Planning Criteria for the assignment of

SSR Mode S Interrogator Identifier (II) Codes in the AFI Region

1. Introduction

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

1.2 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 address and its approximate position. To acquire the address 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 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[1] is programmed in the SSR interrogator and is promulgated by the State responsible for the SSR Mode S ground station.

1.3 Once the aircraft is in the acquired state (i.e., 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 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.

1.4 When an aircraft is within the designated operational range of 2 (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 multi-site acquisition and multi-site lock out. Measures must be taken to avoid that aircraft within the designated operational range of more than one SSR Mode S interrogator (the SSR Mode S ground stations have overlapping coverage) will receive interrogations from these interrogators with the same Interrogator Identifier. This is achieved by ensuring that Mode S interrogators with overlapping designated operational range have been assigned different Interrogator Identifiers. The assignment of Interrogator Identifier codes is subject to Regional coordination.

1.5 In order to allow the aircraft to identify the ground station, each Mode S interrogator has been assigned an interrogator code. Fifteen SSR Mode S Interrogator Identifier (II) codes are available. For aircraft complying with the provisions of Annex 10, Volume IV, Amendment 73[2] (or later) an additional 63 codes known as Surveillance Identifier (SI) codes can be used. This technique is not further addressed here because of the significant additional complexity required for the assignment and operation with SI codes.

1.5.1 This complexity results from the fact that SI codes are a later addition to the ICAO SARPs for SSR Mode S transponders (1998). Currently many Mode S transponders in operation do not have SI code capability. Therefore it cannot be assumed that all transponders in any region of airspace are 100% equipped to handle both SI and II codes even if a mandate exists.

[1] The designated operational range of the SSR Mode S interrogator is the range within which the interrogator is needed operationally and within which the interrogator identifier code is uniquely protected.

[2] Amendment 73 became applicable in 1998

1.5.2 Aircraft without SI code capability operating in designated II/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 below. Therefore, the algorithms in this paper and related software can only be used for assignment of II codes.

Note 1: Detailed information is available in Annex 10, Volume IV and the ICAO Aeronautical Surveillance Manual (Doc 9924), which has been the main source for the information provided in this material. This ICAO publication is recommended for further consultation and details on the use of SSR Mode S.

Note 2: The designated operational range of the SSR Mode S interrogator is the range within which the interrogator accepts all-call replies from aircraft or generates selective interrogations to aircraft. When the aircraft is outside the designated operational range of the SSR Mode S interrogator, the interrogator does not accept all-call replies received from the aircraft transponder to all-call interrogations. The interrogator will also no longer generate selective interrogations to "acquired" aircraft that have left the designated operational range, in which case, after 18 seconds, the aircraft will no longer be locked-out for all-call interrogations from this interrogator. 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).

2 Interrogator Identifier

2.1 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 selective) interrogation. It serves the purpose to identify 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 the aircraft independent from each other. In special cases (see 3.3) overlapping SSR Mode S ground stations may share the same II code.

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 as follows (See Annex 10, Volume IV, §3.1.2.5.2.1):

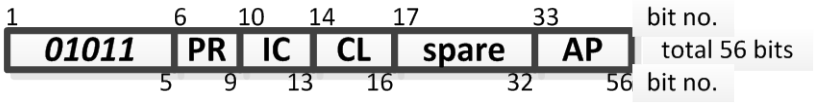


Figure 1 Uplink Format 11

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) (See paragraph 1.5)

Bit 14-16 CL (Code Label):

If CL=000, the information in the IC field is the Interrogator Identifier.

If CL is 001 to 100 (decimal value 1 to 4), the information in the IC field contains the last four bits of the Surveillance Identifier (See paragraph 1.5 above).

Bit 33-56 AP (Address/Parity):

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

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 following format (See Annex 10, Volume IV, §3.1.2.5.2.2):

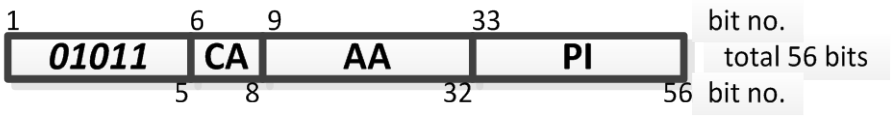


Figure 2 Downlink Format 11

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 as received by the aircraft in the all-call message as described in paragraph 2.1 above.

2.4 Following the Mode S only all-call reply, the ground station will send a selective interrogation, which has the following format (See Annex 10, Volume IV, §3.1.2.6.1 to §3.1.2.6.4):

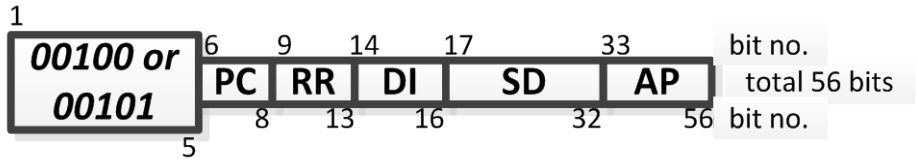


Figure 3A Uplink Format 4 and 5



Figure 3B Uplink Format 20 or 21

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 with 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 in the Flight Status Field of a Mode S reply with the downlink format DF = 4, 5, 20 or 21 changes in the Mode A code are indicated.

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 A

nex 10, Vol. IV, §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 LOS bit that commands multisite lockout (See Annex 10, Vol. IV, §3.1.2.6.1.4 for details).

Bit 33-56 AP (Address/Parity) ***Uplink Format 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.

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 from all-calls from that interrogator.

Note: The ICAO Aeronautical Surveillance Manual (Doc. 9924) provides a more detailed description of the coordination of SSR Mode S Interrogator Identifier codes.

3. Coordination of II codes of adjacent SSR Mode S interrogators (ground stations)

3.1 Coordination of the SSR Mode S II code is required when adjacent Mode S ground stations have overlapping designated operational coverage. Coordination must be ensured between adjacent States and Regions.

3.2 The example 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.

3.3 In Figure 4, 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 (see §2.2 above), the aircraft transponder will generate an all-call reply (see §2.3 above). 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 (see §2.3 above) from the aircraft transponder will be accepted by interrogator P and a selective interrogation (see §2.4 above) commanding lockout to II=1will be sent to the aircraft. The aircraft will be added to the list of “acquired aircraft” that is maintained by interrogator P.

3.4 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).

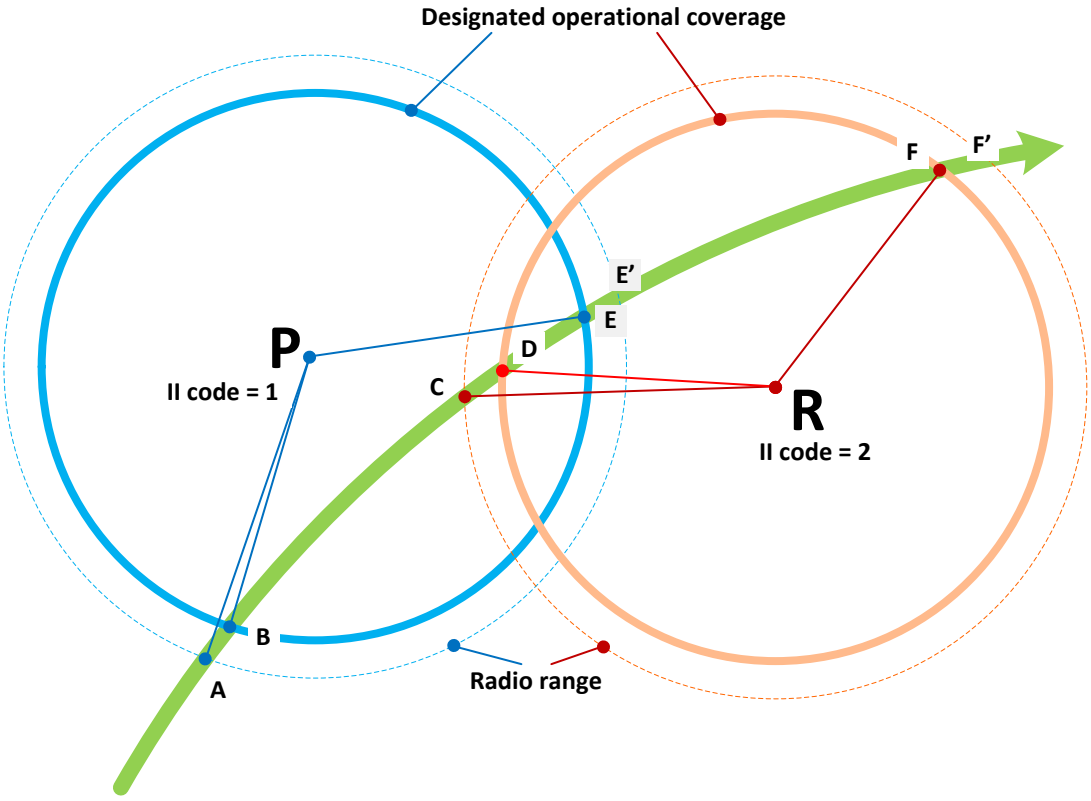


Figure 4 Process for II code acquisition and lock-out

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 (see §2.2 above), the aircraft transponder will generate an all-call reply (see §2.3) 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 transponder it 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 (see §2.3 above) from the aircraft transponder will be accepted by interrogator R and a selective interrogation (see §2.4 above) will be sent to the aircraft commanding lockout to II=2. 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 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 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. The aircraft will after a period of 18 seconds lose its lock-out 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 the 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 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. The aircraft will after a period of 18 seconds loses its lock-out 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.

3.3 Clustering of interrogators (ground station networking).

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 by two (or more) interrogators with overlapping coverage areas. This method is called "clustering"; the group of cooperating ground stations is a "cluster". See Figure 5.

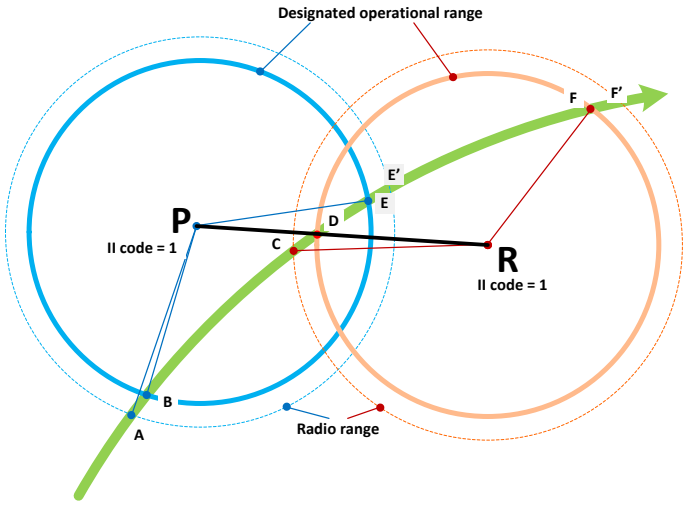


Figure 5 – SSR Mode S interrogator clustering (interrogators with same II code)

3.4 Techniques for managing overlapping coverage

3.4.1 Using multiple Interrogator Identifier codes by a single Mode S ground station.

Another method to improve the efficient use of II codes is using two (or more) II codes by a single interrogator. In this method, different sectors of the interrogator can be assigned different II codes. The sector that overlaps with another interrogator will have a different II code while the parts of the coverage that is not overlapping can have the same II code. However, it is recommended to use the minimum possible number of Interrogation Identifiers by one single Mode S ground station. Figure 6 gives an example of sectorized use of II codes.

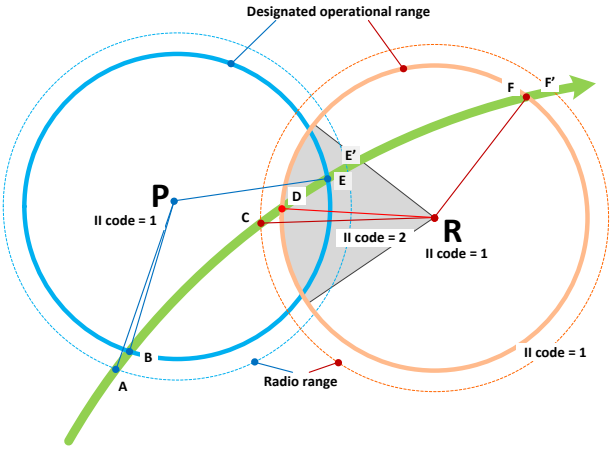


Figure 6 – Sectorized use of II codes

3.4.2 Define the maximum designated operational range on a sector basis

In some cases, adjacent SSR Mode S ground stations may have limited overlapping coverage areas. For this case it is possible to use the same II 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 7 gives an example of the used of sectored range reduction to eliminate overlap.

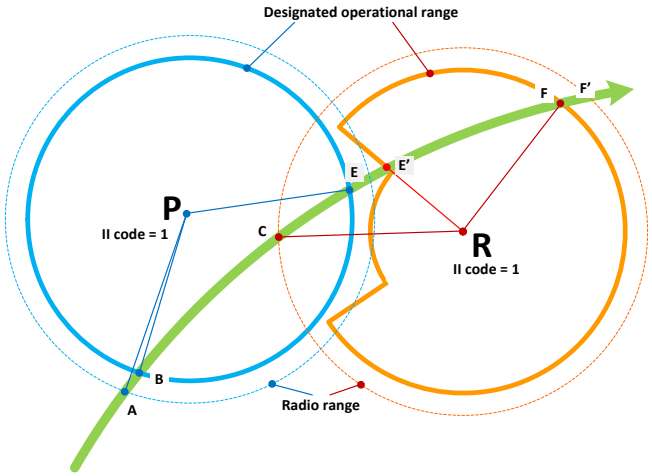


Figure 7 – Sectorized maximum range

3.5 The above examples illustrates the need for SSR Mode-S ground stations having overlapping coverage, to be assigned a unique Mode S II code, except in the case where SSR Mode S ground stations are clustered as described in §3.3.

4. Interrogator Identifier codes.

4.1 Four bits are available for 16 different Interrogator Identifier codes (see §2.2 above).

4.1.1 Interrogator Identifier code 0 (zero)

4.1.1.1 Interrogator Identifier code 0 (zero) requires special handling and is beyond the scope of this paper.

4.1.1.2 This leaves Interrogator Identifier codes 1-15 for assignment to Mode S ground stations with overlapping coverage.

Note 1: An additional 63 codes are available as Surveillance Identifier codes for use in areas where the available 15 Interrogator Identifier codes are not sufficient. The use of the Surveillance Identifier codes is not addressed here as it requires aircraft to comply with specific provisions; see §1.5 above.

5. Practical examples of Interrogator Identifier code assignments

(See also the ICAO Aeronautical Surveillance Manual, Doc 9924, Appendix J)

5.1 Figure 8 provides an example of assigned Interrogator Identifier code 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.

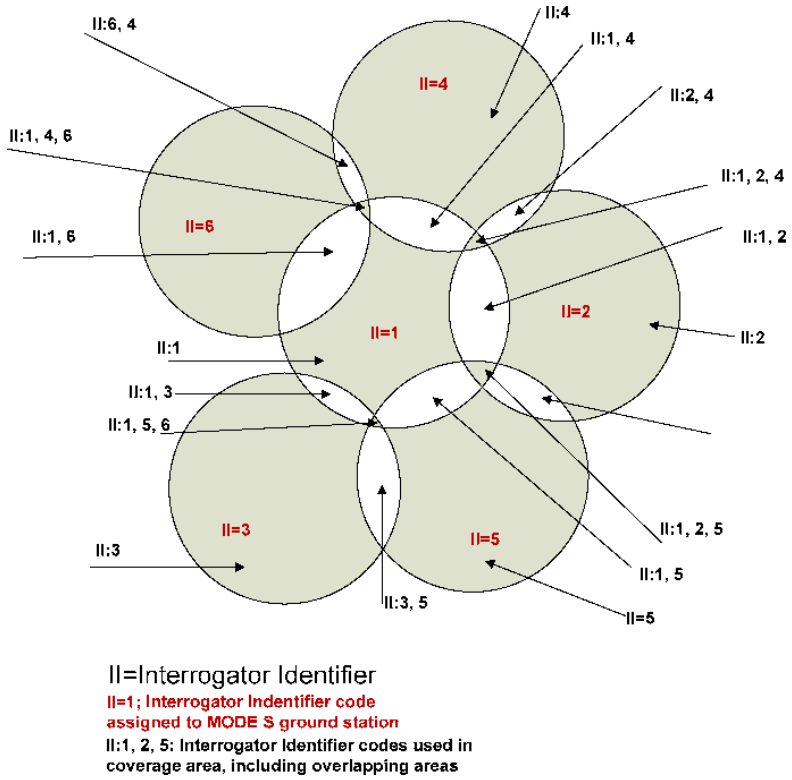


Figure 8 – Example of II code assignments

Note: More examples of II code assignments are in the ICAO Aeronautical Surveillance Manual, Doc 9924.

6. Planning parameters for SSR Mode S ground stations.

6.1 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 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 be not be accepted by the interrogator after it has determined that the aircraft is outside the designated operational range.

6.2 SSR Mode S ground stations with the same II code

6.2.1 The minimum geographical separation between two SSR Mode S interrogators which have been assigned the same II code is the sum or 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 lock-out status for all-call interrogations plus a margin that would cater for certain processing delays. The aircraft transponder cancels its lock-out 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. 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.

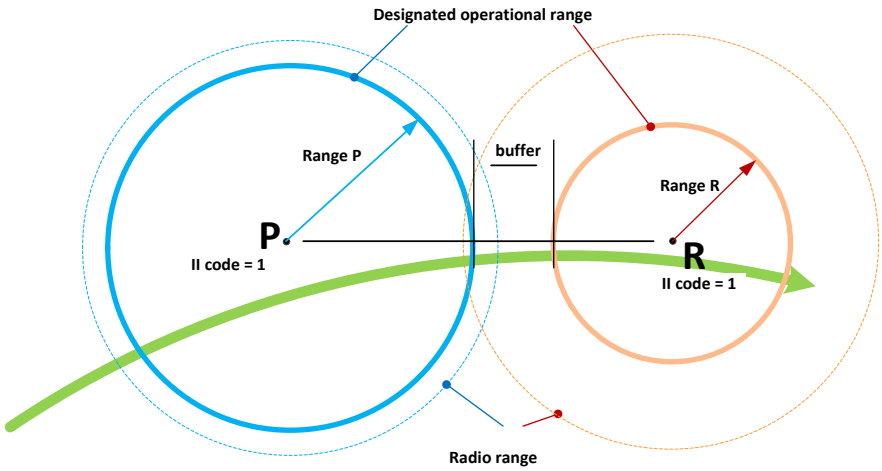


Figure 9 – Minimum separation distance between interrogators having the same II code

The minimum separation distance between two SSR Mode S interrogators with the same II code as shown in Figure 9 is:

Range P + 10NM + Range R

6.3 Mode S ground stations with different II codes.

6.3.1 When SSR Mode S ground stations have different II codes, no separation criteria between the Mode S ground stations need to be applied.

-END-