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100km Pipeline Monitoring:
Record Length For Intrusion And Leakage Detection

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Abstract

We demonstrate a record length of distributed acoustic fiber sensing (DAS) for pipeline monitoring. Both intrusion (third party interference) and leakage can be detected. An ultra-sensitive architecture enables record length (100km for a single ended fiber sensing system or 200km for sensing from both ends) detection while advanced classification capabilities minimize both false and nuisance alarms. Targets are localized (high resolution of few meters) and classified.

While conventional DAS fiber sensing is limited to 20-50km, increasing the effective range to 100km can significantly decrease the number of systems and number of stations needed for long range pipeline monitoring.

Using both the Hyper-Scan technology and our Smart Amplification scheme, we overcome these challenges. The combination of the very high SNR, rich data, and novel classification algorithms enable us to detect and classify different events at distances of up to 100km, using a pre-existing optical cable in a conduit deployed along a pipeline.

MEDIUM RANGE SENSING DATA

In this section we will present real-life generated data gathered and processed in real-time along a pipeline infrastructure. The pipeline is buried at a depth of 1.5-2m, varying according to ground conditions. The sensing fiber is a standard SM fiber, originally deployed for the purpose of optical communication, buried in a plastic conduit at a distance of 1-2m from the pipeline. The data below shows a 9km section, out of the hundreds of kilometers of pipeline infrastructure.

The pipeline passes near roads, railways and settlements. The environment is thus noisy and includes many sources of different acoustic signals. Many of them are harmless events that do not require special attention, such as cars passing, humans walking, farm animals grazing and such. The high quality of the gathered data enables our advanced algorithms to detect and classify correctly all the targets in the vicinity of the pipeline, both the harmless background sources and sources that are threats to the pipeline, such as machine digging and even human digging with a hoe. Once all the targets are classified correctly, the system clears the nuisance alarm (harmless targets) and alerts the user only when a pre-defined target is detected. In our case, the pipeline crosses agricultural and rural areas. It is buried under and parallel to highways and train tracks. These busy areas are fruitful grounds to numerous different strong and weak background signals. If the classifying algorithm would not disregard them, the high nuisance alarm rate of the system would deem it useless.

The following figures show data examples recorded in real time by the system. In these graphs, the x-axis presents the location along the interrogated fiber and the y-axis presents the time. Figure 1 shows the trace of a car driving back and forth at a varying distance of 10-50m from the pipeline, around the 7th km of the fiber. One can also clearly see the acoustic noise (at 5.5km) generated by cars passing on a road that crosses the pipeline route.

Figure 2 below shows human digging activity, comprised of 20 hits to the ground with ah hoe at a distance of 10 m from the pipeline. In Figure 3 machine digging activity at the same location is presented, over a much longer time.

Figure 4 is a snapshot of the PrismaSense graphical user interface. The presented snapshot is of the machine digging of Figure 3. The detected and classified events are presented both on a map, and in a table, providing the user with additional detailed information about the event. According to user supplied rules, part of the events are classified as threats and appear in a table of alerts. An additional, optional table presents all the events, including both alerts and harmless events. Here, the system detected and classified two irrigation water pumps which are presented only in this table, as they pose no threat to the monitored pipeline, and only the digging is presented as a threat.

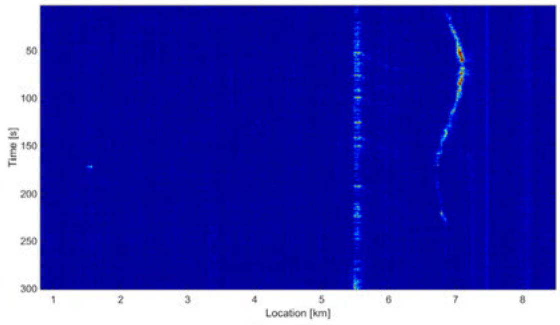

Figure 1: Vehicle trace at 7km

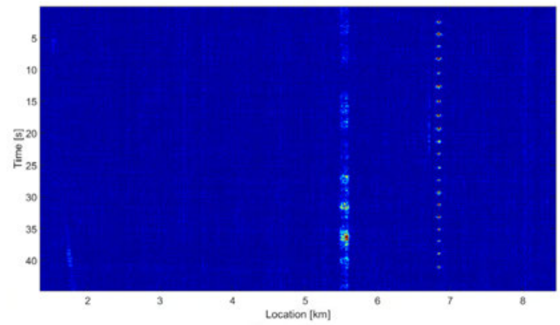

Figure 2: Human digging activity at 7km

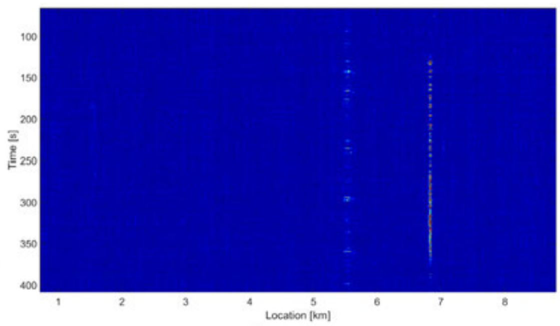

Figure 3: Machine digging activity at 7km

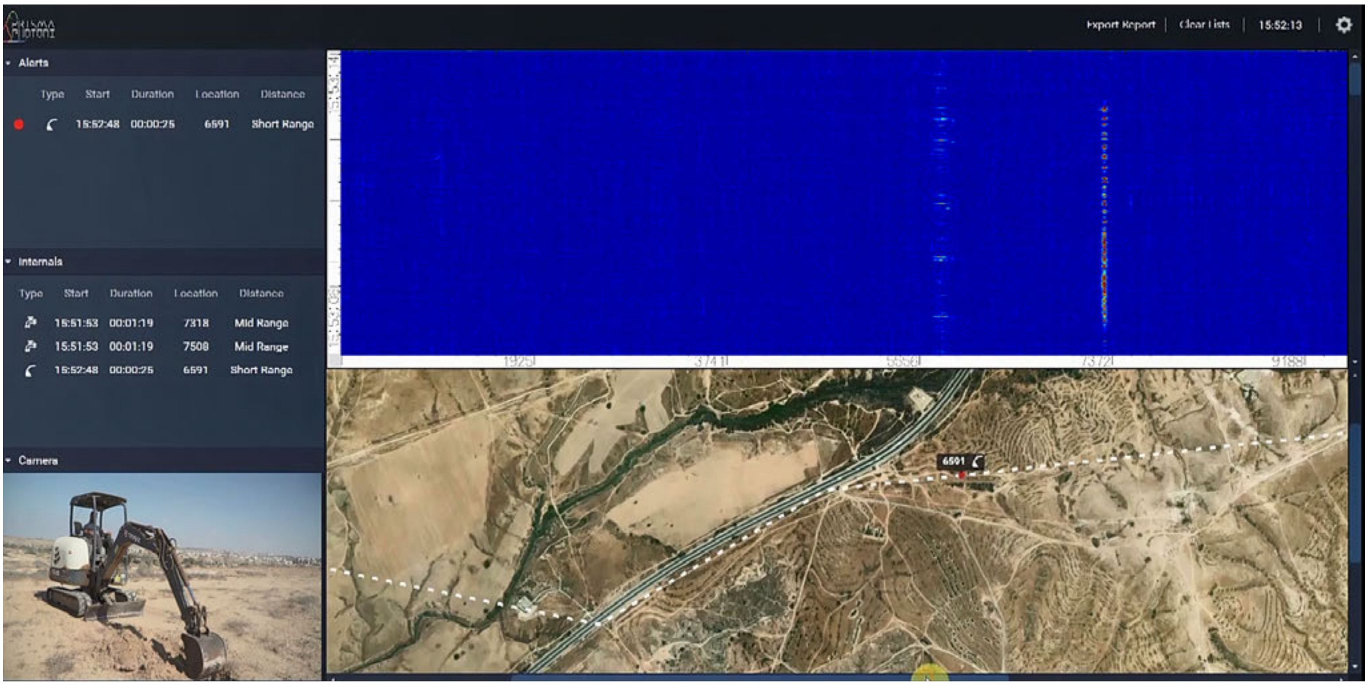

Figure 4: System user interface

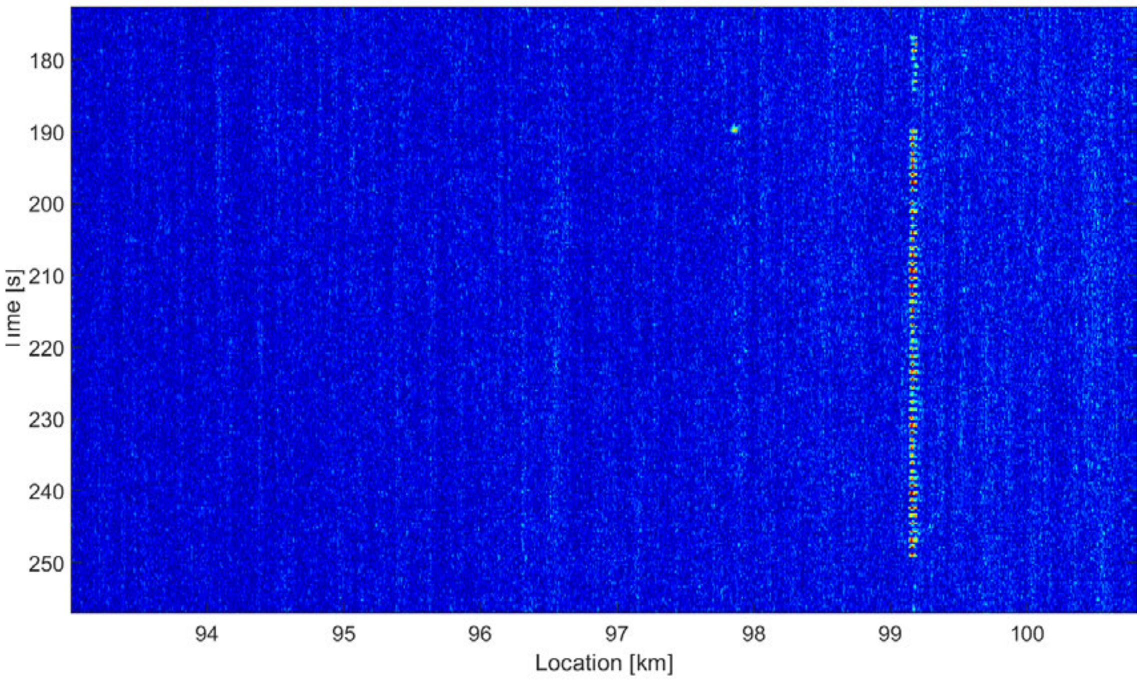

Figure 5: Human digging activity at 99km

EXTENDING THE SNSING RANGE TO 100KM

This section demonstrates the unique PrismaSense system capability of monitoring a record length of 100km, in a distributed manner, with a single interrogator. Figure 5 and Figure 6 show a closeup of a fiber section starting 93-94km away from the interrogator. As briefly described in Section 2, the combination of the unique Hyper-Scan technology and tailored Smart Amplification, improve SNR significantly, enabling us to extend the sensing range to 100km. The expected SNR degradation is apparent in the 100km data, remains sufficient for detection and classification of the events of interest, in this case, human and machine digging.

SUMMARY

We presented fiber-sensing DAS detection capabilities at record length of 100km. A high-quality (high SNR) data was achieved even for relatively weak targets (for example: human digging 10m away from the fiber). The testing scenario was even more challenging since all those measurements were taken using "pre-existing" optical communication fibers (fiber optic cables in conduit, which, based on [4], reflects additional 20dB of signal attenuation).

The high signal to noise ratio (SNR) and very rich data is the foundation for FAR (false alarm rate) and NAR (nuisance alarm rate) reduction and performance optimization.

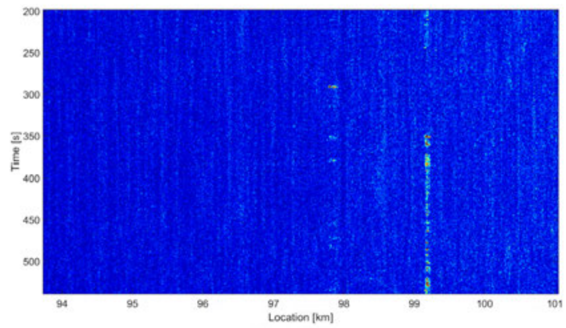

Figure 6: Machine digging activity at 99km

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