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# Design of Adaptive 2x2 Space-Time Block Codes for Broadcasting Applications

## Motivations

- Future broadcasting systems will call for multi-antenna (MIMO) transmission techniques.
- Space-time block codes (STBC) are conventionally designed according to rank-determinant criteria, efficient at high signal-to-noise ratios (SNR).
- Broadcasting transmissions are protected by powerful forward error correcting (FEC) codes able to operate at low to moderate SNRs.
- Aim:** design **full-rate full-diversity STBCs** with **low detection complexity**, optimized for a **wide range of SNRs**.

## STBC design criteria

- High SNR:** rank-determinant criteria
  - Rank criterion:** maximize the rank of  $\Delta = X - \hat{X}$  for all possible transmitted codeword pairs  $(X, \hat{X})$
  - Determinant criterion:** maximize the minimum determinant

$$\delta = \min_{X \neq \hat{X}} \prod_{i=1}^r \lambda_i$$

where  $\lambda_i$  are the non-zero eigen values of  $\Delta \Delta^H$

- Any SNR:** Bitwise mutual information (BMI) criterion
    - Maximize**

$$\text{BMI}(c, \hat{c}) = 1 - E[\log_2(1 + e^{-LLR})]$$
    - The optimized STBC parameters depend on the SNR
- ⇒ **construction of adaptive STBCs**

## Design of adaptive STBCs

- Example of full-rate full-diversity STBC: the “**Matrix D**” code

$$\mathbf{X} = \begin{bmatrix} aS_1 + bS_3 & -cS_2^* - dS_4^* \\ aS_2 + bS_4 & cS_1^* + dS_3^* \end{bmatrix}$$

with  $a = c = \frac{1}{\sqrt{2}}$ ,  $d = be^{-i\pi/2}$ ,  $b = \frac{1}{\sqrt{2}}e^{i\varphi}$ ,  $\varphi$  being the design parameter

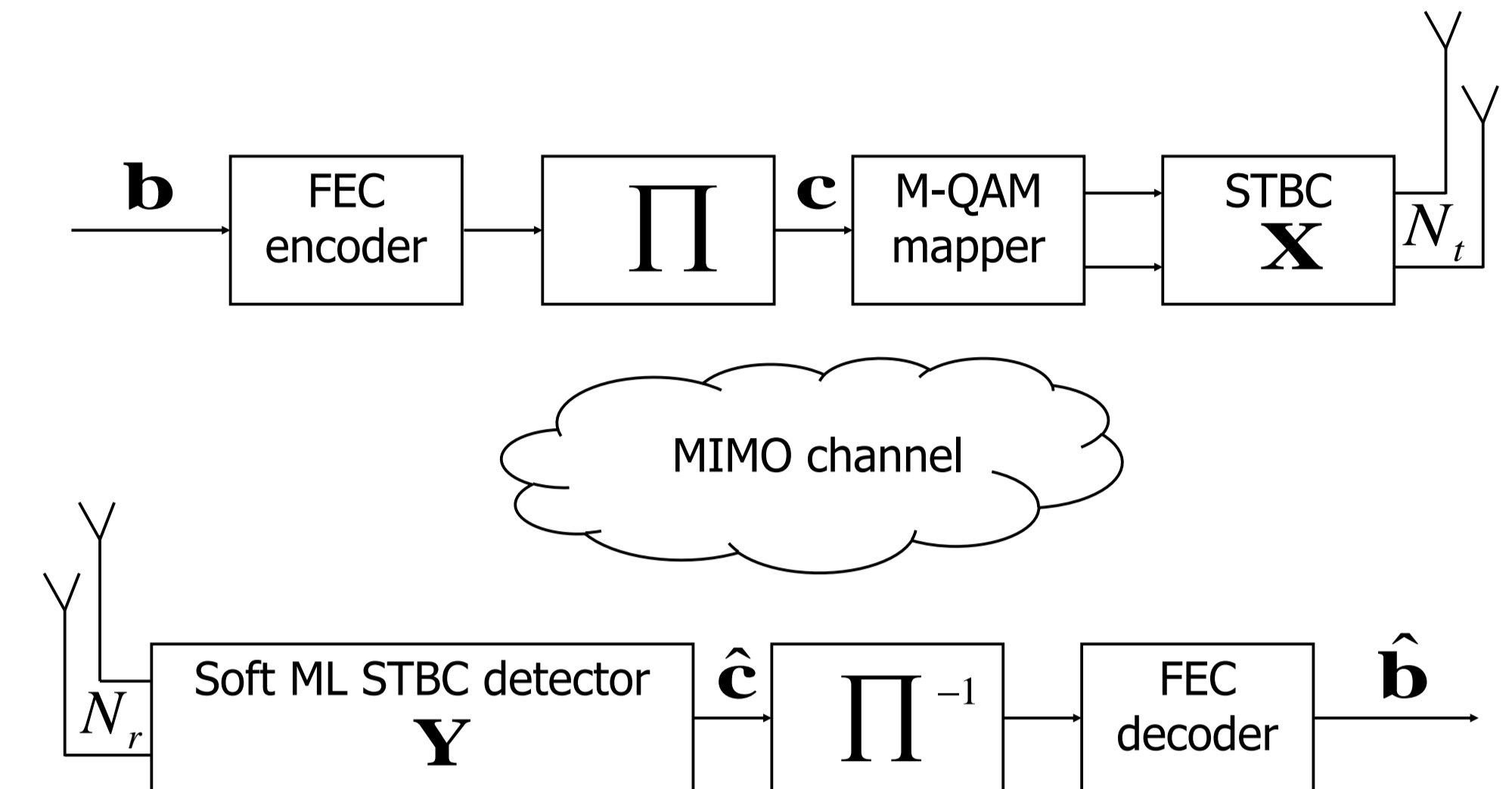
- Rank-determinant criteria (original value):  $\varphi = 114.29^\circ$
- BMI criterion: a value of  $\varphi$  is obtained at each SNR
- Based on a polynomial interpolation,  $\varphi$  is given (in degrees) by

$$\varphi = \begin{cases} 135; & \text{for } \frac{E_b}{N_0} \leq 5.5 \text{ dB} \\ -0.55 \left(\frac{E_b}{N_0}\right)^3 - 14.32 \left(\frac{E_b}{N_0}\right)^2 - 123.35 \frac{E_b}{N_0} + 432.32; & \text{for } 5.5 \text{ dB} < \frac{E_b}{N_0} \leq 11 \text{ dB} \\ 114.29; & \text{for } \frac{E_b}{N_0} > 11 \text{ dB} \end{cases}$$

- Adaptive STBC is more efficient than conventional STBC used with powerful FEC coding and/or adaptive modulation and coding (e.g. in broadcasting systems).
- Proposed adaptive MD STBC closes the gap to the Golden code to less than 0.2 dB with approximately 3 times less complexity.
- Adaptive MD STBCs represent a good trade-off between performance and detection complexity.

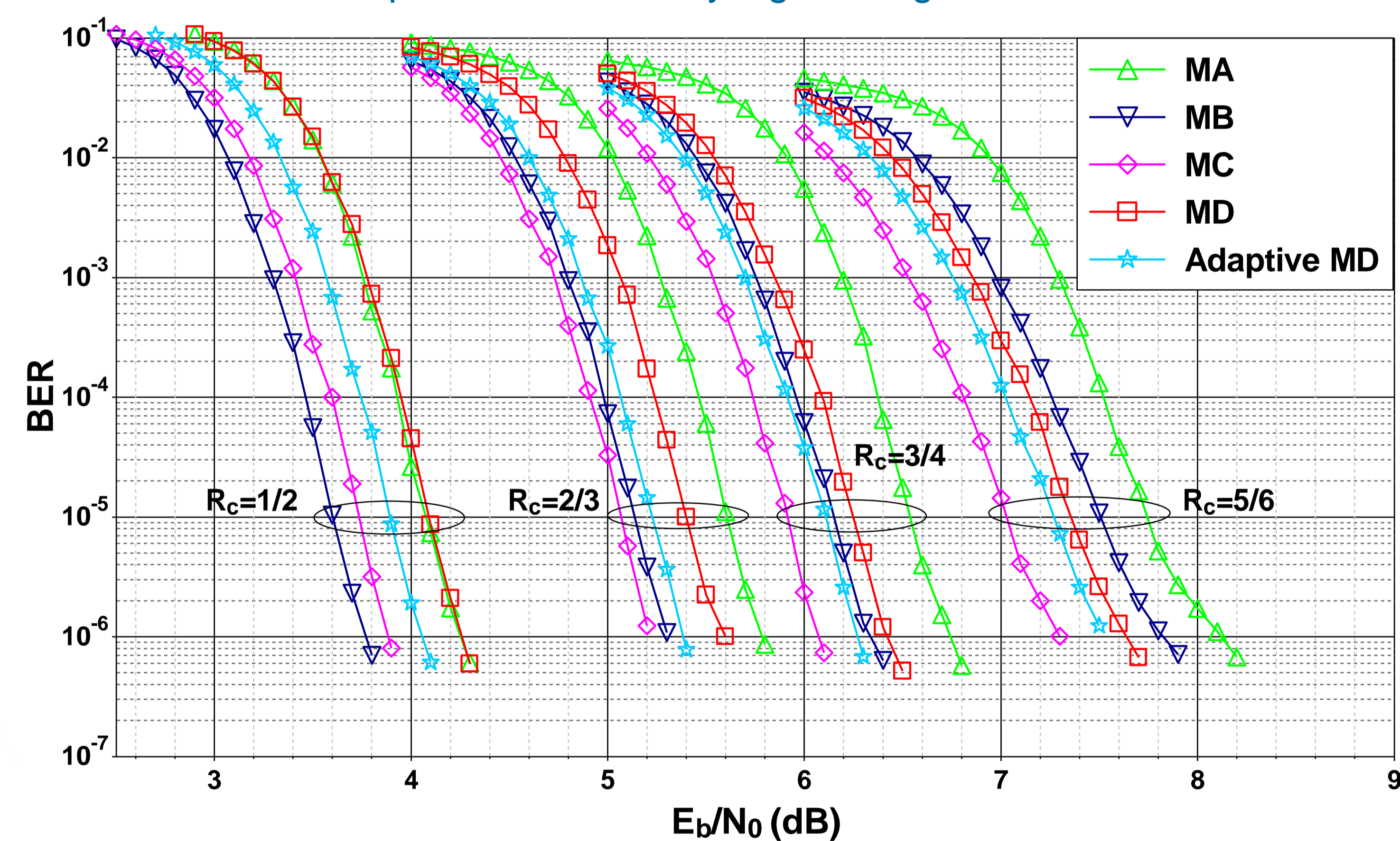
## Performance comparison with state-of-the-art MIMO codes

### Transmission chain model



### Simulation parameters

- FEC code:** WiMAX 8-state double-binary turbo code, coding rates 1/2, 2/3, 3/4, 5/6
- Block size:** 4,800 bits
- MIMO codes:** MA = Alamouti code, MB = spatial multiplexing, MC = Golden code, MD = original matrix D STBC, Adaptive MD = proposed STBC
- Constellation:** 16-QAM for MA and QPSK for MB, MC, MD
- Channel:** quasi-static flat Rayleigh fading 2x2 MIMO channel



## Maximum likelihood detection complexity per coded bit

MIMO profiles	4-QAM		16-QAM	
	#Add	#Mult	#Add	#Mult
MA/Alamouti	41.5	53	82.75	99
MB/Spatial Multiplexing	84	81	640	641
<b>Adaptive MD and MD</b>	<b>421</b>	<b>510</b>	<b>4,096</b>	<b>4,257</b>
MC/Golden Code	1,168	1,284	147,520	163,844