Minimum Operational Performance Standards for Automatic Direction Finding (ADF) Equipment

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Prepared by SC-146

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RADIO TECHNICAL COMMISSION FOR AERONAUTICS

DEDICATED TO THE ADVANCEMENT OF AERONAUTICS

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MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AUTOMATIC DIRECTION FINDING (ADF) EQUIPMENT

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May 13, 1982

Prepared by:
SC-146

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FOREWORD

This document was prepared by Special Committee 146 of the Radio Technical Commission for Aeronautics (RTCA). It was approved by RTCA on May 13, 1982, and supersedes RTCA/DO-137, "Minimum Operational Characteristics Airborne Automatic Direction Finding (ADF) Systems," April 11, 1968 and RTCA/DO-142, "Minimum Performance Standards - Airborne Radio Receiving and Direction Finding Equipment Operating Within the Radio-Frequency Range of 200-850 Kilohertz," January 8, 1970.

RTCA is an association of aeronautical organizations of the United States from both government and industry. Dedicated to the advancement of aeronautics, RTCA seeks sound technical solutions to problems involving the application of electronics and telecommunications to aeronautical operations. Its objective is the resolution of such problems by mutual agreement of concerned organizations.

The findings of RTCA are in the nature of recommendations to all organizations concerned. As RTCA is not an official agency of the Government of the United States, its recommendations may not be regarded as statements of official government policy unless so enunciated by the federal government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

Although these standards were coordinated with the European Organisation for Civil Aviation Electronics (EUROCAE) WG-7D, it should be noted that the NDB environment in Europe is significantly different from that in the United States and the work of EUROCAE addresses factors outside the scope of this document. Therefore, the standards specified in this document pertain only to the NDB environment of the United States.

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1.0 PURPOSE AND SCOPE

1.1 Introduction

This document sets forth minimum operational performance standards for automatic direction finding (ADF) equipment within the United States NDB environment. Incorporated in these standards are system characteristics that will benefit users of the system as well as designers, manufacturers and installers. These characteristics are intended to be in accord with requirements of various users. These characteristics are also intended to be in accord with the ground system characteristics and the intended operational use.

Section 1.0 of this document is intended to be tutorial in nature and provides information needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals, as envisioned by the members of Special Committee 146, and is the basis for the standards stated in Sections 2.0 through 4.0. Definitions and assumptions essential to proper understanding of this document are also provided in Section 1.0.

Section 2.0 contains the minimum performance standards for the equipment. These standards define the required performance under standard operating conditions and stressed physical environmental conditions. It also details the recommended bench test procedures necessary to demonstrate compliance.

Section 3.0 describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4.0 describes the operational characteristics for equipment installations and defines conditions that will assure the operator that operations can be conducted safely and reliably in the expected operational environment.

Compliance with these standards by manufacturers, installers and users is recommended as a means of assuring that the equipment will satisfactorily perform its intended function(s) under all conditions normally encountered in routine aeronautical operations.

If the equipment implementation includes a computer software package, the guidelines contained in RTCA/DO-178, "Software Considerations in Airborne Systems and Equipment Certification," November 18, 1981, should be considered.

It is recognized that any regulatory application of this document in whole, or in part, is the sole reponsibility of appropriate governmental agencies.

Since the measured values of equipment performance characteristics may be a function of the method of measurement, standard test conditions and methods of test are recommended in this document.

This document considers a configuration of airborne receiving equipment including: Antenna system(s), transmission lines, radio receiver, receiver control unit and a bearing indication display. Additional functions and components that refer to expanded capabilities are identified as optional features. Features that are beyond the scope of this document may be developed in future RTCA activities.

The word "system" as used in this document refers to the NDB/ADF system. It includes all portions of both the NDB ground transmitter and the ADF equipment.

The word "equipment" as used in this document includes all components necessary for the equipment to properly perform its intended function. For example, ADF receiving "equipment" may include an antenna, a receiver unit, a control unit, a bearing indicator, a shock mount, etc. In the case of this example, all of the foregoing components or units comprise the "equipment." It should not be inferred from this example, however, that every receiving equipment will necessarily include all of the foregoing components. This will depend on the design used by the equipment manufacturer.

1.2 System Overview

1.2.1 Basic System Description

The NDB/ADF system consists of airborne direction finders (ADF) and ground stations called nondirectional beacons (NDB).

The ADF senses and automatically indicates the direction of arrival of the NDB signal. Direction is indicated to the pilot as a magnetic bearing or as a relative bearing to the longitudinal axis of the aircraft, depending on the type of indicator installed in the aircraft. The equipment may be used to monitor MCW or CW transmissions. A typical example of this operation is the reception of the NDB station identifier.

The NDB is a ground station transmitting omni-directional signals. When the NDB is operational, it transmits a station identifier using either MCW or CW modulation. When the NDB is installed as a part of the instrument landing system (ILS), it is normally called a compass locator.

1.2.2 Background

During the early 1960s there was some thought that NDBs might become obsolete with the wide implementation of VOR/DME/TACAN. However, the continuing need for NDB services, which were not provided by VOR/DME/TACAN, prevented this occurrence. In addition, several other recent developments have caused a dramatic increase in the number of NDB requirements. These include:

a. The development of low-cost, digitally tuned ADFs.

b. The use of NDBs on offshore oil rigs and in other remote locations.

c. The increase in corporate jet operations over the North Atlantic and into Europe.

During the 1975-1980 time frame, nongovernment NDB assignments increased by approximately 50 percent. Federal Aviation Administration NDB assignments increased by approximately 10 percent during the same period. This growth is expected to continue. Eventually the NDB/ADF system will be replaced, but at present there are no known alternative systems that are as cost effective for the user and the government. No end of service can be foreseen between now and the year 2000 because of the wide and increasing acceptance by the users and the lack of a lower-cost alternative.

1.2.3 Future Direction

NDB frequency congestion has been a long-standing problem. In order to satisfy operational requirements, a number of alternatives have been pursued. These include reducing power and coverage, and spectrum reallocation. These alternatives are reaching the point of diminishing returns. In order to continue satisfying operational requirements, other alternatives must be sought. ADF receiver selectivity is the assignment constraint most susceptible to improvement. The minimum selectivity of this MOPS is narrower than the minimum selectivity of the MOC (RTCA/DO-137) and the MPS (RTCA/DO-142) which it replaces. Narrowing the selectivity to the extent reflected in paragraphs 2.2.11 and 2.2.12 will enable a significantly greater number of NDB assignments to be made in the United States.

RTCA has concluded that the Category A receiver selectivity contained in RTCA/DO-142 is as narrow as it could be while still providing adequate voice reception. The selectivity of this MOPS is substantially narrower than DO-142, Category A. Consequently, the adoption of this MOPS can be expected to be an additional factor contributing toward the curtailment and eventual elimination of voice on NDBs in the 190-535 kHz band. It is recognized, however, that there will still be a vital need for the dissemination of a variety of weather information. The FAA is currently planning or studying a number of systems which could serve as replacements for voice on NDBs. It is essential that this effort be carried to its conclusion and that replacement systems be implemented before the end of this decade.

The bandwidth contained in this MOPS is dependent on the need to receive the 1020 Hz identification signal. Selectivity could be further narrowed if a lower modulation frequency were chosen and implemented internationally. At this time, however, this appears unlikely. (ICAO Annex 10 does allow a 400 Hz identification, and a number of ICAO member states have implemented this lower modulation. However, some member states have found 400 Hz identification unacceptable because in areas of high ambient noise, 400 Hz is more difficult to discern than 1020 Hz.) Consequently, further narrowing of ADF selectivity should not be expected.

1.2.4 Transition Strategy

The narrower selectivity of this MOPS will allow the FAA to tighten their NDB assignment criteria, thereby permitting a greater number of NDB assignments to be made. However, the assignment criteria cannot be tightened until the vast majority of avionics meet the tighter selectivity requirements. This change should take place as follows:

Stage 1:

Adoption of an Assignment Criteria Narrower than DO-142 Category B but not as Narrow as DO-142 Category A

In the United States, approximately 62% of ADFs already meet the selectivity of DO-142 Category A. The remaining 38% are composed of nine receiver types. Of these nine types, three are 15 to 22 years old and of low volume (1% of the total U.S. population). During the 1980s, the NDB frequency assignment criteria should be based on the remaining six receiver types. (Only one of these is still in production.)

Stage 2:

Adoption of an Assignment Criteria Equivalent to DO-142 Category A

Nine types of receivers (38% of the existing population) do not meet this selectivity requirement. As these receivers are replaced, the replacement avionics will meet either DO-142 Category A or the narrower selectivity of this MOPS. When the vast majority of ADFs meet at least DO-142 Category A, the FAA should tighten the NDB assignment criteria accordingly. This might be expected to happen in the early 1990s.

Stage 3:

Adoption of an Assignment Criteria Equivalent to This MOPS

The selectivity of this MOPS is narrower than most existing ADF receivers. However, it will be many years, perhaps near the turn of the century, before the vast majority of avionics meets the narrower MOPS selectivity. The FAA should not take this third step in revising the NDB assignment criteria until this occurs.

NOTE: During each of the three stages described above, the FAA should provide the following desired to undesired signal in space ratios:

Frequency Difference	Stage 1	Stage 2	Stage 3
1.0 kHz	+11 dB	+10 dB	+10 dB
1.5 kHz	+9.5 dB	+8 dB	+4 dB
2.0 kHz	+7 dB	+4 dB	-2 dB
2.5 kHz	+1.5 dB	-3 dB	-9 dB
3.0 kHz	-5 dB	-10 dB	-17 dB
4.0 kHz	-19 dB	-25 dB	-32 dB
5.0 kHz	-32 dB	-40 dB	-47 dB
6.0 kHz	-38 dB	-55 dB	-62 dB
7.0 kHz	-39 dB	-70 dB	-70 dB

NOTE: In the environment where some receivers tune only in 1 kHz increments, this tuning limitation must be considered in the assignment of NDBs on 1/2 kHz frequencies (e.g. 200.5 kHz). This is necessary so that adequate frequency protection can be provided for those receivers which do not tune closer than 1/2 kHz removed from an NDB assignment on a 1/2 kHz frequency.

1.3 Operational Applications

The NDB/ADF system can satisfy user needs during the en route, transition, approach, departure or missed approach phases of flight. The system is in widespread use at low density or small community airports because of the relative low cost of the NDB ground transmitter. At medium or high density airports, the system is often used in conjunction with the ILS system (compass locator). In this latter application, the system may provide navigational guidance during the transition phase of flight or a secondary instrument approach system if the localizer portion of the ILS fails.

In Europe and in the contiguous 48 states, NDBs are primarily used as approach aids. In Alaska and in some other parts of the world, NDBs are extensively used as en route facilities as well as transition and approach facilities.

Although voice capability in the 535-1605 kHz band is optional, it is recognized that the marketplace has indicated a strong desire for this capability. Consequently, ADF receivers will continue to provide it.

1.4 Operational Goals

The general operational goals of the ADF equipment are described in the following subparagraphs. Only general operational goals are identified. The detailed operational requirements for the equipment are provided in Sections 2.0, 3.0 and 4.0 of this document.

1.4.1 Sensitivity

The equipment should be of sufficient sensitivity to provide the pilot with adequate radio reception throughout the entire NDB coverage volume.

1.4.2 Receiver Selectivity

The equipment should have sufficient selectivity in all modes of operation to provide the pilot with safe and accurate service within the NDB coverage volume. It should provide intelligible and positive audio identification of the ground station to which the ADF is tuned in the presence of undesired signals at the relative signal levels and frequency separations specified in Section 2.0. The directional information should meet the accuracy requirements contained in Section 2.0 of this document in the presence of undesired signals at the relative signal levels and frequency separations specified in Section 2.0.

It is not always feasible to provide sufficient selectivity in the ADF equipment to achieve complete protection from all sources of interfering signals, and combinations of interfering signals, under all conditions. The relative signal levels that are specified in Section 2.0 realistically represent conditions that will be encountered. However, they may be exceeded in small volumes of airspace. When the conditions specified in Section 2.0 are exceeded, the aural identification will be garbled and there is a high probability that the source of the interference will not be 90 degrees from the desired station. Thus, the probability is high that the bearing information provided may be within the accuracy specified. In any event, the garbled identification signal provides a warning that the bearing information should not be used.

1.4.3 Spurious Response, Cross Modulation and Intermodulation

Equipment spurious responses, cross modulation effects or intermodulation effects should not inhibit the pilot from receiving the NDB within the NDB coverage volume (see paragraphs 2.2.13, 2.2.14 and 2.2.15).

1.4.4 Bearing Accuracy

The basic purpose of an NDB is to allow a pilot to fly from one point to another and to stay within a given volume of airspace in the process. In designing procedures which use an NDB, the designer ensures obstacle clearance in the protected airspace. Total system accuracy then should permit a pilot to stay within this airspace. A portion of the total bearing accuracy error budget is allocated to the avionics. The avionics should be capable of meeting this bearing accuracy even if antenna impedances are changed, as might occur during in-flight icing conditions, or if the receiver is slightly detuned, as might occur during in-flight temperature changes.

The equipment should provide a means for quadrantal error correction.

1.5 Assumptions

The following assumptions were used in preparing this MOPS.

1.5.1 Field Strength

A 50 microvolts per meter signal is the minimum field strength at the coverage limits in the U.S. (70 microvolts per meter minus 3 dB allowable degradation in beacon transmitter power).

A receiver sensitivity which provides a 3 dB signal-plus-noise to noise ratio is acceptable at 50 microvolts per meter. Measurement methods are more accurate with a 6 dB signal-plus-noise to noise ratio. Therefore, system performance is established with a 70 microvolts per meter field strength corresponding to a 6 dB signal-plus-noise to noise ratio. For a definition of rated coverage of NDBs under various noise conditions in other areas of the world, see paragraph 6.3.3, Attachment C to Part 1 of the International Civil Aviation Organization (ICAO) publication, "Aeronautical Telecommunications Annex 10, Third Edition of Volume I, July, 1972."

1.5.2 Selectivity

The selectivities in paragraphs 2.2.11 and 2.2.12 assume that a 10 dB minimum desired/undesired signal ratio at the input to the detector will provide no more than 3 degrees bearing error. (Reference: The Technique of Radio Design by E. E. Zepler)

1.5.3 Warnings and Flags

Unlike some other navigational aids, the NDB/ADF system does not require a warning or a flag if the received signal is deficient in level or quality. The pilot must determine whether the received signal is reliable by listening to the identification and observing the needle movements. The reception of two identification signals or the lack of any identification means that the ADF bearing may be unreliable. Similarly, unusual needle variations are also an indication of unreliable bearing. If the NDB/ADF system does not provide a warning or flag, the pilot should monitor identification and needle variation while making use of the ADF bearing.

1.6 Test Procedures

The test procedures and associated limits specified throughout this document are intended to be used as one means of demonstrating compliance with the minimum acceptable performance parameters. Although specific test procedures are cited, it is recognized that other methods may be preferred by the test activity. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

The order of tests suggests that the equipment be subjected to a succession of different tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Section 2.0 should have been demonstrated as a precondition to satisfactory completion of the installed system tests of Section 3.0.

Four types of test procedures are included which should be used at different stages in the equipment life cycle. These are discussed in the following paragraphs.

1.6.1 Environmental Tests

Environmental tests are specified in Subsection 2.3. The procedures and their associated limits are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations. Test results may be used by equipment manufacturers as design guidance, in preparation of installation instructions and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.6.2 Bench Tests

Bench test procedures are specified in Subsection 2.4. These tests are intended to provide a laboratory means of demonstrating compliance with the requirements of Subsections 2.1 and 2.2. Test results may be used by equipment manufacturers as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.6.3 Installed System Tests

The installed system test procedures and their associated limits are specified in Section 3.0. Although bench and environmental test procedures are not included in the installed system tests, their successful completion is a precondition to completion of the installed tests. In certain instances, however, installed system tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or to other equipment installed on the aircraft, etc. Installed tests are normally performed under two conditions:

a. With the aircraft on the ground and using simulated or operational system inputs.

b. With the aircraft in flight using operational system signals appropriate to the equipment under test.

Test results may be used to demonstrate functional performance in the environment in which the equipment is intended to operate.

In addition, the ground test procedures may be used as an optional check of equipment performance following corrective maintenance.

1.6.4 Operational Tests

The operational tests are specified in Section 4.0. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function.

1.7 Definitions of Terms

Automatic Direction Finder Function - An operational mode in which navigation information is presented on a bearing display that is automatically controlled to indicate the direction of arrival of radio waves. In addition, the identification of the NDB ground station is audible to the pilot.

CW Receiver Function - An operational mode in which the output is an audio signal derived from the on and off keying of the ground station. Simultaneous bearing information to indicate the direction of arrival of the radio waves may be presented on a bearing display.

MCW Receiver Function - An operational mode in which received amplitude modulated or equivalent signals provide an audio output signal.

Quadrantal Error - Angular error of a measured bearing caused by disturbances due to the characteristics of the airframe.

Rated Audio Output Power - The manufacturer's maximum specified audio output power that is obtained with a standard input signal with a field strength of 1000 microvolts per meter.

Signal-Plus-Noise to Noise Ratio (CW) - This ratio shall be determined with the receiver beat frequency oscillator "ON," and with the carrier "ON" and "OFF," for "SIGNAL + NOISE" and "NOISE," respectively.

Signal-Plus-Noise to Noise Ratio (MCW) - This ratio shall be determined with the carrier "ON" and the modulation "ON" and "OFF", for "SIGNAL + NOISE" and "NOISE," respectively.

Standard Input Signal - Unless otherwise specified, the RF signal shall be modulated 30% at 400 Hz.

2.0 AUTOMATIC DIRECTION FINDING EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

The design and manufacture of the airborne equipment must provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2 Intended Function

All equipment must perform its intended function(s), as defined by the manufacturer, and its proper use must not create a hazard to other users of the National Airspace System.

2.1.3 Federal Communications Commission Rules

All equipment must comply with the applicable rules of the Federal Communications Commission.

2.1.4 Fire Protection

Except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire, all materials used shall be self-extinguishing.

NOTE: One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.

2.1.5 Operation of Controls

The design of the equipment shall be such that the controls intended for use during flight cannot be operated in any position, combination or sequence which would result in a condition detrimental to the reliability of the equipment or operation of the aircraft.

2.1.6 Accessibility of Controls

Controls which are not normally adjusted in flight shall not be readily available to flight personnel.

2.1.7 Effects of Test

The design of the equipment shall be such that the application of bench and environmental tests will not result in any discernible condition detrimental to the reliability of equipment manufactured in accordance with that design.

2.2 Equipment Performance - Standard Conditions

Two categories of equipment are specified for some of the standards contained in this document. These categories are identified as Category A and Category B. Definitions of the categories are stated below. If a particular standard is not categorized, it applies as written to both categories of equipment.

Category A - Equipment intended for operation in the European-Mediterranean Area (EUM), and in other areas where NDB/ADF operations are similar. The equipment shall be capable of selecting any assignable frequency within the range of 190-850 kHz and 1615-1799 kHz.

Category B - Equipment intended for operation in the United States of America and its possessions, and in other areas where NDB/ADF operations are similar. The equipment shall be capable of selecting any assignable frequency within the range of 190-535 kHz and 1615-1799 kHz.

NOTE: The following standards are based on the equipment being used with an antenna(s) having electrical characteristics equivalent to that for which the equipment was designed.

2.2.1 Tuning Resolution

The frequency indicator shall indicate in steps no larger than 1000 Hz the frequency to which the equipment is tuned.

2.2.2 Ground Station Interoperability

The receiver shall operate with a ground station transmitter whose carrier differs from the assigned frequency by as much as 0.01%.

2.2.3 Sensitivity (MCW) - (MCW Receiver Function)

The level of a standard input signal required to produce reference output with a signal-plus-noise to noise ratio of 6 dB shall not exceed 70 microvolts per meter.

2.2.4 Sensitivity (CW) - (CW Receiver Function)

The level of an unmodulated RF input signal required to produce reference output with a signal-plus-noise to noise ratio of 6 dB shall not exceed 70 microvolts per meter.

NOTE: This standard is applicable only to receivers equipped with a beat frequency oscillator (BFO) or equivalent means to identify keyed CW signals.

2.2.5 Bearing Accuracy - (ADF Function)

At all bearing positions of the loop assembly, the indicated bearing shall not differ from the direction of arrival of the radio signal to which the equipment is tuned by more than three degrees for tuned frequencies below 850 kHz and eight degrees for frequencies above 850 kHz. This requirement shall apply when the input signal field strength is varied between 70 microvolts per meter and 0.2 volt per meter. For equipment including a fixed amount of quandrantal error compensation, the indicated bearing shall be corrected by the amount of quandrantal error compensation so included. For equipment including an error compensating device which is adjustable, this device may be set prior to testing the equipment so as to obtain a minimum bearing error. However, no adjustment of this device shall be made during conduct of the test. This requirement shall be met using both unmodulated signals and signals modulated up to a depth of 80% from 400 to 1000 Hz.

2.2.6 Station Passage - (ADF Function)

When the direction of arrival of a signal is abruptly changed through 175 degrees, the bearing indicator shall indicate a corresponding 170-degree change in less than seven seconds.

2.2.7 Audio Frequency Response

With a constant field strength of 1000 microvolts per meter modulated 30% and with the receiver gain adjusted to produce 30% of rated power output into a resistive load equal to the design load impedance, the audio output level shall not vary more than 6 dB from a 700 Hz reference level over the audio frequency range of 350 Hz to 1100 Hz.

2.2.8 Audio Output Level Variation With Load Impedance

The change in level of the output signal shall not exceed 3 dB and the distortion in the output signal shall not exceed 10%, when the output load impedance for which the receiver is designed is changed to 50% and to 200% of the design output load impedance. The RF input signal level shall be 1000 microvolts per meter modulated 30% at 400 Hz and the audio gain shall be adjusted to produce 30% of rated audio output power with design load impedance.

2.2.9 Distortion

The combined noise and distortion in the receiver output signal shall not exceed 25% at rated audio output power, when the receiver input signal is 1000 microvolts per meter modulated 85% at 400 Hz.

2.2.10 AGC Characteristics

When the RF input level is increased from 100 microvolts per meter to 0.2 volt per meter, the audio output power shall not increase more than 8 dB nor shall it decrease more than 2 dB from the maximum value.

2.2.11 Receiver Selectivity - (MCW Receiver Function)

The RF signal field strengths required to produce the same receiver output at specified frequencies off resonance shall not be less than the values given below.

kHz Above and Below the Selected Frequency	Signal Level in dB Above That at the Selected Frequency
0	0
1.0	0
1.5	6.0
2.0	12.0
3.0	27.0
4.0	42.0
5.0	57.0
6.0	72.0
7.0	greater than 80.0

2.2.12 Receiver Selectivity - (ADF Function)

The change in indicated bearing shall not exceed the requirements of paragraph 2.2.5 when an undesired signal from a source 90 degrees to that of the desired signal differs in frequency from, and exceeds in field strength, that of the desired signal in the following amounts:

Frequency Difference	Minimum Field Strength Ratio
±1 kHz	-10 dB
±1.5 kHz	- 4 dB
±2 kHz	2 dB
±3 kHz	17 dB
±4 kHz	32 dB
±5 kHz	47 dB
±6 kHz	62 dB
±7 kHz	greater than 70 dB

2.2.13 Spurious Response

All spurious responses from 50 kHz to 150 MHz, excluding the band from 10 kHz above to 10 kHz below the tuned frequency, shall be down at least:

a. 80 dB when the receiver is tuned anywhere in the frequency range of 190-850 kHz.

b. 60 dB when the receiver is tuned above 850 kHz.

2.2.14 Cross Modulation

With the simultaneous application of a 30%, 400 Hz modulated undesired signal not less than 10 kHz removed from the tuned frequency, and an unmodulated desired signal at the channel frequency as shown below, the aural output produced by the undesired signal should not exceed 90% of rated audio output power when the audio gain control is adjusted to produce rated audio output power when the desired signal is at 1000 microvolts per meter modulated 30% at 400 Hz.

a. The desired RF signal is at any level between 100 microvolts per meter and 0.2 volt per meter.

b. The undesired RF signal is:

(1) At any level between 100 microvolts per meter and 1.0 volt per meter for signals between 550 kHz and 150 MHz.

(2) At any level between 100 microvolts per meter and 0.2 volt per meter for signals between 50 and 550 kHz, except those signals which fall within the band 10 kHz above and below the frequency to which the receiver is tuned.

2.2.15 Intermodulation 1/

The simultaneous application of two signals as specified in Table 2-1 below shall result in a receiver output of no more than 90% of rated audio output power. This standard applies when the audio gain control is adjusted to produce rated audio output power when a desired signal at 1000 microvolts per meter is modulated 30% at 400 Hz.

SIGNAL	FREQUENCY RANGE	SIGNAL LEVEL	MODULATION
1	50 to 550 kHz, excluding the frequency band from 10 kHz above to 10 kHz below the frequency to which the receiver is tuned.	100 microvolts per meter to 0.2 volt per meter	NONE
	550 kHz to 150 MHz	100 microvolts per meter to 0.4 volt per meter	NONE
2	50 to 550 kHz, excluding the frequency band from 10 kHz above to 10 kHz below the frequency to which the receiver is tuned.	100 microvolts per meter to 0.2 volt per meter	30% at 400 Hz
	550 kHz to 150 MHz	100 microvolts per meter to 0.4 volt per meter	30% at 400 Hz

TABLE 2-1 INTERMODULATION SIGNALS

2.2.16 Direction Finder Operation With Beat Frequency Oscillator

If a beat frequency oscillator is incorporated in the equipment design and if it is intended for operation in the ADF function, no observable bearing error shall result from such operation when the level of the RF signal to which the equipment is tuned is varied over the range of 70 microvolts per meter to 0.2 volt per meter.

1/ It should be recognized that the environment does present undesired signals in excess of the maximum levels specified in Table 2-1. These test levels are a compromise based on a number of factors. Consideration has been given to what is achievable at an acceptable cost.

2.3 Equipment Performance - Environmental Conditions

The environmental tests and performance requirements described in this subsection are intended to provide a laboratory means of determining the equipment's overall performance characteristics under conditions representative of those which may be encountered in actual operations.

Some of the environmental tests contained in this subsection do not have to be performed unless the manufacturer wishes to qualify the equipment for that particular environmental condition. These tests are identified by the phrase "When Required." If the manufacturer wishes to qualify the equipment to these additional environmental conditions, then these "When Required" tests shall be performed.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160A, "Environmental Conditions and Test Procedures for Airborne Equipment," dated January 1980.

Some of the performance requirements in Subsections 2.1 and 2.2 are not required to be tested to all of the conditions contained in RTCA/DO-160A. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Subsections 2.1 and 2.2 will not be measurably degraded by exposure to these particular environmental conditions.

2.3.1 Temperature and Altitude Tests (DO-160A, Section 4.0)

RTCA/DO-160A contains several temperature and altitude test procedures which are specified according to the category for which the equipment will be used. These categories are included in paragraph 4.2 of DO-160A. The following sub-paragraphs contain the applicable test conditions specified in Section 4.0 of DO-160A.

2.3.1.1 Low Temperature Test

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 4.4, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy
d. Paragraph 2.2.11 - Receiver Selectivity - (MCW Receiver Function)

2.3.1.2 High Temperature Test

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 4.5, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy
d. Paragraph 2.2.11 - Receiver Selectivity - (MCW Receiver Function)

2.3.1.3 Altitude Tests

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 4.6, and the following requirements of this standard shall be met:

a. During the test:

Paragraph 2.2.5 - Bearing Accuracy (At 0 degrees and one frequency)

b. Following the test:

(1) Paragraph 2.2.3 - Sensitivity (MCW)
(2) Paragraph 2.2.4 - Sensitivity (CW)
(3) Paragraph 2.2.5 - Bearing Accuracy

2.3.1.4 Decompression Test - (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 4.6.2, and the following requirements of this standard shall be met:

a. During the test:

Paragraph 2.2.5 - Bearing Accuracy (At 0 degrees and one frequency)

b. Following the test:

(1) Paragraph 2.2.3 - Sensitivity (MCW)
(2) Paragraph 2.2.4 - Sensitivity (CW)
(3) Paragraph 2.2.5 - Bearing Accuracy

2.3.1.5 Overpressure Test - (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 4.6.3, and the following requirements of this standard shall be met:

a. During the test:

Paragraph 2.2.5 - Bearing Accuracy (At 0 degrees and one frequency)

b. Following the test:

(1) Paragraph 2.2.3 - Sensitivity (MCW)
(2) Paragraph 2.2.4 - Sensitivity (CW)
(3) Paragraph 2.2.5 - Bearing Accuracy

2.3.2 Temperature Variation Test (DO-160A, Section 5.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 5.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.3 Humidity Test (DO-160A, Section 6.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 6.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 - Tuning Resolution
b. Paragraph 2.2.3 - Sensitivity (MCW)
c. Paragraph 2.2.4 - Sensitivity (CW)
d. Paragraph 2.2.5 - Bearing Accuracy
e. Paragraph 2.2.11 - Receiver Selectivity - (MCW Receiver Function)

2.3.4 Shock Tests (DO-160A, Section 7.0)

2.3.4.1 Operational Shocks

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 7.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy
d. Paragraph 2.2.11 - Receiver Selectivity - (MCW Receiver Function)

2.3.4.2 Crash Safety Shocks

The application of the Crash Safety Shock tests may result in damage to the equipment under test. Therefore this test may be conducted after the other tests have been completed. In this case paragraph 2.1.7, "Effects of Test," of this standard does not apply.

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 7.2, and shall meet the requirements specified therein.

2.3.5 Vibration Tests (DO-160A, Section 8.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 8.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 - Tuning Resolution
b. Paragraph 2.2.3 - Sensitivity (MCW)
c. Paragraph 2.2.4 - Sensitivity (CW)
d. Paragraph 2.2.5 - Bearing Accuracy

2.3.6 Explosion Test (DO-160A, Section 9.0) (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 9.0. During these tests, the equipment shall not cause detonation of the explosive mixture within the test chamber.

2.3.7 Waterproofness Test (DO-160A, Section 10.0)

2.3.7.1 Drip Proof Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 10.2.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.7.2 Spray Proof Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 10.2.2, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

This test shall be conducted with the spray directed perpendicular to the most vulnerable area(s) as determined by the manufacturer.

2.3.8 Fluids Susceptibility Tests (DO-160A, Section 11.0)

The following subparagraphs contain the applicable test conditions specified in Section 11.0 of DO-160A.

2.3.8.1 Spray Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 11.2.1, and the following requirements of this standard shall apply:

a. At the end of the 24-hour exposure period, the equipment shall operate at a level of performance which indicates that no significant failures of components or circuitry have occurred.

b. Following the two-hour operational period at ambient temperature, after the 160-hour exposure period at elevated temperature, the following requirements of this standard shall be met:

(1) Paragraph 2.2.3 - Sensitivity (MCW)
(2) Paragraph 2.2.4 - Sensitivity (CW)
(3) Paragraph 2.2.5 - Bearing Accuracy

2.3.8.2 Immersion Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 11.2.2, and the following requirements of this standard shall apply:

a. At the end of the 24-hour immersion period, the equipment shall operate at a level of performance which indicates that no significant failures of components or circuitry have occurred.

b. Following the two-hour operational period at ambient temperature, after the 160-hour exposure period at elevated temperature, the following requirements of this standard shall be met:

(1) Paragraph 2.2.3 - Sensitivity (MCW)
(2) Paragraph 2.2.4 - Sensitivity (CW)
(3) Paragraph 2.2.5 - Bearing Accuracy

2.3.9 Sand and Dust Test (DO-160A, Section 12.0) (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 12.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.10 Fungus Resistance Test (DO-160A, Section 13.0) (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 13.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.11 Salt Spray Test (DO-160A, Section 14.0) (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 14.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.12 Magnetic Effect Test (DO-160A, Section 15.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 15.0, and the equipment shall meet the requirements of the appropriate instrument or equipment class specified therein.

2.3.13 Power Input Tests (DO-160A, Section 16.0)

2.3.13.1 Normal Operating Conditions

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraphs 16.3.1 and 16.3.2, as appropriate, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.13.2 Abnormal Operating Conditions

The application of the Low Voltage Conditions (DC) (Category B Equipment) test may result in damage to the equipment under test. Therefore this test may be conducted after the other tests have been completed. Paragraph 2.1.7, "Effects of Test," does not apply.

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraphs 16.3.3 and 16.3.4, as appropriate, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.14 Voltage Spike Conducted Test (DO-160A, Section 17.0)

The following subparagraphs contain the applicable test conditions specified in Section 17.0 of DO-160A.

2.3.14.1 Category A Requirements (If Applicable)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraph 17.3, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.14.2 Category B Requirements (If Applicable)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, paragraphs 17.4.1, "Intermittent Transients," and 17.4.2, "Repetitive Transients," and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.15 Audio Frequency Conducted Susceptibility Test (DO-160A, Section 18.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 18.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.16 Induced Signal Susceptibility Test (DO-160A, Section 19.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 19.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.17 Radio Frequency Susceptibility Test (Radiated & Conducted) (DO-160A, Section 20.0)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160A, Section 20.0, and the following requirements of this standard shall be met:

a. Paragraph 2.2.3 - Sensitivity (MCW)
b. Paragraph 2.2.4 - Sensitivity (CW)
c. Paragraph 2.2.5 - Bearing Accuracy

2.3.18 Emission of Radio Frequency Energy Test (DO-160A, Section 21.0)

When the equipment, including the antenna, is subjected to the test conditions as specified in RTCA/DO-160A, Section 21.0, the equipment shall meet the requirements specified therein.

2.4 Equipment Test Procedures

2.4.1 Definitions of Terms and Conditions of Test

The following definitions of terms and conditions of test are applicable to the equipment tests specified herein:

a. Power Input Voltage - Unless otherwise specified, all tests shall be conducted with the power input voltage adjusted to design voltage plus or minus 2%. The input voltage shall be measured at the input terminals of the equipment under test.

b. Power Input Frequency

(1) In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency plus or minus 2%.

(2) In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 1000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency and within the range for which the equipment is designed.

c. Adjustment of Equipment - The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests. Further adjustment shall not be permitted during the testing.

d. Test Instrument Precautions - Due precautions shall be taken during conduct of the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments across the input and output impedances of the equipment under test.

e. Ambient Conditions - Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure and humidity. However, the room temperature shall not be lower than 10 degrees Centigrade.

f. Warm-up Period - Unless otherwise specified, all tests shall be conducted after a warm-up (stabilization) period of not less than 15 minutes.

g. Connected Loads - Unless otherwise specified, all tests shall be performed with the equipment connected to loads having the impedance values for which it is designed.

h. Standard Shielded Room - Measurements of the performance characteristics of receiving equipment employing loop antennas shall be conducted in a shielded room equipped with a calibrated test transmission line terminated in a resistance equal to the line's characteristic impedance. This line shall be used in conjunction with a standard signal generator to produce a signal of known, controllable strength accurately simulating the conditions under which the loop receiver would operate in a free-space, radiated signal field.

(1) Shielded Room

Prefabricated rooms can be purchased or the room can be constructed as shown in Figure 2-1. Completely shield the room with sheet copper or copper screen and install a second shield, spaced approximately four inches from the first, if interference is severe. The shield(s) should be properly grounded and interconnected. Provision should be made to connect the door shielding to the room, shielding around the entire periphery of the door when it is closed. The power circuits should be brought into the room at the point of the ground connection and should be filtered to remove interference. All conduit within the room should be bonded to the shielding.

(2) Test Transmission Line Construction

The test transmission line shall be parallel to and midway between the side walls of the room. The line shall be horizontal and shall extend to within four inches from the end walls of the room. The line shall be stretched tightly with strain insulators at each end.

Refer to Figure 2-2. The loop shall be located directly below the center of the test transmission line. The distance d from the line to the ceiling and the distance X_0 from the ceiling to the center of the loop may vary somewhat, depending on the height

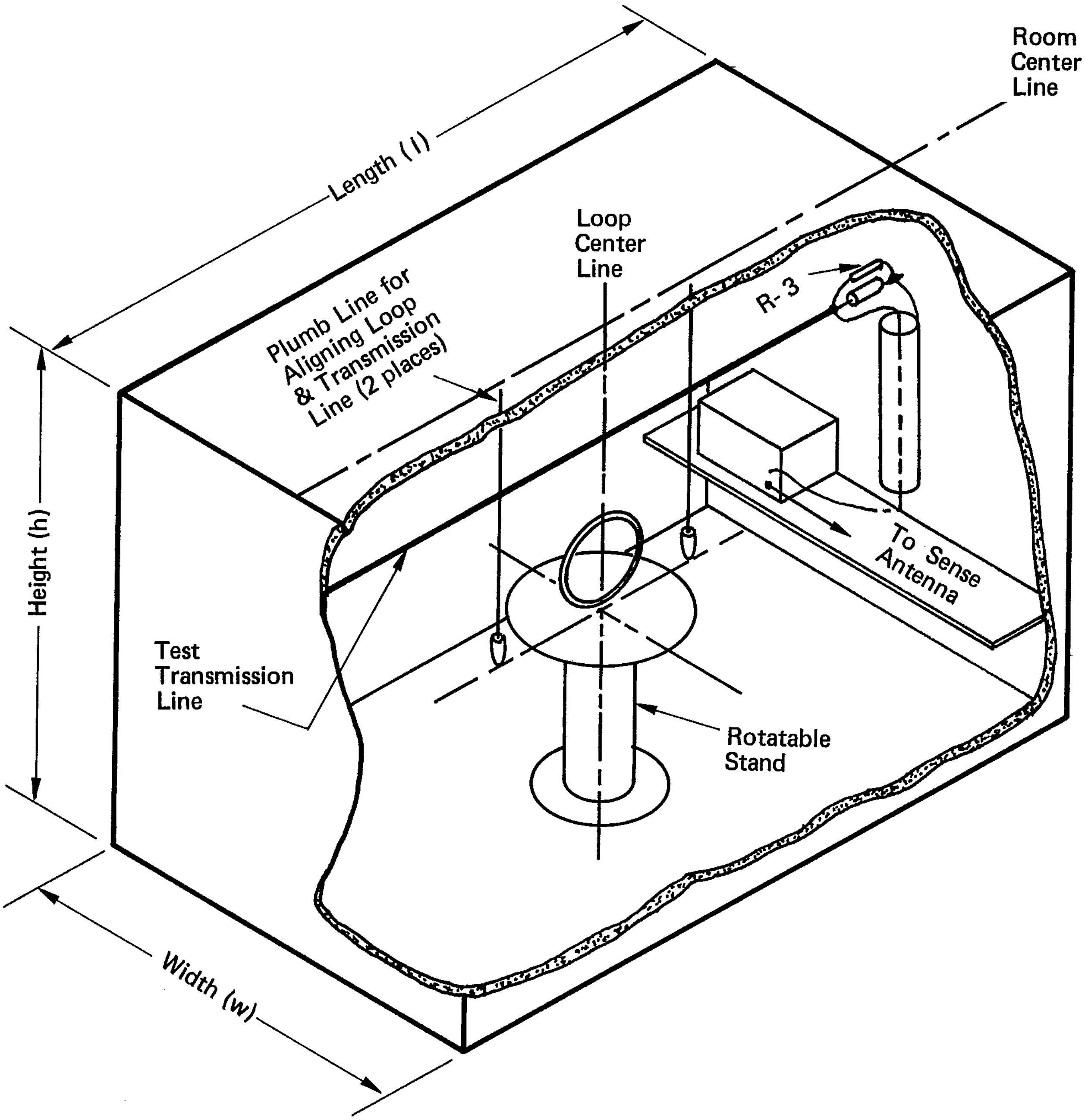


FIGURE 2–1

SHIELDED ROOM

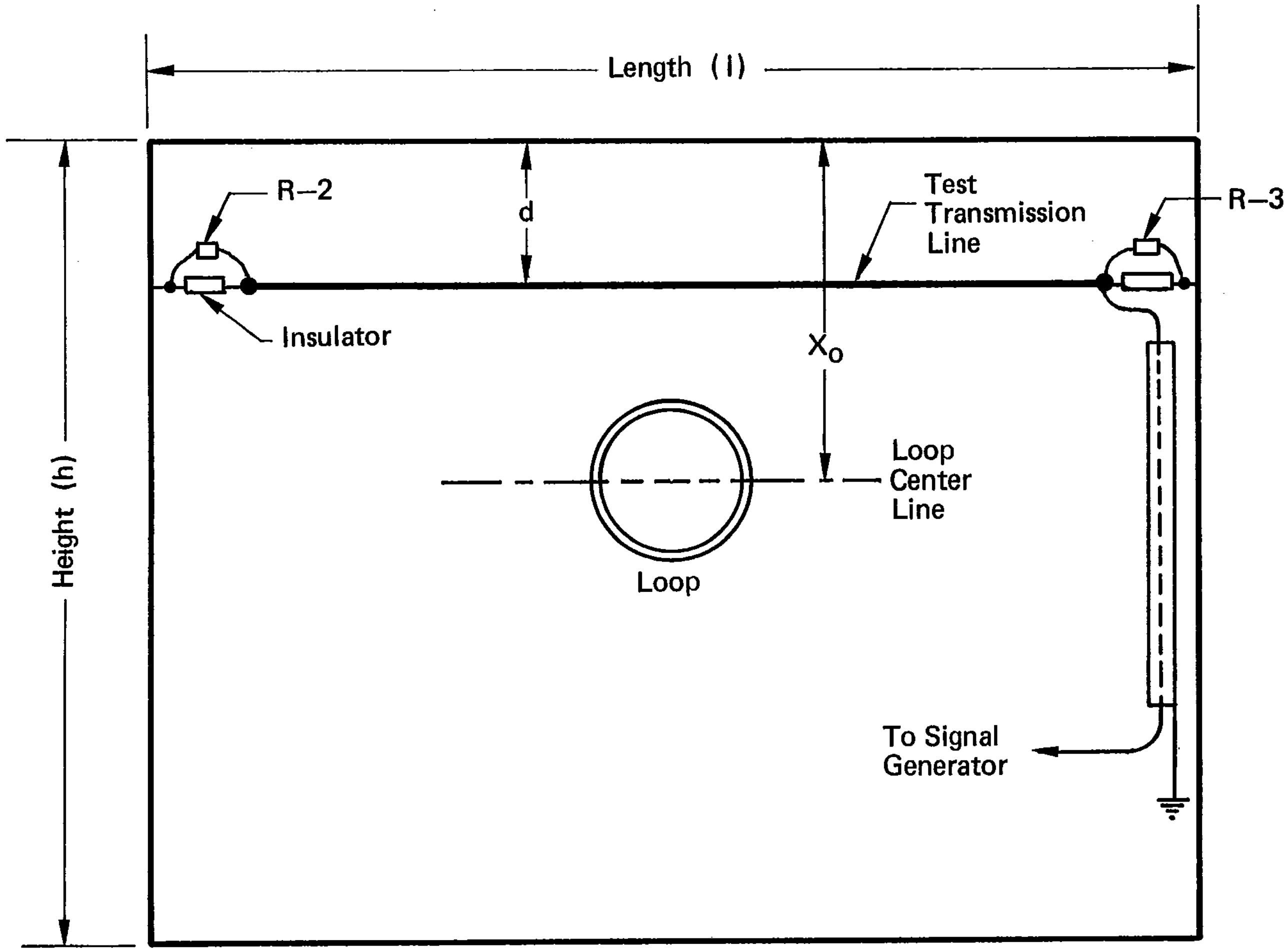


FIGURE 2–2

SHIELDED ROOM (SIDE VIEW)

of the room. However, it is preferable that dimension d be not less than 12 inches and that dimension X_o be not more than 50 inches nor less than 24 inches for loops of average size.

Connect the test transmission line to the signal generator with a length of concentric line, mounted in a vertical position.

(3) Loop Stand

The loop must be mounted on a rotatable table so that its angular position can be accurately determined. Flush or low-silhouette loops should be mounted on a ground plane simulating the aircraft surface. A circular or square plate 18 to 30 inches across is satisfactory.

The spacing between the loop and the line is a compromise. The variation in the field strength over the loop becomes less as the distance between the loop and the line increases. However, the field strength decreases with distance from the line requiring more power from the signal generator. A 0.4 volt per meter field in a room whose factor is 5 requires 5 x 0.4 volt or 2 volts from the generator. This is about the power limit of standard signal generators. To avoid distorting the field at the loop, supports and other structures forming closed conducting loops should be avoided.

(4) Room Factor

The calculations to determine the room factor (K_d) are to be made in accordance with "Generation of Standard Fields in Shielded Enclosures," by Fred Haber, November 1954 issue of the Proceedings of the IRE.

The formula shown is derived from those given in Mr. Haber's article, and provides for direct determination of the field strength in terms of the line voltage. The three factors, "a, b and c" are functions of the vertical distance from the radiating line to the top of the room, the vertical distance from the center of the loop to the top of the room and the overall height of the room, in reference to the width. Also appearing in the formula is Z_L (the terminating impedance on the line), the width of the room and a constant which permits use of the dimensions of the room in inches. The relationship between the field strength at the loop and the voltage fed into the line from the signal generator is known as the "room factor" K_d. This constant is defined as the ratio of the line voltage in volts to the field strength in volts per meter.

As noted in Mr. Haber's paper, this relationship is based upon an approximate solution for the field strength having a value between the bounds of the exact solution. Simplifying assumptions were made, but these will not result in errors of greater than 1% as long as the ratio of height to width of the room is one or greater. If the ratio of height to width is as small as 1/2, an error of up to 4% might be expected.

This relationship gives the field stength at a point directly below the radiating line, and spaced by the dimension X_o from the top of the room. If the loop is large compared to the distance from the center of the loop to the radiating line, a more accurate determination of the average field strength at the loop may be required.

Theoretically, the terminating resistance Z_L should be equal to the characteristic impedance of the line to prevent the formation of standing waves. However, as the dimensions of the average room are usually small compared to the wave length, a considerable mismatch on the line will not result in any appreciable standing wave formation, and a considerable variation in the terminating resistance can be made for the purpose of adjusting the room factor to a convenient value. In any event, the value used in the calculation should be the actual terminating resistance, whether or not it is equal to the characteristic impedance of the line. This is because the field strength is a function of the current in the line, and the line current is, of course, determined by the line voltage and the terminating resistance. A Number 12 wire spaced 20 inches from the ceiling will have a characteristic impedance of 413 ohms. Moderate changes in wire diameter or spacing do not change the Z_L very rapidly. The Z_L is 396 ohms for 15-inch spacing and 426 ohms for 25-inch spacing.

Mr. Haber's formula for calculating the magnetizing force (H total) in terms of signal generator voltage becomes as shown, when $\frac{E_L}{Z_L}$ is substituted for I.

$$H\ total = \frac{E_L}{wZ_L}\left[\frac{\text{Sinh } a}{\text{Cosh } b - \text{Cosh } a} - \frac{\text{Sinh } 2a}{\text{Cosh } 2b - \text{Cosh } 2a} + 4\text{Sinh } a \text{ Cosh } b\ (e^{-2c})\right]$$

Where

$$a = \frac{\pi d}{w}$$

$$b = \frac{\pi X_o}{w}$$

$$c = \frac{\pi h}{w}$$

and d, w, X_o, h, and Z_L are shown in Figure 2-2, and E_L is the signal generator output rms volts.

To convert the above H total to field strength in volts per meter and allow the use of room dimensions in inches, multiply by 14842. (With the room dimensions in meters multiply by 377.) An example of room factor calculations is shown along with further simplification to show that knowledge of hyperbolic functions is not essential to use the formula. In this example, the room factor was set at 5 and determined Z_L.

(5) Example of screen room calculation.

Assume the following dimensions:

d = 20"
X_o = 40"
h = 96"
w = 96"
K_d = 5
Z_L = to be determined

$$a = \frac{\pi d}{w} = \frac{3.14 \times 20}{96} = .655 \qquad 2a = 1.31$$

$$b = \frac{\pi X_o}{w} = \frac{3.14 \times 40}{96} = 1.31 \qquad 2b = 2.62$$

$$c = \frac{\pi h}{w} = \frac{3.14 \times 96}{96} = 3.14 \qquad 2c = 6.28$$

Sinh a = .7028 Sinh 2a - 1.718
Cosh a - 1.222 Cosh 2a - 1.988
Cosh b - 1.988 Cosh 2b = 6.904

$e^{-2c} = .00187$

$$m = \frac{\text{Sinh a}}{\text{Cosh b-Cosh a}} = \frac{.7028}{1.988-1.222} = .9175$$

$$n = \frac{\text{Sinh 2a}}{\text{Cosh 2b-Cosh 2a}} = \frac{1.718}{6.904-1.988} = .3495$$

$$p = 4e^{-2c} \times \text{Sinh a Cosh b} = .0075 \times .7028 \times 1.988$$
$$= .0105$$

$$H = \frac{(m-n+p)}{w} \frac{E_L}{Z_L} = \frac{(.9175-.3495+.0105)}{96} \frac{E_L}{Z_L} = .00603 \frac{E_L}{Z_L}$$

$$\text{volts/meter} = .00603 \frac{E_L}{Z_L} \times 14842 = 89.5 \frac{E_L}{Z_L}$$

Transposing, $Z_L = 89.5 \dfrac{E_L}{\text{volts per meter}}$

For a room factor of 5, K_d, $= 5 = \dfrac{E_L}{\text{volts per meter}}$

Substituting, $Z_L = 89.5 \times 5$

$Z_L = 447.5$

When the line is terminated with 447.5 ohms, the room factor will be 5. Install the resistor (R3) at the junction of the vertical feed and the test transmission line. Compute the value of R3 as follows:

$$R3 = \frac{R2 \times Z_o}{R2 - Z_o}$$

where $R2 = Z_L$, the resistance terminating the transmission line, and

Z_o = the characteristic impedance of the vertical feed coax.

<u>NOTE</u>: It is convenient to make Z_o 50 ohms, when the signal generator output is 50 ohms.

Check the line for standing waves at the highest frequency to be used, by comparing VTVM readings at the feed end of the transmission line and at the terminated end of the line. The largest potential error in percent due to standing waves is equal to $\frac{E_1-E_2}{E_1} \times 100$.

(6) Determination of the value of the Sense Antenna Voltage Divider

C_a of Figure 2-3 is the capacitance of the sense antenna for which the ADF is designed. The voltage divider $\frac{C_c}{C_b}$ ratio is made equal to the room factor divided by the effective height of the sense antenna. For instance, to simulate a 1/4 meter 50 pf antenna with a room factor of 5 requires the following values:

$$C_a = 50 \text{ pf}$$

$$\frac{C_c}{C_b} = \frac{5}{1/4} = 20$$

C_c must be much greater than C_a, so satisfactory values would be:

$$C_b = 100 \text{ pf and } C_c = 2000 \text{ pf.}$$

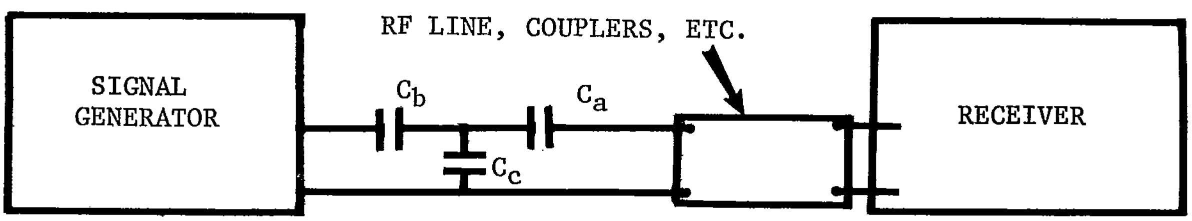


FIGURE 2-3 TEST TRANSMISSION LINE CONSTRUCTION

i. Test Antenna - The test antenna shall be defined by the manufacturer and must be equivalent to the antenna specified for use with the system.

2.4.2 Detailed Test Procedures

The test procedures set forth below are considered satisfactory for use in determining required performance under standard and stressed conditions. Although specific test procedures are cited, it is recognized that other methods may be preferred by the testing activity. These alternate procedures may be used if the manufacturer can show that they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

2.4.2.1 Tuning Resolution (paragraph 2.2.1)

Equipment Required

Standard Signal Generator (Hewlett Packard Model 606A, or equivalent)
Test Antenna
Frequency Meter (Hewlett Packard Model 5245L, or equivalent)

Measurement Procedures

Set the receiver frequency indicator to a desired frequency. Apply to the receiver through the standard test antenna a standard input signal at 100 microvolts per meter. The test shall be performed at the band edges for either Category A or B equipment. Tune the signal generator to the receiver selected frequency and verify that the signal is received.

2.4.2.2 Ground Station Interoperability (paragraph 2.2.2)

Equipment Required

Standard Signal Generator (Hewlett Packard Model 606A, or equivalent)
Test Antenna
Frequency Meter (Hewlett Packard Model 5245L, or equivalent)

Measurement Procedure

Set the receiver frequency indicator to a desired frequency. Apply to the receiver through the standard test antenna a standard input signal at 70 microvolts per meter. The test shall be performed at the band edges and midband frequencies for either Category A or B equipment. Tune the signal generator to the receiver selected frequency plus 0.01% and verify the received signal and the signal-plus-noise to noise ratio is at least 6 dB. Repeat the above test when the signal generator is tuned to the receiver selected frequency minus 0.01%.

2.4.2.3 Sensitivity MCW Receiver Function (paragraph 2.2.3)

Equipment Required

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
Output Power Meter (General Radio 538-A, or equivalent)
Test Antenna

Measurement Procedure

Apply to the input of the test antenna a standard input signal. Determine the RF signal level (equivalent field strength in microvolts per meter) required to obtain a signal-plus-noise to noise ratio of 6 dB in the audio output when the audio gain is adjusted to produce rated audio output power.

2.4.2.4 Sensitivity CW Receiver Function (paragraph 2.2.4)

Equipment Required

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
Output Power Meter (General Radio Model 538-A, or equivalent)
Test Antenna

Measurement Procedure

Apply an unmodulated RF signal to the input of the test antenna. With the beat frequency oscillator "ON," adjust the equipment to produce an output signal of 400 to 1100 Hz. Determine the RF signal level (equivalent field strength in microvolts per meter) required to obtain a 6 dB signal-plus-noise to noise ratio in the audio output, when the gain is adjusted to produce rated audio output power when the beat frequency oscillator is "OFF."

2.4.2.5 Bearing Accuracy, Automatic Direction Finder Function (paragraph 2.2.5)

Equipment Required

Shielded room equipped with a Standard Signal Generator (Hewlett Packard Model 606A, or equivalent) and with a test transmission line properly terminated and calibrated, or test equipment which simulates a standard shielded room.

Measurement Procedure

At each 15-degree incremental setting of the loop antenna assembly throughout 360 degrees (each setting shall be approached from both a clockwise and a counter-clockwise direction of rotation), determine the maximum error of the forward bearing indication as the signal field strength is varied over the range of 70 microvolts per meter to 0.2 volt per meter with the signal (in turn) unmodulated and modulated 80% at 400 Hz.

2.4.2.6 Station Passage (paragraph 2.2.6)

Equipment Required

Shielded room equipped with a Standard Signal Generator (Hewlett Packard Model 606A, or equivalent) and with a test transmission line properly terminated and calibrated, or test equipment which simulates a standard shielded room.

Measurement Procedure

Abruptly rotate the loop antenna 175 degrees and verify that the bearing indicator indicates a corresponding 170-degree change in less than seven seconds. This test should be performed in both the clockwise and counter-clockwise direction with a signal field strength of 100 microvolts per meter.

2.4.2.7 Audio Frequency Response (paragraph 2.2.7)

Equipment Required

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
AF Signal Generator (Hewlett Packard Model 200-B, or equivalent)
Output Power Meter (General Radio Model 538-A, or equivalent)
Test Antenna

Measurement Procedure

Apply to the receiver input a standard input signal at 1000 microvolts per meter. Adjust the audio gain to produce 30% of rated audio output power. Determine the receiver output levels in dB from the above reference as the audio modulation of the RF signal is held constant at 30% and the audio-frequency is varied over the range of 350 to 1100 Hz.

2.4.2.8 Audio Output Level Variation With Load Impedance (paragraph 2.2.8)

Equipment Required

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
Output Power Meter (General Radio Model 538-A, or equivalent)
Distortion and Noise Meter (Hewlett Packard Model 330D, or equivalent)
AF Signal Generator (Hewlett Packard Model 200-B, or equivalent)
Test Antenna

Measurement Procedure

Apply to the receiver a standard input signal at 1000 microvolts per meter. Adjust the audio gain to produce 30% of rated audio output power into the load impedance for which the receiver is designed. Determine the change in output power from the rated output in dB and the percentage of distortion of the output signal when the receiver output load impedance is 50% and when it is 200% of that for which the receiver is designed.

2.4.2.9 Distortion (paragraph 2.2.9)

Equipment Required

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
AF Signal Generator (Hewlett Packard Model 200-B, or equivalent)
Distortion and Noise Meter (Hewlett Packard Model 330D, or equivalent)
Output Power Meter (General Radio Model 583-A, or equivalent)

Measurement Procedure

Apply to the receiver an RF signal modulated 85% at 400 Hz. Adjust the receiver gain to produce rated output. Determine the percentage of distortion and noise in the receiver output signal. Conduct this test at the RF input signal level of 1000 microvolts per meter.

2.4.2.10 AGC Characteristics (paragraph 2.2.10)

Equipment Required

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
Test Antenna
Output Power Meter (General Radio Model 538-A, or equivalent)
Shielded room equipped with a Standard Signal Generator (Hewlett Packard Model 606A or equivalent) and a test transmission line properly terminated and calibrated or a test set which simulates a standard shielded room.

Measurement Procedure

Apply a standard input signal to the receiver through a test antenna, or a test transmission line. Vary the input signal from 100 microvolts per meter to 0.2 volt per meter and determine:

a. The audio output power when the input signal level is 100 microvolts per meter.

b. The dB increase in receiver audio output power from that obtained in a. above to the maximum output power obtained as the input signal is increased to 0.2 volt per meter.

c. The maximum decrease in audio output power over the range of input from that producing maximum audio output power to 0.2 volt per meter.

Conduct this test with the audio gain adjusted to produce rated audio output power.

2.4.2.11 <u>Receiver Selectivity - (MCW Receiver Function) (paragraph 2.2.11)</u>

<u>Equipment Required</u>

RF Signal Generator (Hewlett Packard Model 606A, or equivalent)
Output Power Meter (General Radio Model 538-A, or equivalent)
Test Antenna

<u>Measurement Procedure</u>

Apply to the receiver input a standard input signal of 100 microvolts per meter. Adjust the audio gain to produce rated audio output power. Determine the frequencies above and below the selected frequency to which the signal generator must be tuned to produce rated audio output power when the RF signal field strength is 6, 12, 42, and 72 dB above that required to produce rated audio output power at the frequency of maximum response. A measurement of RF carrier derived voltage (e.g. AGC) may be used in lieu of audio power measurement.

2.4.2.12 <u>Receiver Selectivity - (Automatic Direction Finder Function) (paragraph 2.2.12)</u>

<u>Equipment Required</u>

Shielded room equipped with two Standard Signal Generators (Hewlett Packard Model 606A, or equivalent) and with two test transmission lines crossing each other at 90 degrees, properly terminated and calibrated, or a test set which properly simulates these conditions. (See paragraph 2.4.1 h.). The circuit constants of the sense antenna circuits and line termination resistors, C_a, C_b, C_c, R2 and R3 for ADF receivers must be such that the isolation between the test transmission lines is not less than the null depth of the directional antenna.

Output Power Meter (General Radio Model 538-A, or equivalent)

<u>Measurement Procedure</u>

This test requires the use of two signal generators, one identified as Signal Generator #1 (SG #1) and the other as Signal Generator #2 (SG #2), which are individually coupled to two test transmission lines that cross each other at 90 degrees. Set the receiving equipment to the ADF Function. Adjust SG #1 to produce a standard input signal at a field strength of 100 microvolts per meter. Tune the receiving equipment to the frequency of SG #1 and determine the indicated bearing of the desired signal. By means of SG #2, set up an undesired unmodulated signal field whose direction is 90 degrees from that of the desired signal field. Determine the change in indicated bearing of the desired signal from the indicated bearing determined above, when SG #2 is adjusted to produce signals of the relative field strengths and frequency displacements specified in paragraph 2.2.12.

2.4.2.13 Spurious Response (paragraph 2.2.13)

Equipment Required

RF Signal Generators to cover the range 50 kHz to 150 MHz (Hewlett Packard 606A and 608E, or equivalent)
Output Power Meter (General Radio Model 583-A, or equivalent)
Test Antenna

Measurement Procedure

Apply to the receiver input through a test antenna, a standard input signal at 100 microvolts per meter. Adjust the audio gain to produce rated audio output power. For tuned frequencies below 850 kHz (535 kHz for Category B), increase the input signal level by 80 dB. Determine the input signal frequencies at which the receiver output is rated at audio output power or greater, within the band 50 kHz to 150 kHz, but excluding the frequencies within ± 10 kHz of the frequency to which the equipment is tuned. For tuned frequencies above 850 kHz (535 kHz for Category B), repeat the above measurement, but this time increase the input signal level by only 60 dB. The test shall be performed at the band edges and the mid-band frequencies for either Category A or B equipment. A measurement of RF carrier-derived voltage (e.g., AGC) may be used in lieu of audio power measurement.

2.4.2.14 Cross Modulation (paragraph 2.2.14)

Equipment Required

Two RF Signal Generators covering the frequency range of 50 kHz to 150 MHz (Hewlett Packard Models 606A and 608E, or equivalent)
Output Power Meter (General Radio Model 538-A, or equivalent)
Test Antenna

Measurement Procedure

This test requires the use of two signal generators, one identified as Signal Generator #1 (SG #1), and the second as Signal

Generator #2 (SG #2). Connect the equipment as shown in Figure 2-4. 1/ Set the output of SG #2 to produce a standard input signal and reduce the RF output level to zero. Set the output of SG #1 to produce a standard input signal of 1000 microvolts per meter. Adjust the audio gain to produce rated audio output power. Reduce SG #1 output to produce a standard input signal of 100 microvolts per meter. Remove the modulation from SG #1. Increase the output of SG #2 to 0.2 V when its frequency is 50 to 550 kHz, or to 1.0 V when its frequency is 550 kHz to 150 MHz. Determine the frequencies (excluding frequencies within 10 kHz of the receiver tuned frequency) to which SG #2 must be tuned to produce 90% of rated audio output power. Repeat the procedure for other receiver sensitivity settings.

NOTE: The presence of cross modulation can be determined by reducing the output of SG #1 to zero. If the receiver output decreases when the output of SG #1 is reduced, cross modulation is present.

2.4.2.15 Intermodulation (paragraph 2.2.15)

Equipment Required

Two RF Signal Generators covering the frequency range of 50 kHz to 150 MHz (Hewlett Packard Models 606A and 608E, or equivalent).
Output Power Meter (General Radio Model 538A, or equivalent).
Test Antenna.

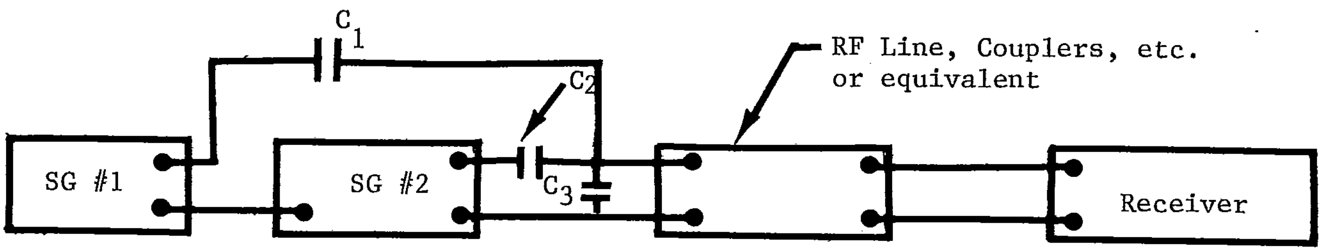
Measurement Procedure

Connect the equipment as shown in Figure 2-4. 1/ Set the output of SG #2 to zero and the output of SG #1 to produce a standard input signal of 1000 microvolts per meter on the resonant frequency of the receiver. Adjust the audio gain to produce rated audio output power. Reduce SG #1 output to produce a standard input signal at a level of 100 microvolts per meter. Determine the combinations of SG #1 and SG #2 frequencies and output levels within the confines of Table 2-1 that produces 90% of rated audio output power.

To determine the intermodulation characteristics of the receiver for second order distortion, set the frequencies of SG #1 and SG #2 so that the sum or difference equals the resonant frequency of the receiver.

1/ Figure 2-4 is only schematic and the coupling of the two signal generators should be such as to avoid intermodulation being generated within the test set-up.

To determine the intermodulation characteristics of the receiver for third order distortion, set the frequencies of SG #1 and SG #2 such that $2F_1 \pm F_2$, or $F_1 \pm 2F_2$ equals the resonant frequency of the receiver.



$C_1 + C_2 + C_3 = C_a$ mmf

$C_1 = C_2 = H_e\ C_a$

NOTE: The receiver input voltages specified in this test procedure are those in series with C_1 and C_2 of Figure 2-4 and are equivalent to the respective input signal field strengths at the antenna with which the equipment is designed to be operated.

FIGURE 2-4 CROSS- AND INTERMODULATION TEST SET-UP

NOTE 1: Intermodulation tests should be made with all combinations of receiver and signal generator frequencies which may produce harmful intermodulation. Particular attention should be given to frequencies of series or parallel resonances in the input circuit. For instance, an antenna input transformer for the 190-535 kHz band might have a primary resonance about 100 kHz. In this case, one of the undesired frequencies should be 100 kHz. Another resonance is that due to the physical length of the antenna and transmission line. Intermodulation due to third order distortion should be checked, particularly at frequencies just outside the receiver selectivity passband. For instance, 400 kHz, and 390 kHz would produce a $2F_1 - F_2$ response at 410 kHz.

NOTE 2: This test procedure is intended to be accomplished with the equipment's mode selector switch set to the "sense antenna" position. If the equipment does not employ a sense antenna, an equivalent test (developed by the equipment manufacturer) shall be conducted on the equipment using such antenna(s) as are incorporated in the equipment's design. Additionally, this test procedure is intended to be used with equipment which employs a manual RF gain control when functioning in the "sense antenna" mode of operation. If such control is not used in the equipment under test, a measurement of RF carrier-derived voltage (e.g., AGC) may be used in lieu of measuring the equipment's audio output.

2.4.2.16 Direction Finder Operation With Beat Frequency Oscillator (paragraph 2.2.16)

Equipment Required

Shielded room equipped with a standard signal generator (Hewlett Packard Model 606A, or equivalent) and with a test transmission line properly terminated and calibrated, or test equipment which simulates a standard shielded room.

Measurement Procedure

With the beat frequency oscillator "OFF," adjust the signal generator to produce a field strength of 70 microvolts per meter and determine the indicated bearing. Turn the beat frequency oscillator "ON" and vary the field strength between 70 microvolts per meter and 0.5 volt per meter. Determine if there is any observable difference in bearing indication.

3.0 INSTALLED EQUIPMENT PERFORMANCE

3.1 Test Conditions

3.1.1 Power Input

Unless otherwise specified, tests are conducted with the equipment powered by the aircraft's electrical power generating system or equivalent source if required.

3.1.2 Associated Equipment

All aircraft electrically operated systems and equipment must be operational before conducting electronic interference tests.

3.1.3 Environment

During the following tests, the equipment shall not be subjected to environmental conditions that exceed those specified by the manufacturer.

3.1.4 Adjustment of Equipment

The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices.

3.1.5 Warm-up Period

Unless otherwise specified by the equipment manufacturer, tests shall be conducted after a suitable warm-up period not to exceed 15 minutes.

3.2 Equipment Installation

3.2.1 Equipment Accessibility

The equipment controls and display(s) installed for in-flight operation shall be readily accessible to a crew member from the normal seated position. The appropriate operator/crew member(s) shall have an unobstructed view of the display(s) when in the normal sitting position.

3.2.2 Display Visibility

The display brilliance shall be capable of display interpretation under all cockpit conditions of ambient light ranging from total darkness to sunlight. Filters and brightness adjustments are acceptable means of obtaining visibility in daylight.

3.2.3 Interference Effects

ADF equipment shall be electromagnetically compatible with all other installed equipment.

3.2.4 Dynamic Response During Maneuvers

Operation of the equipment shall not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal flight operations.

3.2.5 Inadvertent Turnoff

Appropriate controls shall be provided with adequate protection against inadvertent turnoff.

3.2.6 Aircraft Power Source

The voltage and voltage tolerance characteristics of the ADF shall be compatible with the aircraft power source.

3.3 Minimum Installed Equipment Performance

3.3.1 Controls and Displays

Proper operation of all controls and displays installed for in-flight operation shall be confirmed.

3.3.2 Audio Reception

Audio reception shall be confirmed by tuning the receiver to a local NDB and listening for an audio output. If the equipment has separate modes for the ADF function and the MCW receiver function, audio reception shall be confirmed in both modes. If the receiver is equipped with a beat frequency oscillator or equivalent means to identify keyed CW signals, a tone shall be heard whenever a carrier is present while the receiver is in the CW receiver mode.

3.3.3 Bearing Accuracy

With the aircraft on the ground and the receiver tuned to a local NDB, the aircraft shall be turned to produce a relative ADF bearing indication of 0 degrees. The aircraft shall then be rotated 360 degrees in 45 degree increments, with the relative bearing indication noted after each increment. The error in the relative bearing indication shall not exceed 5 degrees at any of these points below 850 kHz and 10 degrees above 850 kHz. If a ground test is not feasible due to proximity of buildings, ground effects or other difficulties, an equivalent flight test may be substituted.

4.0 OPERATIONAL CHARACTERISTICS

4.1 Required Operational Characteristics

To ensure that operations can be conducted safely and reliably in the expected operational environment, specific minimum acceptable performance parameters must be met. The following paragraphs identify those equipment operational characteristics which, if met, constitute an overall confidence check of equipment operation.

4.1.1 Power Input

Prior to flight it should be possible to verify that the equipment is receiving primary input power necessary for equipment operation.

4.1.2 Equipment Operating Modes

The equipment must be capable of operating in each of its operating modes.

4.2 Test Procedures for Operational Characteristics

Operational equipment tests may be run as part of the normal preflight tests prior to the start of a flight in which the equipment is expected to be used. For those tests which can only be run in flight, procedures should be developed by the user to perform these tests as early during the flight as possible in order to establish confidence that the equipment is performing its intended function(s).

4.2.1 Power Input

With the aircraft's electrical power generating system operating, energize the equipment and verify that electrical power is available to the equipment.

4.2.2 Equipment Operating Modes

If a nearby ground station can be received, verify that the equipment can provide audio signals in the MCW or ADF mode and that relative bearing information is provided in the ADF mode.

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M E M B E R S H I P

Special Committee 146

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