(2)

AD-A213 581

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. Agency Use Only *(Leave blank).*

2. Report Date.
18-21 September 1989

3. Report Type and Dates Covered.
Proceedings Oceans' 89

4. Title and Subtitle.
A Compact Acoustic Recorder

5. Funding Numbers.
Program Element No. 62435N
Project No. RJ035
Task No. I21
Accession No. DN496433

6. Author(s).
Ronald Stein

7. Performing Organization Name(s) and Address(es).
Applied Physics Laboratory
College of Ocean Fishery Sciences
University of Washington
Seattle, WA 98105-6698

8. Performing Organization Report Number.
PR 89:047:242

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Naval Ocean Research and Development Activity
Code 242
SSC, MS 39529-5004

10. Sponsoring/Monitoring Agency Report Number.
PR 89:047:242

11. Supplementary Notes.

12a. Distribution/Availability Statement.
Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract *(Maximum 200 words).*

OCT 3 1 1989

A-1

14. Subject Terms.
Acoustic Propagation, Sea Ice; Noise

15. Number of Pages.
5

16. Price Code.

17. Security Classification of Report.
Unclassified

18. Security Classification of This Page.
Unclassified

19. Security Classification of Abstract.
Unclassified

20. Limitation of Abstract.

NORDA Contribution No. PR 89:047:242
Approved for Public Release

Preprint: OCEANS '89,
18–21 September 1989, Seattle

A COMPACT ACOUSTIC RECORDER

Ronald Stein

Applied Physics Laboratory, College of Ocean and Fishery Sciences
University of Washington, Seattle, Washington 98105-6698

ABSTRACT

This paper discusses the design and operation of a portable compact acoustic recorder. Designed to be used in arctic conditions for applications that require portable equipment, the device is configured to fit into a lightweight briefcase. It will operate for eight hours at –40°F with heat provided by a hot water bottle. It has proven to be an effective scientific tool in the measurement of underwater acoustic signals in arctic experiments. It has also been used successfully in warmer climates, e.g., in recording acoustic signals from small boats with no AC power.

The acoustic recorder's cost is moderate since it is based on a Sony Walkman Professional (WM-D6C) tape recorder playback unit. A speaker and battery assembly and a hydrophone interface electronic assembly complete the system electronics. The interface assembly supplies a number of functions, including a calibration tone generator, an audio amplifier, and a hydrophone interface. Calibrated acoustic recordings can be made by comparing the calibration tone amplitude with the acoustic signal amplitude. The distortion of the recording is minimized by using a high quality, consumer tape recorder.

INTRODUCTION

Underwater sound measurements in the Arctic are usually made with stationary systems connected to line or battery power. Long cable runs to the measurement site are often used, and moving the measurement to a new location is not a simple task. On occasion, however, a requirement will arise to make simple acoustic measurements at a location where cable runs are difficult if not impossible. For example, measurements may be required of noise at a pressure ridge where the ice is "working" or of sounds of marine life at a specific location.

A portable acoustic recording system is therefore needed to make sound measurements in the Arctic on such "targets of opportunity." The basic requirements are that the system be relatively inexpensive, lightweight, conveniently packaged, and operable in arctic temperatures for up to 8 hours. Finally, it must make a quality, calibrated sound recording when connected to standard commercial hydrophones. As a byproduct, the system would also be useful in warmer climates to operate from small boats without AC power, in relatively inaccessible locations, and where quick and simple acoustic measurements are desired.

SYSTEM DESIGN

A compact acoustic recorder weighing 23 lb in a briefcase configuration has been designed. Using a hot water bottle to keep it warm, it will operate at least 8 hr in a –40°F environment before requiring recharging or rewarming. The recorder will operate with two common laboratory hydrophones: the Bruel & Kjaer 8101 or the International Transducer Corp. 6050C. The heart of the system is the Sony Professional Walkman (WM-D6C) recorder, which costs approximately $430. This unit supplies high fidelity two-track recording and playback with a 58 dB signal-to-noise ratio (SNR) using the recommended metal IV cassette tape with Dolby off. With Dolby C on, the SNR can be boosted to 71 dB. The frequency response is from 40 Hz to 15 kHz ±3 dB with total harmonic distortion at a maximum of 0.9%. A calibration tone is generated at 1.0 kHz in the compact acoustic receiver for accurate measurement of the actual signal levels.

The compact acoustic recorder costs about $800 for parts and 80 hr for labor exclusive of design and prototype costs. A hydrophone and cable (to be used with the recorder) cost upward of $1,700. The use of the Sony recorder kept the system costs low and the quality of the acoustic recordings high. Obtaining a scientific quality portable tape recorder based on a standard high quality consumer recorder appears simple. However, when the various requirements such as calibrated acoustic recording, audio monitor, and acoustic signal monitoring are included, the system becomes more complicated than expected. The details of how all the various system controls work and how the unit operates are discussed in the next section.

Operation

The first main assembly (see Figure 1) is the Sony tape recorder. This recorder has the normal tape recorder functions. Included are a recording level meter; recording on normal, CrO_2, and metal tapes; recording level control; and a headphone volume control. The second main assembly houses the 6 V, 10 A-h battery and speaker with a DC to DC converter tucked in a corner. The battery supplies all system power. The third main electronic assembly houses the interface between the hydrophone and the tape recorder.

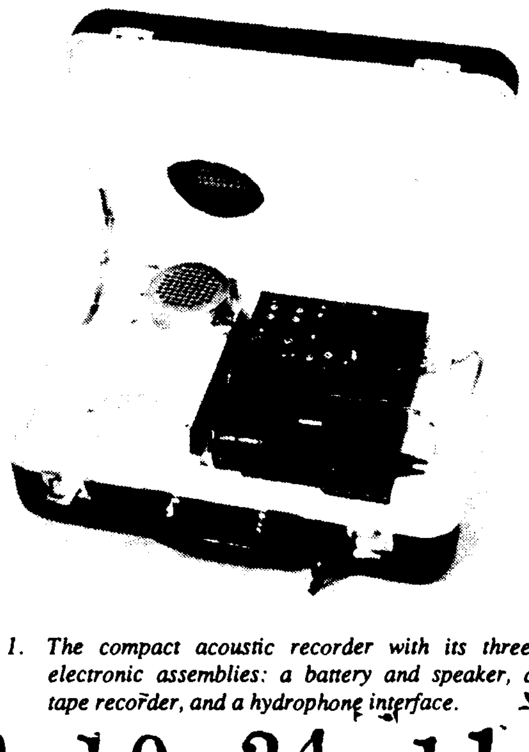

Figure 1. The compact acoustic recorder with its three main electronic assemblies: a battery and speaker, a Sony tape recorder, and a hydrophone interface.

89 10 24 114

Most of the system controls are on the hydrophone interface (see Figure 2). The POWER switch S8 on the hydrophone interface turns on power to all the electronics, including the tape recorder and the interface electronics. The charge connector input is from a 0.8 A wall plug charging module. The LED below it will light when charging is occurring. The BATT MON connector allows a measurement of the battery voltage.

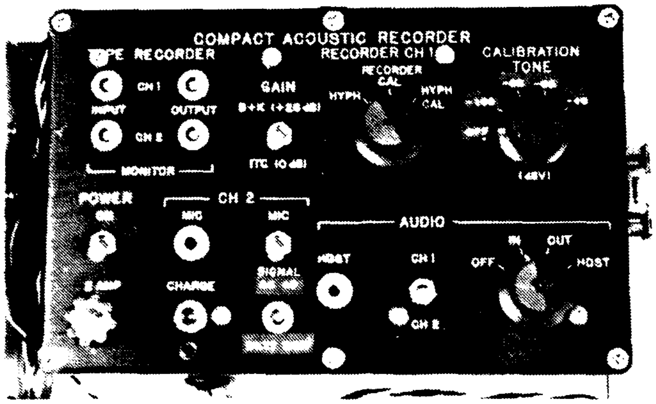

Figure 2. The hydrophone interface supplies a number of functions that include an audio amplifier, a calibration tone, and I/O monitors for the compact acoustic recorder.

Two channels, stereo, are recorded with this tape recorder. Channel 1 records the hydrophone signals, and channel 2 records voice comments or channel 1 at a 30 dB gain level. The 30 dB gain level option allows the acoustic signals to be recorded over a wider dynamic range.

The calibration tone switch sets a calibration tone of 1.0 kHz at a level of −40, −60, −80, −100 dBV or OFF. The switch marked RECORDER chooses the signal seen by channel 1. The signal is the hydrophone input, the calibration tone input, or the hydrophone calibration pad input. The calibration pad is used to check the calibration of the preamplifier. In the hydrophone calibration pad mode a calibration tone is sent to the calibration pad between the transducer element and the preamplifier of the hydrophone. The signal observed is that of the calibration tone added together with any acoustic signals the hydrophone is sensing. The GAIN switch is set to the 0 dB position when the ITC hydrophone is used and to the 26 dB position when the B&K hydrophone is used. The B&K hydrophones are about 26 dB less sensitive than the ITC hydrophones.

Channel 2 has two inputs, a microphone input and channel 1 input at a 30 dB gain. These inputs are selected with the switch marked MIC and SIGNAL, 30 dB. Next to this switch is the microphone input, which is labeled MIC.

The two input channels to the tape recorder are available on the connectors labeled TAPE RECORDER, MONITOR, and INPUT. The two tape recorder OUTPUT monitors are adjacent to the tape recorder monitor INPUTs. When signals reach the recorder, the recording level rotary control on the tape recorder sets the recording level. A 0/20 dB attenuation switch is also available on the tape recorder. The signal amplitude can be observed on an LED VU meter with the larger of the two input signals being sensed for display.

The compact acoustic recorder is designed for scientific quality acoustic recording. A comparison of the calibration tone with the incoming acoustic signal is required for an accurate measurement of the acoustic signal levels. A calibration tone is recorded either before or after the acoustic signal is recorded. This is be done by setting the recorder switch to the CAL position and the calibration tone switch to the level closest to that of the acoustic signal without overloading the recorder input. No changes in the recording level control should be made once a recording of an acoustic signal-calibration tone pair is begun.

Notice that the hydrophone interface box has neither input nor output volume controls for signals going to or from the tape recorder. These two controls are nicely implemented with the REC LEVEL and HEADPHONE VOLUME controls on the tape recorder itself. A design philosophy of this acoustic recorder is to take full advantage of the various tape recorder controls.

When recording or playing back an acoustic signal, the signal can be monitored on a speaker or headset. Since the human ear is an excellent audio signal processor, the audio output allows an assessment of the quality of the acoustic recording as it is being made. For example, if the audio disappears while a recording is being made, nothing is being recorded on the tape. Similarly, if the audio sounds distorted, chances are the recording is distorted also. Since there are no controls external to the case of the acoustic recorder, and the audio output can be heard with the lid closed, the lid of the compact acoustic recorder should be kept closed in cold or rainy weather except when changing tape or adjusting the recorder and electronics.

Electronic

The electronics (see Figure 3) of the compact acoustic recorder are incorporated on three boards mounted on the inside of the interface panel. The board containing the circuitry conditioning electronics for the hydrophone is in a separate metal can to reduce possible electronic interference.

The energy source for this system is a 6 V, 10 A-h sealed lead acid battery. The battery is charged through the charge input, a 6 V, 0.8 A wall plug battery charger. An 1N5825 Schottky diode is in series with the battery and charger combination to allow the inclusion of the LED charging light. This light is activated only when charging voltage is supplied to the battery. A battery monitor output is connected directly across the battery with a 10 K series resistor to protect against a possible short circuit. With most digital multimeters having 10 M or more input impedance, the error in reading the battery voltage caused by the 10 K resistor is no more than 0.1%.

When the S8 POWER switch is turned on, all systems (the Sony WN-D6C, audio amplifier, and DC to DC converter) are powered up. The DC to DC converter changes 6 V to ±12 V for the electronic circuits. The ±12 V power has about 15 mV of ripple at between 30 and 300 kHz with only C29 and C31 connected. Capacitors C28 and C30 and resistors R33 and R34 are designed to reduce this to below 0.1 mV. Since this ripple is above 30 kHz, and since the recorded frequencies are at 15 kHz and below, a residual ripple can be tolerated.

Notice that the grounds are separated out. Ground 1 is the main power ground. Ground 2 is the main electronic ground, with grounds 4, 6, 7, 8, and 9 connected directly to it. Ground 3 is connected directly to the power ground 1. This ground design minimized signal interactions through the ground leads.

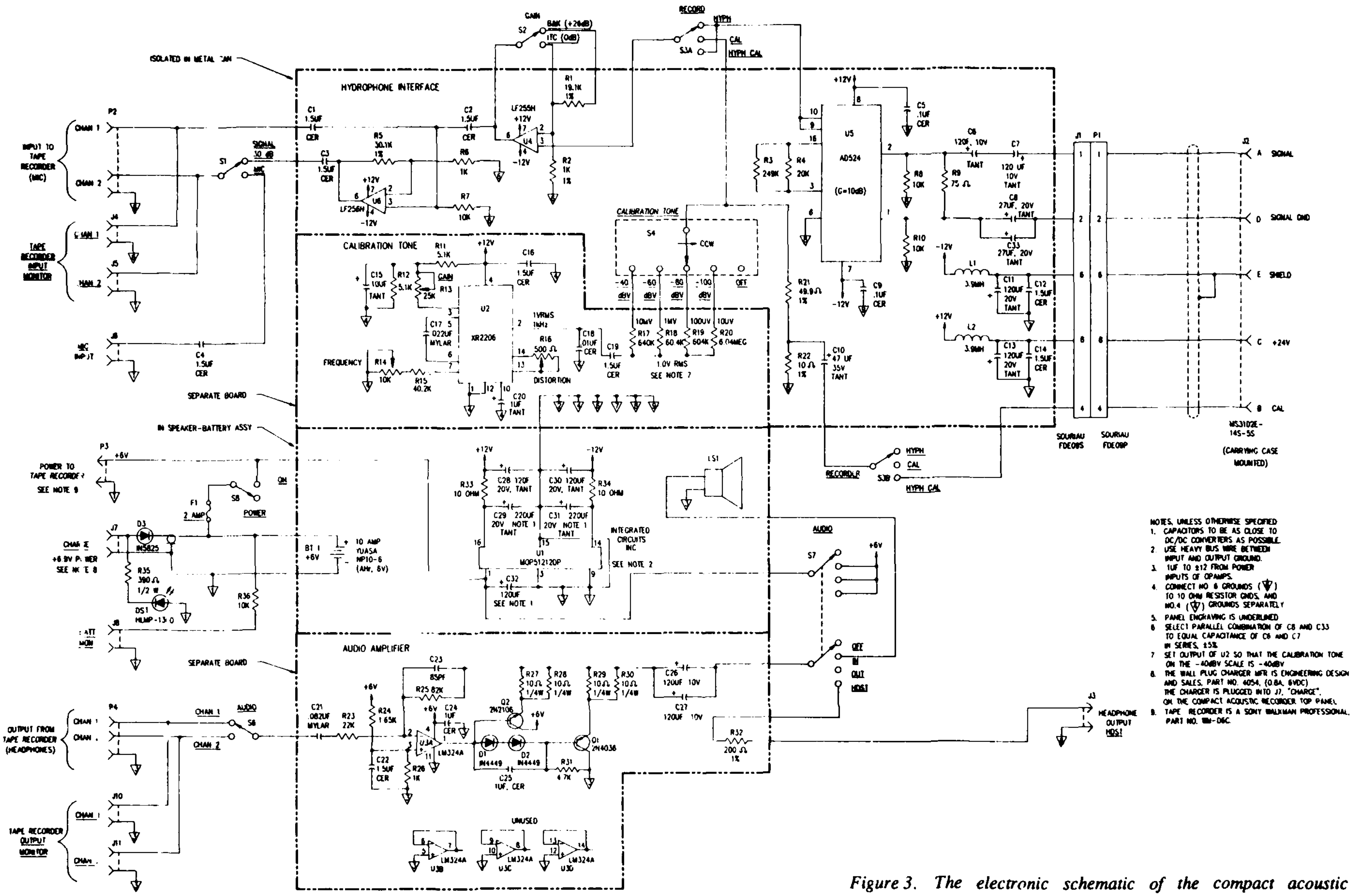

Figure 3. The electronic schematic of the compact acoustic recorder exclusive of the Sony tape recorder. The acoustic recorder electronics include a hydrophone signal conditioning circuit, a calibration tone generator, and an audio amplifier.

The ITC 6050 hydrophone requires 24 V to operate, with the B&K requiring 12 V to 24 V. The hydrophone is supplied through connector J2 with −12 V to its ground (shield pin E) and +12 V to the +24 V input (pin C). The hydrophone then "sees" 24 V with the shield floating at −12 V. All other inputs and outputs are capacitively coupled, which removes any DC offset problems. The inductor-capacitor assemblies on pins E and C are designed to remove additional ripple from the ±12 V power to the hydrophone.

The hydrophone acoustic signals arrive on pins A and D of connector J2. Capacitors C6, C7, C8, and C33 remove the DC offsets. R9 terminates the hydrophone cable, with R8 and R10 holding the inputs to U5 to near ground. U5, an AD524, is an instrumentation amplifier set to a gain of 10 dB by R3 and R4.

The calibration tone is produced by U2, an XR2206 signal generator chip. The output is set to 1.0 Vrms. The voltage divider of 100 to 1 consisting of R17 and R21 in series with R22 produces a 10 mVrms or −40 dBV calibration tone input to S3. R18, R19, and R20 produce a −60 dBV, −80 dBV, and −100 dBV calibration tone respectively. The calibration tone is further divided down by 16 dB and supplied to the calibration pad of the hydrophone through pin B of J2. This signal is boosted by 10 dB in U5 on its return to the hydrophone interface.

The RECORD switch S3 selects either a hydrophone signal or one of two calibration tones. The signal is then sent to U4, where the operational amplifier selects either 0 dB or 26 dB gain depending on S2's position. The high gain is for the B&K hydrophone and the lower gain is for the ITC. This signal is sent to the tape recorder and a second operational amplifier, U6, where it is given a 30 dB gain. Switch S1 selects whether this signal or the microphone signal goes to the second channel of the tape recorder.

On playback the output of the tape recorder is sent to S6 where either channel 1 or channel 2 is selected and fed into the audio amplifier. The amplifier is powered entirely from the 6 V battery. This saves power over using a DC to DC converter since the converter is not 100% efficient. The audio amplifier design is fairly standard, with U3A supplying gain and including the output stage of Q1 and Q2 in its feedback loop to reduce distortion. The AUDIO switch S7 chooses both the on/off function and the speaker vs headset selection. The outside position is not connected to anything since a separate speaker to be mounted for external audio proved unnecessary.

In a circuit with very low signal levels, high levels nearby often produce severe crosstalk problems. This circuit was designed to avoid these problems. The crosstalk problems are minimal. In the final design the hydrophone signal is uncontaminated by the calibration tone, the audio amplifier, and the DC to DC converter ripple.

Mechanical and Heat

The compact acoustic recorder is housed in an ABS plastic briefcase type container measuring 18 × 14 × 6.5 in. The plastic has not cracked with normal handling at −30°F. The electronics are insulated with a minimum of 1 in. of Ethafoam except where equipment protrusions prohibit it. The system internal audio monitor can be heard with the case shut by use of a pattern of holes in the case above the speaker. The holes are backed by a flexible plastic membrane. A rubber ring seals the speaker against the case. The audio level is essentially unchanged when the case is closed.

The three major electronic assemblies—the tape recorder, battery-speaker, and hydrophone interface assemblies—are mounted on an aluminum plate. Under this plate (see Figure 4) is a compartment for a two-quart, hot water bottle. When this bottle is filled with "hot" (110°F) water, the electronics are kept above the required 32°F for 8 hr in a −40°F environment. The aluminum plate helps distribute the heat inside the case so no cold spots develop.

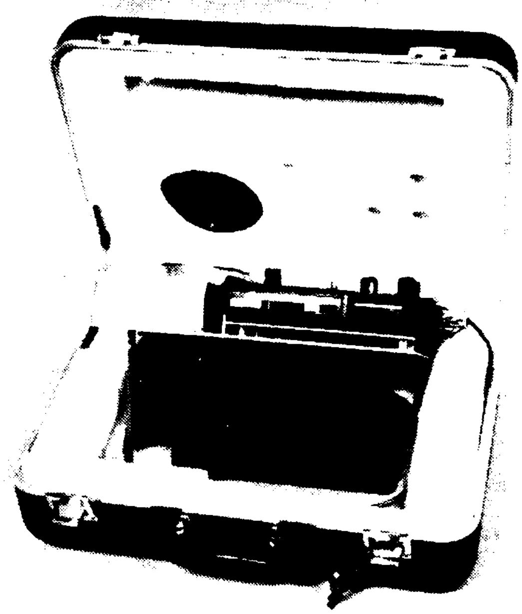

Figure 4. The compact acoustic recorder uses a hot water bottle to keep warm in the Arctic. The bottle space is used to carry the microphone and battery charger when the hot water bottle is empty.

The Sony tape recorder operates normally from 32°F to 104°F and at reduced capability from 14°F to 131°F. If one is willing to accept minimal degradation in performance, the heat of fusion of the water in the hot water bottle will more than double the time the electronics can be kept operational at 32°F or above in a −40°F environment. Also, the electronics requires 0.5 A or less to operate. With a 10 A-h battery, power for at least 14 hr can be expected in the temperature environment inside the recorder case.

The obvious use of battery electrical power to keep the case warm was rejected. The amount of heat available from the electrical energy of a lead acid battery is about half that available from an equal weight of water dropping from 110°F to 32°F. When the heat of fusion of the water is taken into account, the advantage is more than four to one.

PERFORMANCE

The compact acoustic recorder at about 65°F with its hot water bottle at about 110°F was set outside in about −30°F temperatures to test its ability to handle cold temperatures. After 8 hr the unit was examined and found to be at about 55°F. It is concluded that the goal of 8 hr operation at −40°F is easily achieved by this device. In an assessment of self-noise performance, laboratory measurements with a spectrum analyzer indicated that the system noise floor and the hydrophone noise floor were comparable.

The compact acoustic recorder was used in the Arctic in −25°F temperatures on "targets of opportunity." It was also used in a heated building in the Arctic when other equipment had failed. In both cases the equipment worked well and exhibited very low self-noise in a very low noise environment.

In warmer climates the compact acoustic recorder is being used regularly by a project to measure low frequency sound at some dams along the Columbia River in order to assess the effect of acoustics on fish diversion around the dam. The recorder is used on a small boat at varying distances upstream from the dam. The recorder works very well except at the dam face, where the noise is so loud that the recording is distorted and unusable.

SUMMARY

A compact acoustic recorder was developed that is useful in measuring sounds on remote "targets of opportunity" in the Arctic. It is also useful for making acoustic measurements in warmer climates, for example, from small boats without AC power, in relatively inaccessible locations, and where quick and simple acoustic measurements are desired. The device weighs 23 lb with its hot water bottle filled, and has the size and shape of a briefcase. It will operate at least 8 hr between charges in a −40°F environment with the heat for the system coming from a hot water bottle. The heart of the system is a consumer product, the Sony Professional Walkman (WM-D6C) tape recorder. The use of such an inexpensive recording device kept the cost of the system low and the quality of the acoustic recordings high.

Acknowledgments. This work was part of a research project sponsored by the Office of Navy Technology (ONT) with technical management provided by the Naval Ocean Research and Development Activity (NORDA). The author thanks his co-workers at the Applied Physics Laboratory, especially Robert Francois, Fred Brune, and James Luby, for their contributions to the development of this recorder.