Land Information New Zealand
Toitū te whenua

Australian Government
Geoscience Australia

Technical Specifications Document

for

Satellite-Based Augmentation System (SBAS) Testbed

Revision 4 10 July 2017

Table of Contents

Acronym Definitions

APC	Augmentation Processing Centre
CORS	Continuously Operating Reference Station
CRCSI	Cooperative Research Centre for Spatial Information
DFMC	Dual Frequency Multi Constellation
EGNOS	European Geostationary Navigation Overlay Service
GA	Geoscience Australia
GEMINI	GNSS Evaluation and Monitoring of Interoperable Navigation
GEO	Geostationary satellite
GPS	Global Positioning System
GNSS	Global Navigational Satellite System
ISP	Internet Service Provider
LLRx	Long Loop Receiver
LINZ	Land Information New Zealand
OEM	Original Equipment Manufacturer
PPP	Precise Point Positioning
PRN	Pseudo Random Noise
RF	Radio Frequency
RFU	Radio Frequency Antenna
SBAS	Satellite-Based Augmentation System
SGC	Signal Generation Controller
SIGGEN	Signal Generator
SLRx	Short Loop Receiver
SRX	Software Receiver
SW	Software
UAV	Unmanned Aerial Vehicle
USM	Uplink Safety Monitor
WAAS	Wide Area Augmentation System

1. Introduction

Geoscience Australia (GA), Land Information New Zealand (LINZ) and the Cooperative Research Centre for Spatial Information (CRCSI) have commenced a two year Satellite-Based Augmentation System (SBAS) testbed trial to evaluate the performance of SBAS across a number of industries. The trial will test a number of services across nine key industry sectors including aviation, agriculture, mining, road, rail, maritime, spatial, construction and utilities.

SBAS is a well-known technology that can augment standalone GNSS in a number of areas including accuracy, integrity and availability. It works by collecting data from Continuously Operating Reference Stations (CORS) in the region, computing corrections and disseminating these corrections to users via a geostationary communication satellite. SBAS is currently used in United States, Europe, Japan, India, Russia and China to aid positioning and navigation across various user sectors, with aviation being the industry where this technology is being used most.

The standard service that is currently used by the various SBAS systems around the world is the L1 Legacy service, which is transmitted on the L1 frequency and is able to achieve sub-metre positioning in real-time. However, the Australia-NZ SBAS testbed will test the second generation SBAS with the new Dual Frequency Multi Constellation (DFMC) service being transmitted on the L5 frequency and will make use of GPS and Galileo satellite constellations. The DFMC is expected to provide improvements on the L1 Legacy service by using more satellites as well as providing enhanced mitigation of ionospheric errors through the use of L1 and L5 frequencies. No other SBAS in the world is currently offering the DFMC option and Australia and NZ will be the first countries to gain access to and test this next generation SBAS signal.

Additionally, the SBAS testbed trial will evaluate the use of a Precise Point Positioning (PPP) service. PPP is a positioning technique that uses data from a global network of reference stations to compute precise orbits and clocks and transmit these data to users (either via satellite or by other means) which would allow them to compute positions accurate to 5-10cm. Whilst the PPP positioning method is superior compared to SBAS in terms of accuracy, it suffers from long convergence times. Typical convergence time required to achieve this accuracy ranges from 40-60 minutes, and if the satellite lock is lost, then re-convergence would be required. On the other hand, SBAS positioning is achieved in real-time.

Industry partners in this collaborative trial include Lockheed Martin, GMV and Inmarsat. Lockheed Martin will host the SBAS master station at their site in Uralla, NSW and provide systems integration expertise as well as the uplink antenna. GMV will provide the master station based on their “magicGNSS” server. Inmarsat will provide the navigation payload hosted on their 4F1 geostationary satellite. The master station will collect data from reference stations around Australia and New Zealand, compute the corrections for each GNSS satellite and generate augmentation and integrity messages, which will then be uplinked to the 4F1 satellite and disseminated to users in the Australasian region.

2. SBAS Testbed Realisation

The main objective of the SBAS trial is to develop a testbed for SBAS and PPP navigation services in the Australasian region. The trial will provide sufficient infrastructure to setup SBAS L1 and SBAS DFMC navigation system, at the same time allowing real-time PPP corrections to be broadcast, embedded in both SBAS messages. The system architecture is shown in Figure 2.1.

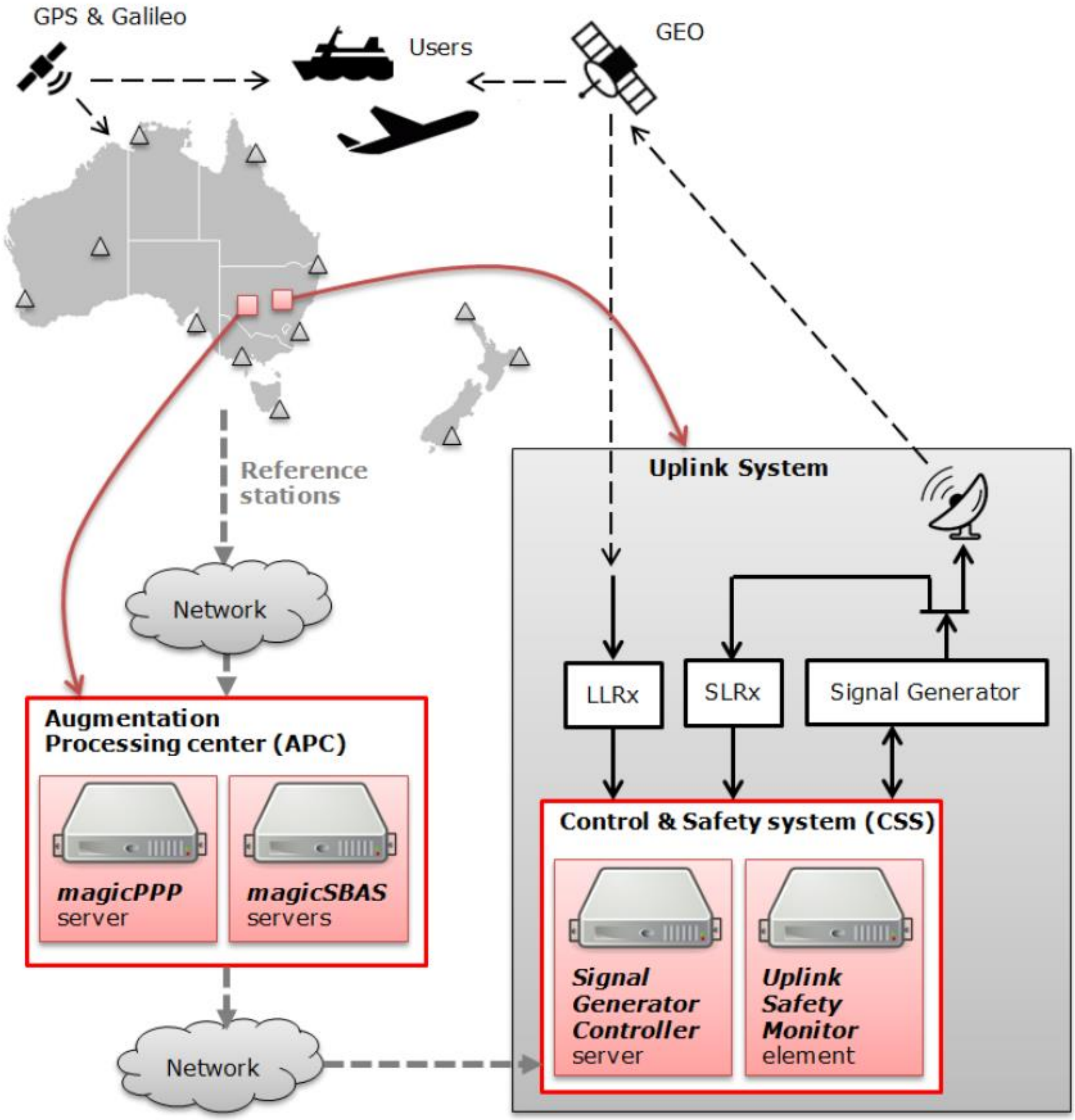

Figure 2.1. SBAS Testbed Architecture (source: Contribution to Architectural Design Document SPADANZ GMV-SPADANZ-ADD-0001_1.B).

The architecture can be split up into four segments as follows:

- Space Segment consisting of GPS and Galileo satellites, as well as the Inmarsat 4F1 satellite responsible for broadcasting the SBAS signal
- Ground Segment consisting of:

- Reference Station Network comprising of stations in Australia and New Zealand that receive raw GNSS observations and transfer them to the Augmentation Processing Centre (APC). The network could be extended to other countries in the region if necessary

- APC gathers the raw GNSS observations from the CORS sites and processes them to compute the SBAS and PPP corrections. GMV's magicSBAS and magicPPP software are used for this purpose

- Uplink system receives digital messages from the APC and transforms them into analog RF signals using the Signal Generator and then sends them to the 4F1 satellite using the RFU antenna. The signal generation process is controlled by the Signal Generation Controller (SGC) and the integrity of the system is checked by the Uplink Safety Monitor (USM)

- User Segment consisting of the users that are receiving GNSS signals together with SBAS or PPP corrections.
- Support Segment, which consists of a web-based tool called magicGNSS Web Monitor and is used to monitor the operation and maintenance of the system. The tool is installed at GMV's premises in Spain and is accessible to the authorised users via a web server.

3. Next Generation SBAS Service Definition

The next generation SBAS testbed will provide access to the following signals:

1. SBAS L1 Legacy Service – GPS single frequency SBAS augmentation signal transmitted on the L1 frequency. Achievable accuracy of sub-metre.
2. SBAS L1/L5 DFMC Service – GPS + Galileo dual frequency SBAS augmentation signal transmitted on the L5 frequency. Improvement in accuracy is expected over the L1 Legacy Service, but the exact amount is unknown since this signal has not been tested anywhere in the world.
3. PPP service – GPS + Galileo precise orbits and clocks broadcast through the SBAS L1 and SBAS L5 signals. PPP broadcast over L1 will be dual-frequency L1-L2 PPP, and over L5 will be dual-frequency L1-L5 PPP. Expected accuracy of 5-10cm.

The signals will be made available in the following order:

- 01 June 2017 SBAS L1 Legacy Service
- 01 August 2017 PPP Service
- 01 October 2017 SBAS DFMC Service

4. User Segment Software Requirements

To carry out the testing of the next generation SBAS signals, some specific field software will be required in addition to the standard GNSS hardware. These software packages will be provided by GMV and are called magicGEMINI, magicAPK and SRX-10 software receiver. These are explained in more detail in this section.

4.1 magicGEMINI

magicGEMINI is a software package running on a Windows platform which is designed to be used with the SBAS services, both Legacy and DFMC. It accepts raw GNSS observations as well as SBAS messages and outputs real-time positioning and corresponding evaluation of the system performance at the user level. Figure 4.1 shows the screen capture of magicGEMINI interface.

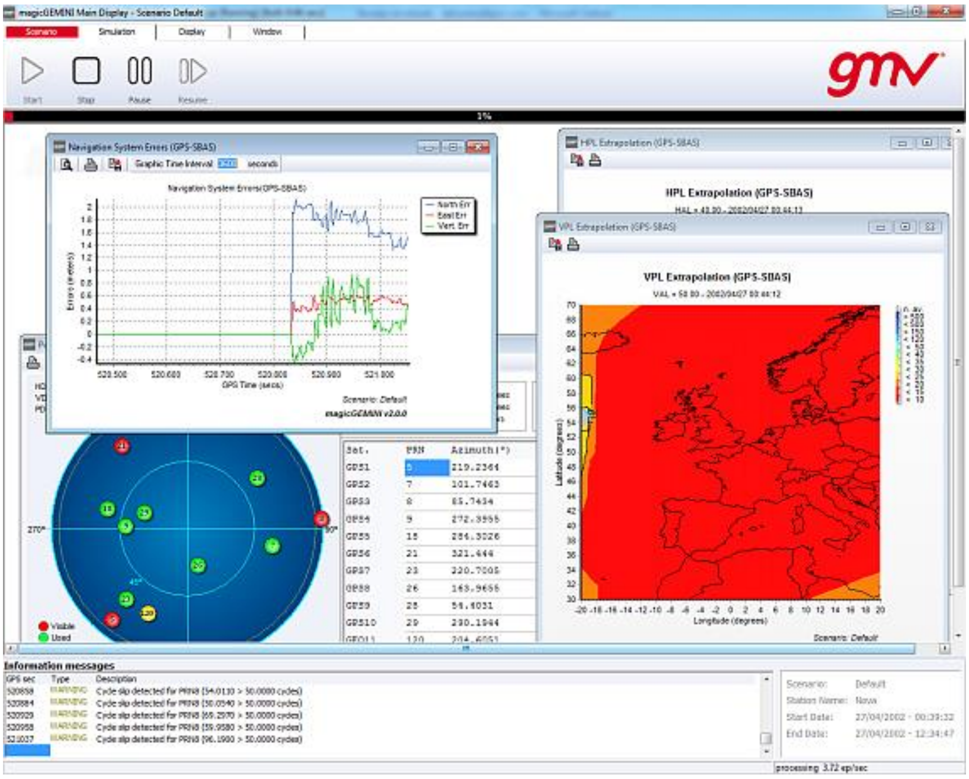

Figure 4.1. magicGEMINI software interface.

magicGEMINI is also capable of post-processing raw GNSS and SBAS data to provide performance of SBAS positioning. magicGEMINI is a performance evaluation software and as such it requires the reference position to be known. For static applications this is a single coordinate, and for kinematic applications this is a trajectory path. An example of the trajectory file is given below:

 # Reference trajectory file
 # GPSweek,GPSsec,latitude,longitude,altitude(meters)
1580,200280,40.9408615,-5.5048119,848.4855
1580,200281,40.9408826,-5.504864536,848.5094
1580,200282,40.94090383,-5.504919136,848.5307
1580,200283,40.94092569,-5.504975981,848.5464

Since for most kinematic applications the reference trajectory will not be known in real-time, it is expected that magicGEMINI will be mainly used in post-processed mode to assess the performance of SBAS positioning.

4.2 magicAPK

magicAPK is PPP client software running on either Android or Linux platform which is designed to be used with the PPP service. The software takes raw GNSS observations as well as the PPP corrections from the geostationary satellite as input and uses it to compute the receiver's position. The output product of the software is real-time GNSS receiver position along with associated quality information. Figure 4.2 shows the screen captures of magicAPK interface.

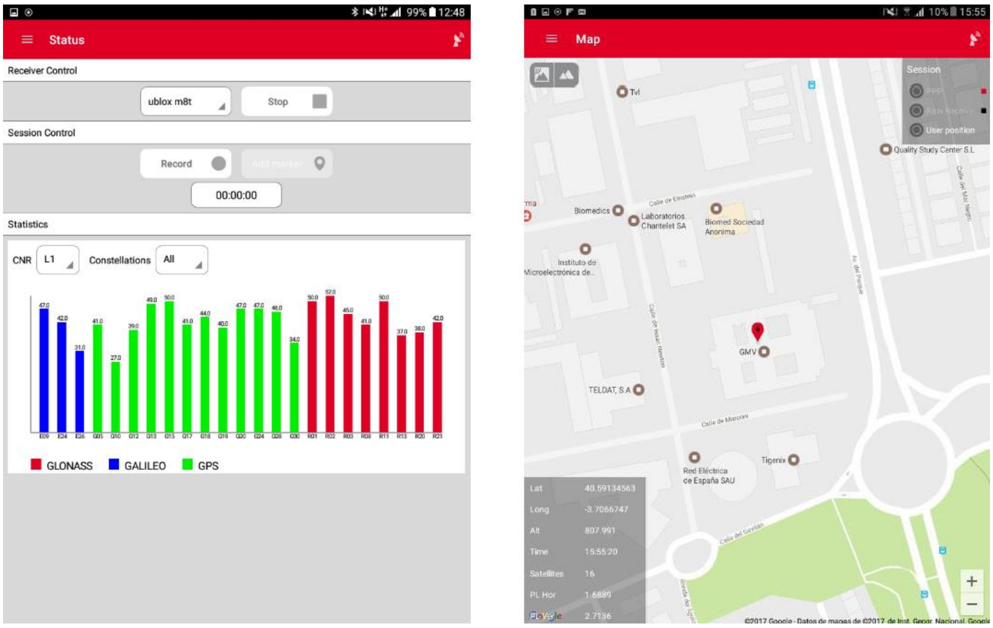

Figure 4.2. magicAPK software interface.

Unlike magicGEMINI, which is a performance evaluation software, magicAPK is a position computation software and as such it will be need to be used in real-time.

4.3 SRX-10 Software receiver

Currently there are no commercial GNSS receivers capable of processing L5 SBAS DFMC and PPP messages, and consequently GMV's SRX-10 software receiver will need to be added to the testing configuration. The software receiver acts exactly like a GNSS hardware receiver except all processing is done on the microprocessor of the PC instead of on the hardware chip of the receiver. The only hardware that is required is known as a *frontend* which digitises the signals from the satellites.

In this case the SRX-10 is used together with a frontend which can capture and decode the DFMC and PPP messages and transfer them to either magicGEMINI or magicAPK software depending on the application. The frontend is shown in Figure 4.3 below.

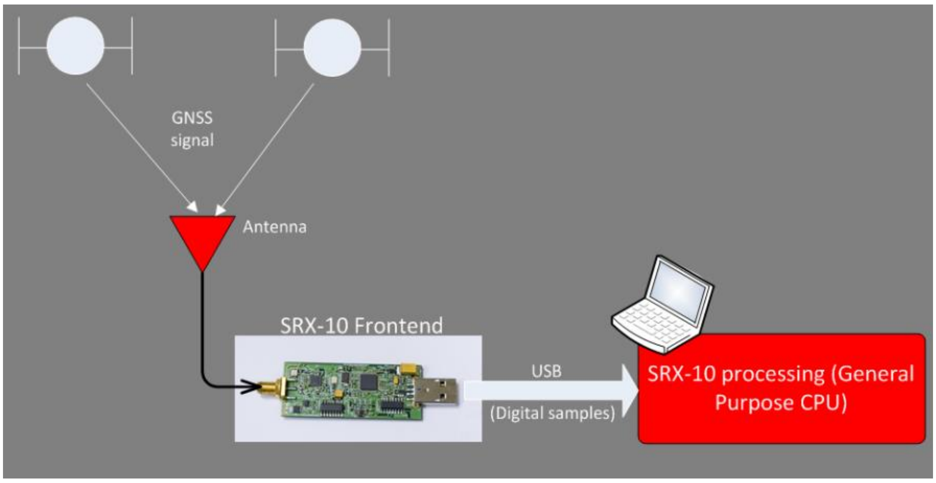

Figure 4.3. SRX-10 frontend.

In case of PPP testing, a single Linux laptop/tablet will be required to run both SRX-10 software receiver and the magicAPK software. In case of DFMC testing, two tablets will be required – a Linux tablet with SRX-10 software receiver and a Windows tablet with magicGEMINI software.

5. User Segment Hardware Requirements

5.1 Current hardware requirements

Hardware requirements will depend on the type of signal being tested and on the application. For the L1 Legacy service, current SBAS-capable GNSS receivers will be suitable without any additional hardware. A firmware upgrade might be required to account for the new PRN number that will be used to transmit the SBAS messages. For the DFMC and PPP testing, an additional software receiver with a frontend and a tablet will be required.

In terms of GNSS equipment, a dual-frequency geodetic receiver would be a preferred option since it will allow the validation of the results by post-processing. However, depending on the application, other (SBAS-capable) devices might also used, including handheld and consumer grade devices.

For SBAS applications a lot of testing can be in post-processed mode, in other words only data logging will take place during the test and the data will be replayed in magicGEMINI software. The data can be processed in a number of ways including GPS only and GPS+SBAS, so that meaningful comparison in positioning can be made.

The hardware requirements are summarised below.

1. a) SBAS L1 Legacy Service with receiver manufacturer tablet and software:

- SBAS capable L1 GNSS receiver with antenna
- Controller/tablet with manufacturer receiver software

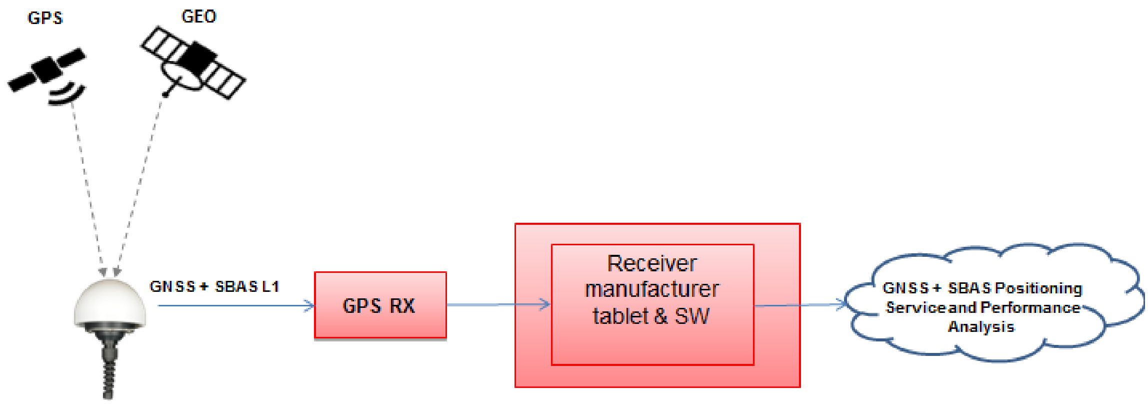

Figure 5.1. SBAS L1 Legacy scenario with receiver manufacturer software.

b) SBAS L1 Legacy Service with magicGEMINI software:

- SBAS capable L1 GNSS receiver with antenna
- Windows tablet with GMV's magicGEMINI software

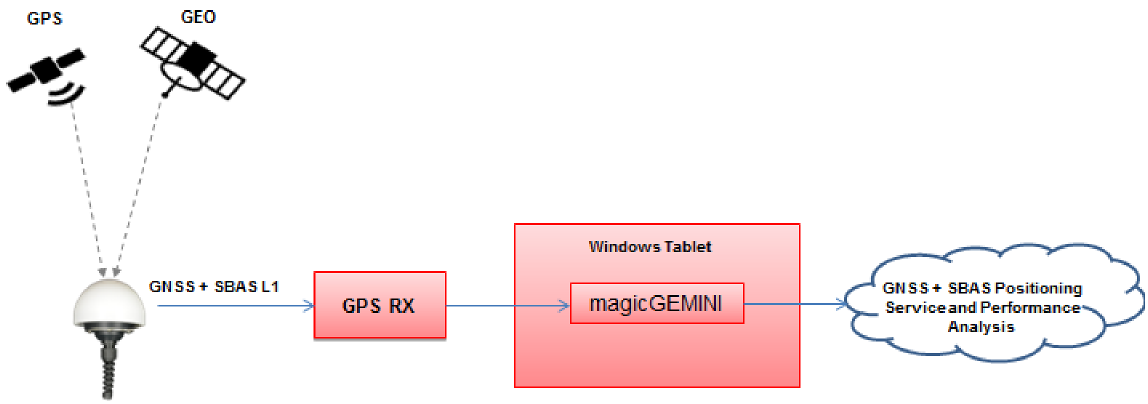

Figure 5.2. SBAS L1 Legacy scenario with magicGEMINI software

2. a) SBAS DFMC L1/L5 GPS + Galileo Service with SBAS L5 capable receiver:

- SBAS capable L1/L5 GNSS receiver with antenna
- Windows tablet with GMV's magicGEMINI software

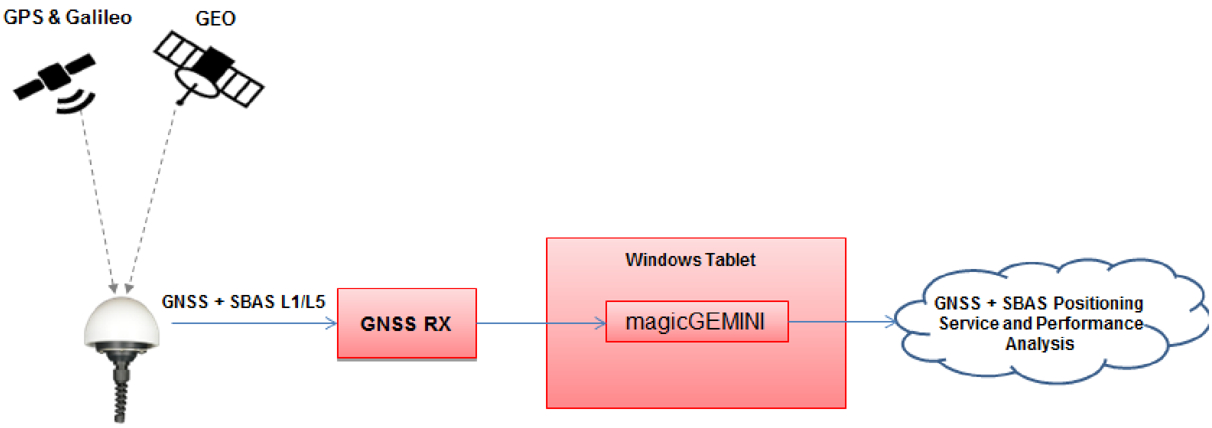

Figure 5.3. SBAS DFMC scenario with SBAS L5 capable receiver.

SBAS DFMC L1/L5 GPS + Galileo Service without SBAS L5 capable receiver

- L1/L5 GNSS receiver with antenna
- GMV's SRX-10 front end including Linux tablet with SRX-10 software receiver
- Windows tablet with magicGEMINI software

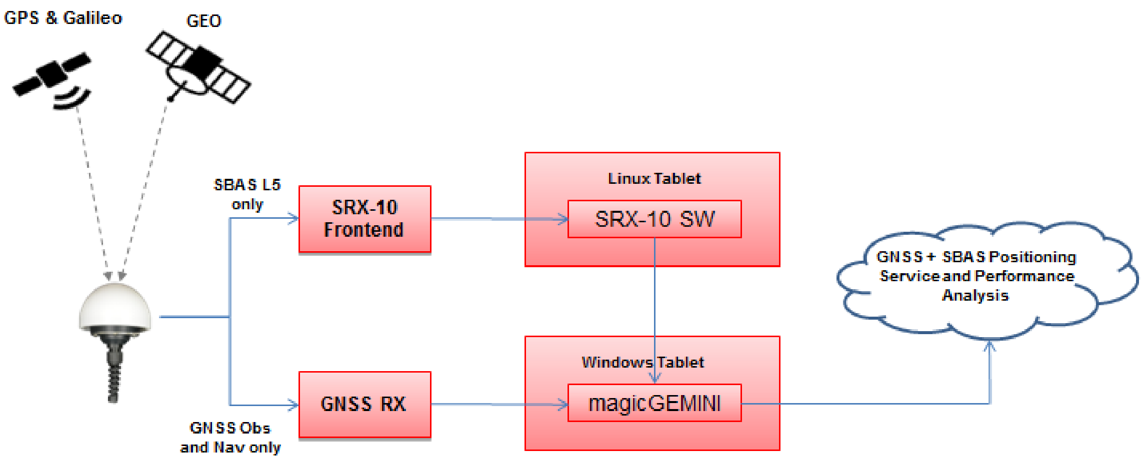

Figure 5.4. SBAS DFMC scenario without SBAS L5 capable receiver.

3. a) PPP Service over L1 with dual frequency GPS receiver

- SBAS capable L1/L2 GPS receiver with antenna
- Android or Linux tablet with GMV's magicAPK software

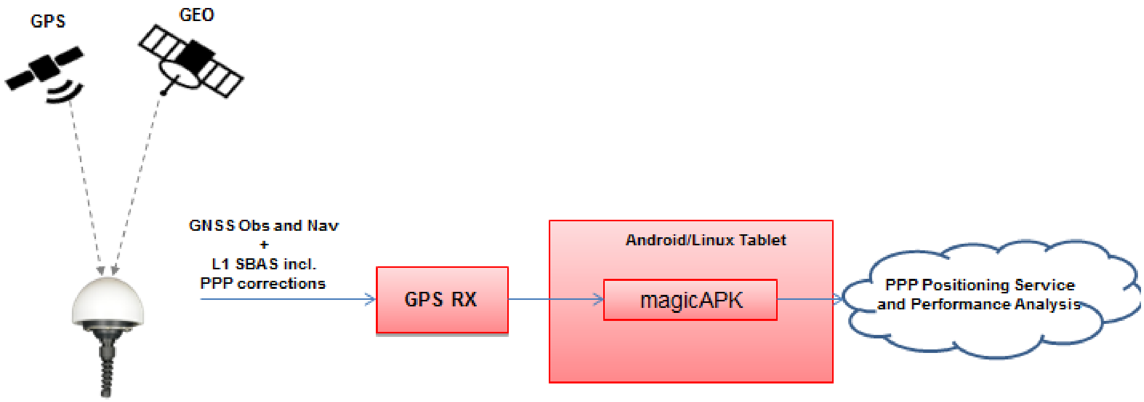

Figure 5.5. PPP over L1 scenario with SBAS L1 capable receiver.

b) PPP Service over L5 with triple frequency GNSS receiver

- L1/L5 GNSS receiver with antenna
- GMV's SRX-10 front end including Linux tablet with SRX-10 software receiver and magicAPK software

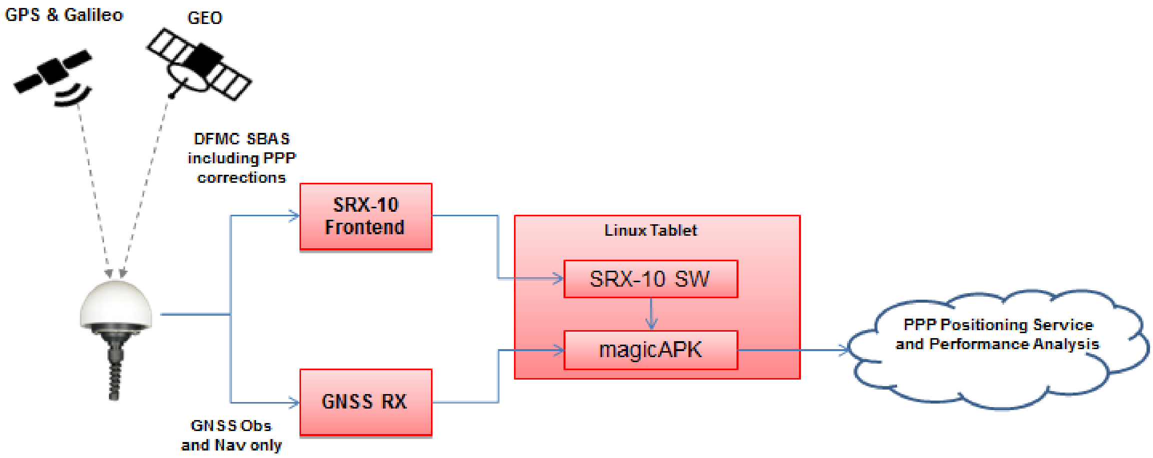

Figure 5.6. PPP over L5 scenario with triple frequency GNSS receiver.

5.2 Future hardware requirements

As stated earlier, currently there are no receivers capable of decoding the DFMC standard. GMV is currently working on a new device which will be able to decode all the signals transmitted through the SBAS testbed. The new receiver will be in a form of a tablet running on an Android platform. It will be used together with a multi-GNSS antenna to track GPS and Galileo signals, and will be able to perform positioning using all the SBAS and PPP services.

It is expected this receiver should become available in February 2018 for the use of SBAS testbed projects. The device will have the following dimensions 210mm x 110mm x 50mm. Other specifications such as weight and battery life are unknown at this point.

6. Satellite Availability

There is currently a limited number of GPS and Galileo satellites that transmit on the L5 frequency. This will place some constraints on DFMC and PPP testing as sufficient number of satellites is needed to achieve high quality positioning. There are currently 12 GPS BlockIIF satellites that transmit on the L5 frequency and 11 Galileo satellites transmitting on the E5b frequency (same as L5) with 4 more Galileo satellites undergoing commissioning and expected to be up and running sometime during 2017. The GPS satellites that transmit on L5 have the following PRNs – 1, 3, 6, 8, 9, 10, 24, 25, 26, 27, 30 and 32.

There are several GNSS planning tools available online to predict the number of satellites above a certain location at a certain point in time. Links to two such resources are provided below:

Trimble - http://www.gnssplanningonline.com[1]
Navmatix - http://gnssmissionplanning.com/

The Navmatix software has included PRN122 under available SBAS satellites. An example simulation is shown below for Melbourne on the 1st January 2018.

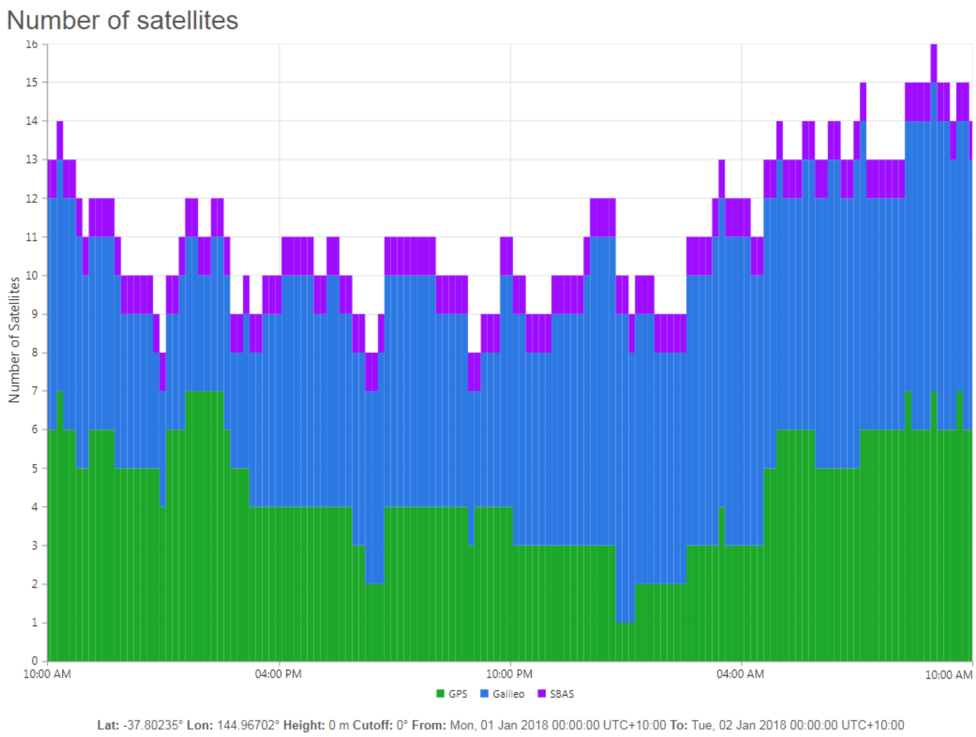

Figure 6.1. GNSS planning simulation.

It can be seen that in this example there are periods of time when total satellite numbers are low (less than 6) and hence testing should not be carried out during these times. These numbers will be different for other locations and other times, so it is up to the users to plan their testing carefully to take full advantage of the new signals without sacrificing the quality of positioning.

[1] This website uses Microsoft Silverlight plug-in and as such may not work in some browsers.