Minimum Operational Performance Standards for Airborne ILS Glide Slope Receiving Equipment Operating Within the Radio Frequency Range of 328.6-335.4 MHz

DOCUMENT NO. RTCA/DO-192
July 1986
Prepared by SC-153

RTCA SINCE 1935

RADIO TECHNICAL COMMISSION FOR AERONAUTICS

DEDICATED TO THE ADVANCEMENT OF AERONAUTICS

Radio Technical Commission for Aeronautics
One McPherson Square
1425 K Street, N.W., Suite 500
Washington, D. C. 20005

MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIRBORNE ILS GLIDE SLOPE RECEIVING EQUIPMENT OPERATING WITHIN THE RADIO FREQUENCY RANGE OF 328.6-335.4 MHZ

RTCA/DO-192
July 18, 1986

Supersedes: RTCA/DO-132A

Prepared by:
SC-153

Copies of this document may be obtained from

RTCA SECRETARIAT
One McPherson Square
1425 K Street, N.W., Suite 500
Washington, D. C. 20005
(202) 682-0266

$25.00 per copy

(50% Discount to RTCA Members and International Associates)

NOTE: All orders for this document shall be accompanied by payment to include shipping and handling fees. These documents will be sent First Class or Priority Mail in the United States, Canada and Mexico. Shipments to other countries will be by International AO Mail. The fee to be added to the basic cost of each document is $3.00 for delivery in the United States, Canada and Mexico, and $6.00 for other countries. Members and International Associates are entitled to a 50% discount on documents, but the full shipping and handling fee is required for each document ordered. Please remit in U. S. funds directly to RTCA.

FOREWORD

This document was prepared by Special Committee 153 of the Radio Technical Commission for Aeronautics. It was approved by RTCA on July 18, 1986, and supersedes RTCA/DO-132A, "Performance Standards Airborne ILS Glide Slope 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 Federal government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

In preparation of these standards RTCA SC-153 took into consideration comments received on behalf of the European Organisation for Civil Aviation Electronics (EUROCAE) WG-5.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

Page

Page

1.0 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards for airborne glide slope 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 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, converter 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 glide slope system. It includes all portions of both the ILS glide slope ground transmitter and the glide slope 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, converter, 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 glide slope 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, the guidelines contained in RTCA/DO-178A, "Software Considerations in Airborne Systems and Equipment Certification," should be considered.

1.2 System Overview

The ILS glide slope system consists of the glide slope airborne equipment and ILS glide slope ground station transmitter operating in the range of 329.15 to 335.0 MHz.

The ground station transmits beams consisting of: 1) an RF carrier amplitude modulated by 90 and 150 Hz tones, and 2) 90 and 150 Hz carrier sidebands only. The resultant RF phase of the signal received at any approach angle determines the relative amplitude of the demodulated 90 and 150 Hz tones at that angle. The pattern of the antenna is such that when an aircraft is on glide path, equal amounts of 90 and 150 Hz tones are received.

1.3 Operational Applications

The ILS glide slope system provides vertical steering information. It is used with an associated ILS localizer system. Together, these two systems make up a precision landing system and give both vertical and horizontal guidance to an aircraft.

Typically, the ILS system is used with a VOR, ADF or marker beacon to identify a point in space from which it is safe to descend to a landing.

1.4 Operational Goals

Operational goals of the glide slope equipment are described in the following subparagraphs. 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 Sensitivity

The RF sensitivity of the installed glide slope equipment should be such that its performance meets the overall requirements of the remaining sections of this document in the presence of a standard glide slope signal having a power density of -95 dBW/m2 (350 microvolts per 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 glide slope service volume. The deviation information should meet the accuracy requirements contained in Section 2.2 in the presence of undesired signals at the relative signal levels and frequency separations specified in Section 2.2.3.

1.4.3 Spurious Response and Intermodulation

Equipment spurious responses or intermodulation effects should not inhibit the pilot from receiving accurate glide slope 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 flight guidance indicator(s) such as CDI, HSI, etc. 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, etc.

1.4.5 Interface with Other Aircraft Systems

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

Certain glide slope airborne equipment may be used to provide sensor inputs to Autoland systems. In these circumstances, attention should be focused on the compatibility of glide slope output navigation signals with these system input requirements.

Glide slope signal interface with other airborne equipment intended for use during flight should not result in a condition where the 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.

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. <u>Environmental Tests</u>

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. <u>Bench Tests</u>

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. <u>Installed Equipment Tests</u>

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 detected signal voltage level over a range of variation of input volume.

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

THIS PAGE INTENTIONALLY LEFT BLANK

2.0 ILS GLIDE SLOPE 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 MOPS. 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 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.

2.1.6 Accessibility of Controls

Controls for use during flight shall be accessible from a pilot's

---

[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.

normal seated position. Controls which 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 13% of standard deflection using standard signal conditions outlined in paragraph 2.4.3.1 a.

b. The centering error as presented to the pilot shall not exceed 13% of standard deflection with a statistical probability of 95% using the signal conditions of paragraph 2.4.3.1 b.

2.2.2 On-Channel Signals

2.2.2.1 AGC

The centering error as presented to the pilot shall not exceed 13% of standard deflection under the following condition:

Variation of RF signal level from -76 dBm to -33 dBm.

2.2.2.2 Bandwidth

The centering error as presented to the pilot shall not exceed 13% of standard deflection under the following condition:

With a standard glide slope centering signal, vary the carrier frequency of the applied signal from fc $\pm$17 kHz, where fc is the assigned channel frequency.

2.2.3 Interfering Signals

2.2.3.1 Adjacent Channel and In Band Signals

The centering error as presented to the pilot shall not exceed 13% of standard deflection under the following conditions:

a. With a standard glide slope centering signal whose level is varied from -76 dBm to -36 dBm and an undesired glide slope signal 20 dB above the desired (but not to exceed -33 dBm) modulated 30% at 150 Hz and whose frequency is varied over the frequency range from 329.15 MHz to 335.0 MHz, excluding the band from fc ±133 kHz, where fc is the center frequency of the desired glide slope frequency.

b. With a standard glide slope centering signal whose level is varied from -76 dBm to -36 dBm and an undesired glide slope signal at a level of -36 dBm modulated 30% at 150 Hz and whose frequency is varied over the frequency range from 329.15 to 335.0 MHz excluding the band from fc ±283 kHz, where fc is the center frequency of the desired glide slope frequency.

2.2.3.2 Receiver Performance With Two Carriers

a. When the following combination of "Course" and "Clearance" signals are applied to the receiver input as set forth in Table 2-1, the centering error shall not change more than ±4% of standard deflection, and the warning device shall not alarm.

Course Signal	Clearance Signal
A standard glide slope centering signal applied at levels from -76 dBm to -33 dBm.	A glide slope test signal modulated with 150 Hz only to a depth of 90%, applied at levels 26 dB below the course signal.

b. When the following combination of "Course" and "Clearance" signals are applied to the receiver input as set forth in Table 2-1, the indicator shall display standard deflection, ±10%, and the warning device shall not alarm.

Course Signal	Clearance Signal
A glide slope test signal in which the ddm is 0.091, 150 Hz predominant, applied at levels from -76 dBm to -33 dBm.	A glide slope test signal modulated with 150 Hz only to a depth of 90%, applied at levels 20 dB below the course signal.

c. When the following combinations of "Course" and "Clearance" signals are applied to the receiver input set forth in Table 2-1, the indicator shall display not less than full scale deflection and the warning device shall not alarm.

	Course Signal	Clearance Signal
(1)	A glide slope test signal in which the ddm is 0.266, 150 Hz predominant, applied at levels from -76 dBm to -33 dBm.	A glide slope test signal modulated with 150 Hz only to a depth of 90%, applied initially 3 dB below the course signal, then increased at a rate not less than 1 dB/sec to a value 3 dB above the course signal.
(2)	A glide slope test signal in which the ddm is 0.266, 90 Hz predominant, applied at levels -76 dBm to -33 dBm.	A glide slope test signal modulated with 150 Hz only to a depth of 90%, applied at levels 14 dB below the course signal.

d. When the following "Clearance" signal is applied to the receiver input, the indicator shall display not less than full scale deflection and the warning device shall not alarm.

Course Signal	Clearance Signal
None	A glide slope test signal modulated with 150 Hz only to a depth of 90%, applied at levels from -76 dBm to -33 dBm microvolts on the selected channel frequency; 8 kHz above, and 8 kHz below.

TABLE 2-1 COURSE AND CLEARANCE SIGNALS

Course Signal	Clearance Signal
1. 3 kHz above selected channel	3 kHz below selected channel
2. 4 kHz above selected channel	4 kHz below selected channel
3. 5 kHz above selected channel	5 kHz below selected channel
4. On selected channel	8 kHz above selected channel
5. 8 kHz below selected channel	On selected channel

2.2.4 Course Deviation Indication

If a course deviation indication is provided, the following requirements shall be met with input signal levels between -76 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 0.175 ddm above or below center with a resolution of 0.016 ddm or better.

b. Deflection Linearity

The display magnitude shall have linearity of at least 10% of the deviation produced by a 0.175 ddm over the range of 0.0 to 0.091 ddm. The display indication or electrical output shall be monotonic when the input difference in depth of modulation is varied over a range from 0.0 ddm to 0.800 ddm.

c. Deflection Response

When the ddm of a standard glide slope test signal is abruptly changed from zero to any value less than ±0.175 ddm, the pointer shall reach 67% of its ultimate deflection within 2 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.

2.2.4.1 Electrical Course Deviation Output

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

a. Course Deviation Current Linearity

Over the course deviation range from zero to ±0.175 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 0.175 to 0.8 ddm, the deviation current shall not decrease. These standards shall be met over the range of signal input from -76 dBm to -33 dBm.

b. Course Deviation Current Response

When the ddm of a standard glide slope test signal is abruptly changed from zero to any value less than 0.175 ddm, the deviation current shall reach 67% of its ultimate value within 0.6 second and the overshoot shall not exceed 2%.

2.2.4.2 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 -56 dBm standard glide slope deviation signal is simultaneously varied over the range from 98.5% to 101.5% of 90 and 150 Hz.

2.2.5 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 signal is removed and the other is maintained at its normal 40%.

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

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

2.2.6 Spurious Response

The receiver shall meet the following spurious response standard on each frequency channel:

The response of the receiver shall be at least 60 dB below the response at center response frequency when an input signal modulated 30% at 150 Hz is varied over the frequency range of 90 kHz to 1500 MHz, excluding the frequency band 328.6 to 335.4 MHz.

2.2.7 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 glide slope receiver radiation into the aeronautical bands listed above is sufficiently low to minimize interference except when two glide slope receivers share a common antenna. Preferably the local oscillator should be kept out of the band 329.15-335.0 MHz, which will also allow the use of a common antenna for two glide slope receivers.

2.2.8 Antenna Efficiency[1]

Over the frequency range 329-335 MHz, the horizontal component of the radiated signal in the forward direction shall not be down more than 15 dB when compared to the maximum radiation from a standard horizontal dipole antenna resonant at 332 MHz in free space.

2.2.9 Antenna Polarization

Over the frequency range of 329-335 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.

2.2.10 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 329.15-335.0 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.

THIS PAGE INTENTIONALLY LEFT BLANK

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 5.1, and the following requirements of this standard shall be met:

a. Paragraph 2.2.1 a. - Centering Accuracy
b. Paragraph 2.2.4 a. - Deviation Sensitivity
c. Paragraph 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.4 a. - Deviation Sensitivity
c. Paragraph 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.4 a. - Deviation Sensitivity
c. Paragraph 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.4 a. - Deviation Sensitivity
c. Paragraph 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.4 a. - Deviation Sensitivity
c. Paragraph 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 tests may result in damage to the equipment under test. Therefore this test may be conducted after the other tests have been completed. In this case, paragraph 2.1.7, "Effects of Test," 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 2.2.5 - Warnings

Following the test, the requirements of paragraph 2.2.10, 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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) (When Required)

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 which indicates that 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 2.2.5 - Warnings
(3) Paragraph 2.2.10 - 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 which indicates that 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 2.2.5 - Warnings
(3) Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.5 - Warnings
c. Paragraph 2.2.10 - 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 2.2.7 and 2.4.3.8.

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 $\pm$2% for 12-14 V equipment, or to 27.5 V $\pm$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 $\pm$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 $\pm$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 -56 dBm and have a frequency within .001% of the assigned carrier frequency in addition to the following characteristics:

Standard Glide Slope Test Signal - An RF carrier modulated simultaneously by (a) 40 ±2% 90 Hz ±0.3% sine wave and (b) 40 ±2% 150 Hz ±0.3% sine wave.

i. Undesired Test Signal

The standard undesired test signal shall consist of a standard glide slope signal in which the 150 Hz signal is modulated at 30%.

j. Standard Glide Slope Deviation Signal - A standard glide slope test signal in which the difference in depth of modulation of the 90 and 150 Hz signals is 0.091 ±0.002.

k. Standard Glide Slope Centering Signal - A standard glide slope test signal in which the difference in depth of modulation (ddm) of the 90 and 150 Hz signals is less than 0.002.

l. Receiver Sensitivity - The receiver sensitivity is the minimum power level in dBm of a standard glide slope 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.

m. 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.

n. Standard Deflection - "Standard Deflection" shall be 52% (78 microamps) of center to full scale deflection of the deviation indicator. The receiver shall be adjusted to produce standard deflection when the input signal is a standard glide slope deviation signal of -56 dBm.

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 40 channels from 329.15 to 335.0 MHz with a carrier frequency accuracy of 0.001%.

(2) Shall have an output level adjustable from -76 dBm to -27 dBm.

(3) Shall be able to amplitude modulate from 0% to at least 90%.

(4) Shall be able to provide the standard glide slope signal.

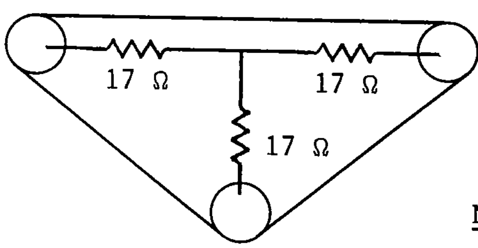
(5) Shall have all modulation frequencies adjustable $\pm 1.5\%$ from the standard values.

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

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

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 glide slope test signal. Determine the centering accuracy when:

(1) The frequency of the 90 Hz and 150 Hz signals shall be held to ±0.3%.

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

(3) The percentage modulation of the 90 and 150 Hz signal held between the limits of 40% ±1%.

(4) The ambient air temperature surrounding the equipment shall be between 20 and 30 degrees Centigrade.

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

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

(7) Interfering signals shall not be present.

(8) RF input of -56 dBm.

(9) With centering signal, vary the carrier frequency of the test signal between limits of ±17 kHz of the assigned channel frequency and determine the maximum algebraic difference in indicated centering caused by the carrier frequency variation for both positive and negative displacements.

b. Repeat the above procedure but with the following special conditions:

(1) With the centering signal, simultaneously vary the frequency of the 90 Hz and 150 Hz signals between the limits of ±1.5% and determine the maximum algebraic difference in indicated up/down displacement caused by the frequency variation.

---

[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.

(2) With the centering signal, vary the primary power voltage at the input terminals of the equipment between the limits of ±10% of the nominal design voltage and determine the maximum algebraic difference in up/down displacement caused by the input voltage variation.

(3) With the centering signal, simultaneously vary the percentage of modulation of the 90 and 150 Hz signals from 37.5% to 42.5%.

(4) Vary the ambient air temperature between the operating temperature limits of the temperature-altitude category for which the equipment is designed and determine the maximum algebraic difference in indicated centering caused by the temperature variation for both high and low temperature excursions.

(5) With the centering signal, vary the power supply frequency (AC source only) between the design limits of the equipment and determine the maximum algebraic difference in indicated bearing caused by the power supply frequency variation for both positive and negative displacements.

(6) With centering signal, vary the RF signal level between -76 dBm to -33 dBm and determine the maximum algebraic difference in indicated centering caused by the RF level variations for both positive and negative displacements.

(7) Variation of the phase relationship of the 90 and 150 Hz modulation signals from the correct phasing ±12 degrees of the common 30 Hz sub-harmonic. During this test a standard glide slope centering signal shall be applied.

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

2.4.3.2 Receiver Performance with Two Carriers (paragraph 2.2.3.2)

Equipment Required

Two glide slope generators
Power divider

Measurement Procedure

Apply to one input of the power divider a standard glide slope centering signal, apply to the other input a glide slope signal modulated with 150 Hz only at 90%. With the two signals applied, perform the test outlined in paragraph 2.2.3.2 using the frequencies outlined in Table 2.1 (4)(5).

Note the power divider has 6 dB of loss.

2.4.3.3 AGC Characteristic (paragraph 2.2.2.1)

Equipment Required

NAV Signal Generator.
Deviation Indicator (which will permit a measurement accuracy of 1%).

Measurement Procedure

Apply to the receiver input a standard glide slope deviation signal. Adjust the receiver for standard deflection with an RF input signal level of -56 dBm. Determine the maximum positive and negative changes of deviation indicator deflection when the level of the input signal is varied over the range of -76 dBm to -33 dBm.

2.4.3.4 Interfering Signals (paragraph 2.2.3)

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 test signal (desired) at a level of -70 dBm to -30 dBm at the frequency to which the receiver is tuned. Apply to the other input of the power divider an undesired glide slope test signal at the first adjacent channel ($\pm$133 kHz). Vary the undesired signal to be 20 dB above the desired but not to exceed -27 dBm. Determine the error caused by the undesired test signal.

(2) Apply to one input of the power divider a standard glide slope test signal (desired) which is varied from -70 dBm to -30 dBm at the frequency to which the receiver is tuned. Apply to the other input of the power divider an undesired glide slope test signal -30 dBm at each second adjacent channel ($\pm$283 kHz), in turn. Set the desired signal to -70 dBm and vary the undesired signal over the frequency range 329.15-335.0 MHz excluding fc $\pm$283 kHz.

NOTE: The above assumes that the power divider has a loss of 6 dB.

2.4.3.5 Course Deviation Indication (paragraph 2.2.4)

Equipment Required

NAV Signal Generator.

Deviation Indicator.
Timing Device.

Measurement Procedure

a. Deflection Sensitivity

To the receiver input, apply a -56 dBm standard glide slope deviation signal with a ddm of .175, 90 Hz. Decrease the ddm to .159, 90 Hz and measure the visible change in deflection. Repeat the above using af ddm of .175, 150 Hz and .159, 150 Hz respectively. Repeat the above at signal input levels of -76 dBm and -33 dBm.

b. Deflection Linearity

To the receiver input, apply a -56 dBm standard glide slope centering signal. Set the test signal ddm in turn to the following values: 0.045, 0.091, and 0.175. For each value, measure the deviation indicator deflection. Increase the ddm, as smoothly as possible, from 0.175 ddm to 0.800 ddm and determine whether the deviation indicator deflection decreases for ddm increase throughout this range. Conduct this test at receiver input signal levels over the range of -76 dBm to -33 dBm.

Repeat the above test with the 150 Hz modulation and for signal input levels of -76 dBm and -33 dBm.

c. Deflection Response

To the receiver input apply a -56 dBm standard glide slope centering signal. Abruptly change the relative levels of the 90 and 150 Hz modulation signals to produce values of ddm between 0 and $\pm$0.175. 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 over-shoot beyond its ultimate deflection.

d. Deflection Stability with Modulation Frequency

Apply to the receiver input a -56 dBm standard glide slope deviation signal. Vary the frequency of the modulation signals simultaneously between 98.5% and 101.5% of 90 and 150 Hz. Determine the maximum change in deflection.

NOTE: If separate electrical outputs are supplied they should be tested in a similar manner to determine that they meet the above criteria.

2.4.3.6 Warnings (paragraph 2.2.5)

Equipment Required

NAV Signal Generator.
Flag Indicating Device.

Measurement Procedure

To the receiver input apply a standard glide slope test signal at center response frequency and having a level of -56 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 -76 dBm and -36 dBm.

   (3) When the 150 Hz modulation is removed and the RF input level is varied between -76 dBm and -36 dBm.

b. When the receiver input signal level is reduced to the point where the deflection sensitivity to a 0.091 ddm is half of that obtained with a -56 dBm input signal.

2.4.3.7 Spurious Response (paragraph 2.2.6)

Equipment Required

NAV Signal Generators, as appropriate.
VTVM or equivalent.

Measurement Procedures

For each glide slope frequency:

(1) Apply a -76 dBm standard glide slope test signal and record the carrier (AGC) output level as a reference.

(2) Apply a -16 dBm RF signal modulated 30% at 150 Hz to the receiver input. Vary the carrier frequency over the range of 90 kHz to 1500 MHz, excluding the frequency band 328.6 to 335.4 MHz, and determine whether the carrier (AGC) output level exceeds the reference value.

2.4.3.8 Emission of Radio Frequency Energy (paragraph 2.2.7)

To be measured using the test setup and procedures defined in Section 21 of RTCA/DO-160B.

2.4.3.9 Antenna Efficiency (paragraph 2.2.8)

Equipment Required

Ground Plane (4 ft x 4 ft or larger, aluminum or equivalent.)
Standard Dipole Antenna (1/2" diameter, length adjusted to 332 MHz, 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 2-1. In free space 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 332 MHz. 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 2-2. 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 in the forward semicircle.

2.4.3.10 Antenna Polarization (paragraph 2.2.9)

Equipment Required

Ground Plane (4 ft x 4 ft or larger, aluminum or equivalent.)
Signal Generator.
Field Strength Meter.
Standard Test Antenna.
(6 dB 50 ohm pad.)

Measurement Procedure

Refer to Figure 2-2. 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 332 MHz and at all azimuth angles which are multiples of 30 degrees.

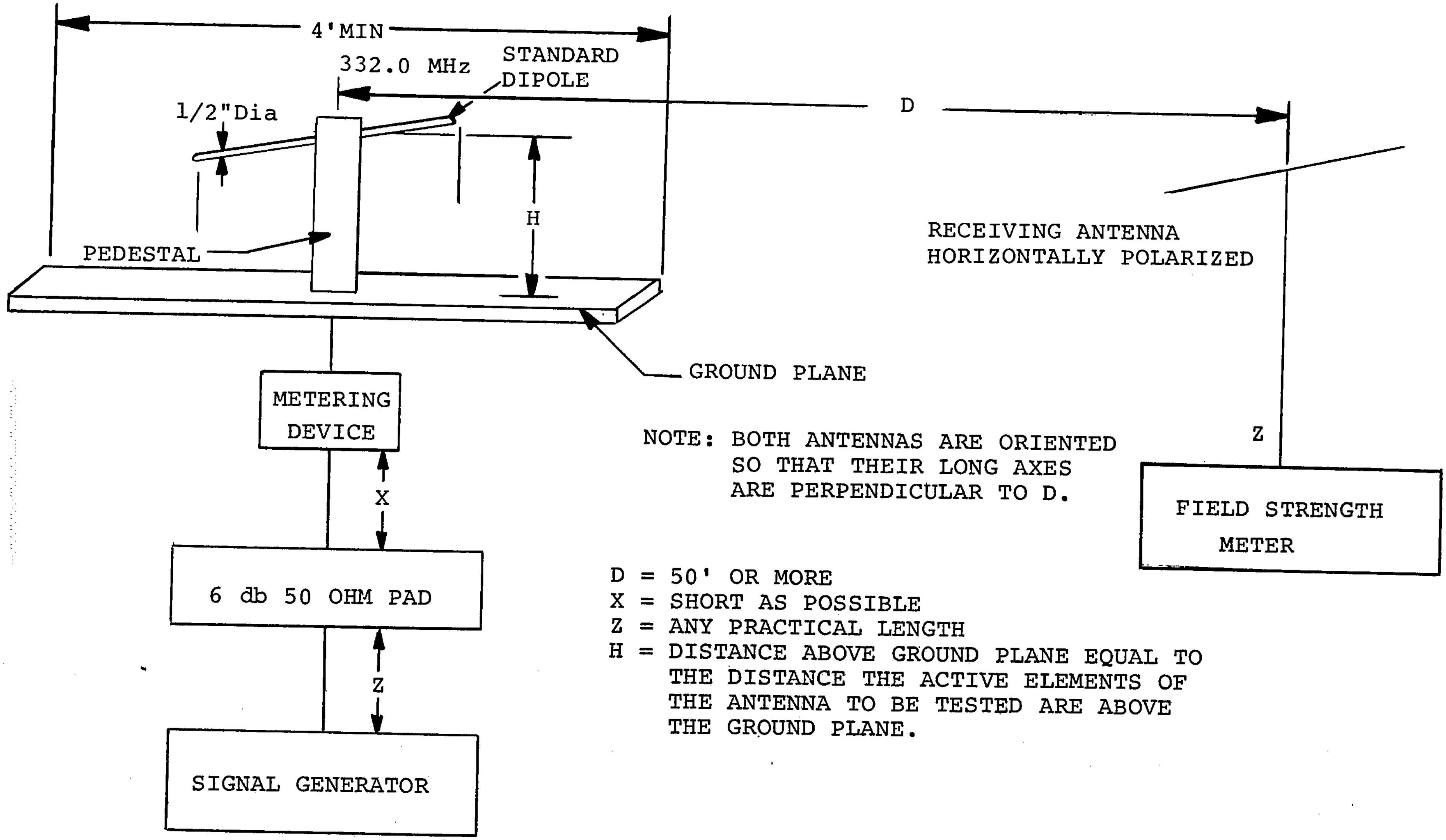
2.4.3.11 Antenna VSWR (paragraph 2.2.10)

Equipment Required

Impedance Bridge.

Measurement Procedure

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



NOTE: BOTH ANTENNAS ARE ORIENTED SO THAT THEIR LONG AXES ARE PERPENDICULAR TO D.

D = 50' OR MORE
X = SHORT AS POSSIBLE
Z = ANY PRACTICAL LENGTH
H = DISTANCE ABOVE GROUND PLANE EQUAL TO THE DISTANCE THE ACTIVE ELEMENTS OF THE ANTENNA TO BE TESTED ARE ABOVE THE GROUND PLANE.

FIGURE 2-1 - SET-UP FOR OBTAINING ANTENNA EFFICIENCY LEVEL

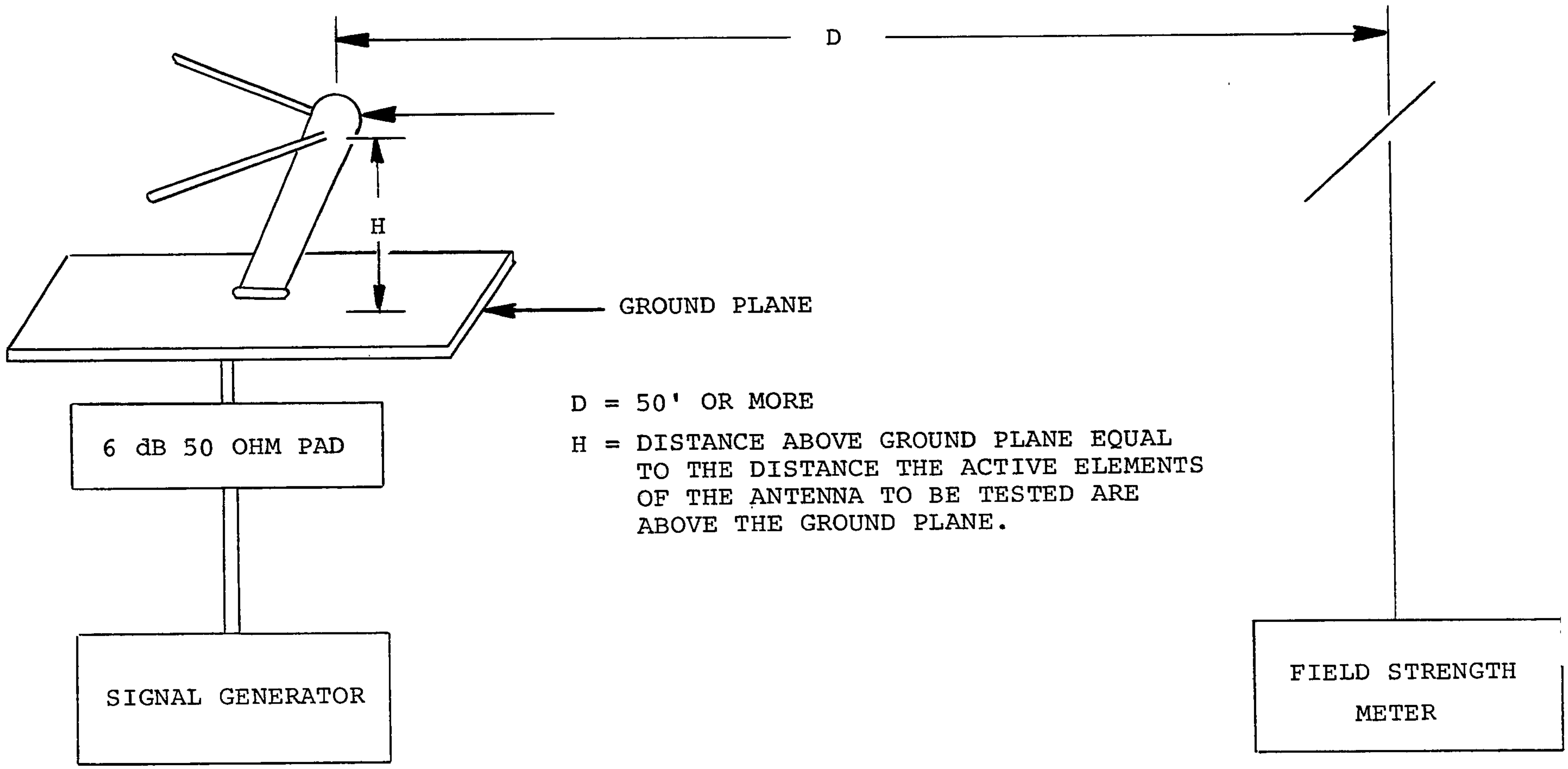


FIGURE 2-2 - SET-UP FOR TESTING ANTENNA EFFICIENCY AND POLARIZATION

3.0 INSTALLED EQUIPMENT PERFORMANCE

3.1 Equipment Installation

When installed in the aircraft, the equipment shall not impair the 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 seated 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 equipments 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 subparagraphs are applicable to the equipment tests specified in paragraph 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.

THIS PAGE INTENTIONALLY LEFT BLANK

M E M B E R S H I P

Special Committee 153

MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIRBORNE ILS GLIDE SLOPE RECEIVING EQUIPMENT OPERATING WITHIN THE RADIO FREQUENCY RANGE OF 328.6-335.4 MHZ

CHAIRMAN

R. Powell	NARCO Avionics, Inc.

SECRETARY

J. Lohr	Radio Technical Commission for Aeronautics

MEMBERS

J. Anderson	Federal Aviation Administration
E. Augstman	Transport Canada
F. Bassett	Federal Aviation Administration
L. R. Berryhill	United Air Lines, Inc.
K. Beseke	Cessna Aircraft Company
L. Bessette	Federal Aviation Administration
K. Bierach	Federal Aviation Administration
R. Bowers	Air Transport Association of America
T. Brewer	U. S. Air Force
R. Broere	Dorne & Margolin, Inc.
D. Bruce	Transportation Systems Division
W. Chapman	Federal Aviation Administration
R. Chelikowsky	Collins Air Transport Division, Rockwell International
B. Climie	Aeronautical Radio, Inc.
T. Cole	Transport Canada
C. Cunningham	Sperry Corporation
S. Dodington	Avionics Consultant
M. de Gironville	EUROCAE
P. Escritt	British Embassy
D. Featherstone	Aeronautical Radio, Inc.
N. Ferrett	Civil Aviation Authority (UK)
R. Frazier	Federal Aviation Administration
W. Fuchs	Radio Technical Commission for Aeronautics
R. Fuller	Sperry Avionics Radio Systems
I. Georgsson	Directorate of Civil Aviation (Iceland)
C. Hale	Federal Aviation Administration
C. Hanneman	King Radio Corporation
A. Helfrick	Consultant
J. Hutter	Cardion Electronics
R. Jago	Systems Control Technology, Inc.
L. James	Trans World Airlines, Inc.
V. Jikharev	All Union Scientific Research Institute of Radio Equipment (USSR)
R. Keating	Trans World Airlines, Inc.

T. Koshio	Electronic Industries Association of Japan
G. Leister	Helicopter Association International
E. Long	Aviation Systems, Inc.
C. Longman	Federal Aviation Administration
J. Longshore	McDonnell Douglas Corporation
D. Martinec	Aeronautical Radio, Inc.
D. Martinson	U. S. Air Force
A. Mayer	Collins Avionics Division, Rockwell International
R. McCarthy	Federal Aviation Administration
J. McDonnell	Douglas Aircraft Company
P. McHugh	Aircraft Owners & Pilots Association
E. Messer	Bendix Avionics Division
M. Miller	Boeing Commercial Airplane Company
D. Morgan	Collins Division, Rockwell International
A. Norwood	Consultant
R. O'Neill	Dorne and Margolin, Inc.
G. Quinby	Aircraft Owners & Pilots Association
I. Reese	Boeing Commercial Airplane Company
F. Rock	Federal Aviation Administration
S. Roederer	Rockwell International
J. Sawicki	Bendix Air Transport Division
E. Scott	Aircraft Owners & Pilots Association
F. Shilling	Aeronautical Radio, Inc.
M. Shuey	Aircraft Owners & Pilots Association
D. Singh	Bendix General Aviation Avionics Division
R. Smith	Federal Aviation Administration
G. Smoak	Sperry Radio Systems
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 Avionics Division, Rockwell International
D. Weber	Becker Flugfunkwerk
F. White	Consultant
R. Wrenn	Federal Aviation Administration
C. Wright	National Business Aircraft Association
R. Zimmerman	Wilcox Electric Company

A P P E N D I X A

STATISTICAL PROCEDURE FOR DETERMINATION OF ILS RECEIVER COURSE ERROR

THIS PAGE INTENTIONALLY LEFT BLANK

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.

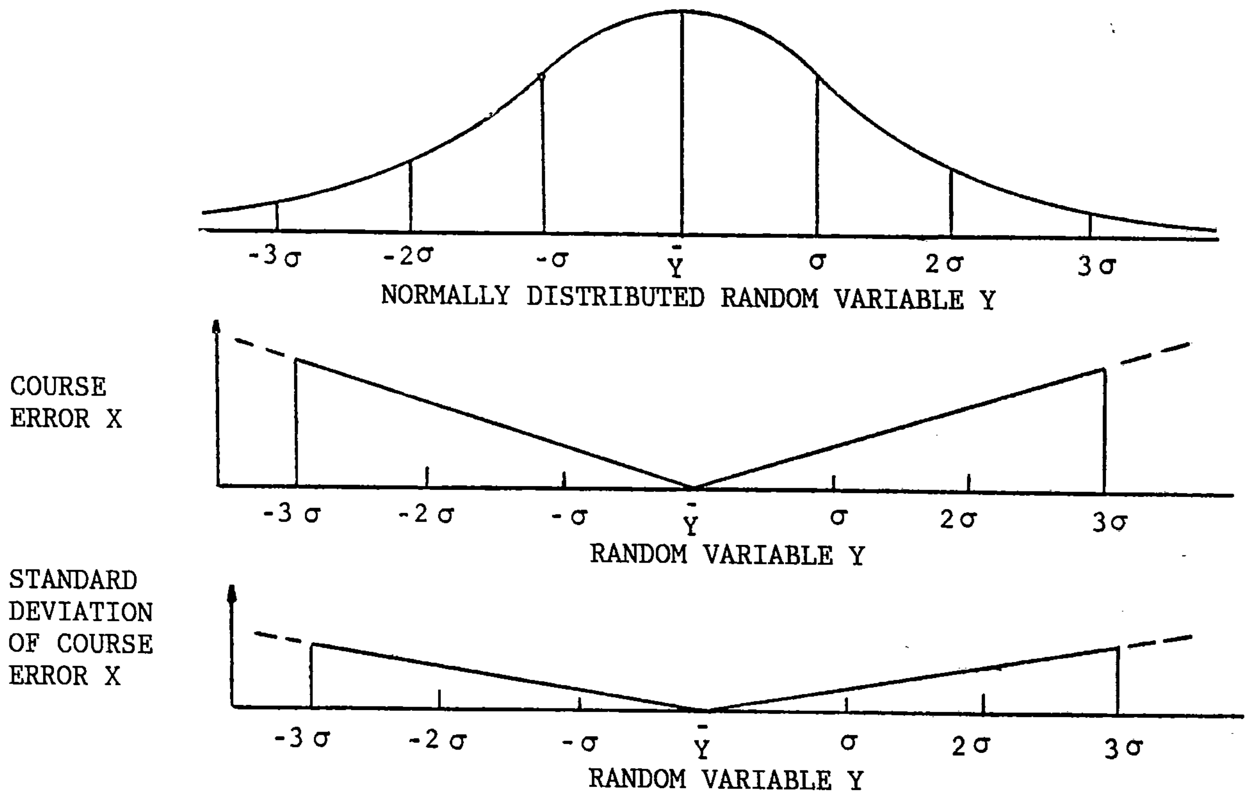


FIGURE A-1 EFFECT OF NORMALLY DISTRIBUTED RANDOM VARIABLE UPON COURSE ERROR

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:

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

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

$$S^2 = K\ (X_L{}^2 + X_H{}^2) - \bar{X}^2 \tag{2}$$

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 $\bar{X}$ 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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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

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.

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

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 $X = X_1 + X_2 + --- + X_n$ is asymptotically normally distributed with mean $m = m_1 + m_2 + --- + m_n$.

variance $\sigma^2 = \sigma_1{}^2 + \sigma_2{}^2 + --- + \sigma_n{}^2$

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

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

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

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	$\overline{X}_i$	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 $\overline{X}_i$ and S_i^2,

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

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

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

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 = $\overline{X}_T \pm 2\sigma_T$ = -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:

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

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

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

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

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

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

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

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

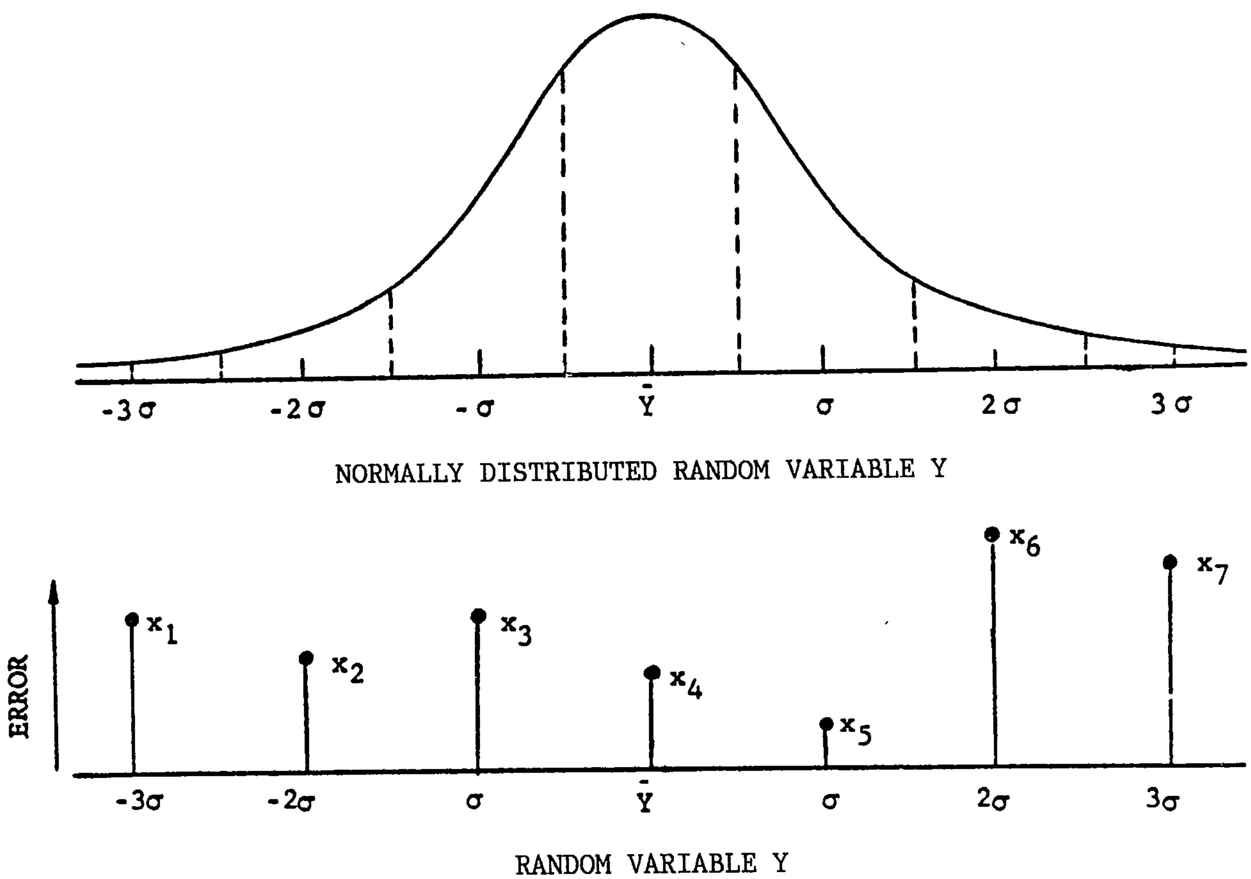


FIGURE A-2 WEIGHTING FACTOR APPLIED TO EACH ERROR x_k

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

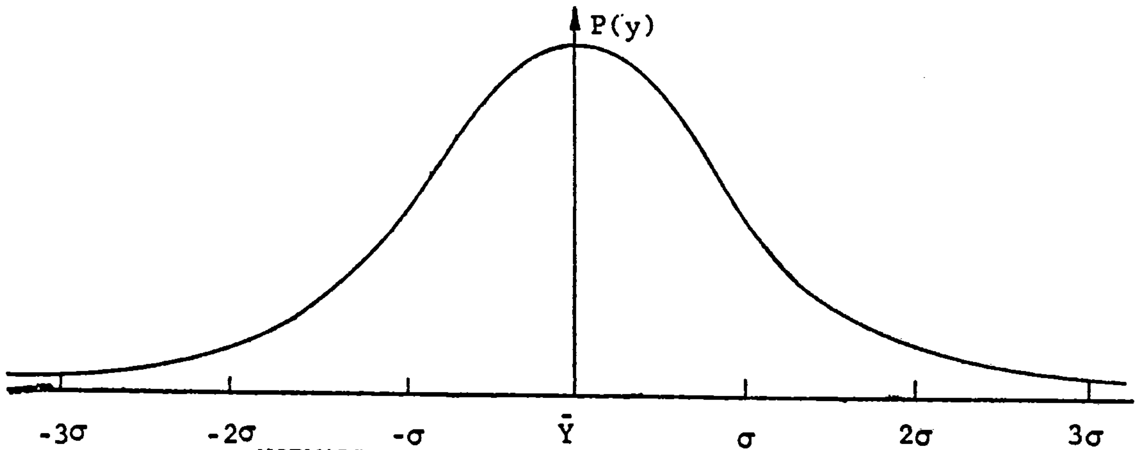
$$\bar{X} = .006x_1 + .06x_2 + .244x_3 + .380x_4 + .244x_5 + .06x_6 + .006x_7 \quad (21)$$

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

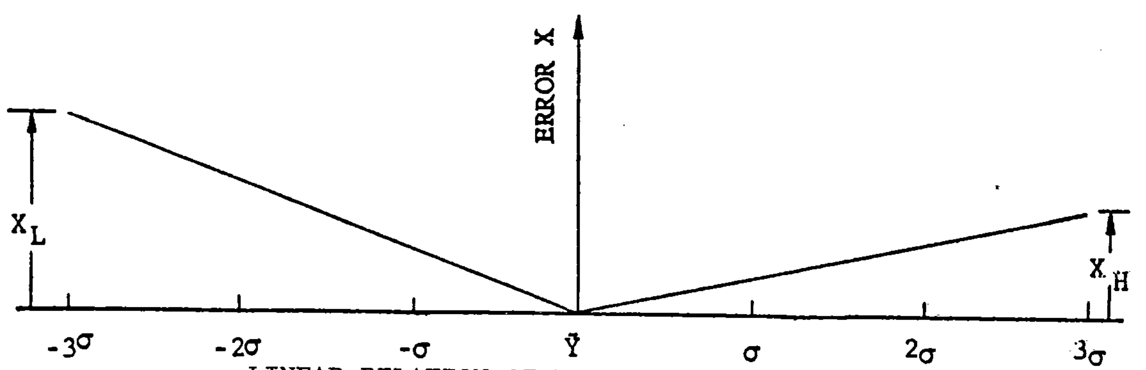
$$X = \frac{-X_L}{3\sigma} Y; \ -3\sigma \le y \le 0 \quad = \frac{X_H}{3\sigma} Y; \ 0 \le y \le 3\sigma \qquad (22)$$

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



NORMALLY DISTRIBUTED RANDOM VARIABLE Y



LINEAR RELATION OF X TO RANDOM VARIABLE Y

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

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

which becomes, upon integration and evaluation of the limits,

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

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

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

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

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

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

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,

$$\text{erf}(t) = \frac{2}{\sqrt{\pi}}\int_0^{t} e^{-t^2}\, dt \qquad (30)$$

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

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

which becomes, upon evaluation of the numerical constants,

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

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

6.0 DERIVATION OF MEAN $\bar{X}$ 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 $\bar{X}$

The derivation of the mean $\bar{X}$ 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

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

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

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

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

Consequently, equation (33) becomes

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

which may be integrated to yield, for the mean,

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

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,

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

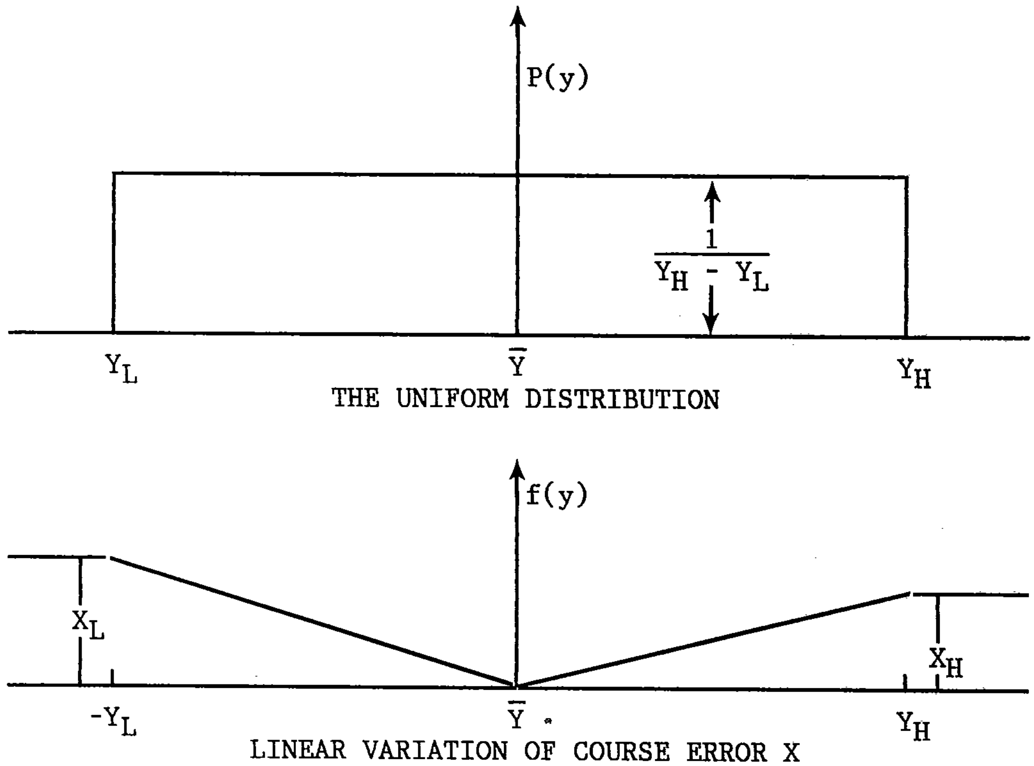


FIGURE A-4 UNIFORM DISTRIBUTION AND THE ASSUMED LINEAR VARIATION OF COURSE ERROR X WITH THE RANDOM VARIABLE y

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

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

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

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

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

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

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

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

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 $\bar{X}$ 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

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

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

$$\bar{X} = P_i \sum_{i=1}^{n} x_i + P_{n+1}\, x_{n+1} \qquad (42)$$

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

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

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

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

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

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

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

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

or, in expanded form,

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

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

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)

THIS PAGE INTENTIONALLY LEFT BLANK

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.

THIS PAGE INTENTIONALLY LEFT BLANK