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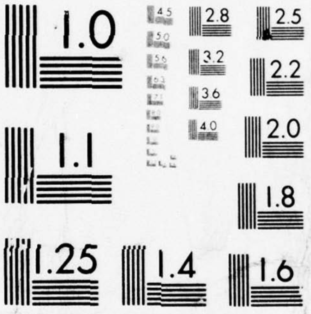

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ARL-TM-73-15
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A MINICOMPUTER, REAL-TIME, ACTIVE SONAR, DATA ACQUISITION SYSTEM

Stephen P. Hufnagel

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-73-C-1070
Proj. Ser. No. SF 11121104 and SF 11121106, Task 8103

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ABSTRACT

A description of a computer-sonar interface between an AN/SQS-23 sonar and two Honeywell Series 16 minicomputers is given. This system was designed for a shipboard high resolution sonar target classifier developed at Applied Research Laboratories. The sonar data acquisition techniques which are discussed are applicable to any active sonar digital processing task.

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I. INTRODUCTION

A computerized sonar data acquisition and computer real-time processing facility has been designed and built, and is operational at ARL. Two minicomputers are integrated into the AN/SQS-23 sonar playback facility (at ARL) to support the research and development program with high quality, precisely measured digital data. These same computers are easily installed aboard a ship to provide high resolution real-time sonar processing at sea. The goal of this report is to describe the computer-sonar interaction in the laboratory and at sea.

The emphasis of ~~our~~ the work with the ARL sonar processors is the development of a high resolution, active sonar automatic submarine classifier. Consequently, many of the described parameters are tailored to this application. It should be realized that the measurement of the raw sonar information is necessary to perform any sophisticated real-time sonar processing in a computer. Minor modifications would allow this acquisition and processing system to perform a wide array of tasks on any active sonar. Relevant parameters of the AN/SQS-23 sonar are reviewed in Appendix A. A detailed explanation of the automatic classifier real-time processing programs will be reported separately.

II. COMPUTER SPECIFICATIONS

The computer portion of the sonar data acquisition and real-time processing system consists of a Honeywell H-316 and a Honeywell H-716 computer, shown in Fig. 1. The computers are connected by means of a high speed parallel data channel. In the laboratory, an additional high speed parallel data channel connected to a CDC 3200 computer is also available. This combination of computers is adequate for almost any realistic sonar data acquisition requirement.

The Honeywell H-316 computer is assigned the primary task of input-output control for both data collection and real-time processing. It has the necessary sonar signals (described below), A/D converters, and utility interfaces (see Table 1), to accomplish all of the sonar sensing, display drive, and data preprocessing required to support the sonar real-time processor and data acquisition system. The H-316 has 16,384 16-bit words of core memory, 1.60 μsec machine cycle time, with hardware double precision integer mathematics capability, and a real-time clock.

The Honeywell H-716 computer performs the majority of the sonar processing tasks. It has a hardware floating point processor (39-bit mantissa, 8-bit exponent plus sign) and sufficient utility interfaces (see Table 2), to allow it to process the raw sonar data asynchronously from the time consuming input-output functions. The processed parameters are stored in an information ID that is available to all of the processors. The H-716 has 16,384 16-bit words of core memory, 0.72 μsec machine cycle time, with hardware double precision integer mathematics capability, and a real-time clock. While running at the laboratory in a

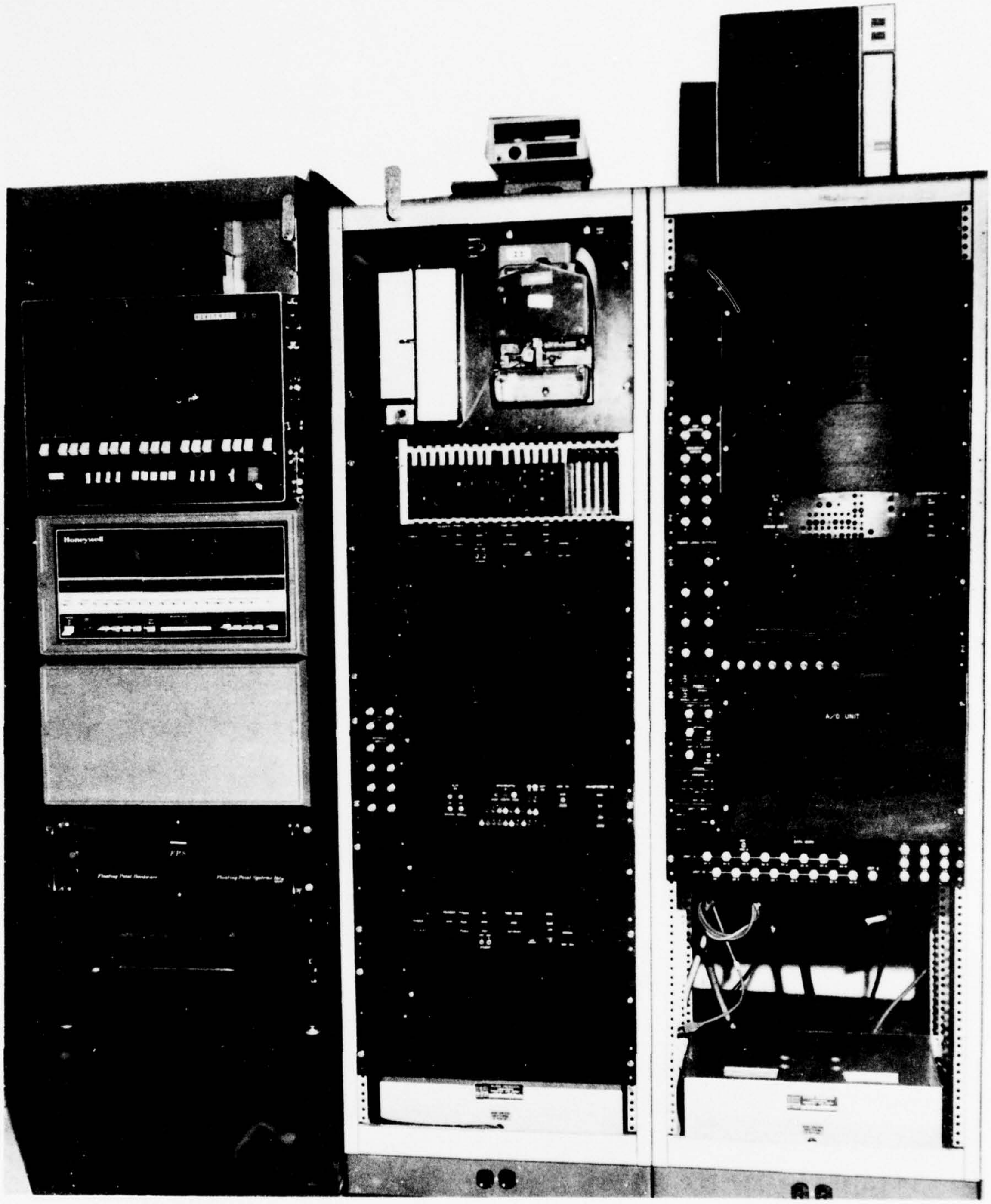

FIGURE 1
HONEYWELL COMPUTERS AND ARL INTERFACE ELECTRONICS

1070-2

TABLE 1

H-316 Interface Configuration

Analog-to-Digital Converters

Digital-to-Analog Converters

Synchro-to-Digital Converters

Sonar Interrupt and Status Sense

Sonar Status Controls

Time Code Reader

Storage Display (DVST)

Keyboard-Transmitter-Receiver-Printer (TTY)

H-716 Communication Channel

CDC 3200 Communication Channel (used at ARL only)

Paper Tape Reader

Paper Tape Punch (used at ARL only)

Magnetic Tape Recorder (used at ARL only)

TABLE 2

H-716 Interface Configuration

Hardware Floating Point Processor

CDC 3200 Communication Channel (used at ARL only)

H-316 Communication Channel

Paper Tape Reader

Paper Tape Punch (used at ARL only)

Keyboard-Transmitter-Receiver-Printer (TTY) data acquisition mode, a high speed parallel data channel transfers the raw and processed data to a CDC 3200 computer. The CDC 3200 performs the burden of data formatting and of recording the data on digital magnetic tape. Afterwards, the raw and processed digital data on the magnetic tapes are easily accessible to research personnel to develop improved sonar processors.

Obviously, the H-716 computer is not essential to the pure data collection task, which can be accomplished by the H-316 alone. However it does allow a tremendous amount of information to be processed at the same time the data are collected. Table 3 is an example of the raw parameters measured by the H-316 while Table 4 presents the additional processed information made available by the H-716. The specific real-time programming techniques used to process the raw sonar data will be the subject of a separate report.

The Honeywell computers and their supporting interfaces are packaged so that this system can be easily installed aboard a U. S. Navy vessel to operate with AN/SQS-23. While at sea, the analog data are recorded on the ship's PME recorder. The processed parameters are used in the high resolution, active sonar, automatic submarine classifier developed at ARL. Upon return from a sea trial, the data link with the CDC 3200 computer is reestablished, the raw data are reconstructed by the AN/SQS-23 playback facility, and a digital data collection mode is assumed in the H-316 and H-716 computers. This allows the data to be digitized for further developmental work, more conveniently performed on the CDC 3200 computer.

TABLE 3

Raw Parameters Measured from the AN/SQS-23 Sonar for Each Ping

Transmit Deviation (-500, 0, +500 Hz)
Transmit Pulse Length (5, 30, or 120 msec)
Transmit Mode (RDT or SDT)
Transmit Type (CW, FM, or programmed)
Transmit Sector Bearing (true, 0 to 360°)
Transmit Sector Width (15 to 120° typically)
Transmit Duration (milliseconds)
Transmit Scanner Rotation Time (milliseconds)
Transmit Waveform (sampled in quadrature at 400 Hz)
Video Scanner Sector Bearing (true, 0 to 360°)
Video Scanner Offset from Split-Beam Scanner (±degrees)
Video Scanner Rotation Time (milliseconds)
Ping Time (milliseconds)
Own Ship's Speed (knots) Measured at Transmit
Own Ship's Speed (knots) Measured at Beginning of Data Window
Own Ship's Speed (knots) Measured at End of Data Window
Own Ship's Course (true, 0 to 360°) Measured at Transmit
Own Ship's Course (true, 0 to 360°) Measured at Beginning of Data Window
Own Ship's Course (true, 0 to 360°) Measured at End of Data Window
Time of Day (from time code generator)
PME Tape Footage
Cursor Range (yards)
Cursor Bearing (true, 0 to 360°)
Video Scanner Waveform (60° by 1000 yd around cursor)
Split-Beam Scanner Waveform (left and right halves, 1000 yd around cursor)

TABLE 4

Processed Parameters Calculated Each Ping by the Real-Time Automatic Classifier

Split-Beam Range (yards)
Split-Beam Bearing (true, 0 to 360°)
Split-Beam Linelikeness (typically less than 300)
Split-Beam Cross Range Extent (feet)
Split-Beam Down Range Extent (feet)
Split-Beam Aspect (single ping)
Split-Beam Aspect (multiping)
Split-Beam Signal-to-Noise (decibels)
Split-Beam Multiping Resultant Vector (0-5)
Split-Beam Target Start (yards)
Audio Correlation Coefficient (0 to 1000)
Video Range (yards)
Video Bearing (true, 0 to 360°)
Video Signal-to-Noise (decibels)
Video Down Range Extent (feet)
Video Context (0 to 1000)
Tracking Predicted Range (yards)
Tracking Predicted Bearing (true, 0 to 360°)
Tracking Search Range (yards)
Tracking Search Bearing (true, 0 to 360°)
Tracking Plus Range Slop (yards after cursor)
Tracking Minus Range Slop (yards before cursor)
Tracking Bearing Slop (degrees around cursor)
Tracking Target Speed (knots)
Tracking Target Course (true, 0 to 360°)
Tracking Target Course from Aspect (true, 0 to 360°)
Tracking Intrack (logical 1 if on)
Tracking Expected Aspect from Track (true, 0 to 360°)
Classifier High Resolution Classification
Classifier Low Resolution Classification
Classifier Combined Classification

III. COMPUTER HARDWARE INTERFACE

The following sonar sense conditions have been made available to the computers since they are essential to digitize and to process the sonar information properly.

1. T/R Interlock - This function switches the relay assembly in the sonar signal path from either the receiver preamplifiers or the transmitters to the transducer array. The computers use this switch signal as a warning to prepare to digitize the transmit waveform, to initialize for the new ping, and to sample own ship's course and speed.

2. T_0- *Also called zero time*, the leading edge of this pulse marks the beginning point for the range count. It is at the transmit sector center for RDT transmissions, and its length controls the pulse length (transmit gate) in the sonar's SDT mode.

3. RANGE PRECURSOR - The AN/SQS-23 RPC's leading edge occurs 400 yd, in time, ahead of the cursor range, allowing the program to begin digitizing a "data window" around an area of interest in the ping receive cycle. Typically, this data window is 1000 yd in range.

4. VIDEO SCANNER SYNC - This pulse, derived from the stern cursor, occurs at a 150 Hz repetition rate and marks the time when the sonar receiver's video scanner passes between staves

24 and 25. This information is used to check the video scanner turning rate (as a diagnostic) and, in combination with BPC, to indicate video scanner cursor bearing. Any offset between the video scanner and split-beam (audio) scanner is calculated to allow comparison in bearing of data from these two sources.

5. BEARING PRECURSOR - The BPC is used to tell the computer that the video scanner is entering the data window bearing sector. This mark is a synchro sense on the rotating video scanner which indicates that the video from the scanner is preceding the cursor in time equivalent to 30° in bearing. It also moves with the operator's cursor bearing. From this pulse the computer is able to digitize a 60° sector in bearing (±30° around cursor) video data window.

6. TRANSMIT GATE - This pulse gates the transmit oscillator, indicating the period of time during which the transducer array is being driven. This signal is used by the computer to digitize the transmit waveform for replica correlation.

7. RDT SCANNER SYNC - This signal, analogous to video scanner sync, marks a transmit bearing of 180° relative. It is used in conjunction with the transmit gate to determine RDT transmit center and transmit width.

The data acquisition systems use several analog signals generated in the AN/SQS-23, most of which must be scaled by instrumentation amplifiers, transmitted via balanced lines to the computer's analog-to-digital (A/D) converters, and digitized. A brief description of these signals follows.

1. A/D SAMPLE REFERENCE - The 10 kHz PME wow and flutter compensation reference signal (9.0 kHz or 11 kHz with frequency deviation) is recovered for use as the sampling signal for A/D converters and also as a computer clock. This 10 kHz signal is divided by 2, using a phase locked oscillator, and is then heterodyned to 17,950 Hz. The procedure is necessary to correct for wow and flutter on the signal correctly, since there is a variable delay in the signal channel and the same delay is provided to the sample clock. A phase locked oscillator tracks the nominal 18 kHz, multiplies by 4, and divides by 3 to give a nominal 24 kHz, for use in quadrature sampling.* The 24 kHz is also divided by 12 to provide a general purpose 2 kHz clock, used for instance for range timing and computer interrupts. The 2 kHz is finally divided by 5 to provide a 400 Hz sampling clock. The quadrature pairs ($3/2\pi$ separation) of the split-beam signals are extracted at the 400 Hz rate; this corresponds to the sonar bandwidth of 400 Hz. The 24 kHz clock is used directly for uniform sampling of the video signals.

---

* Pitt and Grace (ARL-TR-68-39) have shown that, if pairs of samples of a signal are taken separated by 90° at a repetition rate equal to the bandwidth, all the information is preserved. By sampling the 18 kHz signal at the 24 kHz rate, the first sample may be considered the X sample and the second sample (270° in phase later) is -Y. Thus, by changing the sign of the second signal a quadrature pair is formed. The fact that there are 270° between pairs is of no consequence with such narrowband signals as we are dealing with.

At sea, the sample clock reference must come from a fixed oscillator, preferably the 10 kHz output of the TRAM transmit oscillator board used to generate the PME wow and flutter reference frequency.

2. TRANSMIT WAVEFORM - The transmit waveform is recovered from PME tape in the laboratory or is generated within the oscillator-programmer at sea. The split-beam scanner allows phase processing which is essential to improve bearing resolution and to study target structure. It is a 5.0 kHz (4.5 kHz or 5.5 kHz with frequency deviation) signal which must be passed through an analog mixer to obtain 17,950 Hz. The signal waveform is then scaled to 20 V peak to peak by an instrumentation scaling amplifier and is made available to the A/D converter for digitization. This signal is used by the processors as the replica for coherent FM processing.

3. SPLIT-BEAM SIGNALS - Split-beam data are recovered from a special trainable scanner which must be substituted for the audio scanner normally used in AN/SQS-23 sonars. Dual signal outputs, split-beam left and split-beam right, at 17,950 Hz are provided from this special scanner. These outputs are fed to a dual channel programmable (computer controlled) gain scaling amplifier, by means of which the computer can automatically scale the split-beam data inputs to the proper A/D range (nominally ±10 V) as echo levels change. In addition, a fixed gain summing amplifier must be installed in the sonar receiver cabinet to synthesize the audio signal from split-beam left and right for use in place of normal sonar audio. The audio signal is not digitized since it can be generated in the computer from the split-beam quadrature samples.

4. VIDEO SIGNAL - The video signal input to the computer is derived from the sum video transformer located in the AN/SQS-23 receiver. The video passes through a computer programmable instrumentation gain scaling amplifier and is digitized at 24 kHz to allow 2 1/4° bearing resolution.

5. COURSE - A synchro-to-digital converter (S/D) samples the gyro order furnished to the sonar system to indicate the ship's heading relative to true north. The computer processors use this input to stabilize own ship's motion and observed contact motion geographically.

6. RELATIVE BEARING - An S/D samples the split-beam scanner bearing. It indicates the direction in which the split-beam scanner (also cursor relative bearing) is pointed relative to the ship's bow. This information, combined with the course, provides scanner bearing relative to north.

7. SHIP'S SPEED - An S/D which inputs own ship's speed. This is used with ship's course and relative bearing to remove own ship's motion and to geometrically stabilize target motion.

Table 3 summarizes the group of raw parameters and timing signals discussed previously to determine basic data descriptive information. The processed data listed in Table 4 plus the raw parameters in Table 3 are stored as digital words in the computer and are recorded on a digital track of the PME recorder for each ping cycle. A block diagram showing the sonar-computer interaction is presented in Fig. 2.

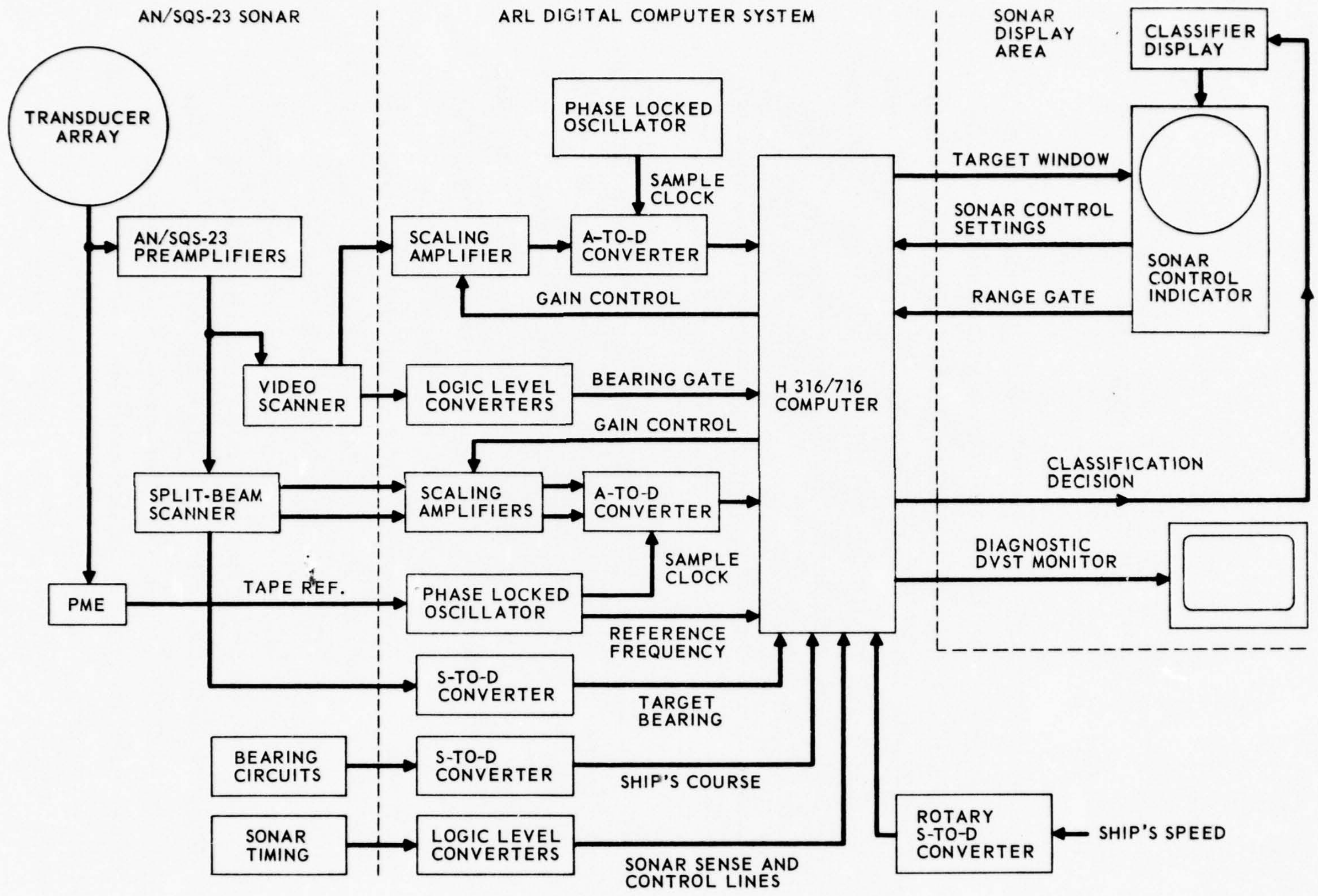

FIGURE 2
BLOCK DIAGRAM OF REAL-TIME SONAR
DATA ACQUISITION SYSTEM

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AS-72-1649
SPH - RFO
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IV. REAL-TIME SONAR EVALUATION

An additional advantage afforded by having a computer monitor the sonar is the computer's ability to test sonar timing sequences. In effect, a great part of the sonar's electrical and mechanical system is tested and certified to be within design specifications each and every ping cycle. This function is a natural one for this computer with the ARL interfaces, and places no serious burden on the computer's data collection and processing ability. When something is wrong, a message plus a diagnostic visual representation of the error is presented on the direct view storage tube (DVST) monitor described in Section V.

Experience has shown that even a minor malfunction in the essential sonar timing circuits is capable of distorting the transmit or receive waveform enough to degrade or annihilate the sonar high resolution processor performance. In the laboratory, it often took weeks of analysis to isolate and trace a particular problem in the sonar receiver, and then the data had to be redigitized. If the malfunction occurred at sea and the data were recorded on the PME recorder in that form, the data recorded at that time, or possibly for a whole sea trial, might be unusable. In a Fleet operation situation, this condition must be corrected, or at least detected, as soon as possible. What is needed is immediate feedback to assure proper operation. The requirements of the computer shipboard sonar processor currently allow computer access to the sonar signals previously listed. This constant check on the sonar's performance has made it possible to have reasonable confidence that the sonar system is working properly at any given time and that the data at sea are being processed and presented to the PME recorder properly.

During nonoperational times, the recorded PME data can be played back and spot checked by the computer system to ensure that the data were recorded as they should have been.

An added feature of the real-time sonar diagnostic package is the ability to troubleshoot and to assure that the ship's sonar is operating properly before entering an operations period by running with the ship's transmitters off and using the ship's PME recorder. In addition to checking the specifications of the basic sonar timing signals, the computer also makes available graphic presentations of the digitized transmit, split-beam and video scanner echoes, and the processed sonar parameter outputs as described below.

V. DIAGNOSTIC DISPLAYS

A visual presentation of data has proved most effective in helping an observer understand how a processor works. Also an abnormal sonar signal can often be easily recognized visually. The digitized sonar data of the automatic sonar processors are easily adapted to visual presentation.

The split-beam scanner is most essential to the high resolution sonar processors and thus its data must be most often and most critically viewed. Fig. 3 is the composite split-beam real-time display format photographed from the Tektronix 611 DVST display. The horizontal axis of the 3-dimensional plot represents plus and minus 12° of bearing around the cursor and the line height reflects envelope energy at that particular range and bearing. The 3-dimensional plot can be replaced with the processor single ping diagnostic printout explained below. At the bottom of the 3-dimensional plot there is a classification summary indicating ping number, classification confidence (single ping), classification confidence (multiping), target bearing, target range, target course, target speed, and if tight track (=1) is on. This line is informationally similar to the sonar operator's primary classifier display, provided separately by the computers to the operator. The composite split-beam return echo display mode (Fig.3) presents to the viewer all of the split-beam information used by the split-beam processor. On the top is the composite range versus crossrange versus amplitude display (like an SSI with amplitude added). On the left are the quadrature components of the two split-beam halves sampled at a 400 Hz rate for 1.25 sec. The right side of the display includes the processed

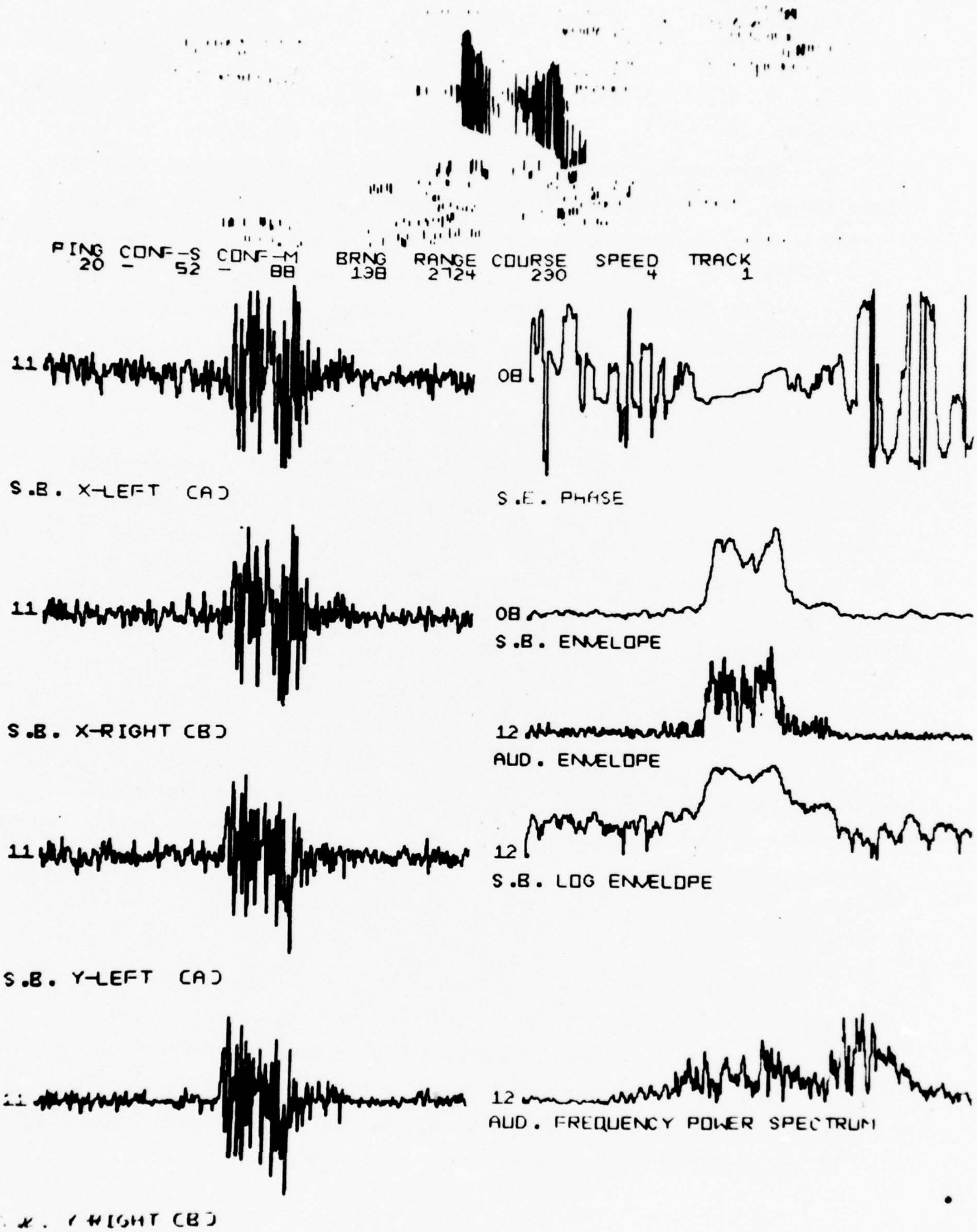

FIGURE 3
DIAGNOSTIC SPLIT-BEAM COMPOSITE DISPLAY

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AS-73-247
SPH - DR
3 - 27 - 73

split-beam phase, split-beam linear envelope, audio linear envelope, split-beam log envelope, and an audio frequency power spectrum.

A multiping 3-dimensional split-beam display with a classification summary beneath each plot (Fig. 4) is available which allows the viewer to check target consistency. In this example, a manual clear control function resets the processors on the upper plot. A reset is indicated by the absence of the processor summary. On ping 1, an additional line of information is always given to help catalog each new run. The sequence number, run number, PME reel number, PME footage, hour, minute, second, and date are also indicated. This information is used to help relocate data on the PME recorder if a repeat run is desired.

The transmitted waveform seen in Fig. 5 has the raw quadrature components on the upper left side sampled at 400 Hz for the length of the transmit sector pulse. Below those scans is a frequency power spectrum. On the right, the phase, instantaneous frequency, and envelope are displayed. At the top, a single ping summary of the previous pings classification clues is available.

Figure 6 illustrates the numerical diagnostic printout. A history of the information from three pings is available at one time for all the important raw and processed information. The meanings of the labels are defined in Table 5.

Finally, a video 3-dimensional plot is available (Fig. 7). The horizontal axis of the video plot indicates bearing plus and minus 30° around the cursor. The vertical axis of the video plot indicates 1000 yd of range, cursor centered, and the line height reflects the energy level at that range and bearing. At the top is a single-ping diagnostic numerical printout of the raw and processed parameters.

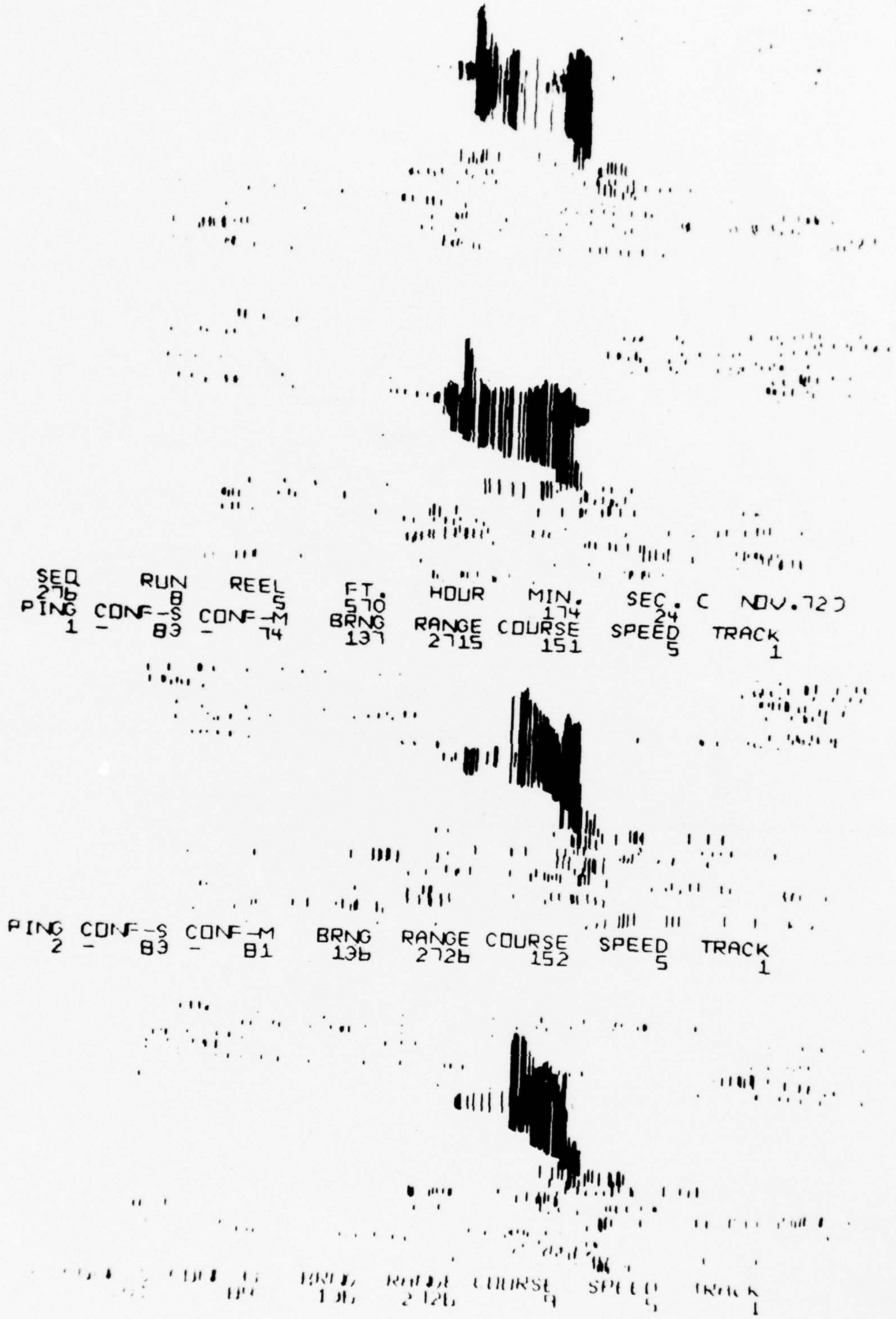

FIGURE 4
DIAGNOSTIC SPLIT-BEAM MULTIPING 3D PLOT

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AS-73-248
SPH - DR
3 - 27 - 73

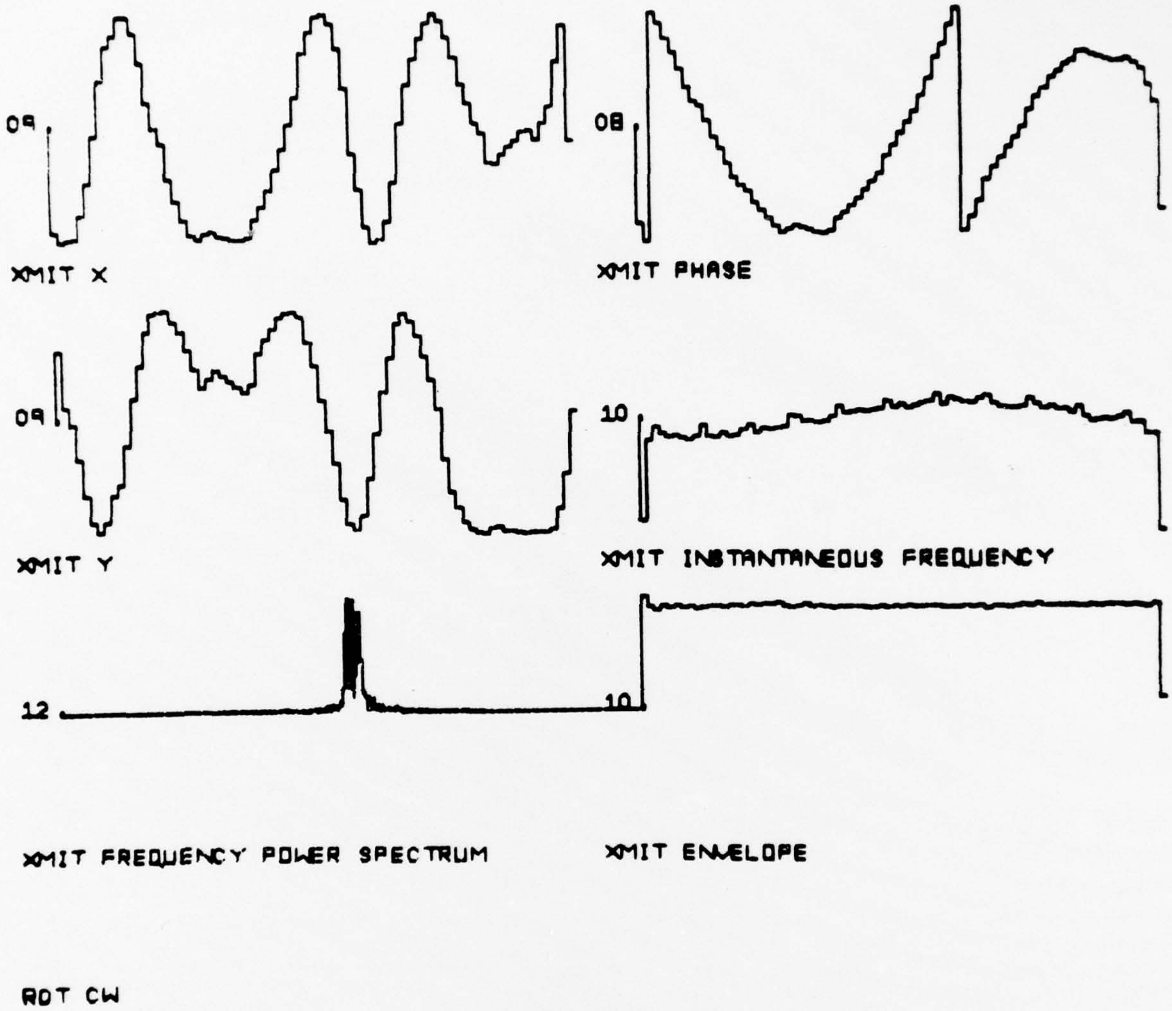

FIGURE 5
DIAGNOSTIC TRANSMIT WAVEFORM COMPOSITE DISPLAY

ARL - UT
AS-73-249
SPH - DR
3 - 27 - 73

```
   SEQ      RUN     REEL      FT.     HOUR     MIN.     SEC. ( NOV.72)
   244        8        5      570               166       37
  PING   CONF-S   CONF-M     BRNG    RANGE   COURSE    SPEED    TRACK
     3 -     71 -     78      137     2704      178        2        1
   SEQ      RUN     PING   COEF-C   SMAL-C   CONF-S   CONF-M   RVCSB)
   244        8        3      257       83 -     71 -     78        4
RNG-SB   BRG-SB   DRE-SB   CRE-SB   S/N-SB   ASPCS)   ASPCM)   L4CSB)
  2704      137      492        2       18 -     16 -     23       15
RNG-VI   BRG-VI   DRE-VI   CRE-VI   S/N-RM   S/N-PK   CXCVI)   TIME-P
  2700      139      560       23       19       24       24    10424
RNG-PR   BRG-PR   RNG-FI   BRG-FI   RNG-SR   BRG-SR   TGT-SP   TGT-CR
  2697      137     2709      137     2697      137        2      178
  TCFA   DIADDT   INTRCK   BRG-XM   WID-XM   BRG-CU   TIME-3   TIME-5
     2                 1                        139       15      272
  CVSN     AVRE     CVRE     AVLL     SDAS     AVCX     CVEC     CVLL
    35      511       65      219       69     1918      429     1086
 SS-TO    SS-TA    SS-TB    SS-TC    SC-TO    SC-TA    SC-TB    SC-TC
     6        6        5        6      165      166      166      167
----------
   SEQ      RUN     REEL      FT.     HOUR     MIN.     SEC. ( NOV.72)
   246        8        5      570               168       47
  PING   CONF-S   CONF-M     BRNG    RANGE   COURSE    SPEED    TRACK
     4 -     53 -     78      137     2709      168        1        1
   SEQ      RUN     PING   COEF-C   SMAL-C   CONF-S   CONF-M   RVCSB)
   246        8        4      433       83 -     53 -     78        4
RNG-SB   BRG-SB   DRE-SB   CRE-SB   S/N-SB   ASPCS)   ASPCM)   L4CSB)
  2709      137      528        3       19 -     26 -     21       20
RNG-VI   BRG-VI   DRE-VI   CRE-VI   S/N-RM   S/N-PK   CXCVI)   TIME-P
  2708      139      480       22       19       25       25    10426
RNG-PR   BRG-PR   RNG-FI   BRG-FI   RNG-SR   BRG-SR   TGT-SP   TGT-CR
  2703      137     2705      137     2703      137        1      168
  TCFA   DIADDT   INTRCK   BRG-XM   WID-XM   BRG-CU   TIME-3   TIME-5
     2       42        1                        139       27      275
  CVSN     AVRE     CVRE     AVLL     SDAS     AVCX     CVEC     CVLL
    56      520       47      212       44     1976      386     1036
 SS-TO    SS-TA    SS-TB    SS-TC    SC-TO    SC-TA    SC-TB    SC-TC
     6        5        5        5      167      167      168      168
----------
   SEQ      RUN     REEL      FT.     HOUR     MIN.     SEC. ( NOV.72)
   248        8        5      570               169       58
  PING   CONF-S   CONF-M     BRNG    RANGE   COURSE    SPEED    TRACK
     5 -     25 -     78      137     2713      165        3        1
   SEQ      RUN     PING   COEF-C   SMAL-C   CONF-S   CONF-M   RVCSB)
   248        8        5      227       89 -     25 -     78        4
RNG-SB   BRG-SB   DRE-SB   CRE-SB   S/N-SB   ASPCS)   ASPCM)   L4CSB)
  2713      137      576        4       19 -     26 -     21       17
RNG-VI   BRG-VI   DRE-VI   CRE-VI   S/N-RM   S/N-PK   CXCVI)   TIME-P
  2707      140      576       23       19       25       25    10433
RNG-PR   BRG-PR   RNG-FI   BRG-FI   RNG-SR   BRG-SR   TGT-SP   TGT-CR
  2710      137     2706      137     2710      137        3      165
  TCFA   DIADDT   INTRCK   BRG-XM   WID-XM   BRG-CU   TIME-3   TIME-5
     3       48        1                        139       35      276
  CVSN     AVRE     CVRE     AVLL     SDAS     AVCX     CVEC     CVLL
    63      549       59      191       43     2029      366      935
 SS-TO    SS-TA    SS-TB    SS-TC    SC-TO    SC-TA    SC-TB    SC-TC
     5        6        6        5      168      169      169      170
----------
```

FIGURE 6
DIAGNOSTIC 3-PING NUMERICAL PRINTOUT.
THE NUMBERS BELOW EACH ABBREVIATION ARE REAL-TIME PARAMETERS. ABBREVIATIONS ARE FROM TABLE 6

TABLE 5

Explanation of Numerical Diagnostic Printout

SEQ - Sequence number
RUN - Run number
REEL - PME tape reel number
FT. - PME tape footage at the beginning of this run
HOUR - Time (hours) at T(o) of the current ping recorded on PME tape
MIN. - Time (minutes) at T(o) of the current ping recorded on PME tape
SEC. - Time (seconds) at T(o) of the current ping recorded on PME tape
DATE - Date on which these data were processed
PING - Ping number relative to the beginning of this run
CONF-S - Classifier single-ping confidence
CONF-M - Classifier multiping confidence
BRNG - Split-beam measured target fine bearing (true, 0 to 360°)
RANGE - Split-beam measured target range (yards)
COURSE - Tracking calculated target course (true, 0 to 360°)
SPEED - Tracking calculated target speed (knots)
TRACK - Tracking tight track indicator (one is on, zero is off)
COEF-C - Audio correlation coefficient (0 to 1000)
SMAL-C - Audio correlation smaller array length
RV(SB) - Split-beam multiping resultant vector
RNG-SB - Split-beam measured target range (yards)
BRG-SB - Split-beam measured target fine bearing (true, 0 to 360°)
DRE-SB - Split-beam measured target down range extent (feet)
CRE-SB - Split-beam measured target cross range extent (feet)
S/N-SB - Split-beam measured target signal-to-noise ratio (decibels)
ASP(S) - Split-beam measured target single-ping aspect (0 to 360°)

TABLE 5 (Cont'd)

ASP(M) - Split-beam measured target multiping aspect (0 to 360°)
L4(SB) - Split-beam measured target linelikeness (0 to 300 ft typically)
RNG-VI - Video measured target range (yards)
BRG-VI - Video measured target bearing (true, 0 to 360°)
DRE-VI - Video measured target downrange extent (feet)
CRE-VI - Video measured target crossrange extent (feet)
S/N-RM - Video measured target signal-to-noise ratio rms (decibels)
S/N-PK - Video measured target signal-to-noise ratio peak (decibels)
CX(VI) - Video measured target context
TIME-P - Ping time (milliseconds)
RNG-PR - Tracking predicted target range (yards)
BRG-PR - Tracking predicted target bearing (true, 0 to 360°)
RNG-FI - Tracking filtered target range (yards)
BRG-FI - Tracking filtered target bearing (true, 0 to 360°)
RNG-SR - Tracking search range (yards)
BRG-SR - Tracking search bearing (true, 0 to 360°)
TGT-SP - Tracking calculated target speed (knots)
TGT-CR - Tracking calculated target course (true, 0 to 360°)
TCFA - Tracking course from aspect (true, 0 to 360°)
DIADOT - Tracking multiping target diameter location change (yd/sec)
INTRCK - Tracking tight track indicator (one is on, zero is off)
BRG-XM - RDT transmit scanner bearing (relative to 0 to 360°).
WID-XM - RDT transmit width (0 to 360°)
BRG-CU - Cursor bearing (true, 0 to 360°).
TIME-3 - H-316 computer processing time (sec*10)
TIME-5 - DDP 516 computer processing time (sec*100)

TABLE 5 (Cont'd)

CVSN - Classifier filter covariance of signal to noise

AVRE - Classifier filter average down range extent

CVRE - Classifier filter covariance of down range extent

AVLL - Classifier filter average linelikeness

SDAS - Classifier filter standard deviation of aspect

AVCX - Classifier filter average video context

CVEC - Classifier filter covariance of audio echo correlation

CVLL - Classifier filter covariance of linelikeness

SS-TO - Ship's speed at T(o) (knots)

SS-TA - Ship's speed at beginning of data window (knots)

SS-TB - Ship's speed at end of data window (knots)

SS-TC - Ship's speed at end of ping cycle (knots)

SC-TO - Ship's course at T(o) (true, 0 to 360°)

SC-TA - Ship's course at beginning of data window (true, 0 to 360°)

SC-TB - Ship's course at end of data window (true, 0 to 360°)

SC-TC - Ship's course at end of ping cycle (true, 0 to 360°)

```
           SEC          HOUR     MIN.      SEC.
                                   8        5
 CON              BRNG   RANGE   COURSE   SPEED   TRACK
                   18     1219
   RNG     RING  CORR C  SMAL C  CONF-S  CONF-M  RUCSBD
           268
BRG-SB   DRE-SB  CRE-SB  S/N SB  ASPCSD  ASPCMD  L4CSBD
  18
BRG-VI   DRE-VI  CRE-VI  S/N-RM  S/N-PK  CXCVID  TIME-P
  14      272      23      30      38      38     1265
BRG-PR   RNG-FI  BRG-FI  RNG-SR  BRG-SR  TGT-SP  TGT-CP

DIADOT   INTRCK  BRG-XM  WID-XM  BRG-CU  TIME-3  TIME-S
                   20              18      55
  AVRE     CVRE    AVLL    SDAS    AVCX    CVEC    CVLL

SS-TA    SS-TB   SS-TC   SC-TO   SC-TA   SC-TB   SC-TC
  33       33      33
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FIGURE 7
DIAGNOSTIC VIDEO 3-D PLOT PLUS NUMERICAL PARAMETER PRINTOUT

All of the described displays are designed to be run while the sonar runs, in real-time, without missing pings on a Tektronix 611 DVST at the computer. Each entire display takes an average of 1 sec to generate.

The viewer may select which display format he prefers by typing a preassigned letter on the computer typewriter at any time in the ping cycle. He turns the display off by retyping the same letter. This arrangement has worked well and is easy to learn and use.

The display information will be presented apart from the sonar operator display and is not currently available as an alternate operator display since it is designed for sonar diagnostic usage. A knowledgable researcher or trained technician should be able to recognize a sonar or processor problem and diagnose the cause in a short period of time with the help of the computer generated sonar diagnostic information and displays.

Although the original concept and plan to implement an automatic classifier did not include accessory displays or a computer check on the sonar operation, experience has shown that these additional features are desirable. With these displays the processing can be readily explained to an inexperienced viewer, the sonar can be easily checked for malfunction, and the sonar processors can be monitored for their performance while running at sea or in the laboratory.

VI. SUMMARY

The ability to have a computer access all of the basic sonar parameters, process them in real-time, and record these data on digital tape while in the laboratory is providing a research capability which was previously unavailable This capability is available at Applied Research Laboratories in the form of an AN/SQS-23 sonar playback facility directly interfaced to a small computer installation which in turn has a high speed parallel data channel to a CDC 3200 computer. The small computers are packaged so that they may be installed aboard any ship having an AN/SQS23 sonar in order that processing algorithms can be tried at sea. After the sea trial, the PME recorded data can be used at the laboratory to reconstruct the sea trial so that data of interest may be digitized and new algorithms developed on the digital tape system and tried on the PME real-time system. This clinical approach has proved most productive in the development of sonar processors. Every relevant sonar timing pulse is measured by the computer to be sure it is within specifications. Raw and processed signals are available graphically in real-time (during the current ping cycle). High resolution measurement of target range, bearing, aspect, signal-to-noise ratio, down range extent, etc., are available on each transmission cycle.

VII. CONCLUSION

The real-time capability of two minicomputers have been shown to perform well as a sonar monitor and high resolution processor. There is no reason why they could not serve the reverse function of target simulator or sonar transmit sequencer. Rather than measure the sonar transmit parameters and transmit waveform, the computers could drive the ship's transmitters and video displays (both of these tasks have already been performed at sea by ARL). As a training device, a simulated target with proper course, speed, and size could be superimposed on the video display and presented to a sonar operator for detection and/or classification, while the computers keep track of range, bearing, SNR, and operator response, for instance. Basically, the computers have the flexibility to perform all or part of the transmit, receive, and training functions for future sonars. While additional development is necessary before this is done, a good start has been made.

REFERENCES

1. O. D. Grace and S. P. Pitt, "Sampling and Interpolation of Bandlimited Signals by Quadrature Methods," J. Acoust. Soc. Amer. 48, 1311-1318 (1970).

APPENDIX A
A DESCRIPTION OF THE AN/SQS-23 SONAR

The AN/ SQS-23 in General

The AN/SQS-23 is a large, low frequency ASW sonar which was developed during the late 1950's. It went through three modifications in the early 1960's, the A, B, and C series. In the late middle 1960's, there was a major modification program, the Transmitter Reliability and Maintainability Retrofit (TRAM), with the TRAMmed AN/SQS-23's designated D, E, F, and G models. The performance monitor equipment (PME) was included as part of TRAM on all models. The PME is a large, 83-track analog tape recorder which records the 48 individual stave signals from the AN/SQS-23 transducer, plus ship's gyro, ship's speed, the sonar synchronizing pulses, and other necessary signals. Tapes recorded on the PME on board any ship can be played back into any other AN/SQS-23 receiving system, recreating the sonar situation that existed when the tape was recorded. ARL has a TRAM G playback facility which has been modified to accommodate the developmental program at the laboratory.

The PME tapes are invaluable for laboratory evaluations and for research and development, since any sonar condition can be treated many different ways, with the only variable being the treatment. It is impossible to do this at sea, where sonar conditions may change significantly as the ship moves a few hundred yards.

Another significant improvement to the AN/SQS-23 was the addition of the modest improvement kit (MIK) to the TRAMmed AN/SQS-23's. This kit included the addition of FM slides to the transmission types, a very good AGC to the sonar's video circuits, and own-ship-doppler-nullification (ODN) on the transmission rather than during reception. The MIK AGC was a major improvement to the AN/SQS-23 since it obviated the necessity for the sonarman to "ride the gain" on the long range scales, a tedious task which was more often neglected than carried out.

AN/SQS-23 Parameters

The major parameters of the AN/SQS-23 are: sonar frequency, 5 kHz and also 4.5 and 5.5 kHz to avoid interference; receiving bandwidth, 400 Hz, centered slightly above center frequency; receive processing, all stave signals amplified and heterodyned to 17.95 kHz for scanning by separate audio and video scanners, further processing mostly amplification, heterodyning, and filtering separately for audio and video; audio scanner trainable, giving a 8° steerable audio beam; video scanner continuously rotating, split-beam type, with separate sum and difference beam processing; maximum range, 40 kyd, with six range scales of 1, 2.5, 5, 10, 20, and 40 kyd; presentations, audio from the audio scanner, an 8° audio beam, through loudspeaker or headset, and video from the video scanner, on a PPI CRT, using the central 5 3/4 in. of a 7 in. CRT, either sum or difference; transmission, either CW pulses of 5, 30, or 120 msec pulse length, or (MIK) FM slides, 400 Hz, of 5, 30, or 120 msec duration; transmissions from the rotating directional transmission (RDT) scanner or from the steered directional transmission (SDT) scanner; RDT coverage, 360°, with transmit sectors from 20° to 357°; SDT coverage, 10° beam steerable through 360°. RDT pulse length is produced by rotating the transmit scanner at different speeds so that the sound beam insonifies a given bearing for 5, 30, or 120 msec. RDT FM pulse length is produced by changing the slope of the FM ramp so that the slide covers 10° of scanner rotation.

AN/SQS-23 Transmission Types

The AN/SQS-23 can produce CW, FM, or mixed transmissions. In the CW mode, the longer, lower bandwidth transmissions are useful for aural determination of target doppler when target motion in the line-of-sound is sufficiently large to produce a discriminable change of the frequency of the target echo when aurally compared to reverberation frequency. For this sonar, doppler shift is about 3 Hz per knot of target motion at the center frequency.

The main advantage of the FM transmission is that it gives rise to broadband reverberation even with the longer pulse/slide lengths, so that the target echo is in contrast with a broadband background. This subtracts from the recognition differential necessary for target detection as a function of bandwidth.

The mixed or combination transmission mode is called the programmed mode. Three FM slides are followed by one CW pulse, so that for three ping cycles the target echo is against a broadband background while the fourth ping allows for possible detection of target doppler. The use of the FM and programmed modes has become standard Fleet practice.

Typical Use of the AN/SQS-23 Sonar

Let us examine the way a sonarman would use the AN/SQS-23 in three proposed scenarios.

First Scenario: own ship is under normal convoy/escort situation, conducting standard long range search, with no suspected threat vehicle.

The sonarman would operate the AN/SQS-23 on the 20 kyd and 40 kyd range scales, with occasional short range, 5 kyd, searches and would be in FM or programmed mode. He would conduct the standard Navy audio beam search pattern and would also watch the PPI for targets appearing outside the audio beam search. The standard audio beam search consists of training the audio beam to about 120° relative to ship's head, moving the beam toward the bow in 10° steps, one step per ping cycle and, after the audio beam is trained ahead, moving it to the opposite side of the ship and again training forward in 10° steps. This is repeated until a target echo is heard, which may be before the target is seen on the PPI. Own ship will be steaming normally, following the point of intended motion (PIM) of the convoy or capital ship it is escorting.

Second Scenario: own ship is conducting an area search for a suspected threat vehicle after a MAD, sonobuoy, or ECM alert. The convoy is alerted for attack.

The sonarman will operate the AN/SQS-23 on varying range scales, spending more time on the 10 kyd scale than on 20 or 5 kyd scales, although he will switch to these scales frequently at random intervals and stay on them for random time periods. He will also change transmission types randomly, probably using FM or programmed modes 60 to 80% of the time. In this situation, the ship will be changing course and might speed fairly frequently to provide the best coverage of the suspected threat area.

Third Scenario: in either the first or second scenarios, the sonarman has detected a possible target.

To evaluate the detected target, the sonarman will watch it carefully for several pings without changing transmission type or mode or doing anything else to alert the target. If the target has enough of the characteristics of a threat target, the sonarman will call for his supervisor, and alert the CIC team that he has a possible target which should be plotted. After the sonar supervisor has watched the target for a while, and CIC has had time to develop a plot of target motion, further action will be taken. If the target shows threat characteristics and the CIC plot shows motion and any sign of a consistent course and speed for the target, it would be considered that the target has been classified as a possible threat. Further action in this case might consist of changing transmission mode or pulse length to enhance target characteristics; for example, pulse length might be changed to 120 msec CW for detection of any target doppler. If, on the other hand, the CIC plot shows little or no motion, and target characteristics are variable, the detected target may either be dismissed as a nonsub, or watched further to see if it becomes more sub-like as time passes. Any action other than these depends on the tactical situation, and must be initiated by the higher command levels.