Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Multiple antenna systems for 802.16 systems**
Date Submitted	**2001-09-07**
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Abstract	This document provides high channel capacity using MIMO systems in 802.16ab systems.
Purpose	This proposal should be used for multiple antenna systems in 802.16ab systems.
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Multiple Antenna Systems

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INDEX

1. Introduction

In general, in order to increase data transmitting rate, we increase channel bandwidth. However, recently due to emerging of advanced antenna technologies, we can extend data transmitting rate without increasing channel bandwidth. That is multiple-input-multiple-output (MIMO) systems.

Among many multiple antenna system algorithms such as space time code (STC) [1], transmission diversity and so on. The efficacy of these methods is that we can increase channel capacity with increasing a number of antennas. However, the STC systems can not achieve the performance linearly when a number of antennas is over two. In addition, when correlations occur between each antennas, their transmitting performances decrease. However, the SVD method exhibits a promising method since the channel capacity can be optimized by a waterfilling method and exhibit a good transmitting performance. However, when this method is used in OFDM/FDD systems, a drawback is found that a receiver has to send transmission channel information to transmitter and its feedback information is huge since its size is proportional to a number of subcarriers of OFDM and a number of antennas. Therefore, as increasing subcarrier, a number of feedback information increases. This fact might prevent implementation of the SVD method on MIMO systems of 80216 systems.

In this document, we present a method that overcomes the drawback and exhibit a strong possibility of MIMO application to 802.16ab (OFDM/FDD) systems using the SVD method to achieve high channel capacity. The following sections describe backgrounds of MIMO systems, how SVD method works in MIMO system, and our proposed method on 802.16ab systems.

2. Background

2.1 MIMO Channel Modeling

First, we consider a single user case with Gaussian channel and multiple transmission and receive antennas. Suppose that the channel has frequency selective fading and quasi-static over one OFDM symbol time duration P. Let a number of transmission antennas TxN, and a number of receive antennas RxM. In this case we can define a received signal matrix **Y** as

$$\mathbf{Y} = \mathbf{HX} + \mathbf{N} \qquad (1)$$

where **Y** denotes received symbol matrix, **H** denotes a channel matrix, **X** denotes an encoded symbol matrix, and **N** denotes white Gaussian random noise. The channel matrix **H** consists of identically independent distributed (i.i.d.) complex Gaussian random variables with zero-mean and variance 0.5 for real and imaginary variables, i.e., $h_{i,j} \sim N(0,0.5)$. The additive noise **N** is i.i.d. and independent over time P with $\sim N(0, \sigma_N^2)$. Thus, in this document we do not consider a correlated case of **H**.

We first review the channel capacity of MIMO systems, its advantages, and then exhibit the proposed reduction feedback scheme of MIMO in 802.16ab (OFDM/FDD) [2].

2.2 Channel Capacity in MIMO Systems

The channel capacity *C* is defined as a mutual information and can be derived as [3,4]

$$C = \frac{1}{N}\sum_{n=1}^{K}\log_2(1+\frac{|\lambda_n|^2}{\sigma^2}) \tag{2}$$

where λ_n denotes the n-th singular value which satisfies, $\lambda_0 > \lambda_1 > \lambda_2 ... > \lambda_N$, σ^2 denotes noise power, and K denotes a rank of channel matrix H. In order to increase channel capacity, if we apply waterfilling method to equation (2), then we can obtain following equation as

$$C = \frac{1}{N}\sum_{n=1}^{K}\log_2(1+\frac{\varepsilon_n|\lambda_n|^2}{\sigma^2}) \tag{3}$$

where ε_n is the n-th waterfilling power defined as

$$\varepsilon_n = (c-\frac{\sigma^2}{|\lambda_n|^2})^+, \text{where } c \text{ is a constant} \tag{4}$$

$$\sum_n \varepsilon_n = P_{total}. \tag{5}$$

Equations (3) and (4) show a solution of waterfilling method that can increase channel capacity. From equation (3), we can figure out the fundamental rules of waterfilling method, i.e., larger weighting values are given to larger singular values, in turn, smaller weighting values to smaller singular values. From the next section, we briefly describe how the SVD method works to multiple antenna systems of OFDM/FDD mode in 802.16ab systems.

2.3 Singular Value Decomposition in MIMO systems

In order to maximize channel capacity in 802.16 MIMO systems, we have to utilize the waterfilling algorithm defined in equation (4). When we apply the SVD method to multiple antenna system we can always obtain the optimum solution [5]. In this section, we briefly touch on how it works to OFDM/FDD in 802.16ab using the SVD method.

Suppose that H is decomposed as $H = U\Lambda V^H$ and we multiply V before transmit and U^H after receive signal, then we can obtain following equations as

$$\mathrm{Y} = \mathrm{U}^H\mathrm{HVX} + \mathrm{U}^H\mathrm{N} \tag{6}$$

$$\mathrm{Y} = \mathrm{U}^H\mathrm{U}\Lambda\mathrm{V}^H\mathrm{VX} + \mathrm{N}_1 = \Lambda\mathrm{X} + \mathrm{N}_1 \tag{7}$$

where Λ denotes a singular value matrix which is a diagonal matrix of H, U is an eigen vector of an outer product H, and V denotes an eigen vector of an inner product H, and N_1 denotes Gaussian noise $\sim N(0,\sigma_N^2)$.. From equation (7), we can observe "*parallel pipeline channels*" between transmit antennas and receive antennas without decreasing of channel rank. Therefore, we can optimize the transmitter since at low and high SNRs the SVD method demonstrates good transmission performance [5].

A block diagram of the SVD method in 802.16ab is depicted in figure 1. In figure 1, ‘S/P’ denotes serial to parallel converter, ‘V’ denotes an eigen value of outer product of H, ‘IFFT’ denotes an inverse Fourier transform, ‘P/S’ denotes parallel to serial converter, ‘TxN’ denotes the N-th tx antenna, ‘RxN’ denotes N-th rx antenna, ‘H_{NN}’ denotes a channel between Tx antenna N to Rx antenna N, and ‘U^{H}’ denotes a Hermitian matrix of an eigen vector of inner product of H.

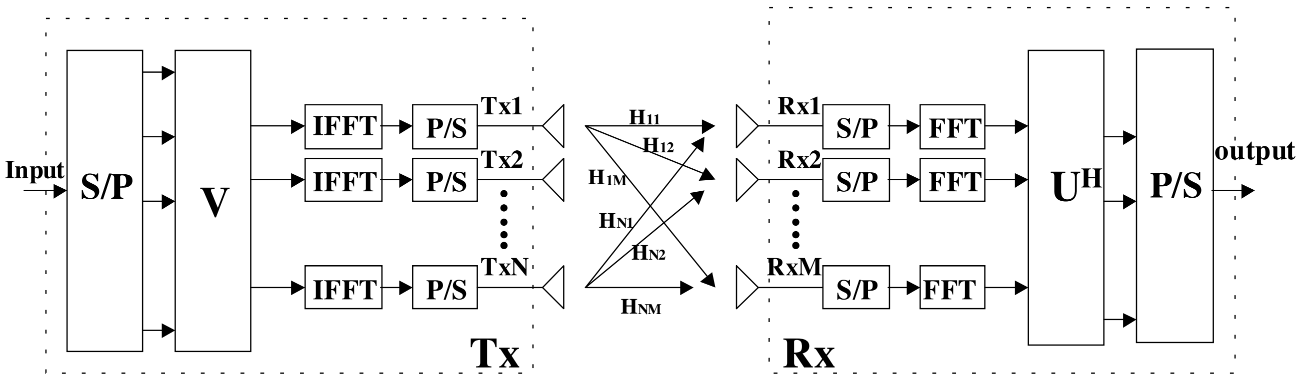

Figure 1 Block Diagram of MIMO for 802.16 (OFDM)

When we utilize FDD mode in this systems, since a transmitter cannot measure transmission channels, we should feedback these channel information from a receiver to a transmitter. Even though the SVD method in MIMO systems provides better performance, unfortunately, if a number of OFDM subcarrier increases and a number of antennas increase, the amount of feedback channels information increases, too. In other words, we have a overhead on a feedback from receiver to transmitter. For an example, if we use two byte resolutions of 256 pt. subcarriers and adopt four transmitter and four receiver antennas, 8192 bytes (256 x 4 x 4 x 2) are needed. This size seems large to be used in 802.16 systems. Therefore, a method that reduces a feedback channel information is required when the SVD MIMO systems is used in 802.16ab systems. In following section, we overcome this drawback and propose the SVD MIMO systems in 802.16ab.

3. Proposed MIMO for 802.16ab

In this section we proposed the reduction method that reduces the size of feedback data of MIMO channel, but keep information. So far, many compression algorithms have been developed. However, their applications are focused on their specific target signals, and these methods cannot be used each other since different signal types have different characteristics. Thus, we have to develop our own compression method based on our communication channel characteristics.

In section 2.1 we assume channel has frequency selective fading. Since this fading occurs due to multipaths, we can assume the channel H in time domain can be modeled by impulse trains as

$$h(t) = \sum_n h(t - \tau_n) \quad (8)$$

Thus, if we transform frequency data to time domain data, we can obtain several impulse trains as shown in equation (8). Thus, we can send time domain channel data rather than frequency domain data, and then reduce a size of feedback data dramatically.

In figures 2 and 3, we display the proposed algorithm block diagram of reduction method that is used in 802.16ab systems. Figure 2 shows a receiver part and figure 3 exhibits a transmitter part. As seen in figure 2, first we estimate channels from channel estimator block, and take IFFT in order to change frequency domain data to time domain data, and then apply an arithmetic coding to quantize time domain data. The converted data is transmitted to the transmitter. In figure 3, the transmitter receives the feedback data from the receiver, decodes to change it into a time domain data, and takes FFT. Then, finally we can obtain frequency domain channel data that will be used for calculating V matrix for the SVD method.

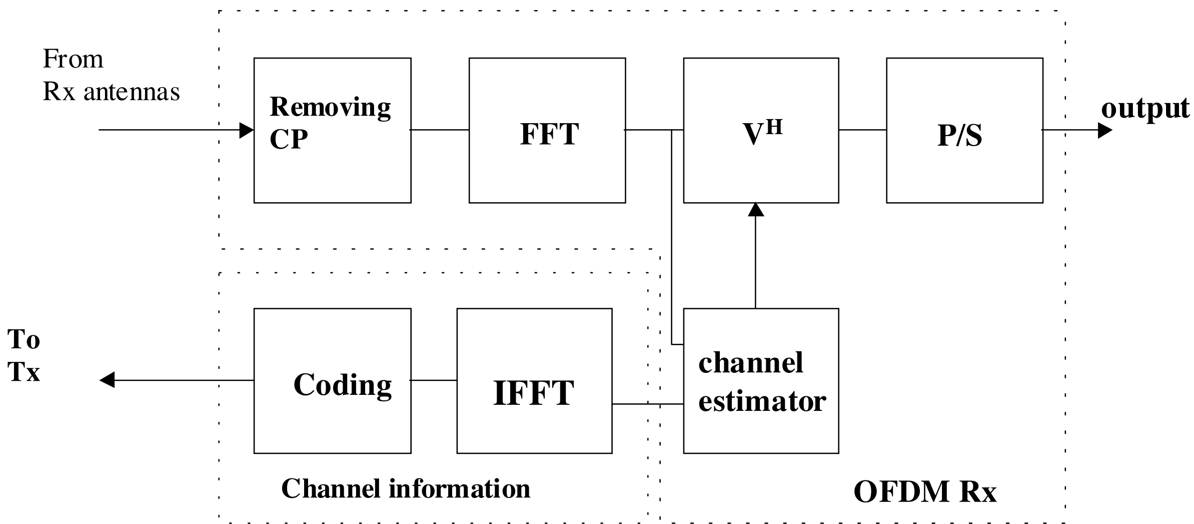

Figure 2. Rx block diagram of MIMO for 802.16ab

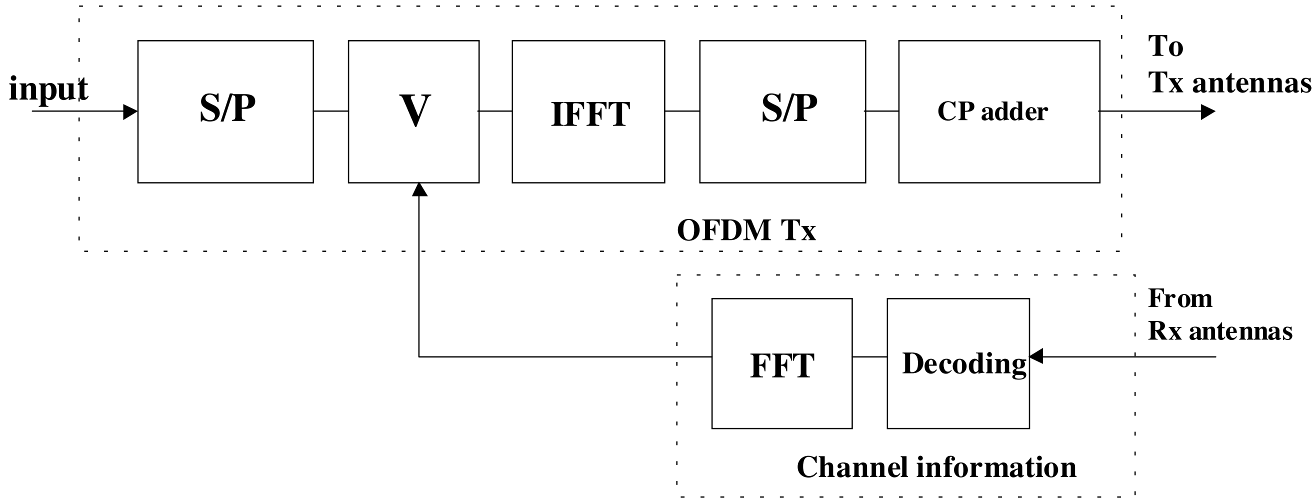

Figure 3 Tx block diagram of MIMO for 802.16ab

4. Simulations

To show the efficacy of MIMO systems in 802.16, we exhibit four Tx and four Rx antenna cases. Let a number of subcarriers be 256 pts. Among 256 pts. subcarriers, we utilize 200 subcarriers due to guard bands. As to fading channels, we employ SUI- 4 proposed in [6].

Figure 4 shows three types of quantization bit performance associated with BER curves MIMO systems of 802.16ab. A horizontal axis denotes signal to noise ratio (SNR) and vertical axis denotes bit error rate (BER). In figure 4, MIMO systems in 802.16 systems with four Tx antennas and four Rx antennas demonstrate four times better performance than a single antenna case. Note that the total power of four antennas is the same as single antenna power. Thus, each antenna radiation power is one over four compared with a single antenna power. Over 16 bit resolution we can transmit quasi-optimum(non-quantized channel information) BER curves. This result is matched with the discussed previous section. In addition, the size of feedback data is less than 1/10 of uncompressed data.

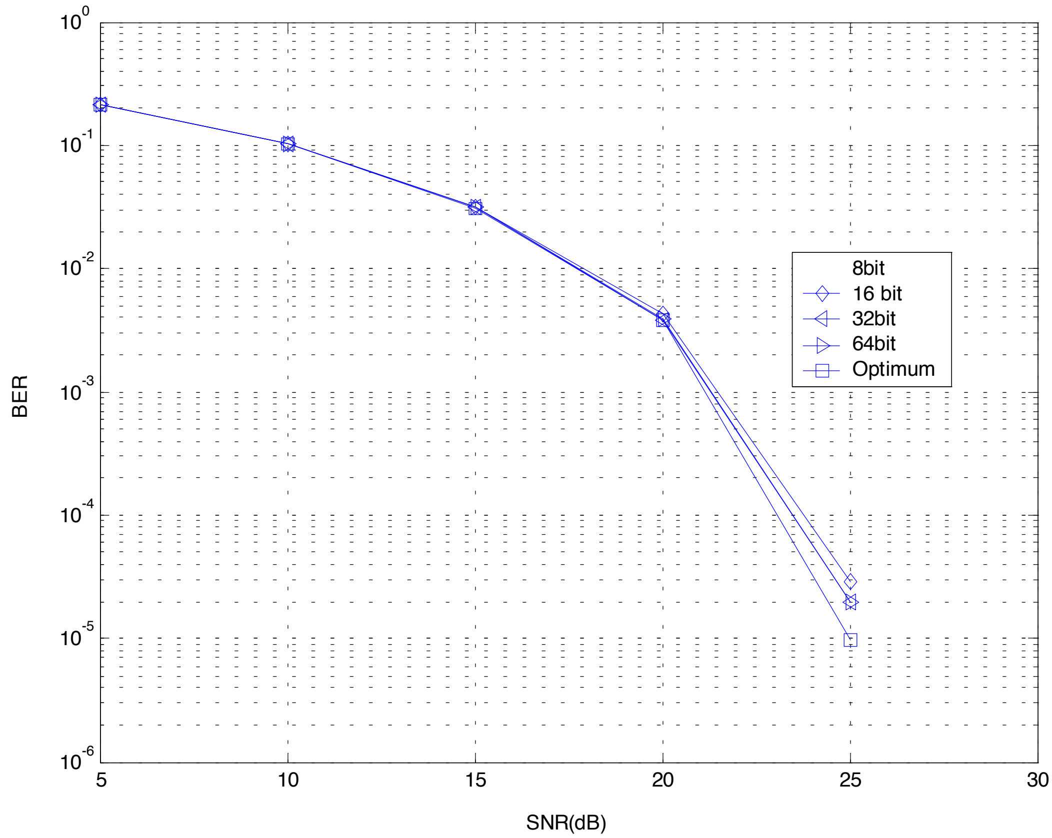

Figure 4.

5. Conclusion

In this document, we exhibit the MIMO systems for 802.16ab. Since multiple antennas increase channel capacity, in order to achieve more channel capacity we simply increase a number of antennas rather than increasing channel bandwidth. However, when antennas are needed more than two, since the STC method has limitation on this condition, we should utilize MIMO systems. Among MIMO systems, the SVD methof and waterfilling provides the optimum solution. When we implement SVD/MIMO systems in 802.16ab, however, we should adopt the proposed data reduction systems to reduce the feedback data (overhead) from receiver to transmitter.

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