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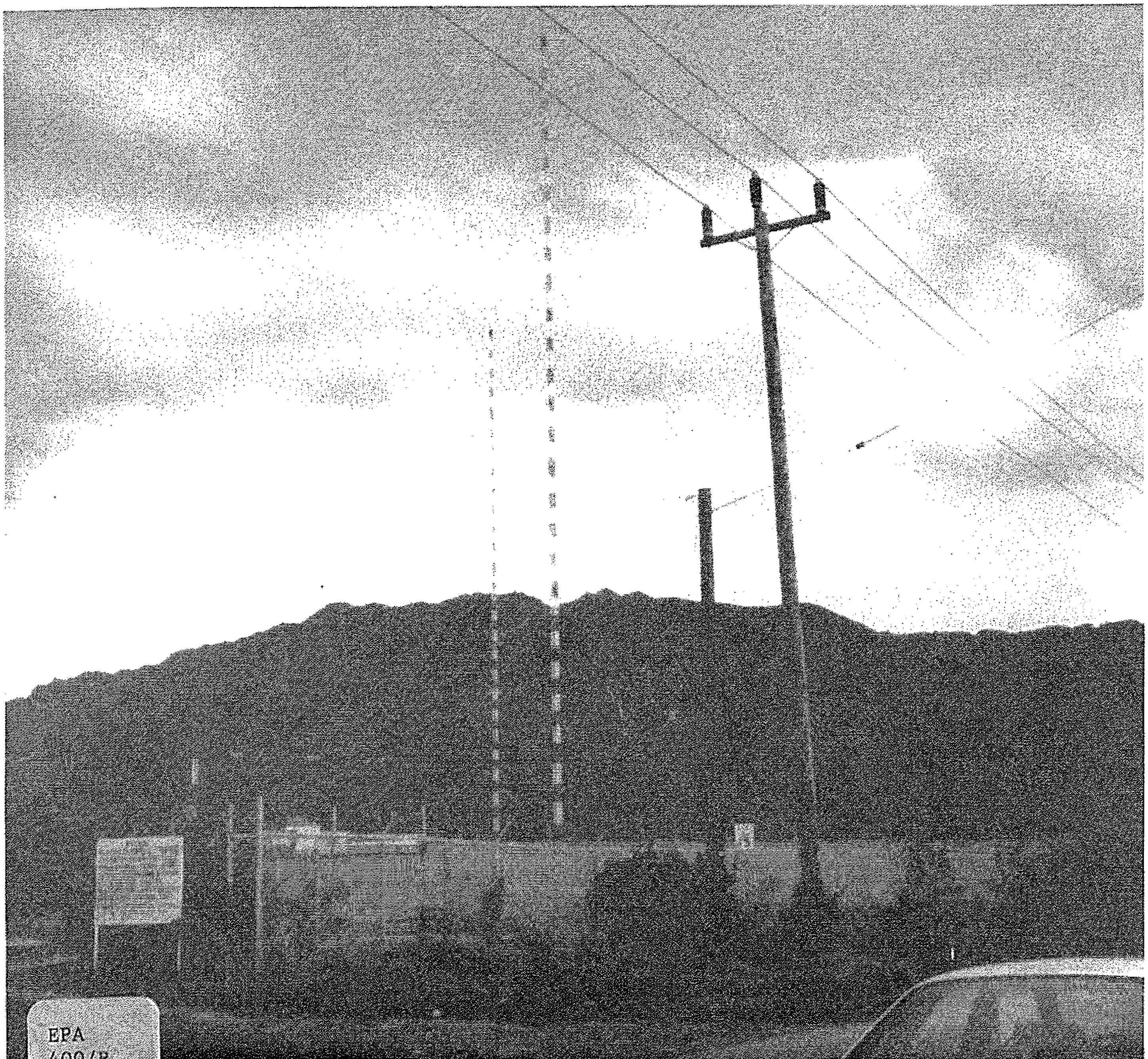
Measurements of Electric and Magnetic Fields in the Waianae, Hawaii Area



MEASUREMENTS OF ELECTRIC AND MAGNETIC FIELDS IN THE WAIANAE, HAWAII AREA

JULY 1992

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U.S. Environmental Protection Agency
Office of Radiation Programs

EXECUTIVE SUMMARY

During November 27-30, 1990, the U.S. Environmental Protection Agency (EPA) conducted a measurement survey of electric and magnetic field levels along the southwest coast of Oahu, Hawaii. These measurements were requested by the State of Hawaii to determine the levels of radiofrequency (RF) electric and magnetic fields near Naval radio transmitters at Lualualei. The objective was to determine maximum fields in residential areas. This report documents the measurement results. Also, a few measurements were made of extremely-low-frequency (ELF) electric and magnetic fields at 60 hertz, the frequency used for electrical power.

Radiofrequency (RF) fields due to operation of the Lualualei Naval transmitters were measured in three frequency bands: very-low-frequency (VLF), low-frequency (LF), and high-frequency (HF). Just outside the Navy site boundary, maximum measured RF electric fields were 82, 0.5, and 8.8 volts/meter (V/m) in the VLF, LF, and HF bands, respectively; maximum measured RF magnetic fields were 99, 0.9, and 22 milliamps/meter (mA/m) in the same three bands. The VLF and LF transmitters operate continuously and the HF transmitters operate intermittently. For the VLF case, measurements were made near the boundary of the transmitter facility and along the coastal highway as a means to bracket the likely range of fields in the area in between. VLF fields ranged from 0.15 V/m to 82 V/m for the electric field and 2.5 to 99 mA/m for the magnetic field. Because of the limited dynamic range of the

equipment, the maximum LF field measured is probably somewhat less than the actual maximum LF field outside the site boundary. The maximum measured level of 60 Hz ELF magnetic and electric fields in the Waianae area were 15 milligauss (mG) and 30 V/m. ELF magnetic fields are generally reported in units of milligauss (mG) while RF magnetic field are reported in units of milliamps per meter (mA/m). For practical purposes 1 mG = 80 mA/m.

CONTENTS

PREFACE

We believe the accuracy of the measurements made in this study is high because of the appropriateness of the measurement approach and because the degree of instrument uncertainty was low. Since the purpose of the study of electric and magnetic fields at Lualualei was to determine the "maximum" fields to which an individual could be exposed, a statistical sampling approach to measurement was unnecessary. The relatively small area outside the Navy property and closest to the antennas could be probed confidently with a field survey meter for the maximum potential levels.

Moreover, the fact that the antennas under study generated fields that were constant, that radiated equally in all directions, and that decreased in intensity with distance allowed measurements sites to be selected with a great degree of freedom, so long as objects that might perturb measurements (introduce shadows and reflections) were avoided. Because these perturbations were avoided whenever possible, we are confident "maximum" fields were measured. Finally, instrument uncertainty, always a factor affecting the accuracy of field measurements, was within ten percent of the measured values in this study.

ACKNOWLEDGMENTS

The support of transmitter operators and Navy specialists in field measurements allowed the study to proceed smoothly. Arnold Den and Shelly Rosenblum of EPA Region 9 provided field support. Toni West, an electrical engineering undergraduate student employed at Environmental Protection Agency-Las Vegas, calibrated instruments, corrected raw data, generated rough maps and plots, provided background information in early drafts, and assembled the report. Richard Levy contributed statistical analyses and the resultant graphics. EPA reviewers included Shelly Rosenblum, Dr. Doreen Hill, Lynne Gillette, and Norbert Hankin. External peer reviewers included Dr. Keith Florig, Research for the Future, Paul Gailey, Oak Ridge National Laboratory, David Janes, Risk Analysis Corporation, Dr. Raymond Neutra, State of California, and Richard Tell, Richard Tell Associates.

FIGURES

TABLES

1. INTRODUCTION

At the request of the Hawaii Department of Health, the U. S. Environmental Protection Agency (EPA) Office of Radiation Programs - Las Vegas Facility and EPA Region 9 measured electric and magnetic fields in the Waianae area along the southwest coast of Oahu. The Hawaii Department of Health and members of the public were concerned that electric and magnetic fields generated by the nearby Lualualei Naval Radio Transmission Facility might be relevant factors in a larger State investigation of childhood cancer cases found in the area. Other environmental agents, such as chemical contamination, are also being investigated by the Hawaii Department of Health.

The electric and magnetic field sources of interest in this study were the radio transmission antennas at the Lualualei Naval Radio Transmission Facility. The Naval Facility operates high-power transmitters at 23.4 kilohertz (kHz) in the very-low-frequency (VLF) range, at 146.1 kHz in the low-frequency (LF) range, and at various frequencies in the high-frequency (HF) or shortwave range of 3 to 30 megahertz (MHz). The VLF and LF transmitters operate continuously and the HF transmitters operate intermittently.

This study was designed to determine fields in residential areas for the limited range of frequencies due to the operation of transmitters at the Lualualei Naval facility. The results of measurements and the equipment and methods used in the study are described in this report. Measurement instruments capable of determining electric and magnetic fields in the frequency bands of VLF, LF, and HF were used. Several of the instruments overlap more than one band.

In addition, some measurements of electric and magnetic fields at the extremely-low-frequency (ELF) of 60 hertz were made to explore whether any unusual circumstances existed with respect to power lines. Power lines operate at 60 cycles per second or hertz (Hz) in the ELF frequency range. Instruments capable of measuring in the ELF frequency band were also used in this study.

2. EQUIPMENT AND METHODS

The equipment used for electric and magnetic field measurements is matched to the frequency of the field source under study. Each measurement device or system has a frequency range over which it is calibrated and operates properly. These instruments not only respond to fields over the specified frequency range but can also respond to fields outside this range. If the frequency cannot be determined with an instrument (usually the case with survey meters), it can be difficult to determine the source of the field causing the instrument response. For example, a radiofrequency electric field survey meter will respond to strong ELF electric fields in addition to the intended radiofrequency response. One approach to identifying the source of an instrument response is to control the source presumed to cause the response. For example, if the power of a transmitter is reduced and the meter reading drops accordingly, then the transmitter being controlled is the cause of the instrument response. In a case where the frequency can be determined with an instrument, the field source can be positively identified from the frequency if no other sources operating on the same frequency are present. Both frequency readout and power control approaches were used to identify field sources in this study. It should be noted that all of the instruments used in this study were single-axis type; that is, only the vector component of the field that is aligned with the instrument sensor or antenna was determined. In all cases the sensor axis was oriented to obtain a single maximal response.

2.1 VLF and LF Equipment and Methods

The same equipment was used to measure both VLF and LF fields. Electric fields were measured with two Model EFS-1 meters manufactured by Instruments for Industry and designed to operate over the frequency range of 10 kHz to 200 MHz. These instruments were calibrated using a transverse electromagnetic (TEM) cell in EPA's Montgomery laboratory [1]. Calibration data for the Instruments for Industry meters are located in the Appendix. These instruments have certain limitations: they measure only electric fields; do not measure frequency; may be susceptible to interference from power line ELF electric fields; and have limited sensitivity. To overcome some of these limitations, special measurement systems were assembled and used as described below.

Magnetic fields were measured with an Eaton Model 94605-1, 5¼-inch loop antenna connected to a Tektronix Model 212 battery-powered oscilloscope through a 50 ohm load resistor. The manufacturer's calibration curve for the 5¼-inch loop is given in the Appendix. Correction factors for the loop and oscilloscope system were determined with a TEM cell; these factors were used to convert oscilloscope readings in millivolts peak-to-peak (mV p-p) to magnetic field in root-mean-square milliamps/meter (mA/m). The results of the TEM cell calibration are also shown on the figure in the Appendix and are in good agreement with the manufacturer's curve. The magnetic fields were measured at locations away from any vehicles or other large conducting objects, orienting the loop for maximum response, and reading the oscilloscope for either the VLF or LF waveforms (see discussion below). The polarization of the magnetic field was always horizontal, as expected, based on the transmitting antenna geometry.

To measure electric fields and frequency, a standard magnetic mount whip antenna about one meter long was attached to the top of a rental car and calibrated in the field (see Figure 1). In this arrangement, the entire vehicle becomes part of an electrically-small capacitive antenna system. The standard antenna cable was replaced with a six-foot section of low capacitance cable (RG 62 A/U) to reduce capacitive loading and increase sensitivity. This cable was connected to both the oscilloscope and a Fluke Model 8060A digital voltage and frequency meter located inside the vehicle. The system was calibrated in the field by approaching either the VLF or LF transmitting antennas on the Navy site so that the field from either antenna was dominant; reading the oscilloscope in the vehicle; and measuring the electric field with both EFS-1 meters at the same location without the vehicle present. The EFS-1 field readings (corrected and averaged) divided by the oscilloscope readings become the calibration factor for the system. The VLF transmitter was shut down for maintenance during the LF calibration. The VLF calibration was rechecked twice during the study and the results are given in Table 1. The calibration factor did not change significantly from VLF to LF frequencies. Proper readings with the whip

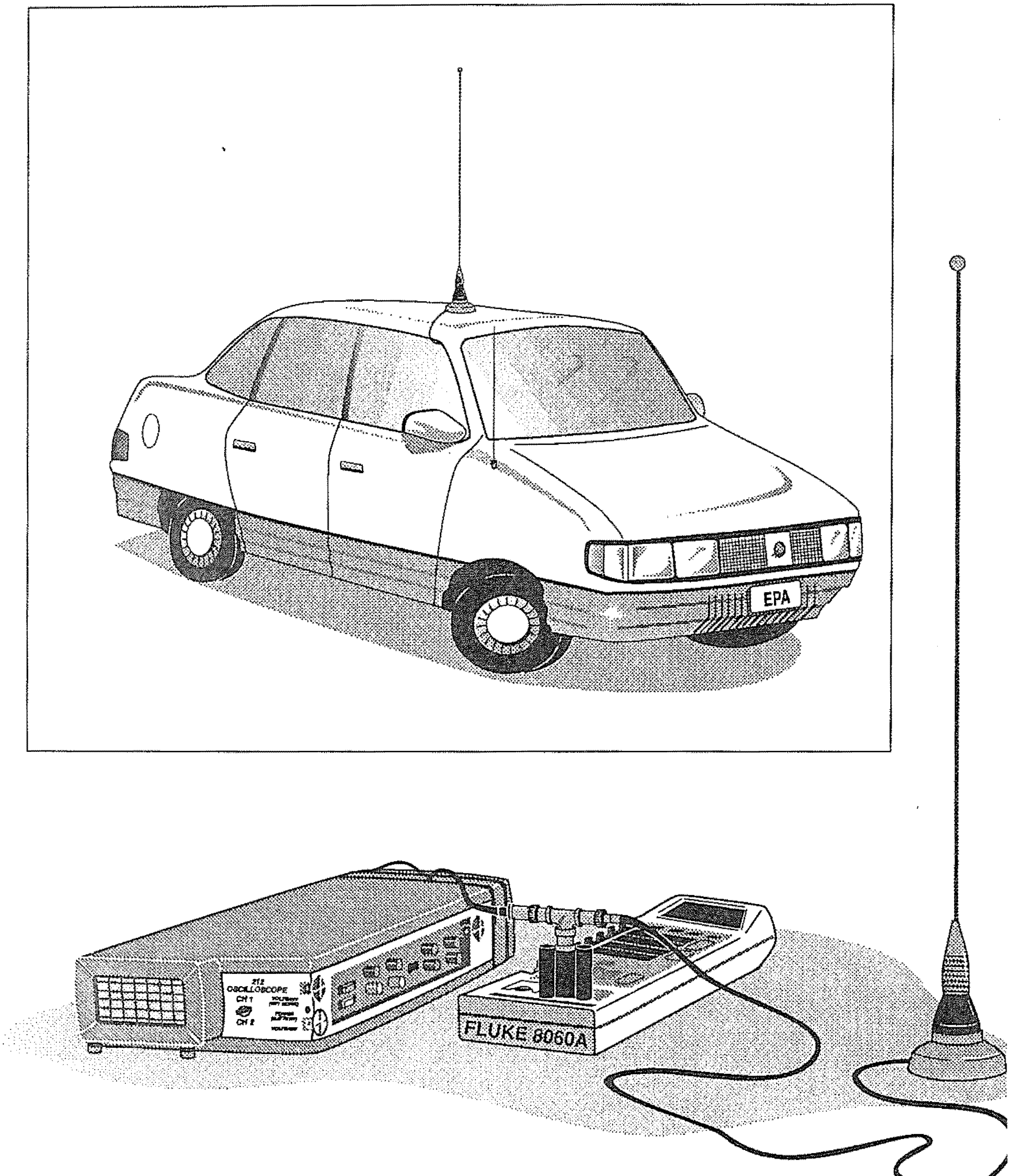

Figure 1. Whip Antenna System

system depend on the electric field being vertical and uniform near ground. For open areas, this is a reasonable assumption for electric fields at VLF and LF frequencies and is supported by the EFS-1 measurements. In processing the data, only the first VLF calibration factor (10.19) was used, as it was obtained in a more open area.

TABLE 1. FIELD CALIBRATION OF WHIP ANTENNA SYSTEM

Calibration Frequency (kHz)	Averaged EFS-1 Field (V/m)	Oscilloscope Reading (V_{p-p})	Factor ($V/m_{rms}/V_{p-p}$)
146.1	8.63	.84	10.27
23.4	8.15	.8	10.19
23.4	54.93	5.2	10.56
23.4	51.45	5.2	9.89

The whip system not only responds to VLF and LF electric fields generated by the Navy transmitters, but also responds to 60 Hz ELF electric fields due to power lines. The system could be used for ELF electric field measurements but was not calibrated at 60 Hz for this study. The voltmeter reading is only useful when one frequency is dominant; however, the oscilloscope display can be used to distinguish the contribution from sources at different frequencies. The oscilloscope may display up to three sinusoidal waveforms superimposed on top of each other. The fast LF waveform "rides on top of" the slower VLF waveform and the LF and VLF combined are on top of the much slower ELF waveform. Careful triggering and reading of the oscilloscope allows the peak-to-peak voltage due to each of the waveforms to be measured separately. An advantage of the whip system is that it allows continuous observation of electric field variations while driving from one measurement location to the next. This characteristic allowed us to observe and document any unusual field variations between measurement sites.

2.2 HF Equipment and Methods

The HF electric field measurements were made using Instruments for Industry EFS-1 survey meters. Magnetic fields at HF were measured using an Eaton Model 92200-3, 15-inch loop antenna connected to a Hewlett Packard Model 8482A power sensor and Hewlett Packard Model 435B battery-operated radiofrequency power meter. The manufacturer's calibration data for the 15-inch loop are included in the Appendix. These data are used to derive an algorithm to convert power meter readings to magnetic field strength in milliamps per meter (mA/m).

2.3 ELF Equipment and Methods

Two ELF survey meters were used in the study. A Monitor Industries Model 42B-1 was used to measure 60 Hz magnetic fields and an Electric Field Measurements Company Model 116 plus-2-60-2-300 was used to determine 60 Hz electric fields. Both instruments have been tested at EPA and are accurate to ± 5 %. The objective of these measurements was to determine the upper limits of fields due to power distribution lines in residential areas. Therefore, measurements were made close to distribution lines but not made inside residences. Generally, a single intersection in a neighborhood that had numerous overhead power distribution lines was chosen. The area of the intersection was probed until a maximum reading was found at any height from zero to two meters above ground.

3. RESULTS AND DISCUSSION

Figure 2 shows the area of study along the southwest coast of Oahu, Hawaii, from Makaha to Nanakuli. Sources of electric and magnetic fields include the radio transmitters at the Lualualei Naval facility and overhead power lines.

3.1 RF Results

Radiofrequency (RF) electric and magnetic fields were measured at the VLF, LF, and HF frequencies of Naval transmitters at Lualualei. Figure 3 shows details of the Lualualei transmitter facility. Two towers at the south end of the facility support the VLF transmitting antenna system operating continuously at a power of 512 kilowatts (kW) and a frequency of 23.4 kHz. Four towers nearby in a triangular arrangement (one in the center) support the LF antenna system operating continuously at a power of 50 kW and a frequency of 146.1 kHz. Many HF antennas are located toward the northern end of the facility. These HF antennas can operate intermittently at a variety of frequencies in the 3 to 30 MHz band at a maximum power of 10 kW on any one antenna. The transmitter operating powers were confirmed by maintaining communication with the operators of the Navy facility during the study period. Also, a lower power Coast Guard transmitter operating at a medium-frequency (MF) between 0.3 and 3 MHz exists at the eastern end of the site (not shown).

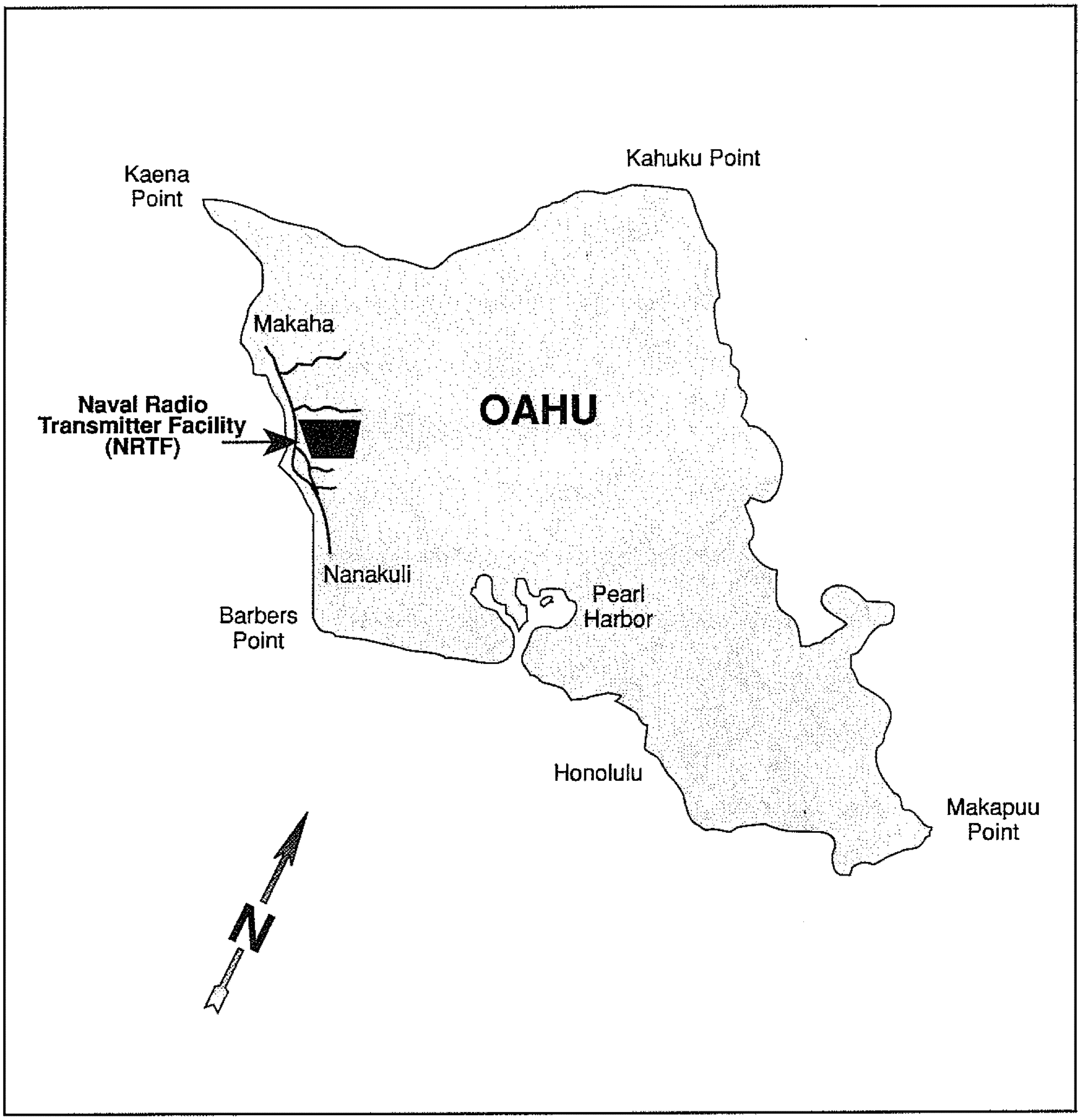

Figure 2. Study Area

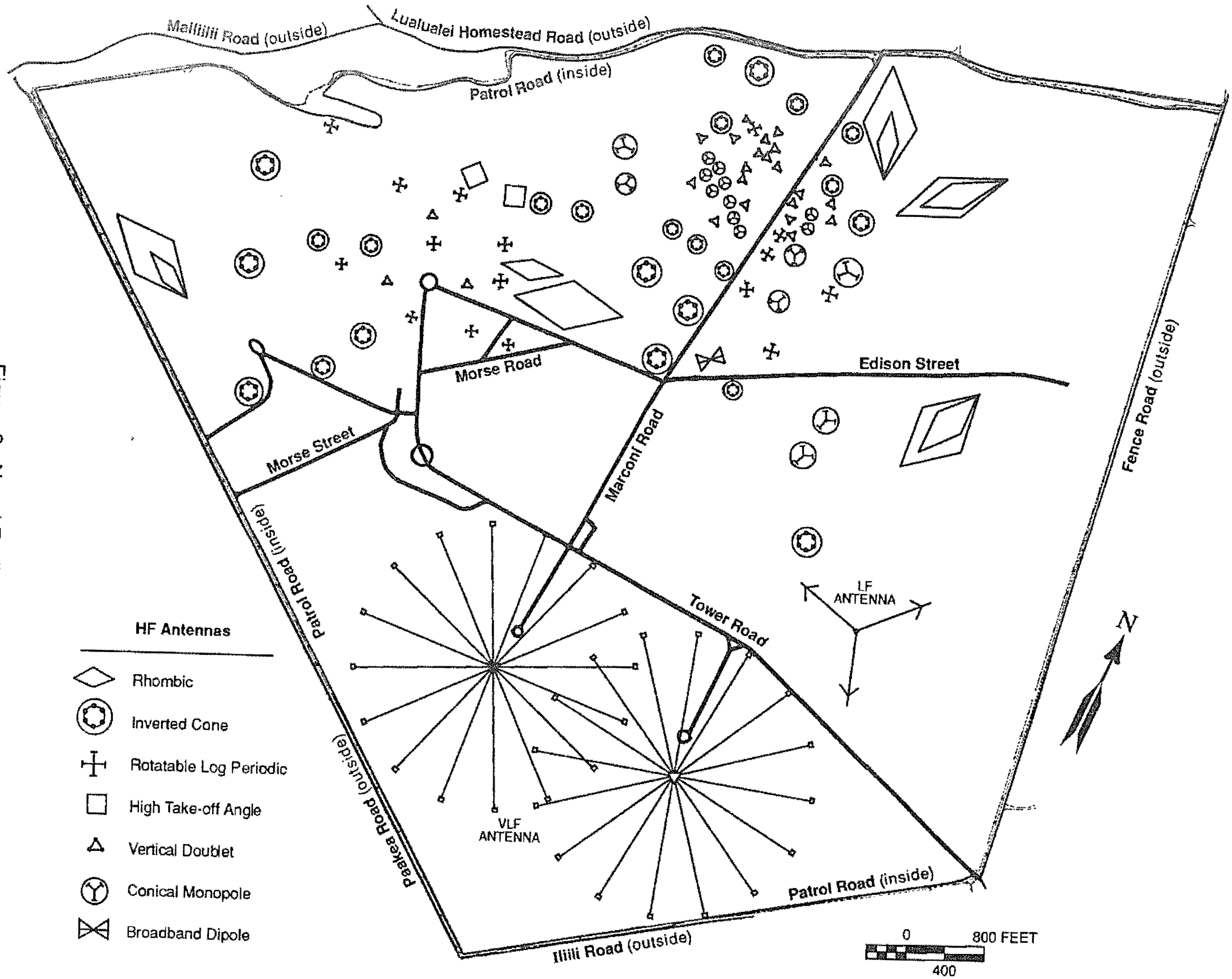

Figure 3. Naval Radio Transmitter Facility - Lualualei

The MF transmitter was not studied because the eastern boundary is not publicly accessible.

3.1.1 VLF Results

VLF (23.4 kHz) electric and magnetic fields were studied much more intensively than fields at other frequencies because of the high power of this transmitter. Measurements were made along roads which were on the perimeter of the Lualualei facility and along the coastal highway. The maximum off-site field strengths should occur near the perimeter of the facility and the highway measurements should include the minimum field strengths in the area studied. Measurements were also made along Waianae Valley Road to the north of the site. The results of these measurements are displayed on the map in Figure 4. Along the perimeter roads electric fields varied from 0.15 to 61 V/m and magnetic fields varied from 4.9 to 92 mA/m. Values of fields along the coastal highway were from 0.17 to 1.5 V/m for the electric field and 2.5 to 9.2 mA/m for the magnetic field. These measurements were made using the 5¼-inch loop and whip antenna system with the oscilloscope. Table 2 lists all of the VLF results. Note that the maximum VLF electric field of 82 V/m was observed in an open area between residences south of Iliili Road. This value was found by searching the area for a maximum that was not perturbed by vegetation or power lines.

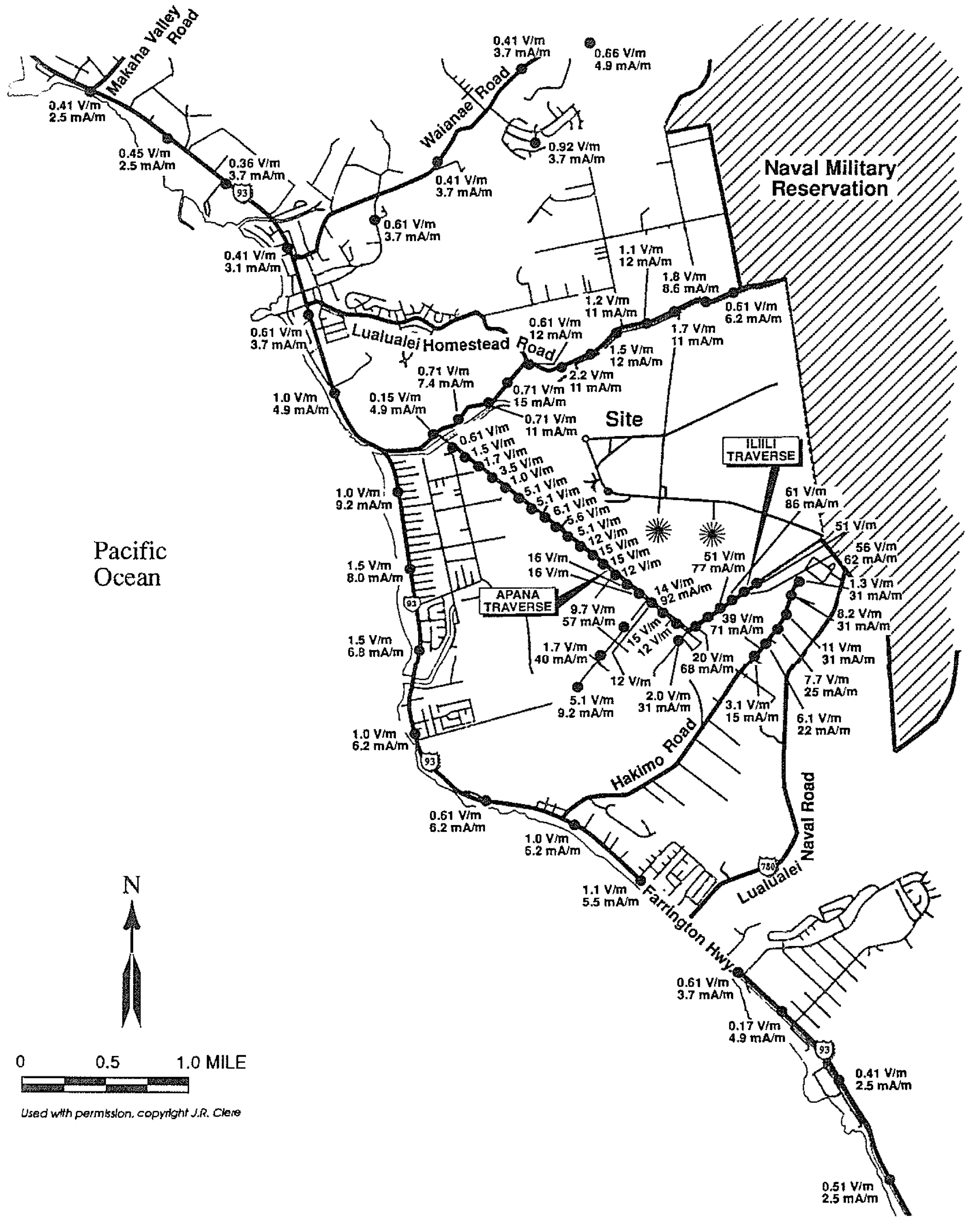

Figure 4. VLF Results

TABLE 2. VLF RESULTS

DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD (mA/m)
Paakea Road from Mailiilii Road to	.61	
Iliili Road	1.5	
(measurements taken every 0.1 mile-	1.7	
electric field only)	3.5	
	1	
	5.1	
	5.1	
	6.1	
	5.6	
	5.1	
	12	
	15	
	15	
	12	
	16	
	16	
	12	
	15	
	12	
Iliili Road from end to	51	
Paakea Road	56	62
(measurements taken every 0.1 mile)	61	86
	51	77
	39	71
	20	68
	2	31
Mailiilii Road continuing on Lualualei	.15	4.9
Homestead Road from Paakea Road to Fence Road	.71	7.4
(measurements taken every 0.2 mile)	.71	11
	.71	15
	.61	12

continued on next page

TABLE 2 -- *Continued*

DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD (mA/m)
	2.2	11
	1.5	12
	1.2	11
	1.1	12
	1.7	11
	1.8	8.6
	.61	6.2
Kaukama Road from Paakea Road to end (measurements taken every 0.2 mile)	14	92
	9.7	57
	1.7	40
	5.1	9.2
Farrington Highway from Makaha Valley Road to Kahe Power Plant (measurements taken every 0.5-0.7 mile)	.41	2.5
	.45	2.5
	.36	3.7
	.41	3.1
	.61	3.7
	1	4.9
	1	9.2
	1.5	8
	1.5	6.8
	1	6.2
	.61	6.2
	1	6.2
	1.1	5.5
	.61	3.7
	.17	4.9
	.41	2.5
	.51	2.5

continued on next page

TABLE 2 -- *Continued*

DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD(mA/m)
Waianae Valley Road and Haleahi Road Intersection	.66	4.9
0.55 mile west from Haleahi Road on Waianae Valley Road	.41	3.7
Punanaula Street and Kaneaki Street	.92	3.7
0.55 mile west from Kaneaki on Waianae Valley Road	.41	3.7
Momona Place and Waianae Valley Road Intersection	.61	3.7
Dead end of Hakimo Road	1.3	31
going toward Paakea Road	8.2	31
(measurements taken every 0.1 mile)	11	31
	7.7	25
	6.1	22
	3.1	15
ILIILI TRAVERSE		
0.2 miles from end of Iliili Road	24	74
going into field perpendicular to Iliili Rd.	64	74
(not shown on map)	72	74
(measurements taken every 20 meters)	75	68
	75	68
	72	77
	63	62
	57	62
	60	62
	52	55
	47	49
	45	49
APANA TRAVERSE		
Paakea Road and Apana Road Intersection	24	92
going parallel to Apana Road	14	92
(measurements taken every 5 meters)	26	99
(not shown on map)	33	80

continued on next page

TABLE 2 -- *Continued*

DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD(mA/m)
	42	74
	44	74
	52	74
(measurements taken every 10 meters)	52	68
	51	62
	47	62
	47	60
	44	62
	48	62
	40	62
In field off Iliili Road*	82	
On Iliili Road*	50	
	45	
Farrington Highway near Manununu Street*	.66	

* Comparison points (see Table 4).

As it became apparent during the study that overhead power lines shielded or reduced VLF electric fields beneath the lines, measurements were taken on the opposite side of the road from power lines whenever possible. To characterize this effect and establish maximum field values, two sets of measurements were made along traverses running perpendicular to power lines immediately outside the southern and western boundary fences of the transmitter facility (see Figures 3 and 4). Results of these traverse measurements are given in Figure 5. Both magnetic and electric fields were measured using hand-held instruments: the 5¼-inch loop and oscilloscope

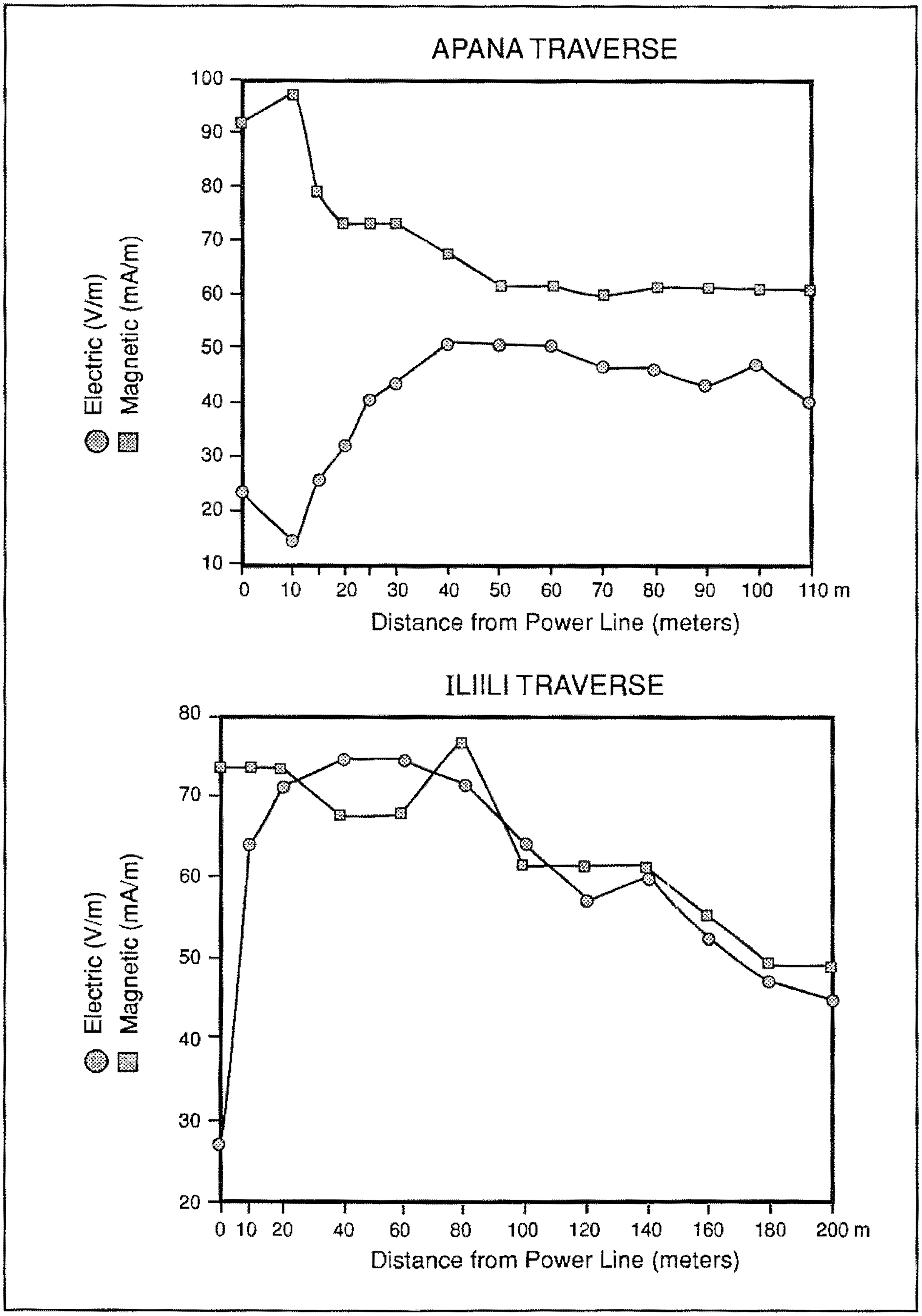

Figure 5. VLF Measurement Traversing Power Lines

and an EFS-1 meter. In the upper plot, "APANA TRAVERSE," power lines are at both 0 and 10 meters; in the lower plot there was only one power line at 0 meters. It was found that VLF electric fields beyond the power lines in an open area could be 4 times greater than fields directly beneath the lines. This implies that other VLF electric field measurements made under power lines may be 4 times less than electric fields in adjacent open areas. It is known that houses also shield VLF electric fields reducing fields inside residences (see reference [2]). The VLF magnetic field was not as strongly affected by the power lines as was the electric field.

To identify the source of field readings more clearly, the Navy, in cooperation with EPA, reduced the VLF transmitter power to 50 percent its normal value at scheduled times. The consistent drop in instrument field strength reading observed at these times in Table 3 confirmed that the source of the field was the VLF antenna. Note that field strength is proportional to the square root of the source power, so that a 0.5 reduction in power implies a 0.707 reduction in field.

TABLE 3. VLF MEASUREMENTS DURING REDUCTION OF POWER

Measurement System	Location	Field Strength at Normal Power	Field Strength at Half Power	Ratio
IFI EFS-1	In Field Off Iliili Road	82 V/m	53 V/m	.65
Whip and Digital Voltmeter	On Iliili Road	50 V/m	35 V/m	.7

continued on next page

TABLE 3 -- *Continued*				
Measurement System	Location	Field Strength at Normal Power	Field Strength at Half Power	Ratio
Whip and Oscilloscope	On Iliili Road	45 V/m	31 V/m	0.69
Whip and Oscilloscope	Farrington Highway Near Manununu Street	0.66 V/m	.49 V/m	.74

Histograms and smoothed data distribution plots for the VLF data are shown in Figures 6 and 7. The distributions are bimodal, which reflects two measurement populations: those at relatively low levels far away from the Navy site and a separate population of measurements at higher levels close to the site (see Section 3.2 ELF Results for explanation of plots).

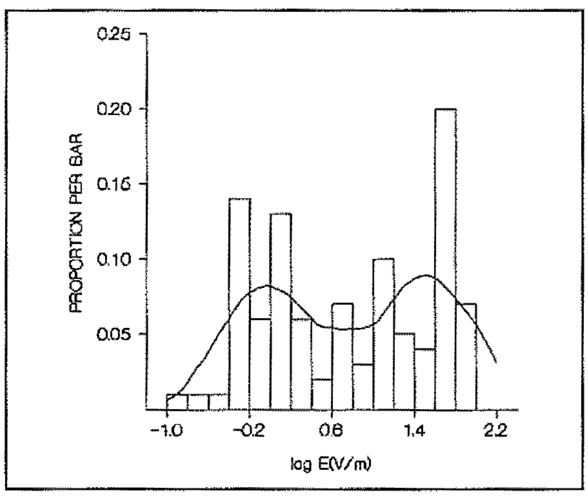

Figure 6. VLF Electric Field Histogram and Smoothed Data

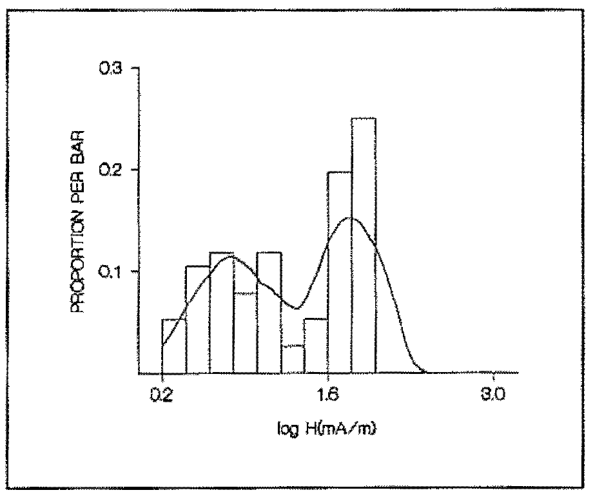

Figure 7. VLF Magnetic Field Histogram and Smoothed Data

3.1.2 LF Results

Low-frequency fields were relatively weak and difficult to detect. The LF (146.1 kHz) waveform could be observed superimposed on the top of the oscilloscop VLF waveform only when the LF response was greater than about one tenth the VLF response. A value is only reported for LF electric and magnetic fields where the LF response could be clearly read. The results are listed in Table 4 and shown on the map in Figure 8. Measured LF electric fields varied from 0.05 to 0.5 V/m. LF magnetic fields were measured at only two sites; both readings were 0.9 mA/m.

TABLE 4. LF RESULTS

DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD (mA/m)
Punanaula Street and Kaneaki Street	.2	
Lualualei Homestead Road from Mailiilii Road	.5	
going east	.5	
(measurements taken every 0.2 mile)	.5	
	.5	.9
		.9
Farrington Highway	.1	
starting at Makaha Valley Road going south	.05	
(measurements taken every 0.5 mile)	.1	
Three values at north end and three values	.1	
at south end of Farrington Highway	.1	
	.1	

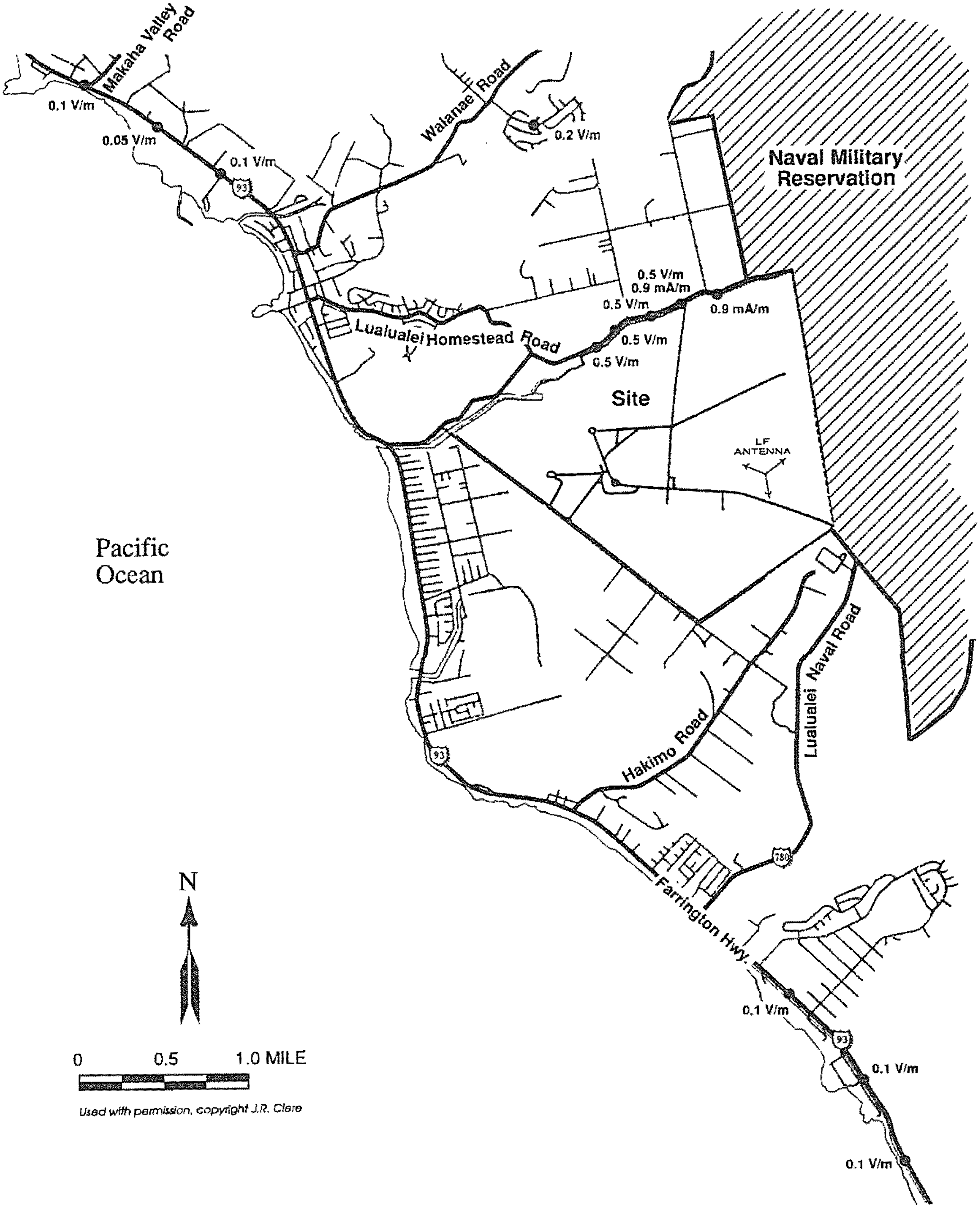

Figure 8. LF Results

The limited measurement data presented here do not allow an accurate estimate of the maximum LF field strength at the site boundary. However, these results are compatible with a maximum LF electric field value at the site boundary of 1.24 V/m reported by the Navy in 1982 [3].

A histogram and smoothed data distribution plot for the LF electric data are shown in Figure 9. No histogram is possible for the magnetic field data, since there were only two sites and both had the same reading.

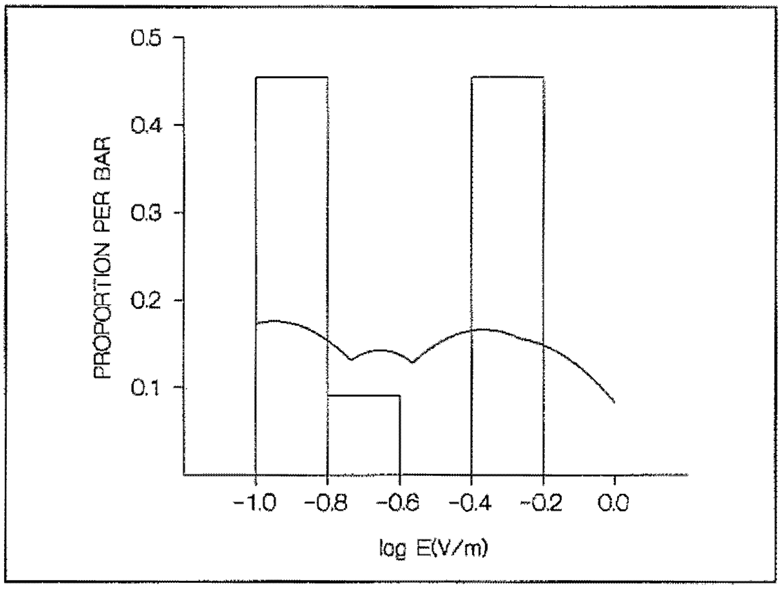

Figure 9. LF Electric Field Histogram and Smoothed Data

3.1.3 HF Results

The large number of HF (3 to 30 MHz) antennas and possible operating frequencies precluded a study of all HF operating conditions. To estimate maximum field strengths outside the Lualualei facility due to HF operations, tests were performed near two antennas close to the northern boundary of the site. Measurements were made along Lualualei Homestead Road near a rhombic type antenna operating at 8.077 MHz and near an inverted cone type antenna operating at 13.523 MHz. These antennas were operated in coordination with the Navy at the maximum of 10 kW of power and at typical operating frequencies. The results are listed in Table 5 and shown in Figure 10. The maximum magnetic field measured was 22 mA/m and the maximum electric field measured was 8.8 V/m. These were due to operation of the inverted cone antenna.

TABLE 5. HF RESULTS

DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD (mA/m)
Lualualei Homestead Road	1.9	6.2
going east along road	1.7	6.4
starting from center of rhombic mainbeam	1.5	7
(measurements taken every 5 meters)	1.8	6.6
	2.3	5.9
	2.7	5.9

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TABLE 5 -- *Continued*		
DESCRIPTOR	ELECTRIC FIELD (V/m)	MAGNETIC FIELD (mA/m)
	2.7	6.4
	3.2	6.6
	3.2	6.6
	2.7	6.4
	2.5	6.1
	2.2	5.8
	2	5.4
	1.9	5.2
	2	4.8
	2	4.4
Lualualei Homestead Road in front of inverted cone antenna	7.1	20
Puhawai Road and Lualualei Homestead	8.8	22

The plot in Figure 11 shows the variation in electric and magnetic fields in front of the rhombic antenna. As expected, electric fields near ground are at a maximum at locations somewhat off the main beam axis [4]. Histograms and smoothed data distribution plots for the HF data are shown in Figures 12 and 13. The distribution is bimodal because data from measurements near the inverted cone and rhombic antennas have been combined.

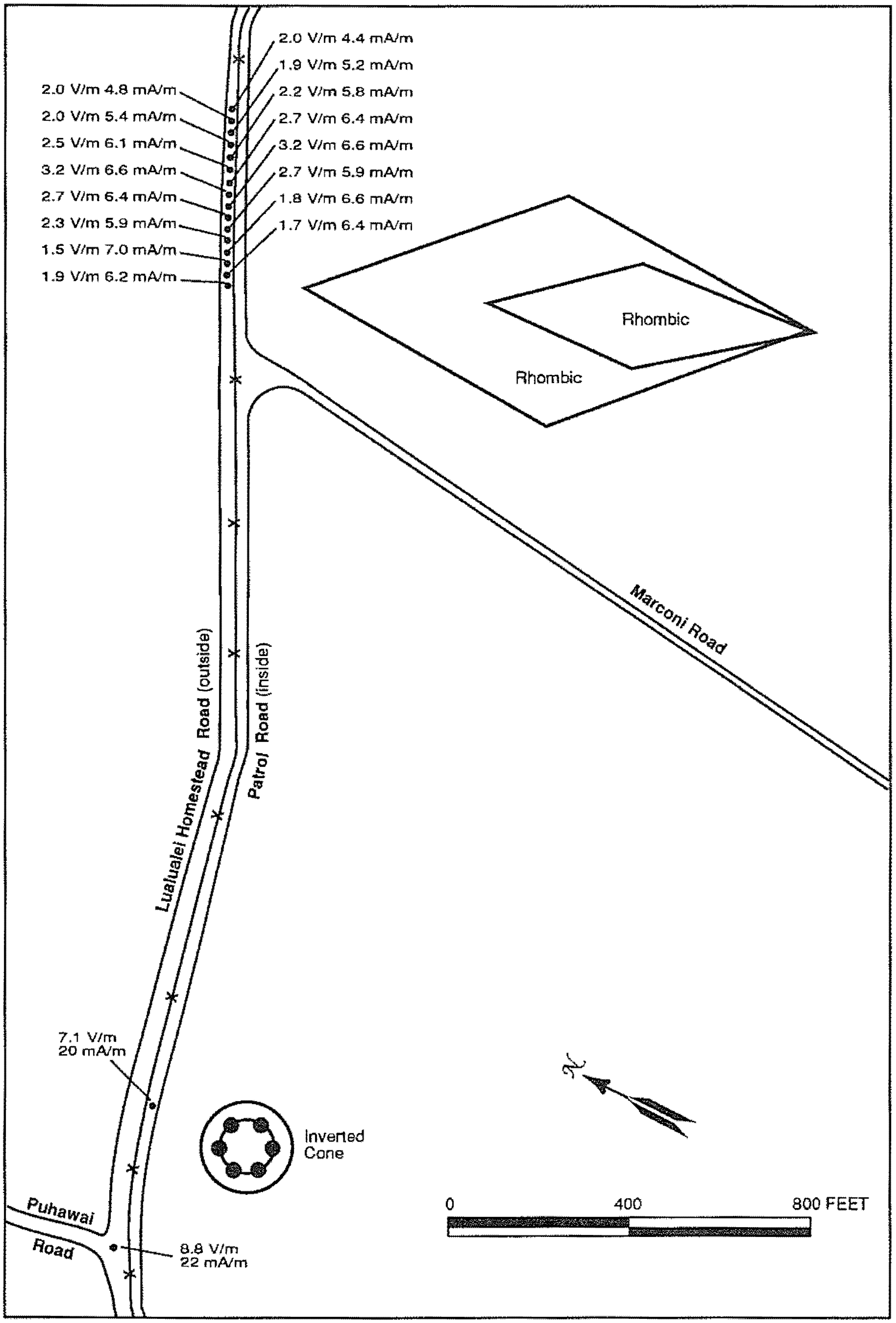


Figure 10. HF results along Lualualei Homestead Rd.

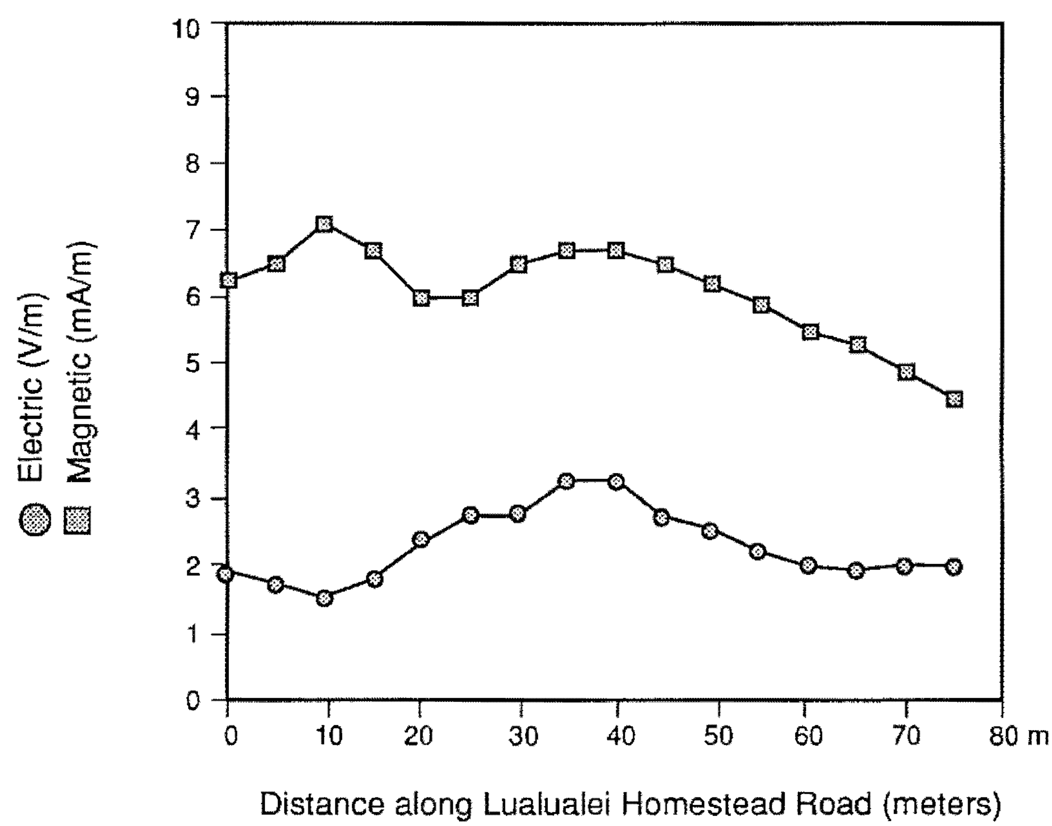


Figure 11. Variation in Electric and Magnetic Fields In Front of Rhombic Antenna

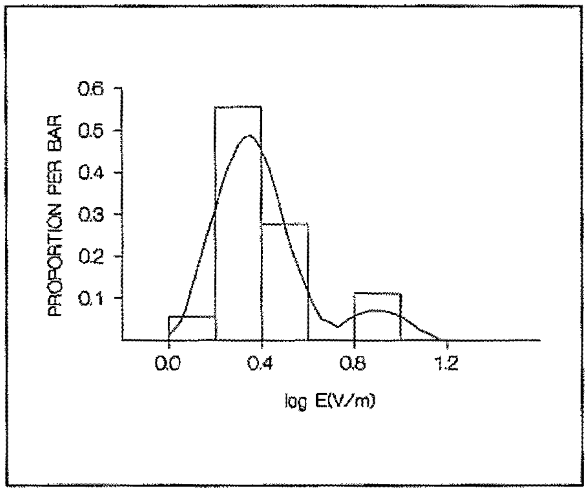


Figure 12. HF Electric Field Histogram and Smoothed Data

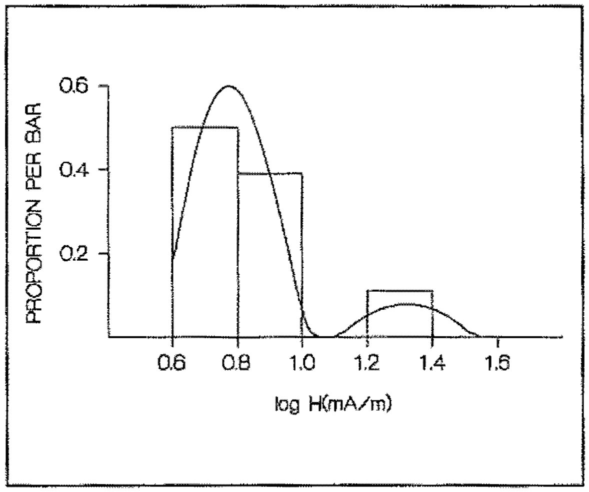


Figure 13. HF Magnetic Field Histogram and Smoothed Data

3.2 ELF Results

ELF electric and magnetic fields were measured at residential street intersections that had numerous power distribution lines. Eleven measurement sites were selected (Fig. 3). Generally, each intersection was probed for a maximum field reading. In some cases, measurements were made at different corners of an intersection or at the middle of a block. Measurements taken in this way should sample the upper limits of fields due to power distribution lines in residential areas. The map in Figure 14 and the list in Table 6 show the results. ELF electric field strength values varied from 3.4 to 30 volts/meter (V/m) and magnetic field flux density varied from 0.5 to 15 milligauss (mG) or 40 to 1200 milliamps/meter (mA/m).

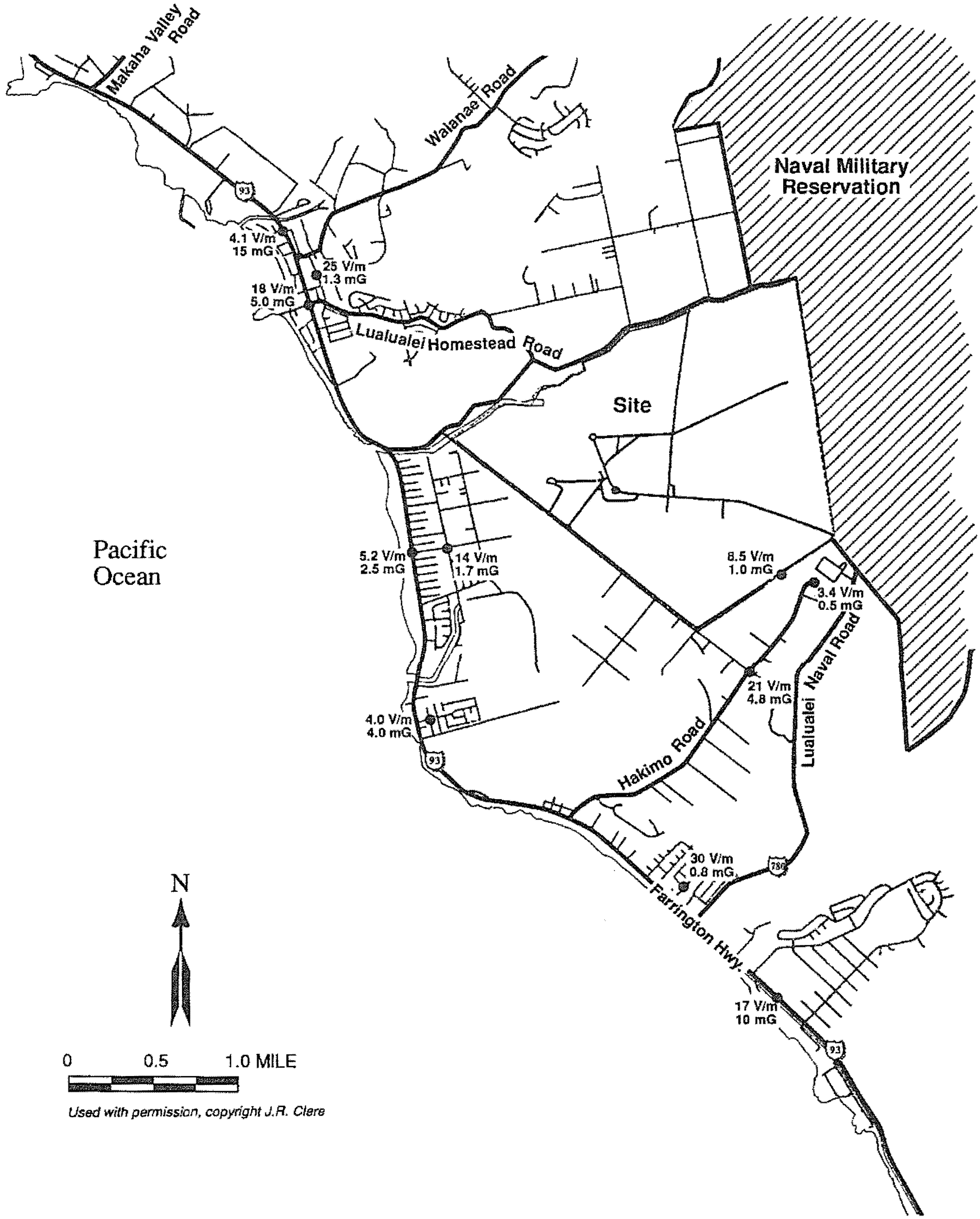


Figure 14. ELF Results

TABLE 6. ELF RESULTS

INTERSECTION	ELECTRIC FIELD (V/m)	MAGNETIC FIELD (mG)
Farrington Highway and Nanakapona School	17	10
Auyong Homestead Road and Holomalia Street	30	.8
Hakimo Road at end of pavement	3.4	.5
Hakimo Road and Paakea Road	21	4.8
0.2 miles from end of Iliili Road	8.5	1
Hookele Street and Ehu Street	4	4
Maliona Street and Farrington Highway	5.2	2.5
Kulaaupuni Street and Maliona Street	14	1.7
Mill Street and Lualualei Homestead Road	18	5
Mill Street and McArthur Street	25	1.3
Farrington Highway and Kaupuni Street	4.1	15

Histograms and smoothed data distribution plots for the ELF data are shown in Figures 15 and 16. In order to avoid highly skewed distributions, the logarithm base 10 of each data value in Table 6 has been calculated before entering the data into a statistical distribution plotting program. In addition, the units for the magnetic field have been converted from milligauss to milliamps per meter by multiplying by 80 before taking the logarithm. Interpreting these distributions is illustrated as follows. The histogram bar plot for the ELF electric field shows that most of the log of measurement values fall between 1.2 and 1.4 or, by taking the antilog (10^x), most of the values fall between 15.8 and 25.1 volts per meter. The proportion per bar for this bar is about 0.37, meaning that 37% of the maximum electric field values measured at selected intersections are between 15.8 and 25.1 V/m. As another example, the smoothed distribution plot for the ELF magnetic field shows a peak in the log of the magnetic field distribution at about 2.2 or, taking the antilog, at 158 milliamps per meter or 2.0 milligauss. Thus, the most probable maximum magnetic field measured in selected residential intersections is 2.0 mG.

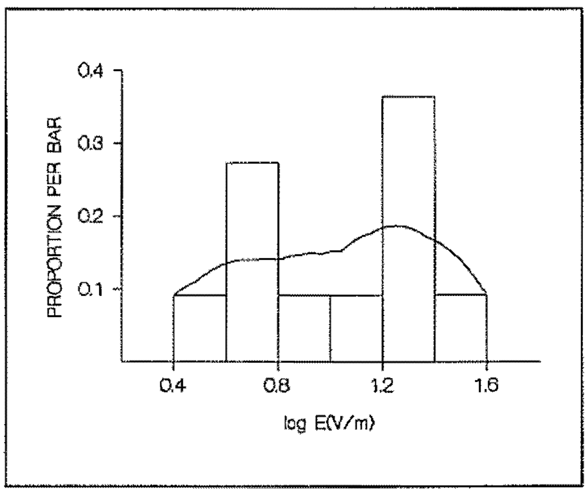


Figure 15. ELF Electric Field Histogram and Smoothed Data

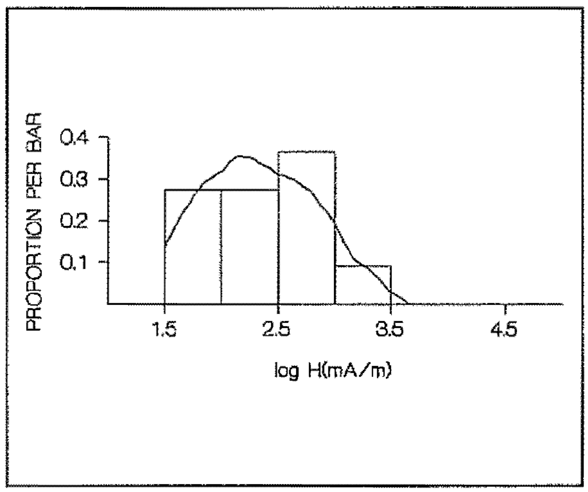


Figure 16. ELF Magnetic Field Histogram and Smoothed Data

3.3 Discussion

This report presents results from a measurement survey intended to identify maximum electric and magnetic field levels in residential areas near Naval radio transmitters at Lualualei. The object was to gain some understanding of field levels in the community rather than conduct a detailed exposure assessment. The survey is thus considered exploratory for that reason, as well as for the following considerations. The equipment used was portable and somewhat limited. Measurement sites were not chosen based on statistical or epidemiological considerations, but, rather, were chosen based on engineering judgment--the primary objective being to find the maximum field in publicly accessible areas out of doors. Finally, even though almost all the measurements were made in residential areas (housing, although sparse, surrounds the Navy site where readings were taken along roads and traversing power lines) the sites chosen for each frequency band are at different locations, which could result in misleading comparisons between data sets for the different bands.

Only in the VLF band are the measurement data adequate to infer a range of field strength in the area. However, the VLF data do not allow prediction of exposure at any particular location. If this information were required, the next logical step would be to define numerical models of the VLF tower system and compare the results of numerical electromagnetic computer calculations to the measurement data. A confirmed model could then be used for field prediction.

4. CONCLUSIONS AND RECOMMENDATIONS

This report documents the results of magnetic and electric field measurements made during the last week of November 1990 in the Waianae area of Oahu, Hawaii. The maximum electric and magnetic fields measured outside of the Navy site boundary in each frequency band are shown in Table 7. The range of VLF fields measured was 0.15 to 82 V/m and 2.5 to 99 mA/m. The lower levels of fields at ELF, LF, and HF can not be inferred from the measurement data.

TABLE 7. MAXIMUM FIELDS MEASURED DURING STUDY

Frequency	Electric Field (V/m)	Magnetic Field (mA/m)
ELF	30	1200 (15 mG)
VLF	82	99
LF	.5	.9
HF	8.8	22

If further efforts to quantify exposures in the area are directed, several activities could be initiated. These could include computer modeling of field sources, modulation measurements, ELF exposure measurements using generally accepted protocols, long-term monitoring of HF exposures, measurements of contact currents, and measurements indoors. However, such efforts could be expensive and may add only a marginal amount of additional information on field levels in the Lualualei area.

REFERENCES

1. Mantiply, Edwin D. An Automated TEM Cell Calibration System. U.S. Environmental Protection Agency, EPA 520/1-84-024, October 1984.

2. Smith, A.A., "Attenuation of Electric and Magnetic Fields by Buildings," IEEE Transaction on Electromagentic Compatibility, EMC-20(3), August 1978.

3. Personnel Radhaz (Radiation Hazard) Measurements at RTF Lualualei; Final Report. Department of the Navy, Naval Communication Area Master Station, Eastern Pacific, Wahiawa, Hawaii 96786-3050, October 1982.

4. Mantiply, Edwin D., Hankin, Norbert N. Radiofrequency Radiation Survey in the McFarland, California Area. U.S. Environmental Protection Agency, EPA/520/6-89/022, September 1989.

APPENDIX

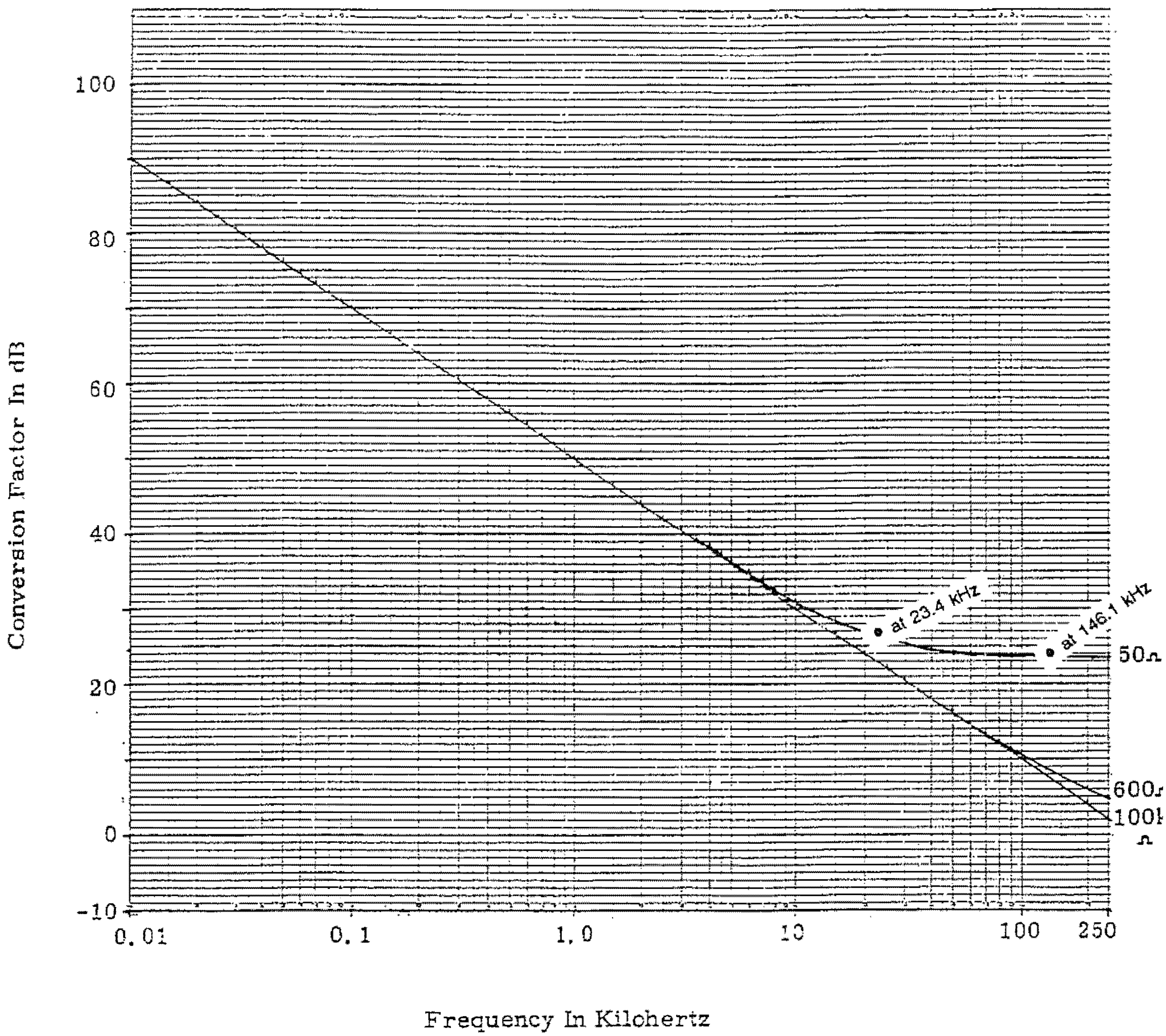
CALIBRATION DATA

IFI EFS-1 1059-E
Correction Factors

Frequency (MHz)	Full Scale (V/m) 3.00	10.0	30.0	100
.0234	1.042	.988	1.046	.964
.1461	.984	.952	.980	.909
8.077	.890	.870	.865	.825
13.523	.880	.860	.859	.825

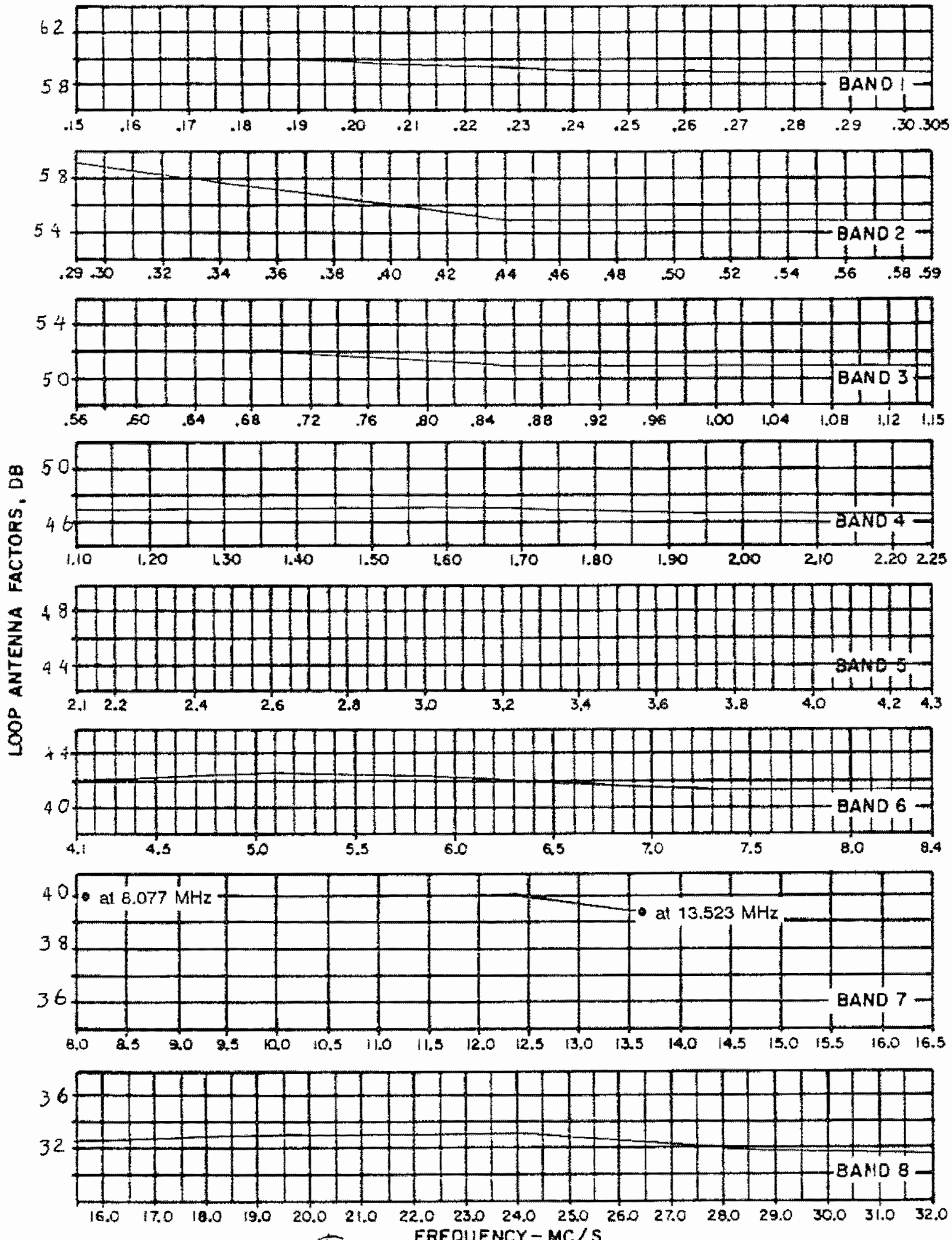
IFI EFS-1 1060-E
Correction Factors

Frequency (MHz)	Full Scale (V/m) 3.00	10.0	30.0	100
.0234	1.087	1.067	1.082	1.039
.1461	.992	.988	.969	.952
8.077	.909	.909	.887	.860
13.523	.887	.889	.865	.860



• measured conversion factors found in TEM cell

Conversion Factors for Picotesla Terms
Model 94605-1 Loop Antenna



CALIBRATED BY: ____________________ FOR SES 92200-3 LOOP ANTENNA

DATE: ____________________ SERIAL NO. ____________________

SES P/N 41009 CHART 4 — CORRECTION FACTORS, REMOTE LOOP ANTENNA

NOTES: • antenna factors used for HF measurements