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FUTURE 6G NETWORK FUNCTIONALITY AND PERFORMANCE

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Функциональные возможности и производительность будущих сетей 6G

В данной статье мы анализируем скорости передачи информации, новые приложения, особенности реализации телекоммуникационных систем в терагерцовом диапазоне частот. Особенностью работы в терагерцовом диапазоне основывается на свойствах материалов, связанных с проблемами зависимости пропускной способности от потребляемой мощности. Показано, что терагерцевые частоты, вероятно, будет первым беспроводным спектром, который может обеспечить расчеты в режиме реального времени.

While 5G is being developed for the spectrum in the millimeter wave range (MMR) and promises data rates of up to 100 Gb/s, future 6G networks will operate in frequency bands from 100 GHz to 1 THz, where higher data rates are possible. Short wavelengths in the MMR and the terahertz (THz) band will allow massive spatial multiplexing when transmitting data through a hub, as well as incredibly accurate sounding, visualization, spectroscopy and other functions.

The THz range, which is described as the range from 100 GHz to 3 THz, can provide secure communication over highly sensitive communication lines, for example, in the sphere of information security, due to the fact that extremely short wavelengths (of the order of microns) allow the use of antennas with extremely high amplification and small dimensions. There is very high atmospheric attenuation at frequencies of the THz range (Fig. 1). Here, highly directional “pencil” beam antennas (phased array antennas) are used to transmit the signal, to compensate the increase in losses, which increase in proportion to the square of the carrier frequency for a fixed antenna aperture size. Although narrowly directed signal emission does not guarantee complete protection against listening, this feature makes THz signals extremely difficult to intercept.

A theory called consumption factor theory (CF with a metric measured in bit/s/W) provides tools for quantitative analysis and development of approaches for understanding the power tradeoff in any communication system, especially when the frequency rises above 100 GHz.

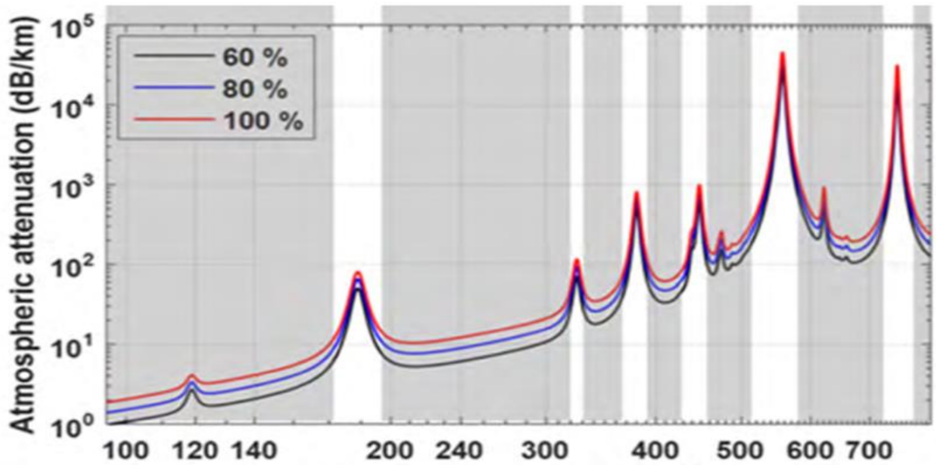

Fig. 1. Absorption in the atmosphere of electromagnetic waves at sea level as a function of frequency under different humidity conditions.

It was justified by the theory of the factor that energy consumption at high frequencies has the greatest impact on CF. The power increases with increasing bandwidth, while for a very simple radio transmitter, the required power for the auxiliary processor of the main frequency band and generator is small compared to the supplied radiated power, energy efficiency does not depend on the bandwidth. CF theory proves that for antennas with a fixed physical aperture it is more energy efficient to switch to the MMR and THz ranges. They provide a significantly wider bandwidth and increase energy efficiency in bits per second per watt (bps/W) compared to existing communications networks operating at frequencies less than 6 GHz.

The European Telecommunications Standards Institute (ETSI) and the International Telecommunication Union (ITU) are currently developing recommendations for allocating frequency bands above 95 GHz. In March 2019, the Federal Communications Commission (FCC) voted to open the spectrum above 95 GHz for the first time in the United States. The FCC provided 21.2 GHz spectrum for unlicensed use and authorized experimental licensing up to 3 THz. A group of innovative companies and universities, united to eliminate regulatory barriers for technologies, which use frequencies in the range from 95 GHz to 275 GHz in the USA, made recommendations to the FCC and the National Committee. The Telecommunications and Information Administration (NTIA) has called for promoting increased access to the spectrum above 95 GHz for non-federal use in January 2019. In 2017, the Institute of Electrical and Electronics Engineers formed the IEEE 802.15.3d task force for the global use of Wi-Fi at frequencies from 252

GHz to 325 GHz. The world's first wireless standard was created for 250-350 GHz, with a nominal PHY data rate of 100 Gbit/s and a channel bandwidth from 2 GHz to 70 GHz. The ultra-high data transfer speeds provided by wireless local area networks and cellular networks in the MMR and THz range will provide in the future: ultra-fast download speeds for computer communications, autonomous vehicles, robotic control, high-resolution holographic applications, video, conferences and high-speed wireless data switching (circuit switching) in data centers.

Terahertz frequencies are likely to be the first wireless spectrum that can provide real-time computing. So in the human brain there are about 100 billion (10^{11}) neurons, each of which can trigger (turn on) 200 times per second. Each neuron connects to 1000 others, resulting in a computational speed of 20 10^{15} operations per second. Another feature of working in the THz range is based on the properties of materials. Since certain materials and gases have vibrational absorption (for example, resonances) at certain frequencies throughout the THz range, it will be possible to detect the presence of certain elements based on frequency scanning spectroscopy. Also, most surfaces of buildings exhibit significant diffuse scattering and strong specular reflections in the THz mode. Therefore, in the THz range, it is proposed to use new sensory applications, such as miniature radars for detecting gestures and contactless smartphones, spectrometers for detecting explosives and gas detection, THz body scans, air quality tests, as well as personal health monitoring systems. These promising custom features highlight the potential for combining imaging and communications in the MMR for precise positioning in 6G systems and around it.

The use of images in the MMR and range for the reconstruction of three-dimensional environmental maps in unknown environments will combine the perception, image formation and location of objects in one function (in one place and time). As shown below, mmWave and THz signals are strongly reflected from most building materials, which allow to obtain images of hidden objects (NLOS images).

Thus, THz frequencies are likely to be the first wireless spectrum in which it is possible to implement complex innovative applications in real time.

References

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