate the width of the patch by using equation (1).

A. MICROSTRIP PATCH ANTENNA

It all began in the early fifty's when Deschamps gave the idea for Microstrip radiator. But Gutton and Baissinot French technicians were the first who generate a patented archive on Microstrip patch antenna in 1955. Howell and Munson was the first two scientists who implemented Microstrip patch antenna practically [6].

The first most application of Microstrip patch antenna was implemented in missile called sidewinder at data link side designed by Munson. After that it was used in a semi active detective side seeker sprint missile.

Great developments is seen the applications and implementation of patch antenna in 1960's and 1970's. After that it starts functioning on high frequencies and with solid state equipments. Munson was working as a defence officer in the ball Aerospace laboratory at the time of cold war so he would have access to all of the advance facilities [7].

B. BASIC OPERATION OF PATCH ANTENNA

A patch antenna usually operates at three different stages i.e. one is the patch element which is the radiating element of the antenna lying at the top of the antenna substrate, while the feed line is at one end of the patch of antenna which provides power to the antenna and at the end ground plane lies on which substrate is put on top of it. In order to vary different properties and circuitry of the antenna like gain, bandwidth, efficiency, far field regions, spectrum etc the dielectric constant and its thickness must be change[8].

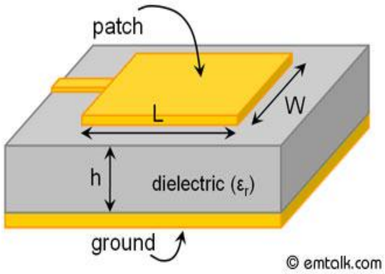

Figure 2 Basic Patch Antenna

These different parameters are discuss below

- ***Dielectric Constant*:** The bandwidth of the antenna depends on the dielectric constant of the antenna substrate if the permittivity of the antenna dielectric is low then it will has a wider value of impedance bandwidth with smaller value of excitation wave of antenna surface.
- ***Thickness of Antenna Substrate*:** It has a direct relationship with the bandwidth of the antenna and inversely proportional to the coupling level of the antenna. If the substrate of the antenna is thick it means it will has a wider bandwidth and similarly with a small value of coupling level of the antenna.
- ***Patch Length*:** The frequency at which antenna resonates is determined by the length of the patch of the antenna.
- ***Patch Width*:** The width of the patch is inversely related to the resonance frequency of the antenna.

C. INVERTED-F ANTENNA

Simple F-antenna is basically derived from the basic quarter wave monopole antenna. It was first invented in the 1940. In inverted-F antenna the feed line does not connected directly to the base but an intermediate point along with the length of the antenna and the ground and base are connected with one another. The benefit of doing such geometry is that it the input impedance of the antenna is completely dependent on the distance of the feed line from the ground end and the area between the feeding point and ground plane is behaving like a short circuit stub. In simple we can match the antenna input impedance with the system impedance by simply adjusting the position of the feed point [9].

After that inverted-L antenna in which the feed line is bent over and goes parallel along with the ground plane and it is a simple monopole antenna. The main two advantages of inverted-L antenna are that it is shorter in length and is compatible with most of the devices. But the most important drawback of the inverted-L antenna is low impedance of the antenna just a few ohms.

The inverted-F antenna has the advantages of both antennae i.e. the F-antenna and the inverted-L antenna collectively which is the compactness of inverted-L antenna and impedance matching of F-antenna [13]. The inverted-F antenna is that type of antenna which is used in the communication systems. It has basic two parts one is the monopole antenna and other one is the ground plane which is grounded at one end and they both are parallel to one another. This antenna is being powered (feed) by an intermediate point at a distance from the grounded end. Such a design is smaller and compatible. Also the manufactures can control the impedance matching by simply varying the feeding point distance without the need of extra impedance matching components [8].

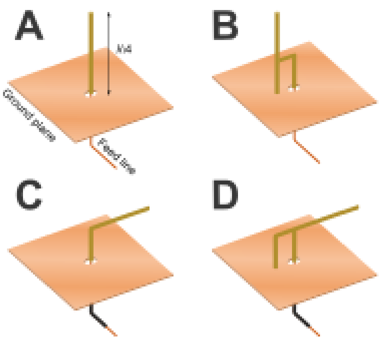

Figure 3 Inverted F-Antennas

A: Quarter Wave Monopole antenna
B: Intermediate Fed Quarter Wave Monopole Antenna
C: Inverted-L Antenna ***D: Inverted-F Antenna***

D. PLANAR INVERTED F-ANTENNA

The planar inverted-F antenna or PIFA is the advancement in the inverted-F antenna used in wireless circuitry implemented on the Microstrip. This format is compatible with the modern communication devices. PIFA can be implemented as the classic inverted-F antenna on one side of the circuit where the ground plan is being removed from beneath [6].

Another method is of the patch antenna. In this method one fringe or some transitional point is being grounded through pins or through ground plane. If patch of the antenna is short it means antenna will have wider bandwidth compare to thin line type due to greater radiation area. Mostly PIFA is printed on their own board or on some dielectric material hooked with the main board [14].

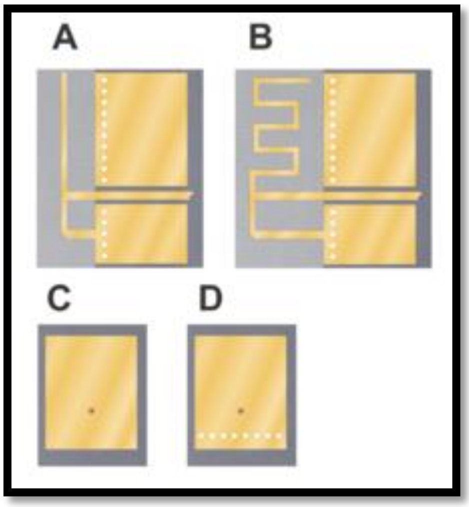

Figure 4 Planar Inverted F-Antennas

A: Printed Inverted F-Antenna
B: Meandered Printed Inverted F-Antenna
C: Patch Antenna
D: Planar Inverted F-Antenna (PIFA)
Board without Ground Plane
Board with Ground Plane
Antenna Feed Pin ***Ground Pin***

III. *COUPLED MICROSTRIP PATCH ANTENNA*

Both designing and functionality of Microstrip patch antenna were rapidly elaborating and improving in 1970's while in 80's the array antenna element structure and its architecture is completely changing in terms of both designing and modelling. Another research was also on going at that time to improve other qualities of antenna like bandwidth, efficiency, gain, spectrum etc [8].

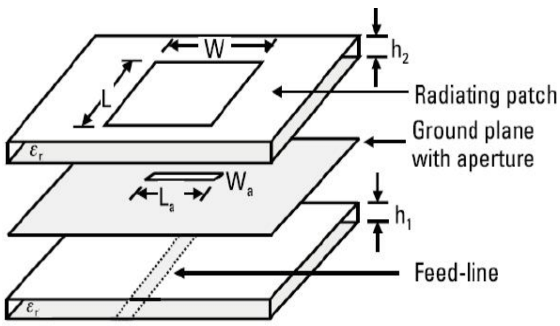

Figure 5 Coupled Microstrip Patch Antenna

A. MULTI-BAND ANTENNAE

A multiband antenna consist of four different patches i.e. a ground patch , first radiating patch, second radiating patch, and last one is the connecting patch. The function of the connecting patch is that it connects the two radiating patches with the ground patch and also with the feeding source. These all patches and feeding source collectively form a loop antenna as shown in figure.

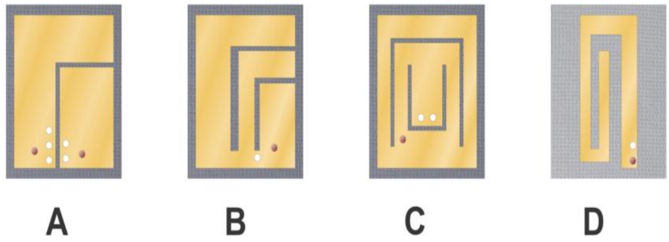

Figure 6 Inverted Multi-Band F-Antenna

A multiband antenna is design to perform different operation at same time at different resonating frequencies. A multiband antenna has the features of different antennas together. The need for multiband antenna is due to the need of greater bandwidth and different features of communication devices like video calling and surfing at same time or surfing at very high data rate etc [15]. A multiband antenna is composed of printed antenna and decoupling network. One of the key characteristic of the antenna is radiation efficiency or simply called antenna efficiency is defined as the ratio of the radiated power of antenna to the input power of the antenna. Antenna having high efficiency has most of input power radiated while a low efficiency antenna absorb its input power mostly as losses or reflect it because of the mismatch impedance.

$$\varepsilon_R = \frac{P_{radiated}}{P_{input}}$$

B. MILLIMETER WAVE SPECTRUM (Releasing THE 3 to 300 GHz spectrum)

Before the millimeter wave spectrum all communication like Amplitude Modulation / Frequency Modulation Radio, HD Television, Cellular Communication, satellite communication, GPS etc all are using a narrow frequency spectrum known as the sweet spot because of its favourable propagation characteristics in commercial wireless application and that sweet spot of frequency ranges from 300MHz to 3GHz respectively. The area of radio frequency spectrum greater then 3GHz is still not completely explored for commercial wireless operations. However a small portion of above 3GHz is being utilized for short range and fixed wireless communication. For example 3.1GHz to 10.0GHz is being used in personal area network as UWB for high data rate. There is another band in the range of 57GHz to 64GHz also called oxygen absorption band is used in some local area networks to provide data rates in gigabits for confidential purposes and security and also for some priority operations. Also LMDS which is local multiple distribution system is using a frequency band between 28GHz to 30GHz for fixed broadband and point to multipoint technologies for high data rate [2].

The spectrum range up to 252GHz is suitable for mobile communication and there is a tremendous feature of millimeter waves that they are absorbed in oxygen and water vapours in the atmosphere. The frequency range of 57 – 67 GHz is oxygen absorption and 164-200 GHz is the water vapour absorption by the atmosphere. We simply exclude these two bands from the wireless communication as the communication in these bands is very much limited. Millimeter wave broad band spectrum promises us to provide a band up to 100GHz for mobile communication which is 200 times greater spectrum than we are currently using for wireless communication [3].

C. FREE SPACE PROPAGATION OF MILLIMETER WAVES

The transmission losses in the millimeter wave are measured as free space losses. One of the greater delusion of wireless engineers is that the free space losses of a wave depends on the frequency of the wave i.e. greater frequency will propagate less compare to smaller frequency. The logic behind that delusion is some engineer's textbook that path loss of transmission loss is calculated at specific frequency between two isotropic antennas is lamda by two ($\lambda/2$). Whose area aperture effectiveness increases with the wavelength and decreases with the carrier frequency [2].

An antenna with more apertures has bigger gain than a smaller antenna because with larger aperture the antenna will abduct more energy from the radio wave that passes compare to a smaller antenna.

IV. PENETRATION AND OTHER LOSSES OF MILLIMETER WAVES

As the spectrum of millimeter waves are from 3-300GHz and the penetration losses and other losses like atmospheric gases and water vapours losses are not greater than a few dBs per kilometre excluding the bands of oxygen absorption and water vapour absorption. As we know that the losses occurs due to reflection and diffraction completely depends on the nature of material and surface area. But as reflection and diffraction minimize the range of the millimeter waves and also it entertain and helps in the communication without line of sight or non line of sight communication. The signals of millimeter waves do not penetrate easily among the solid material compare to low frequency signals.

Table Material and Their Losses at 1 to 2 GHz

Material	**Loss**
Porous concrete	6.5 dB
Reinforced Glass	8.0 dB
Concrete (30 cm)	9.5 dB
Thick Concrete Wall (25cm) with Large Glazed Panes	11.0 dB
Thick Concrete Wall (25cm) without Large Glazed Panes	13.0 dB
Thick Wall (>25cm)	15.0 dB
Tile	23.0 dB

The above mention table of losses is only for frequency of 1 to 2Ghz respectively.

Concuslion

The main theme behind this research is to design and antenna small and compact which can eliminate future bandwidth and high frequency issues most probably of 5G communication and also analyze its different parameters like return losses, radiation pattern , gain etc. The design antenna can provide performance that support the proposed structure but the performance of the antenna can also improved further with fine tunning and material whose relative permittivity is low.

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