Interferometrically Enhanced Sensitivity Buried Zone Sensor

Network Integrity Systems, Inc.

Introduction:

NIS has developed a novel solution for zone-based monitoring of perimeter approach via a buried optical cable. Prior to this innovation, detecting people or vehicle approach required DFOS technologies. For smaller perimeters, where DFOS is too complex and expensive, and where pinpoint location provides little value, zone-based systems can provide tremendous value as a detection mechanism. NIS' SENTINEL buried sensor detection changes the game for zone-based optical systems.

Background:

There is a source of instability caused when many optical signals of precisely the same wavelength are mixed together, thus causing interference. Multiplexing these multiple instances of identical wavelength using traditional detection methods are problematic as the slightest disturbance to any individual fiber causes wild fluctuations in the fiber containing combined signals due to constructive and destructive interference. This invention addresses this by recognizing that these combined optical signals can be used to fill a mode mixing fiber as though they were a conventional multimode signal, and therefore standard multimode detection methods can be employed.

Note:

In this initial embodiment as will be described, the sensing cable contains all single mode fiber. In later experiments it was found that a version could be constructed with multimode sensing fiber. Functional descriptions will be from a single mode sensing perspective; however the concept can be used with multimode sensor cable and Nx1 coupler.

Abstract:

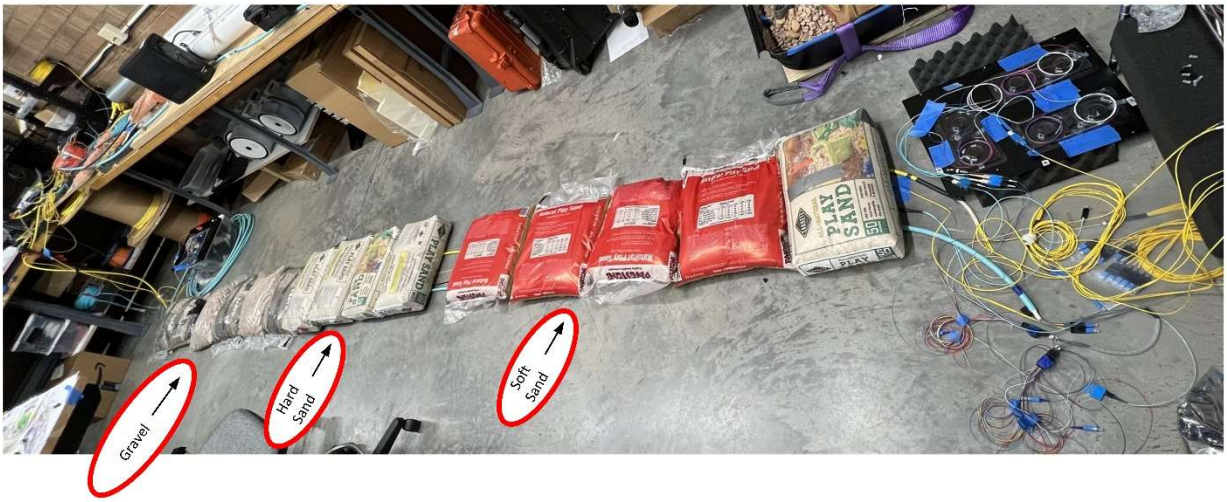
A unique solution is shown for a zone monitoring system that destabilizes the relative phase of a divided laser signal within the strands of a sensing cable and utilizes that instability as a functional amplification of a detected disturbance.

Implementation:

A method is provided for detecting subtle disturbance of an optical cable where similar light signals are transmitted along multiple optical fibers to be monitored along the sensor cable. The received monitoring light signals after transmission along the optical cable are analyzed for changes indicative of movement of the optical cable for detecting a physical disturbance. The monitoring light signals at the receive end of the fiber signals are monitored by feeding the signals from the single mode fiber into a multi-mode fiber in a manner which causes changes in modal power distribution, exacerbated by interference between the identical wavelengths. which can be detected by taking a portion only of the modes.

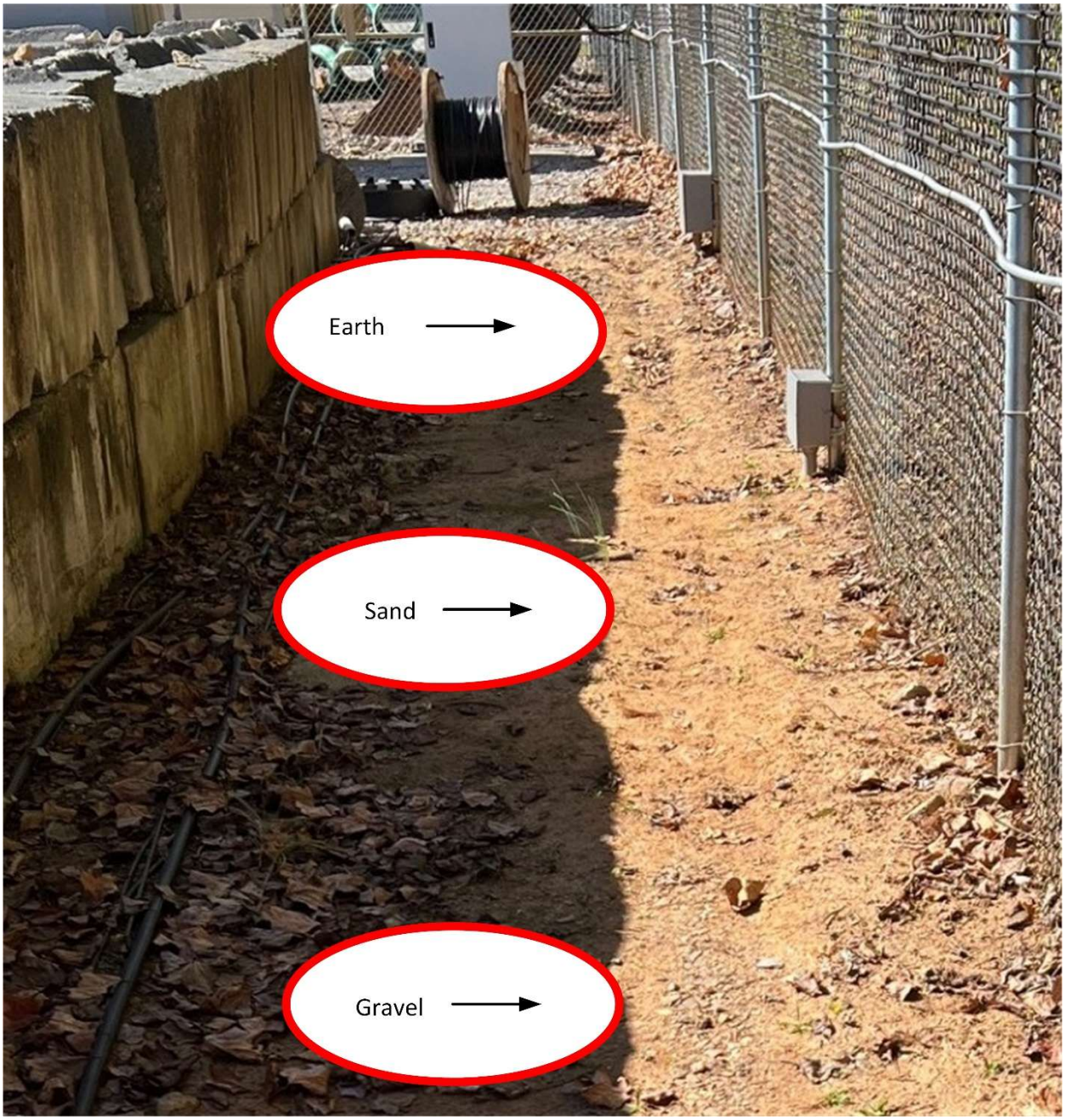
Validation:

The innovation was first tested in the lab on a concrete floor with a multi strand cable and a traditional MM utilizing standard optics as a control, covered by bags of soft play sand, hard landscaping sand, and medium gravel. Both were fed into the same NIS SENTINEL™, running a bandwidth limited version of our Smart Filter Detection algorithm. Inviting colleagues of all sizes to walk on all of the “soil” types. Performance was consistent, only the most stealth of the walking went undetected on the new SM sensing configuration. The control cable of MM performed in the vicinity of a 20% alarm rate.



Next, our services team were asked to bury the tests cables- device under test (DUT) as well as MM control side by side but not touching at our Rock City facility. This was installed as 20 ft of earth, 10ft of sand, 10ft of gravel. Here the results were more impressive:

- Virtually every footstep on all soil types was detected by the new method
- Missed step failure rate on the MM control cable was similar to the lab
- Walking one meter offset the cables detected within a few steps with the new method, none was detected with the MM
- Light jumping, as would be jumping off a 2 ft step ladder 1 meter from the tests sensors yielded 100% detection with the presented method, none with the MM.



Conclusion:

This novel optical design is a substantial leap forward in zone sensitivity. The marriage of interferometry and modal metric sensing brings the best of both. No unique electronics are required, the enhancement is optical and passive.

Intellectual Property:

- 1 US Patent Pending 18/918,871

Timeline

First conception and lab prototype 8 July 2024
SM field installation 11 July 2024
MM Lab prototype 16 Oct 2024

Project or Product Location:

- Hickory NC at NIS' RD&E Lab for prototype
- Hickory NC at NIS' Rock City Engineering and Demonstration Facility for field validation

Why NIS should win the award:

The fiber optic sensing industry has fallen into a pattern of supplying expensive, highly effective, and sophisticated sensing solutions that are increasingly reliant upon distributed sensing. Although these locating solutions are impressive and desirable, they come at a high dollar cost. A lower cost genre of fiber sensing equipment exists that provides what is often adequate sensitivity and protection for many applications such as network security, perimeter fence security, and rooftop monitoring… although many of these often at 1/10th the cost of the DFOS solutions. There are many applications for these so-called zone based systems where one only needs to know that, for example, the west fence is being climbed without needing the exact location, and the budget is not there for a DAS. Examples include car lots, storage facilities, even perimeters within a larger DAS protected perimeter. Although there is a demonstrated need and market for such zone products, there appears to be little innovation in recent years.

One area where zone products have failed to answer the call until now- buried sensors such as protecting a perimeter. The need has always been there, however traditional zone products, be it polarization or modal metric sensing based, traditionally lack the sensitivity to detect footfalls.

This invention overcomes that sensitivity by destabilizing the modal distribution in a speckle detection system by amplifying the interaction interferometrically. For no more cost than a traditional zone product, one can now monitor walking- evaluated and validated in dirt, gravel, and sand environments.

This is important because it furthers the availability and visibility of fiber optic sensing into an entirely new, and massive, market.

For example, a four channel SENTINEL from Network Integrity Systems previously could have monitored the fence with one channel and the roof top with another. Now, with this capability, a customer can add channels 3 & 4 monitoring each side of the fence. A timeline unfolds as a perpetrator is detected approaching the fence (outside buried sensor), climbing the fence, walking inside the fence (inside buried sensor), and climbing the roof for building access… all for roughly 10% of the cost of a similar DAS installation.

Why should this win the award? This is a genuinely new and innovative optical measurement scheme that will put fiber optic sensing into an entirely new market subset… a subset who would never consider the cost of a DAS system will now look at fiber. And that is great for FOSA.