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NAVY ELECTRONICS LAB SAN DIEGO CALIF
AUTOMATIC DATA REDUCTION FOR TONE-PULSE SONAR. (U)
MAR 64 G S YEE, J E HENDERSON
NEL-TM-671

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NEL/Technical Memorandum 672

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AUTOMATIC DATA REDUCTION FOR TONE-PULSE SONAR (U)

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Grant S. Yee • J. E. Henderson (Code 3185)

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AUTOMATIC DATA REDUCTION FOR
TONE-PULSE SONAR

by

G. S. Yee and J. E. Henderson

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This memorandum should not be regarded as a Laboratory report. It's only purpose is to record the flow diagrams and background information relative to a new computer program. It's use will be restricted to NEL personnel and a few naval personnel outside the Laboratory.

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INTRODUCTION

One of the problems that has impeded the progress of sonar echo-ranging type studies is the delay in reduction and inspection of experimental data taken at sea. Many months, and in some cases, years, pass before the data collected are reduced and made ready for analysis. Moreover, in reducing the data, errors may be found in the experimental design procedure that may have a profound effect on the final analysis of the data. Unless the consistency of an experiment performed at sea can be examined immediately, simple errors in the experimental procedures can invalidate large quantities of data acquired in a test.

This report will describe a system that uses a digital computer to reduce sonar echo-ranging data at sea in a manner that will allow the immediate inspection of various echo-ranging results while the experiment is in progress. Monitoring equipment is seldom adequate if it remains simple.

Objectives

A computer program has been written to process data from a tone-pulse sonar system for immediate inspection. The data for this program comes from a low resolution pinging sonar using several preformed receiver beams. Because of high reverberation levels, the first twenty seconds of information are ignored by the program, which is capable of processing the following eighty seconds of information from the receiver. Echo-ranging type results and interfering backgrounds are identified, measured and

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displayed after the returns from each transmission are received.

The specifications and input requirements of this automatic tone-pulse sonar data processing system are as follows:

1. Transmitter - Pulse length, $T=0.5$ sec. except when used for reverberation measurements. Reverberation will be measured with a few 2-second pulses at each station.
2. Receiver - Bandwidth will be 5 cps to accommodate 0.5 second pulse and to allow some small doppler tolerance. Five adjacent preformed beams in a set will be used for receiving data. One preformed beam will be placed a few degrees "off target" to keep a running record of interfering background.
3. Attenuators - Attenuator settings will be arranged so that any manual changes made in the setting will be recognized by the program.
4. Sampling Rate - The sampling rate of the signal will be 10 per second per channel.
5. Bearing - Ships heading information is to be entered into the computer for determining true bearing of "echoes".
6. Calibration - Calibration of the system should be made at each station to insure the stability and consistency of the measurements.
7. Echo-repeater - An echo-repeater will be used as a target. Modification of the echo-repeater will permit transponder action delayed 10 seconds after the termination of the trigger signal.

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8. Outputs of Data System - Outputs will be presented in digital form showing echoes (false and real) vs time after transmission; reverberation; impulse noise bursts and steady-state intensities (± 1 db) will be referred to 1 micro-bar. True bearing will be shown for targets.

9. Monitors - An overall monitor such as an Edin Brush Ink Recorder will be used to guide experiments and check the digitized outputs.

Data Reduction and Analysis System

Figure 1 shows a block diagram of the tone-pulse sonar data reduction and analysis system. Available from the receiving array are the outputs of groups of 5 adjacent preformed beams, each beam being 2° wide. Sector coverage is 28° (347° to 360° to 15°). The signals from 5 adjacent beams plus the signal from a beam not among the 5, and the signal from an omni-directional hydrophone are fed into the "Spectran" receiver. The Spectran is a 7 channel filter-amplifier, with 5 cycles/sec bandwidth, centered at two different carrier frequencies. The signals then go to the Bearing Encoder to be converted from analog to digital. The Bearing Encoder receives its name from another application and consists of a multiplexer and a multiverter and their associated circuitry. The signals of the seven inputs are sampled simultaneously by the multiplexer and then digitized by

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the multiverter sequentially. Sampling rate is 10 samples per channel per second. The digitized data are then entered into the computer (AN/USQ-20).

The interrupt switch provides the signal for the computer program to determine the time of an outgoing pulse and to initiate the beginning of the sampling sequence.

The ship's gyro reading is stored into the computer for determination of the true bearing of echoes and targets.

Any changes in the settings of the attenuators associated with the tone-pulse receiver will be recognized by the computer program through the attenuator input cable.

The results of the data reduction and analysis by the computer program will be displayed or recorded on the following equipments:

1. High speed paper printer.
2. Magnetic Tape Unit - The partially processed data in digitized form will be stored on digital magnetic tape for further analysis if necessary.
3. Flexowriter - Used to monitor specific results of the computer program.
4. BQS-5 Display Unit - This unit will be used only when a high speed printer is not available.

A 6-channel Edin Brush Ink Recorder is used to monitor the output of the receiver beams and to provide a ready refer-

ence of comparison for results obtained from the computer program.

Data Reduction

The purpose and intent of the tone-pulse data reduction program, hereafter to be called the "FASOR" program, is to reduce sonar echo-ranging type data in both deep and shallow water. Figure 2 shows an example of the data in analog form that will be digitized and analyzed by the FASOR program. The signal is digitized during the interval 20 to 100 seconds after the outgoing pulse. The FASOR program determines the presence of echoes, system steady-state noise, impulse noise, reverberation and their time of occurrence referenced to the outgoing pulse.

Figure 3 (abcd) is a flow diagram of the FASOR program. The program reduces the data by comparing the average signal during a time period T, with the average signal level surrounding it. The minimum value of T = 0.5 seconds, which is 5 samples, since the system is sampling at a rate of 10 samples/second. The problem can be expressed as:

$$\begin{array}{ccc}
 \text{(a)} & \text{(b)} & \text{(c)} \\
 \frac{1}{T} \sum_{i=K-T}^{i=K} e_i & < & \frac{1}{T} \sum_{i=K+T}^{i=K+2T} e_i \\
 \frac{1}{T} \sum_{i=K-T}^{i=K} e_i & > & \frac{1}{T} \sum_{i=K+T}^{i=K+2T} e_i
 \end{array} \quad (\text{Eq. 1})$$

K = 5, 6, 7. . . . (nth sample)

T = 5 samples (T), 10 samples (2T), 20 samples (4T)

e_i = signal level at time "i"

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The values in equation (1) are converted to decibels and then if (b) is greater by a predetermined db level than (a) and (c), the signal at (b) is classified as an echo.

Reverberation and steady-state noise levels are found by equation (2) and (3) respectively

$$\frac{1}{8T} \sum_{i=K}^{i=K+8T} e_i \quad (\text{Eq. 2})$$

$$\frac{1}{16T} \sum_{i=K}^{i=K+16T} e_i \quad (\text{Eq. 3})$$

The automatic first classification of the signal (e), depending upon the "T" used, can be summed up as follows:

- T = 0.5 sec "Echo"
- 2T = 1.0 sec "Echo"
- 4T = 2.0 sec "Echo" or "Discrete Reverberation"
- 8T = 4.0 sec "Reverberation"
- 16T = 8.0 sec "Background" or "Noise" (i.g., the lowest signal level over an interval of 8 seconds.

All signal returns that meet the requirements of equation (1) will be tentatively classified as echoes. However, when two "echoes" are found to be 10 seconds apart, the first will be called "target" and the second, "transponder". If it is

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found that the "echo" levels are the same or within a predetermined level of each other on all beams, the "echoes" will be re-classified as impulse noise.

The results obtained by the FASOR program are listed in detail in the section labelled "FASOR OUTPUTS". All resulting signal levels are expressed in db re one microbar. The program takes into account the receiver sensitivity, attenuator setting(s) and the calibration in calculating the signal levels.

Operational Procedure

This section will present the step by step operating instructions for loading the FASOR program into the AN/USQ-20 digital computer. The detailed explanation of the functions of certain instructions are omitted in this section but can be found in Appendix A.

Figure 4 shows a sample configuration of the computer console registers for the setting up of initial conditions that are called for by the FASOR program.

1. Put BQS-5 magnetic tape on Unit 0.
2. Set Key 7.
3. Strike Auto-Recovery switch.
4. Wait for BQS-5 tape to stop, then re-set Key 7.
5. Clear all computer registers.
6. Set P-register to 00001.
7. Put FASOR program in the photo-electric reader.

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8. Strike the Hi-Speed key.
9. Wait for program to load.
10. If calibration desired, see "Calibration Procedure";
if not, continue.
11. Set initial operation conditions (see figure 4)
 - Q - (upper half) T4 criteria (octal)
(lower half) DB criteria (octal)
 - A - (upper half) Zonetime (BCD)
 - B1 through B4 - Time of Day (BCD)
 - B5 - Ping Number (octal)
 - B6 - Month (octal)
 - B7 - Day (octal)
12. Set the P register to 40000 (Starting address of the
FASOR program.)
13. Strike the Hi-speed key.

The program is now operating, waiting for the pulse to be emitted from the tone-pulse system. After each pulse, the program will print the answers on a high-speed paper printer or on the EQS-5 display unit. Once the program has been read into the computer, nothing else is necessary for the program to operate on each successive tone-pulse. However, if changes in the initial conditions are desired, make the changes in the appropriate registers after an output and before another tone-pulse is emitted. Clearing the computer is not necessary before making any change(s).

The FASOR program should be re-loaded into the AN/USQ-20

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before the start of each test station to insure that the program has not been altered while enroute from one station to another.

CALIBRATION PROCEDURES

The computer programs for the reduction of data taken at sea expresses the signal levels in db re 1 μ bar. To accomplish this, calibrations should be made at the start of each event to determine the factors needed to report the data in microbars.

The calibration program is read into the computer along with the FASOR program, and entered into at 40001. The initial conditions of the computer registers should contain the following:

Upper Half of Q - Input voltage (BCD)
B1 through B4 - Time of Day (BCD)
B6 - Month (octal)
B7 - Day (octal)

The location in the program labelled "HYDR" should contain the receiver sensitivity. Under normal circumstances, the sensitivity value is a constant and is part of the written program. However, if the occasion should arrive to have a different value for the sensitivity, insert the new value in the "HYDR" location before continuing on with the calibrate program.

Figure 5 is a block diagram of the calibration system and should be used in reference to the calibration procedure which

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follows. Calibration is accomplished first by equalizing all 5 beams of the delay line sector being used. Then the input voltage is inserted into the center beam and attenuated 30 db and the interrupt switch depressed. The computer program then takes a one second sample of the signal level through the Spectran and Bearing Encoder. The average signal level is determined and stored into memory. The same procedure is repeated with the attenuator set at 40 and 50 db. Upon completion of the sampling at 50 db, the program will compute the "K" FACTOR, which is the constant needed to reference the signal levels of the FASOR program to μ bar. The program then types out on the flexowriter, the "K" FACTOR in db, and the various values associated with the attenuator settings of 30, 40 and 50.

KFACTOR(XXX.X) 30 (XXX) 40(XX.X) 50 (XX.X)

The constant, KFACTOR, is determined by the equation

$KFACTOR = SFG + ATT - REC SENS$ (in db)

SFG: Signal at full gain

ATT: Attenuator setting

REC SENS: Receiver sensitivity

In brief, the calibration procedure can be summarized as follows:

1. Read the FASOR program into the computer.
2. Set the initial conditons.
3. Enter program (Set P = 40001).

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4. Equalize all channels.
5. Set calibrate attenuator to 30 db.
6. Strike interrupt key.
7. Set calibrate attenuator to 40 db.
8. Strike interrupt key.
9. Set calibrate attenuator to 50 db.
10. Strike interrupt key.
11. Program output on flexowriter.
12. Now ready for main FASOR program.

Figure 6 is a flow chart of the calibrate portion of the FASOR program.

To insure that the correct value of the "K" FACTOR is used in the main program, location 43401, the cell where the "K" FACTOR is stored, should be checked for agreement with the latest printout of the calibrate before continuing into the FASOR program.

FASOR OUTPUT

Table I is an example of the output from a pulse after the FASOR program has reduced and analyzed the data relating to that pulse. The output is divided into 4 main sections and the detailed explanation of the entries are as follows:

Section 1

Ping NR : Identifies the ping number. Usually in sequence but can be changed when so desired by placing

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the desired number (in octal notation) into the appropriate B register before the ping is sent out.

Time : Corresponds to time the ping was sent out and the day, month and year.

T⁴ is : The minimum signal level above noise (or background) for a 4T integral analysis of a signal return to be classified as an "echo" or "discrete reverberation".

DB is : The minimum signal level above noise (or background) for a T or 2% integral analysis of a signal return to be classified as "echo".

Zonetime: The suspected or predicted time of the first convergence zone arrival after the outgoing pulse. This time is used to define the time to make an 8T integral on the data for display in Section 2 under the T8 heading.

Heading: Mean ship's true gyro heading during the 80-second data analysis period of a pulse.

Section 2

T¹⁶ : The lowest value of the signal per beam over an 8-second interval (16T integral) in db re 1μbar

Time : This time is associated only with the T¹⁶ integral and tells the time of the lowest T¹⁶ integral found.

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Beam : Self explanatory. Beam 6 is the Off-Beam signal.

T8 : The level of the signal over a 4-second (8T) integral computed at the given zonetime in Section 1. Answer is in db re 1 μ bar. This can be interpreted as the mean zonal reverberation.

Number of Entries: This gives the percentage of the number of entries to be listed in Section 3 as compared to the number of entries to be listed in Section 4.

Section 3

Integral: This heading is divided into the 3 categories that are used to determine the classification of the received signals as echoes. (1=T, 2=2T and 4=4T).

Beam : Tells which beam the "echo" was strongest. Along with the beam number will be the true heading of the "echo". If two numbers appear for the beam number, it will mean that the "echo" is between two adjacent beams; the first beam number having the higher amplitude.

Time : Time when the "echo" was detected after the transmission of the pulse.

Level : The amplitude in db re 1 μ bar.

Class : The "echoes" found are classified into the following:

TGT = Target

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Noise = Classified as such if "echoes"
appear on all 5 beams at the same
time and their amplitudes are within
 ± 8 db of each other.

Echo = Other false echoes or "targets".

TRSP = Transponder

After a TGT is found, the program lists the average level of the signal (4T integral) before and after the target and the average level (8T integral) of the signal on the off beam channel at the time of the target. This listing maintains a rather detailed account of reverberation and/or nearby echoes including some multi-path echoes.

Section 4

The headings in this section are the same as described in Section 3. The information found in this section gives detailed beam data from which the answers in Section 3 are determined.

CONCLUSION

The purpose and intent of the FASOR computer program, besides allowing the immediate inspection of sonar echo-ranging results, is to shorten the length of time between the acquisition of data and the analysis. All results produced by the computer program should not be construed as final. Further analysis of the results may be required in some cases. How,

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ever many tedious tasks in reducing the data will have been eliminated, and this insures more rapid progress in echo-ranging studies, and closer attention to non-routine tasks.

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APPENDIX A

DETAIL INFORMATION OF THE
OPERATING INSTRUCTIONS FOR THE
FASOR PROGRAM

1. The first thing to do is to load the BQS-5 magnetic tape on Unit 0, set Key 7, and hit the Auto Recovery key. Doing this will read into the computer, the SUBRPAK, PTR, and UTILITY routines that are needed in the FASOR program. SUBRPAK will load into location 70000; PTR will load into 75000; and UTILITY will load into 0000. Setting Key 7 prevents the computer from going into the main BQS-5 programs.
2. Put the FASOR program into the hi-speed photoelectric reader. Set the P register to 0001 and hit the hi-speed key. This will read the FASOR program into the computer starting at cell 40,000.
(Key 7 down)
3. The decision to take a calibration must be made now. If a calibration is needed, proceed with the next step. If the calibration is not needed, skip to step 5.
4. Set the P register to 40001 and hit the hi-speed key. This will enter the calibrate program. The steps needed for calibrating can be found in the Calibration Procedures section. The calibration program ends with the KFACTOR, and the corresponding levels for the 30, 40, and 50 db level attenuations. The program

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then jumps to the FASOR program located in cell 40,000 and stops.

5. Before continuing on with the FASOR program, there are certain things that must be done. If a calibrate had not been run immediately preceding this step, cell 43401 must be checked to determine if the proper KFACTOR is stored therein. (This can be verified by the most recent calibrate.) Store the correct KFACTOR into cell 43,401.

6. The initial conditions of the program are now set at this time.

The following registers should contain:

Q - (upper half) T⁴ criteria

(lower half) DB criteria

A - (upper half) Zonetime

B1 through B4 - Time

B5 - Ping Number

B6 - Month

B7 - Day

For detailed explanations of the initial condition settings, refer to Figure 4 or the explanation of the FASOR outputs.

7. After setting the initial conditions, strike the hi-speed key as soon as the time in B1 through B4 agrees with the real-time clock used during the sea tests. The FASOR program is now waiting for a pulse to be sent out.

8. Details of the FASOR program are found elsewhere in this report. Upon completion of the data reduction upon one pulse, the computer will output onto the hi-speed printer or the BQS-5 display

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console and then wait for the next outgoing pulse before doing anything else. Any changes that need to be made from the initial conditions should be performed now and before the next pulse is sent out.

9. The program can be stopped at any time and re-entered at location 40000.

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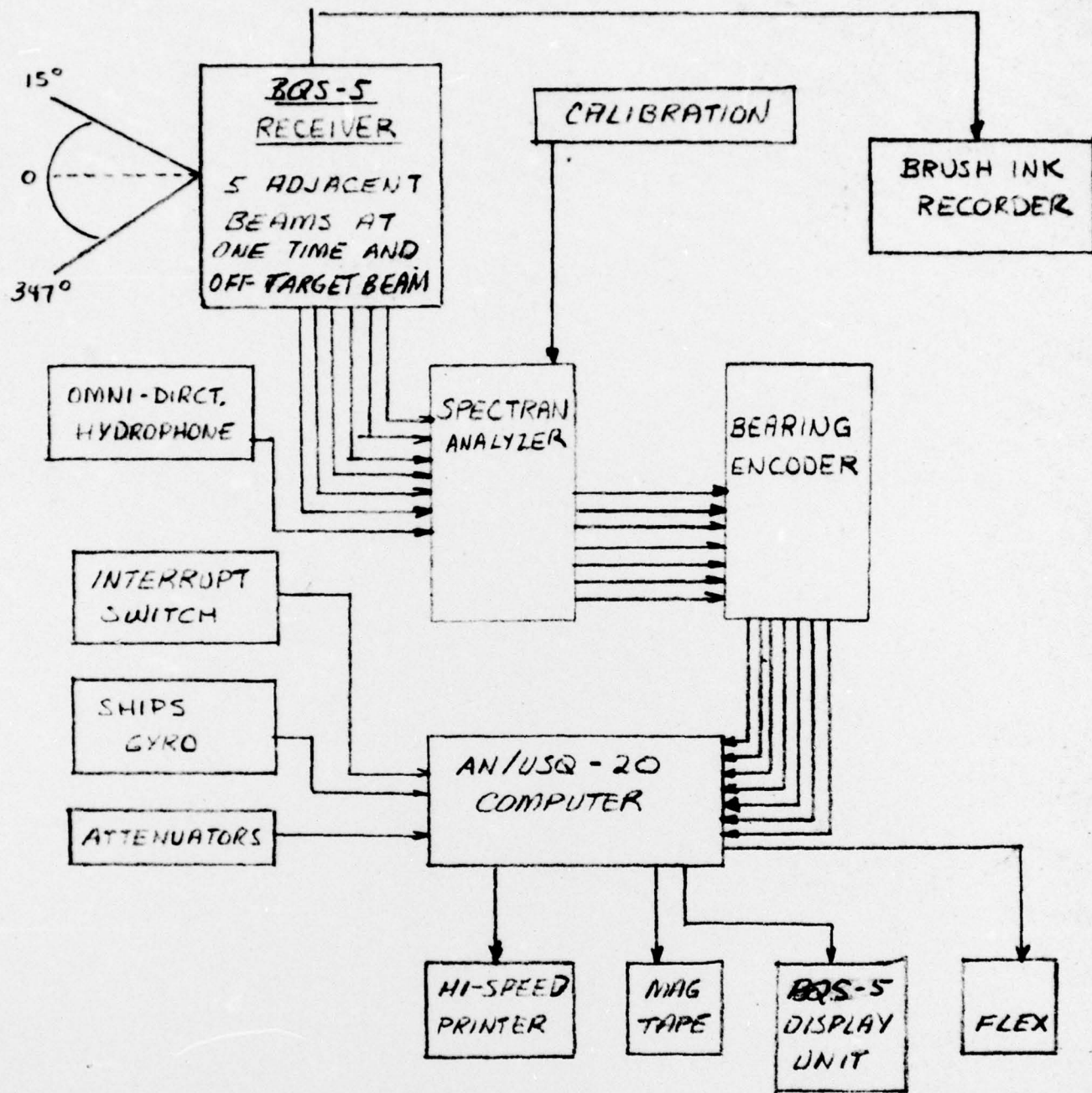


FIGURE 1 SYSTEM BLOCK DIAGRAM
 BLOCK DIAGRAM OF THE TONE-PULSE
 SONAR DATA REDUCTION AND ANALYSIS SYSTEM

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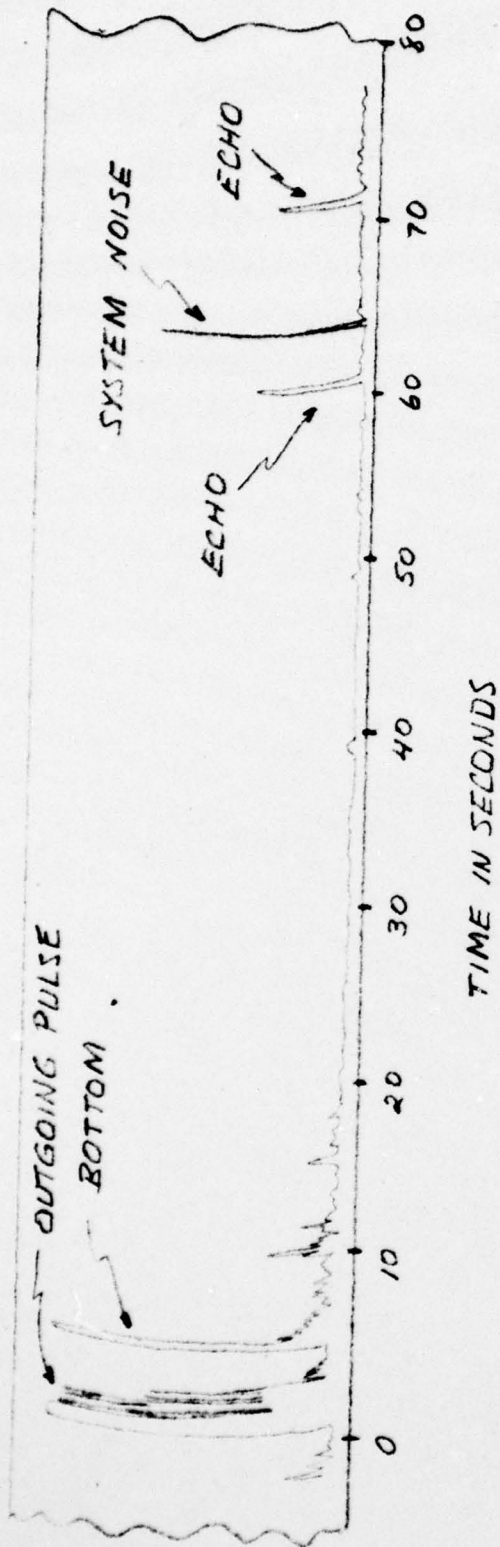


FIGURE 2
EXAMPLE OF SONAR ECHO-RANGING DATA
THAT WILL BE DIGITIZED AND ANALYZED BY THE COMPUTER
PROGRAM.

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FASOR PROGRAM FLOW CHART

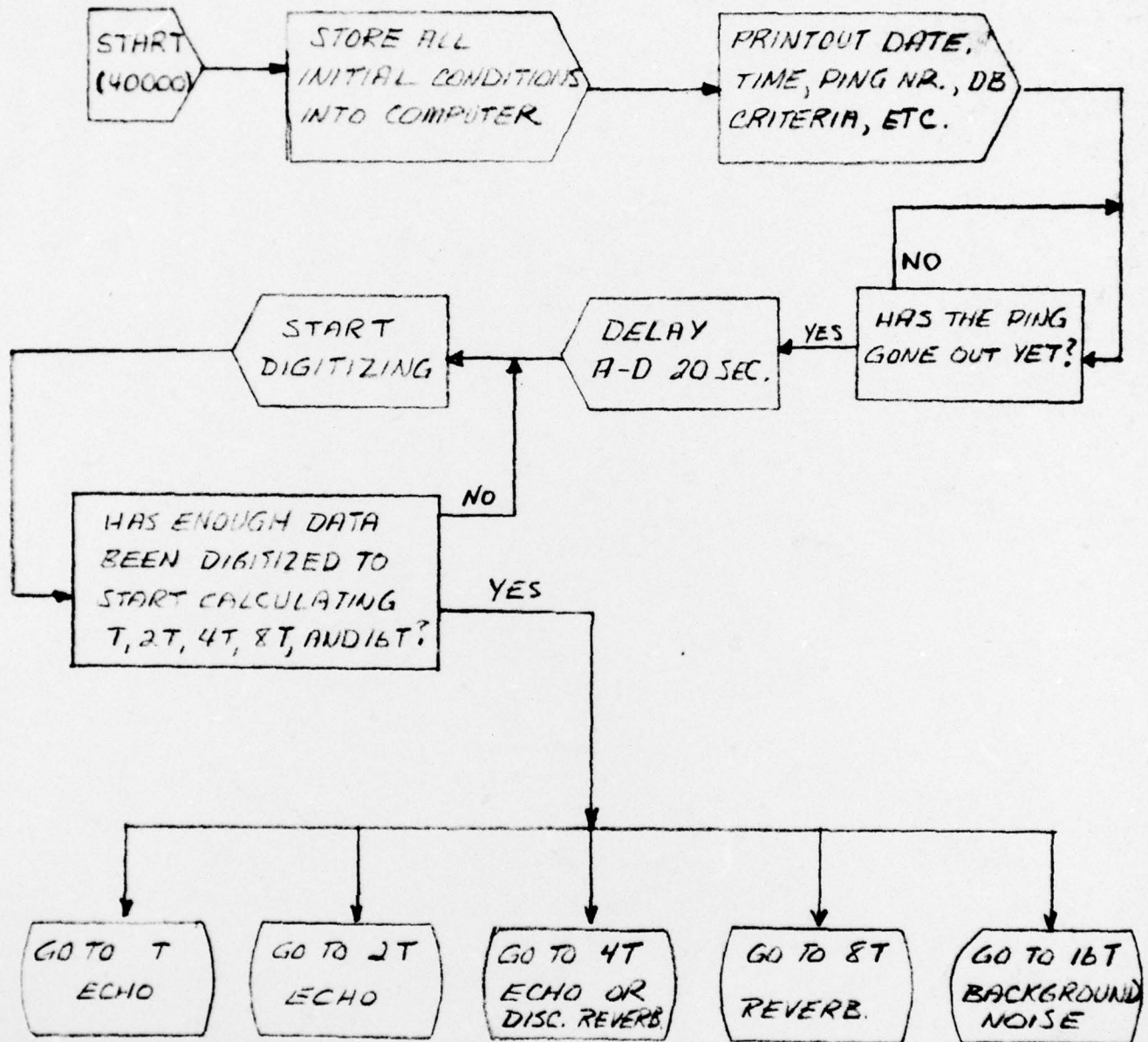


FIGURE 3A

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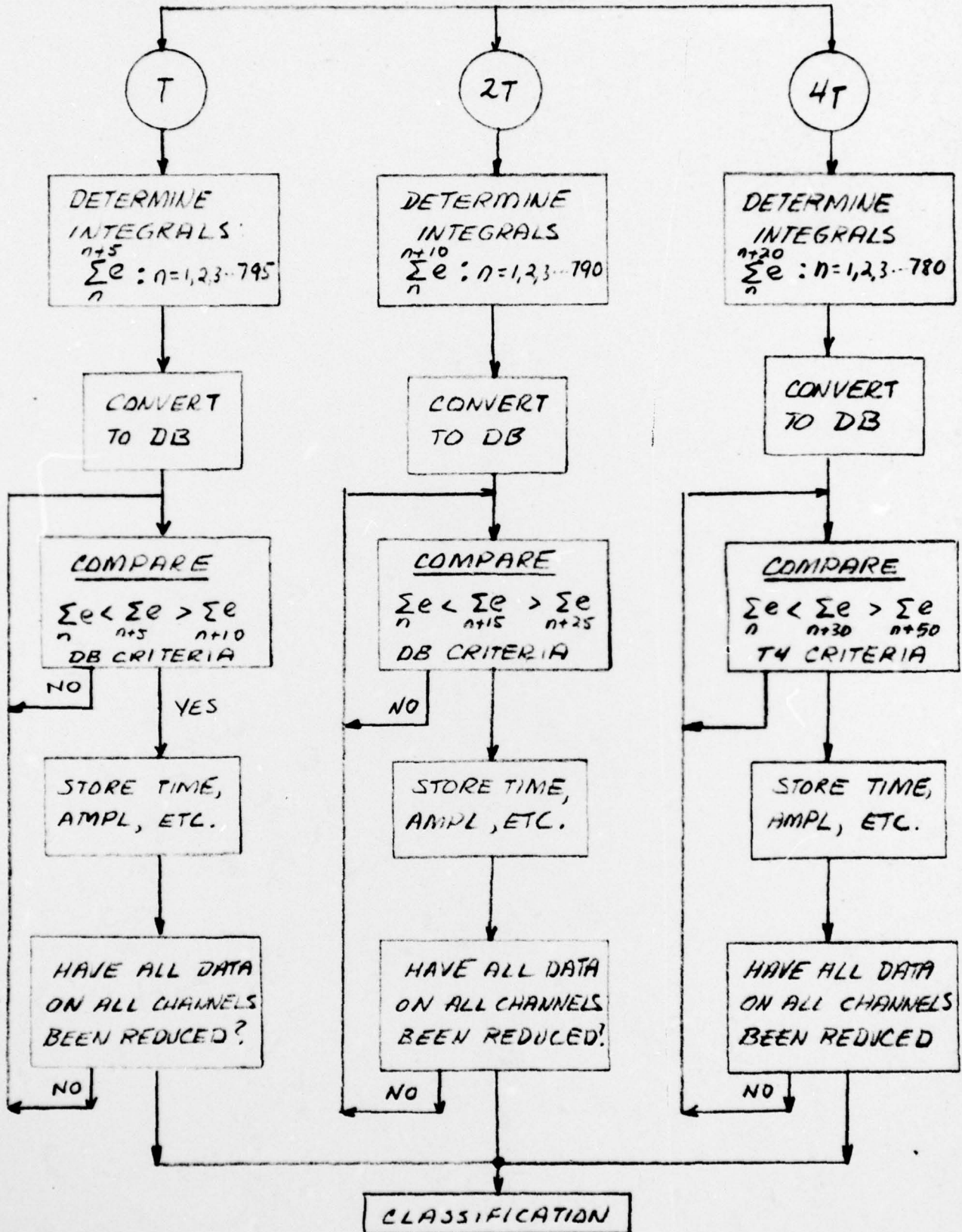


FIGURE 313

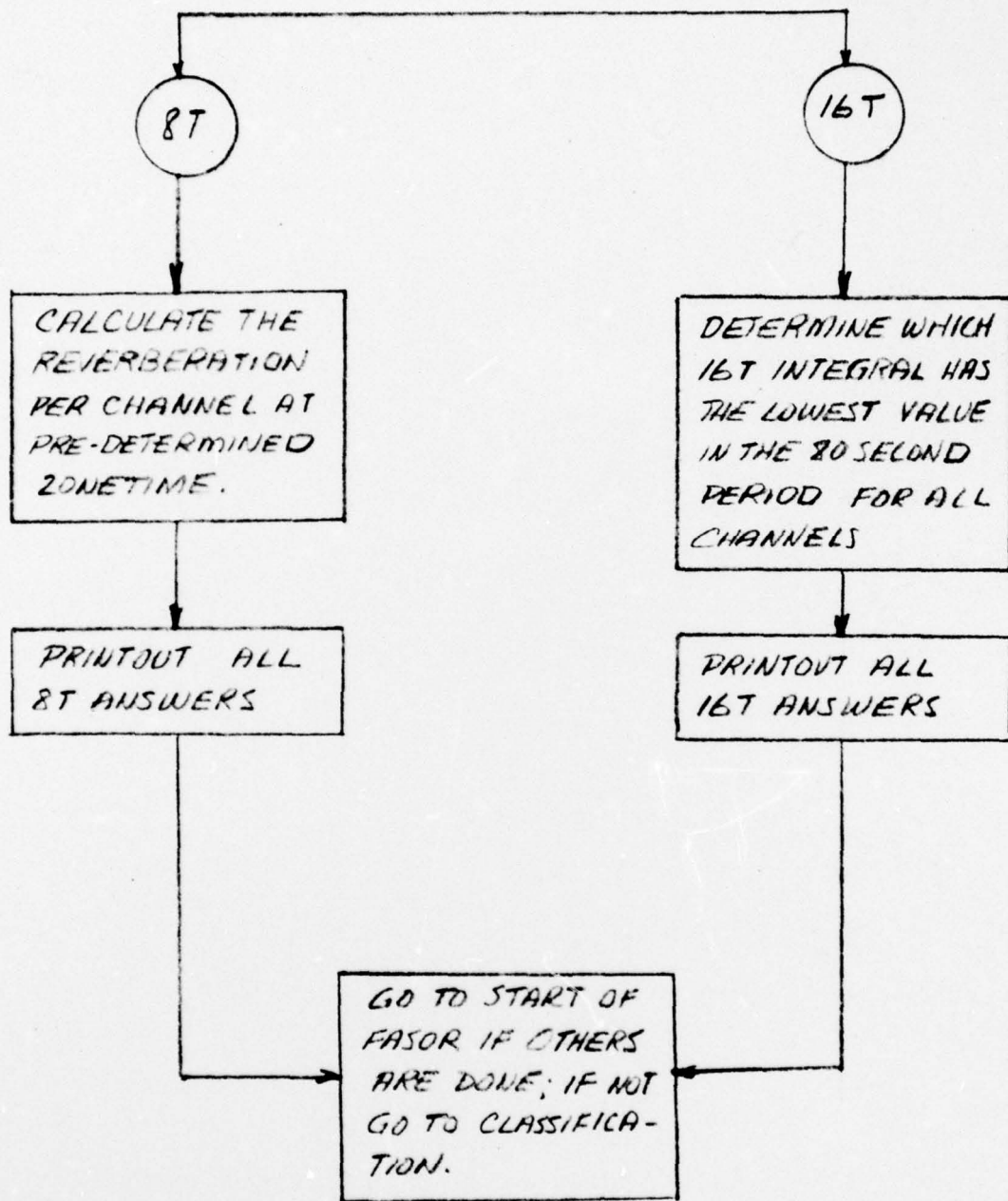


FIGURE 3C

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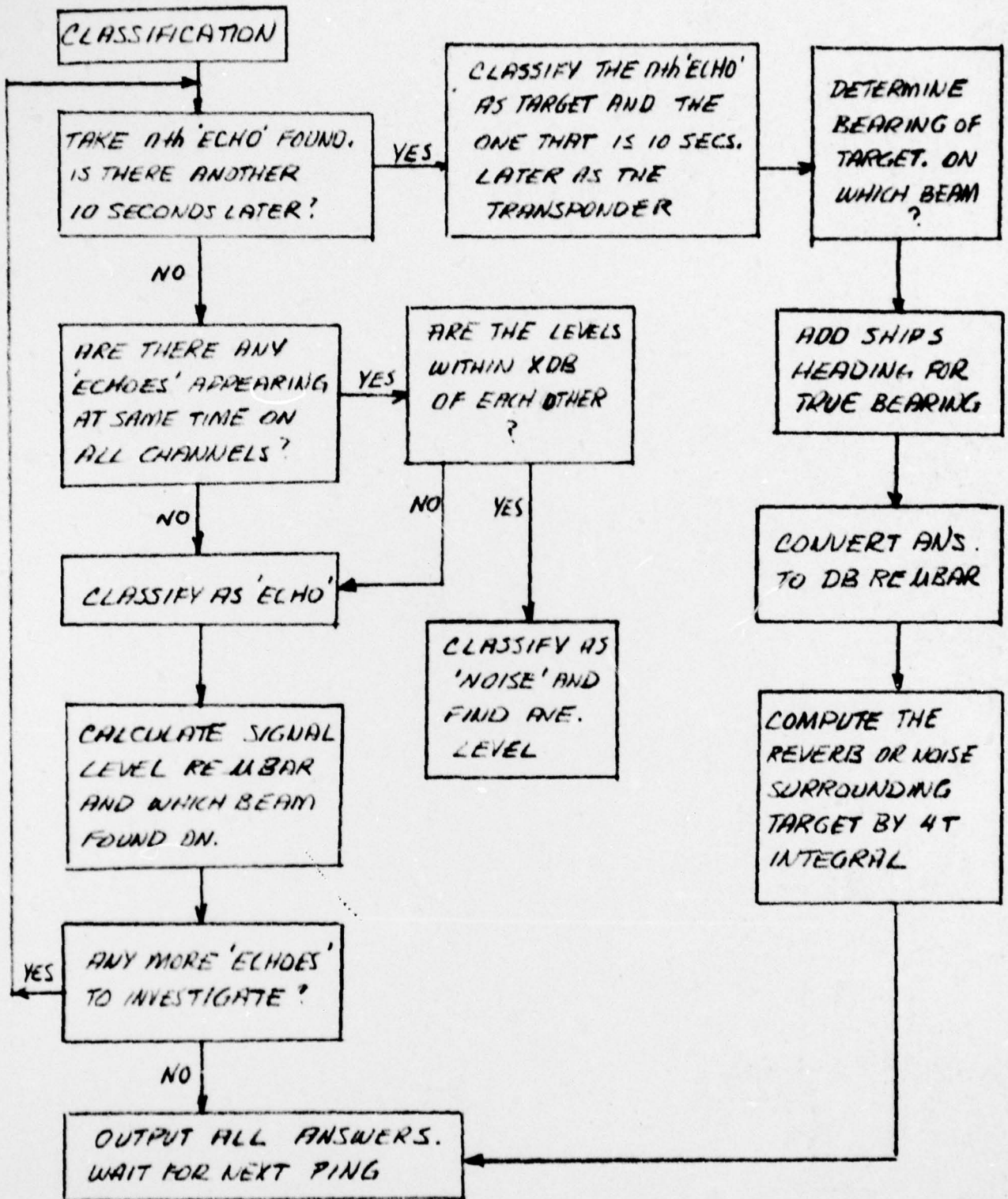


FIGURE 3D

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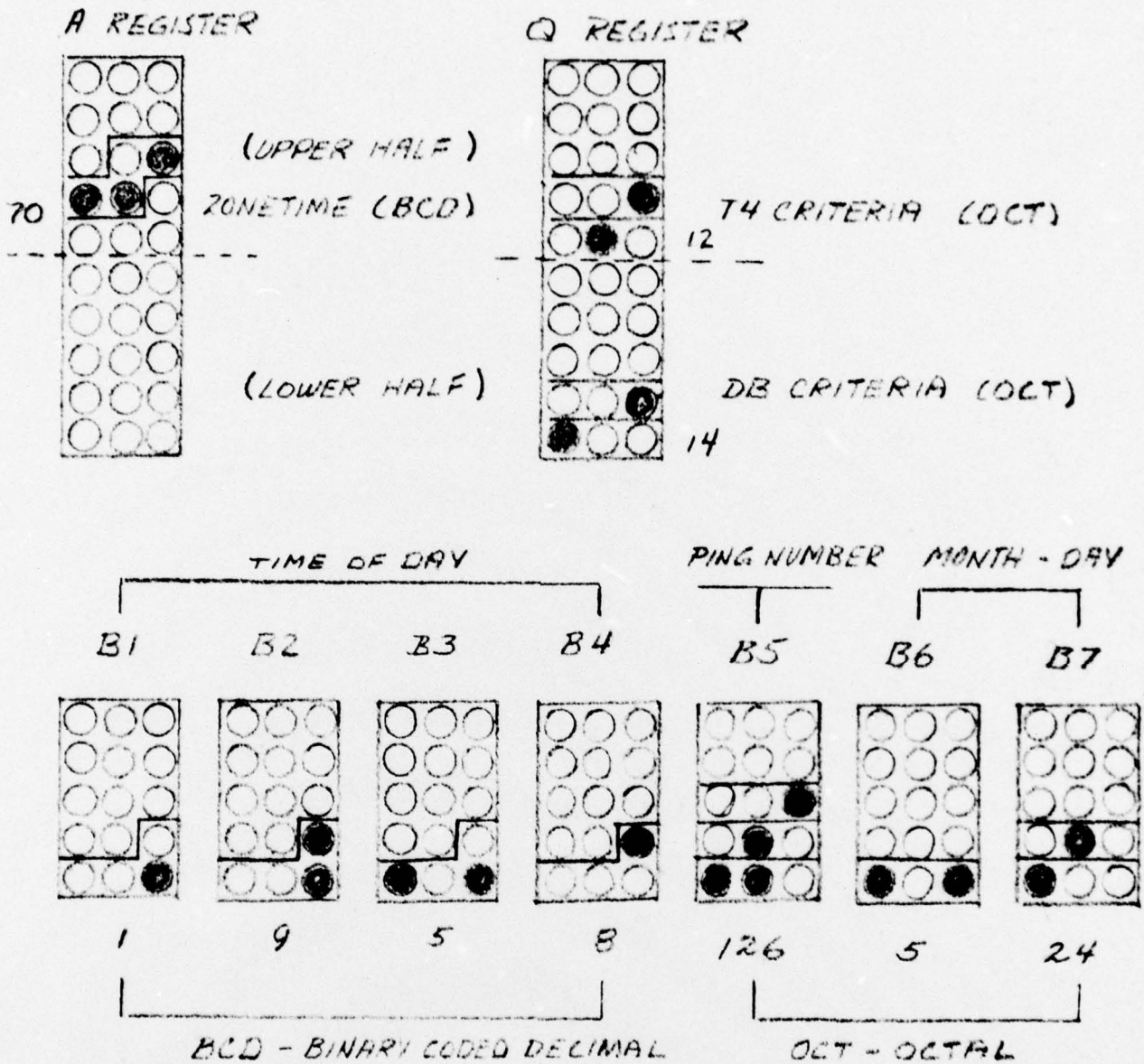


FIGURE 4 COMPUTER CONSOLE DISPLAY

IN THIS FIGURE WITH THE SOLID CIRCLES REPRESENTING THE INITIAL SETTINGS OF THE PROGRAM, THE TIME OF DAY IS 1958; PING NUMBER 126; MAY 20; T4 CRITERIA IS 10; DB CRITERIA IS 12; AND ZONETIME IS 70.

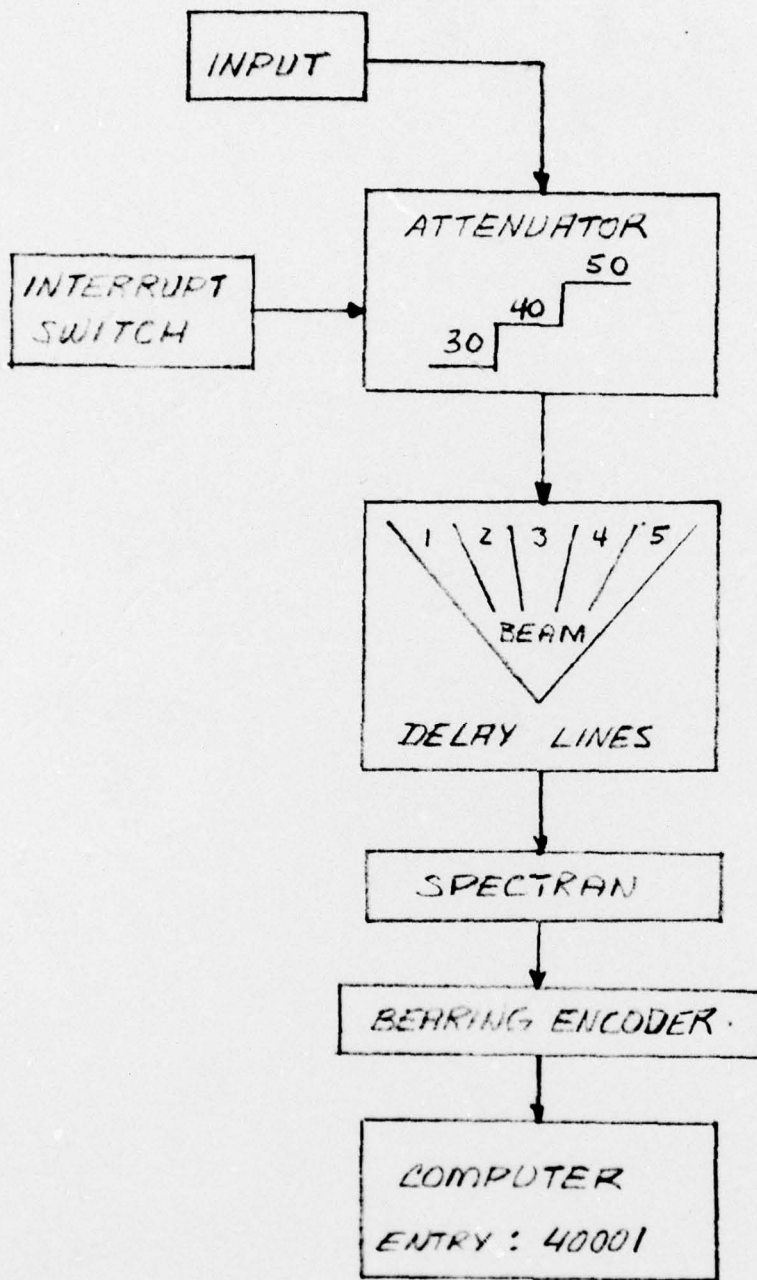


FIGURE 5

BLOCK DIAGRAM OF CALIBRATION SYSTEM.

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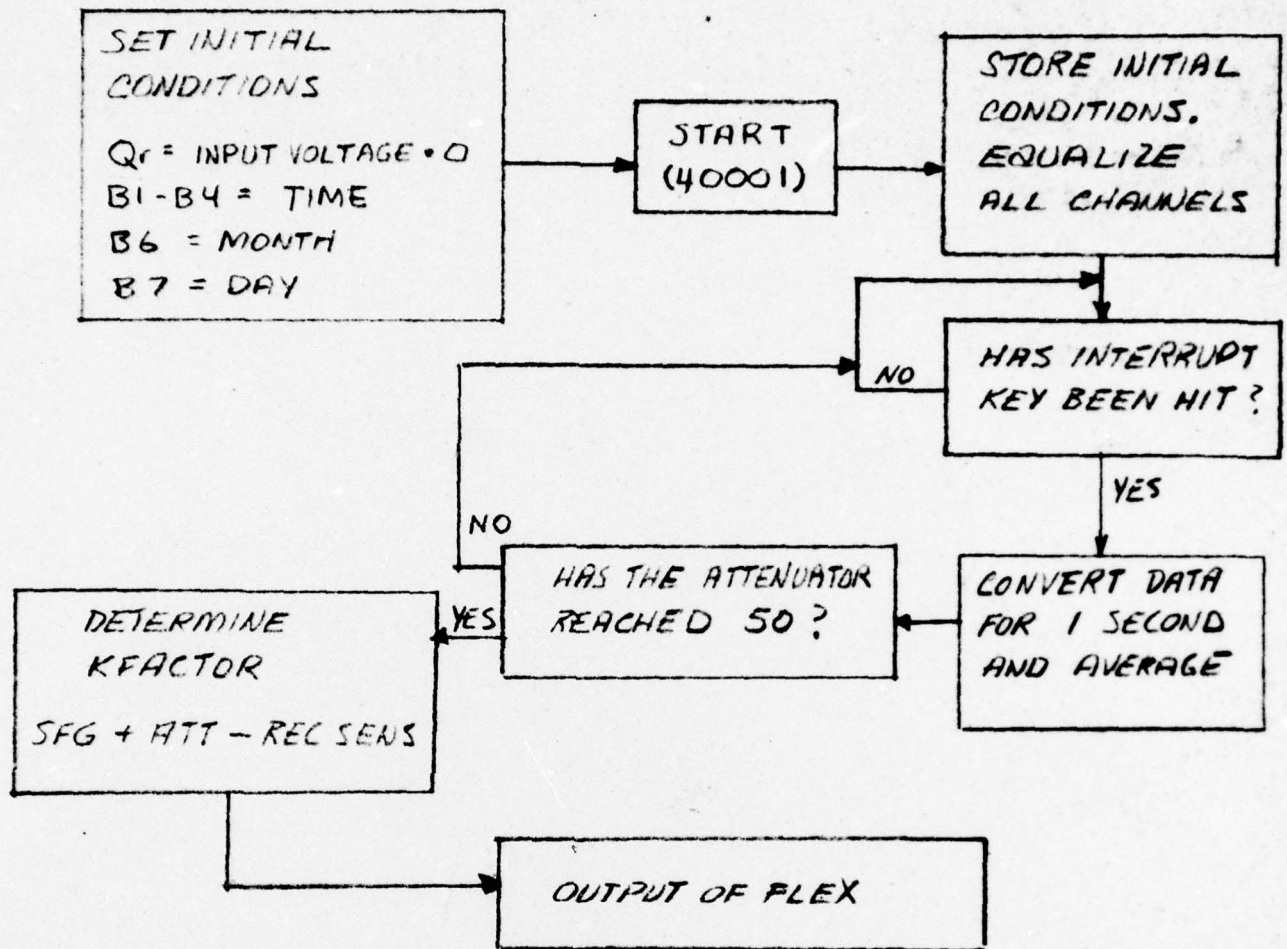


FIGURE 6

CALIBRATE PROGRAM FLOW CHART

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PING NR 115 TIME 2145*00 6 AUG 1964
14 IS 10.0, DB IS 10.0, ZONETIME IS 70.0
HEADING IS 0.0

SECTION 1

116	TIME	BEAM	TBLEVEL
27.5DB	90.8	1	40.5
29.3DB	45.9	2	44.7
29.0DB	93.1	3	45.3
31.4DB	94.1	4	44.1
28.3DB	47.2	5	43.1
30.4DB	93.5	6	42.8

SECTION 2

NUMBER OF ENTRIES IS 15 AND 46 / 32.6 PERCENT

INTEGRAL	BEAM	TIME	LEVEL	CLASS
1	43	22.0	54.4	ECHU
1	32	70.3	61.3	TGT 34.1 BEF, 34.0 AFI, 43.0 OFF.
1	34	73.3	52.2	NOISE
1	32	80.1	61.4	TRSP
1	23	85.8	55.7	NOISE
2	5	22.1	51.4	ECHO
2	32	70.3	55.6	TGT
2	32	80.1	56.0	TRSP
2	2	85.9	50.3	ECHO
4	32	70.2	50.2	TGT
4	32	80.1	51.1	TRSP
4	2	85.1	45.8	ECHO
4	2	85.7	45.5	ECHO
4	2	80.0	45.3	ECHU
4	2	80.2	45.2	ECHU

SECTION 3

RAW DATA

INTEGRAL	BEAM	TIME	LEVEL
1	1	70.3	55.2
1	1	73.3	46.6
1	1	80.1	48.7
1	1	85.8	46.6
1	2	22.0	52.5
1	2	70.3	60.9
1	2	73.3	49.0
1	2	80.1	57.7
1	2	85.8	55.7
1	3	22.0	53.3
1	3	70.3	61.3
1	3	73.3	52.2
1	3	80.1	61.4
1	3	85.8	51.4
1	4	22.0	54.4
1	4	70.3	59.3
1	4	73.3	50.1
1	4	80.1	55.2
1	4	85.8	49.9
1	5	70.3	58.6
1	5	73.3	49.2
1	5	80.1	52.8
1	5	85.8	49.0

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2	1	70.3	50.0
2	2	22.1	48.3
2	2	70.3	55.2
2	2	80.1	52.7
2	2	85.9	50.3
2	3	70.3	55.6
2	3	80.1	56.0
2	4	70.3	53.8
2	4	80.1	50.4
2	5	22.1	51.4
2	5	70.3	53.0
2	5	80.1	48.7
4	1	70.2	44.9
4	2	70.2	49.7
4	2	80.1	48.0
4	2	85.1	45.8
4	2	85.7	45.5
4	2	86.0	45.3
4	2	86.2	45.2
4	3	70.2	50.2
4	3	80.1	51.1
4	4	70.2	48.7
4	5	70.2	47.8

TABLE I

EXAMPLE OF AN OUTPUT FROM THE FASOR PROGRAM

BEST AVAILABLE COPY

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