



International Civil Aviation Organization

**THE FIFTH MEETING OF MODE S DOWNLINKED AIRCRAFT
PARAMETERS WORKING GROUP
(MODE S DAPs WG/5)**

Video Teleconference, 23 – 25 March 2022

Agenda Item 2: Review outcomes of relevant meetings

**AMENDMENT OF APPENDIX H AND APPENDIX J OF DOC 9924 AERONAUTICAL
SURVEILLANCE MANUAL**

(Presented by China, Singapore and the Secretariat)

SUMMARY

This paper shares with the meeting the current proposals for amending the Aeronautical Surveillance Manual (Doc. 9924) Appendix H and J.

These amendments in Appendix H will clarify the steps that can be taken to secure a safe introduction of Mode S II/SI capable interrogators and transponders with the focus on an environment where both Mode S II only and Mode S II/SI capable systems are being introduced.

These amendments in Appendix J will update the Mode S II code assignment planning with Mode S SI code and provide for compatibility with Mode S II interrogators and transponders that are not Mode S SI capable.

1. INTRODUCTION

1.1 To deploy SI codes effectively and safely, the aircraft within the radar coverage must be SI capable. Although ICAO Annex 10 vol 4 required that all Mode S transponders must be SI capable by 1 January 2005, but in practice, not 100% of aircraft are SI capable. Only SI capable transponders will be able to recognize the full SI in the roll-call (lock out) message. Non-SI capable transponders will only be able to recognize the last 4 bits, hence will mistakenly lock out to other radars with different SI codes, but with the same last 4 bits.

1.2 As a work-around, a special mode of operation known as the II/SI Code Operation is used. Under this mode, the radar will only issue lock-out command to SI capable transponders leaving non-SI transponders to reply to further all-calls. It is also noted that II/SI Code Operation mode may not be available in all Mode S radars.

2. DISCUSSION

2.1 The Asia Pacific (APAC) Team is of the view that enhancement of the material in **Appendix H** and **Appendix J** of Doc 9924 Aeronautical Surveillance Manual can help States and regions migrate from II to SI under a mixed environment.

2.2 In particular, the enhancements are proposed to:

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- a) clarifies and elaborates the acquisition and detection of Mode S II-only (non-SI capable) transponders by Mode S II/SI capable interrogators as well as the acquisition and detection of Mode S II/SI capable transponders by Mode S II-only interrogators as currently described in paragraphs 1.2.5 – 1.2.11 of **Appendix H** to the Aeronautical Surveillance Manual (Doc. 9924).
- b) introduces the planning criteria in **Appendix J** for co-existence of II and SI codes under the environment where there are non-SI capable transponders still in operations.

2.3 The proposed amendment in **Annex A** to this paper is being deliberated at the Surveillance Panel. Thus far, it has been endorsed by the Technical Sub-group in Feb 2022. It will be discussed at the Aeronautical Surveillance Working Group in Apr 2022 and Oct 2022 before its formally be adopted.

3. CONCLUSION

3.1 The meeting is invited to:

- a) note the information contained in this paper; and
- b) discuss any relevant matters as appropriate.

PROPOSED AMENDMENT TO
DOC 9924
AERONAUTICAL SURVEILLANCE MANUAL
Appendix H and Appendix J
MODE S PROTOCOL CONSIDERATIONS

NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT

1. The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:
 - a) ~~Text to be deleted is shown with a line through it.~~ text to be deleted
 - b) **New text to be inserted is highlighted with grey shading.** new text to be inserted
 - c) ~~Text to be deleted is shown with a line through it followed~~ **by the replacement text which is highlighted with grey shading.** new text to replace existing text
2. The source of the proposed amendment is the Surveillance Panel (SP).

Appendix H

MODE S PROTOCOL CONSIDERATIONS

Note.— In regions of overlapping coverage, Mode S ground stations must coordinate their activities to permit the correct operation of the Mode S surveillance and communications protocols. The multisite protocols provide this coordination with a minimum of ground cooperation through the use of a site identifier in uplink transmissions. The non-selective protocols require ground-to-ground coordination of ground station activity but are more efficient in the use of channel time. However, the non-selective lockout protocols are not compatible with the Mode S subnetwork protocols.

1. ACQUISITION AND LOCKOUT PROTOCOLS

1.1 General

1.1.1 In order to selectively interrogate a Mode S-equipped aircraft, the **Mode S ground station**¹ must know the aircraft's **24-bit Mode S Aircraft address**² and approximate position. To acquire the addresses of Mode S equipped aircraft, each Mode S ground station transmits all-call interrogations. A Mode S-equipped aircraft will respond to such an interrogation with its unique **24-bit Aircraft address**. On the first or second antenna scan after receiving the initial all-call replies, the **Mode S ground station** will begin to **selectively discretely** interrogate the aircraft and command the lockout condition for the **Interrogator Code**³ (IC) in use by the ground station. The benefit of waiting until the second scan before lockout is that it allows a better estimate of aircraft velocity, which gives a more accurate estimate of the time that the aircraft will be in the main beam on the next scan. **Accurate time estimate can not only improve the success rate of selective interrogation, but also optimize the efficiency of beam-dwell time.** After acquisition, the aircraft's 24-bit **Aircraft address** will be added to the **Mode S ground station's** file of acquired aircraft.

1.1.2 Once acquired, the Mode S-equipped aircraft **must** be locked out from replying (instructed not to respond) to subsequent Mode S all-call interrogations in order to minimize all-call synchronous garbling. This lockout condition is controlled by the Mode S ground station through Mode S selectively addressed interrogations. If for any reason an aircraft ceases to receive **selectively-addressed** interrogations containing a lockout command for a period of approximately 18 seconds (corresponding to a few antenna scans), any existing lockout will lapse so that the aircraft may be reacquired by normal Mode S acquisition.

1.1.2.1 Alternatively, in special cases such as described in paragraphs 1.2.5 to 1.2.11 below, the aircraft equipped with Mode S II-only transponders⁴ should be intermittently locked out or not be locked out.

1.1.3 The interrogation used by the **Mode S** ground station to elicit all-call replies depends upon the acquisition technique in effect at that site.

¹ **Mode S ground station.** Ground equipment that interrogates Mode A/C and Mode S transponders using intermode and Mode S interrogations. A monopulse capable antenna and a rotary joint providing at least two channels for sum and difference processing are a pre-requisite for Mode S operation.

² **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. The 24-bit aircraft address is described in Annex 10, Volume III, Chapter 9 – **AIRCRAFT ADDRESSING SYSTEM**

³ **Interrogator Code (IC).** A code used to identify an interrogator in Mode S protocols. It may be either an Interrogator Identifier (II) or Surveillance Identifier (SI) code.

⁴ A Mode S II-only transponder complies with the provisions of Annex 10, up to and including Amendment 71 (1996)

1.1.4 Operational experience has shown that many Mode S transponders interpret a Mode S interrogation that is received near the minimum trigger level (MTL) or is corrupted by multipath as a Mode A/C/S all-call interrogation. The result is an unwanted all-call reply with an associated interrogator identifier (II) code equal to zero. These unwanted replies result in a significant increase in the rate of all-call replies around busy terminals. Unwanted all-call replies can be eliminated by locking out all Mode S aircraft under surveillance to II=0 in addition to the radar's assigned interrogator code. This dual lockout can be accomplished by locking out to each interrogator code on alternate scans.

1.2 Multisite acquisition and lockout

1.2.1 Multisite acquisition is carried out by using the Mode S-only all-call interrogation uplink format (UF) = 11. The IC of the interrogating site is contained in the interrogation. Two types of ICs are defined:

- a) the II code is used for multisite surveillance and data link coordination. II codes of 1 to 15 are valid (an II code of ZERO (0) is interpreted as non-selective); and
- b) the SI code is used only for multisite surveillance and the limited data link functions (It shall not be used with the multisite uplink or down link ELM protocols). identified-SI codes of 1 to 63 are valid. SI code ZERO (0) is not used.

1.2.2 The transponder replies to this interrogation if it is not in a state of lockout to that specific IC. The Mode S II only transponder has a total of 16 independent lockout timers to maintain the lockout state requested by the ground stations (i.e. 16 II lockout timers). The Mode S II/SI capable⁵ transponder has a total of 79 independent lockout timers to maintain the lockout state requested by the ground stations (i.e. 16 II and 63 SI lockout timers).

1.2.3 Matching SI and II codes.

1.2.3.1 An SI code transmitted in a Mode S-only all-call interrogation by an II/SI capable interrogator⁶ is composed of the IC field and the CL field (Uplink format 11, All Call):

UF11 (01011)	PR (4 bits)	IC (4 bits)	CL (3 bits)	(16 bits)	AP (24 bits)
		Interrogator Code (0 – 15)	Code Label (000 for II codes)	Set to “zeroes”	Address is set to 24 “ones” Parity for the first 32 bit is overlaid

The CL field is encoded (in 3 bits binary format):

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

The IC field is encoded (in 4 bits binary format) from 0 to 15

⁵ A Mode S II/SI capable transponder complies with the provisions of Annex 10, Amendment 73 or higher (1998 or later)

⁶ An II/SI capable interrogator complies with the provisions of Annex 10, including Amendment 73 or higher (1998 or later)

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1.2.3.2 Mode S II/SI capable ~~Only transponders complying with at least Amendment 73 (or higher) of Annex 10~~ will decode the CL field in order to determine whether the content of the IC field is an II code (Field CL = 000) or an SI code (field CL = 001 – 100). A Mode S II-only capable ~~transponder which have not been upgraded to handle SI codes will, by default~~ consider the content of the IC field as being an II code value since it cannot decode the CL field. In the following example: the interrogator transmits a Mode S-only all-call interrogation on SI 37, the CL field contains the code 011 (consistent with the SI codes 32 to 47) and the IC field contains the code 0101 (decimal 5). The SI code that has been transmitted is $32 + 5 = 37$.

UF11 (01011)	PR (4 bits)	IC (4 bits)	CL (3 bits)	(16 bits)	AP (24 bits)
		0101 (decimal 5)	Code Label 011	Set to “zeroes”	Address is set to 24 “ones” Parity for the first 32 bit is overlaid

The Mode S II-only capable transponder decodes the SI code 37 as being the II code 5 since the CL field cannot be decoded. This is, through the field IC, the “matching” II code.

1.2.3.3 Therefore, if the CL field is not equal to zero (meaning that the IC field contains an SI code), the Mode S II-only ~~non-upgraded~~ transponders will encode the parity sequence of the reply using the “matching” II code rather than the SI code contained in the interrogation.

The table of matching II – SI codes is as follows:

II Code	Matching SI code Field CL = 001 SI codes 01 - 15	Matching SI_code Field CL = 010 SI codes 16 - 31	Matching SI_Code Field CL = 011 SI codes 32 - 47	Matching SI_Code Field CL = 100 SI codes 48 - 63
00		16	32	48
01	01	17	33	49
02	02	18	34	50
03	03	19	35	51
04	04	20	36	52
05	05	21	37	53
06	06	22	38	54
07	07	23	39	55
08	08	24	40	56
09	09	25	41	57
10	10	26	42	58
11	11	27	43	59
12	12	28	44	60
13	13	29	45	61
14	14	30	46	62
15	15	31	47	63

1.2.3.4 If the Mode S II/SI capable interrogator transmits a Mode S-only all-call interrogation with the II code (where the field CL is set to 000 (zero)) both the Mode S II/SI capable transponder and the Mode S II-only capable transponder can correctly decode the II code contained in the Mode S-only all-call interrogation (UF11) and reply (DF11) with that II code.

1.2.4 Mode S II-only transponders, when being interrogated with an SI code, reply only with the “matching” II code since it cannot decode the CL field in the Mode S-only all-call interrogation.

1.2.4.1 The interrogator, which will receive Mode S-only all-call replies encoded with the “matching”

II code will normally reject these replies. The consequence is that Mode S II-only transponders which have not been upgraded to handle SI codes will not be detected by the interrogator operating with an SI code.

1.2.5 The following technique enables the acquisition and detection of non-SI capable transponders for the transition period.

Note.- The techniques as clarified in paragraph 1.2.6 – 1.2.10 provides means to acquire and detect non-SI capable transponders that must be implemented during the transition period until all of the Mode S aircraft are equipped with II/SI capable transponder. These techniques define the II/SI code operation mechanism. The Mode S II/SI capable interrogators implementing these techniques support the use of II/SI code operation.

1.2.6 The interrogator that supports the use of II/SI code operation, when operating with an SI code, must be configurable by the user to accept Mode S-only all-call replies for which the "matching" II code has been used to encode the parity sequence.

1.2.6.1 While normally a Mode S II/SI capable interrogator operating with an SI code would reject the replies from Mode S II-only transponders, a Mode S II/SI interrogator that supports the use of II/SI code operation is configurable to acquire these transponders on the "matching" II code during the transition phase to full Mode S SI implementation.

1.2.7 The target which has sent such replies must be considered as equipped with a non-SI capable transponder, even if the content of Register 10₁₆ states that the transponder has the SI capability.

1.2.7.1 The "target" is the transponder that has sent, in response to the Mode S-only all-call interrogation from the Mode S II/SI capable interrogator operating with an SI code, a reply on the "matching" II code. Some Mode S transponders may report they are Mode S II/SI capable (in Bit 35 of Register 10₁₆) whereas they are not Mode S II/SI capable.

1.2.8 The interrogator that supports the use of II/SI code operation, if operating with an SI code, must be configurable by the user to interrogate targets equipped with non-SI capable transponders using the Mode S-selective protocols foreseen for II code operation. The II code to be used must be the "matching" II code.

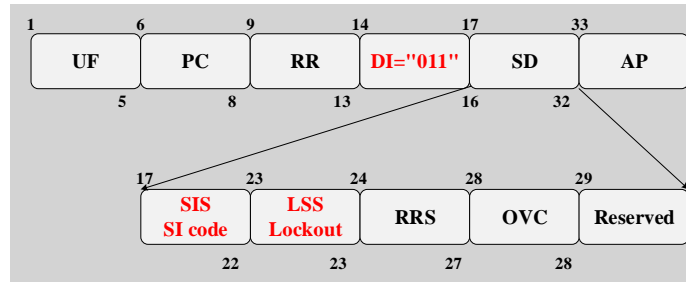
1.2.8.1 The II/SI code operation mechanism, that is to be implemented during the transition period toward full implementation of Mode S II/SI capable transponders allows selective interrogation of a Mode S II-only capable transponder using the "matching" II code.

1.2.9 The Mode II/SI capable interrogator that supports the use of II/SI code operation, if operating with an SI code, must be configurable by the user to either:

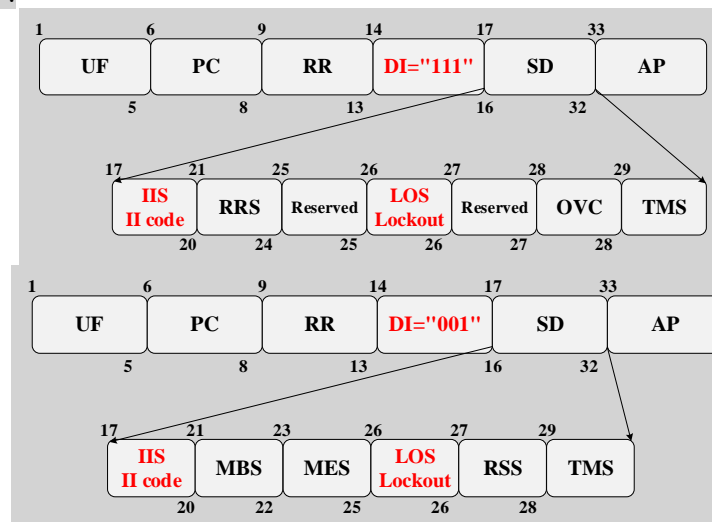
- a) not lockout non-SI capable transponders on the "matching" II code; or
- b) use intermittent lockout for this "matching" II code.

Note.— This is to allow ~~neighbouring~~ interrogators (supporting the use of II/SI code operation) with overlapping coverage and operating with the "matching" II code or with an SI code matching the same II code to acquire the Mode S II-only (non-SI capable) transponders on the "matching" II code.

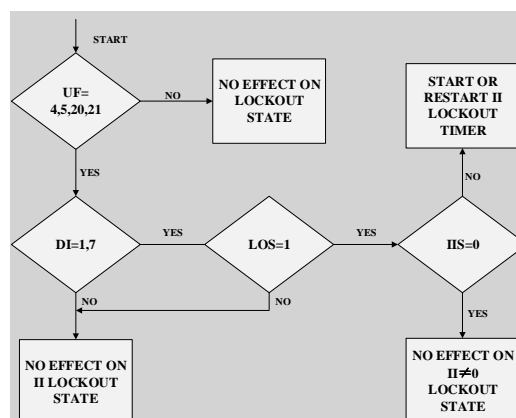
1.2.9.1 A Mode S II/SI capable interrogator operating on SI code will use the selective interrogation (Roll-Call) to provide surveillance and to lockout (or intermittent lockout) the mode S II/SI capable transponder by setting the DI field to "011", and filling the interrogator's SI code into the SIS subfield, setting the LSS subfield to "1". As shown in the figure below. (Re. ICAO Annex 10 Vol.4, Ed. 2017, paragraph 3.1.2.6.1.4)



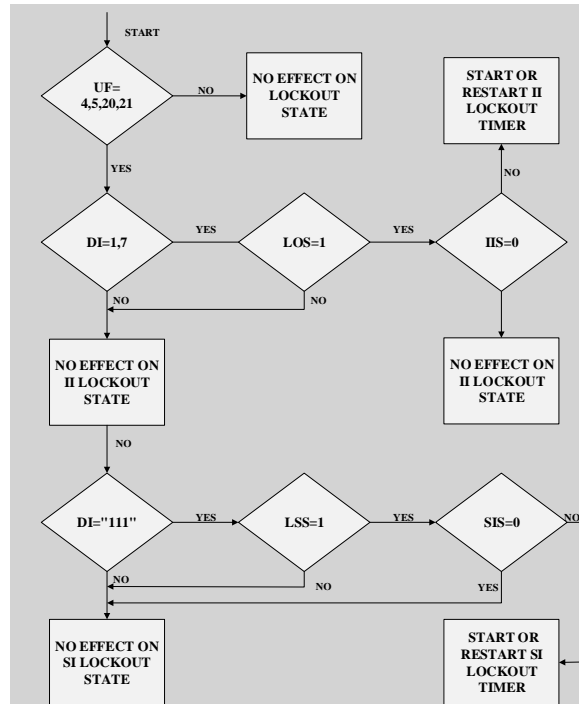
1.2.9.2 The Mode S II/SI interrogator that supports the use of II/SI code operation and that operates on SI code must either not lock-out the Mode S II-only transponder, or use the “matching” II code to lock-out (intermittent lock-out) the Mode S II-only transponder. In that case, the Mode S interrogator can use the selective interrogation (Roll-Call) to lockout the Mode S II only transponder by setting the DI field to “111” or “001, filling the interrogator’s “matching” II code into the IIS subfield and setting the LOS subfield to “1 “.



1.2.9.3 Once a confirmed selective interrogation (Roll-Call) is accepted, the Mode S II-only transponder will use the following logic to determine the lockout activity.



1.2.9.4 Once a confirmed selective interrogation is accepted, the Mode S II/SI capable transponder will use the following logic to determine the lockout activity.



1.2.10 The Mode S II/SI capable interrogator that supports the use of II/SI code operation, if operating with an II code, must be configurable by the user to either:

- a) not lockout Mode S transponders that do not report the SI capability in Register 10₁₆ or cannot report their data link capability (Register 10₁₆); or
- b) use intermittent lockout for Mode S transponders that do not report the SI capability in Register 10₁₆ or cannot report their data link capability (Register 10₁₆).

Note.— This is to allow neighbouring interrogators (supporting the use of II/SI code operation) with overlapping coverage and operating with an SI code and the “matching” the II code to acquire the Mode S II-only (non-SI capable) transponders on the “matching” II code.

1.2.10.1 The Mode S II/SI capable interrogator (supporting the use of II/SI code operation) that operates with an II code can distinguish between a Mode S II-only transponder and a Mode S II/SI capable transponder using the content of the reported register 10₁₆ (Incorrect BDS1,0 information should be taken into consideration). But some Mode S transponders may report they are SI code capable (in Bit 35 of BDS 1,0) whereas they are in practice not SI capable.

1.2.10.2 Using this mechanism, the Mode S II/SI capable transponders will be locked out, whereas the Mode S II-only (non-SI capable) transponders will not be locked out on the II code. Therefore, the Mode S II-only transponder can be acquired on the “matching” II code by an overlapping Mode S II/SI interrogator (supporting the use of II/SI code operation) operating on an SI code “matching” the II code. A Mode S II/SI capable transponder that is locked out on II code by a Mode S II/SI interrogator is not locked out on any “matching” SI code since this transponder can decode the field “CL” and reply with the SI code to the Mode S SI interrogator.

1.2.11 This technique may be used in an environment where there is a need for a region to transit from II to SI codes and at the same time ~~must only be used to detect aircraft not equipped with SI code capable transponders entering mandated SI code airspace so that appropriate action can be taken (e.g. they can be re-routed out of such airspace).~~

1.3 Acquisition and lockout techniques

1.3.1 When the system is operating in the multisite mode, separate interrogation of Mode S and Mode

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A/C targets can be achieved by the use of the Mode A/C-only all-call, together with the Mode S-only all-call, UF = 11.

1.3.2 As the name implies, the Mode S-only all-call interrogation elicits replies only from Mode S transponders. It is therefore used in conjunction with the Mode A/C-only all-call interrogation (distinguished by a short P₄ pulse). This latter interrogation elicits replies only from Mode A/C transponders and therefore complements the Mode S-only all-call so that Mode A/C and Mode S transponders reply to at most one of the interrogations. This avoids the possibility of having the same aircraft under surveillance as both a Mode A/C and a Mode S aircraft.

1.3.3 One technique for managing the RF channel is for each all-call interrogation to be followed by its own listening window. At the expense of more sophisticated management of the reply processors, an alternative technique obtains the benefit of a shared listening interval by pairing the two all-call interrogations as shown in Figure H-1. This shared listening interval results in a much more efficient use of the timeline. The spacing between the interrogations is such that replies are received simultaneously from a Mode A/C transponder and a Mode S transponder at the same range. This allows enough time for a Mode A/C transponder to recover from the SLS caused by the P₁-P₂ Mode S interrogation preamble before it receives the Mode A/C-only all-call.

Note 1.— When operating with overlapping all-calls, there is the possibility for marginally performing transponders to exhibit unexpected results. Some Mode A/C transponders have been observed not to suppress properly to the equal amplitude P₁-P₂ suppression pair of the Mode S preamble. This usually results in the transponder improperly detecting a P₃ pulse within the P₆ waveform and responding with a Mode A reply. This can result in a ghost target being reported up to 10 NM closer in slant range than the actual target position. If the transponder does not recover in time to accept the legitimate interrogation, it will not respond at its actual position.

Note 2.— Some of the benefits of a combined listening interval of Mode A/C-only and Mode S-only all-calls can be obtained without ghost targets by using both combined and separate listening intervals during a beam dwell. In this approach, some interrogations are combined as shown in Figure H-1, but other Mode A/C-only and Mode S-only all-call interrogations with separate listening intervals are interspersed with the combined interrogations during the beam dwell. A Mode A/C track is only initiated on replies received from Mode A/C interrogations with separate listening intervals.

1.3.4 The PI field of an all-call reply, downlink format (DF) = 11, elicited by a Mode S-only all-call interrogation (UF = 11) is encoded using the IC received in the interrogation that elicited the reply. This is composed of CL and IC fields of the all-call interrogation. This address is used in the encoding of the PI field in exactly the same manner as the transponder Mode S address is used to generate the address parity (AP) field. Ground stations operating in the multisite mode decode all-call replies using their own IC as the expected address. All-call FRUIT replies produced by adjacent ground stations will not be accepted by the local ground station since they would be encoded using a different IC. This rejection of all-call replies by the IC eliminates the possibility of extraneous all-call tracks being formed from Mode S FRUIT replies.

1.3.5 The use of all-call lockout makes it necessary for ground stations to coordinate surveillance activities in regions of overlapping coverage to ensure that all ground stations are allowed to acquire Mode S aircraft. If ground stations cannot coordinate via ground communications, the transponder multisite lockout feature is employed.

1.3.6 The multisite lockout feature is based upon the use of ICs (II and SI) and multiple transponder lockout timers. The Mode S transponder can be selectively and independently locked out to multisite all-call interrogations originating from up to 78 different ICs. Adjacent sites using different ICs are unaffected by the other sites' lockout activity and hence can perform acquisition and lockout in a

completely autonomous manner. Restrictions on interrogator operations must be taken into account.

1.3.7 Implementation of SI code capability (Annex 10, Volume IV, Chapter 2, 2.1.5.1.7.1) can be determined by monitoring bit 35 of the data link capability report (register 10₁₆). This report should be routinely extracted at track acquisition. ~~SI codes cannot be used in a region of airspace until all of the Mode S aircraft are equipped for SI codes.~~ This monitoring should continue after SI codes are put into use to identify any transponder that is not SI-capable. Follow-up action should be initiated for aircraft that are detected that are not equipped with SI codes.

~~1.3.8 The reason that all aircraft must be SI equipped is that a non SI code capable Mode S transponder will misinterpret the SI code contained in the Mode S only all call interrogation. The II or SI code included in a Mode S only all call interrogation is contained in a 7 bit field composed of the 3-bit CL field and the 4 bit IC field as follows:~~

~~CL coding (in binary):~~

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

~~1.3.9 A transponder that does not support SI codes will not detect the CL field and will therefore interpret the IC field as always containing an II code. This causes the mapping of a set of SI codes into an II code. For example, ICs of II = 1 and SI = 1, 17, 33 and 49 will all have “0001” in the IC field. If an aircraft not equipped for SI codes is operating in a region of overlapping coverage of interrogators with II = 1 and SI = 17, the following interaction will occur:~~

- ~~a) if the aircraft is acquired first by the II = 1 interrogator, the aircraft will be locked out to II = 1. An all call interrogation from the SI interrogator expressing SI = 17 will not elicit an all call reply because the transponder interprets the code as II = 1, and it is locked out to II = 1; and~~
- ~~b) if the aircraft is acquired first by the SI interrogator, the transponder will reply to the SI = 17 all call interrogation since it is not locked out to II = 1. The SI interrogator will not be able to lock out the transponder, since the mechanism for II and SI code lockout is entirely different. Therefore, the transponder will not recognize the SI lockout command (and will not change its lockout status to any II code).~~

~~1.3.10 Thus, with a transponder not equipped with SI code capability, there will never be a loss of surveillance coverage for an interrogator with an II code. Surveillance loss can only happen to the SI code interrogator and then only for a certain combination of II and SI codes.~~

1.3.11 The transition to SI codes is manageable through monitoring compliance to the SI code requirement via the data link capability report and (where possible for fixed interrogators) assigning II and SI codes for adjacent interrogators to avoid possible interaction. It is possible to assign more than one SI code to an interrogator on a sector basis. This approach might be useful as another means to avoid interacting SI and II codes. For mobile interrogators, or for fixed interrogators where non-interacting SI and II codes cannot be used, a low rate of lockout override Mode S-only all-call interrogations by the SI code interrogator can be used to acquire the occasional non-SI code Mode S transponder. Another means for managing this situation is for the interrogators operating with II codes to periodically remove lockout for non-SI equipped Mode S transponders to ensure acquisition by SI interrogators.

SURVEILLANCE MANUAL (DOC 9924) – APPENDIX J

Mode S II and Mode S SI code assignment planning

8. PLANNING CRITERIA FOR THE COORDINATION OF SSR MODE S INTERROGATOR IDENTIFIER (II) AND SURVEILLANCE IDENTIFIER (SI) CODES

8.1 Introduction

8.1.1 Applicability of planning criteria

8.1.1.1 Mode S surveillance operation requires that both the SSR Mode S ground station and the SSR Mode S equipped aircraft are capable of identifying each other. The aircraft is identified in this process by its 24-bit aircraft address, which is transmitted by the transponder. The SSR Mode S ground station (interrogator) is identified by its interrogator code, Interrogator Code (IC), which can either be an II code (Interrogator Identifier) or an SI code (Surveillance Identifier).

8.1.1.2 Four bits are available for 16 different II codes are available for Mode S II interrogators. II code 0 requires special handling and is does not further addressed here (see Annex 10 Volume IV, Chapter 3, 3.1.2.5.2.1.2.3). participate in the Mode S code assignment activity in this chapter. This leaves II codes 1-15 for assignment to fixed-Mode S II code ground stations with overlapping coverage. In some regions, certain II codes have been reserved for specific purposes and are not available for general assignment. For aircraft complying with the provisions of Annex 10, Volume IV, Amendment 73 (or later), an additional 63 codes known as SI codes can be used, which adds significant complexity when assigning and operating SI codes. Full use of these codes requires that all Mode S transponders in these regions are equipped with these provisions from Annex 10 (Mode S II/SI capable transponders). In regions where Mode S interrogators are planned to operate with SI codes, and where not all Mode S transponders comply with these provisions, special measure can be taken to allow, during the transition phase, for the continued operation of Mode S transponders that do not comply with the provisions from Annex 10 as per Amendment 73 or later (Mode S II-only transponders). This adds significant complexity when assigning and operating SI codes and also reduces significantly the efficiency in Mode S assignment planning during the transition phase.

8.1.1.3 This complexity results from the fact that SI codes are a later addition to the ICAO SARPs for SSR Mode S transponders (1998) and the use of SI codes is basically not compatible with Mode S II transponders that do not comply with these SARPs. Currently, many Mode S interrogators and transponders that are in operation do may not have SI code capability. Therefore, it cannot be assumed that all transponders in any region of airspace are 100 per cent equipped to handle both SI and II codes, even if in areas where a mandate exists.

8.1.1.4 Aircraft without SI code capability operating in designated II and/or SI code airspace require special handling to ensure that they can be placed in surveillance by all covering Mode S interrogators. The level of complexity necessary to provide reliable service to aircraft which are not equipped with SI code capability is beyond the scope of the planning criteria in this appendix. Therefore, this technique of SI code assignment is not further addressed here, and these planning criteria described below can only be used for assignment of II codes that are operating with Mode S SI codes. This can be achieved by configuring the Mode S SI interrogator to accept the all-call reply from a Mode S II-only transponder on the “matching” II code as is clarified in Appendix H.

Note. For more information on the assignment and management of SI codes, see ICAO EUR Doc 024 – IC Allocation for the European Region and Eurocontrol IC Planning Tool.

8.1.2 Selective interrogation of Mode S aircraft

8.1.1.5 Interrogator Codes are a scarce resource. Before implementing Mode S interrogators, it is necessary to coordinate the assignment of the required interrogator codes with *all* users operating Mode S in the same Region or area. This requires the establishment of a regional coordination process to assign Interrogator Codes. The Regional coordination of interrogator code assignments is managed by the Regional Offices of ICAO. Regional agreements need to be in place to facilitate the coordination of the assignment of interrogator codes. The coordination of Mode S interrogator code assignments between regions in case where the coverage of an interrogator overlaps into an adjacent region is also performed by ICAO the Regional Offices.

8.1.2 Acquisition and selective interrogations of Mode S aircraft

8.1.2.1 In order to selectively interrogate a Mode S-equipped aircraft, the interrogator (SSR Mode S ground station) needs to know the aircraft's Mode S 24-bit aircraft address and its approximate position. To acquire the address and position of a Mode S-equipped aircraft, the interrogator transmits all-call interrogations. A Mode S equipped aircraft will respond to such interrogations with its unique 24-bit aircraft address. Once the response from the aircraft is recognized by the interrogator, the aircraft is acquired by the interrogator. Then Mode S-equipped aircraft should be locked out from replying (instructed not to respond) to subsequent Mode S all-call interrogations using the same II or SI code in order to minimize all call synchronous garbling. This lockout condition is controlled by the Mode S interrogator through Mode S selectively addressed interrogations. Acquisition can also be accomplished by provision of the address and position through other means (e.g., clustering of interrogators, which is described in 8.3.3 of this appendix).

8.1.2.2 ~~The~~ One of the conditions for a valid reply is that the aircraft is within the designated operational range of the SSR Mode S interrogator. This is the range within which the interrogator accepts all-call replies from aircraft ~~or generates selective interrogations to~~ and acquires them. Then the aircraft is selectively interrogated in the surveillance coverage of the Mode S interrogator and locked out on the IC of the Mode S interrogator in the lockout coverage ~~aircraft~~. When the aircraft is outside the designated operational range of the SSR Mode S interrogator, while the aircraft may receive (and respond to) all-calls from this interrogator the interrogator does not accept all-call replies received from the aircraft transponder to all-call interrogations. ~~In addition, the~~ interrogator will also no longer ~~generate request lock-out in selective interrogations to the~~ “acquired” aircraft that have left the ~~designated operational range~~ lockout coverage, in which case, after 18 seconds, the aircraft will no longer be locked out for all-call interrogations from this interrogator. The interrogator will also no longer generate selective interrogations to the “acquired” aircraft that have left the surveillance coverage. ~~In both cases, the aircraft may receive (and respond to) all-calls from this interrogator, but the responses will not be accepted by this interrogator (SSR Mode S ground station).~~

8.1.2.3 Once the ~~response~~ reply from the aircraft is received by the interrogator and the aircraft is within the designated operational range of the interrogator, the aircraft will be added to the interrogator's list of acquired aircraft — the aircraft is in an “acquired” state. The designated operational range is programmed into the SSR interrogator and is promulgated by the State responsible for the SSR Mode S ground station.

8.1.2.4 Once the aircraft is in the acquired state (i.e. it has been added to the interrogator's list of aircraft, of which the 24-bit aircraft address has been acquired), the aircraft is instructed to no longer respond to (or be “locked-out” from) Mode S all-calls on the interrogator code used by ~~from~~ that particular ground station, in order to minimize all-call synchronous garbling. This is achieved when the aircraft receives Mode S selectively addressed interrogations that contain an instruction to the on-board SSR Mode S transponder not to respond to Mode S all-call interrogations from that interrogator.

8.1.2.5 ~~When an aircraft is within the designated operational range of two (or more) Mode S ground stations, it must be acquired and locked out (from all call interrogations) by each Mode S ground station. This is known as multisite acquisition and multisite lockout. Measures need to be taken to avoid aircraft, within the designated operational range of more than one SSR Mode S interrogator (the SSR Mode S~~

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ground stations have overlapping coverage), receiving interrogations from interrogators with the same interrogator identifier. This is achieved by ensuring that Mode S interrogators with the overlapping designated operational range have been assigned different interrogator identifiers or are coordinated for ground communications (see 8.3.3 of this appendix). The assignment of interrogator identifier codes is subject to regional coordination.

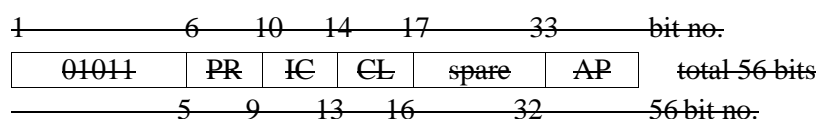
8.1.2.5 When an aircraft is within the designated operational coverage of a Mode S ground station, it must be acquired and locked out (from all-call interrogations) on the interrogator code in use by the Mode S ground station. This is known as multisite acquisition and multisite lockout. The designated operational coverage of a Mode S ground station shall be protected from interference that can be created by other Mode S ground stations having overlapping coverage and operating on the same IC. This is achieved by avoiding that two (or more) Mode S ground stations are applying lockout in the overlapping coverage on the same IC (or “matching” II code). This achievement can be performed by ensuring that Mode S ground station with the overlapping designated operational coverage have been assigned different IC (II or SI code) (and, as necessary, different II or SI codes with the same encoding in the II or IC field as described in section 8.2.6 below) or, alternatively, are coordinated for ground communications (see 8.3.3 of this Appendix). This achievement can also be performed by reducing the designated operational coverage of the Mode S ground station operating on the same IC to ensure there is no overlap of their designated operational coverage (lockout coverage). In certain circumstances, it may be necessary that no lockout is applied by any radar operating on the same IC in a given area. For example, when the designated operational coverages of two radars are overlapping, it may be required not to reduce the designated operational coverage, but to configure smaller lockout coverage to avoid lockout coverage overlapping on the same IC (or “matching” II code). For this purpose, the lockout coverage may be defined separately from the definition of designated operational coverage. When the capability to program different coverage for surveillance and lockout is supported by Mode S radar, the IC allocation can use this capability to perform allocation optimisation. In this case the surveillance coverage corresponds to the designated operational coverage.

8.2 Interrogator Identifier and Surveillance Identifier

8.2.1 Mode S II-only capable interrogators and transponders⁷ (See also Figure J-15/1 and J-16/1)

8.2.1.1 The interrogator identifier (II) is a four-digit code (0 – 15) which is transmitted by the SSR Mode S ground station when transmitting a Mode S-only all-call (or a Mode S II selective) interrogation. The II code serves the purpose of identifying the SSR Mode S ground station. When the aircraft is operating in an area where two (or more) SSR Mode S ground stations have overlapping coverage, different II codes are required to ensure that all SSR Mode S ground stations can provide surveillance on to the aircraft independent from each other. In special cases, overlapping SSR Mode S ground stations may share the same II code (see 8.3.3 of this appendix Appendix).

8.2.2 A Mode S only all call interrogation elicits replies only from Mode S transponders. The (uplink) format of the Mode S only all call is shown in Figure J-15. (See Annex 10, Volume IV, Chapter 3, 3.1.2.5.2.1):



⁷ Mode S II only interrogators and transponders comply with the provisions of Annex 10, Volume IV, up to and including Amendment 71

Figure J-15. Uplink format 11

8.2.2.1 This message contains the following information:

Bit 1-5 01011 (uplink format; decimal value 11):

—— If the uplink format is 01011 (decimal value 11), the content of bits 6-56 is as described below:

Bit 6-9 PR (probability of reply); this information is not further addressed here.

Bit 10-13 IC (interrogator code):

—— These four bits contain the interrogator identifier (0-15) or the last four bits of the surveillance identifier (SI).

Bit 14-16 CL (code label):

—— If CL = 000, the information in the IC field is the interrogator identifier.

—— If CL = 001 to 100 (decimal value 1 to 4), the information in the IC field contains the last four bits of the surveillance identifier.

Bit 33-56 AP (address/parity):

—— For a Mode S only all call, the address consists of 24 one's, on which the parity is overlaid.

8.2.3 A Mode S only all call reply from the aircraft, in which the II (or SI) is encoded in the PI field, has the format shown in Figure J-16. (See Annex 10, Volume IV, Chapter 3, 3.1.2.5.2.2):

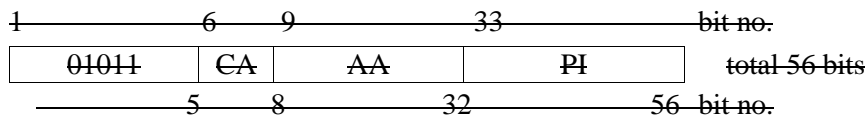


Figure J-16. Downlink format 11

8.2.3.1 This message contains the following information:

Bit 1-5 01011 (downlink format; decimal value 11)

—— If the downlink format is 01011 (decimal value 11), the content of bits 6-56 is as described below:

Bit 6-8 CA (capability)

—— An encoded definition of the communications capability of the transponder.

Bit 9-32 AA (address announced)

—— 24 bit aircraft address.

Bit 33-56 PI (parity/interrogator identifier):

—— Interrogator identifier code (II or SI), on which the parity is overlaid.

—— *Note. The interrogator identifier is the same as that received by the aircraft in the all call message as described in 8.2.1 of this appendix.*

8.2.4 Following the Mode S only all call reply, the ground station will send a selective interrogation, which uses the format shown in Figure J-17 or Figure J-18. (See Annex 10, Volume IV, Chapter 3,

3.1.2.6.1 to 3.1.2.6.4):

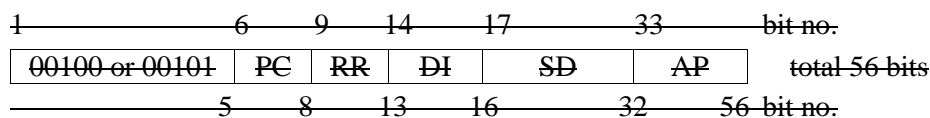


Figure J-17. Uplink formats 4 and 5

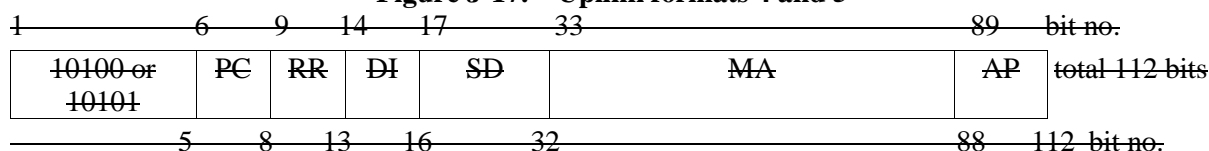


Figure J-18. Uplink format 20 and 21

8.2.4.1 This message contains the following information:

Bit 1-5 00100, 00101, 10100 or 10101 (Uplink Format; decimal value 4, 5, 20 or 21)

----- If the uplink format of the selective interrogation is 00100 (decimal value 4), the selective interrogation is a surveillance interrogation altitude request.

----- If the uplink format of the selective interrogation is 00101 (decimal value 5), the selective interrogation is a surveillance interrogation identity request.

----- If the uplink format of the selective interrogation is 10101 (decimal value 20), the selective interrogation is a Comm A interrogation altitude request.

----- If the uplink format of the selective interrogation is 10101 (decimal value 21), the selective interrogation is a Comm A interrogation identity (Mode A) request.

After obtaining the range, the azimuth and the 24 bit Mode S address from the all call reply, a Mode S interrogator will start selective Mode S surveillance (of the aircraft) using the uplink format 4 (UF=4) interrogation to obtain a surveillance update of the altitude of the aircraft at every scan. At track initiation, the interrogator will also send an interrogation with the uplink format 5 (UF=5) to obtain the aircraft Mode A code. The interrogator does not need to continuously read out the Mode A code since changes in the Mode A code are indicated in the flight status field of a Mode S reply with the downlink format DF=4, 5, 20 or 21.

Bit 6-8 PC (protocol)

----- If PC=1, the transponder shall lock out to II=0 (non-selective lockout).

Bit 9-13 RR (reply request); command the length and content of a requested reply.

Bit 14-16 DI (designator identification).

The designator identification identifies the structure of the SD field. (See Annex 10, Volume IV, Chapter 3, 3.1.2.6.1.3 for details)

Bit 17-32 SD (Special Designator)

Contains a number of control codes, specific to SSR, including the interrogator identifier

~~code of the interrogator and the lockout subfield (LOS) bit that commands multisite lockout (See Annex 10, Volume IV, Chapter 3, 3.1.2.6.1.4 for details).~~

~~Bit 33-56 — AP (address/parity) — Uplink Formats 4 and 5 only:~~

~~24 bit aircraft address of the aircraft which is selectively interrogated and on which the parity is overlaid.~~

~~Bit 33-88 — MA (message; Comm. A) — Uplink format 20 and 21 only:~~

~~The MA field contains a data link message to the aircraft.~~

~~Bit 88-112 — AP (address/parity) — Uplink format 20 and 21 only:~~

~~24 bit aircraft address of the aircraft which is selectively interrogated and on which the parity is overlaid.~~

~~8.2.5. The aircraft responds as requested by the selective interrogation. The process of selective interrogation and replies continues until the aircraft is outside the designated operational range of the SSR interrogator. As long as the aircraft receives the selective interrogations with LOS=1, it is locked out to all calls from that interrogator.~~

8.2.2 Mode S II/SI capable interrogators and transponders⁸ (See also Figure J-15/2 and J-16/2)

8.2.2.1 The surveillance Identifier is a four-bit code in the IC field of the All-Call message from a Mode S II/SI capable interrogator in conjunction with the three-bit code in the CL field that is set from binary code 001 – 100. This combination generates 63 SI codes as described in Appendix H, paragraph 1.2. Similar to the compatibility of Mode S II codes as described in 8.2.1.1, when the aircraft is operating in an area where two (or more) Mode S II/SI capable ground stations are operating with SI codes and overlapping coverage, different SI codes are required to ensure that all SSR Mode S SI interrogators can provide surveillance service to aircraft *which are equipped with Mode S II/SI capable transponders*. (See also Figure J-15/2)

Note: This situation assumes that all aircraft are equipped with Mode S II/SI capable transponders.

8.2.3 Mixed environment with Mode S II-only and II/SI capable interrogators and transponders.

8.2.3.1 Of special concern is the case where in a region a transition of Mode S II-only equipment to Mode S II/SI equipment is taking place and both Mode S II-only and Mode S II/SI capable interrogators and transponders are in use.

8.2.3.2 Using the II/SI code operation technique as is described in Appendix H Paragraphs 1.2.6, 1.2.7, 1.2.8, 1.2.9 and 1.2.10, the Mode S SI interrogator that supports the use of II/SI code operation can be configured to accept the reply from the Mode S II-only capable transponder on the “matching” II code (the Mode S II-only capable transponder is not able to decode the content of the CL field in the all-call interrogations) using only the four-bit code in the IC field. In this case, the Mode S SI interrogator will either not lockout the Mode S II-only transponder or use intermittent lockout on the “matching” II code, to enable its acquisition by other Mode S interrogators (supporting the use of II/SI code operation) with overlapping coverage and operating with other SI or II codes with a matching code in the IC field.

8.2.4 The format of the Mode S All-Call messages and the relevant reply from the transponder is in the figures below:

⁸ Mode S II/SI capable interrogators and transponders comply with the provisions of Annex 10, Volume IV, including Amendment 73

8.2.4.1 **All-Call interrogations.** – A Mode S-only all-call interrogation elicits replies only from Mode S transponders. The (uplink) format of the Mode S- II-only all-call and the Mode S II/SI all-call is shown in Figure J-15/1 and J-15/2

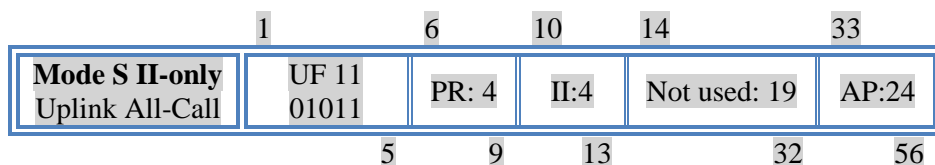


Figure J-15/1 Mode S All-Call structure for Mode S II-only all-call (Uplink format 11)

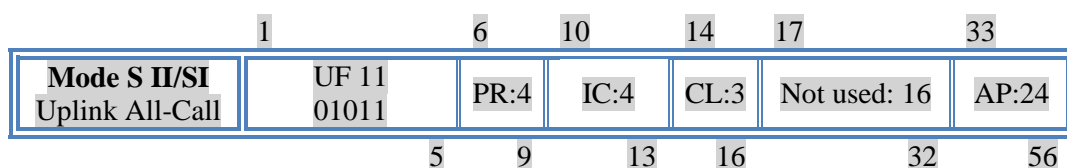


Figure J-15/2 Mode S All-Call structure for Mode S II/SI all-call (Uplink format 11)

8.2.5 **All-Call replies.** A Mode S-only all-call reply from the aircraft, in which the II (or SI) is encoded in the PI field, has the format shown in Figure J-16/1 and J-16/2

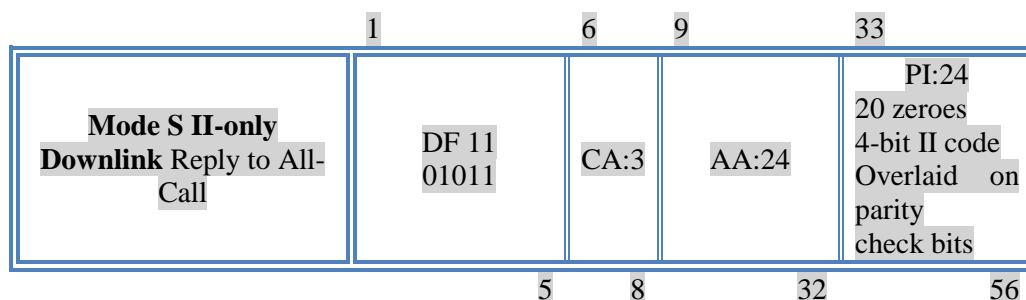


Figure J-16/1 All-Call reply from Mode S II-only transponder, downlink format 11

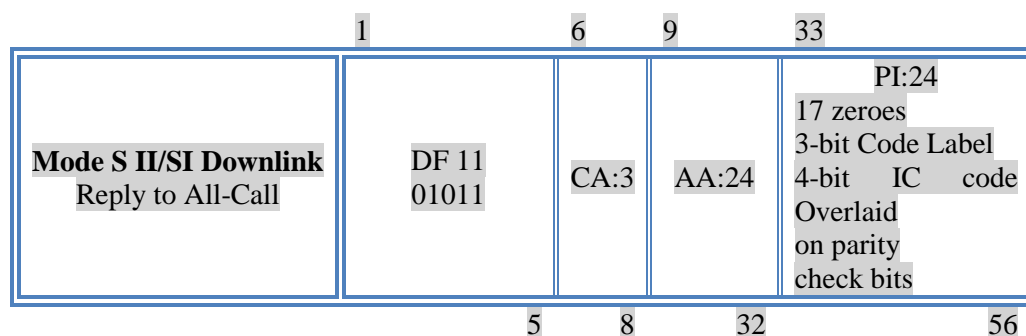


Figure J-16/2 All-Call reply from Mode S II/SI transponder, downlink format 11

8.2.5.1 In these messages:

UF: Uplink format. This uplink format field is the uplink format descriptor in Mode S interrogations and is encoded to 01011 (decimal 11) for all-call interrogations.

DF: Downlink format. This downlink format field is the downlink format descriptor in Mode S replies and is encoded to 01011 (decimal 11) for all-call replies.

AP: Address/parity. This 24-bit uplink field contains parity overlaid on the 24-bit aircraft address.

PI: Parity/interrogator identifier. This 24-bit downlink field contains the parity overlaid on the interrogator's identity code (IC). This field includes:

- For a Mode S II-only transponder: 20 zeroes and the four-bit interrogator identifier
- For a Mode S II/SI capable interrogator 17 zeroes, the three-bit Code Label (CL) and the four-bit Interrogator Code (IC) from the All-Call message

8.2.6 Mode S II code or Mode S SI code assignment planning criteria.

8.2.6.1. Mode S II-only interrogators

8.2.6.1.1 The interrogator must be assigned an II code as SI codes are not supported.

8.2.6.1.2 When the interrogator is a Mode S II-only capable interrogator, no overlap of the coverage is permitted with interrogators that operate on:

- the same II code;
- the “matching” SI code as described in 8.2.6.1.3, because Mode S II-only transponders will be locked on the II code, preventing their acquisition by Mode S interrogators operating on SI codes.

8.2.6.1.3A “matching” SI code is a code where the binary format in the IC field of the SI code is the same as the binary format in the II field/IC field of the II code. Each Mode S II code has four “matching” SI codes. More information is in Doc. 9924, Appendix H, paragraph 1.2.3

Note 1: this requirement is independent to the configuration of the transponder which may be a Mode S II-only transponder or a Mode S II/SI capable transponder.

Note 2: where practicable, it is recommended to limit the II codes assigned to Mode S II-only interrogators to a small set of II codes in order to optimize the IC allocation.

8.2.6.1.4 States need to inform ICAO if the interrogator is Mode S II-only capable.

8.2.6.2. Mode S II/SI capable interrogators that do not support the use of II/SI code operation.

8.2.6.2.1 The interrogator has to be assigned an II code until all of the Mode S aircraft in the airspace are equipped with II/SI capable transponder because the interrogator is not able to acquire Mode S II-only transponders when operating on SI code.

8.2.6.2.2 When the interrogator is a Mode S II/SI capable interrogators that do not support the use of II/SI code operation and is operating on II code, no overlap of the coverage is permitted with interrogators that operate on:

- the same II code
- the “matching” SI code, because Mode S II-only transponders will be locked on the II code, preventing their acquisition by Mode S interrogators operating on SI codes.

Note 1: it is recommended to regroup all Mode S II/SI capable interrogators that do not support the use of II/SI code operation on the same II codes to optimize the IC allocation.

8.2.6.2.3 States need to inform ICAO if the interrogator is Mode S II/SI capable and does not support the use of II/SI code operation.

8.2.6.3. Mode S II/SI capable interrogators supporting the use of II/SI code operation and operating on II code.

8.2.6.3.1 The interrogators need to be configured to not use lockout or use intermittent lockout for the Mode S II-only transponders, i.e. for transponders which report no SI capability in their datalink

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capability report (BDS 10) or cannot report their datalink capability (BDS 10).

8.2.6.3.2 When the interrogator is correctly configured, no overlap of the coverage is permitted with interrogators that operate on the same II code only.

8.2.6.3.3 When the interrogator is correctly configured, Mode S II-only transponders are not locked-out or are intermittently locked-out on the “matching” II code. Therefore they can be acquired by Mode S interrogators supporting the use of II/SI code operation and operating on “matching” SI codes.

Note 1: information on the II/SI code operation techniques that can be used is in Appendix H, paragraph 1.2.6, 1.2.7, 1.2.8, 1.2.9 and 1.2.10.

Note 2: the interrogator relies on the content of Bit 35 of Register 10₁₆ to determine if the aircraft is equipped with a Mode S II-only transponder. If incorrect capability is reported, i.e. Mode S II-only transponder reporting that it supports SI code in Bit 35, the Mode S II-only transponder will be locked on the II code and will not be acquired by Mode S interrogators operating on “matching” SI codes.

8.2.6.3.4 States need to inform ICAO if the interrogator is Mode S II/SI capable and supports the use of II/SI code operation.

8.2.6.4. Mode S II/SI capable interrogators supporting the use of II/SI code operation and operating on SI code.

8.2.6.4.1 Modes S II/SI capable interrogators supporting the use of II/SI code operation and operating with a Mode S SI code that are required to operate with Mode S II-only transponders need to be configured to:

- accept Mode S II-only all call replies from the transponders with the “matching” II code AND
- not lockout (or intermittent lockout) the Mode S II-only transponders

8.2.6.4.2 When the interrogator is a Mode S II/SI capable interrogator supporting the use of II/SI code operation, no overlap of the coverage is permitted with interrogators that operate on:

- the “matching” II code, except if the interrogator on II code supports the II/SI code operation and is correctly configured to not lockout (or intermittent lockout) Mode S II-only transponders on the II code or
- the same SI code

Note 1: These interrogators cannot have overlapping coverage with Mode S II-only interrogators and with Mode S II/SI capable interrogators that do not support the use of II/SI code operation, operating with the same “matching” II code.

Note 2: information on the II/SI code operation techniques that can be used is in Appendix H, paragraph 1.2.6, 1.2.7, 1.2.8, 1.2.9 and 1.2.10.

Note 3: when a Mode S II-only transponder receives an all-call interrogation from a Mode S interrogator operating on SI code, it will reply to the all-call interrogation on the “matching” II code. The interrogator relies on the interrogator code contained in the all-call replies to determine if an aircraft is equipped with a Mode S II-only transponder.

Note 4: when starting operation on SI codes, it is not recommended to allocate Mode S interrogator with the “matching” II code. It is recommended to remove all Mode S interrogators from an II code (and re-allocate them on another II code) prior to allocate the four “matching” SI codes to Mode S

II/SI capable interrogators supporting the use of II/SI code operation.

8.2.6.4.3 States need to inform ICAO if the interrogator is Mode S II/SI capable and supports the use of II/SI code operation.

8.2.6.4 Coverage.

8.2.6.4.1 The allocated coverage map (surveillance, lockout and datalink) programmed in a Mode S interrogator can be defined in different formats as explained in Section 3.5 and 7.4 of Appendix J.

8.2.6.4.2 The designated operational coverage of the SSR Mode S interrogator is as promulgated by States (in the format Range (NM) and Altitude (ft)). Typically, for an upper height of 45000 ft, the operational range is in the order of 250 NM. This can be achieved because of the typical design of Mode S interrogator and transponder transmit power, receiver sensitivity and antenna pattern.

Note: Shorter operational ranges can also be programmed in Mode S radar (e.g. around 100NM for Mode S interrogators used on Airport)

8.2.6.4.2 For Mode S II or SI code assignment planning, it is necessary to ensure that the lockout coverages of two or Mode S radars operating on the same IC do not overlap to avoid IC conflicts.

8.2.6.4.3 In order to allow a Mode S transponder to cancel the lockout status due to an adjacent interrogator operating on the same Mode S (II or SI) code, a buffer zone of 10 NM is to be incorporated in Mode S code assignment planning. This buffer zone shall not be overlapping with the DOC of the adjacent (undesired) interrogator. The range (DOC + 10 NM) only plays a determined role in Mode S interrogator code assignment planning, is not incorporated in the ICAO tables with Mode S interrogator code assignments.

Note: the IC allocation coordination process applied to allocate coverage map (including the lockout coverage) to a Mode S interrogator may differ in different ICAO regions.

8.2.6.5. Mode S II code congestion.

8.2.6.5.1 In areas where a large number of Mode S interrogators are Mode S II-only interrogators, a shortage of assignable II codes may become apparent. In this case, the best way to provide for (and make use of) the additional Mode S SI codes is to introduce Mode S II/SI capable interrogators supporting the II/SI code operation.

8.2.6.5.1.1 Such transition would require Mode S II-only interrogators to be modified into (or replaced with) Mode S II/SI capable interrogators supporting the II/SI code operation.

8.2.6.5.1.2 Other options are stochastic (sectorized) lockout override, sectorized intermittent lockout or no lockout of Mode S II-only transponders. With regard to the option of using stochastic lockout override, this will result in unnecessary increase of all-call replies since it also overrides the lockout of II/SI capable transponders. This option increases potential garbling. This method is not recommended and should only be used in extreme cases where no alternative Mode S II or SI code can be assigned. In order to minimize the RF pollution generated by stochastic lockout override while keeping a minimum of replies to allow acquisition of aircraft within a beam dwell, the Mode S-only all-call interrogation rate shall be limited. The rate can be limited according to the requirements mentioned in ICAO Annex 10 Volume IV (3.1.2.5.2.1.4.1).

8.2.6.5.2 In order to see such transition being implemented efficiently, such transition must take place prior to all Mode S II codes being used. Careful attention must be given to any overlap of the coverage with that of Mode S II-only interrogators.

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Note : when starting operation on SI codes, it is recommended to remove all Mode S interrogators from an II code (and re-allocate them on another II code) prior to allocate the four “matching” SI codes to Mode S II/SI capable interrogators supporting the use of II/SI code operation.

8.2.6.5.3 Additional information on the transition to Mode S SI codes is also include in Doc. 9924, Appendix H, paragraph 1.3.11.

8.2.6.6. Assignable II/SI codes.

8.2.6.6.1 The assignable Mode S II or Mode S SI codes are:

- II codes 1 – 15
- SI codes 1 – 63

Note: in order to support the Mode S SI code assignment planning, States must inform ICAO:

- If the interrogator is II-only capable or II/SI capable, and whether the II/SI capable interrogator is supporting the II/SI code operation.
- If the interrogator is operating with Mode S II-only transponders (i.e., mixed II/SI transponder operations)
- If the interrogator has been configured to accept replies from Mode S II-only transponders and to intermittently locks out these transponders, or not lock them out.

8.3 Coordination of Mode S II codes of adjacent SSR Mode S interrogators (ground stations) and SI codes

Note: The examples below apply equally to the assignment of SI codes or matching II/SI codes

8.3.1 Coordination of the SSR Mode S interrogator identifier codes is required when adjacent Mode S ground stations have overlapping designated operational coverage. ~~Coordination~~ Such coordination normally is required between adjacent States and ~~regions~~ adjacent Regions. The example described below illustrates the process of aircraft becoming (selectively) interrogated by SSR Mode S ground stations when travelling through the designated operational coverage areas of these facilities. The example also clarifies the effect of the interrogator identifier codes in this process.

8.3.2 In Figure J-19, an aircraft travelling from A to B will respond to interrogations of SSR Mode S ground stations (interrogators) P and R as follows:

- a) When the aircraft is outside the designated operational coverage of the interrogator P, but is within the (radio) range (point A) where it can receive all-call interrogations, the aircraft transponder will generate an all-call reply. This reply includes the II code of interrogator P and the 24-bit aircraft address. However, as long as the aircraft is outside the designated operational coverage of interrogator P, it will not accept this reply.
- b) When the aircraft enters the designated operational coverage of interrogator P (point B), the all-call reply from the aircraft transponder will be accepted by interrogator P and a selective interrogation (see 8.2.4 of this appendix) commanding lockout to II=1 will be sent to the aircraft (when the aircraft enters the lockout coverage of the interrogator P). The aircraft will be added to the list of “acquired aircraft” that is maintained by interrogator P.

Upon reception of this (and any further) selective interrogation commanding lockout, the aircraft transponder will not respond to further all-call interrogations from interrogator P (and all-call interrogations from other interrogators that have the same interrogator identifier code = 1).

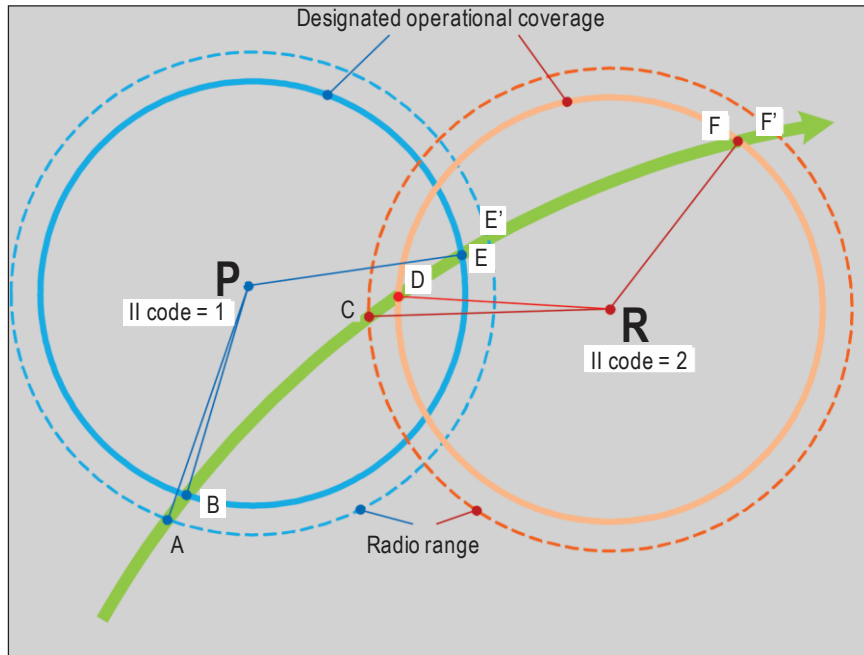


Figure J-19. Process for II (or SI) code acquisition and lockout

- c) When the aircraft is outside the designated operational coverage of the interrogator R, but is within the (radio) range (point C) where it can receive all-call interrogations from interrogator R, the aircraft transponder will generate an all-call reply only when the II code of interrogator R is different from the II code of interrogator P. This reply includes the 24-bit aircraft address. However, as long as the aircraft is outside the designated operational coverage of interrogator R, the interrogator will not accept this reply.

Note.— If the II code of interrogators P and R are the same, the aircraft will not respond to all-call interrogations of interrogator R.

- d) When the aircraft enters the designated operational coverage of interrogator R (point D), the all-call reply from the aircraft transponder will be accepted by interrogator R and a selective interrogation will be sent to the aircraft commanding lockout to II=2 (when the aircraft enters the designated coverage of the interrogator R). The aircraft will be added to the list of “acquired aircraft” that is maintained by the interrogator R. Upon reception of this (and any further) selective interrogation containing a lockout command for II=2, the aircraft transponder will not respond to further all-call interrogations from interrogator R. The aircraft is now “acquired” by two SSR Mode S ground stations and selectively interrogated independently by each interrogator.

Note.— If the II code of interrogators P and R are the same, the aircraft will not respond to all-call interrogations of interrogator R and as a result the aircraft will not be identified by interrogator R until it has left the operational coverage (lockout coverage) of interrogator P.

- e) When the aircraft is outside the designated operational coverage of interrogator P (point E), interrogator P will no longer selectively interrogate the aircraft. After a period of 18 seconds the aircraft will lose its lockout status with respect to interrogator P (II=1). Although the aircraft will respond to all-calls from interrogator P, as long as the aircraft is within the radio range of interrogator P (until point E'), these replies are not accepted by interrogator P. The aircraft is now only under surveillance by interrogator R.

Note.— If the II code of interrogators P and R are the same, the aircraft will start responding to all-call interrogations of interrogator R 18 seconds after it has left the designated operational coverage (lockout coverage) of interrogator P and no longer receives selective interrogations from this interrogator.

- f) When the aircraft is outside the designated operational coverage of interrogator R (point F), the interrogator will no longer selectively interrogate the aircraft. After a period of 18 seconds, the aircraft will lose its lockout status with respect to interrogator R (II=2). Although the aircraft will respond to all-calls from interrogator R as long as it is within the radio range of interrogator R (until point F'), these replies are not accepted by interrogator R. The aircraft is now no longer under surveillance by any interrogator.

8.3.3 Clustering of interrogators (ground station networking)

8.3.3.1 SSR Mode S interrogators can share the same interrogator identifier code in cases where the ground stations are networked and share their tables of acquired aircraft (and in particular the 24-bit aircraft address and the approximate location of the acquired aircraft). In this case, both interrogators P and R in Figure 4 send selective interrogations to the aircraft and obtain valid responses. This process will allow for the use of the same interrogator identifier code by two (or more) interrogators with overlapping coverage areas. This method is called “clustering”; the group of cooperating ground stations is a “cluster”. Two techniques for managing a cluster have been developed:

- a) *Distributed clustering* — A “distributed” cluster of interrogators contains a defined number of interrogators which are interconnected. Using coverage maps, each interrogator knows the designated operational range of all other interrogators within its own coverage. Based on this knowledge, tracking support is given to or requested from other interrogators of the cluster.
- b) *Central clustering* — A “central” cluster of interrogators is basically the same as a “distributed” cluster, but a cluster controller takes care of supplying the interrogators with needed tracking support and node states. Central clustering has been proved to be more powerful, with higher safety capabilities compared to distributed clustering because of:
- permanent availability and consistency check of the complete air situation;
 - possibility of also using non-clustered sensors for tracking support;
 - efficient and safe central cluster control capabilities, e.g. use of alternative cluster states on command, enabling, for example, reaction in case of IC conflicts; and
 - efficient validation and verification possibilities.

8.3.3.2 The operation of a cluster is illustrated in Figure J-20. At point “D”, interrogator “R” gets tracking support containing the Mode S address, position and speed vector of the aircraft at a defined time. This defined time is also included within the tracking support. Taking this information, interrogator “R” can calculate when the antenna beam is over the aircraft the next time. Therefore, it is possible to use a selective interrogation directly without having received any all-call reply from that aircraft. The tracking support message can be sent either by:

- interrogator “P” (distributed clustering), or by

- a cluster controller (central clustering).

8.3.3.3 In terms of RF channel load optimization, it is very advantageous to allocate the same interrogator H-code to adjacent non-overlapping radars, since this reduces the FRUIT in the area between the designated operational range and the radio range.

Note.— For additional recommendations and statement of benefits of clustering, see Appendix J, 4.4.4, Appendix M, 1.10, and Appendix M, 12.2.1.

8.3.4 Techniques for managing overlapping coverage

8.3.4.1 Using multiple interrogator codes by a single Mode S ground station.

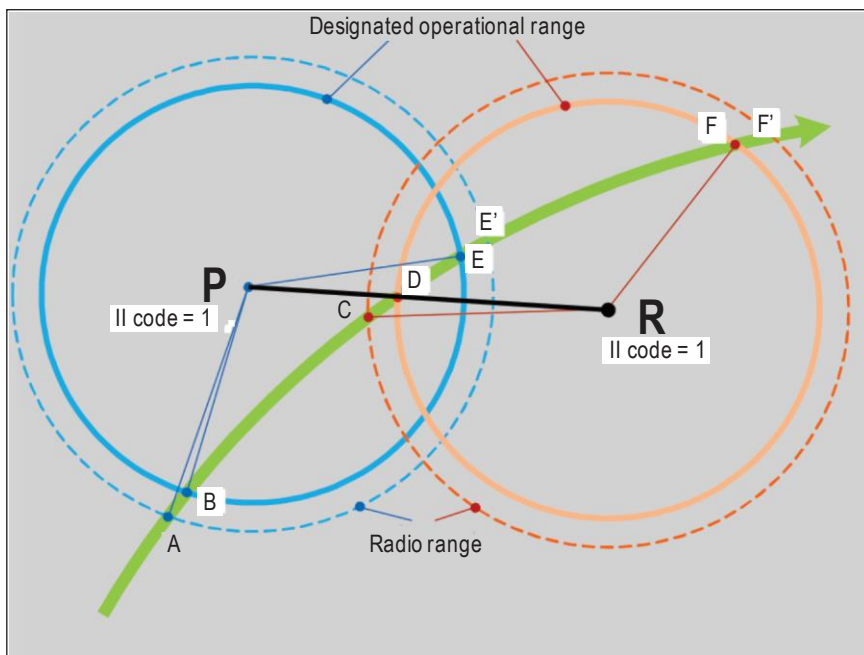


Figure J-20. SSR Mode S interrogator clustering (interrogators with same H interrogator code)

8.3.4.1.1 Another method for improving the efficient use of H-interrogator codes is using two (or more) interrogator H codes by a single interrogator. In this method, different sectors of the interrogator can be assigned different interrogator H codes. The sector that overlaps with another interrogator will have a different interrogator H code, while the parts of the coverage not overlapping can have the same interrogator H code. However, it is recommended to use the minimum possible number of interrogation identifiers codes by one single Mode S ground station. Figure J-21 gives an example of sectorized use of H-interrogator codes.

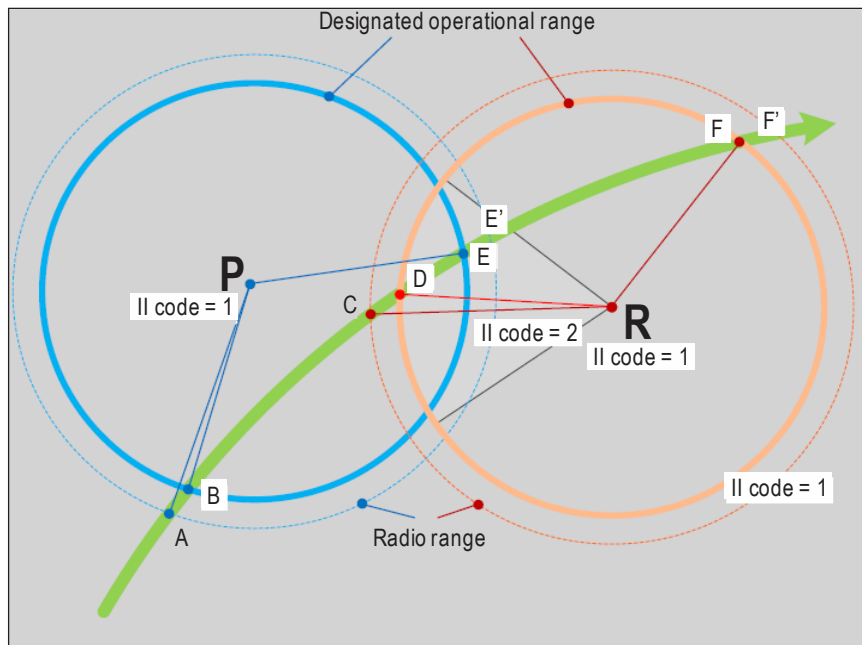


Figure J-21. Sectorized use of II codes

8.3.4.2 Define the maximum designated operational range on a sector basis.

8.3.4.2.1 In some cases, adjacent SSR Mode S ground stations may have limited overlapping coverage areas. In this case, it is possible to use the same interrogator H code for both ground stations if the designated operational range of one or both of the ground stations is reduced in the sector of the overlap. The net effect of the range reduction is to eliminate the overlap. Figure J-22 gives an example of the use of sectorized range reduction to eliminate overlap. This range reduction can also be achieved using a coverage map defining a common grid. In this case, the process consists of specifying an interrogator H-code for a given area in which this interrogator H code can be used for lockout.

8.3.5 The above examples illustrate the need for SSR Mode S ground stations, which have overlapping coverage, to be assigned a unique Mode S H interrogator code, except in the case where SSR Mode S ground stations are clustered, as described in 8.3.3 of this appendix Appendix.

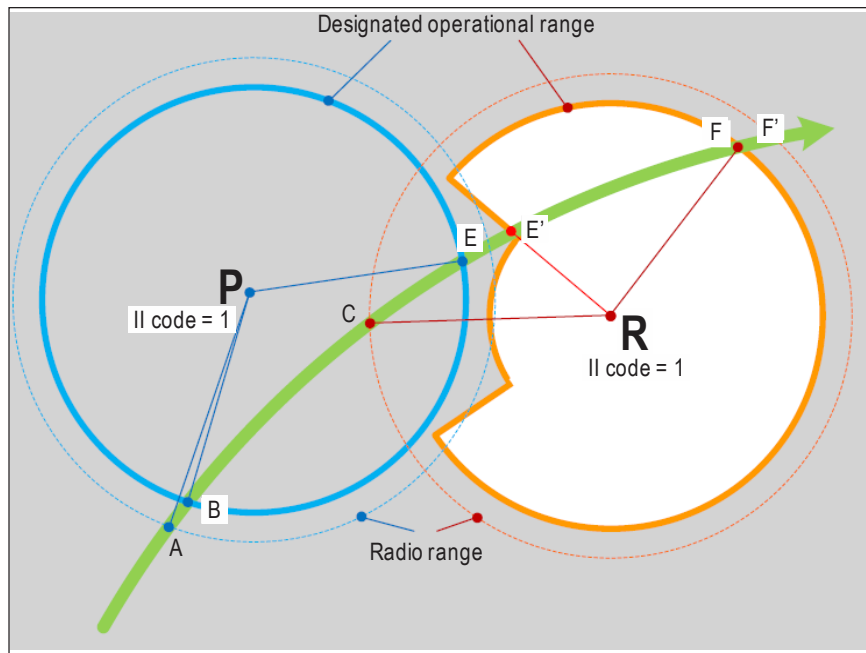


Figure J-22. Sectorized maximum range

8.4 Practical examples of interrogator identifier-code assignments

8.4.1 Figure J-23 provides an example of assigned interrogator identifier-codes for Mode S interrogators with overlapping coverage areas. In the areas of overlap, the aircraft responds to all-call interrogations and selective interrogations from more than one ground station, as indicated.

8.5 Planning parameters for SSR Mode S ground stations

8.5.1 All SSR Mode S interrogators have a maximum operational range within which surveillance service will be offered to aircraft. This maximum range is determined by operational considerations and is referred to as designated operational range (DOR). This DOR can be simply defined by a range valid for all azimuths, by different ranges for different azimuth sectors or by a more complex coverage map indicating where the ground station will selectively interrogate and lock out aircraft. When the aircraft is within the radio range of the interrogator, but outside the designated operational range, the aircraft will reply to all-call interrogations from the interrogator. These replies will not be accepted by the interrogator after it has determined that the aircraft is outside the designated operational range.

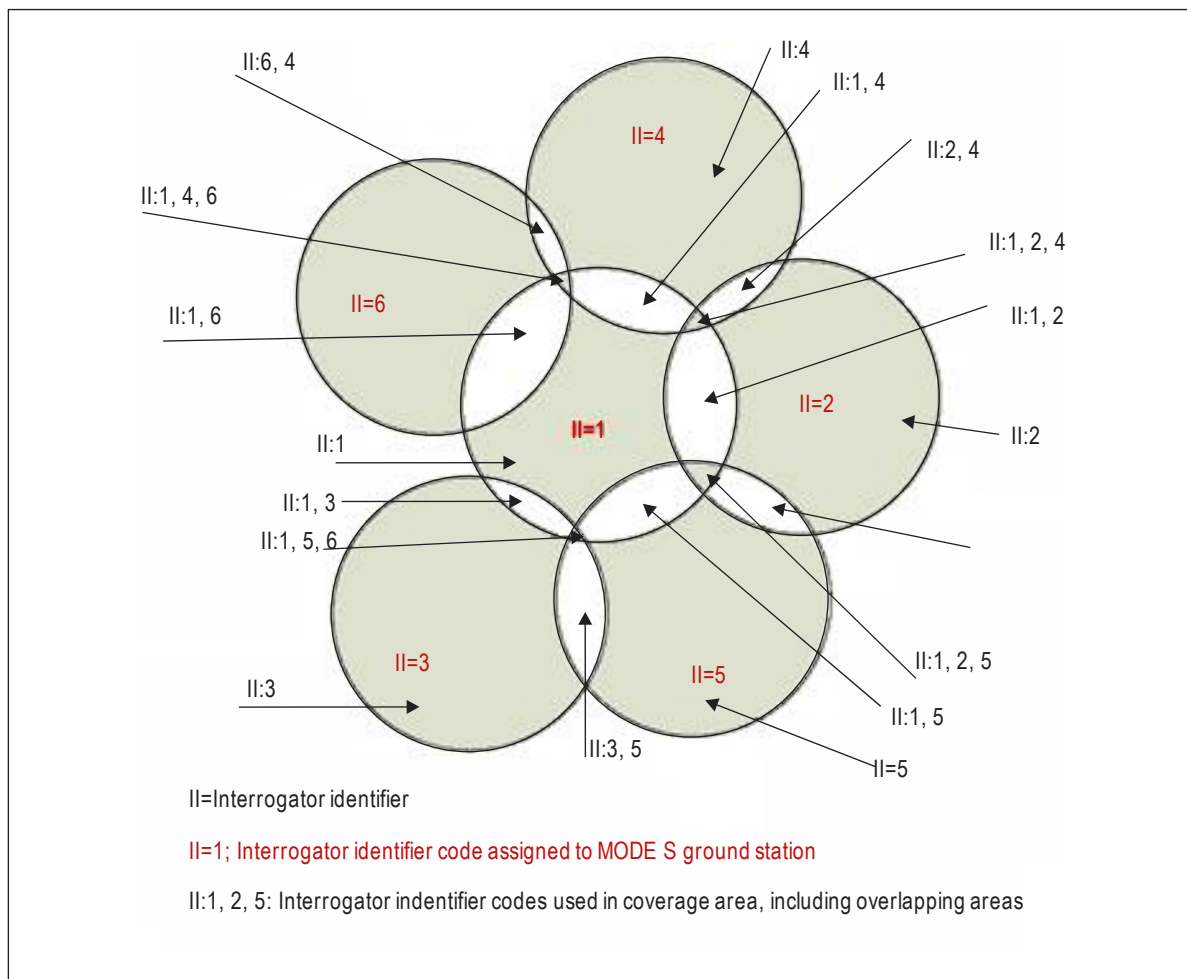


Figure J-23. Example of II code assignments

8.5.2 SSR Mode S ground stations with the same II code

8.5.2.1 As shown in Figure J-24, the minimum geographical separation between two SSR Mode S interrogators, which have been assigned the same II code, is the sum of the respective designated operational range for each interrogator, plus a buffer zone. The buffer zone should be large enough to enable the aircraft to time out of its lockout status for all-call interrogations, plus a margin that would cater for certain processing delays. The aircraft transponder cancels its lockout status for all-call interrogations if, for a period of 18 seconds, no selective interrogation with a lockout command has been received. For an aircraft travelling at a speed of 600 NM/hr, this would be equal to 3 NM. For example, a buffer of 10 NM is adequate to ensure that an incoming aircraft will be unlocked when it enters the operational coverage area of the next interrogator.

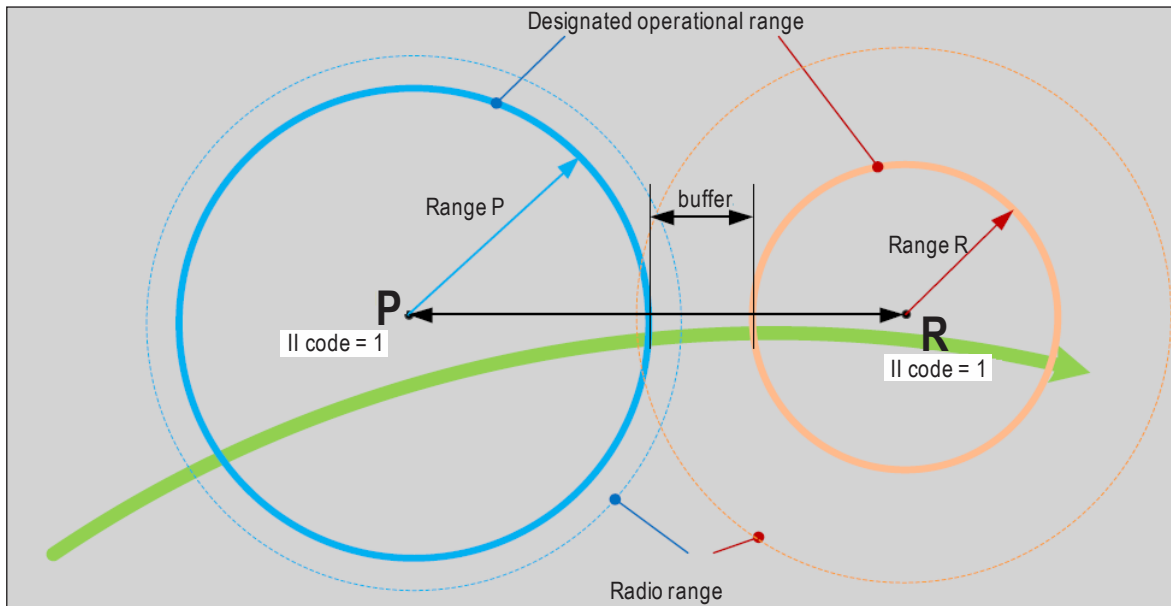


Figure J-24. Minimum separation distance between interrogators having the same II code

8.5.2.2 The minimum separation distance between two SSR Mode S interrogators with the same **Interrogator** code as shown in Figure J-24 is:

$$\text{Range P} + 10 \text{ NM} + \text{range R}$$

8.5.3 Mode S ground stations with different **interrogator H** codes

8.5.3.1 When SSR Mode S ground stations have different **Interrogator** codes, no separation criteria between the Mode S ground stations needs to be applied.