Transmission Power Ratio Optimization on Superposed Low-Speed CDMA Signal Transmission over High-Speed OFDM Signal

Sana Kagaya
Graduate School of Engineering
Kogakuin University
Tokyo, Japan
cm24016@ns.kogakuin.ac.jp

Takatoshi Sugiyama
Graduate School of Engineering
Kogakuin University
Tokyo, Japan
tsugiyama@cc.kogakuin.ac.jp

***Abstract*—In recent years, while Non-Terrestrial Network (NTN) have been attracting attention in Beyond 5G/6G, various systems via LEO (Low Earth Orbit) is superior to wide-area capability are being studied. Moreover, it is desirable to transmit high-speed signal such as video transmission systems and low-speed signal such as IoT data transmission systems simultaneously at the same transponder for effective use of LEO transponder. In this system, the use of CDAM (Code Division Multiple Access) scheme for low-speed signal enables higher frequency utilization efficiency. Therefore, low-speed signal is superposed on the same frequency band over high-speed OFDM (Orthogonal Frequency Division Multiplexing) signal has been proposed. In this paper, the BER (Bit Error Rate) performances both of high-speed OFDM signal and low-speed CDMA signal. Moreover, transmission power ratio is changed and is shown to optimize transmission power ratio.**

Keywords*—NTN, LEO, CDMA, OFDM, superposed transmission, transmission power ratio

I. Introduction

In recent years, while Non-Terrestrial Network (NTN) connecting three dimensional space such as space, sky, and sea have been attracting attention in Beyond5G/6G, in order to provide a wide range of mobile communication services[1]. LEO (Low Earth Orbit) systems, one of the NTN elements, is superior to terrestrial systems wide-area capability and GEO (Geostationary Earth Orbit) systems rapidity capability[2]. Therefore, various systems such as video transmission systems that handle high-speed signals of 12Mbps~54Mbps and IoT (Internet of Things) data transmission systems that handle low-speed signals of 12kbps~325kbps via LEO[3] have been studied, respectively. In the future, it is desirable to transmit high-speed signals and low-speed signals simultaneously at the same transponder in order to make effective use of LEO transponder, as shown in Fig. 1.

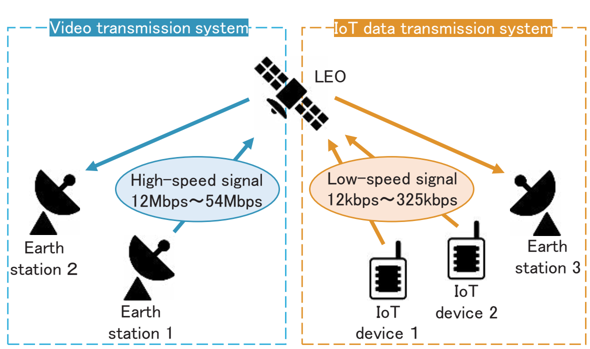

Fig. 1. Simultaneous transmission system of high- and low-speed signals

II. Simaltaneous Transmission Scheme

In communication through LEO, it is necessary to solve issues such as effective use of frequency bandwidth and smaller and more economical earth stations. In this case that high-speed signal and low-speeds signal will be simultaneously transmitted over the same LEO transponder, there have been three multiplexing ways, FDMA (Frequency Division Multiple Access) scheme, TDMA (Time Division Multiple Access) scheme and CDMA (Code Division Multiple Access) scheme.

A. FDMA Scheme

Fig. 2 shows FDMA scheme. FDMA scheme requires splitting the LEO transponder bandwidth for high-speed signal and low-speed signals, and guard bands must also be provided to avoid adjacent channel interferences. Therefore, as the number of low-speed signal channels increases, the total required bandwidths become wider as shown in Fig. 2.

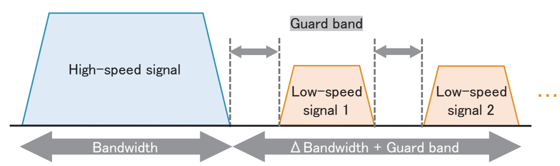

Fig. 2. FDMA scheme

B. TDMA Scheme

Fig. 3 shows TDMA scheme. The TDMA scheme needs combined transmission of high- speed signal and low-speed signals in a time slot, and this needs excess bandwidth for low-speed signals in addition to the bandwidth for high-speed signal as shown Fig. 3. Moreover, TDMA scheme approach leads to a higher-power amplifier for each transmitter.

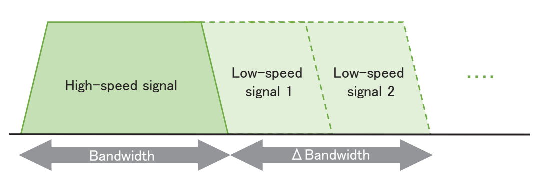

Fig. 3. TDMA scheme

C. CDMA Scheme

As mentioned above, in this case that high-speed signal and low-speed signals will be simultaneously transmitted over the same LEO transponder, the required bandwidth expands as the number of low-speed signals increase in FDMA scheme and TDMA scheme. Therefore, FDMA and TDMA schemes don't make effective use of frequency bandwidth. In order to achieve a higher frequency utilization efficiency, CDMA scheme for low-speed signals which allow them to be used over high-speed signal has been superposed[4].

Fig. 4 shows CDMA scheme. In this scheme, the bandwidth of low-speed signals are spread to the same bandwidth as high-speed signal without increasing the required bandwidth as shown in Fig. 4. This scheme needs no excess bandwidth and enables to use lower-power amplifier of less for low-speed signal transmission. Thus, the earth stations which transmit only low-speed signals are very reasonably small-sized. Moreover, it is easy to realize the demand assignment of low-speed signals without complicated synchronization control schemes. In addition, high-speed signal canceller such as NOMA[5] might not be required by using the de-spreading receiver.

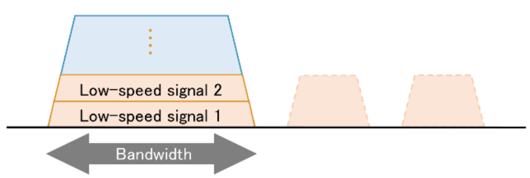

Fig. 4. CDMA scheme

In the conventional scheme[6], single carrier modulation schemes have been used for high-speed signal. As the results, it has been clarified that this scheme is more useful than FDMA and TDMA scheme.

III. Proposed Shcheme in The Previous Studied

We have proposed a new superposed transmission scheme of high-speed OFDM (Orthogonal Frequency Division Multiplexing) signal and low-speed CDMA signals in which OFDM modulation that has been mainstream in Beyond5G/6G and used in the majority of a wide range of mobile systems, is applied to high-speed signal[7]. An overview of the proposed superposed transmission scheme is shown Fig. 5. High-speed OFDM signal transmits the data without modification, whereas low-speed CDMA signal uses a spreading code to spread the data to the same bandwidth as high-speed OFDM signal. Moreover, high-speed OFDM signal is transmitted at higher-power, while low-speed CDMA signal is transmitted at lower-power. When demodulating, the difference in power allows high-speed OFDM signal to be demodulated without any interference from low-speed CDMA signal, because the effect of interference from low-speed CDMA signal can be ignored. On the other hand, low-speed CDMA signal is de-spread code to the original required bandwidth by adding a de-spreading code identical to the same used at the transmitter side and the effect of interference from high-speed OFDM signal can be reduced by passing it through a narrow bandwidth filter matching the required bandwidth of the original.

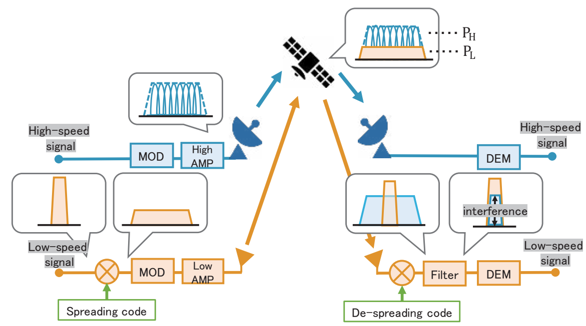

Fig. 5. An overview superposed transmission scheme of the proposed

Transmission power ratio is defined as P_H/P_L. Previous studies have evaluated the transmission power ratio at 20dB only. Therefore, this paper evaluates the BER (bit error rate) performance of high-speed OFDM signal and low-speed CDMA signal with regard to changes in transmission power ratio and optimizes transmission power ratio based on the number of simultaneously transmitted low-speed CDMA signal channel.

IV. Simulation with Variable Transmission Power Ratio

A. Simulation Parameters

Simulation parameters and simulation block diagram of the proposed are shown in Fig. 6 and TABLE I. High-speed OFDM signal was assumed to 12Mbps for video transmission system and low-speed CDMA signals was assumed to 20kbps for IoT data transmission system[8]. FEC (Forward Error Correction) scheme is convolutional coding (R = 1/2, K = 7) and Viterbi decoding. The first modulator scheme for both of high-speed OFDM and low-speed CDMA signal is QPSK (Quadrature Phase Shift Keying) modulation. The second modulator scheme for high-speed OFDM signal is OFDM modulation (symbol lengths = 4μs, number of subcarriers = 48). On the other hand, for low-speed CDMA signal is CDMA scheme (spreading factor = 30dB, chip rate = 20Mchip/s) is applied. Moreover, the required bandwidth is selected to be 20MHz assuming Wi-Fi because of the simplicity of high-speed OFDM signal and transmission power ratio of high-speed OFDM signal to low-speed CDMA signal is changed from 10dB to 30dB. AWGN is used as the propagation path.

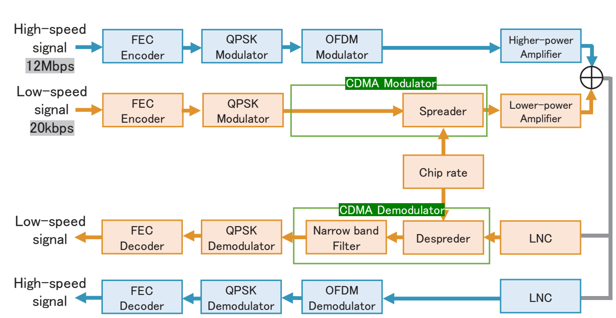

Fig. 6. Simulation block diagram of the proposed

TABLE I. SIMULATION PARAMETERS OF THE PROPOSED

Parameter	***High-speed OFDM signal***	***Low-speed CDMA signal***
Information bit rate	12Mbps	20kbps
FEC	Convolutional coding-Viterbi decoding (R = 1/2, K = 7)	
1st modulator scheme	QPSK	
2nd modulator scheme	OFDM Symbol lengths = 4µs Number of subcarriers = 48	CDMA Spreading factor = 30dB Chip rate = 20Mchip/s
Required bandwidth	20MHz	
Transmission Power ratio (P_H/P_L)	10, 20, 22, 24, 26, 28, 30dB	
Propagation path	AWGN	

B. The BER Paformance

As simulation result, first, the BER performance of high-speed OFDM signal are shown in Fig. 7. The vertical axis is BER and horizontal axis is SNR (signal to noise power ratio) with parameter of P_H/P_L. For spreading factor of 30dB, as smaller P_H/P_L the BER performances become decreasing. For example, When evaluated at the required SNR at BER = 10^{-4}, the SNR = 3.75dB at P_H/P_L = 30dB, SNR = 6.6dB at P_H/P_L = 20dB compared to SNR=3.5dB without low-speed CDMA signal, showing that the BER degrades with decreasing transmission power ratio.

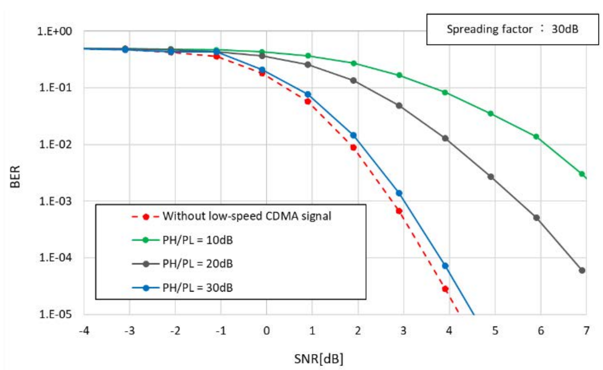

Fig. 7. The BER of high-speed OFDM signal

Second, BER performances of low-speed CDMA signal are shown in Fig. 8. The vertical axis is BER and horizontal axis is SNR[dB] with parameter of P_H/P_L. From this figure as higher P_H/P_L the BER performances become worse. For example, When evaluated at the required SNR at BER = 10^{-4}, the SNR = 5dB at P_H/P_L = 10dB, SNR = 5.5dB at P_H/P_L = 20dB compared to SNR = 3.75dB without high-speed OFDM signal, showing that the BER degrades with increasing transmission power ratio.

Identify applicable funding agency here. If none, delete this text box.

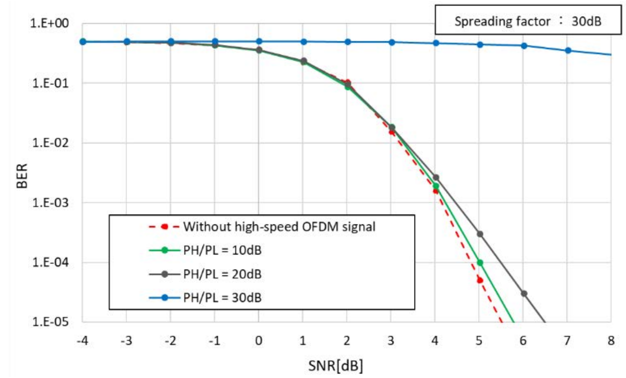

Fig. 8. The BER of low-speed CDMA signal

C. Transmission Power Ratio Optimization

Finally, the optimized transmission power ratio of high-speed OFDM signal and low-speed CDMA signal is shown in Fig. 9. This figure is evaluated in P_H/P_L at the required SNR at the BER = 10^{-4} of high-speed OFDM signal and low-speed CDMA signal. When spreading factor at 30dB, in the required SNR degradation in BER=10^{-4} is allowed to be 3dB, as a result of considering the figure of high-speed OFDM signal and low-speed CDMA signal, P_H/P_L = 19~24dB is the optimized figure for superposed transmission.

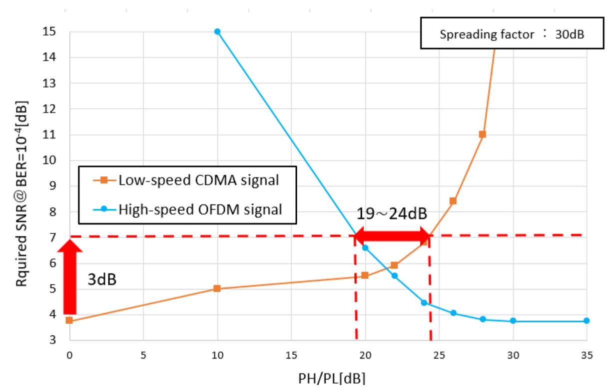

Fig. 9. Evaluation of transmission power ratio optimization

V. CONCLUSION

In recent years, while NTN have been attracting attention in Beyond 5G/6G, various systems using LEO is superior to wide-area capability are being studied. Moreover, it is desirable to transmit high-speed signal such as video transmission system and low-speed signal such as IoT data transmission systems simultaneously at the same transponder for effective use of transponder. In this system, the use of CDAM scheme for the low-speed signal enables higher frequency utilization efficiency and low-speed signals are superposed on the same frequency band over high-speed OFDM signal has been proposed. In this Paper, the bit error rate performance of high-speed OFDM signal and low-speed CDMA signal and transmission power ratio is changed and is shown to optimize power ratio. As a result, it was confirmed that the BER performances changes depending on the transmission power ratio**.** Moreover, in the required SNR degradation in BER = 10^{-4} is allowed to be 3dB, as a result of considering the figure of high-speed OFDM signal and low-speed CDMA signal, P_H/P_L = 19~24dB is the optimized figure for superposed transmission.

REFERENCES

[1] F.Rinaldi, H. Maattanen, J. Torsner, S. Pizzi, S. Andreev, A. lera, Y. Koucheryavy and G. Araniti, "Non-Terrestrial Networks in 5G & Beyond: A Survey," in IEEE Access, Vol.8, pp.165178-165200, Sep 2020.

[2] H. Tsuji, A. Miura and M. Toyoshima, "Research and Development of Satellite Communications in Non-terrestrial Network," IEICE Technical Report, Vol.121, No.102, pp31-35, July 2021.

[3] T. Tanamachi, "IoT Data Collection Service Using the Satellite Communication System -The Business of Utilizing BigLEO Communication satellites-," IEICE Technical Report, Vol.119, No.467, pp.59-64, March 2019.

[4] M. Morikura, K. Enomoto, S. Kubota, S. Kato, "SSMA signal transmission over QPSK modulated signal," IEEE Globecom'90, pp.751-755, Dec 1990.

[5] K. Higuchi, "Non-orthogonal Multiple Access (NOMA) with Successive Interference Cancellation for Future Radio Access," IEICE Trans Commun, Vol.E98-B, No.3, pp.403-414, May 2015.

[6] T. Sugiyama, H. Kazama, M. Morikura, S. Kubota and S. Kato, "A Frequency Utilization Efficiency Improvement on Superposed SSMA-QPSK Signal Transmission over High Speed QPSK Signals in Nonlinear Channels," IEICE Trans, Commun, Vol.E76-B, No.5, pp.480-487, May 1993.

[7] T. Owaki, H. Okada, K. Tategami, D. Goto, M. Matsui, K. Itokawa and F. Yamashita, "Effect of Satellite Movement and Evaluation of Transmission Control Scheme on SA/CRDSA in Satellite IoT Systam," IEEE Technical Report, Vol.124, No.128, pp.77-82, July 2024.

[8] K. Sakamoto, T. Kageyama, K. Yoshizawa, Y. Fujino, Y. Kozima, K. Itokawa, and F. Yamashita, "Capacity evaluation for each LPWA terminal in 920 MHz band IoT platform via LEO satellite," IEICE Technical Report, Vol.120, No.372, pp.35-40, February 2021.