Wireless Antennas for Mobile Application

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Abstract. Technology is very fast developing which gives a huge impact on social life nowadays. This wireless technology urges a study need for antenna development where the antenna can be said as the core device for this technology. Researches on the antenna are rapidly developing in the current research trend resulting in many antenna designs in modern wireless technology because it allows single antenna to be employed in many systems. Fifth Generation is the next generation for mobile technology, which have many advantages such as better data rate, better reliability, network scalability and flexibility, amazingly fast, super real time, better efficiency and great service in a crowded area. Fifth Generation (5G) Fifth generation (5G) is the next major phase of mobile telecommunications standards beyond the current 4G, which will operate at 26 GHz until 30 GHz. In any wireless device, the performance of radio communications depends on the design of an efficient antenna. Microstrip antenna has several advantages compared to the conventional microwave antenna. These types of antenna are lightweight, low volume and thin profile configurations, which can be made conformal. The cost of fabrication is also low and can be manufactured in a large quantity. This project will discuss the microstrip antenna and its application in the car. This research work is focusing on design, simulate, fabricate and analyze a 5G wireless antenna that operates at 26 GHz and above by using Flame Retardant 4 (FR4), where the frequency is one of the standard frequencies of the 5G communication. Then, it also aims to develop wireless device prototype for car application and then to test the prototype for real application. This project is divided into three major parts which are calculation, simulation and hardware design. Computer Simulation Technology (CST) microwave studio software used to analyze the radiation pattern of the antenna before fabricated the antenna. Vector Network Analyzer (VNA) used to measure the fabricated antenna to obtain the measurement result. The results of the simulation after being optimization is 28.023 GHz at return loss -450.41 dB. The gain of this antenna is 3.636 dB.

1. Introduction
At the beginning of the 1990s, when wireless device technology first emerged, the first generation published. The second generation known as 2G appeared when devices able to send text messages between the device to another device. Then after the phenomenon of 2G telecom providers progress on to the third generation that is known as 3G which allowed users to access anything including calls,
texting and even browsing the internet by using their devices. The 4G which is the fourth generation improved the quality capabilities by providing faster wireless access and better connectivity no matter where the user’s places that enable them to stream content via services for example like YouTube and Netflix. Long-term Evolution (LTE) was announced into the 4G to point out an even bigger boost in performance. Finally, the fifth generation (5G) expected will be launch in 2020. It will improve 4G LTE technology to significantly increase connection and browsing speed that enables increasing the speed of data transfer which means, in fact, it will not take too much time to share Ultra HD or 3D videos, HDR-quality photos and more.

First generation (1G) wireless telephone technology of network were published for the first time in July 1978 in the USA. Transceivers were shared consisted in form of 1G that helped in communicating with a device like a mobile phone. They were old analog system and supported the first generation of analog cell phones speed up to 2.4 kbps which is it could only be used for voice traffic and allows users to make voice calls in 1 country. For the transmission of signals, frequency modulation was in use. There was one 25MHZ frequency band allocation from the cell base station to the device and another 25MHZ frequency band allocation for the signal from the device to the base station. In order to help more users to the network each channel was separated from the other by a spacing of 30 kHz, but it was not effective enough in terms of the available spectrum. 1G would use frequency division multiple access (FDMA) techniques where the user had to wait for the first user to hang up. The network capacity in 1G was increased by implementing the frequency reuse. All the systems offered handover and roaming capability but the cellular networks were unable to interpret between countries. 1G has low capacity unreliable handoff, poor voice links, and no security since voice call susceptible to unwanted [1, 2].

On the other hand, 5G abbreviated as Fifth Generation wireless or mobile networks, are the suggested next telecommunication standards after the 4G and LTE standard. 5G wireless is based on mm-wave communications so that it will in the frequency range of 30 to 300 GHz which refer to electromagnetic signals with a wavelength of 1-10 mm millimeters. Wireless communication in 5G performs higher capacity than current 4G and LTE communication standards to allow a larger density of mobile broadband users per area and support of ultra-reliable device-to-device and machine-to-machine communications [3].

Cellular systems in 5G technology are in its early developmental stages with technology giants working towards introducing modems and similar communication devices in the market. The bands set for testing 5G cellular systems are 28 GHz in the US and 39 GHz in Europe. The frequency ranges are 24.5 to 29.5 GHz and 37.0 to 43.5 GHz for the 28 and 39 GHz spectrum, respectively. Improved data rates of up to 2.5 Gbps with reduced latency and support of multiple connections are the key features of 5G cellular communications. A relatively new Wi-Fi standard IEEE 802.11ad that operates in the 60 GHz band to achieve as much as 7 Gbps data transfer rate is also under development. This band can be used without a license for short-range communication. It was launched by the Wireless Gigabit Alliance back in 2009 and is poised to be an essential enabling technology with the increase in demand of bandwidth for applications such as gaming and HD video streaming. It is often termed as Wi-Gig due to its immensely fast data rates as compared to the current Wi-Fi standards operating at 2.4 and 5 GHz. Other bands such as 71-76, 81-86 and 92-95 GHz bands are also used for high-bandwidth communication links as these frequencies do not suffer from environmental absorption. In case of the 92-95 GHz band, 100 MHz has been reserved for space-borne radios to limit this reserved range to a transmission rate of a few gigabits per second [3].

For the past years, the development of a network for wireless technology antenna application has been increased widely in order to improve the performance of the current network wireless technology system. For this project, the main issue is that the application of antenna 5G that is vehicle-to-vehicle (V2V) should have better performance since the frequency band set for this system cannot support a large number of vehicles. In order to overcome this problem, the frequency band must be set widely since it will support a large number of vehicles simultaneously. Apart from that, the V2V application could get complicated since it signals as well as the V2V application could get complicated since it signals given by it sometimes not be correct. So, to overcome this problem, the material used for design antenna must be chosen carefully since it will give lots of effect towards the
antenna and application performance. The design of the 5G antenna will be increased of attenuation since it uses high frequency which is 26 GHz to 30 GHz. To overcome this problem, antennas will design with high gain, small size and the directive beam [4].

2. Antenna Design, Fabrication and Performances
The microstrip antenna was designed and simulated at the frequency between 26 GHz to 30 GHz by using CST Software. The designed process started with a blank schematic. The brick component was chosen from the modeling palette tools on the schematic window. The first layer was designed is a layered ground then continuous with layer substrate and lastly patch layer. Then on the patch layer, some staging of the patch was made which are different small 1mm from the upper patch. Then on that patch, one slot was designed. All of them were connected together with an insert feeding line in a schematic through one port that attached together. Figure 1 shows the design of the microstrip patch antenna with insert feeding in layout 3D. The ground and patch layer which is copper material is set to its thickness of 0.035 mm. While the thickness of the substrate layer which is FR4 is 1.6mm. Then the component is simulated by setting the impedance matching 50Ω [5].

![Figure 1. Design of Microstrip Patch Antenna in 3D Layout](image)

Antenna optimization aims at creating advanced and complex electromagnetic devices that must be competitive in terms of performance, serviceability, and cost-effectiveness. This process involves the selection of appropriate objective functions, design variables, parameters and constraints [6]. The microstrip antenna that had been designed undergoes optimization process where the staging of patch antenna has been tested the simulation by resizing the design to a smaller size. While the size of the slot also is resizing to decrease size [7]. The simulation of optimization continues until it gets the best result as shown in Figure 2.
The simulation parameters involving the return loss (S11), the bandwidth of the antenna, gain, radiation pattern was performed by using CST Software. Meanwhile, the measurement result in terms of return loss (S11) and radiation pattern has been done by using equipment such as Vector Network Analyzer provided at the laboratory. The important of parameters to measure the microstrip patch antenna performance can be done by using CST software. It is significant to run for a simulation of the antenna performances before proceeding with fabrication and measurement of the antenna. Thus, it is important to make sure the entire antenna parameters can be exactly as in theoretical [8]. However, during the simulation process few adjustment and optimization on the sketch of the designed antenna in order to provide for a better simulation result. During the simulation process, few adjustment and optimization on the sketch of designed antenna have been done in order to provide for a better simulation result. In this project, the designed antenna on the patch was optimized where the staging and slot of the patch were decreases into a smaller size as shown in Figure 3 and Figure 4. The simulation was done every 1 mm decrease for staging and every 0.5 mm for a slot. Figure 5 and Figure 6 shows the results of the optimization.
Figure 3. The original designed of antenna

Figure 4. The optimization on the staging of the patch antenna

Figure 5. The result optimization on slot of the patch antenna

Figure 6. The result optimization on the staging of the patch antenna
3. Simulation results
Return loss or reflection coefficient describes how much of an electromagnetic wave is reflected by an impedance discontinuity in the transmission medium. On the other hand, return lost in antenna means parameter that states the total of power that is lost to the load and does not return as a reflection [9-10]. In order for the antenna to have a good performance, its return loss should be less than -10 dB at the desired frequency [11]. Based on Figure 7, the achieved value of return loss at 28.203 GHz is -45.041 dB.

![Figure 7. The Return Loss of Designed Antenna](image)

The bandwidth of the antenna is one of the important parameters which refers to the range of frequencies over which the antenna satisfies a particular parameter specification. The parameters generally specified are gain and radiation pattern [12]. The actual bandwidth of the designed antenna can be calculated by using formula (1).

\[
\text{Bandwidth} = \text{High frequency} - \text{Low frequency}
\]  

(1)

The highest frequency at -15 dB is 28.782 GHz meanwhile the lowest frequency at -15 dB is 27.651 GHz as shown in Figure 8 below. The bandwidth of the designed antenna can be calculated as equation 4.1 and falls within 1.131 GHz. For this project, the bandwidth of the designed antenna is acceptable.

![Figure 8. The Bandwidth of the Proposed Antenna](image)
Basically, the radiation pattern is the directional dependence of the strength of the radio waves from the antenna. Based on the desired antenna, the radiation pattern in the 3D dimension is shown in Figure 9. The radiation pattern showed up as directional pattern which does not have symmetry in the radiation pattern. Usually, the dish and waveguide antenna has a single peak direction whereby this is the direction where the bulk of the radiated power travel [13]. On the other hand, Figure 10 shows the radiation pattern in polar view.

**Figure 9.** 3D radiation pattern of the proposed antenna

**Figure 10.** 2D radiation pattern of the proposed antenna
The gain of the antenna is another crucial parameter for determining its whole performances [14]. The antenna gain for this design is 3.636 dB which describes how the antenna converts input power into radio waves in a specified direction[15]. Meanwhile, the directivity of an antenna is another fundamental thing. For this design, the directivity value is 7.975 dBi which can be considered as a good directivity since the theory of directivity of microstrip patch antenna lies between 5-8 dBi [16]. It also can be said that the higher the value of its directivity, the higher the overall performances of the antenna. The radiation efficiency of the antenna is -4.339 dB.

4. Conclusion
The antenna must be matched nearly to 50 Ω impedance in the frequency range covering LTE-Advanced band. It can be concluded that the objectives of this project have been successfully achieved. The designed antenna has found to be operating in the frequency of 5G which is 28.023 GHz. However, the design 5G antenna can function very well for wireless car application. Based on the simulation result by using CST software, the performance of the antenna parameters can be said successfully achieved since the return loss at the desired frequency 28.023 GHz is -45.041 dB and impedance matching is 50 Ω. All of the value of these parameters still gave a good sign that the antenna has a high gain and efficiency.

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