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Editors:
CHARLES J. AMLANER, Jr.
and
DAVID W. MACDONALD

Animal Behaviour Research Group, University of Oxford

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Automation of Data Collection in Ultrasonic Biotelemetry

D. PINCOCK

*Electrical Engineering Department, University of New Brunswick,
Fredericton, N.B., Canada*

Abstract — The validity of many studies using ultrasonic bio-
telemetry for determining fish behavior can be questioned
because of the small number of fish involved. The reason for
this small number is often the fact that the task of decoding
and analyzing sensor data is extremely time consuming. For this
reason, an on-going objective of our work at the University of
New Brunswick has been to develop telemetry systems in which
sensor data is produced in a format permitting immediate computer
analysis of field data. This objective has now been met and
the methods used are described in this paper.

In general, the data gathering system consists of three compon-
ents — an ultrasonic receiver, a decoder and a digital recorder.
The receiver, on detecting a transmitted pulse should produce
a logical indication for processing by the decoder. This task
is complicated by highly variable noise levels and echoes which
can be delayed even hundreds of milliseconds. Receiving tech-
niques and detection methods which work satisfactorily in this
environment are discussed. The decoder accepts signals from
one or a number of receivers, extracts sensor data and passes
it (usually along with a time of day indication) to the recorder.
To accomplish these tasks, while achieving a package suitable
for use on small boats, microprocessor-based logic is used. The
paper discusses several special purpose systems which have been
used as well as a subsequent system which should be adaptable
to most applications. Finally, the paper describes the cassette
recording and playback system which has been developed.

INTRODUCTION

In many studies which use ultrasonic biotelemetry for determining fish behavior, the
results are somewhat inconclusive because of the small number of fish involved. The
cost of transmitters, boat time, etc. is certainly a factor contributing to these
small samples but a more serious limitation is encountered in cases in which data
from sensors is being transmitted. Because of the characteristics of the medium
and the requirement for simple transmitter electronics, transmission is usually
pulsed with data encoded either by pulse repetition rate or, in the case of several

sensors, by a pulse train containing several pulse intervals (Stasko and Pincock, 1977). Usually, decoding of this information is done either manually in the field or by subsequent interpretation of recorded (e.g. strip charts) signals. The former method makes field work very tedious and, in many cases, leads to an inadequate sampling frequency while the latter often leads to an accumulation of 'data' whose interpretation is so time consuming that it often lags the field work by months or years. A continuing objective of our work at the University of New Brunswick, Canada, has been the development of telemetry systems which overcome the problems described above and permit the true potential of ultrasonic biotelemetry to be realized. It is the purpose of this paper to give an *overview* of this work and to present some of the *systems aspects* entering into the design of an automated system.

In concept, the automated system is very straightforward consisting of a hydrophone, receiver, decoder and a digital recorder. The receiver, on detecting a transmitted pulse, should produce a logical indication for processing by the decoder. The decoder accepts signals from one or a number of receivers, extracts sensor data and passes it (usually along with a time of day indication) to the recorder. To provide interaction in the field, the decoder would have some sort of display and would possibly produce an analog recreation of the sensor signal suitable for strip chart recording. It should be noted that such chart recordings do not eliminate the need for digital recording since it is usually necessary to convert this information to computer-readable form for analysis. This task is extremely time consuming while the digitally recorded data is directly readable by a computer. The following sections give details on major system components.

RECEIVER

Because of the highly variable noise conditions and severe multipath which exist, the design of a suitable receiver is the most challenging aspect of the entire system. The signals shown in Figs. 1 and 2 are instructive. As can be seen, the main effect of multipath in shallow water (Fig. 1) is to broaden the transmitted pulse. In other situations, such as in relatively deep water (Fig. 2), distinct echoes can occur even hundreds of milliseconds after reception of the pulse. Transmitter coding and signal detection method must be chosen with these propagation conditions in mind.
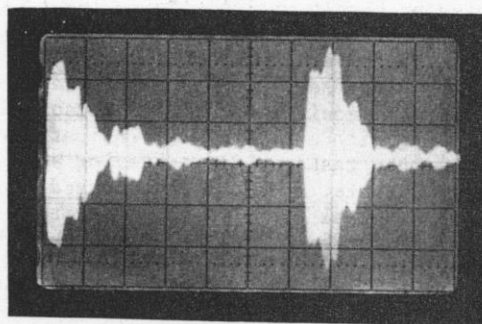

Fig. 1. Effect of multipath in shallow water (water depth 20 m; range 100 m; transmitted pulse width 16 ms; horizontal scale 20 ms div^{-1}).

For most of our work we have used a superheterodyne type of receiver which is now commercially available (CR-40, Communication Associates, Huntington, N.Y.) and have processed the output of an audio detector to obtain a logical signal indication. The basis of this processing is to say that a signal or echo is present if the detector output exceeds some multiple of the average level for at least a few milliseconds.
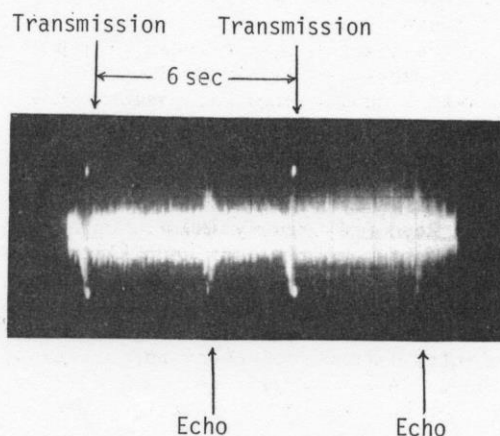
Fig. 2. Effect of multipath in deeper water (water depth 500 m; range 1000 m; transmitted pulse separation 0.6 s).

(typical transmitter pulse durations are at least 10 ms). Once this is done it is only necessary to reject the echoes. The techniques used to accomplish this are outlined below.

For situations in which multipath produces the effects typified by Fig. 1, the rejection of echoes is straightforward. All that is necessary is a disabling of the signal detection logic for an appropriate period (typically 150 ms) after each detection. At the end of this period echoes will have vanished. Of course, in order for this approach to be successful, the minimum interval between transmissions must be longer than the period during which the receiver is effectively disabled. Therefore, our transmitters are designed not to transmit pulses less than 300 ms apart.

When the effects typified by Fig. 2 exist, the situation is somewhat more difficult. While it is possible to use the same approach as outlined above, the interval that the receiver would have to be disabled would be much longer. This would impose a requirement on the minimum transmitter pulse spacing which would be so long that, for many applications, the data rate would be too low. In addition, the long silences between transmitted pulses would cause difficulties in applications in which the transmitter must be tracked. Therefore, these echoes are rejected on the basis of their amplitude which, because of increased propagation distance and reflection loss, is smaller than that of direct signals. This technique has worked fairly well but is not foolproof. In particular, for areas in which reflection losses are small (e.g. rocky bottom) and the range is large, the amplitude difference between signal and echo can be small and reliable detection can only occur by decreasing the range. Also, saturation of the receiver (such as is evidenced by the brightening at the signal peaks of Fig. 2) must be avoided or amplitude information is lost. Of course, receivers which destroy amplitude information (for instance, those based on phaselocked loops or those possessing a fast acting AGC) are not suitable.

DECODER

Two approaches are possible for design of the decoder. The first involves the construction of a special purpose instrument while the second involves the use of a general purpose computer or calculator. To date, we have tended to use the former approach but for certain applications we are implementing the latter for reasons which are explained below.

Figure 3 shows a typical decoder developed at the University of New Brunswick. This particular decoder is for single sensor transmitters (temperature, pressure or swimming speed) whose pulse repetition rate is linearly proportional to the sensor volta (Pincock and Luke, 1975; Pincock *et al.*, 1978; Pincock *et al.*, 1979). The decoder measures the period between received signals, checks for validity and then applies the linear calibration specified by the front panel switches and displays the data. In addition, at user-selectable intervals, data is presented along with an elapsed time indication at the output connector for recording. Decoders of this type are microprocessor-based (either SC/MP or 8085 because of their hardware simplicity) with software resident in Read Only Memory (ROM). Other similar decoders incorporat such features as analog outputs, multisensor capability, time of day entry, etc. One of the main problems with this approach to decoder design is its inflexibility. Each new application requires redesign of the front panel and circuitry before the software can be written. Furthermore, the ability to communicate with the program is limited by the data entry method (switches) and, therefore, many functions which could easily be implemented in the program (e.g. calculations involving nonlinear calibration curves) are not because of the relatively large amount of operator input required.
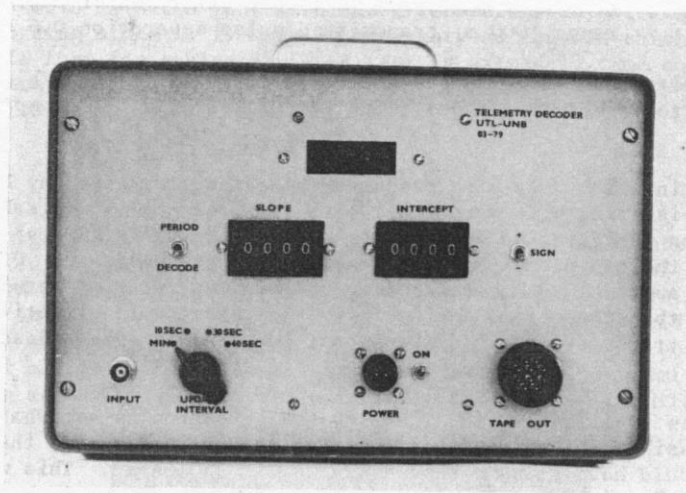

Fig. 3. A typical special purpose decoder.

Because of the difficulties mentioned above, we have undertaken the design of a decoder whose hardware is more general. Data entry is accomplished by means of a calculator-type keyboard, and eight digits of display are available. The entry of such information as calibration data, time of day, update interval, display data, etc. is accomplished by an interractive dialog involving the keyboard and display. Thus, not only is the ability to pass data to the program greatly enhanced, but new applications are implemented through software modifications only.

The decoders described above are most suitable in applications where portability is very important, but in other applications where more bulky equipment is acceptable their disadvantages become limiting. In particular, the decoder performs basically a data collection function and, therefore, there is little possibility of analyzing the data as it is being collected. This is certainly unsatisfactory for long field experiments. Also, the development of the ROM — based program can only be carried out in a laboratory which has the proper development tools (PROM programmer, logic analyzer, cross-assemblers, etc.).

The disadvantages mentioned above are overcome through the use of a general purpose

computer which examines the receiver output, does the required decoding, displays results on associated peripherals (printer, screen, plotter, etc.) and stores data on some mass storage device (tape, floppy disc, etc.). With the possible exception of an interface to the receiver, this approach involves no hardware design, but, rather, a selection of computer and peripherals with the desired input, display and storage capabilities. Software is structured so that the basic decoding and data storage functions are initialized through a dialog with the operator. This implements the function of the special purpose decoders described above but with more power because of more flexible input/output devices (e.g. video terminal). In addition to this data collection function, the software can be structured to permit analysis and display of collected data through programs written in higher level languages (e.g. FORTRAN, BASIC). Thus, for example, the progress of a long experiment can be checked and different analysis techniques tried as the experiment is being conducted. This permits modification of the experiment or data collection if results are not totally satisfactory. It should be re-emphasized that the size, power requirements and cost of the general purpose computer rule out its use for a large number of applications.

RECORDER

Cassette recording offers the advantages of relatively large capacity at low cost and power consumption, and was used for this application. Experience gained with audio cassette units indicated that reliable recording was best achieved through bypassing the record electronics and using saturation recording. This being the case, it was decided to base the recording system around one of the several digital cassette units now available at a cost comparable to that of a good audio unit (we use the CM-600 from Braeman Computer Devices, Burnsville Minnesota).

The logic of the recorder unit is also microprocessor-based. The main functions performed by the microprocessor are blocking of data (to obtain a reasonable recording density), tape motion control and phase encoding on recording and unblocking and decoding on playback. In order that decoders and recorders can be easily tested in the laboratory and can communicate easily with computers which will analyze data, all communication between them is according to the RS-232C standard using ASCII characters.

FUTURE DEVELOPMENTS

There are always situations in which the echo rejection techniques described above could fail. Greatly improved echo rejection will be achieved by means of software running either on the decoder or on a microprocessor integrated into the receiver. Another shortcoming of the present method is that the threshold test used for signal detection is inefficient in that it does not make full use of the available signal energy. Implementation of a matched filter will permit a given range to be achieved with less transmitter power.

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