# Performance Analysis of LDPC Encoded LTE Downlink and Uplink Transceiver

Rakesh Sharma, Nitish Gupta, and Ashish Goswami

***Abstract*—**In this paper, the need of LDPC encoding scheme in LTE/LTE-A system is analyzed in terms of BER performance. It is shown that the target BER of $10^{-4}$ can be achieved at relatively lower SNRs. The link performance of the LDPC encoded uplink and downlink is analyzed for AWGN, Rayleigh and Ped A channels. The OFDMA multiple access technique is used in downlink and SC-FDMA is used in the uplink of the fourth generation 4G wireless communication systems LTE/LTE-A. The simulation results show the considerable improvement in BER performance for multipath fading channel with LDPC encoding scheme in the transceivers. For both Uplink and Downlink transceivers the improvement in BER performance is compared for different scenarios and it is shown that $10^{-4}$ can be achieved at SNR 14 dB (approx.).

***Keywords*—**AWGN channel, BER, LDPC, LTE/LTE-A OFDMA, PedA channel, Rayleigh channel, SCFDMA.

## I. Introduction

THE evolution of new standards in future wireless communication systems have always considered the high data rates along with good error performance in noise and influence limited wireless scenarios. The increasing demand of the data rates in wireless communication and a steady increase of the subscribers are pushing towards high speed mobile broadband technologies. The Long term evolution (LTE) of the 3rd generation partnership project (3GPP) is designed for improved services, high data rate, and good quality of service in mobility, higher spectral efficiency as well as lower latency [1]. LTE uses single carrier frequency division multiple access (SC-FDMA) for the uplink transmission and orthogonal frequency division multiplexing access (OFDMA) in downlink [2], [3]. However other standards such as Worldwide Interoperability for Microwave Access (WiMax) use OFDMA in both links, given the benefits of having the same access scheme in terms of reciprocity, allocation flexibility ,and bandwidth efficiency.SC-FDMA utilizes single carrier modulation and frequency domain equalization, and has similar performance and essentially the same overall complexity as those of OFDMA system. A salient advantage over OFDMA is that the SC-FDMA signal has lower peak to average power ratio (PAPR) because of its inherent single carrier transmission structure. It is important for the uplink transmission, due to the high importance of low mobile station power consumption and manufacturing low cost power amplifier.

A stream of bits is encoded and decoded using LDPC encoder and decoder to improve the BER and also user performance in ISI and noise limited scenarios. LDPC are a class of linear block codes that approach Shannon's Channel Capacity Limit. LDPC Codes use code rate of 1/2 are characterized by sparseness of ones in the parity check matrix.

In section II of this paper, we have discussed the system model for LDPC encoded LTE uplink/downlink transceiver. Also the subcarrier mapping used in downlink and uplink transceiver are discussed in this section. We have presented the simulation parameter and results in Section III is followed by section IV where the conclusion are formulated based on simulation result.

## II. System Model

The proposed system model for high data rate using LDPC encoded downlink and uplink transceiver shown in Fig. 1 and Fig. 2. The use of different subsystems used in the system are as followed.

### *A. LDPC Coding*

Please A stream of bits are encoded using LDPC encoder to improve the BER and also user performance in ISI and noise limited scenarios. LDPC are a class of linear block codes that approach Shannon's Channel Capacity Limit. LDPC Codes use code rate of 1/2 are characterized by sparseness of ones in the parity check matrix [4], [5]. This low number of ones allow for a large minimum distance of the code, resulting in improved performance. These codes are suitable for high data rate. LDPC codes are having capacity approaching near to the Shannon capacity.

### *B. Modulation*

In LTE at the transmitter side, a baseband modulator transmits the binary input to one of several possible modulation formats such as binary phase shift keying (BPSK), quandary PSK (QPSK), 8 level PSK (8PSK), I6 QAM, and 64-QAM. Using high order modulation scheme, high spectral efficiency and high data rate but having less susceptibility noise and interference. Hence we focused in lower modulation

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to achieve better noise performance using error correcting codes. These modulated symbols, are passed through N-point discrete Fourier transform (DFT) to generate SC-FDMA symbol and will have poor noise/interference.

### *C. OFDMA*

The main principle of OFDMA is to split the data stream to be transmitted onto a high number of narrowband orthogonal subcarriers by means of an inverse fast Fourier transform (IFFT) chip, which in turn increase symbol period known as OFDM symbol period. The cyclic prefix is appended to the initial portion of the OFDM symbol as the starting portion of the OFDM is prone to ISI due multipath propagation. A realization of this guard interval is the so-called cyclic prefix (CP), which the repetition of the last portion of an OFDM symbol.

As long as the guard interval is longer than the maximum excess delay spread of the channel, degradations due to intersymbol interference (ISI) and intercarrier interference (ICI) are avoided. Furthermore, the goal of employing narrowband subcarriers is to obtain a channel that is roughly constant over each given subband, which makes equalization simpler at the receiver. Finally, since these subcarriers are mutually orthogonal, overlapping between them is allowed, yielding to spectral efficient system.

But, despite all these benefits, OFDM also have some drawbacks: sensitivity to Doppler shift, synchronization problems, and high power consumption & inefficient power amplifier design due to high PAPR.

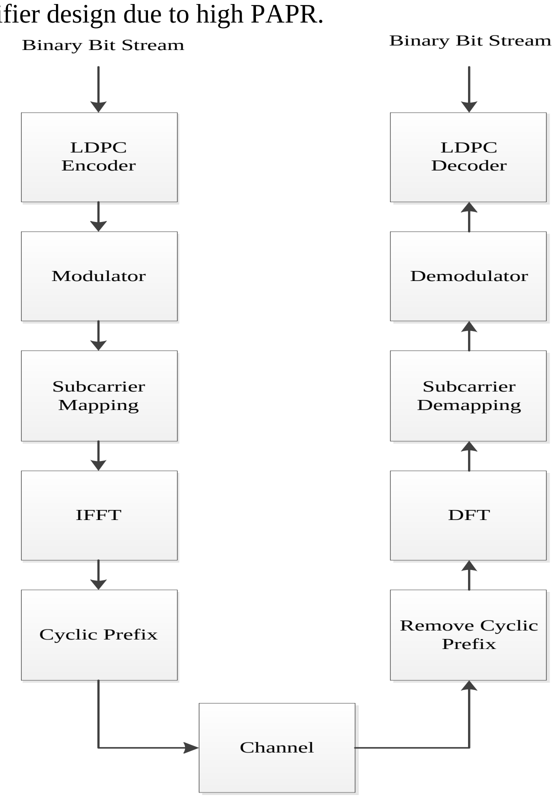


Fig. 1 LTE downlink transceiver

### *D. SC-FDMA*

SC-FDMA is a multiple access scheme based on the single-carrier frequency-division multiplexing (SC-FDM) modulation technique, sometimes is also referred as discrete fourier transform (DFT)-spread OFDM. Its main principle is the same as OFDM that of and hence benefits in terms of multipath mitigation and low-complexity equalization are still achievable. The difference though is that a DFT is performed prior to the IFFT operation, which spreads the data symbols over all the subcarriers carrying information and produces a virtual single-carrier structure. As a consequence, SC-FDM presents a lower PAPR than OFDM. This property makes SC-FDM attractive for uplink transmissions, as the user equipment (UE) benefits in terms of transmitted power efficiency. On one hand, DFT spreading allows the frequency selectivity of the channel to be exploited, since all symbols are present in all subcarriers. Therefore, if some subcarriers are in deep fade, the information can still be recovered from other subcarriers experiencing better channel conditions. On the other hand, when DFT despreading is performed at the receiver, the noise is spread over all the subcarriers and generates an effect called noise enhancement, which degrades the SC-FDM performance and requires the use of a more complex equalization based on a minimum mean square error (MMSE) receiver.

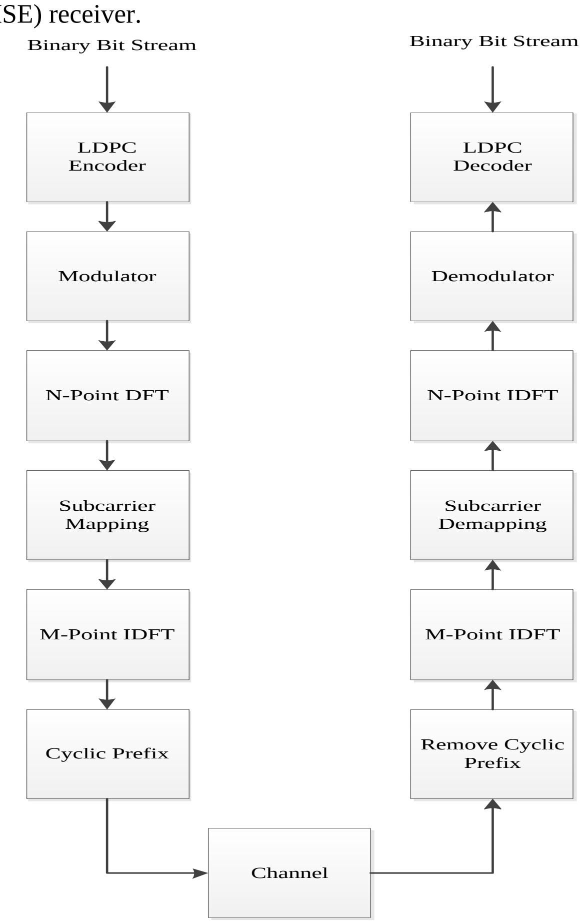


Fig. 2 LTE uplink transceiver

DFT output of the data symbols is mapped to a subset of subcarriers, a process called subcarrier mapping. The subcarrier mapping assigns DFT output complex values as the amplitudes of some of the selected subcarriers. Subcarrier mapping can be classified into two types: localized mapping and distributed mapping.

In localized mapping, the DFT outputs are mapped to a subset of consecutive sub-carriers thereby confining them to only a fraction of the system bandwidth.

In distributed mapping, the DFT outputs of the input data are assigned to subcarriers over the entire bandwidth non continuously, resulting in zero amplitude for the remaining subcarriers.

### *E. Subcarrier mapping*

A special case of distributed SC FDMA is called interleaved SC-FDMA, where the occupied subcarriers are equally spaced over the entire bandwidth. Figure 6 is a general picture of localized and distributed mapping.

| | | | |
|---|---|---|---|
| X0 | X1 | X2 | X3 |

Time domain symbols

| | | | |
|---|---|---|---|
| N0 | N1 | N2 | N3 |

Frequency domain symbols

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | N0 | N1 | N2 | N3 |

1(a)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N0 | N1 | N2 | N3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

2

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | N0 | N1 | N2 | N3 | 0 | 0 | 0 | 0 |

3

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N0 | 0 | 0 | 0 | N1 | 0 | 0 | N1 | 0 | 0 | N2 | 0 |

4

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N0 | 0 | 0 | N1 | 0 | 0 | N2 | 0 | 0 | N3 | 0 | 0 |

4

Fig. 3 Types of SC-FDMA subcarrier mapping schemes 1(a)-1(c) LFDMA (2) DFDMA (3) IFDMA

### *F. Channel*

In this paper we have use three different type of channel model to analyze the performance of the system such as AWGN channel, Rayleigh channel and Extended Pedestrian.

For the channel model Extended Pedestrian-A (EPA) channel model, which 3GPP has approved for LTE modeling. It's a multipath fading channel which might be modeled as a tapped-delay line with 7 non-uniform delay taps.

## III. Result

The BER performance using LDPC coded QPSK modulation scheme used in LTE downlink and uplink transceiver shown in Figure. Due to requirement of high data rate we use higher order of modulation scheme but use of higher modulation there is slightly increase PAPR value in SC-FDMA. But by using LDPC error correction codes an increase in PAPR can be used in uplink as well in downlink.

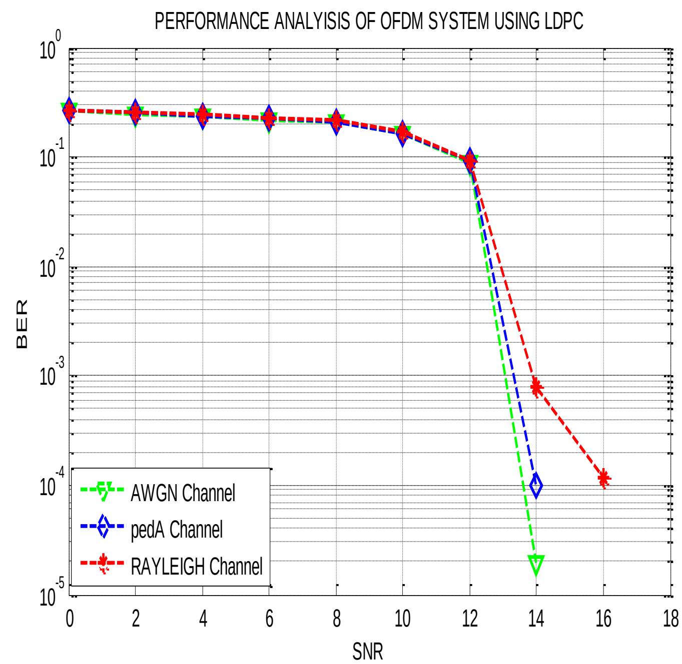


Fig. 4 BER performance of OFDM using LDPC

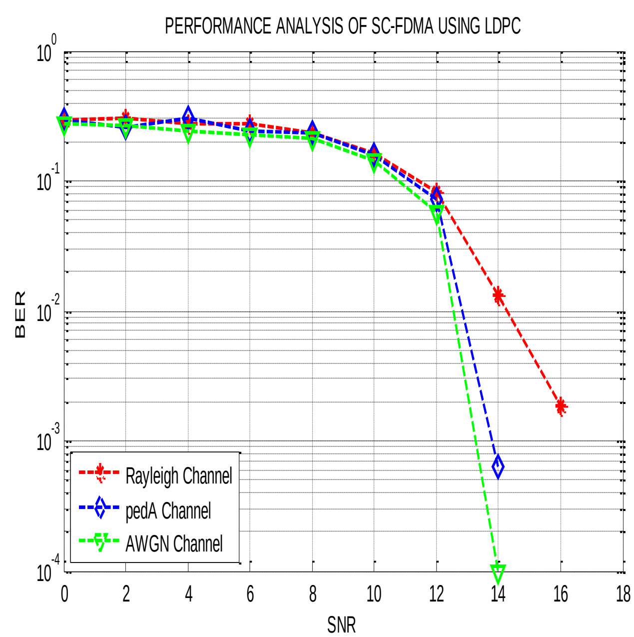


Fig. 5 BER performance of SC-FDMA using LDPC

## IV. Conclusion

This paper provides a simulation for finding the optimum pair for the high data rate LTE transceiver. LDPC codes are used to provide the reliability of the system, which is more suitable for higher data rates. For the high data rate requirements of LTE transceiver, 64–QAM is used. IFDMA subcarrier mapping is used in SC–FDMA since it is more energy efficient in higher order modulation schemes. Hence, the best optimal pair for the high data rate LTE uplink transceiver is LDPC and SC–FDMA pair which provides less PAPR value in higher data rates i.e. its energy efficiency is more.

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## References

[1] Dr. G. Indumathi and D. Allin Joe, "Design of Optimum Physical Layer Architecture for a High Data Rate LTE Uplink Transceiver," IEEE International Conference, March 2013.

[2] M. M. Rana, 1. Kim, and W. K. Cho, "Low complexity downlink channel estimation for LTE systems," in Proc.12th International Conference on Advanced Communiction Technology on, Feb. 2010, pp. 1198-1202.Science, 1989.

[3] M. Zhou, B. Jiang, T. Li, W. Zhong, and X. Gao, "DCT - based channel estimation techniques for LTE uplink," in Proc. Personal, Indoor and Mobile Radio Commun., Sept. 2009. M. Zhou, B. Jiang, T. Li, W. Zhong, and X. Gao, "DCT -based channel estimation techniques for LTE uplink," in Proc. Personal, Indoor and Mobile Radio Commun.,Sept.2009.

[4] Hao Zhong, and Tong Zhang, "Block-LDPC: A Practical LDPC Coding System Design Approach," IEEE Transactions On Circuits And Systems— I: Regular Papers, vol. 52, no. 4, pp. 766–775, April 2005. http://dx.doi.org/10.1109/TCSI.2005.844113

[5] Ying Wang, Lei Xie, Huifang Chen, and Kuang Wang,"Improved Decoding Algorithm of Bit-Interleaved Coded Modulation for LDPC code," IEEE Transactions On Broadcasting, vol. 56, no. 1, pp. 103–109, March 2010.
http://dx.doi.org/10.1109/TBC.2009.2036950