Overview of Transmit Diversity

이 광복

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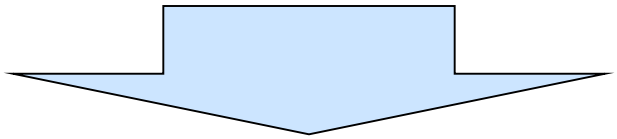
Introduction

- Fading
  - Fluctuation of Received SNR
- Diversity
  - Reduce the fluctuation of Received SNR
  - Time, Space(antenna), Frequency, Polarization
- Antenna Diversity
  - Conventional System: Receiver Diversity
  - Multiple mobile antennas: 구현어려움
  - Future system: Forward Traffic량 증가

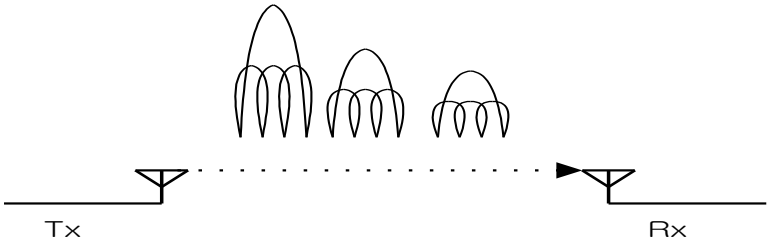


Transmit Diversity

Introduction(cont'd)

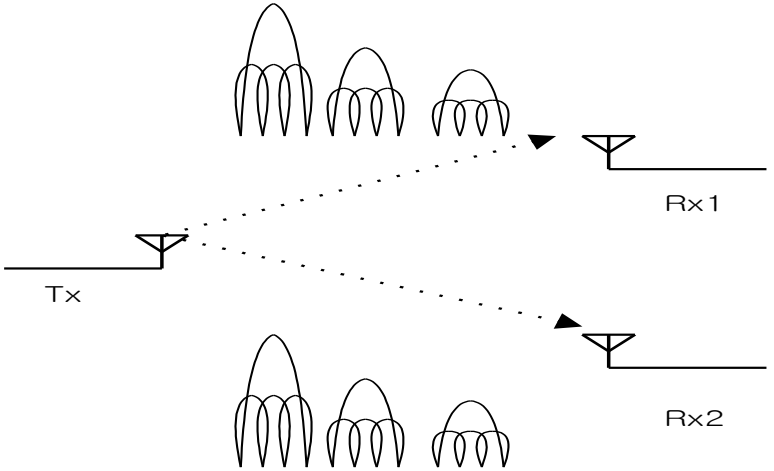
- Transmit Diversity in 3GPP
  - Space-Time Transmit Diversity(STTD)
  - Orthogonal Transmit Diversity(OTD)
  - Time Switched Transmit Diversity(TSTD)
  - Transmit Antenna Array(TxAA)
- STTD, OTD, TSTD
  - Open Loop: No feedback information
- TxAA
  - Closed Loop: Feedback information
- Base selection Tx Div
- MIMO

RAKE & Rx Antenna Diversity



RAKE

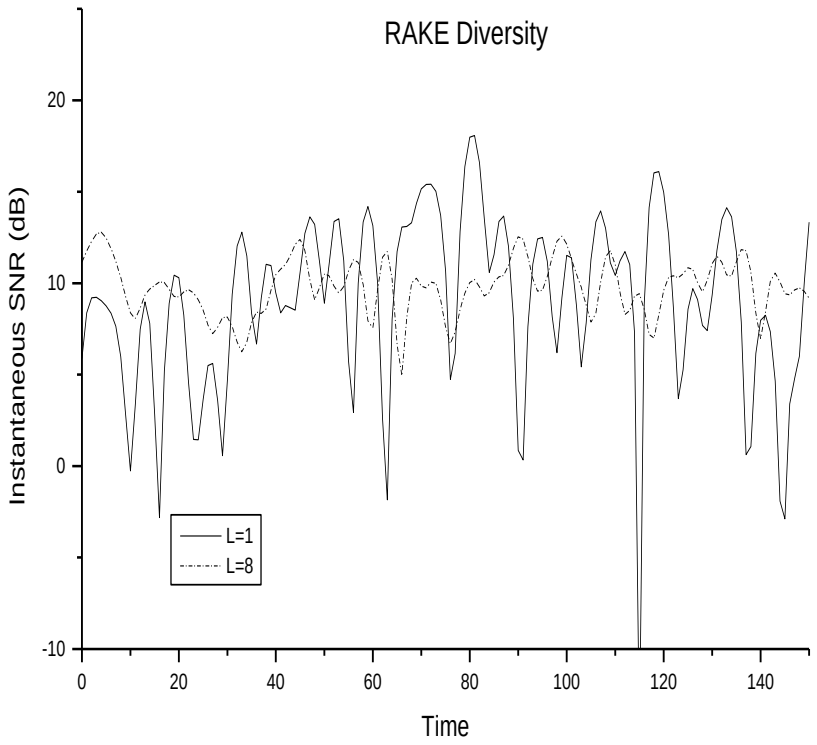
- Diversity Order $\propto L$
- Average SNR Gain = 0

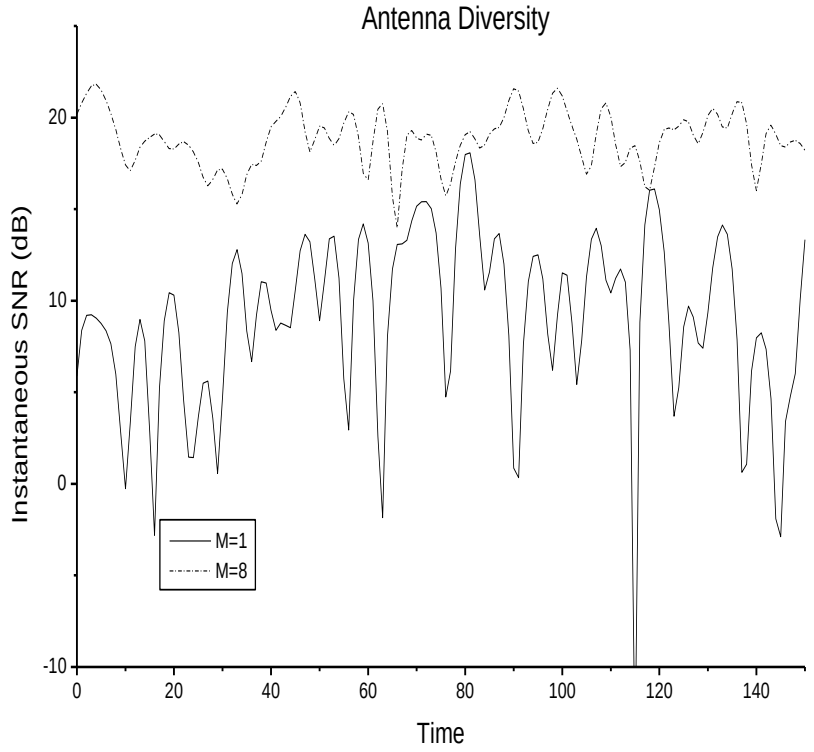


Rx Antenna

- Diversity Order $\propto M \cdot L$
- Average SNR Gain $\propto M$

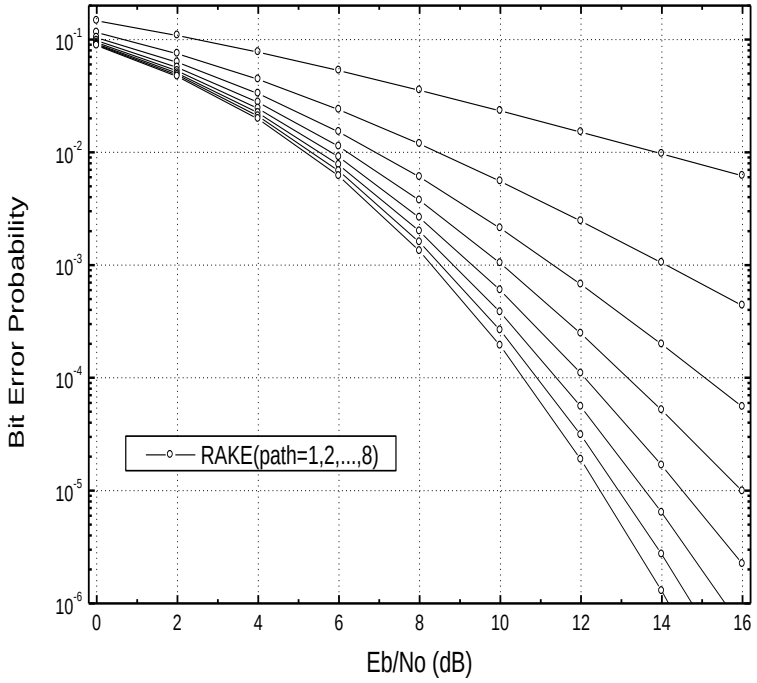
Performance of Rx Diversity





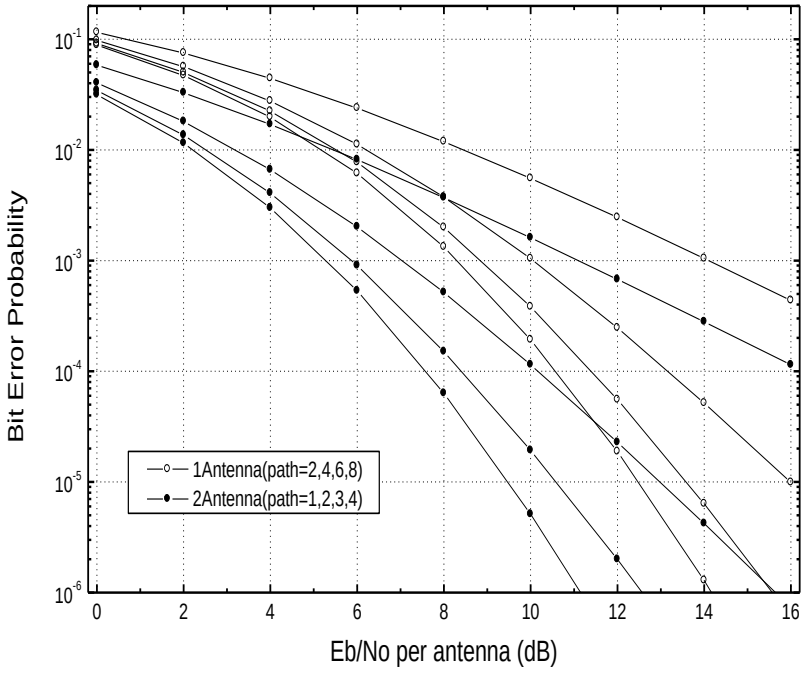
Performance of Rx Diversity(cont'd)

<RAKE>



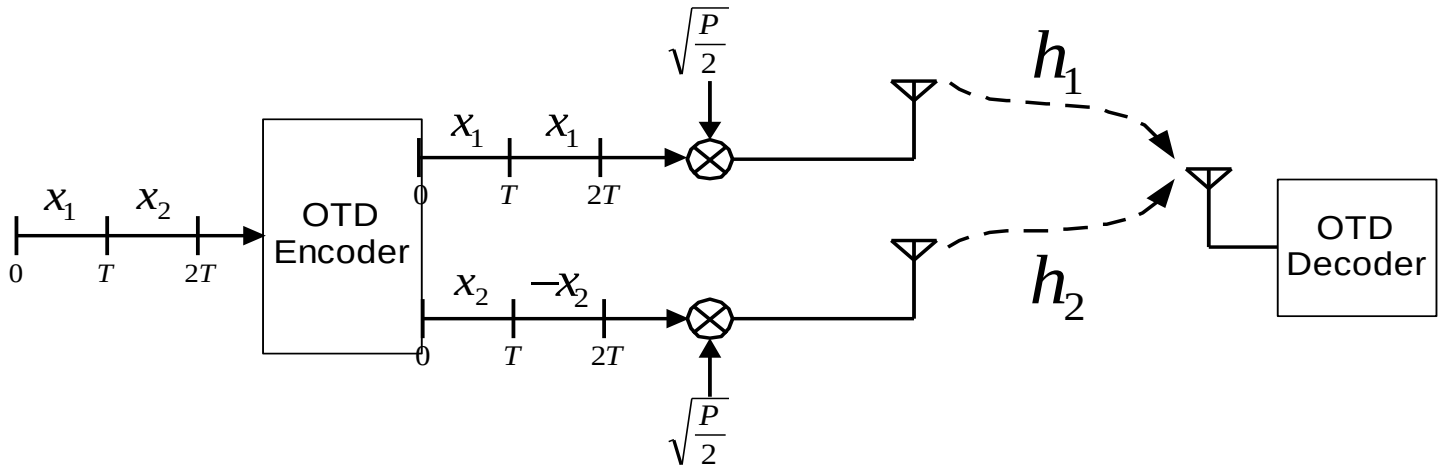
- Diversity Order $\propto L$
- Average SNR Gain = 0

<Antenna+RAKE>



- Diversity Order $\propto M \cdot L$
- Average SNR Gain $\propto M$

Orthogonal Transmit Diversity (OTD)



- OTD Encoder:

	Time 1	Time 2
Ant. 1	x_1	x_1
Ant. 2	x_2	$-x_2$

- Received Signal:

$$r_1 = \sqrt{\tfrac{P}{2}}\left(h_1 x_1 + h_2 x_2\right) + n_1$$

$$r_2 = \sqrt{\tfrac{P}{2}}\left(h_1 x_1 - h_2 x_2\right) + n_2$$

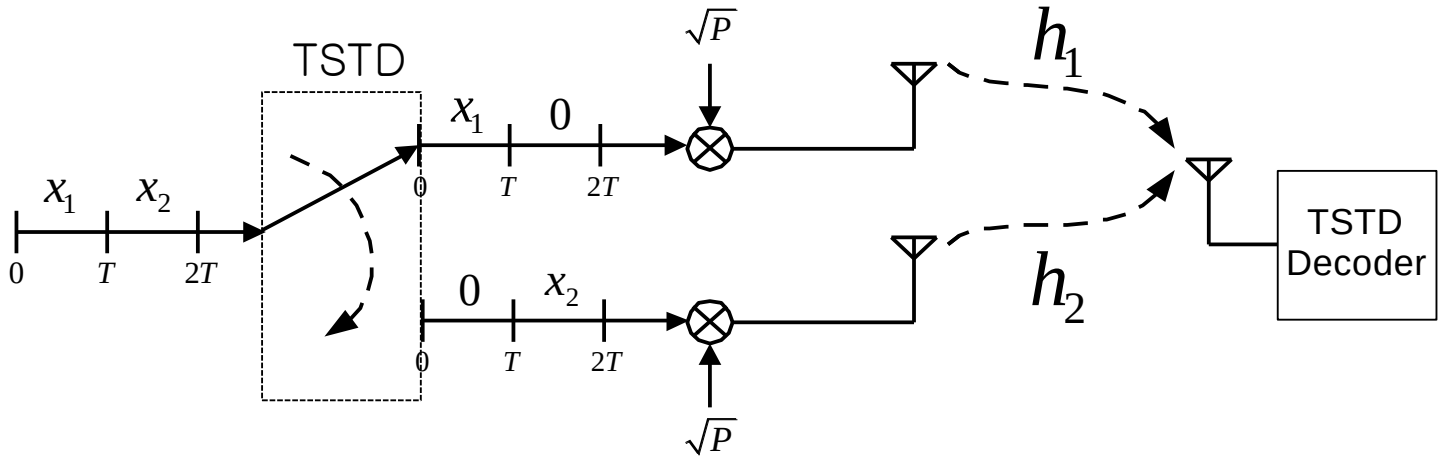
- OTD Decoder:

$$\hat{x}_1 = h_1^*\left(r_1 + r_2\right) = \sqrt{2P}\left|h_1\right|^2 x_1 + \eta_1$$

$$\hat{x}_2 = h_2^*\left(r_1 - r_2\right) = \sqrt{2P}\left|h_2\right|^2 x_2 + \eta_2$$

- Different Symbol → Different Fading
- Interleaving Effects
- Useful at Slow Fading Environment

Time Switched Transmit Diversity (TSTD)



- TSTD Encoder:

	Time 1	Time 2
Ant. 1	x_1	0
Ant. 2	0	x_2

- Received Signal:

$$r_1 = \sqrt{P}\left(h_1 x_1\right) + n_1$$

$$r_2 = \sqrt{P}\left(h_2 x_2\right) + n_2$$

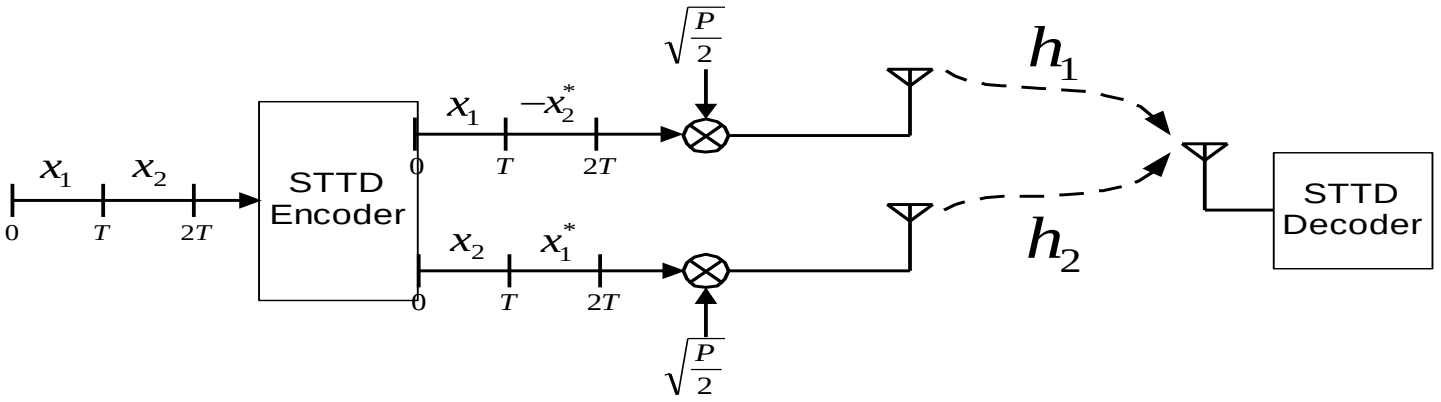
- TSTD Decoder:

$$\hat{x}_1 = h_1^* \cdot r_1 = \sqrt{P}\left|h_1\right|^2 x_1 + \eta_1$$

$$\hat{x}_2 = h_2^* \cdot r_2 = \sqrt{P}\left|h_2\right|^2 x_2 + \eta_2$$

- Different Symbol → Different Fading
- Interleaving Effects
- Useful at Slow Fading Environment

Space-Time Transmit Diversity (STTD)



- STTD Encoder:

$$\begin{array}{c} \\ \text{Ant. 1} \\ \text{Ant. 2} \end{array} \begin{array}{c} \begin{array}{cc} \text{Time 1} & \text{Time 2} \end{array} \\ \begin{pmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{pmatrix} \end{array}$$

- Received Signal:

$$r_1 = \sqrt{\tfrac{P}{2}}\left(h_1 x_1 + h_2 x_2\right) + n_1$$

$$r_2 = \sqrt{\tfrac{P}{2}}\left(-h_1 x_2^* + h_2 x_1^*\right) + n_2$$

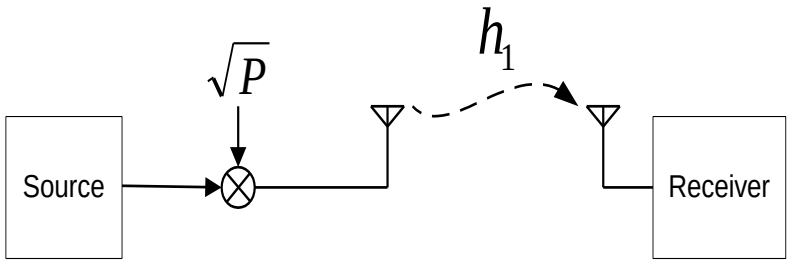
- STTD Decoder:

$$\hat{x}_1 = r_1 h_1^* + r_2^* h_2 = \sqrt{\tfrac{P}{2}}\left(|h_1|^2 + |h_2|^2\right) x_1 + \eta_1$$

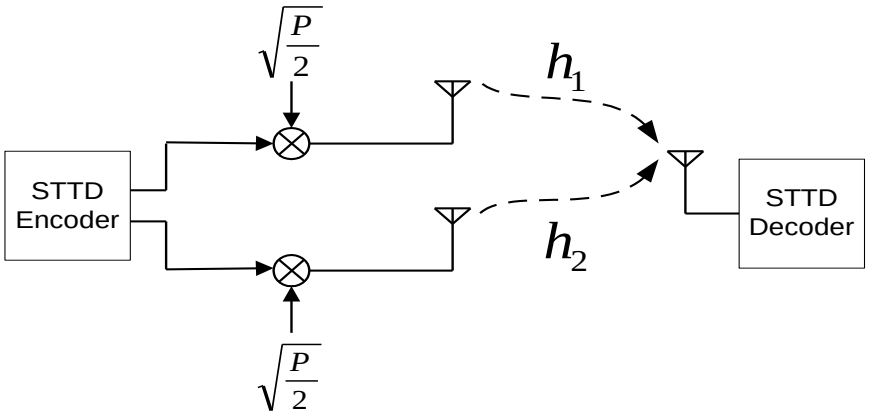
$$\hat{x}_2 = r_1 h_2^* - r_2^* h_1 = \sqrt{\tfrac{P}{2}}\left(|h_1|^2 + |h_2|^2\right) x_2 + \eta_2$$

Diversity
without BW Expansion

No Tx Diversity VS STTD

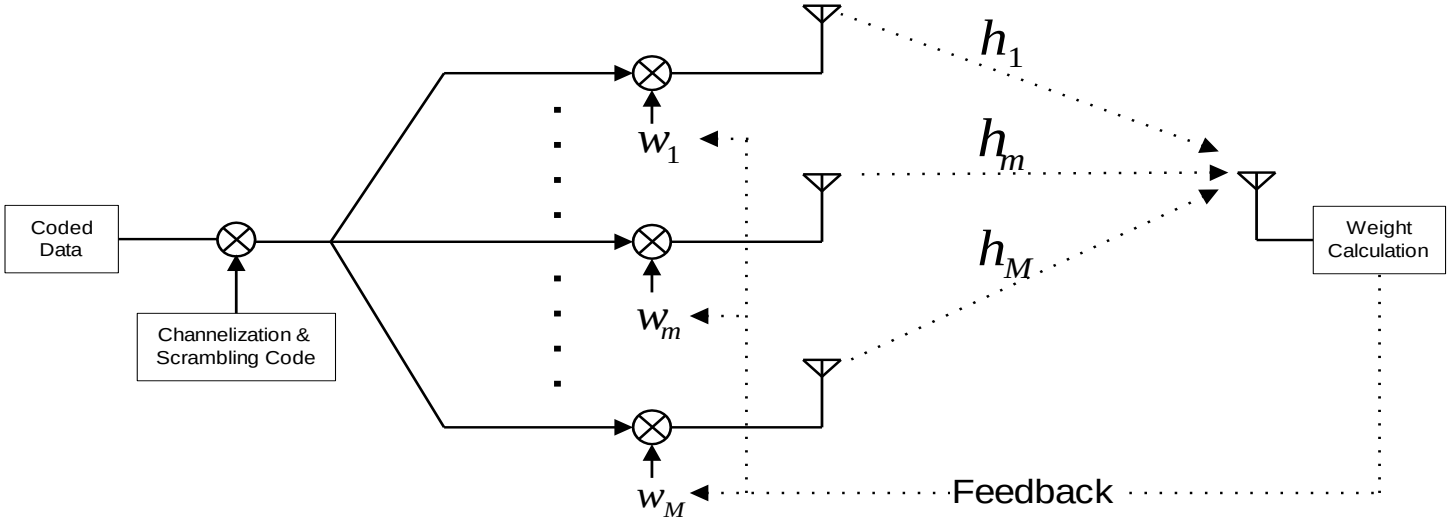


- Tx. Power= P
- SNR: $\gamma \propto P \cdot |h_1|^2$
- Avg. SNR: $\gamma \propto P \cdot \sigma_0^2$
- Average SNR Gain =0
- Diversity Order =1



- Tx. Power= P
- SNR: $\gamma \propto \frac{P}{2} \cdot \left\{ |h_1|^2 + |h_2|^2 \right\}$
- Avg. SNR: $\gamma \propto P \cdot \sigma_0^2$
- Average SNR Gain =0
- Diversity Order =2

Transmit Antenna Array (TxAA)



- Weighting

$$w_m = \frac{h_m^*}{\sqrt{\sum_{i=1}^{M} |h_i|^2}}$$

- Received signal

$$r = \left(\sum_{m=1}^{M} w_m h_m \right) x + n$$

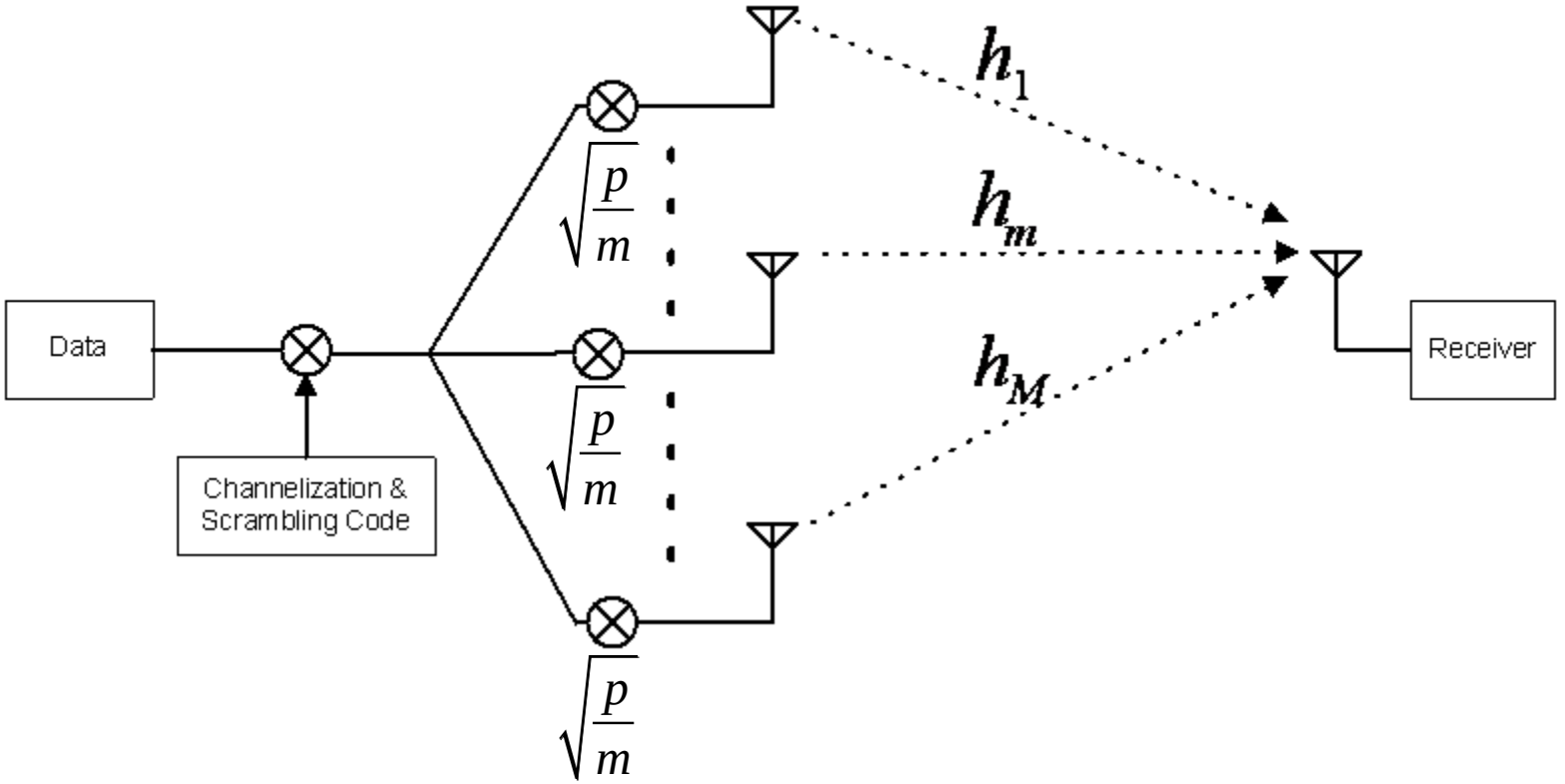
$$= x \sqrt{\sum_{m=1}^{M} |h_m|^2} + n$$

- SNR

$$\gamma \propto \sum_{m=1}^{M} |h_m|^2$$

- Diversity Order $\propto M$
- Average SNR Gain $\propto M$

Transmit Diversity

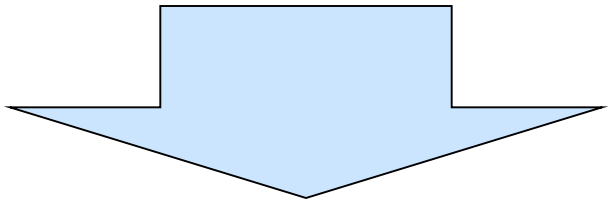


- Performance ???

Efficient Weight Vector Representation (***Basis Selection)***

Basis selection Tx Div

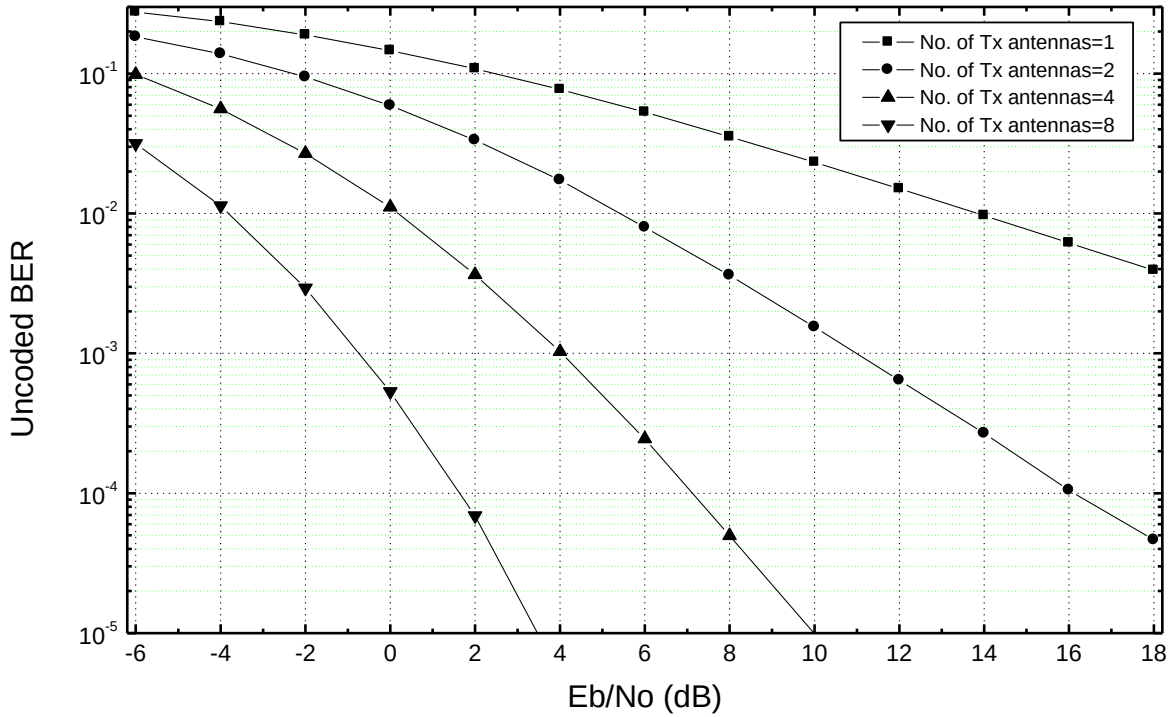
- STTD: Open Loop
  - 장점: No Feedback Information
  - 단점: 확장성(M>2이상의 경우, Coding scheme 없음)
- TxAA: Closed Loop
  - 장점: 성능향상 $\propto M$
  - 단점: Feedback Data량 $\propto M$, Channel Tracking



Basis Selection

* 서울대 이동통신연구실, 삼성

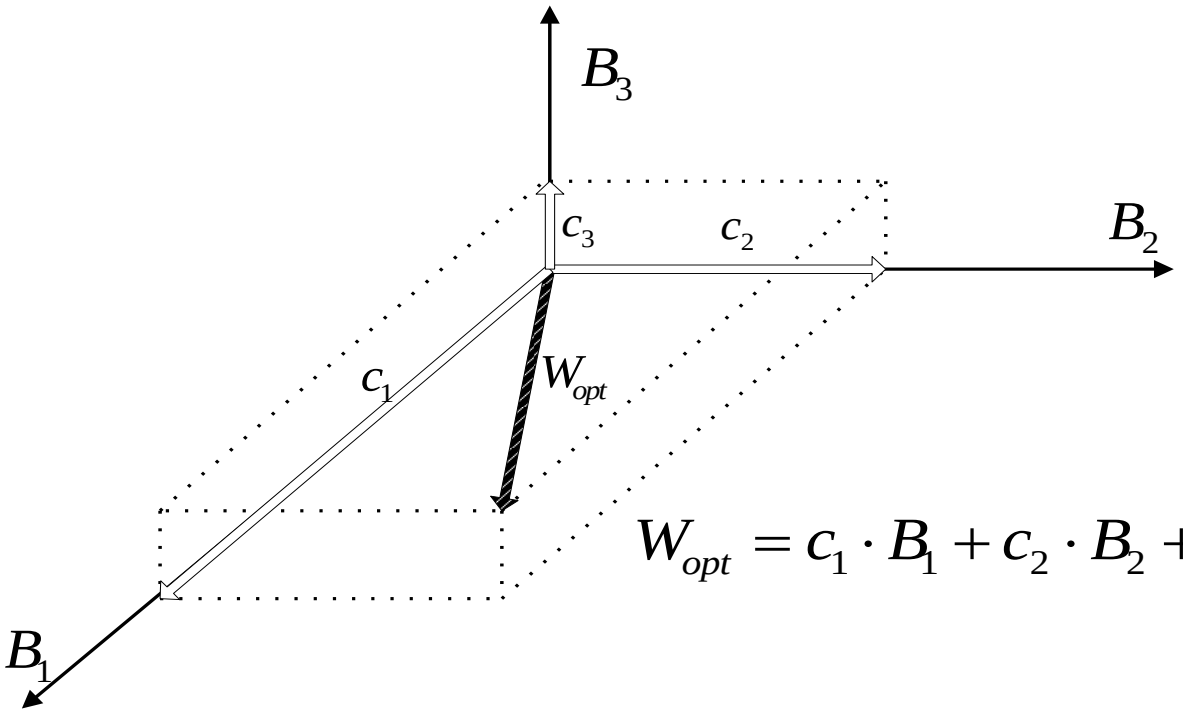
Performace of Tx Diversity



- 4 tx antennas: 5.2dB gain at 10-2 BER w.r.t. 2 antennas
- 8 tx antennas: 8.8dB gain at 10-2 BER w.r.t. 2 antennas

Basis Selection

- Basis Selection: Noble Approximation Technique



$$W_{opt} = c_1 \cdot B_1 + c_2 \cdot B_2 + c_3 \cdot B_3$$

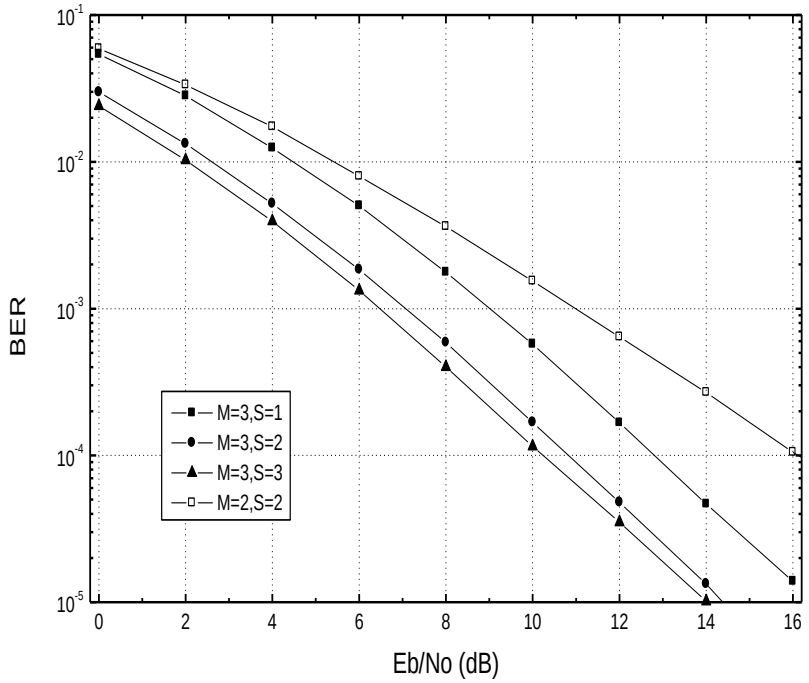
- $W_{opt} \cong \sum_{i=1}^{S} c_i \cdot B_i$, S: Selection Order

Basis Selection(cont'd)

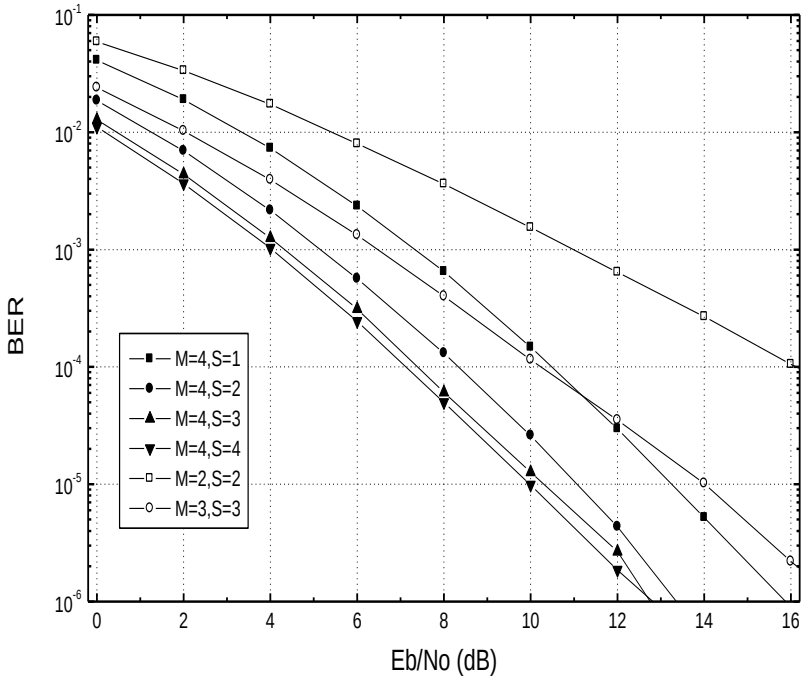
- Algorithm
  - ✶ Calculate W_{opt}
  - ✸ Project W_{opt} to M bases, and Calculate c_i
  - ✹ Select the bases with the S largest coefficients
  - ✵ Feedback the basis indices and the coefficients
- Feedback Data량: 감소
- 성능

Performance (No. of paths=1)

< M=3>



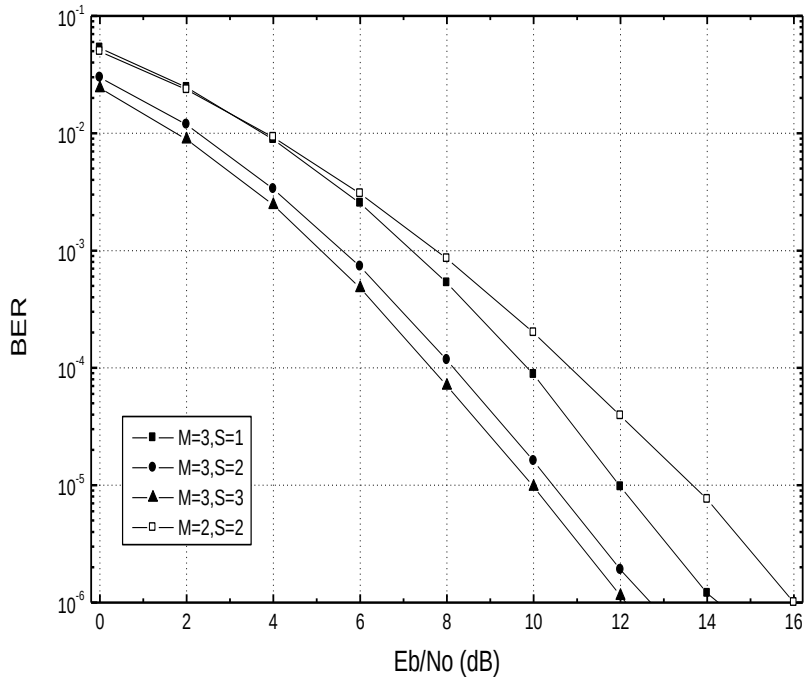
< M=4>



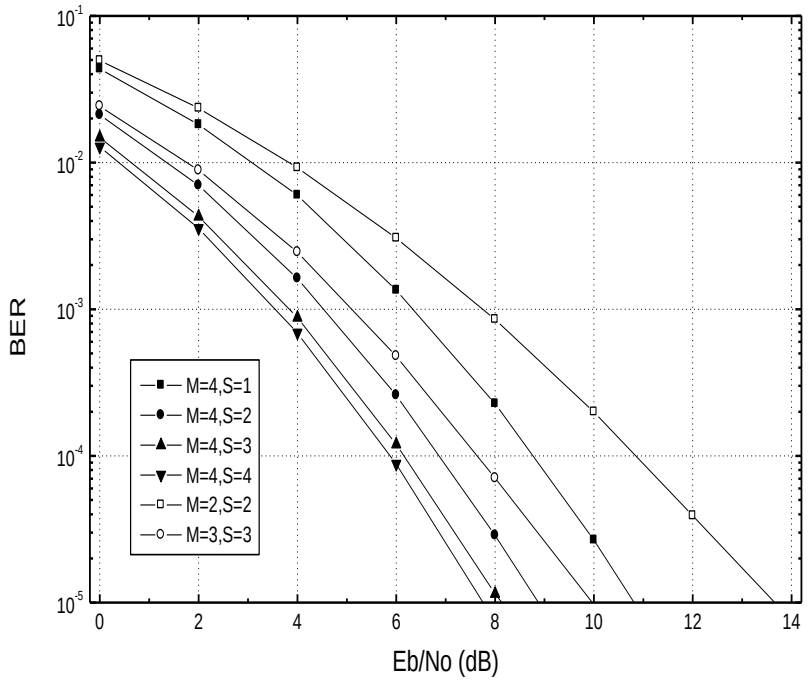
- Diversity order: slope

Performance (No. of paths=2)

< M=3>



< M=4>



Feedback Data량

- Direct Extension of 2 Antennas TxAA

$$N_D = (M-1)\cdot N_2 \quad \text{where} \quad M\text{: No of Antennas}$$
$$N_2\text{: Required Bits for each antenna weight}$$

- Basis Selection

$$N_S = \left\lceil \log_2 \binom{M}{S} \right\rceil + (S-1)\cdot N_2$$

- Examples(N_2=4 bits)

<No. of Antennas=4>

S	Direct Ext.	Basis Sel.
1	12 bits	2 bits
2		7 bits
3		10 bits
4		12 bits

<No. of Antennas=8>

S	Direct Ext.	Basis Sel.
1	28 bits	3 bits
2		9 bits
3		14 bits
4		19 bits

Multiple Tx and Multiple Rx