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A Proposal of Received Response Code Sequence in DS/UWB

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1. Introduction

The demand for a large capacity, high-reliability and high-quality has recently increased in communication systems such as wireless LAN. As a system for this demand, Spread Spectrum (SS) system and Orthogonal Frequency Division Multiplexing (OFDM) system have been studied [1], [2]. Various communication systems are used by the usage for a wireless communication and Ultra Wideband (UWB) has attracted much attention as an indoor short range high-speed wireless communication in the next-generation. Frequency band used of UWB communication is larger than that of a conventional SS communication, and the UWB communication system has high-speed transmission rate [3], [4].

UWB communication has high resolution for multipath to use nano-order pulses, assuming a lot of paths delayed by walls and obstacles in an indoor environment. Furthermore, due to a long delay-path exists, it has known to cause Inter-Symbol Interference (ISI) that influences a next demodulated signal, and the performance of receiver is degraded.

In UWB communications, there is a DS/UWB system applied Direct Sequence (DS) method as one of SS modulated methods. When a binary sequence such as M sequence is adopted as a code sequence, its sequence may cause complicated ISI by a multipath environment. Then, to improve Signal-to-Noise Ratio (SNR), a selective RAKE reception method is adopted at a receiver. A selective RAKE reception method can gather peaks of scattered various signals for one peak [5]-[7]. However, when an interference is too large by a multipath environment, it is difficult to gather receive energy efficiently.

In this chapter, to resolve the ISI problem caused by a multipath environment, a novel Received Response (RR) sequence that has better properties than a M sequence is proposed, and its generation method is shown. The RR sequence is generated by using estimated channel information at a transmitter. Furthermore, the properties of the RR sequence are evaluated for the number of pulses of the RR sequence and the number of RAKE fingers in UWB system, and the effectiveness of RR sequence is shown.

The main contents of this chapter are presented in the below Sections. The explanation of the DS/UWB system and the RR sequence is presented in Section 2. The explanation of the generation method of the RR sequence will be explained in Section 3. In Section 4, simulation conditions and results are shown and discussed. Conclusion of this chapter is presented in Section 5. References are added in Section 6.

2. DS/UWB and Received Response sequence

A Direct Sequence Spread Spectrum (DS/SS) system, in which the bandwidth is spread by using extremely short duration pulses, has high resolution for paths. A DS/UWB system is applied UWB to DS/SS system. Only short duration pulse is used, that system is basically the same one as DS/SS. In a UWB system, a method for getting large SNR is needed to secure reliability of communication at a receiver though power spectrum density of transmitted signals is less than noise level. However, due to transmitting signals are reflected by walls and obstacles and ISI is caused by long delayed multipath in a UWB receiver. Therefore, for multipath in wideband signal, RAKE reception method has been known, which separates paths from an output of Matched Filter (MF) of received signals in some interval and gathers them as path diversity.

When signals continue in one code sequence, a multipath environment causes complicated ISI. Therefore, when such a binary code sequence as a conventional M sequence is used under a multipath environment, the received energy can not be gathered efficiently if RAKE reception method is used at a receiver.

In this chapter, we propose Received Response (RR) sequence that the time which signals dare not to be transmitted is made, and ternary sequence of +1, 0, -1 is used. In using RR sequence, channel information is estimated at a transmitter, and the ISI component known from channel information is used. Then a generation interval of chip and polarity are adjusted, and the delayed chips are composed chips of dominant wave. Therefore, it is possible to made high level peaks from these signal components.

3. A generation method of RR sequence

At a transmitter, RR sequence can be generated in the following procedure (A), (B) and (C).

- a. A pulse of UWB and an estimated impulse response are convoluted. Then an ideal received response is obtained before passing of a MF.
- b. From the ideal received response like Figure 1, the biggest response is decided as a dominant wave. Then two components of "An estimated position of a selective RAKE finger" and "A polarity of the response of an estimated position (± 1)" are obtained within a code length.
- c. Its estimated position and polarity are corresponded, and RR sequence is generated.

Furthermore, the position of a selective RAKE finger and the polarity are corresponded with information of Proc. (B), that is, with RR sequence. The shorter an interval of estimated position of a selective RAKE finger, the better the performance. In this chapter, we determine that the interval is one-tenth a chip time.

As an example of using an impulse response of a Non Line of Site (NLOS) environment more than 10 meters in a multipath channel model (named as CM4) adopted IEEE802.15.3a [8], 6RR sequence is generated. Information estimated position of the 6 RAKE fingers is obtained in Figure 1, then Figure 2 shows 6RR sequence of 6 pulses (a code length of 15[ns] is assumed here). If the number of pulse for RR sequence is changed, it had better change the number of information estimated position of the selective RAKE finger in Proc. (B).

Next, a construction and effect of RR sequence is shown using a simplistic ideal received response and RR sequence obtained from its response. Figure 3 shows a received response

and an example RR sequence (4RR sequence is assumed here for simplicity) obtained from its response. Then using 4RR sequence that showed in Figure 3, Figure 4 shows a combined transmitting signal after passing multipath channel and before passing a matched filter when RR sequence is transmitted actually.

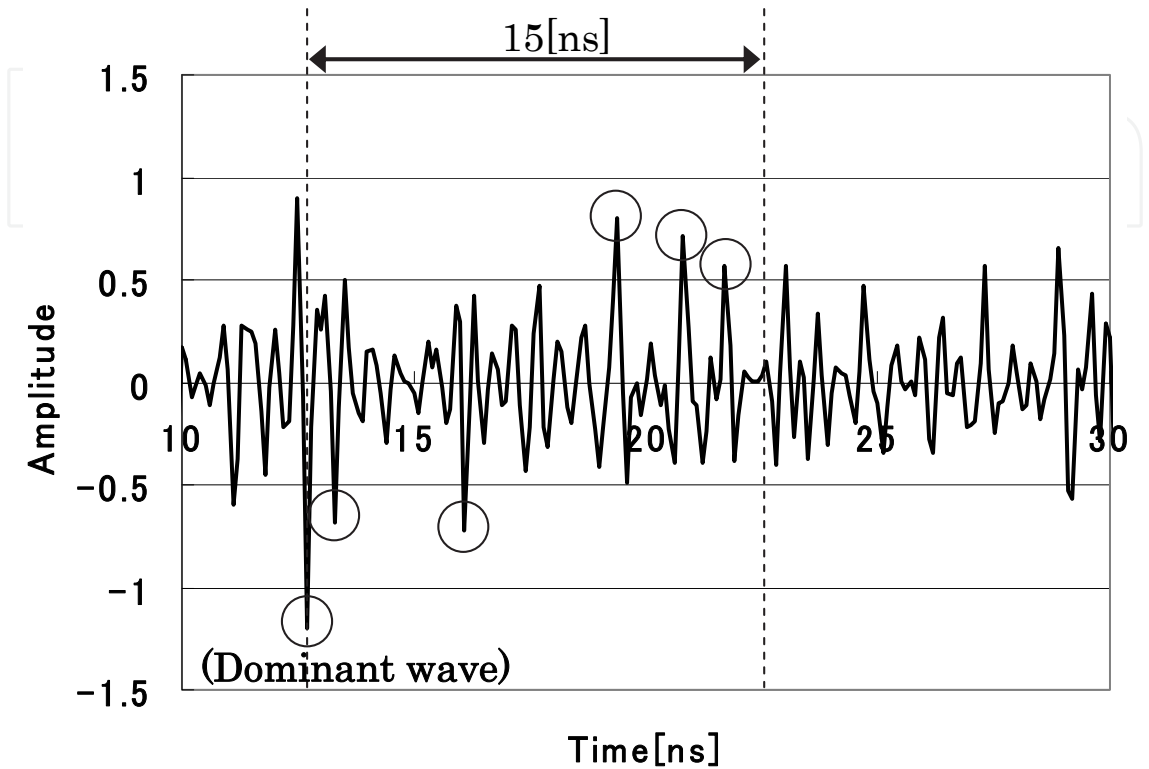


Fig. 1. An example of an ideal received response under the CM4 environment

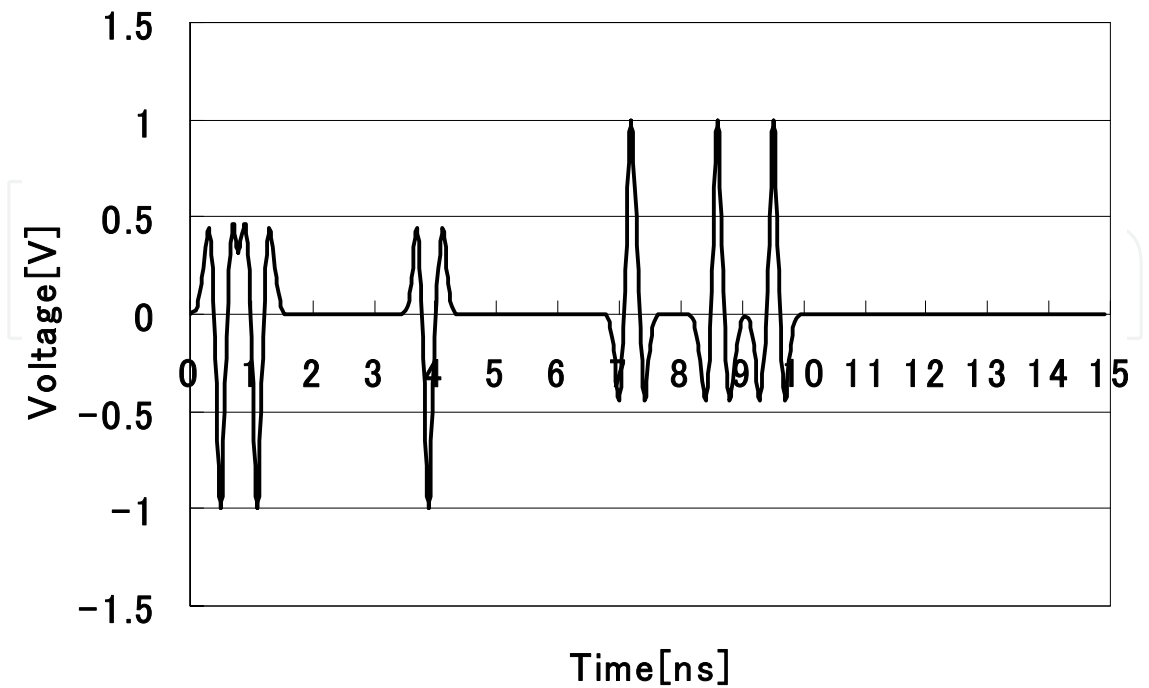


Fig. 2. An example of 6RR sequence

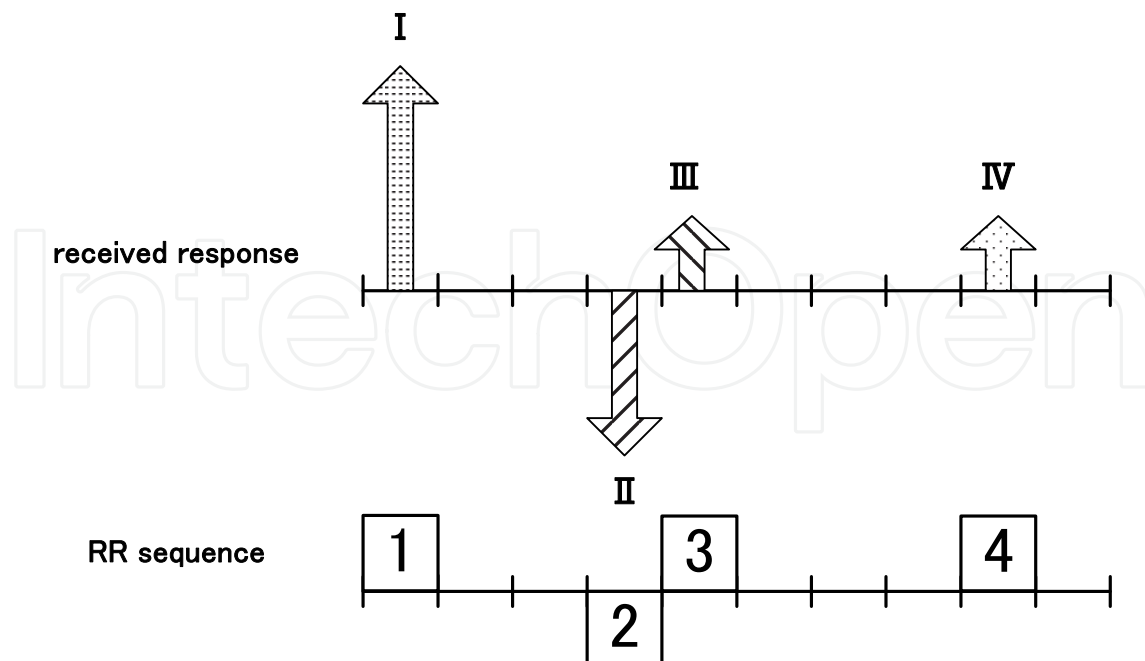


Fig. 3. An example of an ideal received response and RR sequence

In Figure 4, when (I) component is paid attention as a dominant wave, it can be confirmed that 2nd, 3rd and 4th pulse of (I) component combined with each 1st pulse of components except (I) component delayed from dominant wave (where (II), (III) and (IV) components are shown). The delayed components emphasize the pulse of (I) component on In-phase, and besides the 4th pulse of (I) component is combined with the 3rd pulse of (III) component on In-phase except 1st pulse of (IV) component. This cause is to be combined on In-phase accidentally by the type of received response, and to be combine reversed phase too. These can be similarly said even other components. For example, when (III) component is paid attention, it can be confirmed that 1st, 2nd and 4th pulse of (III) component combined with each 3rd pulse of components except (III) component. The components except (III) emphasize the pulse of (III) component on In-phase.

By intentionally combining delayed components with received signals like emphasizing each other, when RR sequence is transmitted instead of a code sequence like simple M sequence, components at finger positions selecting RAKE can be emphasized and properties of receiver can be improved. In this example, although the simple example is showed, the actual selecting paths for the selective RAKE reception are selected sequentially from large one in many paths. Therefore, combining signals is large, and properties of receiver are improved greatly.

4. Simulation results

By the MF reception, the Bit Error Rate (BER) characteristics of proposed RR sequence are compared with that of conventional M sequence. Then BER characteristics when the number of RAKE finger is changed are shown in the selective RAKE reception. For the selective RAKE reception method, a LMS RAKE reception method [9] that has an effect in a channel existing ISI is adopted. For the channel, CM4 of NLOS environment and CM1 of LOS environment [8] are adopted.

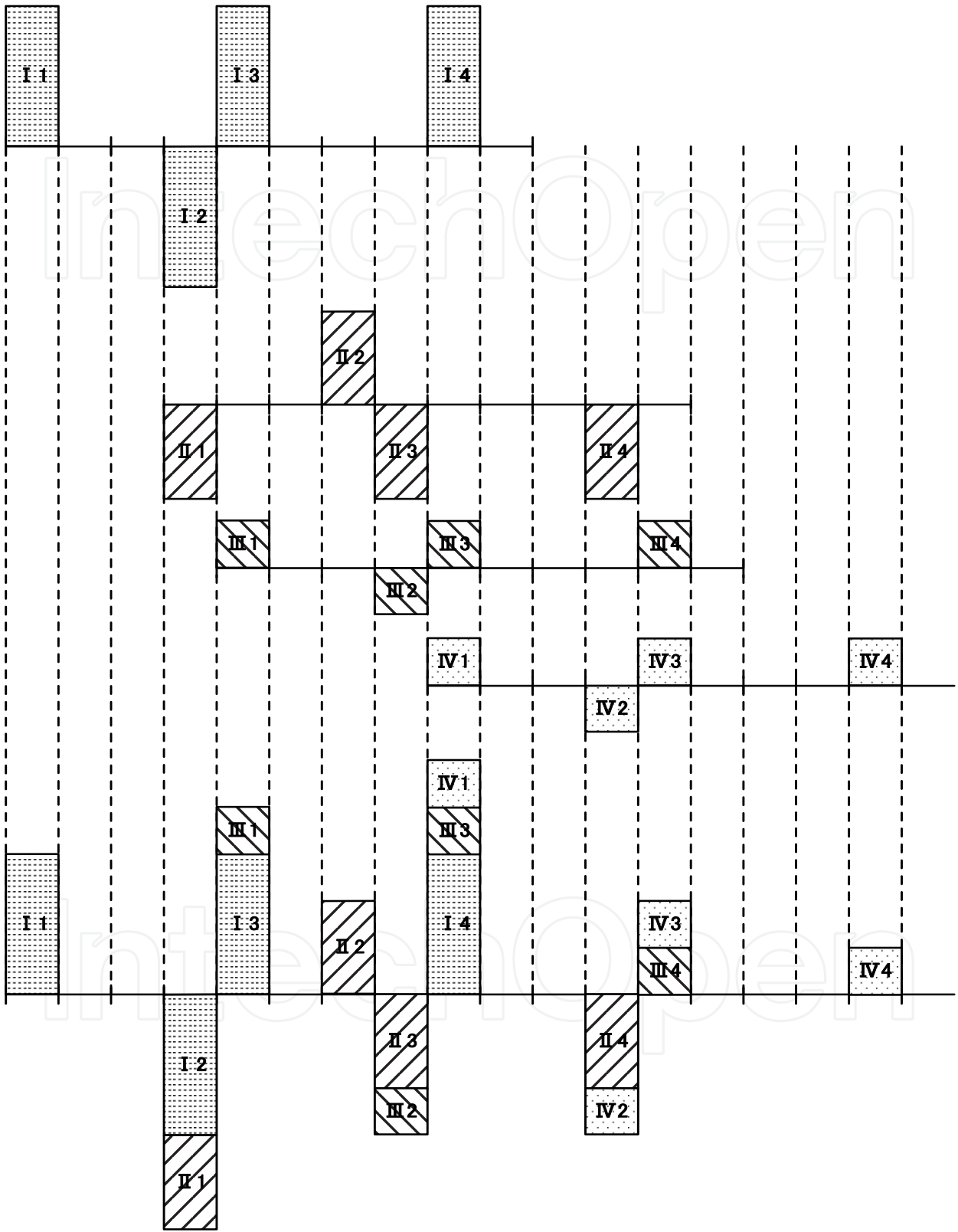


Fig. 4. An example of a combined transmitting signal

To compare superiority or inferiority of the BER characteristics for digital communication method, the BER characteristics are compared and discussed by using E_b/N_0 . And E_b originally shows received bit energy at the receiver. However E_b is greatly changed by the various channels in UWB systems. So that, when the channel is changed, the BER characteristics are not compared correctly. Therefore in this chapter, in the between transmitter and receiver, as the received energy when a only dominant wave arrived in the receiver under a channel condition having no delayed wave, that is to say, E_b' of transmission output, BER characteristics are compared and discussed by using E_b'/N_0 . By using E_b' , E_b' is not changed for the change of the channel models, so the superiority or inferiority of BER characteristics can be compared.

4.1 Comparisons of characteristics for the number of transmitted pulses

To confirm the effect of RR sequence of receiving performance against multipath environments, by using the BER characteristics in the MF reception, RR sequence is compared with M sequence that is used as spread sequence of a conventional DS system. And the effect is confirmed when the number of pulses is changed.

Figure 5 shows an example of an ideal received response under the CM1 environment (LOS environment). Table 1 shows the specification of simulations 1. Figure 6 (1) - (5) shows the transmitted sequences adopting the channel of CM4 in which the received response like Figure 1 can be obtained. And Figure 7 shows its BER characteristics. Then Figure 8 (1)-(5) shows the transmitted sequences adopting the channel of CM1 in which the received response like Figure 5 can be obtained. And Figure 9 shows its BER characteristics.

At first, in Figure 7 of the BER characteristics adopting CM4, as the number of pulses in RR sequence is increased to 6RR sequence using 6 pulses, the good BER characteristics can be obtained. However, when the number of pulses is increased to 15RR sequence using 15 pulses from 6RR sequence, the BER characteristics becomes degraded. From the above, it can be confirmed that the suitable number of the pulses exists by the channel model in RR sequences. In this case, 6RR sequence is the best number of the pulses in CM4 using this simulation. And 6RR sequence is best though 5RR sequence and 7RR sequence aren't shown here. When 6RR sequence is compared with M sequence of the code length 15, it is shown that the BER characteristic is improved greatly in 6RR sequence.

Next, in Figure 9 of the BER characteristics adopting CM1, 3RR sequence using 3 pulses becomes the good BER characteristic. And 3RR sequence is best though 2RR sequence and 4RR sequence aren't shown here. Furthermore, if the number of pulses is increased more than 3 pulses, it is confirmed that the BER characteristics is so degraded. As this reason, in CM1, the 3 higher paths occupy the greater part of the energy in the whole received response, therefore, it is considered that the best characteristic is obtained by generating RR sequence using the information of the 3 higher paths. And even if the number of pulses is increased by using the information of paths after them, it is considered that the great change of the characteristics is not appeared because the energy of the rest received paths is small.

Thus, the energy of received response in CM4 can be scattered not only a dominant wave but also delayed waves. Therefore, if RR sequence is generated, it is possible to compose delayed waves like emphasizing the received signal. However, using many pulses might

negatively affect the receiving performance by complicated ISI components, so it is supposed that the suitable number of pulses exists. On the other hand, as CM1 has a few delayed waves and has a few ISI components, too, the RR sequence is generated by using the information of paths in which the energy of the received response is large, even though the pulses are increased by using the information of paths after them, the interference components are not occurred in CM1, which is different from CM4, and the change of the BER characteristics is little in CM1.

The suitable number of pulses for the smallest BER is changed by the channel models like as 6RR sequence in CM4 and 3RR sequence CM1 used in this section.

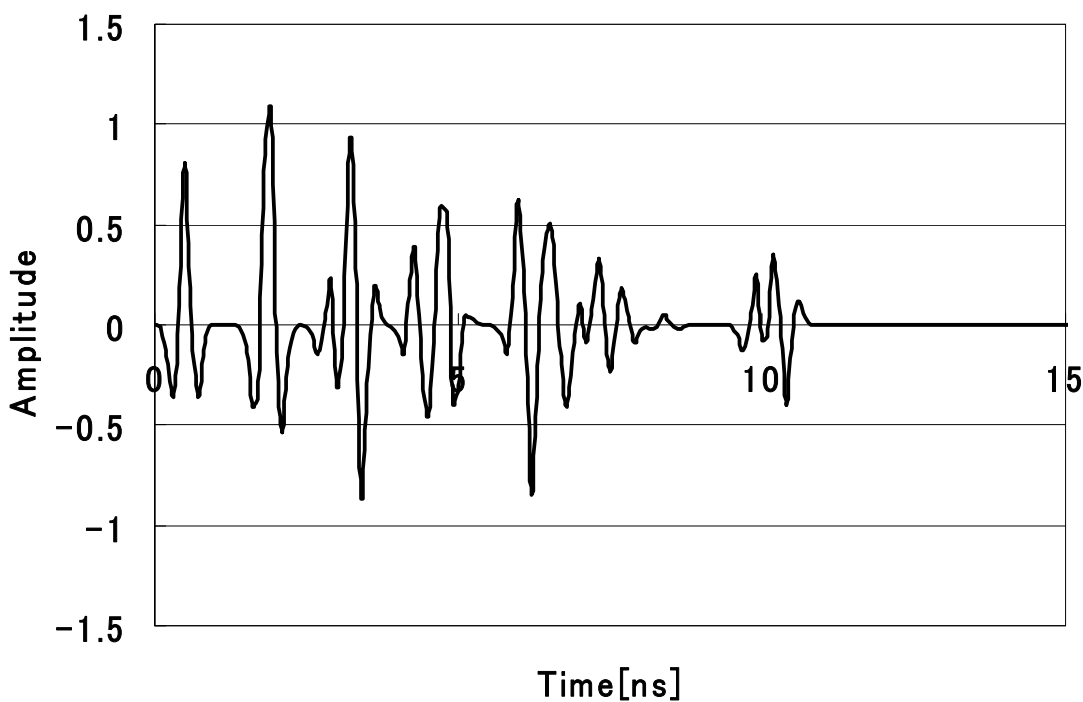
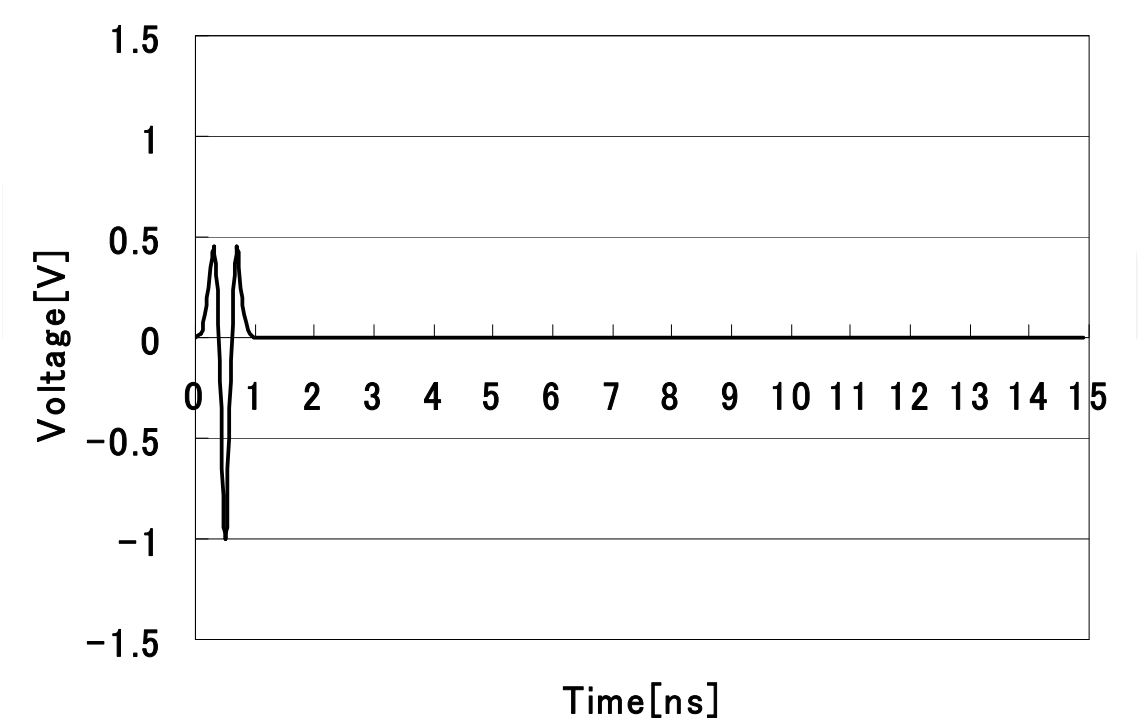


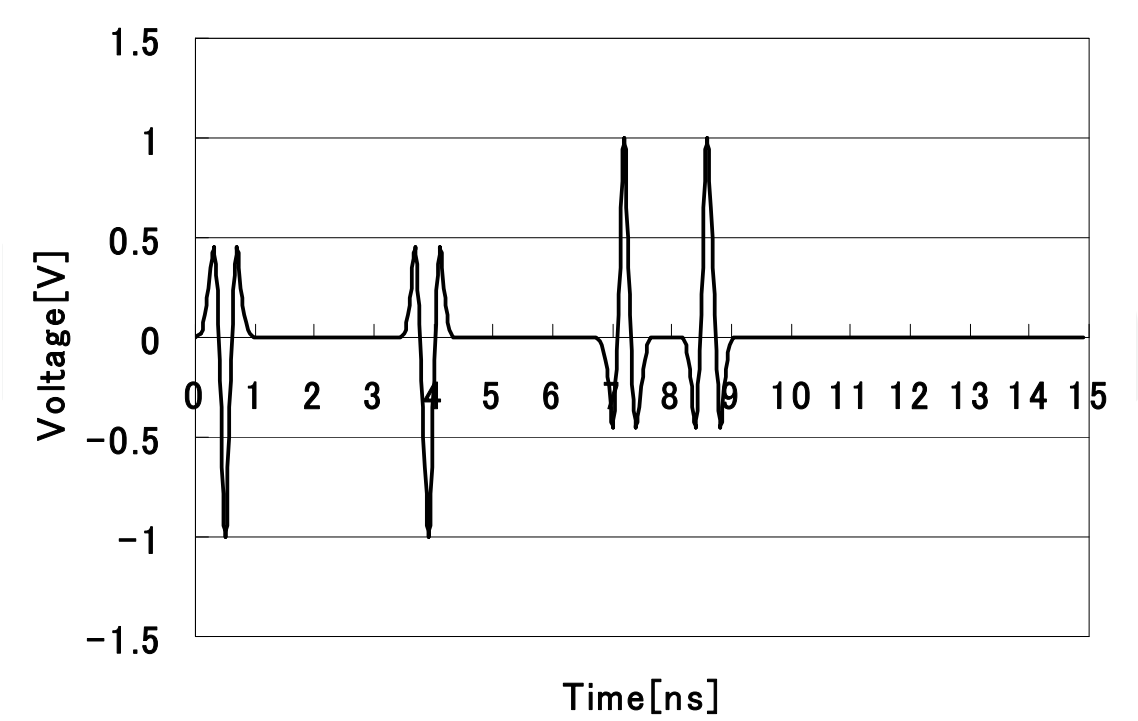
Fig. 5. An example of an ideal received response under the CM1 environment

Primary Modulation	BPSK	
Secondary modulation	DS (1pulse, 4, 6, 15RR seq., M seq.)	DS (1pulse, 3, 6, 13RR seq., M seq.)
Pulse Model	Monocycle Pulse	
Receivers	MF	
Pulse Width [ns]	1	
Transmission Rate [Mbps]	66.7	
Code Length N	15	
Transmission Channel	AWGN + CM4	AWGN + CM1

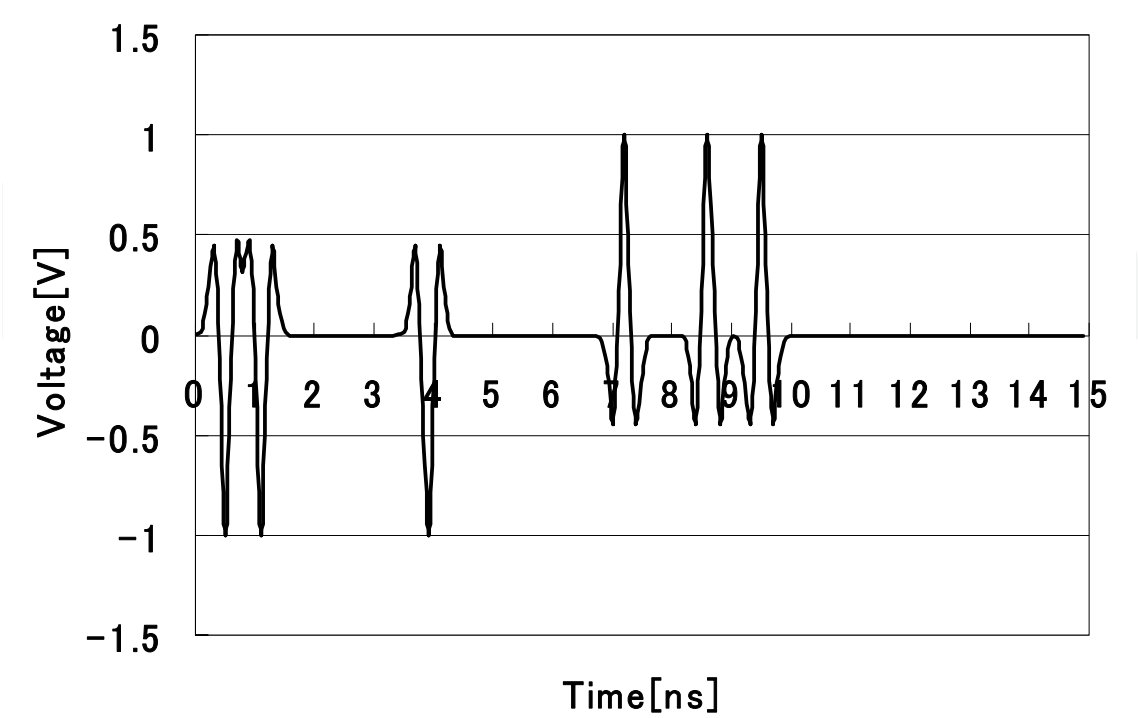
Table 1. Specification of simulations 1



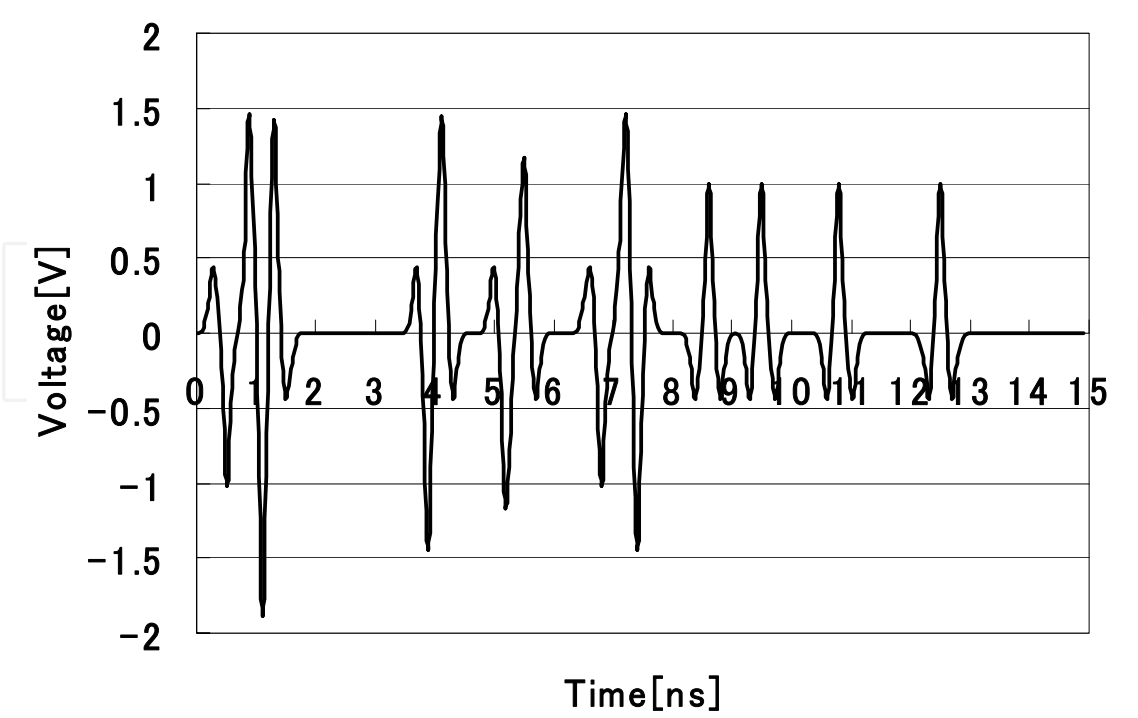
(1) 1 pulse sequence under the CM4 environment



(2) 4RR sequence under the CM4 environment



(3) 6RR sequence under the CM4 environment



(4) 15RR sequence under the CM4 environment

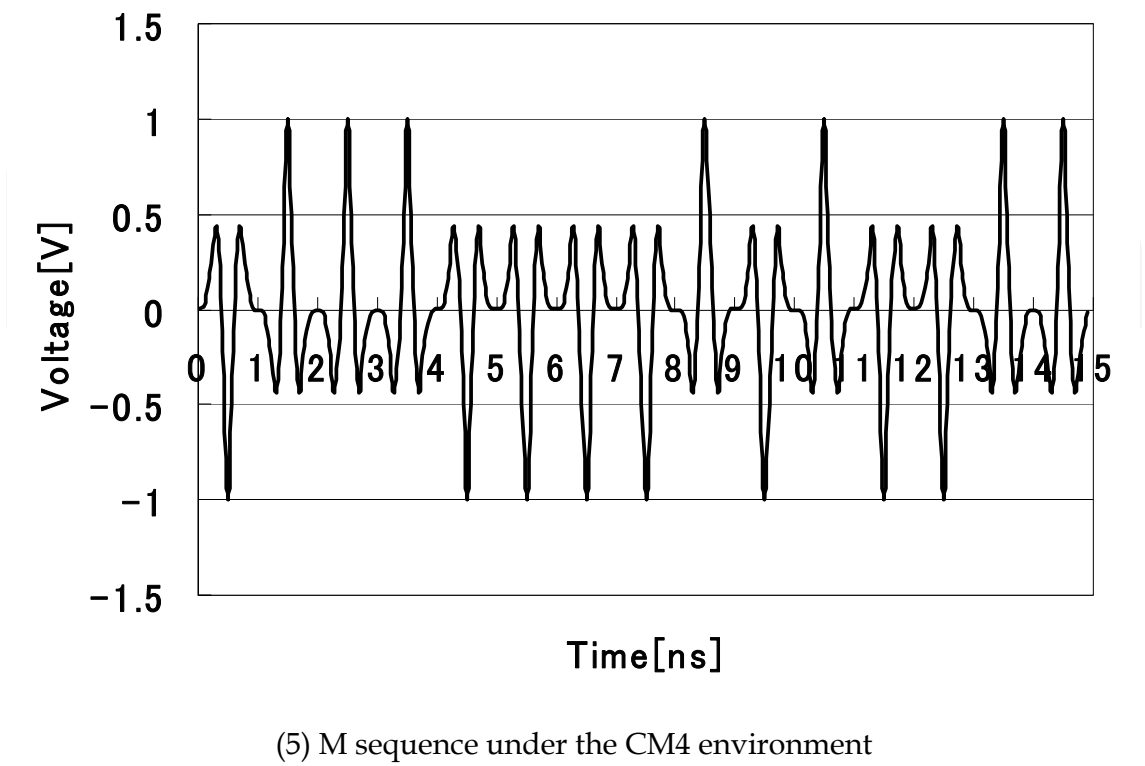


Fig. 6. Transmitted sequences under the CM4 environment

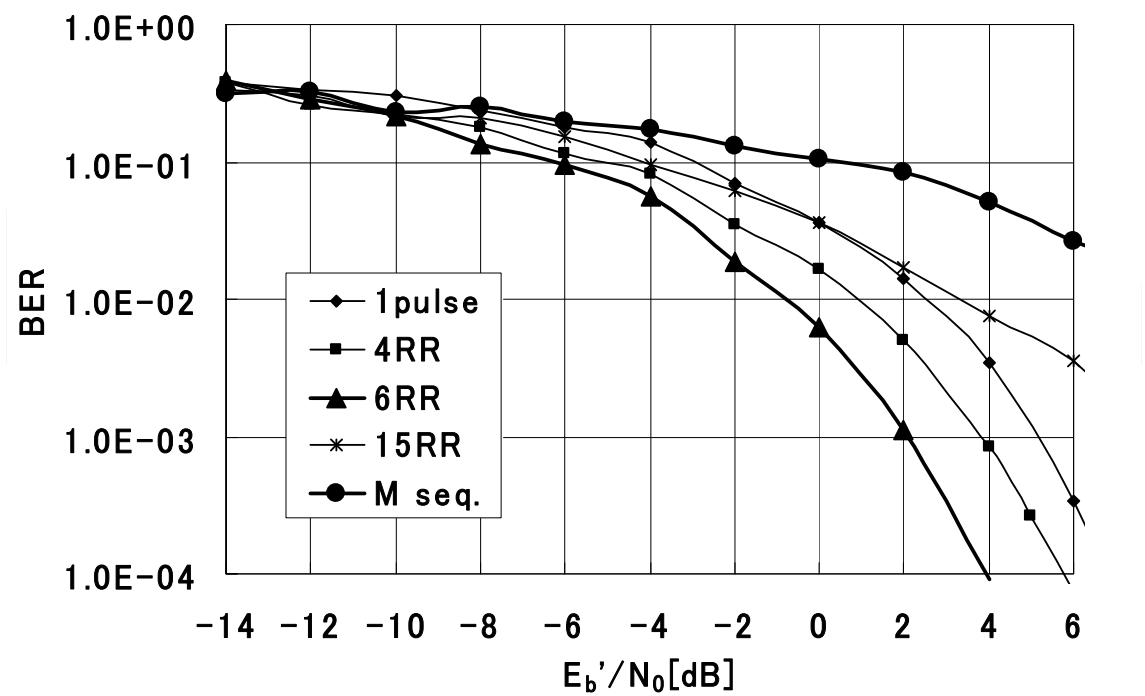
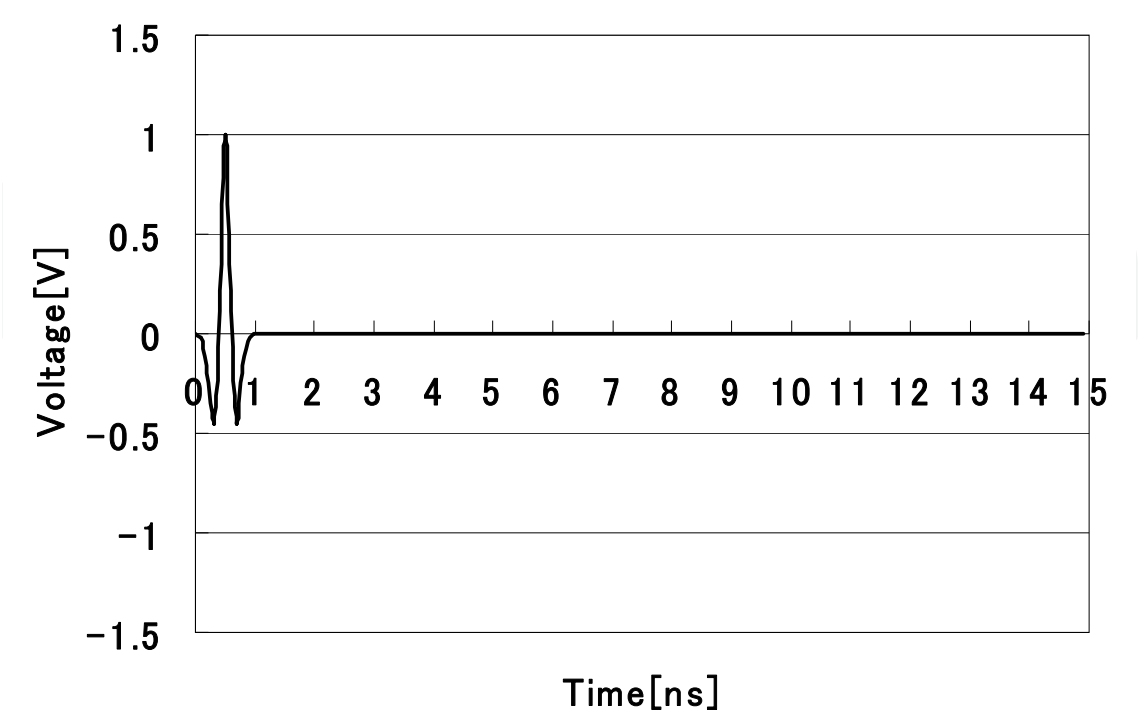
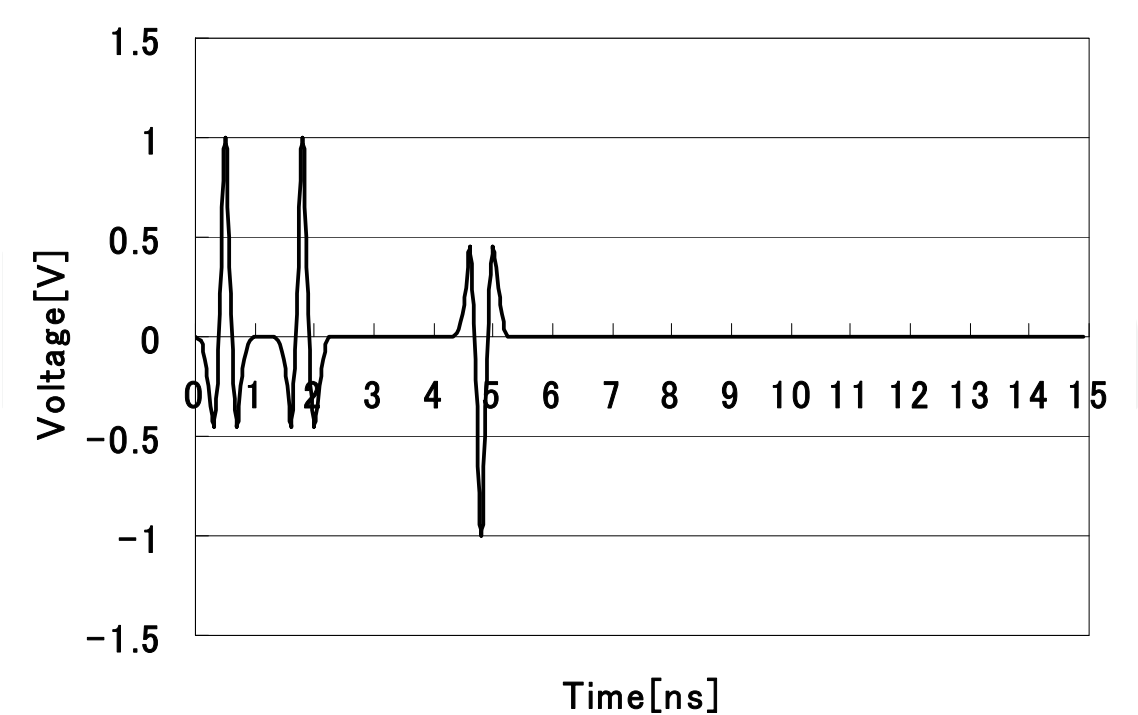


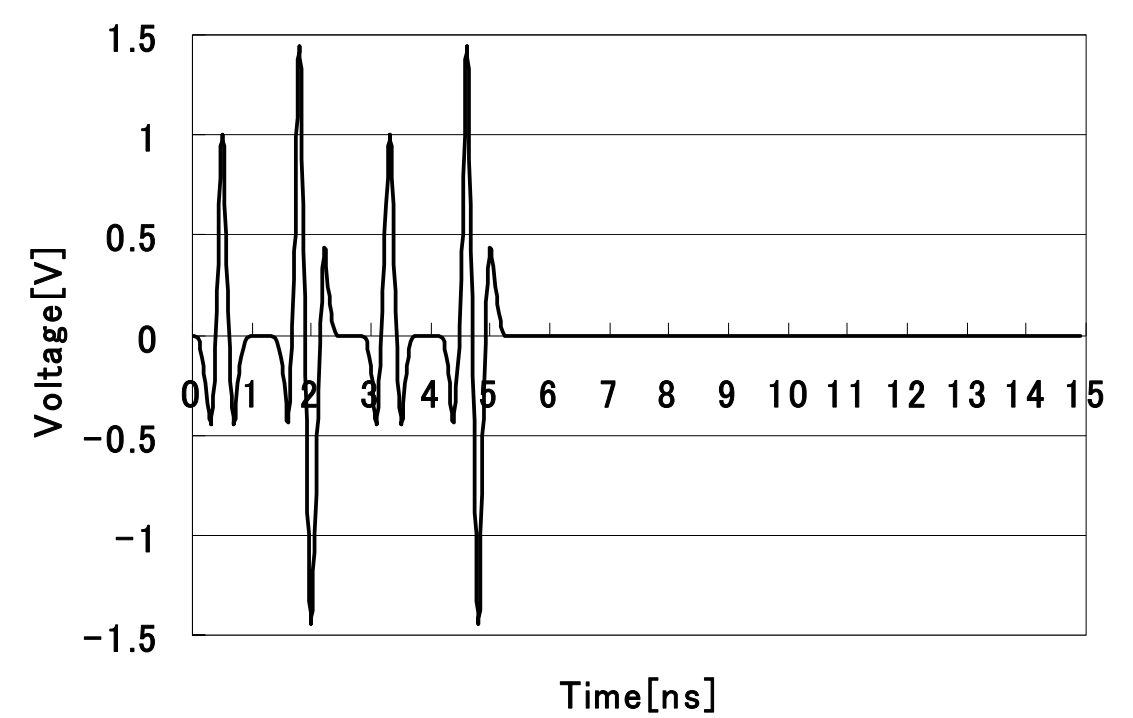
Fig. 7. BER characteristics of MF reception under the CM4 environment



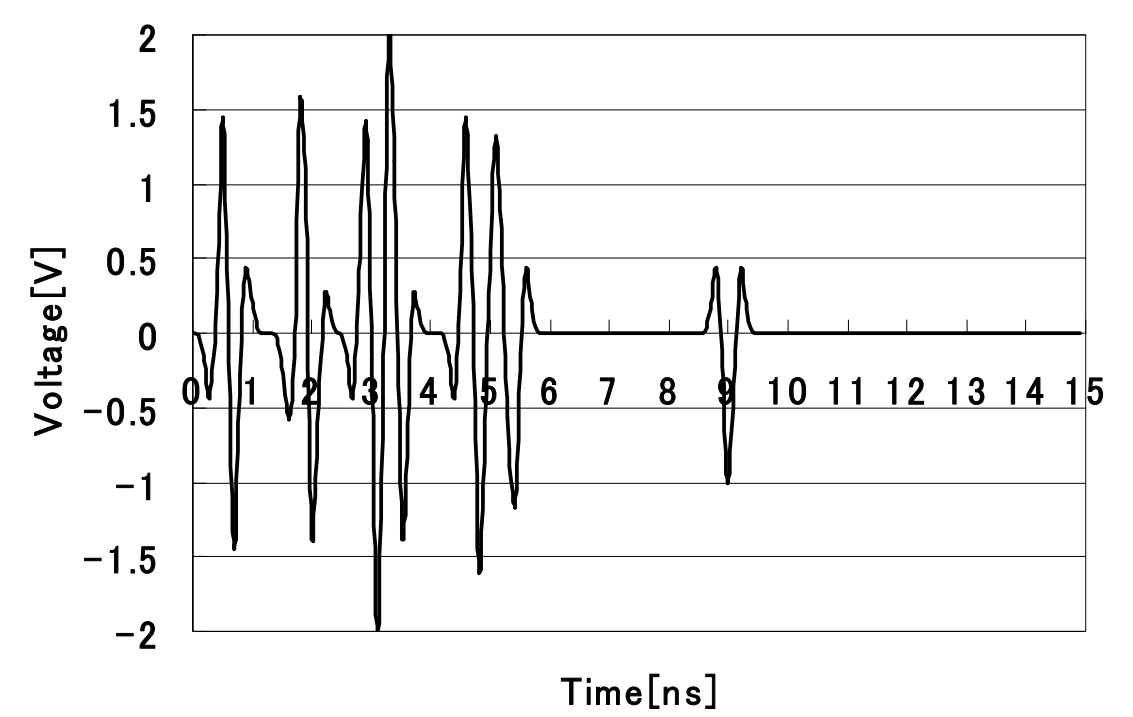
(1) 1 pulse sequence under the CM1 environment



(2) 3RR sequence under the CM1 environment



(3) 6RR sequence under the CM1 environment



(4) 13RR sequence under the CM1 environment

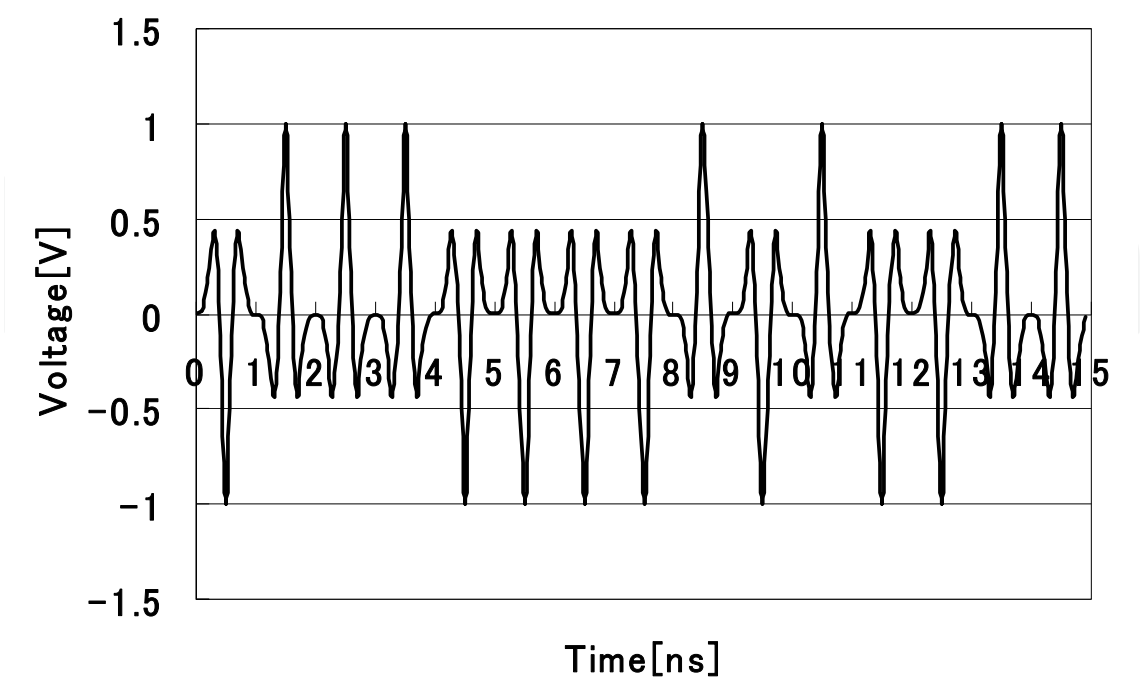


Fig. 8. Transmitted sequences under the CM1 environment

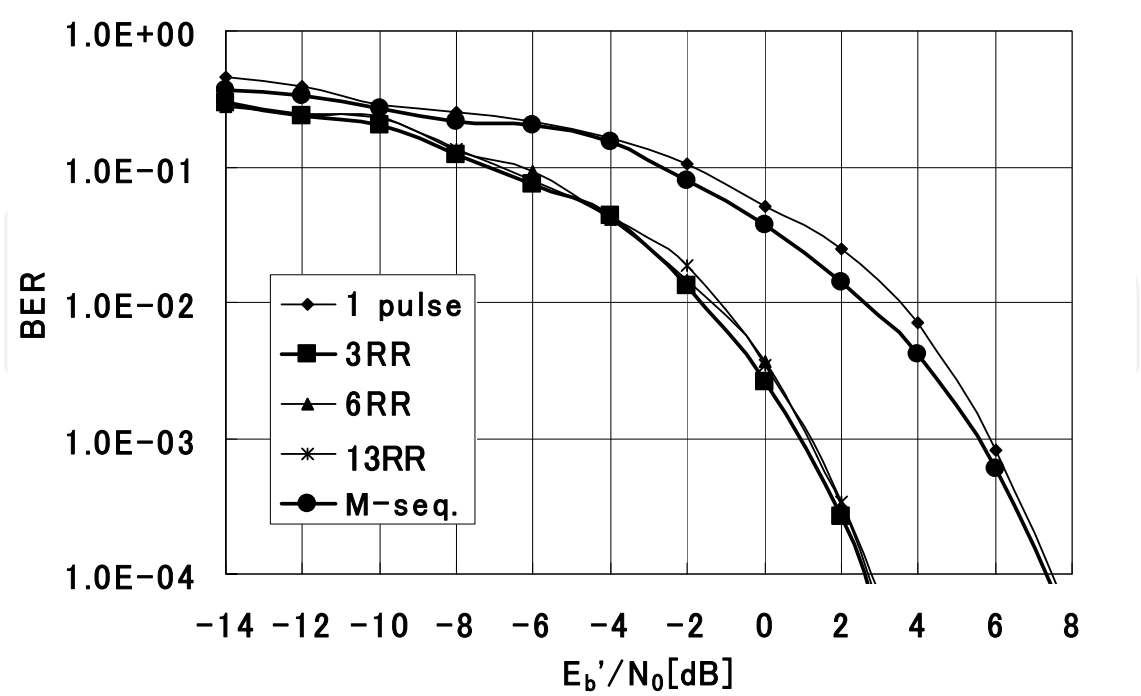


Fig. 9. BER characteristics of MF reception under the CM1 environment

4.2 Comparisons of characteristics for the number of selective RAKE fingers

Under CM4 and CM1 environments, receiving performance for the number of RAKE fingers when RR sequence is combined with LMS-RAKE reception system [9] is discussed by using the BER characteristics. Table 2 shows the specification of simulations 2. Figure 10 shows the BER characteristics when 6RR sequence is used under the CM4 environment. Figure 11 shows the BER characteristics when 3RR sequence is used under the CM1 environment. In this section the BER characteristics using M sequence also is shows for comparison. In each figure, the curve that the number of RAKE fingers is one means that it is the same results with the MF reception.

At first, in Figure 10 of the BER characteristics adopting CM4, as the number of RAKE fingers of 6RR sequence and M sequence is increased, it can be confirmed that the BER characteristics are improved. And an amount of improvement becomes small as the number of RAKE fingers of the combined system is increased. When the number of RAKE fingers is increased from 10 to 20 in 6RR sequence, the BER characteristics are improved only a little. The BER characteristics are saturated. On the other hand, when the number of RAKE fingers is 20 in M sequence, the BER characteristics are not yet saturated. Therefore, it is necessary to increase more the number of RAKE fingers. From the above, the number of RAKE fingers of 6RR sequence has fewer than that of M sequence, so that, the BER characteristics can be improved to a saturated condition. In other words, the energy scattering under the multipath environment is captured efficiently by using RR sequence, and the almost part of the scattering energy can be captured with about 10 fingers.

Next, the BER characteristics under CM1 environment in Figure 11 show similar with that of Figure 10. Even in the case of M sequence, the property approaching the saturated condition is shown according to increment of the number of RAKE fingers. Additionally when BER characteristics of the case of 20 fingers in 3RR sequence, which is approaching the saturated condition, is compared with that in M sequence, the difference of the performance of 3 [dB] can be obtained, that is, the difference of performance between 3RR sequence and M sequence is shown by using the LMS-RAKE reception method.

Consequently, RR sequence has better performances than that of M sequence in the number of a few RAKE fingers. And RR sequence can be approach the saturated condition of the BER characteristics. Therefore, a circuit scale in the receiver is reduced by using RR sequence, and a cost of the system can be reduced.

Primary Modulation	BPSK	
Secondary modulation	DS (6RR seq., M seq.)	DS (3RR seq., M seq.)
Pulse Model	Monocycle Pulse	
Receivers	LMS-RAKE	
Pulse Width [ns]	1	
Transmission Rate [Mbps]	66.7	
Code Length N	15	
Number of RAKE Finger F	1, 10, 20	
Transmission Channel	AWGN + CM4	AWGN + CM1
Step Size Parameter μ	10^{-6}	10^{-5}
Training bit [bits]	200000	200000

Table 2. Specification of simulations 2

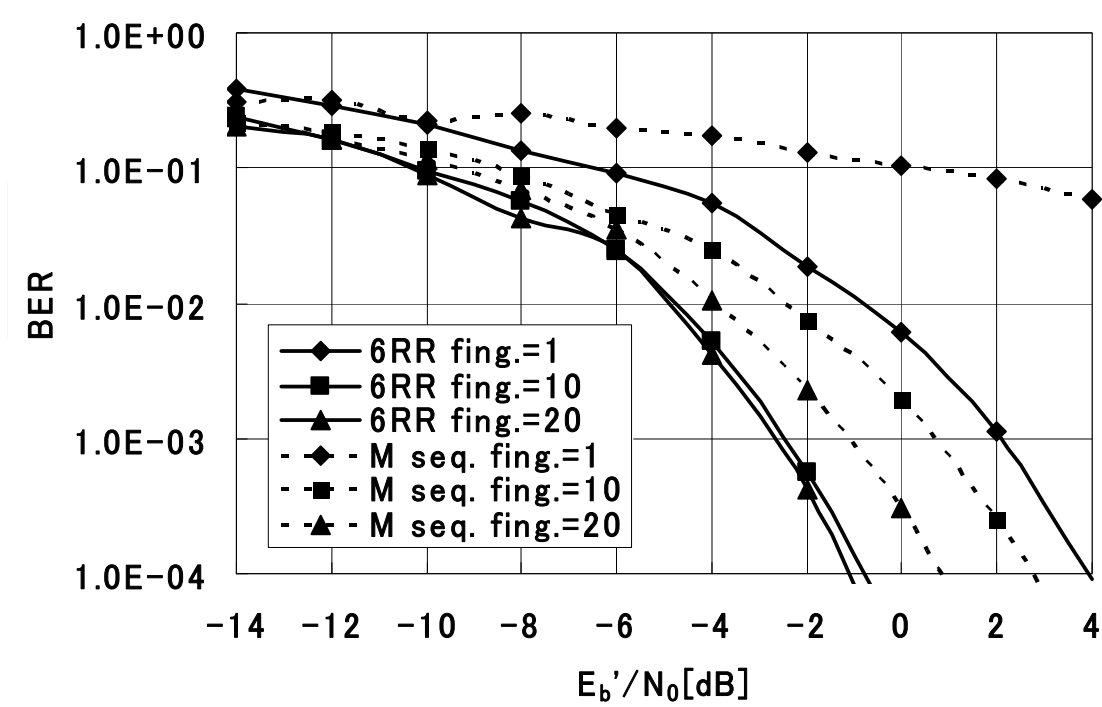


Fig. 10. BER characteristics by the number of RAKE fingers under the CM4 environment

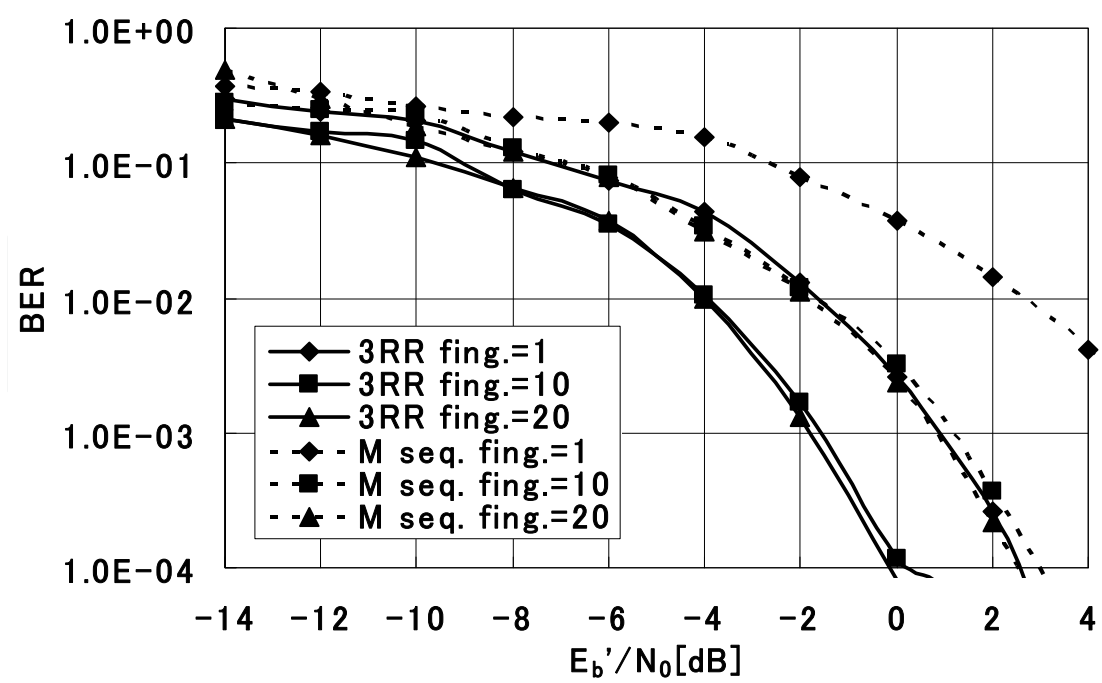


Fig. 11. BER characteristics by the number of RAKE fingers under the CM1 environment

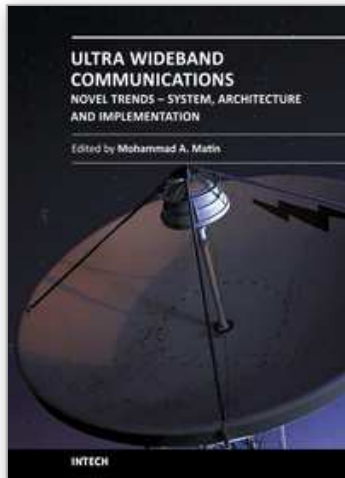
5. Conclusions

In this chapter, in order to solve the ISI problem caused by the multipath environments, we have proposed the received response sequence (ternary code sequence) in DS/UWB which is generated by using the channel information of the multipath environment, and have shown the generating method. By using the proposed sequence, it has been shown that the BER characteristics have been improved greater than that of M sequence in a conventional sequence when the number of pulses has been selected properly. And the receiving energy has been captured efficiently even if the number of selective RAKE fingers has been a few. Therefore, the circuit scale in the receiver has become small and the cost of the system can be reduced.

For further studies, it will be necessary that the effectiveness of the received response is discussed by using a pilot signal which is estimated the channel information in the transmitter practically.

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This book has addressed few challenges to ensure the success of UWB technologies and covers several research areas including UWB low cost transceiver, low noise amplifier (LNA), ADC architectures, UWB filter, and high power UWB amplifiers. It is believed that this book serves as a comprehensive reference for graduate students in UWB technologies.

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