Special Technical Report 44

VHF DIFFRACTION AND GROUNDWAVE PROPAGATION TESTS USING IONOSPHERIC SOUNDERS

By: J. E. van der LAAN D. J. LYONS D. J. BARNES G. H. HAGN

Prepared for:

U.S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NEW JERSEY 07703

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ERRATA

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Page	Line	Now Reads	Should Read
iii	6	These tests...	This test...
13	6	[Note: Diffraction tests did not become a part of the subsequent sounder test program in Thailand--where the units were used almost exclusively for ionospheric studies. All VHF data obtained with the sounders (both in CONUS and in Thailand) are presented and discussed in this report.]	
19	4	...ampligrams).	...ampligrams). These records were taken with 4 pulses per channel. It took 8 seconds when using a PRF of 20 pulses per second to complete one 32-64 MHz ampligram.
19	13	...is due to...	...possibly is due to...
21, 23, 25		[Note: The ordinate of the ionograms reads time delay and should read relative time delay. It should be noted that sounder synchronization can cause this time delay to bear no relation to the actual time of propagation of the pulse from the transmitter to the receiver.]	
26	last	...Figure 17(b).	...Figure 17(b). These data indicate a time delay spread between the direct (diffracted) signal and that scattered from the aircraft of about 1/3 microsecond.

Page	Line	Now Reads	Should Read
28	Fig. 18	[<u>Note</u>: Delete the elevation angle at the receiver, 3.7°, since it is misleading. The "local" take-off angles are the important ones and they were about 1°. Unfortunately, these angles were not accurately determined while the equipment was in the field.]	
28	Table I	G_R = -16.0 dB	G_R = -15.5 dB
30	4th from bottom	...dipole,...	...dipole (see pp. 60-61),...
33	last	...calculated.	...calculated. It may turn out that the calculation for received signal is so sensitive to elevation angle (primarily due to the antenna pattern factor) as to be relatively meaningless at very small angles. The antenna pattern approach is an alternative formulation to the more commonly used two-ray (direct and ground-reflected) approach.
42	4	...tests at 49.2 MHz	...tests at 49.2 MHz.* * This work was done as part of a system check-out and it was subsequently learned that this limitation did not exist (see Section VI for measurements at 50 MHz).
44	Item	...Figure 29).	...Figure 29). The data plotted in this figure were obtained by setting the gains of the horizontal dipoles equal to each other and letting the relative gains of the other antennas fall where they may.

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SRI Project 4240

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ABSTRACT

Two Granger Associates Model 911 sounders were used at VHF (32 to 64 MHz) to make path-loss measurements and relative antenna efficiency measurements on short groundwave paths (less than 50 km) in the United States and in Thailand. The first test consisted of measuring the path loss as a function of frequency on a 40-km diffraction path over a low, wooded ridge. These tests indicated that a simple scalar diffraction model did not predict enough loss by about 20 to 40 dB. Tests on 49.2 MHz over a 5-km level, forested path near Ban Mun Chit, Thailand showed that broadside alignment of horizontal dipoles at 10 ft above ground produced signal strengths 15 dB greater than any other combination of horizontal dipoles, and 20 dB greater than when the dipoles were aligned end-on (the worst alignment). In the forest, the broadside dipoles also produced signals more than 20 dB greater than vertical dipoles center-fed at the same height above ground. The vertical dipole pair produced about the same signal as the horizontal dipole pair when both antennas were moved into clearings adjacent to the forest, although the propagation path was through essentially the same vegetation. The vertical dipoles were better than quarter-wave vertical monopoles in the clearing. Also the vertically polarized antennas suffered significantly more degradation in the forest than the horizontally polarized antennas. Tests made on 31.8, 40.4, and 50.0 MHz near Chumphon, Thailand on 15- and 20-km paths using dipoles at 10 ft above ground and log-periodic antennas (LPA's) at 15 ft above ground indicated the superiority of the LPA's. When set up for vertical polarization, the pair of LPA's was typically 3 dB better than a pair of vertical dipoles; when set up for horizontal polarization, the LPA pair was about 11 dB better than the dipole pair set up horizontally at the slightly lower height.

FOREWORD

The work described in this report was performed in part with the support, and using the facilities, of the Military Research and Development Center (MRDC) in Bangkok, Thailand. The MRDC is a joint Thai-U.S. organization established to conduct research and development work in the tropical environment. The overall direction of the U.S. portion of the MRDC has been assigned to the Advanced Research Projects Agency (ARPA) of the U.S. Department of Defense which, in 1962, asked the U.S. Army Electronics Command (USAECOM) and the Stanford Research Institute (SRI) to establish an electronics laboratory in Thailand to facilitate the study of radio communications in the tropics and related topics. The MRDC-Electronics Laboratory (MRDC-EL) began operation in 1963 [under Contract DA 36-039 AMC-00040(E)], and since that time ARPA has actively monitored and directed the efforts of USAECOM and SRI. In Bangkok, this function is carried out by the ARPA Research and Development Field Unit (RDFU-T). The cooperation of the Thai Ministry of Defense and the Thailand and CONUS representatives of the ARPA and USAECOM made possible the work presented in this report.

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I INTRODUCTION

Two Granger Associates Model 911 sounders were used at VHF to make path-loss measurements and relative gain measurements on short groundwave paths (less than 50 km) in the United States and in Thailand. The first tests were made in California during the summer of 1965 on three paths over the Santa Cruz Mountains with the objective of studying diffraction effects over a low wooded ridge. Log-periodic antennas (LPA's) were employed, and tests were performed as the sounders were stepped in 800-kHz steps through the band 32-64 MHz. The second set of tests was made on 49.2 MHz in February 1966 over a 5-km forested path near Ban Mun Chit, Thailand, with the objective of determining the relative gains of monopoles and dipoles located in the tropical forest and in small clearings at the forest edge.[1]* The third set of tests was performed in the vicinity of Chumphon, Thailand, for the purpose of determining the effectiveness of horizontal and vertical λ/2 dipole antennas relative to each other and to LPA's similar to those used in the first test. Data were obtained at the Chumphon site on three paths of about 5, 15, and 20 km, respectively. These tests were made on 31.8, 40.4 and 50.0 MHz. This report describes and presents the results of these tests.

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* References are listed at the end of this report.

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II SUMMARY OF MAJOR FINDINGS

The tests described in this report were brief and nonexhaustive. In some cases, conflicting results were obtained and there were not enough data to resolve the conflict. Nevertheless, some of the findings pertinent to the use of VHF antennas on groundwave paths in the tropics may be listed:

(1) Horizontal dipole antennas (one transmitting and one receiving) aligned broadside in a forest on a short (5-km) path were 15 dB better than any other combination of horizontal dipoles and were more than 20 dB better than end-on (the worst alignment) or vertically polarized dipoles.

(2) Center-fed vertically polarized dipoles were superior to quarter-wave monopoles and, when set up in a clearing, proved the best combination by about 0.5 dB over the horizontal-broadside pair.

(3) Both the vertical monopole and vertical dipole showed substantially improved performance on a short, vegetated path in the tropics when placed in cleared areas rather than in dense vegetation, whereas the horizontal dipole showed less change when moved from forest to clearing. Indeed, the broadside pair of horizontally polarized dipoles showed about the same performance in the clearing as in one jungle location, and about 6 dB better performance in the clearing than in the other jungle location tested.

(4) A small change in antenna location in the jungle can produce a relatively large change in the performance [illegible] pair of antennas, and this effect seems more pronounced for vertically polarized antennas.

(5) A pair of horizontally polarized LPA's, when set up 15 ft above ground in clearings and used on 15- to 20-km paths, were about 4 dB better than the same LPA pair set up for vertical polarization.

A test of propagation on a 40-km path over a low, wooded ridge in California indicated that a simple scalar diffraction model does not predict enough loss by 20 to 40 dB, although the exact amount of error is not easy to calculate because of the difficulty in accurately determining the antenna gain for low take-off angles. Also, the appropriateness of the knife-edge approximation is difficult to determine from path-profile data available from topographic maps.

III DESCRIPTION OF EQUIPMENT

A. Antennas

1. Log-Periodic Antennas

Simple biplanar dipole log-periodic antennas, designed for use in the 32-64 MHz band, were employed with the sounders. Figure 1 is a sketch of the antenna. For the California tests,[*] balanced-to-unbalanced ferrite-core transformers (baluns) capable of pulse operation with 30-kW peak power were used at the antenna feed, which was driven by the sounder through RG-8/U coaxial cable. Design prototypes--capable of horizontally polarized operation only--were used for the California tests.[*] More sturdy antennas with the same electrical characteristics were built for use in Thailand on both horizontal and vertical polarization. Figure 2 is a sketch of the antenna configurations as used at Chumphon, Thailand; and Fig. 3 is an aerial photograph of the Chumphon, Thailand test site showing the VHF LPA setup for tests on horizontal polarization.

2. Monopole Antennas Used at Ban Mun Chit

The monopole antennas used at Ban Mun Chit were cut for quarter-wave resonance at 50 MHz. The 56-inch-high vertical elements were constructed of No. 12 copper wire, suspended from wooden poles, and operated without a ground plane (see Fig. 4).

3. Dipole Antennas Used at Ban Mun Chit

The 112-inch dipole antennas were constructed of No. 12 copper wire. The center conductor of the coaxial cable fed one dipole element, and the shield fed the other; no balun was used. Figure 4 shows the various dipole configurations tested. The same feedline was

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[*] At the receiving sites in California a 200-Ω to 50-Ω balun designed for low-power operation was used: North Hills Type 0500BB.

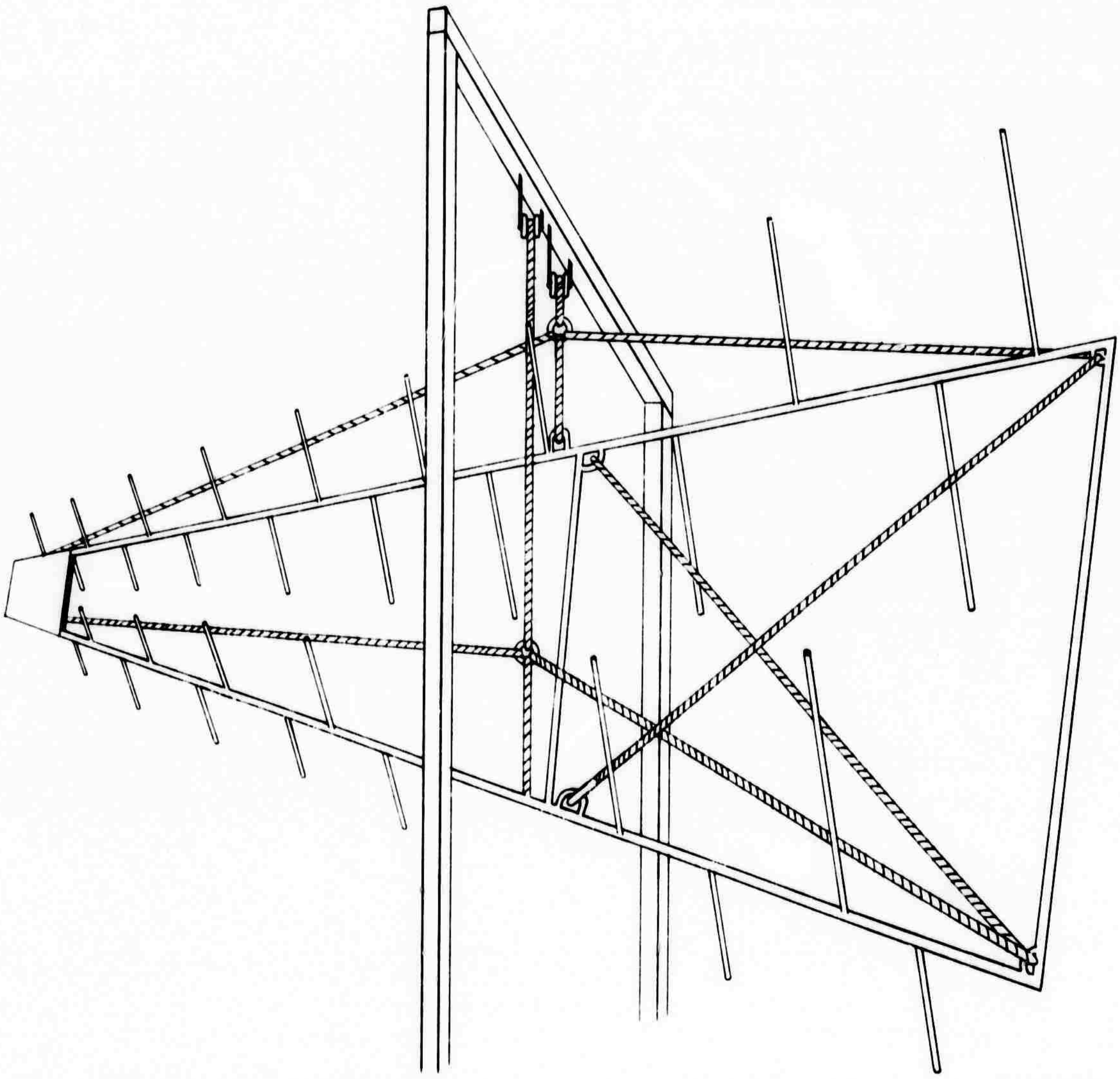
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FIG. 1 SKETCH OF VHF LOG-PERIODIC ANTENNA

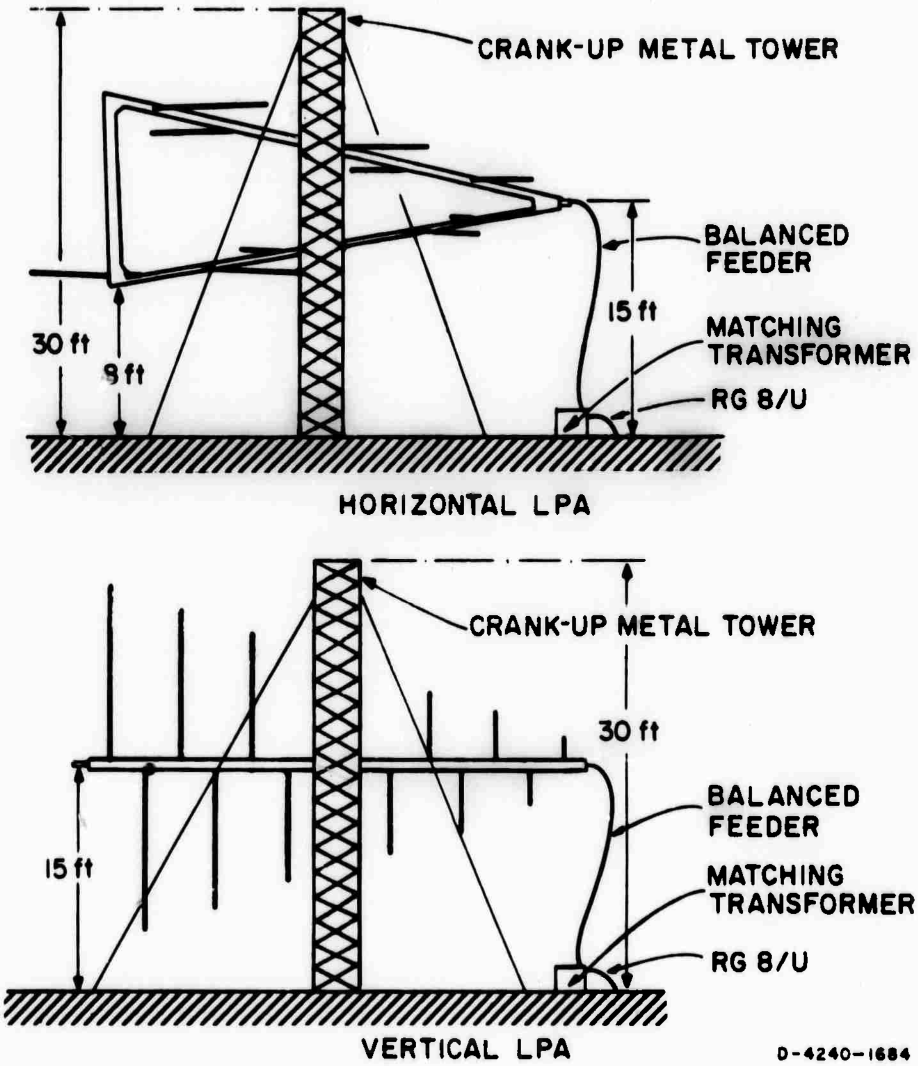

FIG. 2 VHF LPA CONFIGURATIONS USED AT CHUMPHON, THAILAND

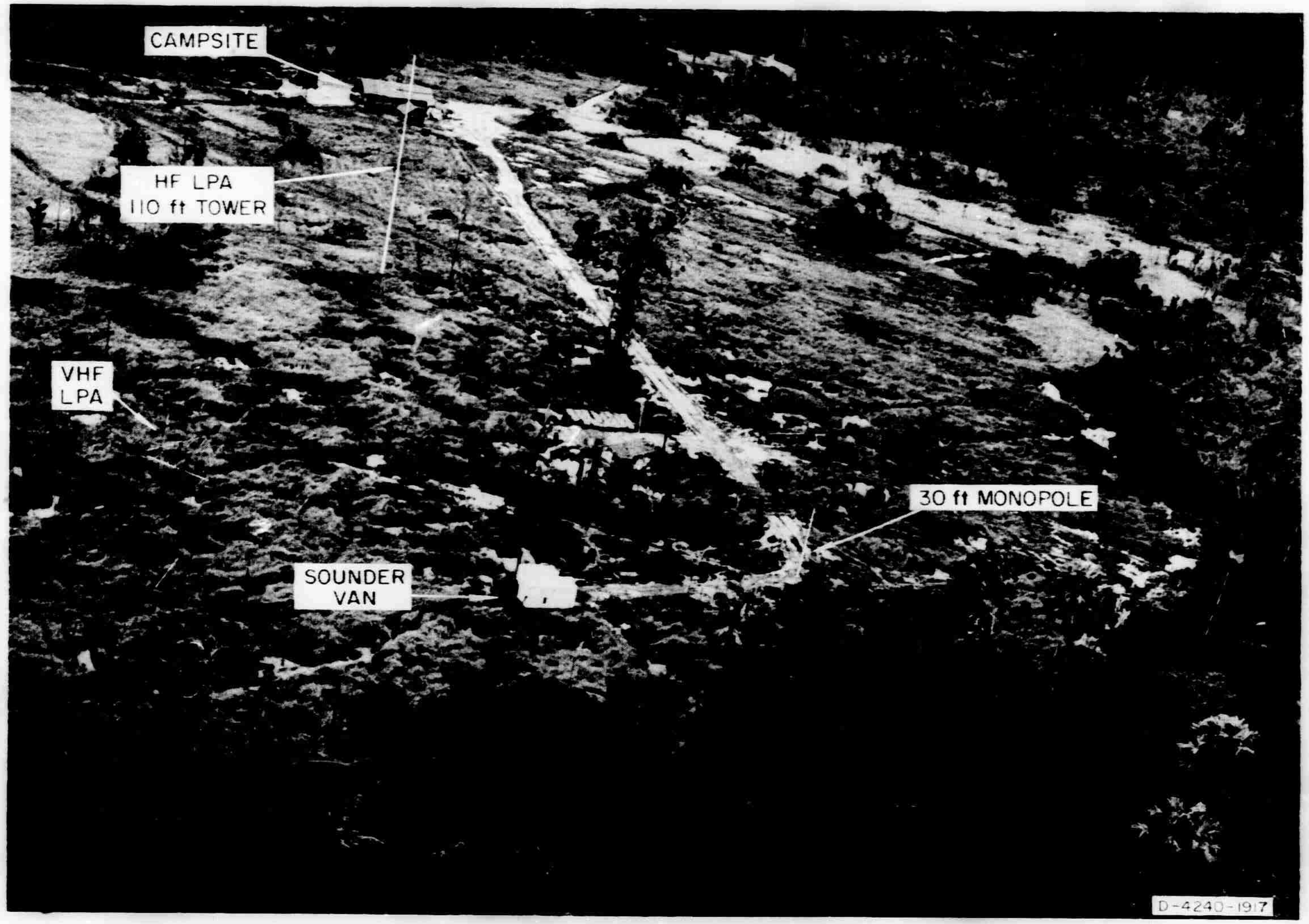

FIG. 3 AERIAL PHOTOGRAPH OF CHUMPHON BASE AND CAMP SHOWING HF AND VHF LPA'S

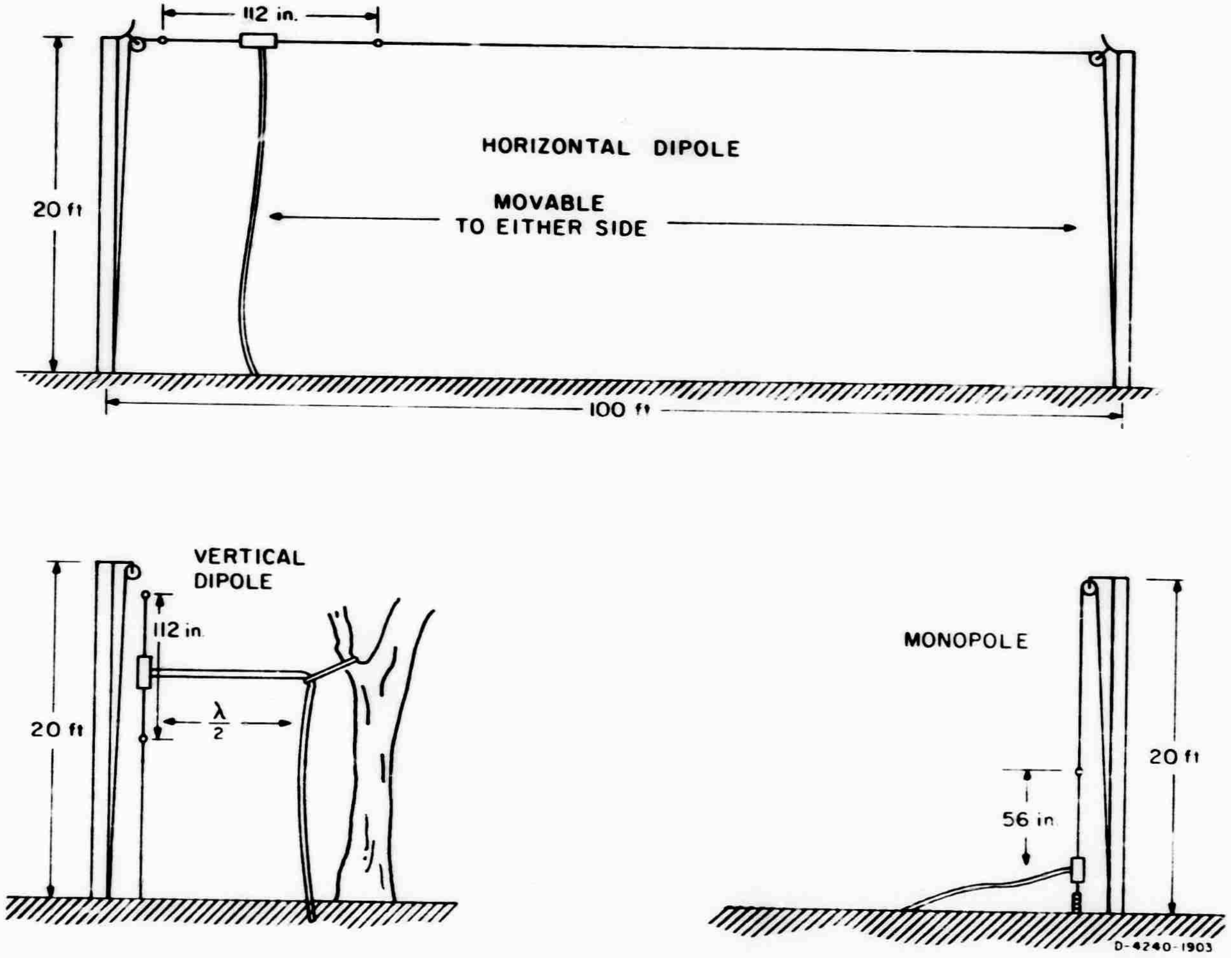

FIG. 4 VHF ANTENNAS USED AT BAN MUN CHIT THAILAND

used sequentially) for all antennas located in the forest, and lines of the same length were used at each site to feed all antennas located in the clearings.

4. Dipole Antennas Used at Chumphon

The dipole antennas used at Chumphon were the same antennas that were used as receiving antennas at that site in the VHF manpack Xeledop test program. The elements were constructed from telescoping automobile antennas that could be adjusted to resonant length over a wide range of frequencies. These antennas were set up as indicated in Fig. 5.

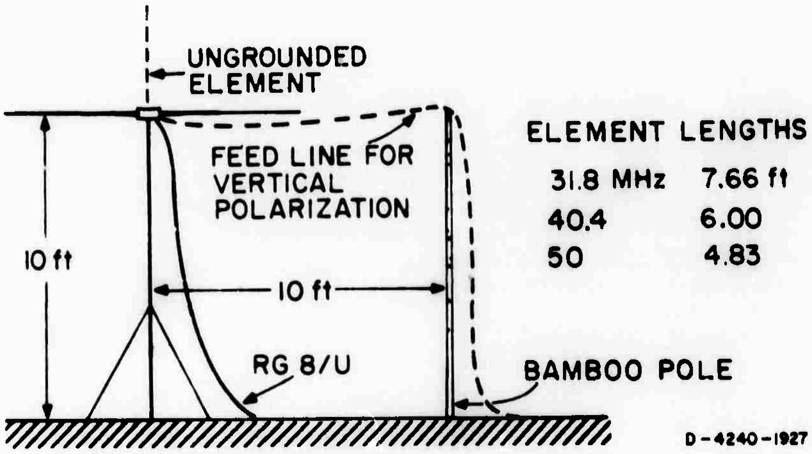

FIG. 5 VHF DIPOLES USED AT CHUMPHON, THAILAND

B. Granger Associates Model 911 Sounders

The major equipments (in addition to the antennas) used in the tests described in this report consisted of two Granger Associates Model 911 Transportable Ionospheric Sounder systems. These units are relatively compact transceiver systems covering the frequency range 4 to 64 MHz in 160 steps (Granger Associates 1900 series sounders housed in S-141 shelters). These units are designed to operate in the pulse mode and are capable of generating 30-kW peak pulse power. Pulse lengths of 50μs, 100μs, 200μs, 500μs, and 1ms are available. When operated in the step-frequency mode, these units cover the 4- to 8-MHz band in 100-kHz steps, the 8- to 16-MHz band in 200-kHz steps, the 16- to 32-MHz band in 400-kHz steps, and the 32- to 64-MHz band in 800-kHz steps. These units can also be programmed for fixed-frequency operation on any of the frequencies available for use during stepping. While the primary use of these equipments on this contract was for ionospheric sounding [1,2,3,4,5,6] and HF antenna studies, [7,8] they have also proven useful at VHF in the 32- to 64-MHz band. The units were used in both the fixed-frequency and step-frequency mode for VHF antenna and propagation studies.

Both an oscilloscope display and an electrostatic hard-copy display were available. The Granger Associates Model 9190 electrostatic display, modified to present amplitude versus frequency (or time), was used to record the step-frequency (or the fixed-frequency) records during the tests discussed in this report.

The sounder receivers have a sensitivity of about 1 to 10 μV, but the response of the receiver in the 32- to 64-MHz band is nonuniform. Therefore, it was necessary to make individual calibrations on each frequency of interest in order to ensure accurate receiver calibration. Consequently, the amplitude scales were not the same at the different sites. Calibration details pertinent to each test are given in the sections describing the individual tests.

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IV DIFFRACTION TESTS OVER THE SANTA CRUZ MOUNTAINS IN CALIFORNIA

A. Introduction

Obstacle-gain communication paths have been in operation for many years and in many cases the calculated transmission loss and measured path loss are in very close agreement.[9] The usual "knife-edge" approach to calculation of loss (first used in 1933 by Schelleng, Burrows, and Ferrell),[10] has proven to be a very accurate procedure when a definite diffraction-path profile has been established over one obstacle of small radius of curvature (small relative to a wavelength). The test described in this section involved the use of a fixed transmitter (sounder)--located at Mountain View, California, near San Francisco Bay--and a transportable sounder receiver, which was moved to three sites on the Pacific Ocean side of the Santa Cruz mountains (see Fig. 6), to test simple knife-edge diffraction theory for the case of a low wooded ridge at VHF. Signal amplitudes were recorded on frequencies between 32 MHz and 64 MHz.

B. Experimental Planning

It was originally desired to make measurements over a diffraction path that would approximate a theoretically ideal single-obstacle (i.e., one-diffraction) path. The path chosen was from Mountain View, California, across the Santa Cruz mountains. This path was chosen because it would minimize costs and also because there is a similarity between this mountain range and those found in Thailand, the eventual destination of the portable sounder systems. It was thought that a pilot study could best be done in CONUS because of the less severe logistics and support problems. Since the Mountain View transmitter site is a fixed site (only one transportable sounder van was available during the experiment), one point of the path was determine. Therefore, selection of a diffraction obstacle and a receiver site remained. From a

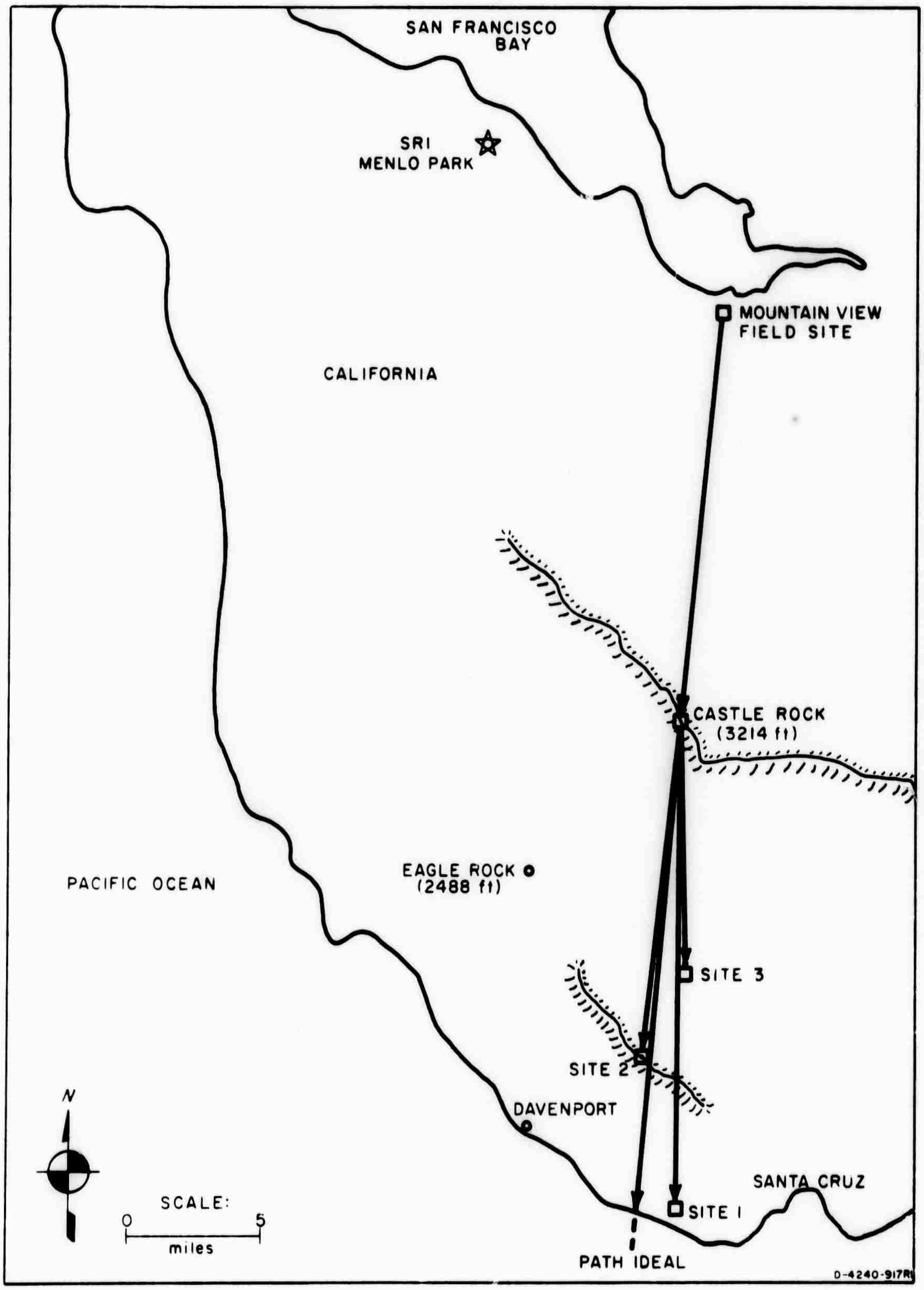

FIG. 6 DIFFRACTION PATH SITE LOCATIONS

topographical map, Castle Rock peak seemed to be a desirable obstacle for our path profile. A line was drawn from the Mountain View site through Castle Rock peak to represent the ideal path (see Fig. 6). We wanted to locate a receiver site on this planned path approximately the same distance from the peak as the Mountain View site. In determining this location it also was necessary to use a profile of the ideal path in order to eliminate poor site locations and to look more closely at nearby obstacles (see Figs. 7, 8). These considerations and allowable access limited our site planning to the areas indicated. Site 1 is a two-obstacle path, and Sites 2 and 3 appear to be single-diffraction paths. After receiver sites were selected, a somewhat more exact path profile* was constructed yielding the necessary values for the mathematical calculations (see Fig. 9).

C. Measurement Techniques

Ionospheric measurements are generally made with the sounder system generating a display of frequency versus virtual range (ionogram), and the signal amplitude range of the display is extremely limited. However, prior to this experiment, tests had been run in which amplitude data were required, and the recording equipment had been modified to measure the increased signal amplitude change (see Sec. III-B and Ref. 7). This record, called an ampligram, gives us signal amplitude as a function of frequency. In addition to the sweep-frequency ampligram records, single-frequency checks were made on selected frequencies by allowing both the sounder transmitter and receiver to run continuously on that frequency. This type of record allows us to make more accurate measurements on a specific frequency and to check for possible variation with time (fading). As previously mentioned, the nonuniform response of the receiver necessitated calibration at each frequency of interest. It should be noted here that the amplitude

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* These profiles are still approximate. All three sites are shown, but they are not quite on the same great circle path from the transmitter (see Fig. 6).

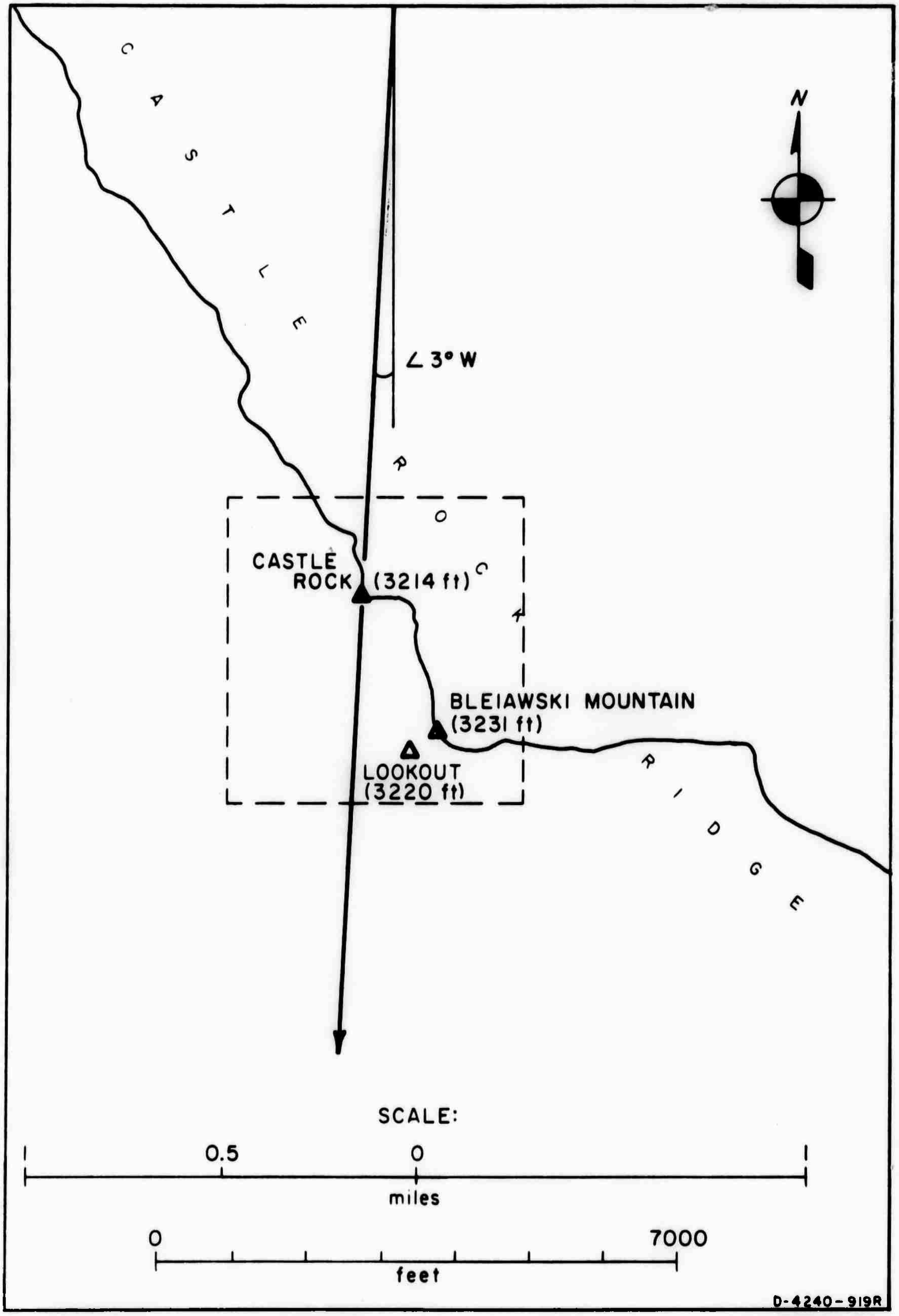

FIG. 7 OBSTACLES ON CASTLE ROCK RIDGE

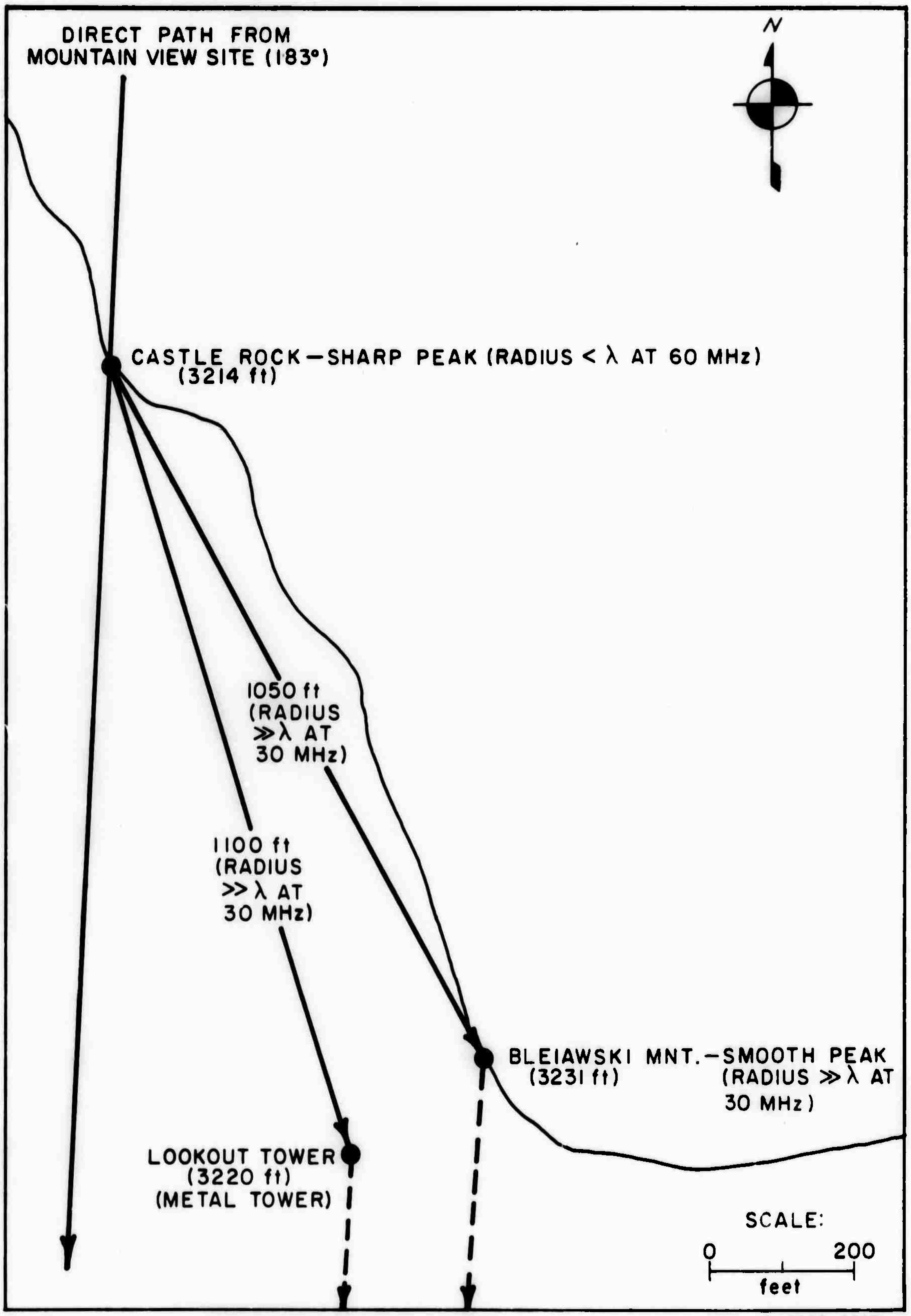

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FIG. 8 POSSIBLE MULTIPLE DIFFRACTION PATHS NEAR CASTLE ROCK PEAK

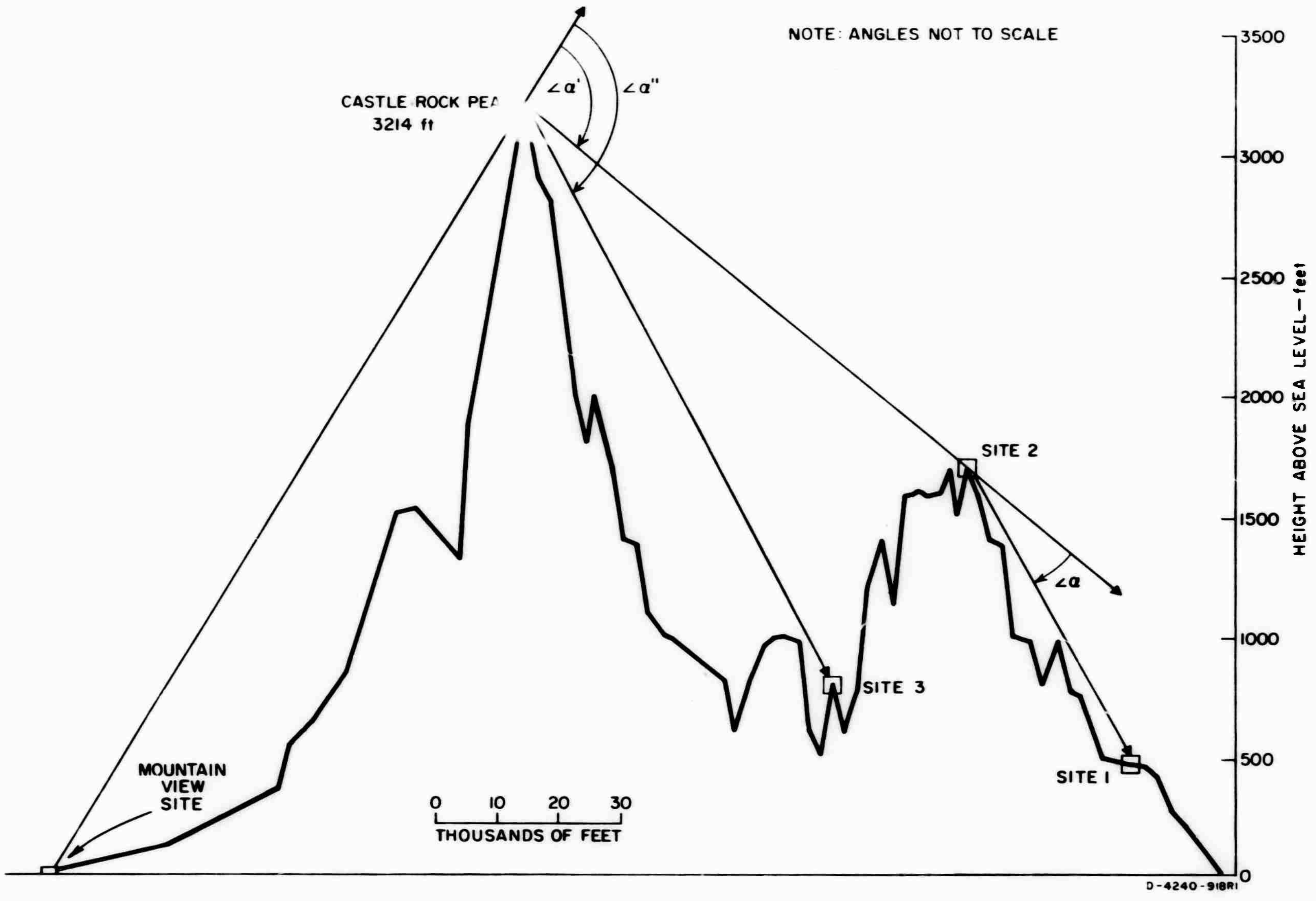


FIG. 9 APPROXIMATE PATH PROFILES OVER CASTLE ROCK PEAK

scales for sites 1, 2, and 3 are quite different. The change in amplitude scale at the second and third sites was thought necessary in order to display a greater dynamic range (see the receiver calibration records of Fig. 10, which take the form of overlays for the ampligrams).

Simple biplanar dipole log-periodic antennas were used with the sounders (see Sec. III-A-1).

D. Data

1. Path 1

Data recorded at Site 1 with a 4-kHz receiver bandwidth are presented in Fig. 11. The ionogram (time delay versus frequency, with intensity modulation) indicates that no significant multipath components were resolved by the 1-ms pulses. The apparent hole in the received record at 36 MHz is due to increased effective insertion loss of the balun used on the transmitting antenna. It is not possible to calibrate the ampligram (amplitude versus frequency) record with a single amplitude scale since the spectrum is not flat. Therefore, to put the data in a more meaningful form, we must combine data from the ampligram record and the calibration record of Fig. 10(a) to obtain a more useful display. When this is done, we obtain the display of Fig. 12, which represents a five-point received-signal spectrum in dB above 1 μV across 50 ohms. It should be noted that the insertion loss of the transmitting balun was negligible (less than 1 dB) on each of the five frequencies for which the data were reduced.

2. Path 2

Path 2 data are presented in Fig. 13 and are similar to those shown for Path 1. They also were obtained by transmitting 1-ms pulses and using the 4-kHz bandwidth receiver setting. The received signal in dB above 1 μV across 50 ohms is given in Fig. 14.

3. Path 3

Data obtained at Site 3 using 1-ms pulses and a 4-kHz receiver bandwidth are presented in Fig. 15. After the completion of the

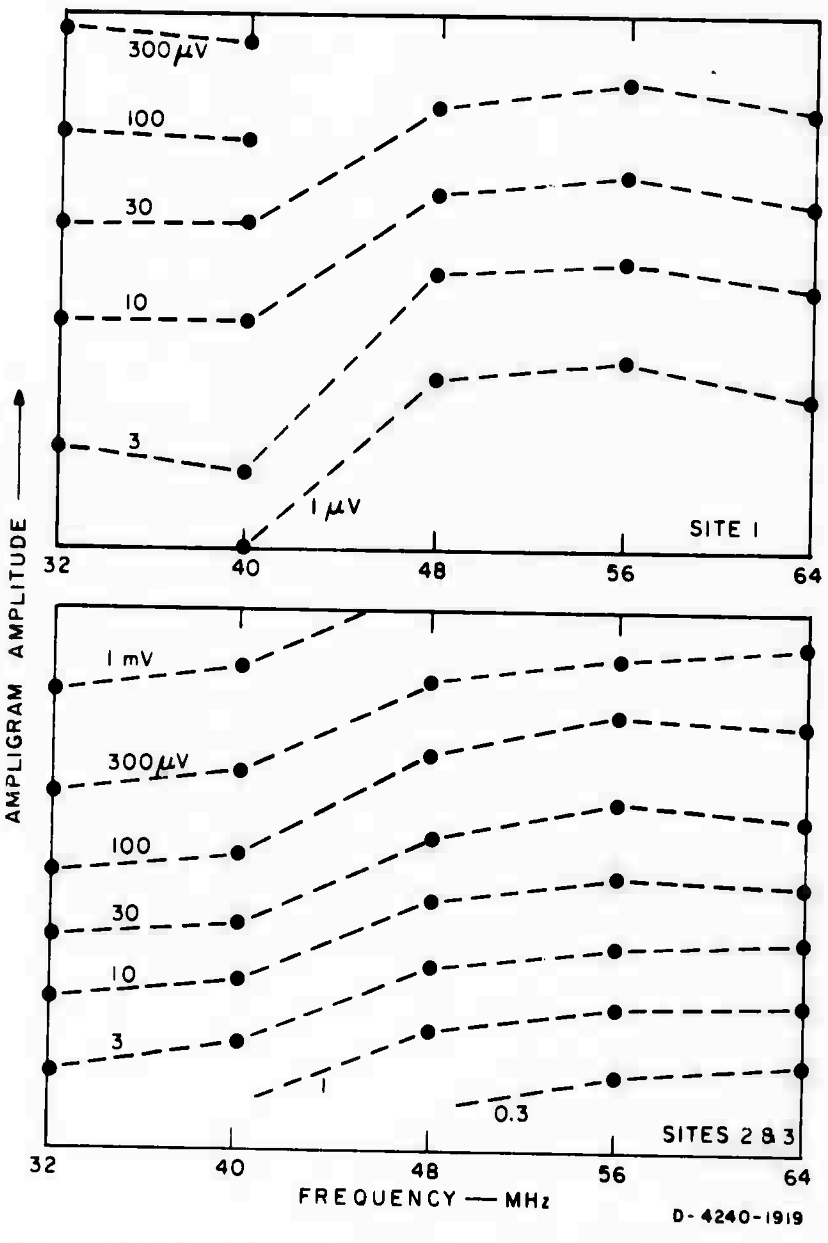
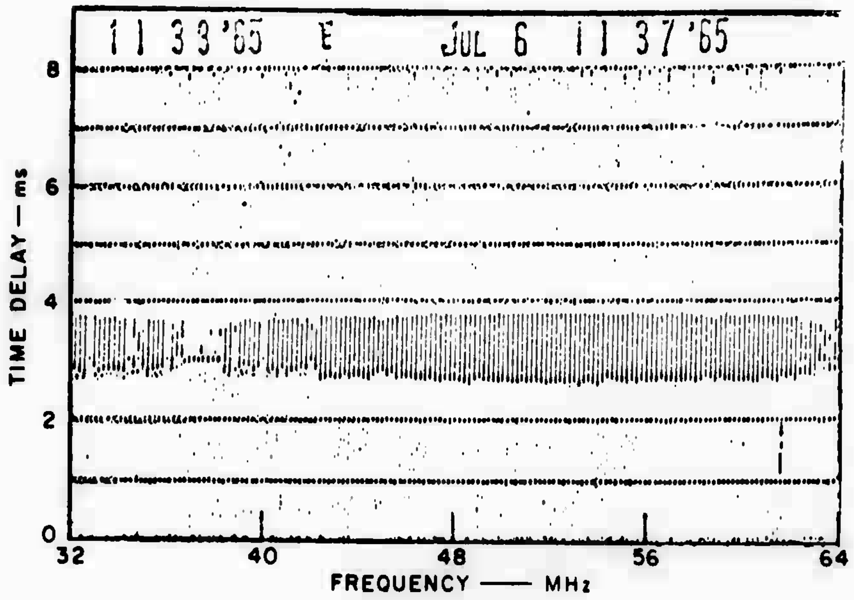
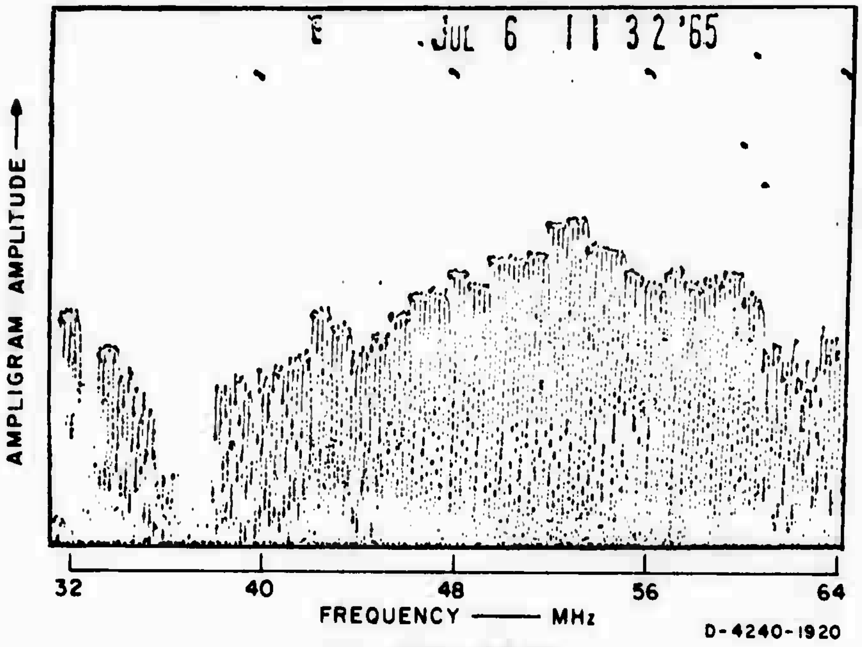


FIG. 10 RECEIVER CALIBRATIONS — AMPLIGRAM OVERLAYS



(a) IONOGRAM



(b) AMPLIGRAM

FIG. 11 STEP-FREQUENCY RECORDS OBTAINED ON PATH 1

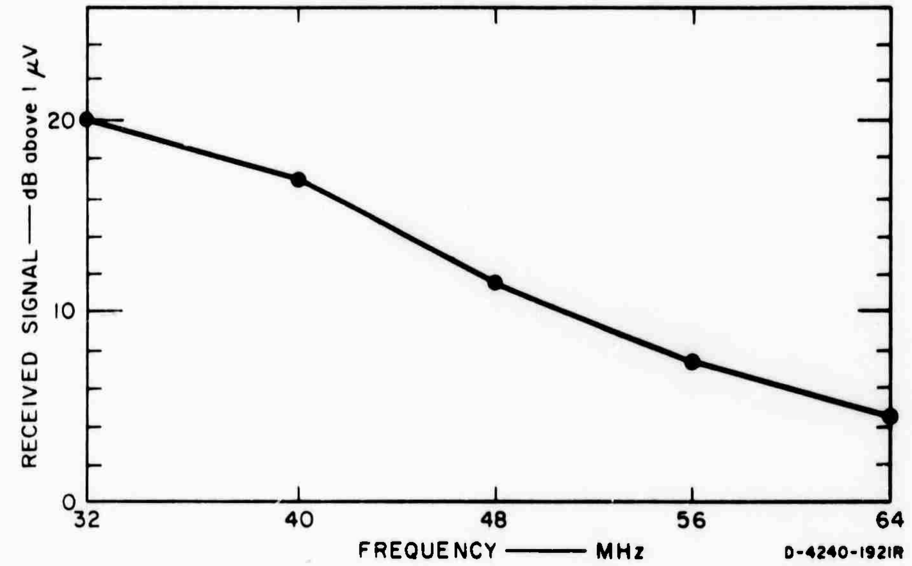
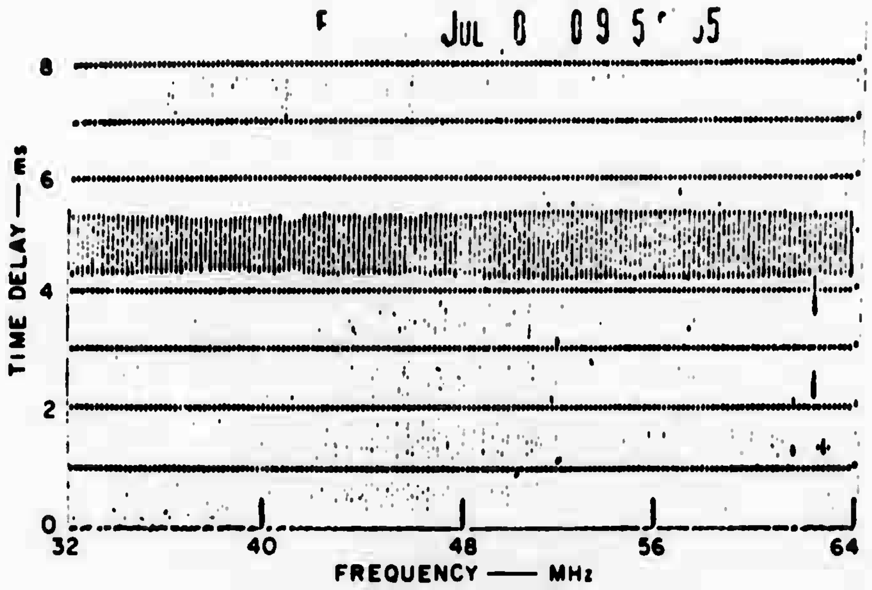
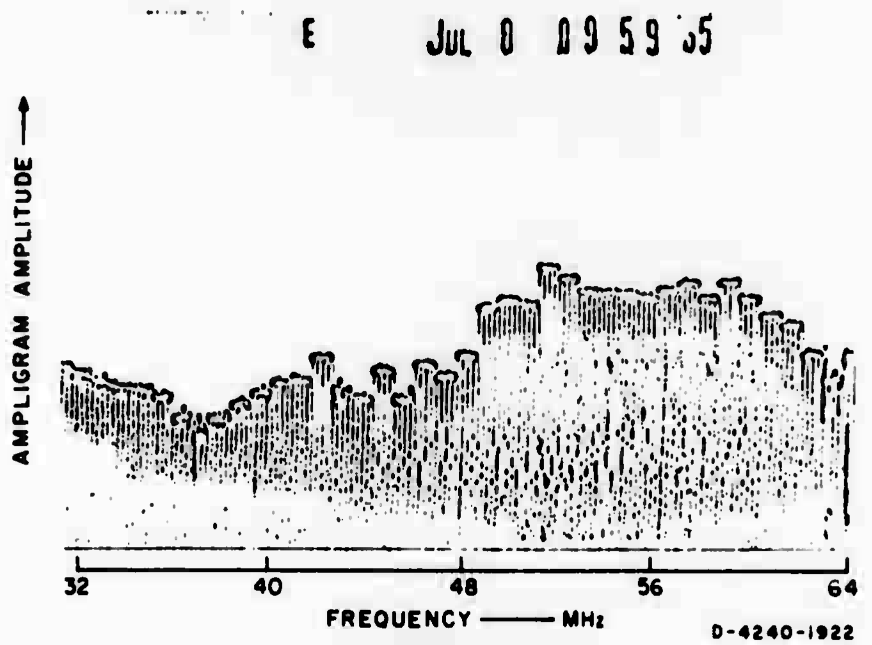


FIG. 12 RECEIVED SIGNAL VERSUS FREQUENCY ON PATH 1 — AFTER DATA REDUCTION



(a) IONOGRAM



(b) AMPLIGRAM

FIG. 13 STEP-FREQUENCY RECORDS OBTAINED ON PATH 2

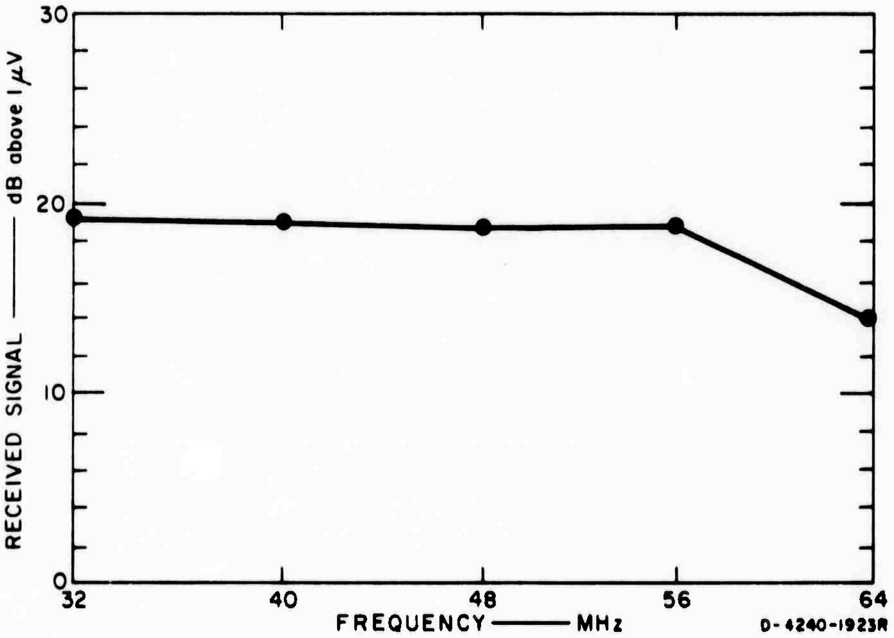
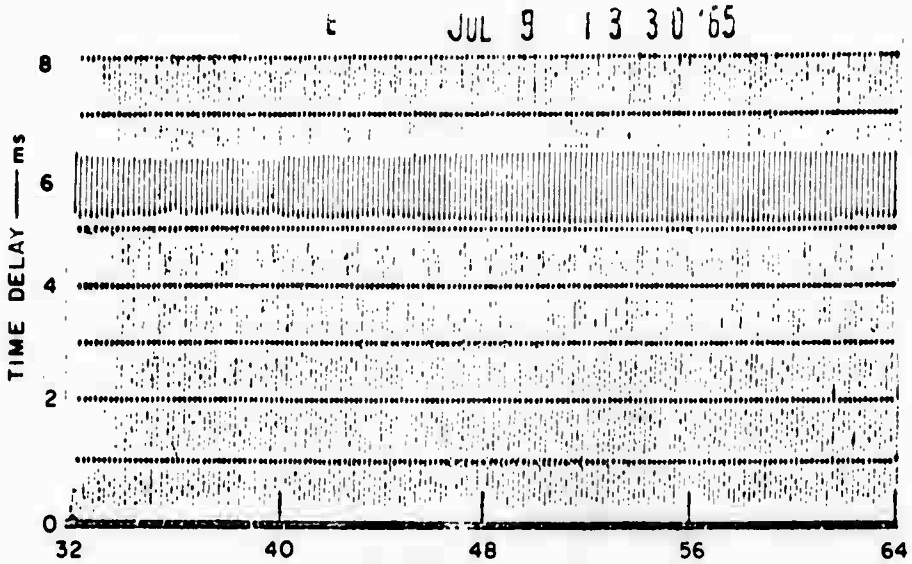
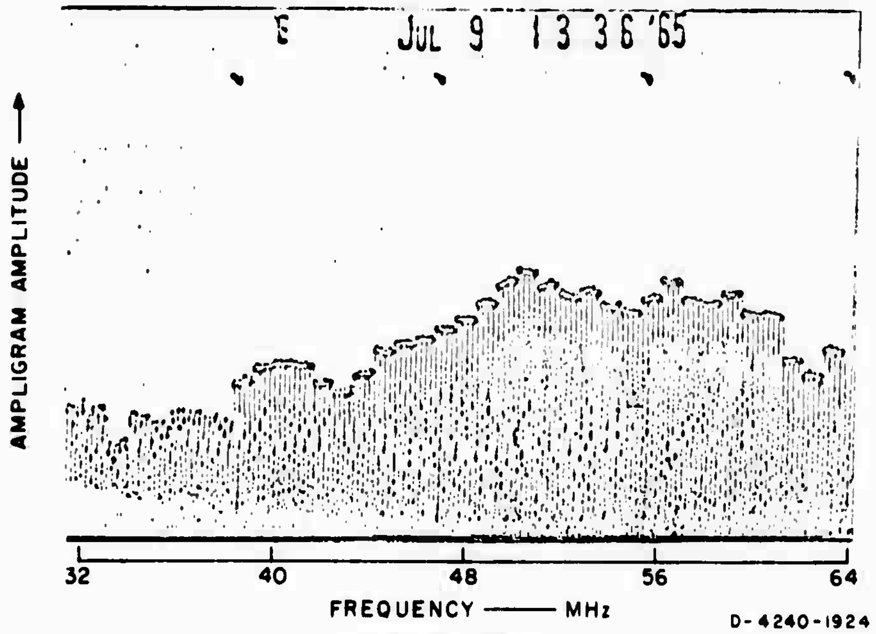


FIG. 14 RECEIVED SIGNAL VERSUS FREQUENCY ON PATH 2 — AFTER DATA REDUCTION



(a) IONOGRAM



(b) AMPLIGRAM

FIG. 15 STEP-FREQUENCY RECORDS OBTAINED ON PATH 3

standard tests and from observation of the geometry of the local test sites, it became apparent that Path 3 was probably the only single-diffraction path. Consequently, more data were obtained on this path using the sounders in their fixed-frequency mode and recording amplitude versus time (A-scope type of display). The results of these tests are presented in Fig. 16.

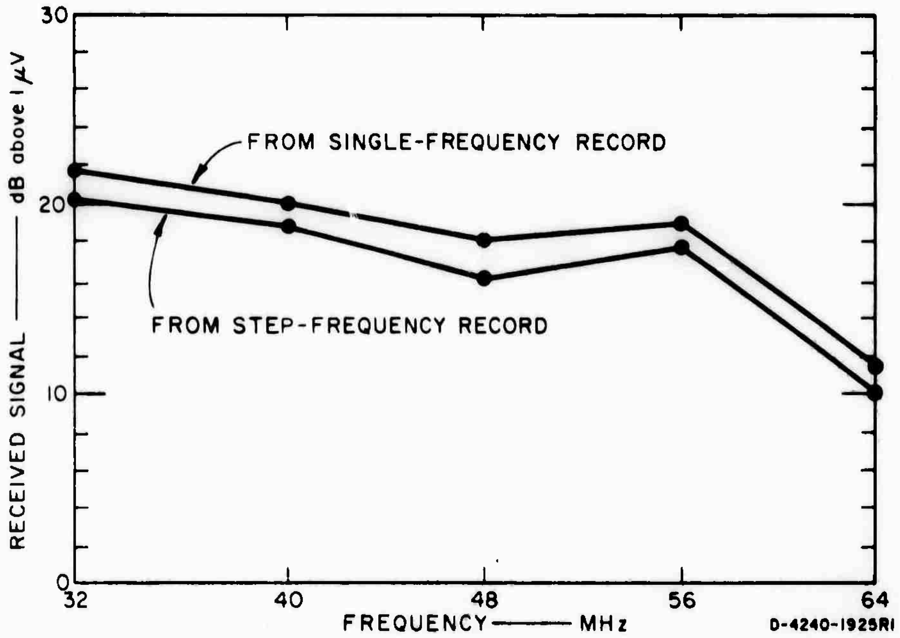


FIG. 16 RECEIVED SIGNAL VERSUS FREQUENCY ON PATH 3 — AFTER DATA REDUCTION

The A-scope type of display also yielded information on the fading on a given frequency. A constant signal amplitude as a function of time was observed except when an aircraft passed nearby [see Fig. 17(a)]. This type of fading causes the familiar "flutter" on a TV screen when an aircraft flies by. One ampligram record was obtained on Path 3 during the passage of an aircraft and this is shown in Fig. 17(b).

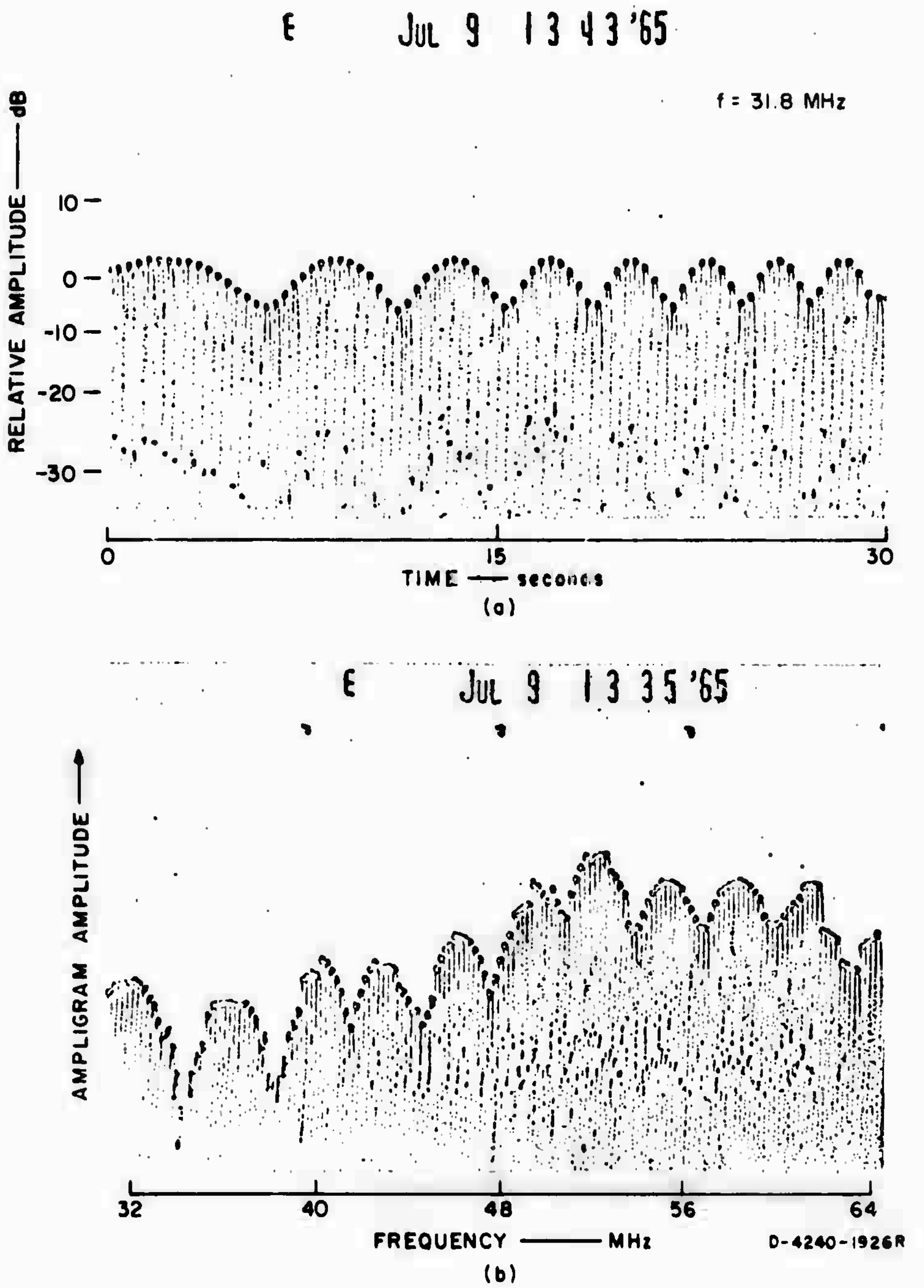


FIG. 17 EXAMPLES OF FADING CAUSED BY MULTIPATH FROM AIRCRAFT

E. Results and Discussion of Error

1. Data Analysis

Before an analysis of the data is presented, a mathematical calculation should be made from the known equipment information (given in Table I) and path geometry shown in Fig. 18 to estimate the expected received signal as a function of frequency.

Table I

DIFFRACTION-PATH EQUIPMENT DATA

Parameter	Known Value	
	32 MHz	64 MHz
Wavelength	30.6 ft	15.3 ft
Transmitter power in watts (P_T)	30 kW peak	30 kW peak
Antenna Gain Transmitting (G_T) (relative to isotropic)	-4.3 dB	+1.0 dB
Antenna Gain Receiving (G_R) (relative to isotropic)	-16.0 dB	-10.0 dB
Antenna Polarization	horizontal	
Input and Output Impedances	50 ohms	

	LENGTH (feet)		
DIMENSION	PATH 1	PATH 2	PATH 3
d_2	100,000	73,000	52,000
d	175,000	148,000	127,000
h_0	2,800	2,400	2,750

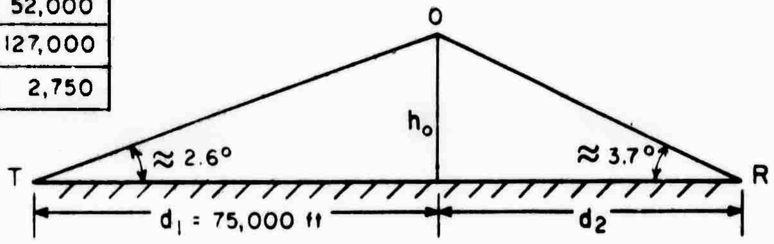


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FIG. 18 DIFFRACTION-PATH GEOMETRY AND NOMENCLATURE

The calculated value of received signal is obtained by adding the shadow loss to the equivalent free-space loss:

$$P_{R_{\text{free space}}} = \frac{P_T \lambda^2 G_T G_R}{(4\pi d)^2} \quad ,$$

where

$P_{R_{\text{free space}}}$ = received power in watts, under free-space conditions

P_T = transmitter power in watts

λ = wavelength in feet

$d \approx d_1 + d_2$ = equivalent free-space distance between transmitter and receiver in feet

G_T = transmitter antenna gain over isotropic radiator

G_R = receiver antenna gain over isotropic radiator.

The shadow loss in dB is given by 20 $\log_{10}$ $(v_o/0.225)$, where

$$v_o = h_o\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)} \quad .^{9*}$$

The antenna gain values are rather difficult to calculate for the small take-off angles involved (less than 5 degrees, see Fig. 18). Actually the foreground take-off angle is the one that counts. Furthermore, the antenna gains are a function of frequency for the antenna geometry used (i.e., the phase center is at approximately a constant physical height, making the height in wavelengths undergo a 2:1 change between 32 and 64 MHz). Assuming that the LPA is located as shown in Fig. 19, the height in wavelengths is given in Table II.

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[*] The two-ray model can be used because the definition of antenna gain takes the ground reflections into account (see Table II).

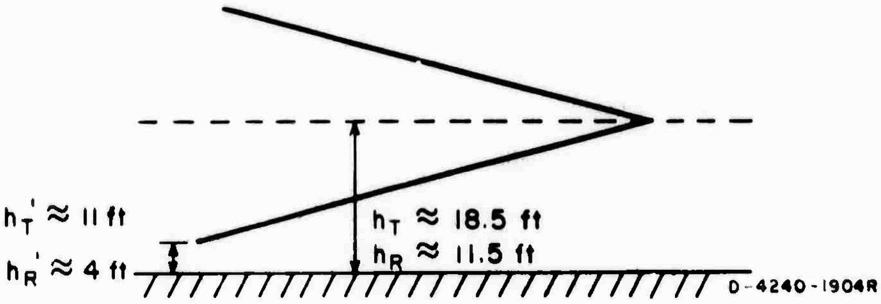

FIG. 19 LPA CONFIGURATION USED ON DIFFRACTION PATHS

Table II

DIFFRACTION-PATH ANTENNA GAINS

Frequency (MHz)	h_T/λ	h_R/λ	G_T (dB)	G_R (dB)
32	0.6	0.37	-4.3	-15.5
64	1.2	0.75	+1.0	-10.0

The gain of a horizontal dipole as a function of take-off angle and height is shown in Fig. 20 for very good ground. Notice the sharp gradient with take-off angle for small angles (i.e., a small error in angle corresponds to a large error in antenna gain). These curves are for $\epsilon_r = 10$, and loss tangent $\delta = \sigma/\omega\epsilon = 1$. For values of $h/\lambda \leq 0.2$, these curves are equally applicable for $\delta = 0.01$ and $5 \leq \epsilon_r \leq 15$ to within less than 1 dB.*

The LPA is assumed to have a gain of 3 dB over a dipole, including balun and transmission line losses, and this is independent of frequency. Thus, the gain of each LPA is found by consulting Fig. 20 to obtain the appropriate dipole gain estimate (using the foreground take-off angle

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* Private communication, Dr. John Taylor, University of South Carolina (September 1965).

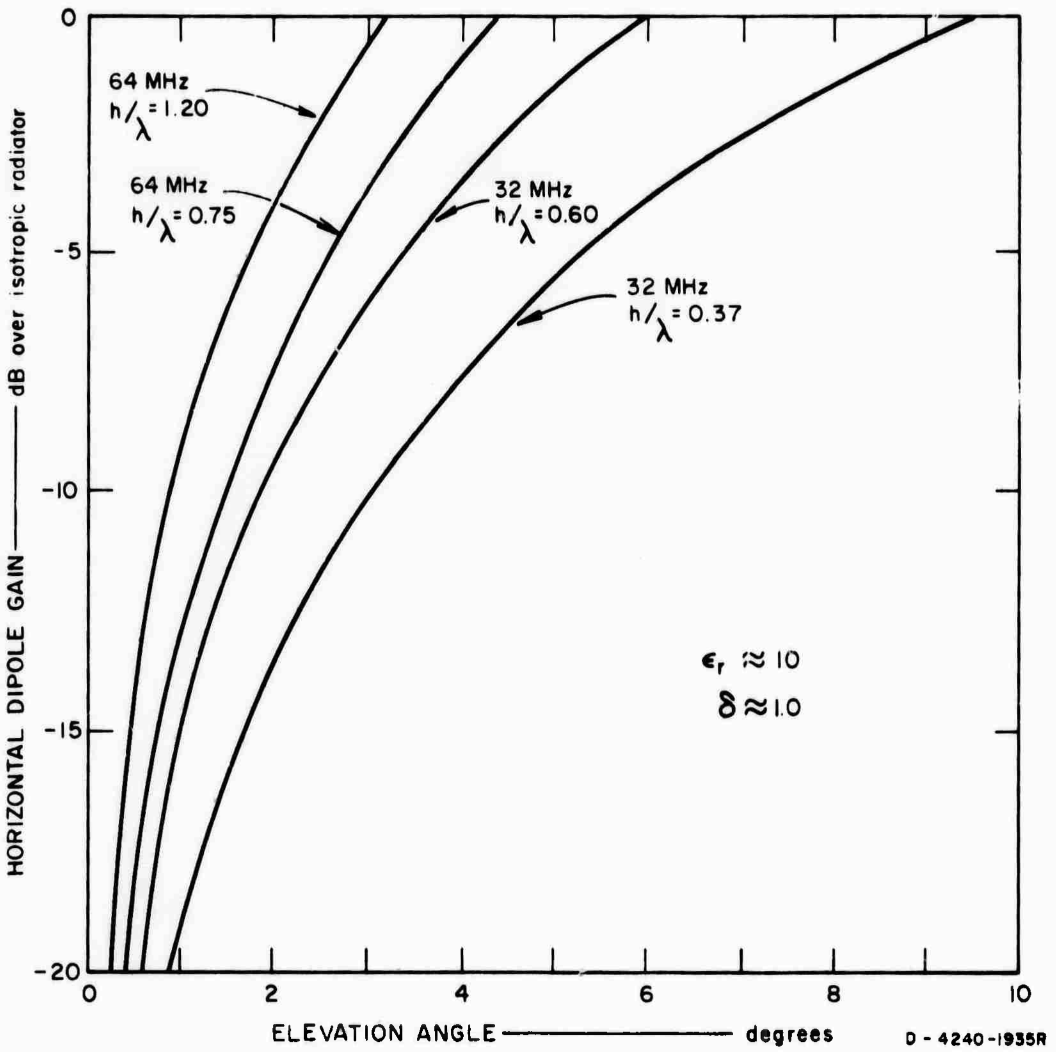

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FIG. 20 DIPOLE ANTENNA GAIN VERSUS ELEVATION ANGLE and h/λ) and adding 3 dB to it. The transmitter site take-off angle was 2.6 degrees whereas the effective take-off angle at the receiver sites was about 1 degree.

Using the data of Tables I and II, we calculated the received signal for the free-space case and subtracted the diffraction loss from it. The resultant received signal calculated in this matter in dB above 1 μV across 50 ohms is summarized in Table III, which also presents the measured results.

Table III

CALCULATED AND MEASURED DIFFRACTION-PATH SIGNAL STRENGTHS

Path	Freq (MHz)	Free-Space Received Signal (dB > 1μV)	Diffraction Loss (dB)	Received Signal (dB > 1 μV)		Calculation Error (dB)
				Calculated	Measured	
1	32	64.8	23.6	41.2	20	21.2
	64	68.9	26.9	42.0	5	37.0
2	32	66.2	23.1	43.1	19	24.1
	64	71.1	26.0	45.1	14	31.1
3	32	67.6	25.3	42.3	20	22.3
	64	72.4	28.0	44.4	10	34.4

2. Discussion of Error

The calculated values of received signal are always at least 20 dB greater than the observed values. The calculation error (also shown in Table III) was essentially constant (to within ±3 dB) for a given measurement frequency, amounting to about 22 dB at 32 MHz and 34 dB at 64 MHz. It should be noted, however, that an error of only 0.5 degree in apparent take-off angle (e.g., take-off angle 0.5 degree instead of 1 degree at the receiving site) could cause an error greater than 10 dB in the calculated signal strength.

Although the calculated diffraction loss is typically about 3 dB greater at 64 MHz than at 32 MHz, the signal strengths predicted for the higher frequency were greater in each case by about 1.7 dB ± 1 dB. This is in contrast to our observations, where the higher frequency had the lower signal strength in each by 10 dB ± 5 dB. This agreement is not very good. For Paths 2 and 3, however, if we exclude the data at 64 MHz (i.e., limit ourselves to data obtained on 32, 40, 48, and 56 MHz--see Figs. 14 and 16) then the agreement with scalar knife-edge diffraction theory is reasonable regarding variation of signal strength with frequency in the lower part of the VHF band.

F. Conclusions

The Granger sounder units can be used without difficulty to measure path loss on over-the-horizon paths in the vicinity of 50 km, provided a peak 1/6 km to 1-1/2 km is situated so as to provide a single-obstacle path. Such paths exist in southern and northern Thailand, and the sounder units could possibly be used to check whether various proposed VHF systems would work between villages there. The sounder units could also be used to measure ground-wave propagation and relative antenna effectiveness, although at lesser ranges.

The measurements do not agree well with calculations based on a scalar diffraction model. The calculated signal values were, however, about 22 dB too high at 32 MHz and about 34 dB too high at 64 MHz. This error is possibly due to the uncertainty of the antenna gains for the low take-off angles involved. Other possible causes of this error are lack of an ideal knife-edge multiple diffraction (when the model assumes only one predominant obstacle), or foliage (mostly redwood trees about 60-ft high) on the ridge. The only way to sort out these effects is by a thorough, accurate system calibration and better documentation of the propagation path. Future investigations should include a measurement of relative gain as a function of elevation angle from ground level up to about 5 or 10 degrees, where reasonably accurate absolute gain values can be calculated.

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V VHF GROUNDWAVE TESTS AT BAN MUN CHIT, THAILAND

A. Introduction

The purpose of the tests described in this section was to evaluate the relative performance of selected field-expedient VHF antennas for use over a short, forested path. Tests were made on 23 February 1966 at Ban Mun Chit, Thailand (approximately 150 km southeast of Bangkok--see Fig. 21) between two sites separated by about 5 km of dense tropical vegetation using monopole and dipole antennas. Preliminary results of these tests were presented in Ref. 1, p.66. HF groundwave tests also were made at this site.[8]

B. Site Description

The principal requirements for this site were:

(1) An evergreen forest with canopy and undergrowth

(2) A cleared area either in the center of the forest or immediately adjacent to it

(3) A sufficiently large forested area to provide reasonably long groundwave paths through dense vegetation

(4) Reasonable access to the site by road for heavy equipment.

The site selected was part of a forested region gradually being turned to agricultural use. Consequently, logging roads were available for access, and a cleared area adjacent to heavy forest (jungle) was easily found.

The site was near the village of Ban Mun Chit in the Ban Bung district of Chon Buri Province--approximately 85 km southeast of Bangkok, and almost due east of Siricha, a small fishing port on the east coast of the Gulf of Thailand. The topography of the site is a region of slightly rolling country approximately 70 m above mean sea level.

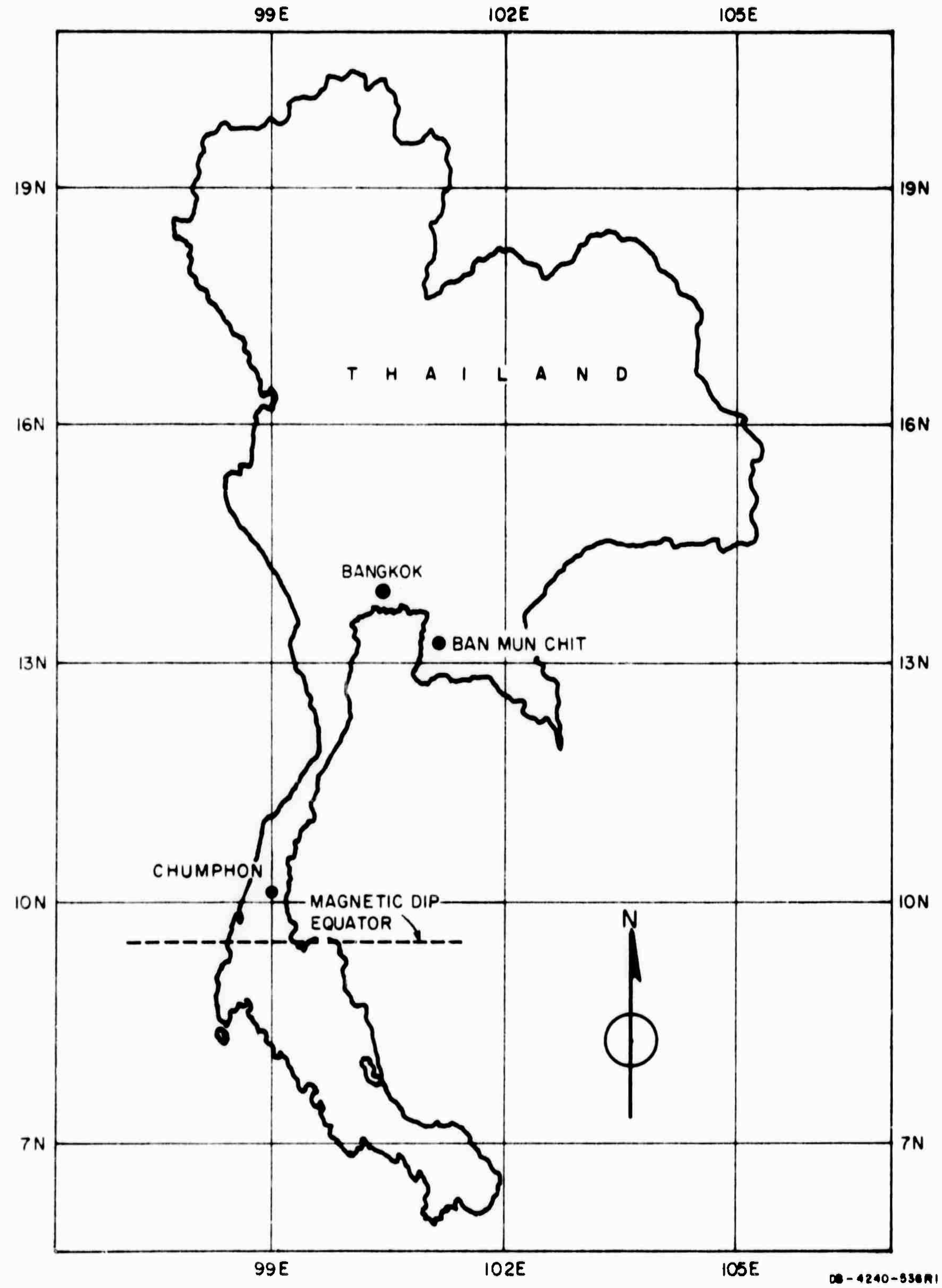


FIG. 21 SRI SITE LOCATIONS IN THAILAND

Two locations for antennas and equipment were used in the forest, separated by a distance of approximately 4.8 km, as shown in Fig. 22. The terrain between the sites was fairly flat and free of large clearings. Fig. 23 is an aerial photograph of the Ban Mun Chit forest with the sites marked. Ground views of the site are shown in the photographs of Figs. 24 and 25, which show an antenna in the clearing and a sounder van at the edge of the forest.

The forest has been classified as a dry-evergreen forest of a secondary nature.[11] Most of the valuable timber had already been removed, leaving only scattered rotten stumps and fallen trunks. The remaining stand is now formed either by species of little commercial value or by small trees associated with a dense undergrowth layer. Consequently, the crown canopy is discontinuous and of an uneven height of not less than 25 m. A second layer of foliage is formed by trees having a height of between 15 and 24 m. This layer too has been disturbed and is discontinuous. As a result of the gaps in the upper layers of the forest, the undergrowth is very dense and is composed of seedlings, climbers, herbs, and shrubs. Since nearly nine tenths of the trees are under 15 m in height, the foliage is chiefly found from ground level to a height of about 15 m. The foliage constants measured by open-wire line techniques[12] at a number of points in the forest at Ban Mun Chit showed that at 50 MHz the average value of relative dielectric constant, ϵ_r, varied from about 1.03 to 1.06. Conductivity of the foliage to 50 MHz measured at the same test points averaged from about 100 to 200 μ mho/m.

The topsoil is sandy and drains well after heavy rains. It is covered with a thick layer of humus and leaf litter. Ground constants were also measured at Ban Mun Chit. Three samples were measured at 50 MHz and yielded these average values: relative dielectric constant 11 and conductivity approximately 17 mmho/m which yield a loss tangent of about 0.5.

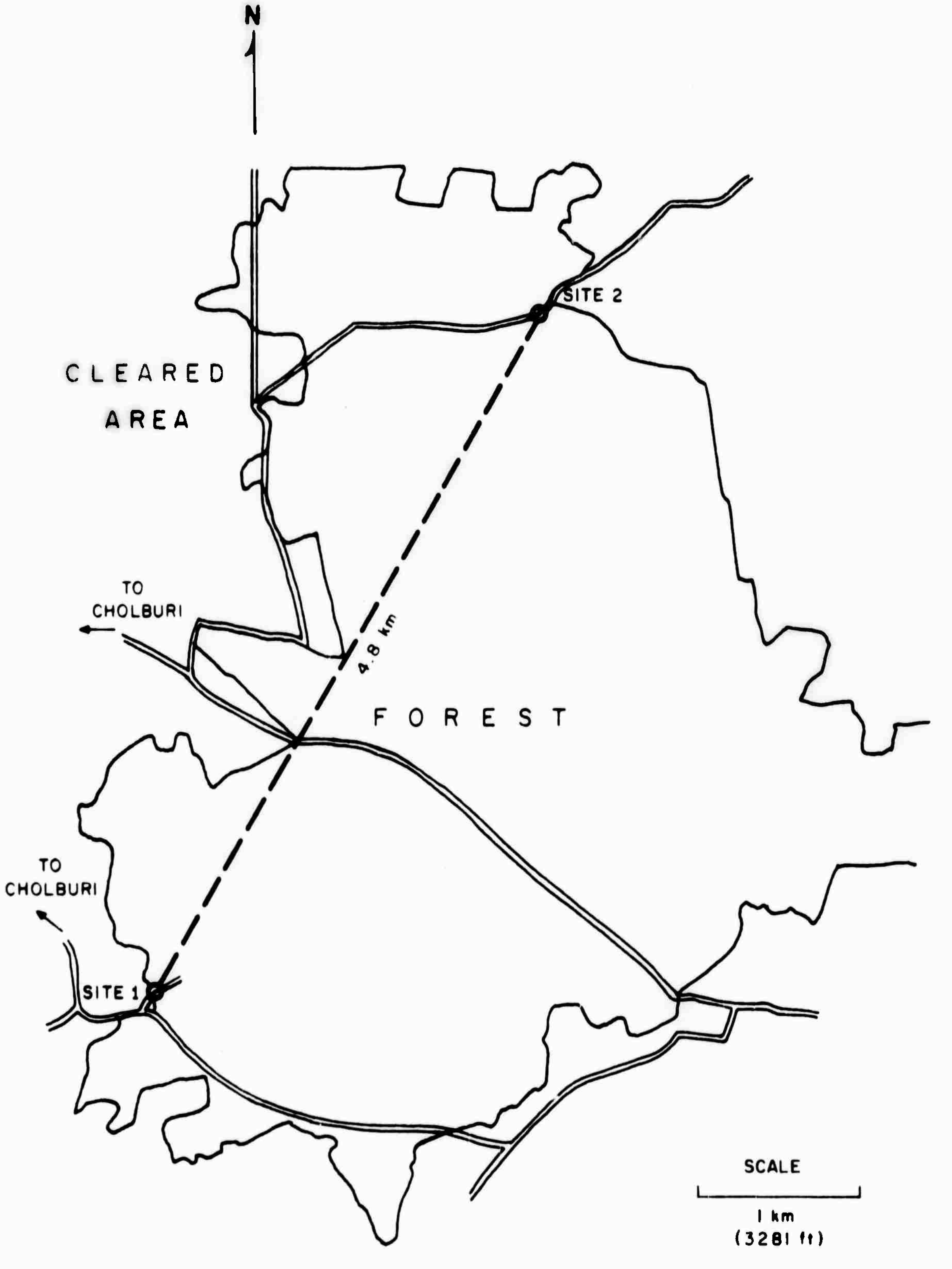


FIG. 22 FIELD SITES USED AT BAN MUN CHIT, THAILAND

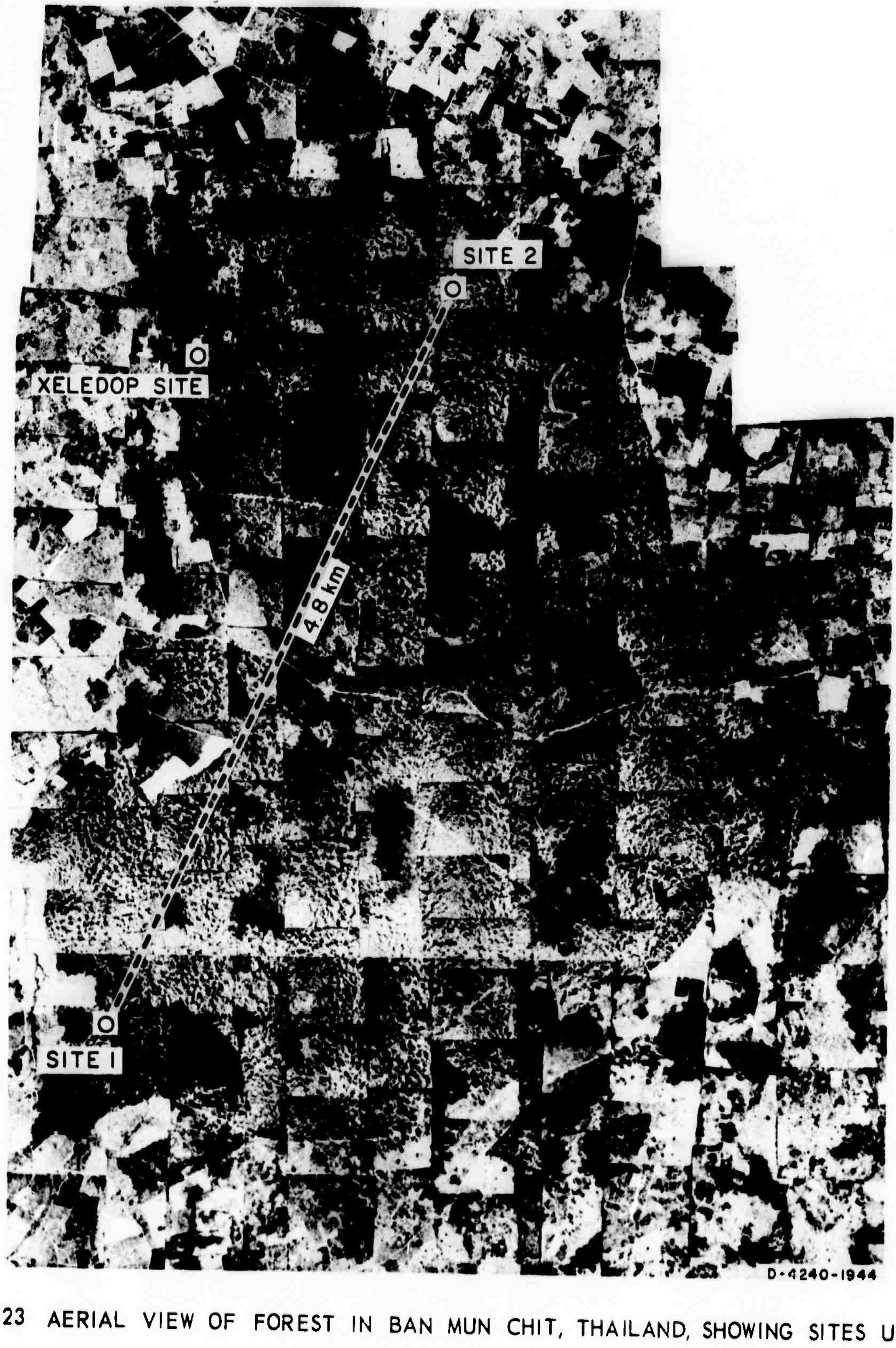


FIG. 23 AERIAL VIEW OF FOREST IN BAN MUN CHIT, THAILAND, SHOWING SITES USED

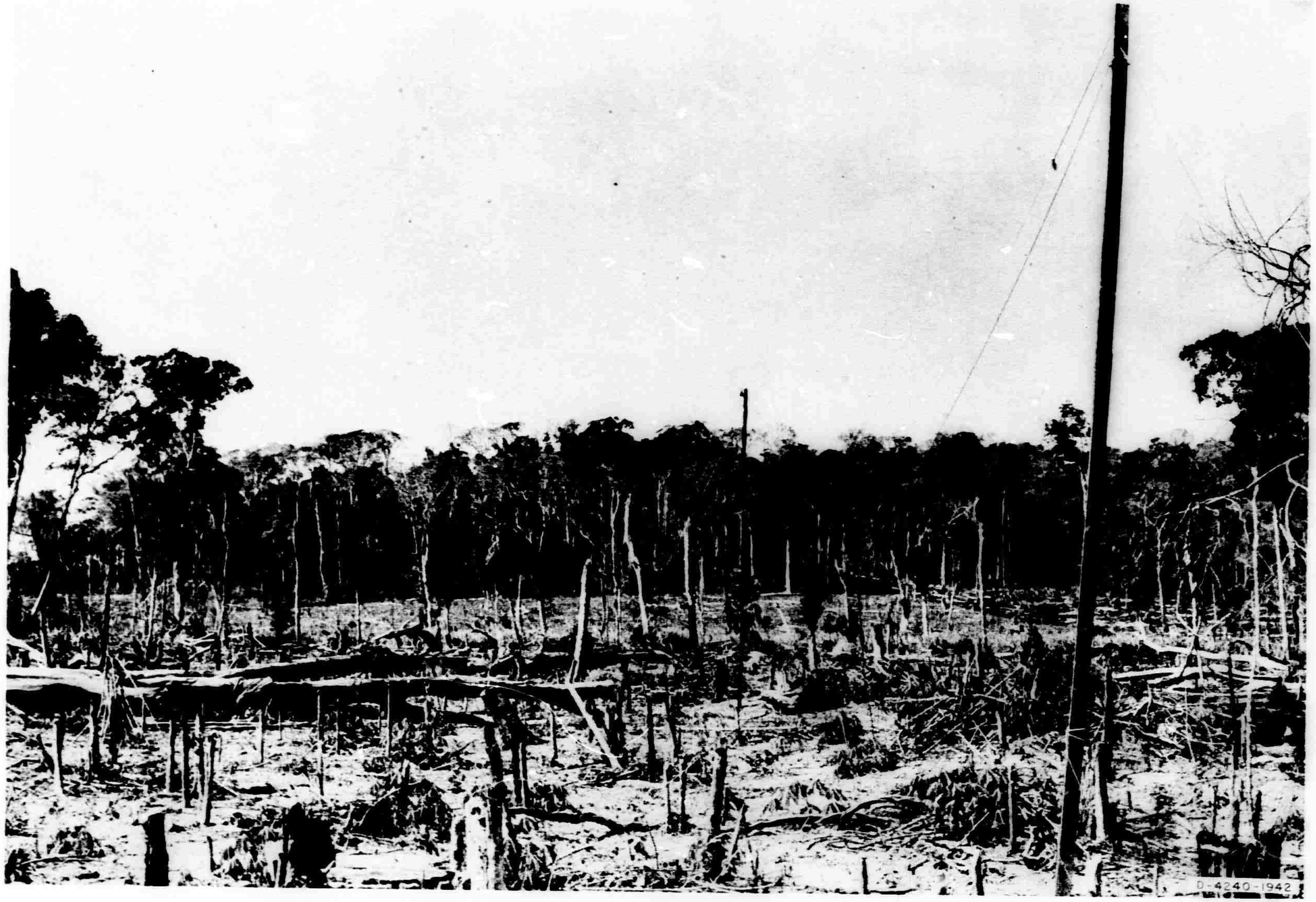


FIG. 24 ANTENNA IN CLEARING AT BAN MUN CHIT, THAILAND

FIG. 25 PHOTOGRAPH OF SOUNDER VAN AT EDGE OF FOREST IN BAN MUN CHIT, THAILAND

C. Test Procedure

One antenna of each type (see Sec. III-A-2 and Sec. III-A-3) was erected at each of the two sounder sites. Though the antennas were cut to resonate at 50 MHz, limitations in the frequency source of the sounders made us perform the tests at 49.2 MHz. Since only relative measurements were attempted, this fact is not felt to be important. The antennas were tested in various polarization and alignment configurations in three locations at each site (see Fig. 26). Two of the antenna locations were in the jungle approximately 100 ft apart. The third location was in a cleared area near the sites. The purpose of using two locations in the jungle was to note the difference in performance caused by a small change in antenna location. There was little observable difference in type and amount of surrounding foliage between the two jungle locations.

Radio communication between sites was used to coordinate on the type, alignment, and location of the particular antenna under test. On completion of antenna installation and alignment, Sounder Van 2 would begin transmitting 1-ms pulses at a 20-pulse-per-second rate for 10 seconds. This was repeated once per minute until sufficient data had been recorded at Sounder Van 1. The transmitter output level at Sounder Van 2 was closely monitored to ensure the same power level for all antennas. At Sounder Van 1, the signals were received and recorded on the electrostatic printer. When sufficient data were collected on a particular antenna, it was removed and replaced with the next antenna to be tested. This procedure was repeated for the various configurations and locations for each antenna type.

As was previously mentioned, the electrostatic printer produces a record of amplitude versus time, and in this case the received signals show up as a series of closely spaced black dots on the record. Each black dot in the series represents one received pulse, and the vertical displacement of each dot represents the amplitude of that particular received pulse. The horizontal dotted lines are amplitude marks and are calibrated in 3-dB steps, with the top line representing a

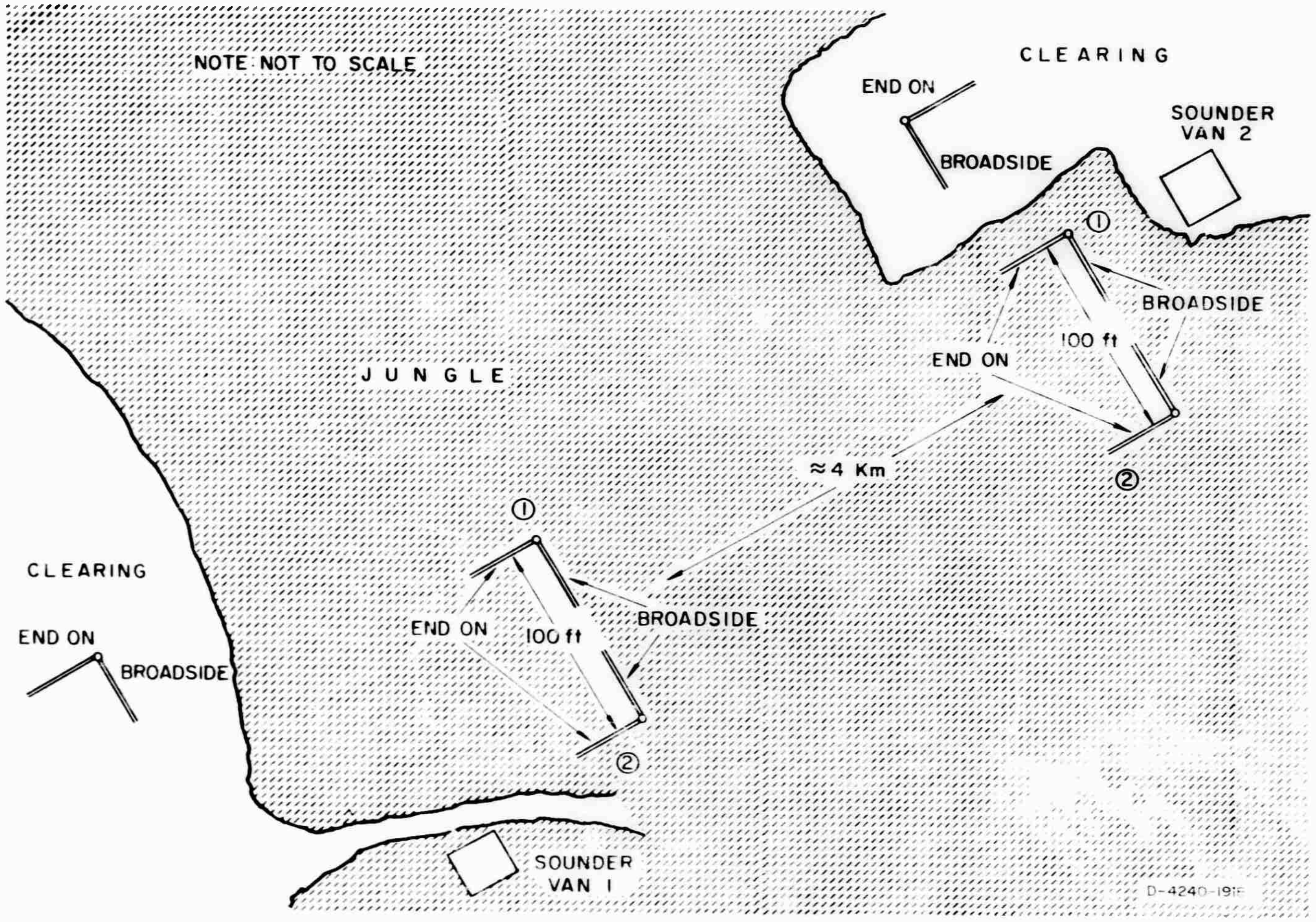


FIG. 26 ANTENNA AND EQUIPMENT LOCATIONS AT BAN MUN CHIT, THAILAND

received signal level of approximately 6 microvolts at the receiver terminals. Since a fairly wide range of received signal levels was encountered, fixed attenuation was inserted in the transmission line to the receiver on some samples to keep the received signal level within the range of the electrostatic printer. Figure 27 shows a selected example of received signal data: 49.2-MHz vertical dipoles in jungle and clearing. The relative gain data scaled from these records are probably accurate to ±1 dB.

Unfortunately no antenna feed-point impedance data were obtained at this site. Consequently, it is not possible to determine the contribution to the observed relative gain data resulting from differential mismatch loss.

D. Discussion of Results

The following results (see Fig. 28) were obtained using the previously described equipment and test procedures.

1) Best performance was obtained in the jungle using horizontally polarized dipoles aligned broadside to each other, and this combination was more than 15 dB better than any other combination of horizontal dipole alignments and at least 23 dB better than vertical dipoles at the same jungle location.

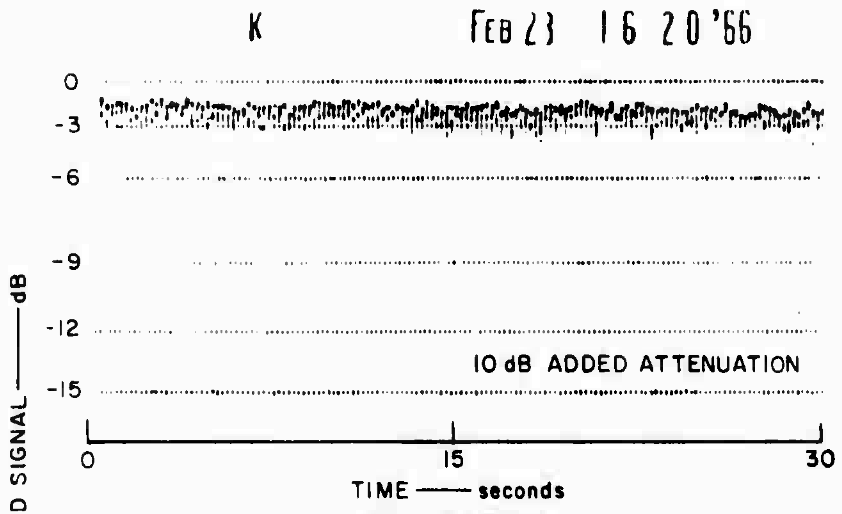
2) The relative gain of the horizontal dipole pair (aligned broadside) at a given location over the other combinations tested in the jungle at the same location was essentially the same for the two jungle locations tested, with one exception: the case where the horizontal dipoles were aligned end-on (see Fig. 29).

3) Best performance was obtained in the clearing using vertically polarized dipoles; but the relative gain of the horizontally polarized dipoles (aligned broadside) in the clearing was essentially the same (down only 0.5 dB), and at Jungle Site 2 was still about 6 dB greater than for the vertically polarized dipoles in the clearing.

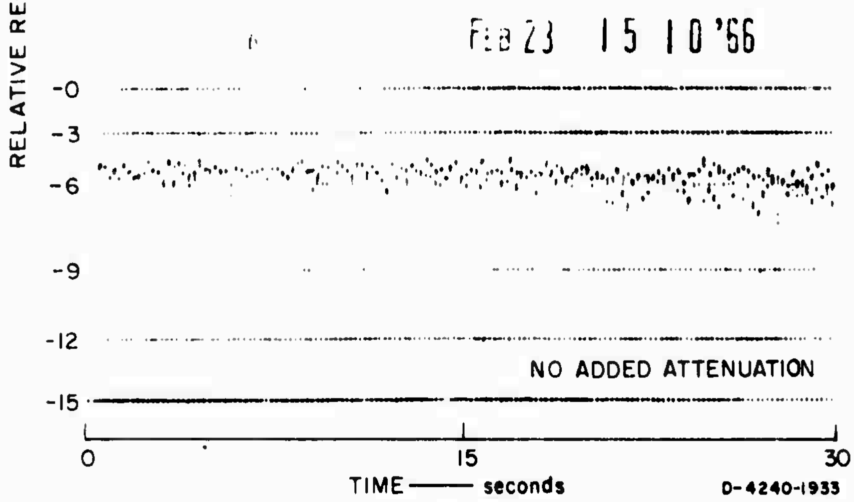
(4) Both the monopole and the vertical dipole showed substantial improvement in the clearing, indicating that foliage near the antenna can have a pronounced effect on vertically polarized antennas.

(5) Less difference was noted between the performance of the horizontal dipoles in the jungle and in the clearing, indicating that the surrounding foliage has relatively less effect on the horizontally polarized antennas.

(6) A small change in location within the jungle produced a significant change in antenna performance, perhaps because of scattering from surrounding vegetation.



(a) CLEARING



(b) JUNGLE J2

FIG. 27 9190 ELECTROSTATIC PRINTER RECORD OF RELATIVE RECEIVED SIGNAL VERSUS TIME

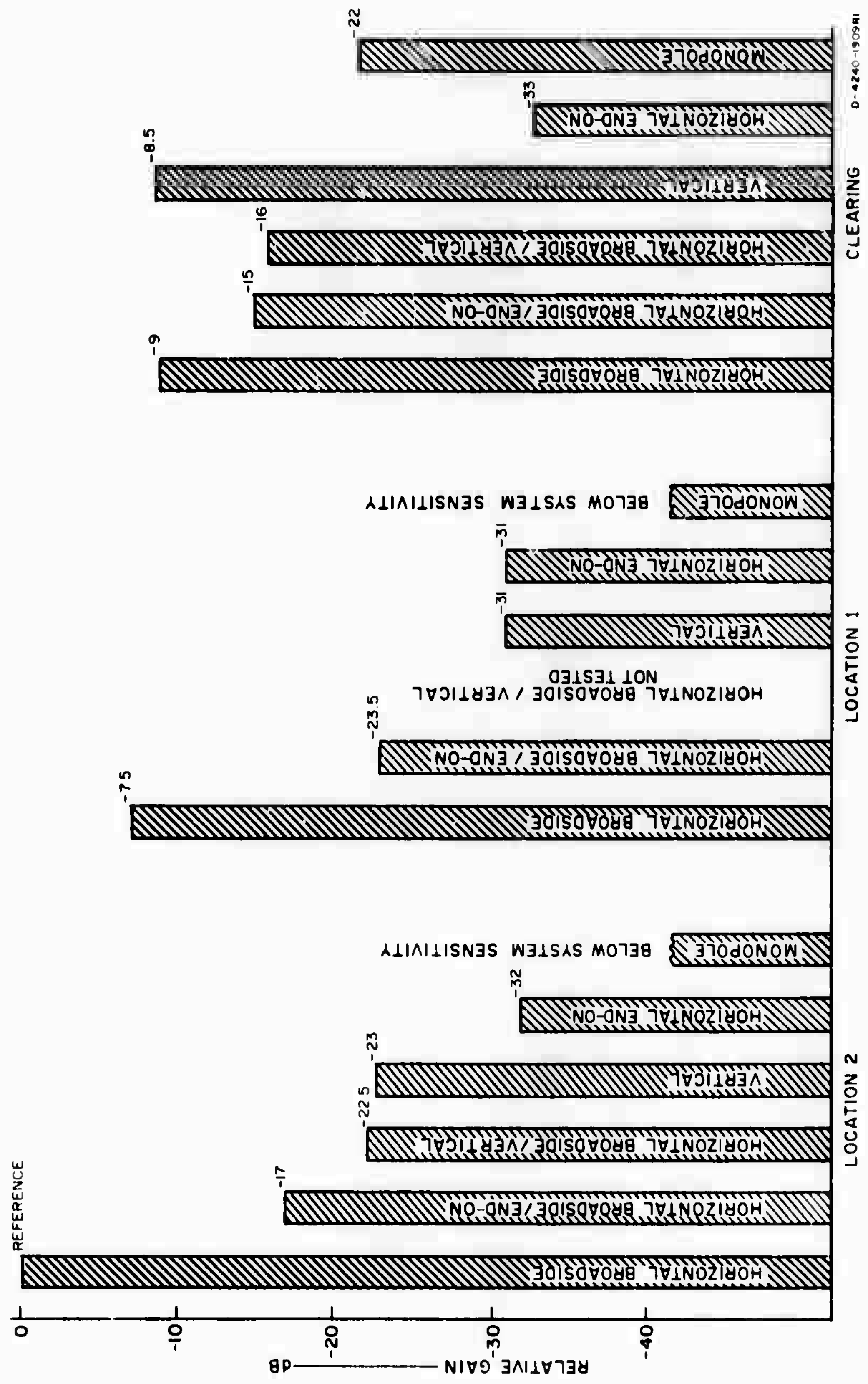


FIG. 28 RELATIVE GAIN RESULTS AT BAN MUN CHIT, THAILAND

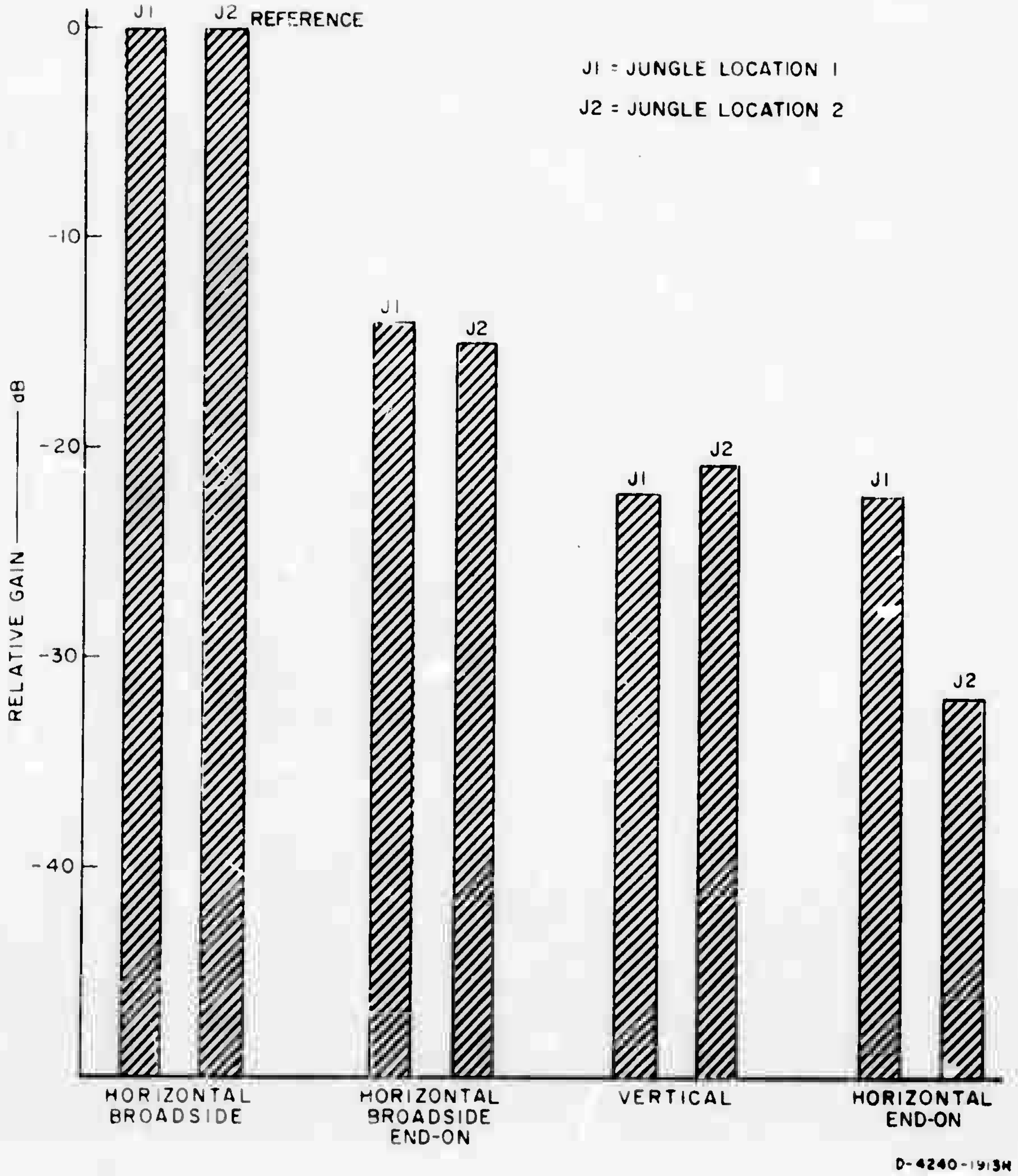


FIG. 29 COMPARISON OF RELATIVE GAINS AT TWO JUNGLE LOCATIONS

VI VHF GROUNDWAVE TESTS AT CHUMPHON, THAILAND

A. Introduction

The main purpose of the VHF groundwave tests in the vicinity of Chumphon, Thailand (about 400 km south of Bangkok on the Maylay Peninsula near the Isthmus of Kra--see Fig. 21) was to determine the relative effective gain of a pair of resonant horizontal dipoles over that of a pair of resonant vertical dipoles on paths of different lengths and characteristics. A secondary purpose was to measure the gain of the dipoles relative to the gain of log-periodic antennas (LPA's) similar to those used in the diffraction tests. To accomplish these goals three remote sites were chosen at about 5, 15, and 20 km from the base camp in the Wisai Nua forest. Their positions are shown on the map in Fig. 30.

B. Description of Sites and Propagation Paths

The soil and vegetation at the base camp in the Wisai Nua forest are described in Refs. 12 and 13. Figure 31 shows the antenna locations at the base camp and the bearings to the three remote sites. Profiles along these paths are shown in Fig. 32 with the vertical scale expanded by 16:1 over the horizontal scale.

Remote Site 1 was selected to provide a path between the main base camp and a remote site that lay over rough terrain. Along its 15.9-km length were a number of steep-sided hills with heavily forested sides and tops rising to heights over 150 m. Most of this region was inaccessible from the ground and from the air gave the impression of being heavily forested and undisturbed. Figure 33 shows the antenna locations at Remote Site 1.

Remote Site 2 was chosen to provide a path of length similar to Path 1 but over entirely different terrain. About one third of this path lay over cultivated paddy areas that were flat and clear except for a few palm trees. The remainder of the path near the Wisai Nua base

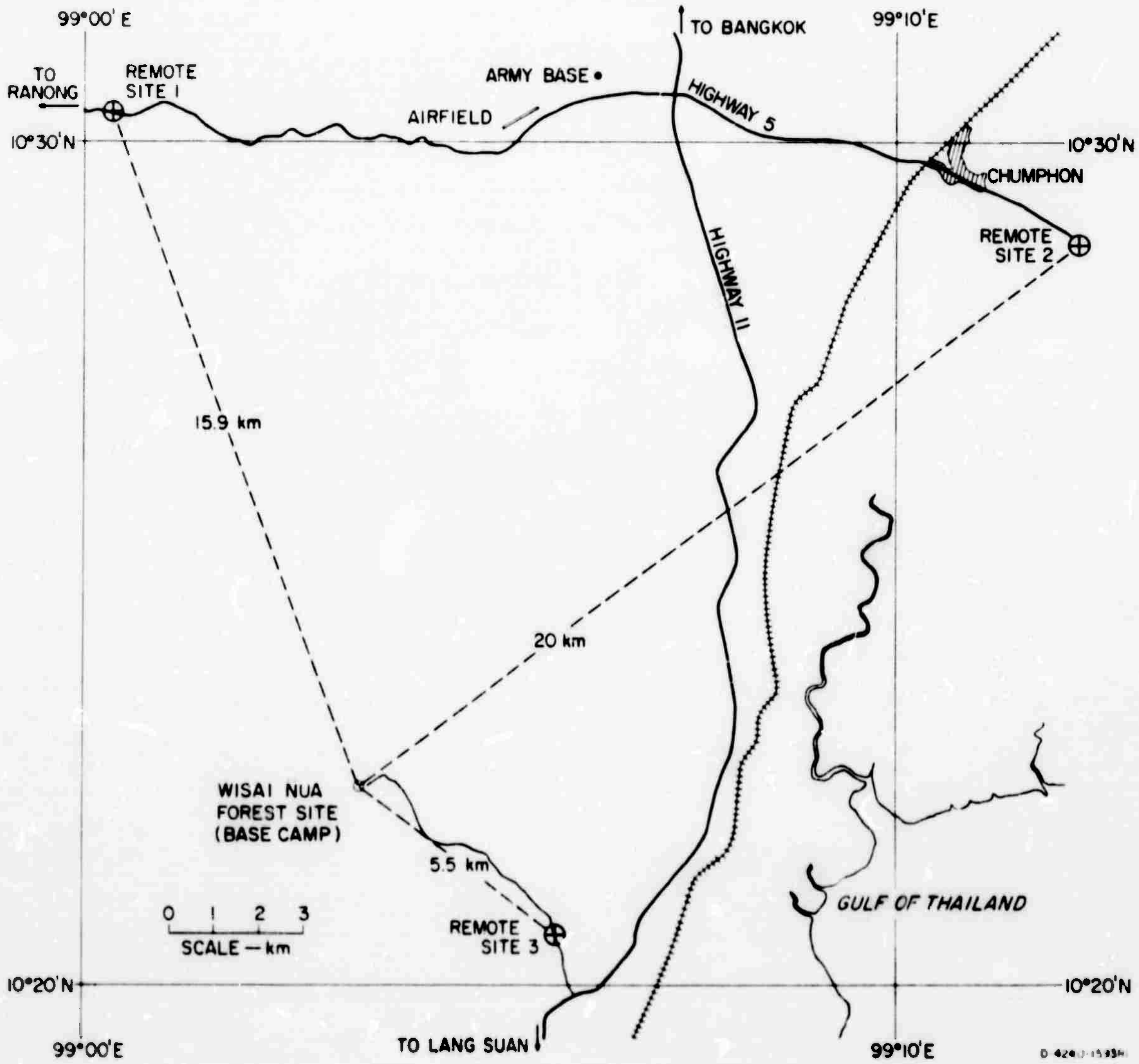


FIG. 30 MAP OF CHUMPHON, THAILAND AREA SHOWING TEST SITES

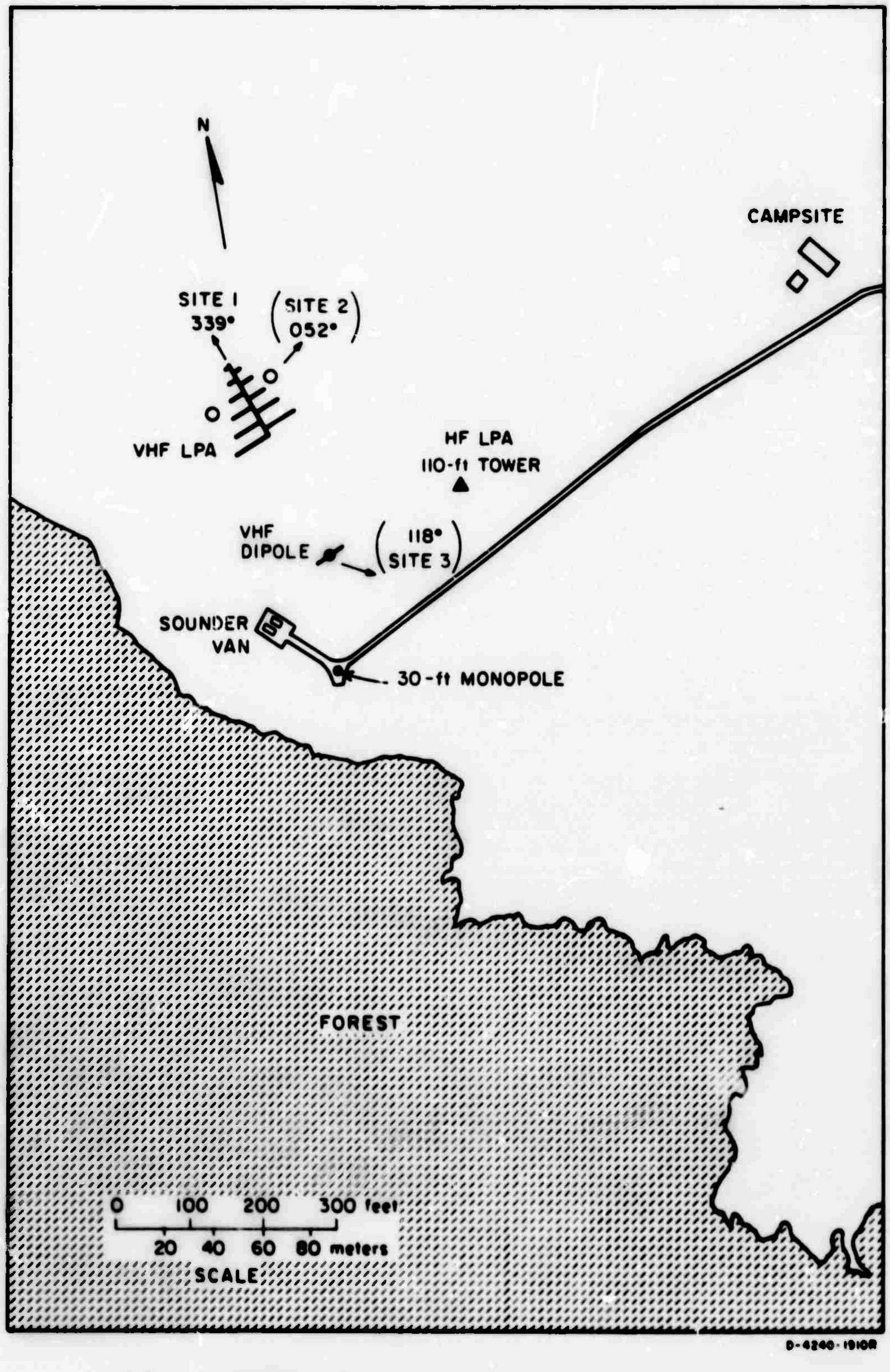


FIG. 31 ANTENNA LAYOUT AT WISAI NUA FOREST BASE CAMP
(near Chumphon, Thailand)

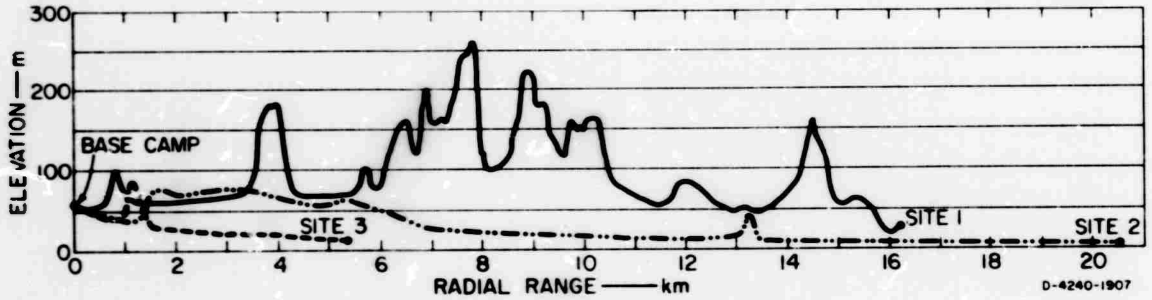


FIG. 32 PATH PROFILES FROM CHUMPHON BASE CAMP TO REMOTE SITES 1, 2, AND 3

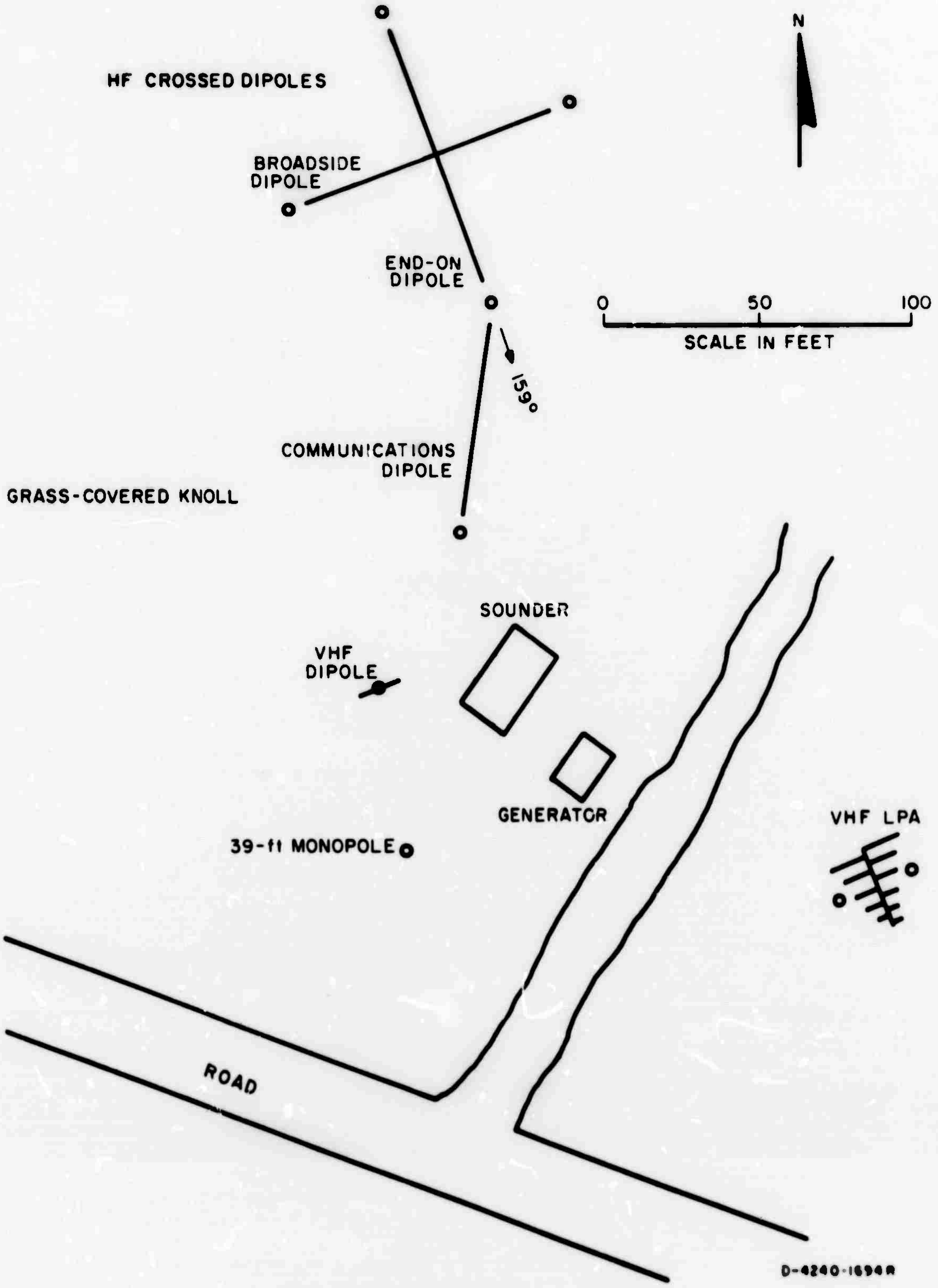


FIG. 33 REMOTE SITE 1 LAYOUT

camp lay over open, partially cultivated terrain that was flat with some trees. The path generally sloped down from the base camp at an altitude of about 50 m to the paddy areas near the river at an elevation of about 5 m. One small ridge of high ground rising to about 40 m cut across the path about 13 km from the main site. The path length was 20 km, about 4 km longer than Path 1, but the soft paddy areas devoid of roads prevented the heavy sounder from being moved closer to the main camp site along this bearing. Figure 34 shows the antenna locations at Remote Site 2.

Remote Site 3 was selected to provide a shorter path (5.5 km). It is over rather flat land with a small hillock near the base camp--the only major path obstacle. Most of the area was sparsely covered with trees or cultivated for banana and coconut palm crops. Figure 35 shows the antenna locations at Remote Site 3.

The ground at each site can be classified as electrically "good" ground. There was standing water at each of the sites during most of the test period. The ground constants were measured at the base camp;[12] and at 50 MHz a value of 30 was observed for the relative dielectric constant, while the effective conductive of the rather soupy soil was about 8×10^{-2} mho/m. The values at the remote sites were not measured, but they were probably somewhat lower than the values for the base camp stated above.

C. Measured Impedance Results

The LPA's were installed as indicated in Fig. 2. Dipoles were set up as indicated in Fig. 5. The feed-point impedance of these antennas was measured using a Dielectric Products Impedance Plotter. The values observed at each site are summarized in Table IV.

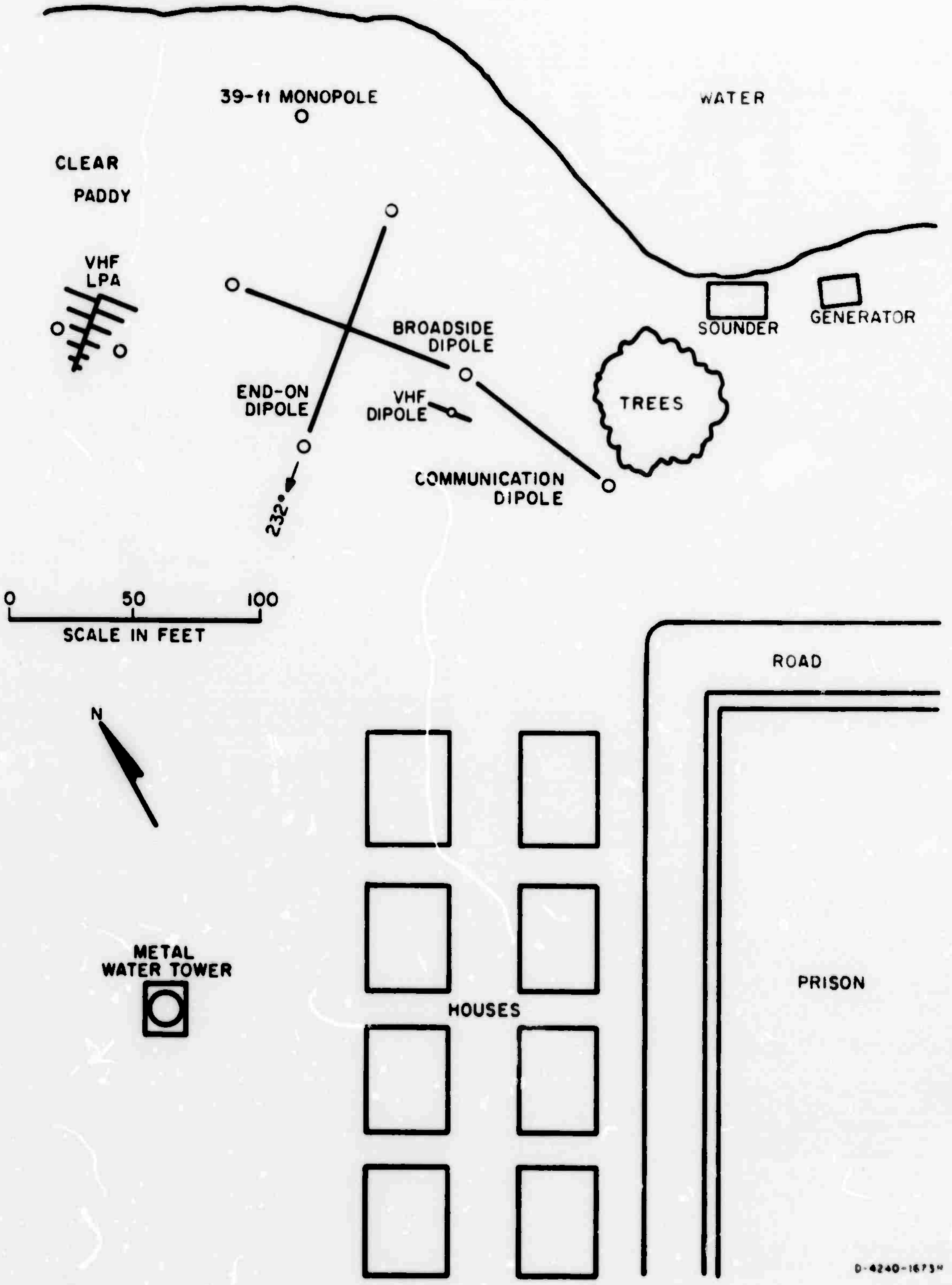


FIG. 34 REMOTE SITE 2 LAYOUT

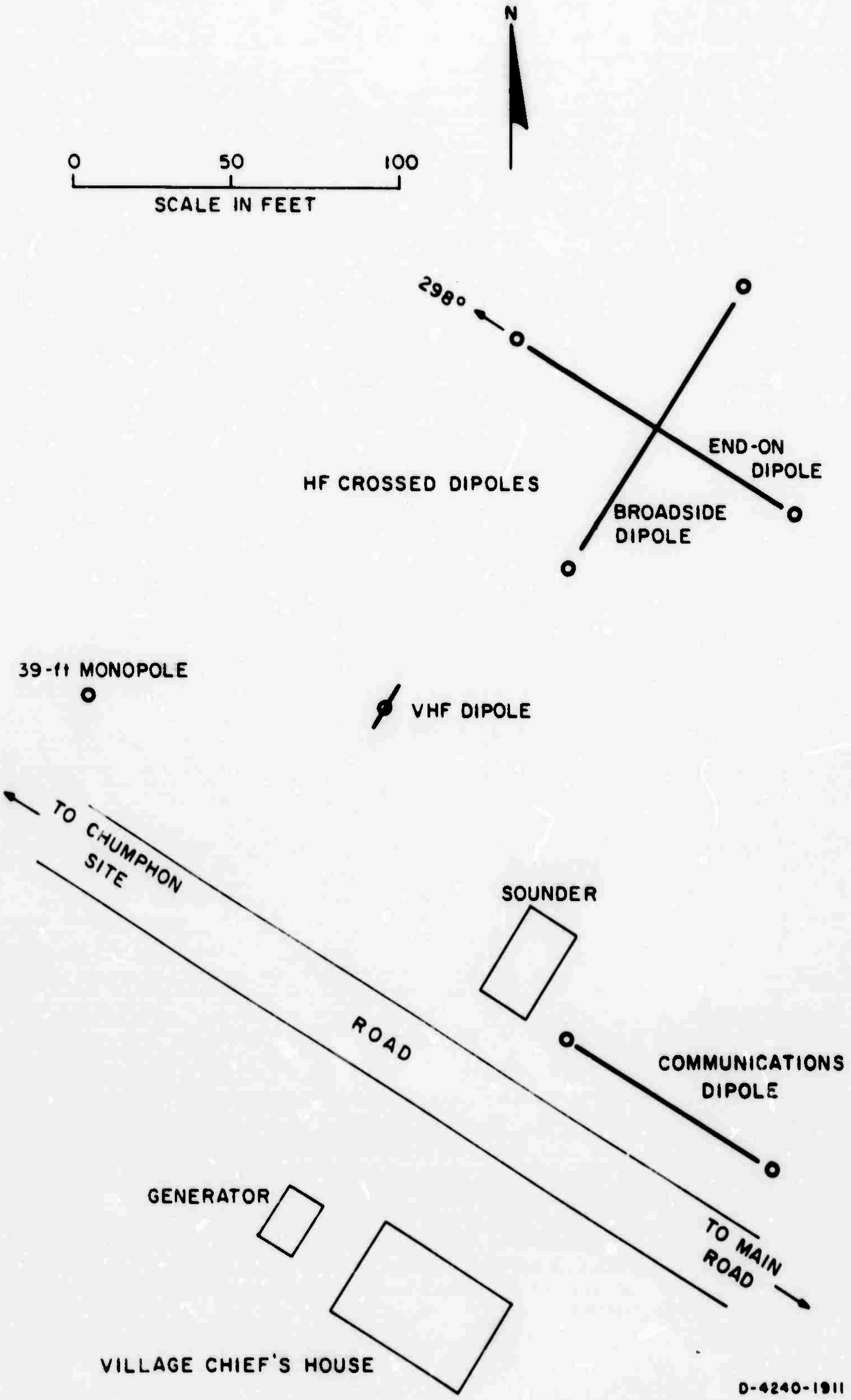


FIG. 35 REMOTE SITE 3 LAYOUT

Table IV

MEASURED FEED-POINT IMPEDANCE OF VHF ANTENNAS
USED AT CHUMPHON, THAILAND

Antenna Type	Freq. (MHz)	Impedance (Normalized to 50 ohms)			
		Base Camp	Site 1	Site 2	Site 3
Horizontal Dipole	31.8	1.40 - j0.60	1.80 - j0.20	1.65 - j0.19	1.88 + j0.40
	40.4	1.25 - j0.80	1.70 - j0.10	1.55 - j0.18	1.50 + j0.14
	50.0	1.03 - j0.69	1.42 - j0.28	1.28 - j0.29	1.20 - j0.40
Vertical Dipole	31.8	1.00 - j0.95	1.90 + j0.10	1.79 + j0.19	1.70 - j0.18
	40.4	1.09 - j0.78	1.41 - j0.41	1.50 - j0.28	1.25 - j0.25
	50.0	1.00 - j0.95	1.49 - j0.35	1.34 - j0.09	1.60 - j0.70
Horizontal LPA	31.8	0.13 - j0.15	0.30 + j0.05	0.08 - j0.05	Not Measured
	40.4	1.90 - j0.39	1.27 + j0.37	2.70 - j0.10	
	50.0	2.00 + j2.20	2.00 - j0.39	3.30 - j0.70	
Vertical LPA	31.8	0.38 + j0.04	0.30 + j0.24	0.25 + j0.26	
	40.4	1.48 + j1.00	1.40 + j0.35	1.21 + j0.38	
	50.0	1.98 + j0.59	2.60 - j0.40	2.50 + j0.00	

D. Relative Gain Results

The relative received signal results are presented in Table V. These data have been corrected for differential cable loss[*] but have not been corrected for mismatch loss which, for dipoles, was always less than 1 dB. Mismatch loss for the LPA's was 2 dB or less, except for the horizontally polarized LPA at 31.8 MHz at the base camp and Remote Site 2, and at 50.0 MHz at the base camp. Several useful comparisons can be made from these data: comparisons between different polarizations for the same antenna type, comparisons between antenna types, and (for Path 3 only) comparisons between different antenna configurations for the same type. These comparisons are discussed in the following subsections.

1. Comparison Between the Same Antenna Type Used in Different Polarization

The relative gains of the LPA and dipole pairs when used horizontally polarized over the same pairs when used vertically polarized are summarized in Table VI.

The results obtained with the VHF LPA's were in rather close agreement for all frequencies tested on both paths. The horizontally polarized LPA pair typically exhibited 4 dB (±2 dB) more received signal than the vertically polarized pair. When mismatch loss is not charged against relative antenna gain, the agreement is even better, since the horizontally polarized LPA's exhibited the greatest mismatch loss at the lowest frequency.

The results with the dipoles were less consistent. On Path 1, the vertical dipoles were 6 dB (±3 dB) better, and the 50-MHz result agrees reasonably well with the 0.5-dB relative gain of the 49.2-MHz vertical dipoles over the broadside horizontal dipoles in the clearing at Ban Mun Chit; but on all the other paths at Chumphon (excepting the 31.8-MHz results on Path 3) the horizontal-dipole pair performed better. When the LPA's were used, changing polarization generally caused less difference in received signal on a given path.

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[*] The actual cable loss was about 3.3 dB ± 0.5 dB for each antenna and in the frequency range of interest.

Table V

RECEIVED SIGNAL STRENGTHS AT CHUMPHON, THAILAND*

Path	Freq. (MHz)	Vertical Polarization			Horizontal Polarization		
		Trans. Ant.†	LPA Rec. Ant.§	VD Rec. Ant.	Trans. Ant.	LPA Rec. Ant.§	BSD Rec. Ant.
1	31.8	LPA	-19.4	-21.4	LPA	-17.4	-21.4
	31.8	VD	-13.9	-15.4	BSD	-22.4	-23.9
	40.4	LPA	-23.9	-18.4	LPA	-20.4	-27.4
	40.4	VD	-26.9	-26.9	BSD	-26.4	-35.4
	50.0	LPA	-15.4	-18.4	LPA	-10.4	-14.9
	50.0	VD	-16.4	-18.4	BSD	-16.9	-21.4
2	31.8	LPA	-13.0	-15.0	LPA	-9.0	-32.0
	31.8	VD	-12.5	-14.5	BSD	--	--
	40.4	LPA	-10.0	-16.5	LPA	-5.0	-29.0
	40.4	VD	-7.0	-14.5	BSD	-11.0	Δ
	50.0	LPA	-8.0	-16.0	LPA	-2.5	-13.5
	50.0	VD	-14.5	-24.0	BSD	-9.5	-14.0
			EOD Rec. Ant.			EOD Rec. Ant.	
3 (with HF LPA tower)	31.8	VD	-16.0	-3.0	BSD	-15.0	-5.0
	31.8	EOD	-28.0	-3.0	EOD	--	-5.0
	40.4	VD	--	-40.0	BSD	§	-18.5
	40.4	EOD	Δ	§	EOD	--	-18.0
	50.0	VD	-27.0	-16.0	BSD	-29.5	-10.0
	50.0	EOD	-27.0	-16.5	EOD	--	-8.0
3 (without HF LPA tower)	31.8	VD	-11.5	+3.0	BSD	-15.0	-4.0
	31.8	EOD	-27.5	-8.0	EOD	--	-18.0
	40.4	VD	-5.3	+3.0	BSD	-11.0	+4.8
	40.4	EOD	-18.0	-8.0	EOD	--	-8.0
	50.0	VD	-7.5	+4.0	BSD	-5.0	+9.0
	50.0	EOD	-17.5	-10.0	EOD	--	-8.8

* The received signal strengths are given in dB relative to 100 µV across 50 ohms.

† LPA--log-periodic antenna BSD--broadside horizontal dipole
VD--vertical dipole EOD--end-on horizontal dipole

§ The antennas were used on Paths 1 and 2 only. The data for the EOD are placed in these columns for Path 3.

Δ Below system sensitivity.

Table VI

RELATIVE GAIN OF HORIZONTALLY POLARIZED ANTENNA PAIRS OVER VERTICALLY POLARIZED PAIRS

Antenna Pair	Frequency (MHz)	Path			
		1	2	W/HF LPA Tower 3	W/O HF LPA Tower 3
VHF LPA's	31.8	+2.0	+4.0	No Data	
	40.4	+3.5	+5.0		
	50.0	+5.0	+5.5		
Dipoles	31.8	-8.5	+18.5	-2.0	-7.0
	40.4	-8.5	No Data	+22.0	+1.0
	50.0	-3.0	+10.0	+8.0	+5.0

2. Comparison Between Antenna Types

Two basic types of antennas were used during the Chumphon VHF two-sounder tests: half-wave dipoles and LPA's. The dipoles were fed 10 ft above ground and the LPA's were fed at 15 ft above ground for both polarizations (see Figs. 2 and 5). For a given polarization the four possible combinations of transmitting and receiving antennas were used.

The antennas were located relatively close to each other, but they were not used in identically the same locations (see Figs. 31, 33, and 34). One measure of the importance of local siting effects is the apparent reciprocity (or lack thereof) in the results obtained by switching antenna types. In other words, if local siting effects are not significant, then the same received signal level should result when transmitting on an LPA and receiving on a dipole as when transmitting on the dipole and receiving on the LPA, etc. Good apparent reciprocity (within 2 dB) existed on Path 1, except for vertical polarization on 31.8 MHz. This was not the case for Path 2, where only the 31.8- and 50.0-MHz data for vertical polarization showed reasonable apparent reciprocity. It should be noted that the 40.4-MHz records were not of very good quality at any of the sites, and the results are probably less accurate on this frequency than on the other two VHF test frequencies.

The log-periodic antennas were generally superior to the dipoles on both paths and for both polarizations. The vertically polarized LPA pairs produced signal strengths 3 dB(±2 dB) greater than the vertically polarized dipole pairs in all but two cases: the nonreciprocal 31.8-MHz case on Path 1 and 50.0 MHz on Path 2, where the LPA pair produced a 16-dB greater signal than the dipoles. Possibly the presence of the 110-ft HF LPA tower (see Fig. 31) caused these differences. When these same LPA's and dipoles were used in horizontally polarized configurations, the LPA's were 11 dB(±4 dB) better than the dipoles. This gives an observed gain for a single LPA of about 5.5 dB over a horizontal dipole, and implies that the assumption of a 3-dB differential (used in Sec. IV) is reasonable. The extra 5 feet in LPA height probably was more significant in giving an advantage to the LPA's when the antennas were set up for horizontal polarization. A single dipole, when elevated from 10 to 15 feet, would experience an increase in gain (for a 1-degree take-off angle--see Fig. 20) of about 2 dB.

3. Relative Gain of Broadside-Dipole Pair Over End-On Pair

The relative gain of the broadside pair of horizontally polarized dipoles over the end-on pair was measured on the 5.5-km path (Path 3) at Chumphon. The antennas were set up in cleared areas and tested on 31.8, 40.4, and 50.0 MHz. Measurements were made before and after the 110-ft tower (HF LPA) was removed from the Chumphon base camp, and identical results were obtained on 31.8 and 40.4 MHz. The broadside pair produced received signals 22 dB(±1 dB) greater than the end-on pair. The 50.0-MHz tests indicated only a 17-dB superiority for the broadside pair prior to tower removal, but this increased to +26 dB after the tower was removed.

These results compare favorably with those obtained over a 5-km path on 49.2 MHz at Ban Mun Chit, where the broadside pair was 24 dB better than the end-on pair when the antennas were set up in cleared areas. Consequently, one can conclude that the relative gain of a broadside pair probably will be about 22 dB greater than that of an end-on pair in the lower part of the VHF band when the antennas are located in a clearing. This test also was performed on 49.2 MHz at Ban Mun Chit with the antennas located in the jungle. At Jungle Location 1 the broadside pair was 23.5 dB better--in good agreement with the clearing values--but at Jungle Location 2 it was 32 dB better.

4. Effect of HF LPA Tower on Results

The 110-ft HF LPA--used for ionospheric sounding at the Chumphon base camp--was present during VHF tests on all three paths at Chumphon. After the tests on the last path had been completed, the tower was removed and the Path-3 tests were repeated. Significantly different results were obtained except on the lowest frequency (31.8 MHz). It might be noted that the HF groundwave tests on 6.05 and 12.10 MHz[8] also were repeated on Path 3 after the tower was removed, and the tower apparently did not have a significant effect on the HF results.

5. Cross-Polarization Tests on Path 3

Tests also were made on Path 3 between the vertical dipole and the broadside dipole. The results for the VD transmitting to the BSD after the towers were removed was -13 dB (±2 dB) relative to 100 μV across 50 ohms on all three frequencies. The results obtained transmitting on the BSD were essentially reciprocal (to within ±3 dB) on the two lower frequencies and were within ±1 dB of the results obtained when receiving BSD transmissions on the EOD. At 50 MHz, however, a somewhat larger signal was received on both the VD and EOD (only -5 dB relative to 100 μV across 50 ohms). The results did not show reciprocity between antenna combinations when the towers were present.

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13. ABSTRACT

Two Granger Associates Model 911 sounders were used at VHF (32 to 64 MHz) to make path-loss measurements and relative antenna efficiency measurements on short groundwave paths (less than 50 km) in the United States and in Thailand. The first test consisted of measuring the path loss as a function of frequency on a 40-km diffraction path over a low, wooded ridge. These tests indicated that a simple scalar diffraction model did not predict enough loss by about 20 to 40 dB. Tests on 49.2 MHz over a 5-km level, forested path near Ban Mun Chit, Thailand showed that broadside alignment of horizontal dipoles at 10 ft above ground produced signal strengths 15 dB greater than any other combination of horizontal dipoles, and 20 dB greater than when the dipoles were aligned end-on (the worst alignment). In the forest, the broadside dipoles also produced signals more than 20 dB greater than vertical dipoles center-fed at the same height above ground. The vertical dipole pair produced about the same signal as the horizontal dipole pair when both antennas were moved into clearings adjacent to the forest, although the propagation path was through essentially the same vegetation. The vertical dipoles were better than quarter-wave vertical monopoles in the clearing. These vertically polarized antennas suffered significantly more degradation in the forest than the horizontally polarized antennas. Tests made on 31.8, 40.4, and 50.0 MHz near Chumphon, Thailand on 15- and 20-km paths using dipoles at 10 ft above ground and log-periodic antennas (LPAs) at 15 ft above ground indicated the superiority of the LPAs. When set up for vertical polarization, the pair of LPA's was typically 3 dB better than a pair of vertical dipoles; when set up for horizontal polarization, the LPA pair was about 11 dB better than the dipole pair set up horizontally at the slightly lower height.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
VHF Propagation						
Antenna Relative Gain						
Dipoles, Monopoles, LPA's						
Terrain Effects						
Diffraction Path						
Santa Cruz Mountains, California						
Foilage Effects						
Southeast Asia						
Thailand						
SEACORE						