Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	Hybrid ARQ Scheme for IEEE 802.16m
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Re:	IEEE 802.16m-09/0021, Call for Comments and Contributions on Project 802.16m System Description Document (SDD) on topic Hybrid ARQ (PHY aspects)
Abstract	This contribution proposes a Hybrid ARQ schemes: Hybrid ARQ scheme based on codebook for MIMO systems
Purpose	Adoption of the proposed text into SDD
Notice	
Release	
Patent Policy	

Hybrid ARQ Scheme based on codebook for IEEE 802.16m

1. Hybrid ARQ based on codebook for MIMO Systems

Introduction and Background

In order to fully utilize multiple receptions of MIMO signals, a pre-coding matrix is updated for every retransmission by taking a symbol level combining gain obtained with the previous receptions into account. Towards this end, there must be an appropriate criterion of the pre-coding matrix selection so as to minimize the error probability of retransmission.

System Model

Let use consider a MIMO system with N_T transmit antennas and N_R receive antennas (In general, $N_R \geq N_T$). A signal vector $\mathbf{s}$ is first coded by an $N_T \times N_T$ pre-coding matrix, each of which is selected from a predefined set of the pre-coding matrices, S, and then, transmitted over the given $N_R \times N_T$ MIMO channel $\mathbf{H}$. Then, the received signal is represented as follows:

$$\mathbf{y} = \mathbf{HFs} + \mathbf{w} = \tilde{\mathbf{H}}\mathbf{s} + \mathbf{w} \quad (1)$$

where $\tilde{\mathbf{H}} = \mathbf{HF}$ and $\mathbf{w}$ is the thermal noise vector. Denoting the channel matrix and pre-coding matrix at the l-th transmission by $\mathbf{H}_l$ and $\mathbf{F}_l$, respectively, the above relationship for the lth transmission can be written as follows:

$$\mathbf{y}_l = \mathbf{H}_l\mathbf{F}_l\mathbf{s} + \mathbf{w}_l = \tilde{\mathbf{H}}_l\mathbf{s} + \mathbf{w}_l \,. \quad (2)$$

where $\tilde{\mathbf{H}}_l = \mathbf{H}_l\mathbf{F}_l$. If the channel coefficients remain constant during every transmission attempt for single block, i.e., $\mathbf{H}_l = \mathbf{H}_k$, for all l and k, the corresponding channel is referred to a Long-Term-Static (LTS) channel. Otherwise, i.e., the channel changes independently at every transmission, then it is referred to as a Short-Term-Static (STS) channel. After L receptions and concatenation, the relationship between transmitted and received signal is given by

$$\mathbf{y} = \begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \vdots \\ \mathbf{y}_L \end{bmatrix} = \begin{bmatrix} \mathbf{H}_1\mathbf{F}_1 \\ \mathbf{H}_2\mathbf{F}_2 \\ \vdots \\ \mathbf{H}_L\mathbf{F}_L \end{bmatrix}\mathbf{s} + \begin{bmatrix} \mathbf{w}_1 \\ \mathbf{w}_2 \\ \vdots \\ \mathbf{w}_L \end{bmatrix} = \mathbf{H}_{CONC}\mathbf{s} + \mathbf{w} \,. \quad (3)$$

where $\mathbf{H}_{CONC}$ represents an overall diversity matrix concatenated from a sequence of the selected pre-code matrices $\mathbf{F}_l$ for the given channel conditions $\mathbf{H}_l$, $l = 1, 2, \cdots, L$. Meanwhile, the transmitted signal vector $\mathbf{s}$ and thermal noise vector $\mathbf{w}_l$, the followings are assumed:

$$\mathbf{R}_{\mathbf{s}} = \sigma_{\mathbf{s}}^2 \mathbf{I}_{N_T} \quad (4)$$

and

$$\mathbf{R}_{\mathbf{w}_l} = \sigma_{\mathbf{w}_l}^2 \mathbf{I}_{N_R} \,. \quad (5)$$

Subsequently, the average SNR is defined as $\bar{\gamma} = \sigma_s^2 / \sigma_w^2$. Let $\mathbf{G}_l$ be an equalizing matrix in the receiver for the L-th transmission. For example, detection for the initial transmission is given as follows:

$$\hat{\mathbf{s}} = \mathbf{G}_1\mathbf{H}_1\mathbf{F}_1\mathbf{s} + \mathbf{G}_1\mathbf{w}_1$$

where $\mathbf{F}_1$ and $\mathbf{G}_1$ are jointly determined by the following MMSE criterion:

$$\left(\mathbf{F}_1^{MMSE}, \mathbf{G}_1^{MMSE}\right) = \underset{(\mathbf{F}_1,\, \mathbf{G}_1)}{\arg\min}\, E\left\{\left\|\hat{\mathbf{s}} - \mathbf{s}\right\|^2\right\}$$

Furthermore, detection for the L-th transmission is given as follows:

$$\hat{\mathbf{s}} = \mathbf{G}_L\mathbf{r} = \mathbf{G}_L\begin{bmatrix}\mathbf{r}_1\\ \mathbf{r}_2\\ \vdots\\ \mathbf{r}_L\end{bmatrix} = \mathbf{G}_L\begin{bmatrix}\mathbf{H}_1\mathbf{F}_1\\ \vdots\\ \mathbf{H}_{L-1}\mathbf{F}_{L-1}\\ \mathbf{H}_L\mathbf{F}_L\end{bmatrix}\mathbf{s} + \mathbf{G}_L\begin{bmatrix}\mathbf{w}_1\\ \vdots\\ \mathbf{w}_{L-1}\\ \mathbf{w}_L\end{bmatrix} \quad (5)$$

where $\mathbf{F}_l$ and $\mathbf{G}_l$ are jointly determined by the following MMSE criterion:

$$\left(\mathbf{F}_l^{MMSE}, \mathbf{G}_l^{MMSE}\right) = \underset{(\mathbf{F}_l,\, \mathbf{G}_l)}{\arg\min}\, E\left\{\left\|\hat{\mathbf{s}} - \mathbf{s}\right\|^2\right\} \quad (6)$$

For the MMSE criterion, note that the linear equalizing matrix $\mathbf{G}_L$ for the given $(\mathbf{F}_1, \mathbf{F}_2, \cdots, \mathbf{F}_L)$ is given as follows:

$$\mathbf{G}_L = \left(\mathbf{H}_{CONC}^H\mathbf{H}_{CONC} + \mathbf{I}_{N_T} / \bar{\gamma}\right)^{-1}\mathbf{H}_{CONC}^H. \quad (7)$$

For the L-th transmission, then, the signal is recovered as $\hat{\mathbf{s}} = \mathbf{G}_L\mathbf{y}$. This particular approach is referred to as a progressive linear pre-coding scheme in [1]. The overall system structure is illustrated in Fig. 1.

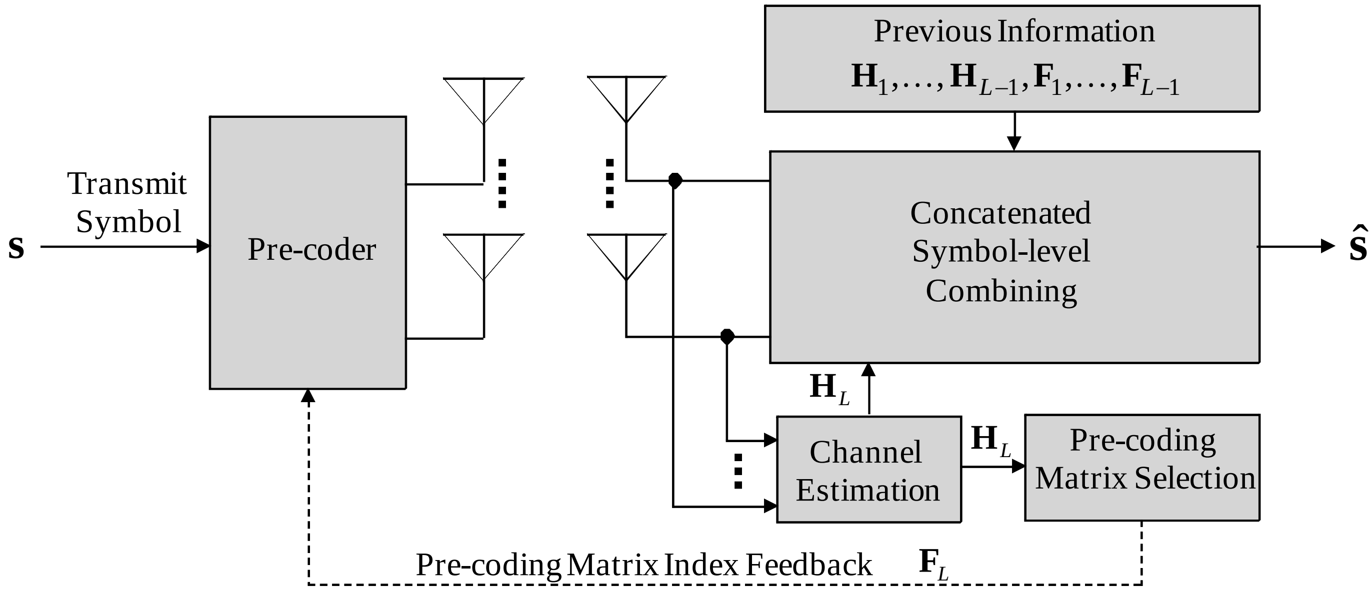


Figure 1. Retransmission System Structure

Pre-coding Matrix Selection: Example

For the L-th transmission, the pre-coding selection problem is to determine a pre-coding matrix $\mathbf{F}_L$ out of the pre-defined set $\mathbf{S}$, that maximizes the given cost function under the condition that the pre-coding matrices and channel matrices for the previous transmissions. For the given channel conditions for all transmissions, the cost function depends on the previous pre-coding matrix as well as the pre-coding matrix for the current transmission. As an example, we consider an effective SNR (ESNR) as the corresponding cost function in the subsequent discussion. Note that ESNR is given by the post-detection SNR's (PD-SNR) of the linear equalizer for all different streams. For the given receiver $\mathbf{G}$ and the channel $\tilde{\mathbf{H}} = \mathbf{HF}$, PD-SNR for i th symbol is expressed as follows:

$$\gamma_i = \frac{\left|\mathbf{g}_i \tilde{\mathbf{h}}_i\right|^2 \sigma_{\mathbf{s}}^2}{\sum_{j \neq i}^{N_T} \left|\mathbf{g}_j \tilde{\mathbf{h}}_i\right|^2 \sigma_{\mathbf{s}}^2 + \left\|\mathbf{g}_i\right\|^2 \sigma_{\mathbf{w}}^2} \quad (8)$$

where $\mathbf{g}_i$ and $\tilde{\mathbf{h}}_j$ are i th row and j th column of $\mathbf{G}$ and $\tilde{\mathbf{H}} = \mathbf{HF}$, respectively. In fact, PD-SNR vector is a function of $\tilde{\mathbf{H}}$ only, since the equalizing matrix $\mathbf{G}$ is calculated for the given $\tilde{\mathbf{H}}$. Given the PD-SNRs for all the different streams, $(\gamma_1, \gamma_2, \cdots, \gamma_{N_T})$, there are many different methods of ESNR mapping[2-7]. In the current discussion, we consider a Shannon capacity-based mapping method, which is given as follows:

$$\gamma_{eff} = 2^{\frac{1}{N_T}\sum_{i=1}^{N_T} \log_2\left(1+\gamma_i\left(\mathbf{H}_{CONC}\right)\right)} - 1 \quad (9)$$

$\mathbf{H}_{CONC}$ is constructed for all possible pre-coding matrices $\mathbf{F} \in S$ and then, a pre-coding matrix which maximizes the corresponding ESNR is selected. Fig. 2 summarizes the overall steps to select the pre-coding matrix for the L-th transmission.

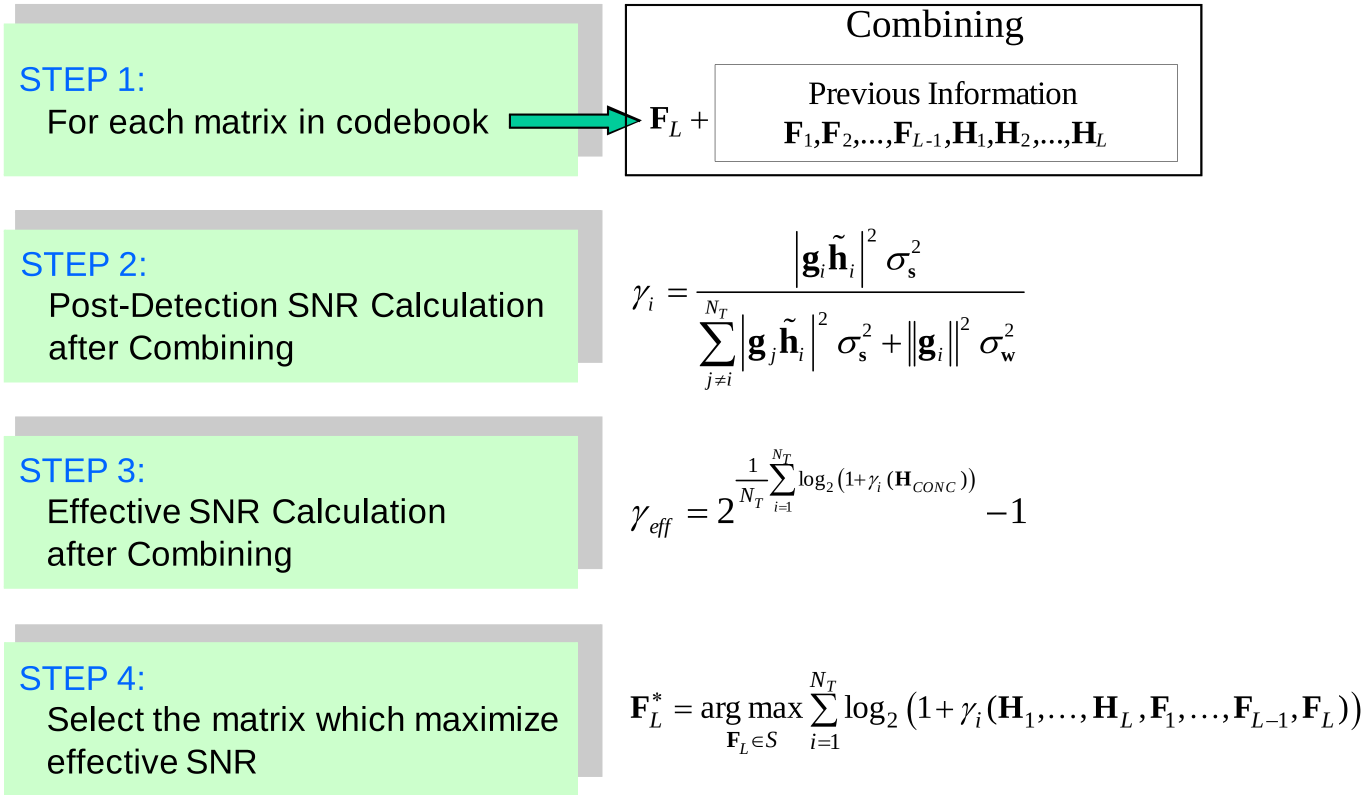


Figure 2. Effective SNR-based Pre-coding Matrix Selection

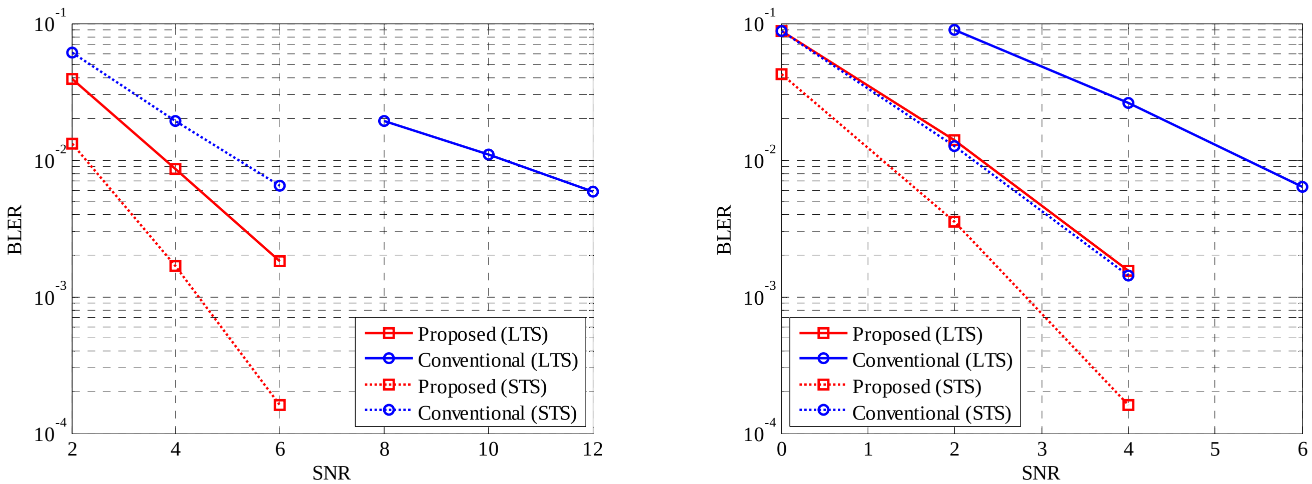
Simulation Results

In the current simulation, the numbers of transmit and receive antennas are given by 4 and 2, respectively (N_T = 4 and N_R = 2). QPSK-modulated signals are linearly pre-coded by using the codebook specified by IEEE 802.16e standard and transmitted over 12 continuous subcarriers of OFDM system. We consider both correlated and uncorrelated MIMO channels. For the correlated case, we consider one associated with the urban macro-cell environment. The simulation parameters are summarized in Table 1.

Fig. 3 shows a BLER performance of the 2nd transmission under the correlated and uncorrelated environments. For the spatially correlated environment (Fig. 3(a)), it is shown that the progressive linear pre-coding scheme provides an approximately 6dB gain over the conventional retransmission scheme under the long-term-static channel. Under the short-term-static channel, we still find an almost 3dB gain over the conventional one, which implies that a time diversity gain can be maintained over the STS channel for the progressive linear pre-coding scheme. For the spatially uncorrelated environment (Fig. 3(b)), the overall gain is relative reduced as compared that for the spatially correlated environment, but the progressive linear pre-coding scheme is still useful for both STS and LTS channels.

Table 1. Simulation Parameters

Parameters	Value
Channel	Short-Term-Static (STS) or Long-Term-Static (LTS)
Codebook	IEEE 802.16e 3bit codebook
Antenna	4 Tx & 2 Rx antennas
Spatial Correlation	Urban macro in 16m EMD
Subcarrier Allocation	Localized mode (14 subcarriers)



(a) Spatially Correlated Channel (b) Spatially Uncorrelated Channel

Figure 3. Block Error Rate for 2nd Transmission

Conclusion

It has been shown that a progressive codebook subset selection scheme can be useful for a hybrid ARQ process in MIMO systems, even with an existing set of the pre-coding matrix in IEEE 802.16m.

Proposed Text for SDD

***Insert the following text into* SDD Section 11.13.2**

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11.13.2.8. Codebook based MIMO HARQ

In a codebook-based MIMO system, a new PMI for retransmission can be selected by taking a symbol level combining gain with the previous reception into account.

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References

[1] Haitong Sun, Jonathan H. Manton, and Zhi Ding, "Progressive Linear Precoder Optimization for MIMO Packet Retransmissions," IEEE Journal on Selected Areas in Communications, vol. 24, no. 3, March 2006.

[2] IEEE 802.16m-08/003r8, "IEEE 802.16m system description document [draft]", 2009.04.10.