Batteryless Wireless Sensors for Structural Health Monitoring and In-Situ Decommissioning Tasks

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Introduction

The U.S. Department of Energy (DOE) has been involved in many in-situ decommissioning tasks in the old nuclear plants. Some of these decommissioning tasks consist of filling the reactors with special grouts. Therefore, monitoring of parameters such as temperature and humidity during the curing process becomes an important task. The technology used for accomplishing this job is known as Structural Health Monitoring.

Background

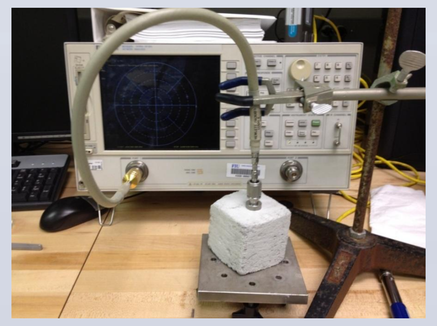
The use of sensors inside structures is known as Structural Health Monitoring (SHM). It is commonly used for assessing the state of structures such as bridges, roads, dams, etc. Nowadays, wireless sensors are very attractive options. However, some challenges must be properly addressed :

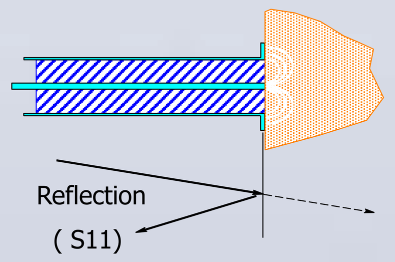
- ❑ Powering the active components used for computing and sensing (sensors and microcontrollers).
- ❑ Radio link between the wireless sensors and the DAS cannot be predicted unless a proper analysis of the propagation medium is performed.

Methods

1. *Measuring Complex Dielectric Permittivity*

This method covers frequencies from 200 MHz to 50 GHz. It is used for characterizing the dielectric complex permittivity of lossy materials. It uses a commercial open-ended coaxial probe and a vector network analyzer.





2. *Mathematical modelling of propagation of microwaves inside materials*

After measuring the dielectric permittivity of concrete and grout, the transmission and propagations losses of a uniform plane wave inside both materials can be calculated via Maxwell Equations.

Transmission Loss

$$A_{trans} = 10 * \log_{10}\left(|T|^2 * \mathrm{Re}\left\{\frac{\eta_0}{\eta_1}\right\}\right)$$

Losses when traveling from one medium to another

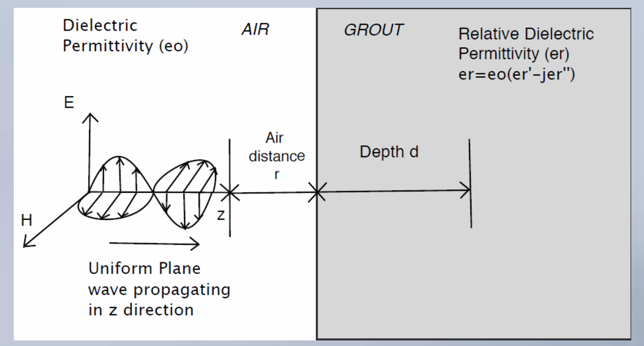
Propagation Loss

$$A_{propag} = 10 * \log_{10}\left(e^{-2\alpha d}\right)$$

Losses when traveling a distance d inside a medium

Total Loss

$$A_{total} = A_{trans} + A_{propag}$$



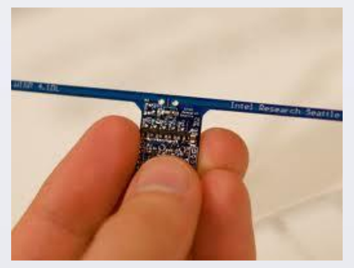
Methods (Cont'd)

3 . *Wireless Identification and Sensing Platform (WISP)*

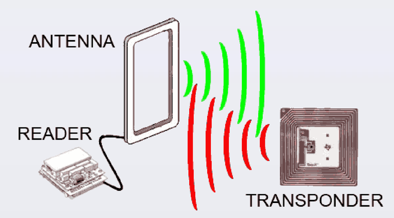
The WISP was created by Intel Research Lab. It is device that combines both RFID (wireless communication), computing (data transfer), and sensing.

Advantages:

- ❑Batteryless device.
- ❑Flexible platform that can add different sensors such as temperature, light, strain, acceleration.
- ❑Small size and easy installation.



WISP



RFID Operation

4. *Radiofrequency (RF) Link Budget*

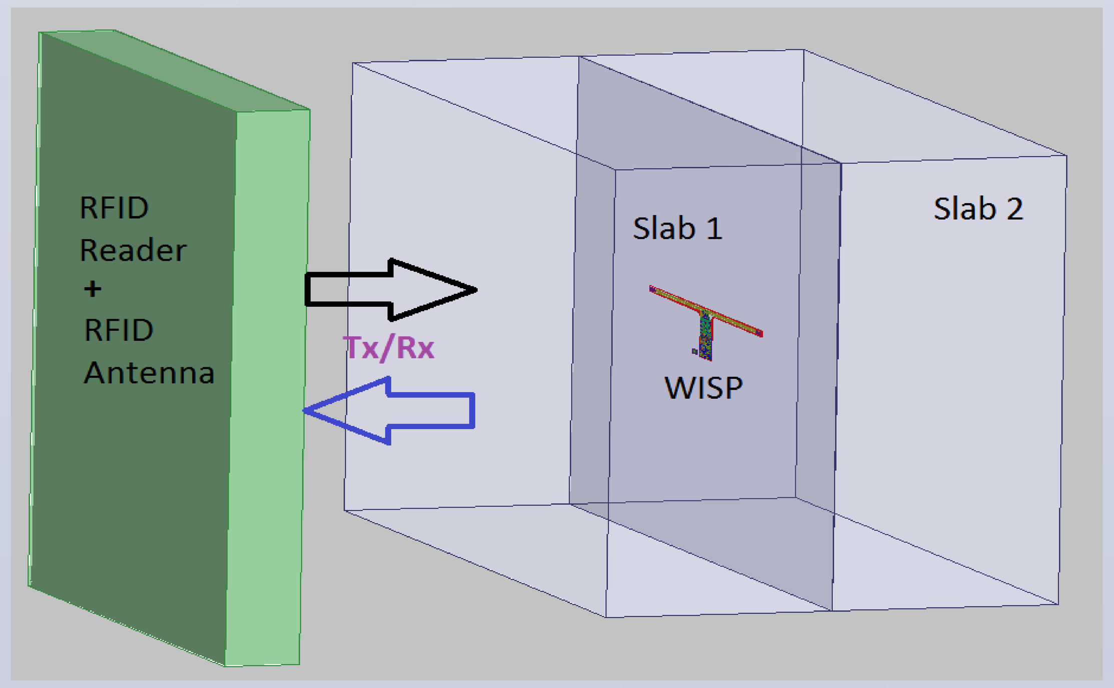
A link budget is used in communications for accounting all the gains and losses from the transmitter to a receiver. It allows to assure a reliable communication link is established.

$$P_R(dBm) = P_T(dBm) + G_T(dB) + G_R(dB) - L_P(dB) - A_T(dB)$$

Where the transmitted power P_T, the transmitter antenna gain G_T, the receiving antenna gain G_R, and the polarization loss L_P are known and fixed parameters. Therefore, total attenuation A_T suffered inside grout will determine the amount of power received P_R.

5. *Experimental Setup*

In order to validate the mathematical model and evaluate the performance of the WISP inside concrete and grout, there were framed six (6) grout samples with different thicknesses of 4, 8, and 10 inches. First, the WISP will be tested with dried slabs and finally embedded inside grout.



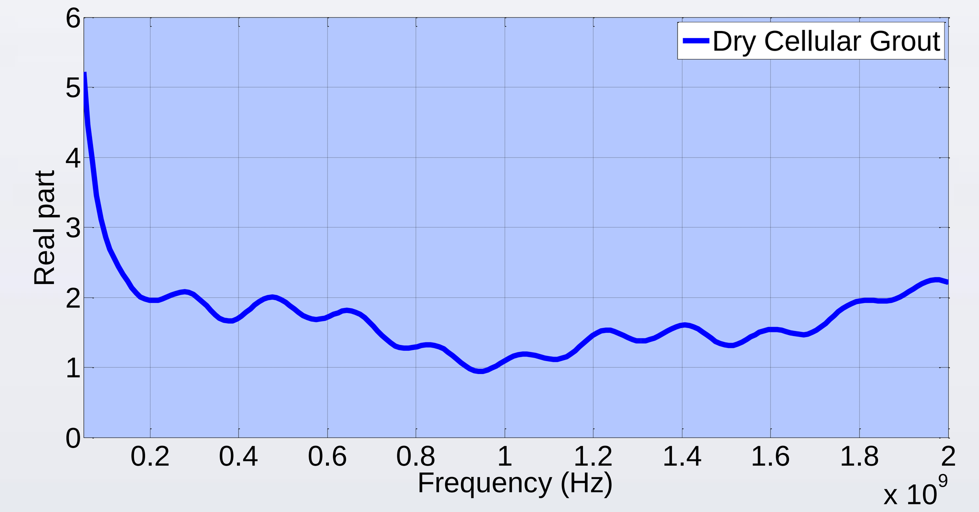
Validation Model

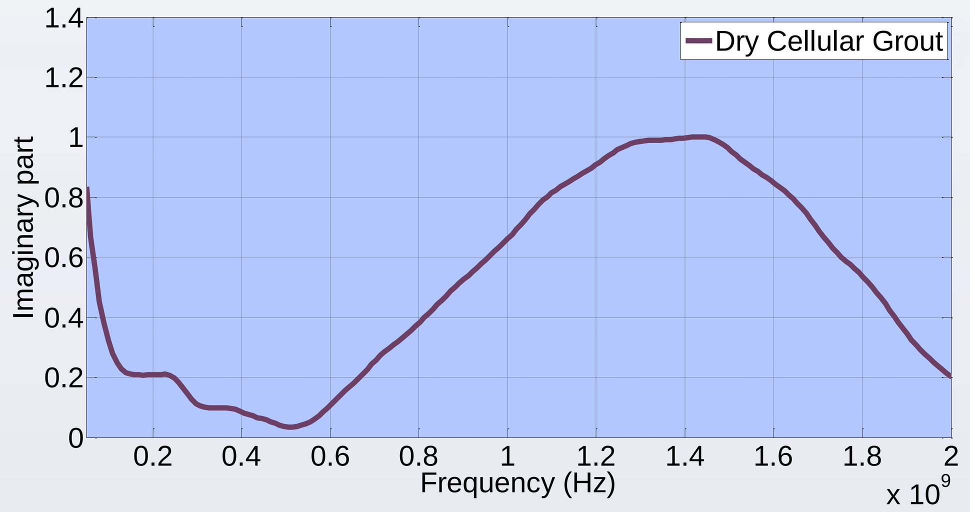
Casted Grout Slabs

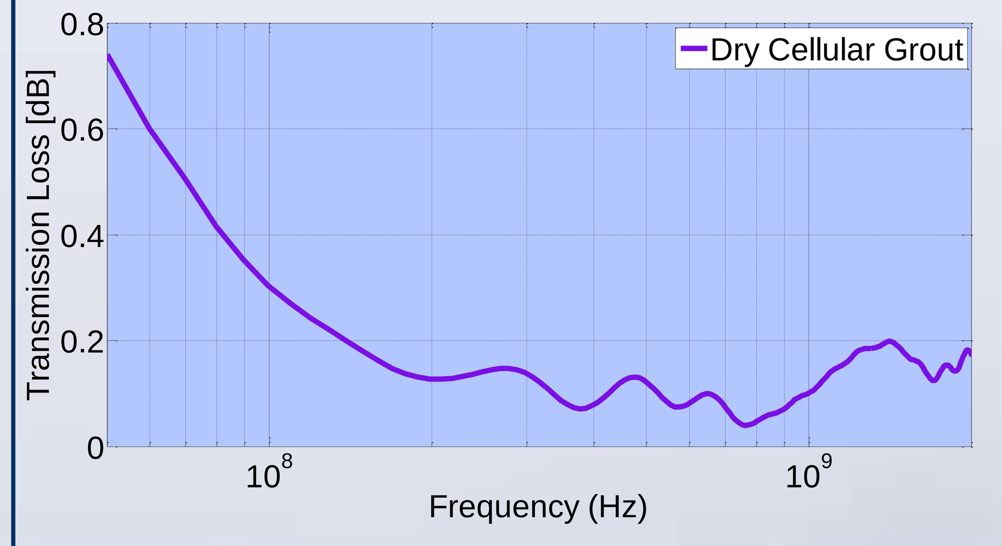
RFID Reader

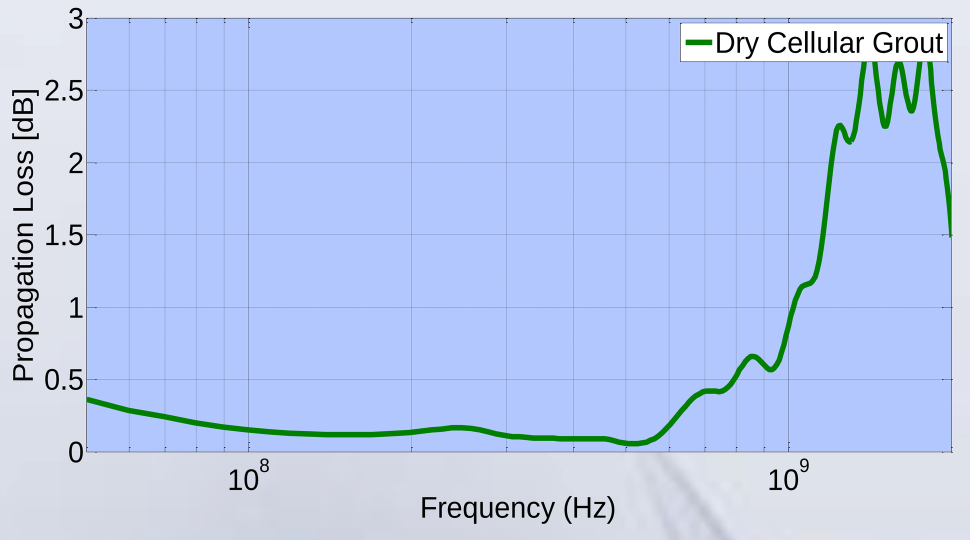
RFID Antenna

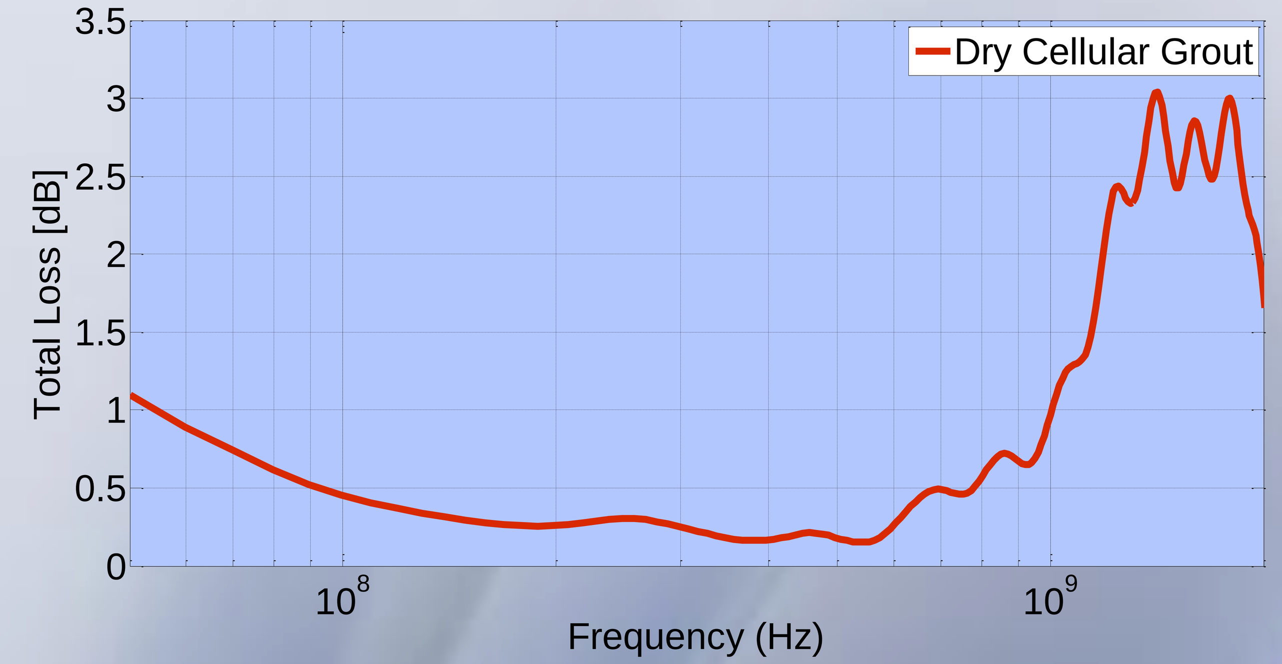
Results











References

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❑ "Optimum Power Transmission of wireless sensors embedded in concrete", Shan Jiang, Stavros Georgakopoulos, 2010 IEEE International Conference in RFID, May, 2010, pp 237-244.

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