THIRD MEETING OF THE ALLPIRG/ADVISORY GROUP

(Montreal, 6 – 8 April 1999)

Agenda Item 5.8: **Interregional coordination and harmonization mechanism – ICAO position for WRC-2000**

SELECTION RATIONALE FOR A NEW CIVIL GLOBAL POSITIONING SYSTEM (GPS) SIGNAL

(Presented by the United States)

SUMMARY

In support of ICAO's GNSS program and as part of our GPS modernization initiative, the US selected the frequency 1176.45 MHz as the second GPS aeronautical safety-of-life signal (L5). Since our selection of L5 in January 1999, there has been many questions concerning the rationale, which led us to select 1176.45 MHz. The most critical element in the selection process was that the second GPS aeronautical frequency must be in an exclusive aeronautical radio navigation frequency band in order to protect it from other services. All the exclusive aeronautical radionavigation spectrum bands were evaluated (i.e. 5000-5150 MHz and 960-1215 MHz) to determine if we had the necessary bandwidth and separation from 1575.42 (L1) to meet aviation requirements. After this policy & technical evaluation, the best frequency band was 960-1215 MHz aeronautical radionavigation band and we selected 1176.45MHz +/- 12 MHz. This frequency, L5, will not cause interference problems to existing DME systems. Depending on existing DME densities, States may have to clear out up to 24 DME channels in order to use GPS for some aeronautical radionavigation services. However, if States elect to continue their use of DME in the 1164-1188 MHz portion of the 960-1215 MHz aeronautical radionavigation band they can do so without encountering any frequency interference from the GPS L5 signal, since the signals from these DMEs are significantly higher than L5. Furthermore, even without changing any current DME usage, it is expected that ground, and some aeronautical applications, could still make full use of L5. In light of the above rationale, the US believes that 1176.45 MHz is the best frequency for a second aeronautical radionavigation signal.

1. INTRODUCTION

1.1 The International Civil Aviation Organization (ICAO) has defined the constituent elements of its global navigation satellite system (GNSS) as being the United States' global positioning system (GPS), the Russian Federation GLONASS, and augmentation systems. In support of GNSS, the United States, as part of its GPS modernization initiative, has identified two new coded signals for civil use. One of these will be placed co-frequency with an existing government signal at 1227.6 MHz (designated as L2). This frequency falls in a band utilized extensively by high power air traffic control and military surveillance radar, however it should be available in most locations for ground-based use. The latter new signal was selected as being centered on 1176.45 MHz (designated as L5). The purpose of this paper is to identify the rationale leading to the L5 frequency decision.

2. DISCUSSION

2.1 A number of inter-related factors were integral to the selection process. It is important to note however that in today's environment there is considerable pressure on spectral resources, and there is no frequency band lying fallow that is suitable for Radio navigation satellite service (RNSS) use.

2.2 In a national debate ranging over several years, factors such as satellite vehicle constraints, no-interference and minimizing impacts to existing systems, operational environment considerations, aviation use versus non-aviation use, and other factors were the subject of considerable trade studies and technical analysis. Frequency bands from 900 MHz to above 5 GHz were considered, and sufficient data were collected to identify a band centered on 1176.45 MHz as the best candidate. The following sections summarize important points from those discussions.

Basic GPS signal requirements

2.3 In order for the signal to be useful to the full civil community – including aviation – the following high-level requirements were identified:

a) separated at least 200 MHz from GPS L1 (1575.42 MHz) to allow accurate ionospheric corrections to be computed using the L1/L5 combination;

b) at least 20 MHz bandwidth available to enable aircraft to achieve required accuracy for precision landings in high multipath environments; and

c) a frequency band which currently offered, or could be reasonably expected to achieve, an exclusive RNSS/aeronautical radio navigation service (ARNS) allocation. This requirement, consistent with the objectives of ICAO[1], would provide L5 with regulatory protection similar to that existing at L1, and ensure a stable, controlled, worldwide operating environment.

[1] Reflected in letter from GNSSP Working Groups (17th-28th February 1997) to Department of Transportation, United States of America, Subject: Second civil GPS Frequency, L5. Notes in particular that "The candidate 960-1215 MHz band is therefore recommended for L5".

Satellite vehicle constraints

2.4 In order to offer a near-term cost effective solution, L5 (together with L1 and L2) will be transmitted from the next-generation GPS satellites. This configuration introduces certain constraints which must be considered in the frequency selection process. Specifically:

a) the amount of power available was limited, both by physical area on the solar panel arrays, and by heat dissipation constraints. This limitation essentially ruled-out proposed 5 GHz candidates due to the considerably higher power necessary at those frequencies to overcome increased signal propagation losses;

b) the current satellite antenna design limits the effective transmission frequency range to approximately 1140-1650 MHz. Selecting candidates outside of that range would introduce costs for antenna re-design; and

c) in order to reduce phase noise on the transmitted signal, it is desirable that the center frequency be a multiple of 10.23 MHz (i.e., the satellite system clock) from GPS L1.

2.5 Taken in combination, the above considerations focussed deliberations on the 960-1215 MHz band. This band is currently allocated exclusively for ARNS, and utilized worldwide for navigation systems such as distance measuring equipment (DME) and tactical air navigation (TACAN), and surveillance systems such as the air traffic control radar beacon system (ATCRBS), the Mode-S system, and the military Identification Friend or Foe (IFF) systems. The upper adjacent band (1215-1400 MHz) is populated by a number of air traffic control and surveillance radar systems, and government RNSS links (GPS L2 and Russian GLONASS L2). With this information in mind, additional considerations were developed.

Non-interference to existing systems

2.6 An overriding concern was to ensure that the addition of the proposed L5 signal to the operational environment would not cause interference to any existing systems. With an expected L5 received signal level at the earth of –154 dBW, Tables 1 and 2 quantify the results of expected impact to existing systems. As the L5 signal is more than 40 dB weaker than the receiver sensitivity of existing systems, no interference is expected.

Table 1. Calculated interference power levels and thresholds for aeronautical radionavigation receivers in the 960-1215 MHz band

Aeronautical Radionavigation Receiver	Interference Level (dBW)	Threshold (dBW)	I/T* (dB)
ATCRBS Interrogator	-173	-114	-59
ATCRBS Transponder	-197	-110	-87
Mode S Interrogator	-193	-114	-79
Mode S Transponder	-217	-110	-107
TCAS	-217	-109	-108
TACAN/DME Interrogator	-205	-120	-85
TACAN/DME Interrogator	-165	-120	-45
TACAN/DME Transponder	-205	-125	-80

*A negative value for I/T level indicates that the worst-case interfering signal is below the aeronautical radionavigation receiver threshold. As shown in Table 1, the I/T values range from 45 dB to 108 dB below the aeronautical radionavigation receiver threshold. Based on these results L5 will not cause interference to the aeronautical radionavigation receivers in the 960-1215 MHz band.

Table 2. Calculated interference levels and thresholds for radar receivers in the 1215-1400 MHz band

Radar Receiver Type	Interference Level (dBW)	Threshold (dBW)	I/T (dB)
Sample Air Surveillance Radar	-195	-150	-45.1
Sample Air Traffic Control Radar	-196.8	-144	-52.8

Minimizing impacts to TACAN/DME

2.7 TACAN/DME frequency assignments conform worldwide to a standard ICAO channel plan. This plan not only identifies TACAN/DME interrogation and reply frequencies, it also delineates associated frequency pairings with other – VHF band – aeronautical navigation systems such as the VHF omnidirectional radio range (VOR), the instrument landing system (ILS), and the microwave landing system (MLS). This facilitates analysis in that it defines a consistent global environment. Issues considered to minimize impacts to TACAN/DME systems included:

a) attempting to stay higher in frequency than 1150 MHz. This reduces effects due to on-board interrogator transmissions, and limits the affected TACAN/DME channels to X-mode replies (see Figure 1). Existing Y-mode, and ICAO-defined W- and Z-mode channels are not affected;

b) attempting to use the National Allotment channels. Unfortunately, these channels, not generally used for civil navigation, turned out to be not acceptable for L5[2];

c) avoid channels that are paired with MLS or ILS equipment;

d) consider existing use of the channels. For example, in the United States, a number of the higher frequency X-mode channels are used for higher power en-route systems. This could facilitate transition, as it is expected that any migration to a GNSS-based navigation system would begin with en-route applications.

e) These channels – like all X- and Y-mode channels – are paired with VORs, and often that VOR-pairing is the driving factor in setting frequency re-use/site separation criteria. States concerned with the possible loss of TACAN/DME frequencies because their future plans call for DME-DME area-navigation (RNAV), should also investigate the increase in channel re-use derived from their associated plan to decommission VORs;

[2]Frequencies at 962-977 MHz were not supportable by the GPS satellites without incurring significant time delays in implementation, and costs for antenna redesign and installation; 1147-1150 MHz are utilized by other, non Allotment channels; 1151-1156 MHz are too close to on-board interrogation frequencies.

f) it is expected that full utilization of the signal by aviation may require some limited re-assignment; of existing TACAN/DME stations. However, in States with a low density of TACAN/DMEs, or for aviation applications such as runway/taxiway or final approach and landing where the GPS line-of-sight to TACAN/DMEs is limited, such re-assignment may not be required.

Figure 1. ICAO standard DME/TACAN channel plan

Operational environment considerations

2.8 In order to maximize GPS performance, attempts should be made to:

a) stay away, in frequency, from high power/high duty cycle radar systems operating above 1215 MHz; and

b) stay away, in frequency, from high duty cycle, slow spectral roll-off 1030 and 1090 MHz surveillance systems.

Non-aviation considerations

2.9 Because all existing emitters are ground-based, a number of additional benefits accrue for non-aviation users of L5. Specifically:

a) users could make use of the other additional civil signal to be added to GPS L2, and derive tri-laning[3] capability; and

b) due to their limited line-of-sight, it is expected that ground-based GPS users will be able to utilize L5 even in States where any band clearing necessary to enable aviation use is not accomplished.

3. RECOMMENDATIONS

3.1 Based on the factors identified in Section 2, the U.S. selected 1176.45 MHz as the preferred center frequency for the new civil GPS L5. The frequency falls in a band which is protected worldwide for aeronautical radionavigation, and that selection will result in a signal which causes no interference to existing systems, while, with no modification to those systems, provides complete radionavigation service for ground-based users, and many aviation applications. In order to facilitate more challenging aviation applications (due to increased GPS-receiver line-of-sight) such as en-route navigation, a number of GPS signal and GPS receiver enhancements are proposed:

a) make the GPS signal and any satellite-based augmentation system (SBAS) signals 6 dB stronger than that provided at L1 (i.e., -154 dBW). This greatly improves tolerance to interference;

b) improve the navigation message and message coding;

c) improve the navigation signal (e.g., 10.23 MHz chip rate); and

d) make use of advances in receiver design to improve pulsed interference tolerance (e.g., pulse blanking, receiver filtering, advanced signal processing).

3.2 In recognition of fact that new global RNSS systems are of international benefit, the ICAO regional offices are requested to encourage States within their regions to support a proposed new co-primary RNSS allocation at 1164-1188 MHz. This will allow States with extensive DMEs the flexibility to gracefully transition to satellite based navigation at a time of their own choosing, while expanding the capabilities of States with limited infrastructure.

– END –

[3] A form of wide-laning whereby receivers can identify and isolate carrier-cycle integer ambiguities between two frequencies and greatly increase positional accuracy.