A low-noise ocean bottom integrated receiver for electromagnetic and seismic exploration

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SUMMARY

Marine geophysical methods are important technological means for exploring seabed geological structures and resources. Among these, marine electromagnetic exploration and marine seismic exploration are widely used methods. However, the instruments for these two methods are usually independent, making it difficult to collect data from the same location simultaneously. Additionally, marine electromagnetic instruments still have issues such as high noise level, significant time drift, susceptibility to interference, limited data storage space and so on. Based on these challenges, we have developed a combined ocean bottom electromagnetic and seismic receiver(OBEMSR) aimed at deep-sea exploration applications, integrated electromagnetic and seismic data collection, and low-noise, low-interference requirements.

We designed 12 analog channels and developed a chopper amplifier circuit for the weak electrical field signals in the seabed. To reduce noise, we optimized the design of the induction coil magnetic sensor. To capture seismic signals, we selected omnidirectional seismic geophones and horizontal omnidirectional hydrophones. The developed OBEMSR offers selectable sampling rates of 250Hz, 500Hz，and 1kHz, with an operational frequency band ranging from 0.00001Hz to 500Hz. Using an embedded STM32 as the control core, we designed an SD card storage array. For timing synchronization, we used a GPS+atomic clock method, where the atomic clock is calibrated with GPS on deck, and the GPS antenna is removed before submersion, leaving the atomic clock to keep time. We developed an Android-based APP control software for convenient operation before deployment and a computer will be used to download recorded data via USB interface during recovery, facilitating data analysis and processing.

Testing showed that the induction coil magnetic sensor achieved an extremely low noise of 50fT/√Hz at 1Hz, better than commercial induction coil magnetic sensors. The chopper amplifier circuit's input voltage noise density is 0.86nV/√Hz at 1Hz, and the Ag/AgCl non-polarizing electrode used has a noise level of 0.653nV/√Hz at 1Hz. The seismic geophone has a frequency of 14Hz with a sensitivity of 78V/m/s, and the hydrophone has a receiving sensitivity of 2.5nV/μPa. At room temperature, the atomic clock's timekeeping performance had an average time drift of 77us/day over 15 days. The instrument uses 16 32GB SD cards to achieve a total storage capacity of 512GB. The key components of the instrument have passed a water pressure test of 72MPa, which means it can be used at a depth of 7200 meters.

The OBEMSR underwent land and shallow sea testing, obtaining effective data. The instrument can collect electromagnetic and seismic signals at the same time and location. This reduces error factors and improves the effectiveness of joint inversion. Additionally, deploying both exploration methods at once greatly improves exploration efficiency and reduces costs.

Keywords: ocean bottom electromagnetic receiver, ocean bottom seismometer, low-noise, time drift, deep-sea exploration