PREDICTION OF CODED SIGNAL PROPAGATION IN FADING CHANNEL

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ABSTRACT This paper presents a method to predict in statistics the coded signal propagation in fading channel with the help of the ray theory. This method features its high speed and efficiency. The predictions of received signal envelope and pulse width can be give out quickly.

1. INTRODUCTION

The prediction of coded signal propagation is important in underwater digital communication, for information is always modulated on coded signals. The underwater channel is suitable for the propagation of sound energy but not for the propagation of coded signals. Coded signals are inevitable distorted after long range propagation in fading channel because of multi-path effect. The signal changes in envelope and pulse width when it reaches the receive hydrophone. This makes the received signal much different from the original signal. One pulse can be spliced into a pulse series in some situation. If coded signal distorts, any communications fail. The prediction of coded signal propagation supplies information that is important to the design of communication system.

However, the underwater channel is complicit and time variable. It is impossible to predict exactly the receiving form of a signal. Any predictions are meaningful and valid only in statistics. The method presented in this paper is a statistical method. The prediction it gives does not represent exactly any real signals but their general form in a piece of time interval.

2. PROPAGATING MODEL ON RAY THEORY

The carrier frequency of coded signal is often between 1KHz and 10KHZ. It is considered high frequency signal when comparing with the sea depth (often between 50m and 5000m) since it satisfies the formula (1).

$$\frac{2H}{\lambda} >> 1, \qquad (1)$$

Propagating model based on ray theory is appropriate in this case.

The energy emitted from the source transports through rays. The paths of rays are determined by Eikonal equation, while the energy that passes through individual ray follows the equation. The value of sound field at the receiver is the accumulation of all arriving rays. The ray that connects the source and the receiver is called eigenray in ray theory. The channel is described between the source and the receiver by a linear filter which impulse response in a short time interval h(t). The channel transfer function is here simplified to be formula(2) in a piece of time.

$$h(t) = \sum A_n \delta(t-\tau_n), \qquad (2)$$

where An represents the amplitude of the nth eigenray and τn represents the transfer delay.

When emitting signal is in form of formula (3),

$$P_S(t) = E(t)e^{i\omega t}, \qquad (3)$$

where E(t) is the slow varying envelope, and ω is the radical frequency of carrier signal, the received signal is then expressed as formula (4).

$$P_R(t) = \sum A_n E(t-\tau_n) e^{i\omega(t-\tau_n)}, \qquad (4)$$

However, higher order eigenrays are greatly attenuated after long range propagation because of the absorption of sound in the sea. It is accurate to evaluate the sound filed at the receiver taking care of lower order eigenrays only. We pay attention to 20 eigenrays at most in the prediction of coded signal propagation.

The underwater channel is a sever fluctuate channel, especially in shallow water. The envelope and phase of carrier signal are all affected when propagating in such a channel. It is incorrect to give prediction by formula (3) which suggests the signal envelope and its phase be un-time-varying. We suppose that the fluctuation of signal comes from the fluctuation of water structure in the channel, while the ray paths fix in their position and the energy each ray carried fix during a piece of time interval. The fluctuation of received signal causes by the phase fluctuation.

We get general prediction formula as follow:

$$P_R(t) = \sum_{i=1}^{N} \sqrt{A_n^2 E^2(t-\tau n)} e^{i\omega t}, \qquad (5)$$

Formula (5) is a general formula to predict coded signal propagation in fading channel, especially for long range communication in shallow water. It shall be noted that formula (5) fails in case ray theory fails.

3. PREDICTION

Program Eigenrays is applied here to calculate eigenrays in constant-depth isovelocity water with range and frequency both scaled according to the sea depth. Channel sound velocity profile, source depth, receiver range, receiver depth and carrier frequency are parameters we should specify to the program. The energy each eigenray carries and the travel time it takes to get to the receiver is given out simultaneously. Channel transfer function is then abstained with this information. Substitute the emitting signal in formula (5), and we get the prediction.

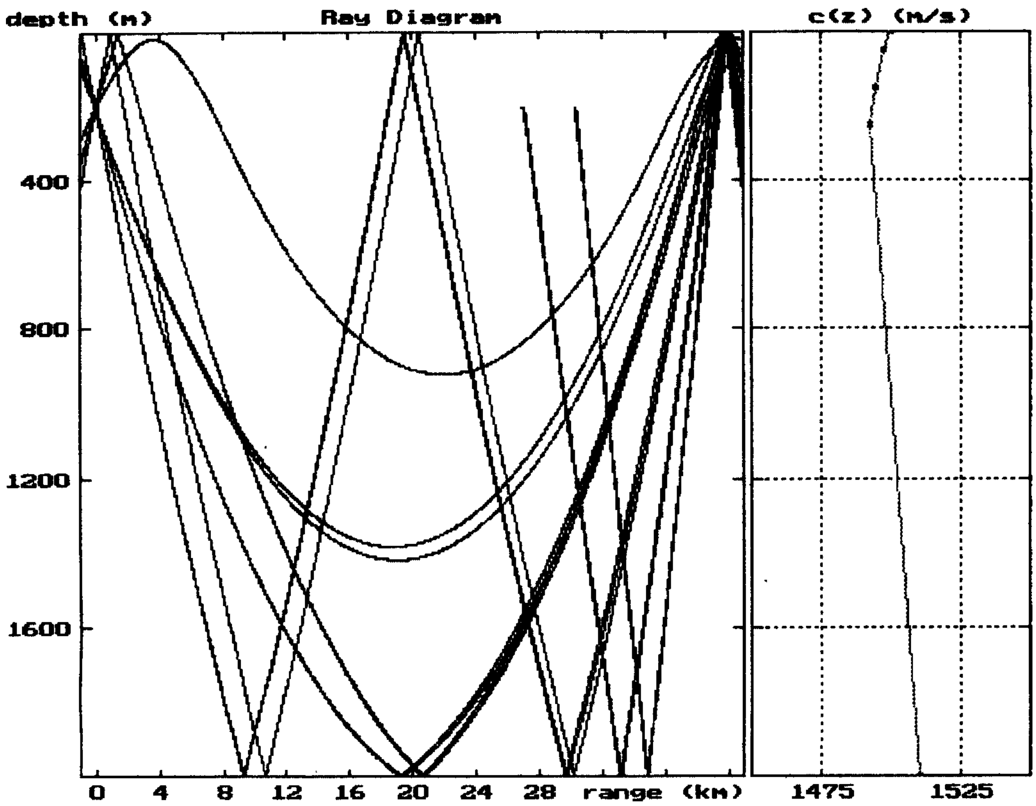

Fig. 1 Ray diagram in a typical underwater channel.

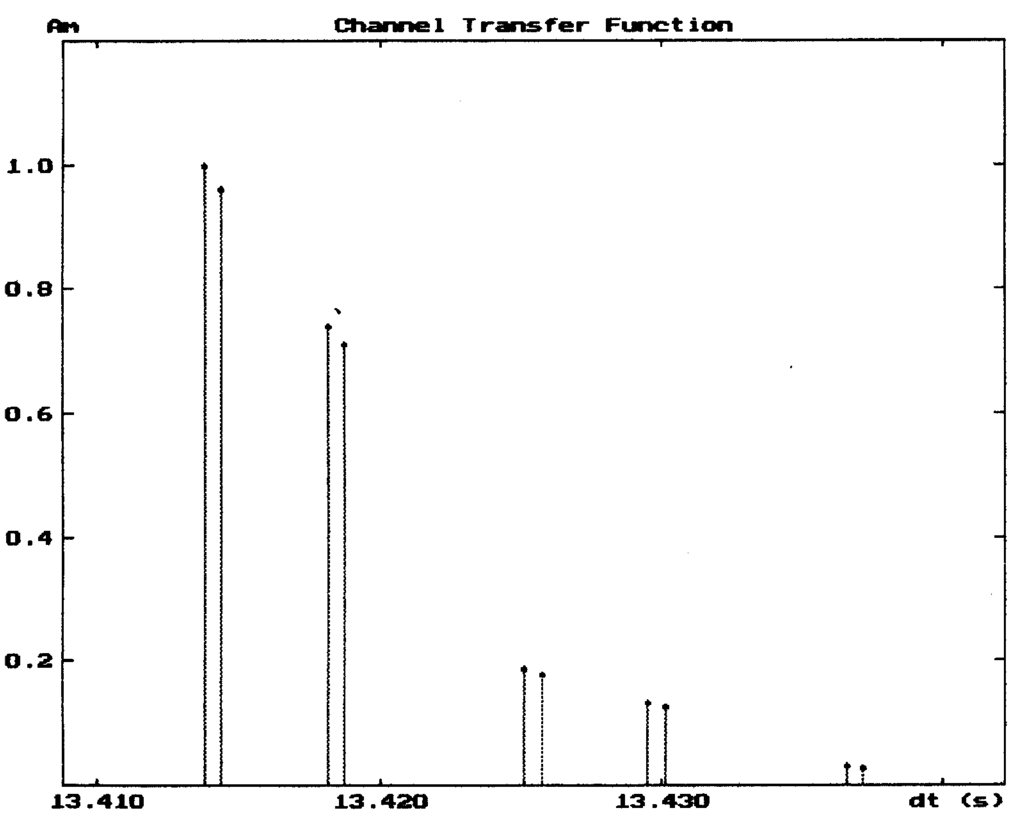

Fig. 2 Channel transfer function evaluate at frequency f0=4.0KHZ

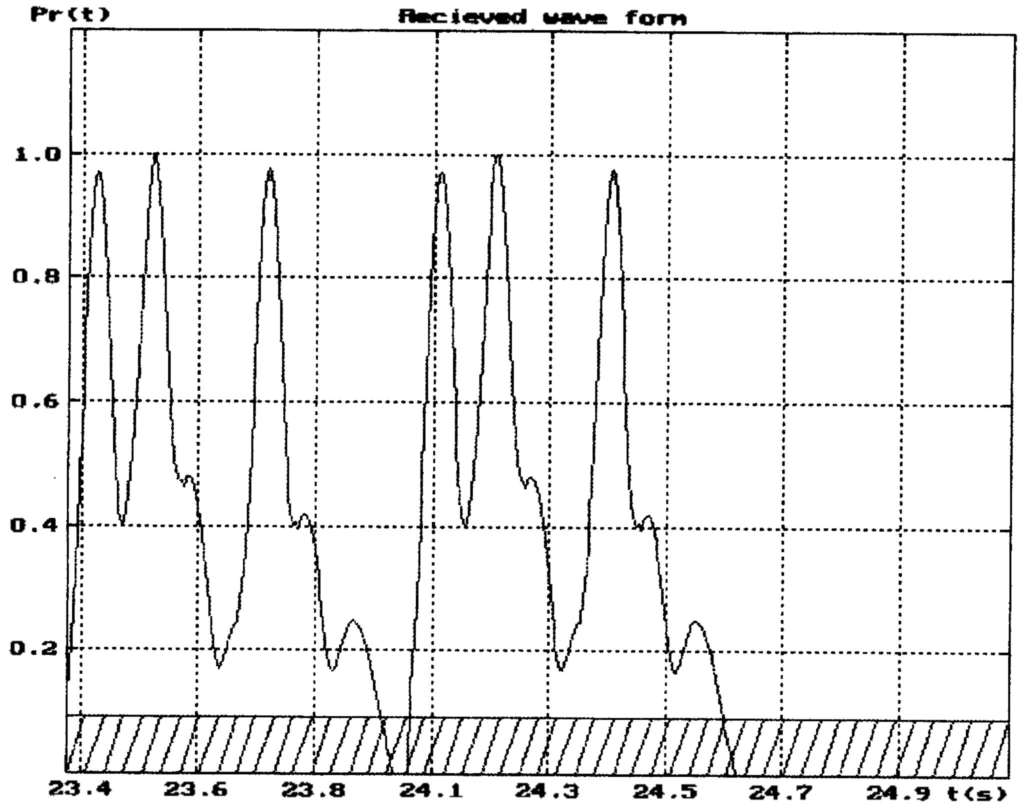

Fig 3. The envelope of predicted arrival signal.

4. CONCLUSION

We find some general laws in under water digital communication after theoretical studies. These laws are verified in experiment in Bohai sea.

(1) The condition suitable for sound energy transportation in fading cannel is different from the condition suitable for coded signals. We find that the conditions suitable for energy detection are often unsuitable for digital communication.

(2) The pulse width of coded signal can affect greatly the received signal. The distortion of short pulse is more sever than that of long pulse. Long pulse is recommended to be used in underwater digital communication.

(3) The DOA of eigenrays are always between -10 and 10. One can use a short line array to receive signal. A narrow vertical beam width of the receive array can be applied to improve system performance.

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