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Development of an Airborne Antenna operating in Ka/EHF Bandwidth for Dual-use satellites

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Abstract

The development and implementation by Elital srl of an Airborne Antenna operating in the Ka and EHF bands is part of a research program funded by the Italian Ministry of Defence Aeronautics Department (Armaereo).
The designed antenna is shaped Cassegrain (elliptical main reflector) and its optics includes a dichroic mirror that maximizes the performances in Ka and EHF bands. In order to obtain a low aerodynamic profile the antenna has be conceived with an elliptical main reflector having an aperture of 38 x 28 cm.
The antenna bandwidth ranges from 19,2 to 44,5 GHz (about 25 GHz bandwidth) and can operate with dual-use satellites like Athena Fidus. This antenna is equipped with two Feeds: one for the receiving bandwidth of 2.0 GHz (from 19.2 to 21.2 GHz) and the other one for the transmission bandwidths (1 GHz centered at 29.5 GHz and 1 GHz centered at 44.0 GHz).
The two Feeds are separated by a dichroic mirror that reflects the received band and lets the two-transmitting bands passing through. In this way the radio characteristics of both Ka and EHF bands are optimized and the antenna is equivalent to a centered optics reflector (30 cm) with an efficiency of 75%.
The two Feeds operate in circular and linear polarization for both EHF and Ka band. The Antenna performances have been fully tested and validated by LEHA facilities in Madrid.

R&D Project Objectives

The R&D project, funded by Italian MoD, aimed to design and implement a working demonstrator of Ka/EHF bandwidth Satellite Avionic Terminal to be integrated in tactical Unmanned Aerial Vehicle (UAV) .
The MoD R&D Contract has been awarded for the construction of a satellite avionics terminal with innovative technologies that allow to operate interchangeably both in the Ka and in the EHF bandwidth with an extremely lightweight antenna made in carbon fiber.
The complete Avionic Terminal has been conceived to provide a two-way satellite data link in the Ka and EHF frequency bands with the use of DVB S2 Spread Spectrum technology allowing strong and secure communications to aircraft such as UAV. The communication channel can be used for:

- Data Transmission on board
- Equipment Remote Control
- Mission Data Update
- Data Transmissions to ground
- Image Transmission
- Data Transmission
- Transmission of information from on-board sensors

This terminal has the ability to work with multiple satellites, both commercial and governmental, operating either in Ka (Kasat, Global Xpress, etc.) and Ka/EHF bandwidths (such as for example Sicral and Athena Fidus) together with the use of DVB S2 Spread Spectrum technology.
This R&D contract awarded by Italian MoD has been subdivided into 3 distinct phases as listed below:

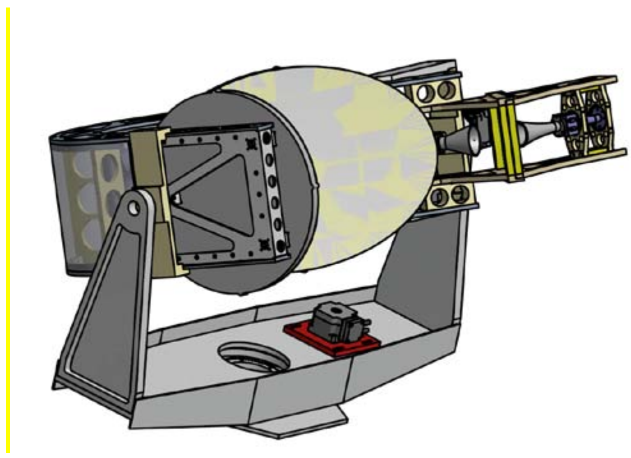
- Phase 1: Implementation of a Ka/EHF Antenna including Feeds complete of motion handling;
- Phase 2: Completion of the Ka/EHF Antenna in Carbon Fiber, Implementation of the Antenna ACU and Ka/EHF Transceiver;
- Phase 3: Implementation of the DVB S2 communication system (with Spread Spectrum) integrated with ACU.

This paper is relevant to the Phase 1 for the Ka/EHF Antenna development which has been completed at the end of April 2014.

Ka/EHF Dual Band Avionic Antenna Design and Development

The realized Antenna is a shaped Cassegrain and its optics includes a dichroic mirror which has the purpose of providing a low aerodynamic profile with an elliptical main reflector having an aperture of 38 x 28 cm. Furthermore this optics maximizes the performances in the Ka and EHF bandwidth. The complete Antenna assembly including servo is shown in Figure 1.

Figure 1 – Ka/EHF SOTM Antenna Layout

	
Antenna Assembly - view 1	**Antenna Assembly - view 2**

The realized antenna is equipped with two Feed (Illuminators): one for the receiving bandwidth (19.2 to 21.2 GHz - 2.0 GHz bandwidth) and the other for the transmitting bandwidth (29 , 5 GHz and 44.0 GHz - 1.0 GHz each bandwidth).
The two feeds are separated by a dichroic mirror that reflects the receiving bandwidth (19.2 to 21.2 GHz) on Rx Feed at 20 GHz and allows the transparent transmission of the transmitting bandwidth from 30/44 GHz Feed. In this way the radio characteristics of the Ka and EHF bandwidths are optimized with a high efficiency (optical see Figure 2). The measured Antenna electrical characteristics are shown in Table 1.

Figure 2 –Ka/EHF SOTM Antenna Optics

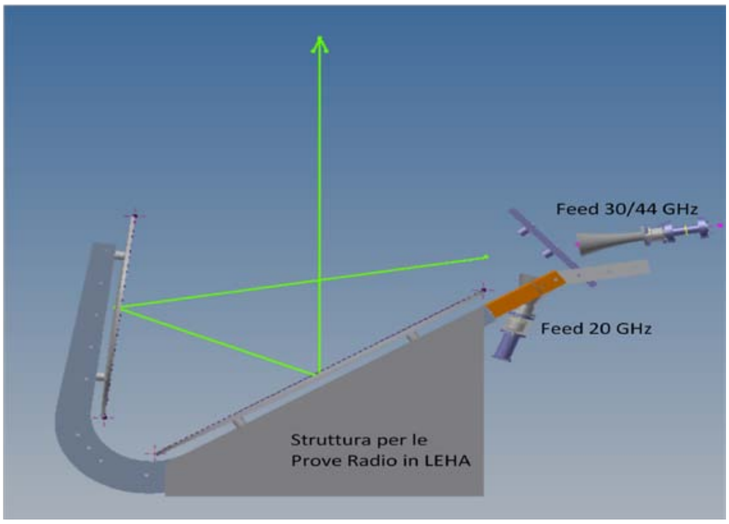


Table 1 – Ka/EHF Antenna measured Main Electrical characteristics

	Parameter	measured characteristics
1	Ka Tx Gain	36,5 dBi @ 29,5 GHz
2	EHF Tx Gain	40,5 dBi @ 44,0 GHz
3	Rx Gain	32,5 dBi @ 20,2 GHz
4	G/T	8,5 dBi/K @ 20,2 GHz
5	Polarization	Circular and Linear

The main Phase 1 activities have been concentrated in the following developments:

- Antenna Optics Design with dichroic mirror (to optimize the aerodynamic profile) and equipped with two feed (Illuminators): one for the receiving bandwidth (19.2 to 21.2 GHz) and the other for the transmitting bandwidth (29.5 GHz and 44.0 GHz);
- Design of Linear and Circular Polarization for both bandwidths.

These activities have provided excellent results either for the Antenna Radio performances obtained during either the Antenna & RF test tests carried out in the LEHA labs in Madrid and the Motion Functional tests with Flight Simulator in the Elital labs in L’Aquila.

Experimental Activities Description

The experimental activities have focused on radio measurements on Feed and Antenna (anechoic chamber and boresight respectively) with regard to the following parameters:

- EHF bandwidth Tx Gain (44.0 GHz)
- Ka bandwidth Tx Gain (29.5 GHz)
- Copolar and Crosspolar EHF bandwidth Tx Pattern (44.0 GHz)

- Copolar and Crosspolar Ka bandwidth Tx Pattern (29.5 GHz)
- EHF bandwidth Rx Gain (20.7 GHz)
- Ka bandwidth Rx Gain (19.7 GHz)
- Copolar and Crosspolar EHF bandwidth Rx Pattern (20.7 GHz)
- Copolar and Crosspolar Ka bandwidth Rx Pattern (19.7 GHz)

Figure 3 shows the measured antenna patterns at the different transmission and reception frequencies.

Figure 3 – Measured Antenna Patterns

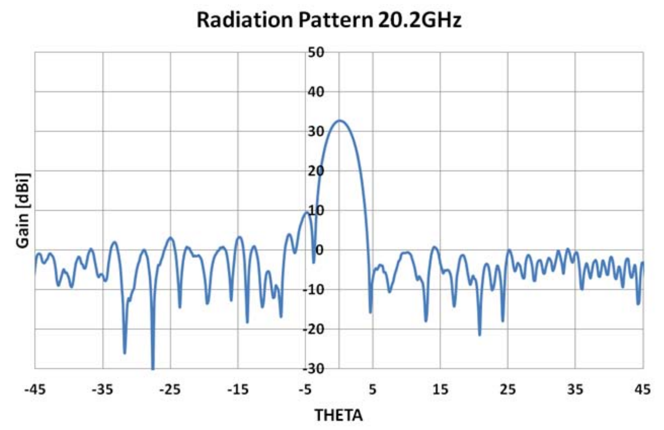


Figure 3a - 20,2 GHz Patterns

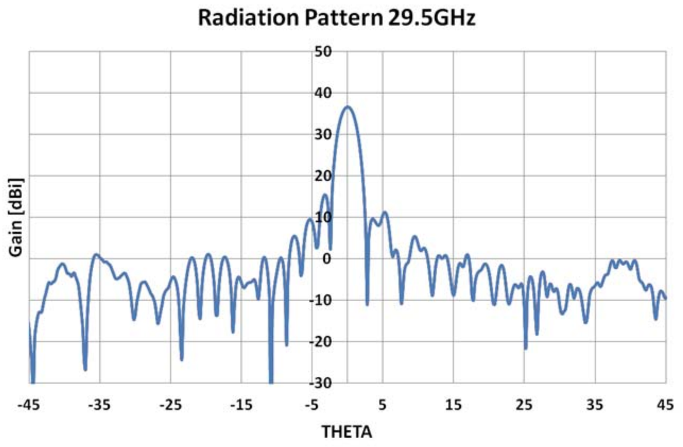


Figure 3b - 29,5 GHz Patterns

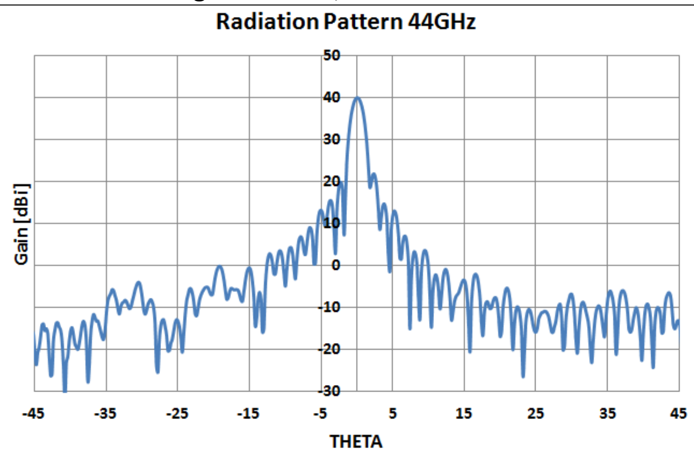
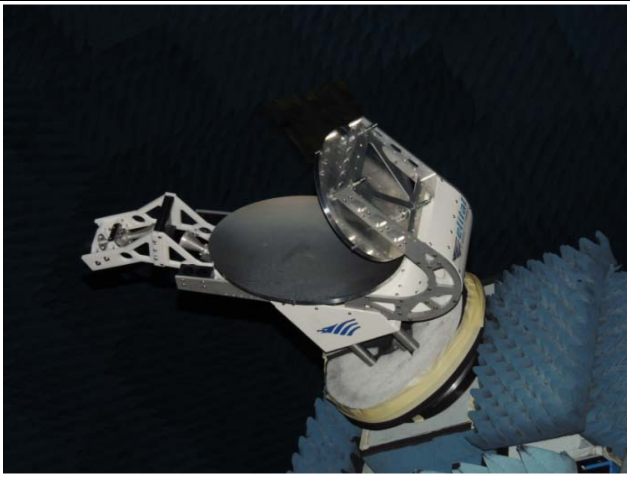
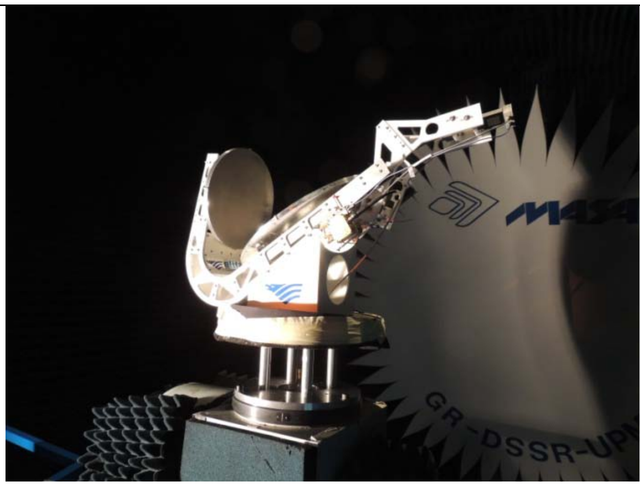


Figure 3c - 44,0 GHz Patterns

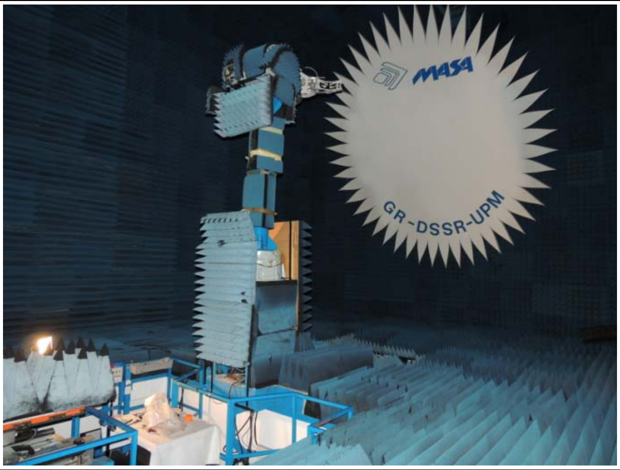
In Figure 4 the antenna pictures are shown during radio tests carried out in the LEHA Laboratory in March 2014.

Figure 4 –Antenna Pictures during Antenna and RF tests in LEHA





Antenna and RF Test in Anechoic Chamber in LEHA



LEHA Anechoic Chamber

Dual Band Antenna Assembly

In addition functional motion tests have been carried out in factory (Elital premises in L'Aquila) with Dual Band Antenna with Motion Assembly mounted on Flight Simulator. The Antenna with Motion Assembly is shown in Figure 5 where the Flight Simulator Controller is also shown.

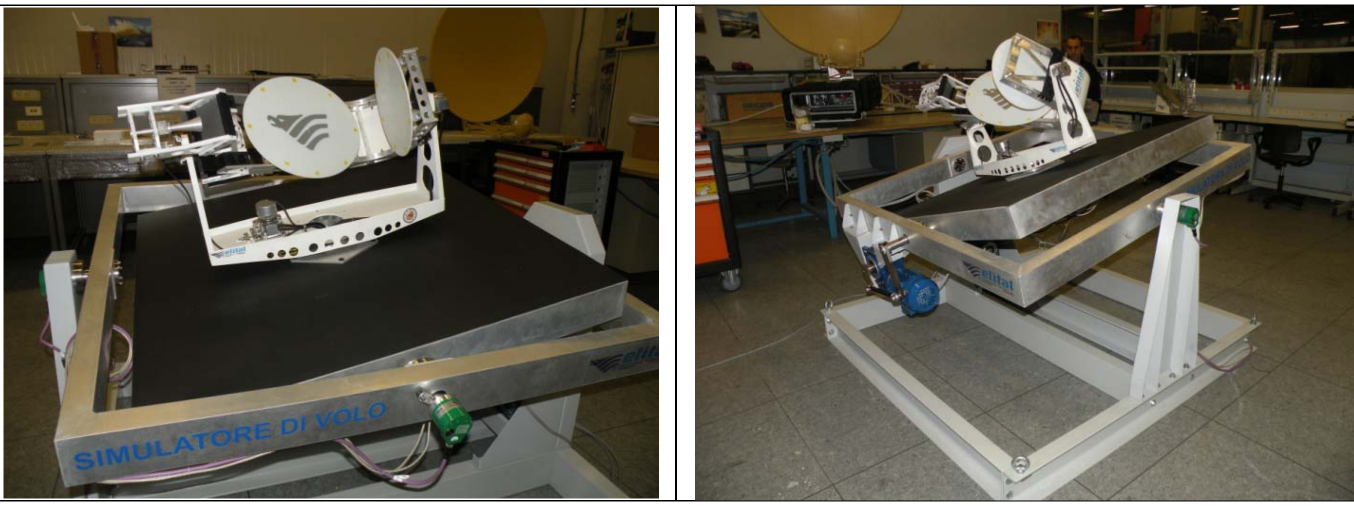
Figure 5 – Dual Band Antenna and Motion Assemby on Flight Simulator

Antenna and Motion Assemby on Flight Simulator

Flight Simulator Controller

The Motion Functional Tests have provided good Azimuth and Elevation pointing results varying the position of the 2-axis Flight Simulator. Some images are shown in Figure 6.

Figure 6 – Antenna Pictures during the Motion Functional tests



Antenna on Flight Simulator during motion functional tests

Achievements versus set Project Objectives

Please note that respect the main specifications of the avionic antenna, the achieved antenna radio results were considerable improved. In fact the Antenna and Feed radio tests carried out in LEHA Labs (Polytechnic University of Madrid) in March 2014 shew improvements of the following parameters:

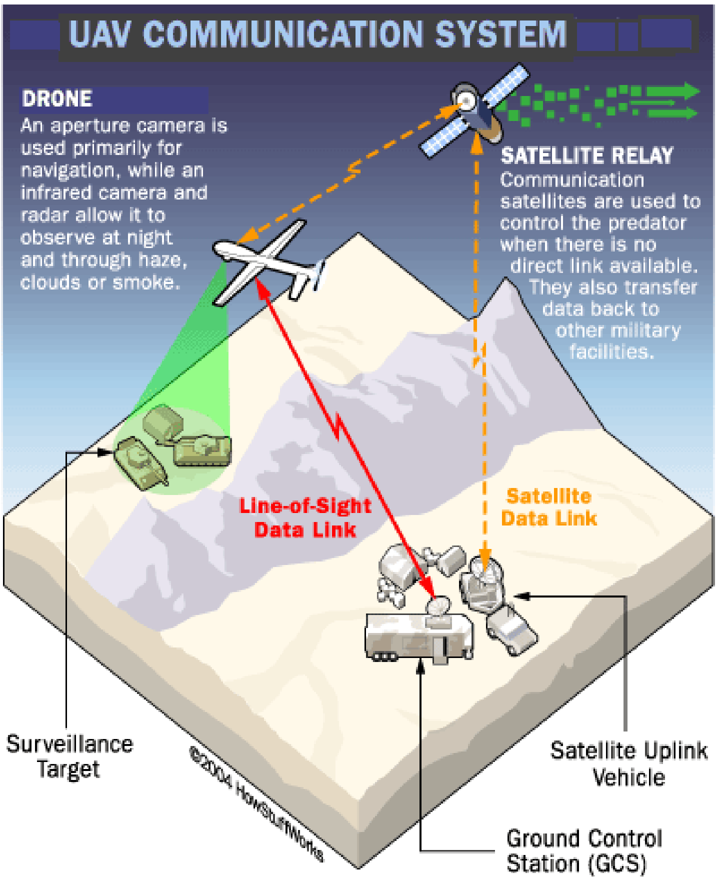
- Antenna Transmission Gain Characteristics in Ka bandwidth (36,5 dBi @ 29,5 GHz instead of 33,5 dBi);
- Antenna Transmission Gain Characteristics in EHF bandwidth (40,5 dBi @ 44,0 GHz instead of 37,5 dBi).

Furthermore at the end of the Antenna integration with servo structure (late March 2014), the obtained measured weight of the entire Antenna was 11.5 kg compared to 16 kg defined in the contractual Technical Specifications.

Usability for Military Applications

The industrialized terminal can be used for UAV Remote Control with ground-board communications, as shown in Figure 7, in Ka and EHF bandwidth using the Athena Fidus and Sicral satellite network.
Furthermore, many of the achievements obtained in this R&D contract are replicable, appropriately industrialized, for the Development of Satellite Communication Terminals mounted on moving Military Tracks for tactical communication applications taking into account that Dual Ka and EHF terminals are not yet available on the market.

Figure 7 – UAV Communication System



Possible International Cooperations for industrial phase

The following international cooperations have been already set:

- International market selection of the Ka and EHF components for the Realization of the Dual Ka/EHF Transceiver planned in Phase 2 of the Contract;
- Cooperation with the iDirect company for the realization of the DVB S2 communication system integrated with ACU equipment developed by Elital planned in Phase 3 of the Contract.