Design and Analysis of a Proximity Fuse Antenna for an Air Defence Missile

This white paper is an example of how Antenna Magus can be used to generate antennas for antenna placement studies in FEKO.

Introduction and Specification

Air defence missiles typically require a proximity fuse, instructing the missile warhead to detonate when the missile is close enough to the target. One of the ways that such a proximity fuse can be implemented is with a small radar that is used in short-range low power mode. The antenna for such a radar has to have relatively good gain in the main lobe and side lobe levels (SLL) that are well below the main lobe level. This antenna has to be mounted conformal to the airframe of the missile and have main lobe squint angle towards the nose of the missile.

Specifications for a typical proximity fuse radar antenna:

- Gain > 10 dBi in the main lobe
- SLL < -20 dB in all forward-looking directions
- 45° main lobe squint (measured from nose of missile)
- Must conform to the body of a pre-existing missile
- Centre frequency = 2.4 GHz, allowing electronics designers to take advantage of multitude of components available in this frequency band

This white paper will use the following steps to demonstrate how Antenna Magus and FEKO may be used to design and test such an antenna:

1. Model the array in FEKO, using an appropriate radiating element
2. Model the conformal antenna in FEKO
3. Mount the conformal antenna on a missile to test array operation in its operating environment
4.

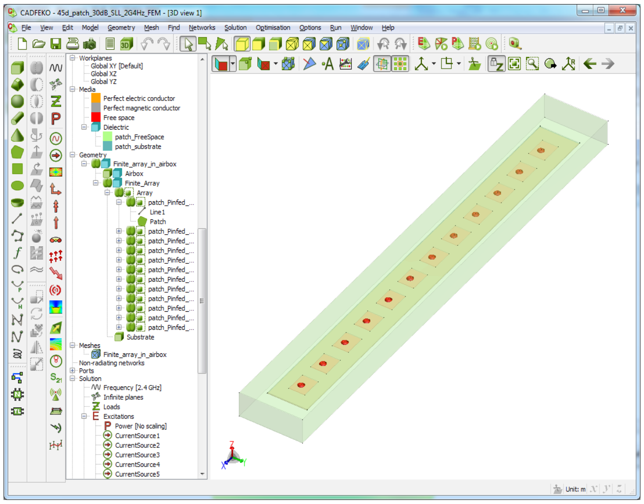
Antenna Magus is used to synthesize the patch antenna array initially.

Modeling of Planar Arrays in FEKO

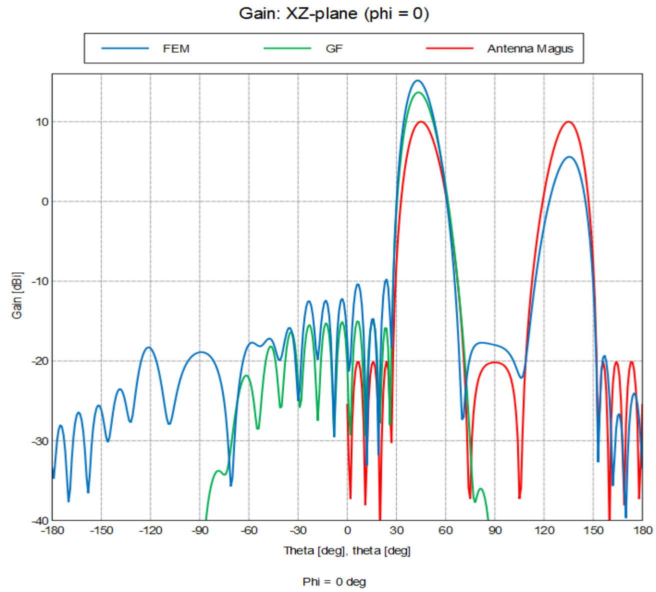
Antenna Magus uses array theory to estimate array radiation performance, which means that mutual coupling between radiating elements and finite ground plane effects are ignored in the estimate. For this reason, it is important that FEKO be used to analyse the predicted performance of the antenna array, while taking all such spurious effects into account. To do this, two FEKO models (using different simulation methods) were created:

- A model based on the method of moments (MoM) planar Green's function (MoM-GF). This full-wave solution method takes mutual coupling (but not finite ground plane effects) into account and is a fast and optimal way of checking the antenna design.
- A model based on the multilevel fast multipole method combined with the finite element method (MLFMM-FEM). This combination of full-wave solution methods include both mutual coupling and finite ground plane effects in the analysis. The FEM is well suited to the modelling of dielectric antennas, while the MLFMM is well suited at modelling the large bounding box of the FEM region (finite element boundary integral (FEBI) method). This model can easily be modified to implement the eventual curved ground plane and the placement of the conformal antenna on the missile airframe.

The prediction of radiation performance that was made by Antenna Magus was exported to a FEKO file format, which made the task of comparing predicted performance to true performance of the two FEKO models an easy one. Both of the FEKO models show excellent correlation with the Antenna Magus predicted results, indicating that full-wave simulation effects do not excessively affect side lobe levels and that both FEKO simulation methods yield accurate results and can be used in further analyses.



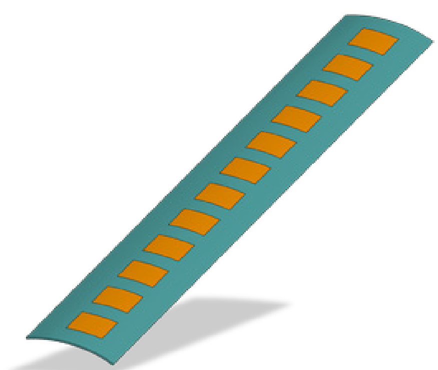
FEM model of finite ground plane microstrip antenna array in CADFEKO



Comparison of FEKO planar antenna model (FEM = blue, GF = Green) with Antenna Magus estimate (red)

Modeling of Conformal Arrays in FEKO

CADFEKO provides users with a wide range of features for geometry manipulation. These features were used to define a conformal finite FR4 substrate with the same surface area as for the planar model, but now curved to have the same radius of curvature that the eventual application would require. The curved model is then compared to the planar model (both using MLFMM-FEM) to test whether radius of curvature has a significant negative effect on the radiation properties of the antenna. The radius of curvature was fortunately large, compared to size of the radiating element (4.52 λ), and there were no adverse effects.

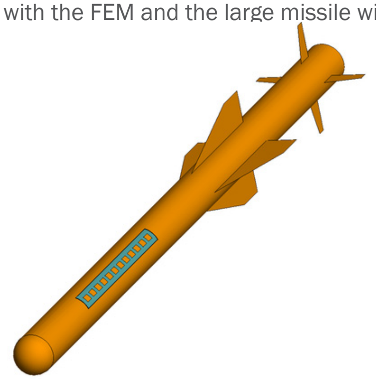


Conformal linear microstrip antenna array

Modeling of Conformal Array Placed on a Missile in FEKO

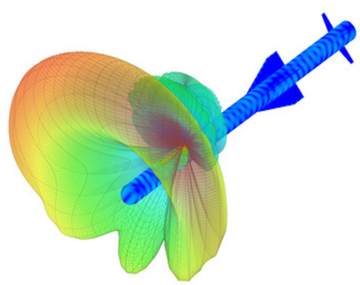
The conformal antenna was integrated onto a mock-up of an IR air defence missile to find out whether the actual operating environment of the conformal antenna had excessive adverse effects on the antenna's performance. The model of the missile was entire constructed in CADFEKO, using only CADFEKO geometry primitives.

The model of the antenna on the missile leveraged the power of the MLFMM-FEM hybrid formulation, treating the complex conformal, dielectric antenna and the cavity that it resides in with the FEM and the large missile with the MLFMM.

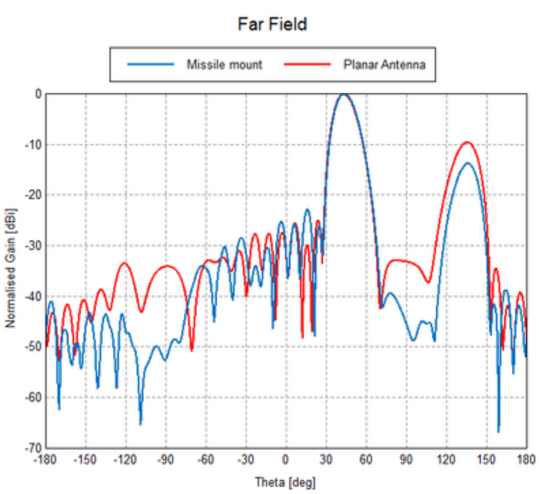


Conformal linear microstrip antenna array mounted on an air defence missile

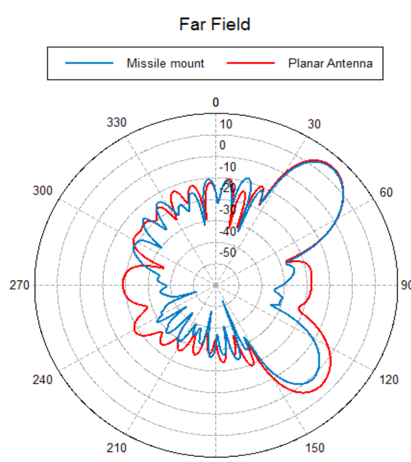
POSTFEKO made it a simple task to visualize the radiation patterns of the antenna mounted on the missile in 3D, providing good qualitative insight into the antenna's radiation performance. Cartesian and polar plots of the principle plane of radiation prooved that the antenna performs as desired and that no modifications are required.



3D far-field gain of the conformal antenna mounted on the missile airframe



Normalized 2D Cartesian graph confirms that side lobes are below -20 dB



Main lobe of antenna has the required 45° squint when mounted on missile

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