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A Review of A Multi-Band and Multi-Generation Antenna System For 5G

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ABSTRACT - With the technological advancement in the field of mobile networks and the deployment of 5G technologies, the research on 5G antennas in the context of communication devices has an important aspect. Indeed, one of the important components of the communication system is notably an antenna which is essential for the transmission and reception of signals. However, instead of designing an antenna only for 5G communication it would be interesting to design one that could also take into account all the previous technologies already existing. The study of the frequency bands of the different generations of mobile networks as well as the various antenna models adapted for 5G technology will be the subject of this document. The types of antennas used in various 5G applications such as Smartphones, Base Stations and IoT based devices will also be the subject of our study.

Keywords :

5G, antenna, frequency bands, generations, Base Station

I- INTRODUCTION

Since the advent of mobile networks, the change from one technology to another has always been guided by the desire to offer more value-added services to users. From the transition from 1G to 4G, the introduction of new features and better performance in order to guarantee better quality of service to users has always been the credo. Nowadays, with the advent of 5G these objectives have not changed.

One of the major elements of a communications network is the antenna, especially since it gives users access to it. Its sizing and design are therefore important. Designing an antenna suitable for 5G technology is very important. What would be even more important is to design a 5G antenna that can also take previous technologies into account. In other words, a multi-band, multi-generation antenna.

5G technology can open up new opportunities for social benefits. This 5G technology supports not only smartphones but also Internet of Things (IoT) devices. Therefore, 5G technology has the ability to use information technology in education, health, industry, agriculture, finance and many others to usher in a remarkable societal transformation.

Regarding the antennas suitable for 5G we could have the classification of antennas based on their structure and the classification of antennas based on the number of input-output ports [1]. Depending on the structure of an antenna, antennas are classified as follows:

- Dipole antenna: it can be in the form of wire or printed on a substrate with a length of λ/2 where λ is the wavelength of the resonant frequency. The dipole antenna feed is provided in its center. It is easy to design and manufacture, but it offers low gain and bandwidth.
- Monopole Antenna: It is also available in wire form or printed on the substrate and is of length λ/4. It is easy to design and implement but performs poorly in bad weather.
- ME Dipole: It consists of vertical magnetic dipole and horizontal electric dipole planar antenna elements. It offers a high front-to-back ratio and wide bandwidth, but its design is complex.
- Loop antenna: It is in the form of a ring which can be circular, rectangular or square. It improves the channel capacity but its gain is low.
- Vivaldi Antipodal Antenna (AVA) : It consists of two metal patches which are mirror images of each other and are present on opposite sides of the substrate. It offers wider bandwidth and gain at the cost of a larger antenna size.
- Fractal Antenna: To design this antenna, a mathematical rule is used for the repetition of the same structure. Some fractal antenna structures are leaves, hexagons, rectangles, triangles and stars. It

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reduces the size of the antenna but the complexity of the design increases after the third iteration.

- Inverted F Antenna (IFA): The monopole antenna is curved on one side so that there will be two arms, one should be one size longer and the other arm should be one size longer small. Additionally, power is supplied to the long arm and parallel to the smaller curved arm. This structure translates to inverted F and hence the name is inverted F antenna (IFA). As power is supplied at the intermediate point, there is good impedance matching but it provides low gain.
- Planar Inverted F Antenna (PIFA): This is a multi-layer antenna. At the top there is a radiator, the middle layer is air, and at the bottom there is a layer of soil. It is a compact antenna because it only requires λ/4 space but it offers less gain.

Depending on the number of input/output ports we have:

- Single Input Single Output (SISO): This is the simplest type of antenna in which power is supplied at one point and only one signal is transmitted or received at a time. Such an antenna can be divided into single-element and multi-element, that is, an array antenna. SISO antennas are suitable for IoT-based devices for 5G applications. As the array antenna offers higher gain and a stable radiation pattern, it is preferable to a single patch antenna.
- Multiple Input Multiple Outputs (MIMO): As the name suggests, it consists of more than one power port and copies of the same single are transmitted or received. As multiple copies of the same signal are received at the receiver, the received signal can be reconstructed efficiently, which in turn improves the quality of services. In addition, many researchers have designed broadband and multi-band MIMO antennas for 5G applications. These two wideband and multi-band MIMO antennas are further classified into a phased array antenna with or without a metal rim. The metal edge antenna provides mechanical strength to the device. The challenging task in MIMO design is to reduce the interactions between the antenna elements and this is called mutual coupling. Several techniques have been proposed in the literature to reduce this mutual coupling.

The prospects for using 5G antennas are multiple and according to [1] we have:

- Smartphones: Multi-band MIMO antenna is the best antenna for 5G Smartphones, but designing such an antenna in a compact space is a daunting task. Many researchers have suggested using Monopoly, IFA and PIFA due to their compactness and ease of integration into Smartphones.
- Base station: The 5G base station must use massive MIMO antennas, which is a group of antennas working together to improve throughput and spectrum efficiency. Massive MIMO also increases channel capacity and reduces latency. These antennas also offer beamforming, which means that the direction of the antenna's maximum directivity can be changed to send the signals only to the intended user .
- 5G – IoT: 5G technology supports millions of IoT-based devices. This also supports faster device-to-device (D2D) communication. This important application will bring revolutionary and evolutionary changes in different social sectors. Some important applications are automated industry controls, smart cities, public safety, e-health, smart farm, etc. With 5G technology offering very low latency, remote control operations are also possible. Additionally, IoT with artificial intelligence (AI) and cognitive radio will play a vital role in 5G technology .

In the following we will first provide a literature review on 5G antennas before giving the objectives of our research and finally we will present the materials and methods that we plan to use in our study.

II- LITERATURE PAPER

In this part we will see the 5G frequency bands, the types of antenna used in 5G and their prospects for use, and the multi-band and multi-generation 5G antenna systems.

1. Frequency bands used in 5G

5G aims to provide ultra-high speed, low latency and reliability to registered users using a wide spectrum which can be divided into three layers, namely the “coverage layer” (spectrum below 2 GHz), the “coverage and capacity layer” (spectrum between 2 and 6 GHz) and “super data layer” (spectrum above 6 GHz). For the main deployment of 5G networks, service providers will use 5G C-band (sub-6 GHz band with the frequency range of 3300–4200 MHz and 4400–5000 MHz), as this frequency range is suitable for providing the better negotiation between extensive coverage and good capacity [2].

Several bands are reserved for testing and deployment of 5th generation mobile communications: 3.4 – 3.8 GHz, 25.5 – 27.0 GHz [3]. Although without a new standard, these bands are not fixed nor do they limit the frequencies that can be used in 5G. 3GPP proposes the use of different frequency bands 450 – 960 MHz, 3 – 6 GHz, 24.25 – 52.6 GHz, 66 – 86 GHz [4], while the exact bands could be chosen depending on the application of the communication link.

At present, all radio frequencies are divided into two large groups depending on the possibility of implementing the 5G system: below 6 GHz and above 6 GHz. Frequencies above 6 GHz are little used in mobile communications and require additional hardware development, particularly in millimeter waves (above 30 GHz). The design of amplifiers, antennas and broadband antenna arrays is required before the deployment of 5G systems, leading to high development costs. Therefore, mobile communications providers in Russia, for example, will be able to test 5G devices and algorithms in the 2.5 GHz and 3.6 GHz bands. The ITU also suggests the band 694 – 790 MHz, which is used in Russia for digital video broadcasting [5].

Considering that there are several frequency bands that can be used for 5G system development and testing, the bands for system implementation should be chosen based on 5G transmission requirements, such as spectrum efficiency ,energy efficiency and speed of user equipment [6].

2. 5G antennas

According to [7] the circularly polarized patch antenna is designed for 5G technology. 5G offers precise global positioning, a wide range of bandwidth, good coverage and high quality of service. To design an antenna suitable for 5G networks, certain parameters must be taken into account such as the operating frequency, the size of the antenna, the polarization, the manufacturing cost, the bandwidth. Mobile communications require that the radiation pattern of the new antenna design be capable of covering full azimuth angles and maximum elevation angles. Directional antennas are preferred because they have good beam tracking capability for satellite communications. Folded type antenna in circular shape with 4 and 8 slots are introduced to reduce the size of an antenna. To improve the beamwidth of the patch antenna, two techniques are followed. One is a dielectric substrate surrounded by a patch antenna and another method is to add a metal block to the back of the antenna.

[8] introduces the directional antenna with mm-wave spectrum: Due to the rapid usage of mobile users, service providers find it difficult to increase the spectrum band to avoid bandwidth shortage and also to provide effective communication. In this article, a directional antenna is used with the frequency of 2.8 GHz. For the need of less weight, small size, simple design micro strip patch antenna is used. 5G mobile phones offer efficient communication, low latency and massive connectivity.

In [9] the rectangular shaped broadband antenna with micro strip line feed is used for 5G technology. The operating frequency of this antenna is 6 GHz. This results in a gain of 3.7 dB with a directivity of 6.62 dB and a bandwidth of 500 MHz. Antenna parameters are measured to meet the needs of 5G technology as well as certain parameters such as atmospheric absorption of waves due to rain or wind which can lead to information loss. The far field radiation pattern is used for this antenna design.

In [10], steerable directional antennas are used in millimeter wave mobile communications. The antenna works with the frequency of 28 and 38 GHz. The antenna design includes two rectangular patch antennas with a single element of RT/Duroid Substrate 5880. Various parameters are measured to check whether the antenna could work with 5G technology to meet the needs of mobile users and also the network provider. services. Some effective approaches are followed in this design, such as designing an antenna that should work with multiple resonances, optimizing impedance matching; increase the thickness of the substrate and reduce the effective permittivity of the substrate. Radiation losses can be reduced by designing a thin and high dielectric constant of the substrate . It offers 9.0 dB gain and 83% efficiency.

In [11], the antenna is designed with CPW feed which can be suitable for future 5G technology. The operating frequencies of an antenna are 3.73 GHz, 5.56 GHz and 8.4 GHz, which are suitable for WLAN, WSN, Wi-Fi/WiMax and HyperLAN. Microstrip patch antenna is preferred due to its cost, size, weight, flexibility, etc. Fractal technology is used with these designs which provide good impedance matching and can operate with multiple frequency bands simultaneously.

In [12], the antenna array is modified with a subarray which is placed along the mobile phone to cover a wide area. This technique will avoid the traffic rate. A linear phased array antenna with an omnidirectional radiation pattern is used with this design. The antenna operates with a frequency of 18-28 GHz. To cover a wide space in 5G mobile phones, beam steering is proposed. Three identical subnets are used, which are placed next to

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the mobile phones where high gain is achieved. A coaxial or probe feed is used to design this antenna.

The Microstrip Slot Wideband Rectangular Patch Antenna is designed for 5G technology. It works with the frequency of 5GHz. MIMO technology is implemented to increase the quality of service, gain. The antenna design includes an RT5880 substrate with a thickness of 0.6 mm and 2.2 as the dielectric constant. This antenna design is well suited for 5G cellular mobile phones which provide a reflection coefficient of -36.54 dB and a bandwidth of 300 MHz [13].

For the application of video and multimedia, mobile users need high quality and low latency transmission, which creates a new challenge for the service provider to satisfy customer needs. In order to provide new features and avoid spectrum shortage, 5G technology is introduced. Due to bandwidth scarcity, mmWave spectrum is used for 5G technology. Mm wave spectrum could support simultaneous use of mobile phones. CMOS technology is integrated with 5G technology. Instead of increasing the wide bandwidth, spatial reuse technique is introduced in these designs which provide flexibility, reduced cost with efficient communication. The atmospheric absorption of radiant waves due to rainfall is measured. While designing an antenna with a low loss tangent substrate will increase the efficiency of the antenna and reduce the microstrip loss. A coaxial feed is used with this design, internal connector contacts with a patch antenna and external connector contacts with a dielectric constant. The resonant frequency of this antenna is at 59.5 GHz, which produces a return loss of -44.99 dB [14].

3. Multi-band and multi-generation 5G antenna systems

[15] proposes a multi-band patch antenna for Wi-Fi, WiMAX and 5G applications. The proposed antenna can efficiently operate at 2.4 GHz in Wi-Fi, 7.8 GHz in WiMAX and 33.5 GHz in 5G communication. The proposed antenna arrays gave directional radiation patterns, very small voltage standing wave ratio, high gain (VSWR) and directivity for each operating frequency of the aforementioned systems. This antenna is designed for multi-band use which can be effective not only for Wi-Fi and WiMAX applications but also for 5G applications.

[16] focuses on the design and simulation of a microstrip patch antenna. Many applications such as radiolocation, radio astronomy, mobile and satellite communications and space research are considered and the antenna is designed specifically for these applications. The antenna operates at three frequencies. The 23.9 GHz frequency finds application in space applications such as radio astronomy and satellites. The frequency of 35.5 GHz is applied for radio localization. Additionally, 70.9 GHz finds its place in 5G mobile communications. The antenna is compact and consumes less power. Justified reflection loss, positive gain makes the antenna suitable for all the above applications. Future work would include fabricating the antenna and verifying the results obtained in the real environment. The low gain, narrow bandwidth, low efficiency and low power of the antenna must be considered.

[17] presents a triangular-shaped multi-band microstrip patch antenna for 5G applications. The proposed antenna is designed and simulated on FR-4 substrate and is capable of operating in different sets of frequency regions in 5G. The antenna provides a bandwidth of 3.255 GHz, 7.132 GHz, 7.721 GHz and 8.434 GHz at a resonant frequency of 43.9 GHz, 61.8 GHz, 75.8 GHz and 94 GHz respectively and has a return loss of 19.233 dB, -28.209 dB, -41.89 dB and -19.035 dB at resonant frequencies. The proposed antenna also provides VSWR<2 in each band obtained by the antenna.

[18] presents the design, optimization, fabrication and measurement of the compact high gain micro strip antenna with a split ring resonator and an array of inverted F slots as well as a corresponding stub for subsurface applications. 6GHz 5G. In this investigation, different iterations are visualized by incorporating inverted F-slots, a split ring resonator and a corresponding stub in the transmission line. The advantages of each incorporated structure are analyzed and a hybrid antenna composed of the combination is proposed as the final antenna configuration with the optimal results. The final proposed design achieves compactness and multi-band operation. Impedance matching is improved using the stub matching technique at the feedline. The designed antenna shows the resonances at precisely 2.1 GHz, 3.3 GHz and 4.1 GHz. The proposed antenna is suitable for mobile cellular communications such as LTE band (2.1 GHz), n78 band (3.3 GHz) and n77 band (4.1 GHz) of 5G bands. The gain recovered from each band reaches a value greater than 5 dB.

[19] describes the concept of two multi-band antennas suitable for 5G communication. One of them is designed in such a way that the resonant frequencies are in the 450 MHz to 6 GHz range. This proposed antenna has resonant frequencies such as 2.4 GHz, 2.8 GHz, 4.1 GHz, 5.5 GHz, 5.9 GHz, 6.6 GHz, 7.9 GHz and 9.3 GHz. Another multi-band antenna operates in millimeter band (24 GHz-86 GHz) resonating at 14.601 GHz, 23.3.01 GHz and 28.9 GHz. The substrate chosen for the designs is FR-4 for εr = 4.4 dielectric constant and designed using HFSS software. The antennas have low return loss, high gain and high directivity and low VSWR. These patch antennas are not only suitable for 5G applications, but also for Wi-Fi, WiMax, Bluetooth and WLAN applications.

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A low-profile four-element planar MIMO antenna is proposed in this paper which can be integrated inside wireless portable devices. Each unit antenna consists of a simple L-shaped planar monopole placed over an etched non-terrestrial area of 10 × 5 mm2. The optimized antenna elements cover three 5G New Radio bands falling under the C-band: the n77 band (3.3 - 4.2 GHz), the n78 band (3.3-3.8 GHz) and the n79 band (4.4-5 GHz), with isolation better than 18.8 dB, without the requirement for additional decoupling structure. The designed antenna is fabricated on an FR4 substrate with dimensions of 120 × 65 × 1.6 mm3. The antenna characteristics regarding reflection coefficient, mutual coupling, radiation pattern and gain are measured and discussed. The envelope correlation coefficient is calculated and is less than 0.018 for the entire frequency range considered. The simplicity and compactness of the proposed MIMO antenna provides sufficient space for the integration of other circuits inside the portable mobile terminal. Furthermore, integration with lower generation antennas is studied; the result indicates that the placement of the proposed antenna system on the two long arms of the ground plane provides sufficient space for the integration of lower generation antennas without affecting the performance of the other [20] .

In [21] , a simple planar multiband antenna for GSM, Galileo, GPS, Glonass, DCS, PCS, UMTS, LTE2300/LTE2500, WLAN (2.4–5.2–5.8 GHz), WiMAX (2) applications. ,5–3.5–5.5 GHz) and 5G is presented and discussed. The antenna has a small, ultra thin and simple structure. We show that by inserting different slits of appropriate size into the truncated radiation patch, good multiband characteristics can be obtained. It is also shown that the suggested antenna has good radiation characteristics such as stable radiation patterns, high radiation efficiency and also acceptable gain values. A simple ultrathin multiband antenna is introduced. The proposed four-band antenna covers many wireless applications. The proposed antenna has a simple configuration comprising two open L-shaped slots to create a resonant mode on the GSM and GPS bands and also two rectangular slots on the radiating element to create multi-resonant modes to meet the specifications of the frequency bands mentioned. According to the simple, small and planar configuration, the proposed antenna design is low cost and can be easily integrated with the other microwave circuit boards. The proposed antenna has a small size of 10 mm and a total size of 120 mm × 60 mm × 0.5 mm, promising to be widely used in compact and ultra-thin handsets.

III- PROPOSED METHODS

A popular technique for telecommunications in the modern era is massive MIMO, which is applied in long-term evolution (LTE) and wireless local area networks (WLAN). 5G communication relies heavily on this technology [22]. To meet the needs of 5G and beyond, massive MIMO is the most exciting wireless access technology. MIMO technology is expanded with massive MIMO, an innovative method of improving spectral efficiency and throughput using hundreds or even thousands of antennas. The technology involves combining antennas, radios and spectrum to create a system that delivers higher speeds and capacities for the upcoming 5G [23]. For wireless standards to be standardized, massive MIMO is essential due to its ability to increase throughput and spectral efficiency [24]. Massive MIMO with multiple antennas achieves considerable network gains [25]. Security lenses use massive MIMO to identify the legitimate user with as accurate beam guidance as possible. This significantly reduces the likelihood of unauthorized access to information. With MIMO technology, wireless communication range and speeds are significantly improved, and additional bandwidth and power are not required. The complex system of 5G relies heavily on the massive MIMO system. High spectral efficiency can be achieved by transmitting different signals simultaneously on multiple transmitting antennas and receiving them simultaneously on multiple receiving antennas. MIMO systems must be very efficient in terms of spectral efficiency [26].

As with massive MIMO, large-scale MIMO is a promising way to increase spectral efficiency. A large number of antennas will be added to the base station. A large-scale statistical effect is invoked using this technology. Transmission is generally free of fading, interference and noise, and the transmitted energy is focused only on the intended target.

IV- CONCLUSION AND PERSPECTIVES

The growing need of mobile network users for services pushes researchers to constantly develop innovative technologies. This is how we moved from 1st generation mobile networks to 5G today. However, it would not be smart for the transition to a new technology to lead to the repeal of the previous one, but rather, on the contrary, to possible interoperability. An essential part of mobile networks is the access part, characterized by the antennas. Antenna design for 5G is the subject of particular study these days, especially knowing the requirements in terms of speeds and latency of this technology. In addition, the challenge would be the design of a 5G antenna that takes into account several frequency bands and previous generations. Our work therefore consisted of reviewing the literature on multi-band and multi-generation 5G antenna systems. As a result, we can conclude that patch antennas are ideal for 5G and massive MIMO technology makes it possible to meet the throughput and latency requirements of 5G.

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