Abstract

Multiple-Input Multiple-Output (MIMO) technology in Digital Terrestrial Television (DTT) networks has the potential to increase the spectral efficiency and improve network coverage to cope with the competition of limited spectrum use (e.g., assignment of digital dividend and spectrum demands of mobile broadband), the appearance of new high data rate services (e.g., ultra-high definition TV - UHDTV), and the ubiquity of the content (e.g., fixed, portable, and mobile). It is widely recognised that MIMO can provide multiple benefits such as additional receive power due to array gain, higher resilience against signal outages due to spatial diversity, and higher data rates due to the spatial multiplexing gain of the MIMO channel. These benefits can be achieved without additional transmit power nor additional bandwidth, but normally come at the expense of a higher system complexity at the transmitter and receiver ends. The final system performance gains due to the use of MIMO directly depend on physical characteristics of the propagation environment such as spatial correlation, antenna orientation, and/or power imbalances experienced at the transmit aerials. Additionally, due to complexity constraints and finite-precision arithmetic at the receivers, it is crucial for the overall system performance to carefully design specific signal processing algorithms.

This dissertation focuses on transmit and received signal processing for DTT systems using MIMO-BICM (Bit-Interleaved Coded Modulation) without feedback channel to the transmitter from the receiver terminals. At the transmitter side, this thesis presents investigations on MIMO precoding in DTT systems to overcome system degradations due to different channel conditions. At the receiver side, the focus is given on design and evaluation of practical MIMO-BICM receivers based on quantized information and its impact in both the in-chip memory size and system performance. These investigations are carried within the standardization process of DVB-NGH (Digital Video Broadcasting - Next Generation Handheld) the handheld evolution of DVB-T2 (Terrestrial - Second Generation), and ATSC 3.0 (Advanced Television Systems Committee - Third Generation), which incorporate MIMO-BICM as key technology to overcome the Shannon limit of single antenna communications. Nonetheless, this dissertation employs a generic approach in the design, analysis and evaluations, hence, the results and ideas can be applied to other wireless broadcast communication systems using MIMO-BICM.

The first part of the thesis analyses the performance and structure of MIMO precoders based on rotation matrices for 2×2 MIMO and focus on the case of cross-polar antennas, which is the preferred configuration in DTT systems in the UHF band. Analysis and evaluation with the information-theoretic limits of BICM systems and bit-error-rate simulations including channel coding show the interesting results that the performance of the precoder depends on the selected code-rate. While rotation can provide significant improvements when connected with high code-rates, the performance improvement diminishes with lower code-rates. The results obtained in this part of the dissertation provide new insights on the performance of these type precoders in typical DTT scenarios and the dependences with channel characteristics and system parameters. Furthermore, a channel-precoder is proposed that exploits statistical information of the MIMO channel. The performance of the channel-precoder is evaluated in a wide set of channel scenarios and mismatched channel conditions, a typical situation in the broadcast set-up. Capacity results show performance improvements in the case of strong line-of-sight scenarios with correlated antenna components and resilience against mismatched condition. Finally, bit-error-rate simulation results compare the performance of single-input single-output, 2×2 and 4×2 MIMO systems and the proposed MIMO channel-precoder.

The second part of the thesis is devoted to investigations of memory and performance trade-offs of soft-quantized information in MIMO receivers. DTT systems rely on time-interleaving techniques to overcome signal fluctuations and improve the system performance. Yet, time-interleaving imposes the highest in-chip memory requirements which depend on the quantization resolution and algorithms employed at the receiver terminal. Since on-chip memory accounts for a large fraction of the chip area, it is desirable to have small word length with reduced performance loss. Two types of quantized receivers are investigated: quantization of In-phase and Quadrature (I&Q) samples and quantization of log-likelihood ratios. The implications on the in-chip memory and the possibility of implementing MIMO-BICM with iterative decoding are presented and discussed. The performance of uniform quantization and non-uniform quantization is evaluated showing potential benefits for non-uniform quantization adapted to the signal statistics. The results obtained in this chapter provide new insights on the important trade-off between in-chip memory and system performance for receiver architectures with quantized information.