International Civil Aviation Organization

Communication Navigation and Surveillance Sub-Group (CNS SG)

Fifth Meeting
(Cairo, Egypt, 11 - 13 December 2012)

Agenda Item 4: Developments related to CNS

GNSS SIGNAL JAMMING

(Presented by Oman)

SUMMARY

This paper presents the threat of GNSS Signal Jamming and the potential effects on civil aviation.

Action by the meeting is at paragraph 3.

REFERENCE

- AN Conf/12 report
- MIDANPIRG/13 Report
- Studies in UK

1. INTRODUCTION

1.1 The Aviation industry now relies on GNSS that are satellite signals to find a location or to keep time. The Global Positioning System (GPS) set up by the USA Government and GLONASS a similar Russian system where both built for military purposes but are now available to anyone with device to receive a signal.

2. DISCUSSION

2.1 The meeting may wish to note that there is a big worry especially in the Aviation that havoc can be caused if GNSS signals were illegally jammed. This is a real threat as this can be caused by very cheap, low power devices available on the internet. Studies carryout in the UK for a period of 6 months in one location found 60 incidences of jamming and the trend is on increase. Some of the devices available now are of very high power in comparison to the satellite signal which has serious implications on the Aviation industry.

2.2 Some jamming incidences have been shown to be caused by harmonics – where the frequencies used for GNSS have been a harmonic of frequencies used for ground-based aeronautical equipment or other equipment.

2.3 Although jamming is relatively easy, but it is also much localised and also GNSS receivers are able to pick out the signal because of the unique coding. The GNSS receivers in critical applications (e.g. aviation) have integrity warning functions. The RAIM requirement for on-board receivers is equally stringent. If on-board RAIM detects outages that prevent the procedure being flown then the pilot in command must discontinue the GNSS procedure and fly – if feasible - (in controlled airspace - with ATC approval) an alternative precision or non-precision procedure or departure procedure.

2.4 The essential part of is that aircraft authorised to fly GNSS procedures must have on-board equipment that meets the requirements for a specific aircraft type. Each aircraft type (variant) can be different in terms of FMS equipage. Accordingly, all CAA regulators should support ICAO initiatives but balance reliance on use of a specific technology and mandate robust alternative(s) in their local environment, so that the risk is minimised.

2.5 The meeting sources of GNSS vulnerabilities and detailed in **Appendix A** to this working paper, as can be seen that the sources of GNSS vulnerabilities can be categorized as follows:

a) unintentional interference;

b) intentional interference;

c) effects of the ionosphere and solar activity (space weather); and

d) others.

2.6 With the recent incidents of recurring interference to the global navigation satellite system (GNSS) on board civil aircraft have emphasized the fact that GNSS interference can cause a hazard to aviation safety and even lead to accidents through the malfunctioning of GNSS receivers and the ground proximity warning system (GPWS). ICAO issued State Letter AN 13/4.5-12/50 dated 9 July 2012 reproduced at **Appendix B** to this working paper urging all ICAO Member States to take action to ensure that sources of GPS interference signals are identified and mitigated to ensure that the integrity of international air navigation is maintained.

3. ACTION BY THE MEETING

3.1 The meeting is invited to urge States to:

a) discuss with the Agency that allocates radio spectrum about potential GPS jamming ; and

b) understand the Agency’s processes for minimising harmonics .

APPENDIX A

SOURCES OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) VULNERABILITIES

1. UNINTENTIONAL INTERFERENCE

1.1 The GNSS systems standardized by ICAO or under consideration for future standardization operate or are planned to operate in the bands 1559 – 1610 MHz (GPS, GLONASS, Galileo, BeiDou and SBAS); 108 – 117.975 MHz (GBAS); and 1164 – 1215 MHz (GPS, GLONASS, Galileo and BeiDou).

1.2 GNSS receivers in those bands must meet specified performance requirements in the presence of levels of interference defined by ICAO in Annex 10 — *Aeronautical Telecommunications* and used within the relevant International Telecommunication Union (ITU) recommendations. Interference above defined levels may cause degradation or loss of service, but avionics standards require that such interference shall not result in hazardously misleading information.

1.3 There are a number of sources of unintentional interference to GNSS from both in-band and out-of-band emitters, including mobile and fixed VHF communications, harmonics of television stations, certain radars, mobile satellite communications and military systems. Of specific concern is the use of the 1559 – 1610 MHz band by point-to-point microwave links that are allowed by a number of States. The use of these links is due to be phased out no later than 2015.

1.4 Additional sources of potential unintentional interference include GNSS repeaters and pseudolites (systems that transmit signals to supplement GNSS coverage in buildings and other areas where normal GNSS signals cannot be readily received), and aeronautical test equipment acting as a GNSS signal generator. When such equipment does not operate in accordance with specified conditions, it may interfere with GNSS avionics and CNS ground equipment. In some cases these systems can cause GNSS receivers within range to calculate erroneous positions. Such cases should be detectable because they would cause effects such as sudden, readily evident position shifts.

1.5 Many instances of reported GNSS interference events have been traced to on-board systems; experience has identified several sources, including VHF and satellite communications equipment and portable electronic devices. Such interference can be prevented by proper installation of GNSS avionics (e.g. shielding, antenna separation and out-of-band filtering), integration with other aircraft systems and restrictions on the use of portable electronic devices.

1.6 States can greatly reduce the threat of unintentional interference by applying effective spectrum management, as discussed in the body of this paper.

1.7 Current GNSS core constellations use a single frequency band (1559 – 1610 MHz). The introduction of GNSS signals on additional frequencies in the 1164 – 1215 MHz band will effectively eliminate the likelihood that unintentional interference would cause the complete loss of GNSS service. Enhanced services depending upon the availability of multiple frequencies could, however, be degraded by such interference.

1.8 The additional GNSS signals in the band 1164 - 1215 MHz to be broadcast by second-generation core satellites share the same frequency band as distance measuring equipment (DME) and TACtical air navigation system (TACAN). ITU rules require that DME/TACAN must be protected from interference. Compatibility studies based on the current DME/TACAN infrastructure concluded that the impact of radio frequency interference on the processing of the new GNSS signals is tolerable. The studies also concluded that a high density of DME/TACAN facilities operating in or near the new GNSS band could result in interference with GNSS signals at high altitudes. States should assess whether an increase of the DME/TACAN infrastructure is compatible with expanded use of GNSS or reallocate DME assignments away from GNSS frequencies.

2. INTENTIONAL INTERFERENCE AND SPOOFING

2.1 Today, essentially all conventional navigation aids remain in service, and all aircraft are still equipped to use them. Thus, there is little motivation to deliberately interfere with GNSS-based aviation services. As reliance on GNSS increases, however, the threat of intentional interference ("jamming") could increase.

2.2 GNSS is used in many applications: financial, security and tracking, transportation, agriculture, communications, numerical weather prediction, scientific research, etc. Intentional threat analysis must consider all the applications of GNSS technology and the likelihood that jamming directed at non-aviation users would affect aircraft operations. It should also consider the mitigations put in place by non-aviation services. Of primary concern is the proliferation of personal privacy jammers designed to defeat vehicle-tracking systems.

2.3 States must evaluate and address the risk of intentional interference in their airspace. If States determine that the risk is unacceptable in specific areas, they can adopt a mitigation strategy as discussed in the body of the paper.

2.4 Spoofing is the broadcast of GNSS-like signals to cause GNSS avionics to calculate erroneous positions and provide false guidance. Spoofing of GNSS is less likely than the spoofing of traditional aids because it is technically much more complex. To avoid immediate detection, spoofing requires accurate, continuous aircraft position information. It is very difficult to match the spoofing signal to the dynamics of a target receiver and maintain sufficient signal strength to enable the receiver to remain locked to the spoofing signal. If the avionics did remain locked to a spoofing signal, there are various ways that it could be detected: integrated avionics could annunciate discrepancies between GNSS and INS or DME-DME positions; pilots could note deviations through normal monitoring of instruments and displays; and, in a radar environment, ATC could observe deviations. If an aircraft did deviate from track, ground proximity warning systems (GPWS) and aircraft collision avoidance systems (ACAS) would provide protection against collision with the ground and other aircraft.

2.5 Spoofing of the GBAS data broadcast is at least as difficult as spoofing conventional landing aids. To further protect GBAS an authentication scheme has been developed that will make spoofing virtually impossible.

3. EFFECTS OF THE IONOSPHERE AND SOLAR ACTIVITY

3.1 The ionosphere is a region of the upper atmosphere that is partially ionized by radiation from the sun. GNSS signals are delayed by a varying amount depending on the density of ionized particles in the ionosphere, which itself depends on the intensity of solar radiation and other solar bursts of energy. Two ionosphere phenomena must be considered: rapid and large ionosphere delay changes; and scintillation (rapid amplitude and phase fluctuations). Ionosphere delay changes result in range measurement errors that must be addressed by system design. Severe scintillation can result in temporary loss of one or more satellite signals.

3.2 The impact of ionosphere storms on en route through non-precision approach operations is negligible.

3.3 Severe scintillation can disrupt signals from satellites, but it does not affect wide areas of the ionosphere simultaneously; rather it occurs in patches. It therefore generally affects only a few of the satellites in view of a user. Losses of signal tracking due to scintillation are of short duration, but they may occur repeatedly during periods of several hours. Such losses can possibly cause GNSS service to be degraded or temporarily lost. One mitigation is the receiver's ability to rapidly reacquire a satellite signal following a scintillation event. Scintillation affects all GNSS frequencies, so multi-frequency receivers will not offer stronger protection. Another mitigation is the use of multiple constellations. If the receiver is able to track more satellites, the likelihood of service disruption is greatly reduced because more satellites would be unaffected.

3.4 Scintillation is virtually non-existent in mid-latitudes, except at low to moderate levels, which can occur during rare severe ionosphere storms. Severe scintillation is fairly common in equatorial regions where it typically occurs after sunset and before local midnight. Moderate scintillation occurs frequently in high-latitude regions, and can reach severe levels during ionosphere storms.

3.5 Ionosphere delay can be compensated by using dual GNSS frequencies. As the effects are frequency-dependant, the use of dual frequency allows the GNSS receivers to detect and compute these ionosphere delays.

3.6 SBAS can detect the effects of ionosphere storms that might threaten the integrity of broadcast corrections and can ensure that LPV operations do not continue when and where the broadcast ionospheric corrections may not adequately compensate for these effects. This type of mitigation is effective because ionosphere storms that are sufficiently severe to threaten the validity of SBAS corrections are infrequent (they are expected to affect LPV service about 1% of the time in mid-latitude regions).

3.7 While in mid-latitudes severe ionosphere storms may infrequently cause outages of SBAS LPV service, in equatorial regions service outages would be much more frequent due to the formation of wide bands of accumulated ionized particles located approximately 15 degrees north and south of the magnetic equator. Narrow, elongated volumes, called depletions (or bubbles), in which the density of ionized particles can drop well below that in the surrounding ionosphere, often develop in the midst of these bands just after local sunset and persist late into the local night. The combination of these phenomena results in large spatial and temporal ionosphere delay variations and therefore presents a major challenge to the integrity of SBAS ionospheric corrections. It is therefore not practical to provide single-frequency SBAS LPV service in equatorial regions with a high level of availability.

3.8 GBAS broadcasts pseudo-range corrections that account for all error sources, as well as integrity information that is effective even when the local ionosphere is severely disturbed. GBAS service would, however, be lost if severe scintillation caused avionics or the GBAS station to lose lock on enough satellite signals. The GBAS broadcast itself is not affected by ionosphere conditions. However, the ionosphere threat model used by GBAS integrity monitors must be consistent with local conditions, which may result in lower service availability or more siting constraints in equatorial regions than in mid-latitude regions. Dual frequency GBAS systems can compensate ionosphere delay effects allowing improved performance with fewer constraints.

3.9 In general, space weather can have a direct impact on GNSS. Space weather can be defined as the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health of aviation flight crews and passengers. Disturbances in the Sun's corona[2] can create solar radio bursts that may cause an increase in the level of radio frequency noise in the GNSS frequency band(s), thereby affecting the reception of signals from all satellites in view on the dayside of the Earth. In some rare cases, the intensity and frequency band of a solar radio burst can cause GNSS receivers to temporarily drop track on all satellites in view. Experience has shown that these events may last up to an hour, during which geodesy GNSS receivers have lost track on all satellites in view for a couple of minutes. However, the vulnerability of receivers to such events is highly dependent on their design. Aviation GNSS receivers design is different from geodesy receiver design and so far, no significant impact has been detected on aviation receivers.

4. OTHER VULNERABILITIES

4.1 Programmatic issues, including a lack of resources, launch failures or unanticipated satellite failures could result in insufficient satellites being available to support specific GNSS based services. Control segment failure or human error could also potentially cause service outages and common-mode errors on several satellites of a single constellation. The provision of reliable services from core satellite constellations requires robust system management and funding.

4.2 States must anticipate the possibility of GNSS and conventional navigation aid service interruption or degradation during a national emergency situation (Article 89 of the Chicago Convention refers). States must also have contingency plans in the event of an international conflict or if another State jams GNSS signals in such a way that service is disrupted beyond its borders. GNSS security aspects are being addressed by some States and may result in new procedures to protect the safety and efficiency of aeronautical navigation.

4.3 In some States, military authorities test the capabilities of their equipment and systems occasionally by transmitting jamming signals that deny service in a specific area. This activity is normally coordinated with State spectrum offices and ANSPs. Military and other authorities operating jamming devices should coordinate with ANSPs to enable them to determine the airspace affected, advise aircraft operators and develop any required procedures.

4.4 The security of ground navigation aids that support aeronautical navigation is the responsibility of State authorities. GNSS coverage extends over the territory of many States, so security should be addressed at a regional or global level. It is important that the GNSS elements used by civil aviation are protected against terrorism or hostile acts.

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[2] These disturbances, known as coronal mass ejections (CMEs), release huge quantities of matter and electromagnetic radiation into space and may travel towards Earth at speeds of up to several thousand kilometres per second.

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9 July 2012

Subject: Recent GPS interference incidents and their implication on the safety and security of international civil aviation

Action required: Note the information provided and take action as required.

Sir/Madam,

1. Recent incidents of recurring interference to the global navigation satellite system (GNSS) on board civil aircraft have emphasized the fact that GNSS interference can cause a hazard to aviation safety and even lead to accidents through the malfunctioning of GNSS receivers and the ground proximity warning system (GPWS). The interference with vital systems to assist the safe landing of these aircraft illustrates how essential the interference-free operation of GNSS services has become to the safety of air navigation.

2. I wish to inform you that the Council of ICAO, during the fourth meeting of its 196th Session on 18 June 2012, considered C-WP/13872 on the matter of GNSS interference and its implications on the safety and security of international civil aviation, and took the following action:

a) noted with grave concern the recurrence of global positioning system (GPS) interference incidents affecting the safety of international air navigation in the Incheon Flight Information Region (FIR);

b) urged the Contracting State with the source of such GPS interference signals to ensure that any similar incidents do not take place again;

c) noted that GPS interference can cause a hazard to aviation safety and even lead to accidents through the malfunctioning of GPS receivers and the ground proximity warning system (GPWS);

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d) recognized that GPS interference, if it is intended to jeopardize the safety of civil aviation, is not only in contravention of the principles of the *Convention on International Civil Aviation*, but also poses a hazard to civil aviation in a manner that undermines the objectives of Annex 17 — *Security* to the Convention;

e) requested the Secretary General to study, in collaboration with the ITU, when necessary, the implications of GNSS interference on the safety of international civil aviation with a view to preventing or addressing any similar incidents in the future;

f) noted that the Twelfth Air Navigation Conference (AN-Conf/12) would consider the issue of interference with the GNSS; and

g) requested the Secretary General to issue a State letter informing States of the Council's decision on this subject.

3. Furthermore, you may wish to consult Electronic Bulletin 2011/56 *Interference to Global Navigation Satellite System (GNSS) Signals* available on the ICAO-NET website.

4. Finally, in light of these recent GNSS interference incidents affecting the safety of international air navigation, I would urge all ICAO Member States to take action to ensure that sources of GPS interference signals are identified and mitigated to ensure that the integrity of international air navigation is maintained.

Accept, Sir/Madam, the assurances of my highest consideration.

Raymond Benjamin
Secretary General