The croissant: a smaller, fluffier, flakier pretzel

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ABSTRACT

While we have a working experimental directional DAS sensor (DDS) at Carbon Management Canada's Newell County Facility, it is quite large (10x10m), and being horizontal and flat, has no way to record vertical component data (Hall et al., This volume). Logistically, we need a smaller sensor that can record vertical motion and is easier to bury for permanence and coupling. Testing has shown that we can record reasonably consistent data on a sensor where the one-meter-long sides of the sensor are smaller than the default seven-meter gauge length used in our DAS interrogator. In future, after further testing, we plan to install a receiver line containing more than one directional DAS sensor at the Facility.

INTRODUCTION

While we have a working experimental directional DAS sensor (DDS) at Carbon Management Canada's Newell County Facility, it is quite large (10x10m), and being horizontal and flat, has no way to record vertical component data (Hall et al., This volume). Logistically, we need a smaller sensor that can record vertical motion and is easier to bury for permanence and coupling. Ideally, we would also like to install a receiver line containing more than one directional DAS sensor at the Facility.

The 10 m size of the DDS was chosen so the straight lengths of fiber would match a 10 m gauge length, or less, set in a DAS interrogator. Due to stiffness of the cable used to construct the DDS, we wound up with 1 m radius corners, and an effective gauge length of 8 m or less that could be acquired with no effects from the corners or other sides of the DDS. Takekawa et al. (2022) presented results from a directional sensor with two horizontal components and one vertical component that is on the order of 25x25x25 cm in size, meaning the fiber forming the sides for each component of their sensor are 40 times smaller than the sides of our DDS. Data was recorded with a 20 cm gauge length, meaning that, like our DDS, the gauge length used for recording was less than the length of one side of the sensor.

We have now seen on multiple datasets from the DDS and from the 5 km fiber loop at the Facility that the polarity of recorded data does not change when the direction laser light travels along a fiber is in the opposite direction, for example in a well where the fiber was run to the bottom of the well and the back up to the surface. Examples of DAS VSP data showing no polarity reversals can be found in Hall et al. (2021,2022a,2022b). This led us to speculate that we might be able to effectively record data on a loop of fiber with small radius 180 degree corners, and directionality provided by the length of fiber between the corners, where said length is on the order of 1 m or less, even with gauge length larger than the length of the sensor.

We plan to create three 1x1 m directional sensors, bury them 10 m apart at the Facility in 2023 and acquire some test shots. In preparation, we purchased a spool with 500 m of Series W7T FTTP fiber manufactured by Superior Essex. This fiber cable contains one single-mode fiber, is designed for indoor/outdoor usage, can be buried, can be located after burial, and can be wrapped around tight corners with minimal signal loss.

Questions to be answered before burial of any new sensors include:

- Will the W7T FTTP cable work with the University of Calgary's OptaSense ODH4 interrogator?
- Do we need more than three components?
- What is the optimal length of the sensor sides?
- What is the minimum usable bend radius of the cable?
- How many wraps of fiber will be required per sensor component?
- How much additional cable is required between any two sides of the sensor?
- Can we see a change in the data that can be attributed to orientation of the sensor sides?

METHOD

The initial plan is to construct two (vertical) 1x1 m square frames using plastic pipe and corners for each sensor (Figure 1). One frame would then be wrapped with fiber cable both horizontally and vertically, and the other frame just horizontally (Figure 2). Placing sensors permanently in the ground would involve digging narrow vertical trenches with a trenching machine, with short perpendicular trenches for the second frame (Figure 3). Note that this design means that we do not have to dig a 1x1 m hole in order to install a horizontal frame.

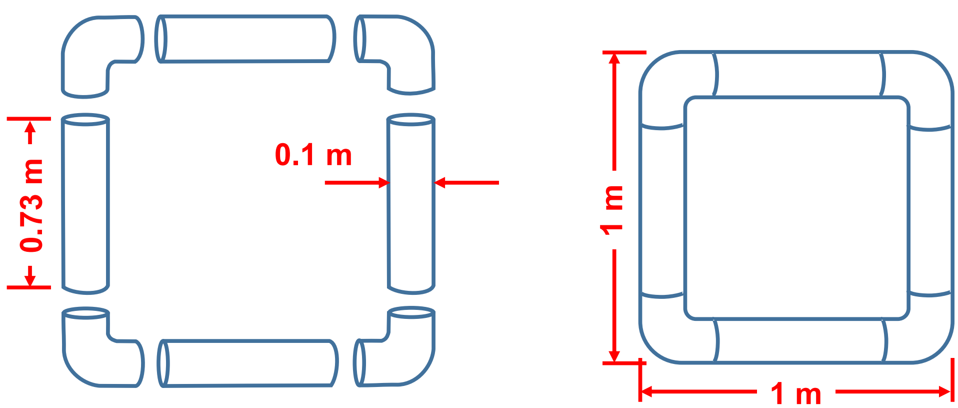

FIG. 1. Initial concept for plastic frame construction. The 0.73 m length sides shown will result in a 1 m square for 10.2 cm (4") diameter ABS sewer pipe and corners.

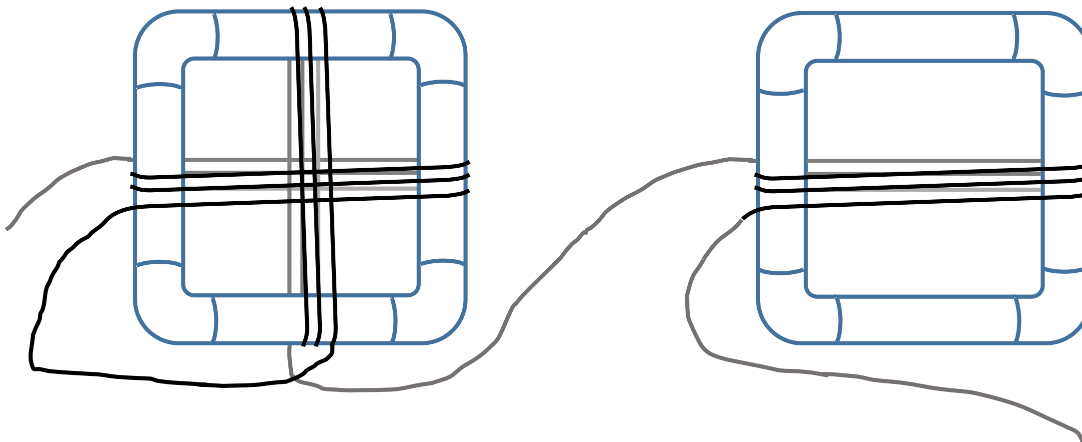

FIG. 2. Initial plan for wrapping plastic frames with fiber optic cable to obtain three directions of sensitivity.

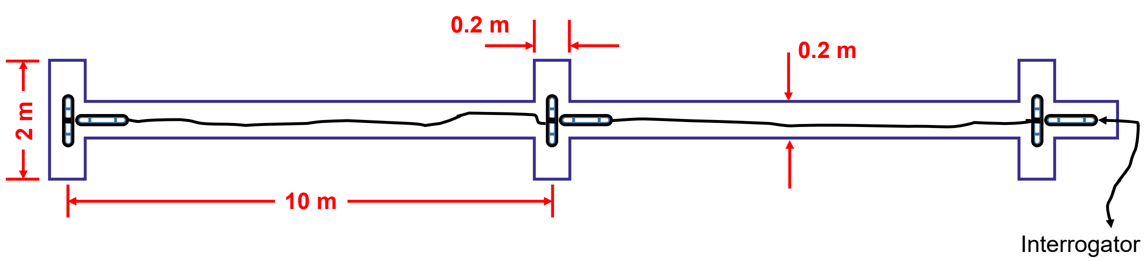

FIG. 3. Initial plan for trenching to bury three 3C fiber sensors.

METHOD

Two tests were conducted. The first (Test1) was to see if the fiber would work with the University of Calgary's OptaSense ODH4 interrogator with a 7 m gauge length, and to prove we could observe directional effects due to spool orientation but no polarity reversals in the data. As such, a connector was spliced onto the fiber without unwrapping any fiber from the spool. The spool was placed on the ground 15.6 m from the VP and connected to the interrogator using a 40 m patch cable. Four 10-150 Hz 16 s linear sweeps were recorded for each of three different spool orientations using the University of Calgary's IVI EnviroVibe, with the axis of the spool oriented vertically, cross-line and in-line (Figure 4). For the in-line and cross-line orientations, the spool was blocked on both sides with wood beams in an attempt to prevent rolling during the sweep. Ground coupling was purely provided by the weight of the spool.

a) b) c)

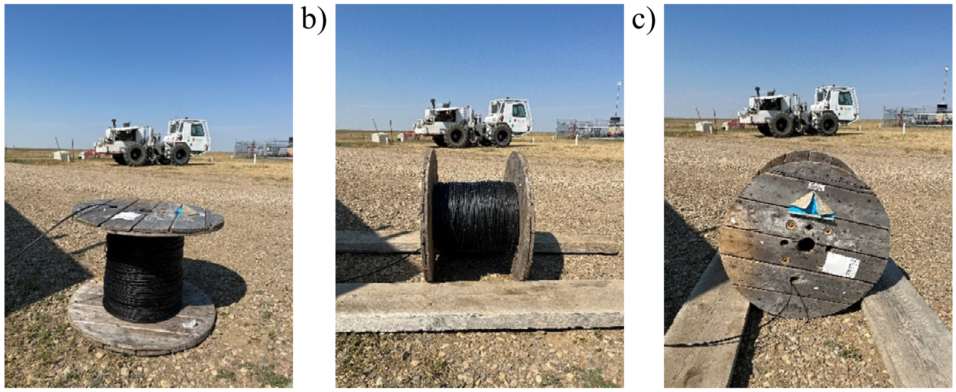

FIG. 4. Test 1: A 500 m spool of fiber located 15.6 m from the VP with the axis of the spool oriented vertically (a), cross-line (b), and in-line (c) relative to the Vibe location.

a) b) c)

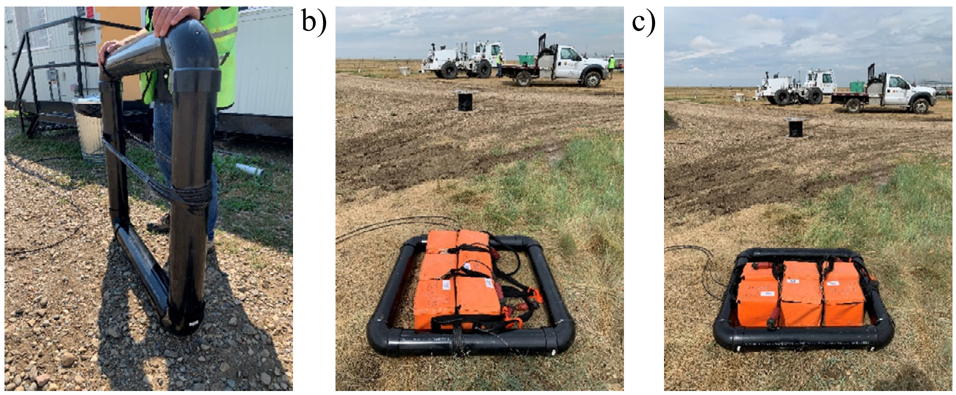

FIG. 5. Test 2: A 1x1 m frame was wrapped with 14 m of fiber cable (a) and placed flat on the ground with the fiber oriented in-line (b) and cross-line (c). Coupling was provided by stacking batteries on top of the fiber. The remainder of the fiber was left on the spool, which was placed 15.6 m from the VP with the axis of the spool oriented vertically.

For the second test (Test2) we constructed a 1x1 m square frame from 4" diameter ABS sewer pipe and wrapped it with two-gauge lengths (14 m) of cable (Figure 5a). This process proved that, given enough slack, we can wrap one of the frames without having access to the ends of the cable. Note that the fiber cable is not attached to the frame in any way other than friction, the frame is just being used to form the fiber cable.

While we are planning to install frames vertically, it made sense to test with our test frame horizontal. The frame was placed flat on the ground 22.6 m from the Vibe with the fiber oriented in-line (Figure 5b) and cross-line (Figure 5c). Fiber coupling to the ground was provided by stacking seismic batteries on top of the fiber inside the frame. The remainder of the fiber was left on the spool, which was placed 15.6 m from the Vibe as a control. Over 15 m (> 2 gauge lengths) was left on the ground between the frame and the spool. We used the 40 m patch cable again, giving 50 m of fiber between the interrogator and the frame. We were initially unable to acquire data on the interrogator for this setup. Splicing a new connector onto the fiber cable fixed the issue, leading us to believe the original connector was damaged when storing the spool two days earlier. As with Test1, Test2 was acquired with 4 sweeps per frame orientation. Additionally, the Vibe was also pulsed 11 times per frame orientation.

RESULTS

While the Test1 data cannot be trusted due to the loose wind on the spool and coupling issues, it was repeatable, with each of the field records generated with four sweeps per spool orientation looking the same. Figure 6 shows stacked and correlated source gathers (vertical fold equals 4) with AGC for display. We can see differences in the data that we believe can only be attributed to the directionality of the spool. Less encouragingly, apparent polarity reversals are visible, but closer inspection reveals that these traverse multiple traces. For now, we are attributing these to the cable not being tight on the spool. The cable did work with the interrogator, and we do observe changes in the data that can be attributed to the spool orientation.

Figures 7 and 8 show stacked and correlated data for Test2 for stacked and correlated Vibe sweeps (vertical fold = 4) and stacked vibe pulses (vertical fold = 11). Figures 7a and 8a show results for the fiber on the frame oriented in-line to the vibe, and 7b and 8b show results for fiber oriented cross-line with respect the vibe. For both vibe sweeps and pulses, we can see that data from the spool is repeatable, but changing the orientation of the fiber, labelled ‘F’ in the figures results in an obvious change in the data. Further, we see relatively consistent data from fiber on the frame even with 1 m sides while recording with a 7 m gauge length, with no polarity reversals.

Extracting frame traces and spool traces and stacking them gives us the results shown in Figures 7c and 8c, where the stacked traces have been repeated ten times for visibility. We can clearly see differences between the in-line and cross-line frame data, while the vertical-axis spool data is identical, as we would expect since the spool was not moved when the frame was rotated. Interestingly, air blast is clearly visible on the Vibe sweep data (high frequency noise before 10 ms), but is not apparent on the Vibe pulse data.

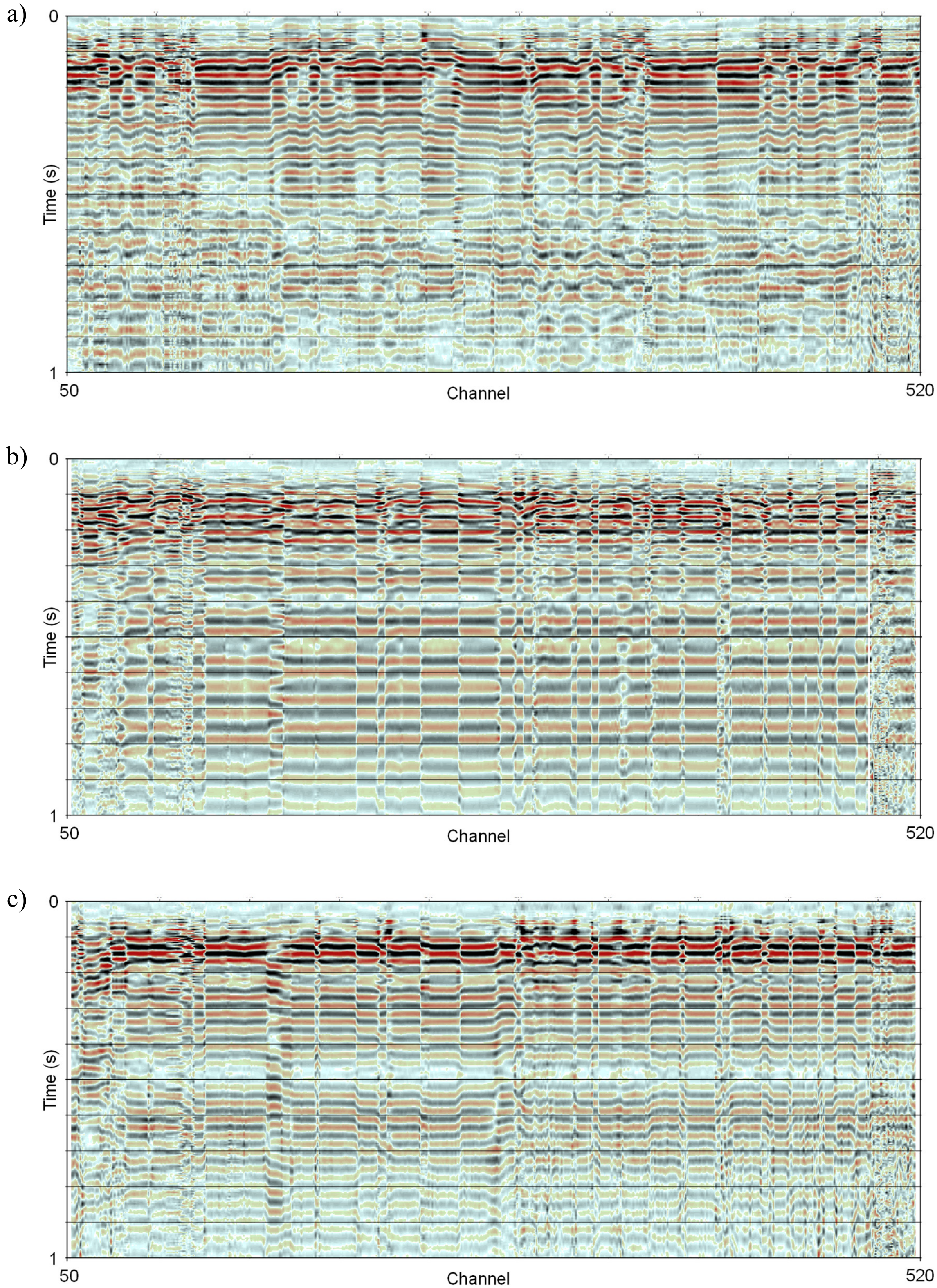

FIG. 6. Data recorded for Test1 with the spool axis oriented vertically (a), cross-line (b), and in-line (c) relative to the Vibe location (cf. Figure 4).

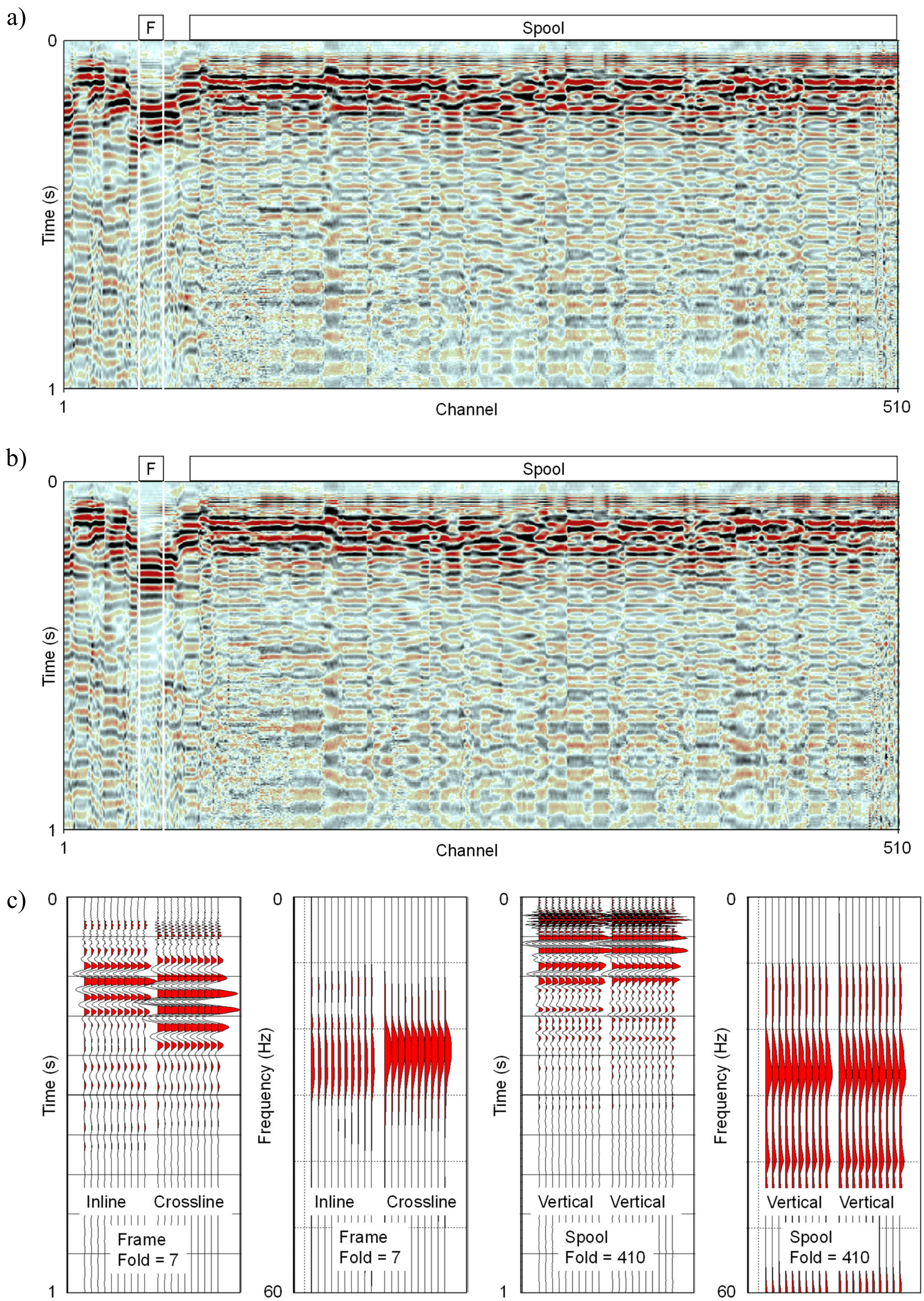

FIG. 7. Stacked and correlated data recorded for Test2 sweeps with fiber on the frame oriented in-line (a), and cross-line (b) relative to the Vibe location (cf. Figure 5). Figure 7c shows stacked traces and amplitude spectra from the frame and spool repeated 10 times for visibility.

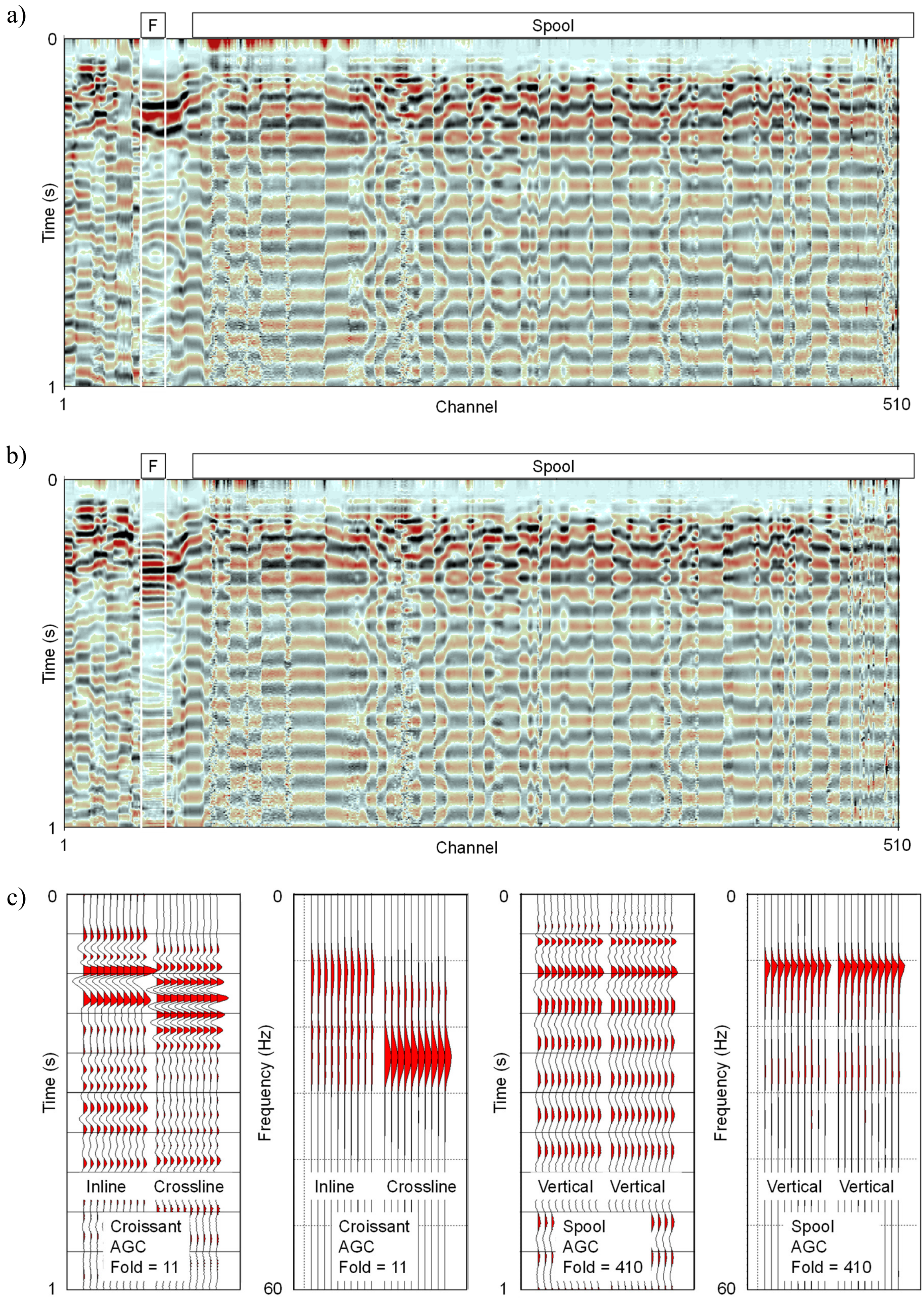

FIG. 8. Stacked and correlated data recorded for Test2 pulses with fiber on the frame oriented in-line (a), and cross-line (b) relative to the Vibe location (cf. Figure 5). Figure 8c shows stacked traces and amplitude spectra from the frame and spool repeated 10 times for visibility.

DISCUSSION/FUTURE WORK

Testing thus far has shown that W7T FTTP cable 1) will work with an OptaSense ODH4 interrogator and can be wrapped around four inch diameter corners with no apparent signal loss. Data recorded on round and oblong coils of this cable exhibit differences that can be attributed to the orientation of the coil. When the cable is wrapped around a 1 m diameter frame and has good coupling with the ground, we can record consistent data from the coil that no polarity reversals, even when the length of an oblong coil is less than the interrogators gauge length.

Unfortunately, the interrogator was shipped to the Yukon shortly after the testing in this report was completed, so future testing will have to wait until summer of 2023. We would like to further test the diameter of the coil, length of sensor sides, and number and orientation of coils prior to burial of any new sensors. For example, if it turns out that two horizontal components are not sufficient due to broadside insensitivity, we can imagine burying more than one vertical frame, edge-to-edge in a star pattern. We plan to complete testing, bury three sensors spaced 10 m apart at the Facility, and record data on the new sensors prior to the 2023 CREWES sponsors meeting.

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