Orthogonal frequency division multiplexing (OFDM) has become a widely accepted technique for high data rate wireless access systems. Indeed, due to its inherent robustness to multipath propagation, OFDM has become the modulation choice for many communication systems. Moreover, multiple antennas placed at the transmitter and/or receiver in wireless communication systems can be used to substantially improve system performance by leveraging the "spatial" characteristics of the wireless channel. These systems, now widely termed as Multiple Input Multiple Output (MIMO), require two or more antennas placed at the transmitter and at the receiver. OFDM can be used in conjunction with a MIMO transceiver to increase the diversity gain and/or the system capacity.

This research considers various problems of transmitting multi-carrier signals over peak-limited channels. Peak-limited channels provide more design challenges as it imposes the peak power constraints to the transmitted signals. The motivation behind peak-limited channels is to capture the negative effects of the high power amplifiers (HPA) saturation and thereby mitigate the induced signal distortions. This research investigates low-complexity algorithms for mitigating the nonlinear distortions in OFDM systems over peak-power-limited channels. Several problems in wireless OFDM communications under various channel impairments (channel distortions) have been identified and solved. The undertaken research focuses on preamble and pilot symbols design for estimation and compensation of channel impairments in OFDM systems while capturing the negative effect of peak-limitation. The research also studies the problem of designing pilot symbols for channel estimation in OFDM-based cognitive radio systems.

Both single-input-single-output (SISO) as well as MIMO systems are studied. Several algorithms for estimating and compensating for the channel distortion parameters such as carrier frequency offset (CFO), in-phase/quadrature phase (I/Q) imbalances and minimization of peak to average power ratio (PAPR) have been proposed. Low complexity algorithms that can be adopted in practical systems have been proposed. Through mathematical analysis and numerical simulations, it has been demonstrated that, the proposed algorithms outperform some of the conventional methods under different performance measures. It is also demonstrated that the achievable performance of OFDM systems in a peak-limited and frequency-selective channel is a function of the OFDM design parameters.

Chapter 1 gives the general overview of the problem of transmitting OFDM signal over peak-limited channel. Several channel impairments and their effects in OFDM communication
systems are described. Channel impairments in signal transmission refer to noise, fading, and any distortion that result in transmission quality degradation. The motivation of this research, together with the main contributions of the research is explained in detail.

In Chapter 2 designs of preamble for channel estimation and pilot symbols for pilot-assisted channel estimation in OFDM system with null subcarriers is studied. Both the preambles and pilot symbols are designed to minimize the $L_2$ or the $L_\infty$ norm of the channel estimate mean-squared errors (MSE) in frequency-selective environments. We use convex optimization technique to find optimal power distribution to the preamble by casting the MSE minimization problem into a semi-definite programming problem. Then, using the designed optimal preamble as an initial value, we iteratively select the placement and optimally distribute power to the selected pilot symbols. Design examples consistent with IEEE 802.11a as well as IEEE 802.16e are provided to illustrate the superior performance of our proposed method over the equi-spaced equi-powered pilot symbols and the partially equi-spaced pilot symbols.

In Chapter 3, we study the design of long preambles as well as pilot symbols for OFDM that jointly captures the aggregate effects of channel estimation error and peak to average power ratio (PAPR). To the preambles and pilot symbols designed to minimize the mean squared error (MSE) of the channel estimate, we propose an algorithm based on cross entropy (CE) optimization techniques to design phases of the training symbols in order to minimize peak powers of the training symbols. Compared to the exhaustive search method, the proposed algorithm converges fast to the near optimal solution. Due to its high convergence rate, our proposed scheme has a potential to make practical design of phases for different pilot subcarrier sets. Several design examples including the one consistent with IEEE 802.11a/g are provided to illustrate the superior performance of our proposed method over the conventional standards.

Chapter 4 addresses the challenges regarding the provision of channel state information as well as reducing PAPR of a MIMO OFDM system. The MSE of the channel estimate is adopted as the optimization criterion to design pilot symbols for channel estimation in MIMO–OFDM systems with null subcarriers. We design the placement and power distribution to the pilot symbols for multiple transmits antennas to minimize the MSE of the least square (LS) channel estimates. To reduce interference of the pilot symbols transmitted from different antennas, an algorithm to guarantee that pilot symbols are disjoint from any other transmitter pilot set is proposed. To efficiently reduce the PAPR of the MIMO–OFDM signals, a method that mixes dummy symbols and phase information of the pilot symbols is presented. Simulation results based on IEEE 802.16e are presented to illustrate the superior performance of our proposed channel estimation method over the existing standard and the partially equi-spaced pilot symbols. We also demonstrate that, by mixing the dummy symbols and phase information of the pilot symbols, the PAPR of the MIMO–OFDM signals can significantly be reduced.

In Chapter 5, challenges regarding the provision of channel state information (CSI) and carrier frequency synchronization for OFDM systems with null subcarriers are addressed. We propose
novel maximum likelihood (ML) based schemes that estimate the aggregate effects of the carrier frequency offset (CFO) and channel by using two successive OFDM preambles. In the presented scheme, CFO is estimated by considering the phase rotation between two consecutive received OFDM preambles. Both SISO as well as MIMO-OFDM systems are considered. The MSE of the channel and CFO are used to evaluate the performance of our proposed scheme. By using two successive OFDM preambles, the estimation of channel and the estimation of CFO are decoupled, which leads to a simple estimation method. Simulation results show that the BER performance of the proposed estimators is comparable to that of known channel state information and the CFO MSE performance achieves the Cramer-Rao bound (CRB) of the fully loaded OFDM system.

In Chapter 6 training symbol designs for estimation of frequency selective channels and compensation of in-phase (I) and quadrature (Q) imbalances on OFDM transmitters and receivers are studied. We utilize cross entropy (CE) optimization techniques together with convex optimization to design training sequences having low channel estimate MSE and minimum effects of I/Q mismatch, while lowering the peak power of the training signals. The proposed design provides better channel estimate MSE and BER performances and is applicable to OFDM systems with and without null subcarriers. The efficacies of the proposed designs are corroborated by analysis and simulation results.

In Chapter 7 challenges regarding the provision of channel state information in non-contiguous (NC)-OFDM cognitive radio (CR) systems is addressed. We propose a novel scheme that utilizes CE optimization together with an analytical pilot power distribution technique to design pilot symbols that minimizes the channel estimate MSE of frequency selective channels. The optimal selection of pilot subcarriers is a combinatorial problem that requires heavy computations. To reduce the computational complexity, the CE optimization is utilized to determine the position of pilot subcarriers. Then, for a given pilot placement obtained by the CE algorithm, a closed form expression to obtain optimal pilot power distribution is employed. Simulation results indicate that, the proposed pilot symbol design provides better channel estimate MSE as well as the BER performance when compared with the conventional equal powered pilot design.

Finally, Chapter 8 concludes the thesis by summarizing the work done and provides a quick look on the future challenges in estimation and compensation of channel impairments in OFDM wireless communications.