A field test of land 3-C geophone planting techniques

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ABSTRACT

Three component geophone plant techniques are an important part of land 3-C acquisition. Correctly-planting a 3-C geophone is time consuming, and potentially costly. A field experiment is conducted to see if 3-C geophone planting technique has an impact on recorded data quality. A field experiment was designed to test four geophone plant techniques: (1) careful insertion of the geophone while maintaining correct orientation and plant, (2) planting of the geophone without regard to precise orientation, then re-orienting the phone, (3) planting of the geophone without regard to level, then re-leveling the geophone, and (4) planting the geophone without regard to orientation or level, then re-orienting and re-leveling the geophone. A field experiment is performed using a vibratory source and spike-shaped 3-C geophone cases. Analysis of the data indicates that, for the test area, the geophone plant technique had little effect on the signal to noise ratio or the frequency content of the recorded signal. We conclude that the soil conditions at the test site were permissive of poor plant technique, and that under these or similar conditions, a two-part or three-part geophone plant technique is acceptable. We propose a repeat test under different soil conditions.

INTRODUCTION

Three-component geophones, designed for land-seismic acquisition, required careful planting. They must be planted firmly in the soil, they must be oriented correctly (relative to a fixed compass bearing), and they must be planted with the horizontal axes level to the ground. Incorrect orientation and incorrect leveling can diminish the value of the survey and pose a data processing challenge. Multicomponent acquisition can prove costly if an excessive amount of time is spent making the perfect 3-C geophone plant. How much care is really required? An experiment was designed to test different approaches to 3-C geophone planting. The conventional approach to 3-C geophone planting is to keep the geophone oriented and level, while simultaneously pushing it into the ground. A faster technique is to plant the geophone first, then rotate it to the optimal orientation and then (if necessary) level it. It has been proposed, though never experimentally confirmed, that orientating and leveling a geophone *after* it is planted is bad: Conventional wisdom is that doing so loosens the soil on which the geophone is planted and reduces coupling.

A field test was designed to see if the 3-C geophone planting method makes a difference in the quality of recorded data. A dense 3-D spread of 24 geophones was planted in an open prairie pasture. Six geophones were planted in one of four different ways:

(1) A Slow and careful geophone planting in which the correct orientation and level were established and maintained as the geophone was inserted in the ground

(2) The geophone was planted as above, but the orientation was purposely misaligned by approximately 30 degrees. After the geophone was planted, it was rotated through 30 degree to place it back into the correct azimuthal orientation. No attempt was made to push down on the geophone after this rotation.

(3) The geophone was planted with the correct orientation, but no effort was made to level it until after it was fully planted. To over-emphasize any negative effect of leveling, the geophone was purposely titled out of level, and then the tilt azimuth was swept through a full 360 degrees of rotation. Finally, the tilt was reduced to zero, leaving the geophone perfectly level.

(4) The geophone was planted and rotated into the correct orientation (like in 3) and the correct level (like in 4). We fully expected these geophones to have the worst coupling.

After planting the test patch of geophones and shooting into them with a vibrator source, we compare receiver gathers from the different planting methods and see if there are any notable differences related to geophone plant technique.

FIG. 1. Sensor SM24 Geophone elements in a PE-6/S case.

FIG. 2. Seismic equipment at the field site. The IVI Envirovibe (left) was used as the vibratory source. Data were recorded with the ARAM Aries-equipped recording truck (centre-right).

THE EXPERIMENT

The experiment was executed in conjunction was other fieldwork. In addition to performing the geophone plant test, a seismic survey was performed to obtain a shallow image along two short seismic lines.

The study area was one of the fields surrounding the Rothney Astrophysical Observatory near Priddis, Alberta, Canada. This site, a satellite campus of the University of Calgary, is in a rural area about 26 km southwest of downtown Calgary. Based on previous excavation at the site, we believe the near surface consists of a 0.5 m layer of organically-rich, spongy, black top soil over a thick layer of loose clay.

A total of five receiver lines were deployed: These were two lines of single component geophones and three lines of 3-C geophones. Two converging source lines ran alongside the single-component geophone lines. An IVM Envirovibe vibratory source was employed to generate source energy. A 16-second source sweep and 19 second listen time was used. The sweep was linear, covering frequencies from 10 Hz to 200 Hz. A cosine taper was applied to the sweep with a 1 s start ramp and a 0.5 s end ramp. Four sweeps were performed at each source location to increase the signal to noise ratio. Data were correlated in the field using a diversity stack method to edit any bursts of environmental noise.

The geophones under test were newly-acquired Sensor SM-24 geophone elements mounted in PE-6/S spike-shaped cases (Figure 1). These geophones require a small, 15 cm deep by 6 cm wide hole to be drilled for each geophone. Holes were drilled with a gas-powered handheld auger. Geophones were connected to an Aries 24-bit recording system manufactured by ARAM Systems Inc. The recording system uses field digitizing boxes, each supporting eight acquisition channels. A total of 240 channels were deployed with 72 channels devoted to this experiment. Purpose-built 3-C geophone cables are still under development for the Aries system, single-component geophone cables had to be used to hook up the 3-C geophones to the digitizing boxes. A convoluted cable layout (Figure 3) was required to connect all three components of all 24 geophones in the test patch. The close spacing of the geophones resulted in high cable density, and the need for great care in layout to avoid tangles and wiring errors. The author highly recommends the use of purpose-build 3-C geophone cables for work of this nature.

As mentioned before, the goal of this experiment was to see if the geophone planting technique (slow, single motion versus a quick multi-step) has an impact on recorded data. Our hypothesis is that after-plant manipulation of the geophone (re-orienting or re-leveling), causes a deterioration of plant quality. Poor plant quality should result in less recorded energy, a decrease in the signal-to-noise ratio, and a change in frequency content (Krohn, 1984).

RESULTS

In order to compare the output of four groups of geophones, the systematic difference in source/receiver geometry had to be minimized. By analyzing data from shots with longer offsets (>200 m) the amount of offset variation from one geophone to another is minimized. Given the source geometry (two lines of source) there were two options for “long” offsets: either take a set of shots toward the north end of line 1 (near station 1001) or use shots from line 2. We elected to use source locations from line 2 (stations 2101-2180) as these provided a multiplicity of shots with similar offsets. The source spacing was nominally 10 m over this range of stations.

One quick way of comparing geophones is to sort data into receiver gathers and plot these gathers for plant methods 1 through 4 beside each other. Figure 6 shows a sample of four receiver gathers from plant methods 1 through 4. Each gather is formed from a single geophone (not a combination of six). The geophones shown are representative for their plant technique. Figure 6 shows geophone vertical components while Figure 7 and Figure 8 show transverse and radial components respectively. We define the radial component as the component oriented East-West (in-line with the source-receiver azimuth) and the transverse component oriented North-South. (perpendicular to the source-receiver azimuth). These receiver gathers show a first-arrival event at about 150 ms, and an air-wave event starting at 750 ms. Although there are differences in the first-arrival wavelet from panel to panel, these differences are relatively minor. Looking below the first arrival there are vestiges of reflections. What is notable is that there is no discernable difference in signal to noise ratio – even toward the bottom of the section. In fact, qualitatively speaking, there is very little difference between any of the geophone plant techniques based on these figure.

If we pay close attention to the shallow part of the section, shown in Figure 9, Figure 10, and Figure 11 (again, Vertical, Transverse, and Radial) we see some minor geophone-to-geophone differences. Specifically, the second and third cycles beyond the first break occasionally appear as doublets on some geophone plant/component combinations, while on others they are combined into a singlet. Beyond this difference, the remainder of these time-limited gathers looks very much the same. Considering that the geophones were planted with effort to induce a pronounced difference in coupling, no such pronounced difference exists in the time-domain records.

Frequency analysis for the geophone plant types was performed using the ProMAX interactive spectrum analysis software. Selecting a signal window from 100-400 ms, we compare the recorded frequency of each geophone plant method. Figure 12 illustrates the frequency analysis program in action. Here, we see an analysis window drawn over a portion of the section. The associated spectrum is plotted.

Figure 13, Figure 14 and Figure 15 show the computed frequency response of a time window between 100 and 400 ms. This time window includes the first breaks. The spectra show that data acquired with plant method 1 differs little in frequency content from data collected with methods 2 to 4. We see a spike at 180 Hz, which is probably a harmonic of 60 Hz power-line noise. Other than this, the spectra match remarkably well.

CONCLUSIONS

Based on a qualitative review of the time and frequency response of geophones planted with different plant techniques, it appears that, for this soil type and geophone case, the geophone plant is not affected by post-plant rotation or orientation. Other papers indicate that soil type is a large factor in geophone plant quality. It would appear that the soil type is ideal at this site, and that the soil conditions are very tolerant of post-planting adjustment of the geophone. Clearly, more experiments need to be performed in different soil conditions before we can conclusively state that post-planting rotation and orientation are harmless. Based on the data collected, it appear that there is little harm caused by a two or three step planting method, where geophone orientation and leveling is performed after the geophone has been planted firmly in the ground.

ACKNOWLEDGEMENTS

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REFERENCES

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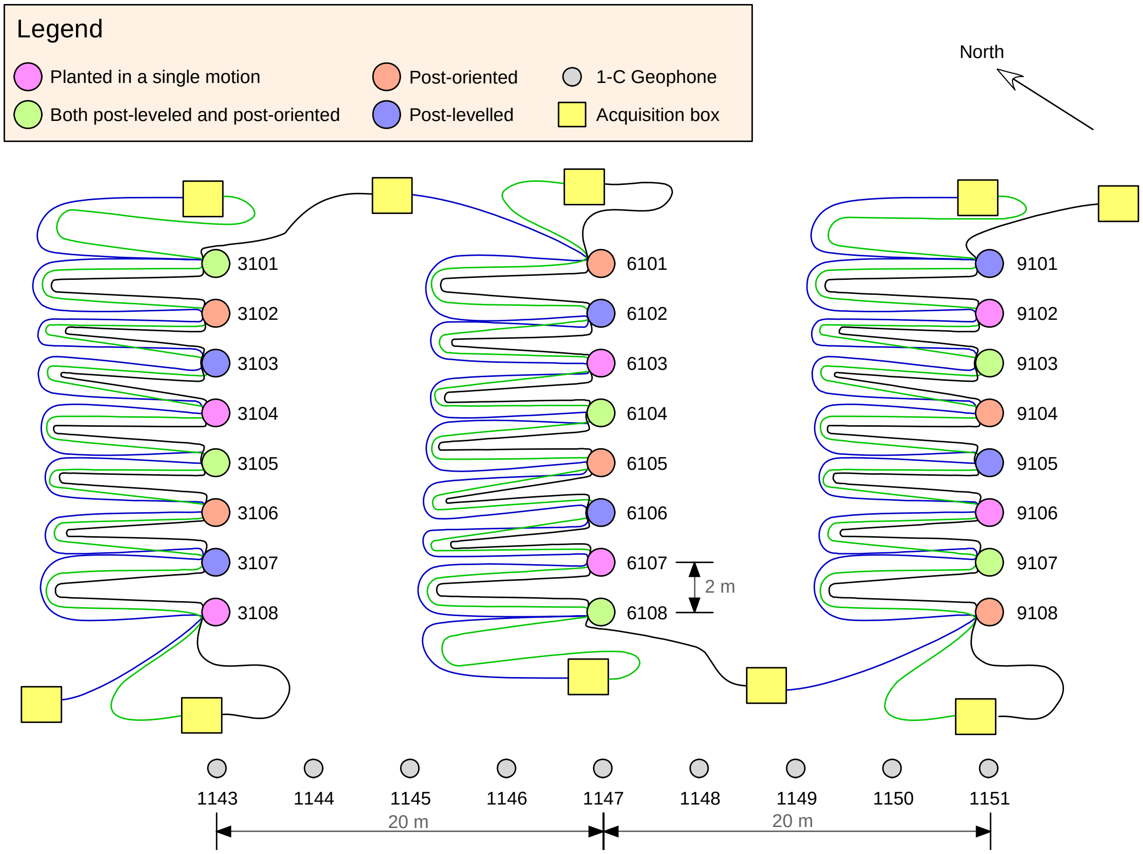

FIG. 3. Schematic layout of the dense test patch of 3-C geophones.

FIG. 4. The chaining crew marks out the site of the test patch. Geophones, planted using four variations of planting technique, are interspersed along three lines of geophones. The geophones are 2 m apart and the geophone lines are separated by 20 m.

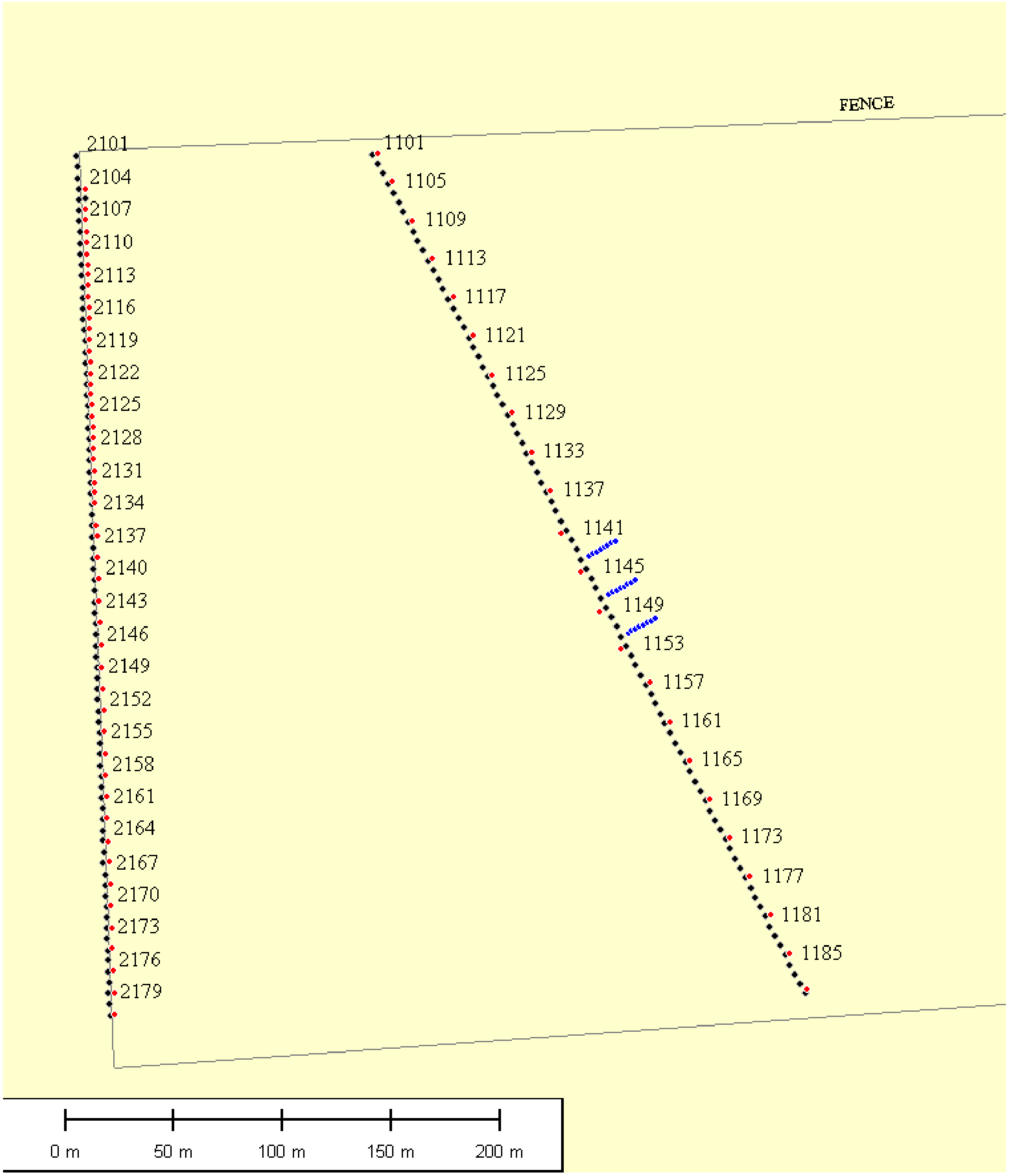

FIG. 5. Base map showing the seismic program. Shots (red) were located along two diverging source lines. Single-component geophones were placed along the two source lines. The densely-packed test patch of 3-C geophones (blue) was located near station 1145.

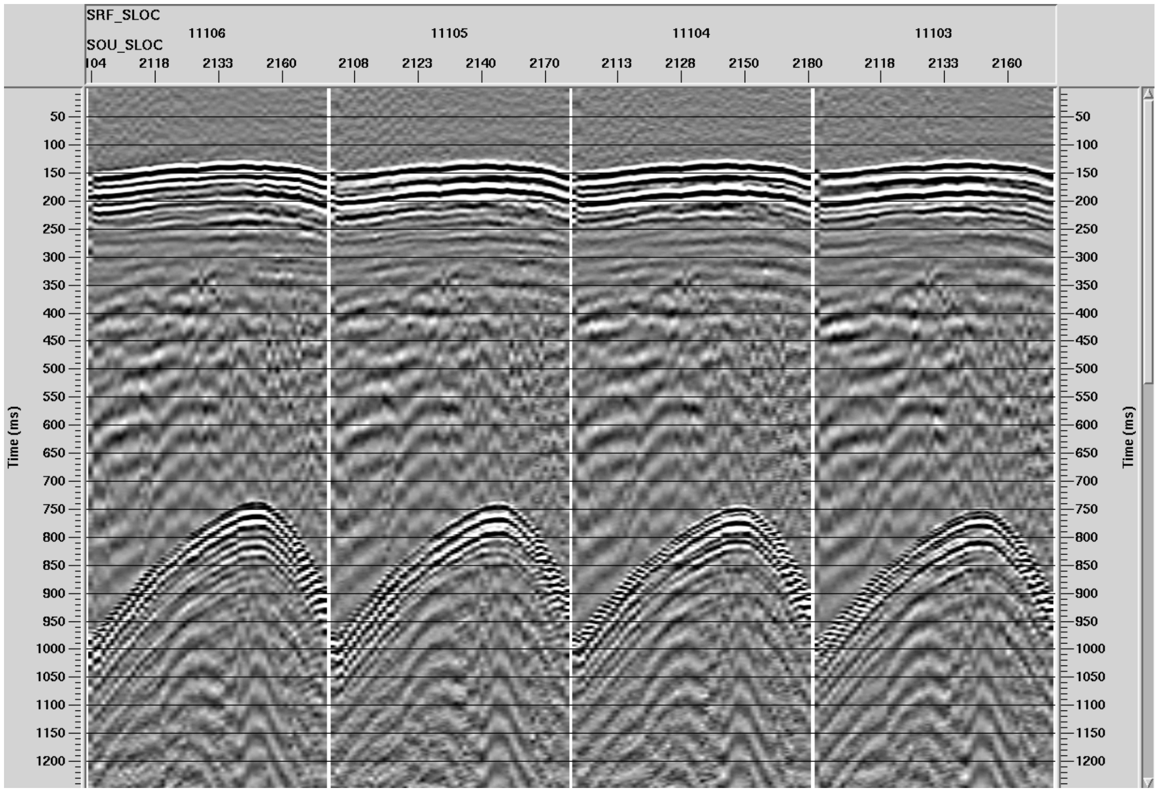

FIG. 6. Section (AGC 300ms, median) from vertical components. Each of the four panels corresponds to a receiver gather involving a different geophone plant method. Panels have been ordered as plant method 1, 2, 3, and 4 from left to right. Plant method 1 is the slow, single-motion plant. Plant type 2 includes re-orientation. Plant type 3 involves re-leveling, and plant type 4 includes both re-orientation and re-leveling.

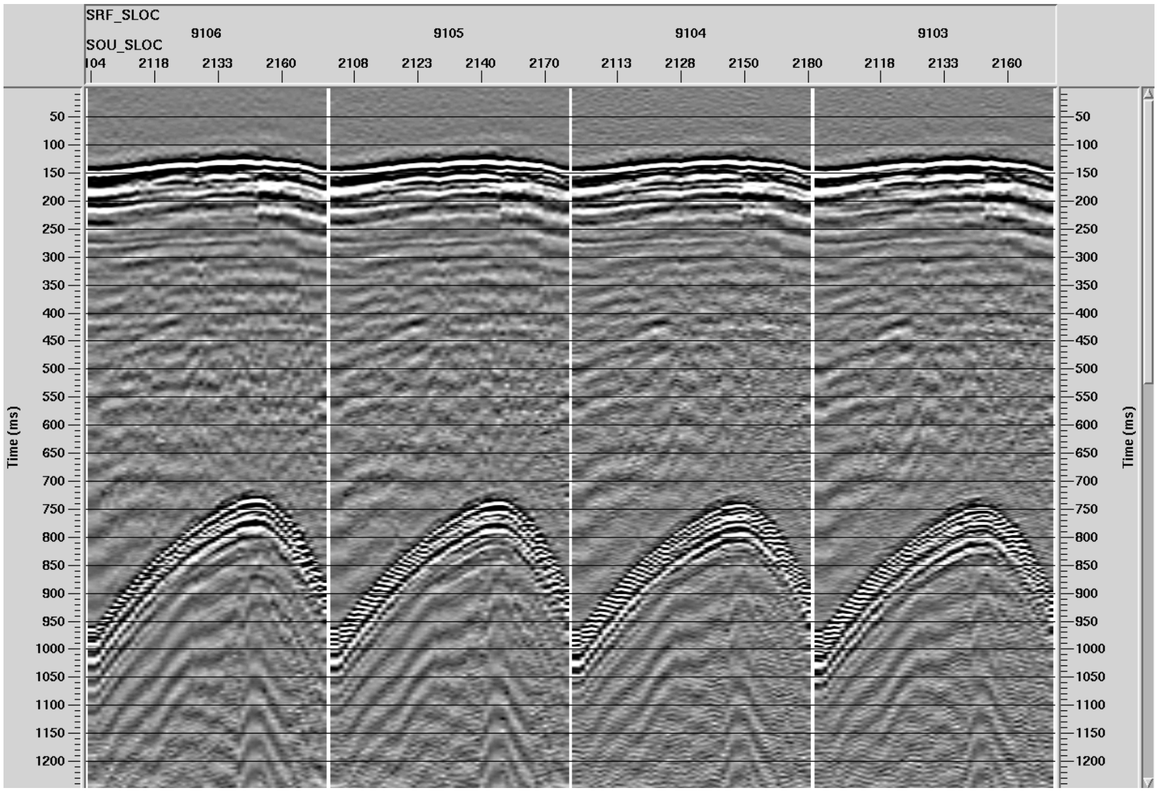

FIG. 7. Section (AGC 300ms, median) from transverse components

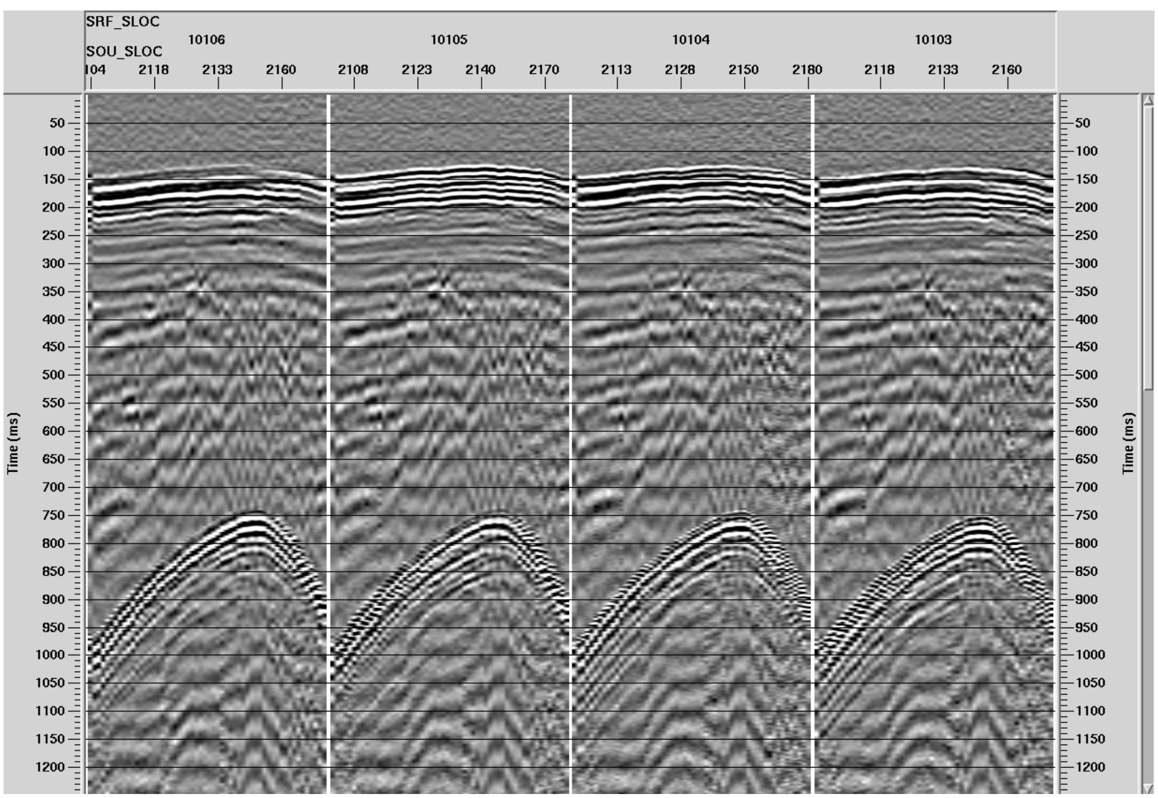

FIG. 8. Section (AGC 300ms, mean) from radial component

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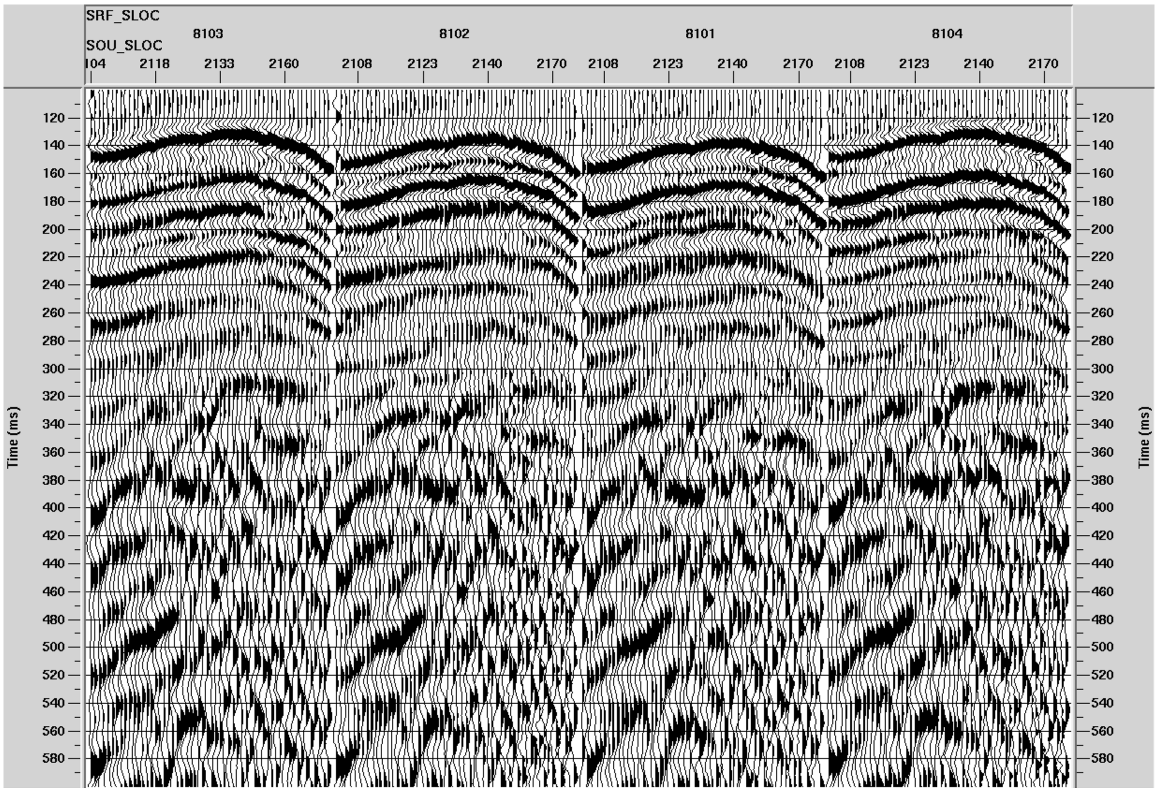

FIG. 9. Vertical component receiver gathers for each of the 4 plant methods.

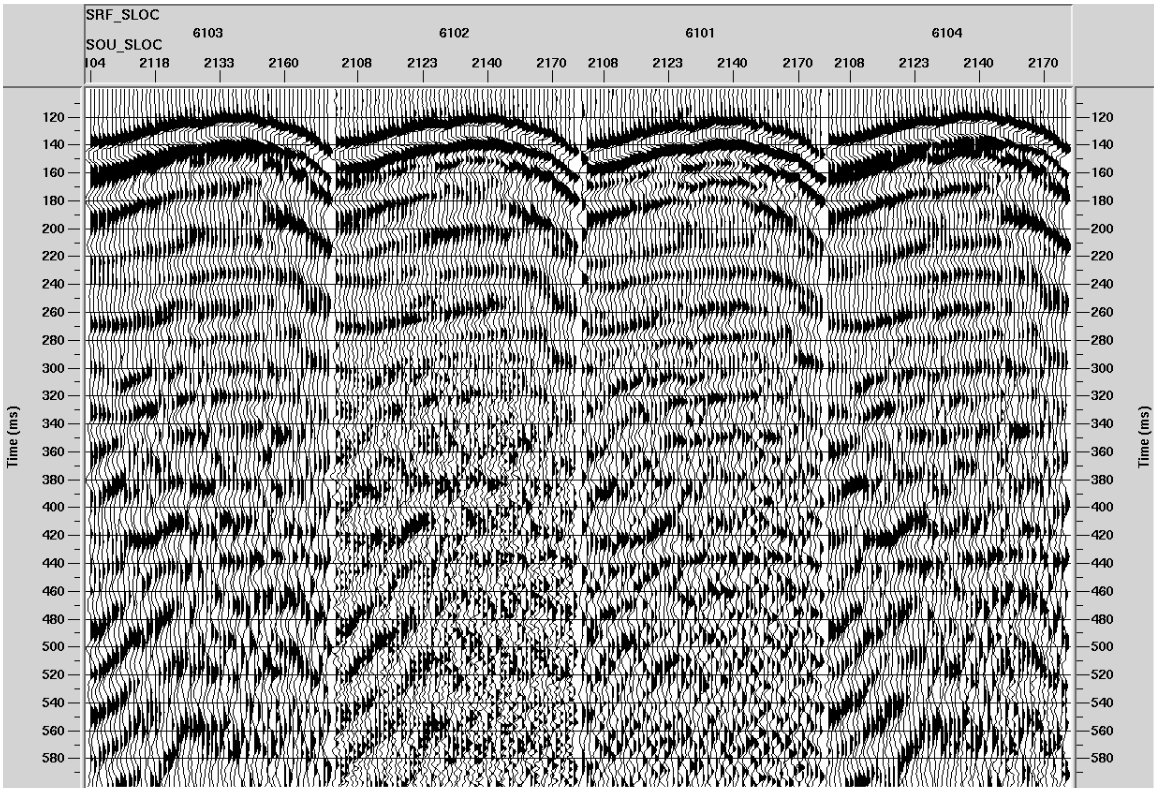

FIG. 10. Transverse component gathers.

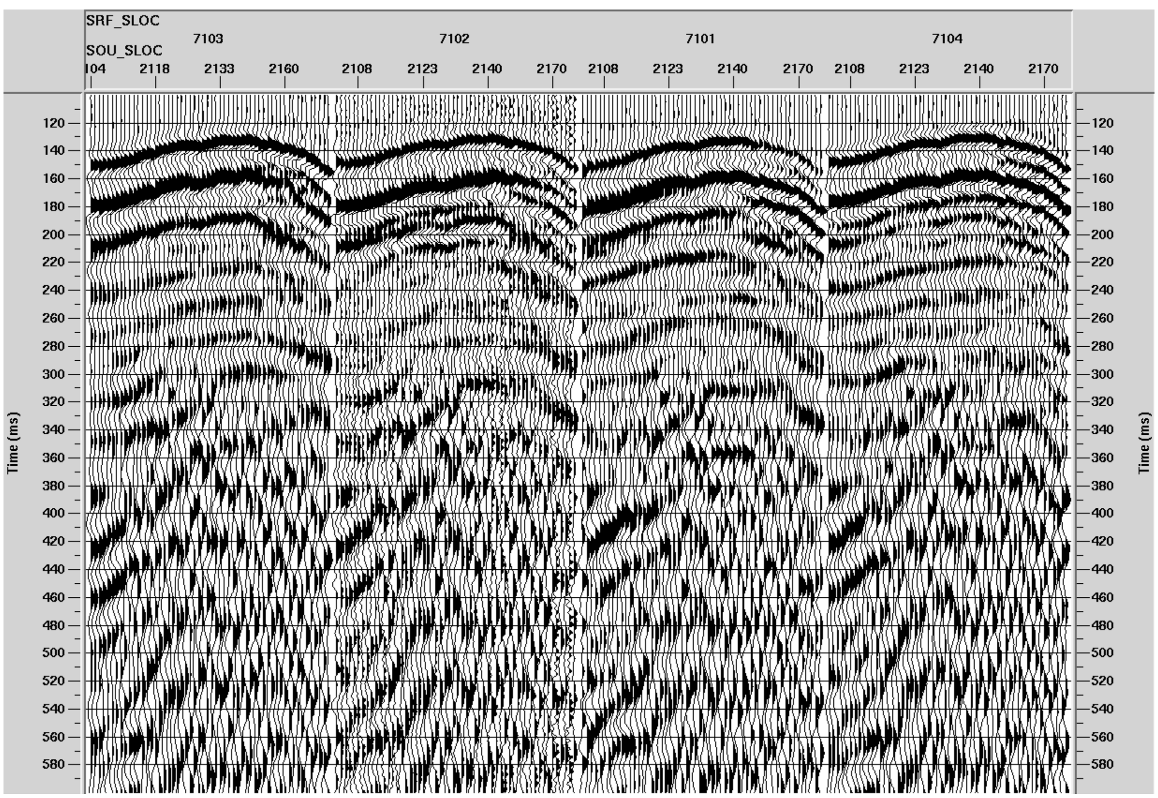

FIG. 11. Radial component gathers.

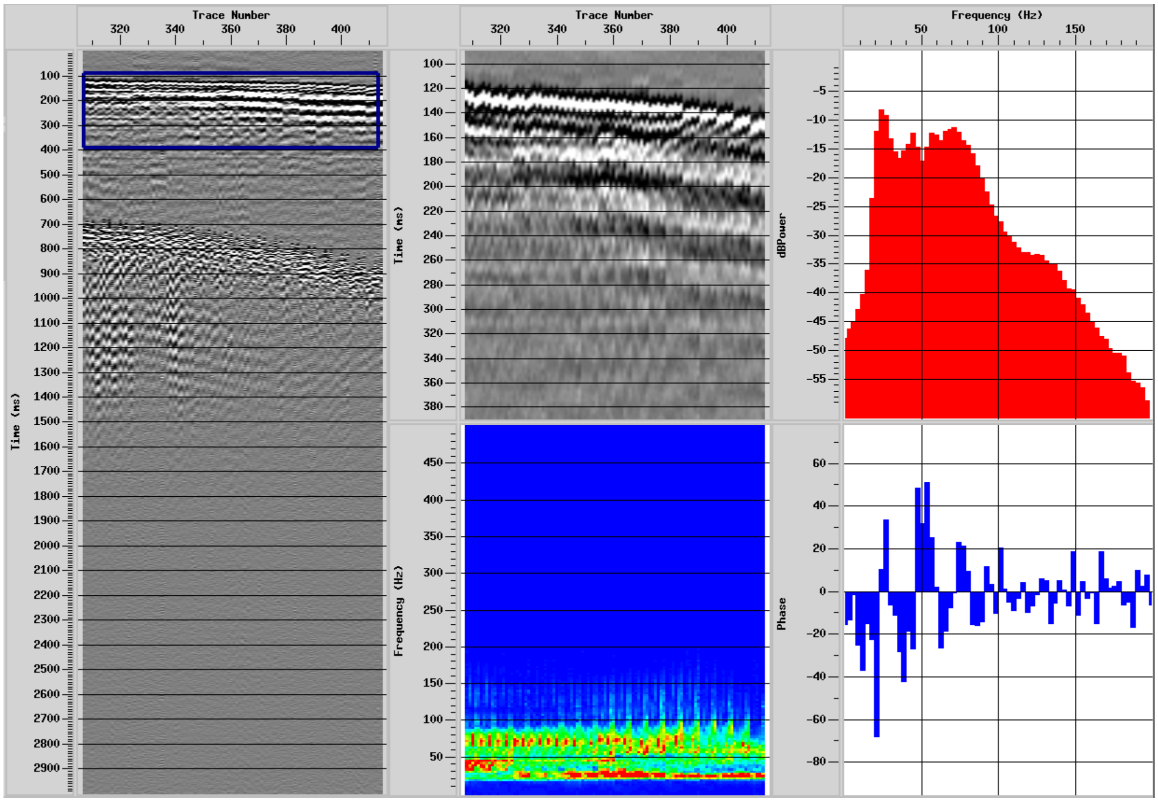

FIG. 12. Spectrum analysis in ProMAX.

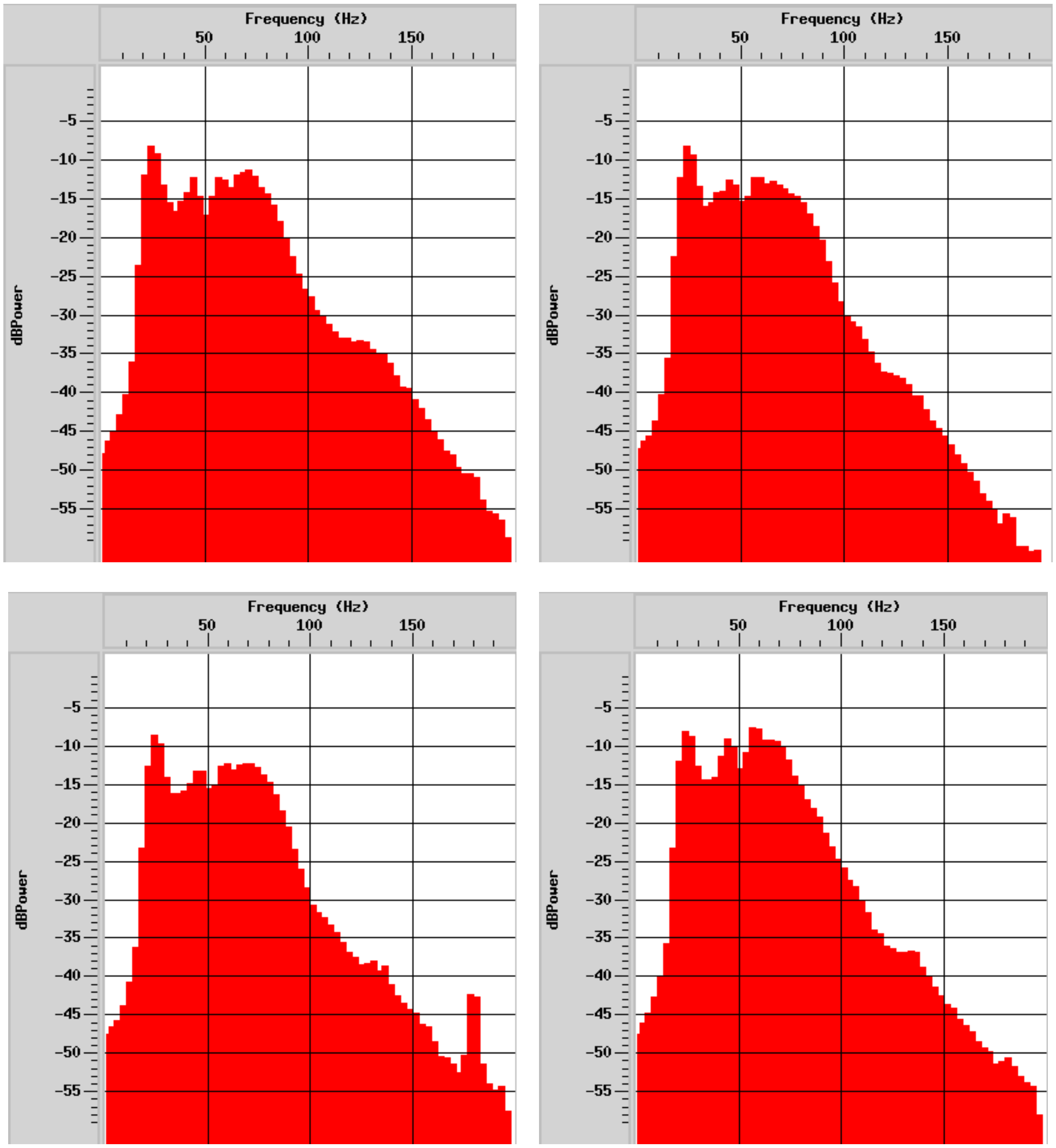

FIG. 13. Vertical component frequency comparison.

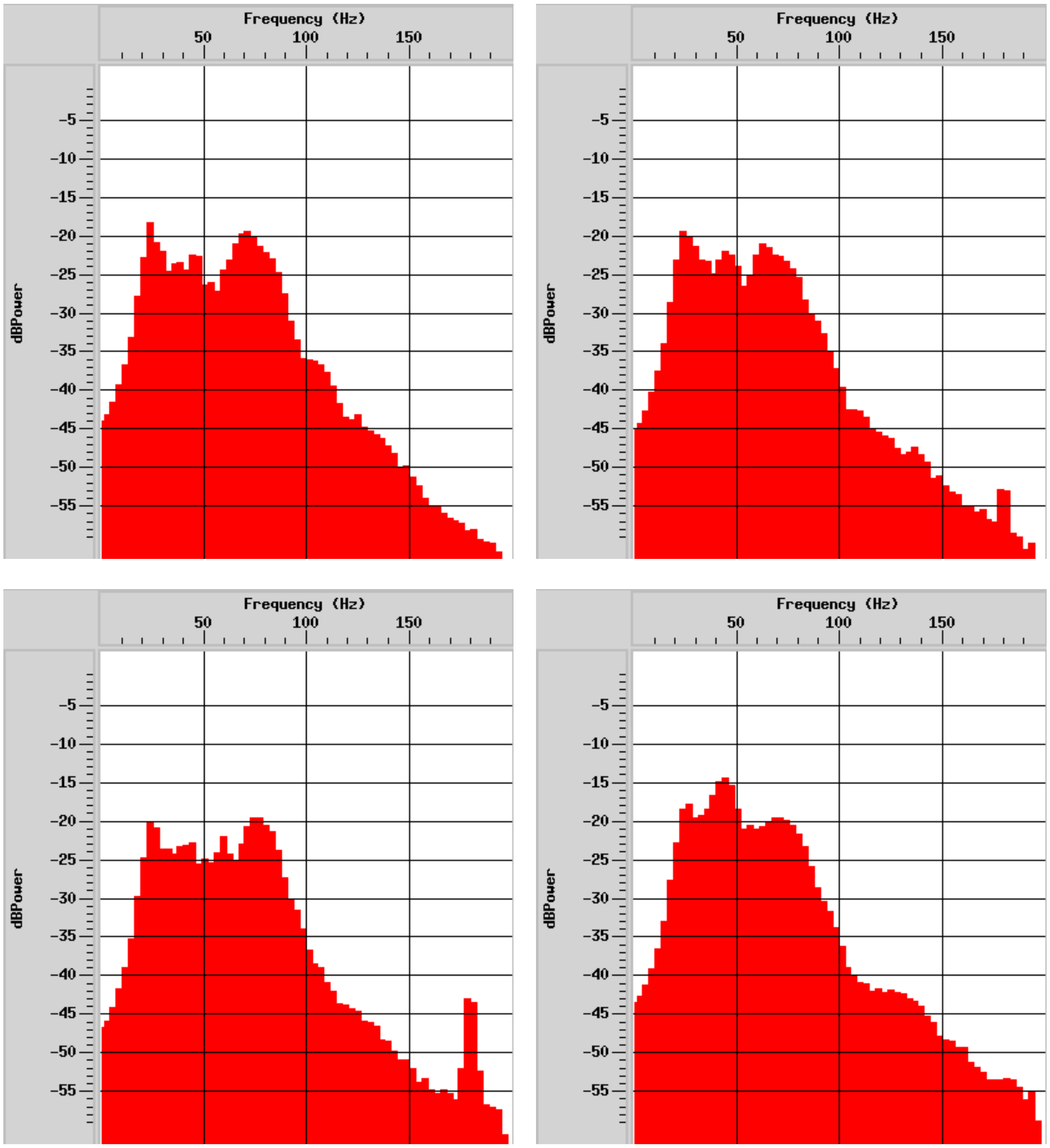

FIG. 14. Transverse component

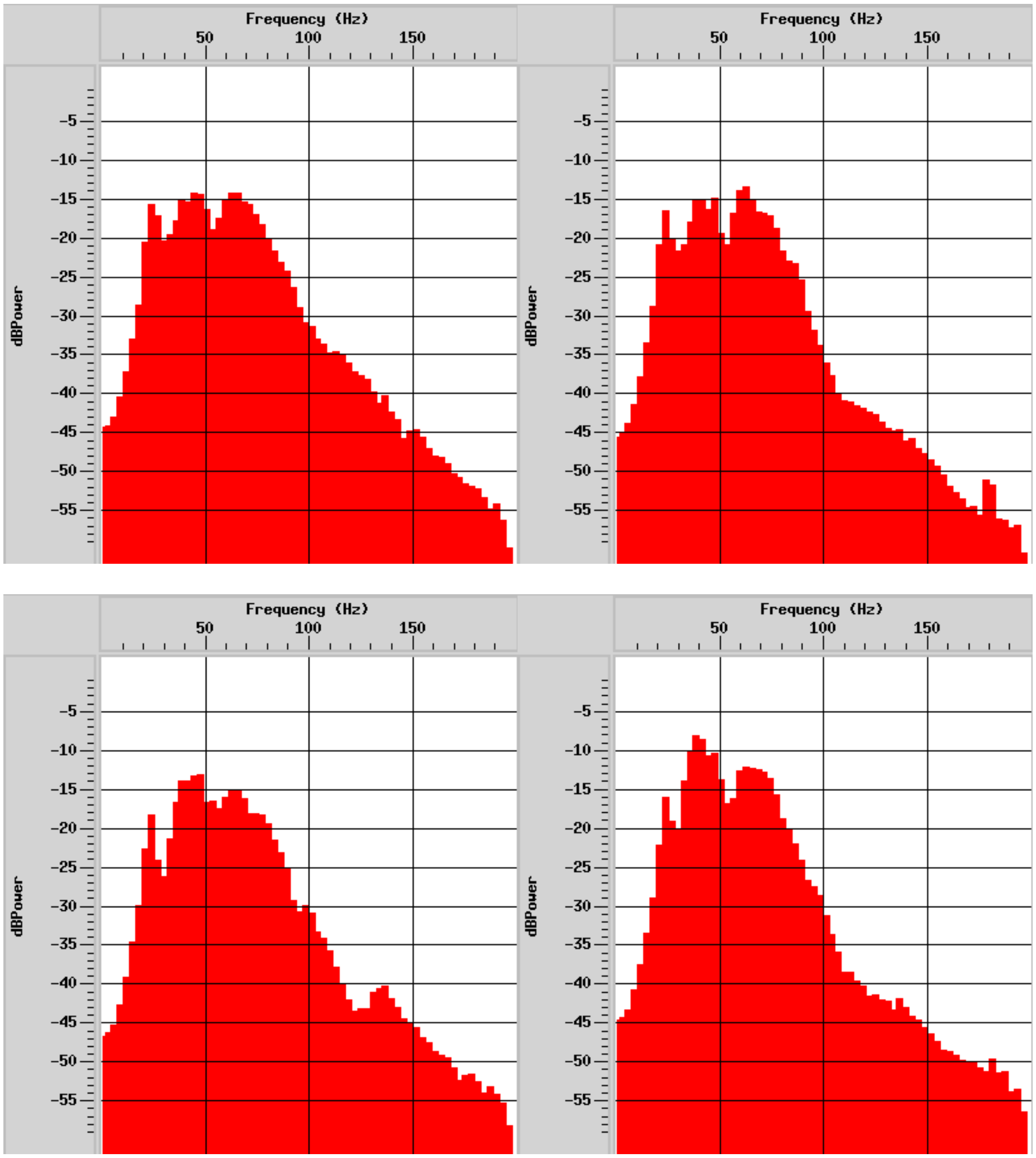

FIG. 15. Radial components