

Multiple Subcarrier Multiple Access: A Frequency Efficient Concurrent Wireless Access Method for Backscatter Sensors

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Who we are

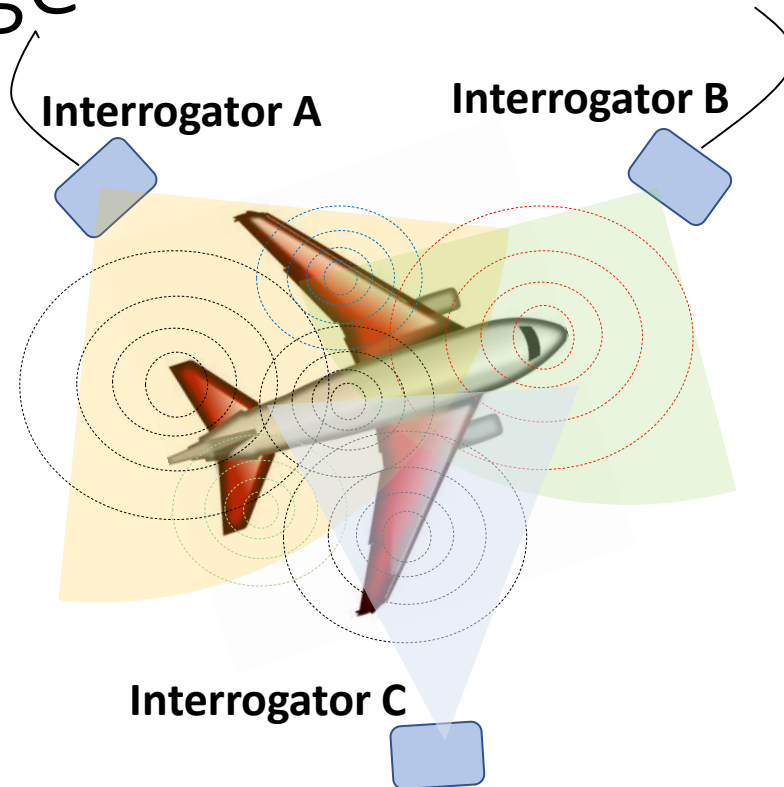
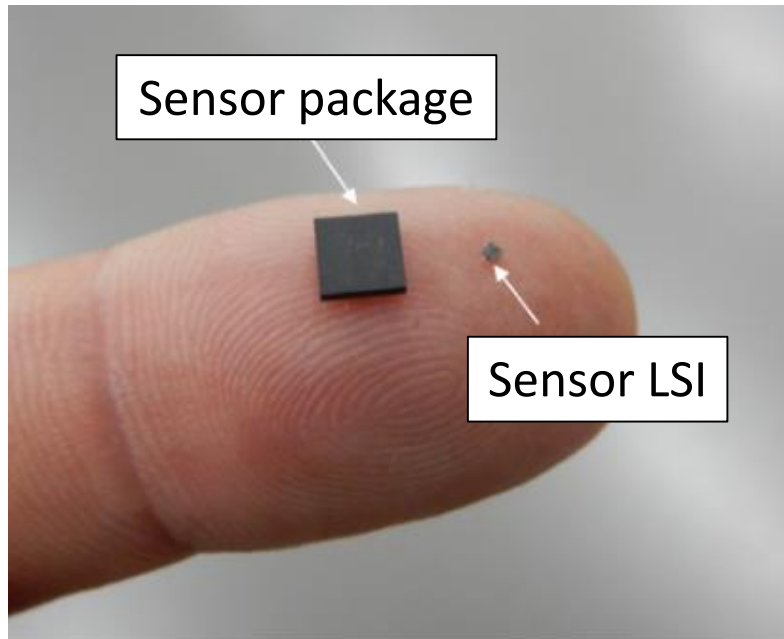
- We are a research team composed of 3 Japanese universities and 1 company.
- We have developed a wireless access technique, named **MSMA: Multiple Subcarrier Multiple Access**, for passive wireless sensors in structural health monitoring (SHM).
 - Fundamental theory has been developed and verified.
 - We are now looking for collaborators to conduct further researches for its practical realization.

Our goal & approach

- Battery-less wireless sensing for SHM.
 - Perfectly synchronized sensor data streaming from multiple sensor nodes.
 - 100~1000Hz sampling rate
 - Up to 70 sensors
 - Synchronization below 120μs
- Approach: utilizing backscatter communication
 - Commonly used in passive RFID. (**But it is TDMA!**)
 - Developing a method to realize simultaneous transmission from multiple backscatter sensor tags.

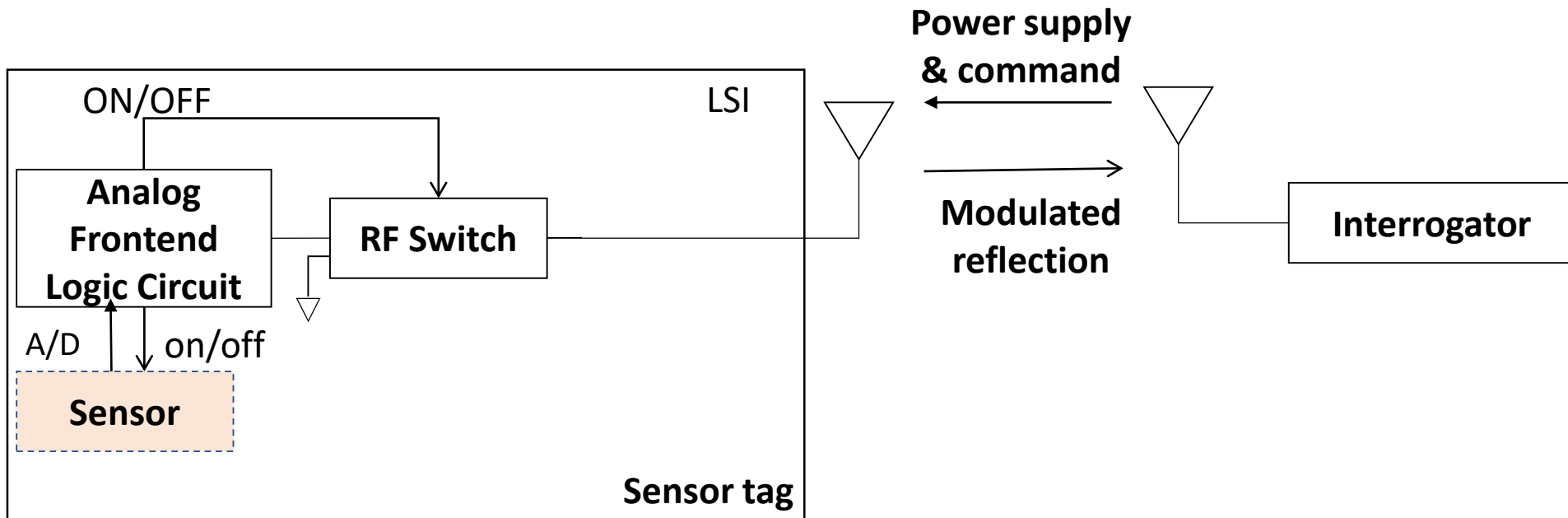
* Noel et.al. "Structural Health Monitoring using Wireless Sensor Networks: A Comprehensive Survey", IEEE Communications Survey, Vol.19, Issue 3, (2017) , pp.1403-1423.

Utilization image



- Implanting wireless battery-less LSI sensors into structures at the production time of their components.
- Feeding power from interrogators to multiple implanted sensors, then collecting sensor data streams simultaneously.
 - Perfectly synchronized sensor data streams from multiple sensors.

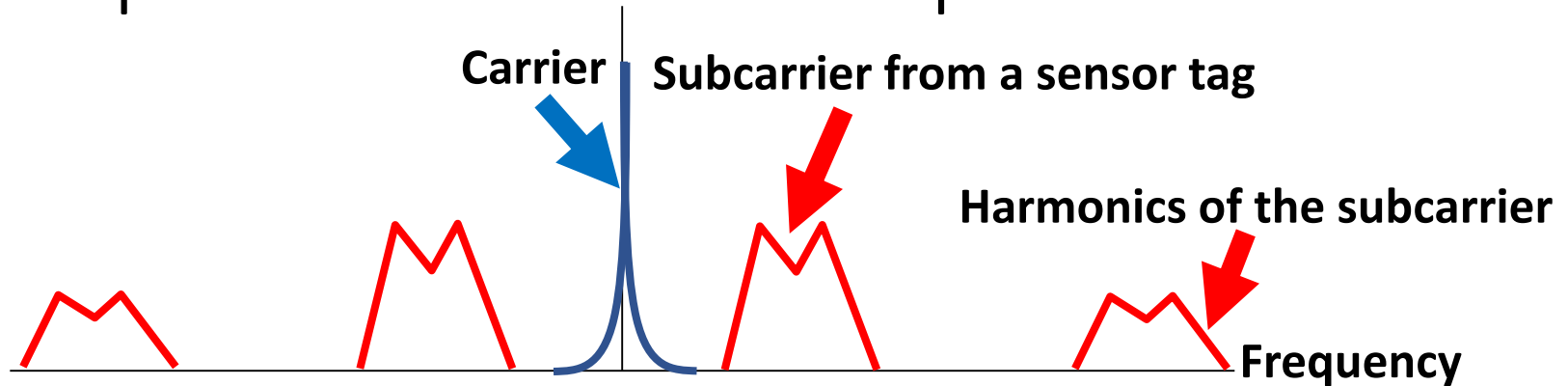
Backscatter sensors



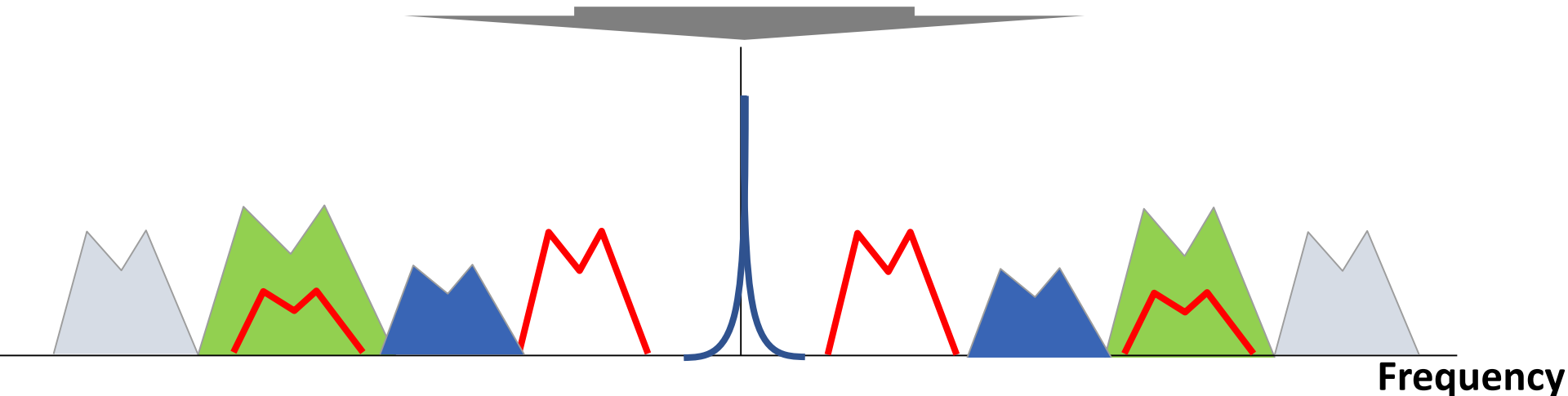
Functionalities are basically the same to existing RFID tags.

-> Possible to make battery-less LSI sensors.

MSMA: Multiple Subcarrier Multiple Access



Subcarrier generation at the sensor tag incurs inevitable harmonics.



MSMA cancels interference from subcarrier harmonics at interrogator side. -> **Simultaneous transmission with dense frequency utilization**

Interference rejection

Received signals
at an interrogator

$$\begin{Bmatrix} R_\phi \\ R_{2\phi} \\ R_{3\phi} \\ R_{4\phi} \end{Bmatrix} =$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \frac{1}{3} & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transmitted signals
at sensor tags

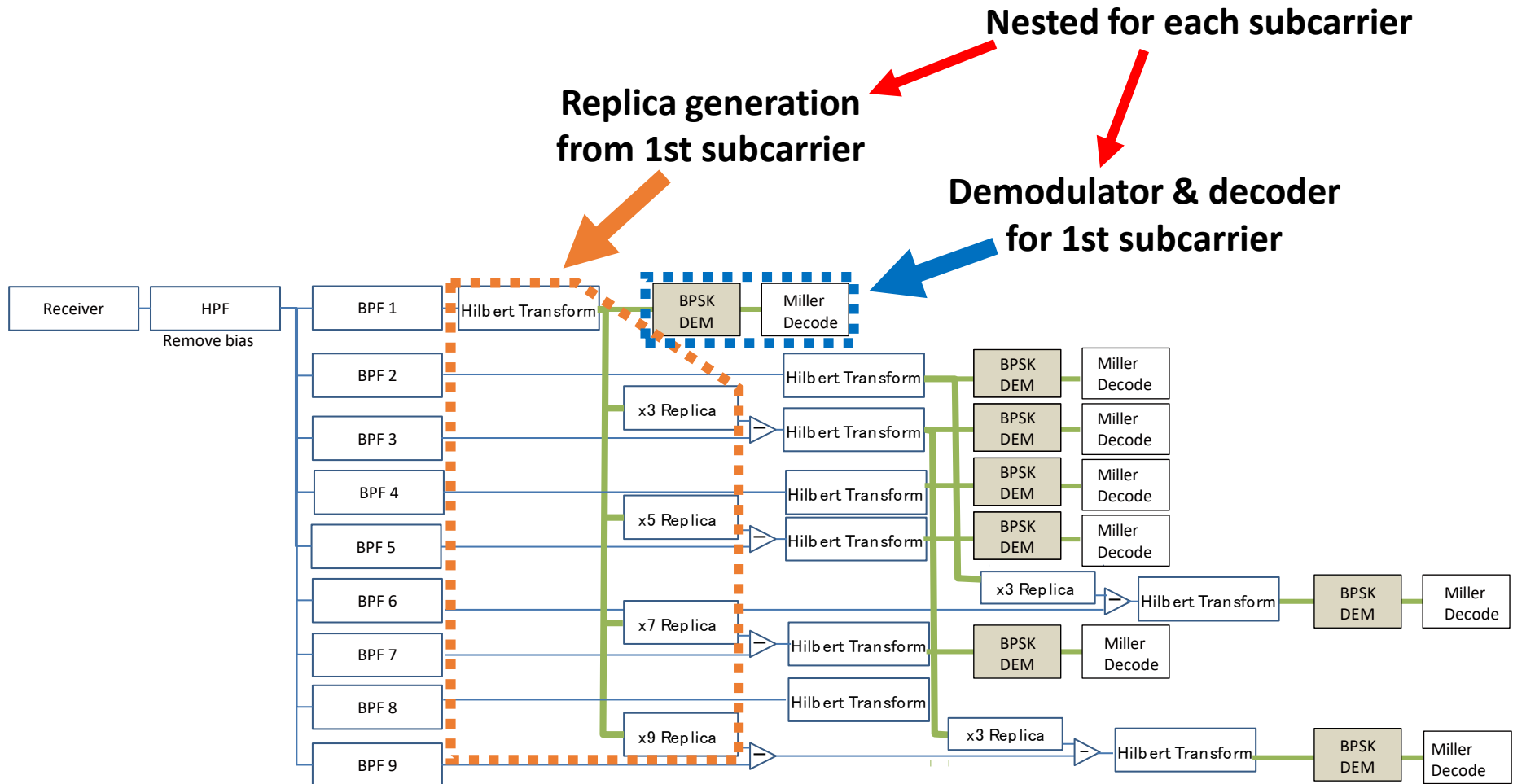
$$\begin{Bmatrix} T_\phi \\ T_{2\phi} \\ T_{3\phi} \\ T_{4\phi} \end{Bmatrix}$$

$$\begin{aligned} T_\phi &= R_\phi \\ T_{2\phi} &= R_{2\phi} \\ T_{3\phi} &= R_{3\phi} - \frac{1}{3}R_\phi \\ T_{4\phi} &= R_{4\phi} \end{aligned}$$

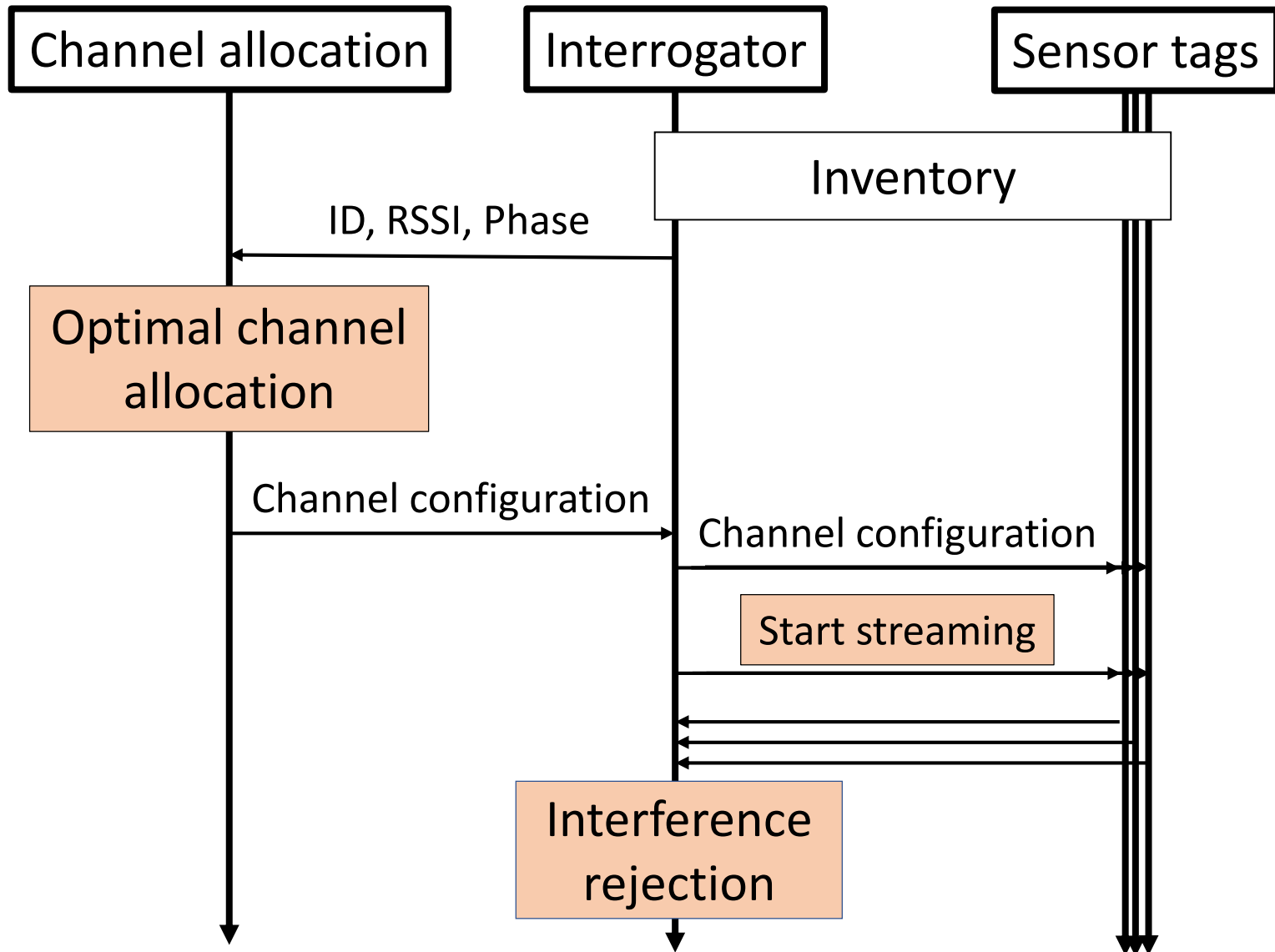
Lower triangular matrix

Forward substitution can
resolve transmitted signals.

Interrogator diagram



MSMA communication protocol



Considerations on protocol & radio regulation

- Concepts of existing passive RFID protocols, such as UHF Gen2, can be used, but need extension.
- Current implementation is based on Japanese UHF passive RFID regulation.
 - Different for each countries/regions.
 - (In Japan) 4W EIRP around 920MHz.
 - Higher transmitter power will expand interrogation zone.
 - Higher carrier frequency will realize smaller antenna.
- International standards/regulations are needed.

Prototype sensor tag

Antenna

CPLD

MCU

Power
harvester

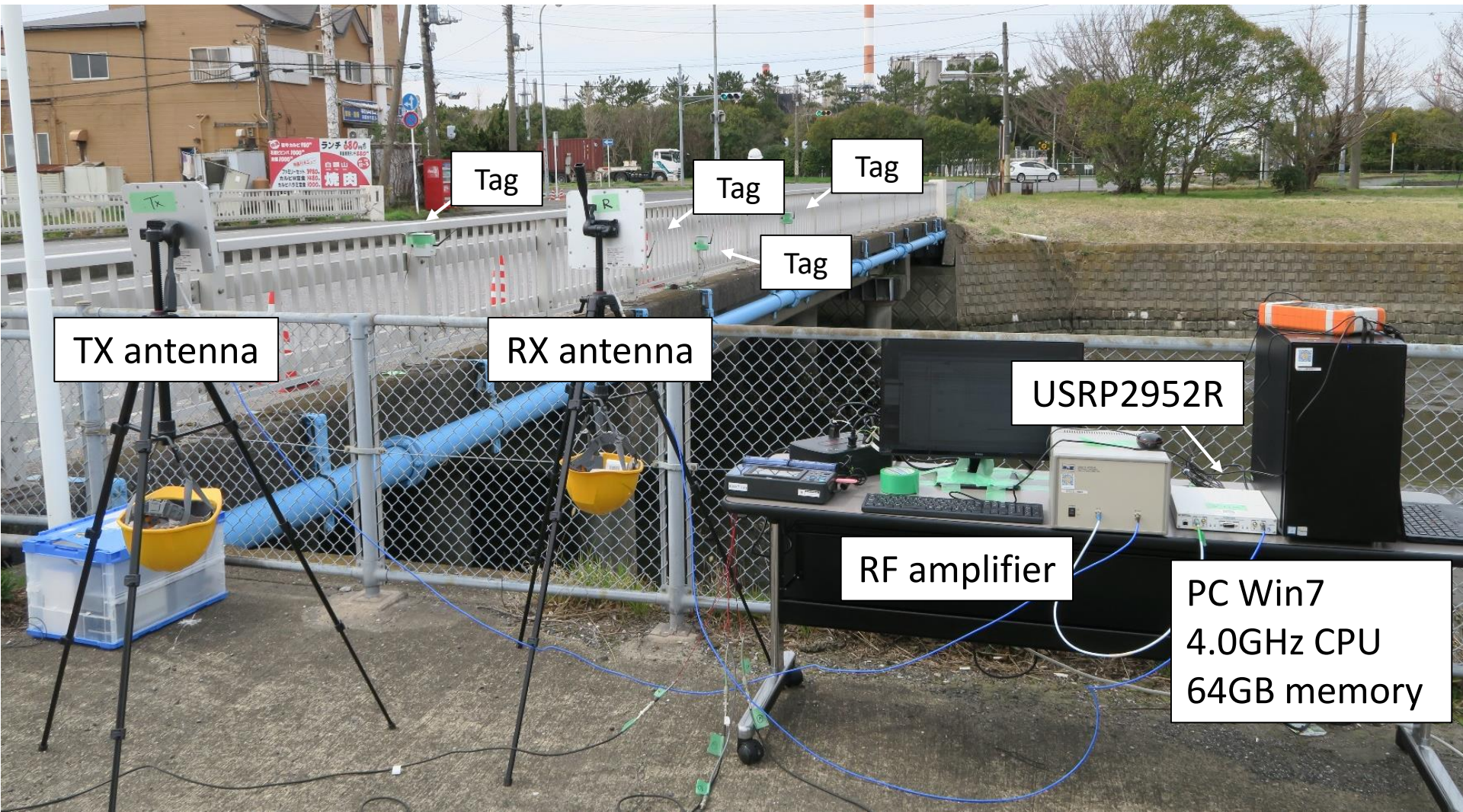
Power supply

Analog sensor input

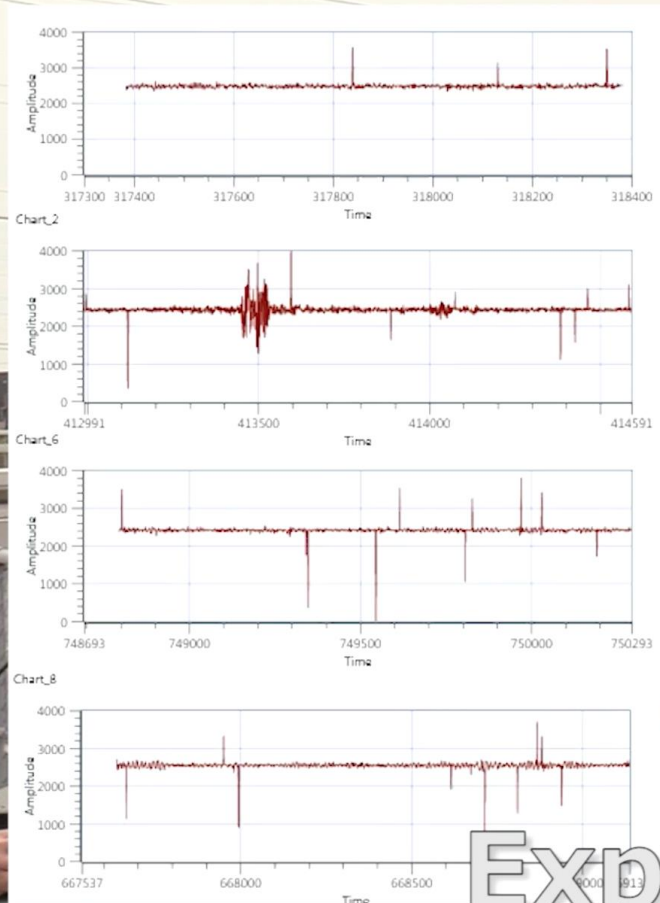


Functionalities are basically the same to existing RFID tags.
Currently battery-powered, but LSI can be battery-less.

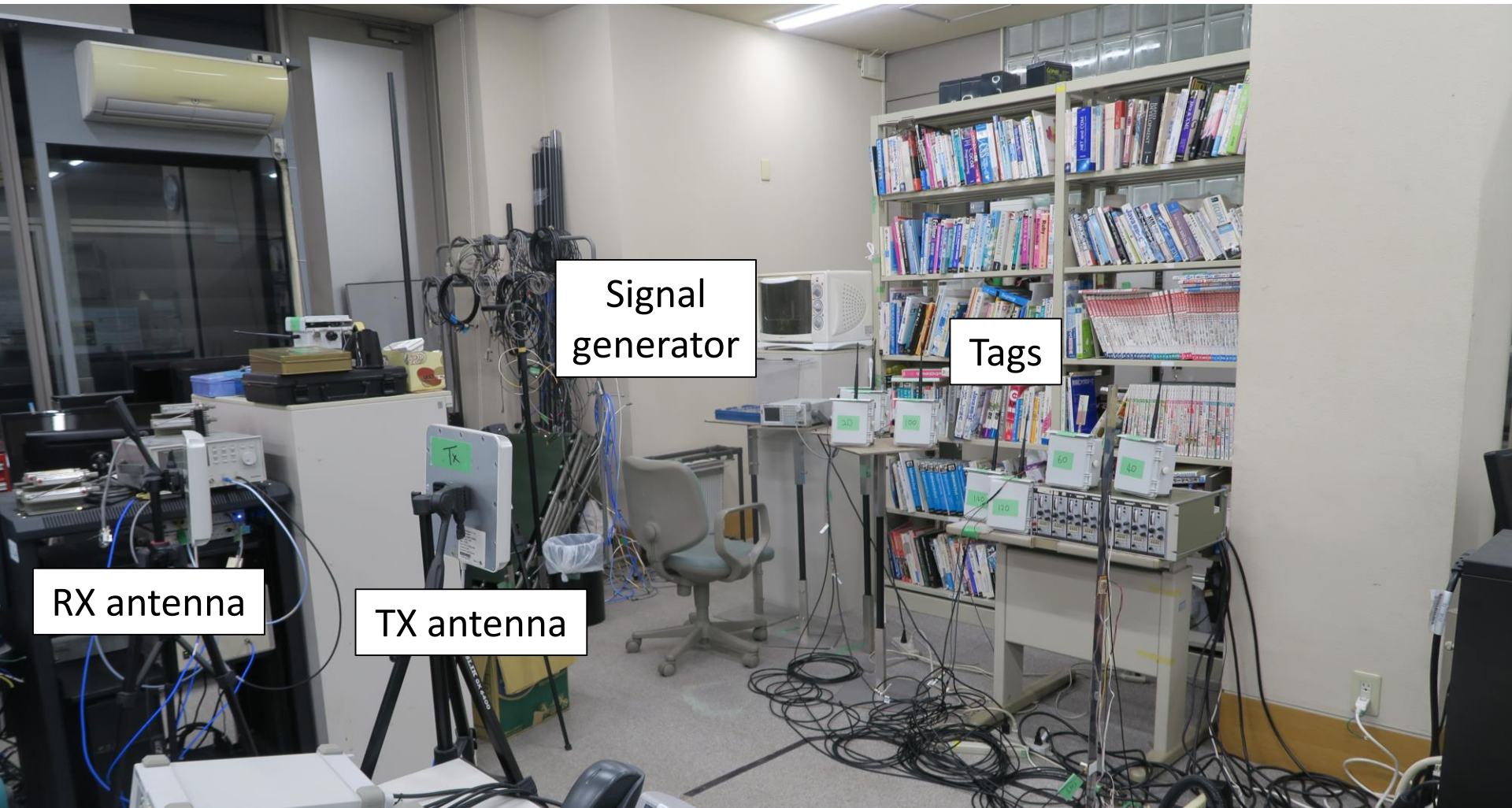
Prototype interrogator with SDR



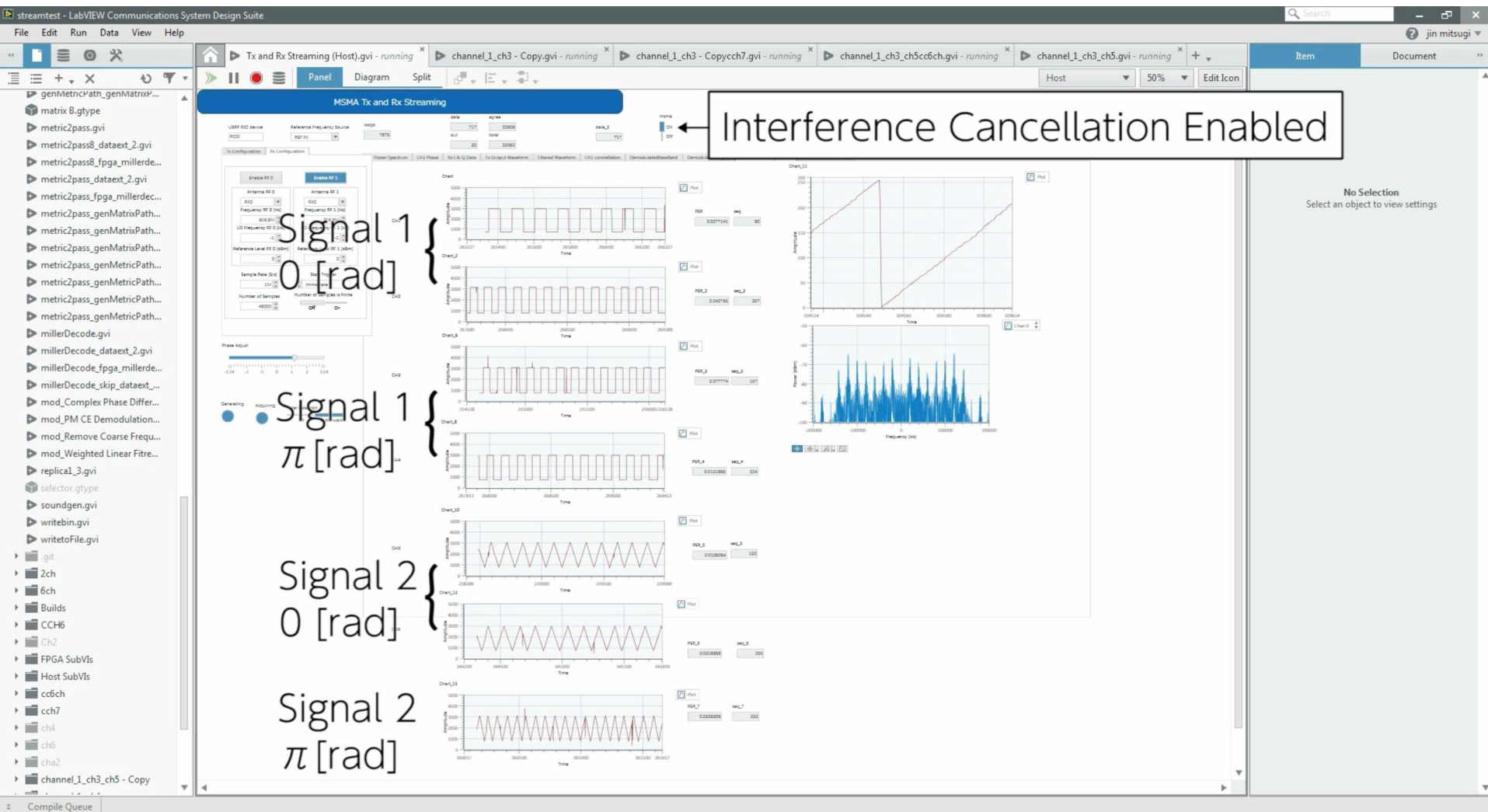
Outdoor experiment (Vibration measurement of a bridge)



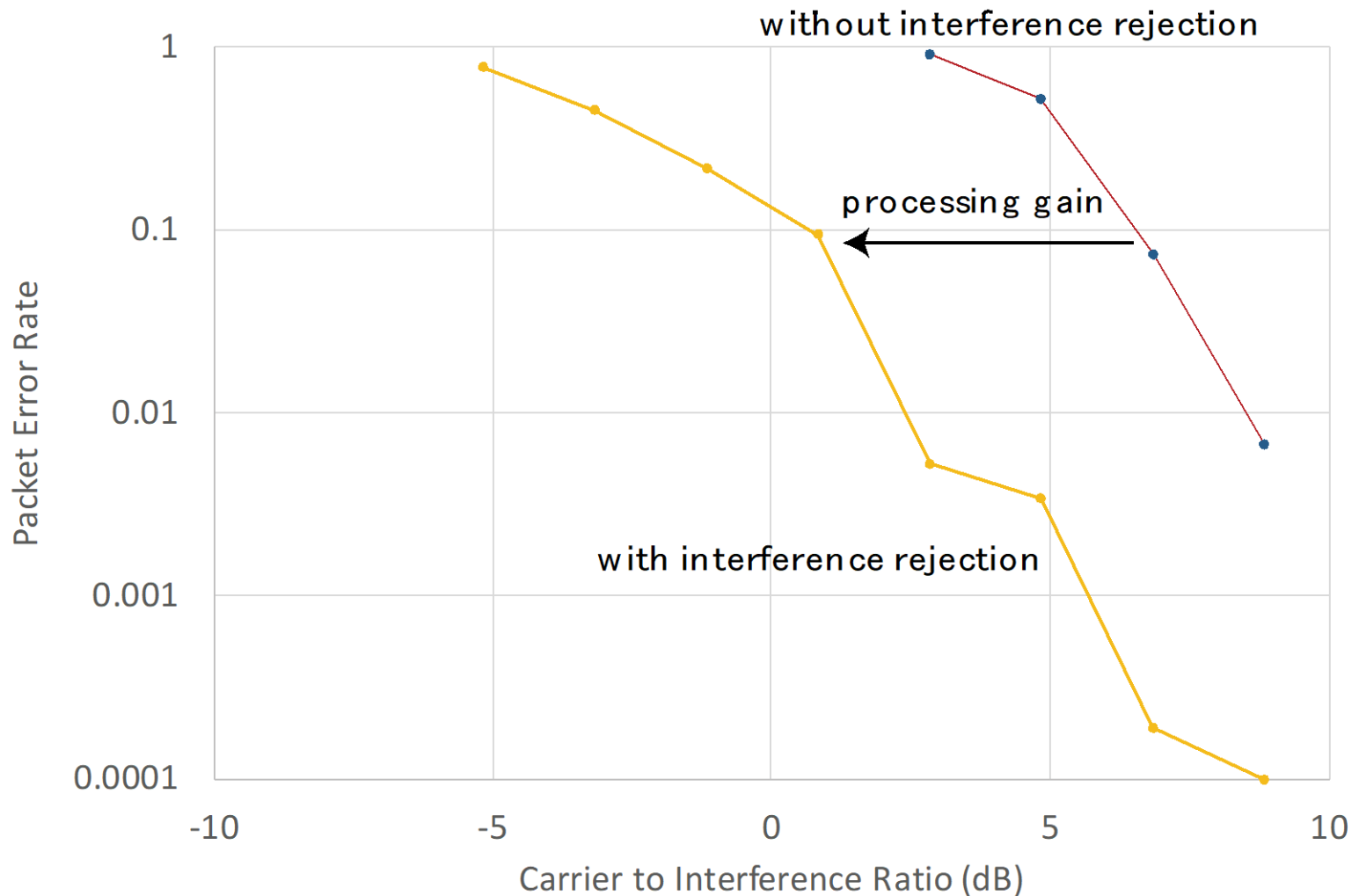
Indoor experiments setup



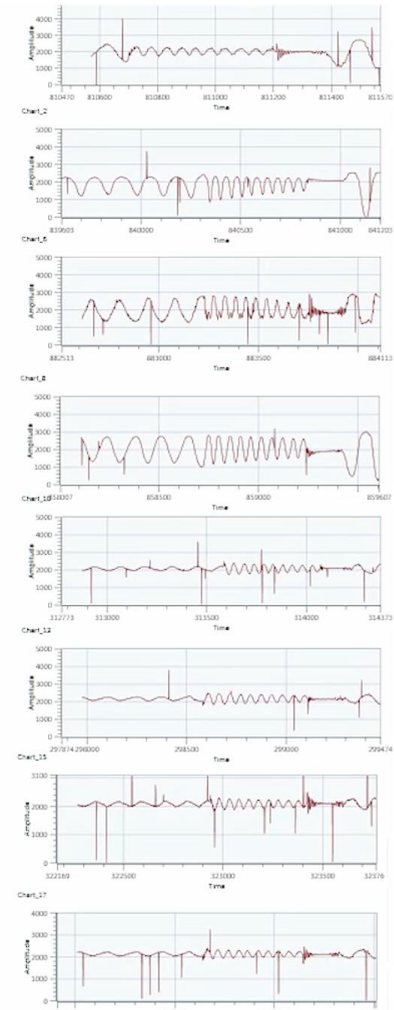
Interference rejection effect (7ch wireless transmission)



Interference rejection effect (wired measurement)



8ch strain & acceleration



MSMA
Strain/Acceleration Meas.

Conclusion

- MSMA: Multiple Subcarrier Multiple Access
 - Interference rejection at the interrogator side realizes simultaneous sensor data streaming from multiple backscatter sensors.

**We are going to launch a research consortium.
Please join & support us.**

What we are going to work on

- Fast and robust interrogator
- Sensor tag LSI
- Multi-zone operation
- Communication protocol implementation
- International standardization & radio regulation
- System integration