Closed Loop MIMO Precoding

IEEE 802.16 Presentation Submission Template (Rev. 8.3)

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Purpose:
Introduce changes according to IEEEC80216e-04/293r2 to 802.16e/D4

General Approach

- Exploit all available information
  - Instantaneous channel knowledge
  - Long term channel statistics
    - Mean
    - Spatial covariance
- Switch between short term and long term precoder
- Mobility cases
  - Low mobility => Use short term precoder
  - High mobility => Use long term precoder

Short Term Precoding

- Precoding matrix selected based on short term channel knowledge.
- Select precoding matrix from code book with 64 entries
  - Six bits quantization per precoding matrix irrespective of nr Tx antennas and spatial rate.
  - One CQICH channel
- Code books consists of unitary matrices selecting a subspace of rank equal to the spatial rate used.
- No STBC used, simply Eigenbeamforming with 1,2 or 3 spatial streams.

Long Term Precoding

- Precoding matrix selected based on long term channel knowledge.
- Same code books as for short term precoding.
- The code book rank is selected depending on how many dimensions one wants to put energy into.
- Use standard space time code for nr Tx antennas equal to the rank of the code book used:
  - Rank 1 code book – Use SISO transmission
  - Rank 2 code book – Use 2 Tx antenna STC matrices
  - Rank 3 code book – Use 3 Tx antenna STC matrices
  - Rank 4 – Open loop is used
- Very low feedback bandwidth requirements
  - For 200 users/sector and 6 bit per user per second, we need only the equivalent of a single CQICH slot per 5 ms frame.

Long Term and Short Term Precoding Setup

- BS can start long term precoding for a relatively larger number of active users.
- SS feeds back long term code book rank and long term precoding matrix index as well as life span of short term precoding matrix.
- The short term precoding matrix life span helps the BS choose the short term precoding feedback rate.
- BS can set up short term precoding when desired.
- SS feeds back short term precoding matrix index from code book of rank matching the spatial rate recommended by the SS link-adaptation algorithm.
- BS uses short term precoder when available and valid
- BS uses long term precoder if available otherwise

Precoding Matrix Selection

- Short term precoding rate 1
  - Maximize received power:

$$\mathbf{W} = \arg\max_{i} \left\| \mathbf{H}\mathbf{W}_i \right\|_{Frob}$$

- Short term precoding rate 2 and 3 or 4
  - Use Adhoc selection criteria
- Long term precoder matrix rate 1
  - Optimal or simplified Adhoc criteria
- Long term precoder rate 2 and 3 or 4
  - Use Adhoc selection criteria.

Code Book

- *L* is the total number of entries in the codebook. Similar to [Hochwald et al], given the *s* x *Mt* matrix *U* = [*I U'*], *Mt* x *Mt* diagonal matrices

$$[C_k]_{m,m} = e^{\frac{j2\pi}{\sqrt{L}}[U]_{k,m}}, k = 1,2; m = 1,\ldots,M_t; C_k^{\sqrt{L}} = I$$

  and *Mt* x *B* matrix Y (*B*<=*Mt*), the entries in the codebook are given as

$$W_l = C_1^{l_1} C_2^{l_2} \ldots C_2^{l_s} Y$$

  where l_i are elements in the ring of integers mod $L^{\frac{1}{s}}$. For simplicity, the basis matrix Y is given as selection of total of *B* columns (set of indexes ***B****c*) of the *DFT* matrix

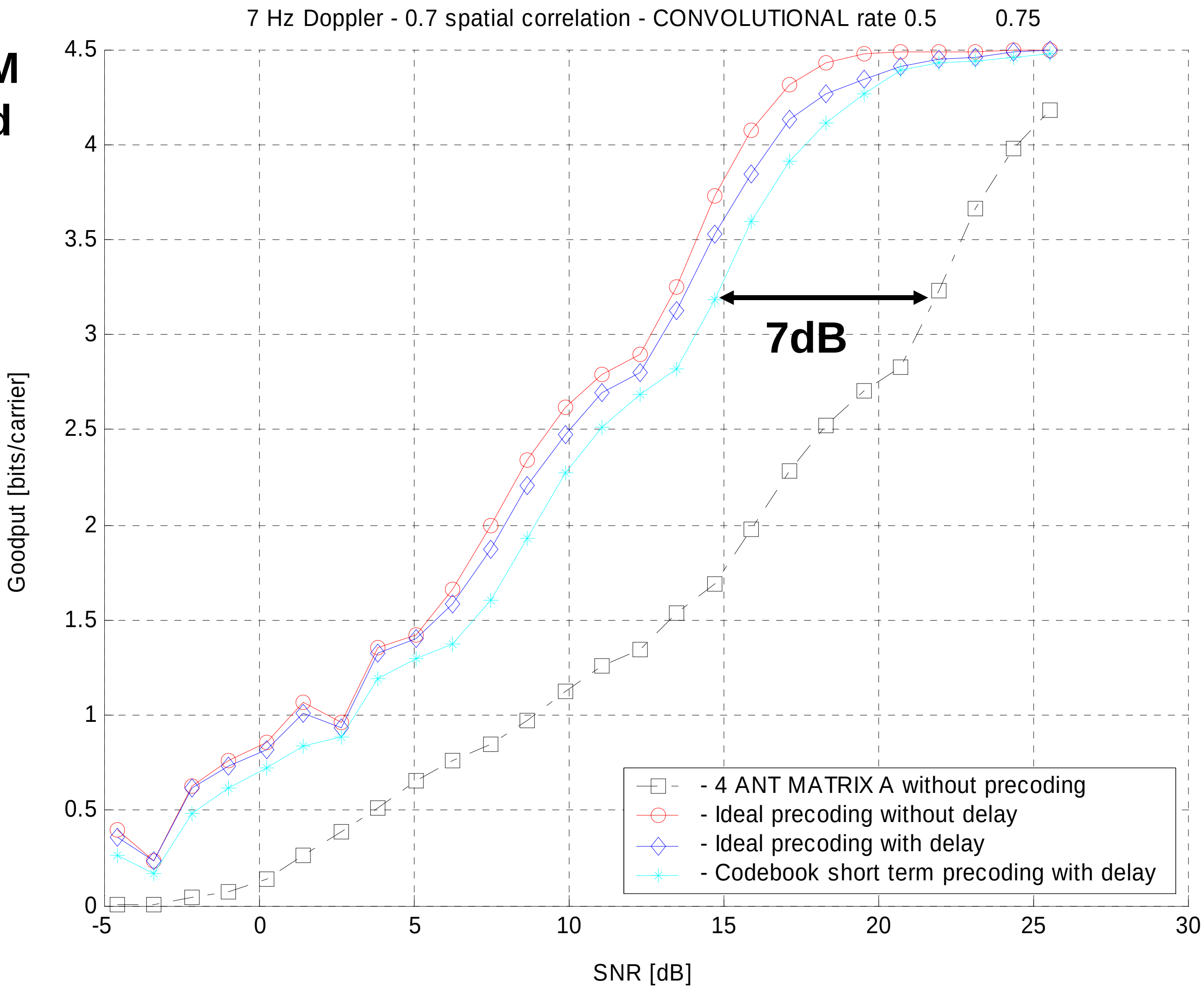
$$[DFT]_{m,b} = e^{j\frac{2\pi}{M_t}(m-1)(b-1)}, \qquad m,b = 1,\ldots,M_t$$

- General approach to codebook set partitioning which could enable more degrees of freedom for variety of feedback rates (e.g., for *s*=2, sending back l_1 with one rate and l_2 with another)
- In the current simulations, *L*=64, *s*=1 and *U* chosen as in Nokia's proposal

Short Term Results

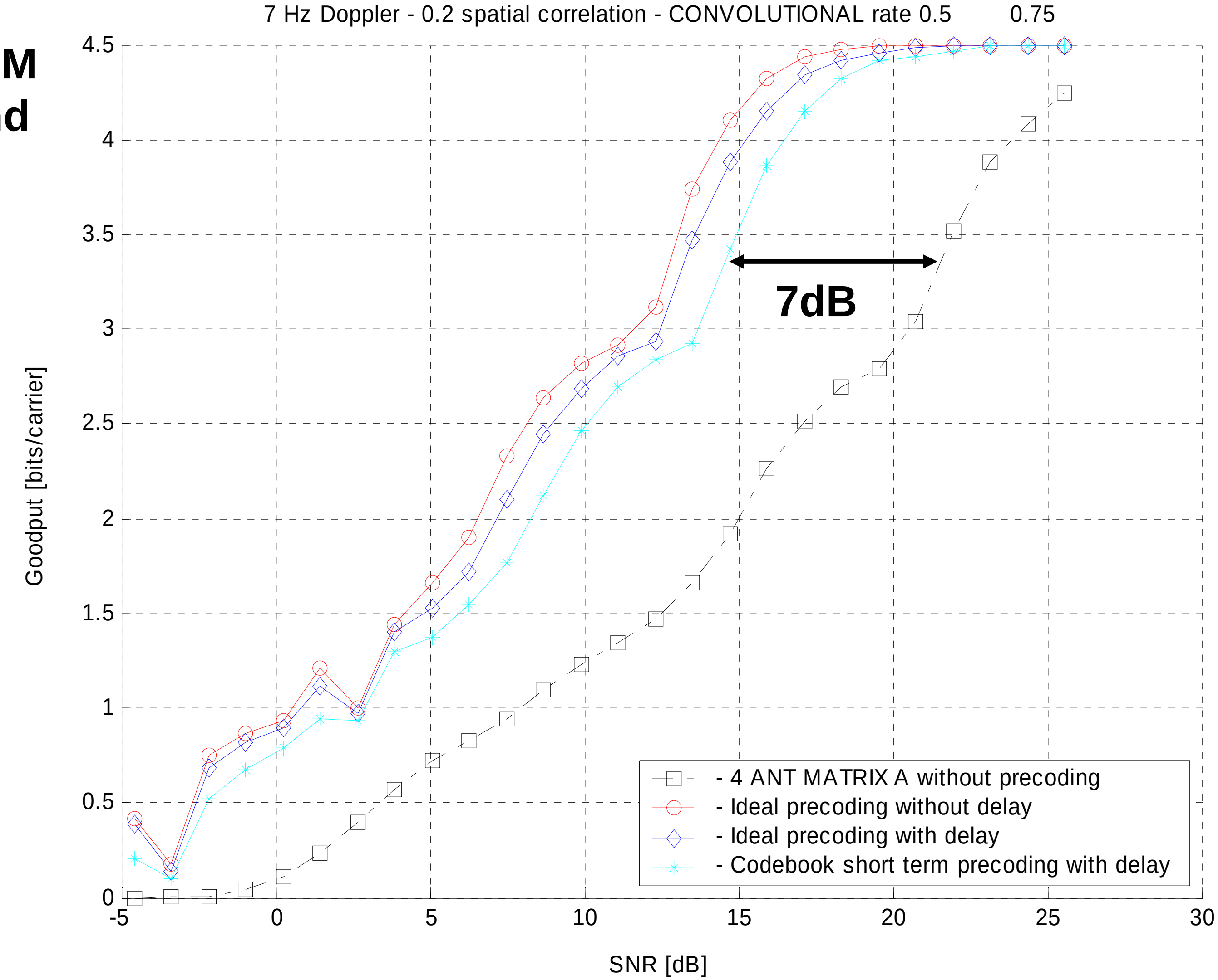
Short Term Example 1

- **4,16 and 64 QAM**
- **FEC rate 0.5 and 0.75**
- **2 frames delay**
- **STC rate 1**



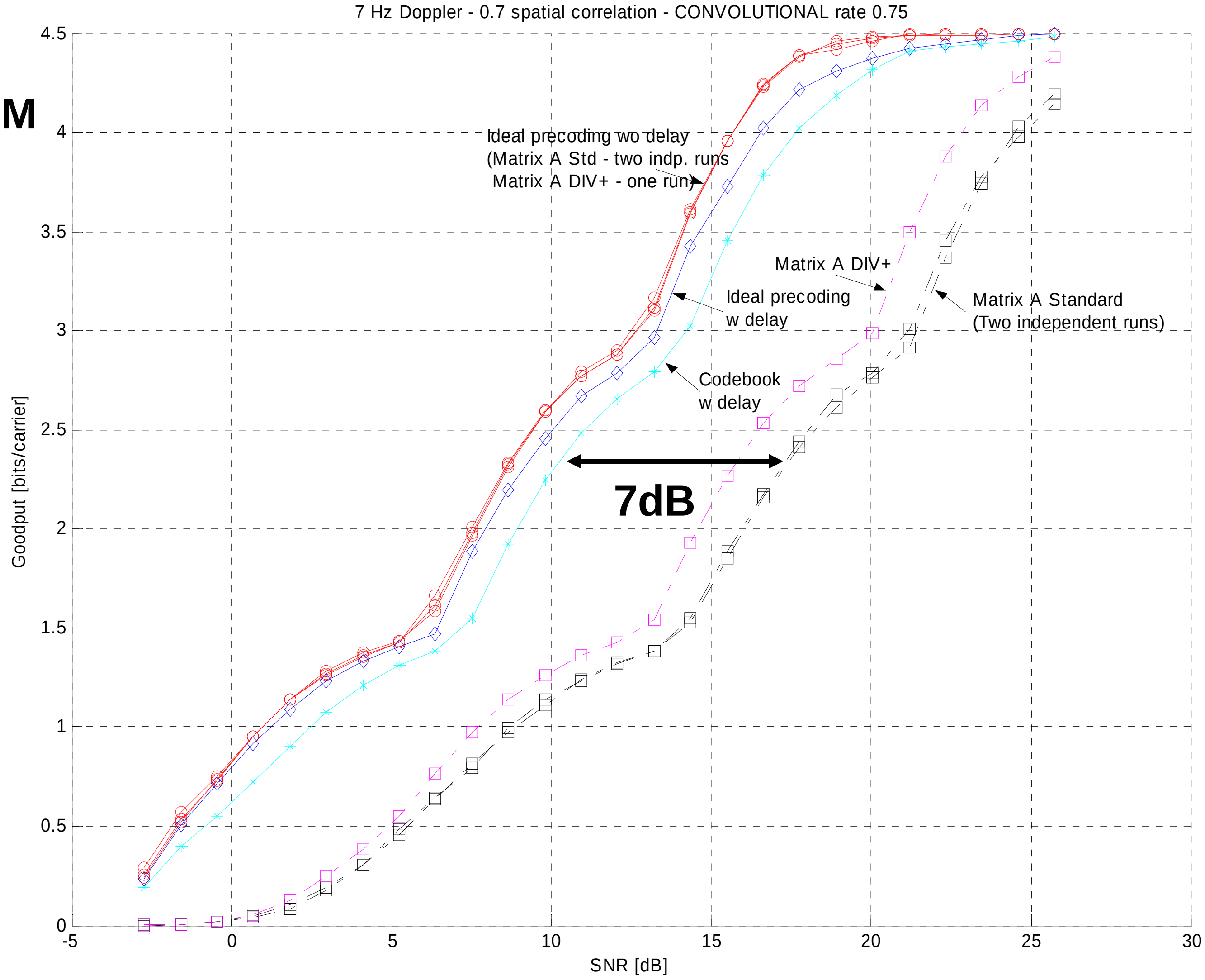
Short Term Example 2

- 4,16 and 64 QAM
- FEC rate 0.5 and 0.75
- 2 frames delay
- STC rate 1



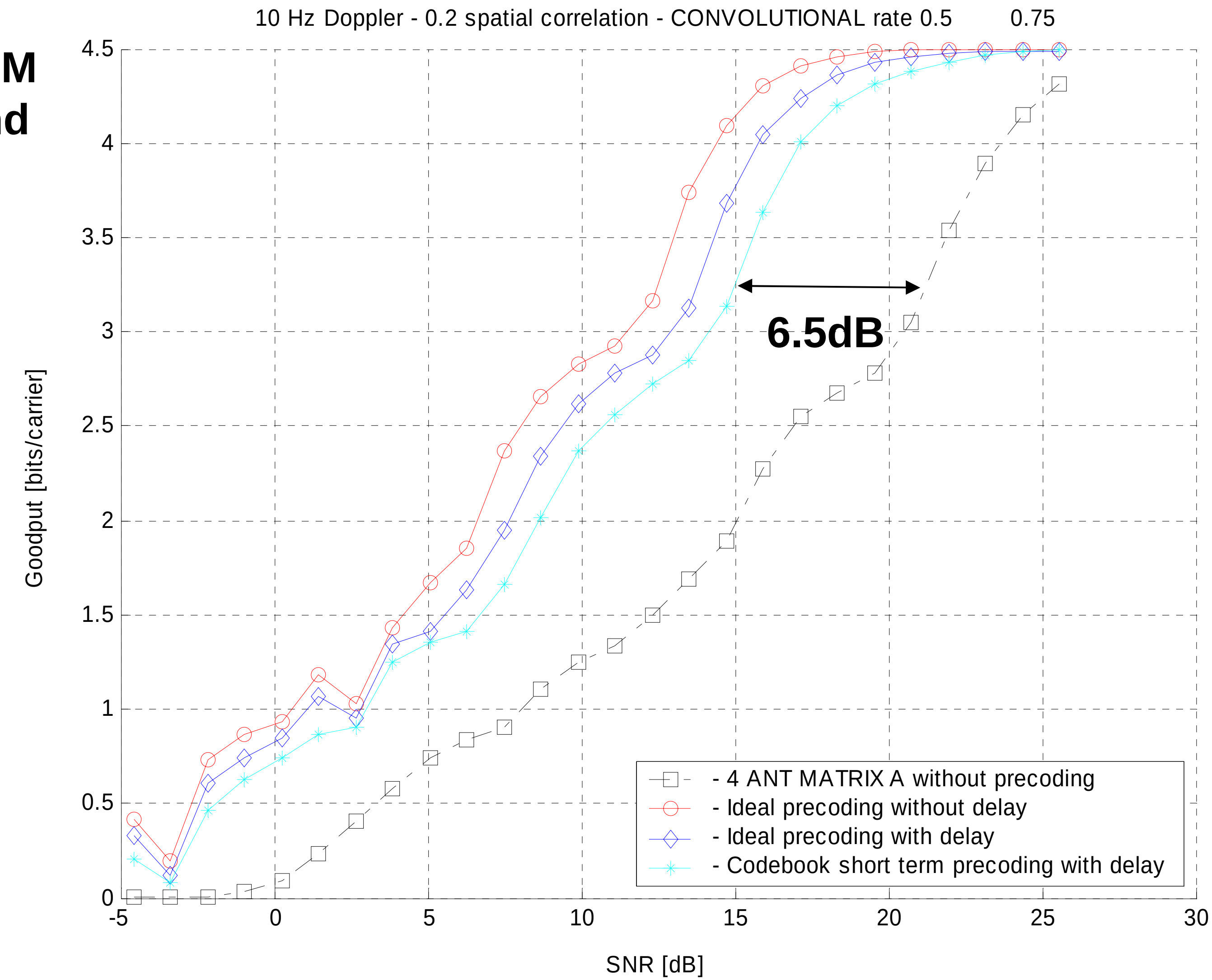
Short Term Example 3

- 4,16 and 64 QAM
- FEC rate 0.75
- 2 frames delay
- STC rate 1



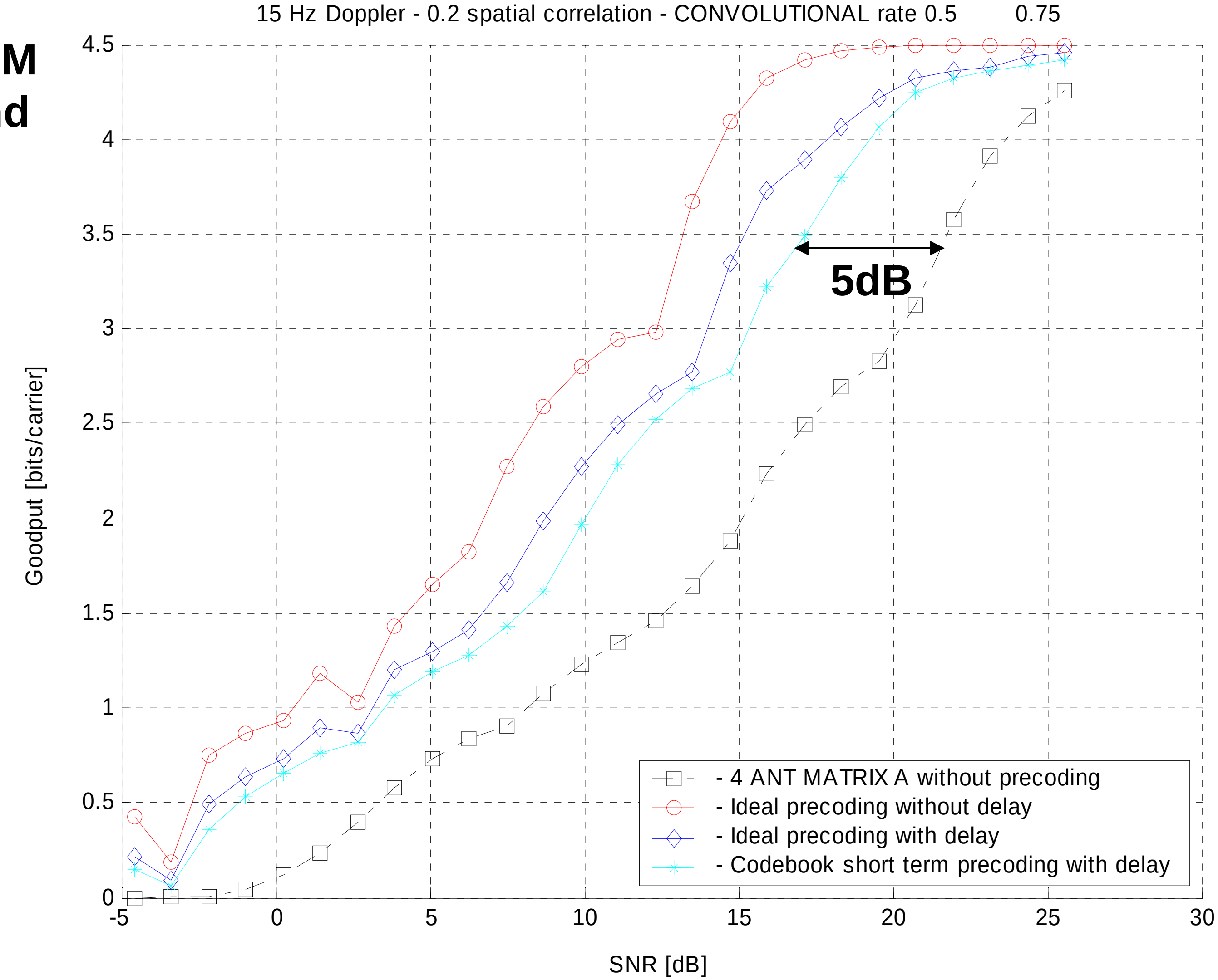
Short Term Example 4

- 4,16 and 64 QAM
- FEC rate 0.5 and 0.75
- 2 frames delay
- STC rate 1



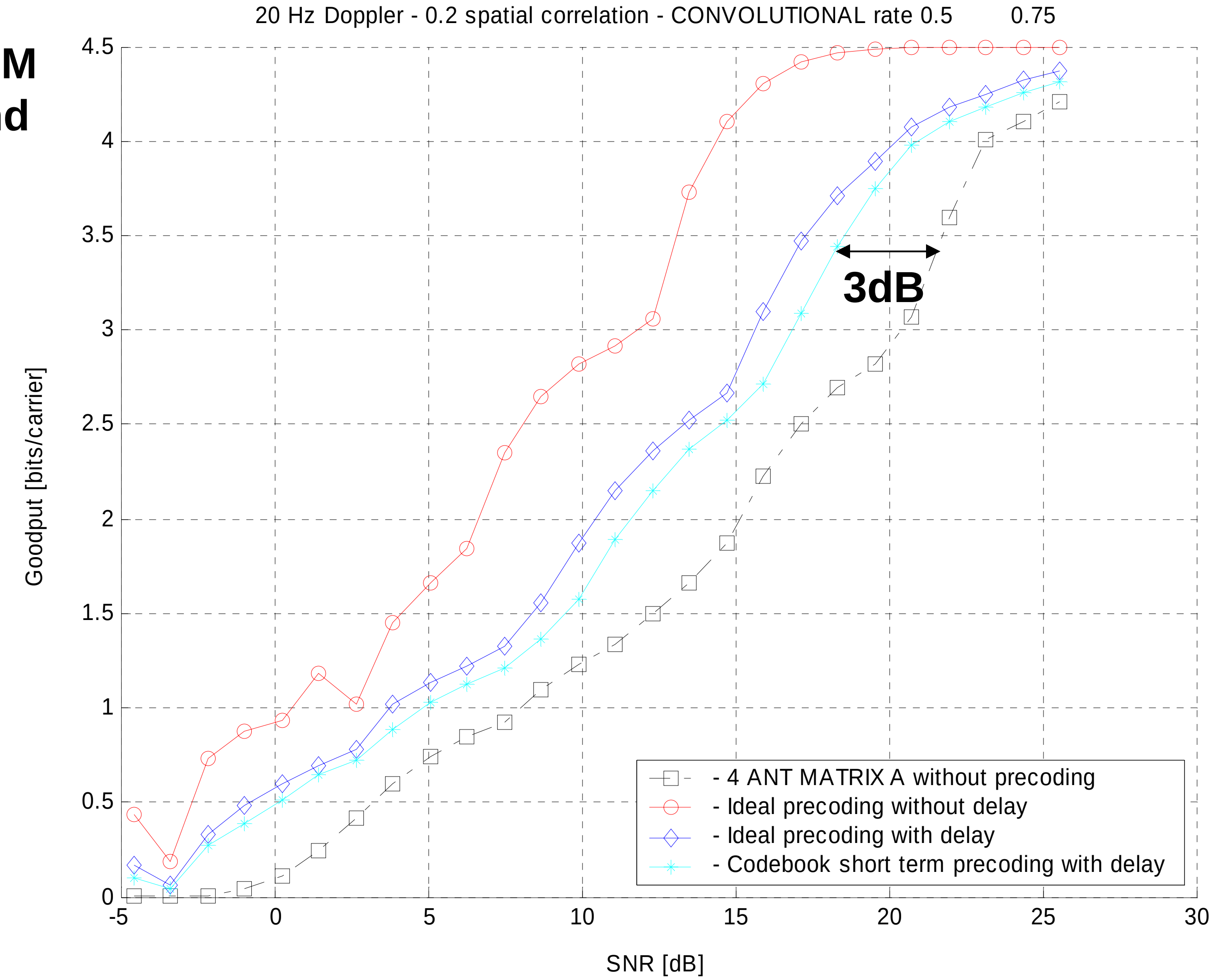
Short Term Example 5

- 4,16 and 64 QAM
- FEC rate 0.5 and 0.75
- 2 frames delay
- STC rate 1



Short Term Example 6

- **4,16 and 64 QAM**
- **FEC rate 0.5 and 0.75**
- **2 frames delay**
- **STC rate 1**



Long Term Results

Antenna Correlations

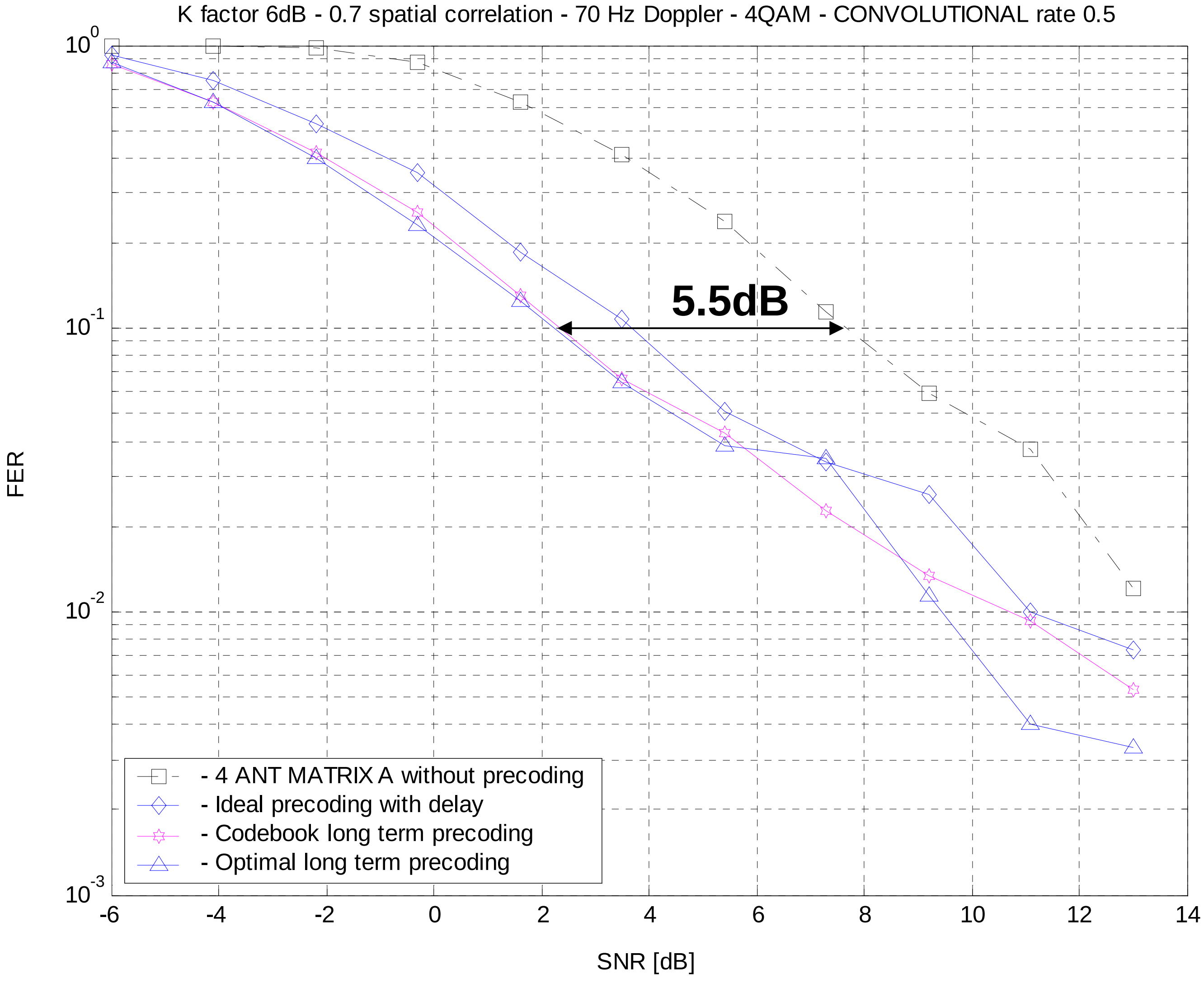
- SCM channel model with:
  - 4 lambda antenna spacing
  - 2 degrees Lapacian angular spread
  - 4 antennas makes a total width of ~1.5 m for a 2.5 GHz system.
  - Spatial correlation between adjacent antennas: 0.8624
  - Reference: 3GPP TR 25.996 V6.1.0 or SMC V7.0.
- SUI Channel models
  - Large K-factors are frequent, e.g.
    - SUI-1: 14.0 (linear, 90% cell coverage, 30 degree antenna)
    - SUI-2: 6.9 (same)

Reasoning why transmit antenna covariance matrix and channel mean is frequency independent

- Tx antenna covariance matrix reflects angular power spectrum.
- Angular power spectrum is frequency independent.
- Channel mean comes from a Ricean component.
- With a single Ricean component the channel mean is frequency independent.

Long Term Example 1

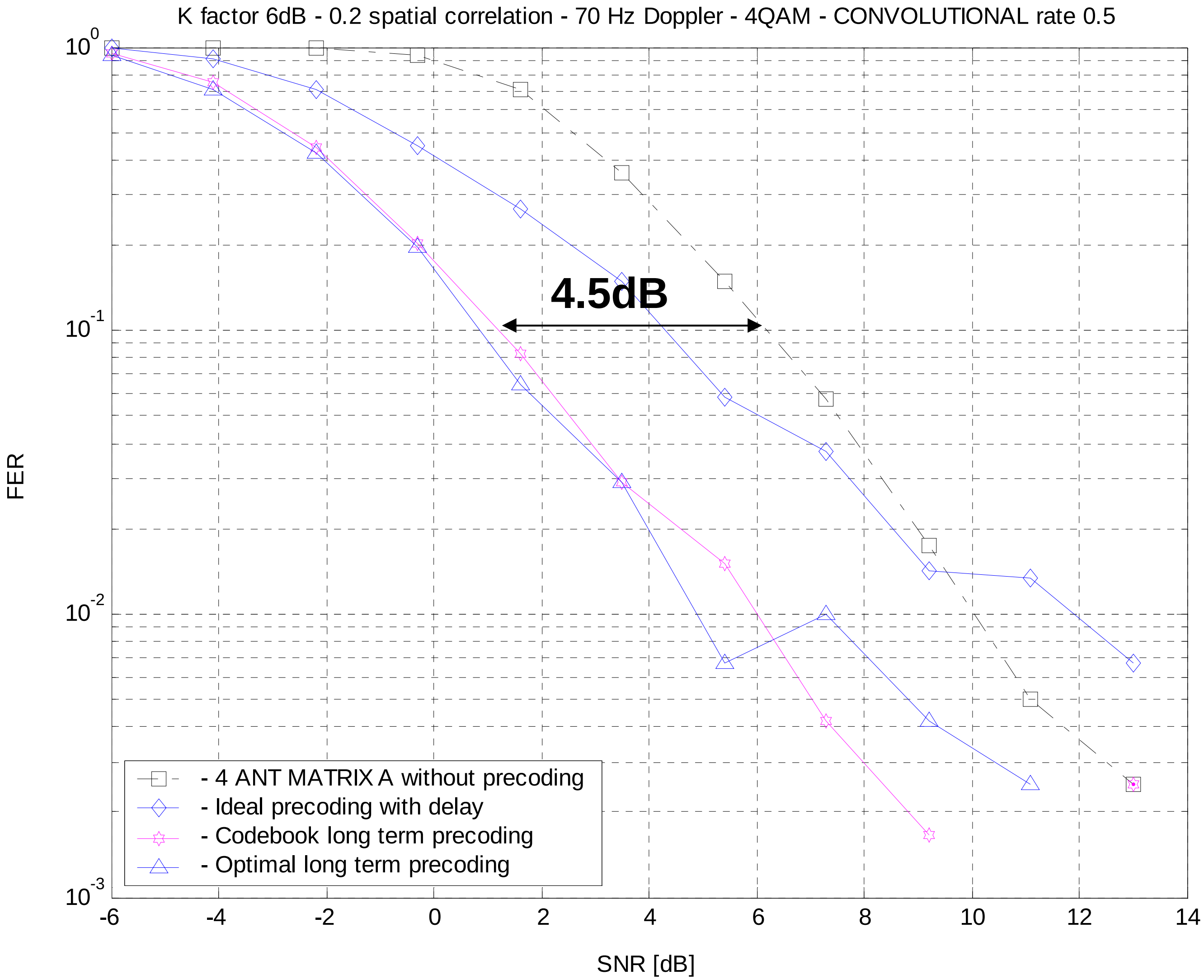
- 0.7 spatial correlation
- 6dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 5.5dB gain over open-loop STBC

Long Term Example 2

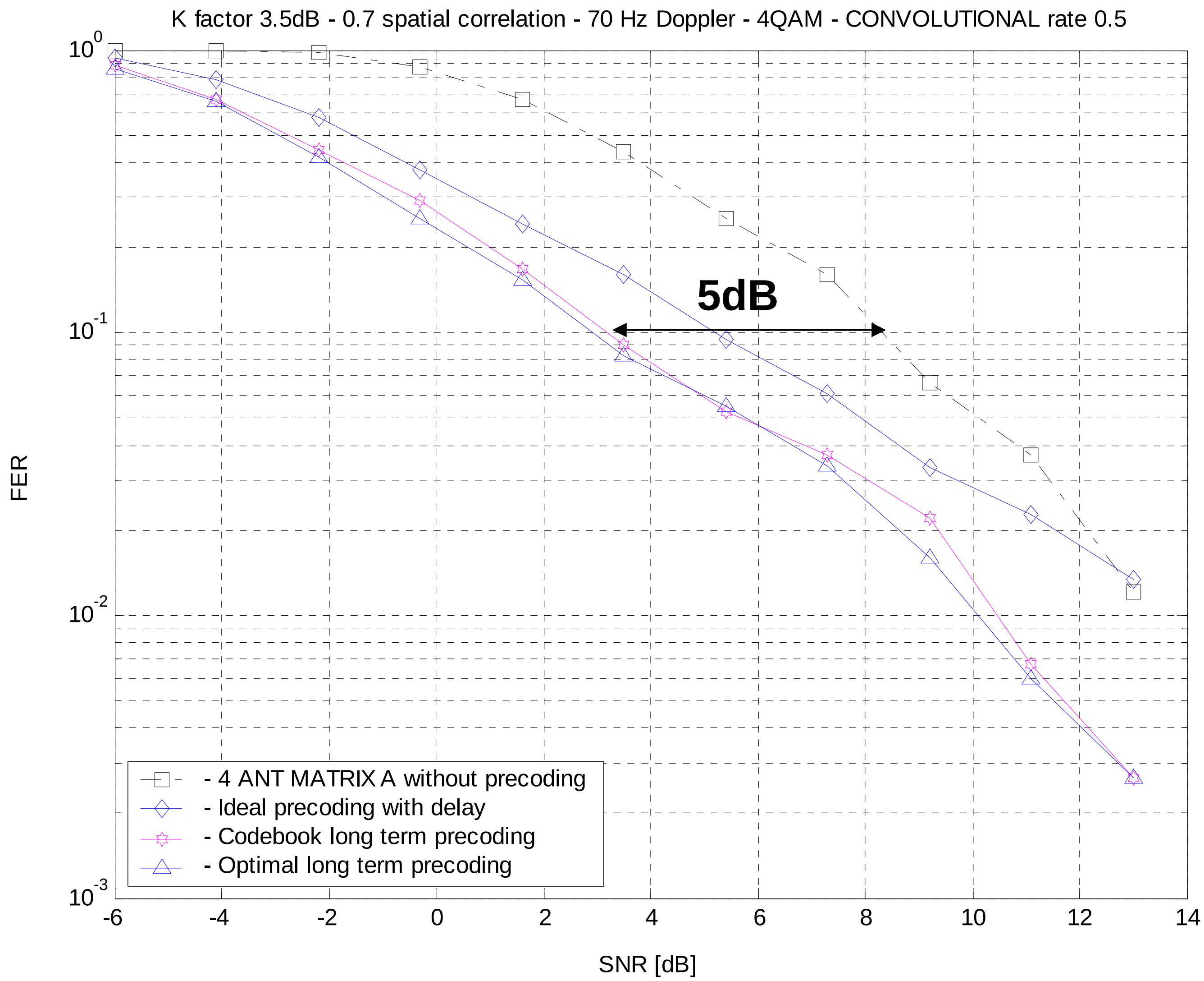
- 0.2 spatial correlation
- 6dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 4.5dB gain over open-loop STBC

Long Term Example 3

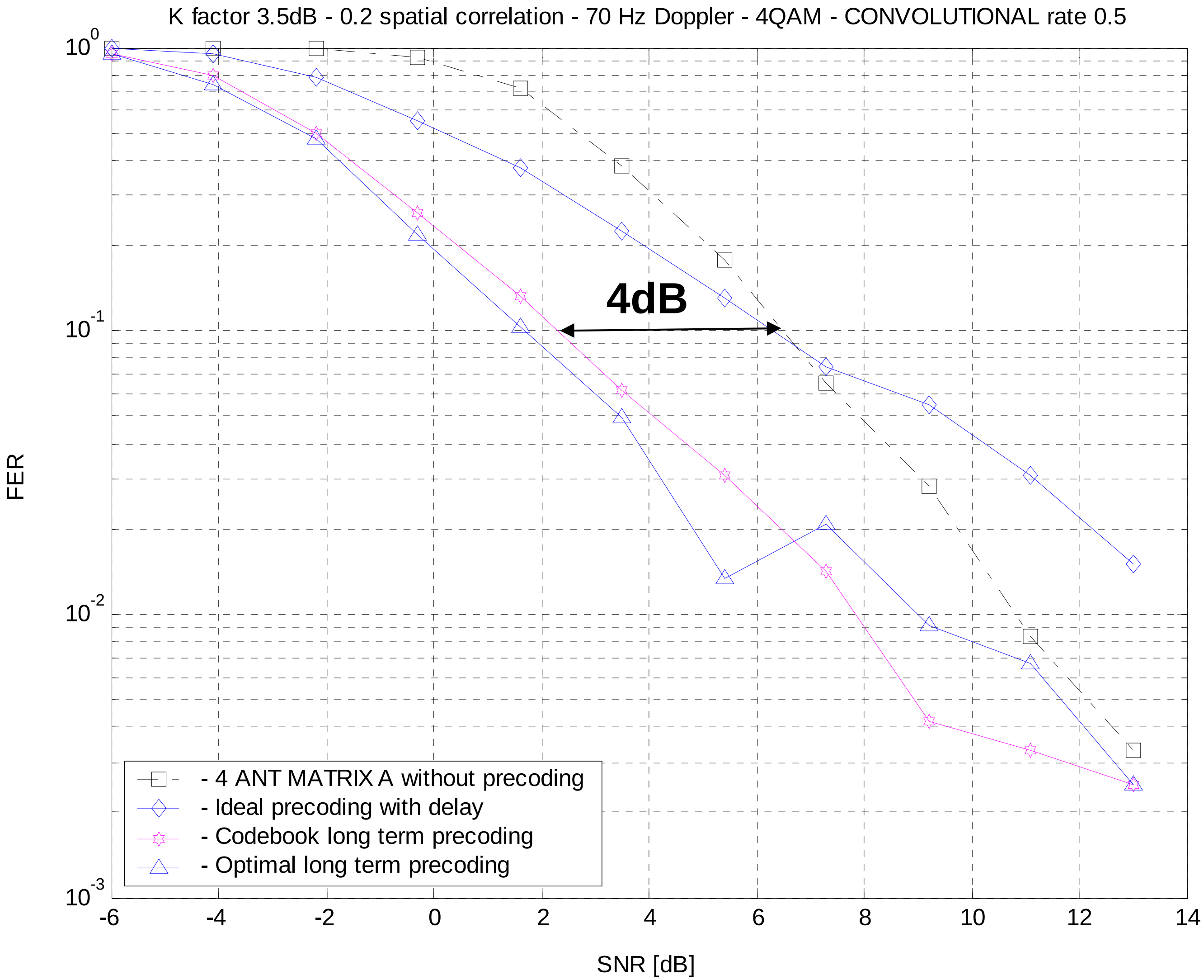
- 0.7 spatial correlation
- 3.5dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 5dB gain over open-loop STBC

Long Term Example 4

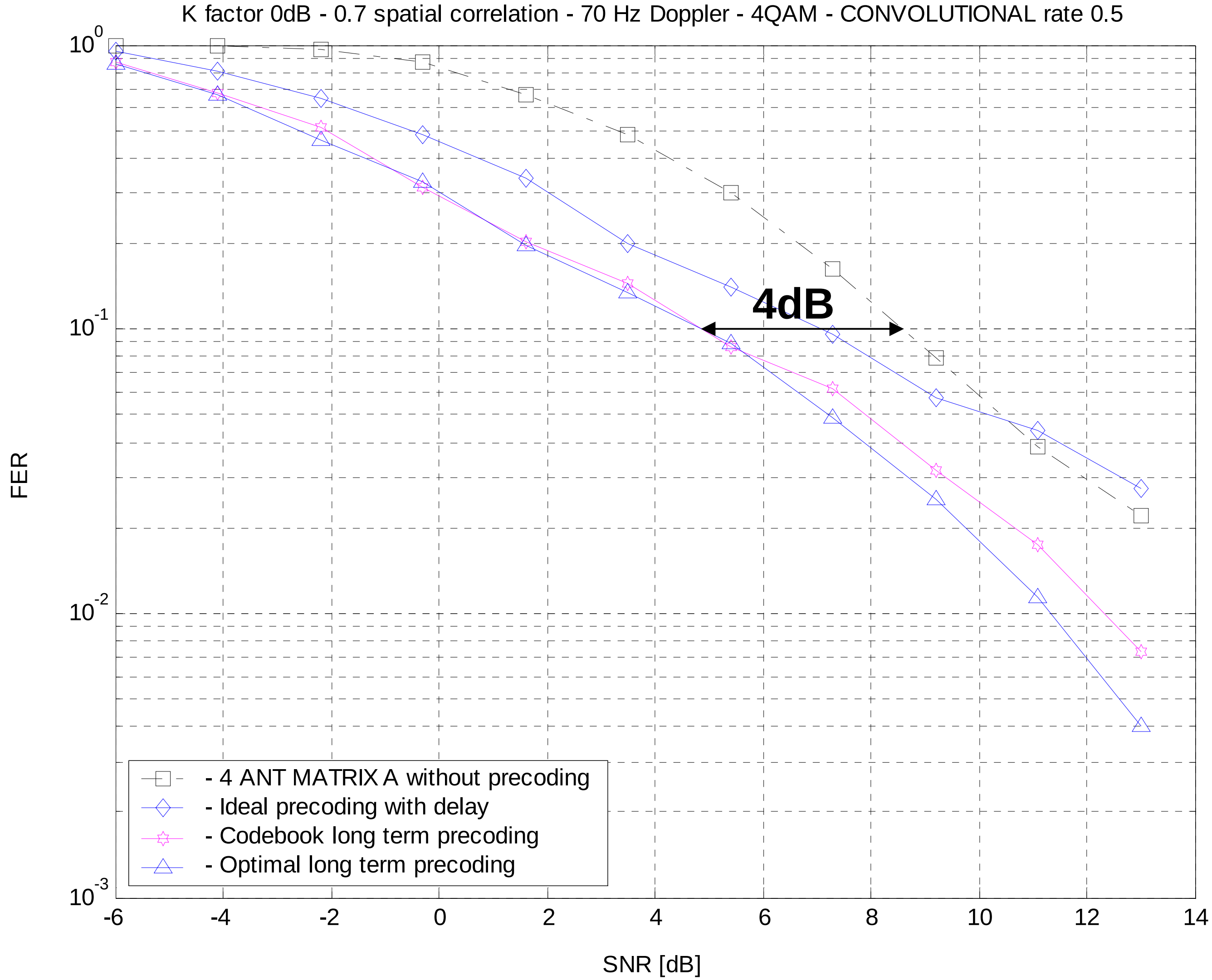
- 0.2 spatial correlation
- 3.5dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 4dB gain over open-loop STBC

Long Term Example 5

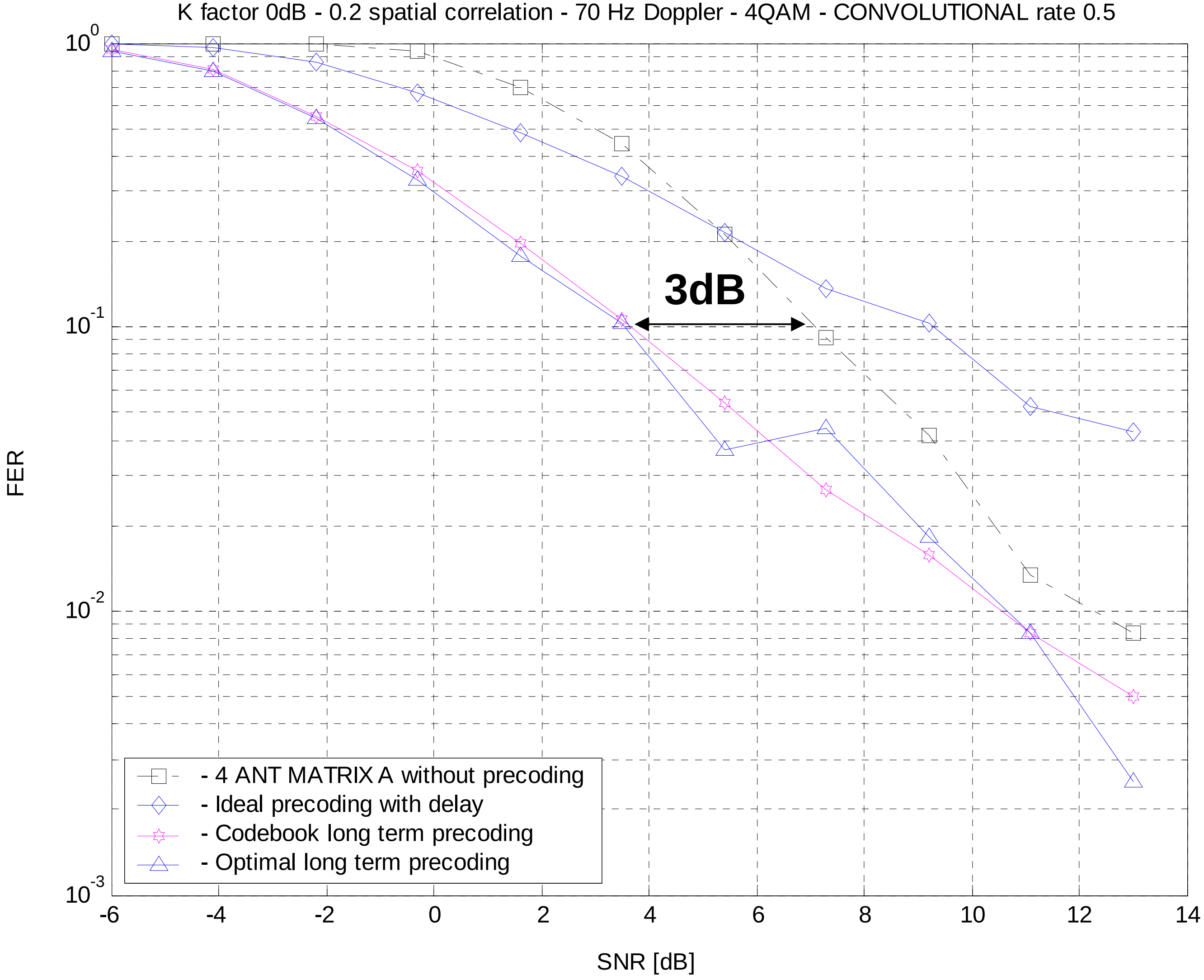
- 0.7 spatial correlation
- 0dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 3dB gain over open-loop STBC

Long Term Example 6

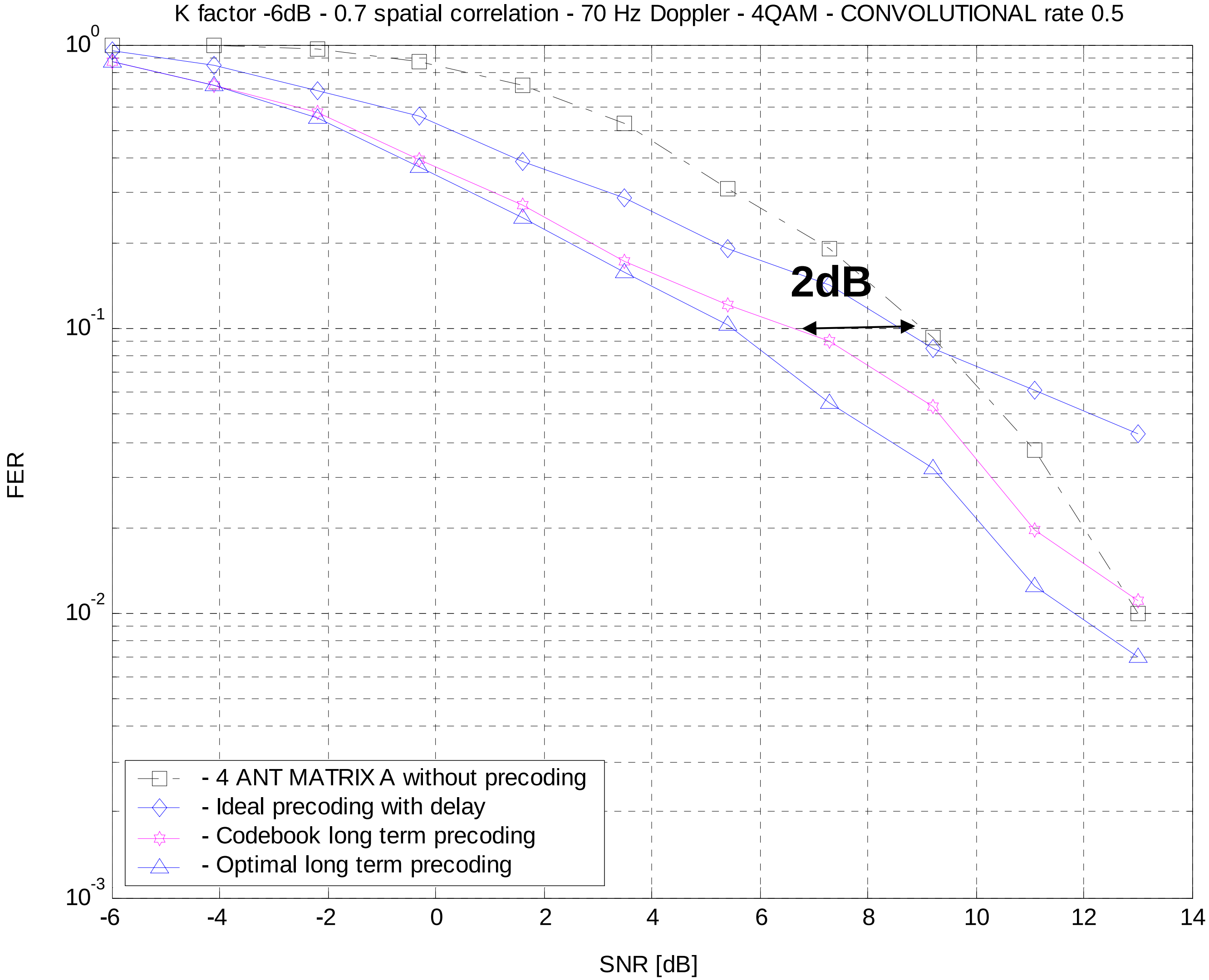
- 0.2 spatial correlation
- 0dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 3dB gain over open-loop STBC

Long Term Example 7

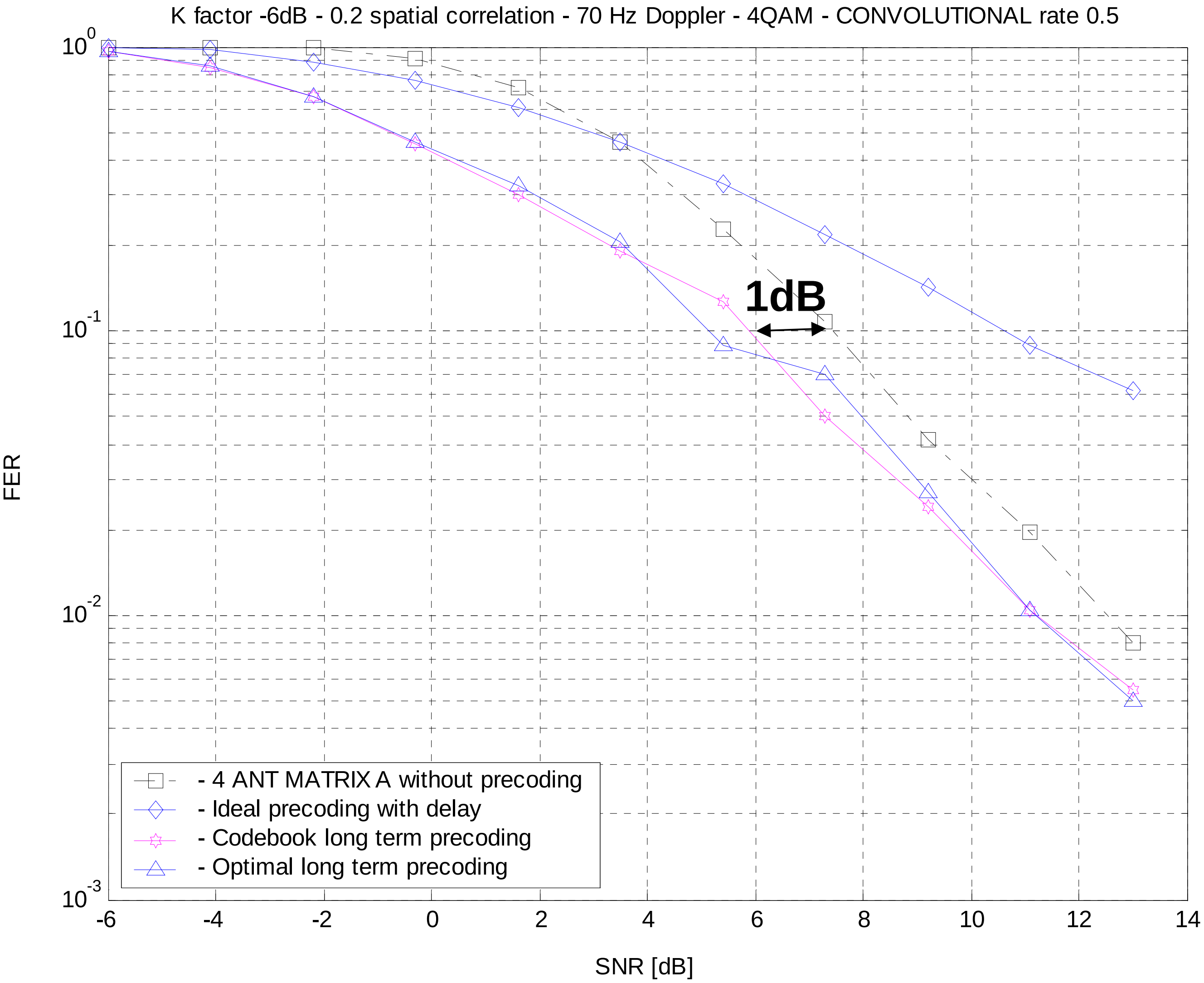
- 0.7 spatial correlation
- -6dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 2dB gain over open-loop STBC

Long Term Example 8

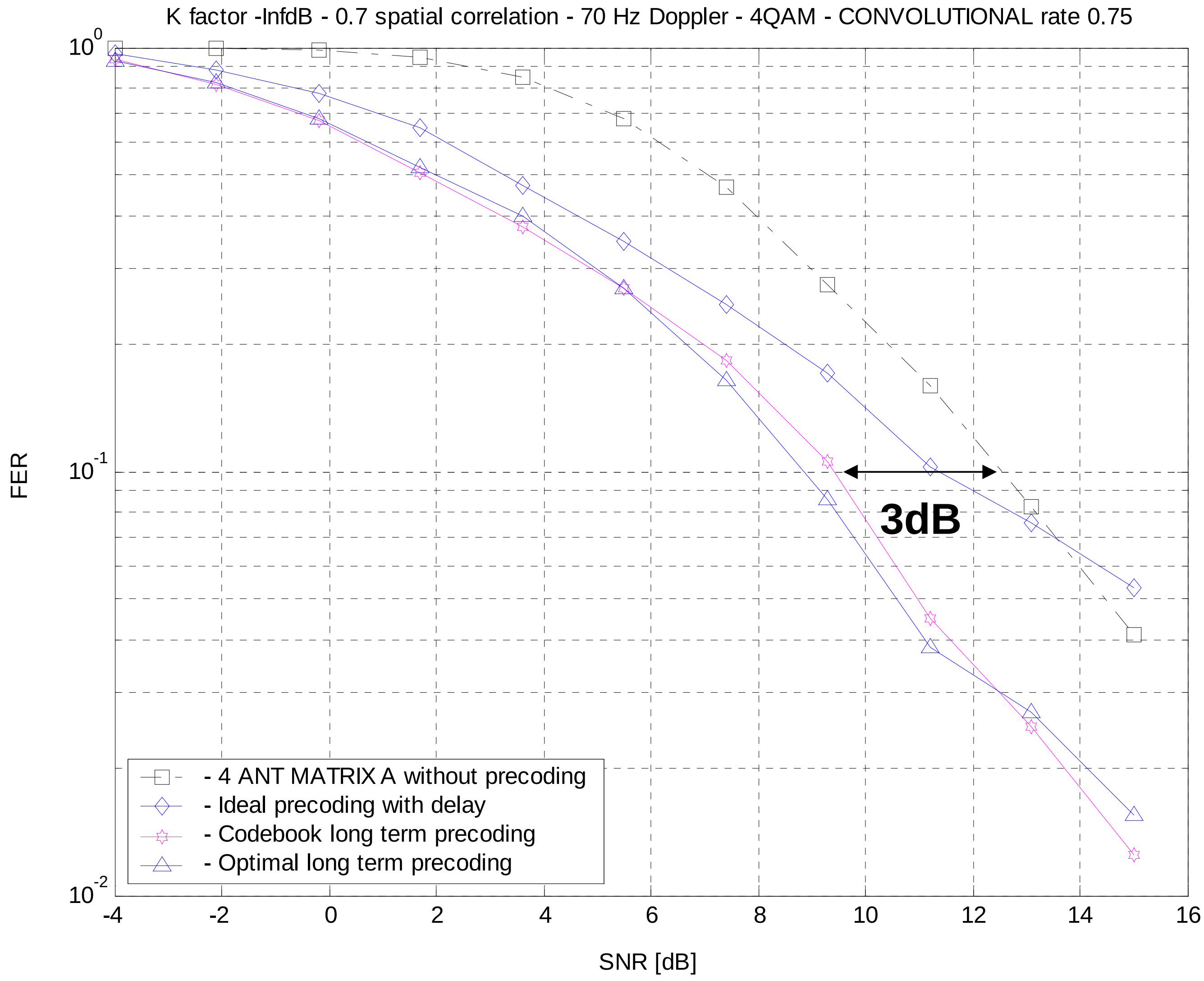
- 0.2 spatial correlation
- -6dB K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has about 1dB gain over open-loop STBC

Long Term Example 9

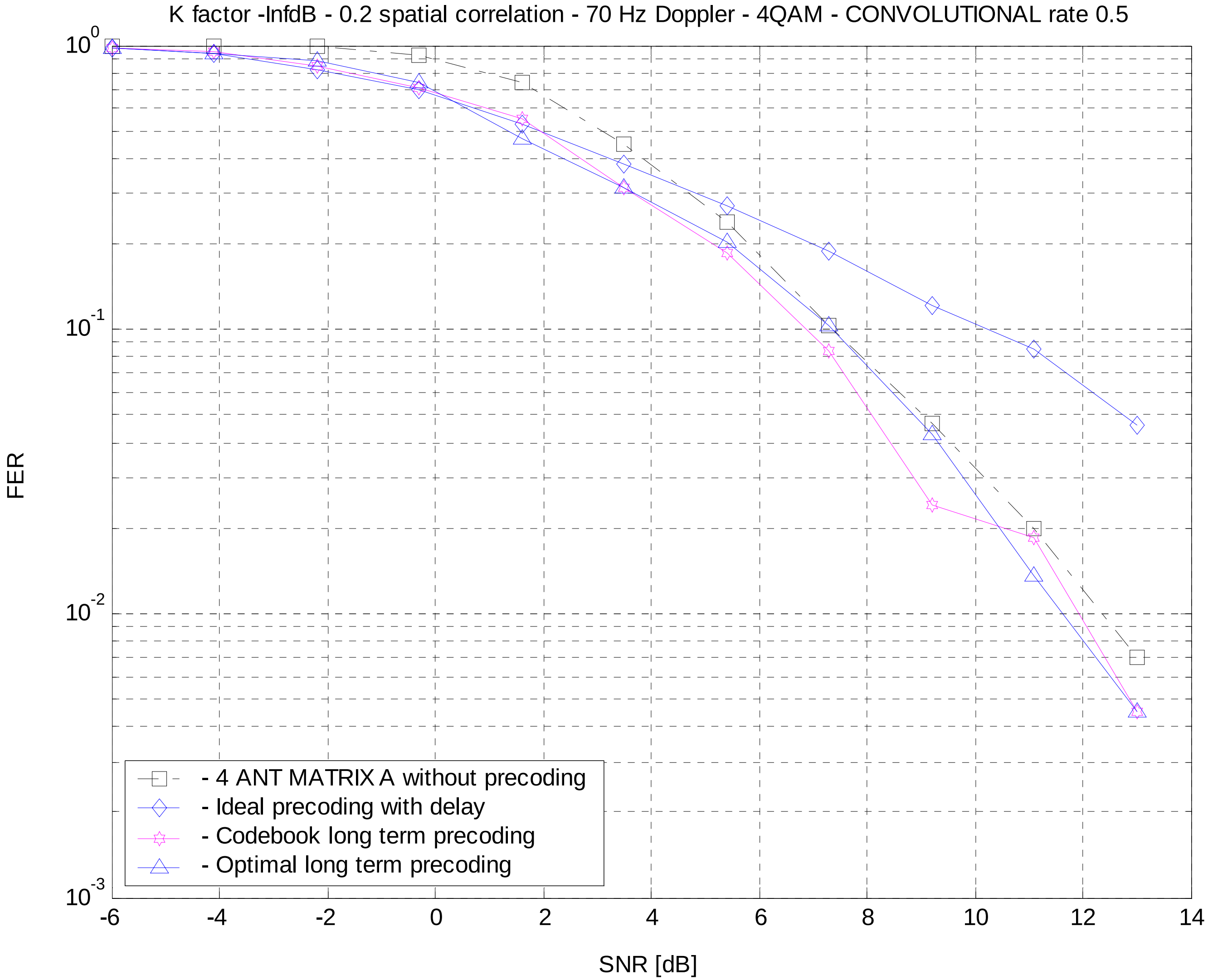
- 0.7 spatial correlation
- No K factor
- 2 frames delay
- 4QAM
- FEC rate 0.75
- 70 Hz Doppler



Long term precoding has about 3dB gain over open-loop STBC

Long Term Example 10

- 0.2 spatial correlation
- No K factor
- 2 frames delay
- 4QAM
- FEC rate 0.5
- 70 Hz Doppler



Long term precoding has no gain over open-loop STBC, but no loss either

Summary of Precoding Results

- Short term precoding gains of 6-7 dB for fading rates below 10 Hz using a single CQICH channel.
- Long term precoding gains from 1 to 5.5 dB depending on antenna correlation and K-factor.
- Presence of a modest K-factor, e.g. 0 dB, gives long term precoding gains of 3 dB even for low antenna correlation!
- Long term precoding gains are applicable to the broadband diversity allocation and to the case of high fading rates.