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Design of THz Space Application System

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Abstract

Two kinds of space applications of THz band are proposed. A novel method for the THz band signal propagation in the satellite-earth link is studied in order to overcome the huge loss in the atmosphere. The THz signal should be transformed to Ka band by data processor on satellite, and then be transmitted to the earth station in order to avoid the THz loss in the atmosphere. The design can realize at least 10 Gbps space communication or data relay. Furthermore, three aspects of challenges in THz band are analyzed.

Keywords

THz Band, Space Communication, Data Relay, System Design, Inter-Satellite Link

1. Introduction

The Terahertz (THz) wave is about from 0.1 THz to 30 THz, which is between the microwave and the infrared band. Due to the unique advantages of THz wave, it is suitable for the application in the inter-satellite links, which can support the high-throughput communication with high security as well as the ability to defeat the interference. However, the significant path loss and the atmosphere propagation loss lead to the difficulty of THz wave used in satellite-earth communication [1].

Communication utilizing THz wave can combine the advantages of both optical and microwave, and can overcome their limitation [2]-[4]. Compared with the microwave, the THz wave is more preferred for ultra-wide band communication. Different from optical communication, the THz wave is not visible and the problems in optical communication such as low sensitivity of IM/DD, huge complexity of coherent communication equipment and narrow beam for tracking would not occur in THz communication system. The current research on THz space application focused on the telemetry and telecommand of aircraft during the black-out-area, the communication among formation flying satellites network and the spatial trunking communication [5].

In this paper, we propose to utilize THz communication in the inter-satellite links, and use Ka band communication in the satellite-earth link. The loss of THz wave in the atmosphere is too heavy to transmit to the earth

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from a satellite. Hence, the novel method of the THz/Ka transformation in space application is developed in order to overcome its huge loss in the atmosphere.

2. System Design

2.1. Scope of Application

The space application of THz wave in this paper is focused on the communication and data relay in the long distance of GEO-GEO or LEO-GEO inter-satellite link (shown as in **Figure 1**), although there are many other applications of THz wave in space.

Due to the huge path loss and atmosphere loss of THz wave, more attention should be paid to the transmission in the link of satellite-to-earth. In the scheme presented as follows, THz band is used in the inter-satellite link for high capacity transmission, and Ka band is chosen in the satellite-to-earth link for high communication reliability.

The GEO-GEO link mode (named MODE 1, **Figure 2**) is used for communication or data relay by THz wave between two GEO satellites, so an enormous amount of information can be transmitted. The LEO-GEO link mode (named MODE 2, **Figure 3**) is connected by THz wave between a LEO satellite and a GEO satellite, which helps deliver the remote sensing data from LEO satellite to the earth station in time.

2.2. THz/Ka Transformation

The satellite-to-earth link is the bottleneck of the THz application in space because of its enormous path loss and atmosphere loss compared with the tiny THz transmission power. Hence, Ka band is chosen to replace THz band to overcome the hung loss. The transformation from THz band to Ka band is the core part of the link. The novel transform method includes data processing, router optimizing, coding, modulating, RF amplifying and the transmitting. The block diagram is shown as **Figure 4**.

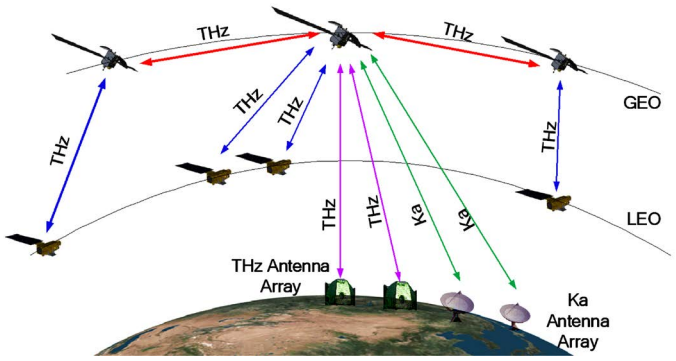

Figure 1. THz application in space.

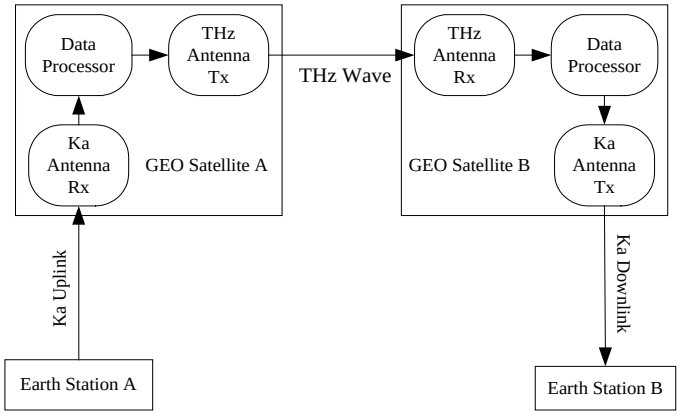

Figure 2. Block diagram of MODE 1 (GEO-GEO link).

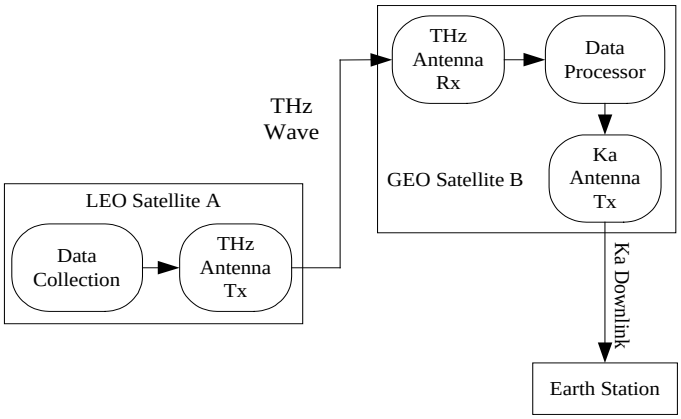

Figure 3. Block diagram of MODE 2 (LEO-GEO link).

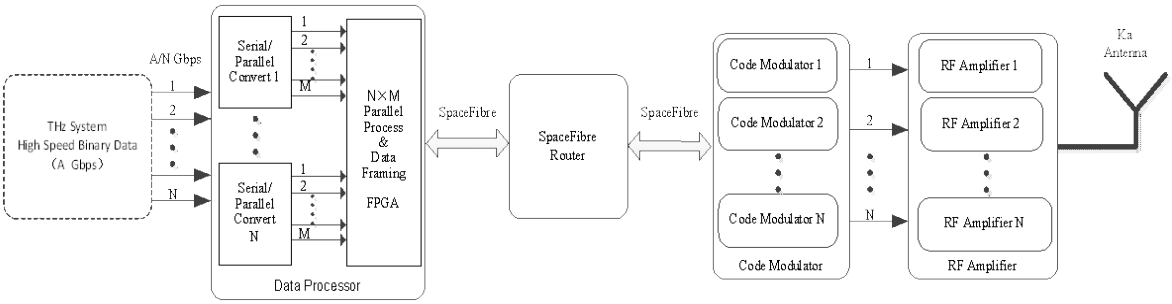

Figure 4. Block diagram of THz/Ka transform.

1) Data divided: a high data rate (A Gbps) binary data received by THz wave should be divided into N part equally, which is still serial data.

2) Serial parallel conversion: the serial data of each divided part will convert to M channels parallel data in the data processor, in order to depress the requirement of the processing rate of FPGA and clock.

3) Data framing: the N × M parallel data are made into specific format frame in FPGA for distinguishing these characters at the earth station.

4) Router distribution: the framed data are distributed into any idle RF amplification channel, which can utilize the transponder effectively.

5) RF channels: the framed data are coded, modulated and amplified in the Ka channels, and then transmitted by Ka antenna. Space division multiplexing, frequency division multiplexing and polarization multiplexing should be used to utilize the spectrum resources effectively.

The satellite-to-earth link is the crucial part of the THz application in space. However, the tiny THz transmission power, enormous path loss, huge atmosphere loss, and low antenna gain result in the difficulty of utilizing the THz band in the satellite-to-earth link. The performance of Ka band in the atmosphere is better than THz band. Therefore, the THz band signal should be transformed to Ka band. The novel transforming channel proposed in this paper includes data processor, space fiber router, code modulator, RF amplification and the transmitting antenna.

The BER performance of Ka link has been simulated as in **Figure 5**. The results of three coding and modulation schemes, shown as 8PSK, LDPC_GF(2) + 8PSK and LDPC_GF(8) + 8PSK in **Figure 5**, have be demonstrated, and the LDPC_GF(8) in octonary number system with 8PSK achieves better performance for high SNR. Hence, the 8PSK is selected as the modulation strategy and the LDPC_GF(8) is chosen as the channel coding scheme.

The data rate of the satellite-earth link can achieve 10 Gbps with the space division multiplexing, frequency division multiplexing and polarization multiplexing, when the bandwidth is 750 MHz, the molding coefficient α is adopted as 0.5 and two Ka antennas are used for communication. The date rate can grow linearly as the increase of the bandwidth. When the bandwidth is 1.5 GHz, the data rate raises up to 20 Gbps.

3. Challenges in THz Band

The space applications of THz wave are introduced in the paper. The THz/Ka transformation is used to realize the transmission through the atmosphere. However, there are still several challenges in this aspect.

3.1. THz Power Amplifier

The limitation of the power capacity in THz band amplifier restricts the application of THz devices. The novel transistors with higher output power are expected. Hence, the research on hetero-junction bipolar transistor (HBT), high-electronics mobility transistor (HEMT), ballistic deflection transistor (BDT) and nano-wire field-effect transistor (NWFET) is undergoing for realizing higher power [4]. Meanwhile, the vacuum electronics devices, such as THz klystron (EIK), TWT and gyrotron, are studied to produce huge output power.

On the other hand, in order to overcome the limitation of the power in a single THz amplifier, the power combining technique using an array of antennas was proposed [2] [4]. Actually, the multi-port-amplifier (MPA, **Figure 6**) can be used as the power combining method. When all the active elements in the input antenna are used as a single beam, the MPA (N × N) can amplify the signal by N times.

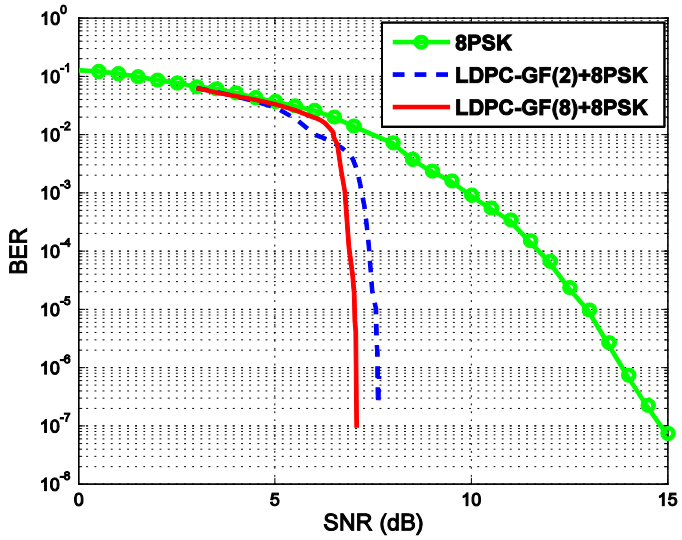

Figure 5. BER v.s. SNR of Ka Link.

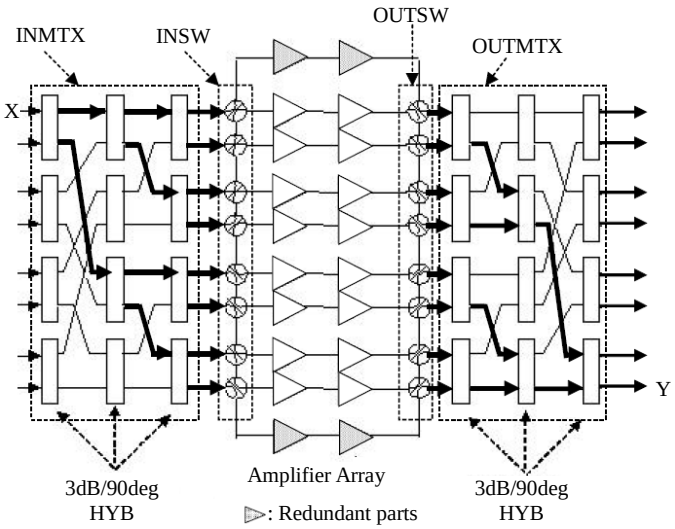

Figure 6. Block diagram of MPA.

3.2. THz Antenna

Due to the enormous path loss for long distance in space and tiny power capacity, the high gain antenna is preferred. The traditional reflector antenna used for THz band will bring some problems because of the extremely higher requirement of surface precision, although this kind of antenna has larger gain. Furthermore, the appropriate beam width is necessary for the acquisition, tracking and pointing.

The massive MIMO (multiple input multiple output) antenna can be used for THz band. In the space application, the most case is that all the elements of MIMO antenna array can create a single razor-sharp beam between the transmitter and the receiver [2] [4] [6].

3.3. THz Signal Processing

The classical signal processing method cannot fully benefit from the properties of the THz band signal. The new channel models are required for the THz wave propagation. New coding schemes are needed to overcome the channel errors in the THz band. Different bandwidths and transmission distances of THz wave applications require various adaptable modulations [2]-[4].

Moreover, high data rate THz signal needs to be converted quickly between serial data and parallel data according to Section 2.2, in order to realize the THz/Ka transformation. The receiving and detection of THz signal are both complicated for space application.

4. Conclusion

In this paper, the THz space application system was proposed, where the THz band is utilized in the inter-satellite links, and the Ka band is used in the satellite-earth link. The novel method of the THz/Ka transformation in space application is developed to overcome the huge loss in the atmosphere. The design can realize at least 10 Gbps space communication or data relay. Furthermore, the application challenges for THz power amplifier, THz antenna and THz signal processing are demonstrated.

References

[1] Song, H.J. and Nagatsuma, T. (2011) Present and Future of Terahertz Communications. *IEEE Trans. on Terahertz Science and Technology*, **1**, 256-263. http://dx.doi.org/10.1109/TTHZ.2011.2159552

[2] Akyildiz, I.F., Jornet, J.M. and Han, C. (2014) Ternets: Ultra-broadband Communication Networks in the Teraherta Band. *IEEE Wireless Communication*, 130-135.

[3] Ostmann, T.K. and Nagatsuma, T. (2011) A Review on Terahertz Communications Research. *Journal Infrared Milli Terahz Waves*, **32**, 143-171. http://dx.doi.org/10.1007/s10762-010-9758-1

[4] Huang, K.C. and Wang, Z.C. (2011) Terahertz Terabit Wireless Communication. *IEEE Microwave Magazine*, 108-116. http://dx.doi.org/10.1109/MMM.2011.940596

[5] Liu, F., Zhu, Z.B., Cui, W.Z., *et al.* (2013) Application of Terahertz Techniques in Space Science. *Journal of Terahertz Science and Electronic Information Technology*, **11**, 857-866.

[6] Shimizu, N. and Nagatsuma, T. (2006) Photodiode-integrated Microstrip Antenna Array for Subterahertz Radiation. *IEEE Photon. Technol. Lett.*, **18**, 743-745. http://dx.doi.org/10.1109/LPT.2006.871131