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Sandia National Laboratories

Mitigating Radar-Windfarm Interaction: At the Turbine Solutions

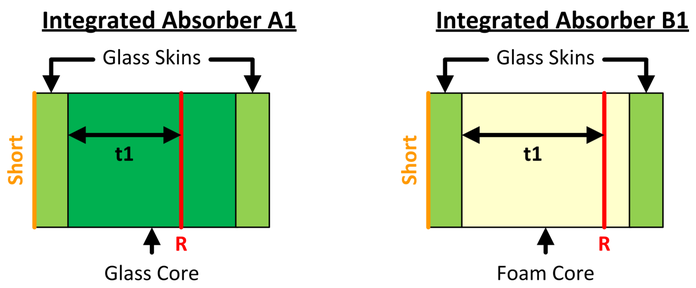
A radar absorbing treatment has been developed to reduce blade radar cross section (RCS) by 20 dB or greater with minimal cost impact.

Problem Statement

- Large wind farms increasingly impede radar operation for air traffic control, weather sensing, and other applications
- A treatment is needed at the turbine to reduce both static radar cross section (RCS) and Doppler shift due to blade motion

Integrated Absorber Design

- Thin layers of radar absorbing material (RAM) included in blade structure
- RAM can be integrated into foam or composite, depending on desired fabrication approach and RF performance
- Models of absorptive treatments allow rapid optimization over wide bandwidth and multiple incident angles
- Design parameters include RAM position, RAM conductivity, and composite material properties

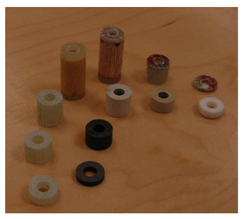


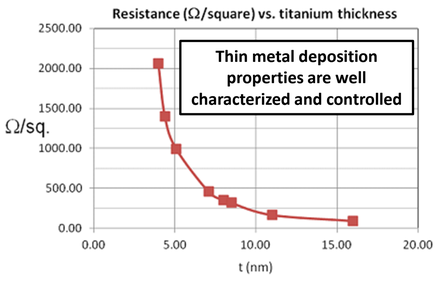
Material Development

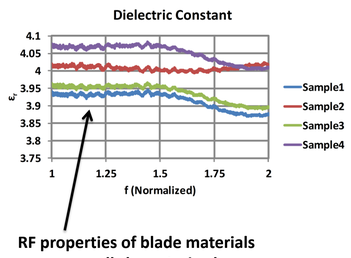
- Measured RF material properties of common blade composites, foam, and balsa used to design integrated RF absorbers
- Developed RAM for integration in blade construction
  - Conductively coated fabrics
  - Carbon enhanced reinforcements
  - Thin metal depositions

Coaxial test fixture for characterizing RF properties of blade materials and RAM

Coaxial samples of various blade materials and RAM



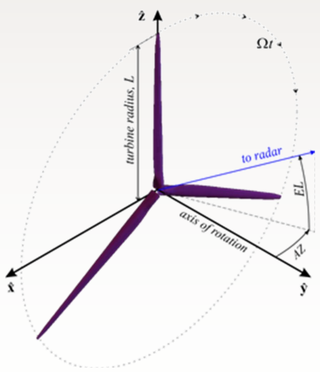


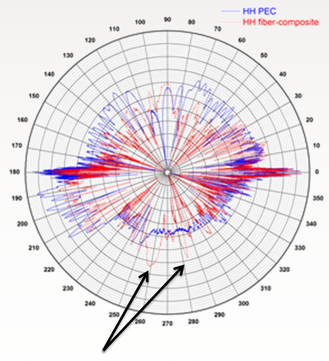


RF properties of blade materials are well characterized

Rotor Scattering Analysis

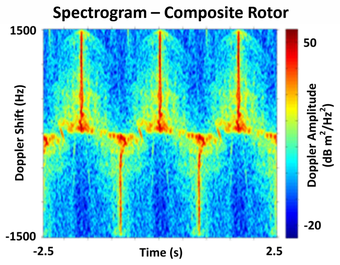
- Modeled RCS of a 60 m blade set (diameter 126 m)
- Findings indicate the full composite structure must be modeled, as metal (PEC) blades underestimate Doppler shift
- Models identify key areas requiring RAM treatment



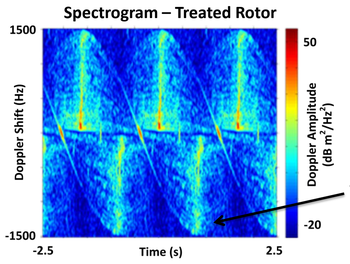


Composite rotor RCS exceeds that of PEC rotor in several directions

Spectrogram – Composite Rotor

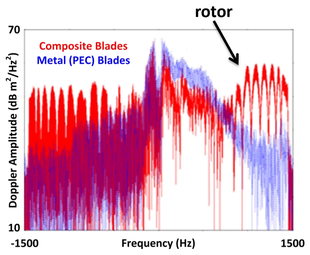


Spectrogram – Treated Rotor



Treating shear web and spar cap with perfect absorber reduces Doppler component

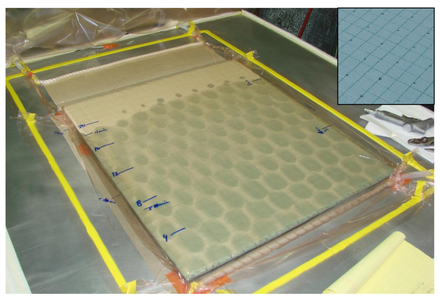
Composite rotor exhibits worse scattering at large Doppler shift than PEC rotor

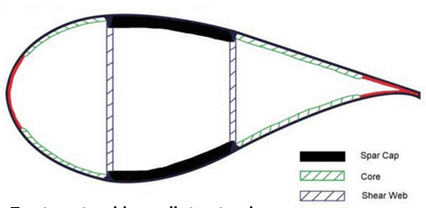


Fabrication Approach

- RAM integrated in vacuum assisted resin transfer molding (VARTM) with no process modification
- Treatments developed for both solid composite and sandwich constructions

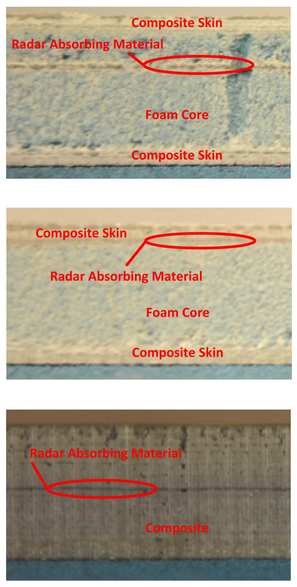
VARTM Process – No modification required other than addition of RAM





Treatments address all structural components in blade cross section

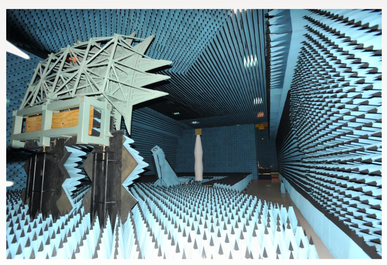
Integrated Absorber Cross Sections

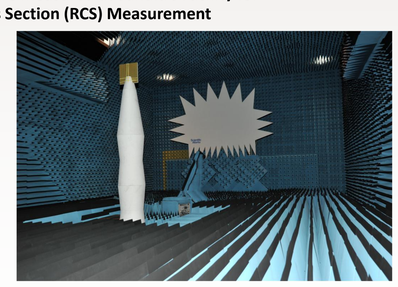


Measured RCS

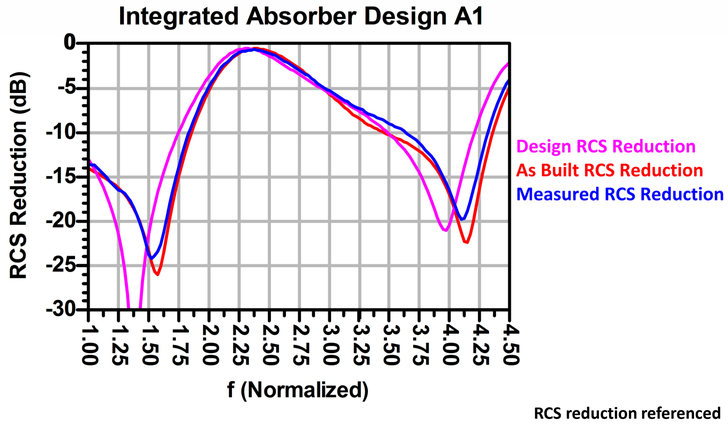
- 20 dB or greater RCS reduction achieved
- Performance validated for both narrowband and broadband designs, solid composite and sandwich constructions
- Conductively coated fabrics integrated with standard blade materials

Integrated Absorber designs were measured at Sandia's Facility for Antenna and Radar Cross Section (RCS) Measurement



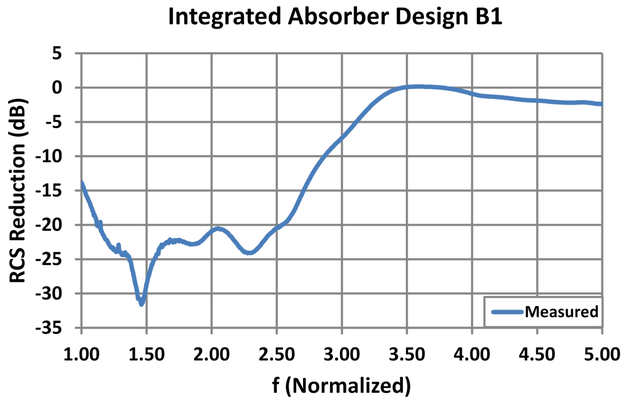


Integrated Absorber Design A1



RCS reduction referenced to a metal plate of equivalent size

Integrated Absorber Design B1



Cost Scaling

- Preliminary cost analysis indicates RCS treatment increases blade cost 7-8 % and turbine cost 1-2 % in mass production
- Assumptions – No additional labor or process modification, entire blade surface area treated with a single RAM layer

Future Work

- Additional rotor scattering analysis to identify key blade regions needing treatment
- Construction and testing of 9-13m treated and untreated blades
- Further materials and process characterization to improve agreement between models and constructed designs

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

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