TELEMETRY RECEIVER AND ACOUSTIC COMMAND SYSTEM

K.H. Burt, D.C. Webb, D.L. Dorson, A.J. Williams 3rd
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Abstract

A shipboard Telemetry Receiver Acoustic Command System (TRACS) was designed to be used for two-way acoustic communication with and relocation of underwater instruments. The design objectives were compact size, low cost, multi-purpose capabilities, and ease of operation and maintenance of the system. The telemetry receiver system utilizes a four-hydrophone array, bandpass filters and amplifiers, precision time-base for synchronization, a writing amplifier, and a helix, wet-paper recorder. The Acoustic Command System (ACS) incorporates an adjustable digital acoustic command generator, a power amplifier, an underwater sound transducer and an adjustable ACS test output circuit useful for alignment of underwater acoustic receivers. Two systems have been used successfully at sea on four cruises.

Introduction

The Telemetry Receiver Acoustic Command System (TRACS) is a general purpose shipboard subsystem used for sending acoustic commands to and receiving telemetry from a variety of autonomous underwater instruments. The additional equipment necessary for the operation of TRACS consists of a four-hydrophone array, an acoustic transducer, and a helix, wet-paper recorder. A photograph of TRACS and the recorder is shown in Figure 1. The TRACS incorporates some features of an earlier system designed at the Woods Hole Oceanographic Institution (WHOI).[1] This paper describes the TRACS design and operation.

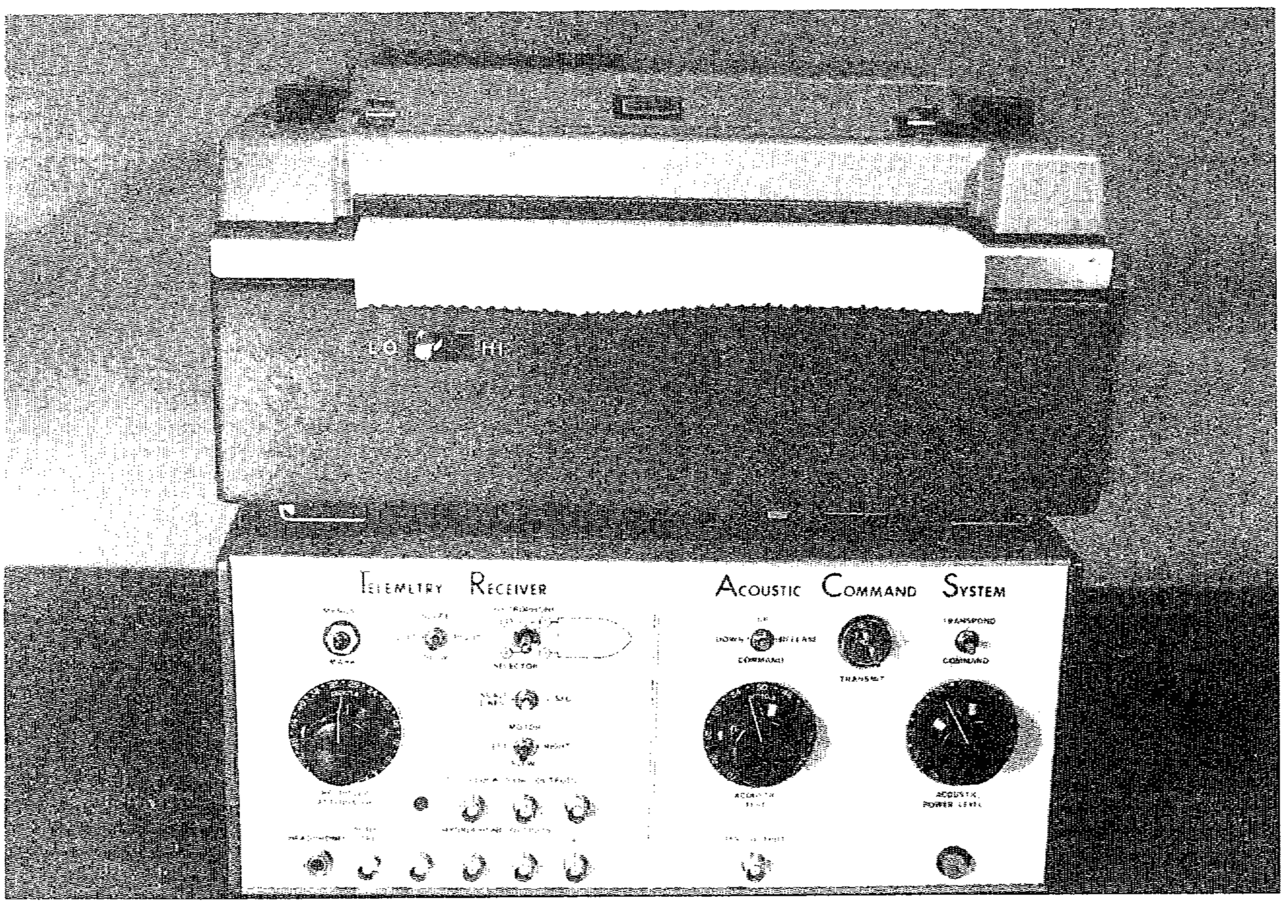

Figure 1. The Telemetry Receiver Acoustic Command System (TRACS) shown with the helix wet-paper recorder.

Telemetry Receiver

The Telemetry Receiver (TR) was designed to receive acoustic telemetry signals from underwater instruments. The signals are filtered, amplified, displayed on a scope, and permanently recorded on a helix, wet-paper recorder. The acoustic signal is received by a rectangular array of hydrophones towed 30 meters behind the ship. The hydrophone array consists of two strings of two hydrophones each separated by 30 meters. A block diagram of the Telemetry Receiver is shown in Figure 2 with a schematic diagram of the ship and the four hydrophone array. Range and bearing for location of the instrument relative to the ship is available using TRACS as well as the acoustic telemetry data. Location of an underwater instrument requires a good receiver sensitivity, noise rejection, and accurate time synchronization between the ship's telemetry receiver and the underwater instrument. Absolute range error is less than 50 meters in a day.

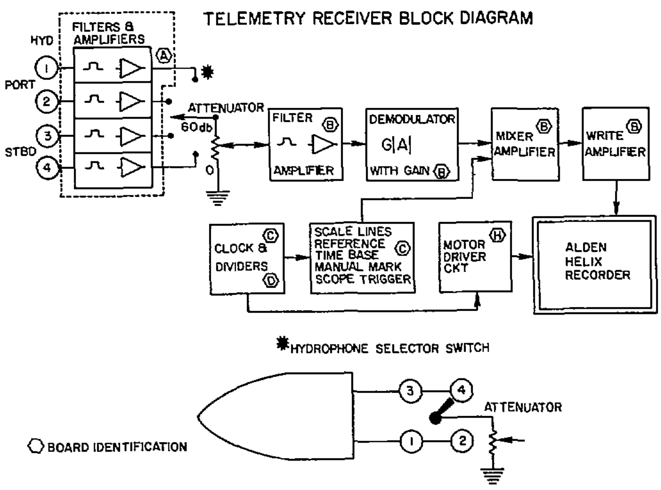

Figure 2. The Telemetry Receiver block diagram showing the signal flow from the hydrophones to the recorder, and a diagram of a ship showing a towed four hydrophone array.

TR Description

Acoustic signals are received with the hydrophone array at 5 KHz, filtered using active bandpass filters with a Q of 50, and amplified for presentation on an oscilloscope. The scope display is useful when a comparison between the acoustic travel times to different hydrophones is desired. Acoustic ranging is accomplished by first synchronizing the master clock in TRACS with the clock in the underwater unit. The scope is then triggered at the repetition rate of the underwater instrument every 2 seconds from the TRACS clock, and two hydrophone signals are displayed on two traces of the scope. The hydrophone closest to the instrument will receive the signal first, since it has the shortest slant range. The slant range is determined from the one-way acoustic travel time. This technique can be used for all four hydrophone signals using a four-trace scope or for comparison of any two hydrophones at a time on a two-trace scope.

One hydrophone signal is selected on the front panel for recording. This signal is passed through an attenuator, where the amplitude may be varied in 2 db steps from 0 - 60 db. The signal is again filtered at a Q of 50, amplified and demodulated. The acoustic envelope is mixed with the digitally generated signals (i.e., the scale lines, 2 second reference time base, scope trigger) and the manual mark signal. These functions are controlled on the front panel. A scope trigger identification signal is also displayed on the recorder for convenience of the operator. The mixer amplifier is connected to the write amplifier which conditions the signals for the recorder. The helix, wet-paper recorder is made by Alden Research. The intensity of the mark is approximately proportional to the write current.

The recorder helix is driven at exactly 30 rpm by a gear-belted synchronous motor. The helix, therefore, makes a precise 2 second sweep across the paper. The acoustic telemetry to be recorded is usually transmitted from the underwater instruments every 2 or 4 seconds, so that the traces accumulate on the slowly advancing paper. The recorder synchronization can be slewed at the front panel to move the trace left or right. The normal procedure is to synchronize the underwater instrument with the TRACS recorder by slewing the motor until the two second reference signal is at the left hand edge of the paper.

An example of the TRACS recording showing the acoustic telemetry is shown in Figure 3. The calibrated pressure and temperature signals are proportional to time delay from the main reference (2 second) signal. The reference signal is easily distinguished from the pressure and temperature signals since every fifth pulse is twice as long (20 msec). This method is used in several instruments such as the Autoprobe,[2] Vertical Current Meters,[3] and a Free-Fall Electromagnetic Current Meter.[4] The digital telemetry technique using the TRACS recorder has also been successfully used.[5]

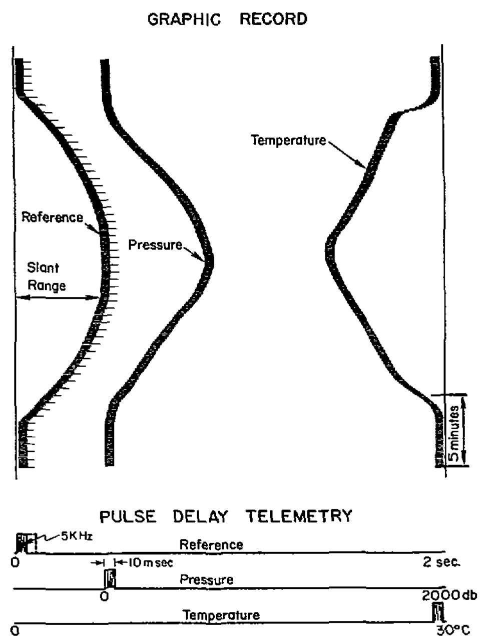

Figure 3. An example of a graphic record showing pulse delay telemetry. The telemetered pressure or temperature is measured from the start of the reference to the start of the pressure or temperature.

Acoustic Command System

The Acoustic Command System (ACS) was designed for one-way communication with underwater equipment for the purpose of surface control of up to three functions. Usually, an acoustic command is sent to an instrument to recall it to the surface by activating an underwater receiver to trigger a weight jettison circuit. The underwater receiving equipment used and activated by the ACS is the Model 200 receiver made by American Machine and Foundry (AMF).[6] The underwater receiver requires a five-level code for operation: (1) carrier frequency, (2) frequency of amplitude modulation, (3) pulse width, (4) one of three possible pulse repetition frequencies (PRF), and (5) time duration. There are three separate commands using the five-level code, and a transpond command using a three-level code. A shipboard ACS, made by AMF (Model 200), is commercially available for this function. However, the AMF shipboard ACS was not used for several reasons. The overall objective was to provide an economical ACS with digitally generated command codes in the same box as the Telemetry Receiver (TR), with an adjustable alignment capability for initial adjustment and testing the underwater receiver. The advantages of digitally generated codes are: the adjustments are free of drift; the commands can be varied precisely over a wide range for receiver alignment; all receiver channels can be synthesized by the same circuit. This compact ACS unit replaces the normal AMF deck system which requires three independent large boxes for the coder, power amplifier and receiver alignment equipment in addition to the output transducer.

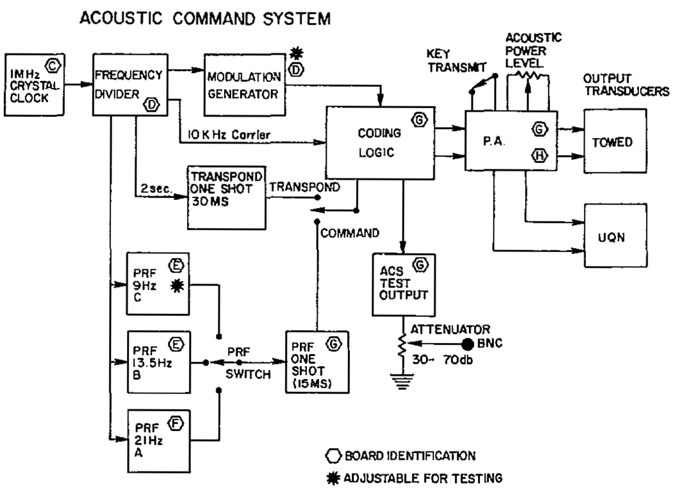

Figure 4. A block diagram of the Acoustic Command System showing the major components and interconnections.

ACS Description

The Acoustic Command System (ACS) is shown in a block diagram in Figure 4. The AMF acoustic codes are generated digitally using the temperature compensated crystal oscillator (TCXO) and frequency divider circuits as the reference signals. The ACS consists of the coding logic, modulation generator, PRF's, power amplifier (P.A.), transducers and receiver alignment and testing circuitry. The coding logic combines the digitally generated signals necessary to create the five-level code. The 10 KHz carrier frequency is derived directly from the frequency divider circuit (consisting of 4 decade dividing ICs). COS/MOS integrated circuits are used everywhere, except in the power amplifier. The modulation frequency is digitally generated using presettable counters/dividers and 4 thumbwheel switches. The thumbwheel switches are preset to a number which when divided into the input frequency (500 KHz) results in twice the modulation frequency. A final division-by-two results in a signal (650 Hz to 1550 Hz) for amplitude modulating the carrier. The three pulse repetition frequency (PRF) rates (9, 13.5, 21 Hz) are also digitally generated using presettable counters/dividers for each PRF. Selection of the particular PRF is accomplished via a front panel switch. The pulse width (15 msec) is set by the PRF one-shot circuit, and the resulting 15 ms pulses at the selected PRF are available as an input to the coding logic circuit. The transpond signal is derived from a 2 second output of the frequency divider which triggers a 30 ms one-shot circuit, resulting in a 30 ms pulse every 2 seconds. Selection of transpond or command mode is provided on a front panel switch. The time duration requirement of the command code requires the operator to manually send at least ten consecutive pulses, which the receiver then integrates. In summary, when the five levels are received and detected in the receiver, the command can be used to perform the desired function, i.e., triggering a squib-firing circuit to release a weight.

The digitally generated components of the command code, the carrier frequency, the modulation frequency, and the PRFs, are gated together with the pulse width and time duration in the coding logic circuit. The resultant modulated square wave output is then amplified by a switching power amplifier. A front panel control is provided to adjust the output power, and a key switch is provided to prevent unauthorized operation of the equipment. The output of the power amplifier is transformer coupled to a loading coil and transducer which is series resonant at 10 KHz. The Q of the transducer is approximately 5 in seawater at resonance, which suppresses the high frequency components of the square wave drive at the output. The output signal is approximately 90% amplitude modulated in the water as measured with a separate hydrophone. The output will drive either a towed transducer or the ship's UQN hull-mounted transducer at a maximum of 40 watts electrical into the transducer.

The underwater receiver can be checked for proper alignment with an acoustic or cable connection by using the ACS test output and acoustic test attenuator on the front panel. A receiver to be tested is hard-wired to the ACS test output, where the sensitivity, the amplitude modulation frequency, and PRF rates of the receiver are checked for proper alignment. The digitally generated command codes may be varied by changing the PC board-mounted thumbwheel switches. The acoustic test output is set and can be attenuated in 2 db steps from -30 db to -70 db with respect to 320 mV peak to peak.

Conclusions

TRACS was designed and built at the Woods Hole Oceanographic Institution. It was operated successfully at sea and fulfilled the design objectives set forth. This resulted in a finished, well-documented shipboard system. This second generation TRACS has incorporated several changes which have improved its ease of operation and overall capabilities.

Acknowledgements

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