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JANSKY & BAILEY RESEARCH and ENGINEERING DIVISION

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REVISED
ACOUSTIC AND SEISMIC RESEARCH
FIELD TEST PLAN

October 1965

Prepared for

OFFICE OF SECRETARY OF DEFENSE
Advanced Research Projects Agency
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ATLANTIC RESEARCH

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ACOUSTIC AND SEISMIC RESEARCH FIELD TEST PLAN

Jansky & Bailey
Research and Engineering Division

of

Atlantic Research Corporation
Alexandria, Virginia

Prepared for

OFFICE OF SECRETARY OF DEFENSE

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PREFACE

The Jansky & Bailey Division of the Atlantic Research Corporation has been awarded a contract by the Advanced Research Projects Agency, Department of Defense, to conduct an Acoustic and Seismic Research Program involving the acquisition of data in tropical environments and the subsequent analysis of this data. Most of the experimental work under this project will be carried out in Thailand, and the analysis, evaluation and interpretation of the resulting field data will be completed in the United States. The purpose of this program is to provide basic information about acoustic and seismic phenomena that are needed to develop, or specify, future acoustic and seismic combat surveillance and target acquisition techniques and equipments for ultimate use by military forces in Southeast Asia, or other areas with similar environments.

Through competitive solicitation, Atlantic Research Corporation, the prime contractor, awarded a subcontract to the Institute of Science and Technology, University of Michigan. Under this subcontract the Institute of Science and Technology assumed the prime technical responsibilities for the program. Jansky & Bailey provides personnel to conduct the field measurements in Thailand under the technical supervision of IST.

Under the terms of the prime contract, a detailed plan for the collection of data in Thailand is to be prepared and submitted for ARPA approval prior to the initiation of the field work. A test plan was submitted in August 1964 and approved by ARPA. In accordance with that test plan, field measurements were begun in Thailand and continued through Site 9 (of the 10 sites designated in the original test plan) on schedule.

On 1 July 1965 ARPA requested that the field measurements be suspended to allow a review and possible revision of the field program plan, and to permit considerations of modifications to the field equipment. As a result of the various review conferences, certain elements of the program have been replanned and the Field Test Plan has been revised.

Accordingly, this Revised Field Test Plan, prepared jointly by Jansky & Bailey and IST, is submitted in pursuance of the contractual requirements.

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1. INTRODUCTION

The program of acoustic and seismic combat surveillance and target acquisition described in this Test Plan is intended to produce quantitative measurements of acoustic and seismic wave fields to determine the feasibility of their use for several types of combat surveillance that may be desirable in the Southeast Asian environment. By making the measurements over broad regions of the acoustic and seismic spectra it should be possible to determine what portions of the spectra are most applicable for particular surveillance problems. Surveillance experiments for a number of types of sources of acoustic and seismic waves are to be considered for each locality. Variations in detection capability between localities in particular areas and between different regions are to be studied. Attempts will be made to relate these variations in detection capability to the meteorological, geological, and vegetation conditions at the test sites. Measurements of background noise for both acoustic and seismic wave fields will be made.

The following definitions are introduced and will be used throughout this Test Plan:

Region: Physiographic region such as central lowland, continental plateau, continental highland, or coastal highland.

Area: A subdivision of a region such that similar experiments can be conducted within the same region and without excessive travel between localities where field measurements are made.

Locality or Site: The particular area occupied by the detecting and recording equipment. An example might be a portion of a rice paddy in which seismometers and microphones are located with cables leading to a central tape recorder. A temporary camp might also be located within the site.

Point: The particular spot where a piece of equipment is located. The selection of points will have to be made by the chief of the field party.

The field work specified by this Test Plan will be conducted at the sites listed in Section 3 and at additional sites to be selected in coordination with RDFU-Thailand.

2. PURPOSE AND SCOPE

The field measurement program described in this Test Plan has been designed to investigate the acoustic and seismic parameters established during the technical re-evaluation of the project.

In the area of acoustic measurements and analysis, it is the objective to accomplish the following specific items:

1. Determine the natural acoustic background and its variation as a function of time of day, season, and location.

2. Determine the existence or nonexistence of constants in the acoustic background.

3. Determine the change in the natural acoustic background caused by human intrusion as a function of (a) elapsed time since disturbance with the disturbance still in place and with the disturbance removed, and (b) distance from the disturbance.

4. Determine the values of attenuation and variation of attenuation of acoustic energy vs frequency at the measurement site.

5. Determine the existence or nonexistence of an acoustic duct as a function of time of day, audio frequency, season, and tree canopy height.

With respect to the seismic measurements, it is the objective to accomplish the following items:

1. Determine the characteristics of the natural seismic background and its variation as a function of time of day, season, geological formation, and degree of foliation.

2. Determine the velocity, attenuation, and characteristics of propagation of a signal generated by a human intruder.

The field measurement program will produce data in the form of analog magnetic tape recordings. These data tapes will be sent to the Geophysics Laboratory at the University of Michigan for reduction and analysis.

3. FIELD SURVEY AND SITE SELECTION

The technical objectives of this study require test areas that cover the major physiographic regions of Thailand. The physics of the acoustic and seismic problems demand sites within these areas that include variations in (1) above-surface vegetation, (2) surface conditions, and (3) shallow sub-surface media typical of Thailand. Measurements should extend from coastal regions to continental regions and sites should be selected so that acquired data will accurately represent the natural background. The selected sites should also resemble potential military operational areas as closely as possible. For example, an open desolate area with no obstructions to vision would not be a satisfactory site. On the other hand, a trail through a dense forest would be a satisfactory site. A vegetated area normally devoid of human activity at night, such as a rubber plantation, would also be a site of interest in the program.

In 1964 a site study was conducted in Thailand. At that time conferences were held with representatives of the Mobility Environmental Research Studies (MERS), U. S. Military Surveillance and Environment Groups, Thai Government, Jansky & Bailey, and the Acoustics and Seismics Laboratory (now the Geophysics Laboratory). Aerial photos, topographic and geological maps, and environmental reports prepared by Waterways Experiment Station were carefully examined. Specific sites accessible by Jeep transportation were visited.

One result of this was the classification of Thailand into four broad environments for acoustic and seismic phenomena. These are:

Environment A: Alluvial terrace, cultivated lowland, rice paddy, sparse tall vegetation.

Environment B: Dense tropical vegetation, thick ground cover and undergrowth, maximum tree heights exceeding 10 meters, lowlands, animal trails necessary for passage through area.

Environment C: Continental plateau, open land, less than 10 per cent tree cover and canopy, scrub brush, savanna padi.

Environment D: Forested highland, mountainous, outcroppings of bedrock and basement ridges, maximum tree heights exceeding 10 meters, canopy closure variable, rubber plantations, variable undergrowth, animal trails not necessary for passage through area.

Test areas were selected in accordance with this breakdown of environments. The areas were chosen to coincide with MERS study areas as much as possible because of the availability of descriptive data for these locations.

The areas chosen were as follows:

Environment	Area	Physiographic Region
A	Bangkok	Central lowland
B	Pak Chong	Central lowland
C	Khon Kaen	Continental plateau
D	Chanthaburi	Coastal highland
	Chiang Mai	Continental highland

Ten specific sites within these areas were selected during the initial and subsequent survey trips in 1964. All of these sites have been re-evaluated by representatives of RDFU-Thailand from the point of view the new criteria established during the program redirection conferences. Among the previously selected locations, Sites 3 and 4, both in the Pak Chong area, meet the newly established criteria for the acoustic and seismic objectives. This area is shown on Figure 3.1. Site 3 is located in the Jansky & Bailey test area at FPA-4. Site 4 is also located in the Jansky & Bailey test area about halfway between field points A11 and A12.

Accordingly, the measurement plan has been revised to start measurements at these sites in numerical order. This is shown on the simplified PERT diagram (Figure 10.1) included with this Test Plan. Also shown on the diagram are measurement plans for up to four additional sites which are to be selected to meet the new criteria by representatives of Jansky & Bailey, IST, and RDFU-Thailand. It is planned that these selections will be made in time to avoid delays in the measurement program. That is, Site A will be selected and adequate preparations completed by the time field testing is finished at Site 4. The total number of sites at which measurements are to be made depends upon the availability of the sites and the extent of the measurement program at each site.

General meteorological data, where available, will be obtained from the Thai Metro Department as furnished to MRDC. Meteorological observations will also be made by field personnel conducting the tests. These will include measurements of temperature, humidity, wind speed, and rainfall. Upon completion of the acoustic and seismic tests,

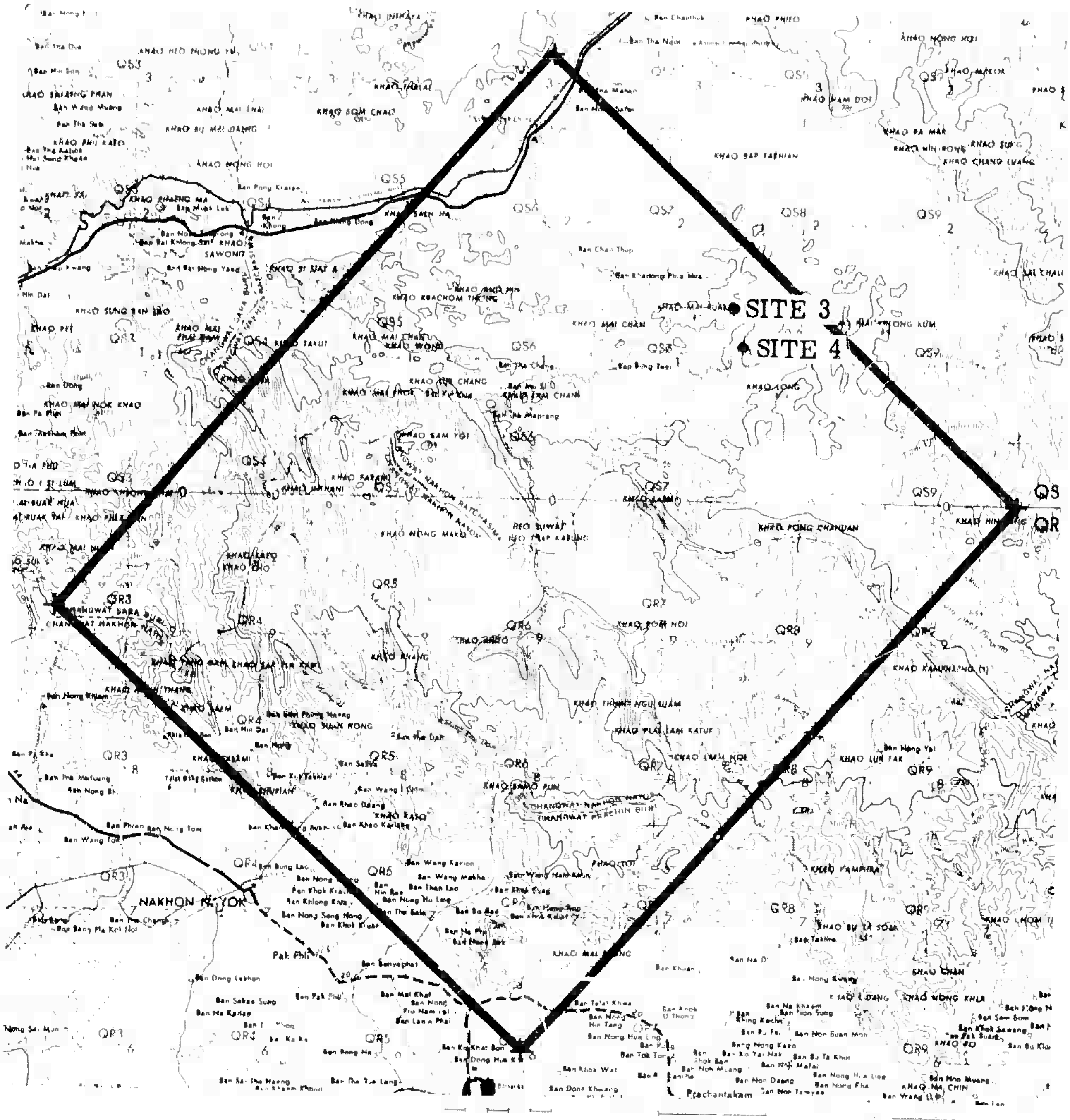

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Figure 3.1 Acoustic and Seismic Measurement Area Sites 3 and 4, Existing J&B Test Area the soil and vegetation in the test area will be characterized in quantitative terms. For the vegetated areas, the office of Lt. Col. W. R. Schieble, Program Manager, Environmental Research, OSD/ARPA Field Unit, will furnish a standardized description of the vegetation. It is expected that such descriptions will yield dat- on tree diameters, basal areas, tree heights, and tree positions in 10-by-40 meter sample areas. This data shall be sufficient to calculate the "biomass factor" of the vegetation as outlined in "A Method for Estimating Biomass of Tropical Forests" by Dr. L. T. Burcham, dated 29 April 1965 and 12 October 1965.

Soil samples will be taken at the surface and at a depth of 1 meter at two points at each site. The parameters required to describe the soil are in situ bulk density (before dehydration), porosity and soil classification. Elastic soil parameters will be determined by IST from the records obtained from the seismic measurements. The office of Lt. Col. A. R. Simpson of Mobility Environment Research Studies in Thailand has indicated that it will process these soil samples up to a quantity of 10 or so. Arrangements for additional soil processing will be made with the Thai Soils Laboratory in Bangkok.

4. TEST PROCEDURES

4.1 Introduction

The proposed field measurement program is to be conducted at former Sites 3 and 4 and at up to four other sites, presently not selected, as discussed in Section 3. The test procedures described herein are organized into three subtests which are planned to afford a logical sequence for the various recordings and to maximize the usefulness of the calibration procedures and reduce operating time. Subtest 1 is designed to measure the natural acoustic and seismic background. Subtest 2 is concerned with measurements of the variations in acoustic background with elevation and acoustic attenuation along a horizontal profile. Subtest 3 measures the attenuation of seismic waves and the limits of acoustic and seismic detectability.

There are certain differences in the procedures of Subtests 1 and 2 which are dependent upon the foliage cover at the measurement site. Therefore, different procedures are detailed for each of these subtests under the broad classification of densely foliated areas and sparsely foliated areas. The procedures described for use in densely foliated areas would, in general, be used in areas having dense tropical vegetation with thick ground cover and undergrowth, making it necessary to use trails for passage through the area. Former Sites 3 and 4 are in such an environment. The procedures detailed for use in sparsely foliated areas would be applied in areas where there are variations in undergrowth and canopy cover and where trails are not necessary for passage through the area. The procedures for Subtest 3 are the same regardless of the foliage.

It is not intended that the complete set of test procedures shall be used at all test sites. Several of the tests are either special or more thorough than would be necessary, or even desirable, to be repeated at all sites. Instead, it is planned that appropriate subtest procedures will be detailed for each of the sites after they are selected. This planning will be done by Jansky & Bailey and IST representatives in cooperation with RDFU-Thailand personnel. Similar planning must also be undertaken to review and detail the acoustic and seismic background tests with respect to the requirements for information regarding natural background change as a function of intrusion.

4.1.1 General Equipment Operational Precautions

During the previous set of measurements, it became obvious that the high ambient temperatures in Thailand require that special care be taken in the operation of the seismic and acoustic amplifiers. When these amplifiers are operated in the direct sunlight, they reach temperatures high enough to cause drifting. Therefore, amplifiers used in the field should be shaded and operated in an upright position. Care should be taken to ensure that the shading device does not restrict air circulation around the amplifier case. In addition, seismic and acoustic amplifiers must not be operated on batteries whose voltage under load is less than 10 volts, dc, as the performance of the amplifiers is no longer stable below this supply voltage.

Rainfall is to be measured throughout the tests at each site by means of a standard rain gauge, and the amount of rain in inches is to be recorded together with the time period during which the rain fell.

4.2 Calibration Procedures

The following procedures are to be performed at the times specified in the Test Plan. At least 5 minutes of warm-up time should be allowed before continuing with this procedure. Do not remove or replace any record-reproduce amplifiers with the power on. Sufficient additional tape will be provided to perform all the specified calibrations.

4.2.1 SP-300 Calibration

The following procedure will allow the field crew to vary the gain of the tape system. This is necessary to compensate for variations in gain due to severe physical vibration and long-term aging. This adjustment does not calibrate the tape system but simply allows the recording levels to be set near optimum. It will be necessary to perform this adjustment before each subtest and before any of the recorded calibrations which are sent to IST. The tape gains must never be changed unless they are followed by a recorded calibration tape. (See FM Mode Calibration and Direct Mode Calibration.)

4.2.2 FM Mode Calibration

Before and after all subtests in which the tape system will be used in the FM mode, the following procedure is to be followed. This procedure will be applied only to those channels actually used in the FM mode. A standard FM calibration tape will be provided which has a true center carrier frequency on the first and last portion and a 1 vrms at 1000 cps sine wave recorded on the center third of the tape. The signal has been recorded on all channels and will provide a properly recorded signal simultaneously to all amplifiers. Never record on this tape.

Thread the standard tape on the tape recorder, and connect the Tektronix type 321A oscilloscope to the reproduce terminals on the monitor panel. Start the tape transport, and while the center carrier portion of the standard tape is being reproduced, adjust the amplifier for zero dc output as indicated by the Tektronix oscilloscope. This is accomplished by adjusting the "Zero Adjust" control on the front panel of the record-reproduce amplifier. Now disconnect the oscilloscope and connect the Ballantine 302-C voltmeter to the monitor panel. Proceeding to the 1 vrms at 1000 cps portion of the tape, measure the signal level at the output of the reproduce amplifier. Enter this level for each channel on the calibration log sheet.

Having measured the output level from the calibrated tape, it will be necessary to duplicate this result using a new reel of unrecorded tape. Set the signal generator for 1 kc. Set the output level to 1 vrms as measured on the Ballantine voltmeter. Record this signal and simultaneously observe the output level from the playback electronics. Adjust the record "level" control on the front panel of each amplifier until the output levels are the same as those measured with the standard tape. This adjustment assures that the proper full record level of 1 vrms is being recorded even though the playback amplitude is some value other than 1 vrms. After each of the channels being used in the FM mode has been adjusted by this procedure it is necessary only to continue recording enough of the signal to guarantee that IST can determine the exact level of recording. Voice comments on Channel 7 will indicate when the adjustments have been completed. A minimum of 1 minute after adjustment should be sufficient to make such a measurement. Never touch the level control except as a part of this calibration procedure. This tape establishes the actual calibration of the tape system when it is reproduced under laboratory conditions.

4.2.3 Direct Mode Calibration

Before and after all subtests in which the tape system will be used in the Direct Mode, the following procedure is to be followed. This procedure will be applied only to those channels actually used in the Direct Mode. A standard direct record calibration tape has been provided which has 1 vrms at 1000 cps recorded on all channels. This tape is to be reproduced only. Never record on this tape. This signal represents a carefully controlled record amplitude which we wish to approach with our calibration tape. To set the record amplitude, it is necessary to play back the standard tape and measure the amplitude of the reproduced signal at the output of each direct channel with the Ballantine voltmeter. Enter this level on the calibration log sheet. Put a new, unrecorded tape on the machine and, adjusting the signal generator to 1 vrms, (as read on the Ballantine voltmeter), begin recording a 1-kc signal from the signal generator. Again using the Ballantine voltmeter measure the amplitude of this signal at the output of the reproduce amplifier. Using the "level" control on the front of the record-reproduce amplifier, set this amplitude to the same level as was observed with the standard tape.

After the amplitude is set on a channel it is necessary to record a minimum of 1 minute of the 1 vrms signal. It is this section of tape which will establish the calibration for that channel. Duplicate this recording for each channel used in the Direct Mode and return this tape to IST. Never adjust the "level" control except as a part of this calibration procedure.

4.2.4 Seismic Amplifier Calibration

The following procedure will calibrate all of the seismic amplifiers being used to gatner seismic data. Use a new unrecorded reel of tape.

Connect the output of each amplifier to the tape recorder as specified in the particular subtest. Be sure to log each amplifier number and the tape channel to which it is connected. Before recording, check the following steps:

(1) Set the proper tape channels to the FM mode.

(2) Set amplifier gains to 48 db.

(3) Set the PUSH-BUTTON low-level signal generator to -48 db.

Record on each of the seismic channels about 1 minute of the low-level signal generator output. This is done sequentially by connecting the low-level signal generator to each amplifier in turn starting with the lowest numbered channel (1 minute on each channel). Remember that the button on the low-level signal generator must be pushed continuously during recording.

4.2.5 Acoustic Amplifier Calibration

In this portion we establish the calibration of the microphone, and amplifier combination. Connect the acoustic amplifiers to the tape recorder channels as specified for the particular subtest, and set the record amplifiers for FM or Direct Mode as specified. The same microphone-amplifier combinations that are used to gather data are to be used for this calibration. The acoustic amplifiers must be set to the broadband position and returned to the specified bandpass when the calibration is completed.

The calibration source for the acoustic system is a pistonphone (B&K 4220). One minute of this source, applied to each microphone in turn, will be recorded on the tape. For the pistonphone calibration, set all amplifiers at gain. Hold the pistonphone firmly over the face of the microphone and turn the pistonphone on by the slide switch on its side. Record this source on each channel used to gather acoustic data.

Be certain that the log sheet gives a complete description of the equipment connections for the calibration. All amplifier numbers and channels should be carefully checked and logged.

4.2.6 Geophone Polarity Check

To make a polarity check on the geophones it is necessary only to set the amplifier gain at -12 db (2 switch positions below "0" position) and gently shake the geophone in its normal mode. This procedure should be done with the same exact wire and amplifier combinations as were used to gather data. For this reason it should be done immediately after the data gathering is complete and before any of the cabling is changed. This will be after Subtests 1 and 3 and should take only 15 seconds or so per geophone (recorded on tape of course with the channel being used in the FM mode).

4.2.7 Signal-to-Noise Check

This check should be the last procedure at the recording site. If all of the available tapes have been used, it will be permissible to skip this procedure. At least 70 per cent of the sites should be followed by this tape and as the program progresses it becomes more important.

Simply short the input to all of the tape recorder channels and put all of the recorder electronics in the FM mode. Record an entire tape in this manner and label it. This will give IST an indication of the general mechanical and electronic alignment of the tape recorder. It establishes the signal-to-noise ratio for all of the data and will certainly affect the analysis of such data.

Note: In all of the discussions concerning the decibel (db), 1 vrms is considered 0 db. The use of db is confined to a "level" description and is described by

$$20 \log \frac{E1}{E2}$$

4.3 Subtest 1: Acoustic and Seismic Background in Densely Foliated Areas

The purpose of this subtest is to record natural acoustic and seismic background information in a densely foliated area. The sensors are installed 72 hours prior to starting the recordings, which are to be continued for a period of 48 hours.

A three-component seismometer system will be recorded on three FM channels of a seven-channel Ampex SP-300 tape recorder. Channel 1 will be used for the east-west component, Channel 2 will be used for the north-south component and Channel 3 will be used for the vertical component. The acoustic recordings will be made on three additional channels with Channel 4 operated in the FM mode and connected to the acoustic amplifier having a passband of 15-1000 cps. Channel 5 will be operated in the Direct Mode and connected to the acoustic amplifier having a passband of 500-5000 cps, and Channel 6 will be operated in the Direct Mode and connected to the acoustic amplifier having a passband of 4000-40,000 cps. Channel 7 will be operated in the Direct Mode and will be used for voice announcements which will supplement the written field log for the data. The experimental arrangement of the equipment for this subtest is shown in Figure 4.1.

The three-component seismometer package is to be placed 150 to 200 m (492 to 656 feet) from the recording location. The horizontal component seismometers are to be directed north-south and east-west, as determined by magnetic compass bearings. Seismic amplifier gains are to be set by observing on the oscilloscope the maximum gain that can be used during the daytime when no obvious noise

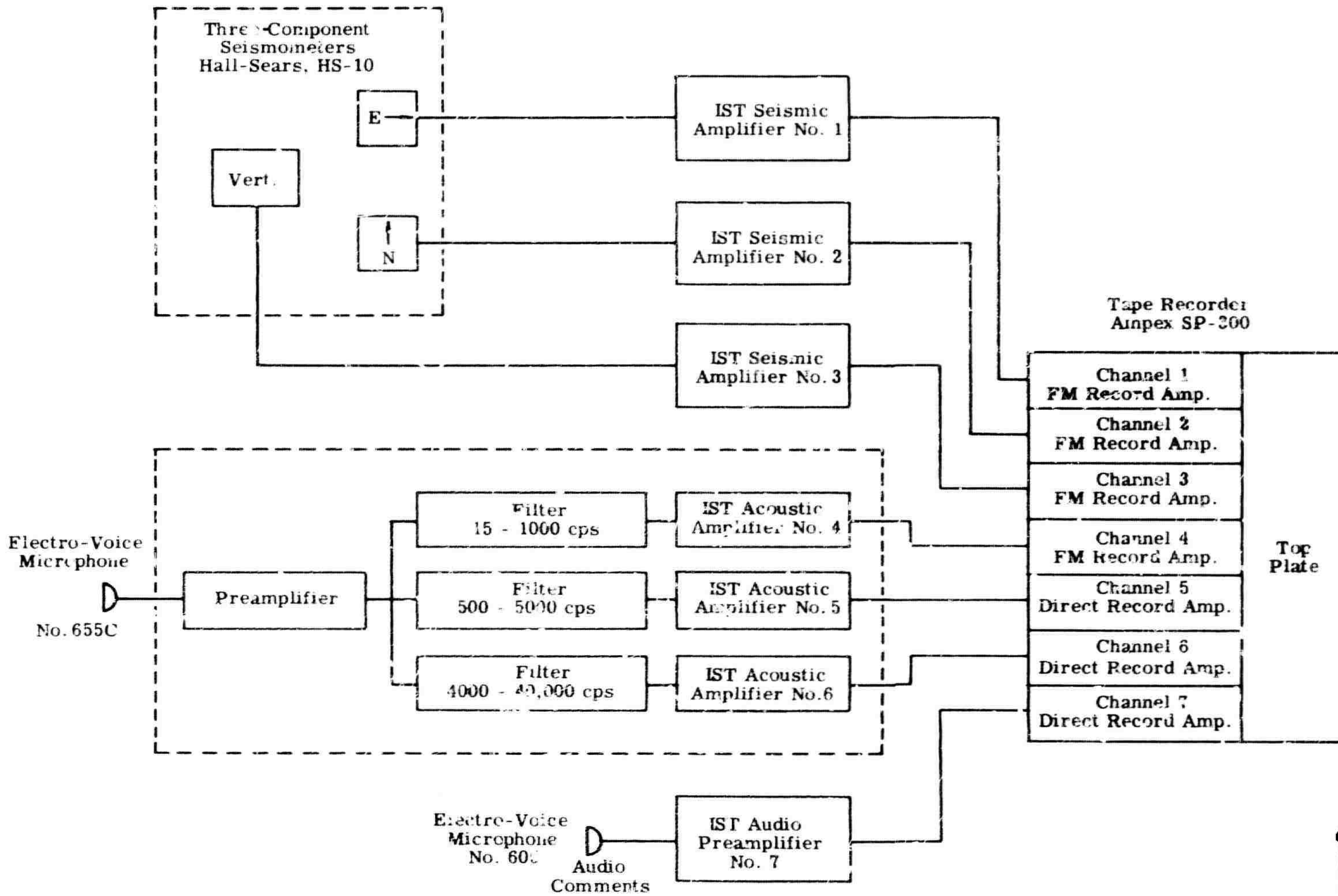

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Figure 4.1 Subtest 1 and 1A Equipment Configuration sources are present and then reducing the amplifier gain by 6 db. Obvious noise sources include people or animals walking within 400 m (1300 feet) of the seismometers, vehicles on roads, aircraft within visual or audible range, and high winds.

One Electro-Voice 655-C microphone without a windscreen is to be used for acoustic background measurements. This microphone is to be mounted pointing downward 3 m (10 feet) above the ground level and 250 to 300 m (800 to 1000 feet) from the recording shelter. The microphone used will provide signals for three separate acoustic amplifiers with passbands of 15-1000 cps, 500-5000 cps, and 4000-40,000 cps. The FM recording mode will be used for the 15-1000 cps acoustic channel and Direct Mode recording will be used for the 500-5000 cps and 4000-40,000 cps channels. Different amplifier gains will be required for each channel. The gains are to be set 6 db below full record level for each channel as observed on the oscilloscope. The microphone will be placed in position at least 72 hours before the start of the background recordings and no intrusion will be made within 150 m (500 feet) of the microphone location except for equipment repairs until the background recordings have been completed.

Immediately before the start of the recording period, the equipment is to be calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures. A substitute microphone and a 1000-foot cable will be used in lieu of placing the pistonphone on the acoustic background microphone since this cannot be done without violating the no intrusion rule stated above. The substitute microphone will be identified by serial number on both the comment channel and the field log. The calibration procedure is to be repeated for any recording channel in which equipment replacement is necessary during the recording period, as soon as such replacement is made. Another complete equipment calibration is to be performed at the end of the recording period. This "end of run" calibration is to be made using the microphone which was gathering acoustic data during the recording period.

Acoustic and seismic background samples are to be recorded at approximately 3-hour intervals for a 48-hour period. Each sample will be 7 minutes long. Three such samples will be recorded on a single reel of tape. The background samples should be collected at times when no obvious man-made acoustic or seismic noise sources are present. The time each noise sample is recorded should be noted in the log and also put on the tape as a voice announcement. Any noise source that is noticed after the recording has started must be identified on the voice channel and in the log. The purpose of the extended background measurement at this site is primarily to obtain acoustic data, so that, although seismic background will be recording during the entire 48-hour period, it is <u>necessary</u> only to obtain seismic data for a 24-hour period. This means that the three-component seismometer system will be used during the entire recording period if it remains functional, but after a 24-hour seismic history has been recorded, the test will not be interrupted for seismic data channel repairs.

The proper gain setting for the acoustic and seismic background recording is to be checked throughout the 24-hour recording period. Adjustments may become necessary for either the acoustic or seismic system. Gain changes should not be made unless there is danger of overrecording or the signal level drops more than 12 db below full record level. When gain changes are necessary, care must be taken to prevent the natural acoustic background from being disturbed. Gain changes on the acoustic and seismic amplifiers should be made right after a recording rather than right before. The trend of signal levels will have to be observed and a prediction of the proper gain setting for the next recording made by the operator at the end of each background sample.

Temperature, relative humidity, and wind velocity at a height of 3 m (10 feet) are to be measured after each background measurement.

4.3.1 Subtest 1A: Acoustic and Seismic Background in Sparsely Foliated Areas

In this subtest recordings are made of the natural acoustic and seismic background in a sparsely foliated area. Recordings are made for 24 hours and with acoustic samples taken only during the period from sunset to sunrise.

A three-component seismometer system will be recorded on three FM channels of a seven-channel Ampex SP-300 tape recorder. Channel 1 will be used for the east-west component, Channel 2 will be used for the north-south component, and Channel 3 will be used for the vertical component. The acoustic recordings will be made on three additional channels, with Channel 4 operated in the FM mode and connected to the acoustic amplifier having a passband of 15-1000 cps. Channel 5 will be operated in the Direct Mode and connected to the acoustic amplifier having a passband of 500-5000 cps, and Channel 6 will be operated in the Direct Mode and connected to the acoustic amplifier having a passband of 4000-40,000 cps. Channel 7 will be operated in the Direct Mode and will be used for voice announcements which will supplement the written field log for the data. The experimental arrangement of the equipment for this sub test is shown in Figure 4.1.

The three-component seismometer package is to be placed 150 to 200 m (492 to 656 feet) from the recording shelter. The horizontal component seismometers are to be directed north-south and east-west, as determined by magnetic compass bearings. Seismic amplifier gains are to be set by observing on the oscilloscope the maximum gain that can be used during the daytime when no obvious noise sources are present, and then reducing the amplifier gain by 6 db. Obvious noise sources include people or animals walking within 400 m (1300 feet) of the seismometers, vehicles on roads, aircraft within visual or audible range, motor-driven boats on canals, and high winds.

One Electro-Voice 655 C microphone equipped with a windscreen is to be used for acoustic background measurements. This microphone is to be mounted pointing downward 3 m (10 feet) above the top of the rice, water, or ground level. In the event of rain during the period of this subtest, the microphone will be covered for the duration of the rainfall with a waterproof plastic bag to prevent the windscreen from being saturated with moisture since a moisture-saturated windscreen will attenuate the high frequencies. Recordings of background will be made only while no rain is falling. Wet windscreens will be replaced and thoroughly dried out before being reused. The microphone location should be 50 m (164 feet) beyond the seismometers. If the area is flooded, the microphone cable must be supported above water level. The microphone used will provide signals for three separate acoustic amplifiers with passbands of 15-1000 cps, 500-5000 cps, and 4000-40,000 cps. The FM recording mode will be used for the 15-1000 cps acoustic channel and direct recording will be used for the 500-5000 cps and 4000-40,000 cps channels. Different amplifier gains will be required for each channel. The gains are to be set 6 db below full record level for each channel, as observed on the oscilloscope.

Immediately before the start of the 24-hour recording period the equipment is to be calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures. The calibration procedure is to be repeated for any recording channel in which equipment replacement is necessary during the 24-hour recording period, as soon as such replacement is made. Another complete equipment calibration is to be performed at the end of the 24-hour recording period.

Seismic background samples are to be recorded at approximately 1-hour intervals for a 24-hour period. Acoustic background samples are to be recorded at approximately 1-hour intervals for the period from sundown to sunrise. The spot on the tape at which acoustic samples begin and end will be noted on both the log and the voice comment channel. Each sample will be 7 minutes long. Three such samples will be recorded on a single reel of tape. The background samples should be collected at times when no obvious man-made acoustic or seismic noise sources are present. The time each noise sample is recorded should be noted in the log and also put on the tape as a voice announcement. Any noise source that is noticed after the recording has started must be identified on the voice channel and in the log.

The proper gain setting for the acoustic and seismic background recording is to be checked throughout the 24-hour recording period. Adjustments may become necessary for either the acoustic or seismic system. Gain changes should not be made unless there is danger of overrecording or the signal level drops more than 12 db below full record level. When gain changes are necessary, care must be taken to prevent the natural acoustic background from being disturbed. Gain changes on the acoustic and seismic amplifiers should be made right after a recording rather than right before. The trend of signal levels will have to be observed and a prediction of the proper gain setting for the next recording made by the operator at the end of each background sample.

Temperature, relative humidity, and wind velocity at the recording shelter at a height of 3 m (10 feet) are to be measured after each background measurement.

4.4 Subtest 2: Variations in Acoustic Background with Elevation and Acoustic Attenuation Along a Horizontal Profile in Densely Foliated Areas

This subtest, which is conducted in a densely foliated area, is designed to measure the variations in natural acoustic background as a function of elevation, the variations in generated acoustic signals as a function of elevation, and acoustic attenuation along a horizontal profile. In these tests the elevation ranges from 30 cm to 20 m above ground level.

The acoustic sound source is to be placed with the speaker pointed in the direction of the tower and is to be mounted so its base is 1 m (3.3 feet) above ground level. A reference microphone is to be placed 5 m (16.4 feet) in front of the speaker at a height of 1 m (3.3 feet). This microphone is to be pointed toward the speaker. The reference microphone should be in thick vegetation.

Five microphones will be placed at 15-m (50-foot) intervals. These microphones are to be at a height of 3 m (10 feet) and are to be placed in dense vegetation. Since the sound sources will not necessarily be off the end of the line of microphones, care must be taken to describe the microphone and sound source positions sufficiently well so that distances can be computed to within 3-m (10-foot) accuracy. All five microphones are to be pointed toward the speaker and used without windscreens.

The tower which is to contain the vertical array of five microphones shall be erected and the microphones placed at heights of 30 cm (1 foot), 5 m (16.4 feet), 10 m (33 feet), 15 m (50 feet), and 20 m (66 feet). If it is impractical to use these heights, the intervals between microphones can be reduced by 30 to 50 cm (1 to 1.6 feet). These microphones are to be mounted on brackets pointing down. Windscreens are not to be used in any part of this subtest.

In the event of rain during any period in this entire subtest, each microphone will be covered for the duration of the rainfall with a waterproof plastic bag to prevent the microphones from becoming saturated with moisture. Recordings will be made only while no rain is falling.

This subtest is divided into five recording periods, 12 hours apart. They are to be carried out near noon and at midnight of each day. Two and one-half days will be required to make the necessary recordings.

Preceding the noon recording of the first day all equipment to be used in this portion of the subtest will be calibration in accordance with the procedures described in Section 4.2, Calibration Procedures. Should any equipment change be necessary during any part of the noon or midnight run of the first day, a recalibration is to be repeated for that recording channel in which equipment replacement is necessary.

The noon run of the first day will be divided into three parts. The first part will record on one full reel of tape natural background noise using equipment arrangement of Figure 4.2. The gains are to be set 6 db below full record level, as noted on the Tektronix Type 321A oscilloscope. Temperature and relative humidity profiles and wind velocity measurements will be made at each microphone position on the tower after the background noise recording.

The second part of the noon run of the first day will record a set of prerecorded frequencies and Thai conversation to measure variations in acoustic background with elevation. Elevations of 30 cm and 5, 10, 15 and 20 m will be used. The microphones and acoustic amplifiers will be connected to the Ampex SP-300 tape recorder according to Figure 4.3. A prerecorded tape will be played back on the Ampex SP-300 through the speaker system and acoustic signals from the six microphones rerecorded on the same prerecorded tape. For the set of prerecorded frequencies gain at each microphone will be adjusted so as to give full record level, as noted on the Tektronix Type 321A oscilloscope, for that frequency that has the greatest output from the speaker. This is to be determined experimentally. For Thai conversation the gain of the playback amplifier will be adjusted to give normal conversation level at the reference microphone (70-db sound pressure level). Immediately following this recording, temperature and relative humidity profiles and wind velocity measurements will be made at each microphone position on the tower.

The third part of the noon run of the first day will record a set of prerecorded frequencies and Thai conversation along a horizontal profile for acoustic attenuation measurements through the dense vegetation. The microphones and acoustic amplifiers will be connected to the Ampex SP-300 tape recorder according to Figure 4.4. A prerecorded tape will be played back on the Ampex SP-300 through the speaker system and the acoustic signals from the six microphones rerecorded on the same prerecorded tape. Gains for the set of prerecorded frequencies and Thai conversation will be set as described in the preceding paragraph. Temperature, relative humidity and wind velocity are to be measured at a height of 3 m (10 feet) after the horizontal profile run. These measurements are to be made at the first microphone position in the dense vegetation.

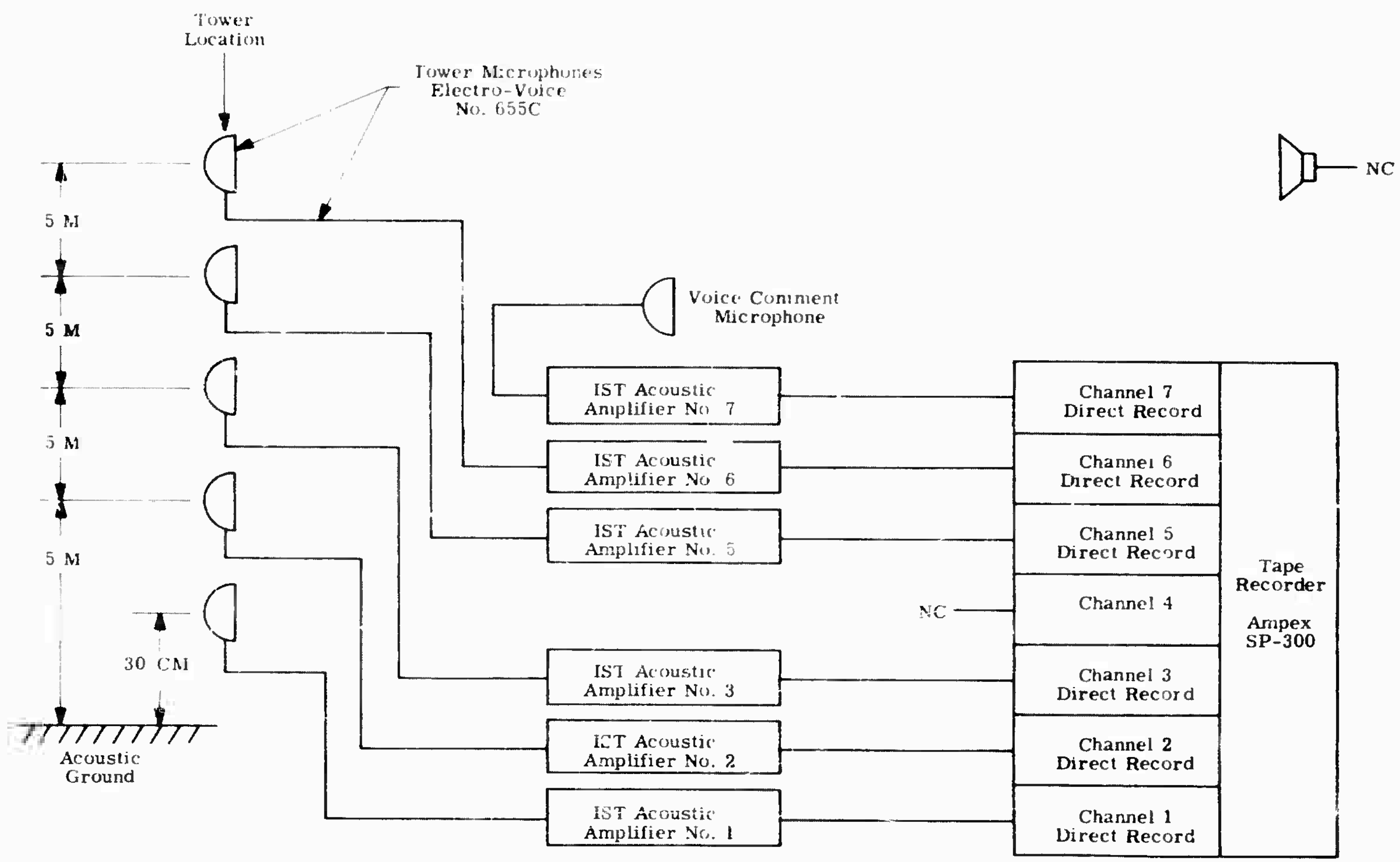

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Figure 4.2 Subtest 2 Equipment Configuration, Natural Background Variations with Elevation

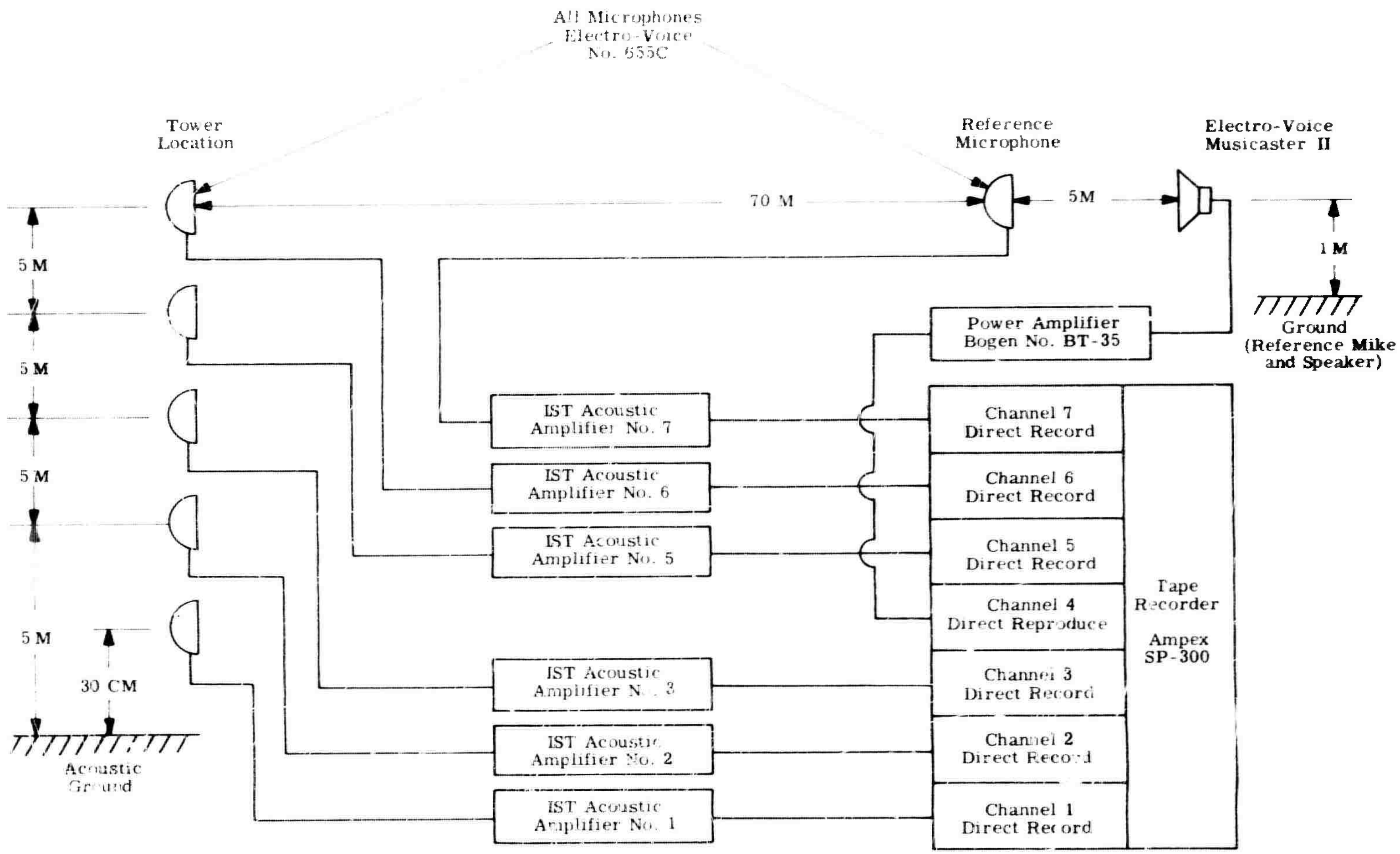

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Figure 4.3 Subtest 2 Equipment Configuration, Acoustic Variations with Elevation

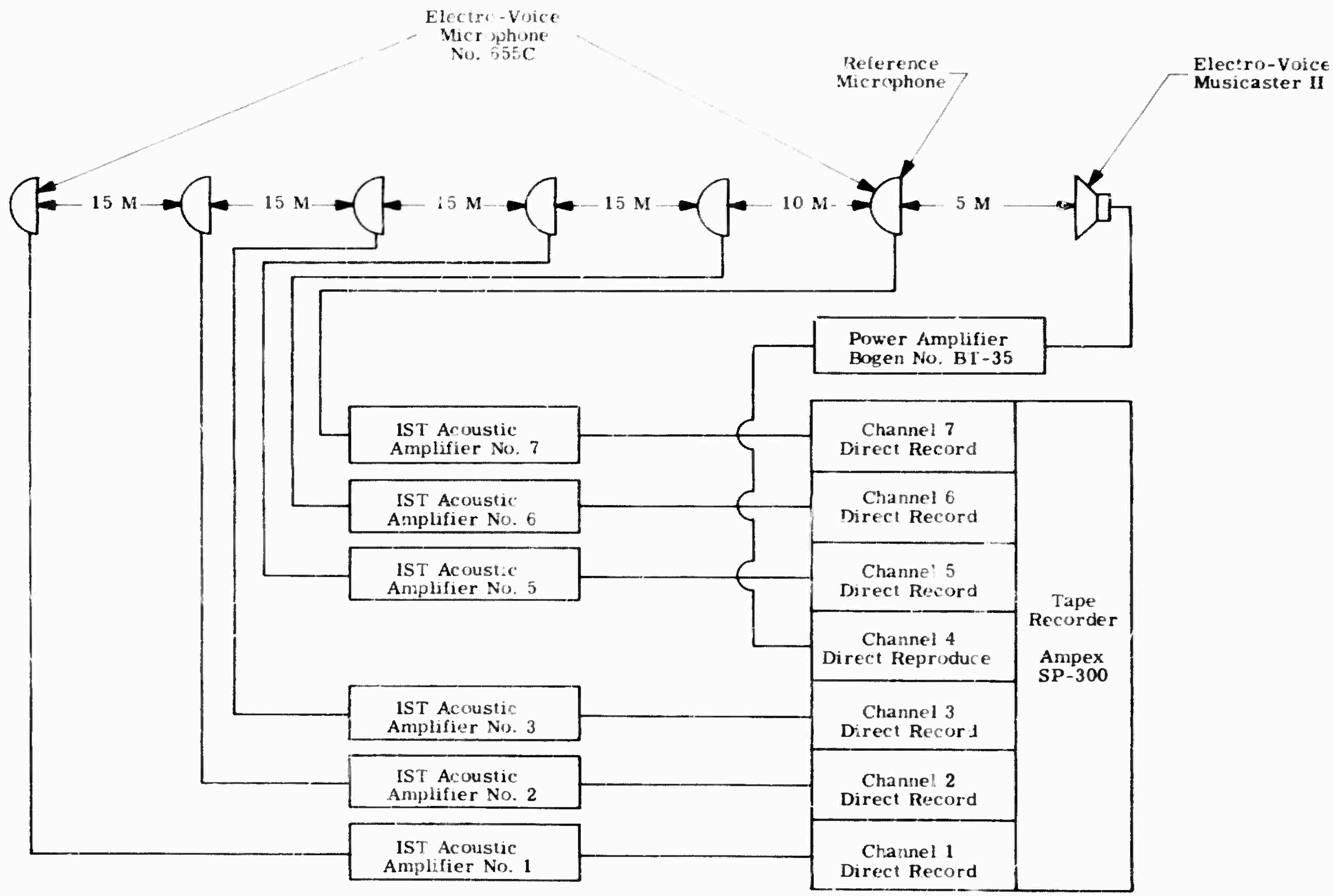

Figure 4.4 Subtest 2 Equipment Configuration, Horizontal Attenuation

Throughout this portion of the subtest the acoustic amplifiers are to be in a broadband mode of operation (15 cps - 40 kc). All SP-300 record amplifiers will be set in Direct Mode. When prerecorded tapes are used the erase current will be turned off and the Channel 4 Meter switch will be set in REC OFF position.

The midnight run of the first day will be a repeat of the noon run in the same order. The exact procedures and equipment arrangement used in the noon run will be followed for the midnight run.

The noon run of the second day will be divided into two parts. The first part will measure acoustic attenuation along a trail. The sound source is to be moved to the trail. The speaker is to be pointed toward the six microphones which are to be placed along the center of the trail. Microphones are to be pointed toward the sound source and mounted at a height of 3 m (10 feet). The reference microphone is to be 5 m (16.4 feet) from the sound source at a height of 1 m (3.3 feet). The other five microphones are to be placed at 15-m (50 foot) intervals from the speaker. Windscreens will not be used on the microphones.

A prerecorded tape will be used for signal source for this measurement. The microphones and acoustic amplifiers will be connected to the Ampex SP-300 tape recorder according to Figure 4.4. Gains will be set in accordance with the procedures outlined in the third part of the noon run of the first day. Temperature, relative humidity, and wind velocity are to be measured immediately before and after this recording. These measurements are to be made at the first microphone placed 15 m (50 feet) from the speaker and at a height of 3 m (10 feet).

After completion of the test for attenuation along a trail, the five microphones that were moved to the center of the trail will be moved back into the dense vegetation to reoccupy their former position.

The second part of the noon run of the second day will measure acoustic ducting along a trail. The speaker will be placed at a height of 1 m (3.3 feet) in the center of the trail pointed toward the tower and 75 m (246 feet) from the tower. The reference microphone is to be 5 m (16.4 feet) from the speaker and at a height of 1 m (3.3 feet). The microphones and acoustic amplifiers are to be connected to the SP-300 tape recorder according to Figure 4.3. A prerecorded tape will be played on the Ampex SP-300 through the speaker system and the acoustic signals from the six microphones rerecorded on the prerecorded tape. Gains will be set according to the procedures outlined in the second part of the noon run of the first day.

The procedure outlined in the above paragraph is to be repeated after the speaker location has been moved to 60 m (200 feet) from the tower. The reference microphone is to remain 5 m (16.4 feet) from the speaker and at a height of 1 m (3.3 feet).

The exact measurements will be repeated a third time after the speaker location has been moved to 45 m (150 feet) from the tower. Again the reference microphone will remain 5 m (16.4 feet) in front of the speaker and at a height of 1 m (3.3 feet).

The temperature, relative humidity and wind velocity are to be measured immediately before and after the recording for all three sets of measurements at the tower location.

Throughout this portion of the subtest the acoustic amplifiers are to be in a broadband mode of operation (15 cps - 40 kc). All SP-300 record amplifiers will be set in Direct Mode. The erase current will be turned off and Channel 4 Meter switch will be set in REC OFF position. Windscreens will not be used on the microphones.

Following the noon run of the second day all equipment used in this portion of the subtest will be recalibrated in accordance with the procedures described in Section 4.2, Calibration Procedures.

The midnight run of the second day and the noon run of the third day are to be divided into two parts. Both parts will record motor generator low-frequency noise, first to measure low-frequency attenuation along the horizontal profile through thick vegetation, and second to measure low-frequency attenuation with elevation. Elevations of 30 cm and 5, 10, 15, and 20 m will be used. The motor generator is to be located in the same position that was occupied by the speaker in the noon run of the first day. All microphones and acoustic amplifiers used in the noon run of the first day are to be used in this subtest and occupy the same positions. All SP-300 record amplifiers will be set in the FM mode with the exception of Channel 7 which will be in the Direct Mode.

Immediately before the start of the midnight run of the second day the equipment to be used in this portion of the subtest will be calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures. Should any equipment change be necessary during any part of the midnight run of the second day or the noon run of the third day a recalibration is to be repeated for that recording channel in which equipment replacement is necessary.

The first part of the midnight run of the second day will measure horizontal acoustic attenuation of low frequencies as generated by a motor generator exhaust. For this recording the equipment arrangement will be set up as indicated in Figure 4-4, except the speaker system is replaced by the motor generator. The gain of each microphone will be set such that the noise bursts from the motor generator exhaust will not exceed full record level. This will be determined by monitoring the output of the acoustic amplifiers with the Tektronix Type 321A oscilloscope. This recording should last one-half a reel of tape. Temperature, relative humidity and wind velocity are to be made at the first microphone.

The second part of the midnight run of the second day will measure acoustic attenuation with elevation of low frequencies generated by a motor generator exhaust. For this recording the equipment arrangement will be set as indicated in Figure 4.3 with the exception the speaker system is replaced by the motor generator. The gain of each microphone will be set such that the noise bursts from the motor generator exhaust will not exceed full record level. This will be determined by monitoring the output of the acoustic amplifiers with the Tektronix Type 321A oscilloscope. This recording should last the remaining half reel of tape. Temperature, relative humidity profiles and wind velocity measurements will be made at each microphone position on the tower after the recording.

The noon run of the third day will be a repeat of the midnight run of the second day in the same order. The exact procedures and equipment arrangement used in the previous midnight run will be followed for the noon run.

Throughout this portion of the subtest the acoustic amplifiers are to be in a broadband mode of operation (15 cps - 40 kc).

Following the noon run of the third day all equipment used for this portion of the subtest will be recalibrated in accordance with the procedures described in Section 4.2, Calibration Procedures.

This completes Subtest 2.

4.4.1 Subtest 2A: Variations in Acoustic Background with Elevation and Acoustic Attenuation Along a Horizontal Profile in a Sparsely Foliated Area

This subtest is to be conducted in sparsely foliated areas and is designed to obtain information similar to that obtained from Subtest 2. The primary difference is the maximum elevation at which measurements are made.

The acoustic sound source is to be placed with its base at a height of 1 m (3.3 feet) above the rice or water or ground level, whichever is higher. The speaker is to be placed at a distance of 10 m (33 feet) from the recording shelter. A reference microphone is to be placed 5 m (16.4 feet) in front of the speaker and at a height of 1 m (3.3 feet) above the rice or water or ground level, whichever is higher. This microphone is to be pointed toward the speaker.

Four more microphones will be placed in line and mounted at a height of 3 m (10 feet) above the rice or water or ground level, whichever is higher, and at 15-m (50-foot) intervals from the speaker. All four microphones will be pointing toward the speaker.

Three more microphones will be placed 75 m (246 feet) in front of the speaker and in line with the above four microphones. These three microphones will be mounted on a single bamboo pole. The first microphone will be placed 3 cm (1 foot) above the height of the rice or water or ground level, whichever is higher. The second microphone will be placed 3 m (10 feet) above the lowest microphone and the third microphone will be placed 5 m (16.4 feet) above the lowest microphone. All three microphones will be pointed toward the speaker.

All eight microphones used in this subtest will be equipped with windscreens. In the event of rain during the period of this subtest, each microphone will be covered for the duration of the rainfall with a waterproof plastic bag to prevent the windscreens from becoming saturated with moisture since a moisture-saturated windscreen will attenuate the high frequencies. Recordings will be made only while no rain is falling. Wet windscreens will be replaced and thoroughly dried out before being reused.

This subtest is divided into four recording periods, 12 hours apart. They are to be carried out near noon and at midnight of each day. Two days will be required to make the necessary recordings.

Preceding the noon recording of the first day all equipment to be used in thir portion of the subtest will be calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures. Should any equipment change be necessary during any part of the noon or midnight run of the first day a recalibration is to be repeated for that recording channel in which equipment replacement is necessary.

The noon run of the first day will be divided into three parts. The first part will record a set of frequencies and Thai conversation along a horizontal profile for acoustic attenuation measurements. The microphones and acoustic amplifiers will be connected to the Ampex SP-300 tape recorder according to Figure 4.5. A prerecorded tape will be played back on the Ampex SP-300 through the speaker system and the acoustic signals from the six microphones rerecorded on the same prerecorded tape. For the set of prerecorded frequencies gains at each microphone will be adjusted so as to give full record level, as noted on the Tektronix Type 321A oscilloscope, for that frequency that has the greatest output from the speaker. This is to be determined experimentally. For Thai conversation the gain of the playback amplifier will be adjusted to give normal conversation level at the reference microphone (70 db sound pressure level).

The second part of the noon run of the first day will record a set of prerecorded frequencies and Thai conversation to measure variations in acoustic background with elevation. The microphones and acoustic amplifiers will be connected to the Ampex SP-300 tape recorder according to Figure 4.6. A prerecorded tape will be played back on the Ampex SP-300 through the speaker system and the acoustic signals from the four microphones rerecorded on the same prerecorded tape. Gains for the set of prerecorded frequencies and Thai conversation will be set as described in the preceding paragraph.

The third part of the noon run of the first day will be to record on one-half a reel of tape natural background noise using equipment arrangement of Figure 4.7. The gains are to be set 6 db below full record level as noted on the Tektronix Type 321A oscilloscope.

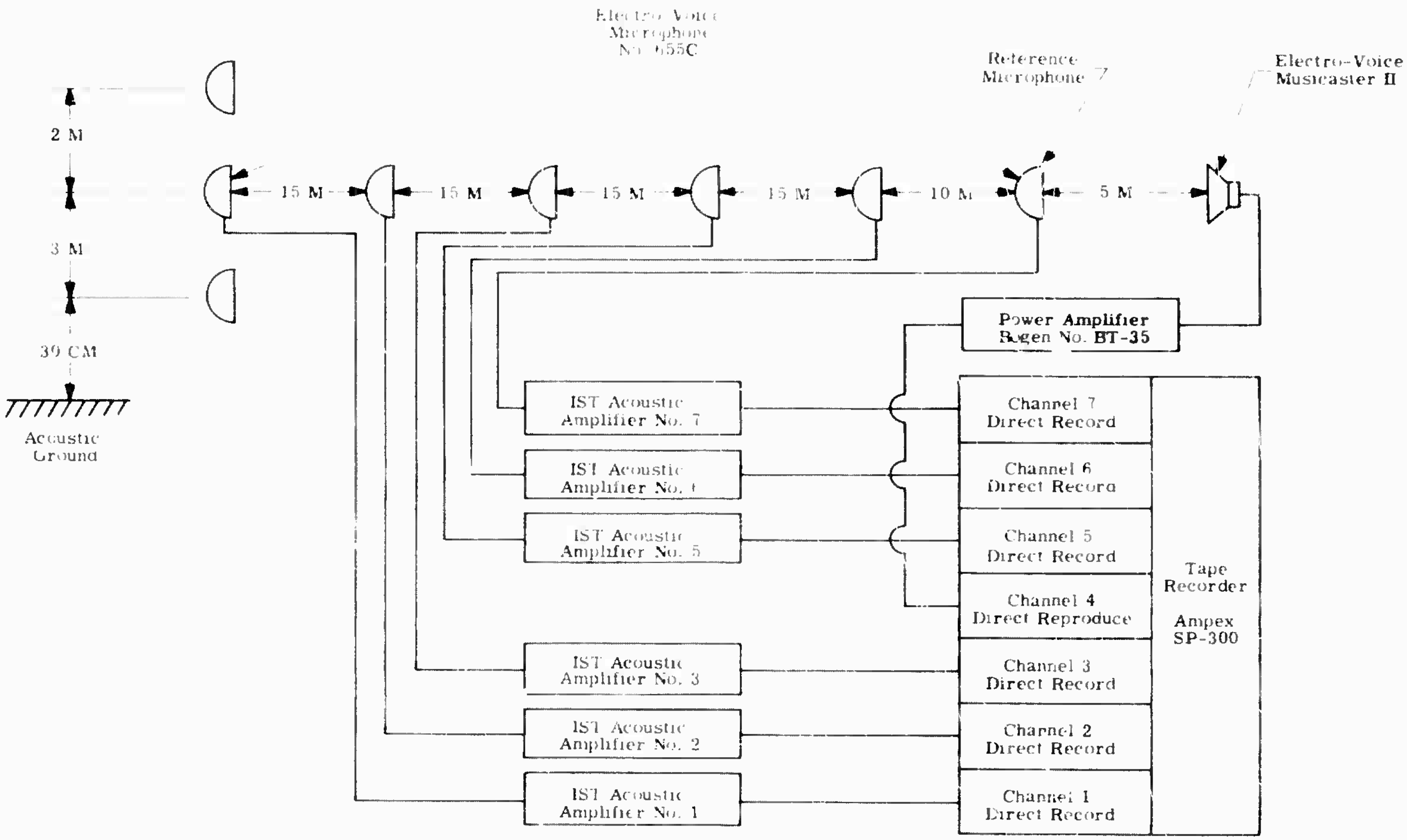

Figure 4.5 Subtest 2A Equipment Configuration, Horizontal Attenuation

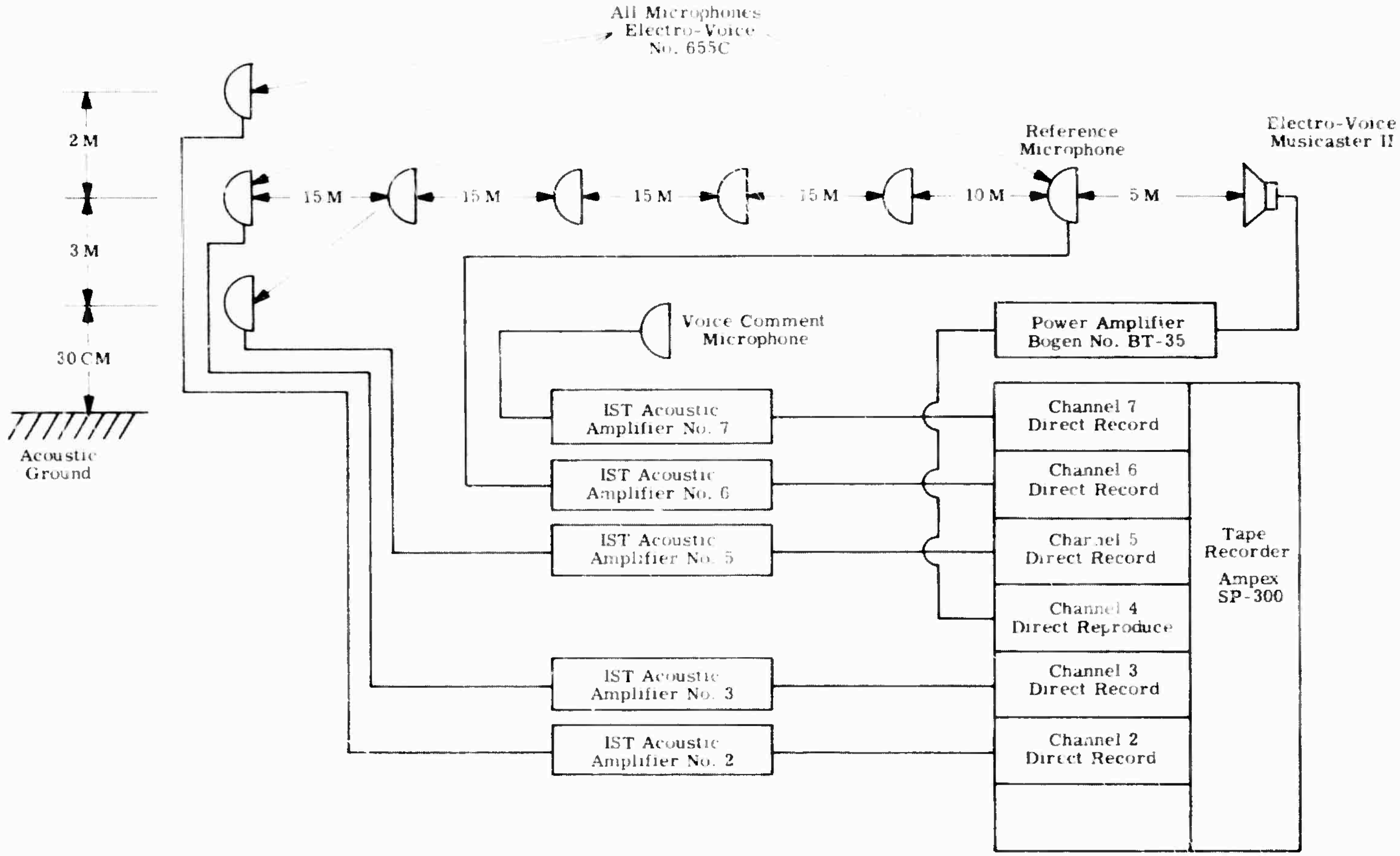

Figure 4.6 Subtest 2A Equipment Configuration, Acoustic Variations with Elevation

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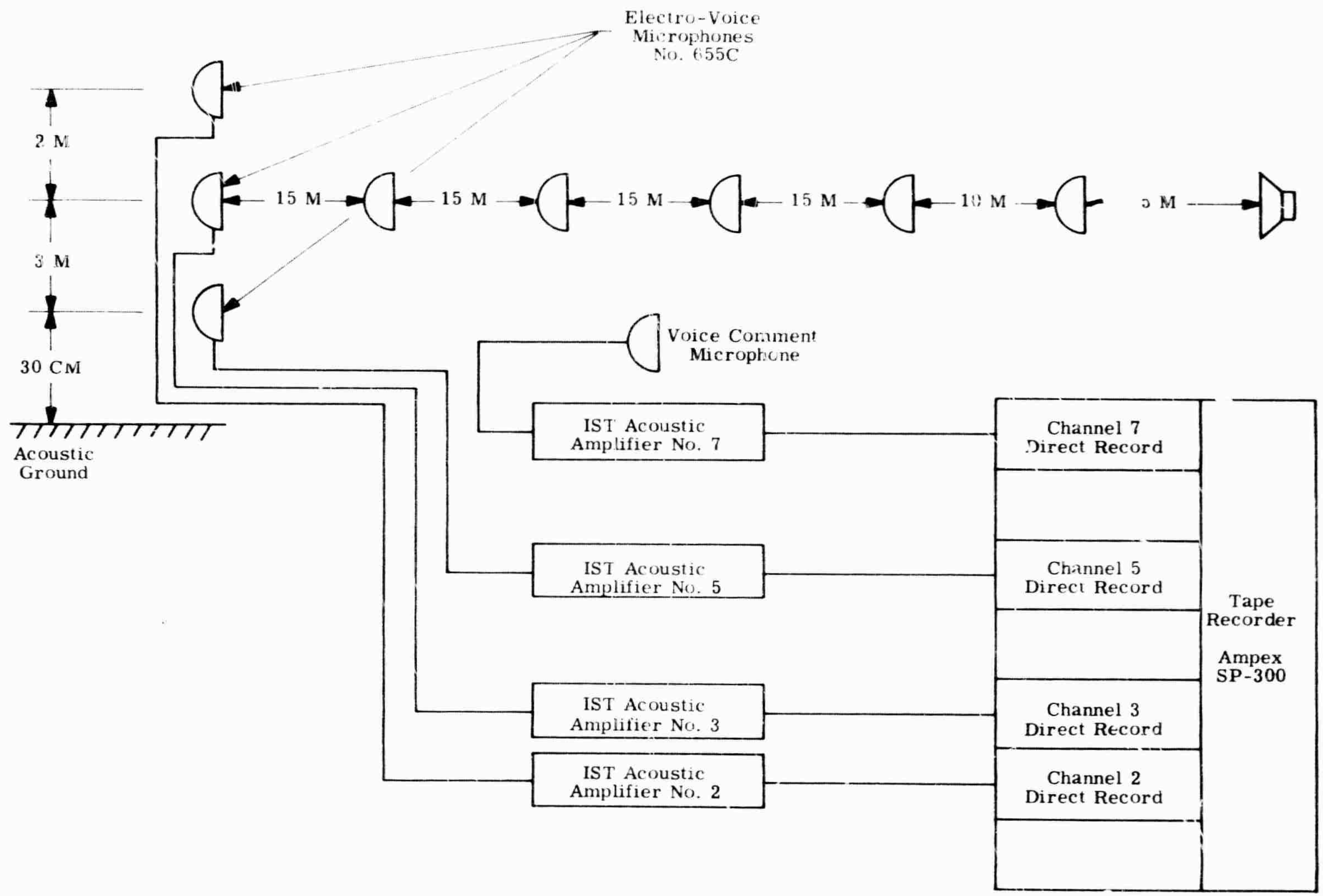

Figure 4.7 Subtest 2A Equipment Configuration, Natural Background Variations with Elevation

Throughout this portion of the subtest the acoustic amplifiers are to be in a broadband mode of operation (15 cps to 40 kc). All SP-300 record amplifiers will be set in Direct de. When prerecorded tapes are used, the erase current will be turned off and Channel 4 Meter switch will be set in REC OFF position.

The temperature, relative humidity and wind velocity are to be measured at a height of 3 m (10 feet) after each portion of these measurements. These measurements will be made at the recording shelter.

The midnight run of the first day will be a repeat of the noon run in reverse order. The exact procedures and equipment arrangement used in the noon run will be followed for the midnight run, first completing the remaining half reel of tape recording natural background noise on the vertical profile, followed by the rerecording of the prerecorded set of frequencies and Thai conversation tape on the vertical profile and last by the rerecording of the prerecorded set of frequencies and Thai conversation tape on the horizontal profile.

Temperature, relative humidity and wind velocity are to be measured at a height of 3 m (10 feet) after each portion of these measurements. These measurements will be made at the recording shelter.

Following the midnight run of the first day all equipment used for this portion of the subtest will be recalibrated in accordance with the procedures described in Section 4.2, Calibration Procedures.

The noon and midnight runs of the second day are to be divided into two parts. Both parts will record motor generator low-frequency noise. The motor generator is to be run at the speaker position. All SP-300 record amplifiers will be set in the FM mode with the exception of Channel 7 which will be in the Direct Mode.

Immediately before the start of the noon run of the second day the equipment to be used in this portion at the subtest will be calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures. Should any equipment change be necessary during any part of the noon or midnight run of the second day a recalibration is to be repeated for that recording channel in which equipment replacement is necessary.

Part 1 of the noon run of the second day will measure acoustic attenuation with elevation of low frequencies generated by a motor generator exhaust. For this recording the equipment arrangement will be set up as indicated in Figure 4.6, with the exception that the speaker system is replaced by the motor generator. The gain of each microphone will be set such that the noise bursts from the motor generator exhaust will not exceed full record level. This will be determined by monitoring the output of the acoustic amplifiers with the Tektronix Type 321A oscilloscope. This recording should last one-half a reel of tape.

The second part of the noon run of the second day will measure horizontal acoustic attenuation of low frequencies as generated by a motor generator exhaust. For this recording the equipment arrangement will be set up as indicated in Figure 4.5, with the exception the speaker system is replaced by the motor generator. The gain of each microphone will be set such that the noise bursts from the motor generator exhaust will not exceed full record level. This will be determined by monitoring the output of the acoustic amplifiers with the Tektronix Type 321A oscilloscope. This recording should last the remaining half reel of tape.

Temperature, relative humidity and wind velocity are to be measured at a height of 3 m (10 feet) after each portion of these measurements. These measurements will be made at the recording shelter. The midnight run of the second day will be a repeat of the noon run in reverse order. The exact procedures and equipment arrangement used in the noon run will be followed for the midnight run, first recording one-half a reel of tape to measure horizontal acoustic attenuation and then recording the remaining half reel of tape to measure acoustic attenuation with elevation.

Temperature, relative humidity and wind velocity are to be measured at a height of 3 m (10 feet) after this portion of these measurements. These measurements will be made at the recording shelter.

Throughout this portion of the subtest the acoustic amplifiers are to be in a broadband mode of operation (15 cps - 40 kc).

Following the midnight run of the second day all equipment used for this portion of the subtest will be re-calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures.

This completes Subtest 2A.

4.5 Subtest 3: Attenuation of Seismic Waves and Limit of Detectability

This subtest consists of four parts:

Part 1 - Attenuation measurements for both forward and reverse profiles using a line of six vertical seismometers and weight drops.

Part 2 - Limit of detectability of people walking using a line of six vertical seismometers with one man walking normally, one man walking quietly, and four men walking normally.

Part 3 - Attenuation measurements using a three-component seismometer system, a line of three vertical seismometers, and weight drops for the forward profile only.

Part 4 - Limit of detectability of people walking using a three-component seismometer system and three microphones with one man walking normally, one man walking quietly, and four men conversing while walking normally.

4.5.1 Part 1: Attenuation Measurements Using Six Vertical Seismometers

A line of six vertical component seismometers is to be used to measure the attenuation characteristics of the soil and to provide data on the near-surface geologic conditions at the recording site. Five vertical Hall-Sears HS-10 seismometers and a three-component seismometer system will be used for this test. The seismometers will be arranged in a line according to the following table:

Seismometer	Number	Distance	SP-300 Tape Recorder Channel
HS-10 Vertical	1	25 m (82 ft) from recording shelter	1
HS-10 Vertical	2	15 m (49 ft) from Seismometer 1	2
HS-10 Vertical	3	45 m (148 ft) from Seismometer 2	3
HS-10 Vertical	4	45 m (148 ft) from Seismometer 3	4
HS-10 Vertical	5	45 m (148 ft) from Seismometer 4	5
Three-component* Seismometer System (Vertical Component)	6	15 m (49 ft) from Seismometer 5	6

*Note: To avoid the necessity of repositioning this three-component seismometer system for later tests, see Section 4.5.3 for proper orientation.

These seismometers are to be placed in line and the instruments are to be buried in undisturbed soil. The line of seismometers should start 25 m (82 feet) from the recording shelter and extend in a line away from this point.

The equipment configuration is shown in Figure 4.8. The signals developed by the vertical seismometers will be recorded on six FM channels of an Ampex SP-300 tape recorder. Each seismometer will be connected to a separate seismic amplifier, and the seismic amplifiers will be connected to FM tape recorder channels in the order shown in the preceding table and in Figure 4.8. Channel 7 will be operated in the Direct Mode and will be used for voice announcements which will supplement the written field log for the data.

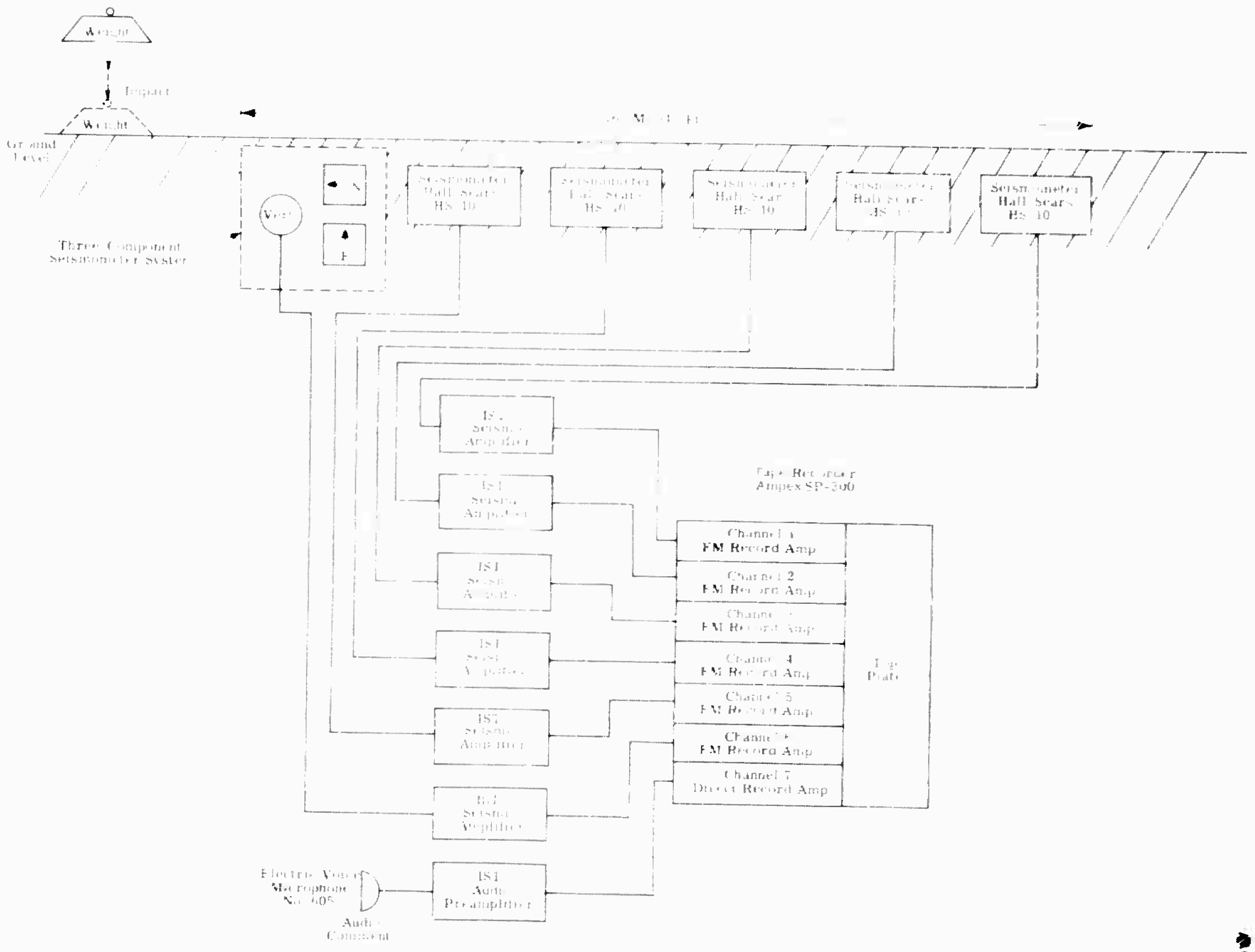

Figure 4.8 Subtest 3 Natural Background Variations wi'h Elevation for Parts 1 and 2

A weight drop will be used as a seismic source. This weight should be made of concrete or similar material and shaped roughly as a sphere. It should weigh 20 to 25 kg. The weight should be dropped from a height of 1 to 1.5 m (3 to 5 feet). The weight should be dropped 15 m (49 feet) from the nearest seismometer. The point of impact should be in line with the seismometers.

Immediately before starting to record the seismic attenuation data, the equipment is to be calibrated in accordance with the procedures described in Section 4.2, Calibration Procedures. The calibration procedure is to be repeated for any channel in which equipment replacement is necessary during the performance of this subtest.

Seismic amplifier gains will have to be set by observing the signal level on the oscilloscope from practice weight drops. Care should be taken to prevent overrecording, particularly at the near seismometers, with the signal from the weight drop. Amplifier gains used for the farthest seismometers should not be set higher than within 6 db of full record level for background noise. The weight should be dropped four or five times at the same spot before gain settings are attempted. When gain settings are satisfactory, three weight drops should be recorded. This experiment is to be repeated with a weight drop at the other end of the seismometer line. The point of impact of the weight should be 15 m (49 feet) from the end of the line.

Soil samples are to be taken from points near each end of the seismometer line.

4.5.2 Part 2: Limit of Detectability Using Six Vertical Seismometers

The second part of this subtest will use the same line of vertical seismometers that was used in Part 1 to measure attenuation of seismic waves in the soil, to measure the limit of detectability for people walking. For this test, recordings will be made of people walking toward and in line with the seismometer array. Amplifier gain settings are to be adjusted so the signal level as observed on the oscilloscope will be 12 db below full record level for background noise. The gain of Channel 1 (Seismometer 1) is then to be reduced an additional 18 db.

Markers at 15-m (49-foot) intervals are to be placed along the approach path of the people who will be walking for the detection test. These markers will extend from a point 300 m (984 feet) in front of Seismometer 6, through the area where the seismometers are buried, to a point 60 m (198 feet) beyond Seismometer 1. (See Figure 4.9.) Local conditions may require modification of this arrangement, but this configuration should be followed as closely as possible. A sketch similar to Figure 4.9 will be made for the configuration actually used. Each marker is to be equipped with a push button so located that the walker can depress the push button without breaking stride. The push buttons will operate a signaling device in the recording shelter to indicate to the tape recorder operator that the walker has reached a particular station along the approach route. An announcement will be made on the voice comment channel to identify the stations as the signaling device indicates they have been reached.

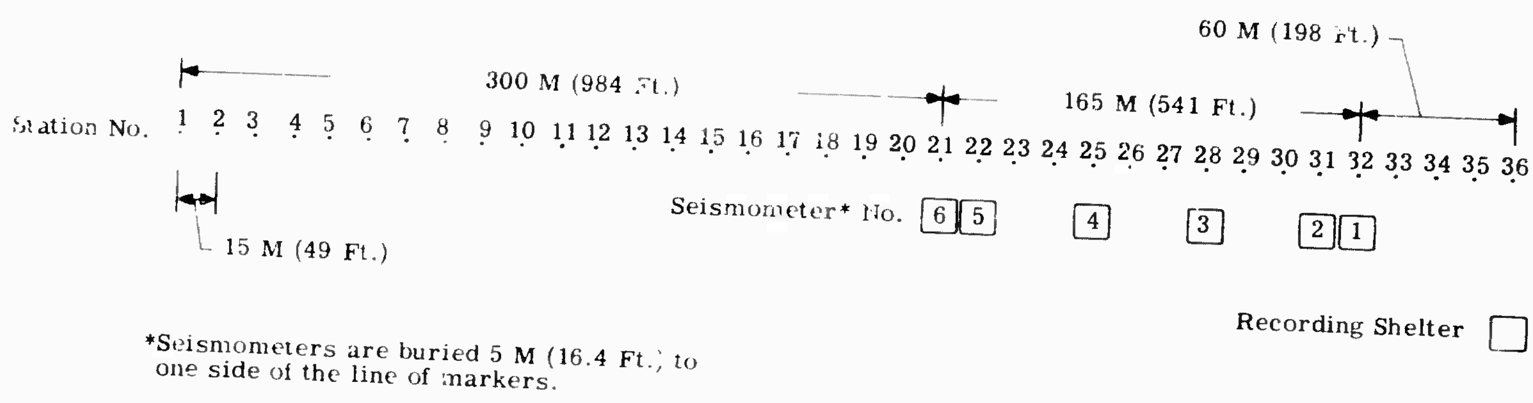

Figure 4.9 Subtest 3 Layout of Markers and Seismometers for Part 2

Three recordings are required for this test. Recordings are to be made of one person walking at a normal pace, and one person walking quietly over the full distance from the starting point at Station 1 through the line of seismometers to Station 36, 60 m (198 feet) beyond Seismometer 1. These recordings are to be repeated for a group of four men walking at a normal pace out of step. Care should be taken to ensure that the four walkers remain out of step as much as possible. As the walkers reach the markers along the approach route, the signaling push buttons mounted on each marker will be depressed. The people used for the walking test shall be Thai and not American and the same individuals wearing the same footwear shall perform this test at each site to assure the uniformity of the test signal generated by the walking. A picture and a physical description of the test subjects, including height, weight, and footwear, shall accompany the data sent to IST for analysis.

Before and after the walking people travel the approach route, background recordings of at least 2 minutes' duration will be made. The coordination between walkers and the tape recorder operator will be obtained by means of the push-button-operated signaling device previously referred to. When the equipment is ready for the test to begin, the people who will do the walking will proceed to the starting point at Station 1. When the walker is in position he will signal the tape recorder operator with the push button at Station 1. The tape recorder operator will begin recording the 2-minute background run. At the end of the 2-minute period the walker will signal again and begin his approach along the marked route signaling as he passes each station. When the walker has reached Station 36 he will stop and remain quiet for 2 minutes while the final 2 minutes of background is recorded.

The recorder will then be stopped, completing the run. It is to be emphasized that all personnel on the crew should remain as quiet as possible during the runs. This caution applies to the crew members in the recording shelter in particular, who must not move around at all during the entire run. In addition, the walkers must not move around during the background runs. The start and end of these background runs will be identified by voice announcement on the comment channel.

4.5.3 Part 3: Attenuation Measurements Using a Three-Component Seismometer System and Three Vertical Seismometers

The third part of Subtest 3 is a repeat of the first part of this subtest with vertical Seismometers 4 and 5 replaced with the horizontal components of the three-component seismometer system. The new arrangement is shown below and in Figure 4.10.

Seismometer	Number	Distance	SP-300 Tape Recorder Channel
HS-10 Vertical	1	25 m (82 ft) from recording shelter	1
HS-10 Vertical	2	15 m (49 ft) from Seismometer 1	2
HS-10 Vertical	3	45 m (148 ft) from Seismometer 2	3
Three-Component Seismometer System (North-South Component)	4	105 m (344 ft) from Seismometer 3	4
Three-Component Seismometer System (East-West Component)	5	105 m (344 ft) from Seismometer 3	5
Three-Component Seismometer System (Vertical Component)	6	105 m (344 ft) from Seismometer 3	6

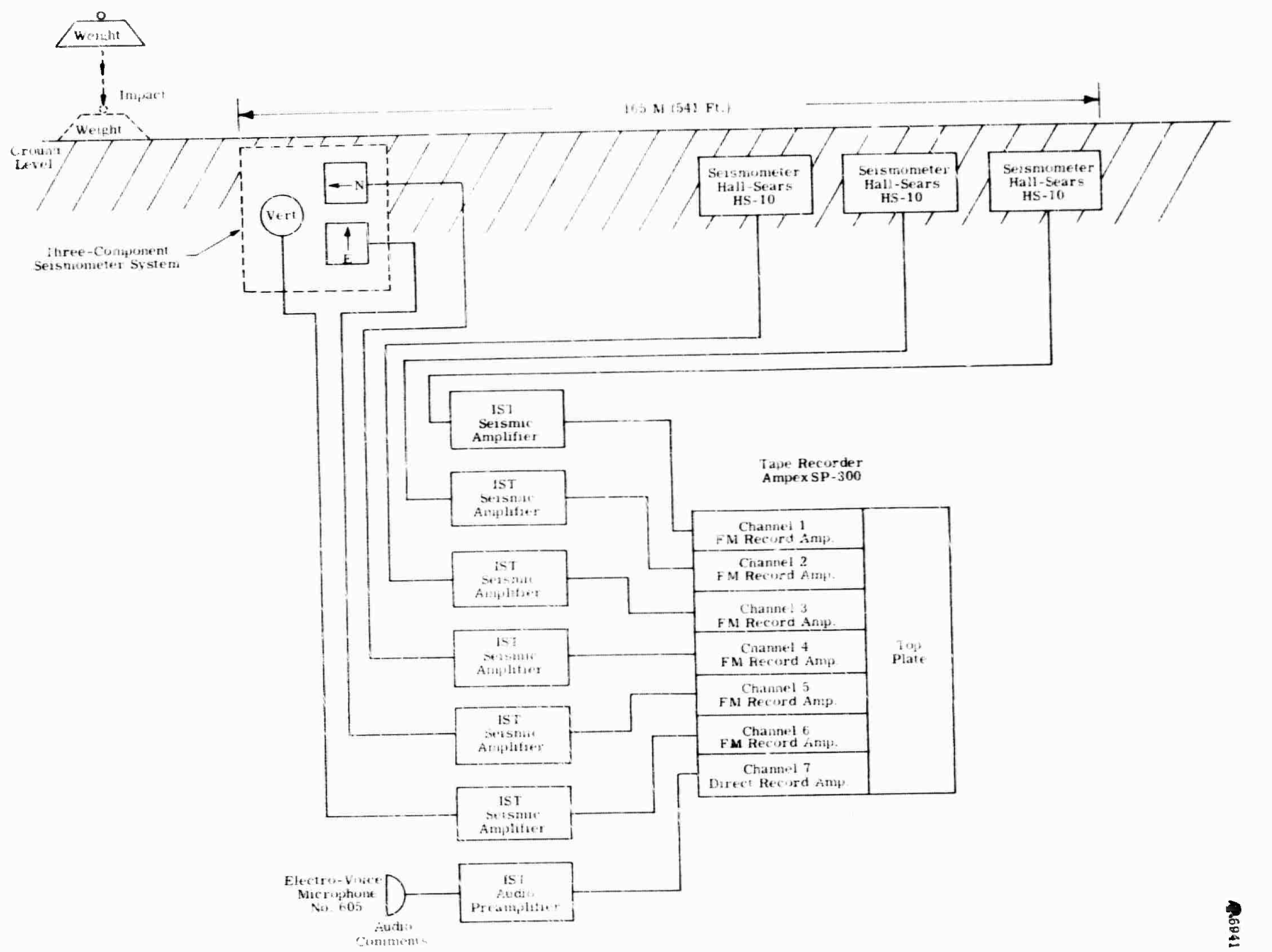

Figure 4.10 Subtest 3 Equipment Configuration for Part 3

The three-component seismometer system is to be oriented so as to direct the north arrow away from Seismometer 1 and toward the seismic source.

This arrangement makes the north-south horizontal component measure the longitudinal propagation and the east-west horizontal component measure the transverse propagation.

The weight drop will again be used as a seismic source The point of impact should be in line with the seismometers and 15 m (49 feet) from Seismometer 1.

Seismic amplifier gains will have to be set by observing the signal level on the oscilloscope from practice weight drops. Care should be taken to prevent overrecording at the near seismometers with the signal from the weight drop. Amplifier gains used for the farthest seismometers should not be set higher than within 6 db of full record level for background noise. The weight should be dropped four or five times at the same spot before gain settings are attempted. When gain settings are satisfactory, three weight drops should be recorded. The weight drop series will not be repeated at the other end of the line of seismometers.

4.5.4 Part 4: Limit of Detectability Using a Three-Component Seismometer System and Three Microphones

The fourth part of Subtest 3 is a repeat of the limit-of-detectability test, using the equipment configuration shown in Figure 4.11. The three-component seismometer system remains emplaced and connected as it was in Part 3. Vertical Seismometers 1, 2, and 3 are replaced by Electro-Voice 655-C microphones equipped with windscreens, and connected to IST acoustic amplifiers. The three

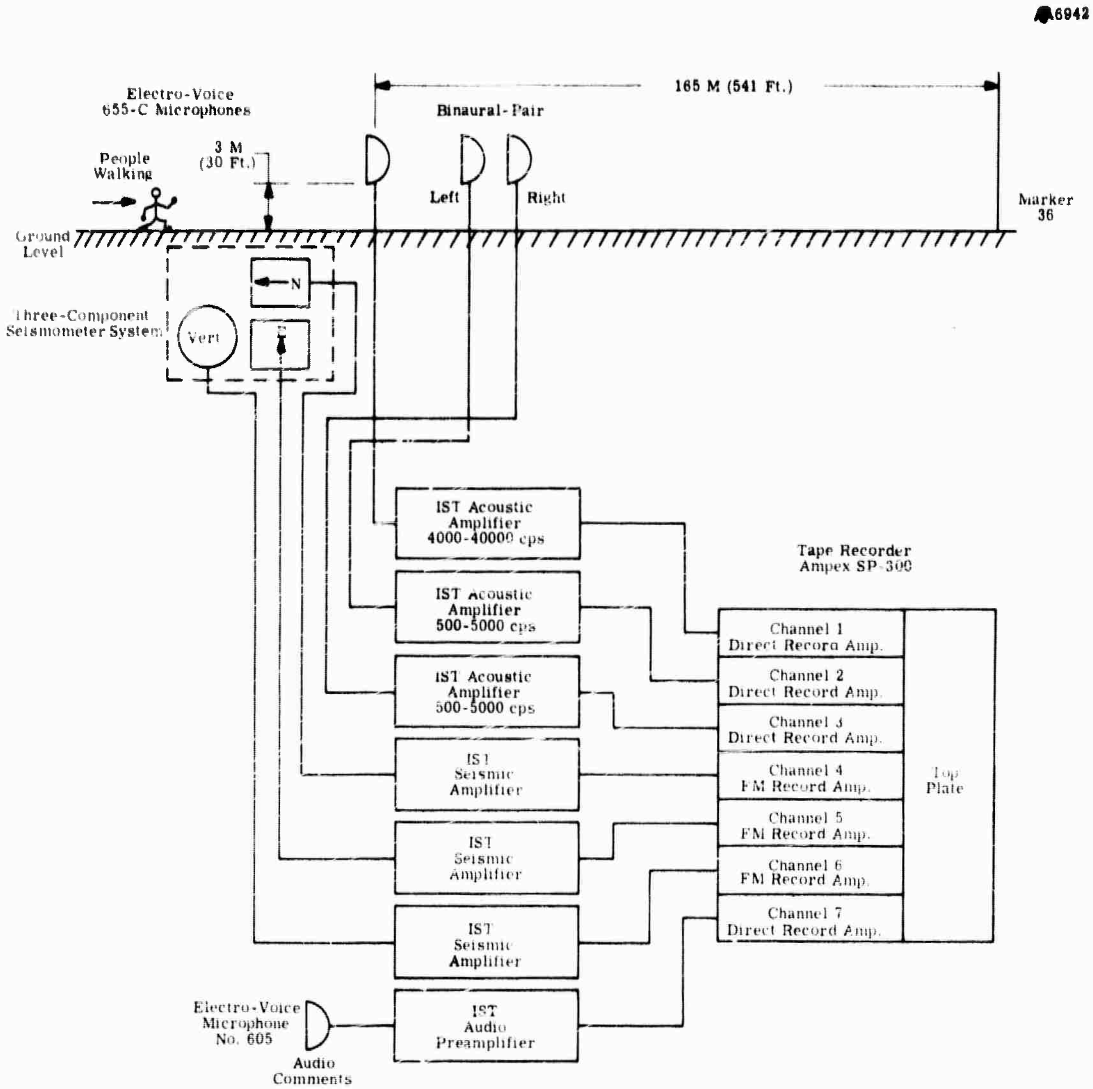

Figure 4.11 Subtest 3 Equipment Configuration for Part 4

microphones are to be placed in a group at the location of the three-component seismometer system (Location 6) and are to be pointing toward the poeple who will be walking. In the event of rain during the period of this subtest, the microphones will be covered for the duration of the rainfall with a waterproof plastic bag to prevent the windscreen from being saturated with moisture since a moisture-saturated windscreen will attenuate the high frequencies. Recordings of walking will be made only when no rain is falling. Wet windscreens will be replaced and thoroughly dried before being reused.

The three microphones are to be mounted on a single bamboo pole, one microphone at a height of 3 m (10 feet) above the ground level, and two microphones mounted on a binaural-pair bracket as close as possible to the height of the first microphone. The first microphone at the top of the pole is to be connected to Channel 1 of the Ampex SP-300 tape recorder through an IST acoustic amplifier with a bandpass of 4000-40,000 cps. The binaural-pair microphones are designated left and right as determined by standing at the pole and facing the direction of approach of the people who will be walking. The left microphone is to be connected to Channel 2 of the tape recorder through an IST acoustic amplifier with a passband of 500-5000 cps. The right microphone is to be connected to Channel 3 of the tape recorder through an IST acoustic amplifier with a passband of 500-5000 cps.

Immediately before starting this portion of the subtest the equipment will be recalibrated. If this portion of Subtest 3 follows Part 3 of Subtest 3 by 2 hours or less, only Channels 1, 2, and 3 need to be calibrated as long as the remaining equipment performance remains normal. If other equipment replacements are made or the interval between Part 3 and Part 4 of Subtest 3 is more than 2 hours, a complete recalibration will be performed. Follow the procedures of Section 4.2, Calibration Procedures, in either case.

Amplifier gain settings for the acoustic and seismic channels are to be set so the signal level as observed on the oscilloscope will be 12 db below full record level of the background noise.

The limit of detectability test will be conducted as a repeat of the procedures of Subtest 3, Part 2.

Three recordings are required for this test. Recordings are to be made of one person walking at a normal pace, and one person walking quietly over the full distance from the starting point at Station 1 through the entire route to Station 36. These recordings are to be repeated for a group of four men walking at a normal pace out of step. Care should be taken to ensure that the four walkers remain out of step as much as possible. As the walkers reach the markers along the approach route, the signaling push buttons mounted on each marker will be depressed. When the four people are walking together they will talk in a normal tone of voice. The people used for the walking test shall be Thai and not American and the same individuals wearing the same type footwear shall perform this test at each site to assure the uniformity of the test signal generated by the walking. A picture and a physical description of the test subjects, including height, weight, and footwear, shall accompany the data sent to IST for analysis.

Before and after the walking people travel the approach route, background recordings of at least 2 minutes' duration will be made. The coordination between walkers and the tape recorder operator will be obtained by means of the push-button-operated signaling device previously referred to. When the equipment is ready for the test to begin, the people who will do the walking will proceed to the starting point at Station 1. When the walker is in position he will signal the tape recorder operator with the push button at Station 1. The tape recorder operator will begin recording the 2-minute background run. At the end of the 2-minute period the walker will signal again and begin his approach along the marked route, signaling as he passes each station. When the walker has reached Station 36 he will stop and remain quiet for 2 minutes while the final 2 minutes of background is recorded. The recorder will then be stopped, completing the run. It is to be emphasized that all personnel on the crew should remain as quiet as possible during the runs. This caution applies to the crew members in the recording shelter in particular who must not move around at all during the entire run. In addition, the walkers must not move around during the background runs. Since this part of the subtest involves acoustic recording which will be evaluated to determine the maximum detection range of intruders, all unnecessary talking will be eliminated, also. The voice comments on the tape should be adequate but not loud or verbose. No other talking or moving around will be permitted during the recording. The start and end of the background runs will be identified by voice announcements on the comment channel.

Temperature, relative humidity, and wind velocity measurements are to be made at the recording shelter at a height of 3 m (10 feet) at the beginning and end of the recording period for this part of this subtest.

4.5.5 Special Walking Tests

Several additional walking tests are required to be performed at one site. Every available Thai on the field crew will take his turn walking individually at a normal pace from Station 15 as a starting point, through the line of seismometers to Station 36. These tests will be run at a different seismic amplifier gain setting, also. The seismic gain setting is to be adjusted so the signal level as observed on the oscilloscope will be 30 db below full record level of the background noise. The acoustic amplifier gain settings are to be set, as before, so the signal level as observed on the oscilloscope will be 12 db below full record level of the background noise.

The walking tests are to be conducted in the same manner as the standard tests with a 2-minute background sample preceding and following each walking test, and the walkers' position during the test indicated by the push-button-equipped markers. The cautions previously stated with regard to the necessity of refraining from extraneous moving and talking during the recordings, obviously still must be observed.

The final group of tests at one site involves using the Thai crew member who has been selected to do the walking at all the other sites (the standard signal source walker) to test the influence of various types of footwear. This standard Thai will walk at a normal pace from Station 15 to Station 36 wearing on successive trials as many types of footwear as may be possible to provide, consistent with the local conditions prevailing at the time. This group of footwear will include that worn normally at the other sites.

The Thai should also walk in his bare feet if it is possible to walk on the terrain without footwear.

A picture and a physical description of the test subjects including height, weight, and footwear, shall accompany the data sent to IST for analysis. A close-up picture of each type of footwear tested will also be included.

Temperature, relative humidity, and wind velocity measurements are to be made at the recording shelter at a height of 3 m (10 feet) at the beginning and end of the recording period for this part of this subtest.

5. FIELD INSTRUMENTATION

The test objectives of this program are the propagation characteristics, discrete signal sources, and background noise characteristics for acoustic and seismic waves in several Southeast Asian regions. Equipment to make measurements for these tests will, in general, be standard acoustic and seismic detectors, standard and special-purpose amplifiers, and recording equipment. The basic types of equipment have been in use by the Geophysics Laboratory for several years. Field-tested equipment components will be used. In some cases, experience has indicated that specific modifications are necessary for operation under difficult field conditions.

The particular equipment concept is based on a detector microphone(s) or seismometer(s) to provide the input data signal to an amplifier. This signal, in turn, is transmitted over a cable to the recorder which records the data on a seven-channel magnetic tape. Power to supply the tape recorder and amplifiers must, in general, be obtained from battery sources. Generators operating in the vicinity of the recording site produce too much noise to make either acoustic or seismic measurements. Generators will be used for charging batteries when recordings are not being made. Batteries will be charged during recording if the distance from the recording points is sufficiently great that the background noise is not increased by the generator. This distance varies with the type of generator used and propagation characteristics of the region. In general, a minimum of 1000 feet is necessary for very quiet specially selected generators. Many generators require separations from recording points of a mile or more.

The primary modification that is anticipated is in the tape recorder. The recorder to be used is an Ampex SP-300. Extra precautions will be required to prevent this instrument from being damaged under the environmental conditions in Southeast Asia. Shock mounting of the top plate, construction of a stronger case, and changing of some cable connectors should make this recorder satisfactory for all portions of the recording program.

Previous field experience has revealed that the condenser-type microphone is very susceptible to damage under the severe environmental conditions existing in Thailand. In addition, this type of microphone requires operator attention, making it incompatible with the no-intrusion principle of obtaining undisturbed background measurements. This reasoning has led to the addition of 12 Electro-Voice Model 655-C dynamic microphones and 24 Electro-Voice Model 355 windscreens to the original complement of equipment.

Major equipment items used to conduct the field measurements are listed below.

Quantity	Item
1	Tape recorder, 7-channel, Ampex type SP-300
12	Microphones, Electro-Voice type 655-C
3	Microphones, Bruel & Kjaer type 4134
1	Pistonphone, Bruel & Kjaer type 4220
1	Dynamic microphone
6	Vertical component seismometers, Hall-Sears type HS-10

Equipment items, continued

Quantity	Item
1	Three-component seismometer package; 1-vertical 2-horizontal Hall-Sears type HS-10
3	Microphone stands, Bruel & Kjaer type UA 0026
24	Windscreens, Electro-Voice type 355
3	Rain covers, Bruel & Kjaer type UA 0056
3	Windscreens, Bruel & Kjaer type UA 0082
3	Cathode followers, Bruel & Kjaer type 2615 and power supplies
7	Seismic amplifiers
1	Audio mixer, 4-channel, model 3761 and audio preamplifiers
1	Audio sound source and driver amplifier
250	Reels, magnetic tape
Asst.	Microphone cables
Asst.	Seismometer cables
-	Spare parts

The seismometers and microphones will be calibrated at the Geophysics Laboratory before they are sent to Thailand. Experience with the Hall-Sears HS-10 seismometer indicates that the instrument is very stable in response characteristics. The B&K microphones are also stable in response characteristics. It would, however, be desirable to have these seismometers and microphones returned to the Geophysics Laboratory to have their calibration checked after the total recording program has been finished. Some field calibration tests will be included in the equipment to check amplifier response in the field. Obvious malfunctions of equipment will be detected as data tapes are given preliminary analysis at the Geophysics Laboratory.

Equipment that will be used for these measurements is designed for research purposes and should not be considered operational in nature. This series of experiments is designed primarily to make the measurements that would be needed to define proper parameters for an operational system of acoustic and seismic surveillance in Southeast Asian environments.

6. DATA REDUCTION AND ANALYSIS

Tape recordings of data taken under subtests described in Section 4 with voice comments and written field logs will be sent to the Geophysics Laboratory for analysis. All items of analysis equipment will be in operation before the field recording program begins in Thailand.

When data tapes are received at the Laboratory they will be scanned for quality control purposes and to select the data samples for which detailed analysis will be done. The exact methods of analysis vary with the type of data that is being studied. In the range of seismic frequencies that are of interest, special-purpose filter systems are available for making measurements of the spectra. A variety of spectral analysis methods is available for acoustic data. Some of these produce qualitative spectral outputs that will be valuable for selecting data samples for more quantitative measurements.

The purposes of this program of recording and analysis are to:

a. Determine the spectral characteristics of background noise for acoustic and seismic waves in the various environments of Thailand where measurements have been made.

b. Determine the diurnal and seasonal variations that can be expected in the acoustic and seismic background noise in the various environments and to relate these variations to characteristics of the environment such as meteorological conditions, botanical environment, and geological characteristics of the region.

c. Determine attenuation rates for seismic waves in each environment and the expected ranges of variation in attenuation rates. Estimates of acoustic attenuation will be made from existing data and the acoustic measurements that are to be made in Thailand.

d. Make measurements of acoustic and seismic signals from known sources to determine their spectral characteristics, detectability, and ability to identify the nature of the source.

Analysis of the data collected for Items "a" through "d" will be used to define what portions of the spectrum appear to be the most promising for acoustic and seismic surveillance in the Southeast Asian environment. Limitations in detectability and identification ability will be estimated from the data collected and from other existing information.

7. LABORATORY INSTRUMENTATION

Spectra will be obtained by analog computer methods, using the B&K frequency analyzer, or a special Bell Laboratories frequency analyzer, together with special filters combined with tape loop machines. When desirable, an optical computer avilable at IST will be used. This computer has the capability of taking one- or two-dimensional Fourier transforms and can compute auto- or cross-correlation functions.

Detailed information on these analysis methods can be found in the following references:

McIvor, I. K., "Methods of Spectral Analysis of Seismic Data," Bulletin of the Seismological Society of America, Vol. 54, pp. 1213-1232, 1964.

Willis, D. E., "Some Seismic Results Using Magnetic Tape Recording," Earthquake Notes, Vol. 30, pp. 21-25.

Larrowe, V. L. and Crabtree, R. E., "Analog Computation of Time-Varying Power Spectra of Seismic Waves," Report No. 3708-15-T/5178-8-T, Institute of Science and Technology, The University of Michigan.

Willis, D. E., "Collection of Seismic and Acoustic Signals," (U) Report Nos. 2407-12-F and 2900-56-S, The University of Michigan, Willow Run Labs., Ann Arbor, Michigan, 123 pages (SECRET Report) AD-306564.

Jackson, P. L., "Analysis of Variable-Density Seismograms by Means of Optical Diffraction," Geophysics (to be published in February).

8. PROJECT ORGANIZATION

The project organizational structure is shown in the organization chart, Figure 8.1. Lester G. Sturgill, Project Director, is responsible for over-all direction and coordination of the program. Neil J. Schairer, Project Engineer, is responsible to the Project Director for the direct management of this program and will monitor and coordinate the activities of the Institute of Science and Technology. IST has prime technical responsibility for the project. Rowland McLaughlin of IST is Principal Investigator for the program.

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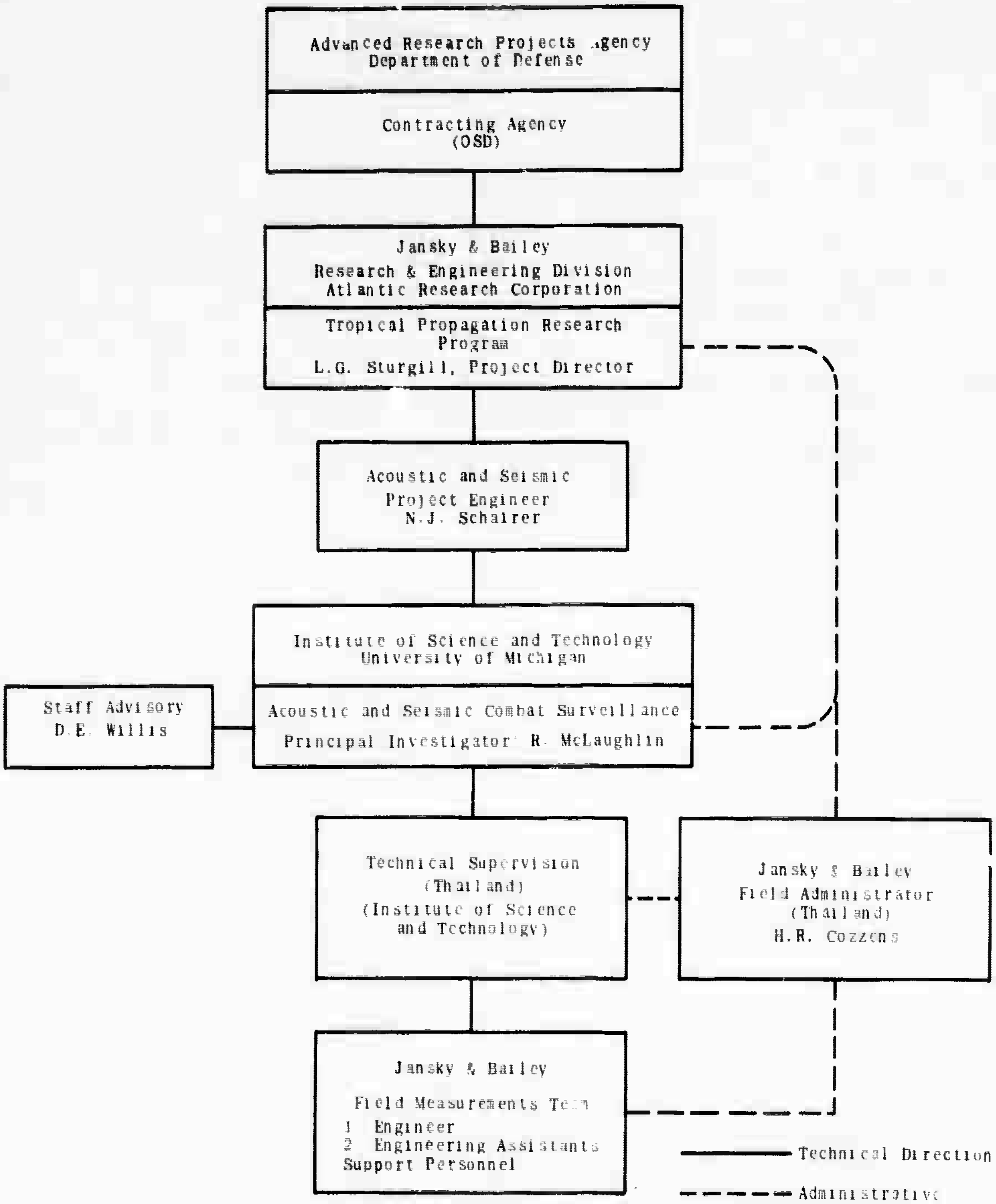

Figure 8.1 Acoustic and Seismic Research Program Organization Chart

9. LOGISTICS

The field work portion of this program will have the full support of the administrative, logistical and technical services which Jansky & Bailey has already established in Thailand under the Tropical Propagation Research Program the Company is conducting in that country under the sponsorship of the Advanced Research Projects Agency, Department of Defense, through Signal Corps Contract DA 36-039 SC-90889. This contract is directed by the U. S. Army Electronics Command, Fort Monmouth, New Jersey.

10. WORK PLAN

The project schedule and the relation between activities are illustrated in the attached simplified PERT diagram, Figure 10.1.


PRESENT TIME
REVISED TEST PLAN SUBMITTED TO ARPA
EQUIPMENT ARRIVES THAILAND 1 NOV 1965
EQUIPMENT SHIPPED TO THAILAND FROM IST 20 OCT 1965
SITE A SELECTED BY ARPA 1 DEC 1965
SITE B SELECTED BY ARPA 22 DEC 1965
SITE A INSPECTION AND PREPARATION 21 DEC 1965
SITE B INSPECTION AND PREPARATION 12 JAN 1966
SITE 3 PAK CHONG #1 MEASUREMENTS START 15 NOV 1965
SITE 4 PAK CHONG #2 MEASUREMENTS START 11 DEC 1965
SITE A NOT YET SELECTED MEASUREMENTS START 5 JAN 1966
SITE B
SITE 3 MEASUREMENTS COMPLETED 10 DEC 1965
SITE 4 MEASUREMENTS COMPLETED 3 JAN 1966
SITE A MEASUREMENTS COMPLETED 24 JAN 1966
SITE 3 DATA CATALOGED AND SHIPPED TO IST 14 DEC 1965
SITE 4 DATA CATALOGED AND SHIPPED TO IST 6 JAN 1966
SITE A DATA CATALOGED AND SHIPPED TO IST 28 JAN 1966
SITE 3 DATA ARRIVES AT IST 20 DEC 1965
SITE 4 DATA ARRIVES AT IST 10 JAN 1966
SITE A DATA ARRIVES AT IST 3 FEB 1966
SITE 3 DATA ANALYZED AT IST 21 FEB 1966
SITE 4 DATA ANALYZED AT IST 10 MARCH 1966
SITE A DATA ANALYZED AT IST 4 APRIL 1966

Figure 10.1 Revised Acoustic and Seismic Schedule, October 1965