675459

Semiannuol Report 8

Covering the Period 1 October 1966 through 31 March 1967

RESEARCH-ENGINEERING AND SUPPORT FOR TROPICAL COMMUNICATIONS

By: E. L. YOUNKER G. H. HAGN

H. W. PARKER

Prepored for:

U.S. ARMY ELECTRONICS COMMAND FORT MONMOUTH, NEW JERSEY 07703 CONTRACT DA 36-039 AMC-00040(E) ORDER NO. 5384-PM-63-91

SEP 3 0 1968

Distribution of this document is unlimited

TUTE

Reproduced by the

CLEARINGHOUSE for Federal Scientific & Technical Information Springfield Va. 22151



BEST AVAILABLE COPY

\$

STANFORD RESEARCH INSTITUTE

MENTO PARK CATLEORNEA



March 1967

Semiannual Report 8

Covering the Period 1 October 1966 through 31 March 1967

RESEARCH-ENGINEERING AND SUPPORT FOR TROPICAL COMMUNICATIONS

Prepared for:

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

CONTRACT DA 36-039 AMC-00040(E) ORDER NO. 5384-PM-63-91

By: E. L. YOUNKER G. H. HAGN H. W. PARKER

SRI Project 4240

Distribution of this document is unlimited.

Approved: W. R. VINCENT, MANAGER Communication Laborotary

> D. R. SCHEUCH, EXECUTIVE DIRECTOR Electronics ond Radio Sciences

> > Sponsored by ADVANCED RESEARCH PROJECTS AGENCY ARPA Order 371



ABSTRACT

Communication research in a tropical environment is needed to develop improved equipment and techniques for use by military forces in tropical environments. This report describes Stanford Research Institute's work on SEACORE (an acronym for Southeast Asia Communication Research) during the period 1 October 1966 through 31 March 1967. Among the topics under study were:

- (1) Airborne pattern measurements of antennas in vegetation
- (2) Measurement of electrical properties of vegetation and ground
- (3) Modeling of propagation through a scattering medium
- (4) Ionopsheric propagation and frequency prediction
- (5) Atmospheric radio noise.

PREFACE

The work described in this report was performed with the support, and using the facilities, of the Military Research and Development Center at Bangkok, Thailand, a joint Thai/U.S. organization. The cooperation of staff members of the Thailand Ministry of Defense, the United States Advanced Research Projects Agency, and the United States Army Electronics Command made possible the work described.

This report summarizes the technical effort conducted under Contract DA 36-039 AMC-00040(E) for the period covering 1 October 1966 through 31 March 1967. In several cases, work described has been conducted by Thai personnel assigned to the Military Research and Development Center. Readers interested in additional technical detail of the work accomplished are urged to consult the published reports listed in Sec. III for discussions of specific scientific investigations.

The operations analysis work conducted under the contract was reported separately in accordance with a special report schedule.

CONTENTS

ABST	RACT	• • •	· · · · · · · · · · · · · · · · · · ·	11
PREF	ACE	• • •		v
LIST	OF I	LLUST	RATIONS	ix
LIST	OF T	ABLES	•••••••••••••••••••••••	xi
I	INTR	ODUCT	TON	1
	Α.	Hist	orical Background	1
	В.	0bje	ctives	1
II	SCIE	NTIFI	C AND TECHNICAL INVESTIGATIONS	3
	A.	Scop	e	3
		1.	Task AAntenna Environment and Antenna System Investigations	3
		2.	Task BIonospheric and Frequency Spectrum Investigations	4
		3.	Task CSystem Test Format and Procedure	·
			Investigations	4
	Β.	Work	Accomplished During the Reporting Period	4
		1.	Task A: Antenna Environment andAntenna System Investigations	4
			a. Airborne Xeledop Studies	4
			b. Ionospheric Sounder Studies on Commonly Used Field Antennas	10
			c. Theoretical Models of Forest Electromagnetic Effects	10
		2.	Task B: Ionospheric and Frequency	
			Spectrum investigations	!4
			a. Bangkok-Chantaburi Oblique Path Experiment 2	!4
			b. Sounder and Auxiliary CW Measurements on N-S Paths in Thailand	31
			c. Frequency Prediction for 1967 4	0
			d. Faraday Rotation Experiments 4	1
			e. Magnetometer Results	45
			f. Atmospheric Radio Noise Measurements	15
III	PUBL	ICATI	ONS • • • • • • • • • • • • • • • • • • •	;9
	Α.	Publ	ished Reports	9

В.	Reports	App	ro	ved	a	hd	in	F:	ina	1	Pı	ep	a	at	10	n	•	•	•	•	•	٠	•	51
С.	Reports	Sub	mi	tte	d 1	to	C0'	TR	fo	r	Ap	pr	ov	al	•	•	•	•	•	•	•	•	•	62
REFERENCES	s 	• •	•	•	•	• •	• •	٠	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	63
PROJECT PI	ERSONNEL	• •	•	•	•	•	• •	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	67
DISTRIBUT	ION LIST	• •	•	•	•	•	• •	•	•	•	•	•	¢	•	•	•	•	•	•	•	•	•	•	69
DD FORM 14	473																							

ILLUSTRATIONS

Fig.	1	E ₀ Pattern of 23-ft Unbalanced 8-MHz Dipole in Thailand Foliage
Fig.	2	E Pattern of 23-ft Unbalanced 8-MHz Dipole in Thailand Foliage
Fig.	3	Signal Strength as a Function of Azimuth Received by Three Antennas in Forest
Fig.	4	Contour of Constant Power Density around Conductors of 300-ohm Balanced OWL
Fig.	5	Experimental Setup for Measuring Effect of Tree on Dipole Impedance
Fig.	6	Variation of Input Impedance of Resonant 100-MHz Dipole
Fig.	7	VHF Manpack Xeledop near Single Tree
Fig.	8	Conductivity of Foliage at Ban Mun Chit
Fig.	9	Open-Wire Line in Foliage at Pak Chong
Fig.	10	Electric Constants of Foliage at Pak Chong
Fig.	11	HF Open-Wire Line Setup for Calibration at Ban Mun Chit
Fig.	12	HF Open-Wire Line Immersed in Foliage at Ban Mun Chit
Fig.	13	VHF Equipment for Foliage Measurements at Ban Mun Chit
Fig.	14	Open-Wire Probe Measurement of Ground at Pak Chong 26
Fig.	15	Pak Chong Ground Constants as a Function of Frequency . 27
Fig.	16	Comparison of foF2 and MOF on Oplique Path (Bangkok-Chantaburi)
Fig.	17	Comparison of foEs and Maximum Frequency for Es on Oblique Path (Bangkok-Chantaburi)
Fig.	18	Occurence of Es at Terminals and on Bangkok-Chantaburi Path
Fig.	19	Comparison of MOF and Frequency of Maximum Multipath on Bangkok-Chantaburi Path
Fig.	20	Maximum Time Spread as a Function of Local Time for Bangkok-Chantaburi Path
Fig.	21	Map of Sounder Sites in Thailand

III MARCA

Fig.	22	Envelope Correlation of Signal Fading on Nakon Sawan-Prachuab Path	35
Fig.	23	Doppler Spread 5843-kHz Signal as a Function of Local Time	35
Fig.	24	Strength of 5843-kHz Signal as a Function of Local Time • • • • • • • • • • • • • • • • • • •	37
Fig.	25	Radio Teletype Errors as a Function of Local Time	37
Fig.	26	Equipment Vans at Songkhla Site	38
Fig.	27	LP Antenna at Songkhla Site	39
Fig.	28	Error in foF2 Predictions for Bangkok	42
Fig.	29	Electron Content for Faraday Rotation Data	43
Fig.	30	Faraday Rotation Fading Record	45
Fig.	31	Magnetic Dip Angle as a Function of Latitude	46
Fig.	32	Radio Noise for March-May 1966	48
Fig.	33	Radio Noise for September-November 1966	48
Fig.	34	Comparison of Measured and Predicted NoiseSpring 1966 .	50
Fig.	35	Comparison of Measured and Predicted NoiseFall 1966	50
Fig.	36	Comparison of Noise Measured at Three Stations in Asia	51
Fig.	37	Location of Low Man-Made Noise Site	5-
Fig.	38	Laem Chabang Installation of ARN-3 Equipment.	54
Fig.	39	Lightning Flash Count for December 1966	56
Fig.	40	Effect of Threshold on Lightning Flash Count	57
Fig.	41	Impulses at 20 Milz	58

x

TABLES

Table I	Comparison of Elevation Angles Associated with a Given Relative Gain in Three Environments	8
Table II	Comparison of Calculated and Measured (OWL) Properities of a Scattering Medium	.2
Table III	ARN-3 Noise-Measuring Equipment Specifications	55

xi

=

I INTRODUCTION

A. HISTORICAL BACKGROUND

During World War II, United States military forces operated extensively in tropical areas, thereby gaining considerable practical experience in communication problems in tropical forest and jungle areas. The pressure of military objectives limited scientific explorations into many of the specific problems that arose, resulting in sizable gaps in our knowledge of radio communication in equatorial regions. The Military Research and Development Center (MRDC) was organized as a joint Thai/U.S. Agency to conduct research on many subjects in a tropical environment, including communication research.

In 1962, the United States Army Electronics Command (USAECOM) and Stanford Research Institute (SRI) undertook the task of establishing an electronics laboratory in Thailand to facilitate a first-hand study of tropical communication problems. The MRDC Electronics Laboratory (MRDC-EL) was officially dedicated in September 1963. Staffing of the laboratory is a joint Thai/U.S. venture, with U.S. participation largely from members of the staff of SRI.

Overall direction of the U.S. portion of the MRDC has been assigned to the Advanced Research Projects Agency (ARPA) of the Department of Defense. The ARPA actively monitors and directs the work of the USAECOM and SRI. This function is carried out in Bangkok by the ARPA Research and Development Field Unit-Thailand (RDFU-T).

B. OBJECTIVES

The purpose of the work under Contract DA 36-039 AMC-00040(E) is to perform scientific and technical investigations and to support the MRDC in the areas of tactical and tropical communications. The original objectives of this effort were to:

- (1) Establish a facility for radio communication research in Thailand.
- (2) Establish suitability of various communication techniques in the tropical environment and establish values of pertinent environmental factors.

- (3) Solve existing communication problems and provide necessary engineering data to solve future communication problems.
- (4) Conduct technical tests of appropriate off-the-shelf equipments.
- (5) Analyze and evaluate these tests and recommend areas for future effort.
- (6) Formulate the equipment requirements to accomplish the task of field communication in the jungle, based upon existing and anticipated tactical requirements.
- (7) Train the Thai personnel assigned to the Electronics Laboratory so that they can utilize the facility, accomplishing this training as a natural course of operating the laboratory.
- (8) Aid those electronics projects in Thailand that appear especially useful to MRDC basic objectives and that enhance the scientific development of Thailand.

The task structure for accomplishing these objectives has necessarily changed during the progress of the work, but the basic objectives have been essentially constant during the several years of effort under this contract.

II SCIENTIFIC AND TECHNICAL INVESTIGATIONS

A. SCOPE

The project effort is concerned with radio communication in Southeast Asia. Support is furnished to the PRDC in the investigation and solution of radio communication problems in Thailand; however, most efforts are applicable to equatorial (or cronical) zone communication in general. Military communications with Thailand are typically medium-distance point-to-point communications or short-distance contact between a base station and mobile patrol. These operations take place in many types of terrain and vegetation.

The VIIF band may be used for short-distance paths where the signal attenuation due to terrain features or dense intervening forest is not too great; HF skywave communication is used for path lengths beyond VHF capabilities or for short paths in heavy forest or mountainous areas.

Unique questions arise from the use of HF for short skyvave paths and the use of HF and VFF in heavily forested areas, as well as from the special military problems encountered in Southeast Asia. In particular, the high radio noise level in Thailand due to tropical thunderstorm activity and the influence of proximity to the magnetic equator on ionospherically propagated waves are important factors related to the use of HF radio equipment. Furthermore, the effects of heavy forest on HF and VHF antennas and propagation have a significant bearing on the operation of equipment in these frequency ranges. Generally, these questions involve optimizing frequency allocation, radio set design, and tactical usage of equipment in this special environment.

To study such problems, several related research areas are being investigated. These are specified by the current Technical Guidelines (dated 20 May 1966) as follows:

1. Task A--Antenna Environment and Antenna System Investigations

- (a) Subtask a--Airborne Xeledop Studies
- (b) Subtask b--Ionospheric Sounder Studies on Commonly Used Field-Type Antennas

- (c) Subtask c--Theoretical Models of Antennas in Forests
- (d) Subtask d--Manpack Xeledop Work and Related Studies
- 2. Task B--Ionospheric and Frequency Spectrum Investigations
 - (a) Subtask a--Ionospheric and Frequency Predictions for Bangkok
 - (b) Subtask b--Faraday Rotation Studies
 - (c) Subtask c--Radio Noise Studies
 - (d) Subtask d--Anomalous Ionospheric Reflections Studies
 - (e) Subtask e--Oblique Sounder Studies

3. Task C--System Test Format and Procedure Investigations

(a) Subtask a--Survey of Military Testing Facilities

B. WORK ACCOMPLISHED DURING THE REPORTING PERIOD

- 1. Task A: Antenna Environment and Antenna System Investigations
 - (a) Airborne Xeledop Studies

The major effort on this task during the reporting period was processing the data obtained at Ban Mun Chit during the previous reporting period.

(1) HF Measurements

Processing of the HF data recorded on analog chart recordings has progressed favorably to produce stereographic contour plots of the relative received signal strength as a function of azimuth and elevation angle. Contour plots of the F_{ϕ} (horizontal) and E_{θ} (vertical) polarization response of the 8-MHz, 23-ft-high unbalanced dipole are shown in Figs. 1 and 2. This antenna was erected about 350 ft inside the forest and to the same specifications as used at the previous sites. The relative gain values on the contour plots are referenced to the largest observed signal strength, which (for these dipoles) occurred during the highest orbit (highest elevation angle for which data were obtained). Therefore, the dB contours are not referenced to the maximum gain of the dipole (which should occur at the zenith). Model calculations





indicate the increase in gain from 60 degrees (near the highest orbit) to 90 degrees is only a few dB at the azimuth of maximum gain. 1*

One objective of the HF airborne Xeledop measurement program is to document the change in antenna performance when the same antenna structure is employed in different environments: level, open field (Lodi, California),^{2,3} U.S. conifer forest (Lake Almanor, California),⁴ and Thailand forest (Ban Mun Chit, Thailand).⁵ This is now possible for the 8-MHz, 23-ft-high, unbalanced dipole, even though the data are incomplete in places owing to loss of some data because of contamination of the records by man-made interference on the crystal-controlled Xeledop frequency.

The patterns are essentially "dipolar" in each case, although minor perturbations can be observed. The perturbations for the dipoles located in the vegetation are slightly greater than for the dipole in the clearing, and the patterns for the antennas in the vegetation display somewhat less symmetry.

A comparison of the elevation angles at which a given relative directivity occurred for the same dipole in the three different locations is given in Table I. The range of elevation angles indicated corresponds to the azimuth of maximum gain for a given polarization (i.e., broadside for horizontal polarization and end-on for vertical polarization). This elevation angle range was scaled from both main lobes of each patterns; in all three cases--for Lodi (clear), Almanor (conifers), and Ban Mun Chit (jungle)--these dB contours fall within the ranges indicated in Table I.

We noted that E_{ϕ} main lobes usually had their directivity patterns broadened out toward lower angles when going from clearing to forest; but the directivity of the E_{θ} main lobes was essentially unchanged when the antenna was in forest. The horizontal patterns showed more variations, especially assymmetry.

(2) VHF Measurements

Processing the magnetic tape records obtained in connection with the digitizer (used to convert the received signals to digital form and recorded on magnetic tape at the time it was taken) proved

References are listed at the end of this report.

TABLE I

COMPARISON OF ELEVATION ANGLES ASSOCIATED WITH A GIVEN RELATIVE GAIN IN THREE ENVIRONMENTS

Contour	Elevation Angle Range									
(dB Relative	llorizor	ntal Polariza	tion (E_{ϕ})	Vertical Polarization (E_{θ})						
maximum)	Clear	Conifers	Jungle	Clear	Conifers	Jungle				
- 3 - 6 - 9	40° 20° 15°	25° - 30° 20° - 25° 10° - 20°	40° -45° 10° -20° 5° -10°	45° 35° -40° 30° -35°	45° - 50° 35° - 40° 30° - 35°	40° -45° 35° -40° 30° - 35°				

more difficult than originally anticipated. Nevertheless, most of the magnetic tape records have been converted to a usable form. Scaling of analog records taken as backup was initiated for the few remaining runs.

Figure 3 is an example of signal strength received on three antennas located about 150 feet into the forest at Ban Mun Chit as a function of azimuth:

- C1 = 50-Mlz vertical folded dipole
- C2 = 75-Miz horizontal unbalanced dipole
- C3 = 100-Miz vertical sleeve dipole.

Each ordinate tick represents a 10 dB change in amplitude. The feed point of these antennas was located about 10 feet above ground.

The Xeledon was oriented vertically and flown at a slant range of 4 miles and an elevation angle of 25 degrees. These plots of raw data are examples of a preliminary computer plot produced on a cathode-ray tube (CRT) display and photographed. These are used to check the data for gross errors prior to final processing. Notice the significant perturbations (nulls to greater than 20 dB) similar to those observed on similar antennas in the eucalyptus grove in California.⁶





b. Ionospheric Sounder Studies on Commonly Used Field Antennas

No work was done on this task during the reporting period; however, it is anticipated that this task will be completed during the next reporting period.

c. Theoretical Models of Forest Electromagnetic Effects

(1) General

In the use of open-wire transmission lines (OWL) to make measurements among plant stems and branches, the question arises as to what degree measurements are affected by scatterers at different distances from the OWL. Figure 4 is a plot of contours of consumt power density[†] around the conductors of a 300 ohm (in air) balanced OWL. The conductors are at $X = \pm 1.0$. The values of the power contours have been normalized to that of the contour through the origin (bipolar center). Obviously the regions nearest the conductors carry the greatest power, so that scatterers there would have the greatest effect on the measurements. Theoretical work in this context has shown that more than 99 percent of the power in the transmission line mode is carried within a cylinder whose radius is three times the conductor spacing (S) centered on the origin in Fig. 4.

Using the fact that only scatterers in the immediate vicinity of the OWL (especially between the conductors) are important, and assuming trees appear as lossy dielectric cylinders, theorists at University of South Carolina have reduced the study of the scattering problem to one of finding the effects of a lossy capacitor shunting the line. The effects on open- and shorted-end impedance of a theoretical OWL have been computed under assumed conditions of random distribution of the lossy circuit elements along its length. A computer model has been written to perform the operations, based on knowledge of the statistical distributions of tree positions and

This section of the report deals with modeling work in progress at the University of South Carolina, supported under subcontract to SRI.

[†] The derivation of this power density was carried out by C. C. Han, and will be included in a Special Technical Report 42 (in preparation).



FIG. 4 CONTOUR OF CONSTANT POWER DENSITY AROUND CONDUCTORS OF 300-ohm BALANCED OWL

sizes in a forest. The user need only specify the intrinsic electric constants of tree stems in order to calculate the equivalent lossy capacitor representing any tree at any distance from the OWL.

An experiment was performed to verify this approach by comparing predictions from the scatter model with measurements made on an OWL repeatedly surrounded by wet wooden bars whose positions (80 in all) were assigned by throwing a die. The equivalent admittances of the wooden bars (for input to the model) were measured using the OWL. Two

sizes of bars were used: 1-square-inch and 4-square-inch cross section. The results averaged for five measurement trials and ten model permutations in each case are shown in Table II.

TABLE II COMPARISON OF CALCULATED AND MEASURED (OWL) PROPERTIES OF A SCATTERING MEDIUM

Scatterer Cross Section	Measur	ement	Model Computation				
(inches)	° r	δ	۴r	δ			
1 X 1 2 X 2	1.027 1.108	0.005 0.010	1.046 1.130	0.004 0.013			

The model obviously gave a reasonable prediction of the measurements made on an OWL placed at five positions among simulated "tree trunks." The work outlined here, together with results of further modeling studies on antennas placed in forests, which has continued at University of South Carolins, will be reported in forthcoming Special Technical Reports.*

(2) VHF Manpack Xeledop Measurements

Special Technical Report 26,⁷ covering the investigation of several types of terrain with the VHF manpack Xeledop, was prepared and submitted for approval for publication. Examples of the results of this work were given in Semiannual Report 6.⁸ One type of terrain investigated was foliaged beach, represented by an example near the Laem Chabang low-noise site. In order to check these measurements at a later time and in a different season (March rather than December), the VHF manpack Xeledop measurements on the foliaged trails were repeated and supplemented by open-wire line measurements of the electrical characteristics of the dense low shrubs

The original three-layer slab model reported in Ref. 1 has been extended to handle an n-layer slab and the following simple antenna types in addition to the short dipole: loop, monopole. along the trail. The data from this study are being analyzed and should provide a check of the lossy dielectric slab model for the case of propagation in undergrowth.

Preliminary work on the investigation of the effect of a single tree on the transmission of VHF signals from transmitter to receiver was reported previously.⁹ This work was continued along two lines. First, the effect of a nearby tree upon input impedance of a balanced^{*} resonant half-wave dipole was observed by measuring the resistive and reactive components of antenna input impedance as functions of distance between the tree and the antenna. Second, the VHF manpack Xeledop was carried along prescribed paths near the tree under study and the amplitude of the signal received at a fixed receiving site was measured. Impedance and signal strength were measured at frequencies of 50, 75, and 100 MHz with both horizontal and vertical polarization. Impedance measurements

were made on a large tree (about 5 ft in diameter at breast height), a small tree (about 2 inches in diameter at breast height), and a 4-inch OD aluminum mast about 20 ft high. A photograph of the experimental setup for measuring the variation in antenna impedance is shown in Fig. 5. The dipole is shown at a height of 10 ft (antenna feedpoint), vertically polarized, and very near the large tree. The antenna was supported by a stable tripod, which was moved along a level track and positioned at precise distances from the tree indicated by the stakes driven into the ground at the center rail.

Appreciable variation of the input impedance of the antenna was observed near the large tree and the aluminum mast, but the effect caused by the small tree was negligible. The variation of the resistive and reactive components of input impedance for the vertically polarized antenna at 100 MHz is shown in Fig. 6. The feedpoint of the antenna was set at 10 ft above ground (and at the beginning of the run at 14 ft from the tree), and the length of the dipole was adjusted to give zero reactive component. Only small impedance changes were observed at distances beyond about a quarter wavelength from the tree, but substantial

Baluns manufactured by North Hills (BB1105) were used at the antenna feed points.





FIG. 6 VARIATION OF INPUT IMPEDANCE OF RESONANT 100-MHz DIPOLE

changes took place at distances closer to the tree. Similar measurements made with the dipole in the horizontal position showed variations having the same general characteristics and somewhat smaller amplitude. These observations indicate that, even for a large tree, changes in input immedance of the antenna as it passes at distances more than a quarter wavelength from the tree cause less than 1 dB variation in the power transmitted from the antenna of a typical VHF manpack radio. Thus the large decreases in received signal strength experienced in the forest environment are caused by other factors than detuning of the antenna.

These impedance measurements were made on trees located at the Ban Mun Chit site on the edge of the area used in the May-June 1966 airborne Xeledop measurements of radiation patterns of tactical antennas.¹⁰

An attempt to measure the effect of single trees on VHF signal propagation was then made by measuring the signal received at a point remote from a tree as the VHF manpack Xeledop transmitter was carried near the tree. The receiving antennas used in the impedance tests were also used in this experiment and the standard manpack Xeledop receiver system was employed. It was found that the null in received signal was not as large as indicated by preliminary experiments⁹ using the same tree; furthermore relatively small perturbations -- such as tree stumps and unevenness of the ground--apparently tended to reduce variations in signal strength caused by the tree. Further measurements were made at a different site, where the land had recently been cleared and plowed and where all stumps and underbrush had been removed and the surface leveled (Fig. 7). More consistent results were obtained at this location but the magnitude of the tree effect was still smaller than that previously observed. These experiments show that there is some dependence of the magnitude of the single tree effect upon polarization: the larger effects occur with vertical polarization. Another interesting observation is that the metal pole produced effects similar to those for the tree on vertically polarized signals, but not for horizontally polarized signals. There was virtually no effect upon the received signal strength when the horizontally polarized Xeledop transmitter was carried past the metal pole; however, there was an observable effect nearly as large as that for vertical polarization when the horizontal Xeledop was carried past the large tree. Further work is needed in this study area.

(3) Open-Wire Line Measurements in Thailand

Considerable effort was spent in reducing the data on foliage and ground electrical characteristics obtained at the Ban Mun Chit field site during the previous reporting period.¹¹

Two computer programs have been developed in connection with the work. One accepts field measurements (impedance bridge readings) and computes open- and short-circuit impedances of the open-wire transmission line, automatically transforming past any standard connecting circuitry to the OWL input. The second accepts the computed line impedances and calculates the electrical parameters--such as dielectric constant, conductivity,



loss tangent, etc.--of the medium into which the line was inserted. Raw data from Ban Mun Chit for foliage considered typical of undisturbed growth between heights of 1.5 and 5 meters in semideciduous tropical forest, for an exceptionally dense volume of this foliage, and for tall tapioca plants were processed in Bangkok on an IBM 1620, which computed one numerical value for each parameter at each station measured. The validity of the results of the computation was checked and median and variance values were computed for each of the types of foliage. The results of the Ban Mun Chit foliage measurements of conductivity are summarized in Fig. 8. Significant differences can be seen between the typical undergrowth, the exceptionally dense undergrowth, and the tapioca plants.

The VHF open wire line and associated equinment were taken to the Jansky & Bailey (J&B) field site near Pak Chong for a brief series of tests (use of the site by J&B ended in September 1966) and measurements were made at a field point (FPB-1) on one of the trails used in the J&B measurements of path loss.¹² A volume of foliage typical of this field point (as well as of foliage along the entire trail) was selected with the help of members of the MRDC Environmental Sciences Division who accompanied the SRI crew. The open-wire line is shown in Fig. 9 inserted at one of the stations in this volume. The dark line running diagonally across the bottom of this photo is a small rope that was used to outline the matrix volume. Most of the measurements were made at 50, 75, and 100 MHz, but some were at 6 and 15 MHz. All measurements used the VHF open-wire line at 3-inch spacing. Median values of vegetation permittivity, conductivity, and loss tangent representing the foliage in the matrix at FPB-1 are shown in Fig. 10.

Further foliage measurements were made at the Ban Mun Chit site using the large HF version of the open-wire line. Two foliage samples were selected to be typical of the areas in which the HF and VHF antenna patterns had been measured by the airborne Xeledop technique in May and June of 1966. The HF OWL measurements were made in the 3 to 30 MHz frequency range to supplement data previously obtained with smaller VHF open-wire line. In the experiments, the length of the HF line was varied



FIG. 8 CONDUCTIVITY OF FOLIAGE AT BAN MUN CHIT

in increments of 20 ft by adding lengths of the 4-inch-diameter pipe of which the transmission line was constructed. A photograph of the HF line setup for calibration in the clearing is shown in Fig. 11. The large coil of coaxial cable in the foreground is a balun for matching unbalanced impedance bridges to the balanced open-wire line.

Figure 12 shows the open-wire line immersed in foliage typical of the forest at the Ban Mun Chit site. The equipment



FIG. 9 OPEN-WIRE LINE IN FOLIAGE AT PAK CHONG





FIG. 11 HF OPEN-WIRE LINE SETUP FOR CALIBRATION AT BAN MUN CHIT



.

setup for the open-wire line work is shown in Fig. 13, illustrating some of the practical difficulties of performing experimental work in a field environment. At one of the HF foliage samples, the small VHF open-wire line was used for measurements at 6, 15, and 30 MHz to allow comparison between the December HF and VHF line measurements and the VHF line measurements made in June 1966. Results are plotted on Fig. 8. The VHF OWL spacing used was 3 inches in all cases reported here; the HF OWL spacing was one meter, so that it could measure larger tree stems. The median results for both probes were fairly similar in these Ban Mun Chit data. Although June is a rainy season month, and December a drier one there, the reader is cautioned against drawing any conclusions about seasonal variation from these preliminary data.

We should stress that the measurements made with the OWL do not directly relate to either vertical or horizontal polarizations of plane waves, but lie somewhere in between. Integration of the power density in the OWL'S E-field, done as part of the theoretical modeling discussed in Section C, has given information about the power contained in each of the orthogonal E-field components for a 300-ohm OWL whose conductors are in the horizontal plane. For this case, the ratio of horizontal to vertical power densities is 3/2 when the orthogonal components are summed over the entire active region of the OWL. Since the CWL was most often used in the horizontal plane, there is some bias toward measurement of the effective horizontal electric constants of anisotropic vegetation, but the true anisotropy cannot be separated out.

In conjunction with the foliage measurements at the Pak Chong site, the electrical properties of the ground were also investigated. Measurements were made at dc as well as with the open-wire line probe at several frequencies in the range 6-100 MHz. The equipment setup during an open-wire probe ground measurement is shown in Fig. 14 and the variations of conductivity and dielectric constant with frequency are given in Fig. 15.

2. Task B: Ionospheric and Frequency Spectrum Investigations

(a) Bangkok-Chantaburi Oblique Path Experiment

During the previous reporting period an experiment¹³ was carried out to provide the basis for a comparison of vertical-incidence








ionospheric-sounding parameters measured at Bangkok and Chantaburi and corresponding parameters measured on the oblique path between the two terminals. In this work, one Granger sounder was located at the Bangkok laboratory and the other sounder was about 200 km distant. The sounders transmitted with a frequency sweep of 4-32 MHz in a sequence which permitted the recording of vertical-incidence ionograms at Bangkok and oblique-incidence ionograms at Chantaburi, followed immediately by recording of vertical-incidence ionograms at Chantaburi and obliqueincidence ionograms at Bangkok. Scaling of the vertical and obliqueincidence ionograms obtained during the Bangkok-Chantaburi experiment was completed and medians and quartile ranges were computed for all significant parameters. The results were supplied to MRDC in computer printout format for use in analysis of equipment performance on the Chantaburi-Bangkok path. One of the most significant results of this work is illustrated by Fig. 16, which shows median value of the F2 critical frequency measured at Bangkok, the F2 critical frequency measured on the oblique path between the two sites.* The two verticalincidence critical frequency curves are nearly identical, with a median difference of 0.2 Mllz. The difference between the vertical-incidence critical frequency and the MOF is somewhat larger, but generally is less than 0.5 MHz. This shows that the vertical-incidence measurements made at Bangkok can be used to predict the Maximum Usable Frequency (MUF) for vertical-incidence skywave paths near Chantaburi and the MUF on oblique paths between Bangkok and points in the vicinity of Chantaburi.

The characteristics of sporadic E measured at the terminals and on the oblique path are shown in Figs. 17 and 18. The three curves of Fig. 17 show that Sporadic E was observed between about 0700 and 1900 hours with an upper frequency limit extending to 6-8 MHz. The percentage of occurrence of Sporadic E at Chantaburi, at Bangkok, and on the oblique path is shown in Fig. 18.

No data are presented between 0300 and 0600 hours in Fig. 16. During this interval the critical frequency often dropped below 4 MHz, the lower limit of measurement of the Granger sounder; and the quantity of data was too small to calculate a reliable median.





FIG. 17 COMPARISON OF foEs AND MAXIMUM FREQUENCY FOR Es ON OBLIQUE PATH (Bangkok-Chantaburi)





An interesting test of definition is illustrated by Fig. 19, which shows median values of the MOF on the path between Bangkok and Chantaburi, a group of values equal to 85 percent of the MOF-usually defined as the frequency optimum for traffic (FOT)--and the frequency of maximum multipath occurrence. The curve of frequency of maximum multipath is always close to the FOT and in several cases overlaps it. This shows that a frequency selected to lie a fixed percentage below the maximum observed frequency is not necessarily the frequency for optimum transfer of information,¹⁴ because deterioration of the communication channel due to multipath can occur. Supplementary information in multipath is included in Fig. 20, which shows the maximum time delay of reflected returns as a function of local time.

(b) Sounder and Auxiliary CW Measurements on N-S Paths in Thailand

(1) Introduction

A major experiment using the Granger sounders in a program for mapping the ionosphere over Thailand was started during the previous period.¹⁵ The purpose of this study is to provide data and the resulting understanding necessary to improve frequency prediction for HF skywave communication. In addition to operating the Granger sounders to obtain vertical incidence and oblique path ionospheric data, experiments were carried out using a CW signal to gather data on ionospheric path loss and ionospheric stability. Radio teletype equipment was operated in parallel with the sounder and CW experiments to measure performance during the day and night and to relate it to ionospheric conditions. In the previous period, the sounder and auxiliary experiments were performed with the equipments located at Prachuab and Nakon Sawan, Thailand, which lie approximately 220 km south and north of Bangkok respectively (see map, Fig. 21).

(2) <u>Results of Auxiliary Experiments on</u> Nakon Sawan-Prachuab Path

In one of the CW experiments that was run in parallel with the sounder measurements, a 5843-kHz signal was transmitted by a NE-SW oriented dipole from Nakon Sawan to Prachuab, where the amplitude



FIG. 19 COMPARISON OF MOF AND FREQUENCY OF MAXIMUM MULTIPATH ON BANGKOK-CHANTABURI PATH



FIG. 20 MAXIMUM TIME SPREAD AS A FUNCTION OF LOCAL TIME FOR BANGKOK-CHANTABURI PATH

of the signals received on orthogonal dipoles (one oriented N-S, the other E-W) and the correlation of the fading of these two signals was measured. The median envelope correlation of the fading patterns for a period of four weeks (9 July to 5 August) is shown in Fig. 22. This figure illustrates that there is little correlation between the fading patterns except during the period between 1000 and 1400 hours corresponding to the time of day when Sporodic E is prevalent (see Fig. 18). A measure of the ionospheric layer stability in terms of Doppler spread is found in Fig. 23, which shows that the greatest instability occurs when spread F conditions are likely to be present (see Ref. 13). The magnitude of the signal received on the dipoles used on the correlation measurements is shown







the local sector and the

FIG. 22 ENVELOPE CORRELATION OF SIGNAL FADING ON NAKON SAWAN-PRACHUA8 PATH





in Fig. 24 as a function of time of day for the period of the experiment. The signal is quite strong in late evening, at midnight, and morning; however, it is much weaker in the few hours before sunrise and again at noon. The broad minimum centered at noon indicates increased ion spheric absorption.

The reliability of a radio teletype transmission at 60 wom as a function of local time is illustrated in Fig. 25, which shows the percentage of received characters containing one or more errors. The peak of errors occurs during the interval when the signal strength is low and the spread F conditions are maximum. Time-delay spreads at 5.8 MHz were only about half those shown in Fig. 20 for the shorter path. Preliminary analysis of the data indicates that low signal-to-noise ratio, rather than large Doppler or timedelay spreads, is the factor controlling the teletype error rate. Since initial measurements indicated a very low error rate during the day and a high rate at night, substantial data were collected only during the period 2000 to 0700.

(3) Further Sounder Measurements on N-S Paths in Thailand

In late September 1966, the sounder at Prachuap was moved to Songkhla and measurements were made on a path between Songkhla and Nakon Sawan until the middle of November, when the Nakon Sawan site was dismantled and its equipment moved to Chiengmai (see Fig. 21). The sounders were operated on the Chiengmai-Songkhla path from early December until the middle of March 1967. Vertical-incidence data on both paths were obtained at the terminals and oblique-path data were obtained for transmissions in both directions between the terminal sites. Continuous good data spanning at least four weeks were obtained for both vertical and oblique measurements for both paths, in addition to smaller quantities of valid data obtained hetween periods of equipment problems. Sounder equipment failure, mostly in the power amplifier section, and much diesel generator trouble, caused significant down time. The ionograms obtained during these experiments were sent to Menlo Park for processing and scaling, which has not yet been completed.

The Songkhla sounder site is shown in Fig. 26. The Granger sounder is housed in the van in the foreground, and the transmitter for the CW experiment, the receiving system for the S66 transmissions and a magnetometer are housed in the S141 shelter that sits beyond the sounder



FIG. 25 RADIO TELETYPE ERRORS AS A FUNCTION OF LOCAL TIME



FIG. 26 EQUIPMENT VANS AT SONGKHLA SITE

van. The antenna on top of this shelter is for receiving the 41-MHz satellite signals. The log periodic antenna used for both vertical and oblique incidence sounding is shown in Fig. 27. It will be observed that the bottom of the antenna curtain was raised to about 18 ft above ground. This change was necessary to improve the low-frequency performance of the antenna on the long oblique paths between Songkhla and Nakon Sawan and Songkhla and Chiengmai. The vertical radiation pattern of this antenna is broad enough that the quality of the vertical incidence ionograms did



FIG. 27 LP ANTENNA AT SONGKHLA SITE

not suffer appreciably. In the previous experiments where the distance between sounder sites did not exceed about 400 km, the LPA operated successfully when the lower end of the antenna array was only a few feet above ground.

(4) Continued Auxiliary Experiments to Supplement the N-S Sounder Tests

Auxiliary experiments were continued to gather data to supplement the results of the ionospheric soundings. A CW signal was transmitted from Songkhla to Nakon Sawan, where the signals were received on an E-W and a N-S dipole and recorded, and the correlation between the fading of the two signals was measured by the SRI correlation computer.¹⁶ The signal received from the N-S antenna was also applied to the Doppler spread meter to record the dispersion of power in the CW signal due to ionospheric instability. For these experiments a test frequency of 5843 kHz was used. In an additional experiment, an AN/MRC-95 radio teletype unit transmitted from Songkhla to Nakon Sawan on 5885 kHz. A prescribed test message was transmitted and the received message, which was later scaled for errors, was printed at the Nakon Sawan receiving site. The CW and radio teletype experiments were later carried out on the Songkhla-Chiengmai path, but because of the longer distance, frequencies of 7970 and 8015 kHz were used for the CW and radio teletype respectively. Reduction of the data from these experiments has begun in Bangkok.

(c) Frequency Prediction for 1967

Predictions of monthly medians for the F2 critical frequency at Bangkok for 1967 were generated and submitted to USAECOM for approval as Special Technical Report 28.¹⁷ The predictions were obtained by first generating a set of "standard" predictions from a computer program developed by SRI for the U.S. Army Radio Propagation Agency (RPA) several years ago¹⁸ and applying the correction function to these standard predictions. The correction function was derived from a comparison of SRI/RPA standard predictions for the period of April 1965 through August 1966 with monthly medians of actual measured values at Bangkok obtained by the C2 sounder. The predictions for 1967 show an average increase of about 1 MHz over the 1966 predictions and indicate that in 1967 an operating frequency up to 8 MHz

during the daytime with a minimum of 3 MHz just before sunrise can be selected as a conservative estimate for the vicinity of Bangkok.

In the study that produced the 1967 predictions, the effectiveness of similar corrections to predictions for the period 1965-66 was evaluated. The generation of these correction functions goes back to still earlier work¹⁹ in which predictions for the period September 1963 through March 1965 obtained from the SRI/RPA computer program and from world-wide maps prepared by the National Bureau of Standards^{*} (NBS)²⁰ were compared with C2 measured values obtained at Bangkok. The comparison of the resulting corrected SRI/RPA and NBS predictions for 1965-66 with the medians of actual measured values at Bangkok showed that for both methods of predictions. Figure 28 shows the degree of improvement of the corrected predictions relative to the standard and also illustrates that the corrected NBS prediction is more accurate than the corrected SRI/RPA prediction.

As a result of this evaluation, it was recognized that corrected predictions for 1967, based on NBS world maps, would be very desirable. However, the NBS computer program for the standard predictions was modified²¹ starting with the January 1967 predictions and therefore a correction function based on comparison of 1965-66 data cannot be applied with confidence to 1967 predictions.

(d) Faraday Rotation Experiments

Recordings from the Beacon satellite S66 were made on 40 and 41 MHz during the day and night at the Bangkok Laboratory throughout this period. Recording on 20 MHz at night was discontinued because usable records could not be obtained because of low 20-MHz signal strength and considerable interference. The recording and control equipment continued to operate reliably and more than 85 percent of the fading records show

The Central Radio Propagation Laboratory of the National Bureau of Standards, Boulder, Colorado--now called the Environmental Science Services Administration (ESSA) of the Institute of Telecommunication Sciences and Aeronomy (ITSA), U.S. Dept. of Commerce.



FIG. 28 ERROR IN foF2 PREDICTIONS FOR BANGKOK

the transverse position (T₀) required for reducing the data. Data reduction continued on a current basis and a Faraday rotation bulletin²² for the period of July-December 1966 was published. The plot of total electron content against local time taken from this bulletin is shown in Fig. 29. A secondary maximum of electron content occurred near midnight in early November (see ascending data) and to a much smaller extent early in August (descending data). The secondary maximum was also observed during May 1966.²³ Private communications with members of the Physics Department at the University of Hong Kong disclose that these effects have also been observed at that laboratory.

A 41-MHz satellite receiving station operated day and night at the Songkhla field site from September 1966 until the middle of March



FIG. 29 ELECTRON CONTENT FOR FARADAY ROTATION DATA

1967. A similar receiving station was operated at Nakon Sawan during October, November 1966 and at Chiengmai from December to mid-March 1967. Data from these field sites have been partially reduced, but the actual calculation of electron content depends upon a set of G constants, which is still being calculated. Considerable progress has been made in the programming of the mathematical equations for the calculation of these constants and the entire job will be completed early in the next period. Having detailed values of these constants for the range of latitude between Songkhla and Chiengmai will make possible the calculation of electron content by the simple analysis method at each of the remote sites. In addition, by means of the full analysis, the variation of electron content as a function of latitude may be obtained over a range of approximately 22 degrees, centered at Bangkok.

Data collected for calculating electron content of the ionosphere by the Faraday rotation technique have been used to calculate the magnetic dip angle at ionospheric heights. This calculation is based on accurate knowledge of the time, T_0 , when the signal ray path is orthogonal to the earth's magnetic field. This time is read from the chart recordings (Fig. 30) and the satellite position at this time is derived from the satellite ephemeris.²⁴ When the locations of the satellite and the receiving station are known and the rotation effect is assumed to be localized at a height corresponding to the centroid of the electron density profile, calculation of the dip angle becomes a problem of geometry. Magnetic dip angle for each station was calculated ^{*} from the transverse position (T_0) data collected at satellite receiving stations in Songkhla, Prachuab, Bangkok, Nakon Sawan, and Chiengmai. The results are shown in Fig 31, which also includes values of surface magnetic dip angle measured by the Geodesy Department, Ministry of Defense, Thailand.

The actual calculation was made for the latitude of the subionospheric point (the projection on the earth of the intersection of the ray path between the satellite and ground station with the centroid of the ionospheric electron density profile). The subionospheric point is slightly north of the ground stations for stations north of the dip equator, and slightly south for stations south of the dip equator. Extrapolation of the results from these stations (north and south of the dip equator), as a function of latitude (Fig. 31), places the magnetic equator very near 9.3 degrees N geographic latitude for this area, regardless of whether the surface or ionospheric data are used.



FIG. 30 FARADAY ROTATION FADING RECORD

The close agreement of the two sets of data indicate that the dip angle at ionospheric height is very close to the surface value in Thailand.

(e) <u>Magnetometer Results</u>

The Varian rubidium vapor magnetometer was operated at the Bangkok laboratory throughout this reporting period, and a second unit was operated at the Songkhla field site for about 90 percent of the time. For quiet days, diurnal variations of magnetic field strength as high as about $100-110\gamma$ at Songkhla and about $40-50\gamma$ at Bangkok were observed. Several severe magnetic storms were recorded. Following the magnetic disturbance of 16 February 1967 the ionospheric absorption near noon was abnormally high for about 10 days. In the other cases of magnetic disturbances however, no corresponding ionospheric effects were observed.

(f) Atmospheric Radio Noise Measurements

The ARN-3 noise measuring equipment was operated at the Laem Chabang low man-made noise site, and two parameters of atmospheric noise--the mean noise power, F_a , and the mean deviation of envelope voltage from the average power, V_d --were measured on a continuous basis throughout the period at 0.53, 2.3, 5.0, and 10.0 MHz. In November



.

the VLF converters were put into operation and measurement of noise at 3, 10, 27, and 160 kHz was initiated. The two lowest frequencies were later changed to 6 and 13 kHz to give a better balance of measuring frequencies. Noise data bulletins containing information on the four MF and HF frequencies for the March-April-May and June-July-August quarters of 1966 were prepared and the format was submitted to USAECOM for approval.

Operation of the ARN-3 noise measuring equipment at Laem Chabang during the 13 months following 1 March 1966 proved to be quite satisfactory. Calibrations were made weekly and it was found that during the first 50 weeks the average drift from one week to the next ranged from 2 to 3 dB for the four frequencies. This means that the average uncertainty of F readings due to drift in the equipment was less than 3 dB for all measured frequencies. A moderate number of component failures was experienced but on the average the measuring equipment was operable more than 75 percent of the time. During the first year of operation (March 1966 through February 1967) the monthly median value of F was based on an average of 22 days per month. For 75 percent of the time, 20 days or more were used in calculating the monthly median. The loss of data due to man-made radio interference (QRM) which propagated in did not change significantly from that reported in Semiannual 7.²⁵ The procedure for manually monitoring the equipment for about five hours in the morning and five hours in the evening to keep the recording pens on scale was followed without change. This has proved to be a satisfactory procedure since the operator can adjust the fine tuning of the receiver to avoid QRM in addition to adjusting the series attenuation to keep the pens on scale. Indeed avoiding interference by manual tuning of the receiver while listening is essential to the collection of reliable atmospheric noise data.

Seasonal time-block values of radio noise are given in Fig. 32 for the March through April 1966 quarter and in Fig. 33 for the September through November 1966 quarter. Each point on these curves represents the median of three months data for a four-hour time block. The quarterly median for the 0000 to 0400 time block, for example, is



plotted at 0200. The wide dispersion of noise amplitude with frequency between 0.5 and 10 MHz can be seen as well as the characteristic daytime minimum for all frequencies. It will be noted that the spread with frequency is more uniform in the Fall (September, October, and November) data than in the Spring data, and that the magnitude of noise for all frequencies is lower. A comparison of measured noise with that predicted from CCIR noise contour maps for 5 MHz for the Spring quarter is shown in Fig. 34 and a similar comparison for the Fall quarter is shown in Fig. 35. It will be observed that the measured noise is higher than the predicted noise during the spring, but that the agreement between predicted and measured noise in the Fall is excellent. An explanation of the difference in agreement between predicted and measured noise for the two seasons may be the difference in the contribution of local thunderstorms to the ARN-3 readings. The prediction should agree better with measured noise in the absence of local thunderstorms because predictions do not take into account local disturbances. Unfortunately, lightning flash data for Laem Chabang during the Spring months of 1966 are not available because the lightning flash analyzer had not been placed into operation.

Some work was done on the analysis of noise data received from ESSA for the Singapore and New Delhi stations. Figure 36 shows a comparison of noise measured at Laem Chabang with noise measured by ARN-2 equipment at Singapore and New Delhi. There is considerable similarity in magnitude as wel! as in the shape of diurnal variation from the data from the three measuring stations.

After the portable ARN-3 equipment was returned from the Khon Kaen field site at the end of the previous period, it was checked over carefully and modified to conform with the permanent equipment at Laem Chabang. It was then moved to the Laem Chabang site and set about 200 feet away from the permanent installation. The equipment was checked out thoroughly in the low man-made noise environment and was used to measure noise induced in the standard monopole without a ground plane. Near the end of the period experiments to measure the noise induced in a horizontal dipole were initiated. Four available channels in the portable





equipment were used as follows: a trapped dipole designed to operate as a tuned half-wave antenna at the frequencies of 2.3, 5.0, and 10.0 MHz was connected through a switch to an input of the measuring set and the receivers were tuned to 2.3, 5, and 10 MHz. This dipole was oriented N-S. A second trapped dipole of identical design was oriented E-W and connected through the switch to the input of the measuring set. The switch was operated automatically each 30 minutes giving alternate recordings on three frequencies of noise from the two dipoles. Two simple half-wave dipoles cut for 2.5 MHz were connected through another switch to the fourth channel of the noise measuring equipment. Noise induced in these dipoles, one oriented N-S in the open and the other N-S immersed in beach foliage was measured on a time-sharing basis on the same schedule as the trapped dipoles.

A comprehensive manual for users of the ARN-3 equipment was prepared and submitted to the sponsor for approval as Special Technical Report 27.²⁶ Excerpts from the manual are shown in Fig. 37, a map illustrating the relationship of Laem Chabang with other key points of Southeast Asia, Fig. 38, a photograph of the equipment installed at Laem Chabang, and Table III which gives a detailed list of specifications of the ARN-3 equipment.

The lightning flash analyzer was operated at the Laem Chabang site throughout this reporting period. Procedures for reducing the data obtained by photographing Veeder-Root counters each half hour were worked out and a standard tabular presentation was adopted. Lightning flash data for September 1966 through February 1967 were tabulated in this form and analysis was begun. An example of recent lightning flash data is shown in Fig. '39 which gives the monthly mean count for December 1966 as a function of local time. Some results of the preliminary analysis of the number of lightning flashes measured as a function of the threshold of the recording equipment are shown in Fig. 40, which compares the mean number of flashes for one month for the CCIR-type equipment at 1, 3 and 10 volt thresholds.

Supplementary information on impulsive noise observed at Laem Chabang is given in Fig. 41 which shows the signal level across the input to a receiving system intended to record the strength of a 20 MHz signal from an orbiting satellite as part of another project which was







FIG. 38 LAEM CHABANG INSTALLATION OF ARN-3 EQUIPMENT

Table III

ARN-3 NOISE-MEASURING

EQUIPMENT SPECIFICATIONS

Packaging: Three standard five-foot relay racks and two seven-foot relay racks. **Power Requirements:** 115 V, 60 Hz, 20 A; isclated. Frequencies: HF, four channels, each tunable 0.53 to 54 MHz. normally tuned to 0.53, 2.3, 5.0, and 10.0 MHz respectively. LF, four fixed-frequency converters accepting 160, 27, 13, and 6 kHz, respectively. Band-Pass: HF, 200 Hz normal operation (adjustable in steps up to 13 kHz). LF, 200 Hz LFA; ERA band 100 Hz to 2500 Hz; CCIR band 2 kHz to 50 kHz. Sensitivity: HF, -97 dBm, LF, -46 dBm, LFA, 1 V, 3 V, and 10 V thresholds. Power integration, 0.5 s, 5 s, or 500 s. Time Constants: Voltage integration, 0.1 s, 1 s, or 100 s. LFA, 0.6 s dead time. Dynamic Range: 40 dB (30 dB on chart) plus 70 dB attenuation in 10-dB steps. Antenna: 21.75-foot telescoping whip, 1.5 inch diameter at base with ground plane consisting of 90 radials of #12 copperweld wire each 100 feet long, equally spaced. Ambient Temperature: 18 to 24 degrees C, 22 degrees C nominal (65 to 75 degrees F). Outputs: Integrated power and voltage in four channels (chart recorded). Count of number of impulses above 1, 3, and 10 V in each of two bands each half hour (photograph). Timing and Switching: Internal time standard with power amplifier to drive clocks and recorders. Switching of channels available each 15 minutes or each 30 minutes. Photograph of LFA taken automatically each 30 minutes or each hour.



FIG. 39 LIGHTNING FLASH COUNT FOR DECEMBER 1966

sharing the Laem Chabang field site.²⁷ The short interval shown in Fig. 41 occurred at 1000 hours GMT on 2 January 1967. The origin of these impulses is unknown.



• •





III PUBLICATIONS

A. PUBLISHED REPORTS

1. Semiannual Reports

W. R. Vincent, "Research-Engineering and Support for Tropical Communications," Semiannual Report 1 (March 1963).

"Research-Engineering and Support for Tropical Communications," Semiannual Report 2 (September 1963).

"Research-Engineering and Support for Tropical Communications," Semiannual Report 3 (October 1964).

R. E. Leo, G. H. Hagn, and W. R. Vincent, "Research-Engineering and Support for Tropical Communications," Semiannual Report 4 (October 1965).

G. H. Hagn, H. W. Parker, and E. L. Younker, "Research-Engineering and Support for Tropical Communications," Semiannual Report 5 (May 1966).

2. Final Reports

"Research-Engineering and Support for Tropical Communications," Final Report--Volume 1 (September 1964).

3. Special Technical Reports and Research Memoranda

*Kenneth Dimmick, "Communications Systems Implications of Thai Speech," Special Technical Report 1 (June 1965).

W. R. Vincent, "Voice Tests on Man-Pack Radios in a Tropical Environment," Research Memorandum 2 (July 1963).

W. R. Vincent, "Field Tests on Man-Pack Radios in a Tropical Environment," Research Memorandum 3 (July 1963).

T. S. Cory, "Scale-Model Measurements on a Sloping-Wire Antenna," Research Memorandum 4 (June 1963).

Prepared under Task I, Operations Analysis Program, Subtask 4, Communications Systems Implications of Major Thai Dialects, of the previous contract.

George H. Hagn, "Orientation of Linearly Polarized HF Antennas for Short-Path Communication via the Ionosphere near the Geomagnetic Equator," Research Memorandum 5 (August 1963, Revised June 1964).

Terry S. Cory and William A. Ray, "Measured Impedances of Some Tactical Antennas near Ground," Research Memorandum 7 (February 1964).

N. K. Shrauger, "Field Tests of VHF Man-Pack Radios," Special Technical Report 8 (April 1965).

George H. Hagn, "Absorption of Ionospherically Propagated HF Radio Waves under Conditions where the Quasi-Transverse (QT) Approximation Is Valid," Special Technical Report 9 (September 1964).

William A. Ray, "Full-Scale Pattern Measurements of Simple HF Field Antennas," Special Technical Report 10 (May 1966).

George H. Hagn and Kenneth A. Posey, "Survey of Literature Pertaining to the Equatorial Ionosphere and Tropical Communication," Special Technical Report 12 (February 1966).

George H. Hagn and Harold W. Parker, "Feasibility Study of the Use of Open-Wire Transmission Lines, Capacitors, and Cavities to Measure the Electrical Properties of Vegetation," Special Technical Report 13 (August 1966).

C. L. Rufenach, Vichai T. Nimit, and R. E. Leo, "Faraday Rotation Measurements of Electron Content near the Magnetic Equator Using the Transit IV-A Satellite," Special Technical Report 14 (January (1966).

John Taylor, "A Note on the Computed Radiation Patterns of Dipole Antennas in Dense Vegetation," Special Technical Report 16 (February 1966).

John Taylor, Kenneth A. Posey, and George H. Hagn, "Literature Survey Pertaining to Electrically Small Antennas, Propagation Through Vegetation, and Related Topics," Special Technical Report 17 (January 1966).

George H. Hagn, Jan E. van der Laan, David J. Lyons, and Edwin M. Kreinberg, "Ionospheric Sounder Measurement of Relative Gains and Bandwidths of Selected Field-Expedient Antennas for Skywave Propagation at Near Vertical Incidence," Special Technical Report 18 (January 1966). George H. Hagn, Gary E. Barker, Harold W. Parker, James D. Hice, and William A. Ray, "Preliminary Results of Full-Scale Pattern Measurements of Simple VHF Antennas in a Eucalyptus Grove," Special Technical Report 19 (January 1966).

Sven E. Wahlstrom, "Controller's Data Display Mark II--Instruction Manual," Special Technical Report 21 (June 1966).

Vichai T. Nimit, "Ionospheric Data: Bangkok, Thailand," 25 Ionospheric Data Reports (September 1963 through September 1965).

Vichai T. Nimit, Boonsong Punyarat, and Clifford L. Rufenach, "Faraday Rotation Data: Bangkok, Thailand," Geophysical Data Reports--November 1964 through June 1965 (July 1966).

Vichai T. Nimit, Boonsong Punyarat, and Clifford L. Rufenach, "Faraday Rotation Data: Bangkok, Thailand," Geophysical Data Reports-July 1965 through December 1965 (July 1966).

Vichai T. Nimit, "Faraday Rotation Data: Bangkok, Thailand," Geophysical Data Report--January through June 1966 (July 1966).

Vichai T. Nimit, "Faraday Rotation Data: Bangkok, Thailand," Geophysical Data Report-July through December 1966 (January 1967).

B. REPORTS APPROVED AND IN FINAL PREPARATION

1. Semiannual Reports

G. H. Hagn, E. L. Younker, and H. W. Parker, "Research-Engineering and Support for Tropical Communications," Semiannual Report 6.

2. Special Technical Reports

Clifford L. Rufenach and George H. Hagn, "Predicted Useful Frequency Spectrum for Man-Pack Transceivers Considering Short-Path Skywave Propagation and Comparison with C-2 Sounder Data for Bangkok, Thailand," Special Technical Report 15.

C. REPORTS SUBMITTED TO COTR FOR APPROVAL

1. Semiannual Reports

E. L. Younker, H. W. Parker, and G. H. Hagn, "Research-Engineering and Support for Tropical Communications," Semiannual Report 7.

2. Special Technical Reports

George H. Hagn, "The Use of Ground Wave Path Loss Data to Predict the Effective Range and Performance of VHF Man-Pack Radios in Forests," Special Technical Report 11.

William A. Ray, Gary E. Barker and Sandra S. Martensen, "Full-Scale Pattern Measurements of Simple HF Field Antennas in a U.S. Conifer Forest," Special Technical Report 25.

N. K. Shrauger and K. L. Taylor, "Initial VHF Propagation Results Using Xeledop Techniques and Low Antenna Heights," Special Technical Report 26.

R. L. Brown, "Manual for ARN-3 Type Atmospheric Noise Measuring Equipment," Special Technical Report 27.

Clifford L. Rufenach, "Evaluation and Frediction of Maximum Usable Frequency (MUF) over Bangkok," Special Technical Report 28.

Termpoon Kovattana, "Electrical Ground Constants of Central, Eastern, and Northeastern Thailand," Special Technical Report 29.

H. W. Parker, N. E. Goldstein, and G. H. Hagn, "Feasibility Study on the Measurement of Ground Constants in the Presence of Vegetation," Special Technical Report 30.

Rangsit Chindahporn, Lt. Chaikamol Lumjiak, and Prajuab Nimityongskul, "Atmospheric Radio Noise Data, Bangkok, Thailand--March-May 1966," Geophysical Data Report.
REFERENCES

- John Taylor, "A Note on the Computed Radiation of Dipole Antennas in Dense Vegetation," Special Technical Report 16, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (February 1966).
- William A. Ray, "Full-Scale Pattern Measurements of Simple HF Field Antennas," Special Technical Report 10, Contract DA 36-039 AMC-G0040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (N.y 1966).
- X. E. Leo, G. H. Hagn, and W. R. Vincent, "Research-Engineering and Support for Tropical Communications," Semiannual Report 4, covering the period 1 October 1964 through 31 March 1965, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford " 3arch Institute, Menlo Park, California (October 1965).
- 4. William A. Ray, Gary E. Barker, and Sandra S. Martensen, "Full-Scale Pattern Measurements of Simple HF Antennas in a U.S. Conifer Forest," Special Technical Report 25, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (February 1967).
- 5. Gary E. Barker, "Full-Scale Pattern Measurements of Simple HF Antennas in a Thailand Tropical Forest," Special Technical Report 35, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Fark, California (in preparation).
- 6. George H. Hagn et al., "Preliminary Results of Full-Scale Pattern Measurements of Simple VHF Antennas in a Eucalyptus Grove," Special Technical Report 19, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (January 1966).
- N. K. Shrauger and K. L. Taylor, "Initial VHF Propagation Results Using Xeledop Techniques and Low Antenna Heights," Special Technical Report 26, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (December 1966).
- G. H. Hagn, E. L. Younker, and H. W. Parker, "Research-Engineering and Support for Tropical Communications," Semiannual Report 6, covering the period 1 October 1965 through 31 March 1966, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute Menlo Park, California (June 1966), pp. 44-57.
- 9. E. L. Younker, G. H. Hagn, and H. W. Parker, "Research-Engineering and Support for Tropical Communications," Semiannual Report 7, covering the period 1 April through 30 September 1966, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (September 1966), pp. 60-64.

- 10. G. E. Barker and W. A. Hall, "Full-Scale Pattern Measurements of Simple VHF Antennas in a Thailand Tropical Forest," Special Technical Report 45, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (in preparation).
- 11. Younker, Hagn, and Parker, op. cit., pp. 42-55.
- 12. "Tropical Propagation Research," Semiannual Report No. 7, covering the period 1 July through 31 December 1965, Contract DA 36-039 SC-90889, Jansky and Bailey Research and Engineering Division, Atlantic Research Corporation, Alexandria, Virginia, pp. 2-9 through 2-13.
- 13. Younker, Hagn, and Parker, op. cit., pp. 23-28.
- 14. K. Davies, <u>Ionospheric Radio Propagation</u>, p. 192 (U.S. Government Printing Office, Washington, D.C., 1 April 1965).
- 15. Younker, Hagn, and Parker, op. cit., pp. 22-36.
- 16. K. D. Felperin, D. Barnes, and R. Wolfram, "SRI Correlation Computer," Instruction Manual, Stanford Research Institute, Menlo Park, California (June 1965).
- 17. C. L. Rufenach, "Evaluation and Prediction of Maximum Usable Frequency (MUF) over Bangkok," Special Technical Report 28, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (January 1967).
- E. A. Clarke, "IBM 704 Program to Determine the Maximum Usable Frequency (MUF) and the Lowest Useful High Frequency (LUF) for HF Radio Propagation," Technical Report 1, Contract DA 36-039 SC-66381, SRI Project 2124, Stanford Research Institute, Menlo Park, California (March 1959).
- 19. C. L. Rufenach and G. H. Hagn, "Predicted Useful Frequency Spectrum for Man-Pack Transceivers Considering Short-Path Skywave Propagation and Comparison with C-2 Sounder Data for Bangkok, Thailand," Special Technical Report 15, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (August 1966).
- 20. <u>Ionospheric Predictions</u> (U.S. Department of Commerce, Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado, published monthly).
- 21. W. B. Jones, R. P. Graham, and M. Leftin, "Advances in Ionospheric Mapping by Numerical Methods," NBS Technical Note 337, Institute for Telecommunication Sciences and Aeronomy, Environmental Science Services Administration, Boulder, Colorado.

- 22. V. T. Nimit, "Faraday Rotation Data: Bangkok, Thailand, July-December 1966," Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (January 1967).
- V. T. Nimit, "Faraday Rotation Data: Bangkok, Thailand, January-June 1966," Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (July 1966).
- 24. "Satellite S66 Predictions for 1966" (Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, Maryland).
- 25. Younker, Hagn, and Parker, op. cit., pp. 7-17.
- R. L. Brown, "Manual for ARN-3 Type Noise Measuring Equipment," Special Technical Report 27, Contract DA 36-039 AMC-00040(E), SRI Project 4240, Stanford Research Institute, Menlo Park, California (November 1966).
- 27. E. N. Clark, "Equatorial Sporadic-E Experiment: Data Collection," Tech. Report AFAL-TR-6746, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio (February 1967) [Prepared under Contract F33(615)-67-C-1086 by Stanford Research Institute, Menlo Park, California; SRI Project 6298].

PROJECT PERSONNEL

Δ	Manla	Davb
	1161111) FALK

W. R. Vincent
G. H. Hagn
A. O. Williams
E. T. Pierce
G. E. Barker
M. Brusberg
B. E. Frank
W. A. Hall

Supervisor Project Leader Administrator Staff Scientist Research Engineer Programmer Programmer Programmer

B. Bangkok

1. Stanford Research Institute

Period)
Period)
E

Montana State University

С.	L.	Rufenach	Research	Engineer
N.	Κ.	Shrauger	Research	Engineer

Pan Supplies

Prajuab Nimityongskul	Research	Engineer
Rangsit Chindaphorn	Research	Engineer
Vichai Thepgoonhanimitta	Research	Engineer
Withan Makarabhiromya	Research	Engineer

Vitro Corporation

J.	₩.	Chapman	Field	Engineer
κ.	L.	Taylor	Field	Engineer

2. Military Research and Development Center Personnel

Prapat Chandaket, Captain R.T.N., Communications Program Manager Termpoon Kovattana, Squadron Leader, R.T.A.F., Deputy Communications Program Manager

Paibul Nacaskul, Lieutenant Commander, R.T.N., Project Officer Udom Suwanpramott, Major, R.T.A., Project Officer

67

Jamnong Sowanna, Lieutenant Commander, R.T.N., Project Officer Sukdichai Nivatmaraka, Flight Lieutenant, R.T.A.F., Project Officer Chaikamol Lumjiak, Flying Officer, R.T.A.F. Project Officer Manit Dowkhanon, C.P.O., R.T.N., Radio Technician Vichcha Kanitchaya, S/SGT., R.T.A.F., Radio Technician Sopin Viriyanapaporn, S/SGT., R.T.A.F., Communications

C. University of South Carolina

John Taylor	Head, Electrical Engineering
Ching Chun Han	Student Engineer
Robert Padowicz	Student Engineer
Gerald Bright	Student Engineer

UNCLASSIFIED			
Security Classification			
Security classification of title, body of aborated and indexin,		a e ntere Estado et	he werall report in the discussion
ORIGINATING ACTIVITY (Corporate author)		24. Fri B. C. Ir T.	FCUR TECLASSIER ATOR
Stanford Research Institute		U	nclassified
333 Ravenswood Avenue		2h CONS	N/A
Menio Park, California 94025		1	·
RESEARCH ENGINEERING AND SUPPORT FOR TH	ROPICAL COMMU	NICATION	S
OESCRIPTIVE NOTES (Type of report and inclusive dates) Semiannual Report 8 Covering the Period	i 1 October 1	966 thro	ugh 31 March 1967
E. L. Younker G. H. Hagn	H. W. Pa	rker	
REPORT OATE May 1967	74. TOTAL NO OF	PAGES	10. NJ OF REFS
CONTRACT OR GRANT NO	90. OHIGINATORS	HEPORT NU	Z/
DA 36-039 AMC-000040 (E)	Semiann	al Report	rt 8
D. PROJECT NO	SRI Pro	ject 4240	0
Order No. 5384-PM-63-91			
ARPA Order No. 371	+ OTHER HEPOI this report)	AT SOLD (Any	other numbers that may be assigned
d.			
Report on communication research in tropical vegetated environments	Advanced Washingt	Researc	ch Projects Agency
Communications research in a tropi improved equipment and techniques for u ronments. This report describes Stanfo (an acronym for Southeast Asia Communic 1 October 1966 through 31 March 1967. (1) Airborne pattern measurements (2) Measurement of electrical pro (3) Modeling of propagation throu (4) Ionospheric propagation and f (5) Atmospheric radio noise.	cal environme se by militar ord Research l ation Research Among the top of antennas perties of ve gh a scatteri requency pred	ent is nervy forces institute (h) during (ics under in veget getation ng mediu (ction	eeded to develop in tropical envi- e's work on SEACORE og the period er study were: ation and ground m
D FORM 1473 (PAGE 1)			

S/N 0101-807-6801

UNCLASSIFIED

Security Classification

14 KEY WORDS	LIN	K A	LIN	IK B	LINK C	
	ROLE	w T	ROLE	W T	ROLE	WT
Tropical communication						
Southeast Asia						
Bangkok, Thailand				1		
Radio noise						
Foliage constants						
Antenna performance in foliage						
Magnetic investigations						
Ionospheric investigations						
SEACORE						
• • • • • • • • • • • • • • • • • • •						
			ĺ			
DD 1 NEV 1473 (BACK)		UNC	LASSIF	TED		