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TEAL WING OWR (OVER WATER RESEARCH) PROGRAM

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ITT Electro-Physics Laboratories, Incorporated

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Progress, to date of report, consists primarily of preparation of equipment and procedures for collecting and processing data as to broadband atmospheric noise in the upper MF-lower HF portion of the frequency spectrum. (Progress on two other tasks of later scheduling not stressed.) Some equipment details and photographs are included. Equipment was readied for shipboard measurements in the North Atlantic in early April, late June and in winter circumstances. Processing is to be done off-line from taped digital data. Both omnidirectional and limited directional (azimuthal statistics) data will be collected. Radiometer techniques are used in the latter.

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KEY WORDS	LINK A		LINK B		LINK C	
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TEAL WING OWR PROGRAM
SEMI-ANNUAL TECHNICAL REPORT
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1. INTRODUCTION

Effective 15 January 1973, the ITT Electro-Physics Laboratories, Inc. (ITT-EPL) was given authorization to proceed on the TEAL WING Over Water Research (OWR) program by the Office of Naval Research (ONR) Scientific Officer. A contract negotiating meeting was held on 18 January 1973, and the contract amendment was signed on 25 January 1973.

Work is proceeding in accordance with the schedule outlined in ITT-EPL letter RD-5784 of 2 January 1973, with the exception that a winter-solstice measurement in the North Atlantic was patently impossible due to the late start of the program. It is intended that that measurement be replaced by a southern hemisphere measurement during late June or early July 1973.

The objectives of the TEAL WING Over Water Research program are threefold:

(1) Perform broadband noise measurements at sea during winter, equinox and summer seasons, between 1.5 and 6 MHz.

(2) Investigate existing fleet-deployed antennas for suitability in surface-wave operation in the 1.5- to 6-MHz region.

(3) Perform channel measurements over a water path of 150 to 300 miles, with particular emphasis on dispersion over wide bandwidths, during a variety of sea-state and atmospheric conditions.

2. PROGRESS THROUGH MARCH 1973

2.1 SUMMARY OF PROGRESS

The work has proceeded on all three objectives listed in Section 1, with emphasis on the first.

(1) Equipment was prepared for a noise measurement in the North Atlantic aboard a ship scheduled to depart from Bayonne, New Jersey, in early April 1973.

(2) The antenna investigation is underway, with meetings having been held at the Naval Ships Engineering Command, the Naval Research Laboratory, and the U. S. Naval Underwater Systems Center (New London Laboratory). Documentation for certain antennas is on order.

(3) The channel measurement experiment is scheduled for August - September 1973, which is beyond the present partial funding period. The only present effort which is applicable is that of fabricating some equipment for the noise measurements compatible with these future requirements.

The remainder of this report is devoted to progress on the first task.

2.2 SHIP ARRANGEMENTS FOR THE FIRST NOISE MEASUREMENT

The use of the GTS Admiral Wm. M. Callaghan for the first noise measurement was arranged, with ONR assistance, through the Military Sealift Command (MSC). The Callaghan is owned and operated by the American Export Lines under lease to the MSC, and travels from Bayonne, New Jersey, to Bremerhaven, Germany, and return in approximately 16 days. Pertinent data on the Callaghan are:

Length:	694 feet
Beam:	92 feet
Displacement:	24, 471 tons
Speed:	23 knots

It is gas-turbine -powered, hence the prefix GTS.

For the equinoctial season measurement, the first trip after 20 March 1973 was requested. This trip was scheduled to depart from Bayonne late on 5 April. The equipment was ready to be put aboard by the end of the reporting period. The compartment allocated for ITT-EPL use had a bench-height shelf across one bulkhead and space for one standard rack of equipment. Consequently, the equipment was configured as shown in Figure 1. All equipment on the shelf was strapped down on compressible padding and the rack was framed in place with 2x4-inch lumber in anticipation of heavy seas.

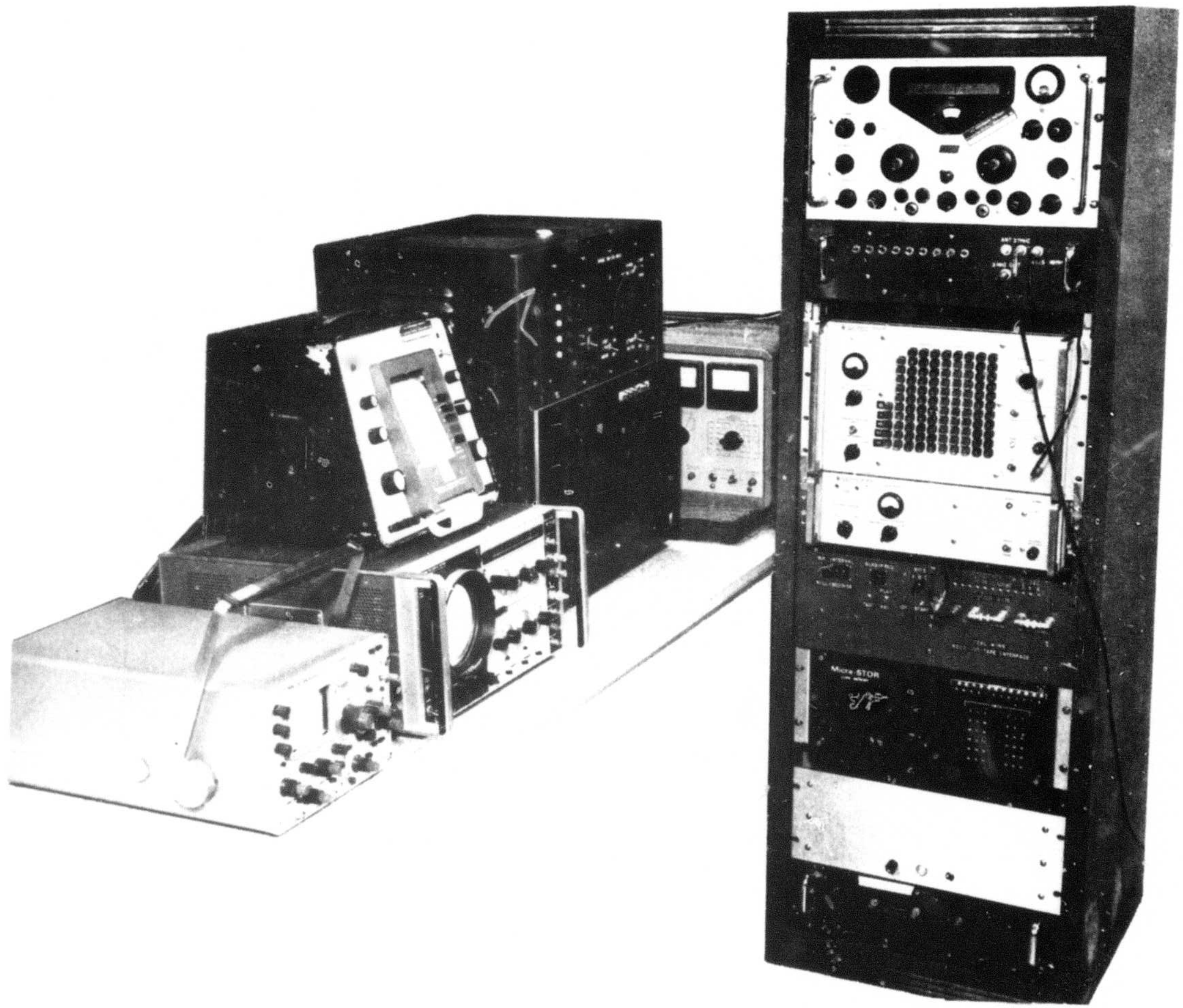

Figure 1. Arrangement of Equipment for the Equinoctial Noise Measurement

3. TECHNICAL DESCRIPTION OF NOISE MEASUREMENT EQUIPMENT

The measurement test plan, included as an appendix to this report, indicates the type of measurements and the processing techniques to be applied. The equipment prepared for the measurement phases consists of two antennas, a wideband receiver, a tape controller/interface, and recorder mechanisms. Ancillary measurements (antenna efficiencies, patterns, calibration techniques, etc.) are covered in the appendix.

3.1 OMNI ANTENNA

After a preliminary assessment as to the ship's configuration, and the constraints attendant with the ship's primary mission, a variety of antenna configurations were modeled at 1:18 scale on the ITT-EPL model range, Figure 2, and a configuration chosen on the basis of practical installation and impedance uniformity. The selected configuration is shown in Figure 3. The impedance plot of the shipboard-installed antenna is not available as of this writing, but is expected to exhibit increasing mismatch loss below 3 MHz.

3.2 LOOP ANTENNA

It was recognized at the outset of discussions on the OWR program that an efficient steerable antenna would be unattainable on a ship of opportunity. It was agreed, however, that a loop antenna might give some measure of azimuthal distributions and was worth a try. Consequently, the loop antenna shown in Figure 4 was prepared. To achieve some respectable efficiency, and yet operability, the loop is tuned remotely by synchro torque. This method allows proportional, rather than prechosen, discrete tuning so that the operator can select frequencies not occupied by other users. A radiometer technique is employed to sample the difference in received noise power, with respect to a termination, rather than to record a large integrated noise power and be concerned with small differences with respect to integrated equipment noise. The schematic diagram of the entire loop antenna assembly is shown in Figure 5.

The loop reciprocates over a 180° span when in motion, since it has unity front-to-back ratio. The rotation and tuning mechanisms are shown in Figure 6.

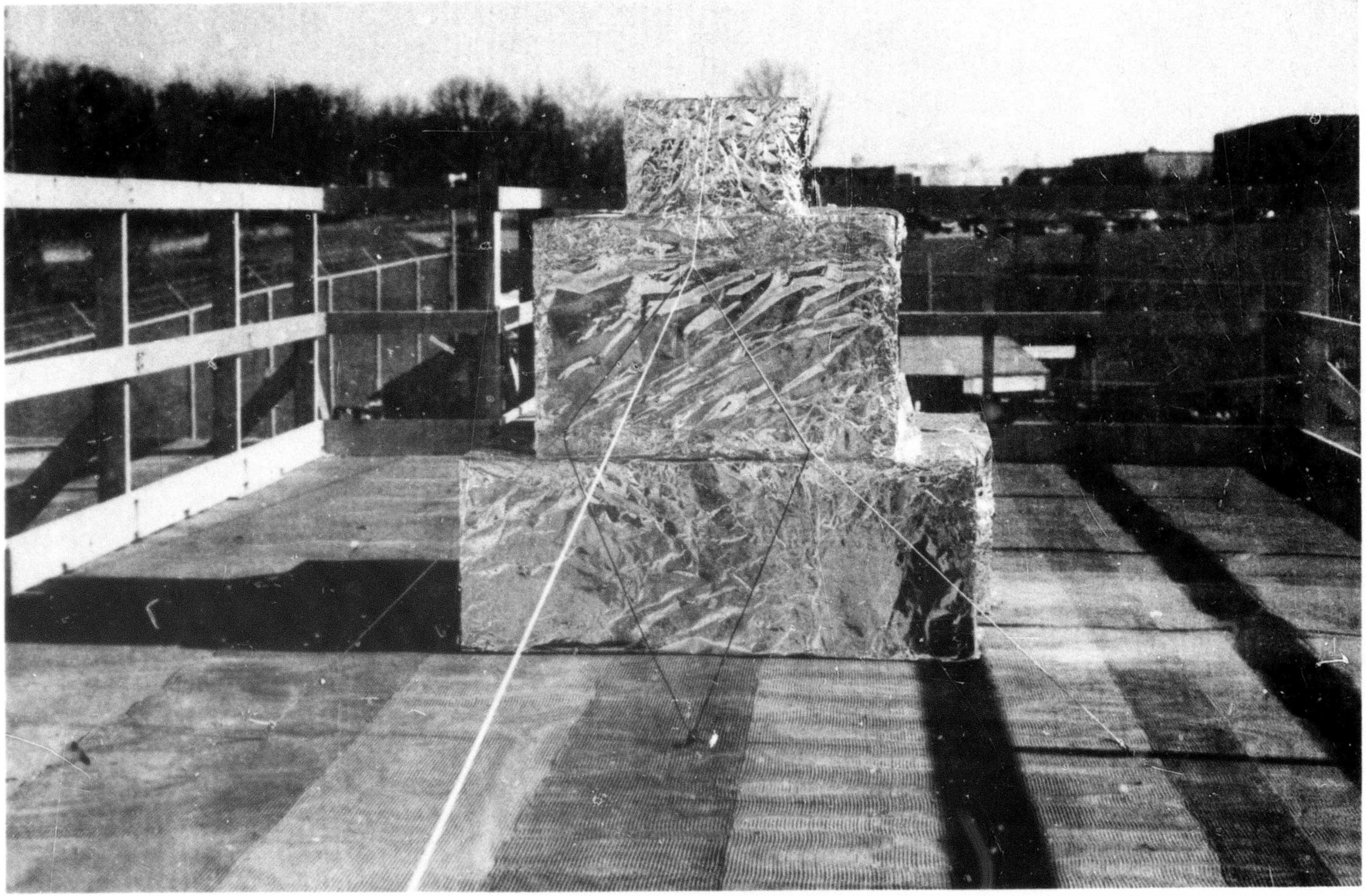

Figure 2. ITT-EPL Antenna Model Range

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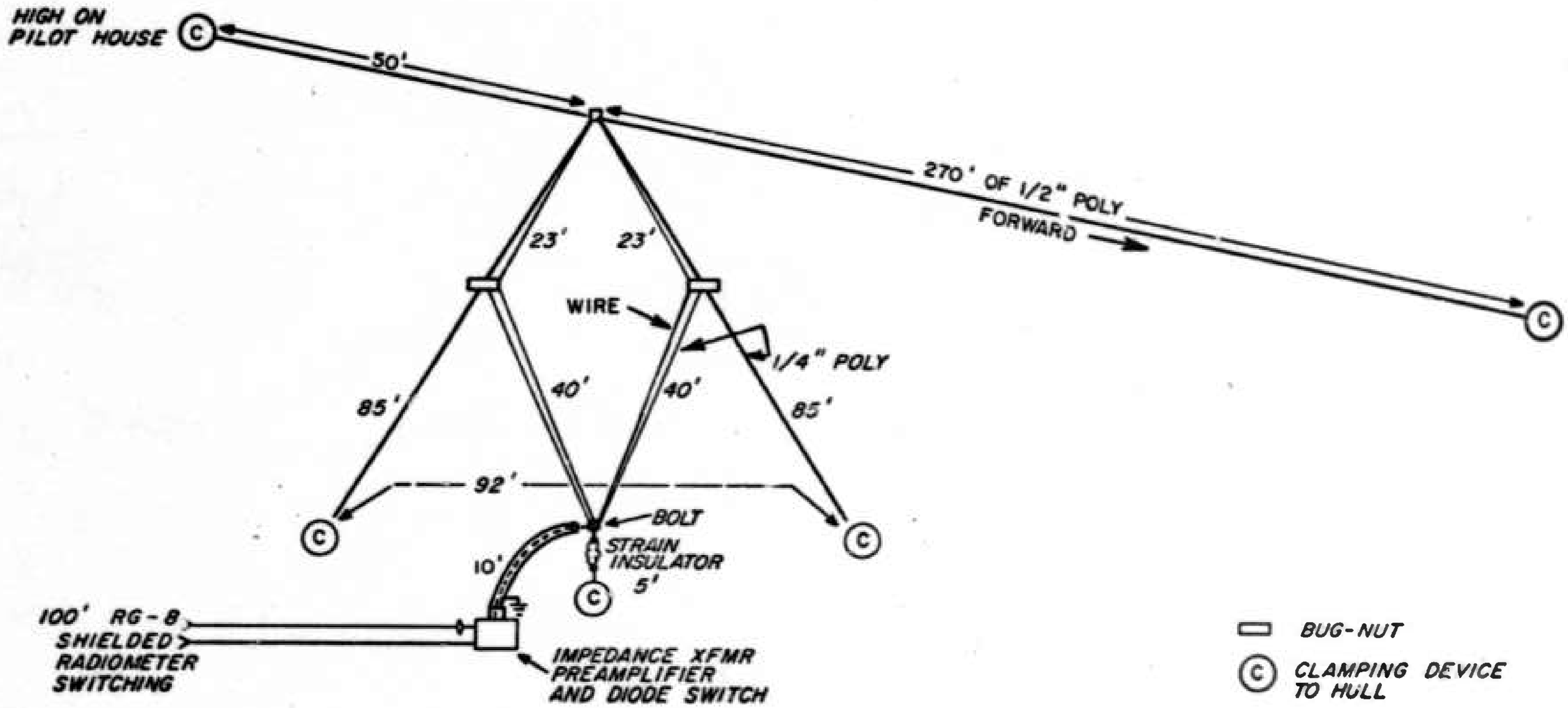

Figure 3. TEAL WING OWR Omni Antenna

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Figure 4. Loop Antenna

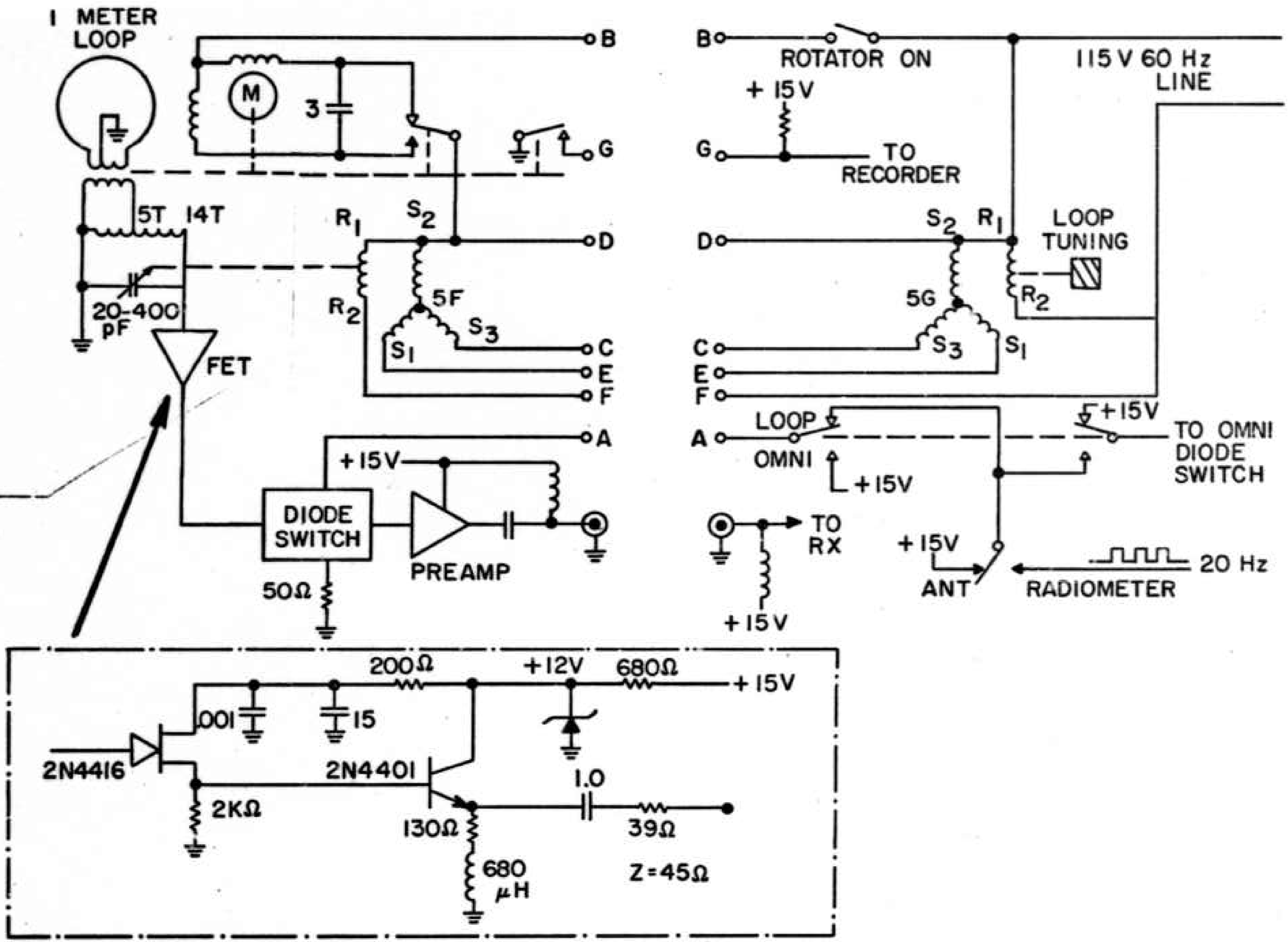

Figure 5. Loop Antenna Controls

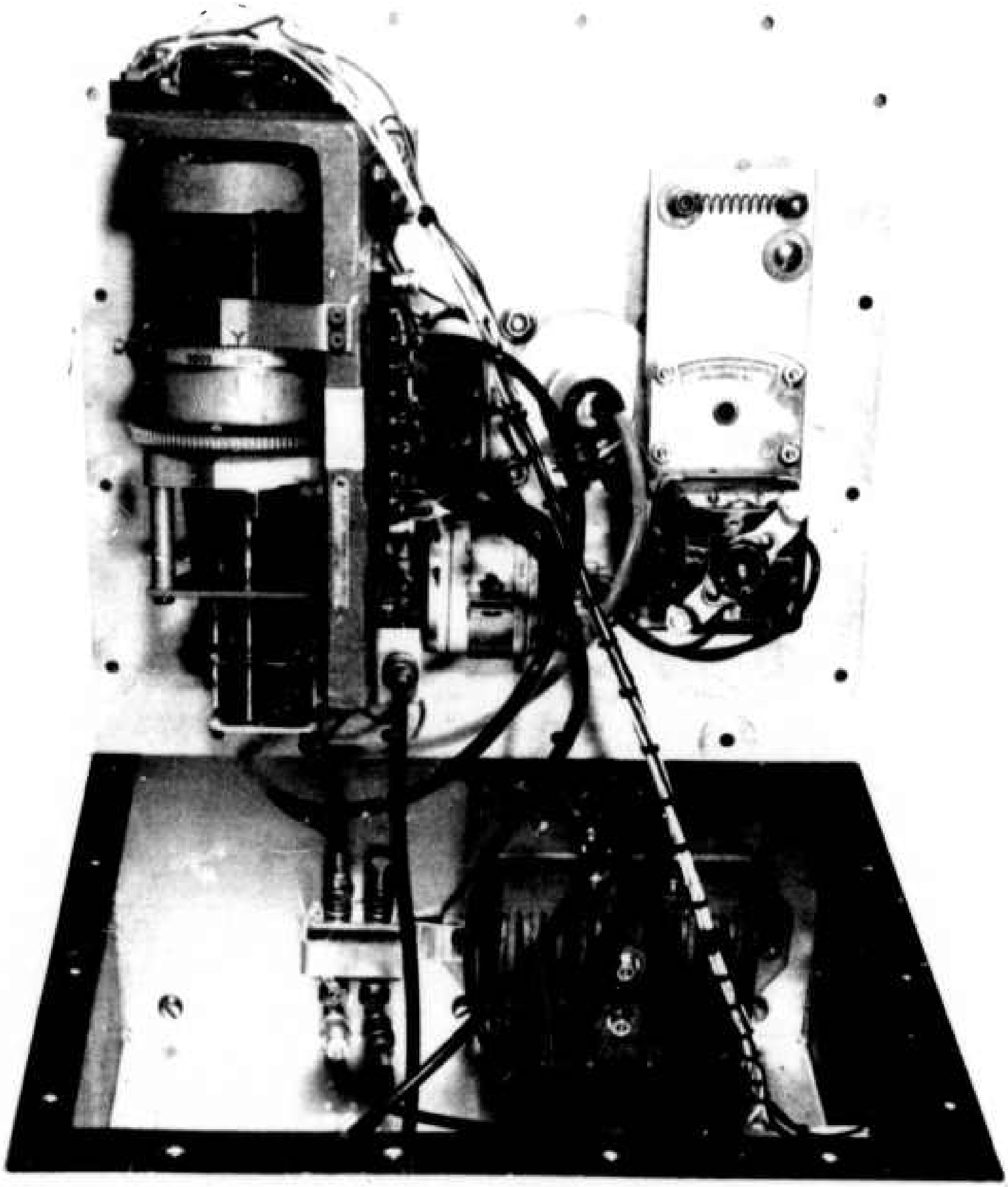

Figure 6. Rotation and Tuning Mechanisms for the Loop Antenna

The 1-meter diameter loop is made of low-loss coaxial cable with a balanced-to-unbalanced transformation at the output terminals. The unbalanced leads are brought through the base as a flexible pair so that the loop can be rotated. In the mounting, these leads were tapped into a high-Q tuned circuit whose output is transformed to 50 ohms by an FET source follower-emitter follower unit. The gain of this unit is 0. 5 and the noise figure is low. The overall Q of the system is about 35 to 50 over the range from 1. 5 to 6 MHz, and refinement of the coupling arrangement should permit this to be doubled in the future, if necessary. As it stands, the tuned loop is equivalent to a short monopole of about 1 meter length, so it is shorter than a CCIR monopole by a factor of about 7. This factor could be reduced by attention to the coupling, and the consequences of not doing so may be that the loop system, as it now stands, will be "set-noise-limited" when the external noise is low. The interpretation of the direction of noise sources which are propagated via the ionosphere will require careful consideration. These impulses are likely to be of random polarization and the well-known polarization error of the loop will tend to give a random indication of direction, even when there is only one storm area.

Because the direct waves of the horizontally polarized impulses tend to be balanced out by the sea-reflected waves when the loop is near the sea surface, whereas the vertically polarized impulses are enhanced in that location, the placement of the loop at deck level should allow some discrimination to be achieved. Storm centers which are just beyond the horizon should propagate as vertically polarized waves and the loop should give a good indication of their direction. These storms will tend to appear more impulsive than Gaussian, and the record may show this. In any case, the problem of polarization error in shipboard HF direction finders is a difficult one, because anything that improves the antenna response in this respect also cuts its sensitivity. It is concluded that the loop is a proper compromise in this case, however.

3.3 RADIOMETER SUBSYSTEM

In anticipation of very low noise power levels at certain times of measurement, a radiometer configuration is available to both the loop and omni antenna systems.

A radiometer measures the difference in noise temperature between a radiation source as seen by an antenna and the noise temperature of a matched, shielded termination. For "Johnson" or "white" noise, the noise temperature is proportional to the power density in watts/Hz or the noise energy in joules, i.e.,

$$T_N = \frac{P_N}{K_B} = \frac{\Phi_N}{K}$$

where

T_N = effective noise temperature in degrees Kelvin

P_N = noise power in watts

B = radiometer input bandwidth in Hz

$\Phi_N = \frac{P_N}{B}$ = power density in watts/Hz or joules

K = Boltzmann's constant = 1.38×10^{-23} joules/^{o}Kelvin

The TEAL WING OWR radiometer circuit (Figure 7) consists of a low-frequency oscillator (approximately 20 Hz) with two outputs having an adjustable phase relationship, and the radiometer receiver. The radiometer receiver consists of a front-end diode switch which connects the receiver, in sequence at the low frequency switching rate, to either the antenna or the reference load. The RF receiver is a superheterodyne unit which is normally used in the non-radiometer mode for other purposes. In the radiometer mode of operation, the receiver 100-kHz IF output is applied to the radiometer's square law detector. The output of the square law detector is a square wave, at the switch frequency, with an amplitude which is proportional to the difference in noise temperature between the antenna and the matched load.

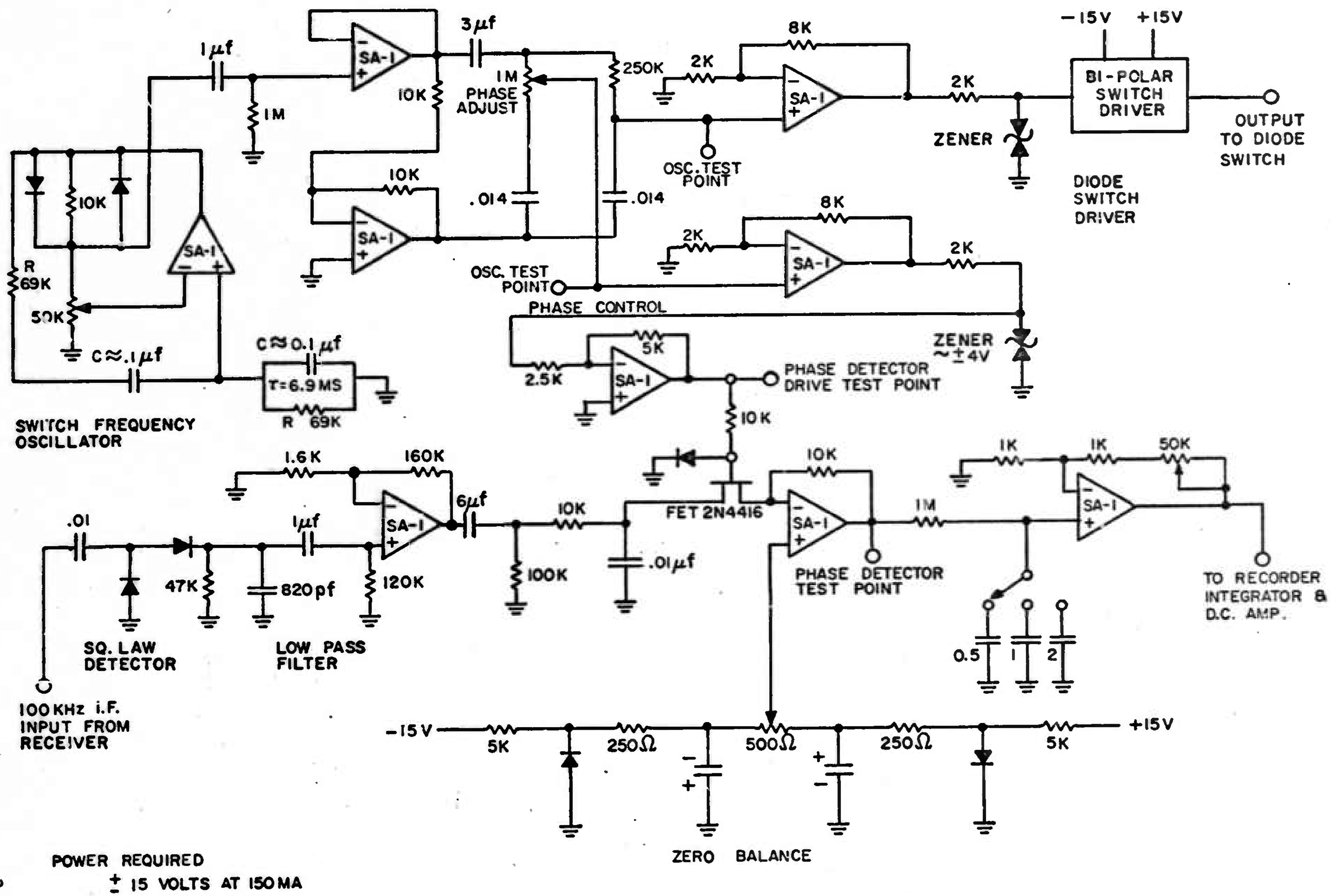

Figure 7. Circuit Diagram of the TEAL WING OWR Radiometer

This square wave is synchronously detected to obtain a DC voltage proportional to the temperature difference. The difference voltage is integrated by a low-pass filter of selectable time constant and recorded on a chart recorder.

Calibration is performed by comparing the radiometer output to a calibrated field strength test set when both units are tuned with equal bandwidth to a common signal source.

3.4 WIDEBAND RECEIVER

A simplified block diagram of the TEAL WING OWR receiver is shown in Figure 8. A double-superheterodyne configuration with RF preselection of the 1.5- to 6-MHz signal band is utilized.

Up-conversion occurs at the first mixer and down-conversion at the second, resulting in an overall design with good image and spurious rejection characteristics. The specific choice of intermediate frequencies (40 and 3 MHz) was made to allow the use of existing filter designs and amplifiers.

The image is the frequency removed from the desired signal by twice the intermediate frequency. Thus, the image response of the first mixer is not a problem, and all of the image frequencies are effectively removed by the preselect filter. The 3-MHz second IF imposes a selectivity requirement on the first IF filter to attenuate the translated input signal image (the signal which would, for any given first local oscillator setting, be translated to 34 MHz, e.g., 6 MHz removed from the desired 40-MHz frequency). Primarily, the concern is with the lower sideband of a 7.5-MHz image signal when the receiver is tuned to 1.5 MHz. The other image terms all fall within the stop band of the preselect filter.

The ratios of intermediate and signal frequencies (IF/sig >6 in up-conversion mode and sig/IF > 10 in down-conversion mode) are sufficient to guarantee insignificantly low mixer spurious responses, and large dynamic range mixers and amplifiers are used to minimize intermodulation distortions.

The bandpass filter (at 3 MHz) determines the final bandwidth of the receiver as 320 kHz. An additional low pass filter with a cutoff frequency of

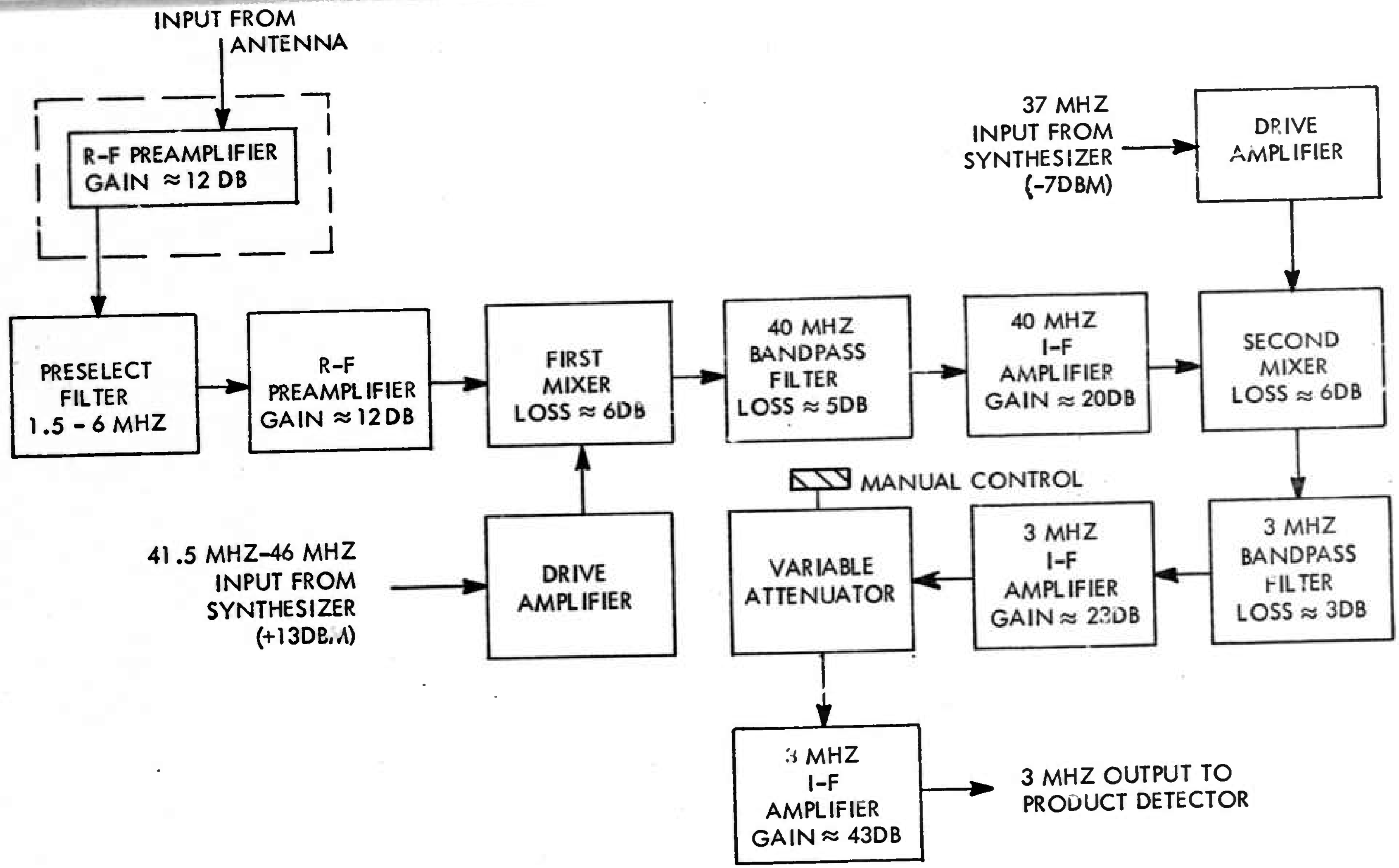

Figure 8. Block Diagram, TEAL WING OWR Receiver

approximately 3.5 MHz is placed after the second mixer to insure that any local oscillator "feedthrough" will not appear at the receiver output.

A variable attenuator (100-db range in 1-db steps) is placed between the amplification stages of the 3 MHz IF to allow the operator to select a convenient output level.

A plot of the measured receiver response is shown in Figure 9, and the other characteristics are summarized in Table 1.

Table 1. TEAL WING Receiver Characteristics

Operating Frequency Range	1.5 - 6 MHz
Tuned Bandwidth	320 kHz
Noise Figure	≤ 10 db
Maximum Gain (Nominal - without Antenna Preamplifier)	≥ 77 db
Manual Gain Control	100 db in 1-db steps
Maximum Output Level	+ 25 dbm
Power Requirements	± 12 volts @ 1.3 amperes

The receiver construction, shown in Figure 10, is modular and makes maximum use of existing design subassemblies, with modifications as necessary.

3.5 TAPE CONTROLLER

The TEAL WING OWR tape controller provides an interface between the wideband receiver and the digital magnetic tape unit. The receiver output is a 320-kHz bandwidth signal, on a 3-MHz IF, of which 250 kHz is digitized and recorded. To achieve in-phase (I) and quadrature (Q) processing of the data, the receiver output is split into two channels and inputted into two product detectors in the controller chassis (shown on the right in Figure 11), where it is mixed with a 3-MHz injection in one channel and 3 MHz with a 90^{o} phase displacement in the other. This restores the video information to baseband. Both channels are outputted through 130-kHz bandwidth low-pass filters and identified as I channel and Q channel at the front panel, where

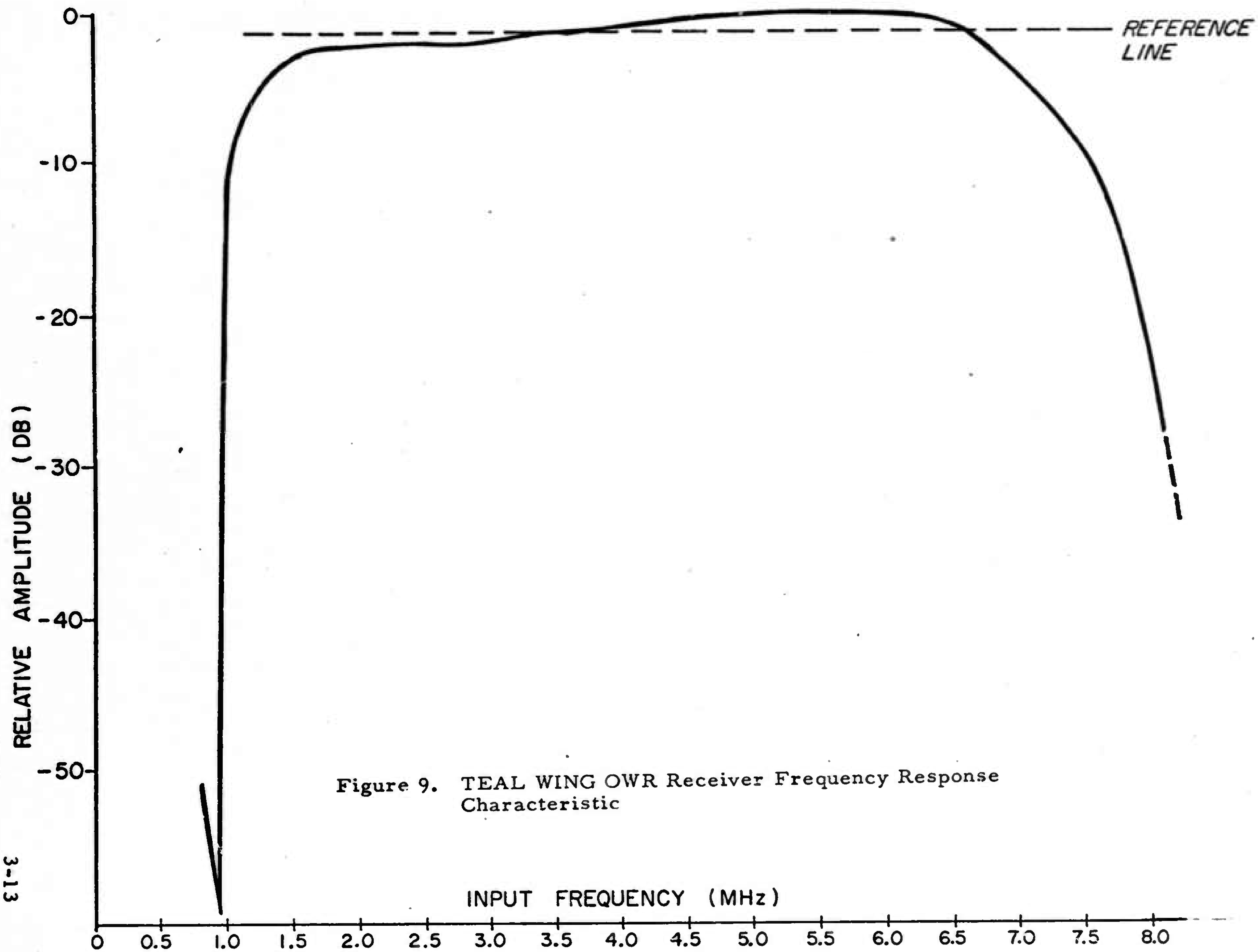

Figure 9. TEAL WING OWR Receiver Frequency Response Characteristic

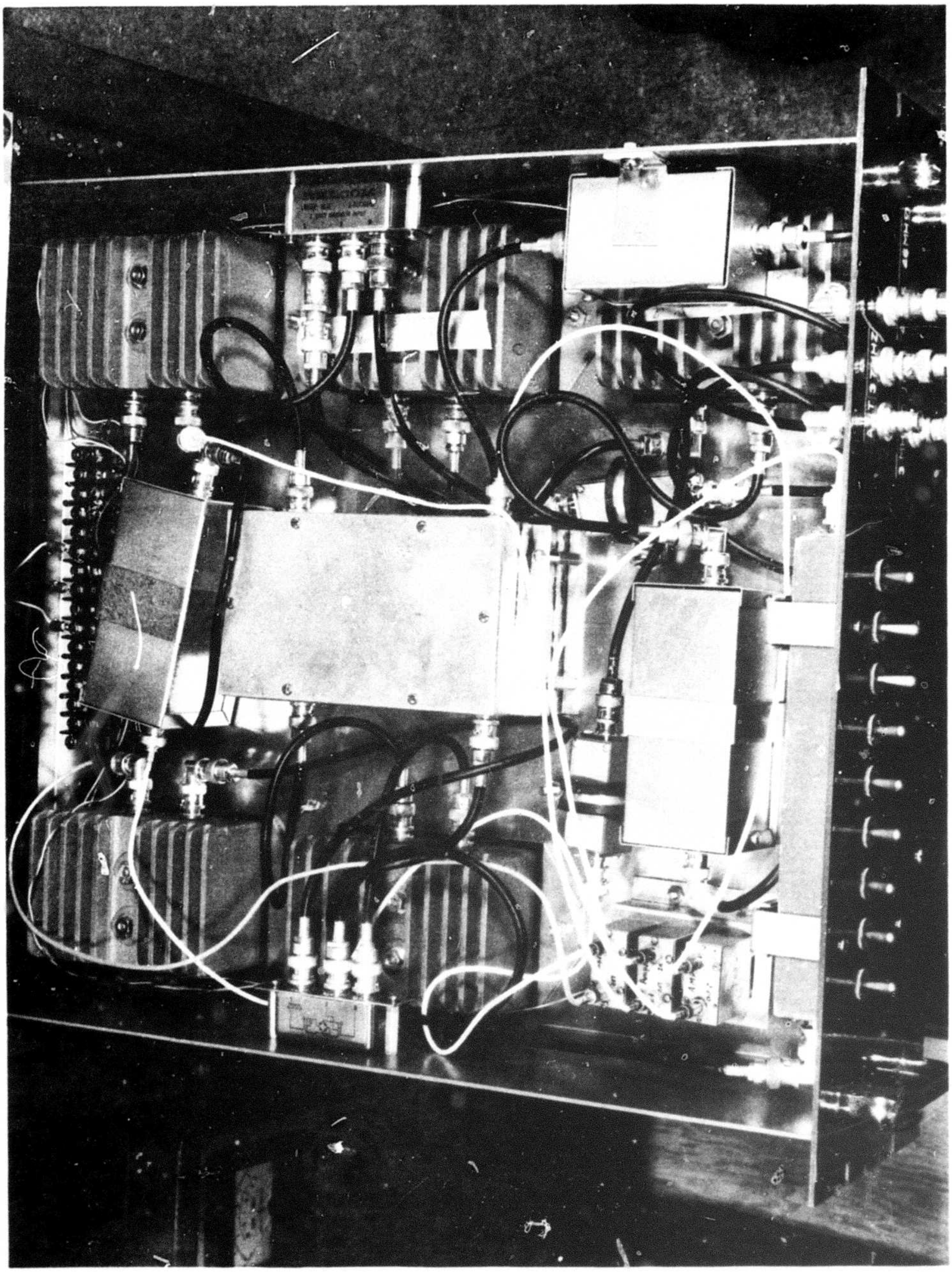

Figure 10. Wideband Receiver

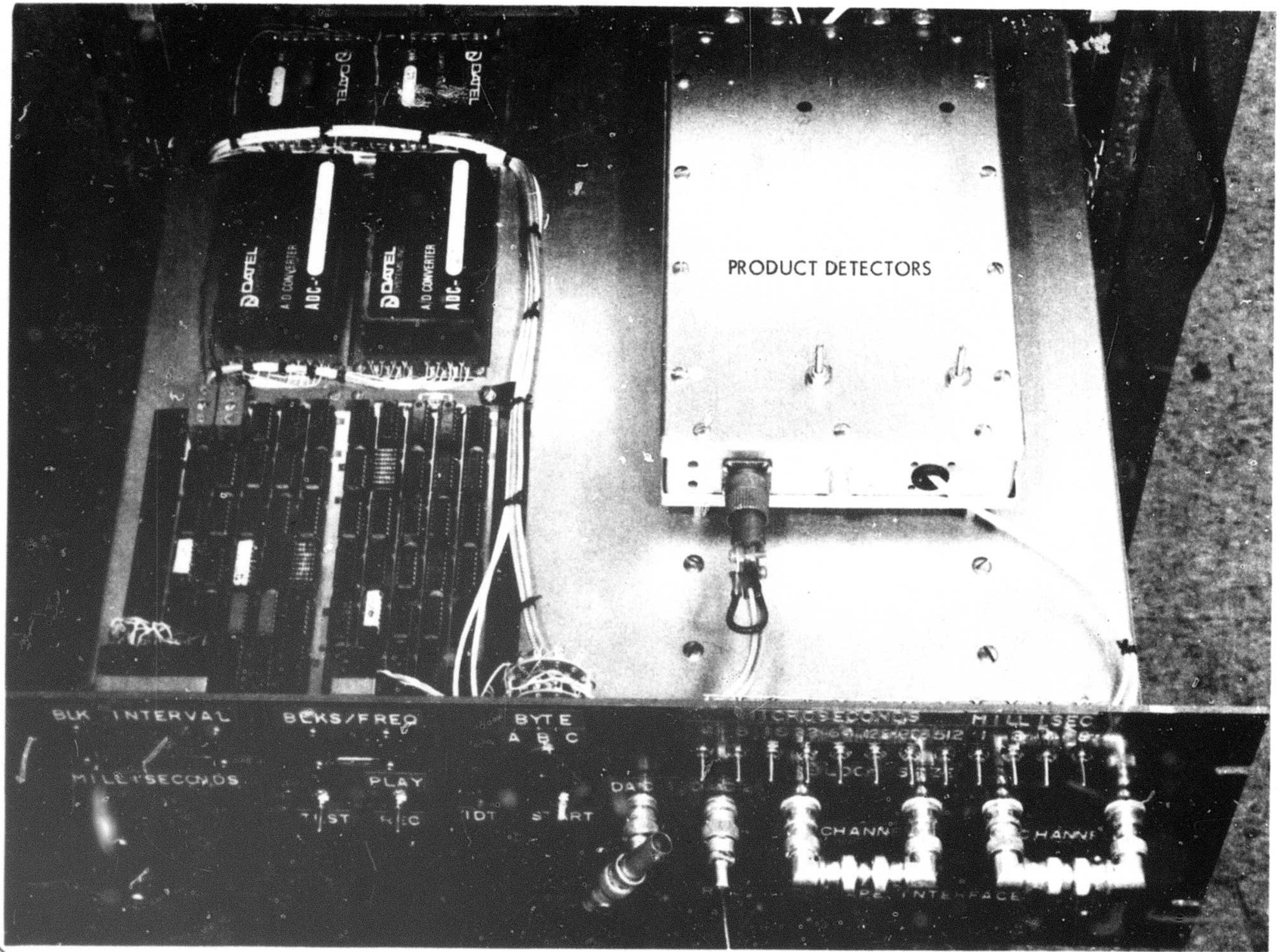

Figure 11. Product Detectors and Logic Interface for Recorder

they may be connected to the remainder of the system (or if the operator desires, an external test signal may be inputted).

These two analog input signals are converted to 12-bit (11 plus sign) binary words in 2's complement code. In addition, the analog inputs are inverted by this analog-to-digital conversion process. Each channel is sampled at a 250-kHz rate by a high-speed "sample-and-hold" circuit preceding the analog-to-digital converter. The input of the analog-to-digital converter is limited to $\pm$ 5 volts.

The I and Q channels are inputted to a 4K-by-24-bit buffer memory at the conversion word rate of 250 kHz. The number of samples inputted to the buffer memory may be selected by the operator using the front panel switches labeled "Block Size."

Upon completion of the input cycle, the data must be transferred from the buffer memory onto the incremental tape recorder shown on the left in Figure 12. Each 24-bit word in memory must be "unpacked" to provide three 8-bit bytes for the tape input. The necessary controls to format the tape to be IBM-compatible are incorporated within the controller. Each block on tape contains a minimum of 24 bytes, and blocks larger than 1536 bytes have inter-record gaps after 1536 bytes. File marks are added at the completion of each set of data input, and logic "ones" are used as the filler required to make up a minimum block size of 24 bytes onto the tape.

The rate and number of these data sets are also operator-selected. The rate at which the input cycles are initiated is selected by the "Block Interval" switches on the front panel, and is shown in milliseconds. The number of cycles inputted is selected by the "Blocks/Frequency" switch, which permits from one to nine cycles to be inputted in response to the operator depressing the "Start" button. If it is desired to cycle continuously (which is very useful in testing the system), the front panel switch labeled "Test" may be used to preempt the "Blocks/Frequency" selection. In the event that the operator runs too small a "Block Interval," the incomplete data transfer light (labeled "IDT") will be red, rather than green, to indicate an operational error.

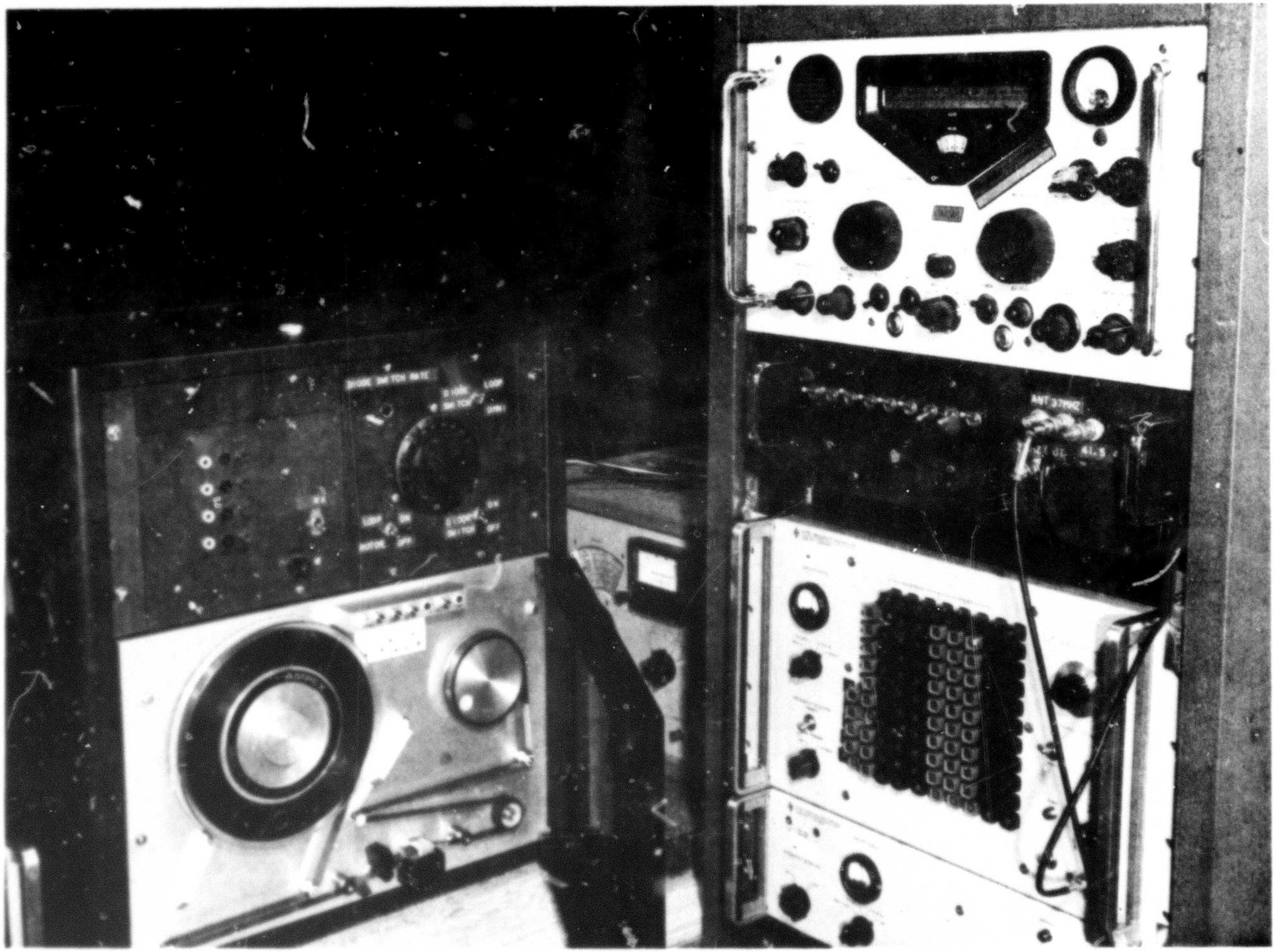

Figure 12. Recording Equipment

As part of the built-in test facility, an 8-bit digital-to-analog converter, comprising two 4-bit digital-to-converters scaled 16:1, is provided. To use both as an 8-bit digital-to-analog converter, it is necessary to connect the two outputs together at the front panel. The fact that two 4-bit units, rather than one 8-bit unit, were provided enables the operator to examine "Byte B," which contains 4 bits of I channel and 8 bits of Q channel.

The "Byte Select" switch allows the operator to monitor either the most significant 8 bits, including the sign bit, of I channel in position A, or the most significant 8 bits, including the sign bit, of Q channel in position C. "Byte B" contains the 4 least significant bits of I and Q which must be monitored separately.

APPENDIX

TEST PLAN FOR THE TEAL WING NOISE MEASUREMENTS

Date: March 1973

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1. INTRODUCTION

This test plan details an experimental program for characterizing the noise fields that would be encountered by high and/or medium frequency communication systems designed specifically for the oceanic areas of the world. Both the method of making the needed measurements of noise and the method of analyzing the data to determine such things as their temporal and spectral structure are described. All of the required tasks will be performed by the ITT Electro-Physics Laboratories, Inc., under the guidance and with the support of the Defense Advanced Research Projects Agency (ARPA) and the Office of Naval Reaearch (ONR).

Measurements are planned for each of the three seasons - equinox, summer, and winter - with the first data being collected in April, 1973. In each case, the antennas, receivers, and recording apparatus required for the measurements will either be installed aboard a cooperating commercial vessel or a vessel on lease to the Military Sealift Command of the U.S. Navy, and the measurements made on a non-interference basis as the ship goes about its normal business. During late March or early April, the equipment will be placed aboard the Gas Turbine Ship (GTS) Admiral Wm. M. Callaghan and measurements made as it makes a 15-18-day round trip between Bayonne, New Jersey and Bremerhaven, Germany.

2. DATA COLLECTION PROCEDURES

Two types of data will be collected. A vertically polarized receiving system with a signal bandwidth of 250 kHz will be used to collect data that can be used: (1) to characterize atmospheric noise and, thus, to predict the effect of this type of noise on the performance of wideband communications systems; and (2) to develop processing methods for reducing the deleterious effects of impulse noise on wideband systems. The observations will be made simultaneously at all frequencies within the 250 kHz bandwidth, as opposed to making them sequentially, so that, as implied above, the properties of those components that are not independent over the band can be appraised. These data will also be used to develop improved methods of reducing the effect of narrowband interference on wideband systems. Steps will be taken during the data collection process to specify the origin of the atmospherics as being remote or local to the ship's position, so that each class of noise can be separately characterized.

A modulated radiometer with a 3-kHz bandwidth will be used together with a rotating loop antenna to collect atmospheric noise data complementary to the 250-kHz bandwidth data. The narrowband data will be used primarily to determine whether the atmospheric noise observed with the wideband system originates with a large number of small, uniformly distributed sources of about the same intensity, or whether they originate with a few intense sources. A large uniform source population will not give rise to an azimuthally dependent noise component, since for every source entering one of the pattern nulls of the antenna there will be another source leaving one of the nulls, whereas the entry or exit of a few relatively large sources will be discernible, with an azimuthal dependence that can be characterized.

2.1 ATMOSPHERICS OF REMOTE ORIGIN

Samples of radio noise reaching the collection point from distant sources will be collected in such a way as to provide information concerning both the long-term and the short-term characteristics of atmospherics of remote origin. Frequencies regularly spaced in the interval from 1.625 MHz to 5.625 MHz will be systematically sampled to provide the long-term characteristics of the noise. Data reflecting the short-term variation in the noise will also be collected for a period of approximately one hour during each scheduled work period.

Data representative of all times of day and of all locations along the ship's course will be collected. Special attention will be given, however, to collecting samples representative of mid-ocean conditions and of conditions about 200 n.m. from the U. S. and European coasts, respectively. The procedures for collecting the data are outlined in Figures 1 and 2.

As indicated in Figure 1a, a spectrum analyzer will be used to make certain: (1) that to the extent possible, the wideband receiver will not be "receiver-noise-limited" during the measurements; (2) that nowhere does the noise level in the passband of interest exceed the linear dynamic range of the wideband receiver; and (3) that the data samples are free of narrowband interference, to the extent possible. Because of low external noise figures, the daytime measurements are expected to be "receiver-noise-limited" part of the time. A preamplifier will be used to minimize this condition, but there will probably be times when the external noise power drops below that of the preamplifier itself. In these cases, the modulated radiometer will be used with the vertically polarized antenna to measure the temperature of the source giving rise to the low values of noise.

The field operator will carefully examine each segment of bandwidth for which data are collected, with a swept-frequency spectrum analyzer, to determine if narrowband signals are present. If possible, only frequencies free of interference will be used for data collection. This task will be performed before data have been collected on a given set of frequencies. It may prove desirable to choose test frequencies one at a time, as opposed to 8 at a time as indicated in Figure 1a. In any case, frequencies will be selected and data collected, as necessary to obtain a suitable data base as free of interference as is possible. However, *Calibrating the receivers at this time implies a flat response with frequency. If this should not be the case, the receivers will be calibrated at each test frequency used to collect the data.

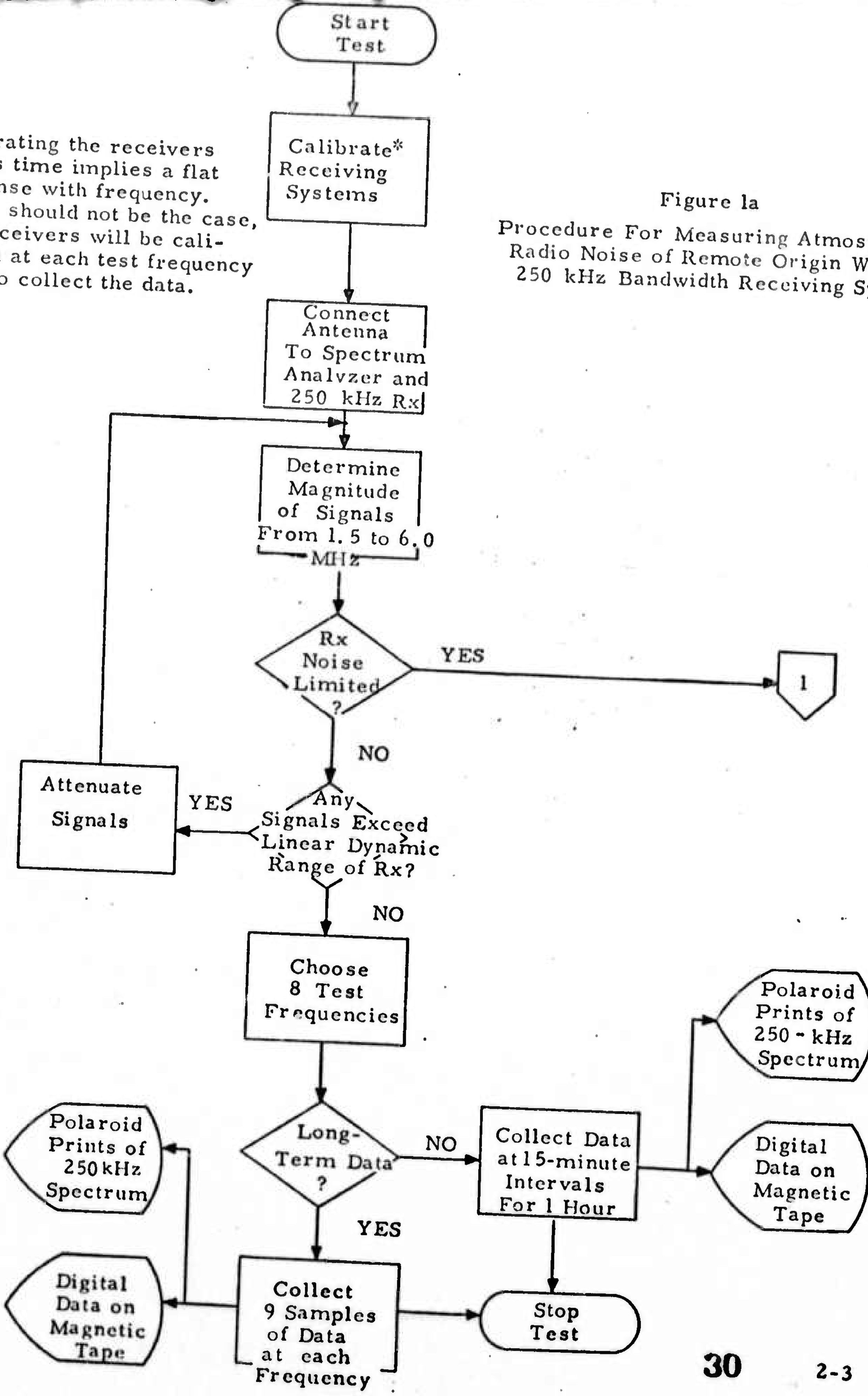


Figure la

Procedure For Measuring Atmospheric Radio Noise of Remote Origin With A 250 kHz Bandwidth Receiving System

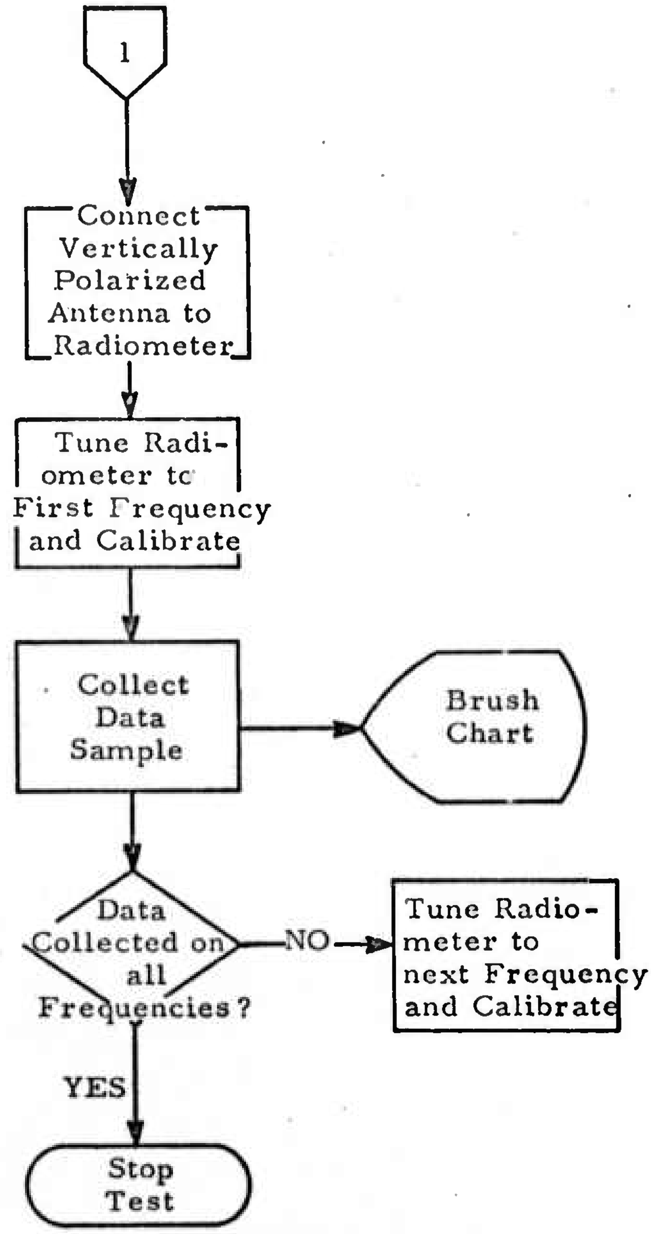


Figure 1b. Procedure for Measuring the Noise Temperature when the External Noise Figure is Very Small

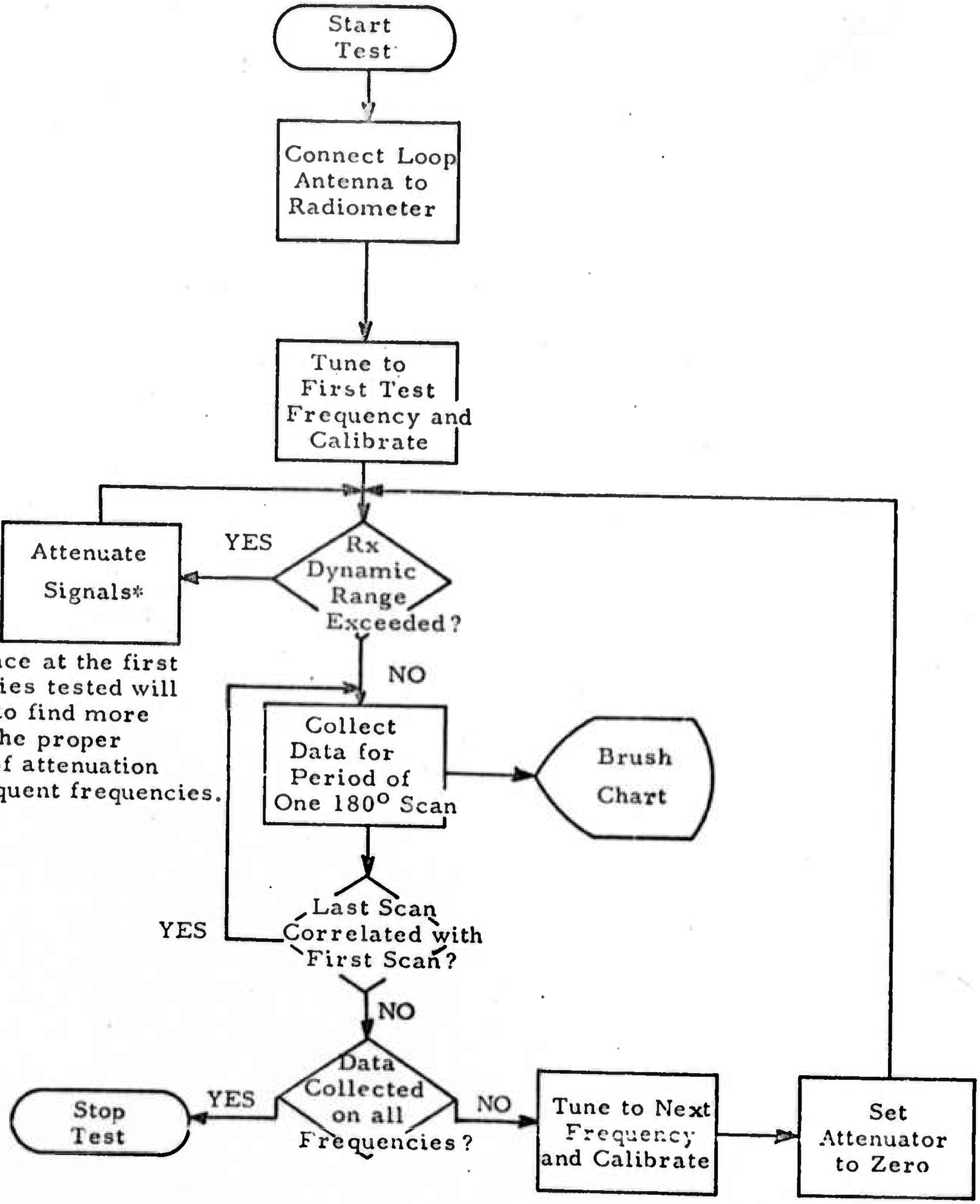
avoidance of interference must not prevent adequately sampling the full frequency band.

The presence or absence of narrowband interference will be indicated in the operator's logbook. In addition, a Polaroid photograph of an 'A'-scope presentation of the spectrum which the digital data represents will be obtained, during the 14.5-second period when the 9-digital data samples are being collected on a given frequency. This information will be used in the data analysis to help determine the type of analysis to be performed.

The noise waveforms will be represented by their complex values at 4 us intervals, spaced to correspond to a signal bandwidth of 250 kHz. Nine 16.4 ms samples of data will be collected on a given frequency before the receiver is tuned to the next frequency. Each sample will consist of 4096 complex numbers representing the inphase (I) and quadrature (Q) components of the noise waveform at 4096 sampling points. On playback of the recorded data, the spectrum of the noise will be obtained with a maximum resolution of about 60-100 Hz, depending on the weighting function used to smooth the estimates of spectral density.

The logbook entries associated with the data will also include such information as the date, time, and frequency of each sample, the geographic coordinates corresponding to the ship's position at the time, the local windspeed in knots, the local weather situation, and any other environmental circumstance that may, in the operator's judgment, affect the noise observations.

Relatively long samples of analog data, recorded on a Brush chart recorder, will be collected with the modulated radiometer, in accordance with the procedures of Figure 2. Several scans of the loop antenna will be made on each test frequency, with the exact number being dependent on the correlation of the records from one scan to the next. The field operator will monitor the records and continue collecting data on a given frequency until the appearance of the most recent scan is substantially different from the first one for that frequency.



*Experience at the first frequencies tested will be used to find more rapidly the proper amount of attenuation at subsequent frequencies.

Figure 2. Procedure for Measuring Atmospheric Radio Noise with a Modulated Radiometer and a Loop Antenna

This procedure assumes (1) that the integration time of the radiometer (0.5 second) is sufficient to make the external noise field observable in the presence of receiver noise, and (2) that the external noise characteristics will indeed change with time. If either of these conditions are not met, the operator will cease the measurements after a reasonable amount of time. Only frequencies found by the operator to be most free of other-user interference will be used for the radiometer measurements.

There are several calibration tests that must be performed each time data are collected. The normal voltage transfer characteristics of the different receiving systems, for example, must be confirmed each test period at each frequency. Calibration signals of known intensity must be introduced at some appropriate point in the system and the output of the system viewed in real time, and permanently recorded in digital form on the magnetic tape, as the level of the calibration signal is varied over the linear dynamic range of the system being calibrated. If either of the two systems fail to meet specified standards, they must be repaired before data are collected.

Two-tone dynamic range calibration tests must be performed often enough to assure the field operator that the specified standards are being met in this respect also. They need not be made each time data are collected, however.

Measurements must also be made of receiver noise at each frequency each test period, with the antenna disconnected and the receiver terminated in its characteristic impedance. Any time deviations from normal expectations are noted, the cause of the deviation will be isolated and corrected before data are collected. The records of these tests must be clearly identified as to date, time, and frequency.

2.2 ATMOSPHERICS OF LOCAL ORIGIN

Within reason, locally generated atmospherics will be measured as often as the opportunity presents itself. While the equipment configuration will closely resemble that used to measure the noise generated by remote thunderstorm activity, special precautions will be exercised to prevent the extreme magnitude of out-of-band spectral components from overloading the wideband receiving system. It is expected that the field operator will maintain close contact with the ship's personnel, in order to keep informed of the local (within the radar radius of the ship's position) weather situation. The data collection procedure outlined in Figure 3 will be repeated several times when local atmospherics are known to predominate.

Narrowband radiometer data will be collected after the wideband measurements have been completed, in exactly the manner previously outlined for atmospherics of remote origin. A check will first be made to make certain that the signals to be recorded do not exceed the linear dynamic range of the receiving system. Then samples of data will be collected on each of 8 frequencies, as indicated.

A check for making certain that out-of-band signals do not exceed the two-tone dynamic range of the receiving system was not included in the narrowband measurement procedure, because it was felt that the inefficiency of the loop antenna, at frequencies other than that to which it is tuned, would prevent the receiver from being overloaded. This point will be checked and confirmed by the field operator, however, before atmospherics of local origin are measured the first time. If local atmospherics should happen to exceed the two-tone dynamic range of the narrowband receiving system, even after being attenuated by the loop antenna, then of course they will be further attenuated to a proper level before the measurements are made.

As indicated in Figure 3, the radio frequency portion of the spectrum will be checked each time wideband data are collected, to make certain that the two-tone dynamic range of the wideband receiver is not exceeded. The check will be made with the spectrum analyzer at the output of a 4.5 MHz bandpass filter. This filter will always be used to prefilter the signals, even when signals of remote origin are being measured. The check to make certain that the system is not "receiver noise limited" was omitted, since this is not expected to ever be the case when the atmospherics are generated by local thunderstorm activity.

*Calibrating the receiver at this time implies a flat response with frequency. Should this not be the case, the receiver will be calibrated at each test frequency used to collect data.

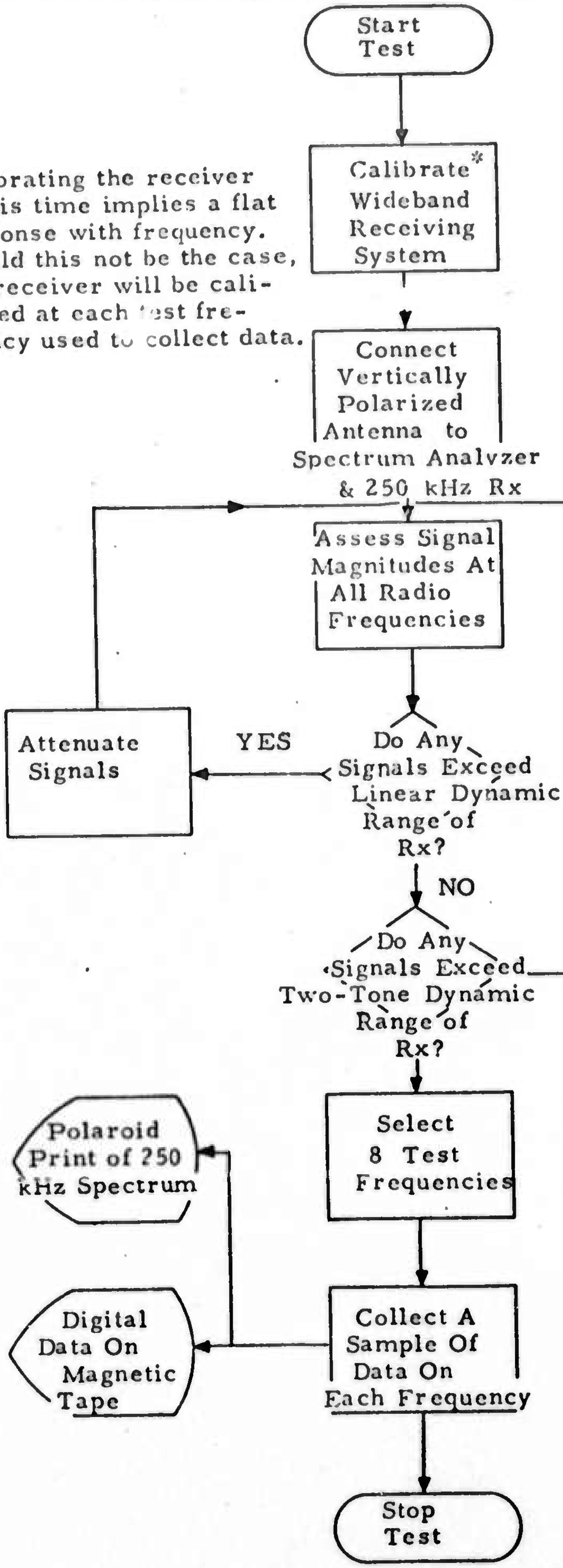


Figure 3

Procedure For Collecting Wideband Data When Local Atmospherics Predominate

2.3 RADIO FREQUENCY NOISE ORIGINATING ABOARD THE SHIP

Every effort will be made to collect data uncontaminated by radio frequency noise generated either by the ship's radio or by other of its electrical equipment. A survey will be made by the field operator before the noise measuring equipment is installed to ensure that it is located in an area free from other electrical equipment so that contamination via direct radiation into the receiver cannot occur. It will also be the responsibility of the field operator to collect data only when the ship's radio is not being used. Further, if the ship is equipped with a microwave radar system, it will be up to the field operator to determine its effect, if any, on the data. If at all possible, the noise measurements will only be made during times when there are no electromagnetic signals being radiated from the ship's antennas. In any case, the condition of the ship's electromagnetic environment should be assessed and documented each time data are collected.

A noise "floor" created by static associated with points of contact between metal parts of the ship is also expected to prevail. The magnitude of this noise cannot be predicted, however, since it depends on such factors as the age of the ship and the manner of its construction. This type of noise will be watched for, both during the data collection and the data analysis phases of the tests.

2.4 WRITTEN RECORD OF PERFORMANCE

The field operator will maintain a written account of all his activities while conducting the tests. It is felt that every aspect of the tests should be documented, even if the impact on the data analysis cannot be seen immediately. All technical problems encountered along the way should, for example, be indicated along with the solution. Every engineering test conducted to confirm that the equipment is operating correctly should be quantitatively documented with calibrated photographs of 'A'-scope presentations, paper chart records, or other means. All information available concerning such matters as the weather and the roughness of the sea should also be included regularly. In addition, a special form will be provided for use when data are being collected, to ensure adequate documentation of the data placed on magnetic tape.

3. EQUIPMENT REQUIREMENTS

Two completely different sets of equipment will be required for the basic measurements of noise. One subsystem will be used to collect wideband digital data, while a second arrangement of equipment will be used to collect narrowband analog data. In addition, there are engineering tests that must be performed in the field, which will require the availability of other special-purpose equipment.

3.1 VERTICALLY POLARIZED WIDEBAND MEASUREMENTS

A block diagram of the wideband receiving system is shown in Figure 4. The essential parts of the system are: a vertically polarized antenna, a preselection filter, a preamplifier, a radio frequency attenuator, the receiver, a digital tape recording system, a logic package interfacing the receiver and tape recorder a swept-frequency spectrum analyzer, and a signal generator for calibrating the data.

The measurements will always be made with the largest antenna that can be supported by the ship's super-structure. Both the azimuthal pattern and the efficiency of the antenna used for each series of measurements will be determined at representative frequencies, using the test procedures outlined in Section 3.3. The impedance of this antenna will be carefully determined as a function of frequency before data are collected.

A wideband preamplifier with a built-in preselection filter will be installed at, or near, the base of the receiving antenna. The preselection filter will be 4.5 MHz wide at the half-power points, which will occur at 1.5 and 6.0 MHz, respectively. The preamplifier will have a noise figure of about 8 db.

A wideband, up-conversion receiver will be used to make the measurements. This receiver has all of the characteristics needed to assure reliable results, including a low noise figure, good isolation of all injection ports, and excellent single tone and two-tone dynamic range responses.

A 9-track synchronous tape transport (Model 1600 MIDIDEK) will be used in conjunction with an internally mounted magnetic tape formatter to record the data. The formatter contains all of the logic necessary for the generation and the full-read recovery of IBM-compatible tapes. It separates

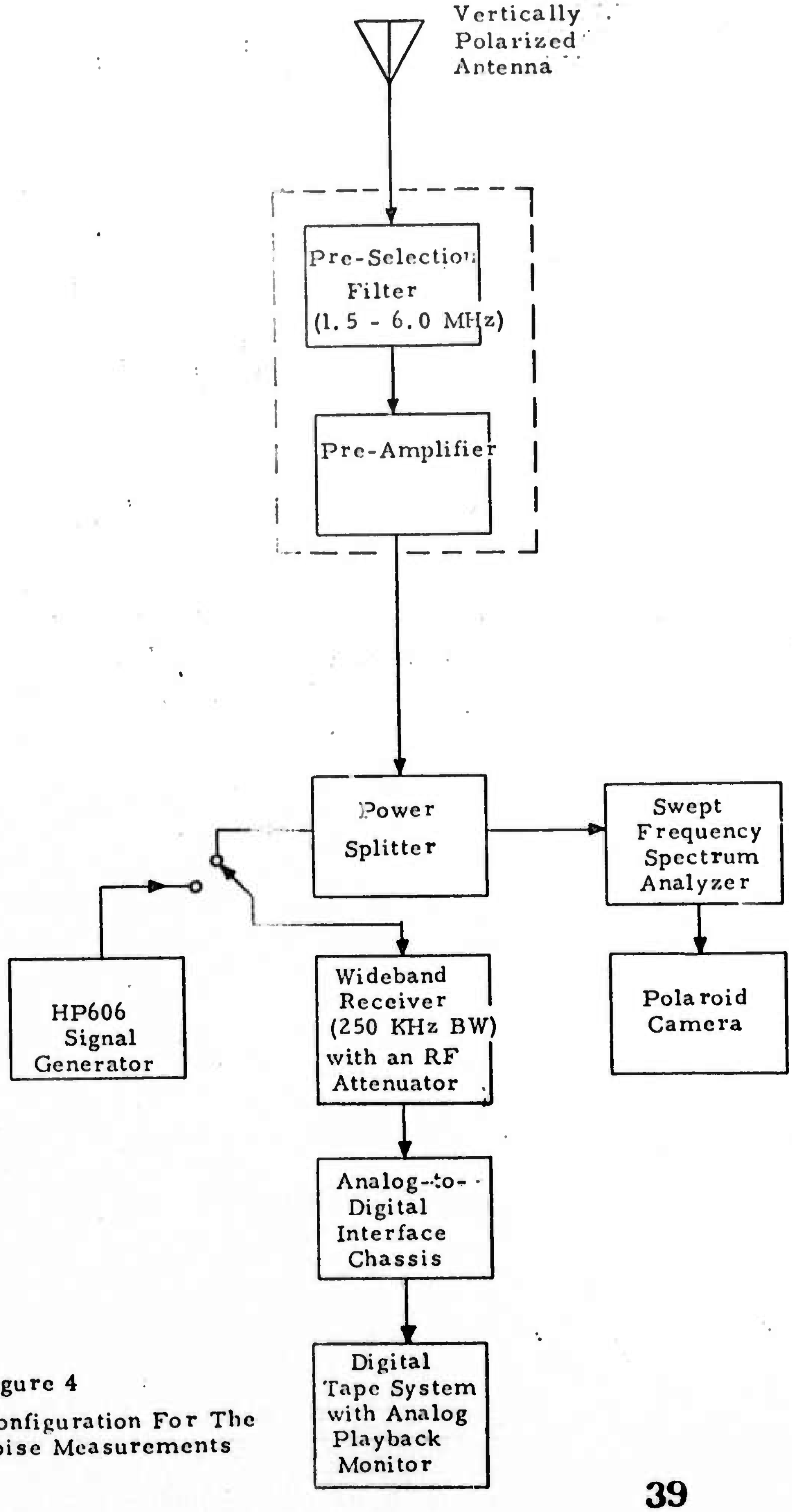


Figure 4

Equipment Configuration For The Wideband Noise Measurements data and "check" characters, performs required error checks, and permits a selected record to be changed, as well as performing other functions. This digital recording system will be interfaced with the receiver by means of a logic package developed by ITT Electro-Physics Laboratories, Inc., the details of which are described elsewhere.

3.2 MODULATION RADIOMETER MEASUREMENTS

Figure 5 is a block diagram of the radiometer to be used for assessing the azimuthal dependence of the noise sources. As indicated, the receiver input will be alternately connected to the loop antenna and to a resistor with the same impedance as the antenna. A switching rate that is slow compared to the inverse of receiver bandwidth, but fast compared to the length of time the noise power must be integrated, will be used for this purpose. After passing through the receiver, the signals will be synchronously detected to produce a voltage proportional to the difference in noise power measured on the antenna and resistor, respectively. (If, for example, the two measurements of power were equal, the output of the synchronous detector would be zero volts.) A simple resistor-capacitor integrator will be used to accumulate the difference for the required length of time, before it is recorded on a BRUSH chart recorder.

The loop antenna will consist of a Faraday-shielded turn of copper wire of 1 meter in diameter. It will be manually tuned at each new test frequency, in order to maintain its efficiency as high as possible. A reversible motor will be used to sweep it back and forth over a 180-degree sector. The events of reversal will be sensed and used to indicate the position of the pattern nulls on a separate channel of the recorder. The records will be linearly interpolated to obtain the position of the nulls at other times.

A terminator with the same impedance as the vertical polarized antenna will also be provided, so that the radiometer can be used with that antenna.

3.3 ENGINEERING TESTS TO BE CONDUCTED IN THE FIELD

Engineering tests will be made, before data are collected the first time, to establish that each element of the measuring apparatus is functioning properly. These tests will be made after the gear has been installed aboard

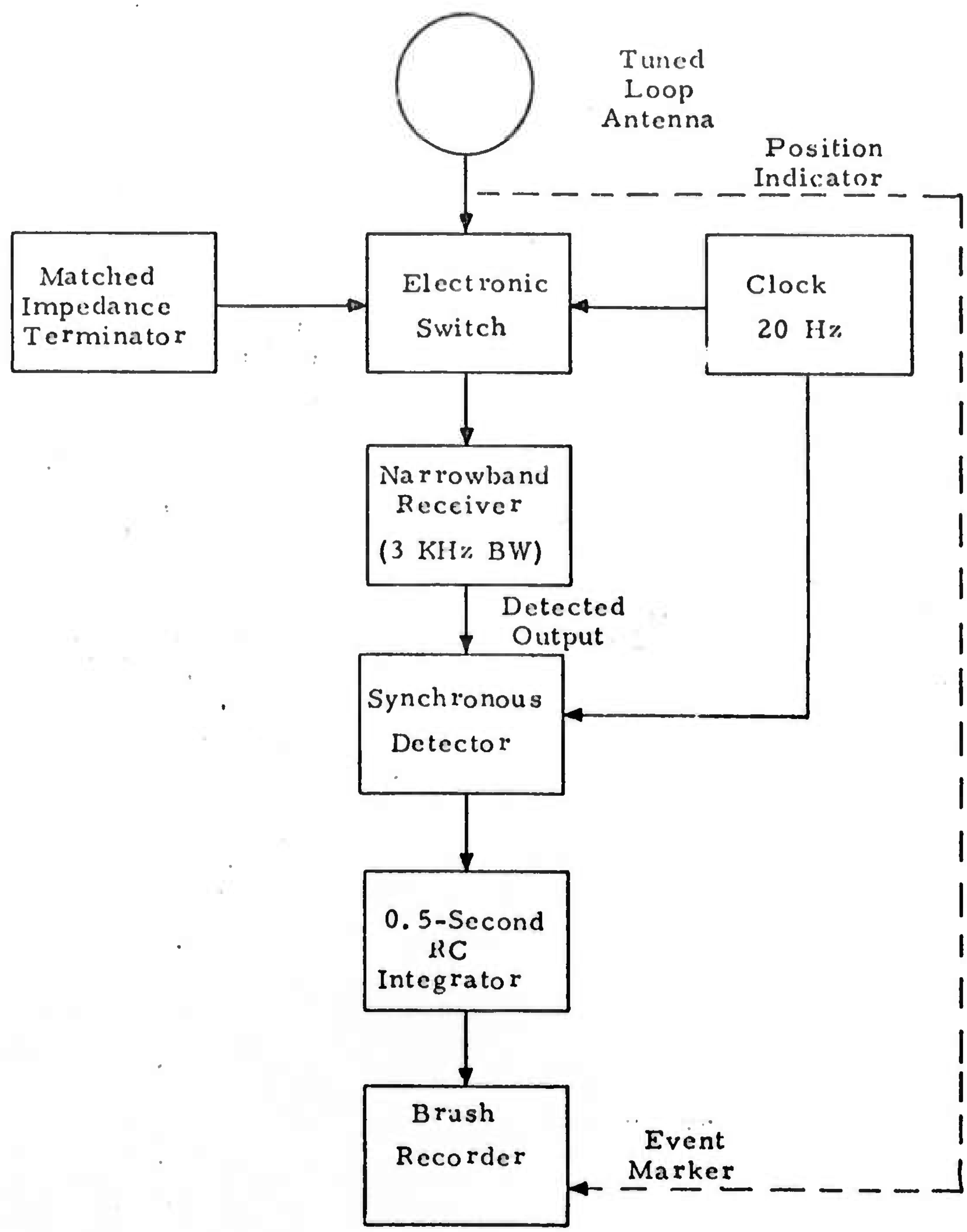


Figure 5

Equipment Configuration For The Modulation Radiometer Measurements the ship, either while the ship is still docked or during the first few hours of its voyage. Additional tests will be made throughout the voyage to ensure that all remains well.

The electrical characteristics of each component of each system will be checked to make certain that they agree with the specified values. All externally supplied timing and injection signals will be monitored. Signal input levels required to achieve satisfactory performance will be established and standardized at all appropriate points in the different systems. Quantitative data will be collected and presented as evidence of satisfactory performance.

Antenna efficiencies and pattern characteristics will be determined, to the maximum extent possible, by comparing results achieved with Stoddard field intensity meter with those achieved with the loop and vertically polarized antennas, respectively. Signals of opportunity, from Loran stations and other sources such as local broadcast stations will be used for this purpose. If possible, by arrangement with the ship's master, at least one Loran station will be monitored while the ship moves in a circle to measure pattern variations, in azimuth, of the vertically polarized antenna.

Measurements will be made with signals from CW or broadcast stations, since Stoddard field intensity meters are internally calibrated for CW signals and not pulse modulated ones. Measurements will be made from time-to-time, as the ship moves toward the open ocean, to take full advantage of any differences in position the ship makes with the calibration source. A plot of the ship's position and heading as a function of time will be required to take full advantage of this method of calibration.

4. METHOD OF ANALYSIS

4.1 WIDEBAND DIGITAL DATA

The main goal of the data analysis will be to establish the wideband characteristics of spontaneous radio noise found at oceanic locations of varying distance from land. Algorithms for excising atmospheric impulse noise will be developed and applied to data with amplitude distributions that deviate from the normal or Gaussian distribution characteristic of thermal noise. The RMS value of each data ensemble, as well as other parameters normally used to characterize atmospheric noise, will be computed.

In anticipation of an insufficient data base naturally free of narrowband interference, an algorithm for excising such noise will also be developed. This algorithm will be applied, as necessary, to obtain residual noise samples which can be used to provide the desired information about the spontaneous noise environment. A twofold secondary goal of the data analysis will thus be: (1) to establish the need for narrowband excising in the geographical locations and at the frequencies of interest; and (2) to specify the optimum resolution bandwidth for excising the narrowband interference.

Selected data will be studied to determine the practicability of excising the different types of non-random noise by a method which exactly matches the excising bandwidth to that of the interferer to be excised.

4.1.1 General Analysis Procedures

The wideband digital data will be processed in a manner similar to that outlined in Figure 6. Data determined to be free of narrowband interference will be processed first. Descriptive parameters such as the mean noise power per Hertz, and the Rice parameter 'a' will be computed for each sample of data. The average value will then be computed for each set of 9 samples and combined with other such averages, according to time, frequency, location, and origin of the atmospherics (remote or local), to

* For the purposes of this figure, a data ensemble is understood to be a set of 9 - 16.4 ms samples of data.

N_o = mean noise power per Hz

F_a = effective external antenna noise factor

T = effective antenna temperature in the presence of external noise

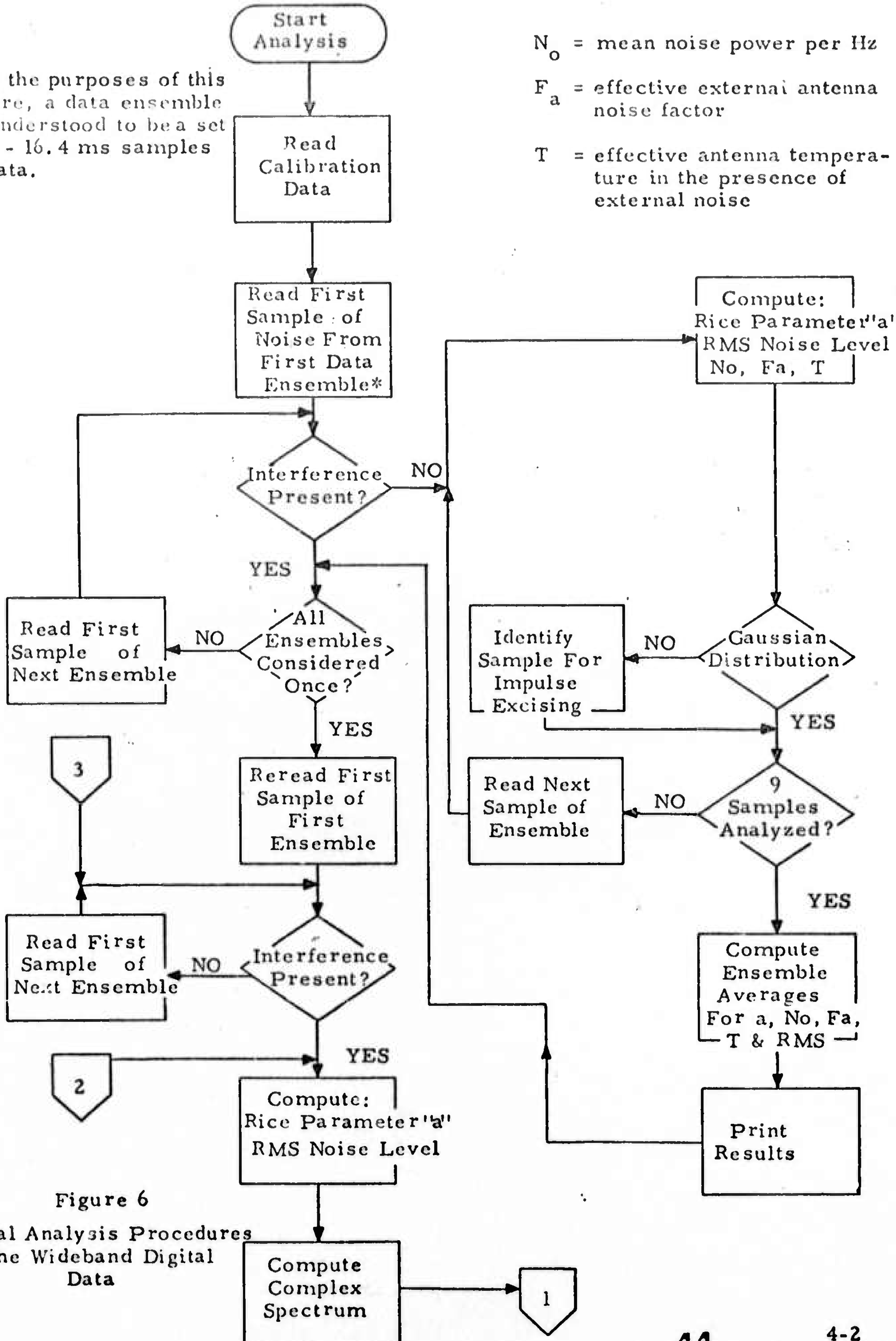


Figure 6

General Analysis Procedures For The Wideband Digital Data

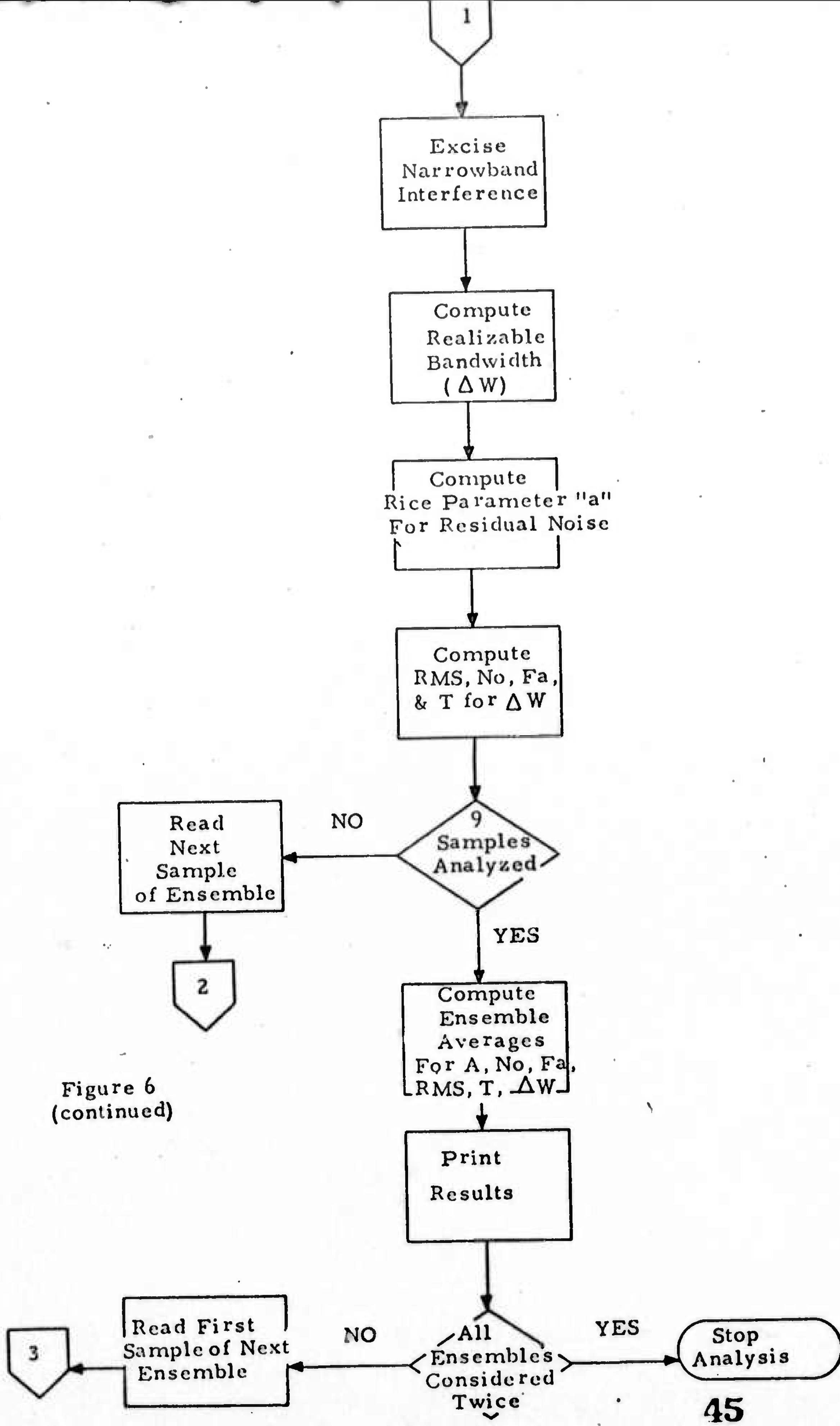


Figure 6
(continued)

increase the effective size of the ensemble. The various parameters of each group (or ensemble) of data thus formed will be statistically characterized.

The interference-free samples of data will be individually tested to determine if they can be described by the Gaussian distribution function, i.e., they will be tested to see if the value of the Rice parameter 'a' computed for them is equal to zero. Those that cannot be thus described will be identified for further analysis involving impulse noise excising.

Information about the filter resolutions that would be required to implement matched-filter excising will be derived from an analysis of the number of spectral lines excised and the order in which they were excised. The bandwidth required to excise a given interferer at a given threshold will be determined simply by counting the number of contiguous 100 Hz lines excised at each threshold. (As noted earlier, the basic resolution for the general analysis of the noise data will be about 100 Hz.) The results of this analysis will be summarized and displayed as histograms.

After a sample of data has been decontaminated, the residual noise will be characterized in the same terms as those used for the uncontaminated samples. In addition, the realizable bandwidth, i.e., the bandwidth containing the residual noise, will be characterized in statistical terms. Results obtained after excising will be compared with results obtained before the interference was removed.

4.1.2 Procedures for Excising Impulsive Noise

Samples of interference-free data with non-Gaussian amplitude distributions will be subjected to excising procedures similar to those outlined in Figure 7. The goal of applying these procedures will be to excise undispersed atmospherics of local origin, and thereby make the residual noise more random and of lower intensity. Atmospherics of remote origin will be little affected by these procedures.

The initial excising threashold will be set at twice the RMS noise level of the sample, and then raised or lowered as necessary to achieve the desired results. If the first residue is Gaussian, the threshold will be raised until the final residue is non-Gaussian. In this case, the mean power per

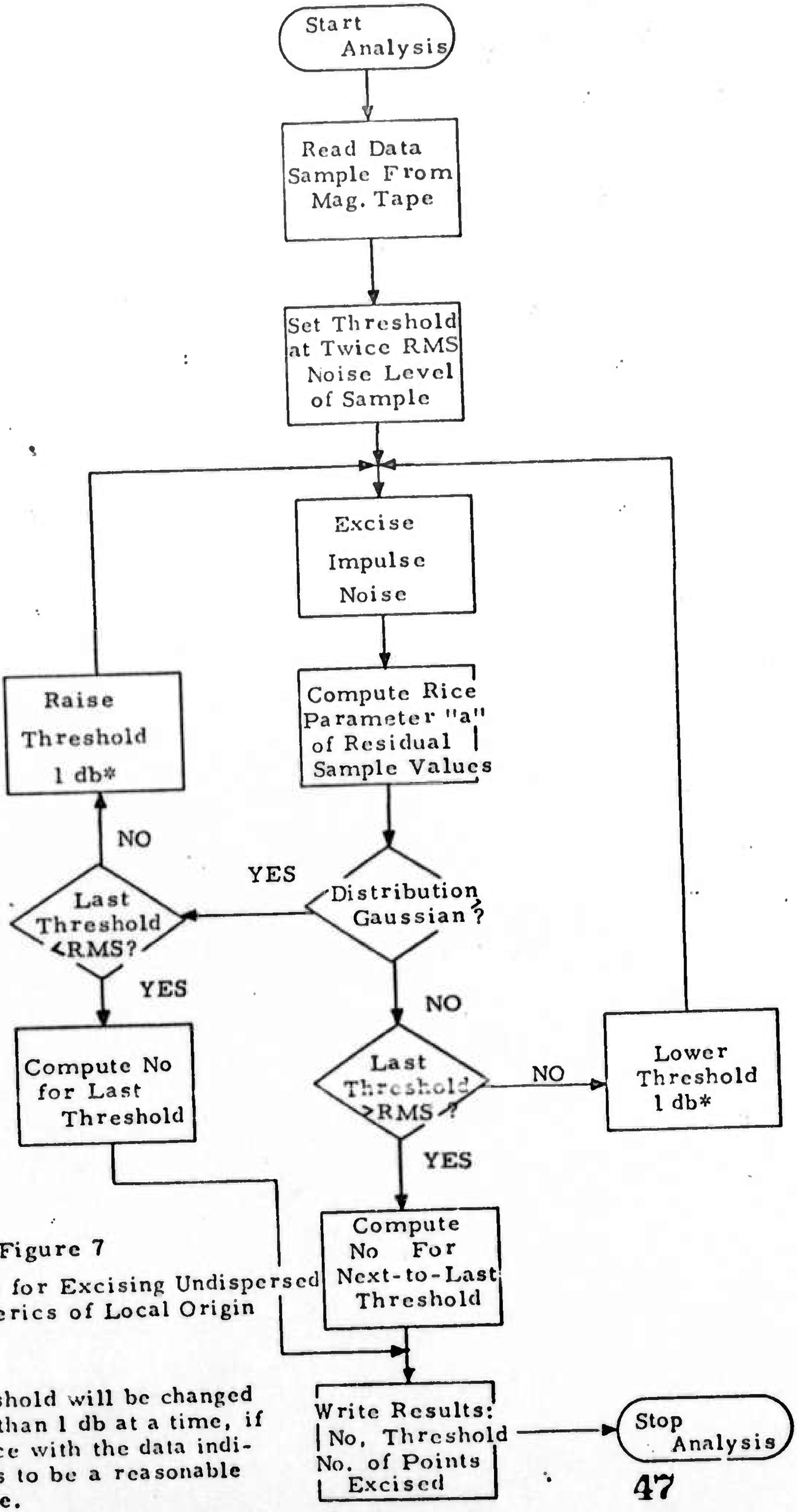


Figure 7

Procedures for Excising Undispersed Atmospherics of Local Origin

* The threshold will be changed by more than 1 db at a time, if experience with the data indicates this to be a reasonable procedure.

Hertz (N_o) will be computed for the last residue with a Gaussian distribution. But if the first residue is non-Gaussian, the threshold will be lowered until the resulting residue is Gaussian. All values of N_o thus obtained will be compared with that expected for system noise alone, as well as well as those obtained originally for the samples of data.

4.1.3 Matched Bandwidth Excising of Narrowband Interferers

A few samples of data highly contaminated with narrowband interference will be subjected to excising procedures that match the excising bandwidth to that of the interferer. In principle several different excising bandwidths could be required for a single sample of data. The basic goal will be a quantitative measure of the improvement of this method of excising over the usual method which utilizes a fixed excising bandwidth. The results obtained in the general analysis concerning the filter resolutions required to implement matched-filter excising will be used to guide this effort. This task will be considered subsidiary to all other tasks outlined in this test plan, and will, therefore, be only briefly considered.

4.2 NARROWBAND ANALOG DATA

The records of the modulated radiometer output will be analyzed for the purpose of characterizing three properties of natural noise sources. Information concerning the number and distribution of the sources will be of primary importance, since the pattern of the vertically polarized antenna need not be considered in the basic calculations of noise power if the sources are great in number and uniformly distributed in the azimuthal plane. The span of time over which the sources produce a recognizable pattern is the second characteristic of interest. Finally, all radiometer data collected with the vertically polarized antenna will be used to determine the effective antenna temperature in those cases where the external noise figure is too low to be measured in the normal way.

5. SCHEDULE INFORMATION

Two schedules for the tests to be conducted in April, 1973, are presented in this section. A gross time schedule for a one-way crossing of the Atlantic Ocean is given in Table 1. This schedule indicates the type of work to be performed on each day of the trip. The second schedule which appears in Table 2, indicates the sequence of measurements to be made each work period.

As indicated in Table 1, the first day out of port will be spent installing and calibrating the antennas. Impedance measurements will be made first, followed by efficiency and azimuthal pattern measurements using the Stoddard field intensity meter. Additional pattern and efficiency measurements will be made on the seventh day out of port. (All other equipment will have been installed and checked before the ship embarks for Germany.) The remaining five days required for each crossing will be spent collecting data. The operator's basic work schedule will be four hours on and six hours off, resulting in collection of data representing a total of four solar days.

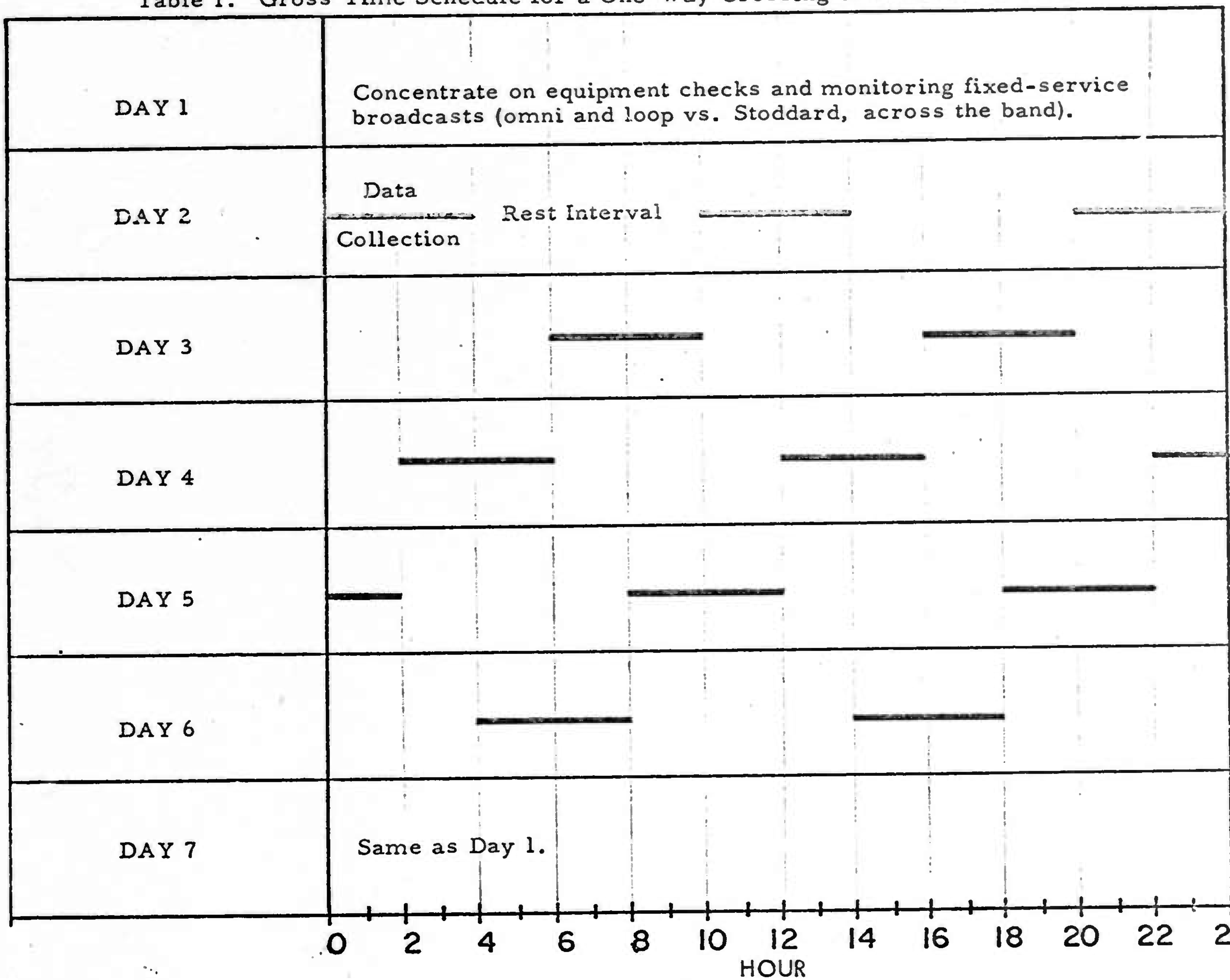
The tasks to be performed during a typical four-hour work period are outlined in Table 2 on a form of the type to be used for the wide-band data. Several specific tasks other than measuring the noise environment will be performed during the first and last half hours of each period. During the first half hour the operator will: (1) establish the general operating condition of the equipment and (2) acquire information from the ship's personnel concerning the ship's position. the weather. and the status of the ship's radio and radar equipment. The last half hour will be spent updating information of the type obtained at the beginning of the period.

As soon as the preliminary tasks have been completed, the first test frequency will be selected from the low end of the band of interest, the receiving system calibrated at this frequency, and nine samples of data recorded on magnetic tape. The frequency selection process is expected to take about three minutes; the calibration process, about 2 minutes; and the data recording process, about 15 seconds. This entire process will be repeated at eight different frequencies across the band. A second, third, and fourth set of data will be collected on each test frequency selected for the first set. It should take no more than seventeen minutes to generate each of these additional sets of data.

A fifth and final set of wideband measurements will be made at the end of each work period, starting about the beginning of the fourth hour. New test frequencies will be selected for this series of measurements unless, of course, the previously selected frequencies are still the best choice. In any case, the frequency spectrum will be carefully examined with the spectrum analyzer and a new decision made as to which frequencies to use.

Observations will be made with the loop antenna during a 50-minute period available between the fourth and fifth sets of wideband data. Three of the eight frequencies used for the fourth set of wideband measurements will be used for the radiometer measurements. They will be spaced to span the 4.5 MHz band of interest.

Table 1. Gross Time Schedule for a One-Way Crossing of the Atlantic Ocean



ATE (UT)	TIME (UT)	ENSEMBLE NO.*	FREQUENCY (MHz)	SEA STATE	NARROWBAND INTERFERENCE	SHIP'S LOC. LAT., LONG.	REMARKS
April 10	1430-1500	PERFORM ENGINEERING TESTS, ETC.					
	1500	— — —	1.57				Calibrate
	1502	Run 1-A1	1.57	1	Yes	35.1W, 45.2N	
	1505		2.30				Calibrate
	1507	Run 1-A2	2.30				
	.	.	.				.
	.	.	.				.
	1535		5.75				Calibrate
	1537	Run 1-A8	5.75				
	1538		1.57				Calibrate
	1540	Run 1-B1	1.57				
	1540:15		2.30				Calibrate
	1542	Run 1-B2	2.30				
	.	.					.
	.	.					.
	.	.					.
	1553:15		5.75				Calibrate
	1555	Run 1-B8	5.75				
	1556		1.57				Calibrate
	1558	Run 1-C1	1.57				
	1558:15		2.30				Calibrate
	1600	Run 1-C2	2.30				
	.	.	.				.
	.	.	.				.
	.	.	.				.
	1611:15		5.75				Calibrate
	1613	Run 1-C8	5.75	1	Yes	35.1W, 45.2N	Calibrate

*In this table, an ensemble consists of 9-16.4 ms samples of data at a single frequency

TE (UT)	TIME (UT)	ENSEMBLE NO.	FREQUENCY (MHz)	SEA STATE	NARROWBAND INTERFERENCE	SHIP'S LOC. LAT., LONG.	REMARKS
April 10	1614		1.57				Calibrate
	1616	Run 1-D1	1.57	1	Yes	35.1W, 45.2N	
	1616:15		2.30				Calibrate
	1618	Run 1-D2	2.30				
	.	.	.				.
	.	.	.				.
	.	.	.				.
	1629:15		5.75				Calibrate
	1631	Run 1-D8	5.75	1	Yes	35.1W, 45.2N	
	1631-1720	MAKE LOOP ANTENNA MEASUREMENTS					
	1723		1.78				Calibrate
	1725	Run 1-E1	1.78	1	No	35.1W, 45.2N	
	1728		2.65		No		Calibrate
	1730	Run 1-E2	2.65		No		
	.	.			.		.
	.	.			.		.
	.	.			.		.
	1758		5.54				Calibrate
	1800	Run 1-E8	5.54	1	Yes	35.1W, 45.2N	
	1800-1830	UPDATE INFORMATION ON SHIP'S POSITION, ETC.					

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