A Design of Ultraphonic Tubulous Water Communication System Based on OFDM

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Abstract—**In this paper, a design of ultraphonic tubulous water communication system based on OFDM is introduced. The system takes PL3106 which is embedded enhanced 8051 microprocessor as the control chip and takes TMS320VC5509 as the core of OFDM modulation-demodulation. In the paper, the principle of OFDM is introduced briefly. The hardware and software of the system are designed and the experimental results are analysed and concluded.**

Keywords* — *Ultraphonic tubulous water communication; Orthogonal Frequency Division Multiplexing (OFDM); channel attenuation; multipath effect; ultrasonic transducer

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1 Introduction

As the rapid development of science and technology, especially as the study of hydroacoustics is deeper, people begin to pay more and more attention to the research and development of underwater acoustic communication system[1]. Underwater acoustic channel is very complicated. Its noise, multipath effect and channel attenuation are serious. At present, the underwater acoustic communication mainly makes use of acoustic to transmit signals in the sea. Ultraphonic tubulous water communication is one kind of underwater acoustic communication. It makes use of ultraphonic to transmit signals through the tubulous water channel. It can save resources, reduce cost and it is easy to popularize. Its network can cover large area. In the area of wiring difficultly, the ultraphonic tubulous water communication has obvious advantages. Because water pipe is the basic installation of people's life, it is an abundant resource. In addition, the ultraphonic tubulous water communication is accord with the requirement for building an economical society, so its application prospect is rather considerable.

2 Development Situation of Ultrasonic Water Communication

Currently acoustic wave is the main carrier of information transmission and underwater acoustic communication is the only available communication form of remote information transmission. The underwater acoustic communication technology was born in the middle of the twentieth century, the same as other signal processing technology, it also experienced from the initial stage of analog communication to the current stage of digital communication[2]. At home, Harbin Engineering University, Institute of Acoustics, Xiamen University, Northwestern Polytechnical University and so on, they did underwater acoustic communication research successively[3]. During the last ten years, underwater acoustic communication, especially the high-speed underwater acoustic communication has developed along with the trend: from coherent communication to incoherent communication[4]. As the improvement of hardware and the calculating capacity of signal processing chip, modulation system and signal processing algorithm of underwater acoustic communication are gradually using new and complicated technology, such as spatial modulation technology, adaptive equalization technology, and diversity reception technology[5]. Earlier DPSK underwater acoustic communication system was presented by GR. Makelburg in 1981[6].

Orthogonal Frequency Division Multiplexing (OFDM) is a new technology which is used in wireless high-speed data transmission channel in recent years. It is one kind of carrier modulation technologies and now it also begins to be applied in underwater acoustic communication[7]. Underwater acoustic communication which once was just applied in the military area is extending into commercial fields now, and current research is paying more attention to the development of efficient communication and signal processing algorithms. Although underwater acoustic communication has made great progress in its relevant technologies, it still uses seawater as the transmission medium. The

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research which uses tubulous water channel as the transmission medium hasn't appeared.

3 Principle of OFDM Technology

Orthogonal Frequency Division Multiplexing (OFDM) technology is a kind of carrier modulation technology, the biggest characteristic is high-usage spectrum and strong capacity of competing channel decline and intersymbol interference. Its basic block diagram is shown in Fig. 1.

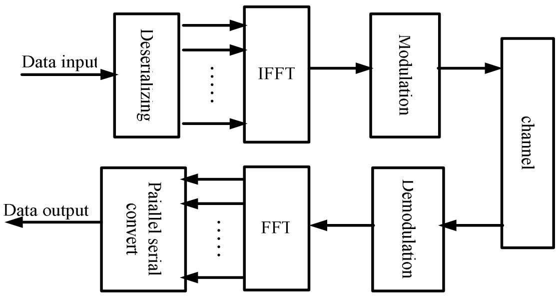

Fig. 1 The basic block diagram of OFDM system

Actually OFDM technology divides the channel into several sub-channels, converts serial data flow into N low-speed parallel data flow, and then modulates N subcarriers to transmit separately. One OFDM symbol includes many carrier signals, and these signals are all modulated by the way of Phase Shift Keying (PSK) and Quadrature Amplitude Modulation (QAM). Assume the subcarrier number is N, the continuous time of OFDM symbol is T, the data symbols distributed to each sub-channel is $d_i(i=0,1,\ldots,N-1)$, and the ith carrier frequency is f_i, so the complex equivalent baseband signal of OFDM can be described by formula 1.

$$s(t)=\sum_{i=0}^{N-1} d_i rect(t-t_S-\frac{T}{2})\exp[j2\pi f_i(t-t_S)], t_S \le t \le t_S+T \tag{1}$$

During an OFDM symbol cycle, each subcarrier includes integral multiple cycles. Between two contiguous subcarriers, there is one cycle discrepancy. According to formula 1, demodulate the ith subcarrier and integrate it during the T time. Formula 2 can be obtained.

$$\begin{aligned}\hat{d}_j &= \frac{1}{T}\int_{t_S}^{t_S+T}\exp[-j2\pi\frac{j}{T}(t-t_S)]\bullet\sum_{i=0}^{N-1} d_i\exp[-j2\pi\frac{i}{T}(t-t_S)]dt \\ &= \frac{1}{T}\sum_{i=0}^{N-1} d_i\int_{t_S}^{t_S+T}\exp[j2\pi\frac{i-j}{T}(t-t_S)]dt \\ &= d_j\end{aligned} \tag{2}$$

It can be seen that the expected symbol d_j can be recovered after demodulating the ith subcarrier. Due to frequency difference $(i\text{-}j)/T$ can produce integral multiple cycles, so for other carrier the result of demodulating during integral interval is zero. It means that there is no mutual interference among subcarriers. They are orthogonal in time and overlap in frequency.

In this paper, the ultrasonic tubulous water communication system is designed to adopt OFDM technology to reduce the adverse effect, which is brought by multipath interference, channel decline and so on. Then it can realize high-speed transmission. Therefore, the application of OFDM in the ultrasonic tubulous water communication system has great advantage.

4 System Implementation

4.1 System Hardware Design

In order to implement the function of ultrasonic tubulous water communication, we selected PL3106 which is embedded enhanced 8051 compatible microprocessor as the main controller and TMS320VC5509 as the operation core of OFDM modulation-demodulation, the system diagram is shown in Fig. 2.

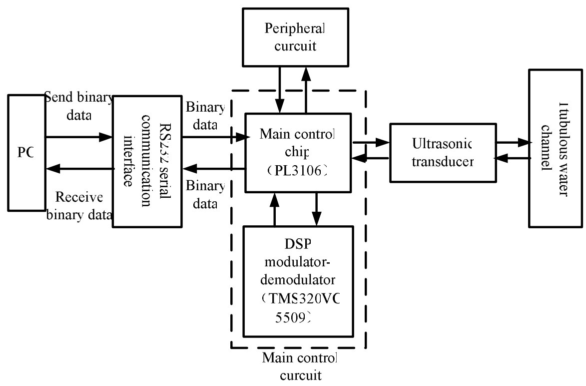

Fig. 2 The general block diagram of system

The system mainly consists of PC, RS232 interface circuit, controlling circuit and peripheral circuit. Thereinto, controlling circuit is in charge of data processing. Peripheral circuit mainly provides controlling circuit with power, external storage, reset circuit and real-time clock, etc. Ultrasound tubulous water communication system includes two parts: the sending end and receiving end.

In the sending end, PC sends binary data to the main control chip PL3106 through RS232 interface and start deserializing and PSK modulation in the chip. Then the modulated data goes through OFDM modulation in the TMS320VC5509, and it is sent back to the main control chip. After adding circular prefix and modulation, it will be send to the tubulous water channel by ultrasonic transducer.

In the receiving end, ultrasonic transducer receives data from water channel and sends it to main control chip. The control chip demodulates the data and removes circular prefix first, then it sends the data to TMS320VC5509 to carry out OFDM demodulation.

After demodulating, the signal returns to control chip to carry out PSK demodulation and parallel serial conversion. Finally, the ultimate data will be sent to the PC by RS232 interface and shown on it.

4.2 System Software Design

This system software design mainly includes two parts: the MCU software design and DSP software design. The following work is to introduce the two parts software flow.

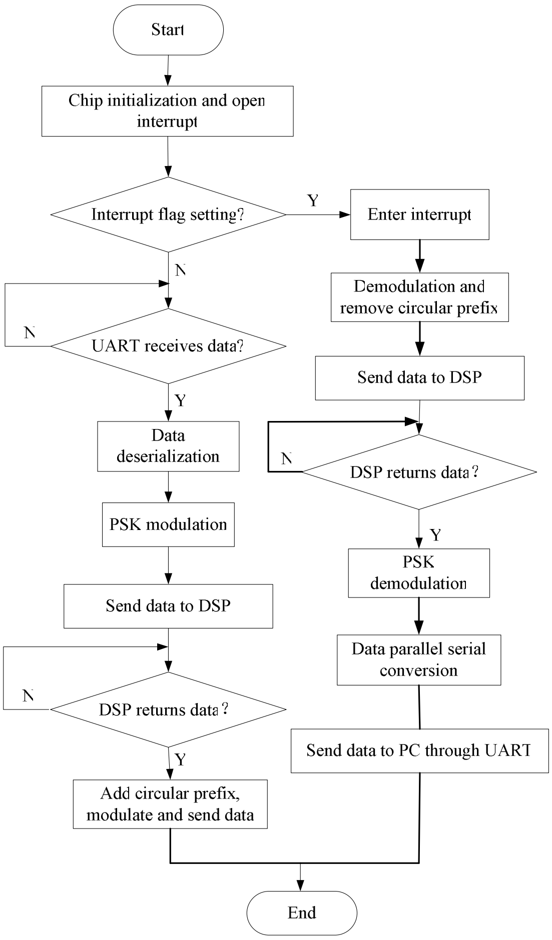

Fig. 3 The flow chart of program

When power is on, MCU initializes its basic modules first. By judging the interrupt flag MCU can ensure whether it is the sending end or the receiving end. If it is the receiving end, MCU will demodulate the received signals, remove the circular prefix, and send them to the DSP to proceed with FFT algorithm. MCU demodulates returned PSK data, carries on parallel serial conversion and sends them to the PC to display them. But if MCU ensure itself is the sending end, it will deserialize the data, start PSK modulation and send data to the DSP through SPI interface. After being disposed with IFFT algorithm, MCU will add circular prefix, modulate them, and send them out. The program flow chart is shown in Fig. 3.

DSP chip also initializes itself first after power on. When it receives data sent by MCU, it will store them in the buffer and wait for the interrupt flag setting after receiving over, then trigger interrupt, close it and skip to the IFFT or FFT algorithm processing unit. After that, it will send data to MCU through the SPI interface. The DSP program flow chart is shown in Fig. 4.

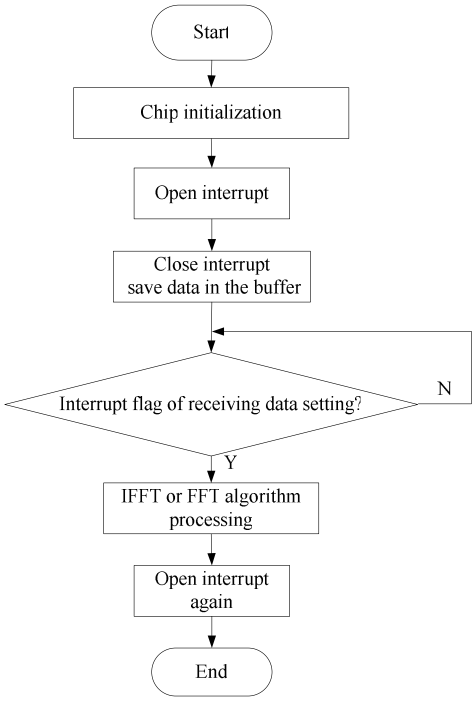

Fig. 4 The program diagram of DSP

5 Conclusions

At the sending end, PC sends binary data at random. Received data will be shown on the PC at the receiving end and be verified. The test results are shown inTab.1 and Tab.2.

Tab.1 The statistical chart of test results using OFDM

Type / Time	Sending bytes number	Correct revived time	Error rate
100	32	98	2%
100	64	97	3%
200	32	194	3%
200	64	194	3 %
300	32	291	3%
300	64	290	3.3%

(Continued on P.22)

The retrieved effective parameters (Fig. 10(a) and 10(b)) show a negative real part for the permittivity and a positive real part for the permeability. A near to zero refractive index in the 2.4Ghz band is shown in the Fig. 10(c).

4 Conclusion

Patch antennas have been researched, our proposed metamaterial patch antenna has more gain than those. The simulation results are compared for 2 types of antennas. The ordinary patch antenna and proposed metamaterial patch antenna have gain 7.7dBi and 14.7dBi, respectively. Therefore, the gain of the proposed metamaterial patch antenna is improved by 7dB than that of the ordinary patch antenna.

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(From P.29)

Tab.2 The statistical chart of test results without using OFDM

Type / Time	Sending bytes number	Correct revived time	Error rate
100	32	98	2%
100	64	98	2%
200	32	195	2.5%
200	64	194	3 %
300	32	293	2.3%
300	64	292	2.6%

The test results show that with the increasing of data, error rate maintains in 2.89% without using OFDM. This is mainly caused by many negative factors, such as channel noise, multipath effect, channel decline. In addition, the equipment of this system also has a certain error rate. After using OFDM method, error rate maintains in 2.4%. It shows that the error rate has been decreased. The results have basically achieved the expected aim and implemented the function of communicating through the tubulous water channel.

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