Downlink MIMO Schemes for IEEE 802.16m

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Venue:

Call for Contributions on IEEE 802.16m-08/003r1 System Description Document (SDD)

Topic: Downlink MIMO schemes

Base Contribution:

C80216m-08_285r2

Purpose:

Discussion and approval

Notice:

Release:

Patent Policy:

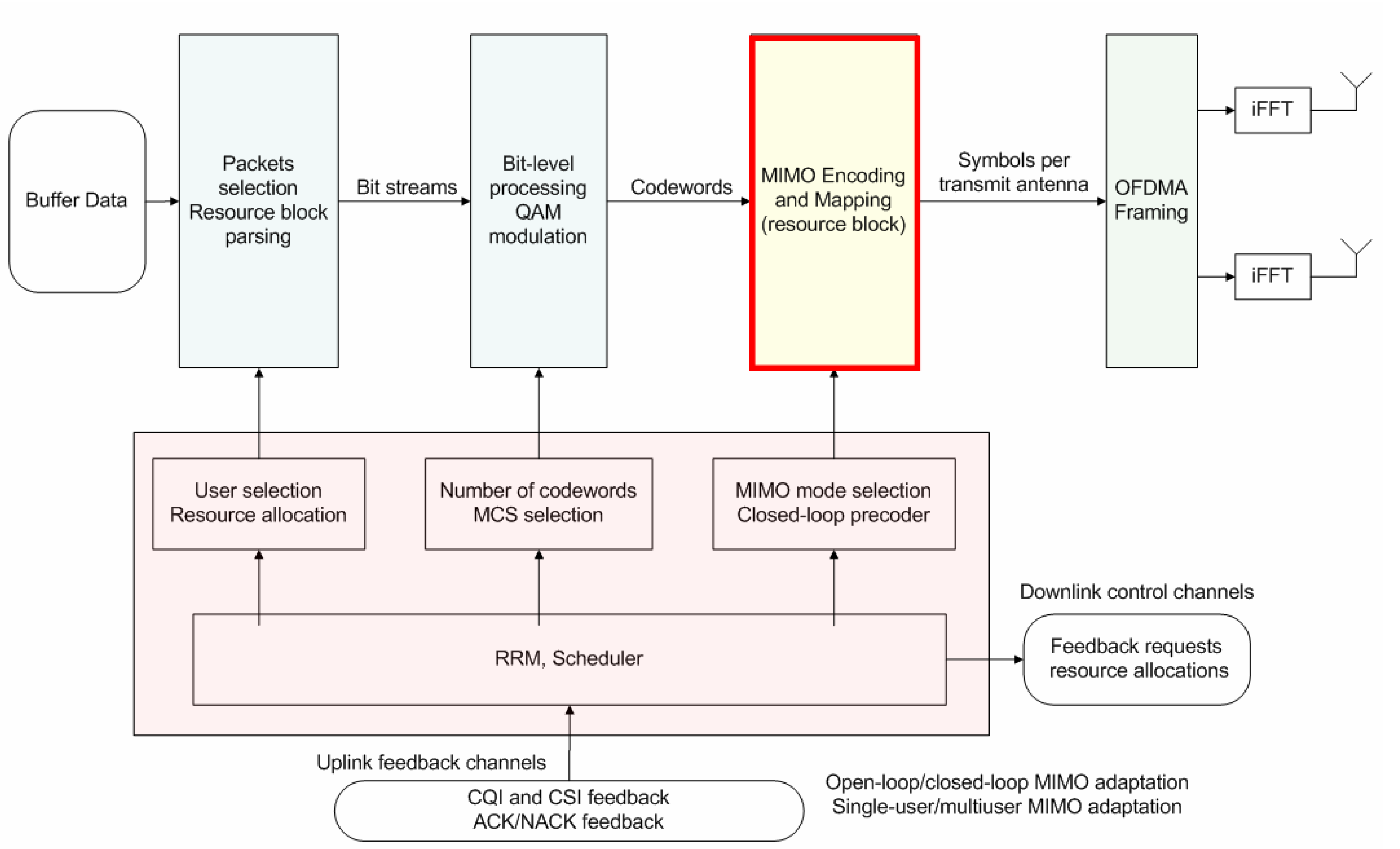
Scope of MIMO Proposal for May 2008

- DL MIMO schemes
- UL control structures (related to MIMO)

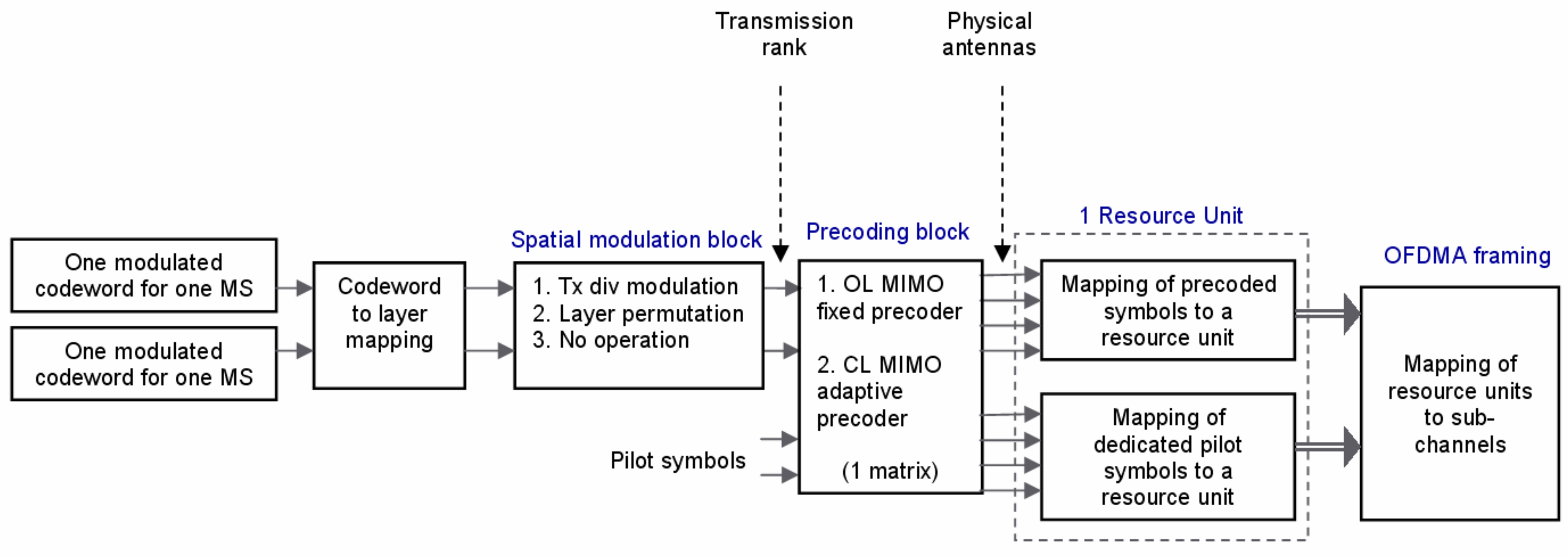
Proposed Scope of Downlink MIMO

Scope of support	Method of support
Support of robust MIMO on traffic channels	Downlink single-user open-loop MIMO
Support of high downlink user throughput	Downlink single-user open-loop MIMO Downlink single-user closed-loop MIMO
Support of high downlink sector throughput	Downlink multiuser MIMO (SDMA) for fixed and nomadic users
Flexible MIMO CQI and CSI Feedback	Unquantized and quantized CSI feedback CQI (CINR and ESINR, wideband and differential) Adapted to MS conditions and duplexing mode
Support of various cell configurations	Optimized for robustness in channel with correlated, uncorrelated, cross-polarized BS antennas

MIMO Architecture



MIMO Processing



Note 1: optional layer permutation block for spatial multiplexing and single-user precoding

Note 2: the precoder is never applied to measurement pilots (i.e. MIMO CQI pilots)

Note 3: the number of codewords per MS, the transmission rank per MS, and the number of MS per resource unit are configurable

Definitions

- Transmission rank in SU MIMO
  - Number of columns of the precoder
  - i.e. number of dedicated pilots in a Resource Unit
- Fixed pre-determined precoder in OL MIMO
  - To set the transmission rank in SU OL MIMO
- Adaptive closed-loop precoder in CL MIMO
  - Adapted to feedback of channel state information (CSI)
    (i.e. with uplink sounding, codebook feedback)

Usage of Precoders

- MIMO precoder
  - Fixed pre-determined "open-loop" precoder
    - For transmit power balance among physical antennas
    - For transmission rank adaptation in SU OL MIMO
  - Adaptive closed-loop precoder
    - For matching beams to the actual channel condition
    - Inherent rank adaptation in SU and MU CL MIMO
- Both precoders are supported by a single precoding block
  - Fixed precoder is not applied to the measurement (MIMO CQI) pilots
  - Fixed and closed-loop precoders are never concatenated

Downlink MIMO Modes

BS transmit antennas	Transmission scheme	Rank	Precoder
N 2, 4, 8	OL MIMO (SU)	$r \leq 4$	$r \times N$ fixed precoder Frequency-dependent known at MS unitary constant modulus matrix
N 2, 4, 8	CL precoding (SU, MU)	1 to 4	Adaptive precoder

In diversity sub-channels: maximum rank is 2 supported by common pilots, so closed-loop precoding is not allowed

Downlink Open-Loop MIMO Schemes

- Transmission of downlink control channels
  - Using baseline 2 transmit antennas
  - Baseline transmit diversity scheme is TBD
  - With 2 or more antennas at the base station
    - the fixed pre-determined precoder shall be applied to common pilots and data in diversity sub-channels to enable the use of the baseline TBD transmit diversity scheme

- Transmission of downlink traffic channels
  - Fixed precoder (+ open-loop spatial multiplexing)
  - Fixed precoder (+ transmit diversity scheme TBD)

Closed-Loop Precoding
single-user and multiuser

- TDD with DL/UL channel reciprocity
  - Feedback: uplink sounding
  - Precoding: implementation-dependent

- FDD
  - Feedback: index of precoder in a codebook
  - Precoding: unitary precoding matrix

- Codebook size
  - Simple codebook that reduce as much as possible the complexity of codebook search and CQI calculation
  - Small memory size requirements

Closed-Loop Precoding

BS transmit antennas	Single-user MIMO Scheme Codebook size	Multiuser MIMO Scheme Codebook size
2 Tx	3 bits	2 bits
4 Tx	4 bits	3 bits
8 Tx	3 bits	3 bits

- Codebook-based unitary precoding with rank adaptation
- Consider the use of differential codebooks to reduce the feedback overhead or to decrease the quantization error

SU MIMO Unitary Precoding

Feature	Properties
Codebook = set of unitary matrices	• DFT matrices for robustness in correlated and uncorrelated channels • Additional unitary matrices for cross-polarized channels • Constant modulus for power balance of transmit power amplifiers
Feedback = MS preferred precoder index (PCI) and CQI	• Determine the preferred precoder among all possible unitary precoders (whose size vary from [Nt×1] to [Nt×r] with r = min{ Nt, Nr }) • Feedback one or more CQIs → Accurate ESINR prediction
BS precoding	Downlink transmission using selected columns from one unitary matrix of the same codebook

MU MIMO Unitary Precoding

Feature	Properties
Codebook = set of unitary matrices Same codebook at BS and MS	• DFT matrices for robustness in correlated and uncorrelated channels • Constant modulus for power balance of transmit power amplifiers
Feedback = MS preferred precoder index (PCI) and CQI	• Determine the preferred column in preferred unitary matrix (PCI) • Assume interference from other columns of the same unitary matrix in the CQI feedback → Accurate ESINR prediction
BS precoding	• Downlink transmission using columns from one unitary matrix of the same codebook • Transmit to several MS with 1 beam per MS

Downlink Pilots

- Measurement (CQI) pilots
  - For MIMO feedback (MIMO scheme, CQI, PCI)
  - Scattered common pilots in one subframe every frame (5 ms)
  - Not precoded by fixed precoder
  - Support up to 2, 4 and 8 transmit antennas at the BS
  - 1.11 % overhead to support MIMO measurements (4, 8 Tx)

- Demodulation pilots
  - The downlink dedicated pilots shall be processed by the same precoding matrix as used on the data (either the fixed or adaptive precoder)

Feedback Information

Feedback information	Features
Full channel state information (TDD with channel reciprocity)	BS measure downlink channel from uplink sounding signals Support any implementation-dependent solution
Index of precoder from a codebook	Codebook search required at MS Accurate prediction of CQI (i.e. ESINR) at MS

Uplink Control Structures
Feedback Channels

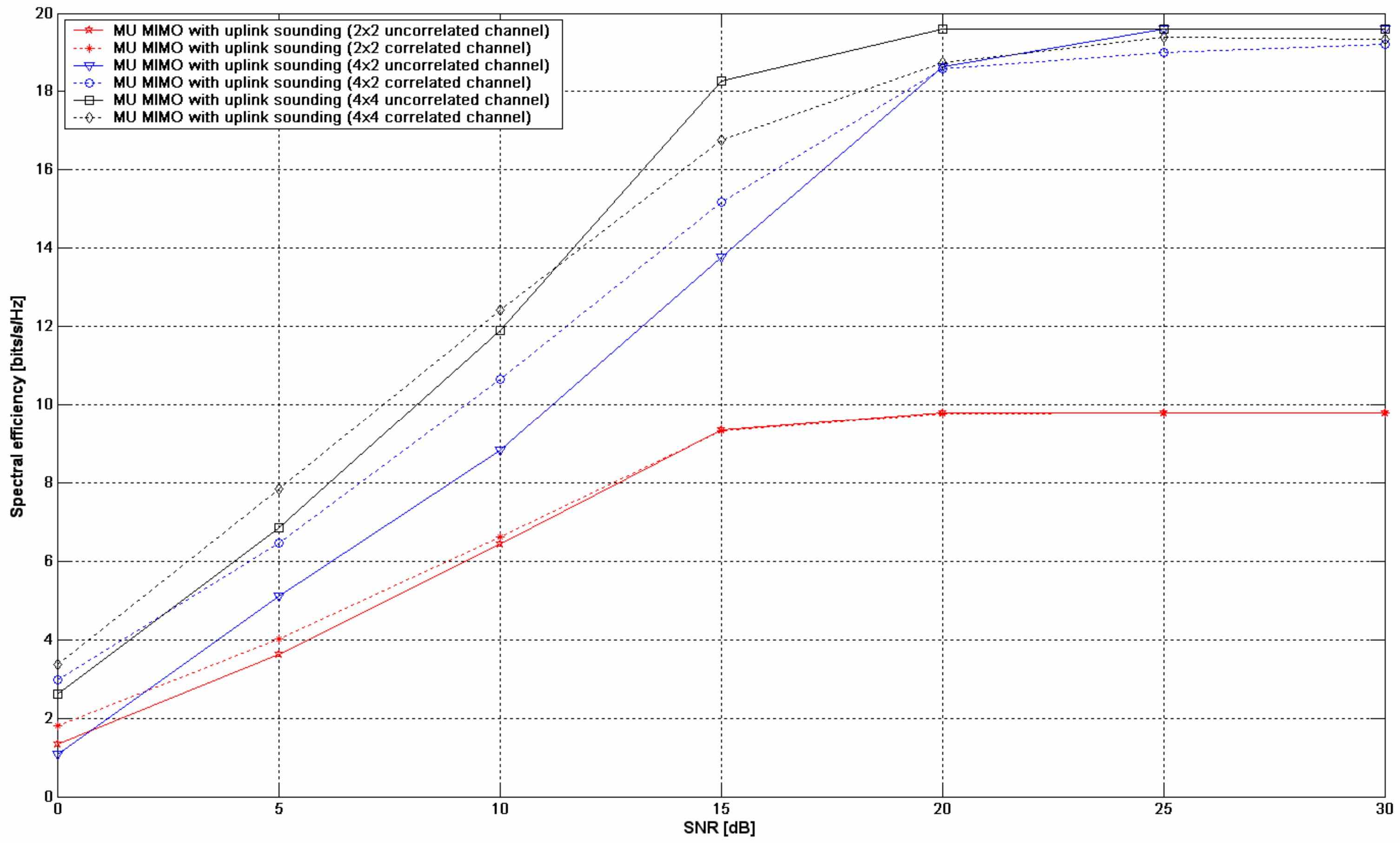
Uplink control channel	Properties
Uplink Sounding Symbol	An uplink sounding OFDM symbol shall be supported
CQICH	Uplink physical CQICH • Very robust modulation and coding scheme • Distributed fractional resource units
Feedback header	Efficient feedback method with allocation of uplink resource outside CQICH with adaptive MCS
Feedback sub-header	Sending control information in traffic channels • Efficient feedback method with allocated uplink resource for traffic

Simulation Conditions

Transmission bandwidth	20 MHz
Centre frequency	2.5 GHz
Subframe duration	0.6171 ms
Subcarrier spacing	10. 938 kHz
FFT size	1024
Number of occupied subcarriers	1008
Number of OFDM symbols per subframe	6
Number of subcarriers per Resource Unit	18
Spatial channel environment	Modified PedB channel, 3 km.h, uncorrelated at MS - Uncorrelated case: 4 wavelengths spacing and 15 degree angular spread at the base - Correlated case: ½ wavelength spacing and 3 degree angular spread at the base - Dual polarized case: +/-45 → V-H, ½ wavelength spacing and 3 degree angular spread at the base
CQI feedback	6 subframes delay, error-free
Uplink sounding	18 dB power difference between DL and UL
Feedback load	Full feedback (for every resource unit), 10 users
Downlink pilot overhead	2 Tx: 11.11%, 4 Tx: 22.22%
Channel estimation	Ideal
MIMO detection method	Linear MMSE
Modulation and coding	10 MCS levels
HARQ	Chase Combining, non-adaptive, 8 subframes retransmission delay, maximum 4 retransmissions

Multi-User Closed-loop MIMO

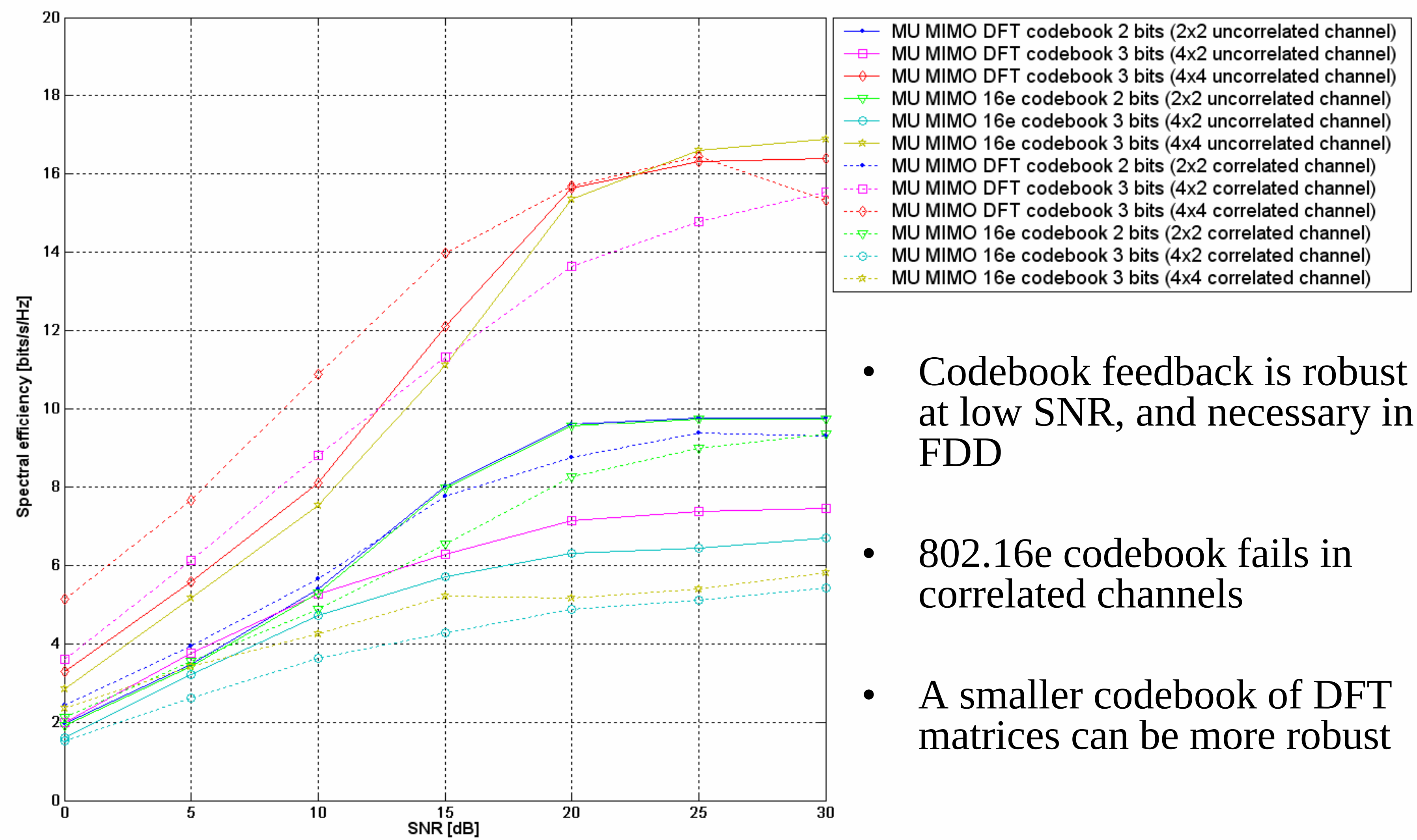
Feedback: uplink sounding



- Uplink sounding allows to achieve the highest spectral efficiency at high SNR

Multi-User Closed-loop MIMO

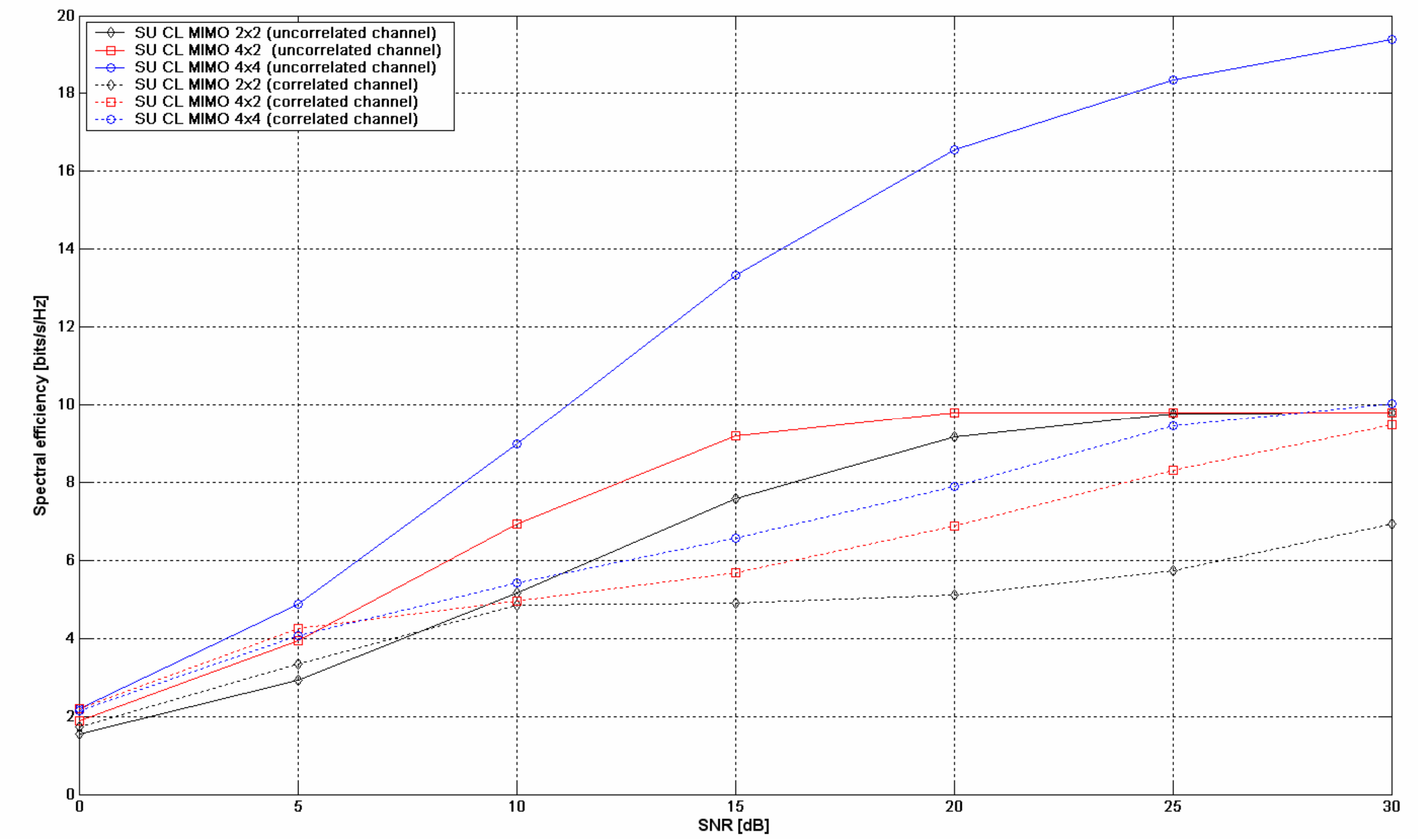
Feedback: codebook-based



- Codebook feedback is robust at low SNR, and necessary in FDD
- 802.16e codebook fails in correlated channels
- A smaller codebook of DFT matrices can be more robust

Single-User Closed-loop MIMO

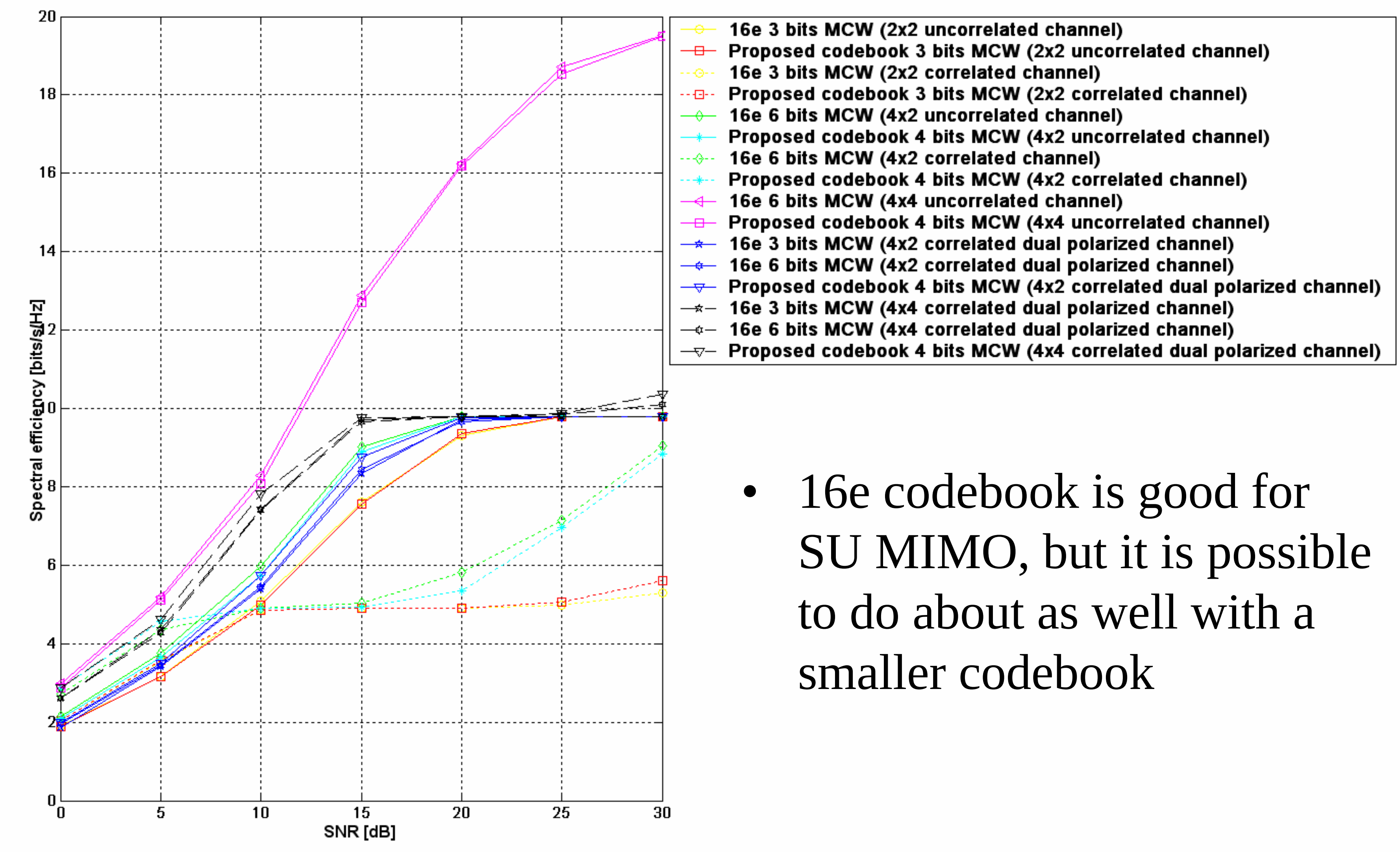
Feedback: uplink sounding



- Uplink sounding allows to achieve a higher spectral efficiency at medium to high SNR than with codebook-based feedback

Single-User Closed-loop MIMO

Feedback: codebook-based



- 16e codebook is good for SU MIMO, but it is possible to do about as well with a smaller codebook