Stealthy building panels

Eliminating unwanted reflection of the Instrument Landing System signals

The new Airbus stealthy facade technology allows buildings to be constructed closer to airport runways without compromising aircraft safety. The facade panels allow constructions to be built in the vicinity of the airport landside area by cancelling ILS signal reflections likely to disturb an aircraft's approach and landing.

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Airports: attractive areas for building development

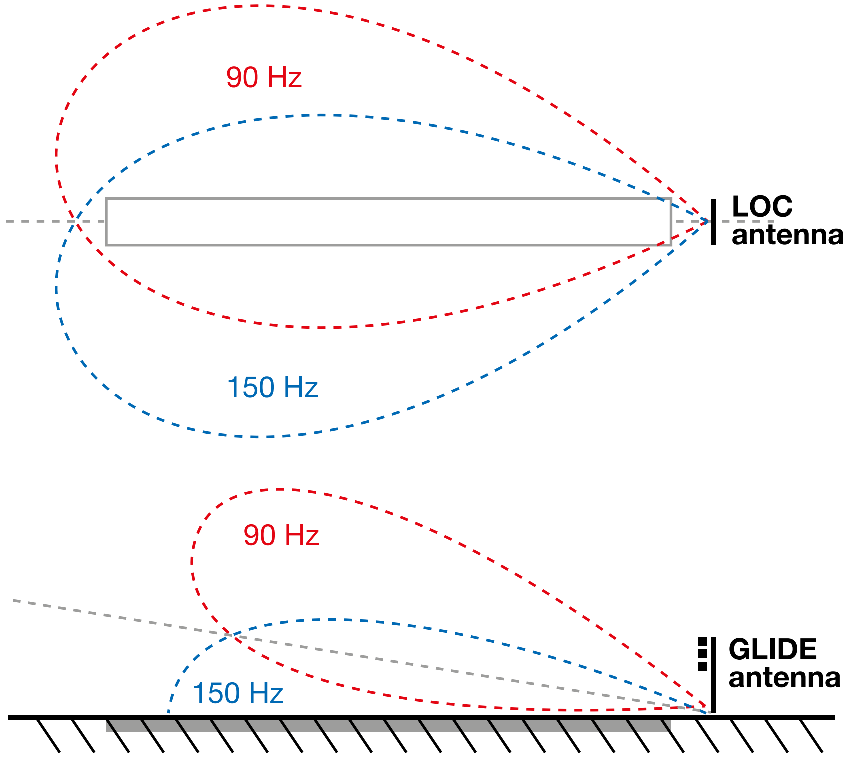
Any frequent air traveller will have noticed that there are an increasingly varied range of activities that take place within airport premises and surroundings. Indeed they are becoming mini-cities in their own right. Several buildings are required for airport operations such as air terminals themselves, of course, but many other satellite businesses and car parks. Developers recognize the importance of building hotels and exhibition centres at such important transport hubs, which are also frequently well connected to city centres. It is also particularly important for aircraft manufacturers such as Airbus, to install their premises close to runways to facilitate aircraft tests and deliveries.

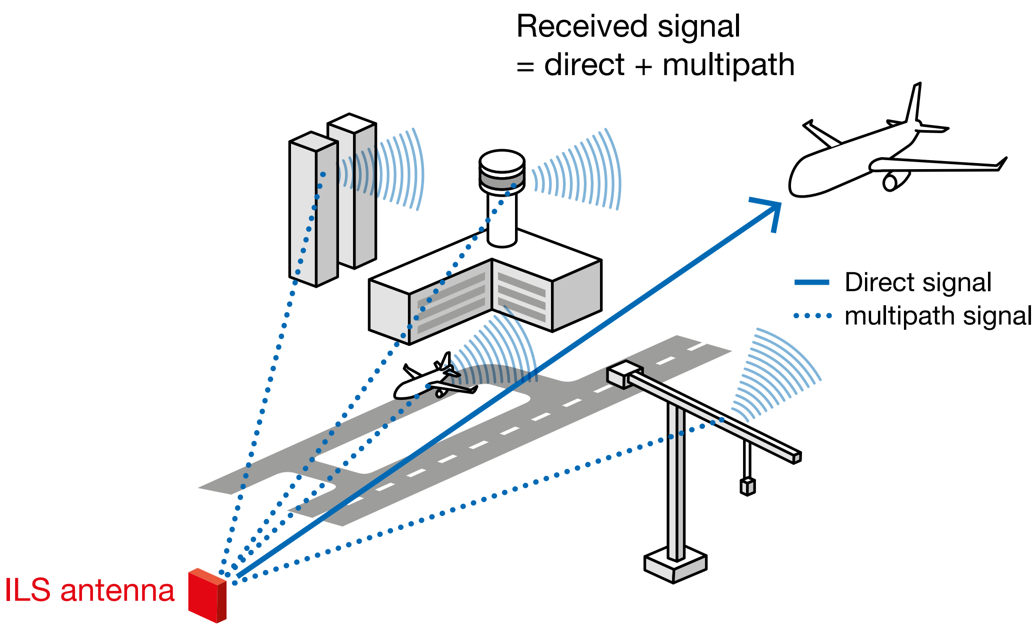
And yet, despite this pressure to develop airports, they remain remarkably underdeveloped. Try the experiment yourself using Google Earth: navigate to any major city and its airport is immediately visible due to the large amount of unexploited land in its proximity. There are two main reasons for this:

- Firstly, there is an area very close to the runways, known as the Obstacle Limitation Surface (OLS), whose role is to prevent aircraft colliding into buildings. This area will always remain undeveloped.

But, beyond this zone is a large area that would be exploitable but carries the risk of interfering with aircraft landing systems.

- The Instrument Landing System signal which provides guidance in the vertical and horizontal planes by emitting a signal with a spatially varying modulation (following the vertical and horizontal position of the aircraft). If the aircraft approaches to the left of the runway, it receives a signal with a stronger 90 Hz component and if it is towards the right, it will then receive a stronger 150 Hz component. By comparing the relative 'weights' of the two components (the Difference of Depth of Modulation - DDM) one has a measure of the deviation from the runway axis, and it is this value that is displayed in the cockpit. This is the operation of the localizer (LOC) antenna. The same principles hold in the vertical plane for the glide slope antenna.
  If obstacles are present in the vicinity of the runway, the ILS can provide unwanted multipath signals that provide a non-zero DDM, even when one is on the runway axis.





Airbus faced this problem in 2012 when planning to construct a new hangar on the Toulouse (France) site. The building was expected to be a continuation of a corridor linking several other hangars. This made perfect industrial sense but unfortunately, it brought the building within 380 metres of the runway centre-line of Toulouse International Airport.

Simulations performed with the Airbus in-house ILS prediction tool, Exact Landing Interference Simulation Environment (ELISE Consulting Services in FAST#49), indicated that the building would produce ILS perturbations of 15 µA (microampere) which are far in excess of the ICAO (International Civil Aviation Organization) regulatory limits set at 7.2 µA. Construction permission was refused by the French civil aviation authorities (DGAC) until a solution could be found. For this reason, the Airbus Facility Management and the Airport Operation departments turned to Airbus Group Innovations (AGI) Electromagnetism department for a technical solution.

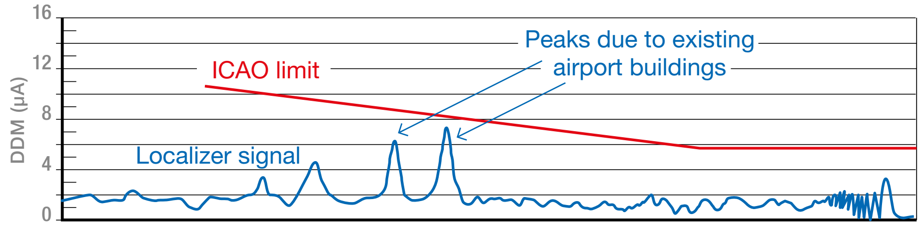
Stealthy building solutions' development

Although stealth is a very mature subject, having benefited from several decades of studies from numerous research groups, the subject of stealthy buildings for radio navigation applications presents an interesting challenge, mainly because the constraints are different to those of military applications. To list just a few:

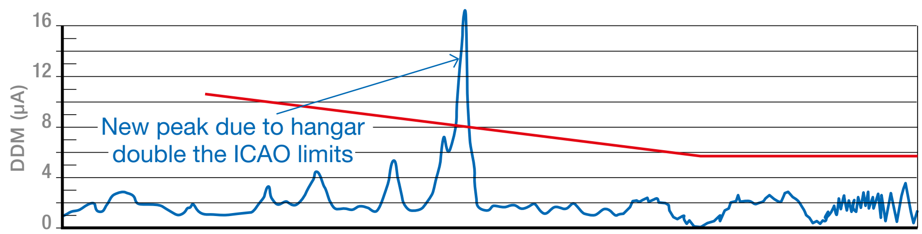
- Cost is the major constraint for stealthy building applications, because of the large surface area of building facades and because the solution should not represent a significant fraction of the total cost of the building.
- For a solution to be implemented on a building, it should preferentially use materials that are commonly used in the building industry. Indeed, most architects insist that a material be accompanied by a 10 year guarantee and an installation manual. This precludes the use of several conventional stealth materials.
- Many of the aircraft navigation systems operate in the VHF (Very High Frequency) band, where stealth materials frequently do not excel. They are often either thick (as in the case of foam) or expensive (as in the case of ceramic).
- The building is a cooperative target: The position of both, the source of radio waves and the building, are fixed. The frequency band is usually fixed and is of limited extent. Wide-band or wide-angle solutions are therefore not required.
- It is usually only necessary to redirect the scattered radiation in a selected direction rather than absorb it.

For the construction of its new hangar Airbus chose to redirect radiation with a diffraction grating rather than a system that would absorb incoming radiation.

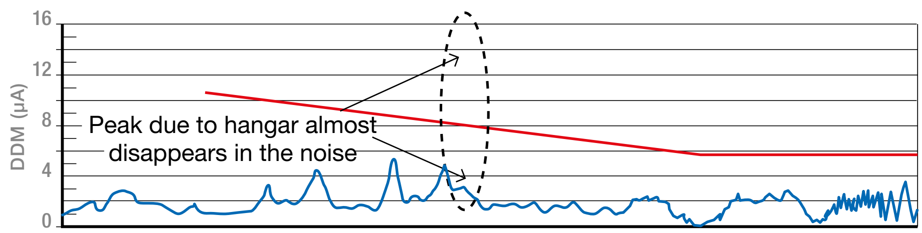
1. Before construction



2. Before installation of stealth solution



3. After the installation of stealth solution



DDM: Difference of Depth of Modulation

µA: microampere

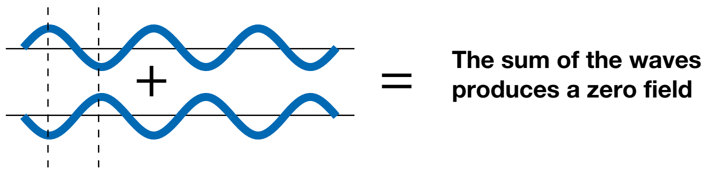
In the photo above we see the installed stealthy solution. Although it proved to be very effective, some shortcomings were identified with this solution:

- Its striking appearance makes it unsuitable for non-industrial structures such as hotels and exhibition centres,
- It overhangs the building facade by 70 cm and requires a steel reinforcement structure,
- It cannot be applied to an existing building.

Airbus therefore identified the need for a thin, lightweight, aesthetic alternative.

Stealthy panels produce destructive interference

Peaks from one source arrive
at the same time as troughs from another



An interesting side effect of diffraction grating is that waves add constructively at the angle of incidence, so a signal is redirected back to where it comes from.

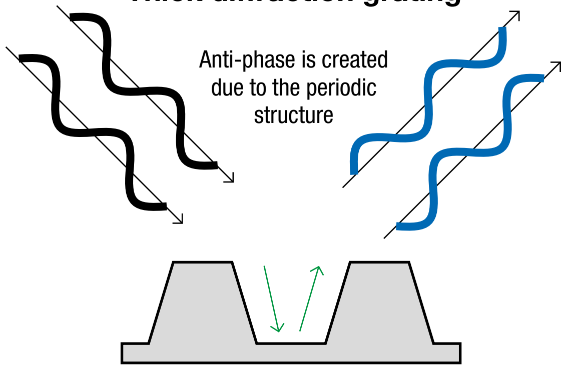
Fig. 1 shows a classic facade that sends a diffracted field towards the runway causing interference on the runway

Fig. 2 shows customized stealthy panels that send a diffracted field back to the localizer (LOC) antenna, creating no interference on the runway

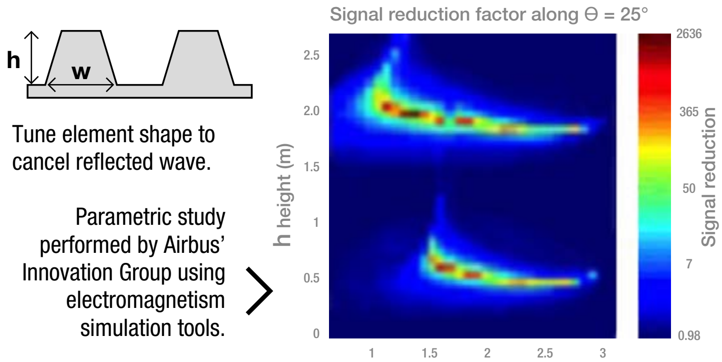
Thick versus thin diffraction grating reflections

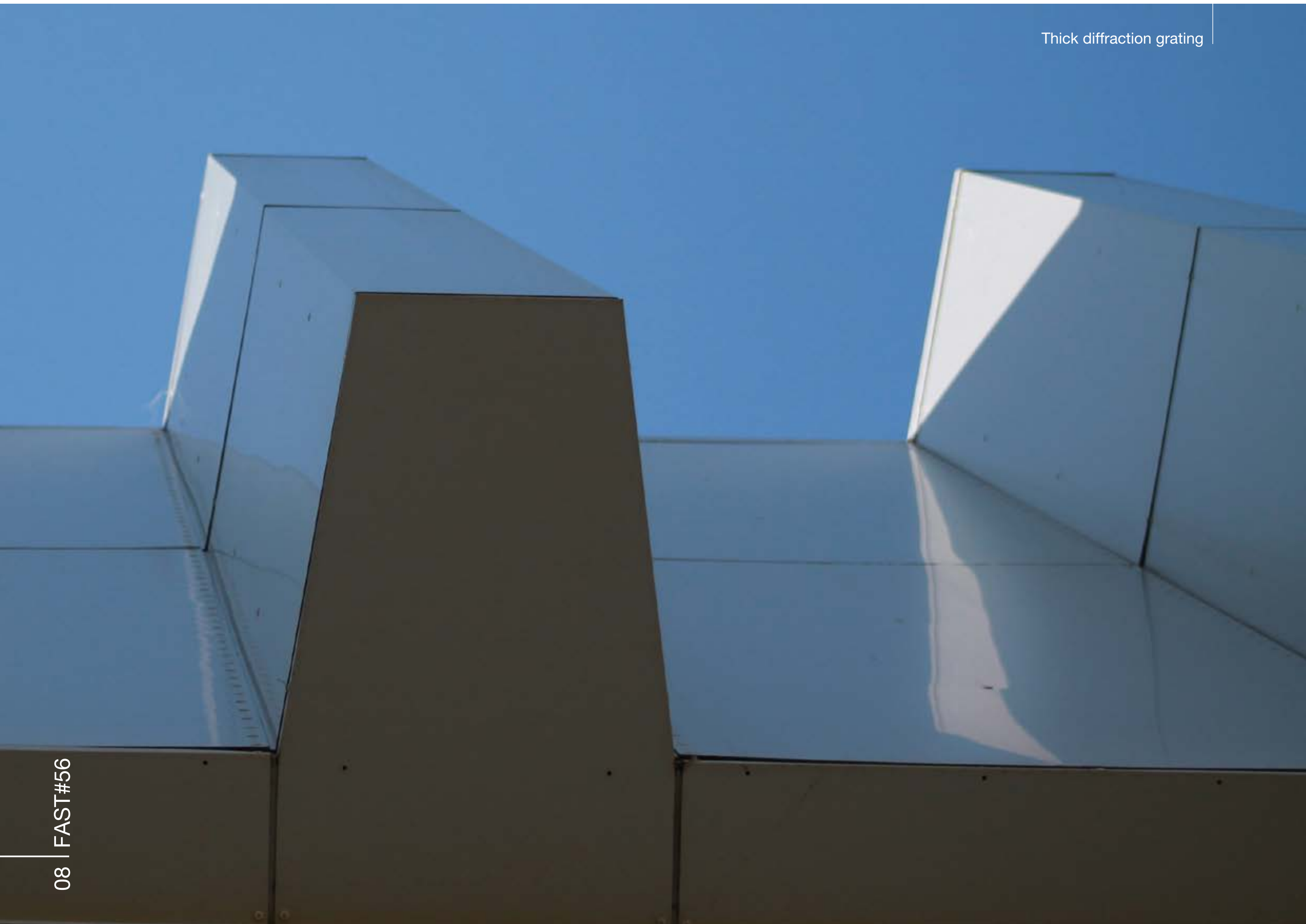
In the case of the thick diffraction grating, destructive interference is generated by a path difference. This does not appear possible with a thin solution. Indeed, with the thin solution, we introduce a phase change directly on the surface currents of the building façade. To do so, we implement a form of electronic circuit, but rather than attaching individual electronic components to the building, we form our circuit by carefully folding metallic panels with precise dimensions. By doing so, we create a gap that acts as a capacitor and a loop that acts as an inductor. Together, they form a resonant circuit much like those in a simple radio receiver. It is this circuit that can be tuned to the frequency of the ILS signal and provide the appropriate cancellation.

Thick diffraction grating

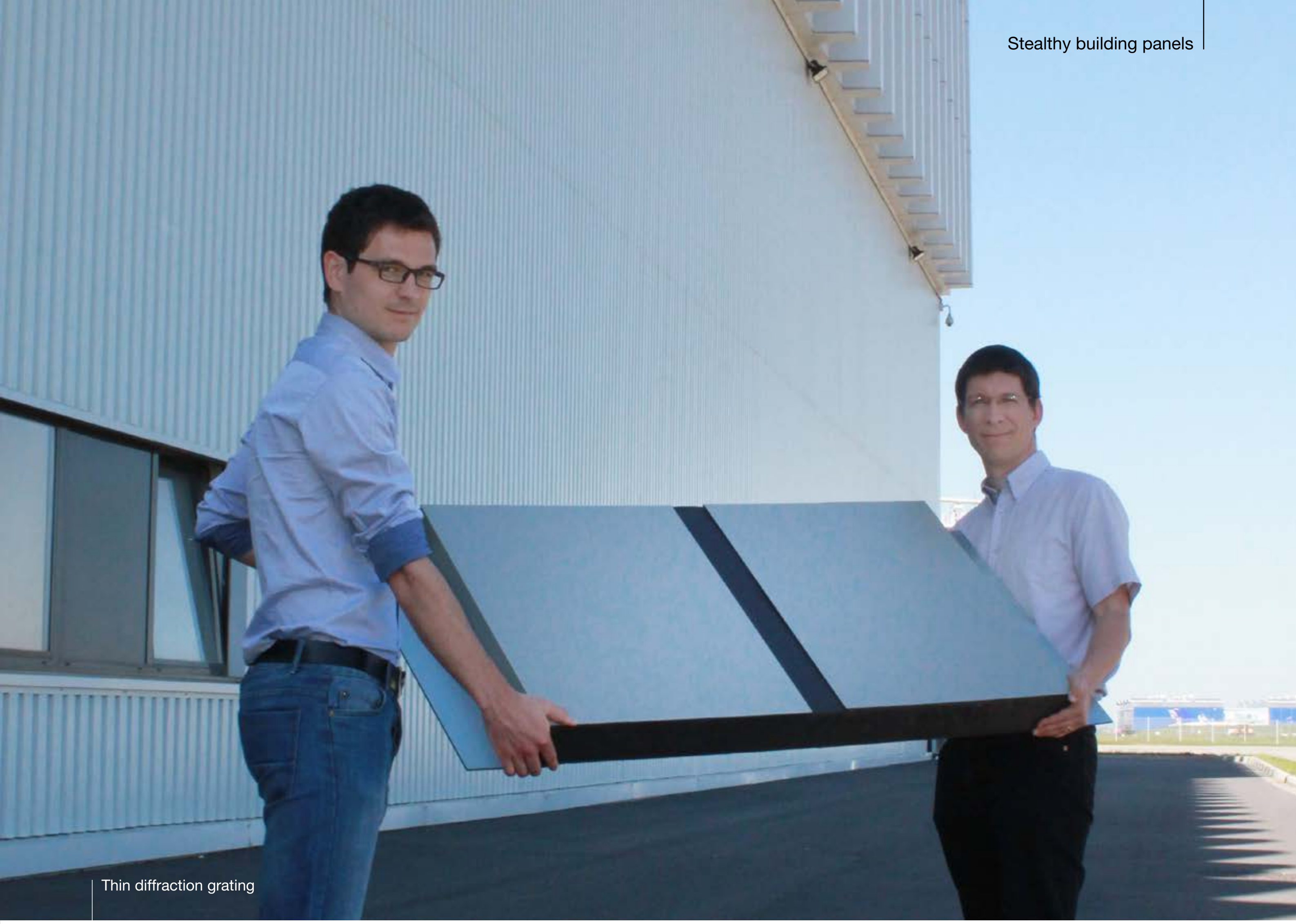


Electromagnetic optimisation





Thick diffraction grating

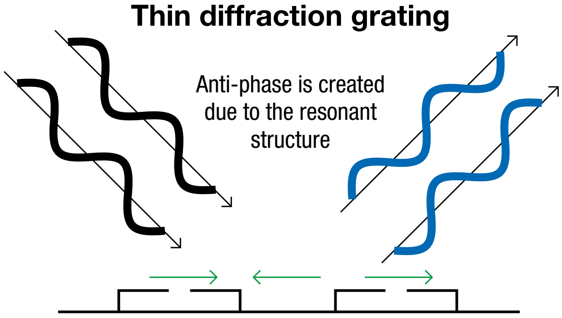


Thin diffraction grating

Through extensive simulations, we were able to establish that thin diffraction grating could produce large signal attenuations. We also came to the conclusion that heavy rain could have an effect on the solution if we did not take appropriate precautions. This is not, as one might think, because the rain creates 'short-circuits' in our resonant structures, but is due to the fact that when there is a large quantity of water close to a capacitor, it can change the value of its capacitance. For this reason, Airbus designed a protective screen to preserve a distance between the capacitor and the rain-layer.

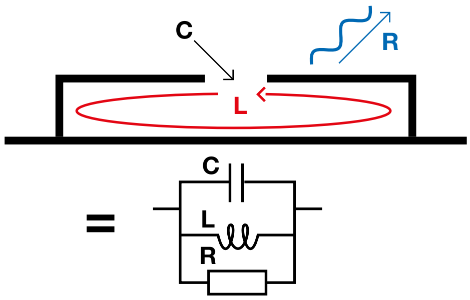
Before trying this new technology on an existing building, Airbus decided that it would be better to perform tests on a full-scale prototype. To do so, Airbus collaborated with the French civil aviation authorities (DGAC) who possess a fully functioning ILS antenna at the small aerodrome: Cahors-Lalbenque (France). This technology, initially imagined by the Electromagnetism department of Airbus Group Innovations, was validated in 2014 on a prototype at the Cahors airfield, thanks to the support of the Airbus Business Nursery (now named Airbus BizLab), and is currently being commercialized by Airbus through its 100% ATM subsidiary: Airbus ProSky.

Thin diffraction grating



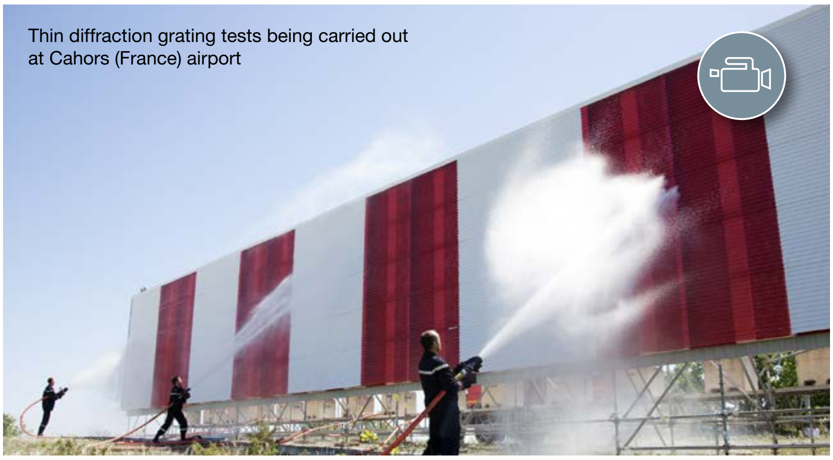
Currents are in different directions
on the resonant structures and on the surface

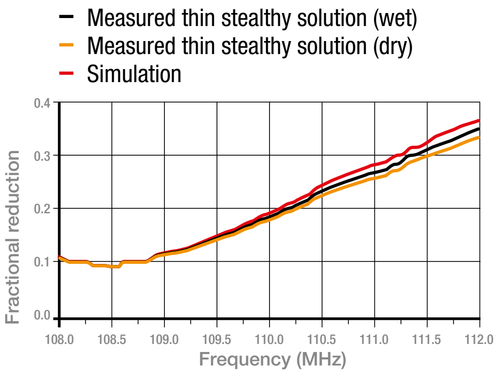
Creating a resonant circuit

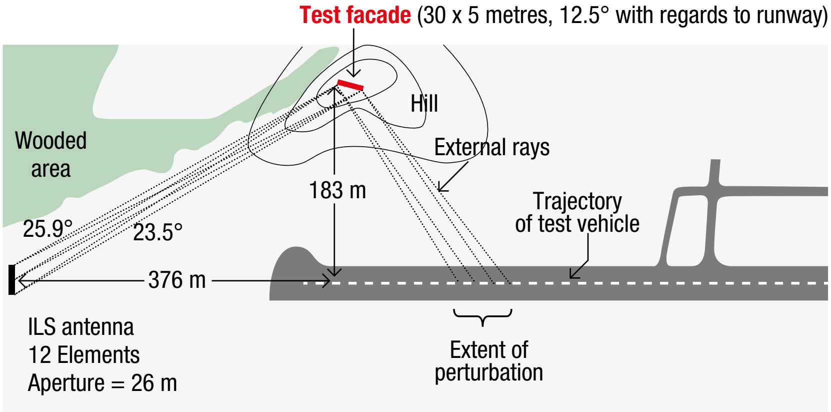


Design optimisation to produce exact structure

A panel measuring 30 x 5 metres was installed upon a nearby hill to maximize its reflected signal. To avoid creating a hazard to the other users of the aerodrome, it was necessary to adopt the regulatory colours of red and white and to install solar powered beacons.


Thin diffraction grating tests being carried out at Cahors (France) airport



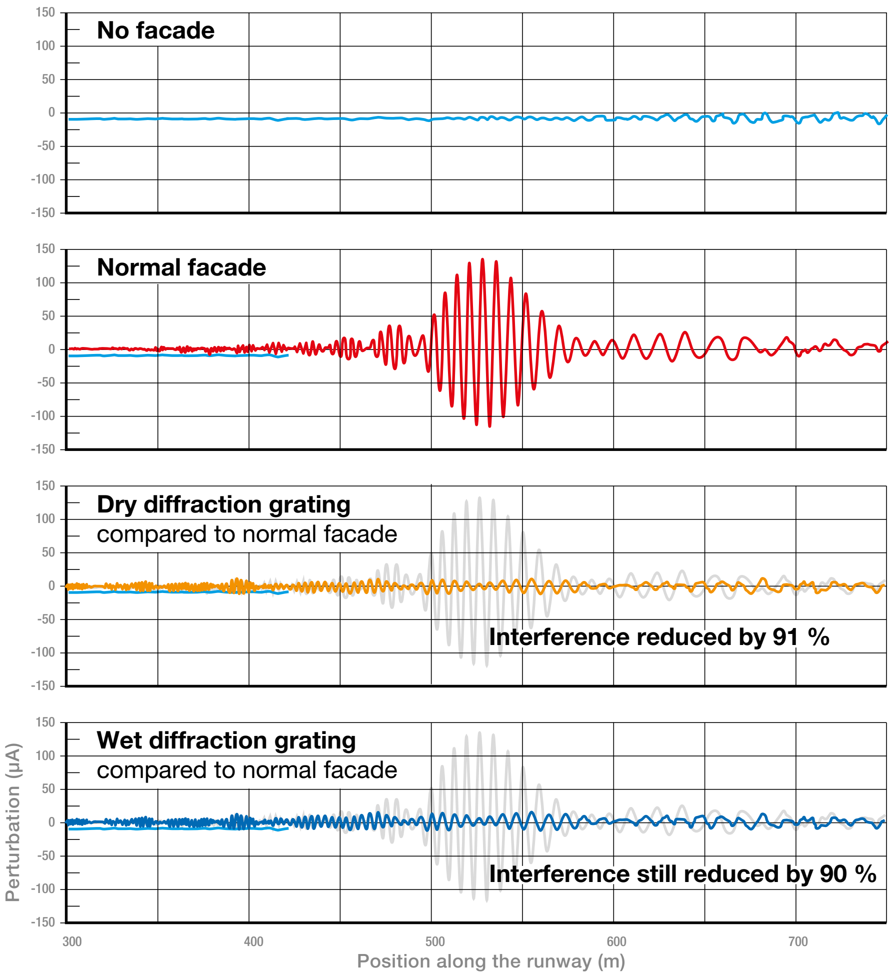


The results of the measurement campaign

The first curve shows the reference signal, before the façade was installed. The oscillations present are due to the surrounding environment such as the hill upon which the façade was mounted.
The red curve displays the signal when a planar façade was installed. A very significant perturbation of 262 µA peak to peak was observed.

Then, once the thin diffraction grating was installed (orange curve), this perturbation decreased by 91% (we estimated that an 80% reduction is sufficient for almost all applications).

Finally, the blue curve displays the effect of a water layer. There are almost no changes when compared to the dry test.



Stealthy facades commercialization

Once the technology was validated, Airbus decided to open the commercialization of this promising technology through Airbus ProSky.

The building industry is constantly innovating in response to new challenges, such as unusual structural geometries or large “name plates” and stealthy building panels are another example of this innovation. This is why Airbus Group Innovations remains involved in the dimensioning of optimal solutions on a case-by-case basis.

More than 150 airports in the world could be interested in this technology. Most of them are surrounded by cities that have no more expendable building land. This technology would offer them the possibility to construct buildings closer to the runways and to use land that could not be fully exploited otherwise. When we consider the price of one square metre in London Heathrow Airport (UK) or Tokyo Narita Airport (Japan), it is easy to imagine how this solution could be very interesting for all airport stakeholders.

Airbus ProSky

company overview

Airbus ProSky is a 100 percent Airbus subsidiary dedicated to delivering Air Traffic Management (ATM) performance and transformation. Through its airspace design services, air traffic flow management (ATFM), Collaborative Decision Making (CDM) and airport technology, such as ELISE and stealthy technology, Airbus ProSky delivers predictability, efficiency, sustainability and capacity to its customers worldwide.

A partner of more than 100 airlines, airports and air navigation service providers (ANSPs) worldwide, Airbus ProSky has been delivering these benefits alongside Metron Aviation since 2011.

Through the SESAR JU (Single European Sky ATM Research Joint Undertaking) flight trials – where Airbus ProSky was actively participating in over a dozen projects, Airbus ProSky has demonstrated that ATM modernization is an attainable reality.

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CONCLUSION

Airbus’ stealthy panels proved to be efficient in the reduction of unwanted disturbances of Instrument Landing System signals due to building facades. The thinner of the two technologies suits installation onto existing buildings as well as new projects. These new panels could resolve known cases of spurious reflections that disturb ILS and render parcels of land in proximity to runways constructible.