

# Extension of Interrogation Zone of Backscatter Sensors with Multiple Interrogators

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# Agenda

- Backscatter communication overview
- Multiple zone backscatter communication technology
  - Problem definition
  - Real-time and blind separation of collided backscatters
- Backscatter communications research consortium at Keio university update.

# History of Maintenance of artifacts

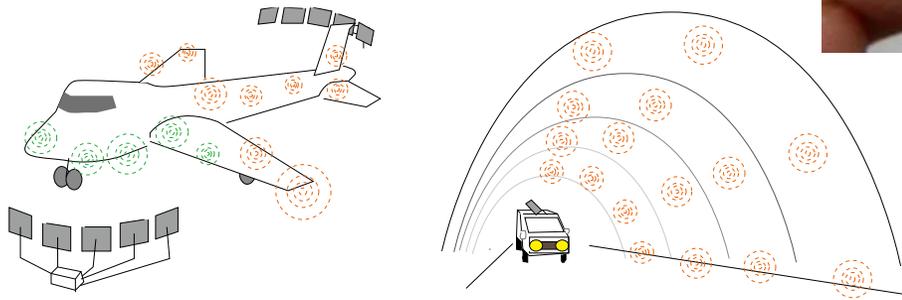
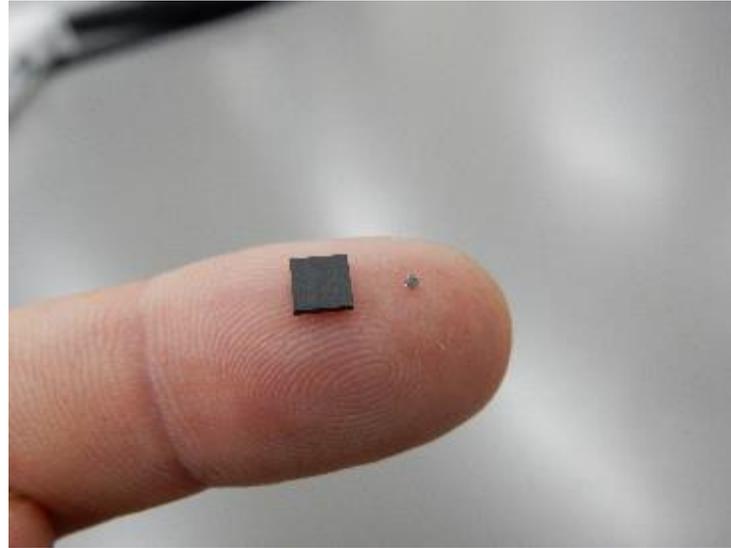
- First Generation (1940-1950)
  - Reactive Maintenance: Fix when something go wrong.
- Second Generation (1950-1980)
  - Preventative Maintenance: Time-based Maintenance
- Third Generation (1980- present)
  - Predictive/Proactive Maintenance: Condition-based Maintenance

# Challenge for Predictive/Proactive Maintenance

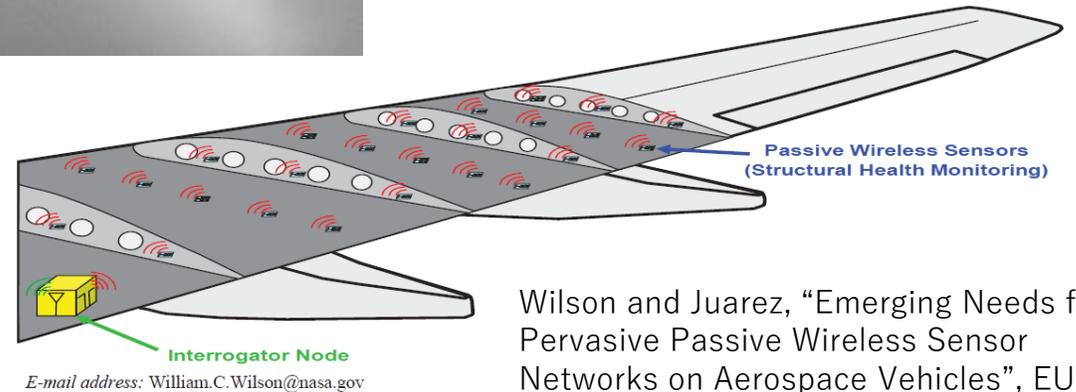
- Collect many data including **in operation data**

-> Batteryless and wireless sensing with ultra small sensors.

# Big Picture: Proactive maintenance with implanted batteryless and wireless sensors



Daily sensing/diagnosis without sacrificing the operation



E-mail address: William.C.Wilson@nasa.gov

Wilson and Juarez, "Emerging Needs for Pervasive Passive Wireless Sensor Networks on Aerospace Vehicles", EUSPN-2014.

Fig. 1. Concept for pervasive passive wireless sensors for structural health monitoring for aerospace vehicles.

In operation monitoring

# Application Area: Aerospace

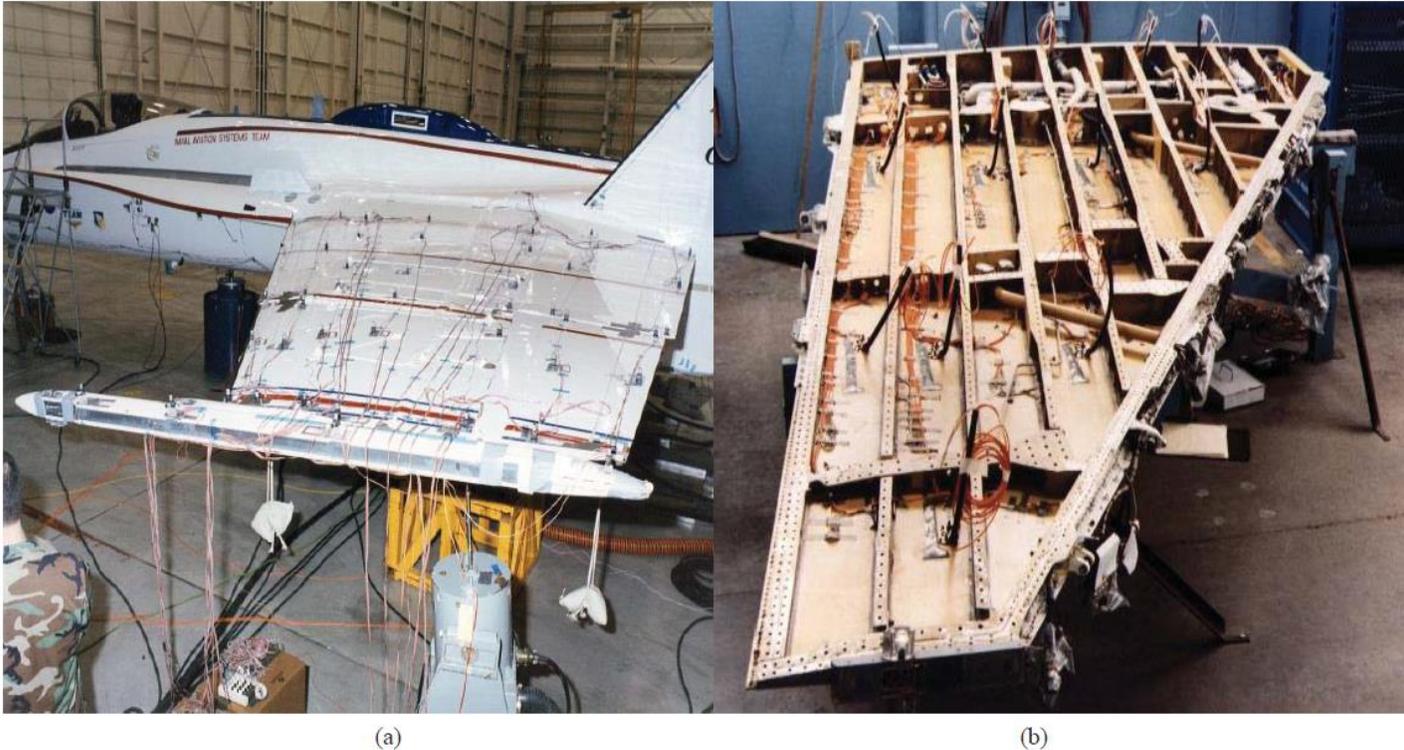
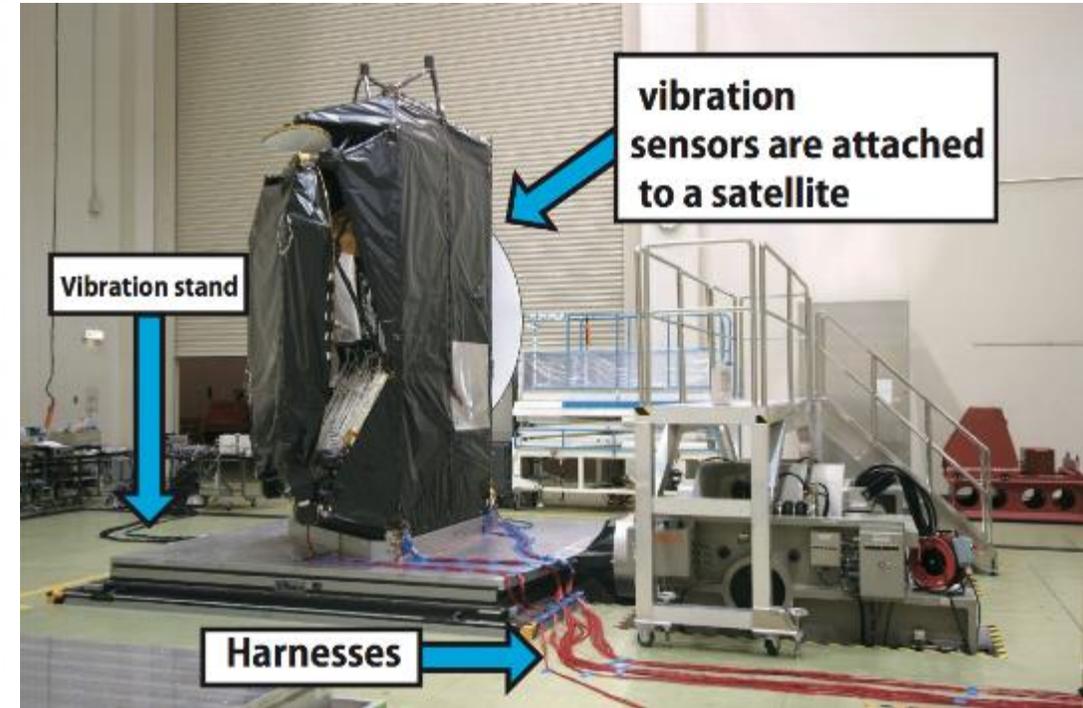
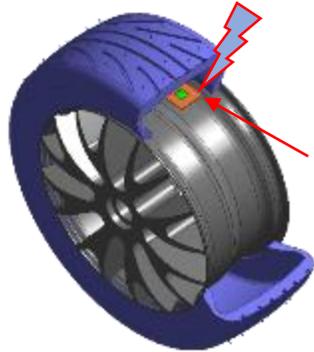


Fig. 6. (a) Accelerometer wiring hanging down from an F/A-18 test aircraft at NASA Armstrong Research Center.  
(b) Strain gauge wiring (orange wires) installed on the interior of the AFTI/F-16 wing.

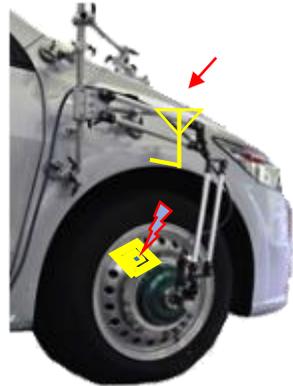


Wilson and Juarez, "Emerging Needs for Pervasive Passive Wireless Sensor Networks on Aerospace Vehicles", EUSPN-2014.

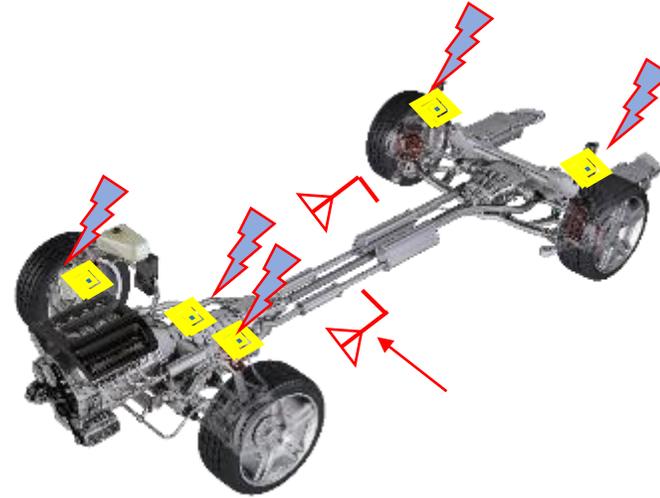
# Application Area: Automobile/Industrial Machines



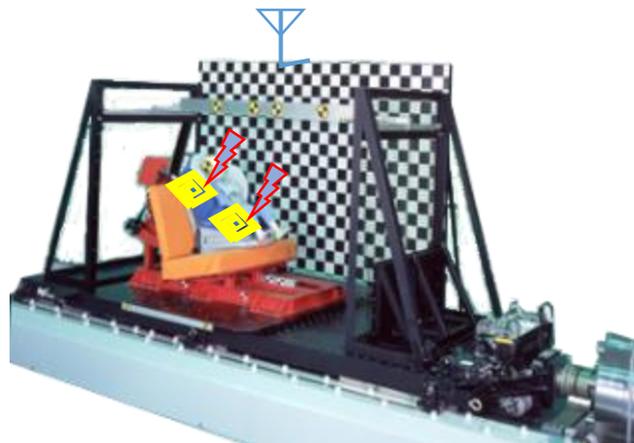
Pressure



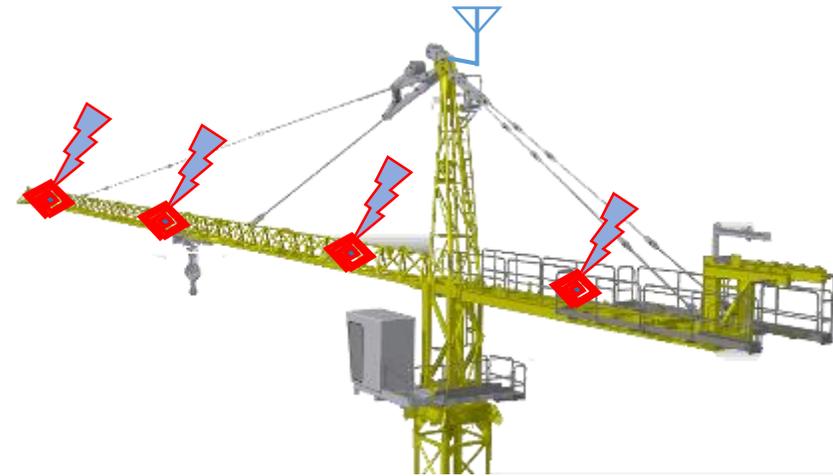
Acceleration



Acceleration Strain



Acceleration



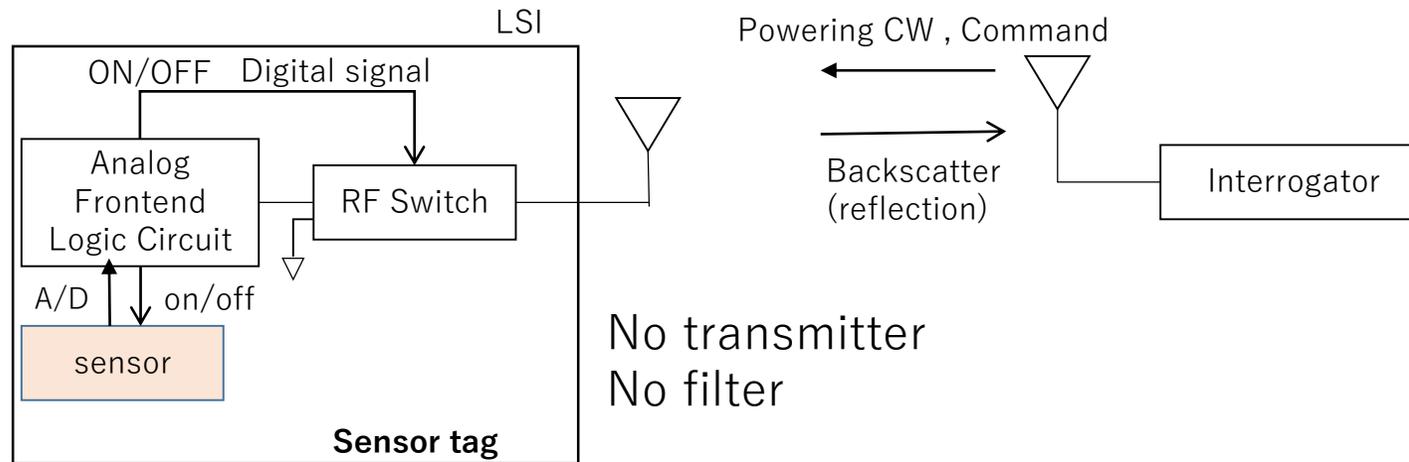
Vibration/Displacement

# Wireless SHM requirements

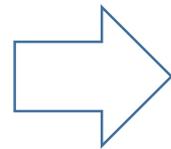
- Sampling rate is from 100 Hz to 1000Hz
- Number of sensors is up to 70
- Sensor data synchronization is below 120 micro second

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

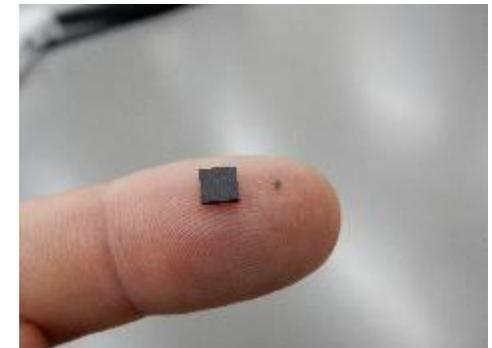
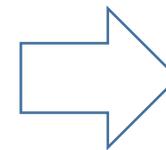
# Batteryless and Wireless Sensing with Backscatter Sensors



Battery-assisted with power harvester



Battery-assisted



Batteryless

# Pros and Cons of backscatter communication

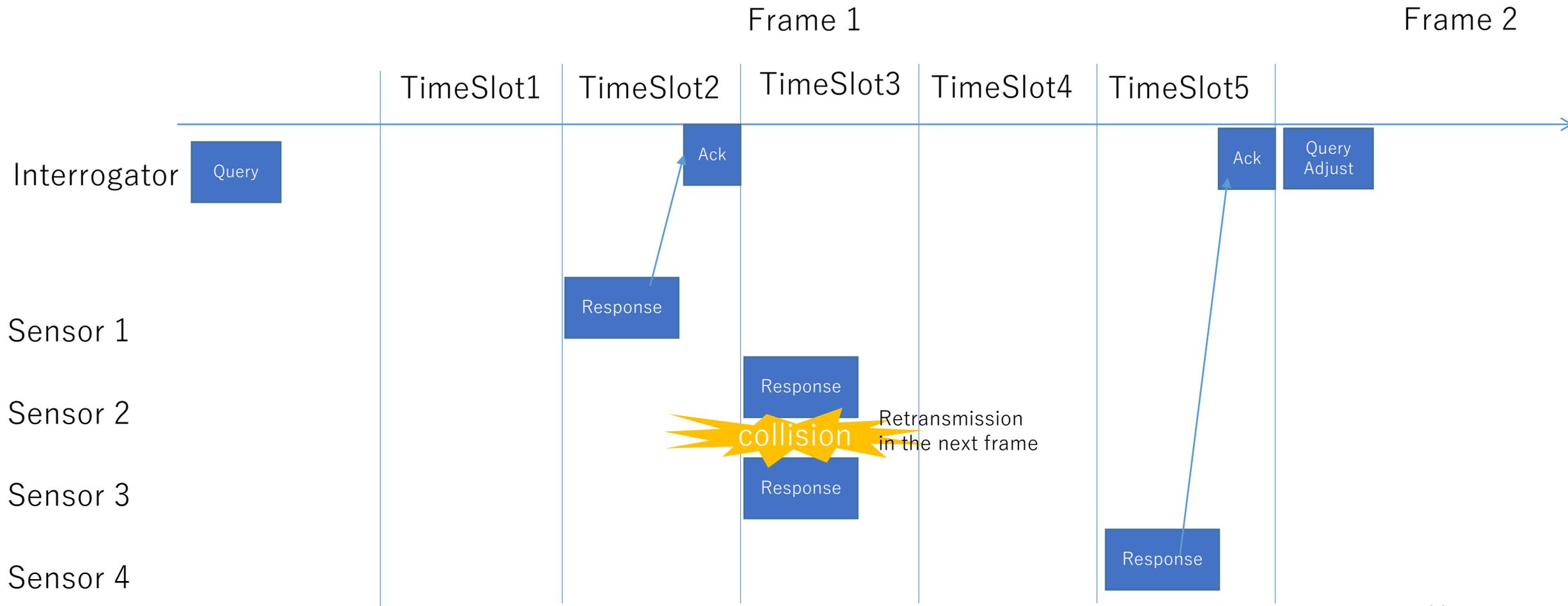
- Pros

- Can be batteryless.
- Sensors can be very cheap and small.
- Non line-of-sight sensing is possible.

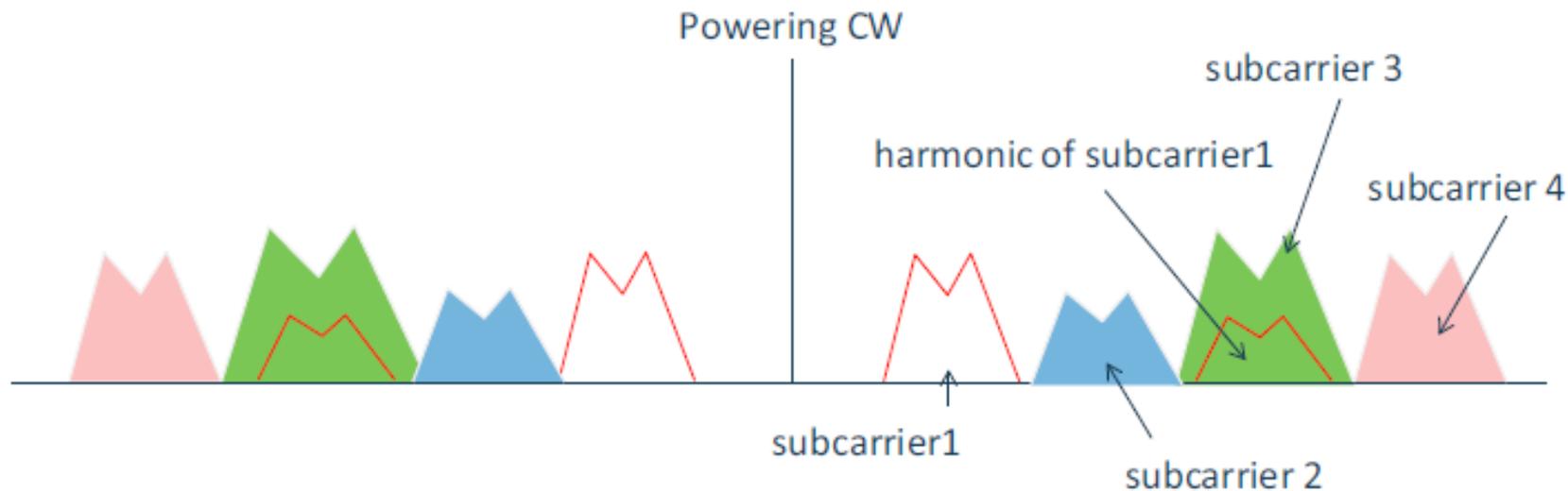
- Cons

- Interrogation distance is short (less than 20m for 4W reader/writer.)
- Concurrent access from sensors is conventionally difficult. (we solved this.)

Traditional multiple access of backscatter system is time division = Concurrent sensing is impracticable

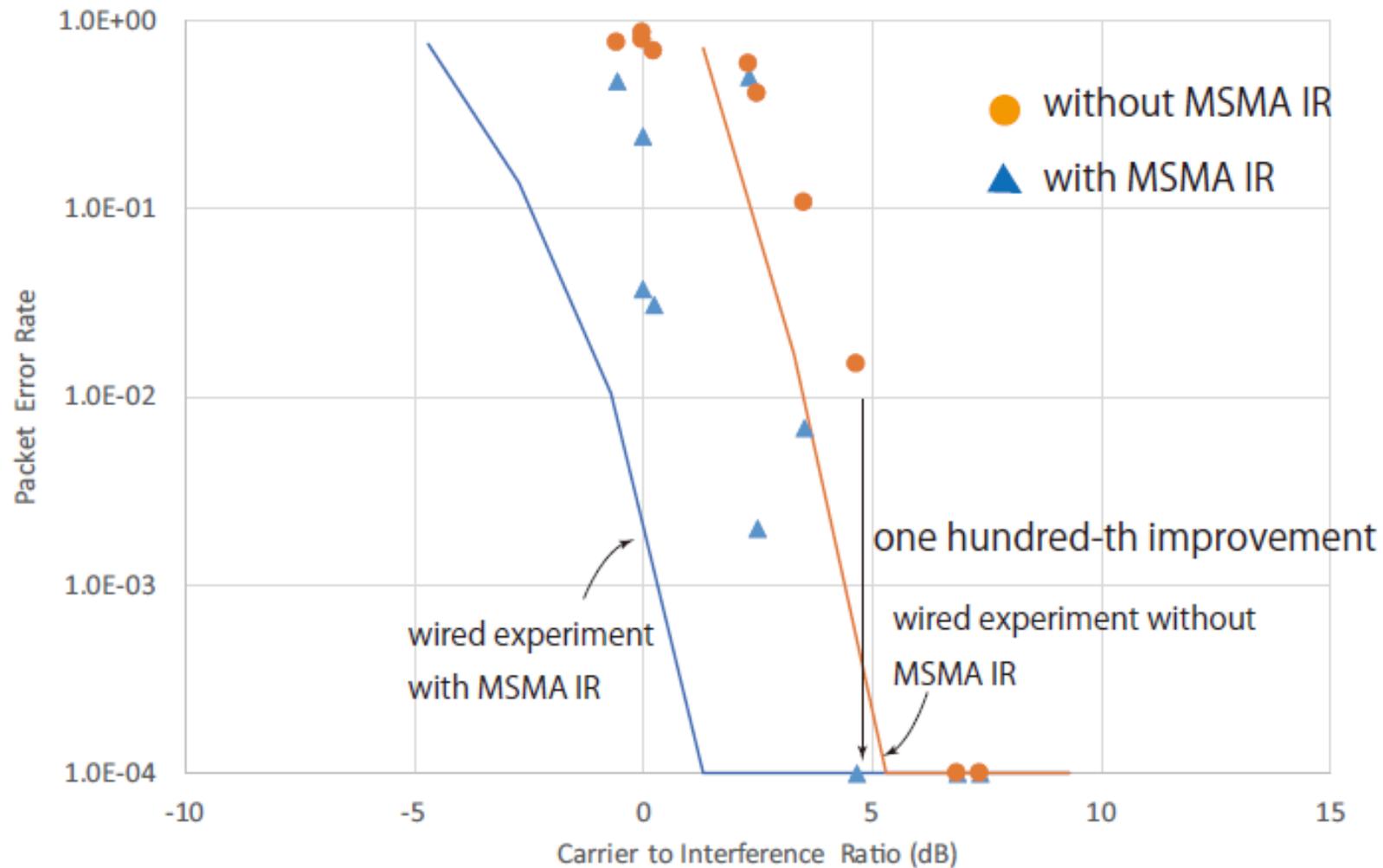


Concurrent use of multiple backscatter causes interference because of the absence of filter



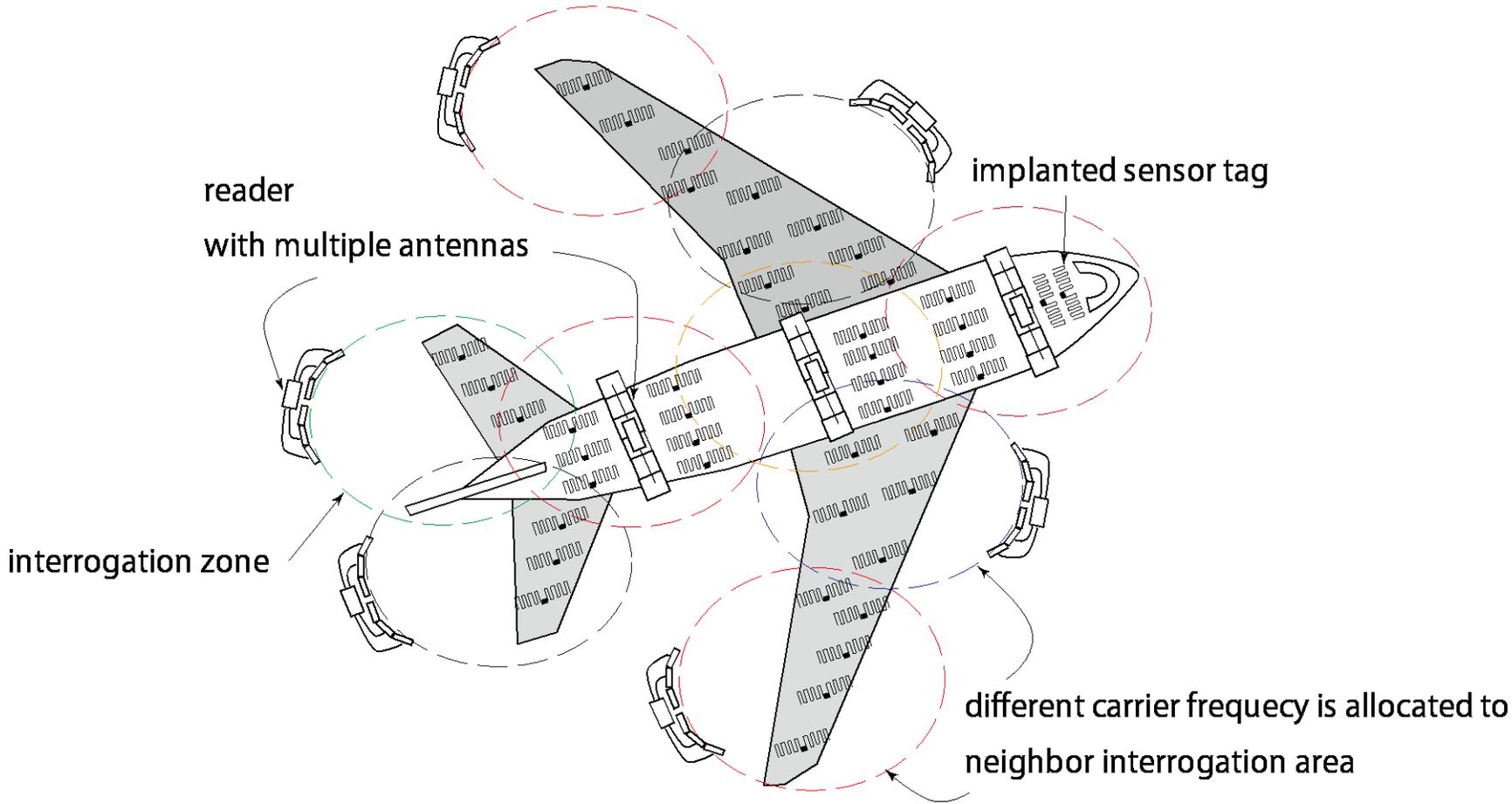
Our idea 1 : harmonic of backscatter can be rejected by signal processing in the interrogator

# Interference Rejection Contribution (Indoor Propagation)

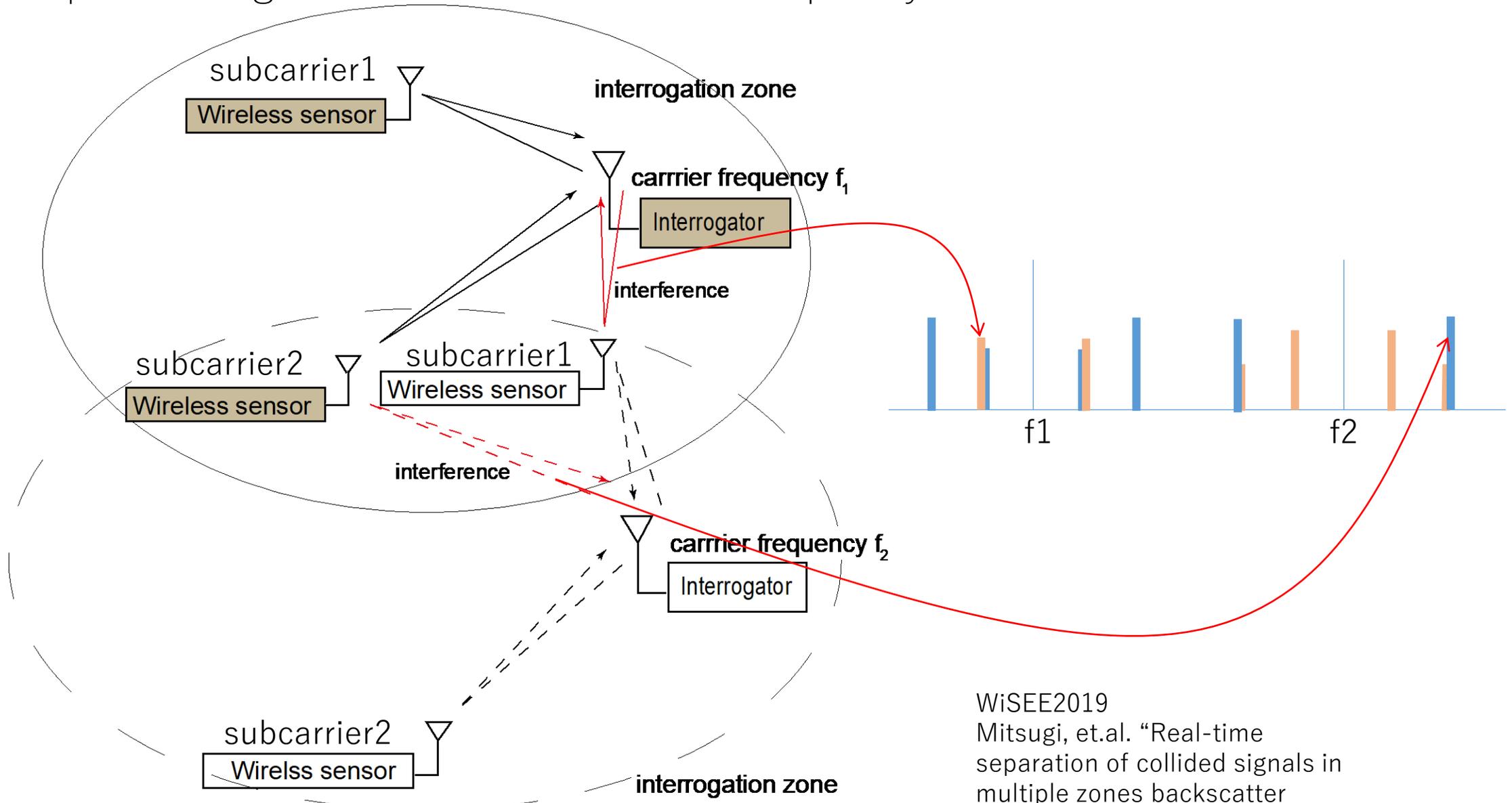


Interference rejection achieves 100 times PER improvement

# Extending Coverage with Multiple Zones

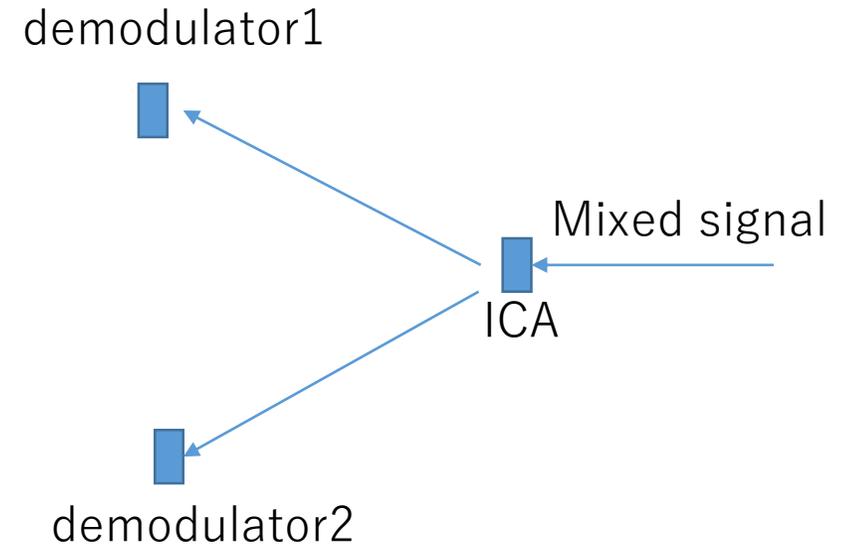
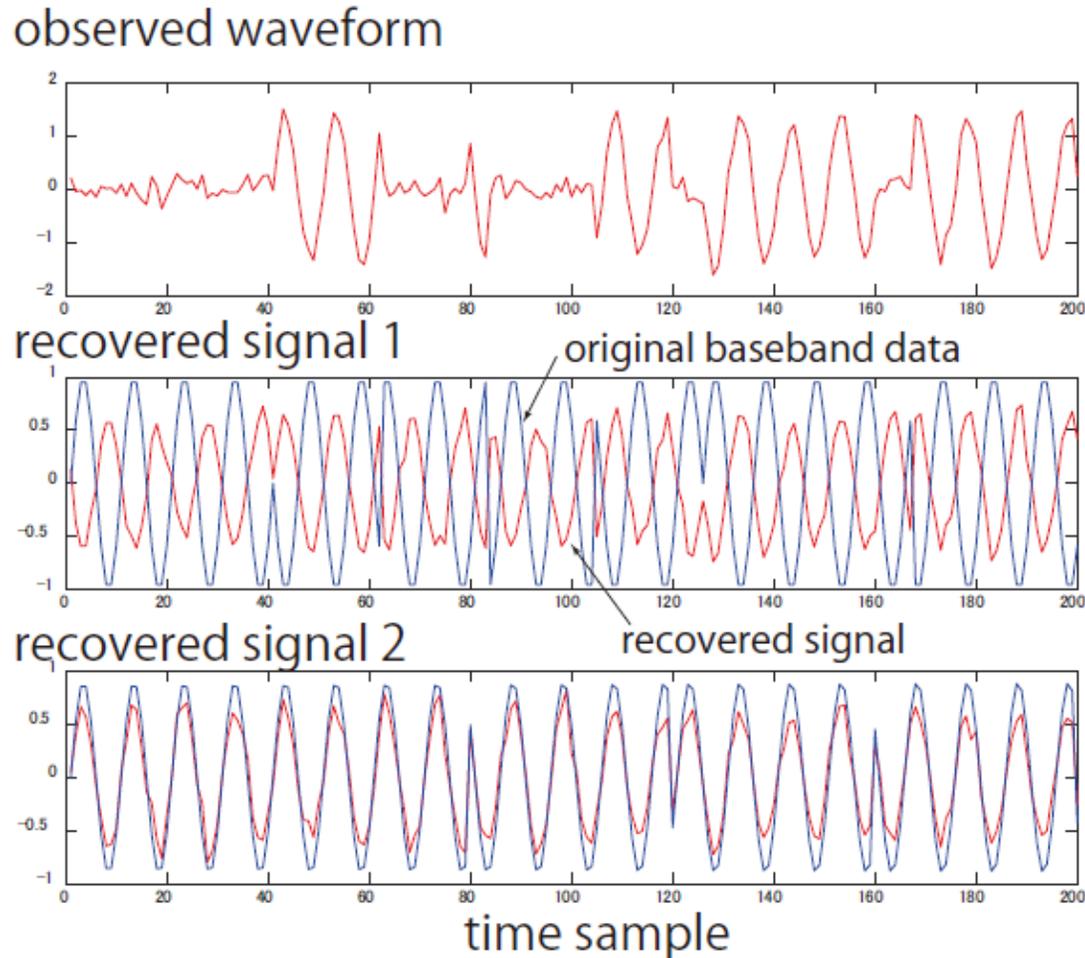


Multi-Zone Problem: Reuse of subcarrier channel is challenging even if we use multiple interrogator with different carrier frequency.

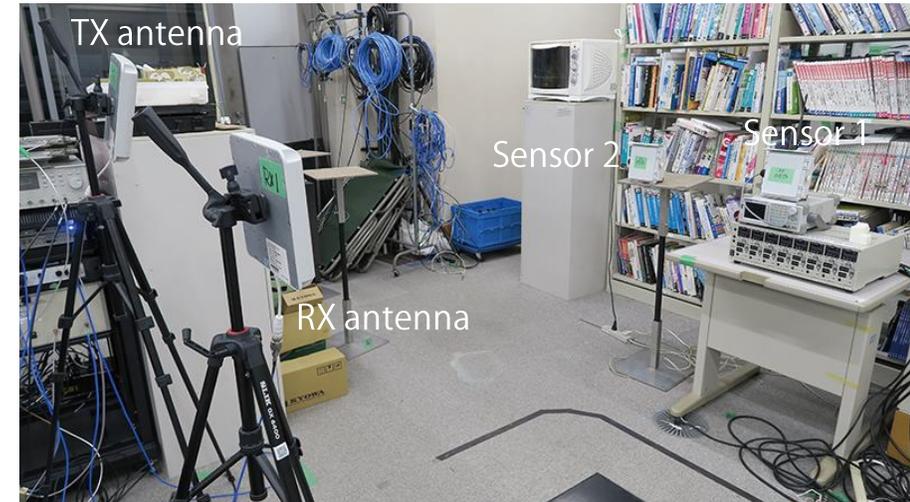
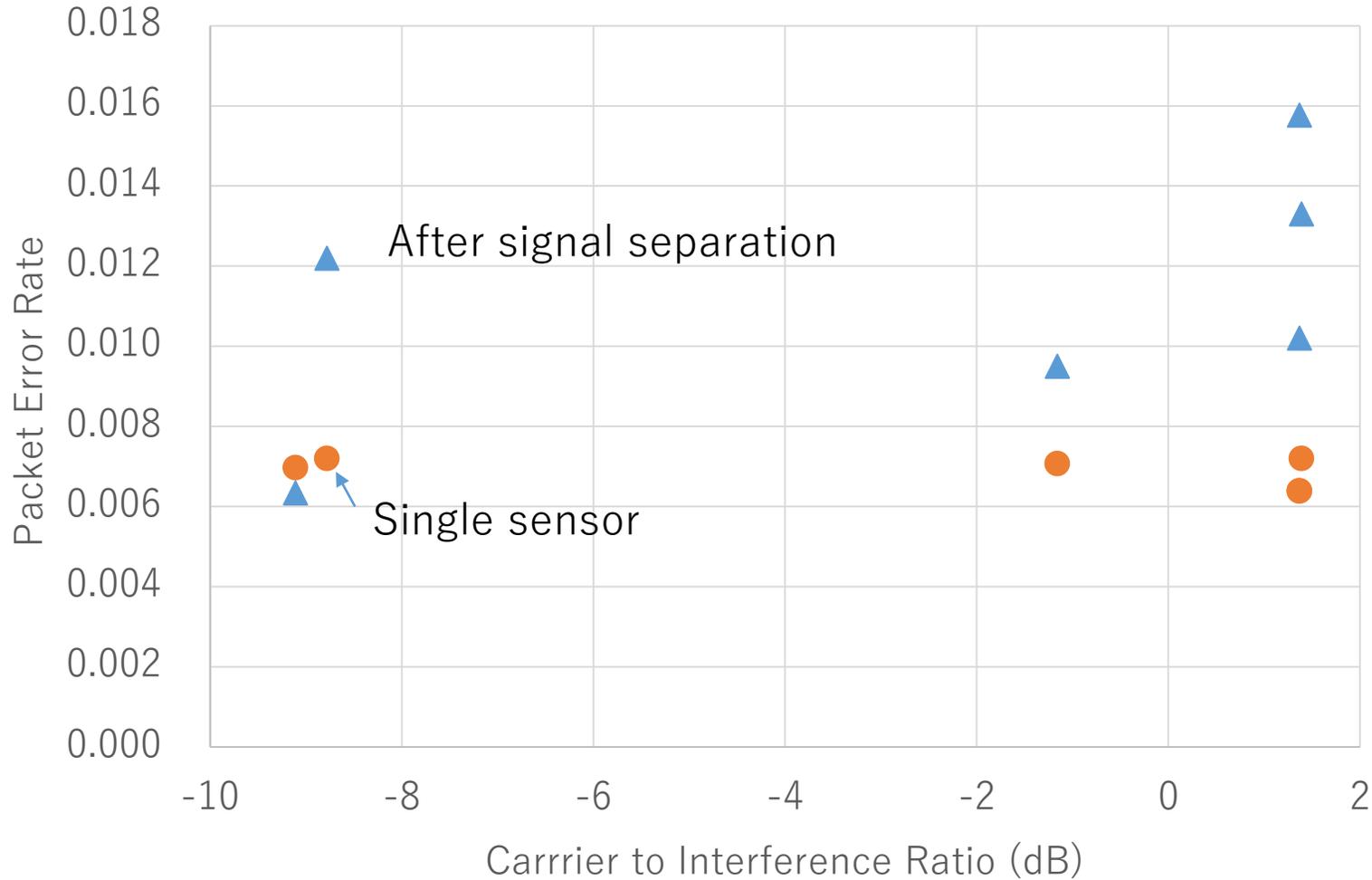


WiSEE2019  
Mitsugi, et.al. "Real-time separation of collided signals in multiple zones backscatter communication system"

# Single channel signals separation using statistical independence of signals (Fast Independent Component Analysis)



# Packet error after signal separation is equivalent to that of single sensor.

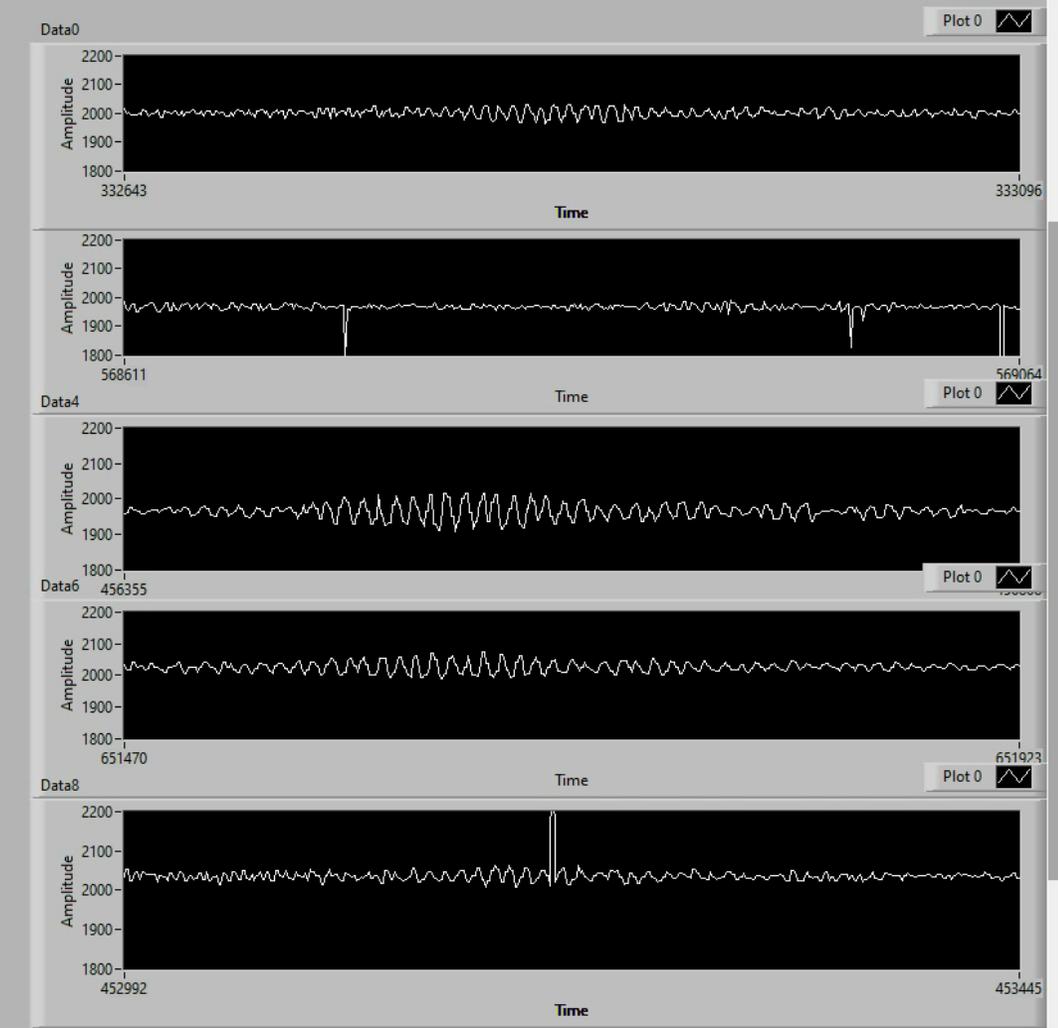
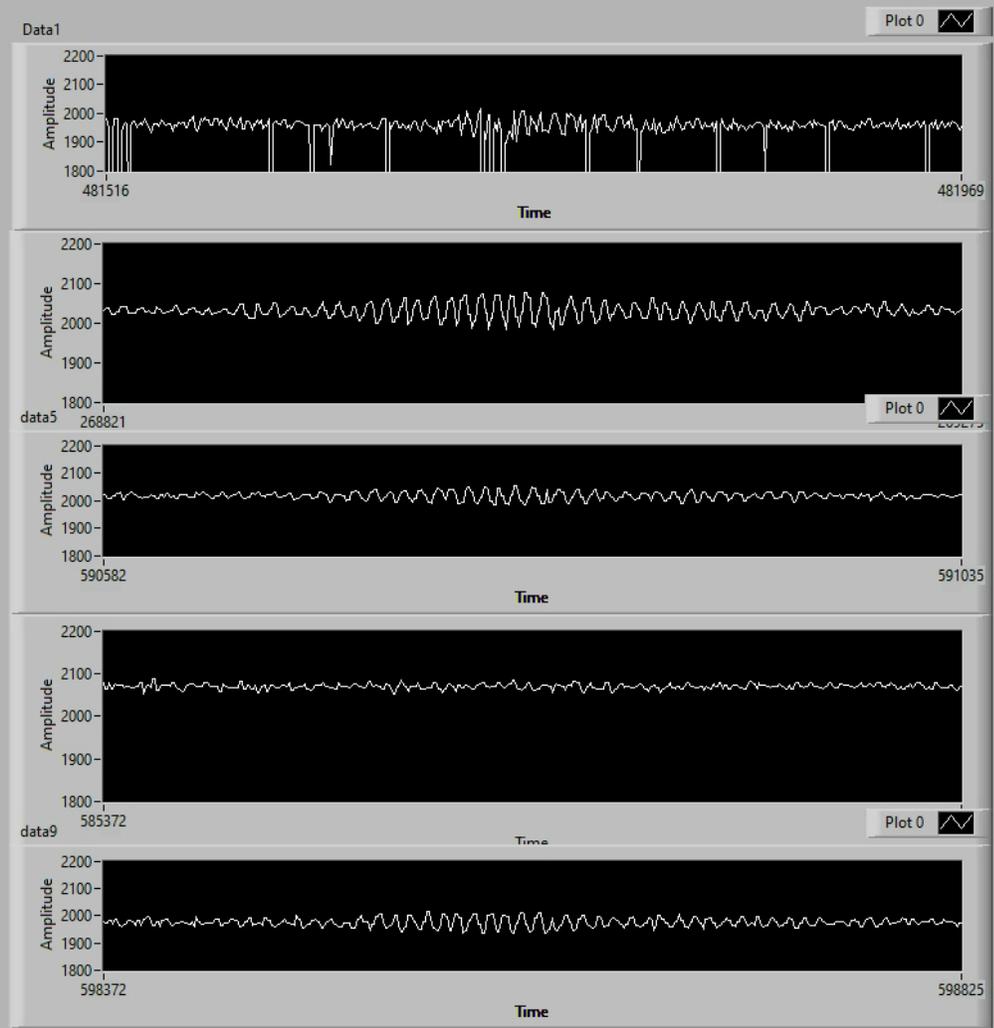


# 10 signals concurrent streaming with two receiving zones





Odd Ch





# Multizones Synchronization Evaluation

