International Standards
and Recommended Practices

**Annex 10**
to the Convention on
International Civil Aviation

# Aeronautical Telecommunications

## Volume IV
Surveillance and Collision Avoidance Systems

This edition incorporates all amendments adopted by the Council prior to 4 March 2014 and supersedes, on 13 November 2014, all previous editions of Annex 10, Volume IV.

For information regarding the applicability of the Standards and Recommended Practices, *see* Foreword.

Fifth Edition
July 2014

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Published in separate English, French, Russian and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 University Street, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents
and booksellers, please go to the ICAO website at www.icao.int

*First edition 1995*
*Fourth edition 2007*
*Fifth edition 2014*

***Annex 10 — Aeronautical Telecommunications***
***Volume IV — Surveillance and Collision Avoidance Systems***
Order Number: AN 10-4
ISBN 978-92-9249-537-4

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# AMENDMENTS

Amendments are announced in the supplements to the *Publications Catalogue;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

## RECORD OF AMENDMENTS AND CORRIGENDA

| AMENDMENTS | | | |
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# FOREWORD

## Historical background

Standards and Recommended Practices for Aeronautical Telecommunications were first adopted by the Council on 30 May 1949 pursuant to the provisions of Article 37 of the Convention on International Civil Aviation (Chicago 1944) and designated as Annex 10 to the Convention. They became effective on 1 March 1950. The Standards and Recommended Practices were based on recommendations of the Communications Division at its Third Session in January 1949.

Up to and including the Seventh Edition, Annex 10 was published in one volume containing four Parts together with associated attachments: Part I — Equipment and Systems, Part II — Radio Frequencies, Part III — Procedures, and Part IV — Codes and Abbreviations.

By Amendment 42, Part IV was deleted from the Annex; the codes and abbreviations contained in that Part were transferred to a new document, Doc 8400.

As a result of the adoption of Amendment 44 on 31 May 1965, the Seventh Edition of Annex 10 was replaced by two volumes: Volume I (First Edition) containing Part I — Equipment and Systems, and Part II — Radio Frequencies, and Volume II (First Edition) containing Communication Procedures.

As a result of the adoption of Amendment 70 on 20 March 1995, Annex 10 was restructured to include five volumes: Volume I — Radio Navigation Aids; Volume II — Communication Procedures; Volume III — Communication Systems; Volume IV — Surveillance Radar and Collision Avoidance Systems; and Volume V — Aeronautical Radio Frequency Spectrum Utilization. By Amendment 70, Volumes III and IV were published in 1995 and Volume V was planned for publication with Amendment 71.

Table A shows the origin of amendments to Annex 10, Volume IV subsequent to Amendment 70, together with a summary of the principal subjects involved and the dates on which the Annex and the amendments were adopted by Council, when they became effective and when they became applicable.

## Action by Contracting States

*Notification of differences.* The attention of Contracting States is drawn to the obligation imposed by Article 38 of the Convention by which Contracting States are required to notify the Organization of any differences between their national regulations and practices and the International Standards contained in this Annex and any amendments thereto. Contracting States are invited to extend such notification to any differences from the Recommended Practices contained in this Annex and any amendments thereto, when the notification of such differences is important for the safety of air navigation. Further, Contracting States are invited to keep the Organization currently informed of any differences which may subsequently occur, or of the withdrawal of any differences previously notified. A specific request for notification of differences will be sent to Contracting States immediately after the adoption of each amendment to this Annex.

The attention of States is also drawn to the provisions of Annex 15 related to the publication of differences between their national regulations and practices and the related ICAO Standards and Recommended Practices through the Aeronautical Information Service, in addition to the obligation of States under Article 38 of the Convention.



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*Promulgation of information.* The establishment and withdrawal of and changes to facilities, services and procedures affecting aircraft operations provided in accordance with the Standards, Recommended Practices and Procedures specified in Annex 10 should be notified and take effect in accordance with the provisions of Annex 15.

*Use of the text of the Annex in national regulations.* The Council, on 13 April 1948, adopted a resolution inviting the attention of Contracting States to the desirability of using in their own national regulations, as far as practicable, the precise language of those ICAO Standards that are of a regulatory character and also of indicating departures from the Standards, including any additional national regulations that were important for the safety or regularity of air navigation. Wherever possible, the provisions of this Annex have been deliberately written in such a way as would facilitate incorporation, without major textual changes, into national legislation.

**Status of Annex components**

An Annex is made up of the following component parts, not all of which, however, are necessarily found in every Annex; they have the status indicated:

1.— *Material comprising the Annex proper:*

a) *Standards* and *Recommended Practices adopted by the Council under the provisions of the Convention.* They are defined as follows:

*Standard:* Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

*Recommended Practice:* Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.

b) *Appendices* comprising material grouped separately for convenience but forming part of the Standards and Recommended Practices adopted by the Council.

c) *Definitions* of terms used in the Standards and Recommended Practices which are not self-explanatory in that they do not have accepted dictionary meanings. A definition does not have independent status but is an essential part of each Standard and Recommended Practice in which the term is used, since a change in the meaning of the term would affect the specification.

d) *Tables* and *Figures* which add to or illustrate a Standard or Recommended Practice and which are referred to therein, form part of the associated Standard or Recommended Practice and have the same status.

2.— *Material approved by the Council for publication in association with the Standards and Recommended Practices:*

a) *Forewords* comprising historical and explanatory material based on the action of the Council and including an explanation of the obligations of States with regard to the application of the Standards and Recommended Practices ensuing from the Convention and the Resolution of Adoption;

b) *Introductions* comprising explanatory material introduced at the beginning of parts, chapters or sections of the Annex to assist in the understanding of the application of the text;



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c) *Notes* included in the text, where appropriate, to give factual information or references bearing on the Standards or Recommended Practices in question, but not constituting part of the Standards or Recommended Practices;

d) *Attachments* comprising material supplementary to the Standards and Recommended Practices, or included as a guide to their application.

### Disclaimer regarding patents

Attention is drawn to the possibility that certain elements of Standards and Recommended Practices in this Annex may be the subject of patents or other intellectual property rights. ICAO shall not be responsible or liable for not identifying any or all such rights. ICAO takes no position regarding the existence, validity, scope or applicability of any claimed patents or other intellectual property rights, and accepts no responsibility or liability therefore or relating thereto.

### Selection of language

This Annex has been adopted in four languages — English, French, Russian and Spanish. Each Contracting State is requested to select one of those texts for the purpose of national implementation and for other effects provided for in the Convention, either through direct use or through translation into its own national language, and to notify the Organization accordingly.

### Editorial practices

The following practice has been adhered to in order to indicate at a glance the status of each statement: *Standards* have been printed in light face roman; *Recommended Practices* have been printed in light face italics, the status being indicated by the prefix **Recommendation**; *Notes* have been printed in light face italics, the status being indicated by the prefix Note.

The following editorial practice has been followed in the writing of specifications: for Standards the operative verb “shall” is used, and for Recommended Practices the operative verb “should” is used.

The units of measurement used in this document are in accordance with the International System of Units (SI) as specified in Annex 5 to the Convention on International Civil Aviation. Where Annex 5 permits the use of non-SI alternative units these are shown in parentheses following the basic units. Where two sets of units are quoted it must not be assumed that the pairs of values are equal and interchangeable. It may, however, be inferred that an equivalent level of safety is achieved when either set of units is used exclusively.

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## Table A. Amendments to Annex 10, Volume IV

| *Amendment* | *Source(s)* | *Subject(s)* | *Adopted/approved*<br>*Effective*<br>*Applicable* |
|---|---|---|---|
| 70 | Air Navigation Commission; Fifth meeting of the Secondary Surveillance Radar Improvements and Collision Avoidance Systems Panel | Creation of Volume IV and introduction of Standards and Recommended Practices and related guidance material for the airborne collision avoidance system (ACAS). | 20 March 1995<br>24 July 1995<br>9 November 1995 |
| 71 | Air Navigation Commission; Fourth and fifth meetings of the Secondary Surveillance Radar Improvements and Collision Avoidance Systems Panel (SICASP) | Changes to material related to SSR Mode S air-ground data link system and the carriage of SSR transponders. | 12 March 1996<br>15 July 1996<br>7 November 1996 |
| 72 | — | No change. | — |
| 73<br>(2nd edition) | Air Navigation Commission; Sixth meeting of the Secondary Surveillance Radar Improvements and Collision Avoidance Systems Panel (SICASP) | Addition of specifications for the SSR Mode S system; introduction of material related to the performance of the collision avoidance logic; changes to guidance material related to the airborne collision avoidance system; introduction of Human Factors related material. | 19 March 1998<br>20 July 1998<br>5 November 1998 |
| 74 | Air Navigation Commission | Note related to the waiving of patent rights on Mode S extended squitter technique. | 18 March 1999<br>18 March 1999<br>— |
| 75 | — | No change. | — |
| 76 | Seventh meeting of the Aeronautical Mobile Communications Panel (AMCP) | Note related to update of references to the ITU Radio Regulations. | 12 March 2001<br>12 March 2001<br>— |
| 77<br>(3rd edition) | Seventh meeting of the Secondary Surveillance Radar Improvements and Collision Avoidance Systems Panel (SICASP) | SSR Mode S (Chapters 2 and 3); and ACAS (Chapters 1 and 4). | 27 February 2002<br>15 July 2002<br>28 November 2002 |
| 78 | — | No change. | — |
| 79 | — | No change. | — |
| 80 | — | No change. | — |
| 81 | — | No change. | — |
| 82<br>(4th edition) | Surveillance and Conflict Resolution Systems Panel (SCRSP) | Updates to SARPs on ADS-B | 26 February 2007<br>16 July 2007<br>22 November 2007 |
| 83 | — | No change. | — |
| 84 | — | No change. | — |



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| *Amendment* | *Source(s)* | *Subject(s)* | *Adopted/approved*<br>*Effective*<br>*Applicable* |
|---|---|---|---|
| 85 | Aeronautical Surveillance Panel (ASP) | a) Update of provisions relating to secondary surveillance radar (SSR) (Modes A/C and S) and automatic dependent surveillance — broadcast (ADS-B) using 1 090 MHz extended squitter resulting from operational experience;<br>b) introduction of a system-level and functional requirement for multilateration systems used for air traffic surveillance;<br>c) introduction of an initial set of technical requirements for airborne surveillance applications that are enabled by the use of ADS-B IN messages on the flight deck;<br>d) new requirements for display of proximate traffic, traffic advisory (TA) and resolution advisory (RA);<br>e) update of provisions on hybrid surveillance in light of relevant recent developments; and<br>f) introduction of a new functional requirement for monitoring own aircraft's vertical rate during an RA which would be affected by implementing a new version of the collision avoidance system (CAS) logic (commonly referred to as traffic alert and collision avoidance system (TCAS) Version 7.1). The new version of the CAS logic would also include a change in the annunciation of the RA "Adjust Vertical Speed, Adjust" to "Level Off". | 26 February 2010<br>12 July 2010<br>18 November 2010 |
| 86 | — | No change. | — |
| 87 | — | No change. | — |
| 88-A | — | No change. | — |
| 88-B | — | No change. | — |
| 89<br>(5th edition) | Aeronautical Surveillance Panel (ASP) | Surveillance systems | 3 March 2014<br>14 July 2014<br>13 November 2014 |



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# INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

## CHAPTER 1. DEFINITIONS

*Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the* Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies *(Doc 9718).*

*Note 2.— The Mode S extended squitter system is subject to patent rights from the Massachusetts Institute of Technology (MIT) Lincoln Laboratory. On 22 August 1996, MIT Lincoln Laboratory issued a notice in the Commerce Business Daily (CBD), a United States Government publication, of its intent not to assert its rights as patent owner against any and all persons in the commercial or non-commercial practice of the patent, in order to promote the widest possible use of the Mode S extended squitter technology. Further, by letter to ICAO dated 27 August 1998, MIT Lincoln Laboratory confirmed that the CBD notice has been provided to satisfy ICAO requirements for a statement of patent rights for techniques that are included in SARPs, and that the patent holders offer this technique free of charge for any use.*

***Airborne collision avoidance system (ACAS).*** An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

*Note.— SSR transponders referred to above are those operating in Mode C or Mode S.*

***Aircraft address.*** A unique combination of twenty-four bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

*Note.— SSR Mode S transponders transmit extended squitters to support the broadcast of aircraft-derived position for surveillance purposes. The broadcast of this type of information is a form of automatic dependent surveillance (ADS) known as ADS-broadcast (ADS-B).*

***Automatic dependent surveillance-broadcast (ADS-B) OUT.*** A function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers.

***Automatic dependent surveillance-broadcast (ADS-B) IN.*** A function that receives surveillance data from ADS-B OUT data sources.

***Collision avoidance logic.*** The sub-system or part of ACAS that analyses data relating to an intruder and own aircraft, decides whether or not advisories are appropriate and, if so, generates the advisories. It includes the following functions: range and altitude tracking, threat detection and RA generation. It excludes surveillance.

***Human Factors principles.*** Principles which apply to design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.



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***Secondary surveillance radar (SSR).*** A surveillance radar system which uses transmitters/receivers (interrogators) and transponders.

*Note.— The requirements for interrogators and transponders are specified in Chapter 3.*

***Surveillance radar.*** Radar equipment used to determine the position of an aircraft in range and azimuth.

***Traffic information service – broadcast (TIS-B) IN.*** A surveillance function that receives and processes surveillance data from TIS-B OUT data sources.

***Traffic information service – broadcast (TIS-B) OUT.*** A function on the ground that periodically broadcasts the surveillance information made available by ground sensors in a format suitable for TIS-B IN capable receivers.

*Note.— This technique can be achieved through different data links. The requirements for Mode S extended squitters are specified in Annex 10, Volume IV, Chapter 5. The requirements for VHF digital link (VDL) Mode 4 and universal access transceiver (UAT) are specified in Annex 10, Volume III, Part I.*



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# CHAPTER 2. GENERAL

## 2.1 SECONDARY SURVEILLANCE RADAR (SSR)

2.1.1 When SSR is installed and maintained in operation as an aid to air traffic services, it shall conform with the provisions of 3.1 unless otherwise specified in this 2.1.

*Note.— As referred to in this Annex, Mode A/C transponders are those which conform to the characteristics prescribed in 3.1.1. Mode S transponders are those which conform to the characteristics prescribed in 3.1.2. The functional capabilities of Mode A/C transponders are an integral part of those of Mode S transponders.*

### 2.1.2 Interrogation modes (ground-to-air)

2.1.2.1 Interrogation for air traffic services shall be performed on the modes described in 3.1.1.4.3 or 3.1.2. The uses of each mode shall be as follows:

1) *Mode A* — to elicit transponder replies for identity and surveillance.

2) *Mode C* — to elicit transponder replies for automatic pressure-altitude transmission and surveillance.

3) *Intermode* —

   a) *Mode A/C/S all-call:* to elicit replies for surveillance of Mode A/C transponders and for the acquisition of Mode S transponders.

   b) *Mode A/C-only all-call:* to elicit replies for surveillance of Mode A/C transponders. Mode S transponders do not reply.

4) *Mode S* —

   a) *Mode S-only all-call:* to elicit replies for acquisition of Mode S transponders.

   b) *Broadcast:* to transmit information to all Mode S transponders. No replies are elicited.

   c) *Selective:* for surveillance of, and communication with, individual Mode S transponders. For each interrogation, a reply is elicited only from the transponder uniquely addressed by the interrogation.

*Note 1.— Mode A/C transponders are suppressed by Mode S interrogations and do not reply.*

*Note 2.— There are 25 possible interrogation (uplink) formats and 25 possible Mode S reply (downlink) formats. For format assignment see 3.1.2.3.2, Figures 3-7 and 3-8.*

2.1.2.1.1 **Recommendation.—** *Administrations should coordinate with appropriate national and international authorities those implementation aspects of the SSR system which will permit its optimum use.*

*Note.— In order to permit the efficient operation of ground equipment designed to eliminate interference from unwanted aircraft transponder replies to adjacent interrogators (defruiting equipment), States may need to develop coordinated plans for the assignment of pulse recurrence frequencies (PRF) to SSR interrogators.*



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2.1.2.1.2 The assignment of interrogator identifier (II) codes, where necessary in areas of overlapping coverage, across international boundaries of flight information regions, shall be the subject of regional air navigation agreements.

2.1.2.1.3 The assignment of surveillance identifier (SI) codes, where necessary in areas of overlapping coverage, shall be the subject of regional air navigation agreements.

*Note.— The SI lockout facility cannot be used unless all Mode S transponders within coverage range are equipped for this purpose.*

2.1.2.2 Mode A and Mode C interrogations shall be provided.

*Note.— This requirement may be satisfied by intermode interrogations which elicit Mode A and Mode C replies from Mode A/C transponders.*

2.1.2.3 **Recommendation.—** *In areas where improved aircraft identification is necessary to enhance the effectiveness of the ATC system, SSR ground facilities having Mode S features should include aircraft identification capability.*

*Note.— Aircraft identification reporting through the Mode S data link provides unambiguous identification of aircraft suitably equipped.*

#### 2.1.2.4 SIDE-LOBE SUPPRESSION CONTROL INTERROGATION

2.1.2.4.1 Side-lobe suppression shall be provided in accordance with the provisions of 3.1.1.4 and 3.1.1.5 on all Mode A, Mode C and intermode interrogations.

2.1.2.4.2 Side-lobe suppression shall be provided in accordance with the provisions of 3.1.2.1.5.2.1 on all Mode S-only all-call interrogations.

### 2.1.3 Transponder reply modes (air-to-ground)

2.1.3.1 Transponders shall respond to Mode A interrogations in accordance with the provisions of 3.1.1.7.12.1 and to Mode C interrogations in accordance with the provisions of 3.1.1.7.12.2.

*Note.— If pressure-altitude information is not available, transponders reply to Mode C interrogations with framing pulses only.*

2.1.3.1.1 The pressure-altitude reports contained in Mode S replies shall be derived as specified in 3.1.1.7.12.2.

*Note.— 3.1.1.7.12.2 is intended to relate to Mode C replies and specifies*, inter alia*, that Mode C pressure-altitude reports be referenced to a standard pressure setting of 1 013.25 hectopascals. The intention of 2.1.3.1.1 is to ensure that all transponders, not just Mode C transponders, report uncorrected pressure-altitude.*

2.1.3.2 Where the need for Mode C automatic pressure-altitude transmission capability within a specified airspace has been determined, transponders, when used within the airspace concerned, shall respond to Mode C interrogations with pressure-altitude encoding in the information pulses.

2.1.3.2.1 From 1 January 1999, all transponders, regardless of the airspace in which they will be used, shall respond to Mode C interrogations with pressure-altitude information.

*Note.— Operation of the airborne collision avoidance system (ACAS) depends upon intruder aircraft reporting pressure-altitude in Mode C replies.*



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2.1.3.2.2 For aircraft equipped with 7.62 m (25 ft) or better pressure-altitude sources, the pressure-altitude information provided by Mode S transponders in response to selective interrogations (i.e. in the AC field, 3.1.2.6.5.4) shall be reported in 7.62 m (25 ft) increments.

*Note.— Performance of the ACAS is significantly enhanced when an intruder aircraft is reporting pressure-altitude in 7.62 m (25 ft) increments.*

2.1.3.2.3 All Mode A/C transponders shall report pressure-altitude encoded in the information pulses in Mode C replies.

2.1.3.2.4 All Mode S transponders shall report pressure-altitude encoded in the information pulses in Mode C replies and in the AC field of Mode S replies.

2.1.3.2.5 When a Mode S transponder is not receiving more pressure-altitude information from a source with a quantization of 7.62 m (25 ft) or better increments, the reported value of the altitude shall be the value obtained by expressing the measured value of the uncorrected pressure-altitude of the aircraft in 30.48 m (100 ft) increments and the Q bit (see 3.1.2.6.5.4 b)) shall be set to 0.

*Note.— This requirement relates to the installation and use of the Mode S transponder. The purpose is to ensure that altitude data obtained from a 30.48 m (100 ft) increment source are not reported using the formats intended for 7.62 m (25 ft) data.*

2.1.3.3 Transponders used within airspace where the need for Mode S airborne capability has been determined shall also respond to intermode and Mode S interrogations in accordance with the applicable provisions of 3.1.2.

2.1.3.3.1 Requirements for mandatory carriage of SSR Mode S transponders shall be on the basis of regional air navigation agreements which shall specify the airspace and the airborne implementation timescales.

2.1.3.3.2 **Recommendation.—** *The agreements indicated in 2.1.3.3.1 should provide at least five years' notice.*

### 2.1.4 Mode A reply codes (information pulses)

2.1.4.1 All transponders shall be capable of generating 4 096 reply codes conforming to the characteristics given in 3.1.1.6.2.

2.1.4.1.1 **Recommendation.—** *ATS authorities should establish the procedures for the allotment of SSR codes in conformity with Regional Air Navigation agreements, taking into account other users of the system.*

*Note.— Principles for the allocation of SSR codes are given in Doc 4444, Chapter 8.*

2.1.4.2 The following Mode A codes shall be reserved for special purposes:

2.1.4.2.1 Code 7700 to provide recognition of an aircraft in an emergency.

2.1.4.2.2 Code 7600 to provide recognition of an aircraft with radiocommunication failure.

2.1.4.2.3 Code 7500 to provide recognition of an aircraft which is being subjected to unlawful interference.

2.1.4.3 Appropriate provisions shall be made in ground decoding equipment to ensure immediate recognition of Mode A codes 7500, 7600 and 7700.

2.1.4.4 **Recommendation.—** *Mode A code 0000 should be reserved for allocation subject to regional agreement, as a general purpose code.*



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2.1.4.5 Mode A code 2000 shall be reserved to provide recognition of an aircraft which has not received any instructions from air traffic control units to operate the transponder.

### 2.1.5 Mode S airborne equipment capability

2.1.5.1 All Mode S transponders shall conform to one of the following five levels:

*Note.— The transponder used for a Mode S site monitor may differ from the requirements defined for a normal Mode S transponder. For example, it may be necessary to reply to all-call interrogations when on the ground. For more details see the* Aeronautical Surveillance Manual *(Doc 9924) Appendix D.*

2.1.5.1.1 Level 1 — Level 1 transponders shall have the capabilities prescribed for:

a) Mode A identity and Mode C pressure-altitude reporting (3.1.1);

b) intermode and Mode S all-call transactions (3.1.2.5);

c) addressed surveillance altitude and identity transaction (3.1.2.6.1, 3.1.2.6.3, 3.1.2.6.5 and 3.1.2.6.7);

d) lockout protocols (3.1.2.6.9);

e) basic data protocols except data link capability reporting (3.1.2.6.10); and

f) air-air service and squitter transactions (3.1.2.8).

*Note.— Level 1 permits SSR surveillance based on pressure-altitude reporting and the Mode A identity code. In an SSR Mode S environment, technical performance relative to a Mode A/C transponder is improved due to Mode S selective aircraft interrogation.*

2.1.5.1.2 Level 2 — Level 2 transponders shall have the capabilities of 2.1.5.1.1 and also those prescribed for:

a) standard length communications (Comm-A and Comm-B) (3.1.2.6.2, 3.1.2.6.4, 3.1.2.6.6, 3.1.2.6.8 and 3.1.2.6.11);

b) data link capability reporting (3.1.2.6.10.2.2);

c) aircraft identification reporting (3.1.2.9); and

d) data parity with overlay control (3.1.2.6.11.2.5) for equipment certified on or after 1 January 2020.

*Note.— Level 2 permits aircraft identification reporting and other standard length data link communications from ground to air and air to ground. The aircraft identification reporting capability requires an interface and appropriate input device.*

2.1.5.1.3 Level 3 — Level 3 transponders shall have the capabilities of 2.1.5.1.2 and also those prescribed for ground-to-air extended length message (ELM) communications (3.1.2.7.1 to 3.1.2.7.5).

*Note.— Level 3 permits extended length data link communications from ground to air and thus may provide retrieval from ground-based data banks and receipt of other air traffic services which are not available with Level 2 transponders.*

2.1.5.1.4 Level 4 — Level 4 transponders shall have the capabilities of 2.1.5.1.3 and also those prescribed for air-to-ground extended length message (ELM) communications (3.1.2.7.7 and 3.1.2.7.8).



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*Note.— Level 4 permits extended length data link communications from air to ground and thus may provide access from the ground to airborne data sources and the transmission of other data required by air traffic services which are not available with Level 2 transponders.*

2.1.5.1.5 Level 5 — Level 5 transponders shall have the capabilities of 2.1.5.1.4 and also those prescribed for enhanced Comm-B and extended length message (ELM) communications (3.1.2.6.11.3.4, 3.1.2.7.6 and 3.1.2.7.9).

*Note.— Level 5 permits Comm-B and extended length data link communications with multiple interrogators without requiring the use of multisite reservations. This level of transponder has a higher minimum data link capacity than the other transponder levels.*

2.1.5.1.6 *Extended squitter* — Extended squitter transponders shall have the capabilities of 2.1.5.1.2, 2.1.5.1.3, 2.1.5.1.4 or 2.1.5.1.5, the capabilities prescribed for extended squitter operation (3.1.2.8.6) and the capabilities prescribed for ACAS cross-link operation (3.1.2.8.3 and 3.1.2.8.4). Transponders with these capabilities shall be designated with a suffix "e".

*Note.— For example, a level 4 transponder with extended squitter capability would be designated "level 4e".*

2.1.5.1.7 *SI capability* — Transponders with the ability to process SI codes shall have the capabilities of 2.1.5.1.1, 2.1.5.1.2, 2.1.5.1.3, 2.1.5.1.4 or 2.1.5.1.5 and also those prescribed for SI code operation (3.1.2.3.2.1.4, 3.1.2.5.2.1, 3.1.2.6.1.3, 3.1.2.6.1.4.1, 3.1.2.6.9.1.1 and 3.1.2.6.9.2). Transponders with this capability shall be designated with a suffix "s".

*Note.— For example, a level 4 transponder with extended squitter capability and SI capability would be designated "level 4es".*

2.1.5.1.7.1 SI code capability shall be provided in accordance with the provisions of 2.1.5.1.7 for all Mode S transponders installed on or after 1 January 2003 and by all Mode S transponders by 1 January 2005.

*Note.— Mandates from certain States may require applicability in advance of these dates.*

2.1.5.1.8 *Extended squitter non-transponder devices.* Devices that are capable of broadcasting extended squitters that are not part of a Mode S transponder shall conform to all of the 1 090 MHz RF signals in space requirements specified for a Mode S transponder, except for transmit power levels for the identified equipment class as specified in 5.1.1.

2.1.5.2 All Mode S transponders used by international civil air traffic shall conform, at least, to the requirements of Level 2 prescribed in 2.1.5.1.2.

*Note 1.— Level 1 may be admitted for use within an individual State or within the terms of a regional air navigation agreement. The Mode S Level 1 transponder comprises the minimum set of features for compatible operation of Mode S transponders with SSR Mode S interrogators. It is defined to prevent a proliferation of transponder types below Level 2 which would be incompatible with SSR Mode S interrogators.*

*Note 2.— The intent of the requirement for a Level 2 capability is to ensure the widespread use of an ICAO standard transponder capability to allow worldwide planning of Mode S ground facilities and services. The requirement also discourages an initial installation with Level 1 transponders that would be rendered obsolete by later requirements in certain airspace for mandatory carriage of transponders having Level 2 capabilities.*

2.1.5.3 Mode S transponders installed on aircraft with gross mass in excess of 5 700 kg or a maximum cruising true airspeed capability in excess of 463 km/h (250 kt) shall operate with antenna diversity as prescribed in 3.1.2.10.4 if:

a) the aircraft individual certificate of airworthiness is first issued on or after 1 January 1990; or



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b) Mode S transponder carriage is required on the basis of regional air navigation agreement in accordance with 2.1.3.3.1 and 2.1.3.3.2.

*Note.— Aircraft with maximum cruising true airspeed exceeding 324 km/h (175 kt) are required to operate with a peak power of not less than 21.0 dBW as specified in 3.1.2.10.2 c).*

#### 2.1.5.4 CAPABILITY REPORTING IN MODE S SQUITTERS

2.1.5.4.1 Capability reporting in Mode S acquisition squitters (unsolicited downlink transmissions) shall be provided in accordance with the provisions of 3.1.2.8.5.1 for all Mode S transponders installed on or after 1 January 1995.

2.1.5.4.2 **Recommendation.—** *Transponders equipped for extended squitter operation should have a means to disable acquisition squitters when extended squitters are being emitted.*

*Note.— This will facilitate the suppression of acquisition squitters if all ACAS units have been converted to receive the extended squitter.*

#### 2.1.5.5 EXTENDED LENGTH MESSAGE (ELM) TRANSMIT POWER

In order to facilitate the conversion of existing Mode S transponders to include full Mode S capability, transponders originally manufactured before 1 January 1999 shall be permitted to transmit a burst of 16 ELM segments at a minimum power level of 20 dBW.

*Note.— This represents a 1 dB relaxation from the power requirement specified in 3.1.2.10.2.*

### 2.1.6 SSR Mode S address (aircraft address)

The SSR Mode S address shall be one of 16 777 214 twenty-four-bit aircraft addresses allocated by ICAO to the State of Registry or common mark registering authority and assigned as prescribed in 3.1.2.4.1.2.3.1.1 and the Appendix to Chapter 9, Part I, Volume III, Annex 10.

## 2.2 HUMAN FACTORS CONSIDERATIONS

**Recommendation.—** *Human Factors principles should be observed in the design and certification of surveillance radar, transponder and collision avoidance systems.*

*Note.— Guidance material on Human Factors principles can be found in Doc 9683,* Human Factors Training Manual *and Circular 249* (Human Factors Digest No. 11 — Human Factors in CNS/ATM Systems).

### 2.2.1 Operation of controls

2.2.1.1 Transponder controls which are not intended to be operated in flight shall not be directly accessible to the flight crew.

2.2.1.2 **Recommendation.—** *The operation of transponder controls, intended for use during flight, should be evaluated to ensure they are logical and tolerant to human error. In particular, where transponder functions are integrated with other system controls, the manufacturer should ensure that unintentional transponder mode switching (i.e. an operational state to 'STANDBY' or 'OFF') is minimized.*



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*Note.— This may take the form of a confirmation of mode switching, required by the flight crew. Typically 'Line Select' Keys, 'Touch Screen' or 'Cursor Controlled/Tracker-ball' methods used to change transponder modes should be carefully designed to minimize flight crew error.*

2.2.1.3 **Recommendation.—** *The flight crew should have access at all times to the information of the operational state of the transponder.*

*Note.— Information on the monitoring of the operational state of the transponder is provided in* RTCA DO-181 E, Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/ Mode Select (ATCRBS/Mode S) Airborne Equipment, *and in* EUROCAE ED-73E, Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders.



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# CHAPTER 3. SURVEILLANCE SYSTEMS

## 3.1 SECONDARY SURVEILLANCE RADAR (SSR) SYSTEM CHARACTERISTICS

*Note 1.— Section 3.1.1 prescribes the technical characteristics of SSR systems having only Mode A and Mode C capabilities. Section 3.1.2 prescribes the characteristics of systems with Mode S capabilities. Chapter 5 prescribes additional requirements on Mode S extended squitters.*

*Note 2.— Systems using Mode S capabilities are generally used for air traffic control surveillance systems. In addition, certain ATC applications may use Mode S emitters, e.g. for vehicle surface surveillance or for fixed target detection on surveillance systems. Under such specific conditions, the term "aircraft" can be understood as "aircraft or vehicle (A/V)". While those applications may use a limited set of data, any deviation from standard physical characteristics must be considered very carefully by the appropriate authorities. They must take into account not only their own surveillance (SSR) environment but also possible effects on other systems like ACAS.*

*Note 3.— Non-Standard-International alternative units are used as permitted by Annex 5, Chapter 3, 3.2.2.*

### 3.1.1 Systems having only Mode A and Mode C capabilities

*Note 1.— In this section, SSR modes are designated by letters A and C. Suffixed letters, e.g. $A_2$, $C_4$, are used to designate the individual pulses used in the air-to-ground pulse trains. This common use of letters is not to be construed as implying any particular association of modes and codes.*

*Note 2.— Provisions for the recording and retention of radar data are contained in Annex 11, Chapter 6.*

#### 3.1.1.1 INTERROGATION AND CONTROL (INTERROGATION SIDE-LOBE SUPPRESSION) RADIO FREQUENCIES (GROUND-TO-AIR)

3.1.1.1.1 The carrier frequency of the interrogation and control transmissions shall be 1 030 MHz.

3.1.1.1.2 The frequency tolerance shall be plus or minus 0.2 MHz.

3.1.1.1.3 The carrier frequencies of the control transmission and of each of the interrogation pulse transmissions shall not differ from each other by more than 0.2 MHz.

#### 3.1.1.2 REPLY CARRIER FREQUENCY (AIR-TO-GROUND)

3.1.1.2.1 The carrier frequency of the reply transmission shall be 1 090 MHz.

3.1.1.2.2 The frequency tolerance shall be plus or minus 3 MHz.



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#### 3.1.1.3 POLARIZATION

Polarization of the interrogation, control and reply transmissions shall be predominantly vertical.

#### 3.1.1.4 INTERROGATION MODES (SIGNALS-IN-SPACE)

3.1.1.4.1 The interrogation shall consist of two transmitted pulses designated $P_1$ and $P_3$. A control pulse $P_2$ shall be transmitted following the first interrogation pulse $P_1$.

3.1.1.4.2 Interrogation Modes A and C shall be as defined in 3.1.1.4.3.

3.1.1.4.3 The interval between $P_1$ and $P_3$ shall determine the mode of interrogation and shall be as follows:

Mode A 8 ±0.2 microseconds
Mode C 21 ±0.2 microseconds

3.1.1.4.4 The interval between $P_1$ and $P_2$ shall be 2.0 plus or minus 0.15 microseconds.

3.1.1.4.5 The duration of pulses $P_1$, $P_2$ and $P_3$ shall be 0.8 plus or minus 0.1 microsecond.

3.1.1.4.6 The rise time of pulses $P_1$, $P_2$ and $P_3$ shall be between 0.05 and 0.1 microsecond.

*Note 1.— The definitions are contained in Figure 3-1 "Definitions of secondary surveillance radar waveform shapes, intervals and the reference point for sensitivity and power".*

*Note 2.— The intent of the lower limit of rise time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise time.*

3.1.1.4.7 The decay time of pulses $P_1$, $P_2$ and $P_3$ shall be between 0.05 and 0.2 microsecond.

*Note.— The intent of the lower limit of decay time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated decay time.*

#### 3.1.1.5 INTERROGATOR AND CONTROL TRANSMISSION CHARACTERISTICS (INTERROGATION SIDE-LOBE SUPPRESSION — SIGNALS-IN-SPACE)

3.1.1.5.1 The radiated amplitude of $P_2$ at the antenna of the transponder shall be:

a) equal to or greater than the radiated amplitude of $P_1$ from the side-lobe transmissions of the antenna radiating $P_1$; and

b) at a level lower than 9 dB below the radiated amplitude of $P_1$, within the desired arc of interrogation.

3.1.1.5.2 Within the desired beam width of the directional interrogation (main lobe), the radiated amplitude of $P_3$ shall be within 1 dB of the radiated amplitude of $P_1$.



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3.1.1.6 REPLY TRANSMISSION CHARACTERISTICS (SIGNALS-IN-SPACE)

3.1.1.6.1 *Framing pulses*. The reply function shall employ a signal comprising two framing pulses spaced 20.3 microseconds as the most elementary code.

3.1.1.6.2 *Information pulses*. Information pulses shall be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses shall be as follows:

| *Pulses* | *Position (microseconds)* |
|---|---|
| $C_1$ | 1.45 |
| $A_1$ | 2.90 |
| $C_2$ | 4.35 |
| $A_2$ | 5.80 |
| $C_4$ | 7.25 |
| $A_4$ | 8.70 |
| X | 10.15 |
| $B_1$ | 11.60 |
| $D_1$ | 13.05 |
| $B_2$ | 14.50 |
| $D_2$ | 15.95 |
| $B_4$ | 17.40 |
| $D_4$ | 18.85 |

*Note.— The Standard relating to the use of these pulses is given in 2.1.4.1. However, the position of the "X" pulse is not used in replies to Mode A or Mode C interrogations and is specified only as a technical standard to safeguard possible future expansion of the system. It has nevertheless been decided that such expansion should be achieved using Mode S. The presence of a pulse in the X pulse position is used in some States to invalidate replies.*

3.1.1.6.3 *Special position identification pulse (SPI).* In addition to the information pulses provided, a special position identification pulse shall be transmitted but only as a result of manual (pilot) selection. When transmitted, it shall be spaced at an interval of 4.35 microseconds following the last framing pulse of Mode A replies only.

3.1.1.6.4 *Reply pulse shape.* All reply pulses shall have a pulse duration of 0.45 plus or minus 0.1 microsecond, a pulse rise time between 0.05 and 0.1 microsecond and a pulse decay time between 0.05 and 0.2 microsecond. The pulse amplitude variation of one pulse with respect to any other pulse in a reply train shall not exceed 1 dB.

*Note.— The intent of the lower limit of rise and decay times (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is not greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise and decay times.*

3.1.1.6.5 *Reply pulse position tolerances.* The pulse spacing tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse interval tolerance of the special position identification pulse with respect to the last framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse spacing tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) shall not exceed plus or minus 0.15 microsecond.

3.1.1.6.6 *Code nomenclature.* The code designation shall consist of digits between 0 and 7 inclusive, and shall consist of the sum of the subscripts of the pulse numbers given in 3.1.1.6.2 above, employed as follows:



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| *Digit* | *Pulse Group* |
|---|---|
| First (most significant) | A |
| Second | B |
| Third | C |
| Fourth | D |

### 3.1.1.7 TECHNICAL CHARACTERISTICS OF TRANSPONDERS WITH MODE A AND MODE C CAPABILITIES ONLY

3.1.1.7.1 *Reply.* The transponder shall reply (not less than 90 per cent triggering) when all of the following conditions have been met:

a) the received amplitude of $P_3$ is in excess of a level 1 dB below the received amplitude of $P_1$ but no greater than 3 dB above the received amplitude of $P_1$;

b) either no pulse is received in the interval 1.3 microseconds to 2.7 microseconds after $P_1$, or $P_1$ exceeds by more than 9 dB any pulse received in this interval;

c) the received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the latter are not recognized by the transponder as $P_1$, $P_2$ or $P_3$.

3.1.1.7.2 The transponder shall not reply under the following conditions:

a) to interrogations when the interval between pulses $P_1$ and $P_3$ differs from those specified in 3.1.1.4.3 by more than plus or minus 1.0 microsecond;

b) upon receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

3.1.1.7.3 *Dead time.* After recognition of a proper interrogation, the transponder shall not reply to any other interrogation, at least for the duration of the reply pulse train. This dead time shall end no later than 125 microseconds after the transmission of the last reply pulse of the group.

#### 3.1.1.7.4 *SUPPRESSION*

*Note.— This characteristic is used to prevent replies to interrogations received via the side lobes of the interrogator antenna, and to prevent Mode A/C transponders from replying to Mode S interrogations.*

3.1.1.7.4.1 The transponder shall be suppressed when the received amplitude of $P_2$ is equal to, or in excess of, the received amplitude of $P_1$ and spaced 2.0 plus or minus 0.15 microseconds. The detection of $P_3$ is not required as a prerequisite for initiation of suppression action.

3.1.1.7.4.2 The transponder suppression shall be for a period of 35 plus or minus 10 microseconds.

3.1.1.7.4.2.1 The suppression shall be capable of being reinitiated for the full duration within 2 microseconds after the end of any suppression period.



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3.1.1.7.4.3 *Suppression in presence of* $S_1$ *pulse*

*Note.— The* $S_1$ *pulse is used in a technique employed by ACAS known as "whisper-shout" to facilitate ACAS surveillance of Mode A/C aircraft in higher traffic densities. The whisper-shout technique is explained in the* Airborne Collision Avoidance System (ACAS) Manual *(Doc 9863).*

When an $S_1$ pulse is detected 2.0 plus or minus 0.15 microseconds before the $P_1$ of a Mode A or Mode C interrogation:

a) with $S_1$ and $P_1$ above MTL, the transponder shall be suppressed as specified in 3.1.1.7.4.1;

b) with $P_1$ at MTL and $S_1$ at MTL, the transponder shall be suppressed and shall reply to no more than 10 per cent of Mode A/C interrogations;

c) with $P_1$ at MTL and $S_1$ at MTL –3 dB, the transponder shall reply to Mode A/C interrogations at least 70 per cent of the time; and

d) with $P_1$ at MTL and $S_1$ at MTL –6 dB, the transponder shall reply to Mode A/C interrogations at least 90 per cent of the time.

*Note 1.— The suppression action is because of the detection of* $S_1$ *and* $P_1$ *and does not require detection of a* $P_2$ *or* $P_3$ *pulse.*

*Note 2.—* $S_1$ *has a lower amplitude than* $P_1$*. Certain ACAS use this mechanism to improve target detection (4.3.7.1).*

*Note 3.— These requirements also apply to a Mode A/C only capable transponder when an* $S_1$ *precedes an intermode interrogation (2.1.2.1).*

3.1.1.7.5 *RECEIVER SENSITIVITY AND DYNAMIC RANGE*

3.1.1.7.5.1 The minimum triggering level of the transponder shall be such that replies are generated to at least 90 per cent of the interrogation signals when:

a) the two pulses $P_1$ and $P_3$ constituting an interrogation are of equal amplitude and $P_2$ is not detected; and

b) the amplitude of these signals is nominally 71 dB below 1 mW, with limits between 69 dB and 77 dB below 1 mW.

3.1.1.7.5.2 The reply and suppression characteristics shall apply over a received amplitude of $P_1$ between minimum triggering level and 50 dB above that level.

3.1.1.7.5.3 The variation of the minimum triggering level between modes shall not exceed 1 dB for nominal pulse spacings and pulse widths.

3.1.1.7.6 *Pulse duration discrimination.* Signals of received amplitude between minimum triggering level and 6 dB above this level, and of a duration less than 0.3 microsecond, shall not cause the transponder to initiate reply or suppression action. With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of a duration more than 1.5 microseconds shall not cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level (MTL) to 50 dB above that level.

3.1.1.7.7 *Echo suppression and recovery.* The transponder shall contain an echo suppression facility designed to permit normal operation in the presence of echoes of signals-in-space. The provision of this facility shall be compatible with the requirements for suppression of side lobes given in 3.1.1.7.4.1.



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3.1.1.7.7.1 *Desensitization.* Upon receipt of any pulse more than 0.7 microsecond in duration, the receiver shall be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse but shall at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse.

*Note.— Single pulses of duration less than 0.7 microsecond are not required to cause the specified desensitization nor to cause desensitization of duration greater than permitted by 3.1.1.7.7.1 and 3.1.1.7.7.2.*

3.1.1.7.7.2 *Recovery.* Following desensitization, the receiver shall recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. Recovery shall be at an average rate not exceeding 4.0 dB per microsecond.

3.1.1.7.8 *Random triggering rate.* In the absence of valid interrogation signals, Mode A/C transponders shall not generate more than 30 unwanted Mode A or Mode C replies per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less. This random triggering rate shall not be exceeded when all possible interfering equipments installed in the same aircraft are operating at maximum interference levels.

3.1.1.7.8.1 *Random triggering rate in the presence of low-level in-band continuous wave (CW) interference.* The total random trigger rate on all Mode A and/or Mode C replies shall not be greater than 10 reply pulse groups or suppressions per second, averaged over a period of 30 seconds, when operated in the presence of non-coherent CW interference at a frequency of 1 030 ±0.2 MHz and a signal level of –60 dBm or less.

3.1.1.7.9 *REPLY RATE*

3.1.1.7.9.1 All transponders shall be capable of continuously generating at least 500 replies per second for a 15-pulse coded reply. Transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, and in aircraft with a maximum cruising true airspeed not exceeding 175 kt (324 km/h) shall be capable of generating at least 1 000 15-pulse coded replies per second for a duration of 100 milliseconds. Transponder installations operated above 4 500 m (15 000 ft) or in aircraft with a maximum cruising true airspeed in excess of 175 kt (324 km/h), shall be capable of generating at least 1 200 15-pulse coded replies per second for a duration of 100 milliseconds.

*Note 1.— A 15-pulse reply includes 2 framing pulses, 12 information pulses, and the SPI pulse.*

*Note 2.— The reply rate requirement of 500 replies per second establishes the minimum continuous reply rate capability of the transponder. As per the altitude and speed criteria above, the 100 or 120 replies in a 100-millisecond interval defines the peak capability of the transponder. The transponder must be capable of replying to this short-term burst rate, even though the transponder may not be capable of sustaining this rate. If the transponder is subjected to interrogation rates beyond its reply rate capability, the reply rate limit control of 3.1.1.7.9.2 acts to gracefully desensitize the transponder in a manner that favours closer interrogators. Desensitization eliminates weaker interrogation signals.*

3.1.1.7.9.2 *Reply rate limit control.* To protect the system from the effects of transponder over-interrogation by preventing response to weaker signals when a predetermined reply rate has been reached, a sensitivity reduction type reply limit control shall be incorporated in the equipment. The range of this control shall permit adjustment, as a minimum, to any value between 500 and 2 000 replies per second, or to the maximum reply rate capability if less than 2 000 replies per second, without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB shall not take effect until 90 per cent of the selected value is exceeded. Sensitivity reduction shall be at least 30 dB for rates in excess of 150 per cent of the selected value.

3.1.1.7.10 *Reply delay and jitter.* The time delay between the arrival, at the transponder receiver, of the leading edge of $P_3$ and the transmission of the leading edge of the first pulse of the reply shall be 3 plus or minus 0.5 microseconds. The total jitter of the reply pulse code group, with respect to $P_3$, shall not exceed 0.1 microsecond for receiver input levels between



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3 dB and 50 dB above minimum triggering level. Delay variations between modes on which the transponder is capable of replying shall not exceed 0.2 microsecond.

3.1.1.7.11 *TRANSPONDER POWER OUTPUT AND DUTY CYCLE*

3.1.1.7.11.1 The peak pulse power available at the antenna end of the transmission line of the transponder shall be at least 21 dB and not more than 27 dB above 1 W, except that for transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, a peak pulse power available at the antenna end of the transmission line of the transponder of at least 18.5 dB and not more than 27 dB above 1 W shall be permitted.

*Note.— An extended squitter non-transponder device on an aerodrome surface vehicle may operate with a lower minimum power output as specified in 5.1.1.2.*

3.1.1.7.11.2 **Recommendation.—** *The peak pulse power specified in 3.1.1.7.11.1 should be maintained over a range of replies from code 0000 at a rate of 400 replies per second to a maximum pulse content at a rate of 1 200 replies per second or a maximum value below 1 200 replies per second of which the transponder is capable.*

3.1.1.7.12 *REPLY CODES*

3.1.1.7.12.1 *Identification.* The reply to a Mode A interrogation shall consist of the two framing pulses specified in 3.1.1.6.1 together with the information pulses (Mode A code) specified in 3.1.1.6.2.

*Note.— The Mode A code designation is a sequence of four digits in accordance with 3.1.1.6.6.*

3.1.1.7.12.1.1 The Mode A code shall be manually selected from the 4 096 codes available.

3.1.1.7.12.2 *Pressure-altitude transmission.* The reply to Mode C interrogation shall consist of the two framing pulses specified in 3.1.1.6.1 above. When digitized pressure-altitude information is available, the information pulses specified in 3.1.1.6.2 shall also be transmitted.

3.1.1.7.12.2.1 Transponders shall be provided with means to remove the information pulses but to retain the framing pulses when the provision of 3.1.1.7.12.2.4 below is not complied with in reply to Mode C interrogation.

3.1.1.7.12.2.2 The information pulses shall be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 1 013.25 hectopascals.

*Note.— The pressure setting of 1 013.25 hectopascals is equal to 29.92 inches of mercury.*

3.1.1.7.12.2.3 Pressure-altitude shall be reported in 100-ft increments by selection of pulses as shown in the Appendix to this chapter.

3.1.1.7.12.2.4 The digitizer code selected shall correspond to within plus or minus 38.1 m (125 ft), on a 95 per cent probability basis, with the pressure-altitude information (referenced to the standard pressure setting of 1 013.25 hectopascals), used on board the aircraft to adhere to the assigned flight profile.

3.1.1.7.13 *Transmission of the special position identification (SPI) pulse.* When required, this pulse shall be transmitted with Mode A replies, as specified in 3.1.1.6.3, for a period of between 15 and 30 seconds.



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3.1.1.7.14 *ANTENNA*

3.1.1.7.14.1 The transponder antenna system, when installed on an aircraft, shall have a radiation pattern which is essentially omnidirectional in the horizontal plane.

3.1.1.7.14.2 **Recommendation.—** *The vertical radiation pattern should be nominally equivalent to that of a quarter-wave monopole on a ground plane.*

### 3.1.1.8 TECHNICAL CHARACTERISTICS OF GROUND INTERROGATORS WITH MODE A AND MODE C CAPABILITIES ONLY

3.1.1.8.1 *Interrogation repetition frequency.* The maximum interrogation repetition frequency shall be 450 interrogations per second.

3.1.1.8.1.1 **Recommendation.—** *To minimize unnecessary transponder triggering and the resulting high density of mutual interference, all interrogators should use the lowest practicable interrogator repetition frequency that is consistent with the display characteristics, interrogator antenna beam width and antenna rotation speed employed.*

3.1.1.8.2 *RADIATED POWER*

**Recommendation.—** *In order to minimize system interference the effective radiated power of interrogators should be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.*

3.1.1.8.3 **Recommendation.—** *When Mode C information is to be used from aircraft flying below transition levels, the altimeter pressure reference datum should be taken into account.*

*Note.— Use of Mode C below transition levels is in accordance with the philosophy that Mode C can usefully be employed in all environments.*

### 3.1.1.9 INTERROGATOR RADIATED FIELD PATTERN

**Recommendation.—** *The beam width of the directional interrogator antenna radiating* $P_3$ *should not be wider than is operationally required. The side- and back-lobe radiation of the directional antenna should be at least 24 dB below the peak of the main-lobe radiation.*

### 3.1.1.10 INTERROGATOR MONITOR

3.1.1.10.1 The range and azimuth accuracy of the ground interrogator shall be monitored at sufficiently frequent intervals to ensure system integrity.

*Note.— Interrogators that are associated with and operated in conjunction with primary radar may use the primary radar as the monitoring device; alternatively, an electronic range and azimuth accuracy monitor would be required.*

3.1.1.10.2 **Recommendation.—** *In addition to range and azimuth monitoring, provision should be made to monitor continuously the other critical parameters of the ground interrogator for any degradation of performance exceeding the allowable system tolerances and to provide an indication of any such occurrence.*



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3.1.1.11 SPURIOUS EMISSIONS AND SPURIOUS RESPONSES

3.1.1.11.1 *SPURIOUS RADIATION*

**Recommendation.—** *CW radiation should not exceed 76 dB below 1 W for the interrogator and 70 dB below 1 W for the transponder.*

3.1.1.11.2 *SPURIOUS RESPONSES*

**Recommendation.—** *The response of both airborne and ground equipment to signals not within the receiver pass band should be at least 60 dB below normal sensitivity.*

### 3.1.2 Systems having Mode S capabilities

3.1.2.1 *Interrogation signals-in-space characteristics.* The paragraphs herein describe the signals-in-space as they can be expected to appear at the antenna of the transponder.

*Note.— Because signals can be corrupted in propagation, certain interrogation pulse duration, pulse spacing and pulse amplitude tolerances are more stringent for interrogators as described in 3.1.2.11.4.*

3.1.2.1.1 *Interrogation carrier frequency.* The carrier frequency of all interrogations (uplink transmissions) from ground facilities with Mode S capabilities shall be 1 030 plus or minus 0.01 MHz, except during the phase reversal, while maintaining the spectrum requirements of 3.1.2.1.2.

*Note.— During the phase reversal the frequency of the signal may shift by several MHz before returning to the specified value.*

3.1.2.1.2 *Interrogation spectrum.* The spectrum of a Mode S interrogation about the carrier frequency shall not exceed the limits specified in Figure 3-2.

*Note.— The Mode S interrogation spectrum is data dependent. The broadest spectrum is generated by an interrogation that contains all binary ONEs.*

3.1.2.1.3 *Polarization.* Polarization of the interrogation and control transmissions shall be nominally vertical.

3.1.2.1.4 *Modulation.* For Mode S interrogations, the carrier frequency shall be pulse modulated. In addition, the data pulse, $P_6$, shall have internal phase modulation.

3.1.2.1.4.1 *Pulse modulation.* Intermode and Mode S interrogations shall consist of a sequence of pulses as specified in 3.1.2.1.5 and Tables 3-1, 3-2, 3-3, and 3-4.

*Note.— The 0.8 microsecond pulses used in intermode and Mode S interrogations are identical in shape to those used in Modes A and C as defined in 3.1.1.4.*

3.1.2.1.4.2 *Phase modulation.* The short (16.25-microsecond) and long (30.25-microsecond) $P_6$ pulses of 3.1.2.1.4.1 shall have internal binary differential phase modulation consisting of 180-degree phase reversals of the carrier at a 4 megabit per second rate.



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3.1.2.1.4.2.1 *Phase reversal duration.* The duration of the phase reversal shall be less than 0.08 microsecond and the phase shall advance (or retard) monotonically throughout the transition region. There shall be no amplitude modulation applied during the phase transition.

*Note 1.— The minimum duration of the phase reversal is not specified. Nonetheless, the spectrum requirements of 3.1.2.1.2 must be met.*

*Note 2.— The phase reversal can be generated using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or other techniques with little or no amplitude drop, but with frequency shift during the phase reversal and slow phase reversal (80ns). A demodulator cannot make any assumption on the type of modulation technology used and therefore cannot rely on the specificities of the signal during the phase reversal to detect a phase reversal.*

3.1.2.1.4.2.2 *Phase relationship.* The tolerance on the 0 and 180-degree phase relationship between successive chips and on the sync phase reversal (3.1.2.1.5.2.2) within the $P_6$ pulse shall be plus or minus 5 degrees.

*Note.— In Mode S a "chip" is the 0.25 microsecond carrier interval between possible data phase reversals.*

3.1.2.1.5 *Pulse and phase reversal sequences.* Specific sequences of the pulses or phase reversals described in 3.1.2.1.4 shall constitute interrogations.

3.1.2.1.5.1 *Intermode interrogation*

3.1.2.1.5.1.1 *Mode A/C/S all-call interrogation.* This interrogation shall consist of three pulses: $P_1$, $P_3$, and the long $P_4$ as shown in Figure 3-3. One or two control pulses ($P_2$ alone, or $P_1$ and $P_2$) shall be transmitted using a separate antenna pattern to suppress responses from aircraft in the side lobes of the interrogator antenna.

*Note.— The Mode A/C/S all-call interrogation elicits a Mode A or Mode C reply (depending on the* $P_1$-$P_3$ *pulse spacing) from a Mode A/C transponder because it does not recognize the* $P_4$ *pulse. A Mode S transponder recognizes the long* $P_4$ *pulse and responds with a Mode S reply. This interrogation was originally planned for use by isolated or clustered interrogators. Lockout for this interrogation was based on the use of II equals 0. The development of the Mode S subnetwork now dictates the use of a non-zero II code for communication purposes. For this reason, II equals 0 has been reserved for use in support of a form of Mode S acquisition that uses stochastic/lockout override (3.1.2.5.2.1.4 and 3.1.2.5.2.1.5). The Mode A/C/S all-call cannot be used with full Mode S operation since II equals 0 can only be locked out for short time periods (3.1.2.5.2.1.5.2.1). This interrogation cannot be used with stochastic/lockout override, since probability of reply cannot be specified.*

3.1.2.1.5.1.1.1 Mode A/C/S all-call interrogations shall not be used on or after 1 January 2020.

*Note 1.— The use of Mode A/C/S all-call interrogations does not allow the use of stochastic lockout override and therefore might not ensure a good probability of acquisition in areas of high density of flights or when other interrogators lockout transponder on II=0 for supplementary acquisition.*

*Note 2.— The replies to Mode A/C/S all-call interrogations will no longer be supported by equipment certified on or after 1 January 2020 in order to reduce the RF pollution generated by the replies triggered by the false detection of Mode A/C/S all-call interrogations within other types of interrogation.*

3.1.2.1.5.1.2 *Mode A/C-only all-call interrogation.* This interrogation shall be identical to that of the Mode A/C/S all-call interrogation except that the short $P_4$ pulse shall be used.

*Note.— The Mode A/C-only all-call interrogation elicits a Mode A or Mode C reply from a Mode A/C transponder. A Mode S transponder recognizes the short* $P_4$ *pulse and does not reply to this interrogation.*



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3.1.2.1.5.1.3 *Pulse intervals.* The pulse intervals between $P_1$, $P_2$ and $P_3$ shall be as defined in 3.1.1.4.3 and 3.1.1.4.4. The pulse interval between $P_3$ and $P_4$ shall be 2 plus or minus 0.05 microsecond.

3.1.2.1.5.1.4 *Pulse amplitudes.* Relative amplitudes between pulses $P_1$, $P_2$ and $P_3$ shall be in accordance with 3.1.1.5. The amplitude of $P_4$ shall be within 1 dB of the amplitude of $P_3$.

3.1.2.1.5.2 *Mode S interrogation.* The Mode S interrogation shall consist of three pulses: $P_1$, $P_2$ and $P_6$ as shown in Figure 3-4.

*Note.— $P_6$ is preceded by a $P_1 - P_2$ pair which suppresses replies from Mode A/C transponders to avoid synchronous garble due to random triggering by the Mode S interrogation. The sync phase reversal within $P_6$ is the timing mark for demodulation of a series of time intervals (chips) of 0.25 microsecond duration. This series of chips starts 0.5 microsecond after the sync phase reversal and ends 0.5 microsecond before the trailing edge of $P_6$. A phase reversal may or may not precede each chip to encode its binary information value.*

3.1.2.1.5.2.1 *Mode S side-lobe suppression.* The $P_5$ pulse shall be used with the Mode S-only all-call interrogation (UF = 11, see 3.1.2.5.2) to prevent replies from aircraft in the side and back lobes of the antenna (3.1.2.1.5.2.5). When used, $P_5$ shall be transmitted using a separate antenna pattern.

*Note 1.— The action of $P_5$ is automatic. Its presence, if of sufficient amplitude at the receiving location, masks the sync phase reversal of $P_6$.*

*Note 2.— The $P_5$ pulse may be used with other Mode S interrogations.*

3.1.2.1.5.2.2 *Sync phase reversal.* The first phase reversal in the $P_6$ pulse shall be the sync phase reversal. It shall be the timing reference for subsequent transponder operations related to the interrogation.

3.1.2.1.5.2.3 *Data phase reversals.* Each data phase reversal shall occur only at a time interval (N times 0.25) plus or minus 0.02 microsecond (N equal to, or greater than 2) after the sync phase reversal. The 16.25-microsecond $P_6$ pulse shall contain at most 56 data phase reversals. The 30.25-microsecond $P_6$ pulse shall contain at most 112 data phase reversals. The last chip, that is the 0.25-microsecond time interval following the last data phase reversal position, shall be followed by a 0.5-microsecond guard interval.

*Note.— The 0.5-microsecond guard interval following the last chip prevents the trailing edge of $P_6$ from interfering with the demodulation process.*

3.1.2.1.5.2.4 *Intervals.* The pulse interval between $P_1$ and $P_2$ shall be 2 plus or minus 0.05 microsecond. The interval between the leading edge of $P_2$ and the sync phase reversal of $P_6$ shall be 2.75 plus or minus 0.05 microsecond. The leading edge of $P_6$ shall occur 1.25 plus or minus 0.05 microsecond before the sync phase reversal. $P_5$, if transmitted, shall be centred over the sync phase reversal; the leading edge of $P_5$ shall occur 0.4 plus or minus 0.05 microsecond before the sync phase reversal.

3.1.2.1.5.2.5 *Pulse amplitudes.* The amplitude of $P_2$ and the amplitude of the first microsecond of $P_6$ shall be greater than the amplitude of $P_1$ minus 0.25 dB. Exclusive of the amplitude transients associated with phase reversals, the amplitude variation of $P_6$ shall be less than 1 dB and the amplitude variation between successive chips in $P_6$ shall be less than 0.25 dB. The radiated amplitude of $P_5$ at the antenna of the transponder shall be:

a) equal to or greater than the radiated amplitude of $P_6$ from the side-lobe transmissions of the antenna radiating $P_6$; and

b) at a level lower than 9 dB below the radiated amplitude of $P_6$ within the desired arc of interrogation.



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### 3.1.2.2 REPLY SIGNALS-IN-SPACE CHARACTERISTICS

3.1.2.2.1 *Reply carrier frequency.* The carrier frequency of all replies (downlink transmissions) from transponders with Mode S capabilities shall be 1 090 plus or minus 1 MHz.

3.1.2.2.2 *Reply spectrum.* The spectrum of a Mode S reply about the carrier frequency shall not exceed the limits specified in Figure 3-5.

3.1.2.2.3 *Polarization.* Polarization of the reply transmissions shall be nominally vertical.

3.1.2.2.4 *Modulation.* The Mode S reply shall consist of a preamble and a data block. The preamble shall be a 4-pulse sequence and the data block shall be binary pulse-position modulated at a 1 megabit per second data rate.

3.1.2.2.4.1 *Pulse shapes.* Pulse shapes shall be as defined in Table 3-2. All values are in microseconds.

3.1.2.2.5 *Mode S reply.* The Mode S reply shall be as shown in Figure 3-6. The data block in Mode S replies shall consist of either 56 or 112 information bits.

3.1.2.2.5.1 *Pulse intervals.* All reply pulses shall start at a defined multiple of 0.5 microsecond from the first transmitted pulse. The tolerance in all cases shall be plus or minus 0.05 microsecond.

3.1.2.2.5.1.1 *Reply preamble.* The preamble shall consist of four pulses, each with a duration of 0.5 microsecond. The pulse intervals from the first transmitted pulse to the second, third and fourth transmitted pulses shall be 1, 3.5 and 4.5 microseconds, respectively.

3.1.2.2.5.1.2 *Reply data pulses.* The reply data block shall begin 8 microseconds after the leading edge of the first transmitted pulse. Either 56 or 112 one-microsecond bit intervals shall be assigned to each transmission. A 0.5-microsecond pulse shall be transmitted either in the first or in the second half of each interval. When a pulse transmitted in the second half of one interval is followed by another pulse transmitted in the first half of the next interval, the two pulses merge and a one-microsecond pulse shall be transmitted.

3.1.2.2.5.2 *Pulse amplitudes.* The pulse amplitude variation between one pulse and any other pulse in a Mode S reply shall not exceed 2 dB.

### 3.1.2.3 MODE S DATA STRUCTURE

#### 3.1.2.3.1 *DATA ENCODING*

3.1.2.3.1.1 *Interrogation data.* The interrogation data block shall consist of the sequence of 56 or 112 data chips positioned after the data phase reversals within $P_6$ (3.1.2.1.5.2.3). A 180-degree carrier phase reversal preceding a chip shall characterize that chip as a binary ONE. The absence of a preceding phase reversal shall denote a binary ZERO.

3.1.2.3.1.2 *Reply data.* The reply data block shall consist of 56 or 112 data bits formed by binary pulse position modulation encoding of the reply data as described in 3.1.2.2.5.1.2. A pulse transmitted in the first half of the interval shall represent a binary ONE whereas a pulse transmitted in the second half shall represent a binary ZERO.

3.1.2.3.1.3 *Bit numbering.* The bits shall be numbered in the order of their transmission, beginning with bit 1. Unless otherwise stated, numerical values encoded by groups (fields) of bits shall be encoded using positive binary notation and the first bit transmitted shall be the most significant bit (MSB). Information shall be coded in fields which consist of at least one bit.



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*Note.— In the description of Mode S formats the decimal equivalent of the binary code formed by the bit sequence within a field is used as the designator of the field function or command.*

3.1.2.3.2 *FORMATS OF MODE S INTERROGATIONS AND REPLIES*

*Note.— A summary of all Mode S interrogation and reply formats is presented in Figures 3-7 and 3-8. A summary of all fields appearing in uplink and downlink formats is given in Table 3-3 and a summary of all subfields is given in Table 3-4.*

3.1.2.3.2.1 *Essential fields.* Every Mode S transmission shall contain two essential fields. One is a descriptor which shall uniquely define the format of the transmission. This shall appear at the beginning of the transmission for all formats. The descriptors are designated by the UF (uplink format) or DF (downlink format) fields. The second essential field shall be a 24-bit field appearing at the end of each transmission and shall contain parity information. In all uplink and in currently defined downlink formats parity information shall be overlaid either on the aircraft address (3.1.2.4.1.2.3.1) or on the interrogator identifier according to 3.1.2.3.3.2. The designators are AP (address/parity) or PI (parity/interrogator identifier).

*Note.— The remaining coding space is used to transmit the mission fields. For specific functions, a specific set of mission fields is prescribed. Mode S mission fields have two-letter designators. Subfields may appear within mission fields. Mode S subfields are labelled with three-letter designators.*

3.1.2.3.2.1.1 *UF: Uplink format.* This uplink format field (5 bits long except in format 24 where it is 2 bits long) shall serve as the uplink format descriptor in all Mode S interrogations and shall be coded according to Figure 3-7.

3.1.2.3.2.1.2 *DF: Downlink format.* This downlink format field (5 bits long except in format 24 where it is 2 bits long) shall serve as the downlink format descriptor in all Mode S replies and shall be coded according to Figure 3-8.

3.1.2.3.2.1.3 *AP: Address/parity.* This 24-bit (33-56 or 89-112) field shall appear in all uplink and currently defined downlink formats except the Mode S-only all-call reply, DF = 11. The field shall contain parity overlaid on the aircraft address according to 3.1.2.3.3.2.

3.1.2.3.2.1.4 *PI: Parity/interrogator identifier.* This 24-bit (33-56) or (89-112) downlink field shall have parity overlaid on the interrogator's identity code according to 3.1.2.3.3.2 and shall appear in the Mode S all-call reply, DF = 11 and in the extended squitter, DF = 17 or DF = 18. If the reply is made in response to a Mode A/C/S all-call, a Mode S-only all-call with CL field (3.1.2.5.2.1.3) and IC field (3.1.2.5.2.1.2) equal to 0, or is an acquisition or an extended squitter (3.1.2.8.5, 3.1.2.8.6 or 3.1.2.8.7), the II and the SI codes shall be 0.

3.1.2.3.2.1.5 *DP: Data parity.* This 24-bit (89-112) downlink field shall contain the parity overlaid on a "Modified AA" field which is established by performing a modulo-2 summation (e.g. Exclusive-Or function) of the discrete address most significant 8 bits and BDS1, BDS2, where BDS1 (3.1.2.6.11.2.2) and BDS2 (3.1.2.6.11.2.3) are provided by the "RR" (3.1.2.6.1.2) and "RRS" (3.1.2.6.1.4.1) as specified in 3.1.2.6.11.2.2 and 3.1.2.6.11.2.3.

Example:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Discrete address | = | AA AA AA Hex | = | 1010 | 1010 | 1010 | 1010 | 1010 | 1010 |
| BDS1, BDS2 | = | 5F 00 00 Hex | = | 0101 | 1111 | 0000 | 0000 | 0000 | 0000 |
| Discrete address | ⊕ | BDS1, BDS2 Hex | = | 1111 | 0101 | 1010 | 1010 | 1010 | 1010 |
| "Modified AA" | = | F5 AA AA Hex | = | 1111 | 0101 | 1010 | 1010 | 1010 | 1010 |

where "⊕" prescribes modulo-2 addition



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The resulting "Modified AA" field then represents the 24-bit sequence (a1, a2…a24) that shall be used to generate the DP field in accordance with paragraph 3.1.2.3.3.2.

The DP field shall be used in DF=20 and DF=21 replies if the transponder is capable of supporting the DP field and if the overlay control (OVC - 3.1.2.6.1.4.1.i)) bit is set to one (1) in the interrogation requesting downlink of GICB registers.

3.1.2.3.2.2 *Unassigned coding space.* Unassigned coding space shall contain all ZEROs as transmitted by interrogators and transponders.

*Note.— Certain coding space indicated as unassigned in this section is reserved for other applications such as ACAS, data link, etc.*

3.1.2.3.2.3 *Zero and unassigned codes*. A zero code assignment in all defined fields shall indicate that no action is required by the field. In addition, codes not assigned within the fields shall indicate that no action is required.

*Note.— The provisions of 3.1.2.3.2.2 and 3.1.2.3.2.3 ensure that future assignments of previously unassigned coding space will not result in ambiguity. That is, Mode S equipment in which the new coding has not been implemented will clearly indicate that no information is being transmitted in newly assigned coding space.*

3.1.2.3.2.4 *Formats reserved for military use*. States shall ensure that uplink formats are only used for selectively addressed interrogations and that transmissions of uplink or downlink formats do not exceed the RF power, interrogation rate, reply rate and squitter rate requirements of Annex 10.

3.1.2.3.2.4.1 **Recommendation.—** *Through investigation and validation, States should ensure that military applications do not unduly affect the existing 1 030/1 090 MHz civil aviation operations environment.*

### 3.1.2.3.3 *ERROR PROTECTION*

3.1.2.3.3.1 *Technique.* Parity check coding shall be used within Mode S interrogations and replies to provide protection against the occurrence of errors.

3.1.2.3.3.1.1 *Parity check sequence.* A sequence of 24 parity check bits shall be generated by the rule described in 3.1.2.3.3.1.2 and shall be incorporated into the field formed by the last 24 bits of all Mode S transmissions. The 24 parity check bits shall be combined with either the address coding or the interrogator identifier coding as described in 3.1.2.3.3.2. The resulting combination then forms either the AP (address/parity, 3.1.2.3.2.1.3) field or the PI (parity/interrogator identifier, 3.1.2.3.2.1.4) field.

3.1.2.3.3.1.2 *Parity check sequence generation.* The sequence of 24 parity bits ($p_1$, $p_2$,..., $p_{24}$) shall be generated from the sequence of information bits ($m_1$, $m_2$,..., $m_k$) where k is 32 or 88 for short or long transmissions respectively. This shall be done by means of a code generated by the polynomial:

$$G(x) = 1 + x^3 + x^{10} + x^{12} + x^{13} + x^{14} + x^{15} + x^{16}$$
$$+ x^{17} + x^{18} + x^{19} + x^{20} + x^{21} + x^{22} + x^{23} + x^{24}$$

When by the application of binary polynomial algebra, $x^{24}$ $[M(x)]$ is divided by $G(x)$ where the information sequence $M(x)$ is:

$$m_k + m_{k-1}x + m_{k-2}x^2 + ... + m_1x^{k-1}$$

the result is a quotient and a remainder $R(x)$ of degree less than 24. The bit sequence formed by this remainder represents the parity check sequence. Parity bit $p_i$, for any $i$ from 1 to 24, is the coefficient of $x^{24-i}$ in $R(x)$.



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*Note.— The effect of multiplying M(x) by $x^{24}$ is to append 24 ZERO bits to the end of the sequence.*

3.1.2.3.3.2 *AP and PI field generation.* Different address parity sequences shall be used for the uplink and downlink.

*Note.— The uplink sequence is appropriate for a transponder decoder implementation. The downlink sequence facilitates the use of error correction in downlink decoding.*

The code used in uplink AP field generation shall be formed as specified below from either the aircraft address (3.1.2.4.1.2.3.1.1), the all-call address (3.1.2.4.1.2.3.1.2) or the broadcast address (3.1.2.4.1.2.3.1.3).

The code used in downlink AP field generation shall be formed directly from the sequence of 24 Mode S address bits ($a_1$, $a_2$,..., $a_{24}$), where $a_i$ is the $i$-th bit transmitted in the aircraft address (AA) field of an all-call reply (3.1.2.5.2.2.2).

The code used in downlink PI field generation shall be formed by a sequence of 24 bits ($a_1$, $a_2$,..., $a_{24}$), where the first 17 bits are ZEROs, the next three bits are a replica of the code label (CL) field (3.1.2.5.2.1.3) and the last four bits are a replica of the interrogator code (IC) field (3.1.2.5.2.1.2).

*Note.— The PI code is not used in uplink transmissions.*

A modified sequence ($b_1$, $b_2$,..., $b_{24}$) shall be used for uplink AP field generation. Bit $b_i$ is the coefficient of $x^{48-i}$ in the polynomial $G(x)A(x)$, where:

$$A(x) = a_1x^{23} + a_2x^{22} + ... + a_{24}$$

and $G(x)$ is as defined in 3.1.2.3.3.1.2.

In the aircraft address $a_i$ shall be the $i$-th bit transmitted in the AA field of an all-call reply. In the all-call and broadcast addresses $a_i$ shall equal 1 for all values of $i$.

3.1.2.3.3.2.1 *Uplink transmission order.* The sequence of bits transmitted in the uplink AP field is:

$$t_{k+1}, t_{k+2} \ldots t_{k+24}$$

where the bits are numbered in order of transmission, starting with $k + 1$.

In uplink transmissions:

$$t_{k+i} = b_i \oplus p_i$$

where "⊕" prescribes modulo-2 addition: $i$ equals 1 is the first bit transmitted in the AP field.

3.1.2.3.3.2.2 *Downlink transmission order.* The sequence of bits transmitted in the downlink AP and PI field is:

$$t_{k+1}, t_{k+2} \ldots t_{k+24}$$

where the bits are numbered in order of transmission, starting with $k + 1$. In downlink transmissions:

$$t_{k+i} = a_i \oplus p_i$$

where "⊕" prescribes modulo-2 addition: $i$ equals 1 is the first bit transmitted in the AP or PI field.



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### 3.1.2.4 GENERAL INTERROGATION-REPLY PROTOCOL

3.1.2.4.1 *Transponder transaction cycle.* A transponder transaction cycle shall begin when the SSR Mode S transponder has recognized an interrogation. The transponder shall then evaluate the interrogation and determine whether it shall be accepted. If accepted, it shall then process the received interrogation and generate a reply, if appropriate. The transaction cycle shall end when:

a) any one of the necessary conditions for acceptance has not been met, or

b) an interrogation has been accepted and the transponder has either:

1) completed the processing of the accepted interrogation if no reply is required, or

2) completed the transmission of a reply.

A new transponder transaction cycle shall not begin until the previous cycle has ended.

3.1.2.4.1.1 *Interrogation recognition.* SSR Mode S transponders shall be capable of recognizing the following distinct types of interrogations:

a) Modes A and C;

b) intermode; and

c) Mode S.

*Note.— The recognition process is dependent upon the signal input level and the specified dynamic range (3.1.2.10.1).*

3.1.2.4.1.1.1 *Mode A and Mode C interrogation recognition.* A Mode A or Mode C interrogation shall be recognized when a $P_1 - P_3$ pulse pair meeting the requirements of 3.1.1.4 has been received, and the leading edge of a $P_4$ pulse with an amplitude that is greater than a level 6 dB below the amplitude of $P_3$ is not received within the interval from 1.7 to 2.3 microseconds following the leading edge of $P_3$.

If a $P_1 - P_2$ suppression pair and a Mode A or Mode C interrogation are recognized simultaneously, the transponder shall be suppressed. An interrogation shall not be recognized as Mode A or Mode C if the transponder is in suppression (3.1.2.4.2). If a Mode A and a Mode C interrogation are recognized simultaneously the transponder shall complete the transaction cycle as if only a Mode C interrogation had been recognized.

3.1.2.4.1.1.2 *Intermode interrogation recognition.* An intermode interrogation shall be recognized when a $P_1 - P_3 - P_4$ pulse triplet meeting the requirements of 3.1.2.1.5.1 is received. An interrogation shall not be recognized as an intermode interrogation if:

a) the received amplitude of the pulse in the $P_4$ position is smaller than 6 dB below the amplitude of $P_3$; or

b) the pulse interval between $P_3$ and $P_4$ is larger than 2.3 microseconds or shorter than 1.7 microseconds; or

c) the received amplitude of $P_1$ and $P_3$ is between MTL and –45 dBm and the pulse duration of $P_1$ or $P_3$ is less than 0.3 microsecond; or

d) the transponder is in suppression (3.1.2.4.2).

If a $P_1 - P_2$ suppression pair and a Mode A or Mode C intermode interrogation are recognized simultaneously the transponder shall be suppressed.



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3.1.2.4.1.1.3 *Mode S interrogation recognition.* A Mode S interrogation shall be recognized when a $P_6$ pulse is received with a sync phase reversal within the interval from 1.20 to 1.30 microseconds following the leading edge of $P_6$. A Mode S interrogation shall not be recognized if a sync phase reversal is not received within the interval from 1.05 to 1.45 microseconds following the leading edge of $P_6$.

3.1.2.4.1.2 *Interrogation acceptance.* Recognition according to 3.1.2.4.1 shall be a prerequisite for acceptance of any interrogation.

3.1.2.4.1.2.1 *Mode A and Mode C interrogation acceptance.* Mode A and Mode C interrogations shall be accepted when recognized (3.1.2.4.1.1.1).

3.1.2.4.1.2.2 *Intermode interrogation acceptance*

3.1.2.4.1.2.2.1 *Mode A/C/S all-call interrogation acceptance.* A Mode A/C/S all-call interrogation shall be accepted if the trailing edge of $P_4$ is received within 3.45 to 3.75 microseconds following the leading edge of $P_3$ and no lockout condition (3.1.2.6.9) prevents acceptance. A Mode A/C/S all-call shall not be accepted if the trailing edge of $P_4$ is received earlier than 3.3 or later than 4.2 microseconds following the leading edge of $P_3$, or if a lockout condition (3.1.2.6.9) prevents acceptance.

3.1.2.4.1.2.2.2 *Mode A/C-only all-call interrogation acceptance.* A Mode A/C-only all-call interrogation shall not be accepted by a Mode S transponder.

*Note.— The technical condition for non-acceptance of a Mode A/C-only all-call is given in the preceding paragraph by the requirement for rejecting an intermode interrogation with a* $P_4$ *pulse having a trailing edge following the leading edge of* $P_3$ *by less than 3.3 microseconds.*

3.1.2.4.1.2.3 *Mode S interrogation acceptance.* A Mode S interrogation shall only be accepted if:

a) the transponder is capable of processing the uplink format (UF) of the interrogation (3.1.2.3.2.1.1);

b) the address of the interrogation matches one of the addresses as defined in 3.1.2.4.1.2.3.1 implying that parity is established, as defined in 3.1.2.3.3;

c) in the case of an all-call interrogation, no all-call lockout condition applies, as defined in 3.1.2.6.9; and

d) the transponder is capable of processing the uplinked data of a long air-air surveillance (ACAS) interrogation (UF-16) and presenting it at an output interface as prescribed in 3.1.2.10.5.2.2.1.

*Note.— A Mode S interrogation may be accepted if the conditions specified in 3.1.2.4.1.2.3 a) and b) are met and the transponder is not capable of both processing the uplinked data of a Comm-A interrogation (UF=20 and 21) and presenting it at an output interface as prescribed in 3.1.2.10.5.2.2.1.*

3.1.2.4.1.2.3.1 *Addresses.* Mode S interrogations shall contain either:

a) aircraft address; or

b) the all-call address; or

c) the broadcast address.

3.1.2.4.1.2.3.1.1 *Aircraft address.* If the aircraft's address is identical to the address extracted from a received interrogation according to the procedure of 3.1.2.3.3.2 and 3.1.2.3.3.2.1, the extracted address shall be considered correct for purposes of Mode S interrogation acceptance.



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3.1.2.4.1.2.3.1.2 *All-call address.* A Mode S-only all-call interrogation (uplink format UF = 11) shall contain an address, designated the all-call address, consisting of twenty-four consecutive ONEs. If the all-call address is extracted from a received interrogation with format UF = 11 according to the procedure of 3.1.2.3.3.2 and 3.1.2.3.3.2.1, the address shall be considered correct for Mode S-only all-call interrogation acceptance.

3.1.2.4.1.2.3.1.3 *Broadcast address.* To broadcast a message to all Mode S transponders within the interrogator beam, a Mode S interrogation uplink format 20 or 21 shall be used and an address of twenty-four consecutive ONEs shall be substituted for the aircraft address. If the UF code is 20 or 21 and this broadcast address is extracted from a received interrogation according to the procedure of 3.1.2.3.3.2 and 3.1.2.3.3.2.1, the address shall be considered correct for Mode S broadcast interrogation acceptance.

*Note.— Transponders associated with airborne collision avoidance systems also accept a broadcast with UF = 16.*

3.1.2.4.1.3 *Transponder replies.* Mode S transponders shall transmit the following reply types:

a) Mode A and Mode C replies; and

b) Mode S replies.

3.1.2.4.1.3.1 *Mode A and Mode C replies.* A Mode A (Mode C) reply shall be transmitted as specified in 3.1.1.6 when a Mode A (Mode C) interrogation has been accepted.

3.1.2.4.1.3.2 *Mode S replies.* Replies to other than Mode A and Mode C interrogations shall be Mode S replies.

3.1.2.4.1.3.2.1 *Replies to intermode interrogations.* A Mode S reply with downlink format 11 shall be transmitted in accordance with the provisions of 3.1.2.5.2.2 when a Mode A/C/S all-call interrogation has been accepted. Equipment certified on or after 1 January 2020 shall not reply to Intermode Mode A/C/S all-call interrogations.

*Note.— Since Mode S transponders do not accept Mode A/C-only all-call interrogations, no reply is generated.*

3.1.2.4.1.3.2.2 *Replies to Mode S interrogations.* The information content of a Mode S reply shall reflect the conditions existing in the transponder after completion of all processing of the interrogation eliciting that reply. The correspondence between uplink and downlink formats shall be as summarized in Table 3-5.

*Note.— Four categories of Mode S replies may be transmitted in response to Mode S interrogations:*

*a) Mode S all-call replies (DF = 11);*

*b) surveillance and standard-length communications replies (DF = 4, 5, 20 and 21);*

*c) extended length communications replies (DF = 24); and*

*d) air-air surveillance replies (DF = 0 and 16).*

3.1.2.4.1.3.2.2.1 *Replies to SSR Mode S-only all-call interrogations.* The downlink format of the reply to a Mode S-only all-call interrogation (if required) shall be DF = 11. The reply content and rules for determining the requirement to reply shall be as defined in 3.1.2.5.

*Note.— A Mode S reply may or may not be transmitted when a Mode S interrogation with UF = 11 has been accepted.*

3.1.2.4.1.3.2.2.2 *Replies to surveillance and standard length communications interrogations.* A Mode S reply shall be transmitted when a Mode S interrogation with UF = 4, 5, 20 or 21 and an aircraft address has been accepted. The contents of these interrogations and replies shall be as defined in 3.1.2.6.



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*Note.— If a Mode S interrogation with UF = 20 or 21 and a broadcast address is accepted, no reply is transmitted (3.1.2.4.1.2.3.1.3).*

3.1.2.4.1.3.2.2.3 *Replies to extended length communications interrogations.* A series of Mode S replies ranging in number from 0 to 16 shall be transmitted when a Mode S interrogation with UF = 24 has been accepted. The downlink format of the reply (if any) shall be DF = 24. Protocols defining the number and content of the replies shall be as defined in 3.1.2.7.

3.1.2.4.1.3.2.2.4 *Replies to air-air surveillance interrogations.* A Mode S reply shall be transmitted when a Mode S interrogation with UF = 0 and an aircraft address has been accepted. The contents of these interrogations and replies shall be as defined in 3.1.2.8.

### 3.1.2.4.2 *SUPPRESSION*

3.1.2.4.2.1 *Effects of suppression.* A transponder in suppression (3.1.1.7.4) shall not recognize Mode A, Mode C or intermode interrogations if either the $P_1$ pulse alone or both the $P_1$ and $P_3$ pulses of the interrogation are received during the suppression interval. Suppression shall not affect the recognition of, acceptance of, or replies to Mode S interrogations.

3.1.2.4.2.2 *Suppression pairs.* The two-pulse Mode A/C suppression pair defined in 3.1.1.7.4.1 shall initiate suppression in a Mode S transponder regardless of the position of the pulse pair in a group of pulses, provided the transponder is not already suppressed or in a transaction cycle.

*Note.— The $P_3$ – $P_4$ pair of the Mode A/C-only all-call interrogation both prevents a reply and initiates suppression. Likewise, the $P_1$ – $P_2$ preamble of a Mode S interrogation initiates suppression independently of the waveform that follows it.*

3.1.2.4.2.3 Suppression in presence of $S_1$ pulse shall be as defined in 3.1.1.7.4.3.

## 3.1.2.5 INTERMODE AND MODE S ALL-CALL TRANSACTIONS

### 3.1.2.5.1 *INTERMODE TRANSACTIONS*

*Note.— Intermode transactions permit the surveillance of Mode A/C-only aircraft and the acquisition of Mode S aircraft. The Mode A/C/S all-call interrogation allows Mode A/C-only and Mode S transponders to be interrogated by the same transmissions. The Mode A/C-only all-call interrogation makes it possible to elicit replies only from Mode A/C transponders. In multisite scenarios, the interrogator must transmit its identifier code in the Mode S only all-call interrogation. Thus, a pair of Mode S-only and Mode A/C-only all-call interrogations are used. The intermode interrogations are defined in 3.1.2.1.5.1 and the corresponding interrogation-reply protocols are defined in 3.1.2.4.*

### 3.1.2.5.2 *MODE S-ONLY ALL-CALL TRANSACTIONS*

*Note.— These transactions allow the ground to acquire Mode S aircraft by use of an interrogation addressed to all Mode S-equipped aircraft. The reply is via downlink format 11 which returns the aircraft address. The interrogation-reply protocols are defined in 3.1.2.4.*



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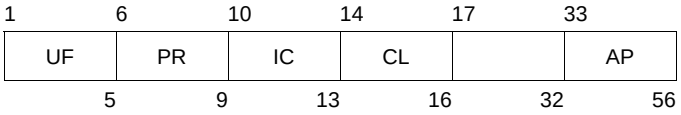
3.1.2.5.2.1 *Mode S-only all-call interrogation, uplink format 11*




The format of this interrogation shall consist of these fields:

| *Field* | *Reference* |
|---|---|
| UF uplink format | 3.1.2.3.2.1.1 |
| PR probability of reply | 3.1.2.5.2.1.1 |
| IC interrogator code | 3.1.2.5.2.1.2 |
| CL code label | 3.1.2.5.2.1.3 |
| spare — 16 bits | |
| AP address/parity | 3.1.2.3.2.1.3 |

3.1.2.5.2.1.1 *PR: Probability of reply.* This 4-bit (6-9) uplink field shall contain commands to the transponder specifying the probability of reply to that interrogation (3.1.2.5.4). Codes are as follows:

| | |
|---|---|
| 0 | signifies reply with probability of 1 |
| 1 | signifies reply with probability of 1/2 |
| 2 | signifies reply with probability of 1/4 |
| 3 | signifies reply with probability of 1/8 |
| 4 | signifies reply with probability of 1/16 |
| 5, 6, 7 | not assigned |
| 8 | signifies disregard lockout, reply with probability of 1 |
| 9 | signifies disregard lockout, reply with probability of 1/2 |
| 10 | signifies disregard lockout, reply with probability of 1/4 |
| 11 | signifies disregard lockout, reply with probability of 1/8 |
| 12 | signifies disregard lockout, reply with probability of 1/16 |
| 13, 14, 15 | not assigned. |

3.1.2.5.2.1.2 *IC: Interrogator code.* This 4-bit (10-13) uplink field shall contain either the 4-bit interrogator identifier code (3.1.2.5.2.1.2.3) or the lower 4 bits of the 6-bit surveillance identifier code (3.1.2.5.2.1.2.4) depending on the value of the CL field (3.1.2.5.2.1.3).

3.1.2.5.2.1.2.1 **Recommendation.—** *It is recommended that whenever possible an interrogator should operate using a single interrogator code.*

3.1.2.5.2.1.2.2 *The use of multiple interrogator codes by one interrogator.* An interrogator shall not interleave Mode S-only all-call interrogations using different interrogator codes.

*Note.— An explanation of RF interference issues, sector size and impact on data link transactions is presented in the* Aeronautical Surveillance Manual *(Doc 9924).*

3.1.2.5.2.1.2.3 *II: Interrogator identifier*. This 4-bit value shall define an interrogator identifier (II) code. These II codes shall be assigned to interrogators in the range from 0 to 15. The II code value of 0 shall only be used for supplementary acquisition in conjunction with acquisition based on lockout override (3.1.2.5.2.1.4 and 3.1.2.5.2.1.5). When two II codes are assigned to one interrogator only, one II code shall be used for full data link purposes.



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*Note.— Limited data link activity including single segment Comm-A, uplink and downlink broadcast protocols and GICB extraction may be performed by both II codes.*

3.1.2.5.2.1.2.4 *SI: Surveillance identifier*. This 6-bit value shall define a surveillance identifier (SI) code. These SI codes shall be assigned to interrogators in the range from 1 to 63. The SI code value of 0 shall not be used. The SI codes shall be used with the multisite lockout protocols (3.1.2.6.9.1). The SI codes shall not be used with the multisite communications protocols (3.1.2.6.11.3.2, 3.1.2.7.4 or 3.1.2.7.7).

3.1.2.5.2.1.3 *CL: Code label.* This 3-bit (14-16) uplink field shall define the contents of the IC field.

*Coding* (in binary)

000 signifies that the IC field contains the II code
001 signifies that the IC field contains SI codes 1 to 15
010 signifies that the IC field contains SI codes 16 to 31
011 signifies that the IC field contains SI codes 32 to 47
100 signifies that the IC field contains SI codes 48 to 63

The other values of the CL field shall not be used.

3.1.2.5.2.1.3.1 *Surveillance identifier (SI) code capability report.* Transponders which process the SI codes (3.1.2.5.2.1.2.4) shall report this capability by setting bit 35 to 1 in the surveillance identifier capability (SIC) subfield of the MB field of the data link capability report (3.1.2.6.10.2.2).

3.1.2.5.2.1.4 *Operation based on lockout override*

*Note 1.— The Mode S-only all-call lockout override provides the basis for acquisition of Mode S aircraft for interrogators that have not been assigned a unique IC (II or SI code) for full Mode S operation (protected acquisition by ensuring that no other interrogator on the same IC can lock out the target in the same coverage area).*

*Note 2.— Lockout override is possible using any interrogator code.*

3.1.2.5.2.1.4.1 *Maximum Mode S-only all-call interrogation rate.* The maximum rate of Mode S-only all-call interrogations made by an interrogator using acquisition based on lockout override shall depend on the reply probability as follows:

a) for a reply probability equal to 1.0:

the smaller of 3 interrogations per 3 dB beam dwell or 30 interrogations per second;

b) for a reply probability equal to 0.5:

the smaller of 5 interrogations per 3 dB beam dwell or 60 interrogations per second; and

c) for a reply probability equal to 0.25 or less:

the smaller of 10 interrogations per 3 dB beam dwell or 125 interrogations per second.

*Note.— These limits have been defined in order to minimize the RF pollution generated by such a method while keeping a minimum of replies to allow acquisition of aircraft within a beam dwell.*



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3.1.2.5.2.1.4.2 **Recommendation.—** *Passive acquisition without using all-call interrogations should be used in the place of lockout override.*

*Note.— The* Aeronautical Surveillance Manual *(Doc 9924) provides guidance on different passive acquisition methods.*

3.1.2.5.2.1.4.3 *Field content for a selectively addressed interrogation used by an interrogator without an assigned interrogator code.* An interrogator that has not been assigned with a unique discrete interrogator code and is authorized to transmit shall use the II code 0 to perform the selective interrogations. In this case, selectively addressed interrogations used in connection with acquisition using lockout override shall have interrogation field contents restricted as follows:

UF = 4, 5, 20 or 21
PC = 0
RR ≠ 16 if RRS = 0
DI = 7
IIS = 0
LOS = 0 except as specified in 3.1.2.5.2.1.5
TMS = 0

*Note.— These restrictions permit surveillance and GICB transactions, but prevent the interrogation from making any changes to transponder multisite lockout or communications protocol states.*

3.1.2.5.2.1.5 *Supplementary acquisition using II equals 0*

*Note 1.— The acquisition technique defined in 3.1.2.5.2.1.4 provides rapid acquisition for most aircraft. Due to the probabilistic nature of the process, it may take many interrogations to acquire the last aircraft of a large set of aircraft in the same beam dwell and near the same range (termed a local garble zone). Acquisition performance is greatly improved for the acquisition of these aircraft through the use of limited selective lockout using II equals 0.*

*Note 2.— Supplementary acquisition consists of locking out acquired aircraft to II=0 followed by acquisition by means of the Mode S-only all-call interrogation with II=0. Only the aircraft not yet acquired and not yet locked-out will reply resulting in an easier acquisition.*

3.1.2.5.2.1.5.1 *Lockout within a beam dwell*

3.1.2.5.2.1.5.1.1 **Recommendation.—** *When II equals 0 lockout is used to supplement acquisition, all aircraft within the beam dwell of the aircraft being acquired should be commanded to lock out to II equals 0, not just those in the garble zone.*

*Note.— Lockout of all aircraft in the beam dwell will reduce the amount of all-call fruit replies generated to the II equals 0 all-call interrogations.*

3.1.2.5.2.1.5.2 *Duration of lockout*

3.1.2.5.2.1.5.2.1 Interrogators performing supplementary acquisition using II equals 0 shall perform acquisition by transmitting a lockout command for no more than two consecutive scans to each of the aircraft already acquired in the beam dwell containing the garble zone and shall not repeat it before 48 seconds have elapsed.

*Note.— Minimizing the lockout time reduces the probability of conflict with the acquisition activities of a neighbouring interrogator that is also using II equals 0 for supplementary acquisition.*

3.1.2.5.2.1.5.2.2 **Recommendation**.— *Mode S only all-call interrogations with II=0 for the purpose of supplementary acquisition should take place within a garble zone over no more than two consecutive scans or a maximum of 18 seconds.*



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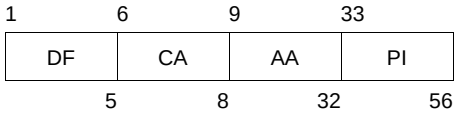
3.1.2.5.2.2 *All-call reply, downlink format 11*




The reply to the Mode S-only all-call or the Mode A/C/S all-call interrogation shall be the Mode S all-call reply, downlink format 11. The format of this reply shall consist of these fields:

| *Field* | *Reference* |
|---|---|
| DF downlink format | 3.1.2.3.2.1.2 |
| CA capability | 3.1.2.5.2.2.1 |
| AA address announced | 3.1.2.5.2.2.2 |
| PI parity/interrogator identifier | 3.1.2.3.2.1.4 |

3.1.2.5.2.2.1 *CA: Capability.* This 3-bit (6-8) downlink field shall convey information on the transponder level, the additional information below, and shall be used in formats DF = 11 and DF = 17.

*Coding*

0 signifies Level 1 transponder (surveillance only), and no ability to set CA code 7 and either airborne or on the ground
1 reserved
2 reserved
3 reserved
4 signifies Level 2 or above transponder and ability to set CA code 7 and on the ground
5 signifies Level 2 or above transponder and ability to set CA code 7 and airborne
6 signifies Level 2 or above transponder and ability to set CA code 7 and either airborne or on the ground
7 signifies the DR field is not equal to 0 or the FS field equals 2, 3, 4 or 5, and either airborne or on the ground

When the conditions for CA code 7 are not satisfied, aircraft with Level 2 or above transponders:

a) that do not have automatic means to set the on-the-ground condition shall use CA code 6; and

b) with automatic on-the-ground determination shall use CA code 4 when on the ground and 5 when airborne.

Data link capability reports (3.1.2.6.10.2.2) shall be available from aircraft installations that set CA code 4, 5, 6 or 7.

*Note.— CA codes 1 to 3 are reserved to maintain backward compatibility.*

3.1.2.5.2.2.2 *AA: Address announced.* This 24-bit (9-32) downlink field shall contain the aircraft address which provides unambiguous identification of the aircraft.

3.1.2.5.3 *Lockout protocol.* The all-call lockout protocol defined in 3.1.2.6.9 shall be used by the interrogator with respect to an aircraft once the address of that specific aircraft has been acquired by an interrogator provided that:

— the interrogator is using an IC code different from zero; and

— the aircraft is located in an area where the interrogator is authorized to use lockout.



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*Note 1.— Following acquisition, a transponder is interrogated by discretely addressed interrogations as prescribed in 3.1.2.6, 3.1.2.7 and 3.1.2.8 and the all-call lockout protocol is used to inhibit replies to further all-call interrogations.*

*Note 2.— Regional IC allocation bodies may define rules limiting the use of selective interrogation and lockout protocol (e.g. no lockout in defined limited area, use of intermittent lockout in defined areas, and no lockout of aircraft not yet equipped with SI code capability).*

3.1.2.5.4 *Stochastic all-call protocol.* The transponder shall execute a random process upon acceptance of a Mode S-only all-call with a PR code equal to 1 to 4 or 9 to 12. A decision to reply shall be made in accordance with the probability specified in the interrogation. A transponder shall not reply if a PR code equal to 5, 6, 7, 13, 14 or 15 is received (3.1.2.5.2.1.1).

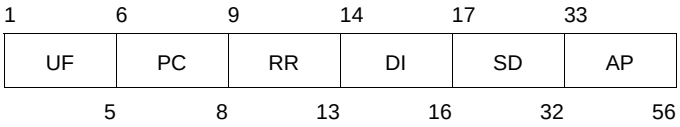
*Note.— The random occurrence of replies makes it possible for the interrogator to acquire closely spaced aircraft, replies from which would otherwise synchronously garble each other.*

### 3.1.2.6 ADDRESSED SURVEILLANCE AND STANDARD LENGTH COMMUNICATION TRANSACTIONS

*Note 1.— The interrogations described in this section are addressed to specific aircraft. There are two basic interrogation and reply types, short and long. The short interrogations and replies are UF 4 and 5 and DF 4 and 5, while the long interrogations and replies are UF 20 and 21 and DF 20 and 21.*

*Note 2.— The communications protocols are given in 3.1.2.6.11. These protocols describe the control of the data exchange.*

#### 3.1.2.6.1 *SURVEILLANCE, ALTITUDE REQUEST, UPLINK FORMAT 4*




The format of this interrogation shall consist of these fields:

| *Field* | *Reference* |
|---|---|
| UF uplink format | 3.1.2.3.2.1.1 |
| PC protocol | 3.1.2.6.1.1 |
| RR reply request | 3.1.2.6.1.2 |
| DI designator identification | 3.1.2.6.1.3 |
| SD special designator | 3.1.2.6.1.4 |
| AP address/parity | 3.1.2.3.2.1.3 |

3.1.2.6.1.1 *PC: Protocol.* This 3-bit, (6-8) uplink field shall contain operating commands to the transponder. The PC field values 2 through 7 shall be ignored and the values 0 and 1 shall be processed for surveillance or Comm-A interrogations containing DI = 3 (3.1.2.6.1.4.1).



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*Coding*

0 signifies no action
1 signifies non-selective all-call lockout (3.1.2.6.9.2)
2 not assigned
3 not assigned
4 signifies close out Comm-B (3.1.2.6.11.3.2.3)
5 signifies close out uplink ELM (3.1.2.7.4.2.8)
6 signifies close out downlink ELM (3.1.2.7.7.3)
7 not assigned.

3.1.2.6.1.2 *RR: Reply request.* This 5-bit, (9-13) uplink field shall command the length and content of a requested reply.

The last four bits of the 5-bit RR code, transformed into their decimal equivalent, shall designate the BDS1 code (3.1.2.6.11.2 or 3.1.2.6.11.3) of the requested Comm-B message if the most significant bit (MSB) of the RR code is 1 (RR is equal to or greater than 16).

*Coding*

RR = 0-15 shall be used to request a reply with surveillance format (DF = 4 or 5);
RR = 16-31 shall be used to request a reply with Comm-B format (DF = 20 or 21);
RR = 16 shall be used to request transmission of an air-initiated Comm-B according to 3.1.2.6.11.3;
RR = 17 shall be used to request a data link capability report according to 3.1.2.6.10.2.2;
RR = 18 shall be used to request aircraft identification according to 3.1.2.9;
19-31 are not assigned in section 3.1.

*Note.— Codes 19-31 are reserved for applications such as data link communications, airborne collision avoidance systems (ACAS), etc.*

3.1.2.6.1.3 *DI: Designator identification.* This 3-bit (14-16) uplink field shall identify the structure of the SD field (3.1.2.6.1.4).

*Coding*

0 signifies SD not assigned except for IIS, bits 21-27 and 29-32 are not assigned, and bit 28 contains the "OVC" (overlay control - 3.1.2.6.1.4.1 i))
1 signifies SD contains multisite and communications control information
2 signifies SD contains control data for extended squitter
3 signifies SD contains SI multisite lockout, broadcast and GICB control information, and bit 28 contains the "OVC" (overlay control - 3.1.2.6.1.4.1 i))
4-6 signifies SD not assigned
7 signifies SD contains extended data readout request, multisite and communications control information, and bit 28 contains the "OVC" (overlay control - 3.1.2.6.1.4.1 i))

3.1.2.6.1.4 *SD: Special designator.* This 16-bit (17-32) uplink field shall contain control codes which depend on the coding in the DI field.

*Note.— The special designator (SD) field is provided to accomplish the transfer of multisite, lockout and communications control information from the ground station to the transponder.*



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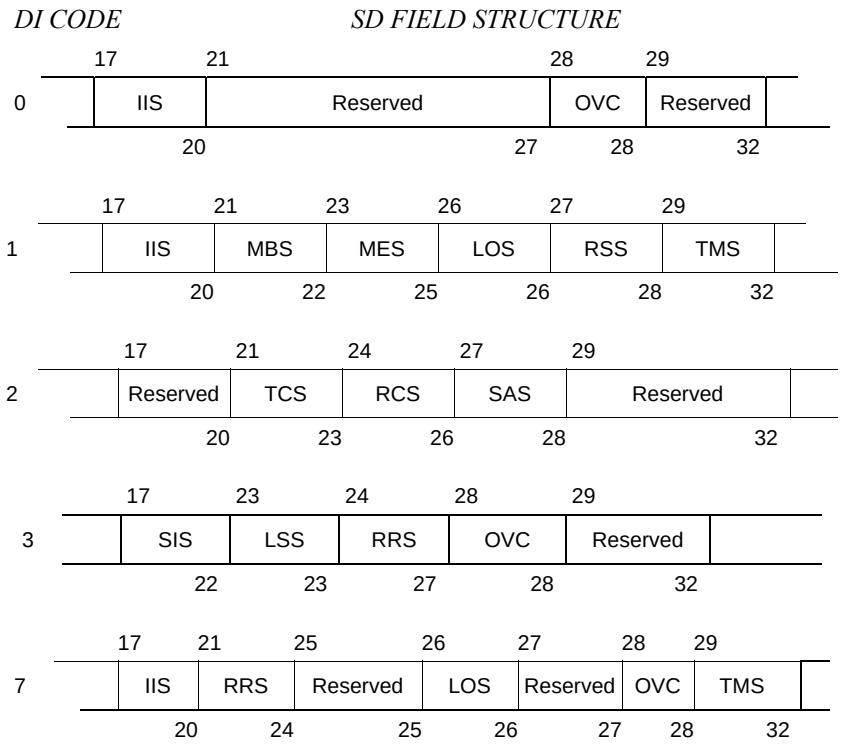


3.1.2.6.1.4.1 *Subfields in SD.* The SD field shall contain information as follows:

a) If DI = 0, 1 or 7:

IIS, the 4-bit (17-20) interrogator identifier subfield shall contain an assigned identifier code of the interrogator (3.1.2.5.2.1.2.3).

b) If DI = 0:

bits 21-32 are not assigned.

c) If DI = 1:

MBS, the 2-bit (21, 22) multisite Comm-B subfield shall have the following codes:

0 signifies no Comm-B action
1 signifies air-initiated Comm-B reservation request (3.1.2.6.11.3.1)
2 signifies Comm-B closeout (3.1.2.6.11.3.2.3)
3 not assigned.

MES, the 3-bit (23-25) multisite ELM subfield shall contain reservation and closeout commands for ELM as follows:

0 signifies no ELM action
1 signifies uplink ELM reservation request (3.1.2.7.4.1)
2 signifies uplink ELM closeout (3.1.2.7.4.2.8)
3 signifies downlink ELM reservation request (3.1.2.7.7.1.1)



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