International Civil Aviation Organization

Sixth Meeting of the Surveillance Implementation Coordination Group (SURICG/6)

Video Teleconference, 24 – 27 August 2021

Agenda Item 3: Review Report of DAPs WG/4 Meeting

STATUS ON THE UPDATES TO THE SI/II CODES ASSIGNMENT CRITERIA IN DOC 9924

(Presented by China, Japan, Singapore and the Secretariat)

SUMMARY

It is recognised that Doc 9924 does not contain sufficient guidance material in order to help the APAC region to plan the implementation of II and SI mixed environment. A small working party comprising of representatives from China, Japan, Singapore and ICAO hence attempted to improve the Doc 9924 and to provide the necessary guidance material.

This paper provides an update on the status thus far.

1 Introduction

1.1 At the DAPs/WG/4 meeting (29 – 32 March 2021) it was noted that due to a higher density of Mode S radar, a shortage of Mode S II codes is experienced and a transition from Mode S II codes to Mode S SI codes is necessary in some States or areas. The draft conclusion DAPs WG/4/4 was agreed.

<table>
<tr><td colspan="3">Draft Conclusion DAPs WG/4/4 - Transition from II code to II and SI mixed code</td></tr>
<tr><td colspan="2">What: States with Mode S radar capable of performing II/SI mode operations are encouraged to transit from II code to II and SI mixed code, so as to ease the shortage of II codes. States planning to perform the transition shall coordinate with ICAO APAC Regional Office to obtain the SI codes.</td><td>Expected impact:
☐ Political / Global
☐ Inter-regional
☒ Economic
☐ Environmental
☒ Ops/Technical</td></tr>
<tr><td>Why: Due to higher density of radars, some states are facing a shortage of IC codes, which has to be solved by transiting from II to II and SI mixed code. It is noted that radars using II and SI codes can co-exist, hence there is no need for a big bang approach. However, States still have to coordinate with ICAO APAC Regional Office on the allocation of SI codes.</td><td colspan="2">Follow-up: ☐Required from States</td></tr>
<tr><td>When: 31-Mar-21</td><td colspan="2">Status: To be adopted by PIRG</td></tr>
</table>

Who: ☐Sub groups ☐APAC States ☒ICAO APAC RO ☐ICAO HQ ☒Other: SURICG

1.2 For SI codes to be deployed on the interrogators, the transponder population must be SI code capable, basically. This is because non-SI code capable transponders will misinterpret the SI code in the interrogation message (i.e. read only the last 4 bits), resulting in either misdetection or unintentional lock out depending on the settings. However, there are non-SI code capable transponders still in operations.

1.3 Appendix H of Doc 9924 offered workarounds using "matching" II code whereby SI interrogators can be configured to detect both SI and non-SI capable transponders. But there will be mis-detections of non-SI transponders when coverages of interrogators with "matching" codes overlap on normal operation (e.g. either last 4 bit of SI code of an interrogator matches that of the II code of another interrogator). To avoid the mis-detections in the workarounds, SI interrogators operate without lockout (or with intermittent lockout) to non-SI capable transponders and II only interrogators operate without lockout (or with intermittent lockout) to transponders that do not report the SI capability in the overlapping coverages.

1.4 When transponders are interrogated without lockout, there is a concern that signal interference may occur frequently due to an increase in all-call reply signals. If SI and II codes are properly assigned in the overlap coverages, all transponders can be locked-out in the workarounds. However, quite a bit of precise SI and II code planning must be done in order to implement a mixed environment of SI and II transponders. Therefore, it is considered useful to develop materials for assigning SI and II codes accurately in the mixed environment.

1.5 The DAPs/WG/4 meeting noted that the Surveillance Manual (Doc 9924) does not provide material on the Mode S code assignment planning in areas where a mixture of SI and II codes is planned. The DAPS/WG/4 meeting agreed that it would be necessary to prepare some guidance material on the assignment planning for Mode S SI codes for incorporation in Doc. 9924. Such material should consider the need for a smooth transition from Mode S II code assignments to Mode S SI code assignment planning. The DAPs/WG4 meeting agreed to the following action item:

Propose to Surveillance Panel on the addition of SI code allocation criteria in a mixed II and SI mode into Doc 9924

1.6 It was the intention at DAPs WG/4 that such material would be better placed in Doc 9924 with the view to achieve global harmonization of these criteria. A small working party, which included participation from China, Japan, and Singapore, was established to support the Secretariat with this action item.

2 Material that was developed by the working party for review by Surveillance Panel

2.1 A proposal was submitted to the Surveillance Panel-Aeronautical Surveillance Working Group (SP-ASWG) on 12-14 April 2021 to initiate the review of the Doc 9924 on the portion of II and SI code allocation.

2.2 Subsequently, the working party generated two papers addressing elements to be considered when introducing SI code assignments in the APAC Region, considering that during the transition phase not all aircraft may be equipped with SI capable transponders. These papers are attached

in **Appendix A** and **Appendix B** and were presented at the Aeronautical Surveillance Working Group-Technical Subgroup (ASWG-TSG).

2.3 First paper (ASWG-TSG WP/13-26R1), in **Appendix A** of this paper, addresses the interactions between SSR Mode S interrogators and transponders. This paper clarifies the conditions with which non-SI capable transponders can operate with SI interrogators.

2.3.1 The paper was developed with the intention to better clarify the material in Doc 9924, Appendix H and in particular the sections on Multisite acquisition and lockout and on acquisition and lockout techniques. (Sections 1.2 and 1.3),

2.4 The second paper (ASWG-TSG WP/13-27R1), in **Appendix B** of this paper, addresses the assignment planning criteria for II and SI code for the interrogators. Currently, Doc 9924 only provided the planning criteria for the coordination of Mode S II codes in section 8 of Appendix J of Doc 9924.

2.4.1 The paper explains in detail how the Mode S II/SI codes should be planned and coordinated, considering the capability of the transponder to operate with II codes only or also with SI codes. This paper also includes specific material that may be used to enhance the relevant material in the relevant portions of Doc. 9924.

2.5 The ASWG-TSG agreed to include the technical material that was presented in these papers. There were however several comments made on the constructive aspect, which will be reviewed at the next meeting of the ASWG-TSG (first quarter 2022).

3 Proposal

3.1 It was established that there is a shortage of II codes in the APAC Region and its urgent to start using SI codes.

3.2 In order to progress the development of assignment planning material for the mix environment of II and SI codes, it is proposed that the DAPs WG continue work on this matter in parallel with the Surveillance Panel. This work should be based on the relevant material in Doc 9924 with the view to improve current guidance in the Appendices H and J of Doc 9924 and be based on the material developed to date within the context of the DAPs activities.

3.3 In coordination with the Secretary of the Surveillance Panel, the results of this work may be presented to the Surveillance Panel as draft updates to Doc 9924.

4 Action by the meeting

4.1 The meeting is invited to:

a) note the progress of the works done on the II/SI code assignment planning criteria at both the Surveillance Panel level and the DAPs WG level; and

b) discuss any relevant matters as appropriate.

ASWG TSG WP13-26R1
14 June 2021

International Civil Aviation Organization

WORKING PAPER

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO)
SURVEILLANCE PANEL (SP)

AERONAUTICAL SURVEILLANCE WORKING GROUP (ASWG)
TECHNICAL SUBGROUP MEETING 13

Virtual Meeting, 14-June through 25-June 2021

Interactions between SSR Mode S interrogators and SSR Mode S transponders

(Prepared by **Robert Witzen, Chen Yang** and **Wee Sin Ho**)
(Presented by **Wee Sin Ho**)

SUMMARY

The material in this working paper was originally developed in response of the work of the APAC – DAPs[1] working group to support SSR Mode S II /SI code assignment planning when introducing in this Region the use of Mode S SI code interrogators and transponders.
This requires a common understanding of the interactions between SSR Mode S interrogators and transponders, including those that comply with the provisions of Annex 10 in force prior to 1998 and after 1998.
Within the APAC Region it was agreed to present this material to the Surveillance Panel (SP) as an initial step to develop guidance material to be included in the Aeronautical Surveillance Manual (Doc 9924) on Mode S II code assignment planning. This would support global implementation of these planning criteria.
This working paper presents an overview of the [technical] interactions between SSR Mode S interrogators and transponders.

Note. - The material in this WP was prepared in response to Action Item ASWG/13-33.

Action by the meeting is in paragraph 9

[1] DAPs is the APAC Downlinked Aircraft Parameters Working Group of APANPIRG

1. Introduction

1.1 This paper describes the interactions between SSR Mode S interrogators and transponders that comply with the relevant provisions in Annex 10, Volume IV, up to and including amendment 71, 1996, referenced in this paper as Amdt-71 Mode S II interrogators and Amdt-71 Mode-S II transponders as well as with interrogators and transponders that comply with the relevant provisions in Annex 10, Volume IV, including Amendment 73 (1998) and later amendments, referenced in this paper as Amdt-90 Mode S II or Amdt-90 mode S SI interrogators and Amdt-90 Mode S II/SI transponders.

Note 1: While SSR Mode S interrogators can operate as stand-alone interrogators (i.e., as Amdt-71 Mode S II interrogator, Amdt-90 Mode S II interrogator or Amdt-90 Mode S SI interrogator), the transponders in use are either a (stand-alone) Amdt-71 Mode S II transponder or a Amdt-90 Mode S II/SI transponder which combines the capability of responding to Mode S II as well as to Mode S SI codes.

Note 2: Technical specifications for Amdt-71 Mode S II transponders are also included in the RTCA Specifications as per RTCA Doc 181A and for Amdt-90 transponders in RTCA Doc 181F (Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment)

1.2 In the following sections the interactions between Amdt-71 interrogators and transponders as well as Amdt-90 interrogators and transponders are discussed as per Figure 1.

1.3 When the Mode II/SI capable transponder is interrogated by a Mode S II interrogator the reply is a message relevant to the Mode S II interrogation. When the Mode S II/SI capable transponder interrogated by a Mode S SI interrogator, the reply is a message relevant to the Mode S SI interrogation. When the Mode S II only capable transponder is interrogated by the Mode S SI interrogator, the reply is in the format of a Mode S II reply.

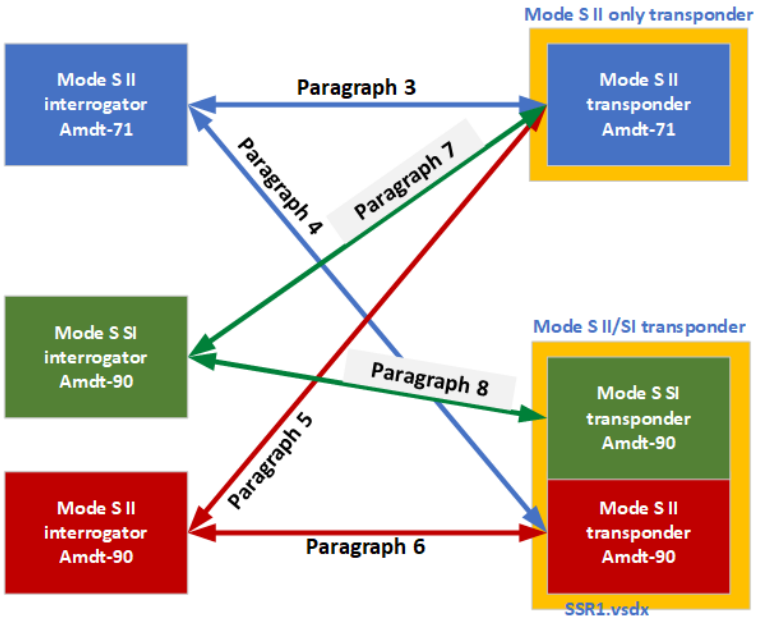


Figure 1 – Interactions between Amdt-71 interrogators and transponders and Amdt-90 interrogators and transponders

2. Sequence of Mode S messages.

2.1 The Mode S interrogator sends regularly an All-Call message, that includes the Mode S II code or the Mode S SI code.

2.2 The transponder (aircraft) replies to the All-Call message from the interrogator which includes the 24-bit aircraft address and the Mode S II code or the Mode S SI code.

2.3 Upon the reception (and validation) of the Mode S II or the Mode S SI code in the reply from the transponder, the interrogator acquires the 24-bit aircraft address and sends an addressed message to the transponder that will lock-out the transponder to prevent this transponder to respond to further All-Calls from the interrogator.

Note: Further interrogations from the interrogator will be addressed to this specific aircraft/transponder

2.4 The transponder can lose the lock-out status if after a period of 18 seconds no addressed message with a lockout command has been received from the interrogator.

Note: When the transponder has lost the lockout status for the Mode S II or the Mode S SI code, it will respond to All-Calls for this Mode S II or Mode S SI code.

2.5 The transponder can interact with different (interrogators) which have different Mode S II or Mode S SI codes simultaneously (multi-site operation).

Note: This requires interrogators with the same Mode S II or Mode S SI code to not have overlapping coverage. This has been described in the Aeronautical Surveillance Manual, Doc.9924, Appendix J paragraph 8.3.

2.6 With monopulse azimuth measurement, the azimuth of the target (aircraft/transponder) relative to the location of the interrogator can be assessed on a single pulse from any transponder reply. The time between the interrogation from the interrogator (e.g., the All-Call or Roll-CALL) and the reply from the transponder/aircraft is applied to determine the slant-range of the target from the interrogator. This provides for the capability to offer acquisition or surveillance for the aircraft

3. Mode S II interrogator (Amdt-71) and Mode S II transponder (Amdt-71).

3.1 SSR Mode S II Amdt-71 interrogator sends with a Mode S All-Call with uplink format 11 the following message (total 56 bits):

UF11 (01011)	PR (4 bits)	IC (II, 4 bits)	(19 bits)	AP (24 bits)
		Set to 0 - 15	Set to “zeroes”	Address is set to 24 “ones”

Note: The 24-bit address/parity field (AP) contains the address (set to 24 “ones”) overlaid on (summed bit-by-bit modulo 2) with 24 parity check bits generated on the preceding 32 bits of the transmission.

3.2. The Mode S Amdt-71 transponder notices the 4-bit II code (Interrogator Identifier) in the field IC (II) as a valid II code. The Mode S Amdt-71 transponder sends the following reply (download format 11; 56 bits) in response to the All-Call message:

DF11 (01011)	CA (3 bits)	AA: (24 bits)	PI (24 bits)
		24-bit aircraft address	The first 20 bits are zero, last four bits are the II code (0 – 15)

Note: PI is Parity / Identifier

Note: The 24-bit Parity / Identifier field contains the 20 "zeroes" and the 4-bit II code overlaid (summed bit-by-bit modulo 2) with 24 parity check bits generated from the preceding 32 bits of the transmission.

Note: The Amdt-71 interrogator does not include the three bits in the CL field, which were introduced in 1998 (See paragraph 5 below).

3.2.1 In this reply message the field AA (Address Announced) contains the 24-bit aircraft address which provides unambiguous identification of the aircraft. The field PI Parity/Interrogator Identifier) contains the parity of the first 32 bits overlaid on the interrogator's identity (II) code and appears in the Mode S all-call reply, DF = 11. The code used in the PI field is formed by a sequence of 24 bits *(a1, a2, . . . a24*, where the first 20 bits are ZEROS and the last four bits are a replica of the 4-bit interrogator identifier (II) field.

3.2.1.1 The 24-bit aircraft address in the downlink message permits the Mode S II interrogator to acquire the aircraft. The Mode S II code in PI field of the downlink message permits the interrogator to recognize (validate) the downlink message as a valid response to the All-Call.

3.2.2 Once the specific address of the aircraft has been acquired by the interrogator, the aircraft is interrogated by the interrogator with discretely addressed interrogations and locked out to reply to further All-Call from this interrogator (or from any All-Calls with the same II code). All-Call lockout protocols shall be used to inhibit further replies of this aircraft to All-Calls from the interrogator.

Note: The same principles / techniques are used with all replies to an All-Call interrogation

4. Mode S II interrogator (Amdt-71) and Mode S II transponder (Amdt-90).

4.1 SSR Mode S II Amdt-71 interrogators send with a Mode S All-Call with uplink format 11 the following message (total 56 bits):

UF11 (01011)	PR (4 bits)	IC (II, 4 bits)	(19 bits)	AP (24 bits)
		Set to 0 - 15	Set to "zeroes"	Address is set to 24 "ones" Parity for the first 32 bit is overlaid

4.2. The Mode S Amdt-90 transponder notices the 4-bit II code in the field IC (II) and sees "000" in the CL field (it is not the code "001", "010", "011" or "100" in CL field that is mentioned in ICAO ANNEX 10 Volume IV 2014). In this case the Amdt-90 transponder will find 3 "zeroes" in the CL field. Note that the Amdt-71 interrogator include the 3 "zeroes" in bits that are reserved for the CL field for the Amdt-90 transponder in the uplink message from the Amdt-71 interrogator.

Note: The 24-bit address/parity field contains the address (set to 24 "ones") overlaid on (summed bit-by-bit modulo 2) with 24 parity check bits generated from the preceding 32 bits of the transmission.

4.3 The Mode S Amdt-90 transponder sends the following reply (download format 11; 56 bits) in response to the All-Call message from the Amdt-71 interrogator:

DF11 (01011)	CA (3 bits)	AA: (24 bits)	PI (24 bits)
		24-bit aircraft address	First 17 bits are zero, next three bits from the "CL" field has 3 "zeroes" and the last four bits are the II code (0 – 15)

Note: The 24-bit address/parity field (PI) contains 17 "zeroes", the CL field with three "zeroes" and the 4-bits Mode S II code overlaid on (summed bit-by-bit modulo 2) with 24 parity check bits generated on the preceding 32 bits of the transmission. This is essentially the same encoding as for the reply from a Amdt-71 transponder.

4.3.1 In this reply message, the field PI includes a replica of the Mode S II code that was sent with the uplink All-Call (UF 11) from the Amdt-71 interrogator.

4.4 The 24-bit aircraft address in the downlink message permits the Amdt-71 interrogator to acquire the aircraft and the Mode S II code in the downlink message from the Amdt-90 transponder, including the 3 "zeroes" reserved for the CL field, permits the interrogator to recognize the downlink message as a valid response to the Mode S II code All-Call.

Note RW: The last three bits from the first 20 bits that are set to "zeroes" are recognized by the Amdt-90 Mode S II/SI transponder as presenting a CL field that has been set to 000. Therefore, the Amdt-90 Mode S II/SI transponder considers the All-Call as from a Mode S II interrogator.

4.5 Once the specific address of the aircraft has been acquired by the Amdt-71 Mode S II interrogator, the aircraft (with a Amdt-90 transponder) is interrogated by the interrogator with discretely addressed interrogations and locked out to reply to further All-Call from this transponder (or from any All-Calls with the same II code). All-Call lockout protocols should be used to inhibit further replies of this aircraft to All-Calls from the interrogator.

Editorial note RW: The lockout protocols for Mode S II codes are the same for Amdt-90 transponders.

4.6 As described in this paragraph, Amdt-90 Mode S transponders can operate with Mode S Amdt-71 interrogators in exactly the same way as with Amdt-71 interrogators. This provides for backwards compatibility when the (new) Amdt-90 Mode S transponders are put into operational use in areas where Amdt-71 interrogators are in use.

5. Mode S II interrogator (Amdt-90) and Mode S II transponder (Amdt-71).

5.1 SSR Mode S II Amdt-90 interrogators send with a Mode S All-Call with uplink format 11 the following message (total 56 bits):

UF11 (01011)	PR (4 bits)	IC (4 bits)	CL (3 bits)	(16 bits)	AP (24 bits)
		Interrogator Identifier (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

5.1.1. For the All-Call message from the Mode S Amdt-90 II interrogator the Code Label is "000".

5.2. The Mode S Amdt-71 transponder notices the 4-bit II code in the field IC but cannot see (or decode or process) any bit in the CL field.

Editorial note: It is assumed that in this case the Amdt-71 transponder either ignores the encoding in the CL field or assumes zeroes.

5.2.1 The Mode S Amdt-71 transponder responds to the Mode S All-Call from the Amdt-90 interrogator ignoring the CL field with the following format:

DF11 (01011)	CA (3 bits)	AA: (24 bits)	PI (24 bits)
		24 bit aircraft address	Include: first 20 bit are zero, last four bits are the II code (0 – 15)

5.2.2 In this message, the field PI includes a replica of the IC (II) code that was sent with the uplink All-Call (UF 11) but does not include the CL field. The relevant "CL" bits (#18, 19 and 20" in the PI field are set to "000".

5.2.3 The 24-bit aircraft address in the downlink message permits the Amdt-90 interrogator to acquire the aircraft. The first 20 bits in the PI field (before the parity bits were overlaid) include 3 "zeroes" (bit 18, 19 and 20) that are considered by the Amdt-90 interrogator as Code Label "000" and the II code in the downlink message from the Amdt-71 transponder and permits the interrogator to recognize the downlink message as a valid response to the Amdt-90 interrogator All-Call.

5.2.4 Once the specific address of the aircraft has been acquired by the interrogator, the aircraft is interrogated by the interrogator with discretely addressed interrogations. All-Call lockout protocols should be used to inhibit further replies of this Amdt-71 transponder to All-Calls from the Amdt-90 interrogator.

6. Mode S II interrogator (Amdt-90) and Mode S II transponder (Amdt-90).

6.1 SSR Mode S II Amdt-90 interrogators send with a Mode S All-Call with uplink format 11 the following message (total 56 bits):

UF11 (01011)	PR (4 bits)	IC (4 bits)	CL (3 bits)	(16 bits)	AP (24 bits)
		Interrogator Identifier (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

6.2 The Mode S Amdt-90 Mode S II transponder notices the 4-bit II code in the field IC *and* the Code Label "000" in the CL field. As a result, the Mode S Amdt-90 transponder replies with the following message:

DF11 (01011)	CA (3 bits)	AA: (24 bits)	PI (24 bits)
		24-bit aircraft address	First 17 bits are zero, next 3 bits (CL) are 000 and the last four bits are the II code (0 – 15)

6.3 The 24-bit aircraft address in the downlink message permits the Amdt-90 interrogator to acquire the aircraft. The first 17 bits in the PI field (before the parity bits were overlaid) are zeroes, the next three bits (the Code Label) have been set to "000" (signifying the IC code is for an II interrogation) and the last four bit represent the II code. This permits the Amdt-90 Mode S II interrogator to recognize the downlink message as a valid response to the (original) Amdt-90 interrogator All-Call.

6.4 Once the specific address of the aircraft has been acquired by the interrogator, the aircraft is interrogated by the interrogator with discretely addressed interrogations. All-Call lockout protocols should be used to inhibit further replies of this Amdt-90 transponder to All-Calls from the Amdt-90 interrogator.

7. Mode S SI interrogator (Amdt-90) and Mode S II transponder (Amdt-71).

7.1 SSR Mode S SI Amdt-90 interrogator sends with a Mode S SI All-Call with uplink format 11 the following message (total 56 bits):

UF11 (01011)	PR (4 bits)	IC (4 bits)	CL (3 bits)	(16 bits)	AP (24 bits)
		Interrogator Identifier (0 – 15)	Code Label (001 → 100 or 1 to 4 for SI codes)	Set to "zeroes"	Address is set to 24 "ones". Parity for the first 32 bit is overlaid

7.2 The Mode S Amdt-71 Mode S II transponder notices only the four-bit IC code in the field IC and *not* the Code Label in the CL field. As a result, the Mode S II Amdt-71 transponder replies with the following message:

DF11 (01011)	CA (3 bits)	AA: (24 bits)	PI (24 bits)
		24-bit aircraft address	First 20 bits are zero and the last four bits are the IC code (0 – 15). The parity for the first 32 bit is overlaid.

7.3 The 24-bit aircraft address in the downlink message permits the Amdt-90 interrogator to acquire the aircraft. The first 20 bits in the PI field (before the parity bits were overlayed) are zeroes and the last four bits represent the (an) II code. Since the reply from the Amdt-71 Mode S II transponder is not a valid SI code (because in the reply the bits 17-20 are set by the Amdt-71 transponder to "000" and do not match the CL code from the All-Call message), the interrogator cannot acquire the transponder and cannot lock this transponder out.

Note: In addition, some interrogator (Amdt-90) can be configured to capture aircraft by the "matching" II code and can (or not) lockout the aircraft by the "matching" II code operation mode.

Note: Surveillance service can be provided to this transponder/aircraft as long as this transponder is not locked out by a Mode S II interrogator that has overlapping coverage and operates with a "matching" II code.

8. Mode S SI interrogator (Amdt-90) and Mode S SI transponder (Amdt-90).

Note: Mode S SI interrogators and Mode S SI transponders always comply with the Amdt-90 SARPS.

8.1 The SSR Mode S SI Amdt-90 interrogator sends with a Mode S SI All-Call with uplink format 11 the following message (total 56 bits):

UF11 (01011)	PR (4 bits)	IC (4 bits)	CL (3 bits)	(16 bits)	AP (24 bits)
		Interrogator Identifier (0 – 15)	Code Label (001 → 100 or 1 to 4 for SI codes)	Set to "zeroes"	Address is set to 24 "ones". Parity for the first 32 bits is overlaid

8.2 The Mode S Amdt-90 Mode S SI transponder notices the 4-bit code in the field IC *and* the Code Label "001 → 100" in the CL field. As a result, the Mode S Amdt-90 transponder replies with the following message:

DF11 (01011)	CA (3 bits)	AA: (24 bits)	PI (24 bits)
		24-bit aircraft address	First 17 bits are zero, next 3 bits (CL) are "001→100" and the last four bits are the replica of the interrogator code (IC) field

8.3 The 24-bit aircraft address in the downlink message permits the Amdt-90 interrogator to acquire the aircraft. The first 17 bits in the PI field (before the parity bits were overlaid) are zeroes, the next three bits (the Code Label) has been set to replica of the field CL and the last four bits are set to the replica of the field IC (the IC and CL code together map to a SI code of the interrogator Amdt-90). This permits the Amdt-90 Mode S SI interrogator to recognize the downlink message as a valid response to the (original) Amdt-90 Mode S SI interrogator All-Call.

8.4 Once the specific address of the aircraft has been acquired by the interrogator, the aircraft is interrogated by the interrogator with discretely addressed interrogations. All-Call lockout protocols should be used to inhibit further replies of this Amdt-90 transponder to All-Calls from the Amdt-90 interrogator.

Note 1: This process is the same as described in paragraph 5

Note 2: Mode S SI interrogators can operate with other overlapping Mode S SI interrogators that have been a different SI code (either in the IC field or the CL field). In this case, the interrogator is capable to lock out the transponder on the basis of the response to the All-Call from these interrogators. (See also the Note to paragraph 6).

9 Action by the meeting

9.1 The meeting is invited

- to review the material in this paper, in particular paragraph 3 – 8
- to agree that this material should be used in response to Action Item **ASWG/13-33** for incorporation in Doc. 9924

ASWG TSG WP13-27R1
14 June 2021

International Civil Aviation Organization

WORKING PAPER

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO)
SURVEILLANCE PANEL (SP)

AERONAUTICAL SURVEILLANCE WORKING GROUP (ASWG)
TECHNICAL SUBGROUP MEETING 13

Virtual Meeting, 14-June through 25-June 2021

Assignment planning criteria for SSR Mode S II and SI code interrogators

(Prepared by **Robert Witzen, Chen Yang,** and **Wee Sin Ho**)
(Presented by **Wee Sin Ho**)

SUMMARY

This paper presents SSR Mode S assignment planning criteria that would accommodate the introduction of SSR Mode S SI codes.
With regard to the transition to using Mode S SI codes, further guidance, based on material in the Surveillance manual (Doc. 9924) is presented. This further guidance explains measure that can be taken during the transition phase as well as after the transition is completed.
For the variety of mechanisms to assess compatibility between SSR Mode S II/SI code assignments detailed considerations are presented.
Within the APAC Region it was agreed to present this material to the Surveillance Panel (SP) as an initial step to develop guidance material to be included in the Aeronautical Surveillance Manual (Doc 9924) on Mode S II code assignment planning. This would support global implementation of these planning criteria.
Note. - The material in this WP was prepared in response to Action Item ASWG/13-33.

Action by the meeting is in paragraph 9

1. Introduction

1.1. During the transition from Mode S Amdt-71[1] interrogators and transponders towards Amdt-90[2] interrogators and transponders it is necessary to consider (and protect) the use of both systems.

1.1.1 In this paper an Amdt-71 interrogator or transponder is an interrogator/transponder that complies with the provisions in Annex 10, Volume IV, up to and including Amendment 71 (1996). A Amdt-90 interrogator or transponder is and interrogator/transponder that complies with the provisions in Annex 10, Volume IV, including Amendment 73 (1998) and later.

1.2 Of particular concern is the use of Amdt-71 Mode S II interrogators with regard to (Amdt-90) Mode S SI transponders and of (Amdt-90) interrogators with Amdt-71 Mode S II only transponders (Amdt-71 non-SI capable transponder).

2. Transfer to Mode S II/SI codes

2.1 The introduction of Amdt-90 Mode S interrogators and transponders *operating exclusively* on Mode S II codes is feasible and interoperable with Amdt-71 interrogators and transponders. The only requirement is that the coverage of the Mode S II interrogator does not overlap with another interrogator operating with the same Mode S II code. However, this will not allow for increasing the possibility for adding interrogators in areas where the 15 Mode S II code assignments are congested or even saturated.

2.2 For the transition period towards the implementation of 63 Mode S SI codes, the Surveillance Manual offers the following options (Re. Doc. 9924, Appendix H):

- **Doc. 9924, App. H: 1.2.5 The following technique enables the acquisition and detection of non-SI capable transponders for the transition period.**

2.2.1 It is assumed that this technique applies to the acquisition of a Amdt-71 non-SI capable transponder.

- **Doc. 9924, App. H: 1.2.6 The interrogator, 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.**

2.2.2 While normally an interrogator operating with a Mode S SI code would discard replies from Amdt-71 Mode S II transponders, the Mode S SI interrogator must be configurable to acquire these transponders during the transition phase to full Mode S SI implementation. The “matching” II code is used for this. This means that the Mode S SI interrogator cannot overlap with other Mode S SI interrogators (or Mode S II interrogators) that are using the same “matching” II code in the field IC.

[1] Amdt-71 includes all provisions in Annex 10, up to and including Amendment 71 (1996)
[2] Amdt-90 includes all provisions in Annex 10, up to and including Amendment 90 (2018)

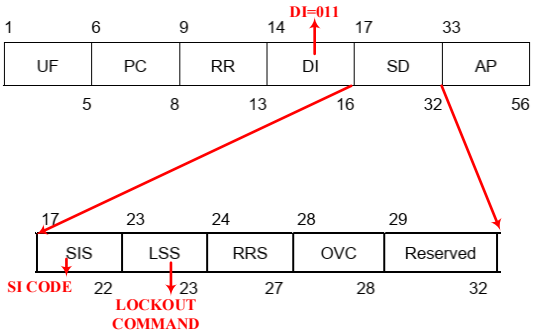
- **Doc. 9924, App H: 1.2.7 The target which has sent such replies must be considered as equipped with a non-SI capable transponder, even if the content of Register 10_{16} states that the transponder has the SI capability.**

2.2.3 The "target" is the transponder that has sent, in response to the All-Call from the Mode S SI interrogator, a reply with only the II code. This II code matches the encoding of the Mode S SI interrogator in the field "IC". It also implies that some Mode S transponders may report they are Mode S SI code capable (in Bit 35 of BDS 1, 0) whereas they are not Mode S SI capable.

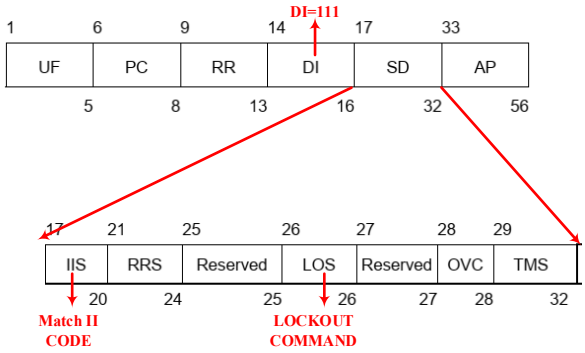
- **Doc. 9924, App. H: 1.2.8 The interrogator, if operating with a SI code, must be configurable by the user to interrogate targets equipped with non-SI capable transponders using the Mode S-selective protocols foreseen for II code operation. The II code to be used must be the "matching" II code.**

2.2.4 This technique, that is to be implemented during the transition period toward full implementation of Amdt-90 Mode S transponders allows for the acquisition and selective interrogation of a Amdt-71 transponder on the basis of the "matching" II code.

2.2.5 A Amdt-90 mode S SI interrogator will use the Roll-Call to surveillance and lockout (or intermittent lockout) the Amdt-90 mode S 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. (ICAO Annex 10 Vol.4, Ed. 2017) paragraph 3.1.2.6.1.4



2.2.6 If the Amdt-90 interrogator needs to lock-out (intermittent lock-out) the Amdt-71 transponder, the "matching" II code must be used. A Amdt-90 mode S SI interrogator can use the Roll-Call to lockout the Amdt-71 mode S transponder by setting the DI field to "111", and filling the interrogator's "matching" II code into the IIS subfield, setting the LOS subfield to "1 ".



2.3 After all interrogators and transponders comply with the provisions of Annex 10, Volume IV, including Amendment 73 and later (Amdt-90) the full implementation of both SSR Mode S II and SSR Mode S SI codes can be completed. Full benefits if the additional Mode S SI codes can be obtained.

2.3.1 With the view to detect aircraft not equipped with Mode S SI code capable transponders, the following techniques are possible:

- **Doc. 9924, App. H: 1.2.9 The interrogator, 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 operating with the "matching" II code to acquire the non-SI capable transponders.

2.3.1.1 It is assumed that the intention of the ***Note*** is to allow for *overlapping* SI interrogators (*only?*), operating with the "matching" II codes to acquire the Amdt-71 transponder.

2.3.1.2 Paragraph **1.2.9** stipulates that while the Mode S SI interrogator can selectively address the Amdt-71 transponder, this Amdt-71 transponder should not be locked out to respond to All-Calls from [overlapping] SI interrogators (or only intermittently be locked out).

2.3.1.3 This technique may allow for overlapping Mode S SI transponders to acquire Amdt-71 Mode S II [only] transponders.

- **Doc. 9924, App. H: 1.2.10 The interrogator, 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 10_{16}; or**
  b) **use intermittent lockout for Mode S transponders that do not report the SI capability in Register 10_{16}.**

Note.— This is to allow neighbouring interrogators operating with an SI code and the "matching" II code to acquire the non-SI capable transponders.

2.3.2 It is assumed that the interrogator is a Amdt-90 interrogator that operates with a Mode S II code. This interrogator can distinguish between a Mode S II code and a Mode S SI code according to the Mode S DAPs BDS 1,0 (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. This configuration would mean that Amdt-90 transponders will be locked out but Amdt-71 transponders will not be locked out so they can be acquired by an overlapping (Amdt-90) Mode S SI interrogator when operating with a "matching" II code. A Amdt-90 transponder that ls locked out by a [Amdt-90] interrogator is not locked out by any "matching" Mode S SI interrogator since this transponder can decode the field "CL" ad reply with the Mode S SI code to the Mode S SI interrogator.

- **Doc. 9924, App. H: 1.2.11 This technique 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).**

2.3.2.1 The TSG is invited to provide more information on how the technique in 1.2.9 and 1.2.11 can help in identifying a Amdt-71 Mode S II only transponder. This may be more an operational issue than a technical issue.

3. Mode S II code assignment planning

3.1 The situation as described in paragraph 2.1 is described in detail in Doc. 9924, Appendix J, section 8. In summary, all Mode S II codes can be used except in cases where the coverage of one interrogator overlaps with another interrogator and both interrogators operate with the same II code. The interrogator locks out the transponder from replying to Mode S II code All-Calls. Surveillance service is offered through selecting calling (Roll-Call) the relevant transponder.

3.2 Combination of using Amdt-71 as well as Amdt-90 interrogators and/or transponders as per paragraph 2.2.

3.2.1 Introducing of Mode S (Amdt-90) II interrogators

3.2.1.2 Introduction of Amdt-90 Mode S II code interrogators can take place as long as the coverage of the new interrogator does not overlap with any other II interrogator operating with the same Mode S II code.

3.2.1.2 Similarly, without the need for a new coordination of Mode S II codes, a Amdt-71 Mode S II code interrogator can be replaced with a Amdt-90 Mode S II code interrogator.

3.2.2 Introduction of Mode S II/SI (Amdt-90) transponders

3.2.2.1 Mode S II/SI (Amdt-90) transponders can be introduced at any time, operating with Mode S II interrogators (either as per Amdt-71 or as per Amdt-90). They can operate side-by-side with Mode S II only (Amdt-71) transponders.

3.2.3 Use of interrogators operating with Mode S SI codes.

3.2.3.1 Interrogators operating with Mode S SI codes are typically introduced when a significant part of the aircraft is equipped with transponders that have the capability to respond properly to All-Calls from the Mode S SI interrogator and will therefore be locked out to respond to All-Calls from this Mode S SI interrogator. These transponders comply with the Amdt-90 SARPs in Annex 10, Volume IV. However, the surveillance of aircraft not yet equipped with these transponders needs to be secured during the transition phase towards full implementation of interrogators and transponders operating with Amdt-90 SARPs. This places restrictions or limitations on the availability of new Mode S SI codes to be implemented.

4. Overlapping interrogators

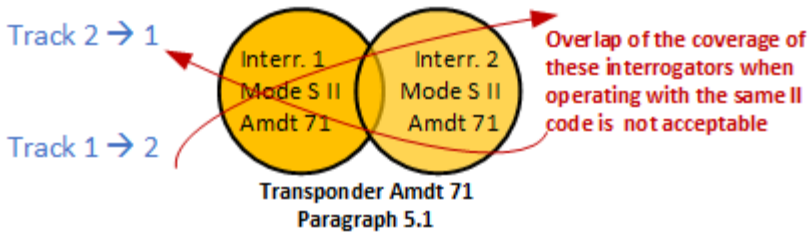
The following cases with overlapping interrogators have been reviewed for operating with Amdt-71 and Amdt-90 transponders as further detailed in paragraphs 5, 6 and 7.

5. Interrogators operate with the same II code.

Note 1: all interrogators operating with different Mode S II codes can be assigned a (different) Mode S II code while the coverage of the interrogators overlaps.

Note 2: In some cases, the planning constraints identified in this section may collapse into a common scenario

5.1 The interrogators 1 and 2 are Amdt-71 interrogators and operate with the same II code and with a Amdt-71 transponder



5.1.1 Track 1 → 2.

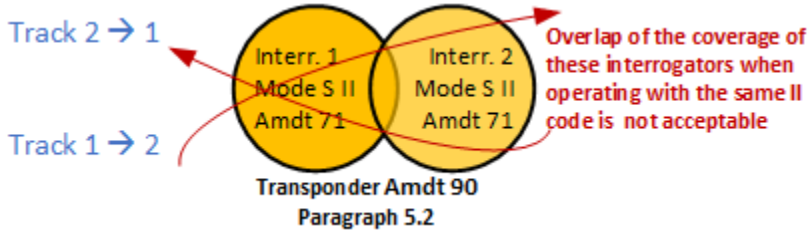
5.1.1.1 The Amdt-71 transponder is first locked out to respond to All-Calls by Mode S II interrogator 1. The Amdt-71 transponder therefore cannot reply to All-Calls from any interrogator that is operating with the same Mode S II code. When entering the area where the coverage of both interrogators overlaps, the transponder cannot reply to All-Calls from interrogator 2 and not be acquired by Interrogator 2. As a result, the aircraft (*carrying the Amdt-71 transponder)* cannot be provided with surveillance service by interrogator 2 in the area of overlapping.

5.1.2 Track 2 → 1

5.1.2.1 This also applies for track 2. When the Amdt-71 transponder is first acquired and locked out by interrogator 2 it cannot reply to All-Calls from any interrogator that is operating with the same Mode S II code. When the transponder enters the area where the coverage of both interrogators overlaps it cannot reply to All-Calls from interrogator 1. As a result, the aircraft (*carrying the Amdt-71 transponder)* cannot be provided with surveillance service by interrogator 1 in the area of overlapping.

5.1.3 **Planning criterium:** For two Amdt-71 interrogators, when operating with the same Mode S II code and a Amdt-71 transponder, the coverage needs to be separated by at least 10 NM[3]. In this scenario an overlap of the coverage of the interrogators is not acceptable

5.2 The interrogators 1 and 2 are Amdt-71 interrogators and operate with the same II code and with a Amdt-90 transponder



5.2.1 Track 1 → 2.

[3] The transponder cancels its lockout status for All-Call if, for a period of 18 seconds, no Roll-Call 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. The buffer of 10NM is adequate to ensure that an incoming aircraft will be unlocked when it enters the operational coverage area of the next interrogator with the same II code.

5.2.1.1 The Amdt-90 transponder is first locked out to respond to All-Calls by Mode S II interrogator 1. The Amdt-90 transponder therefore cannot reply to All-Calls from any interrogator that is operating with the same Mode S II code. When entering the area where the coverage of both interrogators overlaps, the transponder cannot reply to All-Calls from interrogator 2 and not be acquired by Interrogator 2. As a result, the aircraft (*carrying the Amdt-90 transponder)* cannot be provided with surveillance service by interrogator 2 in the area of overlapping.

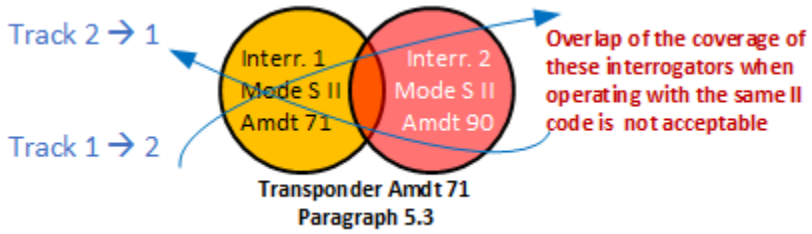
5.2.2 Track 2 → 1

5.2.2.1 This also applies for track 2. When the Amdt-90 transponder is first acquired and locked out by interrogator 2 it cannot reply to All-Calls from any interrogator that is operating with the same Mode S II code. When the transponder enters the area where the coverage of both interrogators overlaps it cannot reply to All-Calls from interrogator 1. As a result, the aircraft (*carrying the Amdt-90 transponder)* cannot be provided with surveillance service by interrogator 1 in the area of overlapping.

5.2.3 **Planning criterium:** For two Amdt-71 interrogators, when operating with the same Mode S II code and a Amdt-90 transponder, the coverage needs to be separated by at least 10 NM. In this scenario an overlap of the coverage of the interrogators is not acceptable

Note: the planning criteria in 5.1.3 and 5.2.3 provide for a seamless introduction of Amdt-90 Mode S transponders when operating with Amdt-71 interrogators operating with II codes.

5.3 Interrogator 1 is a Amdt-71 interrogator and interrogator 2 is a Amdt-90 interrogator. Both interrogators operate with the same Mode S II code and with a Amdt-71 transponder



5.3.1 Track 1 → 2.

5.3.1.1 The Amdt-71 transponder is first locked out to respond to All-Calls by the Amdt-71 Mode S II interrogator 1. The Amdt-71 transponder therefore cannot reply to All-Calls from any other interrogator that is operating with the same Mode S II code. When entering the area where the coverage of the Amdt-71 interrogator overlaps with the Amdt-90 interrogator, the Amdt-71 transponder cannot reply to All-Calls from Amdt-90 interrogator 2 and not be acquired by Interrogator 2. As a result, the aircraft (*carrying the Amdt-71 transponder)* cannot be provided with surveillance service by interrogator 2 in the area of overlapping.

5.3.2 Track 2 → 1.

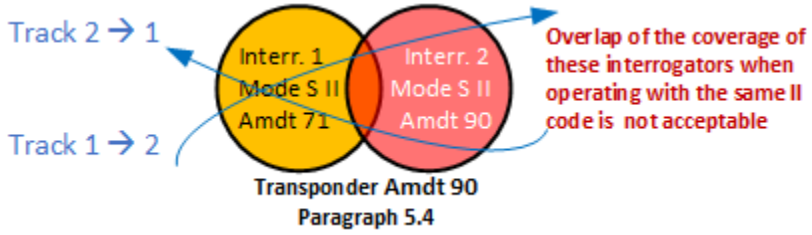
5.3.2.1 This also applies for track 2. When the Amdt-71 transponder is first acquired and locked out by the Amdt-71 interrogator 2 it cannot reply to All-Calls from any other interrogator that is operating with the same Mode S II code. When the transponder enters the area where the coverage of the Amdt-

90 interrogator overlaps with the Amdt-71 interrogator 1 it cannot reply to All-Calls from interrogator 1. As a result, the aircraft (*carrying the Amdt-71 transponder)* cannot be provided with surveillance service by interrogator 1 in the area of overlapping.

5.3.3 **Planning criterium:** For Amdt-71 interrogators as well as (nearby) Amdt-90 interrogators, when operating with the same Mode S II code and a Amdt-71 transponder, the coverage needs to be separated by at least 10 NM. In this scenario an overlap of the coverage of the interrogators is not acceptable

Note: This is the same mechanism as described in paragraph 5.1. For overlapping of Amdt-71 interrogators with Mode S SI interrogators see paragraph 6.

5.4 The interrogator 1 is a Amdt-71 interrogator and interrogator 2 is a Amdt-90 interrogator. Both interrogators operate with the same II code and with a Amdt-90 transponder



5.4.1 Track 1 → 2.

5.4.1.1 The Amdt-90 transponder is first locked out to respond to All-Calls by the Amdt-71 Mode S II interrogator 1. The Amdt-90 transponder therefore cannot reply to All-Calls from any other interrogator that is operating with the same Mode S II code. When entering the area where the coverage of Amdt-71 interrogator overlaps with the Amdt-90 interrogator 2, the transponder cannot reply to All-Calls from interrogator 2 and not be acquired by Interrogator 2. As a result, the aircraft (*carrying the Amdt-90 transponder)* cannot be provided with surveillance service by interrogator 2 in the area of overlapping.

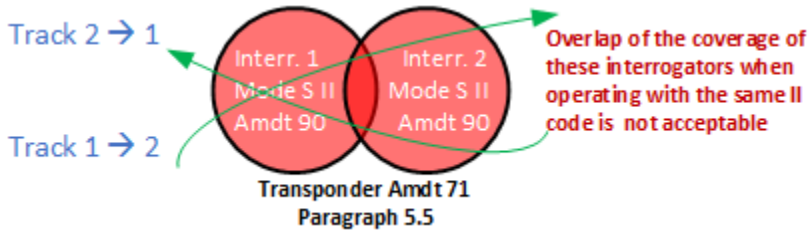
5.4.2 Track 2 → 1

5.4.2.1 This also applies for track 2. When the Amdt-90 transponder is first acquired and locked out by the Amdt-90 interrogator 2 it cannot reply to All-Calls from any interrogator that is operating with the same Mode S II code. When the transponder enters the area where the coverage of the Amdt-90 interrogator overlaps with the coverage of the Amdt-71 interrogator 1 (which is operating with the same Mode S II code) it cannot reply to All-Calls from interrogator 1. As a result, the aircraft (*carrying the Amdt-90 transponder)* cannot be provided with surveillance service by interrogator 1 in the area of overlapping.

5.4.3 **Planning criterium:** For Amdt-71 interrogators, when operating with a nearby Amdt-90 interrogator with the same Mode S II code and a Amdt-90 transponder, the coverage needs to be separated by at least 10 NM. In this scenario an overlap of the coverage of the interrogators is not acceptable

Note: the planning criteria in 5.3.3 and 5.4.3 provide for a seamless introduction of Amdt-90 Mode S interrogators when operating with Amdt-71 or Amdt-90 transponders operating with II codes.

5.5 Interrogators 1 and 2 are both Amdt-90 interrogators. Both interrogators operate with the same II code and with a Amdt-71 transponder



5.5.1 Track 1 → 2.

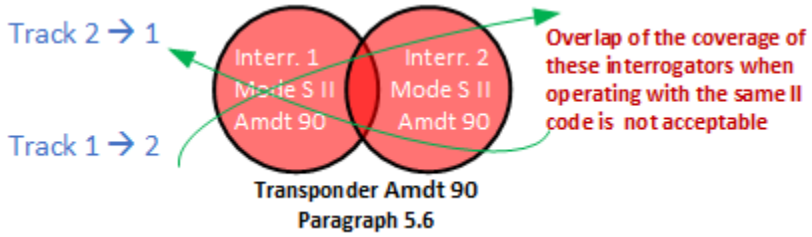
5.5.1.1 The Amdt-71 transponder is first locked out to respond to All-Calls by the Amdt-90 Mode S II interrogator 1. The Amdt-71 transponder therefore cannot reply to All-Calls from any other interrogator that is operating with the same Mode S II code. When entering the area where the coverage of the Amdt-90 interrogator 1 overlaps with the coverage of the Amdt-90 interrogator 2, the Amdt-71 transponder cannot reply to All-Calls from Amdt-90 interrogator 2 and not be acquired by Interrogator 2. As a result, the aircraft (*carrying the Amdt-71 transponder)* cannot be provided with surveillance service by interrogator 2 in the area of overlapping.

5.5.2 Track 2 → 1.

5.5.2.1 This also applies for track 2. When the Amdt-71 transponder is first acquired and locked out by the Amdt-90 interrogator 2 it cannot reply to All-Calls from any other interrogator that is operating with the same Mode S II code. When the transponder enters the area where the coverage of the Amdt-90 interrogator 2 overlaps with the coverage of the Amdt-90 interrogator 1 it cannot reply to All-Calls from interrogator 1. As a result, the aircraft (*carrying the Amdt-71 transponder)* cannot be provided with surveillance service by interrogator 1 in the area of overlapping.

5.5.3 **Planning criterium:** For Amdt-90 interrogators, when operating with the same Mode S II code and a Amdt-71 transponder, the coverage needs to be separated by at least 10 NM. In this scenario an overlap of the coverage of the interrogators is not acceptable

5.6 Interrogators 1 and 2 are Amdt-90 interrogators. Both interrogators operate with the same II code and with a Amdt-90 transponder



5.6.1 Track 1 → 2.

5.6.1.1 The Amdt-90 transponder is first locked out to respond to All-Calls by the Amdt-90 Mode S II interrogator 1. The Amdt-90 transponder therefore cannot reply to All-Calls from any other

interrogator that is operating with the same Mode S II code. When entering the area where the coverage of the Amdt-90 interrogator 1 overlaps with the Amdt-90 interrogator 2, the transponder cannot reply to All-Calls from interrogator 2 and not be acquired by Interrogator 2. As a result, the aircraft (*carrying the Amdt-90 transponder)* cannot be provided with surveillance service by interrogator 2 in the area of overlapping.

5.6.2 Track 2 → 1

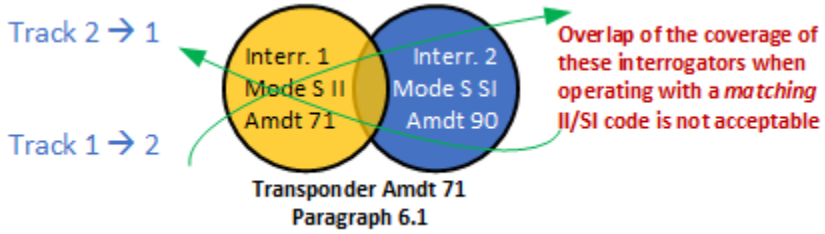
5.6.2.1 This also applies for track 2. When the Amdt-90 transponder is first acquired and locked out by the Amdt-90 interrogator 2 it cannot reply to All-Calls from any interrogator that is operating with the same Mode S II code. When the transponder enters the area where the coverage of the Amdt-90 interrogator overlaps with the coverage of the Amdt-90 interrogator 1 (which is operating with the same Mode S II code) it cannot reply to All-Calls from interrogator 1. As a result, the aircraft (*carrying the Amdt-90 transponder)* cannot be provided with surveillance service by interrogator 1 in the area of overlapping.

5.6.3 **Planning criterium:** For Amdt-90 interrogators, when operating with a nearby Amdt-90 interrogator with the same Mode S II code and a Amdt-90 transponder, the coverage needs to be separated by at least 10 NM. In this scenario an overlap of the coverage of the interrogators is not acceptable

Note: the planning criteria in 5.5.3 and 5.6.3 provide for a seamless introduction of Amdt-90 Mode S interrogators when operating with Amdt-71 or Amdt-90 transponders operating with II codes.

6. Interrogators operating with Mode S II code and Mode S SI code

6.1 Amdt-71 Mode S II interrogator is overlapping with a [Amdt-90] Mode S SI interrogator and operating with a Amdt-71 transponder



6.1.1 Track 1 → 2

6.1.1.1 The Amdt-71 transponder is first locked out to respond to All-Calls by the Amdt-71 interrogator 1. The Amdt-71 transponder can only interpret an All-Call from the Mode S SI interrogator as All-Calls with the II code that matches the field IC and would reply with the "matching" II code[4]. When the interrogator 2 operates on one of the "matching" codes and the Amdt-71 transponder has been locked out by the Amdt-71 interrogator 1 it will not respond to the All-Call from the Mode S SI interrogator 2.

6.1.2 Track 2 →1

[4] *Note: A matching II code is a code where, in the All-Call (UF=11), the (binary) content in the field II of the Amdt-71 interrogator is the same as in the field IC of the Amdt-90 Mode S SI interrogator.*

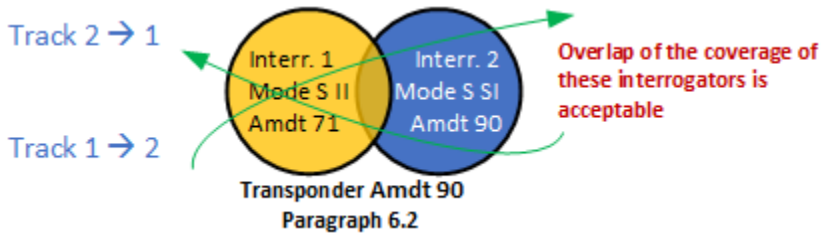
6.1.2.1 The Amdt-71 transponder, which responds to the All-Call from the Mode S SI interrogator, will not be acquired and locked out by the Mode S SI interrogator. The transponder continues to reply to the All-Calls from this interrogator with a Mode S II code which is not recognized as a valid response to the All-Calls by the Mode S SI interrogator. When the Amdt-71 transponder enters the coverage from the Amdt-71 interrogator 1 (including in the overlapping area), it will be acquired first by interrogator 1 then locked out from All-Calls with the Mode S II code from interrogator 1. The Amdt-71 transponder will be locked out from All-Calls from the Mode S SI code interrogator 2.

6.1.2.1 **Planning criterium:** The Mode S SI interrogator 2 cannot provide the surveillance service for the Amdt-71 transponder at any time, unless the Mode S SI interrogator 2 use the technology mentioned in Doc. 9924, Appendix H, paragraph 1.2.6 and 1.2.8. If a Amdt-90 Mode S SI transponder use that technology for surveillance service of the Amdt-71 transponder, the Amdt-71 Mode S II interrogators cannot overlap with Mode S SI interrogators when the Mode S SI interrogator is operating with a code in the IC field that matches the II code of the Amdt-71 Mode S II interrogator.

Note When the Mode S SI interrogator 2 (using the technology mentioned in DOC 9924, Appendix H, paragraph 1.2.6 & 1.2.8) is operating with a non-matching II code in the field IC the interrogators can have overlapping coverage.

Note: This criterium is highly restrictive to assigning SI codes to an interrogator and will not offer relief in the possibility to assign a proper SI code to an interrogator, compared to the assignment of Mode S II codes. The need to continue operating with Amdt-71 transponders is the restraining factor.

6.2 Amdt-71 Mode S II interrogator overlapping with a [Amdt-90] Mode S SI interrogator and operating with a Amdt-90 transponder



6.2.1 Track 1 → 2

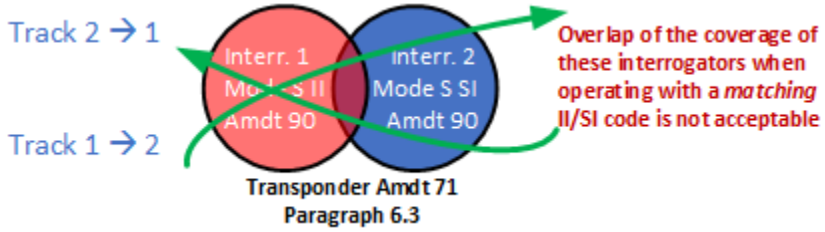
6.2.1.1 The Amdt-90 transponder is locked out to respond to All-Calls by the Amdt-71 interrogator 1 with the II code. While being locked out by the Amdt-71 interrogator, the Amdt-90 transponder is capable to interpret an All-Call from the Mode S SI interrogator as a valid Mode S SI code All-Call, even in case the binary content in the field II of the Amdt-71 Mode S II interrogator matches the binary content of the field IC of the Mode S SI interrogator. When the Amdt-90 transponder enters the area of overlap of the two interrogators, the transponder replies to an All-Call from interrogator 2 with a proper message and will be further locked out for All-Calls from this Mode S SI interrogator.

6.2.2 Track 2 →1

6.2.2.1 The Amdt-90 transponder, responds to an All-Call from the Mode S SI interrogator and replies with a valid response to the Mode S SI interrogator. The Amdt-90 transponder will be locked out from responding to further All-Calls from this Mode S SI interrogator. When entering into the area of overlapping with the Amdt-71 Mode S II interrogator, the Amdt-90 transponder is capable of recognizing the All-Calls from the Amdt-71 interrogator 1 as a valid II code and replies accordingly. The Amdt-90 transponder will be locked out from replying to All-Calls from interrogator 1 and continues to respond properly to further Roll-Calls from this interrogator.

6.2.1.1 **Planning criterium:** Amdt-71 Mode S II interrogators can overlap with Mode S SI interrogators when all transponders comply with Amdt-90 SARPS.

6.3 Amdt-90 Interrogator operating with a Mode S II code and a post interrogator operating with a "matching" SI code and a Amdt-71 transponder



6.3.1 Track 1 → 2

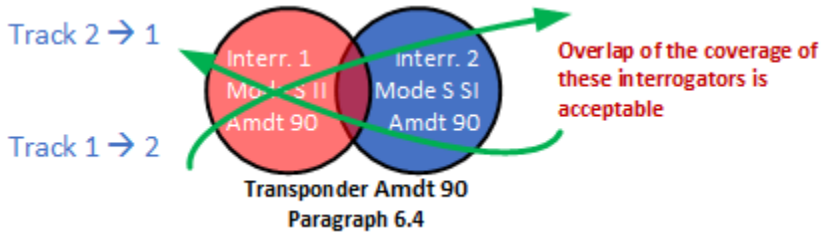
6.3.1 The Amdt-71 transponder will respond to the All-Call from the Amdt-90 Mode S II interrogator as a valid Mode S II interrogation and replies with a message that allows the Amdt-90 Mode S II interrogator to acquire and lock out the Amdt-71 transponder from replying to further All Calls. The transponder will respond to further Roll-Calls from this interrogator. When the Amdt-71 transponder enters in the area where interrogator 1 and 2 overlap (and interrogator 2 operates with a "matching" II code), the transponder will not respond to All-Calls from transponder 2 since the Amdt-71 transponder can only interpret the Mode S SI code from interrogator 2 with the "matching" II code as a Mode S II code. As a result, the transponder will not reply to All-Calls from the Mode S SI interrogator 2. When leaving the overlap, the Amdt-71 transponder will reply to All-Calls from the Mode S SI interrogator 2 but, since the reply from the Amdt-71 transponder is not a valid Mode S SI code, the transponder will not be acquired by the interrogator.

6.3.2 Track 2 → 1

6.3.2.1 Vice versa, when the transponder is in the area of the Mode S SI interrogator 2, the transponder will reply to All-Calls from transponder 2 on the basis of the "matching II" code. However, the reply from the Amdt-71 Mode S II (only) transponder is not seen by the interrogator as a valid Mode S SI code and the transponder will not be acquired and locked out from responding to further All-Calls from interrogator 2. When the transponder enters the area of overlap, it will respond to All-Calls from the Amdt-90 Mode S II interrogator 1. Since Interrogator 1 operates with an II code, it will lock-out the Amdt-71 Mode S II (only) transponder from further replies to the All-Calls. As a result, the transponder will not respond to any more All-Calls from transponder 2 (operating with the matching II code in the field IC and not be provided with a surveillance service from the Mode S SI interrogator 2.

6.3.3 **Planning criterium:** The Mode S SI interrogator 2 cannot provide the surveillance service for the Amdt-71 transponder at any time, unless the Mode S SI interrogator 2 use the technology mentioned in Doc. 9924, Appendix H, paragraph 1.2.6 and 1.2.8. If a Amdt-90 Mode S SI transponder use that technology for surveillance service of the Amdt-71 transponder, a Amdt-90 Mode S II interrogator cannot overlap with a [Amdt-90] Mode S SI interrogator when operating with a "matching" II code in the IC field.

6.4 Amdt-90 Interrogator operating with a Mode S II code and a post interrogator operating with a "matching" SI code and a Amdt-90 transponder



6.4.1 Track 1 →2

6.4.1.1 The Amdt-90 transponder can be acquired and locked out from responding to further All-Calls from Amdt-90 Mode S II interrogator 1. Additional surveillance is provided through Roll-Calls from interrogator 1. When the Amdt-90 transponder enters the area of overlap, the transponder can identify the All-Calls from Mode S SI interrogator 2 with the proper SI code, even both interrogators operate with "matching" Mode S II and Mode S SI codes. The Amdt-90 transponder can be acquired by the Mode S SI interrogator 2 and further respond to roll-calls from interrogator 2.

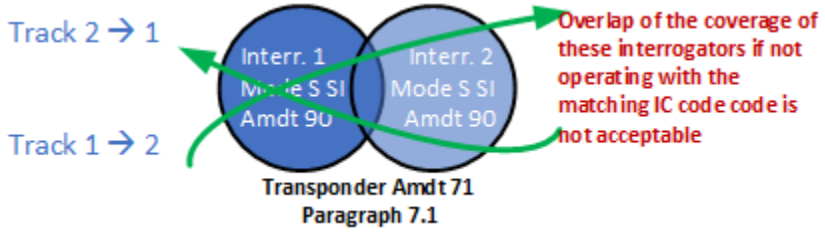
6.4.2 Track 2 → 1

6.4.2.1 The Amdt-90 transponder can be acquired and locked out from responding to further All-Calls from the Amdt-90 Mode S SI interrogator 2. Additional surveillance is provided through Roll-Calls from interrogator 2. When the Amdt-90 transponder enters the area of overlap, the transponder can identify the All-Calls from Mode S II interrogator 1 with the proper II code, even both interrogators operate with "matching" Mode S II and Mode S SI codes. The Amdt-90 transponder can be acquired by the Mode S II interrogator 1 and further respond to Roll-Calls from interrogator 2. Surveillance service in the area of overlap is not interrupted.

6.4.3 **Planning criterium:** An Amdt-90 interrogator operating with a Mode S II code can overlap with a [Amdt-90] Mode S SI interrogator when operating with a Amdt-90 transponder.

7 Interrogators operating with Mode S SI codes

7.1 Amdt-90 interrogators both operating with a Mode S SI code with the same "matching" II code in the IC field and with a Amdt-71 transponder



7.1.1 Track 1 → 2

7.1.1.1 The Amdt-71 transponder will reply to an All-Call from Mode S SI interrogator 1 with an II code that matches the field "IC" of the All-Call. This reply will not be recognized by the Mode S SI interrogator as valid response to the Mode S SI code in the All Call. The transponder will not be acquired and locked out for further replies to the All-Calls from either interrogator (see also paragraph 2.3.1 above).

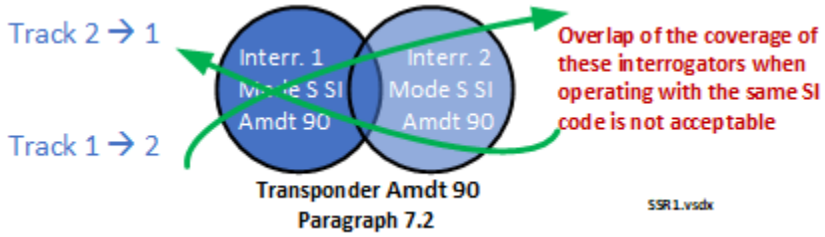
7.1.2 Track 2 →1

7.1.2.1 The Amdt-71 transponder will reply to an All-Call from Mode S SI interrogator 2 with an II code that matches the field "IC" of the All-Call. This reply will not be recognized by the Mode S SI interrogator as valid response to the Mode S SI code in the All Call. The transponder will not be acquired and locked out for further replies to the All-Call from either interrogator.

7.1.3 **Planning criterium:** For SSR Mode S SI interrogators no restrictions are necessary when operating with a Amdt-71 transponder. However, all of the Amdt-90 SI code interrogator can't provide the surveillance services for the Amdt-71 transponder, unless the Amdt-90 SI code interrogators use the technology mentioned in Doc. 9924, Appendix H, paragraph 1.2.6, 1.2.8, 1.2.9 and 1.2.10.

Note: If one or both interrogators are configured to accept replies from the Amdt-71 transponder (Re. Doc. 9924, Appendix H, paragraph 1.2.6 and 1.2.8 without applying 1.2.9 and 1.2.10, the interrogators cannot operate on the matching code in the field "IC".

7.2. Amdt-90 interrogators both operating with a Mode S SI code and a Amdt-90 transponder



7.2.1 Track 1 → 2

7.2.1.1 The Amdt-90 transponder will reply and be acquired by the Mode S SI interrogator 1 and locked out from responding to All-Calls *with the same SI code*. When the Mode S SI interrogator 2 is

operating with the same SI code, the Amdt-90 transponder, which has been locked out by Mode S SI transponder 1 from responding to All-Calls with the same Mode S SI code will not reply to All-Calls from interrogator 2. As a result, the aircraft carrying this transponder cannot be provided with surveillance service from interrogator 2 in the area of overlap.

7.2.2 Track 2 → 1

7.2.2.1 The Amdt-90 transponder will reply and be acquired by the Mode S SI interrogator 2 and locked out from responding to All-Calls *with the same SI code*. When the Mode S SI interrogator 1 is operating with the same SI code, the Amdt-90 transponder, which has been locked out by Mode S SI transponder 2 from responding to All-Calls with the same Mode S SI code will not reply to All-Calls from interrogator 1. As a result, the aircraft carrying this transponder cannot be provided with surveillance service from interrogator 1 in the area of overlap.

7.2.3 **Planning criterium:** SSR Mode S SI interrogators operating with Amdt-90 transponders cannot overlap when operating with the same SI codes.

8 Summary of the planning criteria

8.1a Two overlapping interrogators cannot have the same II code. This applies to both Amdt-71 or Amdt-90 interrogators operating with Amdt-71 or Amdt-90 transponders (Re. 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6)

8.1b Two overlapping interrogators cannot have the SI code. This applies to Amdt-90 interrogators operating with Amdt-90 transponders. (Re. 7.2)

8.2 If the transponder meets the requirements of Amdt-90, overlapping SI interrogators with "matching" II codes is permitted. (Re. Para 6.4 and 7.2)

8.3 If the transponder meets the requirements of Amdt-90, overlapping of an II interrogator with an SI interrogator with a "matching" SI code is permitted (Re. Para 6.2)

8.4 **If the transponder only meets the requirements of Amdt-71**.

8.4.1 For an II interrogator to overlap with SI interrogators with matching II codes, the following needs to be considered before a Mode-S code assignment can be made. The SI interrogator cannot acquire the Amdt-71 transponder by default. The SI interrogator may acquire the Amdt-71 transponder using the technique in Doc. 9924, Appendix H, paragraph 1.2.6 and 1.2.8, but the Amdt-71 transponder may already have been locked out by the II interrogator. Even if the Amdt-71 transponder was not yet locked out, the SI interrogator will cause the Amdt-71 transponder to be locked out to the II interrogator. (Re. Para 6.1 and 6.3)

8.4.2 There will be problem with two overlapping SI interrogators with "matching" codes. Both SI interrogators will not acquire the Amdt-71 transponder unless the techniques in Doc. 9924, Appendix H, paragraphs 1.2.6, 1.2.8, 1.2.9 and 1.2.10 are applied. Paragraphs 1.2.9 and 1.2.10 are to ensure that the other SI interrogators with "matching" codes can also acquire the Amdt-71 transponder. (Re. Para 7.1)
Note: SI interrogators and SI transponders comply with Amdt-90

8.5 In summary, overlapping of II interrogators with “matching” SI interrogators is not recommended. “Matching” SI interrogators can overlap with other SI interrogators with “matching” codes but the user must ensure that they apply the techniques as described in Doc 9924, Appendix H, paragraphs 1.2.6, 1.2.8, 1.2.9 and 1.2.10. If there are already 15 II code interrogators in use (on the basis that II=0 is not used), it would be necessary remove one II interrogator first (or modify this interrogator to an Amdt-90 interrogator to use SI codes) before introducing up to four SI interrogators with a “matching” II code.

9. Action by the meeting.

9.1 The meeting is invited

- to review the material in this paper
- to agree that this material should be used in response to Action Item **ASWG/13-33** for incorporation in Doc. 9924