University of Missouri-Rolla

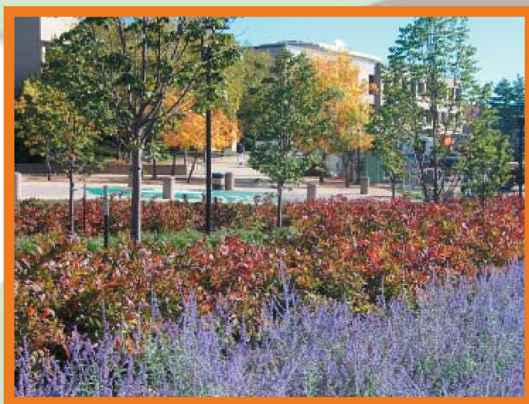
UTC NEWS

Fall 2006 Volume 2, Issue 1

University Transportation Center

Inside...

Welcome Back!



Announcement

The Department of Civil, Architectural, and Environmental Engineering has posted an opening for the endowed Vernon and Maralee Jones Chair in Civil Engineering. According to the posting, "This Endowed chair is a commitment to the continuing effort by the department to maintain and enhance its national prominence in undergraduate and graduate education and research. The Jones Chair will take an active role in expanding on the current research strength in infrastructure engineering and developing new research initiatives. The Jones Chair will have the opportunity to be appointed as the Director of the existing Center for Infrastructure Engineering Studies (http://www.cies.umr.edu/). The Jones Chair may be expected to interact with on-going UMR research activities and UMR research centers including: UMR's National and Regional University Transportation Centers (http://www.utc.umr.edu/) and Intelligent Systems Center (http://www.isc.umr.edu/) and may have a major role in the enhancement and use of current outstanding laboratory facilities including the existing High-Bay Structural Engineering Laboratory." More information and application instructions can be found on the Web (campus.umr.edu/hrsinfo/employment/faculty/soe).

Upcoming Events

5th National Seismic Conference on Bridges & Highways

September 18–20, 2006

San Francisco, CA

mceer.buffalo.edu /meetings/5nsc

Artificial Neural Networks in Engineering Conference

November 5–8, 2006

St. Louis, MO

web.umr.edu/~annie

10th North American Masonry Conference

June 3–6, 2007

St. Louis, MO

www.masonrysociety.org/NAMC

Sixth International Conference on Case Histories in Geotechnical Engineering*

August 4–9, 2008

Washington D.C.

www.6icchge2008.org

**See call for papers on page 2*

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UMR

Call for Papers

Are you an engineer, geologist, scientist, teacher, or other professional? You are invited to submit original and unpublished papers for the Sixth International Conference on Case Histories in Geotechnical Engineering. Abstracts are currently being accepted, and the deadline for submissions is March 15, 2007. Abstract instructions can be found at http://www.6icchge2008.org. Even if you aren't planning on submitting an abstract, check out the Web site for information on attending this exciting, internationally attended conference.

This conference will take place August 12–16, 2008, in Arlington, Virginia, and includes special lectures, state of the art and practice presentations, exhibitions, a short course, a special symposium, and professional development credit availability. Please bring your families and discover the rich history and interesting sites of Arlington, Washington D.C., and surrounding areas.

You may also contact the conference chairman, Shamsher Prakash, at prakash@umr.edu.

Night to Network

On Wednesday, September 27, 2006, over 200 students and 100 corporate representatives participated in the semi-annual Night to Network (NTN) student professional development workshop. "The purpose of the workshop is designed to help students recognize the importance of, gain insight into, and obtain skills regarding this socially acceptable practice we call networking," explains WISE Program Coordinator, Cindi Vogt.

Created in 2001, NTN continues to be administered by the WISE program, with the collaboration of UMR's Student Diversity Programs, Women's Leadership Institute, National Society of Black Engineers, Society of Hispanic Engineers, Society of Women Engineers, and the Career Opportunities Center. This event originated in a corporate advisory board meeting as a "mentoring" concept for UMR women students to informally interact with alumni and corporate professionals. However, recognizing the similar interests of other minority groups, the event was marketed to all underrepresented student groups. Activities for NTN are coordinated by the student leaders in the minority and women engineering professional societies, at no cost to the employers. This program has grown in popularity with UMR employers and has taken the shape of a social event held the night before each UMR career fair.

Bringing students and corporate recruiters together (many of whom are UMR alumni) helped create a setting that is very conducive for learning and practice of "Networking Know-How." UMR students Stephanie Hurtado and Yasmin Hassen gave the welcome, presented a few tips, and conducted an ice-breaker. The mixer and networking portion of the program gave students the opportunity to practice meeting someone new and developing, in a brief period of time, positive support. Many UMR students were observed to be excellent communicators and highly skilled in networking "small talk."

Sponsors of NTN included UMR and the University Transportation Center.

Application of Chirped Measurements to Embedded Modulated Scatter Technique

Kristen M. Muñoz and Reza Zoughi

Introduction

Health monitoring of the nation's infrastructure is an important ongoing national concern. Both the existing cement-based infrastructure and new composite structures are regularly subjected to loading beyond the original design considerations. Environmental factors such as freeze-thaw cycles, seismic activity, and chloride ingress can also cause structural degradation. Repairing and/or replacing every existing structure is costly and unrealistic. Accordingly, a practical, cost effective means to evaluate the condition of cement-based and composite infrastructure is needed. Numerous nondestructive inspection (NDI) techniques may be successful at evaluating some of the issues mentioned above. However, a technique that can handle a majority of the cement-based and composite infrastructure characterization requirements has yet to be developed. To this end, this investigation focuses on the development of an embedded Modulated Scatter Technique (MST), using PIN diode-loaded dipole probes, for evaluation of structural health and integrity.

Background

At microwave frequencies, materials are described by their dielectric properties, which can be related to physical, chemical, and mechanical properties of a material. By characterizing the dielectric properties of a material, important information about the material can be obtained. The MST technique is based on illuminating a modulated probe (here, a resonant dipole loaded with a PIN diode) with an electromagnetic wave (see Figure 1). Modulating the probe changes the properties of the probe, in this case, from a high state (Z_{high}) to a low state (Z_{low}). The measured field that is scattered (reflected) from the probe can be used to recreate the electric field anywhere including in between the source and MST probe [1]. When such a probe is embedded in a dielectric material, the measured reflected wave can be used to determine the dielectric properties of that material [2]. Reflections also come from other structures nearby and from the interface at the source (*e.g.,* open-ended waveguide or horn antenna) aperture and material. These reflections will be referred to as the static reflection coefficient (Γ_{static}). To use the reflected wave from the probe to determine the dielectric properties of the material in question, the effects of Γ_{static} must be accurately removed [2]. Removing the effects of Γstatic is problematic because of measurement difficulties and the probe response (Γ_{probe}) being much smaller than Γ_{static}. If the probe were to be removed from the material, then Γ_{static} could be measured. However, the very nature of the technique renders removal impossible. Thus, a method to determine Γ_{static} in the presence of the probe is necessary. This task can be accomplished by using swept frequency (chirped) measurements to discriminate between Γ_{static} and Γ_{probe}.

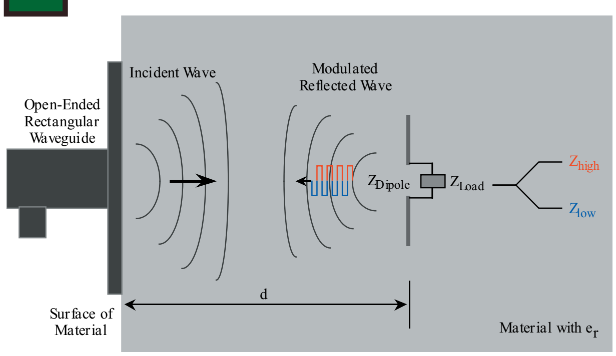

Figure 1: Measurement schematic with modulated prove illuminated by an open-ended waveguide.

Approach

To implement swept frequency measurements in conjunction with a modulated probe in a useful manner, the sweep and modulation rates must be carefully considered (*i.e.,* changing the state of the probe in the middle of a frequency sweep will not render useful information). As such, the probe must be modulated such that a complete frequency sweep occurs prior to the probe changing state. When such a procedure is implemented, two sets of frequency data, Forward (FWD) and Reverse (RVS), are obtained. The Fourier Transform of these data sets provides the time domain response that includes Γ_{static} and Γ_{probe} for both the FWD and RVS states. Figure 2 depicts measured frequency data (magnitude and phase) obtained using calibrated 8510C Agilent Network Analyzer operating at X-band (8.2–12.4 GHz). This data was obtained by placing a resonant dipole probe in an anechoic chamber (to reduce environmental interference) 7.5 cm in front of an X-band pyramidal horn. Figure 3 shows the time domain representation of the measured (frequency domain) data in Figure 2.

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The data in Figure 3 clearly indicates three peaks, excluding the small peak located in negative time. The peak located in negative time can be attributed to connections between the network analyzer or a calibration error and has no bearing on the rest of the data. Each peak located in positive time corresponds to a reflection. The peak located at time t=0 is caused by the transition from waveguide adaptor to pyramidal horn, and the subsequent peak is because of the transition from horn to freespace. These peaks constitute Γ_{static} and must be removed to isolate the probe response. The third peak is a result of the probe, Γ_{probe}. Note that this reflection changes per modulation state of the probe. In addition, the first two peaks are clearly equivalent in both FWD and RVS data sets. Most importantly, the data in Figure 3 shows that the probe response is separable (in time) from the first two peaks (*i.e,* static reflections).

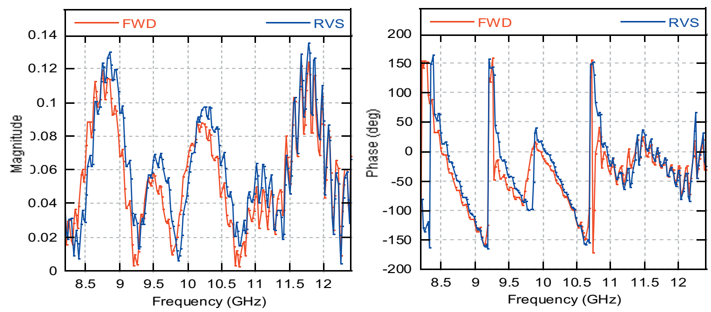

Figure 2: Magnitude and phase of reflection coefficient of a horn antenna radiating into freespace with a dipole probe 7.5 cm away from the horn aperture.

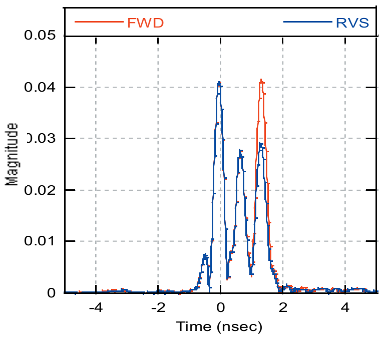

Figure 3: Time domain representation of measured data shown in Figure 2.

Conclusion

The application of a chirped (swept frequency signal) was investigated with respect to its application to MST. The relationship between the sweep rate and the modulation is important; namely, the modulation rate must be such that the frequency sweep completes a full cycle prior to the modulation changing state.

The probe response can be detected separate from other reflections; therefore, it can be used in conjunction with inversion routines and an appropriate gating process (to isolate the probe response) to determine the dielectric properties for the material in which the probe is located. Other possibilities for further development include improved probes, increased operating frequency, etc.

References

1. Bolomey, J.C. and F.E. Gardiol, "Engineering applications of the Modulated Scatterer Technique," Artech House, Norwood, MA, 2001.

2. Hughes, D.T. and R. Zoughi, "A Novel Method for Determination of Dielectric Properties of Materials using a combined Embedded Modulated Scattering and Near-Field Microwave Techniques. Part I – Forward Model," IEEE Trans. on Instrumentation and Measurement, Dec 2005.

This work was supported by a University Transportation Center Graduate Research Assistantship.

Women's Lock-In

The biannual women's "Lock-In" at UMR was held September 29–30, 2006, and was hosted by UMR's Women In Science & Engineering program (WISE) and the Society of Women Engineers student chapter. Thirty high school junior and senior women participated in this program, which will help increase the number of female students in the fields of science, technology, engineering, and math (STEM) at UMR and give valuable education information to participants. Fawn Kostal, a junior from Turney, MO, when asked about the value of her Lock-In experience said, "I learned a lot about engineering, the lock-in was very helpful." Kelly McMullen, a senior from Imperial, MO, said, "Overall I thought everything was awesome! I learned a lot about UMR and had all my questions answered." The program paints a clear picture of STEM careers as both caring and enabling, and the women are shown "what it takes" to succeed in these fields.

The Lock-In was sponsored by UTC, WISE program, The Society of Women Engineers student chapter, and Key Sport.

NDE CONFERENCE ON CIVIL ENGINEERING

A joint conference of the 7th Structural Materials Technology Conference (SMT) and the 6th International Symposium on Nondestructive Testing in Civil Engineering (NDT-CE)

The 2006 NDE Conference on Civil Engineering was held in St. Louis, MO, on August 14–18, 2006. The conference combined the 7th Structural Materials Technology Conference (SMT) with the 6th International Symposium on Nondestructive Testing in Civil Engineering (NDT-CE) to provide a program with a full range of topical interests, from case studies of nondestructive evaluation (NDE) applications to advanced theoretical research. The conference chairs were Dr. Imad Al Qadi, University of Illinois Urbana-Champaign, and Glenn Washer, University of Missouri.

The University Transportation Center (UTC) at the University of Missouri-Rolla (UMR) was a cosponsor of the conference and helped support the conference participation of state bridge inspectors and maintenance personnel from across the country. The conference support from UTC, Missouri Department of Transportation (MoDOT), and the Federal Highway Administration (FHWA) enabled state bridge inspection and management personnel to attend the conference and learn about the newest NDE technologies and research from around the world. These attendees came from Missouri, Texas, Florida, Kentucky, South Carolina, California, Virginia, and New York State departments of transportation.

The conference was organized into two technical tracks. Track I was the SMT track and included case histories, field measurements, and technology implementation related to NDE for highways, bridges, and other civil structures. Track II was an international track that focused on technology development, advanced research, and theoretical investigation and modeling for NDE of civil structures.

The conference enjoyed a keynote address from Dr. John Bungey, Emeritus Professor of Civil Engineering, University of Liverpool. His speech, entitled "35 Years of NDE of Concrete–A UK Perspective," reviewed technologies available for the NDT of concrete, and how these technologies have advanced within the United States and in Europe in the past 35 years. Dr. Bungey is a renowned researcher in the field of NDT methods for concrete and has published several books on the topic.

The conference also featured panel discussion sessions that were well attended. One session, entitled "Structural Health Monitoring for Enhancing Bridge Security," was chaired by Dr. Sreenivas Alampali, New York State Department of Transportation (NYSDOT). This session featured three topical presentations and a panel discussion with presenter and audience participation. The session focused on the use of structural health monitoring for enhancing bridge security and included presentations by Hamid Ghasemi of the FHWA and Harry Capers, a recently retired state bridge engineer from New Jersey. Discussions centered on methods and approaches to identifying at-risk bridges, protective measures, and the potential role of health monitoring technologies.

A second discussion session focused on issues for bridge inspection practices and state inspection programs. This session featured a presentation on the bridge inspection practices in New York. Carl Callahan, a state bridge maintenance engineer in Missouri, chaired the session. Discussions centered on variations between state DOT practices and programs for the inspection of highway bridges. The effectiveness of various inspection practices and policies was also discussed.

The conference proceedings included 67 papers from around the world addressing the NDT of civil infrastructure. Authors from 14 different countries submitted papers that appear in the proceedings, and the international nature of the program brought some fresh perspectives and opportunities for international collaborations. A special topical session, entitled "Bridge NDE Research in Missouri," was held during the conference and featured presentations by Dr. John Myers and Dr. Genda Chen of UMR.

Conference attendees experienced many opportunities to collaborate and discuss their activities, including a banquet that was highly attended by conference participants. The conference setting in downtown St. Louis was appreciated by the conference attendees, many of whom enjoyed an opportunity to visit the new baseball stadium and see a Cardinals game.

The Blanchette Bridge Investigation: Cause of the Cracked Stringer

I-70 Blanchette Bridge

The Blanchette Bridge carries Interstate 70 across the Missouri River, connecting St. Louis and St. Charles counties in eastern Missouri. The westbound bridge was constructed in 1958. In 1979, the original reinforced concrete roadway deck on the bridge was replaced with a steel grid deck system, welded to supporting girders and stringers.

In 1999 and 2005, cracks were discovered in stringers on the bridge approach spans. The members cracked in a counter-intuitive fashion—from top to bottom at midspan between supports, where positive bending would be expected. The stringers were repaired with bolted splices. The Missouri Department of Transportation (MoDOT) worked with UMR to investigate the cause of these cracks. The investigative effort included site visits, review of bridge documents, preliminary fatigue analyses, review of material property information, detailed analyses, and field testing.

Strain gage installation

The general construction sequence of the redecking project was to remove the existing concrete deck, attach shim plates to top of plate girders and stringers (shims in the negative moment areas of the plate girders were bolted to the top flange angles, and shims on stringers were field welded to the top flanges), place the grid deck, field weld grid deck to top of shims, and place wearing surface on grid deck. Steel shims were needed on top of the plate girders and stringers to allow the steel grid deck to be set at the correct elevation and bear fully on the girders and stringers. The grid deck transverse bars were welded to these shims.

The treatment of the fillet welds connecting the shim plate to the stringer top flange is a significant detail. Field inspection of the open butt joints in the shim plates showed that the fillet welds frequently were run across the gap between the shims. Field observations also show that the fillet welds are typically 3/8” to 1/2” in size, compared to the 1/4” size shown in the project drawings. The design drawings did not include a detail showing how the fillet weld should be treated at the butt joints in the shim plates.

Another important factor relates to the fit of the grid deck to the structure. The installation notes for the grid deck state that it is essential for the bearing bars of the grid deck to be in full contact with the stringer flanges prior to welding. The grid deck is a relatively stiff element. Two deck panels are used to cross the bridge deck width. Each deck panel would be supported by an exterior stringer, the exterior plate girder, two interior stringers, and the center plate girder. Any variations in the relative top elevations of these elements will cause a “misfit” or gap between the bottom of the grid deck and the top of the shim material at one or more of the support locations. Misfits could also be caused by variations in the depth of the grid deck (tolerances of +/- 1/16” are shown for the bearing bar depth on the shop drawing). Grid decks are welded, and distortion from these misfits can occur. This distortion would result in the deck warping, so the affected panel would no longer be planar, thereby providing an additional source for misfits.

Discussions with one of the contractor’s project engineers revealed that a number of these misfits occurred during the construction and that the typical solution to the problem was parking a piece of construction equipment on the panel, forcing it to seat itself on all of the shim plates for welding. Apparently this “fix” was not a common occurrence, but was not rare, either.

See page 7 for the conclusions...

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An approximate assessment of the fatigue life of the weld detail showed that if bending effects caused a net tensile stress at the shim plate butt joint, fatigue could cause cracking of the weld and stringer. A finite element analysis showed very high stress concentration at the butt joint.

Analysis of the grid deck-stringer interaction showed that the stiffness of the grid deck would carry more load to the plate girders than a simple analysis using a "tributary area" approach would. This factor, combined with the reduction in dead load due to replacement of the original concrete deck with the grid deck, would reduce the dead load moment in the stringers and could allow net tensile stresses at the butt joint locations under service load.

The following conclusions were reached on the cause of the cracked stringers:

1. The stringer cracking occurred at details that had very high stress concentration factors due to open shim butt joints with fillet welds crossing the joint.
2. Fatigue of the fillet welds due to traffic loading led to cracking of the weld material.
3. High negative bending stresses in the stringer resulted in cracking through most of the section after the weld crack propagated into the stringer.
4. The high negative bending stresses result from construction or temperature forces, or some combination of those, in addition to the effects of continuity on the stringer force distribution.
5. The redundancy and strength of the grid deck and stringers prevented serious distress or failure in the bridge deck.

The detail that led to the cracking was due to decisions made during the design and construction phases of the redecking project. A better understanding of the impact of replacing the original concrete deck with a grid deck, along with specific direction to the welders on how to terminate the shim plate fillet weld could have prevented this detail from occurring.

Field measurements of stringer stresses were taken over a several week period. These measurements showed that negative bending in the stringers occurred under live load. In addition, negative bending was caused in the stringers by thermal deformations in the grid deck due to day-night temperature cycling.

High School Girls "Walk on the WISE Side" at UMR's Summer Solutions Engineering and Science Camp

Who says girls and women aren't cut out for science or engineering?

During the week of June 19–23, 2006, 24 girls from high schools across the nation were on the campus of the University of Missouri-Rolla to participate in UMR's Women In Science and Engineering (WISE) annual Summer Solutions Camp. This camp is designed to introduce young female students to careers in science, engineering, and technology.

"We are trying to continue to increase the number of female students in the fields of science and engineering at UMR," says Cindi Vogt, coordinator of UMR's WISE program.

Vogt explains that during the camp, students interacted with UMR professionals and got an introduction to various fields of study. The program prepares students for college and also gives them a better understanding of what it will take to pursue engineering or science as a profession.

The girls, who are freshmen or sophomores in high school, came from five states, including Missouri. They experienced campus life during the week, staying in one of UMR's residence halls.

"The girls participated in fun, hands-on learning activities," Vogt says. "They also learned what kinds of jobs, salaries, and benefits come with science and engineering. They interacted with professors and current students, competed in team design projects, learned about college admissions and financial assistance, and enjoyed evening socials."

UMR's 2006 Summer Solutions Camp was coordinated by UMR's Women's Leadership Institute and the WISE program at UMR. Sponsors of the camp included UMR and the University Transportation Center.

University of Missouri-Rolla
UTC News

Increasing the Survivability of Monitoring Devices

Wireless devices can be used to monitor and record a broad range of phenomena. Their advantages include ease of installation and maintenance as well as considerable reduction in wiring costs. The addition of battery power and radio communication to such wireless devices can result in a completely autonomous system. The operating environment of monitoring systems is often hostile, due to temperature fluctuations, humidity, electromagnetic noise, and other interfering phenomena. An effective device should be able to adapt to changing conditions to maintain dependability in its operations.

The flexibility and low cost achieved by wireless devices has led to their near-ubiquity in recent years. In particular, wireless sensor networks have been successfully used in applications ranging from shooter localization to habitat monitoring. The size, unobtrusiveness, and expendability of wireless sensor nodes make them ideal candidates for detection and monitoring systems. In our approach, one or more sensor nodes are distributed in areas of interest. Each node is equipped with sensors that measure relevant environmental and structural parameters. These sensors collect data that is transmitted to a base station for processing. The base station processes the data received from the network and announces the detection of an event of interest if a sufficient number of nodes provide consistent supporting data.

The case study at hand is a wireless flood monitoring device for bridges or dams. It is primarily designed to trigger an alarm in case of flood, but can be adapted to survive and continue normal operation while submerged. Depending on the size of the structure being monitored, the wireless sensor network is composed of one or more instances of the flood monitoring device. Each instance of the device is enclosed in a waterproof box and can function under water. The main challenge that arises from submersion is continuing radio communication, which can be severely affected by the water overlay. For either long range communication (*e.g.,* mobile GSM network) or short range communication (*e.g.,* ZigBee or custom protocol), the water may become an obstacle that completely detaches the device from the external world. The system installation requires the box be close to the water level. The basic architecture has been designed to recognize when the water level reaches a prespecified threshold. As illustrated in Figure 1, the device is fixed on the structure (*e.g.,* a dam), with the magnetic floater encased in an empty pipe. Two magnetic reeds regularly check for the presence of the floater. In the default position, which appears on the left side of Figure 1, the floater is located in front of the lower reed. If the water level exceeds the threshold, the floater will rise to face the upper magnetic reed, as seen on the right side of Figure 1, and the flood alarm and related actuators are activated. In its simplest form, this application is a binary detection system that sends an alarm in the event of a flood. The device is installed in a fixed position on the monitored structure, and is not able to adapt in the event of a flash flood.

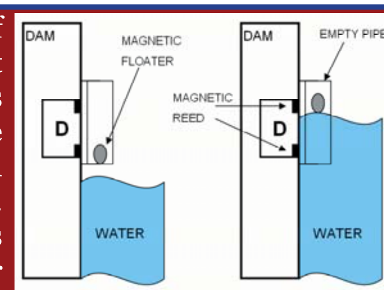

Figure 1: Initial design

To increase the survivability of the system, the device needs to adapt to rising water levels during a flood. System functionality needs to be maintained under these conditions, and radio communication is critical. This factor necessitates keeping the box above the water level at all times, which in turn implies major modifications to the physical installation of the system. In the simple architecture described above, the box was stationary and the floater in motion. In the modified architecture, the box will move, essentially serving as the floater, and the magnets will remain stationary. To guarantee radio communication during a flood, the device will be placed on a large floater, as depicted in Figure 2. The floater slides along a vertical shaft installed on the wall of the dam, but always remains above the water. In this new configuration, the magnets are placed inside the vertical shaft, so as the box moves, the two reeds open and close, allowing the controller to recognize the direction of the movement (upward or downward). This modification also allows for measurement of the water level, which can be carried out by placing a series of equally spaced magnets inside the shaft and implementing a state machine to record the current position and update each time the box moves.

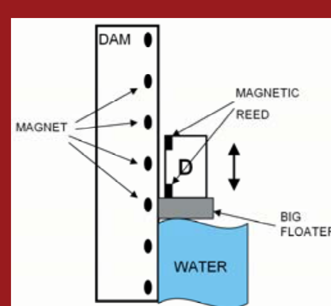

Figure 2: Improved installation

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Fall Comes to UMR