Equalizers for transmultiplexers in orthogonal multiple carrier data transmission

Thomas WIEGAND *
Norbert J. FLIEGE **

Abstract

Orthogonal multiple carrier data transmission systems are efficiently realized using modified DFT transmultiplexer filter banks. In data transmission applications, a non-ideal transmission channel causes distortions such as intersymbol interference and crosstalk between the subrate bands of the transmultiplexer. Hence, in order to equalize these distortions, subband equalizers, which affect the intersymbol interference and crosstalk behavior, are considered for implementation. The special structure of modified DFT transmultiplexers requires a discussion concerning the various possibilities of placing the subband equalizers at the receiver. Wiener solutions and LMS adaptive algorithms for various new subband equalizer structures are derived and compared by means of simulation results.

Key words: Equalizer, Transmultiplexer, Multichannel transmission, Orthogonal signal, Data communication, Discrete Fourier transform.

In [1] a novel orthogonal multiple carrier (OMC) data transmission system is presented, which is based on a computationally efficient implementation of a modified DFT (MDFT) transmultiplexer filter bank. The MDFT transmultiplexer filter bank provides almost perfect reconstruction, i.e. intersymbol interference within the subbands and crosstalk between the subbands can be kept arbitrarily small [2].
This paper is organized as follows. In Section II, we derive a mathematical description in the time domain which lays bare several characteristics of the MDFT filter bank. The various equalization approaches for channel distortions when applying the MDFT transmultiplexer to OMC data transmission are discussed in Section III. Section IV demonstrates the performance of the different subband equalizers by means of simulation results, whereas Section V concludes the paper.

**Notations.** Vectors are indicated by small italic bold faced letters and matrices by capital italic letters. The superscripts *, T and \( \dagger \) denote complex conjugation, transposition and Hermitian transposition, respectively. The separation of a complex signal into its real and imaginary part is denoted by the subscripts \( r \) and \( i \), respectively.

**II. DESCRIPTION OF THE MDFT TRANSMULTIPLEXER**

Basically, an \( M \)-band MDFT transmultiplexer filter bank consists of a signal splitter, an up-sampler by \( M/2 \), a synthesis filter bank (SFB), an analysis filter bank (AFB), a down-sampler by \( M/2 \), and a signal merger, as shown in Figure 1. At the transmitters side, a complex input data vector \( \mathbf{d} \) with size \( M \) at rate \( m \) is split producing two vectors \( \mathbf{d}_0 \) and \( \mathbf{d}_1 \) with size \( M \) at rate \( 2m \). The signal splitter can be implemented, for instance, by taking the real part of each component with even index of \( \mathbf{d} \) and the imaginary part of the components with odd indexes for the first vector \( \mathbf{d}_0 \). In order to generate the successive vector \( \mathbf{d}_1 \) the remaining part of \( \mathbf{d} \) that is not fed into \( \mathbf{d}_0 \) is used, i.e. \( \mathbf{d}_1 = \mathbf{d} - \mathbf{d}_0 \). The vectors \( \mathbf{d}_0 \) and \( \mathbf{d}_1 \) are up-sampled by \( M/2 \) producing vectors at rate of \( n = Mm \) and fed into the SFB which consists of \( M \) filters. The receiver consisting AFB, down-sampling, and merger performs the opposite processing to the transmitter reproducing under ideal channel conditions the input data vector \( \mathbf{d} \) in \( \mathbf{x} \).

In what follows, a more detailed system description of the MDFT transmultiplexer, suitable for understanding the various subband equalizer approaches below, is given. For sake of simplicity, we use the direct implementation of the MDFT transmultiplexer as depicted in Figure 2, since the direct implementation can be modified to the computationally efficient implementation of [1] by simply shifting the system components.

Given a complex signal \( \mathbf{d}_\mu(m) \) with:

\[
(1) \quad \mathbf{d}^T(m) = (d_0(m), \ldots, d_\mu(m), \ldots, d_M(m)),
\]

**Fig. 1.** — Block diagram of MDFT transmultiplexer filter bank realizing an OMC data transmission system.

**Schéma d'un banc de filtres de transmultiplexeur à TFD modifié réalisant une transmission multiporteuse.**

**SFB : banc de filtres de synthèse ; AFB : banc de filtres d'analyse.**

**Fig. 2.** — Detail of an \( M \)-band MDFT transmultiplexer filter bank in direct implementation realizing an OMC data transmission system.

**Schéma détaillé du banc de filtres en réalisation directe.**