Data Direct from the Ocean Bottom to the Laboratory

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Abstract - Data was transmitted in near real time from the ocean bottom to a scientist's desk, and commands were sent back to the ocean bottom. The communication system used a 1185 bits/s acoustic modem to send the data to a nearby surface buoy. VHF packet radio relayed the data at 1200 bits/s to a shore station where it was stored. The stored data was transferred by telephone modem to the scientist's desk. Commands were sent back to the bottom by a slower reverse channel. The system worked for three weeks until the buoy mooring was damaged. The difficult parts of the system, the acoustic modem and the packet radio, worked on real data. Some improvements have been made in the acoustic modem, some improvements are necessary to make the data more readable and to correct the mooring fault, and other refinements are desirable.

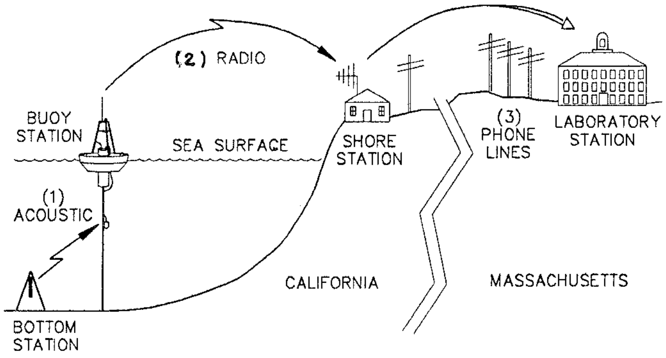

Fig. 1. Overall communication path: (1) by acoustic modem from the ocean bottom to the surface buoy, (2) by VHF packet radio from the surface buoy to the shore station, and (3) by telephone from the shore station to the laboratory.

INTRODUCTION

In January, 1991, two bottom tripods with BASS current meter arrays were deployed as part of the STRESS experiment. The goal was to measure the movement of sediment along the northern California shelf, near Sea Ranch. Deployed at sites five miles from shore in 90 meters of water and 10 miles from shore in 130 meters of water, these current meter arrays had a unique communication system which provided for two way communication with STRESS scientists from their homes and laboratories in Woods Hole, Mass. In this paper the communication system is described in detail, its performance is evaluated, and suggestions for improvement are made.

DESCRIPTION OF THE COMMUNICATION SYSTEM

Fig. 1 shows the communications path from the ocean bottom to the laboratory. Data at each site was processed by a low power computer and stored on its 20 Mbyte hard disk. The processed data was also transmitted to a surface buoy by an acoustic modem and then transmitted to shore by VHF packet radio. The data received by radio on shore was stored on an optical disk by an AT type computer.

The shore computer could communicate through a telephone modem to the lab or home where the user could receive a data summary from the previous half hour. The user could also send commands to the bottom mounted instrument over a slower reverse channel. He could command the bottom mounted instrument to send raw current meter data when desired.

The user would monitor the bottom currents to determine when they were strong enough to suspend bottom sediment. Then the user would command the current meter on the bottom to send raw data for 0.5 to 8 hours. If the raw data were recorded on the bottom continuously, it would have filled up the 20 Mbyte disk in 2 days. Thus the user could receive raw data during bottom storms even though there was not enough space on the bottom hard disk for the data.

Bottom station

The bottom tripod is shown in Fig. 2. The vertical column in the center of the tripod measured current at six points every half second. The acoustic transducer for the acoustic modem was near the top of the tripod. The block diagram for the bottom station is shown in Fig. 3. The data was processed by an Onset Tattletale model VI low power computer, then stored on its 20 Mbyte disk every 30 minutes. The 2304 bytes of processed data was also sent to the acoustic modem, Datasonics model ATM-840. The tripod-mounted ATM-840 sent the data at 1185 bits/sec to an ATM-850 acoustic receiver on the buoy. No data error detection or correction was used by the data source or the acoustic modem, in part because the high data rate used left no transmission capacity for error correction.

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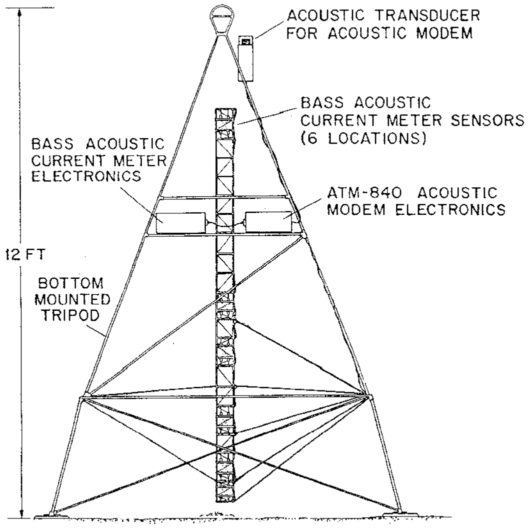

Fig. 2. Bottom tripod with BASS acoustic current meter and ATM-850 acoustic modem.

Buoy station

The acoustic transducer, below the buoy in Fig. 4, was 14 feet below the surface to avoid the bubbles in the water, which could block acoustic transmission. The transducer was baffled from reflections from the surface. The acoustic transducer cable ran to the top of the buoy center well. The center well contained the acoustic modem, VHF packet radio and battery. The VHF antenna and navigation light were mounted on the top of the buoy tower.

A block diagram of the buoy station is shown in Fig.5. Acoustic data transmissions from the ocean bottom mounted acoustic modem were received by the acoustic transducer, which was connected to the Datasonics ATM-850 acoustic modem. Data received by the acoustic modem were sent through an interface circuit to the PacComm Micropower-2 Terminal Node Controller (TNC). The interface circuit turned the TNC on only when the TNC was needed by the acoustic modem or the VHF transceiver, in order to save energy.

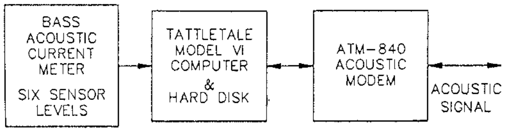

Fig. 3. Block diagram of the bottom mounted current meter and acoustic modem.

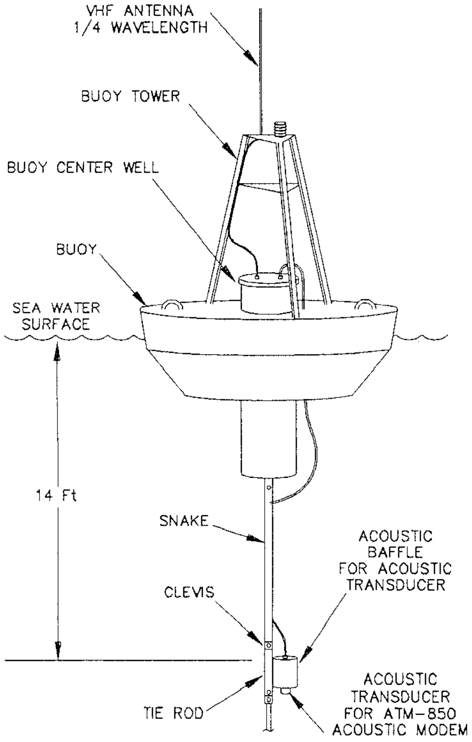

Fig. 4. The buoy station. The ATM-850 acoustic modem, the TNC, VHF transceiver, and 250 pound battery are in the waterproof center well. The acoustic transducer is located below the bubbles that are near the surface. The flexible non-twisting snake connects the acoustic hydrophone to the buoy.

The TNC, using AX.25 packet protocol, divided the data up into 256 byte blocks and added the station name, the length of the data block, and an error detection code. The data were sent without request for acknowledgment from the destination. This speeded up the data transmission by eliminating the need to wait for an acknowledgment. The data went through a 1200 baud modem to the three Watt VHF transceiver, Kantronics model drr 2-2, which was connected to a quarter wave whip antenna at the top of the buoy tower. The radio signal is transmitted from the buoy to a similar transceiver on shore.

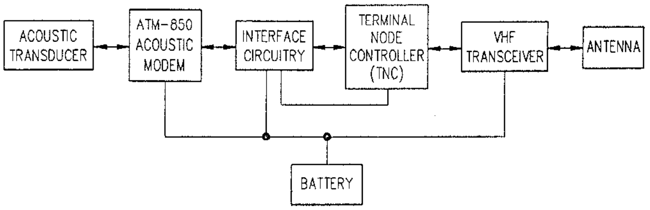

Fig. 5. Block diagram of the buoy station. Data flows from the acoustic modem to the VHF transceiver. Commands flow in the opposite direction.

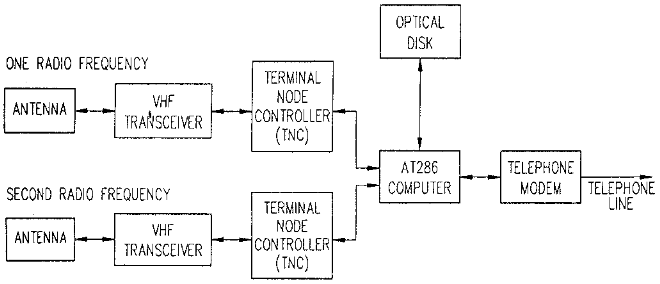

Fig. 6. Block diagram of the shore station. The shore station communicates by packet radio with the buoys and by telephone to the laboratory.

Shore station

The block diagram of the shore station, Fig. 6, shows two separate radio frequency channels, one for each buoy. The shore station used a yaggi antenna connected to a transceiver and TNC for each frequency channel. Error detection and correction using acknowledge and retransmission was available for the radio and TNCs, but error correction was not enabled in order to transmit data continuously to obtain a higher data rate.

The shore based computer had a separate RS-232 input for each channel. The 286 AT type personal computer stored the data as received onto optical disk, with channel identification and time appended. The program also displayed portions of the data from each buoy on the screen.

The shore computer had an internal Intel 2400B MNP (Hayes compatible) 2400 bits/s modem, with error detection and correction. This modem was connected to the telephone for access by a computer at a remote laboratory. BLAST, a program for transfer of data to a remote location, and SATELLITE, a program allowing the shore computer to be operated from a remote location ran in the background.

Laboratory station

The laboratory station consisted of a 286 AT type personal computer with the same type modem used at the shore station and a telephone. The BLAST program, running on the laboratory computer, was able to telephone the shore computer, establish connection first with the modem, then with the shore computer BLAST data transfer program. Data files stored on the shore computer's optical disk could be transferred to the laboratory computer. These files could be reviewed for any ocean bottom storm activity.

The shore computer could be commanded to start the remote control program. Then the shore computer screen would be reproduced on the laboratory computer, and the shore computer could be operated from the laboratory keyboard. This mode allowed the most recent bottom current meter data summary to be read to see if any ocean bottom storms were brewing. In that case, the ocean bottom computer could be commanded through the reverse channel to send a 20 minute segment of raw data from the current meters. A second command would cause eight 20 minute segments of raw data, spaced one hour apart, to be transmitted from the bottom. After storage on the optical disk at the shore station, the data could be transferred to the laboratory computer.

EVALUATION OF SYSTEM PERFORMANCE

After the initial deployment, the system operated successfully for three weeks. Data were logged on shore from the bottom current meter that was 10 miles offshore, and the reverse channel commanding the current meter to send data worked well. The laboratory station could communicate with the shore station, many files were transferred and the shore computer was operated remotely from the laboratory.

Several problems tempered the success of the system during this time. A data format error from the bottom station made the data screen display useless. The data header was missing about two-thirds of the time which made deciphering the data difficult. The remote control program was sluggish and making connection with the data transfer program was often difficult. However, useful current meter data was successfully conveyed from the Pacific Ocean bottom to an East Coast laboratory through this highly complex link for three weeks.

After 3 weeks of operation, however, data from the acoustic modem was interrupted during a storm. A 1/4-20 bolt acting as a pin that held a threaded clevis onto a threaded tie rod came out, allowing the tie rod to turn, twisting the hydrophone cable until the wires broke. The radio modem link between the buoy and shore continued to work. The same problem with the bolt occurred with the buoy that was 5 miles offshore while its electronics were ashore being serviced. However, the clevis completely unscrewed on this buoy and the buoy was lost. Improving this mechanical linkage must be the first priority for any future attempts to use this system.

SUGGESTIONS FOR IMPROVEMENTS

The system designed for use in STRESS provides an excellent basis for a future sea floor to laboratory transmission scheme. If improvements are made to each link in the communication path, a reliable and robust system will emerge. The most important improvements address the problems detailed in the evaluation of system performance. Several improvements have been made to the acoustic modem to improve transmission reliability. There are also suggestions which would improve field testing and repair. In addition, the operation of the purchased components (for example, the TNC) could be modified slightly to improve their usefulness for this application. Finally, several suggestions address the power limitations due to the use of batteries for the equipment in the buoy stations.

The mechanical problem which stopped the successful data transfer after three weeks was the clevis securing pin failure described above which detached the acoustic transducer below the buoy from the acoustic modem inside the buoy. In the future, the clevis should be welded to its tie rod instead of threaded and pinned with a peened bolt.

The 1/2 inch chain in a nearby pickup mooring rang at 12.5 kHz, the wake-up frequency for the ATM-850 acoustic modem. This chain had to be dropped to the bottom to keep it from continuously waking up the acoustic modem. The wake-up signal that starts the ATM-850 receiving has been changed from a single frequency to three frequencies. Thus a single frequency (such as chain ringing) will not start the reception. However, make sure that chain used does not ring at any frequencies used by the acoustic modem for wake-up or data transmission. Also, self generated noise in the digital-to-analog converter of the acoustic modem transmitter has been reduced since we ran this experiment.

Data can be encoded for error detection and correction in the updated acoustic modem. Error correction is used because the round trip propagation time in water required for an acknowledgment is too long. This new error correction feature consumes half the data transmission capacity, however, so the data bit rate is lowered from about 1200 to 600 bits/second.

The ATM-850 requires a 24 volt power source. The radio transmitter uses a 12 volt source. If solar cells were being used to charge one set of batteries in the buoy, the ATM-850 could be lowered to a 12 volt supply (not a trival task), since it does not need high power output when transmitting to ATM-840.

To ensure a comprehensible data display and error free stored data, the data format in the source must be corrected, and frequent sequential data delimiters and error detection must be added to the data.

Data integrity in the packet radio transmission was good, but can be improved by making use of the acknowledge feature available in the packet radio protocol. Since acknowledgment takes more time, a higher speed modem would be used with the transceiver if necessary. However, there might be interference between two transceivers operating simultaneously at the shore station.

The data transfer and remote control software should be upgraded to remove the speed and connection difficulties discussed above.

Several improvements can be made to improve field testing and repair. These include redesign of the acoustic modem components on the buoy including the changing to underwater pluggable connectors for the transducer and cable, redesign of the acoustic baffle which holds the hydrophone, and rerouting of a shielded hydrophone cable so that it is protected and replaceable by divers. A splash cover for the buoy electronics can be added to protect them during removal and installation in the moored buoy.

A method should be devised for monitoring the data at all points along the data path for system debugging. The TNC has an excellent monitor mode for debugging. Appropriate test equipment to simplify testing and debugging should include a field strength meter to measure the power output from the buoy antenna to check for broken antenna wires and an FM deviation meter to set the frequency modulation levels for the transceiver. Finally, anti-fouling paint on the snake under the buoy would prevent marine growth from adding to the wave stress on the buoy.

Improvements to the radio equipment could also improve system performance. Unreliable battery backup in the TNC, which caused the loss of stored parameters when the power was cycled, was overcome by the use of an EPROM with the desired parameters stored as default values. These special EPROMS are available from the manufacturer, but he should solve the battery backup problem. A sleep mode should be added to the TNC as a more convent way to save power than switching the TNC power off. TNC data block errors should be flagged rather than only discarded or passed through. A command which instructs the TNC not to respond to further commands should be removed from its firmware to prevent a potentially fatal latchup problem on the buoy.

A dead soft copper female contact in a BNC RF connector on the Kantronics transceivers, which deformed and lost connection, should be replaced with a connector with a spring metal center contact.

To improve the power system on the buoy, a solar battery charging system could be added. This would allow more radio transmissions and would prevent the delay, expense, and service call to the buoy which can occur when a huge alkaline battery is accidently discharged. Improving the efficiency of the radio transceivers, by replacing the 1/4 wavelength antenna with a higher gain 5/8 wavelength antenna and replacing the RG-58 antenna cable with lower loss RG-8 cable would also save energy, if the transmitter power is a lowered corresponding amount. A Radiocom transceiver with a 6 mA receiver current which was used in one buoy, would save power over the less expensive Kantronics transceiver used in the other buoy which drew 40 mA.

CONCLUSION

The communication system developed for the stress experiment demonstrated the feasibility of bringing large amounts of data from the ocean bottom to scientists in their laboratories in real time. While improvements are necessary to make the system reliable and robust, the overall system design proved to be sound. This system can easily evolve into a data telemetry method of immense use to scientists for real time monitoring of oceanographic phenomena from their desks.

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This is WHOI Contribution #8088.