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Measuring Extinction and Monostatic Radar Cross-Sections of Low-Scattering Antennas

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This abstract describes methods used to experimentally determine the extinction and monostatic radar cross-sections of objects as small as we can measure, as used over a frequency band from 6.6 - 15 GHz. This is motivated by our recent design and fabrication of a dipole antenna which is expected to provide little interference to co-polarized incoming waves at frequencies around 10 GHz. We wished to measure how small this interference is at these frequencies as characterized by the extinction cross-section, σ_{ext}, which is the sum of the scattering and absorption cross-sections. Because this property is difficult to measure accurately for small cross-sections we also measure the monostatic radar cross-section (RCS), σ_{mono}, which can be more accurately measured down to very low levels. We were able to measure σ_{mono} down to -70 dBsm, matching the smallest reference object we had, and σ_{ext} down to about -45 dBsm. We follow on methods previously used for similar measurements [1], and discuss the effects of different analytical techniques.

Determinations of σ_{ext} are difficult to make since the scattering of interest is forward scattering, which must be contrasted with the direct transmission. Measurements of the monostatic radar cross-section are much easier, and can accurately measure much lower cross-sections since the antenna will receive little signal other than the scattering of interest. For both of these measurements, to obtain best results the experimental setup must be relatively free of signals other than the direct signal we wish to measure, such as scattering from nearby objects or noise - these should be reduced as much as possible. For this reason we performed measurements using an anechoic chamber at DTU Space, in Denmark. In the chamber, we arranged two X-band standard gain horn antennas, pointed at each other with a foam sample holder between them. Using a VNA we measured S_{11} and S_{21} in the frequency interval of 6.6 - 15 GHz for a variety of antennas, as well as a number of metallic spheres of different radii, and this is the data we used to obtain our results.

For both of these measurements we used the techniques of time gating, zero padding, and calibration with a reference object to analyze our measurements. Time gating allows us to isolate the scattering of interest, zero padding makes the analysis more robust to changes in parameters, and by calibrating measurements with an object similar to what we want to measure, we can scale our results and better compensate for deviations from an ideal setup. After this analysis we concluded that the main source of measurement error came from deviations in the setup introduced over time, and when measurement objects were added or removed from the chamber. This is largely unavoidable since the object being measured must be moved at least once for any complete measurement.

The extinction cross-section can be calculated as in: $\sigma_{\text{ext}} = -\text{Im}\left(A_{\text{cal}}\frac{S_{21}^{\text{test}}-S_{21}^{\text{bg}}}{S_{21}^{\text{cal}}-S_{21}^{\text{bg}}}\right)$, where the calibration vector $A_{\text{cal}} = \frac{2\lambda F_{\text{cal}}}{E_0}$. F_{cal} is the theoretically calculated forward far-field scattering amplitude, for our case of metallic spheres. This requires three measurements of S_{21} - one for the object being tested, one for the reference object, and one background measurement without any object.

The monostatic RCS can be calculated as in: $\sigma_{\text{mono, test}} = \sigma_{\text{mono, cal}} \cdot \frac{|S_{11,\text{test}}-S_{11,\text{bg}}|^2}{|S_{11,\text{cal}}-S_{11,\text{bg}}|^2}$, where $\sigma_{\text{mono, cal}}$ is the monostatic RCS of the reference object, also found theoretically for our spheres. This requires three measurement as well, which can be taken with the three measurements used for the extinction cross-section.

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References

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