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Design of Adaptively Operated Underwater Acoustic Communication Modem in Shallow Water

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1. Introduction

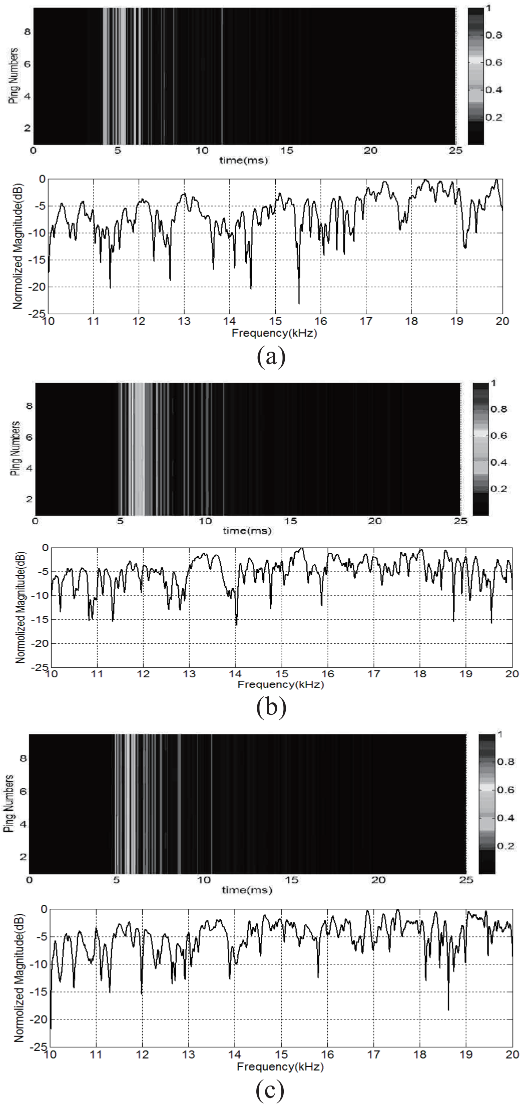
Underwater acoustic communication systems are used in broad range of application such as underwater acoustic communication networks, autonomous underwater vehicles, environment monitoring and naval underwater warfare1). However, the objective performances of the systems are very much influenced by an acoustical channel characteristics between a transmitter (Tx) and a receiver (Rx).

To quantify effects of the acoustical channel characteristics on the system performance, various studies such as acoustical physics, modem structure and channel encoder structure have been conducted. It is certain that any system can combat time, frequency and space dependent fading channel with a predefined bit-error-rate (BER). Fortunately, an operating range of a underwater acoustic system is limited in a given oceanic area with fixed positions of Tx and Rx within a given time interval2,3).

In this study, QPSK system is designed to operate adaptively in a given range between Tx and Rx. The pilot signal of linear frequency modulated (LFM) signal which measures a channel impulse response is transmitted. A carrier frequency of QPSK is changed adaptively on a destructive or a constructive interference pattern analysis from a received pilot signal.

2. Characteristics of Multipath Fading Channels

As shown in **Fig. 1**, channel multipath intensity profiles generally consist of discrete strong paths and as a result, receiving signal spectra show a destructive or constructive interference patterns for given Tx and Rx ranges. In each interference pattern, the dips and the maxima correspond to a destructive and a constructive interference frequency, respectively and it depends on Tx to Rx range. In our concurrent study of shallow water channel characterization, at the corresponding frequencies of dips and maxima the fading statistics became a Rayleigh and a Ricean distribution, respectively. For given range, the mean and the standard deviation of the statistics are changed with sea surface roughness and frequency.



(a)

(b)

(c)

Fig. 1 Normalized receiving signal multipath intensity profiles and spectra for three Tx-Rx ranges: (a) 0.4 m; (b) 0.6 m; (c) 0.8 m.

3. Carrier Frequency Set of QPSK System

Whatever the sea surface roughness changes, the frequencies of dips and maxima may not change even if the means and the standard deviations of corresponding frequency statistics change. The maxima frequencies are better choice as carrier frequency set since the signal to noise ratio (SNR) of maximum frequency is larger than that of dip frequency.

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In our study, the amount of the symbol bandwidth in each dip frequency is excluded in carrier frequency set. **Fig. 2** shows the flowchart of the adaptively selecting a carrier frequency of underwater acoustic comunication system.

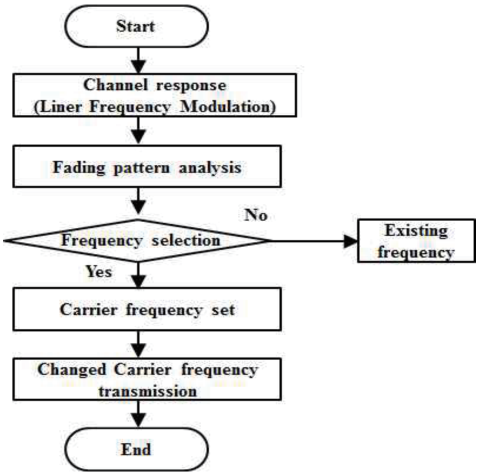


Fig. 2 Flowchart of a carrier frequency selection of underwater acoustic comunication system.

4. Experiments

As a preliminary experiment before a real ocean, the experiment was conducted in about 1 m depth water tank on Aug. 10, 2015. The experimental configuration and parameters are shown in **Fig. 3** and **Table I**. The ranges between Tx and Rx are set to be about 0.4, 0.6 and 0.8 m and the depth of Tx and Rx are both set to be 0.2 m, respectively. QPSK system is applied and the carrier frequencies are set to be 13, 16, and 19 kHz to verify our design principle.

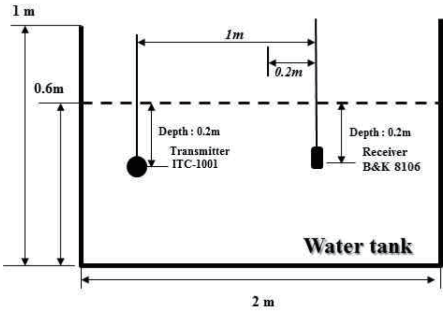


Fig.3 Experimental configuration.

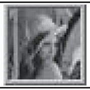
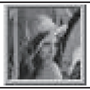
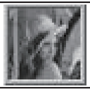
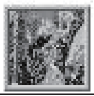
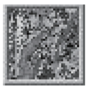
Table I. Experiment parameters.

Modulation	QPSK
Tank depth(m)	0.6
Bit rate(bps)	100
Select frequency(kHz)	13, 16, 19
Distance(m)	0.4, 0.6, 0.8
Tx and Rx depth(m)	0.2
Transmission data	Image (9800bit)

5. Results

Table II shows the received images and BERs of three different carrier frequencies at 0.4, 0.6 and 0.8m Tx-Rx ranges. At the 0.4 m range, BER in 13 kHz is 0 but in 16 kHz it is 0.38. The 13 and 16 kHz correspond to maximum and dip frequencies, respectively, in Fig. 1. At the 0.6 m range, BERs are 0 in both of 13 and 19 kHz which correspond to maxima frequencies in Fig. 1. At 0.8 m range, the BER of 16 and 19 kHz are 0 and 0.37 which correspond to maximum and dip frequencies, respectively.

Table II. Received images and BERs.

Range(m)	0.4	0.6	0.8m
Freq.	13kHz	13kHz	16kHz
Image			
BER	0	0	0
Freq.	16kHz	19kHz	19kHz
Image			
BER	0.38	0	0.37

6. Conclusions

The carrier frequency of underwater acoustic system can be selected based on multipath interference pattern. By applying this principle, underwater acoustic communication system can be adaptively operated in a given Tx-Rx range or a given spatial range in shallow water which has a few discrete strong multi-paths. QPSK system was applied in a water tank and verified its feasibility.

Acknowledgment

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