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MICROWAVE RADIATION AT THE U.S. EMBASSY IN MOSCOW AND ITS BIOLOGICAL IMPLICATIONS: AN ASSESSMENT

PREPARED FOR THE
U.S. DEPARTMENT OF STATE
WASHINGTON, D.C. 20520

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report presents the results of an assessment of the likelihood of biological effects from the microwave environment within the U.S. Embassy in Moscow, USSR, based on a retrospective analysis of that environment. It contains a description of the microwave fields and models of power density distribution within the Embassy from 1966 to 1977; estimated personnel exposures as a function of work and living locations in the Embassy; and the results of an assessment of the biological implications of the type and levels of exposure described. In summary, it was concluded that no deleterious biological effects to personnel would be anticipated from the microwave exposures as described.

16. Key Words *(Alphabetical order, separated by semicolons)*
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FOREWORD

This report presents the results of an assessment of the likelihood of biological effects from microwave fields in the U.S. Embassy in Moscow. In summary, it was concluded that no deleterious biological effects would be anticipated from the microwave exposures as described in this assessment.

In 1976, press reports on the microwave signals impinging on the U.S. Embassy in Moscow engendered considerable public interest and some concerns over the possible biological effects on personnel who had been stationed at the Embassy.

Measurements by the Department of State, showed the power density levels in the Embassy to be extremely low. Their reviews of medical records and the health of Embassy personnel did not indicate any problems related to microwave exposures. Nevertheless, to insure that nothing had been overlooked, it was decided to undertake a comprehensive epidemiological survey of the health status of people who had been stationed in Moscow between 1953 and 1976. The results were compared with those of personnel at other Eastern European posts, not exposed to the microwave signals. This study was conducted by the Department of Epidemiology at The Johns Hopkins University's School of Hygiene and Public Health at the request of the Department of State. The results were published by The Johns Hopkins University in 1978[1/]. This study did not show any differences in morbidity or mortality attributable to the presence of microwaves in Moscow. However, the report recommended that -

> There is a need for an authoritative biophysical analysis of the microwave field that has been illuminating the Moscow Embassy during the past 25 years with assessments based on theoretical considerations of the likelihood of any biological effects.

To satisfy this recommendation the Department of State requested the cooperation and assistance of the National Telecommunications and Information Administration (NTIA)[2/].

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The approach adopted was to conduct an analysis of the microwave fields in the Moscow Embassy followed by an assessment of the likelihood of biological effects. Additional background for this study is available in the Appendix to this report. Results of the assessment of the potential for biological effects from the microwave fields in the Embassy are summarized in Section A. An estimate of personnel exposures as a function of locations within the Embassy developed by the Department of State is reported in Section B. The results of the retrospective analysis and description of the microwave fields in the Embassy by the Applied Physics Laboratory of The Johns Hopkins University is contained in Section C.

Notes: 1/ Lilienfeld, A.M., Tonascia, J., Tonascia, S., Libauer, C.H., Cauthen, G.M., Markowitz, J.A., Weida, S., Foreign Service Health Status Study: Evaluation of Health Status of Foreign Service and other Employees from Selected Eastern European Posts, Department of Epidemiology, of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Maryland 21205. Final Report, July 31, 1978, 247p. Available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Va. 22161, (703) 487-4650, Accession No. PB 288 163.

2/ The National Telecommunications and Information Administration (NTIA) is responsible for coordinating Federal Government activities to investigate biological effects and ensure safe use of microwaves and other radio frequency radiation. It is assisted by the Electromagnetic Radiation Management Advisory Council (ERMAC) which advises on side effects and the adequacy of control of such radiations and recommended a comprehensive Federal program in their 1971 report.

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ERMAC ASSESSMENT OF THE POTENTIAL FOR BIOLOGICAL EFFECTS FROM MICROWAVE ILLUMINATION OF THE U.S. EMBASSY IN MOSCOW

The Electromagnetic Radiation Management Advisory Council (ERMAC)* met on August 26, 1980 to assess the biological implications of the microwave environment within the U.S. Embassy in Moscow, based on a retrospective analysis of that environment. This assessment was undertaken in response to a recommendation in the 1978 "Foreign Service Health Status Study" by The Johns Hopkins University School of Hygiene and Public Health which reads as follows:

> There is a need for an authoritative biophysical analysis of the microwave field that has been illuminating the Moscow Embassy during the past 25 years with assessments based on theoretical considerations of the likelihood of any biological effects.

To implement this recommendation, the Department of State requested the assistance of the National Telecommunications and Information Administration (NTIA). The Johns Hopkins University Applied Physics Laboratory was requested to develop as complete a physical description of the U.S. Embassy microwave environment as possible using all available data. Models were developed describing the microwave power density distribution within the Embassy during the period January 1966 to February 1977. Based on these models, the Department of State estimated personnel exposure as a function of location in the Embassy. After reviewing this information, the ERMAC was asked to assess the likelihood of any biological effects from the microwave environment and estimated exposures described.

The Council agreed that the models presented tend to overstate rather than understate the probable microwave levels and that there is no indication of any significant variations from the models over time.

The Council discussed the current state of knowledge and on-going research on biological effects of microwave radiation. A considerable number of scientific investigations have been conducted and biological effects have been reported from

* Membership and Charter attached.

exposures to power densities higher than those under assessment and to specific modulation frequencies not found in the Moscow signals. It was agreed that there is no scientific evidence, nor are there any theoretical grounds to suggest that biological effects would be expected to occur from the type and low levels of exposure as presented in the models.

Consequently, the ERMAC concluded that no deleterious biological effects to personnel would be anticipated from the microwave exposures at the U.S. Embassy in Moscow as described in this assessment.

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ELECTROMAGNETIC RADIATION MANAGEMENT ADVISORY COUNCIL

ESTABLISHMENT

The Electromagnetic Radiation Management Advosory Council (the Council) was established on December 11, 1968 and provided advice to the Director, Office of Telecommunications Management and his successor, the Director, Office of Telecommunications Policy, Executive Office of the President. The majority of the functions of the latter office (and the Council) were transferred to the Department of Commerce by Executive Order 12046 of March 27, 1978 and are performed by the National Telecommunications and Information Administration.

The Secretary of Commerce having determined after consultation with the General Services Administration that is in the public interest in connection with performing duties imposed on the Department by and executive order 12046 hereby continues the Electromagnetic Radiation Management Advisory Council pursuant to the Federal Advisory Committee Act, 5 U.S. C. App. (1976).

SOCPE AND OBJECTIVES

The Electromagnetic Radiation Management Advisory Council will advise the Secretary of Commerce on side effects and the adequacy of control of electromagnetic radiations arising from telecommunications activities. It will review, evaluate, and recommend measures to investigate and mitigate potential undesirable effects on the environment. Its objectives include:

(a) the review of Government and non-Government activities bearing upon the adequacy of control of electromagnetic applications which may involve directly or indirectly the production of radiant energy in any portion of the spectrum capable of causing either harmful biological effects, or harm to equipment and material. (The spectrum is presumed to consist of the electromagnetic spectrum range from electrostatic and constant magnetic fields through the radio frequency to the optical spectrum, including the use of coherent optical radiation (lasers), and x-rays produced by electrical or electromagnetic devices.)

(b) the review, as required, of matters relating to non-electromagnetic radiation phenomena (such as infrasonic and ultrasonic radiation) which may derive from the use of electronic equipment or be under the purview of those agencies of the Government concerned with the electromagnetic spectrum.

The Council will function solely as an advisory body, in accordance with the provisions of the Federal Advisory Committee Act.

MEMBERS AND CHAIRPERSON

(a) The Council shall consist of no more than fifteen members, as needed, to be appointed by the Assistant Secretary for Communications and Information to assure a balanced representation in such areas as engineering, the physical sciences, biomedical and the health sciences. The members will be appointed for a period of two years and will serve at the discretion of the Assistant Secretary. Vacancy appoints shall be for the remainder of the unexpired term of the vacancy.

(b) The Chairperson of the Council is the Assistant Secretary for Communications and Information or designee.

ADMINISTRATIVE PROVISIONS

(a) The Council will report to the Secretary through the Assistant Secretary for Communications and Information.

(b) Members of the Council will not be compensated for their services but will, upon request, be allowed travel expenses incurred in the performance of their duties, as authorized by 5 U.S.C. 5701 et. seq.

(c) Administrative support for its activities will be provided by the National Telecommunications and Information Administration and is estimated not to exceed $25,000 annually which includes one-fourth person year of effort.

(d) Meetings will be held at approximately three-month intervals at the call, or with the approval of the responsible Departmental official or his representative, and with an agenda formulated and approved by such official. No meeting shall be conducted in the absence of this official.

(e) Detailed minutes of each meeting shall be kept and shall contain a record of the persons present, a complete and accurate description of matters discussed and conclusions reached, and copies of all reports received, issued or approved by the Council. The accuracy of all minutes shall be certified to by the Chairperson of the Council.

DURATION

The Electromagnetic Radiation Management Advisory Council shall terminate two years from the date of this charter unless terminated earlier or renewed by proper authority by appropriate action.

9 JAN 1981
Date

Assistant Secretary for Administration

Pursuant to subsection 9(c) of the Federal Advisory Committee Act, 5 U.S.C. App. (1976), this committee was filed with the Assistant Secretary for Administration on January 9, 1981. On the same date, copies were filed with the following committees of Congress, and a copy furnished the Library of Congress:

-- Senate Committee on Commerce, Science, and Transportation
-- House Committee on Energy and Commerce

Jan. 13, 1981
Date

Marilyn S. McLennan, Chief
Information Policy Division
Office of Organization and
Management Systems

SECTION B

A MODEL OF PERSONNEL EXPOSURE

Office of Medical Services
U.S. Department of State

Introduction

One of the recommendations of the Johns Hopkins' Foreign Service Health Status Study was "There is a need for an authoritative biophysical analysis of the microwave field that has been illuminating the Moscow Embassy during the past 25 years with assessments based on theoretical considerations of the likelihood of any biological effects."

The Department of State requested the help of NTIA in carrying out this recommendation. It was planned that the overall approach would consist of three phases: Phase I, as complete a physical description of the Moscow field as possible; Phase II, estimation of exposure for model personnel and Phase III, assessment of the likelihood of any biological effects.

Accordingly the Applied Physics Laboratory (APL) of the Johns Hopkins University (JHU) was asked to carry out Phase I. The document entitled "A MODEL OF THE MICROWAVE INTENSITY DISTRIBUTION WITHIN THE U.S. EMBASSY, MOSCOW 1966 to 1977" prepared by Robert C. Mallalieu of the APL is a description and summary of this phase.

Background

The illumination of the Chancery can be divided into two periods. The first code name TUMS, from 1953 to 26 May 1975, and the second, code name MUTS from 28 May 1975 until February 1977. The MUTS interval is divided into two parts by the installation of window screens on February 5, 1976. The first MTUS interval extends from 28 May 1975 to 5 February 1976 and the second interval, in which the fields were reduced due to both the screening and reductions in transmitter power, extends from 6 February 1976 until 1 February 1977. In 1962 the Department of State instituted a system for continuously monitoring the signals using strip-chart recorders. Power density and frequency measurements also were made but records of actual power density measurements prior to 1966 were not adequate for analysis so that the models of the microwave intensity distribution within the Embassy extend only from January 1966 to February 1977.

For the TUMS period the power density was measured directly. During the MUTS interval the electric-field energy density was measured and the "equivalent" power density calculated.

The APL report was careful to point out "that power density 'values' alone are not sufficient to describe the microwave fields with the Chancery." It is acknowledged that even at the same point in such an environment, the power density as measured by these two methods will differ and so will the electric (E) and magnetic (H) field strengths inferred from the measurements. The "equivalent" power density will be higher if read at an electric-field antinode, but the inferred higher E and H fields are not simultaneous and collocated. The direct power density is lower, but its lower E and H fields are oriented to allow a relatively more efficient transfer of power.

TUMS (Technically Unidentified Moscow Signal)

During the TUMS period there was a single source of the microwave beam from a Soviet apartment house about 100 meters west of the Chancery. The west facade of the central building was illuminated. The highest intensities appeared between the 3rd and 9th floors with lower levels on the 1st, 2nd, and 10th. Only rooms with windows or doors on this west wall were directly affected (although the model assigns lower power density values to interior rooms, no measurable levels were recorded there). The highest levels were within 2 feet of doors and windows on the west wall. The severe winter weather (as low as 45° F and C below zero) usually resulted in placing the desks away from the window areas in the working rooms on the 7th, 8th and 9th floors. The average power density* throughout illuminated exterior rooms, at greater distances from the windows, was about 1.5 microwatts/cm2.

In the living quarters from the 3rd to the 7th floors, the kitchens and main bedrooms had windows in the west wall. The layout of the kitchens, which were about 7 feet wide and 18 feet long put the refrigerator on the west wall just north of the window. When the door was opened it served as a screen across the window, so that any one taking out or putting foods into the refrigerator was shielded from the microwaves coming through the window. The stove and the sink were about 4 feet from the window, the stove on the south wall and the sink on the north wall. The clothes washer was at least 10 feet from the window. The layout in the bedroom usually showed the headboards against the south wall at least 4 feet from the west wall (again this was protection from the cold drafts). The average figure of 1.5 microwatts/cm2 may be applied to these illuminated rooms. Living rooms and dining areas and bathrooms were not exposed in the TUMS period.

MUTS (Moscow Unidentified Technical Signal)

For the MUTS episode the transmission originated from two sources, one the roof of an apartment house about 100 meters east of the Chancery, and the other an office building about the same distance south. Many windows were facing east in the central building, but only two rooms, 901 and 1001 and two south stairway areas on the 8th and 9th floors had windows facing south.

Screening was installed by 6 February 1976 and that, along with a series of transmitter power reductions, reduced the levels within the buildings to "less than 0.1 microwatts/cm2". That figure serves for the second portion of the MUTS model.

* The average power density levels throughout the illuminated rooms can be assumed to be half the working area antinode values.

Prior to the screening, the highest levels were recorded in the offices on the east side of the central building with increasing intensities toward the southeast rooftop corner (above Room 1001). The average antinode equivalent power density was as high as 10.2 microwatts/cm2 within 2 feet of the window in Room 1003 although the average antinode level in the working area of the room was only 3.0 microwatts/cm2. Room 901 had an average antinode level of 9.0 microwatts/cm2 through much of the room in July 1975 although the average was less than 2 microwatts/cm2 when data taking resumed in November 1975. These few values were the highest sustained or repeated levels. Inside the building, the highest reading was 24 microwatts/cm2 within 2 feet of the window in room 1001 during a two hour period of unusual signal strength on 24 January 1976.

Typically, the levels even on the top floors of the central building were lower. On these upper floors, the average antinode within 2 feet of the windows was 3.3 microwatts/cm2; further within the rooms, the average antinode level was 2.2 microwatts/cm2. The average power density away from the windows would have been about 1.5 microwatts/cm2. Again, only the rooms with windows on the east facade were involved. Within the living quarters in the central building and the north and south wings, only one apartment has an average antinode level above 1.3 microwatts/cm2 (Apartment 7B in the south wing had a level of 1.6 microwatts/cm2). The average power density throughout this apartment would have been about half of the antinode level or about 0.8 microwatts/cm2.

Summary of Typical Exposures for Model Personnel

A close approximation can be made of the actual number of people working or living in the various designated regions at the specific times. Over the period of time from 1953 to 1976 there were 1827 employees whose tours of duty were usually two years. A few served only one year. Several extended for two and even three tours. Over the same time there were about 3000 dependents.

During the TUMS period State Department employees in working areas with an average power density of about 1.5 microwatts/cm2 at any given time numbered:

West 8th floor --20
9th floor -- 2

Over the period of 22 years it is estimated that there were about 240 employees exposed to an average power density of about 1.5 microwatts/cm2 for approximately 2 hours during the workday (8 a.m. to 5 p.m.). During weekdays (Monday to Friday) the exposed working areas were illuminated for a maximum of 6 hours during each 24 hour period.

It is difficult to estimate how many people who worked on the 8th and 9th floors also lived in the central wing. However, the few who did received an additional average exposure of about 1.5 microwatts/cm2 for 3 hours a day during the two day weekend.

As to the dependents there were 15 apartments on the 3rd through 7th floors large enough to house several children (an average of 4 in the family). During the TUMS period this group was possibly exposed to an average of about 1.5 microwatts/cm2 (about 660 people over the 22 years). There were 4 smaller double apartments housing about 2 in each or 8 people at a time. These were in region 2 calculated as receiving about 0.75 microwatts/cm2. In the south wing there were 6 apartments occupied by singles. These 6 people were exposed to less than 0.1 microwatts/cm2. During weekdays the above apartments were illuminated for a maximum of 6 hours during each 24 hour period and for 3 hours a day during the two day weekend.

The MUTS episode lasted only about eight months. During this time there were about 26 employees involved. These employees with few exceptions were exposed to an average power density of about 1.5 microwatts/cm2 for 4 to 8 hours during the workday. During weekdays the exposed working areas were illuminated for a maximum of 11 to 16 hours during each 24 hour period.

The exceptions noted above were those who worked in a few offices on the upper floors of the central building (Rooms 701, 802, 804, 901, 1001 and 1002). Antinode levels in those rooms may be found from Table 4, summarizing data from the two MUTS surveys. The average levels in each room would have been about half of the antinode values.

During the MUTS period the microwave beam was focused more sharply on the upper floors. Within the living quarters in the central building and the north and south wings, the highest average power density value in illuminated rooms was about 0.8 microwatts/cm2.

*SUMMARY OF TRANSMITTER OPERATING (RECORDED) TIME

TRANSMITTER	TIME INTERVAL	TIME PERIODS	% OF TIME ON
TUMS	2/1/66 to 12/31/70	morning (midnight to 8 am)	22 (1.8 hrs.)
		workday (8 am-5 pm)	23 (2.1 hrs.)
		evening (5 pm to midnight)	20 (1.4 hrs.)
		weekdays	25 (6 hrs.)
		weekend days	12 (3 hrs.)
		summer (JJAS) days	25 (6 hrs.)
		other than summer days	20 (4.8 hrs.)
MUTS-1	7/1/75 to 10/15/75	morning	35 (2.8 hrs.)
		workday	44 (4.0 hrs.)
		evening	45 (3.2 hrs.)
		weekdays	45 (11 hrs.)
		weekend days	31 (7.5 hrs)
MUTS-1 & MUTS 2	10/16/75 to 2/5/76	morning	47 (4.0 hrs.)
		workday	83 (7.5 hrs.)
		evening	56 (3.9 hrs.)
		weekdays	65 (15.6 hrs.)
		weekend days	58 (13.9 hrs.)
POST SCREENING	2/6/76 to 3/4/76	morning	26 (2.1 hrs.)
		workday	73 (6.6 hrs.)
		evening	26 (1.8 hrs.)
		weekdays	50 (12 hrs.)
		weekend days	30 (7.2 hrs.)

* Based on data in Johns Hopkins Applied Physics Laboratory Report, Appendix E (Summary Time Charts of Transmitter Operating Hours.)

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
LAUREL, MARYLAND

Table 1

TUMS microwave power density model.

Region no.	Description of region	Power density ($\mu W/cm^2$)			
		Antinode within 2 ft of window	Antinode elsewhere in the room	Average throughout the room	Transient during mode changes
1	Central building rooms and stairways adjacent to the west wall of the building that have a window or door on the west wall, third to ninth floors, inclusive (the region with the highest power density)	4	2.5	1.5	20 (lasting between 10 seconds and 2 minutes)
2	Central building rooms and stairways as described in Region 1, but on the first, second, and tenth floors; any basement rooms in the central building with a window above ground level on the west wall; aparment rooms over the north and south courtyard entrances with a window or door on the west wall; rooftops of all three buildings	2	1.3	0.8	10 (lasting between 10 seconds and 2 minutes)
3	All other unshielded rooms and areas above ground level in all three buildings	less than 0.1	less than 0.1	less than 0.1	less than 0.1
4	All shielded rooms; all rooms below ground level in all three buildings with no west window	Too low to estimate	Too low to estimate	Too low to estimate	Too low to estimate

Table 2

First MUTS survey (24 to 31 July 1975).

Room	Equivalent plane-wave power density (μW/cm²)			Comments
	Near closed window	Work area	Resonant zone	
701	3.9	3.9	4.8	Note 1
702	3.6	2.1	Note 2	
703	Negligible			
704	3.1	2.7	4.2	
705	3.6	2.7	3.9	
706	2.7	3.0	Note 2	
707	3.9	2.6	Note 2	
708	3.6	3.0	Note 2	
709	Negligible			
801	2.1	1.2	3.9	
802	7.8	3.0	7.2	
803a	4.8	1.2	8.4	Note 3
803b	3.6	3.6	-	
804	4.5	3.0	-	
805	3.0	1.5	-	
806	3.9	1.5	-	
807	4.2	1.2	-	
808	2.4	2.4	-	
809	1.5	1.5	3.9	
901	6.6	9.0	9.0	Note 4
902	3.3	2.4	6.6	
903	3.0	1.5	4.8	
904	2.4	1.8	-	
905	-	-	4.2	
1001	8.7	4.5	8.7	
1002	8.4	6.9	8.7	
1003	10.2	3.0	9.6	
1004	Negligible			
1005	Negligible			
1006	2.7	1.0	Note 2	
1007	-	1.2	-	
1008	2.4	1.0	-	Note 5

Notes:

1. For this table, rooms are numbered from south to north according to unnumbered layouts in Ref. 15.

2. Not significantly higher than the work area value.

3. Two entries were made for the room. Entry a is on the south side and b on the north side.

4. In Room 901, the 9.0 μW/cm² power density existed throughout most of the work area.

5. Reference 49 mentions a rooftop power density of 24 μW/cm² and a reading on an eighth floor balcony of 13.2 μW/cm² contained in "associated working papers" for this survey. These were the highest readings obtained during this first survey.

   Table entries are the mean of all readings for the most intense electric-field antinode found at each location.

Attachment III

Table 3

Second MUTS survey (30 November 1975 to 5 February 1976).

Room	Number of measurements	Equivalent plane-wave power density (μW/cm²) Near closed window: Mean	Standard deviation	Extreme	Date of Extreme	Throughout working area: Mean	Standard deviation	Extreme	Date of extreme	Comments
701	2	1.4	-	1.5	13 Dec	1.1	-	1.2	5 Dec	
702	2	1.8	-	2.4	14 Dec	1.4	-	1.8	14 Dec	
703	1					0.3			5 Dec	
704	3	1.5	0.8	2.4	14 Dec	0.9	0.3	1.2	14 Dec	
705	1	0.9			5 Dec	0.6			5 Dec	
707	1	0.6			5 Dec	0.6			5 Dec	
709	1	1.8			1 Dec	1.2			1 Dec	
801	5	3.4	1.2	5.4	3 Dec	1.3	1.3	3.0	24 Jan	
802	5	4.6	3.1	9.6	5 Dec	3.3	2.2	6.0	24 Jan	
803	3	3.5	1.8	4.8	3 Dec	1.0	0.7	1.8	3 Dec	
804	1	4.8			24 Jan	6.0			24 Jan	
805	3	2.4	0.6	3.0	30 Nov	1.5	1.1	2.4	30 Nov	
806	3	2.6	0.4	3.0	3 Dec	1.2	0	1.2		
807	5	2.4	0.6	3.0	3 Dec	1.3	1.0	2.4	24 Jan	
808	1	2.4			24 Jan	1.8			24 Jan	
809	4	1.6	0.6	2.4	24 Jan	1.1	0.9	2.4	24 Jan	
810	1	1.8			24 Jan	1.2			24 Jan	
SS-8	6	0.8	0.4	1.2	1 Dec	0.8	-	1.2	6 Dec	
901-East	93	2.7	1.8	7.8	4 Dec	Rm 901 readings merged below				
901-South	49	0.8	0.6	4.2	5 Dec	1.5	1.2	6.0	4 Dec	
902	65	2.0	1.5	7.2	24 Jan	2.2	2.0	10.2	24 Jan	Note 1
903	32	2.0	1.0	4.0	24 Jan	1.8	1.3	7.2	24 Jan	
904	5	2.0	1.5	4.2	3 Dec	1.0	1.2	3.0	3 Dec	
SS-9	6	2.7	1.3	4.2	16 Jan	1.2	0	1.2		
1001	38	7.2	5.1	24.0	24 Jan	3.7	2.1	8.4	31 Dec	
1002	31	4.4	2.5	12.0	24 Jan	3.4	2.5	13.2	24 Jan	
1003	35			Note 2		3.0	2.2	11.4	24 Jan	
1005	3	1.4	0.9	2.4	10 Dec	0.9	0.8	1.8	10 Dec	
1006	15	2.0	1.1	3.6	3 Dec	1.1	0.5	1.8	24 Jan	
1007	1	0.6			5 Dec	1.2		Note 3	5 Dec	
1008	17	1.8	1.2	4.2	4 Dec	1.7	1.3	3.6	4 Dec	
C5EL	2	0.6	-	0.9	15 Dec					
S5CB	1	0.6			15 Dec	1.2		Note 4	15 Dec	
S5CL	2	0.5	-	0.6	11 Dec	0.3				
S5CR	1	0.6			11 Dec	0.3			11 Dec	
S6BK	3	0.7	0.2	0.9	15 Dec	0.9	0.9	1.5	15 Dec	
S6BL	5	0.3	0.4	0.9	8 Dec	0.6	0.6	1.2	15 Dec	
S6BB	3	0.8	0.2	0.9	15 Dec	0.6	0.5	1.2	15 Dec	
S7AL	2	0				0				
S7BK	2	1.5	-	1.8	15 Dec	1.5	-	2.1	15 Dec	
S7BB	2	1.4	-	1.5	15 Dec	1.6	-	2.1	15 Dec	
S7BL	3	0.8	0.4	1.2	8 Dec	0.3				
NWR	1			Note 5		3.0			9 Dec	
CWR	1			Note 5		13.2 to 15.0			9 Dec	

Notes:

1. Many extreme values were recorded on 24 January 1976 during a period of MUTS-1A transmissions (0.5 to 2 GHz) between 4 and 6 pm (maximum power was at 1.56 GHz).

2. Window area measurements ranged as high as 42.0 μW/cm² due to a standing wave from the back of a safe which partially blocks the window; this is not a work area.

3. Readings quoted as "low" were assumed to be 0.3 μW/cm², as per Ref. 34.

4. Apartment rooms designated in Ref. 50 as "room number called S6BB, S6BL, S6BK, S7BB, S7BL, S7BK, and S7AL refer to south wing apaṛtments. S6BB is the bedroom in Aparment 6B; S6BL is the living room of Apartment 6B; SCBK is the kitchen of Aparment 6B, etc." SS-8 and SS-9 refer to the southernmost stairways in the central building on the eighth and ninth floors.

5. For readings on the north wing roof (NWR) and the central wing roof (CWR), measurements were made as close to the front of the building and as far south as practical.

Table entries are the mean of all readings for the most intense electric-field antinode found at each location.

Attachment IV

Table 4

MUTS microwave power density model.

Location (room no.)	Mean equivalent plane-wave power density ($\mu W/cm^2$)			
	Jul 1975 survey		30 Nov 1975 - 5 Feb 1976 survey	
	Window area	Work area	Window area	Work area
701	3.9	3.9	1.4	1.1
702	3.6	2.1	1.8	1.4
703	NR	NR	NR	0.3
704	3.1	2.7	1.5	0.9
705	3.6	2.7	0.9	0.6
706	2.7	3.0	NR	NR
707	3.9	2.6	0.6	0.6
708	3.6	3.0	NR	NR
709	NR	NR	1.8	1.2
801	2.1	1.2	3.4	1.3
802	7.8	3.0	4.6	3.3
803	4.2	2.4	3.5	1.0
804	4.5	3.0	4.8	6.0
805	3.0	1.5	2.4	1.5
806	3.9	1.5	2.6	1.2
807	4.2	1.2	2.4	1.3
808	2.4	2.4	2.4	1.8
809	1.5	1.5	1.6	1.1
810	NR	NR	1.8	1.2
901	6.6	9.0	1.8	1.5
902	3.3	2.4	2.0	2.2
903	3.0	1.5	2.0	1.8
904	2.4	1.8	2.0	1.0
905	NR	NR	NR	NR
1001	8.7	4.5	7.2	3.7
1002	8.4	6.9	4.4	3.4
1003	10.2	3.0	SW	3.0
1004	NR	NR	NR	NR
1005	NR	NR	1.4	0.9
1006	2.7	1.0	2.0	1.1
1007	NR	1.2	0.6	1.2
1008	2.4	1.0	1.8	1.7
Rooftop*	-	24.0	-	15.0

Notes:

*Rooftop measurements are the highest readings found with the few measurements made; they are reported to have been made at an unusually intense reflective antinode.

NR indicates not recorded

SW indicates standing wave

ROOFTOP*

24.0

1001 8.7	**1002** 8.4	**1003** 10.2	**1004** NR	**1005** NR	**1006** 2.7	**1007** NR	**1008** 2.4		
901 6.6	**902** 3.3	**903** 3.0	**904** 2.4	**905** NR					
801 2.1	**802** 7.8	**803** 4.2	**804** 4.5	**805** 3.0	**806** 3.9	**807** 4.2	**808** 2.4	**809** 1.5	**810** NR
701 3.9	**702** 3.6	**703** NR	**704** 3.1	**705** 3.6	**706** 2.7	**707** 3.9	**708** 3.6	**709** NR	

Key: NR - not recorded

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 4 MUTS microwave power density model — mean equivalent plane-wave power density, July 1975 survey, window areas.

ROOFTOP*

24.0

1001 4.5	**1002** 6.9	**1003** 3.0	**1004** NR	**1005** NR	**1006** 1.0	**1007** 1.2	**1008** 1.0		
901 9.0	**902** 2.4	**903** 1.5	**904** 1.8	**905** NR					
801 1.2	**802** 3.0	**803** 2.4	**804** 3.0	**805** 1.5	**806** 1.5	**807** 1.2	**808** 2.4	**809** 1.5	**810** NR
701 3.9	**702** 2.1	**703** NR	**704** 2.7	**705** 2.7	**706** 3.0	**707** 2.6	**708** 3.0	**709** NR	

Key: NR - not recorded

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 5 MUTS microwave power density model — mean equivalent plane-wave power density, July 1975 survey, work areas.

ROOFTOP*

15.0

1001 7.2	**1002** 4.4	**1003** SW	**1004** NR	**1005** 1.4	**1006** 2.0	**1007** 0.6	**1008** 1.8		
901 1.8	**902** 2.0	**903** 2.0	**904** 2.0	**905** NR					
801 3.4	**802** 4.6	**803** 3.5	**804** 4.8	**805** 2.4	**806** 2.6	**807** 2.4	**808** 2.4	**809** 1.6	**810** 1.8
701 1.4	**702** 1.8	**703** NR	**704** 1.5	**705** 0.9	**706** NR	**707** 0.6	**708** NR	**709** 1.8	

Key: NR - not recorded, SW - standing wave

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 6 MUTS microwave power density model — mean equivalent plane-wave power density, 30 November 1975 to 5 February 1976 survey, window areas.

ROOFTOP*

15.0

1001 3.7	**1002** 3.4	**1003** 3.0	**1004** NR	**1005** 0.9	**1006** 1.1	**1007** 1.2	**1008** 1.7		
901 1.5	**902** 2.2	**903** 1.8	**904** 1.0	**905** NR					
801 1.3	**802** 3.3	**803** 1.0	**804** 6.0	**805** 1.5	**806** 1.2	**807** 1.3	**808** 1.8	**809** 1.1	**810** 1.2
701 1.1	**702** 1.4	**703** 0.3	**704** 0.9	**705** 0.6	**706** NR	**707** 0.6	**708** NR	**709** 1.2	

Key: NR - not recorded

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 7 MUTS microwave power density model — mean equivalent plane-wave power density, 30 November 1975 to 5 February 1976 survey, work areas.

SECTION C

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A MODEL OF THE MICROWAVE INTENSITY DISTRIBUTION WITHIN THE US EMBASSY IN MOSCOW, 1966 to 1977

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1. SUMMARY

Models are presented to describe the microwave power density within the U.S. Embassy in Moscow resulting from Soviet transmitters directed at the building. The models, which cover the period from January 1966 to February 1977, are based on a retrospective study in which numerous State Department documents were reviewed, and on information obtained by interviewing personnel who made the microwave measurements during the period. Power density data were included if they could be validated by determining the time and location of the measurement and also the equipment and procedures used. The critical properties of the antennas and probes used in the measurement were verified as part of the study.

The microwave environment was made more complex by microwave reflections both outside the building and within the rooms. Such fields are exceedingly difficult to quantify because of their complexity. Power density and energy density (the two means of measuring microwave intensity) are indirect measurements that may appear to be in disagreement. Both measurements were made in the Embassy. If interpreted carefully, each yields important information about the intensity of the electric and magnetic fields, which are the most significant parameters. All these considerations are discussed in the text.

Masonry walls are highly opaque to microwave energy; therefore, the microwave energy within the building entered through the windows and doors, which are constructed of glass and wood. Power levels within interior rooms were found to be negligible in comparison with power levels in exterior rooms with a door or window facing the transmitter.

The first model covers the period from January 1966 to 26 May 1975 and considers the TUMS (technically unidentified Moscow signal) transmitter west of the Embassy. The second model covers the period from 28 May 1975 to 1 February 1977 and covers the MUTS-1 and MUTS-2 transmitters east and south of the Embassy, respectively. This model is in two parts, one covering the period up to 5 February 1976, at which time protective screening was installed on the windows, and the second part covering the period after the screening was installed.

For TUMS, power density was measured directly. Inside the rooms having the highest levels, the power density within antinode regions (areas in which reflections reinforced the direct signal) was about 4 $\mu W/cm^2$ within 2 ft of the door or window, and 2.5 $\mu W/cm^2$ elsewhere in the room.* The average power density in these rooms was about 1.5 $\mu W/cm^2$. In interior rooms and in exterior rooms not on the west wall, power density was less than 0.1 $\mu W/cm^2$.

During the MUTS interval, electric-field energy density was measured and the "equivalent" power density calculated.** The first portion of the MUTS model extends from 28 May 1975, when MUTS-1 appeared, to 5 February 1976, when the installation of window screening and also reductions in transmitter power reduced power levels inside the building to very low levels (approximately 0.002 $\mu W/cm^2$). Prior to the screening, at locations near upper-story windows on the east and south walls of the central building, the power density within antinodes averaged 3.3 $\mu W/cm^2$; within these rooms the average antinode measured 2.2 $\mu W/cm^2$. The average value throughout these exterior rooms would have been lower, and 1.5 $\mu W/cm^2$ could be considered as a representative number. The power density was lower in the living quarters of the central building and on all floors of the north and south wings.

The MUTS beam was more intense toward the upper southeast corner of the central building. While the values above were those averaged for all rooms on the upper floors of the central building, several rooms had antinode intensities of 7 to 10 $\mu W/cm^2$. Typical levels within those rooms would be about half of the antinode level (i.e., 3.5 to 5 $\mu W/cm^2$).

These values are long-term averages; the signal level did vary, although generally not to any great extent. In areas of the building in which personnel were exposed, the highest power density recorded throughout the entire study was 24 $\mu W/cm^2$ in Room 1001 on 24 January 1976. This occurred during a two hour period of unusual signal strength. Excluding values recorded during this brief interval, the next highest level was 10.2 $\mu W/cm^2$ near the window in Room 1003 in late July 1975. Both measurements were at electric-field antinodes.

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*See Appendix D for a discussion of the measurement units used in the text.

**See Section 2 for a discussion of power density and energy density.

The second portion of the MUTS model extends from 5 February 1976, when protective screening was installed, to 1 February 1977, the end date of the study. During this period, the MUTS power density within all rooms of the Embassy was 0.1 $\mu W/cm^2$ or less. The intensity on the rooftop was about 2 $\mu W/cm^2$.

After introductory sections that discuss the problems involved in evaluating microwave intensity measurements made within a reflective environment, the text describes the sequence of events pertaining to each signal, its spectrum, the region of exposure, the critical measurements used in defining the fields, and finally the power density model itself. The few equations included are supplementary. They are not essential to the discussion.

Records of transmitter operating hours were maintained at the Embassy. Summary charts showing the percentage of time the signal was recorded are presented in Appendix E. The record is not continuous because time charts could not be found for some intervals.

It must be emphasized that this study was as much a historical as a technical exercise; therefore, it is subject to all the inherent limitations of any attempt to reconstruct the past. With the exception of a few interviews, all the evidence available was that contained in a collection of State Department documents. In any such collection, assembled over a period of years, there will be conflicting statements, outright errors, typographical mistakes, and missing documents. Such problems could usually be resolved by other documents written within the same time frame. Less frequently, the general context of a group of documents had to be considered. On rare occasions, the writer had to make a judgement based on his own knowledge of antennas and measurement problems. The writer believes that the power density models proposed in this report are as accurate and as detailed as the body of evidence will allow.

2. POWER DENSITY AND ENERGY DENSITY

Measurements prior to 1975 were made using a beam-forming microwave antenna such as a horn. Subsequent data were recorded using the probe of an electric-field energy density meter. In both cases, the results are stated in power density units ($\mu W/cm^2$) in order to allow a comparison to various radiation standards. The beam antenna may be used to determine power density by measuring received power and then dividing by the calibrated effective area of the antenna (see Appendix A). The energy density meter, as its name implies, measures total electric-field energy density (see Appendix B). Energy density readings have been converted into "equivalent" plane-wave power densities by multiplying by 2 times the speed of light. Such a conversion is valid only under plane-wave conditions. Within more complex fields, the conversion of energy density to power density will yield excessively high values if the reading is taken in a local electric-field maximum. Because the evidence shows that all data in the Embassy were recorded in a complex RF (radio frequency) environment with many microwave reflections, it is essential that the difference between power density and energy density be understood, as well as the limitations of the equivalent plane-wave power density concept. This in turn requires some familiarity with the concepts of a propagating plane wave and of a standing wave.

At distances not in the immediate vicinity of the source, a simple RF electromagnetic wave consists of uniform electric and magnetic force fields oriented at right angles to each other and transverse to the wave's direction of propagation. This simple wave is called a "plane wave" because at large distances from the source the wavefront is relatively flat. The electric and magnetic forces alternate in intensity and direction at the signal frequency; at any location and instant they are in phase. The changing magnetic field generates an electric field, and vice versa. This is the process, described by Maxwell's equations, through which electromagnetic waves radiate and carry energy away from their source. Each field component contains half the energy of the wave. At a given location, the local field is completely described if the magnitude, the orientation, and the direction of propagation of either component is known. From that information, the other field component, the power density (in W/cm^2), the total energy density (in J/cm^3), and the energy density of either component may be calculated. If the field orientation (polarization) and any one of the density quantities are known, all the other quantities may be calculated.

In a simple plane wave, all these quantities are related to each other unambiguously, and any one quantity plus polarization is enough to evaluate any potential hazard.

As an example, the electric-field energy density at any point is proportional to the square of the electric field strength. A similar relationship defines the magnetic-field energy density. Total energy density is the sum of the two. Power density is the rate at which energy crosses a transverse unit area averaged over a time interval equal to one RF cycle. For the plane wave, the electric and magnetic energy densities (u_e and u_m), power density (PD), and peak (as opposed to rms) field strength vectors* are related to each other as follows (Refs. 1 and 2):

$$PD = \frac{1}{2} \left|Re(\overline{E} \times \overline{H}^*)\right| = \frac{1}{2}\sqrt{\frac{\varepsilon}{\mu}} \left|\overline{E}\right|^2 = \frac{1}{2}\sqrt{\frac{\mu}{\varepsilon}} \left|\overline{H}\right|^2 ,$$

$$u_e = \frac{1}{4} \varepsilon \; (\overline{E} \cdot \overline{E}^*) = \frac{1}{4} \varepsilon \; \left|\overline{E}\right|^2 ,$$

and

$$u_m = \frac{1}{4} \mu \; (\overline{H} \cdot \overline{H}^*) = \frac{1}{4} \mu \; \left|\overline{H}\right|^2 .$$

The vertical bars denote the vector's total magnitude, and the asterisk indicates use of the complex conjugate.** The total energy density (u_t) is

$$u_t = u_e + u_m .$$

*These fields alternate with time in the form of a sine wave. The "effective" or rms (root-mean-square) value of a sinusoid is $1/\sqrt{2}$ of the peak value. This is the hypothetical static (DC) value that would produce the same average power as the alternating (AC) field. A vector has both magnitude and direction. The force of gravity is a vector force.

**Complex numbers are two-dimensional, they are frequently used in physics and engineering.

Power density is related to energy density by

$$PD = v\ u_t\ ,$$

where v, the velocity of propagation, is equal to $1/\sqrt{\mu\varepsilon}$.

If the wave travels in free space (vacuum or air) then, in addition,

$$u_e = u_m\ ,$$

$$\frac{|\bar{E}|}{|\bar{H}|} = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.7\ \Omega\ ,$$

and

$$PD = c\ u_t = 2\ c\ u_e = 2\ c\ u_m\ ,$$

in which c, the speed of light, is equal to $1/\sqrt{\mu_0 e_0}$.* The final equation for PD is the means by which electric-field energy density is converted into equivalent plane-wave power density.

As an example of the magnitudes involved, let us assume a plane wave in free space with a power density of 10 mW/cm^2. The energy densities and field strength values are as follows:

$$u_e = u_m = 0.167\ pJ/cm^3\ ,$$

$$u_t = 0.334\ pJ/cm^3\ ,$$

$$|\bar{E}| = 2.74\ V/cm,\ peak = 1.94\ V/cm,\ rms\ ,$$

and

$$|\bar{H}| = 7.29\ mA/cm,\ peak = 5.15\ mA/cm,\ rms\ .$$

*See Appendix D for a definition of ε, ε_0, μ and μ_0.

This power density is the maximum allowed by the U.S. electromagnetic radiation criterion (Ref. 3). The corresponding rms field strengths approximate the limiting field strengths in the reference.

Once again, these relationships are valid at any location in a plane wave. In free space, a single quantity ($|\bar{E}|$, $|\bar{H}|$, u_e, u_m, u_t, or PD) is sufficient to determine all the others. Therefore, any of the parameters could serve as an indicator of potential biological hazard.

If reflected waves are present in addition to the direct wave, the ratio of $|\bar{E}|$ to $|\bar{H}|$ will vary with location, as will that of u_e to u_m. Also, there is no way to calculate power density from an electric-field or magnetic-field energy density measurement, or vice versa. As an extreme example, consider a large electrically conducting sheet placed broadside to the direction of propagation of the 10 mW/cm^2 plane wave described above. At each point in front of the sheet, the electric and magnetic field is the sum of the direct and reflected components. However, the electric field undergoes an instantaneous reversal of orientation when it is reflected, whereas the magnetic field does not. A stationary oscillatory field structure appears before the sheet. As in hydraulics or acoustics, this fixed pattern is called a "standing wave." Because of the asymmetry at reflection, the antinodes and nodes (stationary regions of maximum and minimum oscillations) are located at different points for the electric and magnetic fields. Adjacent to the sheet and at half-wavelength intervals before it, the magnetic field is twice its original strength and the electric field is zero. The standing wave pattern for the electric field also repeats at half-wavelength intervals, but it is shifted by one-quarter wavelength so that there is a minimum at the reflector. The total electric field intensity is doubled at each antinode, and the magnetic field is zero at these locations.

The implications of this complexity are as follows. If an electric field or magnetic field energy density meter were used to probe the field before the sheet, the energy density would no longer be uniform but would rise and fall (alternately for the two meters) as the probe was moved away from the sheet. At an electric-field antinode, the field is doubled and the electric-field energy density is 0.667 pJ/cm^3, four times that of the original plane wave. There is no magnetic field at this location, but if the plane-wave formula were followed to convert to equivalent plane-wave power density (multiplying by 2 to account for the magnetic energy in a plane wave and then multiplying by the speed of light) the electric-field energy density converts to an equivalent power density of 40 mW/cm^2, four times that of the incident plane wave.

If, instead of an electric-field energy density meter, a horn antenna and power meter were used to measure power density directly, a reading of 10 mW/cm^2 would be obtained with the horn pointing toward the source, and an identical reading would result with the horn turned to point at the reflecting sheet. The horn resolves the incident and reflected waves and reads the power density of each.

When used in the standing wave, an energy density meter would indicate an equivalent power density of 40 mW/cm^2, while the horn resolves two separate waves, each with a 10 mW/cm^2 power density. If taken at face value, these two methods of measurement, each valid in a plane wave, would lead to different evaluations of the field.

There are two errors implicit in this comparison. Both are due to the phenomenon of interference (constructive and destructive) between the incident and the reflected wave. First, the conversion of electric-field energy density to equivalent power density may be in error by an amount depending on the relative magnitude of the reflected wave. The second error is that the electric and magnetic field strengths of the two waves are additive (as vectors) at each point in space, but their power densities are not. The actual power density in a standing wave is zero. There is no time-averaged energy flow at any point. Energy oscillates back and forth between the electric and magnetic antinodes at twice the RF frequency.

In the presence of microwave reflections, the power density criterion is an inconsistant measure of biological hazard. Despite the conflicting readings above and the fact that the standing wave has no power density, the internal fields induced within a man-sized object at microwave frequencies would not be greatly different than those caused by the initial 10 mW/cm^2 plane wave. If far enough from the reflecting sheet to avoid any shadowing effects, the front of the relatively large object would be exposed only to the incident wave and the rear only to the equally intense reflected wave.

The next section will show that the ambient electric and magnetic fields ($\overline{E}$ and $\overline{H}$) are the cause of any biological effects. These fields are extremely difficult to measure adequately, and power density or energy density serve only as simplified and more measurable substitutes. In the example above, in which an electric-field energy density meter and a horn were used one at a time to measure the standing wave, either measurement (plus the variation as the probe or antenna were moved) would allow the observer to evaluate the total magnitudes of the electric and magnetic fields ($|\overline{E}|$ and $|\overline{H}|$) in the area.

As an indication of the extent to which a single relatively weak reflection can distort the total field, consider an oblique reflection in which the reflected electric-field is 12 dB* less than that in the incident field ($E_r/E_i = 0.25$). The standing wave ratio is defined as the ratio of the maximum to minimum in the total field resulting from the interference of the direct and reflected waves. In this case,

$$\mathrm{SWR} = \frac{1 + (E_r/E_i)}{1 - (E_r/E_i)} = 1.67 \quad .$$

This corresponds to power density or energy density variations equal to the square of the SWR. In this case, the reflection would cause the power density to vary by a ratio of 2.8:1, or 4.5 dB.

Although in radiation hazard surveys it is common to measure maximum electric-field energy density and convert to equivalent

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*The dB (decibel) is a compressed logarithmic unit used to express a power ratio that may vary over many orders of magnitude:

$$\mathrm{dB} = 10 \log_{10} (P_2/P_1) \ .$$

The unit may be used as defined in this case for power density or energy density ratios. Since both are proportional to the square of either electric or magnetic field strength, the unit can be restated in those terms as

$$\mathrm{dB} = 10 \log_{10} (E_2/E_1)^2 = 20 \log_{10} (E_2/E_1) \ .$$

A 6 dB change corresponds to a factor of 4 change in power, or a factor of 2 change in field strength (these changes are equivalent, in terms of power).

plane-wave power density (this was done in Moscow during the 1975 and 1976 interval), the above example shows that this conversion is ambiguous in an environment with standing waves.

Within the Embassy, the environment included reflections from outside the building, from the window frames of the Embassy, and from walls and objects inside the rooms. Standing wave nodes and antinodes would appear in combination with spatial variations in power density (caused by the combination of the direct and reflected components). The measured field would show great complexity, whether measured with an isotropic energy density meter (sensitive to reflections from all directions) or with a horn antenna of relatively narrow beamwidth (capable of receiving only the direct and forward-reflected waves and reading power density directly).

To summarize this section, several points may be restated. Because of the complex wave pattern within the rooms of the Embassy, a power density field probe using a microwave horn will differ from that using an electric-field energy density meter. While both measurements are subject to significant error, either may be used with a degree of caution to evaluate the magnitude of the ambient electric and magnetic fields.

If a horn antenna is used, power density is determined by dividing received power by the antenna's effective area. Uncertainties are introduced by the complex spectrum of the signal (see Appendix A) and by various forward reflections. If the antenna's aperture size is increased (thus decreasing beamwidth) in an effort to reject the reflected waves, then spatial resolution is degraded. The corresponding magnitudes for the resultant electric and magnetic fields ($|\overline{E}|$ and $|\overline{H}|$) for all sources within the beam are approximately determined by the plane wave relationships. These field strength values are plotted versus power density in Fig. 1. The E and H fields may be considered coincident and in phase at the location of the measurement. The measurement would not show the effect of reflections coming from outside the antenna's beamwidth.

The electric-field energy density probe was only a small fraction of a wavelength in size; it can resolve small-scale variations in the total electric field. It measures the resultant of waves radiating from all directions. While it yields an accurate reading of electric-field energy density, and hence the magnitude of the electric field, a conversion into equivalent plane-wave power density is accurate only if the field consists of a single plane wave. If, in more complex fields, the energy density reading is taken at an antinode (as was done in all measurements within the

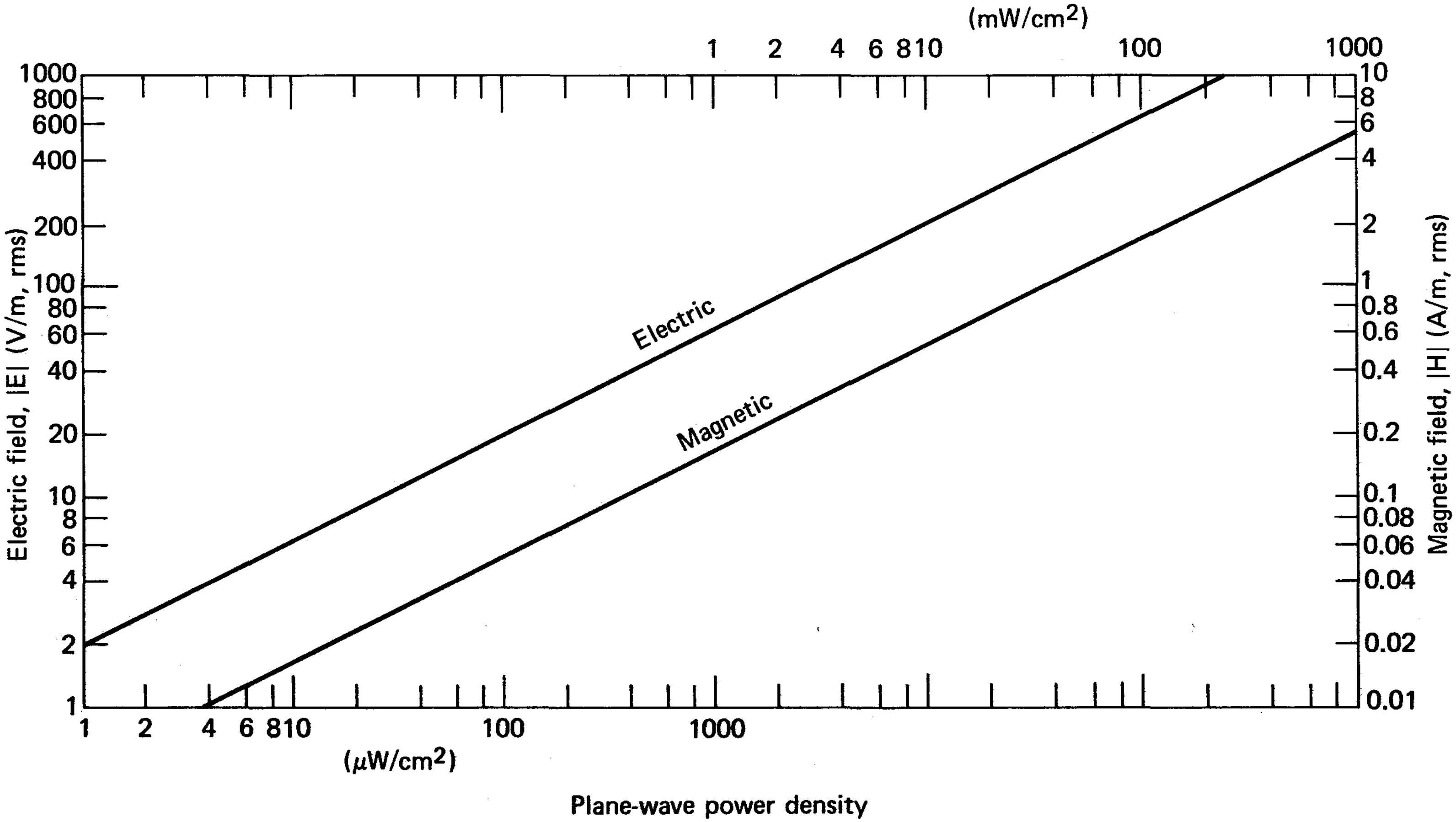

Fig. 1 Plane-wave electric and magnetic field strength (free space).

Embassy, because the highest levels were being sought), the equivalent power density is always greater than the actual power density at that point due to the implied level of the magnetic field (which is greater than that likely to exist at the electric antinode). This bias, unless interpreted with care, may lead to an overestimation of any potential RF hazard. Also, RF magnetic fields are not detected by an electric-field energy density meter. It may be assumed that if a complex field has electrical antinodes of a certain energy density then equally intense magnetic antinodes exist, although probably not at the same locations.

Figure 2 shows the conversion from the electric-field (or magnetic-field) energy density measurements to the equivalent plane-wave power density. Figure 1 may then be used to find the fields corresponding to this value of power density. If reflections were significant, as they were for all the Embassy measurements, these E and H field strengths should not be regarded as existing in phase at the same location. The field values may correspond to those in separate electric and magnetic antinodes.

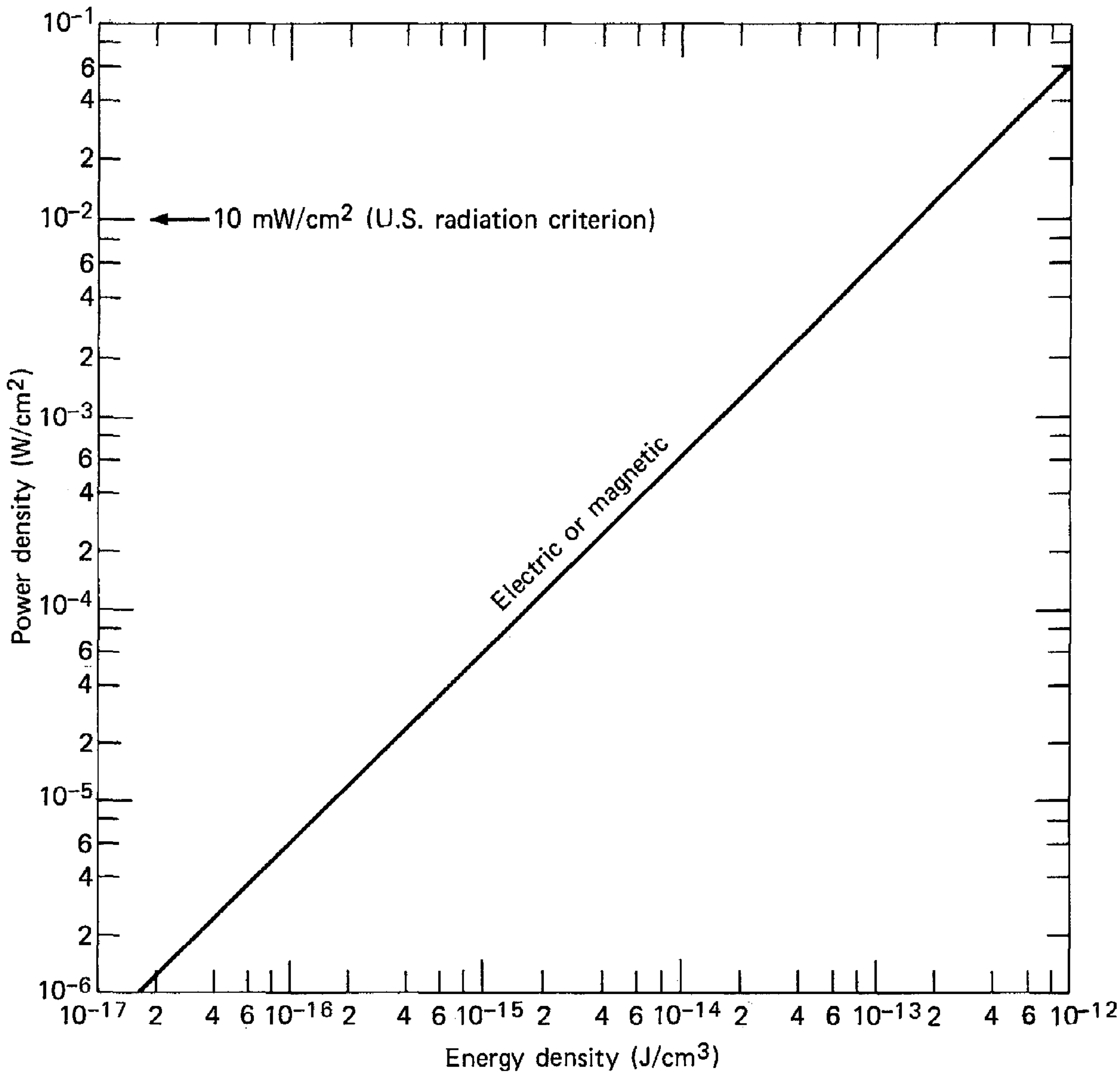

Fig. 2 Energy density to equivalent plane-wave power density conversion.

3. THE ABSORPTION OF MICROWAVES BY MATTER

Section 2 has shown that the electric and magnetic field strengths corresponding to either directly measured power density or equivalent power density may be determined from Fig. 1. The critical difference is the spatial and temporal differences in the distribution of the fields. In the direct case, in which power density is measured by a horn, the electric and magnetic fields exist at the same point and are maximum at the same time. This, on a local scale, is the condition corresponding to a maximum transfer of energy. For the equivalent power density, the E and H fields reach their maximums at different times and at displaced locations.

Power density values alone are not sufficient to describe the microwave fields within the Embassy. For TUMS, power density was measured directly; for MUTS equivalent power density values are presented. The electric and magnetic fields in either case were equally distorted by microwave reflections, and their spatial and temporal characteristics were generally the same (i.e., exceedingly complex) within the Embassy rooms. It should be noted that even at the same point in such an environment, the power density as measured by the two methods will differ and so will the E and H field strengths inferred from the measurements. The equivalent power density will be the higher if read at an electric-field antinode, but the inferred higher E and H fields are not simultaneous and colocated. The direct power density is lower, but its lower E and H fields are oriented to allow a more efficient transfer of power. The differences are subtle, and they may not even be important, but they must be known by those who judge the effect of these complex fields, because they will affect the way in which energy is coupled into an object exposed to such a field.

In order to understand the differences, some understanding is required of the mechanism by which biological tissue absorbs microwave energy. This will be done on a microscopic scale and from an engineer's viewpoint. The discussion will show that while all significant absorption must be caused by the internal electric field, this field depends on both the external incident electric and magnetic fields. These vector fields are difficult to measure in a complex reflective environment. Twelve values are required to define both the electric and magnetic fields at a single point in space. Power density and energy density are useful because they are more readily measured and because either can be used to estimate the actual magnitude of the individual fields.

According to classical electromagnetic theory, the following is the sequence of events by which a radio frequency electromagnetic wave loses energy and interacts with matter. When an object is exposed to an RF electromagnetic field, alternating electric and magnetic force fields are induced on its surface. The induced surface fields depend not only on the incident external fields but also on the size, shape, material composition, and orientation of the object. These alternating fields (specifically, the components tangent to the surface of the object) act as the generating source for two additional and very complex electromagnetic waves. One is the scattered wave, which reflects energy away from the object, and the other is the transmitted wave, which penetrates into the object. The penetrating wave is the one of interest.

Theoretically, if the composition of the object is known in terms of electromagnetic constants describing its various constituent parts, a definition of either the tangential electric or the tangential magnetic field over the surface of the body (the total field at each point due to the incident, scattered, and penetrating waves) is sufficient to allow a complete description of the very complex fields anywhere within its interior (Ref. 4). The entire surface must be considered. Turning this statement around, its meaning is that either the electric or the magnetic field on the surface may be considered the cause of all subsequent internal events. It also means that the spatial and temporal variations of this field are of importance.

At RF frequencies, the incident electric and magnetic fields are equally important in the evaluation of a possible radiation hazard. In a complex field environment, the degree of hazard depends directly on the two vector field strength parameters ($\overline{E}$ and $\overline{H}$) and only indirectly on more measurable combinations of these parameters (such as power density or energy density).

Although the electric and magnetic fields are of equal importance outside the object, on the inside it is the internal electric field through which energy is dissipated. The internal magnetic and electric dissipation mechanisms are discussed separately.

There are two ways in which an internal magnetic field may dissipate energy. The first is through the direct action of the alternating magnetic field on magnetic materials. This requires the presence of a ferromagnetic material in which the alternating field loses energy through hysteresis. This property is extremely rare in biological tissue (Ref. 5) and is of no interest here.*

The second magnetic interaction is through a force exerted on a moving charged particle such as an ion. If a charged particle is exposed to electric and magnetic fields, the resultant force vector is

$$\overline{F} = q[\overline{E} + (\overline{v} \times \overline{B})] \ ,$$

in which $\overline{v}$ is velocity, $\overline{B} = \mu_0\overline{H}$, and q is the charge.** Individually the two forces are

$$\overline{F}_e = q\overline{E}$$

and

$$\overline{F}_m = q(\overline{v} \times \overline{B}) \ .$$

The ratio of the electric force to the maximum magnetic force is

$$\frac{F_e}{F_m} = \frac{|\overline{E}|}{v\mu_0|\overline{H}|} \ .$$

*Some bacteria, molluscs, and arthropods are able to synthesize magnetite (Fe_3O_4). This mineral has also been found in the heads and necks of pigeons. Bacteria and pigeons are known to be able to orient themselves according to weak magnetic fields. In the case of pigeons, flight experiments on cloudy days have shown the birds capable of sensing magnetic field alterations on the order of 1/500 of the earth's field strength.

**The operator "×" denotes vector multiplication. The resultant force vector $\overline{F}_m$ is perpendicular to both $\overline{v}$ and $\overline{B}$. Its magnitude is $[q\ |\overline{v}|\ |\overline{B}|\ \sin\theta]$, in which θ is the angle between the directions of $\overline{v}$ and $\overline{B}$.

In free space, the relative magnitudes of E and H for an RF electromagnetic wave are

$$\frac{\overline{E}}{\overline{H}} = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.7\ \Omega\ .$$

and c, the speed of light, equals $1/\sqrt{\mu_0\varepsilon_0}$. Making these substitutions, the ratio of forces becomes:

$$\frac{F_e}{F_m} = \frac{c}{v}\ .$$

The magnetic force on a charged particle becomes comparable to the force due to the electric field only if the velocity of the particle approaches the speed of light. This conclusion is essentially unchanged even when constants representing muscle tissue were used in the comparison. In an RF electromagnetic wave, the electric field interaction dominates the transfer of energy to tissue. Yet in the process of propagation, the alternating electric and magnetic fields each continuously generates the field of the other type. Essentially, all the energy in the wave is eventually depleted through the action of the electric field component.

In biological tissue, the internal electric field exerts a force on the unbalanced electrical charges of ions and polar molecules. The latter are molecules in which the positive and negative charges are not arranged symmetrically. The alternating electric force causes ions to move and polar molecules to rotate.* This nonrandom motion is superimposed on the random motion of the particles attributable to the temperature of the body. The extent of this forced oscillatory motion is determined by the strength and frequency of the internal electric field, the mass of the ion or molecule affected, and the extent to which connecting or frictional forces bind them to their neighbors. Collisions tend to randomize the forced motion, and the energy is dissipated as heat. According to classical electromagnetic theory, tissue absorption rates change, but not abruptly, with the RF frequency.

Supplementary absorption mechanisms have been postulated that have a more frequency-selective nature. At the present time, the scientific evidence for such mechanisms is still being accumulated and evaluated.

*Water is a polar molecule. It reacts so strongly at microwave frequencies that transmission through muscle tissue may be approximated by that through water alone (Ref. 6).

In summary, it is through the action of the internal electric field that all but a small fraction of the energy contained in the internal electromagnetic wave is converted into kinetic energy on a microscopic scale within the tissue. The internal electric field in turn is generated by the incident electric and magnetic fields over the surface of the body. These two external components are equally important. Their spatial and temporal variations must be considered. Power density and energy density are of value because they are more easily measured and because they serve as approximate indicators (in a reflective environment) of the incident electric and magnetic fields.

4. TUMS

TUMS SEQUENCE OF EVENTS

TUMS was a horizontally polarized signal consisting of a number of discrete frequency components distributed between 2.58 and 4.10 GHz. It was transmitted from a fifth floor window of an apartment building 100 yards west of the Embassy. The signal may have been in existence from time to time as early as 1953, but it was not until the early 1960's that the necessary equipment was on site to characterize its parameters adequately (Ref. 7). At that time, an activity monitor was installed on the tenth floor to record intervals of TUMS transmission on a continuous strip-chart. (Figures that describe and summarize the percent operating time for the TUMS transmitter are presented in Appendix E.) This record was maintained over the years and supplemented from time to time by power density measurements taken at various window locations on the west side of the central Embassy building. The intensity of the TUMS signal appears to have been relatively constant over the years. It was turned off permanently on 26 May 1975. Two days later the MUTS-1 transmitter initiated daily operation from its rooftop location facing the east side of the Embassy.

TUMS REGION OF EXPOSURE

While TUMS initially was thought to be directed against the southern half of the west wall of the central building, the actual extent of the beam is not precisely known. The beam shape had to be inferred from various series of measurements at available window locations. The multipath environment at those windows, compounded by the differing frequency content of the three operating modes, has tended to obscure the shape of the beam. In 1963 the beam was described as 50 feet in width across the building (Ref. 8). Subsequent documents imply a wider beamwidth (Refs. 9 and 10). A series of measurements in 1967 (Refs. 11 and 12) show that the entire height of the building was irradiated. While no measurements appear to have been taken near the north end of the building, from the broad vertical beamwidth it appears likely that the entire west wall of the central building was illuminated. At various times, maximum intensity was recorded at different locations between the third and ninth floors (Ref. 13). This variation is probably caused by multipath propagation and the changing frequency content of the transmission rather than to any directional properties of the transmitter. For the purpose of establishing the model, maximum and uniform intensity is assumed from the third to the ninth floor of the west side of the main building, with lower levels on the other floors and at the apartments over the north and south entrances to the courtyard.

In essence, all energy entering the Embassy did so through glass (or in one case, wooden) windows on the illuminated wall and was dissipated within the adjacent room. Exposure was limited to unshielded rooms* having a window on the illuminated wall. The calculated average transmission loss of double-glazed windows was 0.66 dB, although for some frequencies the loss was as high as 2.4 dB. (This calculation was made over a frequency range containing several complete reflection cycles to reduce errors due to dimensional uncertainties. It is described in Appendix C.) A measurement at APL showed that the transmission loss of masonry walls is ≥30 dB and that levels in interior rooms were 10 dB (a factor of 10 in power) or more lower than in exterior rooms with windows (Ref. 14). During the July 1975 MUTS survey at the Embassy (Ref. 15), power levels in the rooms not directly exposed were below the sensitivity of the instrument. Furthermore, at these frequencies, no energy would be transmitted to other regions of the building by telephone or power lines, water pipes, etc.

TUMS SPECTRUM

TUMS typically consisted of seven independent relatively narrowband components within the total band between 2.58 and 4.10 GHz. The components could differ in level by as much as 10 dB. The bandwidth of each was usually between 0.5 and 15 MHz. Narrowband components typically showed discrete subcomponents indicating 440 Hz modulation (usually AM). Wideband components had both 440 Hz and noise modulation.

The components were distributed across the band differently in each of the three operating modes. These modes are named according to the relative spectral concentration of the components. The following shows a sample distribution:

High mode — 3.08 to 3.39 GHz (7 components)

Medium mode — 2.65, 2.74, 4.01, 4.02, 4.05, 4.06, 4.08, and 4.10 GHz

Low mode — 2.61, 2.75, 2.84, 3.55, 3.58, 3.62, and 3.67 GHz

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*For security purposes, some Embassy rooms were shielded with metal to prevent penetration by or leakage of electromagnetic fields.

When changing from mode to mode, components would be retuned or turned on or off. Each mode usually persisted for several hours. During mode changing, a high power condition could occur lasting from 10 seconds to 2 minutes. In 1967, the level of this transient was described (Ref. 16) as "of the order of 20 $\mu W/cm^2$ within the apartments or offices on the west face of the building" and in 1971 as rising to the 10 $\mu W/cm^2$ level (Ref. 17).

TUMS emissions occasionally contained a much lower level of energy between 8 and 10 GHz. In 1972 this was once observed in the absence of lower frequency radiation (Ref. 18).

TUMS CRITICAL MEASUREMENTS

This section reviews, in sequence, the power measurements from which usable data could be extracted to establish a power density model. While many power density numbers were found in the documents, a large portion were unusable for a retrospective study because they contained no description of how or where the measurements were made. Many documents were found with partial documentation of the measurement conditions. Only by comparing fragmentary information from a number of documents could sufficient information be collected to allow an evaluation of a stated power density number. The required information included:

1. The location of the measurement both within the building and with respect to the window of the room,

2. Calibration data on the antenna used and some description of the characteristics of the detector,

3. How the measurement was made (i.e., the substitution method for each component or an integrated reading by means of a heat-sensitive thermistor and power meter), and

4. Whether the antenna was fixed at an arbitrary location or was moved about to find the local region of highest signal level.

Aperture antennas such as microwave horns were used to directly measure TUMS power density. This procedure differed from that used later for MUTS, in which the electric-field energy density was measured and the equivalent power density calculated. Aperture antennas are polarized and directional and receive only the matched polarization component from within their beam angles. TUMS was horizontally polarized, and the antennas were positioned to receive this component. Their half-power beamwidths vary from 18 to 65°, depending on the frequency and the particular antenna. In all cases, the antenna beam was directed toward the source. In this orientation, power density equals power received divided by the effective area (not the physical area) of the antenna. Effective area, A_{eff}, is derived from the antenna's power gain ratio as

$$A_{eff} = \frac{G\lambda^2}{4\pi} ,$$

where λ is the wavelength. Gain may be determined for each antenna from a calibration chart. A narrow-beam antenna has a higher gain than one with a wide beam. Gain and effective area are described in detail in Appendix A.

Effective area is a function of frequency and can vary by as much as 2.5 to 1 across the TUMS band. This introduces an uncertainty in the computation of the power density for a complex wideband signal. For the present study, gain data were obtained on all antennas involved and their effective areas calculated. Usually, specific information on the frequency content of the TUMS signal at the time of measurement is not available. In those cases, the average antenna effective area over the TUMS band (2.58 to 4.10 GHz) was used to calculate power densities for this report. In some cases, this value differs somewhat from that reported at the time of measurement.

A description of the antennas used, including gain and effective area data, is included in Appendix A.

No measurements were found prior to 1966 that included a good enough description to be included in this study. One 1965 document (Ref. 19) asks for a clarification of a heresay value of 22 dBm/m^2 (16 μW/cm^2) "on the surface of the building" (the power density unit dBm/m^2 is defined in Appendix D). Although no answering document was found, verification must not have been forthcoming, since the same writer (who made many of the measurements during the late 1960's) states repeatedly in later documents his belief that the Soviets intentionally kept the level below their industrial standard of 10 μW/cm^2. Reference 9 contains the statement that "total power level per square meter at the windows of the Embassy was computed in November 1965 as +13 to +17 dBm/m^2" (2 to 5 μW/cm^2).

Other documents indicate that maximum intensity at this time was on the ninth floor at the second window from the south end.

In April 1966, a power density measurement was made in the TUMS observation room.* That room differed from all other rooms in the Embassy in that the inner pane of the double-glazed window was removed and replaced with a sheet of one-quarter inch plywood. In order to relate measurements made within this room to those made elsewhere, transmission loss calculations for this window configuration and for the normal windows were made for this study (see Appendix C). The TUMS observation window has an average transmission loss over the TUMS band of 0.5 dB, although at some frequencies its loss can be as high as 1.5 dB. The ordinary double-glazed windows have an average loss of 0.7 dB, with a maximum loss of 2.4 dB. For the purpose of the study, both window configurations are considered to be low-loss and similar in transmission characteristics. Therefore, measurements made within that room may be considered representative of the levels within nearby rooms.

A Polarad CA-S horn was mounted behind the plywood window and connected to a Polarad receiver. One frequency component was tuned at a time and its power measured by substitution with an equal signal from a calibrated signal generator (Ref. 20). The measurement continued while frequency components were added or deleted until a total of 13 components had been measured. Power density was calculated for each component by dividing by the effective area of the horn. (This calculation was done erroneously in Ref. 20. Someone had later penciled in corrections, and the writer has made an additional small correction to use more accurate values for the effective area.) The power density of the 13 components measured varied over a 65:1 range. Their average is 0.44 $\mu W/cm^2$, and this is significantly weighted by the two strongest components at 3.320 and 3.347 GHz. Using this average value, and the fact that TUMS usually contained only seven simultaneous components, the typical power density at the arbitrary location behind the TUMS observation window is 3.1 $\mu W/cm^2$.

*Monitoring equipment was installed in that room (on the ninth floor just north of the central stairway) to allow the TUMS spectrum to be observed. The location was separate from that of the TUMS activity monitor, which provided only a simple record of the signal's operating hours.

Several documents refer to a power reduction occurring in March or April 1967. This is the only time during the entire period of TUMS transmissions that a long-term power change was believed to have occurred, yet the evidence that a decrease occurred is not convincing. Reference 21 describes a decrease in power level in April 1967 as indicated by the TUMS strip-chart activity monitor. As confirmation, a measurement of the signal in the window area location that had yielded a +17 dBm/m^2 (5 $\mu W/cm^2$) level in November 1965 now implied a level of +11 dBm/m^2 (1.3 $\mu W/cm^2$). In contrast, a 1972 document (Ref. 22) refers to a power decrease of only 25% since TUMS was initially measured. The difficulty with these measurements is that both described the power changes at fixed locations — the TUMS activity monitor on the tenth floor and at a particular ninth floor window. Many documents refer to large variations in observed power as the receiving antenna is moved to probe the region behind various windows or even when the probe was made while standing on a balcony. This signal variation is due to interference (constructive and destructive) caused by microwave reflections from the ground, nearby buildings, and the window frame. The effect of interference is quite frequency-sensitive. As a result, an observed power variation at any fixed location on the Embassy west wall could be caused not only by a transmitter power change but by a change in the frequency composition of the signal. The power density measurements taken before and after this interval do not support the contention that a significant power density decrease took place in the spring of 1967.

The next measurement was in May 1967 (Ref. 23). The CA-S horn was used to probe for the highest field — a constructive interference of the direct and reflected waves — behind the window on the ninth floor in the vicinity of the waiting room balcony. The maximum power of 0.6 mW when divided by 470 cm^2 (the average effective area of the horn over the TUMS band) implies a total power density of 1.3 $\mu W/cm^2$.

In September 1967, a sequence of point-by-point measurements was made by moving the antenna along an 8 cm horizontal traverse behind the window of the waiting room on the ninth floor (Ref. 24). The antenna used was not a horn but a shallow cavity energized by a dipole and surrounded by a small ground-plane. It was manufactured by the Aero-Geo-Astro Company and called by them a "Plantenna" (Ref. 25 and Appendix A). This antenna has a gain of approximately 9 dB across the TUMS band, resulting in an average effective area of 55 cm^2. The resulting power densities quoted below are slightly higher than those in the original documents since the engineer on site, who had no data on the Plantenna, established its effective area as 80 cm^2 by means of a comparison to the signal level received by the CA-S horn. This technique is not valid for a broadband signal because the effective areas of the two antennas do not track with frequency. Considering published data on this type of antenna and also its physical cross-section (an 80 cm^2 effective area implies too high an efficiency), a 55 cm^2 average effective area is more reasonable. Accordingly, the highest power density during the 8 cm traverse was 2.3 $\mu W/cm^2$ and the average was 2.1 $\mu W/cm^2$.

The Plantenna was used again in October 1967 to probe the signal over an 8 cm by 8 cm transverse area behind the plywood window in the TUMS observation room (Ref. 26). The highest power density was 1.5 $\mu W/cm^2$ and the average was 1.3 $\mu W/cm^2$. In both series of point-by-point measurements, the region examined was so small that these high and average values are not typical of the larger variations that would be encountered throughout an entire room.

Whereas the traverse described above measured the field over a fixed and somewhat arbitrary area, another October 1967 measurement sequence probed for the highest field at available window locations over the southern portion of the west wall of the main building. The Plantenna was used in conjunction with a broadband thermistor and a power meter. The area about each window was examined and the intensity recorded at the local maximum of the complex standing wave pattern. For the first series (Ref. 11), the highest reading for all windows examined was 6.2 $\mu W/cm^2$ and the average window maximum was 3.4 $\mu W/cm^2$. This was for an undefined TUMS mode. The next series was for the minimum frequency dispersal mode (Ref. 12). In this case, the highest density was 4.7 $\mu W/cm^2$ and the average 2.6 $\mu W/cm^2$. The last series, for the medium dispersal mode, yielded power densities of 7.6 and 4.7 $\mu W/cm^2$, respectively. The 55 cm^2 average effective area of the Plantenna was used in these calculations. Once again, these are recordings at local maximums; therefore, the levels are higher than that likely to be recorded at an arbitrary location.

While no later TUMS measurements were found, several documents indicated that the activity monitor showed no significant change in power other than that thought to have occurred in March 1967. Since the previous discussion concluded that there was no significant change in March 1967, the TUMS model will assume that power density did not change over this entire interval. These measurements, at arbitrary locations and at local field maximums, are those that the model must approximate.

TUMS MICROWAVE POWER DENSITY MODEL

The rooms in the central building and in the north and south wings of the Embassy were divided into regions based on their estimated exposure. Typical plane-wave power densities were estimated by reviewing the TUMS measurement record and also the more detailed measurements for MUTS (the latter assist in defining the power density variations within each room and also the lower levels in interior rooms). The antinode regions within each room would vary in extent due to the complex reflections involved. In general, they would have dimensions on the order of a wavelength (9 cm).

Table 1 presents the TUMS microwave power density model. The time period covered by the model is January 1966 to 26 May 1975 (TUMS shutdown date). Throughout this interval, the power densities can be assumed to be unchanging.

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Table 1

TUMS microwave power density model.

Region no.	Description of region	Power density (μW/cm²)			
		Antinode within 2 ft of window	Antinode elsewhere in the room	Average throughout the room	Transient during mode changes
1	Central building rooms and stairways adjacent to the west wall of the building that have a window or door on the west wall, third to ninth floors, inclusive (the region with the highest power density)	4	2.5	1.5	20 (lasting between 10 seconds and 2 minutes)
2	Central building rooms and stairways as described in Region 1, but on the first, second, and tenth floors; any basement rooms in the central building with a window above ground level on the west wall; aparment rooms over the north and south courtyard entrances with a window or door on the west wall; rooftops of all three buildings	2	1.3	0.8	10 (lasting between 10 seconds and 2 minutes)
3	All other unshielded rooms and areas above ground level in all three buildings	less than 0.1	less than 0.1	less than 0.1	less than 0.1
4	All shielded rooms; all rooms below ground level in all three buildings with no west window	Too low to estimate	Too low to estimate	Too low to estimate	Too low to estimate

5. SMUT

On 28 March 1972, a second microwave signal (3.2 to 3.6 GHz) was detected and named SMUT. Transmitting 24 hours per day, the signal contained microwave components believed to correspond to Soviet FM and TV broadcasts at lower frequencies (UHF band). These components were in addition to broadband noise modulation that showed evidence of random amplitude modulation and 400 Hz pulse modulation. The source was believed to be about one-half mile northeast of the Embassy (Refs. 27 and 28).

SMUT power density was described in Ref. 1 as 0.0005 mW/m^2. If transcribed correctly, this corresponds to a level of only 5×10^{-5} $\mu W/cm^2$,* yet a statement was made that the SMUT peak power is 7 dB stronger than TUMS. These statements appear at first to be inconsistent, but they are not if the latter refers to spectral power density (W/Hz) as observed on the display of a spectrum analyzer or narrowband receiver.

As of 26 June 1975 (Ref. 2), the SMUT signal with broadband noise modulation had not been observed for almost two years. Only the TV video and audio signals were noted on occasion.

*An unidentified working paper describes this source, although it is not designated by name. The paper mentions a power density of 0.0005 $\mu W/cm^2$, 10 times higher than the above value; either level is insignificant.

6. MUTS

MUTS SEQUENCE OF EVENTS

MUTS began daily operation on 28 May 1975, shortly after the TUMS transmissions were ended. Whereas TUMS illuminated the west side of the Embassy, MUTS originated from a rooftop structure across the street 80 meters to the east. This signal had first been observed in January 1973, and after a few transmissions was turned off on 2 March 1973. It reappeared briefly on 1 February 1974 (Ref. 15). Charts that describe and summarize the percent operating time for the MUTS transmitters are presented in Appendix E.

The new signal presented a more filled-in spectrum than had TUMS. Instead of seven or eight separate components, the spectrum showed a noise modulation originally extending from 1.8 to 8.4 GHz, with most of the energy within the 2 to 3 GHz region (Ref. 29).* In June, the frequency coverage increased, so that the spectrum extended from 0.6 to 8.4 GHz (Ref. 30).

A broadband antenna was installed on the seventh floor to monitor this activity. The signal was divided by bandpass filters, amplified, detected, and plotted continuously on a multichannel strip-chart recorder. The frequency bands were designated as follows (Ref. 31):

Band A — 0.5 to 2 GHz,

Band B — 2 to 4 GHz, and

Band C — 4 to 8 GHz.

This nomenclature was used in many documents to describe the band containing the most energy (but not a transmission limited to that band).

A TUMS microwave intensity survey had been planned for the summer of 1975. Personnel and equipment arrived in Moscow in mid-July. Since TUMS was off the air, a MUTS energy density survey was made within the period 24 to 31 July 1975 (Ref. 15). The results are described later in this report.

*"Noise modulation" does not mean that the spectrum varied with time. The term is used to describe a signal that continuously covers wide regions of the spectrum with an amplitude that appears random with frequency.

Beginning on 25 August 1975 (Ref. 32), numerous CW (continuous wave)* signals appeared superimposed on the MUTS noise spectrum at frequencies ranging from 1.08 to 9.03 GHz. However, this was not a permanent change, and there were many subsequent intervals when CW activity was absent. The energy density meter used in the July survey had been shipped back to the U.S. Personnel at the Embassy, concerned about this addition to the spectrum, measured total power as received through the monitor antenna. When this was reported in the August and September Monthly Status Reports, a typographical error was made. Instead of values of 0.025 and 0.120 mW total power, the reports read "mW/sqcm" implying a power density well above the Soviet standard (0.01 mW/cm^2) although still below the U.S. standard (10 mW/cm^2).

On 16 October 1975 a second source appeared from the top of a building 80 meters south of the Embassy. This source was designated MUTS-2 since its spectrum and power level were similar to MUTS-1 (Ref. 33). While there were many windows and doors with windows facing east toward MUTS-1, only four areas in the central building had windows facing MUTS-2 — rooms 901 and 1001 and the south stairway on the eighth and ninth floors.

Because of concern about these changes, the energy density meter was returned to the Embassy in late November, and the second MUTS energy density survey was initiated. Subsequently, energy density measurements were made on an almost daily basis and the results reported by telegram. These measurements are also described in a following section.

On 3 January 1976, screening materials for the windows were received in Moscow. Temporary screens were constructed and installed in room 901 on that day (Ref. 34) and proved so effective in reducing the signal that plans were made to cover all exterior windows and doors throughout the Embassy. The materials and manpower were available by February, and in five days temporary screens were installed over each window or door facing south or east on floors seven through ten in the central building and on floors six and seven of the south wing. The installation was completed on 8 February 1976 (Refs. 35 and 36). This quite effectively reduced the fields within the buildings. Permanent screening was installed over all areas of the central, north, and south wings in May 1976.

*A CW signal has a very narrow bandwidth; it appears as a line in the spectrum.

Beginning in February 1976, there was a series of reductions in the transmitted power. The level of MUTS-1/band B and MUTS-2/band A were noted to decrease by 6 February 1976 (Ref. 37). The MUTS-1/band B level was so low that it became difficult to measure with the energy meter (Ref. 38), even when the screens were opened, and data were taken using the more sensitive combination of a horn, thermistor, and power meter. At this time the MUTS-1/band A and MUTS-2/band A transmissions remained at their old levels (Ref. 39). In March 1976 the MUTS-1/band B level decreased by another 1 or 2 dB and the MUTS-2/band A level decreased by 5 dB (Refs. 40 and 41). Although the total power of these signals had decreased greatly by 23 August 1976, a comment was made that "the peak power of certain strong peaks in its spectrum has not changed as significantly as the broadband power has" (Ref. 42). Unfortunately, these frequencies were not identified.

Beginning in May 1976, there were occasional intervals of transmission at higher levels in bands A and B. These are called the A(UP) and B(UP) condition in the references, and they usually lasted 30 to 45 minutes with a typical signal increase of 6 dB, although on one occasion a 9 dB increase was noted (Refs. 43 and 44). These increases took place from a diminished reference level. A typical MUTS-2/A(UP) observation is 2.5 $\mu W/cm^2$ in the south window of room 1001 (Ref. 45) with the screens opened to allow the signal to be measured. It is a significantly lower level than the 8 $\mu W/cm^2$ levels recorded at that location during the previous year prior to the MUTS power reduction.

Despite the complexity of the changes recorded after the screens were installed in early February 1976, the signal level incident on the building was at a much lower level than during 1975. Because of the effectiveness of the window screening and the subsequent reduction in transmitted power, the microwave fields within the buildings after 8 February 1976 were reduced to a small fraction of the levels previously observed there.

MUTS SPECTRUM

The MUTS spectrum consists of two basic components: a complex broadband noise-modulated signal extending (although not continuously) from 0.6 to 9.6 GHz, and CW components distributed through the band on frequencies that changed from day to day. Both MUTS-1 to the east and MUTS-2 to the south were described as having similar spectra.

The broadband component is described (Ref. 46) as "apparently generated by at least two and possibly more transmitters whose carriers are locked in sync to provide a contiguous phase relationship. The carriers are overmodulated to produce signal splatter effectively broadening coverage." Photographs in this reference show that at that time (July 1975) most of the energy was between 2 and 3 GHz. However, the energy distribution varied and was at times recorded as being predominately in band A (0.5 to 2 GHz) or band B (2 to 4 GHz); only rarely was the dominant energy described as being in band C (4 to 8 GHz). Another account of the noise spectrum (Ref. 15) describes it as a "pseudo-random noise modulated microwave transmission which fills the RF spectrum from 0.625 to 9.56 GHz. Two spectral modes are observable: a low power mid-band mode covering 1.56 to 5.64 GHz, and a higher power wideband mode expanding RF coverage to 0.625 to 9.56 GHz. Mode 2, the wideband operation, produces a high power level from 0.8 to 1.4 GHz as well as maintaining the mid-range power, though with altered spectrum, from 1.5 to 3.6 GHz." Once again, the noise component continuously covers wide regions of the spectrum with energy that varies randomly with frequency but is unchanging with time.

On 25 August 1975, various CW signals began to appear superimposed on the noise spectrum. If a CW signal was low enough in frequency, higher components sometimes appeared at or very near harmonics of the fundamental. During a transmission, various CW components would appear, disappear, or be tuned to a new position. They sometimes appeared to have sidebands at ±85 MHz that could vary in amplitude from -2 dB to -18 dB with respect to the primary (0.63 to 0.016 power ratio). The polarization of the CW signals (tilted linear) differed from each other and from that of the noise spectrum. A 50 Hz "buzz" was discerned on each CW signal (Ref. 32).

While these CW signals represent a significant local increase in spectral power density, they do not appear to have increased the total transmitted power by any significant amount. As described in the following sections, average energy densities measured at antinodes during the second MUTS survey (which included both the second transmitter and the CW components) were typically slightly less than those recorded in the same areas during the first survey (which had been made prior to these additions).

In reviewing these documents, note was made of each CW frequency encountered. They range from 1.01 to 9.13 GHz, and their distribution is shown in Fig. 3. Figure 3 shows all the frequencies called out in the records, but it is probably not inclusive of all CW frequencies transmitted.

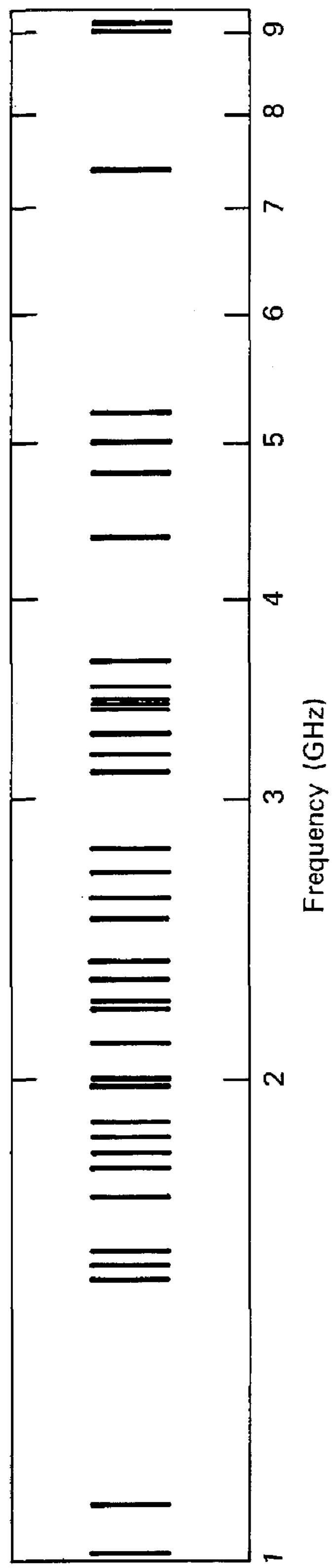

Fig. 3 CW components in MUTS.

Pulse trains were observed on occasion, although infrequently, in MUTS. By the end of August 1975, pulsing was noticed twice (Ref. 32). An oscilloscope photograph was taken showing pulsing of a 3.32 GHz carrier. The pulse widths varied from 0.8 to 1.4 ms. A second reference (Ref. 47) mentions occasional bursts of pulses with a 50 Hz burst rate. The burst consists of 8 to 10 pulses whose width could vary between 0.4 and 2.4 μs. This occurred at various frequencies in the spectrum. The final reference (Ref. 48) mentions a 10 minute transmission on 23 December 1975. A 2 ms burst of three to four pulses was observed at a 1 Hz burst rate. The pulse width was less than 5 μs and the carrier frequency was 4.912 GHz.

MUTS MEASUREMENTS

Shortly after MUTS started continuous operation on 28 May 1975, a Narda radiometer was received at the Embassy. This heat-sensitive device was intended to survey the TUMS power density levels, but since TUMS was now off the air, it was tried on MUTS (Ref. 30). The radiometer had a sensitivity of 10 $\mu W/cm^2$, but no region was found with a field strong enough to deflect the meter enough for a reading to be made.

In July 1975, a National Bureau of Standards energy density meter arrived at the Embassy (Appendix B). As described earlier, this device uses a probe to measure the electric-field energy density. The measurement is essentially independent of the polarization or direction of arrival of the field components, and it is also independent of the orientation of the probe. Once the energy density has been measured, it may be converted to the equivalent power density of a single hypothetical plane wave by doubling the energy density and multiplying by the speed of light. Since the RF exposure standards refer to plane-wave power densities, these values were discussed in the various references and are used for the model. Yet it must be emphasized that the measured electric-field energy density is real, whereas the calculated plane-wave power density is hypothetical and characterizes a plane wave that does not actually exist in a region where microwave reflections cause interference patterns. Nevertheless, the energy density meter is the type of device usually preferred by those making RF intensity surveys in complex environments because it has high spatial resolution and can therefore measure the field in a small antinode.

The first MUTS survey was made between 24 and 31 July 1975 (Ref. 15). Initially, all rooms of the central building from the seventh through the tenth floors were surveyed. Readings could be obtained only in rooms with windows on the east wall. At all other locations the signal was lower than could be measured (i.e., <0.3 $\mu W/cm^2$). Since readings could only be obtained in the offices facing the street, the survey was discontinued in the other areas. On 28 and 29 July, spot checks were made of the staff quarters, the second through the sixth floor of the south wing, and at various locations in the north wing. (No data or statements pertaining to the staff quarters survey appears in the reference.) The survey involved a search for electric-field antinodes since personnel were trying to find maximum rather than typical fields. Because the energy enters through glass windows and doors rather than through the masonry walls, the window areas were surveyed with the windows both opened and closed. Next, the strongest local maximum in each working area (near desks, chairs, and file cabinets) was recorded. Finally, the highest level found in any part of each room was recorded if this was significantly higher than the working area level. The reference presents these data, representing many measurements over the eight-day interval, in the form of the average antinode power density for each type of location in each room. These data are presented in Table 2. No other data or working papers pertaining to this study were found* except for a 1976 comment that a maximum level of 24 $\mu W/cm^2$ was measured on the rooftop during the survey (Ref. 3).

Shortly after the MUTS energy density survey in late July 1975, two changes occurred that made a second survey imperative. On 26 August 1975, numerous CW signals began to appear in the MUTS signal with amplitudes well above the noise spectrum. Then on 16 October 1975, a second source (designated MUTS-2) started transmitting from an apartment building just south of the Embassy. The spectrum of MUTS-2 was similar to that of MUTS-1 and, although the two sources transmitted alternately for the first several months, a capability existed for simultaneous operation.

Adding to the sense of urgency, an unfortunate typographical error occurred in the August and September Monthly Status Reports (MSR). When the spectrum change was noted, received power was measured using an 18 inch parabolic antenna with a broadband log-periodic feed. The effective area of this antenna was (and remains)

*One of the participants recalls that the levels in the north wing were less than those in the south wing, and the latter were less than in the central building. The readings varied less from day to day than in the second MUTS survey. The rooftop reading was at a very strong antinode. The typical antinode level on the roof was 3 to 5 $\mu W/cm^2$.

Table 2

First MUTS survey (24 to 31 July 1975).

Room	Equivalent plane-wave power density (μW/cm^2)			Comments
	Near closed window	Work area	Resonant zone	
701	3.9	3.9	4.8	Note 1
702	3.6	2.1	Note 2	
703	Negligible			
704	3.1	2.7	4.2	
705	3.6	2.7	3.9	
706	2.7	3.0	Note 2	
707	3.9	2.6	Note 2	
708	3.6	3.0	Note 2	
709	Negligible			
801	2.1	1.2	3.9	
802	7.8	3.0	7.2	
803a	4.8	1.2	8.4	Note 3
803b	3.6	3.6	-	
804	4.5	3.0	-	
805	3.0	1.5	-	
806	3.9	1.5	-	
807	4.2	1.2	-	
808	2.4	2.4	-	
809	1.5	1.5	3.9	
901	6.6	9.0	9.0	Note 4
902	3.3	2.4	6.6	
903	3.0	1.5	4.8	
904	2.4	1.8	-	
905	-	-	4.2	
1001	8.7	4.5	8.7	
1002	8.4	6.9	8.7	
1003	10.2	3.0	9.6	
1004	Negligible			
1005	Negligible			
1006	2.7	1.0	Note 2	
1007	-	1.2	-	
1008	2.4	1.0	-	Note 5

Notes:

1. For this table, rooms are numbered from south to north according to unnumbered layouts in Ref. 15.

2. Not significantly higher than the work area value.

3. Two entries were made for the room. Entry a is on the south side and b on the north side.

4. In Room 901, the 9.0 μW/cm^2 power density existed throughout most of the work area.

5. Reference 49 mentions a rooftop power density of 24 μW/cm^2 and a reading on an eighth floor balcony of 13.2 μW/cm^2 contained in "associated working papers" for this survey. These were the highest readings obtained during this first survey.

Table entries are the mean of all readings for the most intense electric-field antinode found at each location.

unknown. Furthermore, its large size makes it unsuited to measure power density in such a reflective environment. The intent was only to report received power and not power density. Instead of reading 0.025 and 0.120 mW, the two MSR's read "mW/sqcm." This error was not noted and corrected until April 1976 (Ref. 49).

After the July survey, the 1C probe for the energy density meter had been returned to the United States. A 1B probe was received at the Embassy on 19 November 1975, but it proved to have insufficient sensitivity to measure the energy density within the building. By the end of November, the 1C probe had been returned to the Embassy, and on 30 November 1975 the second energy density survey began. No energy density or power density measurements were made during the interval between these two surveys.

The second survey involved frequent measurements in many office and apartment areas and was continued well into 1976 on an almost daily basis. By 8 February 1976, temporary screening had been installed over all east- and south-facing windows and doors (Ref. 35). The entire installation took about five days. Since power density decreased to exceedingly low levels within the screened rooms, the writer has chosen to consider only the data taken between 30 November 1975 and 5 February 1976 (the midpoint of the installation) in establishing a power density model.

As in July, the 1C probe was used to find antinodes (regions of maximum electric field) around the windows and throughout the working and living areas. During July, window area readings were taken behind closed windows and with the probe extended out the open window. Because of the multiple reflections involved and because of the more sheltered location of the probe when the window was closed, a significant difference was usually noted between antinode levels with the window opened and closed. Calculations have shown (Appendix C) that the average transmission loss of the double-glazed windows is only 0.7 dB. The two sets of readings do not serve to approximate window transmission loss, and the open window measurements have little meaning. Initially, the second survey's open-window measurements were taken by extending the probe from a very slight opening in the window (it was winter-time!), and this procedure did not allow a very effective search for a field maximum. Subsequently, no open-window readings were taken at all. The open-window readings have been discarded from both surveys because a comparison is meaningless.

All antinode readings (from almost-daily telegrams too numerous to reference) were grouped according to room. For each room, the closed-window and working-area readings were averaged and their standard deviations and extreme values found. These equivalent plane-wave power density values are shown for each location in Table 3. Once again, these values refer to local field maximums. The average power density throughout each room was probably about half the mean value listed under "working area." Rooms 1001 and 1002 had the highest mean antinode intensities in the working area (3.7 and 3.4 $\mu W/cm^2$, respectively).

There are some isolated high values. The levels recorded during a two-hour period on 24 February 1976 were unusually high. Measurements during this interval are shown as the extreme value recorded for many rooms in Table 3. The highest reading during this interval was 24 $\mu W/cm^2$ in Room 1001. Excluding the readings taken during this two-hour period, the highest reading inside the building was 9.6 $\mu W/cm^2$ (slightly exceeded during the July survey).

Note footnote number 2 in Table 3 pertaining to Room 1003. This illustrates the uncertainty when inferring an equivalent plane-wave power density from the antinode reading of an electric-field energy density meter. Because of the standing wave from the back of a safe placed against the window ledge, the maximum electric field is twice that of the incident wave. As described earlier in the report, this implies a quadrupling of power density. Based on the highest equivalent power density reading of 42 $\mu W/cm^2$ in this small area, and also on the assumption that a standing wave exists due to a single reflection, the power density of the incident wave would have been about 10 $\mu W/cm^2$. If a second reflection (such as one from the window frame) had contributed to the 42 $\mu W/cm^2$ reading, then the power density of the incident wave might have been even lower. However, despite the uncertainty about power density, the electric and magnetic fields corresponding to 42 $\mu W/cm^2$ (see Fig. 1) did exist, but at different antinode locations in the standing wave. This small area above the window ledge would not have been entered by anyone except for someone reaching behind the safe to place something on the ledge.

The temporary screens that had been installed by 8 February 1976 were replaced with permanent screens in May 1976. The new screens covered all windows in the central building and in both the north and south wings. The replacement was made on a room-by-room basis. While measurements continued to be recorded in the few offices with screens that could be swung open, the screens reduced the fields within the rooms to very low levels.

Table 3

Second MUTS survey (30 November 1975 to 5 February 1976).

Room	Number of measurements	Equivalent plane-wave power density ($\mu W/cm^2$): Near closed window				Throughout working area				Comments
		Mean	Standard deviation	Extreme	Date of Extreme	Mean	Standard deviation	Extreme	Date of extreme	
701	2	1.4	-	1.5	13 Dec	1.1	-	1.2	5 Dec	
702	2	1.8	-	2.4	14 Dec	1.4	-	1.8	14 Dec	
703	1					0.3			5 Dec	
704	3	1.5	0.8	2.4	14 Dec	0.9	0.3	1.2	14 Dec	
705	1	0.9			5 Dec	0.6			5 Dec	
707	1	0.6			5 Dec	0.6			5 Dec	
709	1	1.8			1 Dec	1.2			1 Dec	
801	5	3.4	1.2	5.4	3 Dec	1.3	1.3	3.0	24 Jan	
802	5	4.6	3.1	9.6	5 Dec	3.3	2.2	6.0	24 Jan	
803	3	3.5	1.8	4.8	3 Dec	1.0	0.7	1.8	3 Dec	
804	1	4.8			24 Jan	6.0			24 Jan	
805	3	2.4	0.6	3.0	30 Nov	1.5	1.1	2.4	30 Nov	
806	3	2.6	0.4	3.0	3 Dec	1.2	0	1.2		
807	5	2.4	0.6	3.0	3 Dec	1.3	1.0	2.4	24 Jan	
808	1	2.4			24 Jan	1.8			24 Jan	
809	4	1.6	0.6	2.4	24 Jan	1.1	0.9	2.4	24 Jan	
810	1	1.8			24 Jan	1.2			24 Jan	
SS-8	6	0.8	0.4	1.2	1 Dec	0.8	-	1.2	6 Dec	
901-East	93	2.7	1.8	7.8	4 Dec	Rm 901 readings merged below				
901-South	49	0.8	0.6	4.2	5 Dec	1.5	1.2	6.0	4 Dec	
902	65	2.0	1.5	7.2	24 Jan	2.2	2.0	10.2	24 Jan	Note 1
903	32	2.0	1.0	4.0	24 Jan	1.8	1.3	7.2	24 Jan	
904	5	2.0	1.5	4.2	3 Dec	1.0	1.2	3.0	3 Dec	
SS-9	6	2.7	1.3	4.2	16 Jan	1.2	0	1.2		
1001	38	7.2	5.1	24.0	24 Jan	3.7	2.1	8.4	31 Dec	
1002	31	4.4	2.5	12.0	24 Jan	3.4	2.5	13.2	24 Jan	
1003	35			Note 2		3.0	2.2	11.4	24 Jan	
1005	3	1.4	0.9	2.4	10 Dec	0.9	0.8	1.8	10 Dec	
1006	15	2.0	1.1	3.6	3 Dec	1.1	0.5	1.8	24 Jan	
1007	1	0.6			5 Dec	1.2		Note 3	5 Dec	
1008	17	1.8	1.2	4.2	4 Dec	1.7	1.3	3.6	4 Dec	
C5EL	2	0.6	-	0.9	15 Dec					
S5CB	1	0.6			15 Dec	1.2		Note 4	15 Dec	
S5CL	2	0.5	-	0.6	11 Dec	0.3				
S5CR	1	0.6			11 Dec	0.3			11 Dec	
S6BK	3	0.7	0.2	0.9	15 Dec	0.9	0.9	1.5	15 Dec	
S6BL	5	0.3	0.4	0.9	8 Dec	0.6	0.6	1.2	15 Dec	
S6BB	3	0.8	0.2	0.9	15 Dec	0.6	0.5	1.2	15 Dec	
S7AL	2	0				0				
S7BK	2	1.5	-	1.8	15 Dec	1.5	-	2.1	15 Dec	
S7BB	2	1.4	-	1.5	15 Dec	1.6	-	2.1	15 Dec	
S7BL	3	0.8	0.4	1.2	8 Dec	0.3				
NWR	1			Note 5		3.0			9 Dec	
CWR	1			Note 5		13.2 to 15.0			9 Dec	

Notes:

1. Many extreme values were recorded on 24 January 1976 during a period of MUTS-1A transmissions (0.5 to 2 GHz) between 4 and 6 pm (maximum power was at 1.56 GHz).

2. Window area measurements ranged as high as 42.0 $\mu W/cm^2$ due to a standing wave from the back of a safe which partially blocks the window; this is not a work area.

3. Readings quoted as "low" were assumed to be 0.3 $\mu W/cm^2$, as per Ref. 34.

4. Apartment rooms designated in Ref. 50 as "room number called S6BB, S6BL, S6BK, 57BB, S7BL, S7BK, and S7AL refer to south wing apartments. S6BB is the bedroom in Aparment 6B; S6BL is the living room of Apartment 6B; SCBK is the kitchen of Aparment 6B, etc." SS-8 and SS-9 refer to the southernmost stairways in the central building on the eighth and ninth floors.

5. For readings on the north wing roof (NWR) and the central wing roof (CWR), measurements were made as close to the front of the building and as far south as practical.

Table entries are the mean of all readings for the most intense electric-field antinode found at each location.

In May 1976, a horn and power meter were used in an attempt to measure the levels within the rooms (Ref. 43). When held 1 foot from the small gaps along the edges of the screen, a signal ranging from 0.001 to 0.008 $\mu W/cm^2$ could be detected. Elsewhere within the rooms, no meter movement was discerned except near the south-facing windows in Rooms 901 and 1001. In those locations, during MUTS-2A operation (0.5 to 2 GHz), levels ranging from 0.001 to 0.002 $\mu W/cm^2$ were read (the minimum perceptible signal on the meter). Because of the difficulties involved in measuring the energy leaking around the edges of the screens, and also because of the problem of maintaining screen integrity, a higher level (0.1 $\mu W/cm^2$) is used in the MUTS model.

In essence, because of the screening and the ensuing decrease in transmitted power, the microwave levels within the buildings may be considered negligible at any time after 8 February 1976. The signal incident on the building was about 2 $\mu W/cm^2$ after this time (Ref. 7); that would have been the exposure level for anyone working on the roof until the time defined as the end of the study (1 February 1977).

MUTS MICROWAVE POWER DENSITY MODEL

Compared to the TUMS study, in which a variety of equipment and techniques were used to measure power density within the building, the MUTS data is more detailed in form and more readily comparable. Other than the unsuccessful attempt in June 1975 to find a power density level within the building that would raise the indicator on the Narda radiometer to its sensitivity limit of 10 $\mu W/cm^2$, only two sets of measurements were made prior to the time when the building's windows and doors were screened. Both used the same equipment, the same procedures, and essentially the same participants. One was made before the CW addition to the MUTS spectrum and the appearance of the MUTS-2 source, and the second survey was performed afterward.

Both surveys used the electric-field energy density meter with the sensitive 1C probe. Window areas and working areas throughout the rooms were probed and the highest fields recorded. These energy density values were converted to the power density of an equivalent plane wave having the same electric field energy density. No field was found above the 0.3 $\mu W/cm^2$ limit of the instrument in any room that did not have a window facing south or east (toward the transmitters). The results of these two surveys have been presented separately in Tables 2 and 3.

The average antinode intensities for the common region of both surveys are given in Table 4 and shown in Figs. 4 through 7. Figures 4 through 7 represent the east side of the building. The general increase in power level toward the upper southeast corner of the building may be seen. Because this includes all the MUTS data, these data represent the power density model for MUTS. Additional areas, with data available only from the second survey, are listed in Table 3. Table 3 also contains standard deviation and extreme values to assist in estimating the variation of these intensities about the mean. In general, the similiarity between the two sets of entries in Table 4 is surprising, considering the changes that took place in the time between them. (Of course only rooms 1001 and 901 and the stairway have windows facing south.)*

Several documents were found that expressed concern about high field intensities occurring in the fall of 1975. This was shown in the last section to have resulted from typographical errors in several monthly status reports. There are no MUTS power density data for the interval prior to the installation of screens that are not listed in Tables 2, 3, and 4. Therefore, there is no reason to believe that power levels were significantly different from those averages shown in Table 4 for any significant period of time. After all, these measurements were made only a half-year apart. To help settle this issue, random sections of the strip charts from the MUTS four-channel activity monitor were examined. October tracings were compared to those made during the July survey. Because of the cumbersome nature of this procedure, only a small interval of the October tracing was examined, but there was no significant difference between the apparent levels shown.

Accordingly, the writer proposes that the high field region for the MUTS model be as shown in Table 4 supplemented by those additional areas described in Table 3. If additional nearby quarters have a southern or eastern window exposure comparable to those listed in Table 3, they should be included in this higher field region. The levels within any such areas must be estimated from those listed in Table 3 subject to the general observation that the levels appeared to decrease with distance from the southeast rooftop corner of the central building.

*According to Table 4, the most significant difference between the two surveys was in the Ambassador's office (room 901). Despite the presence of MUTS-2 and the south-facing window in this room, the levels recorded during the second survey were much lower. Measurement personnel recall this difference and note that the only change was a different arrangement of furnishings.

Table 4

MUTS microwave power density model.

Location (room no.)	Mean equivalent plane-wave power density ($\mu W/cm^2$)			
	Jul 1975 survey		30 Nov 1975 - 5 Feb 1976 survey	
	Window area	Work area	Window area	Work area
701	3.9	3.9	1.4	1.1
702	3.6	2.1	1.8	1.4
703	NR	NR	NR	0.3
704	3.1	2.7	1.5	0.9
705	3.6	2.7	0.9	0.6
706	2.7	3.0	NR	NR
707	3.9	2.6	0.6	0.6
708	3.6	3.0	NR	NR
709	NR	NR	1.8	1.2
801	2.1	1.2	3.4	1.3
802	7.8	3.0	4.6	3.3
803	4.2	2.4	3.5	1.0
804	4.5	3.0	4.8	6.0
805	3.0	1.5	2.4	1.5
806	3.9	1.5	2.6	1.2
807	4.2	1.2	2.4	1.3
808	2.4	2.4	2.4	1.8
809	1.5	1.5	1.6	1.1
810	NR	NR	1.8	1.2
901	6.6	9.0	1.8	1.5
902	3.3	2.4	2.0	2.2
903	3.0	1.5	2.0	1.8
904	2.4	1.8	2.0	1.0
905	NR	NR	NR	NR
1001	8.7	4.5	7.2	3.7
1002	8.4	6.9	4.4	3.4
1003	10.2	3.0	SW	3.0
1004	NR	NR	NR	NR
1005	NR	NR	1.4	0.9
1006	2.7	1.0	2.0	1.1
1007	NR	1.2	0.6	1.2
1008	2.4	1.0	1.8	1.7
Rooftop*	-	24.0	-	15.0

Notes:

*Rooftop measurements are the highest readings found with the few measurements made; they are reported to have been made at an unusually intense reflective antinode.

NR indicates not recorded

SW indicates standing wave

ROOFTOP*

24.0

1001 8.7	**1002** 8.4	**1003** 10.2	**1004** NR	**1005** NR	**1006** 2.7	**1007** NR	**1008** 2.4		
901 6.6	**902** 3.3	**903** 3.0	**904** 2.4	**905** NR					
801 2.1	**802** 7.8	**803** 4.2	**804** 4.5	**805** 3.0	**806** 3.9	**807** 4.2	**808** 2.4	**809** 1.5	**810** NR
701 3.9	**702** 3.6	**703** NR	**704** 3.1	**705** 3.6	**706** 2.7	**707** 3.9	**708** 3.6	**709** NR	

Key: NR - not recorded

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 4 MUTS microwave power density model — mean equivalent plane-wave power density, July 1975 survey, window areas.

ROOFTOP*

24.0

1001 4.5	**1002** 6.9	**1003** 3.0	**1004** NR	**1005** NR	**1006** 1.0	**1007** 1.2	**1008** 1.0		
901 9.0	**902** 2.4	**903** 1.5	**904** 1.8	**905** NR					
801 1.2	**802** 3.0	**803** 2.4	**804** 3.0	**805** 1.5	**806** 1.5	**807** 1.2	**808** 2.4	**809** 1.5	**810** NR
701 3.9	**702** 2.1	**703** NR	**704** 2.7	**705** 2.7	**706** 3.0	**707** 2.6	**708** 3.0	**709** NR	

Key: NR - not recorded

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 5 MUTS microwave power density model — mean equivalent plane-wave power density, July 1975 survey, work areas.

ROOFTOP*

15.0

1001	**1002**	**1003**	**1004**	**1005**	**1006**	**1007**	**1008**		
7.2	4.4	SW	NR	1.4	2.0	0.6	1.8		
901	**902**	**903**	**904**	**905**					
1.8	2.0	2.0	2.0	NR					
801	**802**	**803**	**804**	**805**	**806**	**807**	**808**	**809**	**810**
3.4	4.6	3.5	4.8	2.4	2.6	2.4	2.4	1.6	1.8
701	**702**	**703**	**704**	**705**	**706**	**707**	**708**	**709**	
1.4	1.8	NR	1.5	0.9	NR	0.6	NR	1.8	

Key: NR - not recorded, SW - standing wave

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in $\mu W/cm^2$.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 6 MUTS microwave power density model — mean equivalent plane-wave power density, 30 November 1975 to 5 February 1976 survey, window areas.

ROOFTOP*

15.0

1001	**1002**	**1003**	**1004**	**1005**	**1006**	**1007**	**1008**		
3.7	3.4	3.0	NR	0.9	1.1	1.2	1.7		
901	**902**	**903**	**904**	**905**					
1.5	2.2	1.8	1.0	NR					
801	**802**	**803**	**804**	**805**	**806**	**807**	**808**	**809**	**810**
1.3	3.3	1.0	6.0	1.5	1.2	1.3	1.8	1.1	1.2
701	**702**	**703**	**704**	**705**	**706**	**707**	**708**	**709**	
1.1	1.4	0.3	0.9	0.6	NR	0.6	NR	1.2	

Key: NR - not recorded

Boldface numbers are room numbers. This represents a stylized diagram of the east side of the Embassy; it is not to scale.

The numbers below the room numbers are the mean equivalent plane-wave power density in μW/cm^2.

*The rooftop value is not the average, but is the highest reading found of the few measurements made; it was said to be at an unusually intense reflective antinode.

Fig. 7 MUTS microwave power density model — mean equivalent plane-wave power density, 30 November 1975 to 5 February 1976 survey, work areas.

The window area antinode intensities (Table 4), as for TUMS, are within 2 feet of either windows or glassed doors. The average values throughout the room can be assumed to be half the working area antinode values.

The typical power density for rooms elsewhere in the central building and wings can be assumed to be less than 0.1 $\mu W/cm^2$, as in TUMS, although a few rooms on the east side of the north wing area nearest to the central building may have had levels of 0.2 to 0.5 $\mu W/cm^2$. This initial MUTS model covers the period from 28 May 1975 (date of turn-on) until 5 February 1976 (midpoint of the period of installation of temporary screens).

The second MUTS model covers the period from 6 February 1976 to 1 February 1977 (the date of the end of this study). Because of both the screening and the transmitter power reductions, the highest levels subsequently recorded within the building were less than 0.008 $\mu W/cm^2$. However, because of the poor spatial resolution of the horn antenna and the difficulties involved in its use in measuring energy leaking around the screens, the writer believes a higher value should be used in the MUTS model. Accordingly, a level of 0.1 $\mu W/cm^2$ or less is assigned to all rooms within the building. This assumes a total reduction by a factor of 100 from the highest office value recorded in Table 4. The level on the rooftop is 2 $\mu W/cm^2$ throughout this second interval, as discussed in the preceding section.

The difference between direct power density measurements and equivalent values obtained through the conversion of energy density data was discussed earlier. Figure 1 can be used in either case to find the level of the E and H fields. For the direct measurement, as for TUMS, the E and H fields are those at the point of measurement and they are in phase. For the equivalent case, including all the MUTS data, the indicated E and H fields are maxima which occur at separate, but perhaps nearby, locations. They are also not necessarily in phase. The true power density at the point of measurement is less than the equivalent value (at an antinode) due to the effect of reflections, but the amount of this difference is unknown.

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Appendix A

A DESCRIPTION OF THE ANTENNAS USED

If an antenna is positioned to receive the maximum signal from a single-frequency radio wave of matched polarization, the received power may be calculated from:

$$P_R = (PD)\ A_{eff} , \qquad \text{(A-1)}$$

where PD is the incident power density and A_{eff} is the effective receiving area of the antenna. All antennas have an effective area even if their physical cross section is negligible (such as a whip or long-wire antenna). Effective area is not directly measurable, but is derived from the antenna's gain. Gain is a measure of the relative concentration of an antenna's beam. This value (a ratio) is measured directly by comparing the signal level received by the antenna to that received by a calibrated "standard gain" antenna. This comparison is made at one frequency at a time across the bandwidth of interest. Effective area is then calculated from antenna gain (expressed as a power ratio) as follows:

$$A_{eff} = \frac{G\lambda^2}{4\pi} , \qquad \text{(A-2)}$$

where λ is the wavelength. This equation is valid for any type of antenna.

To calculate incident power density, Eq. A-1 may be rearranged as

$$PD = P_R/A_{eff} .$$

The received power is measured and then divided by the antenna's effective area to determine the power density. For a broadband signal, the calculation should be done bit by bit across the frequency band, because effective area varies with frequency. This procedure was followed when the spectral distribution of TUMS was known at the time of measurement. Usually, the spectral distribution was not known, and power density was determined by using the average antenna effective area across the band. This uncertainty is not significant unless the energy was concentrated near one end of the band, and there is no evidence that this occurred.

Two antennas were used for TUMS power density measurements. The first, a Polarad CA-S antenna, is a linearly polarized microwave horn. Its gain is shown in Fig. A-1 (from Ref. 20), and the derived effective area is plotted in Fig. A-2 (including a small correction to the plotted data). The corrected values were used in the report. Calculated beamwidth is plotted in Fig. A-3.

The second antenna, the Aero-Geo-Astro Corporation's Model PWR-284 Plantenna is also linearly polarized, but of a more unusual design (Ref. 25). A relatively thin antenna with a moderate gain was devised by mounting a dipole feed in a shallow covered cavity and surrounding it with a small groundplane. This is in essence a "box-horn" design (Ref. 51) in which the cavity depth is adjusted to achieve an in-phase condition between the first and third waveguide modes at the aperture. This flattens the amplitude distribution across the aperture and increases gain. References 25 and 52 indicate that the gain of the Plantenna is relatively constant (approximately 9 dB) across the TUMS band. Using this value, the effective area was calculated and plotted in Fig. A-4. Half-power beamwidth is approximately 63° across the band.

When the level of the MUTS signal was reduced in February 1976, the sensitivity of the EDM-1C energy density meter was insufficient to record the signal even when the window screens were opened. For the measurements to continue, the more sensitive combination of a horn and power meter was required.

Before this happened, a series of measurements had been taken to compare the equivalent power density of the EDM-1C to that measured directly at the same point by the combination of a horn and power meter. Empirical adjustment factors were derived from this measurement sequence (Ref. 53) to adjust upward the direct power density reading of the horn to approximate the equivalent value derived from the reading of the energy density meter. These adjustment factors compensate for two gross differences. First, even when the horn is rotated to maximize its signal, there are two remaining polarization components to which it remains insensitive. The second difference is that in the presence of reflections, the equivalent power density is greater than the direct power density if the equivalent reading is taken in an antinode.

These adjustment factors were 1.15 for band A (0.5 to 2 GHz) and 2.1 for band B (2 to 4 GHz). This procedure was used only for

MUTS and only after the temporary screens had been installed (8 February 1976). The horn used was the Sylvania AN-10B. Its gain and calculated effective area are shown in Figs. A-5 and A-6, respectively. The effective area curve for the Sylvania horn (Fig. A-6) is more irregular than the smooth curves shown for the CA-S horn (Fig. A-2). This is due to the more complex feed required for this broadband horn.

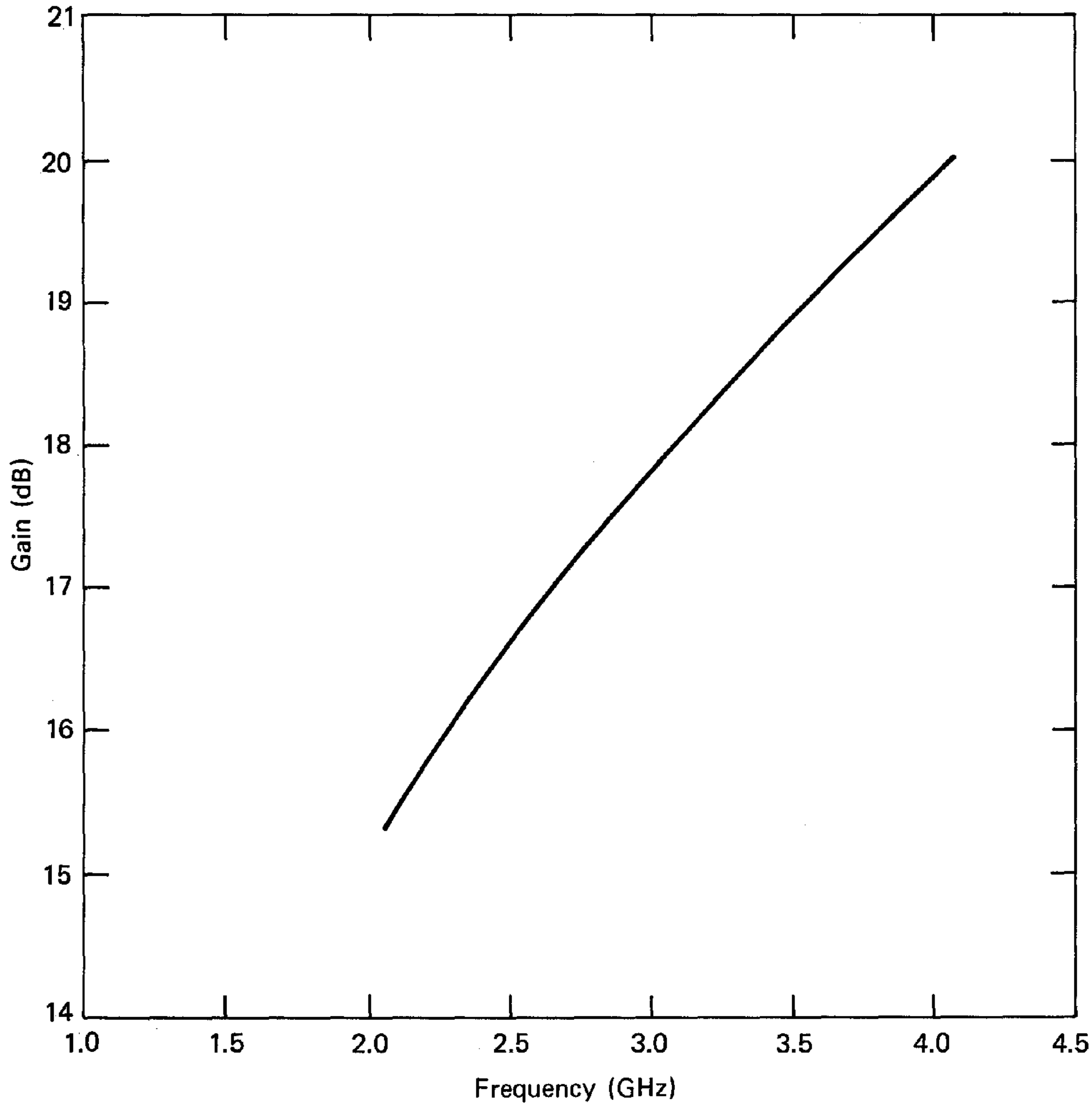

Fig. A-1 Gain versus frequency for Polarad model CA-S antenna.

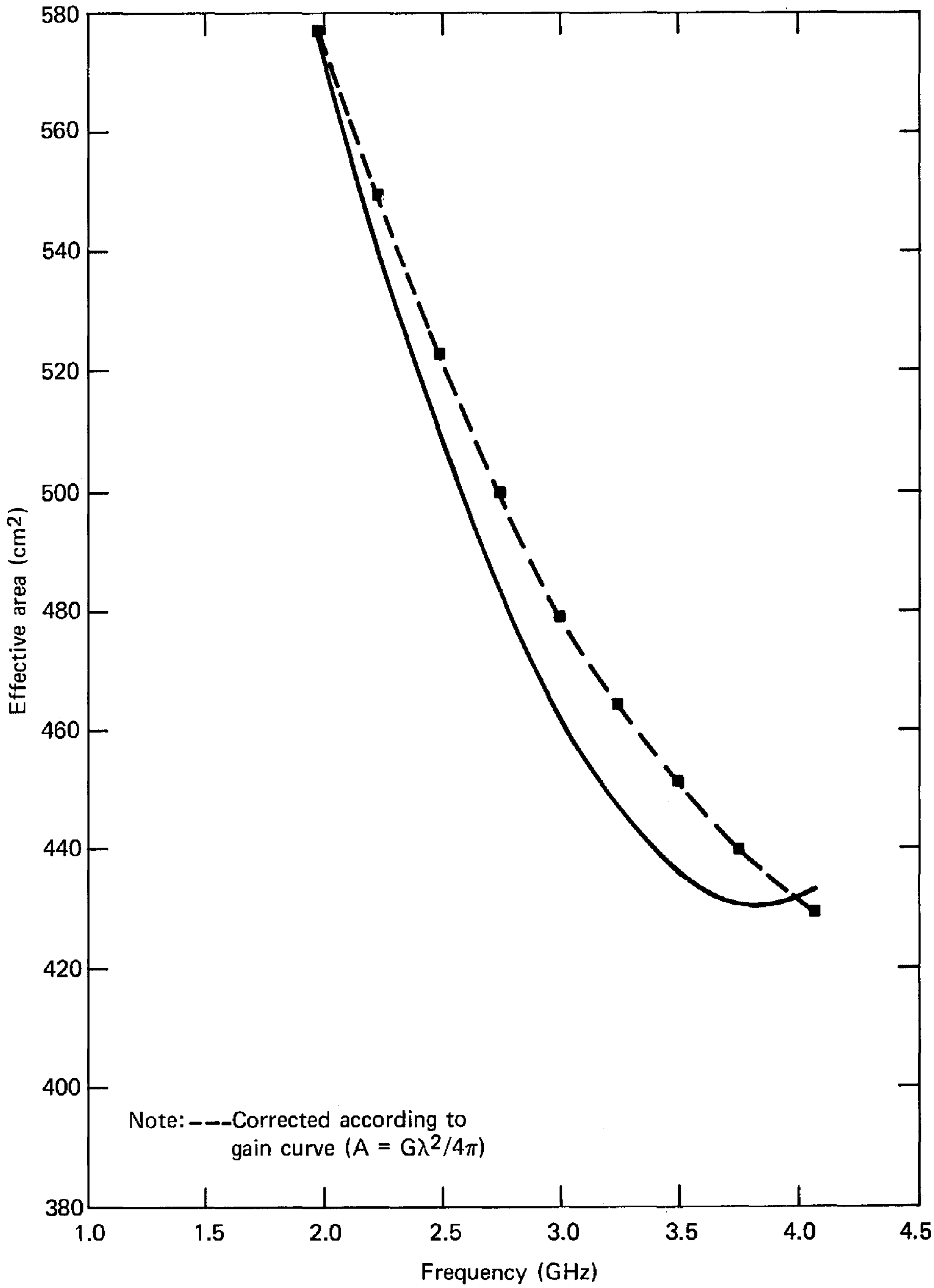

Fig. A-2 Effective area versus frequency for Polarad model CA-S antenna.

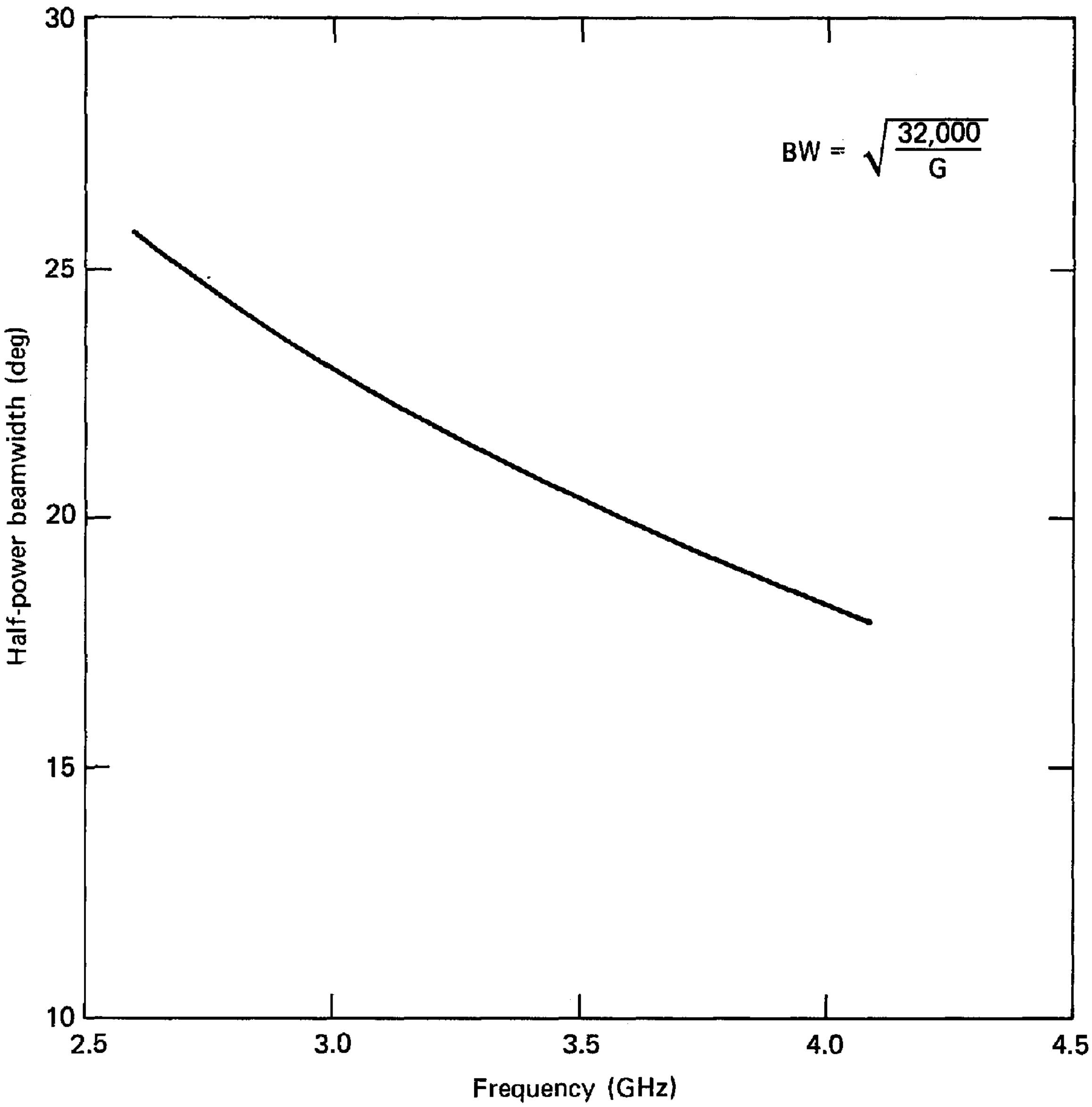

Fig. A-3 Calculated beamwidth of Polarad model CA-S antenna.

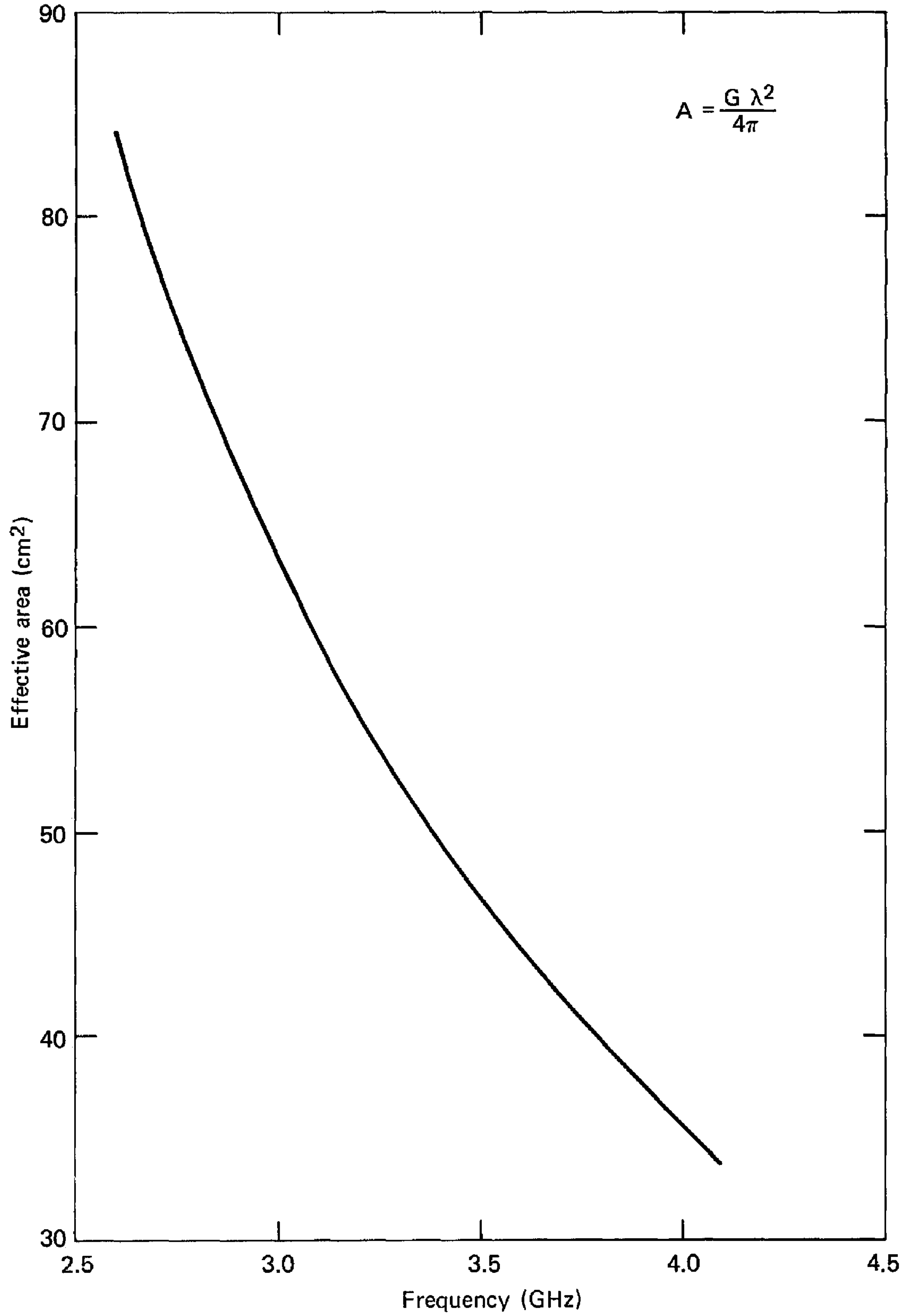

Fig. A-4 Calculated effective area of Plantenna.

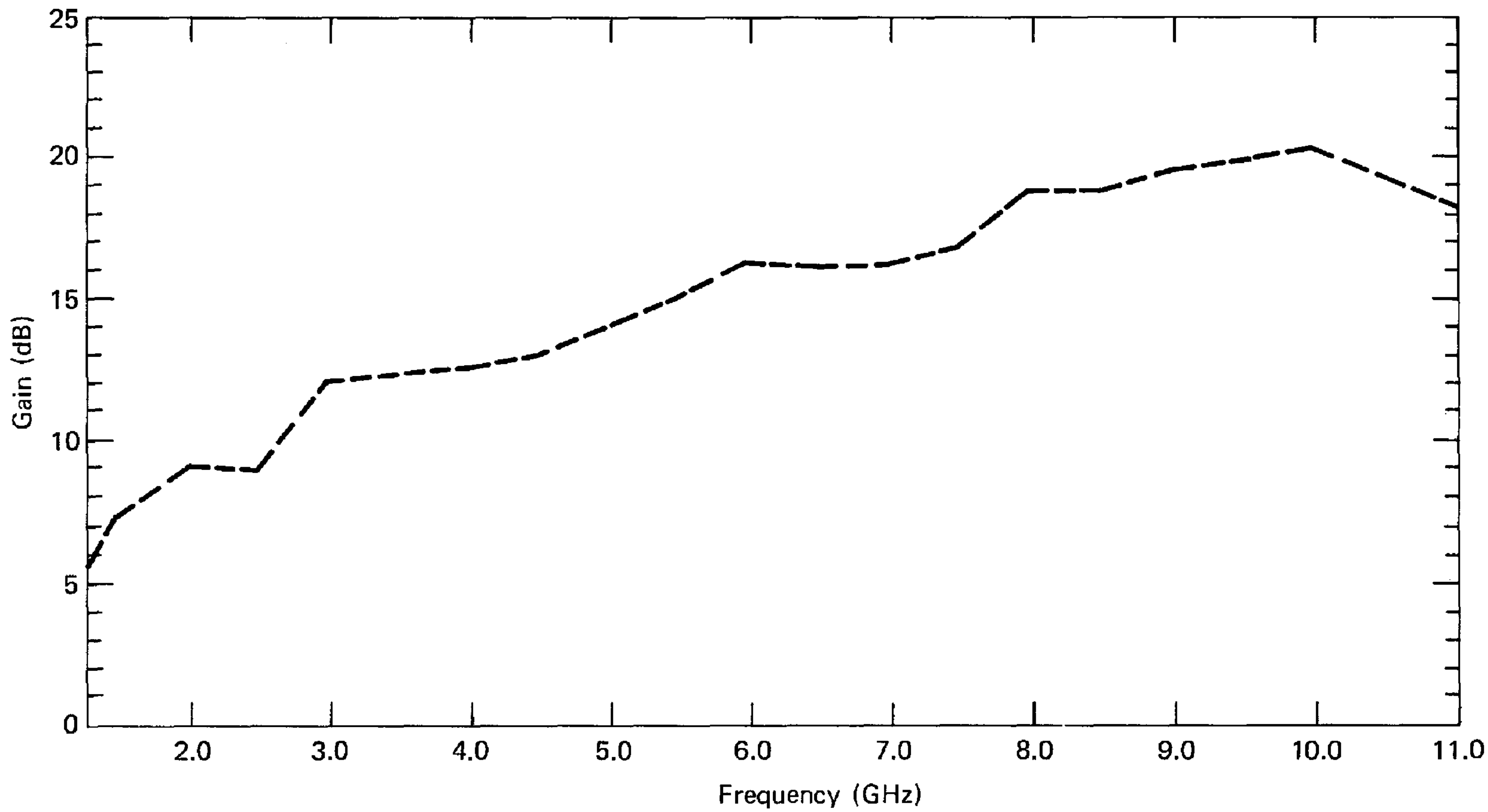

Fig. A-5 Gain versus frequency of AN-10B broadband horn (serial no. 7804).

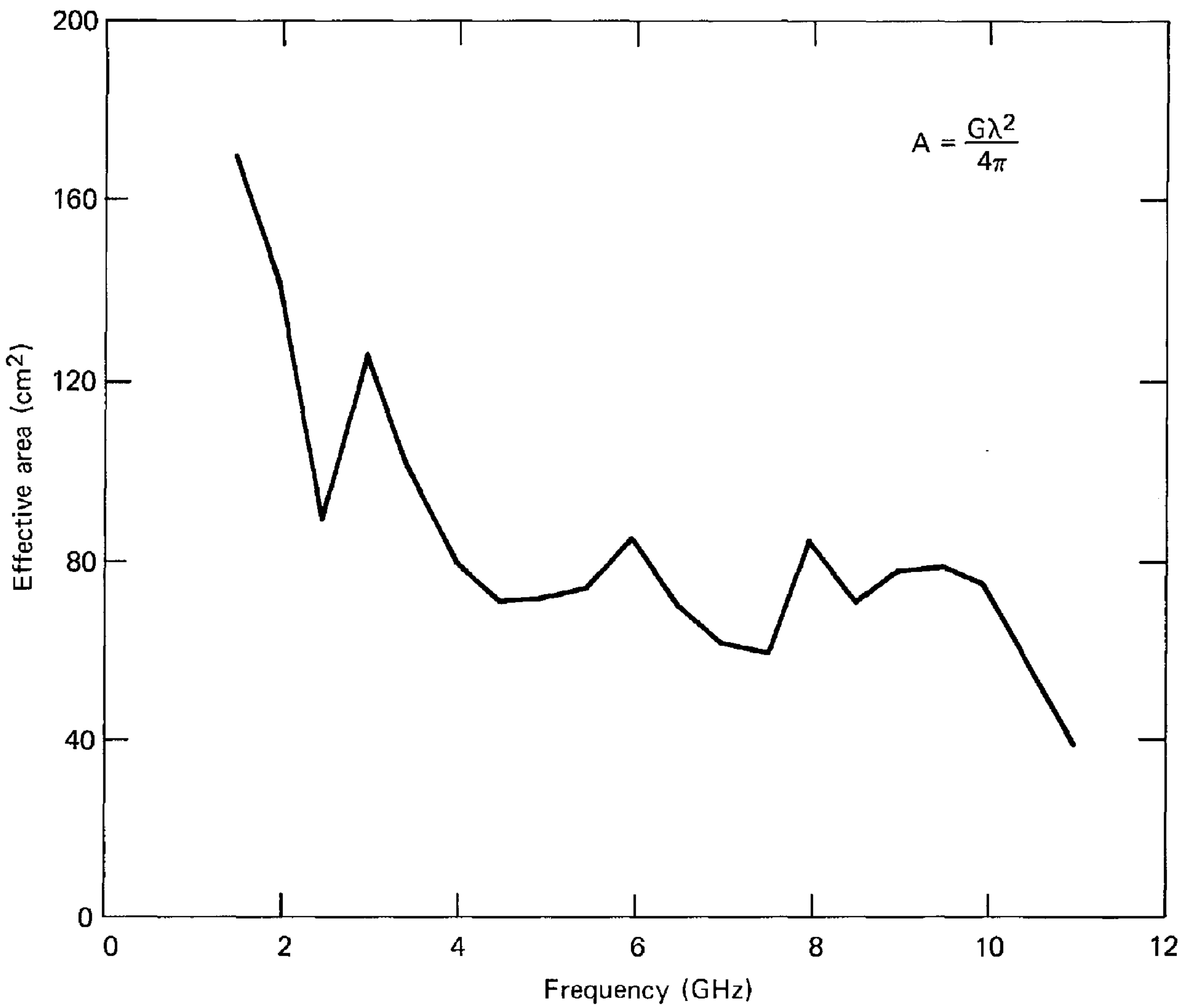

Fig. A-6 Calculated effective area of AN-10B horn.

Appendix B

THE EDM-1C ENERGY DENSITY METER

A straight-wire dipole antenna responds to RF electromagnetic fields in which the electric field has a component parallel to the dipole. If the dipole length is one-half wavelength or less, the intensity of its beam (in terms of the electric field strength) is proportional to the sine of the angle from its axis. It is therefore a wide-beam antenna, isotropic in one plane, with a beam shape that remains the same for any frequency where the dipole is no longer than one-half wavelength. If the received voltage of the electrically short dipole is detected by a diode operating in its square-law region, the output current is proportional to the energy contained in one of the three mutually independent electric-field components. If three such dipoles and detectors are oriented perpendicular to each other so that they cross at the center of each dipole (which calls for very ingenious packaging) and the three outputs are summed, the instrument can be calibrated to read total electric-field energy density (summing the energy of all three orthogonal electric field components, despite their relative phasing) at the location of the probe. The output will be independent of the orientation of the probe at that point and, in addition, the device sums the electric-field energy density at all frequencies within its band of operation. The probe is insensitive to the RF magnetic field components.

The National Bureau of Standard EDM-1C energy density meter is such a device. It was devised for use in microwave hazard surveys (Ref. 2). The basic meter (EDM) may be fitted with different probes. The 1C probe was the more sensitive of the two available during this survey (the 1B was used without success in November 1975 because of its lack of sensitivity). The device reads the total energy density of the electric field in fractions of a joule per cubic meter. To convert to the equivalent power density of a plane wave with an identical electric field strength, the reading is multiplied by 2 to account for the equal magnetic-field energy density at any point in a plane wave. The resulting product is multiplied by the speed of light to convert to watts per square meter, and then multiplied by 100 to convert to microwatts per square centimeter. This conversion is rigorous only for a plane wave, since in a multipath environment the proportion of electric-field to magnetic-field energy will vary from point to point.

The device is calibrated for any microwave frequency up to 3 GHz (most MUTS energy was below 3 GHz). Above that frequency, the device will respond, but its directionless quality (and therefore calibration) is lost because the dipole beam shapes become more complex. The sensitivity of the probe is stated at different values in various documents but it probably is about 0.6 $\mu W/cm^2$ equivalent plane-wave power density, with a meter response at levels as low as 0.3 $\mu W/cm^2$.

Appendix C

WINDOW INSERTION LOSS CALCULATIONS

During the evaluation of the variety of TUMS measurements, it became desirable to be able to compare data taken within the TUMS observation room to those taken elsewhere within the Embassy. While all Embassy windows were double-glazed as a thermal insulation technique (independent inner and outer windows separated by about three inches), the inner glass window in the observation room had been replaced by a sheet of quarter-inch plywood. Since essentially all microwave energy enters these rooms through the windows, we needed to determine if the window insertion loss for the TUMS observation room was significantly different from the other rooms.

To answer this question, a loss calculation was made using a computer program written to compute both the transmission and reflection for a plane wave incident on a large, flat, multilayer structure. This program had been written initially to analyze transmission through radomes (covers enclosing radar antennas). Its validity has been established by comparing its predictions to a large variety of comparison data involving materials as diverse as plastics, ceramics, water, and thin layers of metal.

While relatively insensitive to small errors in the thickness of the glass panes (these effects would show up at higher frequencies or at high angles of incidence), an error in the larger dimension of the air separation between panes could bias the calculation over this limited bandwidth. To avoid this, the air space dimension was purposely set to a value high enough to obtain several full reflection cycles, thus allowing a more accurate evaluation.

As frequency increases, transmission through either window will go through a series of cycles as the various reflections add constructively or destructively. Figure C-1 shows power transmission versus frequency for two one-eighth inch glass panes with eight inch spacing. A dielectric constant of 4.5 (typical for glass) was used with a zero loss tangent* (actually the loss tangent for glass is small but finite; if it were included, it would have caused the

*See Appendix D for a definition of dielectric constant and loss tangent.

maximums to slowly fall away from the unity transmission line). The effect of the reflections going in and out of phase is easily seen. Figure C-2 shows the same calculation for the TUMS observation window with the plywood inner layer. Tabulated electrical constants for plywood were used ($\epsilon_r = 1.5$, $\tan \delta = 0.022$).

In both cases, an average insertion loss was calculated by averaging data in each figure over an integral number of reflection cycles. When this was done, the average loss of the conventional windows was 0.7 dB, as compared to 0.5 dB for the TUMS window. The difference is trivial. This similiarity in average loss can be seen by overlaying the two figures.

In summary, the insertion loss of the two window configurations is nearly the same, so that power density measurements taken within the TUMS observation room may be considered typical of the levels existing in nearby rooms.

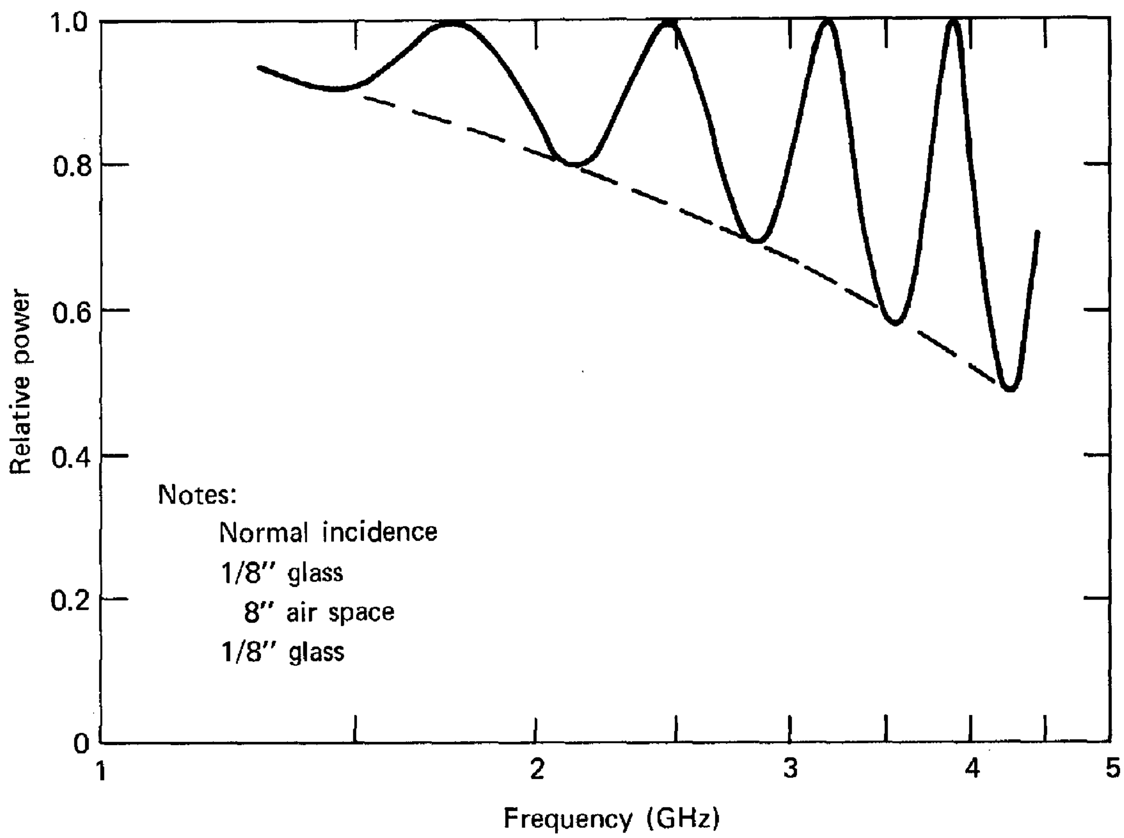

Fig. C-1 Relative power transmitted through window.

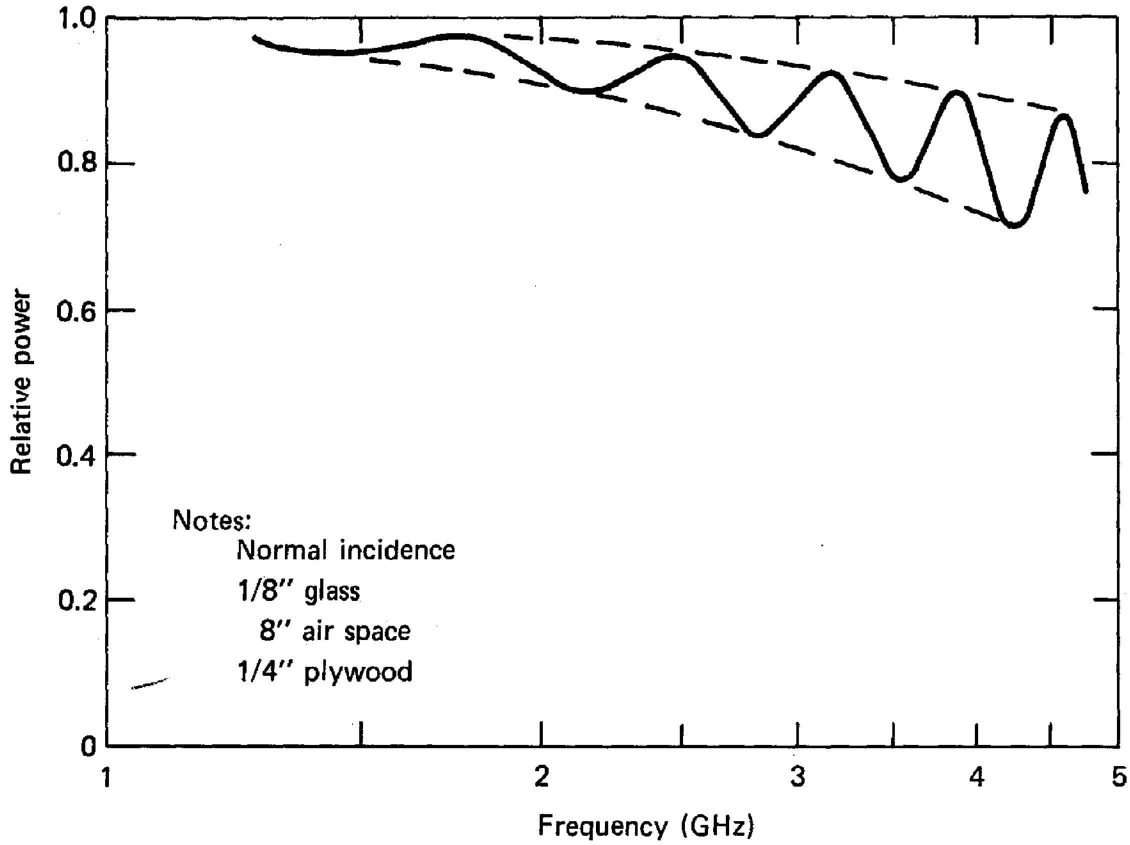

Fig. C-2 Relative power transmitted through observation window.

Appendix D

UNITS AND SOME PHYSICAL CONSTANTS

A standard system of notation is used in which a prefix is attached to the basic unit of measurement to indicate relative magnitude. These prefixes and their magnitudes are listed below. The magnitudes are in scientific notation in which 10^6 means a one followed by six zeroes (one million) and 10^{-6} means the reciprocal (one millionth).

Prefix	Symbol	Magnitude
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Using this notation, the unit of power density used in the text, the microwatt per square centimeter ($\mu W/cm^2$), is one-millionth of a watt per square centimeter. The energy density unit, the picojoule per cubic centimeter (pJ/cm^3) is one-trillionth of a joule per cubic centimeter.

The unit of frequency is the hertz (Hz), and is defined as one cycle per second. A typical microwave frequency of 3 GHz is thus three billion hertz.

A simple example may be used to gain an idea of the magnitude of these power density quantities. One watt of power is defined as an energy flow of one joule per second. A 100 W light bulb converts 100 J/s of electric energy into electromagnetic radiation (light and infrared). Since the surface area of the bulb is about 70 cm^2, the power density on its surface is 1.4 W/cm^2. According to the inverse square law, ignoring any absorption by the intervening air, the power density 10 feet from the bulb is 86 $\mu W/cm^2$. Fifty feet away, the power density has decreased to 3.4 $\mu W/cm^2$. This is similar in magnitude to the power densities described in this report.

Another unit used in the text is the dBm/m^2. This again is power density but it is referred to a square meter rather than a square centimeter. The power portion of the notation (dBm) is decibels referred to one milliwatt (the decibel was discussed earlier). A power density of -3 dBm/m^2 is 0.5 mW/m^2.

The symbols ε and μ were used without definition in earlier equations. In this case, the symbol μ is not a prefix; it has a different usage. These two symbols are constants of proportionality that appear in the basic electric and magnetic force equations. As required by the system of units used (the rationalized MKS system) they are not unity even to characterize these forces in a vacuum. For a particular material these constants are:

$$\varepsilon = \varepsilon_0 \, \varepsilon_r \qquad \text{(permitivity)}$$

and

$$\mu = \mu_0 \, \mu_r \qquad \text{(permeability)} \quad ,$$

in which

$$\varepsilon_0 = 8.854 \times 10^{-12} \qquad \text{farads/meter}$$

and

$$\mu_0 = 4\pi \times 10^{-7} \quad \text{henrys/meter}$$

are the constants of free space or vacuum. The relative constants ε_r and μ_r describe the characteristics of the particular material. For many materials, ε_r and μ_r may be represented by single real numbers. If the material absorbs energy from alternating electric and magnetic fields, the relative constants are complex numbers. If the material has different properties along different axes, the relative constants are tensors. Crystal calcite has a tensor permitivity at optical frequencies. This accounts for the phenomena of double refraction, whereby two displaced images are seen if one looks through the crystal. The relative permitivity is usually called the material's dielectric constant. If the material is absorbent, and its dielectric constant is complex, the ratio of its imaginary to its real part is called the material's loss tangent (tan δ). These constants are used to calculate the reflection from and transmission into material objects.

Appendix E

SUMMARY TIME CHARTS OF TRANSMITTER OPERATING HOURS

For both TUMS and MUTS, activity monitors were constructed to automatically record intervals of transmitter activity on a continuous strip-chart recording. For a number of years, Embassy personnel summarized the information on these traces by re-plotting it in the form of monthly summary charts. For this study, the summary charts were analyzed to determine the percent of the time that the transmitter was radiating (a) during the work day as compared to the morning and evening hours, and (b) during the work week as compared to the weekend. This was done by a combination of manual and computer data sorting. The duration of each interval of transmission, rounded off to the nearest half hour, was tabulated according to its time of occurrence during the day, the day of the week, the month, and the year. The daily time of occurrence was divided into three intervals: midnight to 8 a.m., 8 a.m. to 5 p.m., and 5 p.m. to midnight. This table of data was then read into a desktop computer for further sorting and processing. As an example, the midnight to 8 a.m. bar in Fig. E-1 was obtained by entering the end dates of the interval of interest. The data file was searched for all midnight to 8 a.m. entries between the two dates, their durations were totaled, and the sum was divided by the total midnight to 8 a.m. hours in the interval. This result is plotted as "percent of time the signal was recorded." The other bars were obtained by a similar sorting procedure.

Figure E-1 shows three breakdowns of TUMS activity for the period 1 February 1966 to 31 December 1970. Monitoring data for the remaining TUMS interval (up to 26 May 1975) had been summarized from the original strip charts but the corresponding summary charts could not be found. At the top of Fig. E-1, signal activity is broken down into three periods of the day, so as to show differences in signal activity between the normal work day (8 a.m. to 5 p.m.) and other periods. The middle graph of Fig. E-1 compares signal activity during the normal work week (Monday to Friday) with that for weekends. The graph at the bottom of Fig. E-1 compares TUMS activity during the summer months with that for the remainder of the year.

The MUTS interval was divided into three parts. The first begins on 1 July 1975 (when monitoring started) and ends on 15 October 1975 (the day prior to the initial operation of MUTS-2). The second interval begins on 16 October 1972 (when MUTS-2 began operation) and extends to 5 February 1976 (the midpoint of the five-day period of screen installation). The final MUTS interval extends from 6 February 1976 through 4 March 1976 (the last date on a monthly summary chart). MUTS signal activity for these three intervals is shown in Figs. E-2, E-3, and E-4, respectively.

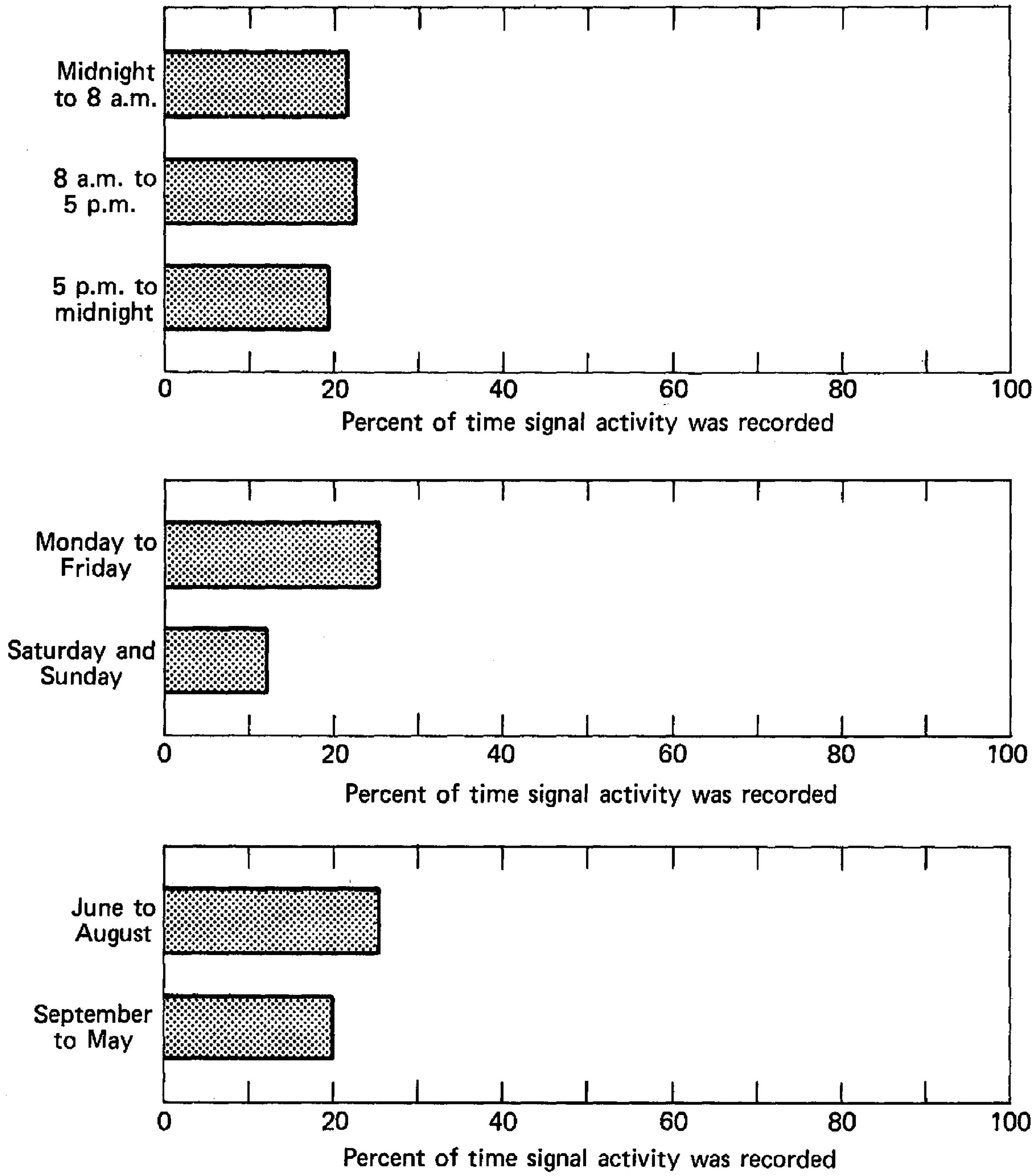

Fig. E-1 TUMS activity, February 1, 1966, to December 31, 1970.

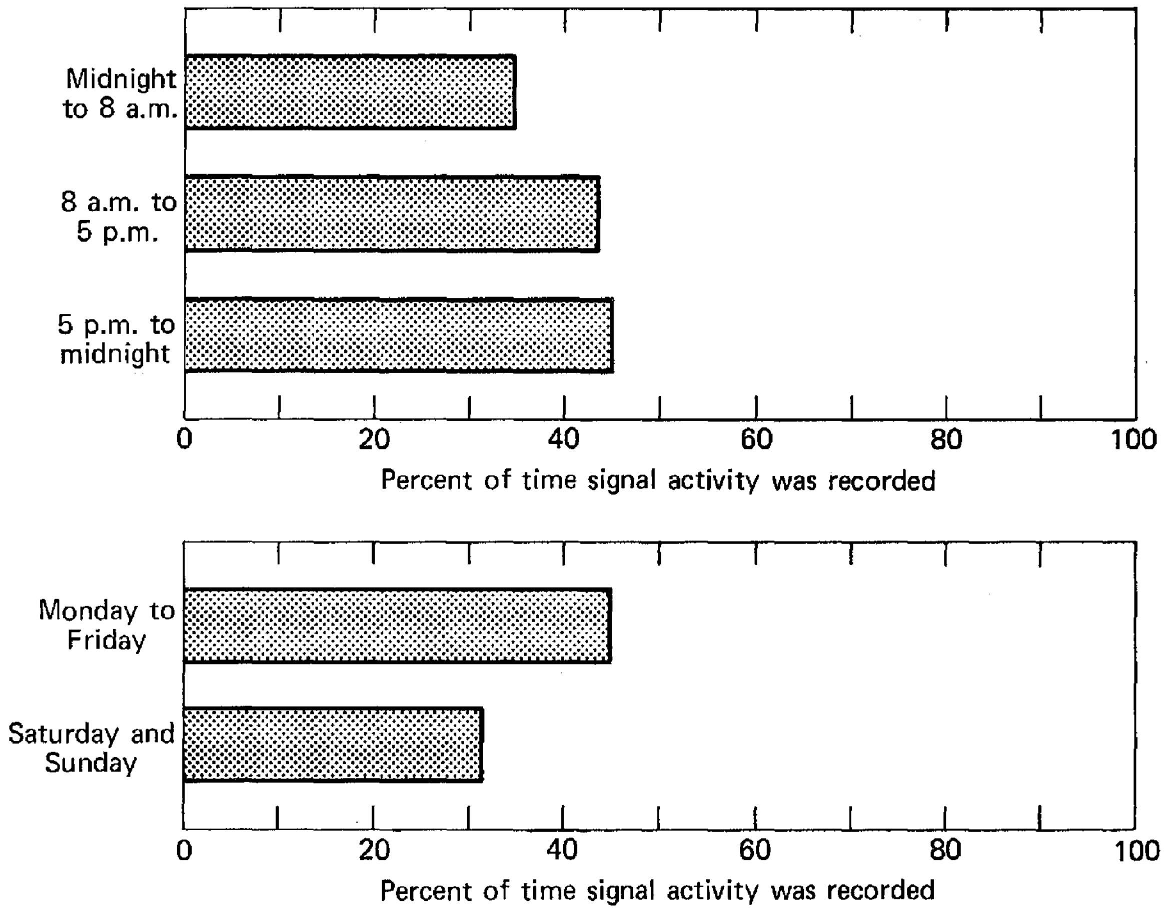

Fig. E-2 MUTS-1 activity, July 1 to October 15, 1975.

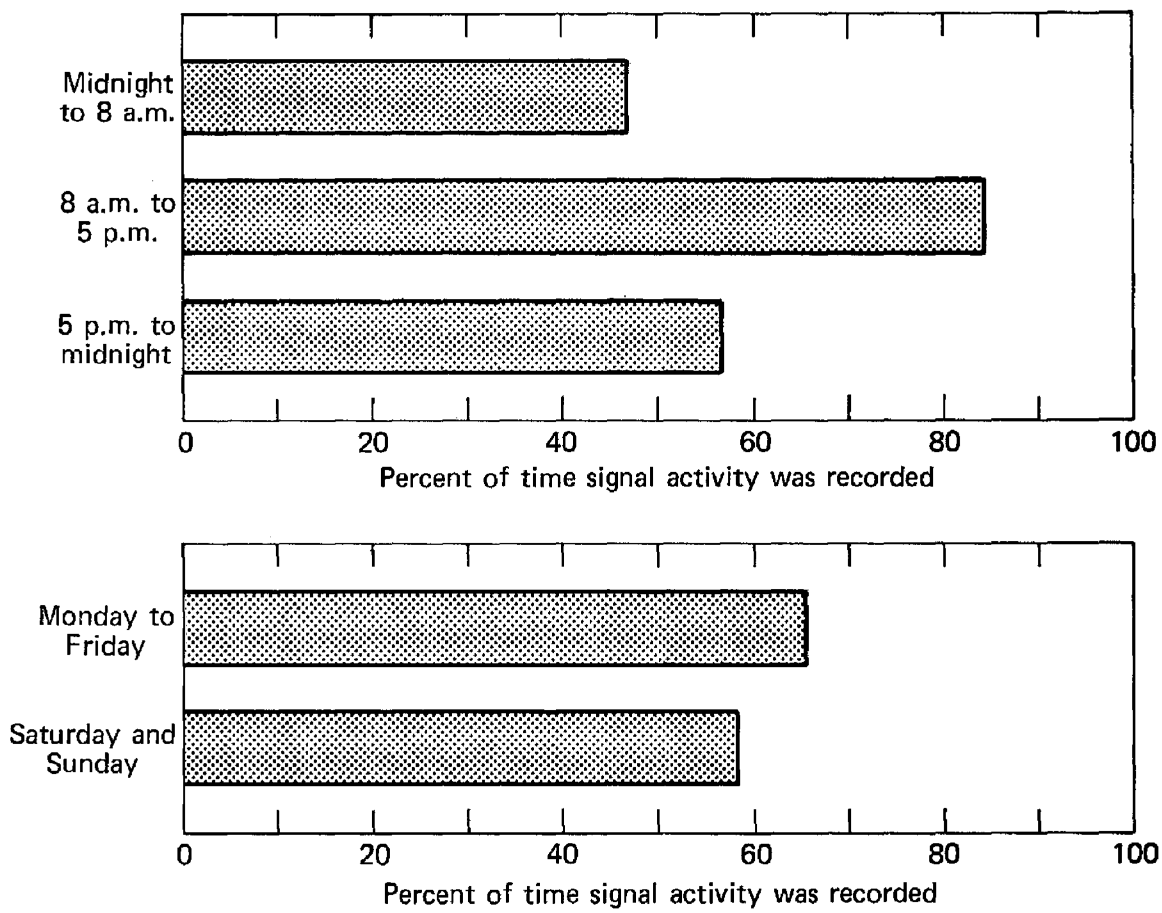

Fig. E-3 MUTS-1 and MUTS-2 combined activity, October 16, 1975 to February 5, 1976.

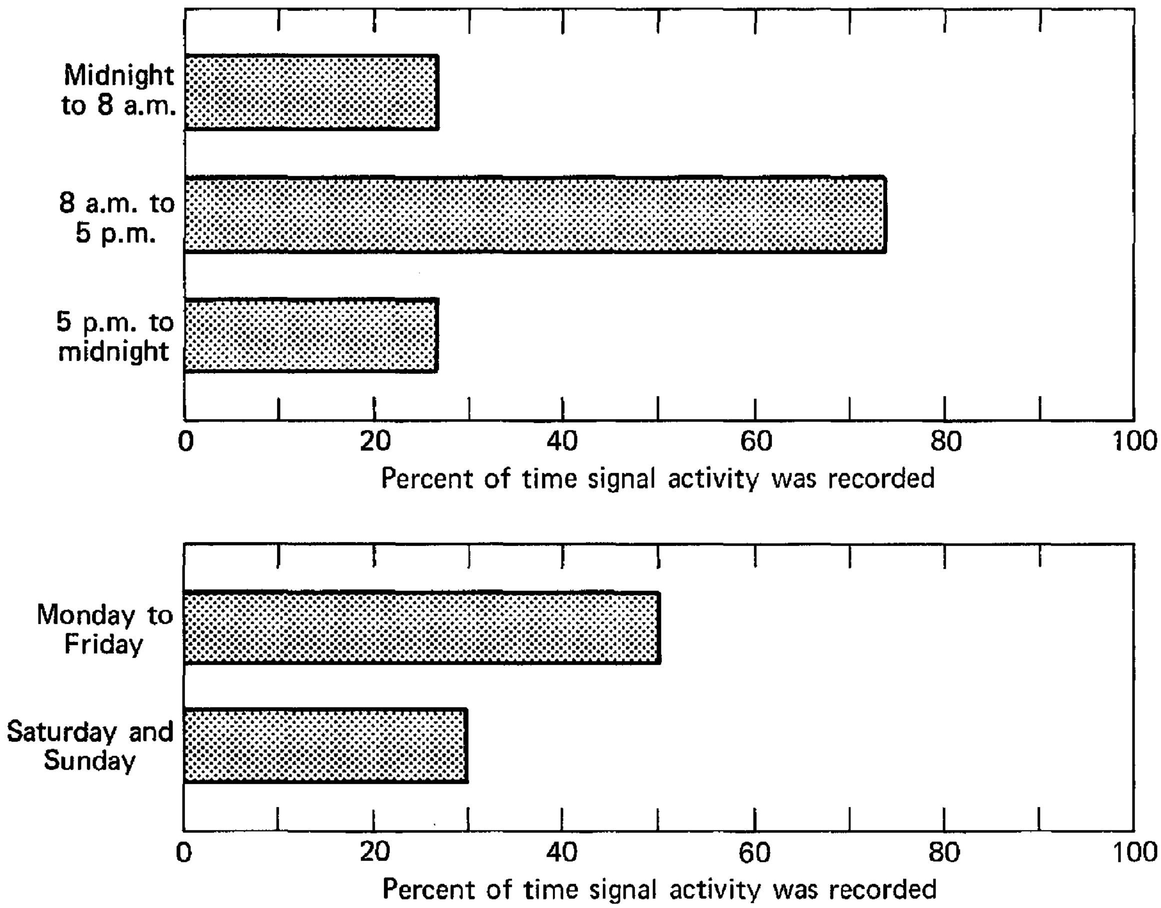

Fig. E-4 **MUTS-1 and MUTS-2 combined activity, February 6 to March 4, 1976 (window screening installed).**

UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and
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Washington, D.C. 20230

APPENDIX

WORK STATEMENT

To Satisfy A Recommendation In the Foreign Service Health Status Study

BACKGROUND

The Foreign Service Health Status Study Recommendation

The recent Foreign Service Health Status Study of Johns Hopkins University examined the possible difference in health status between personnel assigned to the Moscow Embassy during a given time period and the comparison study group. One environmental agent present in Moscow but not present at other sites was a microwave environment generated by Soviet installations.

The following recommendation is contained in the study:

> There is also a need for an authoritative biophysical analysis of the microwave field that has been illuminating the Moscow Embassy during the past 25 years with assessments based on theoretical considerations of the likelihood of any biological effects. Sufficient data was not made available to have included such an analysis in the present study, although much information on the microwave field has been collected by the Department of State and is now available. 1/

1/ Lilienfeld, Abraham M., James Tonascia, Susan Tonascia, Charlotte H. Libauer, George M. Cauthen, Jan Alan Markowitz, and Sally Weida, Foreign Service Health Status Study: Evaluation of Health Status of Foreign Service and Other Employees from Selected Eastern European Posts, Department of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Maryland 21205. Final Report (July 31, 1978). p. 247. NTIS Accession No. PB 288 163.

To carry out the recommendation properly, it is desirable to have a somewhat fuller understanding of the reason for it and its intended purpose and scope. The following discussion amplifies these points.

Reason for Recommendation

The reason for the recommendation is to specify the difference in exposure to microwave radiation, as one environmental agent, between the Moscow study group and the comparison study group. This would be done by establishing the characteristics of the microwave field at the U.S. Embassy in Moscow. The recommendation is responsive to reviewers' comments that the nature of the microwave environmental agent was not fully enough treated.

Purpose Intended by the Recommendation

The purpose of the recommendation is to help form an *a priori* estimate of the likelihood of any biological effects, for comparison with the *a posteriori* results of the hypotheses that were tested by the epidemiological health status study.

In this connection the physical characteristics of the field as to frequency range, spectral distribution, modulation, intensity, and duration are of interest because these physical parameters are the ones that interact with a biological system to influence the occurrence of any biological effect. Biophysical research results in this area are reported in terms of the physical parameters of exposure. Thus, in order to try to relate the Moscow exposure to the available research results, as complete a physical description of the Moscow field as possible is needed.

Additionally, in order to relate any similar future studies to the present study, the Moscow exposure field should be well characterized.

OVERALL PROGRAM

The overall program would consist of three phases:

- Phase 1. The National Telecommunications and Information Administration (NTIA) will arrange for a determination of the frequency, modulation, intensity, and duration of the microwave field in the period of interest for an adequate number of different locations within the Embassy during the period of interest.

- Phase 2. The Department of State will, on the basis of the Phase 1 information, provide NTIA with an estimate of greatest and typical exposures for model personnel during this period in terms of their work and living locations and work programs.

- Phase 3. The Electromagnetic Radiation Management Adivsory Council (ERMAC) and such other experts in biomedical effects of nonionizing radiation who shall act as consultants to NTIA will provide an opinion as to whether existing knowledge of biological interactions could imply likelihood of biomedical hazards, given the results of Phases 1 and 2.

DETAIL OF PHASE I PROGRAM PLAN

Data Base

Data on the nature of the microwave signal have been collected from 1962 to the present. The data over the period 1962-1977 will be the subject of the study. These consist of:

- Strip chart recordings of the average external impinging field averaged over time and frequency.

- Various point measurements, internal and external to the Embassy, designed to characterize the environmental field more specifically and/or to calibrate the level of the strip chart instruments. These data have been incorporated in various "highlight" reports throughout this period.

- Various special measurement programs, such as Pandora, which at specific times during this period have made more extensive measurements and which have developed detailed spectral data.

- Various information about the location of the sources and the spatial extent of the beams, as available.

Data Reduction Plan

Since it is not possible to precisely ascertain the field at any given point within the Embassy at any given time, a model will be developed which will:

- Permit approximate calibration of strip chart values by means of the specific quantified readings and by review and assessment of instrumentation used at the Embassy.

- Allow estimates to be made of maximum probable values for any given strip chart value at positions within the Embassy having any possibility of exposure which may not have records of specific readings.

- Develop the model in the time domain to permit a visual and understandable interpretation of the time duration of the various signals involved.

Emphasis will be on trying to establish what the maximum probable intensity is at points within the Embassy since it is expected that the variability and lack of precise calibration, along with estimates that will have to be made of positions of objects, reflections, attenuation of barriers, etc., cannot permit precise determination at any given level.

Insofar as the data permit, suitable descriptions will be provided of the spatial, temporal, spectral, and modulation characteristics of the field.