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.
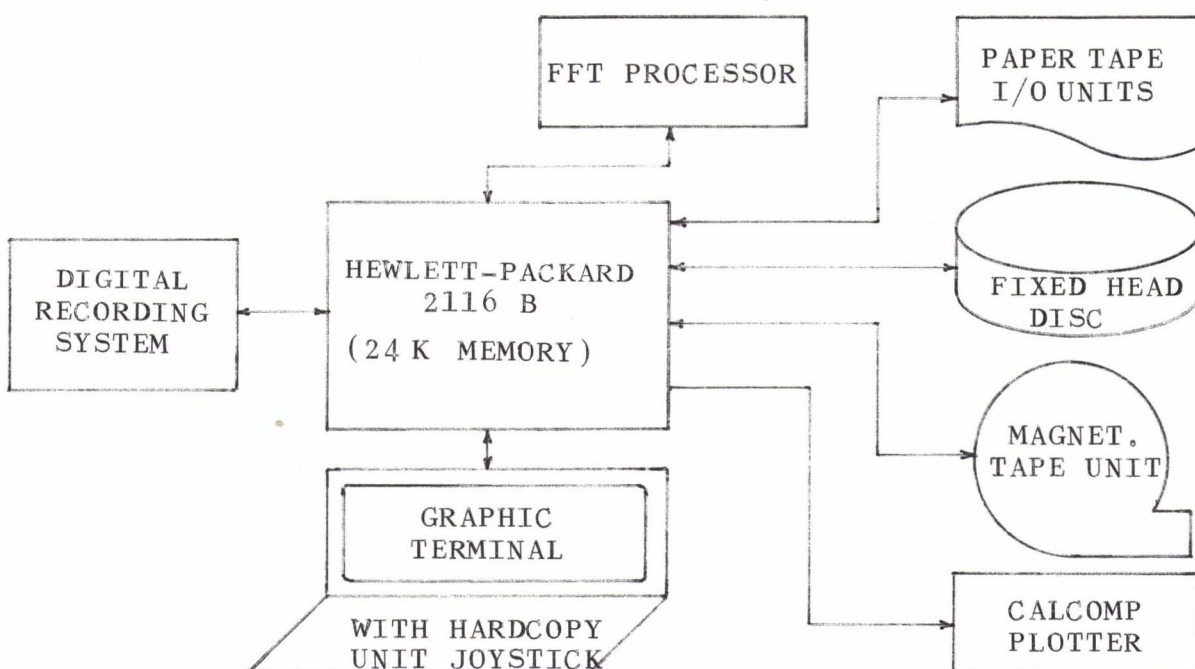
FIG. 1 SPADA CONFIGURATION

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
 	
  Display Unit with Terminal Control Character Generator
		Interfaced via HP TTY-Interface
		
		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
		
		Crosshair Cursor

Interactive Graphic Unit (Joystick) T4901 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
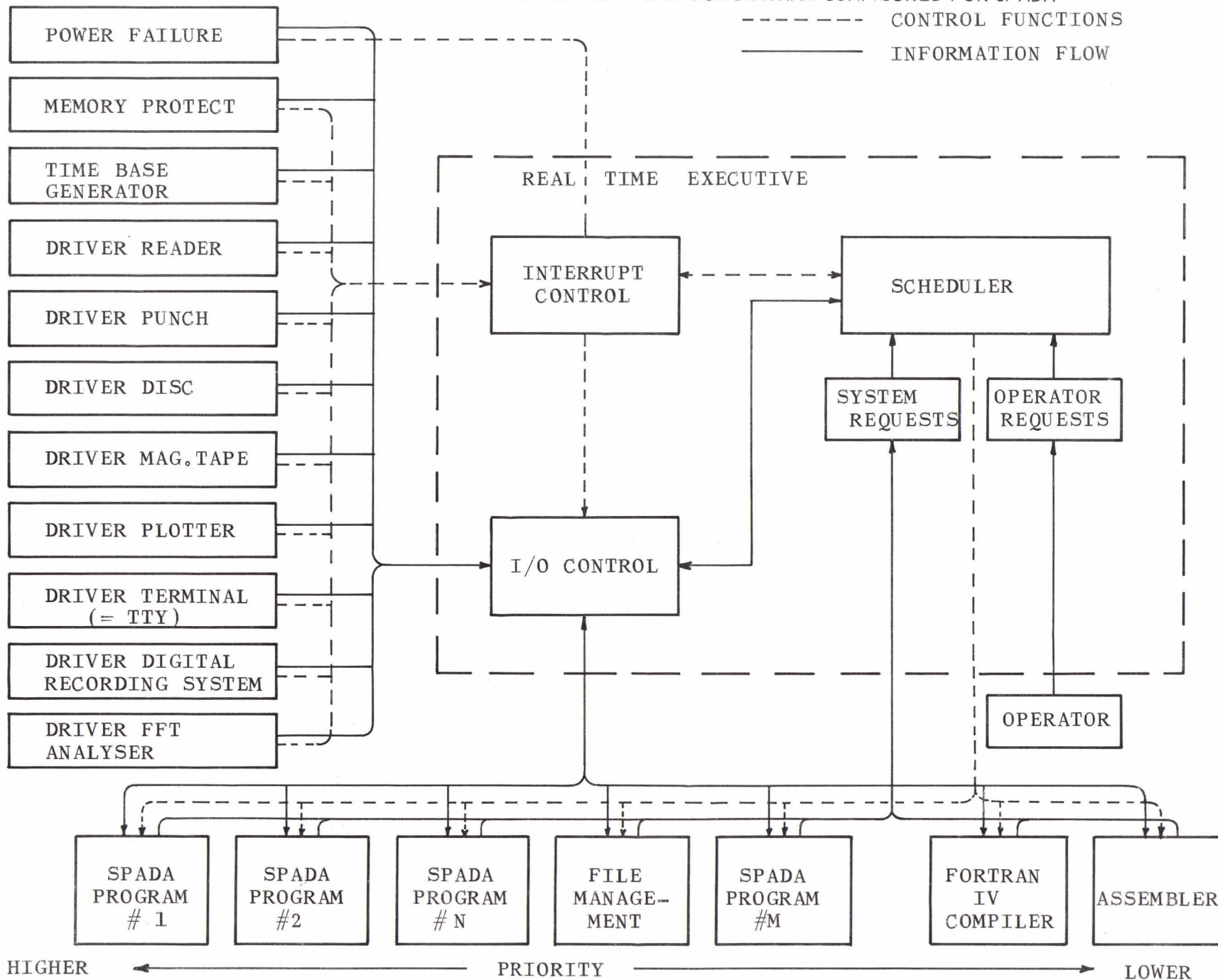
c. The suspension of the interrupt system during the whole transfer for transfer rates that need DMA and response times of less than 100 μs. That is, no interrupt may be processed during the transfer, not even the time-clock interrupts and therefore the duration of the transfer has to be measured. The 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.
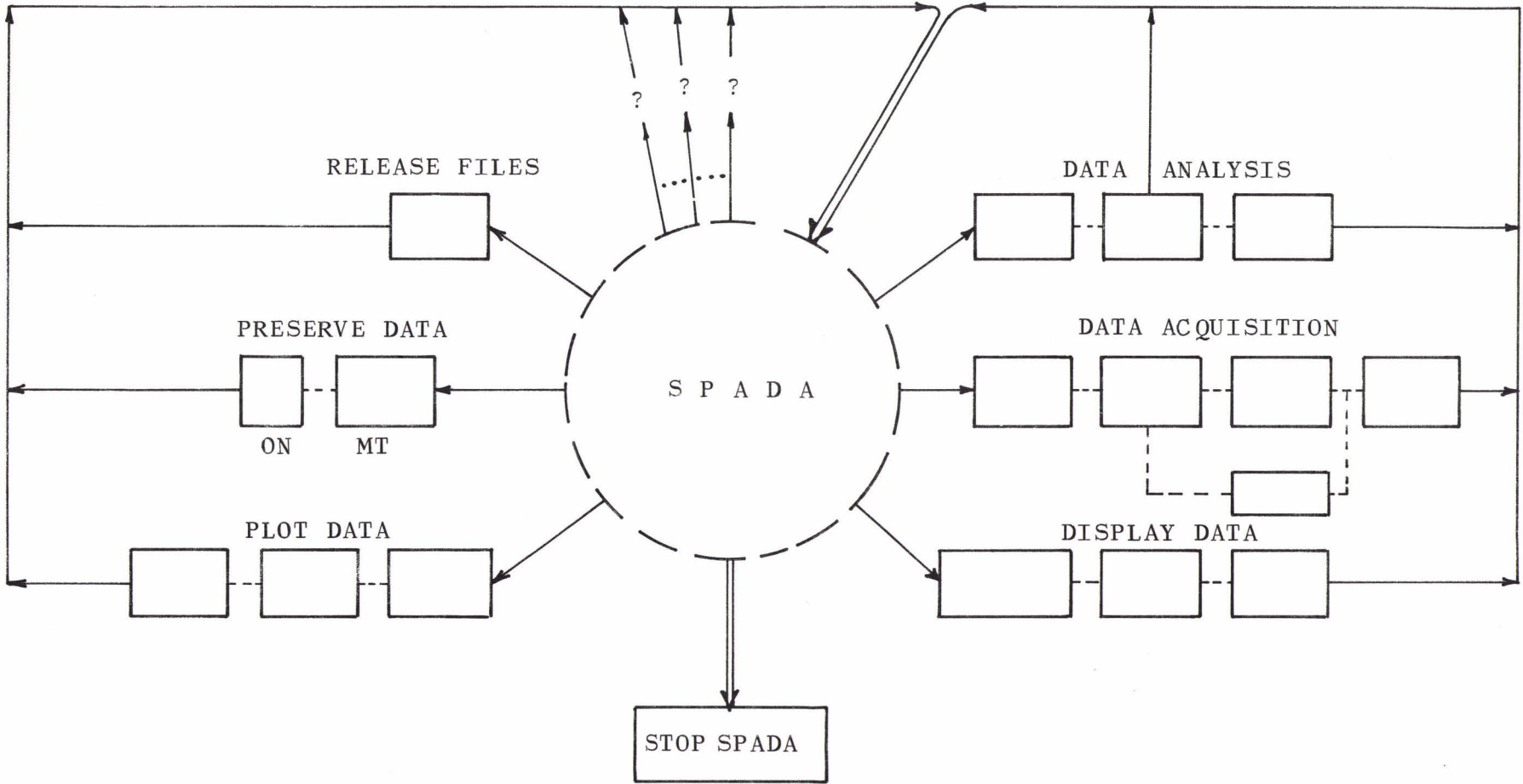
FIG. 3 GENERAL TEXTURE OF THE SPADA SOFTWARE

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.

```
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   5000

ENTER TRANSFER LENGTH IN MILLISECONDS   340

ENTER EVENT CODE   SP2071

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

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

IX (Comments Cont'd)

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.

```
┌─────────────────────────────────────────────────────────────────────┐
│                            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.

```
┌─────────────────────────────────────────────────────────────────────┐
│                           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
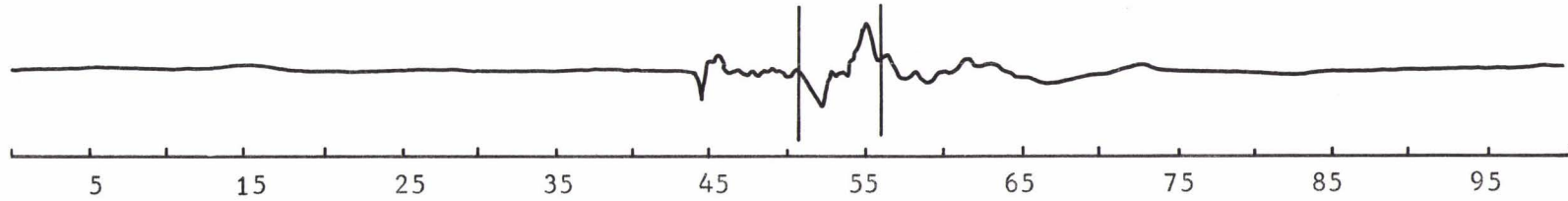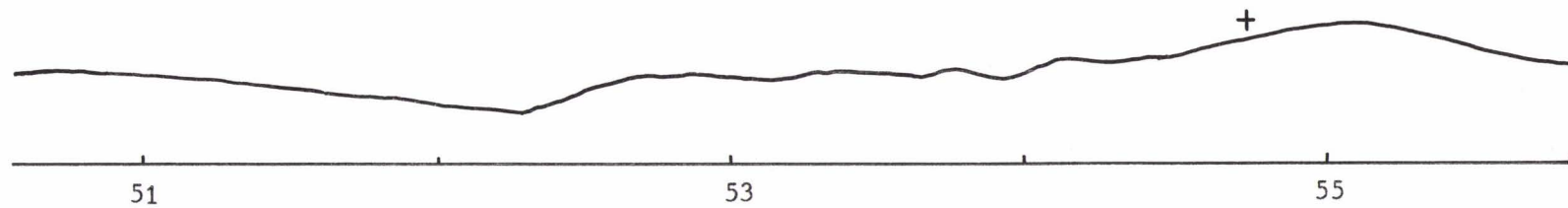   can be seen on the screen.

EVENT = SP2071   HYDROPHONE = 1   CT1 = 7000000.   CT2 1 7000100.

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

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.