Two Novel Interleaving Schemes of the (2,1,3) Convolutional Code And Its Performance in the Mobile Image Communication System*

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Abstract-In this paper, two novel interleaving schemes suitable to convolutional code are given as block interleaving scheme and bit interleaving scheme. Based on convolutional coding with Viterbi decoding, the anti-interference performance of the (2,1,3) convolutional code using these two schemes in the mobile image communication system is studied and compared with the performance using traditional periodic interleaving scheme. The simulation results show that periodic interleaving scheme is not suitable to convolutional code. The reliability of image transmission system in fast fading mobile channel can be improved greatly by adopting the (2,1,3) convolutional code combined with block interleaving scheme or bit interleaving scheme as the anti-interference measure.

I. INTRODUCTION

The image transmission especially through mobile channel has become the advanced form following the rapid prevalence of digital voice transmission in next generation of mobile communication environment. How to transmit image data efficiently and reliably, that is to say, combine source coding with channel coding optimally, has been a new topic in this research area.

We have aimed at the transmission reliability of mobile digital voice data and adopted convolutional codes, BCH codes and interleaving technique to make a series of studies[1-3]. In this paper, we adopt the (2,1,3) convolutional code combined with several interleaving schemes as the anti-interference measure. The reliability problem of a standard gamma image (256×256, 8bits/point) transmitted through fading channel is studied and some significant conclusions are obtained.

II. IMAGE COMPRESSION

The model of a whole mobile image transmission system is showed in Fig.1. 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.

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 because that the "Vector Quantization" 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[4][5]. "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.

III. CODING AND DECODING OF CONVOLUTIONAL CODE

A. Convolutional Coding

Convolutional code is different from BCH code, 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. In this paper, we adopt the typical generating polynomial for a (2,1,3) convolutional code that can be

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expressed as:

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

B. 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 rout".

Ⅳ. TWO NOVEL INTERLEAVING SCHEMES

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 decoding 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,N) 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 relevant codes and decoding will be not satisfactory. The following is to investigate two novel interleaving schemes suitable to convolutional codes.

A. Block Interleaving Scheme

Considering both performance improvement and time delay, 1000 codes after encoding can be seen as a block to interleave. If the interleaving degree is I, the interleaving procedure can be described as:

At first, we transmit the first code in 1000 codes. Then transmit the (I+1)th code, then (2I+1)th code, until xI+1>1000(x=int(1000/I) or x=int(1000/I)-1). After then, the second code will be sent. Then the (I+2)th code, the (2I+2)th code, until xI+2>1000. We transmit 1000 codes just like the above. The next block with 1000 codes will be sent also in this way. At the receiver, make a reverse work on each block with 1000 codes, that is deinterleaving. The advantage of this interleaving scheme is that it can separate long burst errors effectively to unrelevant codes and avoid "error propagation" in decoding procedure when I>N. Taking (2,1,3) convolutional code for example, this interleaving scheme can be expressed as Fig.2.

B. Bit Interleaving Scheme

Long burst errors can be separated to unrelevant codes using block interleaving scheme, but maybe still lie in n bits of one code. To separate long burst errors more effectively, taking (2,1,3) convolutional code with interleaving degree I for example, we use the following interleaving procedure which is shown in Fig.3.

Step 1: 1000 (2,1,3) convolutional codes after encoding are seen as a block to interleave.

Step 2: The first bit of the first code in 1000 codes is sent into the channel firstly. Then the first bit of the (I+1)th code, then the first bit of the (2I+1)th code, until the first bit of the (xI+1)th code is transmitted.

Step 3: Afterwards, the second bit of the first code will be transmitted. Then the second bit of the (I+1)th code, then the second bit of the (2I+1)th code, until the second bit of the (xI+1)th code is transmitted.

Step 4:The first bit of the second code is transmitted afterwards, then the first bit of the (I+2)th code, then the first bit of the (2I+2)th code, until the first bit of the (xI+2)th code is sent into the channel.

Step 5: Circulating like the above, 2000 bits of 1000 codes are all sent into the channel.

Step 6: Go back to step 1, the next block with 1000 codes will be interleaved.

Ⅴ. SIMULATION AND RESULTS ANALYSIS

Having been composed, the standard image data(256×256, 8bit/point) is encoded with (2,1,3) convolutional code(combined with or without interleaving technique) and put into the mobile channel[6]: 8PSK modulation with 4800 bits/s at the vehicle speeds of 40km/h. The simulation results are shown in Fig.4 and Fig.5. To compare conveniently, Table 1 gives the error-correcting performance of (2,1,3) convolutional code using different interleaving schemes. From the results, we can see:

(1)From the comparison between Fig.4 and Fig.5, the efficiency of transmission is developed but the reliability is worse. The interference of the channel added on the no-compressed image with some "nick" or "snowflake", on the compressed image with some "block", which requires some more excellent channel codes.

(2)From the comparison between Fig.4.1 and 4.2, Fig.5.1 and 5.2, the subjective quality becomes very bad when the image data transmitted through fading channel which embodies the long-burst error character of the channel. If the convolutional code is added, the "long nicks" interference on the no-compressed image becomes "shot nick" or "snowflake points", the "block" noise on the compressed image decreases. This shows that within the range of the codes' ability, the convolutional codes can correct a certain length bursting error.

(3)Table 1 shows that the error-correcting performance of (2,1,3) convolutional code using the periodic interleaving scheme is not satisfactory. Sometimes, even the "error propagation" phenomenon happens. From Fig.4.2, 4.3 and 4.6, Fig.5.2, 5.3 and 5.6, we haven't found the image quality quite better after the periodic interleaving is added. So this traditional interleaving scheme suitable to block codes is not suitable to convolutional codes.

(4)From Table 1, when interleaving degree I is small, block interleaving scheme is superior to bit interleaving scheme. And when I is in the range of [10,20], the performance using block interleaving scheme will be the best. With the increase of I, the error correcting performance using block interleaving scheme will be worse, while a considerable improvement with bit interleaving scheme will be obtained. What's more, the performance using bit interleaving scheme will be the best when I is in the range of [70,200]. In Fig.4, the image of Fig.4.5, 4.7 contains little "snowflake", while the image of Fig.4.3, 4.8 revise back to the initial image. In Fig.5, the image quality of Fig.5.4 and 5.8 becomes much better. This shows that these two schemes can separate long burst errors effectively and transform fading channel to quasi-random channel then improve transmission performance. Adopting the (2,1,3) convolutional code combined with these two interleaving schemes 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.

VI. CONCLUSIONS

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

(1)The quality of the image becomes much worse when image data are transmitted in fast fading channels. The interference will add on the image with "nick" or "block" so the subjective quality becomes very bad. If the convolutional code with suitable interleaving scheme is added, the quality of image may be much better and the reliability can be ensured.

(2)In the engineering design of error correcting system, suitable interleaving scheme and suitable interleaving degree should be chosen according to different code structure. Periodic interleaving scheme is suitable to block code, not to convolutional code. For convolutional code, the best performance can be got when I is in the range of [10,20] using block interleaving scheme and when I is in the range of [70,200] using bit interleaving scheme.

(3)According to design for the optimal communication system, the source coding and channel coding should be considered systematically in order to pose the optimal coding scheme both in information source and in channel. In addition, 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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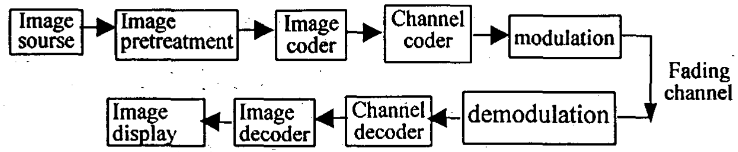

Fig.1. Image transmission system

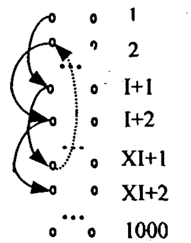

Fig.2. Block interleaving scheme

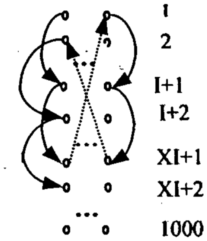

Fig.3. Bit interleaving scheme

Fig.4.1 No compression, no correcting

Fig.4.2 No compression, with correcting

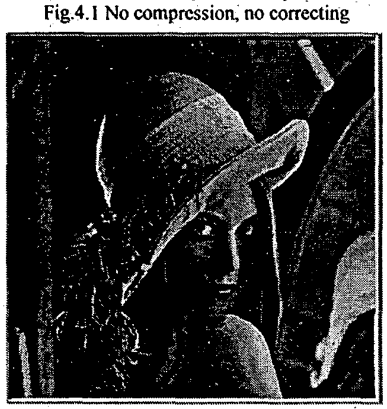

Fig.4.3 No compression, with periodic interleaving(I=10)

Fig.4.4 No compression, with block interleaving(I=10)

Fig.4.5 No compression, with bit interleaving(I=10)

Fig.4.6 No compression, with periodic interleaving(I=150)

Fig.4.7 No compression, with block interleaving(I=150)

Fig.4.8 No compression, with bit interleaving(I=150)

Fig.5.1 With compression, no correcting

Fig.5.2 With compression, with correcting

Fig.5.3 With compression, with periodic interleaving(I=10)

Fig.5.4 With compression, with block interleaving(I=10)

Fig.5.5 With compression, with bit interleaving(I=10)

Fig.5.6 With compression, with periodic interleaving(I=150)

Fig.5.7 With compression, with block interleaving(I=150)

Fig.5.8 With compression, with bit interleaving(I=150)

TABLE I

THE ERROR-CORRECTING PERFORMANCE OF (2,1,3) CONVOLUTIONAL CODE USING DIFFERENT INTERLEAVING SCHEME (8PSK MODULATION,4800BITS/S,VEHICLE SPEED:40KM/H,THE PRIME BER OF CHANNEL:PB=2.8E-03)

Interleaving scheme / Interleaving degree I	Periodic interleaving	Block interleaving	Bit interleaving
1	**4.46401e-04**	**4.46401e-04**	**4.46401e-04**
5	4.42601e-04	2.49000 e-05	1.47700 e-04
10	4.28001e-04	6.40001 e-06	7.22001 e-05
15	8.76201e-04	**5.70001 e-06**	4.12001 e-05
20	4.05701e-04	7.80001 e-06	3.10000 e-05
25	3.93201e-04	1.13000 e-05	2.02000 e-05
50	3.16900e-04	2.78000 e-05	5.40001 e-06
70	3.28930e-03	4.72001 e-05	2.00000 e-06
80	6.18081e-03	5.08001 e-05	2.00000 e-06
100	2.72500e-04	6.99001 e-05	**1.80000 e-06**
150	7.56071e-03	1.16700 e-05	**3.00001 e-07**
200	2.37900e-04	1.45900 e-04	2.00000 e-06
300	1.25020e-02	2.12900 e-04	6.30001 e-06
500	2.4900e-04	3.12100 e-04	4.13001 e-05
1000	1.79000e-04	**4.46401e-04**	**4.46401e-04**