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Guide for Establishing and Maintaining A Calibration Constancy Intercomparison System for Microwave Oven Compliance Survey Instruments

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Food and Drug Administration
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PREFACE

Public Law 90-602, the Radiation Control for Health and Safety Act of 1968 (the Act), directs the Department of Health and Human Services to evaluate production testing and quality control programs carried out by the industry to assure adequacy of safegaurds against hazardous electronic product radiation and to assure that the products comply with performance standards.

Under the Act, manufacturers of microwave ovens, a product listed under 21 CFR 1002.61, are required to certify that their microwave ovens are in compliance with all of the applicable provisions of the Federal Performance Standard for Microwave Ovens, 21 CFR 1030.10. In order to comply with microwave emission level provisions of the performance standard, manufacturers must use properly calibrated microwave leakage measurement instruments in their production and quality control testing programs.

This document has been prepared in order to assist the microwave oven manufacturers in establishing and maintaining a calibration constancy intercomparison system for compliance survey instruments and replaces guidance previously issued by the Center for Devices and Radiological Health (the Center). The guide also contains sample documentation forms for recording calibration data.

Checks on the calibration constancy and use of microwave survey instruments are two vital parts of an adequate quality control and testing program. Please read the guide carefully. If your instrumentation program does not include all the aspects covered in the guide, you should modify your program. Any changes to your quality control program must be reported to the Center using the instructions found in Part 8.0 of the Guide for Preparing Reports of Radiation Safety of Microwave Ovens, March 1985.

Walter E. Gundaker
Director
Office of Compliance

FOREWORD

In October 1982, the Food and Drug Administration established the Center for Devices and Radiological Health (CDRH) by merging the Bureau of Medical Devices and the Bureau of Radiological Health.

The Center develops and implements national programs to protect the public health in the fields of medical devices and radiological health. These programs are intended to assure the safety, effectiveness and proper labeling of medical devices, to control unnecessary human exposure to potentially hazardous ionizing and nonionizing radiation, and to ensure the safe, efficacious use of such radiation.

The Center publishes the results of its work in scientific journals and in its own technical reports. These reports provide a mechanism for disseminating results of CDRH and contractor projects. They are sold by the Government Printing Office and/or the National Technical Information Service.

Also, CDRH technical reports in radiological health are made available to the World Health Organization (WHO) under a memorandum of agreement between WHO and the Department of Health and Human Services. Three WHO Collaborating Centers, established under the Bureau of Radiological Health, continue to function under CDRH:

WHO Collaborating Center for Standardization of Protection Against Nonionizing Radiations;

WHO Collaborating Center for Training and General Tasks in Radiation Medicine; and

WHO Collaborating Center for Nuclear Medicine.

We welcome your comments and requests for further information.

John C. Villforth
Director
Center for Devices and
Radiological Health

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GUIDE FOR ESTABLISHING AND MAINTAINING A CALIBRATION CONSTANCY INTERCOMPARISON SYSTEM FOR MICROWAVE OVEN COMPLIANCE SURVEY INSTRUMENTS

1.0 INTRODUCTION

Manufacturers of microwave ovens must use properly calibrated microwave leakage measurement instruments in their production testing and quality control programs to assure compliance with the Federal Performance Standard for Microwave Ovens (21 CFR 1030.10).

As an alternative to frequent recalibration against absolute standards, the Center for Devices and Radiological Health (CDRH) will allow manufacturers to establish a system that demonstrates that the calibration of each instrument remains within prescribed limits, over time, subsequent to absolute calibration* by the instrument manufacturer or other qualified calibration facility.

This document outlines procedures for establishing and maintaining a "calibration constancy intercomparison system" (referred to as the "system" throughout this document) capable of assuring adequate constancy of calibration, while minimizing the necessity for absolute recalibration.

It must be noted and understood that the system described herein is not intended for use in calibrating hand-held or automated scanning survey instruments, nor is it intended to be used to transfer calibrations from one instrument to another. It is only intended to provide a means to determine whether an instrument's calibration is changing with time, and whether it is continuing to function properly. The underlying principle is that constancy of calibration may be determined by comparing an instrument's reading with its own prior readings and with other meters' readings when it measures a fixed parameter.

The procedures for establishing and maintaining a calibration constancy intercomparison system consist of (1) maintaining an apparatus or system to perform a calibration constancy intercomparison, (2) documenting the results using a log or record to demonstrate constancy over a period of time, and (3) adhering to an appropriate schedule of checks to assure proper function and calibration constancy of each instrument. Such a schedule of checks and a simple acceptable calibration constancy intercomparison system are described below. Briefly, the calibration constancy intercomparison system consists mainly of:

(1) a microwave source,
(2) a radiated power monitor (RPM),
(3) an anechoic environment with a radiator and probe-holding fixture, and
(4) a local calibration reference (LCR).

A more detailed description is given in Appendixes 1 and 2. A system using this apparatus has been demonstrated to be accurate and practical to reproduce and use. Any calibration constancy intercomparison system that can be shown to provide comparable performance (at least within the same limits as the system described above) would be acceptable.

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*Absolute calibration (i.e., calibration against absolute standards) means calibration of a system in which all measurement parameters are traceable, with specified uncertainty, to the absolute standards maintained by the National Bureau of Standards or equivalent.

2.0 PROCEDURES

2.1 PREOPERATIONAL PROCEDURES

2.1.1 Requirement

Preoperational procedures, as described by the manufacturers of the calibration constancy intercomparison system and the survey instruments, must be performed prior to use to assure that the system and survey instruments are functioning correctly and properly adjusted.

2.1.2 Instrumentation and Method

Various preoperational procedures are described in the manuals provided by the manufacturers of the calibration constancy intercomparison system and survey instruments. For example:

(1) a suitable period of time must be allowed after turning on the system and survey instruments for "warm up" or stabilization;

(2) survey instruments' probe cones (spacers) should be checked daily and replaced if dirty or worn;

(3) battery-operated survey instruments must have their batteries checked thoughout the day;

(4) charger covers must be in place on the survey instruments with rechargeable batteries;

(5) the voltage supply for the AC-voltage powered instruments must be checked periodically;

(6) the survey instruments and system should be checked for any evidence of physical damage, and, if damaged, the entire instrument and/or system must be checked prior to each oven survey;

(7) baseline or "zero" reading on the survey instruments and/or system must be checked prior to each oven survey; and

(8) all other preoperational procedures specified in the owner's survey instrument and/or system manuals must be followed.

2.2 DAILY CHECKS

2.2.1 Requirement

The polarization response of each survey instrument must be checked daily prior to its use to determine any gross shifts in response which could indicate instrument damage.

2.2.2 Instrumentation and Method

Make a check of the survey instrument's polarization response using an adequately stable microwave field source. This microwave field should be linearly polarized, have the correct frequency, and cause at least a mid-scale meter reading on the survey instrument. A field setting (or power density) of approximately 1.0 mW/cm^2 can be used for generating a mid-scale meter reading. However, different levels may be necessary for other specialized meters such as probe/pre-amp units from the automated oven survey systems (scanners). Specifications for performing polarization response measurements should be obtained from the survey instrument manufacturer. A probe-holding fixture must be provided to keep the probe on a constant axis while the probe is slowly rotated (approximately 2 revolutions per minute) about the axis normal to its detection plane (usually the handle axis). Because unnecessary changes in the probe orientation or position may alter the measurement of polarization ellipticity, the probe fixture should prevent any unnecessary horizontal, vertical, or transverse motion while the probe is being rotated (see Figure 1).

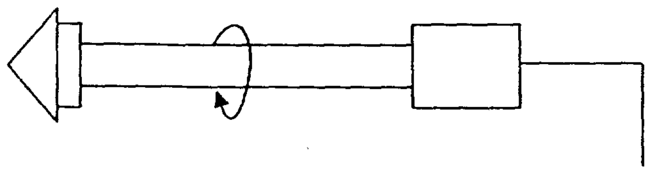


Figure 1. Probe rotation should prevent any horizontal, vertical, or transverse motion while the probe is being rotated

Because each survey instrument has its own ellipse of polarization response (also known as polarization ellipticity error), the percentage or polarization error of each instrument must be calculated to determine whether each instrument is operating within the limit of the manufacturer's specification.

A common way to find the percentage of polarization ellipticity error is as follows:

(1) place the probe in the fixture and turn on the microwave power source so the survey meter reads a mid-scale value (for example 1.0 mW/cm^2);

(2) rotate the probe 360 degrees and note the minimum and maximum readings and calculate the mean (see Equation 1); and

(3) calculate the percentage of polarization ellipticity error using Equation 2. The result must be equal to or less than the percentage error limit of polarization ellipticity specified by the instrument manufacturer (e.g., ±5 percent, or a total of 10 percent). Any instrument with a polarization ellipticity error greater than the allowed tolerance must be repaired or discarded.

Another way to find the percentage polarization ellipticity error is as follows:

(1) place the probe in the fixture and turn the power on so the survey meter reads a mid-scale value of 1.0 mW/cm^2;

(2) rotate the probe 360 degrees and find the minimum reading only;

(3) change the power setting until the survey meter reads 1.0 mW/cm^2 at the minimum polarization response;

(4) rotate the probe again to obtain the highest polarization response reading; and

(5) subtract 1.0 from the highest polarization response reading and multiply the result by 100. The result must be equal to or less than the total percentage polarization ellipticity error specified by the instrument manufacturer (see Equation 3 below).

$$Mean = \frac{Maximum + Minimum}{2} \quad (1)$$

$$\%\,Total\,Polarization\,Ellipticity\,Error = \frac{Maximum - Minimum}{Mean}\left(100\right) \quad (2)$$

Note: to get ± percent, divide Total by 2

$$\%\,Total\,Polarization\,Error = (Maximum - 1.0)100 \quad (3)$$

For example, a total error for this procedure of 10 percent is equivalent to the survey instrument manufacturer's specification of ±5 percent polarization ellipticity error. The daily check method applies to instruments employing planar detectors. Alternate methods for other types of detectors may need to be developed.

2.2.3 Documentation

A separate "daily check" record should be kept for every survey instrument for compliance testing on the production line and audit. The record should include: the model and serial number of the instrument (probe model/serial number if necessary), the percentage error in polarization ellipticity specified by the instrument manufacturer, the results of the test, and the name of the person who performed the test. If an instrument fails the test, the disposition of the instrument should be clearly indicated in the "remarks" column. Following the repair, the instrument's record must be renewed (e.g., started over). See Appendix 3 for an example of the documentation; any equivalent chart is acceptable. Appendix 4 of this guide contains a chart which describes briefly when and under what circumstances certain records must be renewed.

2.3 THIRTY-DAY CHECK: INITIAL ESTABLISHMENT OF THE REFERENCE FIELD

2.3.1 Requirement

A reference field must be established prior to checking the 30-day calibration constancy of every instrument (including spare scanner probes or hand-held survey meters) used for microwave oven compliance determinations.

2.3.2 Instrumentation and Method of Establishing the Reference Field Using the LCR

One instrument suitable for compliance determinations is set aside and not used for production or quality control testing. It is retained as the local calibration reference (LCR), having been calibrated by its manufacturer or other suitable source. This instrument is set aside to minimize the probability of damage and/or loss of calibration through accident or the wear and tear of normal use. It is recommended that the instrument selected as the LCR have a power density calibration which is near the geometric mean of the power density calibrations of all instruments used for compliance determination (e.g., if the spread of calibration factors is .98 to 1.08, then the LCR should have a factor near 1.03). It is also recommended that the LCR be of the same brand/make as the survey instruments being checked.

An LCR is not to be misconstrued as a transfer standard. If its calibration is ±1 dB, it cannot be used as a transfer standard for instruments whose accuracy is also ±1 dB. Using the calibration constancy intercomparison system, an initial reference field is established with the probe of the LCR positioned at the mean of its polarization ellipse. Set the field at a power density of approximately 1.0 mW/cm^2 as read on the LCR. The mean of the polarization ellipse of the LCR must be located by finding the mean of the maximum and minimum readings when the LCR probe is slowly rotated 360 degrees in the calibration constancy intercomparison system chamber. When the LCR probe is positioned in the system at the mean of its polarization ellipse, the power density can be adjusted (if necessary) to the appropriate reference field (usually 1.0 mW/cm^2). The values of the reference field should be specified by the instrument manufacturer or calibration facility. After setting the reference field, the percentage of polarization error of the LCR must be checked to verify that it meets the instrument manufacturer's specification. When the reference field has been set up using the LCR, it is important that the readings on the radiation power monitor (RPM), (e.g., Forward, Reflected, and Difference (Net)) or from another power meter are recorded and noted on the log record (Appendix 5).

2.3.3 Instrumentation and Method of Establishing the Reference Field Using the RPM (Optional)

An alternative method for establishing the reference field can be performed by using the radiated power monitor (RPM). After the LCR has been calibrated by its manufacturer or other suitable source, use the LCR to find the mid-scale value (e.g., obtain a 1.0 mW/cm^2 midpoint scale reading on the LCR, then record the RPM readings). For the subsequent monthly checks, the reference field can be set by using the RPM to repeat the same reading obtained the first month. When the reference field has been set up using the RPM, it is important that the readings from the LCR are recorded and noted on the log record (Appendix 5).

2.3.4 Documentation

A "12-month historical record" should be kept on the reference field instruments. Both the LCR readings (Minimum, Maximum, and Mean readings) and RPM net power readings (Forward, Reflected, and Difference) are to be recorded and noted as reference readings. Other items such as ambient temperature and the name of the person who performed the tests should also be recorded. If the LCR fails the polarization ellipticity check, the disposition of the LCR should be clearly indicated in the "remarks" column. Following the repair of the LCR, the 12-month historical record and all other records must be renewed (see Appendix 4). See Appendixes 5 and 6 for examples of the documentation; any equivalent charts are acceptable.

2.4 THIRTY-DAY CHECK: INITIAL POLARIZATION RESPONSE CHECK OF THE COMPLIANCE INSTRUMENTS

2.4.1 Requirement

After the reference field has been established at a specified power density (for example 1.0 mW/cm^2) as described in Part 2.3.2 or 2.3.3, the polarization response of each survey instrument to be used for compliance testing must be initially checked. The polarization ellipticity error of each survey compliance instrument must meet the instrument manufacturer's specification. This initial check must be performed prior to initial use on the production line, when it is taken out of spare stock, or after it has been returned from repair.

2.4.2 Instrumentation and Method

Follow the same procedures outlined in Part 2.2.2 above.

2.4.3 Documentation

For each instrument used in production or in audit, a separate "30-day instrument comparison log" record should be maintained. This log should include the following: model and serial number of each instrument (and probe model and serial number if necessary); date; the minimum, maximum, and mean of the polarization response readings; percentage of polarization ellipticity error; the highest and lowest mean readings since the last calibration/repair; and verification that each instrument met the polarization ellipticity error limit specified by the instrument manufacturer. If the instrument's polarization ellipticity error is outside the specification, the disposition of the instrument should be clearly indicated on the record. See Appendix 7 for an example of the documentation; any equivalent chart is acceptable.

2.5 THIRTY-DAY CHECK: CONSTANCY OF REFERENCE FIELD AND COMPLIANCE INSTRUMENTS

2.5.1 Requirement for the Reference Field

The reference field must be established for the initial setup of the system and survey instruments (see Part 2.3). For the subsequent monthly checks, the power density of the reference field in the calibration constancy intercomparison system should be re-established by adjusting the microwave power source to repeat either the previous LCR or RPM reference reading. After the reference field is reset using one of these two readings, the other reading (from the RPM or LCR) must agree with all of its preceeding readings within 10 percent. That is, no two of these nonreference readings, from one annual calibration or repair to the next, may disagree by more than 10 percent.

For example, if the reference field is set using the reading of the LCR, then the monthly RPM (Diff) nonreference readings (all readings accumulated since the last LCR calibration) must be verified to be within 10 percent of each other. If the reference field is set using readings of the RPM, then the monthly LCR nonreference mean readings (all mean readings accumulated since the last LCR calibration) of the polarization ellipse must be verified to be within 10 percent of each other. If the nonreference readings disagreed by more than 10 percent, then the nonreference instrument must be repaired (or discarded). See Appendix 6 for an example of the documentation. Following these actions, new 12-month historical records (Appendixes 5 and 6), and all other records, must be renewed (see Appendix 4).

2.5.5 Requirement for Each Compliance Instrument

After each compliance survey instrument receives its initial check of the polarization ellipse (see Part 2.4.1), the mean reading of each instrument must then be compared with all of its own previous monthly mean readings for constancy within 10 percent. For the comparison, use only those mean readings taken since the survey instrument was last calibrated (or repaired), or from when the LCR (or RPM) was last calibrated, whichever is most current.

For those survey instruments falling outside the 10 percent limit, possible sources of the failure must be traced. First, the survey instrument itself should be checked for obvious problems such as weak batteries. Second, the system should be examined. Problems with equipment must be adequately resolved before proceeding further. If the problem was traced to the survey instrument, then the survey instrument must be repaired (or discarded) and the 30-day instrument comparison log (Appendix 7) and daily check record (Appendix 3) for that compliance survey instruments must be renewed. If the problem was traced to the system, then the system must be repaired and all records must be renewed. See Appendix 4 for further explanation regarding renewal of records.

2.5.3 Requirement for Calibration Data Constancy

The least sensitive and most sensitive survey instruments (including the LCR) must not disagree by more than 2 dB, including the extremes of polarization ellipse. A monthly 2 dB check must be performed by comparing the ratio of the highest polarization ellipse reading from all of the instruments (including the LCR) to the lowest polarization ellipse reading from all of the instruments (including the LCR). This ratio must not exceed 1.59 (2 dB). Do not include those instruments that did not pass the daily check or the 10 percent comparison in the 30-day check. The 2-dB check of instruments each month is done on a cumulative basis; that is, the comparison period is the time between LCR calibrations (or repairs).

If, during the comparison check, the ratio exceeded 1.59 (or 2 dB), then the entire system, including the LCR and individual compliance survey instruments, must be examined and repaired as necessary. Repeat the 10 percent comparison check of the individual survey instruments (see Part 2.5.2). Problems with all of the equipment must be adequately resolved before proceeding further. Then repeat the 2 dB comparison check to determine that the ratio is less than or equal to 1.59 and ensure that any remaining defective instruments are found. Following these actions, then a new 2 dB comparison check record (Appendix 8) and most or all other records must be renewed (see Appendix 4). Appendix 9 illustrates the proper 30-day constancy check sequence in the form of a flowchart.

2.5.4 Documentation

Two separate records must be maintained. The first record, "30-Day Instrument Comparison Log" (Appendix 7), should be kept for every instrument used on the production line and in audit. The 30-day instrument comparison log should verify that the highest and lowest mean readings of the individual instrument are within 10 percent of each other. If not, the disposition of the instrument should be clearly indicated on the records. Following these actions, two new records, one for recording results of the daily check (Appendix 3) and a second, the 30-day instrument comparison log (Appendix 7), must be started (see Appendix 4).

The second separate record, "2 dB Comparison Check" (Appendix 8), should be kept to monitor the calibration data constancy of all the instruments used on the production line and in audit since the last LCR calibration. Exclude those instruments that did not pass the daily check, and/or the 10 percent comparison in the 30-day check. This record should include the highest and lowest polarization response readings taken from all of the instruments (including the LCR). These values should be compared and the ratio of the highest polarization ellipse reading to the lowest polarization ellipse reading during the entire period should be less than 1.59 (2 dB).

If the ratio exceeds 1.59, make a complete check of the entire system and record the reason for failure. If the failure is traced to a defective individual survey instrument, the survey instrument must be taken out of production or audit facility for repair. Then continue to use the same 2 dB comparison check log. When the repaired survey instrument comes back, renew the 30-day instrument comparison log (Appendix 7) and daily check record (Appendix 3) for the survey instrument. If the problem is traced to the system, then a new 2 dB comparison check record and all other records must be started following correction of the problems (see Appendix 4). See Appendix 8 for an example of the documentation; any equivalent chart is acceptable.

2.6 ANNUAL CALIBRATION

2.6.1 Requirement

Absolute calibration of the LCR must be performed annually. There may be a need for annual absolute calibration of compliance survey instruments, scanner probe/pre-amp, radiated power monitor (RPM), power meter, etc., depending upon the recommendations of the instrument manufacturer.

It is important that the microwave oven manufacturer check with the instrumentation manufacturer for specifications or recommendations concerning annual calibration. Whenever the LCR has returned after being calibrated and/or repaired, it is important to immediately determine its percentage of polarization ellipticity error and record the results (see Part 2.3).

2.6.2 Instrumentation and Method

The LCR must be returned to the instrument manufacturer or other qualified calibration facility for absolute calibration (12-month intervals). Some compliance survey instruments or other electronic components of the system also may require absolute calibration annually.

2.6.3 Documentation

A separate record of the LCR calibration and repair should be kept. This log should include model and serial number, calibration date, and a list of any repairs and their dates. The 12-month historical record (Appendix 5) of the LCR is renewed every time the LCR has been returned from annual calibration. The 30-day instrument comparison log of each compliance survey instrument (as well as scanner probe/pre-amp units) is renewed when the LCR has been returned from annual calibration.

2.7 PERIODIC RECALIBRATIONS

2.7.1 Requirement

The absolute calibration of all instruments should be performed periodically.

2.7.2 Instrumentation and Method

In accordance with good engineering and manufacturing practice, it is recommended that all instruments used to make compliance determination measurements (with the exception of LCR and RPM) be returned to the instrument manufacturer factory or other qualified calibration facility for absolute calibration at least once every 3 years.

2.7.3 Documentation

See Parts 2.2.3 and 2.3.4

2.8 REPAIR

2.8.1 Requirement

Any instrument which has been found to be damaged or failed to remain within its established constancy limits must not be used in the quality control and testing program until it has been repaired and recalibrated by an instrument manufacturer or other qualified calibration and repair facility. Before repaired instruments are used again, their operational functions and their polarization responses must be checked (see Part 2.2). Following these actions, the instrument's records must be renewed (see Appendix 4). It is recommended that repairs be performed only by the instrument manufacturer or other qualified calibration facility unless the microwave oven manufacturer has in place an adequate repair facility to perform certain minor repairs (such as broken probe cables, defective meters, etc.) and has the capability of checking their results. Microwave oven manufacturers will be required to submit specific technical repair procedures to CDRH for review before implementing them.

2.8.2 Instrumentation and Method

Whenever the compliance survey meters, LCR, or scanner probe/pre-amp units are returned from the instrument manufacturer after repair, their polarization ellipse must be checked against the instrument manufacturers' specifications and verified on the record prior to their use.

2.8.3 Documentation

The disposition of the defective instrument can be recorded in the "remarks" column.

APPENDIX 1

CALIBRATION CONSTANCY INTERCOMPARISON SYSTEM

A block diagram of the calibration constancy intercomparison system is provided in Appendix 2. The parenthetical numbers preceding each paragraph below and used within those paragraphs refer to the numbers in the Appendix 2 diagram.

(1) SOURCE

The source is a microwave generator with (a) an appropriate power output (probably approximately 0.5 to 50 Watts maximum output) that may be variable (either internally or by some external attenuator) and (b) a frequency in the relevant ISM band (915 ± 25 MHz or 2450 ± 50 MHz). Depending on the radiator or anechoic enclosure and on the inherent frequency stability of the source, some control over the source output frequency may be necessary. The source might be a magnetron or klystron oscillator, or might be a low-powered source amplified, e.g., by a traveling wave tube amplifier. However, any type of source with adequately stable or controllable output parameters could be used.

(2), (3), (4) DIRECTIONAL COUPLERS

The directional couplers are used to sample a fixed fraction of the power flowing through them in either the forward or reverse direction. This fraction should be chosen so as to deliver a signal to items (5), (6), or (7) which is of a magnitude appropriate to the specific device. Furthermore, this fraction (or "coupling factor") must be adequately invariant with frequency over the range of frequency variations of the source. Two of these couplers might be replaced by a single bi-directional coupler if desired. Furthermore, if the source has some built-in frequency monitor, (4) might be eliminated. Couplers (2) and (3) should be adequately insensitive to power flowing in a direction opposite to that intended to be measured (i.e., these couplers should have adequate "directivity"). It is not absolutely necessary that directional couplers be used, however some means of differentiating between forward and reflected power (to allow determination of net radiated power) must be included.

(5), (6) POWER METERS

These power meters must provide repeatable, adequately sensitive, and reliable responses to both absolute levels and relative variation of power. They should be relatively insensitive to frequency variation. It may be necessary to insert attenuators between the directional couplers and the power meters to bring the input to the power meters into an appropriate range. It is not absolutely necessary that power meters be used for these applications. Whatever type of detector is used, some reliable means of calibration must be employed in an annual calibration. In the system illustrated, if the source can be demonstrated to be adequately stable, a single power meter might be alternatively switched to the output of the couplers (2) and (3) by means of a coaxial switch. The power meter or meters and directional couplers form the radiated power monitor (RPM).

(7) FREQUENCY MEASURING DEVICE

Some means must be employed to verify that the frequency of the radiated signal remains within appropriate limits. These limits are closely related to the quality of the anechoic environment (9). If standing waves of considerable magnitude exist within this environment, a change in the frequency of the radiated signal can cause a variation in the spatial distribution of the field and have a significant effect on the reading of a stationary probe in the fixture (10). Thus, the choice of both source (1) and anechoic environment (9) must be made with this phenomenon in mind. Although frequency counters are often available in microwave laboratories, any of several other possibilities might be employed (e.g., a tunable cavity might be used with a crystal or power meter monitoring the output).

Clearly, the use of an anechoic environment of appropriate characteristics with an adequately stable source can eliminate the necessity to employ the frequency measuring device shown in the illustration.

(8) RADIATOR

Some means of radiating the generated power into space must be provided. Among a multitude of possible devices that might be employed for this purpose are horn, log periodic and dipole antennas, as well as flared or simply open-ended waveguide sections. Considerations in the choice include directivity of the radiator vs. the reflectivity and absorption of the anechoic environment, as well as the frequency response of the radiator vs. the source frequency stability. If a stable source is to be employed, a waveguide or coaxial tuner may be employed to improve the system match to the radiator to minimize reflected power.

(9) ANECHOIC ENCLOSURE

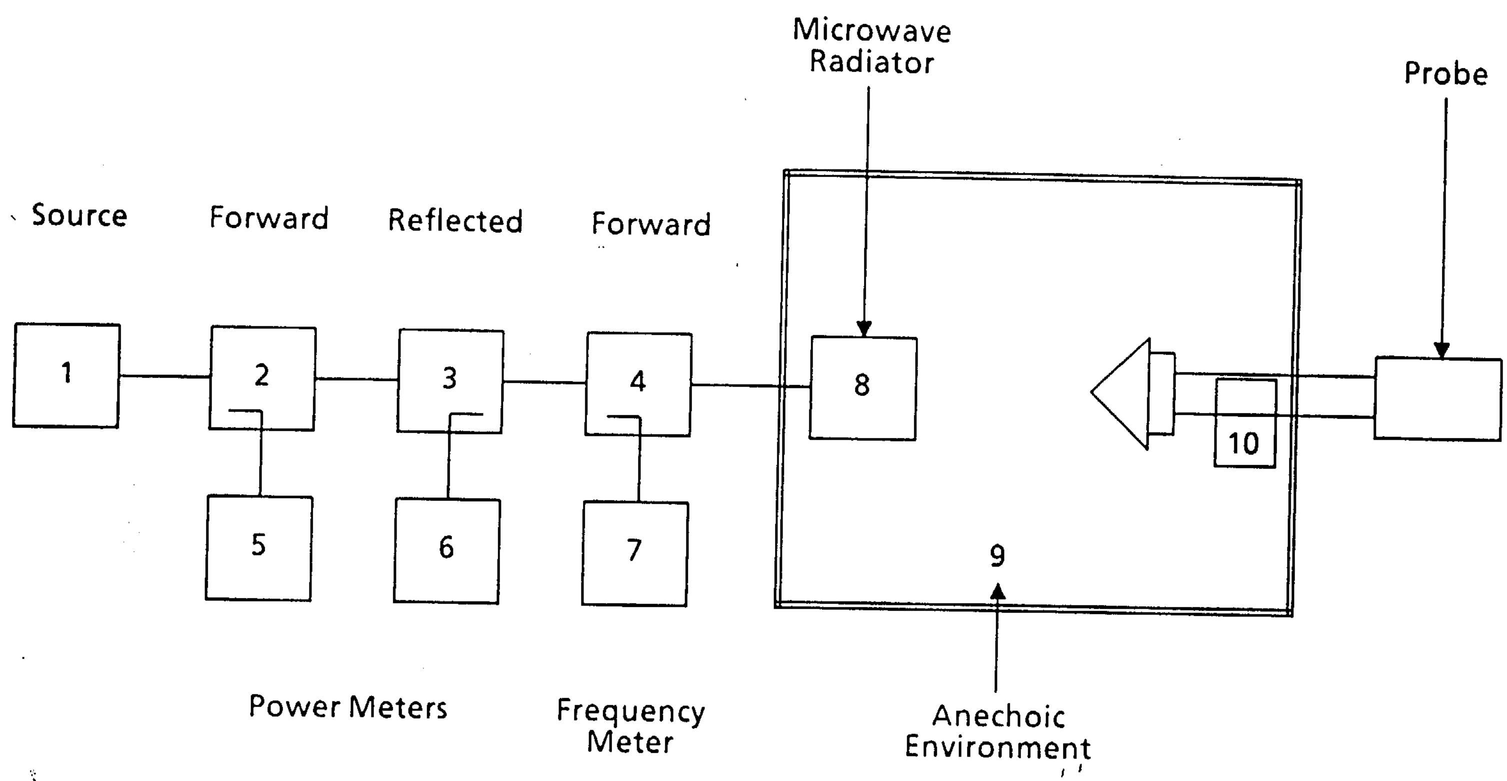
An anechoic environment should be provided to minimize the effects of the laboratory environment on the measurement. The quality and size of this anechoic environment will determine the magnitude of the standing wave in the region of the instrument under comparison.

(10) PROBE-HOLDING FIXTURE

A stable fixture to hold the instrument being evaluated in a rigid, repeatable position must be employed. This fixture should be made of an electrically non-conductive material to minimize standing waves and perturbations of the fields. In general, the greater the magnitude of the standing wave and the closer the probe to the radiator, the more critical are the repositioning requirements of this fixture.

APPENDIX 2

BLOCK DIAGRAM OF THE SYSTEM



APPENDIX 3

DAILY CHECK RECORD

Instrument make: ______________________

Instrument model number: ________________

Instrument serial number: _______________

Probe model number: ___________________

Probe serial number: ___________________

Intercomparison system: ________________

Instrument polarization ellipticity limit: ________

Date	Polarization Ellipticity Readings			% Ellipticity Error	Accept/Reject	Remarks
	Minimum	Maximum	Mean			

Criteria:

$$Mean = \frac{Maximum + Minimum}{2}$$

$$\%\,Total\,Polarization\,Error = \frac{Maximum - Minimum}{Mean}\left(100\right)$$

APPENDIX 4

RENEWAL OF RECORDS

Status	Documentation Forms: Appendix 3 Daily Check Record	Appendix 5 12-Month Historical Record	Appendix 6 Nonreference Constancy	Appendix 7 30-Day Instrument Comparison Log	Appendix 8 2 dB Comparison Check
Daily Check (2.2)					
Failed survey instruments	Renew	Same	Same	Same	Same
LCR/RPM Monthly (2.3.2 - 2.3.3)					
Polarization failure of LCR	Renew	Renew	Renew	Renew	Renew
Failed RPM	Renew	Renew	Renew	Renew	Renew
30-Day Check of Individual Survey Meters (2.4.1, 2.5.2)					
Polarization failure	Renew	Same	Same	Renew	Same
10% comparison failure	Renew	Same	Same	Renew	Same
30-Day Check of Nonreference Meter (2.5.1)					
10% comparison failure	Renew	Renew	Renew	Renew	Renew
2 dB Comparison (2.5.3)					
System or LCR failure	Renew	Renew	Renew	Renew	Renew
Survey meter failure	Renew	Same	Same	Renew	Same
LCR Calibration (2.6)					
Annual calibration	Renew	Renew	Renew	Renew	Renew

Numbers in parentheses refer to sections of this report.

APPENDIX 5

12-MONTH HISTORICAL RECORD

Name of constancy system: ____________________
Date of last LCR/RPM calibration: ____________

Make of LCR/RPM: ____________________
Model number of LCR/RPM: ____________________
Serial number of LCR: ____________________
Probe model number on LCR: ________________
Probe serial number on LCR: ________________

Date	RPM Fwd	RPM Rev	RPM Diff	LCR Polarization Ellipticity Readings: LCR Max	LCR Min	LCR Mean	LCR % Ellip	Ambient Temp	Remarks

NOTES: (1) The LCR must be positioned at its mean polarization response prior to setting the reference field.
(2) If the reference field is set using the LCR readings, then the monthly RPM (Diff) readings must be within 10%.
(3) If the reference field is set using the RPM readings, then the monthly LCR (Mean) readings must be within 10%
(4) If the readings taken from the nonreference instrument disagreed by more than 10%, then this instrument must be repaired (or discarded). Following these actions, a new Daily Check Record (Appendix 3) and all other records, must be renewed (2.5.1).

$$Mean = \frac{Maximum + Minimum}{2} \qquad \%\,Total\ Polarization\ Ellipticity\ Error = \frac{Maximum - Minimum}{Mean}\left(100\right)$$

% Total ellipticity error limit specified by LCR instrument manufacturer is: ____________.

APPENDIX 6

NONREFERENCE FIELD CONSTANCY

The monthly reference field is set by (check one only): ________ LCR ________ RPM

If you selected the **LCR** to set the monthly reference field, use **column 1** only.

If you selected the **RPM** to set the monthly reference field, use **column 2** only.

	Column 1		Column 2			
Monthly Date	(A) Highest RPM Diff (or P)	(B) Lowest RPM Diff (or P)	(A) Highest LCR Mean	(B) Lowest LCR Mean	A/B	Less than 1.10? (Yes/No)*

* NOTES: If the reference field is set using the reading of the LCR, then the monthly RPM (Diff) nonreference readings (all readings accumulated since the last LCR calibration) must be verified to be within 10 percent of each other. If the reference field is set using readings of the RPM, then the monthly LCR mean nonreference readings (all mean readings accumulated since last LCR calibration) of the polarization ellipse must be verified to be within 10 percent of each other. If the nonreference readings failed the 10 percent comparison test, then the nonreference instrument must be repaired and recalibrated. Following this action, all records must be renewed.

APPENDIX 7

30-DAY INSTRUMENT COMPARISON LOG

Instrument make: ______________________

Instrument model number: ______________________

Instrument serial number: ______________________

Probe model number: ______________________

Probe serial number: ______________________

Date of last LCR calibration: ______________________

Instrument polarization ellipticity limit: __________

	Polarization Ellipticity Readings			% Ellipticity	(A) Highest	(B) Lowest		Less than 1.10?	
Date	Minimum	Maximum	Mean	Error	Mean*	Mean*	A/B	(Yes/No)	Disposition

* since the last calibration.

NOTES: (1) Verify that the mean readings are within 10% range (highest to lowest) during the interval between annual LCR calibration.
(2) Each instrument must meet the % total polarization ellipticity error limit specified by the instrument manufacturer.
(3) If the survey meter is defective, it must be repaired and recalibrated (or discarded). Then this record must be renewed.

APPENDIX 8

2 dB COMPARISON CHECK RECORD

Months Since Last LCR Calibration	Date of 30-Day Check	Highest Instrument Reading from 30-Day Check (Incl. LCR)*	Lowest Instrument Reading from 30-Day Check (Incl. LCR)*	(A) Highest Instrument Reading Since Last LCR Calibration or Repair†	(B) Lowest Instrument Reading Since Last LCR Calibration or Repair†	A/B	Less than 2 dB? (<1.59?) (If No, See Criteria)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

* including extremes of polarization ellipse.

† and/or last RPM calibration or repair

Criteria: A/B must be less than 1.59. If not, then the entire system, LCR, and survey instruments must be checked and repaired (see Part 2.5.3 for further explanation. Following these actions, all records must be renewed.

APPENDIX 9

FLOWCHART FOR 30-DAY CALIBRATION CONSTANCY PROGRAM