MICROWAVE EQUIPMENT FOR NAVIGATION OVERLAY (NOS) SERVICE

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Abstract

The aim of the Navigation Overlay Service (NOS) payload (NOS P/L) is to provide an overlay function with supplementary services to the current operating GPS. This kind of services uses existing GEO telecommunications satellite to transmit overlay signals to provide improvement of accuracy, system's integrity information, wide area differential corrections. This service will be provided, in Europe, by EGNOS (European Geostationary Navigation Overlay Service). A similar service, called WAAS (Wide Area Augmentation Service) will operate in U.S.A. Similar services are also provided in Japan with MT-SAT. The paper will present the architecture of the payload manufactured by Alenia Spazio and embarked on the ESA Artemis satellite.

I. Introduction

The future navigation and air traffic control (ATC) systems will provide augmented performance capabilities in particular for "sole means" operation. Availability and reliability of the service is therefore a critical factor. The use of an open standard (GPS signals) allowed to exploit economies-of-scale and today there is a huge market in GPS receivers and related services, therefore a market for EGNOS/WAAS payload is expected for the next years, waiting for the introduction of GNSS-2 services late in the next decade. Conceived as a forerunner of a NOS payloads family, the Artemis NOS P/L has been designed to be fully compliant to EGNOS/WAAS performance requirements and in order to minimize the interfaces with the hosting satellite. The key choice made is to build a transponder in which most of the RF units (and the L band antenna) are accommodated on a small panel, mounted on the satellite top-floor. This solution allows to optimize the payload integration and testing, thus reducing the risks in terms of performance and schedule. The NOS payload here presented has been successfully qualified in the Artemis program frame, through a STM and PFM test campaign.

II. The Artemis NOS Payload

The Artemis NOS payload is a transparent transponder capable to receive a signal from a European coverage and to translate it onto two separate downlink carriers, the first operating at L-band (L1) and the second one at Ku band (channel F2). The signal transmitted from the ground is a single 500 bps carrier modulated with a Timing, Integrity, Ranging and other information data, and spread with a PN code a type compatible to those used for GPS. The code orthogonality properties assure the possibility to transmit the NAV signal on the same nominal carrier frequency of the GPS. The signal is a constant envelope Spreaded Signal with main lobe of ±1.023 MHz. Driver parameters for payload are:

- Frequency selection plan
- Group delay stability
- Minimization of interfaces with the hosting satellite (*plug-and-play*)
- Thermomechanical Interfaces with the spacecraft

Parameter	**Value**
Receive frequency	13875 MHz
Transmit frequency L Band	1574.42 MHz
Transmit frequency Ku Band	12748 MHz
Useful bandwidth (UBW)	4 MHz
Ku Band Noise Figure	≤ 5 dB
Frequency stability	$2 \cdot 10^{-7}$ lifetime
Group delay (GD) vs. freq.	15 ns over UBW
Group delay stability	10ns /24 hours
Ku-L band Differential GD stability	< 10 ns
EIRP L1 channel (L Band)	28.2 dBW min
DC Power	135 W
Mass *(10 MHz ref. Included)*	29.7 Kg

Table 1 - NOS payload key parameters

The payload block diagram is shown in figure 1. The uplink signal is received at 13875 MHz by a Ku band communication antenna and filtered by the input multiplexer. To separate the incoming communication signal from the NOS signal and to reduce interference. This filter is mounted directly on the S/C top floor. The input signal is divided in two paths and translated: the heart of the P/L performing this function is the Channel Amplifier NCAM. The low noise amplification is mainly performed by the NKRX (Ku Band Receiver) which provides a noise figure of 2.3 dB and a gain of about 53 dB. The signal is then fed into the Ku-band channel filter. Realised using high Q waveguide dielectric resonator it gives only 10 nSec of group delay variation into the useful bandwidth of 4 MHz. The signal feeds the channel amplifier (NCAM) at the output of the channel filter. The units splits the signal in two paths: one feeds the Ku band transmit section without frequency conversion whil eth eother is down converted to the GPS frequency. The two NCAM output signals are amplified by two SSPAs (NSSP) providing 16 Watts end of life. All the RF units use latest technologies (hybrids, MMICs, MCMs) both for the RF portion and for the control and interface functions.

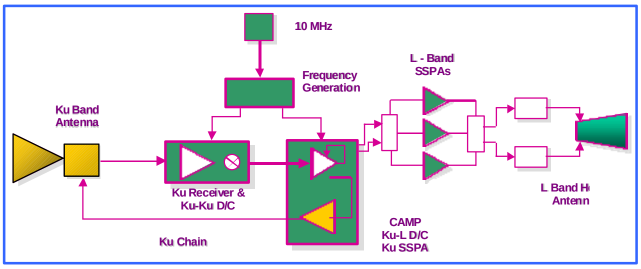

Figure 1 - NOS P/L simplified block diagram (self standing option)

III. The Artemis NOS Payload RF units

Ku Band receiver(NKRX)

The NKRX provides low noise amplification and downconversion of signals at frequency of 13.855-13.895 GHz down to 12.728-12.768 GHz, by means of a net subtraction of an externally generated LO frequency. The equipment is provided with an internal power supply and a command & telemetry interface. The signal is then amplified in a linear amplifier. Group delay, phase, AM/PM conversion and gain are specified as required by NOS P/L performances analysis. The unit is internally redundant and includes a redundant DC/DC converter to derive the required secondary voltages from the satellite main bus. The input interface is WR75 standard, the LO input and the RF output interfaces are SMA 50 ohm. The key technologies characterising the units are:

- MMIC to achieve reduction of dimensions and mass and a high level of reproducibility.
- RF Hybrid technique to house both microwave and low frequency analog/digital integrated circuits.
- ASIC (Application Specific Integrated Circuit) for control and TM/TC interface functions.

A waveguide WR 75 Switch is used to select main or redundant channel. A hybrid hermetic module mostly MMIC based is the core of the NKRX, it integrates the low noise, the mixer and the IF circuits. The low noise amplifier section uses as first stage a hybrid MIC (HMIC) to achieve the best noise figure performances, MMIC exactly the same architecture and circuits described before but is followed in this design by a microstrip filter, providing the proper image frequency rejection. Hybrid mixer using beamlead GaAs Schottky diodes convert the RF signal from the frequency range 12.7-14.7 GHz down to 10.7-12.7 GHz, providing 35 dB typical RF/IF isolation plus strong rejection of even or odd LO harmonics depending on the selected configuration. A IF bandpass filter provides suppression of out-of band mixing products. The rest of the IF section is composed of a cascade of different MMIC circuits which provide the required gain and gain control dynamic. The first gain stage is an MMIC LNA as the one above described: the large passband of the MMIC allows use on the IF section as well, in order for it to have negligible contribution to the overall noise figure. The MESFET process has been used for the MMICs following in the IF chain. The Flatness Corrector (***FC***) circuit gives the possibility to control the gain slope variation consequent to the complete system assembling and possible slope variations over temperature. The gain control block is the ***VGA*** (Variable Gain Amplifier) which is composed of three self-biased stages of amplification with an embedded analog attenuator, allowing compensation of gain drift over temperature of the complete assembly. The analog attenuator design was based on a broadband extended T configuration using cold FETs. This approach was chosen because of its minimal VSWR variation and flat gain response over the attenuation range. A Medium Power Amplifier (***MPA***) is used as the output stage in order to have higher output level and better linearity. The circuit design is single-ended and consists of a two stage amplifier. Output FET gate periphery was selected to achieve a 32 dBm third order intercept point while keeping the channel temperature below 110 °C when in maximum environmental temperature.

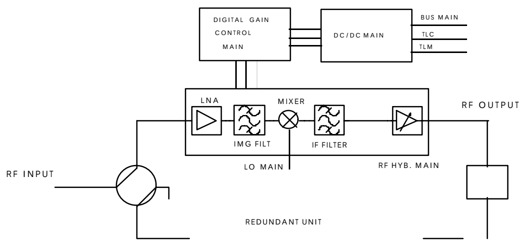

Figure 2 - NKRX conceptual block diagram

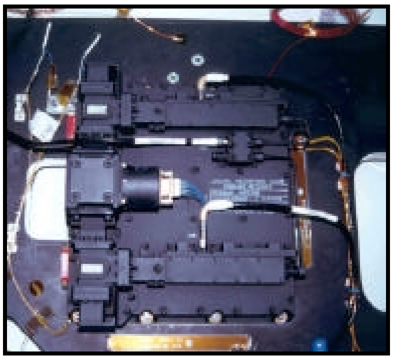

Figure 3 – NKRX mounted on the payload panel

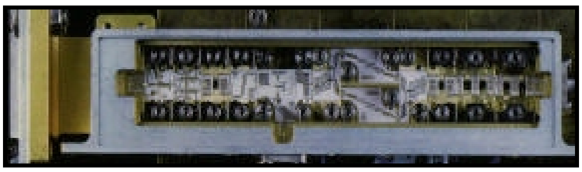

Figure 4 – NKRX Receiver hybrid

Channel Amplifier(NCAM)

The Channel Amplifier (NCAM) is used to amplify the signal to a level suitable to drive the power amplifier. It can be set in two operational modes:

<u>ALC Mode (nominal operation):</u> The amplifier output level is settable, by means of ground command, to different levels. The level control (ALC) loop maintains the output power level within the specified limits recovering uplink variations and input signal dynamic.

<u>Fixed Gain Mode (only for IOT)</u> In Fixed Gain Mode (ALC off) the amplifier provides a fixed gain set by ground command

The unit, internally redundant and equipped with internal DC/DC converter, provides two different outputs:

- **L1** at a frequency of **1575.42 MHz**, generated by means an external local oscillator.
- **F2** at a frequency of **12748 MHz** (no conversion is required).

As in the NKRX, also in NCAM hybrid circuits are used to realize the RF channels and the Digital Control circuits.

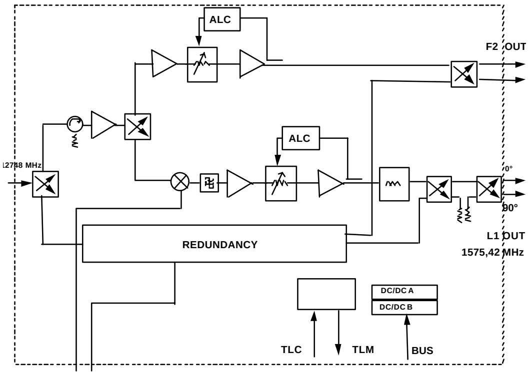

Figure 5 - NCAM Block Diagram

The following modules compose the unit:

- two complete Ku band Channel Amplifier modules (main & redundant)
- two Ku/L RF down converter including channel amplifier functionality (main & redundant)
- Redundant DC/DC Converter
- couplers for redundancy and channels splitting

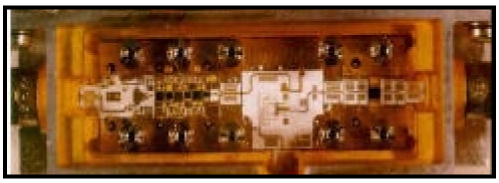

Figure 6 - Ku/L Band downconverter hybrid

Solid State Amplifier (NSSP)

The NSSP Amplifier is used for high power amplification of L band downlink signal.

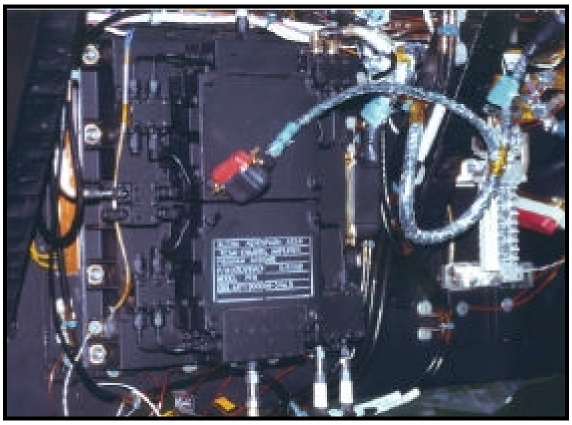

Figure 7 - NCAM units mounted on the panel

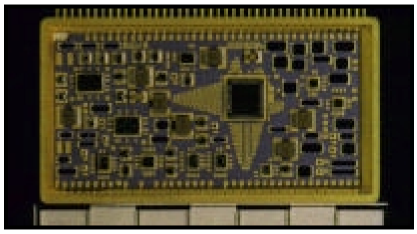

Figure 8 - NCAM TM/TC Multi Chip Module

The NSSP unit, manufactured by MMS, UK (now Astrium UK), consists of:

- An Amplifier module in which high power RF amplification and power generation occur;
- An Electronic Power Conditioner (EPC) which accepts primary bus from the spacecraft and generates the reqired secondary stabilized voltages

The NSSP amplifier is constituted essentially by a MMIC driver stage followed by packaged FET for medium and high power amplification. The EPC foreseen EOL efficiency of 85 %. The amplifier operates in saturation as well as in back-off mode by reducing the input power level. Due to redundancy requirement, three amplifiers are required with two out of three active, each providing 42 dBm min EOL. Matching between amplifiers (in terms of gain and phase) is mandatory.

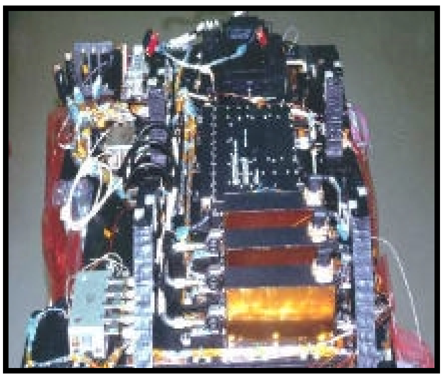

Figure 9 - NSSP units mounted on the panel

Frequency Generation

The Navigation payload Frequency Generation Unit generates two frequencies at L band and X band, using a 10.0 MHz reference signal coming from the external USO. In the Artemis implementation the on-board USO has been used. The unit consisting of the NFRG plus the 10 MHz reference has been specified as a whole, in terms of performance, however the NFRG and the 10 MHz USO are mechanically separated in order to maintain the qualification of the assembly achieved on Artemis for the NFRG and on SICRAL and on UHF Update programs for the 10 MHz USO. The NFRG output frequencies are 1127 MHz and 11172.58 MHz. Direct synthesis approach is used: multiplication is obtained using active stages and step recovery diodes. Quartz filters and helical filters are used to reduce spurs and phase noise to a levels within the specification.

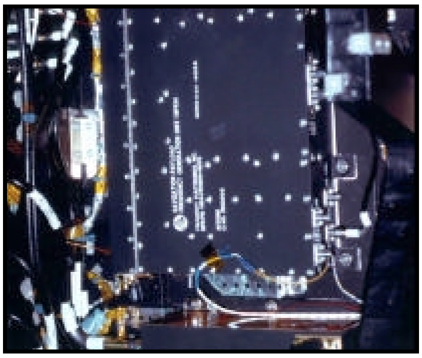

Figure 10 – NFRG mounted on the panel

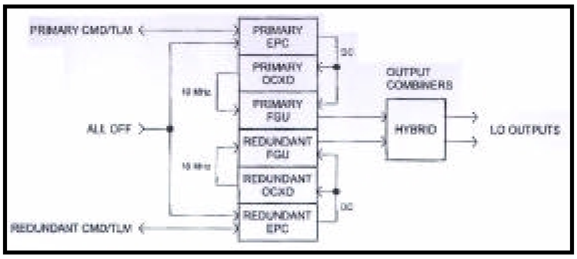

Figure 11 – NFRG Block Diagram

IV. Conclusions

The paper briefly describes the navigation payload embarked on Artemis satellite. The payload operates at Ku band in the uplink and transmits in the down link two replicas of th receiver signal: one at the GPS frequency L1 and the second one at 12.748 GHz.

The key characteristics of the NOS P/L is the accommodation of the RF units and of L band antenna on a small panel. A mass of about 30 Kg and a power consumption of 135 W are the P/L interface figure toward the spacecraft. Advanced microwave design and packaging technologies have been used in the design, development and production of all RF boxes. The Artemis payload is the forerunner of a family of payloads able to fulfill Satellite Based Augmentation Systems (SBAS) and allowing interoperability among the different systems.

Figure 12 – Artemis Navigation complete P/L

Figure 13 – Navigation P/L mounted on the Spacecraft

Evolution of microwave technologies allowed to integrate a quite complex function in a small panel with dimension, power consumption and mechanical constraints such that the allocation on the Artemis spacecraft and in future to GEO telecomm satellites is easily feasible.

V. References

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[3] S.Badessi, G.Leggeri, A.Pullara, G.Oppenhauser: *Toward the EGNOS FOC: the use of ARTEMIS Satellite*; 48th IAF Congress, October 1997