Geophysical Research Abstracts,
Vol. 10, EGU2008-A-09738, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-09738
EGU General Assembly 2008

An Ocean Bottom Seismometer (OBS) Built for Mid-term Marine Active Refraction Seismology

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Historically, seismic methods have played a key role in extension of our knowledge in earth structure and physical properties of different layers that shape the earth's interior. Generally, these methods allow to estimate the geometry of the internal layers as well as propagation velocity of the seismic waves generated by natural sources (earthquakes) and/or artificial sources (air-guns) in the area under study. These structural images have enabled to understand and distinguish better the interaction processes between earth's crust and mantle which are responsible for plaque tectonics. On the other hand, seismic tomography is probably the best method for the determination of physical parameters of rocks and constituting materials. These parameters are obtained indirectly from collection of seismic data and require the knowledge of travel times of artificial acoustic signals and their corresponding path. Seismic sensors (geophones) are used to register the acoustic waveforms with different orthogonal components. The resolution of structural images that can be obtained depends on the number of instruments used.

The instruments that are mostly used for the study of ocean seismic processes are Ocean Bottom Seismometers (OBS). This autonomous equipment is deployed on the seabed where it collects time stamped data of air-guns used to generate the acoustic waves on the surface. Signal recordings are subsequently used to model both the earthquake locations and the crustal structure. In active refraction surveys, scientists are demanding long period instruments with large data storage capacity. Therefore,

increasing the autonomy of the OBS by reducing its power consumption of different electronic modules is one of the objectives of this project which integrates different scientific disciplines as electronics, mechanics, geophysics, acoustics, and communications, etc. In addition, it must be taken into account that modern seismic experiments require fast deployment of several tens of OBSs; therefore another goal is to build small size, light-weight and easy to use instruments.

The instrument is equipped with a heavy anchor to sink it to up to 6000 m depth. The OBS must be able to record continuously for about two months, allowing to do mid-term surveys as well as to plan different seismic experiments without recovering the equipment. Seismic signals are propagated within the sub-seafloor layers and recorded by the sensors: a hydrophone to record water vibration and a geophone to record seabed vibrations, this last one being composed of three 4.5 Hz accelerometers placed perpendicularly, one for every axis, inside an aluminium housing. The equipment is recovered after sending an acoustic signal of a certain code from a telecommand deck unit placed on the surface. A motor driven electro-mechanical module is used to release the anchor weight when the release signal is received. The tracking elements of the instrument on the surface are a radio beacon with a 4 miles range from the oceanographic vessel, a direction finding receiver on the vessel to locate the radio beacon and a xenon flasher, very useful in night recovery.

The acquisition system is based on a four channel 24 bits CS5372/76A Analog-to-Digital system. CS3301 and CS3302 input fully differential amplifiers are used for analog signal amplification in order to reduce the electronic noise level. The microcontroller module is based on a MC68332 microcontroller which includes low power instructions for power consumption optimization. Data storage module is based on a Compactflash memory card with a capacity of up to 4 GB. The development and expansion of Compactflash cards during the last ten years and their rapid increase in storage capacity are the main reasons to use this kind of memory. Data from four channels are collected through a QSPI (Queued Serial Peripheral Interface) bus by the microcontroller, time stamps are added to data before compaction and storage in the Compactflash memory card.

As the instrument has no access to a GPS signal during the experiment, it is equipped with a crystal oscillator that has a low drift with temperature variation. Stability and power consumption of two types of crystals: a Vectron TC-140 TCXO (Temperature Compensated Crystal Oscillator) and a Vectron OC-260 OCXO (Oven Controlled Crystal Oscillator) have been measured using a VC4060 climate chamber to simulate the environmental temperature variations of the OBS. The stability of the TCXO and OCXO crystals measured are 500 ppb and 20 ppb respectively while their power consumption is 100 mW and 1.5 W respectively. These results show that the power consumption of the OCXO crystal sets a major limitation to the autonomy of the overall instrument even though it is more stable than the TCXO. Therefore a TC-140 TCXO crystal is used as the time base of the OBS built.

In order to know the performance of the data acquisition system designed, a series of tests based on the international standards: *IEEE Std 1057 Standard for Digitizing Waveform Recorders* and *IEEE Std 1241 Standard for Terminology and Test Methods for Analog to Digital Converters* are implemented. These characterization tests calculate the desired parameters of the system in the lab after applying a sine wave signal at the input, acquisition of a known number of samples and data transfer to a PC. In order to reduce the effects of the test bech on the results calculated, an ultra low noise and ditortion *DS360 Stanford Research Systems* function generator is used. The datalogger implemented is found to have the following performance:

Total Harmonic Distortion (THD): -125 dB

Dynamic Range: 129 dB

Effective Number of Bits (ENOB): 21.5 bits

Random Noise: 1.15 LSB

Channel crosstalk: -147 dB

Clock drift: 44 ms/day

Autonomy: 2 months

Finally the OBS was tested in real environmental conditions in November 2006 through the CALIBRA test cruise. Two OBS prototypes built were deployed at 1000 m depth and a Geomar K/MT562 OBS was also deployed in the same location with 200 m distance between the three OBSs. The reference OBS has been widely used in active refraction seismology in the past ten years with good data quality. 500 c.i. and 1000 c.i. air-guns were used to generate acoustic signals during three days and data were collected by the three equipments. Data comparison of the three instruments was carried out by direct inspection of their corresponding seismic record sections. These results have shown that the geophone channels of the OBS prototype built have better noise performance than the reference OBS while the noise level of the hydrophone channel is slightly higher than the reference OBS.

At present, we are intending to increase the autonomy of the OBS to six months as well as the storage capacity. Other functionalities as a USB 2.0 interface and battery recharge allow quick download of the collected data without having to open the main housing, optimizing the ship time and therefore reducing the costs significantly. A new mechanical design of the OBS is also needed in order to incorporate the float into the main structure.