SAND2020-11135PE

Wind Turbine Blade RCS Reduction Studies at Sandia National Laboratories




PRESENTED BY

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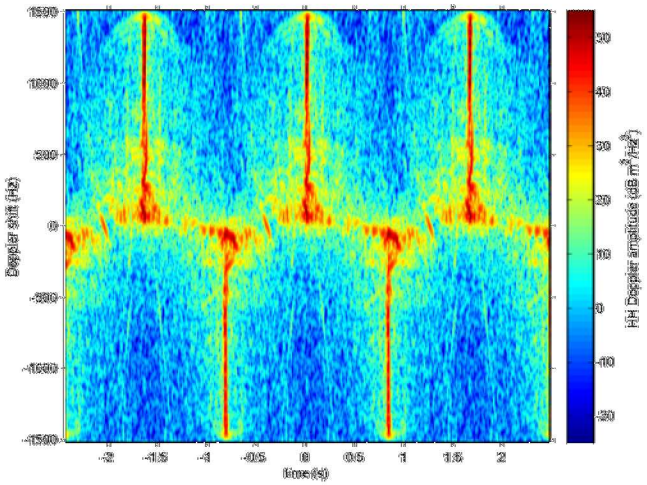
RCS Reduction of Wind Turbines Using Radar Absorbing Material - 2012

SNL developed treatments that can be economically implemented into blade-fabrication processes in order to reduce radar cross section (RCS) of a wind-turbine blade by at least 20 dB.

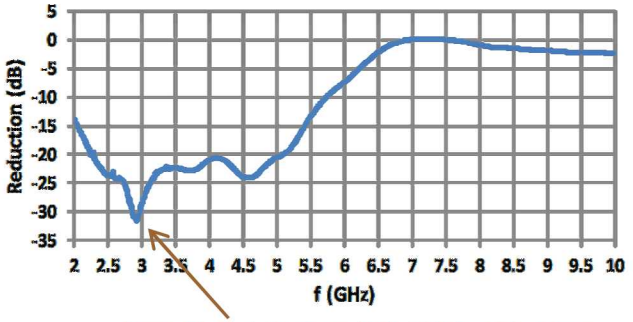
Summary/Accomplishments

- Characterized Blade Materials and Fabrication
- Developed RCS Reduction Treatments at S-band (2 - 4 GHz)
- Integrated RAM Designs into Blade Fabrication Process
  - Low impact integration into standard Vacuum-Assisted Resin-Transfer Molding process
  - As simple as adding two layers with no process changes
  - Predicted cost increase less than **10% per blade, 2% per turbine**
- Measured Flat Panels with and w/o RCS Reduction Treatment
  - **–20 dB or less reflection coefficient measured** for both spar and sandwich panels
- Analyzed Three-Blade Rotor using Realistic Blade Construction and Materials (126-meter Diameter)
  - Generated static RCS and Doppler spectrum responses
  - Compared composite and perfect electric conductor (PEC) rotor scattering
  - Identified significant scattering elements

Full rotor Doppler Spectrogram, AZ = 90°

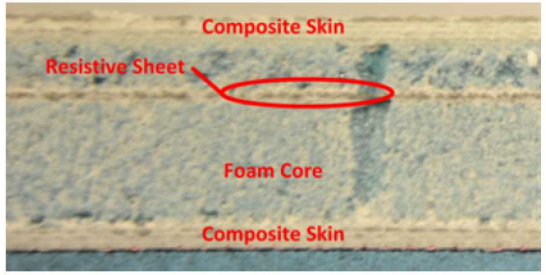


Measured RCS Reduction (PEC Reference)



Broadband (2.3 to 5.1 GHz) reduction (≥ 20 dB) in reflection coefficient

Integrated RAM Cross-Section



Blade Material Samples

Wind Turbine Lightning Protection System RCS Reduction – 2018

SNL modeled new lightning protection cable configurations that show promise to reduce radar cross section (RCS) of a wind-turbine blade at specific frequencies.

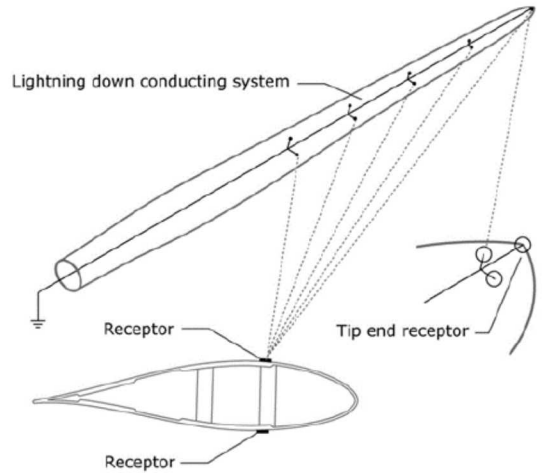
Summary/Accomplishments

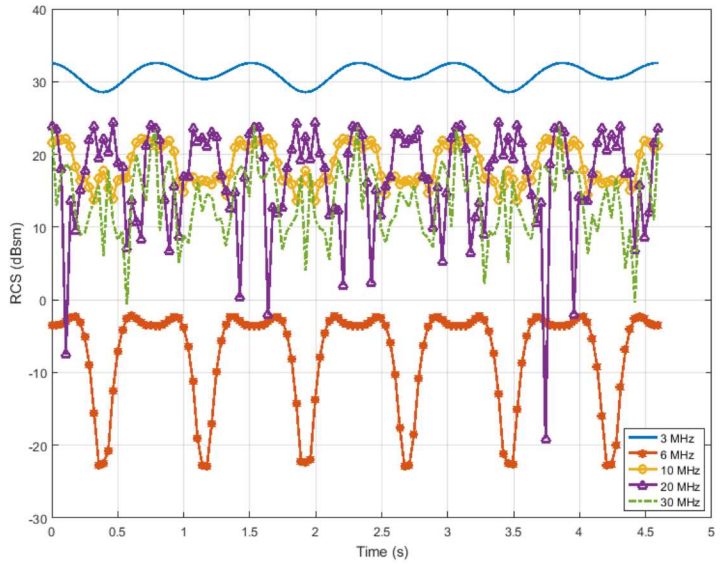
- Modeled RCS of a 50m metal straight LPS cable and compared against new LPS configuration
  - Straight Segmented Cable

    - Segmenting the cable makes smaller cables that resonate at higher frequencies. This can be used to shift resonance above frequencies of interest.
    - More segments require more spark gaps.
  - Zig-Zag Cable

    - No significant changes produced by bending the cable into a Zig-Zag
    - Segmenting results similar to straight wire case
  - Reactively Loaded Cable

    - An example case was investigated by splitting the cable into two segments and loading each segment with a reactive impedance (inductor).
    - Example at 6MHz showed promise in RCS reduction





Summary

- 2012 Radar Absorbing Material Study
  - 20 dB or greater reduction can be achieved by integrating RAM into the existing blade fabrication process
    - However, 20 dB return loss does not necessarily correspond to 20 dB RCS reduction for a complete turbine
  - Predicted cost less than 10% per blade, 2% per turbine
  - A full blade and rotor test plan was developed but was not funded
  - Report can be found at:

https://www.osti.gov/biblio/1038185-radar-cross-section-reduction-wind-turbines-part

- 2018 Wind Turbine Lightning Protection System RCS Reduction Study
  - Segmenting shows promise for RCS reduction depending on length of segments and frequency of impacted radar
  - Inductively loading the lightning protection cable may produce better results and can be tuned for frequencies of interest in a relatively narrow band
  - Study did not look at feasibility or cost of implementation into wind turbine blades

MORE RESEARCH & DEVELOPMENT IS NEEDED TO PROVE OUT THESE APPROACHES