A Wavelet Approach to Doppler-Robust Broadband Communication System Design

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Abstract

This thesis addresses Doppler-robust broadband system design using a wavelet approach. Doppler dispersion arising from the relative motion of transceivers reduces the reliability of communication links and complicates receiver design, especially in a broadband wireless communications system. In this thesis, two extremely different methods - herein termed ‘high-Doppler’ and ‘medium-Doppler’ methods - are exploited to cope with the Doppler dispersion. The high-Doppler method is developed for systems with extremely significant Doppler, e.g. in underwater acoustic (UWA) communications. The proposed method aims to resolve the coexisting multiple Doppler scales, and takes advantage of the multipath and Doppler scaling as another dimension of diversity rather than an impediment to be eliminated. The medium-Doppler method deals with Doppler dispersions smaller than those in the high-Doppler method, but still sufficiently significant to impair the effectiveness of the conventional Doppler compensation methods. This scale of Doppler can be found in many systems of radio vehicular communications. The proposed medium-Doppler method targets at improving the inherent robustness of the signal format rather than any forms of Doppler estimation and compensation techniques. More specifically, the method is developed in the context of orthogonal frequency division multiplexing (OFDM)-based broadband wireless communications.

The above two methods addressing the Doppler are made possible by the development of a new family of wavelets, the complex rational orthogonal wavelets (CROWs), based on the rational multiresolution analysis (MRA) framework. Theorems for the construction of the CROWs and a detailed study of their properties are presented in the first part of the thesis. The good time-frequency localisation and orthogonality of the CROWs form the basis of a CROW-based OFDM scheme presented in the second part of the thesis.
Abstract

The high- and medium-Doppler methods are then detailed in two applications of the CROWs - the application to UWA communications and the application to radio vehicular communications with OFDM-based mobile wireless local area network (WLAN) as a special case. In addition to the above two applications coping with the Doppler dispersion, another direct application of the proposed CROWs in broadband wireless communications is the design of ultra-wideband (UWB) pulses using wavelet basis of the CROWs. These three applications organised into three chapters of the thesis cover the characterisation of CROW's application in single carrier modulation with the first two applications and in multicarrier modulation with the third application.