Features of Equalization in LTE Technology with MIMO and SC-FDMA

Valerij Loshakov, Ali Abdourahaman
Department of Telecommunication Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
ut3ee.v@gmail.com, alzabrmaowy@gmail.com

***Abstract*— LTE is one of the standards for mobile telephones of the next generation, that is why the article provides an overview of the basic methods in the LTE equalization with MIMO and SC-FDMA channels, where the maximum delay is greater than the length of the guard interval. The three methods of compensation: time interval and frequency domain turbo equalization are considered.**

Keywords*— *LTE, SC-FDMA, OFDMA, MIMO, correction, MMSE-BLE, RNN

I. INTRODUCTION

The Long Term Evolution (LTE) is one of communication standards for next-generation mobile phones, which has evolved the high-speed data communication standard HSDPA for the mainstream 3G (third generation) mobile phone system W-CDMA at present. Data communication volume of mobile phones is rapidly increasing at present due to dissemination of smart phones and mobile communication. Therefore, expansion of communication band (capacity) is a critical issue for communication carriers. Because the LTE that allows high-speed data communication with low delay is superior in terms of the radio wave use efficiency, many of major communication carriers in the world have indicated a policy of adopting the LTE. The rapid dissemination of the LTE in the future is expected. In this report we overview the fundamental techniques of equalization in LTE technology with MIMO and SC-FDMA in channels where the maximum delay exceeds the length of the Guard Interval. The goal of employing narrow band sub carriers is to obtain a channel that is roughly constant over each given sub band , which makes equalization much simpler at the receiver. There are three types of equalization techniques considering advantage and disadvantage: time domain, frequency domain and turbo equalization. On the basis of these compeering practical recommendation for choice method of equalization are given. To enhance this frequency use efficiency, antenna technologies, including Multi Input Multi Output (MIMO) that allows transmission/reception with multiple antennas and Space Division Multiple Access (SDMA) that allows multiple access between base stations, have been introduced. Furthermore, Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier Frequency Division Multiple Access (SC-FDMA) are used as multiplexing systems.

II. EQUALIZATION

In report different equalization techniques are briefly considered. In particular very effective is the time domain equalization (TEQ).It is using a short FIR filter at the receiver input that is designed to shorten the duration of the channel impulse response (L). Thus it allows a reduction in the guard interval length. Using a filter with up to 20 coefficients, the effective channel impulse response of a typical AWGN channel can easily be reduced by a factor of 10. Different cost functions such as minimum mean squared error, maximum shortening signal-to-noise ratio (SNR), and minimum inter-symbol interference (ISI), and maximum bit rate have been proposed to design the (TEQ). Each received symbol yi of a block can be written as a sum of the useful part of the symbol, interference and noise

$$\tilde{y} = r_{ii} y_i + \sum_{i=1, i \neq j}^{N} r_{ij} y_i + n_{ci} \ ,$$

$$\tilde{y}_k^{(l)} = yk - \sum_{j=1}^{K} \frac{rkj}{rkk} \tilde{y}_k^{(l-1)} \ ,$$

$$\tilde{y}_k^{(l)} = \theta(\tilde{y}_k^{(l)})$$

In (1) rij are the elements of the discrete-time channel matrix [1]. The idea of the(recurrent neural network) RNN equalizer [2] is to estimate the interference and subtract it from the received symbol. After the final iteration step loglikelihood ratios (LLRs), are calculated and passed to the turbo decoder. The activation function θ(·) builds the core of the RNN equalizer. The optimum activation function for complex-valued symbol alphabets has been derived by Sgraja et al. For binary phase shift keying the well-known hyperbolic tangent function is obtained. Based on the remaining interference power and the noise power the optimum activation function is calculated in each iteration step. For the tangent hyperbolic function the remaining degree of freedom to be adjusted is the slope at the point of inflection.

III. MAIN DIFFER OFDMA AND SC-FDMA OF LTE

OFDMA is a multiple access scheme based on the well-known orthogonal frequency-division multiplexing (OFDM) modulation technique. Its main principle 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) operation, which allows an increased symbol period. The latter, together with the use of a guard interval appended at the beginning of each OFDM symbol, provides this technology with great robustness against multipath transmission [3]. A realization of this guard interval is the so-called cyclic prefix (CP), which consists of a repetition of the last part of an OFDM symbol. As long as the CP is longer than the maximum excess delay of the channel, degradations due to inter symbol interference (ISI) and inter carrier interference (ICI) are avoided. Furthermore, the goal of employing narrowband subcarriers is to obtain a channel that is roughly constant over each given sub band, which makes equalization much simpler at the receiver. Finally, since these subcarriers are mutually orthogonal, overlapping between them is allowed, yielding a highly spectral efficient system. Despite all these benefits, OFDM also presents some drawbacks: sensitivity to Doppler shift, synchronization problems, and inefficient power consumption due to high PAPR [3]. SC-FDMA is a multiple access scheme based on the single-carrier frequency-division multiplexing (SC-FDM) modulation technique, sometimes also referred to as discrete Fourier transform (DFT)-spread OFDM. Its main principle is the same as for OFDM; thus, the same benefits in terms of multipath mitigation and low-complexity equalization are achievable [4]. 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 [5]. 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 dispreading 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 [4].

IV. CONCLUSION

The LTE allows high-speed data communication (reception: 100 Mbps or higher and transmission: 50 Mbps or higher). Since the frequency band is expanded up to 20 MHz, the logical maximum transmission rate is 326.4 Mbps in reception and 86.4 Mbps in transmission. The data communication rate is higher than that of 3G/3.5G even at the same frequency band, which allows acceptance of a lot of users. Furthermore, the LTE achieves low-delay transmission with a connection delay of 100 ms or less and a radio section transmission delay of 5 ms or less. Thus the LTE is suited for audio communication, moving picture distribution, and online games. The best performance is introduced by turbo equalization due to the improvement of the equalized signal estimation on the each iteration and better cancelation of the ISI component. OFDMA and SC-FDMA has several benefits over other transmission schemes like high spectral efficiency due to the orthogonality between subcarriers it is possible to pack them closely together (15kHz subcarrier spacing). Robustness in multi-path environments thanks to the cyclic prefix as mentioned before. A broad frequency range (700 MHz to 2.7 GHz) is adopted for the LTE and frequency bands are allocated to communication carriers in each country.

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