Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Precoding for OFDM Modulation in IEEE 802.16m**
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Re:	IEEE 802.16m-07/040 - Responds to Call for Contributions on Project 802.16m System Description Document (SDD)
Abstract	This document presents the precoding scheme on the symbols of a subchannel at the transmitter to exploit frequency diversity. With the proposed receiver design, performance gain over conventional OFDM modulation could be attained.
Purpose	For discuss and approval by TGm
Notice	
Release	
Patent Policy	

Precoding for OFDM Modulation in IEEE 802.16m

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Summary

Precoding technique for OFDM modulation could increase frequency diversity at high channel coding rate. The proposed receiver design using low complexity equalizer and applying the iterative equalization/decoding method, the performance gain is about 1 dB using QPSK modulation with $R = 3/4$ code rate.

Text Proposal

The following text is proposed to be adopted as an enhanced modulation scheme in 802.16m SDD.

--- **Start of the text** ---

X.1 Transmission schemes

X.1.1 Modulation scheme

X.1.1.1 Basic modulation scheme

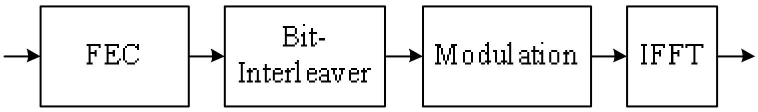

Figure X: Basic OFDM modulation scheme.

X.1.1.2 Enhanced modulation scheme

….. Precoding technique is applied to symbols on subcarriers of a subchannel.

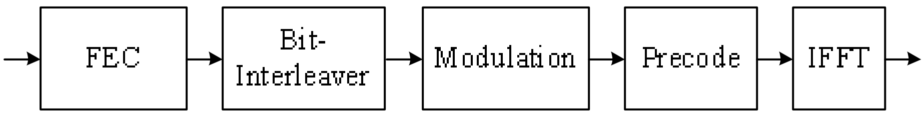

Figure X.1.1.2. Enhanced OFDM modulation scheme.

--- **End of the text** ---

Introduction

Precoding technique for OFDM modulation could increase frequency diversity for high channel coding rate. This contribution depicts a method to increase user throughput by using a precoding before the OFDM modulation scheme and the simulation results has shown notable gain when the channel coding rate is high. Thus, this contribution proposes to adopt the text of apply precoding to symbols before OFDM modulation system.

Precoded OFDM System

For conventional OFDM system with channel coding, the information bits are passed through channel encoder, channel interleaver, high-order symbol modulator and IFFT transformer. Then the OFDM symbol is transmitted through a wireless channel. At the receiver, the signals go through FFT unit, symbol de-mapper, de-interleaver, and channel decoder to obtain the bit estimates. The transmitter and receiver scheme is illustrated in Figure 1.

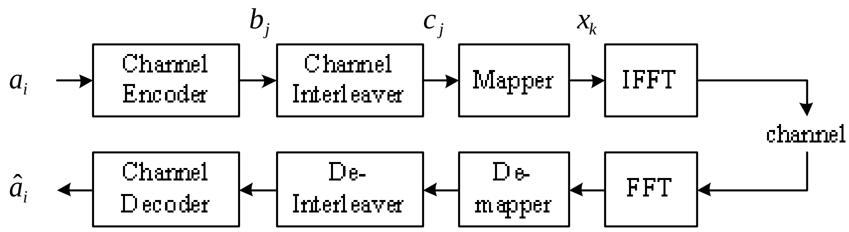

Figure 1. The conventional OFDM system.

Consider an OFDM system applying precoder to the modulated symbols. The precoding matrix is applied before IFFT transformer, e.g., Figure 2, where **W** denotes the precoding matrix, e.g., the Walsh matrix. The size of the precoding matrix is flexible. The larger the size is, the more frequency diversity gain it has. The diversity gain has to be traded off with the complexity of the equalizer. As an example, the size of precoding matrix can be defined according to the number of data subcarriers of a subchannel in the OFDMA system. The receiver with separate equalizer and channel decoder is not optimum. The gain from precoding is not obvious seen. In the case of low channel coding rate, the performance with precoding is even inferior to that without precoding.

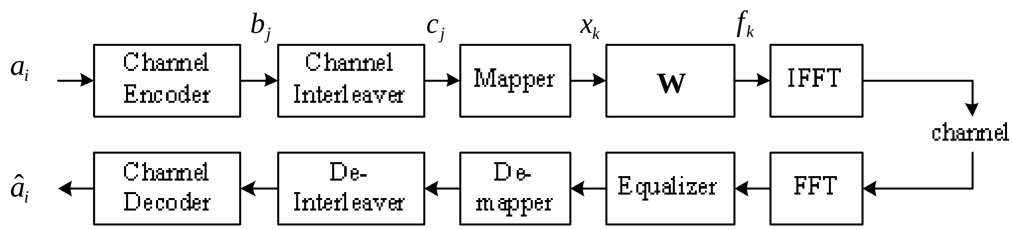

Figure 2. The precoded OFDM system using Walsh matrix.

Iterative Decoder

To improve the performance, and at the same time, not to increase heavy computational complexity, the receiver could be designed to iteratively exchanges the output extrinsic information of the equalizer and the decoder. The output extrinsic information of the equalizer is fed into the channel decoder as priori information, and after decoding, the output extrinsic information of the decoder is fed back to the equalizer as the prior information to re-estimate the data. As the iterations increased, the gain from frequency diversity by precoding can be attained.

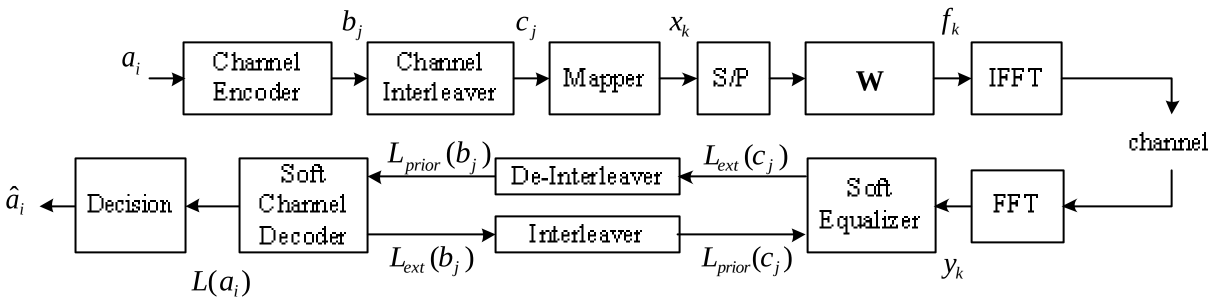

Figure 3. The receiver using iterative decoder.

As illustrated in Figure 3. The soft equalizer receives the FFT output sequence, $\{y_k\}$, and the prior information of coded bit sequence, $\{L_{prior}(c_j)\}$, which is the interleaved extrinsic information from the decoder. $L_{prior}(c_j)$ is the log-likelihood ratio of c_j,

$$L_{prior}(c_j) = \ln \frac{P\{c_j = 0\}}{P\{c_j = 1\}}. \quad (1)$$

For the initial iteration, the prior information is zero. The soft estimate of the interleaved coded bit sequence, $\{L_{ext}(c_j)\}$, which could be defined as the conditional log-likelihood ratio of c_j , subtracting its prior information,

$$L_{ext}(c_j) = \ln \frac{P\{c_j = 0 \mid y_k\}}{P\{c_j = 1 \mid y_k\}} - L_{prior}(c_j), \quad (2)$$

is de-interleaved and is used as the prior information, $\{L_{prior}(b_j)\}$, for the soft decoder. The soft decoder uses the inputted information to estimate the information bits, $\{L(a_i)\}$,

$$L(a_i) = \ln \frac{P\{a_i = 0\}}{P\{a_i = 1\}}, \quad (3)$$

and the extrinsic information of the coded bits, $\{L_{ext}(b_j)\}$. The outputted soft information is interleaved and fed to the soft equalizer serving as the prior information for next iteration. After several iterations, the decision device estimate the information bit a_i based on the log-likelihood ratio, $L(a_i)$.

Performance Evaluation

The following shows the gain from Walsh precoding for different precoding order N. Table 1 lists the simulation parameters.

Table 1. Simulation parameters.

Channel Encoder	Convolutional Turbo Code (K = 4)

Code rate	R = 3/4
# of info bits per code block	960
Modulation	QPSK
Channel Decoder	Max Log-MAP
# of iterations of channel decoder	8 (without precoding) 2 (with precoding)
# of iterations of outer loop	1 (without precoding) 4 (with precoding)
Precoding matrix size	N = 2, 4, 8, 16

The bit error rate (BER) and block error rate (BLER) performances are shown in Figures 4 and 5, respectively. Suppose the number of data subcarriers of one subchannel is 24 [2], the symbols are precoded by three N = 8 precoding matrices. As seen in Figures 4 and 5, the N = 8 precoding matrix has at least 1 dB gain against the non-precoding case.

References

[1] C80216m-07/002r4, "IEEE 802.16m System Requirements," 2007-10-19.
[2] C80216m-07/080r3, "Draft IEEE 802.16m Evaluation Methodology Document," 2007-10-22.

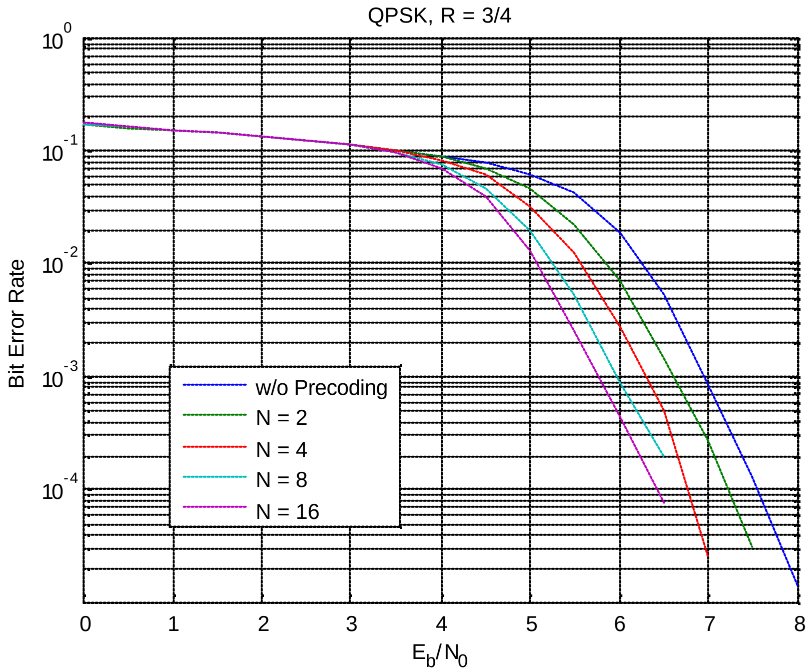

Figure 4. Bit error rate (BER) of precoded OFDM system for various precoding order *N*.

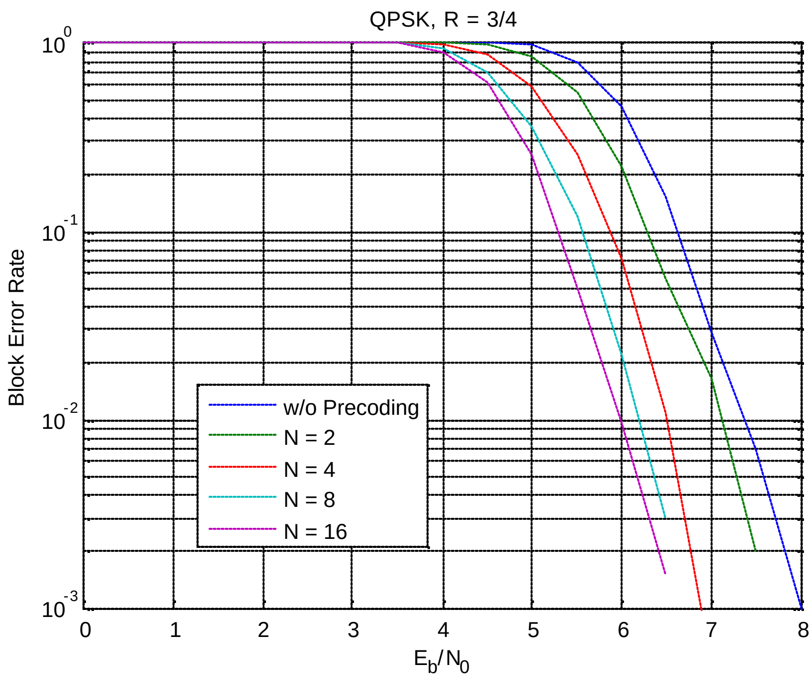

Figure 5. Block error rate (BLER) of precoded OFDM system for various precoding order *N*.