Slides for Space-Time Power Control for MIMO Transmissions

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

Introduction

- Like vectors power control commands can be factored into two components:
  - **Magnitude**: The magnitude of a power change.
  - **Direction**: The direction (power increment or decrement) of a power change.

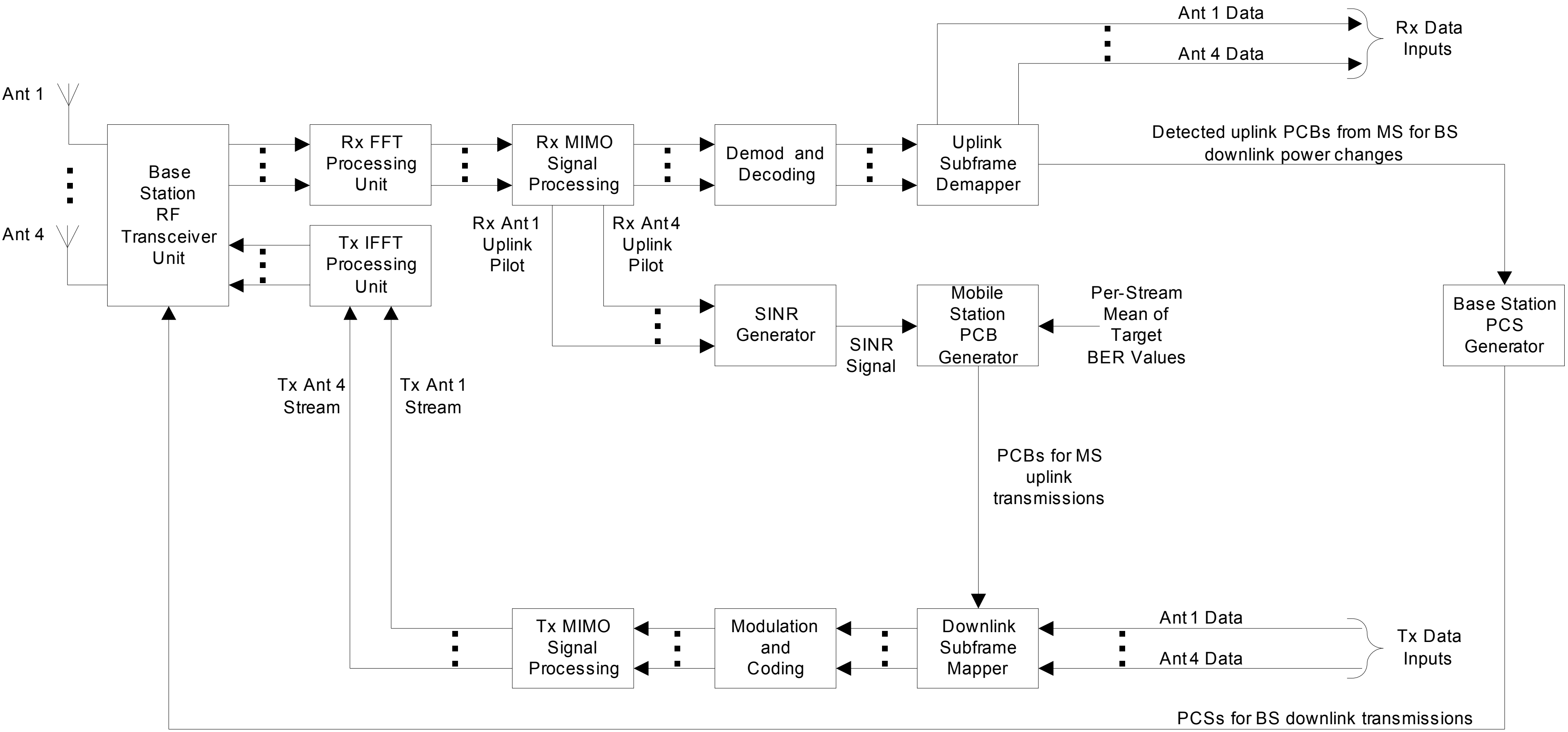
- This contribution proposes the following:
  1. The usage of closed-loop space-time power control techniques with inner and outer power control loops.
  2. The usage of received post-processing SINR measurements and target SINR values to determine power changes.
  3. Only power control bits (PCBs) be used to signal power increments or decrements, hence reduced overhead.
  4. Power control step (PCS) sizes or magnitude changes be derived using received PCBs. Hence, PCS sizes are computed at a receiver rather than being transmitted.

- Transmit power adjustments at an information source should inversely track variations in SINR measured at an information sink. Two types of errors to minimize in this tracking are slope-overload errors and granular errors.

- To show the feasibility of power control using only post-processing SINR values and PCBs a technique for uplink power control is described. The technique minimizes slope-overload and granular errors and can also be used for downlink power control.

BS Operations for Uplink Power Control

(Conceptual Block Diagram)



Power is uniformly distributed over all transmit antennas so power increments/decrements encoded in PCS are equally allocated to all transmit antennas.

SINR Generator

- Given reference signals such as dedicated pilots the SINR Generator first estimates the received post-processing SINRs of an MS's uplink spatial streams.

- The SINR Generator then combines the SINR estimates into a single estimate $\widehat{SINR}_{MS}[n]$ by computing their average (other statistics and/or methods may be used to map the estimates to a single estimate).

- For better performance the SINR Generator may also compute a predicted SINR value $\widehat{SINR}_{MS}[n]$ using the single SINR estimate just computed and past SINR estimates computed in the same manner.

Mobile Station PCB Generator (1/2)

- Given $\widehat{SINR}_{MS}[n]$ the Mobile Station PCB Generator first generates a bit error rate (BER) sample $\widehat{BER}_{MS}[n]$. An example estimate of the BER is

$$\widehat{BER}_{MS}[n] = \frac{4}{\log_2 M}\left(1 - \frac{1}{\sqrt{M}}\right) Q\left(\sqrt{\frac{3}{M-1}\widehat{SINR}_{MS}[n]}\right)$$

  where parameter M defines an M-QAM constellation and Q the Q-function.

- Given $\widehat{BER}_{MS}[n]$ the Mobile Station PCB Generator then generates an SINR target sample $SINR_{MS}[n]$ using a map such as the following example:

$$SINR_{MS}[n] = \begin{cases} SINR_{Up}^{\text{Target}} & \text{if } BER_{MS} < \widehat{BER}_{MS}[n] \\ SINR_{Down}^{\text{Target}} & \text{if } \widehat{BER}_{MS}[n] \leq BER_{MS} \end{cases}$$

  - $SINR_{Up}^{\text{Target}}$ and $SINR_{Down}^{\text{Target}}$ denote increases and decreases in the SINR target. Values used for $SINR_{Up}^{\text{Target}}$ and $SINR_{Down}^{\text{Target}}$ may be derived for BER versus SINR curves. Note that if $\widehat{BER}_{MS}[n] \leq BER_{MS}$ the target SINR is decreased to minimize interference.

  - A target BER value BER_{MS} may be a per-layer mean if a multi-codeword MIMO technique is being used.

Mobile Station PCB Generator (2/2)

- Using $\widehat{SINR}_{MS}[n]$ and $SINR_{MS}[n]$ the Mobile Station PCB Generator then generates a Power Control Bit (PCB) sample $PCB_{MS}[n]$ using the map:

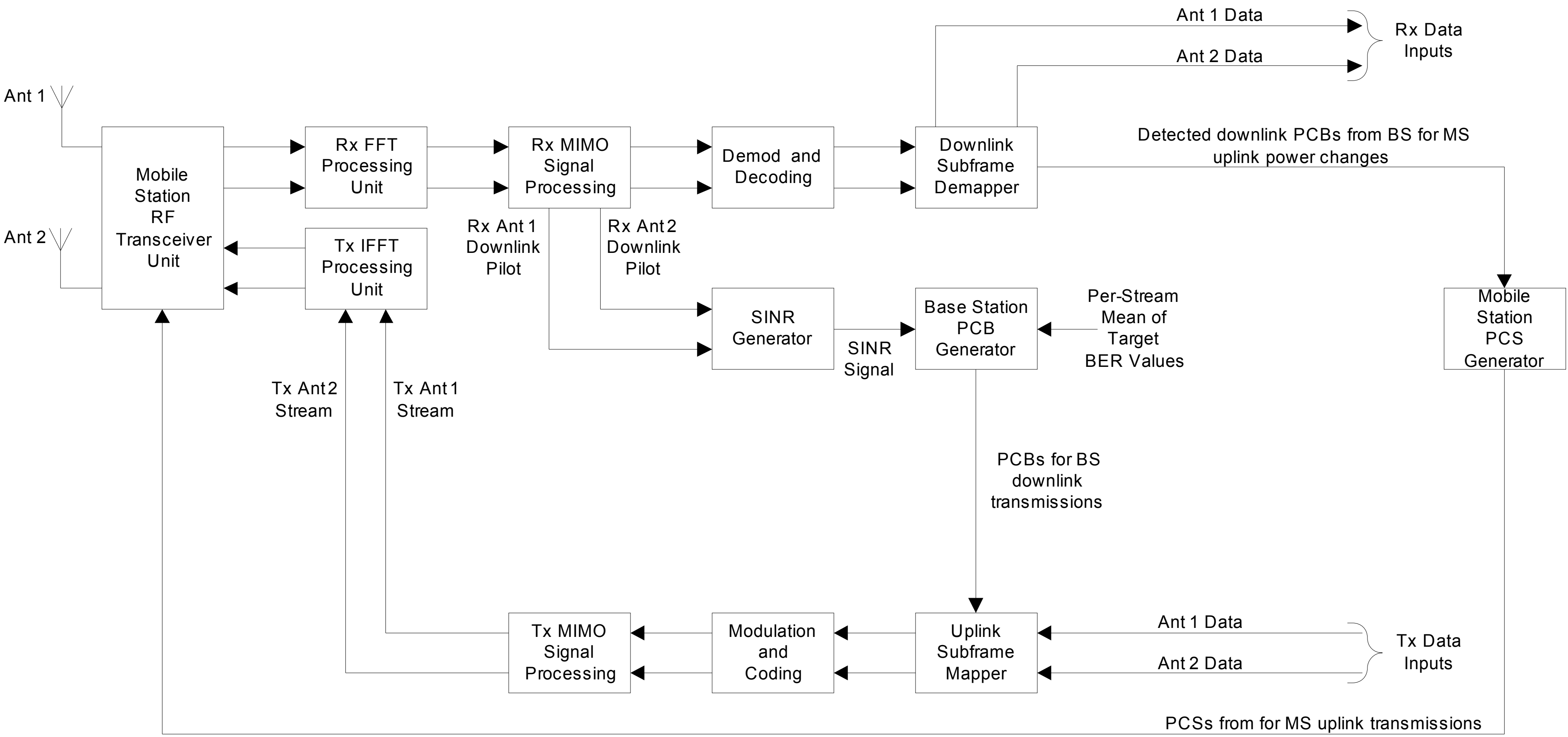
$$PCB_{MS}[n] = \begin{cases} 1 \text{ (Specifies MS power decrease)} & \text{if } SINR_{MS}[n] < \widehat{SINR}_{MS}[n] \\ 0 \text{ (Specifies MS power increase)} & \text{if } SINR_{MS}[n] \geq \widehat{SINR}_{MS}[n] \end{cases}$$

- Samples $PCB_{MS}[n]$ form a binary MS power control signal that will be used by the MS to adjust the power of its uplink transmissions.

- Sample $PCB_{MS}[n]$ is input to the Downlink Subframe Mapper where it is inserted into the control segment of the next downlink subframe. Note that only a single Power Control Bit is transmitted but the bit may be duplicated n times for repetition coding gain.

MS Operations for Uplink Power Control

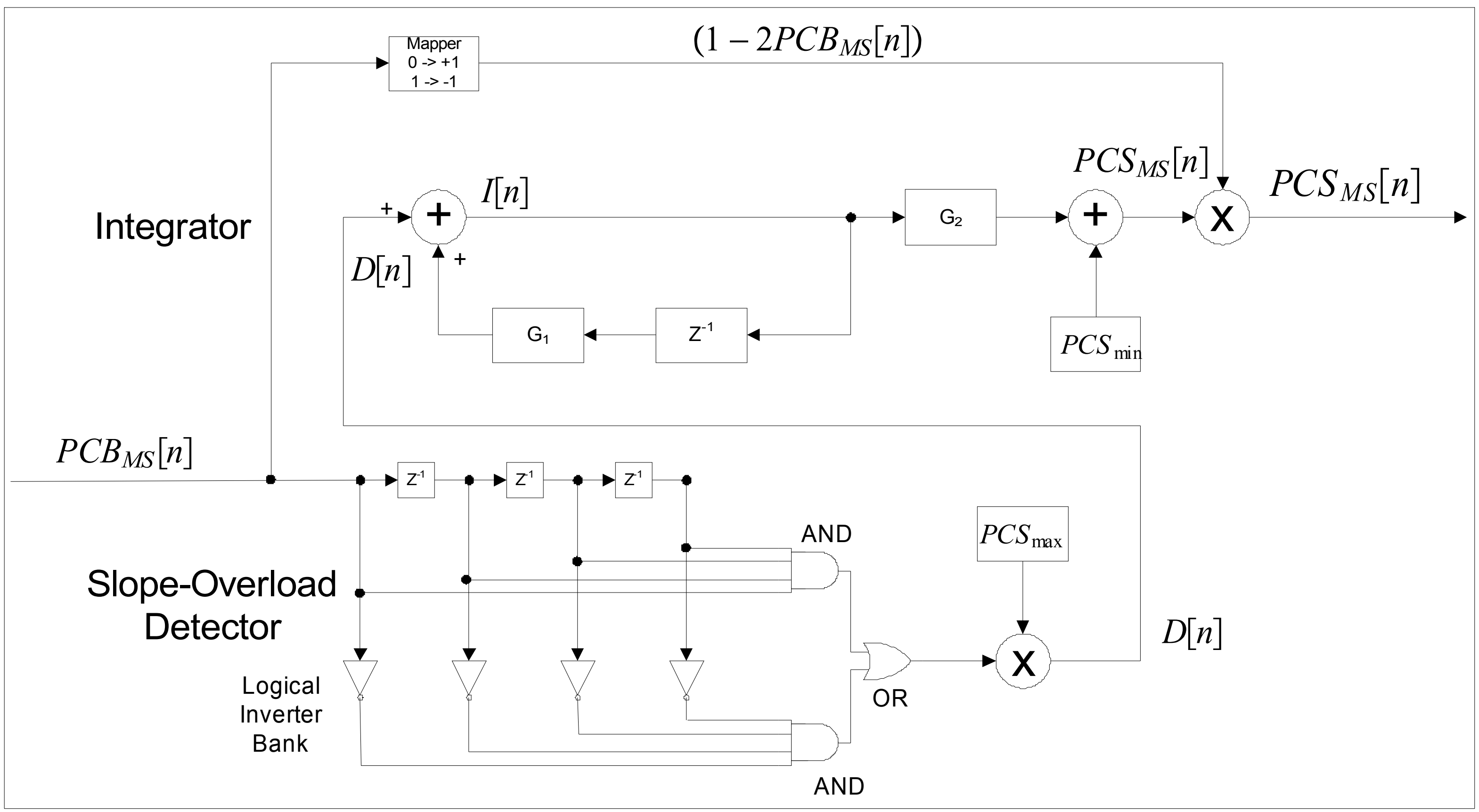
(Conceptual Block Diagram)



Power is uniformly distributed over all transmit antennas so power increments/decrements encoded in PCS are equally allocated to all transmit antennas.

Mobile Station PCS Generator (1/4)

- The MS first detects the power control bit sample $PCB_{MS}[n]$ transmit by the BS.
- Given $PCB_{MS}[n]$ the MS's Power Control Step Size Generator outputs a Power Control Step $PCS_{MS}[n]$ for its transmitter using a continuously Variable Slope Delta-Modulation (CVSD) circuit comprised of a slope-overload detector and an integrator:



Mobile Station PCS Generator (2/4)

- Given $PCB_{MS}[n]$ the Slope-overload Detector of the Power Control Step Size Generator first computes:

$$D[n] = \begin{cases} PCS_{\max} & \text{if } \{PCB_{MS}[j],\ j = n-3,\ldots,n\} = \{0,0,0,0\} \\ PCS_{\max} & \text{if } \{PCB_{MS}[j],\ j = n-3,\ldots,n\} = \{1,1,1,1\} \\ 0 & \text{otherwise} \end{cases}$$

  where positive real-value $PCS_{\max}$ is the maximum allowed power control step size allowed.

- The number of delays used in the Slope-overload Detector is the implementer's decision.

- Segments of slope-overload error will be manifested by runs of consecutive $PCB_{MS}[n]$ values of logic zero or one. For example, a PCB run pattern associated with slope overload may be PCB bit sequence of 0,0,0,0 or 1,1,1,1. When these bit patterns are detected $D[n]$ is set to the maximum allowed step size. Hence, PCS size adaptation is implemented.

Mobile Station PCS Generator (3/4)

- Given $D[n]$ the Integrator of the Power Control Step Size Generator then computes

$$I[n] = G_1 I[n-1] + D[n] = \sum_{k=0}^{\infty} G_1^k D[n-k]$$

followed by the *magnitude* of MS's power control step sample

$$PCS_{MS}[n] = G_2 I[n] + PCS_{\min}$$

Positive real-value $PCS_{\min}$ is the minimum allowed power control step size allowed.

- Sample $PCS_{MS}[n]$ is constrained to lie within the interval $[PCS_{\min}, PCS_{\max}]$. Real values $0 < G_1 < 1$, $0 < G_2 < 1$, $PCS_{\min}$ and $PCS_{\max}$ are tuning parameters. For example, $PCS_{\min}$ and $PCS_{\max}$ values of 0 and 2.0 may be used.

Mobile Station PCS Generator (4/4)

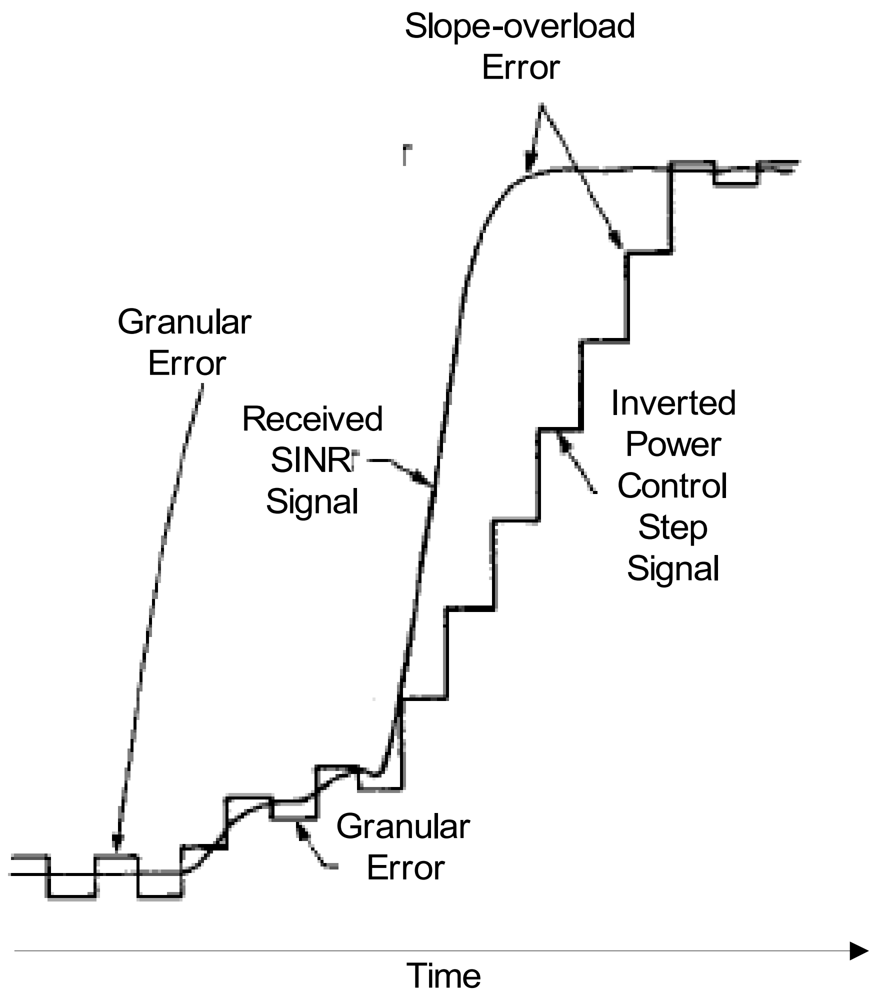
- The Power Control Step Size Generator next updates the magnitude of MS's power control step sample

$$PCS_{MS}[n] = (1 - 2PCB_{MS}[n])PCS_{MS}[n]$$

- Note that $PCS_{MS}[n]$ is computed by multiplying $PCS_{MS}[n]$ with a detected binary-to-bipolar mapped value $(1 - 2PCB_{MS}[n])$. Recall that if $PCB_{MS}[n] = 0$ a MS power increase is specified by the BS and if $PCB_{MS}[n] = 1$ a MS power decrease is specified by the BS. Hence, the update specifies the direction of the power control step $PCS_{MS}[n]$.

- The MS adjusts its transmitter's power amplifier in using the power control step $PCS_{MS}[n]$. Power is assumed to be uniformly distributed over all transmit antennas so power increments/decrements encoded in power control steps are used by all MS transmit antennas.

Slope-Overload and Granular Errors (1/2)



Slope-Overload and Granular Errors (2/2)

- For optimal power control $PCS_{MS}[n]$ values should inversely track or match changes in received SINR $\widehat{SINR}_{MS}[n]$. Power control error increases if PCSs do not inversely match changes in received SINR.

- Slope-Overload Error. A type of error called slope-overload error results if the power control step signal $\{PCS_{MS}[n]\}_n$ is too small to inversely track segments of received SINR signal $\left\{\widehat{SINR}_{MS}[n]\right\}_n$ that have abruptly changing slopes.

- Granular Error. Conversely, if the PCS size signal $\{PCS_{MS}[n]\}_n$ is too large in segments of received SINR $\left\{\widehat{SINR}_{MS}[n]\right\}_n$ that have zero or small slopes a type of error called granular error will arise.

- Power control step (PCS) sizes that better inversely match variations in received SINR will improve closed-loop power control tracking performance and increase network capacity. A larger power control step size is better suited to track rapid deviations in received SINR; slow deviations in received SINR are better tracked using a smaller step size.

- A solution to the slope-overload and granular errors is the incorporation of PCS size adaptation into closed-loop power control. The approach above performs PCS size adaptation.

Proposed Text

Closed-Loop Space-time Power Control

Closed-loop space-time power control will be used to control the transmit power of MIMO spatial streams. Closed-loop power control will be implemented using only received post-processing SINR values and power control bits (PCBs) that specify power increments or decrements. Adaptive SINR prediction and adaptive power control step (PCS) size prediction may be used within a closed-loop power control implementation to improve power control performance.

References

See latest revision of IEEE C802.16m-08/701 for details