For more than one year, the Sound Propagation Group has been using this equipment successfully for digital acquisition and analysis of sea trial data. This complete system can be considered to consist of three parts.

1. The five-channel high-density digital recording system.
2. The edit system.
3. The data transfer system.

The whole of this equipment was designed and built in our laboratory (except the A/D converters and the tape recorder), using micrologic cards for digital circuits and operational amplifiers for analogue devices.

Sound Propagation Group's preference for digital recording can be clearly understood considering the main points in our analysis technique:

a. The study of the impulse response of the medium through the use of explosive charges requires a high dynamic range — more than 60 dB — with bandwidths from a few hertz up to 15 kHz - 20 kHz.

b. Power spectrum measurements require an accurate time base, especially for high frequency resolution.

c. Cross-correlation measurements require a constant time delay between the signals to be correlated.

When recording in analogue form in the FM mode, even with precise adjustment of the recording level, the dynamic range is around 40 dB.
Furthermore the tape speed is not constant (flutter) and the time delay between two signals is not constant, owing to the angular movement of the tape (skew). In our system, which digitizes during the experiment and records onto magnetic tape in digital form, all these difficulties are overcome, because the dynamic and accuracy of the time base no longer depend on the tape recorder, but on the preceding electronics, and the time delay fluctuations between signals can be completely compensated.

The signals coming from the hydrophones are preamplified and via the cable transmitted to the recording system [Ref. 1]. In Fig. 1 the frequency response is shown for the complete receiving link. A block diagram of the five-channel digital recording system [Ref. 4] is shown in Fig. 2. The system is composed of 5 identical data channels, plus a parity track generator and one counter track generator. The analogue signals, 1 to 4 for each channel, are fed to a set of amplifiers with gain variable from 0 to 72 dB in 6 dB steps [Ref. 2] and the outputs are filtered by a set of linear phase filters [Ref. 3] whose performances are shown in Fig. 3. After filtering the analogue signals are converted to digital form in a 15-bit A/D converter with multiplexer. Each 15-bit word, together with the relative 4-bit gain information from the amplifier is transformed into 12-bit floating-point format. Parity and synchronization words are added and the data are then transformed into a special format (NRZ modified) and recorded on ten tracks (two for each channel) of an Ampex AR 1600 wideband analogue tape recorder in direct mode. Track 11 of the tape records parity track which, together with the parity words of each track forms an orthogonal system of parity which allows correction and detection of most of the errors occurring during the reproduce phase. Track 12 records a 7-digit number increasing by one each millisecond, which labels the recorded signals. The system performances are as follows:
Features of particular relevance are the dynamic range for each gain setting of the amplifier and the high recording density achieved with an error rate of $1 \times 10^{-7}$.

Figure 4 shows the system used for reconstitution of the recorded data and transfer to the Elliott 503 computer. Owing to the angular movement of the tape, each track has a different timing, so ten equal circuits are used (one for each track), for bit-restoring, and for discriminating between information-carrying words and parity or synchronization words. Readers for the parity and counter tracks are also provided.

Data are transferred to the Elliott Computer through a high-capacity core memory, capable of storing 315 milliseconds of five 16 kHz bandwidth signals. The transfer is made automatically with remote control of the tape recorder from the computer, which reads the recorded counter track for recognition of the portion of the signal to be transferred. When the indicated counter track number is read, data transfer is started and data flow from the tape through the reading system to the high-capacity core memory, until this is completely full. At this moment data are read block by block from the computer and, after error detection, they are stored for further analysis on the computer magnetic tape.
Figure 5 shows the digital-recording test unit. This unit has proved very useful both on board for recording tests, and ashore for editing. This unit is in fact capable of making parity checks and of converting data back to analogue form allowing display of any selected recorded signal.

Figure 6 shows a unit which is capable of recording and reading the counter track, these functions being coupled with the relative controls of the tape recorder. The system has special provision in order to avoid the overlapping of two consecutive data blocks on the tape, which is very useful if a recorded event is to be played back before the next is recorded. Registers are also provided for storing and subsequently printing any interesting counter track number, and for exact time location of the signal portions to be analysed or displayed.

A demonstration of the equipment was then made in the laboratory using data previously recorded at sea during an experiment with explosive sound sources. Figures 7, 8, 9, 10 show an example of plots of one of these signals with increasing vertical scale, as drawn by an X-Y plotter connected to the digital analysis equipment. Figure 11 shows the digital recording system on board the SACLANTCEN ship during a sea trial.

REFERENCES


10
DIGITAL RECORDING SYSTEM: RECORD SECTION

FIG. 2
THE OVERSHOOT IN THE STEP RESPONSE TOGETHER WITH THE STEP RESPONSE ITSELF FOR A 16 kHz UNIT

THE STEP RESPONSE OF A 16 kHz UNIT TOGETHER WITH THE INPUT STEP

Horiz. speed 20 μs/div.  
Vert. upper 200 mV/div.  
Vert. middle 5V/div.  
Vert. lower 10V/div.

Horiz. speed 20 μs/div.  
Vert. lower 10V/div.  
Vert. upper 2.5V/div.

THE RESPONSE OF AN 8 kHz UNIT TO A SHORT RECTANGULAR PULSE.

FIG. 3
DIGITAL RECORDING TEST UNIT

FIG. 5

MAGNETIC TAPE RECORDER CONTROL AND EDITING AID

FIG. 6
FIG. 7

FIG. 9
THE DIGITAL RECORDING SYSTEM ON BOARD THE MARIA PAOLINA DURING A SEA TRIAL

FIG. 11