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MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AIR TRAFFIC CONTROL RADAR BEACON SYSTEM/MODE SELECT (ATCRBS/MODE S) AIRBORNE EQUIPMENT

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FOREWORD

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- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;

- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and

- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization (ICAO), the International Telecommunication Union (ITU) and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders.

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TABLE OF CONTENTS

1 PURPOSE AND SCOPE 1

1.1 Introduction 1
1.2 System Overview 2
1.2.1 The Function of Mode S 2
1.2.2 Major Operating Characteristics 2
1.2.3 System Performance 3
1.2.4 Basic System Protocol 3
1.2.5 Mode S Message Content 4
1.3 Operational Goals 5
1.4 Operational Applications 5
1.4.1 The ATCRBS Environment 5
1.4.2 The Mode S Environment 6
1.4.3 Mode S Transponder Levels 6
1.4.4 Additional/Specific Features 9
1.4.5 Minimum Output Power Level Designation 10
1.4.6 Transponder Labeling 10
1.4.7 Airborne Equipment 11
1.5 Assumptions 11
1.6 Test Procedures 11
1.6.1 Environmental Tests 12
1.6.2 Detailed Test Procedures 12
1.6.3 Installed System Tests 12
1.7 Definitions of Key Acronyms and Terms 13
1.8 Mode S Specific Services 13
1.9 Aircraft Equipment Information Vulnerabilities 13
1.10 Additional Information 14

2 MODE S TRANSPONDER EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES 15

2.1 General Requirements for All Equipment 15
2.1.1 Airworthiness 15
2.1.2 General Performance 15
2.1.3 Communications Regulations 15
2.1.4 Fire Protection 15
2.1.5 Operation of Controls 15
2.1.6 Accessibility of Controls 16
2.1.7 Flight Crew Control Functions 16
2.1.8 Optional Crew Control Functions 16
2.1.9 Effects of Tests 16
2.1.10 Equipment Configuration 17
2.1.11 Interrogation Signals 17
2.2 Minimum Performance Standards — Standard Conditions and Signals 22
2.2.1 Definition of Standard Conditions 22
2.2.2 Receiver Characteristics 22
2.2.3 Transmitter Characteristics 24

2.2.4 Reply Pulse Characteristics 27
2.2.5 Side Lobe Suppression Characteristics 33
2.2.6 Pulse Decoder Characteristics 35
2.2.7 Desensitization and Recovery Characteristics 36
2.2.8 Response in the Presence of Interference 39
2.2.9 Undesired Replies 41
2.2.10 Self Test and Monitor(s) 42
2.2.11 Response to Mutual Suppression Pulses 43
2.2.12 Diversity Operations 43
2.2.13 Data Handling and Interfaces 45
2.2.14 Description of the Mode S Signal Format 51
2.2.15 Antenna 69
2.2.16 Power Interruption 69
2.2.17 Mode S Transponders 70
2.2.18 Level 2 Transponder – Surveillance Function 71
2.2.19 Level 2 Transponder – Datalink Function 83
2.2.20 Level 3 & Level 4 Transponder – Extended Length Message (ELM) Protocols 109
2.2.21 Level 5 Transponder – Enhanced Protocols 121
2.2.22 CAS-Compatible Mode S Transponder 131
2.2.23 Extended Squitter (ES) 145
2.2.24 Elementary Surveillance Compliant Transponder 146
2.2.25 Enhanced Surveillance Compliant Transponders 156
2.2.26 Generic Register XX_{16} Requirements 175
2.2.27 Basic Dataflash 177
2.2.28 Phase Overlay 184
2.2.29 Air-Air Application Data 185
2.3 Equipment Performance – Environmental Conditions 187
2.3.1 Environmental Test Conditions 187
2.3.2 Detailed Environmental Test Procedures 189
2.4 Equipment Test Procedures 207
2.4.1 Definitions of Terms and Conditions of Test 207
2.4.2 Detailed Test Procedures 210
2.5 Test Procedures for the Surveillance and Communications Protocols 251
2.5.1 Introduction 251
2.5.2 Required Test Equipment 253
2.5.3 Selection and Use of the Test Procedures 254
2.5.4 Test Procedures 255
2.6 Test Procedures for Elementary Surveillance (ELS) Compliant Transponder (§2.2.24) 353
2.6.1 Ground Initiated Comm-B (§2.2.19.1.12.3) 353
2.6.2 Surveillance Identifier (“SI”) Code Requirements (§2.2.24.2 and §2.2.24.2.1) 354
2.6.3 Declaration of Capability in Register 10_{16} – Data Link Capability Report (§2.2.24.3) . 354
2.6.4 Register 17_{16} Common Usage GICB Capability Report (§2.2.24.4) 356
2.6.5 Register 18_{16} to $1C_{16}$, Mode S Specific Services Capability Reports (§2.2.24.5) 357
2.6.6 Baseline Aircraft Identification and Aircraft Registration Testing (§2.2.24.6) 361
2.7 Test Procedures for Enhanced Surveillance (EHS) Compliant Transponder (§2.2.25) . 396
2.7.1 Register 10_{16} – Data Link Capability Report (§2.2.25.1) 396
2.7.2 Register 17_{16}---Common Usage GICB Capability Report (§2.2.25.2) 398
2.7.3 Register 18_{16} to $1C_{16}$, Mode S Specific Services Capability Reports (§2.2.25.3) 401
2.7.4 Register $1D_{16}$ to $1F_{16}$ Mode S Specific Services MSP Capability (§2.2.25.4) 404
2.7.5 Register 40_{16} – Selected Vertical Intention (§2.2.25.5) 406
2.7.6 Register 50_{16} – Protocol and Interface (§2.2.25.6) 437

2.7.7 Register 60_{16} – Protocol and Interface (§2.2.25.8) 463
2.8 Generic Register XX Test Procedures (§2.2.26) 492
2.8.1 Purpose and Definition (§2.2.26.1) 492
2.8.2 Data Requirement (§2.2.26.2) 492
2.8.3 Update Rate (§2.2.26.3) 493
2.8.4 Service Reporting (§2.2.26.4) 493
2.8.5 Register XX_{16} – Repeat §2.8.1 through §2.8.4 using Extended Data Source Extraction with "DI" = 3 (§2.2.26) 494
2.9 Test Procedures for Basic Dataflash Compliant Transponder (§2.2.27) 494
2.9.1 Basic Dataflash Capability (§2.2.27.1) 495
2.9.2 Basic Dataflash Register in Not Monitored State (§2.2.27.3.a) 496
2.9.3 Basic Dataflash Register Monitored State (§2.2.27.3.b) 499
2.9.4 Basic Dataflash Register First Change of Data (§2.2.27.4.b) 518
2.9.5 Basic Dataflash Register Next Change of Data (§2.2.27.4.c) 534
2.9.6 Basic Dataflash Register Subsequent Change of Data (§2.2.27.4.b, d and e) 537
2.9.7 Verification of "Test Timer #2 (§2.2.27.5.a.2) 540
2.9.8 Return to Not Monitored State (§2.2.27.4.f) 543

3 INSTALLED EQUIPMENT PERFORMANCE 547

3.1 Equipment Installation 547
3.1.1 Equipment Accessibility 547
3.1.2 Inadvertent Turn Off 547
3.1.3 Displays 547
3.1.4 Aircraft Power Source 547
3.1.5 Antenna Pattern and Transmission Line(s) 547
3.1.6 Antenna Location 547
3.1.7 Mutual Suppression 548
3.2 Conditions of Test 548
3.2.1 Power Input 548
3.2.2 Interference Effects 548
3.2.3 Environment 549
3.2.4 Adjustment of Equipment 549
3.2.5 Warm-up Period 549
3.3 Test Procedures for Installed Equipment Performance 549
3.3.1 Conformity Inspection 549
3.3.2 Bench Tests 549
3.3.3 Reply Frequency 549
3.3.4 Framing Pulse Spacing 550
3.3.5 Reply Codes 550
3.3.6 Pressure Altitude Transmissions 550
3.3.7 Altitude Reporting Test 551
3.3.8 Reply Pulse Width 551
3.3.9 Receiver Sensitivity 551
3.3.10 Transmitter Power Output 551
3.3.11 Mode S Address 551
3.3.12 Received Reply 551
3.3.13 Airspeed Fixed Field 552
3.3.14 Airborne and On-the-Ground Condition 552
3.3.15 Diversity Antenna Installations 552

4 MEMBERSHIP 553

APPENDIX A ACRONYMS & DEFINITION OF TERMS A-1

A.1 Acronyms A-1
A.2 Definition of Terms A-7

APPENDIX B AIRCRAFT REGISTER FORMATS B-1

B.1 Introduction B-1
B.2 Data Formats for Transponder Registers B-1
B.2.1 Register Allocation B-1
B.2.2 General Conventions on Data Formats B-5
B.3 BDS Register Formats B-7
B.4 Implementation Guidelines B-58
B.4.1 Transponder Register 10_{16} B-58
B.4.2 Transponder Registers 18_{16} to $1C_{16}$ B-63
B.4.3 Transponder Register 20_{16} B-63
B.4.4 Transponder Register 40_{16} B-64
B.4.5 Transponder Register 50_{16} B-79
B.4.6 Transponder Register 60_{16} B-81

APPENDIX C MODE S SPECIFIC SERVICES (MSSS) C-1

C.1 Introduction C-1
C.1.1 Purpose C-1
C.1.2 Scope C-1
C.1.3 Mode S Application Entity (AE) / Transponder Interface Management C-1
C.2 Design Requirements C-1
C.2.1 Basic Operations C-1
C.2.2 Mode S Specific Services Entity (SSE) Interface Requirements C-2
C.3 Mode S Specific Services Test Procedures C-14
C.3.1 General Characteristics C-14
C.3.2 Detailed Test Procedures C-15

APPENDIX D FOR THE POTENTIAL ADDITION OF HIJACK MODE OPERATIONS D-1

D.1 Potential Changes from DO-181D D-1

APPENDIX E BASIC DATAFLASH OPERATION E-1

E.1 Introduction E-1
E.2 Explanation of Basic Dataflash Operation E-1
E.3 Example of Basic Dataflash Operation E-2
E.4 Timing Associated With Basic Dataflash E-4

APPENDIX F INTERROGATION/REPLY MONITOR (IRM) APPLICATION F-1

F.1 Purpose F-1
F.2 Design Requirements F-2

F.2.1 Register 66_{16} – IRM Interrogation Rate Monitor Message F-2
F.2.2 Register 67_{16} – IRM Reply Rate Monitor Message F-8
F.2.3 IRM Phase Overlay Interrogation Rate Monitor Message Data Requirements F-15
F.2.4 IRM Phase Overlay Reply Rate Monitor Message Data Requirements F-19
F.2.5 Maximum Update Interval of Register 66_{16} and Register 67_{16} F-22
F.2.6 Phase Overlay Message Data Timeout F-23
F.2.7 Extended Squitter Type F-23
F.3 Test Procedures F-23
F.3.1 Register 66_{16} – IRM Interrogation Rate Monitor Message F-24
F.3.2 Register 67_{16} – IRM Reply Rate Monitor Message F-26
F.3.3 IRM Phase Overlay Interrogation Rate Monitor Message Data Requirements F-30
F.3.4 IRM Phase Overlay Reply Rate Monitor Message Data Requirements F-31
F.3.5 Squitter Rates (§F.2.5) F-32
F.3.6 Update Rate (§F.2.5) F-33

APPENDIX G COMMITMENT TO LICENSE PHASE OVERLAY TECHNOLOGY G-1

List of Figures

Figure 2-1: General Pulse Patterns for PAM Interrogations 19
Figure 2-2: General Pulse Pattern for DPSK Interrogations 20
Figure 2-3: Unwanted Output Power 25
Figure 2-4: Mode S Reply Waveform 29
Figure 2-5: Spectrum Limits for Mode S Transponder Transmitter 30
Figure 2-6: PPM Data Interval 32
Figure 2-7: Overview of Mode S Interrogation Formats 52
Figure 2-8: Overview of Mode S Reply Formats 53
Figure 2-9: Field Index 56
Figure 2-10: Level 2 Transponder: Surveillance Function Uplink Formats 71
Figure 2-11: Level 2 Transponder: Surveillance Function Downlink Formats 71
Figure 2-12: Functional Diagram of Uplink Coding 74
Figure 2-13: Functional Diagram of Downlink Coding 75
Figure 2-14: The Level 2 Transponder: Surveillance Interrogation Acceptance 76
Figure 2-15: All Transponders: Lockout Initiation 79
Figure 2-16: All Level 2 Transponders: Formats 88
Figure 2-17: Level 2 Transponders: Interrogation Acceptance 89
Figure 2-18: All Level 2 Transponders: Coordination 90
Figure 2-19: All Transponders: FS and VS Protocol 91
Figure 2-20: All Transponders: Reply Content 92
Figure 2-21: All Level 2 Transponders: UM Protocol 93
Figure 2-22: All Data Link Transponders: B-Protocol 94
Figure 2-23: Comm-C Reservation and Closeout 112
Figure 2-24: Comm-C Message Handling 113
Figure 2-25: Comm-D Reservation and Closeout 116
Figure 2-26: Comm-D Message Handling 117
Figure 2-27: Enhanced Comm-B Protocol 124
Figure 2-28: Enhanced Comm-B Protocol – (Continued) 125
Figure 2-29: Enhanced Comm-C Reservation and Closeout 126
Figure 2-30: Enhanced Comm-C Message Handling 127
Figure 2-31: Enhanced Comm-D Reservation and Closeout 129
Figure 2-32: Enhanced Comm-D Message Handling 130
Figure 2-33: Register 20_{16} Data Processing 153
Figure 2-34: Basic Dataflash Process Flow 178
Figure 2-35: Phase Overlay Transmitter Test Setup 191
Figure 2-36: Test Equipment Connection 192
Figure 2-37: Test Equipment Connection 196
Figure 2-38: Test Equipment Connection 197
Figure 2-39: Test Equipment Connection 210
Figure 2-40: Test Equipment Connection 213
Figure 2-41: Test Equipment Connection 215
Figure 2-42: Test Equipment Connection 217
Figure 2-43: Phase Overlay Transmitter Test Setup 220
Figure 2-44: Test Equipment Connection 237
Figure 2-45: Test Equipment Connection 239
Figure B-4-1: Aircraft Flight Path B-65
Figure B-4-2: General Example for the Loading of Data in Register 40_{16} B-75
Figure C-2-1: Mode S Specific Services Architecture C-3

Figure C-2-2: The SD Field Structure C-9
Figure C-3-1: Mode S Specific Services Test Configuration C-15
Figure E-1: Basic Dataflash standalone change – single extraction E-5
Figure E-2: Basic Dataflash combined changes – single extraction E-6
Figure E-3: Basic Dataflash multiple changes – multiple extraction E-7
Figure E-4: Basic Dataflash combined changes – multiple extraction E-8

List of Tables

Table 1-1: Transponder Optional Additional Features 10
Table 2-1: Timer Characteristics 76
Table 2-2: Level 2 Transponder Compliance Matrix 85
Table 2-3: Mode S Subnetwork Version Number Encoding 97
Table 2-4: Uplink ELM Average Throughput Capability Encoding 98
Table 2-5: Downlink ELM Throughput Capability Encoding 98
Table 2-6: CAS Versions 131
Table 2-7: Status of MCP/FCU Mode Bits (Bit 48) Encoding 167
Table 2-8: Vertical Navigation Mode (Bit 49) Encoding 167
Table 2-9: Altitude Hold Mode (Bit 50) Encoding 168
Table 2-10: Approach Mode (Bit 51) Encoding 168
Table 2-11: Status of Target Altitude Source Bits (Bit 54) Encoding 168
Table 2-12: Target Altitude Source (Bit 55, 56) Encoding 169
Table 2-13: PO Message Subtype 185
Table 2-14: Environmental Test Groups 188
Table 2-15: Performance Test Requirements During Environmental Tests 189
Table 2-16: Barometric Altitude Data Inputs 282
Table B-2-1: GICB Register Number Assignments B-1
Table B-2-2: 6-Bit Subset of International Alphabet Number (IA-5) for Character Coding B-7
Table B-3-16a: BDS Code 1,0 – Data Link Capability Report (§2.2.19.1.12.6) B-10
Table B-3-16b: BDS Code 1,0 – Default Phase Overlay Data-Block B-12
Table B-3-17: BDS Code 1,1 – Data Link Capability Report (extension) B-14
Table B-3-23: BDS Code 1,7 – Common Usage GICB Capability Report B-15
Table B-3-24: BDS Code 1,8 – MSSS GICB Capability Report (1 of 5) B-16
Table B-3-25: BDS Code 1,9 – MSSS GICB Capability Report (2 of 5) B-17
Table B-3-26: BDS Code 1,A – MSSS GICB Capability Report (3 of 5) B-18
Table B-3-27: BDS Code 1,B – MSSS GICB Capability Report (4 of 5) B-19
Table B-3-28: BDS Code 1,C – MSSS GICB Capability Report (5 of 5) B-20
Table B-3-29: BDS Code 1,D – MSSS MSP Capability Report (1 of 3) B-21
Table B-3-30: BDS Code 1,E – MSSS MSP Capability Report (2 of 3) B-22
Table B-3-31: BDS Code 1,F – MSSS MSP Capability Report (3 of 3) B-23
Table B-3-32: BDS Code 2,0 – Aircraft Identification (§2.2.19.1.13) B-24
Table B-3-33: BDS Code 2,1 – Aircraft and Airline Registration Markings B-25
Table B-3-37: BDS Code 2,5 – Aircraft Type B-26
Table B-3-48a: BDS Code 3,0 –CAS Active Resolution Advisory B-27
Table B-3-48b: BDS Code 3,0 – Default Phase Overlay Data-Block B-28
Table B-3-49: BDS Code 3,1 – CAS Active Resolution Advisory (Part 2) B-30
Table B-3-51 to B-3-55: BDS Codes 3,3 to 3,7 – ACAS X Operational Coordination Message . B-31
Table B-3-64a: BDS Code 4,0 – Selected Vertical Intention B-32
Table B-3-64b: BDS Code 4,0 – Default Phase Overlay Data-Block B-33
Table B-3-65: BDS Code 4,1 – Next Waypoint Details B-35
Table B-3-66: BDS Code 4,2 – Next Waypoint Details B-36
Table B-3-67: BDS Code 4,3 – Next Waypoint Details B-37
Table B-3-72: BDS Code 4,8 – VHF Channel Report B-38
Table B-3-80a: BDS Code 5,0 – Track and Turn Report B-39
Table B-3-80b: BDS Code 5,0 – Default Phase Overlay Data-Block B-40
Table B-3-81: BDS Code 5,1 – Position Report Coarse B-42

Table B-3-82: BDS Code 5,2 – Position Report Fine B-43
Table B-3-83: BDS Code 5,3 – Air-Referenced State Vector B-44
Table B-3-84 to B-3-86: BDS Codes 5,4 to 5,6 – Waypoints 1, 2 and 3 ..... B-45
Table B-3-96a: BDS Code 6,0 – Heading and Speed Report B-46
Table B-3-96b: BDS Code 6,0 – Default Phase Overlay Data-Block B-47
Table B-3-102: BDS Code 6,6 – IRM - Interrogation Rate Monitor Message B-49
Table B-3-103: BDS Code 6,7 – IRM - Reply Rate Monitor Message B-50
Table B-3-113: BDS Code 7,1 – Interval Management Report B-51
Table B-3-227: BDS Code E,3 – Transponder Type / Part Number B-52
Table B-3-228: BDS Code E,4 – Transponder Software Revision Number B-53
Table B-3-229: BDS Code E,5 –CAS Unit Part Number B-54
Table B-3-230: BDS Code E,6 –CAS Unit Software Revision B-55
Table B-3-231: BDS Code E,7 – Transponder Status and Diagnostics B-56
Table B-3-234: BDS Code E,A – Vendor Specific Status and Diagnostics B-57
Table B-4-1: Register 40_{16} Parameters B-66
Table C-2-1: MSP Channel Number Assignments C-6
Table C-2-2: Broadcast Identifier Number Assignments C-6
Table C-2-3: LAS Subfield Coding C-10
Table C-2-4: LBS Subfield Coding C-12
Table C-2-5: AE Mode S Subnetwork Timers C-14
Table F-1: IRM Interrogation Rate Reports F-1
Table F-2: IRM Reply Rate Reports F-2
Table F-3: "ATCRBS Suppression Rate" Encoding F-3
Table F-4: "ATCRBS-Only All-Call Interrogation Rate" Encoding F-4
Table F-5: "Short Air-Air Surveillance Interrogation Rate" Encoding F-4
Table F-6: "Long Air-Air Surveillance Interrogation Rate" Encoding F-5
Table F-7: "Identity and Altitude Surveillance and Comm-A Interrogation Rate" Encoding F-6
Table F-8: "Mode S-Only All-Call Interrogation Rate" Encoding F-7
Table F-9: "Other Uplink Formats Interrogation Rate" Encoding F-8
Table F-10: "ATCRBS Reply Reporting Capability Bit" Encoding F-9
Table F-11: "Mode A/ATCRBS Reply Rate" Encoding - Mode A Only F-9
Table F-12: "Mode A/ATCRBS Reply Rate" Encoding - Mode A and Mode C F-10
Table F-13: "Mode C Reply Rate" Encoding F-10
Table F-14: "Short Air-Air Surveillance Reply Rate" Encoding F-11
Table F-15: "Long Air-Air Surveillance Reply Rate" Encoding F-12
Table F-16: "Identity and Altitude Surveillance Reply Rate" Encoding F-13
Table F-17: "Identity and Altitude Comm-B Reply Rate" Encoding F-14
Table F-18: "All-Call Reply Rate (DF=11)" Encoding F-15

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1 PURPOSE AND SCOPE

1.1 Introduction

This document sets forth minimum operational performance standards for Mode Select (Mode S)[1] airborne equipment. Incorporated within these standards are system characteristics that will be useful to users of the system as well as designers, manufacturers and installers.

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

It is recognized that any regulatory application of these standards is the responsibility of appropriate government agencies.

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

This document considers an equipment configuration consisting of: transponder, control panel, antenna and interconnecting cables. It should not be inferred that all Mode S airborne equipment will necessarily include all of the foregoing components as separate units; this will depend on the design configuration chosen by the manufacturer. Additional functions and components that may refer to expanded equipment capabilities are identified as additional capabilities. Equipment features that are beyond the scope of this document may be developed in future RTCA activities.

If the equipment implementation includes a computer software package, the guidelines contained in the most current issue of RTCA DO-178, *Software Considerations in Airborne Systems and Equipment Certification*, should be considered. If the equipment implementation includes design considerations for use in conjunction with TCAS functionality, the guidelines contained in the most current issue of RTCA DO-185, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment*, should be considered. If the equipment implementation includes design considerations for use in conjunction with ACAS Xa functionality, the guidelines contained in the most current issue of RTCA DO-385, *Minimum Operational Performance Standards for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo)*, should be considered. If the equipment implementation includes design considerations for use in conjunction with ACAS-Xu functionality, the guidelines contained in the most current issue of RTCA DO-386, *Minimum Operational Performance Standards for Airborne Collision Avoidance System Xu (ACAS Xu)*, should be considered.

Throughout this document, the term CAS is used to mean a generic collision avoidance system, applicable to any of the existing airborne collision avoidance implementations. The specific terms TCAS, ACAS Xa (or RTCA DO-385) and ACAS Xu (or RTCA DO-386) are used when the associated text applies only to a particular implementation. The full descriptor ACAS Xa/Xo is shortened to ACAS Xa, and TCAS II is shortened to

[1] For the purpose of this document, the term "Mode S" implies a combined ATCRBS/Mode S capability.

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TCAS. Specific versions of TCAS (6.04A, 7.0, and 7.1) are identified where necessary by the terms FAA TSO-C119a, RTCA DO-185A, and RTCA DO-185B respectively. In this document, the term ACAS X is used when text applies equally to ACAS Xa and ACAS Xu. Original RF message names, e.g., TCAS Resolution Message, are retained. Note that TCAS 7.1 and ACAS Xa/Xo are the two CAS recognized as ACAS II, i.e., compliant with the ACAS II SARPs as documented in ICAO Annex 10 Volume IV.

1.2 System Overview

1.2.1 The Function of Mode S

Mode S is a cooperative surveillance and communication system for air traffic control. It employs ground-based and airborne sensors (interrogators) and airborne transponders. Ground-air-ground data link communications can be accommodated integrally with the surveillance interrogations and replies. Mode S has been designed as an evolutionary addition to the Air Traffic Control Radar Beacon System (ATCRBS) to provide the enhanced surveillance and communication capability required for air traffic control automation. To facilitate the introduction of Mode S into the ATCRBS system, both ground and airborne Mode S installations include full ATCRBS capability. Mode S interrogators provide surveillance of ATCRBS-equipped aircraft, and Mode S transponders will reply to ATCRBS interrogators. In addition, the data link potential of Mode S permits use of the transponder for a number of air traffic control (ATC) and aircraft separation assurance (ASA) functions.

The monopulse techniques used in Mode S surveillance allow improved position determination of ATCRBS targets while reducing the number of required interrogations. This reduction of ATCRBS interrogations and replies improves the radio frequency (RF) interference environment.

A principal feature of Mode S that differs from ATCRBS is that each aircraft is assigned a unique address code. Using this unique code, interrogations can be directed to a particular aircraft and replies unambiguously identified. Channel interference is minimized because a sensor can limit its interrogations to targets of interest. In addition, by proper timing of interrogations, replies from closely-spaced aircraft can be received without mutual interference. The unique address in each interrogation and reply also permits the inclusion of data link messages to or from a particular aircraft.

1.2.2 Major Operating Characteristics

Mode S uses the same frequencies for interrogations and replies as ATCRBS (1030 and 1090 MHz, respectively). The Mode S waveforms (modulation techniques) were chosen to reduce the interference between ATCRBS and Mode S. The Mode S interrogation is transmitted using binary differential phase shift keying (DPSK). With proper demodulation, the information content is detectable in the presence of overlaid ATCRBS signals. The modulation of the downlink transmission from the transponder is pulse position modulation (PPM) which is inherently resistant to ATCRBS random pulses. The information content of both uplink and downlink transmissions is further protected by parity check bits generated by a cyclic coding algorithm.

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Each Mode S interrogation contains a 24-bit discrete address which allows a very large number of aircraft to operate in the air traffic control environment without occurrence of a redundant address. The overlaying of the parity check bits on the discrete address assures that a message will be accepted only by the aircraft addressed and that the probability of an erroneous message being accepted is extremely small.

Because the interference resistance of the Mode S system relies on the DPSK modulation process on the uplink and the PPM format on the downlink, the DPSK demodulation processor within the transponder must be designed carefully, and precise timing of the downlink pulses is required.

1.2.3 System Performance

1.2.3.1 Surveillance Performance

The Mode S interrogator provides surveillance of all beacon-equipped aircraft (both ATCRBS and Mode S) within its line-of-sight coverage. The nominal maximum range is 200 NM. The Mode S interrogators can provide surveillance of a large number of aircraft with better accuracy than ATCRBS. With the capability to reinterrogate a target within an antenna scan, the overall surveillance reliability of Mode S is greater than 99 percent.

1.2.3.2 Data Link Performance

Mode S can provide for ground-to-air, air-to-ground and air-to-air data link. The critical nature of many of the messages carried by Mode S requires a high degree of message integrity. Error-detecting codes in both interrogations and replies are designed to produce an undetected error rate of better than one in 10^7. By requiring technical acknowledgment of a correct message receipt, along with the sensor's capability to re-interrogate, if necessary, a message delivery reliability of greater than 99 percent in one antenna scan can be achieved. The Mode S data link capacity exceeds the maximum data load expected to exist in the foreseeable future.

1.2.4 Basic System Protocol

As an aircraft equipped with a transponder enters the airspace served by a Mode S interrogator, separate interrogations are used to elicit replies from ATCRBS and Mode S transponders. The ATCRBS-Only All-Call is used by the interrogator so ATCRBS targets are acquired without eliciting replies from Mode S targets. When interrogators transmit ATCRBS-Only All-Call interrogations, ATCRBS transponders reply with a standard ATCRBS reply format. The Mode S-Only All-Call is used by interrogators to acquire Mode S targets without eliciting replies from ATCRBS targets that may be present. When interrogators transmit Mode S-Only All-Calls, Mode S transponders reply with a Mode S format that includes their discrete (24-bit) Mode S address. This address, together with location of the Mode S aircraft, is entered into a file (placed on roll-call), and on the next scan the Mode S-equipped aircraft is discretely addressed. Since azimuth and range are known for all aircraft on roll-call, they are interrogated according to a precomputed schedule. Within this schedule are ATCRBS-Only All-Calls which permit the tracking of known ATCRBS aircraft and the acquisition of additional ATCRBS aircraft entering the served airspace. This schedule also includes Mode S-Only All-Calls that acquire Mode S aircraft entering the served airspace.

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