RTCA DO-189 85 7535344 0005062 7

Minimum Operational Performance Standards for Airborne Distance Measuring Equipment (DME) Operation Within the Radio Frequency Range of 960-1215 Megahertz

DOCUMENT NO. RTCA/DO-189
September 1985
Prepared by SC-149

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 DISTANCE MEASURING EQUIPMENT (DME) OPERATING WITHIN THE RADIO FREQUENCY RANGE OF 960-1215 MEGAHERTZ

RTCA/DO-189
September 20, 1985

Prepared by: SC-149

Supersedes: RTCA/DO-141
RTCA/DO-151A

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.

F O R E W O R D

This document was prepared by Special Committee 149 of the Radio Technical Commission for Aeronautics. It was approved by RTCA on September 20, 1985.

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.

Coordination of these standards was accomplished by RTCA SC-149 with the European Organisation for Civil Aviation Electronics (EUROCAE) WG-25.

TABLE OF CONTENTS

	Page
FOREWORD	i
TABLE OF CONTENTS	iii
1.0 PURPOSE AND SCOPE	1
1.1 Introduction	1
1.2 System Overview	2
1.3 Operational Applications	4
1.3.1 General	4
1.3.2 Typical Applications	4
1.4 Operational Goals	5
1.4.1 Accuracy	5
1.4.2 Range	5
1.4.3 Data Inputs	7
1.4.4 Outputs	7
1.4.5 Warnings	7
1.4.6 Data Display	7
1.5 Test Procedures	7
1.5.1 Environmental Tests	8
1.5.2 Bench Tests	8
1.5.3 Installed Equipment Tests	8
1.5.4 Operational Tests	8
1.6 Definitions of Terms	9
Figure 1-1 Standard High Altitude Service Volume	6
Figure 1-2 Standard Low Altitude Service Volume	6
Figure 1-3 Standard Terminal Service Volume	6
Figure 1-4 Standard DME/P Service Volume	6
Figure 1-5 Virtual Origin	13
2.0 AIRBORNE DISTANCE MEASURING EQUIPMENT REQUIREMENTS AND TEST PROCEDURES	15
2.1 General Requirements	15
2.1.1 Airworthiness	15
2.1.2 Intended Function	15
2.1.3 Federal Communications Commission Rules	15
2.1.4 Fire Protection	15
2.1.5 Operation of Controls	15
2.1.6 Effects of Test	16
2.1.7 Distance Measurement	16
2.1.8 Channel Selection	16

Page

2.2 DME/N Performance - Standard Conditions 17

2.2.1 Accuracy 17
2.2.2 Interrogation Pulse Spectrum 17
2.2.3 Interrogator Pulse Characteristics 18

2.2.3.1 Pulse Rise Time 18
2.2.3.2 Pulse Decay Time 18
2.2.3.3 Pulse Duration 18
2.2.3.4 Pulse Top 18

2.2.4 Interrogator Pulse Coding 18
2.2.5 Interrogator Pulse Repetition Frequency 18
2.2.6 Interrogator Frequency Stability 19
2.2.7 Interrogator Peak Power 19

2.2.7.1 Second Pulse 19
2.2.7.2 First Pulse 19

2.2.8 Receiver Sensitivity 20
2.2.9 Receiver Decoder Selectivity and Rejection 21
2.2.10 ON and OFF Channel Signal Rejection 21

2.2.10.1 Off-Code On-Frequency Signal Rejection 22
2.2.10.2 Off-Frequency On-Code Signal Rejection 22
2.2.10.3 Off-Frequency Off-Code Rejection 22
2.2.10.4 Co-Channel Signal Rejection 23

2.2.11 Receiver Susceptibility to CW Interference 23
2.2.12 Identification 23
2.2.13 Memory 24
2.2.14 Echo Susceptibility 24
2.2.15 Rejection of Inter-Pulse CW 24
2.2.16 Emission of Spurious CW RF Energy 25
2.2.17 Antenna 25

2.2.17.1 Polarization 25
2.2.17.2 Antenna Radiation Pattern 25
2.2.17.3 Antenna Voltage Standing Wave Ratio 26

2.2.18 Warnings 26

2.3 DME/P Performance - Standard Conditions 27

2.3.1 Accuracy 27

2.3.1.1 Standard 1 28
2.3.1.2 Standard 2 29
2.3.1.3 Accuracy in the Presence of Garble 29
2.3.1.4 Accuracy Degradation in the Presence of Multipath 30
2.3.1.5 Range Rate 31

Page

2.3.2 Interrogator Pulse Spectrum 31
2.3.3 Interrogator Pulse Characteristics 31

2.3.3.1 Pulse Rise Time 31
2.3.3.2 Pulse Partial Rise Time - Final Approach Mode 31
2.3.3.3 Pulse Decay Time 31
2.3.3.4 Pulse Duration 31
2.3.3.5 Pulse Top 31
2.3.3.6 Initial Pulse Shape - Final Approach Mode ... 33

2.3.4 Interrogator Pulse Coding 33
2.3.5 Interrogator Pulse Repetition Frequency 33
2.3.6 Interrogator Frequency Stability 34
2.3.7 Interrogator Peak Power 34

2.3.7.1 IA Mode Second Pulse 34
2.3.7.2 FA Mode Second Pulse 34
2.3.7.3 First Pulse 34

2.3.8 Receiver Sensitivity 35
2.3.9 Receiver Selectivity 35
2.3.10 Receiver Decoder Selectivity 36
2.3.11 Search and Track 36

2.3.11.1 IA Mode Acquisition 36
2.3.11.2 Transition to FA Mode 36
2.3.11.3 Track 36
2.3.11.4 Memory 36

2.3.12 ON and OFF Channel Signal Rejection 37

2.3.12.1 Off-Code On-Frequency Signal Rejection 37
2.3.12.2 Off-Frequency On-Code Signal Rejection 37
2.3.12.3 Off-Frequency Off-Code Rejection 38
2.3.12.4 Co-channel Signal Rejection 38

2.3.13 Receiver Susceptibility to CW Interference 39
2.3.14 Identification 39
2.3.15 Echo Susceptibility 40
2.3.16 Rejection of Inter-Pulse CW 40
2.3.17 Emission of Spurious CW RF Energy 40
2.3.18 Antenna 40
2.3.19 Warnings/Annunciated Output Conditions 40
2.3.20 Output Data Filter 40

2.4 Equipment Performance - Environmental Conditions 43

2.4.1 Temperature and Altitude Tests 43

2.4.1.1 Temperature Test 43
2.4.1.2 Altitude Tests 44

Page

2.4.1.3 Decompression Test 44
2.4.1.4 Overpressure Test 44

2.4.2 Temperature Variation 45
2.4.3 Humidity 45
2.4.4 Shock Tests 46

2.4.4.1 Operational Shock 46
2.4.4.2 Crash Safety Shock 46

2.4.5 Vibration 46
2.4.6 Explosion Proofness 47
2.4.7 Waterproofness 47

2.4.7.1 Drip Proof Test 47
2.4.7.2 Spray Proof Test 47

2.4.8 Fluids Susceptibility 48

2.4.8.1 Spray Test 48
2.4.8.2 Immersion Test 48

2.4.9 Sand and Dust 49
2.4.10 Fungus Resistance 49
2.4.11 Salt Spray 49
2.4.12 Magnetic Effect 50
2.4.13 Power Input 50

2.4.13.1 Normal Operating Conditions 50
2.4.13.2 Abnormal Operating Conditions 50

2.4.14 Voltage Spike 51

2.4.14.1 Category A Requirements 51
2.4.14.2 Category B Requirements 51

2.4.15 Audio Frequency Conducted Susceptibility - Power Inputs 52
2.4.16 Induced Signal Susceptibility 52
2.4.17 Radio Frequency Susceptibility 52
2.4.18 Emission of Radio Frequency Energy 52

2.5 DME Test Procedures 53

2.5.1 Test Conditions 53
2.5.2 Description of Test Equipment for DME/N 54
2.5.3 Detailed Test Procedures for DME/N 57

2.5.3.1 Distance Measurement/Accuracy 57
2.5.3.2 Interrogator Pulse Spectrum 57
2.5.3.3 Interrogator Pulse Characteristics 59
2.5.3.4 Interrogator Pulse Coding 62

Page

2.5.3.5 Interrogator Pulse Repetition Frequency (PRF) 62
2.5.3.6 Interrogator Frequency Stability 63
2.5.3.7 Interrogator Peak Power 63
2.5.3.8 Receiver Sensitivity Range 66
2.5.3.9 Channel Selection Receiver Decoder Selectivity and Rejection 66
2.5.3.10 Amplitude Differentiation 67
2.5.3.11 Receiver Susceptibility to CW Interference .. 69
2.5.3.12 Identification 69
2.5.3.13 Memory/Warnings 71
2.5.3.14 Echo Susceptibility 71
2.5.3.15 Rejection of Inter-Pulse CW 72
2.5.3.16 Emission of Spurious Radio-Frequency Energy . 72
2.5.3.17 Antenna Radiation Pattern 73
2.5.3.18 Antenna Voltage Standing Wave Ratio 75

2.5.4 Description of Test Equipment - DME/P 77
2.5.5 Detailed Test Procedures for DME/P 77

2.5.5.1 Distance Measurement/Accuracy 78
2.5.5.2 Accuracy and Efficiency Degradation in the Presence of Garble 82
2.5.5.3 Accuracy Degradation in the Presence of Multipath 86
2.5.5.4 Range Rate 88
2.5.5.5 Interrogator Pulse Spectrum 89
2.5.5.6 Interrogator Pulse Characteristics 89
2.5.5.7 Interrogator Pulse Coding 90
2.5.5.8 Interrogator Pulse Repetition Frequency 90
2.5.5.9 Interrogator Frequency Stability 90
2.5.5.10 Interrogator Peak Power 90
2.5.5.11 Receiver Sensitivity 90
2.5.5.12 Receiver Bandwidth 91
2.5.5.13 Channel Selection/Receiver Decoder Selectivity 92
2.5.5.14 Search, Track and Warning/Annunciated Outputs 92
2.5.5.15 ON and OFF Channel Signal Rejection 95
2.5.5.16 Receiver Susceptibility to CW Interference .. 97
2.5.5.17 Identification 99
2.5.5.18 Echo Susceptibility 100
2.5.5.19 Rejection of Inter-Pulse CW 100
2.5.5.20 Emission Spurious of CW RF Energy 100
2.5.5.21 Antenna 100
2.5.5.22 Output Data Filter 100

Table 2-1 Pulse Pair Spacings 33
Figure 2-1 Pulse Shape Below 30% Amplitude 32
Figure 2-2 Accuracy/Sensitivity/Amplitude Differentiation/ Identification/Echo Susceptibility 58
Figure 2-3 Interrogator Pulse Spectrum 60
Figure 2-4 Interrogator Pulse Characteristics/Pulse Coding/Peak Power 61

Page

Figure 2-5 Interrogator Pulse Repetition Rate/Selectivity/Decoder Selectivity/Search Speed/Memory 64
Figure 2-6 Interrogator Frequency Stability 65
Figure 2-7 Spurious Response 70
Figure 2-8 Spurious Radio - Frequency Emission Measurement 74
Figure 2-9 Distance Measurement Test Setup 79
Figure 2-10A Garble Test Setup 83
Figure 2-10B Garble Test Setup Using TSS 83
Figure 2-11 Multipath Degradation Sensitivity Range Rate Search and Track 87
Figure 2-12 Search and Track 93
Figure 2-13 Spurious Response 98

3.0 INSTALLED EQUIPMENT PERFORMANCE 103

3.1 Equipment Installation 103

3.1.1 Equipment Accessibility 103
3.1.2 Displays 103
3.1.3 Dynamic Response 103
3.1.4 Aircraft Environment 103
3.1.5 Inadvertent Turnoff 103

3.2 Installed Equipment Performance Requirements 103

3.2.1 General Performance Requirements 103
3.2.2 Interference 104
3.2.3 Antenna Performance 104

3.3 Conditions of Test 104

3.3.1 Power Input 104
3.3.2 Associated Equipment or Systems 105
3.3.3 Environment 105
3.3.4 Adjustment of Equipment 105
3.3.5 Warm-up Period 105

3.4 Test Procedures for Installed Equipment Performance 105

3.4.1 Conformity Inspection 105
3.4.2 Ground Test Procedure 105

3.4.2.1 DME/P Test Equipment 105
3.4.2.2 Equipment Function 106
3.4.2.3 Interference Effects 106
3.4.2.4 Power Supply Fluctuations 106
3.4.2.5 Equipment Accessibility 107

3.4.3 Flight Test Procedures 107

3.4.3.1 Interference Effects 107

Page

3.4.3.2 DME/N Equipment 107
3.4.3.3 DME/P Equipment 108

4.0 OPERATIONAL CHARACTERISTICS 111

4.1 Required Operational Characteristics 111

4.1.1 Characteristics Checked in Pre-Flight and Flight Operations 111

4.2 Test Procedures 111

4.2.1 Procedures for Verifying Characteristics Normally Checked in Pre-Flight and Flight Operations 111

4.2.1.1 Power Input 111
4.2.1.2 Data Display 112
4.2.1.3 Facility Identification 112

MEMBERSHIP 113

APPENDIX A - DME Channel Plan
APPENDIX B - DME/P The New International Standard
APPENDIX C - Test Signal For DME/N
APPENDIX D - Measurement Methodology for PFE and CMN
APPENDIX E - Standard Test Signal for DME/P
APPENDIX F - Virtual Origin

1.0 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards for airborne distance measuring equipment (DME) operating within the radio frequency range of 960-1215 MHz. These standards contain system characteristics that should be beneficial to the various users of the system as well as designers, manufacturers and installers.

Section 1.0 of this document 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 is the basis for the standards stated in Sections 2.0 through 4.0. Definitions and assumptions essential to proper understanding of this document are also provided in Section 1.0.

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

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

Section 4.0 describes the operational performance characteristics for equipment installations and defines conditions and tests that will assure the user that the equipment will perform safely and reliably in the expected operational environment.

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

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

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

This document considers a configuration of airborne equipment encompassing: An antenna system, transmission lines, DME interrogator, interrogator control unit and interfaces with aircraft displays/systems. Additional functions and components that refer to expanded capabilities are identified as optional features.

Features that are beyond the scope of this document may be developed in future RTCA activities.

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

Other aircraft systems that may be used with DME interrogating equipment are outside the scope of this document. Where possible, reference is made to other documents that describe such systems, equipment or components.

If the equipment implementation includes a computer software package, the guidelines contained in RTCA/DO-178A, "Software Considerations in Airborne Systems and Equipment Certification," March 22, 1985, should be considered.

Development and approval of International Civil Aviation Organisation (ICAO) Standards and Recommended Practices (SARPS) was monitored continually. The DME/N was updated and the DME/P performance requirements were developed in consonance with the ICAO standards current at the time of MOPS publication.

1.2 System Overview

DME is an air-derived system in which the airborne equipment interrogates a ground transponder with paired pulses at a specific spacing. The ground transponder receives the interrogation and, after a predetermined time delay, transmits a reply on a different carrier frequency. The airborne equipment receives this reply and measures the time difference between its original interrogation and the ground reply. Based upon this time difference, the airborne equipment computes and displays the range of the ground transponder. Both ground and airborne equipment typically transmit and receive 360 degrees of azimuth coverage.

Airborne transmitter minimum peak power output levels of 50 and 250 watts have demonstrated satisfactory performance over several decades of operational use. The equipment specified herein is predicated upon these power levels. However, these values may not be satisfactory for some operational requirements applications which need higher output levels.