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DC-FREE TURBO CODING SCHEME FOR GPRS SYSTEM

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ABSTRACT

A useful tool in the design of reliable digital communication systems is channel coding. Turbo codes have been shown to yield an outstanding coding gain close to theoretical limits in the Additive White Gaussian Noise (AWGN) channel. Recently, they have been studied over Rayleigh fading channel as well and showed a remarkable performance. In this paper, we propose a DC-Free Turbo coding scheme and Turbo coding scheme to replace the Convolutional coding already in use in the General Packet Radio Service (GPRS) system. Evaluation of the proposed encoder by means of computer simulation has shown a performance improvements.

I. INTRODUCTION

Coding aims at improving transmission quality when the signal encounters any type of disturbances. Turbo codes with MAP decoding are one of the most widely used forward error correcting techniques. This is due to relatively large coding gains that can be achieved. Thus it can be expected that the DC-free codes constructed from turbo codes have good error control performance. Turbo codes combine the concepts of parallel concatenated convolutional codes, interleaving and iterative decoding. The outstanding performance achieved was unexpected and raised an explosive amount of literature [1,2]. Turbo code encoder consist as shown in Figure 1, of two (or more) encoders grouped together in a parallel connection, and separated by a random interleaver. Although the component encoder can be of any type (block or convolutional); typically, Turbo codes are built with systematic recursive convolutional encoders [3]. The decoding of Turbo codes is typically accomplished using an iterative decoding algorithm. As shown in simplified form in Figure 2, there are two component decoders operating together and passing soft input information to each other in a feedback loop. The component decoders must be capable to generate soft outputs corresponding to each information symbol. Component decoders for carrying out this task are based on the maximum aposteriori (MAP) symbol-by-symbol algorithm [4] or the soft output Viterbi algorithm (SOVA). For DC-free Turbo codes as shown in Figure 3, its encoder and decoder structures are the same as those of the conventional turbo codes with slight modifications. The proposed scheme can be divided into two parts; the running digital sum (RDS) control encoder/ decoder and the Turbo encoder/ MAP decoder. The RDS control encoder generates only several code words of a window code for selecting a control vector [5]. This paper is organized as follows. In section II, the GPRS is reviewed and details will be given about its already existing channel coding techniques. The proposed DC-free Turbo encoder/ decoder will be presented in section III, comparative simulation results are presented in section IV, finally the conclusion in section V.

II GPRS SYSTEM AND ITS CODING SCHEMES

The General Packet Radio Service (GPRS) allows an end user to send and receive data in packet transfer mode within a public land mobile network (PLMN) without using a permanent connection between the mobile station (MS) and the external network during data transfer. This way, GPRS optimizes the use of network and radio resources (RRs) since, unlike circuit-switched mode, no connection between the MS and the external network is established when there is no data flow in progress. Thus, this RR optimization makes it possible for the operator to offer more attractive fees.The principles defined for the Global System for Mobile Communications (GSM) radio interface were kept for GPRS, since the notions of time slot, frame, multiframe, and hyperframe have not changed for GPRS as compared with GSM. The GPRS standard proposes multislot allocations for data transmission; the network may allocate up to eight time slots per time division multiple access (TDMA) frame for a given mobile on uplink and down-link. The GPRS standard proposes four channel coding types allowing throughput per slot ranging from 9.05 Kbps to 21.4 Kbps. This allows a theoretical throughput going up to 171.2 Kbps for data transmission when eight time slots are allocated to the MS. Four coding schemes (CSs), CS-1 to CS-4, have been defined for GPRS, offering a decreasing level of protection. The coding rate is the lowest with CS-1 (maximum redundancy) and is the highest for CS-4 (no redundancy). The CS to be used is chosen by the network according to the radio environment. This mechanism is called link adaptation. The coding is based on a cyclic redundancy code (CRC), followed by a convolutional encoding, for CS-1 to CS-3. There is only a CRC for CS-4. Puncturing is applied to adapt the convolutional encoder output to the radio block length. Finally, block interleaving over the radio block makes it possible to improve the decoding performance at the receiver. The principle for the coding of one radio block for CS-1 to CS-3 is shown in Figure 4.

The mobile always transmits with a CS ordered by the network, whereas in Rx the mobile performs a blind detection of the used CS. This detection is done by analyzing the stealing flags (8 bits per radio block, at the extremities of the training sequences), one different stealing flag pattern being defined for each of the CSs. A summary of the four CS characteristics is given in Table 1. This table specifies the total coding rate for each CS and for a radio block.

III. Proposed DC-Free Error correcting Codes

A. Introduction.

DC-free coding is widely employed in digital communication and storage areas. "DC-free" means that the coded sequence has no DC spectral component [7]. It is usually required in digital transmission and recording systems to reduce the effect of baseline wander and match spectra of the transmitted signals to frequency characteristics of the transmission media [8]. In this paper, a novel DC-free turbo coding scheme is presented. Fig.3. represents the architecture of the proposed scheme. With this architecture, it is available to exploit soft decision decoding with the MAP algorithm. Moreover, the dashed box part in fig.3. is exactly identical to a conventional turbo coding system with slight modification. The RDS control encoder and decoder can be regarded as a front-end and a back-end of the conventional coding system.

Firstly, the user message sequence $(u_0u_1u_2\ldots\ldots)$is encoded to intermediate sequence $(x_0x_1x_2\ldots\ldots)$ by a RDS control encoder. Then turbo encoder converts an intermediate sequence to the coded sequence $(y_0y_1y_2\ldots\ldots)$. After the binary-bipolar conversion, the coded sequence is transmitted over a noisy channel such as the additive white Gaussian noise (AWGN) channel. The term "RDS" means the running digital sum of a coded sequence. The DC-free property is achieved if and only if the absolute value of the RDS is bounded by a constant value for any time instant.

B. Encoding

Assume that a turbo code C together with the parameter α, β, γ, and a decomposition matrix M are given. The code C is called base turbo code. The message sequence $(u_0u_1u_2\ldots\ldots)$ is divided into blocks of length β. The i-th (i=0, 1, 2 …) message block is denoted by

The message sequences are encoded to the intermediate sequences by the RDS control encoder. The intermediate sequence $(x_0x_1x_2\ldots)$ is divided into the intermediate block of length L. The i-th intermediate block is defined by

$$u_i = (u_{i\beta}, u_{i\beta+1}, u_{i\beta+2}, \ldots, u_{(i+1)\beta-1})$$

where O_i is the first pm-tuple of x_i and n_i is the last $\gamma+\beta$-tuple of x_i such that

$$x_i = (x_{(\gamma+\beta)i}, x_{(\gamma+\beta)i+1}, \ldots x_{(\gamma+\beta)i+L-1})$$

$$x_i = (0_i \setminus n_i)$$

We obtain a coded sequence $(y_oy_1\ldots)$ by encoding the intermediate sequence with the turbo encoder. The coded sequence is divided into the coded blocks of length r. The i-th (i = 0, 1, 2,…) coded block has the form

$$y_i = (y_{ri+qm}, y_{ri+1+qm}, \ldots y_{r(i+1)-1+qm}$$

Note that

$$y_0 = (y_{qm}, \ldots, y_{r-1+qm})$$

The relation between the message, intermediate and coded sequences is shown in figure 5

Notice that the intermediate blocks x_i and x_{i+1} are overlapping. The overlapping part corresponds to o_i. By applying the additive encoder to a window code, the overlapping is taken into account. Within the intermediate block x_i, only the vector n_i can be assigned freely without any influence of the previous block. The overlapping part o_i is determined by the previous intermediate block x_{i-1}. As shown in figure 6, the RDS control encoder adds redundancy (a control vector) to the message sequence and thus the coding rate defined between the message and intermediate sequence becomes $\beta / (\gamma + \beta)$. The turbo encoder appends redundancy to the intermediate sequence. Consequently, the overall rate becomes $R \cong (p\beta)/(q(\gamma+\beta))$. The rate loss can be considered as a price for obtaining a RDS constraint.

C. Decoding

The decoding issue for the proposed scheme is discussed in this section. The received sequence is first decoded by the MAP decoder for the base turbo code C. let the set of all allowable sequences generated by the proposed scheme be C_{RDS}. The minimum free Hamming distance defined on C_{RDS} is denoted by d'_{free}. From the cascaded structure of the proposed scheme, evidently, C_{RDS} is contained in C and the inequality $d'_{free} \geq d_{free}$ holds. The symbol d_{free} denotes the minimum free hamming distance of C.

IV. Simulation Results

In this section, simulation results of BER versus E_b/N_o were plotted to show the influence of various parameters. The channel model used is a frequency non selective slow Rayleigh fading channel, assumed a fully estimated channel fading values. The DC-Free Turbo decoder is used in an iterative fashion until we achieved the 8th iteration. The component decoder based on the MAP algorithm.

The performance of convolutional, Turbo and DC-Free turbo code for CS-1, CS-2 and CS-3 in terms of Bit Error Rate (BER) verses E_b/N_o are shown in figures 6,7 and 8, as a channel interleaver is used (an interleaver for the different consecutive symbols after coding) results in uncorrelated consecutive symbols. Also we assumed a fully estimated channel fading values and the excepted mean value is used at the detector instead of the true channel values.

We can notice that at the same E_b/N_o DC-Free Turbo code gives the most efficient BER than convolutional code and the Turbo code

V. Conclusion

A new construction of DC-free codes based on turbo codes which can simultaneously meet the dc constraint and error-correcting requirement is proposed. The presented scheme divided into two parts: the RDS control encoder/decoder and the turbo encoder/decoder. The RDS control encoder generates several codewords of a window code for selecting a control vector. The decoding requires simpler tasks than the encoder.

In this paper, We have proposed the application of a DC-Free Turbo code and a Turbo code in GPRS instead of convolutional code already used. We can notice that applying DC-Free Turbo code on GPRS system give the best performance than convolution code and the Turbo code.

REFERENCES

[1] S. Benedetto and G. Montorsi, 'Unveiling Turbo Codes: Some Results on Parallel Concatenated Coding Schemes," IEEE Trans. Inform. Theory, vol. IT-42, no. 2, pp. 409-428, March 1996

[2] G. Battail, "A Conceptual Framework for Understanding Turbo Codes," IEEE J. Selected Areas Commun., vol. SAC-16, no. 2,pp.245-254, Feb. 1998

[3] Yasmine Fahmy, Hala G. Abdel Kader, Magdi El-Soudani, "Turbo Coding Scheme for GPRS System," Nineteenth National Radio Science Conference, Alexandria, March, 19-21, 2002

[4] L. R. Bahl, J. Cocke, F. Jelinek, and J. Raviv, "Optimal Decoding of Linear Codes for Minimizing Symbol Error Rate," IEEE Trans. Inform. Theory, vol. IT-20, pp. 248-287, March 1974

[5] Marwa, M. T., "Performance of DC-Free Error Correcting Codes," , M. Sc. Thesis, pp 7-15& 85-90, Egypt, 2004

[6] Proakis, J. G., "Digital Communications," McGraw Hill, Inc., Forth edition, 2001

[7] M.C. Chiu, “DC-Free Error-Correcting Codes Based on Convolutional Codes,” *IEEE Trans. Commun,* vol. 49, no. 4, pp. 609-619, April 2001.

[8] T. Wadayama and A.J. Han Vinck, “DC-Free Convolutional Coding,” *IEEE Trans. Inform. Theory,* vol. 48, no. 1, pp. 162-173, Jan. 2002.

[9] Wicker, S. B., "Error Control Systems for Digital Communication and storage," New Jersey, Prentice-Hall, 1995

[10] Emmanuel S., Patrick S., Pierre-Jean P., " EDGE for Mobile Internet," Boston, London, Artech House, 2003

[11] M. W. Oliphant, "The Mobile Phone Meets the Internet," IEEE Spectrum, vol. 36, no. 8, pp. 20-28, Aug. 1999

[12] M. W. Oliphant, "Radio Interfaces Make the Difference in 3G Cellular Systems," IEEE Spectrum, vol. 37, no. 10, pp. 53-58, Oct. 2000

Table 1. Coding Parameters for the GPRS Coding schemes

Scheme	Code Rate	USF	Pre-coded USF	Radio Block excl. USF and BCS	BCS	Tail Bits	Coded Bits	Punctured Bits	Data Rate (Kbps)
CS-1	1/2	3	3	181	40	4	456	0	9.05
CS-2	≈2/3	3	6	268	16	4	588	132	13.4
CS-3	≈3/4	3	6	312	16	4	676	220	15.6
CS-4	1	3	12	428	16	—	456	—	21.4

Table 2. Comparisons between using convolutional , Turbo and DC-Free Turbo code for the GPRS Coding Schemes at E_b/N_o = 4 dB

Figure 6. CS-1 (E_b/N_o = 4)	Using Convolutional code BER =١,٠٠ E-02	Using Turbo code BER =١,٣٠ E-03	Using DC-Free Turbo code BER =٤,٣٠ E-05
Figure 7. CS-2 (E_b/N_o = 4)	Using Convolutional code BER =٦,٠٠ E-02	Using Turbo code BER =٣,٨٠ E-02	Using DC-Free Turbo code BER = ٩,٤١٠E-03
Figure 8. CS-3 (E_b/N_o = 4)	Using Convolutional code BER =٢,٨٠ E-01	Using Turbo code BER =٧,٧٢ E-02	Using DC-Free Turbo code BER =٥,٣٢ E-02

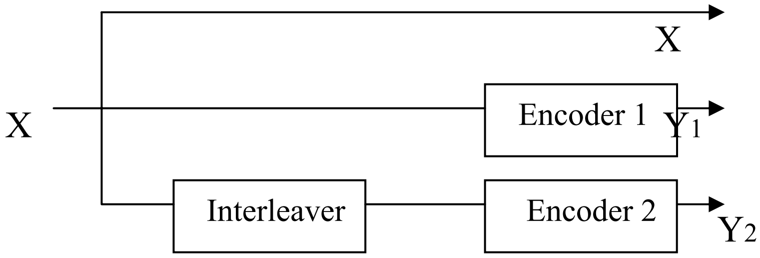

Figure 1. A typical Turbo encoder

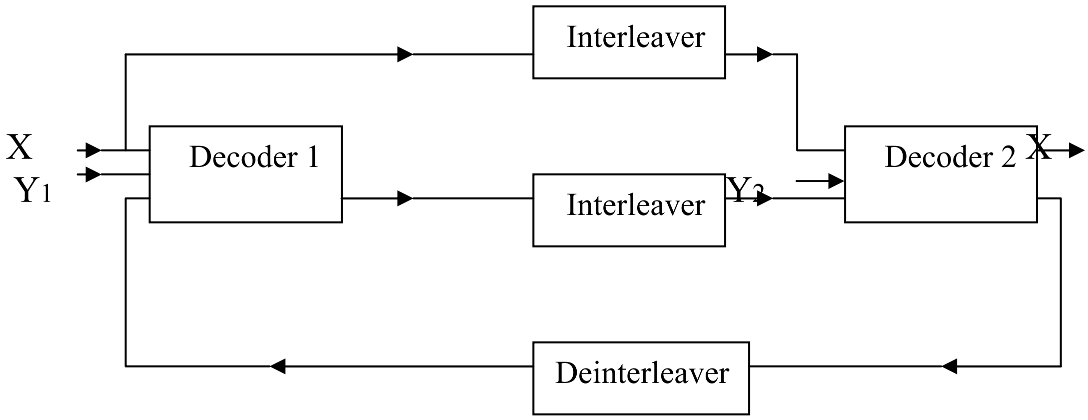

Figure 2. Iterative Turbo decoding Process

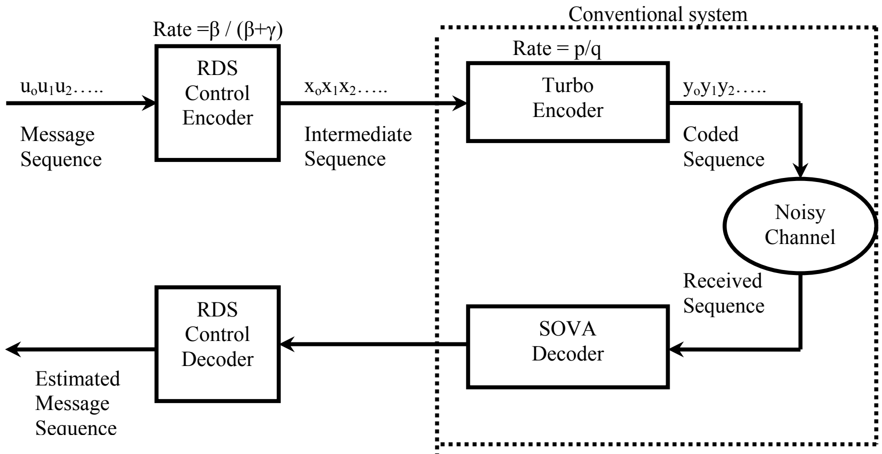

Figure 3. Architecture of DC-Free Turbo codes scheme

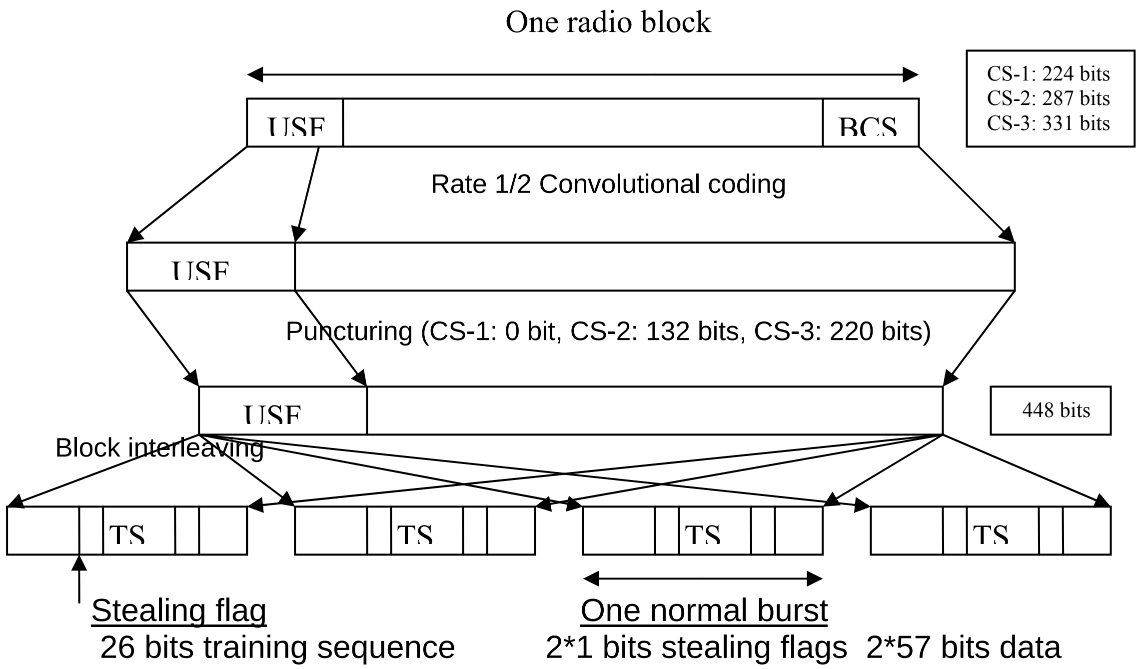

Figure 4. Radio block encoding for CS-1 to CS-3.

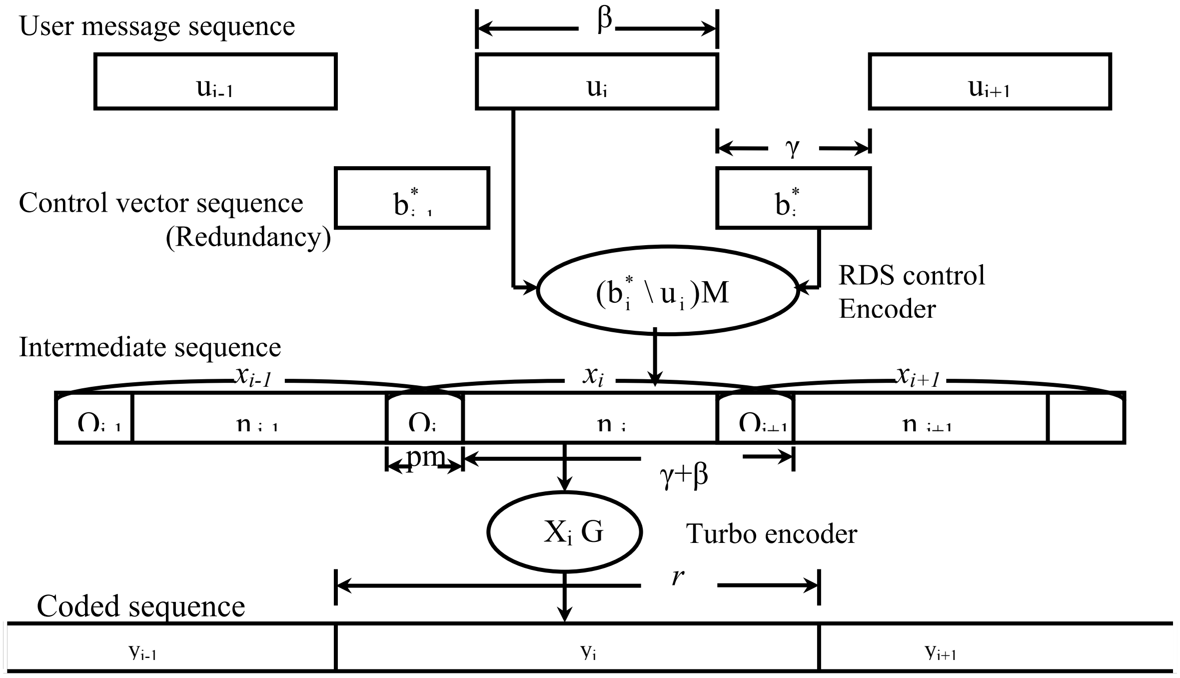

Figure 5. Relations among message, intermediate and coded sequences

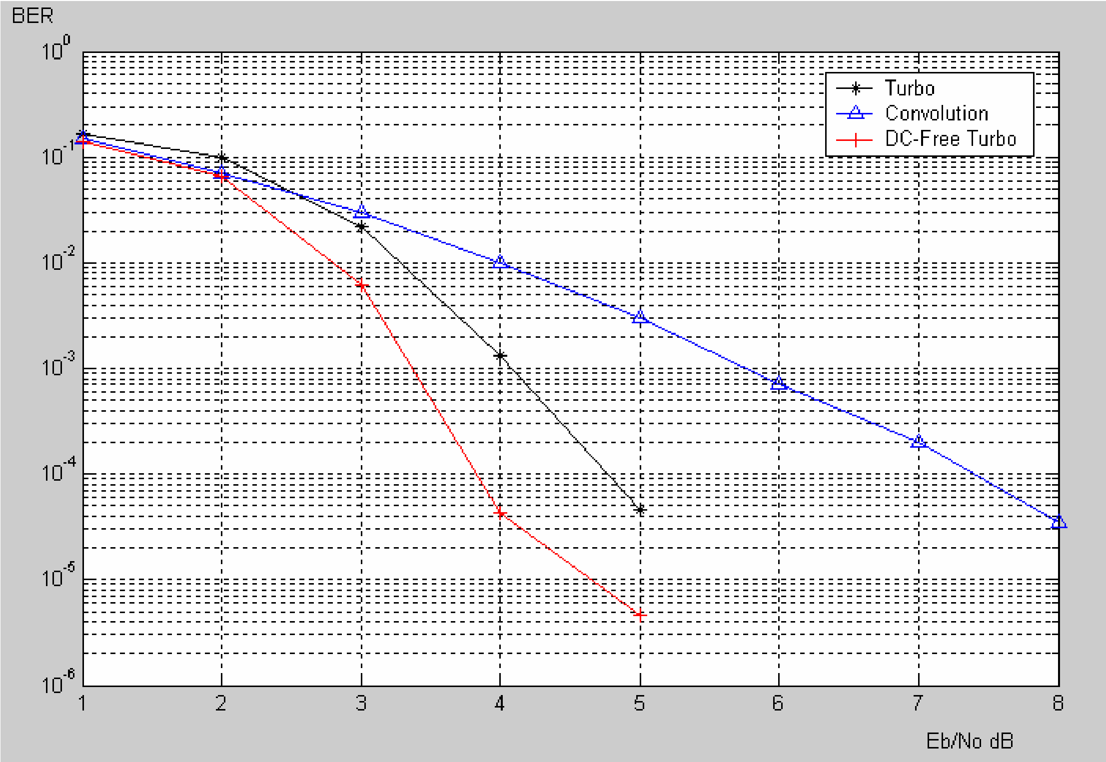

Figure 6. BER for CS-1

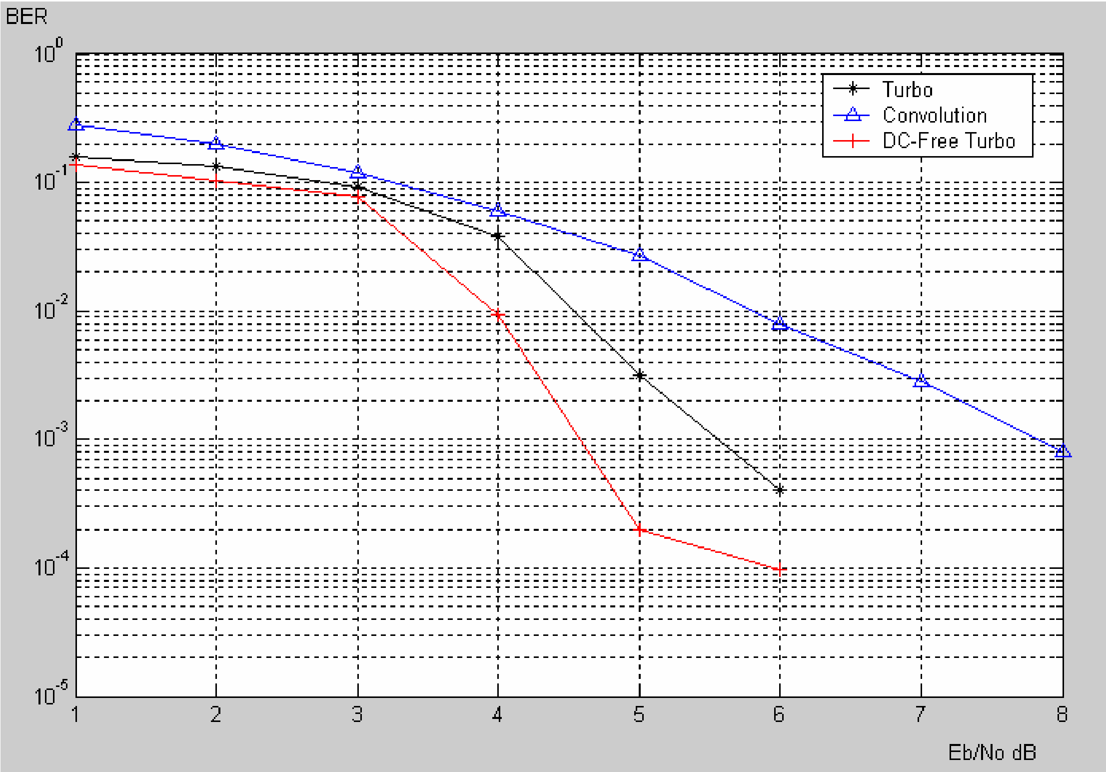

Figure 7. BER for CS-2

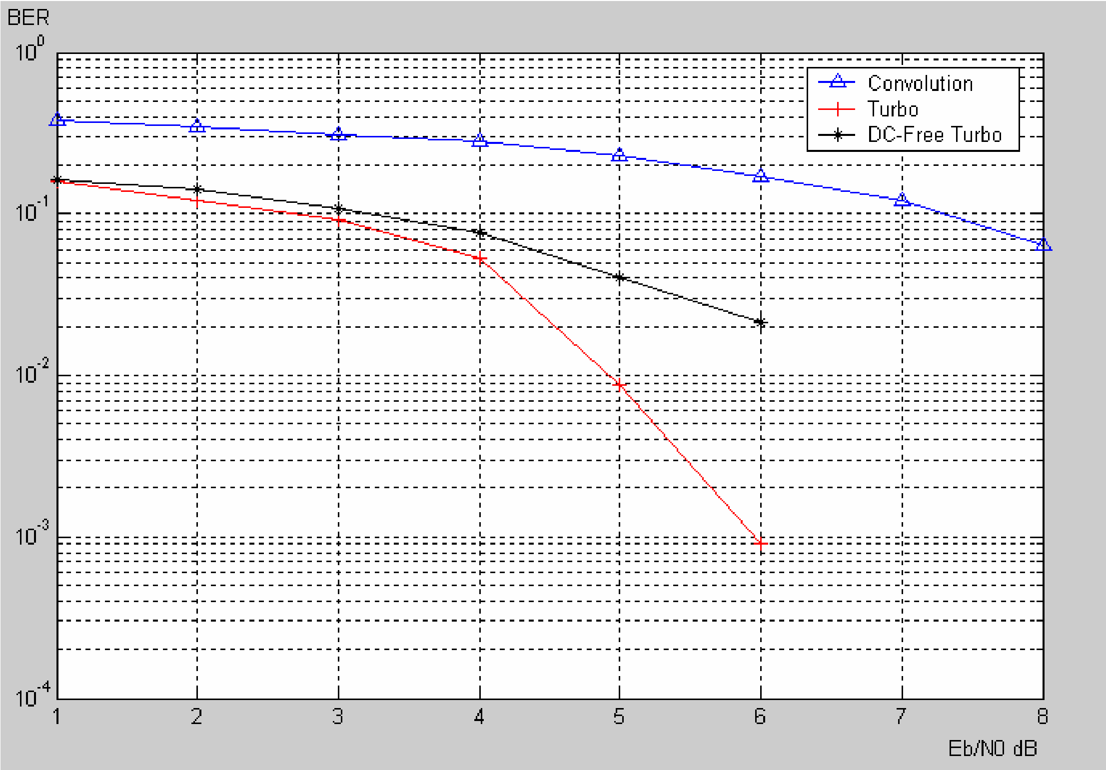

Figure 8. BER for CS-3