

**Source:** Ericsson  
**Title:** Performance of Improve Circular Buffer Rate Matching Design  
**Agenda Item:** 5.5 Channel Coding  
**Document for:** Discussion

## 1. Introduction

It has been agreed in RAN1#49 Kobe to adopt a rate matching algorithm for LTE based on circular buffer designs [1—5]. To further improve the performance of the circular buffer rate matching (CBRM) algorithms, a new CBRM( $\sigma=4, \delta=4$ ) design was proposed in [6] based on avoiding catastrophic puncturing patterns [7]. The analysis shows the new CBRM algorithm avoids catastrophic puncturing at high coding rates and is capable of producing codewords of potentially higher Hamming weights over a wide range of code rates. Extensive simulation results presented in the paper support these claims on performance improvements.

## 2. Performance Analysis

We tested the performance of the rate matching algorithms based on the parameters listed in Table I. In addition to the performance results at very high coding rates analyzed in [6], we focus on the results for coding rates ranging from 0.4 to 0.8 in this paper. Since a resource block carries no more than 144 QPSK modulation symbols, the information block sizes  $K$  for a coding rate  $r$  are limited to those QPP interleaver sizes no smaller than  $288 \times r$ .

The performance for code rate 0.8 is compared in Figure 1. For the CBRM( $\sigma=2, \delta=1$ ) algorithm, 17 SNR spikes of 0.1 dB or greater can be observed (at  $K=376, 2176, 264, 2016, 896, 424, 6144, 392, 928, 504, 1056, 280, 1008, 2112, 784, 448, 1792$ ). One of the spikes ( $K=1792$ ) is greater than 1 dB and three of these ( $K=2112, 784, 448, 1792$ ) are greater than 0.5 dB. For the CBRM( $\sigma=4, \delta=4$ ) algorithm, all these spikes except  $K=392$  are removed. One small spike of 0.2 dB at  $K=1440$  can be also observed. Other than these specific block sizes, the two CBRM algorithms perform similarly.

The performance for code rates 0.7 and 0.6 is compared in Figure 2 and Figure 3, respectively. While there are SNR spikes of at least 0.1 dB at  $K=1792, 264, 280$  and  $448$  for the CBRM( $\sigma=2, \delta=1$ ) algorithm, no such spike is found for the CBRM( $\sigma=4, \delta=4$ ) algorithm. Performance gains of the new CBRM( $\sigma=4, \delta=4$ ) are generally in the range of 0.05—0.1 dB.

Comparison for code rates 0.5 and 0.4 is presented in Figure 4 and Figure 5, respectively. Performance of the two algorithms is essentially identical.

**Table 1 Simulation Parameters**

<b>Common Code Structure</b>	LTE Turbo Coding [8]
<b>Rate Matching Algorithms</b>	1. CBRM( $\sigma=2, \delta=1$ ) as described in [3, 5, 6] 2. CBRM( $\sigma=4, \delta=4$ ) as described in [6]
<b>Coding Rates</b>	$r = 0.4, 0.5, 0.6, 0.7, 0.8$
<b>Test Block Lengths</b>	For all QPP interleaver sizes $K \geq 288 \times r$
<b>Redundancy Version</b>	RV = 0
<b>Decoding Algorithm</b>	Improved Max-Log-MAP (i.e., 0.75 scaling on extrinsic information)
<b>Iterations</b>	8
<b>Modulation</b>	QPSK
<b>Channel</b>	Static AWGN

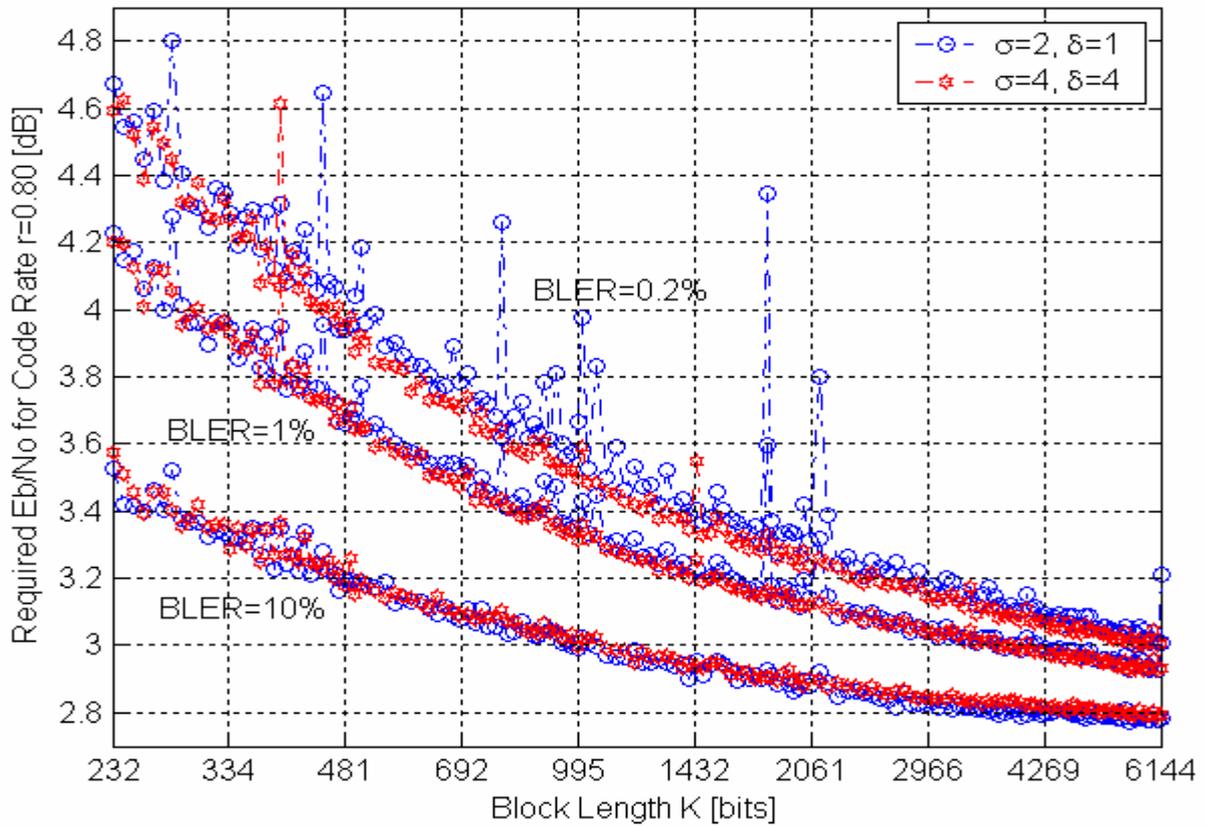


Figure 1 Required  $E_b/N_0$  for RV=0 at code rate  $r=0.8$ . For each of the CBRM( $\sigma=2, \delta=1$ ) and CBRM( $\sigma=4, \delta=4$ ) algorithms, three curves corresponding to BLER targets of 10%, 1%, 0.2% are shown.

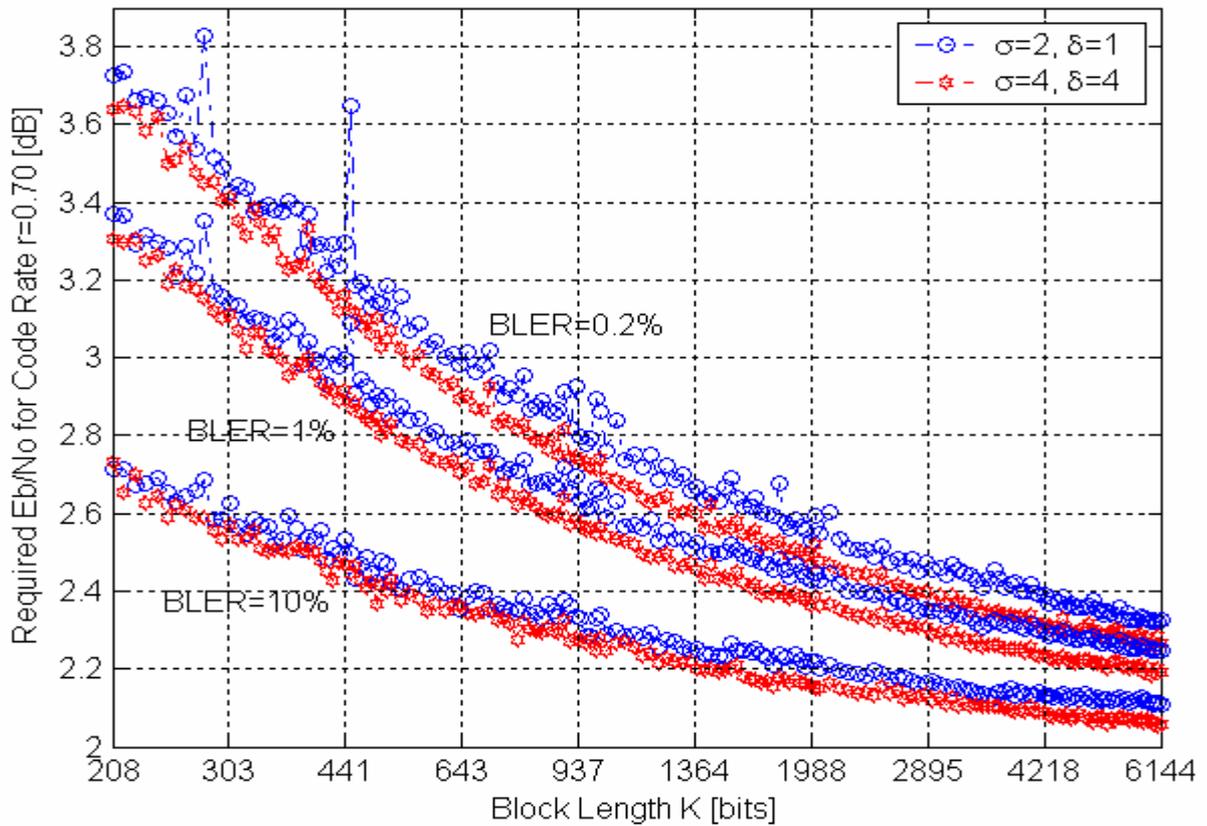
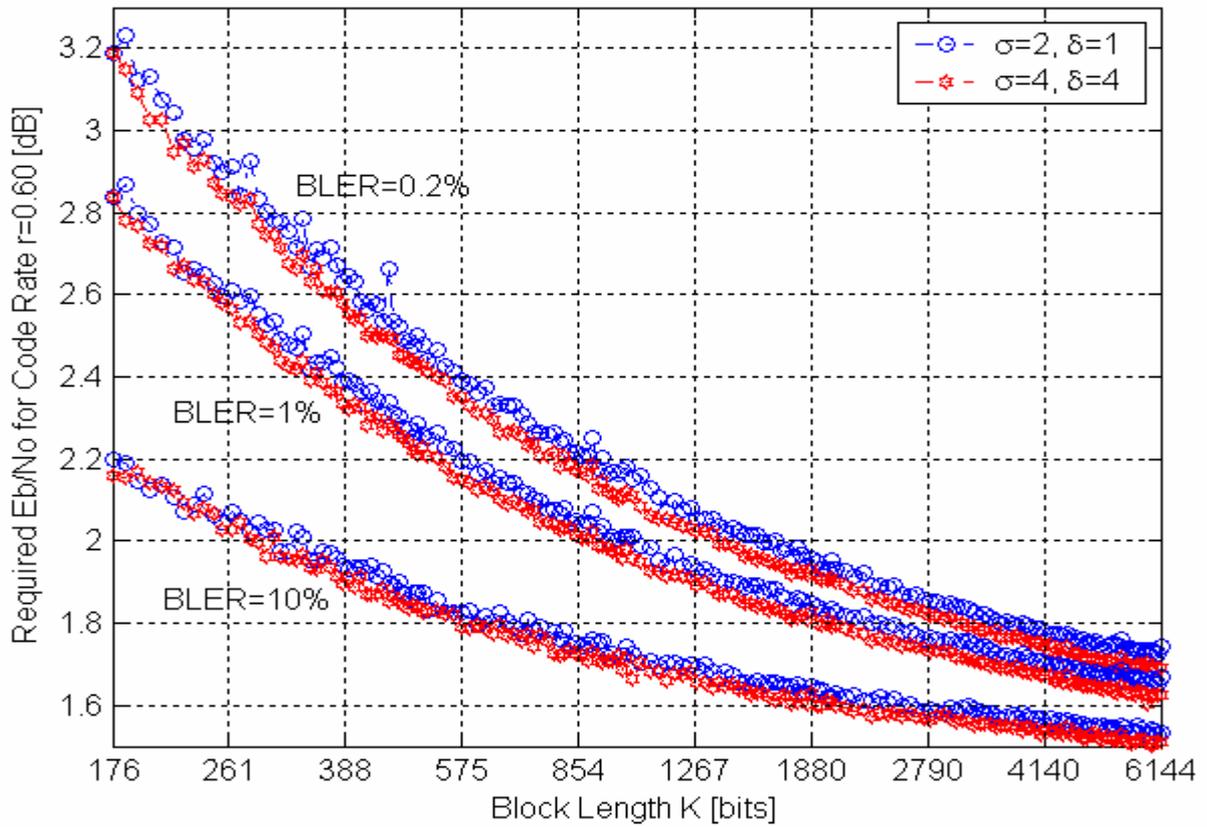
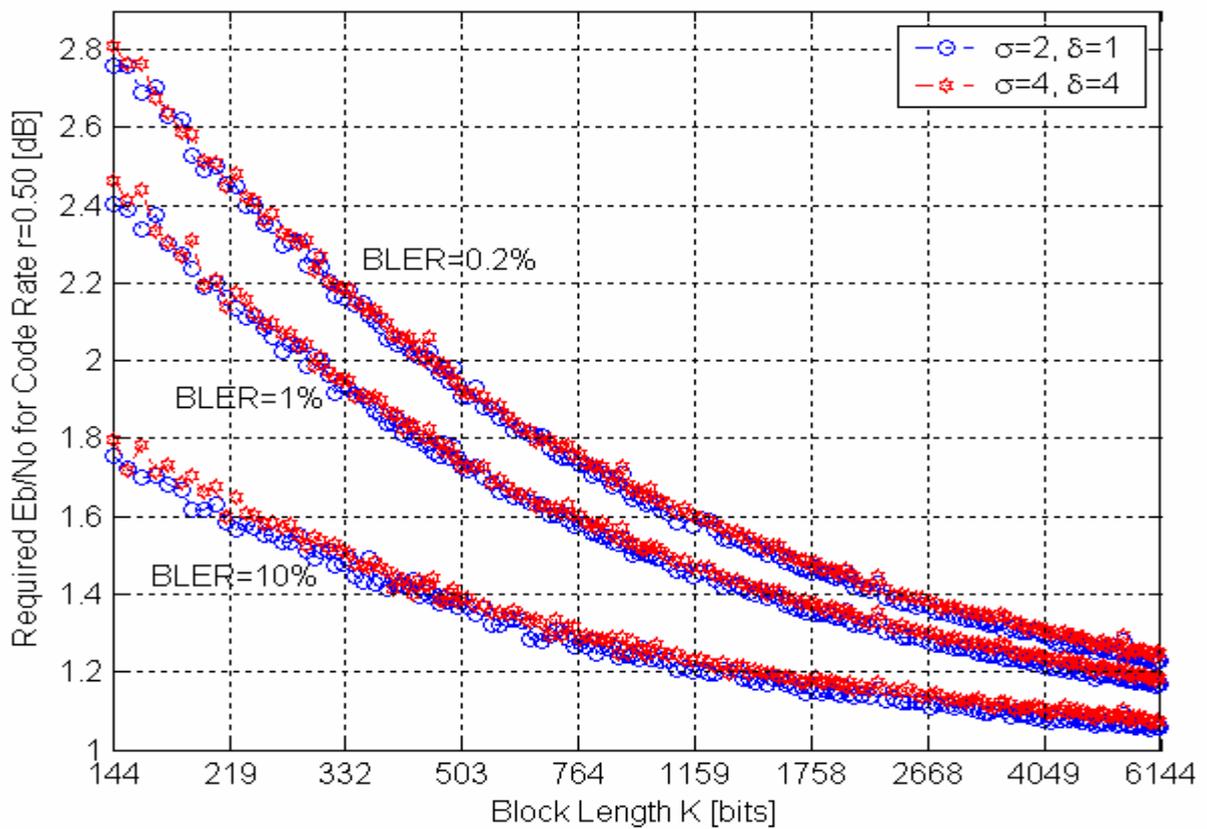


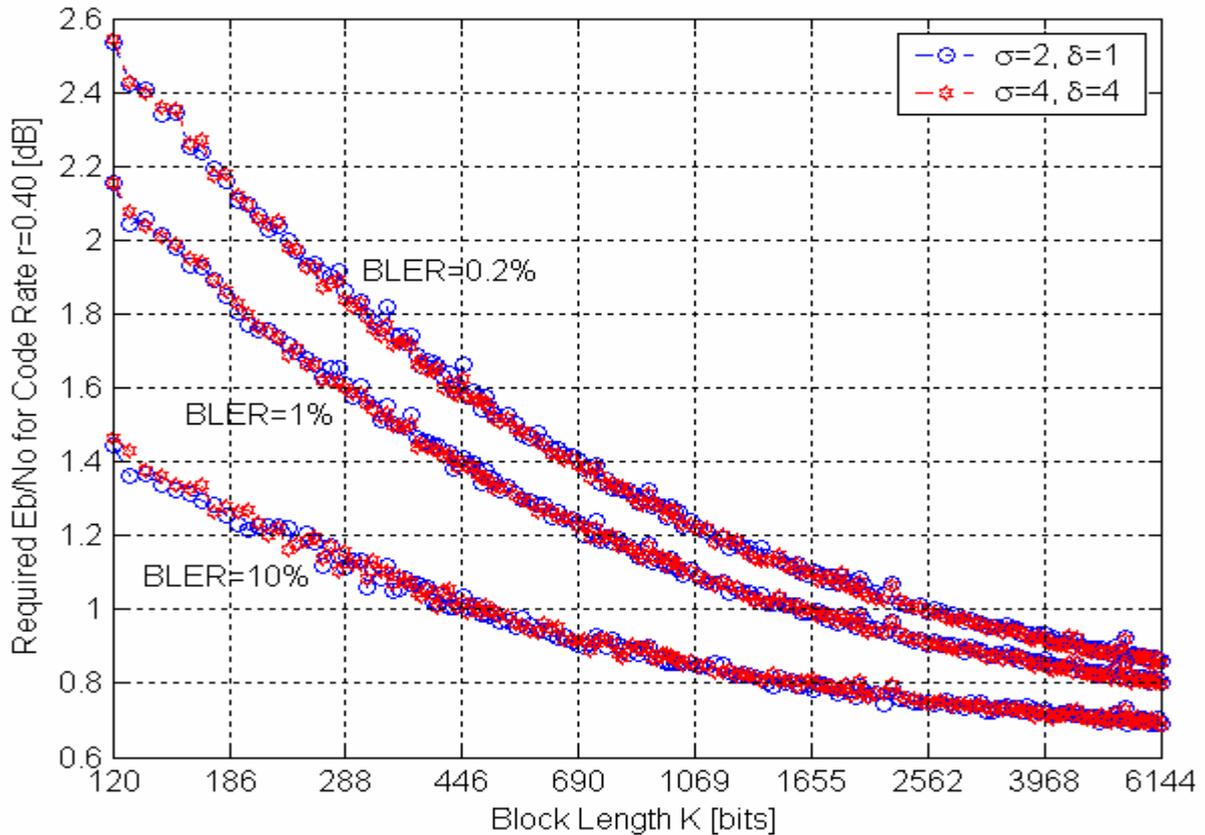
Figure 2 Required  $E_b/N_0$  for RV=0 at code rate  $r=0.7$ . For each of the CBRM( $\sigma=2, \delta=1$ ) and CBRM( $\sigma=4, \delta=4$ ) algorithms, three curves corresponding to BLER targets of 10%, 1%, 0.2% are shown.



**Figure 3** Required  $E_b/N_0$  for RV=0 at code rate  $r=0.6$ . For each of the CBRM( $\sigma=2, \delta=1$ ) and CBRM( $\sigma=4, \delta=4$ ) algorithms, three curves corresponding to BLER targets of 10%, 1%, 0.2% are shown.



**Figure 4** Required  $E_b/N_0$  for RV=0 at code rate  $r=0.5$ . For each of the CBRM( $\sigma=2, \delta=1$ ) and CBRM( $\sigma=4, \delta=4$ ) algorithms, three curves corresponding to BLER targets of 10%, 1%, 0.2% are shown.



**Figure 5** Required  $E_b/N_0$  for RV=0 at code rate  $r=0.4$ . For each of the CBRM( $\sigma=2, \delta=1$ ) and CBRM( $\sigma=4, \delta=4$ ) algorithms, three curves corresponding to BLER targets of 10%, 1%, 0.2% are shown.

### 3. Conclusion

The CBRM( $\sigma=4, \delta=4$ ) algorithm proposed in [6] has been verified to achieve better performance over a wide range of code rates than existing CBRM proposals. It is proposed to adopt this improved CBRM design for LTE.

### 4. References

- [1] R1-072604, Ericsson, ETRI, Freescale, ITRI, LGE, Motorola, Qualcomm, Samsung, ZTE, "Way forward on HARQ rate matching for LTE," 3GPP TSG RAN WG1 #49, Kobe, Japan, May 7– 11, 2007.
- [2] R1-072621, Nokia Siemens Networks, Nokia, Motorola, Qualcomm, ZTE, Ericsson, LGE, Samsung, TI, ETRI, InterDigital, "LTE rate matching conclusion," 3GPP TSG RAN WG1 #49, Kobe, Japan, May 7– 11, 2007.
- [3] R1-072245, Samsung, Qualcomm, LGE, ITRI, "Circular buffer rate matching for LTE," 3GPP TSG RAN WG1 #49, Kobe, Japan, May 7– 11, 2007.
- [4] R1-072138, Motorola, "Redundancy version definition for circular buffer rate matching," 3GPP TSG RAN WG1 #49, Kobe, Japan, May 7– 11, 2007.
- [5] R1-072137, Motorola, "Turbo rate matching in LTE," 3GPP TSG RAN WG1 #49, Kobe, Japan, May 7– 11, 2007.
- [6] R1-073028, Ericsson, "Catastrophic puncturing avoidance," 3GPP TSG RAN WG1#49bis, Orland, USA, June 25– 29, 2007.
- [7] S. Crozier, P. Guinand, and A. Hunt, "On Designing Turbo-Codes with Data Puncturing," Proceedings of the 2005 Canadian Workshop on Information Theory (CWIT 2005), Montréal, Quebec, Canada, June 5– 8, 2005.
- [8] 3GPP TS 36.212 v1, "Multiplexing and Channel Coding (Release 8)," 2007.