SACLANTCEN Conference Proceedings No. 6

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SACLANT ASW RESEARCH CENTRE

DIGITAL ANALYSIS WORKING GROUP

Proceedings of a Conference held at SACLANTCEN on 25–27 May 1971

Organized by

ROBERT LAVAL and ALESSANDRO BARBAGELATA

1 MAY 1972

NORTH ATLANTIC TREATY ORGANIZATION

VIALE SAN BARTOLOMEO 400
I - 19026 - LA SPEZIA, ITALY

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CHAIRMAN'S INTRODUCTION

R. Laval
SACLANT ASW Research Centre
La Spezia, Italy

It is a great pleasure to welcome you to the SACLANT ASW Research Centre for this meeting of a "Working Group for the Study of Common Problems in Digital Analysis of Underwater Acoustic Signals". This meeting is part of a seris of conferences organized by SACLANTCEN on various topics of fundamental interest for ASW.

The subject of this particular meeting is related to what I personally consider as being the most critical factor which has limited the progress of underwater acoustics research during the last decade, i.e. the analysis of the acoustic signals collected during experiments at sea.

The accumulation of unanalysed data collected during old sea trials has been for many years the common nightmare of all the research organizations. Each type of analysis required the assembly or construction of electronic equipment, the complexity of which increased very rapidly with the complexity of the operations to be performed. In general, the scientists were obliged to limit the scope of their experimental work to a rather elementary description of the physical phenomena being studied. Most of the interesting information which was potentially contained in the recorded data was in fact discarded at the analysis stage. Even so, the analysis was a slow and tedious operation that involved a considerable amount of qualified manpower.

The introduction of digital computers in the analysis field with the formidable capabilities they offer for data handling and signal processing is now opening quasi-unlimited perspectives for the future of underwater acoustic research. In fact, nearly all the organizations involved in this field are at present working on the development or at least the potential evaluations of computer analysis methods, and some of them are already using computers systematically for routine analysis.

The first objective of this meeting is in fact a mutual exchange of information concerning the methods of digital analysis that are being used or which are intended to be used in the future by the different organizations represented here. Many of you have accepted to present papers concerning their realization and explaining their problems and we hope that it will be possible during these few days to establish what is the present state of the art.

SACLANTCEN intends, for its part, to make relatively detailed presentations on what has been accomplished here. As you probably know, we started a research and development program in digital analysis a long time ago. Much of the equipment has no commercial equivalent and has had to be designed and constructed. Among the most important of these devices are:

a. A high-density multichannel digital-recording system for the direct recording in digital form of the broadband signals collected during sound propagation trials that make use of explosive charges and a large number of hydrophones.

b. A multi-channel analogue receiving chain that matches the special requirements of the digital recording system.

c. An editing box for the visualization, selection and precise cutting of the portions of the recorded signals to be retained for analysis.

d. A transfer system for the transfer of edited signals to the SACLANTCEN computer (at present an Elliott 503).

In addition, a set of computer programs, which constitute a real analysis language, has been written for signal processing.

These different pieces of hardware and software have been built into a complete system that is still being improved. This may be considered as the first generation of our digital analysis system. For more than two years this system has been the principal working tool of the SACLANTCEN Sound Propagation Group, during which time it has completely changed not only the Group's analysis techniques but also the experimental procedures and the scientific spirit of the research scientists.

With our increasing needs in the analysis field, however, the Elliott system is now insufficient. The edition of the data recorded at sea and their transfer to the computer is still a rather long operation. In fact, a very serious bottleneck has arisen at what we call the "pre-analysis" stage. At the analysis stage the absence of a powerful executive system on the Elliott makes the programming work much longer and more tedious than it would be with a modern computer.

A second-generation analysis system, based on the use of Hewlett Packard 2116B computers, which has been specially studied to avoid all these difficulties is now being prepared. We call it SPADA for Sound Propagation Automatic Data Analyser. In this system all the operations of data handling, editing, display and analysis are directly performed by the computer.

As will be shown during the presentation on this system, nearly all the hardware equipment that has been built at the Cente for the first generation system will continue to be used with the SPADA system, in particular the high-density digital recorder. As this will be a conversational system, entirely devoted to digital analysis, it should considerably increase the flexibility over the present system in which the computer is not directly accessible to the user.

We have actually three computers of the HP 2116B type, two in the laboratory and one on our research ship and they have already been used intensively for many different purposes by several scientists belonging to the different groups.

Although we call them "mini-computers" (as compared with the large computers generally used in the computer centres) they are nevertheless rather powerful machines as soon as they are equipped with a sufficient amount of peripherals. The size and characteristics of these computers appear in fact to be ideally suited to the handling, editing and processing of underwater acoustic signals. The term "mini-computer" is mostly associated with the rather short word length of 16 bits and the fixed point arithmetic of these computers. From the point of view of the electronic engineer, a 16-bit arithmetic corresponds to a dynamic range of 92 dB. When correctly used, such a dynamic range is more than sufficient for any practical application of signal processing.

For standard signal processing, the programming work of these mini-computers is considerably simplified by the availability of an FFT processor, a specialized peripheral, already containing most of the routines commonly used in signal processing, such as power spectrum, cross-correlation, statistical distribution, etc. This FFT processor has now been integrated into a larger signal processing system that presents much more capabilities and flexibilities for the analysis of underwater acoustic signals than the original Hewlett Packard system. In addition to its use on land, the availability of such a computer on our research ship will enable a substantial part of the data to be analysed in real time during sea trials.

Another class of application of the mini-computers in the field of underwater acoustics concerns ray tracing. The ray-tracing program that has just been developed at SACLANTCEN for use on the Hewlett-Packard 2116B is a very classical one for the ray computation itself (the sound velocity profile is approximated by constant gradient layers). The originality of this program lies in its conversational aspect. The ray tracing appears on a memoscope display. The user has the facility of adjusting the different parameters and seeing immediately on the screen the result of any modification of the input data. It is a modular program and many different types of displays can be obtained:

ray diagram, energy, isoloss contour, travel-time difference, angles of departure and arrival, etc. Although ray tracing is a little outside the main subject of this meeting we have thought of taking this opportunity to give you a brief presentation about it.

As you can see SACLANTCEN has already devoted a very substantial effort to the analysis problem.

It may be suggested at this point that although the digital analysis facility was originally developed as an internal research tool to promote basic scientific work, the experience developed in this field by SACLANTCEN's specialists could be useful for guiding those nations that intend to develop their own analysis facilities or are considering the possibility of duplicating part of SACLANTCEN's equipment.

It is believed that nations that have not yet started to develop digital analysis facilities could save substantial time and manpower, and avoid a lot of practical difficulties, by adopting a system similar to that developed by SACLANTCEN. An analysis system is only fully effective when it works as a coherent system, including the hardware and software and all facilities for amplifying, digitalizing, recording, handling, editing, transferring, cataloguing and finally processing the signals. Experience has shown that practical problems tend to be strongly underestimated during the design stage of this kind of project.

Even if not considering duplicating SACLANTCEN's system, it may be of interest for the different research laboratories to study the possibilities of some standardization in their recording and analysis systems and the associated computer programs, so as to facilitate future collaboration and enable recordings and programs to be exchanged. Moreover, the use of similar analysis techniques would encourage the research scientists of different organizations to be in frequent contact, to plan experiments in common, and to develop a common scientific spirit.

Furthermore, it is clear that the capabilities of digital computers as a research tool for underwater acoustic studies is only one aspect of their possible applications to ASW. During the years to come digital computers will probably become the central piece of any operational system. It is extremely important that the very fast progresses in the field of digital computers be closely followed by a group of specialists in order to evaluate their relevance to ASW.

The competence thereby acquired by the research scientists involved in digital analysis may bring tomorrow an invaluable contribution for the preparation of the next generation of computerized sonar systems.

From an organization point of view, it is proposed to divide this meeting into two parts: the first part will be devoted to presentations from the participants:

a. Description of the digital analysis facilities at the SACLANT ASW Research Centre. These presentations will include practical demonstrations.

b. Descriptions of the digital analysis facilities in use by other research organizations.

c. Briefing on the nature of the problems to be solved by organizations intending to develop digital analysis facilities in the near future.

The second part of the meeting will be a round table discussion, where we shall try to define whether it may be worthwhile to unite some of our efforts in the future.

SESSION 1

DIGITAL ACQUISITION OF ACOUSTIC SIGNALS

THE PRESENT SACLANTCEN EQUIPMENT FOR THE DIGITAL RECORDING OF MULTICHANNEL BROADBAND ACOUSTIC SIGNALS, THEIR EDITION AND THEIR TRANSFER TO A DIGITAL COMPUTER

by

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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 dificulties 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:

INPUTS SIGNALS	5	10	20	COMBINATION
SAMPLES PER SECOND	48 000	24 000	12 000	COMBINATION
EQUIVALENT BANDWIDTH	16 kHz	8 kHz	4 kHz	COMBINATION
INPUT RANGE	2 μV - 7 V rms			
ACCURACY OF SAMPLES	1%			
DYNAMIC RANGE OF EACH GAIN SETTING	90 dB			
TAPE SPEED	30 in/s			
BITS PER INCH PER TRACK	12 133			
BITS PER SECOND PER TRACK	364 000			
INFORMATION-CARRYING BITS PER SECOND ON TAPE	2 880 000			
CONTINUOUS RECORDING	1 hour			
BIT ERROR RATE	$\sim 1 \times 10^{-7}$			

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 1×10^{-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.

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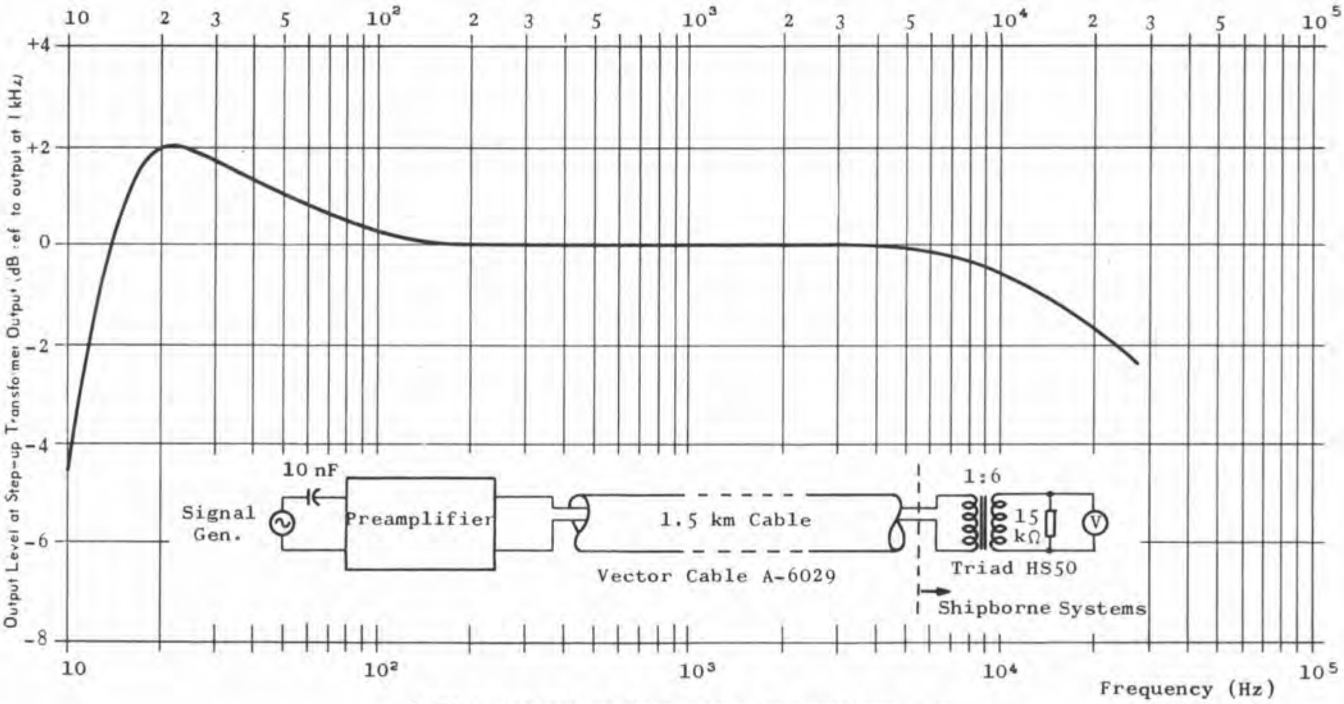
1. A. Figoli and M. Pazzini, "A Low-Noise Hydrophone Pre-amplifier for Experiments with Explosive Sound Sources" SACLANTCEN Technical Memorandum No. 158, November 1970, NATO UNCLASSIFIED

2. M. Pazzini, "A Multichannel Receiving System for Experiments in Sound Propagation", SACLANTCEN Technical Report No. 106, December 1967, NATO UNCLASSIFIED

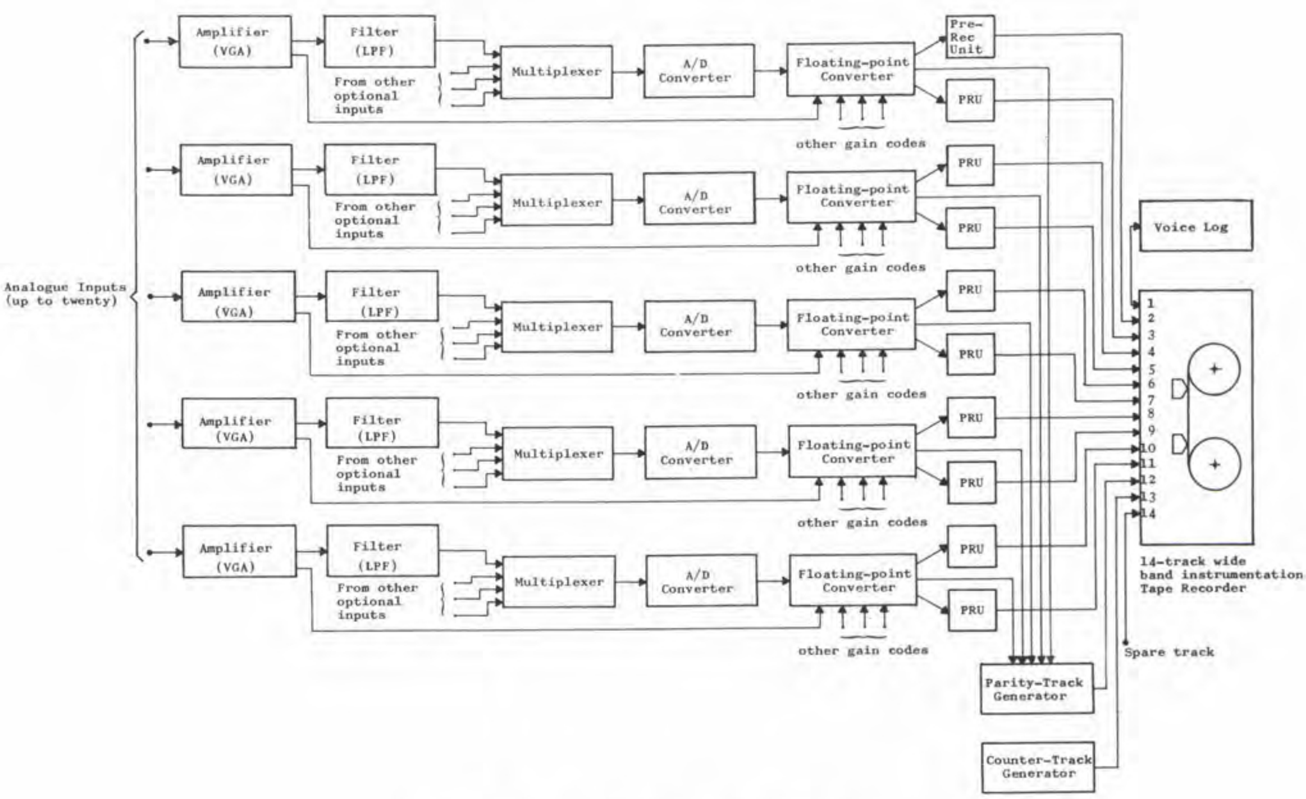
3. M. Pazzini, "Linear-Phase Filters for a Digital Data-Acquisition System Used in Underwater Sound Propagation Experiments", Technical Memorandum No. 148, December 1969.

4. A. Barbagelata, A. Castanet, R. Laval and M. Pazzini, "A High-density Digital Recording System for Underwater Sound Studies", SACLANTCEN Technical Report No. 170, July 1970, NATO UNCLASSIFIED



FREQUENCY RESPONSE FOR THE COMPLETE RECEIVING LINE

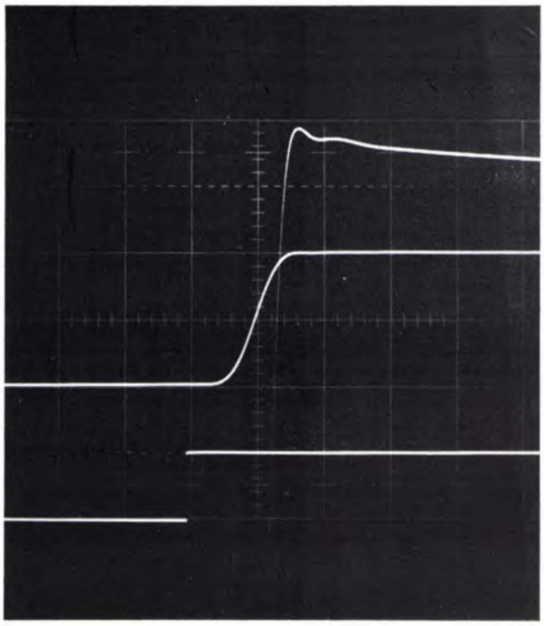
FIG. 1



DIGITAL RECORDING SYSTEM : RECORD SECTION

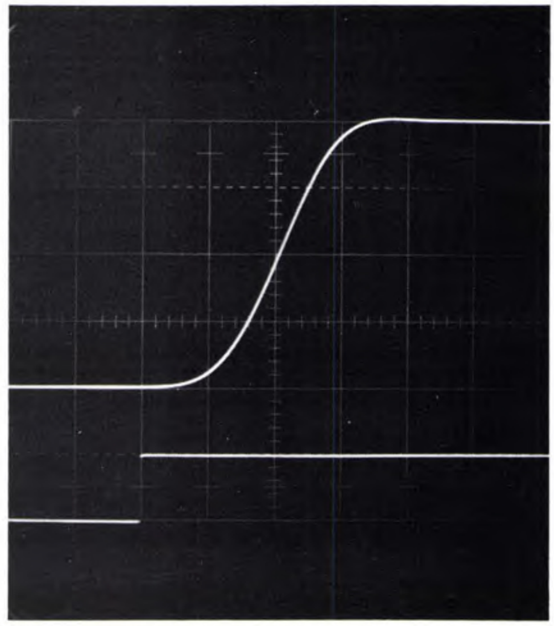
FIG. 2

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



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

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



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.

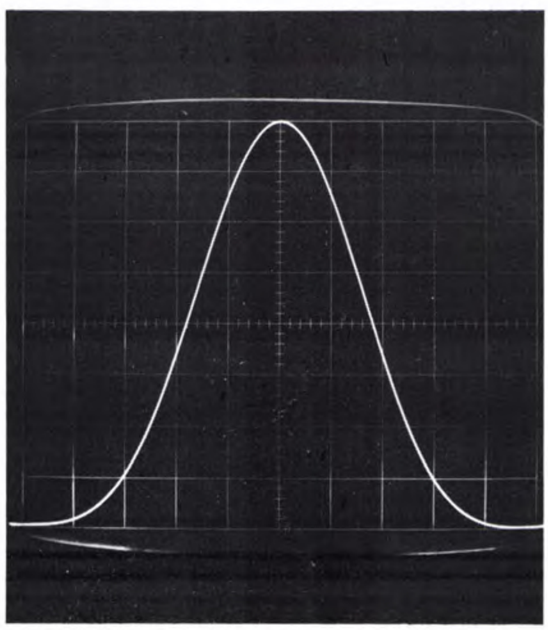


FIG. 3

READING AND TRANSFER SYSTEM

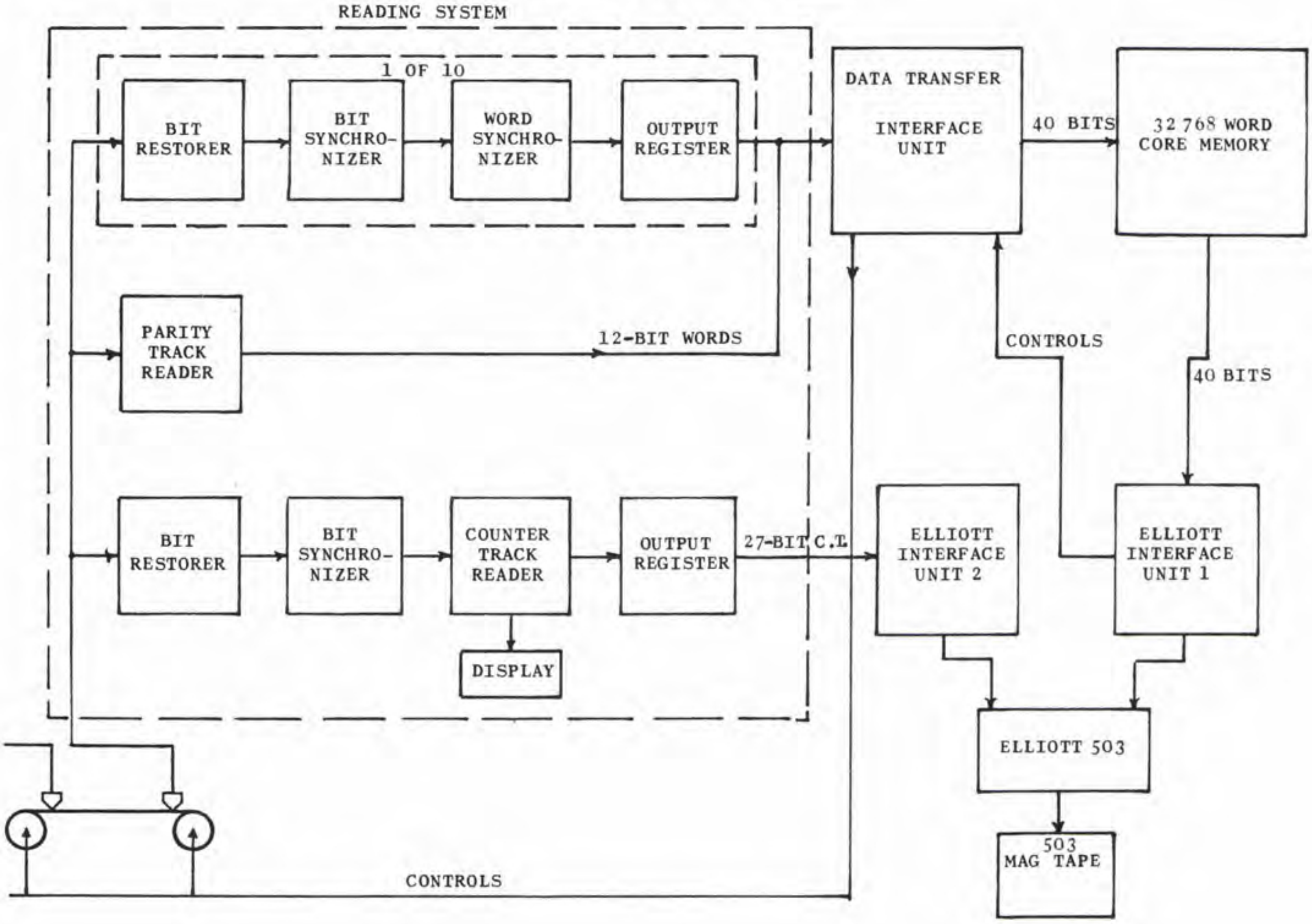


FIG. 4

DIGITAL RECORDING TEST UNIT

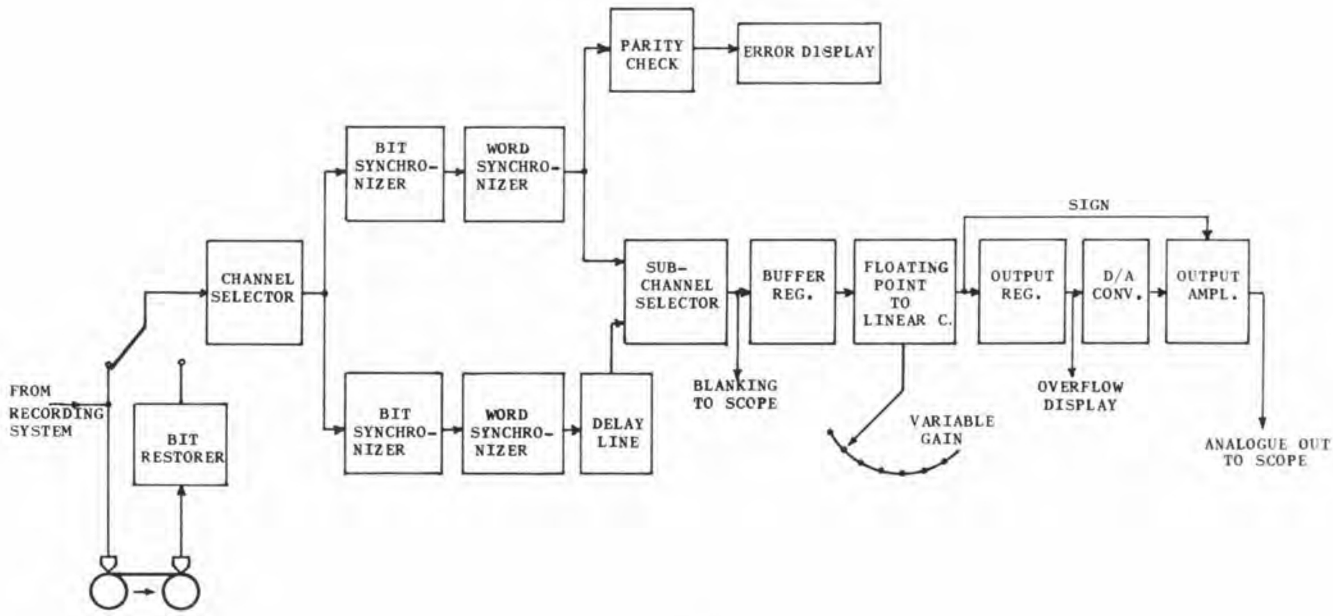


FIG. 5

MAGNETIC TAPE RECORDER CONTROL AND EDITING AID

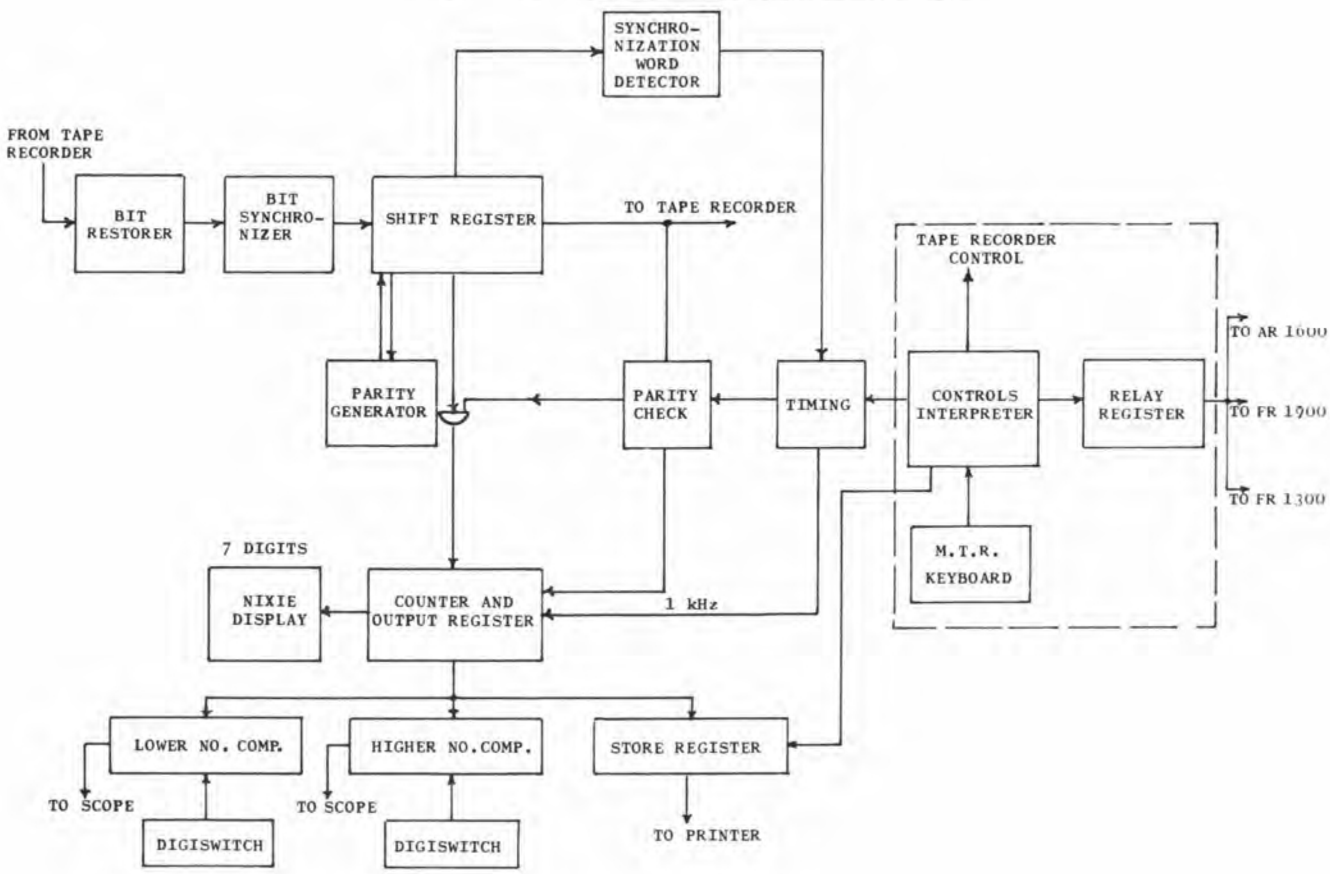


FIG. 6


S2269. 102 103 9 167540 167640 X= 2.0000 MS/CM Y= .01500 V/CM
50 mV
0
0 2 4 6 8 10 ms

FIG. 7

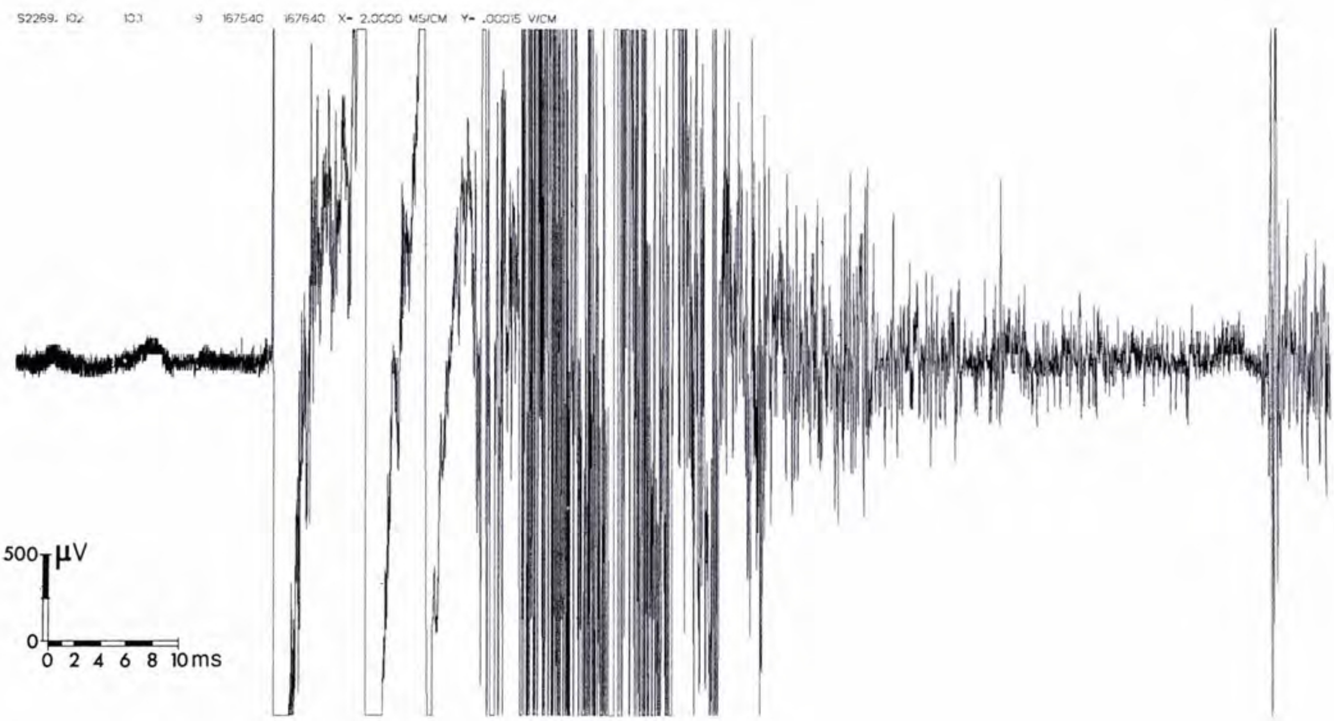

S2269. 102 103 9 167540 167640 X= 2.0000 MS/CM Y= .00015 V/CM
500 µV
0
0 2 4 6 8 10 ms

FIG. 9

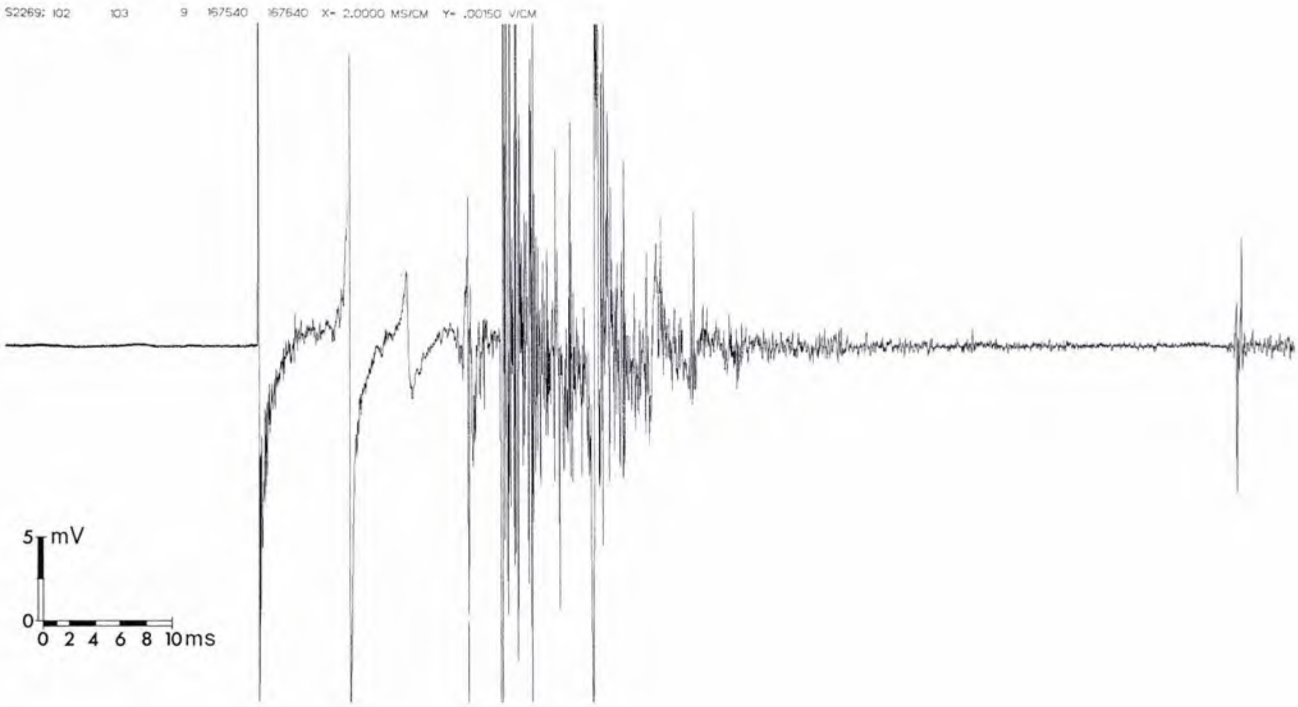

S2269: 102 103 9 167540 167640 X= 2.0000 MS/CM Y= .00150 V/CM
5 mV
0
0 2 4 6 8 10ms

FIG. 8

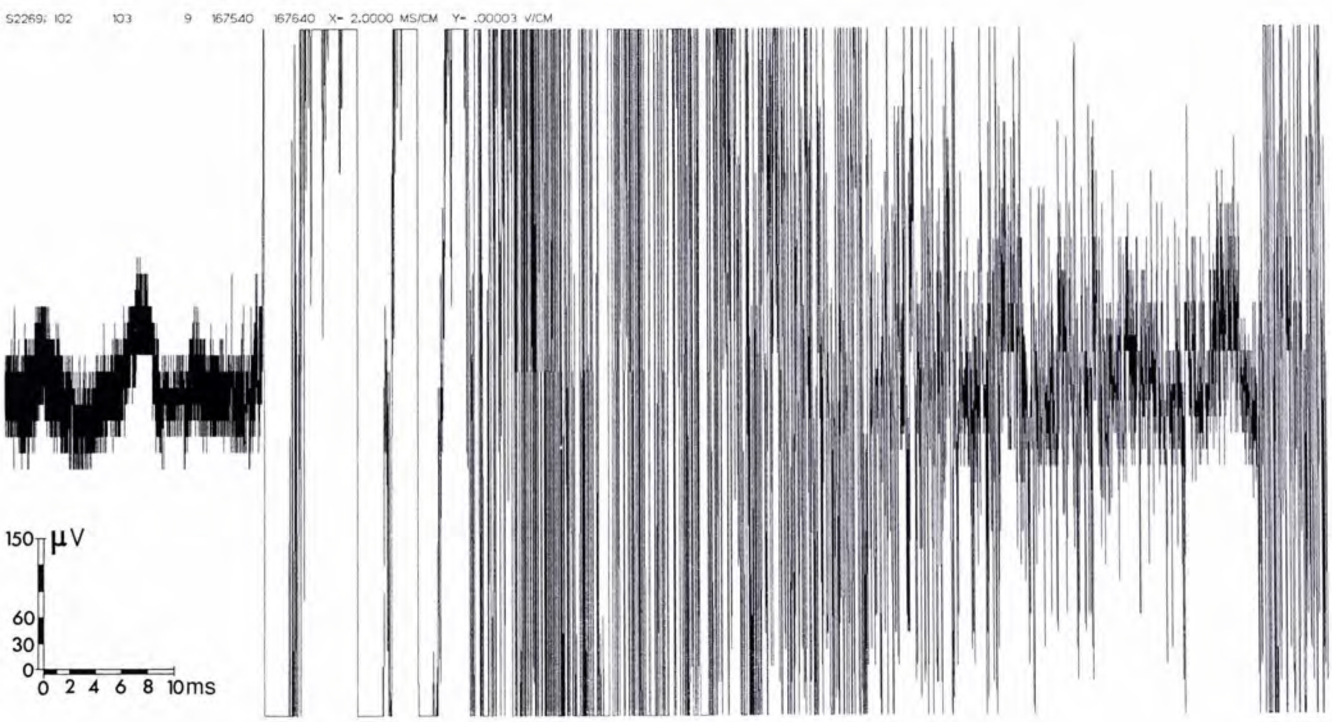
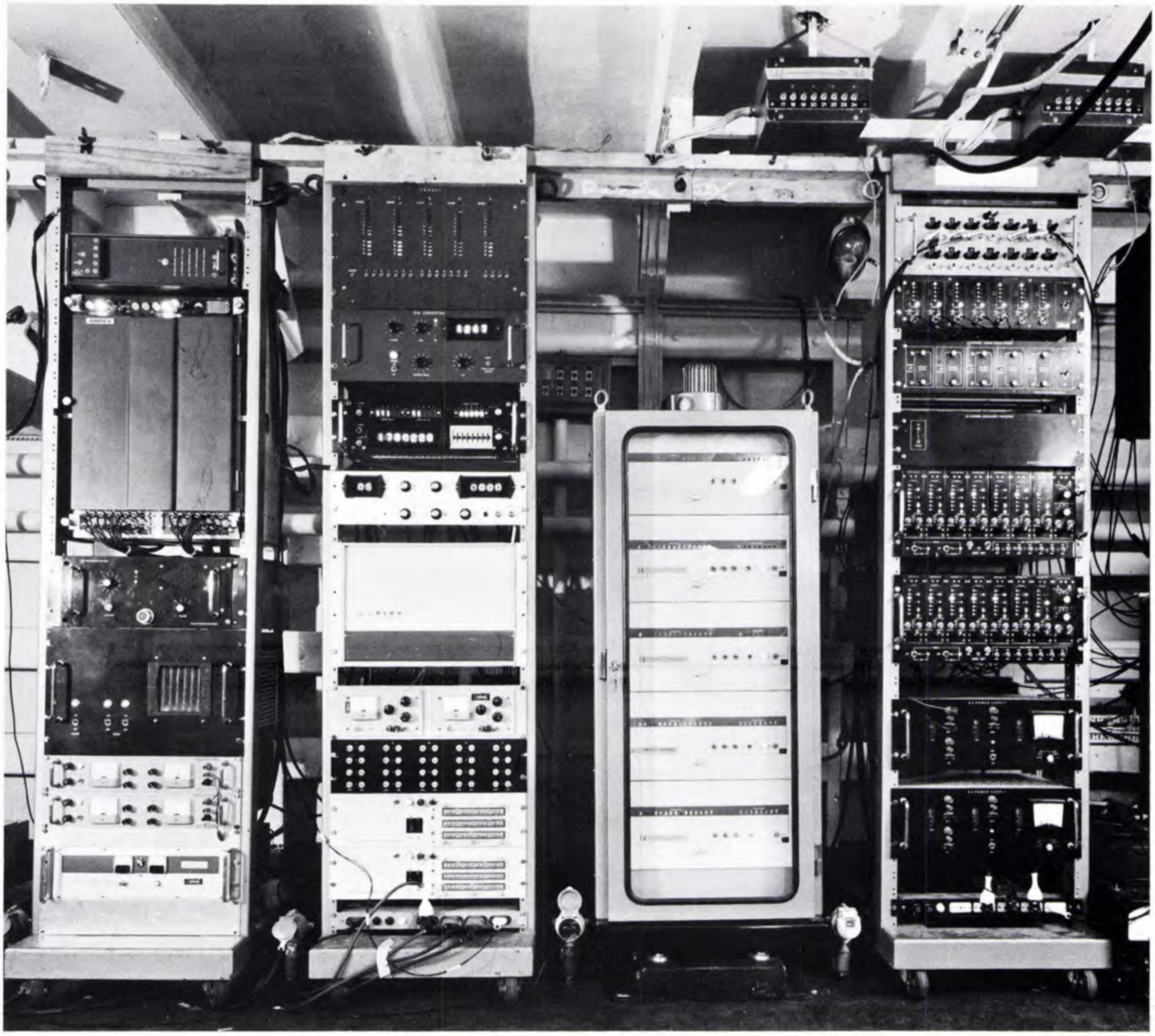

S2269: 102 103 9 167540 167640 X= 2.0000 MS/CM Y= .00003 V/CM
150 μV
60
30
0
0 2 4 6 8 10ms

FIG. 10



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

FIG. 11

THE ARL SHIPBORNE COMPUTER SYSTEM

by

M.J. McCann and R.J. Panter
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The system described is a rugged, portable, data-gathering and processing system based on the Ferranti FM 1600B "mini-computer". It will be used at sea for recording and partial processing of acoustic and environmental data and in the laboratory for further data processing. The system was conceived about two years ago, when it became apparent that unless future data could be collected in a computer-compatible form much of it would not be used. Since our sea trials are conducted from a number of different ships portability and ruggedness were considered of prime importance when selecting equipment. The computer selected has both these qualities. The FM 1600B uses a 24-bit word and contains floating point hardware, the core cycle time is 1μs. The machine code is very powerful, having over 330 instructions, and the use of a 3-address technique gives considerable savings in the core store required for programs. All input channels employ direct memory access and the priority of peripherals is determined by the channel to which they are attached. To complete the system there are two ATM-13 militarised digital tape decks, a 15-bit, 20-channel, multiplexer and ADC, a 14-in incremental plotter and teletype and paper tape peripherals. A CRT graphic display will be added in the next few months. Time information for the system is provided by a crystal oscillator unit within the computer which generates program and data interrupts at rates which can be independently varied between 4 and 2048 per second. 15-bit words from the ADC can be stored on magnetic tape at up to 22 kHz. The central processor, core store, interfaces and power supplies are mounted in one cabinet 2 m high weighing about 250 kg.

Since the computer was delivered towards the end of 1970 most of the available time has been spent writing and testing software to operate the peripherals, but work on data processing programs has now begun. A fast fourier transform program has been written and auto and cross-correlation programs using this routine. An FFT carried out on 2048 points will take 3 to 5 seconds. The complete system, excluding tape decks, has been taken to sea once and performed very well. Installation required about 2 man-days and all peripheral test programs were run successfully immediately after installation was completed. The first use of the system for data gathering and processing should be made later this year when acoustic data from explosive sound sources will be recorded and processed. Some of the preliminary processing, such as total energy calculations, will be carried out between shots. The necessary software will be developed in the future to enable background programs, such as ray tracing, to be run while the computer is gathering data, so using spare computer time to maximum advantage. A typical data logging program of this type will probably require about 8K of store, leaving 8K available for background programs.

(Paper presented in two parts)

PART I

CONTINUOUS RECORDING OF ACTIVE SONAR DATA

by

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An experimental active sonar was described followed by a description of the digital data recording method at present planned and concluded with a proposal to use a video tape recorder to replace the digital tape recorder.

The sonar will not be described in this unclassified abstract, it is suffcient to say that the signals leave the receiver signal processing in the format shown in Fig. 1.

This format is suitable for digital recording on 7 tracks at 556 rows per inch. The tape recorder speed is 36 inches per second giving a total record time of 13 minutes for a 2400 ft tape length. Three hundred and sixteen amplitude and phase samples are recorded every 16 milliseconds followed by a gap of 4 bytes (during which time no read clock pulses are generated). The read clock pulses are used to index phase and beam counters and these are reset by a gap detection circuit every 16 milliseconds.

The contents of the beam and phase counters, together with the amplitude samples are assembled into words as shown in Fig. 2 ready for input to the data processing computer. There are two sonar input channels (SIC 1 and SIC 2) ; SIC 1 accepts the basic resolution samples and SIC 2 post detection integrated samples.

The method of data recording chosen is just adequate for the present sonar, but a full system presenting the computer with four times the samples would require a bit density per second not sensibly achievable using currently available digital tape recording systems (it would be necessary to go to 1600 rows per inch and to run at 75 inches per second giving a total record time of only 6 minutes which would be unacceptable).

Alternative methods of recording are being investigated to overcome these drawbacks, in particular a proposal to use a video tape recording system. This proposal is described in detail in Ref. 1. Because of the advanced development of the sonar and computer it is not possible to change the agreed digital recording format which may not be optimal for a fully serial recording system and therefore the video recorder system is designed to accept the 7 bit (6 data + parity) bytes, converting to serial in an input shift register and converting to parallel form at playback as shown in Fig. 3.

A comparison of three recording methods, digital, video and instrumentation/digital (as the SACLANTCEN method) is shown in Fig. 4.

The video system affords an intermediate solution at around the 1 Megabit per second bit density region, and a very significant advantage in record time for a given length of tape. A record time of about 1 hour is very important for real time data recording of active sonar, both for satisfactory analysis by computer and for sonar operator training in operational situations.

The tape cost comparison was justifiably criticised at the conference.

A simple comparison of existing systems is shown and strictly, for true comparison, allowance should be made for the different bit densities of the system.

REFERENCES

1. "Technical Proposal for a Digital Recording System for A.U.W.E.", Document Ref. No. MCP 8027, Issue 2, EMI Electronics Ltd., Wells, Somerset, U.K.

PART II

SIMULTANEOUS ANALYSIS IN REAL TIME

by

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The stream of input words arrives in the computer by data interrupts interspersed every 16 ms by a program interrupt. The words are stored sequentially in the main input list by using a pointer which is accessable to both hardware and software. This pointer is inspected during program interrupts and its value is stored in an index table. At any time the index contains a complete description of the data which is stored in the main input list. Both the main list and its index are filled cyclically the input data rate will fluctuate but index entries will be inserted regularly every 16 ms [see Fig. 5]

The programs which are analysing the sonar data obtain new information through the index table. It is necessary to keep two pointers to the index table, the first is used by the interrupt program to mark the position of the newest entry and the second by the processing programs to mark the entry which is next due for processing.

The interrupt program inspects these pointers and if temporary overloading is about to occur it will change the pointer which is used by the processing programs so that the stalest data is abandoned.

The details of the software will not be discussed here, in any case there is more than one satisfactory treatment, but the principles which have guided the software design will be enumerated.

Firstly, the interrupt program must not be affected by the content of the input data words. If this is not so then there is a risk that faulty input could cause unexpected actions (e.g., endless loops) in the interrupt program.

Secondly, the converse should also be true, that is the data words should not be changed by the interrupt program, it is advisable to allow the input words to remain unchanged in a cyclic list for as long as possible as an aid to fault diagnosis.

Thirdly, the interrupt programs must not rely on the processing programs to work correctly. Even if the processing programs fail to take any more input data the interrupt programs should continue to run.

DIGITAL RECORDING FORMAT

36 in/s 556 BITS/in 7 TRACK (6 DATA + PARITY)

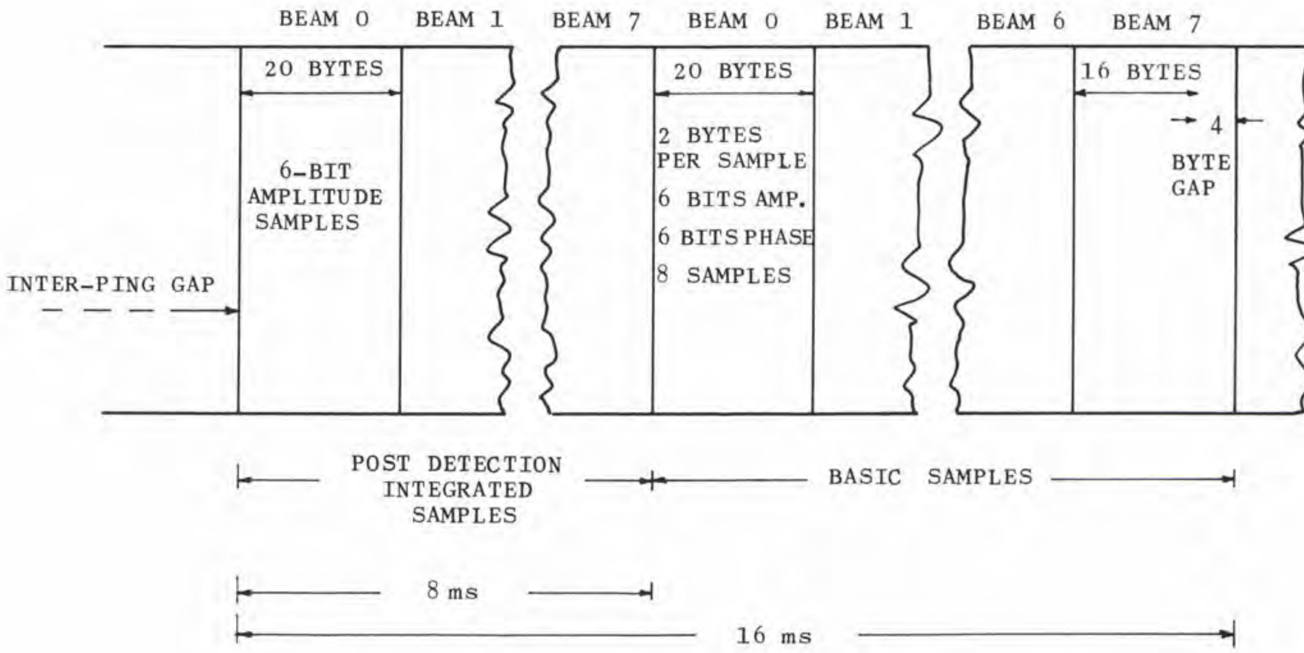

FIG. 1

WORD FORMATS

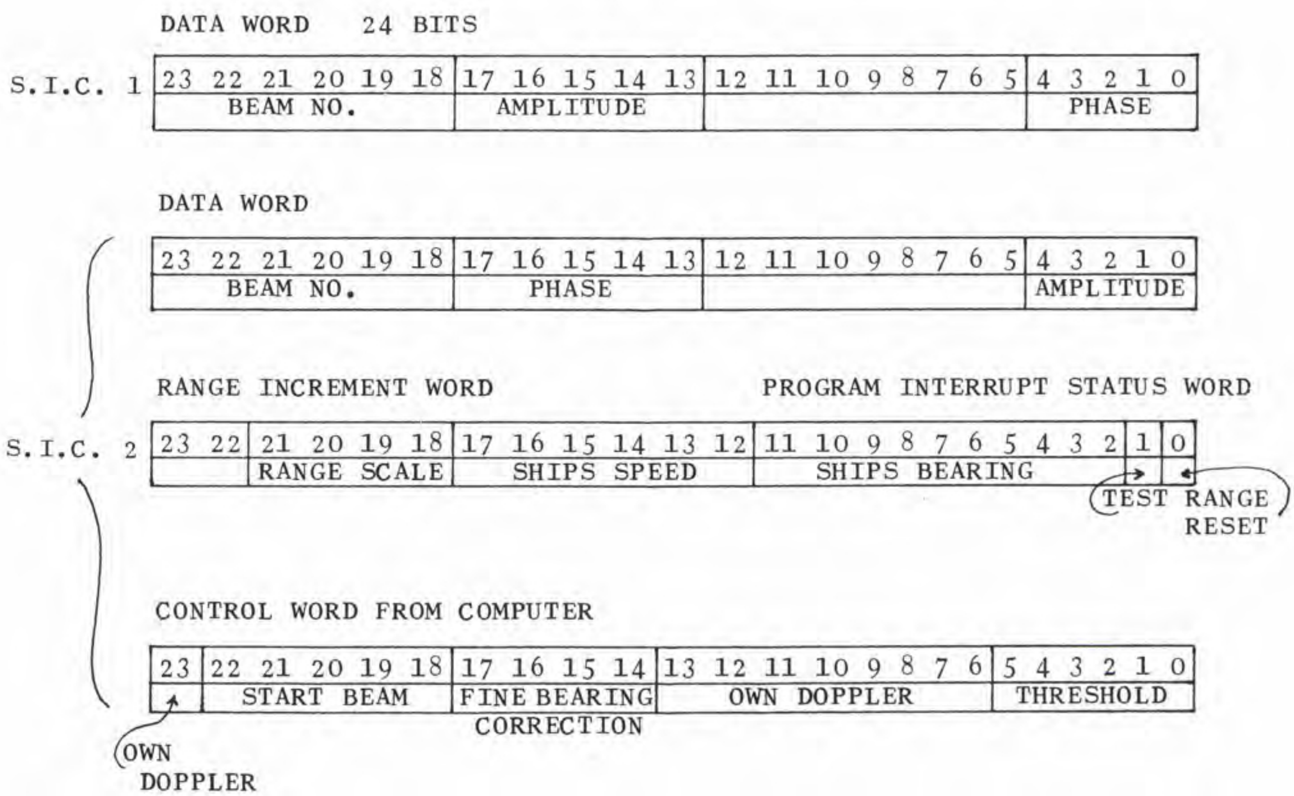

FIG. 2

VIDEO TAPE SYSTEM

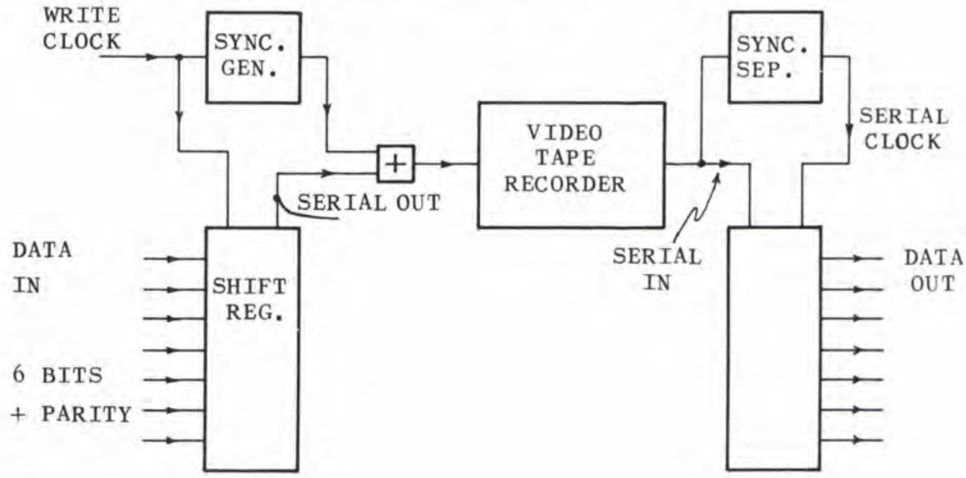

FIG. 3

COMPARISON OF RECORDING SYSTEMS

	DIGITAL	VIDEO	INSTRUMENTATION /DIGITAL	UNITS
TAPE SPEED	36	7	30	Inches/s
BIT DENSITY	0.12	0.56 (1.0 pos)	2.88	Megabits/s
RECORD TIME (2400 ft)	13	70	16	Minutes
TAPE WIDTH	0.5	1	1	Inches
TAPE COST	£50	£20	£50	Per Hour

FIG. 4

DATA STRUCTURE

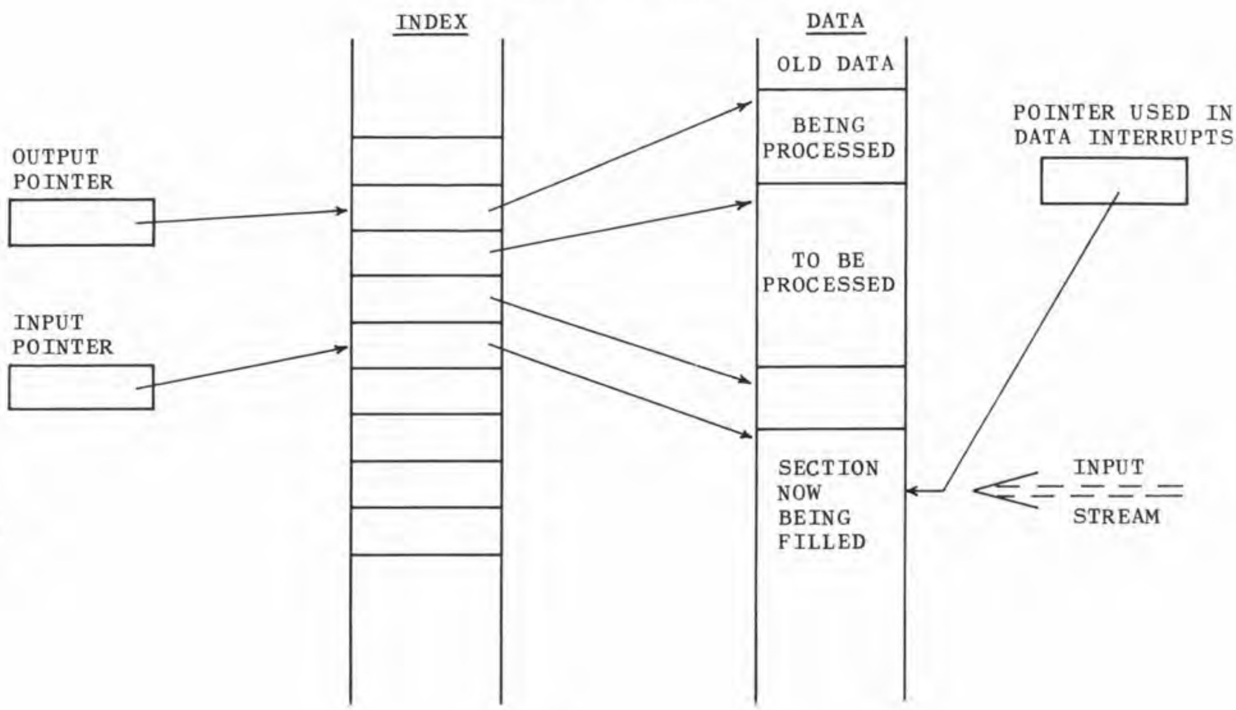

FIG. 5

A DIRECT DIGITAL ACQUISITION SYSTEM

by

G. Grandvaux
Laboratoire de Détection Sous-marine
Le Brusc, France

The low dynamic, the flutter and skew of analogue tape recorders cause considerable distortion of the signals used in underwater acoustic experiments. Digital recorders do not suffer from these shortcomings but are lacking in capacity and endurance.

The SANDRA system described below (SANDRA = Système d'Acquisition Numérique Directe pour la Recherche Acoustique) is a combination of two methods using the principle of high density digital recording with analogue recorders. This equipment, which SACLANTCEN helped to specify, will cost $ 200 000 (including all taxes and custom duties). It is now being completed and will be available in spring 1972.

The system consists of:

A shipboard assembly [Fig. 1] with the following functions:

- Multi-channel collection of analogue information,
- Multiplexing, analogue/digital conversion,
- Generation of synchronization and parity-check signals,
- Recording on magnetic tape,
- Recording check.

A laboratory assembly [Fig. 2] with the following functions:

- Reading of magnetic tape,
- Reshaping and resynchronization of digital signals,
- Localization of useful signals,
- Transfer to computer.

The principle features of this assembly are:

- Maximum sampling frequency: 240 kHz,
- Number of analogue channels: 1 to 60, (from 1 channel sampled at 240 kHz to 60 channels sampled at 4 kHz),
- Input dynamic: 84 dB (14-bit + sign sampling)
- Accuracy: better than 1% (floating point conversion: exponent 3 bits, mantissa 8 bits),
- Digital recording density: 12 000 bits per inch.

The useful signals are distributed over ten magnetic tracks after insertion of longitudinal parity words and synchronization words. The 11th track is solely for coded time signals; the 12th is for transverse parity words. The two outer tracks are not used for digital recording but for auxiliary signals such as voice.

Transfer to the computer is carried out in 12-bit words in parallel at a maximum rate of 12 000 words per second by reducing the reading speed accordingly. Only useful signals are transferred owing to the use of the localization device (time code reader) which permits delimitation of useful sequences up to 1 ms.

The expected error-rate is of the order of 10^{-7} but could be further improved to 10^{-8} through correction of some parity errors by an appropriate computer program.

SANDRA SHIPGOING ASSEMBLY

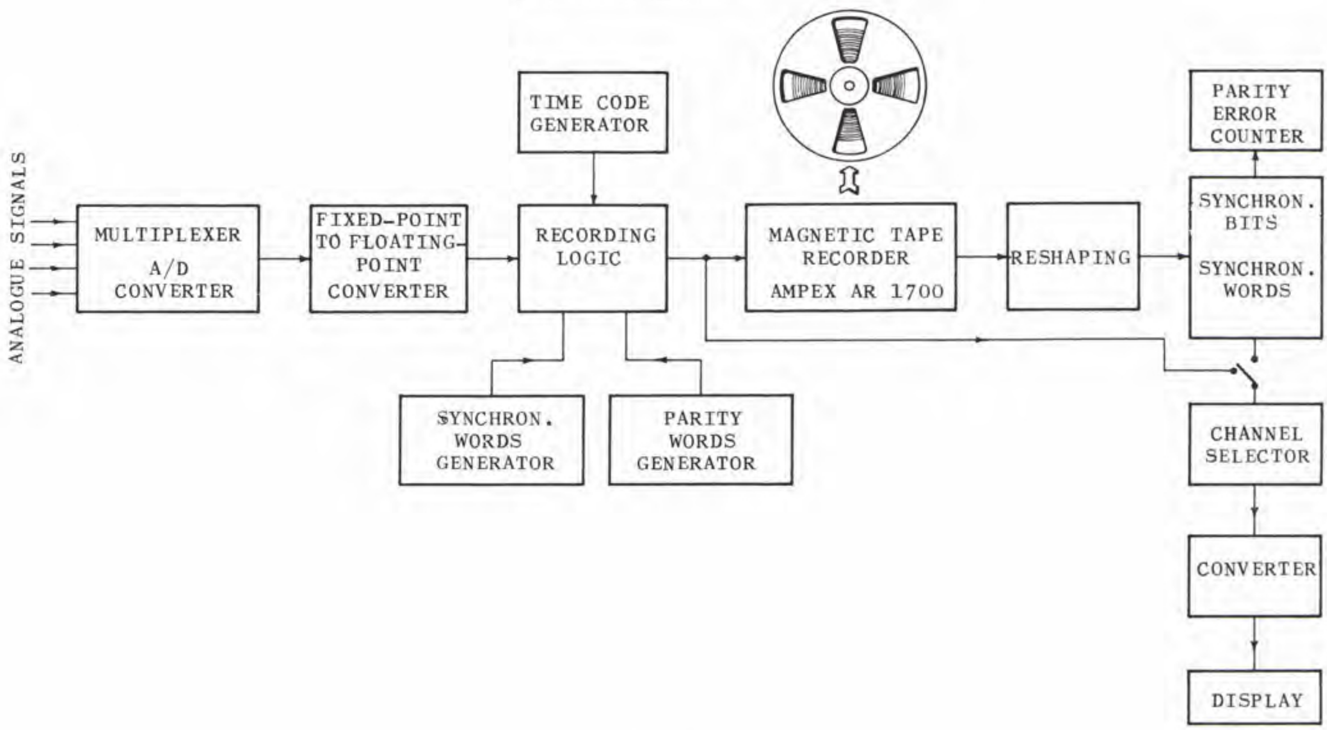

FIG. 1

SANDRA LABORATORY ASSEMBLY

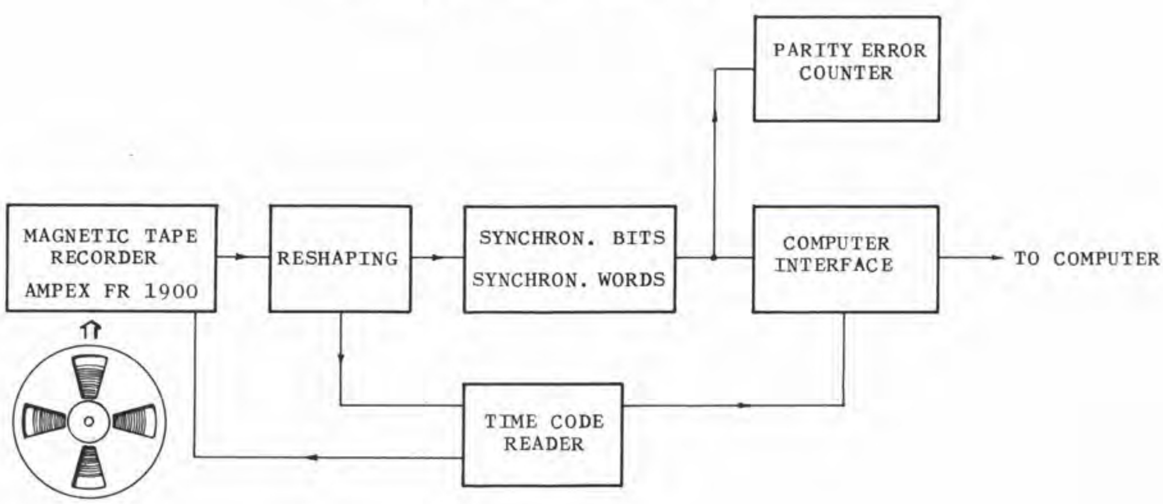

FIG. 2

TACTICAL DATA ACQUISITION EXPERIENCES

by

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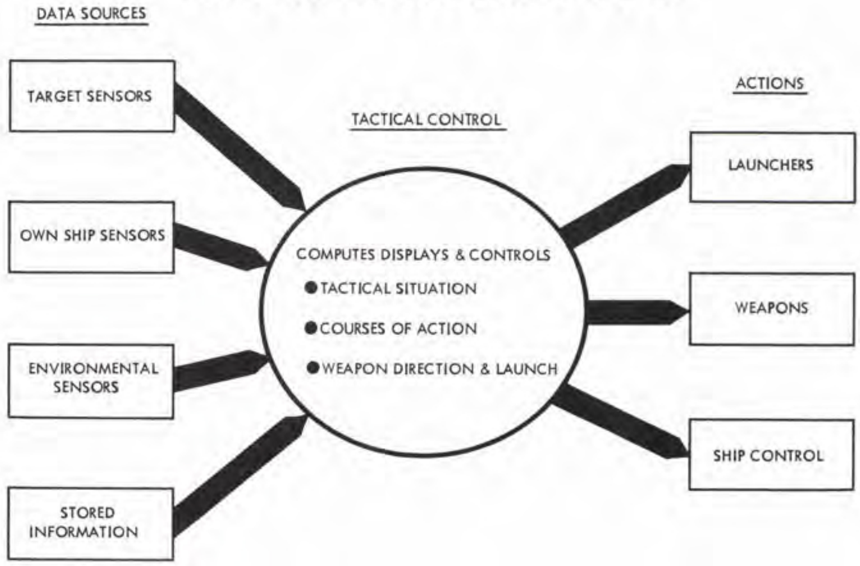
ABSTRACT

The requirements of Tactical Data Acquisition systems are discussed and summarized. Experiences with equipment and their utilization are described including: quantities measured, input signal conditioning, analogue multiplexing, analogue-to-digital conversion, digital formating, real-time accumulation, quick-look display, scaling and merging, recording, and analysis. Finally, an approach to future endeavours of this kind is presented.

GENERALIZED TACTICAL SYSTEM

FIG. 1



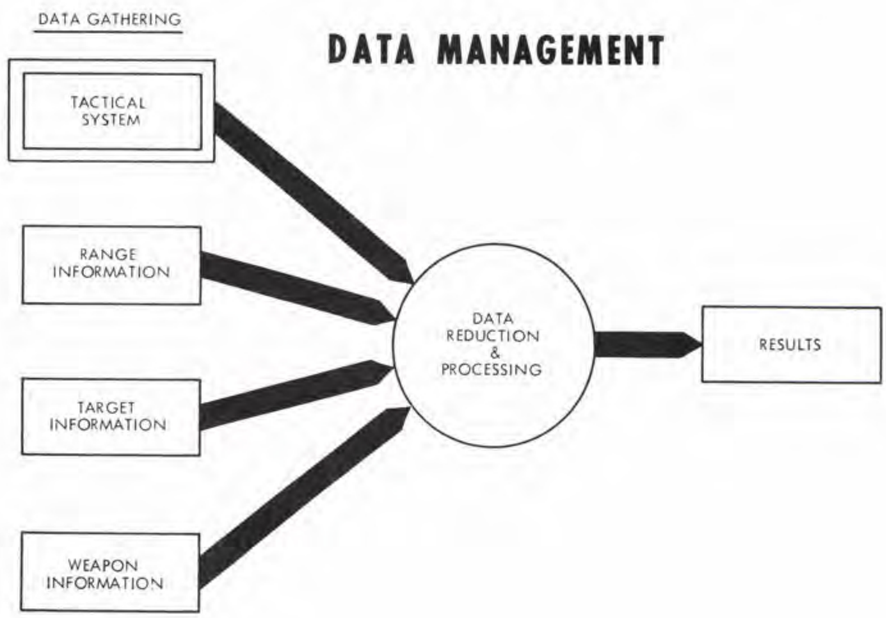
REQUIREMENTS OF A TYPICAL CURRENT TACTICAL DATA AQUISITION SYSTEM

TYPES OF MEASUREMENT / QUANTITIES	TARGET(S) SENSOR(S)						TACTICAL SUBSYSTEM										NAVIGATION SUBSYSTEM								ENVIRONMENTAL					RELATED				
	BEARING	ELEVATION	RANGE	RANGE RATE	S/N	STATUS & MODES	BEARING	RANGE	CAUSE	SPEED	RATES	WEAPON ORDERS	WEAPON SETTINGS	WEAPON SELECTIONS	LAUNCHER STATUS	STATUS & MODES	HEADING	SPEED	VELOCITY	LAT/LONG	PITCH	ROLL	DEPTH	STATUS	SOUND VELOCITY	WIND	SEA STATE	BOTTOM DEPTH	WEATHER	TARGET SHIP(S)	VEHICLE TRAJECTORIES	TIME SYNCHRONIZATION	REFERENCES	OPERATIONAL LOGS
DIGITAL							●	●	●	●	●																							
SYNCHRO SIGNALS	●	●	●	●			●	●	●	●	●	●	●				●	●	●	●	●	●	●											
SYNCHRO REFERENCES																																	●	
A.C. SCALED VOLTAGES					●							●	●		●													●						
D.C. SCALED VOLTAGES					●							●	●		●																			
A.C. & DC REFERENCE VOLTAGES															●																		●	
STATUS VOLTAGES						●						●	●	●	●	●								●										
LOGIC LEVEL												●	●	●										●										
FREQUENCY												●	●																					
TIME REFERENCE PULSE																																●		
RECORDS																									●	●	●		●	●	●			●

FIG. 2

DATA MANAGEMENT

FIG. 3



GENERALIZED DIGITAL DATA AQUISITION SYSTEM

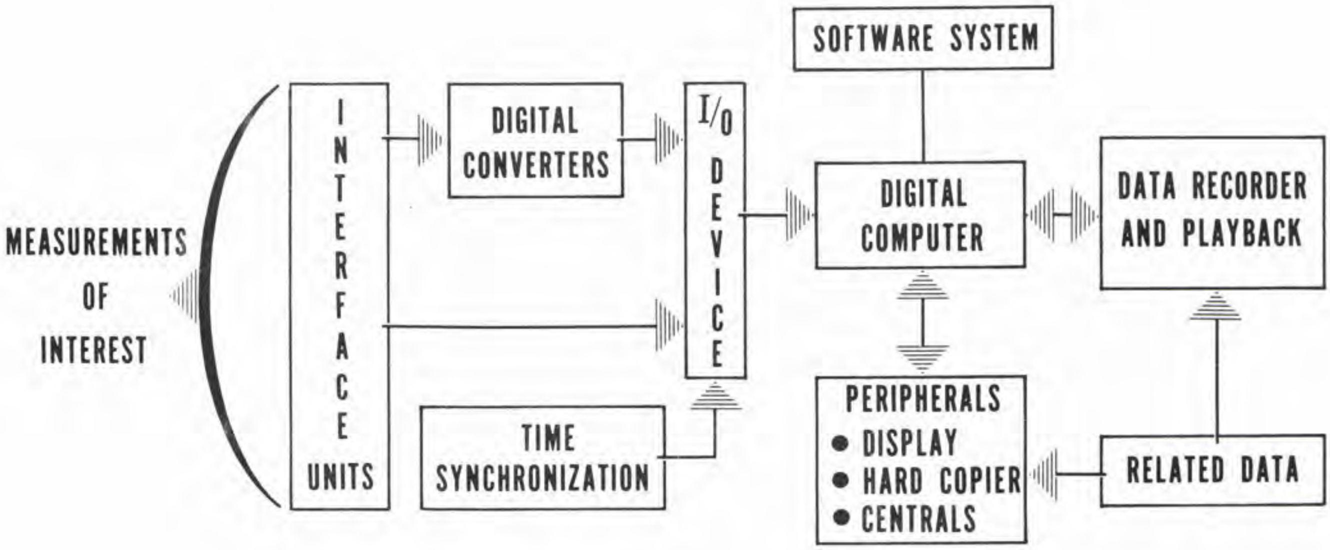
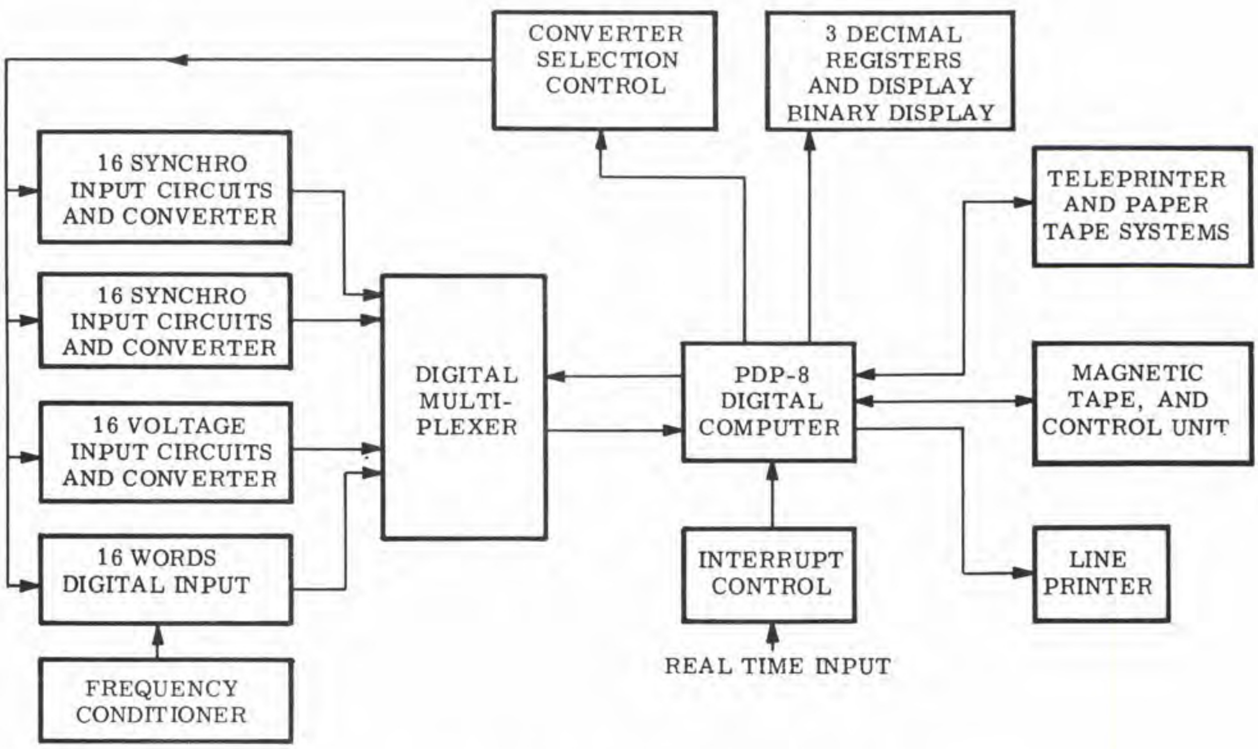


FIG. 4



DIGITAL DATA ACQUISITION SYSTEM, FUNCTIONAL BLOCK DIAGRAM

FIG. 5

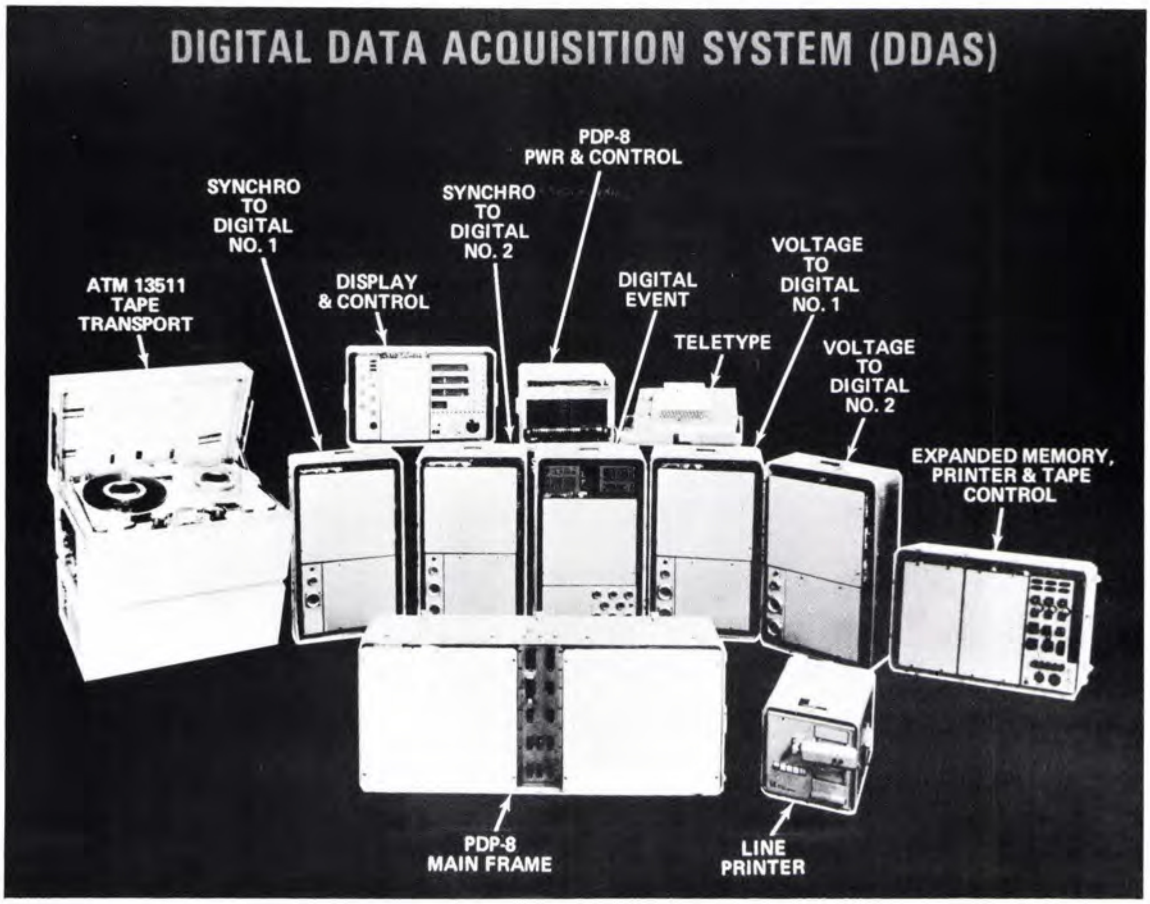
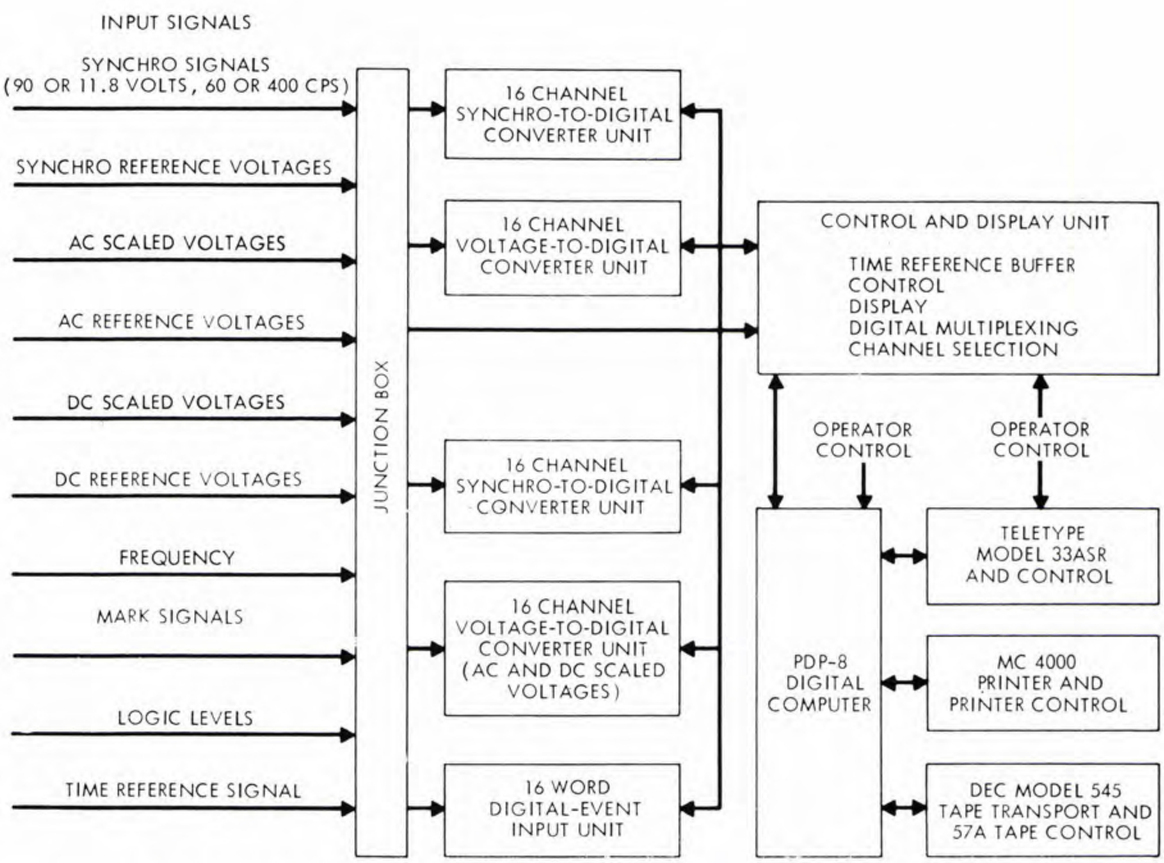


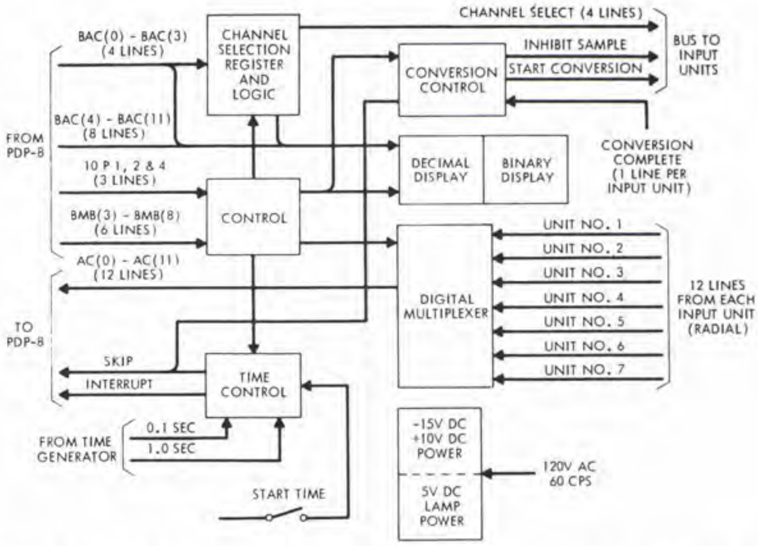
FIG. 6



DDAS SYSTEM FUNCTIONAL BLOCK DIAGRAM (INITIAL VERSION)

FIG. 7

FIG. 8



DISPLAY AND CONTROL UNIT FUNCTIONAL BLOCK DIAGRAM

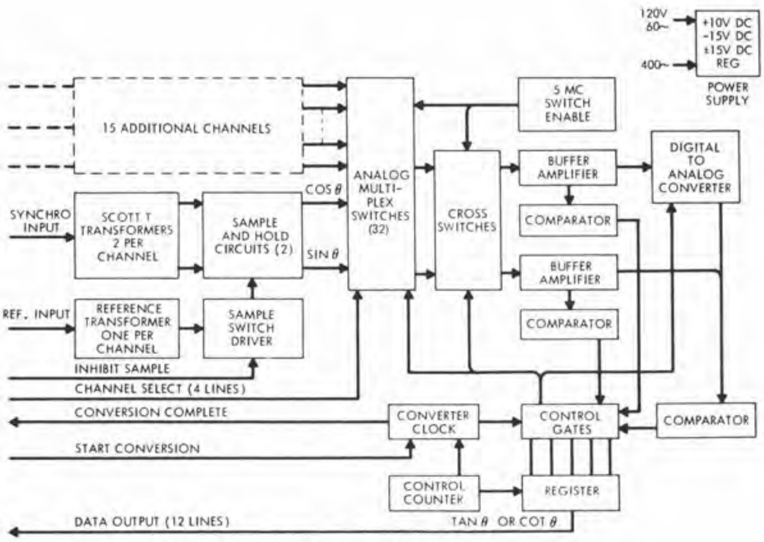
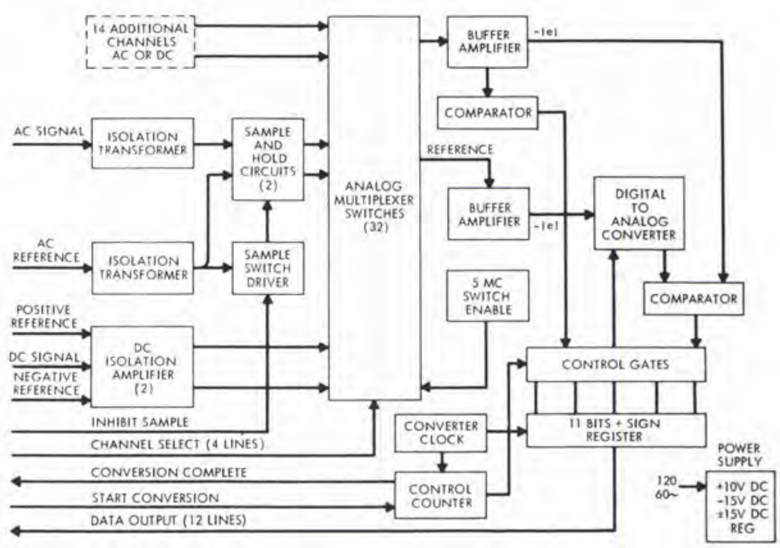


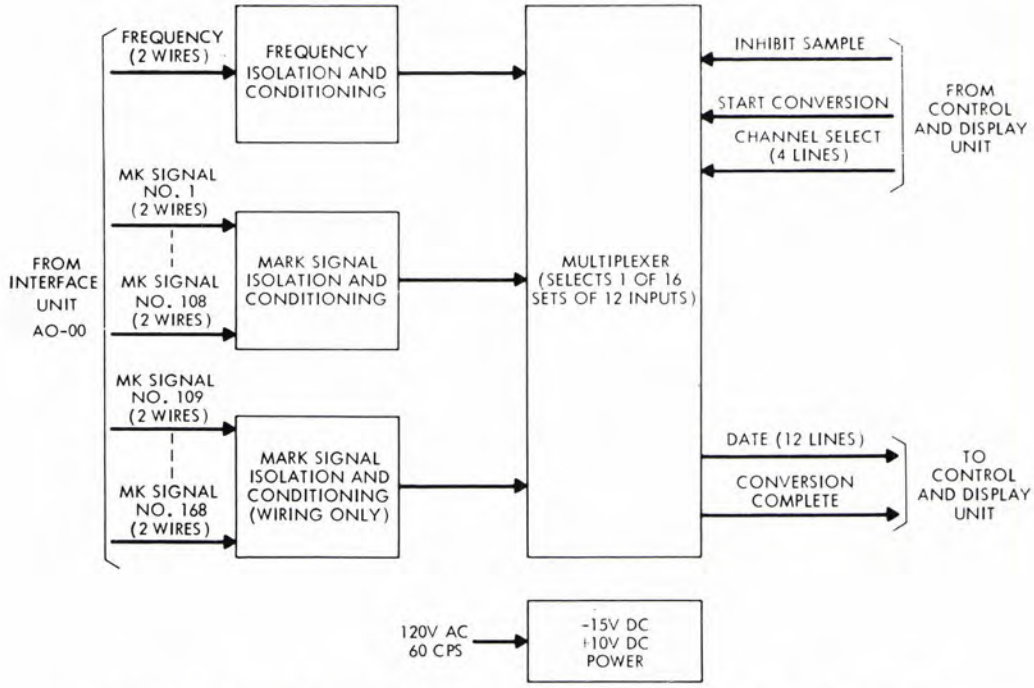
FIG. 9

SYNCHRO-TO-DIGITAL CONVERTER UNIT, FUNCTIONAL BLOCK DIAGRAM

FIG. 10



VOLTAGE-TO-DIGITAL CONVERTER UNIT, FUNCTIONAL BLOCK DIAGRAM



DIGITAL EVENT UNIT FUNCTIONAL BLOCK DIAGRAM

FIG. 11

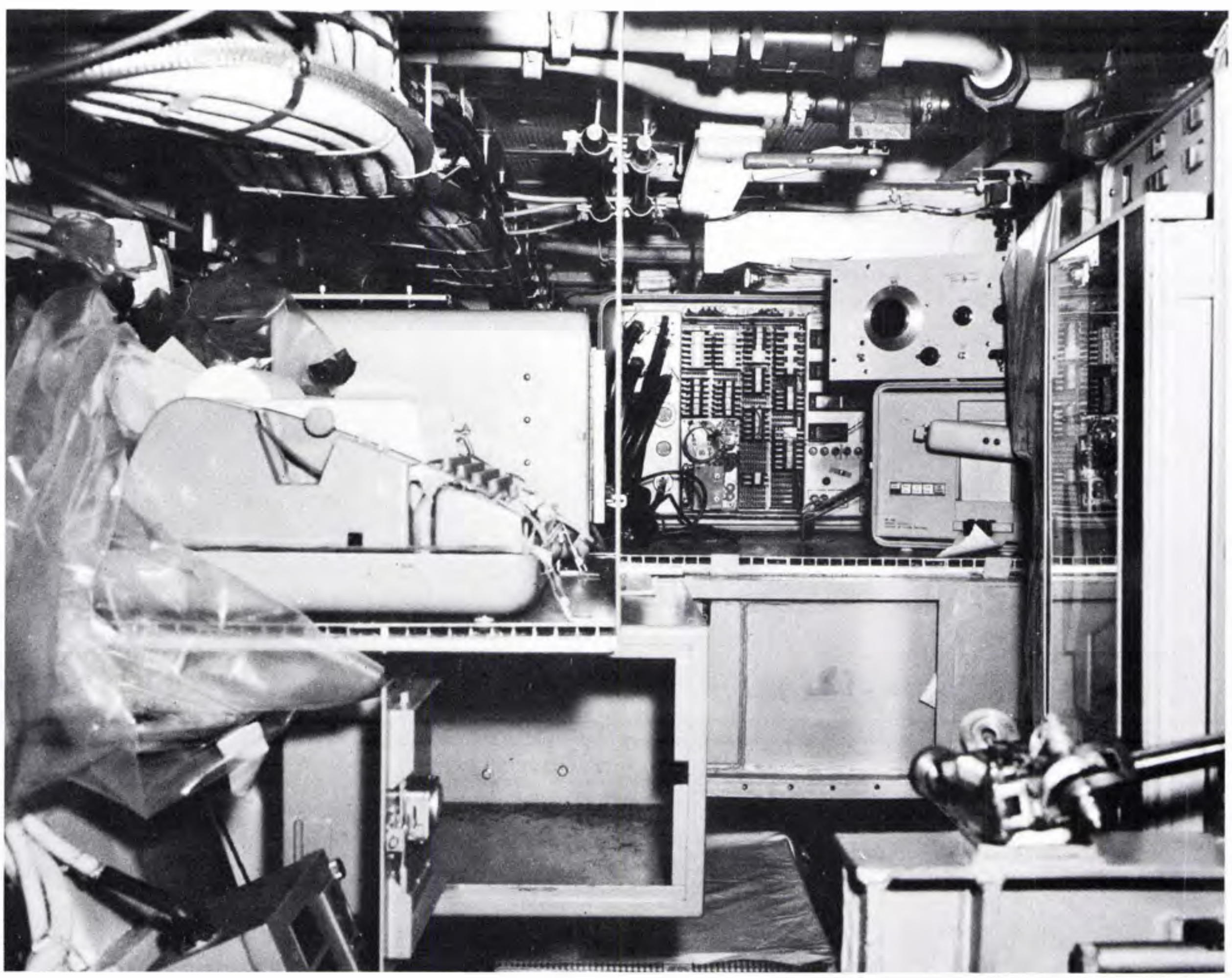


FIG. 12

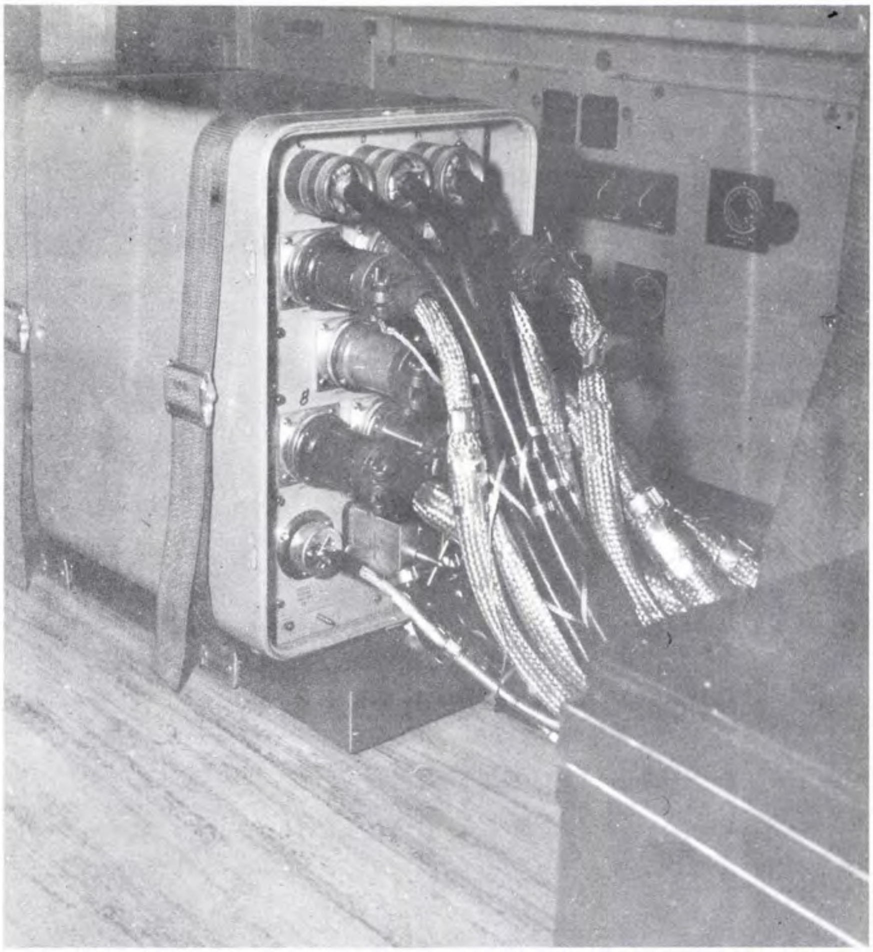


FIG. 13

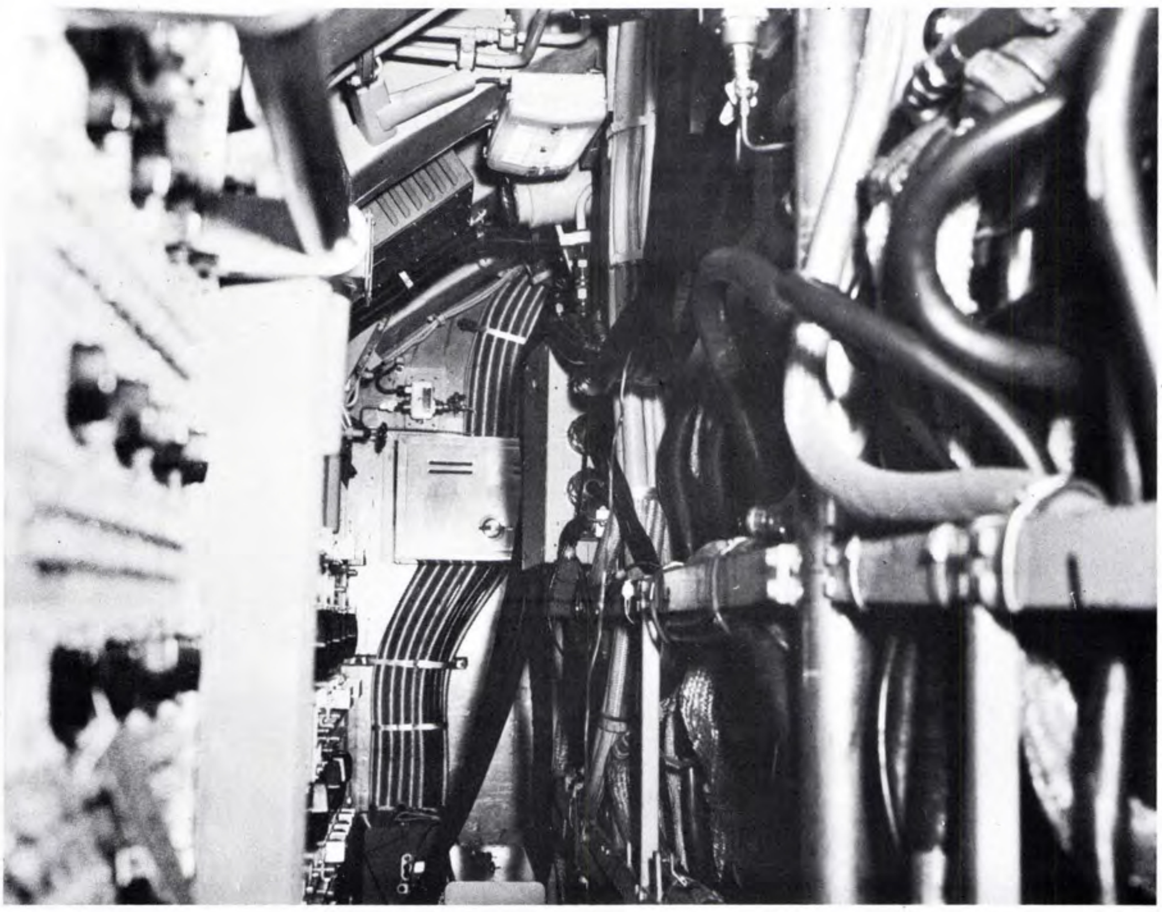


FIG. 14

FIG. 15

SUMMARY OF DIGITAL DATA ACQUISITION SYSTEM CHARACTERISTICS

SYNCHRO INPUTS

- UP TO 32 SINGLE SPEED CHANNELS
- 0.1 ACCURACY SINGLE SPEED
- 0.01 ACCURACY MULTIPLE SPEED

AC / DC SCALED VOLTAGE INPUTS

- UP TO 16 AC OR DC CHANNELS
- 0.05% RATIO ACCURACY

MARK SIGNAL INPUTS

- 8 MARK SIGNAL CHANNELS
- 0.1 SECOND MAXIMUM MARK SIGNAL TIMING ERROR

SAMPLE TIMES

- ALL FUNCTIONS SAMPLED WITHIN 0.001 SECOND
- MAXIMUM SAMPLE RATE 10 TIMES PER SECOND

OUTPUTS

- MAGNETIC TAPE : 7 TRACKS, DENSITIES (200, 556, 800), 3/4" SPACING
- PRINT OUT UP TO 32 ALPA NUMERIC COLUMNS (a) 40 LINES / SEC FOR SELECTIVE QUICK-LOOK
- SELECTIVE REAL-TIME DISPLAY: (3) 6 DIGIT DECIMAL + 3 DIGIT CHANNEL NO.
  (1) 12 BIT BINARY + 3 DIGIT CHANNEL NO.

ON-LINE CONTROL

FIG. 16

DATA ACQUISITION SYSTEM
HISTORY

PROBLEMS EXPERIENCED	SOLUTIONS
INADEQUATE COMPUTER MEMORY	ADDED 4K MODULE
NON-INTEGRATED SOFTWARE	WITH ADDED MEMORY, INTEGRATION WAS POSSIBLE
TAPE INCOMPATIBILITY WITH LAND-BASED SYSTEM (SKEW)	CHANGED UNIT
EXCESSIVE SIZE	REPACKAGED PORTIONS
LOW OPERATIONAL CONFIDENCE	SYSTEM LEVEL TESTING
LONG INSTALLATION TIME	EXPERIENCE HAS REDUCED IT
INEFFICIENT ASSEMBLER COMPILER	USE MACHINE LANGUAGE
SLOW PROGRAM LOAD (PAPER TAPE)	USE OF MAG TAPE RECORDER

FIG. 17

ATM-13 TAPE TRANSPORT

FIG. 18

RECOMMENDATIONS FOR FUTURE ENDEAVORS

- EXPANDED ON-BOARD EDITING AND ANALYSIS CAPABILITY
  - > MORE POWERFUL COMPUTER, E. G., 16 BITS, HARDWARE MULTIPLY / DIVIDE, DOUBLE PRECISION, FLOATING POINT, ETC.
  - > RAW DATA COPYING CAPABILITY
  - > RECONFIGURABLE SOFTWARE
  - > CRT GRAPHICS DISPLAY FOR EDITING
  - > HARD COPY PLOTTER WITH ALPHA NUMERIC CAPABILITY
  - > MORE EFFICIENT COMPILER
- EXPANDED USE OF DIAGNOSTICS AND WELL DOCUMENTED MAINTENANCE TO INCREASE AVAILABILITY AND CONFIDENCE
- REDUNDANCY IN CRITICAL AREAS
- USE OF CRT GRAPHICS DISPLAY FOR EXPANDED QUICK-LOOK
- MINIATURIZATION
- RAPID SYSTEM LEVEL CHECKOUT

FIG. 19

SESSION 2

DIGITAL ANALYSIS OF ACOUSTIC AND OCEANOGRAPHIC DATA

PROCESSING OF BROADBAND ACOUSTIC SIGNALS

by

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La Spezia, Italy

INTRODUCTION

The SACLANTCEN 5-channel digital recording system has been presented by Mr Barbagelata and we will now see some examples of what kind of processing we are applying to the recorded signals. The examples are taken from various studies conducted at SACLANTCEN and more information about these studies is, or will shortly be, published in separate reports.

The examples are all processing of acoustic signals derived from explosive sources with typical bandwidth of 8 kHz, sampled at a frequency of 24 kHz. The elliott 503 computer has been used for the processing.

FFT-TECHNIQUE

We started with signal processing on the computer at about the same time that the Fast Fourier Transformer became known. We were, therefore, fortunate in starting immediately with the new technique.

The use of FFT is now very well known and we shall not got into details but just mention that we are using the FFT as a routine for the following operations:

1. Spectrum calculations.
2. Correlations.
3. Convolutions
4. De-convolutions.
5. Interpolation.

In the following we will comment upon the use of FFT for de-convolution and interpolation being examples of not-so-well known applications of the FFT.

De-convolution

The de-convolution or inverse filtering has been applied for the removal of the effects of the bubble pulses of underwater explosions. The example to be shown is from the bottom reflectivity study, where explosive charges were used to obtain the impulse response of the layered bottom [Refs. 1 and 2]. As can be seen from Fig. 1, however, the responses caused by the bubble pulses render the interpretation of the responses difficult. The de-convolution consists in principle of taking the Fourier Transform of bottom responses and dividing it with the Fourier Transform of the direct signal from the explosion, and then Fourier Transform back to the time domain [Figs. 2 and 3]. Figure 4 shows the final result where the de-convolution has been applied to all responses shown in Fig. 1.

A limitation of the use of this technique is that it requires a record of the direct signal from the explosion. In order to overcome this we are at present studying the use of a model for the direct signal with some parameters which can be changed. Such an inverse filter may be of a recursive type with no restriction on the signal length.

(sin x/x) Interpolation

For technical and economical reasons one will normally try to keep the sampling frequency as low as possible, bearing in mind the permissible folding errors. In some applications, however, it is required to reproduce the continuous wave form more accurately than say, drawing straight lines between the sample values. This requires interpolation and the correct interpolation is the (sin x/x) interpolation which can be done very easily by the use of the FFT [Ref. 3]. Figure 5 shows an example of such interpolation applied on samples derived from a Gaussian pulse.

Another application of this technique is for delaying sampled signals by a fraction of the sampling interval. For instance, this is required for the beam steering of arrays.

RECURSIVE FILTERING

The FFT technique is extremely useful and has wide applications. We have, however, found that in certain applications other methods are preferable. This is the case for certain filtering operations where the use of recursive filters has proved to be of advantage.

For this reason we have recently implemented a set of low and band-pass filters with Butterworth and Bessel characteristics [Ref. 4].

The band-pass filter is at present used in the realization of filter banks and an example of 1/3 octave filter bank using 8-pole Butterworth filters is shown in Fig. 6.

Figure 7 shows an example where this bank of filters has been applied to a transient signal. The output of each filter has been squared and integrated over a certain time interval (in this case 15 ms). The result which is a time-frequency matrix, has been displayed by using the contour program described in Ref. 5.

FUTURE WORK

In the near future we expect to do most of the signal processing on the Hewlett-Packard computers at the Centre and also at sea during the trials.

Some of the programs we have now on the Elliott 503 will have to be converted to the HP computer. This work is not expected to be very extensive as all programs based on the FFT are already available. To convert the recursive filters will be more difficult because, for computation time reasons, they will have to be implemented in integer arithmetic and the word-length of the HP is rather short.

On a longer term basis we would like to do more multi-channel measurements and processing. As a first step in this direction we are now developing a wide band acoustic array which, due to a combination of hydrophone arrangements and processing, will result in a beam pattern independent of frequency of over more than 3 octaves.

The signal processing developed here is for scientific use only. However, we should keep in mind its possible application in future operational systems.

REFERENCES

1. J.M. Hovem, "Removing the Effect of the Bubble Pulses when using Explosive Charges in Underwater Acoustic Experiments". SACLANTCEN Technical Report No. 140, March 1969.

2. J.M. Hovem, "De-convolution for Removing the Effects of the Bubble Pulses of Explosive Charges", J. Acoust. Soc. Am., Vol. 47, No 1 (Pt.2), January 1970, pp. 281-284.

3. J.M. Hovem, "(sin x/x) Interpolation of Sampled Signals", SACLANTCEN Technical Report No. 196, July 1971.

4. J.M. Hovem and M. Thompson, "A Description of Some Recursive Filters", SACLANTCEN Technical Memorandum No. 167, June 1971.

5. J.M. Hovem, "A Computer Program for Contour Mapping", SACLANTCEN Technical Memorandum No. 173, October 1971.

6. A.A.G. Requicha, "Design of Wideband, Constant-Beamwidth Acoustic Arrays", SACLANTCEN Technical Report No. 205, December 1971.

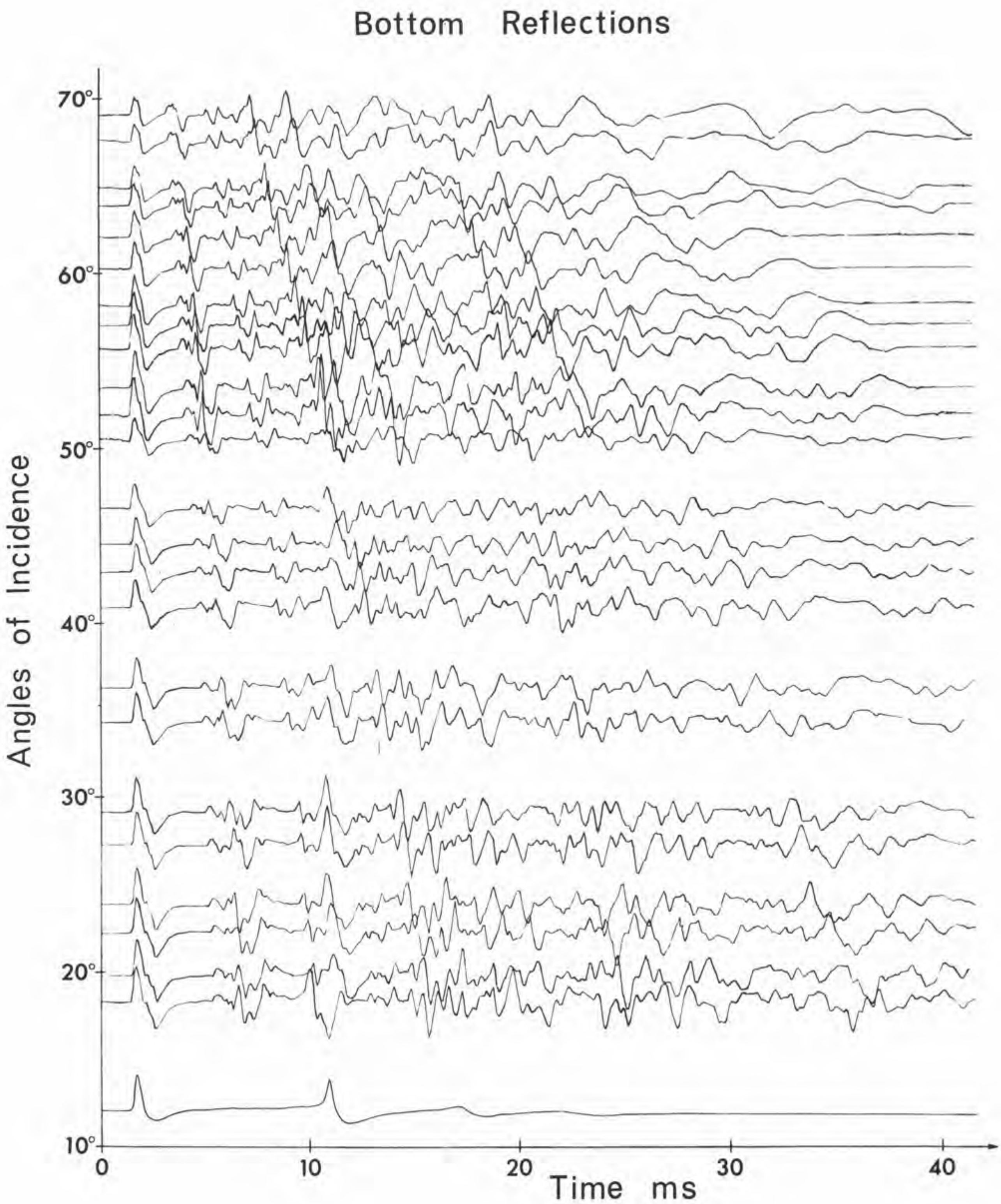

FIG. 1 REFLECTED SIGNALS FOR DIFFERENT ANGLES OF INCIDENCE

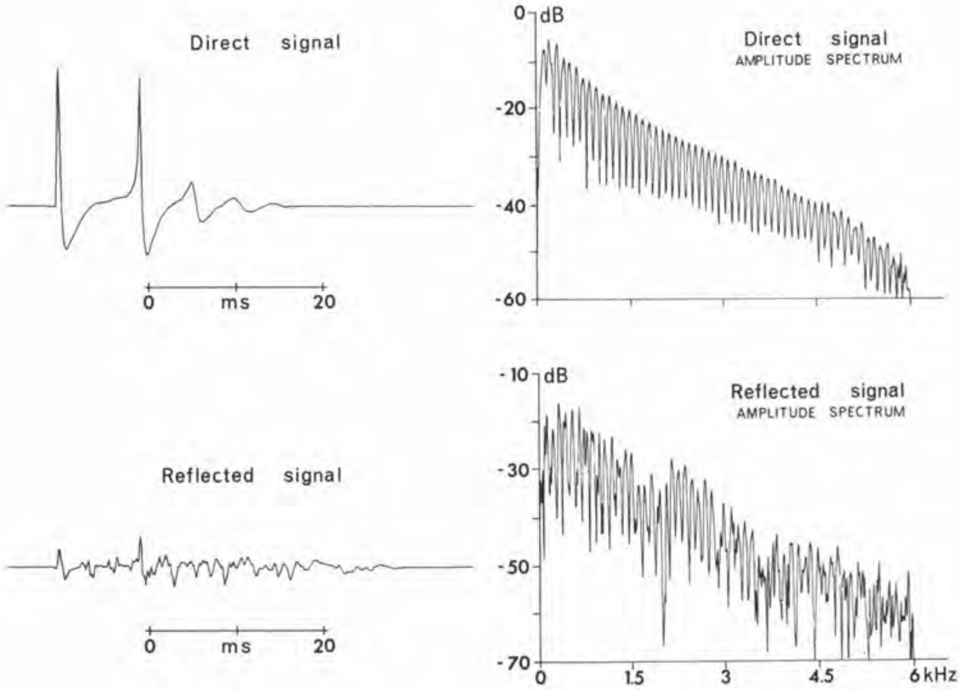

FIG. 2 DIRECT AND REFLECTED SIGNALS

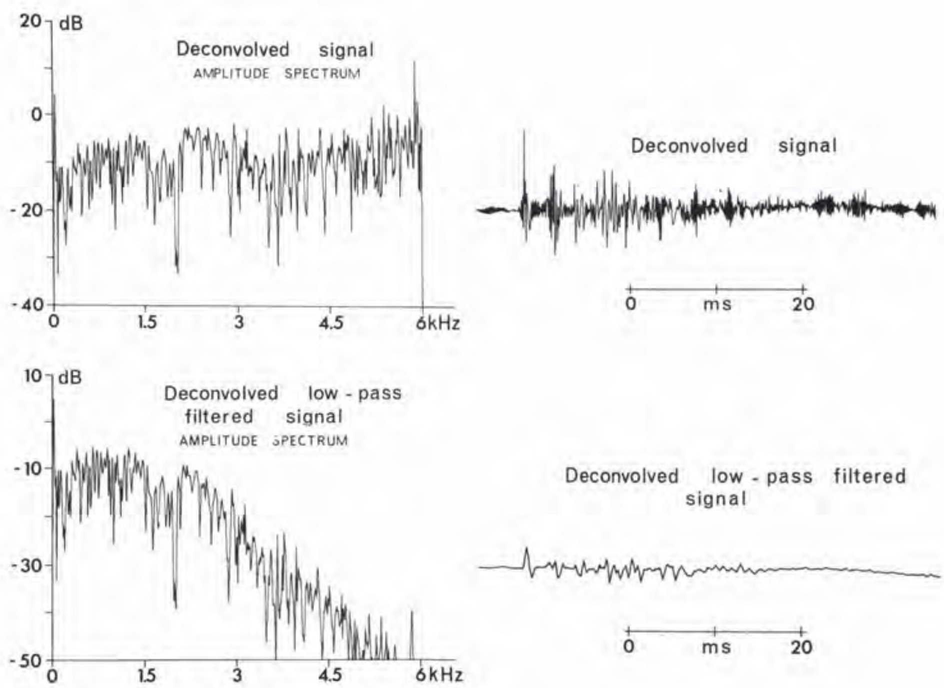

FIG. 3 DECONVOLVED SIGNAL AND DECONVOLVED LOW-PASS FILTERED SIGNAL

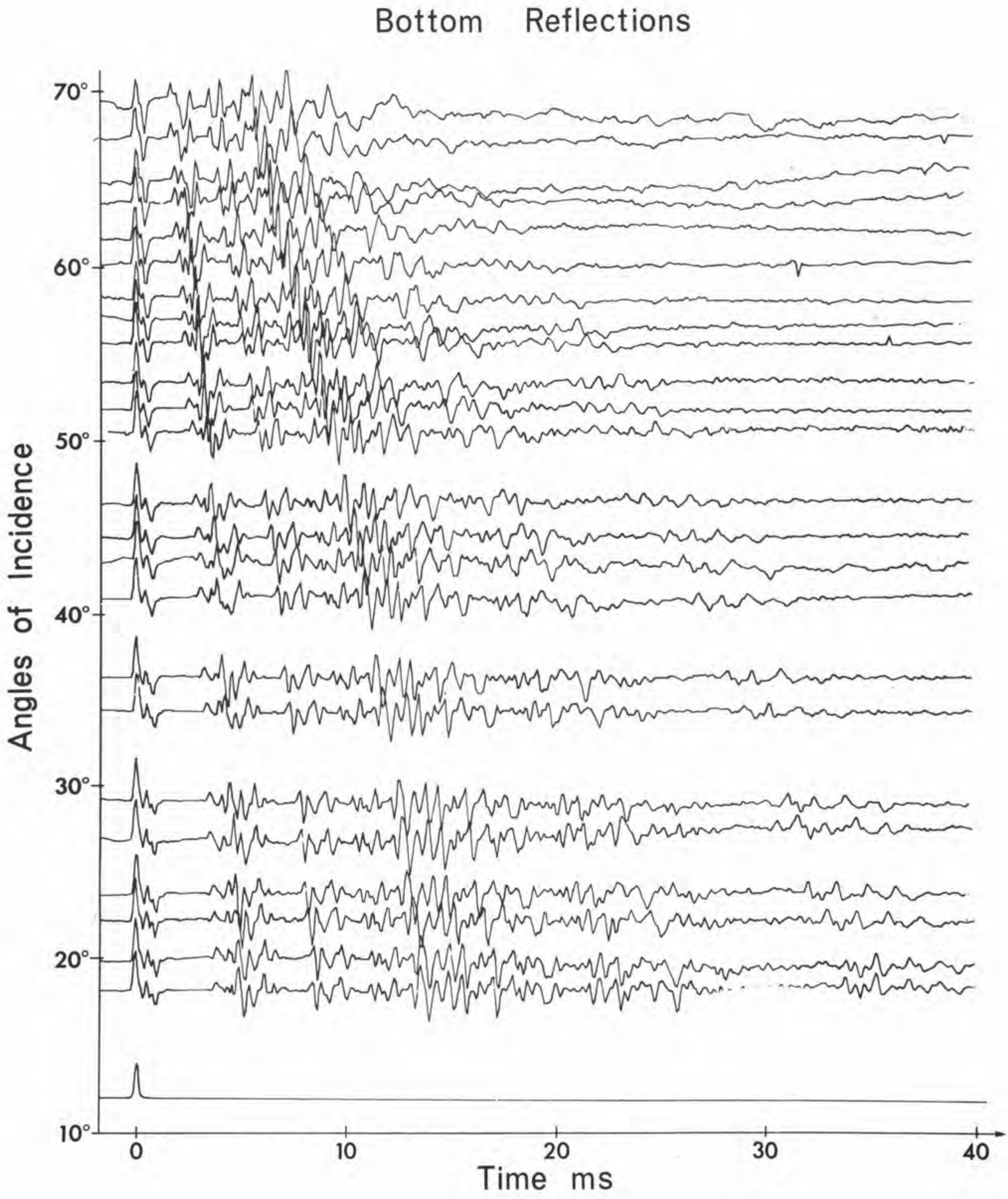

FIG. 4 REFLECTED AND PROCESSED SIGNALS FOR DIFFERENT ANGLES OF INCIDENCE

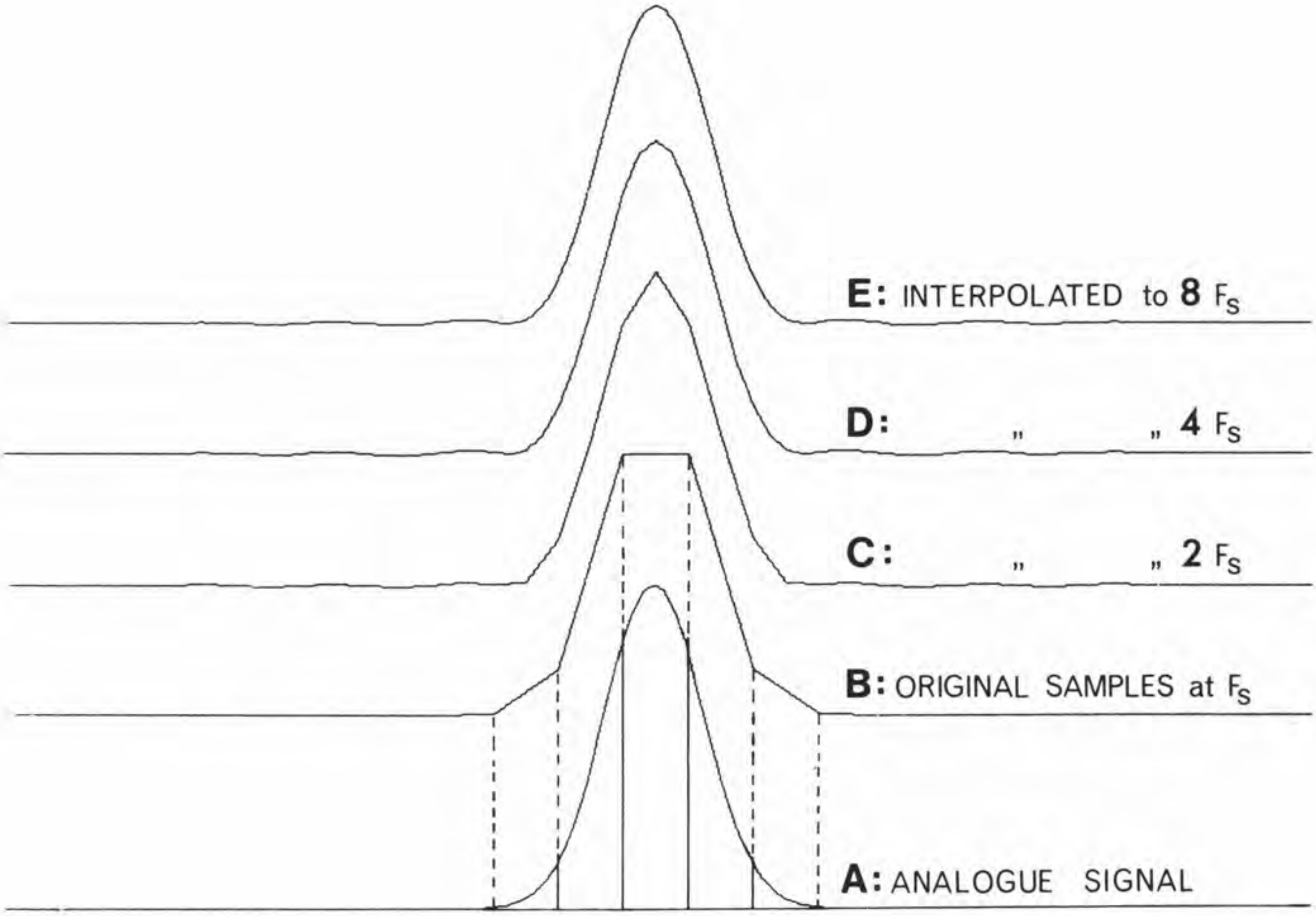

FIG. 5 INTERPOLATION OF A SAMPLED GAUSSIAN PULSE $\exp\left[-\frac{1}{2}(t/\tau)^2\right]$
Original sampling frequency $F_s = 0.8/\tau$
(4 times the 6 dB cut-off frequency)

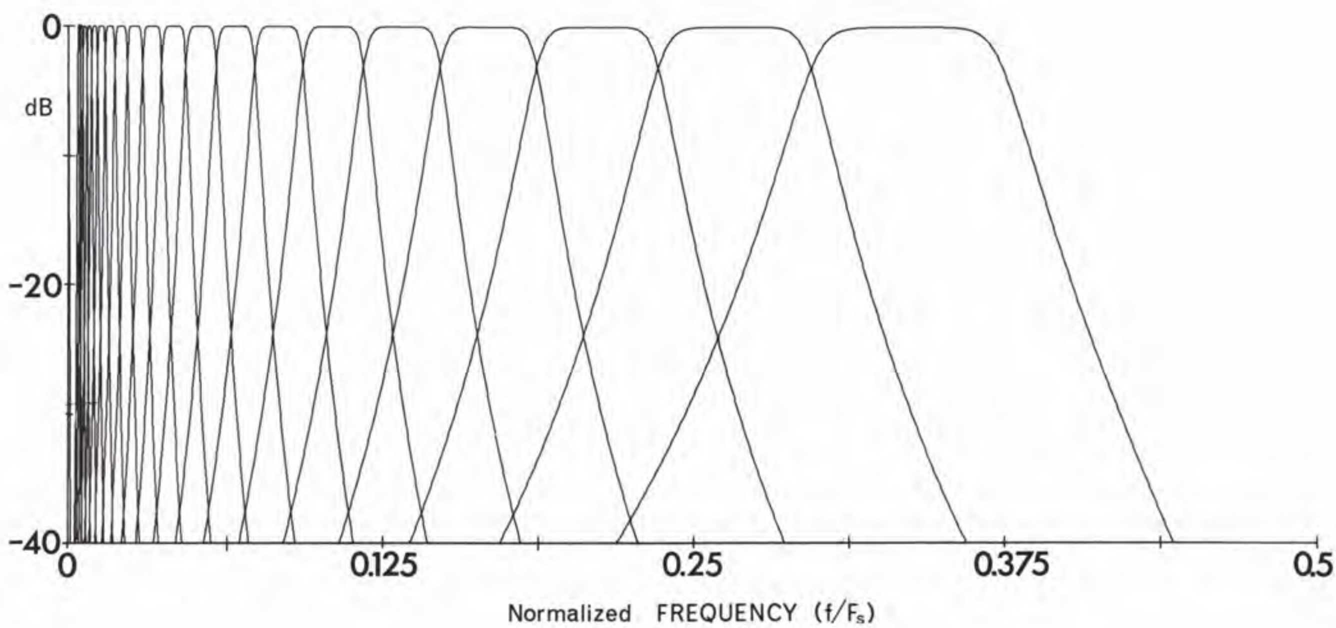

FIG. 6 1/3 OCTAVE FILTER BANK WITH 8-POLE BUTTERWORTH FILTERS

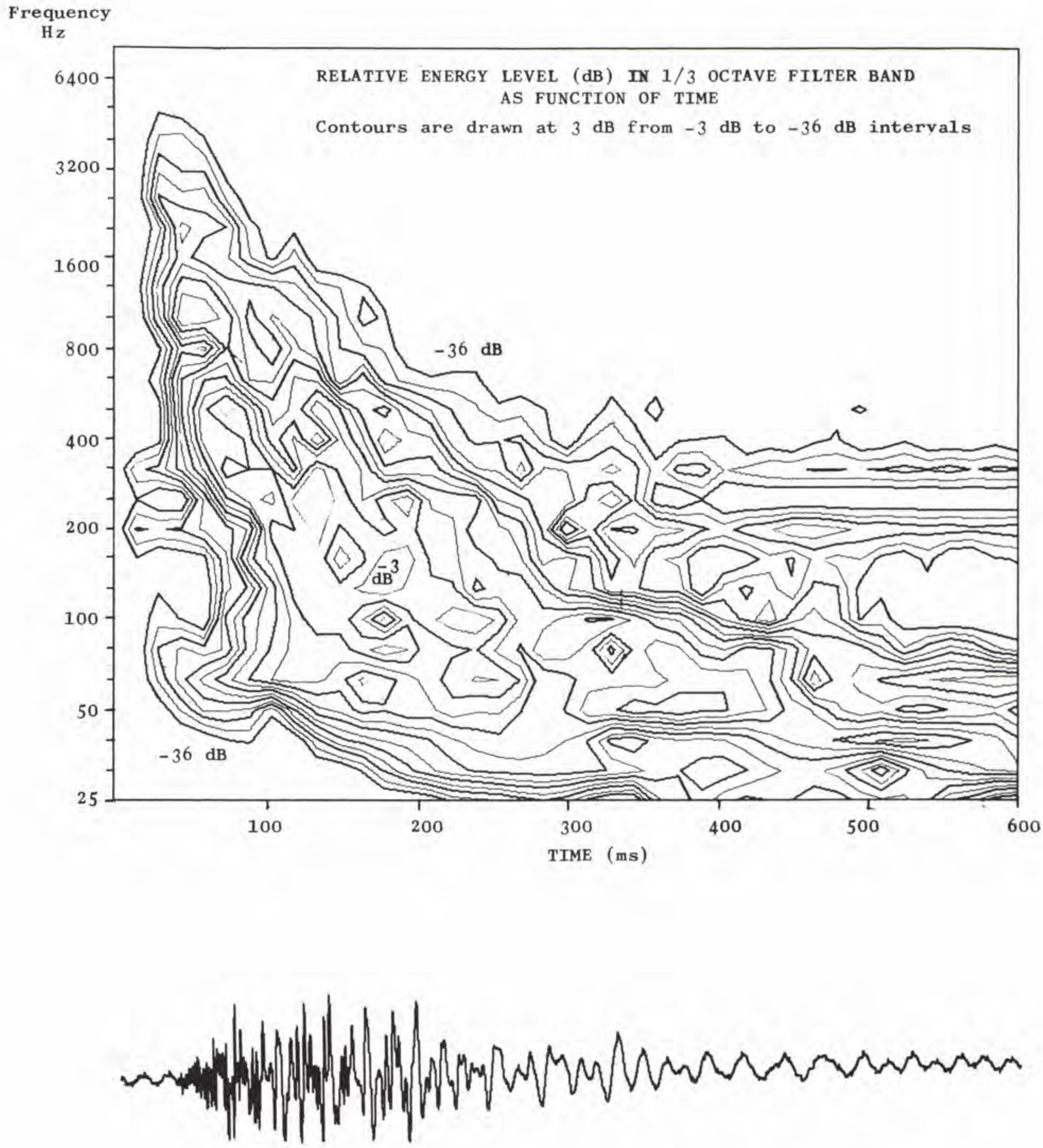

FIG. 7 EXAMPLE OF A CONTOUR MAP

A SURVEY OF PRACTICAL CONSIDERATIONS RELATIVE TO THE PROCESSING AND ANALYSIS OF UNDERWATER ACOUSTIC SIGNALS

by

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ABSTRACT

An investigation, aimed at bringing into sharper focus the strong interrelationships that exist between the measurement, processing, and analysis of underwater acoustic signals, is conducted. Emphasis is on practical considerations relating to these processes.

An overview of a typical underwater acoustic measurement system is presented. Major elements of the system hardware are reviewed in terms of functional operation and ramifications relative to their use. Processing and analysis considerations are those concerned primarily with filtering, correlation and spectral analysis of measurement data obtained.

Emphasis is on digital signal processing, rather than analogue processing of the subject data. The discussion, while not aimed specifically at real-time considerations for processing of the data involved, does cover several important concepts applicable to the real-time processing of underwater acoustic signals.

Finally, some of the inviting prospects for signal processing hardware and software systems with outstanding capabilities, which are likely to appear on the measurement scene in the near term future are reviewed.

REAL-TIME PROCESSING OF ACOUSTIC AND OCEANOGRAPHIC DATA AT SEA

by

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ABSTRACT

A data acquisition and analysis system was developed and installed aboard the oceanographic research vessel USNS SANDS (AGOR-6) to provide a capability for comprehensive data analysis at sea, including the ability to perform data processing in real time. The system is built around the UNIVAC 1230 computer. Peripheral equipment permits up to 64 channels of data to be fed to the computer through a 50-kHz A/D multiverter. The processed output is displayed on a high-speed on-line printer-plotter. Four tape decks for data storage and read-out permit continuous operation with no off-line time required for changing tape or data read-out.

The system was used extensively during a $3\frac{1}{2}$ month cruise devoted to oceanographic and acoustic studies on a track from New London, Connecticut, to Hawaii and return. These studies included measurements of the deep scattering layer and reverberation strength. The processing system was also required to be on line continuously for a three-week period for acoustic propagation studies conducted in the North Pacific. Explosive charges and CW transducers were employed as sources. Acoustic signals from a number of sensors were processed in real time to determine ambient noise levels, propagation loss by total energy and peak response techniques, and signal-to-noise ratios. Processing included individual signatures as well as 30 s and 5 min averages.

A unique feature of the data-processing system included telemetering data from FLIP to the SANDS over an RF as well as hard-wire link with the SANDS anchored in 17 000 ft of water and FLIP tethered to it with 1.6 miles of polypropylene line.

This extended period at sea proved highly successful and demonstrated the desirability of at-sea data processing by permitting scientists aboard ship the opportunity to collect, process, and evaluate results during the course of the experimental exercise.

A CONVERSATIONAL PROCESSING SYSTEM OF ACOUSTIC DATA FOR USE ON LAND AND AT SEA: SPADA

by

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The purpose of the Sound Propagation Data Analyser (SPADA) is to perform pre-analysis and analysis operations on digital and analogue data recorded at sea for underwater sound studies. Its tasks can be described as follows:

- Data acquisition
- Various types of data display
- Data editing
- Preserving data on magnetic tapes
- Data analysis.

SPADA is not just a simple instrument, it consists of a mini-computer system to which certain devices are attached, and is controlled by a sophisticated software package.

The functions to be performed by the SPADA are selected by the operator through an interactive terminal consisting of a keyboard and screen. Parameters needed during processing and certain operator's decisions may also be requested through this terminal. Should a device within the SPADA malfunction, the operator has the possibility of interrupting any process.

The aim of this paper is to give a summarized description of the structure and features of the SPADA.

1. SPADA HARDWARE SPECIFICATIONS

The SPADA is based on the use of a mini-computer in order to minimize the cost of the hardware and to facilitate the transport of the computer between shore and ship.

After a careful study of a large number of mini-computers, we felt that the Hewlett Packard 2116B computer would suit our requirements even though other computers that are faster and more powerful in hardware or software aspects do exist. Our decision was mainly based on the fact that the HP computer is particularly suited in computational power and input/output flexibility for measurement application, i.e., voltmeters and scanners, which are standard HP peripherals. It was not necessary to choose a military version of the computer as its specifications for environmental temperature and humidity were adequate for use on board our research ship. Furthermore, apart from a few restrictions, the software supplied by HP fulfilled our requirements.

The availability of HP's Fourier Processor was most attractive to us, particularly the hardware-wired version recently announced.

Figure 1 demonstrates the HP configuration chosen for the realisation of the SPADA; this block diagram does not, however, show the peripherals used for the oceanographic data acquisition i.e., data logger etc.

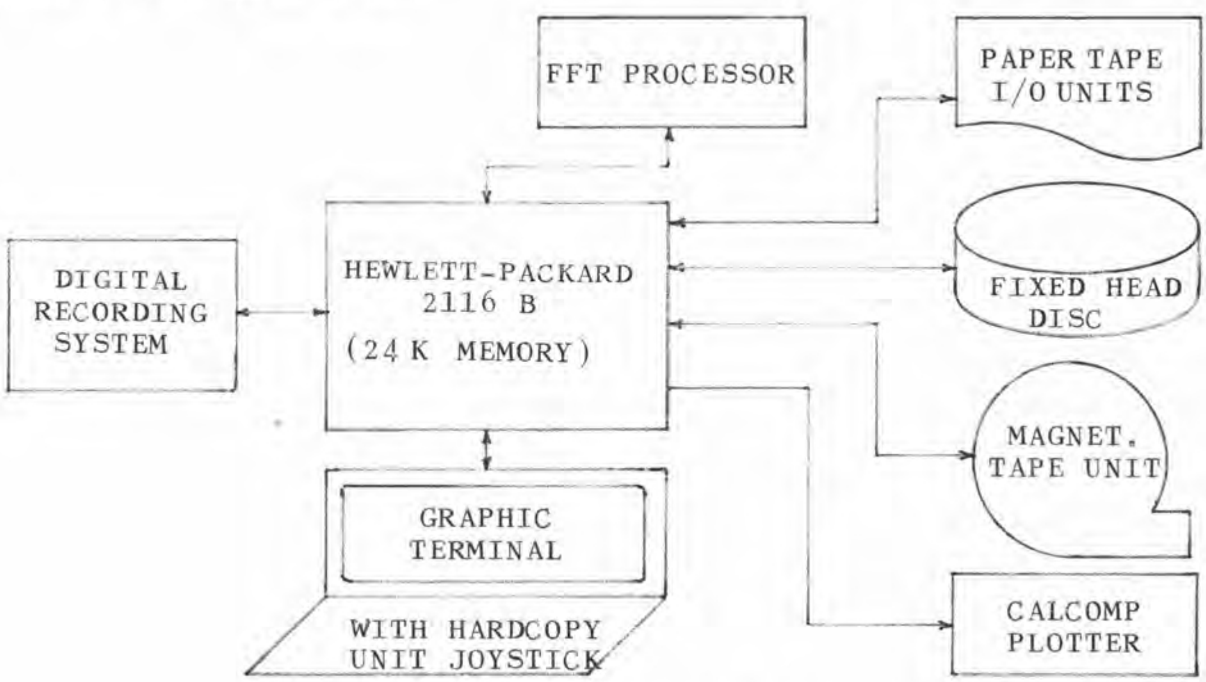


FIG. 1 SPADA CONFIGURATION

Table 1 describes the specifications of all the units shown in Fig. 1.

TABLE 1

Unit	HP Number	Specifications
Computer HP 2116B		Memory : 24 K (extendable up to 32 K)
		Wordsize : 16 bits
		Cycle Time : 1.6 μs
		Options : Two Direct Memory Access Channels with a total transfer rate of 625 Kwords/s
		Extended Arithmetic Unit
		Power Failure Restart Option
		Memory Protect Option
Paper Tape I/O Units		
Punch	HP 8100A	Speed : 75 characters/s
Reader	HP 2758	Speed : 500 characters/s
Fixed-Head Disc	HP 2771A	Maximum Size : 737 Kwords
		Transfer Rate : 176 Kwords/s
		Average Access Time : 17.4 ms
Magnetic Tape Unit	HP 7940	Format : NRZI
		Density : 800 bpi
		Speed : 37.5 ips
		Rack mountable
	HP 3030	Format : NRZI
		Density : 200, 556, & 800 bpi
		Speed : 75 ips
Calcomp Plotter Model 565		Speed : 300 steps/s
		Resolution : 0.01 in
		Plotting Width : 11 in

TABLE 1 (Cont'd)

Unit	HP Number	Specifications
Graphic Terminal Tektronix T4002		Interfaced via HP TTY-Interface
Display Unit with Terminal Control Character Generator		Bi-stable Storage Tube Screen Size : 15.2 cm x 21 cm Contrast Ratio : 6:1 Display Capabilities : Graphics : 1024 x 1024 address points 1024 x 760 viewable points Modes : Incremental Point Linear Interpolation Alphanumerics : 39 lines of 85 characters 2 size characters Speed : 5000 char/s
Interactive Graphic Unit (Joystick) T4901		Crosshair Cursor
Hardcopy Unit T4601		Paper : Dry Silver Paper (5¢ per copy) Time per copy : 11 to 18 s Copy size : 8.5 x 6 inch up to 8.5 x 14 inch.

The following few comments are dedicated to the graphic terminal which is one of the two units not supplied by HP; the other unit being the High Density Digital Recording System (DRS) developed by SACLANTCEN.

As the graphic terminal with its interactive units is the operator's central means of controlling the SPADA operations, a rapid and efficient information exchange is required between man and computer. As this had to be achieved without overloading the computer's power we chose the Tektronix Computer Terminal T4002, since its display unit consists of a direct-view storage tube.

The advantage of a storage tube is the elimination of a separate refreshing memory and of the computer instructions to keep the computer busy in refreshing the screen. On the storage tube the data is written only once at a rate of up to 2000 characters per second. The entire communication interaction is achieved through the data entry keyboard and the Tektronix T4901 Interactive Graphic Unit.

Table 1 does not give the specifications of the HP Fourier Processor and the Sound Propagation Digital Recording system as these units are fully described in the presentations by R. Seynaeve and A. Barbagelata respectively.

The interface of the Digital Recording system to the HP computer has been designed by A. Barbagelata using two standard HP Microcircuit Interface cards (HP 12566A). One of these cards is used for the transfer of data words and counter-track words to the computer, which is based on the use of Direct Memory Access channels. The data words contain a four-bit identification tag, in order to facilitate the necessary unscrambling procedure that has to follow everytime data acquisition is made. The second interface card is used for the remote control of the digital recording system.

2. CONCEPT OF THE SPADA SOFTWARE

The software of the SPADA consists of computer programs that control all implemented peripherals and which activate and monitor the data acquisition, the data display, the editing procedure and analysis functions.

In order to achieve a high flexibility of the SPADA and to meet the user's exact requirements the program set had to be organized as a modular system; each module being activated by the operator, by the preceding modules, or by the real-time clock. Furthermore, some acquisition of oceanographic data had to run in real-time concurrently with the SPADA functions. As only a sophisticated operating system could combine all our requirements we decided to implement the HP supplied Real-Time Executive system as the general operating system.

2.1 HP Real-Time Executive System

The main features of this system are listed in Table 2.

TABLE 2

Multi-programming Capability	:	Interleaved Execution of Programs
Simultaneous I/O Operations	:	I/O Operations performed concurrently with executing programs
Foreground and Background Processing		
Complex Real-time Software, including I/O drivers for all units shown in Fig. 1 except for the FFT-Processor and the Digital Recording System	:	HP Assembler Compilers for Fortran II, IV and ALGOL Editor Loader Library with Plotter routines
Flexible Program Priority Structure	:	Up to 95 priority levels.
Modular System Organisation	:	System configuration on user's requirements
Plug-in Adaptability	:	Interfacing of peripherals simply with plug-in cards.

Figure 2 shows the control functions and the information flow in the Real Time System. Furthermore it demonstrates that the system can be taylored according to the user's requirements with respect to his hardware configuration and his software modules.

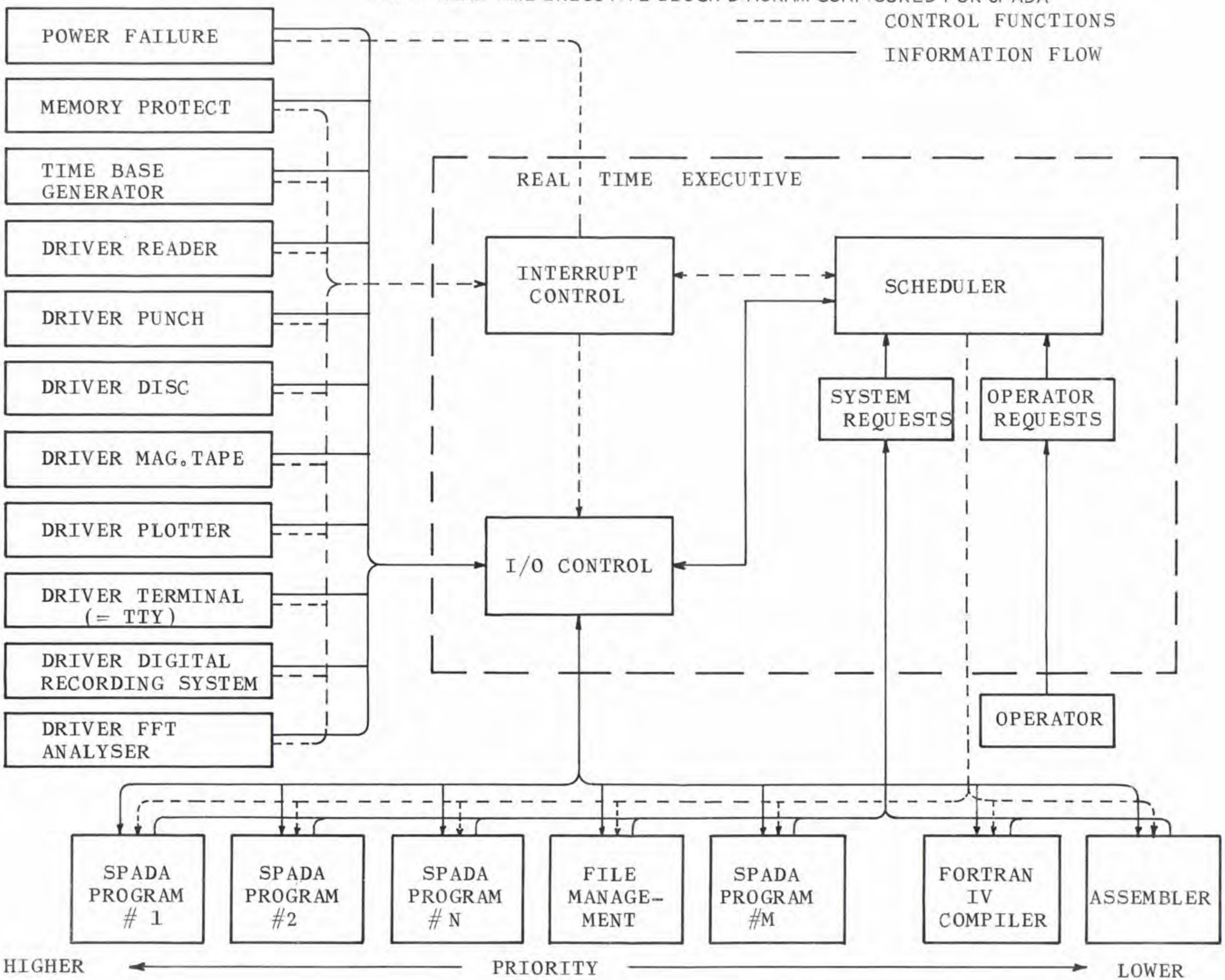
In order to complete its description the following summary is given on the defects of the Real Time Executive:

(1) The response time of the RTE to any type of interrupt is too long — more than 1 ms. Hewlett Packard recommends the following methods to avoid problems in this respect:

a. The use of the DMA even in cases where the transfer rate is around 1 kHz.

b. The priveleged interrupt option decreases the response time to 100 μs, but excludes the use of the DMA.

FIG. 2 REAL TIME EXECUTIVE BLOCK DIAGRAM CONFIGURED FOR SPADA



c. The suspension of the interrupt system during the whole transfer for transfer rates that need DMA and response times of less than 100 μs. That is, no interrupt may be processed during the transfer, not even the time-clock interrupts and therefore the duration of the transfer has to be measured. The clock has to be updated by triggering in a faster rate than its usual rate of 10 ms. This method has to be used for data transfer from the Digital Recording System.

(2) A file management for files on discs and magnetic tapes is missing. We have extended the RTE by a file program but because of its low speed and schedule problems it only permits the filing of background programs.

2.2 Connection of SPADA Peripherals to the Real Time Executive

Since the SPADA uses HP standard peripherals it was only required to connect SACLANTCEN's Digital Recording System to the Real Time Executive and to foresee the needs for the conversational software of the FFT Analyser, in order to operate it under the RTE. The Computer Section has now provided a connection between the Time Series Analysis system and the SPADA system.

The driver for the Digital Recording System (DRS) has the following purposes:

High-speed data transfer from the DRS to the disc.

Input of counter-track numbers.

Remote control of the tape recorder, i.e.

rewind
fast forward
stop
reproduce
record

The counter-track input uses one DMA channel, the tape movements are interrupt controlled.

Two important factors of the data transfer are that the transfer rate should be 286 Kwords/s and the required storage medium should have the capacity for 600 Kwords. Let us consider the available computer storage possibilities where data can be transferred during an experiment. We can have core memory, disc, and computer magnetic tape. Now considering our above mentioned requirements it can be seen from Table 3, referring to 16-bit words, that only the last system will completely satisfy our needs.

Table 3

	Word Rate w/s	Word Capacity K
Core	600 000	32
Disc	150 000	700
Mag Tape	30 000	12 000
Five-channel Recording System	286 000	1 000 000

A fixed-disc had to be implemented to enable the processing of the data by computer. However, the disc has the disadvantage in that the input transfer rate has to be reduced by a factor of two as the disc is too slow. This means that using a disc memory we can perform on-line data acquisition on only two of the five channels. However, all five channels are recorded on our tape recorder, and if we want to have the complete set of signals on the disc we must play back the tape at half speed so dividing the word rate by two.

It is foreseen that in the near future the discs will be replaced by new types of memories that will compete in price with discs and will have the advantage of a faster access time which will, therefore, exclude recording onto magnetic tape.

In order to use the full transfer rate of the disc, the writing onto the disc had to be synchronized with the data input from the DRS. The number of words to be loaded into every disc track had to be equal to the number of words inputted during the disc rotation. It, therefore, follows that about 15% of the space on disc is wasted, but the full disc speed is used.

The start of the data transfer is either determined by its position on the tape (counter track) or it has to be found by means of a level detector. In this case the data transfer continuously cycles on the disc up to the moment the voltage level is reached.

The testing of the driver is rather tedious, because any change in the driver requires a new configuration of the RTE (time required around 30 minutes). You may remember that we had some difficulties during our demonstration when at times the whole system blocked; this trouble was due to a software error.

2.3 General Layout of the SPADA Program System

The heart of all SPADA programs is the program "SPADA" which displays a "menu" of all the available functions in the system. This menu has an open end and therefore may be easily extended according to new requirements.

Upon the operator's decision a certain operation is initiated and since such operations are composed of relatively small modules these have to schedule each other automatically according to the logic of the operation. Every activity terminates by scheduling the "SPADA" program again. The function STOP terminates the whole SPADA system. Figure 3 shows the logic of this concept.

3. EXAMPLE FOR THE USAGE OF THE SPADA

Our aim is the acquisition of the data onto a disc, inputted from the Digital Recording System. The data, produced by a pistol shot,was recorded on the DRS tape and simultaneously transferred via the computer onto the disc. The results are shown on the screen of the terminal. The operator may manipulate these data in order to select an interesting part of the signal for further analysis.

Up to the time of this conference, we have not been able to apply the FFT-Processor to the selected signal. In the meantime, a two-directional link between the SPADA and the FFT Processor has been realised.

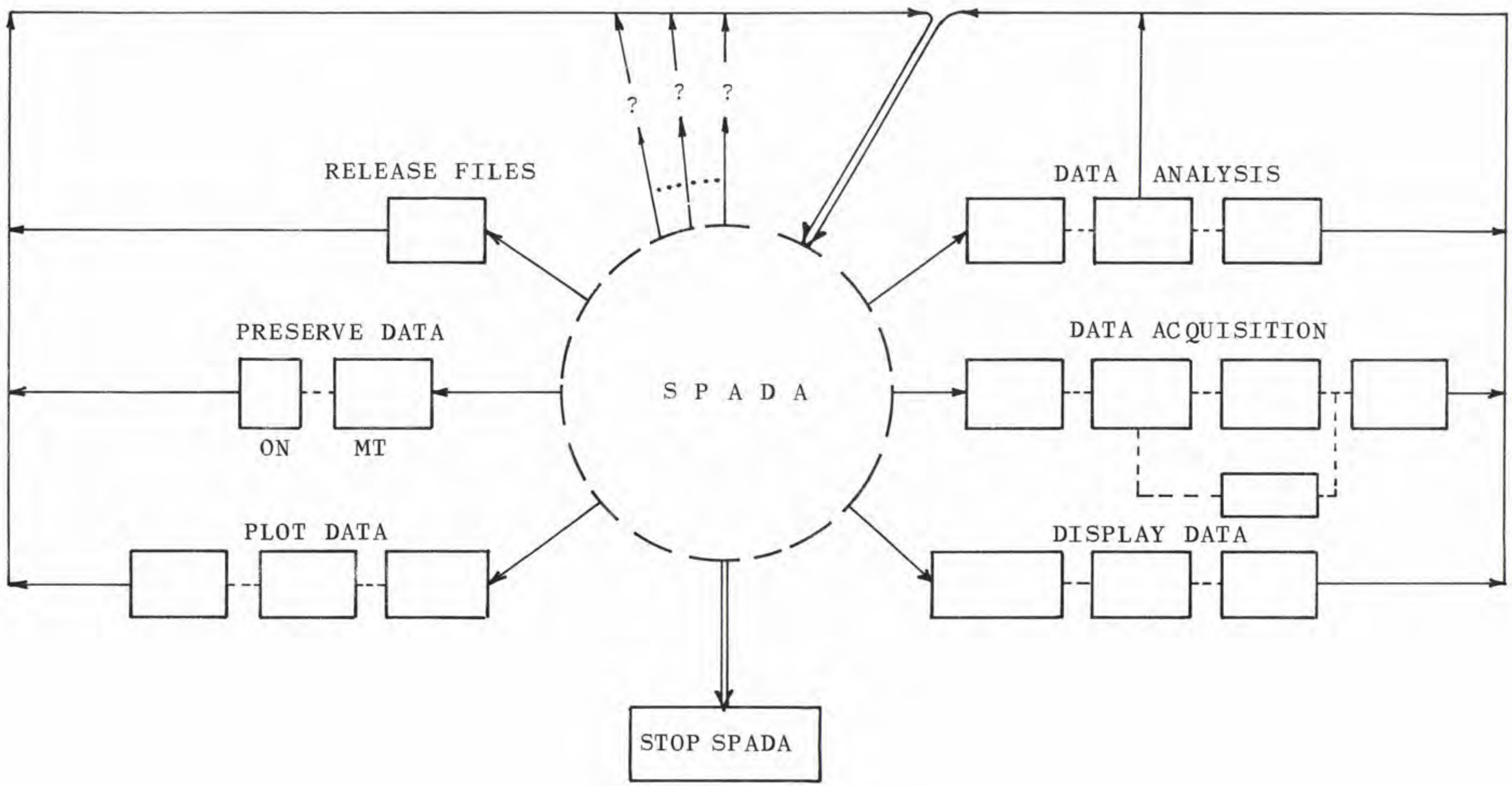


FIG. 3 GENERAL TEXTURE OF THE SPADA SOFTWARE

The following represents a sequence of screen hard copies, which we used to activate the described operations. Generally, in the upper left-hand corner of the screen, the computer displays the operator's previous decisions.

I

```
ON SPADA
```

COMMENTS: This command initiates the SPADA system.
The available function menu is displayed.

II

```
                              SPADA

    SOUND PROPAGATION DATA ACQUISITION AND ANALYSIS SYSTEM
              SELECT BY TYPING TWO CHARACTERS

  AN = ANALYSIS
  DA = DATA ACQUISITION
  DS = DISPLAY FILES
  LA = LABEL MAGNETIC TAPE
  MT = TRANSFER TO COMPUTER MAGNETIC TAPE
  PL = PLOT FILES
  RE = RELEASE DISC FILES
  ST = STOP SPADA

DA
```

COMMENTS: The menu can be extended to implement new functions.
The operator has selected "Data Acquisition" by typing "DA".

III

DATA ACQUISITION

OPERATION MODE
SELECT BY TYPING TWO CHARACTERS

NS = NEW OPERATION SEQUENCE
RS = REPETITION OF PREVIOUS OPERATION

NS

COMMENTS: If the operator activates the data acquisition modules the first time, he has to specify the data acquisition mode. Afterwards he can repeat it under the same conditions.

IV

DATA ACQUISITION

DATA SOURCE
SELECT BY TYPING TWO CHARACTERS

DF = DIGITAL RECORDING SYSTEM OFF LINE
ON = DIGITAL RECORDING SYSTEM ON LINE WITHOUT M.T.
OT = DIGITAL RECORDING SYSTEM ON LINE WITH M.T.
AD = A/D CONVERTER

OT

COMMENTS: ON and OT are the modes that operate at the full speed of the DRS. Less than 5 channels may be transferred to the computer. DF operates it at half the speed. The A/D data acquisition module is not available yet.

V

```
DATA ACQUISITION
DRS ON LINE
                        TAPE CONFIGURATION
                  SELECT BY TYPING TWO CHARACTERS

     NT  =  NEW TAPE CONFIGURATION

     PT  =  REPETITION OF PREVIOUS CONFIGURATION


NT
```

COMMENTS: The system has to know once, the environmental conditions during the experiments.

VI

```
DATA ACQUISITION
DRS ON LINE
                        CONFIGURE TAPE

 RANGE OF SAMPLING  48 KHZ  24 KHZ  12 KHZ
 HYDROPHONE NAMES NOT PERMITTED   AA  XX

 CHANNEL = 1
            HYDROPHONE = 1
            SAMP.FREQ. = 48
 CHANNEL = 2
            HYDROPHONE = 2    HYDROPHONE = 3    HYDROPHONE = 4
            SAMP.FREQ. = 12   SAMP.FREQ. = 12   SAMP.FREQ. = 21
 CHANNEL = 3
            HYDROPHONE = 5    HYDROPHONE = 6    HYDROPHONE = 7    HYDROPHONE = 8
            SAMP.FREQ. = 12   SAMP.FREQ. = 12   SAMP.FREQ. = 12   SAMP.FREQ. = 12
 CHANNEL = 4
            HYDROPHONE = 9    HYDROPHONE = 10
            SAMP.FREQ. = 24   SAMP.FREQ. = 24
 CHANNEL = 5
            HYDROPHONE = 11
            SAMP.FREQ. = 48
```

COMMENTS: The computer asks the operator which hydrophones are recording on the different channels. The possible sampling frequencies are 48 kHz, 24 kHz or 12 kHz per hydrophone. The computer controls the configuration very well: the maximum sampling frequency per channel is 48 kHz, the names of the hydrophones must be unique.

VII

```
DATA ACQUISITION
DRS ON LINE
                         TRANSFER SELECTION

 AVAILABLE HYDROPHONES ON CHANNEL  1    1
 AVAILABLE HYDROPHONES ON CHANNEL  2    2   3   4
 AVAILABLE HYDROPHONES ON CHANNEL  3    5   6   7   8
 AVAILABLE HYDROPHONES ON CHANNEL  4    9   10
 AVAILABLE HYDROPHONES ON CHANNEL  5    11

 SELECT BY TYPING HYDROPHONE NAME AND TERMINATE BY  XX


 HYDROPHONE  1
 HYDROPHONE  XX
```

COMMENTS: The available hydrophones on each channel are displayed in order to facilitate the choice of the hydrophones to be transferred. If the data acquisition operates the DRS in ON-Line mode, the computer accepts only the transfer of up to two channels.

If the operator has already specified one of the operation modes from IV to VII, he is able to repeat the data acquisition for an undetermined time without re-typing IV to VII.

VIII

```
DATA ACQUISITION
DRS ON LINE

                    TRANSFER START
             SELECT BY TYPING TWO CHARACTERS

        CT  =  COUNTER TRACK NUMBER
        EX  =  EXTERNAL PULSE
        LD  =  LEVEL DETECTOR

LD
```

COMMENTS: The mode of controlling the transfer start might differ from event to event. It has to be given every time. Since we want to record the data, the level detector determines the start.

IX

```
DATA ACQUSITION
DRS ON LINE
                    LEVEL DETECTOR

SELECTED HYDROPHONES ON CHANNEL   1   1

        ENTER TRIGGER LEVEL IN MILLIVOLTS       5ØØØ
        ENTER TRANSFER LENGTH IN MILLISECONDS   34Ø
        ENTER EVENT CODE   SP2Ø71
```

COMMENTS: The trigger level is requested and the length of the transfer.

Every event has to have an identifier of up to 6 characters.

This identifier permits the access to the data by all modules of the SPADA. If the transfer is controlled by the counter track, then the counter-track number should be requested instead of the trigger level.

After having specified the acquisition, the data transfer to the computer and the recording onto the tape of the DRS are initiated. The transfer runs in cyclic mode on the disc up to the arrival of the trigger level. One disc track before the level is preserved and the last cycle is completed.

If the transfer is controlled by the counter track, the tape is positioned in front of the given counter track and only one disc transfer is executed.

If the transfer and the necessary unscrambling procedure are completed, the digital tape is stopped and program SPADA is rescheduled.

X

SPADA

SOUND PROPAGATION DATA ACQUISITION AND ANALYSIS SYSTEM

SELECT BY TYPING TWO CHARACTERS

AN = ANALYSIS

DA = DATA ACQUISITION

DS = DISPLAY FILES

LA = LABEL MAGNETIC TAPE

MT = TRANSFER TO COMPUTER MAGNETIC TAPE

PL = PLOT FILES

RE = RELEASE DISC FILES

ST = STOP SPADA

DS

COMMENTS: The operator may choose any function to continue; in our case he wants to see the result of the transfer.

XI

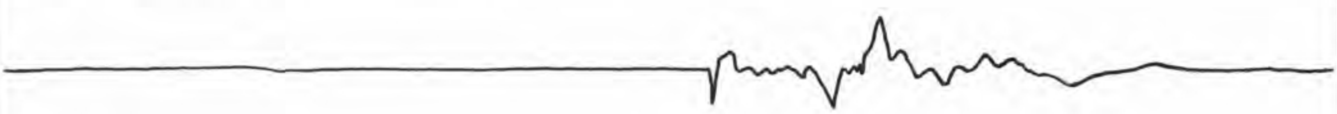
DISPLAY

EVENT = SP 2071

AVAILABLE HYDROPHONES ON CHANNEL 1 1

SELECT BY TYPING TWO CHARACTERS HYDROPHONE NAME
HYDROPHONE 1

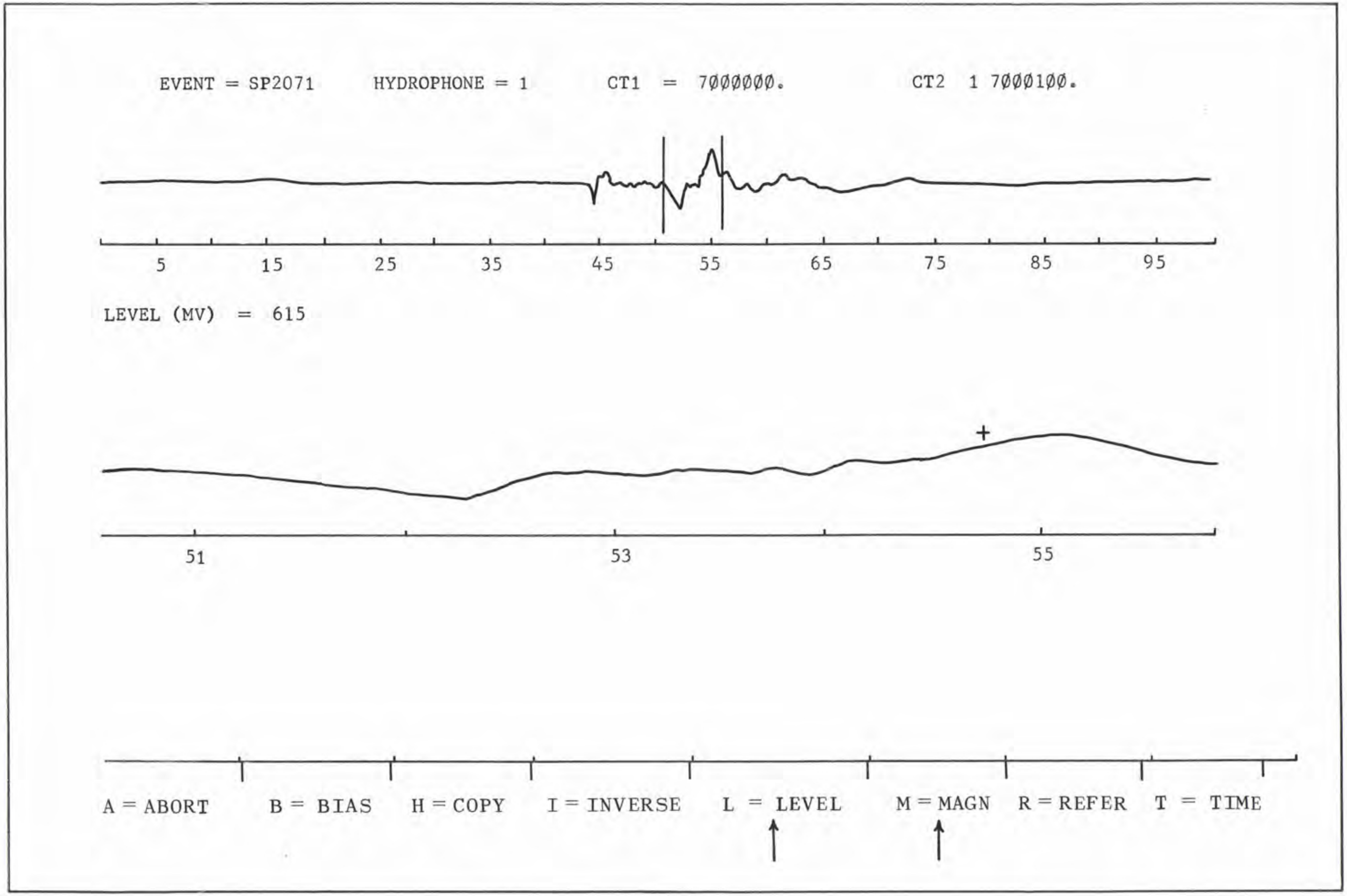
HYDROPHONE XX



1ØØ

COMMENTS: The operator selects the event code, the system displays the names of the available hydrophones. Up to 5 hydrophones can be seen on the screen.

XII


EVENT = SP2071 HYDROPHONE = 1 CT1 = 7ØØØØØØ. CT2 1 7ØØØ1ØØ.
5 15 25 35 45 55 65 75 85 95
LEVEL (MV) = 615
51 53 55
A = ABORT B = BIAS H = COPY I = INVERSE L = LEVEL M = MAGN R = REFER T = TIME

XII

COMMENTS: The selected curve is displayed in the upper part of the screen together with the time base in milliseconds. The software buttons in the lower part of the screen are selected by means of the joystick:

A = ABORT	ABORT the display operation
B = BIAS	Change the 0-line
H = HARD COPY	Copy the momental screen content on the hard copy unit
I = INVERSE	Invert the polarity
L = LEVEL	Measurement of the voltage level at a point selected by the joystick
M = MAGN	Magnify the y-direction up to certain level given by the joystick
R = REFER	Display of the reference curve
T = TIME	Measurement of the length of a time interval

The operator has magnified the time interval <51 ms, 56 ms> in the time direction. The y-amplitude remains unchanged. From now on he may also magnify the curve below in the y-direction as much as he wants. Furthermore, he has measured the level [LEVEL (MV) = 615] of the point on the reference curve indicated by the cross.

For any further manipulation on the curve, an erase of the screen is necessary because no selective erase is possible on a storage tube. In order to avoid unnecessary display times the reference curve is only drawn upon operator's request; it contains indicators that correspond to the position of the magnified curve interval.

The operator after a certain number of manipulations will terminate the display modules by means of the software key A. SPADA is re-scheduled.

Selected parts of the signal could be preserved by typing "MT". Parts of the signal can be Fourier transformed by typing AN.

Finally the demonstration is terminated and we type ST in order to stop the SPADA.

ACQUISITION AND PROCESSING OF OCEANOGRAPHIC DATA BY A SEA-GOING COMPUTER: AN OCEANOGRAPHIC TOOL AND A COMPLEMENTARY FACILITY FOR ACOUSTIC TRIALS

by

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1. HISTORICAL DEVELOPMENTS OF SACLANTCEN SEA-GOING COMPUTER FACILITIES

First of all I would like to describe the development of computer application in data acquisition and experiment control here at SACLANTCEN. When a minicomputer was first used as part of the equipment involved in sea-going experiments it was considered by the majority of us simply as a functional substitute for a larger, more expensive, less useful piece of hardware. This happened about 1968 and at that time this was probably the only practical way of using this class of computer.

A good choice of cheap small machines was already available on the market, but most of them were offered with rudimental sets of software. Systems with much better software were certainly available but their price put them outside the area of interest for minicomputer users. (1800 IBM with TSX, 516 Honeywell with OLERT).

However, after our first experiences a strange thing happened, the scientists who first used this new piece of equipment were impressed by its power, its flexibility, its potential space of application, and the computer system started to grow. A paper-tape puncher, a disc mass memory, a CRT display and other peripherals were acquired. This represented an investment of probably more than double the original value, but there was still a lot of space for growing. A recurrent sentence was "If we add this, we could do much more with our computer".

It very soon became clear that if a small dedicated computer system was convenient for data acquisition, a larger one would be much more powerful and desirable. The problem was what to add: memory, number of peripherals, or speed. All of which would open up new possibilities.

We had the feeling that a more complex system would not be so easy to keep under control as a simple one; that is, for it to be efficiently used to its full capacity so as to obtain the expected returns. When we realized this we decided that the computer to be used on board had to be as large as necessary, but it also had to be controlled by a powerful operating system so as to allow the efficient use of all the available resources. Another possibility was to use several small task-dedicated systems. However, this solution is obviously more expensive since a computer alone is worthless and the required peripherals for each system are much more expensive than the actual computer. The only way to acquire efficient use of the peripherals is to avoid prolipheration of the computer system.

For these reasons when international competitive bids were requested for a sea-going computer we emphasized in our requirements the need for a powerful operating system.

In the meantime (1969) Hewlett-Packard brought onto the market the Real Time Executive. This was probably the cheapest computer offered with the required operating system. The next in price was Honeywell with the 316 and 516 both running under OLERT. The OLERT is much more powerful than the RTE, faster in servicing requests and, from a hardware point of view, the Honeywell computers are more powerful than the Hewlett-Packard. However, since our first experience with a sea-going computer was with a Hewlett-Packard, and since they also provide a wider range of hardware and software connections for the instrumentation, and they also made the cheapest bid, we finally ordered the Hewlett-Packard.

We received the first system in spring of 1970, and the second one in July of the same year.

2. THE COMPUTERIZED ENVIRONMENTAL DATA ACQUISITION SYSTEM

The computer may be used for acoustic oriented application as well as for acquisition and processing of environmental data. At present it handles the meteorological data and the TSD profiler data; automatic navigation recordings and sea state recordings will be added later.

Common to all branches of oceanographic data is the relatively low,but continuous, data rate (24 hours on a routine basis). The result of this is that if the computer is managed by a suitable operating system it is possible that only a small portion of the computer's resources are involved in this task thereby leaving the remainder available for more demanding work.

The environmental data acquisition system is composed of several programs (about 10 at the moment) divided into the following groups:

(a) Data Acquisition: These are very small input/output bound, core resident programs. They are only for inputting data which is buffered in the common area or on a disc. These programs now occupy 7% of the available memory (not taking into account the space used by the operating system) and less than 1% of the computer time.

(b) Processors: These are disc resident programs which are scheduled at regular time intervals for "processing" the collected data. Their product is one or more records in the standard format chosen by SACLANTCEN in the common Magnetic Tape Unit. They only occupy the memory for the time strictly necessary since they are not involved in I/O operations. The computer time presently spent in processors is less than 2%.

(c) Background Programs: These are large programs that are not run on a routine basis but on request, generally processing selected sets of data.

The possibility of running off-line programs in the background add to the data acquisition the facilities of a small scientific computer.

The background area may also be used for the full set of acoustic acquisition and processing programs. The background in the operating system used by us does not mean low priority because priority is an independent parameter, it only means a certain core area allocation.

3. CURRENT STATE OF OUR SYSTEM

The system presently run on board consists of the data acquisition programs and two processors.

3.1 The first two data acquisition programs record voltage measurements from a chain of thermistors and other sensors at two different sampling rates. The measurements are then converted by the first processor, averaged, and the result is the following set of meteorological data:

Dry and wet air temperature
Sea surface temperature
Solar radiation
South/north and east/west wind speed

These data are checked by means of several comparisons so that if one sensor should fail an alarm is immediately given.

The data are also stored in row format in the permanent output file (magnetic tape) in order to allow re-processing at a later date if changes to certain parameters are required.

3.2 The third data acquisition program and the second processor take over the control of the TSD profiler. The frequencies sent by the probe are measured, converted, stored, and checked; alarms are given for several error conditions. Upon request, immediately after the end of the cast, the temperature, density and salinity profile may be computed and plotted using a background program. In the background at the moment we have a program that plots the meteorological data as a function of time.

CONCLUSION

Going back to the basic concepts, what I want to emphasize now is not the fact that in oceanography we use a computer for data logging and for directing an experiment but, with a suitable operating system and with an efficient program organization, it is possible to do a lot of things in this direction leaving most of the computer resources available for other applications. This is not a new practice with large computer systems but it has only recently become feasible with mini-computer systems.

There are two major outcomes from our experiments at sea:

(1) Scientists involved in acoustic trials may also have, at no extra cost, descriptions on magnetic tape of the environmental conditions before, during and after the experiments.

(2) Oceanographers may get data out of cruises as a by-product; they will certainly not all be strictly of scientific value, but they will at least be useful in enriching the files of data describing the environment.

The quality of the data collected by this system will be better than data otherwise collected. Processing will be quicker and easier as time-consuming operations such as editing will not be necessary and the results will be more reliable.

RAY TRACING ON A MINI-COMPUTER

by

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INTRODUCTION

It would appear that most people engaged in solving problems in ray-tracing, use programs written for large computers. These machines commonly have large memory sizes, fast cycle times and large word length. This paper describes how SACLANTCEN has provided a ray-tracing capability on a mini-computer.

Let us firstly define what we mean by a mini-computer. It is typically a machine with a memory size of between 1K and 32K words, each word being of between 12 and 18 bits in length. Cycle times of between 1 μs and 2 μs are the norm of this type of computer. Standard peripherals are a system teletype, photo-reader and paper tape punch. Extra peripherals can be added easily by using plug-in card interfaces; memory expansion is often available so that a user can build up a system to his own requirements.

Reasons for Using Mini-Computer

Now let us consider why we should wish to use a mini-computer instead of a larger, often faster, system.

Firstly, most large ray-tracing programs are very inflexible. Particularly, if the program is of monolithic structure and if a user requires any additions to the program, then major modifications are normally required.

Secondly, complicated data tapes must be produced by the user, [Ref. 1], and if a mistake is made then the error is not found until the job has been run, which depending on the workload of the particular computer, may take several hours.

We have tried to eliminate both these points, as I will describe later.

The third, and possibly most important reason for using a mini-computer is the need to have a ray-tracing capability on board ship during propagation experiments at sea. With this capability available, a scientist on board will be in a better position to decide whether an experiment should continue as planned or be modified because of the prevailing propagation properties of the medium.

Ray Tracing on Board Ship

This latter point was first implemented on an Olivetti 101 desk-top calculator, [Ref. 2], which has a very limited memory size and register length. It was therefore necessary to have the program split into several parts so that memory restrictions were overcome, and to simplify some of the formulae, especially those containing the sines of small angles, to overcome accuracy problems.

Each part of the program was stored on magnetic cards and the output of one program had to be manually input into the next part of the program. Three typical parts of the program could be:

(1) Conversion of depth, temperature, salinity values to a sound speed profile.

(2) Calculation of Snell's constant for a given source depth and initial angle.

(3) Computation of the coordinates of the ray path.

Other cards for the calculation of travel time, path length and intensity made this a comprehensive program but necessitated many hours and much patience to get the desired results.

Last year, however, a number of Hewlett-Packard 2116B mini-computers were purchased by SACLANTCEN. One of these computers is available for shipborne use, and is loaded on board ship as required. This machine has a cycle time of 1.6 μs and a memory size of 32 000 16-bit words. Apart from the standard peripherals we also have a fixed-head disc, magnetic tape, Calcomp incremental plotter and a Tektronix 4002 (visual display device), which is used as the machine-operator interface and fast plotting device.

Its physical size is such that it can easily be transported and loaded on board ship. It is $31\frac{1}{2}$" high, $19\frac{3}{8}$" deep and is mounted in a standard 19" rack. All of its peripherals can also be rack mounted.

We have at present two programs for ray-tracing on this machine. Both are written in Fortran II, which should facilitate easy conversion to most other machines.

The first program is designed to give the scientist on board ship a quick plot of the ray diagram. It has a memory size of 3500 locations and therefore can be run on a basic 4K mini-computer which is fitted with some plot device. It simply calculates the ray paths from a source at a given depth to a given range in constant increment steps of angle, using a sound speed profile divided into layers of constant gradient input on the photo-reader.

The ray diagram is displayed, in our case, on the Tektronix terminal. Using the cursor provided with this terminal, a user can quickly indicate a new source depth on the sound speed profile and obtain a new ray diagram, thus seeing quickly the effect of moving the source on the ray diagram.

The computation time of this program is approximately 60 ms per layer crossing. Using an Epstein profile, as described in Ref. 3, divided into 75 layers, 45 rays from the source and a range of 2500 m, took 4 minutes 10 seconds for computation and plotting.

This program is analogous to some hardware machines which are commercially available solely for ray tracing purposes. The physical dimensions of the equipment necessary, and the time of computation and display, compare favourably with these machines, with the added advantage that the equipment is available for other jobs when ray tracing is not required.

Modular Ray Tracing

The second program being implemented is a comprehensive ray-tracing program which we feel will be easy to modify in the future and easy to run.

It is partly based on the philosophy of the program for the Olivetti machine in that it is of modular structure, each module being a completely self-contained sub-program. We can make an analogy to a loose-leaf book system as shown in Fig. 1, where each 'page' is a separate 'chapter' of the book and all the relevant 'chapters' can be found in the index. For instance, page 1 of Fig. 1 is called 'Fixed RT' and after choosing this option in the index, the fast program described earlier would be called into the memory of the computer ready for execution.

Pages 2 onward are part of the comprehensive program; a user can start from a depth, temperature, salinity profile and calculate a sound speed profile, or alternatively directly input a sound speed profile into the ray calculation page. These profiles can be produced off-line from previous data or on-line from the sensor instruments which are interfaced to the computer.

Other necessary inputs are source depth, bottom depth (a flat bottom is assumed), maximum range and ray information. Rays can either be specified by the user as a set of constant increment angles from the source, or found automatically as the rays from the source which have a vertex at a layer depth in the velocity profile [Fig. 2]. We have termed these rays the 'characteristic' rays, and the user may specify the number of rays to be interpolated between two 'characteristic' rays.

Page 3, the ray calculation page, computes ray coordinates, travel time, path length and intensity at each layer crossing and stores all the information on the disc storage device.

From here, depending on what the user chose from the index (Page 1), the data can be

(a) stored permanently on magnetic tape;

(b) ray diagram plotted;

(c) printed out on line printer;

(d) special plots, i.e. plots of travel time, intesnity, start angle, emergent angle versus range for a given depth, and constant increment intensity contours.

Figure 3 shows the general layout of the system. With this form of system it is hoped that additions and/or modifications to the program should be a simple matter. For instance, Fig. 1 indicates blank pages which we envisage as being addition of continuous gradient sound speed profiles, range dependent ray tracing etc. The flexibility inherent in this system means a user may make his own modifications or replacements and each user can pick a system best suited to his needs.

To ensure that the program is easy to operate by people without experience of either computers or ray tracing, a conversational mode has been employed [Fig. 4]; all data are entered through simple self-explanatory questions and each step in the running of the program is preceded by a set of clear instructions on how to do it.

Figures 5 to 8 show some examples of the output produced by this program.

Using the same Epstein profile as described previously, and all the other data remaining the same, the modular ray tracing took 13 minutes for calculation and display. The greater time as compared to the previous program is due to the greater amount of information that is computed and the file management on the mass storage device that is required.

The size of this program, if considered as a whole, is of the order of 16 000 memory words. However, as it consists of a number of self-contained sub-programs, it is an easy matter to have the program in, say, two or three small parts, where one part automatically calls the next part into the computer memory when necessary. In this way we never use more than 7000 words of memory. This program can therefore be successfully used on a moderate sized mini-computer.

CONCLUSION

Ray tracing is easily implemented on a mini-computer, and can be extended to be a comprehensive program.

For laboratories with only limited computing facilities, and for shipborne use where it is only possible to have a computer installed of small physical dimensions, the programs described provide a powerful tool for the investigation of the propagation properties of the ocean which will satisfy the requirements of most users.

Because of the limited word length available on most mini-computers an accuracy of more than 6 decimal places cannot be expected. Also, computation times are by no means fast when compared to that obtainable with large modern computer systems. If, therefore, we require extra speed and accuracy, we envisage that a modular program like the one described here, with its advantages of flexibility and conversational mode, would be an excellent method of applying ray tracing to a large multi-access machine.

REFERENCES

1. I. Verdoni, "Acoustic Ray Tracing at SACLANTCEN on the Elliott 503 Computer", SACLANTCEN Internal Note No. 260, 1 December 1970.

2. A.Skretting, "Sound Field Computation by Means of Desk Top Computers", SACLANTCEN Technical Report No. 141, 15 March 1969.

3. C.B. Moler and L.P. Solomon, "Use of Splines and Numerical Integration in Geometrical Acoustics", J.Acoust.Soc.Am., Vol.48, 1970, p.739.

RAY DIAGRAM (SOURCE AT 45 m; SURFACE AND BOTTOM REFLECTIONS SUPPRESSED)

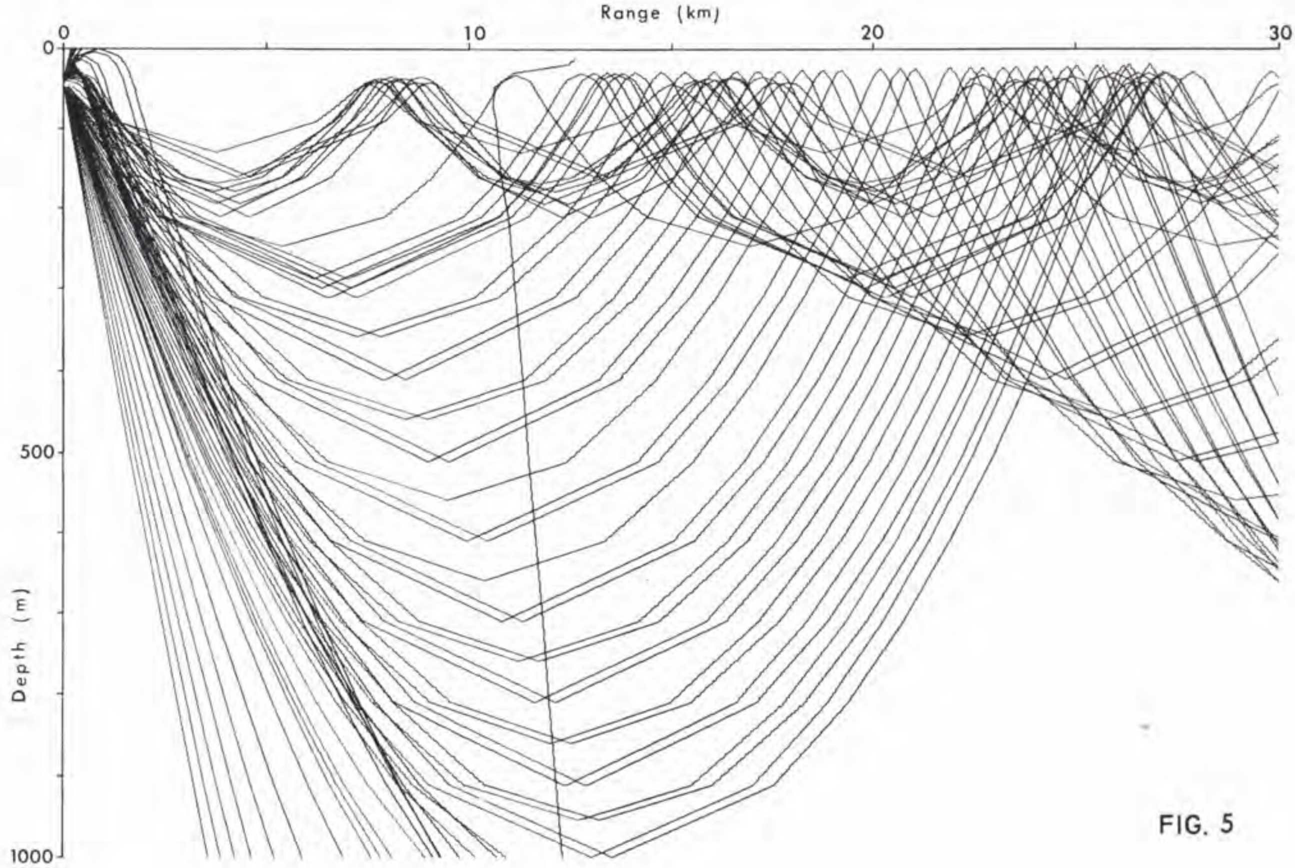

FIG. 5

ANGLE FROM SOURCE vs RANGE
LAYER DEPTH 310 m

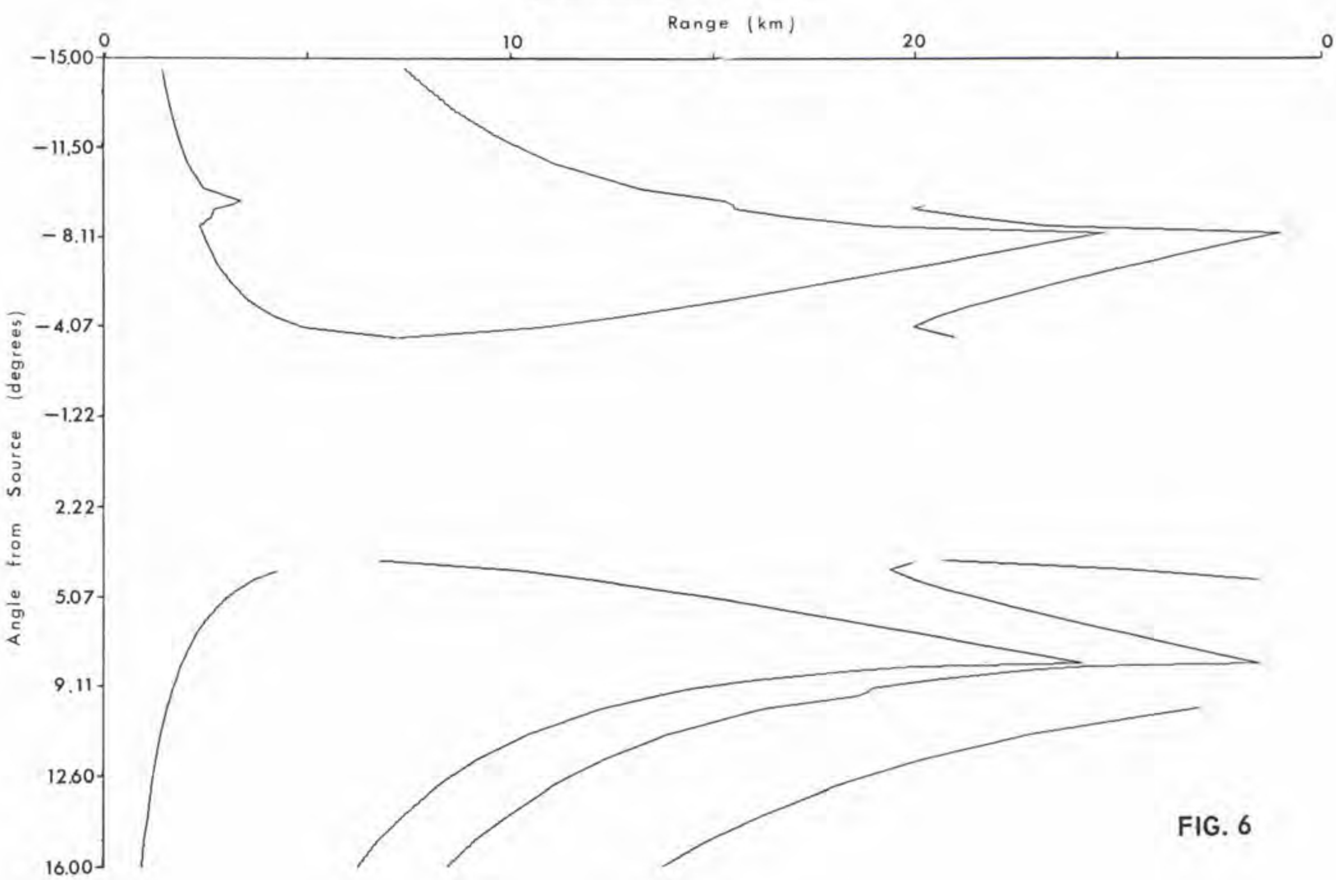

FIG. 6

EMERGENT ANGLE FROM LAYER vs RANGE

LAYER DEPTH 310 m

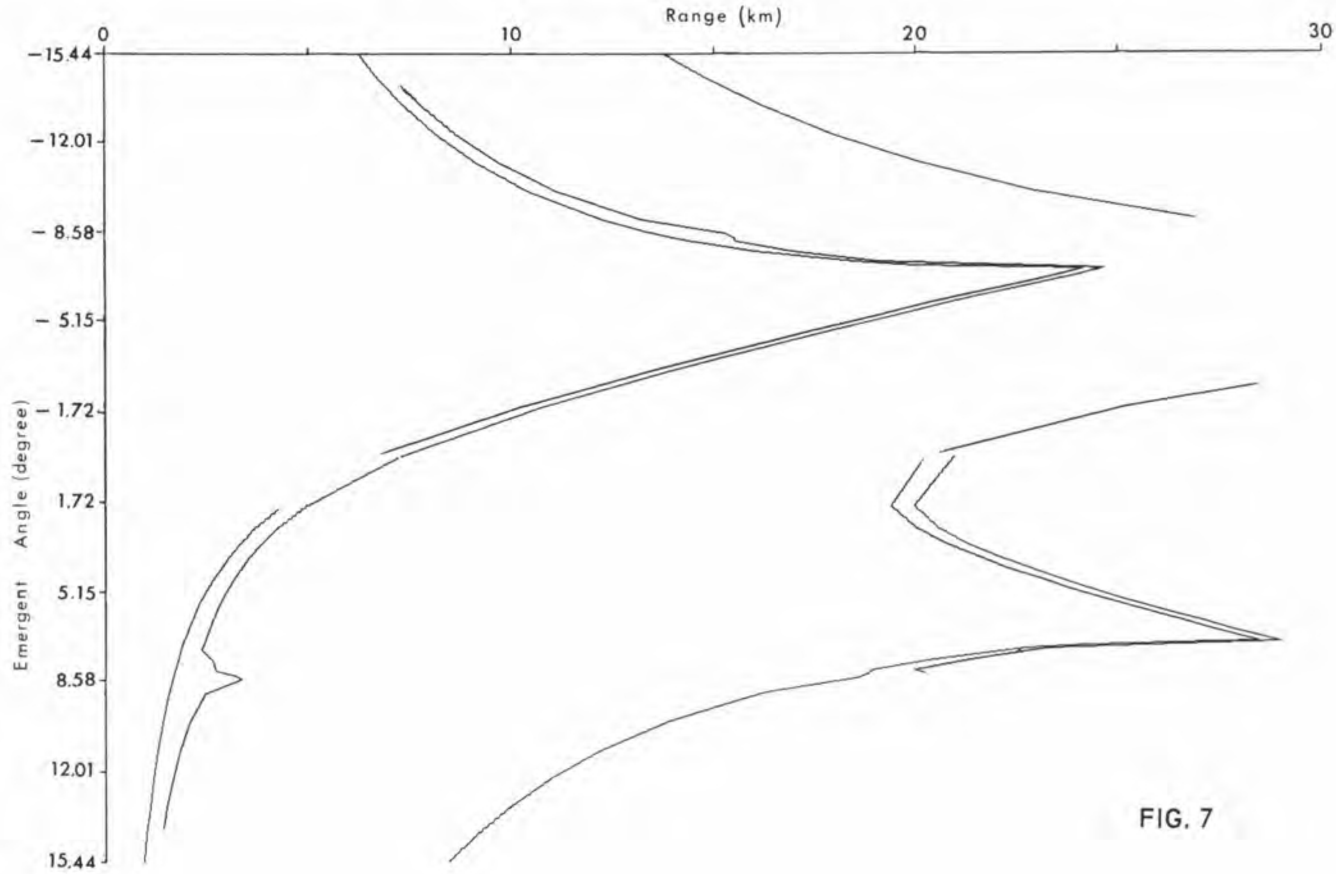

FIG. 7

TRAVEL TIME vs RANGE

LAYER DEPTH 310 m

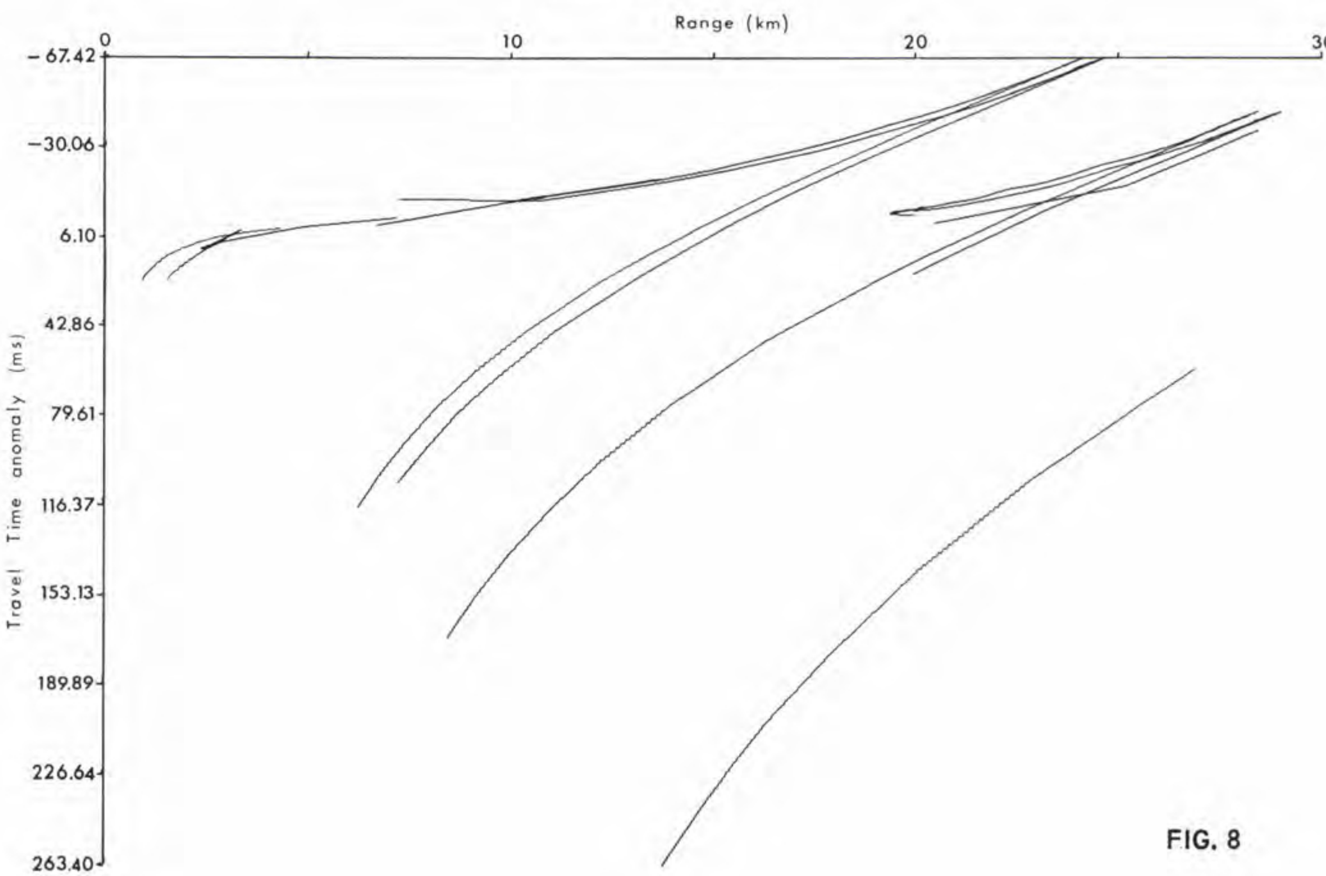

FIG. 8

THE SACLANTCEN INTERACTIVE TIME SERIES ANALYSIS SYSTEM

by

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SACLANT ASW Research Centre
La Spezia, Italy

The purpose of this paper is to describe the new conversational signal processing system which is being developed by the Computer Section at SACLANTCEN. This system, which includes input/output devices, can be used alone or, alternatively, it can be used together with acquisition and preprocessing oriented systems (SPADA and OC Acquisition) as a flexible signal processing module.

It has already been extensively used in various projects and has provided a considerable amount of results which would not have been obtained otherwise, or only at great cost and difficulty. Figure 1 shows the hardward involved.

This facility differs considerably from previous systems in the same field because it is essentially oriented towards an easier communication between the scientist and the computer. It is, therefore, entirely on-line and conversational. It allows the scientist to control it through an application oriented language — quick and easy to learn — provides almost instantaneous results, allows on-the-spot investigations to be carried out with unusual ease and speed. The inputs and outputs of this system are of various kinds and include visual displays, A/D and D/A converter [Fig. 2]. The system can, for example, generate complex sonar waveforms to activate a transmitting transducer, acquire data from a receiving array, process the signals in any programmed way, display the results to the scientist, and file them on some form of digital storage, like disc or magnetic tape. All this in a few seconds; at any given time, any step of the processing can be modified in seconds. In this application the system performs as a general research sonar, whose operation can be varied at will by the scientist and although this is just a good example to illustrate this system, it can operate in many other ways depending on the sort of the data input and on the way it is programmed. It combines the power and versatility of the general purpose computer with the ease of the use and the efficiency of an application oriented software.

The need for a system of this sort has existed for a long time amongst us. It is expected to help the researcher considerably by removing the long delay introduced by program writing, debugging and running with the present scientific computer installation. Also most of the programming used to be lengthy and sophisticated enough to have to be written by dedicated programmers, and this often increased the psychological distance between the researcher and his tool. "Free" investigations were also prohibited because of the high cost or the time required to do them.

The advent of rather cheap mini-computers gave the first opportunity for such systems to be economically feasible. Being mostly designed for process control applications, these computers have just the adequate word and memory size, speed and input/output flexibility for most signal processing applications. Shortly after, one of the first commercial attempts was made by Hewlett-Packard to produce a small general purpose signal processing system, driven by a computer, under the name of "Fourier Analyser 5450". This unit was very successful at the Centre, and it became obvious that the quickest and quite certainly the most efficient way to implement the signal processing facility which was required here, was to adapt, complement and integrate the H.P. unit. A major part of the activity of our team of three has been devoted to that. Through continuous collaboration with the users of our system, we have been able to set up a signal processing facility which has already proved very useful for several research projects.

This system, of course, consists mainly of software operating on our standard mini-computer system, with the help of some dedicated peripherals like control consoles and displays.

Hardwarewise [Fig. 3], the main components of the system are, of course, the computer (HP 2116), and the parts which allow the communication with the user:

Keyboard consoles
CRT displays
Plotters
Two-channel A/D converter
Two-channel D/A converter
Teletype or CRT console

Also included are the usual computer peripherals like paper take reader and punch, disc and magnetic tape.

The system processes time series stored in its memory: the data can be input by blocks up to 4096 words long, via A/D converter, paper tape, disc or magnetic tape. A view of the instrument's keyboard [Fig. 4] gives an idea of the variety of operations which can be executed on the data. To this basic set of operations another set has been added which is controlled by an auxiliary keyboard [Fig. 5]. This set covers more closely the specific needs of SACLANTCEN although one can see that most of the operations are still of rather general use [Fig. 6].

Programming of the system is done by pressing the keys. Simultaneously a listing is produced on a teletype or a memoscope console. The program can be stored and run indefinitely. Program modification is straightforward. The result of any operation can be displayed after the execution which never lasts more than a few seconds. Fast access program and data storage areas are large (700 000 words). Control of external equipment by the system is easy. All these features will probably be better shown during the demonstration after the talk. To give an idea, a typical sonar classification processing including correlations, filtering, spectral analysis, input and output, can be programmed in less than an hour; each processing takes between 6 and 20 seconds depending on the parameters chosen; the resulting curves are available on photographic paper or from a plotter, or can be stored on disc or magnetic tape. The system is connected to the acquisition equipment in a straightforward manner [Fig. 7]. Decisions from the scientist during program execution can be transmitted through the various control units, allowing much interaction. Examples of results are given from Target Classification [Fig. 8] and Oceanography [Fig. 9]. Figure 10 shows processed explosive signals obtained during a joint Target Classification-Sound Propagation cruise. The system has been used as a major monitoring and processing tool in several sea trials and has processed the data presented in several reports.

The system follows strictly all the Centre's computer standards for files and format, and can exchange data with various acquisition/pre-processing systems like SPADA or Oceanography Acquisition.

The system can operate in conjunction with other software like RTE or BCS as long as our standard format has been used for the files; the software can be changed rapidly in and out of the computer core memory from and to the disc, under program control. This is illustrated on Fig. 11. The computer is thus fully occupied by only one software at a time. A drawback of this method, however, is that other operations like low speed data acquisition cannot go on while the signal processing software is in core, and vice versa. But our future systems will solve this problem.

Present Situation - Main Needs [Fig. 12]

We have now reached a level where a comprehensive signal processing system exists which has been adapted to our needs and can be connected on an exchange basis to both RTE — including SPADA — and BCS systems. It is, however, desirable to integrate completely the system into the RTE in order to increase a great deal its capacity for communicating with peripherals and software and to allow simultaneous data acquisition and processing, making it possible for one single computer to take care of all the operations of a large sea-trial. Also, since the system is being used by more and more users for more and more complicated processing a definite need seems to appear for an FFT hardware unit which would increase the overall operation speed by a factor of 20 to 50.

Apart from giving a much better real time performance for the acoustical processing at sea, this unit would also release the CPU from a great deal of special computation and would make the single CPU concept much more workable. The great interest of the present system is that it is conversational, and thus very well adapted for obtaining quick and reliable results under a scientist's control. Not all operations, however, are possible. We have tried, for the time being, to solve users' problem by writing additional special instructions. As a much more powerful and general solution, we are planning to link the Analyser to a general purpose conversational language like Basic. This would solve almost any of the problems currently met in sonar data processing in a very convenient way.

Taking into account our workload in assistance to users, this new system is expected to be available in autumn 1972. In the meantime our present system should be sufficient, after a few more improvements have been made.

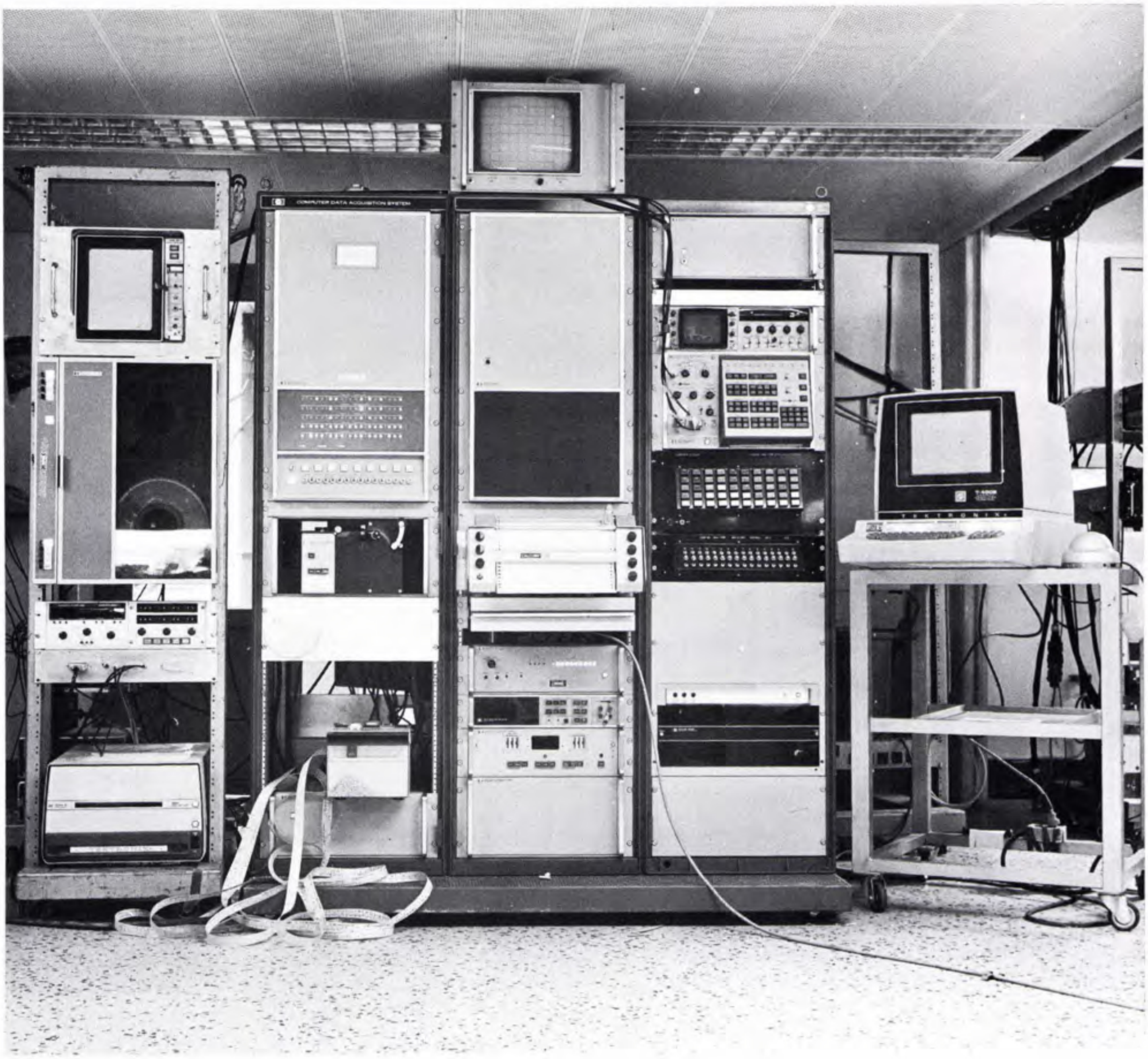


FIG. 1

<u>MAJOR FEATURES</u>

CONVERSATIONAL

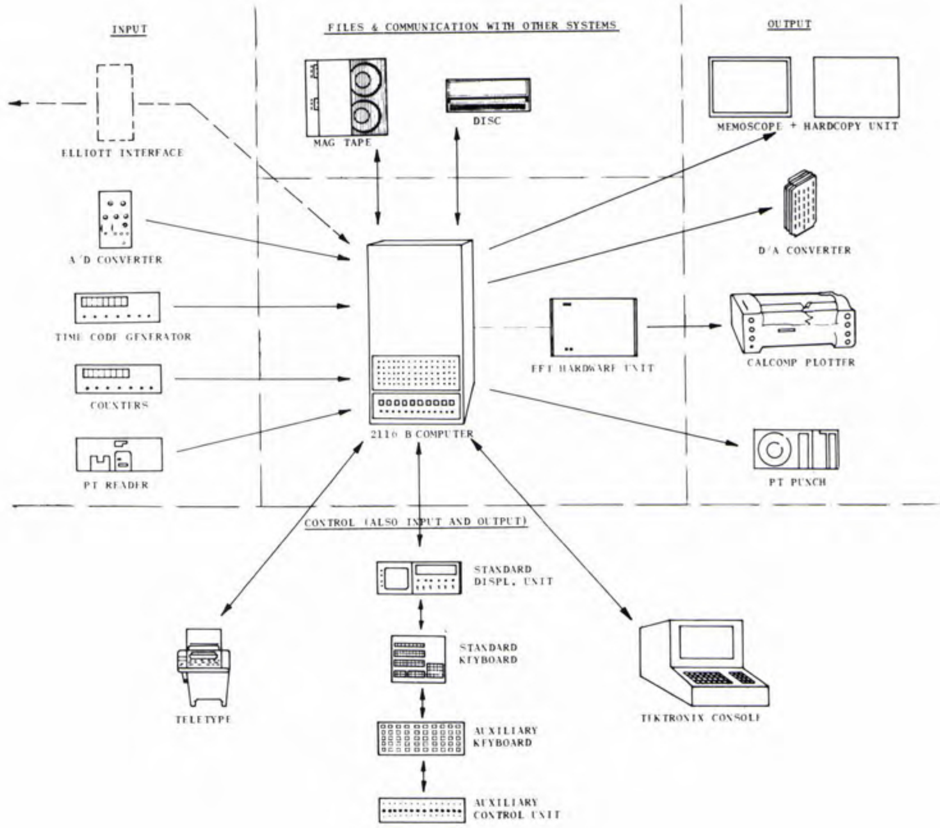
ON-LINE OPERATION

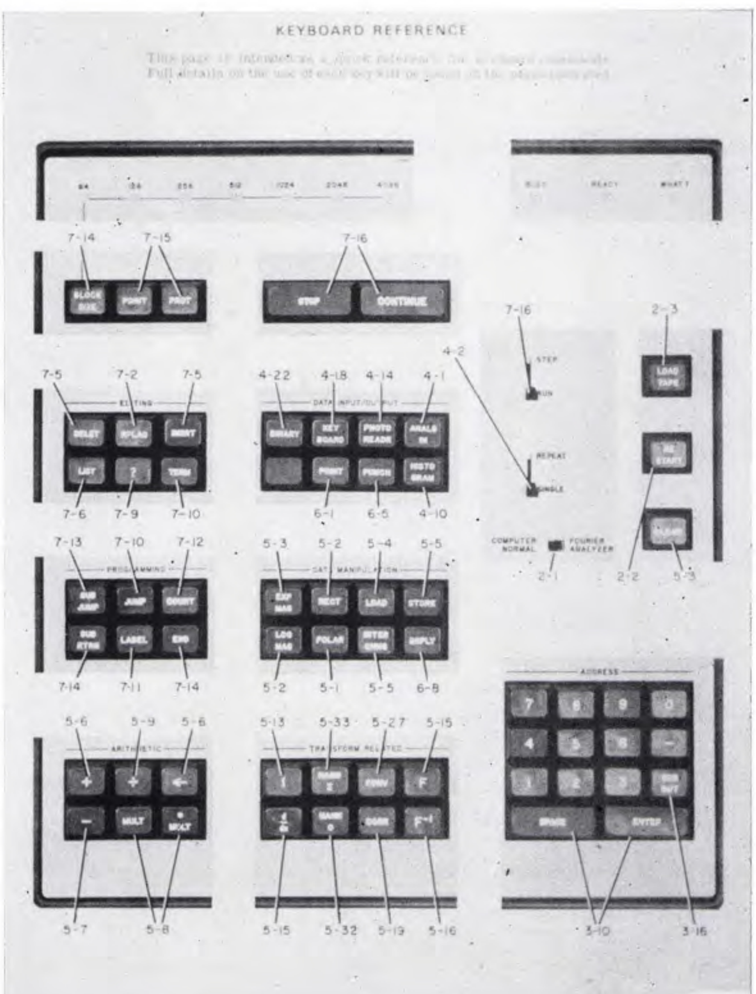
SIMPLE LANGUAGE

ADEQUATE DATA INPUT AND OUTPUT

FIG. 2

FIG. 3


INPUT
FILES & COMMUNICATION WITH OTHER SYSTEMS
OUTPUT
ELLIOTT INTERFACE
MAG TAPE
DISC
MEMOSCOPE + HARDCOPY UNIT
A/D CONVERTER
D/A CONVERTER
TIME CODE GENERATOR
FFT HARDWARE UNIT
CALCOMP PLOTTER
COUNTERS
2116 B COMPUTER
PT READER
PT PUNCH
CONTROL (ALSO INPUT AND OUTPUT)
STANDARD DISPL. UNIT
STANDARD KEYBOARD
AUXILIARY KEYBOARD
AUXILIARY CONTROL UNIT
TELETYPE
TEKTRONIX CONSOLE


KEYBOARD REFERENCE
7-14
7-15
7-16
STOP
CONTINUE
2-3
LOAD TAPE
4-2
7-5
7-2
7-5
4-22
4-18
4-14
4-1
STEP
RUN
REPEAT
SINGLE
RE START
7-6
7-9
7-10
6-1
6-5
4-10
7-13
7-10
7-12
5-3
5-2
5-4
5-5
COMPUTER NORMAL
FOURIER ANALYZER
CLEAR
2-1
2-2
5-3
7-14
7-11
7-14
5-2
5-1
5-5
6-8
ADDRESS
5-6
5-9
5-6
5-13
5-33
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5-15
5-7
5-8
5-15
5-32
5-19
5-16
3-10
3-16

FIG. 4

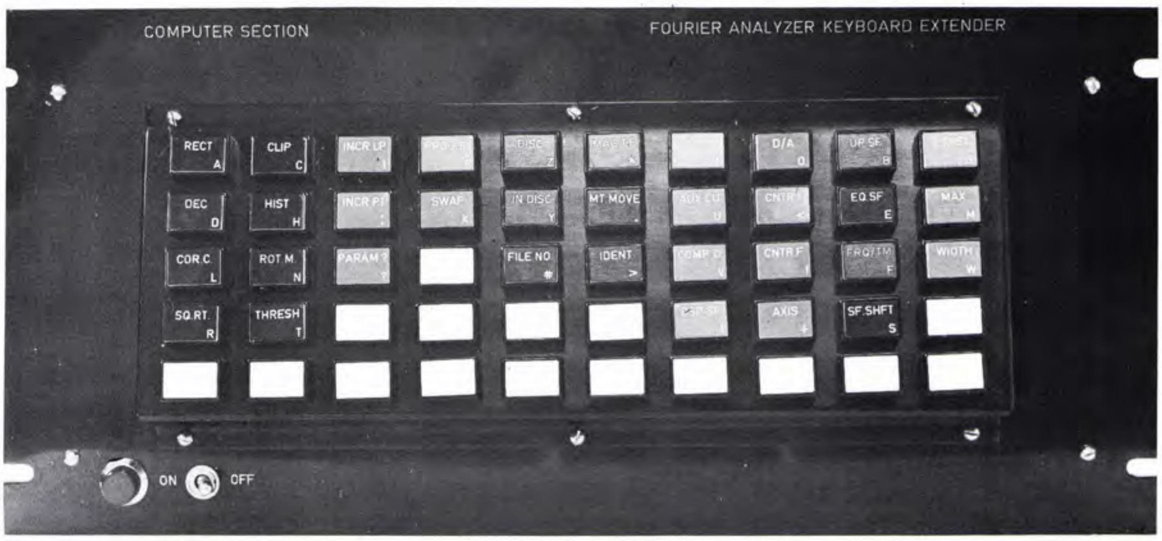


FIG. 5

NEW KEYBOARD

1. DATA MODIFICATION
   - RECTIFICATION
   - CLIPPING
   - DECIMATION
   - HISTOGRAMS
   - THRESHOLD DISPLAY
   - ... ETC ...
2. PROGRAM MANAGEMENT
   - "FOR" STATEMENTS, ETC...
   - PROGRAM AND SUBROUTINES ⇄ DISC
   - SWAPPING

   ... ETC ...
3. FILE HANDLING
   - DISC
   - MAGNETIC TAPE
4. ACCESS TO PERIPHERALS
   - TIME CODE GENERATOR
   - D/A
   - AUXILIARY CONTROL UNIT
   - COUNTERS

   ... ETC ...
5. MISCELLANEOUS

FIG. 6

EXAMPLE OF EQUIPMENT CONFIGURATION
FOR SFC SONAR EXPERIMENT

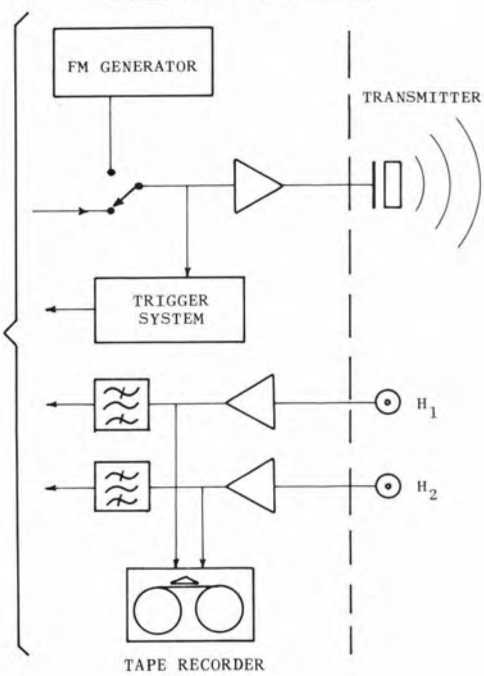


FIG. 7

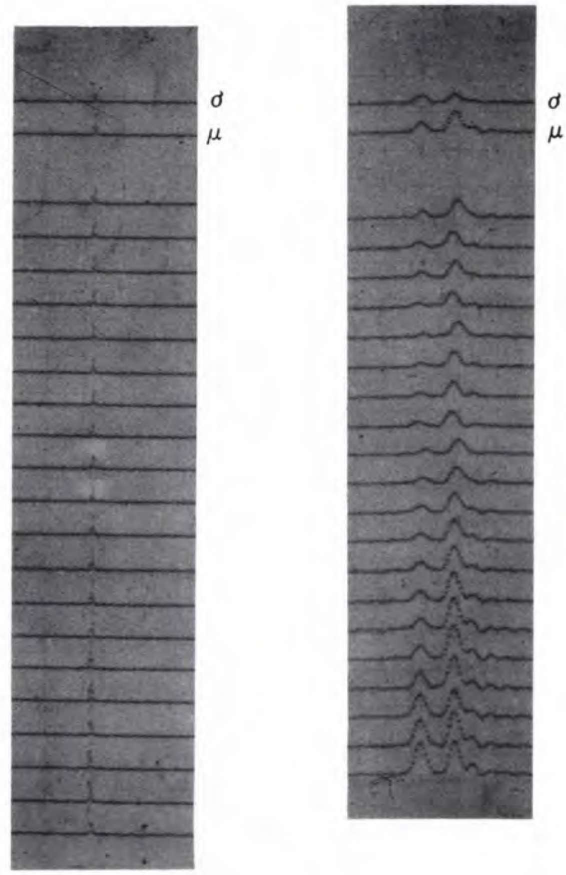

σ
μ
σ
μ

FIG. 8

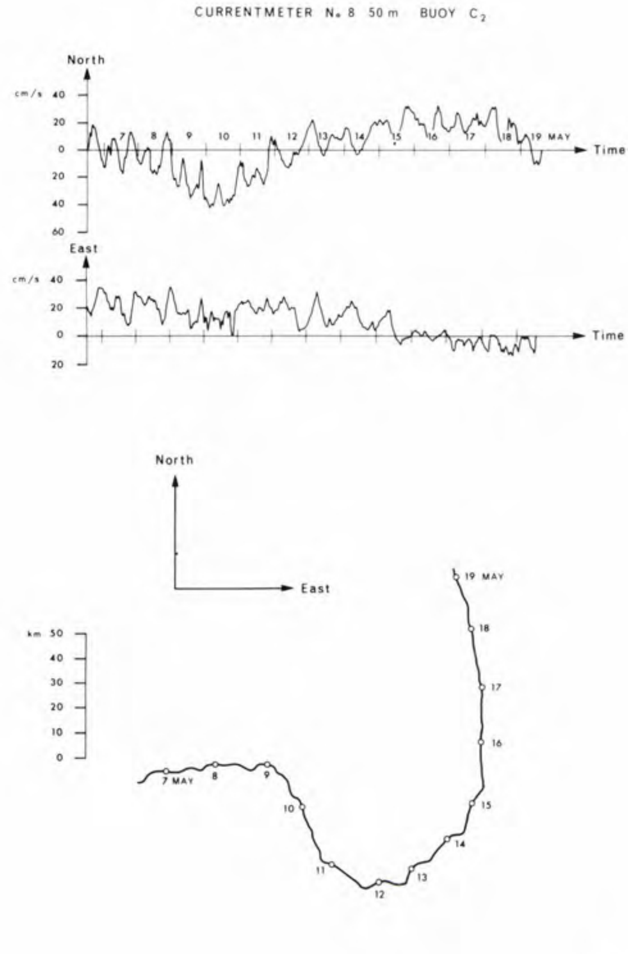
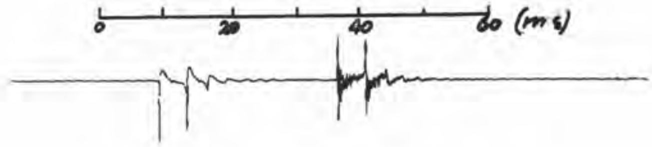

CURRENTMETER N. 8 50 m BUOY C2
North
cm/s
40
20
0
20
40
60
7
8
9
10
11
12
13
14
15
16
17
18
19 MAY
Time
East
cm/s
40
20
0
20
Time
North
East
km
50
40
30
20
10
0
7 MAY
8
9
10
11
12
13
14
15
16
17
18
19 MAY

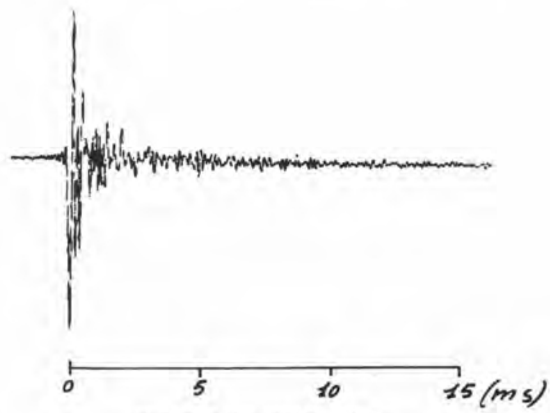
FIG. 9

EXAMPLE OF ON-LINE PROCESSING RESULTS



DIRECT ARRIVALS & SURFACE ECHOES
[EXPLOSION AT 130 m, ARRAY AT 250 m, RANGE 0.73 n.mi]

FIG. 10



DE-CONVOLVED SURFACE ECHO

EXAMPLE OF PROGRAM SWAPPING

STEP 1 - ACQUISITION AND FILING UNDER RTEX

STEP 2 - SWAPPING { RTEX: FROM CORE TO DISC
SIG. PROCESS: FROM DISC TO CORE

STEP 3 - PROCESSING OF FILED DATA BY SIG. PROCESS SOFTWARE FILING OF RESULTS

STEP 4 - SWAPPING

STEP 5 - SPECIAL PLOTTING PROGRAM (RTEX) PLOTS THE FILED RESULTS

RETURN TO STEP 1

FIG. 11

NEXT STEPS

1 INTEGRATION INTO THE RTEX

2 ATTACH BASIC INTERPRETER

3 SPEED UP WITH FAST FOURIER TRANSFORM HARDWARE UNIT

FIG. 12

DIGITAL ACOUSTICAL PROCESSING AT WOODS HOLE OCEANOGRAPHIC INSTITUTION

by

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Hewlett Packard computers were first acquired at the Woods Hole Oceanographic Institution in 1967 for at sea processing of gravity and magnetic data. Since that time seven additional Hewlett Packard of various models and memory sizes have been acquired by various departments. These are used for various purposes from general purpose computing to data acquisition and control. Some of the non-acoustic applications of the Hewlett Packard have been:

1) On-line reduction of navigational satellite data.
2) On-line acquisition and reduction of gravity, magnetics and bathymetry.
3) Merging this geophysical data with navigational data and producing track charts.
4) On-line acquisition and reduction of conductivity, temperature, pressure, and sound velocity data.

The computer is also being heavily used for acoustic processing. The ability to acquire continuous seismic profiling (CSP) data on-line has been achieved and various digital processing techniques are being compared. One simple method which appears promising is the computation of running averages over six or so shots. This process tends to cancel noise which is uncorrelated from shot to shot and enhances the sub-bottom layering. Another program for processing CSP which is under development involves the purchase and use of a Fourier analyser for pulse compression and removal of shallow water reverberation.

Ambient noise data is being processed on the Hewlett Packard. Up to sixteen channels of filtered data from one or more hydrophones are multiplexed and digitized. Data from each channel is continuously sampled at a 850 Hz rate, squared, and summed for thirty seconds. These sums are then punched onto paper tape. In a second pass this tape is read, the values are combined with calibration factors for each channel, and ambient noise levels for each frequency band are typed out. Under development is a processing program which will play back data recorded in a moored buoy to a noise analyser which computes rms noise levels for each of 15 filtered channels. The computer will then sample the analyser, draw plots, and compute statistics on the data.

Data from explosive sound transmission experiments is also being acquired and processed digitally. In an existing on-line program an operator initiates the data acquisition whenever a shot is heard over a loud-speaker connected to the hydrophone. The computer digitizes up to eight frequencies at a 500 Hz rate per channel, squares and sums this data over 20 to 50 points, and writes the sums onto digital magnetic tape for periods up to 30 seconds. In a second pass through the computer the magnetic tape is read, the points are displayed on an oscilloscope, the arrival is manually bracketed by a pair of cursors, and the transmission loss for each frequency band is computed. A third pass is used to plot the data. In a new version of this program an attempt will be made to eliminate pass two by automatically detecting and processing the arrivals on-line.

One of the limiting factors of Hewlett Packard computers at Woods Hole has been the lack of a high speed output device. This should be alleviated somewhat by nine track tape units now on order. However, our experience indicates that a disc storage unit is needed if the full capability of the computer is to be realized.

GENERAL CONCLUSIONS AND RECOMMENDATIONS OF THE CONFERENCE

GENERAL CONCLUSIONS AND RECOMMENDATIONS OF THE CONFERENCE

After the presentations a round table discussion was organized during which all participants expressed their opinion about what had been shown and discussed during the meeting.

Everybody agreed that the papers presented were of great interest and a common agreement was found on the usefulness or organizing also in the future other meetings on the same subject.

With regard to the possibility of a common development of digital analysis techniques, the reactions of the participants were various, but could mainly be divided into two parts. Those working in laboratories where digital analysis techniques were already highly developed expressed a general interest in exchanging information. They were not really interested, however, in developing different kinds of solutions in the immediate future except with regard to some particular and limited applications. On the other hand, participants coming from laboratories where the implementation of new digital analysis techniques were being studied or where an HP 2116B system was already available showed an active interest in the mini-computer systems developed at SACLANTCEN.

In particular, the Danish representative expressed the intention of installing an FFT facility on the HP 2116 computer already available at DDRE and asked about the possibility of having a software exchange with SACLANTCEN.

The Netherlands representative was deeply interested in SACLANTCEN's High Density Digital Recording System and expressed the intention of building a similar system with a view to promoting the possibility of common experiments and exchange of data for the future.

Norway is at an investigatory stage and will keep in mind SACLANTCEN's suggestions when deciding about their system.

The Woods Hole Oceanographic Institution has had an HP 2116 for several years as a shipboard computer. They have no disc, however, and for this reason they are not using the Real Time Executive System. Their representative expressed interest in enlarging the installation in order to have a system compatible with that of SACLANTCEN.

There was a common agreement that a distribution list should be made in such a way that all participants could be kept mutually informed in the future on their progress in the digital analysis field.

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COMCANLANT	1
COMMAIREASTLANT	1
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