연속적 직교시간구간을 갖는 다중반송파 대역확산다중접속기술에 관한 연구

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The study of a multi-carrier SSMA system with orthogonal time duration

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Abstract

In this paper, the implementation of MAI(multiple access interference) -cancelled SSMA(spread spectrum multiple access) system using orthogonal carriers was presented. Employing the pseudo periodic spreading codes and orthogonal carriers frequency offset, proposed system have the features no MAI during a certain local time-duration. Spreading signals designed by pseudo periodic method and repetition, have zero correlation duration(ZCD) by orthogonal frequency shift method. The SSMA modem has been designed and implemented using surface-acoustic-wave (SAW) device as the matched filter of receiver. The effects of frequency offset on stability have been evaluated using computer simulation.

1. Introduction

In the SSMA system using cellular concept such as IMT-2000, complex synchronization technique is required for reduction of MAI among orthogonal spreading codes. This leads to complex and cost-expensive control system implementation especially in up-link. If the spreading signals of up-link are designed to have ZCD property, MAI can be cancelled in the spread spectrum system. [1-7].

In this paper, the implemented MAI-cancelled SSMA system using SAW matched filter and the orthogonal frequency multi-channel method is introduced. Spreading signals are designed by pseudo periodic method and repeated codes. Multiple access scheme is attained by the IF carriers with orthogonal offset-frequency.

The system stability under the oscillator -frequency offset is certified by computer simulation. Furthermore, it has been experimentally shown that the implemented modem has sufficiently low degradation of E_b/N_0 versus bit error rate BER) performance.

2. MAI-cancelled SSMA system

1) Orthogonal Frequency Multi-Channel Method

Orthogonality in the frequency domain is used for channel assignment.

Let

$$S = \{s_0, s_0, \cdots, s_{N-1}\} \qquad (1)$$

be a finite-length-spreading-code of length N which is called a basic code. A repeated code S_0 is designed from the basic code S. The repeating number i is equal to the number of channellization . Each of the channels is given a different carrier frequency, where adjacent channels have a orthogonal offset-frequency Δf. The Δf is the same as the reciprocal value of integration time of the code S_0.

For example, in a repeated code

$$S_0 = \{S, S, S\}, \qquad (2)$$

the channel number i be 3. The signals of 3 channels are $\{S_0\}_{f_0}$, $\{S_0\}_{f_0+\Delta f}$ and $\{S_0\}_{f_0+2\Delta f}$, where $\{S_0\}_f$ is a signal obtained by modulating the code S_0 on the carrier of frequency f.

In this work, as the matched filter of receiver, SAW convolver[8] is used for the modem implementation. And the orthogonal frequency Δf is the reciprocal value of integration time of the SAW convolver. Any code can be used as the basic code for the orthogonal frequency multi-channel method, because the orthogonality originates from only the Δf-shift frequencies.

2) Pseudo Periodic Method

Let

$$S_P = \{\underbrace{s_0, s_0, \cdots, s_{N-1}}_{L\ chip},\ S,\ \underbrace{s_0, s_0, \cdots, s_{N-1}}_{L\ chip}\} \quad (3)$$

be a finite-length-code of length $N+2L$, whose central part of length N is coincident to the basic code S.
When the code S_P is input into the matched filter which is matched to the code S, the output signal of length $2N+2L-1$ is the aperiodic correlation result between S_P and S. However, the central part of length $2L+1$ of the output signal is coincident to the periodic autocorrelation function of periodic code $\{\cdots SSSS\cdots\}$ from $-L$ shift term to L shift term. In this paper, S_P is called a pseudo periodic code of length $N+2L$.

3) SAW device as a matched filter

The structure of the ZnO/Si SAW convolver [8] is shown in Fig.1. The input and reference signals are applied to the each of the interdigital transducers (IDT 's). The output signal from the gate electrode is a correlated signal between the input and the reference signals. The reciprocal value of integration time of the SAW convolver is equal to a theoretical orthogonal offset-frequency Δf. It is emphasized that the SAW convolver can operate as a programmable matched filter for any code, because the reference signal determines the filtering characteristics.

4) The Example of Signal Design

Table 1 show an example of the specifications of MAI-cancelled SSMA system. As an example, the spread bandwidth of 8.421 MHz is given. The basic code [2] of length N =16 used in this work is

$$O = \{0,0,0,0,0,1,2,3,0,2,0,2,0,3,2,1\}, \quad (4)$$

where m =*0* , *1* , *2* and *3* of code elements correspond to $W_4^m = \exp(j\frac{2\pi}{4}m)$. This basic code features the zero out-of-phase periodic autocorrelation characteristics.
The designed code of length $iN+2L=48$ is

$$O_{op} = \{\underbrace{0,2,0,2,0,3,2,1}_{8\ chip},\ O, O,\ \underbrace{0,0,0,0,0,1,2,3}_{8\ chip}\}, \quad (5)$$

where i =*2* and L =8. Since the repeating number i of the basic code O is 2, the orthogonal frequency multi-channel number is also 2.
Figure 2 shows the odd correlation function between the designed code O_{op} and the basic code O. The guard-chip duration T_g is an even periodic correlation duration due to the pseudo periodicity. The correlation peaks and zero out-of-phase autocorrelation appear during the guard-chip duration T_g. The guard-chip duration T_g is given by

$$T_g = \frac{2L}{R_{chip}}, \quad (6)$$

where R_{chip} is the chip rate of transmission signal. R_{chip} is 8.421 Mcps and L is 8, so T_g becomes 1.9 μsec. If we consider cellular concept for MAI-cancelled SSMA, the MAI -cancelled cell-radius such that the received signals from every mobile terminals within a cell can have zero cross-correlation is 143 m.

The bit rate and channel number also can be discussed. For the up-link, combining the SSMA and TDMA, more than 64 channels for voice data transmission is conformed to be available. The bit rate for every up-link channel and the up-link channel number M are

$$R_{bit} = \frac{2 \cdot R_{chip} \cdot r_{TDD}}{M_{TDMA} \cdot (iN + 2L)} \quad (7)$$

and

$$M = \frac{i \cdot 26 \cdot 10^6 \cdot M_{TDMA}}{R_{chip}}, \quad (8)$$

respectively, where M_{TDMA} is the channel number of the TDMA and r_{TDD} is the up-link share of the TDD, *i.e.*, 0.75. Using M_{TDMA} of 12 and the designed signal, , *i.e.*, N =*16* ,*i* =*2* ,*L* =*8* and R_{chip}=8.421×10 6 , R_{bit} and M become 21.9 kbps and72 channels, respectively.

3. MAI Depending on Oscillator Frequency Offset

With the orthogonal frequency multi-channel method, orthogonality in the frequency domain is used for channel assignment. The crystal –oscillator-frequency-offset degrades orthogonality among the channels. The degradation of the orthogonality among the channels leads to MAI. By computer simulation, E_b/N_0 versus BER performances are evaluated varying the oscillator frequency offset between a transmitter and a receiver.
Figure 3 is the E_b/N_0 versus BER performance with the carrier frequency offset of 0,1,3 and 5ppm at 2484 MHz between a transmitter and a receiver . A frequency offset of ±5 ppm is the value that can be obtained in the hard ware implementation using the commercially available crystal oscillator. The solidline is a theoretical curve of QPSK using coherent detection. When the frequency offset is 5 ppm, the degradation of E_b/N_0 is found to be 1 dB at a BER of 10^{-4}.

4. Implementation of up-link modem using SAW convolver

Figure 4 shows a block diagram of the implemented modem using SAW convolver.
The code generators and the data demodulator have been implemented with field programmable gate-arrays (FPGA's).

Figure 5 shows measured waveforms at the points $P_1 \sim P_3$ in Fig.4. Waveform P_1 is the transmission data signal, P_2 the signal after correlation, and P_3 the signal after coherent detection. The guard-chip duration T_g can be clearly observed in the correlation output. The correlation peaks in the guard-chip duration T_g are used for demodulation.

5. Conclusion

In this paper, MAI-cancelled SSMA system using SAW Convolver with the pseudo periodic method and the orthogonal frequency multi-channel method is introduced. It is experimentally confirmed that the implemented up-link modem has low degradation of E_b/N_0 versus BER performance. The introduced system has a potential for being used to the intracellular up-link of the , MAI-cancelled SSMA wireless.

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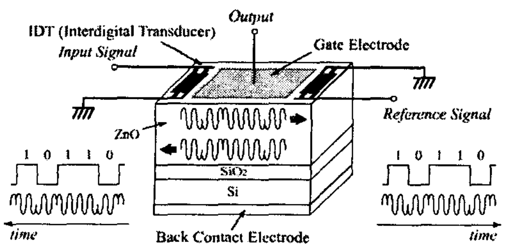

Fig.1 Structure of SAW convolver [8]

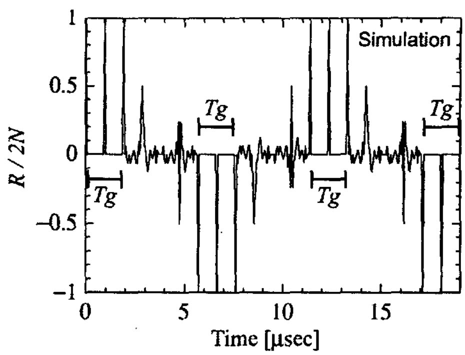

Fig.2 Auto-correlation function of designed signal

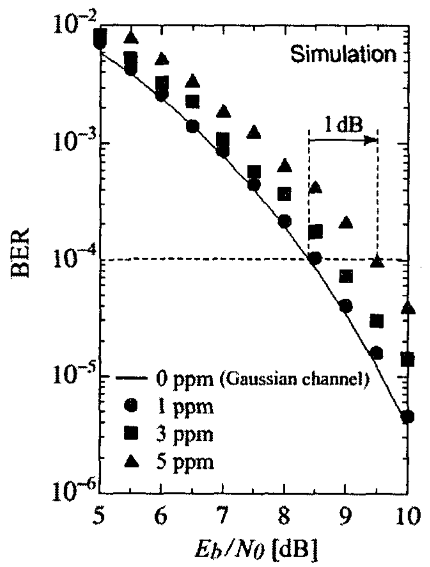

Fig.3 Eb/No versus BER performance under given oscillator frequency offset

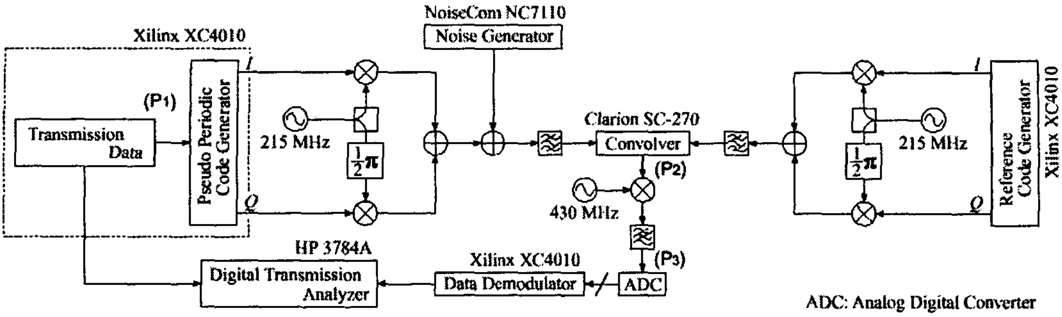

Fig.4 Block diagram of the measurement system

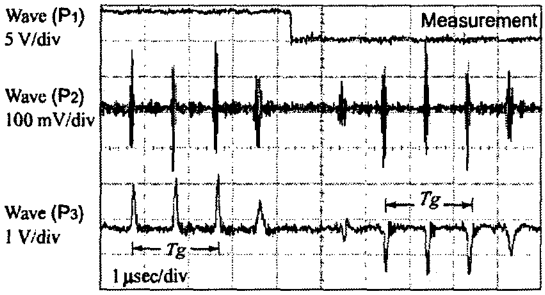

Fig.5 Measured signal waveforms.

Basic Code	Orthogonal code ; O
Period of Code	Tx: $48 = 2 \times 16 + 2 \times 8$ (Pseudo periodic code) Rx: 16 (Periodic code)
Chip Rate (R_{chip})	8.421 Mcps
Symbol Rate	175.4 ksps
Carrier Frequency	$f_c = 215\,\text{MHz} + n\Delta f$ $\Delta f = 263.158\,\text{kHz}$ $n = 0, 1$
Information Modulation	BPSK
Spreading Modulation	QPSK

Table1 An example of specifications