2P6-3

Performance of M-ary Frequency Shift Keying method applying short period raised cosine filter in underwater delay diffusion channel

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1. Introduction

In shallow waters, transmitted acoustic signals are significantly affected by multiple reflected waves from boundaries such as the sea surface and the seabed. The large reflected signals from these boundaries cause inter-symbol interference, which degrades the performance of underwater acoustic communication.

The shaping filter has the characteristics of reducing Inter Symbol-Interference(ISI) from the generation of a band-limited channel and multipath signal reflections. It reduces the increase of high-frequency components in the signal fluctuation due to multipath, thereby limiting the carrier bandwidth, and attenuates the sidelobes that occur at the beginning and end of the signal, thereby lowering the ISI.

In this study, we evaluate the raised cosine filter for image data transmission in shallow waters and propose and evaluate a new modified short period raised cosine filter and matched filter based on this evaluation. The modulation method used in the underwater acoustic communication system is the 8-phase Frequency Shift Keying(FSK) method, and a short period raised cosine filter is applied during modulation. In demodulation, a matched filter for each frequency is applied to restore the signal.

2. M-ary -FSK and Raised Cosine Filter

M-ary FSK is a digital modulation scheme in which information is transmitted by varying the frequency of the carrier signal. A k-bit symbol is mapped to one of $M = 2^k$ frequencies for transmission. The modulated signal can be expressed as follows

$$S_{FSK} = A\cos(2\pi f_M t + \varphi), 0 \le t \le T_s \qquad (1)$$

Here, A represents the amplitude of the carrier, f_m denotes the M-th frequency component, T_s is the symbol duration, and φ is the initial phase. [1,2],

The raised-cosine filter is a filter frequently used for pulse-shaping in digital modulation due to its ability to minimise inter symbol interference (ISI).

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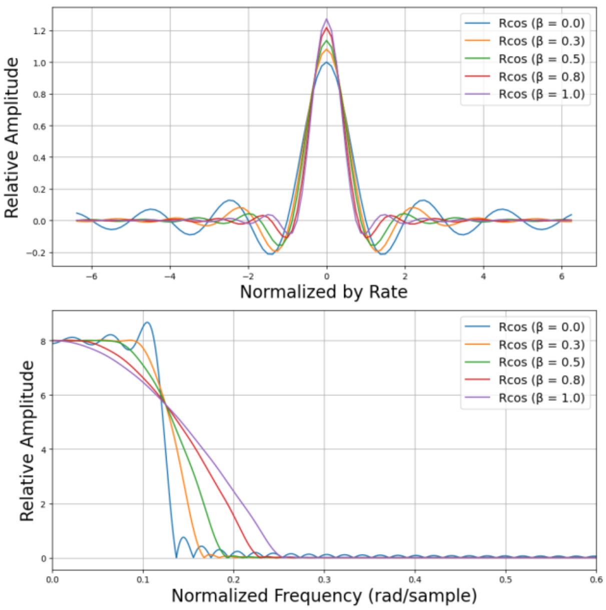

Fig. 1 Variation according to the roll-off factor of the Raised Cosine Filter

It's name stems from the fact that the non-zero portion of the frequency spectrum of its simplest form β = 1 is a cosine function, 'raised' up to sit above the f(horizontal) axis.

Its frequency-domain description is a piecewise-defined function, given by [3-5]

$$\mathbf{H}(f) = \begin{cases} \mathbf{1}, & |f| \le \frac{1-\beta}{2T_s} \\ \frac{1}{2}\left[\mathbf{1} + \cos\left[\frac{\pi T}{\beta}\left(|f| - \frac{1-\beta}{2T}\right)\right]\right], & \frac{1-\beta}{2T} < |f| \le \frac{1+\beta}{2T} \\ \mathbf{0}, & otherwise \end{cases} \qquad (2)$$

for in terms of havercosines

$$\mathbf{H}(f) = \begin{cases} \mathbf{1}, & |f| \le \frac{1-\beta}{2T_s} \\ hvc\left(\frac{\pi T}{\beta}\left(|f| - \frac{1-\beta}{2T}\right)\right), & \frac{1-\beta}{2T} < |f| \le \frac{1+\beta}{2T} \\ \mathbf{0}, & otherwise \end{cases} \qquad (3)$$

Here, T_s is represents the symbol period, β is the roll-off factor.

The impulse response of such a filter is given by

$$h(t) = \frac{\cos\left(\frac{\pi\alpha t}{T_s}\right)}{1-\left(\frac{2\alpha t}{T_s}\right)^2} \operatorname{sinc}\left(\frac{t}{T_s}\right) T_s \tag{3}$$

3. Experiment and result

The water tank (2x1x0.6 m) experimental configuration is shown in **Fig. 2** and **Table 1**. Transmitter to receiver range is 1 m and the transmitter and the receiver are located at same depth of 0.35 m.

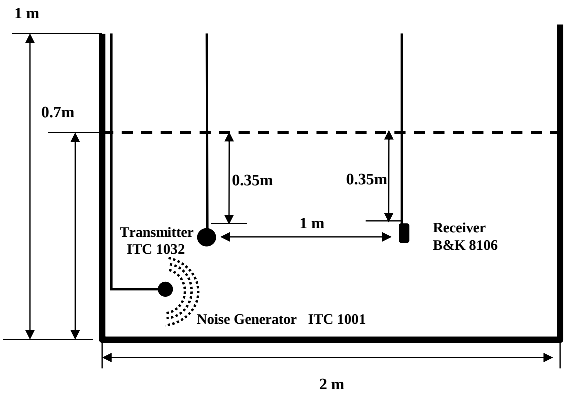

Fig. 2 Water tank experimental

Table I. The experimental parameters.

Modulation	8-FSK
Carrier frequency (kHz)	16 ~18
Bit rate(sps)	300 sps
Transmission bit(bit)	20000 bit
Distance(m)	1m
Transmitter / receiver depth	0.35m, 0.35m

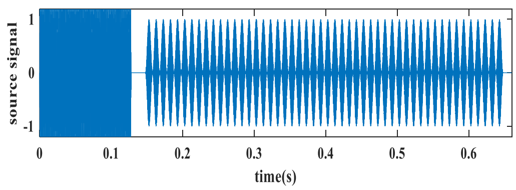

Fig. 3 Raised cosine shaped source signal

Figure 3 shows the transmitted signal with the cosine applied. The 0.128 s section of the signal is the PN signal, and the 0.15~0.65 s section is the shaped data signal.

Figure 4 shows the BER characteristics before and after applying the Raised Cosine filter. When the transmission signal with the Raised Cosine filter applied at Eb/N0 was used, a 10x improvement in transmission performance was confirmed. In addition, a 3dB gain improvement was confirmed from 0dB to 15dB in the Eb/N0 characteristics.

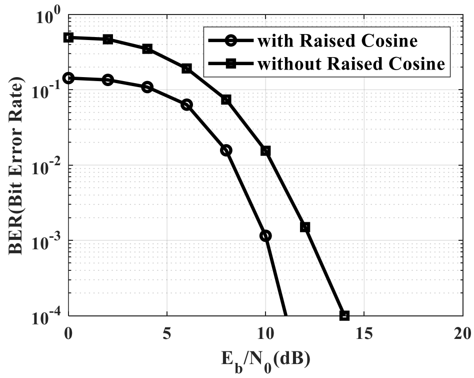

Fig. 4 The BER performance as a function of SNR before and after applying the cosine filter.

4. Conclusion

The objective of this study is to reduce Inter-Symbol Interference (ISI) in underwater acoustic communication environments for 8-ary FSK signals using a Raised Cosine filter. It was observed that the 8-ary FSK modulation method with the Raised Cosine filter achieved a BER below $10^{-4}dB$ at an Eb/N0 of 11 dB. The signal with the Raised Cosine filter demonstrated a 10x improvement in transmission performance compared to the signal without the filter. Additionally, a 3 dB gain improvement was observed in the Eb/N0 characteristics, ranging from 0 dB to 15 dB. Consequently, it can be inferred that applying the Raised Cosine filter to the signal effectively suppresses ISI, thereby improving communication performance.

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