Planning criteria for SSR Mode S Interrogator Identifier codes

1. Introduction

1.1 In order to selectively interrogate a Mode S equipped aircraft, the 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 ground station transmits all-call interrogations. A Mode-S equipped aircraft will respond to such interrogations with its unique address. Once the response is received by the ground station, the aircraft will be added to the ground station's file of acquired aircraft – the aircraft is in an "acquired" state.

1.2 Once the aircraft is in the acquired state (i.e. in the list of aircraft of which the Mode S address has been acquired) the aircraft should be instructed to not longer respond to (or "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 transponder to not respond to Mode S all call interrogations.

1.3 When an aircraft is within the range of 2 (or more) Mode S ground stations, it must acquire the "lock out" status from each ground station. This is known as multi site acquisition and lock out.

1.4 In order to allow the aircraft to identify the ground station, each Mode S station has been assigned a Interrogator Identifier (II). 15 II codes have been identified. (For aircraft complying with the provisions of Annex 10, Volume IV, Amendment 73 or later an additional 63 codes known as Surveillance Identifier (SI) can be used. This technique is not addressed here). The purpose of the II (or SI) is to prevent aircraft that have been acquired by the SSR interrogator to respond to Mode-S all-call requests from that particular interrogator. These aircraft are "locked out" by the transponder to respond to further Mode-S all-call interrogations.

1.5 Measures must be taken to avoid that aircraft within the coverage of more than one SSR Mode S ground station will receive interrogations with the same Interrogator Identifier. This will be achieved by securing that Mode S ground stations with overlapping coverage have been assigned different Interrogator Identifiers. The assignment of Interrogator Identifier codes should be subject to Regional coordination.
Note: Detailed information is available in Annex 10, Volume IV and the ICAO Manual on the Secondary Surveillance Radar (SSR) Systems (Doc 9684) which has been the main source for the information provided in this material. These ICAO publications are recommended for further consultation and details on the use of SSR Mode S

2 Interrogator Identifier

2.1 The Interrogator Identifier (II) is a four digit code (0 – 15) which is transmitted by the SSR-S interrogator when transmitting a Mode S only all-call (or a Mode S selective) interrogation. It serves the purpose to identify (by the SSR transponder in the aircraft) the SSR-S ground station. The purpose of the II is to prevent aircraft that have been acquired by the SSR interrogator to respond to Mode S all-call requests from that particular interrogator (ground station). These aircraft are "locked out" by the transponder to respond to further Mode-S all-call interrogations.

2.2 A Mode-S only all-call interrogation elicits replies only from Mode S transponders and is used in conjunction with the Mode A/C only all-call interrogation. The (uplink) format for the Mode S only all-call is as follows:

1	6	10	14	17	33	bit no.
01011	**PR**	**IC**	**CL**	**spare**	**AP**	**56 bits**
5	9	13	16	32	56	bit no.

Figure 1

This message contains the following information:
Bit 1-5 01011 (decimal value 11); defines the uplink format and the content of bits 6 – 56
Bit 6-9 PR (probability of reply) (this information is not further addressed here)
Bit10-13 IC (Interrogator Code). These four bit contain the Interrogator Identifier (0-15) or the last four bits of the Surveillance Identifier (SI) (See paragraph 1.4)
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 (1 to 4), the information int the ICA field is the Surveillance Identifier (See paragraph 1.4).
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, in which the II (or SI) is encoded in the PI field, has the following format:

1	6	9	33	bit no.
01011	**CA**	**AA**	**PI**	**56 bits**
5	8	32	56	bit no.

Figure 2

This message contains the following information:
Bit 1-5 01011 (decimal value 11); defines the downlink format and the contents of bits 6 – 56
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 identity code, on which the parity is overlaid

2.4 Following the Mode S only all-call reply, the ground station will send a selective interrogation, which has the following format:

1	6	9	14	17	33	bit no.
00100 or 00101	**PC**	**RR**	**DI**	**SD**	**AP**	**56 bits**
5	8	13	16	32	56	bit no.

Figure 3

This message contains the following information:
Bit 1-5 00100 0r 00101 (decimal value 4 or 5); defines the uplink format and the contents of bits 6-56; 4 = altitude request; 5 =identity request
Bit 6-8 PC (Protocol); if PC=1, the transponder shall commence to lock out
Bit 9-13 RR (Reply Request); command the length and content of a requested reply
Bit 14-16 DI (Designator Identification); identifies the structure of the SD field
Bit 17-32 SD (Special Designator); contains a number of control codes, specific to SSR
Bit 33-56 AP (Address/Parity); aircraft address on which the parity is overlaid

2.5. The aircraft responds as requested by the selective interrogation.

3. Coordination and operation of adjacent Mode S ground stations

3.1 Coordination is required when adjacent Mode S ground stations have overlapping coverage. This coordination is particularly important where radar coverage crosses national boundaries. The following example illustrates difficulties that may arise if two Mode S stations, with overlapping coverage, use the same Interrogator Identifier.

3.1.1 In Figure 4, an aircraft travelling from A to B will, when entering the coverage area of SSR Mode-S ground station P, in response to regular all-call interrogations, be acquired by ground station P. From there-on, it will only respond to selective interrogations from ground station P. When the aircraft enters into the (overlapping) coverage of SSR Mode-S ground station R (at point F), it will continue to respond to selective interrogations from ground station P and not respond to any interrogation from ground station R. Only after the aircraft has left the coverage of ground station P (point G in Figure 4), and it has not received any selective interrogation for about 18 seconds, the aircraft returns to the "non-acquired" status and responds to Mode-S all-call requests from ground station R and subsequent selective calls from ground station R. This situation is undesirable.

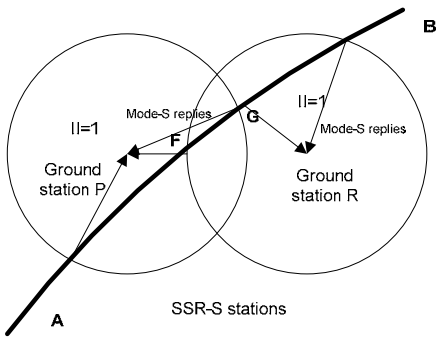

Figure 4

3.1.2 In figure 5, ground station P and ground station R have a different Interrogator Identifier. In this case, an aircraft travelling from A to B will, when entering the coverage area of SSR Mode-S ground station P, in response to regular all-call interrogation, be acquired by ground station P. When entering the coverage of SSR Mode-S ground station R the aircraft will, in response to all-call interrogations from SSR Mode-S ground station R, be acquired by ground station R as well and also respond to selective interrogations from ground station R. on the track between F and G, the aircraft will respond to selective interrogations from ground station P AND ground station R. After leaving the coverage area of ground station P (point G in figure 5) the acquired status of the aircraft with ground station P will be lost.

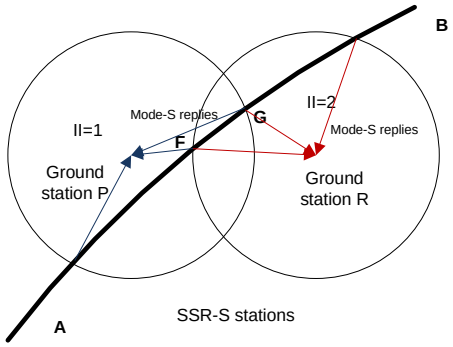

Figure 5

3.1.3 Ground station linking

3.1.3.1 The situation as described in paragraph 3.1.1 above, where the aircraft is not detected by SSR Mode S ground station R on the path between point F and G can be avoided if the two SSR S ground stations share their table of acquired aircraft (in particular the 24 bit aircraft address and the approximate location of the aircraft). In that case, ground station R can send selective interrogations to the aircraft and obtain valid responses. This process, known as ground station linking, will allow for the use of the same Interrogator Identifier by the two ground stations with overlapping coverage areas.

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

3.1.4.1 Another method avoiding the aircraft in the example in paragraph 3.1.1 above not being surveyed by ground station R is the use of two interrogator codes by ground station R. In this case, in the sector of one Mode S ground station that is overlapping with another ground station using the same Interrogator Identifier, a different Interrogator Identifier should be used. However, it is not recommended to use more than one Interrogation Identifier by one single Mode S ground station. When multiple Interrogator Identifier codes are used by one single Mode S ground stations, the total number of interrogator codes used by the ground station shall not be more than 2. Also, the different interrogator codes shall not be interleaved (i.e. in different sectors only different Interrogator Identifier codes shall be used.

3.1.5 The above examples illustrates the need for SSR Mode-S ground stations having overlapping coverage, to be assigned a unique II in the area of overlap, except in the case as described in paragraph 3.1.3. The coverage area is assumed to be the maximum distance/height combination within which the aircraft can receive interrogation requests from the Mode-S ground station. This area may be smaller (or bigger) than the actual operational coverage area of the [ACC/FIR] sector in which ATC provides radar services. As a general rule the coverage area of the SSR Mode S ground station coincides with the radio horizon from the aircraft and is actually depending on the aircraft's operating altitude.

4. Interrogator Identifier codes.

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

4.1.1 Interrogator Identifier code 0 (zero)

4.1.1.1 Interrogator Identifier code 0 (zero) shall only be used for supplementary acquisition based on lockout override. This code is not available for [regular] Mode S acquisition and lockout purposes

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

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Note: additional 63 codes are available as Surveillance Indicator in particular for use in areas where the avai1able 15Interrogator Identifier codes are not sufficient. The use of the Surveillance Indicator is not addressed here as it requires aircraft to comply with specific provisions; see paragraph 1.4 above.

Note: This would allow aircraft operating at higher altitudes to remain undetected by one ground station in case they are already locked out by another ground station with overlapping areas at higher altitudes. In case where operational circumstances require, alternative maximum flight levels and coverage areas can be applied.

5. Practical examples of Interrogator Identifier code assignments

(See also the Manual on Secondary Surveillance Radar (SSR) Systems (ICAO Doc 9684)

5.1 Figure 6 provides an example of assigned Interrogator Identifier code for Mode S stations with overlapping areas. In the areas of overlap, the aircraft responds to all-call interrogations and selective interrogations from more than one ground station, as indicated.

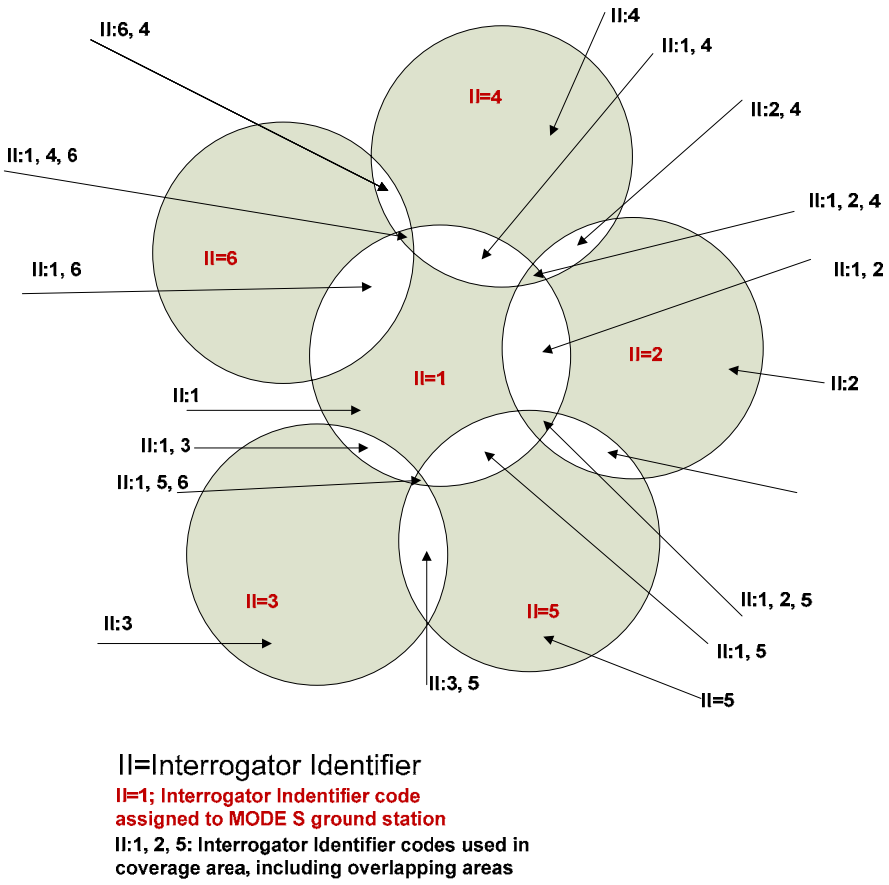

Figure 6

5.2 A more complex example for SSR Mode S Interrogator Identifier code assignments is in Figure 7. It shows that in many cases the Interrogator Identifier codes can be assigned very efficiently. It also shows cases whereby Mode S ground stations are linked, so they can use the same Interrogator Identifier code and a case where one Mode S ground station is assigned two Interrogation Identifier codes

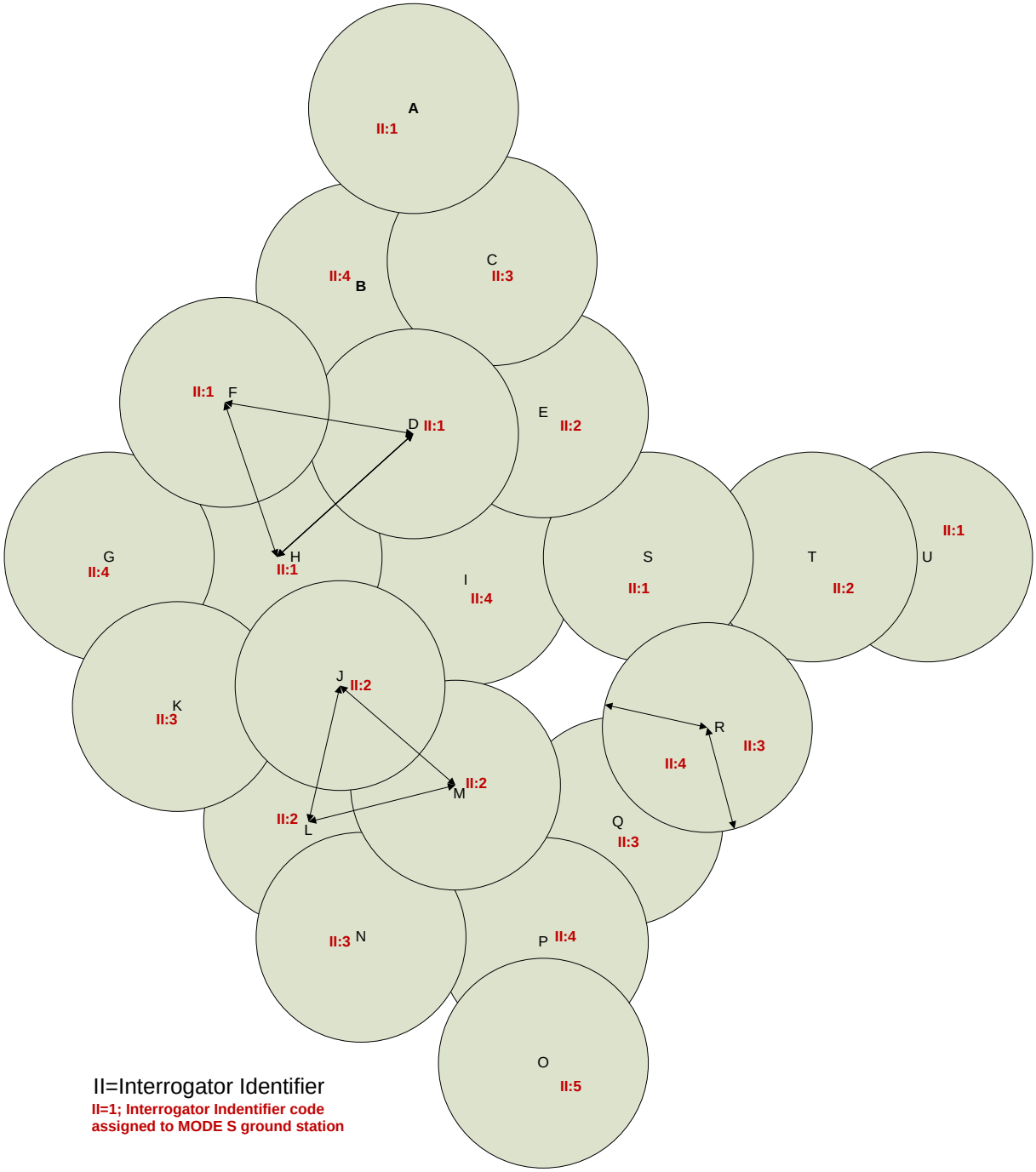

Figure 7

6. Proposed planning parameters for SSR Mode S ground stations.

6.1 DOC of two SSR Mode S ground stations has the same maximum flight level

6.1.1 In Figure 8, SSR Mode S stations P and Q have the same II code assigned. An aircraft travelling from **A** to **B**, will be within the DOC of the SSR Mode S station P and locked out for Mode S All-Calls (it will only respond to selective calls from ground station P). After the aircraft leaves the DOC of ground station P (at **B)**, it will continue to be locked out from All-Calls by Mode S ground station P as well as from All-Calls from ground station Q, although it is now within the coverage of ground station Q as well. (The coverage for ground station P is to point C, but the DOC is only to point B). When the aircraft is beyond point C, it will no longer receive signals from SSR Mode S station P (ground station P is beyond the radio horizon of the aircraft) and after 18 seconds, the aircraft SSR Mode S transponder will be unlocked. It will then start responding to All-Calls from SSR Mode S station Q. In this situation, the DOC of station Q can be close to point C (as shown in the drawing).

In this case, the minimum separation of the two SSR Mode S ground stations in equal to the sum of the distance to the radio horizon of the aircraft to ground station P plus the range (as per DOC) of SSR Mode S ground station Q plus a small buffer (10 NM is proposed).

Note: Once the aircraft is not longer receiving selective interrogations from one ground station, it will, after a period of about 18 seconds start, responding to all calls from any Mode S ground station. Assuming the aircraft travels at a speed of about 1000 km/hr., this would result in an aircraft displacement of 2.6 NM (over the period of 18 seconds).

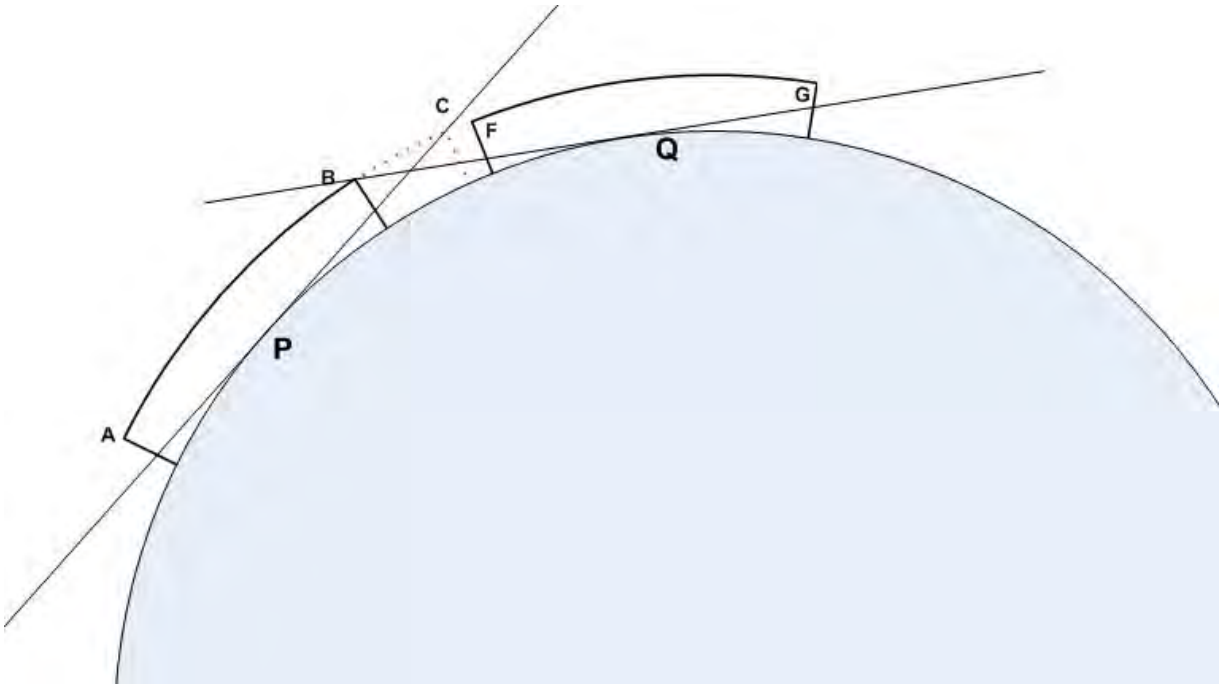

Figure 8

6.1.2 Similarly, for an aircraft travelling from G to F (see Figure 8) and further into the DOC of ground station P, the minimum separation distance needs to be equal to the sum of the distance to the radio horizon of the aircraft to ground station Q plus the distance of the DOC-range from point B to

ground station P plus a small buffer (buffer not shown in Figure 8). Note that in this case the aircraft may still be locked out by ground station Q when inside the coverage of ground station P but, when it reaches point B where the aircraft enters to DOC of ground station P (and where ground station Q is below the radio horizon), it will no longer receive signals from ground station Q, become unlocked and can respond to All-Calls from ground station P.

6.1.3 In summary, the separation distance between two SSR Mode S ground stations, with the same maximum DOC flight level, is the sum of the DOC-range and the distance to the radio horizon at maximum range/altitude. In case range of the DOC-range of the two ground stations is different, the largest of the two values "DOC-range + radio horizon" needs to be selected.

6.1.4 When plotting this information on a map, the DOC of one station and the radio horizon contour of other (nearby) station may not overlap.

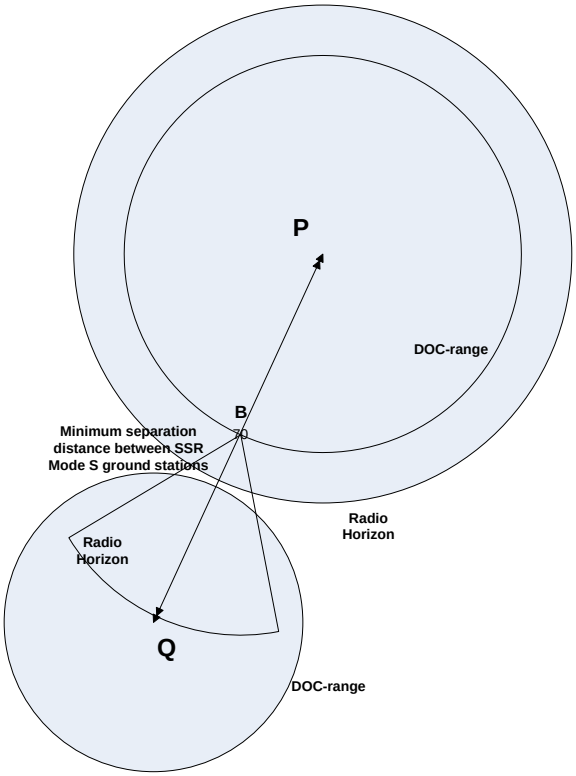

Figure 9

An aircraft entering the DOC of ground station Q needs to be beyond the radio horizon of ground station P; an aircraft entering the DOC of ground station P needs to be beyond the radio horizon of ground station Q.

Note: see paragraph 7.1 for calculation examples

6.1.5 In case the DOC for SSR Mode S ground stations P and Q have a different maximum flight level as in figure 9, the minimum required separation distance between the ground stations can be calculated as follows:

6.2 DOC of two SSR Mode S ground stations has the different maximum flight levels

a. Aircraft travelling from A to B and further, at maximum altitude for ground station P: No constraints with regard to the location of ground station Q, as the aircraft is operating outside the promulgated maximum flight level of ground station Q.

b. Aircraft traveling from G' to F' (at the same flight level as the maximum of the DOC for ground station P) and further to B. Aircraft entering at point B the DOC of ground station P are required to not longer receiving signals from ground station Q. This would require ground station Q to be below the radio horizon, seen from point B. The separation distance in this case needs to be the range of DOC of ground station P plus the distance to the radio horizon of point B plus a small buffer (10 NM is proposed)

c. Aircraft travelling from A' to B' at the same (reduced) flight level as the maximum flight level (DOC) for station Q: Aircraft entering the DOC for ground station F are required to no longer receiving signals from ground station P. The minimum separation distance is the sum of the distance to the radio horizon at point F to ground station P (at the (reduced) flight level for ground station Q) plus the DOC-range for ground station Q plus a small buffer

d. Aircraft travelling from G to F at the maximum flight level (DOC) for station Q: Minimum separation distance is the sum of the distance to the radio horizon at point B' to ground station Q at the reduced flight level plus the DOC-range for ground station P plus a small buffer.

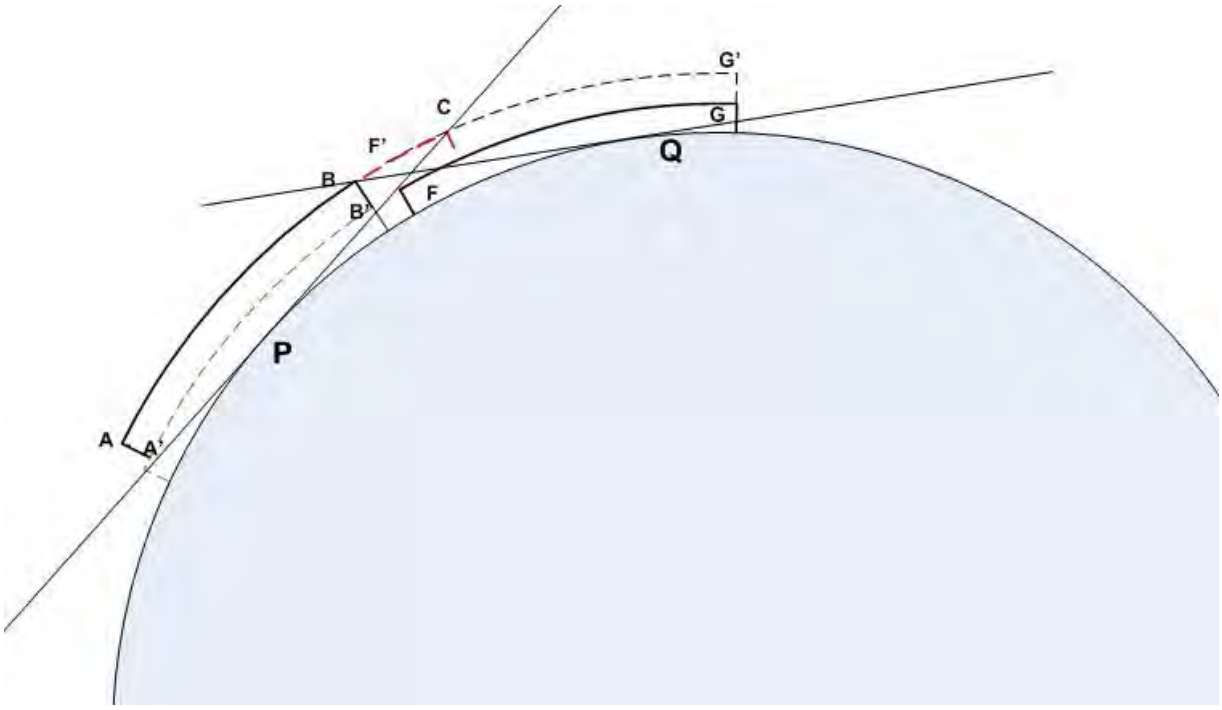

Figure 10

Note: see paragraph 7.2 for calculation examples

6.3 No DOC provided

6.3.1 In case no DOC is provided, maximum coverage is assumed to be protected. In this case, the DOC and the distance to the radio horizon are the same. Coverage areas are compatible if they do not overlap (and maintain a small buffer). In this case it is proposed that SSR Mode S II codes need to be protected up to flight level 450 (45000ft).
Note: The same protection is offered to ACC-upper and FIS upper communication frequencies'

6.4 Mode S ground stations have different II codes.

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

7. Calculation examples.

7.1 DOC same maximum flight level (see also Figure 8)

SSR Mode S station P: DOC 200NM/45000ft
SSR Mode S station Q: DOC 100NM/45000ft

(i) Separation distance between SSR Mode S stations for aircraft travelling from P to Q at FL 450:

Radio horizon [P] +DOC-range [Q] + buffer = 261 +200 + 10 NM = 471 NM (Re. Paragraph 6.1.1)
(Radio horizon [P] is the radio horizon at the maximum DOC-altitude) of ground station P)

(ii) Separation distance for SSR Mode S stations for aircraft travelling from Q to P at FL 450

Radio horizon [Q] + DOC-range [P] + buffer = 261 +100 + 10 NM = 371 NM (Re. Paragraph 6.1.2)
(Radio horizon [Q] is the radio horizon at the maximum DOC-altitude of ground station Q)

Note: Radio horizon [P] is equal to radio horizon [Q]

Minimum separation required: 471 NM

7.2 DOC different maximum flight level (see also Figure 10):

SSR Mode S station P 200 NM/45000 ft
SSR Mode S station Q 60 NM/10000 ft

(i) Separation distance between SSR Mode S stations for aircraft travelling from P to Q at FL 450:

No restrictions (Re. Paragraph 6.2.a)

(ii) Separation distance between SSR Mode S stations for aircraft travelling from Q to P at FL 450:

Radio horizon [Q'] + DOC-range [P] + buffer = 261 + 200 + 10 = 471 NM (Re Paragraph 6.2.b)
(Radio horizon [Q'] is the radio horizon at the maximum DOC-altitude of ground station P)

Note: Radio horizon Q' is equal to radio horizon P

(iii) Separation distance between SSR Mode S stations for aircraft travelling from P to Q at FL 100

Radio horizon [P'] + DOC-range [Q] + buffer = 123 + 60 + 10 NM = 193 NM (Re. Paragraph 6.2.c)
(Radio horizon [P'] is the radio horizon at the maximum DOC-altitude of ground station Q)

Note: Radio horizon P' is equal to radio horizon Q

(iv) Separation distance between SSR Mode S stations for aircraft travelling from Q to P at FL 100:

Radio horizon [Q] + DOC-range [P] = 200 + 123 + 10 NM = 333 NM (Re. Paragraph 6.2.d)
(Radio horizon [Q] is the radio horizon at the maximum DOC-altitude of ground station Q)

The largest of the three separation distances needs to be maintained.

(v) Following the same methodology as in paragraph 6.1, for two SSR Mode S stations with a DOC of 60 NM/10000ft a separation distance of 193 NM is required.

8. The separation distance considerations above do not include for compensation in case the SSR Mode S station is located well above MSL. In case the actual height of the SSR Mode S station is know, the distance to the radio horizon, as shown above, needs to be increased with the distance to the radio horizon, seen from the location of the SSR Mode S ground station.

As an example, a radar station at a height of about 3000 ft (1000 m) would require an additional separation of 67 NM, to be included in the calculation of the separation distances identified in paragraph 7.

It would therefore be necessary to introduce, both in the data relevant to the radar location, to introduce the actual height of the radar station (re. MSL).

9. Effectively, the separation distance required between two SSR Mode S ground stations with the same II code can be summarized as the sum of the range of the ground station plus the distance to the radio horizon at maximum altitude of the designated operational coverage. In case no DOC is specified, a DOC of 260nm/45000ft is assumed.