# Evaluation of high impact resistance radomes for mmWave applications

4a manufacturing's white paper for impact behavior and safety of sandwich radomes

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## Introduction

Antennas for outdoor applications like SatCom or 5G are exposed to environmental conditions. They are deployed around the world. Each of those deployment sites comes with its own set of harsh conditions, potentially damaging to the antenna. It is the radome that protects the antenna and ensures function even in the most challenging environments.

Being aware of these challenges and combining them with the intricacies of mmWave, sandwich radome technology offers superior protection while being almost transparent for the electromagnetic signal. When operating at mmWave frequencies, sandwich radomes excel with their great transmission properties compared to monolithic radomes.

A wide variety of materials and thus material combinations are available at 4a manufacturing, allowing flexible design for both electromagnetic and environmental requirements. Therefore, sandwich radomes can be tailored to individual applications with their respective target in mind e.g. to optimize the costs or performance. (Griffiths, 2008).

## Sandwich Radomes

CIMERA sandwich radomes are characterized by their layered stack-up of multiple materials. Careful combination of materials in tailored thicknesses leads to superior performance compared to using the individual materials alone. The most important types of sandwich radomes are A- and C-radomes. A-radomes have a three-layer stack-up and C-radomes consist of a five-layer stack-up. A-radomes (figure 1) are comprised of two skin layers, typically made of glass fiber reinforced polymer (GFRP) or thermoplastics, and a foam core layer in between. C-radomes (figure 2) have two skin layers and a core that are commonly made from fiber reinforced plastics. In addition, these layers are separated by two low-density foam spacers.

*Figure 1: A-Radome*

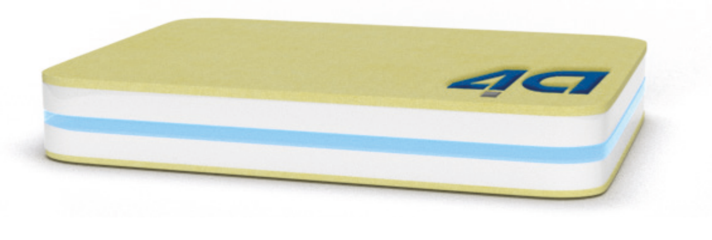

*Figure 2: C-Radome*

## Impact behavior of sandwich radomes

CIMERA sandwich radomes have better impact behavior compared to monolithic radomes due to their structure. While a monolithic material with thickness tuned for mmWave applications would fail ultimately under high impact load, a composite radome maintains function and stiffness.

Impact loads can result in compression of the foam layer and visible dents. Further damage modes of sandwich structures include intra- and interlayer failures. Delamination, an intralayer failure, is characterized by the failure of the bonding between two layers. It occurs when the shear strength of the adhesive is surpassed. Interlayer failure modes comprise matrix cracking and core cracking. Matrix cracking is possible when the strength of the matrix is exceeded and core cracking is a result of high shear stress in the foam core. (Olsson, 1997). The failure modes mentioned are illustrated in figure 3.

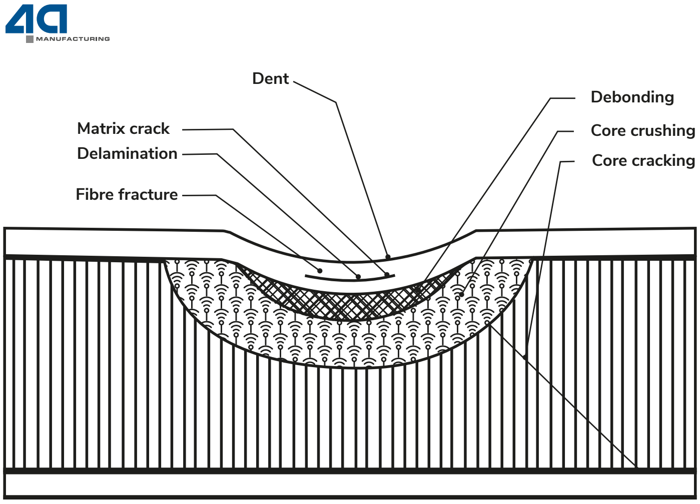

*Figure 3 Sandwich radome failure modes*

## Hail strike testing

Antennas located outside must always be protected to maintain their function. It is therefore vital to understand the behavior of the radome in environmental events, especially at critical impact loads. Thus, 4a manufacturing developed a hail strike testing procedure to make reliable predictions about the hail impact performance of their radomes. At the hail strike test, specimens are shot with an ice ball carved out of an ice block at a velocity that is expected in a real-world scenario. The deployment situation of the radome is approximated with a mounting frame, imitating the assembly on an antenna housing. An angle of 90° was chosen, as this transfers the highest impact energy during the hail strike. Additionally, adjustments to the experimental set-up are possible in order to perform angle-dependent tests.

The diameter of the hailstone is chosen according to the categories of the Hailstorm Intensity Scale (TORRO Hailstorm Intensity Scale). It is possible to vary the diameter of the hailstone in steps of 10 mm. The test starts with the maximum hail diameter of the lowest hail category within the test scope (depends on deployment site). After each shot, the radome is examined and its functionality is evaluated. If the functionality is given, the hail stone diameter is increased to the maximum diameter of the following category.

The damage of the tested radome is evaluated with a digital 3D-scanning-microscope. The critical parameters, dent area and dent depth, are examined. Magnified 3D-height maps (exemplary in Figure 4) are generated in the course of the assessment to visualize the extent of the impact and potential changes in the structure.

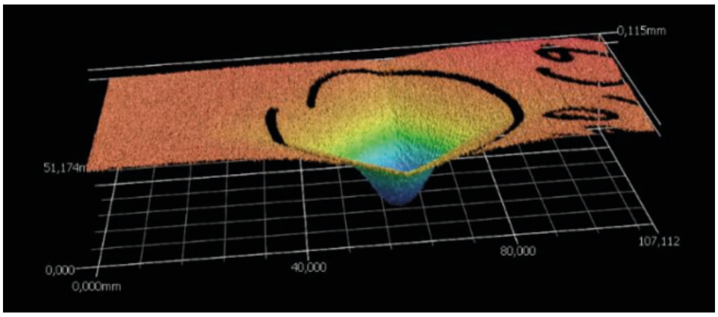

*Figure 4 3D-height map of a 11.3J impact with 40 mm hailstone (magnified)*

## Results

The scope of this test series are tailored CIMERA A- & C-radomes designed for the 5G mmWave market.

The experiments reflect that C-radomes are more resistant to hail impact than A-radomes. This is due to the stack-up of the C-radome, which is very stiff and supportive under impact loads. Moreover, in most of the applications the two foam layers of the C-radome are thinner than the foam layer of the A-radome, minimizing occurring dents.

Hailstorms with hailstone diameters up to 15 mm (H1 in the TORRO scale) can be withstood by this A-radome with no or negligible damage. The C-radome endures hailstone diameters up to 20 mm (H2) with no or negligible damage, respectively. Beyond that, compression of the foam layer is possible, meaning a change in its thickness. As the transmission properties of a sandwich radome is highly dependent on the

thickness of the individual layers, this may result in altered electromagnetic performance.
Ultimate failure occurred at 50 mm (H5) hailstone diameter for the A-Radome and 60 mm (H6) for the C-radome. This shows that protection for the antenna is maintained far beyond the hailstone diameter where dents are first occurring.
Our experiments also showed that coated outer layers do not influence the impact behavior because of their very low thickness.

## Summary

CIMERA sandwich radomes are the perfect solution when operating at high frequencies. While they ensure excellent transmission quality, they also show great impact resistance. The hail strike testing procedure demonstrates that sandwich radomes maintain the protection of the antenna in common hailstorms without taking significant damage. We offer a hail impact testing service for any radome developed by 4a manufacturing. Our customers are supported from the first idea of a radome to prototypes and series production. Therefore, individual requirements can be considered and tested throughout the development process.The impact testing service also includes a detailed report of the test procedure with the diameters of the hailstones and their corresponding damage. Furthermore, the point of ultimate failure is determined, and 3D-height maps are generated to illustrate the impact. A concluding statement is enclosed with the interpretation of the results and further recommendations. If desired, electromagnetic properties and transmission behavior can be measured before and after the testing procedure.

## About 4a manufacturing

4a manufacturing GmbH, part of the 4a technology group, is located in the center of Austria. It is a leader in supplying MILLIFOAM® rigid foam sheets and CIMERA® high performance sandwiches for many industries such as acoustics, mmWave applications and automotive for more than a decade. 4a manufacturing has focused on delivering high tech sandwich radomes for the telecommunications and satellite industry.

For more information please visit:
www.4a-manufacturing.com

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