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Review of Microstrip Patch Antenna for 5G mmWave K-band Application

[1]Shubham Singh Bhadouria, [2]Dr. Soheb Munir
M.Tech Scholar, Associate Professor
Department of Electronics and Communication Engineering,
Lakshmi Narain College of Technology Excellence, Bhopal, India

Abstract : Now a days microstrip patch antenna is using in 5G upeer and lower frequency or satellite band applications. The K band is used for satellite communications, astronomical observations, and radars. Radars in this frequency range provide short range, high resolution and high throughput. The development in communication systems requires the development of low cost, minimal weight and low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. This technological trend has focused much effort into the design of a microstrip patch antenna. This paper reviews about the various research works on 18 to 26 GHz frequency range bandwidth of milli meter wave antenna structures. The necessary parameters, challenges and application are also discussed.

***IndexTerms* - K-band, Microstrip, Antenna, Radar, Satellite, Array.**

I. INTRODUCTION

In recent years there is a need for more compact antennas due to rapid decrease in size of personal communication devices. As communication devices become smaller due to greater integration of electronics, the antenna becomes a significantly larger part of the overall package volume. This results in a demand for similar reductions in antenna size. In addition to this, low profile antenna designs are also important for fixed wireless application. The microstrip antennas used in a wide range of applications from communication systems to satellite and biomedical applications. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, elliptical or some other common shape. The IEEE K band is a portion of the radio spectrum in the microwave range of frequencies from 18 to 27 gigahertz (GHz). The range of frequencies in the center of the K band between 18 and 26.5 GHz is absorbed by water vapor in the atmosphere due to its resonance peak at 22.24 GHz, 1.35 cm. Therefore these frequencies experience high atmospheric attenuation and cannot be used for long distance applications. For this reason the original K band has been split into three bands, Ka band, K-band, and Ku band as detailed below. The meteorological radars having characteristics best suited for atmospheric observation and investigation transmit electromagnetic pulses in the 3–10 GHz frequency range (10–3 cm wavelength, respectively). Primarily, they are designed for detecting and mapping areas of precipitation, measuring their intensity and motion, and their type. Birds, insects ant the turbulent fluctuations can also produce using wind information with Doppler radar. Their intensity patterns can reveal the location of atmospheric boundaries that are indicative of areas of low level convergence where thunderstorms may initiate or develop.

Higher frequencies (35 and 94 GHz) are used to detect smaller hydrometeors, such as cloud, fog, drizzle, snow and light precipitation are becoming prevalent in the research community. These frequencies are generally not used in operational forecasting for precipitation detection or general weather surveillance because of excessive attenuation of the radar signal by the intervening medium and their relatively short range, particularly, in Doppler mode.

At lower frequencies (915-1440Mhz, ~400-440 Mhz and ~50MHz), radars are capable of detecting variations in the refractive index of clear air, and they are used for wind profiling. Although they may detect precipitation, their scanning capabilities are limited by the size and type of the antenna that generally point in the vertical.

The returned signal from the transmitted pulse encountering any target, called an echo, has an amplitude, a phase and a polarization. Most operational radars worldwide are still limited to analysis of the amplitude feature that is related to the size distribution and numbers of particles in the (pulse) volume illuminated by the radar beam. The amplitude is used to determine the reflectivity factor (Z) to estimate the mass of precipitation per unit volume or the intensity of precipitation through the use of empirical relations. A primary application is thus to detect, map and estimate the precipitation at ground level instantaneously, nearly continuously and over large areas.

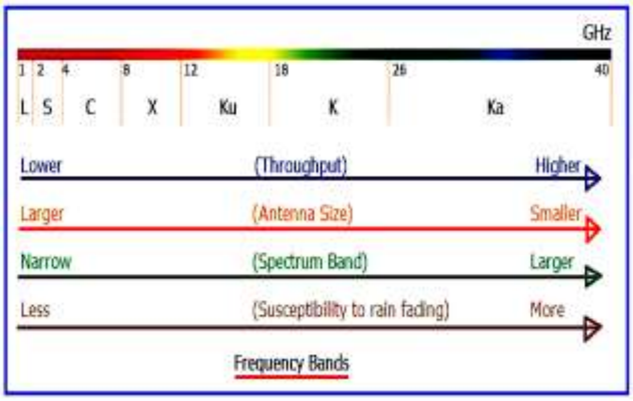

Figure 1: Antenna Ssatellite frequency band

Doppler radars have the capability of determining the phase difference between the transmitted and received pulse and is a measure of the mean radial velocity of the particles. This is the reflectivity weighted average of the radial components of the displacement velocities of the hydrometeors within the pulse volume. The Doppler spectrum width is a measurement of the spatial variability of the Doppler velocities and provides a measure of the wind shear and turbulence. Virtually all currently commercially available weather radars have Doppler capability. An important feature of Doppler is the ability to filter out echoes due to ground targets in the signal processing.

The current generation of radars has polarization capability. Operationally, pulses are transmitted simultaneously with horizontal and vertical polarizations. In the past, the pulses were transmitted in sequence but required a high power polarization switch that was prone to failure. Two receivers (physical or virtual) are used to measure the horizontal and vertical components of the returned signal. The main benefits are improved data quality through the ability to identify characteristics of the target (birds, bugs, precipitation and its type, clutter). For forecast applications, the dual-polarization capability can identify hail and the rain-snow boundary. In addition, high precipitation rates affect the horizontal and vertical phase of the transmitted and received pulses. This can be exploited for precipitation estimation even with partially blocked beams or uncalibrated power calibration.

II. BACKGROUND

A G. Kim et al.,[1] presents a dual polarized broadband microstrip patch antenna for a 5G mmWave antenna module on an FR4 substrate. The proposed antenna was fabricated using a standard FR4 printed circuit board (PCB) process because of its low cost and ease of mass production. The electrical properties of the FR4 substrate in the 5G mmWave frequency band were also characterized. An air cavity structure was introduced to mitigate the high loss tangent of the FR4 substrate.

T. Braun et al.,[2] presents Analog-Front-End-IC (AFE IC) has been packaged as a start in an RDLfirst FOWLP on 300 mm wafer size. Redistribution layers were built-up on a glass carrier consequently followed by plating of the through package vias [TPVs] for later front and backside package connection. The AFE IC is then assembled as a flip chip on the RDL and compression molding is used to underfill the flip chip ICs and overmold the wafer carrier in one step. A backgrinding step is applied to open the TPVs for further electrical connection.

J. Bang et al.,[3] present a method for obtaining the power density value, which is the standard for radio frequency (RF) electromagnetic field (EMF) human exposure from mmWave mobile devices, using a deep learning network. An mmWave mobile communication device that uses an array antenna requires a large number of phase conditions for covering a wide communication range. However, the power density values must be repeatedly obtained every time the phase conditions are changed, which incurs a lot of time and cost. For implementing the process seamlessly, we present a deep learning network that can input the phase conditions of the mmWave array antenna and simultaneously obtain the power density results for the phase conditions of the array antenna as an output.

M. A. Emhemmed et al., [4] proposed antenna resonates at all frequencies between 28 GHz and 60 GHz, with a return loss (S11 $\leq$ -10 dB) for all frequencies. The proposed design provides the high Gain, and good radiation efficiency over the whole operating band. For MIMO antenna, the proposed design consists of 4-elements with a 4-wave ports to provides the most optimum results and fulfill 5G systems requirements, to achieving gain up to 20dB, and other MIMO antenna parameters like Diversity Gain, and Envelope Correlation Coefficient. The overall size of the 4-elements MIMO antenna is 96 x 10 x 1.575 mm 3 . It is also achieving a mutual coupling of less than -20dB in most covered band without utilizing any coupling techniques, defective ground structure (DGS), or slots.

J. Xu et al., [5] presents the array element design adopts a patch antenna structure with a shorting pin, which can excite an extra zero mode resonant frequency. Combined the 2nd zero mode and the original TM01 mode, the proposed array can give a broadband from 23.5-28 GHz, a large-angle beam scanning with ±60° coverage, as well as a low-profile substrate with 0.508 mm. Then, we designed an antenna in package (AiP) antenna module based on the proposed array, and the measured results have demonstrated good performance.

A. A. A. Saeed et al.,[6] presents 5G multiband antenna has been designed with advantages of light weight, low cost, low profile, high gain and efficiency using microstrip feeding technology. The geometry of the proposed antenna and various parameters such as return loss, voltage standing wave ratio (VSWR), gain and impedance bandwidth are evaluated, presented and discussed. The designed multiband antenna provides a sufficient averaged gain of 6.91456 dBi and a total bandwidth of 28.9247 GHz. The compact and flexible structure of the proposed multiband antenna along with excellent matching, large impedance bandwidth, high gain and good efficiency enables it to be a strong candidate for various 5G mmWave applications, services and devices.

R. Q. Shaddad et al.,[7] presents antenna achieves -10 dB bandwidth from 29.55-30.72 GHz with a maximum gain of 6.834 dB, from 57.36-63.34 GHz with a maximum gain of 10.196 dB, and from 68.56-94.281 GHz with a maximum gain of 8.628 dB at resonant frequencies 30.1 GHz, 60 GHz, and 81.3 GHz respectively. The proposed antenna has a high gain and a broad bandwidth making it a candidate for 5G millimeter-wave (mmwave) applications. Higher Frequency Structural Simulator (HFSS v13) tool is used to simulate the proposed antenna.

C. Kim et al.,[8] presents flexible, fully dense Alumina Ribbon Ceramic (ARC) fabricated by Corning's proprietary process of continuously sintered ceramic (CSC) is used as a substrate for the patch antenna and transmission line for 5G mmWave wireless communication systems. The microstrip line on the 40um thick ARC shows a loss of about 1.6dB/cm at 28GHz. The compact (0.2λ 0 × 0.2λ 0), low profile and multilayered patch antenna shows a resonant frequency of 29.35GHz with 2.81dBi peak gain, which could be used for 5G mmWave mobile applications.

A. Qayyum et al.,[9] presents antenna operates at 28GHz (27.68GHz - 28.55GHz, 3.10%), which is a proposed frequency for 5G. A ring-shaped Defected Ground Structure is suitably inserted in the ground plane resulting in an additional frequency band at 38GHz (37.13GHz - 38.20GHz, 2.81%). The gain of the antenna at 28GHz is 6.87dBi and 4.17dBi at 38GHz. The size of the proposed antenna is 7.23mm x 7.23mm. The introduction of Defected Ground Structure also improved the antenna performance. Furthermore, different parameters of the proposed antenna are varied, studied and discussed in detail to observe its effects on the antenna performance.

M. Nurrachman et al.,[10] proposed to be operated in 28 GHz for 5G wireless communication. It has small design and a tapered periperal slit method will be added to reduce the size of the microstrip antenna and other miniaturization techniques to obtain a compact antenna dimension. Using this design our antenna was compact just only 16mm × 14mm in dimension. Furthermore our frequency band was 28 GHz, with frequency center 27.8 GHz (simulation) and 27.44 GHz (measurement), for bandwidth 5.68 GHz (simulation) and 1.57 GHz (measurement), for S11 parameter -32.89 dB (simulation) and -21.14 dB (measurement).

A. M. Tota Khel et al.,[11] presents a four-element multiple-input multiple-output (MIMO) antenna with slotted ground plane and patch for 5G millimeter waves communication systems. It is designed using Computer Simulation Technology (CST) software on Rogers RT/Duriod 5880 with a thickness and dielectric constant of 0.787mm and 2.2, respectively. The inset feeding technique is applied to obtain the matching impedance of 50Ω. The overall size of the antenna is 48×12×0.787mm 3 , and the dimensions of the slots on the ground plane and patch are determined through applying the empirical Hill Climbing algorithm to achieve an enhanced bandwidth and gain.

I. Ahmad et al.,[12] presents a rectangular shape low profile, High gain and high efficiency patch antenna with rectangular slot is presented for 30 GHz 5G wireless communication. In fact 5G wireless communication system requires a compact size, low profile and simple design structure to make sure the reliability, mobility and high efficiency. The proposed antenna is designed on a compact Rogers Substrate Rt-5880 with overall dimensions of 4. 8 × 5 × 0.508 mm with relative permittivity εr of 2.2 and loss tangent δ value, 0.0009. The proposed design provides a very high gain of 10 dBi at resonance frequency of 30 GHz which is one of the distinct features of the proposed Antenna. The Impedance bandwidth of the proposed design ranges from 29.5-30.5 GHz which is sufficient enough spectrum for smooth flawless communication.

III. CHALLENGES AND APPLICATION S

A. Challenges

- Microstrip antennas are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry.
- They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency.
- A single patch antenna provides a maximum directive gain of around 6-9 dBi. It is relatively easy to print an array of patches on a single (large) substrate using lithographic techniques. An advantage inherent to patch antennas is the ability to have polarization diversity.
- Patch antennas can easily be designed to have vertical, horizontal, right hand circular (RHCP) or left hand circular (LHCP) polarizations, using multiple feed points, or a single feedpoint with asymmetric patch structures.[4] This unique property allows patch antennas to be used in many types of communications links that may have varied requirements.

B. Applications

- The Microstrip patch antennas are well known for their performance and their robust design, fabrication and their extent usage.
- The advantages of this Microstrip patch antenna are to overcome their de-merits such as easy to design, light weight etc.,
- The applications are in the various fields such as in the medical applications, satellites and of course even in the military systems just like in the rockets, aircrafts missiles etc.

- The usage of the Microstrip antennas is spreading widely in all the fields and areas and now they are booming in the commercial aspects due to their low cost of the substrate material and the fabrication.
- It is also expected that due to the increasing usage of the patch antennas in the wide range this could take over the usage of the conventional antennas for the maximum applications.

IV. CONCLUSION

Microstrip patch antenna is using in all electronics devices for wireless communication. Array structure is advancement of MIMO and other type of antenna designs. This paper review about various research work based on mm wave microstip patch antenna for satellite k band wireless applications. Therefore it can be sat that there are many challenges to design and performance improvement of k band antenna. K band antenna lies between 18 to 26 GHz so its bandwidth and other necessary parameter should be more improved. So that such antenna gives better performance in 5th generation communications.

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