SNAV: SBAS self-standing Navigation Payload based on Artemis Experience.

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Abstract

The design of the European EGNOS system is conceived taking into consideration its interoperability with other adjacent Satellite Based Augmentation Systems (SBAS), like the U.S. Wide Area Augmentation System (WAAS), the Canadian WAAS (CWAAS) or Japan's Multi-Satellite Augmentation System (MSAS).

Those systems are currently under development, and a market for SBAS payload is expected for the new years, waiting for the introduction of GNSS-2 services late in the next decade.

Based on the development of the Navigation Payload on board the Artemis satellite, Alenia Aerospazio has studied the characteristics of this kind of payload. In particular the modifications and improvements of the qualified flight-unit have been identified in order to minimise the interfaces with the hosting satellite, and to propose a true SBAS "piggy-back" terminal.

This paper summarises the overall measured results of the Artemis navigation flight unit and provides all technical and programmatic indications for a full self-standing SBAS P/L, called SNAV. It is expected that the SNAV product will fulfil future SBAS's GEO upgrade needs with a flexible, economical and fast-to-implement performing solution.

Introduction.

The design of EGNOS is conceived taking into consideration its interoperability with other adjacent Satellite Based Augmentation Systems (SBAS), like the U.S. Wide Area Augmentation System (WAAS), the Canadian WAAS (CWAAS) or Japan's Multi-Satellite Augmentation System (MSAS).

At the moment, the EGNOS system is using the navigation transponders embarked on two Inmarsat satellites (AOR-E and IOR). However, to provide sole means operational capability, additional GEO satellites need to be placed and an adequate replacement policy needs to be defined. The European Space Agency has taken a first step in this direction by implementing a Navigation Payload (NAV-P/L) on board ESA's ARTEMIS satellite manufactured by Alenia Aerospazio

The NAV-P/L has been conceived as separate independent unit, which makes use of the available satellite resources only for the Ku-band link, apart from the power and control functions. Therefore a concept which goes toward the optional "piggy-back" approach has been originally used for this development.

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As those systems are currently under development, a market for SBAS payload is expected for the new years, waiting for the introduction of GNSS-2 services late in the next decade.

Based on the Artemis development, Alenia Aerospazio has studied the characteristics of this kind of payload. In particular the modifications and improvements of the qualified flight payload unit have been identified in order to minimise the interfaces with the hosting satellite, and to propose a true SBAS "piggy-back" terminal.

EGNOS and International systems.

The EGNOS system, jointly implemented by the European Space Agency (ESA), the Commission of the European Union (CEU) and EUROCONTROL, will provide a regional augmentation service to GPS and GLONASS systems. Those augmentations are obtained by providing a GPS-like Geostationary Ranging service (R-GEO) and by broadcasting Wide

Area Differential (WAD) corrections as well as integrity monitoring data through the Ground Integrity Channel (GIC) to the user. The EGNOS system is intended to provide enhanced navigation performance in terms of accuracy and integrity (with the required levels of availability and continuity) over the European Civil Aviation Conference (ECAC) region, expandable over neighbouring regions.

The design of EGNOS is conceived taking into consideration its interoperability with other adjacent Satellite Based Augmentation Systems (SBAS), like the U.S. Wide Area Augmentation System (WAAS), the Canadian WAAS (CWAAS) or Japan's Multi-Satellite Augmentation System (MSAS). For a Tutorial on the EGNOS system, the reader is referred to [1] and [2]. Reference [3], on the other hand, provides a summary of the different SBAS's interoperability objectives under current analysis through dedicated Interoperability Working Groups.

In a first step, EGNOS planned to deploy its Advanced Operational Capability (AOC) using only two of the INMARSAT-III navigation transponders (AOR-E and IOR), and the corresponding Ground Segment and Support Facilities infrastructure. The use of the two INMARSAT satellites provides double coverage in most of the continental ECAC region, while in the EGNOS Atlantic oceanic region, only single coverage is provided in AOC. Aiming at providing sole means operational capability, additional GEO satellites need to be placed and an adequate replacement policy needs to be defined. The European Space Agency has taken a first step in this direction by implementing a Navigation Payload on board ESA's ARTEMIS satellite. When launched in Feb 2000, it is intended that this satellite joins the two INMARSAT satellites, thus enhancing the EGNOS AOC performance. Future EGNOS satellites (needed to replaced existing ones) may well be based on the SNAV concept presented in that paper. In addition, the expansion of EGNOS into other regions and/or the request to provide an adequate service on intermediate regions between the planned SBAS systems (e.g. in the Asian continent between EGNOS and the Japanese MSAS system) may also require dedicated Navigation transponders. Based on the Artemis experience, the SNAV solution discussed in this paper, may well be the most cost/beneficial solution.

The Artemis NAV-P/L.

The NAV-P/L has been conceived as separate independent unit, which makes use of the available satellite resources only for the Ku-band link, apart from the power and control functions. Therefore a concept which goes toward the optional "piggy-back" approach has been used for this development.

The block diagram of the NAV-P/L is given in figure 1. The part inside the dashed box is contained into the terminal, whose photo (PFM model) is in figure 2. The measured performances of the P/L are given in the following table. The NAV-P/L has undergone the final performance qualification tests and is in already integrated on the Artemis satellite (see figure 3) at the time of writing these lines.

A comprehensive description of the Artemis NAV-P/L can be found in [5].

Navigation Payload major Performance Requirements	
Receive Frequency	13875 MHz
Transmit Frequencies	12748 MHz, 1575.42 MHz
Useful Bandwidth	4 MHz
G/T	> -2.3 dB/K
EIRP	> 17 dBW Ku, > 27 dBW L
Frequency stability	$2*10^{-11}$ (1s to 10 s), 10^{-9} (24 h) $2*10^{-7}$ (life)

Table 1 : NAV Payload specified performance

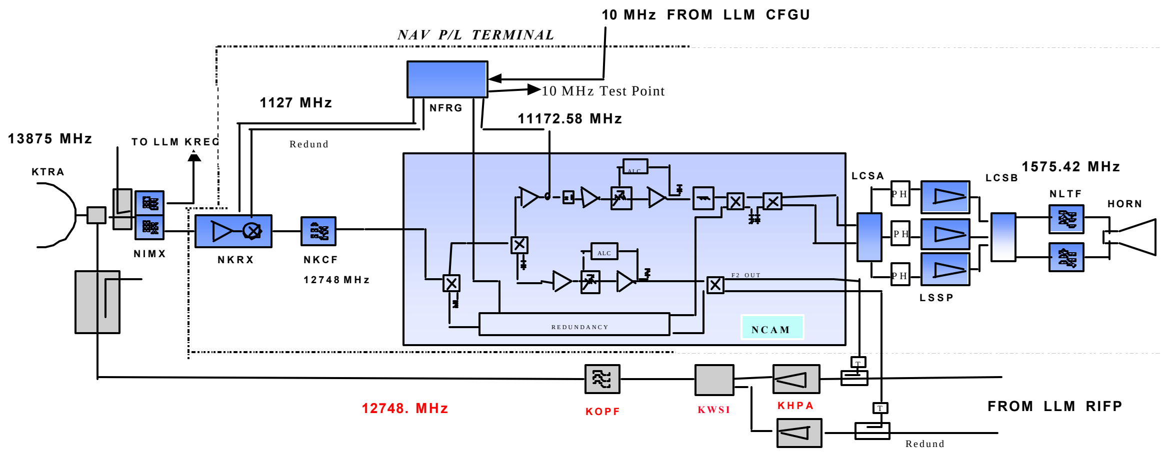


FIGURE 1. NAV P/L Block Diagram

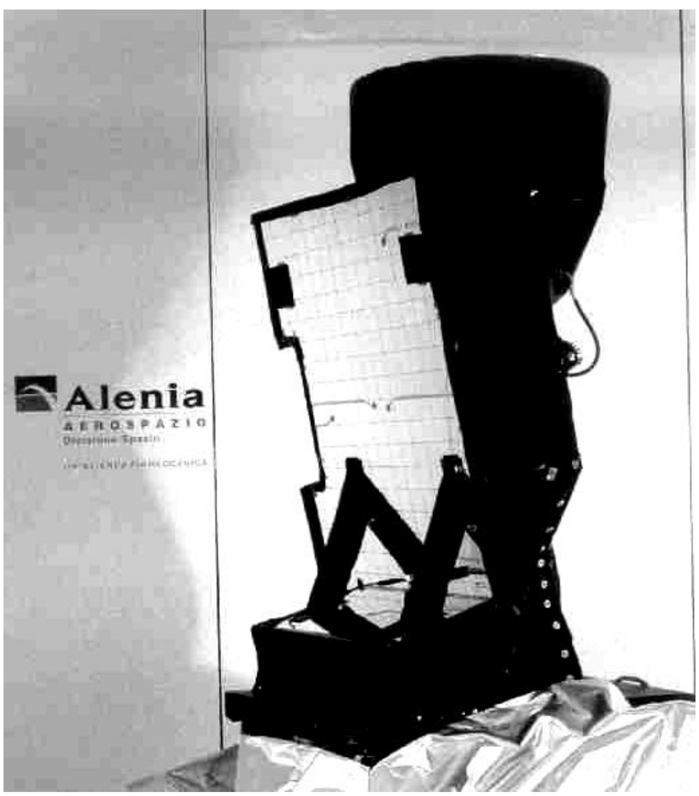


Figure 2. NAV P/L Terminal (PFM).

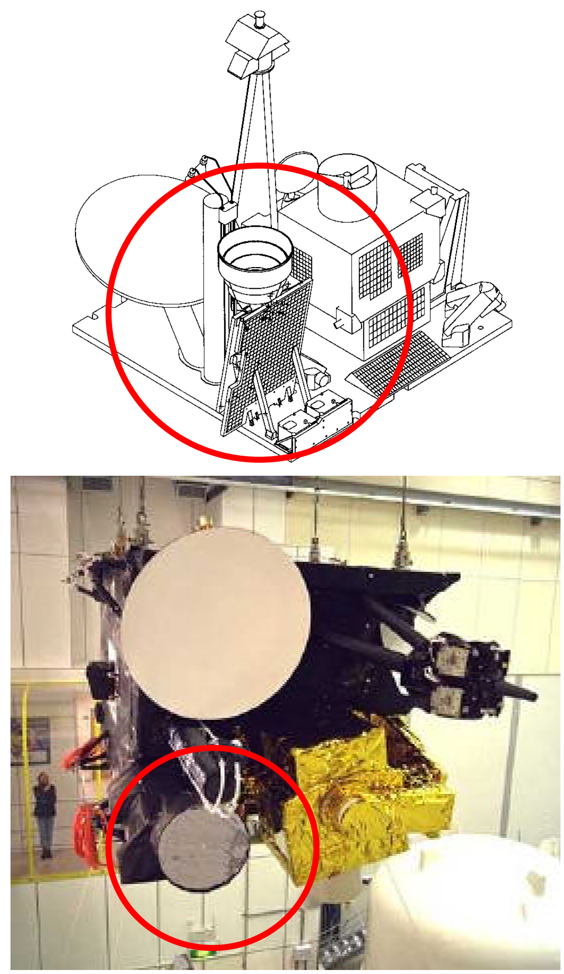


Figure 3: NAV payload on Artemis

SNAV

Based on the experience of the Artemis NAV-P/L, a study has been carried out to identify the modifications to the existing design to use it for any other application beyond Artemis. In particular modifications and improvements to the NAV-P/L have been studied in order to minimise the interfaces to the hosting satellite and to propose a true "piggy-back" terminal. In the following we provide a first level assessment of the Self-Standing payload, at present in the design and specification phase. In the following figure we report the schematic block diagram putting into evidence the areas in which further modifications are foreseen w.r.t. the Artemis Nav P/L.

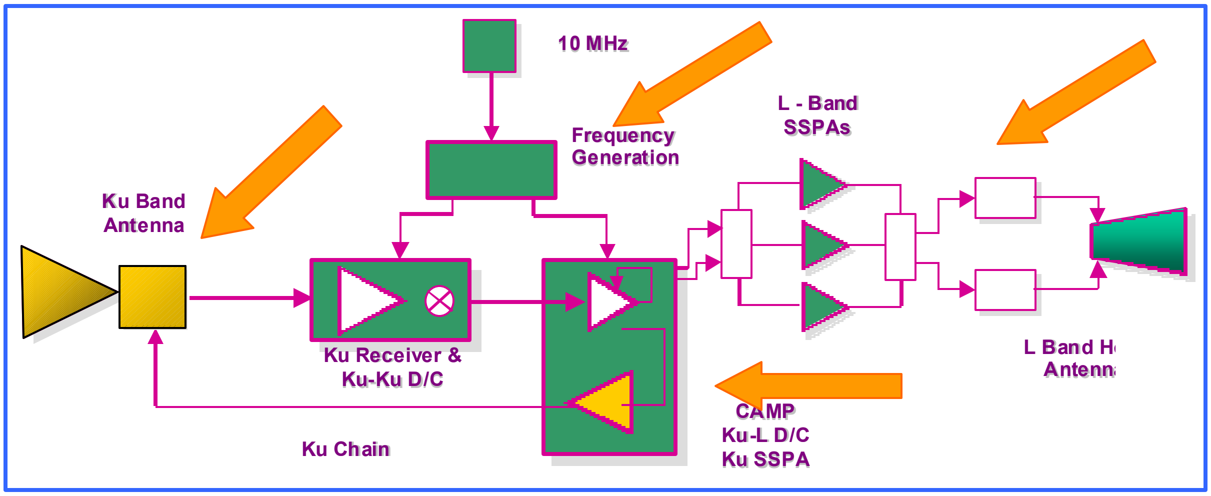


Figure 4: Self-Standing Nav payload –SNAV- schematic block diagram

The basic modifications cover:

- Ku band antenna (horn)
- modified channel amplifier with an additional Ku band SSPA
- a NFRG with the NUSO mounted on the P/L panel
- modified mechanical structure (to accommo date the NUSO and the new NCAM)
- L -Band patch antenna as possible alternative of the L-Band Horn

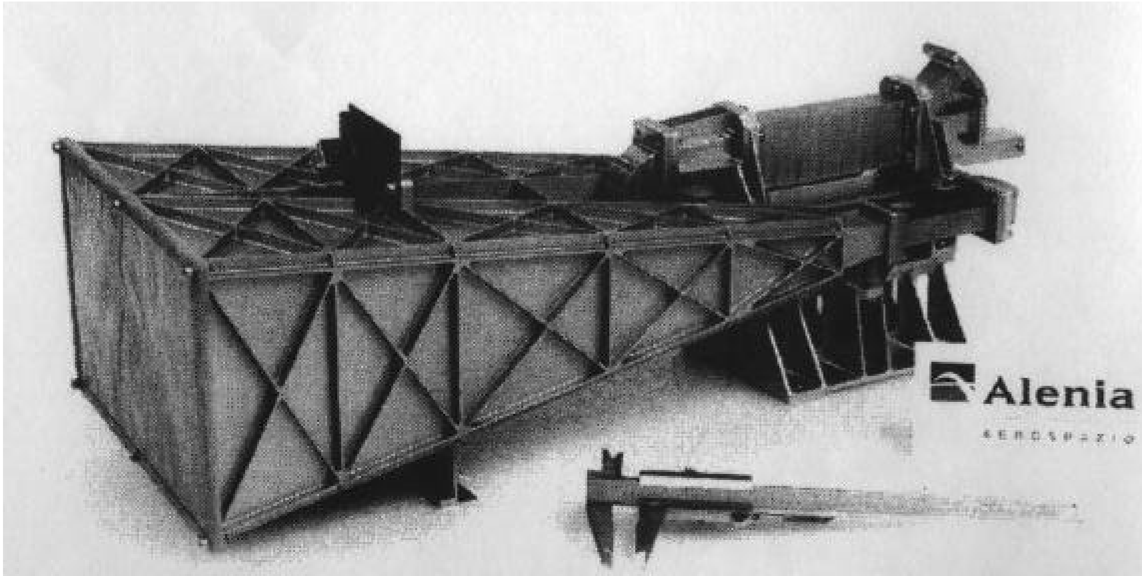
Next table shows the Ku side RF power requirements.

Specified IPFD	Antenna ReceivingGa in EOC	Signal Level at Repeater Input	Required minimum EIRP at Ku Band	Power level at Ku Band Repeater Output
-71 dBW down for 15 dB	22 dBi	-63 to-78 dBm	17 dBW	26 dBm EOL

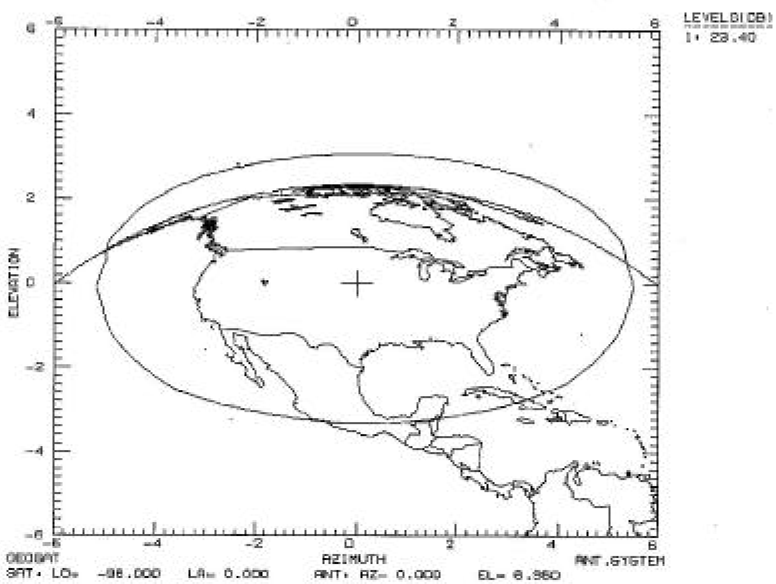
Table 2: Ku band side RF requirements

The payload SNAV is capable to receive a like-GPS signal having the useful bandwidth of 4 MHz around a centre frequency, selectable between 13750.42 and 14000.42 MHz , and to provide a Ku Band signal at the output frequency between 12500.42 MHz and 12750.42 MHz. The L Band output signal is at the fixed frequency of 1575.42 MHz.

The Ku Band antenna is realis ed by using a Two Pyramidal Horn, already developed by ALS in the frame of W24 program, followed by a coupler, able to receive in X or Y polarisation and to transmit in X or Y polarisation. The beam is an elliptical having a width of 11.2°X 6.4°. The EOC gain at the up-link frequency is 22 dB. This Horn has the aperture of 210mm X 132 mm and an axial length of 544 mm. The figure 5 shows this antenna. The Ku Band Horn, together with the WG couplers used for Test Purpose, can be placed on the external side of the Terminal North Panel.



The W24 antenna has been designed to cover the Europe but his pointing can be also changed to cover any zone of the earth with the specified coverage beam. The figure 6 shows a possible coverage of the North America. The hom axis can be rotated by up to 90° prior to the launch with expect to the orientation where the major ellipse axis is aligned in the east-west direction.

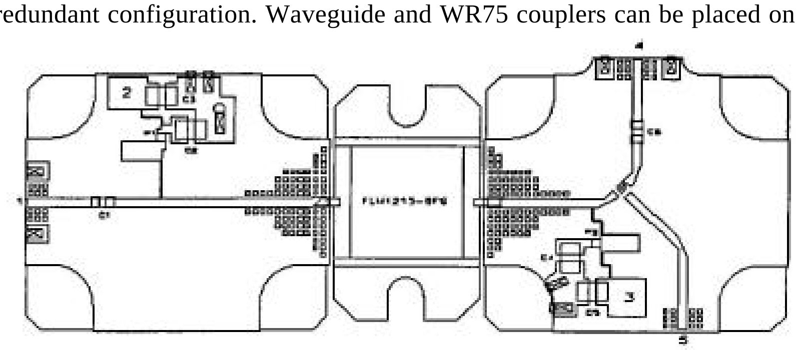


F=13.75 GHz / Y-pol / US-Canada coverage

The transmit L-Band patch antenna is composed by 8 active stacked patches displaced on a circle with an angular step of 45° and a central parasitic stacked patch. The diameter of the whole array is about 500 mm and the weight foreseen is 1.2 Kg. The RHCP signal is obtained starting from two independents linear and orthogonal polarisation.

Figure 6 – USA Coverage

To obtain the needed power at the Repeater Ku Band output, an amplifier of 32 dBm is needed. The NCAM channel amplifier has to be modified to include the power amplifier. The following figure shows the layout of the final power stage realised with the FLM1213-4C Fujitsu. The estimated power consumption for the NCAM will be 17 Watt including DC/DC converter efficiency. This means an increment of 10 Watt compared to the actual power consumption of the NAV P/L. The NFRG used into the Navigation P/L of Artemis uses a 10 MHz reference USO available at Satellite Level. A possible modification of the NFRG can include the 10 MHz reference, in redundant configuration. Waveguide and WR75 couplers can be placed on the external side of the North panel of the Terminal as shown in the next page. The estimated mass of these additional parts is 0.45 Kg.



In addition a couple of filters in the receiving and transmitted side, respectively will be added. It is estimated that the panel will be different from the available in NAV P/L Artemis, where the Terminal panels perimeter was not rectangular for mounting constraints caused by the S/C lack of space. The North panel, in particular, is modified so having an increase of the surface area. This increase is needed to mount the extra hardware. The mass increment is estimated about 200-gr. Total mass/power increment is shown in Table 3.

Mass increment		Power increment
L Band Horn	-3.3 Kg (not used)	
L Band Patch	+1.2 Kg	
Ku Band Horn	+1.7 Kg	
KOPF Output filter	+ 0.40 Kg	
NIMX Input filter	+ 0.20 Kg	
Couplers + WG +Panel	+ 0.65 Kg	
NFRG+n°2 USO	+1.2 Kg	+ 4 W
NCAM	+0.5 Kg	+ 10 W
Total	+ 2.55 Kg	+ 14 W

Table 3: Mass/Power increment

As in the table is evident, small mass and power consumption increments are evaluated for the self-standing navigation payload. The advantage of this new design is the possibility to mount the Terminal for the Navigation service in each possible geo - stationary satellite, providing also the capability to cover an area of the earth indicated by the customer with an elliptical beam.

Conclusions

Based on the development of the Navigation Payload on board the Artemis satellite, Alenia Aerospazio has studied the characteristics of payloads suited for Satellite Based Augmentation Systems (SBAS). Modifications and improvements to the NAV-P/L have been studied in order to minimise the interfaces to the hosting satellite and to propose a true "piggy-back" terminal named SNAV.The study has demonstrated the viability of the approach. It is expected that the SNAV product will fulfil future SBAS's GEO upgrade needs with a flexible, economical and fast-to-implement performing solution.

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