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DESIGN CONSIDERATION FOR FULLY EMBEDDED ELECTRONICALLY STEERABLE SATCOM AIRBORNE ANTENNA

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Abstract. in this paper a conceptual design of a SATCOM On The Move (SOTM) system in the Ka band is presented. This system is intended to be airborne and fully integrated in an AIRBUS C295 Flight Test Bench. The system relies in two separated low profile TX and RX antennas (about half a meter size) which reach up to 10Mbps return link and 50Mbps forward link.

1 INTRODUCTION

So far the inflight Internet connectivity for passengers and crew was low or even none at all based on L band SATCOM systems [1]. However, nowadays there are broadband systems, which are based on parabolic antennas located on top of the aircraft covered by a radome, to establish a satellite communication. These antennas are bulky and they introduce an additional aerodynamic drag which can be translated into higher fuel consumption [2]. Low profile antennas based on phase array solutions have been researched for the last years in the X and Ku frequency bands [2] [4] [5]. This new structural embedded Ka SATCOM antenna is a low profile broadband antenna which will overcome the additional aerodynamic drag because it is embedded in the aircraft structure while maintaining the broadband Internet connection. This high data rate communication system will allow the crew and passengers in an aircraft to stay connected anytime anywhere through a satellite communication link. This system is based on an open architecture IP layer protocol, thus allowing all kinds of data traffic.

Airbus DS in order to boost low profile SATCOM antennas leads a project called Embedded Electronically Steerable SATCOM Airborne Antenna ($E^2S^2A^2$) [6]. The project is in line with a new green and intelligent transport such as the new European policies demand, therefore the project is partially funded by the European Commission under the Clean Sky 2 framework. The project is carried out in collaboration with GILAT, RAYSAT and FBM composite partners.

In this paper the progress of the $E^2S^2A^2$ project is presented. The state of the art is summarized in Section 1. The system architecture is described in section 2. Section 3 and 4 shows the airborne design and the structural substantiation. In section 5 the lightning protection is described. Eventually the conclusions are drawn in section 6.

2 SYSTEM DESCRIPTION

The system design is intended to be aligned with the standard described in ARINC 791 [7] in order to achieve equipment interchangeability. The equipment is 28VDC feed and able to withstand the airborne environmental conditions. This system requires the inertial reference and aircraft location, which receives from the Inertial Navigation Unit (INU) according to ARINC 429 protocol. The system performances fulfils the radio electrical regulations ITU-R M1643, ITU-R S2223, ITU-R S580, ECC 184 and ETSI 303978 in order to avoid interferences to satellites located in the Geostationary belt.

According to the standards, the equipment that compounds the system is divided in two mayor groups: the Outside Antenna Equipment (OAE) and the Cabin Enclosed Equipment.

- Outside Antenna equipment
  - TX antenna
  - RX antenna
- Cabin equipment
  - KANDU
  - MODMAN
  - ARINC 429 converter

The system includes two separated TX and RX antennas with an aperture size of half a meter, located in the wing to fuselage fairing WFF. The TX antenna transmits in the 30GHz band and the RX antenna receives in the 20 GHz band. The Antenna performances are shown in Table 1.

Table 1: Embedded Ka SATCOM Antenna parameters

Parameter	RX	TX
Dimensions	447x582x103mm	401x582x104mm
Frequency band	19,7 – 21,2 GHz	29,5 – 31 GHz
Polarization	LHCP (optional)	RHCP (optional)
FOV	Ele: 20-90º Az:360º	Ele: 20-90º Az:360º
XPD	>20 dB	>20 dB
G/T //EIRP	4,4 – 11 dBK	41,6 -49 dBW
Weight	15Kg	13 Kg
Consumption	370 W (avg)	445 W (avg)

The RX antenna includes the steering control by means of several techniques in order to ensure accurate pointing. This equipment includes a local Inertial Unit, receives the KANDU computed steering direction and all these data is integrated additionally to the direction that is based on the Received Signal Strength Indication (RSSI). The TX antenna pointing is controlled and enabled by means of the RX antenna. The up and down frequency conversion takes place in the TX and RX antennas, therefore Intermediate Frequency is transmitted and received from the antennas to the MODMAN.

The Ka Network Data Unit (KANDU) equipment which stores the satellite ephemeris receives the location and attitude of the aircraft and calculates the steering direction.

The MODEM Manager (MODMAN) interface is based on OpenAMIP ensures total connectivity, management and interoperability. It uses spread spectrum, TX power spectral density enforcement and power limit for skew compensation, overcomes Doppler and supports large number of modulations to ensure adaptive throughput speed depending on radio channel status.

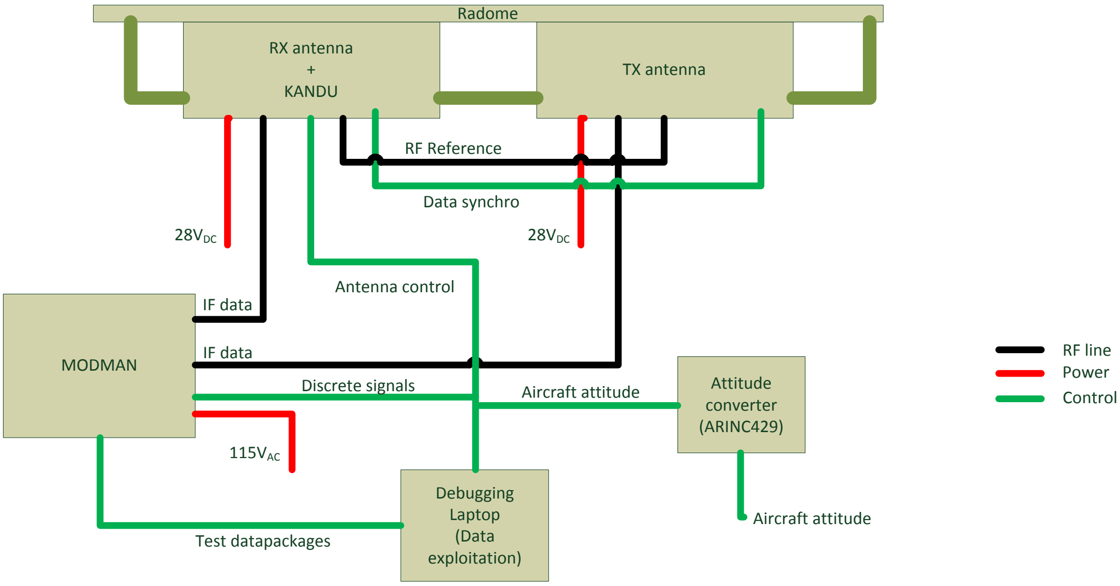

Figure 1: Interface connectivity diagram

3 MECHANICAL DESIGN

The Outside Antenna equipment is located in the external surface of the aircraft in the wing to fuselage fairing area. This zone is environmentally not protected, it is a zone exposed to great temperature changes, weather inclemency's, electromagnetic effects, lightning strike and it is not pressurized.

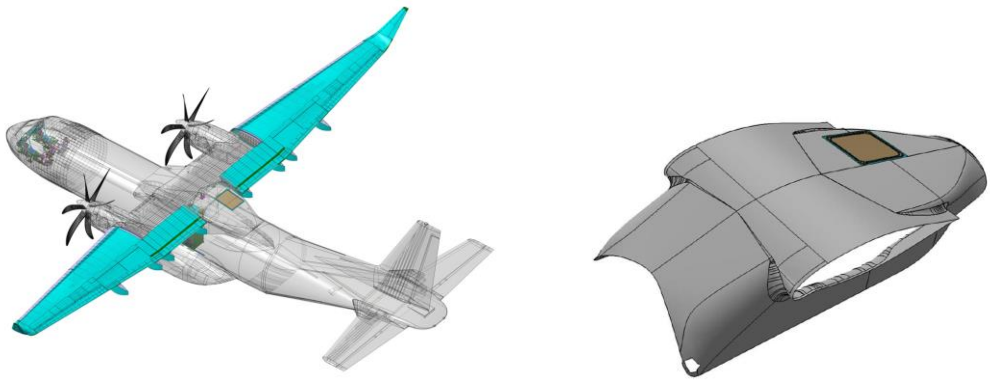

Figure 2: Embedded Ka SATCOM location

One of the old airframe structure sandwich panels that form the wing fuselage fairing structure is replaced by a new subassembly, which incorporates the antenna, and also performs all the structural functions of the substituted panel, respecting the aircraft aerodynamic surfaces. The subassembly if formed by:

- A CFRP solid laminate part to which the antenna equipment’s are fixed, and that is installed on the aircraft airframe substructure respecting the replaced sandwich panel’s mechanical interfaces. This part of the assembly is called the “Carrier”
- The RX antenna and The TX antenna equipment screwed to the Carrier
- A thin sandwich glass fiber reinforced plastic panel, also attached to the carrier, acting as radome but flush with aerodynamic aircraft surface.

The carrier withstands the antenna equipment loads during aircraft operation to ensure no deformation between TX and RX locations, then not compromising the accurate steering algorithm. The carrier and antennas are covered by a radome transparent to RX and TX frequencies. This radome is a multilayered glass fiber composited with diverter strips located on top and bonded to the carrier panel. All the subassembly parts incorporate electrical bonding means to its connection the to the primary aircraft structure in order to ensure low current path in case of a lightning strike.

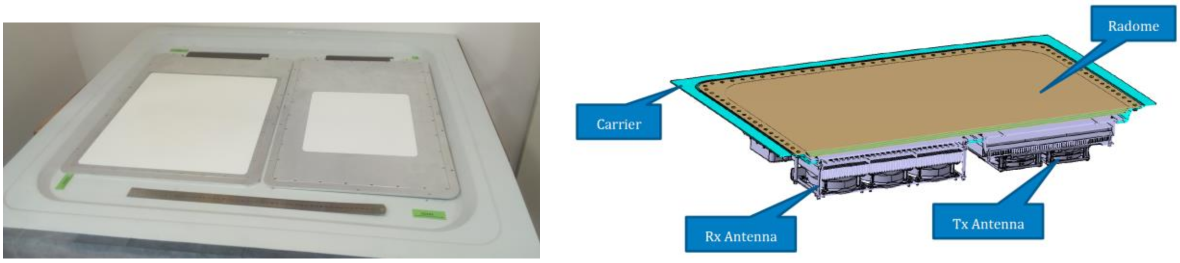

Figure 3: Embedded Ka SATCOM antenna overview

The full subassembly installation process, carrier, antenna equipment, and radome incorporates sealant beads ensuring the full component water tightness, sand or dust ingress and panel edges steps and gaps aerodynamic requirements.

4 STRUCTURAL SUBSTANTIATION

As previously commented, the supporting structure of the outside antenna is joined to the aircraft wing to fuselage fairing so it must comply with common stiffness and strength requirements plus some other specific imposed by the antennas.

Regarding stiffness, radome is directly exposed to the airflow and therefore must guarantee that the aerodynamic shape remains inside tolerances under cruise loads. Carrier, in turn, must resist in-flight inertias of both antennas ensuring small deflections compatible with their correct functionality.

With regards to strength, and despite that both are secondary structural elements, their failure or detachment could indirectly compromise the continuation of safe flight or landing and must be avoided.

4.2 Strength substantiation

Structural strength is to be substantiated by analysis supported by test evidences. Strain fields, deflections and interface loads between components of the assembly (radome to carrier and carrier to fairing) are calculated by using a detailed finite elements model (DFEM) generated on purpose. DFEM reproduces accurately the geometry and thicknesses of the parts accounting also for the laminate stacking sequences and lamina material properties consistent with in-service environmental conditions so that recovered outputs are realistic.

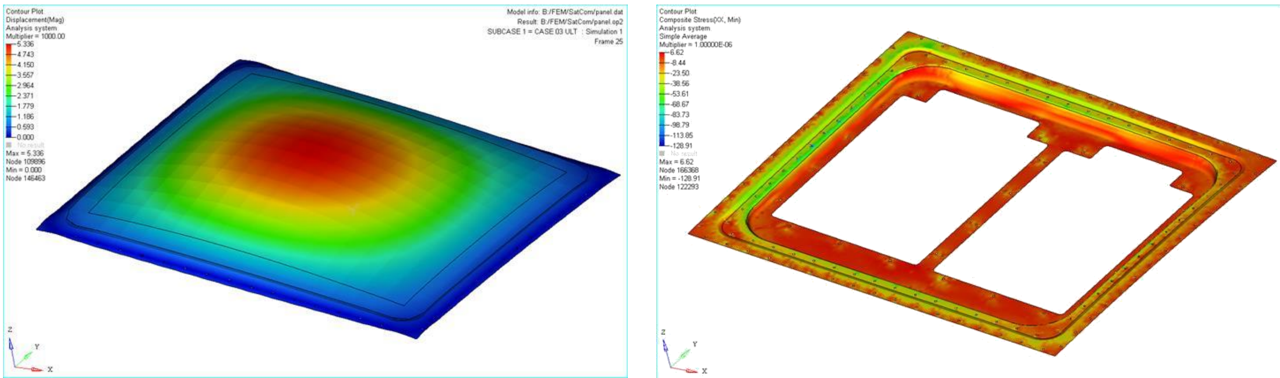

Figure 4: Radome deformed shape (left) and carrier strains distribution (right)

Strength justification is done by classical hand calculations using reliable methods based on worldwide accepted references. Critical failure mode of each particular design detail is identified by exploring all of the relevant.

Testing planned to support the qualification for flight of the supporting structure includes several tests at coupon level to confirm preliminary material allowable values plus one component test at ultimate load to validate DFEM calculations and demonstrate the static strength.

5 LIGHTNING PROTECTION

Aircraft externally mounted equipment are potentially exposed to direct lightning attachment. The consequences of this event are the physical damage on the equipment and the induced current/voltages to internal systems. A concept based on flux antennas reduces the probability of them to suffer a lightning attachment compared with protruding antennas (more attractive for the lightning channel to attach). On the other hand, when the antenna is integrated in the structure, the lightning strike physical damage may have also structural implications that need to be addresses to ensure no compromising structural integrity.

The Outside Antenna equipment is located in the external surface of the aircraft in the wing to fuselage fairing area. This area may be affected by sweeping effect of a lightning channel and it is considered as zone 2A [8]. The design principle in order to ensure minimizing the effects resulting from a lightning strike is based on:

- External metallization of the radome up to a limit to not compromise antenna functionality.

- Lightning unprotected area of the radome with enough dielectric strength so that channel would surface flash over this area to the adjacent metallization instead of puncturing it.
- Provide an electrical bonding path from the radome to the main aircraft structure so the lightning current is transferred in a way that adverse effects are minimized.

6 CONCLUSIONS

In this paper the progress of the $E^2S^2A^2$ project is presented. The design phase is mature and the current solution fulfils the demanding requirements to establish a satellite radio link with an expected throughput of 10Mbps return link and 50Mbps forward link.

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