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BIT ERROR OPTIMIZATION OF CODED OFDM SYSTEM OVER RAYLEIGH FADING CHANNEL

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Abstract: Low Density Parity-Check (LDPC) codes are one of the hottest topics in coding theory today. This code invented in the early 1960's, and it having an amazing comeback in the last few years. In this paper, a scheme is proposed to analyze the performance of LDPC which is considered important rival to turbo codes, Convolutional Code (CC) and Read Solomon (RS) in terms of performance and complexity. This code is utilized in Orthogonal Frequency Division Multiplexing (OFDM) system to evaluate the improvement in the Bit Error Rate (BER) performance of the system. Comparison is done between turbo code and LDPC code through Additive White Gaussian Noise (AWGN) and fading channels. The effect of varying the code rate channel, number of iteration and the code length on the performance of the scheme are also explained.

Key words: *OFDM, LDPC, Turbo code, BPSK, AWGN, Fading channel*.

تحسين خطا البت لنظام OFDM المشفر خلال قناة رايلي متلاشية

الخلاصة: تعد الشفرات المنخفضة التكافؤ(LDPC) حاليا من اهم المواضيع لنظرية الترميز. تم اكتشاف هذه الشفرات سنة 1960،وكان لهل حضور مذهل في السنوات الاخيرة. في هذا البحث يتم اقتراح وتحليل نظام يستخدم هذا النوع من الشفرات والتي تعتبر منافس هام للشفره النفاثة وللشفرات الالتفافية وشفرة RS من حيث الاداء والتعقيد. هذه الشفرة تستخدم مع نظام التعدد التقسيمي الترددي المتعامد OFDMمن اجل تقييم التحسن في اداء النظام المقترح. يتم المقارنة مع الشفرة النفاثة عبر قناتي AWGN و Fading. في هذا البحث يتم كذلك توضيح تاثير تغيير نسبة الشفرة، القناة، عدد التكرار وطول الشفره على اداء النظام المقترح.

1. Introduction

The growing need for transmission and high rates in modern communication systems, have encourage the search for a favorable error correction systems allowing good performance and low bit error rate BER (near the Shannon limit)[1]. Because of the efficiency and the performance of Low Density Parity Check (LDPC) codes compared to other types of error correcting codes, it has become one of the best

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codes used in many applications for wireless communication, such as DVB-S2 standards, WiMAX (IEEE802.16e) and WiFi (IEEE 802.11n)[1].

There are many researches that have looked into properties and performances of LDPC codes and highlighted the importance of using it in many modern communication applications [2, 3]. In [4] schemes with higher rate for quasi-cyclic Low Density Parity Check (QC LDPC) are proposed. This can be realized by removing row blocks from or adding column blocks to the parity check matrix of a mother code. In [5], a combination between an effective modulation and coding system is suggested for satellite ground laser channel. The result shows that the system with 8 PPM and 1/2 code rate binary LDPC code gives more enhancement for the link reliability over different turbulent intensity. For a bit patterned media (BPM) application where a burst error mostly occurred, a system with iterative LDPC-LDPC product code is proposed in [6]. In [7], a scheme for image transmission over AWGN channel is proposed. This system uses the Set Partitioning in Hierarchical Trees (SPIHT) as a type of a source coding technique. In addition to advantages of LDPC code, there is another technique that come to the forefront of technology, namely orthogonal frequency division multiplex (OFDM)[8]. In [9], a combination between QC-LDPC and MIMO OFDM scheme is proposed to reduce the Peak Average Power Ratio (PAPR) which is considered one of the challenges in the OFDM systems. In paper [10], the researcher presents a comparative analysis between turbo code and LDPC code over Nakagami channel. The simulation results show that the performance of LDPC is much better than that of turbo code.

This paper organizes as follows: OFDM technique and LDPC code encoder / decoder are briefly reviewed in sections 2 and 3 respectively. The proposed coded system is explained in section 4. The simulation results are analyzed in section 5. Section 6 contains the conclusions of the proposed system performance depending on the simulation results.

2. OFDM Technique

In FFT based OFDM system, the input data is modulated or mapped using digital modulation technique at transmitter. So, serial binary data are mapped into complex vector X=[X_0, X_1, …..X_{N-1}] ,Where N is the number of subcarrier. Then these complex symbols are transmitted through the IFFT block over N subcarrier. The output of the IFFT block is time domain conversion of the complex data and it is as follows in equation (1):

$$x(n) = \frac{1}{N} x(k) e^{\frac{j2\pi n}{N}} \qquad (1)$$

After the OFDM symbol being generated, a guard interval is inserted to eliminate the effect of ISI. And cyclic prefix is inserted for each OFDM symbol. After that, these output signals are transmitted over AWGN and fading channels.

At the receiver side the steps are reverse procedure for what is done previously. The data are passed through the FFT block in order to reconstruct the transmitted data stream. After that the cyclic prefix is removed and data is demapped to reconstruct the transmitted data. Equation (2) shows the output of the FFT block [11]

$$x(k) = \frac{1}{N}x(n)e^{\frac{-j2\pi n}{N}} \qquad (2)$$

3. LDPC Codes

Error-correcting codes are widely used in many applications such as processing systems, storage systems and information communication. The implementation of error correcting codes has become easier especially after rapid development in optical and electronic devices and systems [12].

Since the 1949 when Shannon presented the theoretical limit of error correcting codes, many of codes were proposed but did not reach to the ideal limit until the turbo coding system. In 1962, a new class of error correcting code was proposed by Gallager to have performance near of Shannon limit. This code is known as Gallager code which is now known as LDPC code. The LDPC code was capable of achieving a good performance by designing a parity check matrix H with a few '1's spread among many '0's and by presenting an iterative decoding technique. There are two types of LDPC codes depending on the number of '1's in rows and columns. If the number of '1's is to be constant in row and column then this type is known as regular LDPC codes. However, if the number of '1's is varied then this is said to be irregular LDPC codes.

Although the BER performance of the turbo code is close to Shannon limit, but the LDPC achieves performance better than this code. As previously mentioned, the LDPC code can be implemented as irregular code which is operating in GF(q), where q = 4,8 and 16 gives better performances and it is preferred in many current applications [13].

3.1. LDPC Encoder

To find the output codeword from the parity check matrix, this relation can be considered

$$CH^{T}=0 \qquad (3)$$

Where C is a codeword vector and H is a parity check matrix. For (mxn) matrix.

$$P = mH_1^{T}+(mH_2^{T})^{-1} \qquad (4)$$

The task of the encoder is then to produce the codeword for the data word by computing the parity matrix P [10].

3.2 LDPC Decoder

In decoding of the LDPC codes, there are many methods used to perform this task. There are Sum Product (SP), Believe Propagation (BP) and Message Passing (MP). In coding theory, a tanner graph which is a bipartite graph is utilized to achieve longer codes from smaller codes. The graph which is used in both encoder and decoder, consists of n variable notes and m check nodes. If the element of H is a “1” then a check node is connected to a variable node [1].

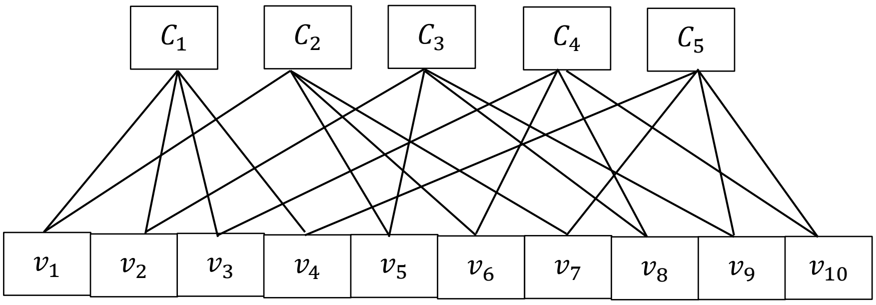

Figure 1. Tanner graph of H matrix.

In message passing algorithm, the decoding process depends on Tanner graph based on the iterative decoding algorithm. In this method, a message is sent to check node from each bit node which is connected to it. Then each check node sends a message to the check node. This process goes on until achieving the result as shown in Figure 1.

4. Proposed LDPC OFDM System

The block diagram of the proposed system is illustrated in Figure 2.The data stream is encoded either by LDPC code or Turbo code then modulated by BPSK modulation to be mapped to a sequence of symbols then converted from serial to parallel. Next, pilot carriers are inserted to enable the system for compensating the channel impact. After that, IFFT is applied to the signal so the subcarriers have been orthogonal to each other. Then the data is converted from parallel to serial to be transmitted through the wireless channel after adding of a cyclic prefix to eliminate the effect of ISI [14].

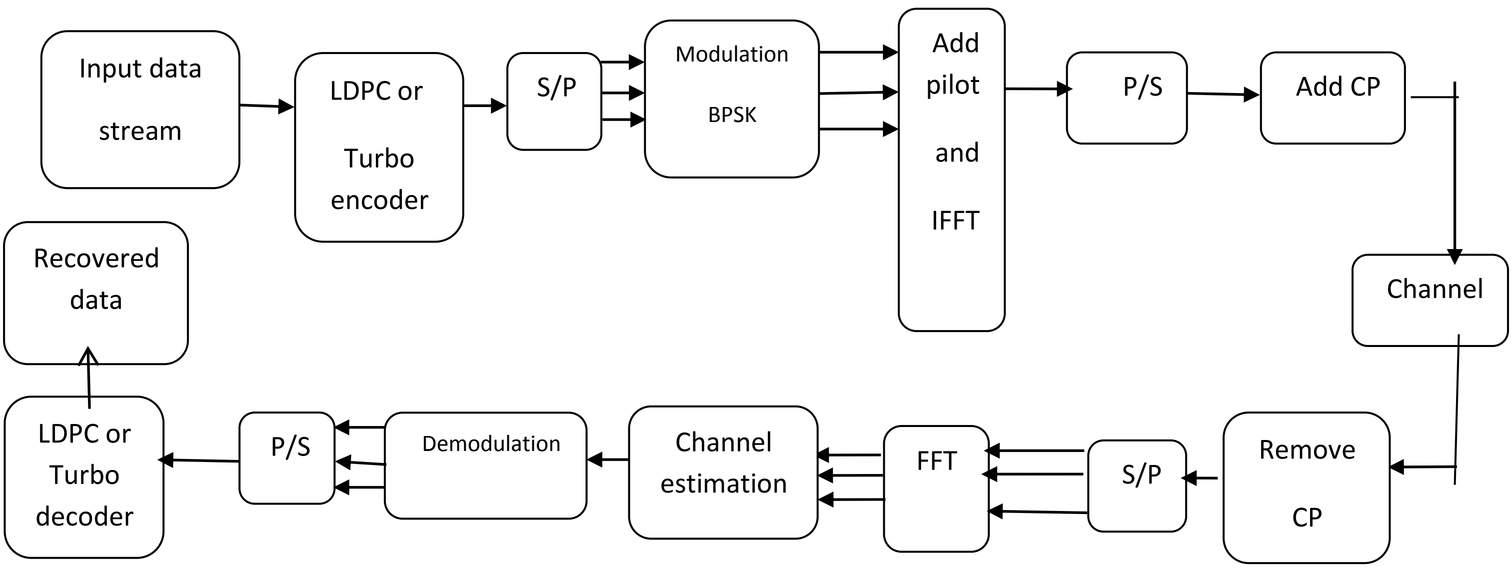

Figure 2. Proposed coded OFDM system

After transmission over the wireless channel, all steps here are the reverse steps to the transmitter side. After removing of CP the conversion from serial to parallel is done then the signal is transformed from time to frequency by passing through the FFT. Then channel estimation using comb type, demodulation before the signal conversion from parallel to serial to prepare the data for the decoding process using Message passing algorithm (hard decision)[12].

5. Simulation Results

The simulation results are obtained using Matlab, the performance of the proposed scheme is tested for parameters presented in Table (1).

Table 1. Performances of the proposed systems

System parameter	Parameter value
Modulation	BPSK
Sample time	$0.05{*}10^{-6}$ sec
Bandwidth	20 MHZ
IFFT/ FFT length	64
Number of pilot subcarrier	4
LDPC rate	1/2,3/4
Turbo code rate	1/2
Channel type	AWGN, Rayliegh channel (static channel Doppler frequency=0 Hz) Rayliegh channel (Doppler frequency =50Hz) Frequency selective channel (2 paths delay[0 2*sample time], gain[0 -1]
Number of data subcarrier	60

In Figure 3 and Figure 4, a comparison between variable code rate and the same code length of two systems of rate 1/2 (1440, 720) WIMAX standard and LDPC with rate (3/4) (1440, 1080) is observed. The other comparison for different code length and code rate is also presented. From these comparisons it can be seen that the rate 1/2 gives better performance than 3/4. The coding gain for these two figures is about 1 dB at BER=10^{-2}. This improvement in BER in case of reducing the code rate and increasing the code length is due to increasing the redundant bits and providing more protection to the data bits.

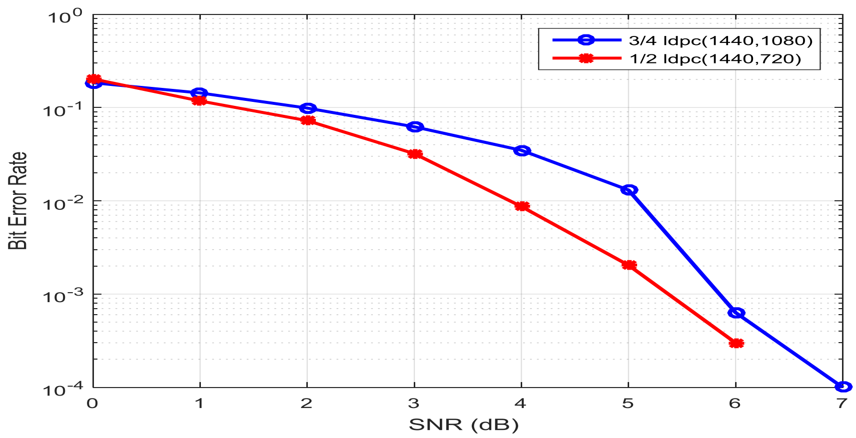

Figure 3. BER performance of LDPC –OFDM system for different rates in Rayleigh channel fd=50 Hz.

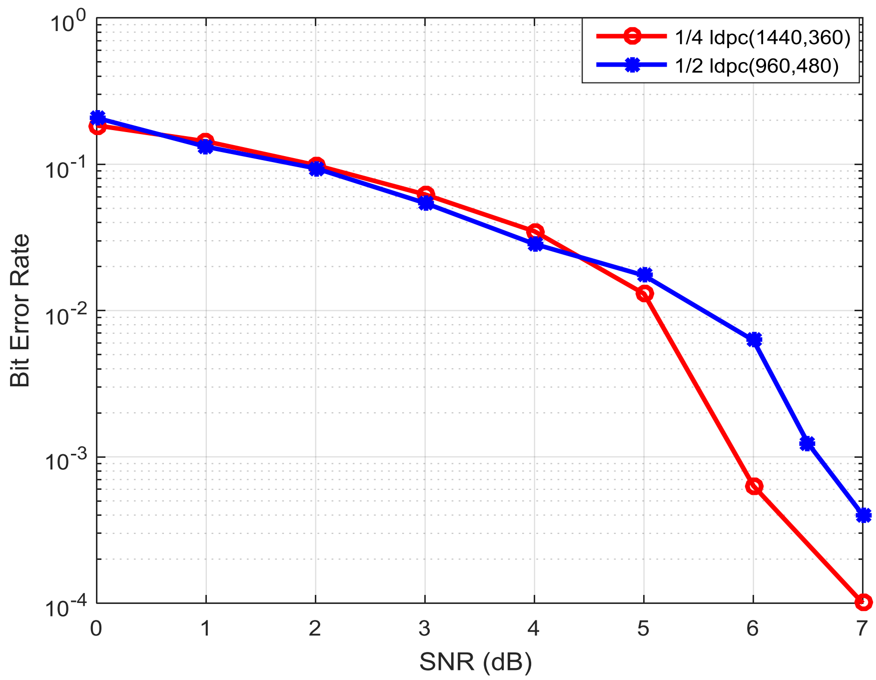

Figure 4. BER performance of LDPC-OFDM system with different lengths and rates in Rayleigh fading channel fd= 30.

The Figure 5 and Figure 6 show the comparison between Turbo code and LDPC code for OFDM systems and encoded OFDM system for a codeword of length 1440 bits through AWGN and Rayleigh fading channel.

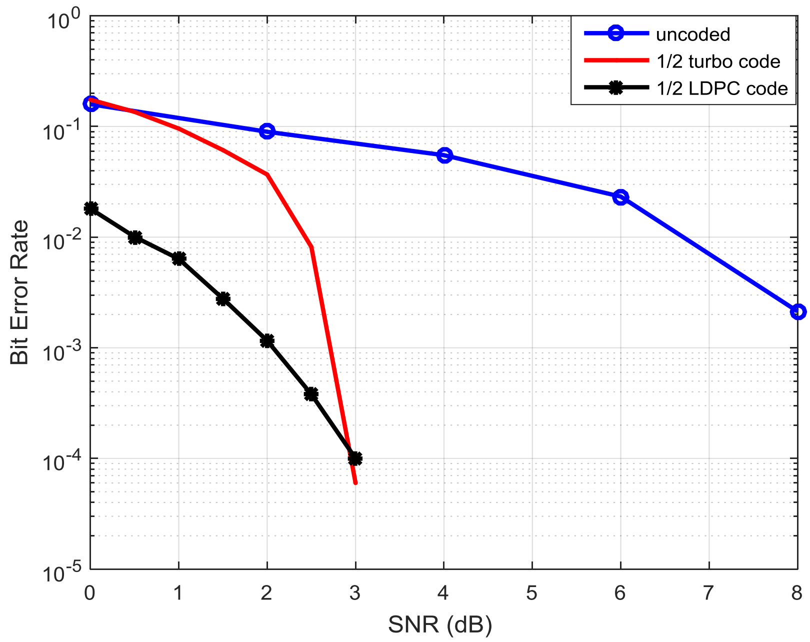

Figure 5. Performance of 1/2 OFDM-LDPC (1440,720) and Turbo coded OFDM systems in AWGN.

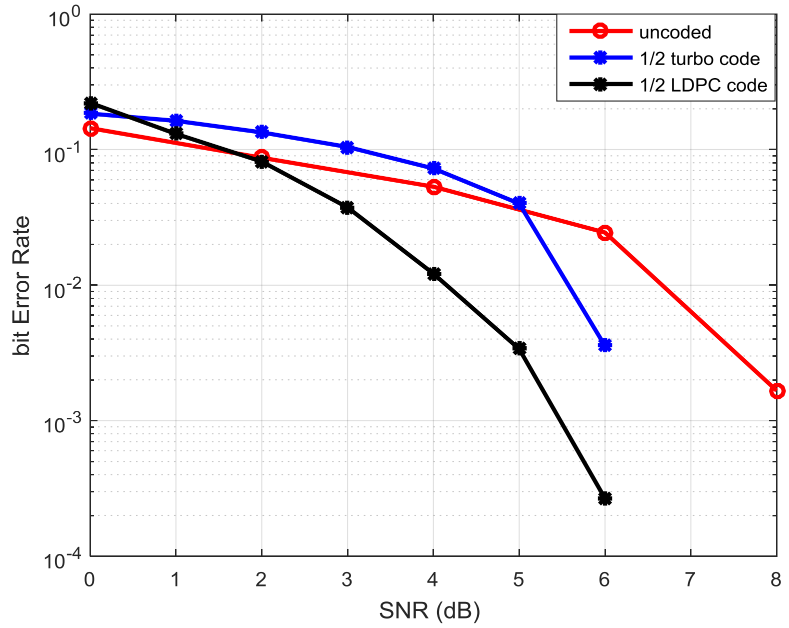

Figure 6. Performance of 1/2 OFDM-LDPC (1440,720) and Turbo coded OFDM system through Rayliegh fading channel fd=50 Hz

From Figure 5and Figure 6 it can be seen that the OFDM-LDPC system provides coding gain of about 6dB through AWGN and 2.6dB through Rayleigh fading channel in comparison to encoded system in case of using codeword of length 1440, and rate of 1/2. While this code provides a coding gain about 0.75dB and 1dB compare with turbo code. This means that the application of LDPC codes provide us with very good improvement in the BER curve and in the performance of the system.

The results of the OFDM-LDPC system for codeword of length 1440 bits through different channel are shown in Figure 7. For the proposed system through selective fading channel, a matrix interleaver is used:

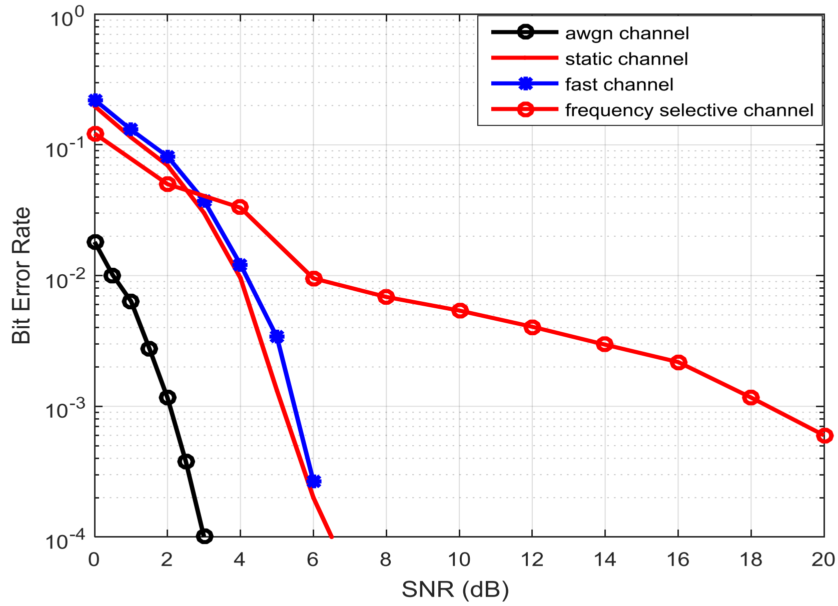

Figure 7. Performance of 1/2coded LDPC (1440, 720) OFDM in different channels.

To study the effect of increasing the number of iteration on the performance of the proposed system, a comparison is done as shown in Figure 8.

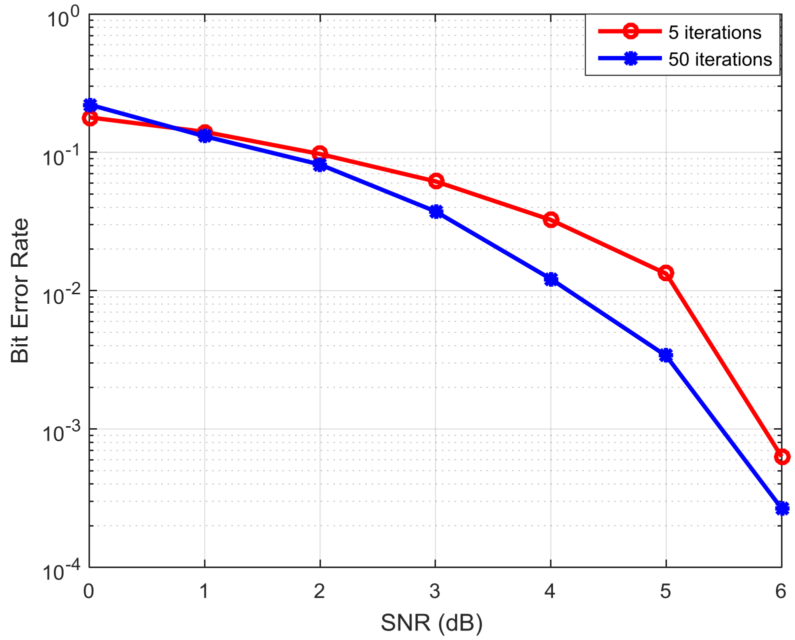

Figure 8. Performance of 1/2 coded OFDM (1440,720) Rayliegh channel fd=50 For different no. of iterations

As shown from this comparison, as the number of iteration increases, the BER performance will be improve about 1dB but from the other side this will cause a delay and complexity for the scheme.

Figure 9 shows the results of the proposed system with and without interleaver for 1/2 code(1440,720) in frequency selective two path channel if fd=50 HZ.

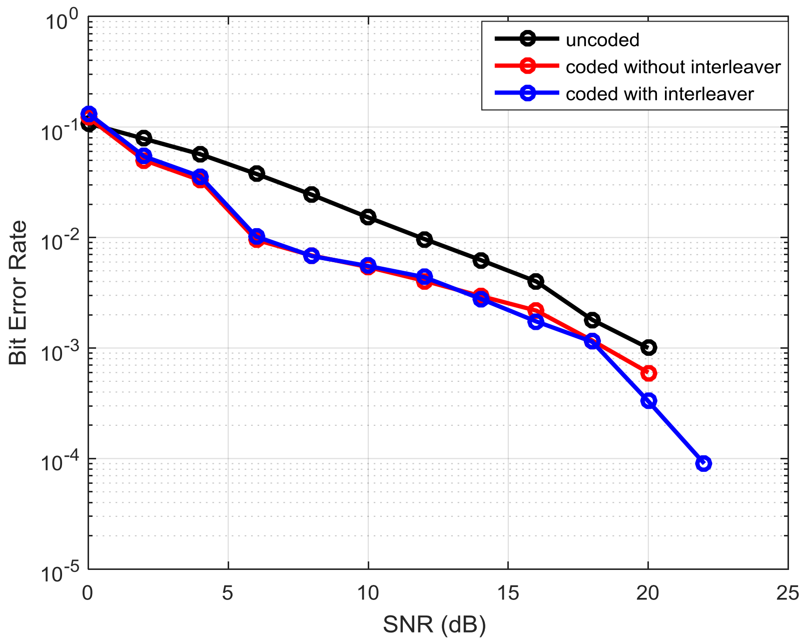

Figure 9. Performance of 1/2 code (1440, 720) OFDM-LDPC in frequency selective two path channel fd=50HZ.

6. Conclusions

In this paper, analysis of OFDM using LDPC code with BPSK modulation technique is explained through different channels. BER performance is the parameter that is used for the analysis of this system. From simulation results, it is clear that using of LDPC in communication systems has the benefit of reducing the effect of multipath channel. It is very evident from the simulation results the improvement in the performance of the system from utilizing this code. From simulation results, it can be seen that the BER performance of LDPC code is better than that of turbo code. The increasing of the number of iteration also enhances the performance of the proposed system.

7. References

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