Research on Wireless Transmission Method of Acoustic Waves in Metal Pipelines

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Abstract. In this paper, an on-line detection device capable of simultaneously detecting the concentration of methane in the shallow gas and the physical and mechanical properties of the soil is designed, and the acoustic transducer is used to wirelessly transmit data by using the metal probes in front of the two parts. The experimental results show that data communication can be performed very well.

1. Introduction

The shallow gas detection method currently used in China is mainly the exploration drilling method. This method mainly collects the sample rich in shallow gas through the probe, and then extracts the shallow gas in the laboratory, and finally measures it with a gas chromatograph. Each gas component in the layer gas. The method has accurate detection results, but the detection time is long, the price is expensive, the online measurement cannot be performed, and the basic physical and mechanical properties of the seabed soil cannot be determined. Therefore, this paper designs a shallow gas on-line detection device combined with a static probe. However, due to the existence of the mechanical structure and the gas-liquid separation membrane, the data measured by the static probe cannot be transmitted by wire. Therefore, the cable-free transmission of the static probe signal in the metal probe is also a major problem to be solved in this paper.

In many complex metal pipeline media, wireless communication is mainly carried out by sound waves, but due to technical blockade and confidentiality, there are few related materials for communicating sound waves in solid media, and most of them are in the field of petroleum exploration. Compared with the structure and size of the probes studied in this paper, it is still necessary to conduct independent research on the basis of relevant data, and research on the acoustic wave communication method based on the probes used in this paper, and finally design can detect An on-line detection device that determines the basic physical and mechanical properties of the soil by the shallow gas at the bottom of the sea.

2. Overall design

Firstly, the whole probe is pressed down at a constant speed by using the hydraulic device on the mother ship. The static penetration probe at the bottom of the probe can measure the cone resistance, the side wall friction and the pore water pressure, and then measure the sound by wireless communication. The signal is transmitted to a data acquisition module located in the sensor placement room. At the same time, the solid-liquid gas separation is realized by using the permeable stone, the
porous ceramic and the waterproof gas permeable membrane, and the infrared methane sensing gas in the sensor placement chamber senses the methane in the separated shallow gas, and outputs a corresponding signal and passes. The data acquisition module obtains the output signal of the sensor. Finally, the signal is transmitted to the host computer on the ground through the cable.

2.1. Communication system design

In free space, electromagnetic waves are the most widely used and most mature wireless transmission methods. Therefore, this design first selects the electromagnetic wave wireless module for wireless communication in the probe. Firstly, the two methods selected are tested. The tested electromagnetic wave wireless transmission mode can spread more than one kilometer in free space. In the metal probe, the electromagnetic wave propagation loss is greatly increased and can only transmit 20cm, while in the underwater experiment, the electromagnetic wave transmission method is completely shielded, so the electromagnetic wave transmission method is not suitable for this design. After a large amount of data search and reading, this design uses a transducer-based acoustic wave wireless transmission method.

2.1.1. Transducer selection. The transducer is a key component in the acoustic communication system. At the transmitting end, it is responsible for converting the electrical signal into a mechanical vibration signal (acoustic signal) and coupling it to the probe for electroacoustic conversion; at the receiving end, it is responsible for receiving the probe. The acoustic signal is converted into an electrical signal to realize acoustic-electrical conversion for subsequent demodulation processing by the receiving circuit. Since the transmitter of the system is packaged inside the probe and the transmitter is powered by the battery, the transducer is required to have a smaller size and a higher conversion efficiency. The selection of a suitable transducer is to ensure the research in this paper. A key to the successful implementation of the communication system. According to the principle of sound generation and working performance, the transducer has several types of piezoelectric transducers, traditional magnetostrictive transducers, rare earth giant magnetostrictive transducers and mechanical shock type high power transducers. Piezoelectric transducers are transducers made using the positive and negative piezoelectric effects of piezoelectric materials. They are the most widely used acoustic transducers in the research. The advantage is that the production process is mature, various shapes can be customized, and the conversion efficiency is high. Other transducers are too large to be suitable for this design, so this paper chose a piezoelectric transducer that is relatively simple to implement.

2.1.2. Signal modulation method selection. The original data obtained by the static probe probe can obtain the digital baseband signal through the encoder. The signal cannot be directly transmitted in the probe. Therefore, the baseband signal is modulated onto a carrier of a certain frequency so that the probe can be transmitted as a channel. The process of moving the baseband signal to the carrier signal is usually called modulation. The commonly used digital modulation methods are amplitude keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). Amplitude keying conveys information by controlling the change of carrier amplitude. The commonly used binary amplitude keying 2ASK represents the "0" and "1" on the baseband by the presence or absence of the carrier. Frequency shift keying is to use a digital signal to modulate the frequency of the carrier. When the signal "0" is transmitted, the sine wave with the frequency $\omega_1$ is output. When the signal is "1", another frequency $\omega_2$ is output. Phase shift keying is a modulation method in which the carrier frequency and amplitude are constant and the carrier phase changes with the modulation signal. Generally, the absolute phase shift $0$ represents the digital signal "0", and the phase shift $\pi$ represents the digital signal "1". Due to the flowing water in the probe, the amplitude and phase rotation of the acoustic signal will occur during transmission. The ASK changes the amplitude to represent different information. The random variation of the amplitude will cause the receiver to judge the signal. The phase shift will make the demodulation of the signal received by the receiver after PSK modulation difficult. Compared with the above two signal modulation methods, FSK modulation is insensitive to
phase and amplitude changes, and the anti-noise interference performance of FSK modulation is compared. So this design uses the FSK modulation method.

2.1.3. Signal demodulation method selection. The demodulation method of 2FSK signals is coherent and non-coherent. Since the 2FSK signal contains carrier signals of two frequencies, the demodulation end is formed by two 2ASK receivers connected in parallel. In addition, 2FSK demodulation has other non-coherent demodulation methods, such as frequency discrimination method, zero-cross comparison method, differential detection method, etc. The demodulation method selected by this design is the frequency discrimination method.

2.2. Circuit design

2.2.1. Transmitting circuit design. Two direct digital frequency synthesis (DDS) modules respectively generate two unipolar sine wave signals suitable for data transmission in the probe, wherein the direct current component cannot carry valid digital information, so it is filtered by a DC blocking capacitor. The analog switch strobes one of the two sinusoidal signals according to the binary information to be transmitted under the control of the microprocessor, and the amplifier is amplified by the amplifying circuit to generate the sound wave. This design uses the AD9851 most carrier generator of DDS special chip produced by Analog Devices, which can respond to frequency changes quickly. This article selected Analog Devices

The company's CMOS switch ADG1433 has a total of three single-pole double-throw analog switches. Its TSSOP package helps reduce the circuit area. EN is the enable port of the analog switch. When enabled, all switches are off. When enable is enabled, SxA or SxB is output according to the input state of the control terminal Inx. EN and IN are directly driven by the microcontroller, and SA and SB are respectively connected to the corresponding carrier signals.

2.2.2. Drive amplifier circuit design. After the DDS and the analog switch, the 2FSK modulated signal is obtained, but the energy of this signal is not enough to drive the transducer to generate sound waves, and the signal needs to be amplified to a certain extent to excite the transducer. The amplifier circuit is shown in Figure 3. The op amp uses the high-speed, low-noise voltage amplifier THS4001 from Analog Devices.
2.2.3. Receiver circuit design. The demodulation circuit in this paper uses the demodulation chip XR2211, which is a dedicated FSK demodulation chip. The highest operating frequency can reach 300kHz. The structure of the demodulation circuit is shown in Figure 4. When the 2FSK signal is input from pin 2, the preamplified signal is sent to the PLL loop. When the input is a high frequency signal, the output voltage of the loop phase detector is greater than the internal reference voltage. After passing through the FSK comparator, the 7 pin outputs a low level. At this time, the phase detector output voltage is less than the internal reference voltage and is locked. After detecting the comparator, the 5 pin outputs a high level; when the input is a low frequency signal, its working process and principle are similar. Finally, the 7 pin outputs a high level, the 5 pin outputs a low level, and detects the positive and negative output level of the 7 pin. You can get the 2FSK demodulated result.

3. Experiment and result
To achieve 2FSK modulation, the frequency of the carrier signal needs to be determined first, so a commercially available acoustic transducer is tested to determine the actual frequency of the carrier signal. Its structure is shown in Figure 5.

Both transducers are glued to the inner wall of the probe with a hot melt adhesive. The center distance is 20 cm. The peak-to-peak value of the bipolar sine wave is fixed at 20 V. The frequency of the signal is constantly changed, and the transducer is driven to be used. The oscilloscope observes the amplitude and frequency of the received signal, and plots the relationship between the amplitude and frequency of the received signal. As shown in Figure 6, in order to ensure that the two carriers are orthogonal and do not interfere with each other, the frequency of the high-frequency carrier is preferably the low-frequency carrier frequency Integer multiple. So choose 45k and 90k two carrier frequencies.

Figure 5. Transducer test chart

Figure 6. Transducer frequency test curve

Figure 7. 45 kHz and 90 kHz carrier signals

Figure 8. FSK modulated waveform
The function of the carrier signal generation circuit is to configure two DDS chips using stm32 to generate carrier signals of 45 kHz and 90 kHz. Figure 7 shows the carrier signal waveform generated by two AD9851 frequency synthesis chips. It can be seen from the figure that the carrier signal generation circuit works normally and can output two sinusoidal carriers with frequencies of 45 kHz and 90 kHz.

The frequency selection circuit selects a corresponding carrier signal according to the binary data to be transmitted, thereby generating a 2FSK signal. Figure 8 shows the test waveform of the frequency selection circuit. In the figure, channel 2 is the binary information to be transmitted, the low frequency signal (45 kHz) in channel 1 corresponds to the symbol 0 to be transmitted, and the high frequency signal (90 kHz) corresponds to the symbol 1 to be transmitted. It can be seen from the test waveform that the frequency selection circuit can select the carrier signal of the corresponding frequency according to the symbol information to be transmitted for modulation, and obtain a 2FSK signal.

![Figure 9. 2FSK modulated amplified waveform](image1)

![Figure 10. Received waveform](image2)

The signal received by the transducer conversion is shown in Figure 10. In the figure, channel 1 is the received modulated signal, and channel 2 is the demodulated binary information.

4. Conclusion
In this paper, a set of data transmission and reception system for metal probes is designed, and it is proved by experiments that it can communicate as expected, but there are still some shortcomings. On the one hand, for long-distance data transmission, the influence of the reverberation effect of sound waves on the digital transmission needs further study; on the other hand, in this design, experiments are carried out in a laboratory environment, and the next step is to verify the communication in the actual working environment. The impact of performance.

Acknowledgments
This work was supported in part by the National Key R&D Program of China under Grant 2017YFF0205501 and 2017YFC0804604, in part by the Zhejiang Key R&D Program under Grant 2018C03031 and 2018C03035, in part by the National Natural Science Foundation of China under Grant 61701467.

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