Minimum Operational Performance Standards for Airborne ILS Localizer Receiving Equipment Operating Within the Radio Frequency Range of 108-112 MHz

DOCUMENT NO. RTCA/DO-195
NOVEMBER 17, 1986
Prepared by SC-153

RTCA
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RADIO TECHNICAL COMMISSION FOR AERONAUTICS

DEDICATED TO THE ADVANCEMENT OF AERONAUTICS

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MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIRBORNE ILS LOCALIZER RECEIVING EQUIPMENT OPERATING WITHIN THE RADIO FREQUENCY RANGE OF 108-112 MHZ

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Prepared by:
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Supersedes: RTCA/DO-131A

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FOREWORD

This document was prepared by Special Committee 153 of the Radio Technical Commission for Aeronautics. It was approved by RTCA on November 17, 1986, and supersedes RTCA/DO-131A, "Performance Standards Airborne ILS Localizer Receiving Equipment," November 2, 1978.

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 its member organizations.

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

Coordination of these standards was accomplished by RTCA SC-153 with the European Organisation for Civil Aviation Electronics (EUROCAE) WG 5.

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TABLE OF CONTENTS

Page

Page

1.0 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards for airborne ILS localizer receiving equipment. These standards specify system characteristics that should be useful to designers, manufacturers, installers and users of the equipment.

Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine operations.

Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

Section 1.0 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 and establishes 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 specify the required performance under standard and environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

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 performance characteristics for equipment installations and defines conditions that will assure the equipment user that operations can be conducted safely and reliably in the expected operational environment.

This document considers an equipment configuration consisting of: Antenna system(s), transmission lines, radio receiver, localizer circuitry and a course deviation indication display. Additional functions and components that refer to expanded equipment capabilities are identified as optional features.

The word "system" as used in this document refers to the ILS localizer system. It includes all portions of both the ILS localizer ground transmitter and the ILS localizer airborne equipment.

The word "equipment" as used in this document includes all components and units necessary for the system to properly perform its intended function. For example, the "equipment" may include an antenna, a receiver unit, localizer circuitry, course deviation indicator, a shock mount, etc. In the case of this example, all of the foregoing components and units comprise the "equipment." It should not be inferred from this example that each airborne localizer receiving equipment design will necessarily include all of the foregoing components or units. This will depend on the specific design chosen by the manufacturer.

If the equipment implementation includes a computer software package, use the guidelines contained in RTCA/DO-178A, "Software Considerations in Airborne Systems and Equipment Certification."

1.2 System Overview

The localizer system consists of the airborne localizer receiver and ground station transmitter. There are forty localizer channels between 108.10 MHz and 111.95 MHz.

The ground station transmits an RF signal, which is divided into two beams. One beam is amplitude modulated by a 90 Hz sine wave while the other is amplitude modulated by a 150 Hz sine wave. The pattern of the antenna is such that when an aircraft is centered on the runway approach centerline, equal amounts of 90 and 150 Hz tones are received. The localizer ground station also transmits a 1020 Hz Morse Code identification tone for positive identification of the station.

The airborne receiver receives and detects the localizer signal. This guidance information is then presented to the pilot on a CDI, HSI or EFIS display. The display operates such that when the aircraft is to the right of the approach centerline, mostly 150 Hz modulation is received and the pilot gets a fly left command. When the aircraft is to the left of the centerline, mostly 90 Hz modulation is received and the pilot gets a fly right command.

1.3 Operational Applications

The localizer system is used for both precision and non-precision approaches. For a precision approach the localizer is used with an associated glide slope transmitter. These two systems together make up a precision landing system and give both vertical and horizontal guidance to an aircraft.

For a non-precision approach, no glide slope transmitter is available and only localizer horizontal information is supplied. In the non-precision approach, another nav-aid such as a VOR, ADF or Marker Beacon is typically used in conjunction with the localizer to identify the final approach fix.

Some airports have a back-course localizer non-precision approach. This type of approach is flown exactly the same as the standard localizer except the guidance information is reversed, i.e. the pilot flies away from the CDI needle to get to the extended runway centerline.

1.4 Operational Goals

Operational goals of the ILS localizer are described in the following paragraphs. Only general operational goals are identified. Detailed operational requirements for the equipment are contained in Sections 2.0, 3.0 and 4.0.

1.4.1 System Sensitivity

The RF sensitivity of the installed ILS localizer equipment should be such that its performance meets the overall requirements of the remaining sections of this document in the presence of a standard ILS localizer signal that has a power density of -114 dBW/m^2 (40 microvolts/meter) or greater.

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 ILS localizer service volume. It should provide positive audio and/or visual identification of the ground station to which the ILS localizer is tuned, in the presence of undesired signals at the relative signal levels and frequency separations specified in Section 2.0. The information should meet the accuracy requirements contained in Section 2.0 in the presence of undesired signals at the relative signal levels and frequency separations specified in Section 2.0.

1.4.3 Spurious Response and Intermodulation

Equipment spurious responses or intermodulation effects should not inhibit the pilot from receiving ILS localizer signals within the facility's operational service volume.

1.4.4 Warnings

A warning system will be incorporated into the equipment to activate a warning display such as instrument flags and to activate the appropriate circuits in associated systems when any unsafe or unreliable condition exists.

Warnings will be integral to the primary ILS localizer flight guidance indicator(s) such as CDI, HSI and EFIS. The warning indication should be easily discernible and indicate unacceptable conditions, e.g., absence of an RF signal from the ground elements, failure in the airborne equipment.

1.4.5 Interface With Other Aircraft Systems

The equipment may provide inputs to other airborne systems. It may provide signals that are adaptable for use by other aircraft instruments, navigation equipment and automatic flight controls.

ILS localizer signal interface with other airborne equipment intended for use during flight should not result in a condition where its presence or continuation would be detrimental to the safe conduct of flight.

1.5 Assumptions

This document assumes a 50 ohm nominal input impedance for the antenna port. All RF levels in this document are in dBm as described in Appendix B.

1.6 Test Procedures

The test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements contained in Section 2.0. Although specific test procedures are cited, it is recognized that other methods may be preferred. 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 specified suggests that the equipment be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Section 2.0 shall have been demonstrated as a precondition to satisfactory completion of the installed system tests of Section 3.0.

Four types of test procedures are specified. These include:

a. Environmental Tests

Environmental tests are in Subsection 2.3. The procedures and their associated limit requirements 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.

Unless otherwise specified, the environmental conditions and test procedures contained in RTCA/DO-160B, "Environmental Conditions and Test Procedures for Airborne Equipment," will be used to demonstrate equipment compliance.

b. Bench Tests

Bench test procedures are in Subsection 2.4. These tests 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.

c. Installed Equipment Tests

The installed equipment test procedures and their associated limits are specified in Section 3.0. Although bench and environmental test procedures are not included in the installed equipment tests, their successful completion is a precondition to completion of the installed tests. In certain instances, however, installed equipment 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:

(1) With the aircraft on the ground and using simulated or operational system inputs.

(2) 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 intended operational environment.

d. 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 Gain Control (AGC) - A method of automatically maintaining a substantially constant audio output volume over a range of variation of input volume.

ddm - Difference in depth of modulation. The absolute difference in percentage of modulation of two tones divided by 100.

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2.0 ILS LOCALIZER EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

The manufacturer shall design the equipment to meet the requirements of Section 2.0 of this document. The manufacturer shall also conduct testing to demonstrate that the equipment performs within specification limits, is free from manufacturing defects and will operate in the specified environments, provided that the equipment is installed in accordance with the manufacturer's installation instructions.

2.1.2 Intended Function

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

2.1.3 Federal Communications Commission Rules

All equipment shall comply with the applicable rules of the Federal Communications Commission.[1]

2.1.4 Fire Protection

All materials used shall be self-extinguishing 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.

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

2.1.5 Operation of Controls

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

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[1]It is not intended that this requirement relating to FCC rules be interpreted as a precondition for obtaining other applicable approvals such as an FAA TSO authorization.

2.1.6 Accessibility of Controls

Controls for use during flight shall be accessible from the pilot's normal seated position. Controls that are not normally adjusted in flight shall not be readily available to flight personnel.

2.1.7 Frequency Display

In order to avoid confusion, the frequency or paired channel or the identification of the navigation facility or facilities in active use must be displayed or capable of recall at all times during flight.

2.1.8 Effects of Test

The equipment shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

2.2 Minimum Performance Standards Under Standard Test Conditions

2.2.1 Centering Accuracy

a. The centering error as presented to the pilot shall not have an error in excess of the limits called out in Table 2-1 using standard signal conditions outlined in paragraph 2.4.3.1 a.

b. The centering error as presented to the pilot shall not exceed the limits specified in Table 2-1 with a statistical probability of 95%, using the signal conditions of paragraph 2.4.3.1 b.

TABLE 2-1 MAXIMUM CENTERING ERROR

CLASS	ERROR PERCENT OF STANDARD DEFLECTION	CATEGORIES
A	11%	Manual
B	5%	(Autoland) Automatic Landing (Based on Time Constant)

2.2.2 Interfering Signals

2.2.2.1 Adjacent Channel and In-Band Signals

The centering error as presented to the pilot shall not exceed those of Table 2-1 under the following conditions:

a. With a standard localizer signal level of -86 dBm and a standard undesired, first adjacent channel VOR test signal at a level of -52 dBm.

b. With a standard desired localizer signal level of -86 dBm and a standard undesired, first adjacent channel localizer test signal at a level of -52 dBm.

c. Adjacent channel signals are defined in paragraph 2.4.1. i.

2.2.2.2 Cross Modulation

The centering error as presented to the pilot shall not exceed those of Table 2-1 when the receiver is subjected to two signals having the following characteristics:

a. Undesired VOR Signal

(1) The desired localizer signal is varied from -86 dBm to -33 dBm.

(2) A -33 dBm undesired VOR signal is varied over the range from 108.00 MHz to 112.00 MHz, excluding the band from fc -98 kHz to fc +98 kHz.

b. Undesired Localizer Signal

(1) The desired localizer signal is varied from -86 dBm to -33 dBm.

(2) A -33 dBm undesired localizer modulated 30% with 150 Hz is varied over the range from 108.00 MHz to 112.00 MHz, excluding the band from fc -141 kHz to fc +141 kHz.

2.2.2.3 Receiver Performance With Two Carriers

a. Centering Signal

With a standard localizer centering signal 5 kHz above the selected channel frequency applied at levels from -82 dBm to -33 dBm, the addition of a second standard localizer signal 5 kHz below the selected channel frequency and at levels 10 dB below the first signal shall not cause additional centering error in excess of 25% of the declared class limit from Table 2-1, and shall not cause the warning device to alarm.

b. Full Scale Signal

With a standard localizer test signal in which the ddm is 0.155 applied 5 kHz above the selected channel frequency and at levels from -82 dBm to -33 dBm, the addition of a second standard localizer test signal 5 kHz below the selected channel in which the ddm is 0.10, and whose level is 10 dB below the level of the first signal, shall not cause additional deviation error in excess of 5% of standard deviation and shall not cause the warning device to alarm.

c. Off Scale Signal

With a standard localizer test signal in which the ddm is 0.4 applied 5 kHz above the selected channel and at levels from -82 dBm to -33 dBm, the addition of a second standard test signal 5 kHz below the selected channel in which the ddm is 0.3 and at a level 3 dB below the first signal shall not cause the indicator to indicate less than full scale or the warning device to alarm. Additionally, as the level of the second signal is slowly increased to a level 3 dB above the first signal, the indicator shall not indicate less than full scale and the warning device shall not alarm.

NOTE: The "direction" of the ddm, 90 Hz greater than 150 Hz, or 150 Hz greater than 90 Hz, should be the same for both signals.

2.2.2.4 Intermodulation

a. Centering Signal

The centering error as presented to the pilot shall not exceed those of Table 2-1 and all valid localizer signals shall remain in valid state when a -86 dBm standard localizer centering signal is added to two simulated FM broadcast signals. The following requirements apply:

$2N_1 + N_2 + 72 < 0$ for VHF FM sound broadcasting signals in the range 107.7 - 108.0 MHz

and

$2N_1 + N_2 + 3(24 - 20 \log \Delta f/0.4) < 0$ for VHF FM sound broadcasting signals below 107.7 MHz

Where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired ILS localizer frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the ILS localizer receiver input. Neither level shall exceed the desensitization criteria set forth in paragraph 2.2.6.

Δf (MHz) = 108.1 MHz - f_1 MHz, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

The levels are indicated in Figure 2-1.

b. Deviation Signal

The change in deviation as presented to the pilot shall not exceed those of Table 2-1 and all valid localizer signals shall remain in valid state when a -86 dBm standard localizer deviation signal is added to two simulated FM broadcast signals with the same conditions as in a.

2.2.2.5 Identification Components

The left/right information as presented to the pilot shall not change by more than the percentage of class selected (Table 2-1) when a standard localizer audio test signal at an RF level of -53 dBm is applied and the modulation signal is varied over the range 1020 $\pm$50 Hz.

2.2.3 Course Deviation Indication

If a course deviation indication is provided, the following requirements shall be met with input signal levels between -81.5 dBm to -33 dBm.

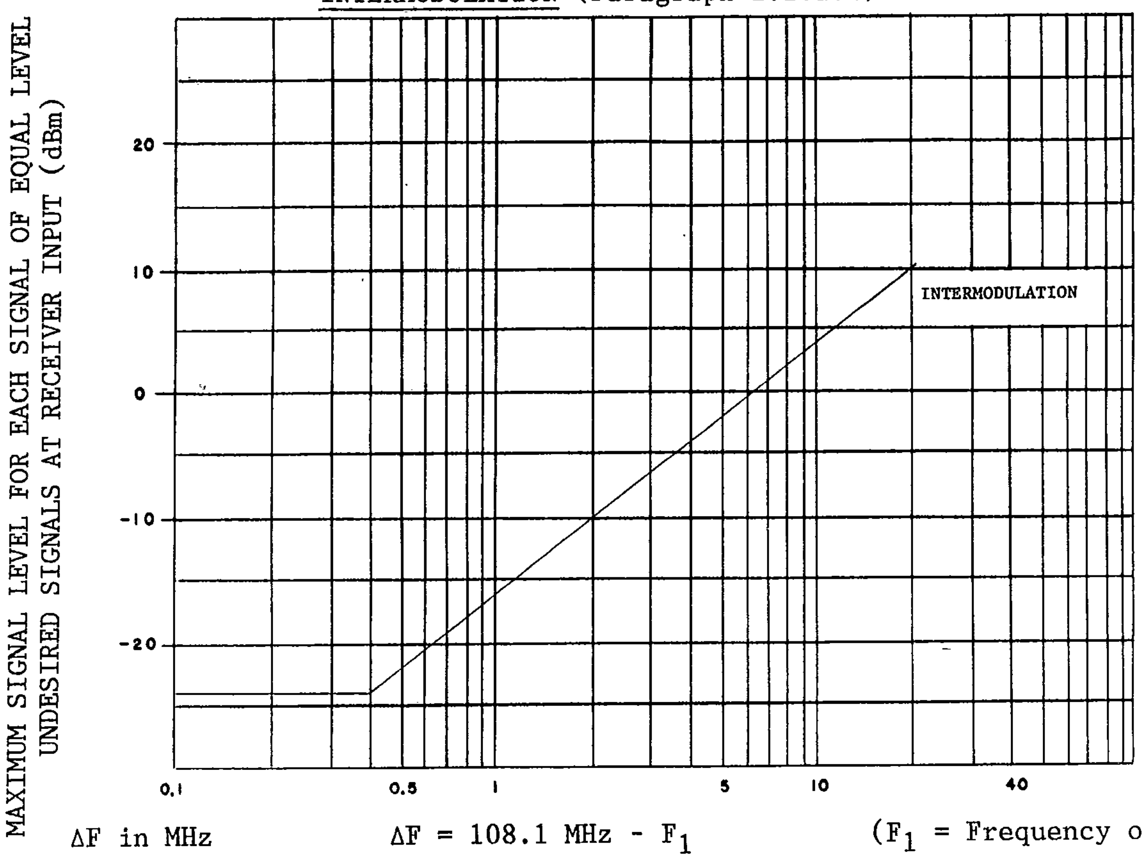
a. Deviation Sensitivity

The equipment shall provide a display for presentation of course deviation magnitude and direction of deviation. This output shall have sufficient dynamic range to display on 0.155 ddm left or right of center with a resolution of 0.016 ddm or better. This standard shall be met over the range of signal input level from -82 dBm to -33 dBm.

b. Deflection Linearity

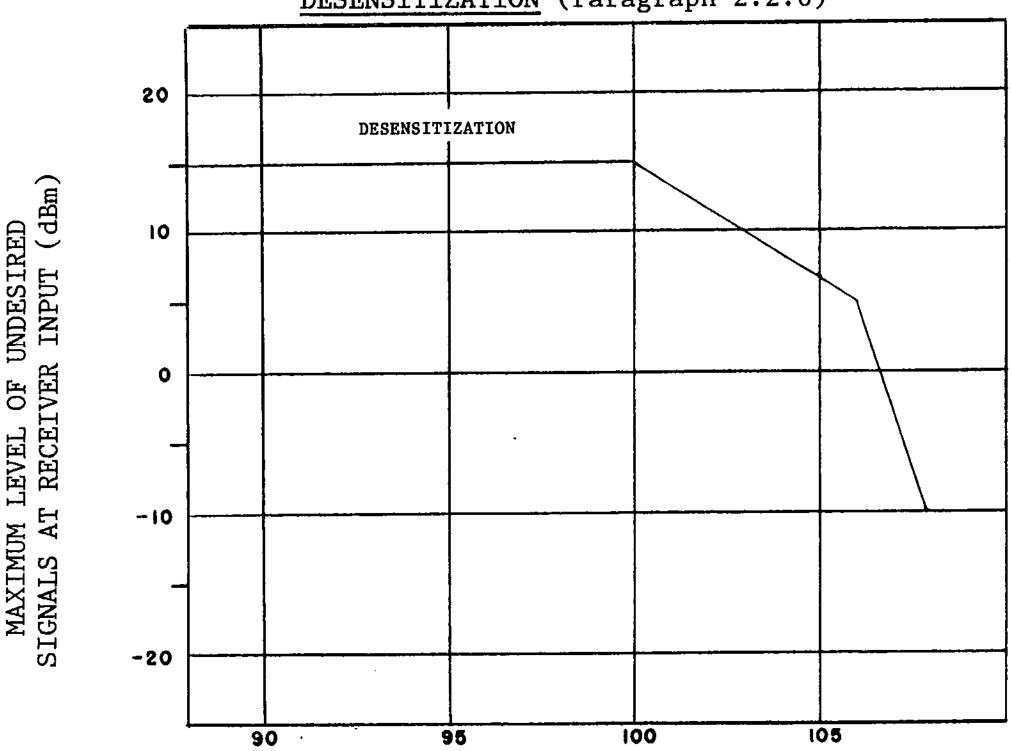
Over the deflection range from zero to 0.093 ddm, the deflection shall be within 10% of being proportional to the difference in depth of modulation of the 90 and 150 Hz signals, or the deflection shall be within 5% of Standard Deflection of being proportional to the difference in depth of modulation, whichever is greater.

INTERMODULATION (Paragraph 2.2.2.4)



ΔF in MHz $\Delta F = 108.1$ MHz - F_1 (F_1 = Frequency of N_1)

DESENSITIZATION (Paragraph 2.2.6)



Frequency in MHz

FIGURE 2-1 FREQUENCY OF UNDESIRED SIGNAL (MHZ)

Additionally, as the difference in depth of modulation is increased beyond that producing full scale deflection to a value of 0.4 ddm, the indicator deflection shall not decrease. These standards shall be met over the range of signal input level from -82 dBm to -33 dBm. In the case of deviation indicators utilizing pivoted pointers, angular linearity is implied.

c. Deflection Response

When the ddm of a standard localizer test signal is abruptly changed from zero to any value less than ± 0.155 ddm, the pointer shall reach 67% of its ultimate deflection within two seconds and pointer overshoot shall not exceed 5%.

d. Indicator Visibility

The display markings shall be visible from any point within the frustum of a cone the sides of which make an angle of 45 degrees with the perpendicular to the display and the small diameter of which is the aperture of the indicator. This requirement does not apply when viewing the indicator from aspect angles below the center of the indicator.

NOTE: Characteristics of the course deviation output of the receiver shall be compatible with the display and other functions for which it is intended. For example, the damping characteristic may differ among display processes (CDI, RMI, RNAV) and in different phases of flight. Output intended for use by flight control systems should have minimal damping and filtering so the installer can adapt to the FCS and aircraft characteristics involved.

2.2.3.1 Electrical Course Deviation Output

If the equipment is intended to provide electrical guidance information to an autopilot/coupler, the following requirement shall be met:

a. Course Deviation Current Linearity

Over the course deviation range from zero to ± 0.155 ddm, the deviation current shall be within 10% of being proportional to the difference in depth of modulation of the 90 and 150 Hz signals, or the deviation current shall be within 5% of standard deviation current of being proportional to the difference in depth of modulation, whichever is greater. Additionally, as the difference in depth of modulation is increased from ± 0.155 to 0.4 ddm, the deviation current shall not decrease. These standards shall be met over the range of signal input from -82 dBm to -33 dBm.

NOTE: For certain autopilot/coupler applications the course deviation current linearity range should extend to 0.10 ddm. Additionally, as the ddm is increased from 0.10 to 0.4 ddm, the current shall increase up to a value of at least 220 microamps and thereafter not decrease with increasing ddm.

b. Course Deviation Current Response

When the ddm of a standard localizer test signal is abruptly changed from zero to any value less than 0.155 ddm, the deviation current shall reach 67% of its ultimate value within 0.6 seconds and the overshoot shall not exceed 2%.

2.2.3.2 Deflection Stability with Modulation Frequency

The display indication or electrical output shall not depart from standard deflection by more than 15% of standard deflection when the frequency of the modulation signal of a -53 dBm standard localizer signal is simultaneously varied over the range from 98.5% to 101.5% of 90 and 150 Hz.

2.2.4 Warnings

A warning device shall be provided. The device shall be at least 50% visible or in the "warning" condition:

a. In the absence of an RF signal.

b. When either the 90 or 150 Hz modulating signals is removed and the other is maintained at its normal 20%.

c. In the absence of both 90 and 150 Hz modulation.

d. When the level of a standard localizer deviation test signal produces 50% or less of standard deflection of the deviation indicator.

2.2.5 Spurious Response

The input signal level of an undesired frequency required to produce a detector-carrier (AGC) level obtained with a -86 dBm standard audio test signal shall not be less than -26 dBm when:

a. The undesired input signal frequency is within 108.0 to 137.0 MHz and is on any frequency within ± 8 kHz of any assignable channel other than the desired channel and the upper and lower adjacent channels.

b. The undesired input signal frequency is between 10 kHz and 1,215 MHz excluding the band 108.0 - 137.0 MHz.

2.2.6 Desensitization

a. The addition of an undesired unmodulated carrier, of RF level and frequencies described below, to a standard localizer centering signal at an RF input level of -86 dBm on the selected channel shall not exceed the following effects on the desired signal.

(1) The centering error shall not change by more than the requirements of Table 2-1.

(2) The audio output level shall not change by more than 3 dB.

(3) The alarm signal shall not be in the "warning" condition.

Frequency (MHz)	Maximum Level of Unwanted Signal at Receiver Input
88-102	+15 dBm
104	+10 dBm
106	+ 5 dBm
107.9	-10 dBm

The relationship is linear between adjacent points designated by the above frequencies. The levels are indicated by Figure 2-1.

(4) The undesired unmodulated carrier will have an RF input level of -13 dBm at the receiver input terminals on any frequency from 50 kHz to 1215 MHz except as follows:

(a) Excluding the frequency range of 108.0 to 118.5 MHz.

(b) Its level shall not exceed the levels shown in Figure 2-1 for frequencies between 88 MHz and 107.9 MHz.

b. The error as presented to the pilot shall not exceed those of Table 2-1 and all valid localizer signals shall remain in valid state when a -86 dBm standard localizer deviation signal is added to the simulated FM broadcast signal with the same conditions as in a.

2.2.7 VOICE/IDENT Audio Output Level

An RF signal, modulated 30% at 1000 Hz, of not more than -86 dBm shall produce not less than the manufacturer's published rated output at a (S+N)/N ratio of not less than 20 dB. This standard shall be met over the range of signal level from -86 dBm to -33 dBm.

2.2.8 VOICE/IDENT Audio Frequency Response

a. The difference between the maximum and minimum VOICE/IDENT audio output levels shall not exceed 6 dB, when the audio modulating frequency of an RF signal, modulated input level varied over the range of 350 to 2,500 Hz, and when the RF input level is held constant at the value which produces a signal-plus-noise to noise ratio of not less than 20 dB at 1,000 Hz. Beyond 2,500 Hz, the audio output level shall not increase, and at frequencies of 150 Hz and below, and 9 kHz and above, it shall be at least 20 dB below the output level at the frequency of maximum response.

b. If a "VOICE/IDENT" filter is employed in the equipment:

(1) When the "IDENT" function is selected, the requirements of subparagraph a., above, shall not apply and the 1,020 Hz keyed identification signal shall be clearly audible. The existence of voice modulation shall be evident.

(2) When the "VOICE" function is selected, the requirements of subparagraph a., above, shall apply, except frequencies near 1,020 Hz may be attenuated. The attenuation of frequencies near 1,020 Hz shall not significantly impair voice intelligibility.

2.2.9 VOICE/IDENT AGC Characteristics

Within the limits of -86 dBm to -33 dBm, input of a standard localizer audio test signal, the difference between the maximum and minimum IDENT audio output levels shall not exceed 6 dB.

2.2.10 Deflection AGC Characteristic

When the receiver has been adjusted to produce deviation indicator standard deflection with a -53 dBm standard localizer deviation signal, the deviation indicator deflection, with RF input varied from -82 dBm to -33 dBm, shall be within ±20% of standard deflection.

2.2.11 Emission of Radio Frequency Energy

a. The conducted and radiated spurious radio frequency energy emission levels shall not exceed those specified in Section 21.0 of RTCA/DO-160B, "Environmental Conditions and Test Procedures for Airborne Equipment."

b. When the receiver is terminated in a resistive load of 50 ohms, the level of any spurious emission into the load shall not exceed -57 dBm over the frequency range of 10 kHz to 10 GHz except on the following frequency ranges:

74 - 76 MHz: -64 dBm
108 - 138 MHz: -64 dBm
329.0 - 335 MHz: -64 dBm
960 - 1,215 MHz: -90 dBm

NOTE: The level of localizer receiver radiation into the aeronautical bands listed above is sufficiently low to minimize interference except when two localizer receivers share a common antenna. Preferably the local oscillator should be kept out of the band 108-138 MHz, which will also allow the use of a common antenna for two localizer receivers.

2.2.12 Receiver Voltage Standing Wave Ratio (VSWR)

When the receiver is designed for use with a transmission line, the VSWR of the receiver input terminals shall not exceed 4:1 on the operating frequency over the radio frequency range of 108-112 MHz.

2.2.13 Antenna Efficiency[1]

a. Over the frequency range 108-112 MHz, the horizontal component of the radiated signal in the forward and rearward directions shall not be down more than 10 dB when compared to the maximum radiation from a standard horizontal dipole antenna resonant at 113 MHz and mounted 10 inches above the ground plane.

b. At any frequency within 108-112 MHz, the difference between the maximum and the minimum field strength of the horizontal component of the radiated signal in the azimuth plane shall not exceed 20 dB.

2.2.14 Antenna Polarization

Over the frequency range of 108-112 MHz, the reception of vertically polarized signals from any horizontal direction with respect to the antenna shall be at least 10 dB below the reception of horizontally polarized signals from the same direction.

2.2.15 Antenna VSWR

When the antenna to be used with the receiver is designed for use with a transmission line, the VSWR on the transmission line shall not exceed 6:1 over the radio frequency range 108-112 MHz.

[1]Although the antenna will be used as a receiving antenna, this standard is written in terms of a radiating antenna for convenience of testing.

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2.3 Equipment Performance - Environmental Conditions

The environmental tests and performance requirements described in this subsection provide a laboratory means of determining the overall performance characteristics of the equipment 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 under any of these additional environmental conditions, then the appropriate "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-160B, "Environmental Conditions and Test Procedures for Airborne Equipment."

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-160B. 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 conditions.

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

RTCA/DO-160B contains several temperature and altitude test procedures, which are specified according to equipment category. These categories are included in paragraph 4.3 of DO-160B. The following subparagraphs contain the applicable test conditions specified in Section 4.0 of DO-160B.

2.3.1.1 Low Temperature Test

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 4.5.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.3 a. - Deviation Sensitivity
c. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

2.3.1.2 High Temperature Test

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.3 a. - Deviation Sensitivity
c. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

2.3.1.3 Altitude Tests

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 4.6.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.3 a. - Deviation Sensitivity
c. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

2.3.1.4 Decompression Test - (When Required)

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

2.3.1.5 Overpressure Test - (When Required)

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

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

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 5.3, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.3 a. - Deviation Sensitivity
c. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

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

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 6.3, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.3 a. - Deviation Sensitivity
c. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

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

2.3.4.1 Operational Shocks

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 7.2.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met. Additionally, all mechanical devices shall perform their intended functions.

2.3.4.2 Crash Safety Shocks

The application of the crash safety shock test 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 2.1.8, "Effects of Test," does not apply.

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 7.3.1, and shall meet the requirements specified therein.

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings

Following the test, the requirements of paragraph 2.2.15, Antenna VSWR, shall be met.

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

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, 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-160B, 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-160B, paragraph 10.3.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR

2.3.7.2 Spray Proof Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 10.3.2, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR

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

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

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

2.3.8.1 Spray Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 11.4.1, 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 that indicates significant failures of components or circuitry have not 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 2.2.1 a. - Centering Accuracy
(2) Paragraph 2.2.4 - Warnings
(3) Paragraph 2.2.15 - Antenna VSWR

2.3.8.2 Immersion Test (When Required)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraph 11.4.2, 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 that indicates significant failures of components or circuitry have not 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 2.2.1 a. - Centering Accuracy
(2) Paragraph 2.2.4 - Warnings
(3) Paragraph 2.2.15 - Antenna VSWR

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR

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

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, 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-160B, Section 16.0)

2.3.13.1 Normal Operating Conditions

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraphs 16.5.1 and 16.5.2, as appropriate, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

2.3.13.2 Abnormal Operating Conditions

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160B, paragraphs 16.5.3 and 16.5.4, as appropriate, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

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

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

2.3.14.1 Category A Requirements (If Applicable)

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

2.3.14.2 Category B Requirements (If Applicable)

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

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

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

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 - Warnings
c. Paragraph 2.2.15 - Antenna VSWR (if applicable)

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

This environmental condition is also covered in paragraphs 2.2.11 and 2.4.3.10.

Test the equipment in accordance with the procedures contained in RTCA/DO-160B, Section 21.0.

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 following equipment tests:

a. Power Input Voltage - Direct Current - Unless otherwise specified, when the equipment is designed for operation from a direct current power source, all measurements shall be conducted with the input voltage adjusted to 13.75 V ±2% for 12-14 V equipment, or to 27.5 V ±2% for 24-28 V equipment. The input voltage shall be measured at the receiver power input terminals.

b. Power Input Voltage - Alternating Current - Unless otherwise specified, when the equipment is designed for operation from an alternating current power source, all tests shall be conducted with the power input voltage adjusted to design voltage ±2%. In the case of equipment designed for operation from a power source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency ±2%. In the case of equipment designed for operation from a power source of variable frequency (e.g., 350 to 1,000 Hz) tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency 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.

d. Test Instrument Precautions - Due precautions shall be taken during the tests to prevent the introduction of errors resulting from the improper connection of headphones, 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. 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.

g. RF Signal Levels - All RF signal levels are expressed in dBm (see Appendix B).

NOTE: In the case of a receiver designed for a transmission line having a nominal characteristic impedance other than 50 ohms, the RF voltage shall produce the same power into the nominal characteristic impedance.

h. Standard Test Signals - Unless otherwise specified, the RF input signals shall be at a level of -53 dBm and have a frequency within .001% of the assigned carrier frequency in addition to the following characteristics:

(1) Standard Localizer Centering Test Signal - An RF carrier modulated simultaneously by (a) 20 ±1% 90 Hz ±0.3% sine wave and (b) 20 ±1% 150 Hz ±0.3% sine wave. The difference in depth of modulation (ddm) is less then 0.002.

(2) Standard Localizer Deviation Test Signal - An RF carrier modulated simultaneously by (a) 90 Hz ±0.3% sine wave and by (b) 150 Hz ±0.3% sine wave with a composite modulation percentage of 40 ±2% with a difference of depth of modulation of 0.093 ±.002 (4 ±0.1 dB).

(3) Standard Localizer Audio Test Signal - A standard localizer test signal to which is added a 1,020 Hz signal amplitude modulating the carrier 30%.

(4) Standard Audio Test Signal - An RF carrier amplitude modulated 30% at 1,020 Hz.

i. Undesired Test Signal

(1) Standard Undesired VOR Test Signal - An RF carrier, amplitude modulated simultaneously (a) 30 +1% by a "reference phase signal," composed of a 9,960 Hz subcarrier, which is, in turn, frequency modulated at a deviation ratio of 16 by a 30 +0.1% Hz signal, and (b) 30 +1% by a 30 +0.1% Hz "variable phase signal" that can be varied in phase with respect to the 30 Hz FM of the reference phase.

(2) Standard Undesired Localizer Test Signal - An RF carrier amplitude modulated 30% at 150 Hz applied at an RF carrier frequency other than the desired channel.

(3) Standard Undesired, First Adjacent Channel VOR Test Signal - A standard undesired VOR test signal separated from the desired signal frequency (fo) by:

a. +50 kHz minus 0.002% of (fo + 50 kHz).
b. -50 kHz plus 0.002% of (fo - 50 kHz).

(4) Standard Undesired, First Adjacent Channel Localizer Test Signal - A standard undesired localizer test signal separated from the desired signal frequency (fo) by:

a. +50 kHz minus 7 kHz minus 0.002% of (fo + 50 kHz).
b. -50 kHz plus 7 kHz plus 0.002% of (fo - 50 kHz).

j. Standard Deflection - Standard deflection shall be either 60% (90 microamps) of full scale deflection, or that deflection which is obtained when the difference in depth of modulation of the 90 and 150 Hz signals is 0.093 in non-linear indicators. In both of the above cases, the receiver shall be adjusted to produce standard deflection when the input signal is a standard localizer deviation signal of -53 dBm.

k. Receiver Sensitivity - The receiver sensitivity is the minimum power level in dBm of a standard localizer test signal required to produce simultaneously (1) a deflection of the deviation indicator of at least 50% of standard deflection, and (2) erratic movement of the deviation indicator due to noise of not more than ±5% of standard deflection.

l. Non-applicability of Conditions of Test - In those cases in which it can be shown that the conditions of test set forth above are not applicable to a particular receiver, the conditions of test may be modified as required by the design of the receiver.

2.4.2 Description of Test Equipment

a. NAV Signal Generator

The NAV signal generator shall be capable of generating the standard test signals described in paragraph 2.4.1 and shall have the following additional capabilities:

(1) Shall tune to all 50 kHz channels from 108.00 to 117.95 MHz with a carrier frequency accuracy of 0.001%.

(2) Shall have an output level adjustable from -92 dBm to -5 dBm.

(3) Shall be able to amplitude modulate from 0% to at least 30%.

(4) Shall be able to provide the standard VOR signal in lieu of the standard localizer test signal.

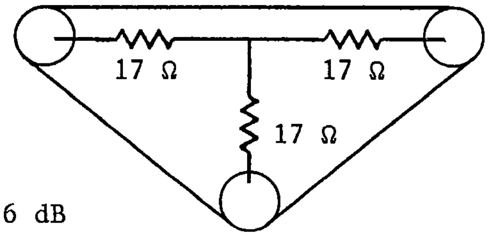
(5) Shall have all modulation frequencies (as a group) adjustable ±1.5% from the standard values.

(6) Shall be able to vary output frequency from standard channel frequencies up to 0.01%.

b. Power Divider

A 3-branch "T" pad allowing mixing of two 50 ohm sources to a 50 ohm load without impedance mismatching.

Representative:



NOTE: insertion loss = 6 dB

c. LF Sine Wave Function Generator

(1) Frequency range 1 Hz to 4,000 Hz.
(2) Output voltage up to 3V peak to peak into 50 ohms.
(3) Distortion less than 2%.

2.4.3 Detailed Test Procedures

The following test procedures are considered satisfactory in determining required performance. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternate procedures may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

2.4.3.1 Centering Accuracy (paragraph 2.2.1)

Equipment Required

NAV signal generator.

Power source providing DC or AC power having a frequency range covering that for which the receiver is designed.

Measurement Procedures[1]

a. Apply to the receiver input a standard localizer centering signal. Determine the centering accuracy when:

   (1) The frequency of the 90 Hz and 150 Hz signals is held to $\pm 0.3\%$.

   (2) The primary power voltage at the input terminals of the equipment is held to within 2% of the nominal design voltage.

   (3) The percentage modulation of the 90 and 150 Hz signal is held between the limits of 20% $\pm 1\%$.

   (4) The ambient air temperature surrounding the equipment is between 10 and 30 degrees Centigrade.

   (5) The carrier frequency of the test signal is within .001% of the assigned channel frequency.

   (6) The power supply frequency (AC source only) is 400 Hz $\pm 2\%$, or within 5% of any other nominal power supply frequency for which equipment is designed.

   (7) Interfering signals are not present.

   (8) RF input voltage is -53 dBm.

b. Apply to the receiver input terminals a standard localizer centering test signal and determine the maximum algebraic difference in indicated left/right displacement for each of the following special conditions.

   (1) Simultaneously, vary the frequency of the 90 Hz and 150 Hz signals between the limits of $\pm 1.5\%$.

   (2) Vary the primary power voltage at the input terminals of the equipment between the limits of $\pm 10\%$ of the nominal design voltage.

   (3) Simultaneously, vary the percentage of modulation of the 90 and 150 Hz signals from 18% to 22%.

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[1] It is not required that equipment be subjected to all combinations of the above variable conditions simultaneously to determine compliance with this standard. Appendix A, "Statistical Procedure for the Determination of ILS Receiver Course Error" sets forth a statistical method for determining the maximum on-course (centering) errors of ILS localizer and glide slope receivers.

(4) Vary the ambient air temperature between the operating temperature limits of the temperature-altitude category for which the equipment is designed.

(5) Vary the carrier frequency of the test signal between limits of ±9 kHz of the assigned channel frequency.

(6) Vary the power supply frequency (AC source only) between the design limits of the equipment.

(7) Vary the RF signal level between -79 dBm to -33 dBm.

(8) Turn on and off the IDENT portion of a standard localizer audio test signal.

(9) Vary the phase relationship of the 90 and 150 Hz modulation signals from the correct phasing ±12 degrees of the common 30 Hz subharmonic. During this test a standard localizer audio test signal shall be applied.

NOTE: During all of the tests ensure that the warning flag always remains out of view.

2.4.3.2 Interfering Signals (paragraph 2.2.2)

a. Adjacent Channel Signals

Equipment Required

2 NAV signal generators.
Power divider.

Measurement Procedure

(1) Apply to one input of the power divider a standard localizer centering test signal (desired) at a level of -80 dBm at the frequency to which the receiver is tuned. Apply to the other input of the power divider a standard undesired, first adjacent channel VOR test signal. Vary the undesired signal level from -80 dBm to -46 dBm at the upper and then lower adjacent channel. Determine the positive and negative centering errors caused by the undesired test signal. The receiver frequency tolerance shall be noted.

(2) Apply Test (1) above using a standard undesired, first adjacent channel localizer test signal in lieu of the undesired VOR test signal.

b. Cross Modulation (paragraph 2.2.2.2)

Equipment Required

2 NAV signal generators.
Power divider.

Measurement Procedure

(1) Apply to one input of the power divider a standard localizer centering test signal (desired) at a level of -80 dBm at the frequency to which the receiver is tuned. Apply to the other input of the power divider an undesired VOR test signal at a level of -27 dBm, which is varied from 108.00 to 112.00 MHz, excluding the band from fc -98 kHz to fc +98 kHz. Determine the positive and negative deviation.

(2) Apply to one input of the power divider a standard localizer centering test signal (desired) at a level of -80 dBm at the frequency to which the receiver is tuned. Apply to the other input of the power divider an undesired localizer test signal at a level of -27 dBm, which is varied from 108.00 to 112.00 MHz, excluding the band from fc -141 kHz to fc +141 kHz.

c. Receiver Performance With Two Carriers (paragraph 2.2.2.3)

Equipment Required

Two NAV signal generators
Power divider

Measurement Procedure

(1) Apply to one input of the power divider a standard localizer centering test signal at a level of -76 dBm, 5 kHz above a selected channel frequency.

(2) Apply to the other input a standard localizer centering test signal 10 dB below the level of (1) above and with the modulation tones phase locked to those in (1), and 5 kHz below the selected channel frequency.

(3) Increase the level of (1) to -67 dBm, -47 dBm and -27 dBm, holding the level of (2) 10 dB lower.

(4) Apply to one input of the power divider a standard localizer test signal at a level of -76 dBm, 5 kHz above the selected channel frequency in which the ddm is 0.155.

(5) Apply to the other input a standard localizer test signal 5 kHz below the selected channel frequency in which the ddm is 0.1 and whose level is 10 dB below the level of (4).

(6) Increase the level of (4) to -67 dBm, -47 ddm and -27 dBm, holding the level of (5) 10 dB lower.

(7) Apply to one input of the power divider a standard localizer test signal at a level of -76 dBm, 5 kHz above the selected channel frequency in which the ddm is 0.4.

(8) Apply to the other input a standard localizer test signal 5 kHz below the selected channel in which the ddm is 0.3 and at a level 3 dB below the level of (7). Slowly vary the level of the second signal to a level 3 dB above the level in (7).

(9) Repeat the test by increasing the level of the signal in (7) to -67 dBm, -47 dBm and -27 dBm, with the level of the signal in (8) 3 dB below the level of the signal in (7), and slowly varying the level of the second signal to a level 3 dB above the first signal.

d. Intermodulation (paragraph 2.2.2.4)

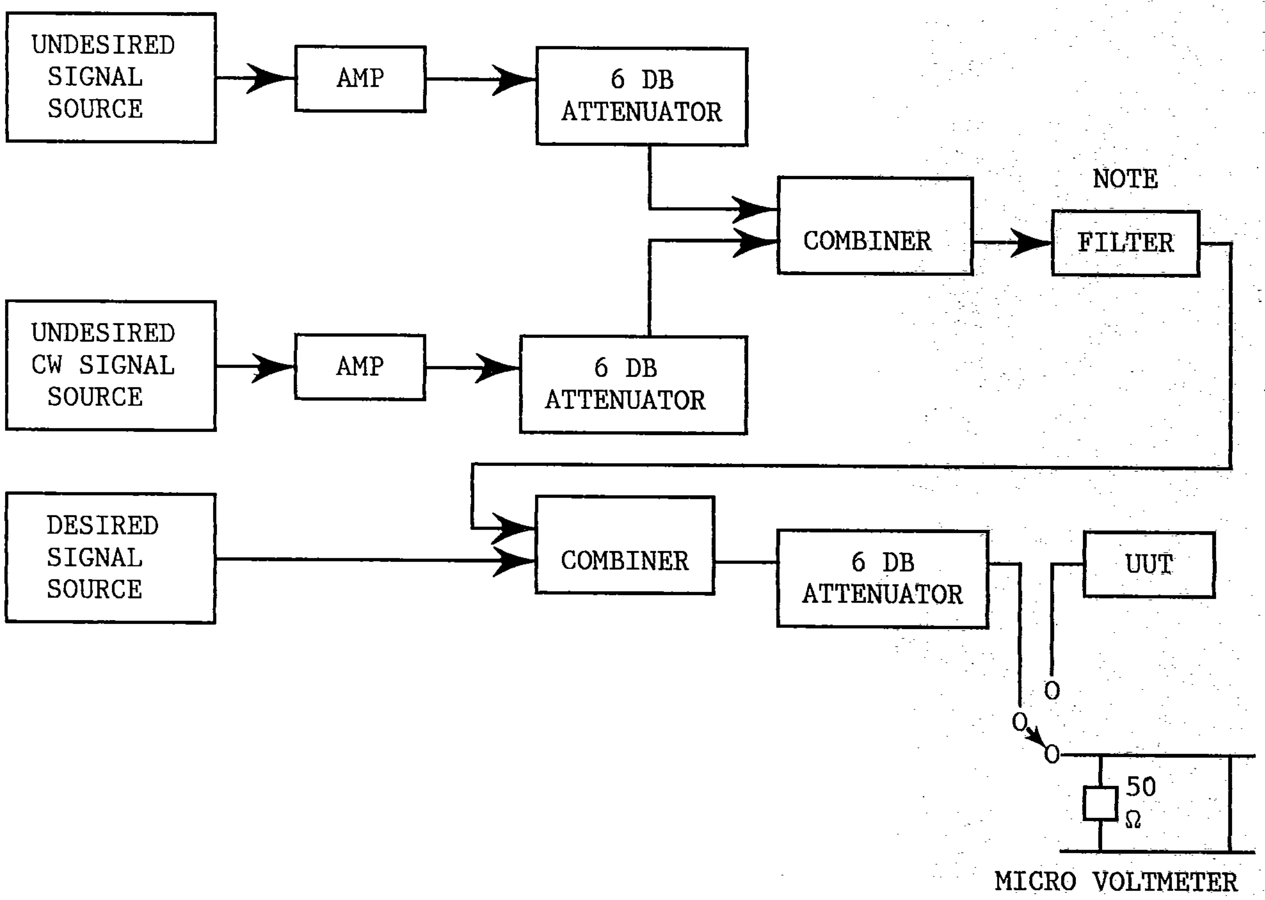
Equipment Required

1 NAV generator
2 CW generators (HP 8640 or equivalent)
2 combiners (Mini-circuits Model ZFSC-2-1)
1 pink noise or CCIR colored noise generator
1 filter (bandpass or low pass as required)
3 6 dB attenuators
1 microvoltmeter
2 linear amplifiers

Measurement Procedure

To one input of the combining unit apply a standard localizer audio test signal. To the other input apply a modulated RF carrier at the level and frequencies specified. Determine the change in localizer centering indication. Identify output level, and condition of the warning due to the addition of the modulated RF carrier.

(1) Connect the receiver to the test setup described in Figure 2-2.



NOTE: A filter configuration may be required to prevent noise and/or harmonics generated by the test equipment from reaching the unit under test. It is permissible to remove any signal(s) not representing the simulated broadcast spectrums.

FIGURE 2-2 INTERMODULATION TEST SETUP

(2) Adjust a standard localizer centering test signal to -86 dBm at receiver input tuned to 108.1 MHz. Apply two undesired signals at levels specified to the combining network. Frequency modulate N_1 with a pink noise or CCIR colored noise source for a peak frequency deviation of + and - 75 kHz.

The test shall be performed at the following discrete frequencies:

N_1	N_2
107.7 MHz	107.3 MHz
103.0 MHz	97.9 MHz
98.0 MHz	87.9 MHz

(3) Determine whether the equipment meets the requirements of paragraph 2.2.2.4 up to when $N_1 = N_2$.

(4) Determine that a warning flag occurs under the following conditions:

(a) When either of the two components are removed from the localizer test generator.

(b) When the desired RF signal is removed.

(5) Repeat steps 1 through 4 with a -86 dBm standard localizer deviation test signal in place of the standard localizer centering signal.

e. Identification Components (paragraph 2.2.2.5)

Equipment Required

NAV signal generator.

Measurement Procedure

Set the NAV signal generator to produce a standard localizer centering test signal at a level of -53 dBm. Apply an Ident signal of 1020 Hz and record any deviation.

2.4.3.3 Course Deviation Indication (paragraph 2.2.3)

Equipment Required

NAV signal generator.

Measurement Procedure

a. Deflection Sensitivity

To the receiver input, apply a -73 dBm standard localizer deviation test signal with a ddm of 0.155, 90 Hz. Decrease the ddm to 0.139, 90 Hz and measure the visible change in deflection. Repeat the above using a ddm of 0.155, 150 Hz and 0.139, 150 Hz respectively. Repeat the above at signal levels of -86 dBm and -33 dBm.

b. Deflection Linearity

To the receiver input, apply a -73 dBm standard localizer centering test signal. Set the centering signal of the signal generator to 0.046, 0.093 and 0.155 ddm. Measure the deviation indicator deflection increments. Increase the ddm to 0.400 and determine whether the deviation indicator deflection decreases for ddm increase throughout this range. Repeat the above at signal levels of -82 dBm and -33 dBm.

c. Deflection Response

Apply to the receiver input a -53 dBm standard localizer centering test signal. Abruptly change the relative levels of the 90 and 150 Hz modulation signals to produce values of ddm between 0 and 0.155. At each value of ddm, determine the time required for the deviation indicator pointer to reach 67% of its ultimate deflection. Also determine the amplitude of the pointer overshoot beyond its ultimate deflection.

2.4.3.3.1 Electrical Course Deviation Output (Paragraph 2.2.3.1)

Equipment Required

Nav signal generator
Deviation indicator

Measurement Procedure

a. Course Deviation Current Linearity

Apply to the receiver input a standard localizer centering signal. Then vary the difference in the depth of modulation of the 90 and 150 Hz modulating signals over the range of 0.000 to 0.400 ddm and determine the proportionality of the difference in depth of modulation to the current through the deviation indicator or load resistor. Conduct this test at receiver input levels over the range of -82 dBm to -33 dBm.

b. Course Deviation Current Response

Apply to the receiver input a -53 dBm standard localizer centering test signal. Abruptly change the relative levels of the 90 and 150 Hz modulation signals to produce values of ddm between 0.000 and .155. At each value of ddm, determine the time required for the deviation current to reach 67% of its ultimate value. Also determine the amplitude of the deflection current overshoot beyond its ultimate value.

2.4.3.3.2 Deflection Stability with Modulation Frequency Variation (Paragraph 2.2.3.2)

Equipment Required

Nav signal generator
Deviation indicator

Measurement Procedure

Apply to the receiver input a standard localizer deviation test signal of -53 dBm. Vary the frequency of the modulation signals simultaneously over the range from 98.5% to 101.5% of 90 and 150 Hz. Determine the change in deviation indicator deflection from standard deflection.

2.4.3.4 Warnings (paragraph 2.2.4)

Equipment Required

NAV signal generator.

Measurement Procedure

To the receiver input apply a standard localizer test signal at center response frequency and having a level of -53 dBm.

a. Determine the position or response of the warning device under the following conditions:

(1) No RF signal.

(2) When the 90 Hz modulation is removed from carrier and the RF input level is varied between -86 dBm and -33 dBm.

(3) When the 150 Hz modulation on an otherwise standard localizer test signal is removed and the RF input level is varied between -86 dBm and -33 dBm.

b. When the receiver input signal level is reduced to the point where the defection sensitivity to a 0.093 ddm is half of that obtained with a -53 dBm input signal.

c. Determine that a warning flag occurs under the following conditions:

(1) When either of the two components are removed from the test generator.

(2) When the RF signal is removed.

2.4.3.5 Spurious Response (paragraph 2.2.5)

Equipment Required

1 Nav signal generator.
Output power meter.

Measurement Procedures

To the receiver input apply a -86 dBm standard audio test signal on the selected frequency. Record the audio or detector carrier (AGC) output level as reference. Change the RF frequency and level to those specified and determine that the audio or detector carrier (AGC) output never exceeds the reference level.

2.4.3.6 Desensitization (paragraph 2.2.6)

Equipment Required

1 NAV signal generator
1 CW signal generator (HP 8640B or equivalent)
1 filter (bandpass or low pass as required)
1 6 dB attenuator (FP 50 Texscan)
1 microvoltmeter
1 amplifier
1 combiner

Measurement Procedure

To one input of the combining unit apply a standard localizer centering test signal tuned to 108.1 MHz. To the other input apply an RF carrier at the level and frequencies specified. Determine the change in centering error, audio output level and condition of the warning due to the addition of the unmodulated RF carrier.

The following discrete frequencies and levels are to be tested.

107.9 MHz/-10 dBm
102.0 MHz/+15 dBm
88.0 MHz/+15 dBm

a. Apply to the UUT a standard localizer centering test signal of -86 dBm and one signal at levels specified in paragraph 2.2.6. Set up test equipment as shown in Figure 2-3.

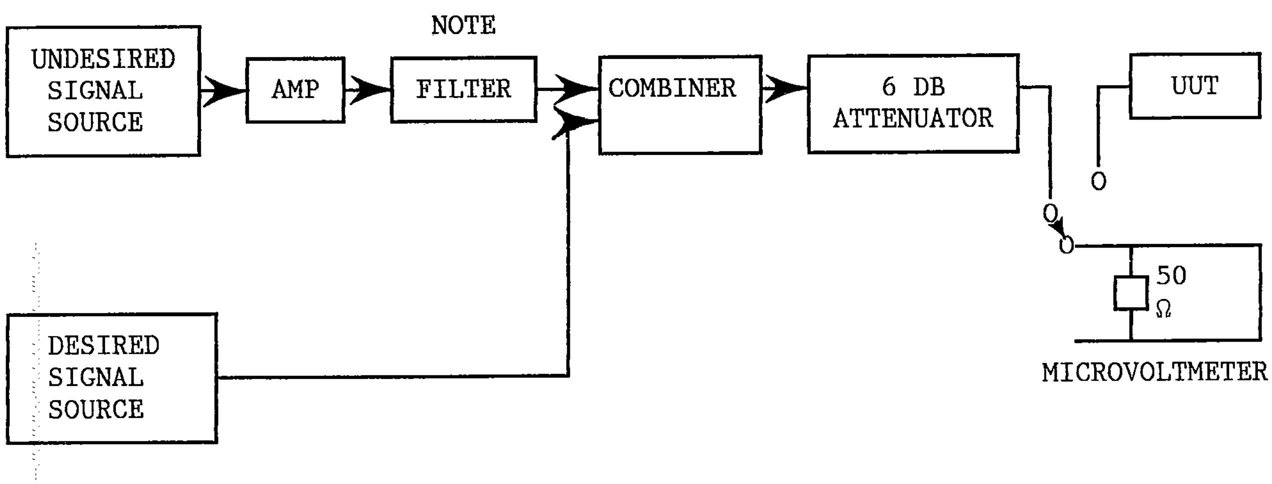
b. Determine whether the UUT meets the requirements of paragraph 2.2.6

c. Determine that a warning flag occurs under the following conditions:

   (1) When either of the two components are removed from the localizer test generator.

   (2) When the desired RF signal is removed.

d. Repeat steps a through c with a -86 dBm standard localizer deviation test signal in place of the standard localizer centering signal.



NOTE: A filter configuration may be required to prevent noise and/or harmonics generated by the test equipment from reaching the unit under test. It is permissible to remove any signal(s) not representing the simulated broadcast spectrums.

FIGURE 2-3 DESENSITIZATION TEST SETUP

2.4.3.7 VOICE/IDENT Audio Output Level (paragraph 2.2.7)

Equipment Required

NAV signal generator.
Output power meter.
Distortion power meter.

Measurement Procedure

To the receiver input apply a standard audio test signal. The RF input level required to produce a signal-plus-noise-to-noise ratio of 20 dB at the manufacturer's published rated output shall not exceed -86 dBm.

2.4.3.8 VOICE/IDENT Audio Response (paragraph 2.2.8)

Equipment Required

NAV signal generator.
Output power meter.
Distortion power meter.

Measurement Procedure

a. Apply to the receiver input a standard localizer audio test signal. Adjust the RF signal level to produce an audio output signal-plus-noise-to-noise ratio of at least 20 dB and the receiver audio gain control (if provided) to produce rated output or greater.

   Change the modulating frequency to cover the range of 350 to 2,500 Hz and determine the difference between maximum and minimum output level.

   Vary the modulating frequency beyond 2,500 Hz and determine that the audio level does not increase.

   Vary the modulating frequency to 150 Hz and below, and 9 kHz and above, and determine that the audio level is at least 20 dB below the output at the frequency of maximum response.

b. If a "VOICE/IDENT" filter is employed in the equipment:

   (1) When the "IDENT" function is selected, the requirements of subparagraph a. above do NOT apply. Determine that a 1,020 Hz keyed identify signal is clearly audible and the existence of voice modulating is evident.

(2) When the "VOICE" function is selected, the requirements of subparagraph a. do apply except that frequencies near 1,020 Hz may be attenuated. However, the voice intelligibility shall not be significantly impaired due to the attenuation of frequencies near 1,020 Hz.

2.4.3.9 AGC Characteristic (paragraph 2.2.10)

Equipment Required

NAV signal generator.
Output power meter.

Measurement Procedure

To the receiver apply a standard localizer centering test signal and adjust the receiver gain control, if provided, for rated audio output at that RF signal input level between -86 dBm and -33 dBm which produces a maximum output. Vary the RF input signal level to cover the range of -86 dBm to -33 dBm and determine the maximum and minimum audio output levels.

2.4.3.9.1 Deflection AGC Characteristics (paragraph 2.2.10)

Equipment Required

Nav signal generator

Measurement Procedure

Apply to the receiver input terminals a standard localizer deviation test signal. Adjust the receiver for standard deflection with an RF input signal of -53 dBm. Determine the maximum positive and negative changes of deviation when the RF level of the input signal is varied over the range of -86 dBm to -33 dBm.

2.4.3.10 Emission of Radio Frequency Energy (paragraph 2.2.11)

To be measured using the test setup and procedures defined in Section 21.0 of RTCA/DO-160B.

2.4.3.11 Receiver VSWR (paragraph 2.2.12)

Equipment Required

Impedance bridge.

Measurement Procedure

With the impedance bridge, measure the impedance of the receiver input circuit when it is tuned to 108.1, 111.95. Compute the VSWR. The level of the input signal shall not overload the receiver input circuit.

2.4.3.12 Antenna Efficiency (paragraph 2.2.13)

Equipment Required

Ground plane.
Standard dipole antenna (1/2" diameter, length adjusted to 113 MHz when testing the narrowband antenna, or 122 MHz when testing the wideband antenna, of aluminum, or equivalent).
NAV signal generator.
Field strength meter.
Matching stubs, or equivalent matching device.
Standard test antenna (6 dB 50 ohm pad).

Measurement Procedure

Refer to Figure 2-4. Mount the standard dipole antenna in a horizontal position at the center of the ground plane. Elevate the dipole 10 inches above the ground plane, using a nonconductive pedestal, such as polystyrene. Match the standard dipole for an SWR of 1.2:1, or less, at the signal generator and transmission line impedance, using the tuning stubs or equivalent device, at a frequency of 113 MHz (narrowband antenna) or 122 MHz (wideband antenna). With the field strength receiving antenna horizontal to the ground, locate it at least 50 feet from the dipole and at the same elevation. Rotate the standard dipole to direct a maximum of radiation toward the field strength receiving antenna. (The axis of both the standard dipole and the field strength antenna should be perpendicular in the horizontal plane to a line connecting the two.) Adjust the input signal level for a satisfactory indication on the field strength meter at the separation distance between the two antennas. Refer to Figure 2-5. Mount the antenna to be tested in the prescribed manner in place of the standard dipole and elevating pedestal. Measure the signal input required to produce the reference field strength at the reference separation and elevation. Rotate the ground plane with the antenna being tested to determine all minimum and maximum radiation points.

2.4.3.13 Antenna Polarization (paragraph 2.2.14)

Equipment Required

Ground plane.
Signal generator.
Field strength meter.
Standard test antenna.

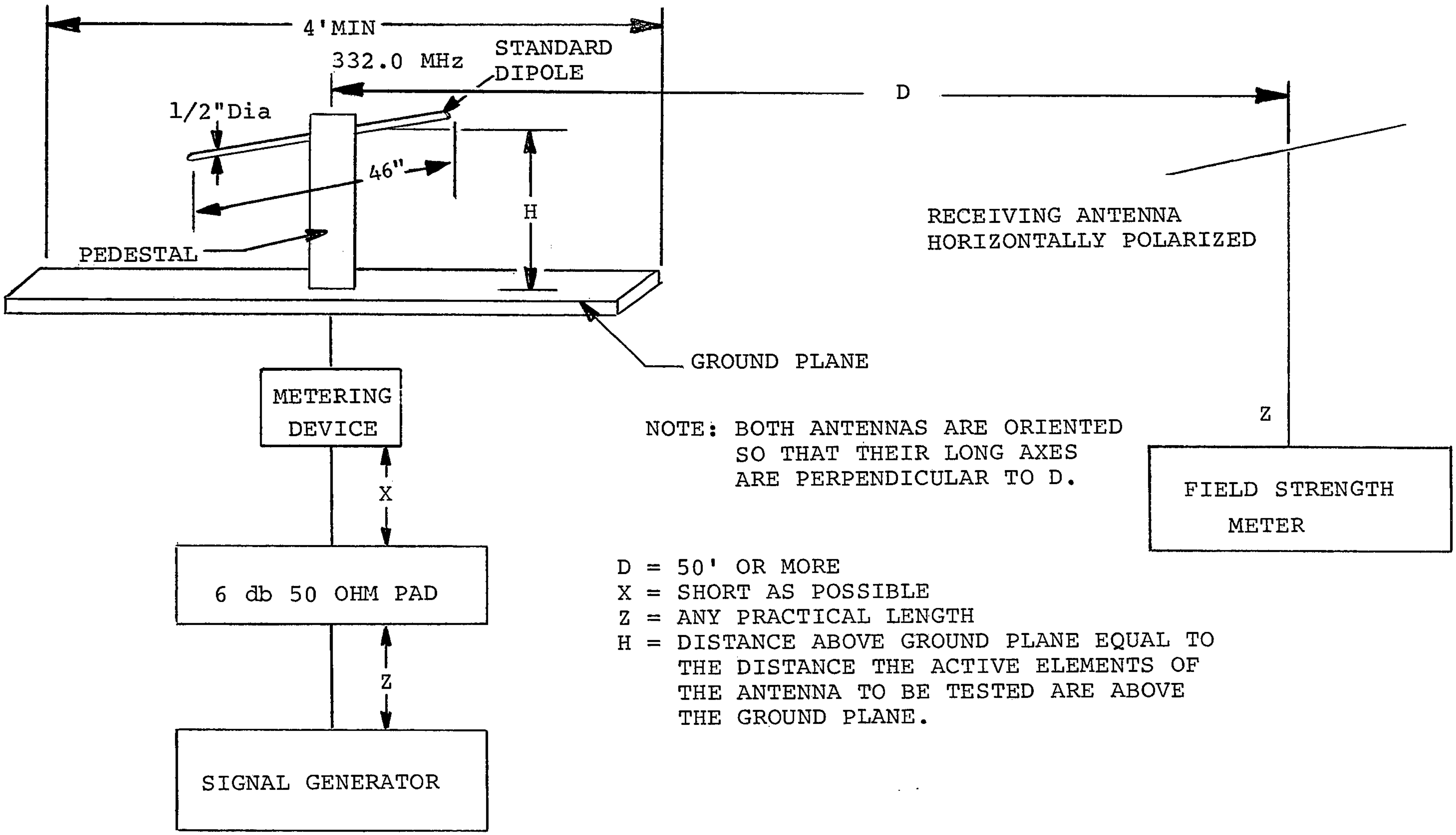


Figure 2-4 - Set-up for Obtaining Antenna Efficiency Level

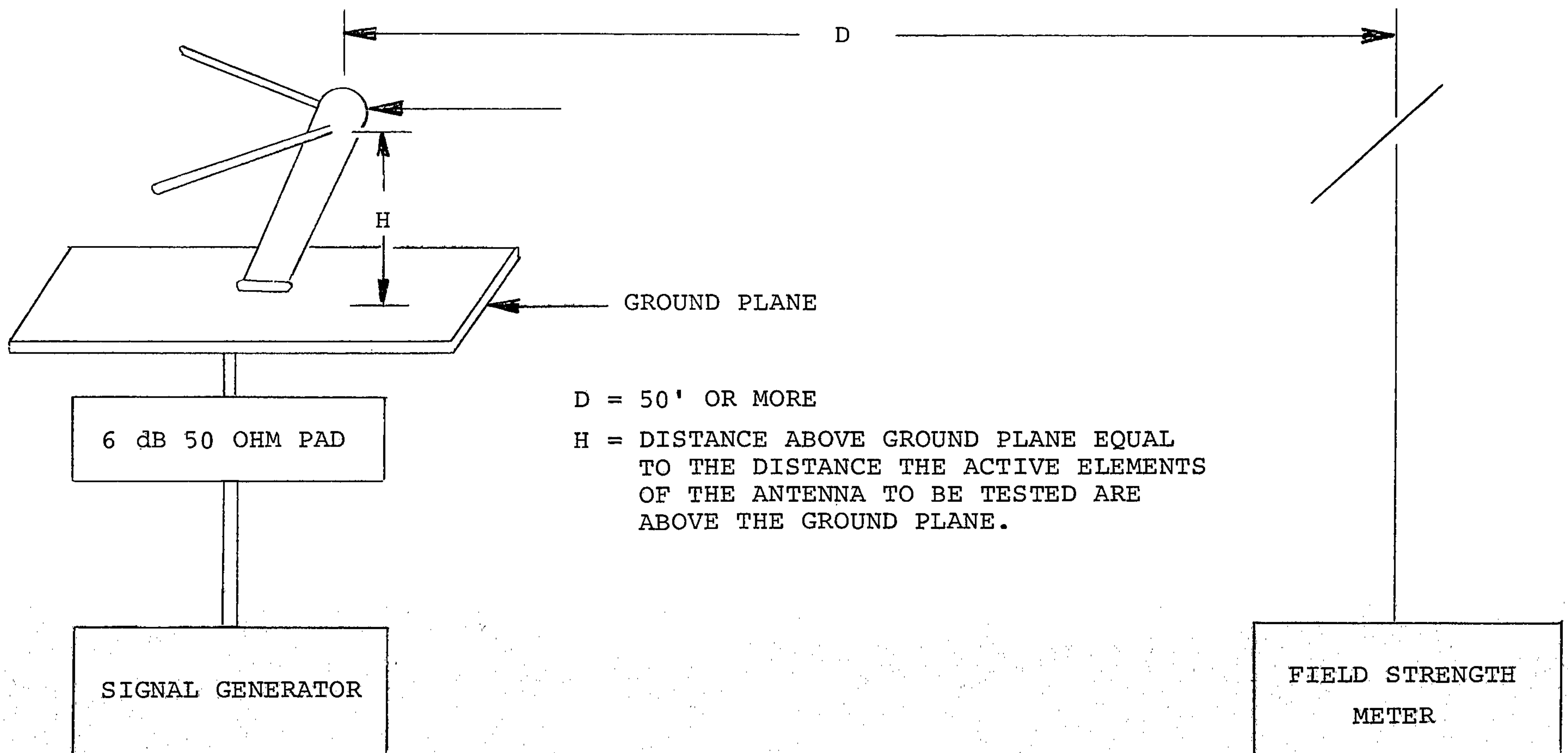


Figure 2-5 - **Set-up for Testing Antenna Efficiency and Polarization**

Measurement Procedure

Refer to Figure 2-4. Mount the antenna to be tested in the prescribed manner at the center of the ground plane. Locate the field strength receiving antenna at least 50 feet from the antenna being tested and at the same elevation. Determine the ratio between the horizontal and vertical components of field strength at 113 MHz and at all azimuth angles that are multiples of 30 degrees.

2.4.3.14 Antenna VSWR (paragraph 2.2.15)

Equipment Required

Impedance bridge.

Measurement Procedure

With the impedance bridge, measure the impedance of the antenna input circuit and compute the VSWR.

3.0 INSTALLED EQUIPMENT PERFORMANCE

3.1 Equipment Installation

When installed in the aircraft, the equipment shall not impair airworthiness of the aircraft.

3.1.1 Equipment Accessibility

The equipment controls installed for in-flight operation shall be readily accessible to a crew member from the normal seated position.

3.1.2 Aircraft Environment

The equipment performance shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed.

3.1.3 Display Visibility

The appropriate operator/crew member(s) shall have an unobstructed view of the display(s) when in the normal sitting position. Display intensity shall be adjustable to levels suitable for data interpretation under all cockpit ambient light conditions ranging from total darkness to reflected sunlight. Visors, glareshields or filters may be an acceptable means of obtaining daylight visibility.

3.1.4 Antenna Location Considerations

Except for antenna blanking causing loss of signals during turns, operation of the equipment shall not be adversely affected by aircraft maneuvering, changes in attitude encountered in normal flight operations or changes in aircraft configurations such as landing gear or flap extension, etc.

3.1.5 Failure Protection

When installed in accordance with the manufacturer's specifications, any probable failure of the installed equipment or system shall not degrade the normal operations of other equipment or systems.

3.1.6 Inadvertent Turnoff

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

3.1.7 Aircraft Power Source

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

3.2 Installed Equipment Performance Requirements

The installed equipment shall meet the requirements in Section 2.0 in addition to, or as modified by, the requirements stated below.

3.2.1 Interference Effects

The equipment shall not be the source of harmful conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

NOTE: Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. It is not intended that the equipment manufacturer design for all installation environments. The installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft.

3.3 Conditions of Test

Conditions stated in the following paragraphs are applicable to the equipment tests specified in Subsection 3.4.

3.3.1 Power Input

Unless otherwise specified, tests shall be conducted with the equipment powered by the aircraft's electrical power generating system.

3.3.2 Associated Equipment or Systems

Unless otherwise specified, all aircraft electrically operated equipment and systems shall be turned on before conducting interference tests.

3.3.3 Environment

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

3.3.4 Adjustment of Equipment

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.

3.4 Test Procedures for Installed Equipment Performance

The following test procedures are considered satisfactory in determining required equipment performance when the equipment is installed in an aircraft. Although specific test procedures are cited, it is recognized that other methods may be preferred by the installing 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 equipment shall be tested to demonstrate compliance with the minimum requirements stated in Section 2.0. In order to meet this requirement, evidence of TSO authorization or test results supplied by the equipment manufacturer as proof of conformity may be accepted in lieu of bench tests performed by the installing activity.

3.4.1 Ground Test Procedures

3.4.1.1 Conformity Inspection

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. Verify that proper mechanical and electrical connections have been made and that the equipment has been located and installed in accordance with the manufacturer's recommendations.

3.4.1.2 Equipment Function

Vary all controls of the equipment through their full range to determine that the equipment is operating according to the manufacturer's instructions and that each control performs its intended function.

3.4.1.3 Interference Effects

With the equipment energized, individually operate each of the other electrically operated aircraft equipment and systems to determine that no significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on at least the low, high and one mid-band frequencies. Make note of systems or modes of operation that should also be evaluated during flight. If appropriate, repeat tests using emergency power with the aircraft's batteries alone and the inverters operating.

3.4.1.4 Power Supply Fluctuations

Under normal aircraft conditions, cycle the aircraft engine(s) through all normal power settings and verify proper operation of the equipment as specified by the equipment manufacturer.

3.4.1.5 Equipment Accessibility

Determine that all equipment controls and displayed data are readily accessible and easily interpreted.

3.4.2 Flight Test Procedures

3.4.2.1 Displayed Data Readability

Determine that normal conditions of flight do not significantly affect the readability of displayed data.

3.4.2.2 Interference Effects

For aircraft equipment and systems that can be checked only in flight, determine that operationally significant conducted or radiated interference does not exist. Evaluate all reasonable combinations of control settings and operating modes. Operate communications and navigation equipment on at least the low, high and one mid-band frequencies.

4.0 EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS

4.1 Required Operational Performance Requirements

To ensure the operator that operations can be conducted safely and reliably in the expected operational environment, there are specific minimum acceptable performance requirements that shall be met. The following paragraphs identify these requirements.

4.1.1 Power Input

Prior to flight, verify that the equipment is receiving primary input power necessary for proper operation.

4.1.2 Equipment Operating Modes

The equipment shall operate in each of its operating modes.

4.2 Test Procedures for Operational Performance Requirements

Operational equipment tests may be conducted as part of the normal pre-flight tests. For those tests which can only be run in flight, procedures should be developed to perform these tests as early during the flight as possible to verify 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

Verify that the equipment performs its intended functions(s) for each of the operating modes available to the operator.

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M E M B E R S H I P

Special Committee 153

MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIRBORNE ILS LOCALIZER RECEIVING EQUIPMENT OPERATING WITHIN THE RADIO FREQUENCY RANGE OF 108-112 MHZ

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D. Martinson	U. S. Air Force
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R. McCarthy	Federal Aviation Administration
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P. McHugh	Aircraft Owners & Pilots Association
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M. Miller	Boeing Commercial Airplane Company
D. Morgan	Collins Division, Rockwell International
A. Norwood	Consultant
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M. Parkes	British Embassy
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G. Quinby	Aircraft Owners & Pilots Association
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R. Smith	Federal Aviation Administration
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C. Sturm	Federal Aviation Administration
R. Sutton	Boeing Commercial Airplane Company
F. Swinburn	Civil Aviation Authority (UK)
J. Vilcans	U. S. Department of Transportation
S. Warner	Collins Division, Rockwell International
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F. White	Consultant
R. Wrenn	Federal Aviation Administration
C. Wright	National Business Aircraft Association
R. Zimmerman	Wilcox Electric Company

APPENDIX A

STATISTICAL PROCEDURE FOR DETERMINATION OF ILS RECEIVER COURSE ERROR

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1.0 INTRODUCTION

It is the purpose of this appendix to present a statistical method for determining the maximum on-course (centering) errors of ILS localizer and glide slope receivers.

NOTE: A determination of the 95% probability may be achieved using this statistical method by utilizing plus or minus two standard deviations ($\pm 2\sigma$) of the normal distribution in the computation. For practical application, the equation for total receiver course error on page 7 may be used to determine the 95% probability.

Total receiver course error is $\bar{X}_T \pm 2_T{}^{\sigma} = \bar{X}_T \pm 2\sqrt{S_T{}^2}$

The techniques described are general in nature and may be applied to other types of equipment with possible modifications of the basic assumptions and values of the constants.

2.0 ASSUMPTIONS

With certain assumptions, analysis of ILS course errors can be simplified to a manageable operation. All assumptions employed in this document can be shown to be realistic or conservative, based on available test experience.

Nine environments (eight for glide slope) must be considered, each consisting of one or more random variables. Each of the primary variables is characterized by an assumed probability density distribution.

Detailed characteristics of the nine environments and corresponding error functions are listed in Table A-1.

When the random variable is normally distributed, the following simplifying assumptions can be made:

a. When the normally distributed random variable is located at its mean value, it contributes zero course error to the accuracy of the system.

b. When this same variable displaces to the right or left of its mean value, the course error increases in magnitude in a linear manner (see Figure A-1).

c. When the random variable displaces to the right or left of its mean value, the standard deviation of the course error increases in a linear manner (see Figure A-1).

d. The maximum limits of variation of the random variable will correspond to the plus or minus three standard deviations ($\pm 3\sigma$) of its normal distribution.

TABLE A-1 ASSUMED DISTRIBUTION AND COURSE ERROR FUNCTIONS OF RANDOM VARIABLES

Environment	Distribution of Primary Variable	Probability of Encountering Primary Variable	Error Function
1. RF Level Variation	Rectangular	1.00	Linear
2. Carrier Frequency Variation	Normal	1.00	Linear
3. Power Source Frequency Variation	Normal	1.00	Linear
4. Power Source Voltage Variation	Normal	1.00	Linear
5. Modulation Frequency Variation	Normal	1.00	Linear
6. Modulation Phase Variation	Normal	1.00	Linear
7. Modulation Percent Variation	Normal	1.00	Linear
8. Ident Modulation Frequency Variation (For Localizer Only)	Normal	1.00 (Loc)	Linear
9. Temperature Variation	Rectangular	1.00	Measured

3.0 COURSE ERROR COMPUTATION PROCEDURE

As shown in Table A-1, three types of computation problems arise. These three cases are treated separately along with the procedure for computing the over-all three-sigma receiver course error.

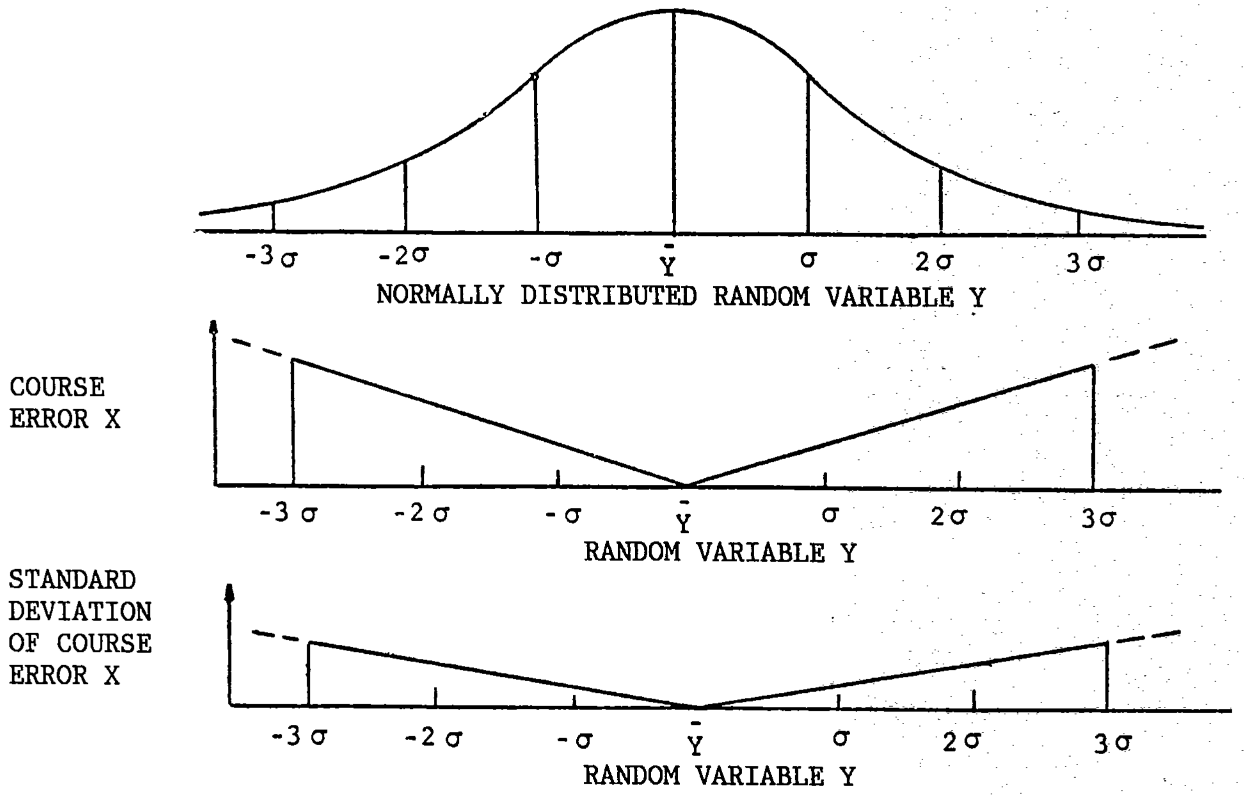

FIGURE A-1 EFFECT OF NORMALLY DISTRIBUTED RANDOM VARIABLE UPON COURSE ERROR

3.1 Case 1 - Normal Distribution of Random Variable with Linear Error Function

Where the course error function is linear, only two measured values of course error are required. The values correspond to the minus three-sigma and plus three-sigma values of the random variable. For evaluation purposes the random variable is cranked to the low and high environment extremes and the course error is recorded as X_L and X_H.

The two values of course error then are used to determine the mean value of the course error X for all values of the random variable, which is defined:

$$\bar{X} = C\,(X_L + X_H) \qquad (1)$$

where X_L = course error with variable displaced to -3σ
X_H = course error with variable displaced to $+3\sigma$
C = 0.13306.

The constant C takes into account the weighting factor from the normal distribution and the linear relationship between the variable and the course error (see Figure A-1). The value of the constant is derived in Section 5.0. In equation (1), the algebraic sign of the errors X_L and X_H must be utilized. Consistency in sign must be maintained throughout the test. That is, errors toward the 90-cps side must be assumed either positive or negative throughout the test program.

In similar manner, the variance S^2 is determined from the formula

$$S^2 = K\,(X_L{}^2 + X_H{}^2) - \overline{X}^2 \qquad (2)$$

where X = the value determined by equation (1)
K = 0.05556.

The constant K is similar to the constant C and takes into account the weighting factor for the normal distribution and the linear error function. The value of the constant is derived in Section 5.0.

Each value of X and S^2 then must be multiplied by the probability of encountering the primary environment factor as listed in Table A-1.

3.2 Case 2 - Rectangular Distribution of Random Variable with Nonlinear Error Function

The environment which exhibits the rectangular probability distribution with nonlinear error function is temperature. Since there are five categories of temperature range, one of five formulas must be used to determine $\overline{X}$ and S^2. The formulas are derived in Section 7.0. In this case, 10°C increments are used to approximate the nonlinear error function. Error measurements are made at the 10°C intervals and applied to the appropriate formulas.

Category A - Temperature Range: -54 to +55 °C

Assume temperature range is -55 to +55 °C.

$$\overline{X}_A = \frac{10}{110}\left[\frac{X_{-55}}{2} + X_{-45} + X_{-35} + X_{-25} + X_{-15} + X_{-5} + X_{+5} + X_{+15} + X_{+25} + X_{+35} + X_{+45} + \frac{X_{+55}}{2}\right] \qquad (3)$$

$$S_A^2 = \frac{10}{440}\Big[(X_{-55}+X_{-45})^2 + (X_{-45}+X_{-35})^2 + (X_{-35}+X_{-25})^2 + (X_{-25}+X_{-15})^2 + (X_{-15}+X_{-5})^2 + (X_{-5}+X_{+5})^2 + (X_{+5}+X_{+15})^2 + (X_{+15}+X_{+25})^2 + (X_{+25}+X_{+35})^2 + (X_{+35}+X_{+45})^2 + (X_{+45}+X_{+55})^2\Big] - \bar{X}_A^2 \qquad (4)$$

Category B - Temperature Range: -46 to +55 °C.

Assume temperature range is -45 to +55 °C.

$$\bar{X}_B = \frac{10}{100}\left[\frac{X_{-45}}{2} + X_{-35} + X_{-25} + X_{-15} + X_{-5} + X_{+5} + X_{+15} + X_{+25} + X_{+35} + X_{+45} + \frac{X_{+55}}{2}\right] \qquad (5)$$

$$S_B^2 = \frac{10}{400}\Big[(X_{-45}+X_{-35})^2 + (X_{-35}+X_{-25})^2 + (X_{-25}+X_{-15})^2 + (X_{-15}+X_{-5})^2 + (X_{-5}+X_{+5})^2 + (X_{+5}+X_{+15})^2 + (X_{+15}+X_{+25})^2 + (X_{+25}+X_{+35})^2 + (X_{+35}+X_{+45})^2 + (X_{+45}+X_{+55})^2\Big] - \bar{X}_B^2 \qquad (6)$$

Category C - Temperature Range -40 to +55 °C.

$$\bar{X}_C = \frac{10}{95}\left[\frac{X_{-40}}{2} + X_{-30} + X_{-20} + X_{-10} + X_0 + X_{+10} + X_{+20} + X_{+30} + X_{+40} + \tfrac{3}{4}X_{+50} + \tfrac{1}{4}X_{+55}\right] \qquad (7)$$

$$S_C^2 = \frac{10}{380}\Big[(X_{-40}+X_{-30})^2 + (X_{-30}+X_{-20})^2 + (X_{-20}+X_{-10})^2 + (X_{-10}+X_0)^2 + (X_0+X_{+10})^2 + (X_{+10}+X_{+20})^2 + (X_{+20}+X_{+30})^2 + (X_{+30}+X_{+40})^2 + (X_{+40}+X_{+50})^2 + \frac{(X_{+50}+X_{+55})^2}{2}\Big] - \bar{X}_C^2 \qquad (8)$$

Category D - Temperature Range -15 to +55 °C.

$$\bar{X}_D = \frac{10}{70}\left[\frac{X_{-15}}{2} + X_{-5} + X_{+5} + X_{+15} + X_{+25} + X_{+35} + X_{+45} + \frac{X_{+55}}{2}\right] \tag{9}$$

$$S_D^2 = \frac{10}{280}\Big[(X_{-15}+X_{-5})^2 + (X_{-5}+X_{+5})^2 + (X_{+5}+X_{+15})^2 + (X_{+15}+X_{+25})^2 + (X_{+25}+X_{+35})^2 + (X_{+35}+X_{+45})^2 + (X_{+45}+X_{+55})^2\Big] - \bar{X}_D^2 \tag{10}$$

Categories E and F - Temperature Range -15 to +40 °C.

$$\bar{X}_{E\&F} = \frac{10}{55}\left[\frac{X_{-15}}{2} + X_{-5} + X_{+5} + X_{+15} + X_{+25} + \tfrac{3}{4}X_{+35} + \tfrac{1}{4}X_{+40}\right] \tag{11}$$

$$S_{E\&F}^2 = \frac{10}{220}\left[(X_{-15}+X_{-5})^2 + (X_{-5}+X_{+5})^2 + (X_{+5}+X_{+15})^2 + (X_{+15}+X_{+25})^2 + (X_{+25}+X_{+35})^2 + \frac{(X_{+35}+X_{+40})^2}{2}\right] - \bar{X}_{E\&F}^2 \tag{12}$$

3.3 Case 3 - Rectangular Distribution of Random Variable with Linear Error

RF signal level is the only variable which normally exhibits rectangular distribution of the random variable with linear error. However, temperature variation may, in some designs, exhibit these characteristics. If so, temperature may be analyzed optionally by this method.

Data are again required only at the plus and minus three-sigma points. These errors then may be applied to the formulas following. In this case, however, the plus and minus environmental limits also must be applied. The formulas are derived in Section 6.0.

$$\bar{X} = \frac{X_H Y_H - X_L Y_L}{2(Y_H - Y_L)} \tag{13}$$

where X_L and X_H = error at low and high environmental extremes.
Y_L and Y_H = environmental range limits to the left and right of the standard condition.

$$S^2 = \frac{X_H^2 Y_H - X_L^2 Y_L}{3(Y_H - Y_L)} - \bar{X}^2 \tag{14}$$

where X_L and X_H = error at low and high environmental extremes.
Y_L and Y_H = low and high environmental range limits, respectively, measured from the point of standard condition.

An example of Y_L and Y_H is the case where localizer RF level is varied from 1000 microvolts to 100 microvolts and from 1000 microvolts to 20,000 microvolts. In this case Y_L is 20 dB and Y_H is 26 dB. Y_L and Y_H are expressed in dB to take into account the exponential effect of RF level.

3.4 Total Receiver Error

The total receiver error is determined from the summation of values of $\bar{X}$ and S^2. Use is made of the central limit theorem of mathematical probability which says:

> Whatever be the distributions of the independent variables X_i - subject to certain very general conditions - the sum $X = X_1 + X_2 + \text{---} + X_n$ is asymptotically normally distributed with mean $m = m_1 + m_2 + \text{---} + m_n$.
>
> variance $\sigma^2 = \sigma_1{}^2 + \sigma_2{}^2 + \text{---} + \sigma_n{}^2$

Thus the total receiver mean X_T and variance $S_T{}^2$ is the sum of the individual means and variances, respectively; that is,

$$\bar{X}_T = \bar{X}_1 + \bar{X}_2 + \bar{X}_3 + \bar{X}_4 + \bar{X}_5 + \bar{X}_6 + \bar{X}_7 \text{ --- } + \bar{X}_n \quad (15)$$

$$S_T{}^2 = S_1{}^2 + S_2{}^2 + S_3{}^2 + S_4{}^2 + S_5{}^2 + S_6{}^2 + S_7{}^2 \text{ --- } + S_n{}^2 \quad (16)$$

The total receiver course error is then

$$\bar{X}_T \pm 2_T{}^{\sigma} = \bar{X}_T \pm 2\sqrt{S_T{}^2}$$

This gives a receiver course error which is not to be exceeded more than 5% of the time.

4.0 NUMERICAL EXAMPLE

Table A-2 provides a tabular sample computation of localizer on-course on centering error using hypothetical data. The first column lists the various environments. Where frequency is a secondary variable, space is provided to list interfering frequencies. Space is also provided to list each temperature measurement point. Test data are recorded in the columns headed X_L and X_H. Appropriate operations from Section 3.0 are performed and recorded in the columns headed X_i and $S_i{}^2$. Appropriate environment probability factors are indicated.

TABLE A-2 SAMPLE LOCALIZER COURSE ERROR COMPUTATION

ENVIRONMENT	X_L	X_H	ENVIRONMENT PROBABILITY FACTOR	$\bar{X}_i$	S_i^2
1. RF LEVEL	-4	+2	1.0	-0.696	4.907
2. CARRIER FREQUENCY	-3	+1	1.0	-0.266	0.485
3. POWER SOURCE FREQUENCY	+3	-1	1.0	+0.266	0.485
4. POWER SOURCE VOLTAGE	-2	+1	1.0	-0.133	0.260
5. MODULATION FREQUENCY	-1	+2	1.0	+0.133	0.260
6. MODULATION PHASE	-4	+4	1.0	0	1.778
7. MODULATION PERCENT	-2	+1	1.0	-0.133	0.260
8. IDENT MODULATION (For Localizer Only)					
f_1 1050 Hz	+1	-2	1.0	-0.133	0.260
9. TEMPERATURE (CATEGORY A)					
t_1 -55° C	+4				
t_2 -45	+1				
t_3 -35	-5				
t_4 -25	0				
t_5 -15	+2				
t_6 -5	-1				
t_7 +5	-3				
t_8 +15	+1				
t_9 +25		0			
t_{10} +35		0			
t_{11} +45		+3			
t_{12} +55		+5			

Using the resulting values of $\bar{X}_i$ and S_i^2,

$$\bar{X}_T = \Sigma\ \bar{X}_i = -0.203$$

$$S_T^2 = \Sigma S_i^2 = 12.395$$

$$\sigma_T = \sqrt{S_T^2} = 3.52$$

No significance should be attached to the data used for this example except that it indicates the type of data possible. The 95% Probability Centering Error = $\bar{X}_T \pm 2\sigma_T = -0.203 \pm 7.04$ microamps.

5.0 DERIVATIONS OF MEAN COURSE ERROR $\overline{X}$ AND VARIANCE OF LINEAR COURSE ERRORS S^2

5.1 Derivation of the Mean Course Error $\overline{X}$

The mean of a discrete set of values $x_1, x_2, ---, x_n$ is defined by the following formula:

$$\overline{X} = \frac{x_1 + x_2 + --- + x_n}{n} = \frac{1}{n} \sum_{i=1}^{n} x_i \tag{17}$$

If there is a probability associated with each of the discrete set of values, the mean is called a weighted mean and is defined as

$$\overline{X} = P_1 x_1 + P_2 x_2 + --- + P_k x_k \tag{18}$$

$$= \sum_{\text{all } k} P_k x_k$$

where P_k is the probability (area under the distribution curve of a random variable Y) with the value x_k. In particular, if we have a continuous variate $x = f(y)$, where y is defined by a probability density function $P(y)$, the mean is defined by

$$\overline{X} = \int_{-\infty}^{+\infty} x\, p(y)\, dy \tag{19}$$

For the normal distribution curve, $P(y)$ is known and given by

$$P(y) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-(y - \overline{Y})^2}{2\sigma^2}}$$

When the random variable is normally distributed with no simple, well-defined relationship existing between the x_k, the P_k may be evaluated from a normal probability table with the location of x_k corresponding to the midpoint of the intervals of the random variable. An example will clarify this procedure.

Let the discrete values of error x_k correspond to integral multiples of σ of the random variable Y. Each interval is σ in length. See Figure A-2. The expression for the mean is

$$\overline{X} = P_1x_1 + P_2x_2 + P_3x_3 + P_4x_4 + P_5x_5 + P_6x_6 + P_7x_7 \tag{20}$$

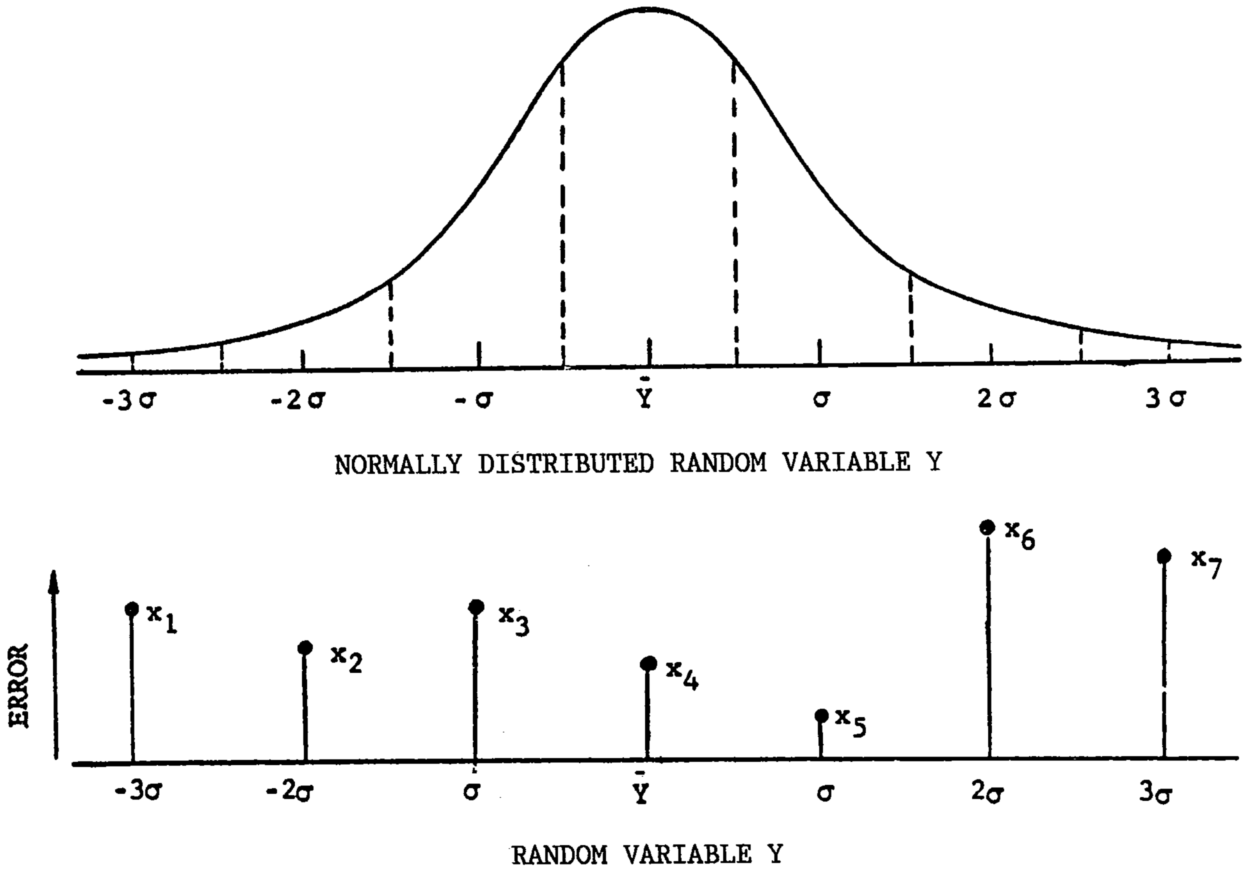

FIGURE A-2 WEIGHTING FACTOR APPLIED TO EACH ERROR x_k

For this example, the area under the distribution curve between the limits of -3.5σ and -2.5σ is .006. This is the value assigned to p_1. Between the limits -2.5σ and -1.5σ, the area under the distribution curve is .06. This is the value assigned to p_2. The remaining values are listed in Table A-3. Equation (20) becomes

$$\overline{X} = .006x_1 + .06x_2 + .244x_3 + .380x_4 + .244x_5 + .06x_6 + .006x_7 \quad (21)$$

If the value of x_k is given by a well-defined function of the random variable to the left or right of its mean, then equation (19) may be used. For example, assume the value of x_i increases in magnitude linearly with variation of the random variable, Y, as depicted in Figure A-3. Hence, from the figure

$$X = \frac{-X_L}{3\sigma} Y; \; -3\sigma \leq y \leq 0 \quad = \frac{X_H}{3\sigma} Y; \; 0 \leq y \leq 3\sigma \qquad (22)$$

TABLE A-3 CALCULATION OF WEIGHTING FACTOR P_k APPLIED TO EACH ERROR x_k

INTERVAL LIMITS IN σs	CLASS MIDPOINT	AREA UNDER DISTRIBUTION CURVE
-3.5 TO -2.5	-3σ	.006
-2.5 to -1.5	-2σ	.060
-1.5 to -0.5	-2σ	.244
-0.5 TO +0.5	$\bar{Y}$	.380
+0.5 TO +1.5	+1σ	.244
+1.5 TO +2.5	+2σ	.060
+2.5 TO +3.5	+3σ	.006

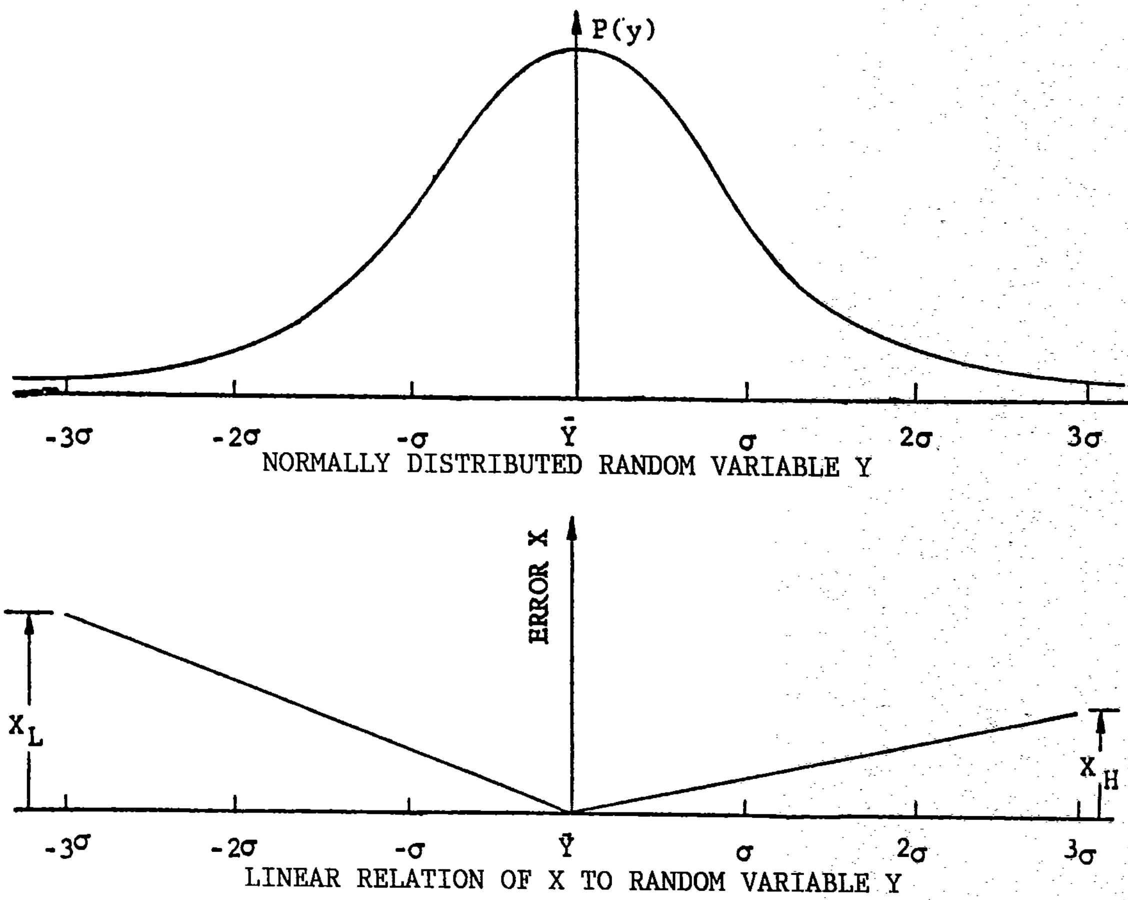

FIGURE A-3 WEIGHTING FACTOR APPLIED TO ERROR X WHEN ERROR IS LINEARLY RELATED TO RANDOM VARIABLE Y and

$$P(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-y^2}{2\sigma^2}}$$

since $\overline{Y} = 0$.

Consequently, the mean may be written as

$$\overline{X} = \frac{1}{\sigma\sqrt{2\pi}} \int_{-3\sigma}^{0} \left(\frac{-x_L y}{3}\right) e^{\frac{-y^2}{\sigma^2 2}} dy + \frac{1}{\sqrt{2\pi\sigma}} \int_{0}^{3\sigma} \left(\frac{x_H y}{3}\right) e^{\frac{-y^2}{\sigma^2 2}} dy \quad (23)$$

which becomes, upon integration and evaluation of the limits,

$$\overline{X} = \frac{-e^{9/2}}{3\sqrt{2\pi}} (x_L + x_H)$$

$$= 0.13306\ (x_L + x_H) \quad (24)$$

The numerical factor in equation (24) is the value of the constant C used in the text.

5.2 Derivation of the Variance of Linear Course Errors S^2

The variance of a discrete set of points x_1, x_2, ---, x_n is defined as

$$S^2 = \frac{1}{n} \sum_{i=1}^{n} (x_i - \overline{X})^2 = \frac{1}{n} \sum_{i=1}^{n} x_i^2 - \overline{X}^2 \; * \quad (25)$$

If there is a probability associated with each of the discrete set of values x_1, x_2, ---, x_n, the variance is called a weighted variance. Similar to the weighted mean, the weighted variance is defined as

$$S^2 = \sum_{\text{all } i} (x_i - \overline{X})^2 P_i = \sum_{\text{all } i} x_i^2 P_i - \overline{X}^2 \quad (26)$$

where $\overline{X}$ is determined from equation (18).

---

* The variance also is defined as

$$S^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \overline{X})^2$$

This definition is called the unbiased estimate of S^2. If n is large, the error involved is small. Since n is large in our case, the simpler equation (25) will be used.

In particular, if the random variable is normally distributed, the P_i may be evaluated from a normal probability table with the location of the x_i corresponding to the midpoint of the intervals of the random variable.

In the case of a continuous variate $x = f(y)$, where y is defined by a probability density function $P(y)$, the variance is given by

$$S^2 = \int_{-\infty}^{+\infty} X^2 \, P(y) \, dy - \overline{X}^2 \qquad (27)$$

Equation (26) is applied exactly as was equation (18) for a former example. An example will now be given to illustrate the application of equation (27).

Let us determine the variance for the variate or error x, for a normally distributed random variable y, for the condition shown in Figure A-3. Employing the defining equations (22), equation (27) takes the form

$$S^2 = \frac{1}{\sqrt{2\pi}\sigma} \left[\int_{-3\sigma}^{0} \left(\frac{-x_L}{3\sigma} \right)^2 y^2 e^{\frac{-y^2}{2\sigma^2}} dy + \int_{0}^{3\sigma} \left(\frac{x_H}{3\sigma} \right)^2 y^2 e^{\frac{-y^2}{2\sigma^2}} dy \right] - \overline{X}^2 \qquad (28)$$

which may be integrated to yield

$$S^2 = \frac{1}{18} \left(x_L^2 + x_H^2 \right) \left[\frac{2}{\sqrt{\pi}} \int_{0}^{3/\sqrt{2}} e^{-t^2} dt - \frac{6e^{-9/2}}{\sqrt{2\pi}} \right] - \overline{X}^2 \qquad (29)$$

The integral term in equation (29) represents an integral of the Gaussian error function and hence is properly called an error integral, although more popularly referred to as the error function. Symbolically,

$$\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_{0}^{t} e^{-t^2} dt \qquad (30)$$

The error function is not directly integrable; however, values of the function are tabulated in various tables. Equation (29) may now be expressed in the more simple form

$$S^2 = \frac{1}{18} \left(x_L^2 + x_H^2 \right) \operatorname{erf}(3/\sqrt{2}) - \frac{6e^{-9/2}}{\sqrt{2\pi}} - X^2 \qquad (31)$$

which becomes, upon evaluation of the numerical constants,

$$S^2 = 0.05556\ (x_L{}^2 + x_H{}^2)\ -\overline{X}^2 \qquad (32)$$

The constant factor in equation (32) is the value for the constant k referred to in the text.

6.0 DERIVATION OF MEAN $\overline{X}$ AND VARIANCE S^2 OF LINEAR COURSE ERROR WHEN A CONTINUOUS RANDOM VARIABLE Y IS UNIFORMLY DISTRIBUTED

6.1 Derivation of the Mean Course Error $\overline{X}$

The derivation of the mean $\overline{X}$ for a linear course error when a continuous random variable y is uniformly distributed proceeds in the same manner as presented in Section 5.0 for the normally distributed random variables. Figure A-4 shows the uniform, or rectangular, distribution. The mean X of the course error is given by equation (19), or

$$\overline{X} = \int_{-\infty}^{+\infty} xP(y)\ dy \qquad (33)$$

For the present case, $P(y) = 1/(y_H - y_L)$ and $x = f(y)$ where

$$f(y) = \frac{x_L}{y_L}\, y,\ y_L \le y \le 0 \qquad (34)$$

$$= \frac{x_H}{y_H}\, y,\ 0 \le y \le y_H$$

Consequently, equation (33) becomes

$$\overline{X} = \frac{1}{y_H - y_L}\left[\int_{y_L}^{o} \frac{x_L}{y_L}\, y\ dy + \int_{0}^{y_H} \frac{x_H}{y_H}\, y\ dy\right] \qquad (35)$$

which may be integrated to yield, for the mean,

$$\overline{X} = 1/2\ \frac{x_H\, y_H - x_L\, y_L}{y_H - y_L} \qquad (36)$$

6.2 Derivation of the Variance S^2 of Linear Course Errors

The variance S^2 for a linear course error when a continuous random variable y is uniformly distributed may be computed using equation (27). That is,

$$S^2 = \int_{-\infty}^{+\infty} x^2 \, P(y) \, dy - \bar{X}^2 \tag{37}$$

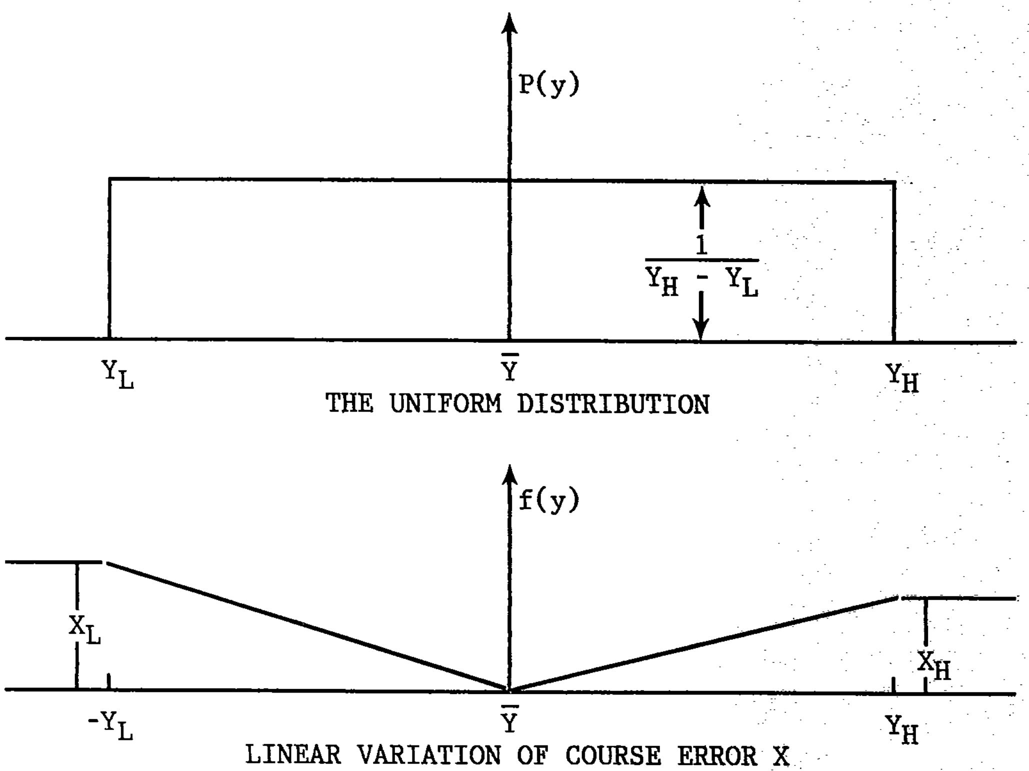

FIGURE A-4 UNIFORM DISTRIBUTION AND THE ASSUMED LINEAR VARIATION OF COURSE ERROR X WITH THE RANDOM VARIABLE y

Again, $P(y) = 1/(y_H - y_L)$, and equation (34) are applicable. Therefore,

$$S^2 = \frac{1}{y_H - y_L} \left[\int_{y_L}^{0} \left(\frac{x_L}{y_L} y \right)^2 dy + \int_{0}^{y_H} \left(\frac{x_H}{y_H} y \right)^2 dy \right] - \bar{X}^2 \tag{38}$$

which reduces to, after integrating and substituting in the limits,

$$S^2 = 1/3 \; \frac{x_H^{\;2} \, y_H - x_L^{\;2} \, y_L}{(y_H - y_L)} - \bar{X}^2 \tag{39}$$

7.0 DERIVATION OF MEAN COURSE ERROR $\overline{X}$ AND VARIANCE S^2 OF A NONLINEAR COURSE ERROR WHEN THE RANDOM VARIABLE IS UNIFORMLY DISTRIBUTED

7.1 Derivation of Mean Course Error $\overline{X}$

General expressions for the mean and variance of course error shall be derived that will apply to all temperature categories into which different glide slope receivers are classified. An example using Category C shall be presented.

The mean value, $\overline{X}$, of course error due to temperature variation is defined as equation (18):

$$\overline{X} = \sum_{\text{all } i} p(x_i)\, x_i \tag{40}$$

where $p(x_i)$ is the weight attached to each x_i, and is the ratio of the ith interval of the random variable (temperature) corresponding to x_i to the total spread of the random variable (temperature). Because of the difficulty in determining a simple, representative expression for the course error as a function of the random temperature variable, it will be necessary to obtain the mean $\overline{X}$ using equation (40) and measured data. Consequently, for purposes of laboratory measurements of course error due to temperature variation, all increments of temperature will be assumed uniform for all i, and

$$x_i = \frac{x_y + x_{y + \Delta y}}{2} \text{ ; all } i \tag{41}$$

where x_y denotes the course error measured at temperature y
$x_{y + \Delta y}$ denotes the course error measured at temperature $y+\Delta y$.

Equation (40) now modifies to

$$\overline{X} = P_i \sum_{i=1}^{n} x_i + P_{n+1}\, x_{n+1} \tag{42}$$

where n is equal to the next largest whole integer determined by computing the ratio of total temperature range to the incremental temperature minus 1. In expanded form equation (42) becomes

$$\overline{X} = \frac{\Delta y}{\Sigma \Delta y} \left[\frac{1}{2} X_y + X_{y+\Delta y} + X_{y+2\Delta y} + \text{---} + X_{y+(n-1)\Delta y} + \frac{k+1}{2k} X_{y+n\Delta y} + \frac{1}{2k} X_{y+n\Delta y + \frac{\Delta y}{k}} \right] \tag{43}$$

Equation (43) is a general expression for $\overline{X}$ applicable to all categories with y corresponding to the lowest value of temperature. When the temperature range is an integral multiple of Δy, k=1. When the temperature range is not an integral multiple of Δ, $k \geq 1$.

As an example, let equation (43) be applied to Category C whose temperature range is -40 to +55°C. Letting Δy = 10 °C and y = -40°C, it is apparent that

$$\overline{X}_c = \frac{10}{95}\left[\frac{1}{2}(x_{-40}) + x_{-30} + x_{-20} + x_{-10} + x_0 + x_{+10} + x_{+20} + x_{+30} + x_{+40} + \frac{3}{4}x_{+50} + \frac{1}{4}(x_{+55})\right] \quad (44)$$

Equation (44) utilizes the laboratory data directly (with the standard condition error x_R subtracted out) to determine the mean course error X for Category C. The procedure for computing the mean course errors for all categories may be summarized by the following steps:

(1) Choose the proper value of temperature range.

(2) Let y equal the lowest value of temperature in that range.

(3) Choose a convenient value for the increment Δy, so that $\Delta y \geq$ 10°C.

(4) Determine the proper value for k.

7.2 Derivation of the Variance S^2 of a Nonlinear Course Error

The variance, S^2, of a set of discrete measurements is defined as

$$S^2 = \sum_{\text{all } i} x_i^2\, p(x_i) - \overline{X}^2 \quad (45)$$

where x_i, $p(x_i)$, and $\overline{X}$ are defined as in Section 7.1.

Again assuming all Δy_i equal, and using equation (41) and equation (45), the variance becomes

$$S^2 = P_i \sum_{i=1}^{n} x_i^2 + P_{n+1}\, x^2_{n+1} - \overline{X}^2 \quad (46)$$

or, in expanded form,

$$S^2 = \frac{\Delta y}{4\Sigma\Delta y}\Bigg[(x_y + x_{y+\Delta y})^2 + (x_{y+\Delta y} + x_{y+2\Delta y})^2 + \cdots \qquad (47)$$

$$+ (X_{y+(n-1)\Delta y} + X_{y+n\Delta y})^2 + \frac{1}{k}(X_{y+n\Delta y} + X_{y+n\Delta y+\Delta y/k})^2\Bigg] - \overline{X}^2$$

Equation (47) is the equation for the variance of course error and is applicable to all temperature categories.

As an example, consider Category C. The temperature range is 95°C, y = -40°C and, assuming Δy equal to 10°C, k=2. Using these values in equation (47) results in the following expression for the variance of bearing error for Category C.

$$S_c^2 = \frac{10}{4 \times 95}\Big[(x_{-40} + x_{-30})^2 + (x_{-30} + x_{-20})^2 + (x_{-20} + x_{-10})^2$$
$$+ (x_{-10} + x_0)^2 + (x_0 + x_{+10})^2 + (x_{+10} + x_{+20})^2$$
$$+ (x_{+20} + x_{+30})^2 + (x_{+30} + x_{+40})^2 + (x_{+40} + x_{+50})^2$$
$$+ \frac{1}{2}(x_{+50} + x_{+55})^2\Big] - X_c^2$$

Computation of the variance for all categories can be performed by following the four steps summarized in Section 7.1 in conjunction with the general relationship given by equation (47).

APPENDIX B

RECEIVER RF INPUT VOLTAGE

(HARD AND EASY MICROVOLTS)

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RECEIVER RF SIGNAL LEVELS

Modern RF signal generators are usually calibrated in dBm (decibels with respect to 1 milliwatt into 50 ohms), and in volts, millivolts or microvolts into a 50 ohm termination. (Note that 0 dBm = .224 volts.)

Therefore, this unit of measurement will be used throughout this document.

Older RF signal generators were calibrated in open circuit voltage, or emf, and would deliver one-half of the open-circuit voltage into a terminating impedance equal to the generator source impedance.

Historically, sensitivity standards for VOR, localizer and glide slope receivers were originally set up using emf-calibrated generators. When the termination-related signal generators came into use, it was not considered desirable to change the sensitivity values. Since the termination-related generator delivered twice as much voltage into the receiver as an emf-rated generator, it was easier to meet sensitivity standards, and the termination-rated voltages were known as "easy" microvolts. In order to get back to the harder-to-meet levels ("hard" microvolts), a 6 dB pad was connected between the termination-rated generator and the receiver.

As a result of the almost universal availability of 50 ohm measurement use and synthesis equipment, the dBm as a unit of measurement has been adopted in this document.

Therefore, when using this document with a 50 ohm generator, a 6 dB attenuator is not necessary and the generator may be read directly.

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