



# ICAO

*International Civil Aviation Organization*

## Seventh Meeting of the Surveillance Implementation Coordination Group (SURICG/7)

Video Teleconference, 24 – 27 May 2022

Agenda Item 7: Report on surveillance ground system and avionics performance monitoring and improvement in compliance

### 1090 CHANNEL OCCUPANCY MONITORING

(Presented by Singapore & ICCAIA)

#### SUMMARY

This paper discusses the need to measure 1090MHz channel occupancy at flight levels rather than just at ground level and some congestion mitigations

## 1. INTRODUCTION

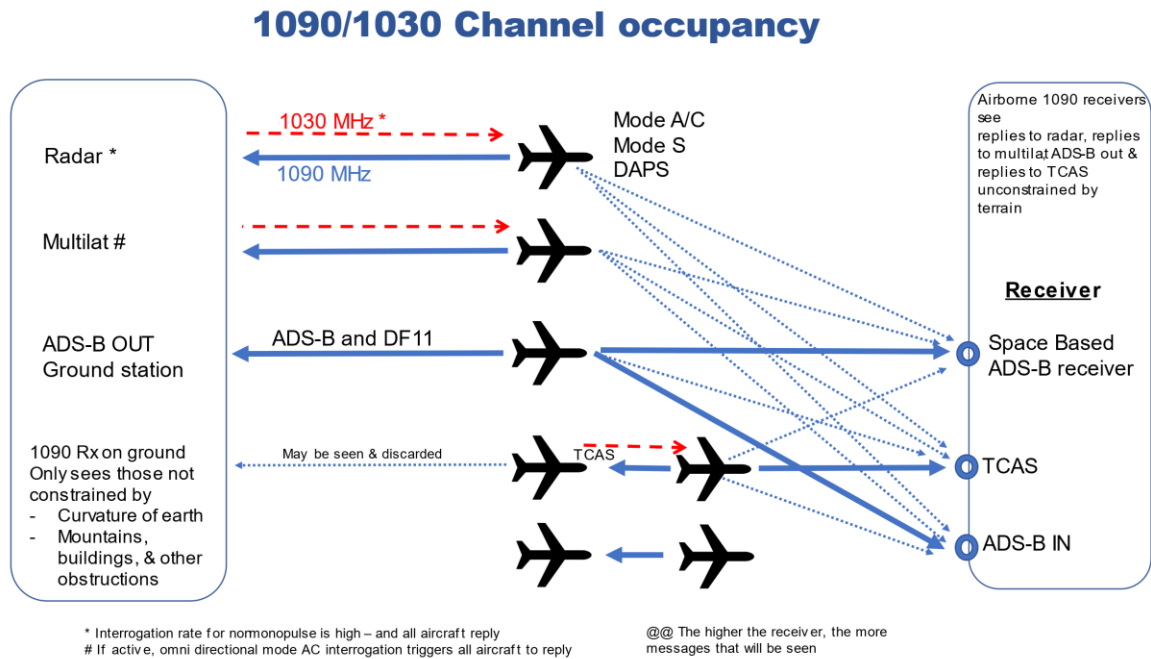
- 1.1 SURICG has previously recognized the need for States to monitor 1090MHz channel occupancy. This paper proposes that the measurement be done whilst Airborne as well as at ground station receivers.
- 1.2 The paper also considers potential mitigation measures for high channel occupancy loads.

## 2. BACKGROUND

- 2.1 Congestion in the 1090MHz band is driven by the
  - Transponders replying to interrogations
  - Autonomous transmission by transponders (ADS-B and DF11 identity squits)
  - Sometimes DME(ICAO) and TACAN (Non-ICAO)
  - Non legal interference
- 2.2 Interrogations can be initiated by
  - Secondary Surveillance Radars
  - Multilateration systems (WAM and surface surveillance)
  - Aircraft ACAS
- 2.3 Channel occupancy can also be impacted by non legal interference

e.g.: poor quality closed-circuit TV extenders or UAV vision downlinks (see SURICG/5 – IP/10 ). Thankfully in recent times the extensive use of WiFi technology, and its use by vendors of security cameras, has reduced but not removed the risk of someone illegally using 1080/1090 MHz.

The following diagram shows this diagrammatically:



2.4 The density of congestions depends on many factors:

- The number of interrogators (radars, multilateration, aircraft with ACAS)
- The interrogation rates
- The interrogation power, because that governs the number of aircraft that reply.
- The number of aircraft within coverage of the receiver
- The number of site monitors that transmit
- The number of aircraft with transponders and/or ADS-B
- The number of ground vehicles that transmit
- The presence of non-ICAO systems present & their characteristics.
- The number of messages and message length of each transmitter.

2.5 The impact of high channel occupancy is collision and consequential corruption of messages. This can result in reduced detection probability for both ground systems as well as ACAS, ADS-B IN and Space based ADS-B.

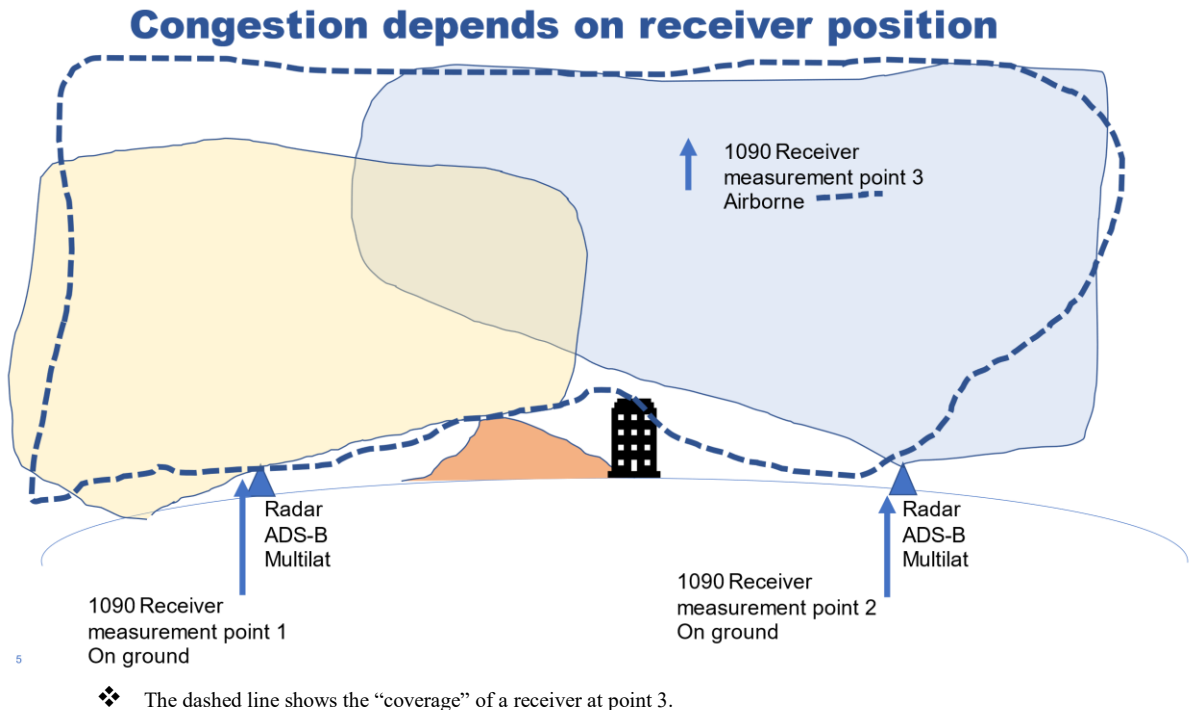
2.6 The impact is also dependent on the receiver capabilities. Of importance is :

- The receiver ability to extract overlapping messages of different power level
- The error detection and correction capabilities of the receiver
- The receiver sensitivity (-74dBm for ACAS and down to -84dBm for ADS-B in and very sensitive for Space based ADS-B)

ADS-B and Mode S based systems have error detection and correction capabilities. Mode A/C has weak protection in this regard.

- 2.7 The congestion seen by a receiver depends on the “coverage volume”. Ground systems are typically constrained by terrain, buildings and earth curvature. At the same time, they are “protected” from receiving transmissions from emitters behind these obstructions.

The diagram below shows how a receiver at position 3 will “see” replies triggered by both radars, where each radar will only see its own coverage volume. Just like a radar on a high mountain, an airborne receiver typically has a larger coverage volume less constrained by the earth curvature.



- 2.8 The proper operation of the aviation system overall also requires both terrestrial and airborne receivers to operate correctly, especially for the correct operation of ACAS. Therefore, when examining 1090MHz channel occupancy/overload, one needs to consider both terrestrial receivers and airborne receivers.

- 2.9 Therefore, it is recommended that 1090 MHz channel occupancy monitoring be conducted at operating Flight levels (eg near FL300) as well as at ground level.

### 3. SOME METHOLOGIES TO AVOID OR REDUCE 1090MHZ CONGESTION

- 3.1 The following methods can be considered by States as a menu of techniques to avoid or reduce 1090MHz congestion

- Make periodic measurements, say every few years so that the environment status is known.
- Reduce the number of SSR radars, especially non Monopulse and Mode A/C radars if operationally viable.
  - Convert Mode A/C to either ADS-B or Mode S
  - Some Secondary surveillance radars can be replaced by using ADS-B. e.g.: Australia removed 2 radars in the last decade in favor of ADS-B.
  - Complement existing coverage with Space based ADS-B

- Use Monopulse radars instead of old conventional radars so that the interrogation rate can be reduced
- Minimise the interrogation rate from radars and active multilateration consistent with the operational objective
- Decommission old Mode A/C radars because they allow multiple aircraft to reply to all interrogations
- Implement radar interrogation patterns to only interrogate on azimuths where additional surveillance is warranted.
- Minimise “all call” rate commensurate with operational needs
- Reduce interrogation transmit power to the minimum needed for the operational objective. Some systems allow this to be changed on different azimuths
- Avoid or reduce active multilateration if possible, and minimize transmit power commensurate with the operational objective
  - Mandate ADS-B fitment in aircraft: Multilateration position can be determined using the DF17 ADS-B message if required, so no interrogation is required
  - Gradually mandate Mode S in aircraft so that the need to interrogate <sup>1</sup>Mode A/C transponders is removed eventually. Multilateration position can be determined using the DF11 message if required. A mode S interrogation still required for altitude and identity to be obtained. Mode S interrogation only triggers a single aircraft to reply.
  - Aircraft with mode A/C transponders (without Mode S require or ADS-B) require multiple interrogations with typically an omni directional antenna which makes all such aircraft to reply.
- Replace or reduce any nav aids (e.g. DME/TACAN, ICAO standard or non ICAO standard) that impinge on the 1090 MHz channel.
- Close any illegal transmissions affecting the 1090MHz band
- Take care with DAPS interrogation to ensure only wanted data is requested

Other methodologies probably also exist, and all States are invited to suggest any.

#### **4. RECOMMENDATIONS**

4.1 States with the necessary capabilities are encouraged to perform 1090 MHz channel occupancy monitoring at operating Flight levels (e.g. near FL300) and at ground level.

4.2 States are encouraged to always seek to minimise 1090MHz channel occupancy commensurate with their operational needs and environment.

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<sup>1</sup> Australia’s CASA CAO 20:18 requires all IFR aircraft to be fitted with ADS-B. In addition, para 9BA.2 requires VFR aircraft to carry Mode S unless the aircraft was manufactured before Feb 2014. Further, if the transponder installation is replaced after Feb 2014 then it must be mode S. see [Civil Aviation Order 20.18 \(Aircraft equipment — basic operational requirements\) Instrument 2014 \(legislation.gov.au\)](#)

**5. ACTION BY THE MEETING**

5.1 The meeting is invited to:

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

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# SURICG 7

1090 MHz Congestion in some regions



AIREON LLC PROPRIETARY INFORMATION

# SURICG previously recognized need to Monitor 1090Mhz occupancy

- WP7 Paper Purpose
  - To note that monitoring needed at altitude as well as at ground level
  - To list a potential menu of mitigation measures
    - Viability depends on environment & applications

# What can cause congestion on 1090 MHz ?

- Transponders responding on 1090 MHz to interrogations from
  - Radars
  - Active Multilateration
  - Airborne collision avoidance system (ACAS)
  - Non ICAO systems
- Autonomous transmission
  - ADS-B, Mode S DF11
  - Aircraft in air and on ground
  - Ground Vehicles
  - Non ICAO systems
- DME and TACAN
- Non legal interference
- The density of congestion depends on :
  - Number interrogators (radar, multilat, ACAS)
    - Including the number of aircraft with ACAS
  - Interrogation rate
  - Interrogate power (the number of aircraft that reply)
  - Number of aircraft and site monitors
  - Number of ground vehicles & number of site monitors
  - Number of non ICAO systems (& their characteristics)
  - The number and length of messages
- The impact is on all users of 1090 MHz
  - Messages collide and corrupt
    - Ground systems
    - Airborne systems (ACAS & ADS-B IN)

# Channel Occupancy

- Channel Occupancy is a combination of
  - Message transmission Rate
    - Higher message Tx rates (DAPS, Higher interrogation and ADS-B) increases the number of messages that the same aircraft produces, which increases the risk of message collision
  - Message Duration
    - Shorter messages take up less “room” in a channel, however they can also be inefficient
    - Longer messages can be more efficient if it lowers the Tx rate
    - Power of Message at the Receiver :
- Successful communication depends also on receiver capabilities too
  - Sensitivity (-74dBm for ACAS, -84dBm for ADS-B IN, -90dBm for ground receiver, very sensitive for Space receiver)
  - The dynamic range of a receiver can help discriminate between near vs. far receptions and separate the messages into “channels” at different power level. (if the receiver is in space, the Rx power is about the same for all aircraft in a beam)
  - Error detection and correction capabilities (mode A/C vs Mode S/ ADS-B)

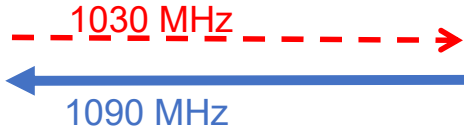
Maximum ADS-B messages that can fit into 1 second back-to-back (known as “line capacity”)  
 $1/120\mu s = 8333 \text{ msgs/s}$

ADS-B aircraft transmit up to ~6 messages per second. So, if messages are back-back then  
 $8333 \text{ msgs/s} @ 6 \text{ msgs/s/acft} = \sim 1389 \text{ aircraft}$

# 1090/1030 Channel users

## Ground based Systems

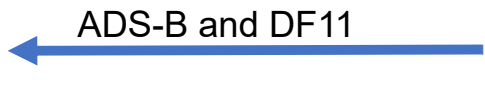
Radar \*



Active Multilat #

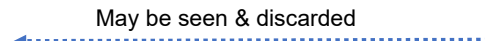


ADS-B OUT  
Ground station



Tx/Rx  
**CONSTRAINED** by

- Curvature of earth
- Mountains, buildings, & other obstructions



## Airborne Receivers

Airborne 1090 receivers see replies to radar, replies to multilat, ADS-B out & replies to TCAS unconstrained by terrain

Space Based  
ADS-B receiver

TCAS

ADS-B IN

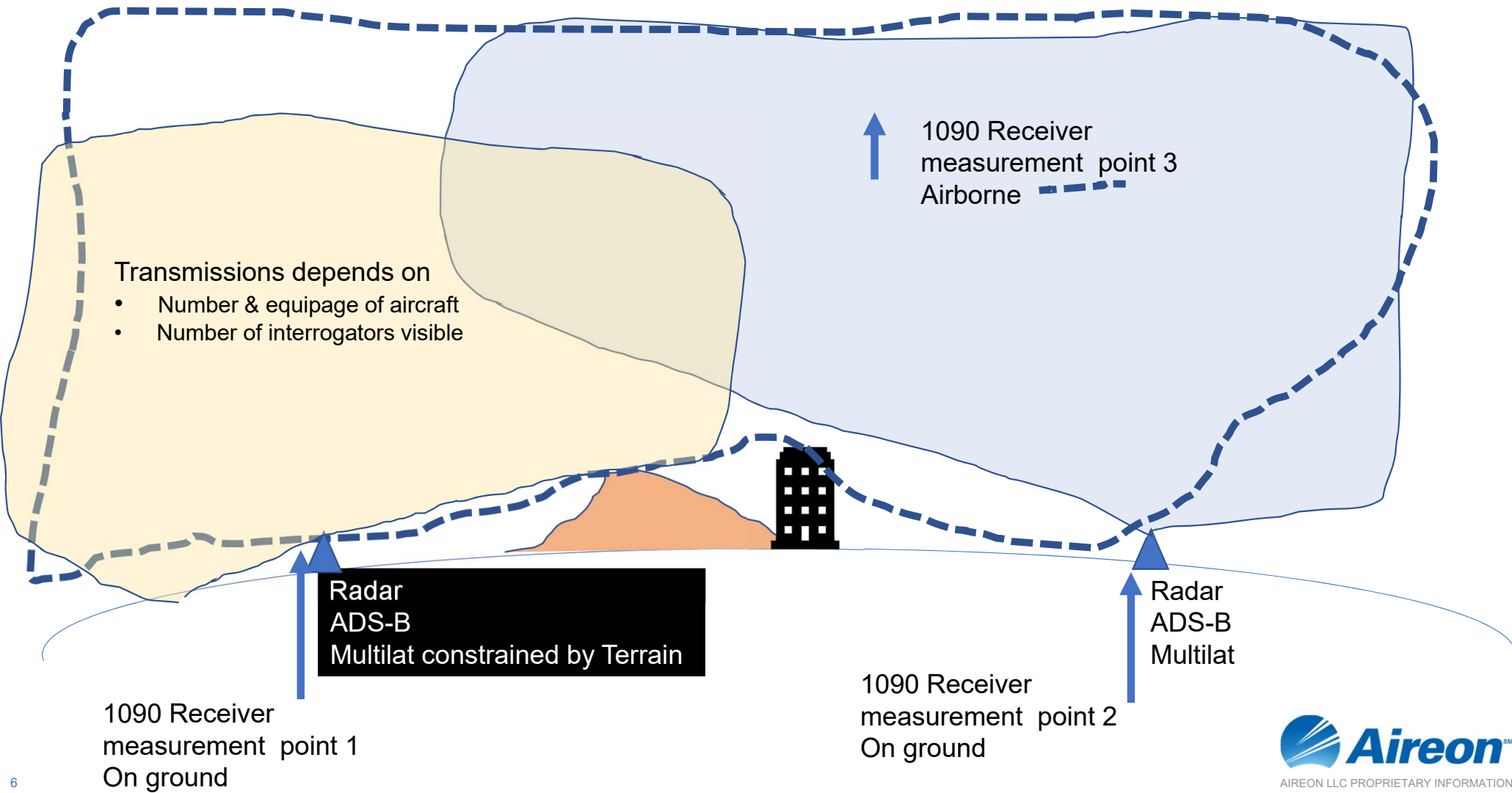
Mode A/C  
Mode S  
DAPS

TCAS

\* Interrogation rate for non monopulse is high – and all aircraft reply  
# If active, omni directional mode AC interrogation triggers all A/C aircraft to reply

@@ The higher the receiver, the more messages that will be seen

# Congestion depends on receiver position




# Potential menu of mitigations (1)


- Monitor/ Measure 1090 Mhz channel occupancy
  - Including at flight levels that “see” many transmitters
- Take action depending on environment
  1. Reduce the number of SSR radars, especially non Monopulse and Mode A/C radars if operationally viable.
    - Convert Mode A/C to Mode S
    - Replace Secondary surveillance radars by using ADS-B. e.g.: Australia removed 2 radars in the last decade in favor of ADS-B.
      - Terrestrial or Space based ADS-B
  2. Use Monopulse radars instead of old conventional radars so that the interrogation rate can be reduced
  3. Minimise the interrogation rate from radars and active multilateration consistent with the operational objective
  4. Decommission old Mode A/C radars because they allow multiple aircraft to reply to all interrogations
  5. Implement radar interrogation patterns to only interrogate on azimuths where additional surveillance is warranted.
  6. Minimise “all call” rate commensurate with operational needs

## Potential menu of mitigations (2)

7. Avoid or reduce active multilateration if possible, and minimize transmit power commensurate with the operational objective
  - Multilateration position can be determined using the DF17 ADS-B message if required, so no interrogation is required.
  - Gradually mandate Mode S in aircraft so that the need to interrogate Mode A/C transponders is removed eventually. Multilateration position can be determined using the DF11 message if required. A mode S interrogation still required for altitude and identity to be obtained. Mode S interrogation only triggers a single aircraft to reply.
  - Aircraft with mode A/C transponders (without Mode S require or ADS-B) require multiple interrogations with typically an omni directional antenna which makes all such aircraft to reply.
8. Replace or reduce any nav aids (e.g. DME/TACAN, ICAO standard or non ICAO standard) that impinge on the 1090 MHz channel.
9. Close any illegal transmissions affecting the 1090MHz band
10. Take care with DAPS interrogation to ensure only wanted data is requested
11. Other methodologies probably also exist, and all States are invited to suggest any.



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