Performance Research of the Convolutional Code Using a Novel Interleaving Scheme in Mobile Image Communication Systems and the Comparison with Interleaved BCH Code*

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Abstract: The image quality can be improved much better by the anti-interference measure which combines the convolutional code with a novel interleaving scheme proposed in this paper than interleaved BCH code in mobile channels.

1.Introduction

Following the rapid prevalence of digital mobile voice transmission, the image transmission has become the advanced form in next generation of mobile communication. For the purpose of improving the transmission reliability of mobile digital voice data, we have already made a series of studies by employing convolutional codes, BCH codes and interleaving technique[1-3]. In this paper, a novel interleaving scheme suitable to convolutional code is proposed, The anti-interference performance of interleaved (2,1,3) convolutional code in mobiel image transmission systems is simulated. And the above is compared with BCH(31,16,3) code. Some significant conclusions are got.

2.Mobile channel modeling

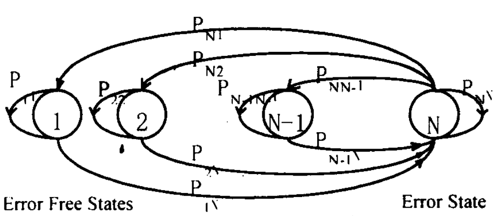

Fig. 1 N-state Markov Model

Research has shown that the mobile channel can be simulated by simply partitioned Markov model[1][4]. Fig.1 shows a Markov model with N states. The states 1,2, ··· N-1 represent error-free bits, while state N represents error bits. The various parameters shown in Fig.1 can be found by fitting an exponential curve to the error-free run distribution $P(0^m/1)$[1].

In 1994, Swart and Ferreira announced their city-test results in Johannesburge, South Africa[4]. The experiments are undertaken with various modulation schemes, different RIT and different vehicle speed. The parameters of the 4-state Markov model we used in this paper are as following:

$$P_8 = \begin{bmatrix} 0.597899 & 0 & 0 & 0.402101 \\ 0 & 0.998611 & 0 & 0.001339 \\ 0 & 0 & 0.999845 & 0.000155 \\ 0.491230 & 0.040017 & 0.020426 & 0.448327 \end{bmatrix} \quad 8PSK, \quad 4800 \text{ bits/s}$$

3.Image compression

The model of a whole mobile image transmission system is showed in Fig.2. Having been sampled and quantified the image data is compressed to reduce the redundant degree or to compress the spectrum width or to cut down the transmission rate of the image so that the image can be transmitted efficiently.

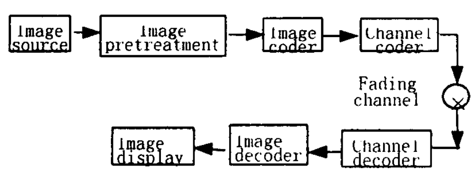

Fig.2 Image transmission system

The compression scheme in this paper is "DCT+Vector Quantization" which is a method considering both the calculating speed. and the communication efficiency so that it can not only ensure the recovered image quality but also realize the high compression ratio and high transmitting speed. It is

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because that the "Vector Qualification" gains much higher compression ratio than "Entropy Coding" and the former is very suitable to the system contains less character codes, that the "DCT+Vector Quantization" is adopted rather than "Entropy Coding" suggested by "JPEG" after "DCT" transmission[5][6]. "Vector Quantization" needs a little more time compared with "Entropy Coding", but the time is much tiny compared with "DCT". The compression ratio in this paper is 23.3:1.

4. Coding and decoding of convolutional code

4.1Convolutional coding

Convolutional codes are different from BCH codes, the former coding course can be looked as convoluting between the input sequence and the other sequence dominated by shifting-bit register and correcting style abides by algorithm of mod 2. Fig.3 shows the encoder of (2,1,3) convolutional code. Its polynomial is expressed by delay operator polynomial:

$G_1(D)=1+D+D^2$, $G_2(D)=1+D^2$

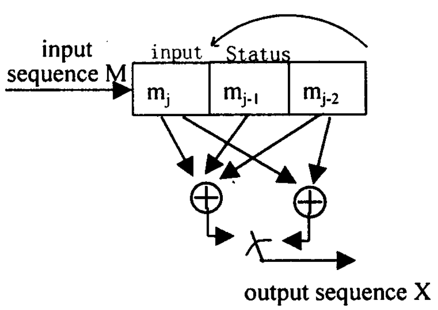

Fig.3 (2,1,3) convolutional encoder

4.2 Viterbi decoding of convolutional code

This paper mainly researches on the error-correcting performance of the Viterbi decoding scheme. There are $2^{K(N-1)}$ states in the convolutional trellis figure, where there are 2^K branches entering every point , and 2^K branches exporting. Compare the accumulative value of logarithm most likely function between the two routes concentrated at every point, and keep the bigger one, abandon the other. After these actions, there will lie 2^{N-1} reliable routes in the Nth stage, which are stored in the decoding register as well as their accumulative logarithm likely function value. The whole decoding process can be looked as "adding-comparing-select". When the accumulative likely function value comes to be equal for each stage, either branch can be selected for the "surviving route".

5.A novel interleaving scheme

The principle of traditional periodic interleaving scheme which is suitable to block codes can be expressed as followings:

We assume that the interleaving degree is I. At first, I (n,k,t) linear block codes are arranged in rows in an array I by n. Then we transmit the array column by column. And at the receiver, the received data are rearranged in the same array column by column, then are decoded rank by rank. That is the whole interleaving procedure. Because the code length n of block code which has better error correcting performance is often long and (n-k) check bits of each code are only related to k information bits, without regard to other codes, interleaving technique can separate long burst errors effectively to different codes. But n is often small for (n,k,t) convolutional code. For instance, n is 2 in this paper. And Nn bits are related to each other in coding and decoding procedure. So, the above interleaving scheme can't separate effectively long burst errors that still lie in the relevant codes, and after decoding the error correcting performance won't be satisfactory. The following is to investigate a novel interleaving scheme suitable to convolutional codes.

Better error correcting performance can compensate additional time delay in interleaving scheme. So, to improve the error correcting performance of convolutional code, additional time delay can be sacrificed. We arrange m (n,k,N) convolutional codes in a row which can be seen as a new convolutional code with code length mn. Then the following interleaving procedure is similar to the above principle suitable to block codes. The following is a metric of codes:

$$
\begin{array}{llllll}
V_{1,0}^{1} & \ldots V_{1,n-1}^{1} & \ldots V_{1,0}^{2} & \ldots V_{1,n-1}^{2} & \ldots V_{10}^{m} & \ldots V_{1,n-1}^{m} \\
V_{2,0}^{m+1} & \ldots V_{2,n-1}^{m+1} & \ldots V_{2,0}^{m+2} & \ldots V_{2,n-1}^{m+2} & \ldots V_{20}^{2m} & \ldots V_{2,n-1}^{2m} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
V_{I,0}^{(I-1)m+1} & \ldots V_{I,n-1}^{(I-1)m+1} & \ldots V_{I,0}^{(I-1)m+2} & \ldots V_{I,n-1}^{(I-1)m+2} & \ldots V_{I,0}^{Im} & \ldots V_{I,n-1}^{Im}
\end{array}
$$

The metric includes I rows. Each row has m (n,k,N) convolutional codes . So there are I*m codes, which means I*m*n bits in the metric. The interleaving codes metric sent into the channel from left to right by columns. Thus, according to an interleaving codes metric with I degree, the metric to be sent into channel should be:

$V_{1,0}^{1}, V_{2,0}^{m+1}, \ldots, V_{I,0}^{(I-1)m+1}, \ldots, V_{1,0}^{2}, V_{2,0}^{m+2}, \ldots,$
$V_{I,0}^{(I-1)m+2}, \ldots, V_{1,n-1}^{m}, V_{2,n-1}^{2m}, \ldots, V_{I,n-1}^{Im}$

At the receiving point, make a reverse work on every metric, that is deinterleaving , decoding by lines, Thus, the whole course of coding and decoding of a interleaving coding system is finished.

In order to compare with the error-correcting performance of BCH(31,16,3) code, (2,1,3) convolution code is used in this paper and the number of interleaved codes in a row is m=16. That is because they have nearly the same coding rate which is $16/31 \approx 1/2=0.5$,and nearly the same time delay which is $2*16*I \approx 31*I$.

6.Simulation and results analysis

Having been composed, the standard image data(256×256, 8bit/point) is encoded with (2,1,3) convolutional code or BCH(31,16,3) code (combined with or without interleaving technique) and put into the mobile channel[4]: 8PSK modulation with 4800 bits/s at the vehicle speeds of 100km/h. The simulation results are shown in Fig.4. From the results, we can see:

(1) Comparing Fig.4.0 with Fig.4.1 and Fig.4.2, we can find that the subjective quality of the compressed image becomes very bad because of the long-burst error character of the fading channel. The decrease of "block" noise on the image with uninterleaved convolutional code or BCH code shows that the convolutional codes and BCH codes, within the range of the codes' ability, can correct some burst errors with a certain length.

(2) From Fig.4.1 and Fig.4.2, we can find that the image quality in Fig.4.1 is much better than that in Fig.4.2. It states that the error correcting performance of uninterleaved (2,1,3) convolutional code is superior to uninterleaved BCH(31,16,3) code, that is to say, convolutional code can separate long burst errors more effectively.

(3) Comparing Fig.4.3 with Fig.4.6, Fig.4.4 with Fig.4.7, Fig.4.5 with Fig.4.8, we can find that the image quality using the interleaved (2,1,3) convolutional code as the anti-interference measure is better than that using the interleaved BCH(31,16,3) code under the same interleaving degree(i.e. the same time delay). Especially the image of Fig.4.5 nearly revises back to the initial image. It states that Convolutional code using suitable scheme has better performance than interleaved BCH code in typical mobile channels. Adopting the (2,1,3) convolutional code combined with this interleaving scheme and with suitable interleaving degree as the anti-interference measure, we have a good trade-off between efficiency and reliability so that the quality of image can be improved greatly.

7.Conclusions

From the above analysis and simulation results, some conclusions can be drawn:

(1)In the engineering design of error correcting system, suitable interleaving scheme and suitable interleaving degree should be chosen according to different code structure. The novel interleaving scheme proposed in this paper is suitable to convolutional code. The quality of image can be much better and the reliability can be ensured by combining the (2,1,3) convolutional code with this interleaving scheme as the anti-interference measure.

(2)Interleaved convolutional code with suitable interleaving scheme is more suitable to image transmission in mobile fading channels than interleaved BCH code. Therefore, it should be suggested as an excellent error control scheme used in mobile image communication systems. The better interleaving scheme more suitable to convolutional code considering both time delay and performance improvement is a further topic to be researched on.

(3)How to encode the image data with unequal protection degree is a significant topic to save coding resource and to improve efficiency of transmission.

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Fig.4.0 No correcting

Fig.4.1 (2,1,3) code,
With correcting, no interleaving

Fig.4.2 BCH (31,16,3) code
With correcting, no interleaving

Fig.4.3 (2,1,3) code
With correcting, I=8

Fig.4.6 BCH (31,16,3) code,
With correcting, I=8

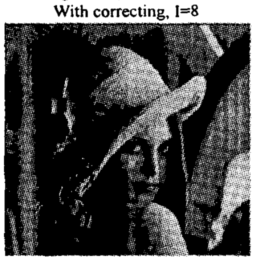

Fig.4.4 (2,1,3) code
With correcting, I=16

Fig.4.7 BCH (31,16,3) code,
With correcting, I=16

Fig.4.5 (2,1,3) code
With correcting, I=32

Fig.4.8 BCH (31,16,3) code,
With correcting, I=32