부호율 1/*L* 길쌈부호를 이용한 *L* 레벨 공간 디버시티를 갖는 Space-Time Trellis Code의 성능분석

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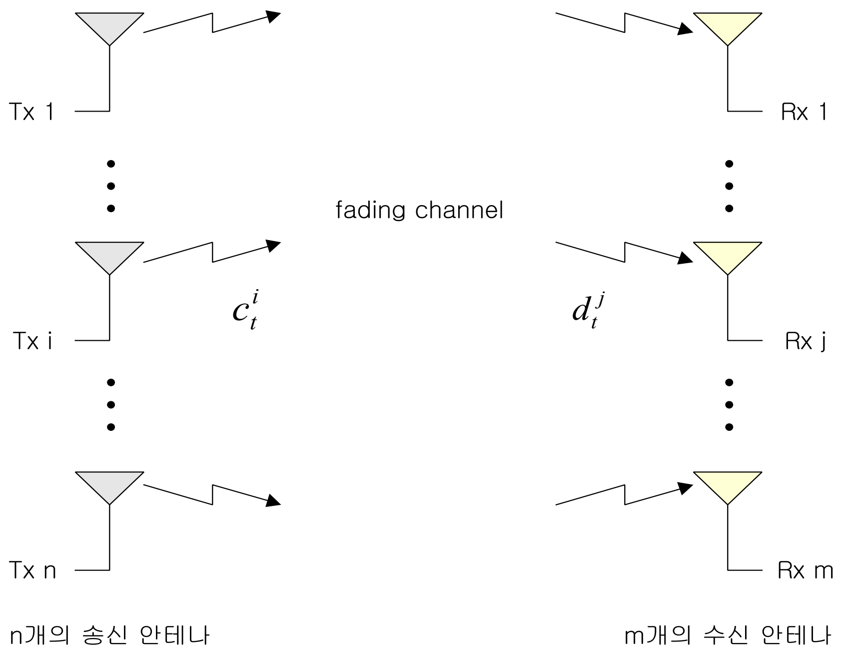
Introduction

- System beyond IMT-2000(4G)
  - Information data transmission rate : 2M – 150Mbps
  - BER: data 10^{-6} , video 10^{-9}
- Space-time Code is attractive for high data transmission.
  - Jointly combing multiple antenna and channel coding without sacrificing the BW.
    - ⇨ improve data rate and reliability in wireless channel
    - ⇨ diversity gain using higher temporal and spatial dimensions
    - ⇨ achieve coding gain
    - ⇨ Increase channel capacity

MIMO System

- MIMO System

$$\mathbf{c} = \begin{bmatrix} c_1^1 & c_2^1 & \cdots & c_l^1 \\ c_1^2 & c_2^2 & \cdots & c_l^2 \\ \vdots & \vdots & \ddots & \vdots \\ c_1^n & c_2^n & \cdots & c_l^n \end{bmatrix}$$



- Fundamental Bound (Tarokh et. al)
  - Quasi-static channel (frame: l symbols)

$$\Pr(\mathbf{c} \rightarrow \mathbf{e}) \leq \left(\frac{\eta E_s}{4N_0} \right)^{-rm}$$

$$r = \text{rank}\big(f(\mathbf{c}) - f(\mathbf{e})\big)$$

$$\eta = (\lambda_1 \lambda_2 \cdots \lambda_r)^{1/r}$$

Design Criteria

Rank Criterion

- Maximize the diversity advantage

$$r = \mathrm{rank}\left(f(\mathbf{c}) - f(\mathbf{e})\right)$$

over all pairs of distinct codewords c, e $\in$ C

Determinant Criterion

- Maximize the coding advantage

$$\eta = \left(\lambda_1 \lambda_2 \cdots \lambda_r\right)^{1/r}$$

over all pairs of distinct codewords c, e $\in$ C

Where η is the geometric mean of nonzero eigenvalues of

$$\mathbf{A} = \left(f(\mathbf{c}) - f(\mathbf{e})\right)\left(f(\mathbf{c}) - f(\mathbf{e})\right)^H$$

Design Rules

- Tarokh's Simple Design Rule (n = 2)
  - Rule1: Transitions departing from the same state differ in the second symbol
  - Rule2: Transitions merging into the same state differ in the first symbol

⇒ Satisfying full rank for the case of n = 2

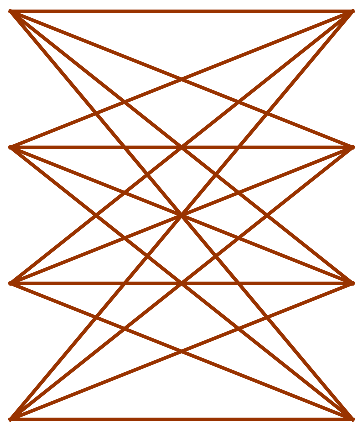
- Example : Delay Diversity

00 01 02 03

10 11 12 13

20 21 22 23

30 31 32 33



Input	0	1	3	2	1	0	3	1
Tx 1	0	0	1	3	2	1	0	3
Tx 2	0	1	3	2	1	0	3	1

Grimm et.al : Zero Symmetry domain for full rank

- Extend the Tarokh's simple design rule to any n

$$\mathbf{G}_i = \begin{bmatrix} y_i(1) & x_i(2) & \cdots & x_i(5) & x_i(8) & 0 & 0 \\ 0 & y_i(2) & x_i(3) & \cdots & x_i(6) & y_i(3) & 0 \\ 0 & 0 & x_i(1) & x_i(4) & \cdots & x_i(7) & y_i(4) \end{bmatrix}$$

Hammons' Design Rule

- Generally applicable to any number of transmit antenna
- BPSK criterion (for 1/L convolutional codes)
  - Example (3 transmit antenna, 8state)

$$\begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Generator Matrix

L	v	Grimm	v	Optimum d_{free}
2	1	$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$	2	$\begin{bmatrix} 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$
	3	$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}$	3	$\begin{bmatrix} 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$
	6	$\begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 & 1 \end{bmatrix}$	6	$\begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$
3	2	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	3	$\begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$
	4	$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 \end{bmatrix}$	4	$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$
	6	$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 1 \end{bmatrix}$	6	$\begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 \end{bmatrix}$
4	3	$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	4	$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$
	6	$\begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$	5	$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 & 1 \end{bmatrix}$
5	4	$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$	5	$\begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$
	6	$\begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$	7	$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$

System Description

Channel Model

- Quasi-static flat fading channel
- 1 frame = 130 symbols (l=130)
- No delay spread (No multipath)
- Complex multiplicative channel

$$\mathbf{r} = \mathbf{H}\mathbf{c} + \mathbf{n}$$

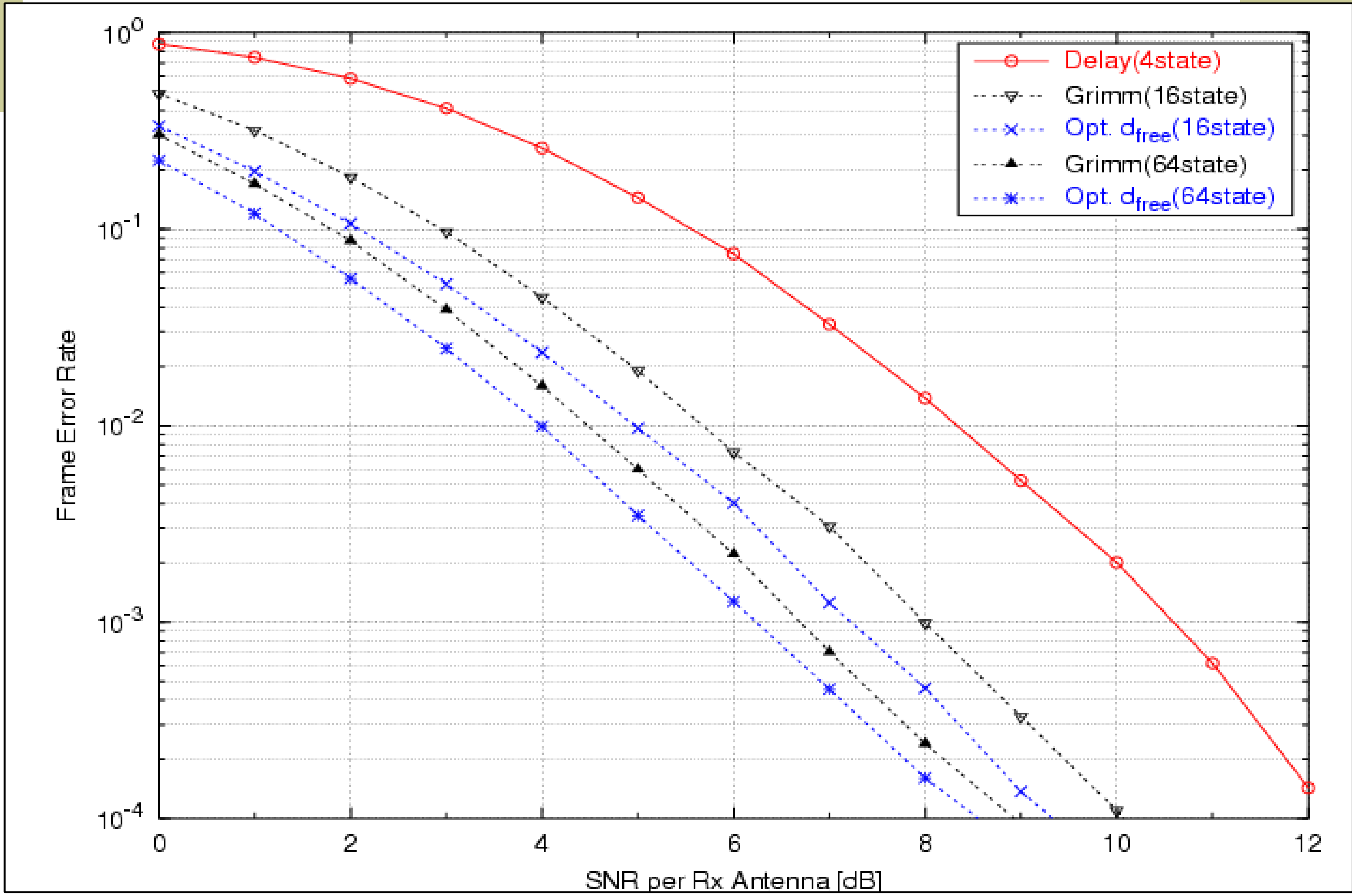
$$\mathbf{H} = [\alpha_{ij}] = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \alpha_{m1} & \alpha_{m2} & \cdots & \alpha_{mn} \end{bmatrix}$$

- Ideal channel estimation

System model

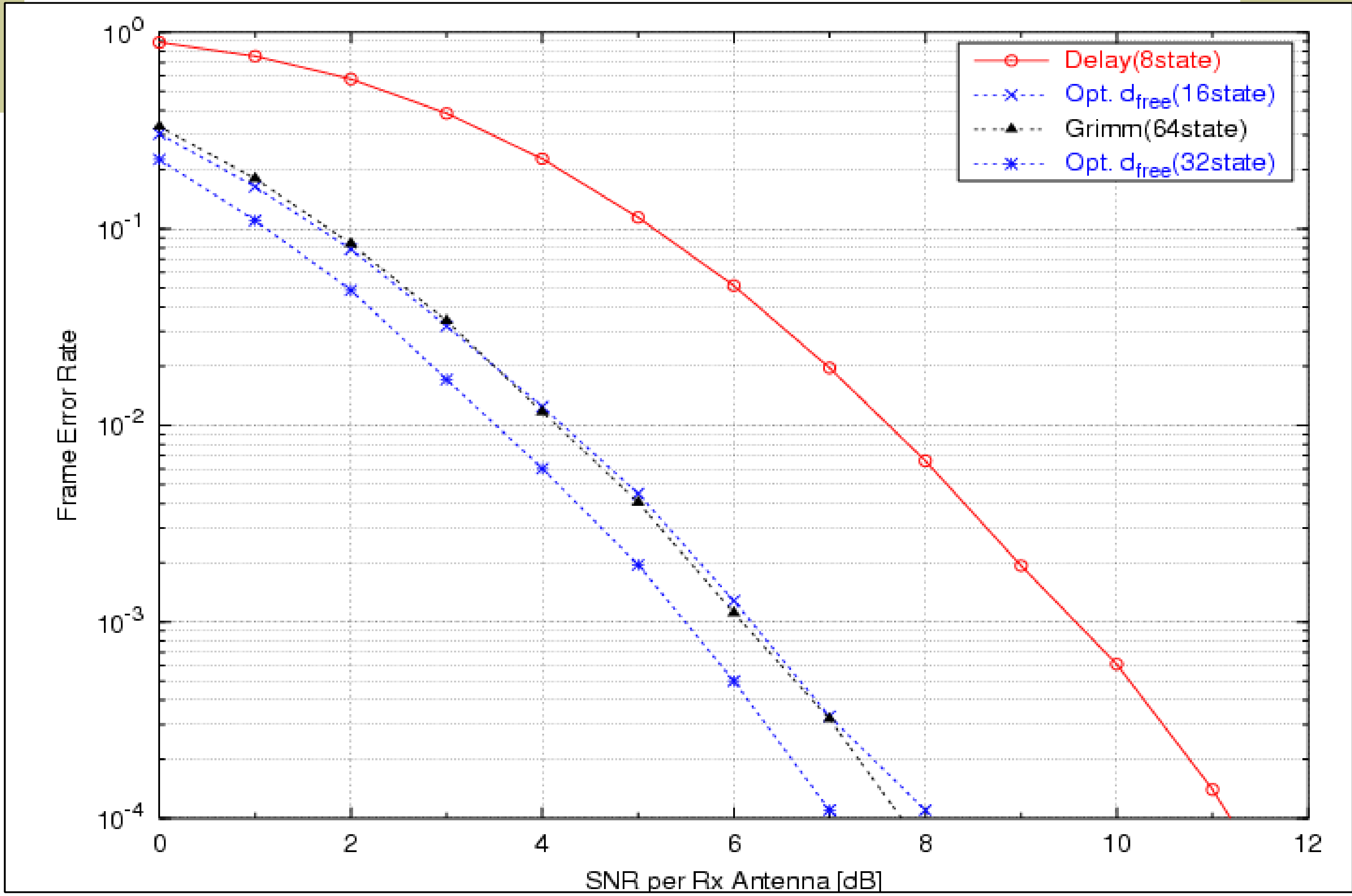
- BPSK modulation
- Tx=2-5, Rx=2
- Viterbi Decoder (ML)
- Unquantized Soft Decision

Performance (Tx=3)



- 송신 안테나 3인 경우 송신 지연 디버시티, Grimm의 STTC, 최적의 d_{free}를 갖는 길쌈부호로부터 설계된 STTC의 성능비교

Performance (Tx=4)



- 송신 안테나 4인 경우 송신 지연 디버시티, Grimm의 STTC, 최적의 d_{free}를 갖는 길쌈부호로부터 설계된 STTC의 성능비교

Conclusion

- Tarokh et.al
  - Geometrically Uniform Code
    - Reduced complexity in computing the coding gain
    - Generally not producing optimal codes
  - 4PSK : 4,8,16,32 state, 8PSK : 8,16,32 state
- Grimm et.al
  - Exhaustive Search for Zero Symmetry code
  - BPSK : 2Tx, 3Tx, 4Tx,   QPSK : 2Tx (4, 8 state)
- Hammons
  - Use the Conventional Convolutional Codes of Rate 1/L
  - Better Performance than Grimm's