ANTENNA DESIGN AND RADIATION PATTERN VISUALIZATION

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Abstract: Characteristics and radiation patterns of many antenna geometries and antenna arrays can be evaluated but not easily visualized. This paper presents a software package that has been developed to allow for 2D and 3D visualization of the radiation patterns for many different types of antennas and antenna arrays. The package allows the user to visualize the field patterns for a given type of antenna, and to display the constituent parameters (input impedance, directivity, gain, etc). The user may inspect the field pattern for a single element of many different types of antennas (such as dipole, loop, aperture) or for arrays of common elements. The parameters for these antennas or arrays may be varied manually or via an automated swept parameter menu. The program allows for the design and study of diverse antenna arrays. Common types of 1-D, 2-D, and 3-D arrays are available, as well as a builder for an arbitrary system of elements. Synthesis and simulation tools are also integrated into the package to allow for automatically determining the best configuration for an array or an element to meet a predetermined radiation characteristic.

1. Introduction

In the course of designing an antenna element or an array of elements it often becomes useful to have a method of visualizing the radiation pattern and for determining the constituent parameters of the antenna system. This program allows for the design and visualization of both single elements and of arrays of common elements. The visualization option in the program allows for the inspection of the radiation pattern in full 3-D or in multiple 2-D and 3-D plane cuts. A great advantage is gained by being able to quickly and efficiently examine the radiation pattern in various manners. The ability to examine the field structure for many common types of antennas and antenna arrays enhances the educational and research value of this package. In addition to being able to examine the field structure of the antenna element or array, the package also allows for certain observational calculations to be displayed as well.

2. Single Element Simulation

Since the radiation patterns and constituent parameters for many common types of elements are well known, calculating the radiation patterns is performed in a straightforward manner. The user first selects one of the element types given (dipole, loop, helix, infinite biconical, aperture, or corner reflector). This will bring up the appropriate basic pattern and initial parameters for this type of element. Many of the element types have various configurations and sub-types available in the program. For example if a dipole is selected, the user may choose the type of dipole (thin wire, thick cylindrical, small vertical with ground plane, or small horizontal with ground plane), and then set the parameters for the dipole (frequency/wavelength, dipole length, maximum current, and far field distance). All these parameters will be used to calculate the field pattern to be displayed and its calculated parameters (gain, directivity, etc.), in separate windows, as seen in Figure 1.

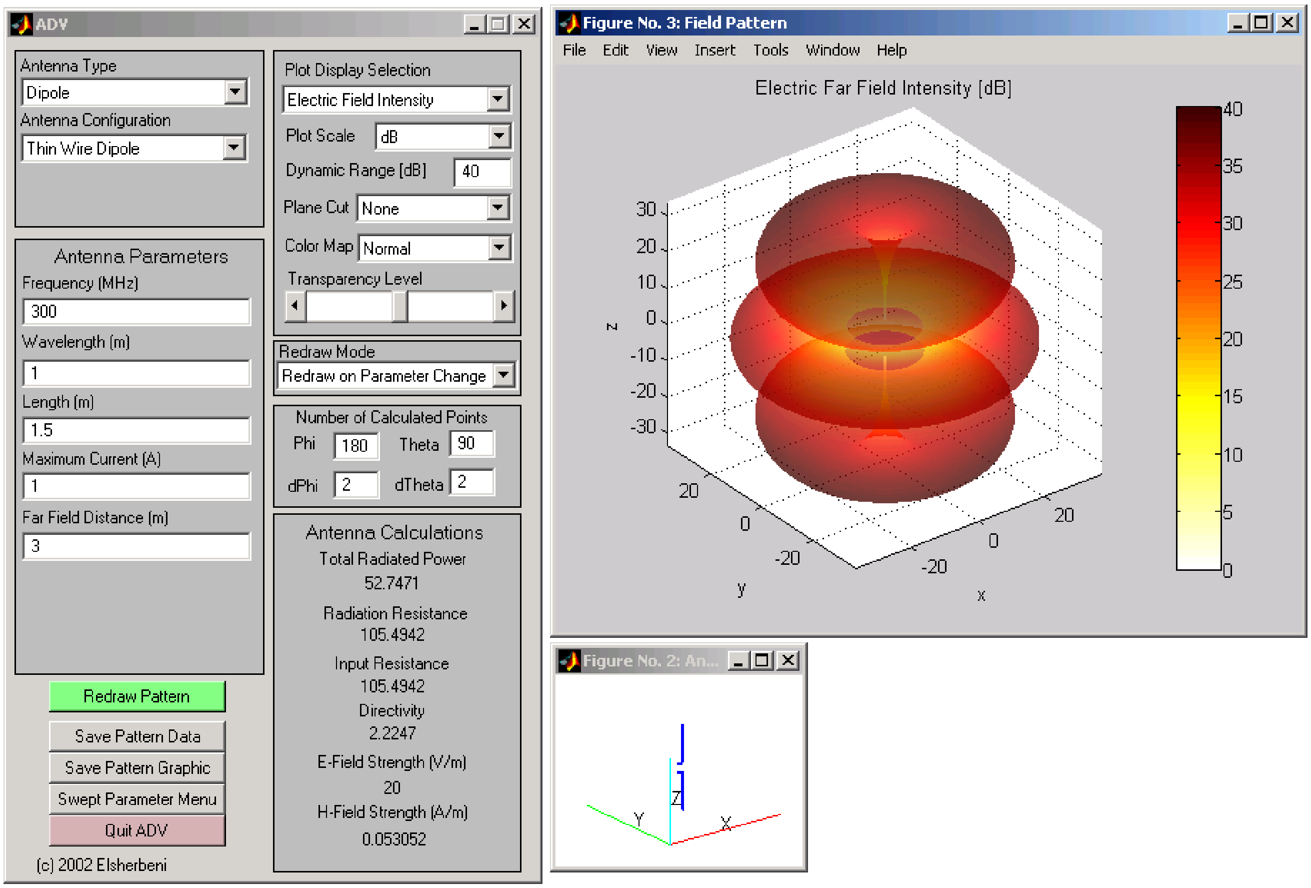

Figure 1. The program windows showing a dipole pattern for L=1.5λ.

Once the antenna type has been selected and the parameters for the antenna have been entered, the program calculates the E and H field patterns from this information. The main program passes off the entered parameters into the appropriate module to perform the field and parameters calculations. By using a modular system, adding new features such as new elements or arrays, becomes a simple matter of loading the appropriate module. The program then calculates the magnitude and phases of each field component at a user selectable number of points in θ (elevation) and φ (azimuth) from the gathered information. By varying the number of points or the step size in each direction, the user may increase or decrease the resolution of the pattern being generated. This saves computational time when the pattern is relatively smooth, and allows for fine detail when the pattern is more complex.

In the main window along with the antenna parameters, are the visualization parameters. These allow for the user to select the type and way the pattern is viewed. The user may select from a list of available patterns and field components (Total E Field, Total H Field, E-Theta, E-Phi, H-Theta, H-Phi, Radiation Intensity, etc.), which allows the user to examine both the total field characteristics and the individual directional characteristics as well. The user may also choose which format they wish to see the pattern displayed in, either in a linear relative format or in a normalized dB format. When the normalized dB format is selected, the user may enter the Dynamic Range for data to be shown. Since in dB format the data can range from 0 down to -∞, the range is a useful tool to examine either the major features of the field pattern or can be varied down to show even small fluctuations. One of the most useful tools in the package allows for the combination of plane cuts and transparency settings for the displayed pattern. When the full pattern is displayed, the transparency slider sets the transparency for the whole figure from completely transparent to completely opaque. When one of the 3-D plane cuts is selected, the slider will go from just showing a small slice of the pattern as seen in Figure 2, to showing a slightly transparent half of the pattern at the halfway point, and up to a completely opaque figure at its highest setting. Likewise the program has the ability to show plain 2-D cuts as well for any figure type.

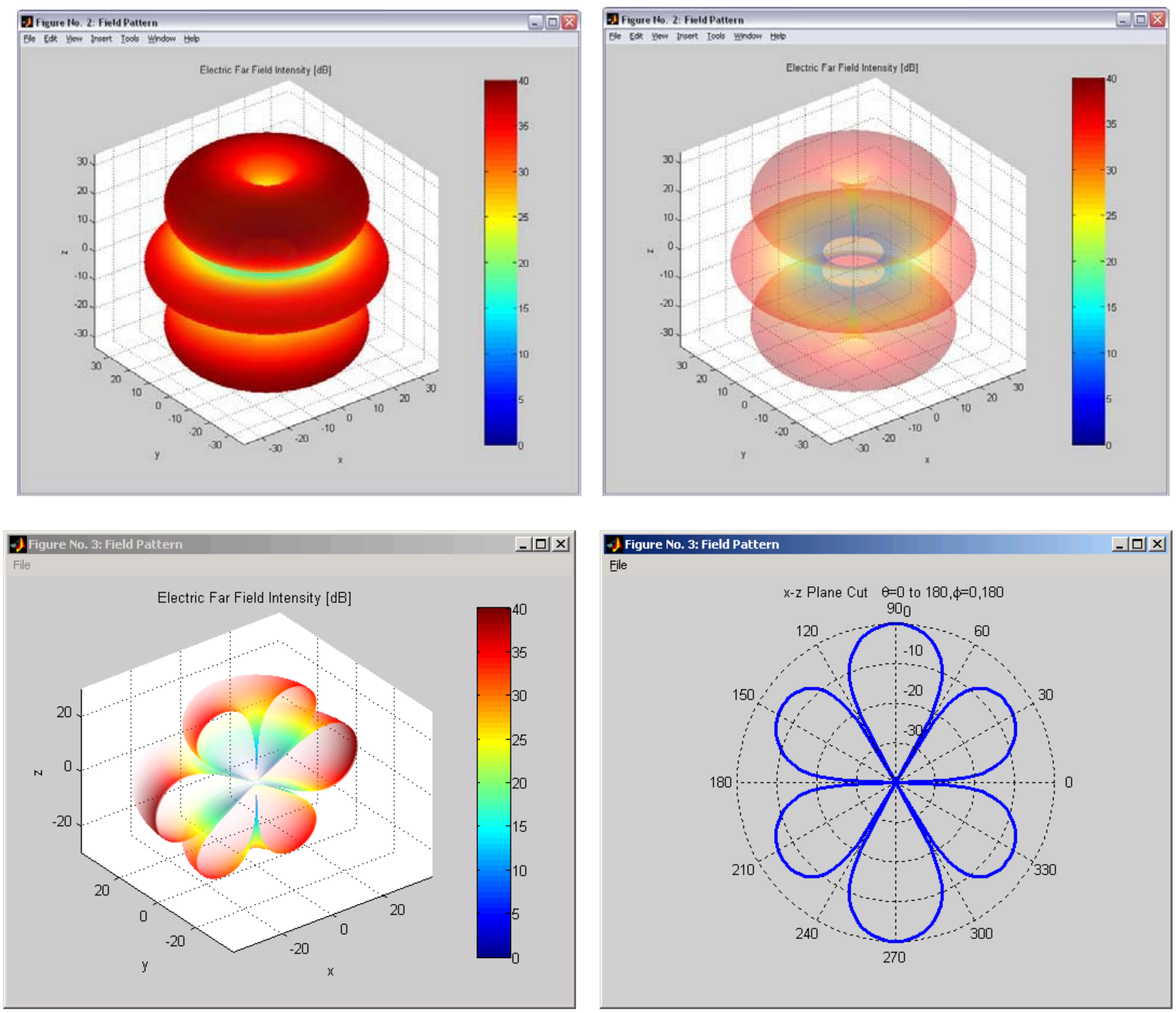

Figure 2. The pattern window showing various 3-D and 2-D plots.

3. Swept Parameters

A very useful tool in antenna design and simulation allows for the program to sweep over a set range of parameters. With the Swept Parameter tool the user may select any one of the active parameters to sweep across. The user then selects the starting and ending points for a parameter to sweep across and also enters the number of increments to be used. When started the program will begin to sweep across this parameter and display the results either as an animated figure in the pattern window (for the type of plot being displayed) or they may step through the sweep one point at a time to examine the results. This ability not only aids in the fine tuning of a desired element by showing the changes in the pattern for small increments, but also adds to the software packages educational value as well.

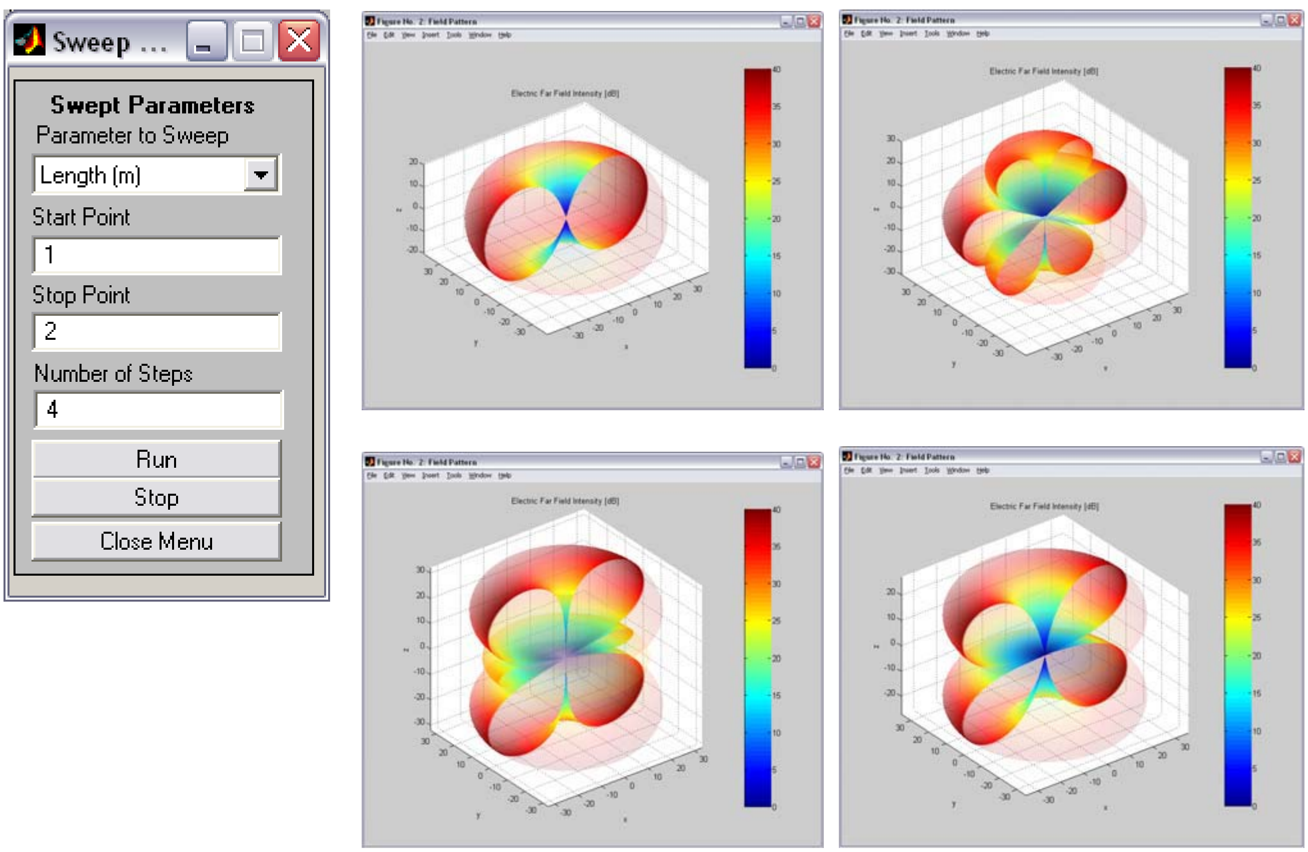

Figure 3. Sweeping a dipole from L=1m to 2m (λ=1m).

4. Antenna Arrays

One of the main features of the program allows for the design of any type of array of common elements. From the main window the user may select any one of the 1-D, 2-D, or 3-D, array types. These include Linear, Circular, Planar, Cubical, Spherical, or the completely arbitrary array. In all but the arbitrary array the user simply selects the desired array, enters the number of elements, the relative amplitudes and phases of the elements (either single elements, rows of elements, or planes of elements depending on the array type) and the corresponding array factor is generated. The array factor itself may be viewed or a composite pattern of the array made with a selected element can be viewed. When an array is chosen an element pattern window will open allowing the user to choose which antenna will be used for the individual elements.

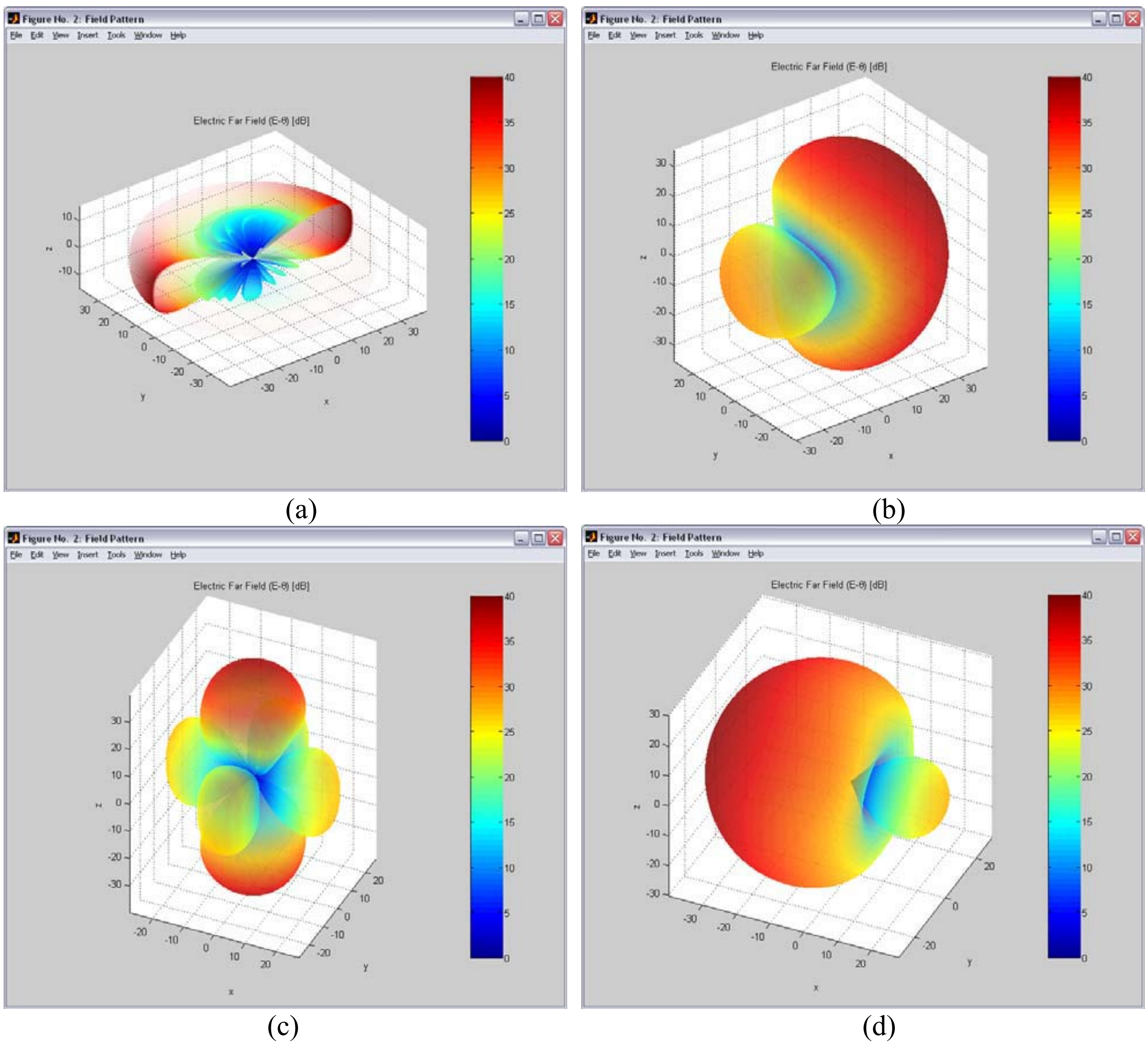

Figure 4. Radiation patterns for arrays of isotropic elements for, (a) Fourier synthesized 1-D array, (b) circular 2-D array, (c) planar array, and (d) spherical array.

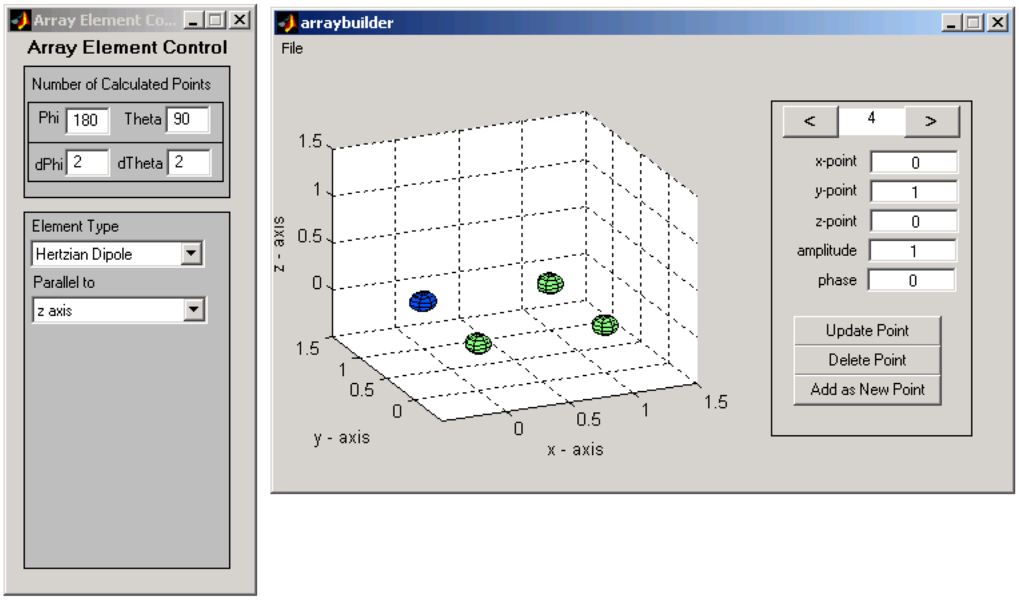

Figure 5. The array element window and arraybuilder window.

A few common types of antenna elements are available here as a matter of convenience, as well as an option for the user to load a pattern file. This file may be generated by this program earlier while designing a single element or may contain data generated elsewhere. This allows for the use of the patterns generated from other programs or gathered from real antennas on an antenna range to be used as elements when analyzing arrays.

Alternatively the program allows for the analysis and visualization of completely arbitrary arrays of elements. In order to accomplish this, the program includes what is known as the arraybuilder. This is a small subprogram that allows for the layout and viewing of the array elements. The user may choose the location in x, y, and z directions (all points are relative to each other and the distance is measured in wavelengths) and the relative amplitude and phase of each element. The arraybuilder allows for the interactive placement and updating of these elements, as changes are shown immediately in the arraybuilder window shown in Figure 3. Elements may be added, updated or deleted at will, and as can be seen in the figure, the currently selected element is highlighted in blue.

5. Conclusions

The program successfully allows the user to interactively design and visualize many common types of antennas as well as arrays of elements. It has great utility not only in its use as a design program for antennas, but as a learning tool as well. It can allow the user to interactively explore antenna patterns and its properties and promotes greater understanding of antenna design. The element design features provide a good platform for design and visualization. The array features allow for the interactive design and visualization of many different types of arrays and allow for the testing and verification of array designs.

References

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Dr. Elsherbeni has conducted research in several areas such as: scattering and diffraction by dielectric and metal objects, inverse scattering, finite difference time domain analysis of passive and active microwave devices, field visualization and software development for EM education, dielectric resonators, interactions of electromagnetic waves with human body, and development of sensors for soil moisture and for monitoring of airports noise levels, reflector antennas and antenna arrays, and analysis and design of printed antennas for wireless communications and for radars and personal communication systems. His recent research has been on the application of numerical techniques to microstrip and planar transmission lines, antenna measurements, and antenna design for radar and personal communication systems. He has published 65 technical journal articles and 12 book chapters on applied electromagnetics, antenna design, and microwave subjects, and contributed to 210 professional presentations. He is the coauthor of the book entitled "MATLAB Simulations for Radar Systems Design", CRC Press, 2003 and the main author of the chapters "*Handheld Antennas*" and "*The Finite Difference Time Domain Technique for Microstrip Antennas*" in Handbook of Antennas in Wireless Communications, CRC Press, 2001.

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