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Comparison of Terahertz channel and SAGINs channel of 6G channels

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Abstract. This paper is mainly about researching some different types of 6G channels. The article introduces two common types of 6G channels: Terahertz channel and SAGINs channel, and studies and summarizes their advantages, problems, and development prospects, and compares them. The paper also introduces three small-scale 6G channel models.

Keywords: 6G Channel, Terahertz Channel, SAGIN Channel.

1. Introduction

A new communication system is introduced almost every ten years, introducing new technologies and providing changes to the whole world. Although 5G has just been put into use and still has untapped potential, researchers have paid their attention to the development of 6G communication technology. The reason is that 6G, compared with 5G, has up to 100 times the transmission speed and microsecond-level network latency, which makes 6G play a huge role in various fields in the future: holographic, haptic, space and underwater communications, Internet of Things and artificial intelligence. Table 1 compares the main characteristics of both 5G and 6G in order to clearly and intuitively demonstrate the superiority of 6G. From the table, we can safely draw the conclusion that compared with 5G, 6G has great advantages in all aspects and the research investment in 6G should be increased.

Table 1. Comparison between 5G and 6G.

Characteristic	6G	5G
Frequency	up to 1 THz	3 - 300 GHz
Uplink data rate	1 Tbps	10 Gbps
Downlink data rate	1 Tbps	20 Gbps
Spectral efficiency	1000 bps/Hz/m2	10 bps/Hz/m2
Reliability	10-9	10-5
Maximum mobility	1000 km/hr	500 km/h
U-plane latency	0.1 msec	0.5 msec
C-plane latency	1 msec	10 msec
Processing delay	10 ns	100 ns
Traffic capacity	1 - 10 Gbps/m2	10 Mbps/m2

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Table 1.(continued).

Localization precision	1 cm on 3D	10 cm on 2D
Uniform user experience	10 Gbps 3D	50 Mbps 2D
Time buffer	real-time	not real-time

Till now, various types of 6G channels have been studied to realize the birth of 6G technology, and in the research process, technical problems have emerged one after another. Among those various types of 6G channel models, Terahertz channel, SAGINs channel and other three small-scale 6G channel models get great attention of 6G researchers. Making comparison of these 6G channels helps deepen the understanding of 6G channels and select the most suitable 6G channel in the future.

The reminder of this paper is organized as follows. Terahertz Channel will be dressed in Section 2, SAGINs Channel will be dressed in Section 3. Comparison of terahertz channels versus channel advantages will be dressed in Section 4. At last, three small-scale 6G channels will be dressed in Section 5.

2. Terahertz Channel

2.1. Features

With the exponential growth of data traffic demand, millimeter wave communication technology below 100GHz officially applied in 5G (5th generation mobile communication technology) cellular network is no longer able to meet a number of key technical indicators of 6G wireless communication, so our group decided to study several typical 6G channels, the THz channel unique four advantages have the potential to meet the future needs of 6G wireless system: tens of GHz or even thousands of GHz bandwidth, picosecond level symbol duration, able to integrate thousands of submillimeter length antennas, and easy to coexist with other standardized frequency bands.

Therefore, terahertz communication makes it possible to use wireless LAN, Internet of Things, integrated access return, space communication, and supports a number of advanced communication technologies such as on-chip network, nano Internet of Things, communication perception integration including virtual, augmented reality and meta-universe.

2.2. Advantages

Terahertz communication refers to the spatial communication using terahertz waves as an information carrier. The terahertz frequency band has a great unallocated bandwidth, has the ability to support a transmission rate of higher than 10Gbps, and has better ability against interference. Using the Terahertz frequency band for communication can alleviate the increasingly tense spectrum resources effectively, which is the primary choice of the future wireless communication. In comparison with optical and microwave communication, it will have wide applications in wireless secure access network, large-capacity military confidential communication and long-distance satellite communication with its high transmission rate.

2.2.1. Outer Space Communication. Outer space communication. Terahertz communication is wider than the optical communication beam, with easy receiving end to align, and low quantum noise; Compared with microwave band, the antenna system can be flattened [1]. Therefore, Terahertz communication is more suitable for satellite space communication, and can be used to build a broadband mobile high-speed information network between satellites, between satellites and between satellites and local area networks. The International Electric Wire Alliance has reserved a 200GHz frequency band for the next step of satellite communication, and with the further development of satellite communication, it will surely enter the communication range of terahertz above 300GHz.

2.2.2. High-speed Aircraft Communication. For high-speed flying near-space vehicles and re-atmospheric aircraft will generate plasma with a frequency of tens of GHz around them, forming a "black barrier" communication blind zone, resulting in rapid attenuation and interruption of radio telemetry signals, terahertz wave communication is the only communication tool that can penetrate plasma.

2.2.3. Military Communication. Military communication large capacity close range military confidential communication can use terahertz communication technology. High frequency THz wave is easy to be absorbed by water in the air, signal attenuation is serious, transmission distance is short; and narrower than microwave beam, wide bandwidth, with stronger anti-interference ability, can realize the battlefield short-distance directional confidential communication within 2~5 km, has the advantage of large capacity communication. Terahertz communication can be used in GHz bandwidth expansion and FM communication, tactical level regional confidential communication and networking, aviation formation communication, etc.

2.2.4. Wireless Secure Access. At present, there is a growing demand for high-speed indoor wireless communication systems. The Terahertz wave has a communication rate of higher than 10GB / S, which can be used for secure wireless access with very high transmission rate, and is likely to replace the current Bluetooth and wireless LAN in the future. Terahertz communication is a promising technology. Terahertz wave has a very wide and unassigned frequency band, and it has a high rate, good direction, high safety, small scattering, and penetration good sex and many other characteristics [2]. Terahertz communication will certainly bring great technological progress to the communication system, solve some current technical problems, and provide technical support for new applications. In the further development of high-speed wireless technology, the trend of high-speed will inevitably develop to the higher frequency terahertz frequency band, and the mature optical communication on the backbone network will inevitably seek to combine with millimeter wave submillimeter wave under the development requirements of human connection network and wireless mobile.

2.3. Challenges

Terahertz bands have irreplaceable advantages for mobile communications but at the same time face many challenges.

2.3.1. Coverage and Directional Communication. Overwrite works with directional communication. The characteristics of electromagnetic wave propagation show the free space decline size is very in proportion to the square of the frequency, therefore the THz has a large decline of free space in the relatively low-frequency stage. THZ propagation distinguishing feature and big aerial arrays signify that THZ communication is a high- directional beam propagation. For this high-directive propagation signal Characteristics we need to design again and majorization the related mechanisms.

2.3.2. Large scale Decline Features. THZ signals are extremely susceptive to shadow and they have big impact on overlap.

2.3.3. Fast Channel Fluctuations and Intermittent Connections. Fast-channel fluctuations are associated with intermittent connections. Speed of given, the channel coherence time is in linearity, which means that it has very small Hz coherence time while it has very large Doppler expansion, much faster than the current frequency stage. Moreover, higher shadow fading will cause THz propagating path fading to fluctuate more sharply. At the same time, the THz system constitutes a small coverage area, and is a highly spatially oriented signal transmission, meaning that the path fading, service beam and cell correlation will change very rapidly [2]. From the aspect of system, the connectivity of flavored THZ communication systems will be highly intermittent, requiring rapid adaptation mechanisms to overcome this rapidly changing intermittent connectivity problem.

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2.3.4. Power Consumption. Deal with watt loss. One grand challenge of using very big scale aerials is analog-to-digital conversion power consumption of broadband THz systems. And watt loss is usually in linearity with the sampling frequency and exponential with the quantities of samples.

2.4. Future Research Direction

The large bandwidth in the Terahertz band requiring high-resolution quantization implementing low-cost and low-power devices will be a huge challenge to sustain THZ communications. Following several aspects need more profound research.

a. The technology of semiconductor of RF, digital logic and analog baseband.

b. Researches on high speed baseband semaphore processing technique and IC design method with low power consumption and low complexity and development terahertz highspeed communication baseband flat.

c. Channel measurement and modeling of terahertz space and terrestrial communications [3].

Above study needs to be taken into account in order to achieve a balance between the complexity, performance and power consumption of Terahertz channel.

2.5. Conclusions of Terahertz Channel

Table II shows the conclusions of the research results in Terahertz channel including its features, challenges and future research direction.

Table 2. Conclusions of Terahertz Channel.

Terahertz Channel	Features	Outer Space Communication
		High-speed Aircraft Communication
		Military Communication
		Wireless Secure Access
	Challenges	Coverage and Directional Communication
		Large-scale Fading Characteristics
		Fast Channel Fluctuations and Intermittent Connections
		Power Consumption
	Future Research Direction	Semiconductor technology, high-speed baseband signal processing technology, Modulation and demodulation, Waveform and channel coding, Synchronization mechanism, Channel measurement

3. SAGINs Channel

With the rapid development of 5G, 6G-related research is also emerging in an endless stream. SAGINs channel is one of the models of 6G channels, which have gained great attention. SAGINs integrate satellite network, space network and ground experiment network together. It brings significant advantages like non-terrestrial networks, seamless global coverage, high flexibility, and enhanced system capacity as mentioned in [4]. The excellent performance of SAGINs in many aspects will inevitably bring more challenges, such as more difficult and complex calculations. At present, there have been a lot of studies on SAGINs, and this paper will sort out and summarize these studies.

3.1. Advantages

The Non-Terrestrial Network (NTN) systems used in 6G have more benefits than 5G, and it mentioned that in 6G wireless communication, NTN may become indispensable in order to make sure total flexibility and integration of terrestrial and satellite networks [5]. But NTN architecture also has lots of disadvantages like high latency and poor flexibility [6]. So compared with 5G NTN communications, the SAGIN architecture has lots of advantages shown as follows (this research has shown the main part):

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3.1.1. Lower latency. In the 5G NTN architecture, the whole communication functions are performed on the ground, many obstacles on land such as bibliography and buildings will interfere with communication. On the contrary, the architecture of 6G SAGIN is a holistic-service architecture, which means some complex processes in the communication, such as encoding and decoding, connection establishment and release, can be organically unified and connected [6]. Therefore, the communication process can be carried out more smoothly so that the latency is reduced a lot.

3.1.2. Better flexibility. In the 5G NTN architecture, all hardware is configured in advance, and it is difficult to change and optimize. But the 6G SAGIN architecture is changeable and customized according to requirements. So compared to 5G non-terrestrial network, the SAGIN channel of 6G have the ability of adapting to the actual application environment. Therefore, better flexibility makes 6G communication greatly improved in terms of time delay, communication quality, etc.

3.2. Challenges and development of SAGINs

Space-Air-Ground integrated Network contains three kinds of channels, while it coordinates and combines their advantages, problems and challenges are inevitably brought in the practical use. One of the main challenges is that the satellite network is vulnerable to physical problems. When the satellite power is reduced due to system maintenance or other problems, the connection will be interrupted. So the backup and recovery of communication data in case of interruption is worth studying and solving in order to protect the connection data completely.

High comprehensiveness and adaptability based on SAGIN channel gives more applications of 6G communication and probabilities of combining with other technology to better improve the communication property. In [7], the Service-based Architecture (SBA) is one of the pivotal innovations and progress of 5G architecture and SBA can be applied to SAGIN to better improve the performance of 6G. In [8] data acquisition and transmission oriented to 6G can be applied on the basis of space air ground integrated network. The SAGIN network built by 6G fills the gap of global network coverage [9]. However, a variety of research ideas and prospects also provide challenges for the future research of 6G channel technology, and the lack of SAGIN related research leads to many unknown challenges and difficulties that have not been explored.

3.3. Conclusions of Terahertz Channel

Table III shows the conclusions of the research of SAGINs channel including its advantages, challenges and further development.

Table 3. The conclusion of SAGINs channel.

<table>
<tr><td rowspan="8">SAGINs Channel</td><td rowspan="4">Advantages</td><td>Lower latency</td></tr>
<tr><td>Better flexibility</td></tr>
<tr><td>Architecture of holistic services</td></tr>
<tr><td>Large system capacity</td></tr>
<tr><td rowspan="4">Challenges and development</td><td>Satellite power</td></tr>
<tr><td>Service-based Architecture (SBA)</td></tr>
<tr><td>Data protection and stability of satellite network</td></tr>
<tr><td>Establishment of the channel model</td></tr>
</table>

4. Comparison between Terahertz Channels and SAGINs Channels

In order to understand the Terahertz channels and SAGINs channels better, a comparison is made mainly in two aspects: difference in their advantages and challenges that may meet in the future.

4.1. Advantages

SAGINs architecture is an architecture of holistic services that integrates satellite networks, space networks and terrestrial experimental networks to achieve non-terrestrial networks, seamless global coverage, and therefore, the use of SAGINs This allows the communication process to proceed more smoothly, greatly reducing latency. Terahertz communication is more suitable for satellite space communication because it is wider than the optical communication beam, the receiving end is easier to adjust, and the quantum noise is also lower. It also can be used to build broadband mobile high-speed communication, between satellites, and between local area networks.

Because the SAGINs architecture can be changed and customized upon request, it is more flexible and has a larger system capacity. While the terahertz band has a large unallocated bandwidth, the application of terahertz band communication can effectively alleviate the increasingly strained spectrum resources, terahertz waves in the high frequency band transmission distance in the air is shorter, and narrower than the microwave beam, the bandwidth is wider, Short-range targeted high-capacity communication can be realized.

4.2. Challenges

As for Teraherze channel, the main challenges are channel fading problems, which may cause the distortion of transmitted signal and so that the receiver gets wrong information. And also challenges like coverage problem and power consumption. As for SAGIN channel, the main problems are the data protection and stability of satellite network. There are some same challenges of both THz and SAGIN channel like the difficulties of application of other technologies and the establishment of the channel model. The various challenges faced by the two channels are also the future research directions.

5. Three Small Scale 6G Channel Models

Although channels mentioned above like Terahertz Channel can be used in most cases, some other 6G channels are needed in special situation like satellite communication or underwater communication. As for various types of frequency bands, here are some small-scale channel models [10].

Optical wireless channels provide a most universal way to transfer information in common situation. It can be used in most situation like indoor, outdoor, underground and so on. However, it may meet the challenge like complex scattering characteristics due to different kinds of materials, high background noise effects and other difficulty which may seriously influence the quality of communication.

Satellite channel, mainly used in GEO, LEO, MEO and HEO, will meet the challenge such as bad attenuation, extremely large Doppler frequency shift caused by high-speed relative motion. Each coin has two sides, it can also provide large coverage range and long communication distance.

Similarly, under communication also has many problems. The communication under water is usually not that good for many reasons, for example facing a high transmission loss, multipath propagation, time-varying and potential interference caused by Doppler effects.

In the table below, three small-scale channel models will be briefly introduced in aspects like measured scenarios, characteristics, frequency bands, deterministic and stochastic.

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TABLE 4. Comparison of Three Small-Scale Channel Models.

Wireless channel	Measured scenarios	Channel probabilities	Frequency bands	Deterministic	Stochastic
Optical wireless channels	In doors, out doors, under the ground, and under the water	Complex scattering characteristics due to several materials, non-linear photoelectric properties at Tx/Rx ends, background noise effects.	Mainly 380-780 nm	Recursive model, iterative model, DUSTIN model, ceiling bounce model, and geometry based deterministic model	GBSM , non-GBSM
Satellite channel	GEO (Geostationary Earth Orbit), LEO(Low Earth Orbit), MEO(Medium Earth Orbit), and HEO(Highly Eccentric Orbit)	Rain/cloud/fog/ Snow attenuation, extremely large Doppler frequency shift and Doppler spread, frequency dependence, large coverage rang, long communication distance	Ku, V, K, and Ka bands	\	GBSM , non-GBSM (Markov model)
Underwater acoustic channel	Under water	High transmission loss, multipath propagation, time-varying, Doppler effects	2-32 kHz	ray tracing	GBSM

6. Conclusion

5G telecommunication technology applied in 2020 would not satisfy the more and more growing demands in the future. Therefore, research in 6G should be carried out to be able to reach the further goals before 2030 and 6G channels should be a focus of 6G researchers. In this paper, different types of 6G channels are summarized. Their features and challenges are presented. It is concluded that with different 6G channels, 6G will make great contributions to the world in the future.

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