2011 2nd International Conference on Networking and Information Technology
IPCSIT vol.17 (2011) © (2011) IACSIT Press, Singapore

Underwater Acoustic Communication based on VMCK Modulation

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Abstract—in this paper, ultra narrow band modulation is applied into acoustic communication, which is original and innovative. The very minimum chirp keying (VMCK) modulation possesses characteristics of an ultra narrow band (UNB) communications. Therefore better spectrum efficiency can be achieved. Experimental results in both air and water demonstrate that the transmission rate can multiply several times of which in conventional modulations [1], and it is expected to be used in future underwater communication occasions such as submarine.

Keywords-very minimum chirp keying(VMCK); acoustic communication; ultra narrow band(UNB)

1. Introduction

Underwater acoustic communication has been a popular field in recent years due to the complexity of ocean channel [2] . Increasing the efficiency of communications between underwater strategic nuclear submarines is extremely urgent. Communications via electric and optical cables restrain the mobility of submarines greatly. Then the wireless occurs.

However, extremely low frequency band must be used to avoid the great attenuation of electromagnetic waves in seawater. Long antenna and high transmission energy must be supplied to emit electromagnetic waves properly. Such requirements are difficult to achieve. Thus, Acoustic wave is regarded as the only way of long range underwater communications.

It is well known that underwater acoustic communication is at a low rate upon the conventional modulations. Evidently, this modulation develops a long gap from the communication demand. With the rapid development of communication industries, increasing the spectrum efficiency becomes an urgent target. Due to its high spectrum efficiency, VMCK modulation is adopted in the experiments, which is an original and innovative method.

2. VMCK Modulation

2.1VMCK signals

The first application of UNB (ultra narrow band) in communication can date back to the patent proposed by H.R. Walker in United States. Compared with the traditional modulations such as FSK, ASK and DPSK, UNB is considered to be a modulation with a higher spectrum utilization rate. It needs only a fraction of or even one of a dozen bandwidth in the same rate. That is, UNB can take advantage of the available band resource effectively [3]. The UNB technique is so traditional that it represents logic 1 or 0 with different carrier waveforms. Each carrier-wave cycle may transmit 1 bit data in theory. Then, the signal's transmission bit rate is equal to the carrier frequency. So the point is to reduce the carrier bandwidth.

As a kind of UNB modulation, VMCK is an extending application of chirp signals.

"Chirp" originally means a sharp sound made by small birds or insects with a varied frequency. The frequency of chirp signals changes linearly in a single cycle while the amplitude and phase maintain continuous.

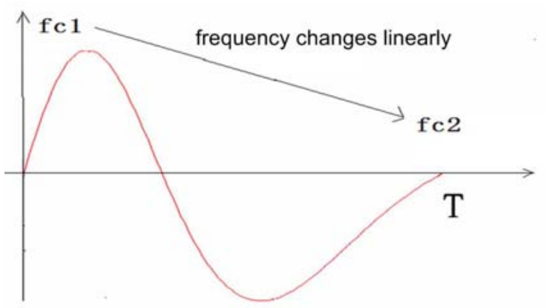
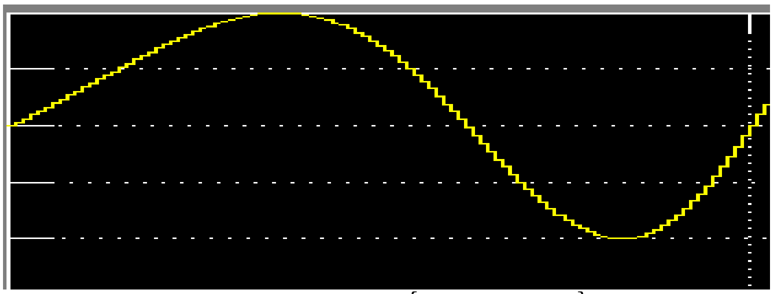
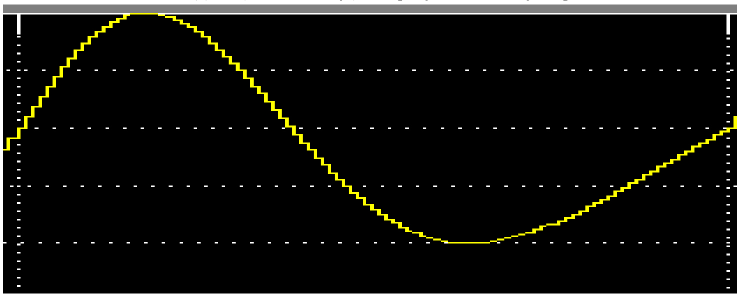


Fig. 1: Chirp signal waveform

VMCK modulated signals represent logic 1or 0 with expressions below. [4]



$$s_0(t) = (1-\alpha+2\alpha f_s)\sin\{2\pi f_s[1-\alpha+\alpha f_s t]t\}$$



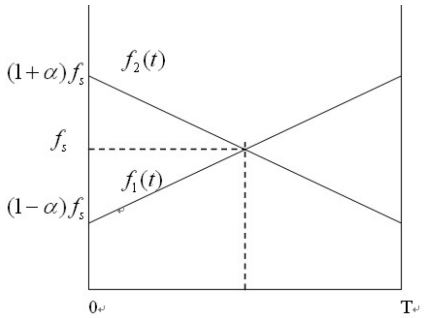
$$s_1(t) = (1+\alpha-2\alpha f_s t)\sin\{2\pi f_s[1+\alpha-\alpha f_s t]t\}$$

Fig. 2: Modulation waveform of VMCK

Under certain circumstances, multi-period waveforms are used to represent 1 or 0 [5].

2.2Advantages

VMCK signal is characterized by its a linear frequency, which is shown in figure 3. The frequency changes from $(1-\alpha)\times f_s$ to $(1+\alpha)\times f_s$ linearly.



$$f_2(t)=\frac{d(f_s[1+\alpha-\alpha f_s t]t)}{dt}=f_s[1+\alpha-2\alpha f_s t]$$

$$f_1(t)=\frac{d(f_s[1-\alpha+\alpha f_s t]t)}{dt}=f_s[1-\alpha+2\alpha f_s t]$$

Fig. 3: VMCK linear frequency

The energy of VMCK signals concentrate in a narrow band [6]. As shown in figure 4, the spectrum band occupies only 2 kHz or so. The zero passing point varies according to its rising or falling frequency. Phase and frequency maintain continuous in this point with no extra frequency components. It can be applied to bandwidth-limited channels due to its low power, narrow band and high channel utilization rate. Traditional modulations such as ASK, FSK and DPSK need several carrier cycles to represent 1 bit data, which restricts the transmission rate. Besides, they need more spectrum resource because of the extra frequency components.

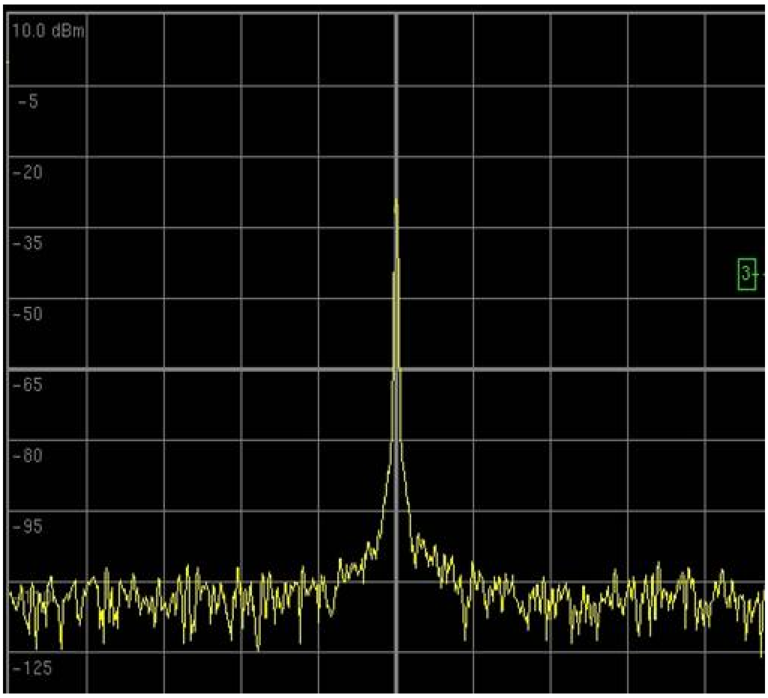


Fig. 4: VMCK spectrum band

3. Acoustic Communication Based on VMCK

3.1 Characteristics

An underwater communication system must be built. Firstly, messages such as texts, voice and images are converted into electrical signals via an electrical transmitter. After the digital processing encoder, electrical signals can be converted into acoustic signals via a transducer. Secondly, underwater acoustic signals carrying information reach the receiving transducer which can restore electrical signals. Thirdly, after a decoder, messages electrical signals carry can be converted into texts, voice or images via an electrical receiver.

Great attention needs to be paid to the transducer's driving voltage, direction, security, operating frequency and other parameters first. However, multi-path interference will occur when acoustic waves transmit underwater, which mainly comes from analog signals and the chaos of sound field due to waves, fish and marine. Thus, further research is essential.

3.2Transmission of acoustic signals based on VMCK

To study the VMCK underwater acoustic communication, some experiments on the sending and receiving of VMCK signals in the air are conducted with the PC sound card, and the results as in the following table.

TABLE I. Factors Affecting Communication in the Air

	sampling rate(Hz)	discrete points in a Cycle	Range (cm)	Numbers of Sending points	conditions	BER
1	22050	50	2	2000	External noise	1.0E-3
2	22050	50	2	2000	External noise	0.0355
3	22050	50	10	2000	External noise	5.0E-4
4	22050	50	20	2000	External noise	0
5	22050	50	30	2000	External noise	0
6	22050	50	60	2000	External noise, no microphone	0.1775
7	22050	50	60	2000	External noise, with microphone	0.011
8	44100	50	5	2000	External noise	0.126
9	44100	20	20	2000	External noise	0.1555
10	22050	50	0	2000	No noise	0
11	22050	50	0	2000	No noise	0
12	44100	20	0	2000	No noise	0

BER in the air channel is mainly affected by the channel's distance, conditions, discrete points on each carrier cycle and the sampling frequency.

3.3Experiments

On the basis of acoustic transmission properties, an underwater communication system can be built, which is shown in figure 5. The application of the way of controlling variables such as depth and distance is for the further research. Standard VMCK signals can be generated, received and demodulated by MATLAB software on PC. Then, it is not difficult to analyze transmission performance such as BER.

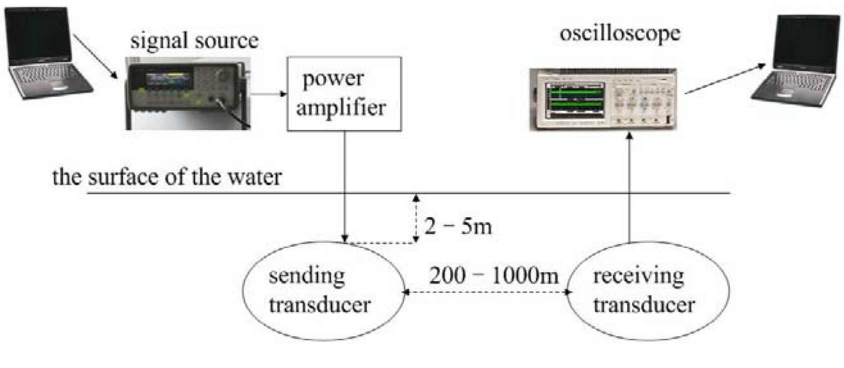


Fig. 5: Underwater acoustic communication system

The signal source can generate electric VMCK signals. The oscilloscope can receive and display. The power amplifier can amplify electric signals. In transducers electric signals are converted to acoustic signals.

Meanwhile, the whole communication process including signal generation, transmission and demodulation can be simulated on MATLAB software by means of simulating the transducer's amplitude-frequency characteristics, which is shown in figure 6. This further validates the feasibility of the subject.

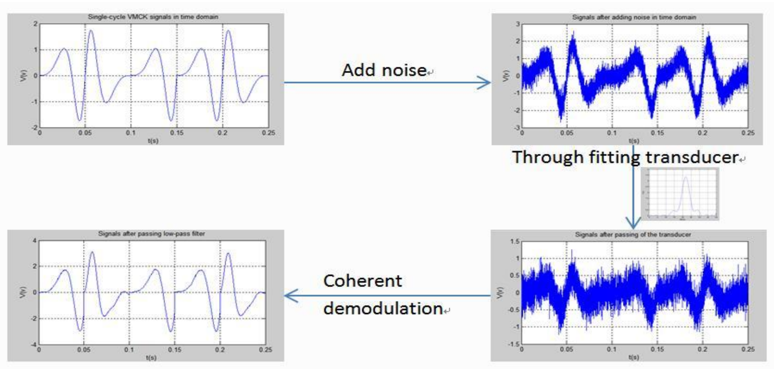


Fig. 6: MATLAB simulation of VMCK signal transmission procedure

4. Conclusion

The bit error rate caused by underwater channel is similar to air channel though the former is more complex. Experiments in the air have directive significance to the further study in underwater field. Study of underwater acoustic communication based on VMCK ultra narrow band modulation is no doubt a pioneering try.

5. Acknowledgements

This work is supported by National Undergraduate Student Innovation Project and NSFC60872021.

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