New Cable Projects in JAMSTEC

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Abstract – JAMSTEC initiated two cable projects. One is to develop a new observatory at the end of a cable, and to use the cable as a long antenna to electrically investigate the inner structure of the crust. The cables to be used in this project are abandoned underwater telecommunication cables off Toyohashi in Central Japan. The other is to expand the existing observatory off Hatsushima in Sagami bay. A new observatory will be connected to the existing one using cable extension technology. A new current-to-voltage converter of high efficiency and a precise clock/time-synchronization signal supply systems are now being developed.

I. INTRODUCTION

Underwater scientific cable networks are expected to provide long-term, continuous, real-time, three dimensional and high-density data which can hardly be obtained otherwise. As many kinds of sensors can be connected to cable networks, they can be used disciplinary including geophysics, seismology, geodynamics, marine environmentanology, ecology and biology.

In Japan, eight scientific cables [1] have already been developed and been operating by Japan Meteorological Agency (JMA), Earthquake Research Institute, University of Tokyo (ERI), National Research Institute for Earth Science and Disaster Prevention (NIED) and Japan Agency for Marine-Earth Science and Technology (JAMSTEC). As Japan is located close to plate boundaries where catastrophic earthquakes take place periodically, disaster mitigation has higher priority. Therefore most of these cables are dedicated to seismic observation. JAMSTEC has developed three of these cable systems [2].

The first one (Fig.1) was developed off Hatsushima in Sagami-bay, in 1993 [3], and was replaced in 2000 [4]. Sagami bay is the one of the scientifically important area to be investigated. It is a swarm earthquake region, and cold seeps exist where the largest chemo-synthetic biological community in Japan exists. The existing observatory is located in one of cold seep sites. As being located close to Tokyo metropolitan area, transportation is convenient and it is suitable place for out reach.

The observatory is equipped with several kinds of sensors including two video cameras, a CTD sensor, a current meter, a seismometer, a sub-bottom thermometer and a hydrophone, and aims at multi-disciplinary observation.

The second one was deployed off Muroto-cape, on the slope of Nankai Trough in 1997. The system consists of two in-line seismometers, two in-line tsunami sensors and an observatory at the end of the cable. The observatory is equipped with a current meter, a CTD sensor, a hydrophone, a sub-bottom thermometer, a video camera and an acoustic Doppler current meter (ADCP).

On September 5th, 2004, two earthquakes of M6.9 and M7.4 took place off Kii peninsula and generated small tsunamis. Pressure fluctuation was successfully detected with the in-line tsunami sensor about 20 minutes before the tsunami wave arriving at Muroto tidal observatory [5]. It is obvious that cable systems are useful for issuing accurate early tsunami-warning.

The third cable system [7], [8] was constructed off Kushiro in Hokkaido, on the slope of Japan Trench in 1999. It consists of three in-line seismometers, two in-line tsunami meters, two branch multiplexers (B-BUX) and an observatory at the cable end. An underwater mateable optical connector is mounted on a B-BUX. An adaptable observation system (AOS), which can be

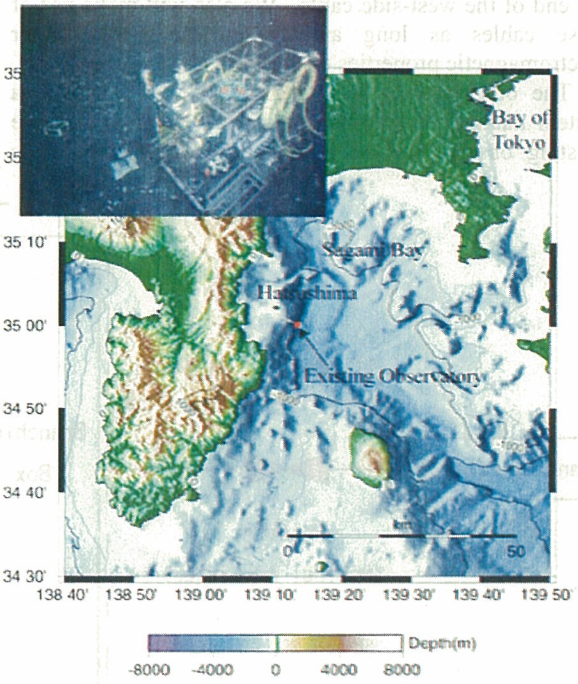

Fig.1 Off Hatsushima observatory

connected to the B-BUX through thin optical cable, can temporarily be deployed. The AOS is driven by a battery.

At the Tokachi-oki earthquake of M8 in 2003, this system recorded not only the waveform of earthquake but also seafloor uplift and generation process of tsunami. It also recorded continuous uplift of seafloor after the main shock [9].

Base on these technical and scientific accomplishments, JAMSTEC recently initiated two new cable projects. One of them is to reuse a couple of telecommunication cables off Toyohashi, in central Japan (Fig.2). The cables were a portion of domestic optical telecommunication cable network called JIH (Japan Information Highway, Table 1) which goes round Japanese Island. It was constructed in 1999 by KDDI using dense wavelength division multiplex (DWDM) and optical amplifier technologies. The cables, which will be transferred to JAMSTEC, were originally connected to Ninomiya which is close to Tokyo and Shima in Kii peninsula. However, the power feeding line of the east-side cable was damaged and shorted to the ground in 2003. As it was the best season for fishery, it was commercially difficult to repair the fault point. Then KDDI abandoned the landing segments off Toyohashi and the landing station, and bypassed the landing cables by connecting two cables from Shima and Ninomiya.

These cables happen to be located in an area where big earthquakes take occur periodically. Moreover DWDM and optical amplifier technologies are the up-to-date ones and provide us a flexible (bit-rate and format free) and large transmission capacity enough for scientific use. Then JAMSTEC is now going to take over these cables from KDDI. The fault point in the east-side cable will be repaired by KDDI after the transfer.

We are now planning to make a new observatory at the end of the west-side cable. We also will make use of these cables as long antennas to study the inner electromagnetic properties of the earth crust.

The other project is to expand the off-Hatsushima system making a new observatory in Sagami Bay. The existing observatory has optional underwater mateable

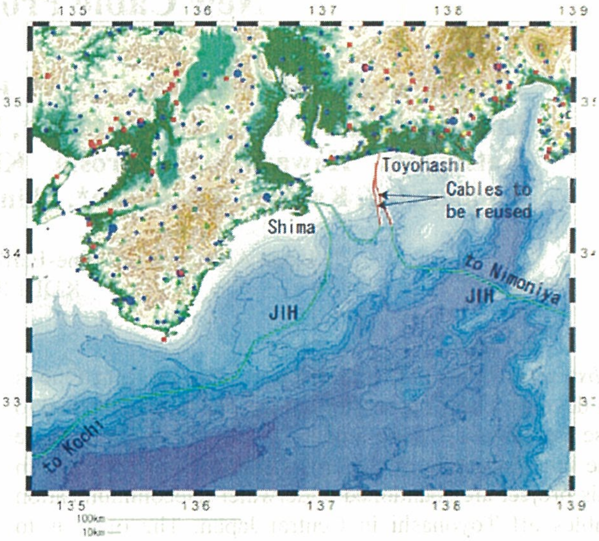

Fig.2 A couple of cables to be re-used for scientific observation

Table 1 Outline of JIH

Beginning of service	April 1st, 1999
Number of landing stations	17
Total cable length	10,300 km
Transmission method	Dense Wavelength Division Multiplex
Nominal transmission capacity for a pair of fibers	2.5 Gbits/s
Number of fiber pairs	3
Number of wavelengthes	14
Wavelength	1,525 +/- 10nm
Interval of repeaters	about 50km
Feeding current	DC 0.92A

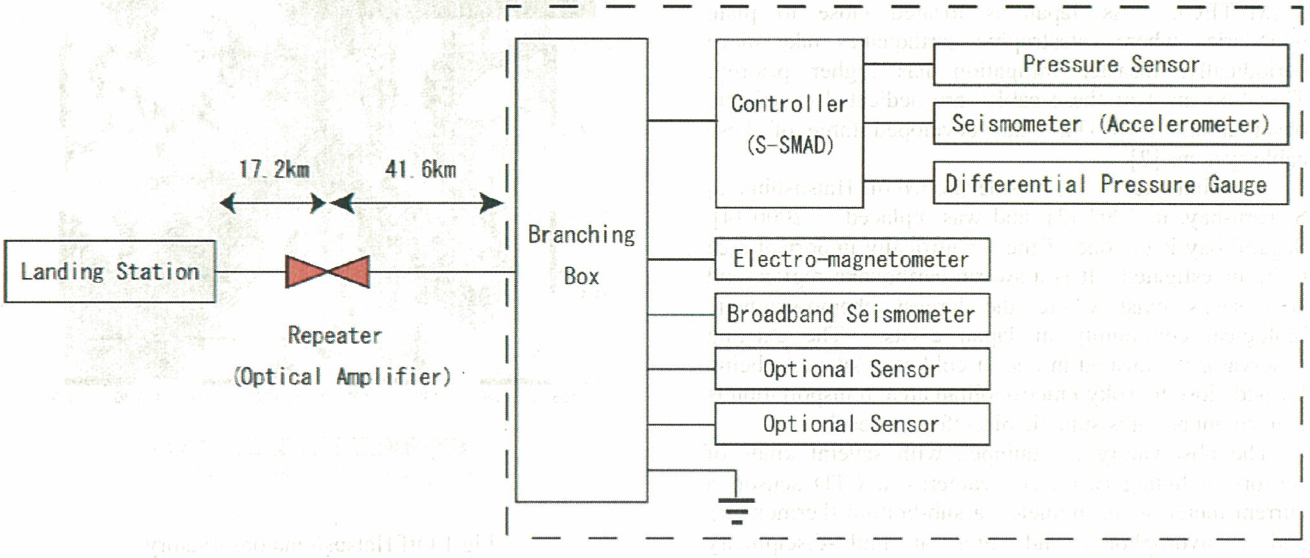

Fig.3 Basic configuration of the off-Toyohashi system (west-side cable)

connectors to which optional unused lines and optical fibers are directly connected from the landing station through a couple of copper wires and some optical fibers. Therefore the existing system has high flexibility for expansion. Using the cable extension technology, the new observatory will be connected to the optional underwater mateable connectors of the existing station.

In this paper, we will present the outline of the off-Toyohashi system, and the outline of new technologies being developed.

For power feeding, constant current power feeding system will be used. Constant current power feeding systems are commonly used for commercial underwater telecommunication systems as they are robust against cable shunt faults, supply circuits in repeaters are simple, and isolation of electric circuits in repeaters against sea water is simple. However developments of current branching devices and current-to-voltage converters with high conversion efficiency were remaining issues to be handled. In this paper, we will propose a new current-to-voltage converter with high conversion efficiency which can handle not only load variation but also input-current variation.

Ethernet will be used for data/command transmission. Precise clock and time-synchronization signal will be provided to the observatories.

For the off-Hatsushima system, the same technology will be used.

II. OFF-TOYOHASHI SYSTEM

A. Outline

As already mentioned, we had a basic plan not only to deploy a new observatory at the end of the cable but also use the cable as electromagnetic antenna to study the inner electromagnetic properties of the earth crust. However when this project started, there was no plan to repair the fault point in the east-side cable. Therefore we decided to use only the west-side cable, and to develop a constant current power feeding system which can vary the value of output current. By changing the current, we can generate a very-low-frequency electromagnetic field. The cable acts as an emitting antenna.

Fig.3 shows the basic configuration of the off-Toyohashi system. The observatory will be deployed at 1,530 meters in water depth. Five sensors will be connected to the branching box attached at the end of the west-side cable. Two additional underwater mateable connectors will be provided for additional sensors.

Table 2 Basic spesification of the power feeding system in the branching box

Range of input current	0.4-1.2A
Polarity	Negative
Maximum speed of current variation	0.8A/sec
Outout power	100W

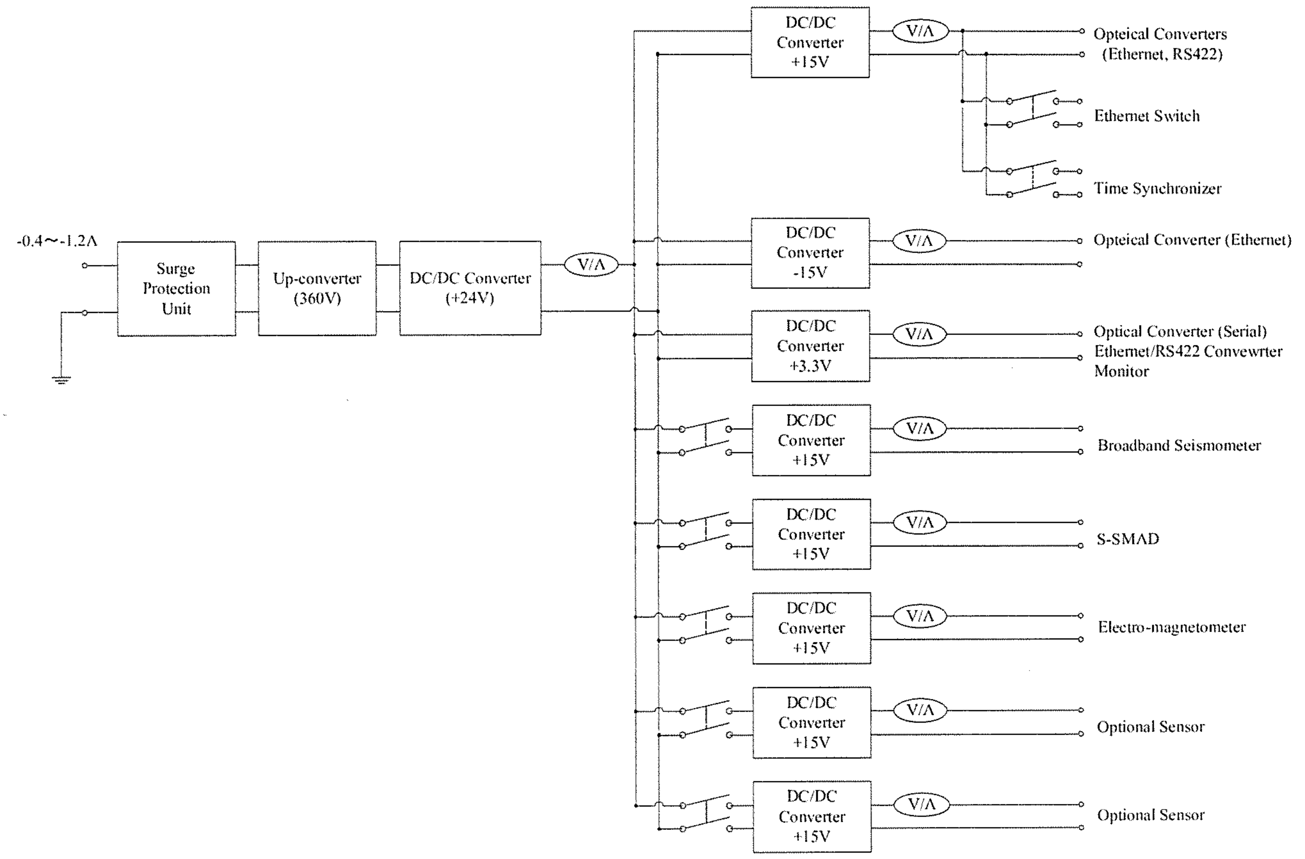

Fig.4 Configuration of the power feeding system in the branching box
V/A means voltage and current sensor

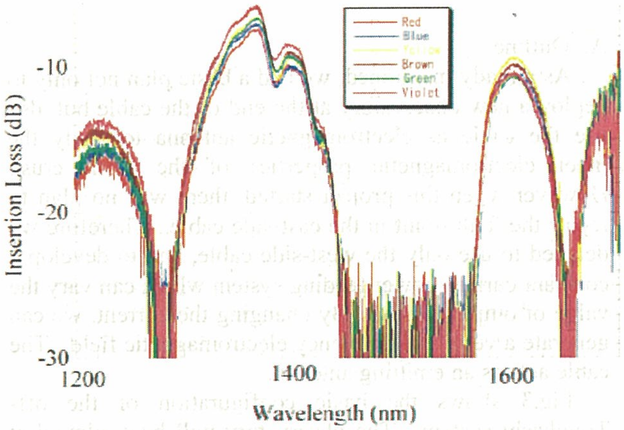

Fig.5 Optical insertion loss of repeaters

B. Power Feeding System

We need to vary the feeding current as mentioned above, but the current applied to the repeater is restricted to 0.92A. In order to avoid this restriction, we will apply a current with the opposite polarity to the normal operation. As the supply circuit in the repeater basically consists of zener diodes, by applying a current with the opposite polarity, we can inactivate the repeater, and can vary the value of the current.

Fig.4 and table 2 show the basic configuration and principal specifications of the power feeding system in the branching box. In the branching box, the current of 0.4 to 1.2A will be upconverted to 360V. Then after being downconverted to 24V, the voltage will be re-converted to several output voltages. Electric power for the sensors will be provided with +15Vdc, which is electrically isolated by isolated converters from the other electric circuits. Output voltage and output currents of converters will be monitored and transmitted to terrestrial station. There are some switches controlled from the terrestrial station.

For the upconverter, power-factor controller (PFC) is used to improve conversion efficiency. We have developed a prototype of this upconverter, and have confirmed that the upconverter can convert the input current of 0.4-1.2A to the output voltage of 360V. The range of the output power is 40-100W, and the conversion efficiency is better than 95%. As it is the first time for us to develop a current-to-voltage converter using PFC, and we have to handle both input current variation and output power variation, we have limited the maximum output power to be 100W.

C. Optical Transmission System

For the off-Toyohashi system, we need three optical transmission channels, i.e. for Ethernet, for clock and time-synchronization and for control and monitor of power feeding system. As there are three fiber pairs in the cable, we decided to assign these three fiber pairs to each three optical transmission channel.

The optical amplifiers in the repeater will be inactivated and will act as optical absorbers as the current will be supplied with the inverted polarity. Fig.5 shows the spectrum of optical insertion loss measured with optical spectrum analyzer using a spare repeater. It can be found that the insertion loss at 1,610nm is less than 12dB. Assuming the transmission loss of the optical fiber at 1,610nm being 0.23dB/km, the total loss of the transmission becomes 25.6dB. As the wavelength of 1,610nm is within the waveband used for coarse wavelength division multiplex (CWDM), various optical

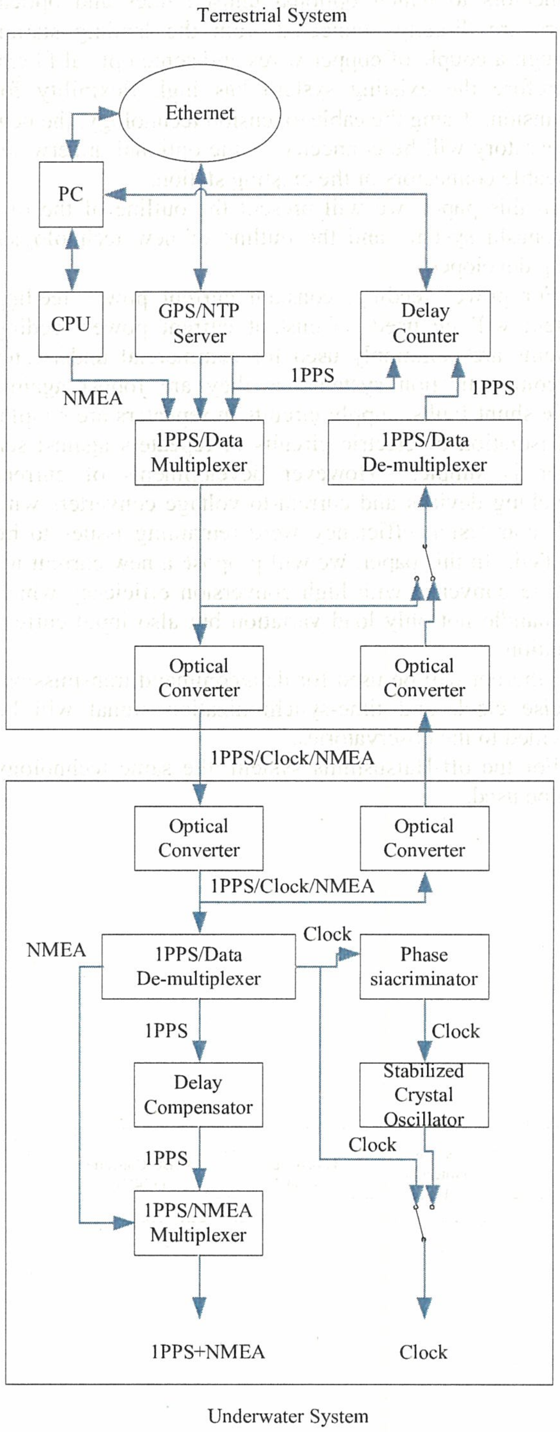

Fig.6 Block diagram of the clock and time-synchronization system

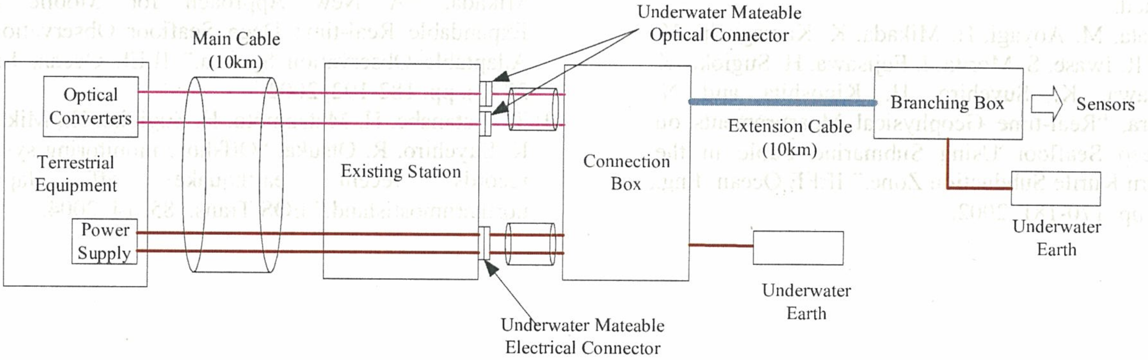

Fig.7 Outline of the off-Hatsushima system expansion

converters can be commercially available with which enough transmission loss margin can be obtained. For clock and time-synchronization channel, a converter which can transmit 10Mbits/s will be used. For the control and monitor of power feeding system, a RS422 converter will be used.

D. Clock and Time-synchronization System

Fig.6 shows the block diagram of the precise clock and time-synchronization system. This system will provide 1PPS signal, 10Mbit/s clock and NMEA data to underwater sensors. 1PPS signal will be used for GPS-Acoustic system and 10Mbits/s clock will be used for pressure sensor for example. These signals will be provided by a terrestrial server, and will be transmitted through the optical transmission channel. The 10Mbit/s clock will be modulated by the 1PPS and the NMEA signals. Transmission delay will be measured and compensated in the underwater system. Thermally stabilized crystal oscillator will be installed in the underwater system. Its frequency will be locked to that of the 10Mbits/s clock transmitted from the terrestrial system. We can select the output clock between the transmitted clock and the stabilized crystal oscillator.

III. EXPANSION OF OFF-HATSUSHIMA SYSTEM

We are now planning to deploy a new observatory using cable extension technology as mentioned in the introduction. The outline of the system expansion is show in Fig.7. Sensors to be connected to the branching box will include a TV camera and optode-microelectrode system. The same technology will be used for power feeding and clock/time-synchronization system. In off-Hatsushima system, power consumption by the sensors will be larger than that of off-Toyohashi system, but the feeding current will not be variable. CWDM technology will be used for optical transmission system.

IV. CONCLUDING REMARKS

In this paper, the outlines of two new cable projects in JAMSTEC were presented. Although the primary aim of the off-Toyohashi system is seismic observation, both systems will be used multidisciplinary.

In Japan, JMA is now constructing a new cable system for seismic monitoring off Tokai district, in Central Japan, close to off-Toyohashi system. It will be in operation in 2008. Ministry of Education, Culture, Sports, Science and Technology (MEXT) is now considering developing a new cable network having twenty observation nodes in Tonankai off Kii peninsula in Central Japan. The project will start in 2006 fiscal year. It will be deployed in 2009. The outline of these projects will also be introduced in the presentation.

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