Microwave Leakage Probe System

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U.S. Army Center for Health Promotion and Preventive Medicine
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USACHPPM
Readiness thru Health

BACKGROUND and PURPOSE

The Army is a large user of many high-power microwave radar and communication systems. During extensive testing or operation of these systems in dummy loaded or free-space radiation configurations, these systems may develop measurable leakage levels of microwave energy over time. These leakage levels can exist along transmission lines, waveguides, or other system components. Army depots and certain maintenance facilities are required to periodically check for such transmission line leakages. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has made recommendations concerning such leakage testing, with particular reference to optimum types of test equipment, acceptable and safe procedures, and maximum allowable leakage levels. This technical guide (TG) presents a summary of those recommendations and may be considered applicable in the general case.

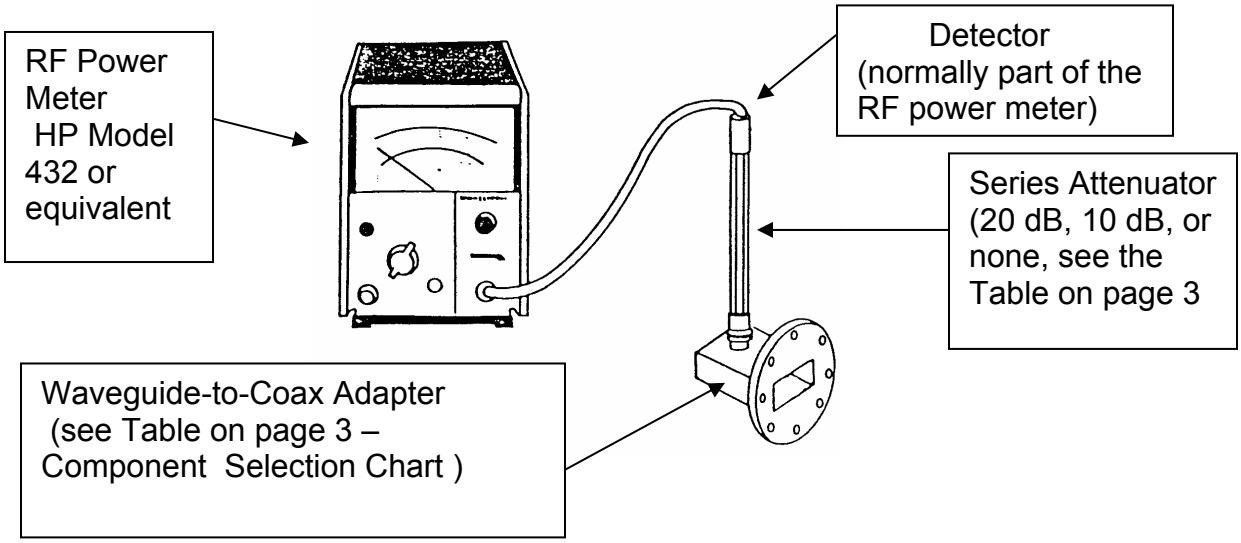
MEASUREMENT REQUIREMENTS

Virtually all high-power microwave systems operating above 1 gigahertz (GHz) use waveguide transmission lines for energy transfer within the system. Both rigid and flexible waveguide transmission lines are easily damaged, and if a fracture occurs, radiation leakage will result. Since extensive quantities of energy are often involved, even a small percent of leakage can produce a potentially hazardous power-density level. On the other hand, even large leakage levels, when radiated, attenuate rapidly with distance since a waveguide leakage source represents a small, low-gain antenna aperture. Any probing for suspected leakage will require a sensitive yet wide amplitude-range-measuring instrument, using a low-gain or small antenna aperture. Probing will normally be done right along the surface of the transmission line or related component. As with any test, measurement, and diagnostic equipment (TMDE), ensure that the required calibration for any component of the probing system is up-to-date and that all component specifications allow for the use of the system in the frequency range of interest.

LEAKAGE PROBE SYSTEM

The Figure (see page 2) presents a schematic diagram of a leakage probe system (LPS) that will meet the testing requirements.

FIGURE. SCHEMATIC DIAGRAM - LEAKAGE PROBE SYSTEM



Note:

- RF – radiofrequency
- dB - decibel

An adequate power meter/detection combination will be one that is calibrated for the appropriate frequency and has a 10 milliwatt (mW) full-scale capability. Where an attenuator is required (see Table on page 3 - Component Selection Chart), the attenuator must also be calibrated over the frequency band of interest. The waveguide-to-coax adapter, which serves as the antenna for the LPS, is also chosen from the selection chart as a function of frequency and does not require calibration. Note that all of the components required for the system will normally be calibrated shelf items in the typical facility, which has a need to utilize leakage probe measurements. There should be no requirement for the purchase or special calibration of equipment in order to implement this system. The following example is presented to illustrate the use of the system:

A signal company is operating the AN/TRC-170(V) Tropospheric Scatter Microwave Radio Terminal Sets. The power amplifier for this troposcatter/line-of-site radio terminal operates in the 4 to5 GHz frequency range with maximum output power of 2 kW. This system is housed in an S-280 or S-250 shelter (V)2 or (V)3, respectively. To check for RF leakage, a Microwave LPS is assembled. The equipment and parts used to make up the LPS are found in most electronic maintenance shops. The LPS may be used to detect RF leakage inside the shelter or along the flexible waveguide lines connecting the shelter waveguide ports to the antenna(s).

From the component selection chart, (shown below), the frequency band of 4 to 5 GHz falls within the band of the WR-187 waveguide-to-coax adapter (3.95 to 5.85 GHz).

TABLE. COMPONENT SELECTION CHART
LEAKAGE PROBE SYSTEM

FREQUENCY BAND (GHz)	1.12-1.70	1.70-2.60	2.60-3.95	3.95-5.85	5.30-8.20	7.05-10.0	8.2-12.4	12.4-18.0
WAVEGUIDE TYPE (WR- NOMENCLATURE)	WR-650	WR-430	WR-284	WR-187	WR-137	WR-112	WR-90	WR-62
WAVEGUIDE DIMENSION (INSIDE) cm	8.3X16.5	5.5X10.9	3.4X7.2	2.2X4.8	1.6X3.5	1.3X2.9	1.0X2.3	0.8X1.6
SERIES * ATTENUATOR REQUIREMENT	20 dB	10 dB	10 dB	10 dB	NONE	NONE	NONE	NONE
CONVERSION **FACTOR (mW to mW/cm^2)	.0065	.0148	.0361	.0840	.158	.235	.385	.690
INDICATED* POWER (for 1.0 mW/cm^2)	1.54 mW	6.70 mW	2.77 mW	1.20 mW	6.33 mW	4.26 mW	2.60 mW	1.45 mW

Note:

- cm – centimeter
- mW/cm^2 – milliwatt per square centimeter

* To determine "Actual Power," multiply "Indicated Power" by Attenuator Factor.
Example: Indicated Power x Attenuation Factor = 1.54 mW x 100 = 154 mW, 100 = 20 dB

† To determine Power density (mW/cm^2), multiply Actual Power by "Conversion Factor."
Example: Actual Power of 154 mW x Conversion Factor = 154 mW x .0065 = 1 mW/cm^2

The component selection chart also recommends the use of a 10 dB series attenuator. Use of the attenuator is optional; however, it should be noted that the last row of the component selection chart has included this attenuator in stating the indicated power for a 1 mW/cm^2 leakage level. If the attenuator is included, 1.20 mW indicated power x 10 (accounting for 10 dB attenuation) is 12.0 mW actual power. The 12.0 mW x .0840 (conversion factor) is 1.0 mW/cm^2 leakage level. The WR-187 waveguide-to-coax adapter, the 10 dB attenuator, and the microwave power meter are used as a probing system.

To check for leakage inside the shelter, switch to the dummy load and move the adaptor around the equipment rack and the positions of the operators. Whenever a reading is obtained, the adapter should be rotated or tilted for maximum power meter indication. Any measurable leakage (0.02 mW/cm^2 or higher) inside the shelter indicated defective/damaged dummy load or waveguide.

To check for waveguide lines leakage, the adapter is moved along the surface of the flexible waveguide transmission line that connects the antenna to the shelter. Loose coupling is recommended: approximately 1 to 2 cm spacing should be maintained between the adapter and the transmission line. Wherever a reading is obtained, the adapter should be rotated or tilted for maximum power meter indication. If leakage is detected, proceed with caution making sure not to exceed the maximum power rating of the detector (usually 10 or 15 mW). If readings close to the maximum input power rating are observed, add series attenuators.

Finally, the power meter indication multiplied by the attenuation value (x 10 for 10 dB, x 100 for 20 dB, x 1 for None) and multiplied by the conversion factor (.0840 for WR-187) gives the leakage level in mW/cm^2. When the measurement is complete, a permanent record should be made, indicating the largest/highest field intensity levels encountered. Regions showing greater than 1.0 mW/cm^2 leakage should be examined while the system is disabled (i.e., turned off). Only then should damaged or loose waveguide fittings be corrected. The system should be rechecked after any repairs, changes, or corrections have been effected.

CAUTION:

Microwave leakage from severely damaged waveguide or loose flanges of the AN/TRC-170 system could produce potentially hazardous power density levels to a range of 2 meters (worst-case being open waveguide).

MEASUREMENT ACCURACY LIMITATIONS AND PRECAUTIONS

The accuracy of the measurements made with the LPS discussed in this TG has been relaxed in the interest of simplicity and operational dependability. Using the selection chart conversion factors and depending upon a nominal 0.2 dB accuracy in both the power meters and attenuator (if required), the overall measurement accuracy of the system is 2.0 dB. For example, a leakage indication of 1.0 mW/cm^2 could lie in the real range from 0.6 to 1.6-mW/cm^2. Better accuracy could be obtained by using a range of correction factors for each frequency band; however, leakage that occurs in even the highest power systems can readily be controlled to less than 1.0 mW/cm^2. There is, consequently, no reason to require greater accuracy since this proposed LPS will suffice to maintain radiated levels well below 10 mW/cm^2.

The LPS should only be used for its intended purpose. Measurement of the radiation levels associated with antenna main beams or spillover regions requires a greater accuracy, and at times, a lower gain (near isotropic) antenna to protect the investigator from exposure to potentially hazardous power density levels. The radiation protection program for free-space radiating systems is specifically based on prohibiting personnel access to the radiation zones of such systems. The recommendations in this TG are consistent with such a program. Consequently, this LPS is designed for use on nonradiating systems or a nonradiating portion of a radiating system.

The following general recommendations should be part of the Standing Operating Procedure (SOP) for use of this LPS:

- Specify those systems that require leakage probing. Include all details as to when probing shall be done, how often, and what components of each system are affected.
- Designate personnel responsible to do leakage probing and verify their capability.
- Maintain a permanent record (e.g., log book) of all leakage probing conducted. Include all necessary details and measurement results.
- Document all aspects of the SOP.

Contact USACHPPM, if further clarification is required, either in the technical aspects of this document or the proper and safe procedures necessary to perform such tests. Further information can be obtained by writing Commander, U.S. Army Center for Health Promotion and Preventive Medicine, ATTN: MCHB-TS-ORF, 5158 Blackhawk Road., Aberdeen Proving Ground, MD 21010-5403 or by calling the Radiofrequency/Ultrasound Program at DSN 584-3353 or commercial (410) 436-3353.

Glossary

Acronyms

cm – centimeter

dB – decibel

GHz – gigahertz

LPS – Leakage Probe System

mW – milliwatt

mW/cm^2 – milliwatt per square centimeter

RF – Radiofrequency

SOP – Standing Operating Procedure

TG – Technical Guide

TMDE – Test, measurement, and diagnostic equipment

USACHPPM – U.S. Army Center for Health Promotion and Preventive Medicine

WR – Rectangular Waveguide