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GPS and Galileo Ground Segment Antenna for Professional Applications

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1. Introduction

Europe has started the development of the Galileo positioning system in order to address the increasing market for positioning applications. Beside the core system including the space segment, satellite constellation and ground segments, user terminals taking full advantage of the Galileo system must be commercially available in time for the Galileo exploitation phase to ease and catalyse the market penetration of the Galileo services. The GARDA project financed by the Galileo Joint undertaking, in the context of the European Commission 6th Framework Programme, has been formed to investigate the development of the user terminals. In the frame of this activity a receiver targeting professional applications based on multi frequency use has been developed.

This paper is divided in four main sections. The first section covers the development strategy and current status of the antenna system. The second section discusses the general specifications parameters of the antenna system for professional applications. The third section describes the selected antenna architecture and the development and trade-off activity on the radiating element, LNA, filters and diplexers. The fourth part describes the antenna measured performance. The next planned activities will also be shortly described with respect to manufacturing of the pre-industrial prototype.

2. Development strategy and status

Initially, the requirements for the user terminal antenna have been defined in collaboration with the end-user. The requirement activity has been performed complementarily with a preliminary design trade-off activity concerning several candidate antennas and antenna architectures using state-of-the art numerical analysis and optimisation algorithms. The trade-off activity comprised more than 15 different radiating elements with technologies including: helices, wire structures, slots, patches, printed antennas and other elements. The three most promising antenna technologies have been selected and further optimised considering the final antenna system requirements including mechanical, environmental, manufacturing, industrialization and cost aspects.

A preliminary prototype of the radiating element including bread boarding of each of the antenna system components LNA, diplexer and filters has been manufactured. The performance of the prototype and RF components has been tested thoroughly before initiating the manufacturing of the pre-industrial prototypes. The conducted and radiated testing of the preliminary prototype also serves as validation and tuning of the numerical models of the antenna. Some design modifications have been applied at this stage. The measured data of the antenna prototype has also allowed completing the libraries for the software simulator of the receiver. Pre-industrial prototypes including all RF components are currently being manufactured. The impact of the industrialization on the design of the pre-industrial prototype will be evaluated and a development plan for industrialization will be defined.

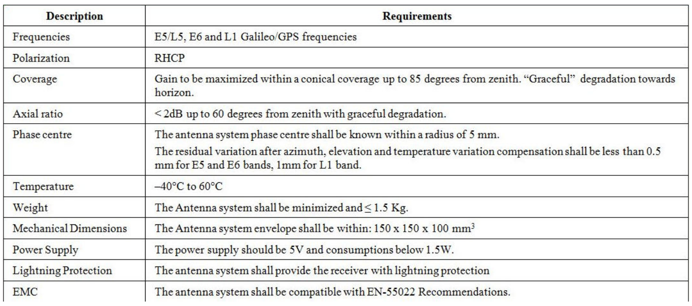
3. Antenna System Specification

The antenna system shall cover the E5/L5, E6 and L1 Galileo/GPS frequency bands with two separate outputs one for each of the L1 and E5/L5/E6 bands. The radiated field is right hand circularly polarized and the gain is maximized within a conical angle up to 85 degrees from the zenith with graceful degradation towards the horizon.

The phase centre location of the antenna system shall be within a 5 mm sphere over each sub-band. The residual variation after azimuth, elevation and temperature variation compensation shall be less than 0.5 mm. The multi-path immunity of the antenna shall be optimised to reduce the influence of the on-site environment close to the antenna.

In addition, the antenna has to be capable of operating in temperature conditions from –40°C to 60°C. The antenna housing shall be hermetically closed such that the antenna is immune to rain water under storming condition.

The main electrical, mechanical and environmental specifications for the antenna system are summarized in Figure 1. Additionally, the antenna system and receiver shall behave nominally when operated in presence of continuous CW interference whose power is defined by the mask reported in Figure 1. This means that the operating point of the antenna LNA in the presence of the useful signal and the interference should be well below saturation. The interference mask shown in the figure is target level for the antenna system since high interference immunity is a trade-off parameter with antenna losses due to filtering. The receiver itself will also provide additional filtering to avoid saturation of the further amplification stages.



Description	Requirements
Frequencies	E5/L5, E6 and L1 Galileo/GPS frequencies
Polarization	RHCP
Coverage	Gain to be maximized within a conical coverage up to 85 degrees from zenith. "Graceful" degradation towards horizon.
Axial ratio	< 2dB up to 60 degrees from zenith with graceful degradation.
Phase centre	The antenna system phase centre shall be known within a radius of 5 mm. The residual variation after azimuth, elevation and temperature variation compensation shall be less than 0.5 mm for E5 and E6 bands, 1mm for L1 band.
Temperature	–40°C to 60°C
Weight	The Antenna system shall be minimized and ≤ 1.5 Kg.
Mechanical Dimensions	The Antenna system envelope shall be within: 150 x 150 x 100 mm^3
Power Supply	The power supply should be 5V and consumptions below 1.5W.
Lightning Protection	The antenna system shall provide the receiver with lightning protection
EMC	The antenna system shall be compatible with EN-55022 Recommendations.

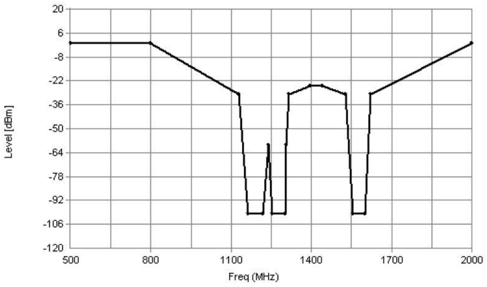


Figure 1: Left: Main electrical, mechanical and environmental specifications for the antenna system. Right: Continuous CW interference mask.

4. Antenna System Description

The radiating element is the first component of the overall antenna and receiver system chain. For this reason ohmic and mismatch losses will have a direct impact on the overall noise figure of the receiver. The seamless integration of the antenna with the LNA is therefore crucial for the functioning of the overall receiver. The two components should be well-matched and ohmic losses avoided by minimizing the path between them. For the same reason losses in the radiating element should be minimized.

The suppression of unwanted signals at neighbouring frequency bands that could cause trouble for further amplification and the functioning of the receiver is also important, although a trade-off between filtering and the associated losses is necessary. The antenna itself will add filtering properties through the matching bandwidth. If the disturbing frequencies are sufficiently distant to the Galileo pertinent frequencies the element itself could provide as much as 20dB filtering when properly optimised.

The size of the radiating element is an important issue for the ease of integration and incorporation of the antenna system with other applications or structures. Minimization of the radiating element is a trade-off between size and the overall antenna efficiency that decreases with the size.

Finally, the choice of suitable materials and components for the antenna, filters and integrated LNA will impact the overall price and quality of the antenna/receiver and impact the feasibility of mass production, if desired. Apart from electrical, manufacturing and cost issues the environmental aspects of the final application will also drive the material selection. Robustness, humidity, corrosion, vibration and thermal issues derived from the application scenario should be taken into account.

The antenna system architecture is such that minor modification to the frequency bands can easily be implemented by changing the filtering units. A block diagram of the antenna system architecture including radiating element, diplexers, filters and LNA's is shown in Figure 2. The selected radiating element is self-diplexing providing separate outputs with the received signals in the L1 and E5/L5/E6 frequency bands. In this way the radiating element provide the first intrinsic interference filtering reducing the additional filtering needed in the subsequent stages and minimizing losses. The design is patent pending so no details of the design will be disclosed here.

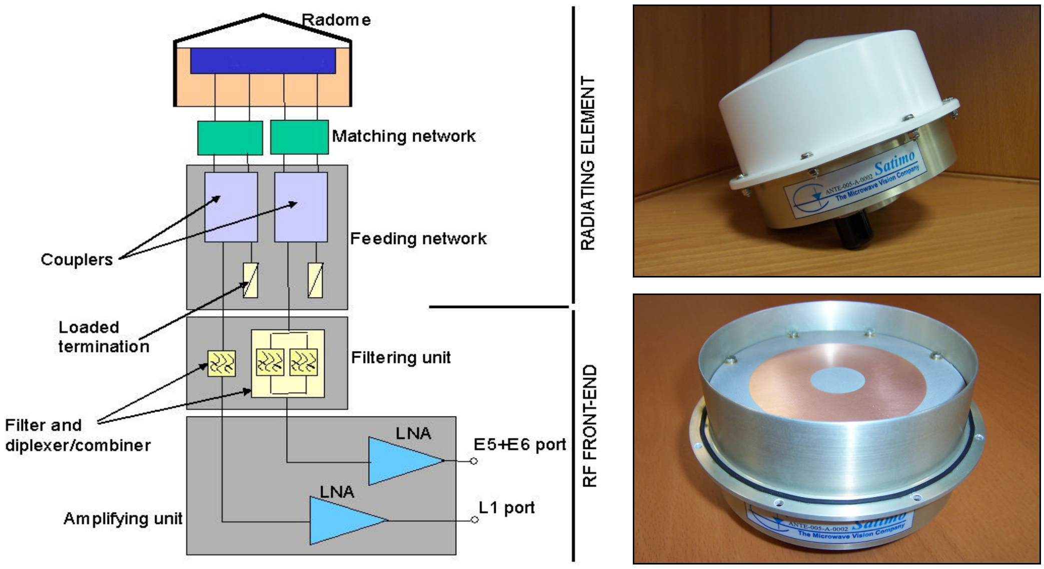


Figure 2: Antenna system architecture; antenna with and without radome.

The couplers serve to provide the correct 3dB/90 deg excitation for the two linear components of the antenna to generate accurately the desired RHCP polarization. The couplers as shown in Figure. 3 are based on a compact branch line design in tri-plate technology and have been optimised and manufactured in-house specifically for the Galileo application.

The filters are realised in low loss ceramic materials with enhanced temperature stability. A further filter design requirement is a limited group delay and group delay variation with temperature.

The LNA is a key component in terms of noise figure and gain. The LNA's have been specifically designed for the Galileo/GPS frequencies. The LNA design requires a 5V power supply, low power consumption, 0.8dB noise figure and comes in two configurations with 20 or 30dB power gain.

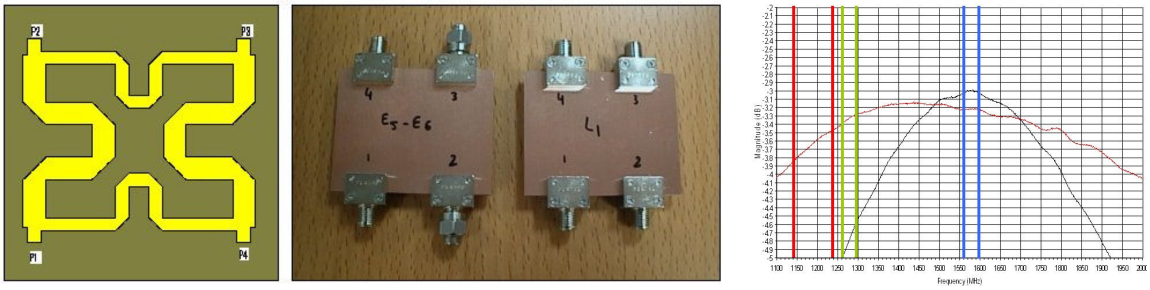


Figure 3: L1 band, 3dB/90deg couplers in tri-plate technology with measured amplitude balance (left: layout, centre: implemented circuits, right: measured amplitude balance)

5. Antenna Measured Performance

The transportable antenna has been measured in the spherical near field test range at Satimo. The measured gain (co- and cross-polarization) is presented in Figure 4 for the center and edge frequencies of the sub-bands. The shape of the radiation pattern is constant over the whole frequency bands. The ohmic losses of the antenna (feeding circuit + patches) are plotted in Figure 5 versus frequency. The mean value of the ohmic losses over the Galileo frequency bands amounts to 0.87 dB. The measured multi-path ratio and phase variations over elevation are shown in Figure 6 and Figure 7, respectively. The results of the measurements including the phase center variations are summarized in Table 1. The phase center sphere variations show the very stable properties of this antenna dedicated for positioning application.

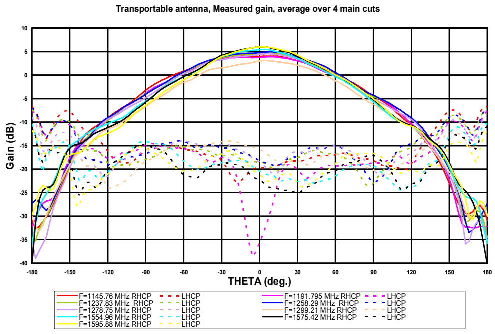


Figure 4: Measured gain

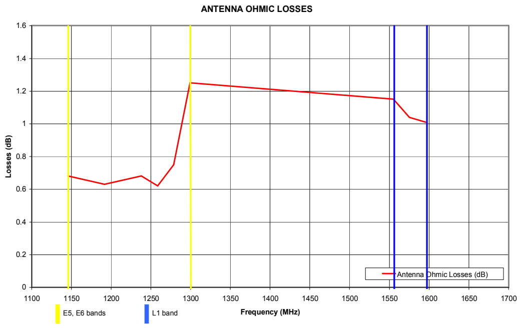


Figure 5: Measured ohmic losses

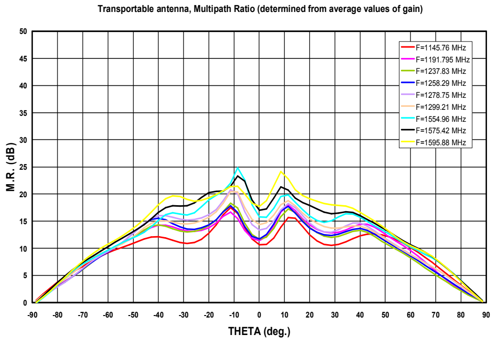


Figure 6: Measured multi-path ratio

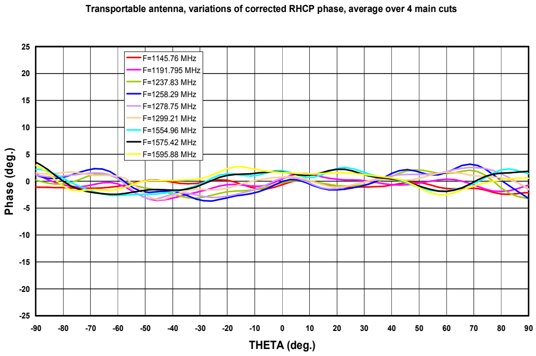


Figure 7: Measured phase variation

Table 1: Summary of measured electrical performance

Galileo band	E5			E6			L1		
Frequency (MHz)	1145.76	1191.795	1237.83	1258.29	1278.75	1299.21	1554.96	1575.42	1595.88
Gain. max. (dBi)	4.1	3.9	4.6	5.0	4.5	3.1	5.4	6.0	6.0
Gain @ 5 deg. el. (dBi)	-3.6	-3.8	-4.0	-3.7	-4.3	-5.7	-4.7	-4.6	-5.4
Axial ratio max. >5 deg. el. (dB)	3.9	4.7	3.4	4.2	4.7	4.5	5.9	5.4	5.3
Radius. (mm) D0_initial	3.6			1.2			1.7		

5. Conclusion

In the frame of the GARDA project an active antenna system targeting professional applications based on multi frequency use has been developed. A prototype of the antenna system has been manufactured and tested.

References

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