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| Title | **Bit Priority Mapping to enhance CTC IR HARQ performance** |
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| Re: | IEEE 802.16m-08/024 –Call for Contributions on Project 802.16m System Description Document (SDD); Hybrid ARQ (PHY aspects) |
| Abstract | In order to improve the performance of CTC IR HARQ processing, Bit Priority Mapping of the HARQ sub-packet would be helpful. Direct BPM, thanks for its symmetry, seems to make a much better balance reliability distribution in the CTC code bits than the No BPM through multiple HARQ. |
| Purpose | To be discussed and adopted by TGm for use in the IEEE 802.16m SDD. |
| Notice |  |
| Release |  |
| Patent Policy |  |

# Bit Priority Mapping to enhance CTC IR HARQ performance

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## 1. Introduction

In order to improve the performance of CTC IR HARQ processing, Bit Priority Mapping of the HARQ subpacket would be helpful. In this contribution, we will study in detail the No BPM and Direct BPM.

For No BPM, every $m_k$ consecutive code bits from “Bit selection” will be mapped into one modulation symbol. Here $m_k$ denotes the modulation order. Whereas Direct BPM maps the beginning bits of the HARQ subpacket to the high reliable bit positions of high-order modulation symbols. Direct BPM scheme has an integrate consideration of the reliability from the high order modulation gain and Chase diversity gain. Thanks for its symmetry, Direct BPM seems to make a much better balance reliability distribution in the CTC code bits than the ‘No BPM’ through multiple HARQ and can enhance the CTC IR HARQ performance.

## 2. CTC IR HARQ and subpacket generation method

Fig. 1 plots CTC based subpacket generation method. This method generates code sequence from the CTC encoder. Actually, the subpacket generation method is based on the so-called Circular Buffer Rate Matching (CBRM) algorithm. Fig. 2 shows the detail of the CBRM algorithm. The channel interleaving applies subblock interleaving on sequences $A$, $B$ , $Y_1$ ,$Y_2$ ,$W_1$ ,$W_2$, respectively. Then subblock interleaved sequences $Y_1$ and $Y_2$ are inter-block permuted into sequences $Y_1$’ and $Y_2$’ and subblock interleaved sequences $W_1$ and $W_2$ are inter-block permuted into sequences $W_1$’ and $W_2$’. Puncturing block selects symbols according to the sequence order $A$, $B$ ,$Y_1'$ ,$Y_2'$ ,$W_1'$ ,$W_2'$, where Table 1 shows the parameters and Table 2 shows the selected symbols.

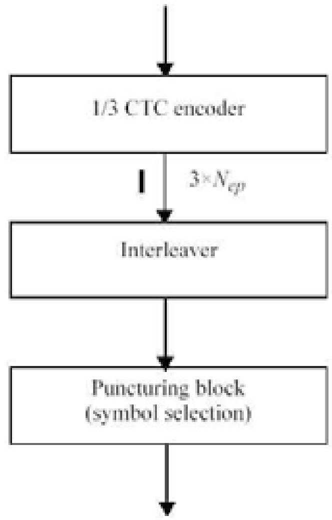



Fig. 1: Subpacket generation method.

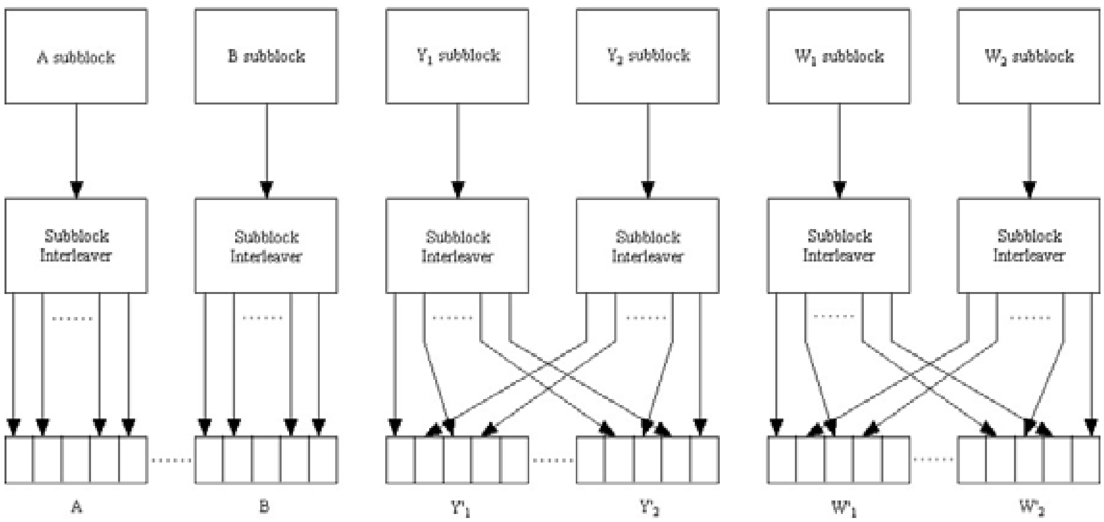



Fig. 2: Channel interleaver.

Table 1: Parameters for the H-ARQ CTC in IEEE 802.16 8.4.9.2.3.4.4 Bit selection [1].

| | |
|---|---|
| $k$ | be the subpacket index when IR HARQ is enabled. k = 0 for the first transmission and increases by one for the next subpacket. k = 0 when IR HARQ is not used. When there are more than one FEC block in a burst, the subpacket index for each FEC block shall be the same. |
| $N_{EP}$ | be the number of bits in the encoder packet (before encoding). |
| $N_{SCHk}$ | be the number of the concatenated slots for the subpacket defined in Table 522 for the non-HARQ and Chase HARQ CTC scheme defined in 8.4.9.2.3.1 and be the same as the $N_{sch}$ that is indicated in the Allocation IE for the HARQ CTC scheme defined in 8.4.9.2.3.5. |
| $m_k$ | be the modulation order for the $k$-th subpacket ($m_k$ = 2 for QPSK, 4 for 16-QAM, and 6 for 64-QAM). |
| $SPID_k$ | be the subpacket ID for the $k$-th subpacket, (for the first subpacket, $SPID_{k=0} = 0$). |

Table 2 The symbol selection in IEEE 802.16 8.4.9.2.3.4. [1].

$$S_{k,i} = (F_k + i) \bmod (3N_{EP})$$
where
$$i = 0,1,2,...,L_k - 1$$
$$L_k = 48 \cdot N_{SCHk} \cdot m_k$$
$$F_k = (SPID_k \cdot L_k) \bmod (3 \cdot N_{EP})$$

## 3. The principles of Direct BPM and No BPM

The symbol selection generates *k*-th subpacket by $SPID_k$. After the symbol selection, the bits of *k*-th subpacket are mapped to the modulation symbols.

For No BPM, every $m_k$ consecutive code bits from the symbol selection will be mapped into one modulation symbol.

Direct BPM maps the beginning bits of the HARQ subpacket to the high reliable bit positions of one modulation symbols.

For example, let's assume that $L_k$=12 binary code bits constitute one HARQ transmission for 16QAM as Figure 3.

For No BPM, four consecutive code bits in time order will be mapped into one modulation symbol. For Direct BPM, the first two bits of the previous half (red part) and the first two bits of the rest half (blue part) together shall be mapped into one modulation symbol, then the second two bits of the previous half (red part) and the second two bits of the rest half (blue part) together shall be mapped into one modulation symbol, and so on.

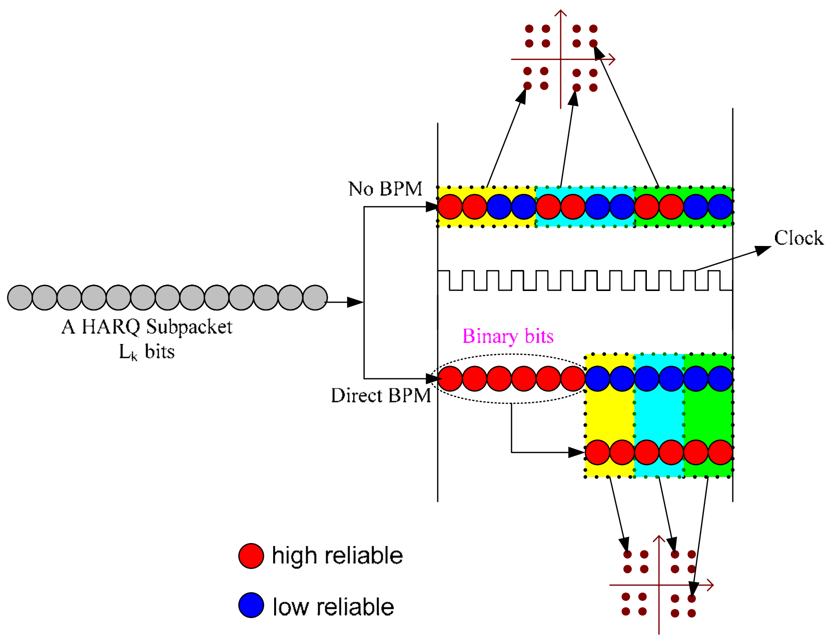



Figure 3 No BPM and Direct BPM for 16QAM

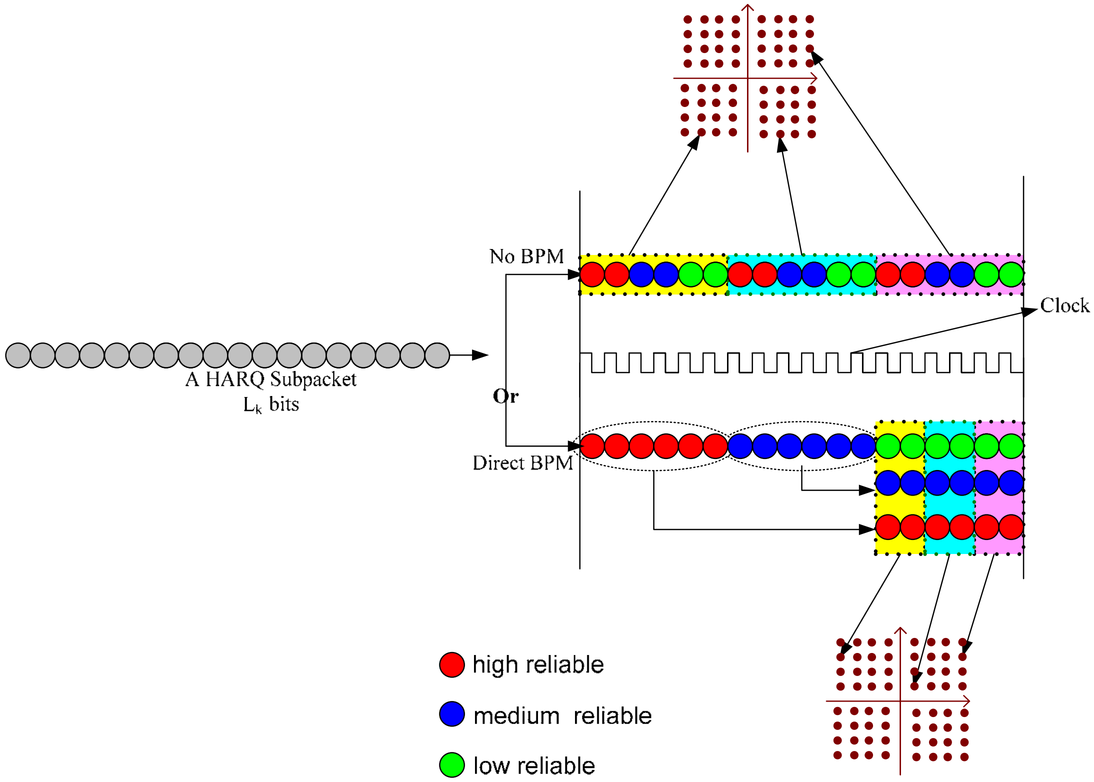



Figure 4 No BPM and Direct BPM for 64QAM

Figure 4 shows the similar example for $L_k$=18 binary code bits constitute one HARQ transmission for 64QAM.

The Direct BPM is very simple in implementation. For example, the Direct BPM can be realized by simple modifying the symbol selection method in Table 2 and the detail modification is shown in Table 3.

Table 3 the modified symbol selection method for Direct BPM.

| |
|---|
| $S_{k,i} = (F_k + j)\bmod(3N_{EP})$ |
| where |
| $i = 0,1,2,...,L_k - 1$ |
| $j = 2\lfloor i/m_k \rfloor + i \bmod 2 + \lfloor L_k/(m_k/2) \rfloor \cdot \lfloor (i \bmod 4)/2 \rfloor$ |
| $L_k = 48 \cdot N_{SCHk} \cdot m_k$ |
| $F_k = (SPID_k \cdot L_k)\bmod(3 \cdot N_{EP})$ |

## 4. Reliability Distribution of Different BPM Scheme

The symbol selection can be view as a more intuitive CBRM based symbol selection, which would help to understand the difference of the two BPM schemes. Figure 5 shows the situation of multiple transmission of synchronous HARQ with Direct BPM, and No BPM respectively. The four lines going by clockwise denote four HARQ subpackets.

If 16QAM/64QAM have been applied, due to the neighbor relationship in the constellation, one modulation symbol can be denoted by 4/6 binary bits, each bit in them has different reliability, for 16QAM two bits have high reliability and anther two bits have low reliability, for 64QAM some two bits have high reliability and another two bits have medium reliability and the rest two bits have low reliability.

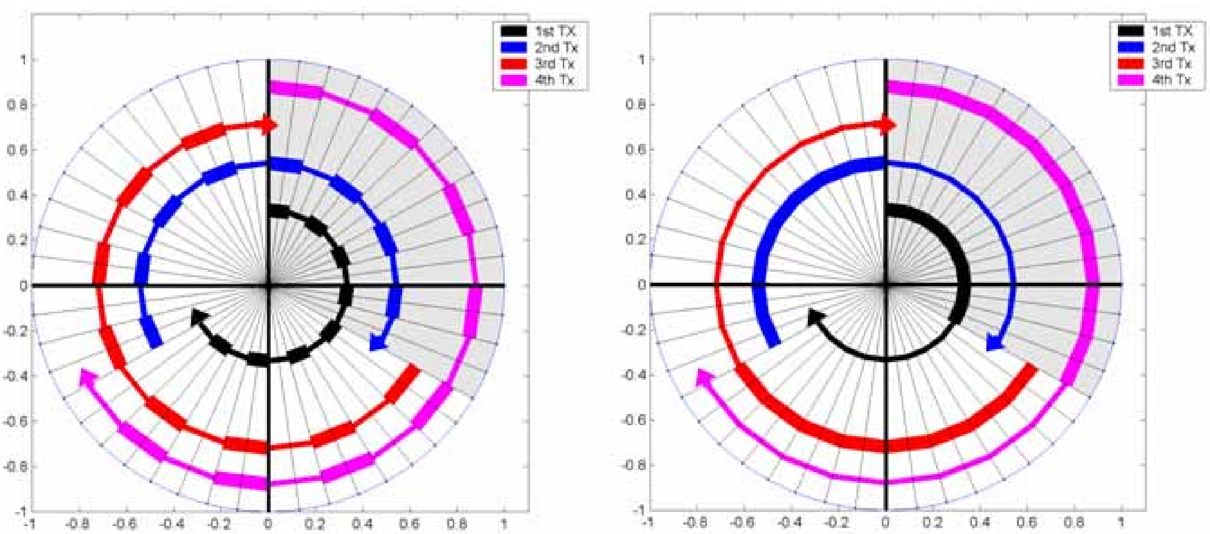
As can be seen from Figure 5, the four lines are drawn by different width, by which the thick line denotes the corresponding code bits to be mapped to the high reliable bits of the High Order Modulation(HOM) symbols; and the thin line denotes mapping to the low reliable bits. Note that 16QAM is used here.

By DBPM, the fore part bits of the HARQ packet is drawn with thick line, for its mapping to high reliable bits of the 16QAM symbol, whereas the latter part of the packet is drawn with thin line for its mapping to low reliable bits of the 16QAM symbol. As a result the fore part and the latter part will get different HOM gain. On the other hand, the overlapping or more overlapping code bits will get much higher reliability than the non-overlapping or less overlapping code bits from Chase combining.

By No BPM, the thick line is alternately distributing through the HARQ sub-packet. What make thing bad is that the some bits are always covered by thick lines; on the contrast, some are always covered by thin lines. As a result, the total reliability after combining HOM gain and chase gain is much uneven.

Under this consideration, a good BPM (including No BPM) is expected to ensure the turbo code bits get a good balance of the Chase diversity gain and the HOM gain through multiple HARQ transmission.

From careful analysis and wide range simulation, we found the Direct BPM, benefited from its symmetry, seems to make a much better balance reliability distribution in the turbo code bits than No BPM through multiple HARQ. By the way, if the 1st HARQ transmission is emphasized, DBPM also ensures the best performance.



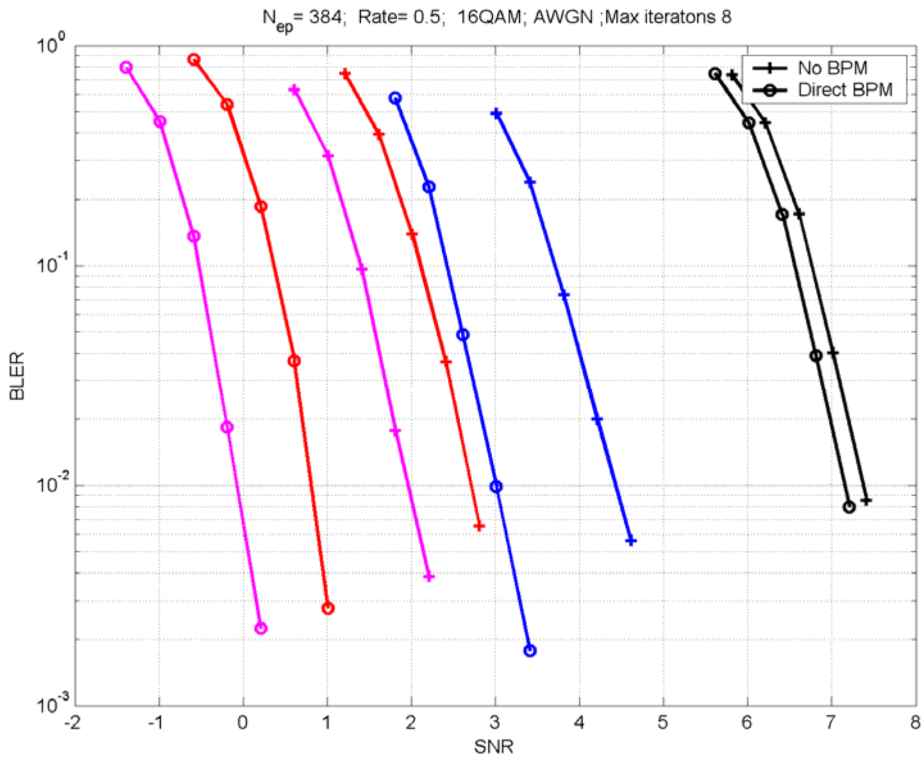

(a)No BPM (b) Direct BPM

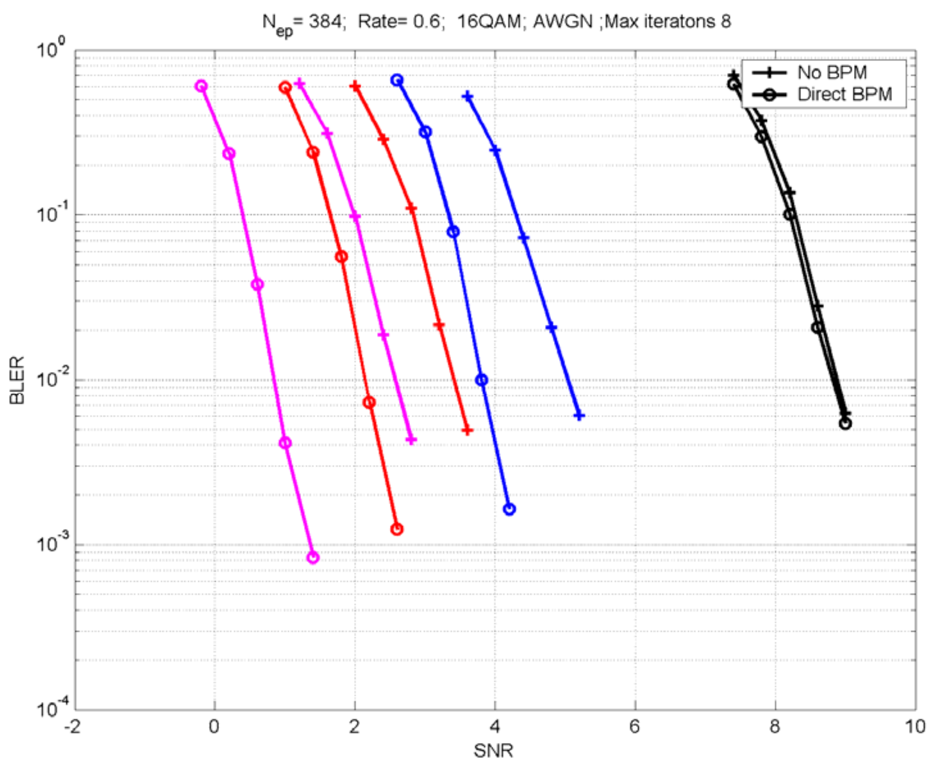
Figure 6 No BPM and Direct BPM for 16QAM

## 5. Simulation results

This part evaluates the error rate performance for No BPM and Direct BPM. Synchronous HARQ is evaluated here. The simulations assume $SPID_k$=0,1,2,3 for $k$=0,1,2,3. The symbol lengths per transmission are $2N_{EP}$, $5/3N_{EP}$, $4/3N_{EP}$ and $6/5N_{EP}$, where respectively the code rates per transmission are 1/2, 3/5 3/4 and 5/6. $N_{EP}$=384 are considered. The simulation environment is AWGN channel, Max-Log-MAP algorithm with maximum 8 iterations with early stopping.

Noted that, the black, blue, red and purple lines have shown the BLER-SNR performance of the first, second, third and fourth transmission respectively.


$N_{ep}$= 384; Rate= 0.5; 16QAM; AWGN ;Max iteratons 8
No BPM
Direct BPM
BLER
SNR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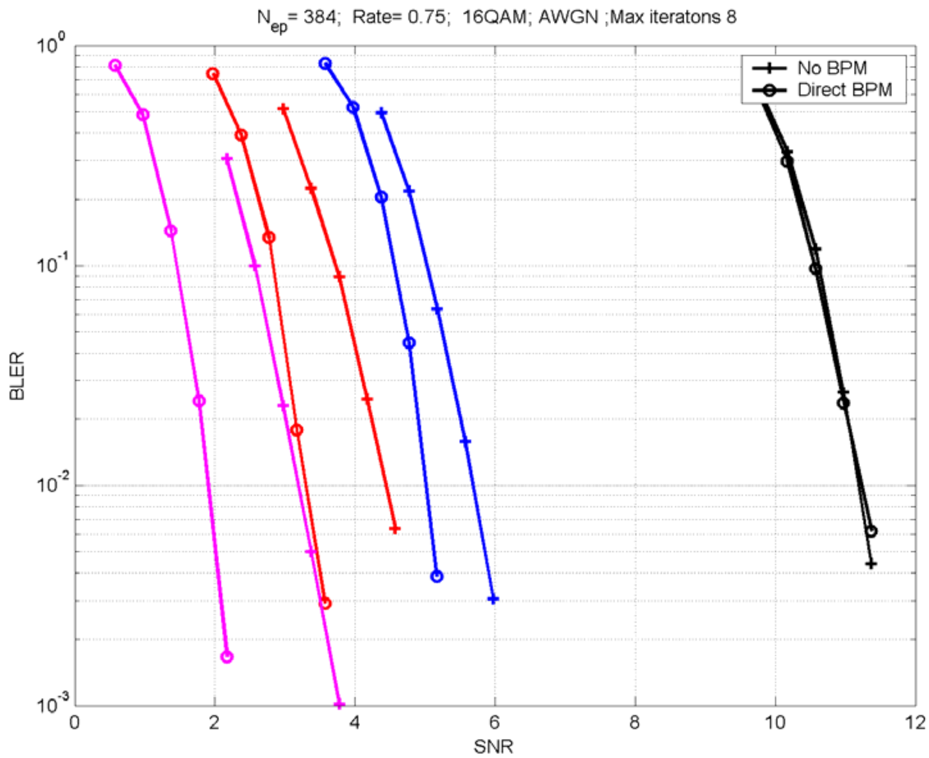
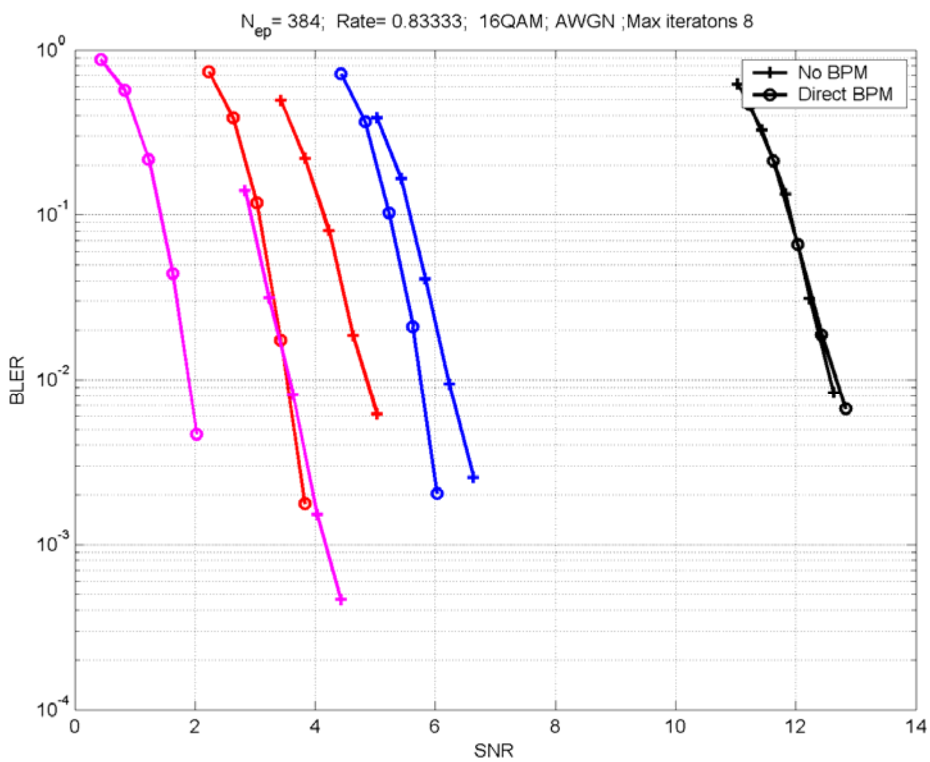
No BPM
Direct BPM
BLER
SNR


N_ep= 384; Rate= 0.75; 16QAM; AWGN ;Max iteratons 8
No BPM
Direct BPM
BLER
SNR
10^0
10^-1
10^-2
10^-3
0
2
4
6
8
10
12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Direct BPM
BLER
SNR
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10^-1
10^-2
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10^-4
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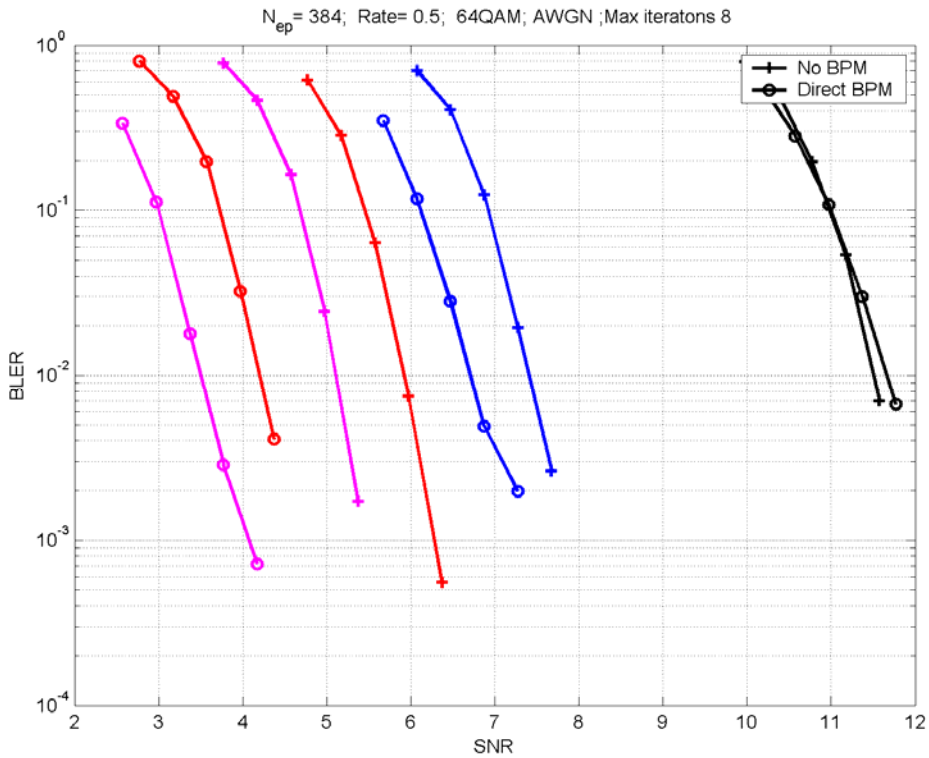
2
4
6
8
10
12
14


N_ep= 384; Rate= 0.5; 64QAM; AWGN ;Max iteratons 8
No BPM
Direct BPM
BLER
SNR
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10^-1
10^-2
10^-3
10^-4
2
3
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5
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9
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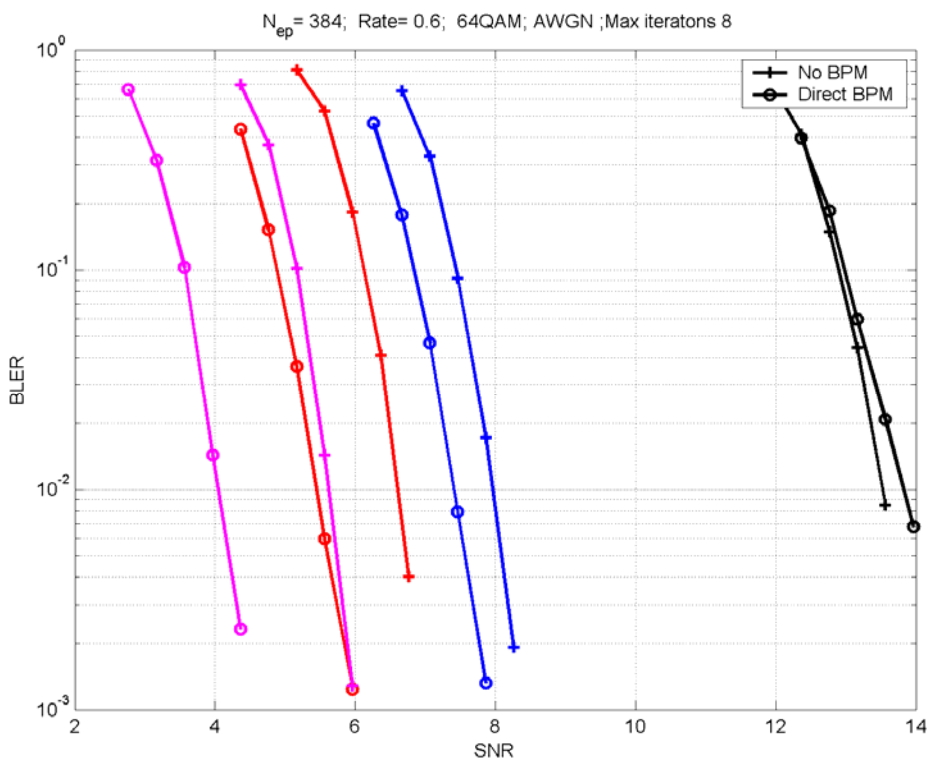
11
12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Direct BPM
BLER
SNR
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10^-3
2
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8
10
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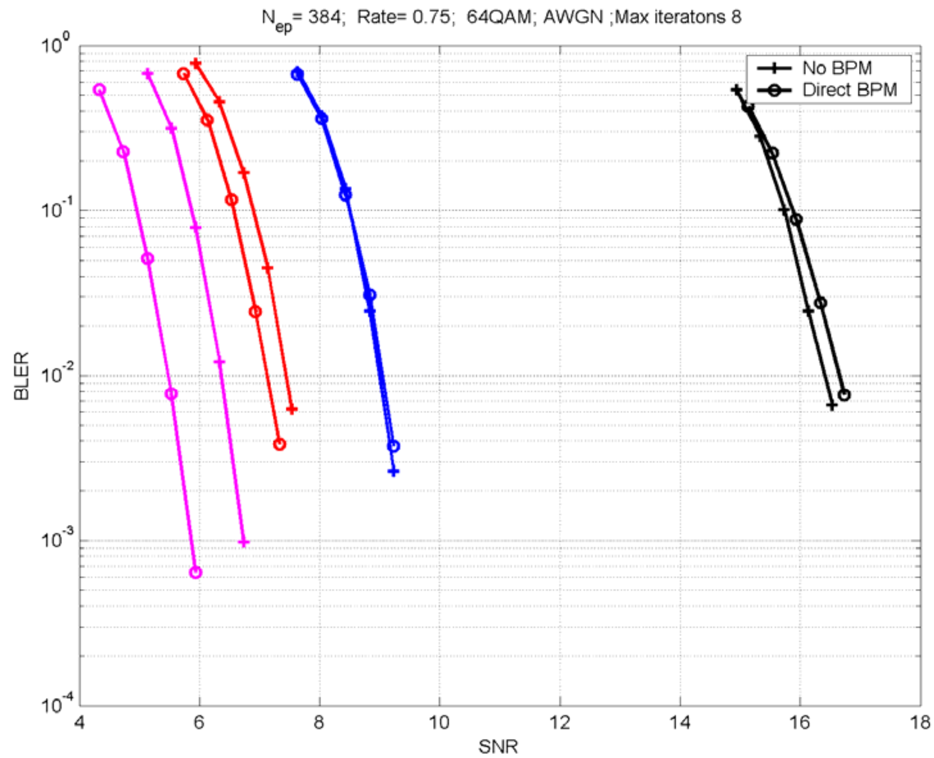
14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No BPM
Direct BPM
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10^-4
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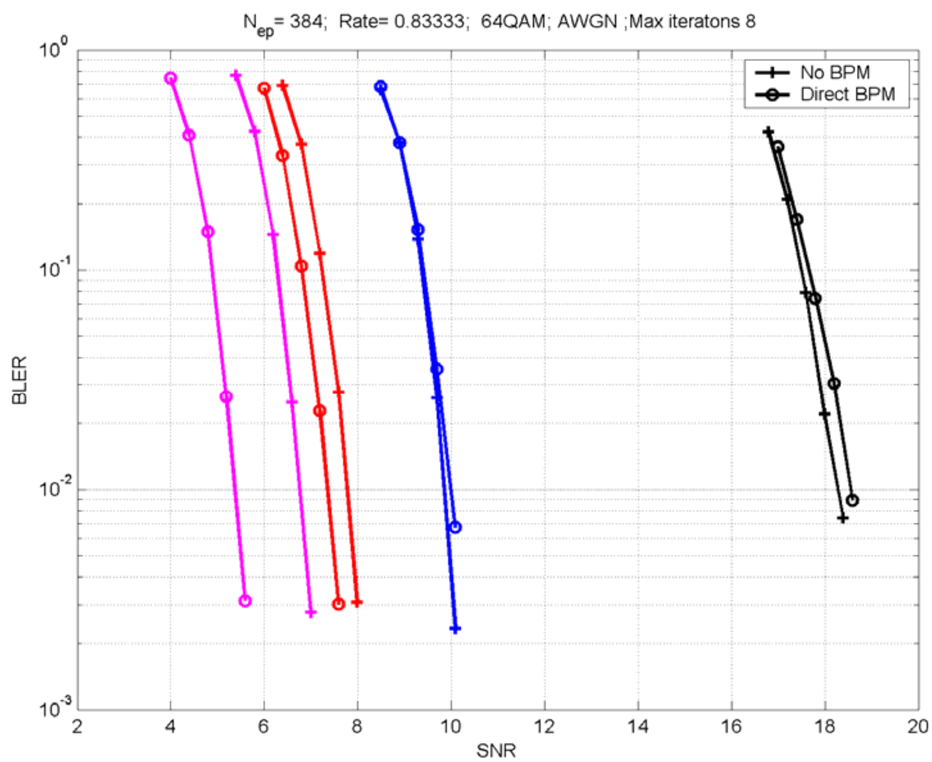
16
18


N_ep= 384;  Rate= 0.83333;  64QAM; AWGN ;Max iteratons 8
No BPM
Direct BPM
BLER
SNR
10^0
10^-1
10^-2
10^-3
2
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16
18
20

## 6. Conclusion

From careful analysis and wide range simulation, we found that Direct BPM could improve the performance of retransmission and its implementation is very simple. So we propose Direct BPM should be considered by CTC IR HARQ.

## 7. Proposed Text for SDD

**----------------------------*Begin Proposed Text* -------------------------------------------------------------------**

11.x.x CTC IR HARQ

Bit Priority Mapping scheme should be studied and considered for CTC IR HARQ.

**--------------------------*End of Text Proposal* ------------------------------------------------------------------**

## References

[1] P80216Rev2_D5, "Part 16: Air interface for fixed broadband wireless access systems," June, 2008.