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Monitoring and Controlling Power Generators in Underwater Environment Using CDMA on Acoustic Communication and Power Line Communication

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Abstract

This paper presents a new approach to monitoring and controlling the distribution substations for the power generators in shallow waters combining the underwater acoustic communication (UAC) system. This system makes use of both UAC and underwater power line communication (UPLC) by means of binary phase shift keying (BPSK) of code division multiple access (CDMA) with Hadamard code, in order to accomplish the smart grid of distribution automation system. The system can be used to evaluate the performance of bit error rate (BER) value in terms of the transmitted distance and the transmitted signal power.

1. Introduction

The amount of oceanic energy, in the form of tidal power (TP), wave energy, ocean thermal energy conversion (OTEC) and marine current power transferring either kinetic energy or thermal energy to electrical power, is estimated more than 750 hundred million kilowatts of renewable energy[1)]. At present, the transmission information of underwater communication system is composed of sound, electromagnetic (EM) or optical waves. The acoustic communication with very poor sound absorption is versatile, and is widely operated at frequency within the range of about 10 kHz-80 kHz.

Generally, UPLC and UAC techniques apply either CDMA or orthogonal frequency division multiplexing (OFDM), altering the bandwidth efficiency on transmission of UPLC and UAC for bursty and data traffic. The comparisons between OFDM and CDMA communication systems have been performed under the same conditions including overall baud rate, bandwidth occupation and equal transmitted power[2)]. The narrow-band underwater UPLC using low-peak approach fits for CDMA system in frequency ranging from 10 kHz to 450 kHz. The wide-band UPLC using chimney approach is suitable for OFDM system in frequency ranging from 2 MHz to 80 MHz.

We apply the BPSK-CDMA combining Hadamard code with spreading spectrum modulation and demodulation to the UPLC and the UAC system. The signals corresponding to different relay and sensor are orthogonal to each other, and thus the mutual interference among them is reduced. On the other hand, the acoustic channel achieves three merits: increasing transmission speed, decreasing the transmitted signal power and extending bandwidth efficiency in UAC system. The signals are transmitted at higher speed to achieve long distance transmission and in the meantime both the quantities of amplifiers and the BER values are also reduced.

2. Distribution Substation Using CDMA on UPLC and UAC System

2.1 Framework of Distribution Substation

The approach monitor and control transmission distribution automation system by means of BPSK spreading spectrum modulation and demodulation for the UPLC and the UAC system as shown in Fig. 1.

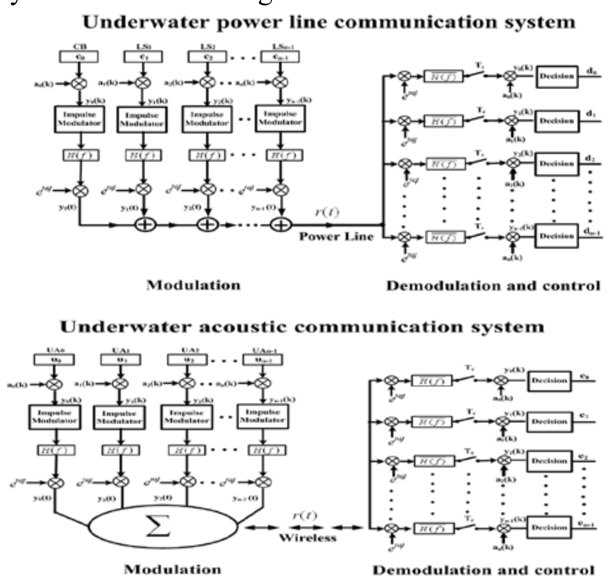

Fig. 1 N schematic configuration of BPSK spreading modulation and demodulation in CDMA

Since Hadamard code has the characteristics that the elements of the core are +1 and -1, and can further be expanded to $N \times N$ with $N = 2^n$. Taking $n = 2$ as an example, the Hadamard code is as follows:

$$H_{4\times 4} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

Each row in the Hadamard transform corresponds to the different code corresponding to the different relay and sensor which represent circuit breaker (CB), Line switch #1 (LS_1), LS_2, …, LS_{n-1} and Underwater acoustic #0 (UA_0), UA_1, …, UA_{n-1}, respectively as shown in Fig. 1.

2.2 Framework of Distribution Substation Using CDMA on UAC System

The UAC system is composed of sensor nodes with data (u_0, u_1, …, u_{n-1}) corresponding to different power generators through the acoustic modem[3], which converts digital data into acoustic signal, to link the UAC network by means of wireless transmitted information using BPSK-CDMA from the underwater network to an onshore the control and monitor center. In the UAC system, decision panel compares default values (a_0, a_1, …, a_{n-1}) with the transmitted thresholds (s_0, s_1, …, s_{n-1}), and then the absolute values Δ_0, Δ_1, …, Δ_{n-1} are obtained, where $\Delta_0 = |s_0 - a_0|$, $\Delta_1 = |s_1 - a_1|$, …, $\Delta_{n-1} = |s_{n-1} - a_{n-1}|$. If any of Δ_0, Δ_1, …, Δ_{n-1} are greater than the corresponding maximum allowed default values, the control signals (e_0, e_1, …, e_{n-1}) through the acoustic modem will be sent to different relays as well as supervisors for further process of either monitoring and controlling the system or turning off the fault switch in the underwater environments.

3. Results and Discussions

For the UAC system of 6 users, the chip spectrogram of signal with additive white Gaussian noise (AWGN) under input signal to noise ratio ($SNR = -13\,dB$) is transmitted in the channel[4]. The power of the noise decreases as the carrier frequency becomes layers as shown in Fig. 2.

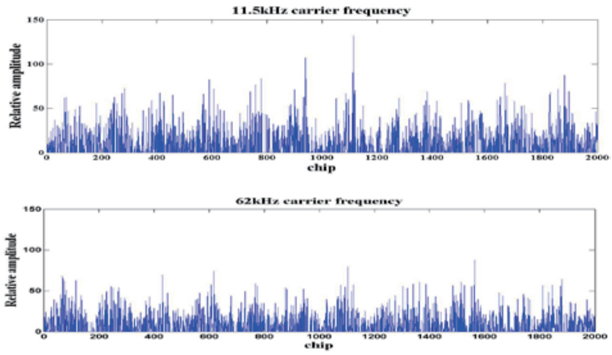

Fig. 2 The signal in AWGN channel with respect to frequencies 11.5 kHz and 62 kHz

The UPLC system with P_s/P_n=7 and the UAC system with P_s/P_n=1.5 corresponding to different BER value calculated by modified Katayama's[5] numerical formula. These BER values are evaluated between five different carrier frequencies (50 kHz, 150 kHz, 250 kHz, 300 kHz and 350 kHz) for UPLC system and other five different carrier frequencies (11.5 kHz, 30 kHz, 45 kHz, 62 kHz and 80 kHz) for UAC system as shown in Figure 3. The numerical methodology will be applied to BPSK-CDMA in the UPLC and the UAC system for the analysis and variation with experimental data.

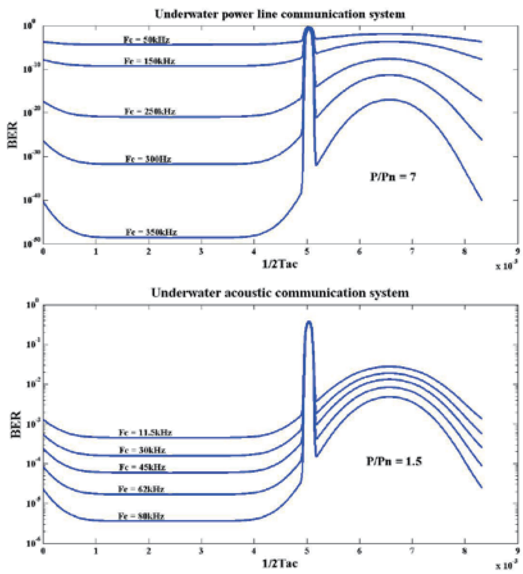

Fig. 3 BER distribution with respect to time and frequency for the UPLC and UAC system

4. References

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