

Source: Ericsson  
Title: Convolutional Coding Rate Matching Based on Circular Buffers  
Agenda Item: 5.5 Channel Coding  
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## 1. Introduction

In RAN1#48bis Malta, tail-biting convolutional coding with constraint length  $K=7$  [1] was adopted as a working assumption for LTE DL control channel while allowing further review of performance improvement techniques. It is proposed in [2] to adopt a rate 1/3 optimal distance spectrum (ODS) convolutional code with polynomials given by [133, 171, 165] (in octal form) [3]. It was pointed out this new set polynomials allows two areas of performance improvement. First, the code itself has been shown to achieve better performance because of its superior distance spectrum. Secondly, the rate 1/2 ODS code (defined by [133, 171]) happens to be nested within the rate 1/3 code. It thus allows a nested puncturing strategy with improved performance. Namely, when puncturing is needed, coded bits produced by the polynomial [165] can be removed first while those from the polynomial [133] are always retained.

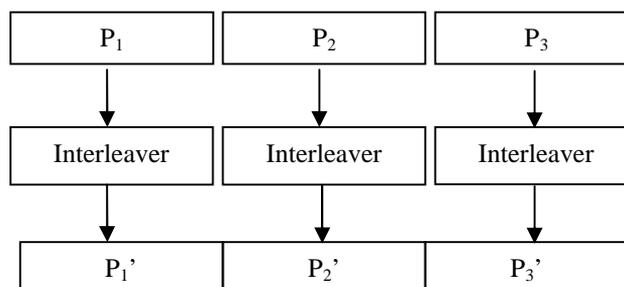
For simplicity of the LTE specifications and readiness of future extensions, a simple generic puncturing method for convolutional coding is preferred. In this paper, we propose a nested puncturing structure similar to that recently agreed for turbo coding [4].

## 2. Circular Buffer Based Rate Matching for Convolutional Coding

The intuitive advantage of nested puncturing discussed in [2] is rigorously justified by the exhaustive puncturing pattern search results reported in [5, 6]. More specifically, the optimal period-2 puncturing patterns are listed in Table 1. According to the optimal puncturing patterns, it can be seen coded bits from [165] indeed should be discarded first and coded bits from [133] should always be transmitted. This puncturing strategy can be easily implemented with a circular buffer rate matching (CBRM) structure with block-level multiplexing of the three coded bit streams. That is, unlike conventional CBRM designs where bits from different parity streams are multiplexed on the bit level, the nested puncturing approach requires separation of the bit streams. As illustrated in Figure 1, with block-level multiplexing, the coded bits from [133] will be read out before those from [171] and, similarly, coded bits from [165] will not read out unless all those from [133] and [171] are selected.

**Table 1 Optimal puncturing patterns for [133, 171, 165] convolutional code reported in [5, 6].**

rate	2/6	2/5	2/4	2/3
Puncturing Pattern	$\begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 0 & 0 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$
$d_f$	15	11	10	6



**Figure 1 Block-level multiplexing for nested puncturing.**

Odd-indexed $P_1'$	Even-indexed $P_1'$	Odd-indexed $P_2'$	Even-indexed $P_2'$	Odd-indexed $P_3'$	Even-indexed $P_3'$
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**Figure 2 Further details on the buffer composition.**

In fact, the optimal puncturing patterns in Table I point to a further level of optimization. Namely, the even-index bits from [171] and [165] are less important than the odd-index bits from the same polynomials. This optimization can be easily implemented by ensuring that the sub-block interleavers place odd-indexed addresses in the front. This is illustrated in Figure 2.

To simplify the specifications, it is proposed to use similar rectangular sub-block interleavers as those for turbo code rate matching [3]. For instance, it is possible to use the  $R \times 32$  rectangular interleaver with the column permutation cyclically shifted to its middle:

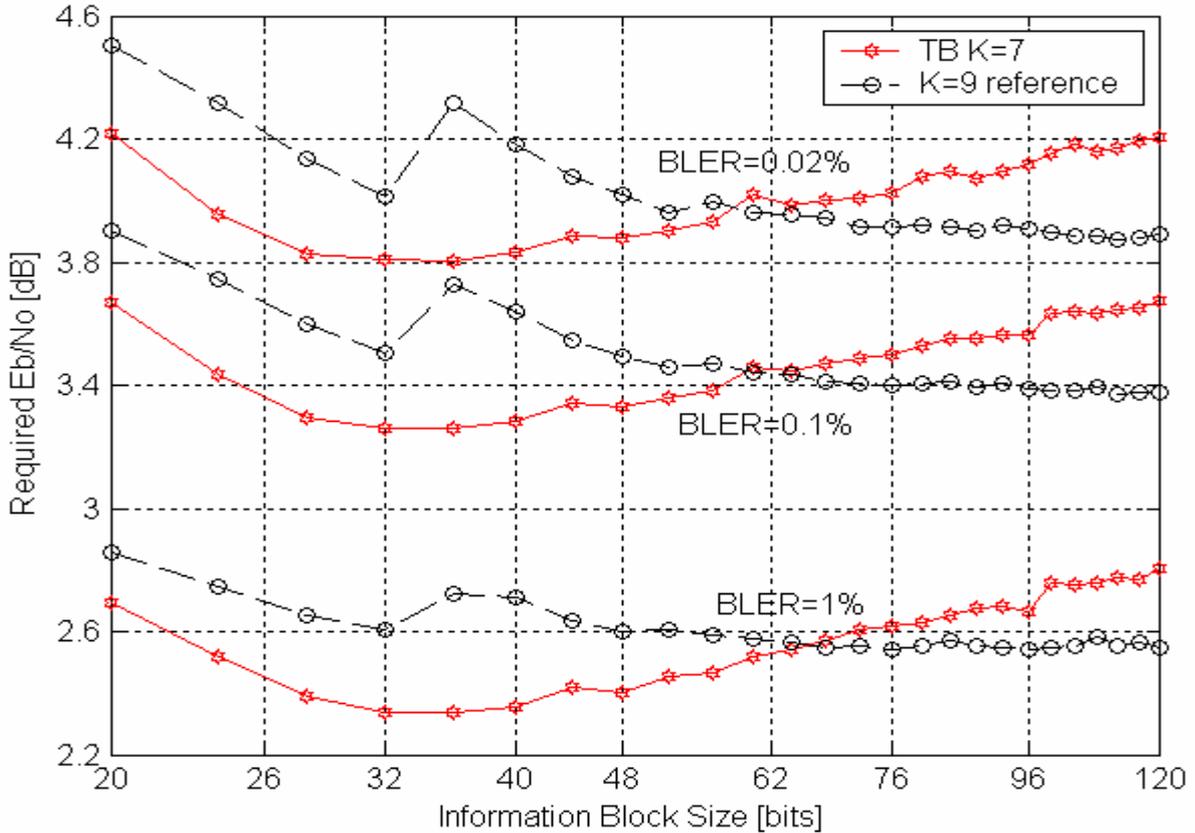
$$\text{ColPermCC} = [1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31, 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30]. \quad (1)$$

(As pointed out in [7], an equivalent approach of ensuring odd addresses in the front is to add an offset of  $\delta=1$  to all the interleaving addresses. We found identical performance based on either adjustment to the column permutation.)

### 3. Performance Analysis

We investigate performance benefits of using the proposed CBMR algorithm with the  $K=7$  tail-biting code with polynomials [133, 171, 165]. It is assumed QPSK modulation is used over the AWGN channel. Performance of the tailed  $K=9$  codes (defined by [557, 663, 711] and [561, 753]) with uniform puncturing is included as reference. The adaptive two-pass Viterbi decoding algorithm [2, 8] is used for the tail-biting code and conventional Viterbi decoding algorithm is used the tailed codes.

The performance results for block sizes  $K = 20, 24, \dots, 120$  and code rate  $r = 0.4, 0.5, 0.6,$  and  $0.7$  are presented in Figures 3—6. The proposed CBMR approach achieves similar performance as those *ad hoc* patterns employed in [2]. When compared to the reference cases, performance of the new convolutional coding scheme is quite beneficial for cases of interest.



**Figure 3 Performance for  $r=0.4$  coding with different block sizes and operating BLER targets.**

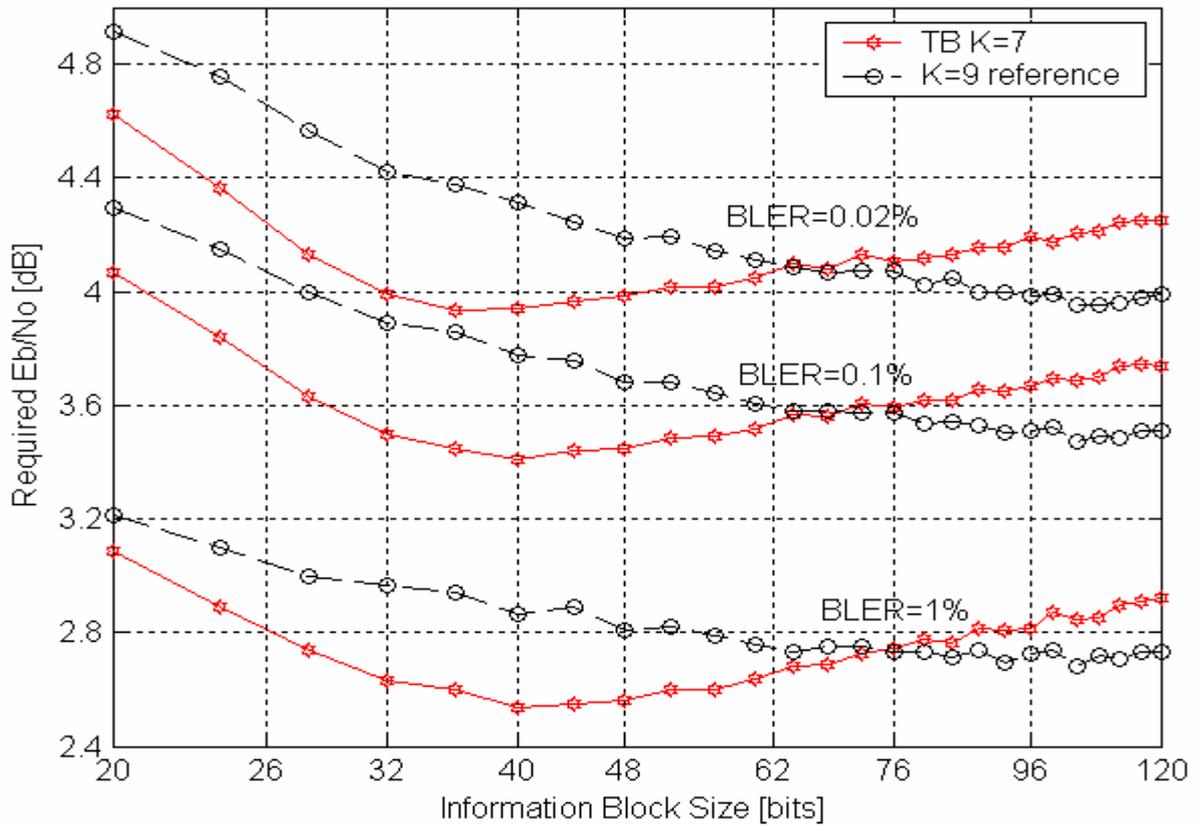


Figure 4 Performance for  $r=0.5$  coding with different block sizes and operating BLER targets.

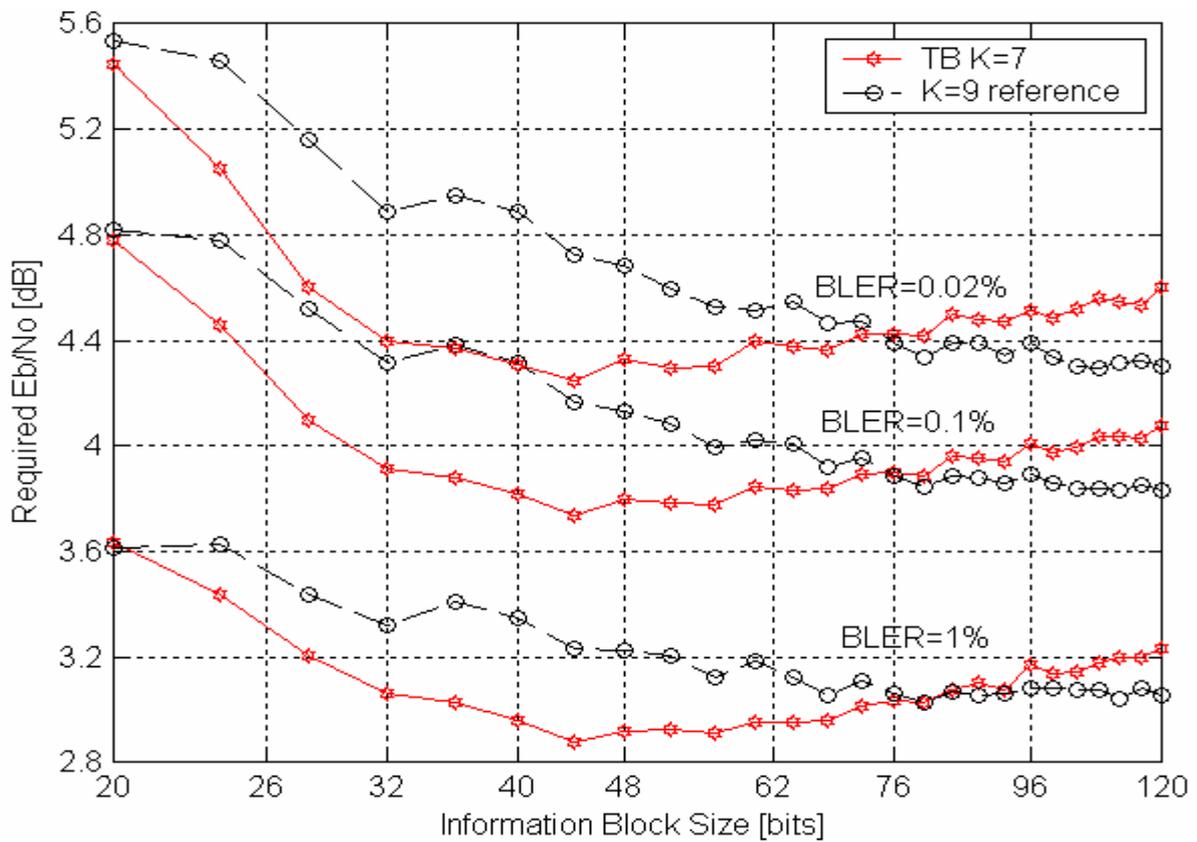


Figure 5 Performance for  $r=0.6$  coding with different block sizes and operating BLER targets.

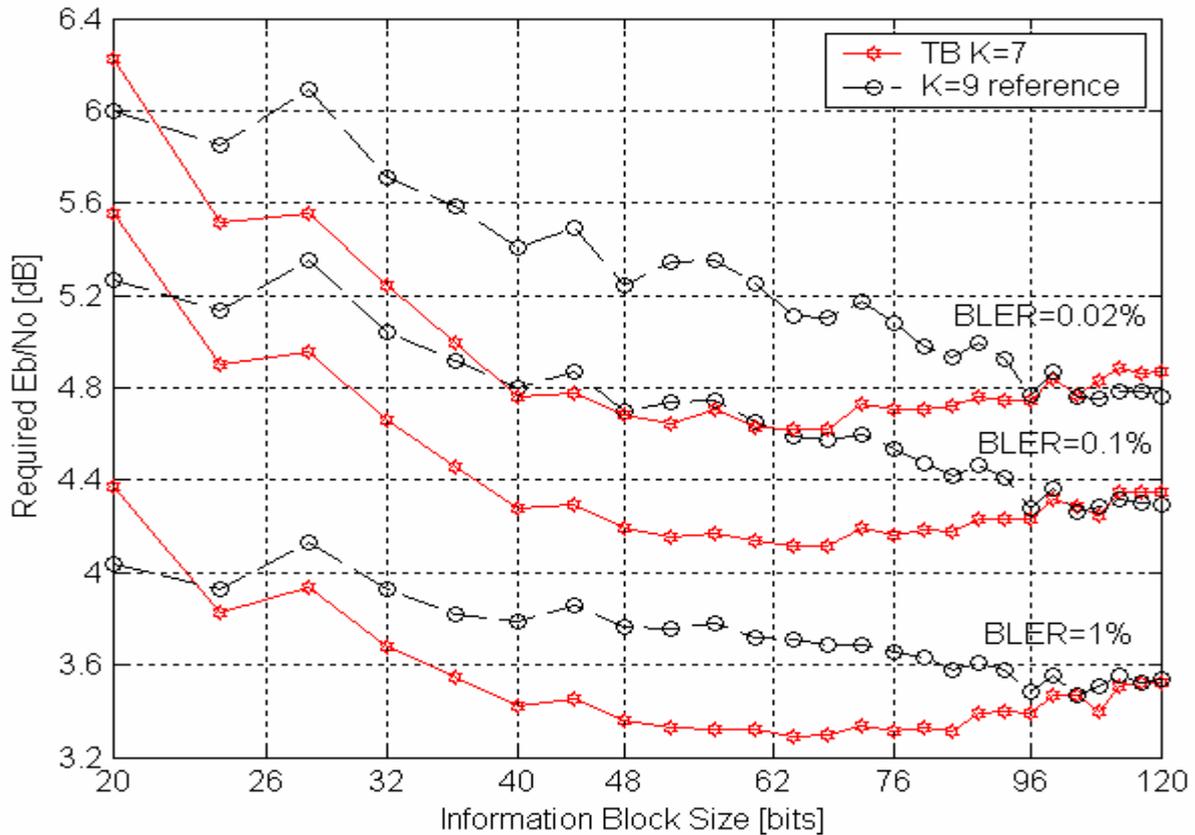


Figure 6 Performance for  $r=0.7$  coding with different block sizes and operating BLER targets.

## 4. Conclusion

An optimized rate matching algorithm for convolutional coding is proposed based on block-multiplexed circular buffers. Based on the complexity and performance advantages, it is proposed to adopt it for LTE.

## 5. References

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