International Civil Aviation Organization

WORKING PAPER

NAVIGATION SYSTEMS PANEL (NSP)

FOURTH MEETING

Montréal, 10 – 20 October 2017

Agenda Item 2e: SARPS for GNSS elements and signals - SBAS L1-L5

DFMC SBAS Key Concepts
(Presented by DS2 Rapporteur)

SUMMARY

This paper identifies key concepts that are part of the proposed DFMC SBAS service and provides some key differences between DFMC SBAS and L1 SBAS service. NSP is invited to comment on the material in this paper.

1. INTRODUCTION

1.1 This paper identifies key concepts that are part of the proposed DFMC SBAS service. Additional information can be found in the DFMC SBAS Definition Document submitted during NSP/3 as IP32, *NSP3_ip32_SBAS L5 ICD and Def Doc_Final*. Chapter 1 of the DFMC SBAS Definition Document provides discussion of the DFMC SBAS Concept. Chapters 2 and 3 provide detailed requirements similar in concept to the method of presentation in an RTCA Minimum Aviation System Performance Specification. This document highlights key concepts and includes discussion of impacts to L1 SBAS. NSP/3 IP-32 also introduced the DMFC SBAS Interface Control Document which describes the L5 messages; this description has been further developed in the SBAS L5 SARPS Appendix B draft material (cf DFMC SBAS SARPs Part B v1.0 submitted as WP-20 to NSP/4).

1.2 This paper was developed by the DS2 sub-group.

2. KEY CONCEPTS FOR DFMC SBAS SERVICE

2.1 Independent Service: The DFMC SBAS service is independent of the L1 SBAS service.

2.1.1 The SBAS data required for the DFMC SBAS service is on the L5 (1176 MHz) frequency. The L5 messages have definitions that are different than the L1 messages. The L5 message header is four bits smaller than the L1 message header, providing more useful data per message when compared to L1 messages. The current message identification scheme uses different numerical identifiers than those used on L1 SBAS to help prevent confusion between the two services, with the exception that the SBAS Do Not Use (Type 0) message, SBAS Reserved (Type 62) message, and SBAS Null (Type 63) message use the same numerical identifiers for both services. It is not required to use different numerical identifiers since the services are different, and the addition of messages in the future is not required to maintain separate numerical identifiers.

2.1.2 The DFMC SBAS SARPs amendment introduces no functional or interface changes to the L1 SBAS service. Existing L1 SBAS avionics will continue to function with the existing L1 SBAS service. All changes proposed in the DFMC SBAS SARPs proposal to the existing SARPs are editorial changes to clarify the requirements that apply to the L1 service.

2.1.3 The DFMC SBAS capable avionics will need the capability to track the L5 frequency in addition to the L1 frequency. While the DFMC SBAS service is a separate service, the expectation is that all DFMC SBAS avionics will include the capability to operate in an L1 SBAS mode of operation in accordance with the existing L1 SBAS SARPs and MOPS.

2.1.4 The DFMC SBAS service comprises two functions: the ionosphere-free differential correction function and the optional ranging function similar to the L1 SBAS ranging function. Those functions are delivered to the DFMC users via an SBAS satellite. The DFMC service is self-contained: all ephemeris parameters, corrections and integrity information are provided within the L5 signal.

2.1.5 The provision of DFMC SBAS services does not require the provision of an L1 SBAS service. If the L1 SBAS service is not provided in a specific region, DFMC SBAS users cannot revert to the L1 SBAS position solution in case of loss of the L5/E5a or SBAS L5 frequency. Current providers intend to maintain their L1 SBAS service.

2.2 SBAS Service Comparison: The minimum DFMC SBAS capability supports the same operational services as L1 SBAS, namely en route through precision approach operations. DMFC SBAS provides this service in much the same way as L1 SBAS, using corrections broadcast by an SBAS satellite applied to the GNSS pseudorange augmented by SBAS. The pseudorange combination used in DFMC SBAS is different: DFMC SBAS uses the ionosphere-free pseudorange derived from the linear combination of two single-frequency pseudorange measurements from the same GNSS satellite. This results in modified uncertainty (sigmas), position and protection level equations. DFMC SBAS is subject to and mitigates threats in the same manner as L1 SBAS, with the exception that differential ionosphere delay threat is mitigated using the ionosphere-free pseudorange. This change results in the benefits listed in the next section.

2.3 DFMC SBAS Benefits: DFMC SBAS provides several benefits. DFMC SBAS enables the provisioning of SBAS service in regions of active ionosphere where availability of an L1 SBAS service would be low. The DFMC SBAS design addresses limitations of the L1 SBAS service to augment multiple constellations. DFMC SBAS receivers have additional resiliency to radiofrequency interference and improved availability during ionospheric storms.

2.3.1 DFMC SBAS service provides vertical guidance in geographic areas and during conditions where legacy L1 SBAS has limitations for providing vertical guidance, i.e. in equatorial areas and in other areas where the ionospheric delay has large spatial gradients and rapid temporal variation. DFMC SBAS uses ionosphere-free pseudoranges to effectively shift the responsibility for ionosphere delay mitigation from the ground segment to the airborne segment.

2.3.2 The DFMC SBAS design addresses limitations of extending the current L1 SBAS service to augment multiple constellations. The DFMC SBAS design permits augmentation of multiple GNSS with up to a total of 92 satellites concurrently. In comparison, the L1 SBAS design only provides an ability to augment up to 51 satellites concurrently, with SARPs only developed for GPS and GLONASS constellations.

2.3.3 DFMC SBAS service provides improved availability, continuity, and accuracy by using ranging sources with two frequencies to provide direct ionosphere delay measurement. DFMC SBAS is not reliant on receipt of ionosphere pierce point data from SBAS. This results in two effects as follows: DFMC SBAS service will not have interruptions during ionosphere storm activity, and the region in which DFMC SBAS can support precision approach will be much broader than the equivalent L1 SBAS precision approach region.

2.3.4 DFMC SBAS service provides better level of service through reduction of calculated Vertical Protection Levels (VPLs). DFMC SBAS should be able to provide VPLs in the 10-12 m range. The achieved reduction in VPL might enable approval of additional operational capabilities, such as Category 1 Autoland. DFMC SBAS achieves this in several ways including the following: changes in the SBAS message structure that permits calculation of smaller VPLs and direct removal of the first order ionosphere delays resulting in lower uncertainty.

2.3.5 DFMC SBAS service provides improved availability and provides robustness against single GNSS constellation degradation. It accomplishes this in two ways. First, the additional constellation(s) provides robustness to failure or degradation of one constellation. Second, when using an SBAS that augments multiple constellations, a DFMC SBAS receiver can select a good set of ranging sources from multiple constellations to improve the geometry of the satellites used in the position solution.

2.3.6 DFMC SBAS avionics will provide robustness against radiofrequency interference on L1. DFMC SBAS avionics will provide horizontal navigation operations using single frequency ABAS on L5/E5a when subject to interference or signal loss on L1/E1. DFMC SBAS avionics will provide L1 SBAS or ABAS service when subject to interference or signal loss on L5/E5a.

2.4 Performance Requirements: DFMC SBAS service complies with the same performance requirements, although there are modifications to the position equations and protection level equations to account for the differences between DFMC SBAS and L1 SBAS services. The position equations add an additional time bias term for each additional constellation augmented. The protection level equations replace the grid ionosphere vertical error terms with significantly smaller ionosphere residual term. The code noise multipath term is larger to account for the increased noise in the ionosphere-free pseudorange. The troposphere noise model and airborne multipath model remain equivalent.

2.5 Service Provider Identification (ID): In L1 SBAS it is only possible to identify 14 unique SBAS Service Providers since the L1 SBAS Service Provider ID field is only 4 bits and two values have special meaning. The L5 message definition adds an additional bit which would enable the definition of an additional 16 SBAS service providers. At present, it would be difficult to use these additional identifiers. The Service Provider ID is also included in the Final Approach Segment (FAS) data block. It will be necessary to modify both the L1 SBAS SARPs and FAS data block definition to use these additional identifiers on the L5 service. ARINC currently has no plan to update the FAS to accommodate the additional Service Provider ID bit, and modifications of the FAS need to consider backward compatibility. Existing L1 SBAS equipment will not be able to use the additional Service Provider identifiers, even if it was added to the L1 message set.

2.6 SBAS Satellites: The DFMC SBAS concept as proposed supports the use of non-Geostationary SBAS satellites. The DFMC SBAS almanac and ephemeris messages can support non-geostationary orbits, as opposed to L1 SBAS equipment which was only designed to operate with geostationary SBAS satellites. Therefore, it is likely that only DFMC SBAS receivers would be able to track non-geostationary SBAS satellites. Receiver manufacturers expect that only geostationary SBAS satellites will use the existing 39 identified SBAS PRNs. It is necessary to designate additional SBAS PRNs for non-geostationary SBAS satellites.

3. ACTION BY THE MEETING

3.1 The meeting is invited to comment on the information presented in this paper.

— END —