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Combined Beamforming and Space-Time Block Coding With Sparse Array Antennas

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Outline

- Adaptive Beamforming and Angular Diversity
- Beamspace-Time Channel Estimation
- Array Antenna
- Channel Model: GBSBEM
- Peak detection and Adaptive Modulation
- Sparse Array Antennas and Beam Correlation
- Channel Estimation Errors
- Conclusions

# Adaptive Beamforming and <u>Angular Diversity</u>

- First introduced in VTC Conference, Spring 2000
  - Macrocells with small angular spread

- Channel knowledge required
  - Reciprocity is assumed (channel same for downlink and uplink)

- Transmit power allocated to <u>peaks of channel response</u>
  - Space-Time Block Coding (STBC) applied to beams as (angular) diversity elements, as opposed to antennas

- Assumes flat fading channel (rich multipath environment)
  - Practical for moderate-rate indoor wireless communications

Beamspace-Time Channel Estimation

➢ Fixed Beamforming Network at base station (BS)

1. Mobile (MS) sends a pilot signal
2. BS does 360-degree beam scanning (switched beam)
3. BS estimates channel spatial gain pattern (CSGP)
4. BS determines beams and their angles, based on CSGP
5. Space-Time Block Coding (STBC) is applied and symbols transmitted
6. Upon reception, MS uses simple linear processing to estimate symbols

Array Antenna (360 degree coverage)

- Linear Equally Spaced Array. N elements per sector
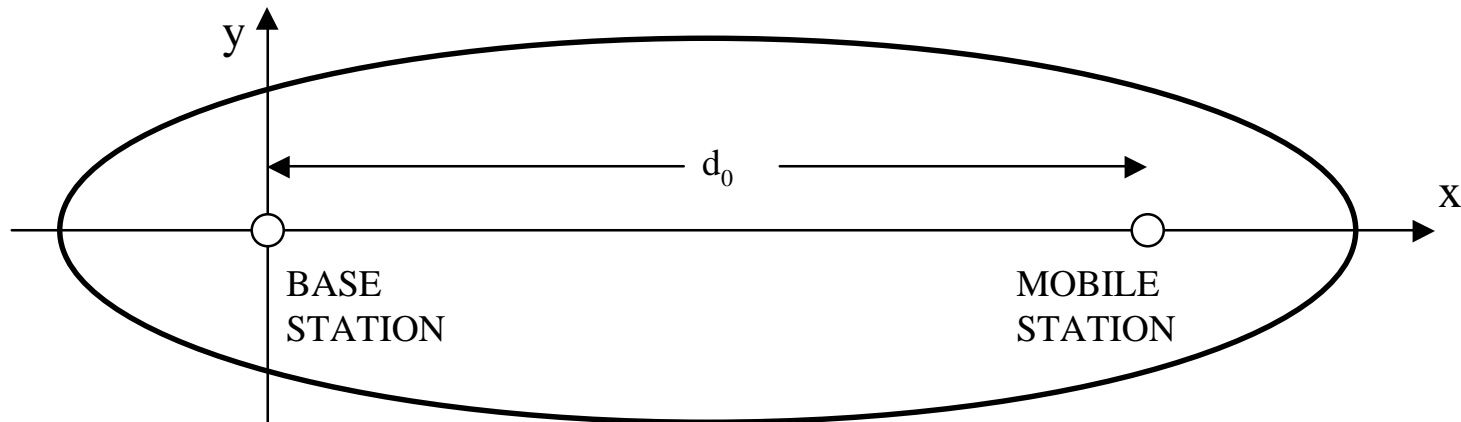
- Three 120-degree sectors

Reference

DOA

n=1

n=N

-60<DOA<60

n=1

n=1

-180<DOA< -60

60<DOA<180

n=N

n=N
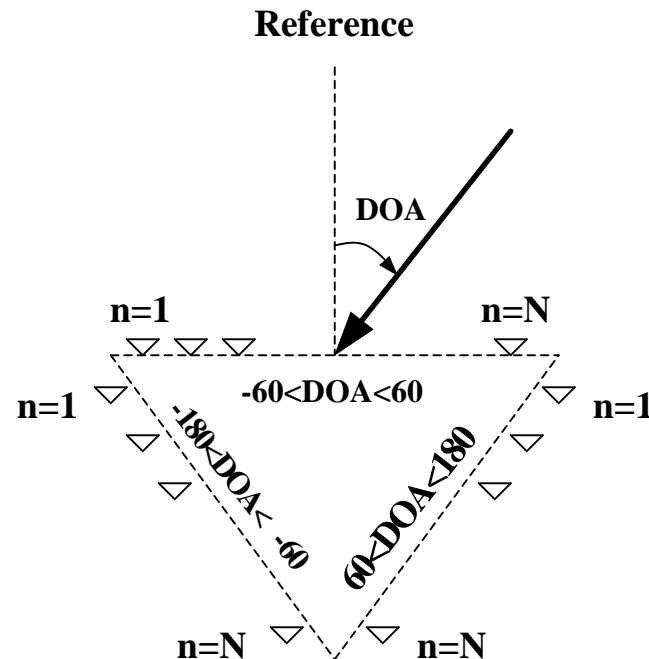
Example Pattern with 4-Antenna Array
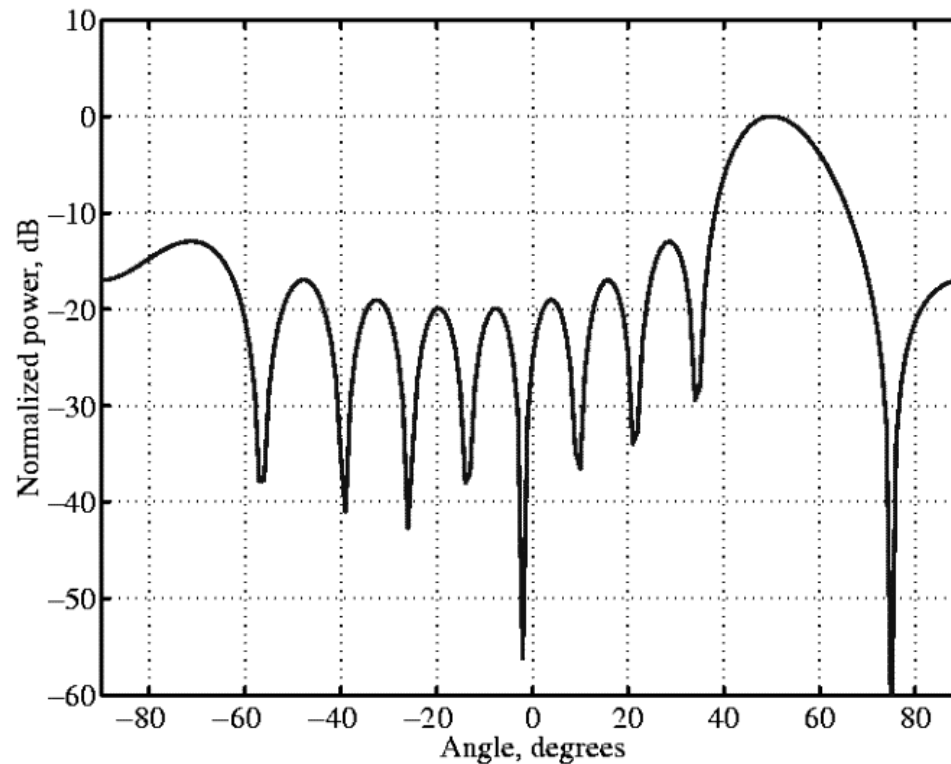
The GBSB[*] Elliptical Model (GBSBEM)

[*] Geometrically-Based Single-Bounce

- Scatterers uniformly distributed within an ellipse
- Low antenna heights
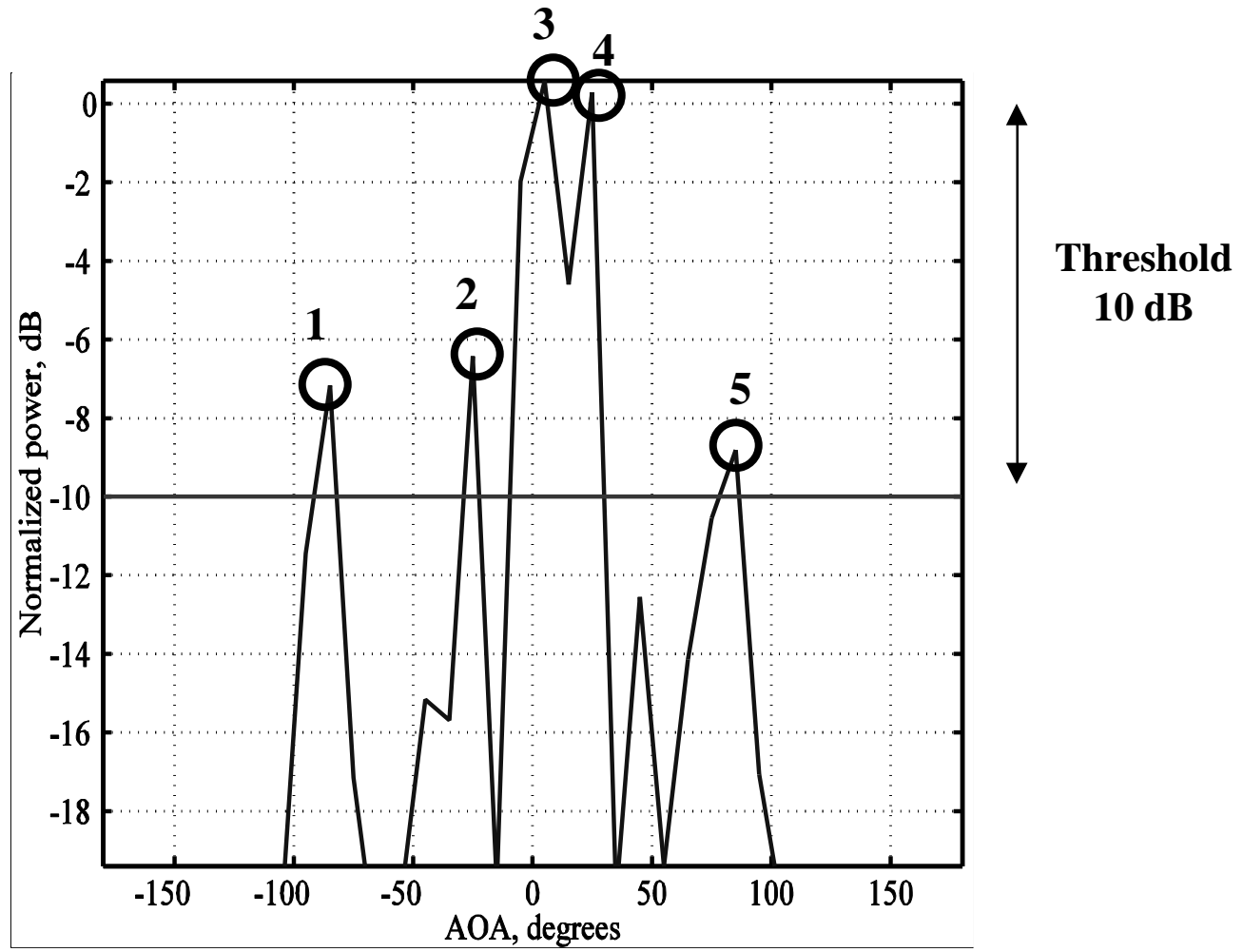- Applicable to picocell (indoor) environments
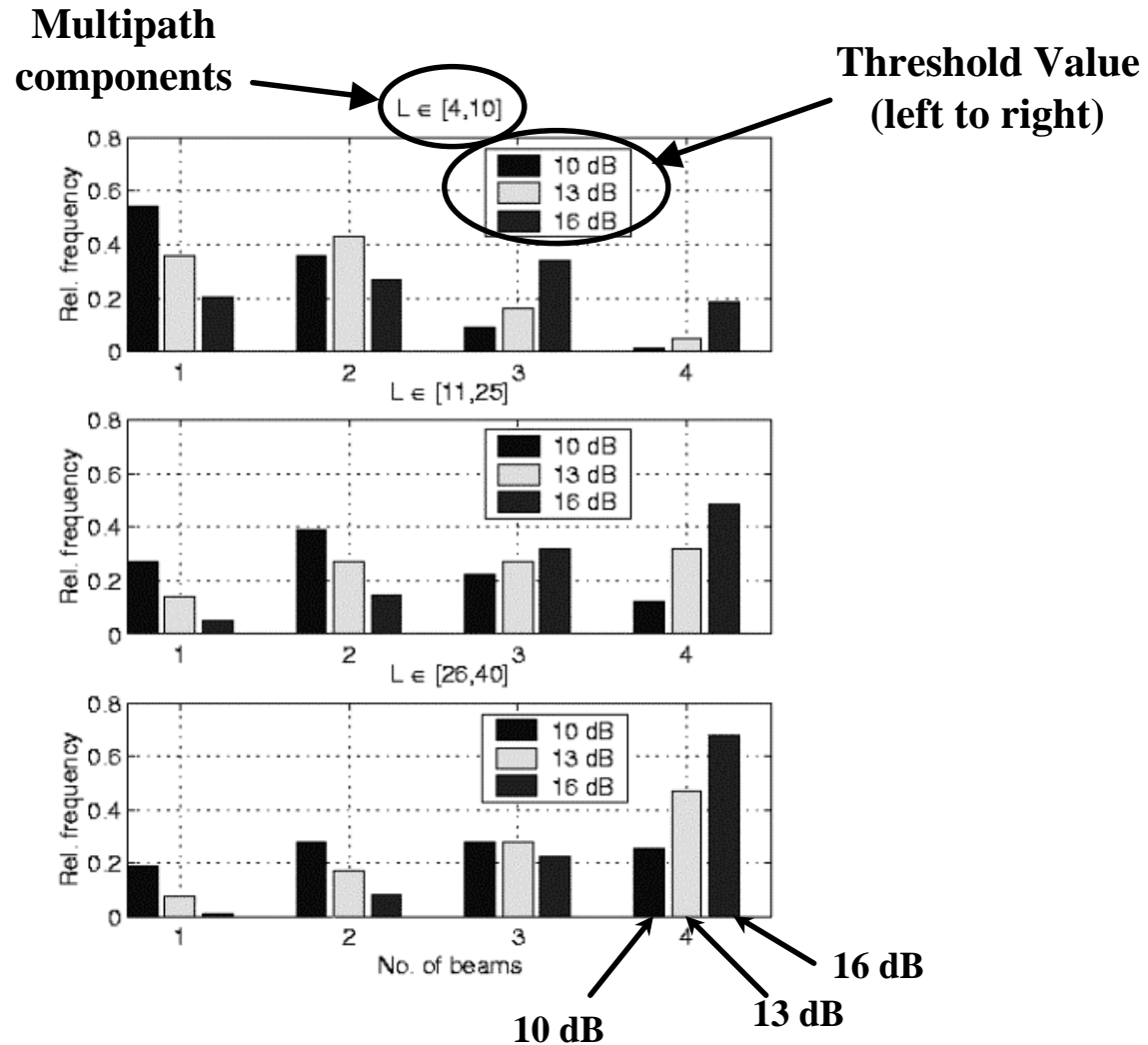

Main parameters

$n=4$ (Loss exponent) $\tau_m = 2\tau_0$ (Maximum delay)

d_0: Uniform [1,100] m   L: Number of multipath components, uniform in [10,50] and [26,50]

Peak Detection

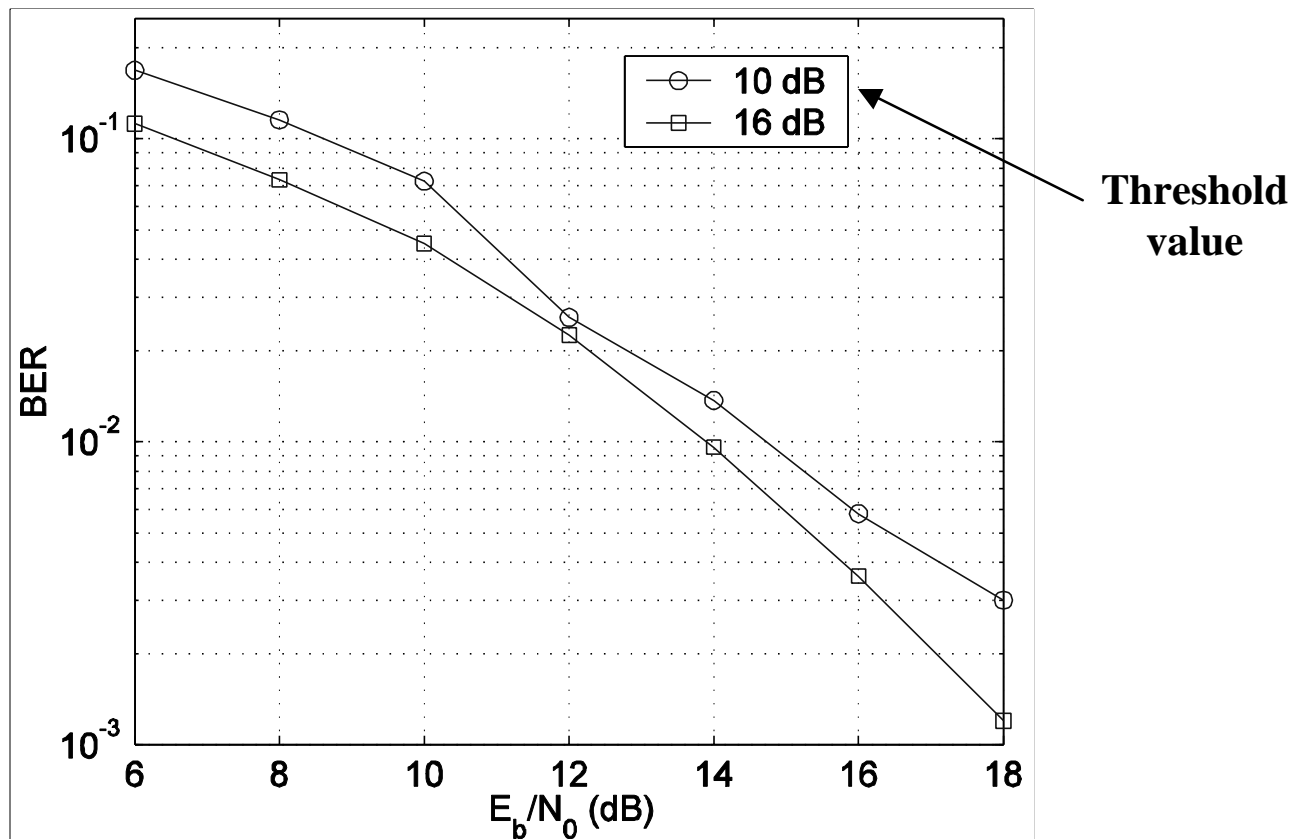Morelos-Zaragoza and Ghavami

Distribution of Number of Beams

Adaptive Modulation

- In accordance to the number of transmit beams, the constellation is modified, to compensate for the rate loss of the STBC scheme:

    - $n_t = 2$: $K/T = 1$ **QPSK modulation**   (2 bps/Hz)
    - $n_t = 3$ and $n_t = 4$: $K/T = ¾$ **8-PSK modulation**   (2.25 bps/Hz)
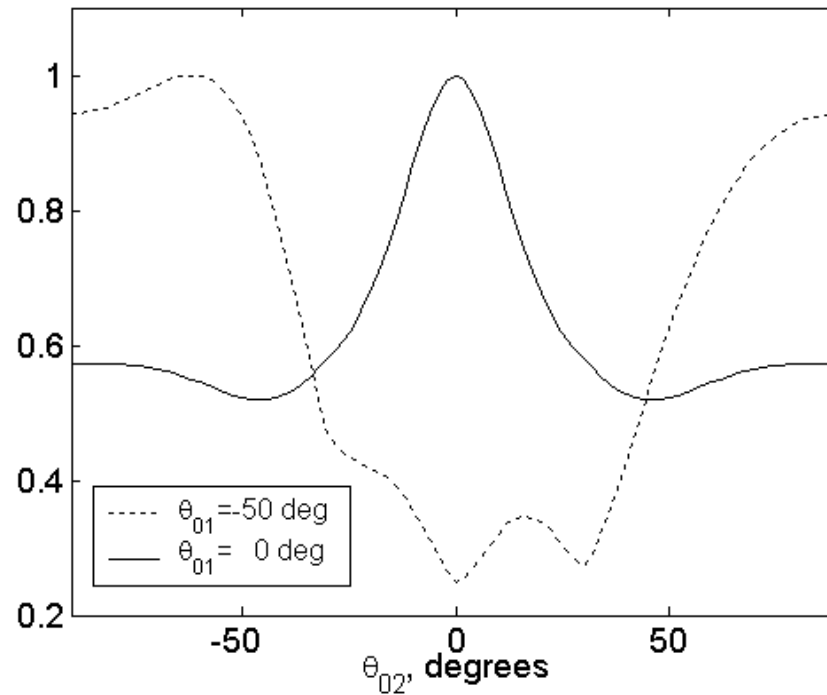
Error Performance of B-STBC: 10-Element Antenna Array

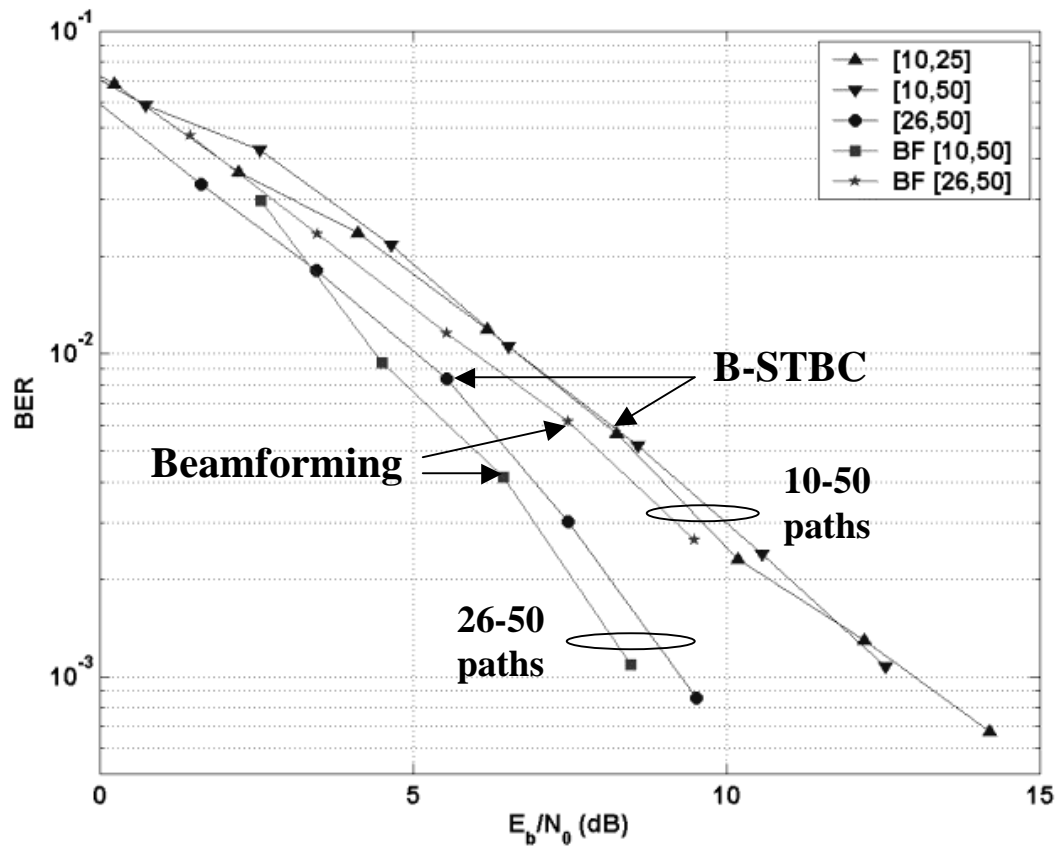# Transmit (Angular) Diversity with Sparse Array Antenna

- Linear equally spaced array with N=4 elements
- Separation of half wavelength
- Switched-beam system
- Beams spaced by 6 degrees
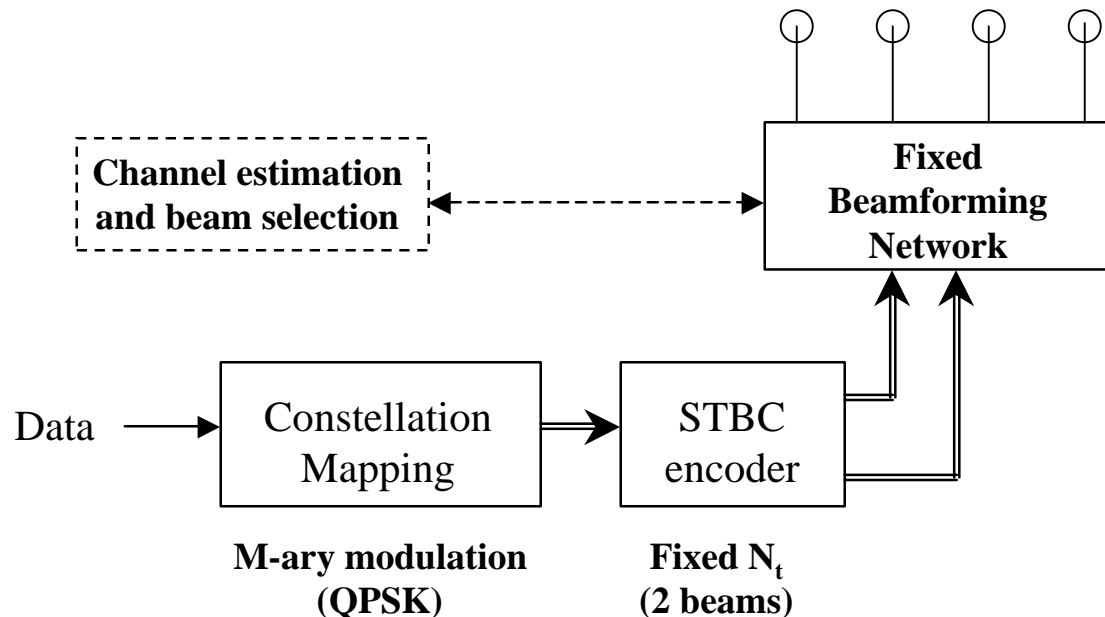
Beam Correlation with 4 Antennas

Performance of B-STBC: Correlated Beams

Channel Estimation Errors

$$\mathrm{r} = \begin{bmatrix} r_0 \\ r_1^* \end{bmatrix}, \qquad \overline{\mathrm{H}} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}, \qquad \mathrm{n} = \begin{bmatrix} n_0 \\ n_1^* \end{bmatrix}, \qquad \mathrm{c} = \begin{bmatrix} c_0 \\ c_1 \end{bmatrix}$$

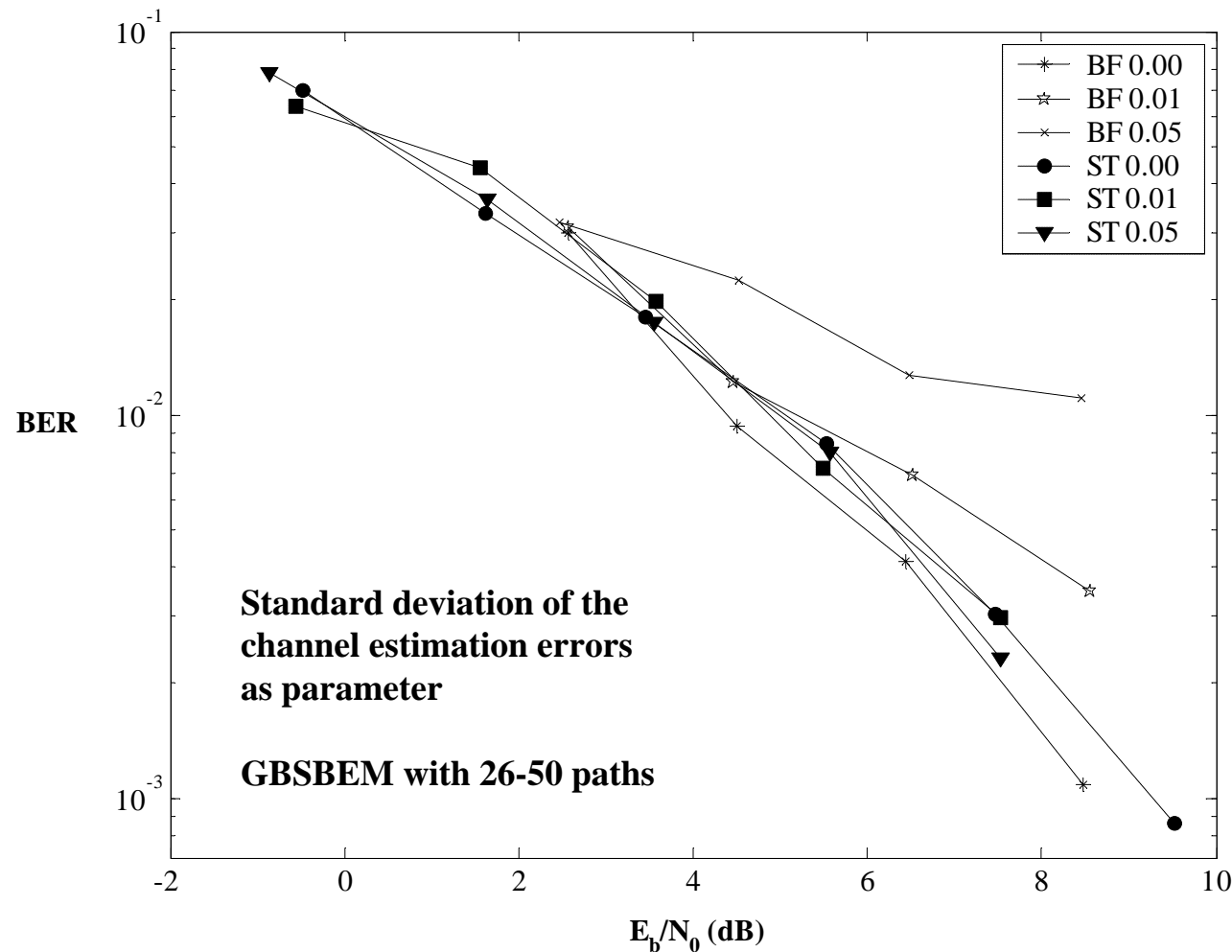**Received vector** **Equivalent channel** **AWGN** **Transmitted vector**

$$\hat{\mathrm{H}} = \overline{\mathrm{H}} + \overline{\mathrm{N}} = \overline{\mathrm{H}} + \begin{bmatrix} n_{e1} & n_{e2} \\ n_{e2}^* & -n_{e1}^* \end{bmatrix}.$$

Estimation errors

$$\begin{aligned} \tilde{\mathrm{r}} &= \hat{\mathrm{H}}^* \mathrm{r} \\ &= \hat{\mathrm{H}}^* \overline{\mathrm{H}} \mathrm{c} + \hat{\mathrm{H}}^* \mathrm{n} \\ &= \left\| \mathrm{H} \right\|_F^2 \mathrm{c} + (\overline{\mathrm{N}}\,\overline{\mathrm{H}} \mathrm{c} + \tilde{\mathrm{n}}) \\ &= \left\| \mathrm{H} \right\|_F^2 \mathrm{c} + \overline{\mathrm{N}}^{'} \mathrm{c} + \tilde{\mathrm{n}} \end{aligned}$$

Performance of Adaptive B-STBC (Channel Estimation Errors)

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Conclusions

- Beamforming (BF) outperforms B-STBC, under *perfect channel knowledge* conditions

- However, in the presence of *channel estimation errors*, the performance of BF degrades considerably, and it becomes worse than B-STBC, as the estimation error increases

- **The proposed adaptive B-STBC scheme is robust against channel estimation errors**

- We note that our work focuses on the use of *beams* as (angular) diversity elements, as opposed to the use of *antennas*