Space-Time Synchronization via Wireless Two-Way Interferometry (Wi-Wi)

2023/3/16

@ WSTS2023

National Institute of information and

communications technology (NICT)

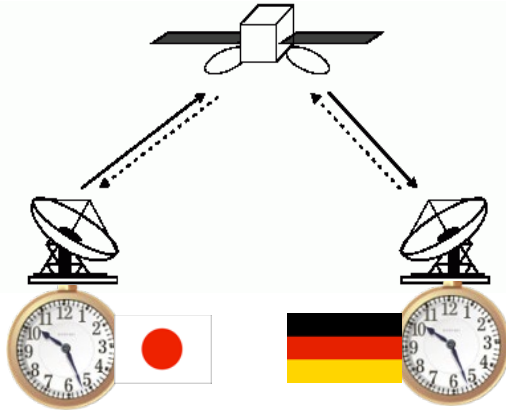Global alliance department

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WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

MARCH 13-16 | VANCOUVER, BC

Wireless 2Way interferometry (Wi-Wi)

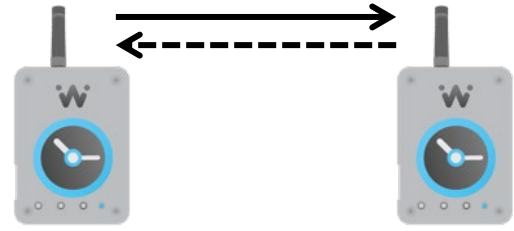Two-way satellite time and frequency transfer (TWSTFT)

measurement of
time difference and
transmission time via
satellite communication.

New!

Wireless two-Way interferometry
（**Wi-Wi**）

measurement of
time and
distance via
wireless communication.

We adopted the satellite technology to achieve
Time synchronization (pico second accuracy) and
Distance measurement (mm accuracy)
at extremely high precision with Low cost and small size.

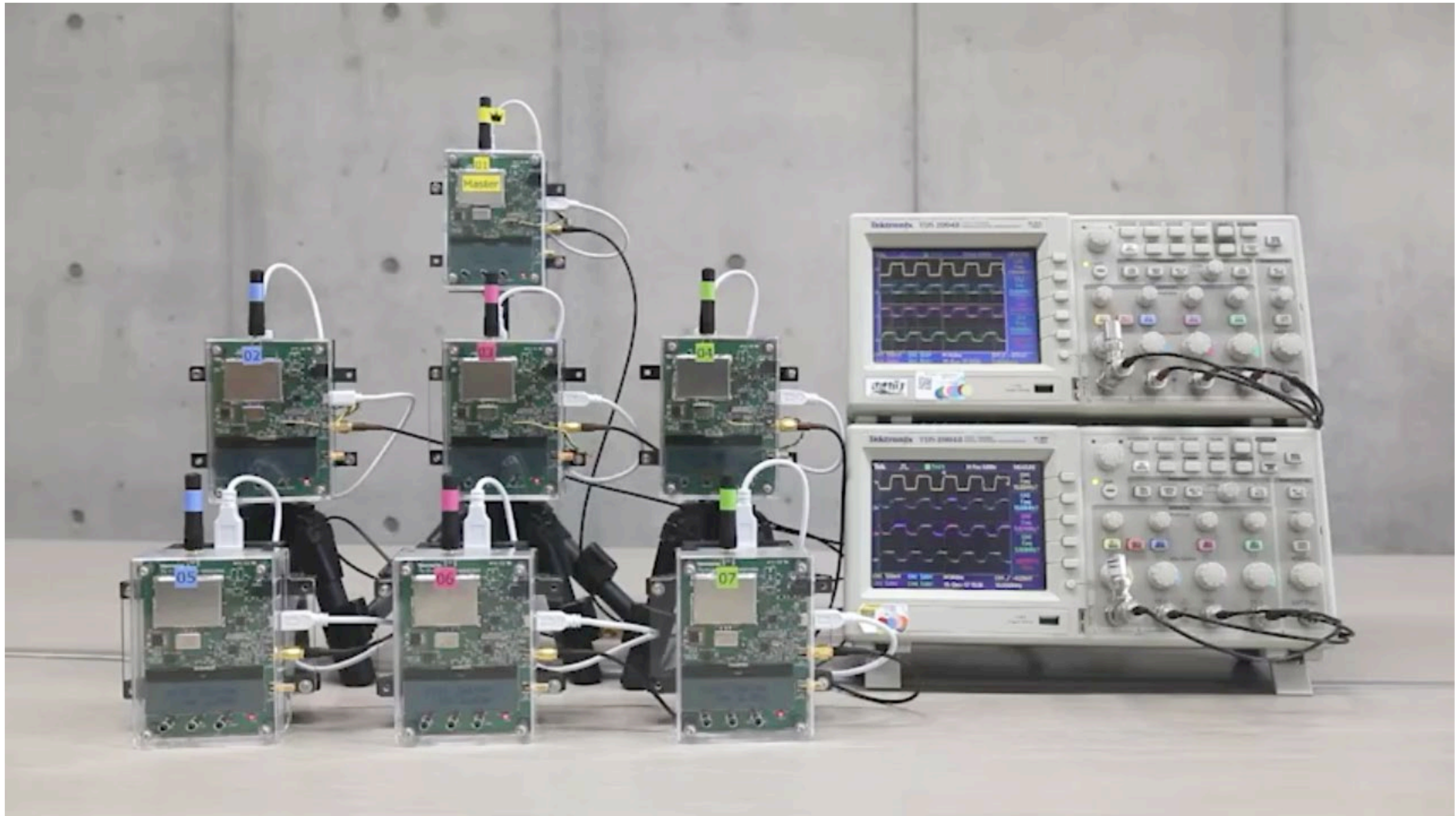# Prototype modules

Satoshi Yasuda
made them all!

- 920MHz wireless communication module
- Fully compatible with IEEE 802.15.4
- Range 100m/5km(high power ver. best effort)
- Phase synchronization jitter: 16ps
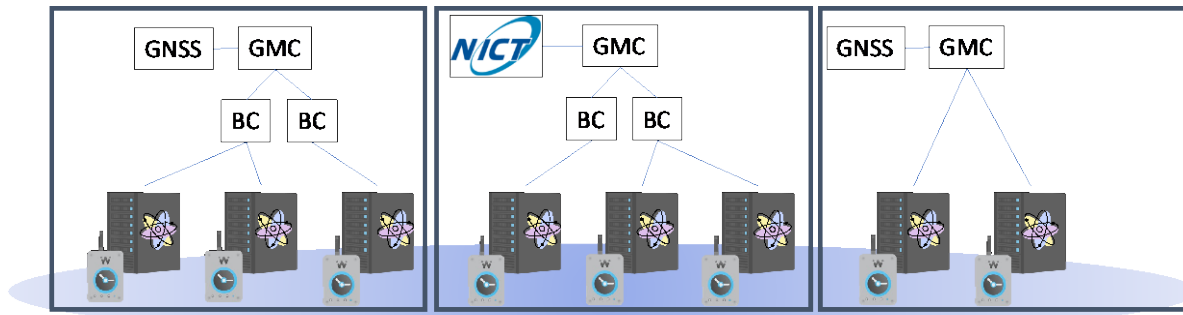- Time synchronization: 35ns

7 modules synchronized
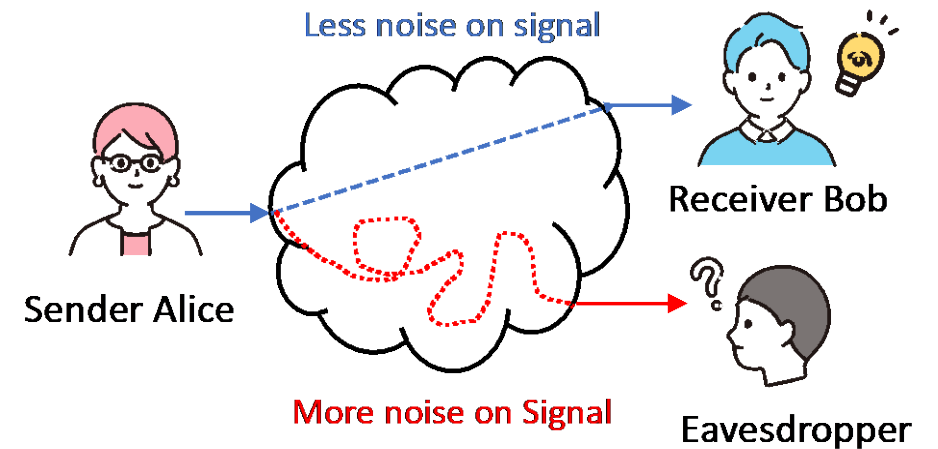
2 applications to introduce

①Data center application
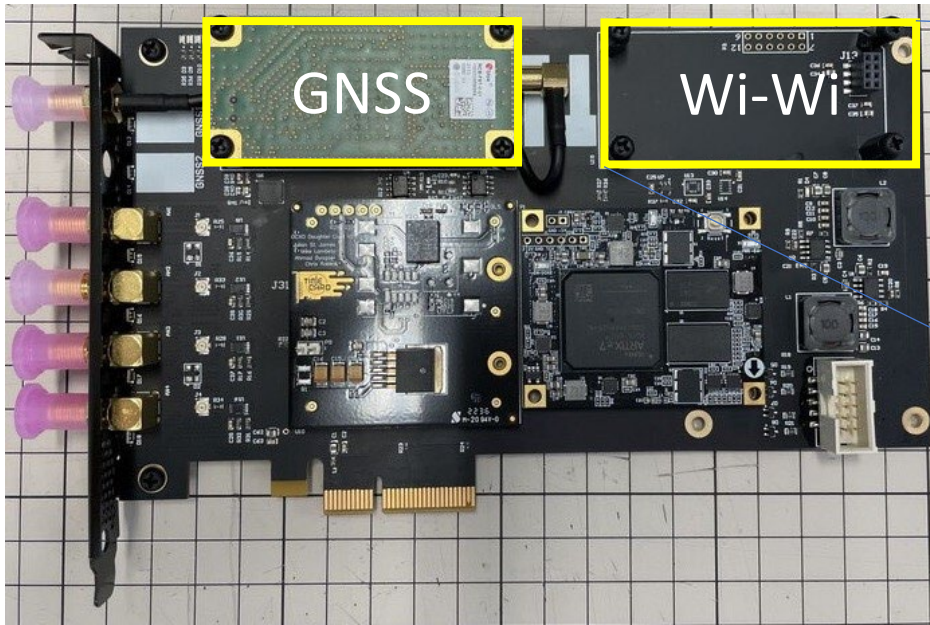

Wi-Wi over the air comparison
inter-connects different clock network

②Security application

Wi-Wi's precise measures of the wireless propagation environment provides **Physical Layer Security**

①Application to Data Center

GNSS   Wi-Wi

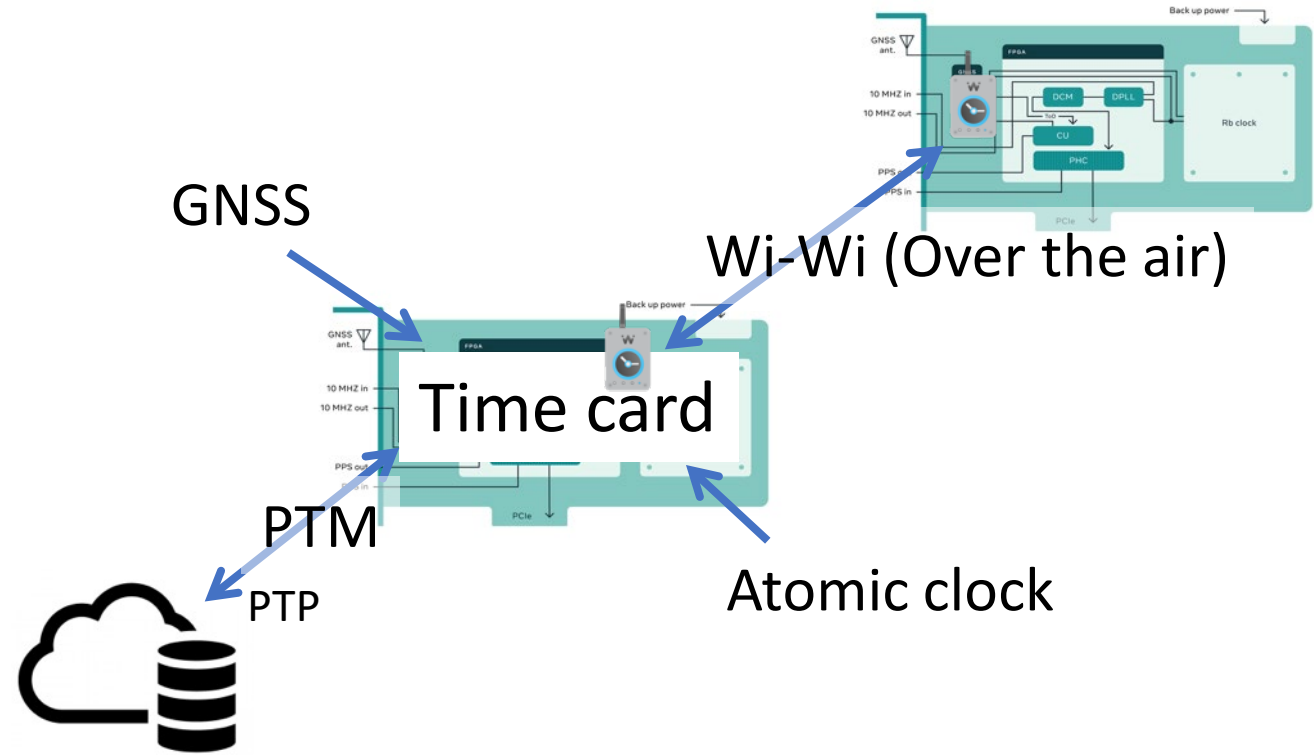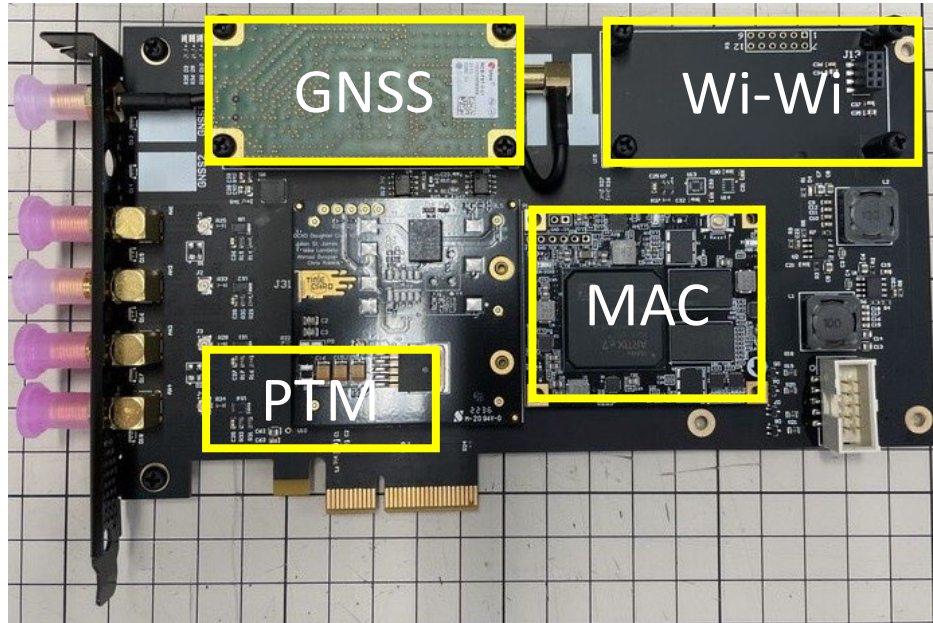Time card (Timebeat version)

Wi-Wi RCB (formfactor)

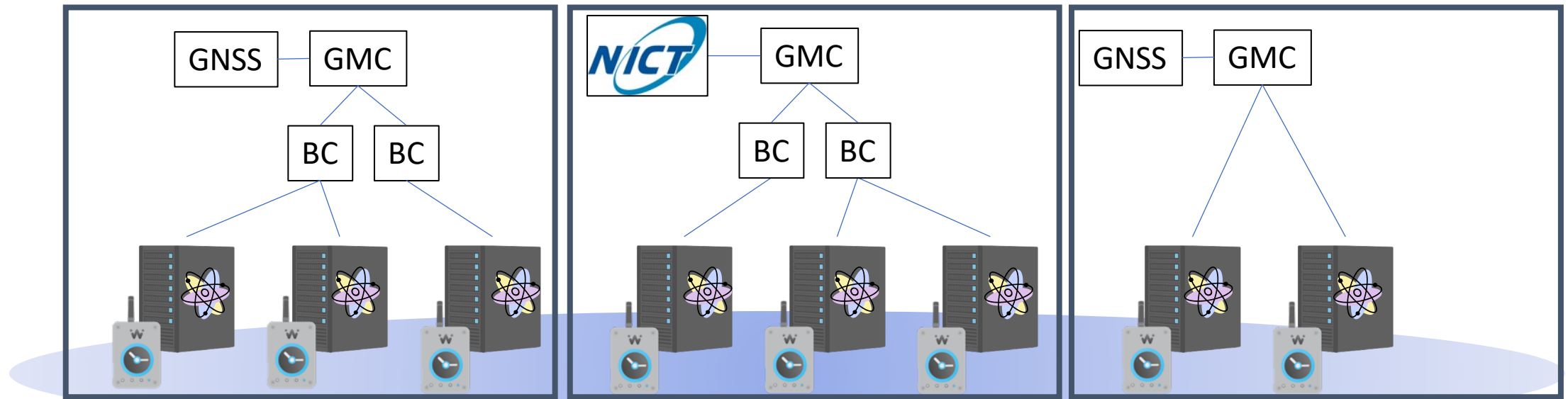- We have Wi-Wi in RCB form factor under development (Bord is ready).

Time card in big picture

- Time card is now equipped with 4-hat time comparison.
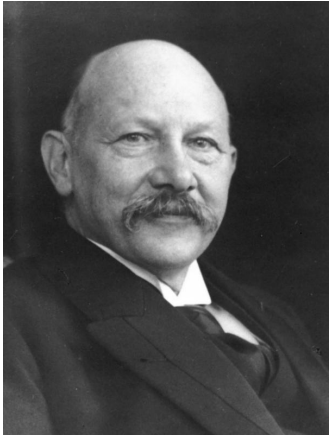- It means it can now pick the best clock autonomously (in theory).

Resilient time network

Wi-Wi over the air comparison
inter-connects different clock network

- Synchronization Over the air introduces another layer of regiliency.

Heike Kamerlingh-Onnes

- A guy who found Superconductivity?
- Yes, but his area of specialty is in Cryogen (Low temperature Physics)
- Nobel prize winner in 1913
- "for his investigations on the properties of matter at low temperatures which led, inter alia, to the production of **liquid helium**"

- Nature always surprise us when we enter into a new regime.
- Pico-second synchronization over wide area will surprise us!

Reflection of wireless signal causes problem?

Open Field

Reflective environment

— 30m Error!
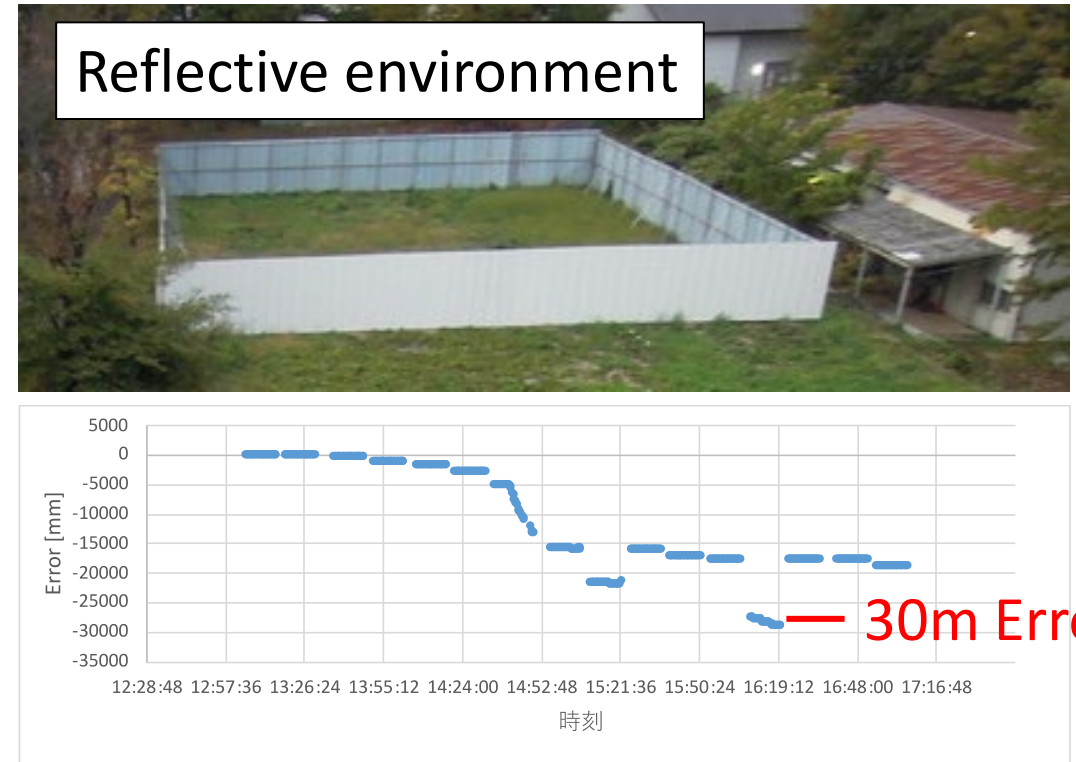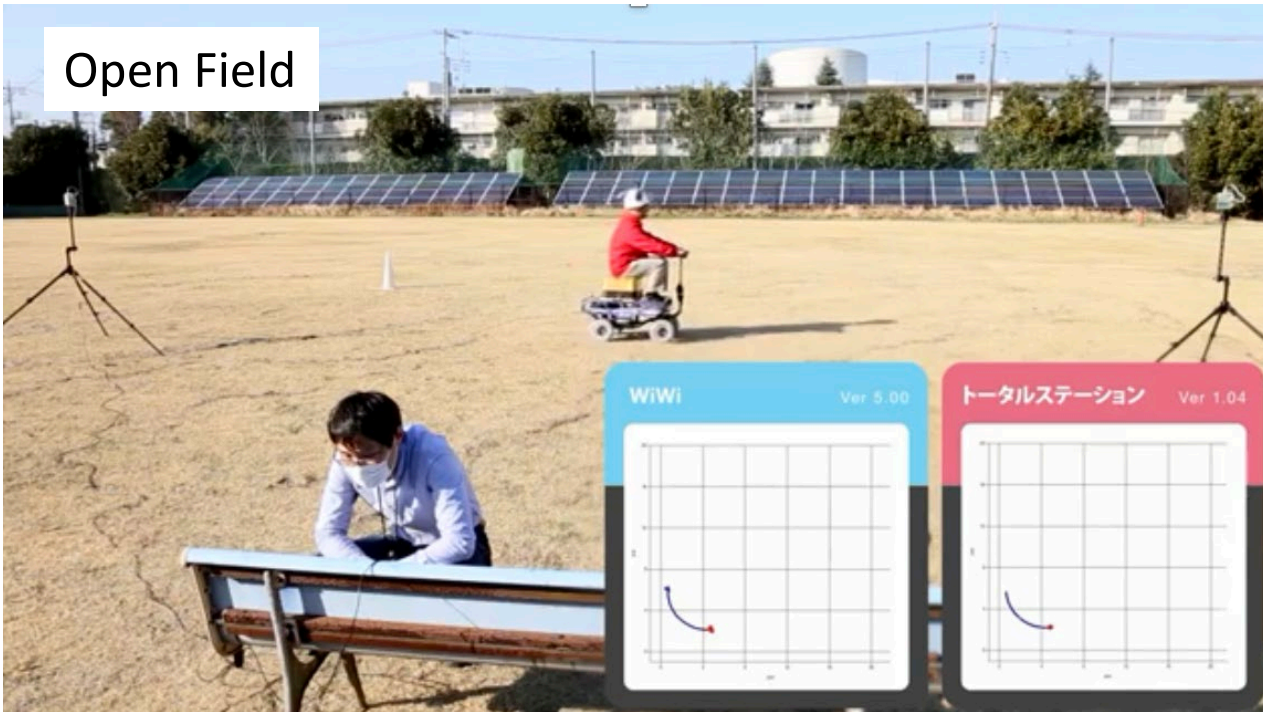
Propagation Phase → distance variation

Phase measurement affected by reflection

- We made use of "unwanted reflection"

Virtual Wiretap Channel
Based on
Wireless Two-way Interferometry
(Wi-Wi)

2022/12/4-8

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National Institute of Information and Communications Technology

(NICT) Japan

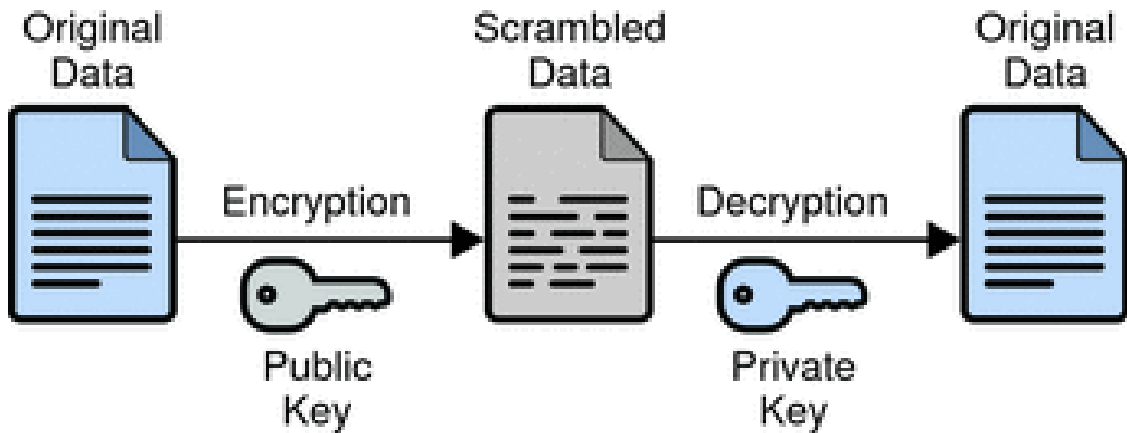N Shiga, S Yasuda, K Yonaga, K Takizawa, M Yoshida

email: shiga@nict.go.jp

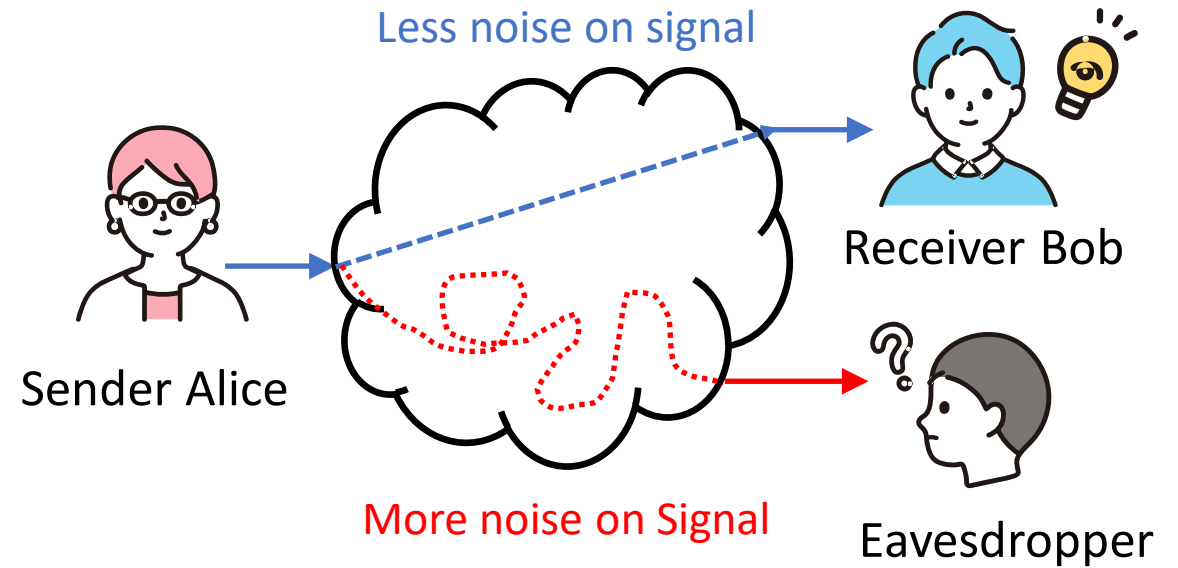- Slide from Globecom 2022: doi.org/10.1109/GLOBECOM48099.2022.10000896
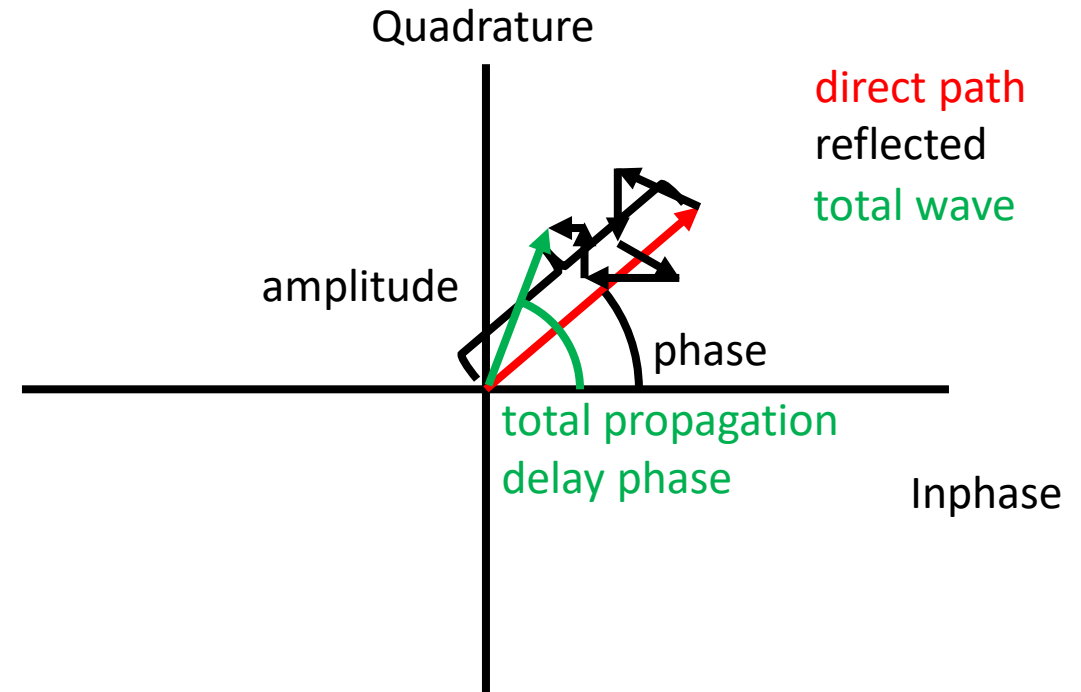
Physical Layer Security

Cryptosystems

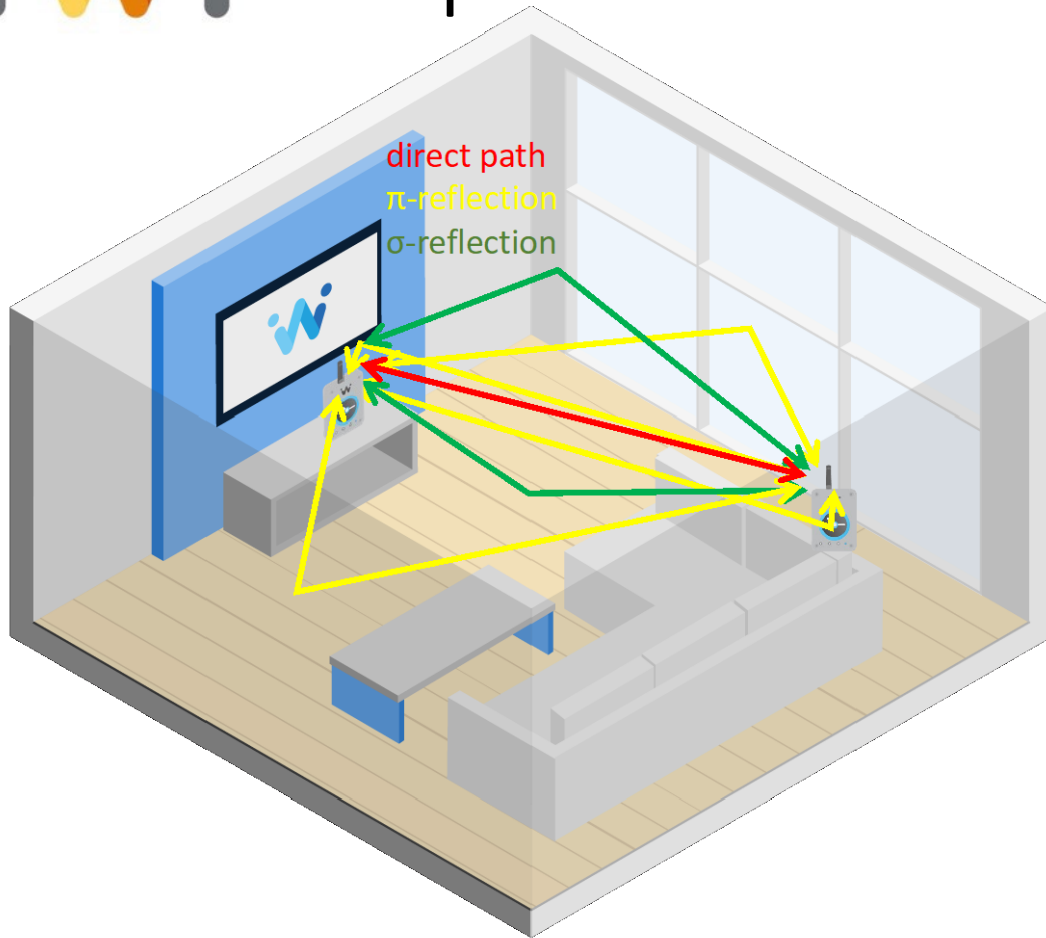- Mathematically reasonable but unproven security
- And/Or pre-shared secret key

Physical Layer Security

Less noise on signal

Receiver Bob

Sender Alice

More noise on Signal

Eavesdropper

- Security based on physical property of communication channel
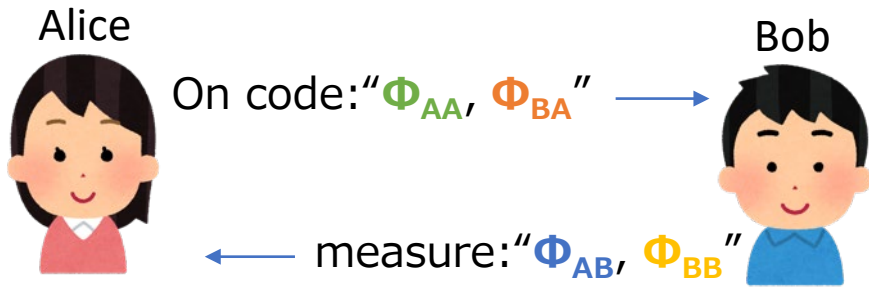- Quantum resistant security

Proposed Wi³-tap channel

- Wi-Wi can measure the **total propagation delay phase accurately**.
- One can send signal by modulating the clock and hide the modulation in the noise of total propagation delay phase.
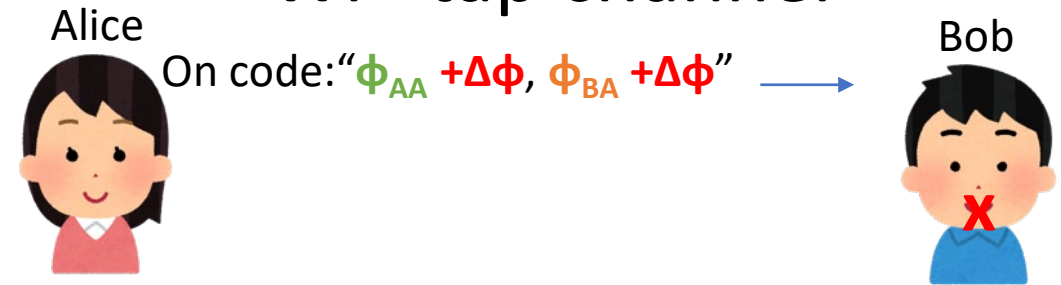
Wi-Wi and Wi³-tap protocol

Wi-Wi

Alice

Bob

On code: "Φ_{AA}, Φ_{BA}" →

← measure: "Φ_{AB}, Φ_{BB}"

$\Phi A \equiv \Phi AB - \Phi AA$

$\Phi B \equiv \Phi BA - \Phi BB$

$\Phi c \equiv (\Phi A - \Phi B) / 2$ (clock phase)

$\Phi d \equiv (\Phi A + \Phi B) / 2$ (Propagation phase)

Wi³-tap channel

Alice

Bob

On code: "$\Phi_{AA} + \Delta\phi$, $\Phi_{BA} + \Delta\phi$" →

$\Phi A \equiv \Phi AB - \Phi AA - \Delta\Phi$

$\Phi B \equiv \Phi BA - \Phi BB + \Delta\Phi$

$\Phi c \equiv (\Phi A - \Phi B) / 2 - \Delta\Phi$

$\Phi d \equiv (\Phi A + \Phi B) / 2$

- Alice modulate the measured value by $\Delta\phi$ and Bob sees it as a modulation on Φc.

Proposed Wi^3-tap channel

direct path

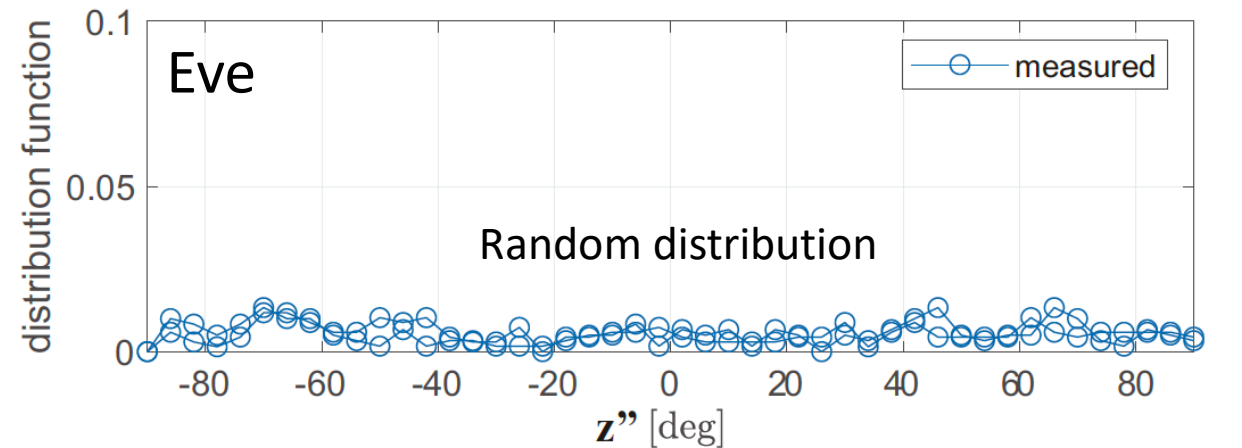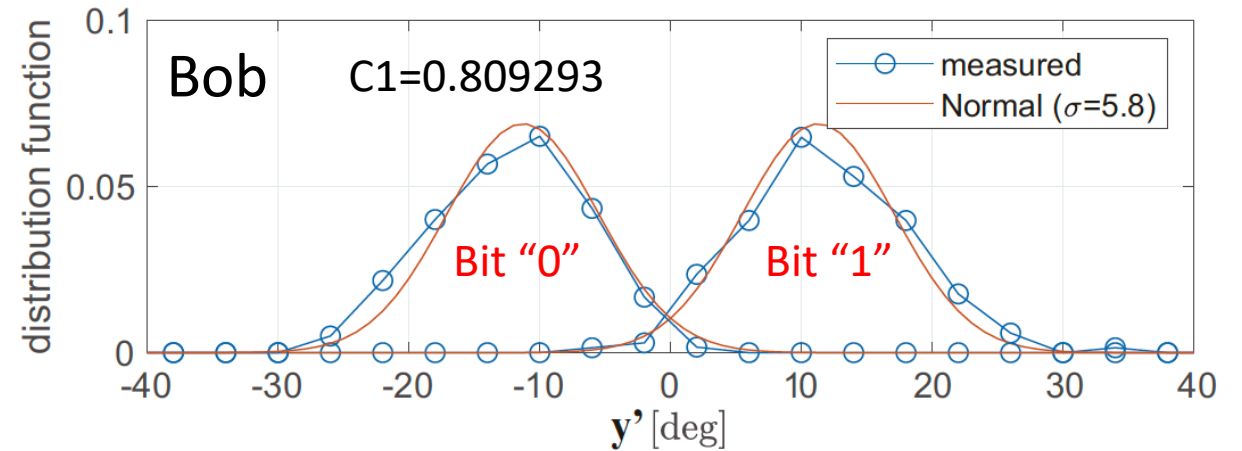- Wi-Wi can measure the clock difference and the **propagation delay phase**.

- We use dynamic reflective environment to hide message.

- It is almost **impossible to estimate** the propagation delay accurately for devices in a reflective environment.
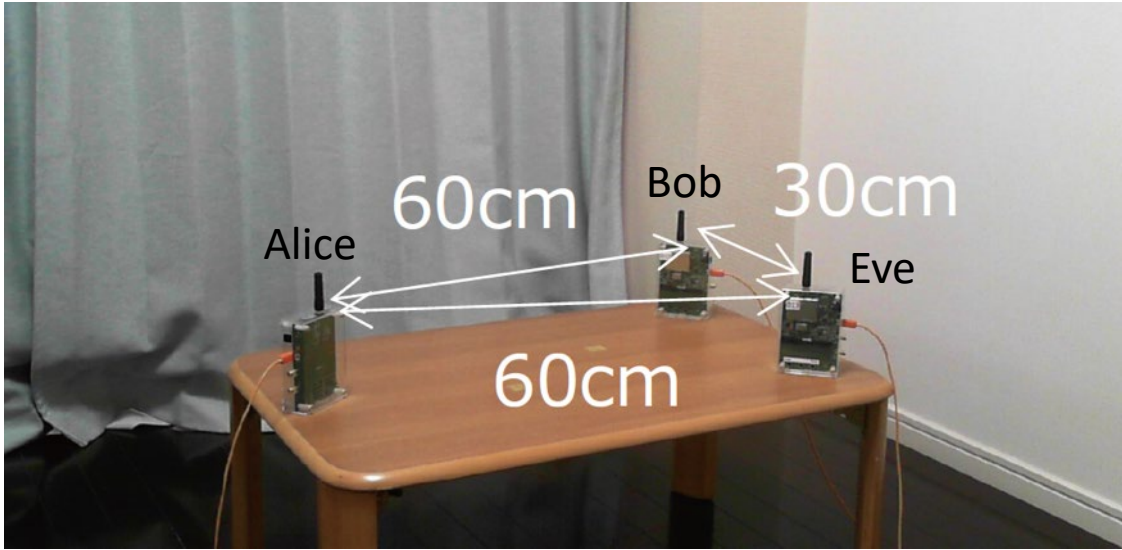
Experiment with Φd-Jammer
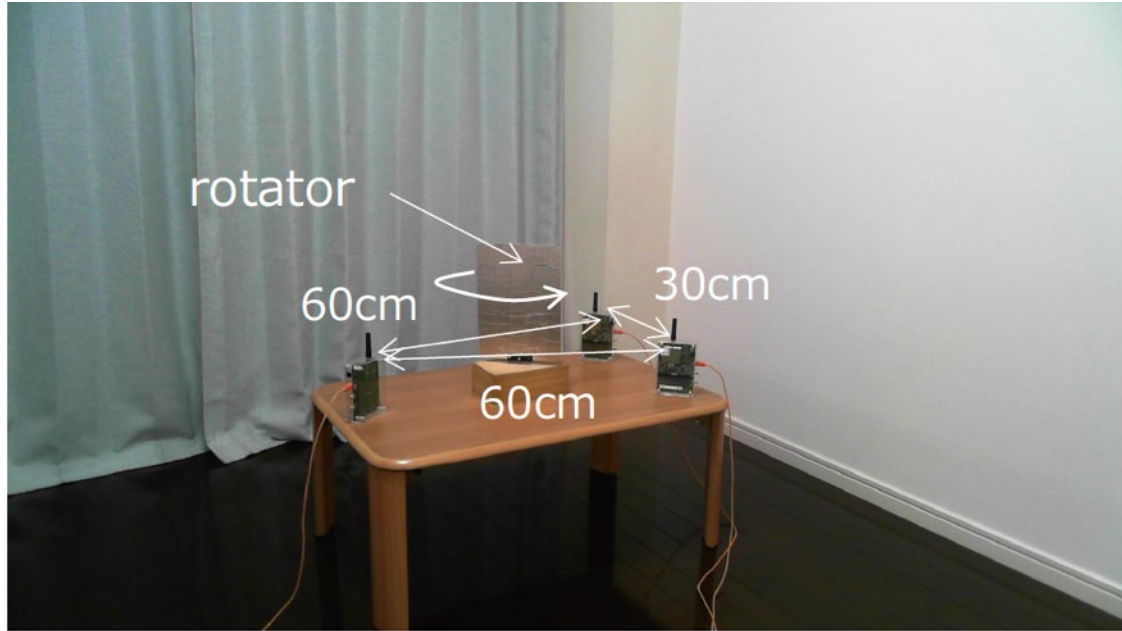
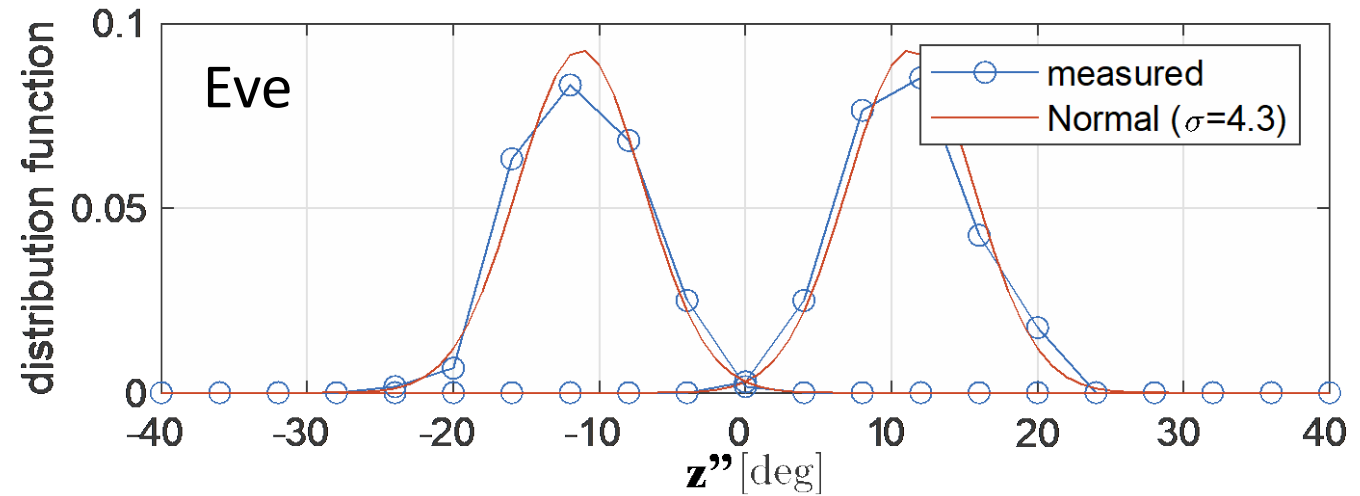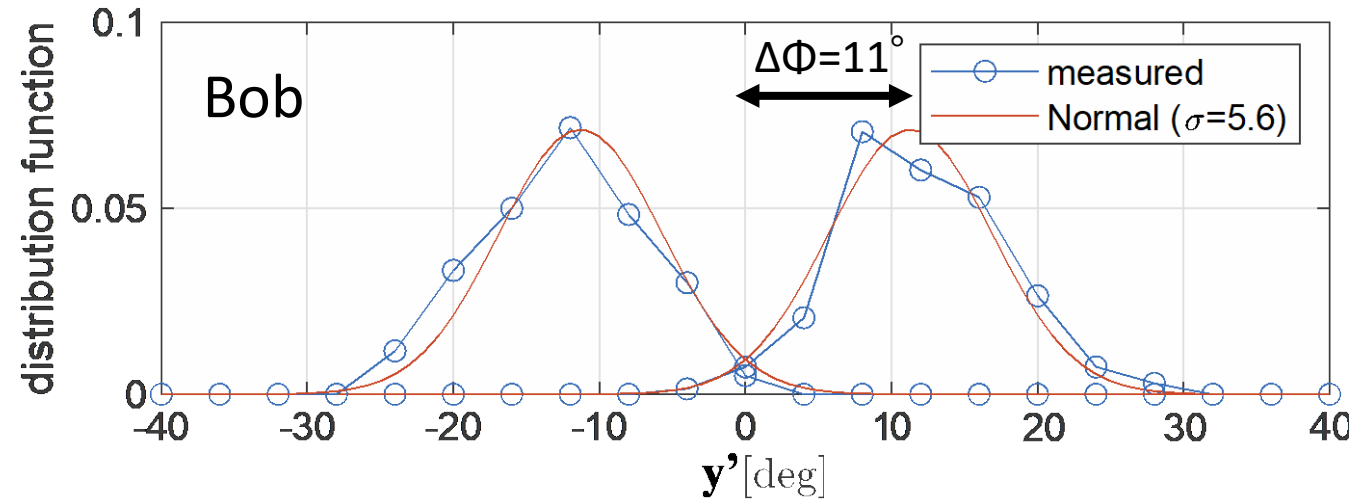- Φd-Jammer made the encryption work!
- Secrecy Capacity Cs=0.8
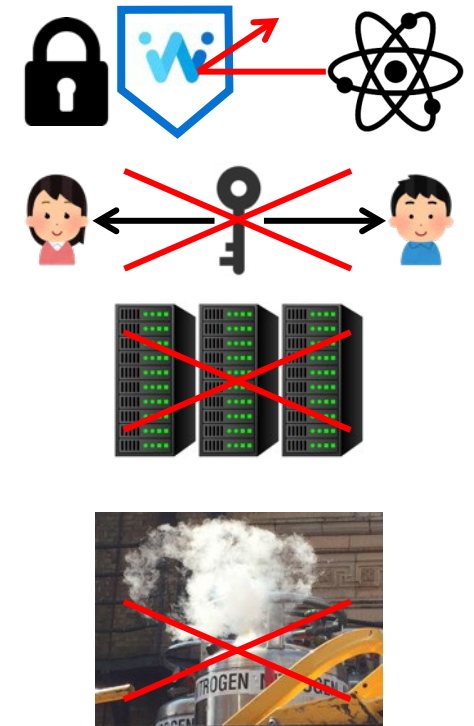
ϕ_d-Jammer is necessary

• If the propagation environment doesn't change, Eve can read the modulation through hi pass filter. (even better!)

Wi^3-tap channel has great potential

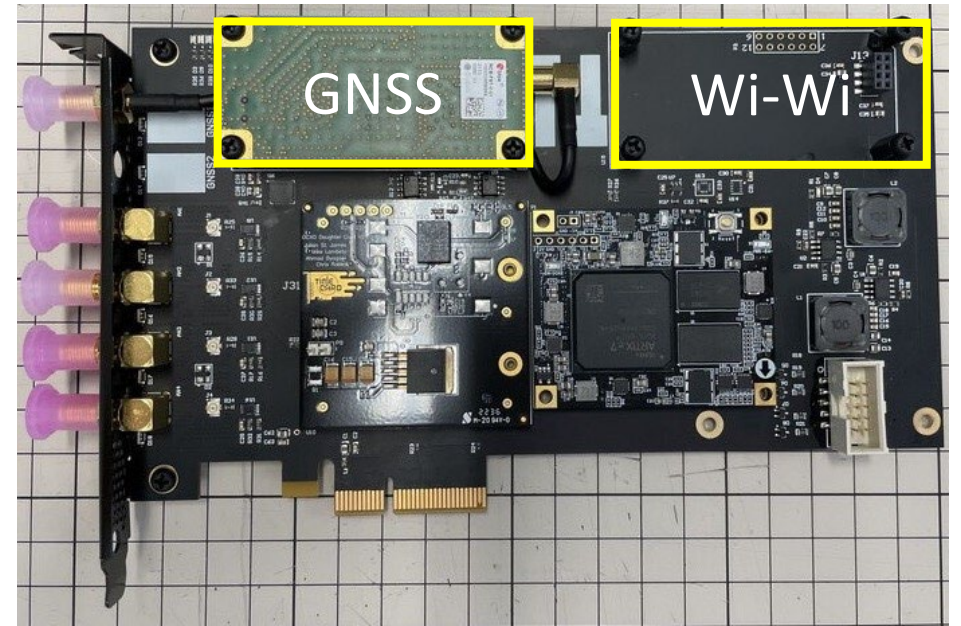Wi^3-tap channel is looking great because

- Quantum resistant cryptography
- No need of pre-shared key
- Requires little Computational resource
- No need of special equipment

The precision of Wi-Wi opens a new regime!

Conclusion

GNSS　　　Wi-Wi

- **Wi-Wi ✕ Time Card** for Data Center application.

- Wi-Wi will provide another route of time synchronization for robustness.

- **Wi-Wi for security**
  Accurate propagation delay measurement provides secure communication

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Let's get surprised by picosecond synchronization!