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# REMOVING ANALOG LINKS IN STRUCTURAL CONTROL

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## INTRODUCTION

- ✓ Structural Control is conceived to mitigate structural response due to external excitation
- ✓ Cables connecting sensors and controller are inconvenient. Wireless sensor is a promising solution
- ✓ For Structural Control, real time communication is important.
- ✓ In this paper, a real time wireless sensor network based on Frequency Division Multiplexing is introduced into a AMD system in our laboratory.

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## SUMMARY OF THE IMPLEMENTED WIRELESS TECHNOLOGY

- ✓ To validate the embedment of such control algorithms, a prototype of a wireless structural sensing and control system is implemented and its performance is verified by analyzing the results from shaking table tests on a three-story, reduced scale steel structure, with an active mass dampers AMD installed on the top floor.
- ✓ The experimental results show that the control solutions can be very effective in achieving a good structural performance even in a wireless environment.

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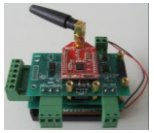
(1)Excitation: Shaking Table



(2)Actuator: Active Mass Driven by DC Motor


(3)Structural Controller: LQG


(5)Connection: Wireless Sensing Unit


(4)Sensors: Accelerometer FBA-11

(6)Structure: 3-Storey Frame



## WIRELESS CONTROL STRATEGY

- ✓ **The control strategy is generally implemented inside a dedicated PC controller, often replaced by a microcontroller, with an independent Digital Signal Processor (DSP) dedicated to calculate the required control force(s).**



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- ✓ **The DSP performs the function of data acquisition through communication with an Analog to Digital Converter (ADC) and a Digital to Analog Converter (DAC). The analog/digital control hardware features a custom-designed signal interface unit which is equipped with the modules of signal conditioning, filtering, monitoring, fail-safe limit detection, signal communication, and remote activation subsystems. It interfaces with the integrated system through a digital computer**



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## WIRELESS UPGRADE SOLUTION

- ✓ **The conventional time division multiplexing (TDM) strategy encounters the problem of high transmission delay when many channels are required.**
- ✓ **To overcome this issue, the adoption of a frequency division multiplexing (FDM) technique is suggested by the authors.**
- ✓ **In the FDM communication, different signal channels operate on different frequency bands, so that the data transmission can occur simultaneously without conflicts.**

## WIRELESS SENSING SYSTEM

- ✓ Each channel of the wireless sensing system is formed by a pair of transceivers, one of which is mounted on the wireless sensing unit and the other is connected to the structural controller by the SPI bus.
- ✓ In the SPI bus, the structural controller is the master end and the other transceivers are the slave ends. In other words, only the structural controller can issue communication.



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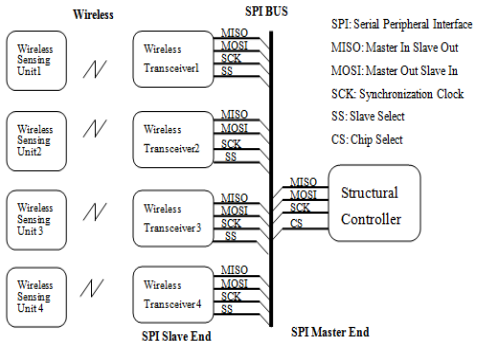


- Each Wireless Sensing Unit uses 1 separate frequency channel
- The Base Station Units are connected to the Structural Controller by SPI Bus

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## WIRELESS SENSING UNIT

- ✓ The wireless sensing unit (WSU) associated to each sensor is installed on the structure and it is responsible for powering the sensor, acquiring the structural response data, and sending them to the wireless station. Therefore, it plays the most important role in the wireless sensing system.

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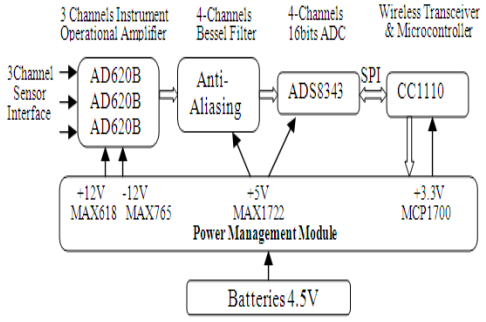


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## CYCLE OF DATA SAMPLING

- ✓ The controller broadcasts a command to the transceivers which then send the wireless request to the corresponding WSUs.
- ✓ When the request is received, the WSUs start to perform the AD conversion, and they send the sampled data back to the corresponding base station transceiver.
- ✓ In this manner, the synchronization of the sensing system is guaranteed.
- ✓ To achieve the sampled data, the structural controller communicates with the four transceivers in turns, during predetermined time intervals.



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## EXPERIMENTAL VERIFICATION

- ✓ A wired data acquisition (DAQ) system from National Instrument is used as reference to carry out a comparison with the wireless sensing system introduced to monitor the response of the controlled frame.
- ✓ Two sets of sinusoidal data, as collected by the two DAQ systems from the sensors located at different levels along the structure height, when the AMD device at the top is on. In this manner, the consistency of the wireless data with the wired data is validated.
- ✓ It is worth noticing that the previous analog PD (proportional-differential) controller, originally adopted is replaced by a newly designed digital PID (proportional-integral-differential) controller to improve the power efficiency. The new controller works in a digital environment



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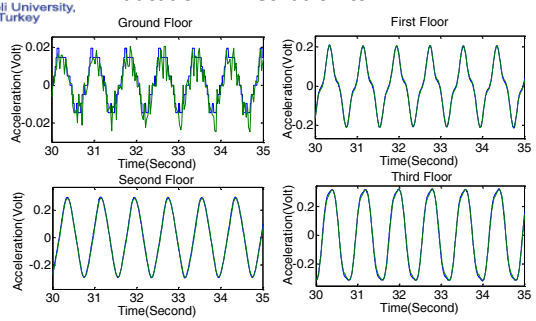


Consistency of wireless data and wired data (sine, 1.25Hz, 2mm)



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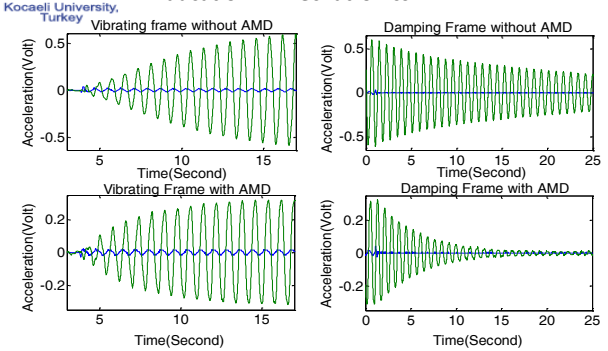


Effectiveness of AMD

## Conclusions

- ➢ Replacement of analog cables between the sensors and the structural controller results in
- ✓ Low cost to large-scale structures related to labor-intensive cabled connections and power supplies
- ✓ Increasing the structural safety in terms of continuous and real-time sensing



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## SYSTEM IDENTIFICATION

- ✓ The structural response measurements, acquired in time domain, were transformed in the frequency domain by Fast Fourier Transform (FFT).
- ✓ The experimental transfer functions, G, were evaluated by polynomials to obtain the system model. The transfer functions were modeled as a ratio of two polynomials using the Laplace transform.
- ✓ The structural system transfer function matrix was represented corresponding to two input signals, the AMD driving signal, and the ground acceleration.

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