Ultrasonic Communication

S. Roa-Prada[1], J. D. Ashdown[1], K. Wilt[1], H. A. Scarton[1], G. J. Saulnier, [1] P. K. Das[2], A. J. Gavens[3], D. A. Shoudy[1],
[1]Rensselaer Polytechnic Institute, Troy, NY, [2]University of California , San Diego, La Jolla, CA, [3]Lockheed Martin, Schenectady , NY

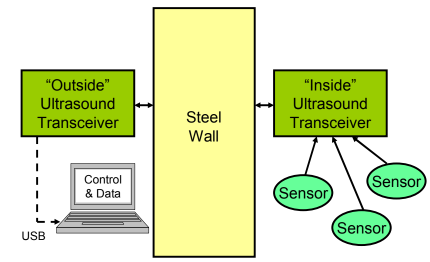
Motivation

- Communicate sensor data through a thick steel barrier without making physical penetrations (holes) through the barrier
  - Holes reduce integrity of the wall
  - Shielding effect makes electromagnetic "wireless" communication techniques ineffective
- Power the sensors from "outside" the barrier
  - No batteries to replace
  - Extended lifetime without servicing

Approach

- Use ultrasound for both communication and power delivery
  - Propagates readily through steel
  - Use power harvesting to produce electrical power from received acoustic power
- Use digital communication techniques
  - Convert sensor data into a binary stream (1's and 0's)
  - Multiplex digital data from multiple sensors into a single stream
- Generate the ultrasound on the "outside"

System Concept



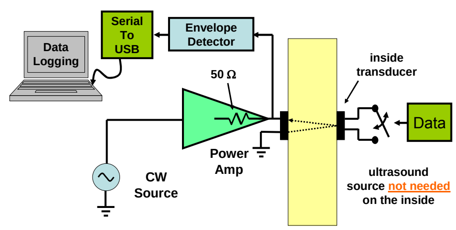
Communication Technique

- Continuous Wave (CW) acoustic signal is applied using the outside transducer
  - CW is amplitude modulated to convey data from outside-to-inside
- Amplitude modulation is observed at the outside transducer due to the sensor data sent from the inside
- Ultrasound source is NOT required on the inside
  - Low complexity and low power

Inside-to-Outside Communication

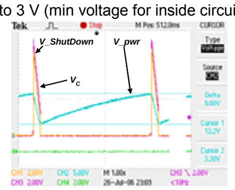
- Vary the electrical load on the inside transducer to send data, e.g. open and short
  - Electrical load variations produce changes in the acoustic impedance of the inside transducer
  - Acoustic impedance variations produce changes in the reflection coefficient at the transducer/wall interface
  - Reflected signal variations change the acoustic impedance seen by the outside transducer
- Result: amplitude modulation at the outside transducer

Inside-to-Outside Communication



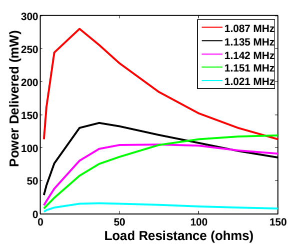
Power Harvesting

- Convert electrical signal from transducer into a DC voltage on a storage capacitor
- When capacitor voltage is sufficiently large, control circuit turns on the voltage regulator to supply DC power to the remainder of the system
- Charge storage capacitor voltage in blue
  - Charge to 12 V (now 10 V)
  - Drop to 3 V (min voltage for inside circuit board)

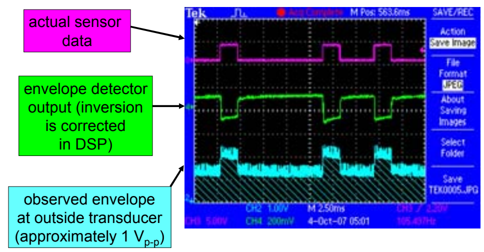


Power Delivery Performance

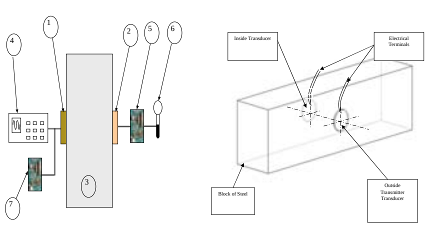
- 40 V_{pp} applied
- Plot power delivered to a load resistor on the load resistor on the inside
- Peak power (280 mW) delivery with a 37 Ω load at 1.087 MHz



Scope Waveforms (588 bits/sec)

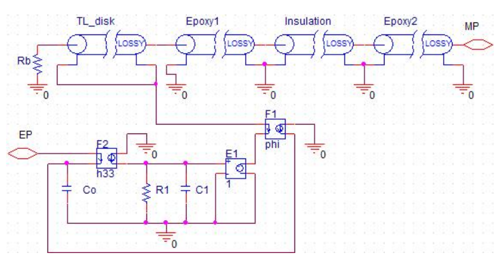


Two Transducer Simulation



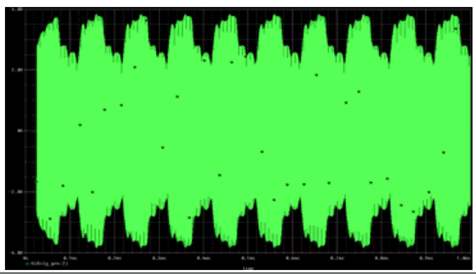
PSpice Model

- Model of an air-backed crystal and its attached layers.



Simulation Results

- Applied voltage when inside load changes from 5Ω to 56Ω every 50μs (20,000 Bits/second)



Rensselaer
CATS Center for Automation Technologies and Systems
NYSTAR