Experimental Analysis of MIMO-OFDM Eigenmode Transmission with MMSE Interference Canceller

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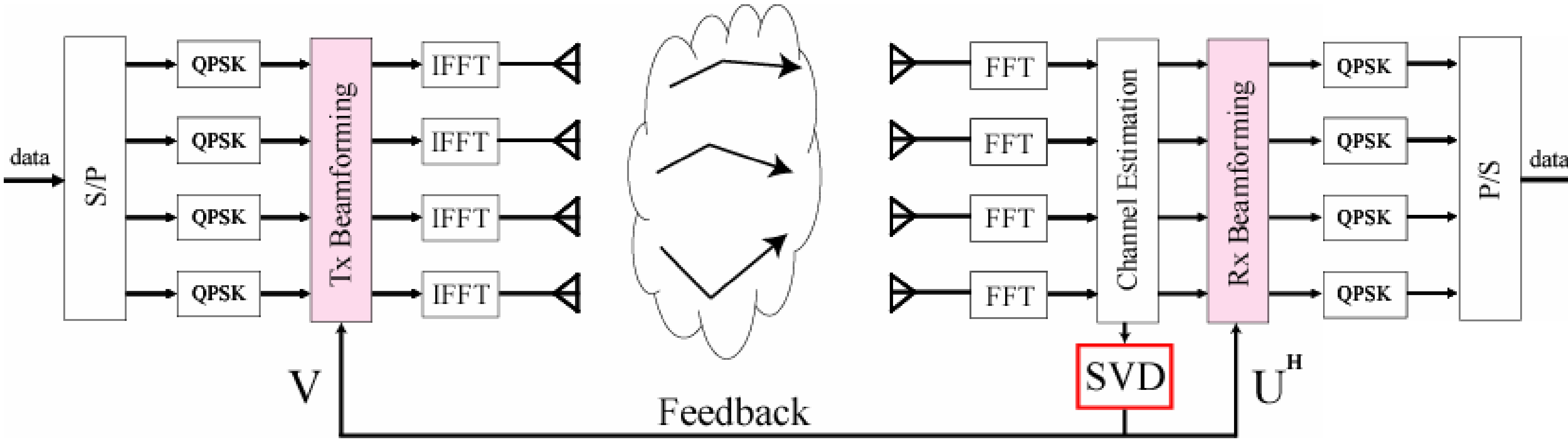
MIMO-OFDM EMTS

➢ MIMO-OFDM eigenmode transmission system (MIMO-OFDM EMTS)



$$\boldsymbol{y} = \boldsymbol{Hx} + \boldsymbol{n}$$

$$\boldsymbol{U}^{\mathrm{H}}\boldsymbol{y} = \boldsymbol{U}^{\mathrm{H}}\boldsymbol{HVs} + \boldsymbol{U}^{\mathrm{H}}\boldsymbol{n}$$

$$\tilde{\boldsymbol{y}} = \boldsymbol{\Sigma s} + \tilde{\boldsymbol{n}}$$

Rx Weight Tx Weight

$$\boldsymbol{U\Sigma V}^{\mathrm{H}} = \boldsymbol{H}$$

$$\Sigma = \mathrm{diag}[\sqrt{\lambda_1} \ldots \sqrt{\lambda_m}]$$

$$m = \min(M_t, M_r)$$

Gain of an each eigenmode

s : Transmit signal
y : Receive signal
H : Channel matrix
n : Noise
λ : Eigen value

Perfect orthogonalization of the channel

↓

No inter-eigenmode interference

Channel Variation

- Channel variation

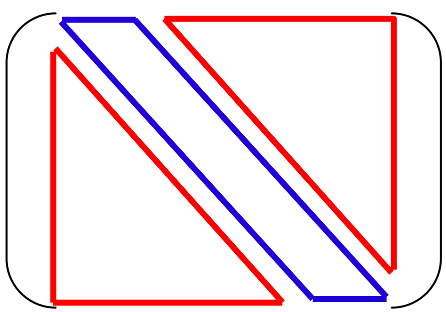
$$\boldsymbol{H}_t = \rho \boldsymbol{H} + \sqrt{1-\rho^2}\,\boldsymbol{H}_{\mathrm{var}}$$

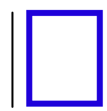
ρ : Correlation coefficient
$\boldsymbol{H}$: Channel used for making Tx/Rx weight
$\boldsymbol{H}_t$: Transmission channel
$\boldsymbol{H}_{\mathrm{var}}$: Variation of the channel

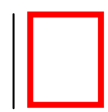
- Inter-eigenmode Interference

$$\begin{aligned}\tilde{\boldsymbol{y}} &= \boldsymbol{U}^{\mathrm{H}}\boldsymbol{y} \\ &= \boldsymbol{U}^{\mathrm{H}}\boldsymbol{H}_t\boldsymbol{V}\boldsymbol{s} + \boldsymbol{U}^{\mathrm{H}}\boldsymbol{n} \\ &= [\rho\boldsymbol{U}^{\mathrm{H}}\boldsymbol{H}\boldsymbol{V} + \sqrt{1-\rho^2}\,\boldsymbol{U}^{\mathrm{H}}\boldsymbol{H}_{\mathrm{var}}\boldsymbol{V}]\boldsymbol{s} + \boldsymbol{U}^{\mathrm{H}}\boldsymbol{n} \\ &= [\rho\boldsymbol{\Sigma} + \sqrt{1-\rho^2}\,\boldsymbol{N}]\boldsymbol{s} + \tilde{\boldsymbol{n}}\end{aligned}$$

$$\boldsymbol{U}^{\mathrm{H}}\boldsymbol{H}_t\boldsymbol{V} = \Sigma' =$$



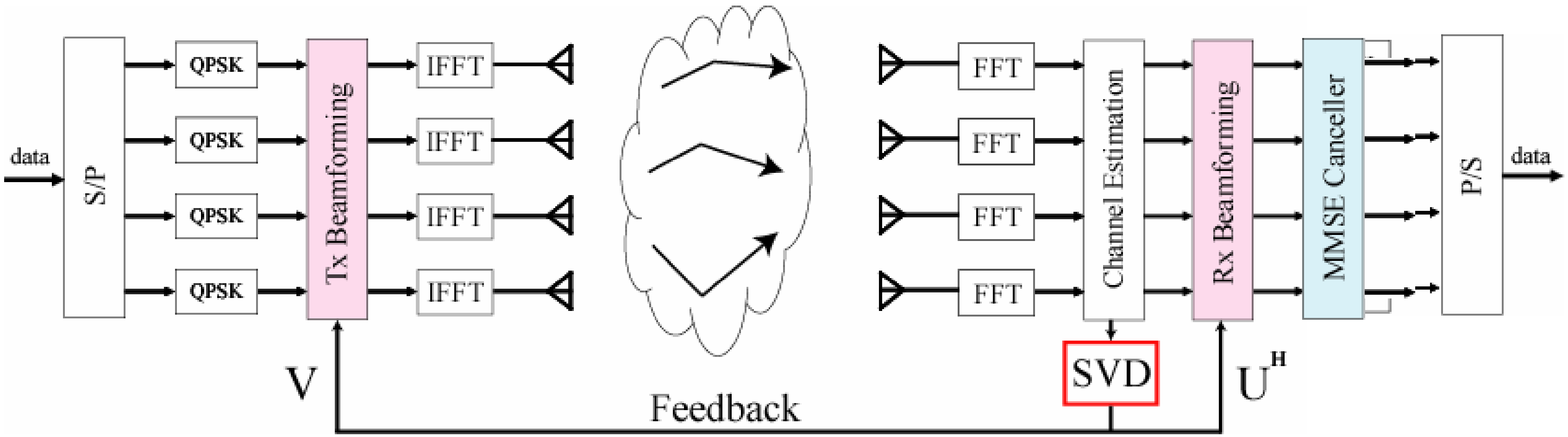
 < 1 : Decrease of the gain

 > 0 : Inter-eigenmode interference

Imperfect orthogonalization of the channel

Performance degradation due to the channel variation

MMSE Canceller

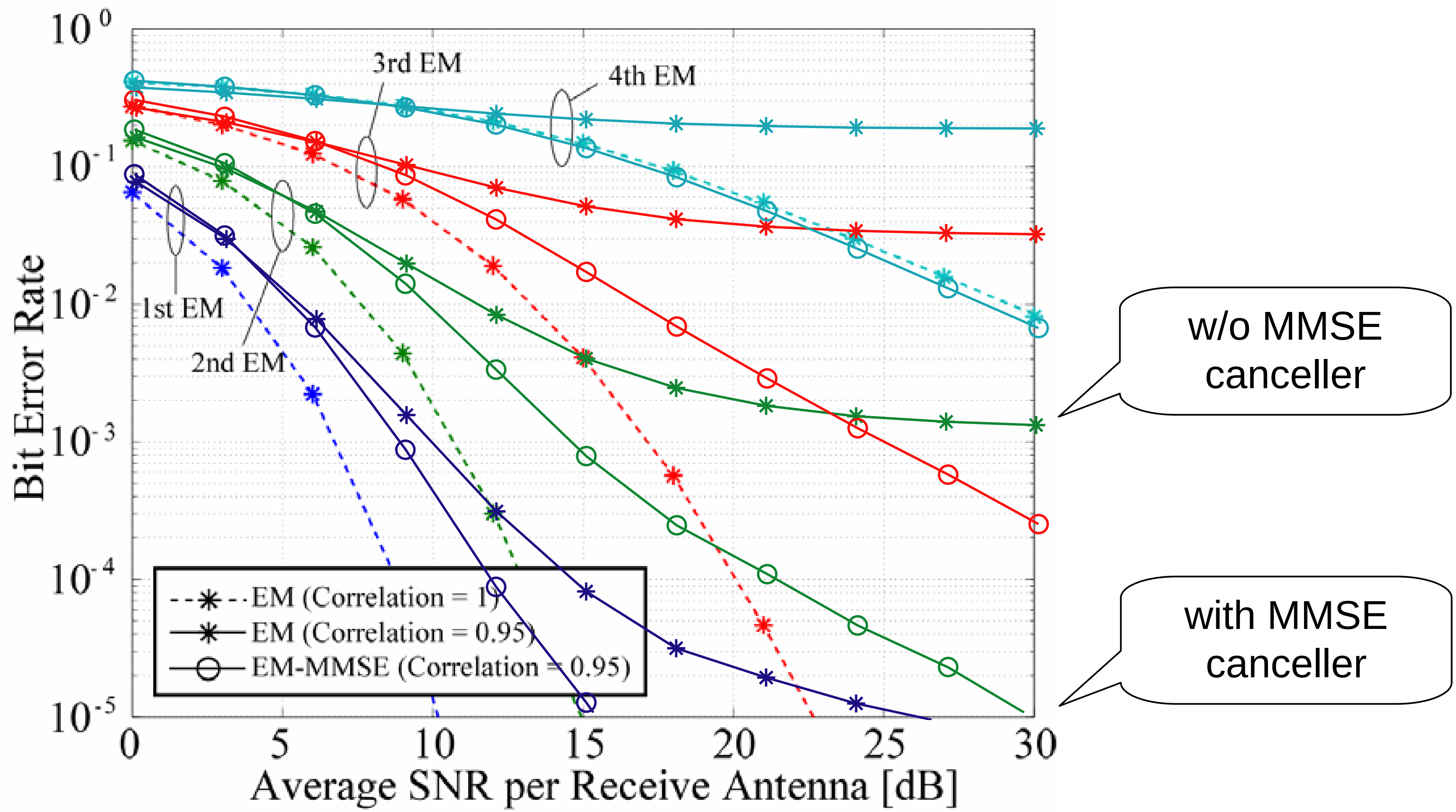


$$\boldsymbol{W}_{\mathrm{MMSE}}\tilde{\boldsymbol{y}} = \boldsymbol{W}_{\mathrm{MMSE}}\boldsymbol{U}^{\mathrm{H}}\boldsymbol{H}_{\mathrm{t}}\boldsymbol{V}\boldsymbol{s} + \boldsymbol{W}_{\mathrm{MMSE}}\boldsymbol{U}^{\mathrm{H}}\boldsymbol{n}$$

$$\boldsymbol{W}_{MMSE} = (\Sigma'^{*}\Sigma' + \frac{m_t I_{m_r}}{\gamma_0})^{-1}\Sigma'^{*}$$

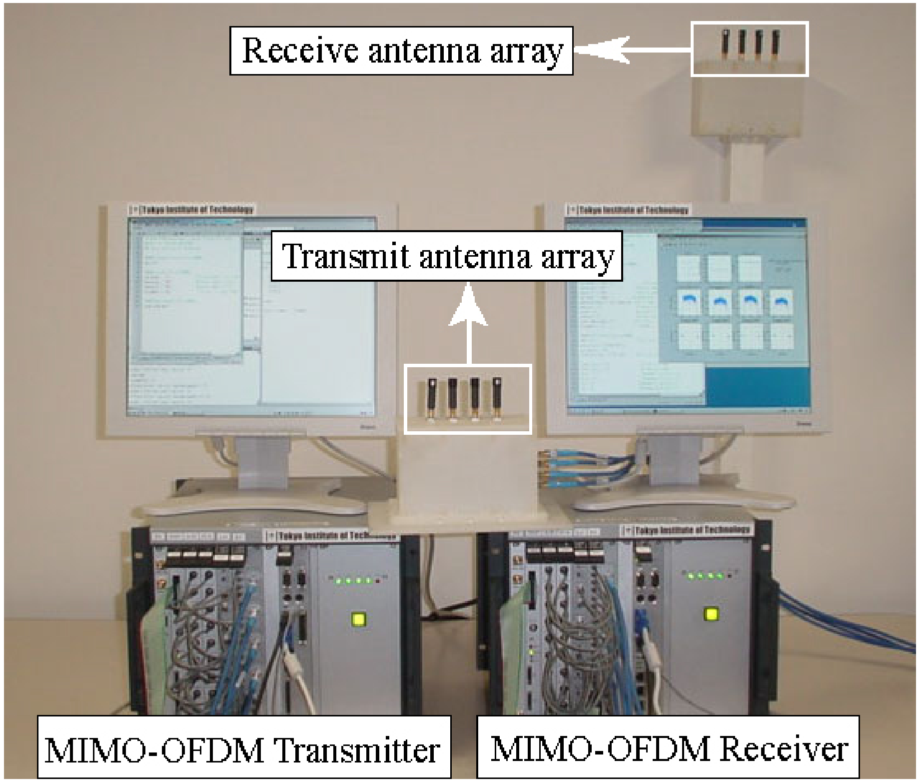
- ✓ Removes inter-eigenmode interference
- ✓ Simply, yet efficiently improves performance

Effect of MMSE Canceller



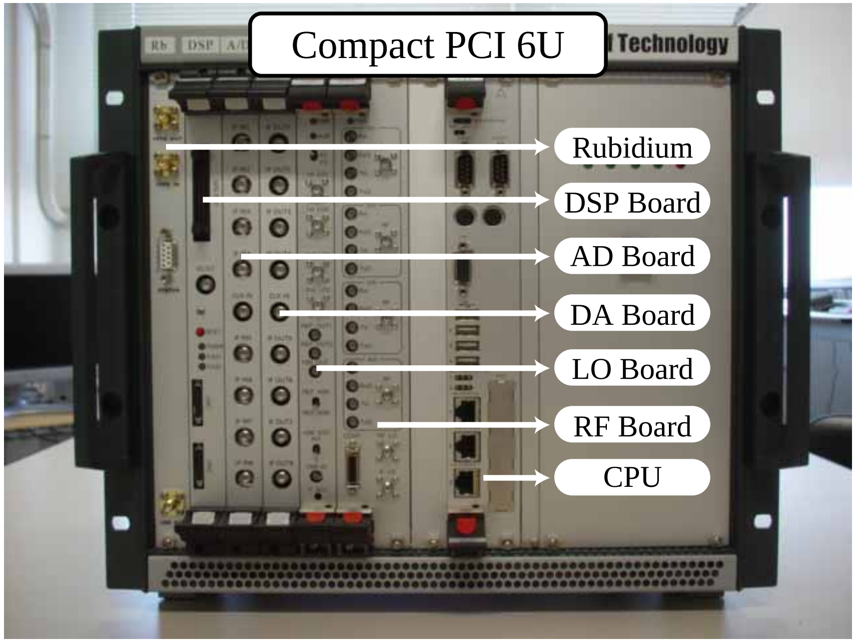
Experimental analysis of MIMO-OFDM EMTS with MMSE interference canceller

Experiment System of MIMO-OFDM EMTS



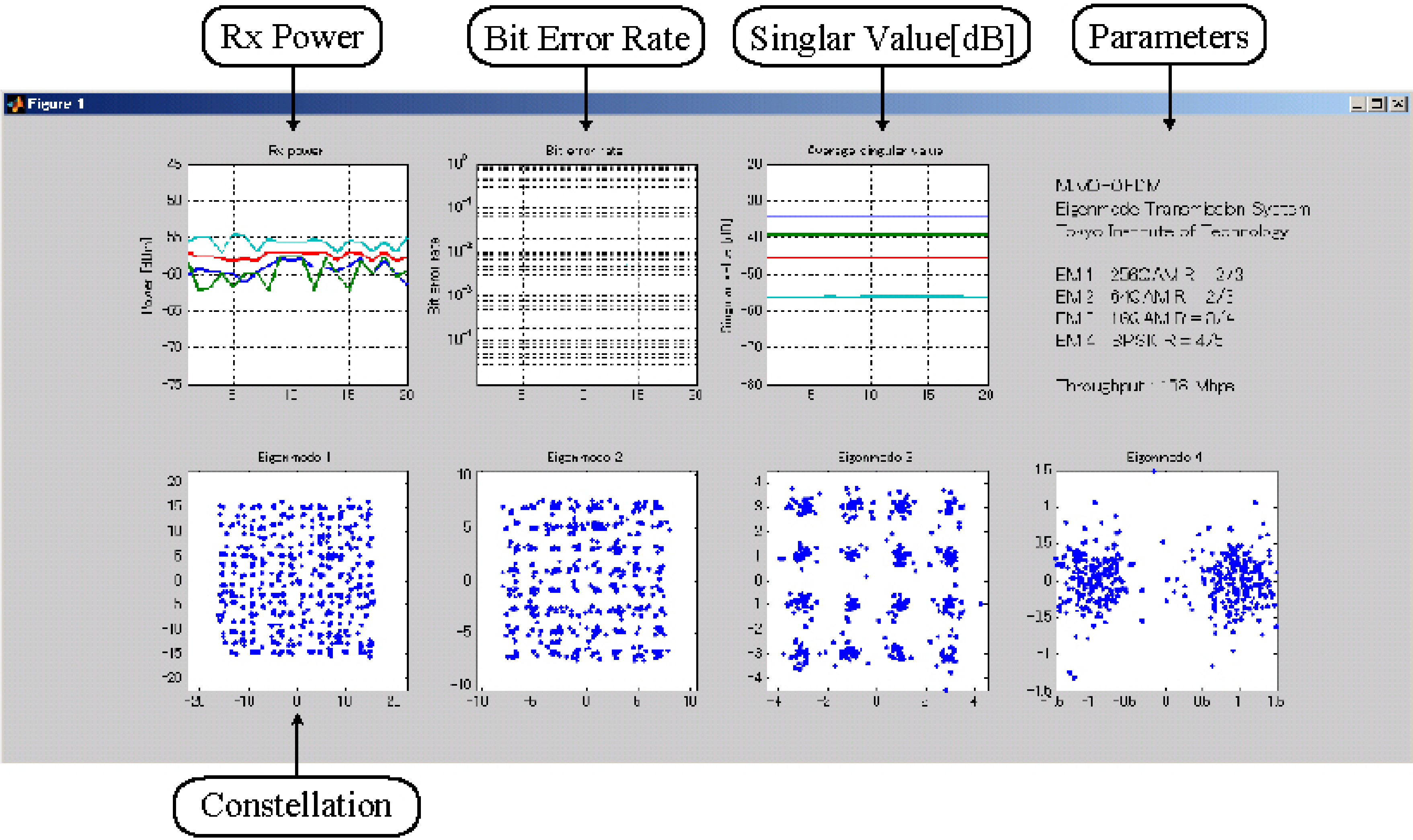
MIMO-OFDM EMTS

- Most of the calculation is conducted in CPU
- Tx weight feedback with LAN
- Feedback delay is about 3 seconds

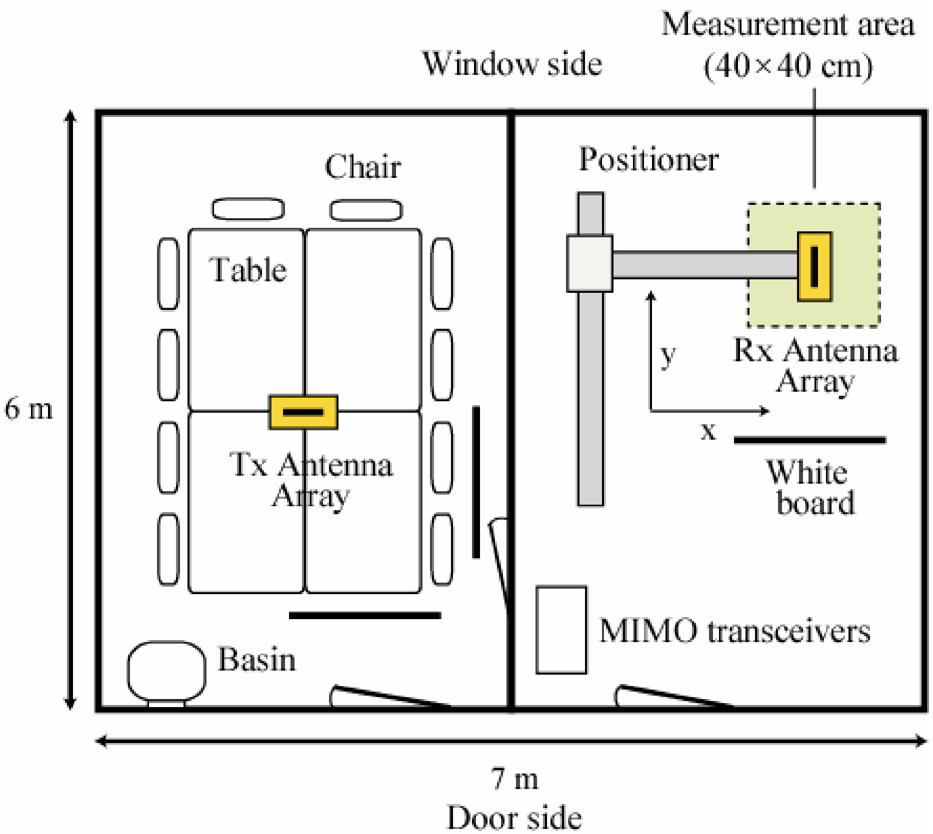


No. of antenna	4 x 4
Antenna specification	λ/2 spacing ULA
Center frequency	5.06 GHz
Bandwidth	20 MHz
FFT point	64 points

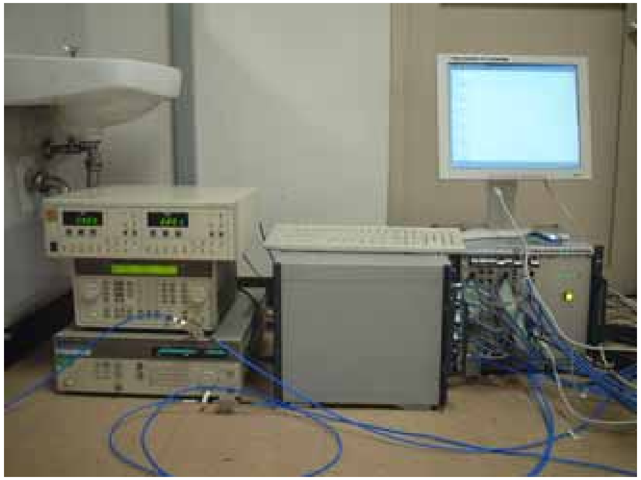
Transmission Result



Measurement Environment



Tx antenna array



Transceivers

- NLOS office environment with furniture
- All doors are closed
- Static condition

Measurement Setup

➢ Channel variation

Time-varying channel

Time correlation

$\boldsymbol{H}_t \Leftrightarrow \boldsymbol{H}_{t+\Delta t}$

→

Static channel

Spatial correlation

$\boldsymbol{H}_d \Leftrightarrow \boldsymbol{H}_{d+\Delta d}$

✓ Feedback delay of 3 seconds
✓ Difficult to regenerate the environment

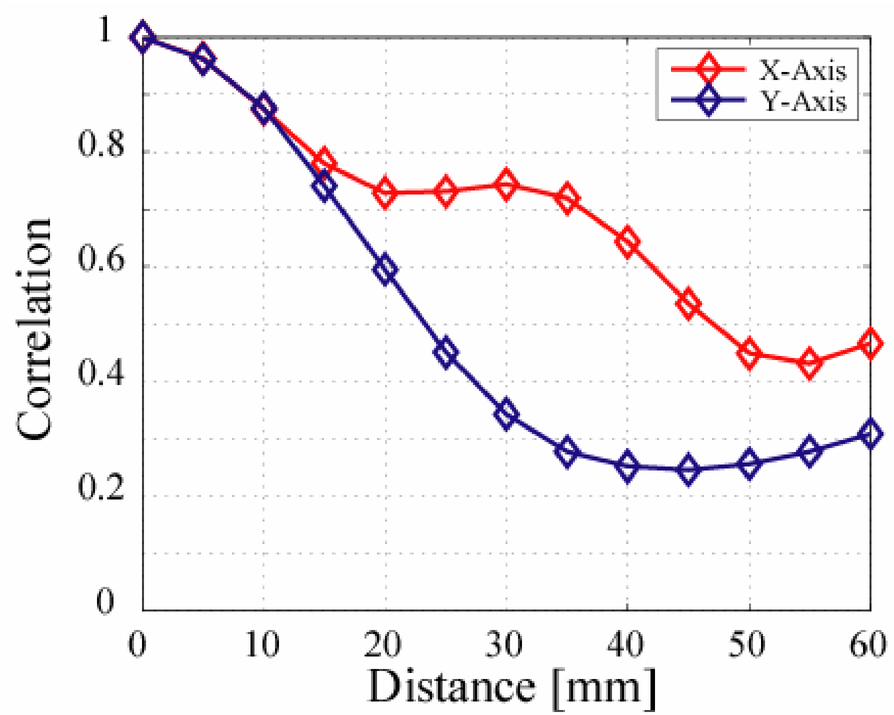
Measurement of the spatial correlation

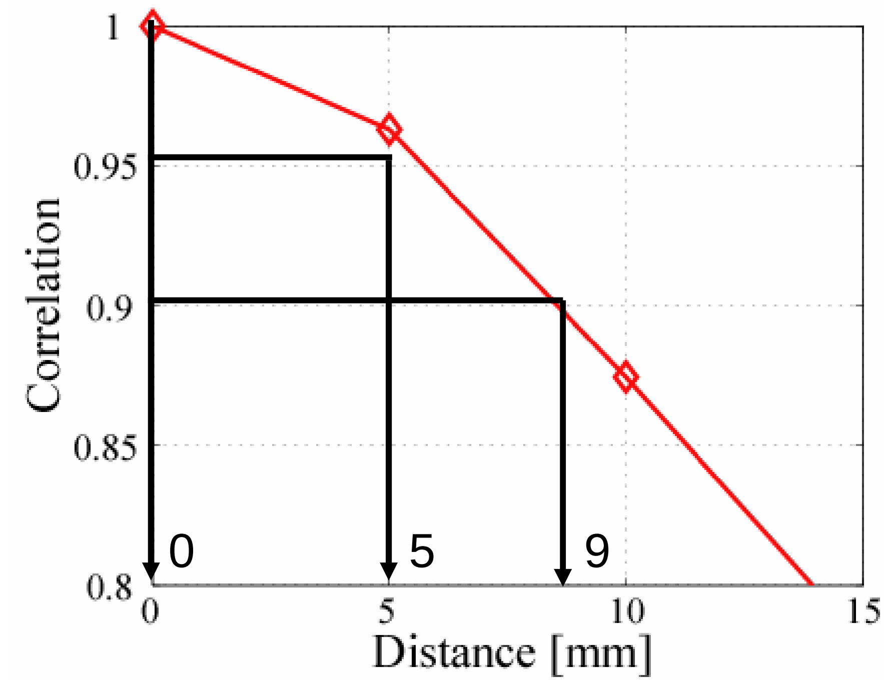
➢ Channel measurement

✓ Same area with the BER measurement
✓ WSS is assumed in the area
✓ Average received SNR for the measurement is about 25 dB

Measurement area	40✕40 cm
Measurement step	5 mm
Training signal	IEEE802.11a base (64OFDM symbols)

Spatial Correlation





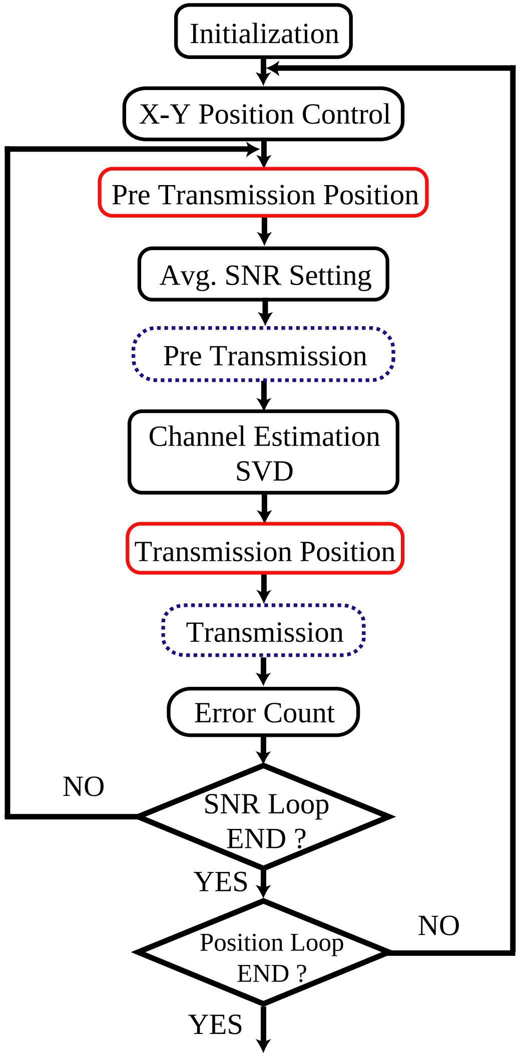
$$\rho = abs\left[\frac{\sum_{i=1}^{position}\sum_{j=1}^{subcarrier}\sum_{k=1}^{mt}\sum_{l=1}^{mr} h_1^{ijkl} h_2^{ijkl*}}{\sqrt{\sum_{i=1}^{position}\sum_{j=1}^{subcarrier}\sum_{k=1}^{mt}\sum_{l=1}^{mr} h_1^{ijkl} h_1^{ijkl*} \sum_{i=1}^{position}\sum_{j=1}^{subcarrier}\sum_{k=1}^{mt}\sum_{l=1}^{mr} h_2^{ijkl} h_2^{ijkl*}}}\right]$$

Correlation	Distance
1	0 mm
0.95	5 mm
0.90	9 mm

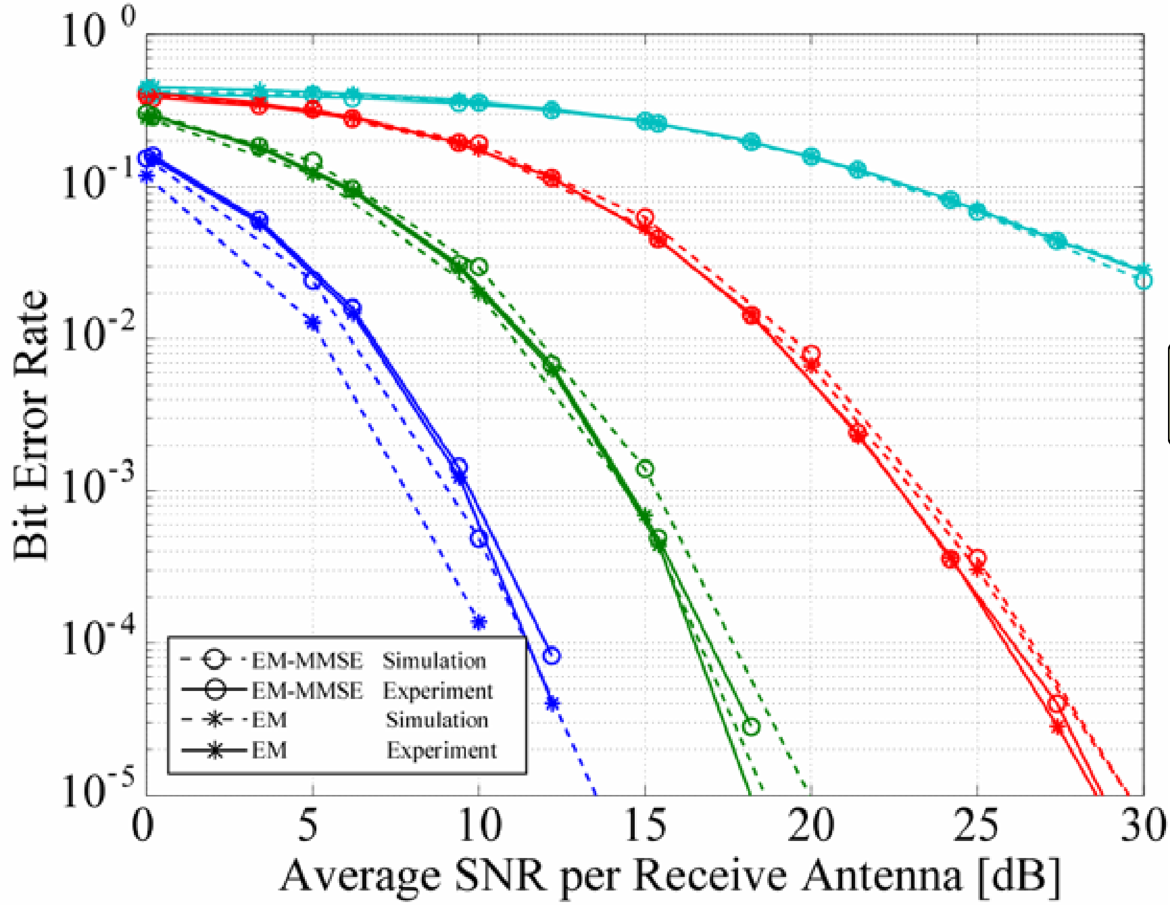
Transmission Experiment

Training signal	IEEE802.11a base (8OFDM symbols)
Modulation	QPSK
FEC	None
Antenna moving distance	0, 5, 9 mm
Measurement area	40 x 40 cm
Measurement step	2 cm
Measurement points	441 Points

- Move Rx antenna to generate channel variation
- 441 points of measurement to average out the effect of the fading
- Range of the SNR is controlled from 0dB to 30dB



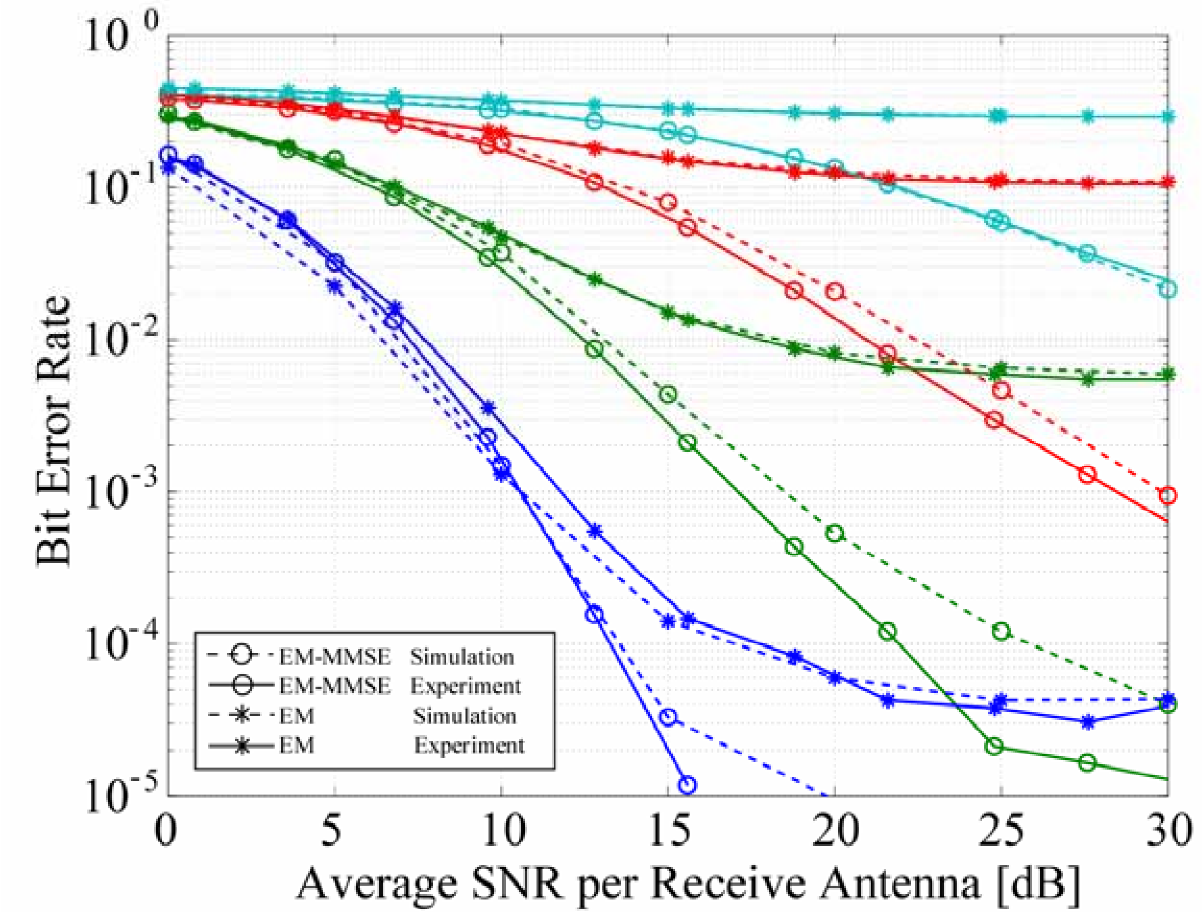
Experimental Result (d = 0 mm)



$\rho = 0.99$

- ➢ Performance w/wo canceller are almost the same
- ➢ Measurement results well agree with simulation

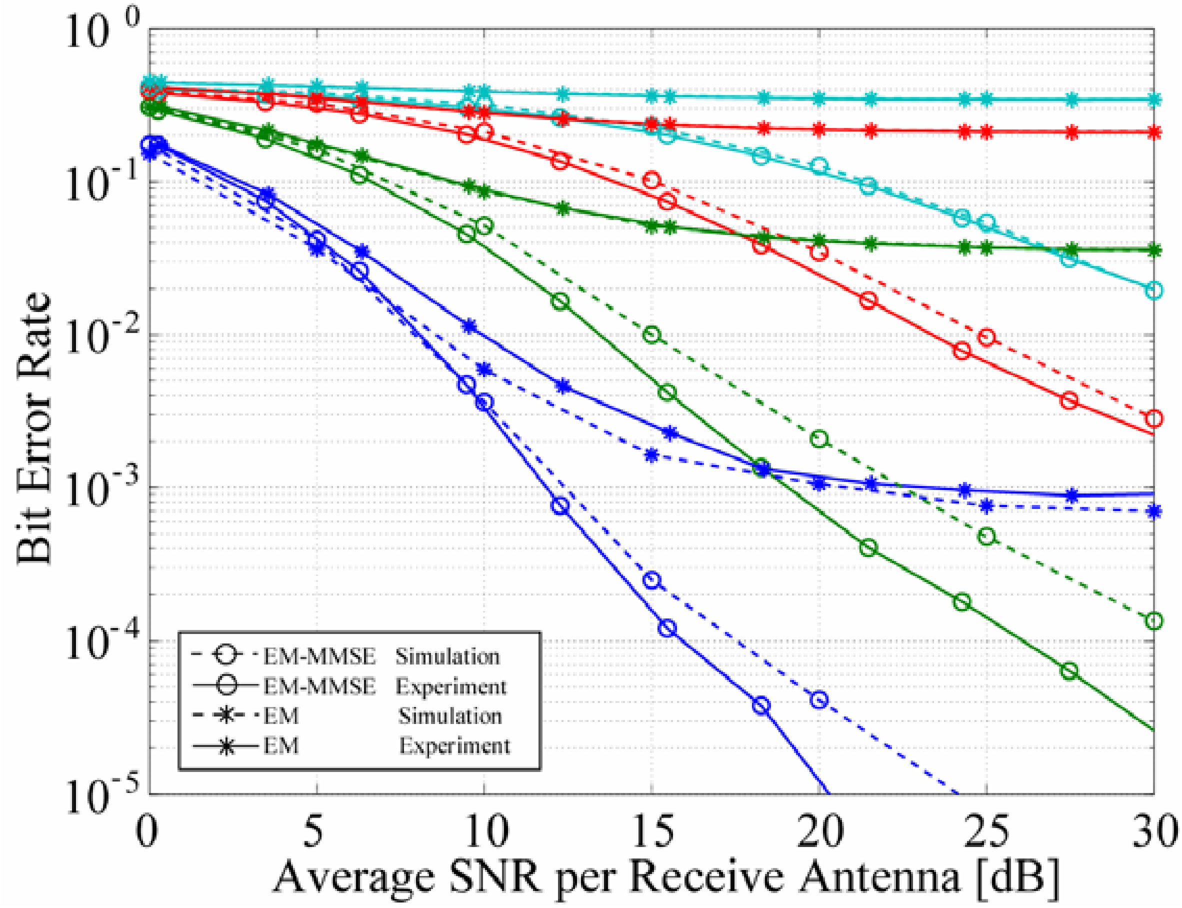
Experimental Result (d = 5mm)



$\rho = 0.95$

➢ Degradation of BER performance w/o canceller

Experimental Result (d = 9mm)



$\rho = 0.89$

➢ Improvement in BER performance with MMSE canceller

Conclusions & Future Works

Conclusions

- Implementation of measurement system of EMTS with channel variation
- Measurement of BER performance for MIMO-OFDM EMTS
- Effect of MMSE interference canceller in the presence of feedback delay

Future works

- Establishment of a theoretical channel model for channel variation
- Comparative analysis with other interference cancellers

Thank you for your attention…