ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics & Communication Engineering (IJARECE)
Volume 8, Issue 6, June 2019

BER Estimation of Low Density Parity Check Decoder in Convergence Digital Radio

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***Abstract*- In Analog Communication, it is adequate to calculate the received field strength to evaluate the performance of communication. However, in digital Communication, Bit Error Rate estimation is required. In real time radio broadcasting, the transmitted bits are completely not known at the receiver side. So pseudo channel BER, can be estimated and used as an evaluation metric to assess the performance of a decoder. When a Low Density Parity Check (LDPC) decoder does not introduce any error, pseudo channel BER is equal to channel BER. In this project, pseudo channel BER is measured for various power levels of transmission and minimum BER required for good playback has been determined.**

Keywords— Convergence Digital Radio, LDPC Decoder, Pseudo Channel BER.

I. INTRODUCTION

The Analog Radio broadcasting is more prone to interference and noise, makes hearing analog radios as a worst experience. Radio is losing its importance in recent years due to the development of other technologies. In order to retain the importance of radios, it is necessary to convert it into digital. The ability to detect and correct errors in digital signal transmission, gives better reception quality of signals in digital radios. Orthogonal Frequency Division Modulation (OFDM) is used for multiplexing and modulation reduces interference in digital radios. Most common digital radio standards are HD Radio, Digital Audio Broadcasting (DAB), Digital Radio Mondiale (DRM) and Convergence Digital Radio (CDR). CDR supports In-Band On Channel (IBOC) which allows simulcast of analog and digital signals. At a single frequency, transmission of two or more station is possible. These benefits make digital radios superior to analog radios.

To improve the performance of digital communication, the metric required to be determined is Bit Error Rate. The bits obtained at the output of decoder has to be compared with the transmitted bits to determine erroneous bits. Numerous techniques are available to determine BER. Most of the techniques assume transmitted bits are known at receiver side. In real time radio broadcasting, transmitted bits are not known at the receiver side. In DAB, to assess the coverage area, BER is required. The BER inside the coverage area is less while BER outside the coverage area is terribly high. For such coverage area measurement, to estimate BER without transmitted bits, R.Schramm in 1997 introduced a terminology called Pseudo channel BER which is not the actual BER but almost an approximation of actual BER. The Pseudo channel BER of convolutional decoder has already done in DAB. This project aims to determine pseudo channel BER of LDPC decoder in Convergence Digital Radio.

II. PSEUDO CHANNEL BER ESTIMATION

The output from the demodulator is in the form of voltages which is given as input to the LDPC decoder. The output from the LDPC decoder is re-encoded at the receiver side. On the other hand, the output from the demodulator is subjected to Hard-decision and compared with the output of LDPC encoder (Method-1). The message bits in the encoded bits are compared with the hard decision bits to find out erroneous bits. As LDPC codes are systematic codes, the pseudo channel BER estimation can be done without re-encoding also (Method-2). Outcome from the Method-1 and Method-2 will be same only in LDPC decoder and different in other decoders such as convolutional decoder. However, pseudo channel BER has been estimated by using Method-1 and Method-2

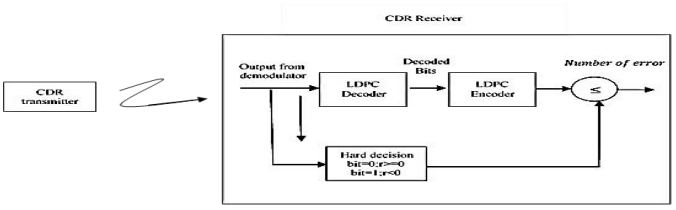

Fig 1. Pseudo channel BER estimation by Method-1

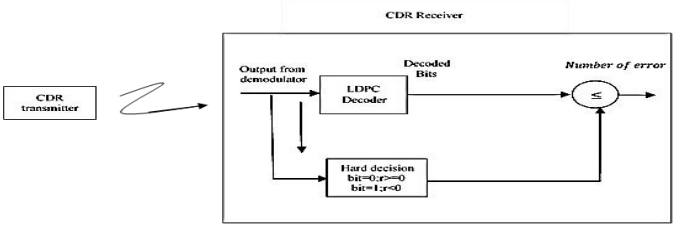

Fig 2. Pseudo channel BER estimation by Method-2

III. PSEUDOCHANNEL BER ESTIMATION BY METHOD-1

The output from the demodulator is subjected to hard-decision using the logic, if received voltage is greater than or equal to zero, then the result of hard-decision is zero. Else, the result of Hard-decision is one. LDPC Encoding is quite complex and it can be done in various ways. New modifications have been done in the already existing Adaptive Message Length Encoding. The Parity Check Matrix (H) of dimension m x n used for encoding is divided into two parts A and B in such a way that A should have dimension equal to t x n-t where t= n-k. k is equal to number of message bits and n is equal to code length. The dimension of B will be t x t. Instead of converting B into lower triangular matrix, it is converted into Identity matrix. In this project, a new algorithm is developed to convert a matrix of zeros and ones into an identity matrix using column swaps and elementary row operations. The flowchart for the algorithm is as follows.

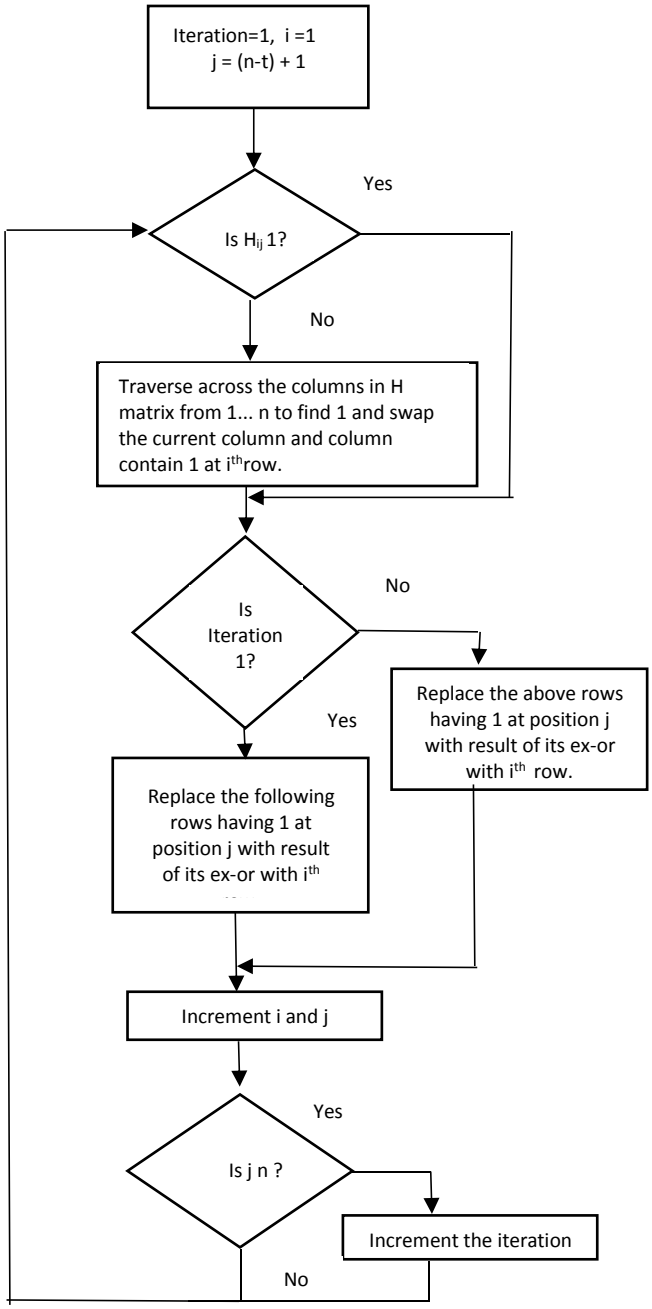

Fig 3. Flowchart of algorithm that convert a matrix into an identity matrix

Using the above algorithm, the part B will be converted into an identity matrix. Then the parity bits are determined using the equation $p^T = B^{-1}Au^T$ where u represents message bits and p represents parity bits. The code rates used in CDR are ¼, ½, 1/3 and ¾. The parity check matrix dimension varies for each code rates. The encoding has done for all four code rates. As the LDPC codes are systematic codes, the message bits are followed by parity bits. The message bits from the encoded bits are compared with the message bits in decoded bits to count error. Then BER is estimated by dividing the number of errors by total number of bits compared. The pseudo channel BER is estimated by using hard-decision bits as reference bits, so that the resultant BER says more bits are erroneous in received bits. Hence, Pseudo channel BER is not much accurate as actual BER.

IV. PSEUDOCHANNEL BER ESTIMATION BY METHOD-2

The pseudo channel BER can be estimated without encoding only in LDPC codes. The decoded bits are directly compared with Hard-decision bits to count error. LDPC codes are systematic codes. So the parity bits are just appended to the block of message bits. So the message bits can be identified and it can be compared with decoded message bits.

V. PSEUDO CHANNEL BER ESTIMATION AT CODE RATES 3/4 AND 1/2

The mostly used code rate in CDR is ¾. The pseudo channel BER measurement was done at code rates ¾ and ½.

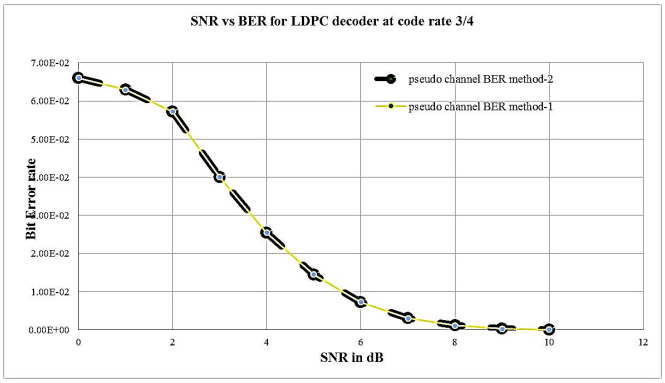

Fig 4. Pseudo channel BER at code rate 3/4 using method-1 and method-2

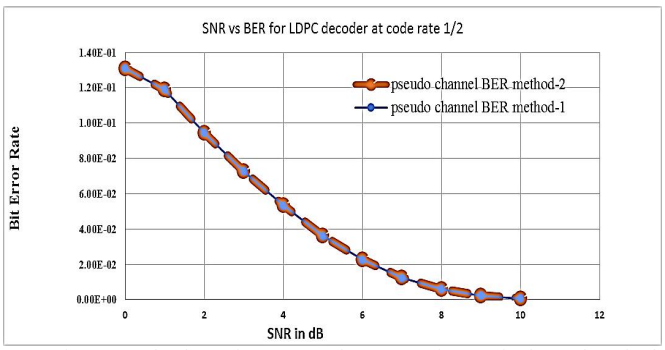

Fig 5. Pseudo channel BER at code rate ½ using method-1 and method-2

It is observed that the pseudo channel BER obtained for various SNR values using Method-1 and Method-2 is same. As encoding is complex, the method-2 is preferable in case of LDPC codes and other systematic codes. Convolutional codes are non- systematic codes and for each message bits there will be parity bits. The pseudo channel BER obtained using Method-1 and Method-2 differs in non-systematic codes such as convolutional codes

VI. REAL TIME IMPLEMENTATION AND TESTING OF PSEUDO CHANNEL BER FOR VARIOUS POWER LEVELS

In real time, the pseudo channel BER estimation (Method-2) has been implemented and tested using ARMCORTEX A72 processor. Using IZT signal generator, signals with various power levels were generated. The pseudo channel BER for these signals was estimated and quality of audio play back was checked.

Signal power	Pseudo channel BER	Audio Quality
10dBm	4.947×10^{-3}	Good
0dBm	4.971×10^{-3}	Good
-10dBm	4.974×10^{-3}	Good
-20dBm	1.1×10^{-2}	Good
-30dBm	1.6×10^{-2}	Noisy
-35dBm	5.2×10^{-2}	Mute

Table 1. Real Time Pseudo Channel BER Estimation for Various Signal Power at Code Rate 3/4

The minimum pseudo channel BER required for a good playback at code rate 3/4 is 1.1×10^{-2}. When the pseudo channel BER exceeds the value, the playback is noisy and for higher values it is mute.

When the actual BER is 10^{-4} or less, the playback is good. As transmitted bits are not known, it cannot be determined. So pseudo channel BER is estimated and considered as an evaluation metric. If pseudo channel BER is 1.1×10^{-2} or less, then the performance of decoder is good and audio playback is also good.

VII. CONCLUSION AND FUTURE WORK

In this paper, pseudo channel BER estimation of LDPC decoder in Convergence Digital Radio has been implemented and tested. Even though the estimated BER is not as accurate as actual BER, it is considered as evaluation metric and it is needed to measure the quality of communication, because, actual BER cannot be determined. The quality of playback was also checked for various signal power and minimum value required for good playback at code rate 3/4 has been determined. For other code rates such as ¼, ½ and 1/3 also, the criteria for good audio playback using pseudo channel BER can be determined in the future. In addition to that, the performance of decoder can be improved so that good playback is obtained for a maximum dynamic range.

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