On Performance of BCH Codes Using Two Novel Interleaving Schemes in Rayleigh Fading Channels*

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Abstract- **Two novel pseudonym random interleaving schemes whose interleaving degrees obey uniform distribution and Rayleigh distribution, respectively, are proposed in this paper. The performance of BCH(63,39,4) and BCH(127,78,7) code using these two schemes as well as periodic interleaving scheme in Rayleigh fading channels are obtained by simulation. The results show that pseudonym random interleaving can decrease the average time delay on some occasions and it is also a good cipher scheme.**

I. INTRODUCTION

Based on the former work[1][2], this paper presents two novel interleaving schemes whose interleaving degrees obey uniform distribution and Rayleigh distribution, respectively. The performance of BCH codes using these two schemes in Rayleigh fading channels and some significant conclusions are obtained by simulation.

II. TWO NOVEL INTERLEAVING SCHEMES

The pseudonym random interleaving scheme is also a good cipher scheme because the deinterleaving can't run with lack of the interleaving degree at the receiver. The following is to discuss two novel schemes.

A. Uniformly Distributed Pseudonym Random Interleaving Scheme

We assume that the interleaving degree is a random variable I which is uniformly distributed between 0 and N. At first, I_i BCH(n,k,t) codes are arranged in rows in an I_i *n array. Then we transmit the array column by column. At the receiver, the received data are rearranged in the same array column by column and then decoded rank by rank. So, the transmission of BCH codes with interleaving degree I_i is completed. Then, the next random variable I_{i+1} is produced and I_{i+1} BCH(n,k,t) codes are arranged in rows in an array I_{i+1}*n. We transmit the array and then deinterleave, then decode, just like the above. The advantage of being a random interleaving degree is that it is able to divide the long burst error into random error and decrease the error possibility and time-delay if large interleaving degree locks the dense errors and small interleaving degree locks the even field. Considering time-delay and error possibility simultaneously, we hope that pseudonym random interleaving scheme is better than periodic interleaving scheme.

A uniformly distributed random variable can be produced by using the expression:

$$N_{i+1}=(N_i*F+C)\bmod M \quad (i=0,1,2,\ldots) \qquad (1)$$

N0 is a non-negative integer , C is an odd integer, M is period and F=4a+1(a is a positive integer).N is uniformly distributed between 0 and M . Let t=N/M, we can get a new random variable t which is uniformly distributed in [0,1]. The random interleaving procedure can be described as follows:

Step1: producing a random number N uniformly distributed in [0,M];

Step2: getting a random number t uniformly distributed in [0,1] by using t=N/M;

Step3: getting a random number N_1 uniformly distributed in [0,K] by using N_1=K*t;

Step4: letting I=(int)N_1 ;

Step5: interleaving , then go back to step 1.

B. Rayleigh Distributed Pseudonym Random Interleaving Scheme

The fast fading characteristics of mobile channels obey Rayleigh distribution, so we expect that the large interleaving degree will correspond to the long burst error by using this scheme. Based on random number uniformly distributed between 0 and 1, Rayleigh distributed random number can be produced by using formula converter technique:

$$S_i = \mu\sqrt{-2\ln r_i} \qquad (2)$$

Where r_i is uniformly distributed in [0,1].S_i obey Rayleigh distribution and their mean is $\sqrt{2}\mu/2$. According to different value of , we can get Rayleigh distributed random numbers with different means. The steps of Rayleigh

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interleaving are similar to those of uniform interleaving with only a little modification in step 3 :

getting Raiyleigh distributed random number S with the mean $\sqrt{2}\mu/2$ by using (2) and different v a lues.

III. SIMULATION

The 4-state simple partitioned Markov model is used in the simulation[3]. The transforming matrix is taken from reference [4]. BCH (63,39,4) code and BCH(127,78,7) code with the same coding rate using two novel interleaving schemes are considered for simulation in Rayleigh fading channels. And the error correcting performance is studied in comparison with using periodic interleaving scheme. Fig.1 shows the block diagram of simulation. Two typical Rayleigh fading channels are simulated: 8PSK modulation with 1600 bits/s at the vehicle speeds of 40km/h and 100km/s, respectively. Table 1 to Table 4 and Fig.2 give the results. In the table the interleaving degrees I in Rayleigh interleaving and uniform interleaving are both average interleaving degrees. From the simulation results, we can see:

(a)Interleaved BCH codes can separate the long-burst error and transform the compound channel with both long burst error and random error into quasi-random channel, and make it possible to get the performance improvement. As Fig.2 shows: the error-free run distribution curve with interleaved scheme is close to that of BSC channel and far away from that of mobile channel. The error-free run distribution G(m) is defined as the probability that at least m error-free bits emerge after one error bit.

(b)The error-correcting performance of different BCH codes will be different in the same channel . The improvement on performance comes with the increase of code length at the same code rate k/n. Table 1-4 show that the error-correcting performance of BCH(127,78,7) code is superior to that of BCH(63,39,4) code.

(c)The error-correcting performance will be different according to different channel with diferent long burst error lengths. From the comparison between table 1 and table 3,for I=40 using Rayeigh interleaving scheme, we can find that when vehicle speed changes from 40km/h to100km/h,the BER changes from 4.05e-05 to 3.56e-04 with the difference of one quantity degree. This result states that the more severe the mobile environment is, the worse the error-correcting performance of codes becomes.

(d)When the interleaving degree is small, uniform interleaving scheme is better than Rayleigh interleaving scheme and the periodic interleaving scheme is the worst. It shows that pseudonym random interleaving scheme can be more efficient to separate long burst error and save the average time delay when the interleaving degree is small. As showing in table 4, uniform interleaving scheme is the best when I<25.

(e)As the interleaving degree increases, Rayleigh interleaving scheme will be better than uniform interleaving scheme. This states that the former is more suitable to fading channel than the latter. As showing in table 4, the BER of BCH (127,78,7) code using Rayleigh interleaving scheme is lower than that using uniform interleaving scheme when I>25.

(f)When the interleaving degree is large, periodic interleaving scheme is the best. Because for pseudonym random interleaving there are both large and small interleaving degree. The BER with large interleaving degree can't compensate for the BER with small interleaving degree because the performance improvement is not outstanding at very large interleaving degree. So the average effect is inferior to periodic interleaving scheme. Table 1 shows that the error-correcting performance using periodic interleaving scheme is the best when I>25.

IV CONCLUSIONS

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

(a)In the engineering design of error control system we should select suitable interleaving scheme and interleaving degree by considering simultaneously many technique indexes such as time delay, BER and complexity etc. When the demand for BER is not high, uniform interleaving scheme with small interleaving degree is the best choice. Otherwise, a periodic interleaving scheme with large interleaving degree is suggested.

(b)Pseudonym random interleaving is also a good cipher scheme. Rayleigh interleaving scheme can meet the demands for both BER and secrecy in system design. The better pseudonym random interleaving scheme considering both interleaving and cipher is a further topic to be researched on.

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TABLE I

ERROR CORRECTING PERFORMANCE OF BCH(63,39,4) CODE USING DIFFERENT INTERLEAVING SCHEMES

(8PSK MODULATION STYLE, 4800BITS/S. VEHICLE SPEED: 40KM/H

NOTE: 200000 CODES ARE USED IN THE SIMULATION, PB=2.402E-03

Interleaving Scheme / Interleaving Degree I	Uniform Interleaving	Rayleigh Interleaving	Periodic Interleaving
1	1.88548e-03	1.96389e-03	2.22468e-03
5	9.39015e-04	9.46326e-04	1.27310e-03
10	4.23713e--04	5.07747e-04	5.95476e-04
15	2.55952e-04	2.58491e-04	3.10143e-04
20	1.67766e-04	**1.30868e-04**	1.50397e-04
25	8.11067e-05	1.20370e-04	9.69841e-05
30	7.42853e-05	7.43536e-04	**5.87272e-05**
35	6.01464e-05	**5.86438e-05**	2.89646e-05
40	3.03111e-05	4.05466e-05	2.24603e-05
45	3.15008e-05	**2.61021e-05**	1.86485e-05
50	3.57095e-05	**2.17433e-05**	8.49206e-06

TABLE II

ERROR CORRECTING PERFORMANCE OF BCH(127,78,7) CODE USING DIFFERENT INTERLEAVING SCHEMES

8 PSK MODULATION STYLE, 4800BITS/S, VEHICLE SPEED: 40KM/H

NOTE: 200000 CODES ARE USED IN THE SIMULATION, PB=2.402E-03

Interleaving Scheme / Interleaving Degree I	Uniform Interleaving	Rayleigh Interleaving	Periodic Interleaving
1	1.53079e-03	1.68516e-03	2.11827e-03
5	4.55378e-04	4.67429e-04	7.37126e-04
10	1.60309e-04	1.89201e-04	1.99921e-04
15	8.07874e-05	1.00118e-04	**6.78706e-05**
20	4.53512e-05	5.18092e-05	1.97244e-05
25	3.63760e-05	**2.25935e-05**	9.01575e-06
30	2.04330e-05	1.81468e-05	2.51956e-06

TABLE III

ERROR CORRECTING PERFORMANCE OF BCH(63,39,4) CODE USING DIFFERENT INTERLEAVING SCHEMES

8 PSK MODULATION STYLE, 4800BITS/S, VEHICLE SPEED: 100KM/H

NOTE: 200000 CODES ARE USED IN THE SIMULATION, PB=6.081E-03

Interleaving scheme / Interleaving Degree I	Uniform interleaving	Rayleigh interleaving	Periodic interleaving
1	4.85310e-03	5.00905e-03	5.53556e-03
5	2.88934e-03	2.96397e-03	3.58603e-03
10	1.65803e-03	1.91560e-03	2.12905e-03
15	1.10786e-03	1.22706e-03	1.35104e-03
20	7.78755e-04	8.35764e-04	8.84286e-04
25	5.97745e-04	6.65102e-04	7.05635e-04
30	4.85649e-04	4.95717e-04	5.07673e-04
35	3.66830e-04	3.87414e-04	4.13520e-04
40	2.96842e-04	3.55636e-04	3.03175e-04
45	2.25981e-04	2.51421e-04	2.74251e-04
50	2.60679e-04	**2.26638e-04**	**2.08571e-04**
55	1.84411e-04	2.18790e-04	1.77905e-04
60	1.88917e-04	**1.61242e-04**	1.64888e-04

TABLE IV

ERROR CORRECTING PERFORMANCE OF BCH(127,78,7) CODE USING DIFFERENT INTERLEAVING SCHEMES

8 PSK MODULATION STYLE, 4800BITS/S, VEHICLE SPEED: 100KM/H

NOTE: 200000 CODES ARE USED IN THE SIMULATION, PB=6.081E-03

Interleaving scheme / Interleaving Degree I	Uniform interleaving	Rayleigh interleaving	Periodic interleaving
1	4.25366 e-03	4.54665e-03	5.37185e-03
5	1.89241e-03	1.94897e-03	2.62051e-03
10	9.25593e-04	1.06734e-03	1.18969e-03
15	5.08110e-04	6.22084e-04	6.22725e-04
20	**3.32418e-04**	3.82624e-04	3.58189e-04
25	2.36916e-04	2.49394e-04	**2.21299e-04**
30	1.86849e-04	**1.38443e-04**	1.44245e-04
35	1.61424e-04	1.35496e-04	**1.01050e-04**
40	1.01829e-04	1.12101e-04	6.62205e-05
45	7.36055e-05	7.33999e-05	5.39303e-05
50	7.28248e-05	6.64484e-05	3.66142e-05

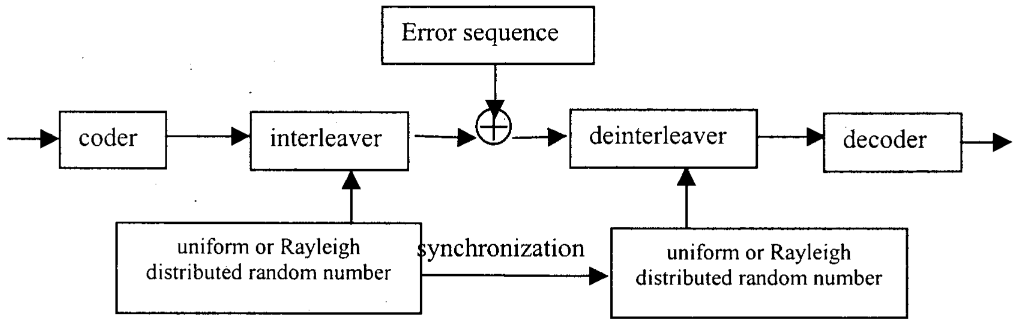

Fig. 1. Block diagram of simulation

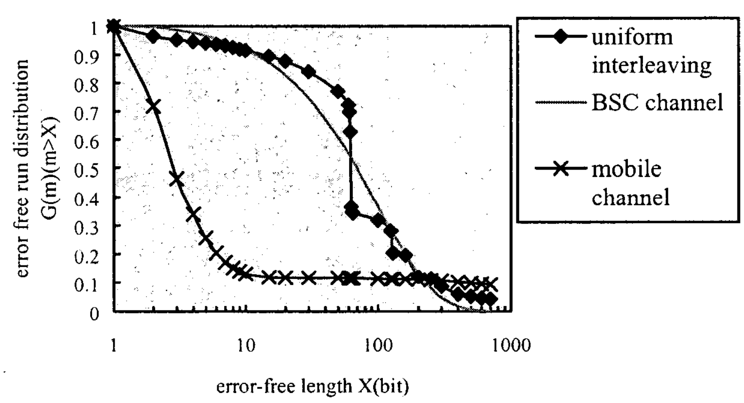

Fig.2. Comparison of error-free run distribution curve among mobile channel, uniform interleaving and BSC channel