# Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

**Submission Title:** [IG DEP Space-time domain interference mitigation using based on OMF and TDL-AA for dependable UWB-BANs]

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**Abstract:** [As a dependable PHY technology for wireless body area network(WBAN), schemes of Space-time domain interference mitigation using based on OMF and TDL-Array Antenna are introduced.]

**Purpose:** [information]

# Space-Time Domain Interference Mitigation Using OMF and TDL-AA for Dependable UWB Wireless Body Area Networks (UWB-WBANs)

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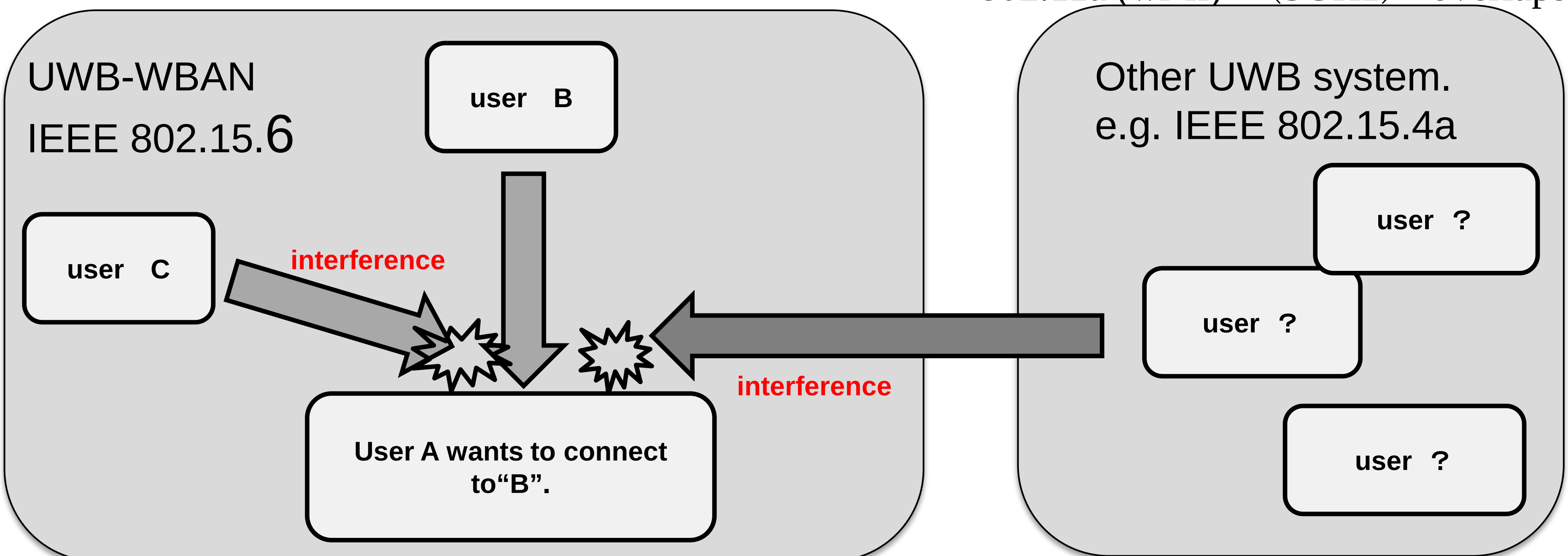
# Issues on multiple BAN environment

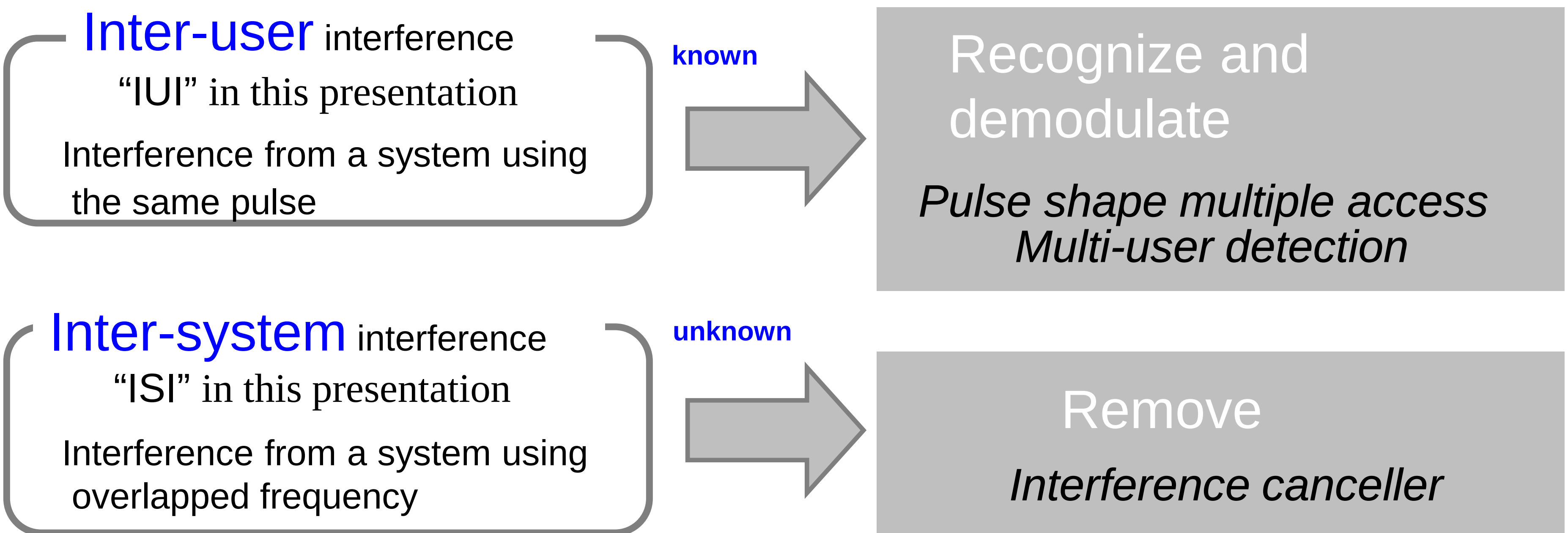
- *Inter-user interference*
  - IR-UWB uses the same pulse as all users signal in the same standard.
  - Other users signal and/or the other network signal would be interference.

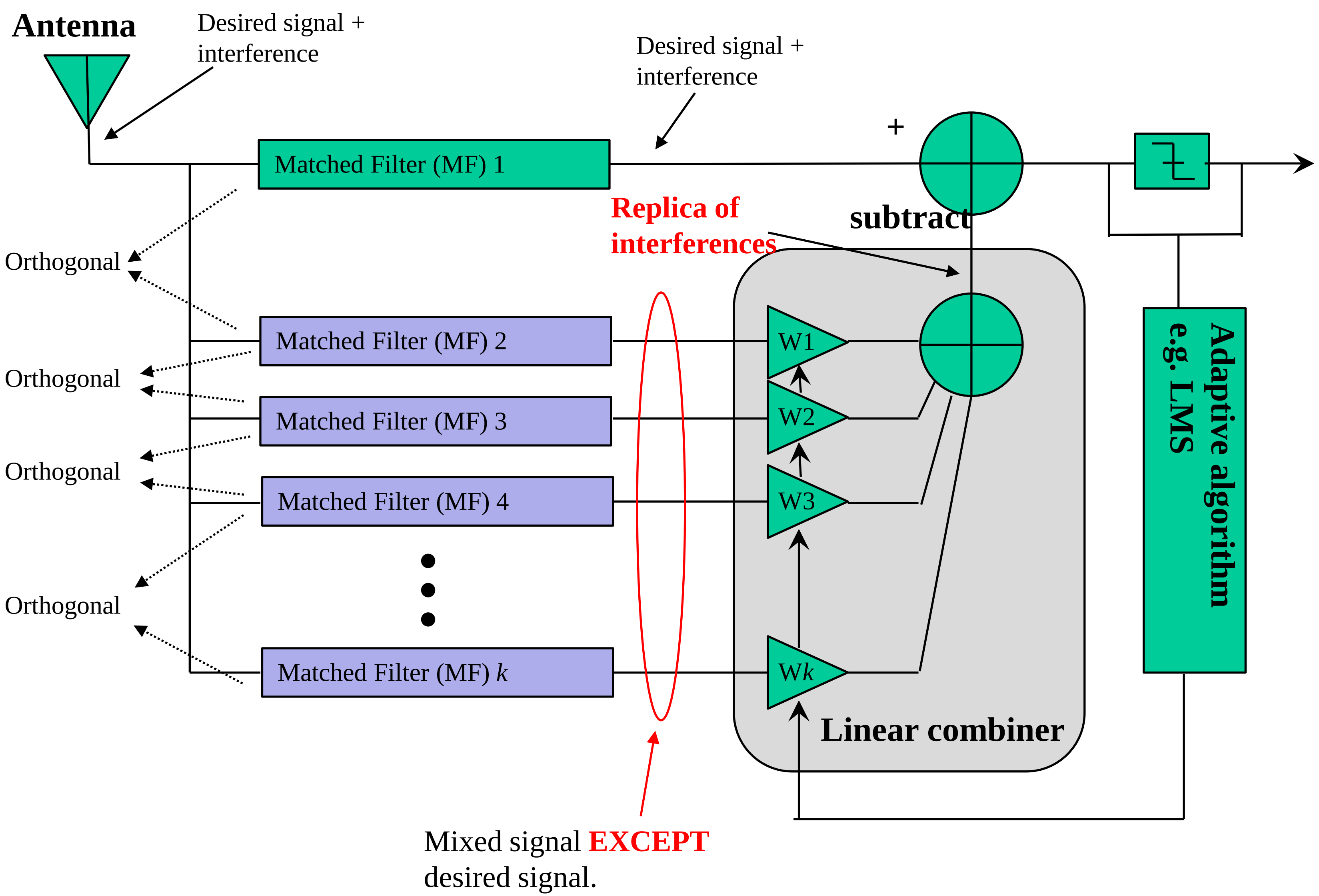
- *Inter-system interference*
  - Interference from the other wreless system using overlapped frequency band. ⇒ Unknown

＊ 802.11a (wi-fi) （5GHz） overlaps



- Purpose and Suggestion
  - **Sparate** and **Recognize** each interference from different source.
    ⇒ Apply suitable interference mitigation method according to source of interference.
  - Using both of Spatial and Temporal signal processing.



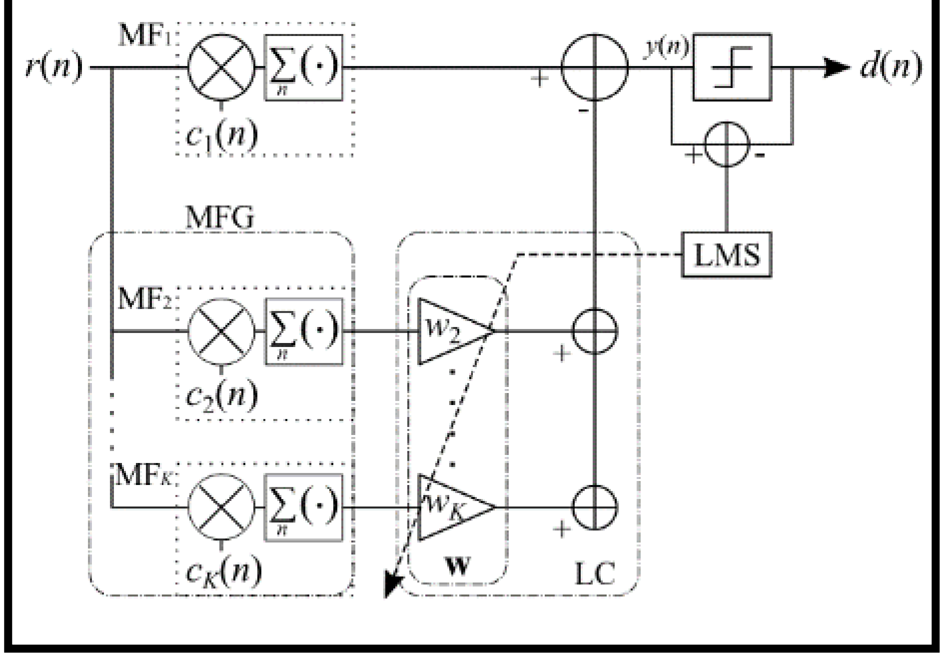


Antenna
Desired signal + interference
Desired signal + interference
+
Matched Filter (MF) 1
Replica of interferences
subtract
Orthogonal
Matched Filter (MF) 2
Orthogonal
Matched Filter (MF) 3
Orthogonal
Matched Filter (MF) 4
Orthogonal
Matched Filter (MF) k
W1
W2
W3
Wk
Linear combiner
Adaptive algorithm e.g. LMS
Mixed signal EXCEPT desired signal.

# OMF； orthogonal matched filter

- consists a matched filter （$MF_1$） and MF Group（MFG）
- Tap coefficients of $MF_1$ are the same as sequence of desired signal.
- Coefficients of $MF_1$ and each $MF_k$ that constituting MFG are orthogonal.
- Desired signal does not through $MF_{2\sim K\text{-}1}$ because orthogonality.
  →only interference can through.
- MFG makes replica of interference signal by lenear combination with weight vector w of linear combiner; LC.
- Subtract interference replica from the output of $MF_1$ .

Principle of OMF

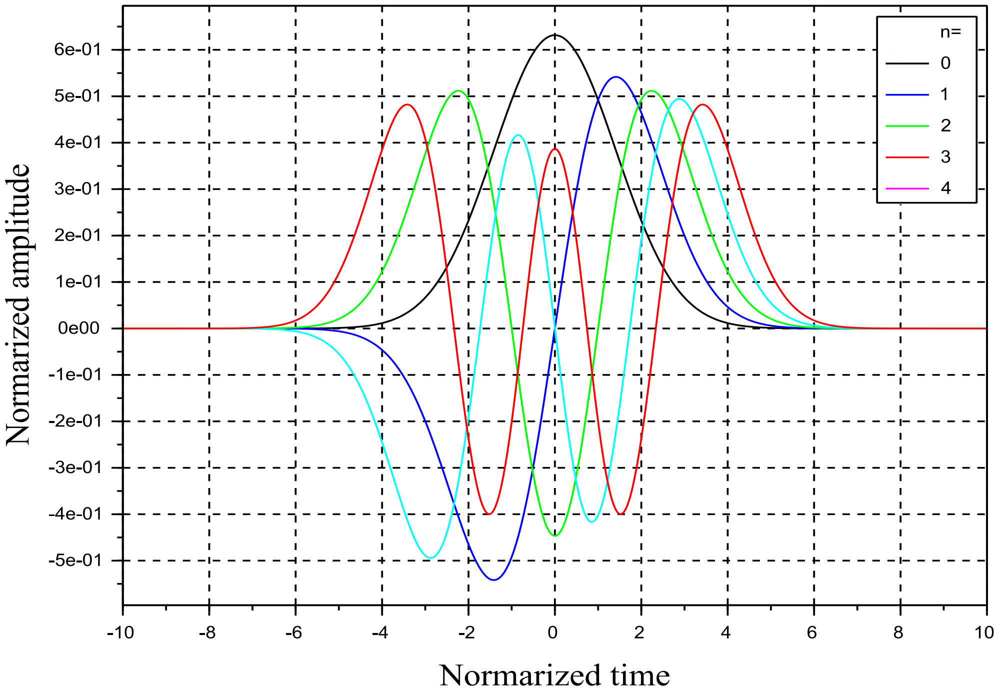



*OMF can remove interference without any pre-knowledge of interference.*

- Modified Hermite pulse; MHP applied to IR-UWB communication (Mohammad Ghavami et al,)

$$h_n = \exp\left(-\frac{(t/t_p)^2}{4}\right)\frac{d^n}{dt^n}\left(\exp\left(-\frac{(t/t_p)^2}{2}\right)\right)$$

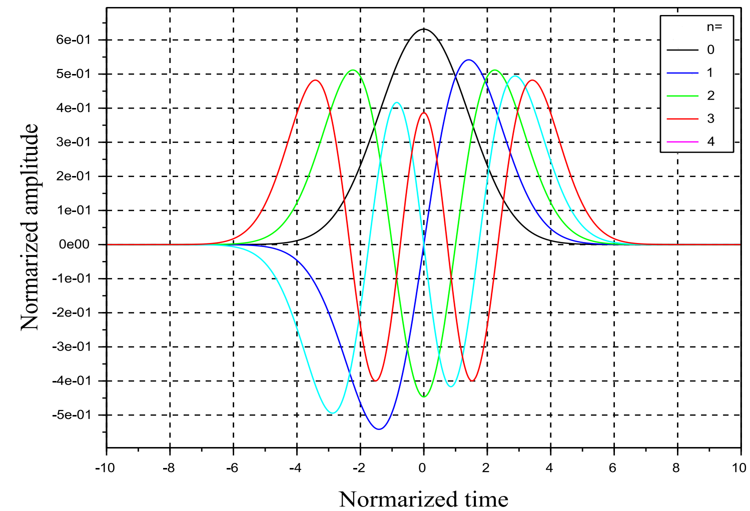
- Pulse function generated by modified Hermitian polynomials.
- Pulses are orthogonal each other in sync. （$t$=0） condition.
- Cross correlation =0. ⇒no interference
- In async. （$t$≠0） condition, not orthogonal.

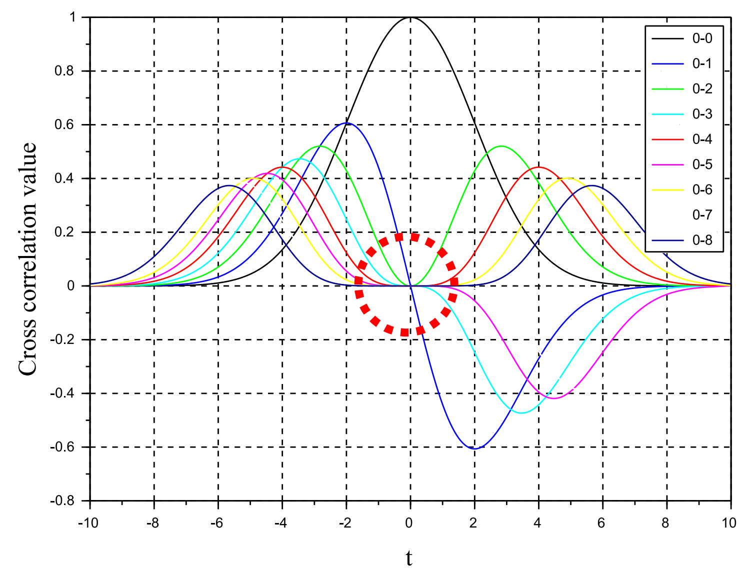


# Orthogonality of MHP

- MHP: Modified Hermite Pulse
- Each user uses unique order MHP as its transmission signal.
- *n*-th order MHP is generated by *n*-th order modified Hermite polynomial.
- In sync.（*t*=0） and no distortion condition, MHPs are orthogonal.
(cross correlation = 0)
- Channel propagation makes it distortion.
⇒NOT orthogonal.

Interference canceller



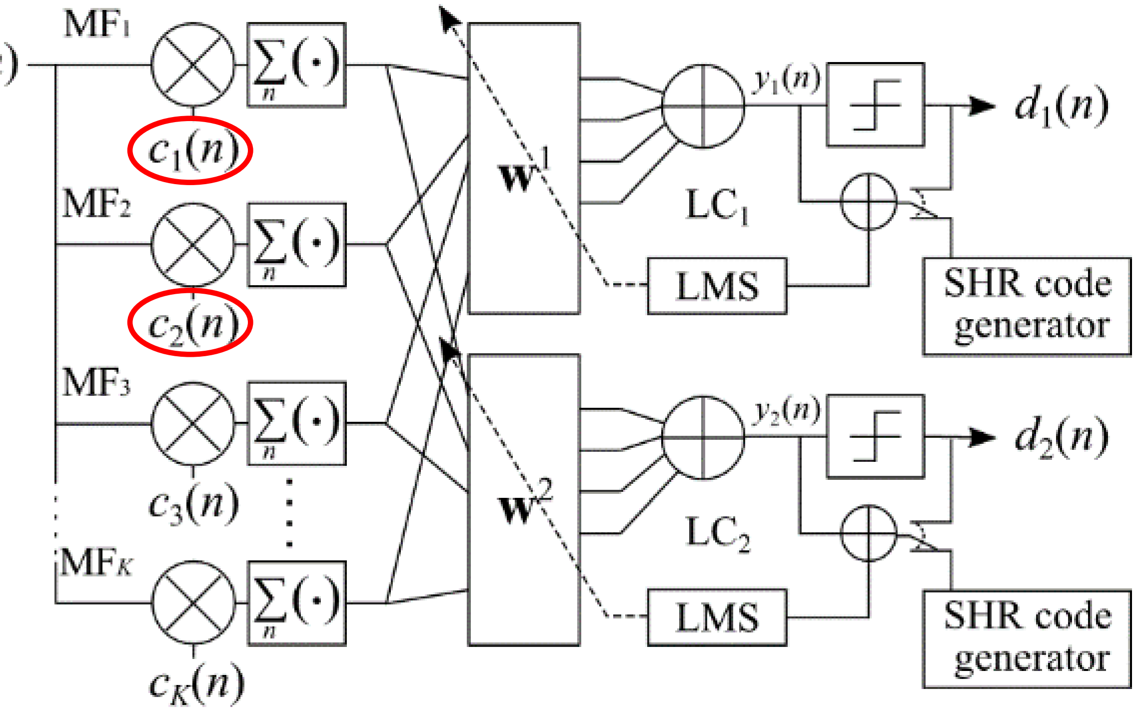
# • Proposed OMF with Multi-user detection

- As MF and MFG of OMF,
  - Use discrete sampled MHP.
  - Gramm-Schmidt orthonormalization is used for fill deficit in MFG.
- By utilizing the MHP as a MFG…
  - Known user's signal which uses same MHP as MFG can be retrieved.

    *MUD*

  - Unknown interference can be cancelled

    *ISI mitigation*




Proposed system for 2 users detection.

*MUD and ISI mitigation*

Works at the same time

# • System model and theoretical analysis.

◆ Rx signal

$$r(n) = \sum_{u=1}^{U} a_u(n) b_u g_u,$$

$b_u(n)$ $u$-th user's data

$g_u(n)$ amplitude

$a_u$ sampled pulse shape

$U$ total user's number

In vector form

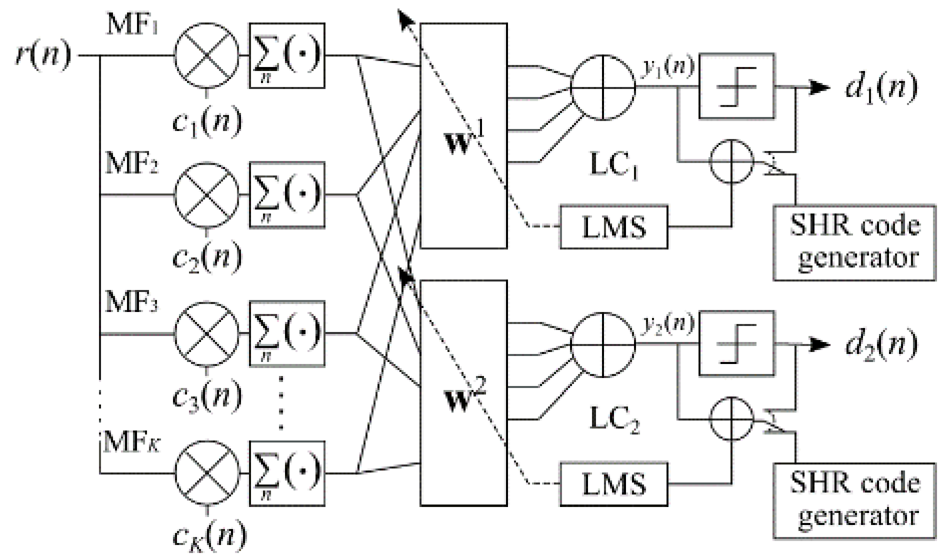
$$\mathbf{a}_u = [a_u(1), a_u(2), \cdots, a_u(N)]^{\mathrm{T}},$$

$$\mathbf{c}_k = [c_k(1), c_k(2), \cdots, c_k(N)]^{\mathrm{T}},$$

$$\mathbf{r} = [r(1), r(2), \cdots, r(N)]^{\mathrm{T}}.$$

$\mathbf{c}_k$ $k$-th orthogonal vector

$\mathbf{a}_1 = \mathbf{c}_1$ is desired user's pulse




$\mathrm{MF}_k$ $(k = 1, 2)$ output included in $\mathrm{LC}_k$

$$w_k^k \mathbf{r}^{\mathrm{T}} \mathbf{c}_k = w_k^k \sum_{u=1}^{U} \mathbf{a}_u^{\mathrm{T}} \mathbf{c}_k b_u g_u.$$

- System model and theoretical analysis

Desired signal is assumed as $a_1$ $w_1^1 = 1$

$k = 1$; $\mathrm{MF}_1$

$$\mathbf{r}^{\mathrm{T}}\mathbf{c}_1 = \mathbf{a}_1^{\mathrm{T}}\mathbf{a}_1 b_1 g_1 + \sum_{u=2}^{U} \mathbf{a}_u^{\mathrm{T}}\mathbf{a}_1 b_u g_u$$

Desired signal

$$= b_1 g_1 + \sum_{u=2}^{U} b_u g_u \mathbf{a}_u^{\mathrm{T}}\mathbf{a}_1,$$

Interference

$b_u(n)$ $u$-th user's data

$g_u(n)$ amplitude

$a_u$ sampled pulse shape

$U$ total user's number

$\mathbf{c}_k$ $k$-th orthogonal vector

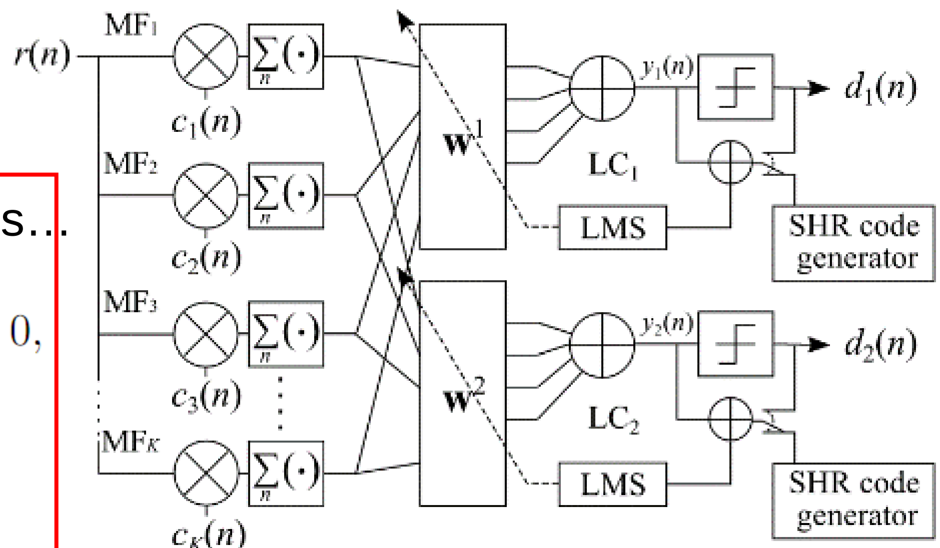
$\mathbf{a}_1 = \mathbf{c}_1$ is desired user's pulse

$$\mathbf{a}_1^{\mathrm{T}}\mathbf{a}_1 = 1$$

$$\mathbf{a}_1^{\mathrm{T}}\mathbf{c}_{k\neq 1} = 0$$

$\mathrm{MF}_{k\neq 1}$ signal included in $\mathrm{LC}_1$

$$\sum_{k=2}^{K} \mathbf{c}_k^{\mathrm{T}}\mathbf{r}w_k^1 = \sum_{u=2}^{U} b_u g_u \sum_{k=2}^{K} w_k^1 \mathbf{c}_k^{\mathrm{T}}\mathbf{a}_u.$$




Interference is cancelled in condition satisfies…

$$\sum_{u=2}^{U} b_u g_u \mathbf{a}_u^{\mathrm{T}}\mathbf{a}_1 + \sum_{u=2}^{U} b_u g_u \sum_{k=2}^{K} w_k^1 \mathbf{c}_k^{\mathrm{T}}\mathbf{a}_u = 0,$$

$$\Rightarrow \mathbf{a}_u^{\mathrm{T}}\mathbf{a}_1 = -\sum_{k=2}^{K} w_k^1 \mathbf{c}_k^{\mathrm{T}}\mathbf{a}_u.$$

- System model and theoretical analysis

$b_u(n)$ $u$-th user's data
$g_u(n)$ amplitude
$a_u$ sampled pulse shape
$U$ total user's number
$\mathbf{c}_k$ $k$-th orthogonal vector
$\mathbf{a}_1 = \mathbf{c}_1$ is desired user's pulse

$$\mathbf{a}_1^{\mathrm{T}}\mathbf{a}_1 = 1$$
$$\mathbf{a}_1^{\mathrm{T}}\mathbf{c}_{k\neq 1} = 0$$

Interference is cancelled in condition satisfies…

$$\sum_{u=2}^{U} b_u g_u \mathbf{a}_u^{\mathrm{T}}\mathbf{a}_1 + \sum_{u=2}^{U} b_u g_u \sum_{k=2}^{K} w_k^1 \mathbf{c}_k^{\mathrm{T}}\mathbf{a}_u = 0,$$
$$\Rightarrow \mathbf{a}_u^{\mathrm{T}}\mathbf{a}_1 = -\sum_{k=2}^{K} w_k^1 \mathbf{c}_k^{\mathrm{T}}\mathbf{a}_u.$$

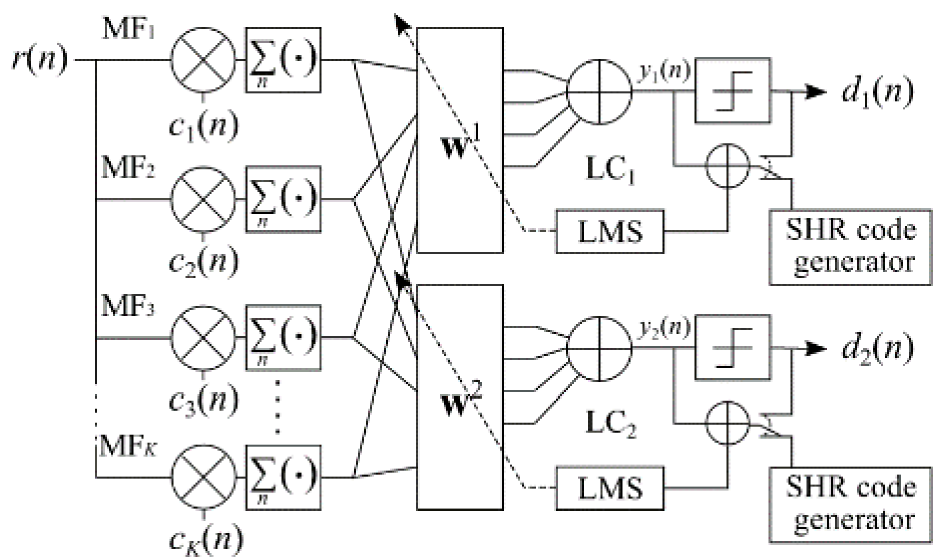
In matrix

$$\begin{pmatrix} \mathbf{a}_2^{\mathrm{T}}\mathbf{a}_1 \\ \vdots \\ \mathbf{a}_U^{\mathrm{T}}\mathbf{a}_1 \end{pmatrix} = -\begin{pmatrix} \mathbf{a}_2^{\mathrm{T}}\mathbf{c}_2 & \dots & \mathbf{a}_2^{\mathrm{T}}\mathbf{c}_K \\ \vdots & \ddots & \vdots \\ \mathbf{a}_U^{\mathrm{T}}\mathbf{c}_2 & \dots & \mathbf{a}_U^{\mathrm{T}}\mathbf{c}_K \end{pmatrix} \begin{pmatrix} w_2^1 \\ \vdots \\ w_K^1 \end{pmatrix}$$
$$\mathbf{A} = -\mathbf{B} \quad \mathbf{w}_{\mathrm{opt}}^1.$$

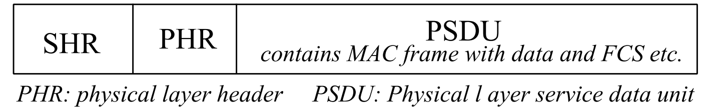
$$\mathbf{w}_{\mathrm{opt}}^1 = -\mathbf{B}^{-1}\mathbf{A}.$$

Optimum weight vector

*without noise

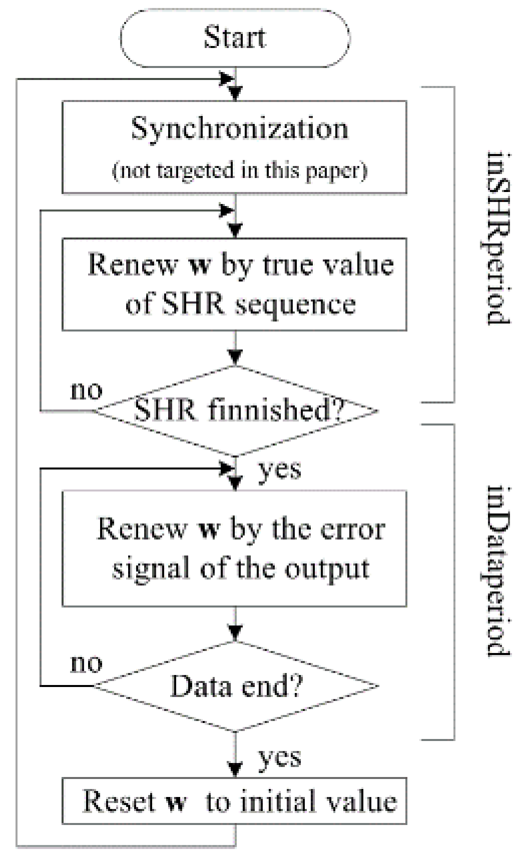


- Numerical evaluation
  - Assumed MHP-UWB which uses MHP as transmission pulse.
  - Each user uses unique order MHP as a transmission pulse.
  - MAC frame has generally known synchronization header (SHR) preamble on its head.
    → Adaptive algorithm estimates an optimum solution by using this known preamble.
  - IUI and ISI exist.

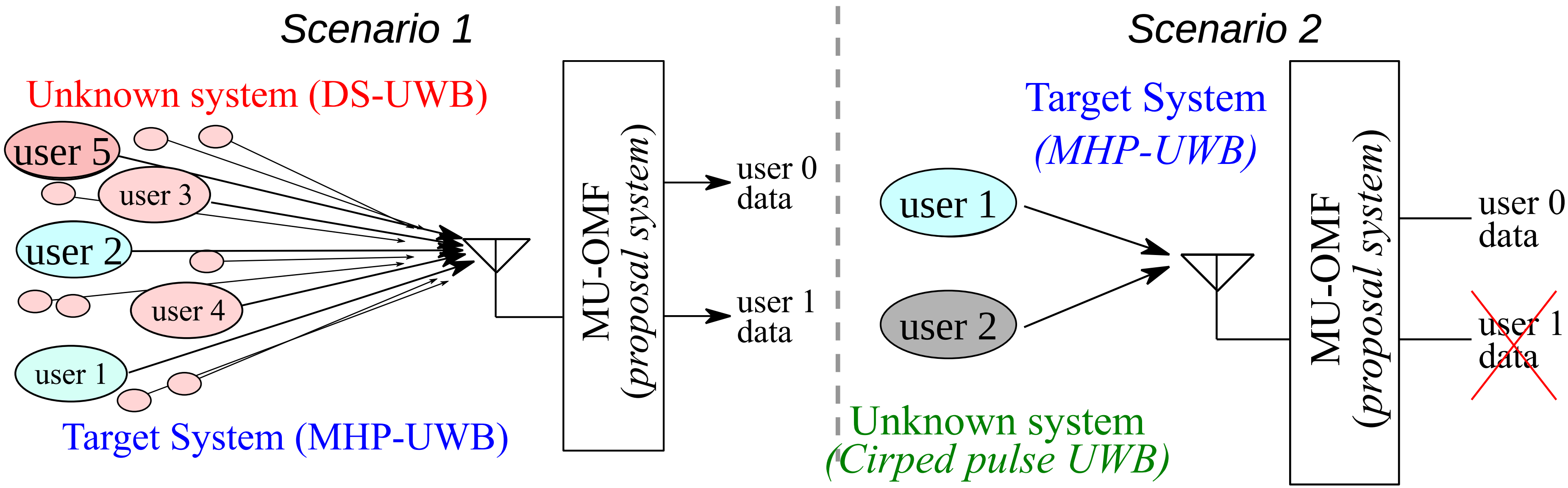



**(a)** IEEE 802.15.6 UWB PHY frame format.


**(b)** Simplified frame structure supposed in this paper.

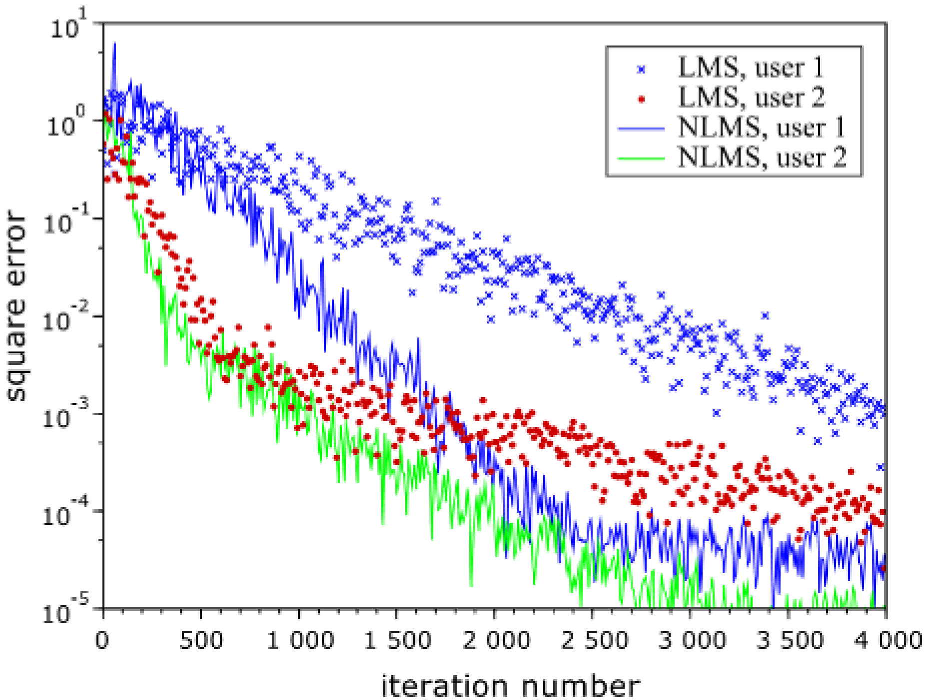


- MUD and ISI canceller – Numerical evaluation.



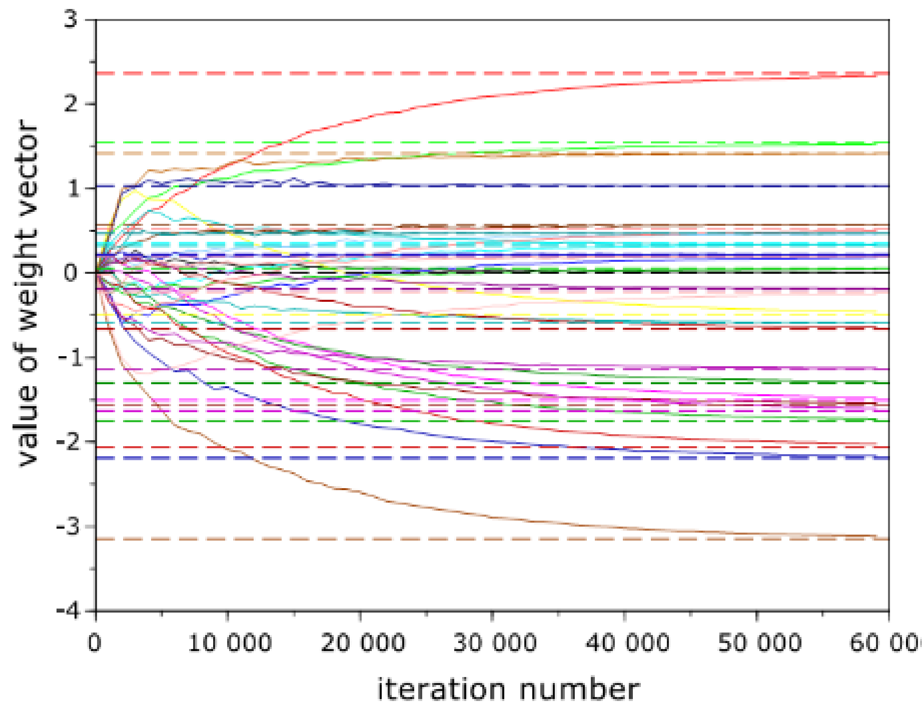

| | | |
|---|---|---|
| DIR [dB] | -40 to +40 | |
| Known user | 2 (0th and 3rd MHP) | 1 (0th MHP) |
| Unknown interference | Gold sequence DS-UWB, 29 users | Chirped pulse UWB, 1user |
| Channel (dist. / noise) | IEEE 802.15.6 CM3 path loss model + AWGN | |
| Iteration for LMS / NLMS | 2,000 ~ 32,000 / 4,000 ~ 64,000 | 250 ~ 3,000 / 80 ~ 1280 |

# Results of *SC.1*




*Square error (SC.1).*

$E_b/N_0$=+60dB, DIR=0dB




Weight coefficients *(SC.1)* $E_b/N_0$=+60dB, DIR=0dB.

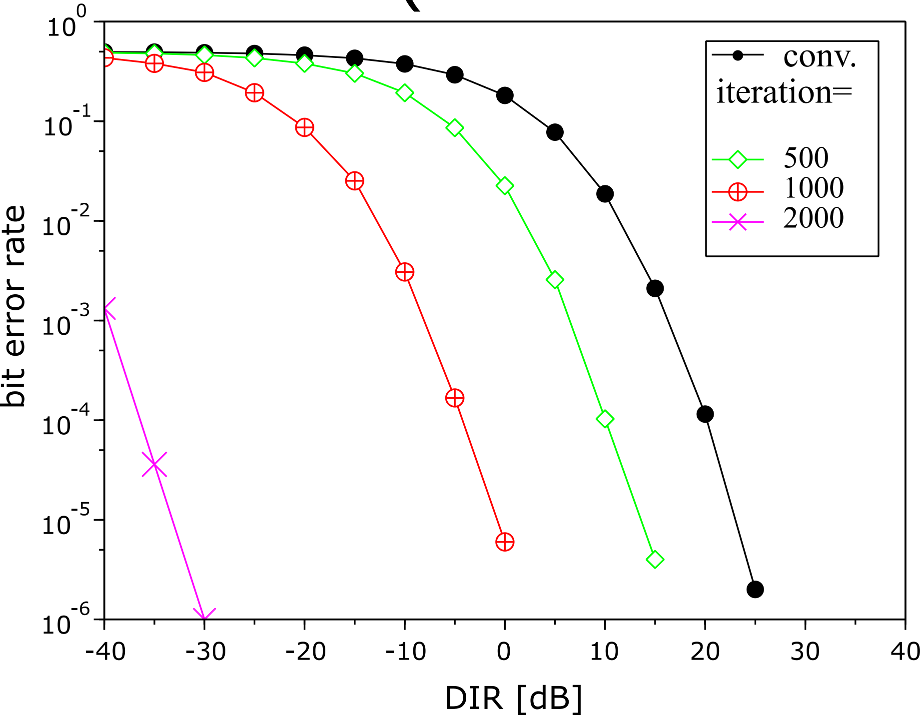
LMS & NLMS algorithm towards to minimum square error.

Multiple user's signal retrieved with interference reduction.

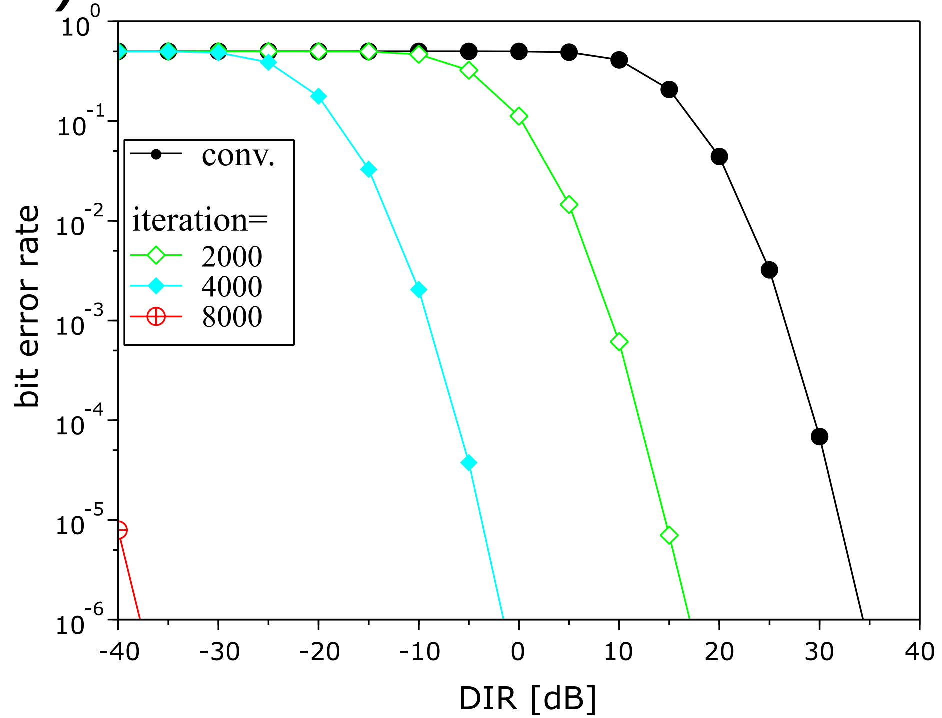
Weight coefficients converge to optimum solution $w_{opt}$.

Adaptive algorithm makes approx. solution.

# Results (noise free channel)



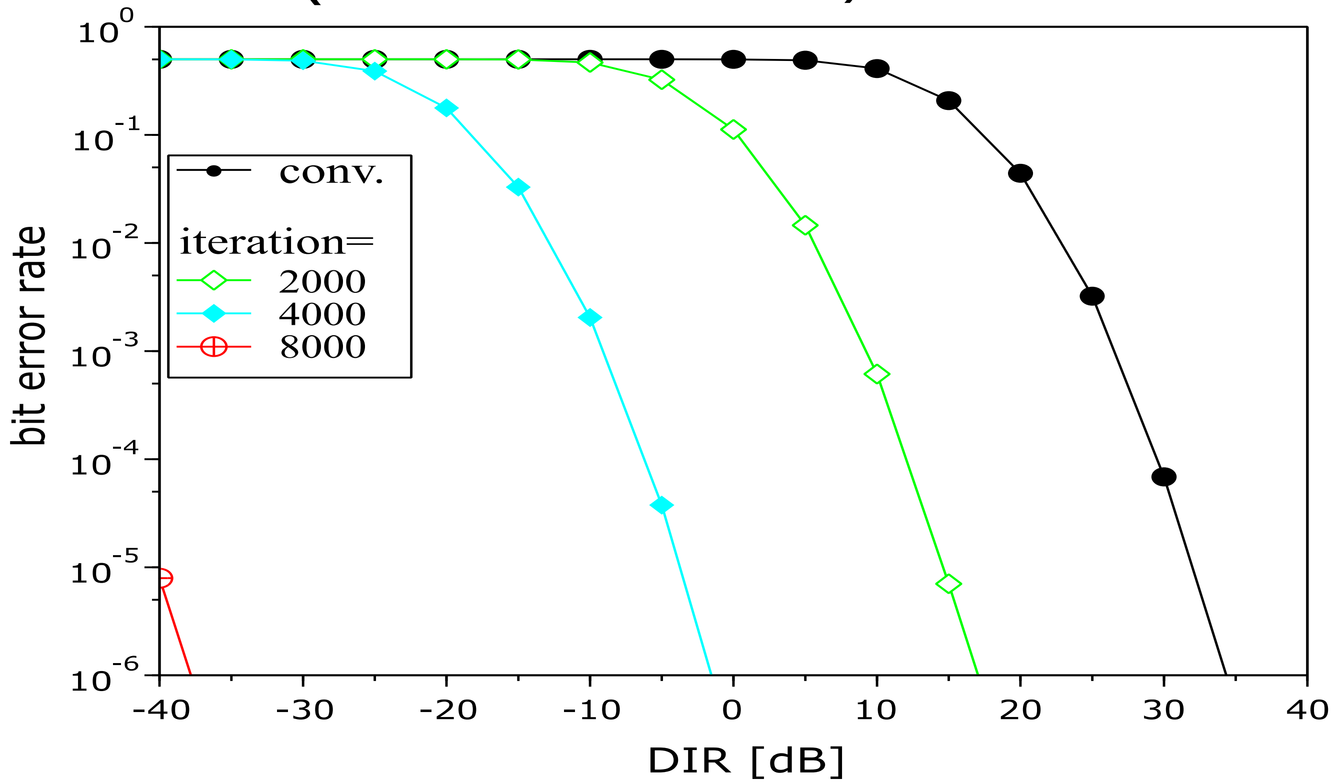

DIR vs. BER *(SC.1)* $E_b/N_0=+\infty$dB.




DIR vs. BER *(SC.2)* $E_b/N_0=+\infty$dB.

More iteration number makes higer capacity of interference reduction

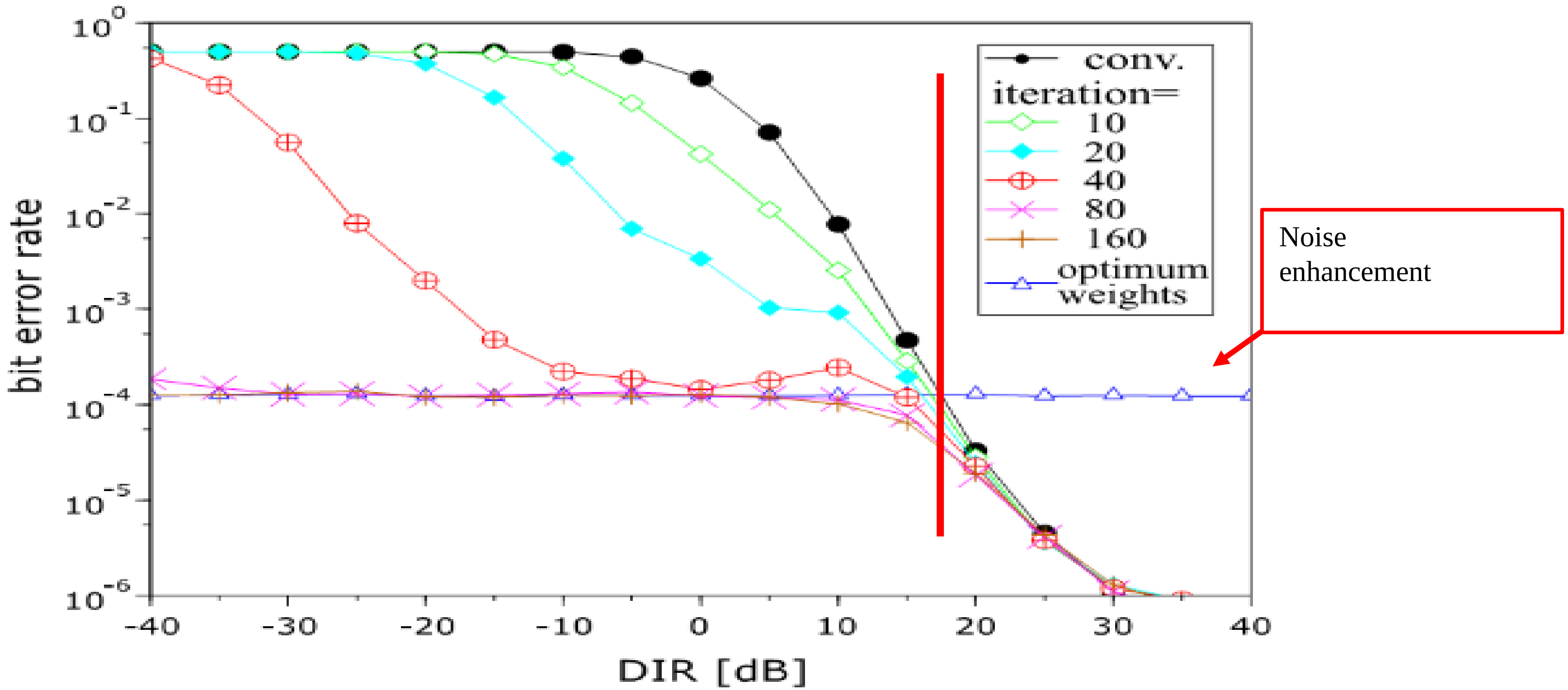
# Simulation results (noise free channel)




DIR vs. BER $E_b/N_0=+\infty$dB.

More iteration number makes higer capacity of interference reduction

# Simulation results (noise & interference channel)

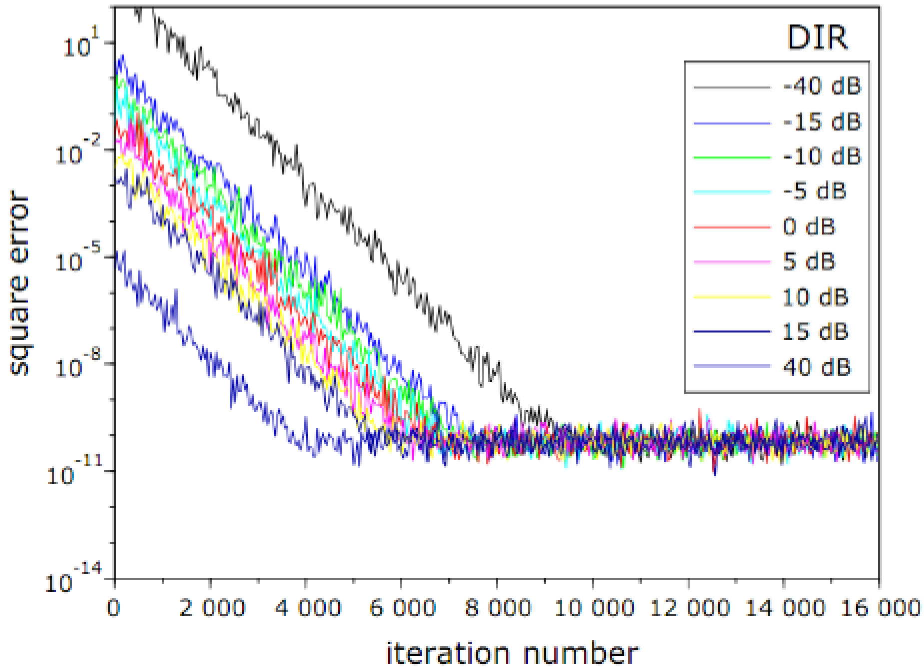



DIR vs. BER *(SC.2)* $E_b/N_0$=+25dB.

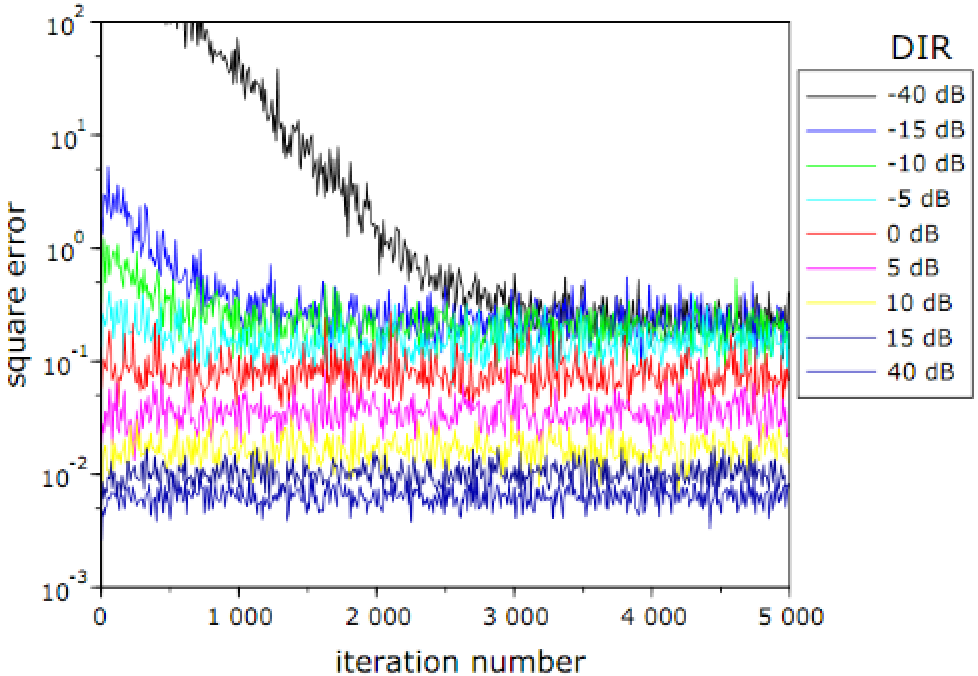
$W_{opt}$ which is generated by theory does not satisfies minimum error In high DIR condition. ⇒ $W_{opt}$ is not optimal solution in environment in which noise exists.

High DIR ➔ dominant cause of bit error is noise

# ◆ Results of *SC.1*




Square error characteristics in various DIR*(SC.1)*.
$E_b/N_0$=+120dB, DIR=-40dB ~ +40dB




Square error characteristics in various DIR *(SC.1)*.
$E_b/N_0$=+25dB, DIR=-40dB ~ +40dB

Adaptive algorithm does not find an optimum weights in low DIR and low $E_b/N_0$. ⇒ ⇒ ⇒ Theoretical analysis with Noise

- Theoretical analysis

$\mathbf{w}' = \Delta \mathbf{w}_{opt}$ Size reduction of weight vector by a coefficient $\Delta$

$$E_{mul}{}^{2} = \left[ \mathbf{a}_1^T \mathbf{n} + \sum_{k=2}^{K} \sum_{u=2}^{U} \mathbf{c}_k^T \mathbf{a}_u b_u g_u \left\{ -w_{opt,k}(1-\Delta) \right\} + \sum_{k=2}^{K} \mathbf{c}_k^T \mathbf{n}\, w_{opt,k} + \sum_{k=2}^{K} \mathbf{c}_k^T \mathbf{n} \left\{ -w_{opt,k}(1-\Delta) \right\} \right]^2$$

noise — Residual interference — Enhanced noise — Suppression of noise enhancement by $\Delta$

$$= \sum_{k=2}^{K} \mathbf{c}_k^T \mathbf{n} \left\{ w_{opt,k} - w_{opt,k}(1-\Delta) \right\}$$

$$= \sum_{k=2}^{K} \mathbf{c}_k^T \mathbf{n} \left( \Delta w_{opt,k} \right)$$

When $W \neq W_{opt}$ , interference remains.

*Δ becomes smaller*

⇒*residual interference is increased* ⇒*noise enhancement is suppressed*

Adaptive algorithm try to find MMSE "as smaller as possible ⇒ not optimum

Analyze a theoretical solution which satisfies MMSE criteria

# Smaller Δ makes

⇒*residual interference is increased*

⇒*noise enhancement is suppressed*

$\mathbf{w}' = \Delta \mathbf{w}_{opt}$ Wopt is shrinked by $\Delta \leqq 1$.

*optimum solution* $= \Delta_{opt} \mathbf{w}_{opt}$

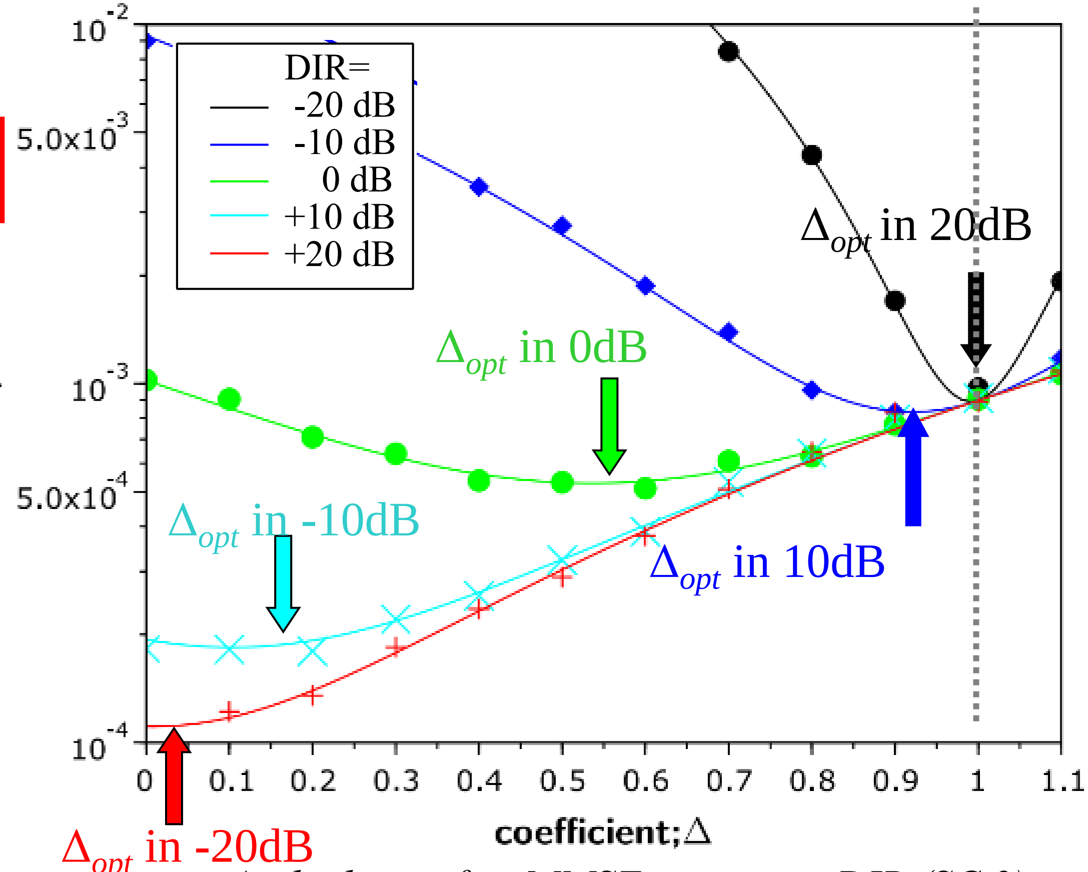
$$\Delta_{opt} = \underset{0 \leq \Delta \leq 1}{\arg\min} f(\Delta)$$

$$f(\Delta) = E_{mul}^2$$

$\Delta_{opt}$ depends on power of interference and noise

Adaptive algoeithm cannot find $\Delta opt$ but it can find approximate solution.

$$\Delta_{opt} = \frac{\sum_{u=2}^{U} \left(\vec{a}_1^{\mathrm{T}} \vec{a}_u\right)^2 G_I^2}{\sigma_{in}^2 \|\vec{\hat{w}}\|^2 + \sum_{u=2}^{U} \left(\vec{a}_1^{\mathrm{T}} \vec{a}_u\right)^2 G_I^2}$$




*Δ which satisfies MMSE in various DIR (SC.2)*

$E_b/N_0$=+25dB.

- Theoretical performance

$$\mathbf{w}' = \Delta \mathbf{w}_{opt}$$

Size reduction of weight vector by a coefficient Δ

## Smaller Δ

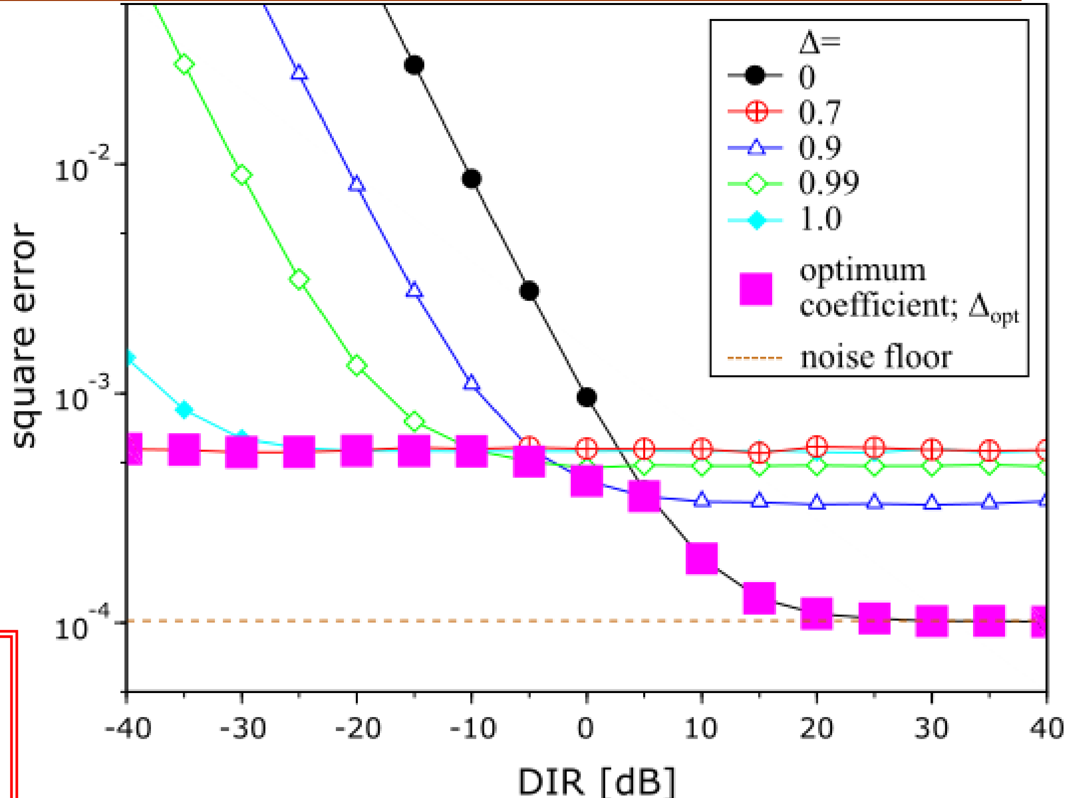
⇒*residual interference is increased*

⇒*noise enhancement is suppressed*

## Larger Δ

⇒*residual interference is suppressed*

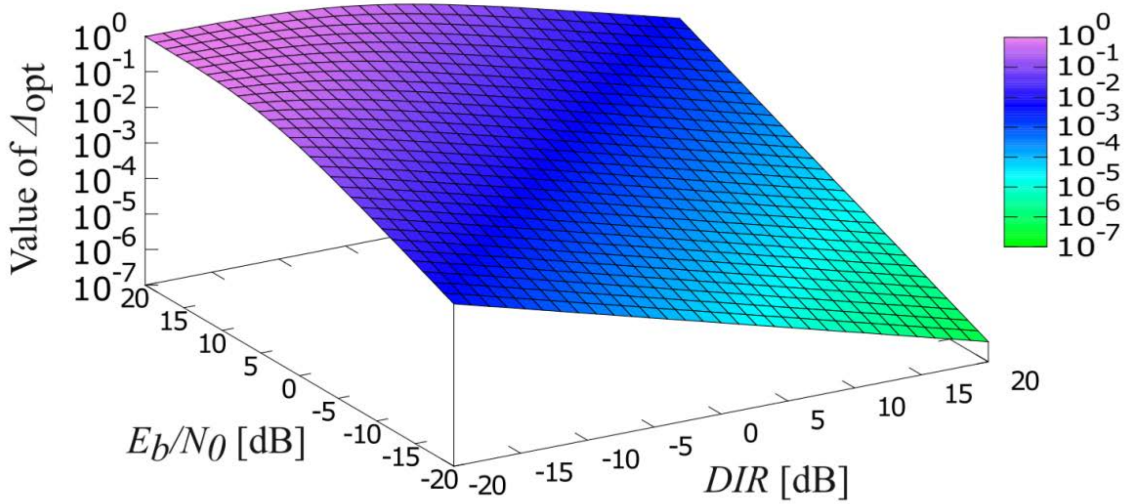
⇒*noise enhancement is increased*




Square error using various fixed Δ and $\Delta_{opt}$ in each DIR *(SC.2)* $E_b/N_0$=+25dB.

Optimum solution

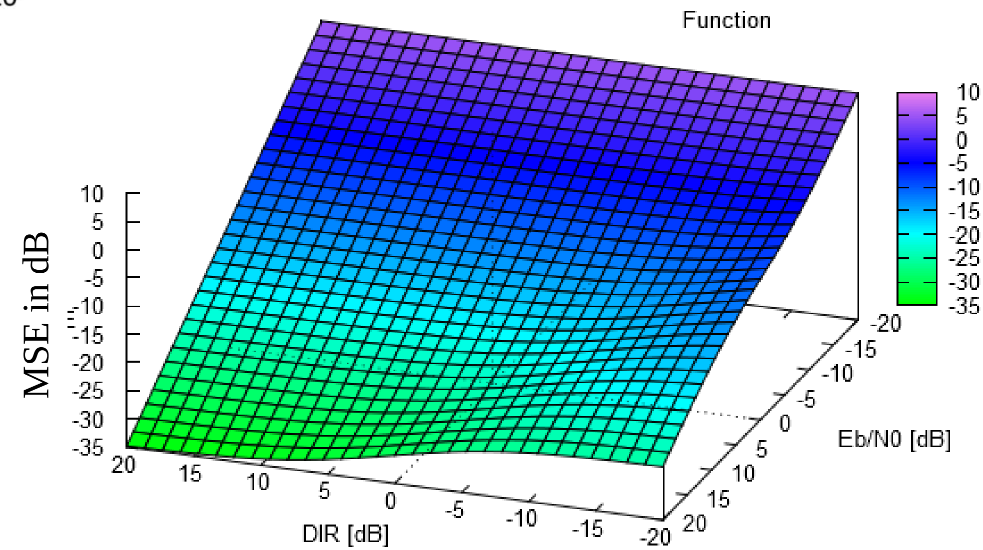
$$optimum\ solution = \Delta_{opt}\mathbf{w}_{opt}$$




In High DIR and Low Eb/N0 channel, $\Delta_{opt}$ becomes close to 0 (zero).

In Low DIR and High Eb/N0 channel, $\Delta_{opt}$ becomes close to 1 (one).

$\Delta_{opt}$ value in each Eb/N0 and DIR conditions




Optimal solution $\Delta_{opt}w_{opt}$ provides a performance limit of our proposing system.

Although our system cannot remove noise, MSE can be reduced in low noise situation.

MSE in optimum slution $\Delta_{opt}\mathbf{w}_{opt}$

# Space-time domain interference mitigation using TDL array antenna for MHP based IR-UWB

*(2) Space Temporal Interference Cancellation Using TDL Array Antenna and Waveform Based OMF for IR-UWB Systems*

## 4.1 Proposed system model and theoretical analysis

## 4.2 Numerical evaluation and results

# TDL-AA；Tapped delay line array antenna

- Array antenna by using multiple antenna elements and tapped delay line.
- Each antenna branch has coefficients.
- Transfer function of this antenna has parameters of signal incoming angle;$\theta$ and frequency; $\omega$.

⇒has characteristics of both of spatial and time domain.

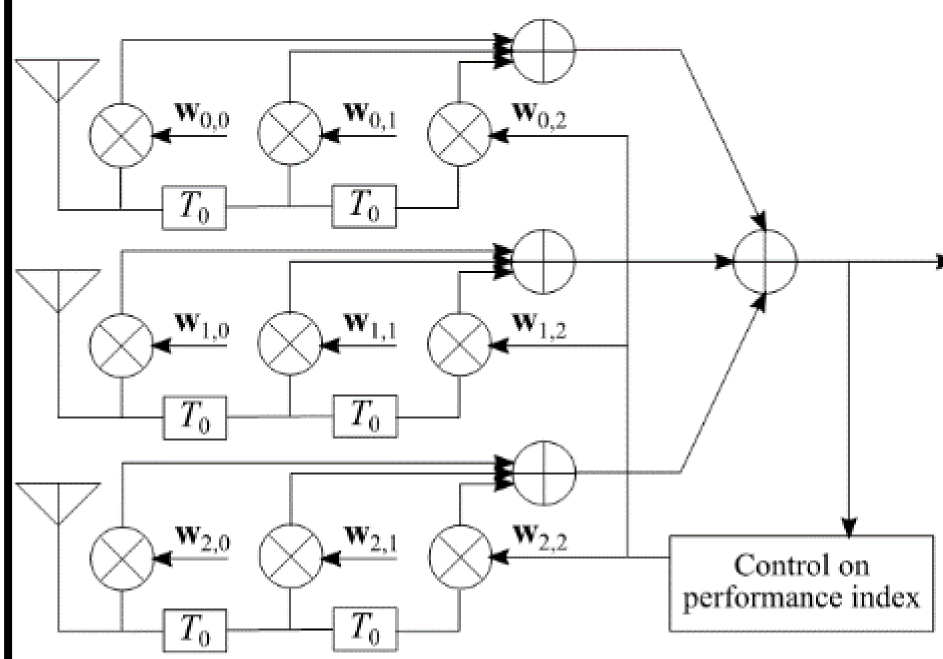
$$\tau_n = n\frac{d}{c}\sin\theta,$$

$$y(t) = \exp(j\omega t)\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}\exp(-j\omega(\tau_n + mT_0))w_{n.m},$$

$$= \exp(j\omega t) \times H(\theta,\omega),$$

$$H(\theta,\omega) = \sum_{n=0}^{N-1}\sum_{m=0}^{M-1} w_{n,m}\exp(-jm\omega T_0)\exp(-jn\omega\frac{d}{c}\sin\theta).$$

（Tapped delay line array antenna）




*TDL-AA can work as interference canceller on both of time and space domains*

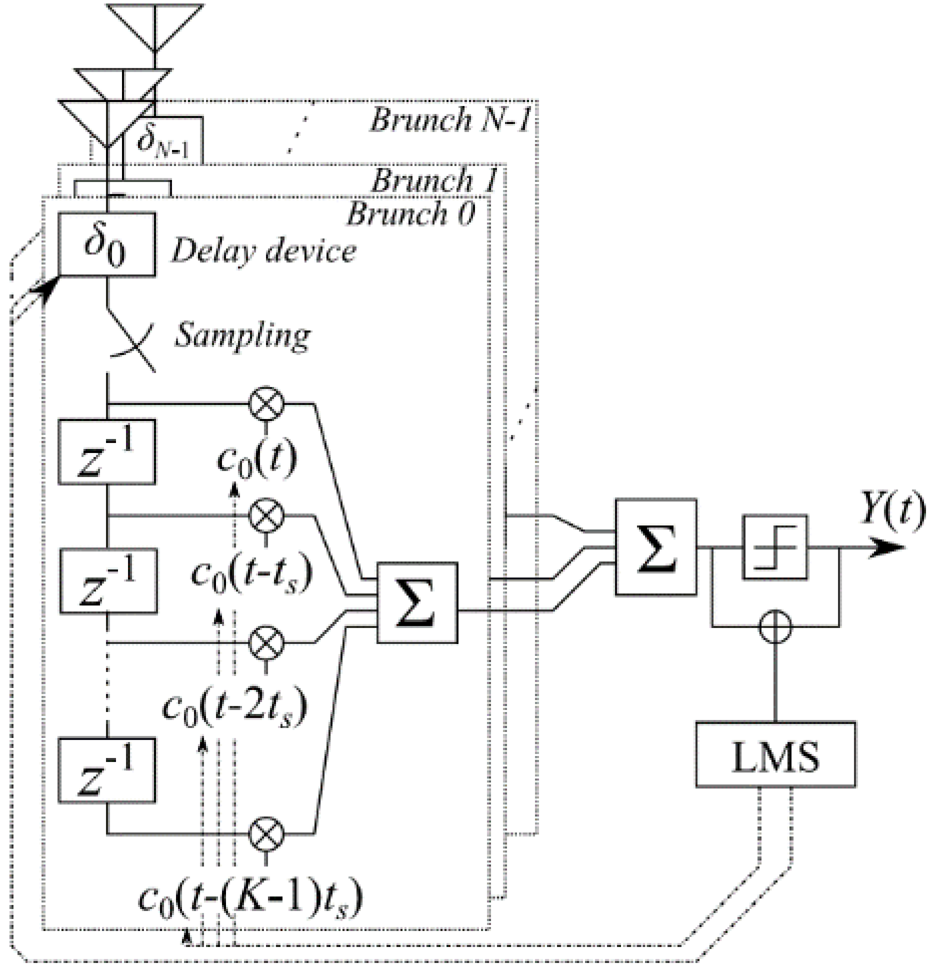
- Apply pulse based OMF to spatial signal processing

◆ TDL array antenna

- Configured by multiple antennas and tapped delay line （TDL）
- TDL-AA can separate the signals which comes from the same direction by using time-domain signal processing.

◆ By applying OMF to TDL-AA

- Interference reduction is performed on the both of domains of time and space.




Space-temporal signal processing

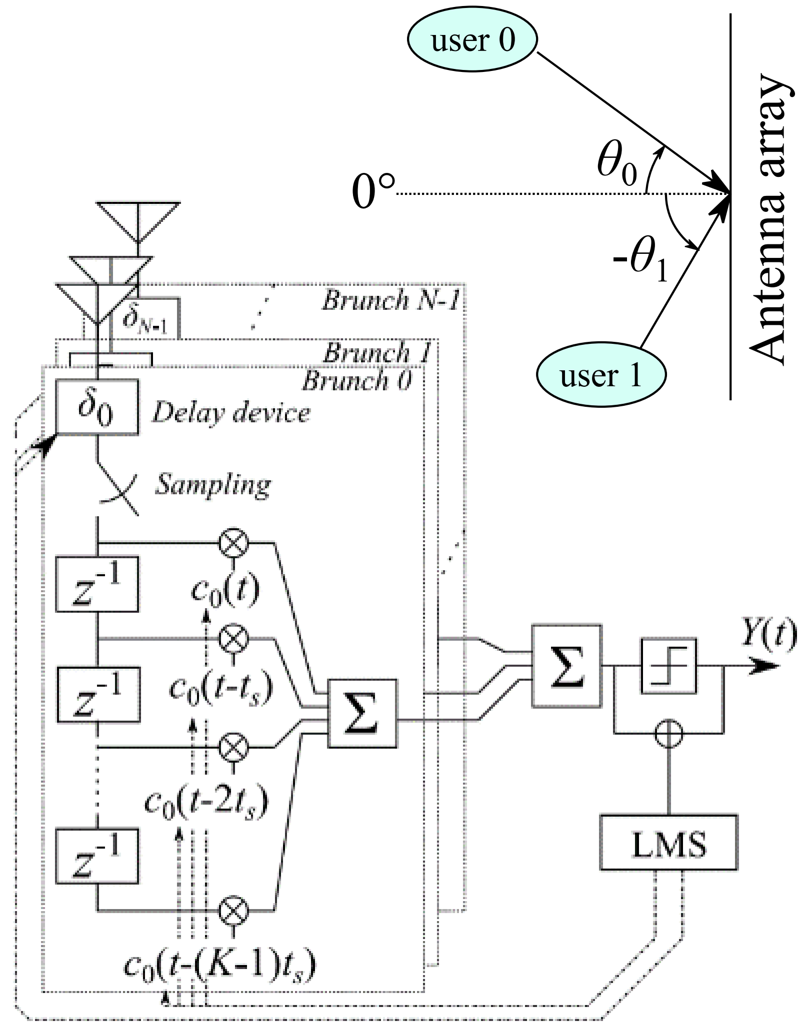
# • System model and optimum parameters.

## Beam forming,

- Delay time of each antenna brunch is adjusted to achieve Maximum Power of desired signal

$$\delta_n = \left( n - \frac{N-1}{2} \right) \frac{d_s}{v} \sin(\theta_0)$$

$N$ : number of antennas,
$v$ : propagation speed
$d_s$ : antenna distance




## Null-steering,

- MHP based OMF is used as a TDL.
- arrival time difference of $u$-th users signal in $n$-th antenna is

$$\tau_{u,n} = -\left( n - \frac{N-1}{2} \right) \frac{d_s}{v} \sin(\theta_u)$$

# • System model

- Delay time for beam forming is

$$\delta_n = -\tau_{0,n}$$

- OMF of *n*-th brunch has coefficients $c_n(t)$ that satisfy bellow

$$\mathbf{c}_n(t) = \mathbf{a}_0 + \sum_{k=1}^{K-1} \mathbf{p}_k(t) w_k$$

where, $w_k$ is determined as

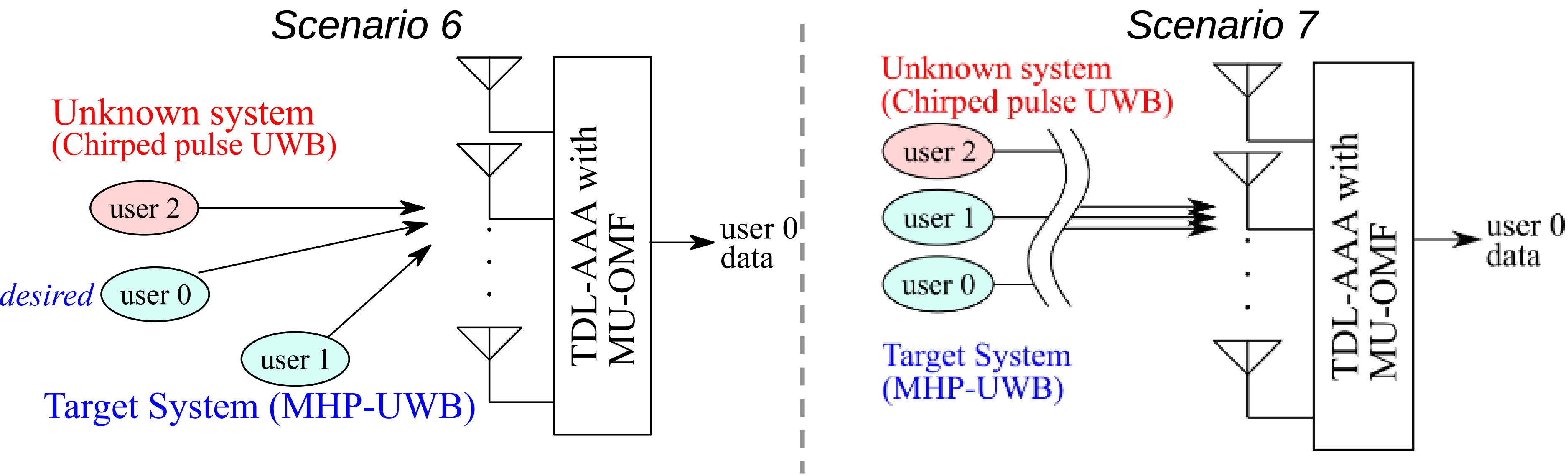
$$\mathbf{a}_0(t)^{\mathrm{T}} \mathbf{a}_u(t+\tau_{u,n}+\delta_n) = -\sum_{k=1}^{K-1} \mathbf{a}_u(t+\tau_{u,n}+\delta_n)^{\mathrm{T}} \mathbf{p}_k(t) w_{k,n} \qquad (u = 1, 2, \cdots, U-1)$$

Matrix form

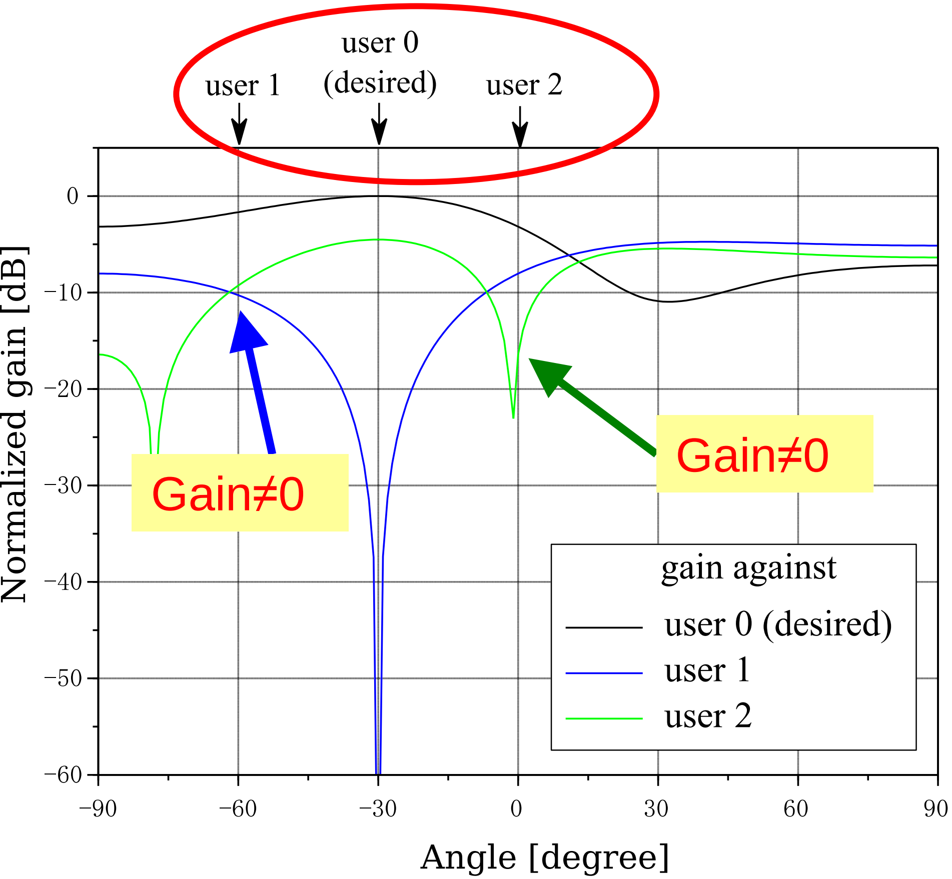
$$\begin{bmatrix} w_{0,n} \\ \vdots \\ w_{K-1,n} \end{bmatrix} = \begin{bmatrix} \mathbf{a}_1(t+\tau_{1,n}+\delta_n)^{\mathrm{T}} \mathbf{p}_1(t) & \cdots & \mathbf{a}_1(t+\tau_{1,n}+\delta_n)^{\mathrm{T}} \mathbf{p}_{K-1}(t) \\ \vdots & \ddots & \vdots \\ \mathbf{a}_{U-1}(t+\tau_{U-1,n}+\delta_n)^{\mathrm{T}} \mathbf{p}_1(t) & \cdots & \mathbf{a}_{U-1}(t+\tau_{U-1,n}+\delta_n)^{\mathrm{T}} \mathbf{p}_{K-1}(t) \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{a}_0(t)^{\mathrm{T}} \mathbf{a}_1(t+\tau_{1,n}+\delta_n) \\ \vdots \\ \mathbf{a}_0(t)^{\mathrm{T}} \mathbf{a}_{U-1}(t+\tau_{U-1,n}+\delta_n) \end{bmatrix}$$

$\mathbf{a}_0 = \mathbf{p}_0$ is desired user's pulse $\mathbf{a}_u$ is *u*-th user's pulse (undesired) $\mathbf{p}_k$ *k*-th orthogonal vector

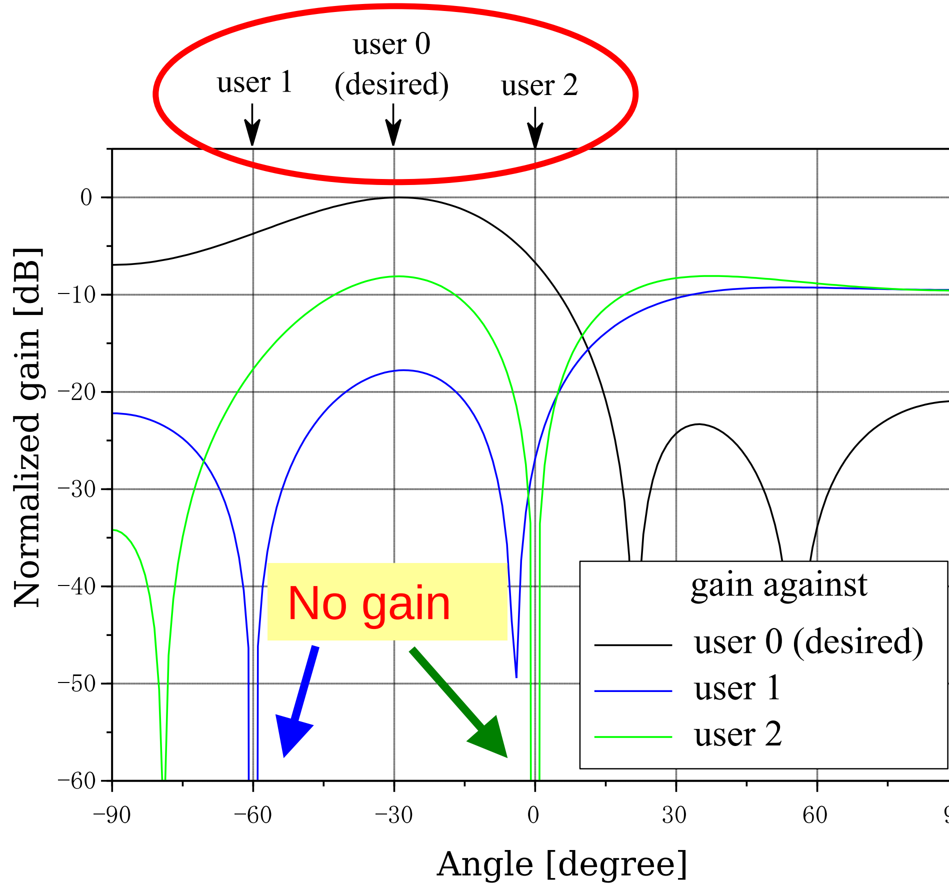
- Characteristics evaluation on each arrival angle




| | | |
|---|---|---|
| Number of antennas / placement | 5 / Linear array | |
| Distance between antennas; $d_s$ [m] | 0.45 | |
| Desired user's pulse | $0^{th}$ order MHP | |
| Interference user's pulse | $2^{nd}$ order MHP (IUI) and chirped pulse UWB (ISI) | |
| Arrival angle of desired signal [degree] | 10 | 0 |
| Arrival angle of interference signal [degree] | 30 and -60 | 0 and 0 |



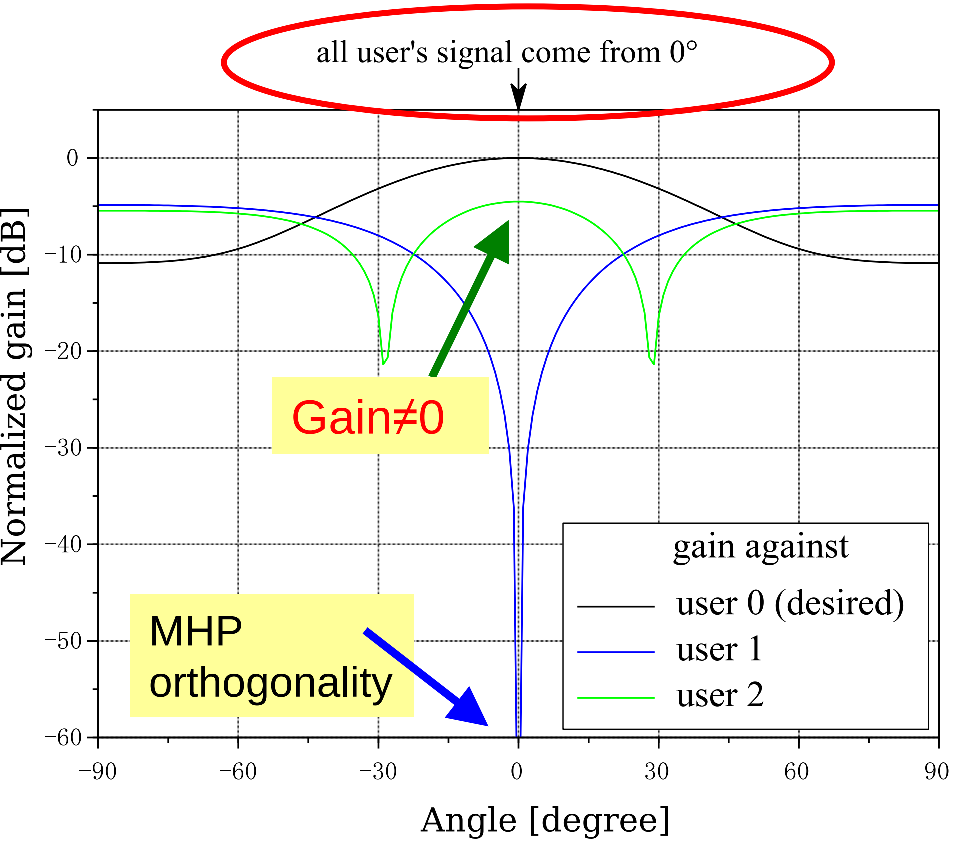

*TDL-AA without null-steering （SC.6）*



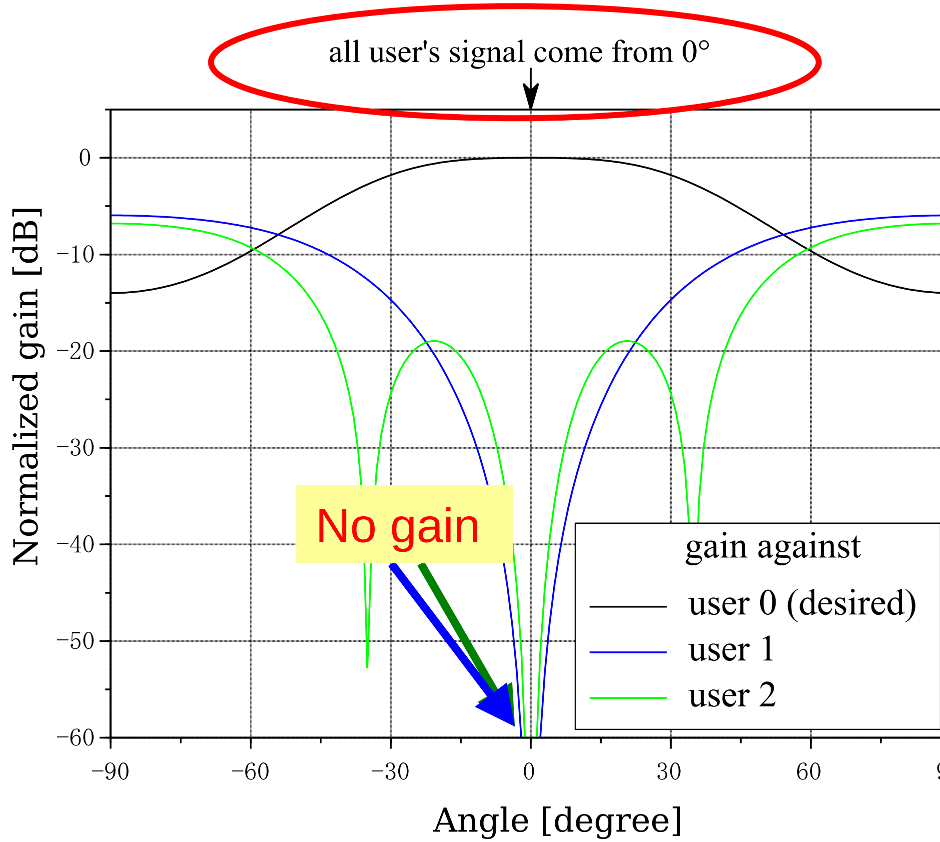

*Space-temporal interference reduction (SC.7)*

System has gain against an interference
→residual interference

Interference signal is reduced




*TDL-AA without null-steering （SC.6）*




*Space-temporal interference reduction(SC.7)*

System has gain against an interference
→residual interference

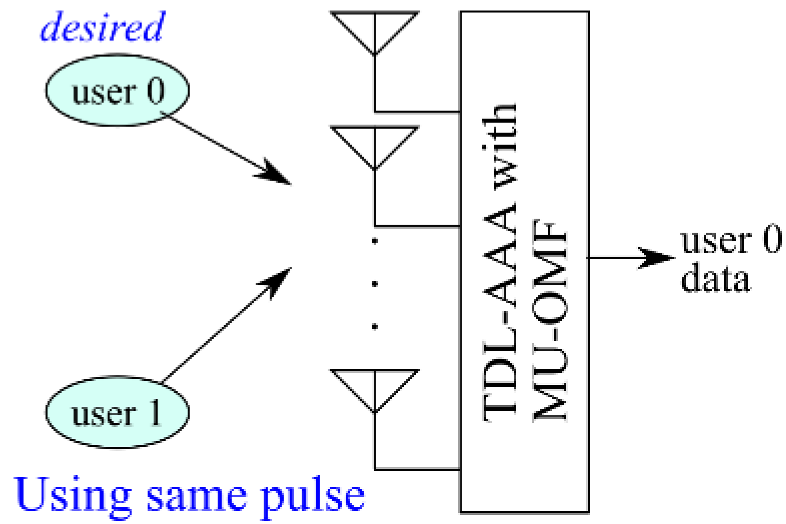
Interference signal is reduced

- Characteristics evaluation on each arrival angle

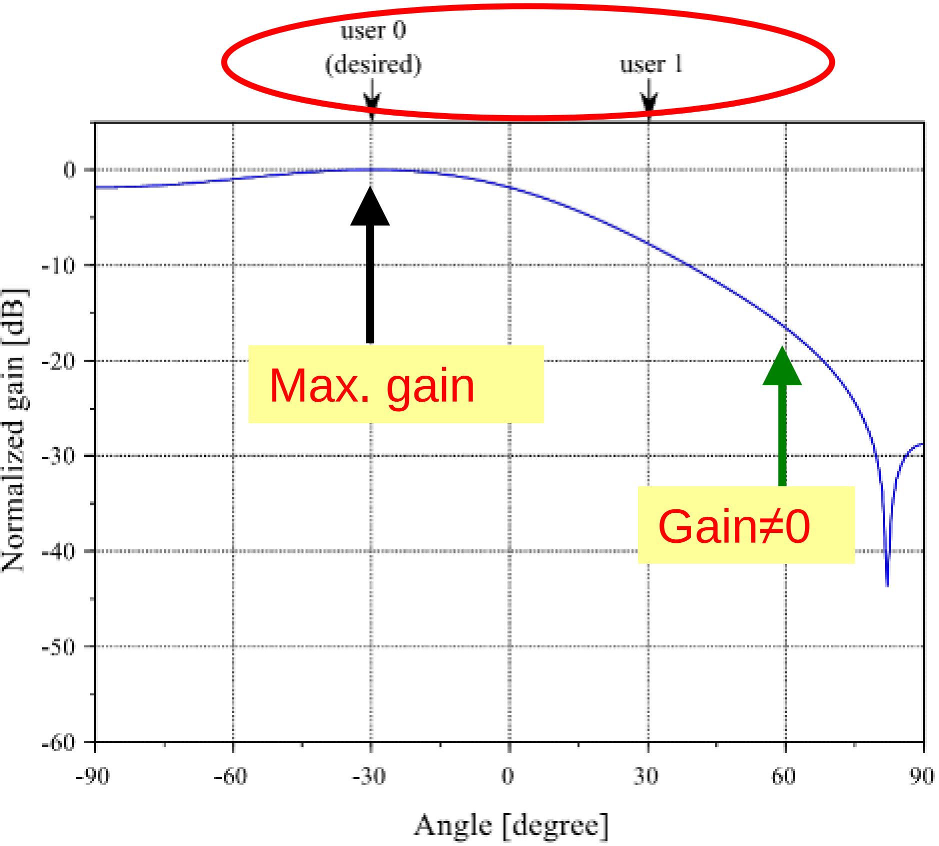
2 users use the same pulse

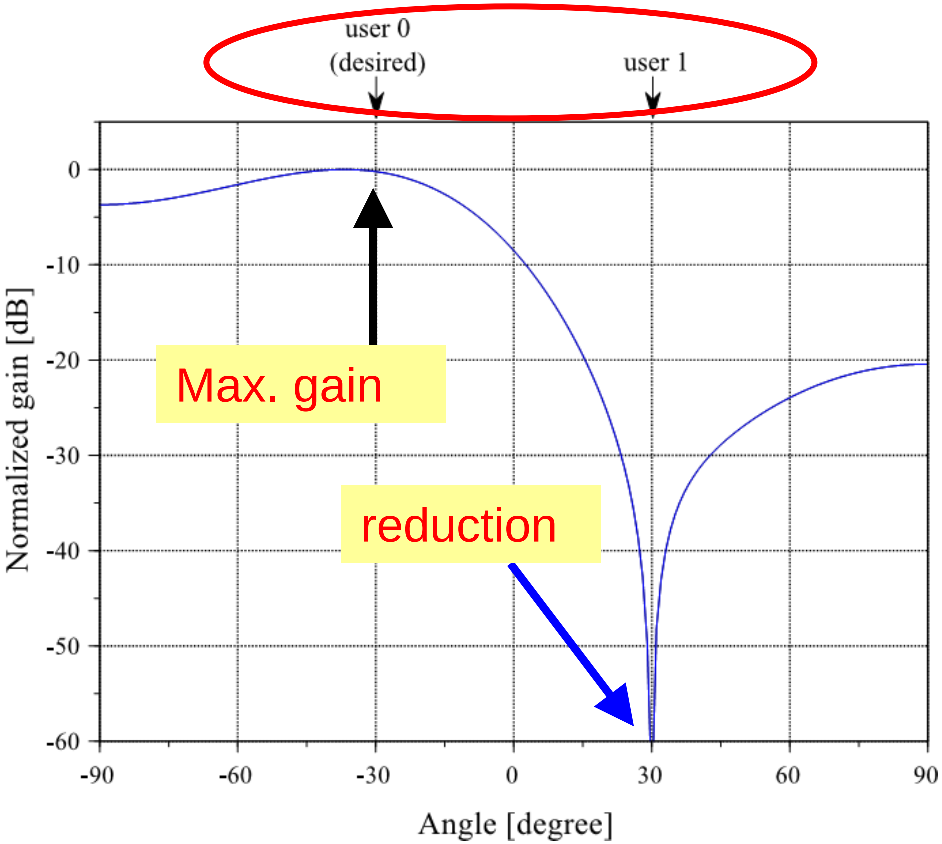
Time-domain signal processing cannot reduce the interference

*Scenario 8*




| | |
|---|---|
| Number of antennas / placement | 5 / Linear array |
| Distance between antennas; $d_s$ [m] | 0.45 |
| Desired user's pulse | **1st order MHP** |
| Interference user's pulse | **1st order MHP** |
| Arrival angle of desired signal [degree] | **-30** |
| Arrival angle of interference signal [degree] | **30** |



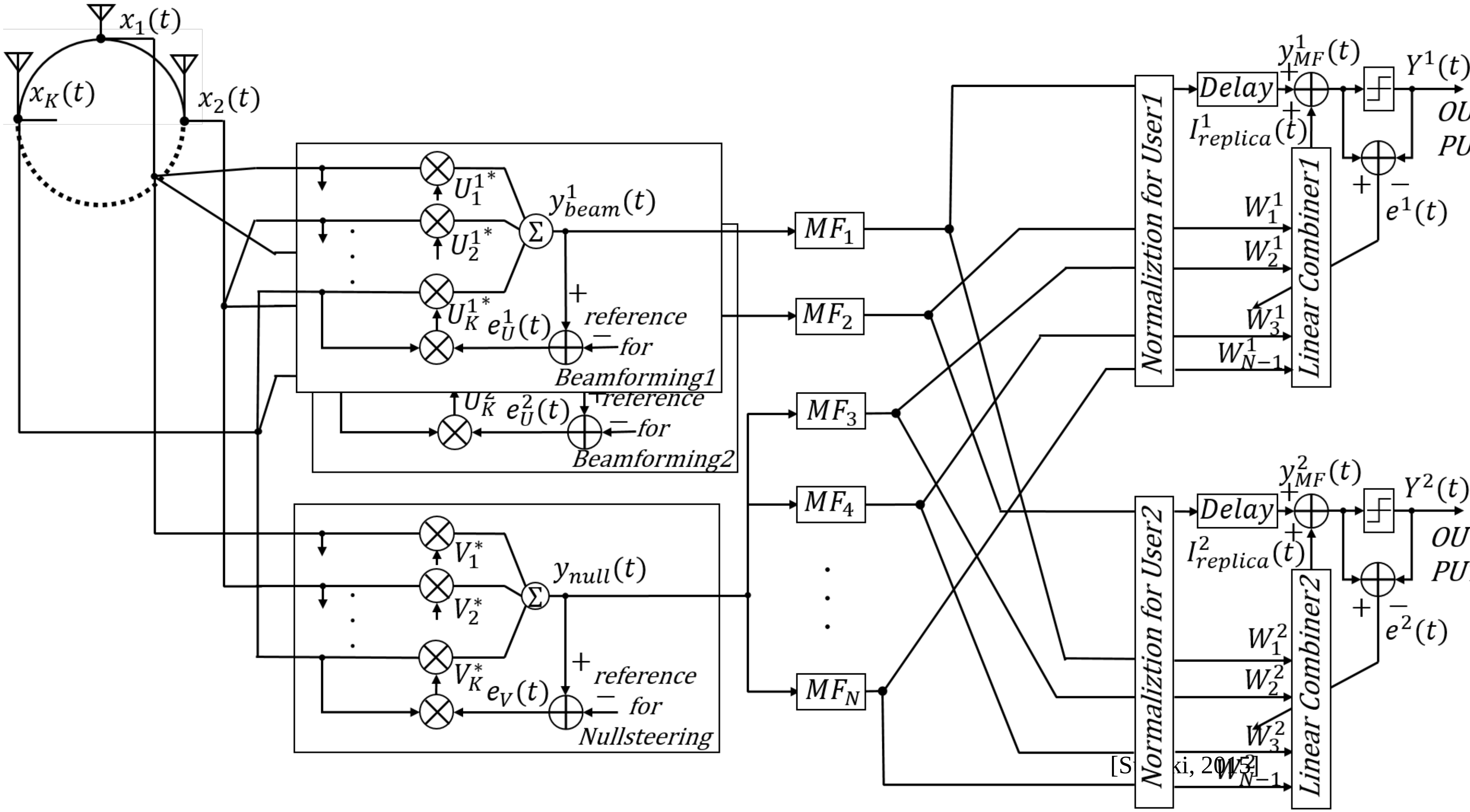

*TDL-AA without null-steering with OMF （SC.8）*

System has gain against an interference→residual interference

*Space-temporal interference reduction(SC.8)*

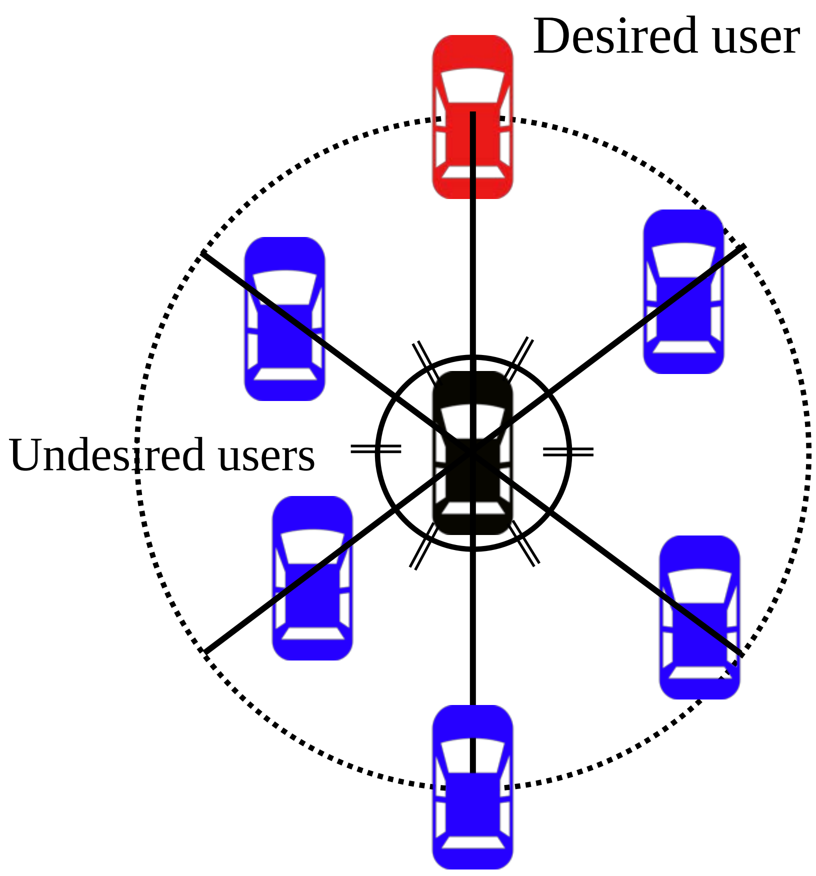
Interference can be eliminated if either one is different from the desired signal

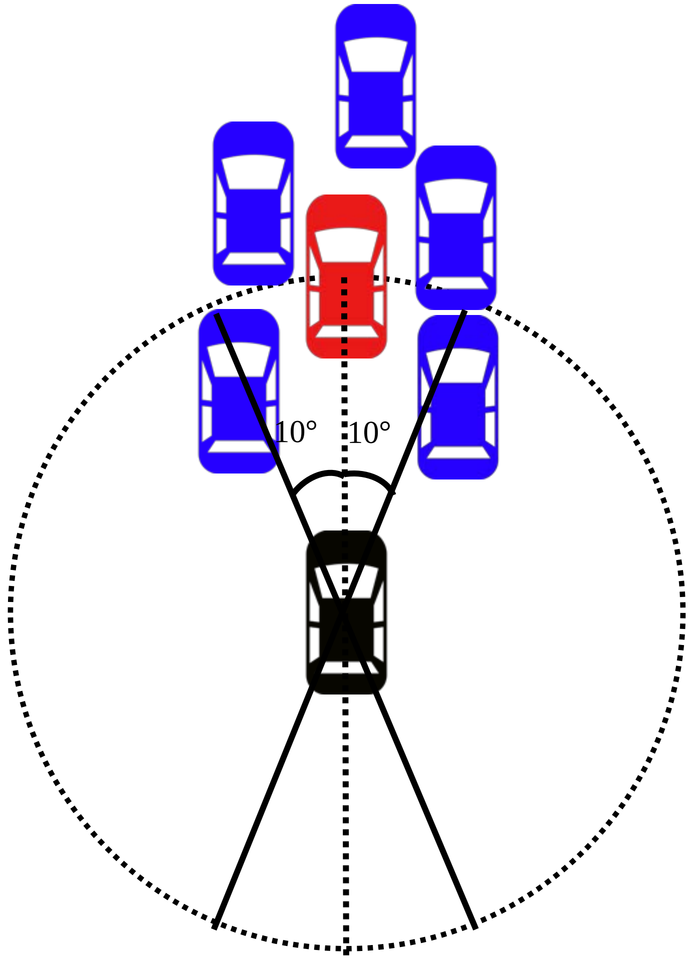
# Enhanced OMF Extended to Circular Array Antenna

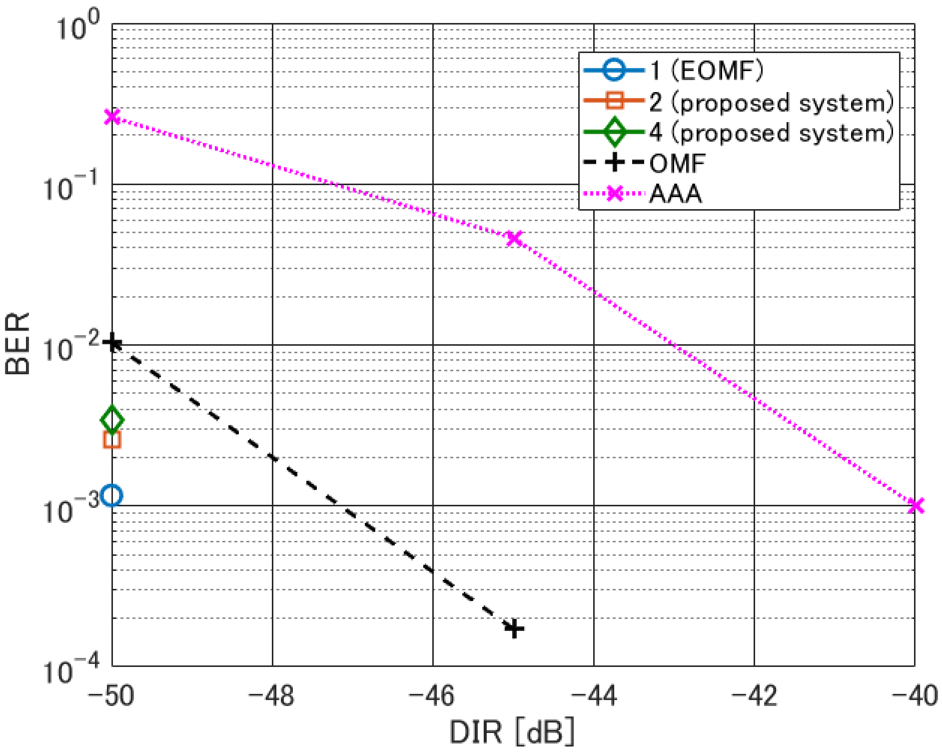



[Suzuki, 2013]

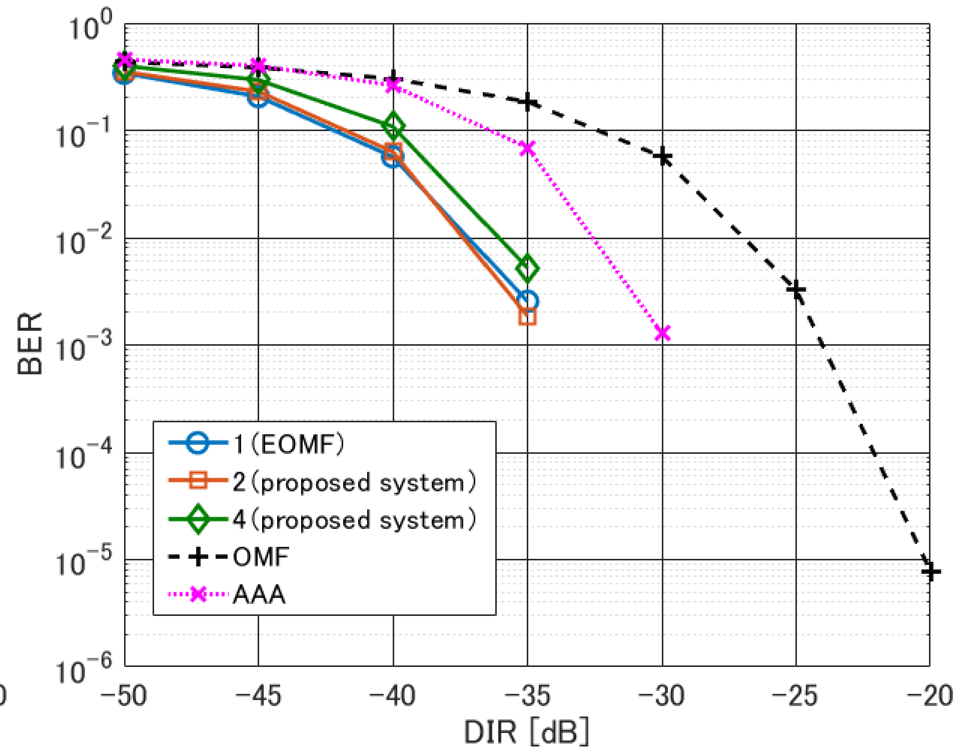
# Application to V2V communication






8 users



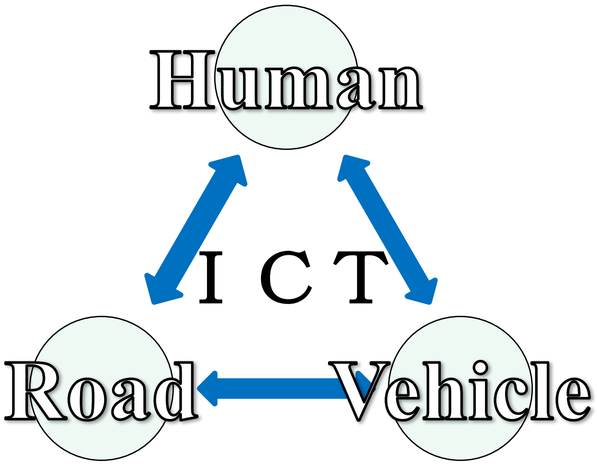

30 users

Extended orthogonal matched filter
into space-time domains
for cancelling interference
in inter-vehicle communication and radar

# ITS・IVC

## ITS : Intelligent Transport System

- ✓ ETC
- ✓ VICS（Vehicle Information and Communication System）
- ✓ Collision avoidance radar
- ✓ Autonomous driving




IVC：Inter-Vehicle Communication

-Wireless communication between vehicle to vehicle

-By sharing position, speed, controlling information, IVC supports safety driving

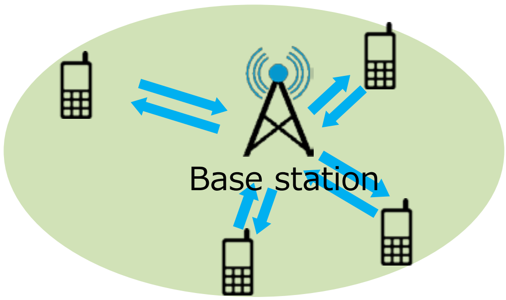
- Should be Realtime and Dependable

# DS/CDMA ：
# Direct-Sequence Code Division Multiple Access

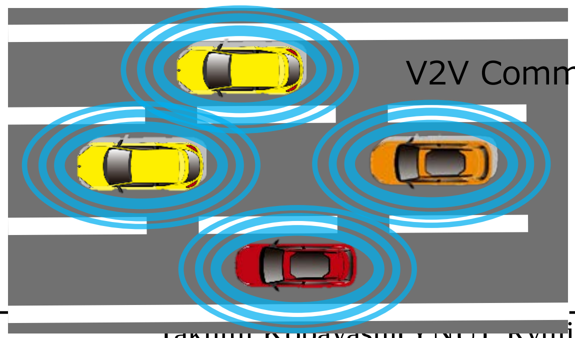
- 3G Cellular etc.･･･
- Each user uses different DS-code
- Spread spectrum
- CDMA is basing on code orthogonality

**Near-far problem**
**System (user) capability**

**Cellular system**
- Base station
- Transmission power control
- Pre-known user code
  - ⇒ interference cancelling




**IVC（ad-hoc network）**
- No base-station
  Vehicle mobility
- No transmission control
- Unknown user code



# Adaptive array antenna

① RF signal is received multiple antennas

② Linear combination by weighting vecto

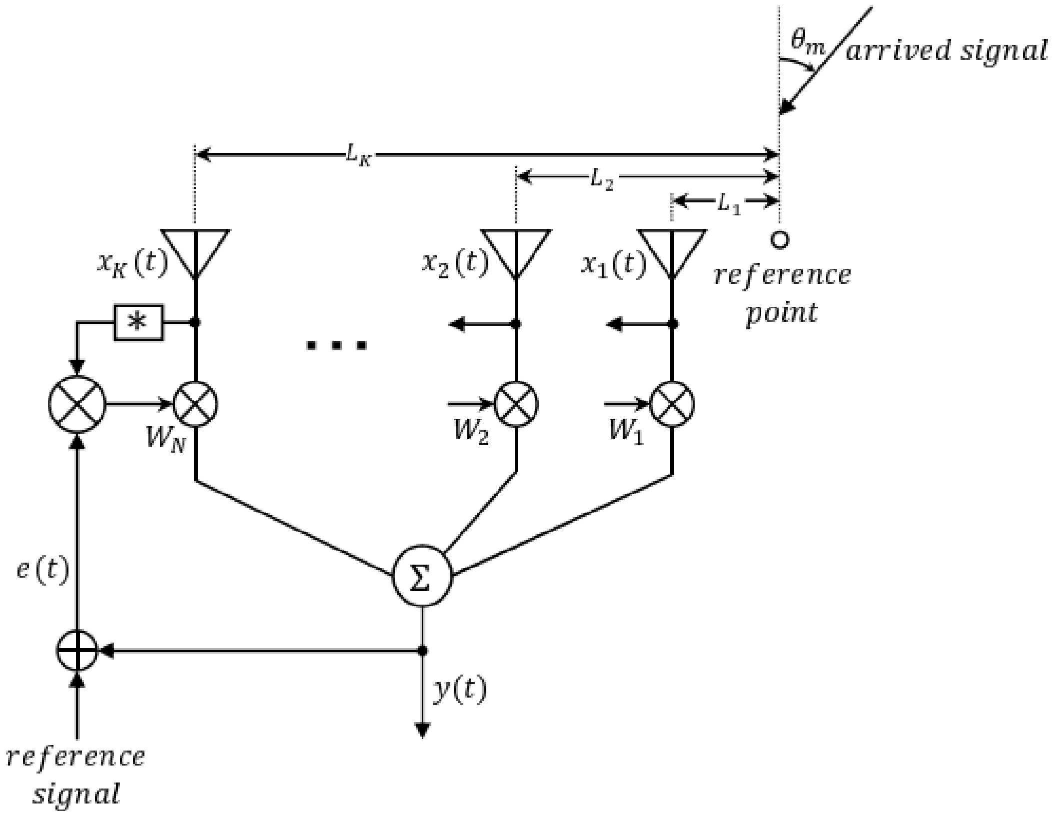
③ Desired signal and interference signal separated spatially.

Beamforming

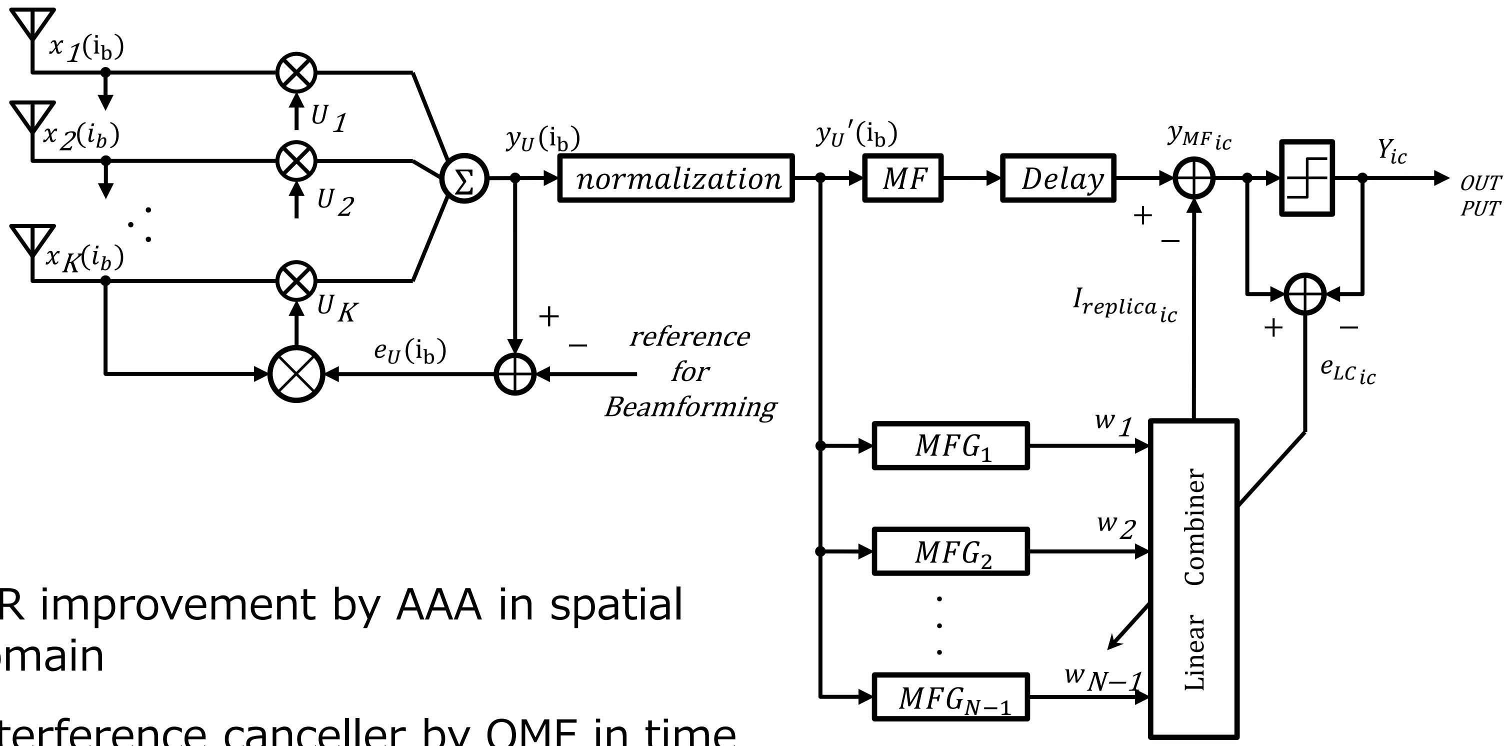
Null steering

**Interference canceller in**

**Space domain**



# Serial combination of OMF and AAA

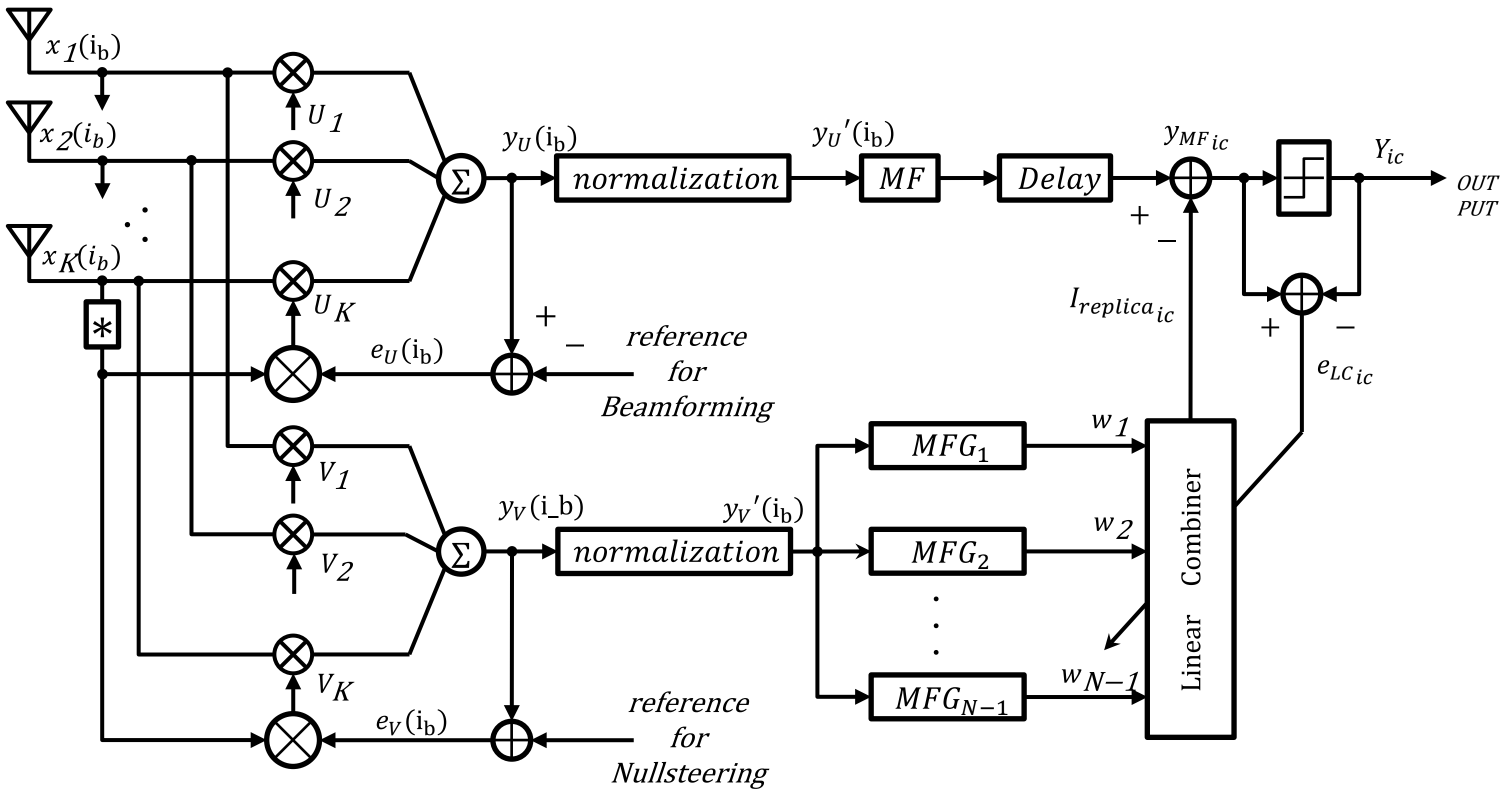



① SIR improvement by AAA in spatial domain

② Interference canceller by OMF in time domain

**AAA and OMF work as interference canceller complementary.**

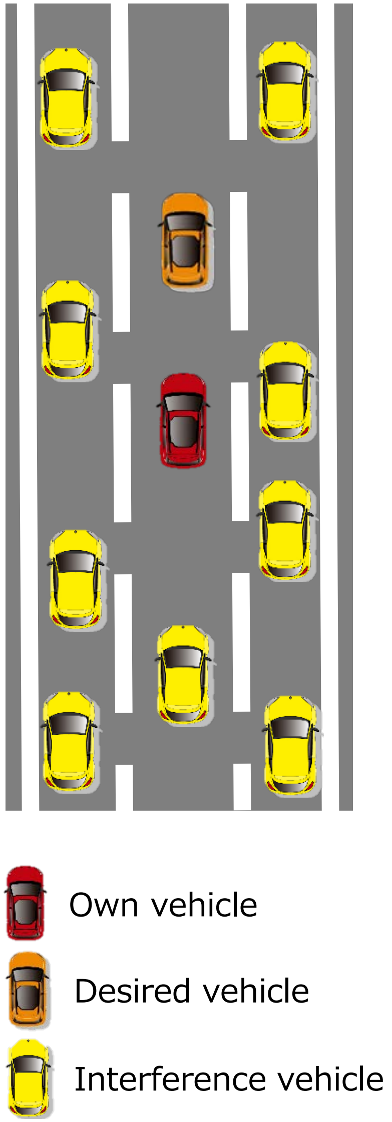
# Extended Space-Time domain OMF




- Filtering for both of desired signal and interference in space-time domain.
- Convergence performance improvement.

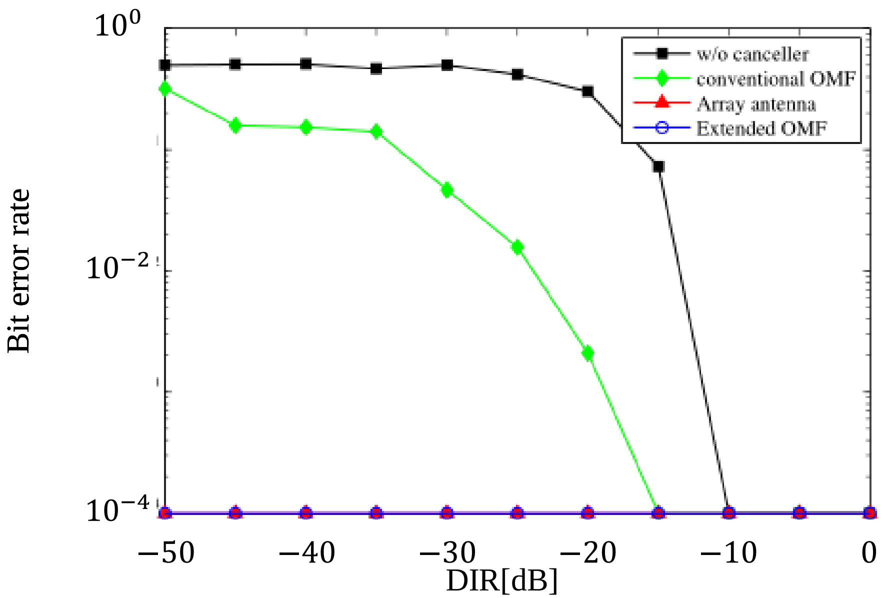
# Simulation

| | |
|---|---|
| modulation | BPSK |
| Spread spectrum | DSSS |
| code | 31bit Gold-sequence |
| Tx power | 10[mW] |
| Center freq. | 760[MHz] |
| Antenna | 5 elements circular array |
| channel | AWGN (-103.8[dBm]) |
| User number | 4<br>30 |
| Data size | 1000[bit] |
| Arrival angle | Desired signal: 0 deg.<br>Interference ±180 deg. or ±10deg |

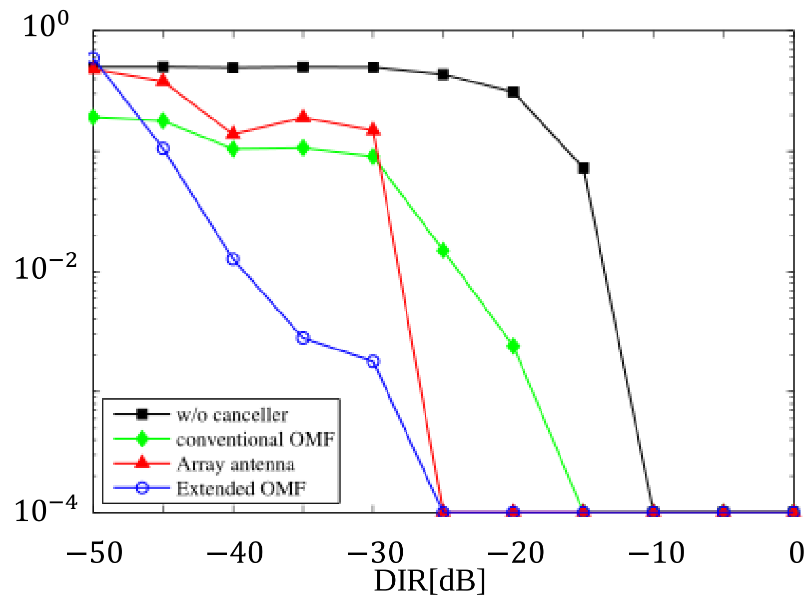


# BER-DIR performance

5 users, ( 1 desired user, 4 interference)




interference : ±180 deg.

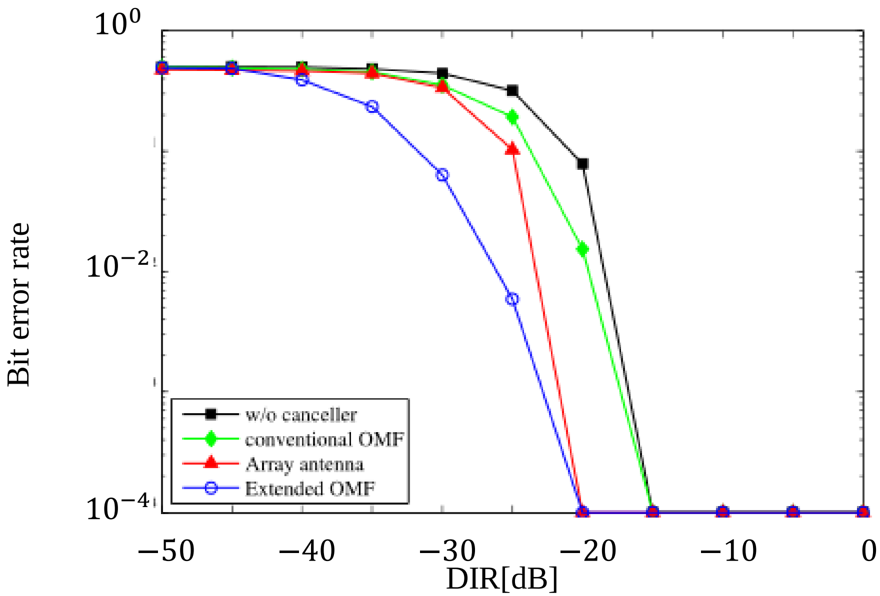



Interference: ±10 deg.

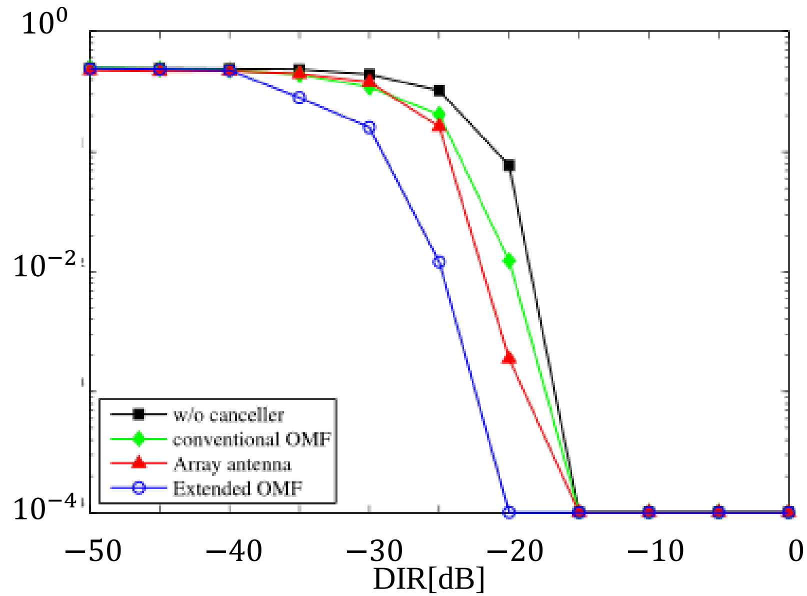
BER performance is improved in high DIR situation.

# BER-DIR performance

30 users, ( 1 desired user, 29 interference)




interference : ±180 deg.




interference : ±10 deg.

Extended OMF can improve BER performance.

# Conclusion

- OMF based on Modified Hermite pulse have been proposed.
  - Interference reduction against unknown interference.
  - Multi user detection for known pulse users signal.

=>Interference mitigation (reduction) in Time-domain.

- MHP based OMF is combined with TDL-AA.
  - Interference mitigation on Time and space domains signal processing.

=> Space-time domain interference mitigation.

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Thank you for your attention.