Solution for the cable pickup problem with the FARA system

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Cable pickup is one of the main problems in the application of the radio imaging method. The essence of the phenomenon and some approaches to preventing its influence are considered. The experiment results demonstrate the effectiveness of eliminating this problem and confirm the almost complete absence of the effect of cable pickup in the FARA system.

The method of cross-hole radio imaging is a highly effective tool for geological exploration at all stages - from the discovery of unknown objects to a detailed study of known mineral deposits. The advantage of the method is the quick receipt of obvious information about the cross-hole space. It can be used to optimize the costs of drilling programs at the exploration and production stages, as well as for prompt correction of exploratory boreholes at the implementation stage. One of the main problems in the application of the radio imaging method is the cable pickup phenomenon.

Cable pickup is explained by the peculiarities of the electromagnetic field behavior in the presence of local long conductors. When approaching the conductor, the electromagnetic wave partially changes its direction and propagates along the boundary of the conductor (Fig. 1). In case of radio imaging, carrying cable with electrical wires can act like a conductor. Electromagnetic wave, propagating along the cable, creates an additional (parasitic) signal, which is similar in terms of its parameters with the useful signal. This makes it impossible to correctly solve the inverse problem of finding the electrical properties of the cross-hole space, which is based on processing the response signal without taking into account the effect of cable pickup. The introduction of the cable influence corrections does not seem to be practically realistic, since the field propagation depends on many unknown parameters, such as the condition of the boreholes, the condition of the cable at depth, local near-hole inhomogeneities of conductivity, general properties of the medium, the chemical composition of the borehole fluid. etc.

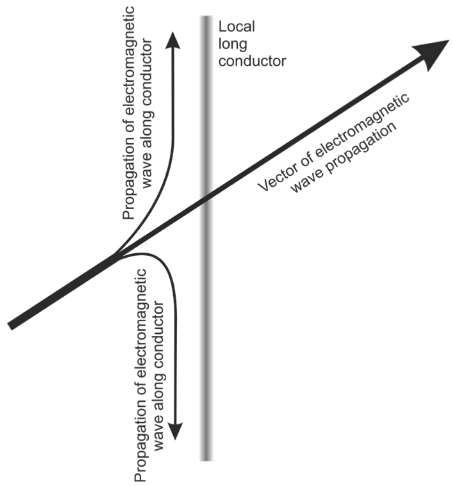

Fig. 1

The classic way to eliminate the cable pickup phenomenon in radio imaging is to exclude conductive elements from the carrying cable. There are two known approaches to solving this problem.

1. Use of non-metal-armored fiber optic cable. Theoretically, this solution is ideal, however, it has a number of practical disadvantages: high cost, low maintainability of the cable, difficulties associated with the implementation of reliable connections under high pressures (deep surveys), etc. All of these factors radically reduces the economic efficiency of using the method and, as a consequence, its competitiveness in the market of geophysical services.
2. Use of independent probes that work autonomously and have no connection with the surface. This way conventional carrying cords (ropes) can be used without conductors inside. This solution does not allow synchronizing the signals of the receiver and transmitter, which cardinally reduces the sensitivity of the system. The consequence of this is a significant decrease in the signal registration distance, i.e. the maximum possible distance between the boreholes for the survey. It also negatively affects the economic efficiency and competitiveness of the method.

A fundamentally different solution is used in the FARA system. Specialized filter systems have been developed that virtually eliminate the cable pickup effect. In this case conventional carrying cables were used with conductive wires, which are characterized by being relative cheap and have high maintainability. Filters are located in the bottom part of the cable above the probes of ~~the~~ receiver and transmitter and do not interfere with the passage of the main information signal through the conductors from the probes to the surface.

The effect of cable pickup is most clearly shown in the presence of a continuous conductive layer in the surveyed section. In this case, when passing through the layer, the electromagnetic energy is completely absorbed, which leads to a drop in the collected signal to the noise level. If the signal does not decrease to the noise level, then this indicates the presence of a parasitic signal, which very likely is a consequence of cable pickup.

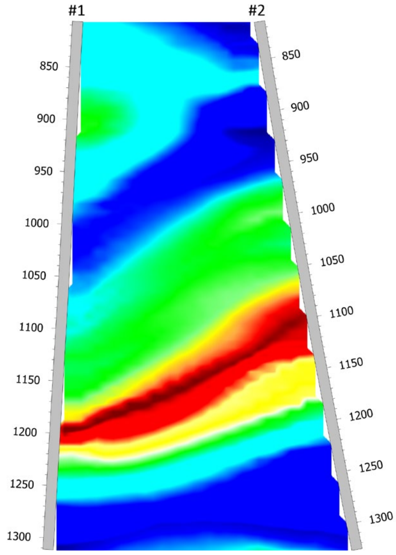

Fig. 2

To check the efficiency of the solution, an experiment was carried out, consisting of comparing the measurement results of the FARA system with the installed filter systems in their absence.

The subject of the experiment was a panel with a known geoelectric section, previously surveyed by radio imaging with the FARA system (Fig. 2). The depth of the boreholes exceeded 1300 m, the distance between the holes in the survey area was 250-300 m. The section has a conductive layer intersected by the first hole at a depth of about 1200m and the second one at a depth of about 1100m.

The measurements were carried out at two stations of the transmitter in the first hole, station # 1 - at a depth of 1020m (above the layer) and station # 2 - at a depth of 1240m (below the layer). The depth range of the receiver motion was from 1050m to 1300m along the second borehole (Fig. 3).

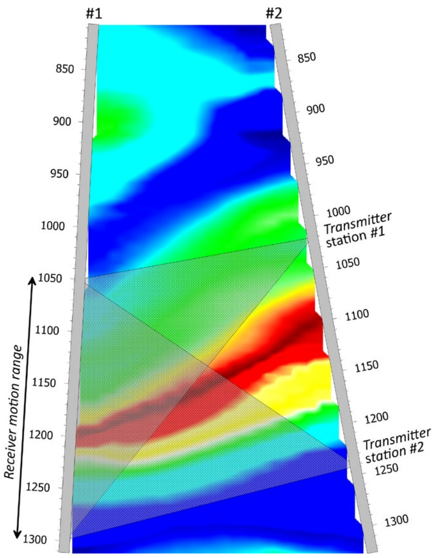

Рис. 3

Fig. 4 shows a scheme of the cable pickup for station # 1 - the transmitter is located above the conductive layer. The transmitter radiates electromagnetic energy towards the receiver. A continuous conducting layer completely shields it and the receiver located below the conducting layer does not register the signal. But the transmitter radiates energy not only towards the receiver but also towards the cable located above the receiver probe. As a result, the effect of cable pickup appears, and the electromagnetic field from the transmitter partially begins to propagate along the receiver cable (Fig. 1). Spreading downward, the pickup passes along the cable through the layer and reaches the receiver probe. As a result, instead of noise (no signal due to complete absorption of energy by the layer), a parasitic signal is registered, which is technically indistinguishable from the useful one.

Figures 5-7 show graphs of the amplitude and phase of the signal recorded by the receiver in the depth range of 1050-1300m for station #1 with (blue curves) and without (red curves) filter systems. Phase graphs help to identify reliable areas corresponding to the absence of a signal. In these areas, the signal level drops below the noise level, and only the background noise signal of the system is registered. In the presence of a signal, the phase values smoothly change as the receiver probe moves, while in the absence of a signal (i.e., the presence of a noise signal), they randomly change over the range from -180 to 180 degrees.

As can be seen, in the presence of filters for all frequencies at a receiver depth of 1070 m and below, the phase has a chaotic character, which is a reliable sign of the presence of a noise-only signal. In the absence of filters, the phase changes smoothly, and the amplitude significantly exceeds the amplitude level in the presence of filters.

Some discrepancy in the depth of the upper boundary of the conducting layer (in the image it corresponds to about 1190m, while on the curves the noise signal starts from 1170m) is explained by the presence of a 20m long antenna located at the bottom of the receiver probe.

Fig. 8 shows a scheme of the cable pickup for station # 2 - the transmitter is located below the conductive layer. Similar to the previous case, the transmitter radiates electromagnetic energy, which is completely shielded by a continuous conductive layer. In the vicinity of the transmitter, an electromagnetic wave is radiated in all directions, including upward. As a result, the cable pickup effect appears, and the wave begins to propagate upward along the transceiver cable. After passing through the layer, according to the Huygens-Fresnel principle, the electromagnetic wave creates a secondary field that is radiated in all directions, including in the direction towards the receiver probe. As a result, similar to the previous case, instead of noise (no signal), a parasitic signal is registered, which is technically indistinguishable from the useful one.

Fig. 9-11 shows the graphs of the amplitude and phase of the signal recorded by the receiver in the depth range of 1050-1300 m for station # 2 using the filter systems (blue curves) and without them (red curves). As in the previous case, the nature of the phase behavior makes it possible to reliably identify areas of the noise signal. In the presence of filters for all frequencies at a receiver depth of 1090 m and above, the phase is chaotic, and in the absence of filters, the phase changes uniformly, while the amplitude significantly exceeds the amplitude level in the presence of filters.

The presented results demonstrate the difference between the signals collected under the conditions of a standard survey (with filters), with the signals obtained under the conditions of a clearly pronounced effect of cable pickup. The results are direct evidence of the effectiveness of the solution used in the FARA system to solve the problem of cable pickup. As can be seen from the presented graphs, the parasitic signal is completely absent in the case of using filter systems.

In conclusion, the authors would like to thank Abitibi Geophysics Incorporated for their support and assistance in conducting the experiments.

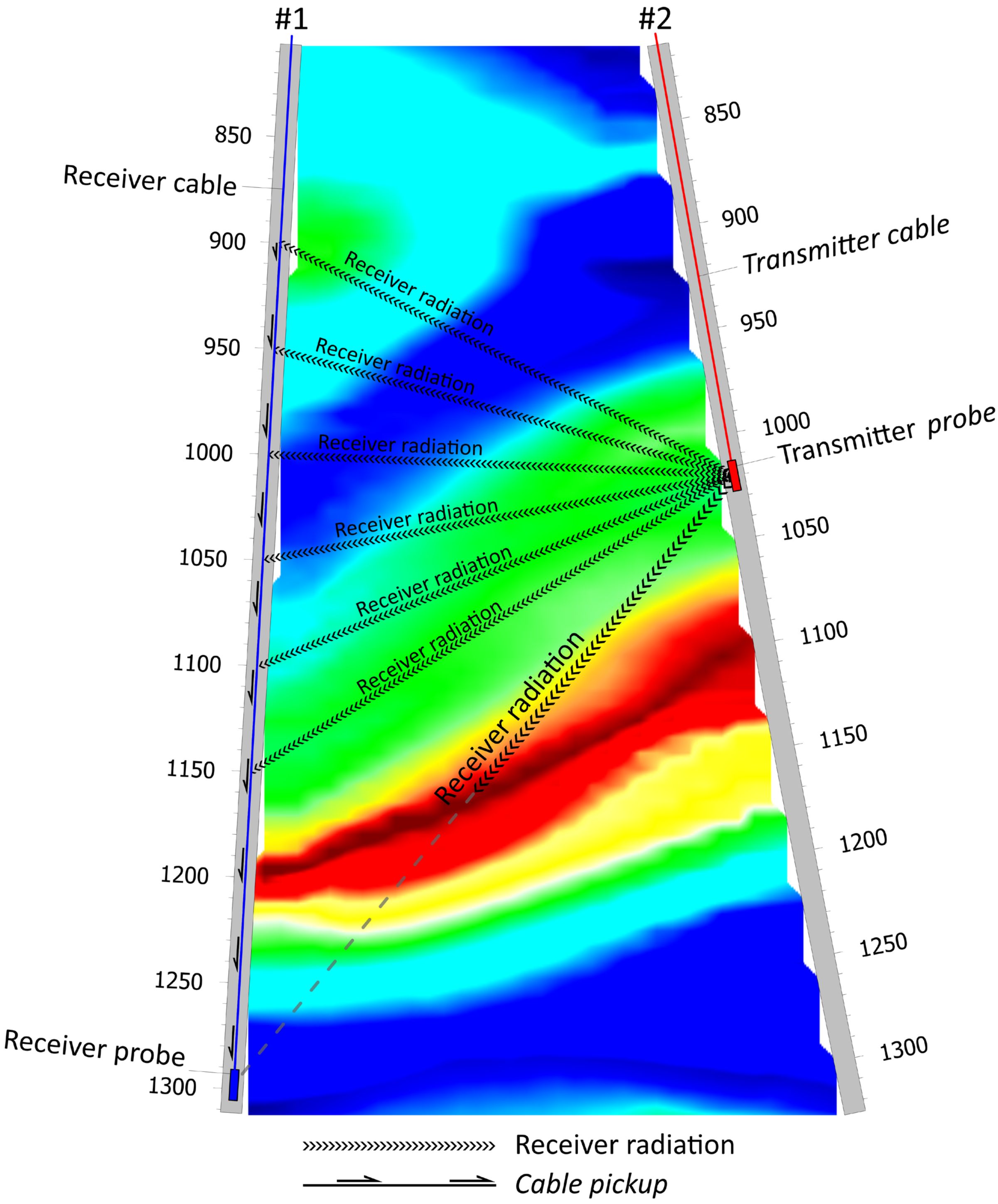

Fig. 4
Scheme of cable pickup for station #1

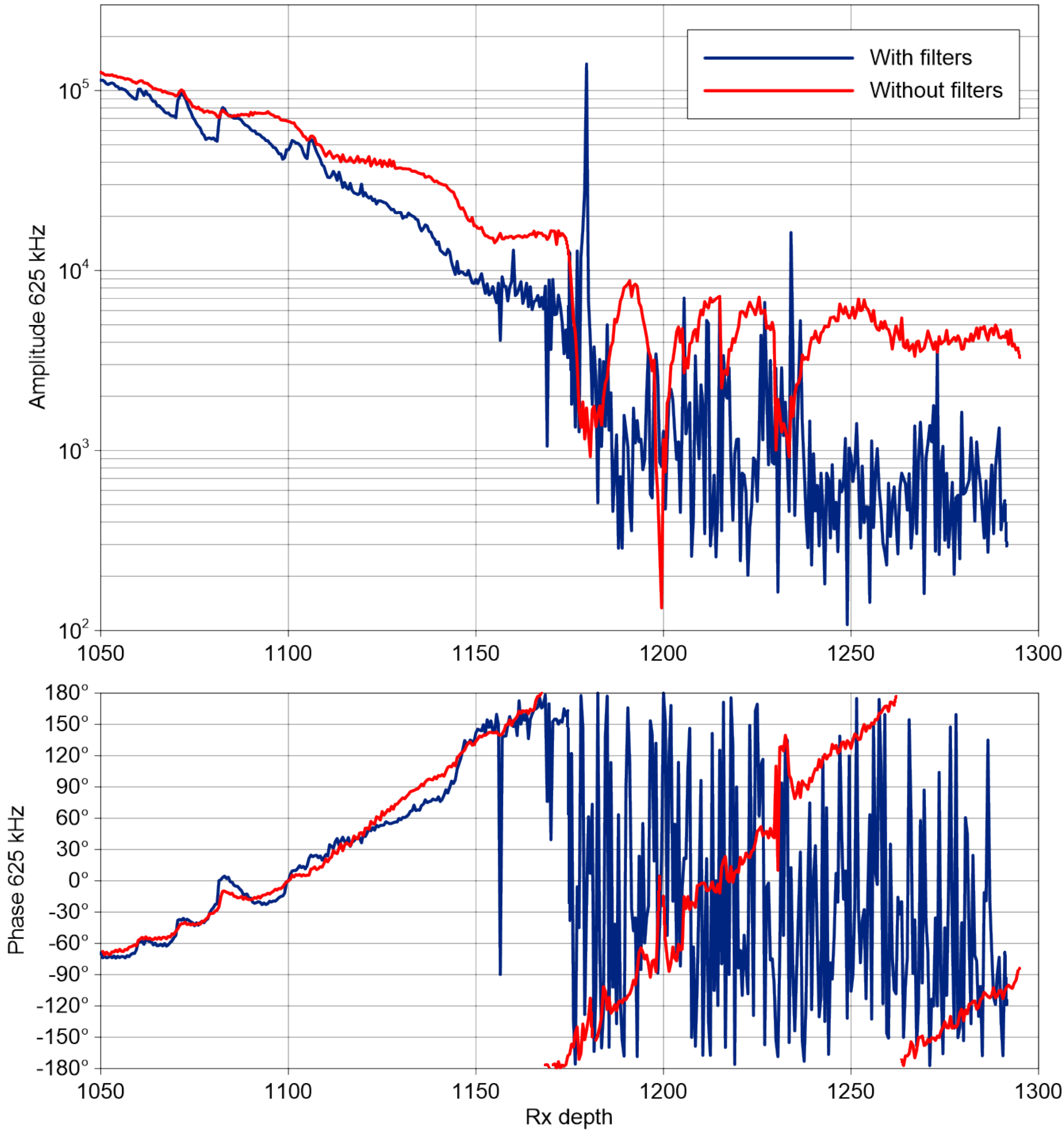

Fig. 5
Plots of receiver signal amplitude and phase
Frequency of 625 kHz, transmitter station #1

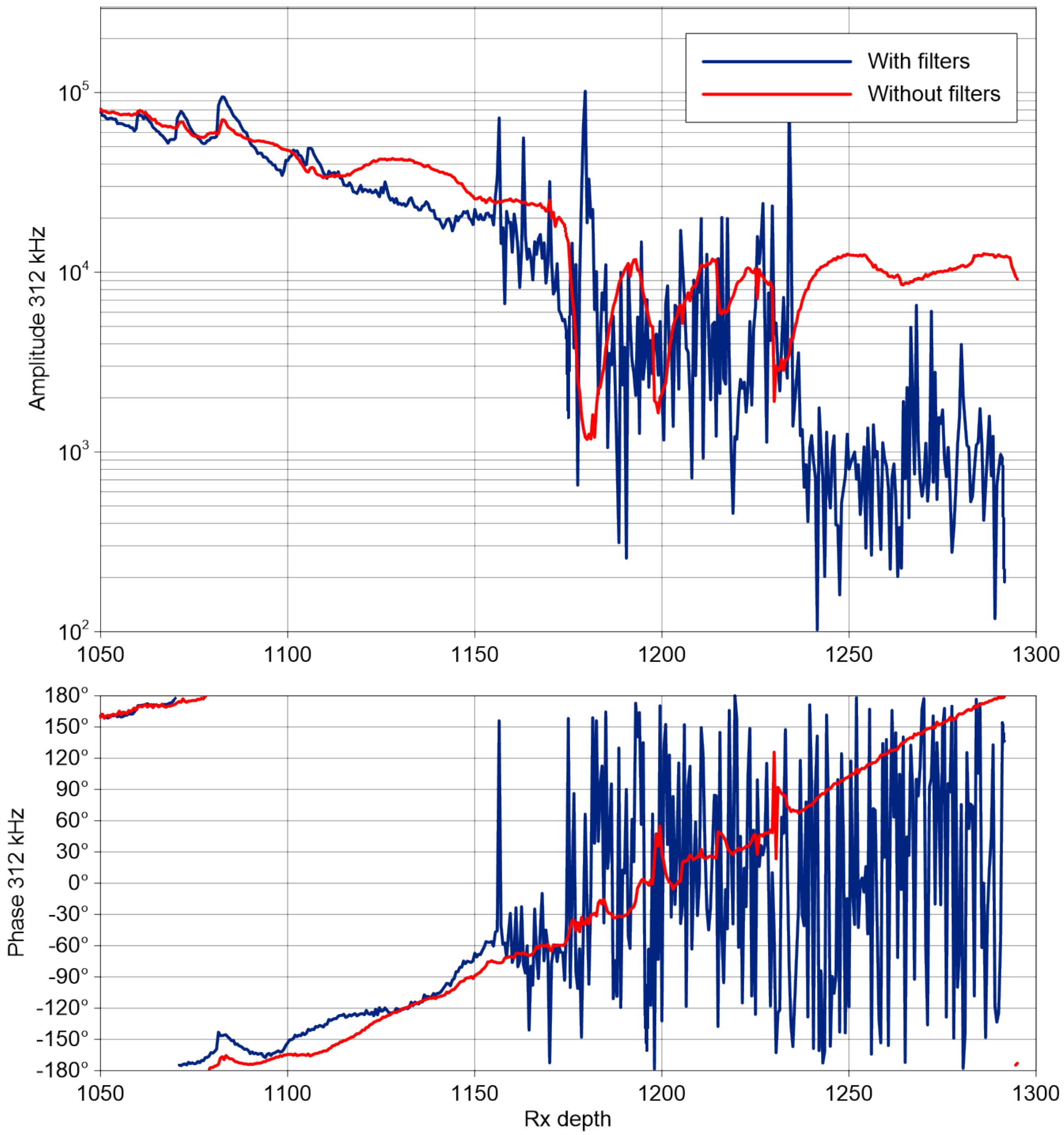

Fig. 6
Plots of receiver signal amplitude and phase
Frequency of 312 kHz, transmitter station #1

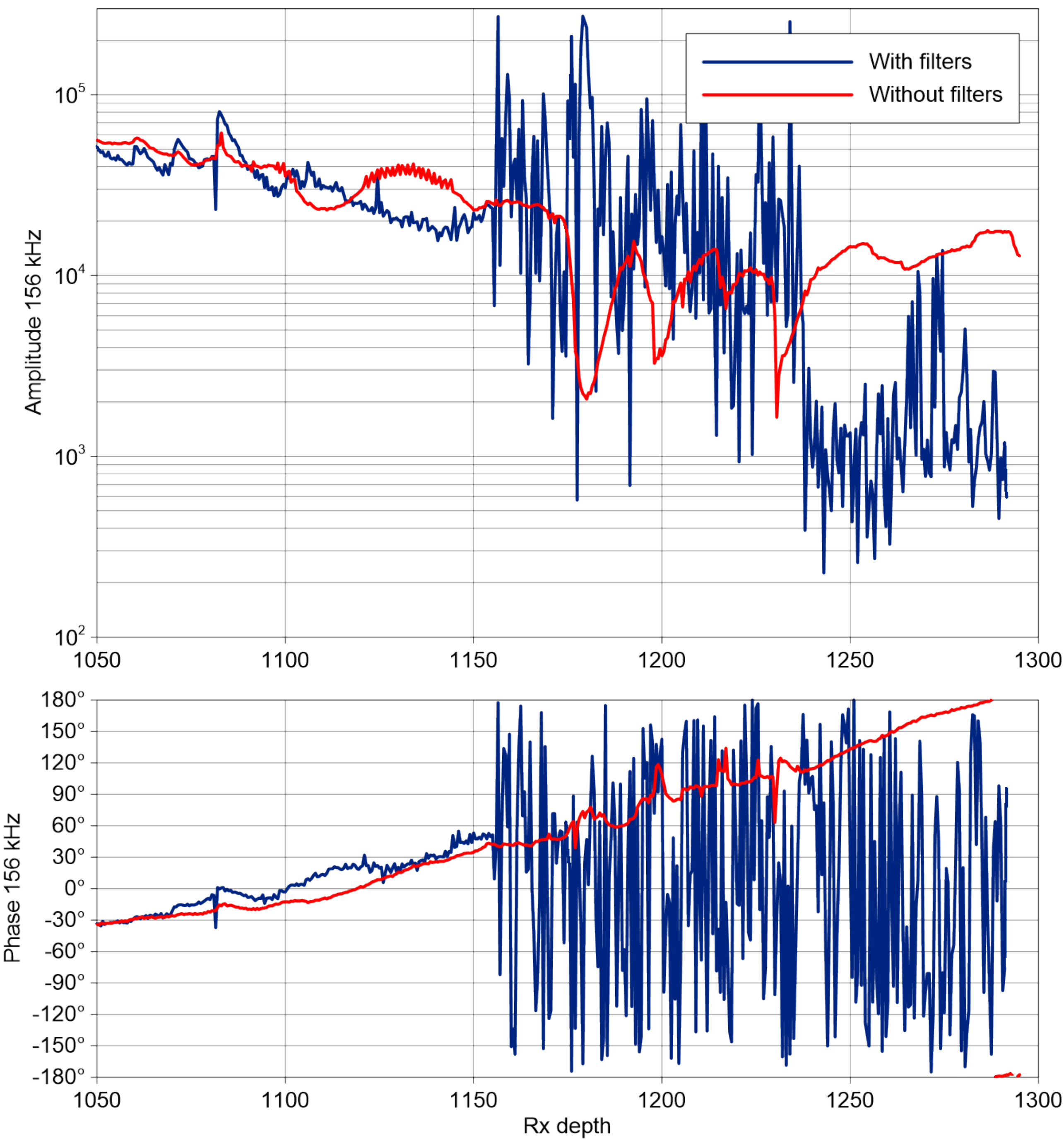

Fig. 7
Plots of receiver signal amplitude and phase
Frequency of 156 kHz, transmitter station #1

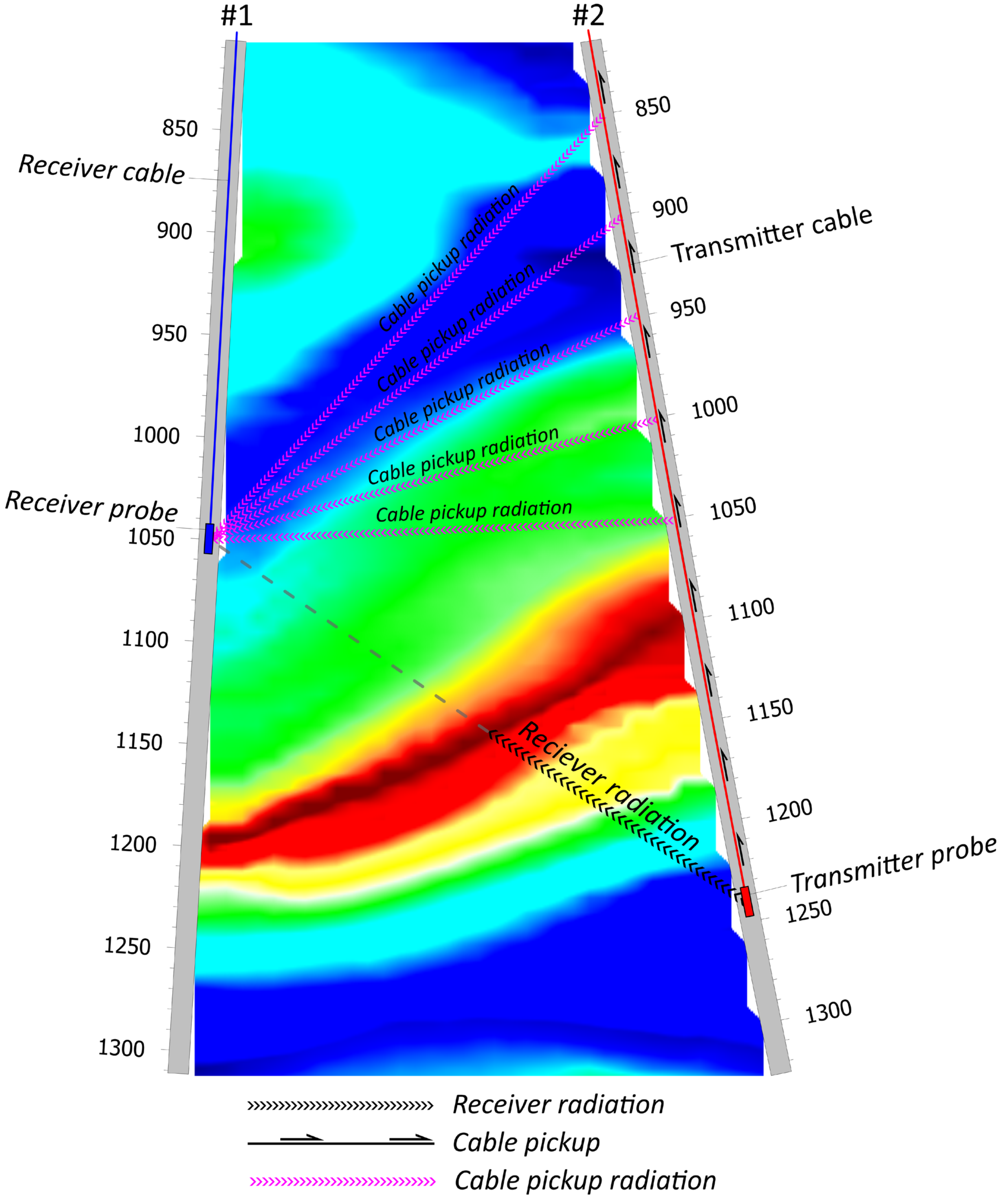

Fig. 8
Scheme of cable pickup for station #2

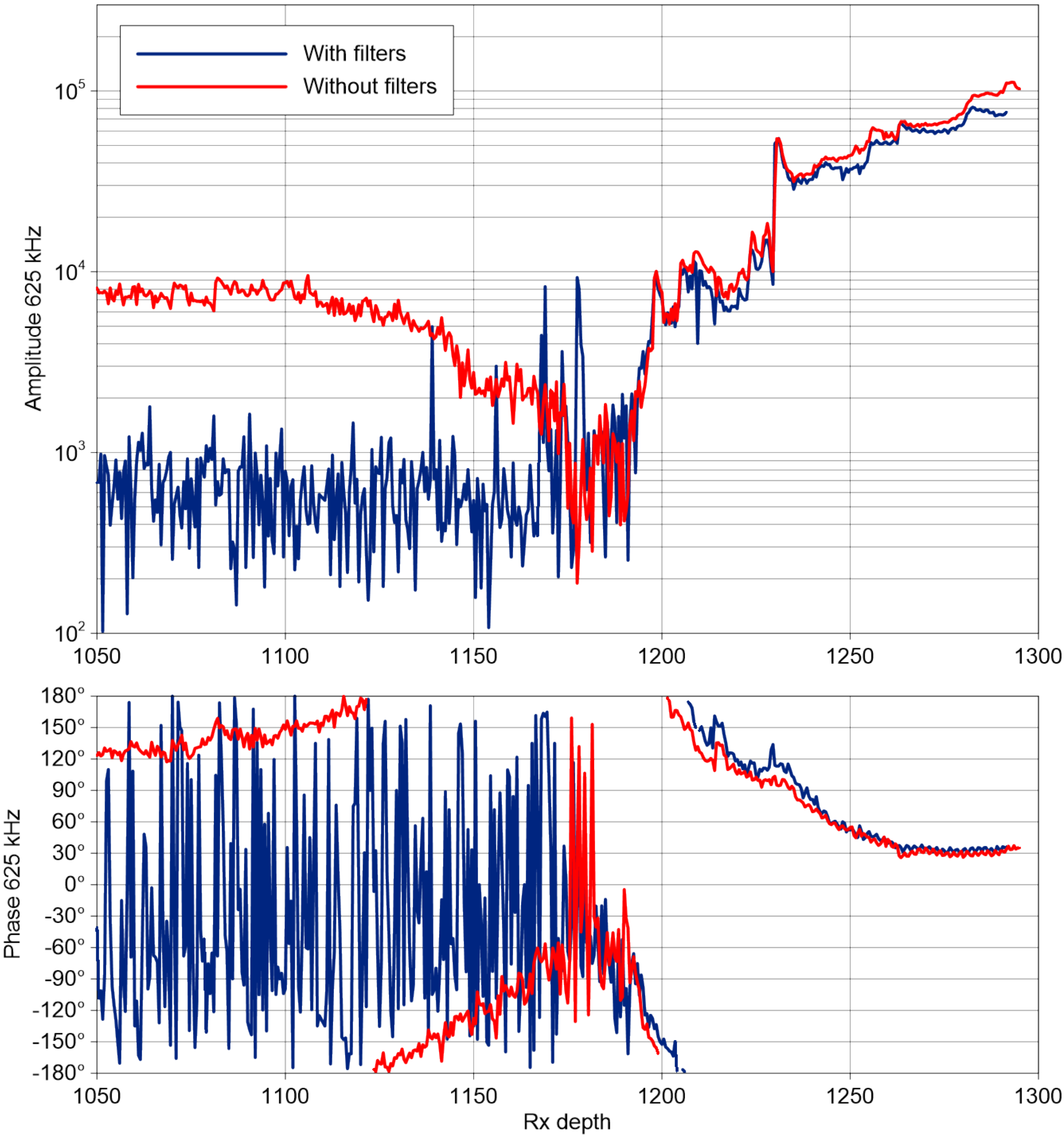

Fig. 9
Plots of receiver signal amplitude and phase
Frequency of 625 kHz, transmitter station #2

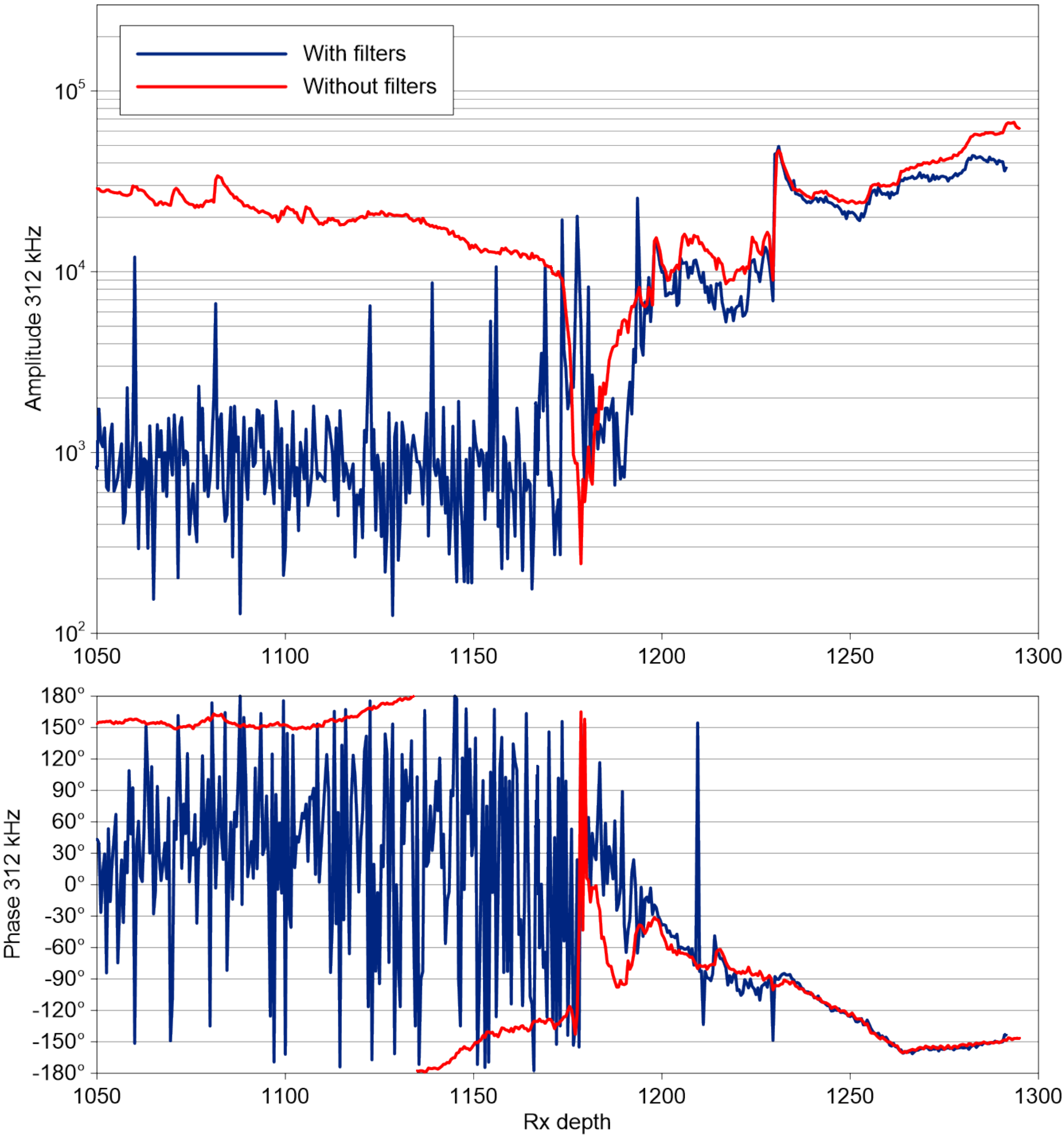

Fig. 10
Plots of receiver signal amplitude and phase
Frequency of 312 kHz, transmitter station #2

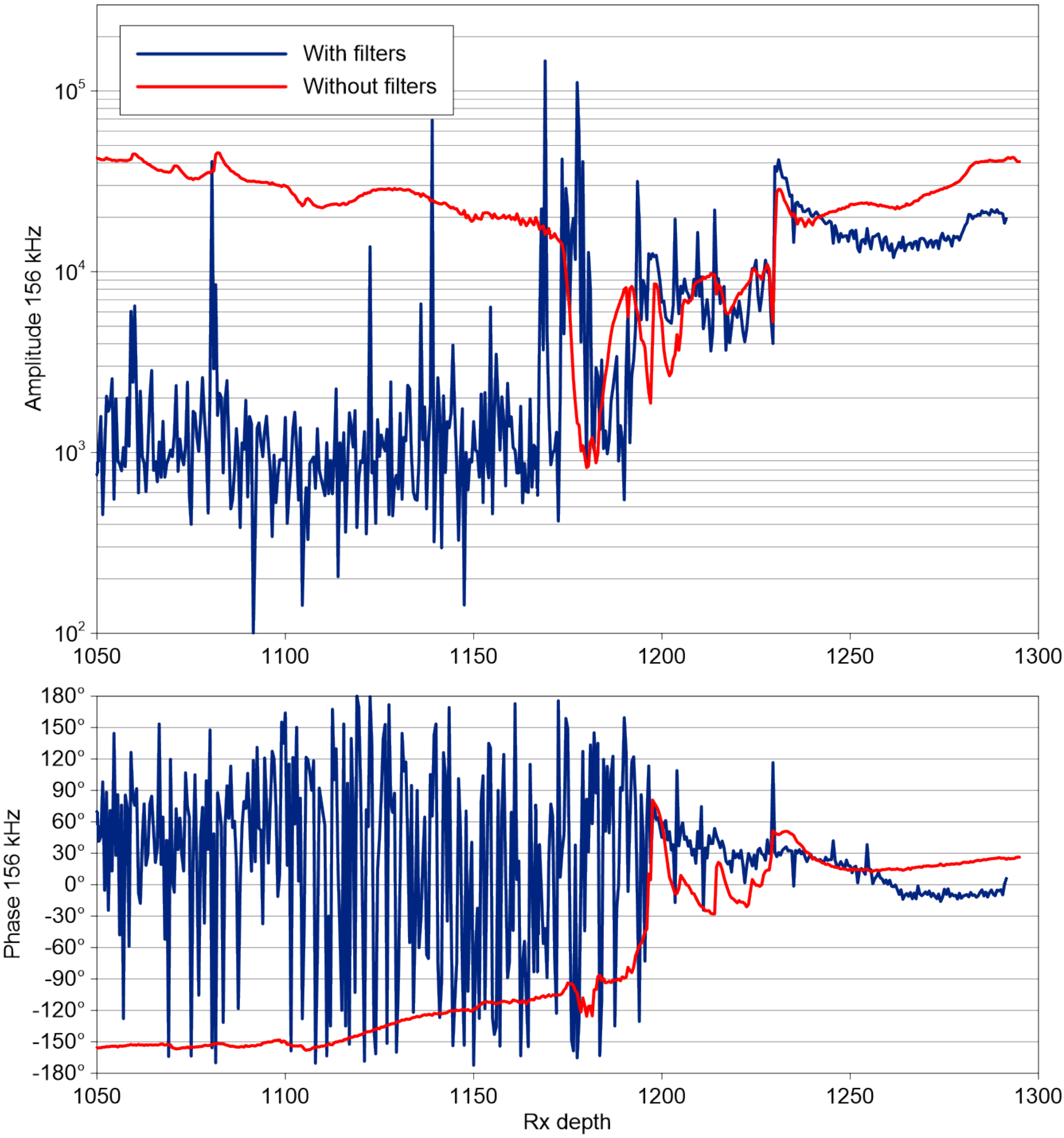

Fig. 11
Plots of receiver signal amplitude and phase
Frequency of 156 kHz, transmitter station #2