The optimization of error floor in M-QAM multilevel coded modulation scheme based on LDPC code

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• Abstract

In M-QAM multilevel coded modulation scheme with LDPC, the system error floor can be effectively reduced and the coding gain can be improved by adjusting the component code rate based on the capacity rule.

• Theoretical Basis and System Construction

The MLC scheme with MSD is shown in Fig.1, taking 16QAM as an example. The MLC scheme divides the real physical channel into log2 (M) equivalent subchannels, each bit b_i (i=0,1,2,3) is protected by different independent LDPC code. When multistage decoding is adopted at the receiver side, the LLR value's calculation of equivalent high-level subchannels will refer to the decoding results of low-level subchannels. The use of mutual information between subchannels makes the decoding results more accurate, but it inevitably leads to error propagation, which is particularly prominent at low SNR.

In the construction of the system as shown in Figure 1, component code rate allocation of equivalent subchannels is a particularly important issue, which will affect the coding gain of the whole system. According to the reference materials[4], the capacity rule is the most commonly used in MQAM MLC-MSD system when using LDPC as component code.

For the convenience of comparison with [4], we make R = 3 bits per symbol in 16QAM and the overhead is 33%. We calculate the equivalent subchannels' capacity according to the mutual information chain rule (1) and AWGN channel transition probability density function (2) . The result of equivalent subchannels' capacity is shown in Table I. In order to get the results more conveniently and will not significantly reduce the system performance, we set the code length N as 5400, and the construction parameters are shown in Table II.

$$I_{MLC}(X;Y)=I(b_0b_1\ldots b_{M-1};Y)= I(b_0;Y)+I(b_1;Y|b_0)+\ldots+I(b_{M-1};Y|b_0\, b_1\ldots b_{M-2}) \quad (1)$$

$$p(y|x)=\exp[-|y-x|^2/\sigma^2]\cdot(2\pi\sigma^2) \quad (2)$$

• Simulation Analysis

We apply binary LDPC shown in Table II as component codes to 16QAM MLC-MSD system for performance simulation with Ungerboeck set partitioning or Gray labeling, the results are shown by the solid line in Figure 2. We can see that the system with Ungerboeck set partitioning exhibits serious error floor phenomenon, and there is a trend of error floor under Gray labeling.

For the purpose of analyzing the causes of error floor phenomenon, we calculate the BER of each level of equivalent subchannels. In the system with Ungerboeck set partitioning, the result shows that the performance of the first three equivalent subchannels is normal, while the BER of the fourth equivalent subchannel remains at 1e-5 at high SNR. In the system with Gray labeling, the result shows that the first and third equivalent subchannel's BER much higher than the others while the BER before decoding is opposite. We adjusting the component codes rate applied to all equivalent subchannels. In the system with Ungerboeck set partitioning, we set the fourth component code rate equals to the third one and remain others unchanged, which makes the total transmission rate is almost constant. In the system with Gray labeling, we reduce the component codes rate of the first and third equivalent subchannel and increase the other two. Through simulation, it can be found that this method can greatly reduce the error floor of the system with Ungerboeck set partitioning and improve the coding gain about 0.3 dB at a BER of 1e-7 in the system with Gray labeling, as shown by the dotted line in Figure 2.

Simulation Results

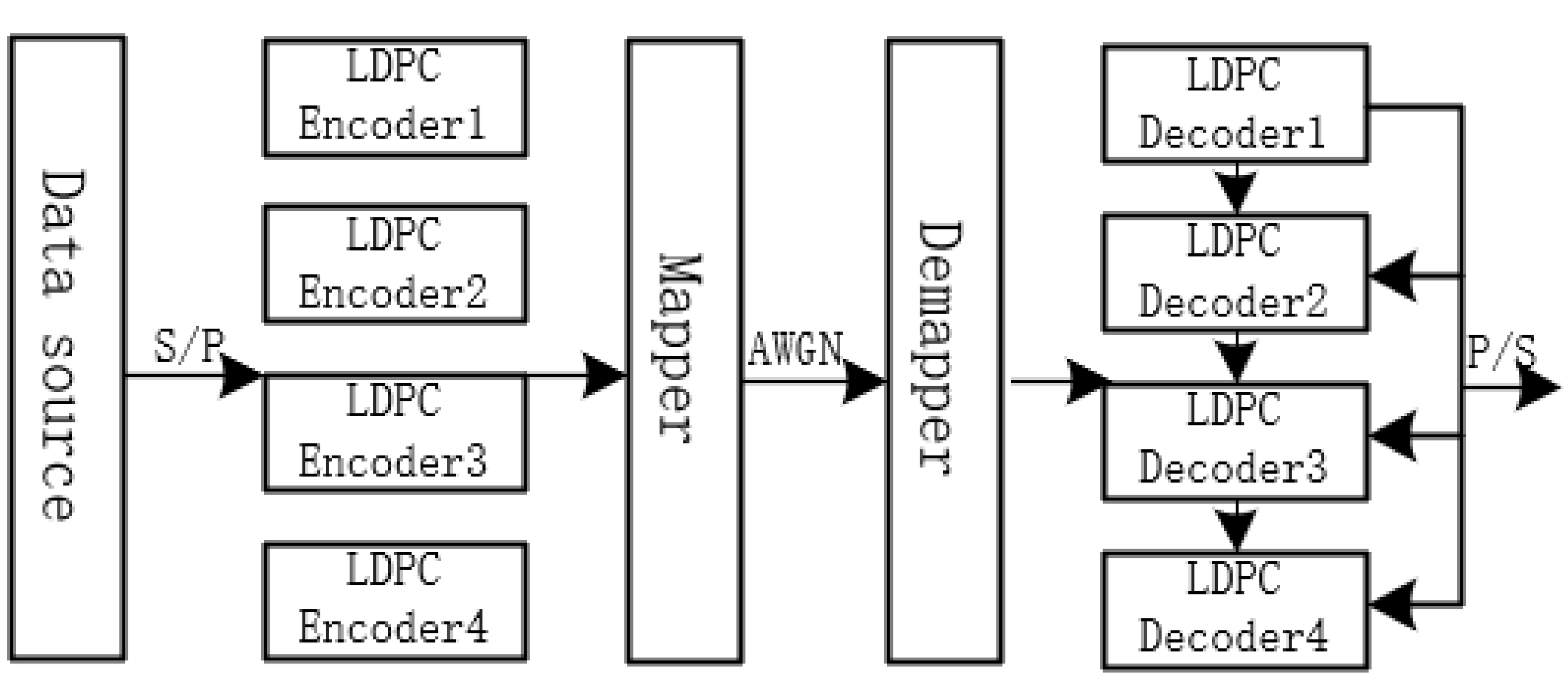

Figure. 1. 16QAM MLC-MSD system structure diagram

R	J*L	N	λ(dv)
0.280	36*54	5400	$\lambda(x)=0.8x^2+0.02x^3+0.02x^4+0.06x^{35}$
0.667	18*54		$\lambda(x)=0.889x^2+0.111x^{17}$
0.685	17*54		$\lambda(x)=0.87x^2+0.093x^{15}+0.037x^{16}$
0.759	13*54		$\lambda(x)=0.852x^2+0.019x^4+0.130x^{12}$
0.815	10*54		$\lambda(x)=0.833x^2+0.019x^4+0.148x^9$
0.833	9*54		$\lambda(x)=0.833x^2+0.167x^8$
0.963	4*108		$\lambda(x)=0.481x^2+0.519x^3$

TABLE II. BINARY LDPC CODE CONSTRUCTION PARAMETERS

labeling strategy	C	C1	C2	C3	C4
Gray	3	0.833	0.667	0.833	0.667
UP	3	0.282	0.753	0.964	1

TABLE I. EQUIVALENT SUBCHANNEL CAPACITY

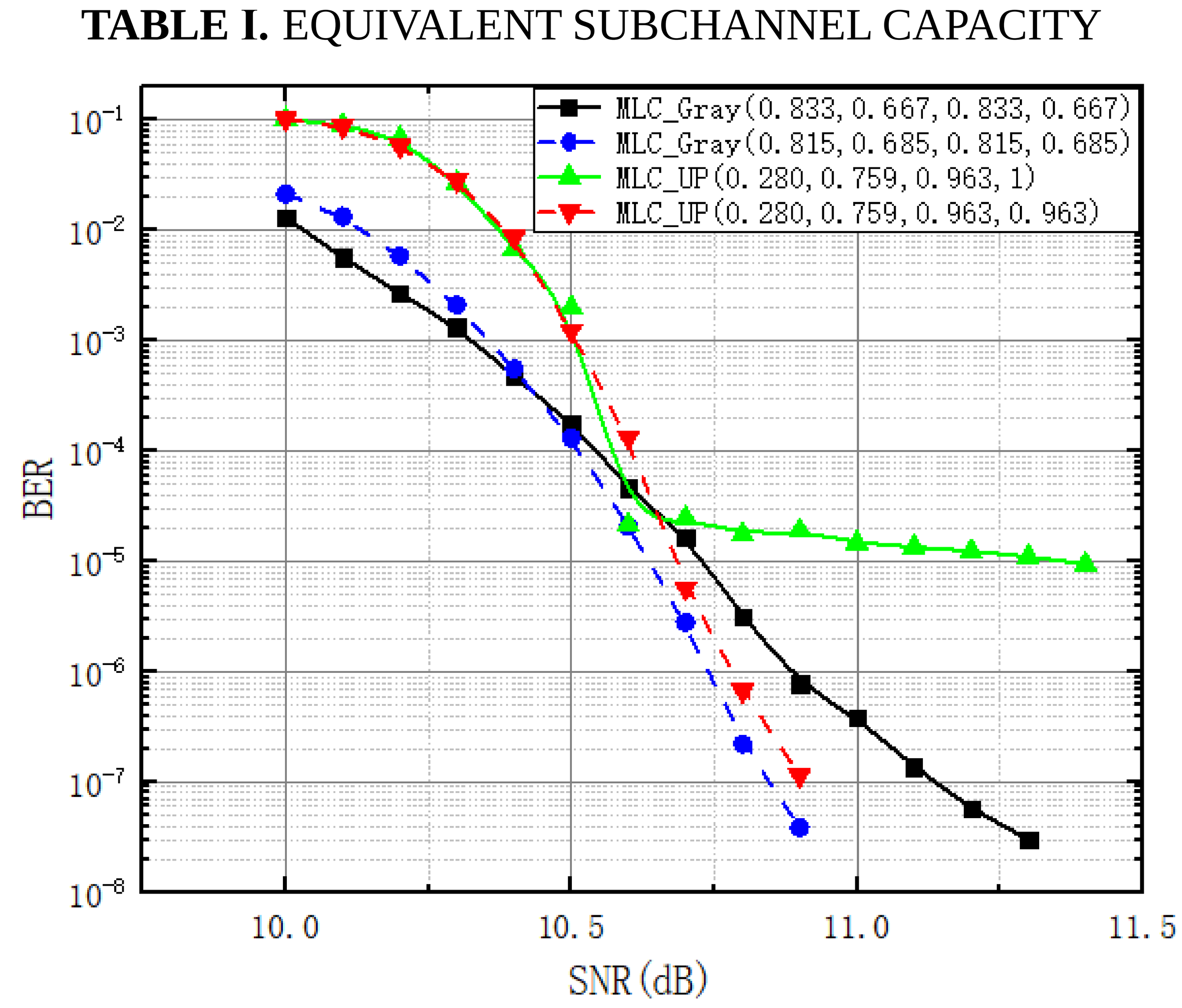

Figure.2 the performance of 16QAM MLC-MSD with Ungerboeck set partitioning or Gray labeling

Conclusion

In application, when applying irregular QC-LDPC as the component code to M-QAM multilevel coded modulation scheme and allocating the code rate strictly according to the capacity rule, the system performs not good as theory and exhibits serious error floor phenomenon. By adjusting the component codes rate, the error floor of the system with Ungerboeck set partitioning could be greatly reduced and the coding gain could be improved about 0.3 dB at a BER of 1e-7 in the system with Gray labeling in 16QAM. The similar conclusion can be extended to 64QAM and other systems.