RS Codes for Downlink LTE System over LTE-MIMO Channel

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Abstract

Nowadays, different applications require a modern generation of mobile communication systems; long term evolution (LTE) is a candidate to achieve this purpose. One important challenge in wireless communications, including LTE systems, is the suitable techniques of controlling errors that degrade system performance in transmission systems over multipath fading channels. Different forward Error correction (FEC) techniques are required to improve the robustness of transmission channels. In this paper, Reed-Solomon (RS) codes were used with a downlink LTE system over a LTE-MIMO channel. This research contributes by combining RS codes that have low decoding complexity (by using hard decision decoding) with a LTE-MIMO channel to improve downlink LTE system performance. The results show that using RS codes clearly improves LTE system performance and thus decreases Bit Error Rates (BER) more than convolutional and turbo codes which have high decoding complexity. Lastly, the results show also extra improvements of downlink LTE system performance by increasing the number of antennas of the LTE-MIMO channel.

Keywords: LTE, RS, MIMO, BPSK, QPSK

1. Introduction

Using data and voice services in mobile communication systems has become a life necessary today, so there is huge demand for improvements in these technologies. LTE is a good solution to provide these applications and thus is a candidate for future technological innovation [1, 2] due to it supports high data rates systems [3, 4]. Orthogonal Frequency Division Multiplexing (OFDM) is considered a key technology of 3GPP LTE and 4G, as well as 802.11n WLAN and IEEE 802.16m WiMAX, due to its combating selective fading channel. It can be easily implemented using Discrete Fourier Transform (DFT), which makes OFDM an attractive technology for Broadband mobile wireless. Combining the Multi Input Multi Output (MIMO) technique with OFDM provides a good solution for 4G networks [5]. MIMO technique is applied through using multi antennas in both of transmitter and receiver to improve data rates, channel capacity, network coverage and link reliability [6].

The channel in mobile environments is divided into frequency and time selective fading; using OFDM will combat any Inter Symbol Interference (ISI) that occurs [5]. An orthogonal Frequency Division Multiplexing Access (OFDMA) is used in the transmission scheme for downlink LTE; this is a multi-user version of OFDM [7, 8]. When time-invariance exists in the frequency selective channel, OFDM systems support using simple one-tap equalization [9]. In contrast, in high mobility cases, performance is degraded and equalization is needed to improve performance [10, 11]. Achieving robustness in the radio link of any wireless communication systems requires channel coding techniques. When performing source coding, channel coding will add a new controlled redundancy [12].

Powerful techniques are needed in a LTE system to control errors in the transmission channel. Adding parity bits to the signal data stream is considered a method of error control; the goal of adding these bits is to detect and correct errors [12, 13]. Some powerful techniques for FEC have been suggested in LTE system such as convolutional codes in [13-15], although their techniques improved the system performance but they also faced the problem of high convolutional decoding complexity [16]. In contrast, other studies such as [17-19] are adopted turbo codes with LTE to improve the reliability. However, high decoding complexity is still a
common demerit of turbo codes [20], as well the results of the decoding are not stable and thus it is necessary to achieve the balance between the decoding performance and complexity [12]. In wireless communication systems, RS codes are widely used due to the high capability of correcting burst errors and random errors. There are two RS decoding processes: Soft Decision Decoding (ASD) and Hard Decision Decoding (HDD). Practically, HDD is popular used in different applications due to its lower complexity than ASD [21]. Therefore, to achieve robust error control in Downlink LTE system over LTE MIMO channel, RS codes (that using HDD) which have low decoding complexity are proposed in this paper, while the channel capacity can be enhanced using MIMO technique [6]. The performance of proposed system was tested using a multipath fading LTE MIMO channel. The simulation was done using two types of modulation (BPSK and QPSK) to show which type gives extra improvement to the system performance.

2. The Proposed Method

The proposed Downlink LTE system by using RS codes has been depicted in Figure 1 to explain the whole block diagram of the proposed LTE system. While, the parameters of LTE environments that used in the suggested LTE system design are explained in Table 1. In this paper, MATLAB software has been used to evaluate the performance of LTE system over LTE-MIMO channel in presence of multipath fading channel.

![Figure 1. Proposed LTE system](image)

<table>
<thead>
<tr>
<th>Table 1. Simulation Environment of the LTE System</th>
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<tbody>
<tr>
<td>Transmission Bandwidth</td>
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<tr>
<td>Channel</td>
</tr>
<tr>
<td>Number of IFFT/FFT Points</td>
</tr>
<tr>
<td>No. of Occupied Sub-carrier</td>
</tr>
<tr>
<td>Cyclic Prefix Length</td>
</tr>
<tr>
<td>Modulation</td>
</tr>
<tr>
<td>Sampling Rate</td>
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<tr>
<td>Error Correcting Techniques</td>
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</tbody>
</table>

2.1. Reed-Solomon Codes

Reed and Solomon proposed a new type of ECC in [22] and called reed-solomon codes. It is considered non-binary cyclic codes. The symbols of RS codes consist of positive integer values (> 2) of m bit sequences. The form of RS codes is represented as [23].

\[ \text{RS}(n, k) \quad 0 < k < n < 2m + 2 \]

Since, n defined as total number of code symbols (in the encoded block) and the value of data symbols k that have been encoded. Classic RS (n, k) code is as follows [23].
The capability of the code’s symbol error correcting is represented by \( t \), where \( t = n - k \) represents the parity symbols number. RS codes have a good capability of error correction, especially when dealing with burst of errors [23].

In general, RS decoding procedure phases as following [24]:

a. Determine the syndrome from received codeword.

b. From syndrome and using own derived equations could select the error location and error value polynomial.

c. By using error value polynomial and error location, could correct the symbols that have errors.

Suppose, \( \alpha \) is the primitive element of GF \((q)\) and \( \alpha^{q-1} \) equal to 1. Then, RS code can be obtained by the following polynomial [25].

\[
g(x) = (X-\alpha) (X-\alpha^2) \ldots (X-\alpha^{n-k}) \\
= (X-\alpha) (X-\alpha^2) \ldots (X-\alpha^{2t}) \\
= g_0 + g_1 X + g_2 X^2 + \ldots + g_{2t-1} X^{2t-1} + g_{2t} X^{2t}
\] (1)

By a given generator polynomial of (1), an RS code \( CRS(n, n-2t) \) is a linear and cyclic block generated consist of code polynomial \( c(x) \) that have \((n-1)\) degree or less. All coefficients of these polynomials are elements in GF\((2^m)\). When multiplies the code polynomials by generator polynomial, will obtaining all its roots [25].

Assume \( m(X) \) is message polynomial and created as in (2). While, all coefficients of these message polynomials are also elements of GF\((2^m)\). The systematic method is used to obtain the remainder \( p(x) \) through divided \( X^{n-k} m(X) \) by \( g(X) \) as in (3) [25].

\[
m(X) = m_0 + m_1 X + m_2 X^2 + \ldots + m_{k-1} X^{k-1}
\] (2)

\[
X^{n-k} m(X) = q(X) g(X) + p(X)
\] (3)

---

2.2. Interleaver/ De-Interleaver

To combat the burst of errors in the transmission channel, an interleaver has been used to re-request input bit series to a non-adjacent method [26]. Where, using the interleaving process after RS encoder is very important to enhancing the capability of error correcting in the receiver [27]. Therefore, by using Interleaver/De-Interleaver process in LTE system, the system will be more effective in combating the errors and thus improving the system performance through decreasing BER.

2.3. Modulation

Two modulation schemes have been used in this paper for comparison in the proposed system. We chose both BPSK and QPSK, due to their good performance compared with other types of modulation. Where, lower order modulations (for instance QPSK and BPSK) improve system performance better than high order modulations (for instance as 64-QAM and 16-QAM) in terms of BER and Signal to Noise Ration (SNR) [28].
2.4. LTE MIMO Channel

A 3GPP-LTE of Release 10 was created in this channel; it was particular for the MIMO system over multipath fading channel. The signal has been passed via multipath fading channel using the LTE-MIMO channel [29]. First, a MIMO system using two transmitter and receiver antennas was used, then four transmitter and receiver antennas were used in a second scenario.

3. Results and Discussion

MATLAB software was used in this paper to simulate a Downlink LTE system. It was done to test the proposed system performance over a multipath fading channel using a LTE-MIMO channel. The performance of Downlink LTE system was improved using RS coding technique for both of modulation types BPSK and QPSK. The system performance is presented by the curve of BER versus SNR.

The comparison of the system performance was done among each of un-coded, convolutional codes, turbo code and reed Solomon codes to show the improvements of BER for each case. Figure 2 shows the simulation results of RS-Downlink LTE system performance using BPSK over (2X2) LTE-MIMO channel against each of un-coded, convolutional codes, turbo code. It is clearly shows that the performance of un-coded system was the worst, while the performance began to improve after (8 dB) SNR using convolutional and turbo codes. The performance when using RS codes was the best compared with un-coded, convolutional and turbo codes for all values of SNR. Therefore, using RS codes with Downlink LTE system over (2X2) LTE-MIMO channel gave good coding gains and thus clearly improved system performance more than using both of convolutional and turbo codes with BPSK.

Figure 2. The Downlink LTE system performance over LTE-MIMO channel (BPSK)

Figure 3 shows the simulation results of RS- Downlink LTE system performance using QPSK over LTE-MIMO channel against each of un-coded, convolutional code, turbo code. The performance of the uncoded system was also the worst with a QPSK modulation scheme compared with using coding techniques. Then, the system performance improved starting after around 12dB by using both of convolutional and turbo codes. The best performance for each values of SNR compared with all of uncoded, convolutional and turbo codes was when using RS codes. Therefore, the Downlink LTE system performance over (2X2) LTE-MIMO channel...
clearly improved for both BPSK and QPSK modulation schemes compared with using both of convolutional or turbo codes, as shown in both of Figures 2 and 3.

Figure 3. The Downlink LTE system performance over LTE-MIMO channel (QPSK)

Figure 4 shows a comparison of proposed system performance when using BPSK versus QPSK modulation schemes. The Downlink LTE system performance over (2X2) LTE-MIMO channel clearly improved more with BPSK than with QPSK modulation scheme for both uncoded and RS codes as shown in Figure 4. The coding gain achieved using RS codes with BPSK in the proposed system was around 4 dB at $10^{-2}$ compared with QPSK.

Figure 4. Comparison between Downlink LTE system performance over LTE-MIMO channel (QPSK versus BPSK)
Figure 5 shows the comparison between using (2X2) versus (4X4) MIMO channel for the proposed system. The comparison shows extra improvement using a (4X4) compared with using a (2X2) antennas MIMO system. Therefore, the Downlink LTE system performance was enhanced by increasing the number of antennas in the MIMO channel for both of BPSK and QPSK modulation schemes.

![Graph showing comparison between (2X2) vs (4X4) MIMO channel](image)

Figure 5. Downlink LTE system performance over LTE-MIMO channel

4. Conclusion

One of the important challenges facing wireless communication systems, including LTE, is controlling errors in transmission systems over multipath fading channels. The simulation of a Downlink LTE system performance over LTE-MIMO channel was carried out using Reed-Solomon (RS) codes. The combining of RS codes with a LTE-MIMO channel to improve the downlink LTE system performance is a novel contribution of this paper. A comparison between using RS codes and both of convolutional and turbo codes that already suggested in Downlink LTE system was presented in this paper. The results show an advantage of using RS codes compared with all of uncoded, convolutional and turbo codes in the proposed system’s performance. On the other hand, the coding gain achieved in the proposed system using RS codes with BPSK was around 4 dB at $10^{-2}$ compared with QPSK. This research proves that Downlink LTE system performance is improving when utilizing RS codes and extra improvements can be gained by increase the number of antennas in the LTE-MIMO channel for both the BPSK and QPSK modulation schemes.

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