MICROWAVE HAZARD EVALUATION
(A Field Survey Form)

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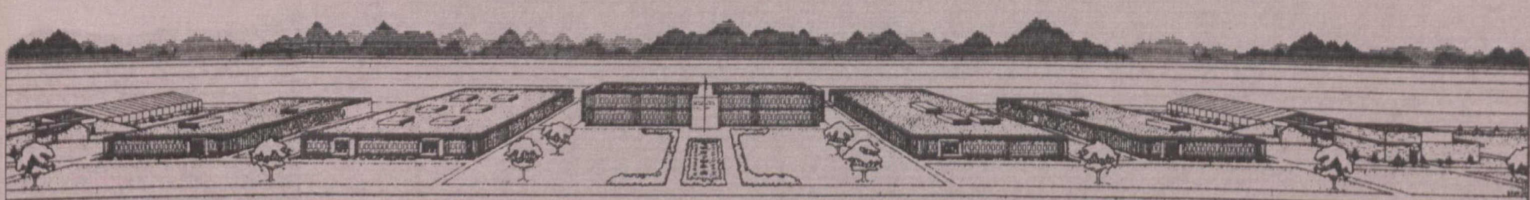

SWRHL-84

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ABSTRACT

A survey form for the evaluation of microwave devices designed for the emission of microwave energy, such as radar, has been developed. Use of the form as well as certain basic survey techniques is discussed. Instrumentation employed in the survey and its application to the field environment are presented along with a sample field survey form.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

In compliance with Public Law 90-602, The Radiation for Health and Safety Act of 1968, the Secretary of Health, Education and Welfare is responsible for developing and applying performance standards to control the emission of electronic product radiation. Under Section 357 of this law, the Secretary is required to initiate practical procedures for detecting and measuring electronic product radiation prior to the effective date of standards that may be established.

This paper presents a method for evaluating open field microwave radiations. Encompassing general survey requisites and techniques, the method is based on utilization of the Field Survey Report Form. The form, which was designed by the Electronic Products Studies Section of the Southwestern Radiological Health Laboratory (SWRHL), is described herein.

CONSIDERATIONS AND PREREQUISITES

Microwave radiation is a potential hazard to man only when man has access to it. When exposure criteria are exceeded a hazard is assumed to exist. It is to be noted, however, that no published exposure standards are recognized as official within this report. For examples of published standards, see References 1, 2 and 3.

The term "microwave" in this context applies to that portion of the electromagnetic spectrum that ranges from 100 to 100,000 megahertz (MHz) or wavelengths from 300 to 0.3 centimeters. This wide range includes such uses as commercial television broadcast, commercial FM broadcast (88 to 108 MHz), microwave cooking (915 to 2,450 MHz) and commercial and military radar. Radars usually operate at distinct frequencies in the L band (1,120 to 1,450 MHz), the S band (2,600 to 3,300 MHz) or the X band (8,200 to 12,400 MHz).

With this diversity in types and applications of microwave sources, it is apparent that no single specific survey procedure would be satisfactory for all types of sources. However, since these sources emit the same type of radiation, the same basic data are needed for hazard analysis in each case. A field survey report which includes the fundamental parameters common to all microwave sources, and at the same time provides a place for specific details concerning the source being surveyed, is sufficiently versatile to accommodate the evaluation of many of the sources encountered in the field.

The Field Survey Report Form incorporates all such appropriate data requirements and provides space for additional information of significance. Sections I and II of the survey report provide spaces for recording pre-evaluation source data including unit identification and the basic operating parameters of the device. Survey instrumentation is identified in Section III and supplemental sections are included for the recording of field measurements and results, and for noting summary recommendations and comment.

USE OF THE FIELD SURVEY REPORT FORM

Section I - Identification

The basic control information, including the source, site and time of the study, is recorded in this identification section. Cross-reference may be made through several entries to facilitate access to the data.

Section II - Operating Characteristics

The specific technical characteristics of the source product under study are recorded in this section. The operating frequency, power output, polarization and other variables of the unit govern the selection of appropriate equipment for measuring its radiation emission. The output of the source product, whether pulsed or continuous (CW), is a prime hazard determinant. For pulsed units, consequently, both the pulse duration and the pulse repetition frequency (prf) are prime factors. Information compiled in conjunction with these data is recorded in Section IV, Field Data.

Devices which are designed to confine microwave energy differ from those which intentionally radiate energy in a well-defined pattern since a containing device (such as a microwave oven) may be leaking, it would be very difficult to measure a beam profile. Measurement of the field pattern may, however, yield much useful insight as to the source of leakage and possible methods of correction.

For devices other than those designed to confine mircrowave energy, the power density along the beam axis is particularly important when there is a probability of personnel exposure. In many instances guidelines of beam axis intensity to be expected may be provided by published technical manuals accompanying the equipment. For many types of U. S. Air Force radar equipment, nominal beam axis intensities are available in the Department of the Air Force Manuals AFM 161-7 and T.O. 31Z-10-4. (See References 4 and 5.) These intensities should be regarded only as rough guides.

The height of the beam above the ground at any given distance from a directional antenna is another factor to be considered when evaluating potential hazards. This information can be determined geometrically from the antenna height and the beam elevation angle(s), with particular consideration applied to the terrain features.

A source which is designed to transmit radiations must be evaluated in terms of the levels of emission as a function of position about the radiating element. Those positions or areas accessible to persons should be given particular attention. As stated, a comparison of the current applicable standards or criteria with the existing power densities in these areas will indicate whether a hazard currently exists.

In a more complex installation, it will be necessary to obtain a plot of the field about the antenna if such information is not available from published information. The surveyor must be aware, however, that objects in the beam path can seriously alter the published field pattern of the radiating antenna by reflecting a portion of the incident energy. Whenever published patterns are available, measurement data should be compared with them. Any discrepancies should be explored.

Repolarization by reflection is possible, and radiations reflected into occupied areas not directly in the beam path may well be polarized in a different state from the polarization of the direct beam. Thus, measurements performed with a linearly polarized antenna, for example, oriented to receive radiations directly from the transmitting antenna, may be insensitive to energy reflected and repolarized. The surveyor should evaluate the polarization of the microwave energy at each point to ensure that the totality of the field intensity is being measured.

Infrequently the surveyor may be forced to make measurements in the near field as, for example, in the case of an operator guiding an antenna from a position immediately adjacent to the antenna. In such circumstances the reading obtained will be seriously inaccurate and the values obtained are not truly representative of the field. Under these circumstances a completely objective measurement is not possible; the surveyor must rely on prior experience in assessing the existence of any hazard.

A free-hand sketch of the microwave source and the surrounding area should be included showing the dimensions of the antenna and the elevation of important points about the antenna. A symbol or reference should indicate the location and number of operating personnel, the areas in which other individuals are likely to work or to which access is permitted, and the time during which an area is occupied.

Section III - Equipment

This section identifies the type(s) of measurement instrumentation required for this particular project. With the use of a calibrated receiving antenna, thermistor and power meter, the power density is computed by dividing the total power by the effective area (aperture) of the receiving antenna.

In making power density measurements, care must be exercised to ensure that the measurement system is operating in the far field. The distance or separation at which far field behavior begins is a complex function of antenna aperture and configuration. One can assume far field conditions when power density decreases following the inverse square law.

Figures 1 through 4 illustrate the component parts of measurement equipment used in SWRHL radiation survey work which is typical of the systems frequently used for power density measurements. Figure 5 shows these component parts assembled and ready for use. The receiving antenna, a standard gain horn, is the pickup device which samples the radiation field and must be constructed and calibrated for the frequency of the radiation being measured. The calibrated attenuator is used to reduce the received power to a level compatible with the thermistor's maximum input power specifications. This attenuator must have a known accuracy but could have either variable or fixed values of attenuation. The attenuator shown in Figure 2 is a fixed value device (at any given frequency). The thermistor, which is connected to the output of the attenuator, is a heat-sensitive device in which resistance changes with temperature. Incident microwave power, when absorbed, causes an increase in temperature and therefore a resistance change. This resistance change is sensed by the power meter which converts the resistance change to a power reading indicated on a meter. The meter shown in Figure 4 is a Hewlett-Packard Model 432A. It is a critical requirement that the components be individually calibrated and be of known accuracy.

When a system is constructed as illustrated and described, the power density can be calculated using the following formulas -- providing the measurements are taken in the far field of the radiating and receiving antennas:

$$P_d = P_r / A_e$$

Where,

P_d = power density (mW/cm^2)

P_r = power received (mW) = (power meter reading) x (attenuation $^{-1}$) x (thermistor calibration factor)

A_e = effective aperture (area) of the antenna (cm^2)

and $A_e = \dfrac{\lambda^2 G}{4\pi}$

where, λ = the wavelength of the radiation (cm) and

G = the absolute power gain of the test antenna.

NOTE: Recording the equipment identification as well as the calibration factors and dates is of vital importance. Space is provided for this purpose on the Survey Report Form, Section III.

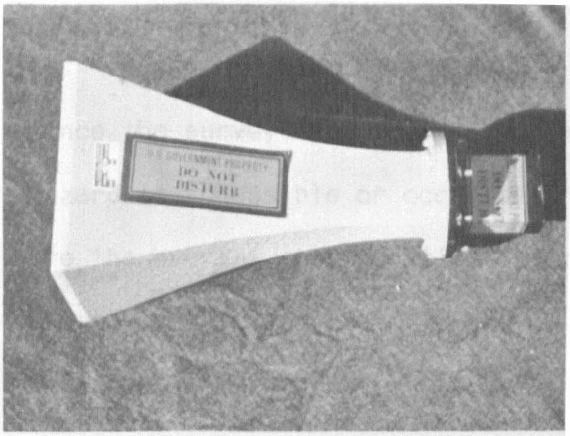

Figure 1. Standard Gain Horn

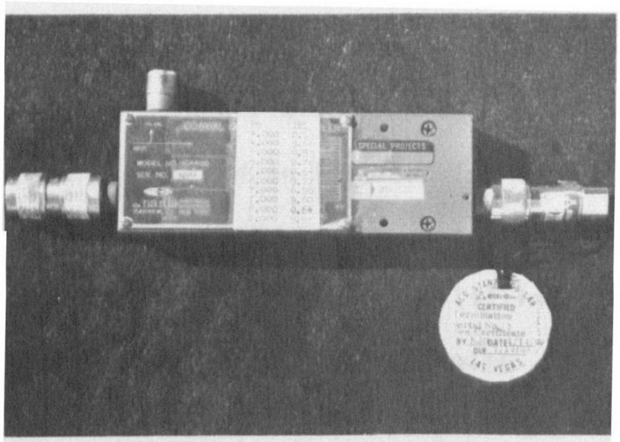

Figure 2. Calibrated Attenuator

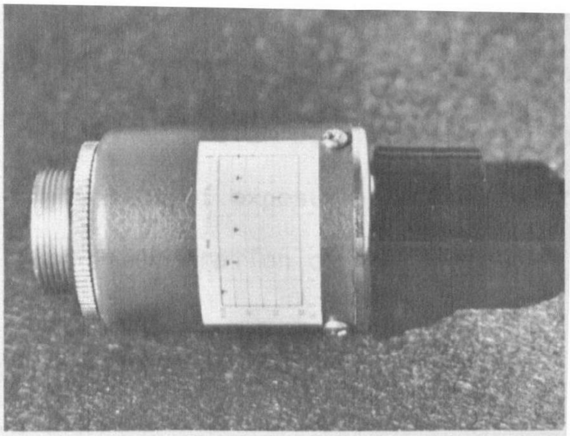

Figure 3. Thermistor Mount

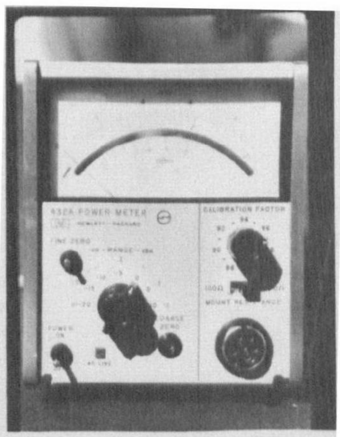

Figure 4. Power Meter

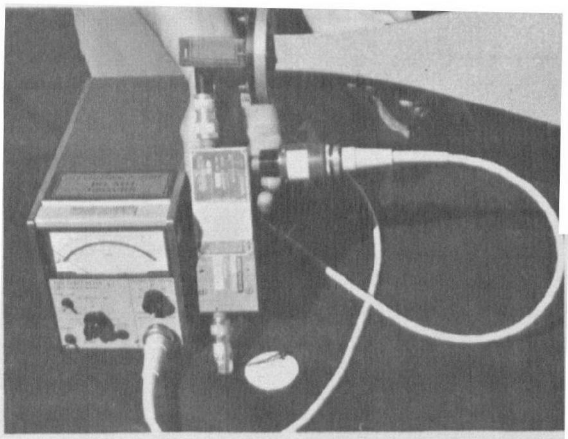

Figure 5. Measurement Assembly

Section IV - Field Data

Since the survey must (a) produce a specific analysis of the existing hazard in accessible or occupied areas around the source, and (b) delineate the overall configuration of potentially hazardous areas, it is essential that measurements of the field around a microwave source be recorded. As information is obtained from field measurements taken as specified in Section II, above, the results are recorded in this Section IV of the Survey Report Form. This process involves the calculation of the power density from the power indicated on the survey power meter. Utilizing this information, it is possible to compare existing power densities with published criteria. From this information recommendations as to the reduction of exposure can be made to the personnel or facility responsible for the operation of the microwave device.

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APPENDIX

FIELD SURVEY REPORT FORM
(OPEN FIELD MICROWAVE)

ELECTRONIC PRODUCTS STUDIES SECTION
SOUTHWESTERN RADIOLOGICAL HEALTH LABORATORY
UNITED STATES PUBLIC HEALTH SERVICE

Report No. ____________

I. Unit Identification: Date ____________

Organization: ________________________________ Telephone: ____________

Address: ____

Date of Survey: __________________ Unit Ident: ______________________

Type/Use: ______________________ Manufacturer: ____________________

Person in Charge: ________________ Person contacted __________________

Address: __________________ ____________________________

Telephone: ________________ ____________________________

II. Operating Characteristics:

Frequency: ______________________Hz

Power: CW ☐ Pulse ☐

Average: __________watts Peak: __________________watts

Use: ____________min/hr Pulse width: ______________sec

prf: ____________________sec^{-1}

Use load: __________________

Beam: Omnidirectional Yes ☐ No ☐

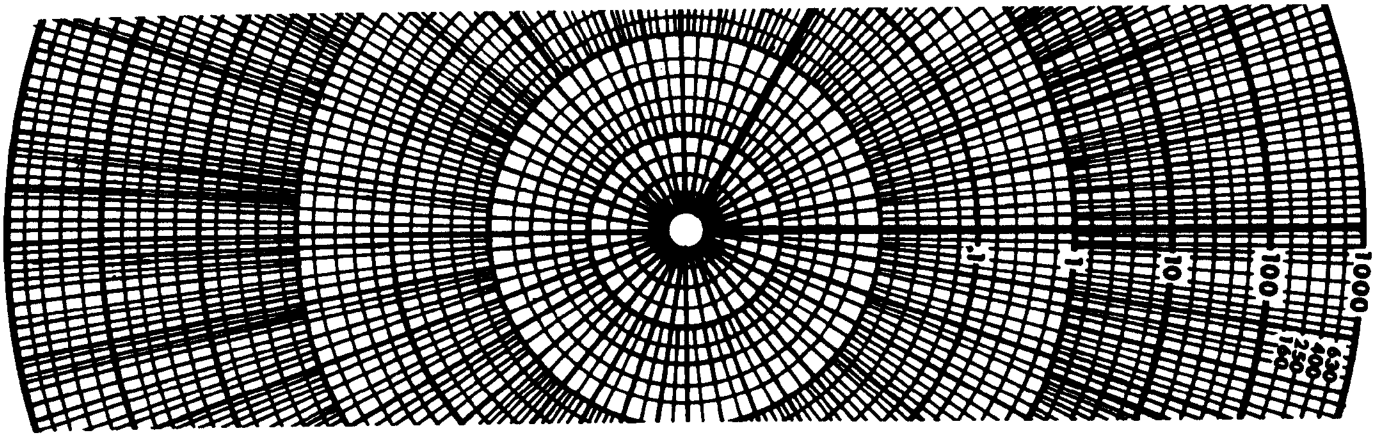
Polarization: Linear __________ Circular __________

Rotation Rate: ______________

Position Limits: Azimuth __________________

Elevation ________________

Beam Power Distribution:



Plot of Antenna Location and Site Area:

Antenna Dimensions: (Sketch)

Height of Antenna(s) (to center line): ______________________________

Location of Operator:

Location(s) of Other Personnel (note the nature and duration of occupation):

III. Equipment:

Meter: Type ______________ Ser. No. __________ Cal. Date ____________

Thermistor: Model __________ Ser. No. __________ Cal. Date ____________

Antenna: Type _____________ Model ____________ Ser. No. ____________

Calibration Date ___________ Gain ________________ Power Ratio

Gain ______ ± ______ db at _______________ Hz

Effective aperture $(A_e) = \frac{G\lambda^2}{4\pi} =$ ____________________________

Attenuators Used:

1. ____ ± ____ db at _________ Hz Model ___________ Ser. No. ___________

2. ____ ± ____ db at _________ Hz Model ___________ Ser. No. ___________

3. ____ ± ____ db at _________ Hz Model ___________ Ser. No. ___________

Calibration Date: __________________

Sketch of Equipment Configuration:

IV. Field Data (Key to Site Plot, page 14):

Location	Height	Meter Pwr (mW)	Attenuation db	Attenuation pwr ratio	Total (mW)	A_e (cm^2)	Power Density (mW/cm^2)

Interlock System:

Cabinet ______________ Functional ____________________

Area ________________ Functional ____________________

Operator Key ________________ Functional ______________

Is overall interlock system adequate?

Remarks:

V. Analysis and Conclusions:

Field Results:

Distance to 10 mW/cm^2 along beam axis: ______________________

Distance to 1 mW/cm^2 along beam axis: ______________________

Remarks:

Recommendations: (Attach additional sheets if needed.)

Date of Signature: ______________________ Surveyors: ______________________

____

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