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MICROWAVE HAZARD EVALUATION OF MICROWAVE SYSTEMS USED IN EDUCATIONAL INSTITUTIONS

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U.S. Department of Health, Education, and Welfare
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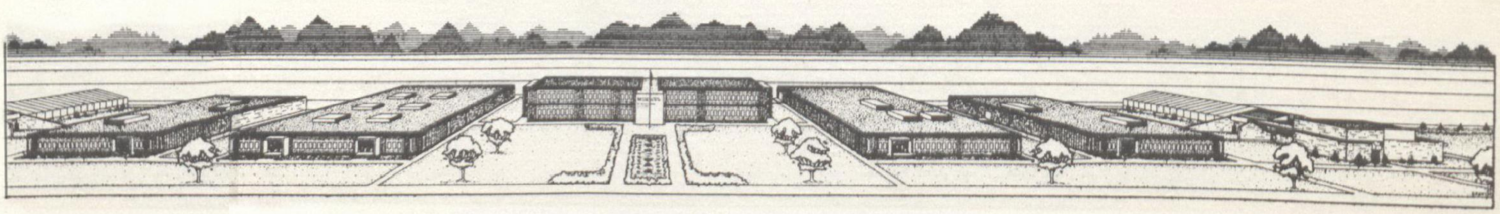

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ABSTRACT

Microwave power generating equipment used in high school and college physics laboratories was analyzed to determine microwave power density levels to which operators might be exposed. Based on an <u>*assumed*</u> *maximum allowable level of 1 mW/cm^2, none of the units, under normal operating conditions and with a minimum separation of 50 centimeters between the operator and the source, was found to be hazardous.*

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INTRODUCTION

Microwave power generating equipment is used in high school and college physics laboratories to teach various aspects of electronics, wave mechanics and electromagnetic radiation properties. College and high school physics classes may use the power generating equipment associated with the Berkeley Physics Laboratory series of experiments. Vocational and technical high schools may use microwave equipment to train students in electronics.

Operation of microwave power generating equipment subjects the operator to microwave radiation exposure. Exposure of the operator to high power densities of microwave radiation may be hazardous. Therefore, the outputs of several selected microwave power generators used for training purposes, were measured to determine the power densities to which the operator might be exposed and the hazard potential involved in this exposure.

A study of catalogs from microwave equipment suppliers and discussions with instructors of physics and electronics on both the high school and college level revealed ten systems constructed specifically for training purposes. A listing of these systems is presented in Appendix A together with pertinent information on each system.

GENERAL DESCRIPTION OF MICROWAVE TRAINING SYSTEMS

All the microwave systems with the exception of the Cenco 80422 unit are designed for X-band operation (8.4 GHz - 12.7 GHz) operation. The Cenco 80422 is designed for LS-band operation at a nominal frequency of 2.45 GHz.

The Heath EPW-25, Lectronic 535, and Hickok B-2 systems are designed specifically for use as part of the Berkeley Physics Laboratory series of experiments. These experiments are designed to demonstrate common physical phenomena through the use of microwave systems. The Cenco 80422 is designed to perform demonstrations of wave behavior, but is not integrated into the Berkeley Physics Laboratory series. The remaining six systems are designed to teach microwave properties to electronics technicians or college students studying electronics engineering.

All power generating systems consist of a power supply, an oscillator tube and an antenna. The Cenco 80422 utilizes a microwave triode (lighthouse) for an oscillator, while the other systems examined utilized reflex klystrons.

Many of the systems incorporate the same basic components and thus it was not necessary to actually measure the output of all ten systems. Those actually measured were:

1. Cenco 80422. This is unique among all the ten systems, because it is the only LS-band generator.

2. Heath EPW-25. This system is comprised of a 2K25 klystron and a pyramidal gain horn, and can simulate the Philco, RCA, PRD (PRD Electronics, Inc.) and ARRA (Antenna and Radome Research Associates, Inc.) training aid systems.

3. Lectronic 535. This system is identical to the Hickok B-2 but uses a 2K25 klystron while the Hickok B-2 uses a 723AB klystron. (The 2K25 and the 723AB are identical tubes electrically. The difference in designation stems from certain mechanical specifications.)

4. Varian X-13. This system is powered by a Hewlett Packard 717A power supply and is used in the microwave training course designed by Hewlett Packard. The Varian X-13 is electrically identical to the MXK-26 used in the Hickok X-100 system.

Although the untested systems cannot be reproduced identically by using the tested systems, the similarity is close (see Appendix A) and variations in output between the tested and untested systems probably would be equal to normal sample-to-sample variations found in klystrons of a designated type.

MEASUREMENT TECHNIQUES

Measurement was performed with an HP432 power meter coupled to a standard gain horn , and the following measurements were made:

1. Power at 100 cm.
2. Power at 50 cm.
3. Beam profile.
4. Near field power density fluctuations.

For X-band measurements the Narda 640 standard gain antenna was used. The LS-band measurements were performed with the Narda 644. Frequencies in the X-band were determined by precision wavemeter cavity and, in the LS-band, by a Polarad Model TSA spectrum analyzer.

In practice, each system was put into operation and tuned for maximum output (except the Cenco 80422 which cannot be tuned). After the maximum output was obtained, the frequency was determined. Appropriate antenna and power meter calibration factors were then used in the determination of output power and power density.

Plots of measured power density vs separation between antennas were made for X and LS band sources (see Appendix D). Based on the plots, a distance of 50 centimeters was picked as the closest distance at which measurements could be made without inducing severe field perturbations. This distance represents a reasonable separation between an operator and the system, and allows reliable far field measurements to be made.

Profiles of the beam from each tested system were made at a distance of 50 centimeters to insure that measurements would be made along the axis of highest power density (Appendix C).

RESULTS

The results obtained from measuring the output power density of five microwave power generating systems are summarized in Appendix B. None of the systems produced greater than 0.35 mW/cm^2 at a distance of 50 cm from the transmitting antenna. The highest output power density was obtained from the Varian X-13 as used by Hewlett Packard. Similar results would be expected from the Hickok X-100 which uses an MXK-26 oscillator, since the MXK-26 is electrically identical to the X-13.

CONCLUSION

The U.S. Public Health Service has neither established microwave exposure guidelines nor endorsed those of any other group. For purposes of this report, an exposure level of 1.0 mW/cm^2 was considered the maximum allowable level.

Normal operation of microwave training and demonstration aids includes the making of power measurements under various conditions. The presence of a foreign object, such as the operator, can cause perturbation of the field and yield erroneous measurements. Therefore, the operator should normally stay well away from the beam of radiation. This report considers 50 centimeters as a reasonable separation between operator and equipment, and hazard evaluations were based on operator exposure at this distance. Under the assumed guideline of 1.0 mW/cm^2 none of the systems tested or considered would pose a hazard in normal operation, so long as the 50 cm separation between equipment and operator is maintained.

It is possible for some part of the operator's body to be in the beam path, particularly when changing the experimental configuration while power is still supplied to the equipment. Under these circumstances it is quite possible that a high power output system which uses the X-13 or MXK-26 (such as those described in this report) could produce a hazardous situation. If, for example, a human eye was located directly in front of the waveguide (cross sectional area = approx. 3 cm^2) of an X-13 klystron, radiating 300 mW of power, it might be exposed to power densities approaching 100 mW/cm^2. (It is possible that reflections from the eyeball back down the waveguide might de-tune the oscillator resulting in a lower power output; however, this seems unlikely to occur.) The remainder of the commercial systems considered in this report should pose no microwave hazard even under very unusual circumstances.

Surplus microwave power generating equipment is available to schools from a number of sources. Much of this equipment is capable of producing hazardous levels of microwave radiation (for example, missile radar sets, and shipboard radar). Some consideration should be given to the advisability of state regulation of the sale of this equipment to educational institutions.

APPENDIX A

Notes on Microwave Systems:

1. Heath Co. EPW-25. This is an X-band transmitter coupled to a horn antenna. The oscillator is a 2K25 reflex klystron.

   This system is designed to be used as part of the Berkeley Physics Laboratory experiment series. The transmitter case is constructed to couple to 0.9" x 0.4" waveguide, thus the system can be used to simulate other systems.

---

2. Lectronic Research Inc. 535. This is an X-band transmitter consisting of a mounting bracket and a short horn antenna. The oscillator can be either a 2K25 or a 723AB reflex klystron. The unit is designed as part of the Berkeley Physics Laboratory equipment marketed by Lectronics.

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3. Hickok B-2. This is an X-band transmitter identical to the Lectronic 535. It is supplied with a 723AB reflex klystron. The transmitter is designed to be used as part of the Berkeley Physics Laboratory system marketed by Hickok.

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4. Cenco Scientific Co. 80422. This is an LS-band transmitter using a 2C40A "lighthouse" tube, coupled to a parabolic antenna. The spectral (frequency) distribution of the output power was observed to be broad.

   The unit and its associated receiver are used for basic demonstrations of microwave radiation properties in high school or college physics laboratories.

5. Philco Electronics Teaching System. This system incorporates several circuit boards with 2K25 reflex klystron tubes coupled through a waveguide to a horn antenna. The training system is designed to teach microwave electronics in a vocational or technical school.

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6. RCA Electronics Teaching System 121-MW. The RCA system incorporates several demonstration boards with 2K25 reflex klystron tubes coupled through a waveguide to a horn antenna. This teaching system is designed to teach microwave electronics in a vocational or technical school.

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7. PRD X980 Universal Microwave Training Lab. This system includes a 2K25 reflex klystron coupled through a waveguide to various pieces of measurement gear. The unit does not, in use, radiate power into free space, though it could be easily modified to do so. The system is designed for use in trade schools, vocational schools, colleges, etc.

---

8. ARRA Model MT-1 Microwave training unit. This is an X-band training system with a 2K25 reflex klystron as power source. The system is designed for vocational technical training and for college use in microwave engineering.

---

9. Varian X-13. The Varian X-13 is a small reflex klystron which operates in the X-band. The klystron is used as a power tube to teach microwave electronics in a course designed by Hewlett Packard Corp.

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10. Hickok X-100. This transmitter is designed as a signal source for a Hickok microwave training system. The output is provided by a MXK-26 which is a military equivalent of the X-13. The output power is listed as a maximum of 600 mW, although 100-300 mW would be normally realized.

APPENDIX B

POWER DENSITY AT VARIOUS DISTANCES

SYSTEM	OUTPUT FREQ. (GHz)	POWER TUBE	ANTENNA	POWER DENSITY (mW/cm^2) AT: 200 cm	100 cm	50 cm
CENCO 80422	1.82 1.95 2.10 2.52 2.64 * 3.47 4.00 5.00	2C40A	PARABOLIC	-------	.0096	.0037
HEATH EPW-25	9.58	2K25	HORN	.0023	.00850	** (a) .0570 (b) .0365
LECTRONIC 535	9.58	2K25	HORN	.0020	.00815	.0322
VARIAN X-13	9.35	X13	HORN	.0258	.0865	.3320

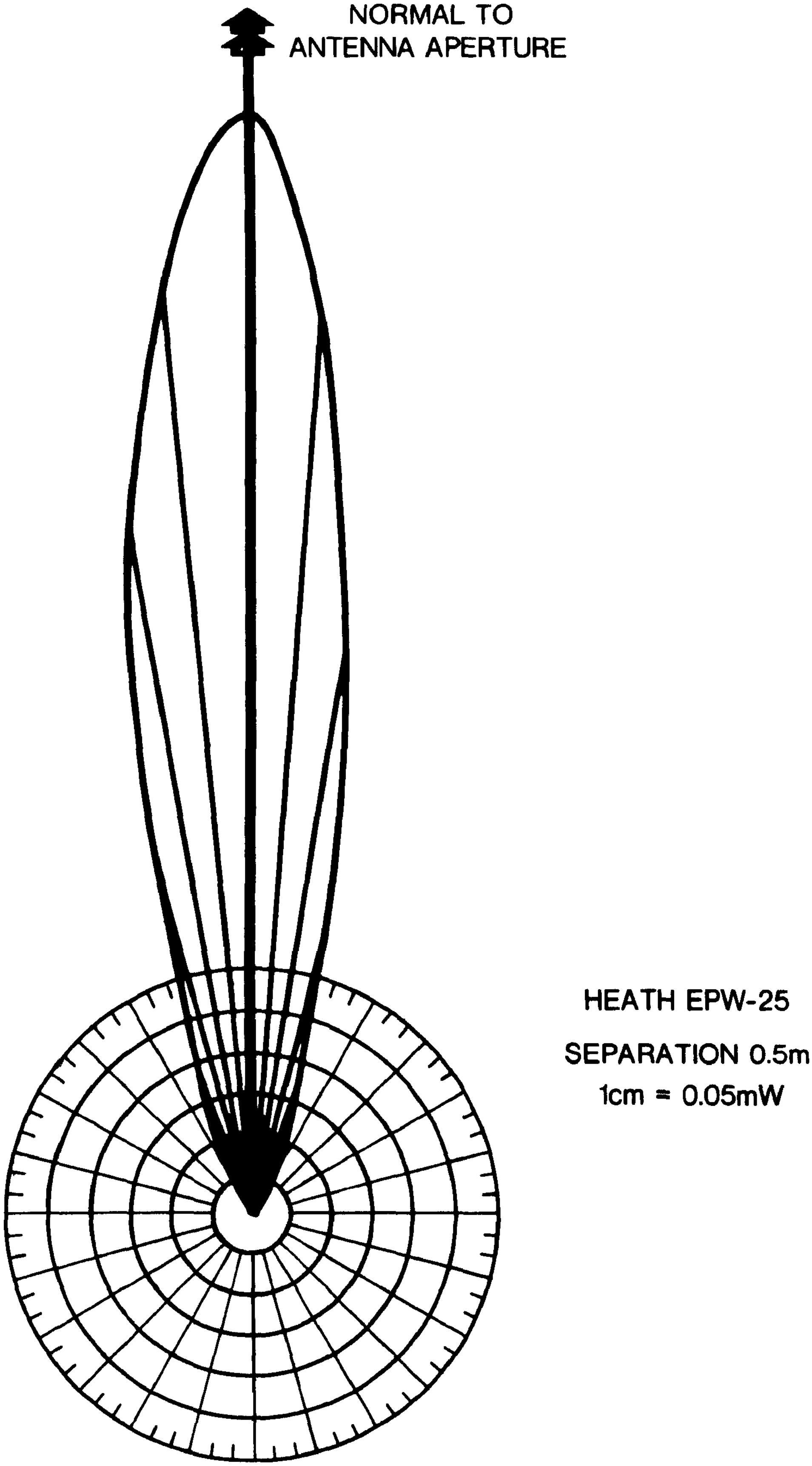
* Major output peak was at 3.47 GHz

** (a) Maximum power density obtainable.

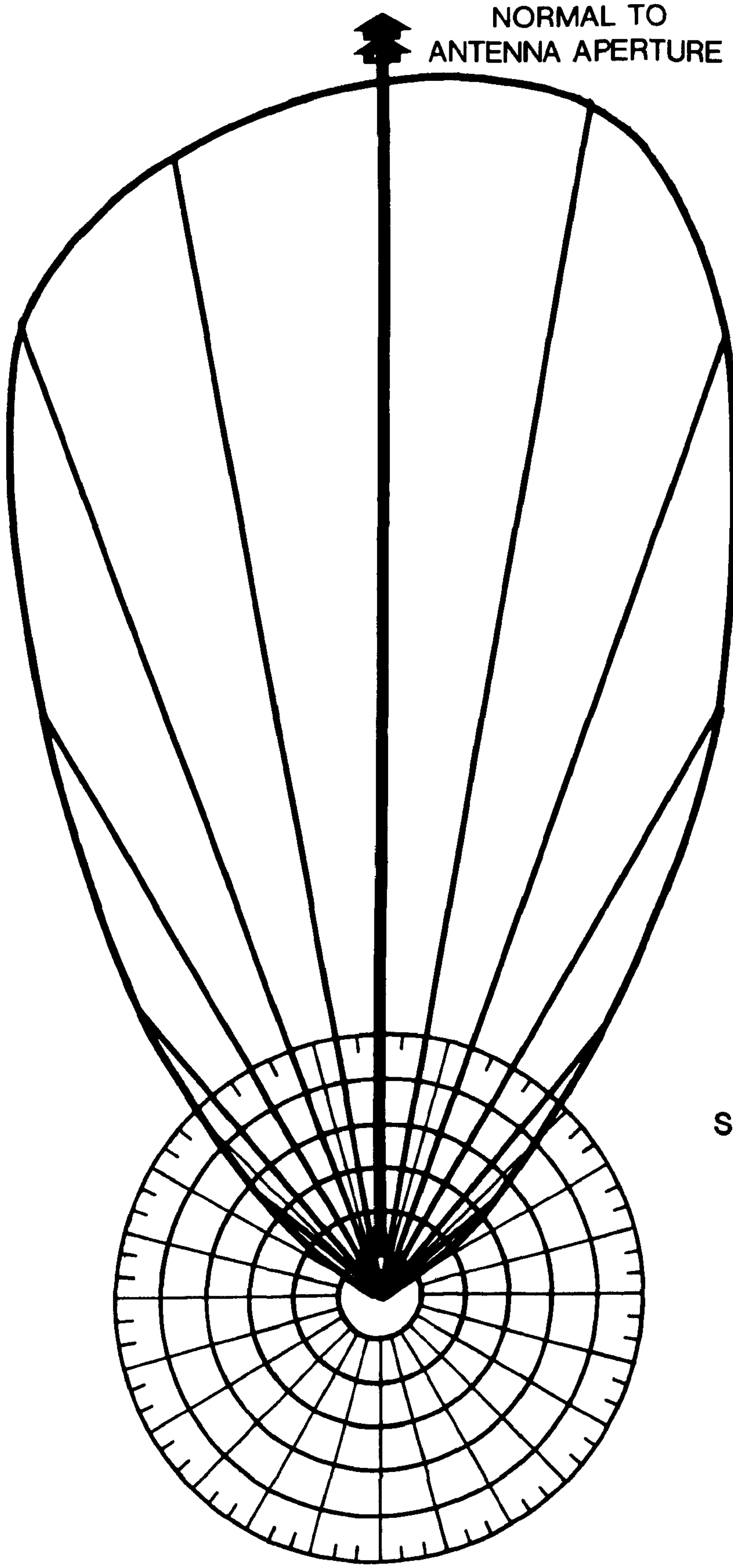
(b) Power density at settings specified by Heath

APPENDIX C

BEAM PROFILES OF MEASURED SYSTEMS



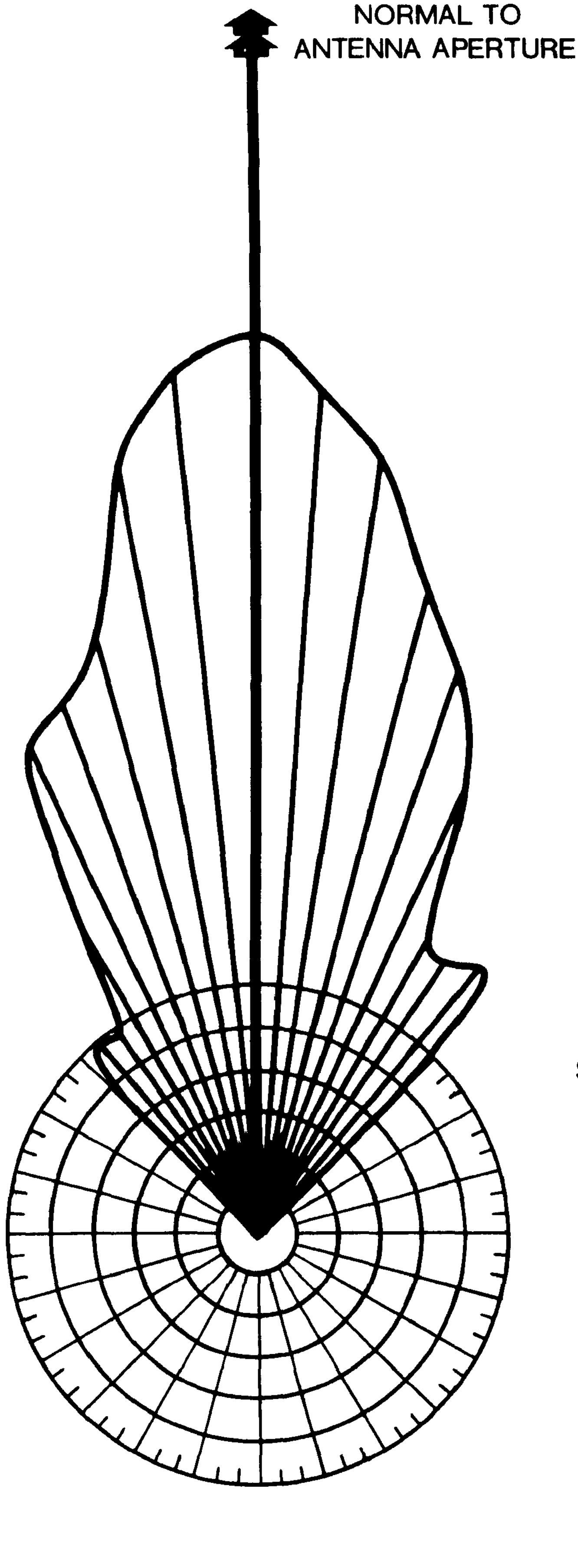
NORMAL TO
ANTENNA APERTURE
HEATH EPW-25
SEPARATION 0.5m
1cm = 0.05mW



CENCO 80422

SEPARATION 0.5m

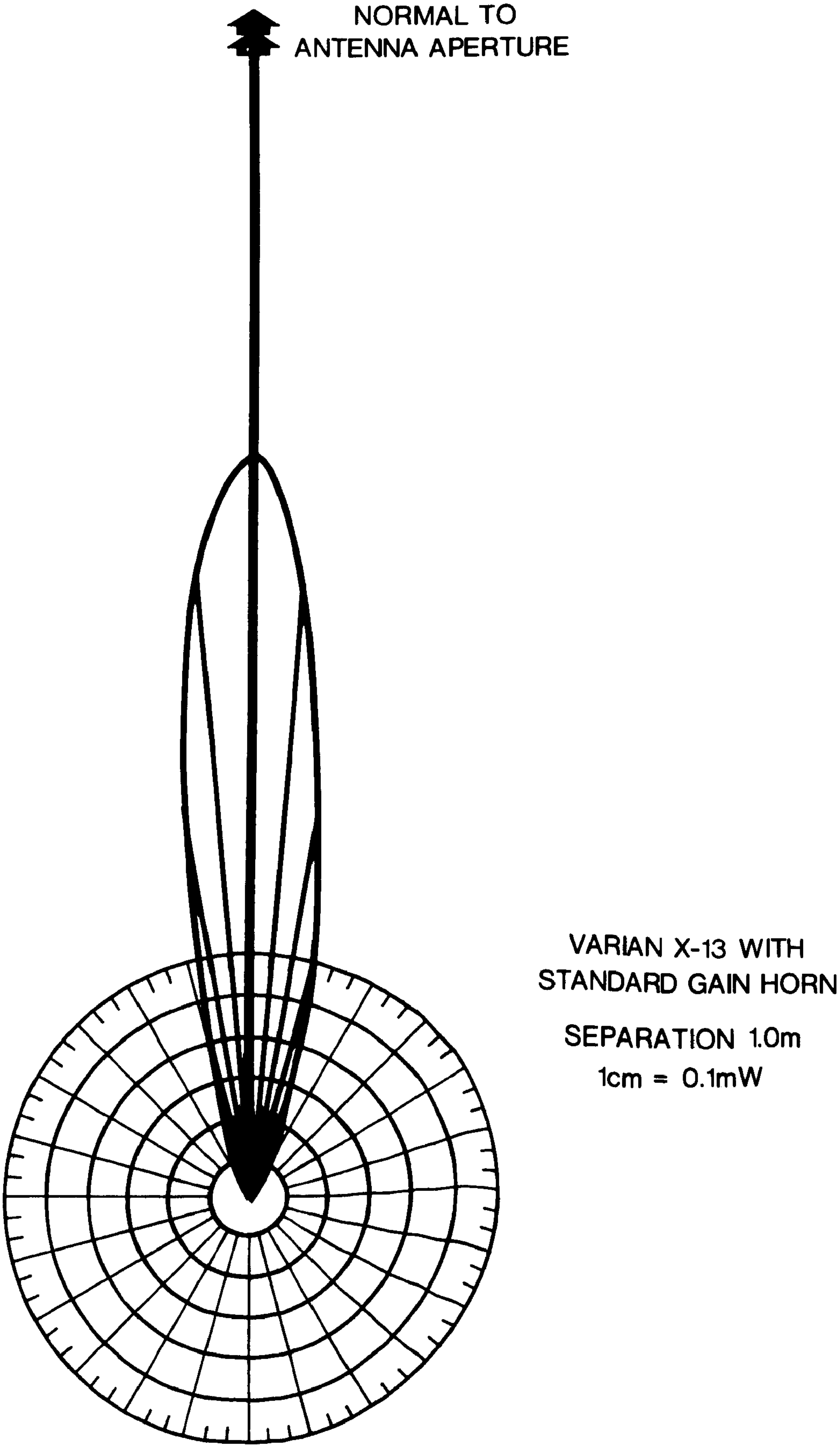
1cm = 0.05mW



LECTRONIC 535

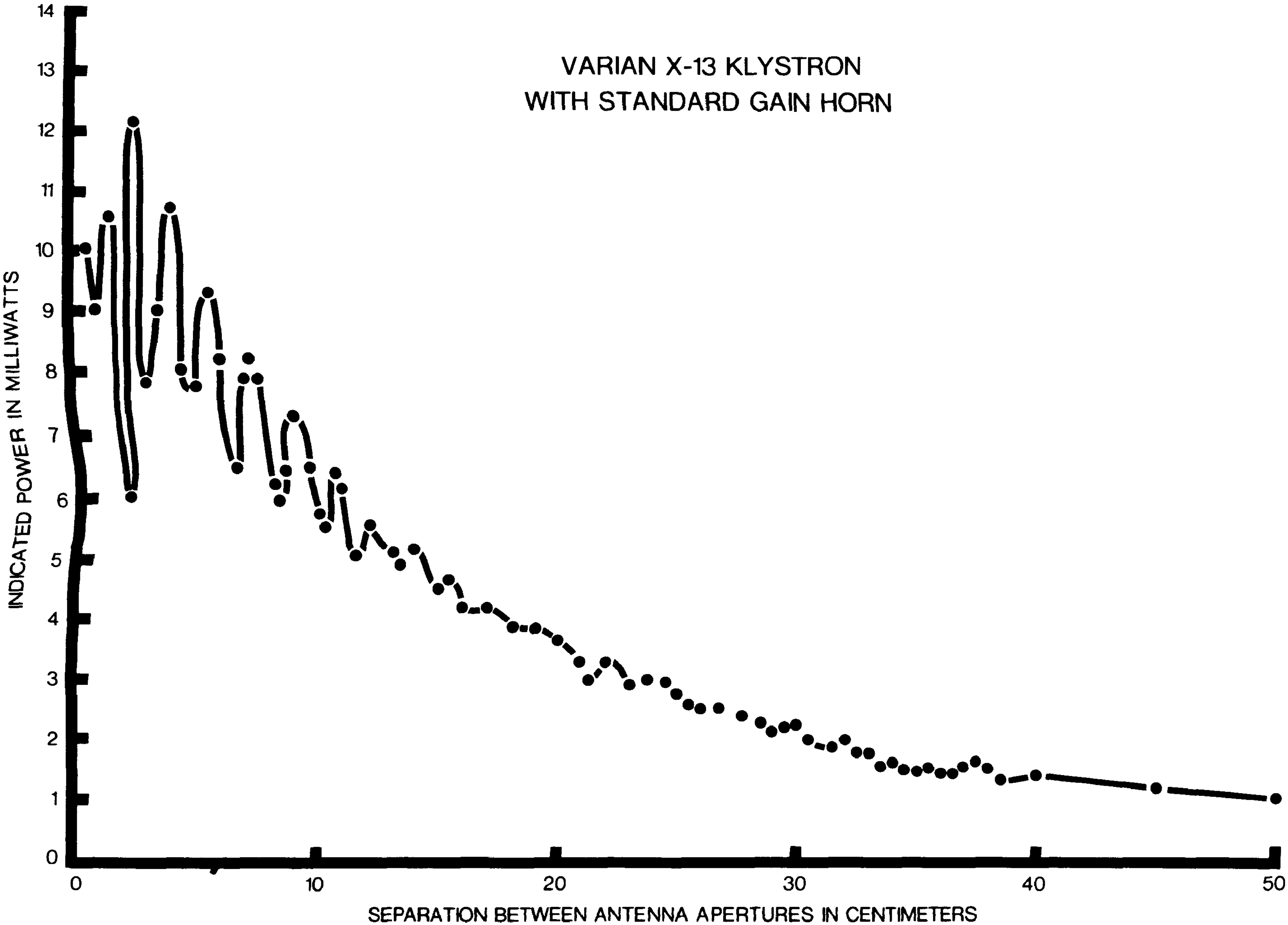
SEPARATION 0.5m

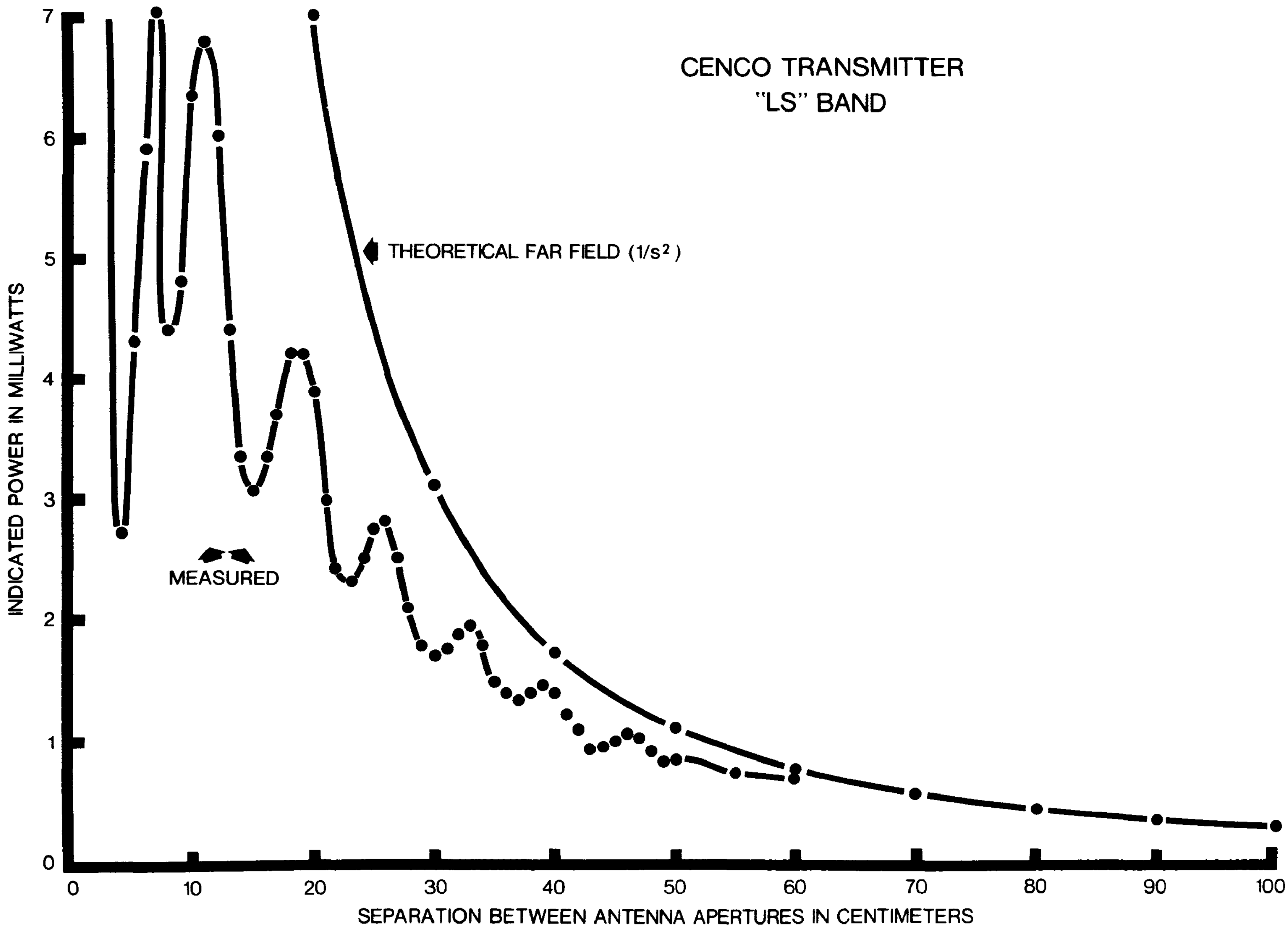
1cm = 0.02mW


NORMAL TO
ANTENNA APERTURE
VARIAN X-13 WITH
STANDARD GAIN HORN
SEPARATION 1.0m
1cm = 0.1mW

APPENDIX D

PLOTS OF INDICATED POWER VS. SEPARATION BETWEEN ANTENNA APERTURES


VARIAN X-13 KLYSTRON
WITH STANDARD GAIN HORN
INDICATED POWER IN MILLIWATTS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
10
20
30
40
50
SEPARATION BETWEEN ANTENNA APERTURES IN CENTIMETERS


CENCO TRANSMITTER
"LS" BAND
THEORETICAL FAR FIELD ($1/s^2$)
MEASURED
INDICATED POWER IN MILLIWATTS
SEPARATION BETWEEN ANTENNA APERTURES IN CENTIMETERS
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100

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