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.

$$L_{E,M}\left(c_i\right) = ln \frac{\sum_{x \in \chi_{i,1}} P\left(y \mid x\right) \prod_{j \neq i} P\left(c_j\right)}{\sum_{x \in \chi_{i,0}} P\left(y \mid x\right) \prod_{j \neq i} P\left(c_j\right)} \tag{5.1}$$

where $\chi_{i,b}$ 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 1×4 =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.

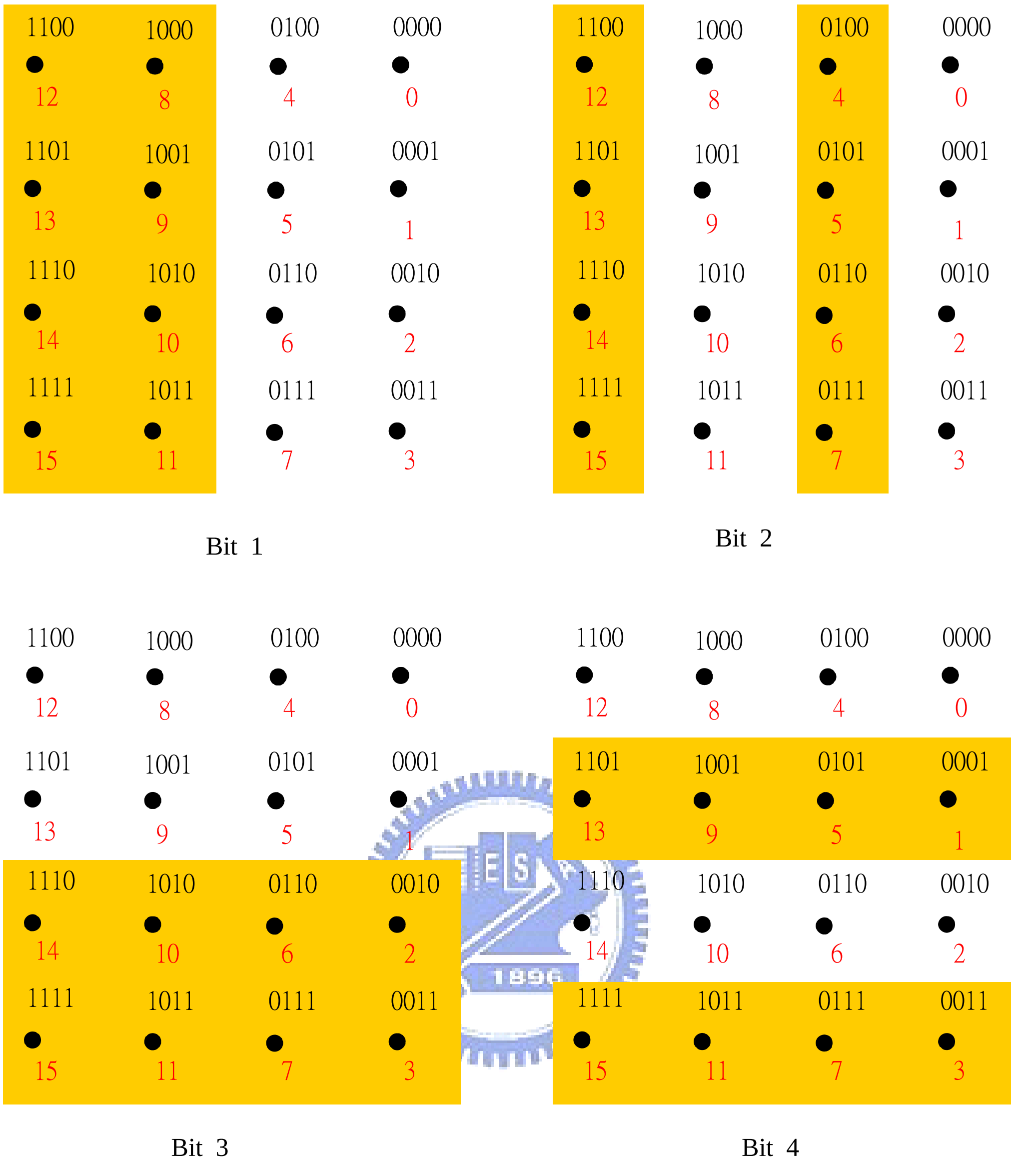

Fig. 5-1: Subset partitions of 16QAM for Natural constellations.

There are three types of mappings in our designs:

A. Based on Natural, Exchange the constellation points 0 and 1 with 2 and 3.

B. Based on type A, exchange the constellation points 12 and 13 with 14 and 15 again.

C. Based on type B, exchange the constellation points 2,4 with 14,8 and 1,7 with 13,11.

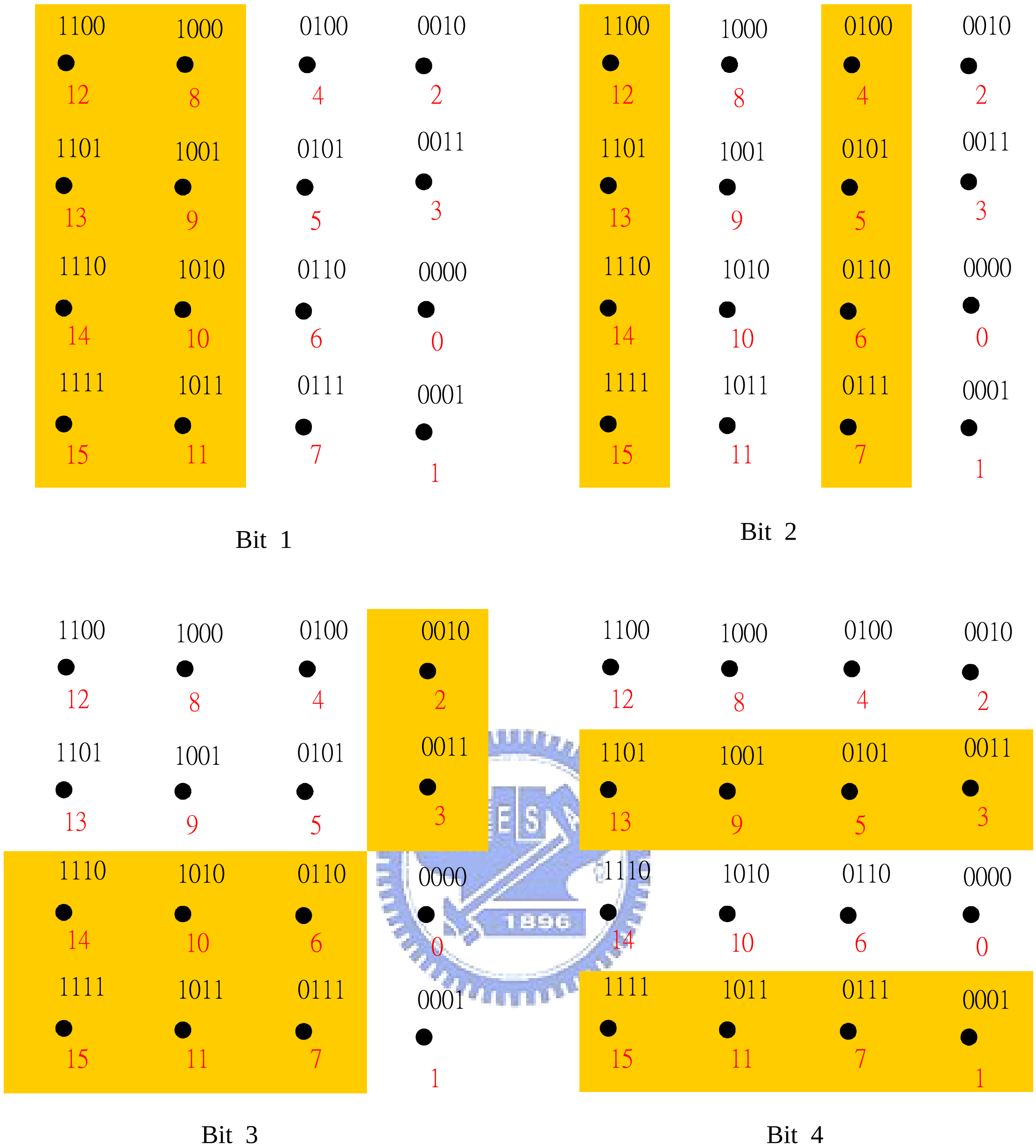

Fig. 5-2: Subset partitions of 16QAM for Type A constellations.

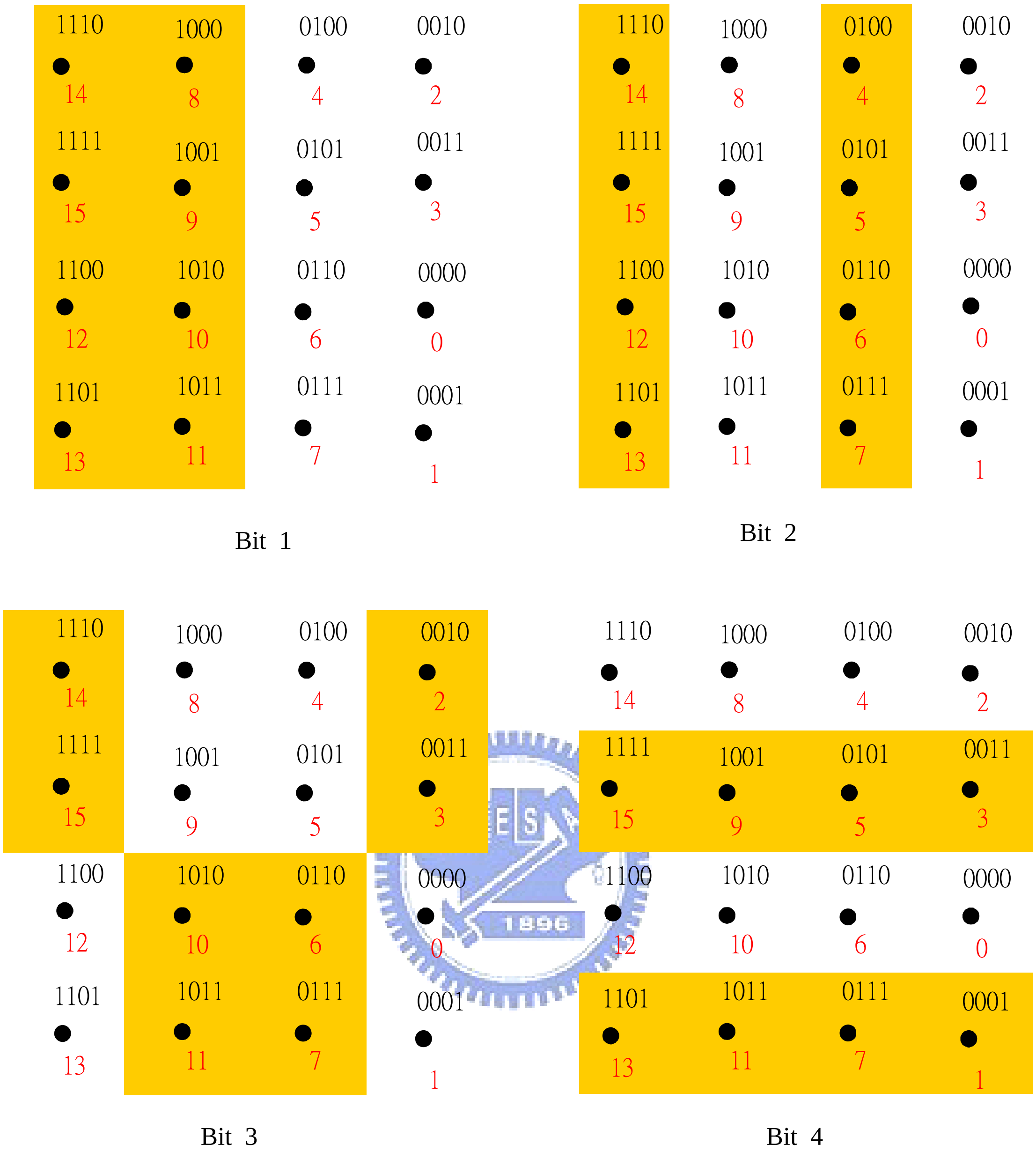

Fig. 5-3: Subset partitions of 16QAM for Type B constellations.

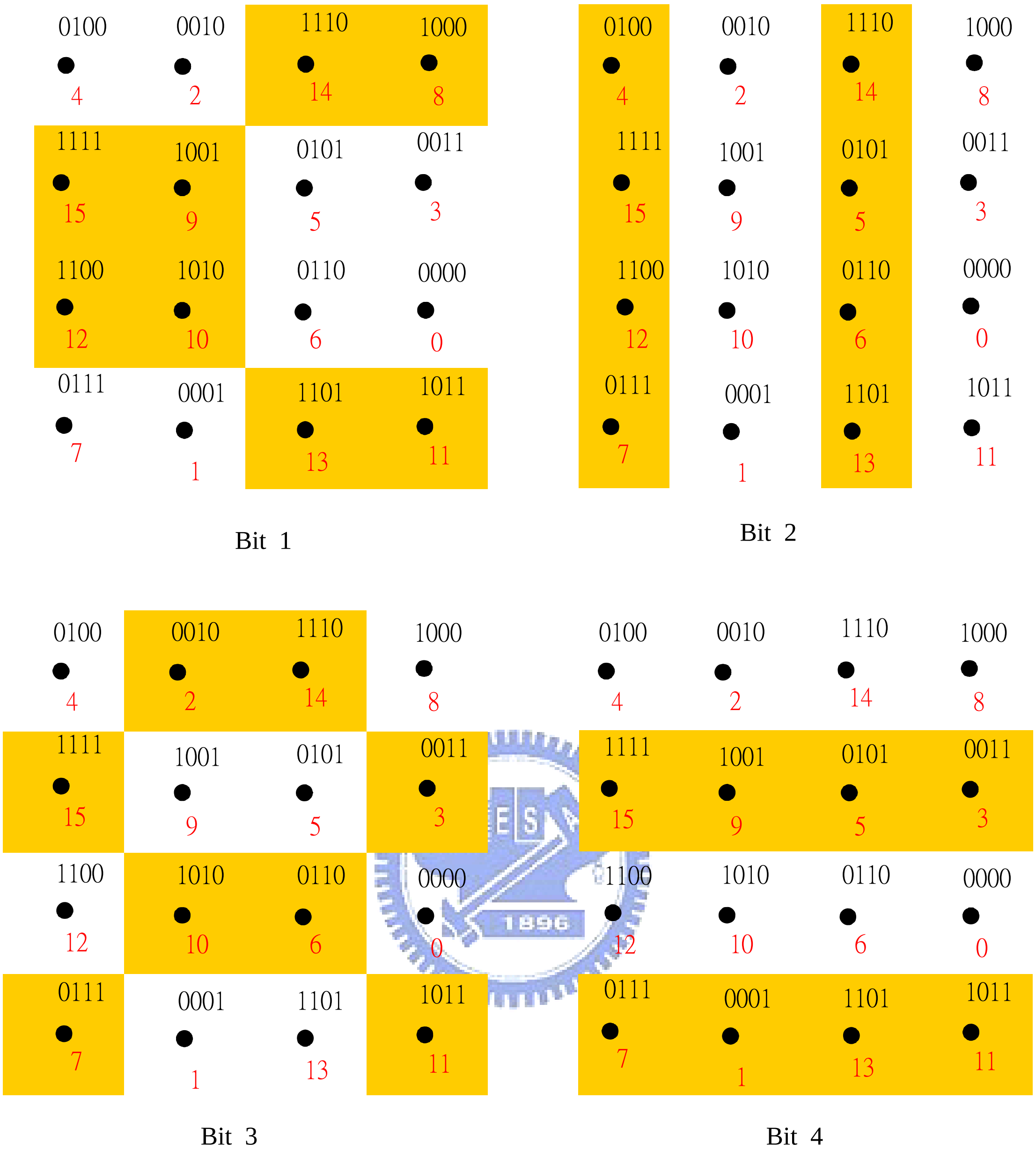

Fig. 5-4: Subset partitions of 16QAM for Type C constellations.

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.

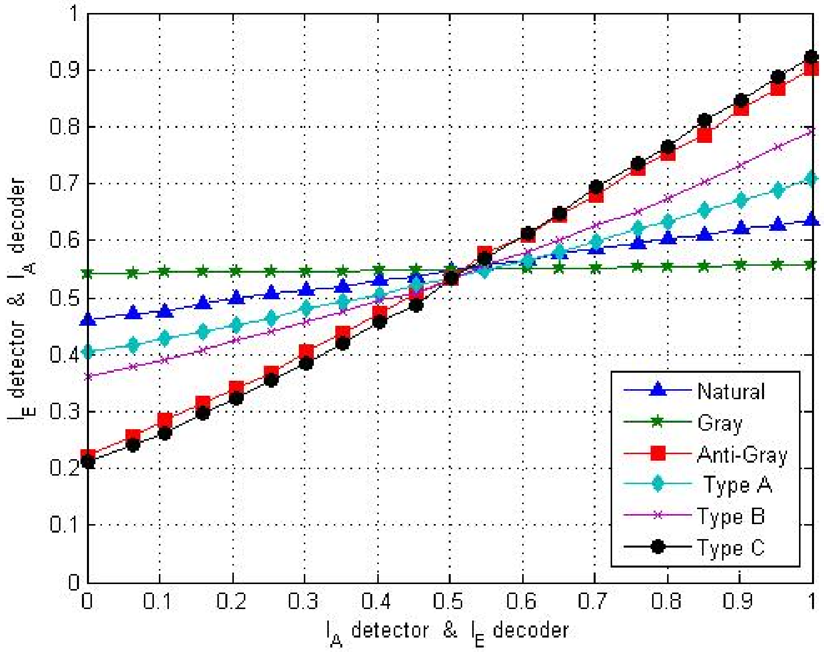

Fig. 5-5: Detector transfer characteristics for six mappings at $E_b / N_0 = 3dB$ and 16-QAM.

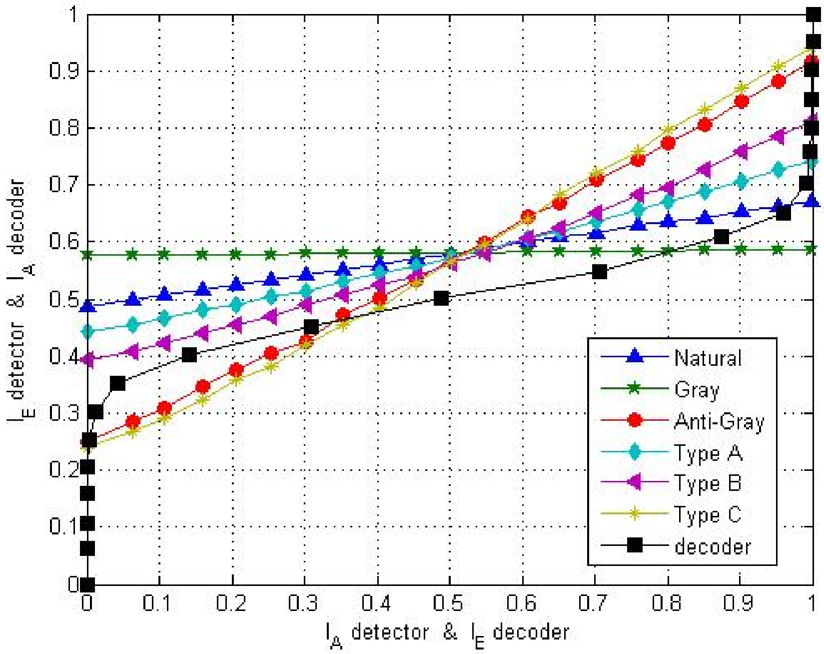

Fig. 5-6: EXIT chart for six mappings at $E_b / N_0 = 3.5\ dB$ and 16-QAM.

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.

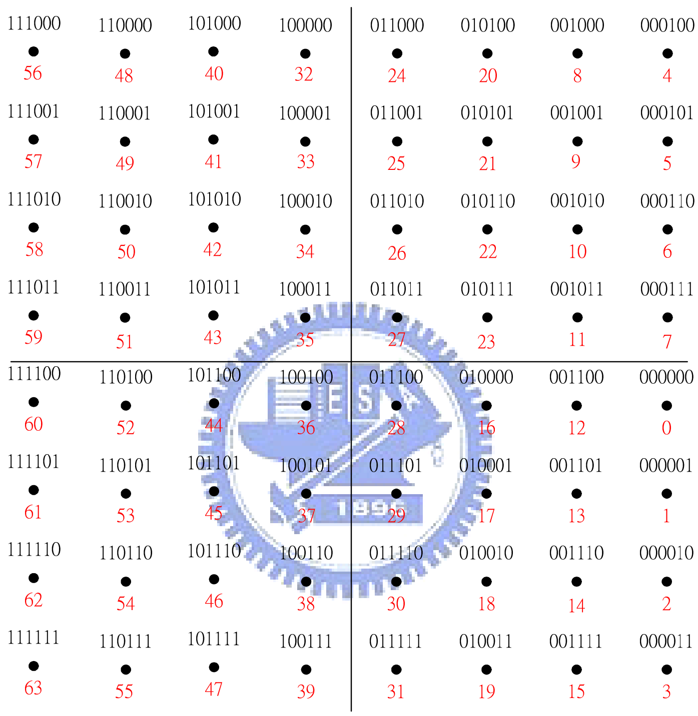

Fig. 5-7: Type A mapping for 64QAM.

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

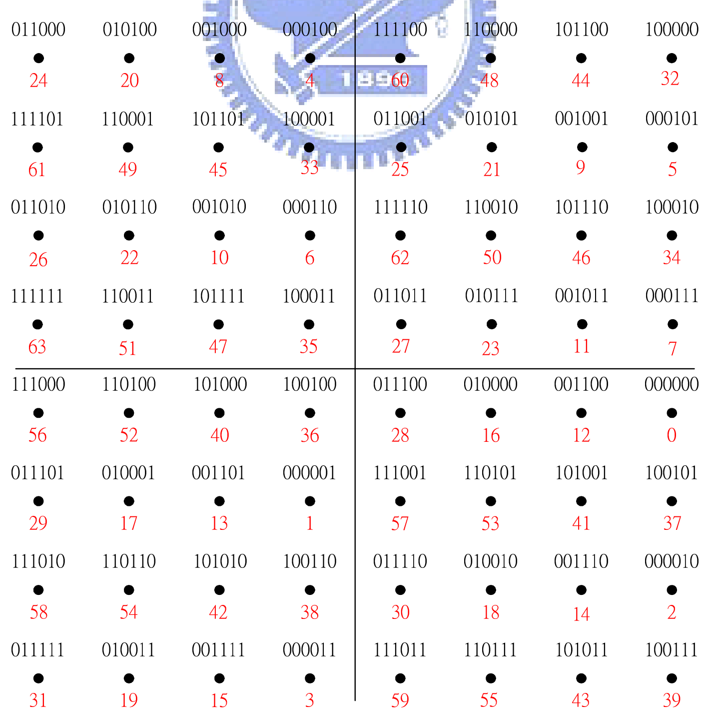

Fig. 5-9: Type C mapping for 64QAM.

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.

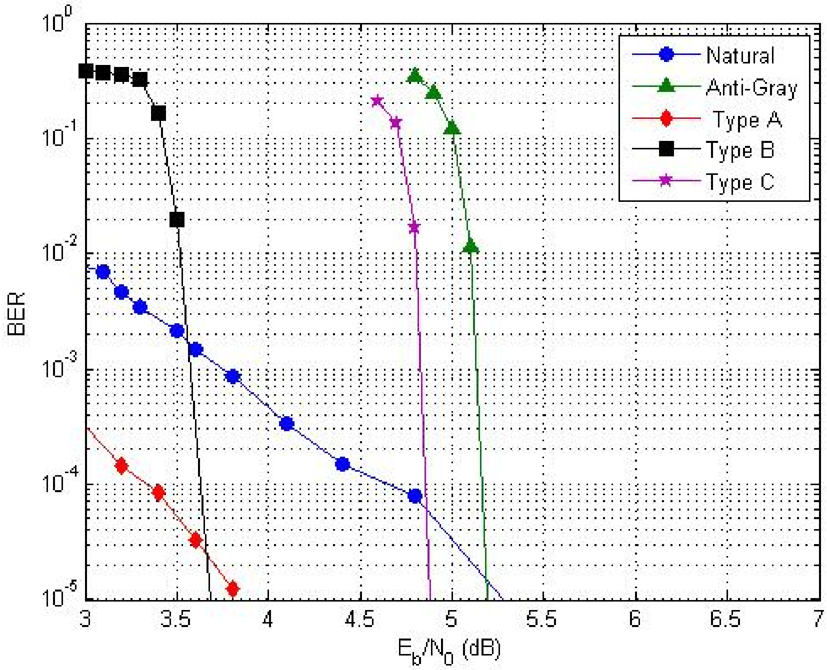

Fig. 5-10: BER of BICM-ID with six mappings with the $(133_8, 171_8)$ convolutional code, 16QAM , 20 iterations.