Advanced Radar Cross Section (RCS) Visualization with POSTFEKO and Lua Scripting

This white paper demonstrates how Lua scripts in POSTFEKO may be used to produce advanced visualizations of RCS data that was computed in FEKO.

Introduction

FEKO is not designed to be a tool for RCS computation, but due to the general nature of its CEM solver it can be applied to RCS problems.

Radar engineers often have special requirements for the visualization of high resolution RCS-related data. These requirements may be simple, for example:

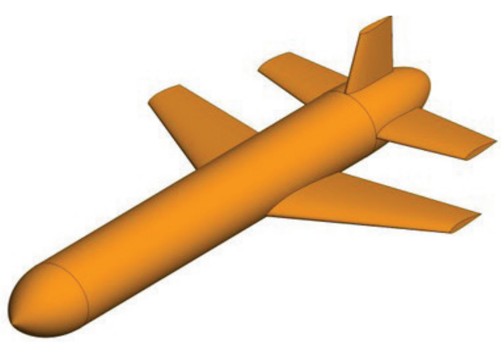
- One-dimensional probability density functions (PDF) that demonstrate the probability of a particular RCS being visible, dependent on taincolorget aspect ratio.
- Two-dimensional RCS intensity plots that demonstrate the intensity of return from a target in relation to two varying angles of incidence.

More complex rendering of RCS information may include inverse synthetic aperture radar (ISAR) images that form a picture of the target, based on varying angles of incidence and frequency of excitation of the relevant radar.

This white paper demonstrates how Lua scripting and POSTFEKO was used to generate such outputs. The work is based on simulation models developed as part of collaboration between EMSS S.A. and CSIR DPSS. Note that the scripts mentioned here are not included in the FEKO suite but are freely available to interested parties.

Target Description

The target used as example in this white paper is a mock-up of a full scale cruise missile with the following dimensions.



Mock-up of generic cruise missile

Physical length

- Length: 0.9906 m
- Wing span: 0.6277 m

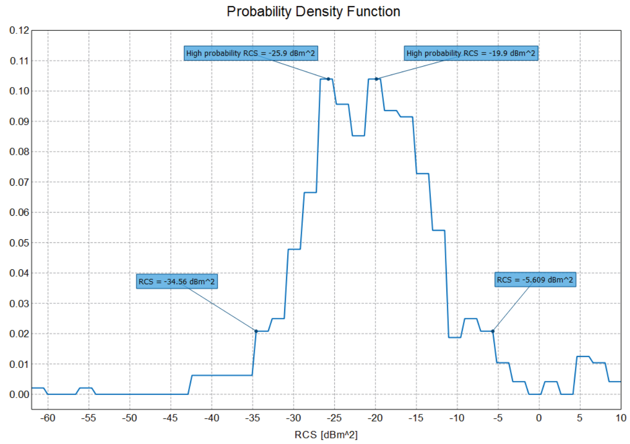
Electrical length

- Length: 39.6 λ
- Wing span: 25.1 λ

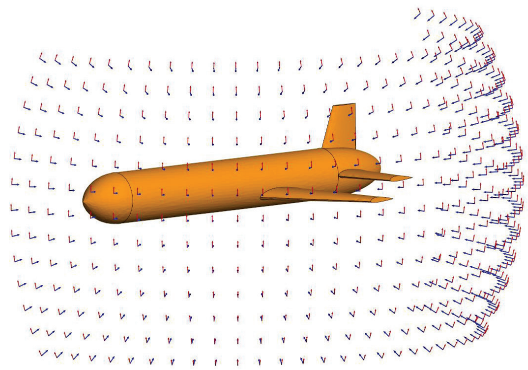
RCS Probability Density Functions (PDF) and 2D Intensity Plots

The purpose of probability density functions and 2D intensity plots is to help form an opinion on the detectability of a target and also which aspect angles of the target have the highest RCS return.

In the case of the cruise missile mock-up the PDF graph demonstrates that the majority of the RCS values for this target (aspect ratio dependent) falls roughly between -34.6 dBm^2 and -5.6 dBm^2. The highest probability of RCS to be detected is roughly -25.9 dBm^2 or equally likely -19.9 dBm^2. The PDF graph was created in POSTFEKO using a Lua script after which the markers were easily added with standard POSTFEKO Cartesian trace measurement and marking tools.



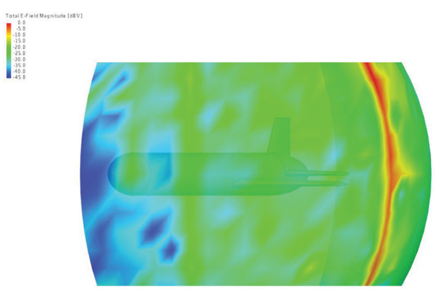
PDF



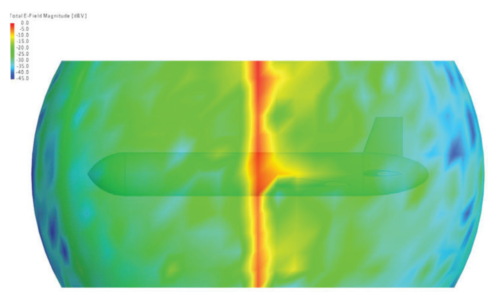
Angles considered

PDF of target aspect angle dependent RCS

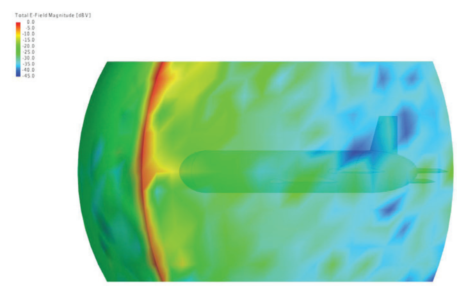
Classic 2D intensity plots are simply a 2D grid plot where colours indicate the magnitude of the plotted variable for any particular XY-variable combination. POSTFEKO may be used to plot a more insightful 3D rendering of this information. A standard 3D plot is made of the RCS in dBm² and the extrusion is set to zero. If the intensity is evaluated over multiple frequencies, an equivalent plot can easily be formed with a Lua script that notes the maximum RCS for a particular aspect angle over all frequencies of interest. The intensity (visible below) is plotted on a spherical co-ordinate system surrounding the object under investigation. If the view is rotated to position any particular aspect angle at the centre of the viewing window, the magnitude of the RCS at that point will correspond to the current view of the target, which is visible below as a result of making the RCS rendering slightly translucent. Rotating this image thus helps the reader learn intuitively which aspect of the target has the biggest RCS.



35°



90°



135°

RCS intensity for side-on aspect at varying azimuth angles

Inverse Synthetic Aperture Radar (ISAR)

ISAR is a signal processing tool for producing two-dimensional images of radar targets. Applications are found in military systems requiring target recognition and classification.

Frequency and aspect diverse back-scattered field data from a target is collected and the scattering centres of the target are displayed on a two-dimensional image. The down-range is defined as the axis parallel to the direction of incidence, with the required resolution achieved by using a finite frequency bandwidth. Perpendicular to the down-range is the cross-range. Scattering data for different viewing angles are collected and are utilized to achieve image resolution in the cross-range. An ISAR image is thus a rectangular plot in the down-range/cross-range rectangular plane, orientated relative to observation angle of the radar.

If the backscattered field values are obtained over a small bandwidth and a small aspect angle width, then the ISAR image can be generated with the use of the two-dimensional inverse Fourier transform (IFT) which has been formulated as follows:

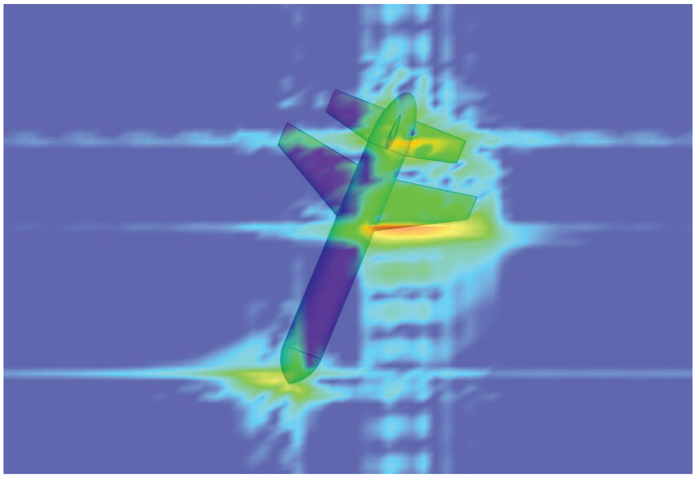
$$ISAR(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}[E^s(k,\phi)]\cdot e^{j2\pi\left(\frac{2f}{c}\right)\cdot x}\cdot e^{j2\pi\left(\frac{k_c\phi}{\pi}\right)\cdot y}\, d\left(\frac{2f}{c}\right) d\left(\frac{k_c\phi}{\pi}\right)$$

In this formulation:

- x, y and φ are spatial coordinates
- f is frequency
- k = 2 πf/c, the wave number

Note that this 2D IFT formulation is only valid for small-bandwidth, small-angle cases where cos φ ~ 1, sin φ ~ φ and k ~ kc

A simulation was setup in CADFEKO to collect frequency data from 7.5 GHz to 12.5 GHz and in the aspect angle range 12° to 32°. As with the intensity plot, this image can be overlaid on the actual target, presenting the viewer with the ISAR image in the context where it was generated and consequently more insight into the formation of the image.



ISAR image of the cruise missile mock target

Conclusion

This white paper demonstrated images of advanced RCS information that was created using standard output results computed by the FEKO solver, which was then cast into the appropriate format using Lua scripts in POSTFEKO. The various FEKO solver methods can clearly be used for RCS and radar research and development purposes, without having to process information in third party tools.

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