片山研究室の無線制御研究

最近の学会発表より

名古屋大学 エコトピア科学研究所　情報・通信科学研究部門
（大学院 工学研究科 電子情報システム専攻 兼担）

片山 正昭

最近の学会発表より

- 複数機器同期のためのクロック配信
  Power Supply Overlaid Communication and Common Clock Delivery for Cooperative Motion Control
  IEEE International Symposium on Power Line Communications and Its Applications, pp.370-375
  2011年4月
  - 電力線通信
  - スペクトル拡散による信号重畳
- 複数機器同期への無線の同報性利用
  A Wireless Cooperative Motion Control System with Mutual Use of Control Signals
  IEEE International Conference on Industrial Electronics (ICIT), pp.25-30 2011年3月
- 非定常（周期定常）チャネルでのフィードバック制御
  電力線通信を用いた回転型倒立振子の制御における周期定常雑音の影響評価
  電子情報通信学会技術研究報告, RRRC2011-06,pp.19-24 2011年6月

IEEE ISPLC 2011 Udine, Italy - April 3-6 - 2011

Power Supply Overlaid Communication and Common Clock Delivery for Cooperative Motion Control

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Kentaro Kobayashi [†]　Masaaki Katayama [†]

[†] Nagoya University, Japan
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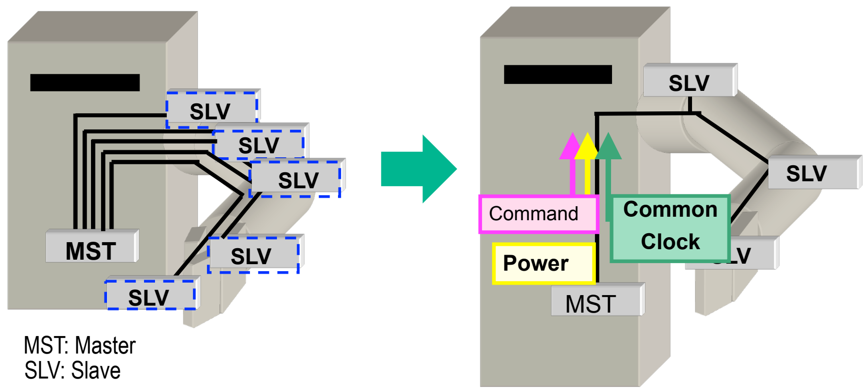
(DC)-PLC for Reduction of Wires

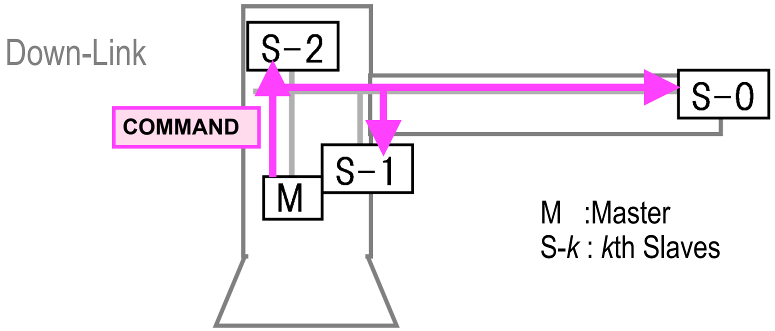


MST: Master
SLV: Slave

Communication of the Control Signal

- Multi-Carrier Modulation

  Down-Link : OFDM, Up-Link : OFDMA

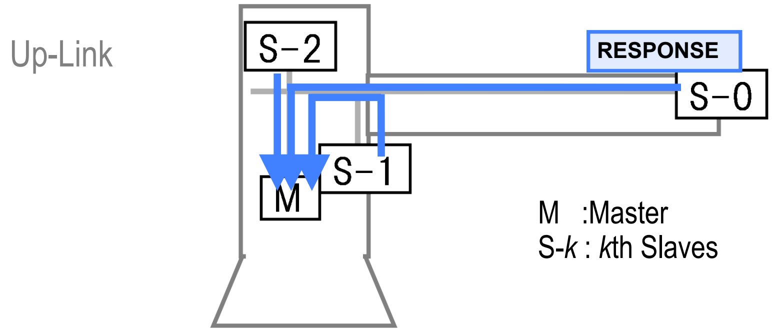


Communication of the Control Signal

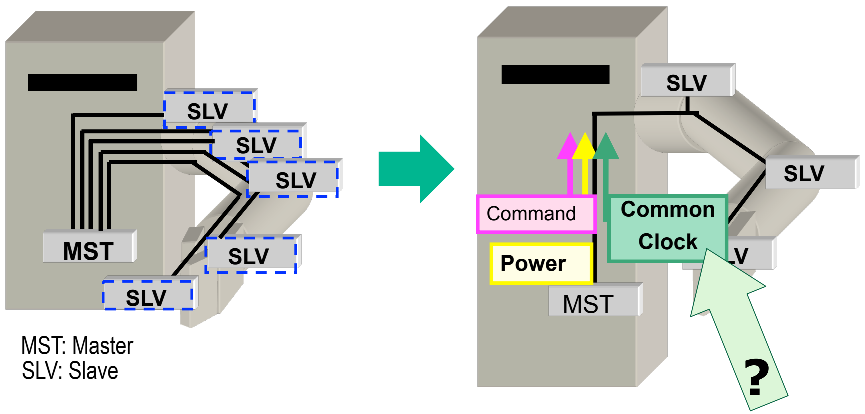
- Multi-Carrier Modulation

  Down-Link : OFDM, **Up-Link : OFDMA**

  - OFDM and OFDMA by **TDD**



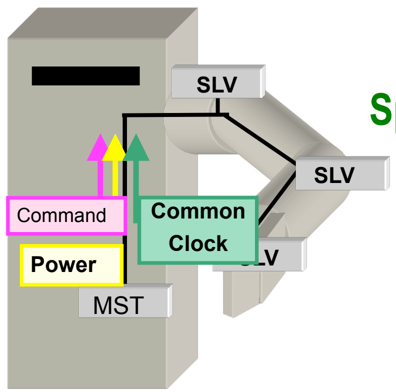
(DC)-**PLC** for Reduction of Wires



MST: Master
SLV: Slave

Common Clock for Synchronized motions

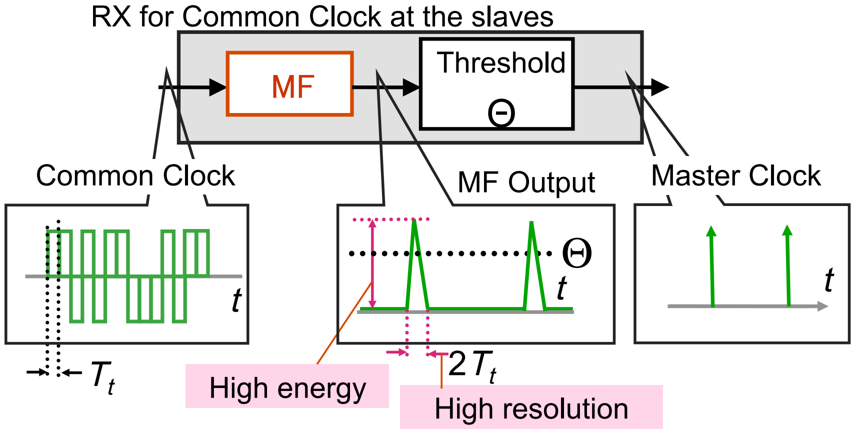
- **Delivery of a high quality common clock signal to each slave to inform the starting time of actions**



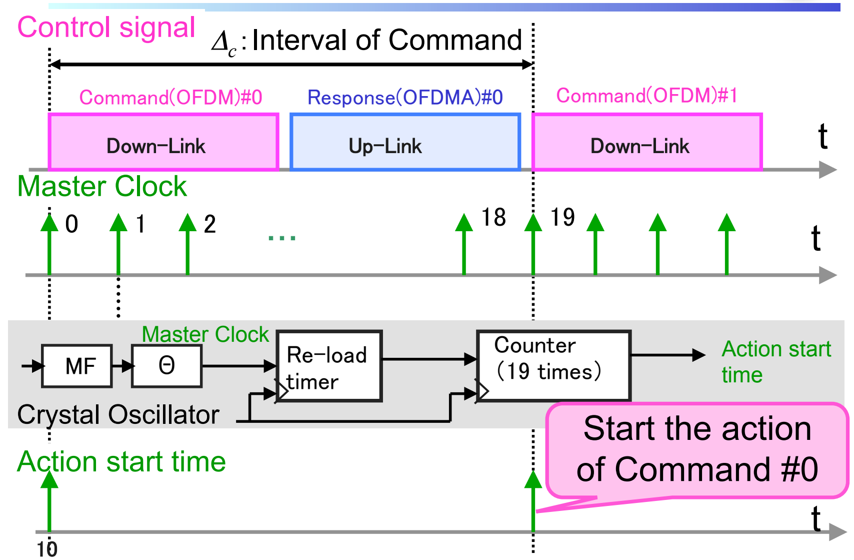
Spread Spectrum (SS)

- Continuous transmission
- High resolution (<1 us)

Reception of the Common

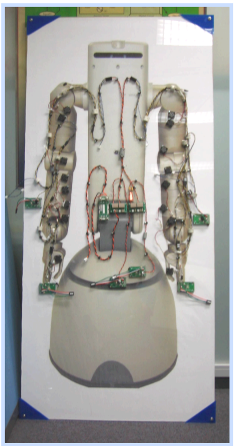


Master Clock to Cue Slaves to Start



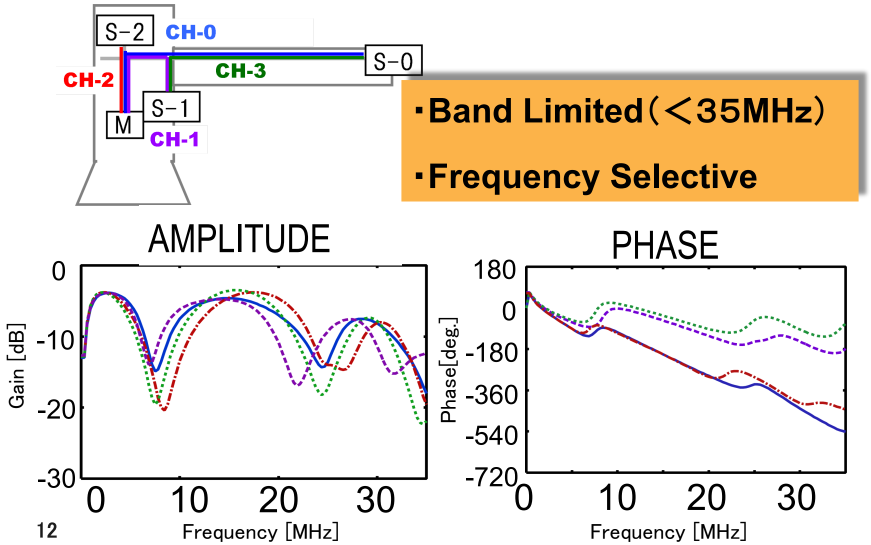
Objective

- Communication over the DC Power lines inside the Robot.

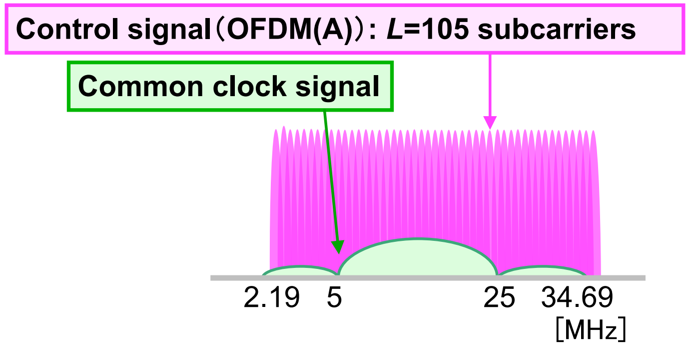


- Command/Response between a Master & Slaves
- Delivery of Common Clock for Cooperative Motion

Channel characteristics

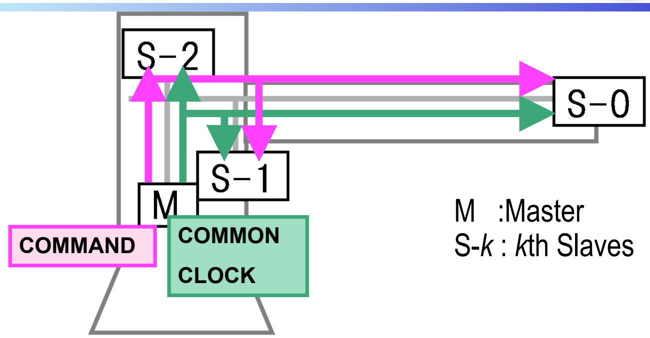


Spectra of Signals



Challenge:
cohabitation of control signal and clock

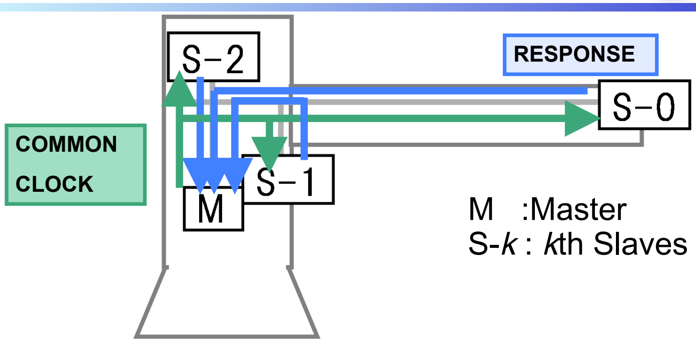
Down-Link



- SS → OFDMA @Slaves
- OFDMA → SS @Slaves

Same Channel for SS & OFDM: Flat Interference

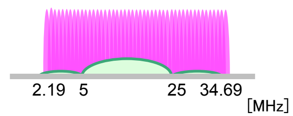
Up-Link



- SS → OFDMA @Master
- OFDMA → SS @Slaves

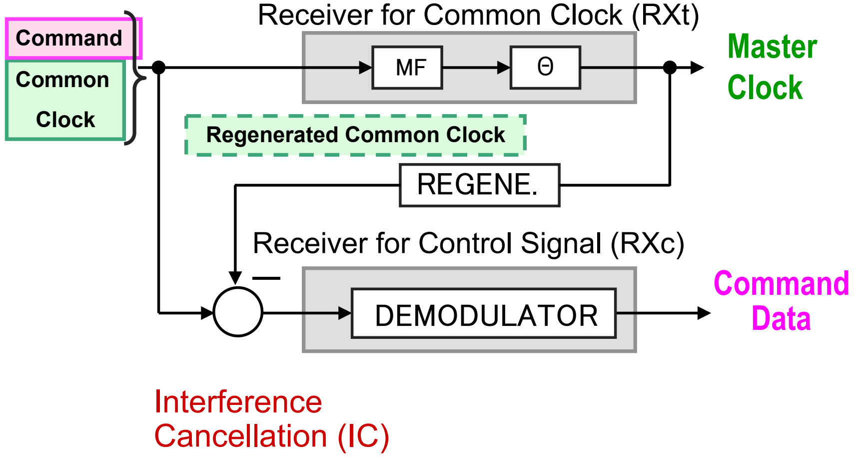
Different Channel for SS & OFDMA: Colored Interference

Solution of Mutual Interference



- OFDM(A) → SS : Process Gain of SS
- SS → OFDM(A) : Interference Cancellation

Reduction of Influence of SS to OFDM(A)



System Parameters

Number of Slaves K	3
Channel	Measured
Noise	None

Common Clock Signal

Carrier Frequency	15 [MHz]
Chip Interval	0.1[μs]
PN Sequence (Interval N)	M sequences ＋ 0 padding (2048(=2^{11}) [bit])

Control Signal

The Lowest Carrier Frequency	2.19 [MHz]
Symbol duration Time	3.2 [μs]
The number of Subcarriers /Allocation	106/Slave with High Gain
Modulation	QPSK

System Requirement

Working Hours a year	1.0512×10^7 s (8h/day×365)
Accuracy of Self-Running OSC	±100ppm

- a pair losses of two successive command packets < once a year
- a misdetection of a start cure < once a year
- cue with timing error more than 1us < once a year

Requirements for Communication Part

[Reception performance]

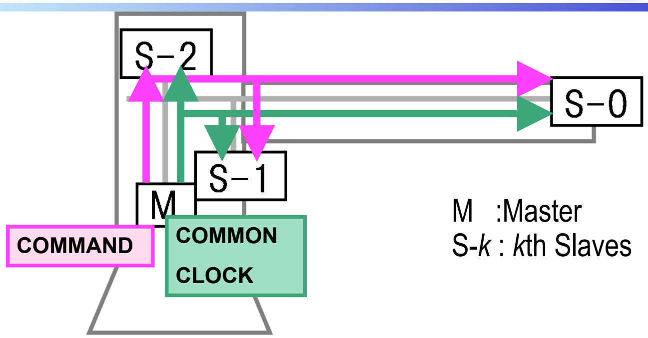
Common Clock Signal (SS) : Prob. of False Alarm
Prob. of Miss Detection

Control Signal (OFDM (A)) : Symbol Error Rate (SER)

Required Conditions for Reception Performance

Prob. of False Alarm ε_f	2.1 x 10^{-7}
Prob. of Miss Detection ε_m	3.2 x 10^{-1}
SER for Control Signal ε_s	3.19 x 10^{-8}

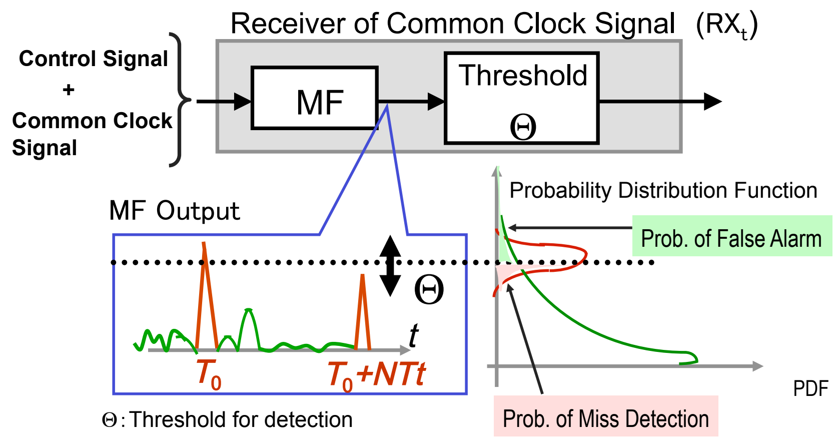
Down-Link



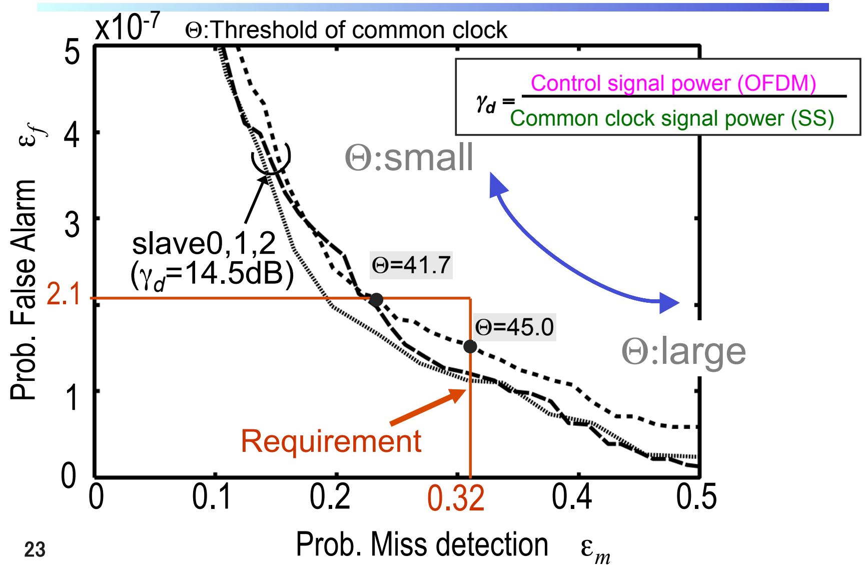
- SS → OFDMA @Slaves
- OFDMA → SS @Slaves

Same Channel for SS & OFDM: Flat Interference

Common Clock Signal



Reception Performance of the Common Clock Signal (Down-Link)



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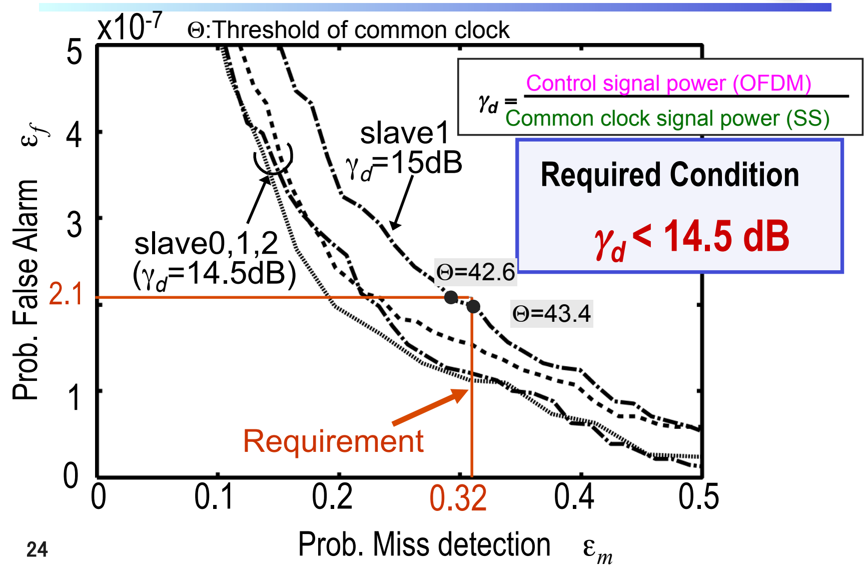
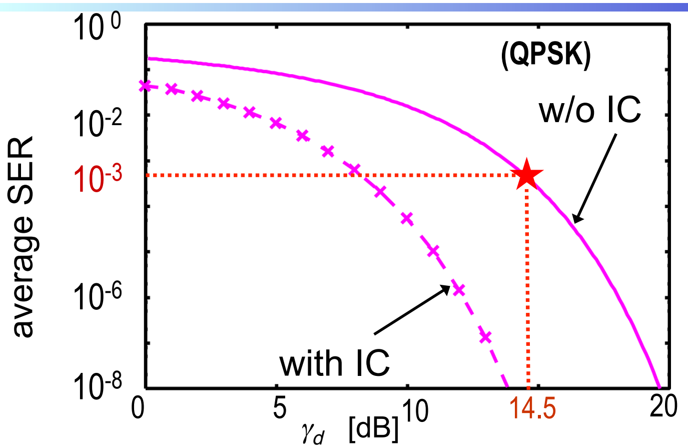
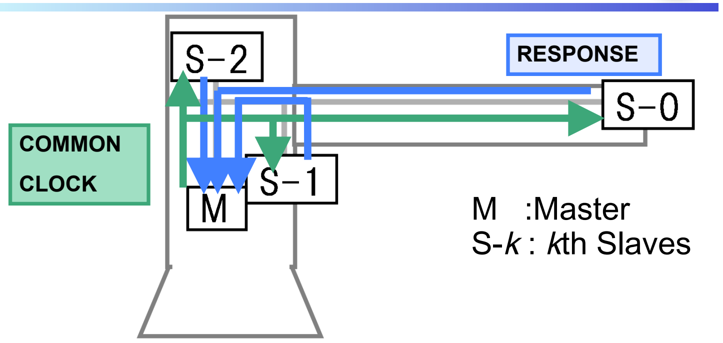


Reception Performance of the Control Signal (Down-Link)



・In the case of using IC, at the γ_d=14.5[dB]
SER <10^{-8} （required SER = 3×10^{-8})

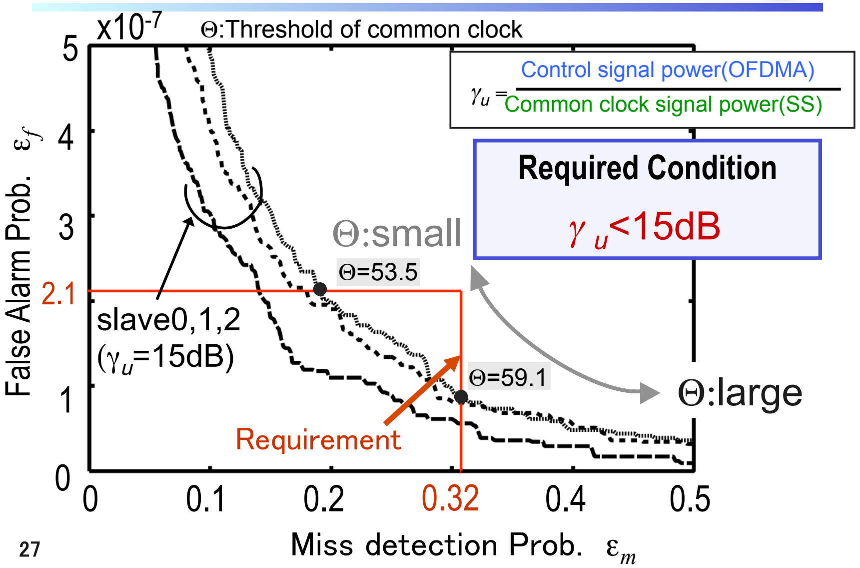
Up-Link



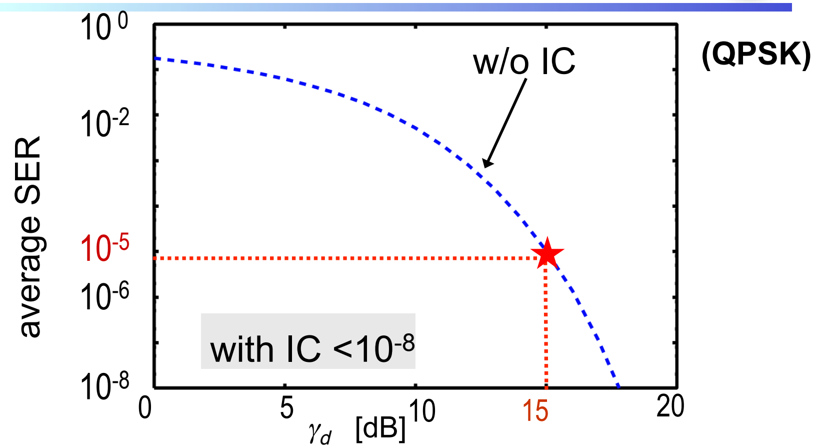
- SS → OFDMA @Master
- OFDMA → SS @Slaves

Different Channel for SS & OFDMA: Colored Interference

Reception Performance of the Common Clock Signal (Up-Link)



Reception Performance of the Control Signal (Up-Link)



・In the case of using IC, at the γ_d=15[dB],
SER <10^{-8} （required SER = 3×10^{-8})

Conclusions

Propose

- A multiple servo control communication system in which the power supply overlaid communications
- Delivery of a common clock for cooperative motion control

Result

- Control signals and master clock can coexist in actually channel.

A Wireless Cooperative Motion Control System with Mutual Use of Control Signals

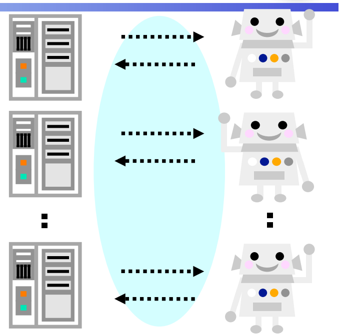
Tsugunori Kondo
Kentaro Kobayashi
Masaaki Katayama

Nagoya University, Japan

Cooperative Motion Control System

Cooperative motion

Multiple machines work at the same time with each other.

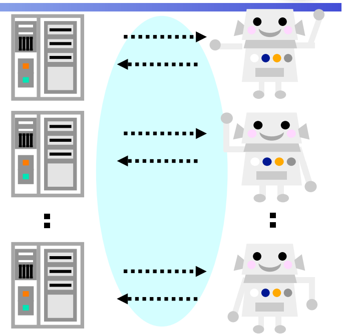


- ☐ **Robot group control**
- ☐ **Assembly lines**
- ☐ **Partner robots**

- ☐ **Control of moving machines**
- ☐ **Relocation of machines**
- ☐ **Saving of space**

Performance of Wireless Cooperative Control

Packet errors



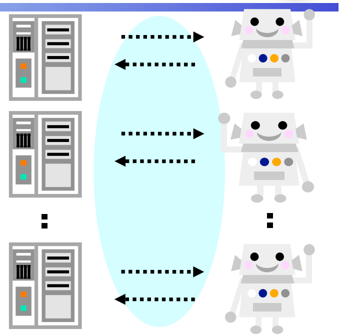
- ☐ **Control performance of each machine (stability, etc.)**
- ☐ **Synchronization of all machines**

New measurement of performance is "the synchronization of all machines".

Conventional Control Signal Transmission

Conventional method

- **One input and one output.**



Mutual Use of Control Signals

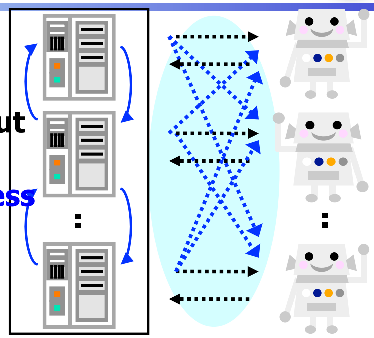
Conventional method

- **One input and one output**

The nature of wireless

Proposed method

- **Multiple input and one output**



We consider to use the control signals of the other machines.

Purpose

A wireless control method for a cooperative motion system

- **Mutual use of the control signals**

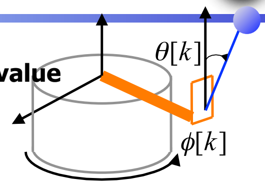
→ **Improvement of control performance and synchronization**

- **New measurement of performance**

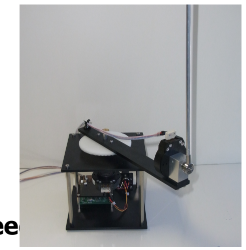
→ **Synchronization of all machines**

Rotary Inverted Pendulum

The pendulums are controlled to make their arm angles $\phi[k]$ follow the target value while keeping the pendulums in an upright position ($\theta[k]$ =0).



- **Basic model**
  - **Bipedal walking robot**
  - **Crane**
  - **Rocket launching pad**
- **Underactuated system**
  - **One actuator for two degrees of free**



$\mathbf{u}[k]$ **:Control information (torque)**
$\mathbf{x}[k]$ **:State information**

$$\mathbf{x}[k] = [\theta[k] \quad \dot{\theta}[k] \quad \phi[k] \quad \dot{\phi}[k]]$$