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Validation of Asymptotic Techniques to Predict Bistatic Radar Cross Section

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Abstract : Simulations are commonly used to predict the bistatic radar cross section (RCS) of military targets since characterization measurements can be expensive and time consuming. It is thus important to accurately predict the bistatic RCS of targets. Computational electromagnetic (CEM) methods can be used for bistatic RCS prediction. CEM methods are divided into full-wave and asymptotic methods. Full-wave methods are numerical approximations to the exact solution of Maxwell’s equations. These methods are very accurate but are computationally very intensive and time consuming. Asymptotic techniques make simplifying assumptions in solving Maxwell's equations and are thus less accurate but require less computational resources and time. Asymptotic techniques can thus be very valuable for the prediction of bistatic RCS of electrically large targets, due to the decreased computational requirements. This study extends previous work by validating the accuracy of asymptotic techniques to predict bistatic RCS through comparison with full-wave simulations as well as measurements. Validation is done with canonical structures as well as complex realistic aircraft models instead of only looking at a complex slicy structure. The slicy structure is a combination of canonical structures, including cylinders, corner reflectors and cubes. Validation is done over large bistatic angles and at different polarizations. Bistatic RCS measurements were conducted in a compact range, at the University of Pretoria, South Africa. The measurements were performed at different polarizations from 2 GHz to 6 GHz. Fixed bistatic angles of β = 30.8°, 45° and 90° were used. The measurements were calibrated with an active calibration target. The EM simulation tool FEKO was used to generate simulated results. The full-wave multi-level fast multipole method (MLFMM) simulated results together with the measured data were used as reference for validation. The accuracy of physical optics (PO) and geometrical optics (GO) was investigated. Differences relating to amplitude, lobing structure and null positions were observed between the asymptotic, full-wave and measured data. PO and GO were more accurate at angles close to the specular scattering directions and the accuracy seemed to decrease as the bistatic angle increased. At large bistatic angles PO did not perform well due to the shadow regions not being treated appropriately. PO also did not perform well for canonical structures where multi-bounce was the main scattering mechanism. PO and GO do not account for diffraction but these inaccuracies tended to decrease as the electrical size of objects increased. It was evident that both asymptotic techniques do not properly account for bistatic structural shadowing. Specular scattering was calculated accurately even if targets did not meet the electrically large criteria. It was evident that the bistatic RCS prediction performance of PO and GO depends on incident angle, frequency, target shape and observation angle. The improved computational efficiency of the asymptotic solvers yields a major advantage over full-wave solvers and measurements; however, there is still much room for improvement of the accuracy of these asymptotic techniques.

Keywords : asymptotic techniques, bistatic RCS, geometrical optics, physical optics
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