8PSK-TCM과 QPSK의 BER 비교

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Comparison between 8PSK-TCM and QPSK of BER

Bin-Bin Wu* · Hee-Jong Suh**

요 약

본 논문에서는 고효율적인 TCM 전송 시스템과 한 8PSK-TCM 시스템을 설명하였다. 이 두 시스템의 BER(bit error rate)을 비교하였다. 8PSK-TCM은 QPSK보다 3db의 성능개선이 있다는 것을 알 수 있었다. 이 비교를 입증하기 위해서 Matlab을 사용해서 모의실험을 하였다. 이 실험에서는 입력신호는 2 bits이고 TCM을 3bits로 엔코딩하는 8PSK-TCM을 구성하였다. 실험결과, 8PSK-TCM은 QPSK보다 3db의 성능개선이 있다는 것을 확인할 수 있었다.

ABSTRACT

In this paper, we studied a high speed Trellis Coded Modulation (TCM) system and 8PSK-TCM system, and compare 8PSK-TCM system with QPSK system of BER. We know that 8PSK-TCM had 3 db improvement of BER than QPSK. And we demonstrated the superiority of 8PSK-TCM by simulating with Matlab. Input signal was 2 bits long, and 8PSK-TCM used 3bits long. Results of this simulation said that 8PSK-TCM had 3 db improvement of BER than QPSK.

키워드

8PSK-TCM, QPSK, BER, Convolutional coder

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I. Introduction

In modern communication system code and modulation are widely used to resist interference and noise in the transmission channel. TCM is a good method in transmission systems. It is based on normal modulation just like Phase Shift Keying but it is more efficient than the normal modulation[1][2][3].

Phase shift keying is a digital modulation scheme that conveys data by changing or modulating the phase of a reference signal. It is widely used in different transmission systems. In PSK, the phase is changed to represent the data signal. There are two fundamental ways of utilizing the phase of a signal in this way:

1) By viewing the phase itself as conveying the information, in which case the demodulator must have a reference signal to compare the received signal’s phase against.
2) By viewing the change in the phase as
conveying information differential schemes, some of which do not need a reference carrier.

In PSK, the constellation points chosen are usually positioned with uniform angular spacing around a circle. This gives maximum phase-separation between adjacent points and thus the best immunity to corruption. They are positioned on a circle so that they can all be transmitted with the same energy. In this way, the moduli of the complex numbers they represent will be the same and thus so will the amplitudes needed for the cosine and sine waves. Two common examples are "binary phase-shift keying" (BPSK) which uses two phases, and "quadrature phase-shift keying" (QPSK) which uses four phases, although any number of phases may be used. Since the data to be conveyed are usually binary, the PSK scheme is usually designed with the number of constellation points being a power of 2[4].

Also PSK is simple to implement, but the relatively inefficient in transmission is a disadvantage that we can not ignore. TCM is a good method to solve this problem. Whereas we normally talk about coding and modulation as two independent aspects of the communications link, in TCM they are combined[5][6].

TCM is a modulation scheme which allows highly efficient transmission of information over band-limited channels such as telephone lines. It was invented by Gottfried Ungerboeck working for IBM in the 1970s, and first described in a conference paper in 1976; but it went largely unnoticed until he published a new detailed exposition in 1982 which achieved sudden widespread recognition[7][8].

TCM provides significant advantages over conventional ones, which rely heavily on reliability and efficacy. Because of that the codec and modem of conventional method are processed by separate systems. In channel coding of communication, redundant is added in the bit sequence to correct the error caused by noise. However the defect of this method is that as the amounts of information grow larger the transfer rates would be reduced. If we would like to keep the same transfer rates, needs to reduce the frequency[9].

The name trellis was coined because a state diagram of the technique, when drawn on paper closely resembles the trellis used in rose gardens.

In a bandwidth-limited environment, the use of higher-order modulation schemes can increase efficiency in frequency utilization. In this case, a large signal power would be required to maintain the same system bit-error-rate (BER). In order to achieve improved reliability of a digital transmission system without increasing transmitted power or required bandwidth, coding and modulation are combining as a whole in TCM technology.

TCM encoder is usual Ungerboeck encoder was invented by Ungerboeck[10]. It is a convolution encoder and a mapper that can mapping b bits code into 2b signal constellations.

This paper uses QPSK compared with the TCM, because the QPSK has widespread application. And the TCM simulation is the 8PSK, called 8PSK-TCM.

The result of the simulation shows the performance of the 8PSK-TCM and QPSK.

Chapter 2 introduces the simulation design method. Chapter 3 provides the results of the 8PSK-TCM system compared with QPSK system. Chapter 4 provides conclusions.

II. TCM set partitioning

Set partitioning is of great significance in the TCM proposed by Ungerboeck as a method for maximizing the minimum Euclidean distance of a code and consequently to optimize its performance on an AWGN channel. The basic idea is to map k information bits to 2k+1 constellation points such
that we can limit the transitions to occur only along the largest SED. It is the source of coding gain. Each set partitioning split the signal set into smaller two subsets that can get a binary tree represents the set partitioning. After each set partitioning the amounts of subsets will be double, and the minimum distance of the subsets will increase with it. After i steps set partitioning the minimum distance of the subsets is \( \Delta_i (i = 0, 1, \cdots) \), then we can get that:

\[
\Delta_0 < \Delta_1 < \Delta_2 \cdots
\]

As the subsets are partitioned, the signals get further apart in increasing the Euclidean distance between the signals in that set.

The Fig. 1 shows how the 8 points of QPSK are successively portioned. The Euclidean distance of these signal points is \( d_0^2=0.586 \). Frist we can divide 8 signal points into two subsets. Each subset has 4 signal points. The Euclidean distance between the signal points of these subsets is \( d_1^2=2 > d_0^2 \). Divide each of these subsets into two subsets, we can get 4 subsets. Each subset has two signal points. The Euclidean distance between the signal points of these subsets is \( d_2^2=4 \).

Fig. 1 Partition of 8PSK–TCM constellation to ever increasing Euclidean distance subsets.

From the partition we can get the constellation of this 8PSK–TCM signal. The different coding methods will bring the different constellations and different performances. A code with best performance is called good code. The constellation is shown in Fig. 2.

\[
\begin{array}{c}
010 \\
011 \\
001 \\
000 \\
100 \\
101 \\
110 \\
111 \\
\end{array}
\]

Fig. 2 The 8PSK–TCM constellation.

### III. Simulation Method and Result

Convolutional coder is indicated by constraint length and code generator polynomials in MATLAB. Constraint length is a vector about input. If constraint length is \( c \), it means that input is bits long and each bit will be delay; if constraint length is \( a \), it means that input is \( a \) bits long and output is \( a \) bits long. Code generator polynomials represent the relationship between input and output. If there are \( n \) inputs and outputs the code generator polynomials is a \( n \times 2^n \) matrix. The element on row \( i \) col \( j \) in matrix means the effect of the input to the output.

The method of finding code generator polynomials is like below:

First, mark the shift registers which connect to the adders as ‘1’, and the other registers are marked as ‘0’.

Second, convert these binary numbers into its octal numbers. Each three binary numbers make up a octal number.

In MATLAB we can use the poly2trellis and istrellis function to express the encoder and its
trellis. Ploy2trellis can change the convolutional encoder into trellis, isrellis can verify the legitimacy of this trellis. If this trellis is verified, the rules can be satisfied simultaneously.

We use well-known (5,7) convolutional coder as a TCM encoder, and get a new TCM encoder as shown in Fig. 3.

Based on this encoder we built a TCM simulation model that includes encoder, modulator, demodulator, decoder and error counting module. The result is the BER of this system.

The simulation is repeated with the different Signal to Noise Ratio (SNR). We used SNR from 2 to 8 in dB in simulation. The results of the BER is shown in one figure, and compared with the BER of QPSK.

![Fig. 3 Block diagram of (5,7) convolutional TCM coder.](image)

As the (5,7) convolutional TCM coder. First we convert this block diagram into polynomials. As the shown Fig. 3, m1 m2 are the two inputs; and y0 y1 y2 are the three outputs. So the constraint length of this encoder is \([3 1]\). Fig. 3 shows the block diagram of (5,7) convolutional TCM coder. The code generator of encoder is \([5 7 0; 0 0 1]\).

The MATLAB input is: ‘s= poly2trellis([3 1],[5 7 0; 0 0 1]);[isok, status]=istrellis(s)’. Then get the output is: isok = 1;

status = ’ ’. It means the validity of this encoder’s polynomials is identified. We can use it in the TCM encoder.

Although the analysis of the states, inputs and outputs we get the result as the Fig. 4 shown.

![Fig. 4 (5,7) convolutional coder’s state analysis.](image)

Then we must find the mapping method of this encoder. Draw the trellis of this (5,7) convolutional coder as the Fig. 5 shown.

![Fig. 5 (5,7) convolutional coder’s trellis.](image)

Referring to this trellis we can get the mapping method as the Table 1. shown easily.

<table>
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<th>input</th>
<th>current state</th>
<th>next state</th>
<th>output</th>
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<td>y2 y1 y0</td>
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</table>

![Table 1. mapping method of (5,7) convolutional code](image)

We simulated a QPSK system and the 8PSK-
TCM system with a block-length of 5000 bits and rate R=0.5.

Fig. 6 shows the BER performance of these two systems. It is easy to see that the performance of the 8PSK–TCM system is much better than the QPSK system.

From this simulation we know that TCM system based on a good encoder can improve the reliability of the signal transmission. The increase of the BER performance is about 3dB. And we do simulation many times with several encoders. After that we can confirm a good encoder for increasing the performance.

IV. Conclusion

8PSK–TCM had 3 dB improvement of BER, compared with QPSK, we do simulation with Matlab. We could see that the 8PSK–TCM has better BER performance than QPSK. The increase of the BER performance is about 3dB.

The simulation results show that the BER performance of 8PSK–TCM is better than QPSK. The same amount of information can be transmitted within the same bandwidth with coding gains of 3dB by 8PSK–TCM. It means that half power of the signal transmitter can be reduced in the 8PSK–TCM system. But we need find the good encoder first to improve the system’s performance.

References

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