Technical Report No. 86

SACLANT ASW

RESEARCH CENTRE

A DIGITAL RECORDING SYSTEM FOR LORAN-C

by

T.D. ALLAN and C. MONTANARI

1 APRIL 1967

NATO

VIALE SAN BARTOLOMEO, 400
LA SPEZIA, ITALY

This document is released to a NATO Government at the direction of the SACLANTCEN subject to the following conditions:

1. The recipient NATO Government agrees to use its best endeavours to ensure that the information herein disclosed, whether or not it bears a security classification, is not dealt with in any manner (a) contrary to the intent of the provisions of the Charter of the Centre, or (b) prejudicial to the rights of the owner thereof to obtain patent, copyright, or other like statutory protection therefor.

2. If the technical information was originally released to the Centre by a NATO Government subject to restrictions clearly marked on this document the recipient NATO Government agrees to use its best endeavours to abide by the terms of the restrictions so imposed by the releasing Government.

TECHNICAL REPORT NO. 86

SACLANT ASW RESEARCH CENTRE
Viale San Bartolomeo 400
La Spezia, Italy

A DIGITAL RECORDING SYSTEM FOR LORAN-C

By

T.D. Allan and C. Montanari

1 April 1967

APPROVED FOR DISTRIBUTION

HENRIK NØDTVEDT
Director

Manuscript Completed:

12 December 1966

TABLE OF CONTENTS

A DIGITAL RECORDING SYSTEM FOR LORAN-C

By

T.D. Allan and C. Montanari

ABSTRACT

A method for digitally recording the readings of a Collins LORAN-C Mk LR 101 Receiver on punched paper tape is described. The various advantages of automatically recording LORAN-C data are examined and it is shown how, with frequent sampling, computer smoothing techniques can be used to reduce significantly the effect of atmospheric noise.

Instructions for operating the SACLANT ASW Centre's Digital Recording System for LORAN-C are included as an appendix.

INTRODUCTION

The observational data recorded at sea are often so numerous that a substantial saving in time and effort can be achieved by adopting an automatic system of recording in a form suitable for acceptance by a digital computer. Not only is analysis made easier but the results are permanently available in a systematic form. There is a great advantage in knowing more certainly how the data have been treated.

A first essential for any ship-borne data acquisition system is an accurate knowledge of the ship's position. This report describes a digital recording system designed and built at SACLANTCEN to be used with a Collins LORAN-C Receiver MK LR 101 (USCG N° AN/SPN 30) and subsequently operated successfully in cruises to the North Atlantic and in the Mediterranean Sea.

A computer method of smoothing the plotted LORAN data has also been developed. This is described in Appendix A.

Instructions for operating the ship-borne equipment are given in Appendix B.

1. THE LORAN-C NAVIGATIONAL SYSTEM

1.1 Basic Principles

The LORAN system is a long-range navigational aid intended primarily for ocean navigation; two versions are currently in use: LORAN-A, and its improved version LORAN-C. Both systems use pairs of pulse-transmitting ground stations, but, whereas LORAN-A uses frequencies around 1.8 MHz, LORAN-C acquires an extended range by transmitting in the low-frequency, 90-110 kHz, band.

One ground station of a LORAN network is designated as the "master" station. This master transmits the groups of pulses received by the ship's receiver and by the slave stations. After a controlled time delay the slaves transmit similar groups of pulses. The constant time differences between the reception of the master and slave pulses establishes a LORAN line of position, which is a hyperbola.

The increased accuracy of LORAN-C is achieved by using pulse envelope measurements for coarse time-difference measurement, and measurement of the radio frequency cycle phase for accurate fine time difference measurement.

1.2 Coverage

Figure 1 shows the positions of the stations in the N.E. Atlantic and the Mediterranean. It can be seen that ground-wave reception is possible over most of the Mediterranean, although in practice it has been found that intervening land masses — Sicily, Corsica, etc. — can mask signals from distant stations.

1.3 Operational Procedure

LORAN-C charts published by the U.S.N. Oceanographic Office are available for the various chains in the world, but the scale of about 1:2 000 000 is too small for accurate position fixing and tables must be used to construct charts to the required scale.

At the start of an operation the LORAN-C receiver must be locked-on to the three stations to be used (master and two slaves). The method for doing this is fully described in the receiver manuals. When lock-on is achieved, time differences are displayed as two 6-digit numbers, the least significant digit representing tenths of microseconds. For example, if the two numbers are 169526 and 503547 then this would represent an X reading of 16952.6 μs and a Z reading of 50354.7 μs. In this example 1695 and 5035 represent the envelope time differences and 2.6 and 4.7 represent the cycle time differences. Separate servo mechanisms drive the envelope and cycle independently of one another. If desired, the envelope servo can be switched off and the envelope reading will be driven from the cycle by direct gearing.

The above remarks refer to a Collins LR 101 (AN/SPW 30) LORAN receiver, the type used by SACLANTCEN since 1962. The usual procedure adopted for survey work was as follows:

A hyperbolic grid was drawn by hand on the nautical chart of the area to be surveyed. The values of the curves were taken from tables prepared by the U.S. Oceanographic Office. During the survey the LORAN-C reading was recorded in a log book every 15 minutes and for any special event. The reading was then plotted by interpolating between adjacent curves of the grid.

1.4 Errors introduced by manual recording

The errors inherent in the manual recording of LORAN data include:

(i) Draughting errors in the original grid.

(ii) Operator's error in recording the readings.

(iii) Errors in recording the reading before and after the stipulated time. (For example, an error of 15 seconds in the time, at a ship's speed of 10 knots, corresponds to a positional error of 250 ft.)

(iv) Errors in plotting the point.

A further error will be introduced into oceanographic measurements if the clock of the measuring instrument (e.g. GEK, depth recorder, magnetometer, etc.) is not properly synchronized with the navigational clock.

For these reasons, a system of recording the LORAN-C readings automatically, which would be free from "human" errors, appeared to be first essential in designing a fully-automated data-logging system.

1.5 Ambiguity

In operation in the Mediterranean, the LORAN envelope reading has frequently given an ambiguous reading with respect to the cycle reading. Figure 2 illustrates how this can arise. In the first example the envelope reading is 1694 and the cycle reading is zero. The graduated scale on the least significant digit of the envelope reading is zero and, since this agrees with the cycle reading, there is no ambiguity. It can happen however that the reading of the envelope in the last digit falls between 3 and 4 as in the second example shown. It is not clear whether the correct reading should be 169300 or 169400. In such a case an "ambiguity" switch on the receiver can help to resolve the ambiguity. But it is not uncommon for the envelope to be more than one revolution out of phase with the cycle, as in the third example. In such a case the reading would be taken by any human operator as 169300, which would introduce an error of 10 μs. To prevent this danger it was found necessary for manual recording to record not only the LORAN readings but also the successive differences. This problem is eliminated, however, in an automatic recording system.

1.6 Environmental factors affecting the range and accuracy of the LORAN-C system

Reference 1, which is an engineering evaluation of the LORAN-C system, lists five factors of radio wave propagation that affect the range and accuracy of LORAN-C in the ground wave area.

It will be shown that some of these factors are less important in areas where relative, rather than absolute, position accuracy is required. Other factors can be effectively reduced by automatic recording techniques.

The factors are:

(1) Amplitude of the skywave and the skywave delay.

(2) Signal-to-noise ratio.

(3) Interference.

(4) Refractivity of the earth's atmosphere.

(5) Conductivity of the earth.

These effects are examined briefly below:

1.6.1 Skywaves

At frequencies near 100 kHz the stability of the reflecting and refracting medium – the ionosphere – is comparatively high. During night-time operation the amplitude of the skywave is higher than the groundwave signal. For example, during summer the ratio of skywave-to-groundwave is 3:1 for ranges greater than 1300 n.mi; this rises to 10:1 in the winter (Ref. 1). Interference from the skywave is not a great problem to groundwave working when the skywave is less than about ten times the groundwave amplitude, which is usual in day-time. The groundwave arrives at the receiver ahead of the skywave so that, in theory, the received signal can be sampled first. In practice, however, if the skywave amplitude is much greater than the groundwave, the receiver will sample the skywave.

The time delay between skywave and groundwave is in the order of 30-60 μs depending on the distance to the transmitting stations.

There is thus little chance of confusing the two readings. The more recently published LORAN charts give corrections to be applied to the skywave reading if groundwave sampling proves to be impossible.

1.6.2 Signal-to-noise ratio

A system of coding the 8-pulse transmission ensures that the LORAN receiver will maintain lock-on to the signals even in a very high noise background. The accuracy of cycle time difference measurements is practically independent of atmospheric noise for signal-to-noise ratios greater than 1-to-1 (0 dB). Figure 3 (reproduced from Ref. 1) shows how the standard deviation of cycle time difference varies with random noise. Note that with a signal-to-noise ratio as low as -20 dB the standard deviation is less than 0.25 μs.

In general, the atmospheric noise increases at night. For the Mediterranean Sea, Ref. 1 quotes the ranges for the signal-to-noise ratio to reach 1-to-1 for a radiated power of 100 kW. These are:

	Day	Night	
Summer	1440	870	n.mi
Winter	1350	870	n.mi

The Mediterranean chain now uses 300 kW of radiated power, so the ranges quoted could probably be increased by about 100 miles.

1.6.3 Interference from other radio services

Again, because of synchronous detection and filtering, the system is almost immune to non-synchronous interference unless this is many times greater than the received signal amplitude.

1.6.4 Refractivity of the Atmosphere

The LORAN-C tables are prepared on the basis of a constant transmission time in a free space having a uniform index of refraction at the surface of the earth. Actually there is a vertical gradient in the refractivity of the atmosphere, which varies seasonally. Tests carried out in the Bermuda area have shown that the variations of transmission time due to variations of mean monthly values of refractivity for February - August, lay in the range of 0.07 - 0.13 μs.

The effect is therefore negligible for ship surveys completed over limited periods.

1.6.5 Conductivity of the Earth

Because of the great difference in conductivity between land and water, the phase of the groundwave will vary according to the type of path it follows. Ideally, the path should be entirely over water.

Corrections to the observed time differences according to the paths taken by the groundwaves, (the so-called "secondary phase corrections") have been calculated for various areas and, for precise absolute measurements, these corrections should be applied if they are available. In most cases, however, relative accuracy over a fairly wide area will only be negligibly reduced if the secondary phase corrections are neglected.

2. THE AUTOMATIC RECORDING SYSTEM

2.1 Purpose

The basic purpose of the recording system is to transform the rotations of a shaft into a digital output that can be punched on to paper tape using standard techniques.

If 'time' is also recorded on the tape, then the ship's tracks can be accurately reconstructed through a computer with plotting capability.

2.2 General Description

A block diagram of the system is shown in Fig. 4. The design is basically simple, consisting of a set of photodiodes to count the rotations of the drive shaft, a set of reversible decade counters for reproducing the receiver readings from pre-set values, a pen recorder that gives continuous registration of X and Y readings, and a tape-punch for recording the last three digits of X and Y at fixed time intervals.

2.2.1 Photodiode system

Light aluminium discs are attached concentrically to the drive shaft of the least significant digit in the cycle of both X and Y (see Fig. 5). (To enable easier access and to accommodate the necessary additional equipment, a special case was built to house the two slave delay servo units of the receiver.)

These discs have ten equally-spaced holes around their periphery, and their revolutions are monitored by light sources and photodiodes mounted on either side. Three photodiodes are necessary to determine the sense of rotation and to reognize "dither" when it occurs.

2.2.2 LORAN Monitor Unit

The signals from the photodiodes pass to the LORAN Monitor Unit which houses an Analogue-to-Pulse Converter, a Sense Detector, and a set of Reversible Decade Counters. (The front panel of the Monitor Unit is shown in Fig. B.1).

The last three digits of the 6-digit LORAN readings are pre-set manually on the counters and displayed on Nixie Tubes. For every 1/10 of a revolution of the discs, "1" is added to or subtracted from the pre-set Monitor reading.

2.2.3 Pen Recorder

A Texas Instrument "Servoriter" Pen Recorder records the last two digits of the X and Y readings through a digital-analogue convertor. The dual traces are recorded on 10 in. wide chart paper (see Fig. 6), each trace employing the full width of the chart so that 0.1 μs can be resolved with no difficulty. A switch to check the recorder zero position and its span is included in the Monitor Unit. An event marker can be activated by the button on the right-hand side of the Monitor Unit.

2.2.4 Tape-Punch Unit

The X and Y values appearing on the Nixie Tubes are punched on to paper tape at selected time intervals of 1, 5, 15, or 60 minutes. The Tape-Punch used is the Invac Model P-135. The operation of the punch is controlled from the panel in the bottom half of the Monitor Unit.

2.2.5 Electronic Clock

An Electronic Clock (Ref. 2) is incorporated in the system. The time in months, days, hours, and minutes is punched automatically every hour and precedes the LORAN reading at that time. In addition, provision has been made for punching "on demand" to record any special event; in this case the readings will always be preceded by the time recorded to the nearest second.

2.2.6 Bridge installation

In the system described, the LORAN receiver, monitor unit, punch, and pen recorder are installed in the ship's laboratory. In addition, a Monitor Repeater and Pen Recorder have been installed on the ship's bridge. The bridge repeater is shown in Fig. 7. This can be mounted in front of the helmsman to allow the ship to follow Loran lanes rather than the conventional compass courses.

The recorder is a Texas Instrument "Rectoriter", which records the dual traces on separate channels each $4\frac{1}{2}$ in. wide and is commanded directly by the laboratory recorder by means of a re-transmitting slide wire. Its function is not to provide accurate registration of X and Y but rather to indicate correct functioning of the apparatus to the officer of the watch. If the receiver should lose "lock-on" then the recorder will no longer show a continuous trace.

3. IMPROVED ACCURACY WITH AUTOMATIC RECORDING

The errors inherent in the LORAN-C system were reviewed in Sects. 1.4, 1.5 and 1.6. In this chapter these errors will be re-examined in the light of the new automatic recording techniques.

Firstly, it was shown in Sect. 1.4 that, regardless of the positional accuracy of the LORAN systems, several "human" errors could be introduced by manual recording of the data. Automatic recording virtually eliminates these errors.

The ambiguity discussed in Sect. 1.5 can give trouble during manual recording unless a scrupulous check is kept on successive differences. There is no such problem with automatic recording, for, provided the correct reading is set on the monitor unit at the start of an operation, the monitor should always give an unambiguous reading, since its function depends only on counting shaft rotations and not on the relative phases of the envelope and cycle servos.

The environmental factors considered in Sect. 1.6 will always inhibit the overall accuracy of LORAN-C positions. However, by using automatic recording systems and sampling at frequent intervals it becomes possible to use smoothing techniques on the computer so as to reduce the effect of noise and interference discussed in Sect. 1.6.2 and 1.6.3. A smoothing program, which has been used successfully on data recorded at night in the Tyrrhenian Sea, is described in the Appendix.

It was shown in Sect. 1.6.1 that if the skywave has an amplitude many times greater than the groundwave amplitude, it is sometimes difficult for the receiver to maintain lock-on to the groundwave. The difference in ground-to-skywave reading is usually in the range 30-60 μs, depending on the distance of the receiver from the shore-stations.

Using the digital recorder it has been found possible to allow the receiver to pass to skywave operation while keeping the monitor unit cut-off from the receiver during the transition, so that the monitor will then give an apparent groundwave reading.

In practice, where the ship is operating at large distances from the transmitting stations, the jump from groundwave to skywave operation can be anticipated in the early evening. The photodiode system is switched off for the few seconds it takes for an operator to manually transport the receiver strobes from the weak groundwave signal to the strong skywave signal. When the strobes are locked-on to the skywave, the photodiode system is switched on and the monitor unit, "unaware" that a change to skywave has been made, will continue to monitor the "apparent" groundwave.

The basic inaccuracy associated with skywave operation is not decreased. This inaccuracy arises largely from the uncertain knowledge of the height of the reflecting ionosphere layer and its variation. However, the recorded LORAN readings are already "corrected" to the same accuracy that would be achieved if the original skywave readings were subsequently corrected manually.

4. DETAILED CIRCUIT DIAGRAMS

Detailed circuit diagrams of the LORAN Monitor Unit are available and can be obtained from SACLANTCEN if desired. To reduce bulk, they have been omitted from most copies of this report.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. J.B. Schipmölder for helpful contributions in the preparation of the program used for smoothing the data.

REFERENCES

1. "Engineering Evaluation of the LORAN-C Navigation System," report prepared by Jansky and Bailey, Inc., for the U.S.C.G., 1959.

2. T.D. Allan and C. Montanari, "A Universal Digital Clock and Timer," SACLANTCEN Technical Report No. 87, NATO UNCLASSIFIED. (In preparation)

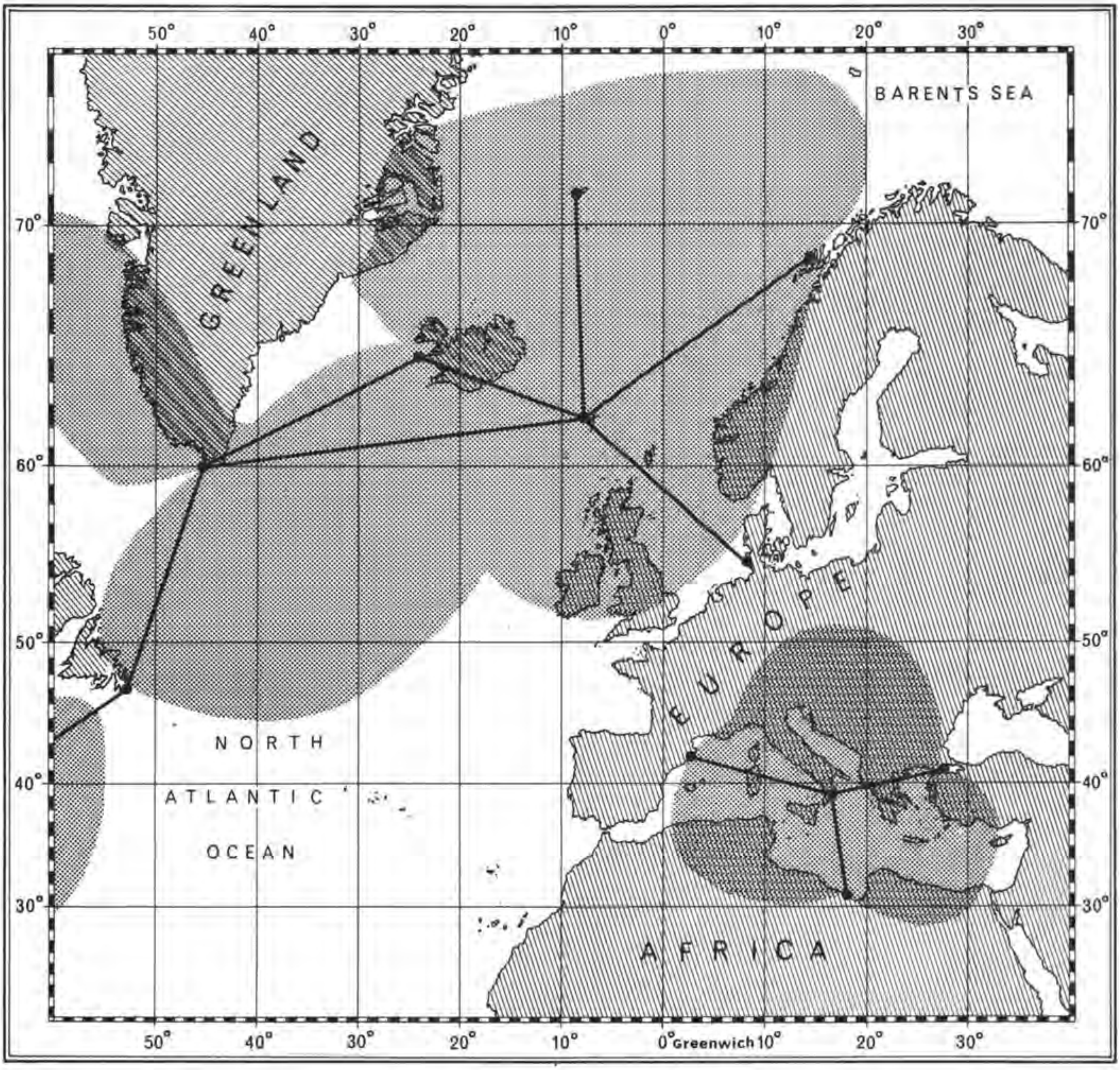


FIG. I POSITIONS OF LORAN–C STATIONS AND COVERAGE

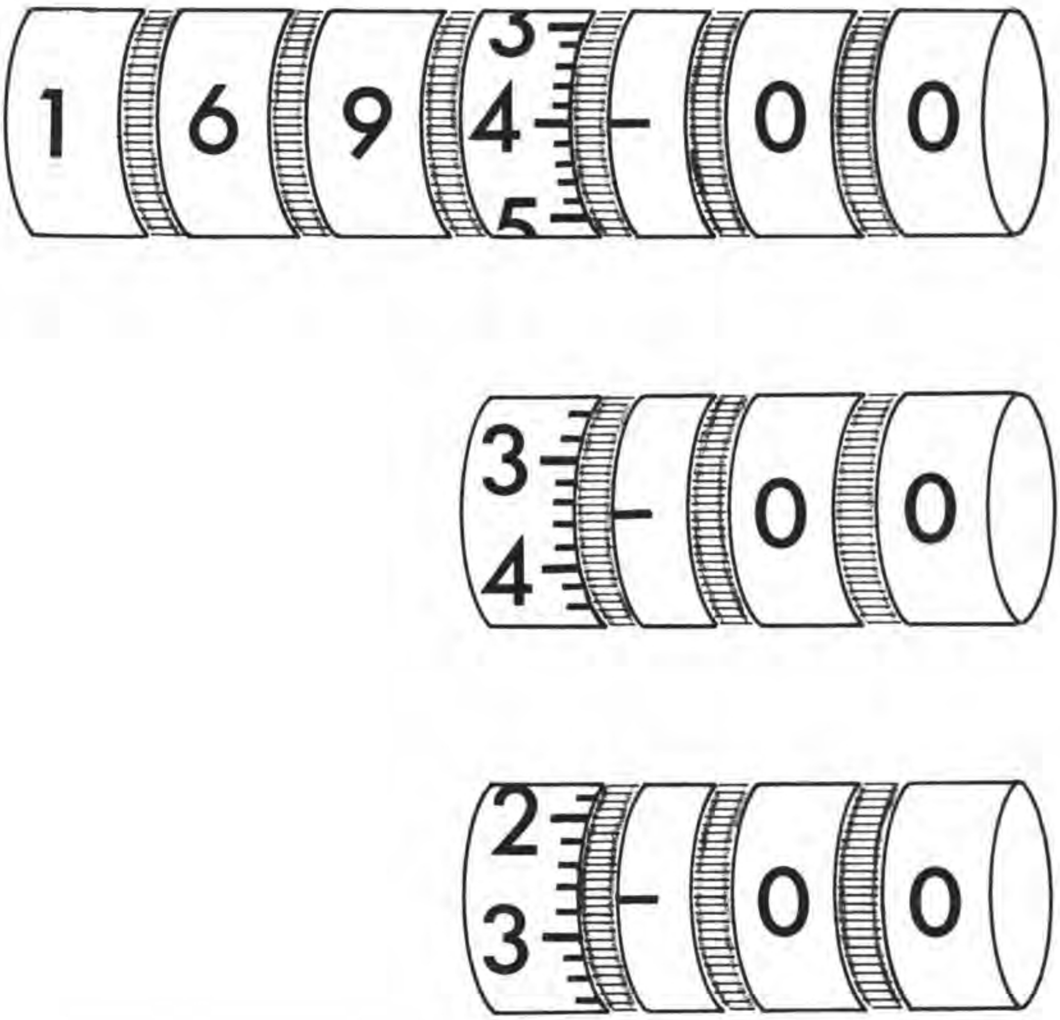


FIG. 2 AMBIGUITY BETWEEN ENVELOPE AND CYCLE READINGS

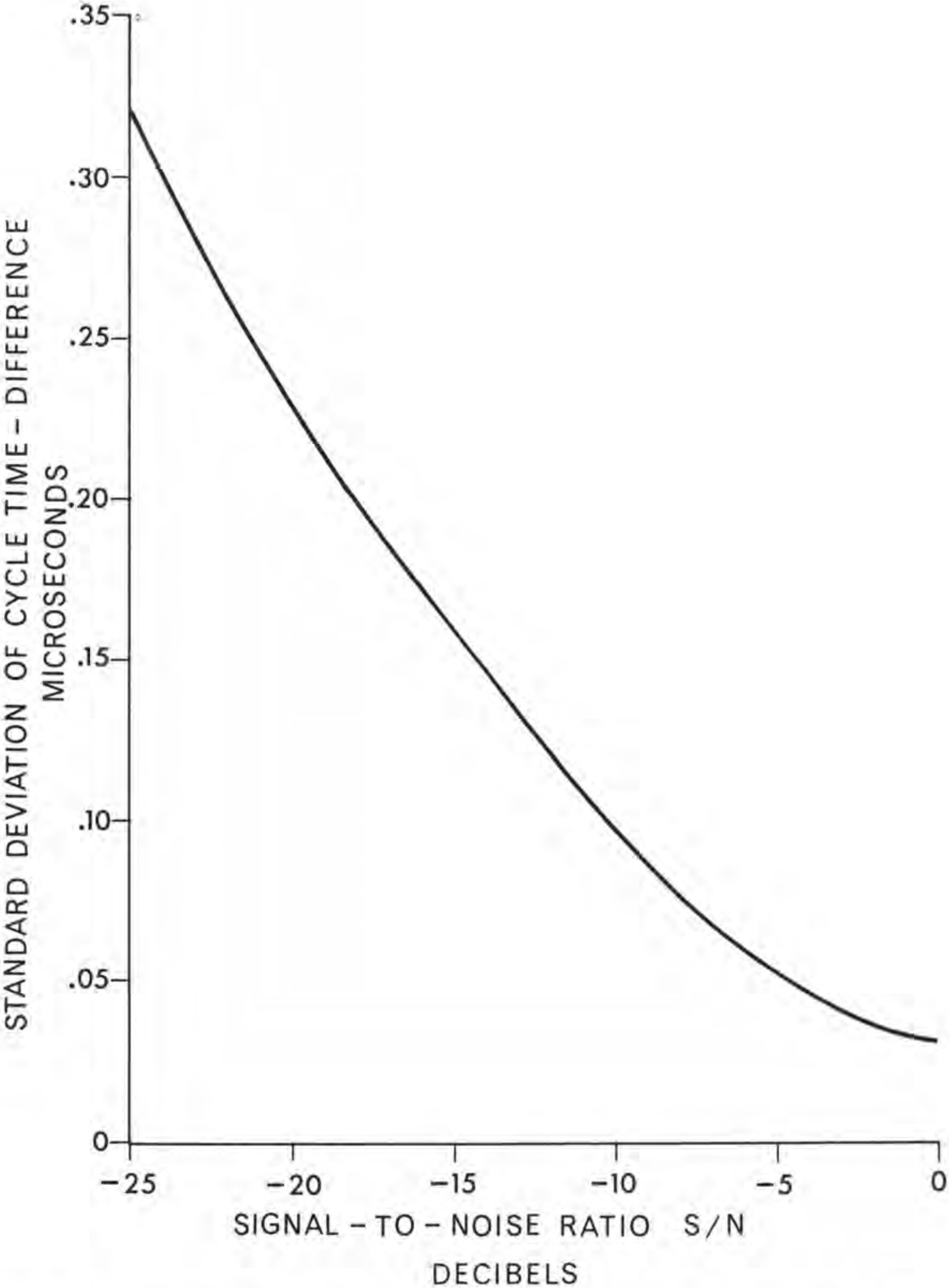


FIG. 3 STANDARD DEVIATION OF CYCLE TIME DIFFERENCE AS A FUNCTION OF SIGNAL–TO–NOISE RATIO

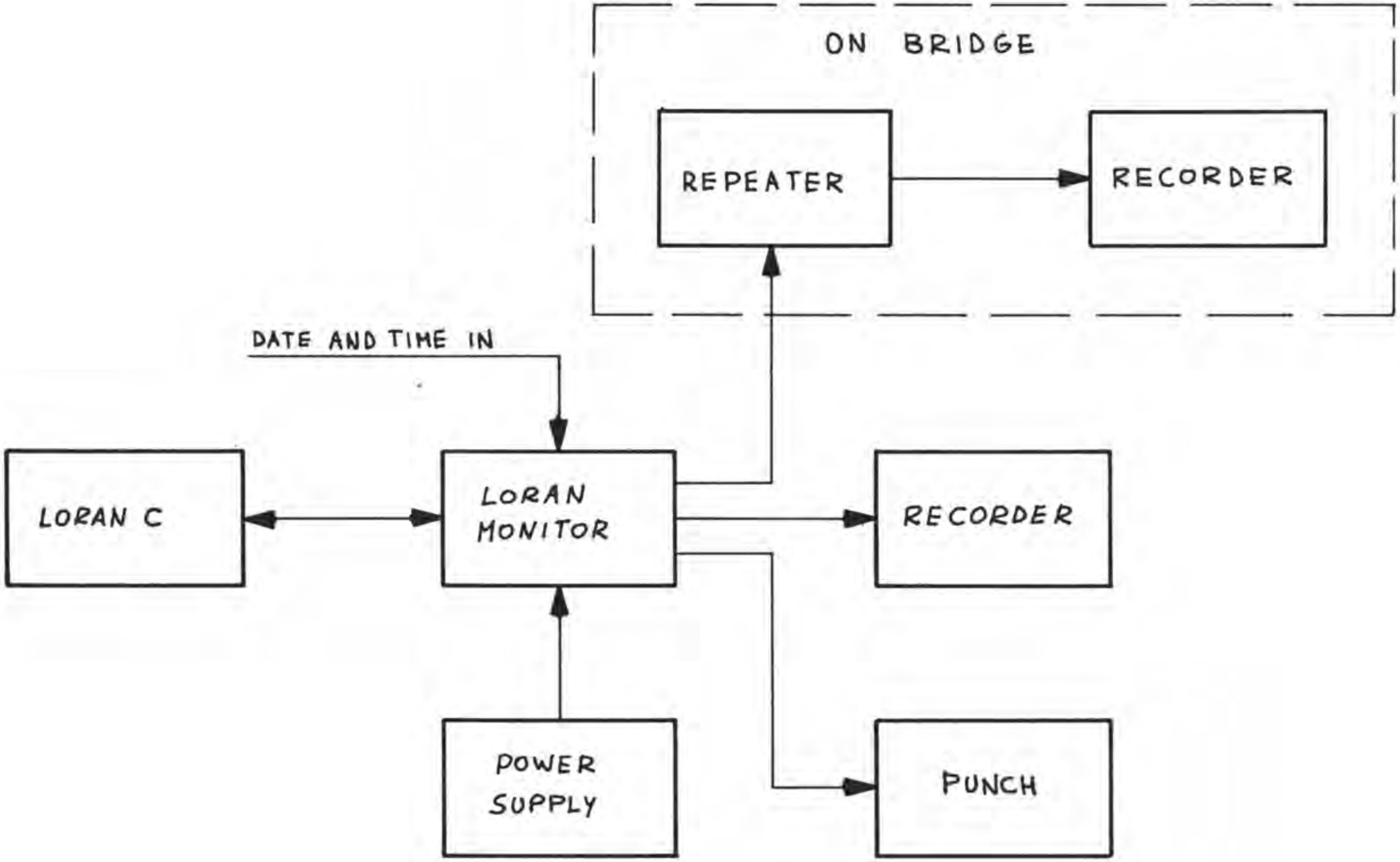


FIG. 4 BLOCK DIAGRAM OF DIGITAL RECORDING SYSTEM

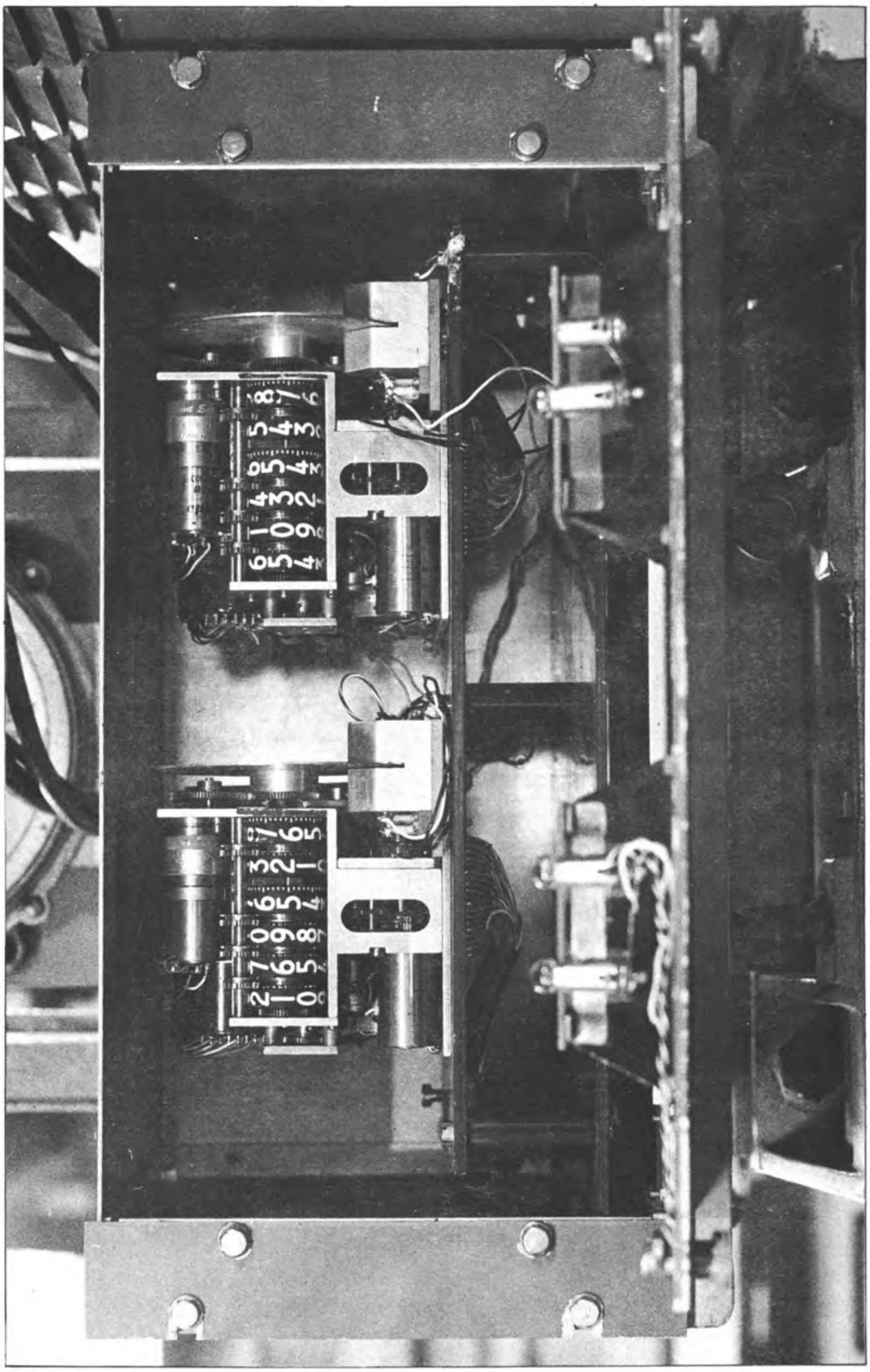
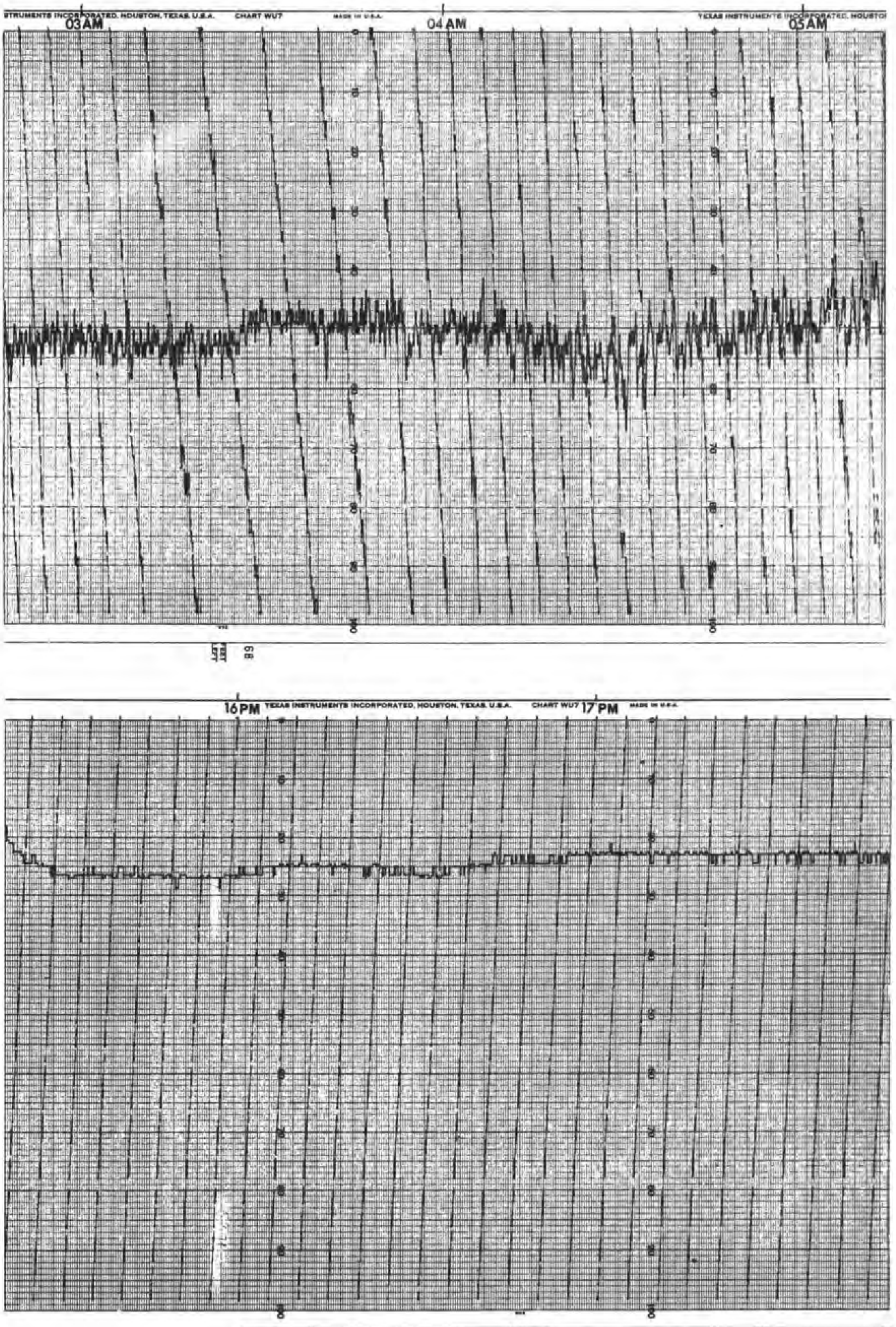


FIG. 5 PHOTODIODE SYSTEM FITTED TO THE SLAVE DELAY MODULES



a

b

FIG. 6 RECORDER TRACES OF NIGHT (a) AND DAY (b) OPERATIONS
The width of the chart paper (100 units) represents 10 μs

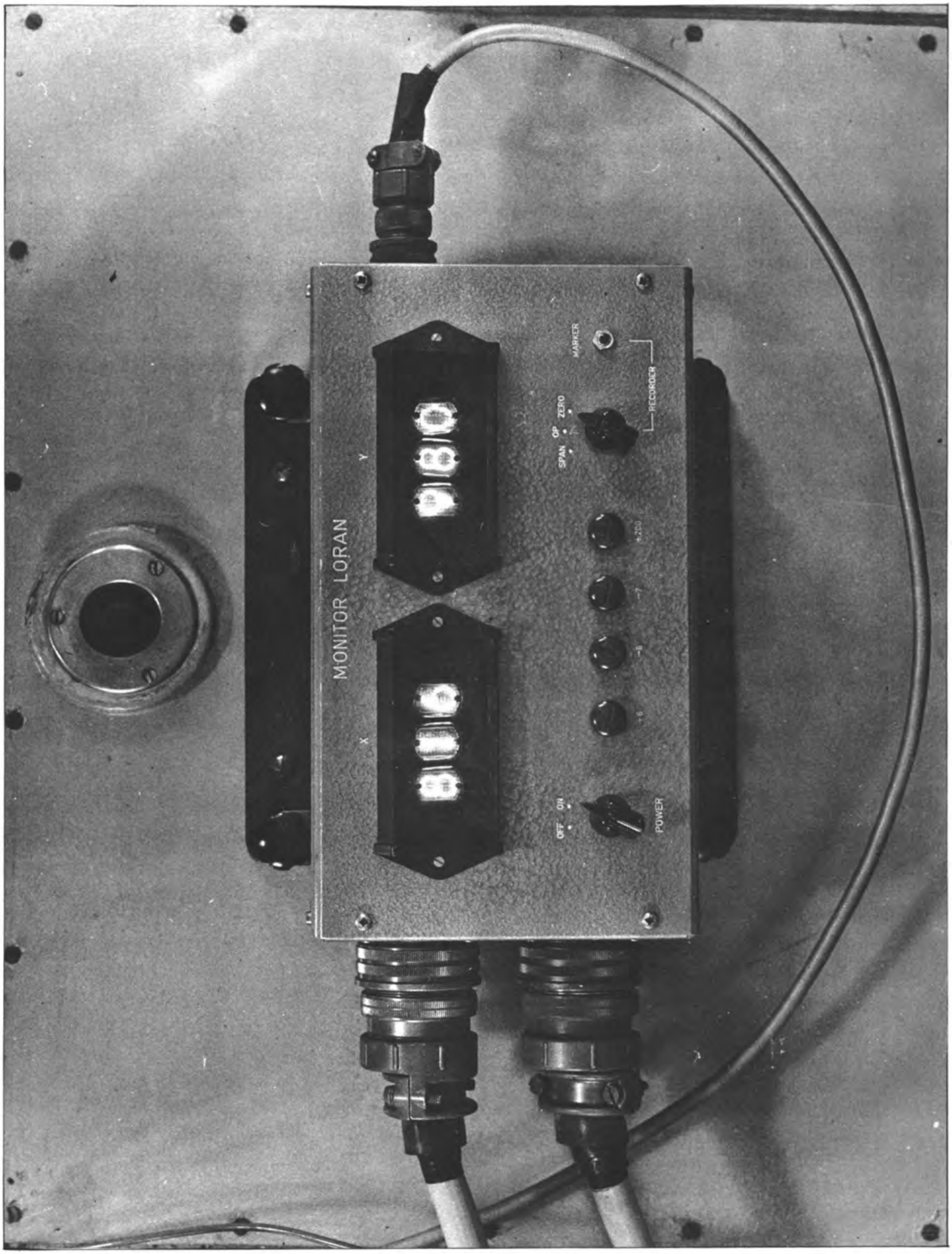


FIG. 7 BRIDGE REPEATER

APPENDIX A

SMOOTHING OF LORAN DATA BY DIGITAL COMPUTER

The increase in the noise level at night frequently causes the readings to "dither", so that observations made at infrequent intervals will be slightly in error. The effect was clearly seen in Fig. 6 where the top trace represents continuous recordings of both X and Y made at night in the Tyrrhenian Sea and the bottom trace represents recordings made during the day in the same area.

One advantage of automatic recording is that frequent sampling allows smoothing techniques to be applied to the recorded data by means of a digital computer.

From an examination of the LORAN recorded traces and of the ship's tracks recorded on a gyro-recorder, it was concluded that, for a ship attempting to follow a straight course, oscillations of a period of about 10 minutes or greater were more likely to be due to real motion of the ship and that apparent oscillations of periods much less than 10 minutes were likely to be introduced by noise. Although the choice of 10 minutes may be rather arbitrary it is probable that the dividing line lies somewhere between 7 and 15 minutes.

Two approaches were made to the problem of smoothing. In the first case a moving average was made over 10 successive observations and in the second case the observations were passed through a filter, the characteristics of which were chosen to cut off oscillations of less than 10 minute periods.

Method 1 - Moving Average

The equation of the best straight line through 10 observations taken at 1 minute intervals was calculated by the method of least squares. The calculated gradient was then used to determine the smoothed interval between the two mid-points of the line. The first point was then dropped, the eleventh point introduced, and the process repeated from points 2 to 11. The process continued in this way for all observations — each smoothed value being derived from a new calculated gradient and the previous smoothed value.

Method 2 - Filter

The filter chosen was No. 91 in Ref. A.1. It has the following characteristics:

No. of points	:	21
Normalized theoretical cut-off frequency	:	0.1 cycles/sampling interval 0.1 cycles/minute
Theoretical cut-off period	:	10 minutes
Normalized actual cut-off frequency	:	0.265 cycles/minute
Actual cut-off period	:	3.8 minutes

The response curves for the least square fit (LSF) on 10 points and for filter 91 are compared in Fig. A.1. It can be seen that the LSF curve essentially cuts-off oscillations with period less than 7 minutes and that periods between 7 and 20 minutes are significantly attenuated.

Positions derived from a 36-hour recording and smoothed by this method are shown plotted in Fig. A.2. (The plotting was made through an Elliott 503 Digital Computer to a Benson-France Electroplotter Model J). A comparison of the positions plotted directly from observed data and those plotted from smoothed data is shown in Fig. A.3.

Figure A.4 shows more clearly the results of the smoothing process. The top two traces represent the plotted differences, in tenth of microseconds, between the recorded X and Y values and the smoothed values. The third trace represents these differences converted into distance in metres. Note the decrease in the corrections from night to day. The bottom trace shows successive differences in distance between the smoothed geographical positions. Note the high relative accuracy that is achieved. Successive positions vary by no more than a few metres.

Reference

Ref. A.1 "Statistical Filters for Smoothing and Filtering Equally-spaced Data" H.M. Linette, U.S.N.E.L. Report 1049, July 1961.

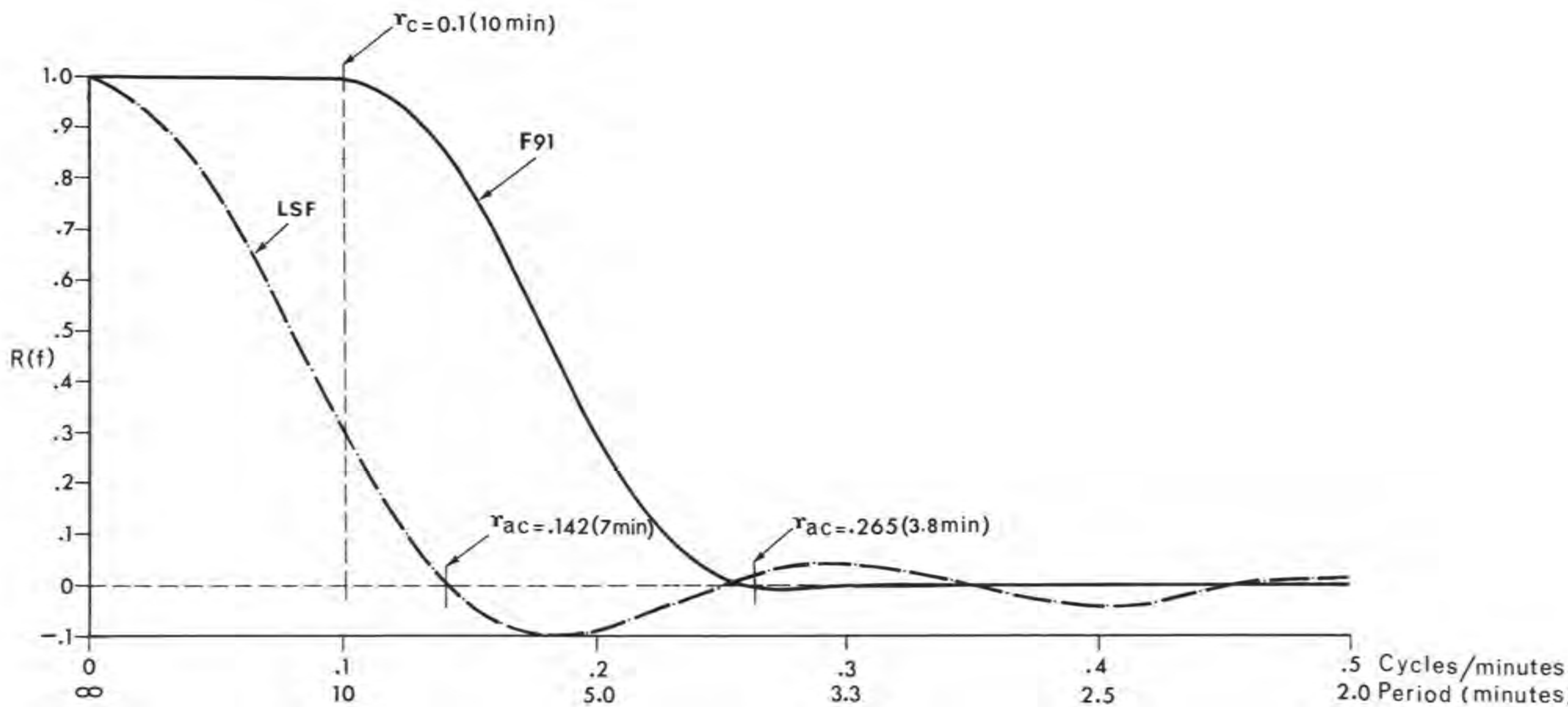


FIG. A.1 RESPONSE CURVE OF FILTER AND LSF

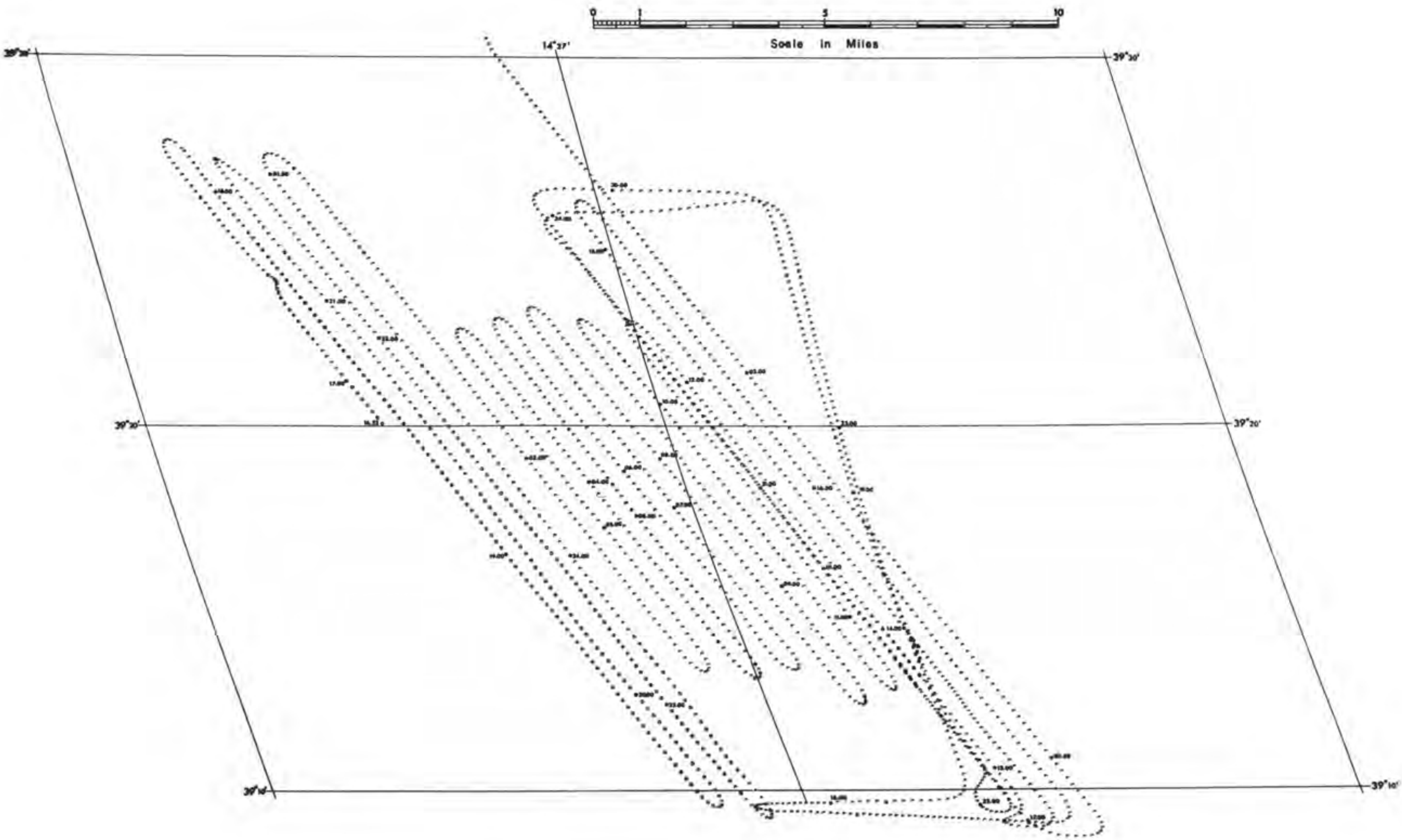


FIG. A.2 PLOTTED SMOOTHED POSITIONS

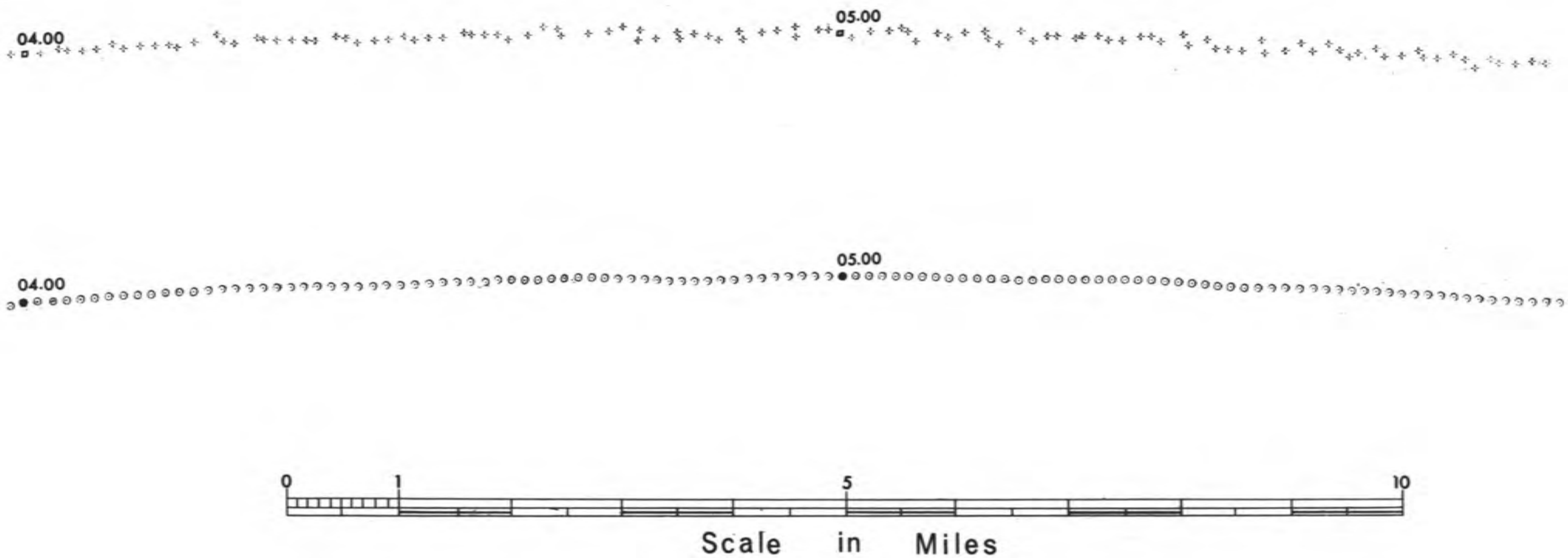


FIG. A.3 COMPARISON OF SMOOTHED AND UNSMOOTHED PLOTTED POSITIONS ALONG ONE PROFILE

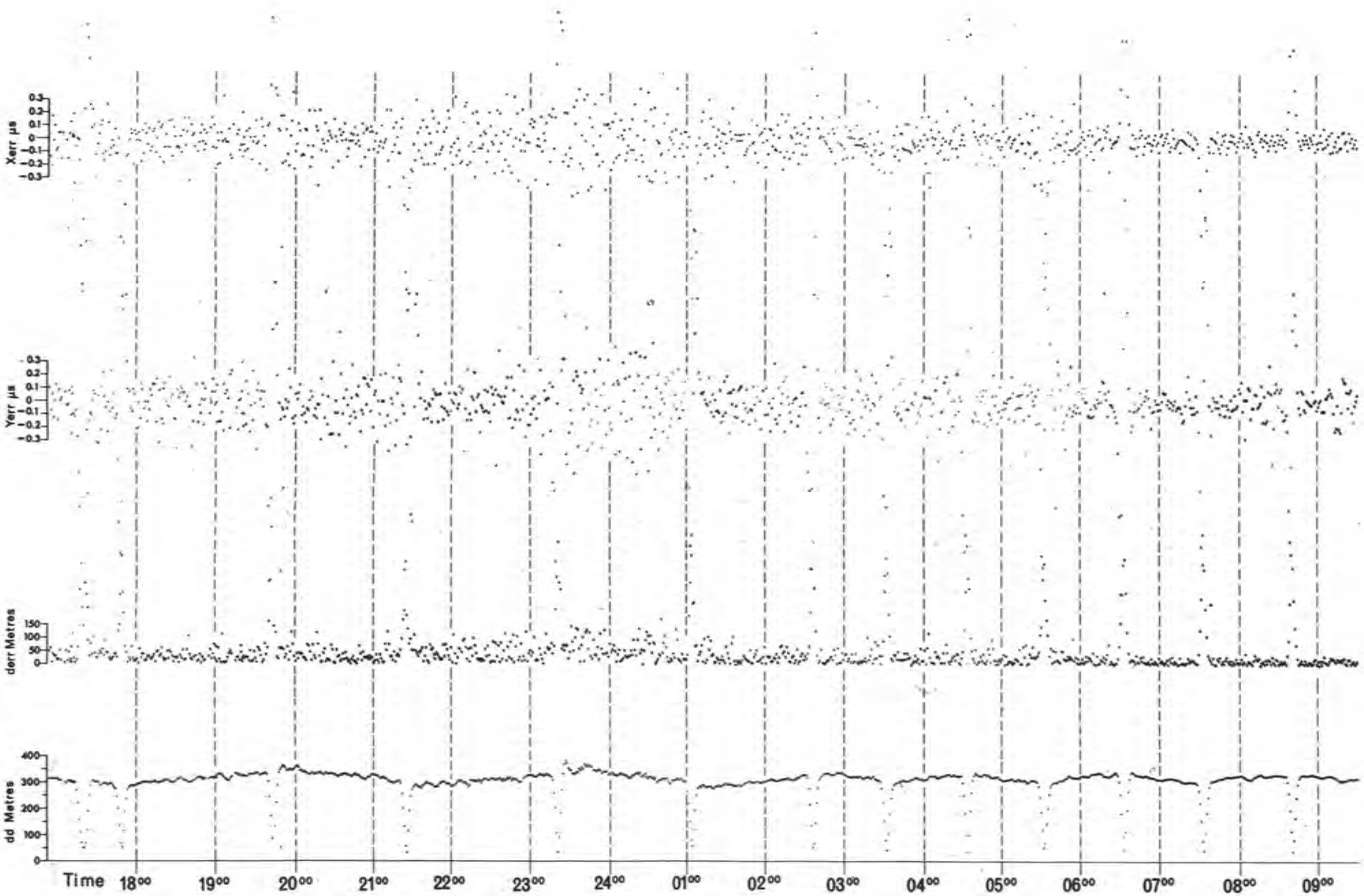


FIG. A.4 EFFECT OF SMOOTHING THE OBSERVATIONS. The top two traces show differences between observed and smoothed X and Y values. The third trace shows differences between observed and smoothed positions. The bottom trace shows differences between successive smoothed positions.

APPENDIX B

OPERATING INSTRUCTIONS

B.1 Operating Instructions

B.1.1 LORAN Monitor Unit

The front panel of the LORAN Monitor Unit is shown in Fig. B.1, and Table B.1 describes the functions of the various controls.

B.1.2 How to test the unit

For test purposes the action of the photodiodes and sense detector can be simulated for each station by depressing the "preset", "advance", and "reverse" buttons (4) at the top of the Monitor Unit. The "preset" button must be pressed first. To add "1" to the count, depress first "advance" and then "reverse". To subtract "1", the order is reversed.

In addition, each decade can be made to count independently by depressing the button (2) below the corresponding Nixie display tube and pulsating the button in the centre of the unit (3). To count in a forward direction the "advance" button should be pressed first; for reverse counting the "reverse" button is depressed first.

B.1.3 How to start

After the receiver is locked-on it is advisable to wait at least 15 minutes for the readings to "settle" to the correct value before recording. The Monitor Unit is then switched on and the X and Y readings are set manually to values that the receiver will shortly attain. (At present the system suffers from the disadvantage of having only one switch to control the photodiode circuits of both the X and Y channels. A modification will be made to control each independently). When the X setting (say) corresponds to the value on the receiver, the photodiodes are switched on (7) and the monitor reading will follow the receiver reading (at present, the Y value must then be adjusted manually to agree with the receiver Y reading).

A suitable paper speed is selected for the recorder (speeds available are 1.25, 2.5, 5, 7.5, 10, 15, 30, and 60 cm/h) and the zero position and span are checked and adjusted if necessary. The recorder can then be set to operate by means of the switch on the Monitor Unit. The values of the first four digits of each channel should be written on the record together with the time.

Prior to activating the punch, the AUT/MANUAL selector (15) on the Monitor is set at MANUAL. The power to the punch is switched on (9), the required time interval is selected (11), the punch trigger selector (14) is set to INT and the tape symbol selector (12) to BLANK. Some blank tape should be run by selecting MANUAL CONT (15) and depressing the START (MAN) button (16).

The PUNCH TIME switch (20) is switched on and the AUT/MANUAL selector (15) is then set to AUT. When the electronic clock (a separate unit) reaches an exact minute (or 5, 15, 60 according to the time interval chosen) the X and Y readings will be punched, preceded by the time in hours and minutes. After one recording, PUNCH TIME (20) can be switched off and the time will then be punched automatically every hour from the first time punched. The marker pen on the recorder will also be activated every hour. If it is desired to reset the time at which TIME will be punched (for example, on the hour) then the TIME SYNC RESET (5) must be depressed at the required time.

It is recommended that the first three digits of the X and Y readings be written at the start of the tape, since these will be required by any computer program that translates the LORAN readings into geographical co-ordinates.

The bridge repeater and monitor recorder can be switched on independently when required.

A variety of symbols are available (12) for punching. In addition, each level can be tested by means of the seven toggle switches (13) at the foot of the Monitor panel. If desired, different symbols can be punched immediately before the different station readings (21). For example, the toggle switches (21) are set to record the X and Z stations of the chain.

Symbols used in the SACLANTCEN programme are described in Chap. 2.

B.1.4 How to change interval

To change interval it is sufficient to set the selector switch (11) at the new interval. Thus, for example, if the interval was

5-minutes and it is changed to 15-minutes at 1305, then the next reading will be punched at 1315 and the following reading at 1330. The first of these new readings, but not any successive readings, will be preceded by the interval symbol and the date/time group.

B.1.5 "On demand" recording

There is provision for punching a reading "on demand" in order to mark some special event (change of ship's course, etc.). Pressing the "on demand" button (19) will cause the reading at that instant to be punched, preceded by the "on demand" symbol and the date and time to the nearest second.

B.1.6 How to end a tape

All tapes should end with the "end of tape" symbol. The procedure is the following: Switch the AUT/MANUAL switch (15) to MANUAL SINGLE, and select "END OF TAPE" on the symbols selector (12). Press the button START (MAN) (16). Select BLANK on the symbol selector (12) and change the AUT/MANUAL switch (15) to CONT. Press the START (MAN) button (16) and blank tape will be run.

B.1.7 Additional features

The punch can also be triggered from the TIMER (Ref. 2). The PUNCH TRIGGER selector (14) should be set to TIMER. Signals from the timer can then enter through the socket marked TIMER (18). The Timer can be used, for example, if intervals other than 1,5, 15, or 60 minutes are required or if any malfunctioning of the clock should occur.

With the MODE selector (10) set at LORAN and the Punch Trigger (14) at INT, the system is in its normal operating conditions; that is, the punch trigger is controlled by the dividing circuit of the electronic clock and LORAN readings are punched on the tape.

It is possible however to use the clock for purposes other than LORAN recordings. If the MODE switch (10) is set to "CLOCK", then the system can be used to record time intervals from one event to another. Alternatively, if it is desired to use the clock as a counter then the readings of the counter can be punched by choosing the mode COUNTER.

B.2 PUNCH-TAPE FORMAT USED BY SACLANTCEN

The last three digits of the X(Y) and Y(Z) readings are punched at the pre-selected time interval, each reading being preceded by its own symbol. Date and time is punched automatically every hour, but is not normally recorded at other times except

a. when the time interval is changed,
b. when the reading is punched "on demand",
c. at the start of a run.

Date and time normally occupy eight consecutive frames (two each for month, day, hour, minute). If seconds are included, then an additional two frames will be occupied.

Four possible time intervals (1, 5, 15, and 60 minutes) have been chosen in the present design, but these could easily be changed if desired.

An "on demand" reading is always preceded by its own symbol as well as the date and time.

The symbols chosen are as follows:

X station	00001001
Y station	00001010
Z station	00001100
Date and time	00000110
1 minute interval	00011110
5 " "	00011101
15 " "	00011011
60 " "	00010111
on demand	00001111

These 9 symbols are the most commonly used and have been chosen so that no single punching error can change one into another.

Additional symbols can be selected by the selector on the Monitor Unit as follows:

end of tape	10011100
tabulate	00010100
paper throw	00000011
spare	00010001
spare	00011000

There is one space between the date/time recording and the associated X-reading but no space between each group of X and Y readings. The date/time group is always preceded by the "interval" symbol as well as its own symbol. The fifth level on the tape is a parity check. The tape thus has the format shown in Fig. B.2.

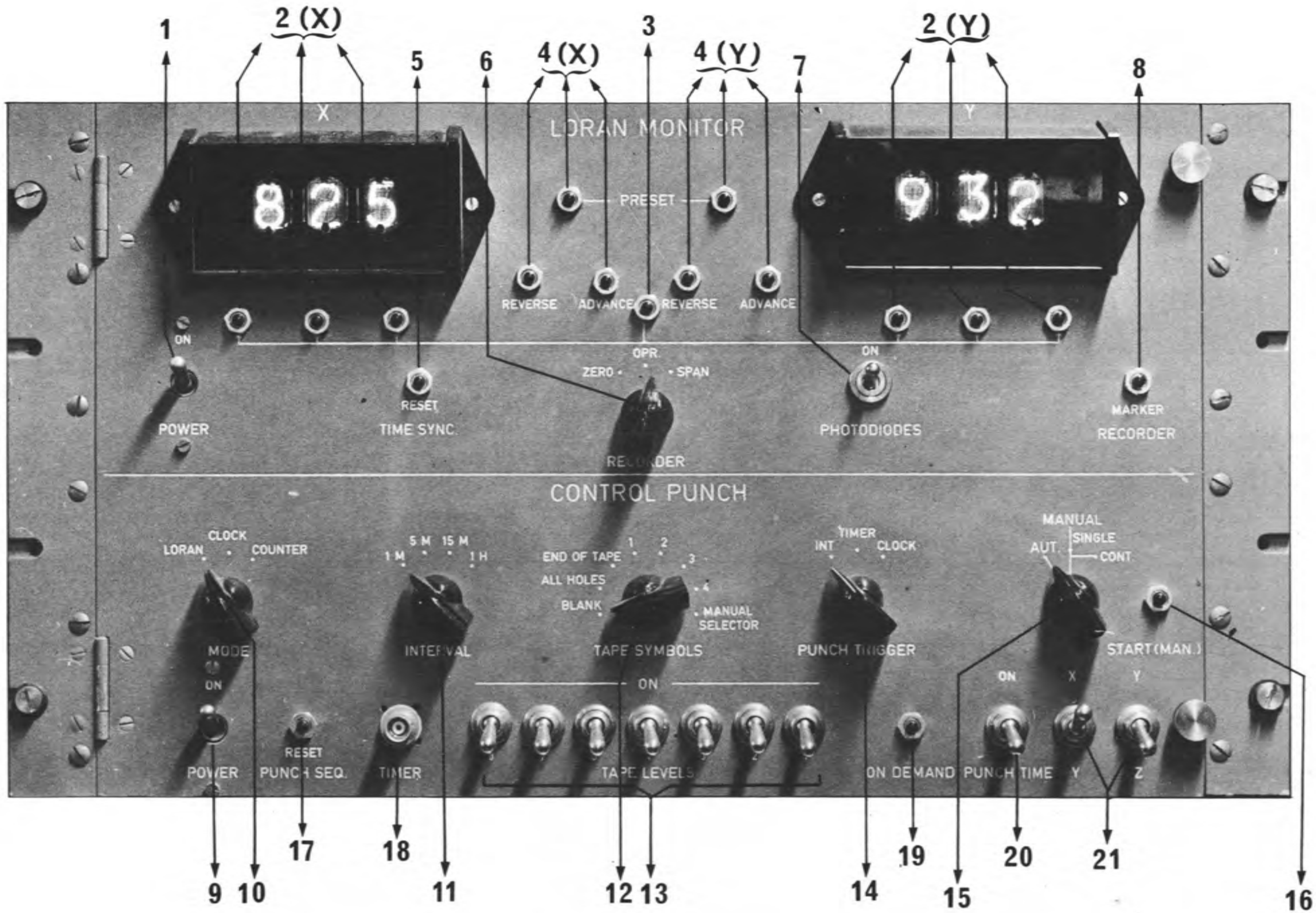


FIG. B. I FRONT PANEL OF LORAN MONITOR UNIT

TABLE B.1

No on figure	Identification	Function
	LORAN MONITOR	
1	Power switch	To supply power to the LORAN Monitor counters, Nixie display tubes, etc.
2 (X and Y)	Buttons under each Nixie tube	To manually operate the counters. If the button under the appropriate decade is held down while button 3 is pulsed, the decades can be made to count independently (See text).
3	Situated between "advance" and "reset" buttons	To cause the counters to count when pulsed as explained above.
4 (X and Y)	Preset, Advance and Reverse buttons for each channel	To simulate the pulses from photodiodes for test purposes. Pulsing "preset", "advance", and "reverse" in that order will cause "one" to be added to the reading. Pulsing "preset", "reverse", and "advance" will subtract one (See text).
5	Reset (TIME SYNC)	To reset the time at which the date/time group is recorded on the tape. Recordings are made automatically every hour from the time at which reset is made.
6	Recorder mode	To control the mode of operation of the pen recorder. Normally set in OPR position. The recorder "zero" and "span" are ckecked in the other two positions.

TABLE B.1 (Continued)

No on figure	Identification	Function
7	Photodiodes power switch	To activate the photodiode and lamp system. When this is switched on the Monitor readings will follow the LORAN Receiver readings.
8	Recorder marker	To actuate the marker pen of the pen recorder.
	CONTROL PUNCH	
9	Power switch	To supply power to all circuits that supply reading information to the punch.
10	Mode selector	To select either LORAN readings, clock readings, or counter readings for punching on the tape. (This facility is seldom used and in normal operation the selector will be set at LORAN (See text).
11	Interval	To select the required time interval between successive recordings.
12	Tape symbols	To select the symbol to be punched when the AUT/MANUAL switch (No. 15) is set to MANUAL.
13	Tape levels	With the "tape symbols" selector in the "manual selector" position any of the 7 levels can be punched on the tape by means of these toggle switches. The AUT/MANUAL selector (No. 15) must be in the MANUAL position.

TABLE B.1 (Continued)

No on figure	Identification	Function
14	Punch Trigger	To select whether the punch should be triggered internally, from the timer, or from the clock. The interval selector (No. 11) commands only internal triggering.
15	AUT/MANUAL selector	Used in the AUT position for normal operation. The selector is switched to MANUAL if it is required to record symbols on the tape. Symbols can be recorded either singly in the MANUAL SINGLE position or continuously in the MANUAL CONT position. To run the tape in either the single or cont mode the START (MAN) button (No. 16) should be pressed. Note – continuous registration should only be used for either blank tape or "all holes".
16	START (MAN)	To run the tape with the AUT/MANUAL selector on MANUAL as described above.
17	Punch Seq. Reset	To put to zero all the flip-flop circuits that determine the sequence of punching. As a precautionary measure this button should be pressed at the start of an operation. There is then no danger of punching more than once at a time or of punching in the wrong sequence.

TABLE B.1 (Continued)

No on figure	Identification	Function
18	Timer	This socket is the input to the Control Punch from the Timer. If it is required to trigger the punch from the Timer, then the Punch Trigger selector is put in the Timer position.
19	"On demand" button	To punch a reading at any time not determined by the selected time it is sufficient to press this button. The date/time group will be recorded to the nearest second and will precede the LORAN reading.
20	Punch Time switch	The date/time group is always punched before the LORAN reading when this switch is on.
21	X or Y and Y or Z	To select the appropriate identification symbol for the two stations used in the chain. These symbols will precede each X, Y, or Z recording.

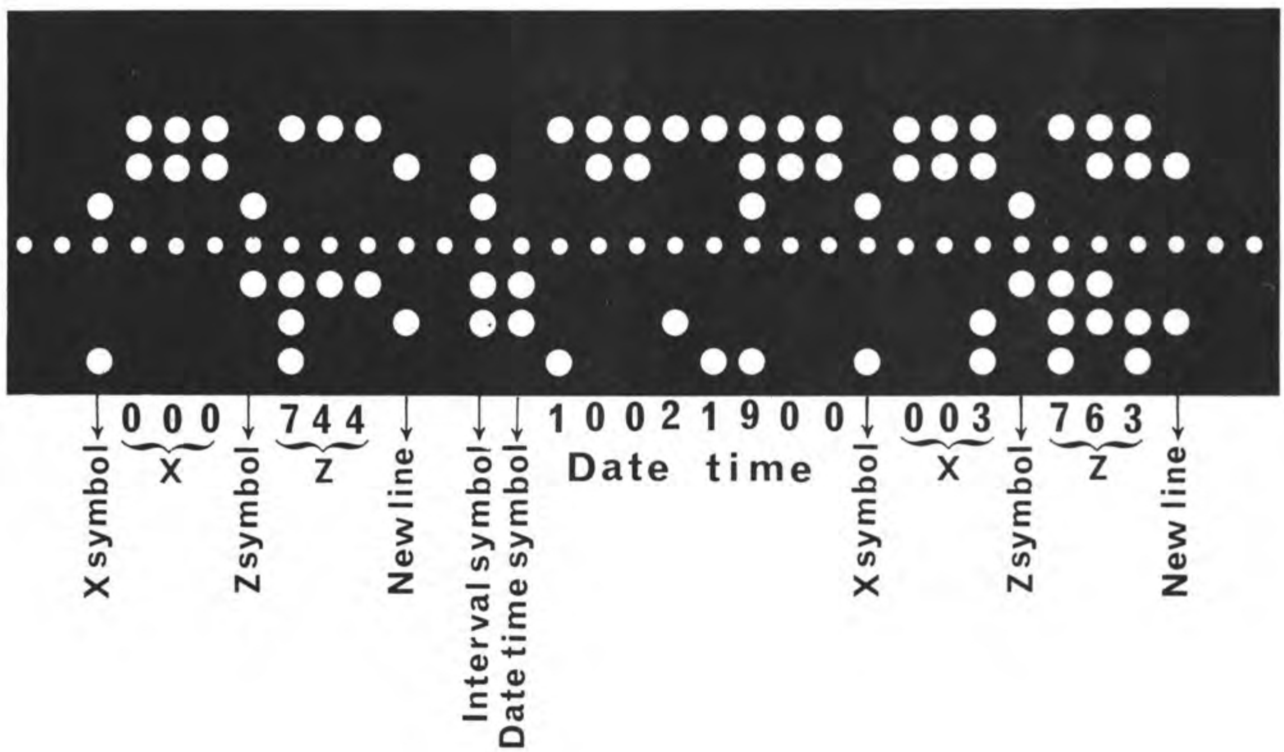


FIG. B.2 TAPE FORMAT

DISTRIBUTION LIST

	COPIES TR	COPIES TM
MINISTRIES OF DEFENCE		
MOD Belgium	5	5
MOD Canada	10	10
MOD Denmark	10	10
MOD France	8	8
MOD Germany	13	6
MOD Greece	11	11
MOD Italy	8	8
MOD Netherlands	10	10
MOD Norway	10	7
MOD Portugal	5	5
MOD Turkey	3	3
MOD U.K.	20	20
SECDEF U.S.	70	70
NATO AUTHORITIES		
SECGEN NATO	1	1
NATO Military Committee	2	2
ASG for Scient. Affairs NATO	1	0
SACLANT	3	1
SACEUR	3	3
CINCHAN	1	1
SACLANTREPEUR	1	1
CINCAFMED	1	1
CINCWESTLANT	1	0
COMSUBEASTLANT	1	1
COMCANLANT	1	1
COMOCEANLANT	1	1
COMEDCENT	1	1
COMSUBACLANT	1	1
COMSUBMED	1	1
CDR Task Force 442	1	1

	COPIES TR	COPIES TM
SCNR for SACLANTCEN		
SCNR Belgium	1	1
SCNR Canada	1	1
SCNR Denmark	1	1
SCNR France	1	1
SCNR Germany	1	1
SCNR Greece	1	1
SCNR Italy	1	1
SCNR Netherlands	1	1
SCNR Norway	1	1
SCNR Turkey	1	1
SCNR U.K.	1	1
SCNR U.S.	1	1
NATIONAL LIAISON OFFICERS		
NLO France	1	1
NLO Italy	1	1
NLO Portugal	1	1
NLO U.S.	1	1
NLR to SACLANT		
NLR Belgium	1	1
NLR Canada	1	1
NLR Denmark	1	1
MM France	1	0
NLR Germany	1	1
NLR Greece	1	1
NLR Italy	1	1
NLR Norway	1	1
NLR Portugal	1	1
NLR Turkey	1	1
NLR U.K.	1	1