A Concept for Mobile and Real-Time Seismic Observation on Seafloor

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I. Introduction

Though submarine cable in-lined seafloor observation system is a very effective tool for real-time / long-term geo-scientific measurement, there is a technological difficulties for deploying as many sensors as on land. To solve the problem, JAMSTEC developed adaptable observation system (AOS: Figure 1) that is an expandable satellite station for submarine cable observatory. The AOS is a battery operated mobile observatory connected to the backbone cable system by the 10km long thin fiber cable to ensure real- time data recovery. The system consists of a Branch Multiplexer (B-MUX), a Joint Multiplexer (J-MUX), a fiber cable, and a Battery Pack for 6-month operation. Installation and construction of AOS planed to conduct by towed vehicle and ROV. This observation system provides a chance to extend existing seafloor network from in line to wider area.

II. Backbone System

The backbone cable system for adaptable observation systems (AOS) consists of approximately 240-km long optic / power submarine cable, three ocean bottom seismometers, two tsunami pressure gauges, a cable end multi sensor station, a power / data management shore station, a control land station, and two B-MUXs (Figure 2) [1]. Six ITU-T654 standard single mode optical fiber cores were molded in submarine cable. Five of six optical fibers assigned to the in-line observation system and cable end multi sensor station. The AOS take the rest of an optical fiber core for two-way data transmission. All components of seafloor were remotely controlled by the land station through the shore station using 256 kbps digital telephone line. The measurement data is managed by the facilities in shore station and telemetered in real-time via same digital telephone line to the land station data base located in JAMSTEC Headquarters. The power management facility for the submarine cable system in shore station is single conductor and seawater grounding return current system. Electricity to the underwater instruments is supplied with constant current at 1.1 A DC and voltages between 490 and 850 V DC that varies with load.

Three in-line ocean bottom seismometer (OBS) and two in-line tsunami pressure gauge (PG) are assigned to the three observation site. The in-line OBS is three components accelerometer with 1K Hz/ch sampling frequency 24bit AtoD converter. The two frequency bands which called low band (DC-200Hz, ±3G) and high band (0.05-200Hz, ±30G) is measured by the pickup. The in-line PG is a quarts crystal frequency counter with 5-mm resolution (at 1sec accumulative value) and ±7cm accuracy. Each sensor unit designed to have more than 10-years of reliability and built in beryllium-copper alloy pressure housing. Maximum operation depth of these systems is 4000-meter (photo 1).

Cable End Multi Sensor station equipped with a triple CCD color video camera with pan / title stage, six underwater lights, a hydrophone, two geo-thermo meters, a electro-magnetic current meter, a CTD sensor, and a acoustic doppler current profiler (ADCP), in a titanium alloy open frame.

III. Adaptable Observation System

The backbone submarine cable system has two branch multiplexers (B-MUX) for AOS. B-MUX branches one of the six main optical-fiber line and allows to install so-called joint multiplexer (J-MUX) at the end of the branched optical fiber line. J-MUX equips a telemetry

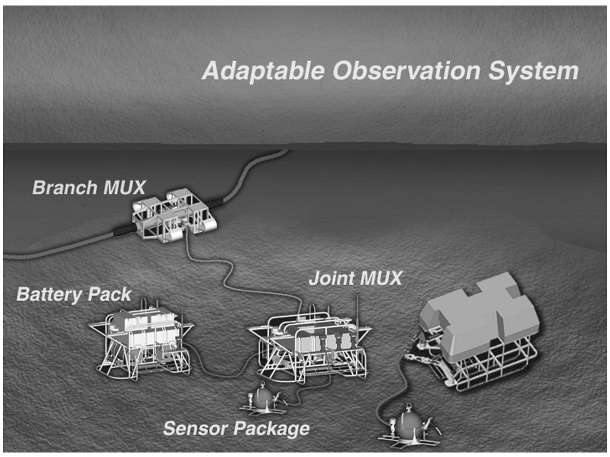

Figure 1. A Deployment and Operation Image of Adaptable Observation System

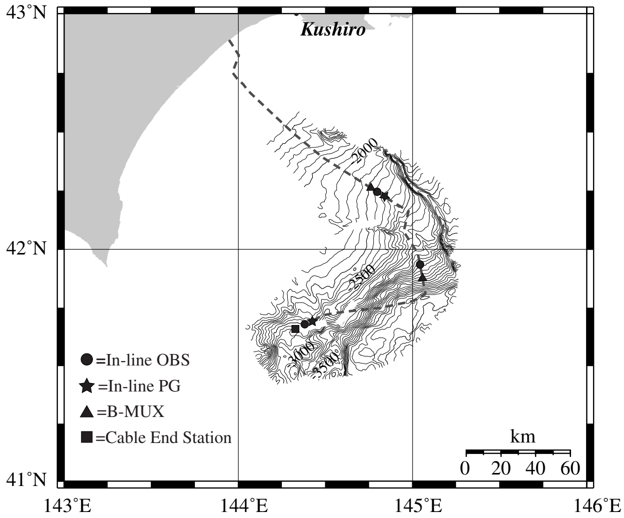

Figure 2.
A Result of Sea Beam Survey at Southern Kuril Subducting Zone and Cable Route for Off Kushiro-Tokachi System.

unit, a multiplexer and works as hub for adaptable sensor packages such as broad band seismometer, etc. Battery pack will be installed to the corner of J-MUX to supplies electric power operate the J-MUX six months. The J-MUX and B-MUX will be connected by the submarine thin fiber cable laying by towed vehicle [2] [3].

A. Branch Multiplexer

The B-MUX consists of a telemetry unit and a fiber optic underwater mateable connector, built in a beryllium-copper alloy pressure housing mounted on titanium alloy chassis. The telemetry unit equipped optical repeater, and physically divides an optical-fiber line from the backbone cable system to AOS. It additionally have the power circuit and function to amplify the optical data signal from other measurement equipment in backbone cable system (such as in-line OBS, in-line PG and cable end multi sensor station) to realize long distance telemeter. The chassis of B-MAX (Figure) is designed to put pressure housing and a UMC, and control the attitude of landing to the seafloor. The chassis keep the UMC location on the seabed always side of the pressure housing. The UMC mount base has a mechanism to rotate its position ±90 degrees, which operate by the ROV manipulator to get the face up position for mating operation. Detail specifications are listed on Table 1.

B. Joint Multiplexer

The J-MUX consist of a telemetry unit, a pressure housing, UMCs, buoyancy materials, an acoustic releaser, a flasher, a beacon and a chassis to mount all equipment. Telemetry unit multiplexes the data from measurement equipment connected with UMC interfaces convert electric data to optic signal and upload to B-MUX. The control signals from land station through the B-MUX are also demultiplexed and distribute by the telemetry unit to the each interface. Telemetry unit has four interfaces for measurement equipment, which is an analog interface together with RS-232C serial interface and three RS422 serial interfaces. The analog interface prepares for the broadband seismometer and connected with 24bits analog to digital converter to telemeter the data from sensor to B-MUX. The RS-232C serial interface which has the 1200bps baud late, control and monitor the seismometer package. Three RS-422 serial interfaces which baud late is 9600bps are available for additional measurement equipment and outside research proposals. Overall weight of the J-MUX is approximately 25kg in seawater to consider the transfer the unit on seafloor by ROV. For the maintenance operation or re-installation, J-MUX has POP-UP mechanism actuate by the acoustic releaser or mechanical releaser after demates UMCs. The power to operate telemetry unit in J-MUX comes from the Battery Pack through the UMC. Specifications of the J-MUX is listed on Table 2.

C. Battery Pack

Battery pack which is a power supply for J-MUX, consist of two cell packs, two pressure housings, a UMC, buoyancy materials, an acoustic releaser, a flasher, a beacon and a chassis to mount all equipment. Nine Mn-Li battery cells are packed in series to generate 27 volts and 1100Ah for 6 months J-MUX operation. Battery cells are put apart two titanium alloy cylindrical pressure housings and mount on the titanium chassis. 30m long of underwater cable is used for connection between Battery pack and J-MUX. Overall weight of the Battery Pack is 885kg in air and adjusted approximately 25kg in seawater to consider the transfer the unit on seafloor by ROV. For the maintenance operation or re-installation, POP-UP mechanism similar as the J-MUX was equipped in the system.

D. OBS Sensor Package

Broadband seismometer is standard measurement equipment for AOS. The appearance of the OBS package is a titanium alloy sphere shape pressure housing mounted on the cross shape anchor base together with an acoustic releaser and a UMC. Overall weight of this

Table 1. Specifications of Branch Multiplexer

Dimensions	2.0x0.5x2.0(m)
Weight	1200kg (in Air)
Pressure Resist	4000m
Power Consumption	20V±5V(1.1A const.)
Carrier Frequency	1.55 μm
Output Level	-10dBm
Transmission Rate	2048Mbps

Table 2. Specifications of Joint Multiplexer

Dimensions	2.0x1.3x2.0(m)
Weight	470kg (in Air) / 25kg (in Water)
Pressure Resist	4000m
Power Consumption	4.8W Max. (27V)
Carrier Frequency	1.55 μm
Output Level	-10dBm
Transmission Rate	2048Mbps
Interface	Analogu+RS-232C x1, RS422 x3

Table 3. Characteristics of Submarine Thin Fiber Cable

Diameter	6.5mm
Weight	39.8kg/km (in Air) / 5.8kg/km (in Water)
Lines	4 Fiber Optic Max
Fiber	ITU-T654
Operational Depth	4000m
Allowable Tensile Strength	484N
Allowable yield Radius	150mm
Tension Member	SUS Pipe
Jacket	Polyethylene

package is 208kg in air and 30kg in seawater. A broadband seismometer mounted on gimbals stage and a battery cell pack are set on the pressure housing. The sensor pickup has 0.01 to 50Hz measurement frequency bandwidth, 1500V/G sensitivity and ±4.5V maximum output. 36 Chloride-Li battery cells are packed to generate 12 volts and 270Ah for 6 months operation. The interface for uplink and downlink of the data between OBS package and J-MUX is a UMC mounted on the flange of pressure housing. This interface has a set of analog connection for OBS sensor output and a 1200bps RS-232c serial interface for sensor control. The measurement data telemeter to shore station real-time through the B-MUX. The pressure housing part of this package is able to recover the acoustic command from surface ship. However, it is necessary to demate the UMC connection from the J-MUX and to put on extra floating device to get the positive buoyant before the recovery operation.

E. Submarine thin fiber cable

AOS secure real time data transmission between mobile sensor package and shore station using submarine thin fiber cable. The mobility of AOS has been achieved by the use of thin fiber cable. This cable has four layers structure that is high density polyethylene (HDPE) outer jacket, adhesive polyolefine inner jacket, SUS pipe (M-PAC) tension member, and optical fiber lines to procure 484N allowable tensile strength and 150mm allowable yield radius for lay on the cable seafloor. Outer diameter of this cable is 6.5mm and it has 39.8kg/km in air / 5.8kg/km in seawater. Four single mode fiber lines (ITU-T654), a set of communication and a set of spare, are installed in the 1.8 (outer)/ 1.6 (inner) mm diameter M-PAC with water blocking compound for 4000m depth operation. Both end of the cable assembled fiber-optic UMCs to link B-MUX and J-MUX. Table 3 listed the characteristic for this cable.

IV. Conclusions

The AOS is very attractive for real-time long-term deep seafloor observation. The manufacture of the all equipment is done already and in the final inspection. Installation and construction of mobile observatory is scheduled in FY 2001 using JAMSTEC towed vehicle and ROV 'KAIKO'. We think the system we developed provides a chance to extend existing seafloor observation network, and any geo-scientific instruments can be connected by setting up their interfaces under a common serial connection rule. Consequently, the extension of existing ocean bottom cable systems has become much easier using this type of adaptive system.

References

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