Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**	
Title	**Proposed Revision to Section 8.3.5.13.1 (Alamouti Transmit Diversity Specification)**	
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Re:	Proposal to revise Section 8.3.5.13.1 of document 80216ab-01_01r2 with provided text. This document is referred to by a comment made on 80216ab-01_01r2 by the Author.	
Abstract	Explanation of benefits of the revision, and full replacement text for this revision.	
Purpose	Incorporate provided text as revision of Section 8.3.5.13.1 of document 80216ab-01_01r2.	
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Patent Policy and Procedures		

Proposed Revision to Section 8.3.5.13.1 (Alamouti Transmit Diversity Specification)

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1. Purpose

The purpose of this proposal is to revise Section 8.3.5.13.1 of the 80216ab-01_01r2 document. This section deals with specification of Alamouti transmit diversity within the Single Carrier mode of the 80216ab-01_01r2d document.

2. Introduction

The Alamouti transmit diversity scheme is one method to achieve 2-way diversity without adding an extra antenna. A description of Alamouti transmit diversity multiplexing, its application in a single carrier transmission, and an outline of framing recommendations was contained in Section 8.3.5.13.1 of the 80216ab-01_01r2 document. The purpose of this proposal is to update Section 8.3.5.13, and thereby improve section readability, correct several errors and inconsistencies in the overall description, generalize the recommended frame formats, and add a burst/continuous frame preamble description.

3. Outline of Modifications

The Alamouti transmit diversity scheme multiplexes a pair of blocks over two antennas. In the previous description, a 'delay spread guard' was depicted between the paired blocks in Figure 169 of the original document). However, this obfuscates ensuing description; this guard is typically contained in either Block 0 or Block 1. The block structure of the analogous figure, Figure 1 (and its ensuing description), were modified to conform with the new descriptive format, where symbol elements between each transmit block are associated with one or the other transmit block.

Next, the discrete-time indices for Transmit Antenna 1 in Table 148 of 80216ab-01_01r2 did describe time reversal, but were off by 1 and did not use modulo N-arithmetic. This result was consistent with both the original continuous time description found in 80216ab-01_01r1, and the intended description of a sequence derived from the IFFT of a conjugated sequence in the frequency domain. This erratum was duly noted and corrected in Table 1 (of the amended text) so that the indices are (N-n)mod(N). Although time reversal was noted in the descriptive text of 80216ab-01_01r2, this text was further qualified, so that the time reversal was described as a "time-reverse---cyclically about zero, modulo-N".

Next, equations 1, 2, 3, and 4 were not entirely consistent with the frequency domain analog of the multiplexing description found in Figure 148, so these equations were corrected in the amended text. (Complex conjugates were switched in some cases.) These changes also motivated similar changes in equations 7 and 8.

Framing structures were also modified. Figure 170 was eliminated as unnecessary. Figure 171 (Figure 2 in amendment proposal) was generalized to illustrate the use of a cyclic prefix to form Alamouti blocks. These cyclic prefixes were assumed to be derived from arbitrary data, which could contain a Unique Word. In 80216ab-01_01r2, Figure 171 was derived from a Unique Word. To capture this application, Figure 3 in the amendment proposal illustrates how a Unique Word would be used as a cyclic prefix. Appropriate text descriptions were also added to accompany these figures.

Since both burst and continuous transmission systems contain frame preambles, a description and illustration of a preamble format for Alamouti transmit diversity systems was added. This preamble is composed of Unique Words, formatted using Alamouti transmit diversity multiplexing. This preamble is completely consistent with scalar (non-Alamouti) frame preambles, which are also composed of Unique Words. It was also duly noted that this preamble format could also be used as a pilot symbol format that is incorporated into the transmit stream.

4. Proposed Replacement Text

The text which follows is the proposed replacement text for Section 8.3.5.13.1.

8.3.5.13.1 Alamouti Transmit Diversity

The Alamouti transmit diversity scheme may be applied to either the continuous or burst formats, if two consecutive blocks of data are logically coupled, and are jointly processed at both the transmitter and receiver. The technique to be described is particularly amenable to frequency domain equalization.

Figure 1 illustrates the concept of block pairing used by a Alamouti transmit diversity scheme. A two-antenna transmitter system must format data into such logically paired blocks to obtain the promised diversity.

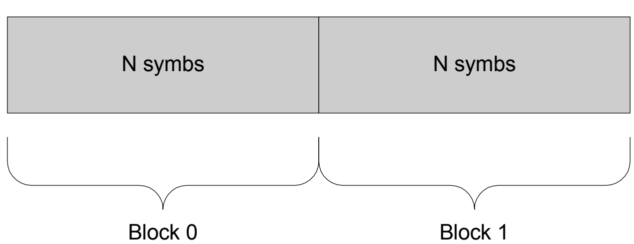

Figure 1—Paired Blocks used for Alamouti transmit diversity

Let $\{s_0[n]\}$ and $\{s_1[n]\}$ be two sequences, each of length N symbols ($0 \le n < N$), that are desired to be delivered to a receiver using the Alamouti transmit diversity scheme. Table 1 indicates the block multiplexing structure that a 2-antenna transmitter would use to transmit the two sequences over the paired blocks illustrated in Figure 1. As Table 1 indicates, transmit Antenna 0 would transmit its data sequences in order, according to burst or continuous format specifications, with no modifications (other than the possible insertion of delay spread guard symbols between the blocks). However, Transmit Antenna 1 must not only reverse the order in which the blocks are transmitted, but must also conjugate the transmitted complex symbols and must also time-reverse---cyclically about zero, modulo-N---the sequence of data symbols within each block.

Table 1—Multiplexing arrangement for block Alamouti processing

TX Antenna	Block 0	Block 1
0	$\{s_0[n]\}$	$\{s_1[n]\}$
1	$\{-s_1{}^*[(N-n)mod(N))]\}$	$\{s_0{}^*[(N-n)mod(N))]\}$

If $S_0(e^{j\omega})$, $S_1(e^{j\omega})$, $H_0(e^{j\omega})$, $H_1(e^{j\omega})$, $N_0(e^{j\omega})$, and $N_1(e^{j\omega})$ represent the Discrete-time Fourier transforms, respectively, of the symbol sequences $\{s_0[n]\}$ and $\{s_1[n]\}$, channel impulse responses (for the channels associated with each transmitter antenna) $\{h_0[n]\}$ and $\{h_1[n]\}$, and additive noise sequences (associated with each block) $\{n_0[n]\}$ and $\{n_1[n]\}$, the received signals associated with each block, interpreted in the frequency domain, are:

$$R_0(e^{j\omega}) = H_0(e^{j\omega})S_0(e^{j\omega}) - H_1(e^{j\omega})S_1{}^*(e^{j\omega}) + N_0(e^{j\omega}) \quad (1)$$

$$R_1(e^{j\omega}) = H_0(e^{j\omega})S_1(e^{j\omega}) - H_1(e^{j\omega})S_0{}^*(e^{j\omega}) + N_1(e^{j\omega}) \quad (2)$$

Assuming that the channel responses $H_0(e^{j\omega})$ and $H_1(e^{j\omega})$ are known, one can use the frequency domain combining scheme

$$C_0(e^{j\omega}) = H_0{}^*(e^{j\omega})R_0(e^{j\omega}) + H_1(e^{j\omega})R_1{}^*(e^{j\omega}) \quad (3)$$

$$C_1(e^{j\omega}) = -H_1(e^{j\omega})R_0{}^*(e^{j\omega}) + H_0{}^*(e^{j\omega})R_1{}^*(e^{j\omega}) \quad (4)$$

to obtain the combiner outputs

$$C_0(e^{j\omega}) = (\left|H_0(e^{j\omega})\right|^2 + \left|H_1(e^{j\omega})\right|^2)S_0(e^{j\omega}) + H_0{}^*(e^{j\omega})N_0(e^{j\omega}) + H_1(e^{j\omega})N_1{}^*(e^{j\omega}) \quad (5)$$

$$C_1(e^{j\omega}) = (\left|H_0(e^{j\omega})\right|^2 + \left|H_1(e^{j\omega})\right|^2)S_1(e^{j\omega}) - H_1(e^{j\omega})N_0{}^*(e^{j\omega}) + H_0{}^*(e^{j\omega})N_1(e^{j\omega}) \quad (6)$$

The combiner outputs of Eq. 5 and Eq. 6 can then be independently equalized using frequency domain equalizer techniques (see [B25], for an example) to obtain estimates for $\{s_0[n]\}$ and $\{s_1[n]\}$.

The channel responses can also be estimated using pilot symbols. In order to demonstrate this, first assume that corresponding pilot symbols are the same in the 0 and 1 blocks, i.e., $S_0^{pilot}(e^{j\omega}) = S_1^{pilot}(e^{j\omega}) = S_{pilot}(e^{j\omega})$, and that $S_{pilot}(e^{j\omega})$ is known.

Upon substituting $S_{pilot}(e^{j\omega})$ for $S_0(e^{j\omega})$ and $S_1(e^{j\omega})$ in Eq. 1 and Eq. 2, one can show

$$S_{pilot}{}^*(e^{j\omega})R_0^{pilot}(e^{j\omega}) + S_{pilot}(e^{j\omega})R_1^{pilot*}(e^{j\omega}) = 2\left|S_{pilot}(e^{j\omega})\right|^2 H_0(e^{j\omega}) \quad (7)$$

$$(-S_{pilot}(e^{j\omega}))R_0^{pilot*}(e^{j\omega}) + S_{pilot}{}^*(e^{j\omega})R_1^{pilot*}(e^{j\omega}) = 2\left|S_{pilot}(e^{j\omega})\right|^2 H_1(e^{j\omega}) \quad (8)$$

Note that Eq. 7 and Eq. 8 are combining relations that resemble those found in Eq. 5 and Eq. 6. As such, they can be used to estimate the channels $H_0(e^{j\omega})$ and $H_1(e^{j\omega})$, using received data from subblocks in which contiguous sequences of pilot symbols were transmitted. The channel estimation task is particularly simple since pilot symbols (for single carrier operation) must be derived from the Unique Words of 8.3.5.12, and these Unique Words have a constant frequency domain magnitude, *i.e.*, $\left|S_{pilot}(e^{j\omega})\right|^2 = \left|S_{UW}(e^{j\omega})\right|^2 = 1$.

Figure 2 and Figure 3 provide illustrations of frame structures that accommodate Alamouti transmit diversity signaling.

Figure 2 illustrates the baseline framing structure for Alamouti transmit multiplexing. This is a cyclic-prefix-based frame structure, with cyclic prefix repetitions chosen to facilitate efficient FFT-based processing at the receiver. Observe that the payload portions of Figure 2 reflect the Alamouti antenna multiplexing format described in Table 1 Transmit Antennas 0 and 1. Note that pilot symbols may be inserted within Payloads 0 and 1 to facilitate the use of frequency domain equalizers with time-domain decision feedback taps.

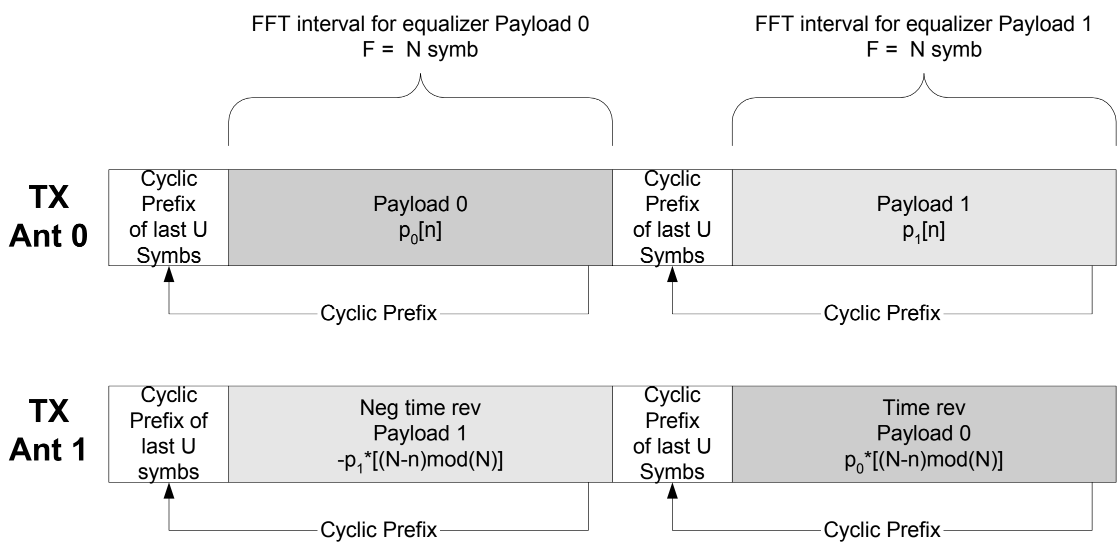

Figure 2—Cyclic Prefix-based Alamouti framing

Figure 3 provides an application example of Figure 2, where Unique Words are used as cyclic prefixes. Mark that the framing profiles of Figure 2 and Figure 3 use cyclic prefix structures, and assume the receiver has an equalizer designed for cyclic prefix-based processing. Other profiles that do not require cyclic prefixes may be conceivable.

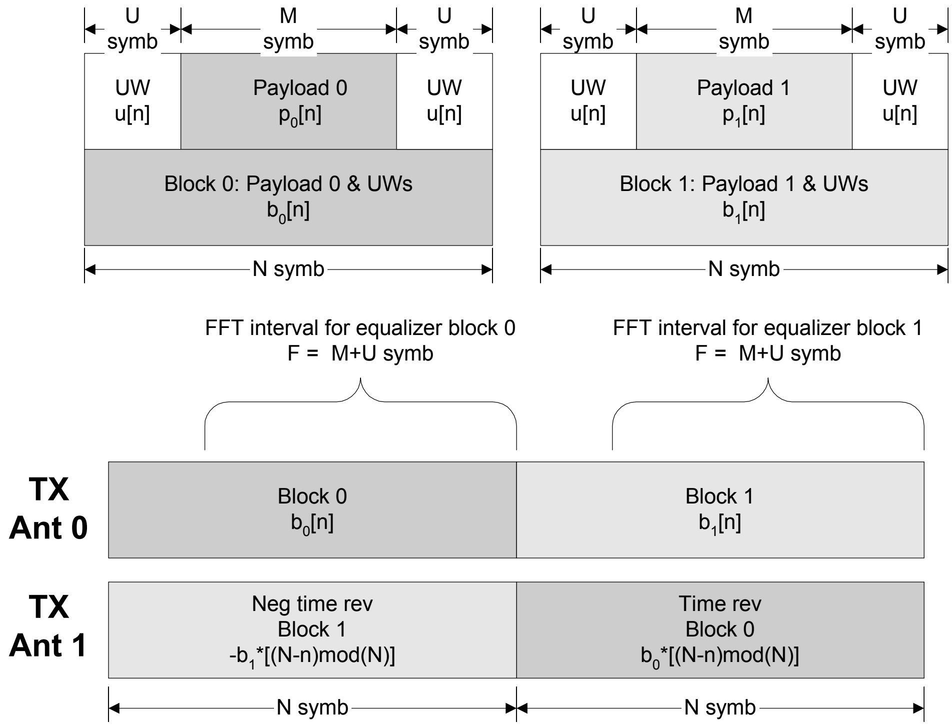

Figure 3—Alamouti framing using UWs as cyclic prefixes

Figure 4 illustrates a structure that shall be used as a burst frame preamble or a continuous frame preamble for a Alamouti transmit diversity system. Note that, like a continuous frame preamble, this structure may also be inserted within a transmission (of burst or continuous format) as group of contiguous pilot symbols, to assist in channel estimation and updating within a burst. In such an instance, this contiguous pilot symbol structure is considered external to the paired Alamouti payload data blocks illustrated in Figure 2, although the pilots may appear after every K-th paired payload block, where K is an integer greater than or equal to 1.

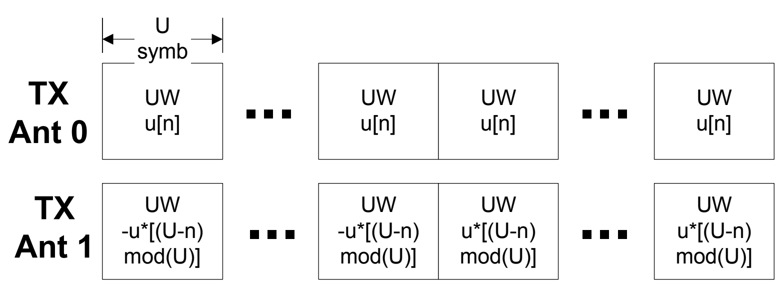

Figure 4—Alamouti Frame Preamble and/or Pilot Structure using UWs