ABSTRACT

In the recent years, it has been observed that the modern broadband cellular communication technologies do not fulfill the higher-data-rate demands and the newly emerging requirements in transmission using wireless channels as there are limitations in terms of bandwidth and power. Orthogonal frequency division multiplexing (OFDM) is a compatible technique that effectively compensates such problems. It is adopted by broadband wireless systems. OFDM offers numerous benefits for wireless communication but the major negative aspect is higher peak-to-average power ratio (PAPR). The addition of OFDM with frequency division multiple access system results in creation of OFDMA. In the third generation partnership project long term evolution(3GPP LTE) wireless standards, single carrier frequency division multiple access (SC-FDMA) system has been adopted for uplink air interface technology, whereas the OFDMA system has been exploited for downlink transmission scheme. SC-FDMA system is more suitable for uplink communication scheme in future cellular system because of its lower PAPR, higher spectral efficiency and robustness to narrowband interference.

In SC-FDMA, the whole transmission bandwidth can be divided into orthogonal subcarriers and they are assigned to multiple user equipments (UEs).The localized FDMA (LFDMA) and interleaved FDMA (IFDMA) allocations are the two popular subcarrier mapping patterns in SC-FDMA. However, SC-FDMA is sensitive to different carrier frequency offsets (CFOs) evolved by oscillator misalignment of the transceiver (UE and uplink receiver) and/or Doppler shifts. The existence of CFO dissolves the orthogonality between subcarriers and generates inter-carrier-interference (ICI) and multiple access interference (MAI), the effects lead to bit error rate (BER) degradation. Multiple UEs occupying overlapped subcarriers have to

be synchronized in terms of proper time and frequency to other UEs that sustain orthogonality among the users.

The main objective of this thesis is to evaluate the SC-FDMA transmission with different scenarios for single-input single-output (SISO) systems as well as for multiple-input multiple-output (MIMO) systems. The thesis presents new low complexity equalization and or a CFO compensation scheme for an uplink SISO SC-FDMA/ MIMO SC-FDMA systems. The proposed scheme effectively mitigates CFO problems such as inter-symbol-interference (ISI), ICI and MAI that are achieved through lower equalization complexity. The new method analyzes the performance of SC-FDMA uplink system for different subcarrier allocation scenarios with different modulation schemes. This thesis proposes two types of equalization schemes to obtain performance improvement. One for linear equalization, which is employed in the uplink single user SC-FDMA/ spatial multiplexing SC-FDMA system and other is nonlinear equalization which is implemented in the space frequency block coding (SFBC) SC-FDMA systems.

Firstly, this thesis investigates iterative minimum mean square error (MMSE) equalization and CFO compensation for the uplink SC-FDMA transmission system. SC-FDMA is greatly sensitive to CFO between transceivers. This leads to destruction of orthogonality among subcarriers which in turn leads to ICI and MAI between different users. MMSE equalizer that uses an inverse operation on an interference matrix quantity with a dimension equal to the number of subcarriers is normally used to invalidate CFO effects. Hence, the terminal processing complexity is very high. The proposed conjugate gradient (CG) method attempts to mitigate the higher computational complexity by iteratively evaluating the MMSE solution without direct matrix inverse operation. To further mitigate the MAI, the MMSE combined with parallel interference cancellation is also implemented.

The analysis of the proposed method shows better performance and fast convergence in SC-FDMA systems. The maximum iteration number to formulate an accurate solution is almost equal to the number of active users in the uplink access. Simulation results bring out the effectiveness of the present method compared to the existing CFO compensation schemes in terms of computational complication and system performance with large frequency offsets.

Second, an iterative CG algorithm based linear detection for uplink MIMO SC-FDMA system is considered. Spatial multiplexing SC-FDMA system with linear detection by the zero forcing (ZF) and/or MMSE filter is generally simple and efficient. However, this method requires an inversion of a matrix whose size equals the number of subcarriers. Also, the linear detector is too complex to be implemented in systems with large number of antennas, large number of subcarriers and users, and higher order modulations. In a practical MIMO SC-FDMA system, receiver complexity is an important concern and a receiver detection scheme with low complexity is always desired. The low complexity linear receivers such as ZF and MMSE receiver have addressed this concern. The proposed CG method attempts to mitigate the higher computational complexity by iteratively evaluating the ZF/ MMSE solution without direct matrix inverse operation. The analysis of the proposed method shows better performance and fast convergence in spatial multiplexing SC-FDMA systems. Simulation results reveal that the proposed algorithms have lower complexity and offer better bandwidth efficiency than the existing schemes. It is also shown that this scheme performance is found to be closer to the matched filter bound (MFB) with only a few iterations of the equalizer.

The final contribution is based on the study of iterative nonlinear detection for SFBC SC-FDMA uplink MIMO transmission systems. SC-

FDMA systems with SFBC transmissions achieve both spatial and frequency diversity gains in wireless communications. However, SFBC SC-FDMA schemes using linear detectors suffer from severe performance deterioration due to noise enhancement propagation and additive noise presence in the detected output. Both issues are similar to ISI. Traditionally, SC-FDMA system decision feedback equalizer (DFE) is often used to eliminate ISI caused by multipath propagation. This thesis proposes frequency domain turbo equalization based on nonlinear multiuser detection for uplink SFBC SC-FDMA transmission systems. The presented iterative receiver performs equalization with soft decisions feedback for ISI mitigation. Its coefficients are derived by using minimum mean squared error criteria. The receiver configuration study is Alamouti's SFBC with two transmit and two receive antennas. The new receiver approach is compared with the recently proposed suboptimal linear detector for SFBC SC-FDMA systems. Simulation results confirm that the performance of the proposed iterative detection outperforms conventional detection techniques. After a few iterations, BER performance of the proposed receiver design is closer to the MFB.

This dissertation is aimed to propose a low complexity iterative detection method for SISO SC-FDMA/ MIMO SC-FDMA uplink system over fading channels. The performances of the proposed systems are evaluated and analyzed based on the simulations that are carried out in the MATLAB environment.