RCS Measurements : Statistical Characterization of the Impact of the Coupling Between a Calibration Sphere and a Styrofoam Positioner

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The acquisition of the Radar Cross Section (RCS) of a target in an anechoic chamber requires a precise measurement of the electromagnetic field (EMf) echoed by a known target for calibration purpose (usually, a sphere or a disc). The usual calibration formula relies on the assertion that the measured echo level of the calibration target is proportional to its theoretical RCS, up to a constant factor (depending only on the frequency) standing for the global transfer function of the measurement system. This constant is supposed to be the same for the target and the sphere, implying that any measurement artifact or residual error should be negligible (if not completely ignored). The evaluation of calibration errors is of main interest as it is one of the several items of the RCS Measurements Error Budget (Kent, Brian M., "RCS Certification for Static and Dynamic RCS Measurement Facilities Volume II – Demonstration Program Results", Air Force Research Laboratory Technical Report AFRL/SNS-2000-03).

Since a positioning system is mandatory to maintain the target or the calibration sphere into the measurement quiet zone, one should take care of the parasitic interaction between the object and the positioning system (usually a styrofoam column) that cannot be removed during the process. Indeed, careful analysis of RCS measurement of calibration spheres exhibits a low residual error of the class of a few 10^{th} of a dB, depending on the sphere RCS level ($|c_0|^2$). Evaluating this error was one of the purpose of a benchmark test case that was submitted to the ISAE 2016 Workshop (http://website.isae.fr/IMG/castest6.pdf).

Our aim is then to set the theoretical probability density function (pdf) of this error and identify its parameters and their connections with the physical parameters of the experiment in order to establish precise bounds on this part of the measurement error budget. Our parametric study is based on exact (EFIE) calculation of the RCS of a sphere on the top of a foam column. The procedure allows to precisely evaluating the coupling level, by vectorially substracting the EMf diffracted by the column alone or by the sphere alone (c_0) to the one diffracted by the assembly "sphere on column"(ρ). We then exhibit a linear relationship between the amplitude of this level and the index of refraction of the Styrofoam positioning column (n), which shows good agreement with actual measurements.

We then establish that the theoretical pdf of the measured RCS is given by :

$$f_\rho(\rho|n) = \frac{\rho(n)}{2\pi\sigma^2} e^{-\frac{\rho(n)^2+c_0^2}{2\sigma^2}} I_0\left(\frac{\rho(n)c_0}{\sigma^2}\right) \quad (1)$$

(where I_0 is the classical Bessel Function) which allows to precisely evaluating the theoretical mean and variance of the RCS, while knowing (even imprecisely) the refraction index of the positioning system. Again, theses theoretical values are compared to the empirical ones obtained from measurements and are shown to be in very good agreements.