

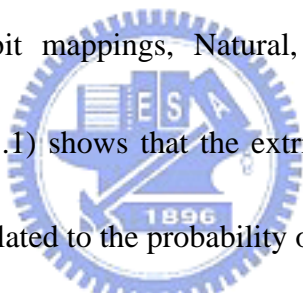
# Chapter 5

## Labeling design in BICM-ID systems

Due to the improvement on the bit-mapping for the BICM-ID systems, we may design more suitable bit-mappings for the convolutional codes in BICM-ID systems.

### 5.1 Labeling design

First, we analyze the bit mappings, Natural, Gray, and Anti-Gray. In the BICM-ID system, equation (3.1) shows that the extrinsic information of the  $i^{th}$  bit calculated by the detector is related to the probability of other bits.


$$L_{E,M}(c_i) = \ln \frac{\sum_{x \in \mathcal{X}_{i,1}} P(y|x) \prod_{j \neq i} P(c_j)}{\sum_{x \in \mathcal{X}_{i,0}} P(y|x) \prod_{j \neq i} P(c_j)} \quad (5.1)$$

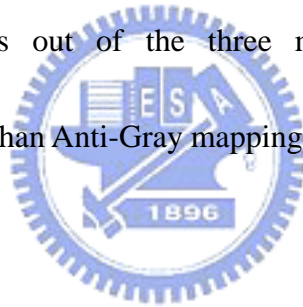
where  $\mathcal{X}_{i,b}$  is the set of symbols with  $c_i = b$ ,  $b \in \{1,0\}$ . If there are more different bits between two distinct symbols, the extrinsic information will be influenced more by the a priori probabilities of the other bits from the decoder. This will result in different shapes of the detector transfer characteristics. The more different bits between two distinct symbols are, the steeper the slopes of the detector transfer characteristics will be. **To simply the design of the bit mappings, we assume that**

**the performance is dominated by the nearest symbols when calculating the bit metrics of one bit.** It is difficult and impractical to exhaustively search all possible bit mappings.

There are some observations on the bit mappings of Gray, Anti-Gray and Natural mappings:

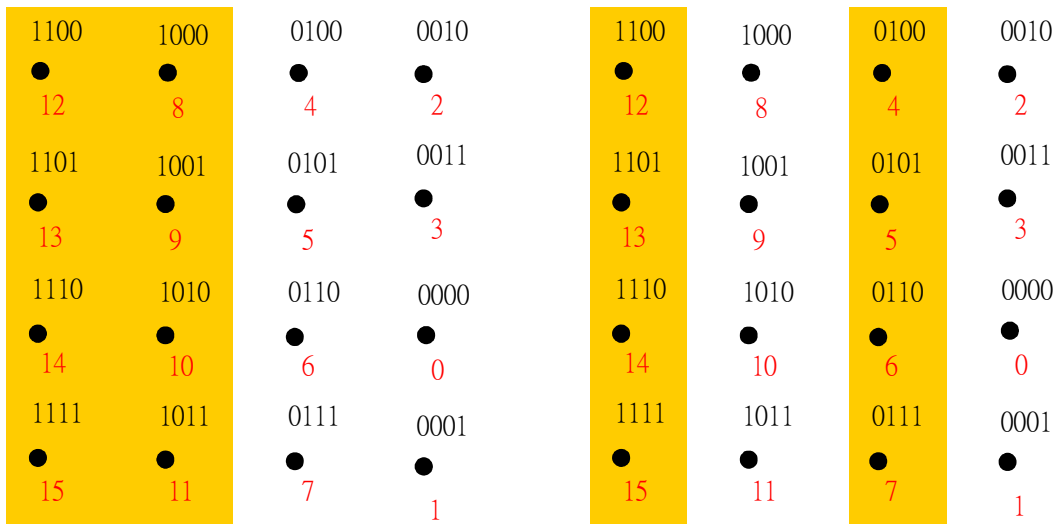
- i. Gray mapping has the least average bit differences between symbols
- ii. Anti-Gray mapping has the most average bit differences between symbols
- iii. Natural mapping is the most suitable mapping for the  $(133_8, 171_8)$

convolutional codes out of the three mapping and the average bit differences are less than Anti-Gray mapping and more than Gray mapping.



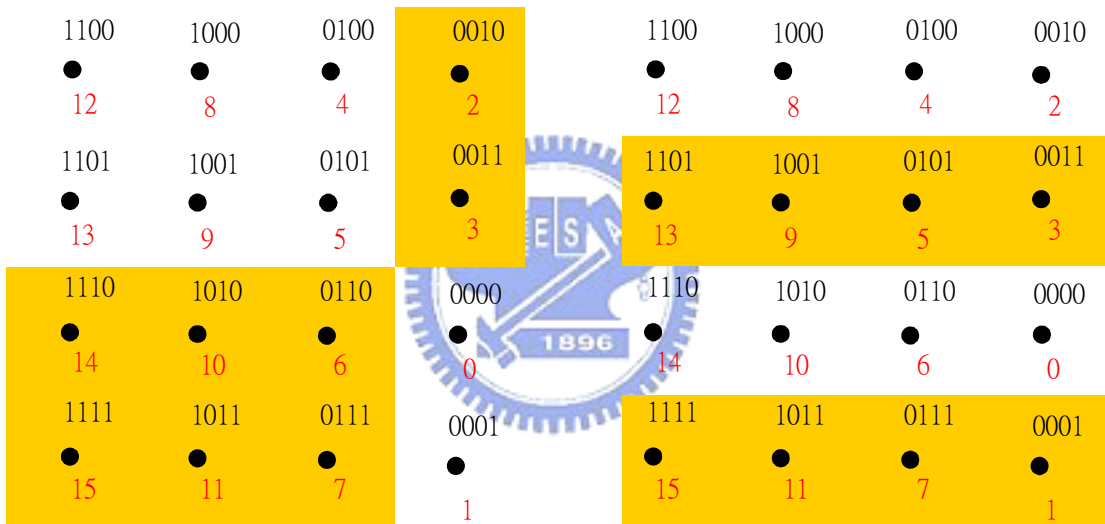
Based on the three observations above, we start at the Natural mapping and make some changes to the constellations to increase bit differences or to decrease bit differences. Fig.5-1 shows the subset partitioning for four bits of 16QAM Natural constellations. When we calculate the bit metrics of the first bit, the bit differences are  $1 \times 4 = 4$  bits. Because there are four pairs of nearest neighbors, the average bit differences of bit 1 are  $4/4 = 1$  bit. The average bit differences of the bits 2,3,4 are  $4/12$ ,  $4/4$ ,  $4/12$  respectively. The average bit differences of the 16QAM Natural mapping are  $1 + 4/12 + 4/4 + 4/12 = 2.67$  bits.





Bit 1

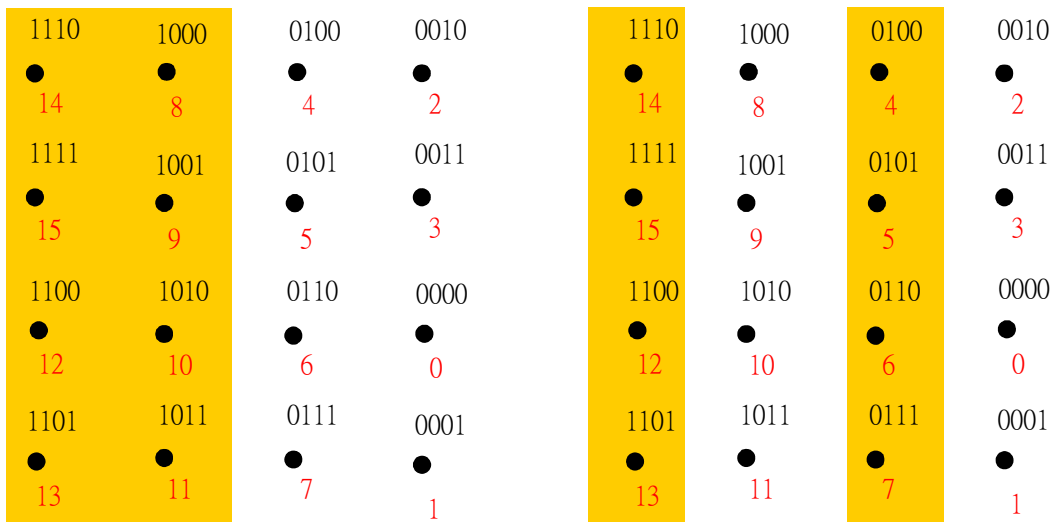
Bit 2



Bit 3

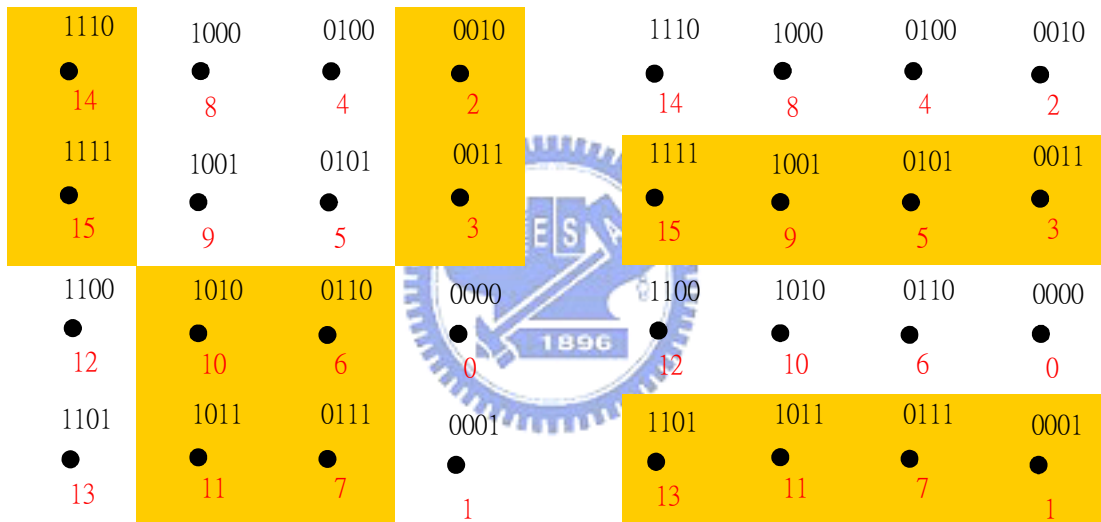
Bit 4

Fig. 5-2: Subset partitions of 16QAM for Type A constellations.



Bit 1

Bit 2



Bit 3

Bit 4

Fig. 5-3: Subset partitions of 16QAM for Type B constellations.

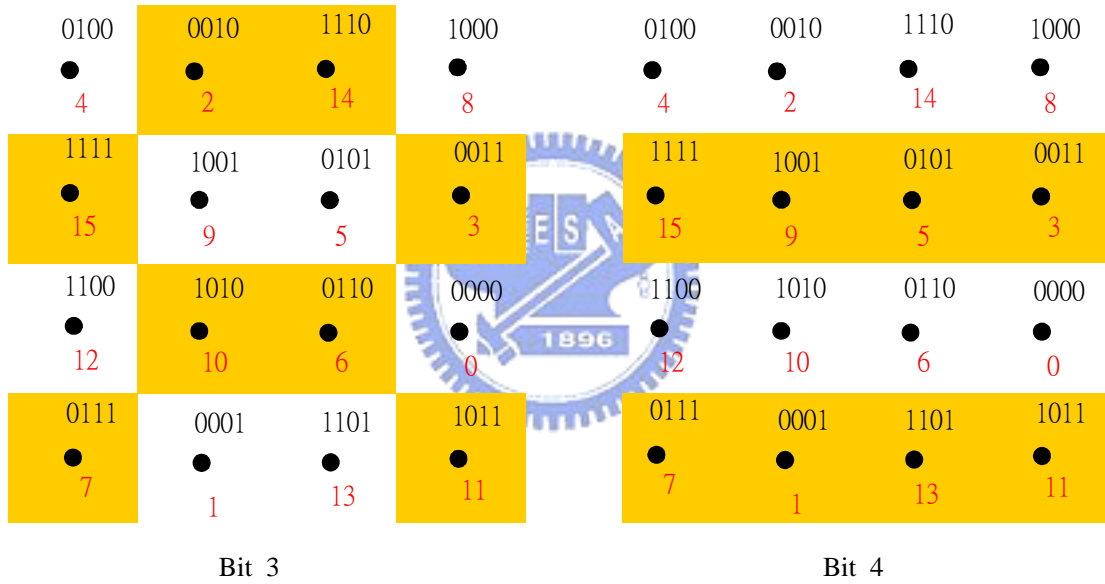
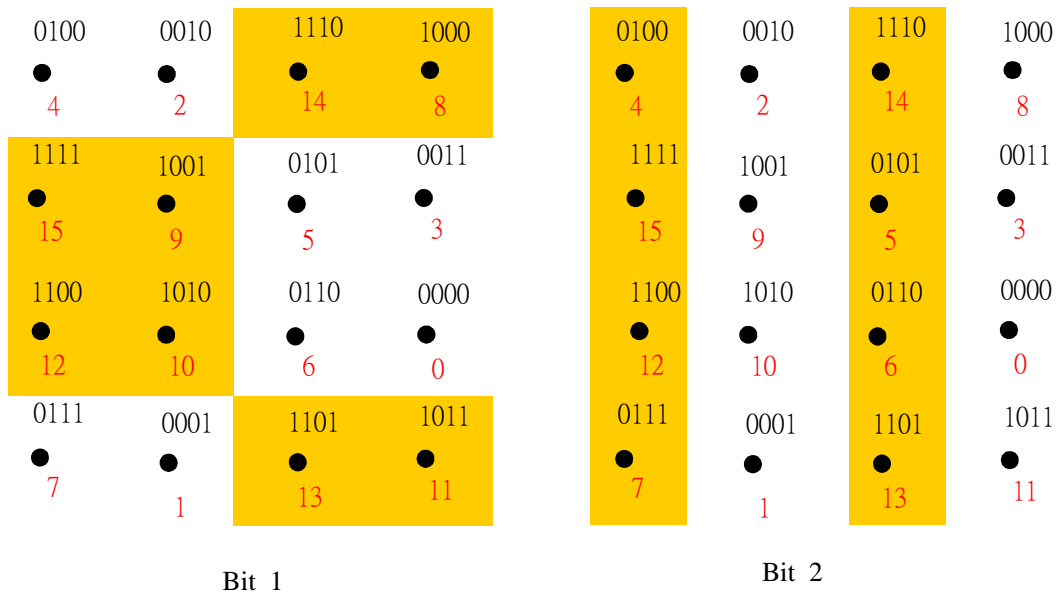


Fig. 5-4: Subset partitions of 16QAM for Type C constellations.

Type A-C mappings are shown in Fig.5-2 to Fig. 5-4. We calculate average bit differences of the above three mapping types.

- Average bit differences of type A mapping is 3.
- Average bit differences of type B mapping is 3.33.
- Average bit differences of type C mapping is 6.33

Besides, the average bit differences of Gray and Anti-Gray labeling are 6.258 and 0 respectively. Compared with the 2.67 bit differences of the Natural mapping, it can be predicted that the slopes of the transfer characteristics will be the order as follow,

**Type C > Anti-Gray > Type B > Type A > Natural > Gray**

The transfer characteristics are depicted in Fig.5-5 at  $E_b / N_0 = 3dB$  and support our predictions.

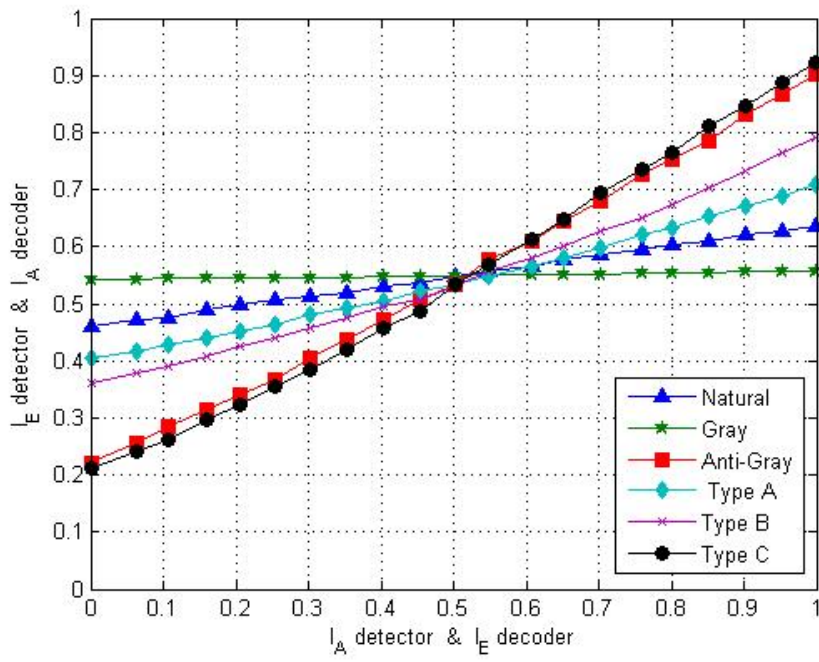


Fig. 5-5: Detector transfer characteristics for six mappings at  $E_b / N_0 = 3dB$  and 16-QAM.

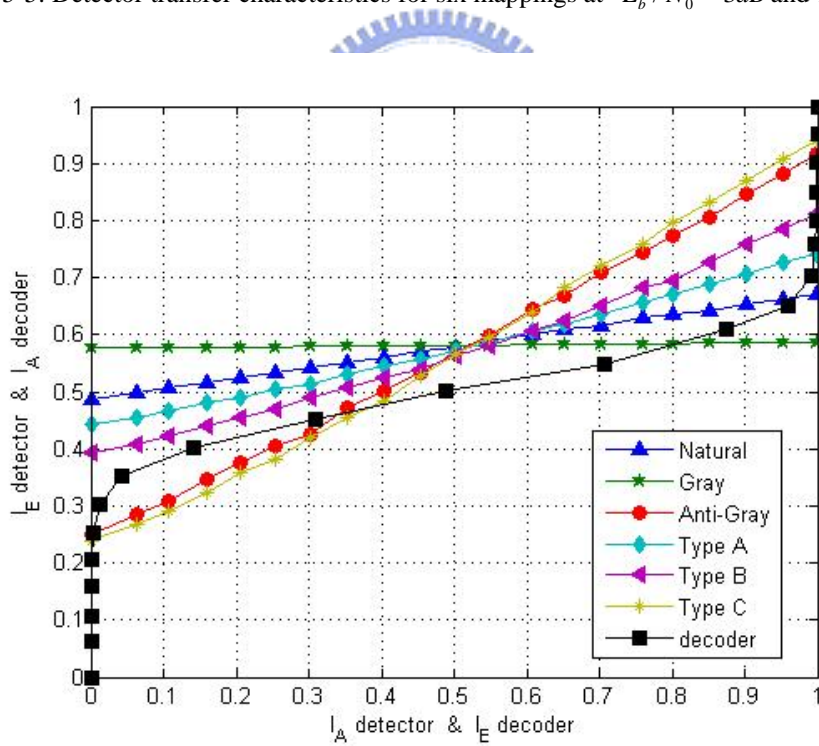


Fig. 5-6: EXIT chart for six mappings at  $E_b / N_0 = 3.5 dB$  and 16-QAM.



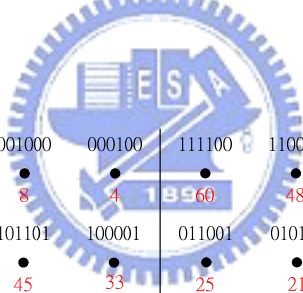
In Fig.5-6, it is obvious that the most suitable mapping for the  $(133_8, 171_8)$  convolutional code is the type B mapping. The same design criteria can also be applied to 64QAM, and we just show the results of the mapping designs.

111000	110000	101000	100000	011000	010100	001000	000100
●	●	●	●	●	●	●	●
56	48	40	32	24	20	8	4
111001	110001	101001	100001	011001	010101	001001	000101
●	●	●	●	●	●	●	●
57	49	41	33	25	21	9	5
111010	110010	101010	100010	011010	010110	001010	000110
●	●	●	●	●	●	●	●
58	50	42	34	26	22	10	6
111011	110011	101011	100011	011011	010111	001011	000111
●	●	●	●	●	●	●	●
59	51	43	35	27	23	11	7
111100	110100	101100	100100	011100	010000	001100	000000
●	●	●	●	●	●	●	●
60	52	44	36	28	16	12	0
111101	110101	101101	100101	011101	010001	001101	000001
●	●	●	●	●	●	●	●
61	53	45	37	29	17	13	1
111110	110110	101110	100110	011110	010010	001110	000010
●	●	●	●	●	●	●	●
62	54	46	38	30	18	14	2
111111	110111	101111	100111	011111	010011	001111	000011
●	●	●	●	●	●	●	●
63	55	47	39	31	19	15	3

Fig. 5-7: Type A mapping for 64QAM.

111100	110000	101100	100000	011000	010100	001000	000100
•	•	•	•	•	•	•	•
60	48	44	32	24	20	8	4
111101	110001	101101	100001	011001	010101	001001	000101
•	•	•	•	•	•	•	•
61	49	45	33	25	21	9	5
111110	110010	101110	100010	011010	010110	001010	000110
•	•	•	•	•	•	•	•
62	50	46	34	26	22	10	6
111111	110011	101111	100011	011011	010111	001011	000111
•	•	•	•	•	•	•	•
63	51	47	35	27	23	11	7
111000	110100	101000	100100	011100	010000	001100	000000
•	•	•	•	•	•	•	•
56	52	40	36	28	16	12	0
111001	110101	101001	100101	011101	010001	001101	000001
•	•	•	•	•	•	•	•
57	53	41	37	29	17	13	1
111010	110110	101010	100110	011110	010010	001110	000010
•	•	•	•	•	•	•	•
58	54	42	38	30	18	14	2
111011	110111	101011	100111	011111	010011	001111	000011
•	•	•	•	•	•	•	•
59	55	43	39	31	19	15	3

Fig. 5-8: Type B mapping for 64QAM.



011000	010100	001000	000100	111100	110000	101100	100000
•	•	•	•	•	•	•	•
24	20	8	4	60	48	44	32
111101	110001	101101	100001	011001	010101	001001	000101
•	•	•	•	•	•	•	•
61	49	45	33	25	21	9	5
011010	010110	001010	000110	111110	110010	101110	100010
•	•	•	•	•	•	•	•
26	22	10	6	62	50	46	34
111111	110011	101111	100011	011011	010111	001011	000111
•	•	•	•	•	•	•	•
63	51	47	35	27	23	11	7
111000	110100	101000	100100	011100	010000	001100	000000
•	•	•	•	•	•	•	•
56	52	40	36	28	16	12	0
011101	010001	001101	000001	111001	110101	101001	100101
•	•	•	•	•	•	•	•
29	17	13	1	57	53	41	37
111010	110110	101010	100110	011110	010010	001110	000010
•	•	•	•	•	•	•	•
58	54	42	38	30	18	14	2
011111	010011	001111	000011	111011	110111	101011	100111
•	•	•	•	•	•	•	•
31	19	15	3	59	55	43	39

Fig. 5-9: Type C mapping for 64QAM.

## 5.2 Simulation results

In Fig.5-10, we show the performance of BICM-ID with the  $(133_8,171_8)$  convolutional code under 20 iterations. As our prediction, the most suitable labeling between the above six labelings is Type B labeling. If we have not labeling designs, the most suitable labeling for the  $(133_8,171_8)$  convolutional code in BICM-ID systems is Anti-Gray and the improvement on performance after labeling designing is about  $5.2-3.7=2$  dB.

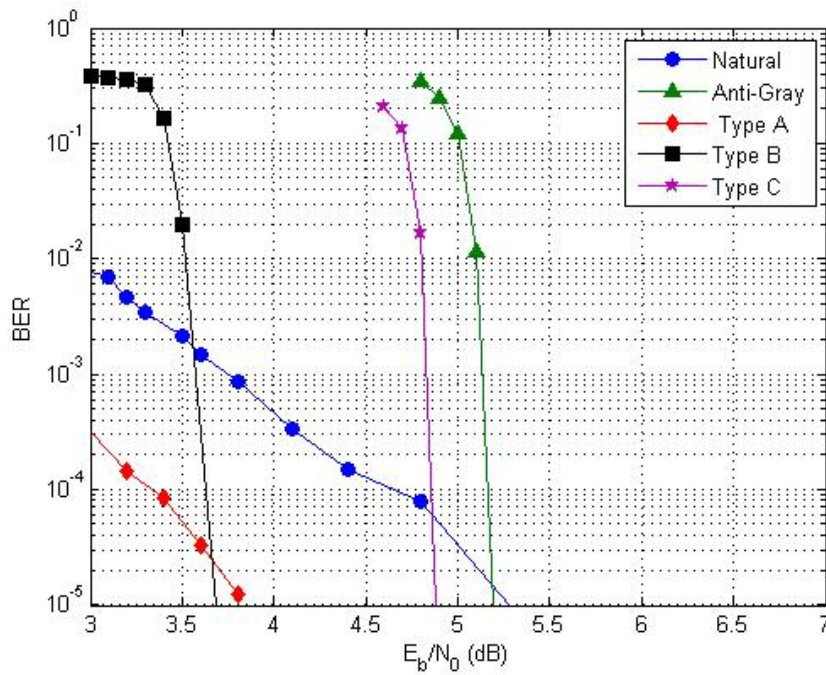


Fig. 5-10: BER of BICM-ID with six mappings with the  $(133_8,171_8)$  convolutional code, 16QAM , 20 iterations.