QinetiQ Proprietary

Stealth blades – a progress report

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Content

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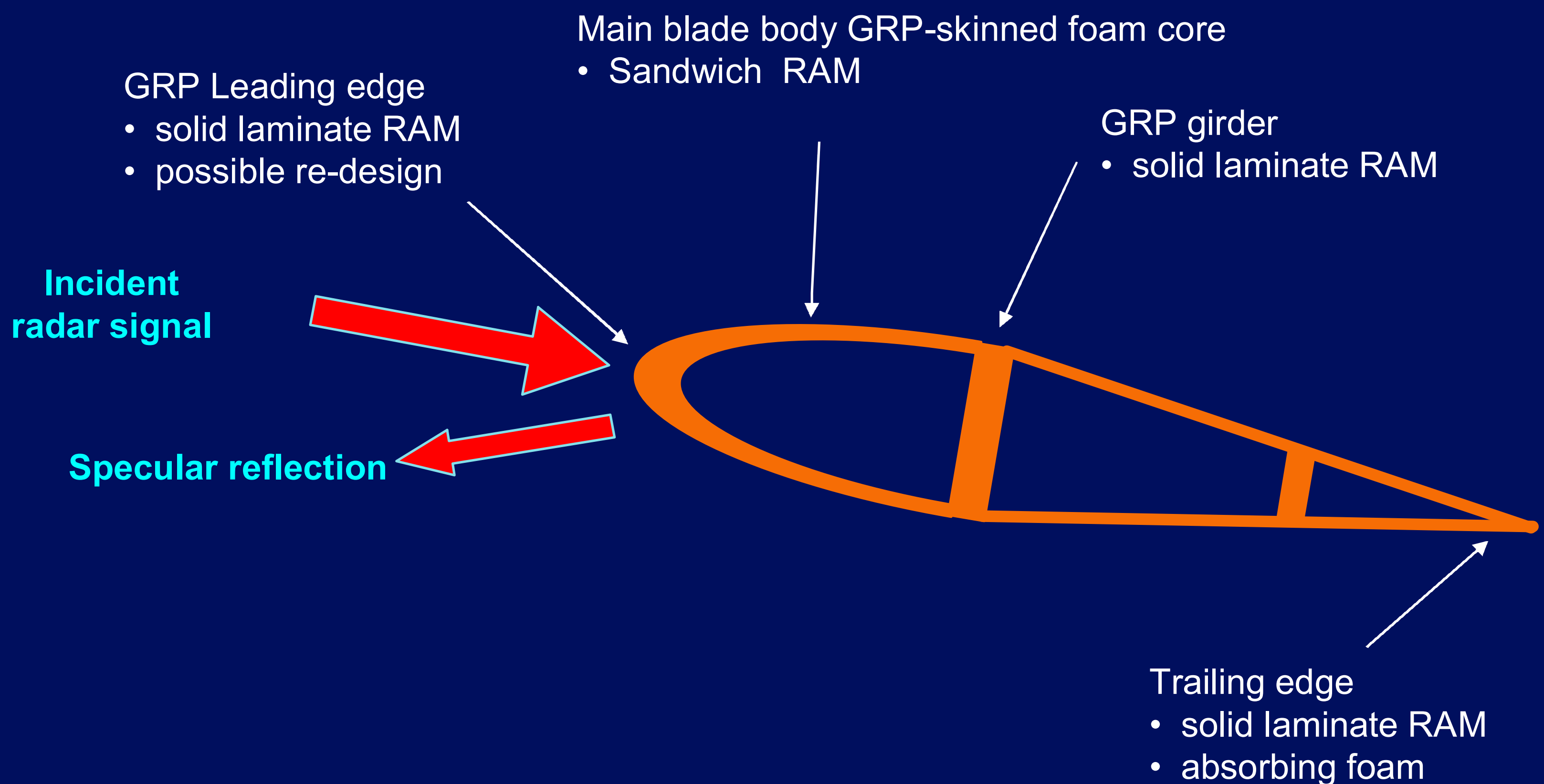
Why turbines are a problem



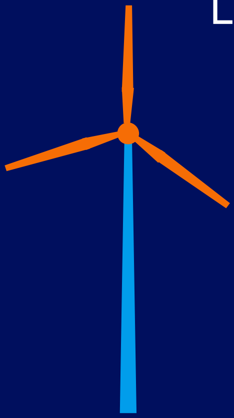
- GRP is partially reflective (~38%)
- RCS of cylinder is large, proportional to Length^2
- Blades, tower and nacelle contribute to RCS

QinetiQ understanding of turbine RCS

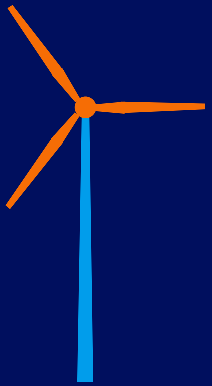
- QinetiQ have completed 2 separate projects under DTI support, both relating to the radar problem of wind turbines.
  - *"Wind Farms Impact on Radar Aviation Interests"*
    - Building on previous RCS prediction expertise, a model was developed that allowed the RCS of a turbine to be predicted as a function of blade yaw and pitch.
    - Predictions were validated by portable RCS measurements of several installed turbines
  - *"Design & Manufacture of Radar Absorbing Wind Turbine Blades"*
    - This project aimed to apply QinetiQ's radar stealth materials expertise to a 34m composite blade made by NOI Scotland
    - All materials found along the blade were considered and a cost-effective, weight-acceptable method for introducing stealth was sought for all materials

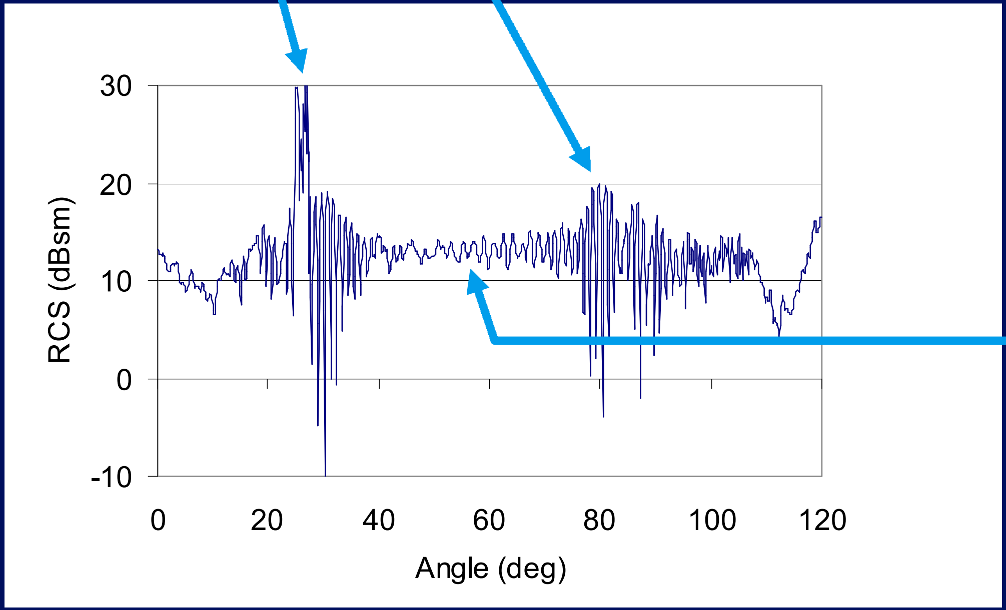
RCS predictions

90° yaw (i.e. blades moving towards and away from the radar) is the most important case for Air Traffic Control (ATC) because it creates the greatest Doppler component



Leading and trailing edge RCS flashes when any blade is vertical





Reduced ‘background’ RCS between flashes

Design & Manufacture of Radar Absorbing Wind Turbine Blades

- DTI-supported project
  - Blade radar cross section (RCS) predictions
    - study based on detailed CAD of 34m blade
    - considered stealthy blades, tower, nacelle
  - Radar system modelling
    - air traffic control 2-3 GHz
    - weather radar 5.6 GHz
    - marine navigation 9 GHz
    - identify benefit of various levels of stealth
  - Manufacture of stealthy blades (RAM), aiming for:
    - small modifications to composite blade
    - little change in manufacturing method
    - no structural detriment

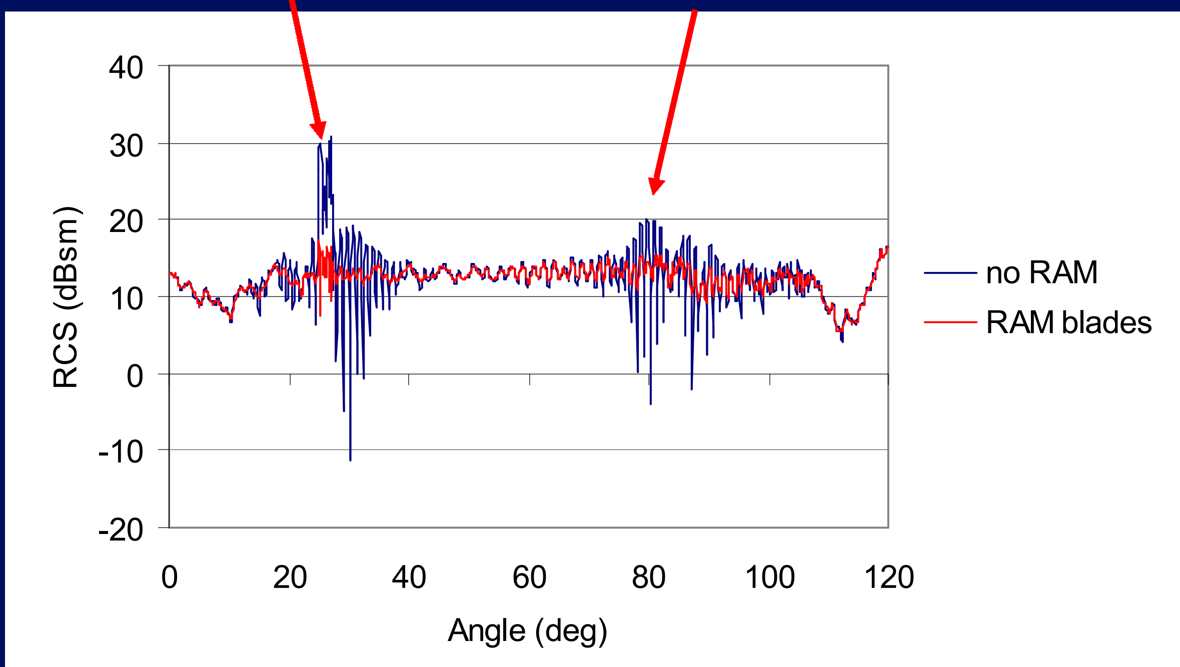
RCS predictions and radar impact modelling

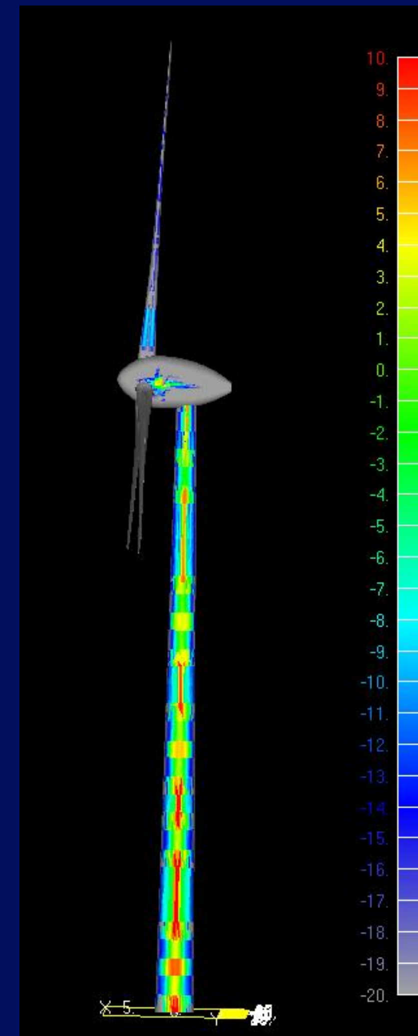
90° yaw / 0° pitch

- blades rotating towards and away from radar
- leading edge pointing directly at radar
- 0dBsm is a typical ‘aircraft size’
- RCS peak is reduced from 30dBsm to 15dBsm
- The tower and nacelle are still contributing strongly

Leading edge vertical

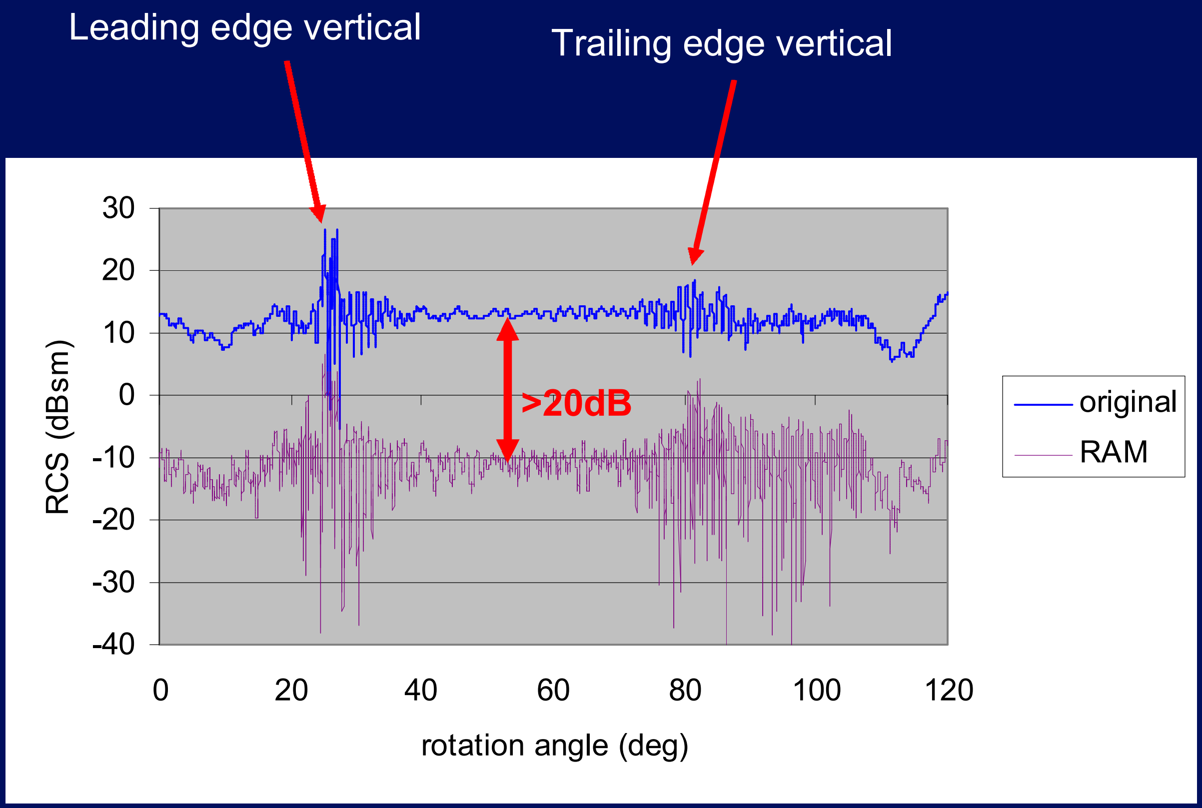
Trailing edge vertical



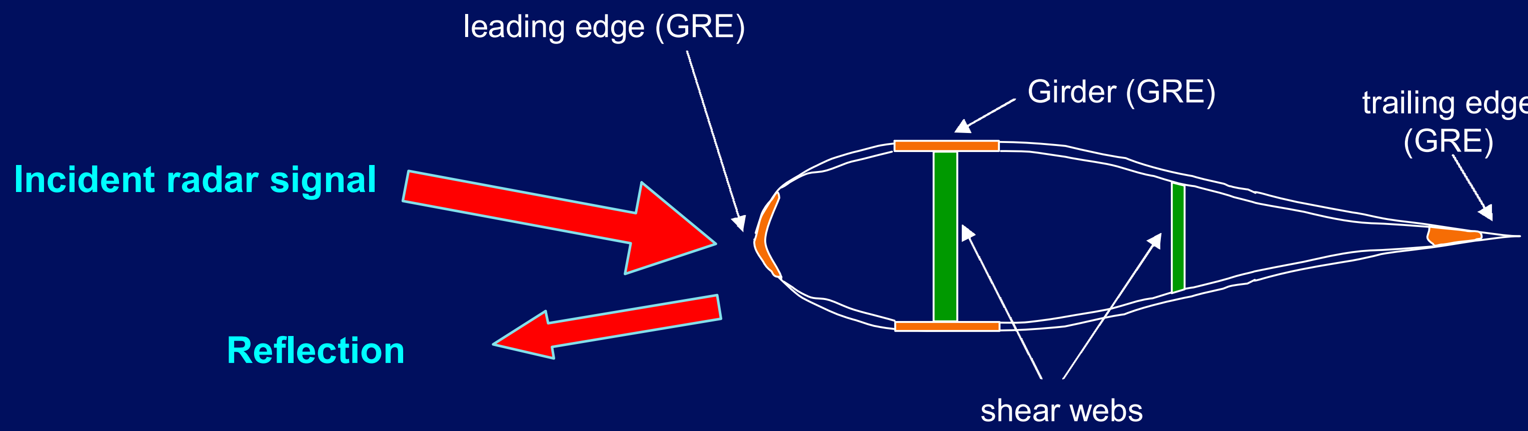


If the whole turbine is treated with RAM, predictions show that the bulk of the RCS spectrum falls below 0dBsm

Only the leading edge spike rises much above 0dBsm

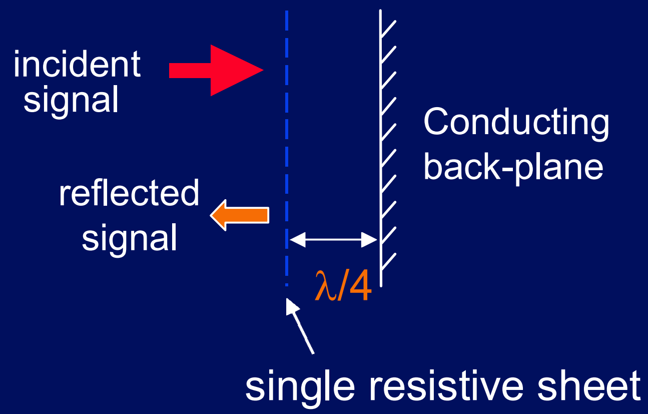


Materials requiring modification (typical)

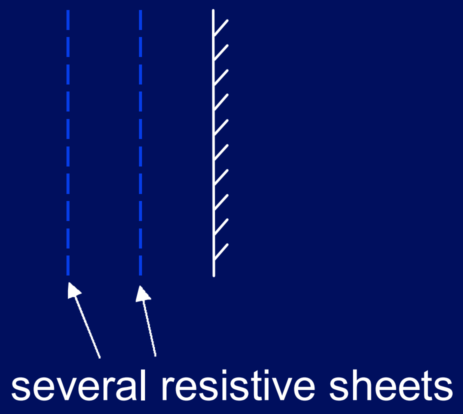


- Solid glass fibre reinforced epoxy (GRE)
- GRE-skinned lightweight foam core sandwich panels (FS)
- Carbon fibre composites in places, especially for larger turbine blades

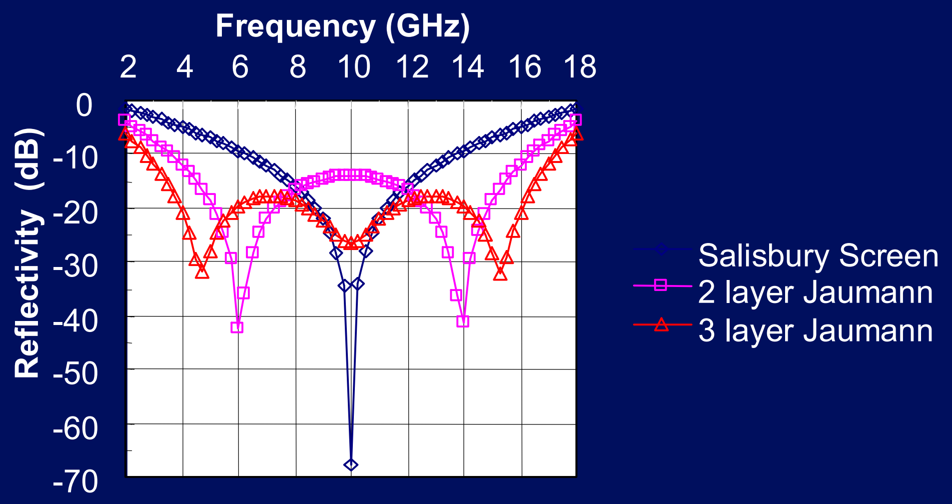
Radar Absorbent Materials (RAM)



Salisbury screen



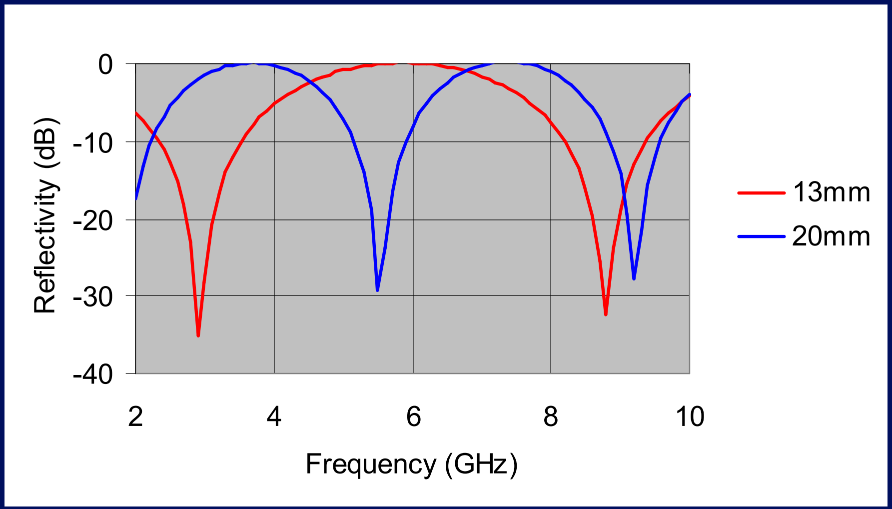
Jaumann absorber



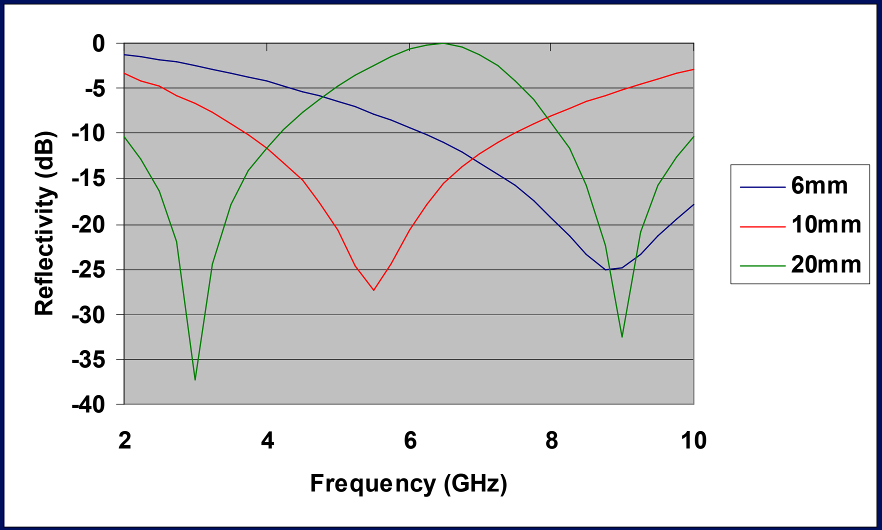
Jaumann RAM performance v number of layers

Some simple RAM designs

Solid GRE laminate RAM



GRE/foam sandwich panel RAM



BUT – these predictions are for purely resistive layers in a ¼ wavelength thick layer. Problem is how to make thinner composites work at ~ 3 GHz

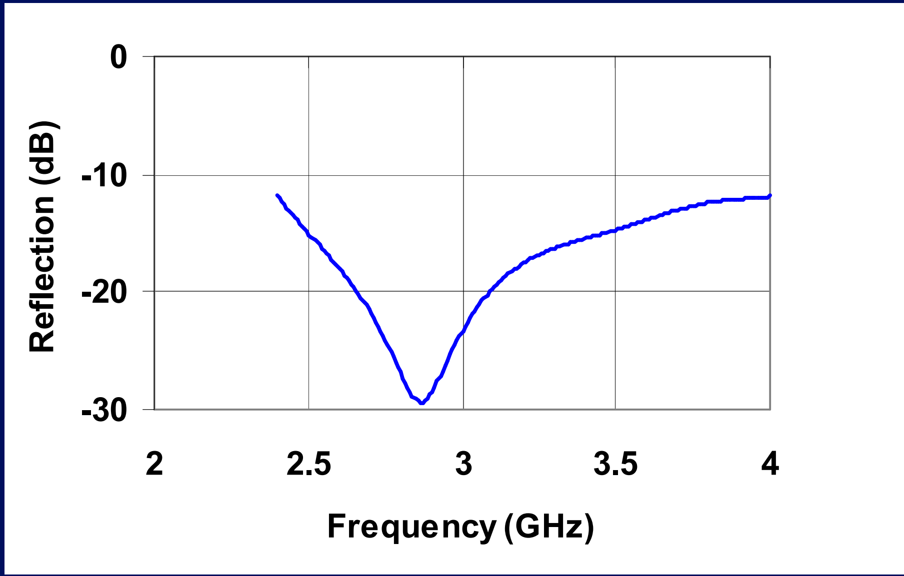
- 1/4 wavelength foam thickness for 3 GHz ~ 25mm
- 20mm case just works, but sandwich panels are often thinner than 20mm
- what if we need to go to 2 GHz ?

- SOLUTION – QinetiQ novel interlayers

The QinetiQ RAM solution

The QinetiQ approach has been to introduce controlled impedance properties into the current glass cloths, to electrically tune even thin (compared to wavelength) composites

- The lossy layers are modified versions of current glass cloths
  - composite 'friendly'
  - minimal change to process (RIFT, wet layup, prepreg are all possible)
  - little or no change in mechanical properties
  - added weight < 0.25% of existing composite structure

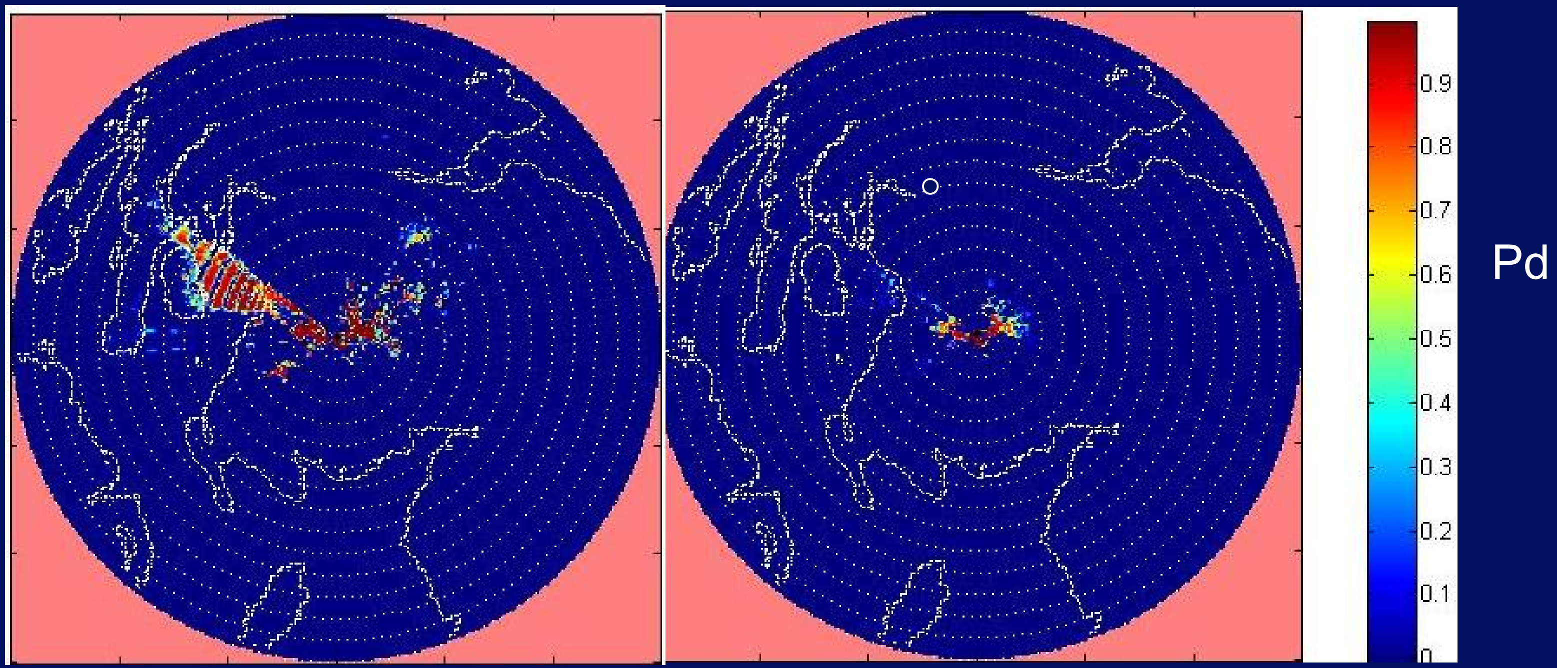


Measured performance for a GRE/foam/GRE sandwich panel

-10dB = 10% reflection
-20dB = 1% reflection
-30dB = 0.1% reflection

- Impact of RAM treatment on Probability of detection of turbine
  - Models use radar operational parameters and terrain data to calculate propagation and detection at any azimuth position

- Hare Hill site near Prestwick Airport, median RCS



Standard turbine

RAM turbine

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Conclusions

With the assistance of DTI funding, QinetiQ have completed separate projects studying the wind farm radar problem and materials solutions, with the following conclusions

- The use of RAM is predicted to significantly reduce the RCS of turbines
- Treatment of the tower, nacelle and blades is required
- QinetiQ are able to modify current turbine composites to create RAM
  - technical approach verified by samples and previous defence applications
  - RAM built-in to composites, not parasitic
  - minimal change to manufacturing method
  - no structural or aerodynamic considerations
  - no extra maintenance required – ‘fit and forget’
  - cost-effective solution

The next logical step is to demonstrate the level of benefit …….

Proposed new project:

Demonstration of a full-scale stealthy turbine to all stakeholders in the "radar problem"

- RCS prediction studies – identify RAM schemes
- Re-design of Vestas blades and nacelle
- RAM trial
  - lightweight, temporary RAM
  - confirmation of predictions
- Produce RAM blades and nacelle cover
- Produce tower RAM
- Install stealthy turbine on a Scottish power site
- Radar measurements – airport and QinetiQ radar (MPR)

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Questions?