Lightning protection in stealth radomes

Björn Widenberg[1], Elisabeth Löfsved[2] and Mats Bäckström[3]

[1]*Applied Composites AB ACAB, P.O. Box 13070, S-58013 Linköping, Sweden*
[2]*Saab Systems, SE-581 88 Linköping, Sweden*
[3]*Combitech AB, SE-581 88 Linköping, Sweden*
E-mail: bjorn.widenberg@acab.se

Applied Composites AB ACAB has in collaboration with Combitech AB performed a study about lightning protection of stealth radomes. Stealth radomes have the task to reduce the radar cross section (RCS) of enclosed sensors. A stealth radome, also called frequency selective (FSS) radome, consists of a sandwich structure, where one or more layers are metallic (the other layers consists of dielectric materials; glass fiber, foam materials, etc.). The metallic layers consist of periodic patterns of metal and non-metal. In this way a filter can be constructed that transmit the radiation from the enclosed sensor, but blocks the incident field at other frequencies. External radar signals therefore apprehend the radome as a smooth metal surface, which greatly reduces the RCS [1].

The overall requirement is that a strike of lightning on the radome shall not to cause a crash (wreck), or risk pilot and crew. But a strike of lightning on the radome can be allowed to impair the stealth performance.

Without any special lightning protection devices radomes (and enclosed sensors) are in generally very vulnerable to damage caused by a direct strike of lightning. A traditional radome is protected by a lightning conductor (for example Pitot tube), and/or by providing the radome with some type of lightning diverters (for example diverter strips). Lightning diverters guide the lightning channel in a controlled way on the face of the radome [2].

On a frequency selective (FSS) radome you want to reduce such lightning diverters/conductors to a minimum, in order to maintain a low RCS. A potential opportunity to obtain an acceptable resistance to lightning could be to make the metallic layer in the FSS-radome sufficiently thick, so that it can take care of lightning current (all or partly) without melting.

Our study has consisted of two parts; on one hand studies and measurements of FSS-structures with thick metallic layers to determine the impact on and consequences for stealth performance, on the other hand simulations and verification of the lightning current through the metallic layers to determine its resistance against a lightning strike.

Simulations and measurements of the FSS parameters indicate that one can increase the thickness of the metallic layers from the traditional 18 μm up 180 μm without any essential changes in the stealth performance of the radome; both the sensor performance and the RCS-performance is retained. At thicknesses over 180 μm the stealth performance is affected, and this must be carefully taken into account in the design of the stealth radome. In addition, a thicker metallic layer has a significant impact on the manufacturing process and on the weight of the radome.

Lightning simulations on FSS structures with thick metallic layers showed that an increase of the layer thickness from today's typical value of 18 μm to approximately 500 μm significantly improved the resistance against typical lightning pulses of the order of 20 kA. However, extreme lightning pulses of 200 kA, which the radome is required to be able to withstand according to applicable standards [3], would require the metallic layer to be at least approximately 2 mm thick. This would not be possible to implement in a radome. These results and conclusions are valid for a direct strike of lightning, any form of spreading the lightning current would improve the lightning resistance significantly.

However, the situation would be improved if the requirement of resistance do not apply directly on whether the metallic structure melts or not, but rather whether the radome as a complete structure can withstand a lightning hit of 200 kA, without breaking down and risk the safety. This latter requirement would presumably soften the demands, because the metallic layers are surrounded by several thick layers of dielectric glass fiber and foam materials. These layers help the radome to keep mechanically together when the evaporation of metallic layers result in an internal pressure that tends to break down and divide the radome.

To validate and supplement the simulation results, lightning tests on samples of FSS-radom-structures were done at Culham Lightning's laboratory of Culham, Oxfordshire, England.

The overall result from the study is that it is difficult to construct a stealth radome with reasonable thick metallic layers, which can cope with the worst possible lightning pulse (200 kA) in accordance with applicable standards, without the help of other internal/external lightning-protection devices. However, if the FSS radome could be equipped with some form of lightning conductors/diverters that spread out the lightning current, then the FSS structure would be able to cope with the lightning pulse. A stealth radome on a ship can e.g. be constructed with a lightning conductor which spreads out the lightning current. On the other hand, a stealth radome on a fighter aircraft needs help of more sophisticated lightning protection devices to cope with a direct strike of lightning.

Acknowledgments – We thank Göran Eriksson, now at ABB, for his contributions and colleagues at the Swedish Defence Material Administration (FMV) for valuable discussions.

References

1. Björn Widenberg, "Thick Frequency Selective Structures", Doctoral Thesis, Department of Electroscience, Lund University, 2003.
2. Fisher, Perala, & Plumer, "Lightning Protection of Aircraft", Lightning Technologies inc., Pittsfield (MA), 1999.
3. SAE Aerospace, "Aircraft Lightning Environment and Related Test Waveforms", ARP5412, 2005.