David B. Davidson
Dept. E&E Engineering
University of Stellenbosch
Stellenbosch 7600, South Africa
(+27) 21 808 4458
(+27) 21 808 4981 (Fax)
davidson@ing.sun.ac.za (e-mail)

Foreword by the Editor

This column frequently features papers describing various computer codes, and this was indeed one of the original aims of the column. The Internet has made it exceptionally easy to distribute such software, and the majority of our columns include sites from which to download the software described in the paper. This issue's contribution addresses reflector-antenna analysis; in the June 2005 column, a paper was published on using the same Jacobi-Bessel series method for analyzing reflector antennas, using *MATHCAD*®. What distinguishes this issue's paper is the use of the Internet to actually *run* the code, via *Java* applets within the browser.

We thank the authors for their submission. It may well be the first submission in this column from South America, and continues to emphasize the global nature of our profession and the IEEE.

Analysis of Reflector Antennas through the World Wide Web

Rafael Rabelo[1], Marco Terada[1], and Warren Stutzman[2]

[1]Antenna Group, Department of Electrical Engineering
University of Brasilia
Brasilia, DF 70919-970 – Brazil
E-mail: terada@ene.unb.br

[2]Antenna Laboratory, Department of Electrical Engineering
Virginia Tech
Blacksburg, VA 24061, USA
E-mail: stutzman@vt.edu

Abstract

This article describes the software *WebPRAC* (Parabolic Reflector Analysis Code for the Web). The Internet version was written as a *Java* applet of *PRAC* for *DOS* [1] and *PRAC* for *Windows* [2]. *PRAC* is a user-friendly code designed for analyzing offset parabolic reflector antennas with high precision and accuracy. It has been extensively used over the past decade in teaching (currently, distributed with [3]), research, and industrial development. *WebPRAC* is intentionally designed for the Internet, running directly from within the Web browser on all usual operating systems (*Windows*, *Linux*, Macintosh, *Solaris*, etc.).

Keywords: Offset reflector antennas; numerical analysis; physical optics; polarization; antenna radiation patterns; Java; Internet; Bessel functions

1. Introduction

The Internet can be deemed the greatest invention of the twentieth century, connecting billions of people from different economic and social backgrounds. Nowadays, surfing the Web is as common as eating, sleeping, working, or talking over a cellular phone (not even considering VoIP). Therefore, it is logical that computer codes intended for widespread use become a dynamic part of the Internet.

The *Java* applet technology [4] (the name stands for small applications, although they can be of virtually any size) is one way to allow users to run codes directly from within their Web browsers, without the need for downloading and installation procedures. In the past few years, there have been reports of codes within the areas of antennas and propagation following this pattern, although not necessarily using *Java* applet technology [5].

This article discusses the implementation in a *Java* applet of the code *WebPRAC*, written to analyze axisymmetric and offset parabolic reflector antennas. *WebPRAC* has been widely used in teaching [3], research, and development, with its accuracy having been validated over the past decade [1, 2, 6]. It employs the Jacobi-Bessel series method [1, 2, 7-9] to evaluate the radiation integral, which yields fast processing even when analyzing very large reflectors, such as the 100-m-projected-diameter Green Bank Radio Telescope [6]. *WebPRAC* is a user-friendly code for the Internet, designed to analyze reflector antennas with high precision and accuracy. Although there are other codes and scripts based on the Jacobi-Bessel method (such as [8]), as far as the authors know, none of them is especially tailored for the Internet, as well as for freely distributed software and operating systems (Linux, Solaris, etc.).

2. The *Java* Applet Technology

The *Java* language [4] is widely known as one of the languages of choice for Internet applications. It has been extensively used over the past decade, and is based on object-oriented programming (OOP), which allows easy maintenance and understanding of the code [4]. A major advantage of *Java* is that the same code runs on all the usual operating systems (*Windows*, *Linux*, Macintosh, *Solaris*, etc.), without the need for recompiling the code. This is possible due to the virtual machine technology, developed and freely distributed by Sun [4] for the users of the aforementioned operating systems.

The virtual machine mimics a processor for which the machine-language instructions are compiled by the *Java* compiler. A complete development kit (the *Java* Development Kit or JDK), as well as integrated development environments (such as *Netbeans*, from which you can write, compile, and test your code), are freely distributed and have been recently open-sourced [4]. Several discussion forums are also available over the Internet.

The applet technology allows the code to be compiled in a way such that it can be run directly from within a Web browser, thus avoiding downloading and installing the code. Of course, if the code is too large and the Internet connection is too slow, it can take a while before the code starts running. *Java* applets currently are up to a few megabytes in size, a figure that can increase as Internet connections become faster. *WebPRAC* is about one megabyte in size. For those familiar with computer languages such as *C* or *FORTRAN*, it is enough to say that once the code is translated to *Java*, or originally written in *Java*, a few commands in the header of the source code instruct the compiler to produce an applet. Then it is necessary to generate a Web page (index.htm for *WebPRAC*) with the necessary instructions to display and run the code when accessed. In order to run the code online, an Internet server is also needed. The home page for WebPRAC is

http://www.ene.unb.br/~terada/antennas

It is worthy mentioning that the compiled code and Web page can also be downloaded and run offline. The aforementioned procedure only works for *Java*-enabled browsers, which must be running on machines where the *Java* virtual machine plug-in (part of the *Java* runtime environment, or JRE) has been previously installed [4]. However, most of today's Web browsers already have the plug-in installed, and many services use the plug-ins, such as Internet banking.

Finally, we mention that the applet technology is very secure. As a matter of fact, security issues are constantly being addressed and improved by the applet community, in order to safeguard the advantages of the technology. Applets such as *WebPRAC* cannot have total access to the user's computer hardware. For example, directly printing and loading/saving files are not allowed. However, it is possible to capture the screen through the "Print Screen" keyboard command, and paste it into another application for printing *WebPRAC* results.

3. Numerical Implementation and Results

The geometry of the offset parabolic reflector antenna is depicted in Figure 1. Note that the symmetrical reflector is a special case where $H = 0$ ($D = D_p$), and is therefore included in the derivations presented in this work. The Jacobi-Bessel series method [1, 2, 7-9] is employed to solve the radiation integral [9]. The procedure consists of expanding part of the kernel of the radiation integral in a function with the modified Jacobi polynomials, which form a complete set of orthogonal functions defined over a disk of unit diameter [9]. A Fourier series is employed in the circumferential direction, and a complex Taylor series expansion is used in the derivations. After several manipulations, the final result for the electric field is given by

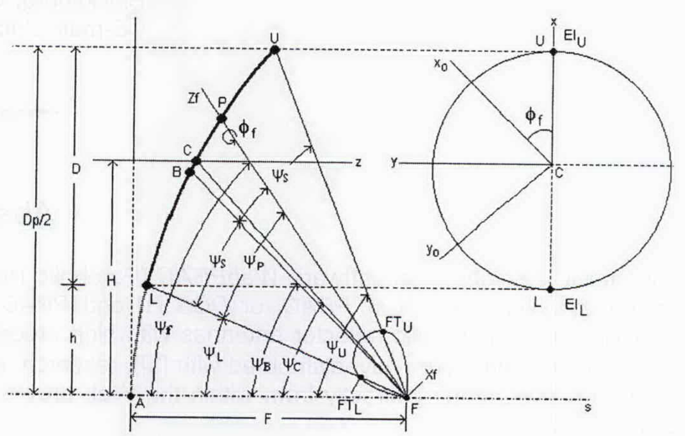

Figure 1. The geometry of the offset parabolic reflector antenna.

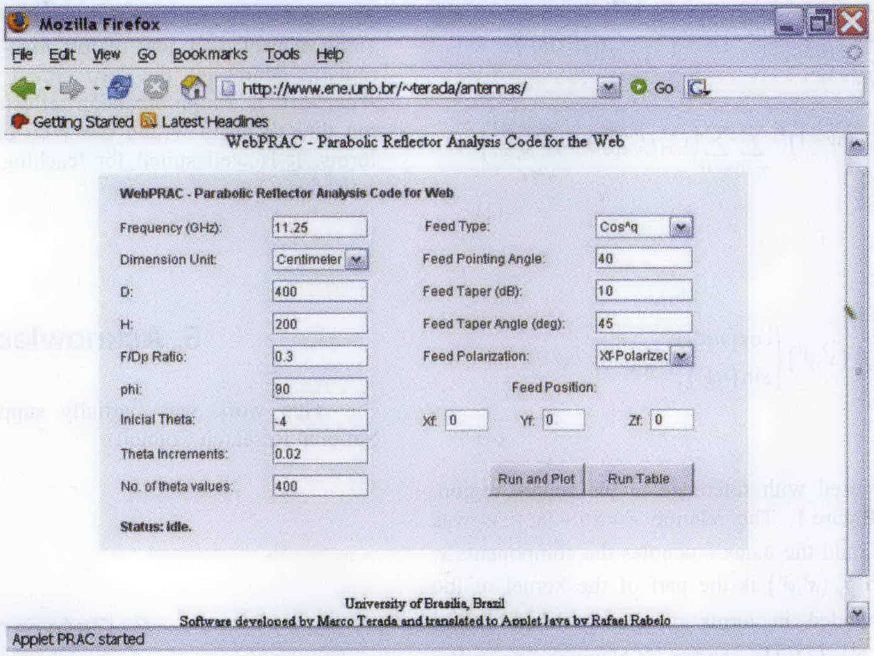

Figure 2. The main screen of *WebPRAC*.

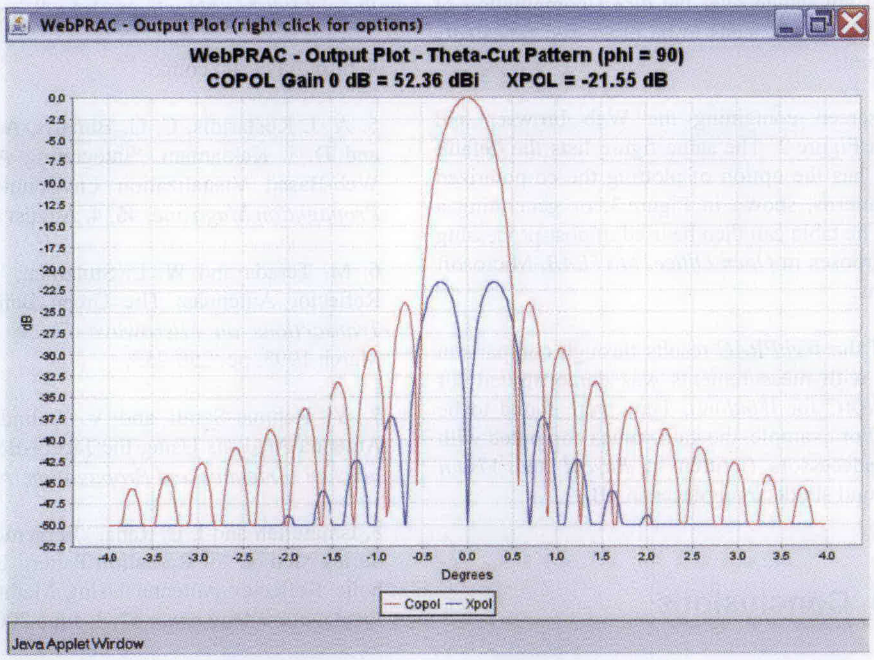

Figure 3. A screen shot of the computed co-polarized (COPOL) and cross-polarized (XPOL) patterns at 11.25 GHz in the plane orthogonal to the plane of offset (H-plane).

$$E_c(\vec{r}) = -j\frac{\eta_0 D^2}{4\lambda}\frac{e^{-jkR}}{4\pi R}e^{jkHu}e^{jk\left(\frac{H^2-4F^2}{4F}\right)w}2\pi e^{jk\left(D^2/16F\right)w}$$
$$\sum_{p=0}^{4}\frac{1}{p!}\left(jk\frac{D^2}{16F}\right)^p(w-1)^p\sum_{m=0}^{7}\sum_{n=0}^{7}\left(C_m^n I_{m,\cos}^{p,n} + D_m^n I_{m,\sin}^{p,n}\right) \quad (1)$$

with

$$\begin{Bmatrix} C_m^n \\ D_m^n \end{Bmatrix} = \frac{\varepsilon_n}{2\pi}\int_0^1\int_0^{2\pi} f_c(s',\phi')\begin{Bmatrix}\cos(n\phi') \\ \sin(n\phi')\end{Bmatrix}F_m^n(s')s'd\phi'ds' \quad (2)$$

where the primes are used with reference to the source region, $x' \equiv x$ and $y' \equiv y$ in Figure 1. The relation $\hat{r} = \hat{x}u + \hat{y}v + \hat{z}w$ was used in the derivations, and the index c denotes the components x, y, and z. The function $f_c(s',\phi')$ is the part of the kernel of the radiation integral expanded in terms of the modified Jacobi polynomials, $F_m^n(s')$, $\rho' = (D/2)s'$, and ε_n is Neumann's number [9].

It is important to note that numerical integration is only necessary for the determination of the coefficients C and D. The coefficients I are computed from recurrent complex relations in closed form, which are herein omitted for simplicity [9]. Once the coefficients C and D are determined, the co-polarization (COPOL) and cross-polarization (XPOL) radiation patterns can be computed at any observation angle without the need of numerical integration. This represents a great advantage over the direct computation of the radiation integral [9], which needs to be processed repeatedly for each observation point.

The computer screen containing the Web browser and *WebPRAC* is shown in Figure 2. The same figure lists the default input values. The user has the option of plotting the co-polarized and cross-polarized patterns, shown in Figure 3, or generating a table with the values. The table can then be used in post-processing routines for various purposes in *Open Office*, *MATLAB*, Microsoft *Excel*, or other programs.

The validation of the *WebPRAC* results through comparison with other codes and with measurements was demonstrated for *PRAC* for *DOS* and *PRAC* for *Windows*. They were found to be very accurate [1, 2, 6]. For example, the gain values computed with *WebPRAC* and its predecessors (written in *Pascal* and *Visual Basic*) agreed up to around six decimal places in dB.

4. Conclusions

This article described the software *WebPRAC* (Parabolic Reflector Analysis Code for the Web). The code was written in *Java* and implemented as an applet. The software was presented, along a brief overview of the *Java*-applet technology, including remarks addressing the *Java* virtual machine and security issues. *WebPRAC* is a high-precision reflector analysis code, designed to run directly from within the Web browser on all common platforms. It is well suited for teaching, research, and development activities.

5. Acknowledgment

This work was partially supported by CNPq (Brazilian National Research Council).

6. References

1. M. Terada and W. L. Stutzman, "Computer-Aided Design of Reflector Antennas," *Microwave Journal*, **38**, August 1995, pp. 64-73.

2. M. Terada, "Reflector Antennas," in Kai Chang (ed.), *Wiley Encyclopedia of RF and Microwave Engineering, Volume 5*, New York, John Wiley and Sons, 2005, pp. 4450-4474.

3. W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design, Second Edition*, New York, John Wiley & Sons, 1998.

4. http://java.sun.com

5. A. J. Kostaridis, C. G. Biniaris, A. J. Marsh, H. T. Anastassiu and D. I. Kaklamani, "Integrating Antenna Modeling Codes in Web-Based Visualization Environments," *IEEE Antennas and Propagation Magazine*, **45**, 4, August 2003, pp. 11-18.

6. M. Terada and W. L. Stutzman, "Computer-Aided Design of Reflector Antennas: The Green Bank Radio Telescope," *IEEE Transactions on Microwave Theory and Techniques*, **MTT-46**, March 1998, pp. 250-253.

7. Y. Rahmat-Samii and V. Galindo-Israel, "Shaped Reflector Antenna Analysis Using the Jacobi-Bessel Series," *IEEE Transactions on Antennas and Propagation*, **AP-28**, 1980, pp. 425-435.

8. Ismatullah and I. E. Rana, "Implementation of the Jacobi-Bessel Series Method for Radiation Pattern Equations of an Offset Parabolic Reflector Antenna Using MathCAD," *IEEE Antennas and Propagation Magazine*, **47**, 3, June 2005, pp. 99-104.

9. C. Scott, *Modern Methods of Reflector Antenna Design*, Norwood, MA, Artech House, 1990.