

Figure 8 Variations of the different gains with frequency for Si-MOSFET

device incorporating the channel-length modulation effect, and give better insight into the device frequency behavior at HF and for a direct extraction of RF model parameters.

REFERENCES

1. A.E. Schmitz, R.H. Walden, L.E. Larson, S.E. Rosenbaum, R.A. Metzber, J.R. Behnke, and P.A. MacDonald, A deep-submicrometer microwave/digital CMOS/SOS technology, *IEEE Electron Device Lett* 12 (1991), 16–17.
2. C. Raynaud, J. Gauthier, G. Guegan, M. Lerme, E. Playes, and G. Dambraïne, High frequency performance of submicrometer channel length silicon MOSFETs, *IEEE Electron Device Lett* 12 (1991), 667–669.
3. N. Camillieri, J. Costa, D. Lovelace, and D. Ngo, Silicon MOSFET's, *The microwave device technology for the 90's*, IEEE MTT-S Dig, Atlanta, GA, 1993, pp. 545–548.
4. J.M. Collantes, J.J. Raoux, J.P. Villotte, R. Quere, G. Montorial, and F. Dupis, A new large-signal model based on pulse measurement techniques for RF power MOSFET, *IEEE MTT-S Dig*, Orlando, FL, 1995, pp. 1553–1556.
5. M.C. Ho, K. Green, R. Culbertson, J.Y. Yang, D. Ladwing, and P. Ehnis, A physical large signal Si-MOSFET model for RF circuit design, *IEEE MTT-S Dig*, Denver, CO, 1997, pp. 391–394.
6. C.E. Biber, M.L. Schmartz, and T. Morf, Improvements on a MOSFET model for nonlinear RF simulation, *IEEE MTT-S Dig*, Denver, CO, 1997, pp. 865–868.
7. A. Goswami, A. Agrawal, S. Bose, S. Haldar, M. Gupta, and R.S. Gupta, Substrate effect dependent scattering parameter extraction of short gate length IGFET for microwave frequency applications, *Microwave Opt Technol Lett* 24 (2000), 341–348.
8. E.A. Allam and T. Manku, A small signal MOSFET model for radio frequency IC application, *IEEE Trans Computer-Aided Design* 16 (1997), 437–457.
9. A. Goswami, A. Agrawal, C. Thomas, M. Gupta, and R.S. Gupta, Small signal analytical MOSFET model for microwave frequency applications, *Microwave Opt Technol Lett* 25 (2000), 346–352.

10. K.N. Ratnakumar and J.D. Meindl, Short-channel MOST threshold voltage model, *IEEE J Solid-State Circuits* SC-17 (1982), 937–948.
11. S.M. Sze, *Physics of semiconductor devices*, New York, 1981, 2nd ed., pp. 480–482.
12. Y. Cheng et al., BSIM3 version 3 user's manual, University of California, Berkeley, memo UCB/ERL M97/2, 1997.
13. R.F. Pierret, *Modular series on solid state devices*, Vol. IV, Field effect transistor, 1983.
14. S.H.M. Jen, C.C. Enz, D.R. Pehle, M. Schroter, and B.J. Sheu, Accurate modeling and parameter extraction for MOS transistor valid up to 10 GHz, *IEEE Trans Electron Devices* 46 (1999), 2217–2227.

© 2000 John Wiley & Sons, Inc.

DESIGN OF SINGLE-SHAPED REFLECTOR ANTENNAS FOR THE SYNTHESIS OF SHAPED CONTOUR BEAMS USING GENETIC ALGORITHMS

Mercè Vall-Ilossera,¹ Juan M. Rius,¹ Nuria Duffo,¹ and Angel Cardama¹

¹ Department of Signal Theory and Communications
Universitat Politècnica de Catalunya (UPC)
08034 Barcelona, Spain

Received 20 June 2000

ABSTRACT: A genetic algorithm (GA) has been developed for designing single-shaped reflector antennas for the synthesis of shaped contour beams. The graphical processing technique is used in order to obtain the antenna radiation patterns very efficiently. Results comparing with the classical conjugate gradient are included to provide validation. © 2000 John Wiley & Sons, Inc. *Microwave Opt Technol Lett* 27: 358–361, 2000.

Key words: conformed reflector antennas design; genetic algorithms; conjugate gradient; graphical processing; optimization

1. INTRODUCTION

In many applications, antennas whose radiation patterns fit the shape of a desired coverage region are needed. Shaped contour beams can be obtained using an array-fed parabolic reflector, a direct radiation planar array, or shaped single reflector antennas [3–4].

In this paper, we present a new method for designing single-shaped reflector antennas in order to configure the far-field radiation pattern to the desired shape. This method incorporates a genetic algorithm (GA) [5] as the optimization technique. Only recently have GAs been applied in electromagnetic problems [6]. As GAs are iterative techniques, many radiation patterns must be computed. Consequently, they are computed by the very efficient GRECO (graphical electromagnetic computing) program, which uses the graphical processing technique [1–2].

On the other hand, in order to reduce the number of degrees of freedom, to have local control of the shape of the surface, and to ensure surface continuity, reflector antennas have been modeled by parametric surfaces (NURBs).

Contract grant sponsor: Spanish Comisión Interministerial de Ciencia y Tecnología (CICYT)

Contract grant number: Project TIC 98-1037

Finally, in order to analyze the behavior of such a technique, results using a GA are compared with those using the classical conjugate gradient.

2. REFLECTOR ANTENNA DESIGN: GENETIC ALGORITHM

The design of shaped reflector antennas is not a direct problem. Consequently, it is necessary to use optimization techniques for obtaining the geometry that best fits the required shaped contour beam. In this paper, we present a genetic algorithm developed for this purpose. Simulations using this algorithm have been compared with others using the classical conjugate gradient method (CG) (see Section 3).

The genetic algorithm, as well as conjugate gradient, are iterative methods. Consequently, many reflector surface configurations will be defined and analyzed in the design process. The GA presented in this paper uses, in fact, nonrational *B*-spline (NURBS) parametric surfaces for the definition of the reflector antennas [2]. Consequently, each surface shape is locally controlled with some control points. The *z*-coordinates (parallel to the revolution axis) of some selected control points are identified as the genes, and the total set of genes as a chromosome (one element of the population), according to the terminology used in [5].

In our optimization process, some geometrical constraints are considered.

- Every designed reflector has the same aperture size. The contour of the surface shape cannot change.
- In order to guarantee surface and first derivative continuity, only changes on the *z*-coordinate of the selected control points are allowed.

The basic GA developed may be described in the following steps.

1. *Generate an initial chromosome population of random genes within the variable constraint range.*

After identifying the earth region to be covered, a convenient offset parabolic reflector is modeled with a CAD program using parametric surfaces. Its surface shape is defined with the control points. Some control points are selected, and their *z*-coordinates configure the chromosome of this structure. Using a random algorithm, other antennas are obtained by varying the *z*-coordinate (parallel to the revolution axis) of those control points. The original antenna is selected as one member of the population.

2. *Evaluate the fitness of the population from the optimization function *F*.*

To ensure the coverage of an earth region, some points are strategically selected inside this region. The objective function is defined as

$$F = \frac{1}{N} \sum_{i=1}^N F_i \quad (1)$$

with *N* the number of sample points on the studied region and

$$F_i = \begin{cases} \left[\frac{G_{ci} - G_{di}}{\Delta_i} \right]^2, & \text{for } G_{ci} < G_{di} \\ F_i = 0, & \text{for } G_{ci} \geq G_{di} \end{cases} \quad (2)$$

where G_{ci} and G_{di} are the computed and the desired power gains in linear scale on the coverage region, respectively, and Δ_i is a weighting factor.

In case power minimization is required in some places, null-powered points are also identified. At these points, the objective function term (F_i) is just the contrary:

$$F_i = \begin{cases} \left[\frac{G_{ci} - G_{di}}{\Delta_i} \right]^2, & \text{for } G_{ci} > G_{di} \\ F_i = 0, & \text{for } G_{ci} \leq G_{di}. \end{cases} \quad (3)$$

The objective function is computed for each individual of the population. The best elements are those with the smallest values of the objective function. The GA procedure tries to obtain the minimum of the objective function.

3. *If *F* satisfies the design specification, then stop; otherwise, go to step 4.*
4. *Generate a new population from the fittest members of the old population by crossover followed by mutation [5].*

The worst members of the population are eliminated. Then, in order to obtain a new population with the same number of individuals, pairs of the best members are selected to act as parents (selection process). The parents undergo crossover and mutation, thereby producing pairs of children. Then, these offspring are placed in the new generation. The selection, crossover, and mutation are repeated until enough children have been created to fill the new generation. The new generation is the same size as the first one, and completely replaces the last generation.

Crossover consists of the division of the chromosomes into two halves and their combination. Meanwhile, mutation changes the value of some genes in some chromosomes randomly selected.

5. *Go to Step 2.*

3. GRAPHICAL PROCESSING TECHNIQUE

As we mentioned, in each design process, the radiation pattern of many conformed reflector antennas must be computed in order to evaluate the optimization function (see step 2 in Section 2). The GRECO (graphical electromagnetic computation) technique is a very efficient approach for obtaining the geometry information required for computing physical-optics and equivalent edge-current integrals defined on arbitrarily shaped surfaces and edges that are illuminated by an incident field. This technique is based on the processing of an image of the object displayed on the screen of a workstation or a PC. A detailed description of this procedure is presented in [2]. The optimization of the shaped contour beam presented in this paper is based on the radiation pattern computed with PO approximation. Only the reflection on the reflector antenna has been taken into account. Nevertheless, the same GA could be applied with other approximations, for example, those that compute second-order effects in the radiation pattern computation [2], such as edge diffraction and/or feeding structure shadows.

4. RESULTS

In this paper, we present the design of a single conformed reflector antenna for covering Japan from a geostationary

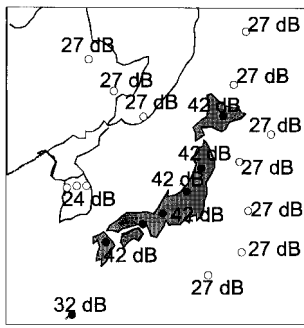


Figure 1

satellite. Also, it is necessary to avoid radiation toward the neighboring countries in order to prevent interference with other signals. Furthermore, the gain on the ocean must be reduced as much as possible, in order not to lose power there. A Hewlett-Packard HP-735 workstation with a CRX-48Z graphics accelerator has been used for the simulations.

Figure 1 shows the reference map, in which the selected points in the coverage region (Japan) with the minimum required level (42 dB) appear in solid circles. Furthermore, some open circles show the maximum required power level in the region where minimum power is desired (Korea, Pacific Ocean, etc.).

Following the steps presented in Section 2, an initial parabolic offset antenna was designed with a reflector diameter of 2.3 m and focus at 1.23 m. Its geometrical configuration is presented in Figure 2. It is necessary to use a large reflector (diameter of 2.3 m and focus at 1.23 m) in order to obtain high directivity, due to the shape of Japan. The feeder radiation pattern is $\cos^{12.28} \theta$, and the edge taper is -4.79 dB. Its contour beam shape over the coverage region is shown in Figure 3. The evaluation of the cost function obtained is 1680.67.

Then, 39 other antennas were obtained using a random algorithm (see step 1 in the previous section). This makes a total population of 40 antennas because the original offset antenna also becomes a member. Chromosomes were defined with 20 control points. Figure 4 presents the contour beam of the optimum antenna obtained with the best simulation. After three iterations (97 surfaces), the GA process was finished, and the cost function value of the optimum antenna was 53.61.

Furthermore, another simulation using the CG algorithm was carried out. This simulation was 15 times faster. Nevertheless, the function cost decreased only to 1140.48. The coverage contour lines presented in Figure 5 demonstrate that the final solution is very far from the optimum.

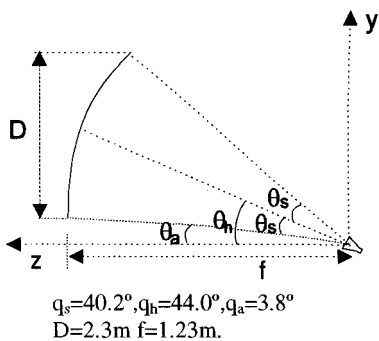


Figure 2

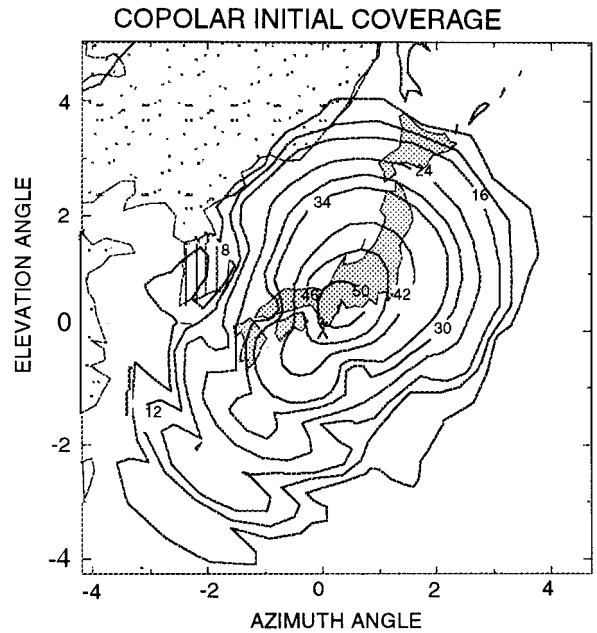


Figure 3

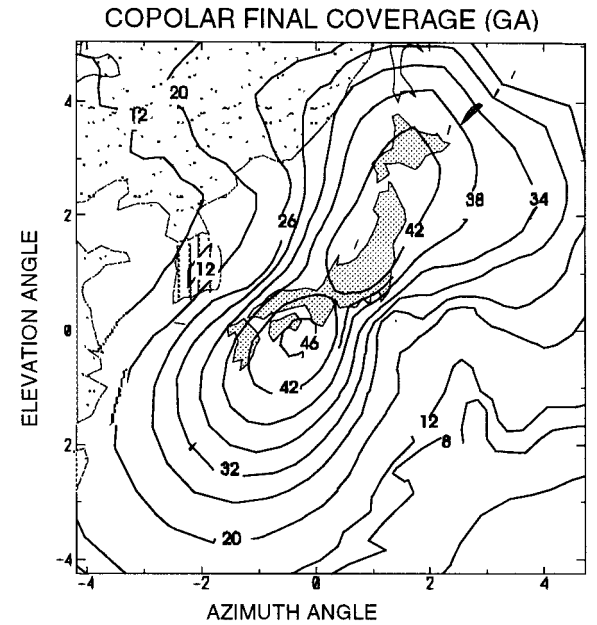


Figure 4

Finally, other simulations using a GA with a less restrictive ending and with the new geometry applying the CG have been carried out. The results were similar to (but always worse than) those using a GA with a considerable reduction of time.

5. CONCLUSIONS

The algorithm developed using GAs has been successfully used in the design of single-shaped reflector antennas. The major advantages of the method presented here are the following.

- As we are using a GA, the probability of obtaining the real optimum is much higher than that using classical optimization methods.

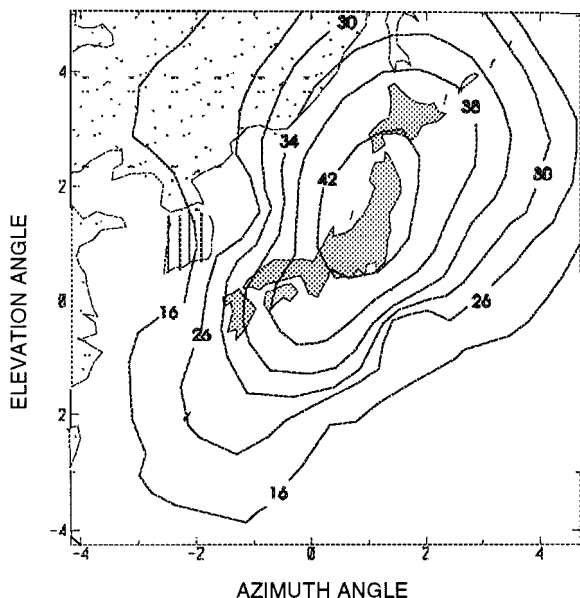


Figure 5

- Although the solutions obtained using a GA with less restrictive ending and then a CG are not as good as a GA with a quite restrictive ending, it represents a solution with a good compromise between time consumption and accuracy.
- Graphical processing obtains a radiation pattern with a physical-optics approximation very efficiently.
- Modeling reflector surfaces with NURBS reduces the number of degrees of freedom to optimize and ensure local control of the surface shape.
- The technique directly works with the surface shape (NURBS control points are the genes).
- Each reflector surface is designed using third-order NURBS. Consequently, no discontinuities on the surface and the first derivative appear.

REFERENCES

1. J.M. Rius, M. Vall-llossera and A. Cardama, GRECO: Graphical processing methods for high-frequency RCS prediction, *Ann Télécommun* (1995), 551–556.
2. J.M. Rius, M. Vall-llossera, C. Salazar, and A. Cardama, Shaped reflector antenna analysis by graphical processing methods, *ACES J* 14 (1999).
3. A.D. Monk and P.J.B. Clarricoats, Null synthesis for shaped reflector antennas, *Electron Lett* 27 (1991), 291–293.
4. A.R. Cherrete, S.-W. Lee, and R.J. Acosta, A method for producing a shaped contour radiation pattern using a single shaped reflector and a single feed, *IEEE Trans Antennas Propagat* 37 (1989), 698–706.
5. D.E. Goldberg, *Genetic algorithms in search, optimization and machine learning*, Addison-Wesley, Reading, MA, 1989.
6. B. Chambers, A.P. Anderson, and R.J. Mitchell, Application of genetic algorithms to the optimization of adaptive antenna arrays and radar absorbers, *1st Int Conf Genetic Algorithms in Eng Syst: Innovations and Appl*, 1995, pp. 94–99.

A NEW ERROR INDICATOR FOR THE ANALYSIS OF WAVEGUIDING STRUCTURES BY THE ADAPTIVE FINITE-ELEMENT METHOD

A. Díaz-Morcillo,¹ L. Nuño,² J. V. Balbastre²

¹ Departamento de Tecnologías de la Información y Comunicaciones Universidad Politécnica de Cartagena 30201 Cartagena, Spain

² Departamento de Comunicaciones Universidad Politécnica de Valencia 46022 Valencia, Spain

Received 22 May 2000

ABSTRACT: An adaptive finite-element method for the analysis of waveguiding structures based on the error at each inner edge of the mesh is presented. The error indicator is based on the fulfillment of the divergence Maxwell equations. The adaptation of the unknowns to the field distribution allows better accuracy in the propagation constant, maintaining a low computational cost. © 2000 John Wiley & Sons, Inc. *Microwave Opt Technol Lett* 27: 361–366, 2000.

Key words: waveguides; adaptive finite-element method; flux continuity; error indicator; refinement strategy

1. INTRODUCTION

The finite-element method (FEM) is a versatile technique which allows the analysis of arbitrary waveguides [1]. As a numerical method, the main drawback of the FEM is its high computational cost. Figure 1 shows the solution time in an HP C-160 700 series when a direct eigensystem solver is used. The computational cost of the problem increases approximately as n^3 , where n is the number of edges in the problem.

Several procedures for reducing this cost, such as using iterative sparse matrix solvers, can be applied. In this context, adaptive methods try to distribute the degrees of freedom of the problem in such a way that an accurate solution can be obtained, maintaining a low number of unknowns. Figure 2 shows the flow diagram of a general adaptive procedure where, at each iterative step, the problem is solved, an indication of the error for each element is obtained, and the mesh is refined in those zones with a bigger error. This approach has been applied successfully in recent years in problems of civil engineering and fluid mechanics, and now it

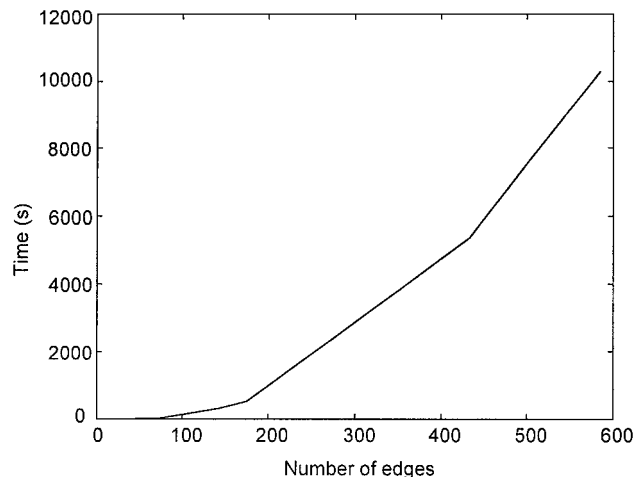


Figure 1 Solving time in the FEM versus number of edges