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Electromagnetic wave for 5G help and development

Zihang Zhang

Fujian Normal University, Fuzhou, Fujian, 350108, China

1377354261@qq.com

Abstract. Compared with 4G, 5G technology mainly realizes high-speed transmission and low-connection communication through high-frequency electromagnetic waves. This article discusses the important role that electromagnetic waves play in the development of 5G communication technology by means of review and qualitative analysis. This paper first introduces the basic characteristics of 5G, and then focuses on the spectrum of electromagnetic waves and the application of signal transmission. In particular, it plays a key role in improving the capacity and speed of data transmission in the millimeter wave band. It further analyzes how electronic wave technology will contribute to the development of 5G. In particular, support for emerging applications such as the Internet of Things and autonomous driving. The innovation of electronic wave technology not only provides the foundation for 5G, but also promotes the improvement of 5G performance and the expansion of application scope. Therefore, electromagnetic wave technology will play a key role in the future development of 5G.

Keywords: 5G technology, Electromagnetic wave, Communication technology, Spectrum management, Signal transmission.

1. Introduction

5G technology, known as the fifth generation mobile communication technology, is creating differentiation with its excellent speed, low latency, and large capacity. This advance marks a significant change for 4G, not only enabling faster connectivity, but also supporting a large number of devices. The implications are profound. Promote the development of the Internet of Things (iot), autonomous driving, telemedicine, smart city infrastructure and other fields. The core of the 5G mechanism is the use of electromagnetic waves. Electromagnetic waves move through space in the form of vibrations of electric and magnetic fields, perpendicular to each other to determine their position, perpendicular to the trajectory of the wave. These waves are characterized by wavelength, frequency, and speed, and each frequency range from radio propagation to the facilitation of optical communication has unique applications.

In the field of 5G technology, the strategic configuration of electromagnetic waves, especially high-frequency electromagnetic waves, is very important. 5G networks mainly make use of this high-frequency wave, including the millimeter wave band, which greatly improves data transmission speed and network bandwidth. This capability meets the need for fast, efficient and powerful communication solutions. Therefore, the exploration and application of electromagnetic waves is crucial to the advancement and practical implementation of 5G technology, supporting the role of electromagnetic waves in the transformation of global communication systems.

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5G is the weak of the fifth-generation mobile communication technology, and compared with 4G, 5G has faster data transmission speed, lower latency and wider connection range. A core aspect of 5G technology is the more efficient use of the electromagnetic spectrum. An important innovation in 5G technology is the use of the millimeter band domain (frequency range above 24Ghz) for communication. Millimeter waves provide greater frequencies, greater bandwidth, and higher data transmission speeds. However, millimeter waves travel a short distance and are easily blocked by obstacles such as buildings.

In the United States, telecommunications companies such as Verizon and AT&T have begun offering millimeter wave-based 5G services in select cities. These services theoretically offer ultra-fast download speeds above 1gbps. However, due to the characteristics of millimeter wave propagation, this service is currently mainly concentrated in specific areas of cities such as stadiums and business areas, and dense 5G small base stations are set up in these areas to ensure coverage and connection quality. Even taking into account atmospheric absorption, only four main frequencies can be used when propagating in the atmosphere, but the bandwidth of these four Windows also reaches 135Ghz, which is 5 times the sum of the bandwidths below the microwave, which is very attractive in today's frequency resources are tight [1].

Therefore, this paper chooses to explore the role of electromagnetic waves in the development of 5G communication technology by means of literature collation, and analyzes how electronic wave technology will promote the development of 5G by introducing the basic features of 5G, the spectrum of electromagnetic waves and the application of signal transmission, especially the support for emerging applications such as the Internet of Things (IoT) and autonomous driving.

2. Application of electromagnetic wave in 5G technology

2.1. Spectrum utilization

In 5G technology, the efficient use of electromagnetic waves is one of the key factors to improve network capacity and expand coverage. 5G networks utilize a wider spectrum range than 4G, including millimeter wave bands that offer higher data rates and lower latency.

2.1.1. Millimeter wave technology. Millimeter wave technology typically operates on the high frequency spectrum between 30ghz and 300ghz. The main reason for using 5G networks is the ability to provide extremely high data transfer speeds, which is ideal for the huge bandwidth demands of today's data-intensive applications. The technology is the basis for the ultra-fast, low-geopolitical communications promised by 5G.

However, there are many challenges with the propagation characteristics of millimeter waves. Compared with lower frequency signals, the range of the high-frequency signal is shorter, and it is also easy to decay under atmospheric conditions such as rain, fog, and leaves. In addition, millimeter waves are difficult to penetrate buildings and solid structures, resulting in greater signal loss.

To overcome these constraints, a more sophisticated network infrastructure is needed. This includes the construction of numerous cells made up of small, low-power base stations, and the construction of a tight network that ensures coverage of the entire urban landscape.

Cutting-edge beamforming technology is another important technology to effectively harness the potential of millimeter wave technology. Wave formation is a signal processing technique for antenna configuration that, instead of spreading the energy of the waves in all directions, directs them in a specific direction. In this way, the frequency beam is able to reach a shorter millimeter wave range, which provides appropriate coverage, improves reception, and minimizes interference.

There are also multiple input/output (mimo) systems, which use large arrays of antennas at base stations to manage multiple simultaneous data signals. This increases the capacity of multiple channels in the network and can provide services to more users at the same time, so in the 5G scenario, it is very important for the high-density utilization of busy streets, arenas, concert venues, etc. To be.

The combination of millimeter wave regions and massive mimo is variable. This not only increases the data transfer speed, but also increases the system capacity several times. From high-quality image

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streaming to virtual reality applications, this joint integration is essential to meet the growing communication needs of people in their daily lives.

Therefore, the effective use of millimeter wave frequencies is not only related to the composition of new technologies, but also related to the innovation of wireless network architecture. For this, there needs to be a shift from existing cellular network designs to more flexible, scalable, and adaptable networks. As technology and network design continue to evolve, the integration of millimeter wave technology into 5G will revolutionize wireless communications, providing unprecedented speed and capacity to meet the growing demands of the digital age [2].

2.1.2. Spectrum sharing. Spectrum sharing is a key and innovative technology in 5G network deployment, which is basically designed to deal with the growing demand for wireless data and the scarcity of available spectrum resources. The core principle of dynamic spectrum sharing (DSS) is the ability for different wireless communication standards, such as the latest 5G technology and existing 4G LTE services, to operate simultaneously on the same frequency band without causing harmful interference with each other.

Dynamic spectrum sharing is not just a coexistence strategy; It is an intelligent spectrum management method that utilizes advanced software algorithms and base station hardware capabilities. By using this technology, network operators can dynamically allocate spectrum in real time based on traffic demand. This means that if there are more 4G devices in an area than 5G devices, the network can allocate more spectrum for 4G services. Conversely, if the demand for 5G increases, networks can seamlessly shift spectrum allocations to 5G traffic.

Dynamic spectrum sharing improves overall network efficiency and is cost-effective. It eliminates the need for network operators to fully rezone bands for 5G, which can be a time-consuming and resource-intensive process. Instead, DSS supports the spectrum needs of 4G and 5G devices, ensuring optimal service for all users during the transition period.

In addition, dynamic spectrum sharing is not limited to LTE and 5G networks. It has the potential to be used across various types of wireless services, including dedicated satellite communications, Wi-Fi and future technologies that may emerge in the spectrum space.

The implementation of dynamic spectrum sharing also reflects a more sophisticated and forward-looking regulatory approach to spectrum management. Regulators around the world are recognizing the benefits of DSS and are adjusting their policies to support this technology, thus promoting more efficient use of the electromagnetic spectrum.

In conclusion, dynamic spectrum sharing is a testament to innovative advances in wireless technology that address spectrum scarcity and pave the way for more powerful, flexible and efficient wireless networks. It shows how technological ingenuity can lead to better resource utilization, enabling multiple generations of wireless technologies to coexist, and enhancing connectivity services for end users.

2.2. Signal transmission and reception

The signal transmission and reception process of 5G networks largely depends on the effective management of electromagnetic waves. Because 5G networks utilize a higher frequency band, new technologies must be adopted to ensure the efficient transmission and reception of signals.

2.2.1. MIMO technology. Multiple-input multiple-Output (MIMO) technology is a wireless communication technology that increases the capacity and rate of a communication system by using multiple antennas at the transmitting and receiving ends. MIMO technology has been widely used in various wireless communication systems.

Include:4G and 5G mobile communication systems: MIMO technology is a core component of 4G LTE and 5G NR standards, using multiple antennas to increase data rates and system capacity while improving signal reliability.

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Wi-Fi: Modern Wi-Fi standards such as IEEE 802.11n, 802.11ac, and 802.11ax also incorporate MIMO technology to improve the speed and coverage of wireless networks.

Radar systems: The application of MIMO technology in radar systems can improve the ability of target detection and resolution.

Satellite communications: MIMO technology is also used in satellite communications to improve the capacity and performance of communication links[3].

2.2.2. Beam forming. Beamforming is a signal processing technique that directs signals directly to user devices rather than broadcasting them in multiple directions. This approach not only improves the quality and transmission efficiency of the signal, but also reduces interference, especially when using the millimeter wave frequency band.

Beamforming can be divided into two main types: traditional beamforming and adaptive beamforming. While traditional beamforming relies on a fixed array of antennas and weight Settings, adaptive beamforming dynamically adjusts the weights based on the characteristics of the received signal to maximize signal reception quality or minimize interference.In 5G and millimeter wave communications, beamforming technology is particularly critical because it can overcome the propagation loss of high-frequency signals and improve the stability and coverage of communication links. In addition, beamforming has found a wide range of applications in radar systems, sonar systems and wireless networks.[4]

When 5G millimeter wave technology is applied in urban rail transit, it can be seen that electromagnetic wave is the effective utilization of 5G technology and the actual effect of signal transmission. In this case, through millimeter wave technology is able to provide high-speed data links passengers enjoy seamless full HD video streaming on the move, fast Internet access to labor-intensive services and other data. Also ensures smooth and efficient connection with mimo's shaping technology in complex environments such as tunnels and subway stations.

3. Conclusion

Electromagnetic waves are the linchpin of 5G technology, facilitating unparalleled advancements in the efficiency and capability of wireless networks. In the context of 5G, spectrum utilization is fundamental; it involves the strategic use of electromagnetic frequencies to enhance network capacity and extend coverage. The crux of signal transmission and reception relies on electromagnetic waves' ability to carry data with high efficiency over air, which is the cornerstone of 5G's connectivity prowess.Recent advancements in antenna design have been crucial for overcoming the inherent limitations of high-frequency signal propagation[5].

The choice of frequency bands significantly affects 5G's performance—high bands like millimeter waves offer vast data throughput but with limited range and penetration, while lower bands provide extensive coverage but with less bandwidth. Overcoming these dichotomies to strike an optimal balance is a key technological challenge. Another pressing issue is interference management, as the increased density of networks and devices can cause signal disruption, potentially compromising 5G's reliability. Innovative solutions are in constant development to mitigate these challenges.

Looking to the future, ongoing innovation in electromagnetic wave technology is essential. Research is poised to explore novel materials and antenna designs that could unlock even higher frequencies for communication, providing more bandwidth. The advancement of cognitive radio technologies that can dynamically switch frequencies in real-time to avoid interference is another promising direction.

The potential applications of electromagnetic waves in 5G are vast, from enabling smart cities and IoT ecosystems to revolutionizing industries with augmented reality and autonomous vehicles. The societal impacts are poised to be profound, dramatically improving how data connectivity integrates into everyday life. The utilization of millimeter-wave frequencies has been a game-changer for 5G networks, enabling data transmission speeds that were previously unattainable in commercial wireless communications"[6].

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It can be seen that electromagnetic waves are the pillar of 5G development, and high-speed, reliable and large-capacity wireless communication is possible. Catching these waves and innovating them will be the key to the next wave of communications technology that will most likely reshape our world. In future studies, we can go to the forefront of frequency repair, evolve interference mitigation techniques, and explore the role of electromagnetic waves in scenarios other than 5G.

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