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Application of CSK-DMF in High Speed Data Transmission System

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Abstract: The paper introduces the CSK-DMF system and its application in high-speed data transmission system. The principle and performance analysis of DMF was developed also. Simulations are carried out to show DMF acquisition performance.

Keywords: Code shift key, Digital matched filter, Spread spectrum

1. Introduction

Spread spectrum communication technology, which has the benefit of anti-jamming, well security ability and easy multiple access implementation, has been widely adopted in personal communications, wireless LAN and other communication systems. Direst sequence spread spectrum (DSSS) and frequency hopping is the mostly adopt method. Another base baud DS technology is code shift key (CSK) spread spectrum, which is an effective method in high-speed data transmission system [1,2,3].

Band limited system, such as wireless LAN and satellite communication, calls for transmit mass data in short time. It required that little delay be imported in transmission process as well as well anti-jamming and efficiency use of transmitter power. When the general DS technology is adopt, it request high system transmission rate that sometimes is unavailable. This puzzle can be settled by the application of CSK. To acquire the acquisition of CSK signal, Digital Matched filter [4] (DMF) is adopted.

2. Code Shift Key System

In CSK system, there are $M = 2^m$ PN sequences that were corresponding with m bits. The m bits data sequence were coded to map one of M PN sequences. The scheme of CSK transmitter is shown in fig.1.

The digital matched filter was used in receiver to implement fast acquisition of PN sequence, Shown in fig.2, the m bits receiver coder convert the M states of Max LLR output into m bits binary sequences.

3. Principle of DMF

Acquisition by DMF has the advantages of fast acquisition, high time domain resolution, programmable and easily implementation in DSP technology. Its structure [4] is shown in fig.3.

Fig.4 is the structure scheme of DMF [5]. The delay taps number is L, and L also is the length of correspond calculation. The multiple coefficients are decided by local PN sequence.

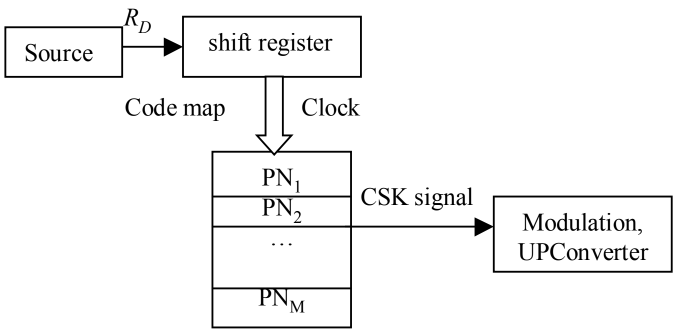

Fig.1 Transmit scheme of CSK system

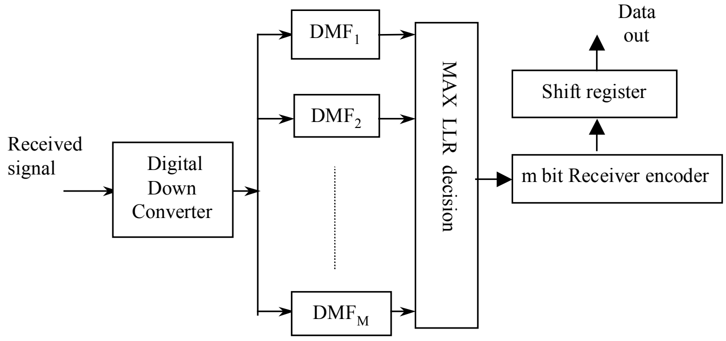

Fig.2 Receiver scheme of CSK system

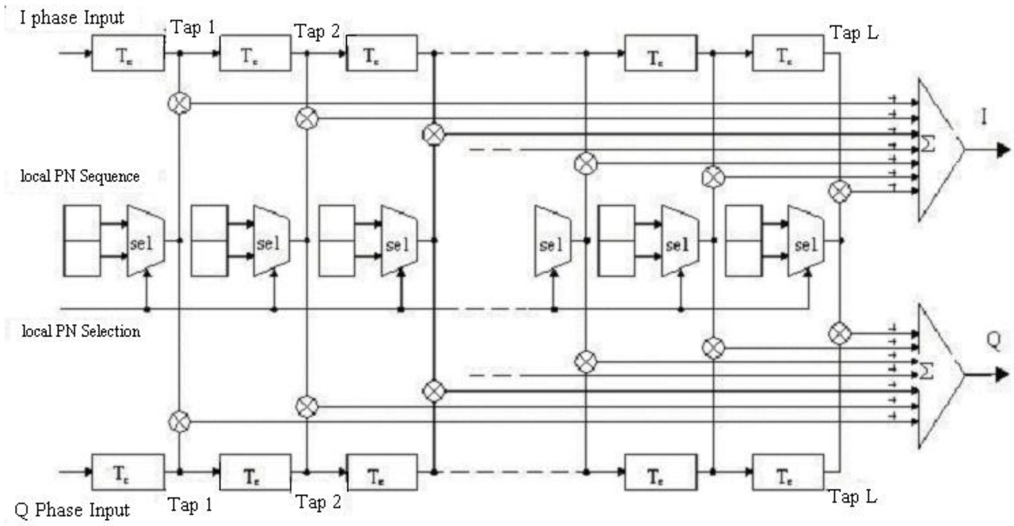

Fig.3 Structure of Digital Matched Filter

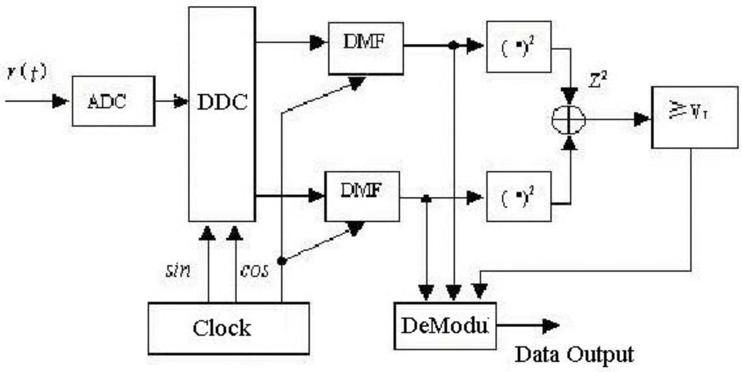

Fig.4 Acquisition Scheme of DMF

When base band signal was sampled N times every code, DMF can determined the correlation value of received PN sequence and its local copy in T_c/N, where T_c is the period of PN sequence. While the received sequence's phase is same as the local code, maximum correlation value is accessible, its polarity is determined by the symbol's polarity, and usually a data bit is corresponding to a PN sequence. Correlation output values of In-phase and Q-phase is added after square, and compared with a threshold. If it big than the threshold, we say that acquisition is successful and the system transfers into tracking state, otherwise, carry out acquisition continue. When local PN sequence is synchronized with the received PN sequence, the I and Q phase outputs of DMF are sent to demodulation system and compared with bit "0 . We will determinant the data bit is "1 when the output is bigger than "0 , otherwise, the receive bit is "0 . With DQPSK modulation scheme, the two data streams finally combination into one sequence and feed to data terminate. The sample clock of data stream is decided by the maximum DMF correlation peak value. We can see, the acquisition of PN sequence is the primary for despreading and demodulation for received signal.

4. Probability of Acquisition under AWGN Channel

When data symbol is synchronized with PN sequence, the affect of modulation on acquisition can be ignored under low SNR. Suppose the input signal is:

$$r(t) = \sqrt{2s}c(t-\tau)\cos(\omega_c t + \theta) + n(t) \qquad (1)$$

Where s 、 ω_c 、 θ is carry's power, frequency and phase respectively. $c(t)$ is the PN sequence. $n(t)$ is additive gauss noise with power spectrum $N_0/2$. The receive signal dived into In-phase and quadrature-phase signal after down-converter. The DMF in-phase and quadrature-phase output is shown follow:

$$y_I = y\cos(\theta) + N_I \qquad (2a)$$

$$y_Q = y\sin(\theta) + N_Q \qquad (2b)$$

In above equations,

$$y = \sqrt{s}T_c \sum_{k=1}^{L} c_{K+k+i}c_{K+k} \qquad (3)$$

N_I and N_Q is zero-means gauss white noise, its variance is:

$$\sigma_n^2 = N_0 L T_c / 2 \qquad (4)$$

L is the length of PN sequence. Consider affair H_1 as the synchronization of received PN sequence and local PN sequence. Otherwise, is affair H_0. y is the self-correlation function and take different value with difference PN sequence. If Gold code is used, three values will appear for y and its frequency is different. To simplify the discussion, we take m sequence as the PN sequence. We can get:

$$y \approx m_i = \begin{cases} \sqrt{s}T_c L & \mathrm{H}_1 \\ 0 & \mathrm{H}_0 \end{cases} \qquad (5)$$

for H_1, the probability density of envelop $Z = \sqrt{y_I^2 + y_Q^2}$ is a Rician distribution:

$$f_{H_1}(x) = \frac{x}{\sigma_n^2}\exp[-\frac{x^2 + m_1^2}{2\sigma_n^2}]I_0(\frac{xm_1}{\sigma_n^2}) \qquad x \ge 0 \qquad (6)$$

Suppose the decision threshold is V_T, we can get the detection probability:

$$P_D = \int_{V_T}^{\infty} f_{H_1}(x)dx = Q\left(\sqrt{\frac{2E_c L}{N_0}}, \sqrt{V_n}\right) \qquad (7)$$

where $E_c = sT_c$ is the average energy per chip, $V_n = {V_T^2}/{\sigma_n^2} = {2V_T^2}/{N_0 L T_c}$ is the normalization threshold, and $Q(\gamma,\beta) = \int_{\beta}^{\gamma} x\exp\left[-\frac{x^2+\gamma^2}{2}\right]I_0(\gamma x)dx$.

For H_0, the probability density of envelop $Z = \sqrt{y_I^2 + y_Q^2}$ is a Rician distribution:

$$f_{H_0}(x) = \frac{x}{\sigma_n^2}\exp[-\frac{x^2}{2\sigma_n^2}] \qquad x \ge 0 \qquad (8)$$

therefore, the false alarm probability is:

$$P_{FA} = \int_{V_T}^{\infty} f_{H_0}(x)dx = \exp(-\frac{V_n}{2}) \tag{9}$$

5. Simulation Results

Adopt m sequence as the spread code, and DMF process whole time correlation, the simulation waveforms of DMF output are shown in fig.5:

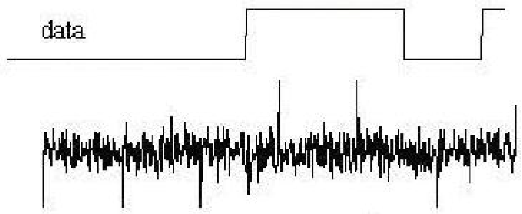

Fig.5a L=127, S/N=-5dB

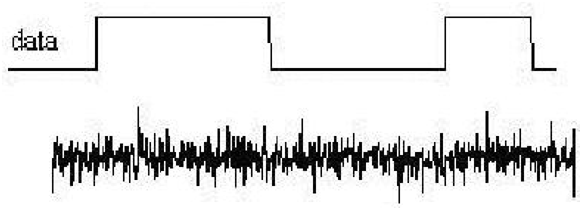

Fig.5b L=127, S/N=-10dB

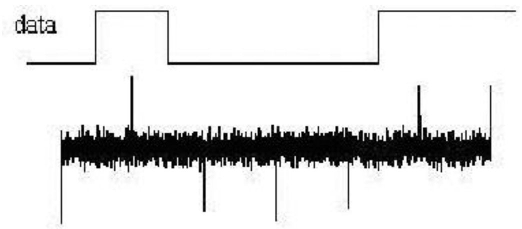

Fig.5c L=1023, S/N=-10dB

From fig.5, we can get the conclusion that correlation peak polarity of DMF output is determined by the polarity of corresponding data symbols, and the decision of data symbol is based it also.

6. Conclusion

Code shift key technology is suitable for high-speed data transmission system under band-limited communication systems, to acquire fast acquisition of CSK signal, Digital Matched filter (DMF) is adopted. The probability analysis and simulation results show that DMF is suitable for CSK signal's acquisition.

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