Eigenmode Tomlinson-Harashima Precoding for Multi-antenna Multi-user MIMO Broadcast Channel

ICICS 2007@Singapore
Dec 10-13 ,2007

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Presentation Outline

- Background
- Theory
  - Multi-antenna multi-user MIMO broadcast channel system model
  - Algorithm
    - Antenna Selection-Zero Forcing(AS-ZF)
    - Iterative Joint Orthogonalization (IJO)
    - Eigenmode Dirty Paper Coding (EM-DPC)
    - Eigenmode Tomlinson-Harashima Precoding (EM-THP)
- Simulation results
- Summary

Background

Multi-user MIMO system

◆MIMO i

◆Multi-us ... sity)

✓ Tran

✓ Dirty

Performance of 3 different transmission algorithms were investigated

As a result…

EM-DPC has the <u>best performance</u>. however results in higher PAPR.

Multi-ante system

✓ Antenna Selection -ZF

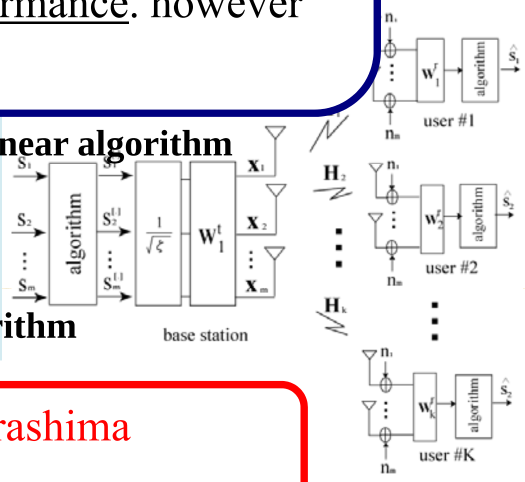
✓ Iterative Joint Othogonalization

✓ Eigenmode - DPC

✓ Eigenmode - THP

Linear algorithm

Non-linear algorithm

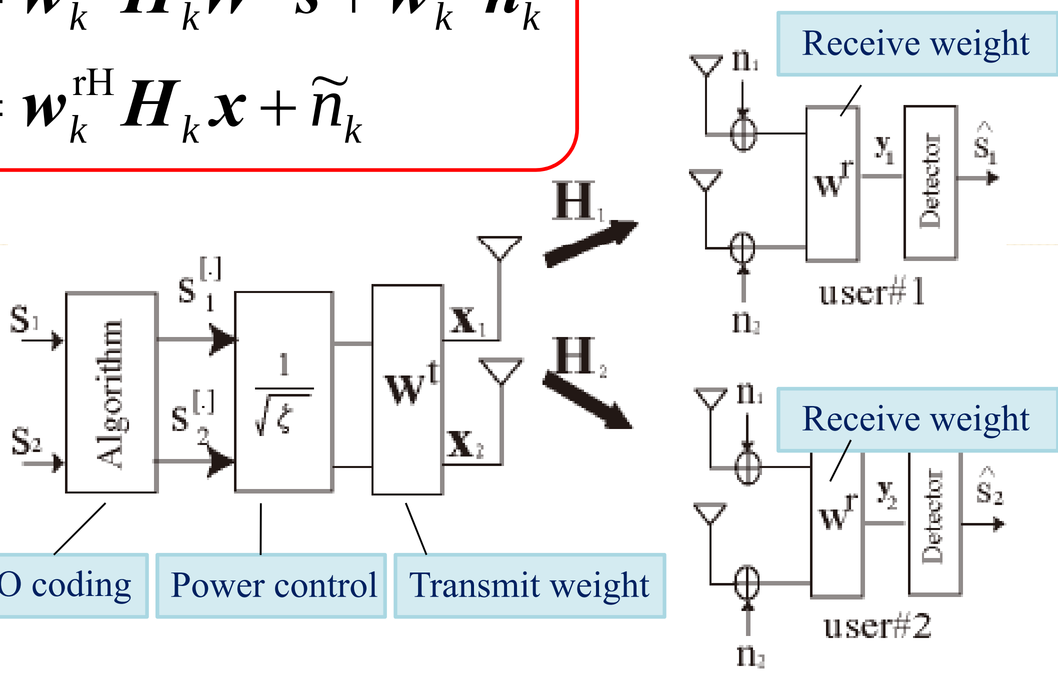


MIMO system

Proposal of Eigenmode Tomlinson-Harashima Precoding (EM-THP)

Multi-antenna Multi-user MIMO Broadcast system model

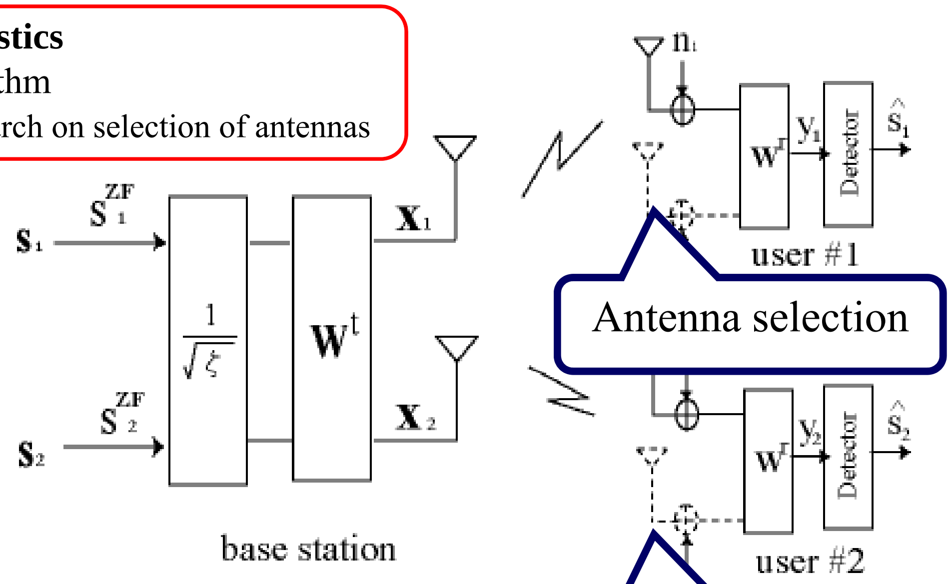
$$
\begin{aligned}
\boldsymbol{y}_k &= \boldsymbol{w}_k^{\mathrm{rH}} \boldsymbol{H}_k \boldsymbol{W}^{\mathrm{t}} \boldsymbol{s} + \boldsymbol{w}_k^{\mathrm{rH}} \boldsymbol{n}_k \\
&= \boldsymbol{w}_k^{\mathrm{rH}} \boldsymbol{H}_k \boldsymbol{x} + \tilde{n}_k
\end{aligned}
$$



Antenna Selection Zero Forcing (AS-ZF)

AS-ZF characteristics

- Linear algorithm
- Exhaustive search on selection of antennas



Transmit weight

$$\boldsymbol{w}_k^{\mathrm{t}} = \frac{\left(\boldsymbol{H}_e^{\dagger}\right)_k}{\sqrt{\left\|\left(\boldsymbol{H}_e^{\dagger}\right)_k\right\|^2}}$$

Transmit power Normalization coefficient

$$\zeta = 2$$

$$\boldsymbol{w}_k^{\mathrm{r}} = [1 \quad 0]^{\mathrm{T}} \, or \, [0 \quad 1]^{\mathrm{T}}$$

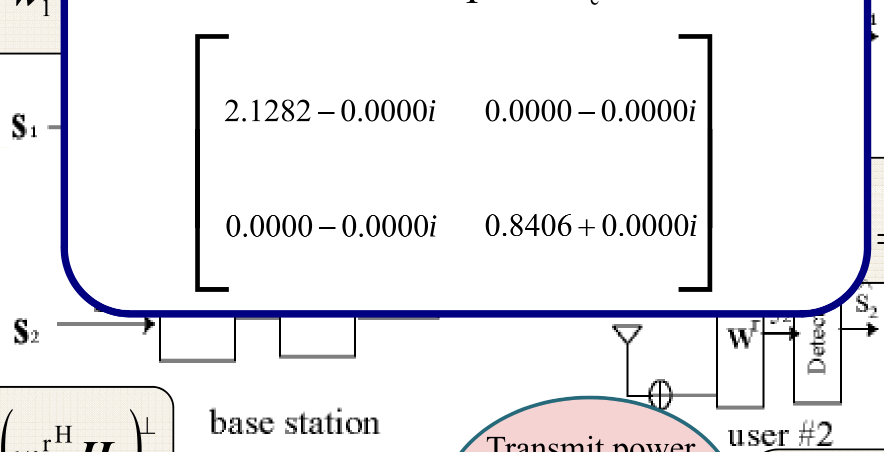
Iterative Joint Orthogonalization (IJO)

IJO characteristics

- Linear algorithm
- Adaptive optimal weights

③ $$\boldsymbol{w}_1^{\mathrm{r}} = \frac{\boldsymbol{H}_1 \boldsymbol{w}_1^{\mathrm{t}}}{\sqrt{\left\|\boldsymbol{H}_1 \boldsymbol{w}_1^{\mathrm{t}}\right\|^2}}$$

② $\boldsymbol{w}_1^{\mathrm{t}}$



For exemple: $\boldsymbol{H}_{\mathrm{e}}$

$$\begin{bmatrix} 2.1282 - 0.0000i & 0.0000 - 0.0000i \\ 0.0000 - 0.0000i & 0.8406 + 0.0000i \end{bmatrix}$$

$= [1 \quad 0]^{\mathrm{T}}$

④ $$\boldsymbol{w}_2^{\mathrm{t}} = \left(\boldsymbol{w}_1^{\mathrm{r}\,\mathrm{H}} \boldsymbol{H}_1\right)^{\perp}$$

Transmit power normalization coefficient

$$\zeta = 2$$

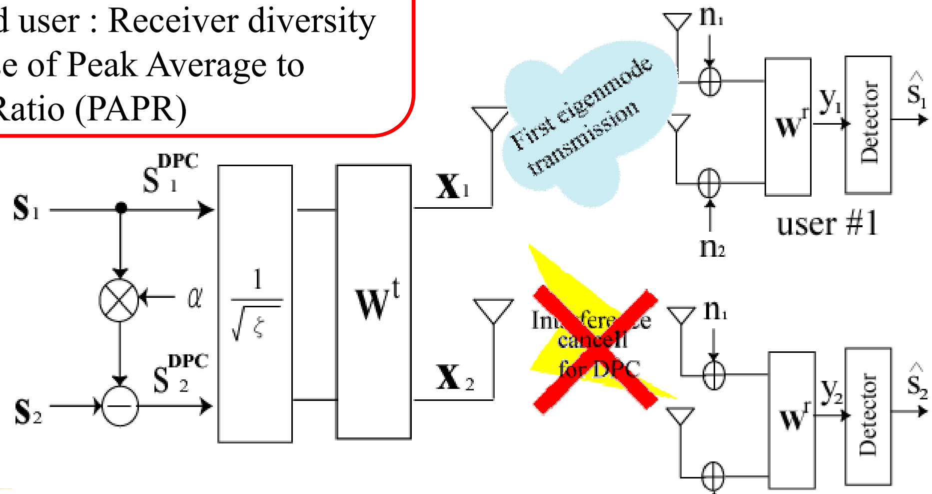
⑤ $$\boldsymbol{w}_2^{\mathrm{r}} = \frac{\boldsymbol{H}_2 \boldsymbol{w}_2^{\mathrm{t}}}{\sqrt{\left\|\boldsymbol{H}_2 \boldsymbol{w}_1^{\mathrm{t}}\right\|^2}}$$

Until every off-diagonal elements of the effective channel matrix $\boldsymbol{H}_e$ become ignorably small, run over from step 2 to 5.

Eigenmode Dirty Paper Coding (EM-DPC)

DPC characteristics & problem

- First user : full diversity
  Second user : Receiver diversity
- Increase of Peak Average to Power Ratio (PAPR)



$$H_1 = U_1 \Sigma_1 V_1^H$$

$$U_1 = [u_1 \quad u_1^{\perp}] \qquad V_1 = [v_1 \quad v_1^{\perp}]$$

Transmit weight

$$w_1^t = v_1$$
$$w_2^t = v_1^{\perp}$$

Receive weight

$$w_1^r = u_1$$
$$w_2^r = H_2 v_1^{\perp}$$

Power control (normalization)

Transmit signal should be normalized to meet the transmit power constraint.

Transmit signal

$$x = W^t s = [w_1^t \quad w_2^t] \begin{bmatrix} s_1^{DPC} \\ s_2^{DPC} \end{bmatrix}$$

$$s^{DPC} = \begin{bmatrix} 1 & 0 \\ \alpha & 1 \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$

$$(w_k^t)^H w_k^t = 1 \ \forall k \qquad E[ss^H] = I$$

$$\alpha = -\frac{w_2 H_2 w_1}{w_2 H_2 w_2}$$

Transmit power normalized coefficient

$$\zeta = E[x^H x] = 2$$

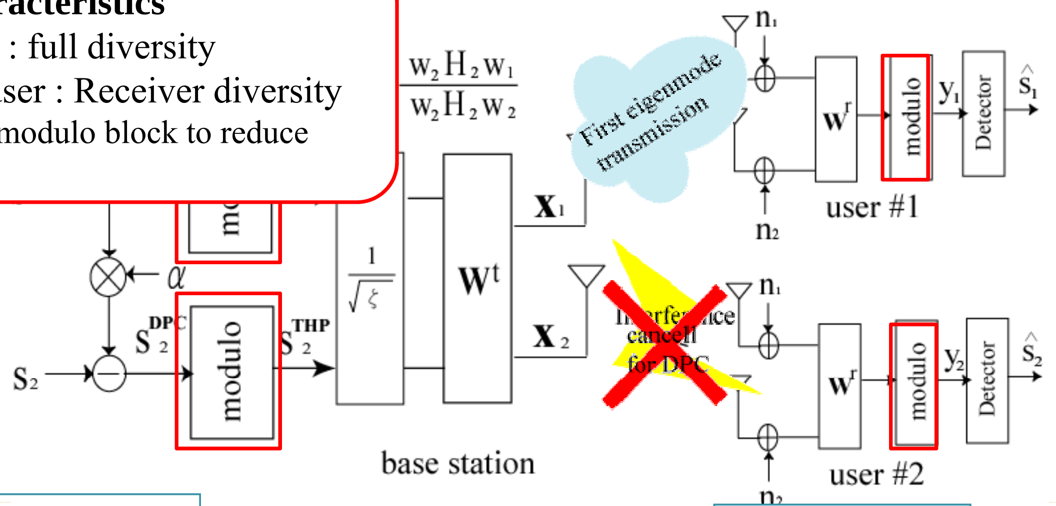
Transmit power normalized coefficient

$$\zeta = E\left[(x^{DPC})^H x^{DPC}\right] = |w_1^t + \alpha w_2^t|^2 + 1$$

Eigenmode Tomlinson Harashima Precoding (EM-THP)

EM-THP characteristics

- First user : full diversity
  Second user : Receiver diversity
- Introduce modulo block to reduce PAPR



Transmit weight
$w_1^t = v_1$
$w_2^t = v_1^\perp$

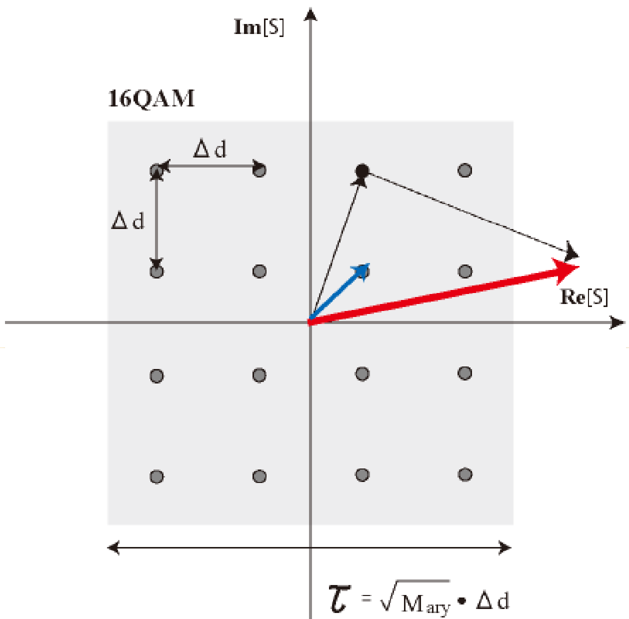
$$H_1 = U_1 \Sigma_1 V_1^H$$

$$V_1 = [v_1 \quad v_1^\perp]$$

$$U_1 = [u_1 \quad u_1^\perp]$$

Receive weight
$w_1^r = u_1$
$w_2^r = H_2 v_1^\perp$

Modulo block



$$\tau \cong \begin{cases} 2\Delta d & Mary = 2 \\ \sqrt{Mary}\Delta d & Mary > 2 \end{cases}$$

Second stream

Transmit signal

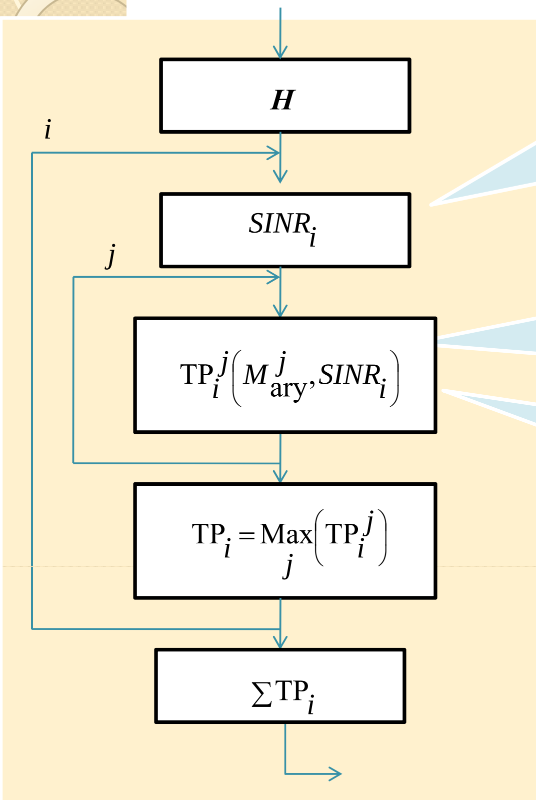
$$s_2^{THP} = \mathrm{mod}(s_2^{DPC}, \tau) = s_2^{DPC} - \left\lfloor \frac{s_2^{DPC} + \tau/2}{\tau} \right\rfloor \tau$$

$\lfloor x \rfloor$ denotes the largest integer less than or equal to its argument

Receive signal

$$\hat{s}_2 = \mathrm{mod}\left(\frac{y_2}{w_2^r H_2 w_2^t}, \tau \right) = \mathrm{mod}\left(s_2^{THP} + \frac{w_2^r H_2 w_1^t}{w_2^r H_2 w_2^t} s_1 + \tilde{n}_2, \tau \right) = \mathrm{mod}(s_2 + \tilde{n}_2, \tau)$$

Simulation method & Parameters



$$\gamma_1 = \frac{\left\| \boldsymbol{w}_1^{\mathrm{rH}} \boldsymbol{H}_1 \boldsymbol{w}_1^{\mathrm{t}} \right\|^2}{\left\| \boldsymbol{w}_1^{\mathrm{rH}} \boldsymbol{H}_1 \boldsymbol{w}_2^{\mathrm{t}} \right\|^2 + \sigma^2}$$

$$\gamma_2 = \frac{\left\| \boldsymbol{w}_2^{\mathrm{rH}} \boldsymbol{H}_2 \boldsymbol{w}_2^{\mathrm{t}} \right\|^2}{\left\| \boldsymbol{w}_2^{\mathrm{rH}} \boldsymbol{H}_2 \boldsymbol{w}_1^{\mathrm{t}} \right\|^2 + \sigma^2}$$

$$SER \cong \begin{cases} \frac{1}{2}\mathrm{erfc}\left(\sqrt{\gamma_i}\right) & \left(M_{\mathrm{ary}} = 2\right) \\ 2\left(1 - \frac{1}{\sqrt{M_{\mathrm{ary}}}}\right)\mathrm{erfc}\left(\sqrt{\frac{3\gamma_i}{2\left(M_{\mathrm{ary}} - 1\right)}}\right) & \left(M_{\mathrm{ary}} > 2\right) \end{cases}$$

$$TP_i = \max_{M_{\mathrm{ary}}} \left\{ \log_2 M_{\mathrm{ary}} \left(1 - SER\left(M_{\mathrm{ary}}, \gamma_i\right)\right) \right\}^l$$

Number of users	2
Number of antennas	2 (mobile station) 2(base station)
Channel model	IID channel
Modulation scheme	Adaptive modulation per user (BPSK,QPSK,16QAM,64QAM)

Throughput performance

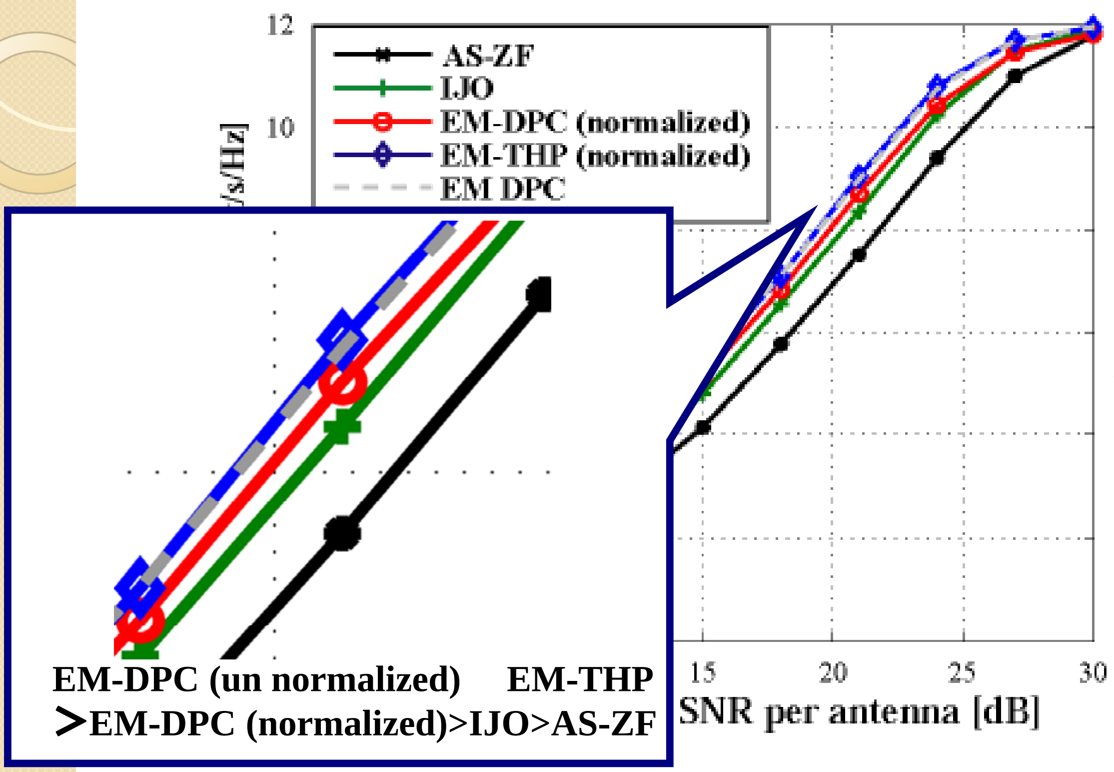


Figure 1. Throughput performance in IID channel

Throughput performance

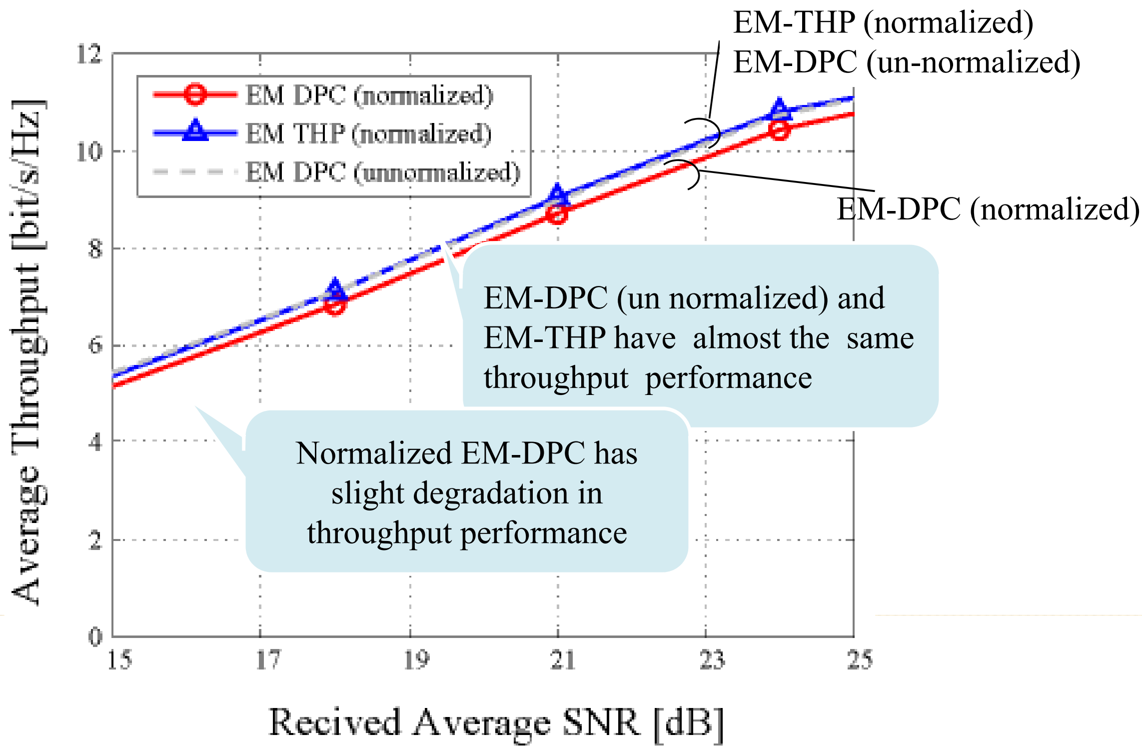


Figure 2. Throughput performance in IID channel

CCDF performance (PAPR)

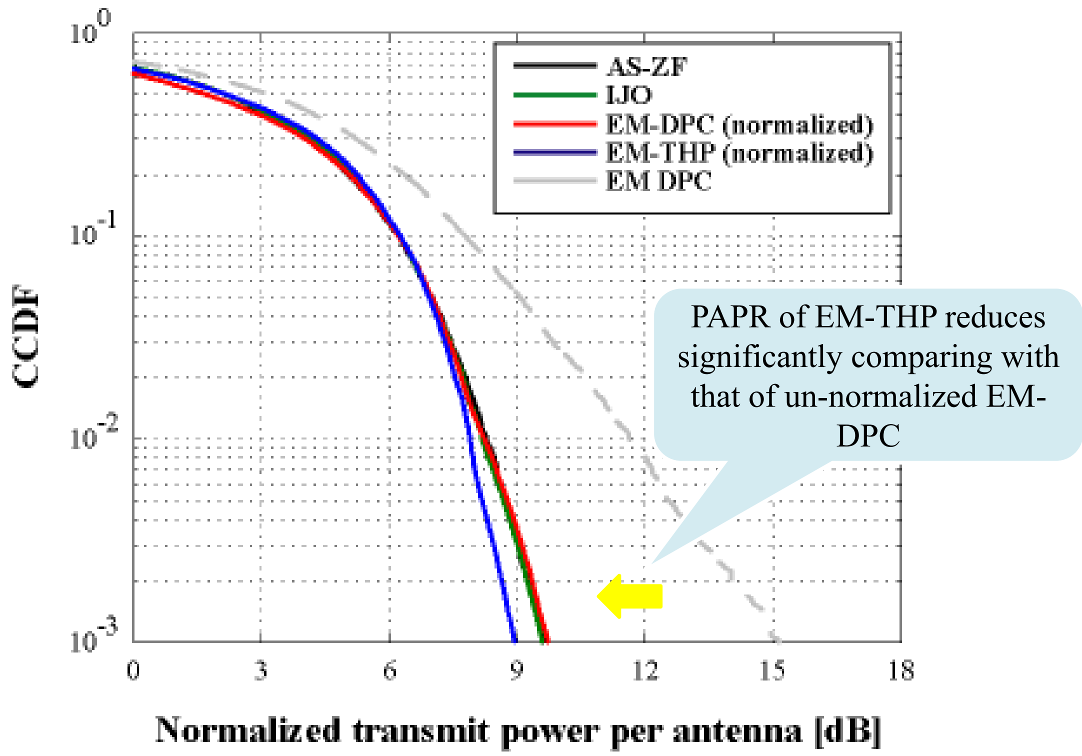


Figure 3. CCDF performance

Summary

- We investigated throughput and PAPR performance of different transmission algorithm in multi-antenna multi-user MIMO broadcast channel.
- The results showed that EM-DPC is a good algorithm that achieves high throughput, however, increases PAPR.
- EM-THP algorithm showed excellent performance in the meaning of throughput as well as PAPR.

Future work

- Extension to number of users larger than two
- Performance analysis in time-varying channel model.