INTMARSIS: A Real Time Seafloor Seismic Observatory

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***Abstract*—In this paper we present the current status of a marine seismometer to be deployed in the Alboran Sea in September 2016. The design consists of a seafloor unit and a surface buoy connected by a cable. This design pretends to be an alternative to OBS (Ocean Bottom Seismometer) in shallow waters (depth $<$ 500 m). In contrast to OBS, a physical connection between the seafloor unit and the surface buoy allows real time data processing and offshore communication.**

Even though an umbilical cable seems to be the more obvious alternative, the low energetic consumption of the seafloor unit and the recent improvements in inductive communications open a very interesting new possibility using steel cables.

Keywords - Sensors, Seismometers, Marine Instrumentation

I. Introduction

In this paper we present a new ocean seismometer that pretends to be an alternative to OBS in shallow waters to be deployed in the Alboran Sea (Western Mediterranean) in September 2016. In contrast to OBS, in our design a physical link connects the seafloor seismometer with a surface buoy allowing real data measurement and time synchronization. Ocean Bottom Seismometers (OBS) is a well-known technology to measure underwater earthquakes. Standard OBS design consists of a seismometer itself (with the associate electronics, data logger and batteries), a weight to sink it to the sea floor, a flotation to bring the instrument back to the surface and a remote acoustic release. An important aspect of the OBS is that it can be deployed and recovered from almost any research vessel. Monitoring high frequencies produces large amounts of data, so that, storage capacity could be a critical point in the OBS design (1). Other critical points are the batteries length and the time synchronization with other devices. Because of the lack of physical or logical connection with ground stations, OBS do not allow real time measurements. Our seismometer was intended to be connected with a buoy at the surface transmitting continuous data to shore. The data is to be continuous vertical data, with a triggering algorithm to switch to 3 components data for events and with enough latency in the transmission for it to be possible to catch up in a reasonable time. This will be especially relevant to equipment located near the coast or in wired network observatory. This system should allow seismic measurements in real time of passive seismicity produced by near faults or active volcano in a range of 200 km. The purpose of these stations is to provide good azimuth observations in relation to the hypocenter. The data will be used for hypocentric location and magnitude determination. The seismic station should be capable of capturing moderate seismicity (1.5 $<$ M $<$ 5), rarely exceeding depths of 20 km and always at depths less than 100 km, being the natural period of 1 second nominal, short period of 1 Hz. Needed bandwidth will be from 0.5 up to 30 Hz (seismic LP events) with a 18 bit resolution. SNR should be above 60 dB and data loss less than 10%. The seismic data transfer assumes that short-term packet loss will occur and assumes that degraded seismic data is better than no seismic data (2).

II. Numerical simulations

Prior to the deployment of the seismometer a model of the system was done and its dynamics was studied (3). The simulations were carried out using OrcaFlex, version 9.3c (4). OrcaFlex is marine dynamic software developed by Orcina for static and dynamic analysis of a wide range of offshore systems. OrcaFlex provides fast and accurate analysis of umbilical and power cables under wave and current loads and externally imposed motions. It is a fully 3D non-linear time domain finite element program capable of dealing with arbitrarily large deflections of the flexible from the initial configuration. In addition to the classical inverse catenary design we also have studied a model with an intermediate underwater buoy linked with the surface buoy with an elastomer. The steel cable allows the inductive communication until intermediate buoy, and from this to the surface buoy, data is conducted by a communication cable rolled along elastomer. We want to keep the seabed anchorage as stable as possible with minimum oscillations and tensions. According to the simulations, the elastomer seems to absorb part of the vertical and horizontal movements of the surface buoy.

III. Seafloor unit transducer

Seafloor unit mainly consists of an anchor and a metallic structure containing 3 geophones (one in each ortogonal axe),

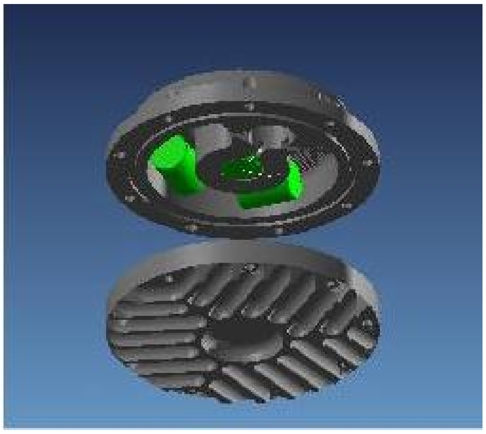

Fig. 1. Seismometer.

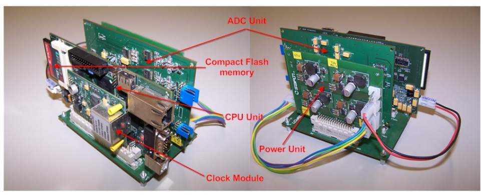

Fig. 2. Acquisition System

the associate electronics and the batteries. In the recovery process the anchor remains in the seafloor and only the metallic structure containing seismometers, electronics and batteries are lifted. In contrast to OBS, and due to physical connection between seafloor unit and the buoy acoustic, release procedures are not necessary.

A low cost seismometer prototype (fig. 1) has been built of 2 aluminium 3005H18 pieces, an upper case covering the GS-11D sensors and their electric connections and a base as an interface to the sea floor and the sensors (5). Its design must be optimal in order to get a successful coupling on the bottom sea (the bottom case is grooved so as to evacuate the exceeding material like a sand, mud, sludge or other kind of sediments). The three electromagnetic seismic sensors placed orthogonal in a blocked structure of the geophone are GS-11D of Geospace, cutting frequency 4.5Hz, sensitivity 85 V/m/s and resistance of 4 kΩ.

The data registered are managed for an electronic acquisition system, which consists of four main blocks: analog-to-digital conversion module, micro-controller and data storage module, power regulation module and time base module (6). A lithium-ion battery pack is built and used as the main power supply. Figure 2 shows the packaging of the acquisition system implemented: the micro-controller and storage module is based on a MCF54455 microcontroller and a 4 GB Compact Flash memory card for data storage. This module is in charge of configuration of the ADC module selecting the sampling rate and low power operations. The acquisition software designed acquires data continuously from input channels through a QSPI (Queued Serial Peripheral Interface) bus, performs time stamping by using the integrated RTC (Real Time Clock) and stores the data in the Compact Flash memory card. Furthermore, this module carries out the following functions:

- Default configuration of the system
- Time synchronization with a GPS signal
- Clock drift calculation
- Low power sleep.

Some alkaline batteries supply are meant to be designed and sized with a 4-month long in service collecting data. In addition to the seismometer, temperature, pH and conductivity measurement are also performed.

IV. Surface buoy

In the design of the surface buoy multiple factors have been taken into account. First of all, the buoy has to support the weight and tensions of the connection cable that links it to the seafloor unit in different sea and weather conditions (as studied in the OrcaFlex simulations described above). Secondly, the buoy has to be larger enough to contain electronics for collecting data, communication devices, energy supply and proper legal signaling. Finally, we are strongly interested in a portable and easy to deploy equipment, ideally to be deployed from vessels that are not fully equipped for research and will likely be done by scientists not familiar with the deployment of this type of equipment. The conjunction of these 3 items is not an easy task and probably need revolutionary changes in miniaturization of sensors that escapes to the purpose of this paper. In the above scenario our best options have been a 2 meter diameter toroidal buoy EMS 2.0 (see fig. 3). This buoy includes an unsinkable float yellow plastic with UV resistant PE filet with high density PU foam, a 316 L marine stainless steel superstructure, an internal box (dimensions 530×530×400 mm) and a lead ballast of 300 kg. Four solar panels (4×12V/32Wp@92Wh) of 440×460 mm, two solar charge controllers and sealed lead-gel batteries 12V/120Ah, supply and store the required energy. Wind mills and other energy harvesting devices have been discarded.

V. Seafloor surface link

Our first attempt was the use of an umbilical dual cable (fiber optic, steel and cooper or aluminium), that not only supplies energy from surface to the seafloor but also a very wide band communication channel (7, 8, 9). Since 2009 our team manages a seafloor observatory and a 7 m high research buoy using this technology. The observatory, called OBSEA, is located 4 km from the cost of Vilanova i la Geltru, ($\phi = 41^0 10^{'} 54^{''} 87N$ and $\lambda = 1^0 45^{'} 08^{''} 43E$) in a 20 m seabed (www.obsea.es). Even though we have broad experience in this technology, the umbilical option was discarded because of its cost and heaviness. Our second option was (in fact is!) the use of inductive communications using steel mooring cables. Steel cables are cheaper than umbilical ones, and also reduce significantly the weight of the cable itself. Due to the imminence of the deployment (September 2016), the classical inverse catenary option has been adopted. Elastomer option needs further analysis. Inductive Modem (IM) telemetry

Fig. 3. EMS buoy.

system uses a Differential Phase Shift Keyed (DPSK) data transmission method that overcomes most of the disadvantages of Frequency Shift Keyed (FSK) transmission, resulting in superior transmission efficiency and much lower error rates. The IM system uses a carrier frequency of 4800 Hz, permitting four cycles of carrier frequency during the time allotted to each data bit.

The Surface Inductive Modem (SIM) is a vital link in inductive modem (IM) telemetry systems, which provide data communications without the need of underwater electrical connections. The system requires a SIM (housed in a buoy) and underwater IM instruments. The SIM provides the link between the underwater IM instruments and computer/buoy controller. Communication with the computer/buoy controller is via full-duplex RS-232. The SIM can link to up to 100 inductively coupled instruments on a jacketed mooring wire. Underwater Inductive Modem Module specifications are:

- Sensor interface: RS-232
- Sensor baud rate: 300, 600, 1200, 2400, 4800, 9600, or 19200 (IM telemetry rate 1200 baud)
- Memory for sensor data: 16 KByte (40 stored samples maximum)
- External power required: 6 - 30 VDC
- Quiescent current: 300 μW
- Operating current: 15 mW
- Material: Plastic housing (350 m)

VI. Offshore communication

On the platform electronics we include a CR1000 datalogger CSI programmable, a GSM communication with a GSM Modem WaveCom marine antenna, and a SpreadSpectrum RF416 RF radio modem, 2.4GHz. Satellite Telemetry using Iridium satellite is also available. Iridium RUDICS transceiver, allows large packets telemetry data and GPS position. Time synchronization is done using GPS signal. Optionally a Bluetooth integrated in the buoy allows short-distance wireless connection without opening the buoy. We consider to send the seismic data from the three channels together with the time and position data in packs stored in the equipment memory and will be sent through the inductive cable to 1200 baud and a memory of 16kBytes (40 stored samples maximum).

VII. Conclusions

A new ocean seismometer, to be deployed in September 2016 in the Alboran Sea, has been presented. The system consists of a seafloor unit (seismometer) and a surface unit (a buoy) connected by a steel cable, deployed precisely in these seismogenic zones in order to observe seismic activities on the sea floor in near real time. Steel cable allows inductive DPSK data transmission between the two units and consequently real time data using RF, GSM or satellite communication to land. We will test this equipment in our observatory OBSEA to get the best performance in seismic records and communication. The results of the experiments and their final deployment will be published shortly.

Acknowledgment

We acknowledge the financial support from Spanish Ministerio de Economa y Competitividad under contract CGL2013-42557-R (Interoperabilidad e instrumentacion de plataformas autonomas marinas para la monitorizacion sismica, INTMARSIS project). The authors extend their thanks to Orcina for their kind support and offer of the academic license N1594 (2015) to Universitat Politecnica de Catalunya.

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