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TUNNEL DETECTION USING CROSS BOREHOLE RADAR

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PROBLEM IDENTIFICATION

Shallow tunnels present both military and homeland security threats. Smugglers with intentions of avoiding border security have turned tunnels into transit routes for trafficking weapons, people, drugs and other illegal materials. Shallow tunnel are also used by prisoners to escape prisons. While drug and human trafficking have long been border concerns, the threat of international terrorism has transformed the effort to detect tunnels into a national security priority. Imminent threats include assailants entering military fortifications by burrowing under buildings, detonation of high grade explosives from foundations of high security facilities, and high level prisoners escaping detention centers through tunnels. Real-time monitoring of the ground surrounding prisons across the country is a desired solution to this problem.

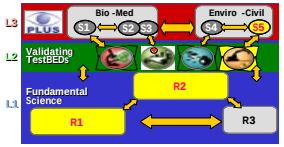
A tunnel near Otay Mesa, California (Sandy H, Getty Images, 2006) and another starting in an abandoned house in Tijuana, Mexico (David Maung, AP, 2004)

OBJECTIVE

Develop and verify an innovative, efficient, practical, reliable and easily deployable technique for real time monitoring of soil structure integrity, and localized detection of shallow tunnels.

SIGNIFICANCE

The threat of assailants accessing vital security locations is becoming a matter of great concern. Although full scale tunnel detection without reconnaissance surveys may be difficult, cross borehole radar may be used for localized monitoring of soil structure integrity and tunnel detection around vulnerable sites.



CHALLENGES

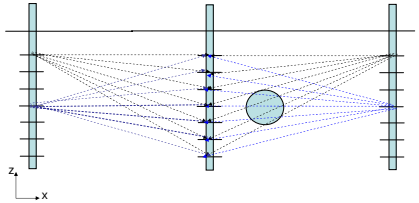
Variation in the soil environment surrounding prisons due to precipitation causes variation in soil properties including dielectric properties, which makes use of radar based geophysical techniques to detect shallow tunnels challenging. Collecting all year round measurement helps to create a database of background information. Besides, different soils demonstrate similar dielectric properties at higher frequencies and high degrees of water saturation, which may help to make tunnel more feasible.

METHODOLOGY

In this study, the feasibility of using cross borehole radar to detect tunnels is experimentally explored in the pilot-scale SoilBED facility. The problem is also theoretically simulated. Cross borehole radar measurements through PVC-cased boreholes is used to monitor localized changes in soil integrity, dielectric properties, transmission and reflection. PVC-cased monopole antennas are installed in the fully saturated sandy soil across a long horizontal PVC-cased tunnel with a diameter of 2", buried between the antenna, to experimentally simulate an infinite tunnel. Multiple-depth transmission and reflection measurements are collected to evaluate the response of background saturated sandy soil with and without the air filled pilot-scale tunnel. Real time monitoring of a pocket of water moving through the PVC tunnel to simulate a human body is also being conducted and evaluated.

EXPERIMENTATION AND DATA COLLECTION

The monopole antennas used were adjusted to take multiple depth transmission and reflection measurements from depths of 11 cm to 35 cm at intervals of 2 cm. **Both deep and shallow tunnels are experimented and studied.**



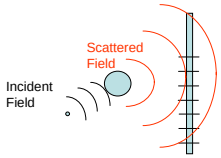
Collection of multiple depth data with a vertically traversing receiver

Comparison Between Intensity of Incident and Total Fields

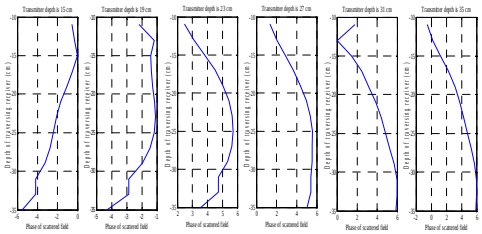
Air-filled Tunnel at 23 cm depth

TECHNICAL APPROACH

Tunnel acts as a secondary source for the scattered field. Therefore, the scattered field can be simulated using numerical or analytical techniques to be used as a forward model. Multiple depth data can be used to find the measured radiation pattern of the scattered field due to each transmitter for inversion and image reconstruction.

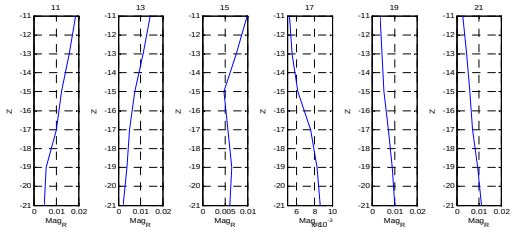


Phase of Scattered Field



Phase of the scattered field along the depth of receiver (f = 1.2 GHz), for transmitters at depths: 11, 13, 15, 17, 19, and 21 cm

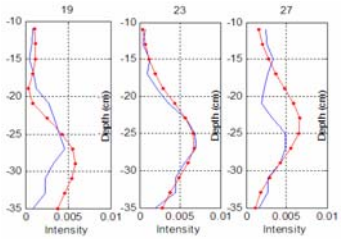
Magnitude of Scattered Field



Magnitude of the scattered field along the depth of receiver (f = 1.2 GHz), for transmitters at depths: 11, 13, 15, 17, 19, and 21 cm

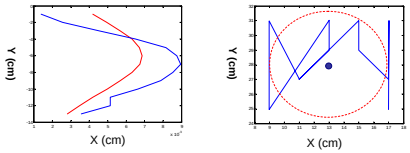
Theory Versus Experiment:

Tunnel detection technique was modeled using Finite Difference Frequency Domain (FDFD) technique. Then, results were compared with the experimental ones to achieve a reliable and realistic forward model for future inversion and image reconstruction.



Fixed Transmitter at Depths 19, 23, and 27 cm

Inversion



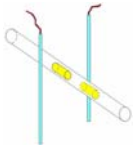
Simulated scattered field at the predicted location in red vs. Experimental results in blue at f=0.85GHz, Transmitter at 25 cm depth, various receivers

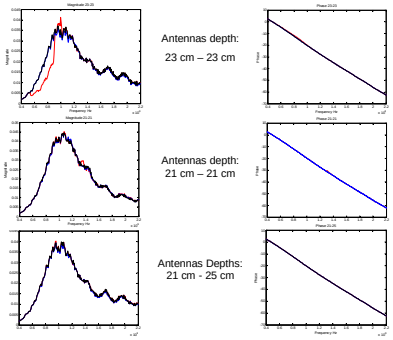
Red Circle: Actual tunnel, Blue: Prediction of center-point of the tunnel, at all frequencies, transmitter at 25 cm depth

Prediction of Location of the Center of the pipe as a point source of anomaly, and comparison between the corresponding simulated scattered filed and experimental results, Transmitter at 19cm

Detecting Moving Objects in Tunnels

Human body contains high content of water. Therefore, to simulate moving human in an air-filled tunnel, a water filled PVC pipe (75% volumetric water content) with the aspect ratio of 3/1 (typical for a human body) is moved through the tunnel and the results are collected and studied. In the future, the results will be used towards image reconstruction. Results are very promising, but do not fit in the extent of this poster.





Comparison between different object locations (blue and black) and no-object case (red), Tunnel Depth:23cm

ROLE OF UNDERGRADUATE STUDENTS IN RERSEARCH

Undergraduate students are involved in setting up experiments, data collection and analysis. Following photos show the experimental setup and data collection phases by undergraduate students under supervision of a graduate student.

CONCLUSIONS

- Comparison between total and incident field measurements illustrate suppression in the signal amplitude, especially when the antennas are at a closer depth to the tunnel.
- The unexpected suppression on magnitude can be due to scattering effect of the tunnel on the field.
- The greatest amplitude suppression was attained when transmitter and receiver antennas were all at the tunnel depth.
- The scattered field variations along depth of receiver for each transmitter have a similar pattern to a filed due a secondary source (target).
- Using proper forward model in frequency domain, variations in phase due to the tunnel, can be directly used for image reconstruction. These phase variations can be converted to travel time and used for travel time tomography. travel time tomography

ACKNOWLEDGMENT

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