VHF/GNSS antennas integrated into a classical Fibre Metal Laminate fuselage panel

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***Abstract*— The main objective of the ACASIAS project is to contribute to the reduction of energy consumption of future aircraft by improving the aerodynamic performance through conformal and structural integration of antennas that are normally protruding. This paper will discuss full integration of two antenna types into a fibre laminate fuselage panel: a VHF communication antenna and a GNSS satellite navigation antenna.**

***Index Terms*—*VHF, GNSS,* antennas, electromagnetics, structural integration, fibre metal laminate, Smart fuselage panel, conformal antenna, hybrid composite skin.**

I. Introduction

Fibre Metal Laminate (FML) is a composite aircraft construction material, consisting of metal layers that are bonded with fibre layers and resin to form a cohesive laminate. Glass laminate aluminium reinforced epoxy (GLARE) is an FML that is being used to construct parts of aircraft fuselages (such as the A380). GLARE consists of layers of aluminium and layers of resin with glass fibres. The principle of the work presented in this paper is based on the observation that these fibre metal laminates resemble the layer build-up of conventional PCB materials. With modifications to the fuselage panel, the fuselage panel can be made to effectively radiate as an antenna. In particular, patch antennas can be integrated directly into a fuselage panel with patches of conductive material directly made in the outer aluminium layers (Fig. 1). These patch antennas can be used effectively for GNSS reception. Alternatively, the large area available on the fuselage allows for large slot antennas which are ideal candidates for VHF antennas (Fig. 2). This paper addresses the design challenges of both the GNSS and the VHF antennas. These challenges are related to satisfying both the structural requirements as well as the electromagnetic requirements.

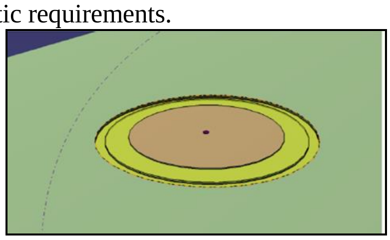

Fig. 1. Patch antenna integrated in Fibre Metal Laminate fuselage panel.

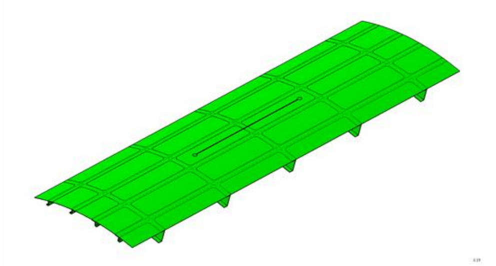

Fig. 2. Slot antenna integrated into fuselage panel.

II. The GNSS antenna

A double circular patch antenna is used to realize a GNSS antenna for both the L1 and L5 bands. The antenna is fed with four feeding probes as proposed by [1]. The four probes are fed with 0^o, 90^o, 180^o and 270^o phase difference in order to achieve Right Handed Circular Polarized (RHCP) radiation. The diameters of the circular patches are adjusted to radiate in the L1 band and the L5 bands.

The challenge of integrating this antenna into FML is to use as much as possible the material properties and distances used in GLARE fuselage panels. The two patch antennas are made directly into the upper two aluminium layers of laminate. The inner aluminium layer of the FML panel is bent to create a tray for the antenna. This layer is used a ground plane for the antenna. The two radiating patches are created in-plane with the two outer aluminium layers (Fig. 3). Because the two circular patches weaken the structure locally, an additional layer is used on the inside to maintain structural integrity.

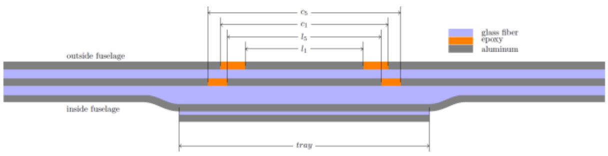

Fig. 3. Cross section of the circular double patch GNSS antenna integrated into a FML panel.

The distance between the radiating patches and the surrounding aluminium plates is large enough to prevent electromagnetic coupling between the two.

The radiation pattern of the antenna is shown in Fig. 4 for both frequency bands L1 and L5. The RHCP radiation pattern shows a good symmetry and provides sufficient gain at low elevations. The cross-polarisation (LHCP) is sufficiently low.

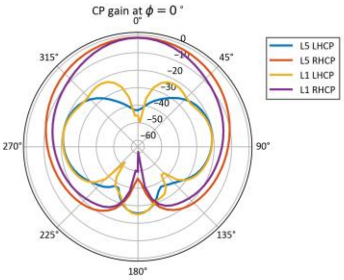

Fig. 4. Radiation pattern of the GNSS antenna (phi=0°).

The axial ratio of the GNSS antenna is shown in Fig. 5 and Fig. 6. The axial ratio is low (below 6 dB) for all elevation angles above 30° and all azimuth angles. The axial ratio at boresight is well below 0.5 dB within the L band.

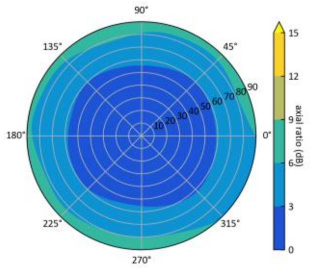

Fig. 5. Axial ratio of the GNSS antenna.

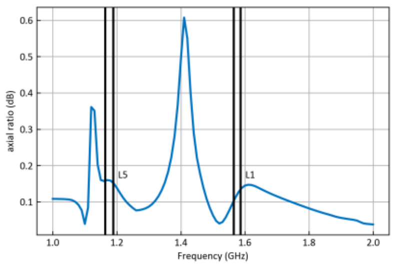

Fig. 6. Axial ratio at boresight of the GNSS antenna in the L band.

III. The VHF Antenna

A fully integrated VHF slot antenna is proposed. The antenna is realized as a horizontal oriented slot created directly in the aluminium fuselage panel. This horizontal slot provides vertical polarisation. A simple slot antenna radiates in both directions away from the conductive plane. Since radiation to the inside of the aircraft is not wanted, a provision has to be made on the inside of the fuselage. The radiation to the inside could be prevented by applying a ground plane at a quarter wavelength distance of the fuselage. However, at VHF frequencies the antenna will become too thick. Therefore a quarter-wavelength waveguide parallel plate resonator (PPR) is applied on the inside of fuselage as proposed by [2]. The PPR is shown in Fig. 7. It is effectively a folded waveguide with a quarter wavelength length. The challenge for integrating the VHF antenna is to use the limited space between the frames and stringers of the fuselage and to limit the size and weight of the antenna (in particular the PPR). The PPR can be implemented with a dual channel or a single channel. Obviously the number of channels used has an impact on the size and weight but also on the electromagnetic performance of the antenna (gain and bandwidth). In addition the material used in the waveguides (e.g. air of a dielectric) has an influence on the size and the weight.

Several prototypes of the antenna have been made at higher frequencies. Fig. 8 shows a prototype at 300 MHz. This prototype is based on FR4 substrate. The layers of this antenna are still quite thick but optimisations are being carried out to reduce the height of these layers.

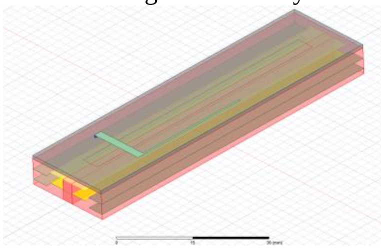

Fig. 7. Slot antenna with feed and Parallel Plate Resonator.

Fig. 8. Prototype slot antenna with PPR at 300 MHz.

Acknowledgment

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