Web-based Interactive Visualization for Electromagnetics and Antennas

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Abstract

This paper reports on three web-based interactive visualization tools developed as an adjunct to instruction in electromagnetics and antennas. The modules (http://www.olemiss.edu/courses/EE/EM/emindex.html) were developed using Macromedia's interactive authoring tool, Authorware, and can be viewed by any internet connected computer using a Netscape or Internet Explorer browser equipped with the Authorware Web Player [*].

1. Background

Many instructors believe that among the reasons that students consider electromagnetics, microwaves, and antennas to be difficult is that humans cannot sense the phenomena being studied without the aid of instruments. In recent years, several visualization tools have been developed using Fortran, Visual Basic, and Java[1-4]. The author and co-PI Professor Elsherbeni settled on Authorware (AW) as a multimedia development tool during work on two NSF ILI grants to introduce multimedia instruction into electrical engineering laboratories[5,6]. In 1996, Macromedia introduced "shockwave" technology that compressed and segmented packaged AW files for delivery over the internet via a user's browser. The modules described here employ this technology to deliver instruction at a time and place convenient to any student who wishes to review or learn this material. The modules described here are intended to augment instruction and have not been created as stand-alone distance learning lessons. While these modules were not developed explicitly during work on the ILI grants, they represent work that has continued since the conclusion of the grant period.

2. The Authoring Environment

Authorware uses a flowline/icon model for programming, and Figure 1 shows a nested flowline construction that includes the structure for a subroutine. "Map" icons allow a hierarchical nesting of functions. Opening the level 1 map icon entitled *Subroutines* shows a framework with another map. Inside *New View* is a calculation icon—"Calculation" icons provide a programming environment similar to Basic. Table 1 shows part of the contents of a calculation icon in a subroutine used in conversion of a 3-D wire model to a screen display. "Display" and "Erase" icons present and remove images and text from the screen; while "Wait" icons control timing. When a piece has been debugged in editing mode, it may be "packaged" into an *.exe file which can be executed on an Intel-based computer running Windows, or, alternatively, into a "player" file which may be viewed on either an Intel-based PC or on a Macintosh using the Authorware

[*] Previously called the Shockwave for Authorware plugin

player. Files packaged using the second option can be segmented and delivered over the Internet using an “embed source” command in an html file.

Modules delivered over the Internet run locally on the user’s computer, so that network traffic on the server does not affect execution speed. This also allows a wide range of interactivity with the user, including keypresses, mouse clicks, dragging, drop-down menus, and text entries.

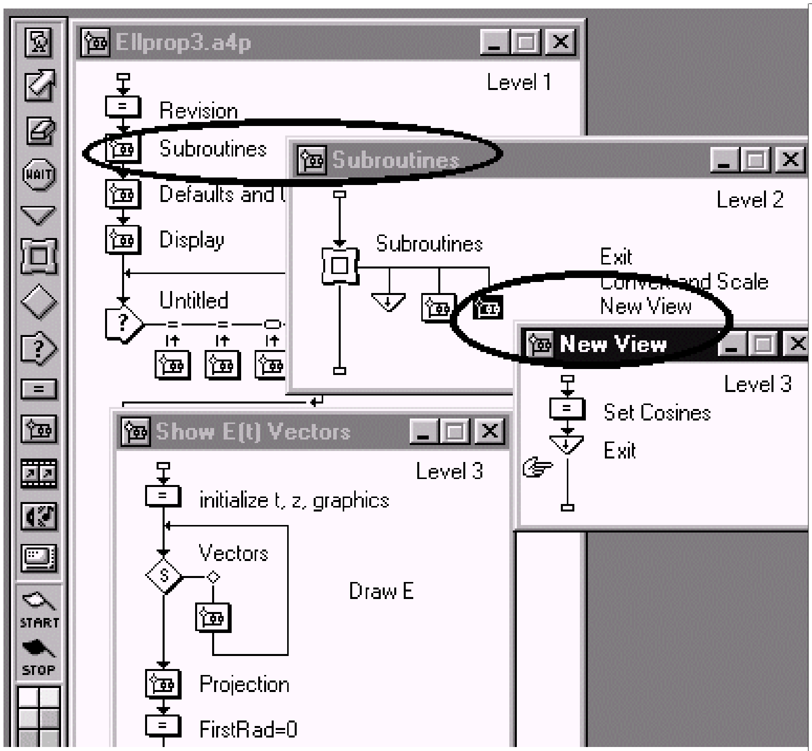


Figure 1. Authorware’s icon/flowline programming

```
…
-- "thetaX" to define angles
relative to the x-axis
     phix:=ATAN(zv/yv)
     thetax:=ABS(ATAN(
       SQRT(yv*yv+zv*zv)/xv))
     ctx:=COS(thetax)
     stx:=SIN(thetax)
     cpx:=COS(phix)
     spx:=SIN(phix)
     ctxcpx:=ctx*cpx
     ctxspx:=ctx*spx
     …
```

Table 1: An excerpt from a calculation icon illustrating Authorware’s programming language

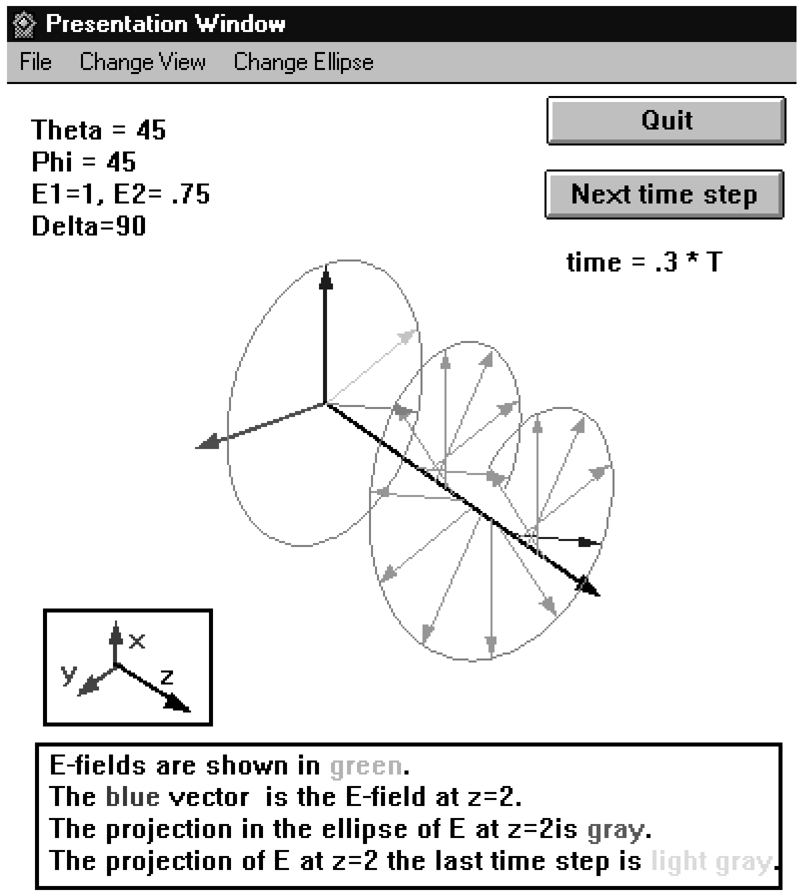
3. Web-based Interactive Visualization Tools

Three web-based interactive visualization tools are presented: “Propagation of an Elliptically Polarized Wave”, “Element Factor x Array Factor = Pattern Factor”, and “Finding a Point in the Spherical Coordinate System.” “Propagation of an Elliptically Polarized Wave” was created to allow a student to visualize an electromagnetic wave in space, to allow him or her to observe the wave propagating, and to illustrate how magnitude and relative phase shift affect the orientation and eccentricity of the polarization ellipse. “Element Factor x Array Factor = Pattern Factor” was created to use the processing power of the computer to generate array factors for an equally spaced, equal magnitude array so that a student can observe how the combination of an antenna element and of the array configuration contributes to the radiation pattern. The programming power and web-delivery of Authorware provide a simulation tool that a student can use from any Web player-equipped computer—no special software is needed to investigate the properties of array antennas. “Finding a Point in the Spherical Coordinate System” addresses the lack of familiarity with the spherical coordinate system that is observed in many students beginning studies in electromagnetics and antennas. We believe that lack of understanding of the coordinate system contributes to the difficulty in understanding radiation from point-type sources.

Propagation of an Elliptically Polarized Wave

Figure 2. An elliptically polarized wave

This module shows a z-propagating elliptically polarized wave captured at a single instant in time. (Figure 2 is a screen capture showing a perspective view of an elliptically polarized wave). Drop-down menus enable the user to: 1) Change the observer's position in the far-field by specifying theta or phi, or, 2) Change the properties of the polarized wave by changing the maximum values of Ex or Ey or the relative phase shift between the two. These parameters encompass linearly polarized, right-hand circularly polarized, left-hand circularly polarized, and elliptically polarized waves.



Once the properties of the ellipse are specified, a button-click shows successive time steps. The projection of the ellipse into the x-y plane is shown in perspective, and the E-field at z=2 is highlighted so that the user can observe the apparent rotation of the field as the wave passes a stationary observer.

This module is an example of displaying a 3-D wireframe model in a two-dimensional screen window from the perspective of an arbitrarily placed observer. Conversion from the three-dimensional description of an object is performed using the set of subroutines shown in Figure 1 and excerpted in Table 1.

This module has been found to be useful in illustrating how an elliptically polarized wave provides a sinusoidal signal to a linearly polarized antenna, and in showing how a wave propagates in space. To observe this, the user sets the observation angle to theta=90 degrees. Then, as the phi-angle changes, the magnitude of the observed sine wave changes depending on the values chosen for Ex and Ey. Successive time steps show the wave propagating along the z-axis.

Element Factor x Array Factor = Pattern Factor

Using drop-down menus the user can specify a uniformly excited, equally spaced array of elemental x-, y-, or z-directed dipoles along the x-, y-, or z-axis. The number of elements and interelement spacing may be specified by the user (Nd <=6), as well as the progressive phase shift between elements. The antenna array is shown in a perspective view, and the user may specify the x-y, y-z, or x-z observation plane. The projected antenna is shown in the specified plane, as are the element pattern, array factor, and resulting radiation pattern of the array antenna. Figure 3 shows an example of the screen display of 4 x-directed dipoles spaced 0.5 wavelengths apart along the z-axis with a 90 degree progressive phase shift as viewed in the x-z plane.

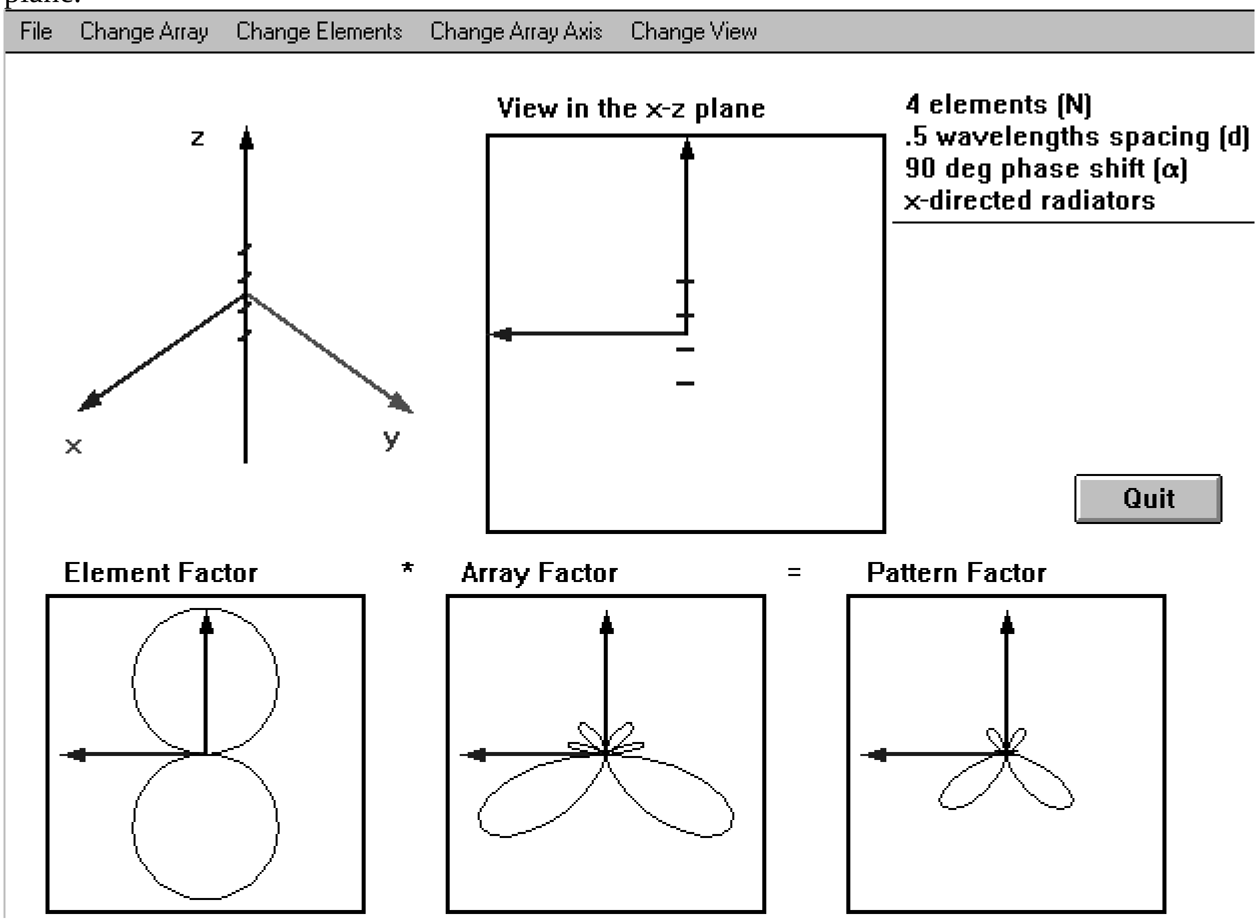


Figure 3. A four-element array of x-directed dipoles

Finding a Point in the Spherical Coordinate System

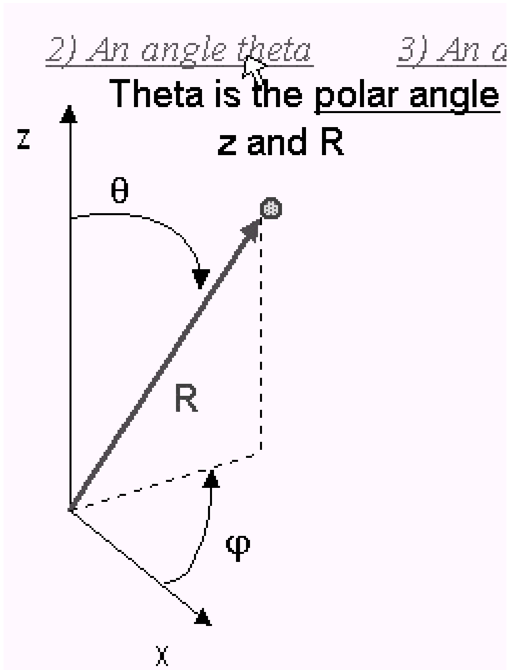


Figure 4. Definition of theta

This module is more tutorial in nature than the others, and uses more of a linear presentation. Mouse-over interactions are used to present definitions of R, theta, and phi, and the user can enter a phi angle and observe a point moving to the correct location.

Conclusions

Three interactive tools have been developed to aid students in understanding and visualizing electromagnetic fields and antennas. The tools are focused on two areas where weaknesses are often encountered—lack of familiarity with the spherical coordinate system and difficulty in visualizing the spatial distribution and propagation of an elliptically polarized wave; and in a third area where the computational power of the computer can be employed to advantage—generation of the array factor of an arbitrary array in one of the three principal planes.

Use of these tools does not require any special software, and they are available to anyone with internet access. All that is required is to download and install the free Authorware Web Player. Since introduction of these tools into classes at the University of Mississippi, they have received favorable comments from students. However, these comments must be treated as anecdotal only due to the limited numbers of students involved and the inability to create controlled trials.

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