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Title	**Modifying CTC symbol selection method to enhance CTC IR H-ARQ performance**
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Re:	IEEE 802.16m-07/040 - Responds to Call for Contributions on Project 802.16m System Description Document (SDD)
Abstract	Modifying CTC symbol selection method enhances CTC H-ARQ IR error rate performance. IR is one of the H-ARQ retransmission mechanisms. This mechanism retransmits pre-defined coded symbols by the symbol selection method. However the symbol selection method limits the types of the symbol selection. This contribution introduces a simple modification method on the symbol selection to increase more versions of selected symbols and enhance the associated performance.
Purpose	For 802.16m discussion and adoption
Notice	
Release	
Patent Policy	

Modifying CTC symbol selection method to enhance CTC IR H-ARQ performance

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1. Summary

This contribution introduces a modified symbol selection method of the CTC IR H-ARQ. This new method provides more versions of selected symbols that improves error rate performance and our simulation results show the enhanced performance. This contribution is a text proposal of adopting a method of CTC symbol selection in the IEEE 802.16m SDD.

Proposed Text

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

x.x.x CTC symbol selection

<Notes: Revisit the equation 174 in IEEE P802.16 section 8.4.9.2.3.4.4. Symbol Selection. Hereof to propose a modified equation; it changes the order of subpacket sequence of re-transmission symbol selection method>

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

2. Introduction

This contribution introduces a modified symbol selection method of the CTC IR H-ARQ. This new method provides more versions of selected symbols that improves error rate performance and our simulation results show the enhanced performance. This contribution is a text proposal of adopting a method of CTC symbol selection in the IEEE 802.16m SDD.

3. Double binary turbo code encoder and subpackage generation method

IEEE 802.16 CTC [1] applies double binary circular recursive systematic convolutional code and Fig. 1 shows the

CTC encoder. The input symbol of this code is composed of a bit pair (A_i, B_i), where A_i and B_i are the ith bits of the input sequences A and B. The output are A, B ,Y_1 ,Y_2 ,W_1 ,W_2.Y_1 and W_1 correspond to the input sequences A and B; Y_2 and W_2 correspond to the permuted input sequences A and B.

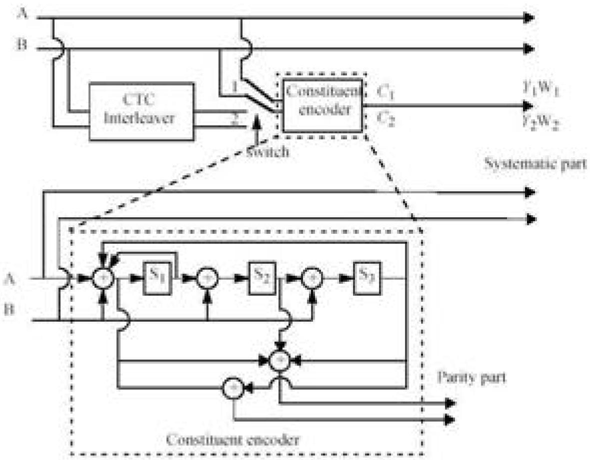


Fig. 1: Double binary turbo code.

Fig. 2 plots subpacket generation method. This method generates code sequence by the CTC encoder. Then the channel interleaver permutes the generated code sequence. After interleaving, the puncturing block selects the associated selected symbols. Fig. 3 shows the channel interleaving. This 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.

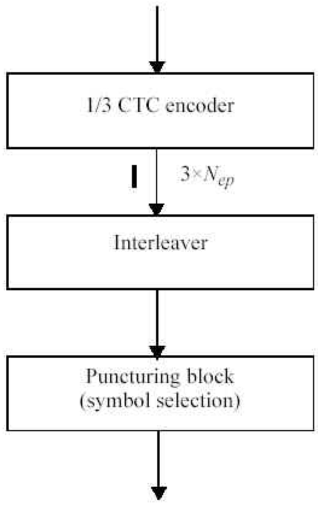


Fig. 2: Subpacket generation method.

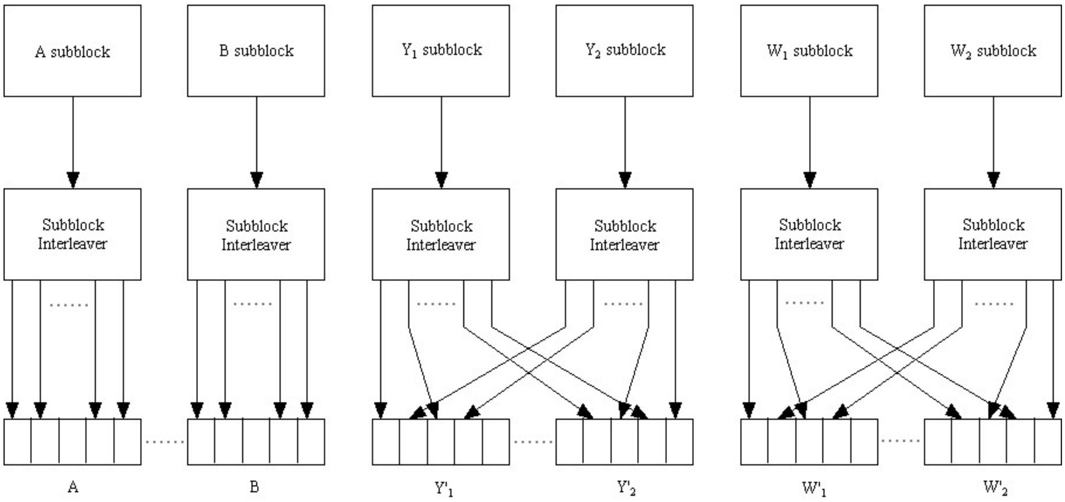


Fig. 3: Channel interleaver.

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

k	be the subpacket index when HARQ is enabled. $k = 0$ for the first transmission and increases by one for the next subpacket. $k = 0$ when 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 560 for the non-HARQ CTC scheme defined in 8.4.9.2.3.1 and be the same as the *Nsch* 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, $\text{SPID}_{k=0} = 0$).

Table 2: The symbol selection in IEEE 802.16 8.4.9.2.3.4.4 [1].

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

4. Modification on the symbol selection method and symbol grouping

Table 2 shows the modified symbol selection method. This method shifts the selected symbol by X if complete codeword is selected, i.e. $S_{k,j} = (F_k + i + X) \bmod (3N_{EP}),\ F_k + i \geq 3N_{EP}$. In general $X=N_{EP}$. We also can set $X=0.5N_{EP}$ or $1.5N_{EP}$. When $X=N_{EP}$, this method firstly selects parity bits to enhance the distance property if a complete codeword is selected. Our simulation will show the error rate performance.

Table 2: The modified symbol selection method.

$S_{k,i} = \begin{cases} (F_k + i)\bmod(3N_{EP}) & F_k + i < 3\cdot N_{EP} \\ (F_k + i + X)\bmod(3N_{EP}) & F_k + i \ge 3\cdot N_{EP} \end{cases}$, where
$i = 1,2,...,L_k - 1$
$L_k = 48\cdot N_{SCHk}\cdot m_k$
$F_k = (SPID_k \cdot L_k)\bmod(3\cdot N_{EP})$

This method provides more flexibility comparing with IEEE 802.16 symbol selection method. If we consider the case L_k=1.5 N_{EP}, IEEE 802.16 symbol selection method only provides two kinds of versions of selected symbols but our method with $X=N_{EP}$ can provide four kinds of versions of selection symbols. Our method give transmitter more degree of freedom in selecting retransmission symbols.

New channel interleaver is introduced for the case $X<N_{EP}$. We further inter-block permute subblock interleaved sequences A and B where this inter-block permutation is the same as the inter-block permutation for subblock interleaved sequences Y_1 and Y_2. This extra inter-block permutation prevent that only partial symbols of sequence B are selected for H-ARQ retransmission.

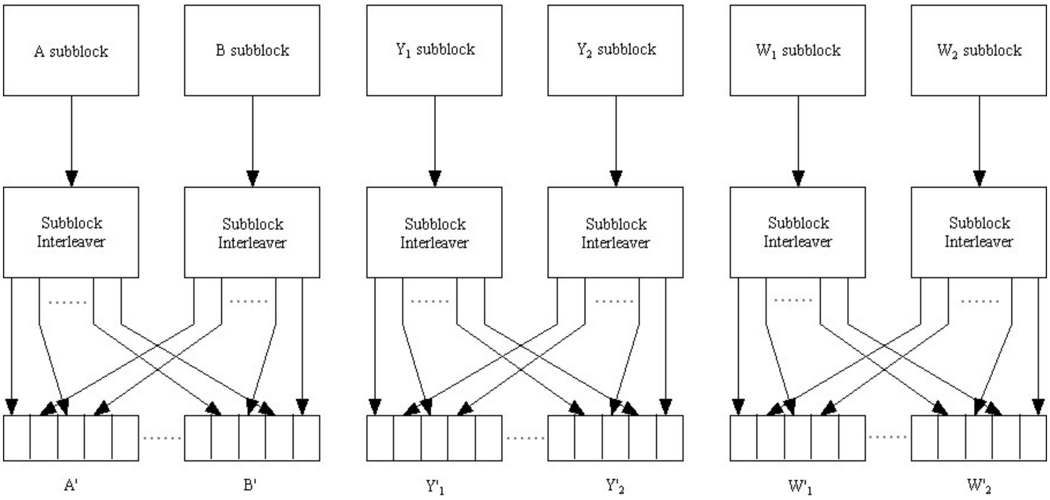


Fig. 4: Modified channel interleaver.

5. Simulation results

This part evaluates the error rate performance for both symbol selection methods. Denote by IR1 and IR2 the IEEE 802.16 [1] symbol selection method and our symbol selection method. We assume $SPID_k$=0,1,2,3 for k=0,1,2,3. The compared symbol lengths per transmission are $2N_{EP}$, $1.5N_{EP}$ and $1.2N_{EP}$, where the code rates for the first transmission are 1/2, 2/3 and 5/6. N_{EP}=480 and 2400 symbols which are equivalent to 960 and 4800 information bits are considered. We simulate the error rate performance of the 1st 2nd, for the cases $2N_{EP}$, $1.5N_{EP}$, respectively, and 2nd and 3rd retransmission for the cases $1.2N_{EP}$. The H-ARQ IR mechanism chooses the selected symbols corresponding to the kth transmission according to $SPID_k$. The simulation environment is AWGN channel. Log-MAP algorithm with 8 iterations is performed in our simulation.

Table 3: Simulation parameters.

Symbol length per transmission	Number of transmission	Mode	Equivalent rate
$2N_{EP}$	2	IR1	1/4
		IR2	1/4
$1.5N_{EP}$	3	IR1	2/9
		IR2	2/9
$1.2N_{EP}$	3	IR1	5/18
		IR2	5/18
	4	IR1	5/24
		IR2	5/24

Fig. 5-12 shows the error rate performance. Blue curve denotes IEEE 802.16 symbol selection method and red cure denotes the new symbol selection method. Obviously, that new symbol selection method provides 0.2-0.3 performance gain to the IEEE 802.16 symbol selection method at frame error rate=10^{-4}.

Fig. 5: $N_{EP}=480$ with two transmissions whose length is $2\,N_{EP}$.

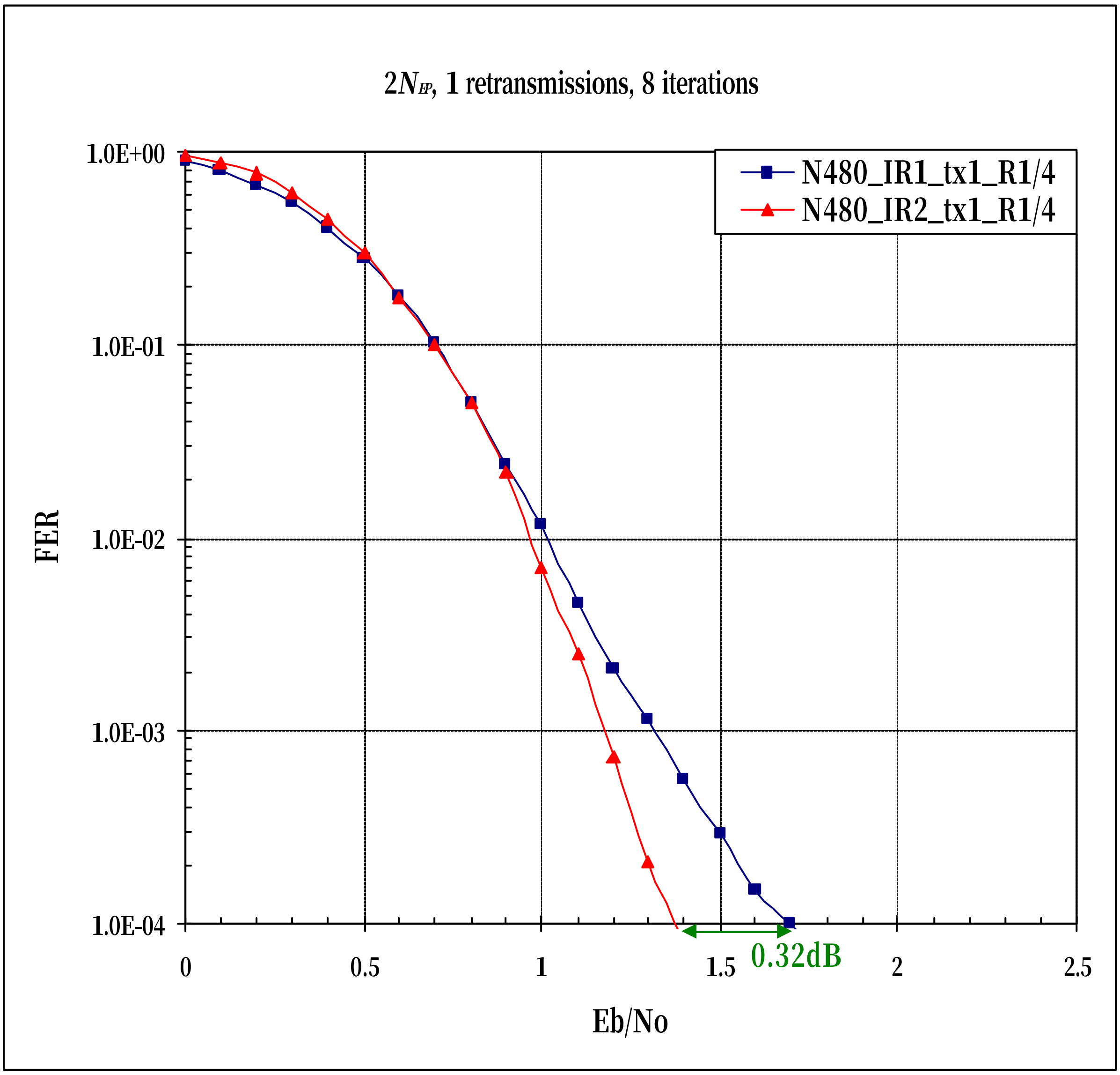


Fig. 6: N_{EP}=2400 with two transmissions whose length is 2 N_{EP}.

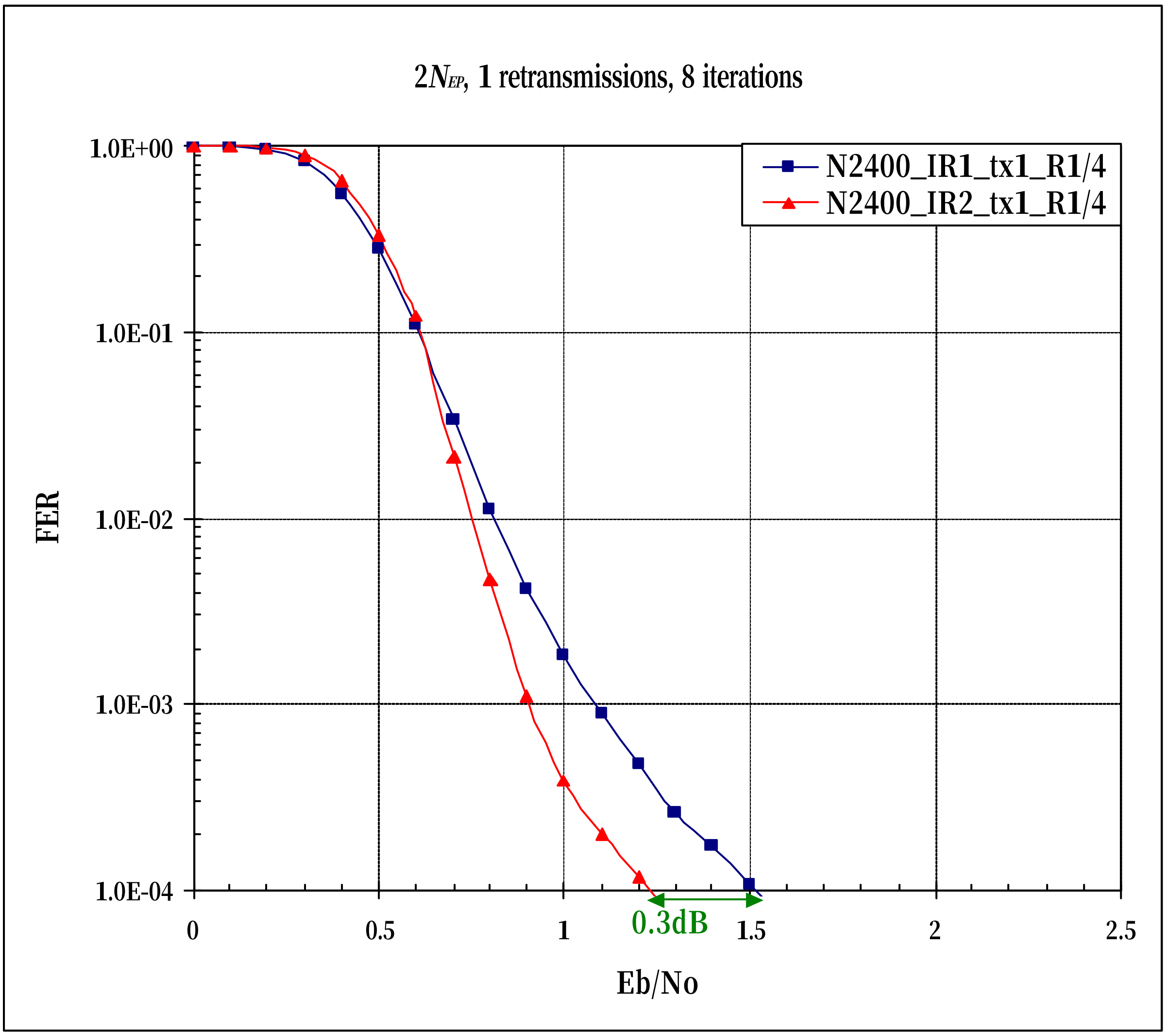


Fig. 7: N_{EP}=480 with three transmissions whose length is 1.5 N_{EP}.

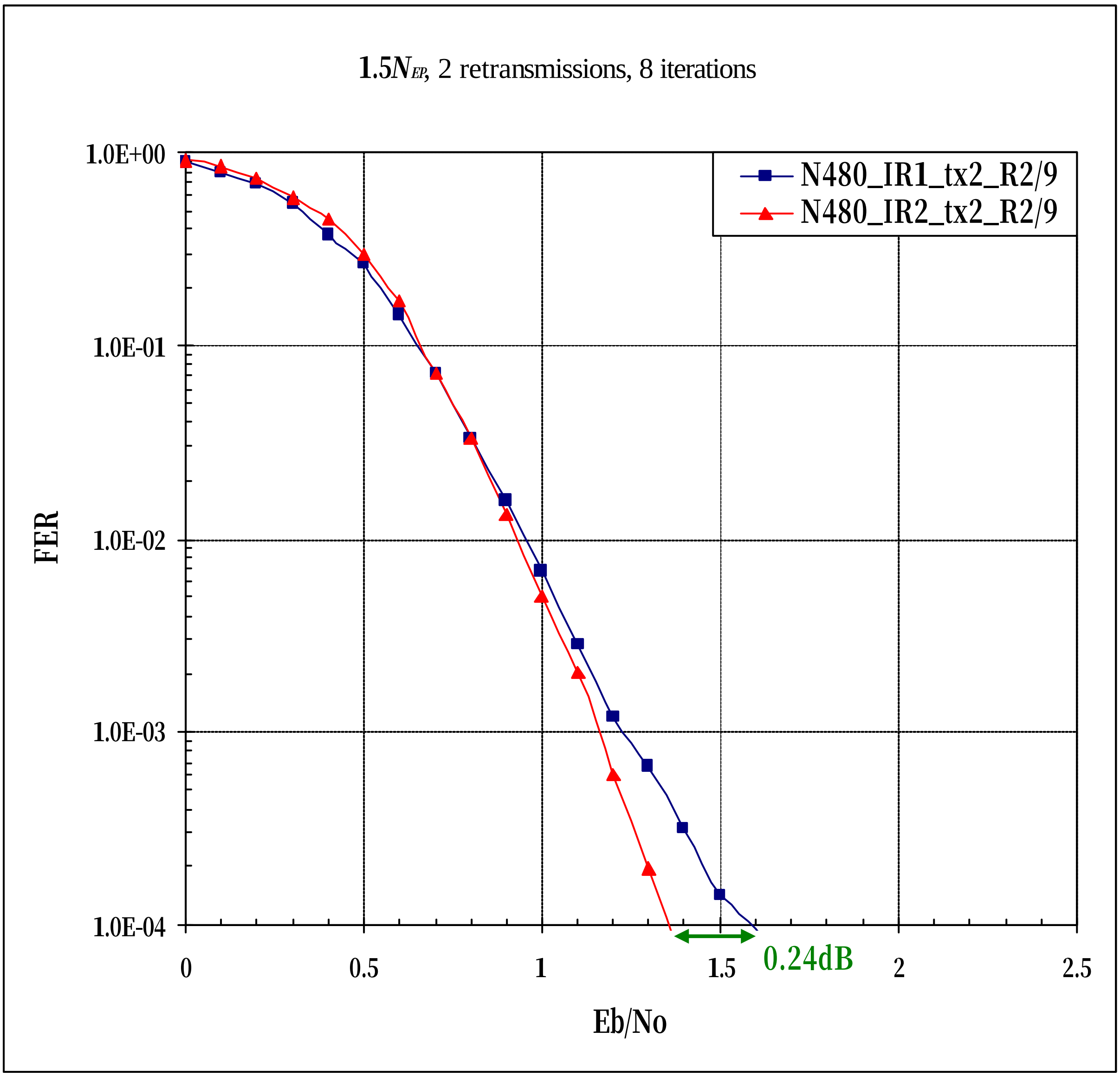


Fig. 8: N_{EP}=2400 with three transmissions whose length is 1.5 N_{EP}.

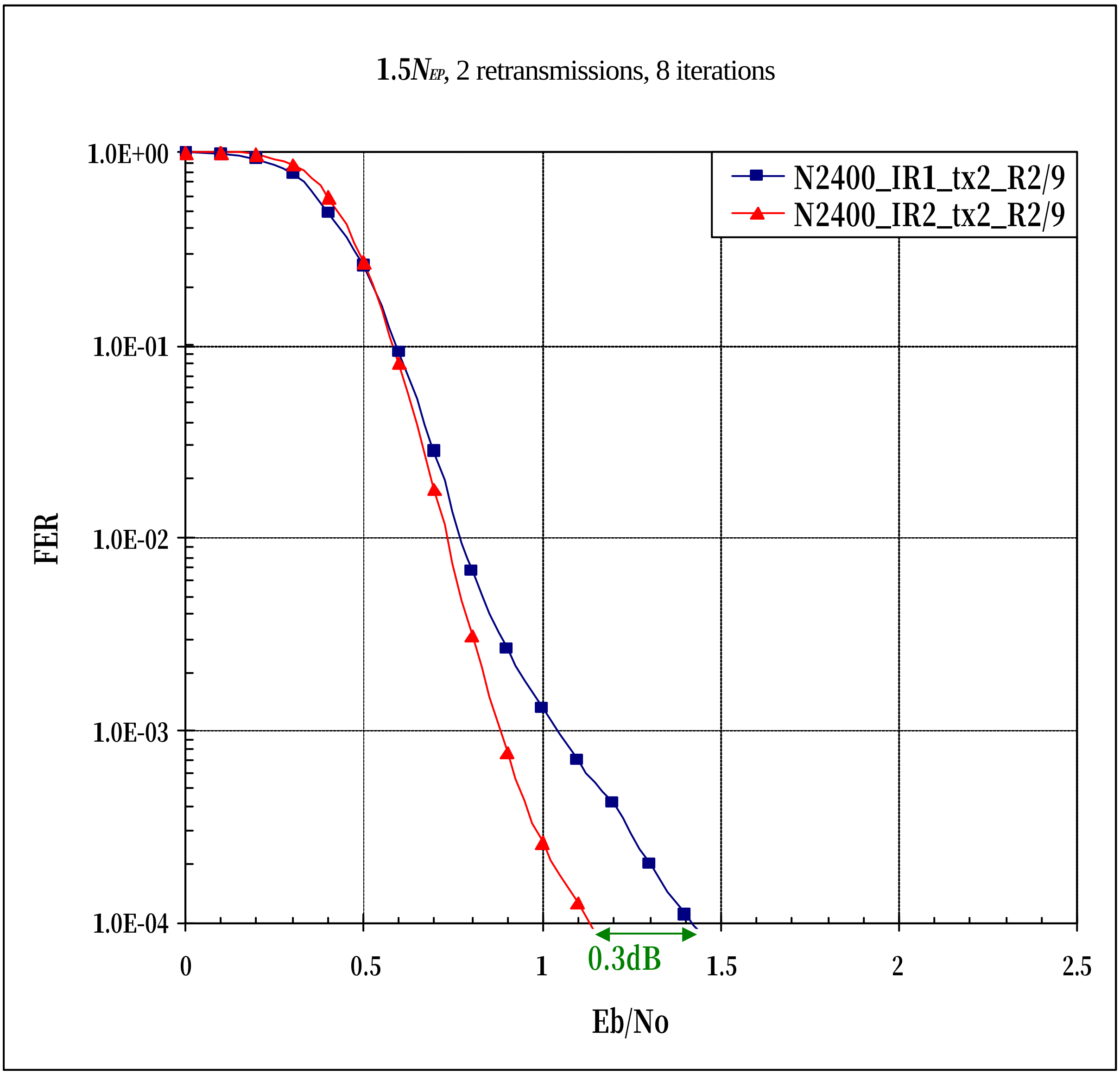


Fig. 9: $N_{EP}=480$ with three transmissions whose length is 1.2 N_{EP}.

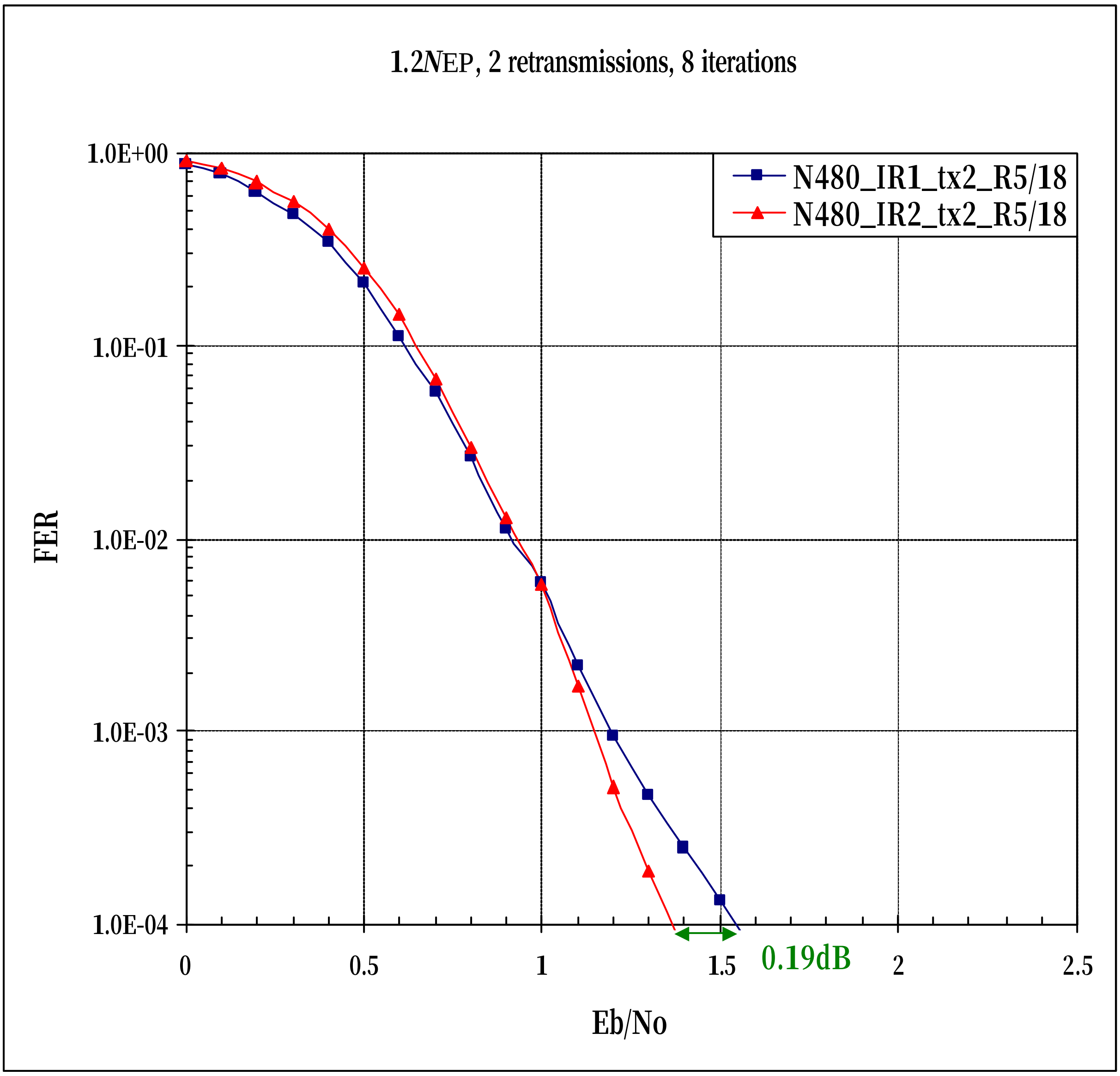


Fig. 10: $N_{EP}=2400$ with three transmissions whose length is 1.2 N_{EP}.

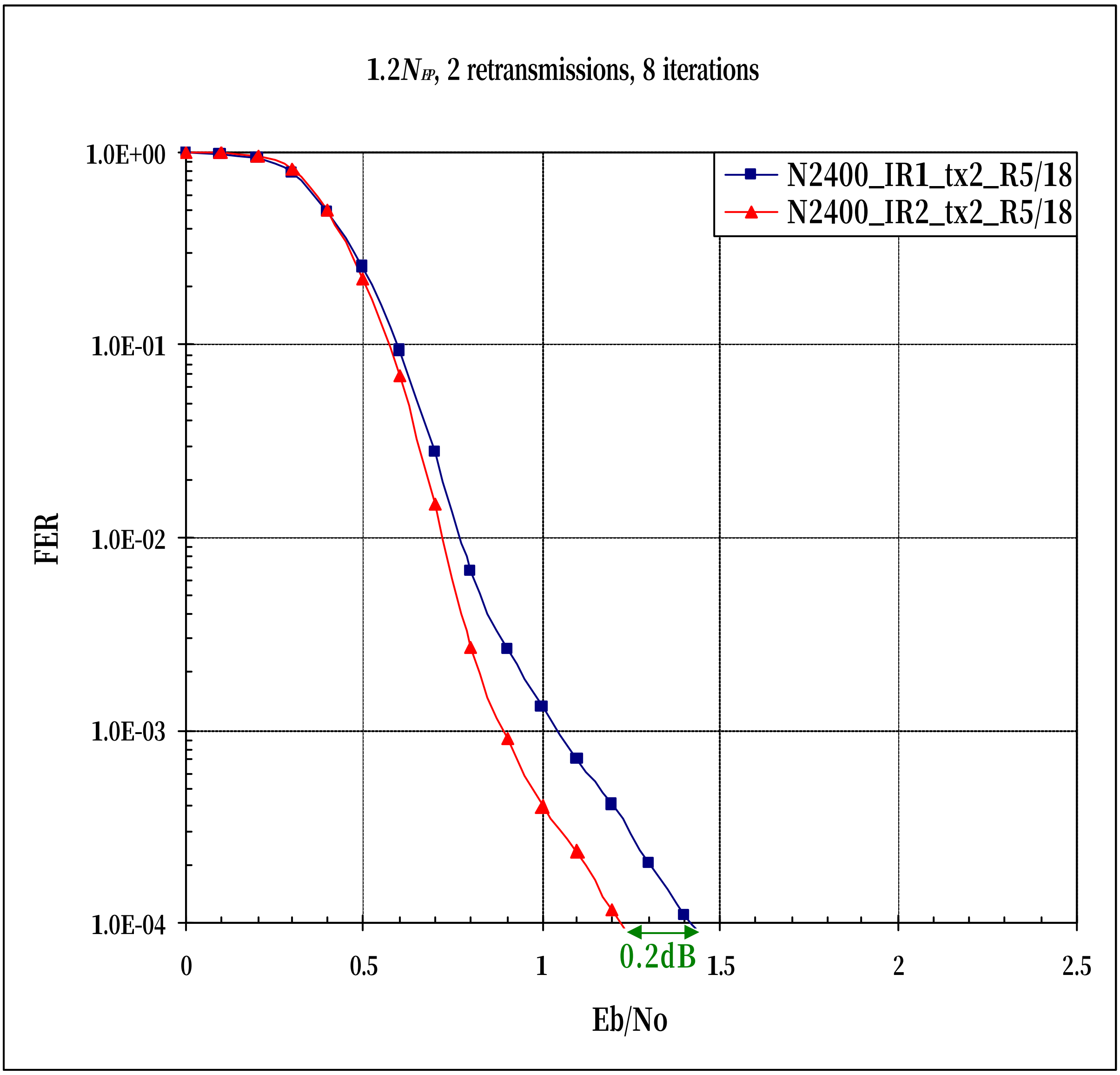


Fig. 11: N_{EP}=480 with four transmissions whose length is 1.2 N_{EP}.

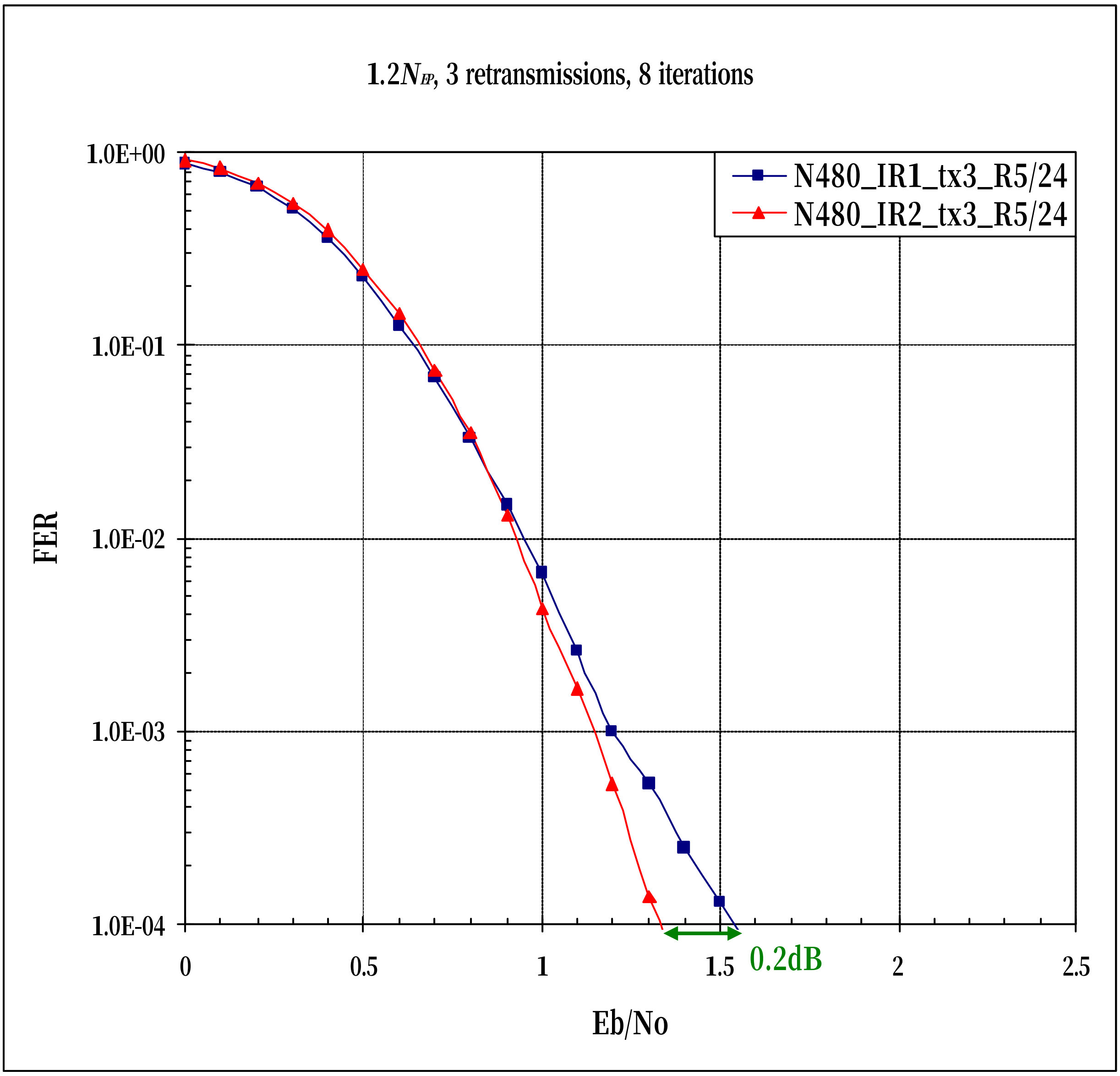
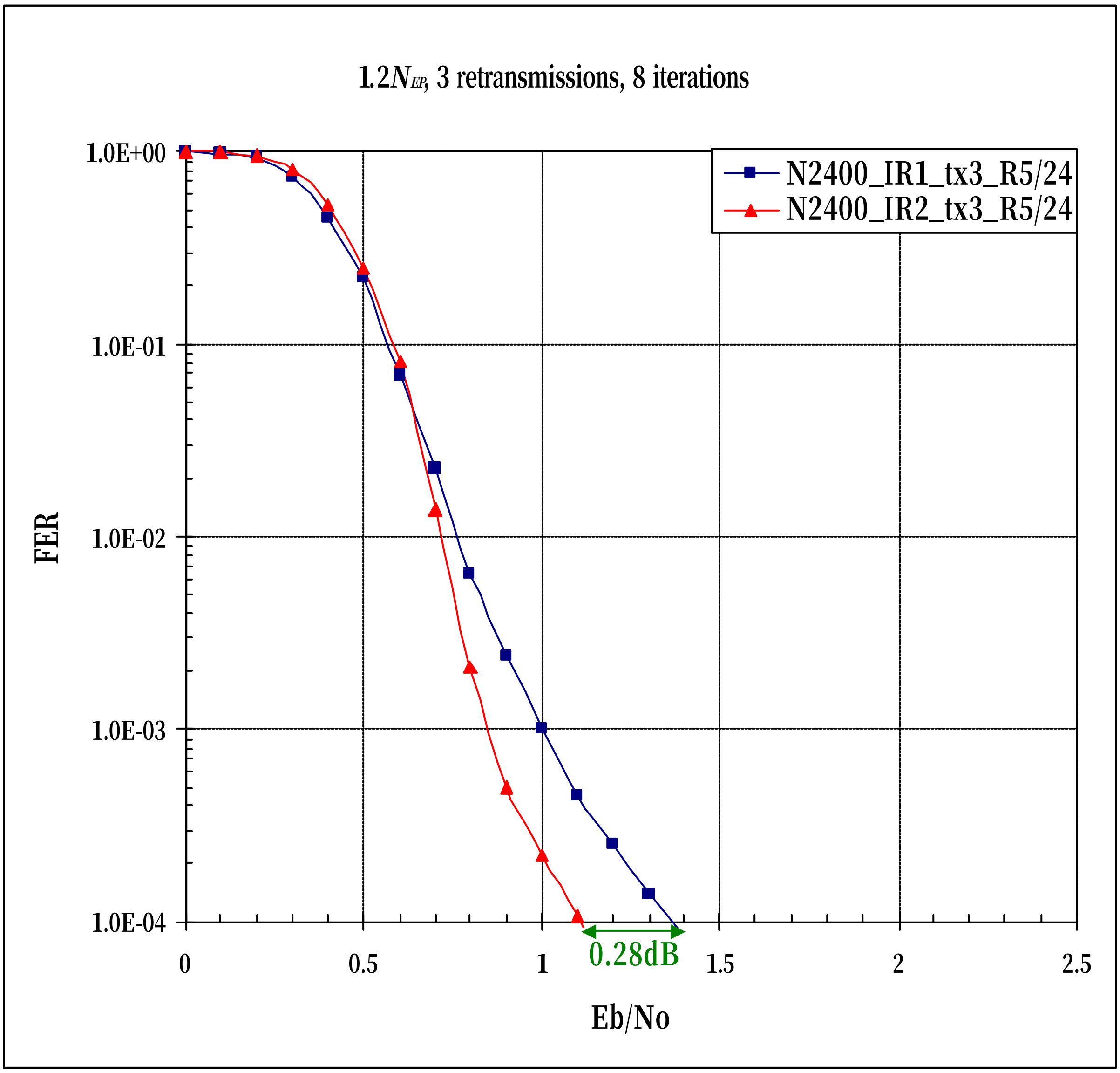


Fig. 12: $N_{EP}=2400$ with four transmissions whose length is 1.2 N_{EP}.



6. Conclusions

This contribution provides new symbol selection method to enhance error rate performance. The modification is simple and mild. The performance gain is attractive. This new method also provides more flexibility in choosing retransmission symbols.

7. Table of contents

Channel coding

Encoding

Convolutional turbo codes (CTCs)

Subpacket generation

Symbol separation

Sybblock interleaving

Symbol grouping

Symbol selection

References

[1] IEEE DRAFT P802.16, "Part 16: Air interface for fixed broadband wireless access systems," March, 2007.