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Microstrip Antenna for 5G Millimetre-Wave Applications

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Abstract. In this paper, a single element antenna is presented for 5G millimeter wave (mm Wave) applications and using single element can be made for MIMO, array of antenna. The bandwidth value of the presented antenna is 11.1 GHz (from 25.1 GHz to 36.2 GHz) and overall size is only 11.5 x 12.5 mm^2. It shows that very good candidate for 5G applications. Future wireless communications services require high data rates as technology is progressing. Multi-input multi-output (MIMO) technology for emerging and future wireless communications systems is seen as a fundamental requirement. Technologies like data rate improvements, transmission speed, channel capacity and throughput increase the performance of wireless communication systems substantially. On the side of the transmitter and the receiver, MIMO antennas are several. The design of effective MIMO antennas with a high rate of data and large capacity presents various obstacles.

Keywords: 5G Technology, MIMO, Antenna, Communication

1. Introduction

A fresh alteration has been introduced into our scenario of communication by proliferating wireless communications with advances in new technologies [1-3]. It develops day after day with the needs of new modern communications technology. In the day-to-day lives of people, demand for information and data rates is increasing [4]. The entire age of communication is divisible into three parts: the era of the pioneer, the precellular, and the cellular. The pioneering era was between 1860 and 1921, when Maxwell conducted experiments in electromagnetic (EM) spread equations [5]. These basic rules for EM waves were developed by Maxwell about 1865. Maxwell says that charges, streams and changing fields create electric and magnetic fields [6]. These equations show how different magnetic and electrical forces travel at light speed and are known as electromagnetic waves. Brilliant researchers such as Heinrich Hertz, Nicola Tesla, Alexander Popov, Chandra Bose, Acharya Jagadish and Marconi, showed numerous experiments on radio waves during this period [3-5]. An experiment was carried out by Heinrich Hertz. First experiment on transmission and reception of EM waves was performed by Hertz [4]. According to him, if EM waves propagate from sparks of the oscillator, a current in the circuit is produced or produced. Around 1893, Nikola Tesla suggested how electromagnetic waves might carry energy from one point to another [6]. Alexander Popov followed him up, and in 1895 he conducted his experiments and submitted article on wireless lightning detectors constructed using a coherer. Jagadish Chandra Bose, physicist, showed radio waves in Calcutta at that period. One of his greatest achievements at that time was the concept of semiconductor interfaces and millimeters of waves [2]. Radio telegraphy was demonstrated by Guglielmo Marconi and radio could be used to convey messages across the Atlantic for 2200 miles. Then in 1948, the mathematical theory of communication proposed by Claude Shannon. He is generally dubbed the information theory father, who altered the systems of communication [7]. First Generation 1G (1970-1980s) is the key determining element for analogue communication and speech is the design and data communication in a system was not supported. Digital voice is characterized by 2G (1980-90) second generation system, supporting digital communication. But speech was still the most crucial traffic to carry. There was a period between2G and 3G, sometimes called 2.5G, where data were introduced for transmission using mobile network systems such as GPRS, EDGE, etc, where data was transmitted using the same voice signal channel. Third generation 3G, which is a digital system, was created around the period 1990 to 2000 and the use of a 3G occurred at the beginning of 2001. And 4G and 5G started in 2010 and 2020 respectively [8-12], [13]. In 5G more advantages as compare to other developed technology in terms of data rate, latency rate, energy saving etc.

2. Literature Review

Micro strip is a sort of electrical line that may be made with the technology of printed circuit boards and is used to transfer signals with a microwave frequency [14]. It is made up of a pipeline separated by a dielectric layer known as a substrate from a ground plane [15]. Microstrip technology can be used for the development of various microwave components such as antennas, couplers, filters, power dividers, etc. This technology enables the complete subsystem to be placed on the same substratum, as a metallization pattern with all devices printed on the substratum. This reduces the cost, lightness and compactness of micro strips as compared with traditional waveguides. This technology has been developed as a strip line rival in ITT laboratories [16]. The advantages of printed antennas are small weight, low volume, low profile and low production cost, but the use of printed antennas is restricted by some limitations [17]. The printed antenna normally consists of metal coating lines on surfaces. This causes substantial radiation leakage from the surface and causes leakage current when this metal line is exposed to air. The ability to handle the antennas is minimal which limits application in the construction of high-frequency antennas [18].

There are several benefits over printed antenna to the utilization of the rectangular waveguide [19]. It comprises of a bonded thick metal wall within the bond structure in which the signal propagates. This leads to low load, minimal leakage, great efficiency and high capacity for handling and reduces cross conversation [21]. However, the volume of the rectangular waveguide is more than the antennas of the microstrip. In addition, typical rectangular waveguides have problems when they are integrated with other circuits. The utility of the waveguide is so limited [20]. The advantages of traditional waveguides in Microstrip technology have been developed by a new technology called a Substrate Integrated Waveguide (SIW). The SIW not only has beneficial features of the microstrip antenna, but also of the traditional waveguide. SIW originates from the idea of Microstrip conjunction with conventional adulator [22]. The structure of SIW as the traditional dielectric waveguide is essentially inseam. It comprises of a cotton sheet equivalent to two metal walls in a waveguide and is similar to a microstrip in which the initial height is 37 times lower than that of a printed circuit board (PCB). The upper and bottom layer of the waveguide is a copper sheet [23].

Coplanar lines microstrip lines are open like a structure that is bound to cause an energy leakage [20-23]. The structure of these leaks usually occurs through the directed path. The improper mode in the guiding structure is another reason for leakage. This leak can be used in the construction of antennas [1]. The discontinuities in the structure's guiding course are deliberately caused by radiation. In general, the antenna designer controls the radiation. A leaky wave antenna normally acts as a complex wave, which is guided, and a complex spreading constant is the radiation pattern of the guided structure. Leaky wave antenna is a subset of wave travelling antenna which is divided into two types, i.e., one dimensional and a two. Most of the antenna radiates in the direction of the end afire. They are also used to scan frequency from an end-fire to the wide side [2].

3. Methodology section

3.1. Basic Design equations of the antenna

Microstrip patch antenna has so many configurations, but the most widely used patch configurations are rectangular patch and circular patch.

For rectangular patch:

(a) Width of the patch $w = \frac{c}{2F\sqrt{\frac{\varepsilon r+1}{2}}}$ (1)

(b) Length of the patch $L = L_{eff} = 2\Delta L$ (2)

(c) Length extended length $\Delta L = 0.412\frac{(\varepsilon eff+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon eff-0.264)\left(\frac{w}{h}+0.8\right)}$ (3)

(d) Effective dielectric constant $\varepsilon_{\varepsilon eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1 + {}^{12h}/_{w}]^{1/2}$ (4)

(e)Effective length L_{eff} $\frac{\lambda}{4\sqrt{Er}}$ (5)

For circular patch:

The radius of the patch

$$a = \frac{F}{\{1 + \frac{2h}{\Pi a \varepsilon r\left[\ln\left(\frac{\Pi a}{2h}\right)\right] + 1.7726}\}^{1/2}} \quad (6)$$

Where, C = Speed of light ε_r = dielectric constant of the substrate, *F* = operating frequency, L_{eff} = Effective length of the patch, ΔL = Extended length due fringing fields, λ = operating wavelength, h = Thickness of substrate and w = Width of patch.

3.2. Design Flow Chart

By following the stages described in Figure 1, the overall purpose of this work was met. The parameter that is being sought is regarded critical before pre-design, as it influences the antenna's overall performance. To construct antennas that could function for a 5G frequency band was the goal. A low reflection coefficient (S_{11}) and a VSWR of 2 dB or lower, and a 50 Ohm impedance match, are required, and the antenna's bandwidth must be at least 10 GHz. This may be seen in Figure 4. Furthermore, an iterative optimization procedure to provide a higher reflection coefficient and a lower VSWR was also employed.

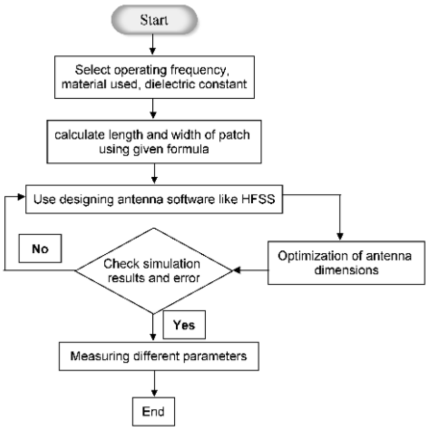

Figure 1: show the design flow chart

The resonant frequency of the antenna can be altered via half ground plane use. In order to achieve miniaturization, a monopole resonator is used on the top of the substrate. A step gradient monopole antenna is used upper side of substrate and a ground plane is on opposite side. This is the parallel inductance and capability combination and has a specified resonating frequency. This structure parallel inductance and capability combination makes an attractive parameter set which attracts numerous applications. It is obvious that for the frequency region from 25.1 to 36.2 GHz. The presented antenna is designed on Rogers RT/duroid 5880 substrate and thickness h = 2.0 mm, and relative permittivity ε_r = 2.2.

The presented antenna is stated in the preceding part has been designed using HFSS and the structure produced is illustrated in Figure 2. Table 1 shows the optimize dimensions of the presented antenna.

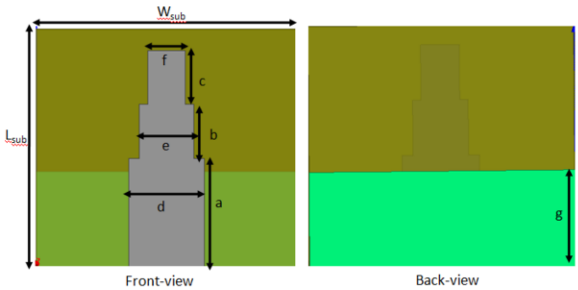

Figure 2: Presented antenna structure of single elements

Table 1: Shows the parameters and its dimensions.

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
L_{sub}	11.5	d	3.4
W_{sub}	12.5	e	2.4
a	5.0	f	1.75
b	2.5	g	4.5
c	2.5		

4. Results and discussions

This paper presents a step gradient loaded antenna on the top floor working in various 5G bands. The increased number of steps on the top plane has produced a high degree of miniaturization. At its operating frequencies, the antenna BW is more than 11 GHz and it is shown in Figure 3. The antenna elements have a radiation pattern in 3-D and 2-D respectively and it can be shown in Figures 4 and 5. Up to till now there is not available for us, however some, researches have started to part to base for the technology that will provide these standards. The technology mostly consists of wireless access system, frequency utilization, power consumption, antenna and the propagation. In this 5G Spectrum there is an economic expanse in the millimeter wave spectrum. The terms IoT and 5G are used conversely because of the shared traits in the intents of both.

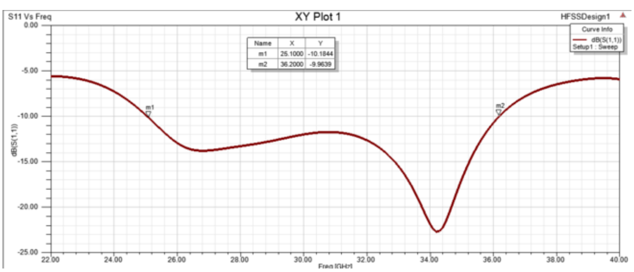

Figure 3: S_{11} characteristics of proposed antenna

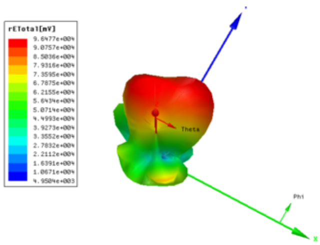

Figure 4: 3-D radiation pattern of antenna

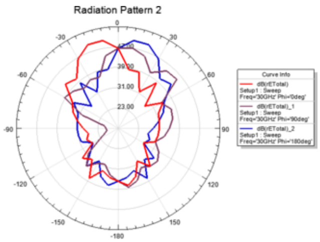

Figure 5: 2-D radiation pattern of antenna

5. Conclusion

In this paper, a step gradient antenna is designed for 5G mm-wave applications. The antenna is associate with a small step size which can be controlled as a major mobile 5G communication technology solution. High-performance antenna is investigated using state-of-the-art technologies. Firstly, for applications in multiple mm-wave band operation and using this single element a MIMO antenna system based can be made. The antenna's operating band covered between 25.1 GHz and 36.2 GHz and radiation pattern trends were also stable. A useful applicant in portable mm-wave applications and is also useful for designing of MIMO antenna array.

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