The following paper was included in the notes from the 6th Global Navigation Satellite System (GNSS) Implementation Team (GIT/6) Meeting in Canberra, Australia, 25 June 97, hosted by AirServices Australia GNSS Program Office.

The paper was originally presented by Chairman Gary Lawson-Smith, Manager AirServices Australia GNSS Program Office, as part of a progress report on current activities of the ICAO GNSS Panel Working Group B&D meeting in Montreal, 26 May- 6 June.

GNSS SPECTRUM ISSUES (Presented by the Ad Hoc Group Rapporteur)

## PROTECTION OF RADIONAVIGATION BAND 1559-1610 Mhz

## EXECUTIVE SUMMARY AND ACTION PROPOSED

**Issues:**

A. Some members of the mobile satellite service (MSS) community are proposing to change international allocations to allow MSS (space to earth) sharing of the band 1559-1567 Mhz which is allocated to the aeronautical radionavigation service and the radionavigation-satellite service and used by the ICAO Global Navigation Satellite System (GNSS).

B. Some members of the MSS community are proposing out-of-band (OOB) spurious emissions limits for MSS terminals operating in the 1610-1626.5 Mhz band which have the potential to interfere with GNSS operations in the 1559-1610 Mhz band.

**Impact:**

A. Acceptance by the ITU of the MSS proposals will result in the inability to utilise GNSS for sole means navigation, precision approaches, or other safety-of-life operations.

B. Inability to utilise GNSS for safety-of-life applications will result in a requirement for the present ground-based navigation/surveillance systems to be maintained and perhaps augmented.

**Position:**

A. Sharing of the band 1559-1610 Mhz, with MSS or other services, is unacceptable.

B. MSS OOB spurious emissions in the frequency band 1559-1610 Mhz must be limited to -70 dBW/MHz for wideband, and -80 dBW for narrowband (<700 Hz) signals.

**Action Required:**

I. Civil Aviation Authorities should participate in related activities and work with their associated frequency management authorities to ensure that the GNSS band is protected.

II. Airlines, aircraft manufacturers and operators, and GNSS equipment manufacturers and users should be made aware of the issues, and the potential impact of an unsatisfactory resolution.

III. ICAO should inform States, international organisations and the ITU with respect to the potential impact of the MSS proposals on GNSS.

Important Meetings Related to These Issues:

a) June, 1997 ITU-R Working Party 8D and Study Group 8

b) October- 21 November 1997 World Radio Conference 1997 (WRC 97)

c) Dates to be decided, 1998 ITU-R Working Party 8D Meetings

(5 pages)

**DRAFT ICAO position on the sharing of the radionavigation band 1559-1610 Mhz.**

**Introduction**

The frequency band 1559-1610 Mhz was identified at the ICAO Special Communications/Operations Divisional Meeting 1995 (SP/COM/OPS/95) as being the only band available for the implementation of the Global Navigation Satellite System (GNSS). The SP/COM/OPS/95 meeting agreed that the band 1559-1610 Mhz needs to be protected for the operation of satellite-based radionavigation systems. Recently two specific proposals have been submitted to the ITU community which could affect the future development and use of GNSS. In particular, it is proposed:

- to set out-of-band (OOB) unwanted emission limits from Mobile Earth Stations operating in the band 1610-1626.5 Mhz in the GNSS band much higher than the levels considered safe by the aviation community; and
- to share a portion of the GNSS band with the Mobile Satellite Service (MSS) links in the space-to-Earth direction.

The ICAO position on the issue of out-of-band emission limits for Mobile Earth Stations operating in the band 1610-1626.5 Mhz has been submitted to the ITU Special Rapporteurs Group Meeting from 19-21 May in Geneva and is attached to the report of that meeting to ITU R Working Party 8D.

The feasibility of sharing the GNSS band with other systems, and in particular MSS (space-to-Earth), is addressed in this paper in two parts. First a general discussion of sharing the GNSS band, and second a technical response to the specific MSS sharing proposal.

**Feasibility of Sharing in the Frequency Band 1559-1610 Mhz**

Though this paper addresses primarily the effects of the MSS proposal as it relates to aviation use of GNSS, the ITU deliberations must consider all GNSS users. Many applications employ receivers which use the full GPS P-code bandwidth in order to enhance accuracy. Effects of the interference on these types of applications must also be studied.

Civil aviation is currently benefiting from the use of satellite navigation, and Civil Aviation Authorities and ICAO have been actively developing satellite and ground-based augmentations to enhance safety requirements and to extend the current benefits both operationally and geographically. Of primary importance however, is that the present GNSS continues to evolve, and the final configuration of the future GNSS has not yet been decided. It is expected that the future GNSS will occupy all of the band 1559-1610 Mhz, and opening the band to sharing by non-radionavigation systems would limit the scope and available options of GNSS.

Technical considerations also preclude band sharing. The aviation community has serious concerns over the introduction of services that conflict with the use of satellite navigation services, particularly for high integrity aeronautical operations. In addition, a number of systems operating in other frequency bands have been shown to have significant levels of unwanted emissions in the 1559-1610 Mhz band. Though this issue is being addressed in other fora, the important point is that the protection of radionavigation operations using GNSS does not allow for other potential sources of interference such as by trying to share the band with non-navigation systems/services.

The 1559-1610 Mhz frequency band is internationally allocated for aeronautical radionavigation and radionavigation-satellite services. Existing ITU regulations recognise the importance of protecting radionavigation systems, and in particular:

RR S4.10 (953) specifies that radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is further stated that it is necessary to take this factor into account in the assignment and use of frequencies.

RR S1.169 (163) defines harmful interference as interference which endangers the functioning of radionavigation services or other safety services or seriously degrades, obstructs or repeatedly interrupts a radio communication service operating in accordance with the Regulations.

RR S4.5 (343) requires that frequency assignments shall be separated from the limits of an allocated band in such a way that no harmful interference is caused to services in the adjoining band.

Currently GPS is being used in several regions for air traffic management in the enroute and terminal phases of flight. Future use of GNSS for more critical operations that have higher continuity and availability requirements depends on additional satellites being present. The combined use of GLONASS and GPS provides the required satellites. The Russian Federation has initiated a spectrum transition plan to protect GLONASS transmissions from MSS operating in the band above 1610 Mhz. In order however, to satisfy civil aviation's concerns, further protection of GPS/GLONASS/GNSS spectra is essential. Not to do so would immediately impact the systems current usage by civil aviation, and the direction ICAO is taking to maximise the benefits of satellite based-navigation systems.

Per the ITU regulations, and noting the predilection for interference sharing of the GNSS band with non-navigation systems/services would cause, such sharing is unacceptable.

**Specific consideration of the INMARSAT sharing proposal**

At the Conference Preparatory Meeting for WRC-97 and WRC-99 (Geneva, 5-16 May 1997), INMARSAT presented a paper (Document CPM97/82-E) entitled "Compatibility between MSS (space-to-earth) in the 1559-1567 Mhz band and ARNS/RNSS including GNSS in the 1559-1610 Mhz band" containing their analysis to support the MSS request for an allocation change to allow sharing of the 1559-1567 Mhz band. The following paragraphs address specific ICAO comments with respect to that INMARSAT analysis.

Recommendation ITU-R M.1088 provides a technical description and characteristics of the Global Positioning System (GPS). Several of the discrepancies noted with the INMARSAT analysis are attributed to the fact that they apparently did not use the information provided in ITU-R M.1088. Again, it needs to be noted that though the primary focus of this discussion is aviation concerns, all GPS receivers aviation and non-aviation -- must be protected.

The INMARSAT bandwidth assumptions for GPS P code and C/A code receivers are incorrect. GPS is registered internationally as having a 24 Mhz (3 12 Mhz) bandwidth. As a result, in order to achieve improved accuracy and provide a multipath discrimination function, a number of aviation and non-aviation C/A code receiver manufacturers utilise narrow correlator/wide bandwidth receivers. As an example, ITU-R M.1088 specifies the 3 dB bandwidth of a typical air-navigation receiver as 317 Mhz. Accordingly, based on the information in paragraph 3.3, the INMARSAT proposal must be considered as not to transmit adjacent to the band utilised by GPS, but rather to transmit within that band. Therefore, all their estimates of "off frequency interference reduction" are in error.

The INMARSAT assumption that their "interference allowance" was 25%-90% of the available "interference margin" is without foundation. ICAO is intending to use GPS to support existing air transport safety levels. As such, a margin must be built-in to account for "the unaccountable" -- that is rare intra-system interference and atmospheric/operational anomalies. Conceptually this is similar to the excess capacity which must be designed into public safety radio networks so that when an incident occurs, and the capacity is needed, it is available. To surrender a large portion of any GNSS safety margin to a known interferer would be as illogical as taking away most of the public safety system capacity just because it is not utilised during normal, non-incident, periods.

The interference-to-signal margin of 24dB, assumed by INMARSAT, is incorrect. That value applies only to interference sources wider than 1 Mhz, and a considerable amount of equipment exists which was built to specifications which were much less stringent In addition to provide a

means of determining ionospheric corrections, many manufacturers are tracking the P code carrier phase in the GPS bands. Codeless tracking introduces at least a 13 dB signal processing loss which is not considered in the INMARSAT analysis.

INMARSAT assumed GNSS receiver antenna gains in the direction of the interference and desired satellite which are not consistent with the Minimum Operational Performance Standards (MOPS) and ICAO Standards and Recommended Practices (SARPs) or measured data.

The INMARSAT methodology results in power flux density (PFD) which would preclude use of any GPS satellites below 5 degrees. Though that elevation is utilised by GNSS system planners for their analyses to predict system availability, it should not be used as a limit to determine useful satellite positioning. Under certain conditions GPS receivers could utilise satellites below 5 degrees and to prohibit that use due to MSS interference would adversely affect GNSS performance in terms of accuracy, integrity, continuity and availability.

The INMARSAT assumption that "there are no plans to implement new ARNS/RNSS systems co-frequency with the existing GPS and GLONASS systems", and their subsequent determination that "no interference allowance is necessary for this", are incorrect. For example, a wideband pulsed pseudolite, on the GPS L1 frequency, is under consideration by RTCA and the ICAO GNSSP. Note also that their assumption that pseudolites would use the same emission characteristics as GPS, and in particular C/A code is also incorrect.

The simulation model used to determine compatibility with the European Space Agency's E-NSS-1 system is fundamentally incorrect as it utilises random values, chosen from within a specified range, for parameters such as satellite e.i.r.p. and atmospheric absorption. This approach does not meet the requirements of an analysis to protect an aeronautical radionavigation safety service. Worst case parameters must be determined, worst case scenarios derived, and margin added to the resultant output.

The INMARSAT catalogue of interference sources is incomplete, as it does not include an allowance for out-of-band (OOB) emissions from MSS (earth-to-space) equipment operating above 1610 Mhz. This is especially critical in light of efforts by the MSS community to gain acceptance of OOB emission levels that are up to 16 dB higher than those proposed by the aviation community. In addition, it does not address the case where an "MSS system" is composed of multiple satellites with overlapping coverage volumes. In these overlap regions it is expected that GNSS equipment would be subject to interference from more than one MSS satellite.

With respect to OOB emissions from MSS (earth-to-space), aviation has proposed a level of -70 dBW/MHz for wideband signals (see reference in paragraph 1.2 above). This value equates to a comparable pfd for an in-band system of approximately -128 dBW/$m^2$/MHz, well below the level proposed by INMARSAT. It must be noted however, that even the -128 value might not be low enough as the -70 level was set based on the fact that the MSS signal would only be strong during a small portion of the total flight. For the situation proposed by INMARSAT, ie. space-to-earth, the MSS signal would be experienced during all phases of flight. As a result, it is expected that a lower pfd would be necessary.

The above discussions demonstrate that the INMARSAT sharing analysis contained a number of flaws in both methodology and assumptions which totally invalidate their conclusion that sharing is possible.

**Conclusions**

Acceptance by the ITU of the MSS proposals will result in the inability to utilise GNSS for sole means navigation, precision approaches, or other safety-of-life operations. As a result the present ground-based navigation/surveillance systems will have to be maintained and perhaps even augmented.

Sharing of the band 1559-1610 Mhz with MSS or other non-radionavigation services, is unacceptable.