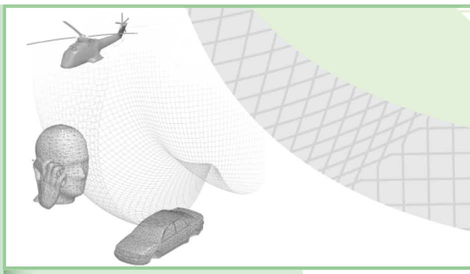


field computations involving objects of arbitrary shape

FEKO

QUARTERLY: September 2004

Inside this issue:

News:

- FEKO Road Show
- German FEKO Users Meeting
- Student Competition

Optimisation: Features and Guidelines

Analytical formulas can often be used to design simple antennas. Optimal designs can often only be achieved through simulation. In this example there is a hidden complexity which is a result of the fact that several valid solutions can be found within a certain design specification.

How does the optimisation work?

In its most basic form a single aim function (e.g. maximum gain) is specified and a number of variables (e.g. antenna dimensions) are then changed through a process of iteration until the aim has been achieved. Optimisation algorithms search through the variable domain based on functional differences or approximate gradients. More complicated optimisation can be done by specifying multiple aim functions.

Multiple aim functions should be coherent!

When defining multiple aim functions, careful consideration of the dependencies between them is required to ensure a coherent design. For example it might seem reasonable to maximize the peak gain and constrain the side-lobe level to a specific level. However, the peak gain and side lobe levels are interdependent.

Example

Specification: 4 element Yagi-Uda antenna with side-lobe level (including the back-lobe) for the H-plane radiation pattern less than -15dB relative to the peak gain, and input reflection coefficient less than -17dB.

Variables: element lengths (four variables), distances between the elements (three variables).

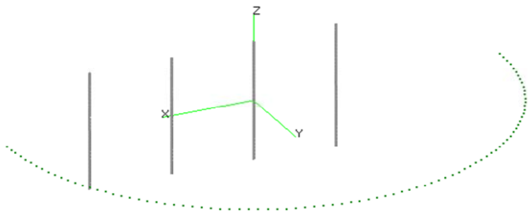


Figure 1: Four-element Yagi-Uda array with the requested far field points in the H-plane.

Design Process

The first two steps are used to get a better understanding of the problem in order to specify realistic aim functions in Step 3.

First Step: Sidelobe and gain from an initial design. An initial Yagi-Uda antenna design is obtained from the literature [1,2]. This design assumes a fixed, 0.3λ element spacing. The normalized E_θ pattern of this "Initial" design, is shown in Figure 2.

Second Step: What is realistic? Using the spacing and element lengths obtained from the first step, what could be achieved if all elements could be excited independently ?

It is known [3] that the Chebyshev distribution will result in the narrowest possible beam width for a specified side-lobe level. The pattern from such a Chebyshev distribution is shown in Figure 2.

Note that the Chebyshev array has a broader main beam compared to the initial design, but has a higher peak gain as less power is radiated over the side-lobe angular range. *Continued on page 2...*

Application Focus: EMC analysis — coupling through a thin slot in a box.

FEKO is suitable to many applications due to a comprehensive implementation and various extensions to the underlying methods on which it is based. This short article will illustrate the application of FEKO specifically to electromagnetic compatibility (EMC) analysis. The coupling through a thin slot in a box is a typical EMC problem and will be used here as a reference [1].

The problem presented is particularly interesting, since the EMI coupling mechanism changes as a function of frequency. The reference article [1] describes the time domain solution to the EMI emission from the enclosure, using the FDTD solution technique. *Continued on page 3...*

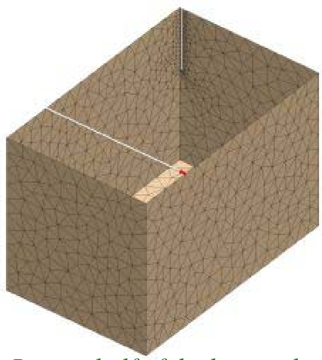
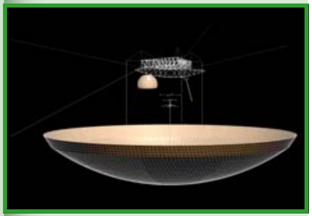


Figure 1: Bottom half of the box enclosure with thin slot.

Optimisation Features and Guidelines.... continued.



FEKO model of the New Arecibo radio telescope.
(From a paper presented at ACES'04 by James Turner, The Pennsylvania State University.)

Given that the element currents of the Yagi-Uda array are not independent of each other, it is expected that the main beam of a Yagi-Uda array will be broader compared to the Chebyshev pattern, for the same side-lobe level. Therefore, based on the initial design and the Chebyshev patterns, a mask with a slightly broader beam can be constructed as shown in Figure 2.

Third Step: Specifying the aim functions

Aim Function 1: Radiation Pattern. The mask as determined in step 2 is now used in the specification of the aim function. The mask, normalized E_θ component versus angle, is constructed, using the "Min/Max values" option of the Radiation Pattern aim function dialog in EDITFEKO.

Aim Function 2: Input Impedance. In addition to specifying the pattern it is also desired to have a well-matched antenna assuming a 50Ω source. Rather than specifying a perfect match, a design with an input reflection coefficient equal, or less, than -17dB, will be acceptable. This will ensure that the optimisation process is not overly constrained and that the impedance aim function does not dominate the optimisation process.

Weighting of Multiple Aim Functions. The radiation pattern and impedance aim functions are combined using equal weighting.

Fourth Step: Choosing the Optimisation Method

It would be ideal to have an optimisation method, which requires the minimum user input and works uniformly for all types of problems. In practice, however, no single method will solve all problems with equal efficiency.

It was decided to use the simplex (Nelder-Mead) search method. This heuristic method uses only the function values (i.e. no gradient or difference approximations are needed). Gradient-based methods could be more efficient, but with multimodal functions some experimentation with step sizes, to compute the approximate gradients, will be required.

Based on the above guidelines and using the 0.3λ fixed spacing Yagi-Uda array as a starting point, a set of parameters that satisfy the design criteria was obtained in 262 iterations. The optimal antenna has a main beam gain (including mismatch) of 10.1dBi and an input reflection coefficient of -17.0dB. The realized pattern is shown in Figure 2.

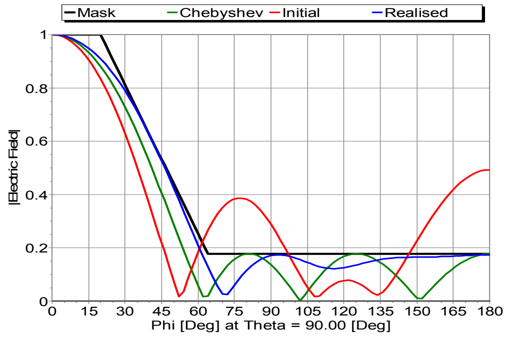


Figure 2: Normalised E_θ in the H-plane.

"Any defined variable can be used as an optimization parameter."

"Adaptive frequency sampling is used to reduce the number of frequency samples required to characterise the response."

Summary:

This example illustrates that optimisation routines are only tools that can assist during the design process and do not replace the requirement for an understanding of the engineering principles.

The design process can be summarized as follows: Understand the physical limitations of the design when defining aim functions. Start from a known design and analytical results where possible. Ensure coherent aim functions when using multiple aim functions. Do not overly constrain the design- rather start with relaxed conditions and see what can be achieved with the optimisation process and then improve the specifications and systematically approach the desired design.

For more information and the model files contact feko_support@emss.co.za.

References

[1] W. L. Stutzman & G. A. Thiele, *Antenna Theory and Design, Second Edition,* Wiley, 1998.

[2] N. Venkatarayalu and T. Ray, *"Optimum Design of Yagi-Uda Antennas Using Computational Intelligence,"* IEEE Trans. Antennas Propagat, vol.52, No.7, July 2004.

[3] R. C. Collin, *Antennas and Radiowave Propagation*, McGraw-Hill, 1985.

Tips and Tricks for Optimisation

- **Any defined variable can be used as an optimisation parameter.**
- **By scaling the optimisation parameters to have similar magnitudes, the next sample point can be computed more effectively.**
- **From Suite 4.2, OptFEKO allows multiple aim functions.**
- **OptFEKO can optimise over multiple frequency blocks using the average or the minimax principle to combine local aim functions.**
- **The `defined` function is useful to set default values for the optimisation parameters when creating and testing the model before using OptFEKO.**

Application Focus: EMC analysis.... continued

The metal enclosure has dimensions 300*220*140mm, with a 120mm x 1mm slot cut in one of the sides, 2mm from the edge. The enclosure is excited by a coaxial line. The position of the excitation, i.e. feed point, is indicated by a red arrow in the FEKO model. The centre conductor runs through the enclosure and terminates in a 47Ω resistor on the opposite side of the enclosure. Further details can be found in [1]. Only half of the enclosure is shown in Figure 1. Note the use of smaller triangles around the slot and the coaxial cable connections. The triangle edge length near the slot is of similar dimension to the slot size. The magnetic symmetry of the problem is exploited by FEKO in order to reduce the memory and run time requirements.

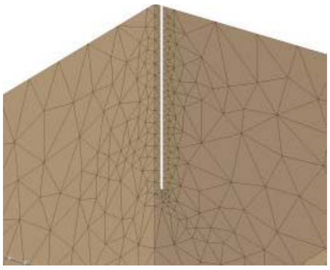


Figure 2: Smaller mesh is used in the region of the thin slot.

Two measurable quantities are required from the simulation. The first is the power delivered to the enclosure by a 50Ω source and the second is the electric field strength at a distance of 3m from the shielding enclosure.

The entire geometry is defined using the standard geometry cards available in EDITFEKO. The problem is set up parametrically, so that future modifications can be easily analysed. The use of variables in defining parametric geometry is also required for optimisation simulations with OPTFEKO. The solution of this problem required 2 764 unknowns and 241 MByte of RAM. Adaptive frequency sampling is used to reduce the number of frequency samples required to characterise the response. Only 39 frequency points were used to obtain the results for both observables in the frequency band from 700 MHz to 1.6 GHz.

The two observables, power absorbed by the enclosure and the RMS electric field, change rapidly as a function of the frequency. The results compare very well to those published. This article is adapted from a technical application note, available with model files, on the members area of the FEKO website.

Reference

[1] "EMI from Cavity Modes of Shielding Enclosures – FDTD Modelling and Measurements," M. Li, J. Nuebel et al, *IEEE Trans on EMC*, Vol. 42, No. 1, February 2000, pp. 29-38.

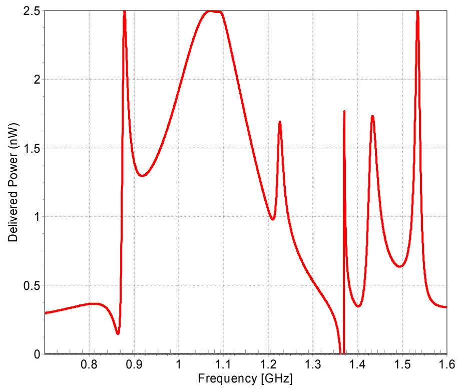


Figure 3: Power absorbed by the enclosure.

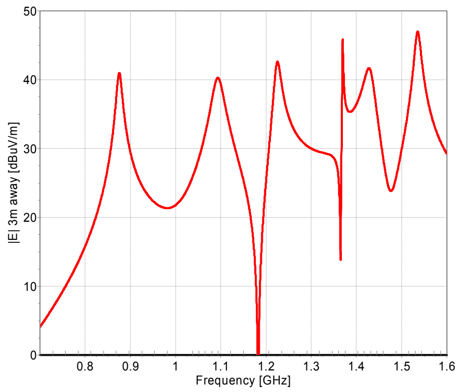
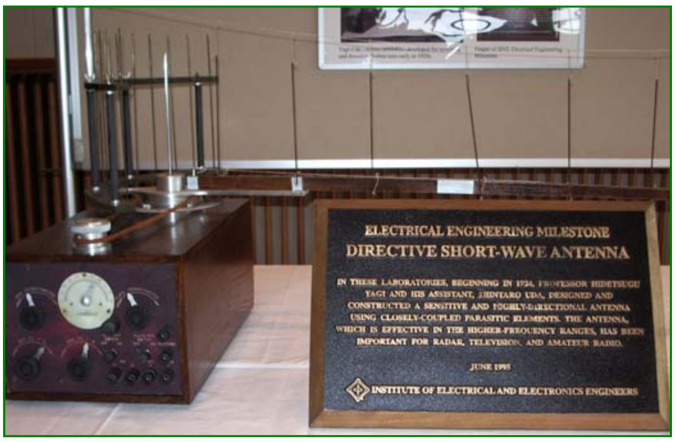


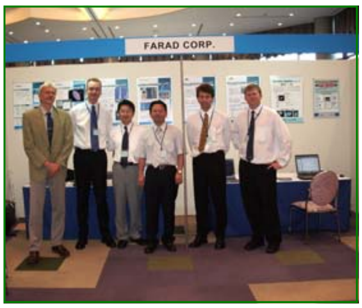
Figure 4: RMS Electric Field at 3m distance.

EMSS and ANSYS-China representatives at one of the three seminars held in China.

Sam Clarke (EMSS) and Dr. C.J. Reddy (President of EMSS-USA Inc.) at MTT, Santa Clara.



A replica of the original Yagi-Uda antenna was on show at the ISAP conference in Sendai where this famous antenna originates.



FARAD Corporation (representing FEKO and TICRA), exhibiting FEKO at ISAP, Sendai, Japan.

News and Events

Exhibitions

Sept 6-10	EMC Europe, Eindhoven, The Netherlands
Oct 6-7	Antenna Systems, Denver, Colorado, USA
Oct 11-15	European Microwave Week, Amsterdam, The Netherlands.
Oct 17-22	AMTA, Stone Mountain, Georgia, USA.
Nov 8-10	Journées Internationales de Nice sur les Antennes (JINA 2004), Nice, France.

German FEKO User Meeting

Oct 27 Stuttgart, Germany.

Annual Student Competition

Aug 27	Application Deadline
Sept 30	Winner Announcement

FEKO on the Road

The past quarter has seen a large number of successful FEKO road shows and exhibitions. The exhibition at the popular Microwave Theory and Techniques Symposium in Fort Worth Texas was followed by an Introductory Short Course and exhibition at the IEEE Antennas and Propagation Symposium in Monterey. Both these exhibitions were coordinated by EMSS-USA.

Over a two week period ANSYS China organised a very successful road show that attracted over 250 attendees in 3 cities – Xi'an, Wuhan and Shanghai. ANSYS is proving their track record of providing excellent support to customers in China.

During June FEKO was exhibited as part of the Intel booth at the International Supercomputer Conference ISC'2004 in Heidelberg, Germany. In July, EMSS GmbH attended EUROEM 2004 in Magdeburg.

Later in July, EMSS USA was back on the road with an exhibition at ANTEM in Ottawa, Canada, followed by an exhibition at the IEEE EMC conference in Santa Clara, California. Most recently, it was the turn of FARAD Corporation to organize the exhibition of FEKO at ISAP in Sendai, Japan.

It has been good to have contact with our customers, and we received many suggestions that we can use to improve our service to you.

FEKO Student Competition

Student Prize: Travel and accommodation expenses to attend the 2005 IEEE Antennas and Propagation Symposium (or similar if not suitable) or visit EM-Software & Systems-SA.

FEKO is a product of EM Software & Systems.