Slides for Closed-loop Multi-user MIMO for Uplink Transmissions

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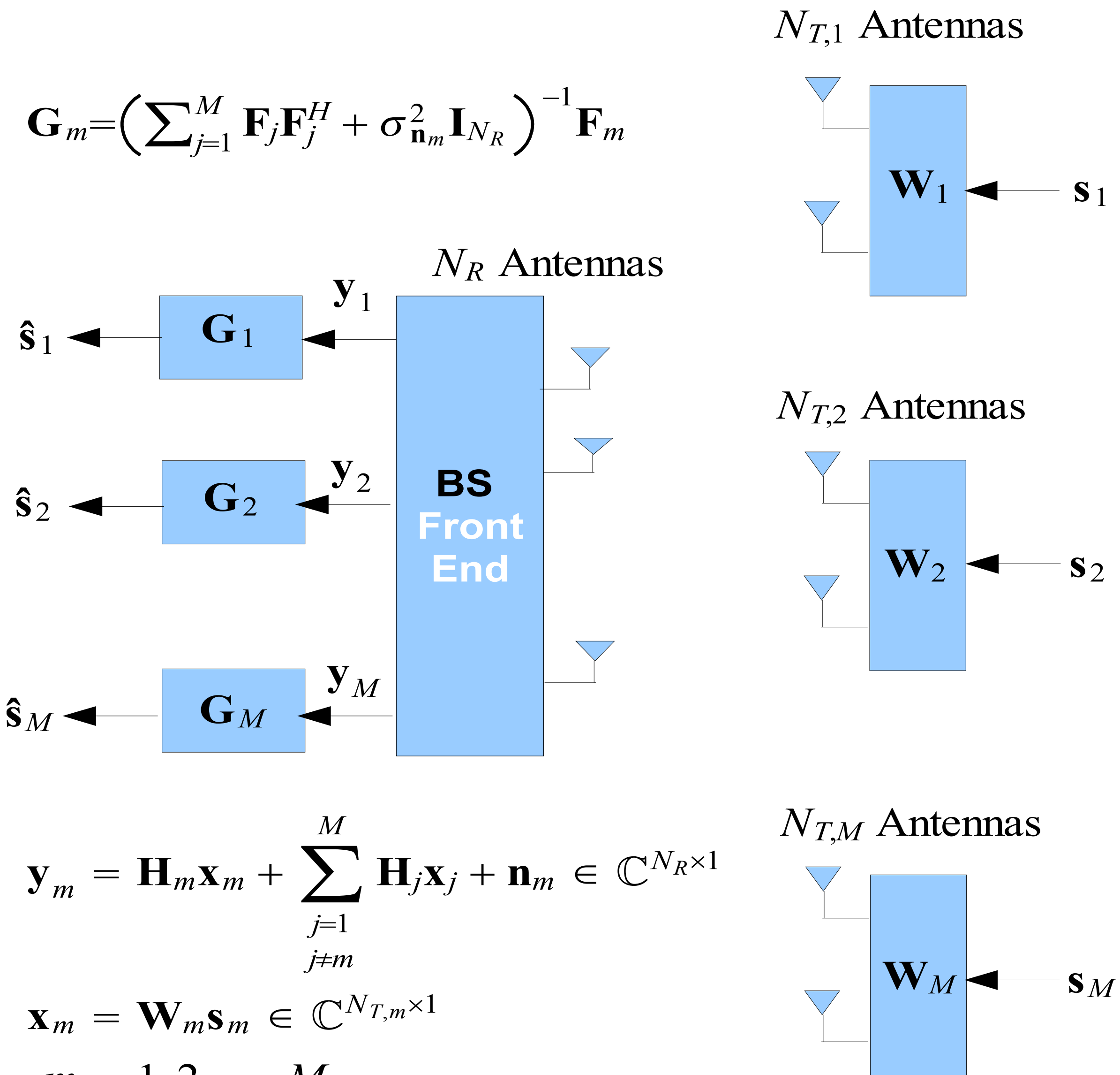
Purpose:
Consideration by the IEEE 802.16m TG for SDD contents

Received Base Station Signal Model

$$\mathbf{G}_m = \left(\sum_{j=1}^{M} \mathbf{F}_j \mathbf{F}_j^H + \sigma_{\mathbf{n}_m}^2 \mathbf{I}_{N_R} \right)^{-1} \mathbf{F}_m$$



$$\mathbf{y}_m = \mathbf{H}_m \mathbf{x}_m + \sum_{\substack{j=1 \\ j \neq m}}^{M} \mathbf{H}_j \mathbf{x}_j + \mathbf{n}_m \in \mathbb{C}^{N_R \times 1}$$

$$\mathbf{x}_m = \mathbf{W}_m \mathbf{s}_m \in \mathbb{C}^{N_{T,m} \times 1}$$

$$m = 1, 2, \ldots, M$$

Precoder and Decoder Designs

- The optimum precoding matrix for the mth MS is defined as

$$\mathbf{W}_m = \mathbf{V}_m \mathbf{P}_m \in \mathbb{C}^{N_{T,m} \times N_{S,m}}$$

- Matrix $\mathbf{V}_m$ is the right singular matrix of the singular value decomposition $\mathbf{H}_m = \mathbf{U}_m \mathbf{\Sigma}_m \mathbf{V}_m^H$ where $\mathbf{U}_m \in \mathbb{C}^{N_R \times N_R}$ and $\mathbf{V}_m \in \mathbb{C}^{N_{T,m} \times N_{T,m}}$ are unitary matrices and $\mathbf{\Sigma}_m \in \mathbb{C}^{N_R \times N_{T,m}}$ a singular value matrix.

- Matrix $\mathbf{P}_m \in \mathbb{R}^{N_{T,m} \times N_{S,m}}$ denotes the diagonal stream power loading matrix for the mth MS.

- The UL-MIMO receiver can be implemented as a bank of M Wiener decoders that each estimate an MS's spatial streams. This structure is illustrated in previous figure.

- A linear estimate of the transmitted vector is $\hat{\mathbf{s}}_m = \mathbf{G}_m^H \mathbf{y}_m \in \mathbb{C}^{N_{S,m} \times 1}$ where the mth Wiener decoder $\mathbf{G}_m$, $m = 1, 2, \ldots, M$, is defined as

$$\begin{aligned}
\mathbf{G}_m &= (\mathbf{F}_m \mathbf{F}_m^H + \mathbf{R}_{\mathbf{v}_m})^{-1} \mathbf{F}_m \\
&= \left(\sum_{j=1}^{M} \mathbf{F}_j \mathbf{F}_j^H + \sigma_{\mathbf{n}_m}^2 \mathbf{I}_{N_R} \right)^{-1} \mathbf{F}_m \\
\mathbf{F}_m &= \mathbf{H}_m \mathbf{W}_m = (\mathbf{U}_m \mathbf{\Sigma}_m \mathbf{V}_m^H)(\mathbf{V}_m \mathbf{P}_m) = \mathbf{U}_m \mathbf{\Sigma}_m \mathbf{P}_m \\
\mathbf{R}_{\mathbf{v}_m} &= \sum_{\substack{j=1 \\ j \neq m}}^{M} \mathbf{F}_j \mathbf{F}_j^H + \sigma_{\mathbf{n}_m}^2 \mathbf{I}_{N_R}
\end{aligned}$$

Codebook for Closed-loop Multi-user MIMO

- From the above equations we see that the above precoding technique requires that the effective channel matrices $\mathbf{F}_m$, $m = 1, 2, \ldots, M$, and $\sigma^2_{\mathbf{n}_m}$ be available at the BS.

- This can be accomplished using a closed-loop approach. For the closed-loop approach it is simple to quantize MS-estimated effective channels $\mathbf{F}_m$ and transmit codebook indices that encode the effective channels back to the BS.

- A large number M of active MSs results in an unacceptably high computational and feedback load. We therefore propose that the maximum number of active or concurrent MSs is $M = 4$.

- It must be emphasized that uplink MS receptions and downlink BS receptions are related as follows

$$\underbrace{\mathbf{H}_m}_{\text{Channel observed at BS for uplink receptions}} = \underbrace{\mathbf{H}_m^T}_{\text{Channel observed at MS for dowmlink receptions}}$$

  Hence to estimate $\mathbf{H}_m^T$ an MS requires downlink pilots for each of the BS's N_R antennas. The same pilot signals can be shared by all M active MSs.

- An alternative is to use uplink pilots dedicated to each of the MS's transmit antennas and let the BS estimate $\mathbf{H}_m$. However, this would require more feedback overhead since there are M active MSs as opposed to one BS.

Proposed Text

11.x.y. Closed-loop Uplink MU-MIMO

Closed-loop MU-MIMO precoding techniques may be used to further increase the spectral efficiency of uplink transmissions. Using closed-loop MU-MIMO identical subframe time-frequency resources (Physical Resource Units) may be concurrently transmitted by two or more active MSs to a BS. The maximum number of active MSs that may be concurrently transmitting using the same uplink Physical Resource Units is four. MS-estimated effective MIMO channel matrices will be provided to a BS in the form of uplink codewords. The BS will use MS-estimated effective MIMO channel matrices to perform its decoding of concurrent uplink transmissions.

References

See latest revision of IEEE C802.16m-08/687 for details