1. Hello, I'm Hiromu Kamei from Keio University, Japan. The title of my presentation is "Implementation of Multi-Subcarrier Multiple Access by Digital Modulation"

2. First, I'm talking about background. Nowadays, many structures are getting old such as tunnels[tʌ□n(ə)l] and bridges in Japan. It became compulsory[kəmpʌ□ls(ə)ri] for local governments to inspect the safety of tunnels and bridges because the ceiling collapse accident happened at Sasago-tunnel. The graph below describes the present state and the future estimation of structures. The number of 50 years passed bridges is approximately 71,000 in 2013 but will be 171,000 in 2023. Similarly, the number of 50 years passed tunnels is approximately 2,000 but will be 3,000.

3. Actually, inspections don't seem to be carried out smoothly because of the lacks of funds and engineers. Approximate 75% of bridges are managed by municipalities[mjunɪ□sɪpæ□ləti] in spite of engineers run short there. There are no engineers in 9% of cities, 29% of towns and 63% of villages. Almost municipalities require financial supports to the government because it costs a lot for inspections. 橋点検：約 25 万(250,000) トンネル：約 200 万(2,000,000)

4. I summarized problems.

5. Our proposal for the problem is "faults detection system for structures by vibration tests with wireless and batteryless sensors" .Generally, we can know faults of structures by vibration tests, which is to vibrate a structure attached many accelerometers. We use the passive RFID technology, low power sensors and an energy harvesting technology to realize the system. The passive RFID technology helps to reduce the cost, wireless and batteryless make it easy to test, and using sensors enable us to inspect without engineers. The image below is our ideal.

6. As a technical problem, we need to get the data from multiple sensors continuously and simultaneously in vibration tests. It is impossible to communicate simultaneously because general RFIDs use Time Division Multiple Access, but we showed its feasibility by the communication with Multi-Subcarrier Multiple Access before. Multi-Subcarrier Multiple Access(MSMA) enable to communicate with multiple RF tags continuously and simultaneously. We also call MSMA as pseudo-FDMA. Tags communicate by using each assigned subcarrier. On modulating a subcarrier to a carrier, interference are generated. However, we can cancel them by digital signal processing.

7. Next, I'm taking about my challenge. Only it has been verified of transmitting data by analog modulation in MSMA so far. It is often required to transmit data by digital modulation because analog signal is not robust against environment noises. Therefore, the purpose is to verify the feasibility of transmitting data by digital modulation in MSMA.

8. I'm talking about implementation. The figure above shows the tag which is used for modulating a subcarrier to a carrier in MSMA. We give a square signal to 'Pins for subcarrier'. The RF switch on the tag selects the route(open end or terminated) according to the given signal from 'Pins for subcarrier', and then the strength of signal changes following the route selected. It means the reflected signal is modulated with ASK(Amplitude Shift Keying). This is how the tag modulates a subcarrier. The figure below is the modulated subcarrier signal. On the transmitter side, I transmitted data by modulating a subcarrier with BPSK(Binary Phase Shift Keying). I regarded several periods of a subcarrier as one symbol. For example, two subcarrier periods are regarded as one symbol in the figure. '0101' equals 0, and '1010' equals 1. The symbols, 0 and 1, can be distinguished by the phase of the subcarrier. On the receiver side, I just put the BPSK demodulator after the MSMA interference rejection process.

9. Briefly, the spectrum of subcarriers are shown like this figure in MSMA. When the 'SC1' which frequency is 'fs' is generated, the interference are also generated at the even number harmonics of the 'fs'. The signal power of interference can be calculated mathematically, so it can be cancel the interference.

10. This is the experimental structure. This time, I experimented with two tags in a wired environment and generated data on MCU with Galois-LFSR(Galois-Linear Feedback Shift Register) instead of using real sensors. The used frequencies are 916.8MHz for a carrier and 10KHz, 30KHz for subcarriers. A signal is generated in signal generator. it goes to tags and reflected there, and then inputed into USRP which converts analog signals to digital. Finally, the digital data generated at USRP, exactly which is IQ data, is processed in Labview.

11. These pictures are frequency spectrums for received signals. The left one is that I tried to transmit by using only10KHz subcarrier. the bottom one is only for 30KHz, and the right one is 10KHz+30KHz. Please look the right one. We can see the interference by 916.01MHz at 916.03MHz.

12. This figure shows the received signal and the signal after interference rejection at 30KHz subcarrier. The red line is rough. It means the received signal is interfered by 10KHz subcarrier. However, the blue line is flat. It means the interference is cancelled after applying MSMA interference rejection.

13. This is a graph in which vertical axis is for BER, and horizontal axis is for CIR. I calculated BER to compare received symbols with prepared Galois-LFSR bits. The graph shows that the accuracy of communication with MSMA is better then without one. Actually, I could not measure the BER at more than 4dB with MSMA and at 8dB without MSMA because I cannot get enough data due to the buffer problem of PC.

I think it would be solved to port some process in LabVIEW into USRP.

14. This is the interface of the program. It shows the constellation of the received signal which is sampled once a symbol. I compared MSMA on with MSMA off. The sampled values are stable with MSMA, but they are not stable without MSMA.

15. Conclusion. I could verify the feasibility of digital modulation in MSMA. As a future work, I will port the program of MSMA into USRP, experiment in wireless, use a real sensor, proceed batteryless part. Thank you for listening.