FDM, CDM link level performance analysis for sounding channel

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Call for Comments on IEEE 802.16m-09/0010 IEEE 802.16m Amendment text

Base Contributions:

N/A

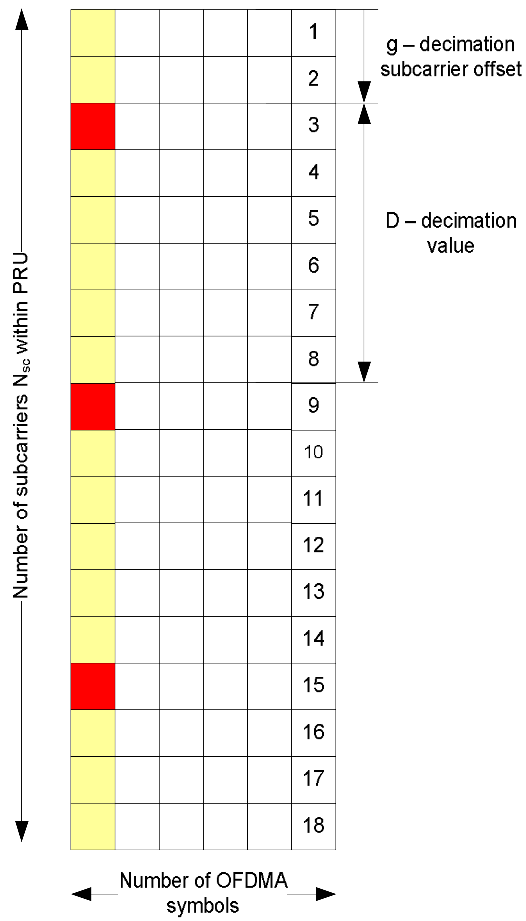
Re:

Purpose: To discuss and adopt in TGm

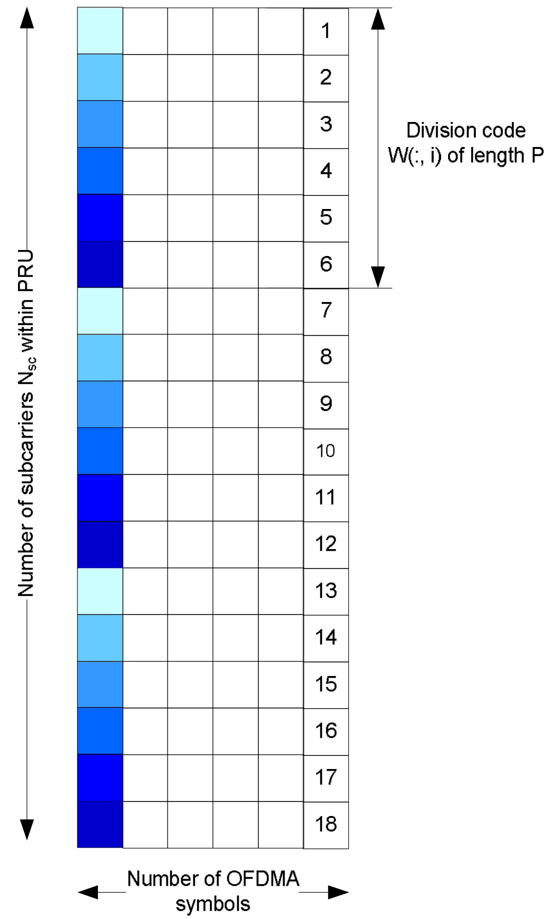
Introduction

- There are two MS multiplexing methods in the current UL control amendment text [1]:
  - Frequency decimation separation (FDM): each MS uses decimated set of subcarriers within sounding frequency allocation with unique subcarrier offset - g
  - Code division separation (CDM): MS occupies all subcarriers of the sounding allocation and uses unique orthogonal sequence Wi
- There are two usage model options for MS multiplexing methods
  - Option 1: decimation separation or cyclic shift separation
  - Option 2: decimation separation

FDM and CDM Physical Structures



Boosting of sqrt(D) is used for FDM sounding band



CDM Sequences

$$\mathbf{W}_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$\mathbf{W}_3 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & e^{-j\frac{2\pi}{3}} & e^{-j\frac{4\pi}{3}} \\ 1 & e^{-j\frac{4\pi}{3}} & e^{-j\frac{\pi}{3}} \end{bmatrix}$$

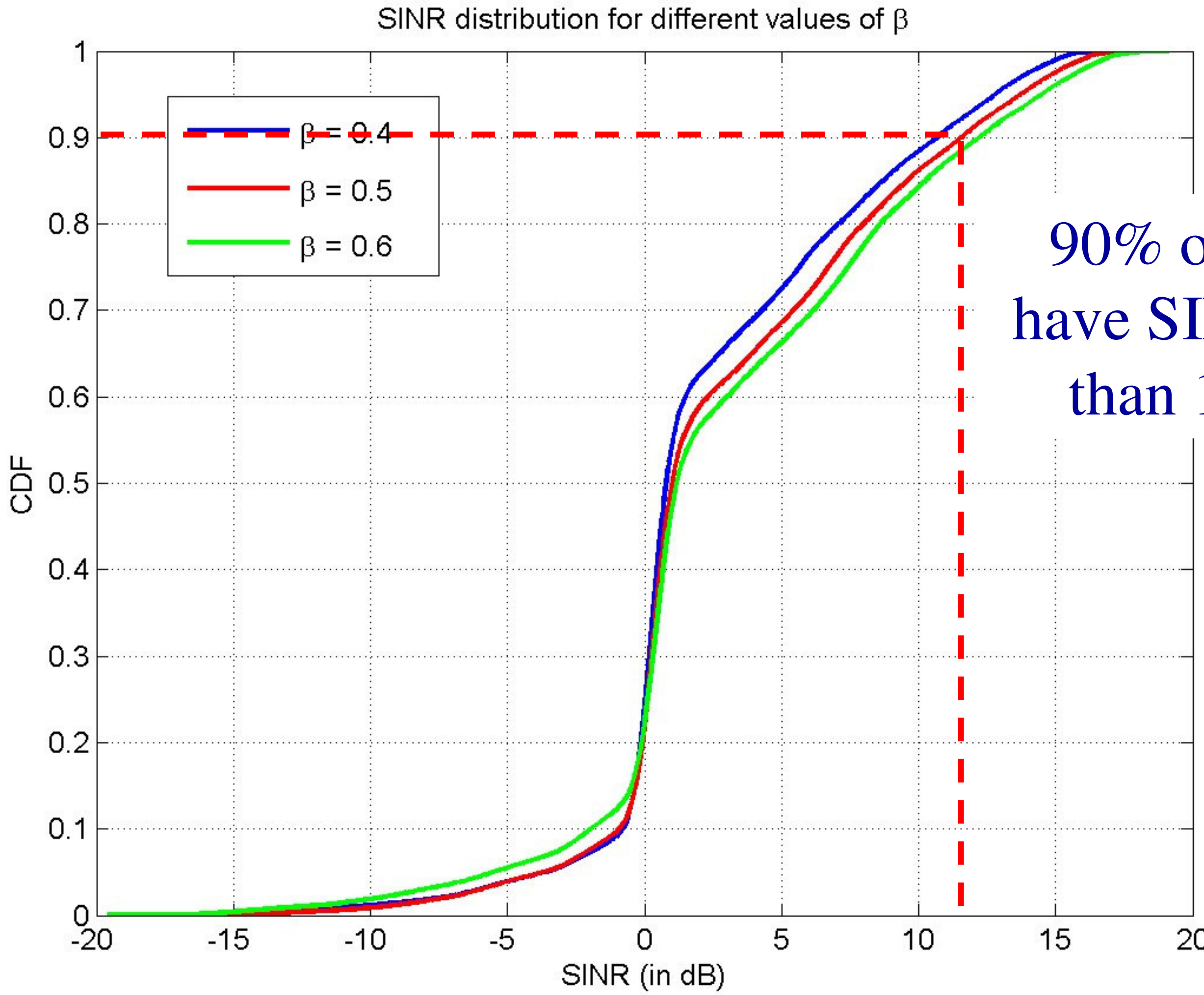
$$\mathbf{W}_6 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & e^{-j\frac{\pi}{3}} & e^{-j\frac{\pi}{3}2} & -1 & e^{-j\frac{\pi}{3}4} & e^{-j\frac{\pi}{3}5} \\ 1 & e^{-j\frac{\pi}{3}2} & e^{-j\frac{\pi}{3}4} & 1 & e^{-j\frac{\pi}{3}2} & e^{-j\frac{\pi}{3}4} \\ 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & e^{-j\frac{\pi}{3}4} & e^{-j2\frac{\pi}{3}} & 1 & e^{-j\frac{\pi}{3}4} & e^{-j\frac{\pi}{3}2} \\ 1 & e^{j\frac{\pi}{3}5} & e^{j\frac{\pi}{3}4} & -1 & e^{-j\frac{\pi}{3}2} & e^{-j\frac{\pi}{3}} \end{bmatrix}$$

Discussion

- The key point for justification of the second option (FDM and CDM) is that each multiplexing method is optimized for the specific scenario
  - FDM method is optimized to the noise-limited scenario (large cell size) when the additional power boosting can be applied to the decimated subcarriers
  - CDM method is optimized to the interference-limited scenario (small cell size) when the code spreading provides additional interference averaging assuming that interfering MSs are using different sounding sequences
- SRD does not require optimization of the system performance for each specific deployment scenario (large and small cell size). It also allows some performance degradation for large cell radius.
- When sounding allocations of serving and interfering cells do not overlap (different frame and sounding resource allocations) the boosting gain of FDM is not eliminated and FDM method performs well in interference limited scenario
- To justify adoption of the second option (FDM and CDM methods) the detailed link and system level analysis for all deployment scenarios are needed

Typical UL SINR distribution

Example of MS SINR distribution in the uplink

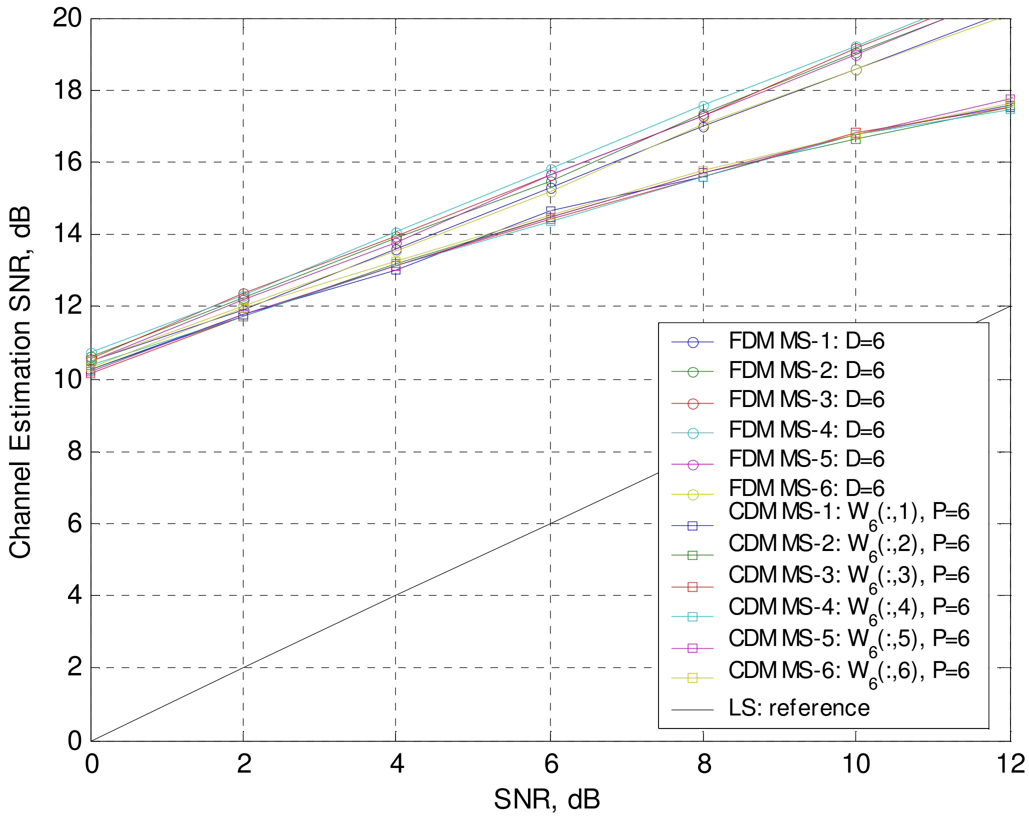


90% of MSs have SINR less than 12 dB

EMD site-to-site difference

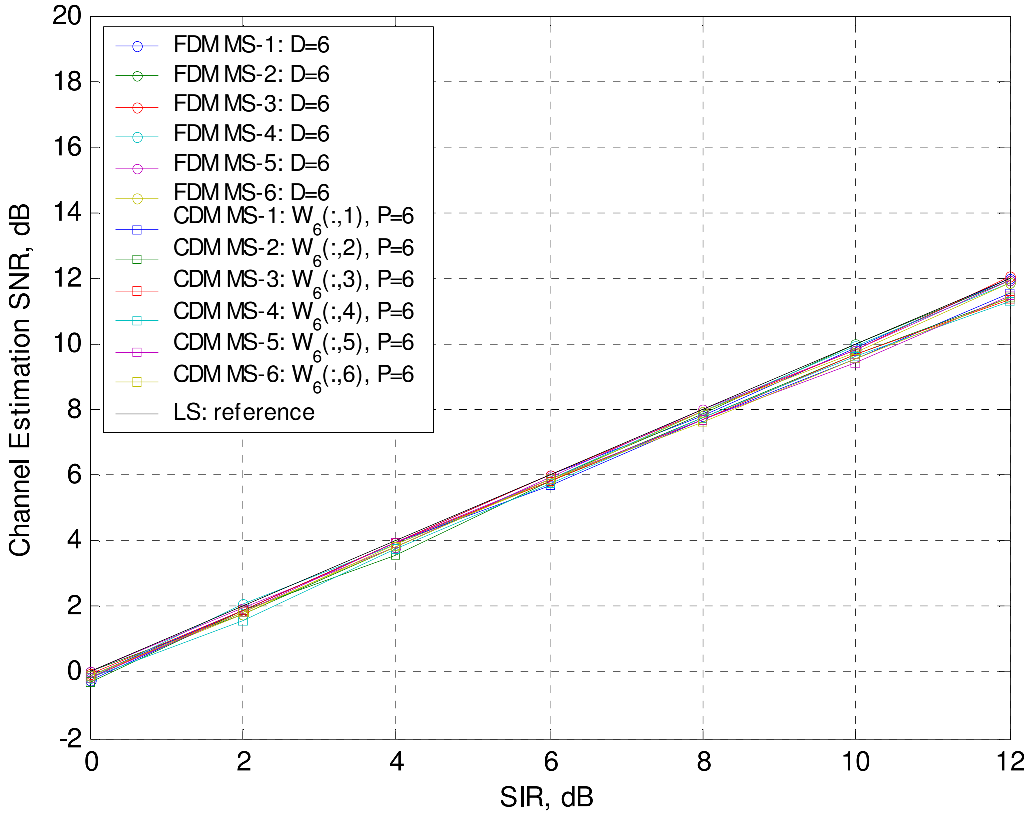
FDM vs. CDM Link Level Performance (1)

Noise-limited scenario or interference-limited scenario with non-overlapping sounding allocations for serving and interfering cells



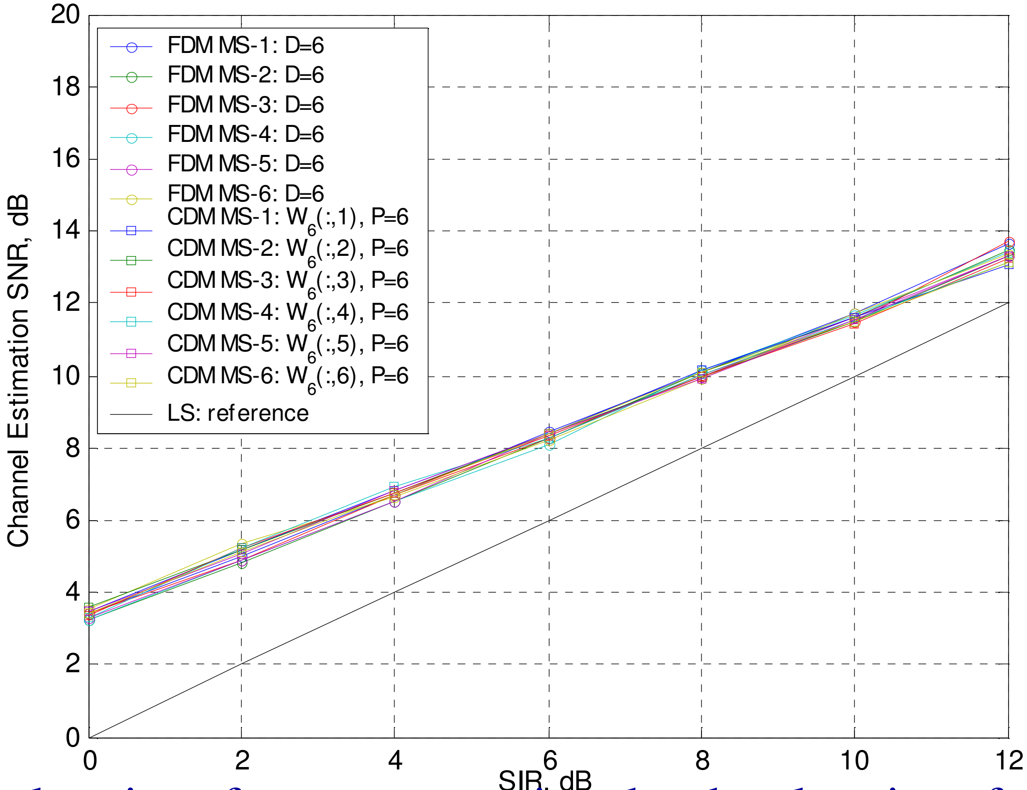
FDM vs. CDM Link Level Performance (2)

Interference-limited scenario with full overlapping sounding allocations of serving and interfering cells. Different cells are using the same baseline sounding sequences



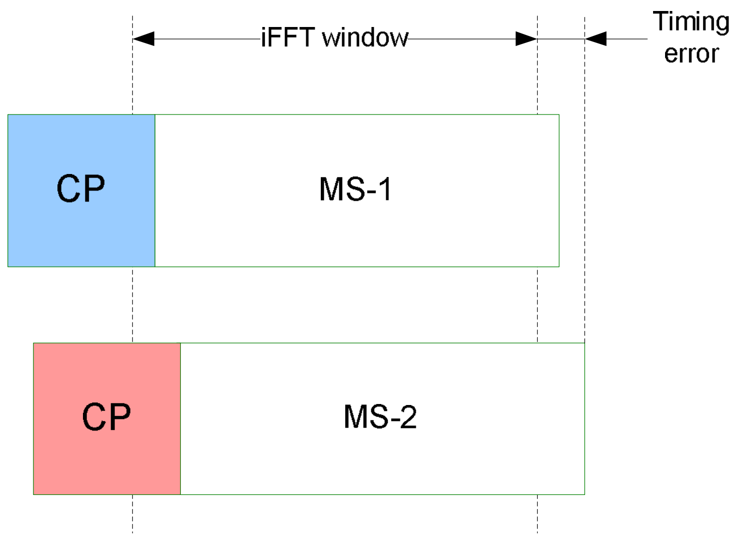
FDM vs. CDM Performance (3)

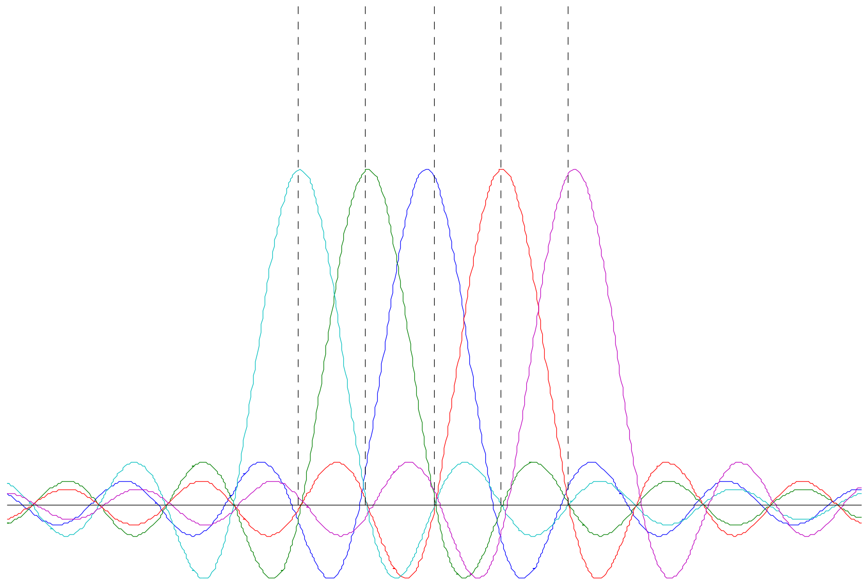
Interference limited scenario with full overlapping sounding allocations for serving and interfering cells. Different cells are using different baseline sounding sequences.



FDM provides less interference averaging, but has less interfering sources; CDM provides more interference averaging, but has more interference sources

Timing and Frequency Errors

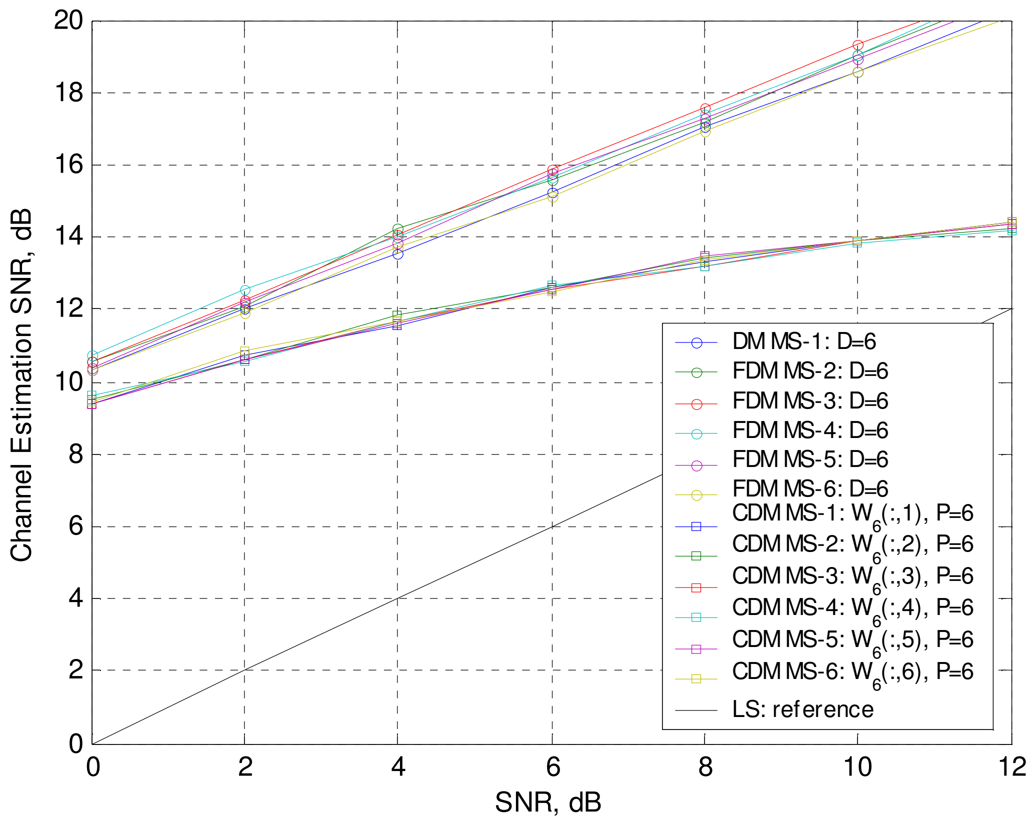




In practical systems the sounding signals transmitted by different MSs are arriving at the BS with different timing and frequency offsets

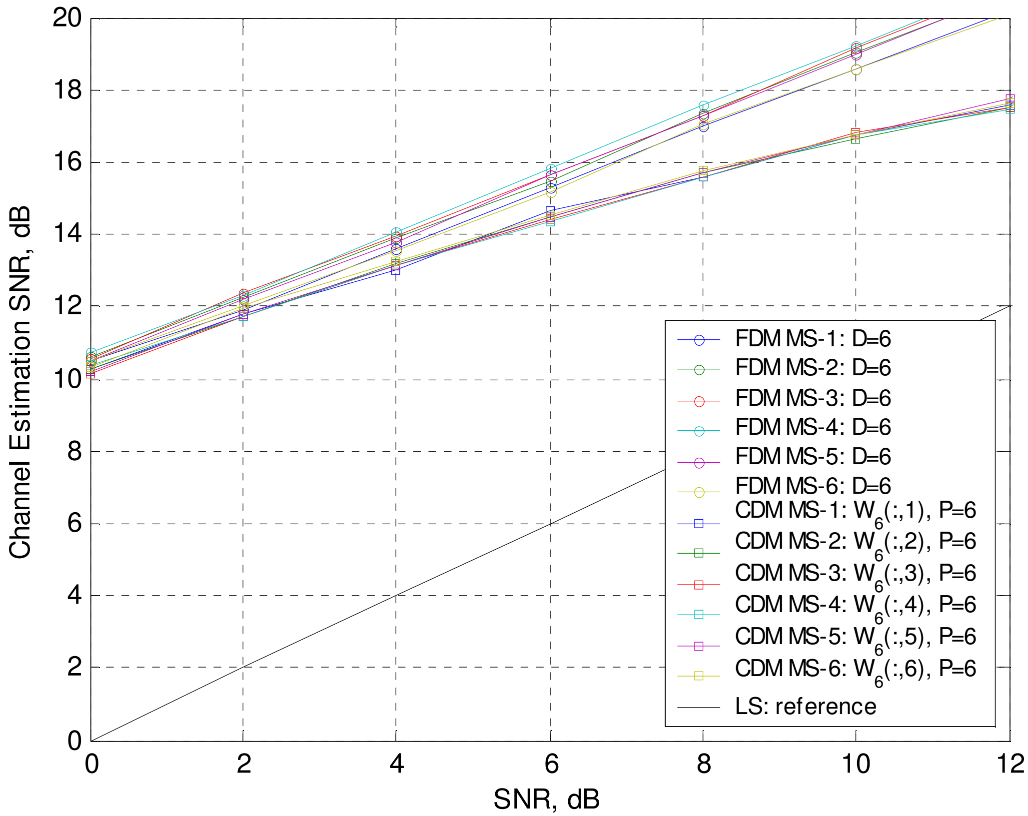
Impact of Imperfect Timing

CDM may be sensitive to timing errors due to loss of orthogonally between spreading codes



Impact of Frequency Offset

FDM and CDM methods are robust to frequency offset errors



Summary

- There is no substantial difference in the average channel estimation error performance between CDM and FDM methods for practical SINR values
- FDM is not sensitive to timing errors and has some performance advantages for noise-limited scenario and interference-limited scenario with non-overlapping sounding allocations (different uplink subframes, mismatch of sounding allocations)
- For interference limited scenario with full overlapping sounding allocations FDM can achieve a similar performance as CDM by applying pseudo random decimation offset
- Adoption of the second usage option (FDM and CDM methods) is not justified

Proposed text remedy

- *Modify the proposed text in line 9, page 14 (section 15.3.9.2.3)*

15.3.9.2.3. Sounding Channel

15.3.9.2.3.1. Sounding sequence

The baseline sounding sequence is based on Golay sequence of length 2048 bits defined in Table 464 of Section 8.4.6.2.7 of WirelessMAN-OFDMA.

Cell-specific time-domain cyclic shift of the sounding waveform generated at the MS can be used for additional inter-cell interference averaging. An alternative strategy for inter-cell interference averaging is a usage of a cell-specific cyclic rotation of the baseline sounding sequence.

15.3.9.2.3.2. Multiplexing for multi-antenna and multi-AMS

The uplink sounding channels of multiple AMS and multiple antennas per AMS can be multiplexed through ~~[Option 1: decimation separation or cyclic shift separation][Option2:~~ decimation separation~~]~~ in each sounding allocation. Also, in case of multiple UL subframes for sounding, time division separation can be applied by assigning different AMS to different UL subframe. ~~For cyclic shift separation each AMS occupies all subcarriers within sounding allocation and uses the different sounding waveform [Editor's note: remove this sentence if Option 2 will be adopted].~~ For frequency decimation separation each AMS uses decimated subcarrier subset from the sounding allocation set with different frequency offset.

A decimation value D means that the MS uses every D-th subcarrier within sounding allocation. Decimation value is transmited in the sounding command and may take one of the values D = TBD. A frequency offset g is unique value assigned in the sounding commands for each MS and specifies the first subcarrier index for the sounding within sounding allocation. For multiple antenna MS the frequency offset value for i-th antenna is equal to $g+i-1$.

References

[1] Proposed Text for the Draft P802.16m Amendment on the PHY Structure for UL Control, IEEE C802.16m-09/386