Republic of the Philippines

CIVIL AVIATION REGULATIONS-AIR NAVIGATION SERVICES (CAR-ANS)

Part 9

MANUAL OF STANDARDS
for Surveillance Radar Systems

22 JUNE 2009

EFFECTIVITY

Part 9 of the Civil Aviation Regulations-Air Navigation Services is issued under the authority of Republic Act 9497 and shall take effect upon approval of the Board of Directors of the Civil Aviation Authority of the Philippines.

APPROVED BY:

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RUBEN F. CIRON, PhD **DATE**

Director General

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FOREWORD

This is a CAAP safety programme document. It contains specifications of uniform application (standards) prescribed and determined to be necessary for the safety of air navigation in the airspace of the Republic of the Philippines.

This manual of standards is referenced in the CAR-ANS Part 10, Series of 2009, Civil Aviation Regulation-Air Navigation Service which is the regulatory requirements and standards on the operation and maintenance of communication, navigation and surveillance (CNS) services.

This manual may be amended from time to time, and the Director General, CAAP will provide such amendment service.

Copies of this manual are available from the:

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Comments about the content of this CAR-ANS are welcome from members of the aviation industry or the public. Any comments or requests for clarification should be directed to the abovementioned address.

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INTRODUCTION

The Civil Aviation Authority of the Philippines (CAAP) is responsible under the Civil Aeronautics Acts (Republic Act No. 776 as amended) and the Act Creating the Civil Aviation Authority of the Philippines (Republic Act No. 9497) for the regulation of civil aviation in the Philippines. The CAAP exercises regulatory oversight by, in part, developing and promulgating appropriate, clear and enforceable aviation safety standards.

This CAR-ANS for Surveillance Radar Systems is one mechanism that CAAP uses to meet the responsibilities of the Republic Acts Nos. 776 and 9497 to ensure safety regulation of air navigation services. This CAR-ANS prescribes the detailed technical requirements (standards for Surveillance Radar systems) that have been determined to be necessary for promoting and supporting aviation safety in general and surveillance applications in particular.

ICAO Annex 10 Standards and Recommended Practices (SARPS) are contained in CAR-ANS. Standards are applicable to all communication, navigation and surveillance facilities used in support of international air navigation.

This CAR-ANS is referenced in CAR-ANS Part 10, Civil Aviation Regulations governing CNS services. Users of this document should refer to the applicable provisions of CAR-ANS, together with this manual, to ascertain the requirements of, and the obligations imposed by, the civil aviation legislation in regard to air navigation service.

The responsibility for matters within this Manual of Standards is with the Aerodrome and Air Navigation Services Safety Oversight Office, CAAP.

RECORDS OF AMENDMENTS AND CORRIGENDA

Amendments			
Number	Date applicable	Date entered	Entered by

Corrigenda			
Number	Date applicable	Date entered	Entered by

STANDARDS FOR SURVEILLANCE RADAR SYSTEMS

1. General

1.1 The CAAP document hierarchy consists of:

a) The Civil Aeronautics Act (Republic Act No. 776 as amended) and the Act Creating the Civil Aviation Authority of the Philippines (Republic Act No. 9497)

b) Relevant Civil Aviation Regulations – Air Navigation Service (CAR-ANS) - establish the regulatory framework rules (regulations) within which all service providers must operate;

c) Advisory Circulars (ACs) - intended to explain elements of the regulatory framework to participants in the aviation industry. Additionally an AC may provide guidance to illustrate a means, but not necessarily the only means, of complying with the requirements of standards. AC may explain certain regulatory requirements by providing interpretive and explanatory materials. As an AC provides only explanatory material, it is expected that service providers will document relevant information in their own operational manuals to put into effect information drawn from an AC.

1.2 This document titled ‘Manual of Standards (MOS) for Surveillance Radar Systems, hereafter referred to as the CAR-ANS Part 9 is made pursuant to CAR-ANS Part 10 sets out the regulatory regime for air navigation facility service providers supporting international and national air transport operations. By complying with the prescribed standards service providers demonstrate that they have discharged their safety obligations to the regulatory authority and to their clients who, ultimately, are the travelling public.

1.3 To assist facility operators or service providers, some general advice about specifications, procedures and other information of an educational or advisory nature may be issued from time to time by CAAP.

2. Applicability

2.1 Based on ICAO SARPS in Annex 10, Volume I, CAR-ANS Part 9 specifies in the appendix hereto the requirements for the surveillance radar systems to be complied with by equipment suppliers and service providers.

2.2 Subject to published conditions of use, air navigation facilities shall be kept continuously available for flight operations during published hours of operation, irrespective of weather conditions. A published condition of use refers to aeronautical data promulgated by Philippines AIP or NOTAM or information broadcast by Air Traffic Control Units.

2.3 Standards are identified by the word ‘shall’ and recommendations by the world ‘should’. Where a specification is expressed in the form of recommendation it does not mean that the specification can be ignored. Rather, the facility operator is encouraged to comply with it or, if the latter is not feasible, to adopt an alternate means to achieve a similar outcome. Any such decision and the alternative means adopted are to be formally recorded and the record maintained while the chosen means of conformance exists.

2.4 Procedure must be in place to ensure that the changes to these documents stemming from the originating authority are available and the CAR-ANS is updated accordingly.

2.5 Under particularly unusual circumstances, the application of a standard or procedure may not be possible or necessary. Such a standard or procedure will be phrased as “if practicable”, “where physically practicable”, “where determined necessary” or similar words. Whilst such phrases may imply compliance is not mandatory, facility operators are required to provide justification for non-compliance. The final decision as to the applicability of the standard to a particular aerodrome facility or procedure rests with CAAP.

3. Periodic Checks

3.1 In accordance with provision of this CAR-ANS, all SSR for use in domestic and international air navigation shall be subject to periodic tests as provided in this document (CAR-ANS Part 9, Appendix B).

3.2 Note: Guidance on methods for the evaluation of the technical and operational performance of surveillance systems is given in ICAO Doc 9684.

4. Amendment procedures and notification of differences to ICAO

4.1 The system specifications in this CAR-ANS (MOS) have to be changed from time to time to meet identified safety needs, technological changes and amendments of ICAO SARPS. AANSOO is responsible for maintaining the currency of CAR-ANS.

4.2 It is recognized that there may be difficulties and limitations in applying new standards to existing systems and facilities. Where there is a difference between a standard prescribed in Annex 10 or other Annexes to the Chicago Convention and one prescribed in this CAR-ANS, the CAR-ANS standard shall prevail. Should such a difference with ICAO SARPS be identified, it is the AANSOO responsibility to initiate notification of difference as per established procedure.

4.3 Differences from ICAO SARPS in Annex 10 shall be published in AIP Philippines and Supplements to the relevant Volumes of this Annex.

4.4 In the event of any perceived disparity of meaning between CAR-ANS and ICAO Annexes, primacy of intent is to be with the CAR-ANS.

4.5 Service providers must document internal actions (rules) in their own operational manuals, to ensure the compliance with, and maintenance of, relevant standards.

4.6 This CAR-ANS is issued and amended under the authority of the Director General, CAAP.

5. Other than SARPS parts of CAR-ANS

5.1 The status of other CAR-ANS material used jointly with standards and recommended practices in this CAR-ANS is explained as follows:

a) *Appendices*

Appendices contain materials grouped separately for convenience and forming part of the standards or practices.

b) *Definitions*

Definitions do not have independent status but each one is an essential part of each standard or practice in which the term is used, since a change in the meaning of the term would affect the specifications.

c) *Tables and Figures*

Tables and Figures add to or illustrate a standard or practice, form part of the associated standard or practice and have the same status.

f) *Notes*

Notes are included in the text, where appropriate, to give factual information or references bearing on the standards or practices in question, but do not constitute part of the standards or practices.

g) *Attachments*

Attachments comprise material supplementary to the standards or practices, or are included as a guide to their application, but do not constitute part of the standards or practices.

6. Related Documents

6.1 This MOS should be read in conjunction with:

(a) ICAO Annex 10, Volume IV – Surveillance and Collision Avoidance Systems;

(b) ICAO Doc 9684 – Manual on Secondary Surveillance Radar

(c) CAR-ANS Part 10

Specifications for Secondary Surveillance Radar (SSR)

Introductory notes:

Note 1. In accordance with the ICAO guidance on the use of the text of the annexes in national regulations this appendix reproduces SARPS for SSR that are of regulatory nature together with signal-in-space specifications essential for intended system operation.

Note 2. Throughout this CAR-ANS, original Annex 10 numbering is maintained for traceability purposes, i.e. MOS requirement 9.2.1.1 corresponds to a standard in paragraph 9.2.1.1 in Chapter 2 of Annex 10, Volume IV. The affixed “9” indicates CAR-ANS Part 9.

9.1. 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 (24) bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Note.- The aircraft address is also referred to as the Mode S address or the aircraft Mode S address.

***All-call*.** An intermode or Mode S interrogation that elicits replies from more than one transponder.

***All-call (Mode A/C-only)*.** An intermode interrogation that elicits replies from Mode A/C transponders only. Mode S transponders do not accept this interrogation.

All-call (Mode A/C/S). An intermode interrogation that elicits Mode A/C replies from Mode A/C transponders and all-call replies from Mode S transponders that are currently not in lockout state.

All-call (Mode S-only). A Mode S interrogation that elicits all-call replies from Mode S transponders that are currently not in the lockout state.

All-call (stochastic). A Mode S-only all-call that elicits all-call replies from only a random subset of the Mode S transponders that are currently not in the lockout state.

Altitude. The vertical distance of a level, point or an object measured above mean sea level.

Antenna (electronically scanned, E-scan). An SSR antenna consisting of a number of planar arrays or a circular array of radiating elements. A beam former unit allows it to electronically steer the beam to the desired azimuth angle by applying phase shifting. The antenna elements may either be active or passive, depending on the order in which the beam former and transmitter(s) are set up.

Antenna (hog-through). An SSR antenna comprising a horizontal linear array of radiating elements installed in an extended corner reflector assembly (resembling in shape a hog-trough). The linear array is usually of sufficient length to give an azimuth beam width of between 2° and 3° and the hog-trough reflector achieves typically between ± 40° and 45° vertical beamwidth. For special purposes shorter arrays can be used. These have increased azimuth beam width.

Antenna (large vertical aperture, LVA). An SSR antenna comprising two-dimensional array radiating elements. A typical LVA consists of a number of columns (each consisting of a vertical linear array designed to produce beam shaping in the vertical plane) arranged in a horizontal linear array to produce 2° and 3° azimuth beamwidth. Typically, LVA antennas are a pre-requisite for monopulse SSR systems.

Antenna (linear array). An antenna consisting of a “battery” or array of radiating elements in a straight line. The desired radiation characteristic of the antenna is obtained by the varied distribution of radio frequency energy in amplitude or phase so as to produce the shaped “beam” or wave front.

Antenna (sum and difference). A hog-trough or LVA antenna which is electrically split into two halves. The two half- antenna outputs are added in phase at one output port (sum,Σ) and added in antiphase at a second output port (difference, Δ) to produce output signals which are sensitive to the azimuth angle of arrival of received signals, enabling an off-boresight angle for the signal source to be obtained.

Antenna (reflector). An antenna producing the beam by a method analogous to optics. In most cases the “reflector” surface of the antenna is illuminated by a radio frequency source (e.g. a radio-frequency “horn” assembly). The dimensions of the reflector antenna both in the horizontal and vertical plane, together with the characteristics of the illuminating source, determine the shape and magnitude of the radar beam produced.

Antenna elevation (tilt). An angle between the direction of maximum gain of the antenna and the tangent to the surface of the earth. A distinction is sometimes made between electronic (radio signal) and mechanical tilt, especially for SSR LVA antennas. In this case the mechanical tilt maybe zero while the antenna is radiating as the electronic tilt of 3°.

Antenna (omnidirectional). An antenna with the same gain in all directions. In earlier side-lobe suppression systems, this antenna type was often used for transmitting the P_2 pulse and sometimes also for transmission of the P_1 pulse (I^2SLS). Modern omnidirectional antennas for ground SSR use include a "notch" coinciding with the peak of the main beam.

Antenna diversity*.* For an installation with a top-end mounted antenna, the selection of the Mode S transponder reply transmission path is based on a comparison of the interrogation signals received on two channels.

Beam sharpening*.* A technique applied to the LVA antenna to decrease the runlength of SSR replies. The reduced runlength is required to improve the resolution capabilities of the extraction system. On the interrogation path, a part of the power of the P_2 is transmitted through the interrogate (P_{1-} P_3) pattern t raise the peaks the control pattern. The crossover points may be raised by about 9dB thus reducing the effective beamwidth. On the reply path, the sum and difference receivers are used to compare the incoming signal. The plot runlength will be adjusted by tuning the amplifier.

Beamwidth*.* An angle subtended (either in azimuth or elevation) at the half-power points (3 dB below maximum) of the main beam of the antenna.

Boresight*.* A main lobe electrical (radio) axis of an antenna.

Bracket decode*.* A decoding of the F_{1-} F_2 framing pulses (nominal interval 20.3μs) without regard to the content of the data pulses between these framing pulses.

Capability report*.* An indication provided by the capability (CA) field of an all-call reply and a squitter transmission of the communications capability of the Mode S transponder (see also "data link capability report").

Chip*.* A 0.25μs carrier interval following possible data phase reversals in the P_6 pulse of Mode S interrogations (see "data phase reversal").

Closeout. A command from the Mode S ground station that terminates a communication transaction.

Code. A combination of data bits contained in signals transmitted by an SSR transponder in reply to an SSR interrogator.

Code train*.* A sequence of bracket (framing) and information pulses in an SSR Mode A or Mode C reply.

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.

Comm-A. A 112-bit interrogation containing the 56-bit MA message field. This field is used by the uplink SLM and broadcast protocols.

Comm-B*.* A 112-bit reply containing the 56-bit MB message field. This field is used by downlink SLM, ground-initiated and broadcast protocols.

Comm-B Data Selector (BDS). The 8-bit BDS code in a surveillance or Comm-A interrogation determines the register whose contents are to be transferred in the MB field of the elicited Comm-B reply. The BDS code is expressed in two groups of 4 bits each, BDS1 (most significant 4 bits) and BDS2 (least significant 4 bits).

BDS1 code. The BDS1 code is defined in the RR field of a surveillance or Comm-A interrogation.

BDS2 code. The BDS2 code is defined in the RRS subfield of the SD field of a surveillance or Comm-A interrogation when DI=7. If no BDS2 code is specified (i.e. DS≠7), it signifies that BDS2=0.

Comm-C. A 112-bit interrogation containing the 80-bit M/C message field. This field is used by the length message (ELM) uplink protocol for uplink data transfer and by the downlink ELM protocol for the transfer of segment readout commands.

Comm-D. A 112-bit reply containing the 80-bit MD message field. This field is used by the extended length message (ELM) downlink protocol for downlink data transfer and by the uplink ELM protocol for the transfer of technical acknowledgements.

Control antenna*.* An SSR antenna having a polar diagram which is designed to "cover" the side lobes of the main interrogating antenna. It is used to radiate a control pulse which, if it exceeds in amplitude the associated interrogation signal at the input to the transponder, will cause the transponder to inhibit responses to the interrogation pulses. Modern SSR antennas have the control elements built into the main array. The control antennas is also known as the SLS (Side-lobe suppression) antenna.

Control pattern*.* A polar diagram of the control antenna. Modern integrated SSR antennas have a "modified cardioid" beamshape.

Control pulse*.* A pulse (P_2 for Mode A and C, P_5 for Mode S) transmitted by the ground equipment (SSR interrogator) in order to ensure side-lobe suppression.

Cone of silence*.* A gap in coverage above a radar due to the limitations of the antenna performance at high elevation angles.

Correlation criteria*.* A number of pulse repetition intervals over which range correlation of replies must be achieved in a sliding or moving window extractor before the presence (or tentative presence, subject to further tests) of a plot can be declared.

Correlated tracks*.* Tracks which have been correlated with a flight plan (sometimes this term applies only to tracks for which the Mode A code has been correlated with a call-sign in the code/call-sign list i.e. flight plan association).

Data link capability report*.* Information in a Comm-B reply identifying the complete Comm-A, Comm-B, ELM and CAS capabilities of the aircraft installation.

Data phase reversal*.* A 180° phase shift which precedes a chip in a Mode S interrogation (see "chip") and is used to encode a binary ONE. The absence of the phase reversal encodes a binary ZERO.

Dead time*.* A period of time during which an SSR transponder is inhibited from receiving signals after a valid interrogation is received and a reply transmitted. The term is also used to describe the time after the normal range for returns and before the next transmission from an interrogator of from a primary radar system.

Defruiter. Equipment used to eliminate unsynchronized replies (fruit) in an SSR ground system.

Defruiting*.* A process by which aircraft replies accepted by the interrogator-responsor are tested by means of storage and a comparator for synchronism with interrogation-repetition frequency. Only replies which are in synchronism (correlate on a repeated basis in range) will e output from the defruiter. Other replies are rejected as "fruit" or false.

Degarbling. A process of separating (and possibly validating) garbled SSR replies. (See “Garbling”)

Delta theta. A number of azimuth count pulses (ACPs) as measured from the plot leading edge t the plot trailing edge in a sliding window plot extractor. Also known as azimuth extension or plot run length.

Difference pattern. A receive (1090 MHz) chracteristic of a monopulse SSR antenna, obtained by connecting in antiphase the signals (replies) received by two partial antennas. The difference pattern has a minimum in the main radiation direction of the antenna and an amplitude and phase characteristic which varies as a function of angle of arrival of the received signal. Used in conjunction with the sum output of the antenna, it enables the off-boresight angle to be found.

Downlink. Associated with signals transmitted on the 1090 Mhz reply frequency channel.

DPSK. Binary differential phase shift keying (DPSK) modulation which uses phase reversal preceding chips to denote binary ONEs and the absence of a phase reversal to denote binary ZEROs.

En-route radar. A surveillance radar for the traffic passing through the area of control. Typically, the range of such a radar is approximately 370 km (200NM) and the information renewal rate for a mechanically rotating antenna is 8 to 12 seconds.

ERP. Effective radiated power (ERP) is the transmitted power enhanced by the gain of the antenna less the losses in cables, rotary joints, etc.

Extended length message (ELM). A series of Comm-C interrogations (uplink ELM) transmitted without the requirement for intervening replies, or a series of Comm-D replies (downlink ELM) transmitted without intervening interrogations.

Extended length communication protocol. A procedure to exchange digital data using extended length messaged.

False plot. A radar plot report which does not correspond to the actual position of a real aircraft (target), within certain limits.

Far field monitor (FFM). See remote field monitor.

Field. A defined number of continuous bits in an interrogation or rely. Fields used in Mode S are listed in Chapter 3, 3.5, Mode S data structure.

Flight status (FS) field. A field of a Mode S reply indicating whether the aircraft is airborne, whether it is transmitting the Mode A/C SPI code and whether it has recently changed its Mode A identity code.

Framing pulses. Pulses which “frame” the information pulses (code) of SSR Mode A and C replies (described as F_1 and F_2 respectively). Also known as “bracket pulses”.

Fringe (inner and outer). A minimum and maximum range respectively for a successful plot detection.

Fruit. A term applied to unwanted SSR replies received by an interrogator which have been triggered by other SSR interrogators. Fruit is the acronym of False Replies Unsynchronized In Time, or False Replies Unsynchronized to Interrogator Transmission.

Garbling. A term applied to the overlapping in range and/or azimuth of two or more SSR replies so that the pulse positions of one reply fall close to or overlap the pulse positions of another reply, thereby making the decoding of reply data prone to error.

Gain (of antenna). A measure for the antenna of the increased (effective) transmitted power density radiated in a particular direction as compared to the power density that would have been radiated from an isotropic antenna (expressed in dB).

Ground-initiated Comm-B protocol (GICB). A procedure initiated by Mode S ground station for eliciting a Comm-B message from a Mode S airborne installation.

Hit*.* A reception by the aircraft equipment (transponder) of one usable set of interrogation pulses as evidenced by a reply code return (i.e. receipt of 2 interrogation pulses and one control pulse).

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.

Improved interrogation side-lobe suppression (I^2SLS)*.* A technique whereby interrogation pulse P_1 is transmitted via both the main beam and the control beam of the SSR antenna, so that a transponder in a side-lobe direction more reliably receives a P_1- P_2 pulse pair.

Interlace. A repeating series of SSR interrogation modes. The interlace pattern may be determined either on a p.r.p (pulse-repetition period) to p.r.p basis or on an antenna rotation to antenna rotation basis. It may also be made on a combined p.r.p/antenna basis.

Interleave. A condition where two or more pulse trains become superimposed in time so that their pulse time spacing can be distinguished and the correct codes established.

Intermode interrogations. Interrogations that consist of 3 pulses ($P_{1,}$ $P_{3,}$ and P_4) and are capable of eliciting replies a)from both Mode A/C and Mode S transponders or b) from Mode A/C transponders but not from Mode S transponders (see “All-call”).

Interrogation. See “Mode”.

Interrogator repetition frequency (IRF)*.* An average number of interrogations per second transmitted by the radar. See also “ Pulse repetition frequency”.

Interrogator side-lobe suppression (ISLS). A method of preventing transponder replies to interrogation transmitted through the ground antenna side lobes.

Interrogator*.* A ground-based (normally) transmitter element of an SSR system.

Interrogator-responsor*.* A ground-based combined transmitter-receiver element of an SSR system.

Interrogator identifier (II). One of the codes (1 to 15) used to identify a Mode S ground station using the multisite protocols.

Lobing (antenna pattern)*.* A process whereby, due to the interference of two waves, one direct and one reflected, differences in phases cause larger or smaller amplitudes than expected for free space, causing differences in signal amplitudes.

Lockout state. A state in which a transponder has been instructed not to accept certain all-call interrogations. Lockout is deliberately induced by command from the Mode S ground station.

Mode A/C transponder*.* Airborne equipment that generates specified responses to Mode A, Mode C and intermode interrogations but does not reply to Mode S interrogations.

Mode S. An enhanced mode of SSR that permits selective interrogation and reply capability.

Mode S ground station. Ground equipment that interrogates Mode A/C and Mode S transponders using intermode and Mode S interrogations.

Mode S interrogations. Interrogations consisting of three pulses ($P_{1,}$ $P_{2,,}$ and P_6) that convey information to and/or elicit replies from Mode S transponders. Mode A/C transponders do not respond to Mode S interrogations because they are suppressed by the ($P_{1,}$ $P_{2,}$) pulse pair.

Mode S transponder. Airborne equipment that generates specified responses to Mode A, Mode C, intermode and Mode S interrogation.

Mode. SSR interrogation mode as specified in Annex 10, Volume IV, Chapter 2.

Monopulse. A technique wherein the amplitudes and/or phases of the signals received in overlapping antenna lobes are compared to estimate the angle of arrival of the signal. The technique determines the angle of a single pulse, or reply, within an antenna beamwidth. The angle of arrival is determined by means of a processor using the replies received through the sum and difference patterns of the antenna. The monopulse technique is generally termed “monopulse direction finding”.

Monopulse plot extractor. A plot extractor using the monopulse direction-finding techniques. See also plot extractor.

Moving window detector. A radar signal processing device which stores radar returns over a given number of pulse repetition periods (the number depending upon the so-called moving window size) and uses these for the automatic detection of radar targets. Also known as sliding window detector.

Multisite Comm-B protocol. A procedure to control air-initiated Comm-B message delivery to Mode S ground stations that have overlapping coverage and that are operating independently (see “multisite protocol”).

Multisite directed Comm-B protocol. A procedure to ensure that a multisite Comm-B message closeout is affected only by the particular Mode S ground station selected by the Mode S airborne installation.

Multisite protocol. Procedures to control message interchange between a Mode S transponder and Mode S ground stations with overlapping coverage and that are operating independently. Multisite protocols allow only a single Mode S ground station to close out a message interchange, thereby assuring that independent operation of Mode S ground stations does not cause messages to be lost.

Non-selective Comm-B protocol. A procedure to control air-initiated Comm-B message delivery to Mode S ground stations operating alone or in overlapping coverage with operations coordinated via ground communications.

*N**on-selective protocol***. Procedures to control message interchange between a Mode S transponder and Mode S ground stations operating alone or in overlapping coverage with operations coordinated via ground communications.

Over-interrogation**.** Interference in the operation of a secondary radar system due to the fact the number of interrogations exceeds the capacity of the transponder (a preset value).

The action of the transponder is an automatic reduction in transponder receiver sensitivity.

Overlapping targets. A condition where radar replies overlaps each other in range and/or azimuth. (See also “garbling”).

Parrot. A fixed transponder referred to as the Position Adjustable Range Reference Orientation Transponder and used as a field monitor. (See “Remote field monitor”).

Plot combiner. A signal-processing device for the combination of PSR and SSR data ascertained as having originated from the same target. Targets failing to meet pre-defined combination criteria will be output as “PSR only” or “SSR only” plots in place of “combined plots”.

Plot extractor. Signal processing equipment which converts PSR or SSR video into an output data message suitable for transmission medium or possibly to further data processing equipment. (See “Plot filter”).

Plot filter. Signal processing equipment which filters out radar plot data positively identified as stationary by a rotation scan-to-scan correlation process.

Plot run length**.** The number of azimuth counts pulses between the first and last detection of a plot presence in a sliding window plot extractor.

Plot resolution. A separation in range and azimuth between two plots, for which the quality of the information of one plot is not affected by the presence of the other plot.

Polar diagrams. Horizontal or vertical radiation patterns for a radar antenna whereby the relative gain is plotted as a function of the relative azimuth (horizontal polar diagram) or as a function of the relative elevation angle (vertical polar diagram). Polar diagrams for LVA antennas are measured separately on uplink and downlink with respect to the main beam axis.

Pulse repetition frequency (PRF). An average number of pulses/interrogations per second transmitted by the radar (see “Stagger”). Also known as pulse recurrence frequency.

Pulse train. A sequence of framing and information pulses in the coded SSR reply.

Pulse position modulation (PPM). Modulation technique used for Mode S replies where a pulse transmitted in the first half of the bit position interval represents a binary ONE, whereas a pulse transmitted in the second half represents a binary ZERO.

Quantized video (QV).

Sec

A pulse generated within a plot extractor on detection of F_1, F_2 pulses, synchronized to the plot extractor timing.

Mor

Analogue video converted to digital words synchronized to the monopulse plot extractor master clock timing.

Quantum. Range unit used for quantization of the range information. Also known as range bin or range cell.

Radar reinforcement. In combined PSR/SSR plot extractors, the term is applied to the successful association of a primary plot with an SSR plot.

Also known as plot combination. If successful association is achieved, the plot extractor generates an SSR message in which an additional bit, radar reinforcement, is set; the remaining primary radar plot information may be merged or it may be discarded.

Raw video*.* Unprocessed, analogue PSR or SSR video information.

Receiver side-lobe suppression (RSLS). A method, using two (or more) receivers to suppress aircraft replies which have been received via side lobes of the main beam of the antenna.

Remote field monitor*.* A system which monitors the uplink and/or downlink performance of an SSR or Mode S system from a site located at the specified distance from the radar (far field). The monitor (see “parrot”)is interrogated by the radar and its replies can be evaluated on the radar site. In addition, the replies may contain data about certain interrogation parameters as seen by the monitor.

Remote monitoring and control system (RMCS)*.* A system which allows manual or automatic reconfiguration of the radar system. The RMCS will also give an over-all indication of the system status (equipment operational, equipment in standby, faults, etc.) The RMCS equipment may have a terminal either at the station level or at the ATC center level and often at both levels.

Reply*.* A pulse train received at an SSR ground station as a result of successful SSR interrogation.

Reply code, reply pulse train. See “Code train”.

Reply preamble. A sequence of four pulses, each with a duration of 0.5 microsecond, indicating the beginning of a Mode S reply.

Residual errors. Errors in position which exist between the corrected positions of an object (measured position minus systematic error) and the corresponding trajectory.

Resolution. Ability of a system to distinguish between two or more targets in close proximity to each other both in range and bearing (azimuth).

Responsor. A ground-based receiver part of SSR. The complete equipment is generally known as the interrogator/responsor.

Ring-around. Continuous reception of replies to interrogations by the side lobes of the ground antenna. This normally occurs only at short ranges, usually due to the non-existence of a side-lobe suppression mechanism or the improper functioning of this mechanism, at either the interrogator or the transponder side.

Round reliability. A probability of receipt of a correct reply, resulting from either an SSR interrogation or a PSR transmission.

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.

Secondary surveillance radar (SSR) system. A radar system which transmits coded interrogations to aircraft transponders in various modes and receives coded replies.

Secondary surveillance radar (SSR) transponder. A unit which transmits a response signal on receiving an SSR interrogation. The term is a derivative of the words transmitter and responders.

Side lobes (antenna). Lobes of the radiation pattern of an antenna, which are not part of the main or principal beam. Radar systems can have sufficient sensitivity via side lobes for successful detection of aircraft (particularly for SSR, but also for PSR). Special precautions are necessary to protect against these false plots.

Side-lobe suppression (SLS). A mechanism in an SSR transponder activated by the transmission (radiation) of a control pulse (P_2 or P_5) of amplitude greater than the antenna side-lobe signals-in-space, which will enable the transponder to prevent itself from replying to the side-lobe interrogation signals.

Squitter. The spontaneous periodic transmission by a Mode S transponder (nominally once per second) of a specified format to permit passive acquisition by Mode S interrogators with broad antenna beams (e.g. ACAS).

Stagger. Deliberate, controlled variation of the pulse repetition frequency of the SSR to prevent aircraft plots due to second-time-around replies.

Standard length communication protocol. A procedure to exchange digital data using Comm-A interrogations and/or Comm-B replies.

Sum pattern. Normal radiation pattern for the main directional beam of an antenna. Contrasts with the “difference-pattern”, where parts of the radiating elements of the antenna are switched in anti-phase to produce signals proportional to the amount by which the source is off the boresight of the sum pattern.

Suppression. A deliberate inhibition of a transponder’s ability to accept or reply to interrogations.

Surveillance interrogation**.** A 56-bit Mode S interrogation containing surveillance and communications control information.

Surveillance processing. A general term covering any processing applied to the target reports after the extraction functions and prior to the data transmission functions. Such processes include filtering, clutter reduction, data rate control and dynamic angle control.

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

Surveillance reply. A 56-bit Mode S reply containing surveillance and communications control information, plus the aircraft’s 4096 identity code or altitude code.

Synch phase reversal. A first phase reversal in the Mode S P_6 interrogation pulse. It is used to synchronize the circuitry in the transponder that decodes the P_6 pulse by detecting data phase reversals, i.e. as a timing reference for subsequent transponder operations related to the interrogation.

Tilt. See antenna elevation.

Track. A succession of radar-reported positions for one aircraft sometimes correlated and smoothed by a special tracking algorithm.

Trailing edge (plot). The azimuth, for which the extractor/plot processor logic detects the “end of plot”.

Transponder transaction cycle. The sequence of Mode S transponder operations required by the reception of an interrogation. The process begins with the recognition of an interrogation and ends either with the non-acceptance of the interrogation or the transmission of a reply or the completion of processing associated with that interrogation.

Uplink. Associated with signals transmitted on the 1030 Mhz interrogation frequency channel.

Validation (code). Process of correlation of the code information used in SSR Mode A/C systems. Generally two identical codes in two successive replies suffice to validate the code. In Mode S, code validation occurs inherently when the reply is decoded (and, if appropriate, error corrected).

> Note.- Modern radar systems may provide “smoothed” code information when the so-called validation serves to indicate non-extrapolated code information.

9.2. GENERAL

9.2.1 SECONDARY SURVEILLANCE RADAR (SSR)

9.2.1.1 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.

9.2.1.2 Interrogation modes (ground-to-air)

9.2.1.2.1 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 — NOT APPLICABLE, RESERVED*

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 — NOT APPLICABLE, RESERVED*

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.

9.2.1.2.1.1 **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.

9.2.1.2.1.2 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. (NOT APPLICABLE, RESERVED)

9.2.1.2.1.3 The assignment of surveillance identifier (SI) codes, where necessary in areas of overlapping coverage, shall be the subject of regional air navigation agreements. (NOT APPLICABLE, RESERVED)

9.2.1.2.2 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.

9.2.1.2.3 **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.* (NOT APPLICABLE, RESERVED)

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Note.— Aircraft identification reporting through the Mode S data link provides unambiguous identification of aircraft suitably equipped. (NOT APPLICABLE, RESERVED)

9.2.1.2.4 SIDE-LOBE SUPPRESSION CONTROL INTERROGATION

9.2.1.2.4.1 Side-lobe suppression shall be provided in accordance with the provisions of 9.3.1.1.4 and 9.3.1.1.5 on all Mode A, Mode C and intermode interrogations.

9.2.1.2.4.2 Side-lobe suppression shall be provided in accordance with the provisions of 9.3.1.2.1.5.2.1 on all Mode S-only all-call interrogations. (NOT APPLICABLE, RESERVED)

9.2.1.3 Transponder reply modes (air-to-ground)

9.2.1.3.1 Transponders shall respond to Mode A interrogations in accordance with the provisions of 9.3.1.1.7.12.1 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.

9.2.1.3.1.1 The pressure altitude reports contained in Mode S replies shall be derived as specified in 9.3.1.1.7.12.2. (NOT APPLICABLE, RESERVED)

Note.— 9.3.1.1.7.12.2 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 ectopascals. The intention of 9.2.1.3.1.1 is to ensure that all transponders, not just Mode C transponders, report uncorrected pressure altitude.*

9.2.1.3.2 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.

9.2.1.3.2.1 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. (NOT APPLICABLE, RESERVED)

9.2.1.3.2.2 **Recommendation.—** *For aircraft 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) should be reported in 7.62 m (25 ft) increments.* (NOT APPLICABLE, RESERVED)

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

9.2.1.3.2.3 All Mode A/C transponders installed on or after 1 January 1992 shall report pressure-altitude encoded in the information pulses in Mode C replies.

9.2.1.3.2.4 All Mode S transponders installed on or after 1 January 1992 shall report pressure-altitude encoded in the information pulses in Mode C replies and in the AC field of Mode S replies. (NOT APPLICABLE, RESERVED)

9.2.1.3.2.5 All Mode S transponder equipped aircraft with 7.62 m (25 ft) or better pressure altitude sources shall report pressure altitude encoded in 7.62 m (25 ft) increments in the AC field of Mode S replies from 1 January 2005. (NOT APPLICABLE, RESERVED)

9.2.1.3.2.6 When a Mode S transponder reports altitude in 7.62 m (25 ft) 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 7.62 m (25 ft) increments.

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.

9.2.1.3.3 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 (see Annex 10, Volume IV, Chapter 3). (NOT APPLICABLE, RESERVED)

9.2.1.3.3.1 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. (NOT APPLICABLE, RESERVED)

9.2.1.3.3.2 **Recommendation.—** *The agreements indicated in 9.2.1.3.3.1 should provide at least five years' notice*.

9.2.1.4 Mode A reply codes (information pulses)

9.2.1.4.1 All transponders shall be capable of generating 4 096 reply codes conforming to the characteristics given in 9.3.1.1.9.2.

9.2.1.4.1.1 **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.

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

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

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

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

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

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

9.2.1.4.5 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.

9.2.1.5 Mode S airborne equipment capability (NOT APPLICABLE, RESERVED)

9.2.1.6 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.

9.2.2 HUMAN FACTORS CONSIDERATIONS

Recommendation.— *Human Factors principles should be observed in the design and certification of surveillance radar 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).

CHAPTER 9.3. SURVEILLANCE RADAR SYSTEMS

9.3.1 SECONDARY SURVEILLANCE RADAR (SSR) SYSTEM CHARACTERISTICS

Note 1.— Section 9.3.1.1 prescribes the technical characteristics of SSR systems having only Mode A and Mode C capabilities. Section 9.3.1.2 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.

9.3.1.1 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. A2, C4, 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.

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

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

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

9.3.1.1.1.3 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.

9.3.1.1.2 REPLY CARRIER FREQUENCY (AIR-TO-GROUND)

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

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

9.3.1.1.3 POLARIZATION

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

9.3.1.1.4 INTERROGATION MODES (SIGNALS-IN-SPACE)

9.3.1.1.4.1 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.

9.3.1.1.4.2 Interrogation Modes A and C shall be as defined in 9.3.1.1.4.3.

9.3.1.1.4.3 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

9.3.1.1.4.4 The interval between *P*1 and *P*2 shall be 2.0 plus or minus 0.15 microseconds.

9.3.1.1.4.5 The duration of pulses *P*1, *P*2 and *P*3 shall be 0.8 plus or minus 0.1 microsecond.

9.3.1.1.4.6 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.

9.3.1.1.4.7 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.

9.3.1.1.5 INTERROGATOR AND CONTROL TRANSMISSION CHARACTERISTICS

(INTERROGATION SIDE-LOBE SUPPRESSION — SIGNALS-IN-SPACE)

9.3.1.1.5.1 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.

9.3.1.1.5.2 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.

9.3.1.1.6 REPLY TRANSMISSION CHARACTERISTICS (SIGNALS-IN-SPACE)

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

9.3.1.1.6.2 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)*
C1	1.45
A1	2.90
C2	4.35
A2	5.80

C4	7.25
A4	8.70
X	10.15
B1	11.60
D1	13.05
B2	14.50
D2	15.95
B4	17.40
D4	18.85

Note.— The Standard relating to the use of these pulses is given in A 2.1.4.1. However, the position of the "X" pulse is specified only as a technical standard to safeguard possible future use.

9.3.1.1.6.3 *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.

9.3.1.1.6.4 *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.

9.3.1.1.6.5 *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.

9.3.1.1.6.6 *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:

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

9.3.1.1.7 TECHNICAL CHARACTERISTICS OF TRANSPONDERS WITH MODE A AND MODE C CAPABILITIES ONLY

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

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

9.3.1.1.8.1.1 **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.*

9.3.1.1.8.2 *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.*

9.3.1.1.8.3 **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.

9.3.1.1.9 INTERROGATOR RADIATED FIELD PATTERN

Recommendation.— *The beam width of the directional interrogator antenna radiating* P3 *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.*

9.3.1.1.10 INTERROGATOR MONITOR

9.3.1.1.10.1 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.

9.3.1.1.10.2 **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.*

9.3.1.1.11 SPURIOUS EMISSIONS AND SPURIOUS RESPONSES

9.3.1.1.11.1 *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.*

9.3.1.1.11.2 *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.

9.3.1.2 Systems having Mode S capabilities (NOT APPLICABLE, RESERVED)

-END-