BLOCK-BASED TRANSCIEVERS FOR FREQUENCY SELECTIVE CHANNELS WITH REDUCED REDUNDANCY

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Abstract— We propose a transceiver structure for a frequency selective channel that allows the introduction of reduced redundancy. We optimize jointly the transmitter and receiver in this structure to maximize the information rate. The simulation results show that the proposed design has good performance while increasing the bandwidth efficiency.

Keywords— Block transceivers, intersymbol interference (ISI), redundancy, inter-block interference (IBI), mutual information.

I. INTRODUCTION

Time invariant single-input-single-output (SISO) communication channels have been studied for a while already. However, the problem of achieving high transmission rates under limited computational resources has not been completely solved yet. For instance, block-by-block communication systems have shown to be efficient schemes for transmitting over inter-symbol interference (ISI) channels (Lechleider, 1990; Scaglione et al., 1999b; Lin and Phoong, 2000). Examples of block-by-block communication systems are orthogonal frequency division multiplexing (OFDM) and discrete multitone modulation (DMT) (Chow et al., 1991). In a block-based system, transmitter and receiver act on a block-by-block basis and redundancy is added to each block in order to remove inter-block interference (IBI). However, the introduction of redundancy leads to a worse bandwidth efficiency. Although this concern is in material for large symbol block sizes, small-sized blocks are still worthy to avoid large decoding delays and computational complexity. In the past, ISI free multirate FIR filterbank transceivers with reduced redundancy have been obtained by Lin and Phoong (2002). However, these solutions may not lead to a block-by-block communication system. Although necessary conditions for the existence of a parameterization for all block-by-block ISI free transceivers with reduced redundancy have been derived by Lin and Phoong (2002), a sufficient condition is still lacking.

In this paper we propose a family of transceivers with reduced redundancy that is obtained by controlling the IBI. Also, we derive all the transceivers that maximize the information rate subject to a constraint of maximum transmit power.

The notation is as follows: boldfaced lower-case letters represent vectors and boldfaced upper-case letters are reserved for matrices. The notation $A^T$ represents the transpose of $A$. The notations $I_{M 	imes M}$ and $0_{M 	imes N}$ represent the $M 	imes M$ identity matrix and $M 	imes N$ null matrix respectively. Also $|A|$ and $|A|_F$ denote the determinant and the Frobenius norm of matrix $A$. The notation $[\cdot]$ stands for the ceiling operation on real numbers and $I(x; y)$ is the mutual information between random variables $x$ and $y$.

II. PROBLEM STATEMENT

Let $h_n$ be the discrete time impulse response of the SISO channel. We assume that $h_n$ is a linear time-invariant (LTI) system with finite impulse response (FIR) of length $L + 1$. We analyze the problem of sending and receiving blocks of $N$ samples. For that, the vectors $s(n) = \left[ s_{nN} \ s_{nN-1} \ldots s_{nN-N+1} \right]^T$, and $y(n) = \left[ y_{nN} \ y_{nN-1} \ldots y_{nN-N+1} \right]^T$ represent the $n$-th blocks sent and received through the channel. Then, assuming that $L + 1 < N$, the IBI is limited to two consecutive blocks only and $y(n)$ is expressed as

$$y(n) = H_3 s(n) + H_2 s(n - 1) + v(n),$$

where $v(n) \in \mathbb{R}^N$ is the $n$-th block of additive noise at the output of the channel, $H_1 \in \mathbb{R}^{N \times N}$, and $H_2 \in \mathbb{R}^{N \times N}$. In particular, $H_1$ is upper triangular Toeplitz whose first row is $[h_0 \ldots h_L \ldots 0] \in \mathbb{R}^N$. Similarly, $H_2$ is lower triangular Toeplitz whose first column is $[0 \ldots h_L \ldots h_1]^T \in \mathbb{R}^N$. Finally, we consider

$$s(n) = A x(n) \quad \text{and} \quad \hat{x}(n) = B y(n),$$

where $x(n) = [x_{nM} \ x_{nM-1} \ldots x_{nM-M+1}]^T$ is the $n$-th transmitted block formed by $M$ symbols, $\hat{x}(n)$ is the $n$-th estimated block, $A \in \mathbb{R}^{N \times M}$ is the transmit matrix, and $B \in \mathbb{R}^{M \times N}$ is the receive matrix.

Well-known transceiver structures as the zero-padding (ZP) (Lin and Phoong, 2002; Lin and Phoong, 2001; Scaglione et al., 1999a,b) and the cyclic prefix (CP) technique (Chow et al., 1991) may be formulated under this framework. For instance, when using ZP with leading zeros, $N = M + L$ and the first $L$