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EM-ANIMATE

A Computer Program for Displaying and Animating Electromagnetic Near-Field and Surface-Current Solutions

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Abstract

A computer program named EM-ANIMATE has been developed to visualize the electromagnetic properties that are obtained from electromagnetic scattering programs. This program is useful as a diagnostic tool for studying the underlying scattering sources that produce the backscatter or bistatic scattering returns from bodies. For any user view option, this program can calculate and display in real time a time-harmonic animation of the surface currents and the near-field quantities that show field and surface-current magnitudes as well as field and surface-current vector directions and magnitudes. The program, which is designed for easy use, presently runs on a Silicon Graphics, Incorporated, workstation running IRIX 3.0 or higher.

Introduction

With the increased availability of high-speed graphics workstations, it is now possible to fully visualize the large amount of data available from analysis programs. The primary emphasis of scientific visualization, especially in the aircraft industry, has been on aerodynamic flow properties, thermodynamics, and structural properties. However, one of the most overlooked areas is the field of electromagnetics. Although electromagnetic analysis programs (such as method of moment techniques) have the capability to furnish detailed information about the body surface currents caused by the electric plane wave excitation or the electric near-field response of the body, the only results used from these tools are usually the monostatic or bistatic radar-cross-section returns. These solutions show the results in an integrated fashion, but they do not show the mechanisms that produce these results. A need exists, therefore, for a technique to visualize the basic quantities of electromagnetic scattering by visualizing the data as a time animation of the steady-state time harmonic solution of the electric fields and the surface currents. Although existing visualization tools, such as FAST (ref. 1) and Tecplot (ref. 2), were available for data visualization, animation capabilities generally were not available. Only recently has animation of postprocessed data been added to data visualization programs (such as FAST).

This report describes a specialized computer program (EM-ANIMATE), which has been developed to visualize and animate the surface currents and the electric near-field data from the MOM3D method of moments electromagnetic scattering program of reference 3 or from any other electromagnetic analysis program that can generate the required input information. Because the nature of the electromagnetic field and surface-current data is composed of real and imaginary terms (i.e., time quadrature data), the time-dependent results can be calculated as a linear combination of the real and imaginary terms with the sine and cosine functions. This property, which is applied in the visualization and animation program, allows the program to calculate the fields and the surface currents at any time between the radian time period of 0 and 2π. Thus, the entire time periodic information is contained in a relatively small data set. The animation of the data can be easily and quickly performed with the EM-ANIMATE program in real time, and it can be accomplished without processing and storing the data at each desired time increment, as required in other data visualization programs (such as FAST). The EM-ANIMATE program performs the animation on precalculated user-defined electric-field planes at a set of initial conditions and at the surface nodes defined at some initial condition; these conditions are calculated in the electromagnetic programs. These data can then be interactively visualized and animated in time at user-selectable view angles.

The visualization and animation capabilities of the EM-ANIMATE program are useful as diagnostics tools for studying the underlying scattering sources that produce the scattering returns from bodies and that can be used in the design process to reduce these scattering sources. This program can also be used as a learning tool for understanding the fundamentals of electromagnetic waves.

The EM-ANIMATE program is a user friendly, interactive, windows-based computer program written in FORTRAN; the program uses the Silicon Graphics, Incorporated (SGI), Graphics Libraries (GL) and window management libraries and, optionally, the SGI Power FORTRAN Accelerator (PFA) parallelization libraries. This program has been optimized for parallelized computational performance to achieve large frame rates if parallel processors are available. Memory requirements will depend on the number of field planes, the number of surface-current descriptions, and the surface node points that will be displayed. This program is presently running on SGI Indigo, IRIS-4D series, 300 series, or 400 series workstations with entry level, GT, GTX, or VGX graphics running the IRIX 3.0 or higher operating system. This program, which is designated LAR-15075, is available through NASA's software technology transfer center COSMIC (Computer Software Management and Information Center) at 382 E. Broad Street, University of Georgia, Athens, GA 30602. A VHS videotape (L-0993-168) that demonstrates the capabilities of the EM-ANIMATE code is available as a supplement to this paper.

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Symbols

$\mathbf{E}$	complex electric-field vector, V/m
$\mathbf{J}$	complex electric surface-current vector, A/m
j	$= \sqrt{-1}$
$\mathbf{r}$	position vector, m
t	time, sec
x, y, z	Cartesian coordinate axes
ω	radian frequency, rad

Abbreviations:

avg	average
PFA	power FORTRAN accelerator
rms	root mean square
SGI	Silicon Graphics, Incorporated

File name convention:

.animation	file containing viewing options saved at end of each session
filename.vec	near-field data file name suffix
filename.cur	surface-current data file name suffix

Description

The EM-ANIMATE program is a specialized visualization program that displays and animates the near-field and surface-current solutions obtained from an electromagnetics program. The EM-ANIMATE program is windows based and contains a user friendly, graphical interface for setting viewing options, case selection, and file manipulation. This program is written in FORTRAN using SGI GL graphics library routines, and it presently runs on SGI workstations from the entry-level Indigo to the Power Station 480 VGX running under the IRIX 3.0 operating system or higher.

The program displays the field and the surface-current magnitude as smooth, shaded color fields (color contours) ranging from a minimum contour value to a maximum contour value for the fields and the surface currents. This program can display either the total electric field or the scattered electric field in either time-harmonic animation mode or in the root mean square (rms) average mode. The default setting is initially set to the minimum and maximum values within the field and surface-current data, but it can be optionally set by the user. The field and surface-current values are animated by calculating and viewing the solution at user-selectable radian time increments between 0 and 2π.

An example of the total electric near fields and the surface-currents display is shown in figure 1(a). This figure shows the resulting total electric fields and the surface currents caused by radar that illuminates a one-wavelength-diameter sphere. The radar, which is positioned in the far field on the negative X-axis, illuminates the sphere in the positive X-axis direction. The incident electric-field vector is in the direction of the positive Y-axis, as shown. This illumination condition exists for all the examples. The total electric-field color contours show the resulting interaction between the scattered field from the sphere and the incident electric far field produced by a radar that propagates in the direction shown. Figure 1(b) shows a time animation sequence of the total electric field between the radian time interval of 0 to $5\pi/6$ in $\pi/6$ steps.

The propagation direction, or excitation direction, and the electric-field orientation are determined by the user in the electromagnetic program that is used to produce this solution. The propagation direction is not graphically displayed in the EM-ANIMATE program, but it is annotated in the viewing window. The field plane shown in figure 1 was aligned along the axis of the propagation. In general, the computational plane can be in any orientation that is defined by the user within the electromagnetic programs. This program does not provide any interpolation capabilities between the input planes of data. The surface-current data are defined at the nodes of the unstructured computational surface mesh, which consists of triangular elements. The surface currents are due to the user set excitation direction and the electric field orientation.

The electric-field and surface-current directions can be displayed as scaled vector arrows (shown as grey-scaled lines in fig. 2); these arrows have a length proportional to the magnitude at each field grid point or surface node point. The starting point of the vector (grid node point) is shaded black, and the end of the vector (the arrow end that shows direction) is shaded grey. These vector properties can be viewed separately or concurrently with the field or surface-current magnitudes. The vector display does not have a subset option that is available at this time. Animation speed is improved by turning off the display of the vector arrows.

An example of the scattered electric field is shown in figure 3. This figure shows the scattered radiation pattern produced by the surface currents on the sphere in the presence of the incident electromagnetic field. The rms scattered electric field and the rms total electric field are shown in figures 4(a) and 4(b). The rms surface currents are also shown in figures 4(a) and 4(b). In rms mode, the color contours do not vary with time, but they show the constant time-averaged field and the surface-current magnitude solution. The direction vectors are still displayed, and they vary with time because the time-averaged direction vectors have no length.

The surface currents can also be displayed in either time-harmonic animation mode or in rms average mode. The rms surface currents for the sphere are shown in figure 4. Other surface properties can optionally be viewed. These properties include the surface grid, the resistance value assigned to each element of the grid, and the power dissipation of each element that has an assigned resistance value. The surface grid for the sphere is shown in figure 5.

The EM-ANIMATE program will accept up to 10 different surface-current cases. Each case consists of up to 20 000 node points and 10 000 triangle definitions. The program will animate one of these cases. This capability is used to compare surface-current distributions that are caused by various initial excitation directions or electric-field orientations. The program can accept up to 50 planes of field data consisting of a grid of 100 by 100 field points. These planes of data are user selectable, and they can be viewed individually or concurrently. With these preset limits, the program requires 55 megabytes of core memory to run. These limits can be changed in the header files to accommodate the available core memory of an individual workstation. An estimate of the required memory M (in bytes) is made as follows:

$$\begin{aligned} M = {} & \text{Number of nodes} \times \text{Number of surfaces} \times 14 \text{ variables} \\ & \times \text{Bytes per word (typically 4 bytes per floating point)} \\ & + \text{Number of field planes} \times \text{Number of nodes per plane} \\ & \times 21 \text{ variables} \times \text{Bytes per word} \end{aligned}$$

This estimate gives the approximate memory size that is required to store the field and the surface-current data. The total memory size is approximately 400 000 bytes plus the data memory size.

The animation calculations are performed in real time at any user set time step. For SGI workstations that have multiple processors, this program has been optimized to perform these calculations on multiple processors to increase animation rates. The optimized program uses the SGI PFA library. On single-processor machines, the parallelization directives are seen as comments to the program, and they will have no effect on compilation or execution.

Theory

The EM-ANIMATE program animates the time-harmonic surface-current vector solution, which has the following form:

$$\mathbf{J}(\mathbf{r}, \omega t) = \text{Real}\left[\mathbf{J}(\mathbf{r})\right] \cos(\omega t) - \text{Imag}\left[\mathbf{J}(\mathbf{r})\right] \sin(\omega t)$$

where $\mathbf{J}$ is the surface-current vector that is a function of position vector $\mathbf{r}$, radian frequency ω, and time t. The program can also animate the electric-field vector that has the following form:

$$\mathbf{E}(\mathbf{r}, \omega t) = \text{Real}\left[\mathbf{E}(\mathbf{r})\right] \cos(\omega t) - \text{Imag}\left[\mathbf{E}(\mathbf{r})\right] \sin(\omega t)$$

where $\mathbf{E}$ is the electric-field vector.

The animation is created by varying the value of ωt in increments between $[0, 2\pi]$. The angular time information is displayed as phase angle in degrees on the screen for readability. The electric-field vector is the total electric field in which

$$\mathbf{E}_{\text{total}} = \mathbf{E}_{\text{incident}} + \mathbf{E}_{\text{scattered}}$$

The animation program displays either the total field or scattered field. The incident fields are a series of plane waves that move in the direction of propagation and have little value for viewing.

Also available for viewing is the rms time-averaged solution obtained by time averaging the real components such that

$$\mathbf{E}_{\text{avg}} = \left(\left\langle \{\text{Real}\,[\mathbf{E}(\exp j\omega t)]\} \cdot \{\text{Real}\,[\mathbf{E}(\exp j\omega t)]\} \right\rangle \right)^{1/2}$$

where $< >$ indicate the average (integral) over $\omega t = 0$ to 2π divided by 2π of the dot product of the two real vectors.

System Requirements

The EM-ANIMATE program requires an SGI workstation with graphics capabilities. The program is presently running on an entry-level SGI Indigo, 4D25GT, 340GTX, and 480VGX operating with the IRIX 3.0 or higher operating system. Twenty-four bit, double-buffered color capability is suggested, but it is not required. The default compilation runs the program in double-buffered color map mode. With 8-bit color graphics, this default will limit the color range to 16 colors in the color map. With 24-bit color, the program displays a continuous range of colors.

An alternate compilation can be used to compile the program in the red, green, and blue color (RGB) component mode for 8-bit graphics; this mode can dither the 8 bits to create the full color range. The RGB mode compilation instructions are included in the UNIX makefile (a file that contains instructions for compiling the source code), which accompanies the source program.

Another alternate compilation involves parallelizing the computation to improve animation speed. This speed increase depends on the number of processors available on the workstation. This option is also explained in the makefile, as shown in appendix A.

User Interface

The EM-ANIMATE program is windows based with the graphical interface control through the mouse or keyboard buttons. This program uses four types of windows, as shown in figure 6. The main graphics window, named VECTOR FIELDS, displays the field and the surface-current visualization and animation. Also displayed in this window are the annotations describing the field and the surface-current case information, the color scale tables, and the selected display mode presently being used. The MENU window contains a set of menu buttons which allow the user to select the various viewing options, the input and output file options, and the field-plane cases or the surface-current cases for display. The DIALOG window displays messages from the program and the header information that describes the initial conditions for each field case and surface-current case. The lines in this window can be scrolled to view previously written information. Popup windows are used for user inputs for specific values. The instructions for using the user interface are described in appendix B.

Input/Output Data Specifications

The near-field animation data consist of rectangular plane cuts in space around the object of interest. These planes of data consist of $n \times m$ data points, where n and m are the number of node points in each direction of the field plain. The data can be specified in two formats, either for versatility or for reduced storage requirements. The first format is ASCII in which the electric field is defined as the total electric-field quantity. Its vectors in real and imaginary space at time 0 are specified along with their corresponding magnitudes of the real and imaginary parts. The same quantities are specified for the scattered electric field. The grid spatial coordinates are also included in the input. An example of this file is shown in table I, and a detailed description is given in appendix C. This data format is useful to transfer data across computer platforms and to use in other visualization programs for static display purposes. The second format is an unformatted FORTRAN file. The electric field in this format is expressed as the complex total and scattered electric-field quantity at each grid point plus the grid spatial coordinates. The animation program then generates the vectors and the magnitudes for the total and scattered electric fields. The unformatted file is preferred, since it is compact and requires less disc space.

A separate surface-current animation data file is based upon the geometry input definition format for the electromagnetic moment program. These files are usually triangle-based surface definitions, and they are defined in an unstructured manner. The surface-current data can be defined in two formats. Again, the ASCII format defines the surface currents as the current magnitude and its real and imaginary unit vectors at each node point; the format also defines the rms magnitude and the spatial coordinates at each node point. An example of the surface-current file is shown in table II, and it is described in detail in appendix C. The FORTRAN unformatted file defines the surface currents as the complex currents and the spatial coordinates of each node point. The program then calculates the required vectors, magnitudes, and the rms averages at each point. In each of these surface-current data files, the triangle connections of the node points are also required. The triangle connection information consists of the triangle number and the three-vertex-node identification numbers.

The EM-ANIMATE program can also generate an output file in the ASCII format data file for the fields and the surface currents as two of its options within the program. This ability is useful for exporting unformatted data to other visualization programs or for exporting unformatted data across different machines. The formats for each file type are described in appendix C.

Concluding Remarks

A computer program named EM-ANIMATE has been developed to visualize and perform time harmonic animation of the electromagnetic properties that are obtained from electromagnetic scattering codes. These properties include the electric near fields and the surface-current magnitudes as well as field and surface-current vectors. The EM-ANIMATE program can display the electric field and the surface-current magnitudes in color-shaded contours. The field and the surface-current directions can be displayed as scaled vector arrows referenced to the magnitude at each field grid point or surface definition node point. Animation of the electric-field properties is performed by displaying results at continuously varying time steps within the period of the harmonic solution. The electric-field and surface-current animation is performed in real time with substantial speed improvements if executed on a parallel processor computer. Visualization and animation of these properties are useful diagnostic tools for studying the underlying electromagnetic scattering sources that produce the backscatter or bistatic scattering returns from bodies. The code is designed for easy use with interactive, user selectable options. The EM-ANIMATE program is written in FORTRAN with Silicon Graphics, Incorporated, parallelization directives included, and it presently runs on the Silicon Graphics, Incorporated, series of workstations.

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Appendix A

UNIX Makefile

```
#       ELECTRIC FIELD AND SURFACE CURRENT ANIMATION CODE MAKEFILE
#
#                         WRITTEN BY KAM W HOM
#                   NASA-LANGLEY RESEARCH CENTER
#
#       This makefile will compile and load the animation source
#       codes.  These routines require the Silicon Graphics GL-Graphics
#       Libraries, and will run on any of the Silicon Graphics
#       Workstations.
#
#       In addition, if you have a multiple processor Silicon Graphics
#       workstation with Power-Fortran installed, these routines have
#       the parallelization calls installed and can be compiled with
#       PFA to improve animation speed.  To compile with PFA, uncomment
#       the f77 compile line which has the -pfa option for the object
#       file drawvectors.o.
#
#       This routine can be compiled in COLOR MAP mode of RGB mode.
#       The RGB mode is useful for INDIGO's which only have 8 bit
#       color graphics and a limited color map in double buffer mode.
#       Uncomment the FFLAGS option which has the -DRGBMODE option to
#       compile in RGB MODE.

DEFAULTS:       animate

#FFLAGS =  -O2 -I. -DRGBMODE
FFLAGS =  -I. -O2

OBJS_RGB = animate.o colmap.o read_field.o labelit.o \
        read_current.o  mom3dlib.o inline_sub.o colormap.o write_opt.o\
        read_ASCII_field.o read_ASCI_current.o files.o support.o\
        write_ASCII_field.o write_ASCII_current.o

LIB =  -lfgl -lgl_s -mp

animate:        $(OBJS_RGB) drawvectors.o
        f77 -o $@ -g $(OBJS_RGB) drawvectors.o $(LIB)

#showimg.o:     showimg.c
#       cc -c showimg.c

drawvectors.o:
        f77  -c drawvectors.f $(FFLAGS) \
        -pfa  keep -WK,-o=5,-so=3,-r=3,-mc=400,-unroll=4,-LR=TCS,-IND=2
#       f77  -c drawvectors.f $(FFLAGS)

clean:
        rm *.o *.l *.m

clobber:
        rm -i .animation *.vec *.cur

dir = /scr/cosmic/animation/

copy:
        cp Makefile $(dir)
        cp *.f $(dir)
        cp *.c $(dir)
        cp *.h $(dir)
        cp animation.rgb $(dir)
```

Appendix B

User Interface

The EM-ANIMATE program is windows based with the graphical interface control through the mouse and/or keyboard buttons. User control is available by clicking the mouse buttons or by dragging with the mouse. Clicking the mouse involves pressing and releasing the right mouse button. This action is used to select a button. Dragging the mouse involves moving the mouse left, right, up, or down while depressing the left mouse button. Option selections and view parameters can also be set through the keyboard.

This program uses four types of windows, as shown in the main text in figure 6. The main graphics window, named VECTOR FIELDS, displays the electric-field and the surface-current visualization and animation. The MENU window contains a set of menu buttons which allow the user to select the various viewing options, the file options, the field planes, and a surface-current case. The DIALOG window displays messages from the program. Popup windows are used for user inputs for specific values.

User Control

Within the main window, the mouse and the keyboard inputs control the viewing parameters of the final picture. Dragging with the left mouse button in the main window, as shown in figure B1, will change the azimuth and the elevation view angles in polar coordinates. The left and the right motions of the mouse change the azimuth angle; the up and the down motions change the elevation angle. Dragging up or down with the middle mouse button zooms the image in or out.

The MENU window is shown in figure B2. The menu buttons in the MENU window are toggle buttons, value buttons, or buttons that bring up a popup menu of options. A toggle button displays the current option for that button. Each selection (which is selected by placing the cursor over the button and pressing the right mouse button) of that button cycles through a series of options, and the new option is then displayed. The present option is always displayed on the menu buttons.

The menu options buttons, when selected, will produce a popup menu that will display a number of options from which the user may select. These buttons have names that are followed by "..." (e.g., FILE...). The popup menus for the FILE... and GRAPHICS... buttons are shown in figure B2.

Value buttons have numerical values displayed on the button. These values can be modified by first selecting the button with the right mouse button and then dragging with the mouse with the left mouse button depressed. Dragging the mouse right or left increases or decreases the value on the button, respectively. The values can also be set using the popup query window by pressing the LEFT CTRL key in conjunction with the right mouse button to select a value button. When this combination is executed, the popup query window will appear. The window contains an entry field to enter the desired numerical value. If a value is present, a vertical bar at the end of the value indicates the editing prompt. This prompt can be moved with the BACKSPACE key or by dragging with the left mouse button. The new value can then be entered. If no value is present, the editing mark will be at the left-hand side of the box and will indicate that the screen is ready for input. Pressing the RETURN key or selecting the OK option in the query window will enter the value and close the popup query window. Modification of the value can be canceled with the CANCEL option in the popup query window.

Menu Window

Main Functions

Files can be read using the FILE... button. This button brings up a menu as shown in figure B2, with options to read over or add to the existing cases (either additional surface-current cases only or additional field cases only). If the animation program was started without any input file names, the READ NEW FILE option is run automatically at startup. This option will open a file selection window (shown in fig. B3) and display a list of available field vector files. The field vector file names must have been saved with a suffix of ".vec." The user then selects the desired file by positioning the cursor over the desired file name and clicking the OPEN button in the file selection window. If no vector file is desired, select the CANCEL button in this window. The MORE button displays more file names if the list exceeds what the window can display. The ENTER FILE NAME button allows you to enter the file name if the name of your file does not adhere to the ".vec" suffix standard. This sequence is repeated to identify the companion surface-current file if a file with the vector file name prefix and the surface-current file suffix of ".cur" is not found. If this file is found in the local directory, then it is loaded automatically. Each case is read in and displayed as button options on the bottom of the MENU window. The default case shown in the main graphics window is the first field plane and the first surface-current data (field plane 1, current data 1). To select additional fields or another surface-current case, click on the desired field plane or current data button at the bottom of the MENU window. The case information can be obtained by viewing the corresponding case header information displayed in the DIALOG window. The first selected field plane header information and the surface-current header information are also displayed as annotations in the main viewing window. The ASCII files of the fields and the surface-current data can be written using the WRITE ASCII options. These ASCII files are compatible with the EM-ANIMATE program or the commercial plotting program Tecplot of reference 2.

The GRAPHICS... button reveals a menu of graphics options; these options are used to set the view angle, toggle on or off the display of vectors, field contours, or surface-current contours, or set the view clipping boundaries. This menu is shown in figure B2. The keyboard keys that control some of the graphics options are shown in parentheses. The FRONT VIEW, TOP VIEW, and SIDE VIEW options set the view angles to the respective views. The TOGGLE VECTORS, TOGGLE CONTOURS, and TOGGLE CURRENTS buttons toggle on or off the display of the various properties. The ENTER CLIPPING BOUNDARIES button allows the user to set the clipping boundaries for display. The default clipping boundary is set to three times the largest length of the body.

The IN MOTION/PAUSE/STEP MODE toggle button controls the animation. This button allows the user to pause the animation, step through this animation in angular time steps that are set by the user, or display the continuous animation of the fields and the surface currents by stepping through the options by pressing this button. The "+" and "−" buttons beside the IN MOTION/PAUSE/STEP MODE button allow the user to raise or lower by an increment the displayed time in STEP MODE.

The EXIT button terminates the execution of the program. Upon termination, the current view settings and the display options will be saved in an options file named ".animation." Upon execution of the next session of the animation program, this defaults file will be read in conjunction with the user-selected input field and the surface-current files. The resulting picture will use the orientation and the viewing option at the previous termination of the program. The defaults file is in ASCII format, and it can be modified by the user to set the desired values at startup. Each line is annotated to show values that are represented.

Display Functions

The FIELD LIMITS button and the CURRENT LIMITS button allow the user to set the maximum limits of the electric-field contours and the surface-current contours. These limits tell the program the values that should be mapped to the color bar range. Values outside these limits are mapped to either the first or the last color value; this color assignment depends on whether the value is less than the minimum value or greater than the maximum value. These buttons will bring up the query popup window for entering these values. The present values are displayed in the query window and in the main window on the color bars.

The HARMONIC/RMS AVERAGE button allows the user to toggle between the time-harmonic animation and the rms average display of the fields and the surface currents.

The button entitled NO TRANSPARENCY/ TRANSP CURRENT/TRANSP VECTORS/VECTORS & CURRENT is a four-position toggle button that allows the user to set a transparent fill pattern on either the field contours, the surface-current magnitude contours, both contours, or a standard solid fill pattern.

The TOTAL FIELD/SCATTERED FIELD button toggles between the display of the total electric field or the scattered electric field.

The button entitled SURFACE MESH/RESISTANCE/CURRENT/POWER toggles the display options for the surface properties. The surface mesh outlines can be displayed, or the resistance values for each surface element can be displayed as a color contour map. The animated surface-current and power dissipation contours can also be selected with this button.

The ANGLE RATE button allows the user to set the angular time increments in which the fields and the surface currents are animated. Angular rates are used instead of radian time steps for clarity. The default rate is 1° per frame. To increase this value, press the "+" button next to the ANGLE RATE button. To decrease this value, press the "−" button. To see or modify the angular rate, press the ANGLE RATE button. This will bring up the query popup window and display the present value for the angular rate.

The VECTOR SIZE button allows the user to vary the size of the direction vector arrows. By pressing the "+" button, the arrow is doubled in length. By pressing the "−" button, the arrow is reduced in length by one-half. The arrows cannot be made smaller than the original size. To see or modify the vector scale value, press the VECTOR SIZE button. This button will bring up the query popup window and display the present value for the vector scale value. The coordinate axis will resize in conjunction with the vector arrows.

The COLOR SCALE button allows the use of different color maps for display of the color contours in the Silicon Graphics, Incorporated, color map mode. The options are full-spectrum COLOR SCALE, GREY SCALE, REVERSE GREY SCALE, and INCREMENTAL COLOR SCALE. In color-map mode using the COLOR SCALE option, the color spectrum is defined and placed in the color map by setting the intensity of the color guns individually or in combination to create the spectrum. The maximum variation of each color gun intensity is 256. Seven specific sets of color gun variations are used to create the color spectrum. The first variation is obtained by varying the blue gun intensity, while the red and green guns remain set to zero. This procedure produces the black-to-blue color scale. The second variation is obtained by setting the intensity of blue to the maximum intensity (256) and varying the intensity of green to produce the blue-to-cyan color range. By decreasing the intensity of blue with the green intensity set to maximum (256), the third color map range is set; this third range produces the cyan-to-green color range. This sequence can be repeated with the green and red color guns and the red and blue color guns to achieve the yellow, red, and magenta color ranges. Finally, white is achieved by setting the maximum intensity of all the color guns. This process results in 1790 continuous colors.

The # of COLORS buttons allow the user to set the number of variations in each of the color ranges in the COLOR SCALE mode. This value can be set between 1 and the maximum of 256. In GREY SCALE mode, all three color guns are varied jointly to produce the grey-scale colors. The REVERSE GREY-SCALE mode maps the minimum contour values to the maximum GREY intensities.

In INCREMENTAL COLOR mode, the # of COLORS buttons set the total number of colors that will be used in the color mapping routine. The N number of colors is generated for the color map. The contour mapping is broken up into N distinct regions.

For workstations with 8-bit graphics, in double-buffered graphics mode (using two graphics buffers for smooth animation), the color map is limited to 16 entries or 16 contour levels. If more contour levels are desired, then the EM-ANIMATE program can be compiled to run in the RGB (red, green, and blue) color component mode. In this mode, the COLOR SCALE and GREY-SCALE options are supported, and they can provide the full 256 variations of colors in each color range.

Body Translation and Data Selection Options

The TRANSLATION BUTTONS, shown in figure B2, allow the user to translate the body either left or right and up or down in relationship to the principal axis of the present view angle of the body. For example, if the body is being displayed predominantly in the front view, the $<$ and $>$ option buttons in the MENU window will translate the body left or right along the principal horizontal axis. The $\wedge$ and $\vee$ option buttons will translate the body up or down along the principal vertical axis. Each additional press of the translation button will increase the rate of translation by one unit, which is 1/100 of the largest length of the body. Pressing the translation option button labeled x will stop the translation.

Beneath the TRANSLATION BUTTONS in the MENU window are the CURRENT ELEMENTS buttons. These buttons allow the user to select the range of surface elements to be displayed. The left button defines the starting element, and the right button defines the last element to be displayed. By default, all elements are shown. To modify these values, first select the button by clicking with the right mouse button and then dragging with the left mouse button to change the button value.

The option buttons labeled FIELD PLANES in the MENU window list the available field planes that can be displayed. All selected planes are highlighted, and the plane number is written in yellow. All the field planes can be selected for display at a single time. The maximum number of field planes that can be displayed is set at compile time depending on the amount of available memory.

The option buttons labeled CURRENT DATA list the available surface-current data that can be displayed. Only one set of currents can be displayed at a time. The selected data button is highlighted.

Keyboard Shortcuts

Keyboard keys that correspond to the menu buttons also exist. The function keys F1 to F10 can be used in place of some of the buttons, and they are listed in red over the associated buttons. The HOME, DELETE, and END keyboard keys can also be used to toggle on or off the displays of vector arrows, color field contours, and surface currents, respectively. These functions can also be accessed through a popup menu associated with the GRAPHICS... button. The keyboard keys that control these options are displayed on the GRAPHICS... popup menu. The PAUSE key will toggle on or off the animation mode. The ENTER key on the numerics pad puts the animation into the STEP MODE. The keyboard arrow keys can also be used to translate the view similar to that of the TRANSLATION BUTTONS in the MENU window.

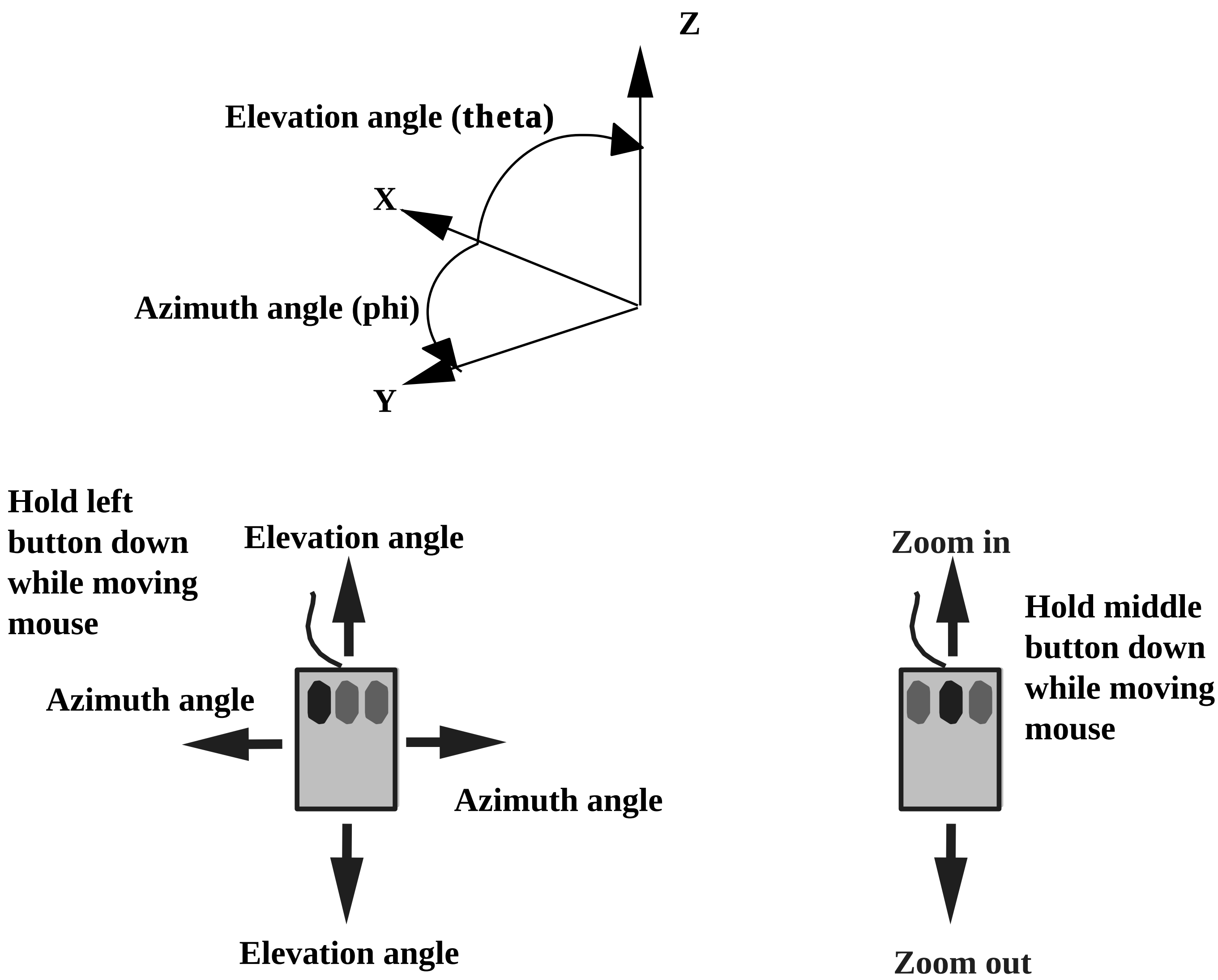

Figure B1. Azimuth and elevation angle directions and mouse controls.

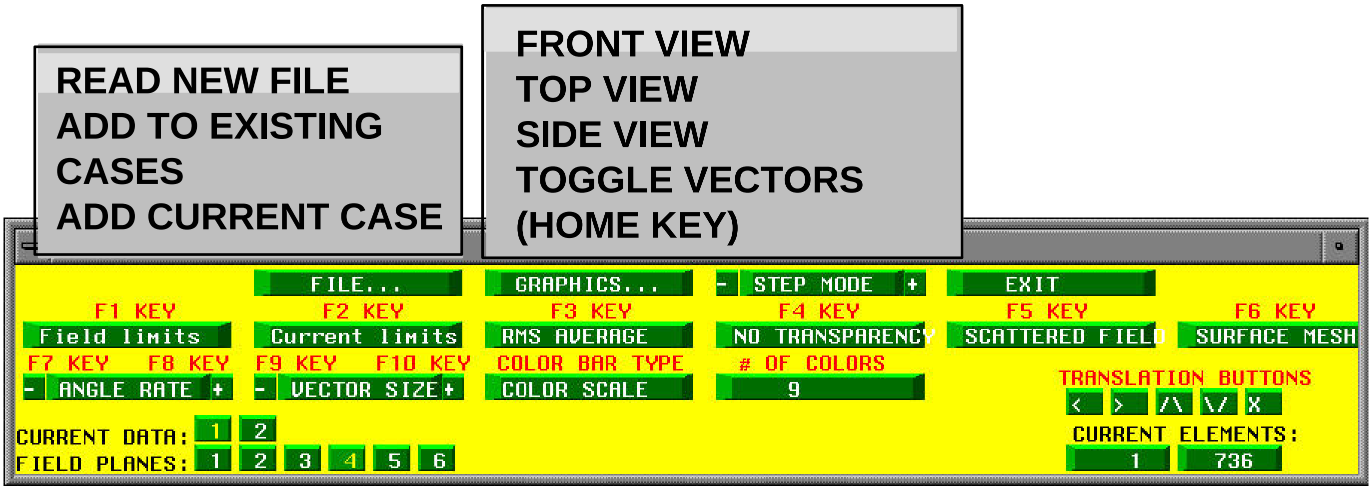

Figure B2. MENU window and popup menus associated with the menu options buttons.

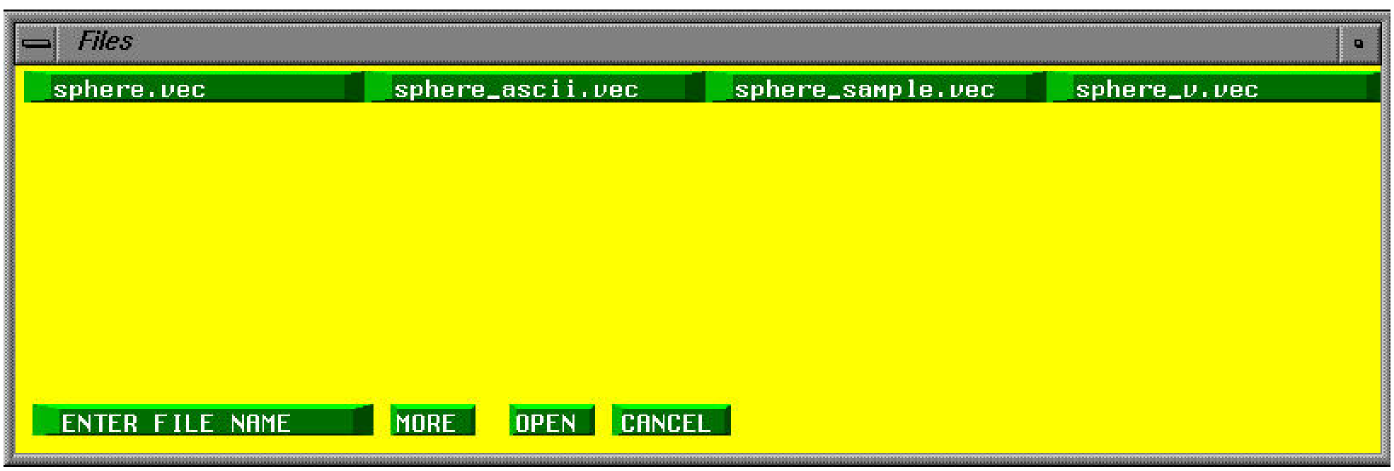

Figure B3. File selection window.

Appendix C

Input/Output File Specifications

The input/output file specifications for the EM-ANIMATION program are described below. The data can either be in ASCII or FORTRAN unformatted data. Both format descriptions are listed for each type of data (i.e., the near-field and the surface-current data).

ASCII Field Data

The ASCII field data are written in the Tecplot (Amtec Engineering, Incorporated, plot format) point format of reference 2, and they can be statically displayed with Tecplot. An example of this file is shown in table I. The file consists of the following:

Card 1 — 80-column title card

Example: TITLE = "NEAR FIELD DATA"

Card 2 — Variable name card; this line lists the names of the variables that are to be read in each column of the input line. In this case, the variables are as follows:

Example: VARIABLES = x, y, z, etot, escat,
etm_r, utr(1), utr(2), utr(3),
etm_i, uti(1), uti(2), uti(3),
esm_r, usr(1), usr(2), usr(3),
esm_i, usi(1), usi(2), usi(3)

where

x, y, z	spatial coordinates of each grid point
etot	total electric-field magnitude
escat	scattered electric-field magnitude
etm_r	magnitude of the real part of the total electric field
utr( )	three-element array containing the unit vector of the real part of the total electric field
etm_i	magnitude of the imaginary part of the total electric field
uti( )	three-element array containing the unit vector of the imaginary part of the total electric field
esm_r	magnitude of the real part of the scattered electric field
usr( )	three-element array containing the unit vector of the real part of the scattered electric field
esm_i	magnitude of the imaginary part of the scattered electric field
usi( )	three-element array containing the unit vector of the imaginary part of the scattered electric field

Card 3 — Case card that defines the size of the grid and the format of the following data:

Example: ZONE T = "Field Vectors", i = 38, j = 31, f = point

The i and j values represent the number of node points (npoint) and the number of triangles (nfacet). The animation program parses out the i and j parameters. The additional data on this line are not used.

Card set 4 - data set — The $i \times j$ number of data lines (which contain the 21 variables specified above) is required. This data set is ordered in ascending values of i, j number of times. The variables are read in free-field format. The 21 variables can all be written on a single line of input or split onto separate lines.

New case — Enter Card 3 and Card set 4 for each new field plane.

FORTRAN Unformatted Field Data

The FORTRAN unformatted field file consists of the following records:

title — 80-character long title record array dimensioned to hold six titles

bkv — Three-value array containing the excitation unit vectors needed for calculating the electric-field unit vectors defined as follows:

bkv(1) = $-$cos(phi) $\times$ sin(theta) $\times$ bk

bkv(2) = $-$sin(phi) $\times$ sin(theta) $\times$ bk

bkv(3) = $-$cos(theta) $\times$ bk

phi azimuthal excitation angle

theta elevation excitation angle

bk — 2π/incident wavelength

r1min — Lower left-hand corner ordinate value of the field plane, meters

r1del — Ordinate interval size of each cell of the field plane, meters

r2min — Lower left-hand corner abscissa value of the field plane, meters

r2del — Abscissa interval size of each cell of the field plane, meters

ur1 — Three-value array containing the unit direction in space of the ordinate axis

ur2 — Three-value array containing the unit direction in space of the abscissa axis

n1 — Number of data points in the ordinate direction

n2 — Number of data points in the abscissa direction

upol — Array dimensioned (3, 2), which holds the unit directions for the theta and phi electric-field orientation relative to the input excitation direction defined as follows:

upol(1, 1) = cos(theta) $\times$ cos(phi)

upol(2, 1) = cos(theta) $\times$ sin(phi)

upol(3, 1) = $-$sin(theta)

upol(1, 2) = $-$sin(phi)

upol(2, 2) = cos(phi)

upol(3, 2) = 0.0

phi azimuthal excitation angle

theta elevation excitation angle

ipolin — Polarization of the calculated field vectors

= 1(E theta direction (vertical))

= 2(E phi direction (horizontal))

rc	Three-value array containing the center coordinate of the field plane in meters
cm2u	Scale factor to convert from meters to user input coordinates units. For example, if user coordinates are inches, this would be the conversion from meters to inches
data records	n1 $\times$ n2 data records containing the following data variables in each data record:
	es — es is a complex, three-element array that contains the electric field in the x, y, and z directions at each grid point
New case	Repeat entire set of records for each new case

ASCII Surface-Current Data

The ASCII surface-current data are written in the Tecplot fepoint format. An example of this file is shown in table II, and it consists of the following input cards:

Card 1 80-column title card

Example: TITLE = “SURFACE CURRENT DATA”

Card 2 Variable name card; this line lists the name of the variables that are to be read in each column of the input line. In this case, the variables are as follows:

Example: VARIABLES = x, y, z, rval, jrms, power,
jmagr, utr(1), utr(2), utr(3),
jmagi, uti(1), uti(2), uti(3)

where:

x, y, z	spatial coordinates of each surface node point
rval	resistance of the node point, ohms
jrms	root mean square average of the surface current at each node point
power	power dissipation at each point, defined as jrms $\times$ jrms $\times$ rval
jmagr	magnitude of the real part of the surface current
utr( )	three-element array containing the unit vector of the real part of the surface current
jmagi	magnitude of the imaginary part of the surface current
uti( )	three-element array containing the unit vector of the imaginary part of the surface current

For ASCII OUTPUT, an additional surface-current output option is available to provide display compatibility with the ASCII Tecplot field file. To concurrently display the fields and the surface currents in Tecplot, both files must have the same number of input variables (21 variables). To meet these requirements for the field-compatible version of the surface-current output file, seven dummy variables are added to the above list. The first seven parameters, starting from the jmagr parameter, are repeated as follows:

Example: VARIABLES = x, y, z, rval, jrms, power,
jmagr, utr(1), utr(2), utr(3),
jmagi, uti(1), uti(2), uti(3),
jmagr, utr(1), utr(2), utr(3),
jmagi, uti(1), uti(2)

Card 3 Case card that specifies the number of node points (I parameter) and the number of triangles (J parameter); the animation program parses out the I and J parameter from the input card

Example: ZONE T = “ Currents”, I = 108, J = 160, F = FEPOINT

Card set 4 Surface-current data set that consists of I number of node lines of data containing the variables listed in Card 2

Card set 5 J number of connection data lines that contain the node numbers of each triangle. Each line consists of the following:

- vertex1 integer value point to the node point of first vertex of the triangle
- vertex2 node point of the second vertex
- vertex3 node point of the third vertex
- dummy dummy vertex value that is the repeated vertex3 value needed for the Tecplot format; the Tecplot format only recognizes four-sided polygons

Repeat this line for J number of triangles

New case Repeat the Cards 3 to 5 for each new case

FORTRAN Unformatted Surface-Current Data

The FORTRAN unformatted surface-current file consists of the following records:

title 80-character long title record array dimensioned to hold six titles

npoint Number of nodes

ipolin Polarization of the calculated surface currents

- = 1 (E theta direction (vertical))
- = 2 (E phi direction (horizontal))

nfacet Number of triangles

Current records npoint number of records containing the following variables:

- points array containing the x, y, and z position of each node point
- resist resistance of the node point, ohms
- jcur complex array that contains the complex surface currents for each of the two plane wave excitation polarizations (i.e., theta and phi); jcur is dimensioned (3, 2)
  - jcur(1,1) x component of the surface current (theta polarization direction)
  - jcur(2,1) y component (theta polarization direction)
  - jcur(3,1) z component (theta polarization direction)
  - jcur(1, 2) x component of the surface current (phi polarization direction)
  - jcur(2, 2) y component (phi polarization direction)
  - jcur(3, 2) z component (phi polarization direction)

Triangle data	Nfacet number of connection data records that contain the node numbers of each triangle. The record consists of the following:
	vertex1 — integer value pointing to the node point of the first vertex of the triangle
	vertex2 — node point of the second vertex
	vertex3 — node point of the third vertex
	dummy — dummy vertex value that is the repeated vertex3 value needed for the Tecplot format; the Tecplot format only recognizes four-sided polygons
	Repeat this line for nfacet number of triangles
New case	Repeat this entire set of records for each new case

References

1. Walatka, Pamela P.; Clucas Jean; McCabe, R. Kevin; Plessel, Todd; and Potter, Rick: *FAST User Guide—FAST 1.1.* RND-93-010, NASA Ames Research Center, June 1993.

2. *Tecplot™. Version 5—User's Manual.* Amtec Eng., Inc., 1992.

3. Shaeffer, John F.: *MOM3D Method of Moments Code Theory Manual.* NASA CR-189594, 1992.

Table I. ASCII Nearfield Data File

Card 1:

```
TITLE = "NEAR FIELD DATA"
```

Card 2:

```
VARIABLES =
x,y,z,etot,escat,etm_r,utr(1),utr(2),utr(3),etm_i,uti(1),uti(2),uti(3
),esm_r,usr(1),usr(2),usr(3),esm_i,usi(1),usi(2),usi(3)
```

Card 3:

```
zone t="field vectors", i=    8, j=    8, f=point
```

Card Set 4:

```
  -1.50000    0.00000   -1.50000    0.70913    0.09657    0.99354
   0.00000    0.99354    0.00000    0.13641    0.00000   -0.13641
   0.00000    0.00646    0.00000   -0.00646    0.00000    0.13641
   0.00000   -0.13641    0.00000
  -1.00000    0.00000   -1.50000    0.59714    0.11156    0.84413
   0.00000   -0.84413    0.00000    0.02439    0.00000    0.02439
   0.00000    0.15587    0.00000    0.15587    0.00000    0.02439
   0.00000    0.02439    0.00000
  -0.50000    0.00000   -1.50000    0.76556    0.12490    1.07048
   0.00000    1.07048    0.00000    0.16196    0.00000    0.16196
   0.00000    0.07048    0.00000    0.07048    0.00000    0.16196
   0.00000    0.16196    0.00000
   0.00000    0.00000   -1.50000    0.64363    0.12916    0.89758
   0.00000   -0.89758    0.00000    0.15124    0.00000    0.15124
   0.00000    0.10242    0.00000    0.10242    0.00000    0.15124
   0.00000    0.15124    0.00000
   0.50000    0.00000   -1.50000    0.83195    0.13450    1.17405
   0.00000    1.17405    0.00000    0.07671    0.00000   -0.07671
   0.00000    0.17405    0.00000    0.17405    0.00000    0.07671
   0.00000   -0.07671    0.00000
   1.00000    0.00000   -1.50000    0.82858    0.14714    1.16490
   0.00000   -1.16490    0.00000    0.12693    0.00000   -0.12693
   0.00000    0.16490    0.00000   -0.16490    0.00000    0.12693
   0.00000   -0.12693    0.00000
   1.50000    0.00000   -1.50000    0.74764    0.15429    1.03516
   0.00000    1.03516    0.00000    0.21535    0.00000    0.21535
   0.00000    0.03516    0.00000    0.03516    0.00000    0.21535
   0.00000    0.21535    0.00000
   2.00000    0.00000   -1.50000    0.66412    0.15148    0.91811
   0.00000   -0.91811    0.00000    0.19795    0.00000   -0.19795
   0.00000    0.08189    0.00000    0.08189    0.00000    0.19795
   0.00000   -0.19795    0.00000
  -1.50000    0.00000   -1.00000    0.80822    0.11731    1.13945
   0.00000    1.13945    0.00000    0.08988    0.00000    0.08988
   0.00000    0.13945    0.00000    0.13945    0.00000    0.08988
   0.00000    0.08988    0.00000
  -1.00000    0.00000   -1.00000    0.84677    0.14695    1.19543
   0.00000   -1.19543    0.00000    0.07069    0.00000    0.07069
   0.00000    0.19543    0.00000   -0.19543    0.00000    0.07069
   0.00000    0.07069    0.00000
  -0.50000    0.00000   -1.00000    0.63824    0.18909    0.87159
   0.00000    0.87159    0.00000    0.23456    0.00000   -0.23456
   0.00000    0.12841    0.00000   -0.12841    0.00000    0.23456
   0.00000   -0.23456    0.00000
```

Table I. Continued

0.00000	0.00000	−1.00000	0.87444	0.21451	1.21864
0.00000	−1.21864	0.00000	0.21031	0.00000	−0.21031
0.00000	0.21864	0.00000	−0.21864	0.00000	0.21030
0.00000	−0.21030	0.00000			
0.50000	0.00000	−1.00000	0.66818	0.22837	0.89432
0.00000	0.89432	0.00000	0.30519	0.00000	0.30519
0.00000	0.10568	0.00000	−0.10568	0.00000	0.30519
0.00000	0.30519	0.00000			
1.00000	0.00000	−1.00000	0.52429	0.24176	0.71643
0.00000	−0.71643	0.00000	0.19101	0.00000	−0.19101
0.00000	0.28357	0.00000	0.28357	0.00000	0.19101
0.00000	−0.19101	0.00000			
1.50000	0.00000	−1.00000	0.48163	0.22814	0.67992
0.00000	0.67992	0.00000	0.04055	0.00000	0.04055
0.00000	0.32008	0.00000	−0.32008	0.00000	0.04055
0.00000	0.04055	0.00000			
2.00000	0.00000	−1.00000	0.50975	0.20303	0.71862
0.00000	−0.71862	0.00000	0.05718	0.00000	0.05718
0.00000	0.28138	0.00000	0.28138	0.00000	0.05718
0.00000	0.05718	0.00000			
−1.50000	0.00000	−0.50000	0.63546	0.14301	0.88336
0.00000	0.88336	0.00000	0.16522	0.00000	0.16522
0.00000	0.11664	0.00000	−0.11664	0.00000	0.16522
0.00000	0.16522	0.00000			
−1.00000	0.00000	−0.50000	0.68740	0.20505	0.93047
0.00000	−0.93047	0.00000	0.28152	0.00000	−0.28152
0.00000	0.06953	0.00000	0.06953	0.00000	0.28152
0.00000	−0.28152	0.00000			
−0.50000	0.00000	−0.50000	0.95974	0.34394	1.30281
0.00000	1.30281	0.00000	0.38066	0.00000	0.38066
0.00000	0.30281	0.00000	0.30281	0.00000	0.38066
0.00000	0.38066	0.00000			
0.00000	0.00000	−0.50000	0.37642	0.41047	0.47321
0.00000	−0.47321	0.00000	0.24385	0.00000	−0.24385
0.00000	0.52679	0.00000	0.52679	0.00000	0.24385
0.00000	−0.24385	0.00000			
0.50000	0.00000	−0.50000	0.23375	0.51115	0.29336
0.00000	0.29336	0.00000	0.15237	0.00000	−0.15237
0.00000	0.70664	0.00000	−0.70664	0.00000	0.15237
0.00000	−0.15237	0.00000			
1.00000	0.00000	−0.50000	0.45160	0.41713	0.52995
0.00000	−0.52995	0.00000	0.35644	0.00000	0.35644
0.00000	0.47005	0.00000	0.47005	0.00000	0.35644
0.00000	0.35644	0.00000			
1.50000	0.00000	−0.50000	0.57312	0.32161	0.72503
0.00000	0.72503	0.00000	0.36230	0.00000	−0.36230
0.00000	0.27497	0.00000	−0.27497	0.00000	0.36230
0.00000	−0.36230	0.00000			

Table I. Continued

2.00000	0.00000	−0.50000	0.62919	0.25520	0.83076
0.00000	−0.83076	0.00000	0.31877	0.00000	0.31877
0.00000	0.16924	0.00000	0.16924	0.00000	0.31877
0.00000	0.31877	0.00000			
−1.50000	0.00000	0.00000	0.55905	0.15933	0.78715
0.00000	0.78715	0.00000	0.07395	0.00000	0.07395
0.00000	0.21285	0.00000	−0.21285	0.00000	0.07395
0.00000	0.07395	0.00000			
−1.00000	0.00000	0.00000	0.47170	0.26950	0.64987
0.00000	−0.64987	0.00000	0.15058	0.00000	−0.15058
0.00000	0.35013	0.00000	0.35013	0.00000	0.15058
0.00000	−0.15058	0.00000			
−0.50000	0.00000	0.00000	0.97690	0.69625	0.96956
0.00000	0.96956	0.00000	0.98418	0.00000	0.98418
0.00000	0.03044	0.00000	−0.03044	0.00000	0.98418
0.00000	0.98418	0.00000			
0.00000	0.00000	0.00000	0.15298	0.71960	0.00558
0.00000	−0.00558	0.00000	0.21628	0.00000	−0.21628
0.00000	0.99442	0.00000	0.99442	0.00000	0.21628
0.00000	−0.21628	0.00000			
0.50000	0.00000	0.00000	0.30729	0.88295	0.18516
0.00000	−0.18516	0.00000	0.39316	0.00000	−0.39316
0.00000	1.18516	0.00000	−1.18516	0.00000	0.39316
0.00000	−0.39316	0.00000			
1.00000	0.00000	0.00000	0.65286	0.54634	0.62775
0.00000	−0.62775	0.00000	0.67705	0.00000	0.67705
0.00000	0.37225	0.00000	0.37225	0.00000	0.67705
0.00000	0.67705	0.00000			
1.50000	0.00000	0.00000	0.70067	0.37293	0.85186
0.00000	0.85186	0.00000	0.50617	0.00000	−0.50617
0.00000	0.14814	0.00000	−0.14814	0.00000	0.50617
0.00000	−0.50617	0.00000			
2.00000	0.00000	0.00000	0.71158	0.28003	0.92793
0.00000	−0.92793	0.00000	0.38941	0.00000	0.38941
0.00000	0.07207	0.00000	0.07207	0.00000	0.38941
0.00000	0.38941	0.00000			
−1.50000	0.00000	0.50000	0.63499	0.14434	0.88238
0.00000	0.88238	0.00000	0.16684	0.00000	0.16684
0.00000	0.11762	0.00000	−0.11762	0.00000	0.16684
0.00000	0.16684	0.00000			
−1.00000	0.00000	0.50000	0.68839	0.20736	0.93089
0.00000	−0.93089	0.00000	0.28499	0.00000	−0.28499
0.00000	0.06911	0.00000	0.06911	0.00000	0.28499
0.00000	−0.28499	0.00000			
−0.50000	0.00000	0.50000	0.96160	0.34455	1.30595
0.00000	1.30595	0.00000	0.37925	0.00000	0.37925
0.00000	0.30595	0.00000	0.30595	0.00000	0.37925
0.00000	0.37925	0.00000			

Table I. Continued

0.00000	0.00000	0.50000	0.38502	0.39506	0.49217
0.00000	−0.49217	0.00000	0.23292	0.00000	−0.23292
0.00000	0.50783	0.00000	0.50783	0.00000	0.23292
0.00000	−0.23292	0.00000			
0.50000	0.00000	0.50000	0.21805	0.52131	0.27578
0.00000	0.27578	0.00000	0.13798	0.00000	−0.13798
0.00000	0.72422	0.00000	−0.72422	0.00000	0.13798
0.00000	−0.13798	0.00000			
1.00000	0.00000	0.50000	0.44537	0.42789	0.51526
0.00000	−0.51526	0.00000	0.36223	0.00000	0.36223
0.00000	0.48474	0.00000	0.48474	0.00000	0.36223
0.00000	0.36223	0.00000			
1.50000	0.00000	0.50000	0.57170	0.32815	0.71915
0.00000	0.71915	0.00000	0.36944	0.00000	−0.36944
0.00000	0.28085	0.00000	−0.28085	0.00000	0.36944
0.00000	−0.36944	0.00000			
2.00000	0.00000	0.50000	0.62906	0.25928	0.82849
0.00000	−0.82849	0.00000	0.32409	0.00000	0.32409
0.00000	0.17151	0.00000	0.17151	0.00000	0.32409
0.00000	0.32409	0.00000			
−1.50000	0.00000	1.00000	0.80987	0.11892	1.14175
0.00000	1.14175	0.00000	0.09051	0.00000	0.09051
0.00000	0.14175	0.00000	0.14175	0.00000	0.09051
0.00000	0.09051	0.00000			
−1.00000	0.00000	1.00000	0.84830	0.14895	1.19742
0.00000	−1.19742	0.00000	0.07348	0.00000	0.07348
0.00000	0.19742	0.00000	−0.19742	0.00000	0.07348
0.00000	0.07348	0.00000			
−0.50000	0.00000	1.00000	0.63555	0.19058	0.86761
0.00000	0.86761	0.00000	0.23477	0.00000	−0.23477
0.00000	0.13239	0.00000	−0.13239	0.00000	0.23477
0.00000	−0.23477	0.00000			
0.00000	0.00000	1.00000	0.87561	0.21314	1.22127
0.00000	−1.22127	0.00000	0.20468	0.00000	−0.20468
0.00000	0.22127	0.00000	−0.22127	0.00000	0.20468
0.00000	−0.20468	0.00000			
0.50000	0.00000	1.00000	0.67848	0.23060	0.90717
0.00000	0.90717	0.00000	0.31262	0.00000	0.31262
0.00000	0.09283	0.00000	−0.09283	0.00000	0.31262
0.00000	0.31262	0.00000			
1.00000	0.00000	1.00000	0.52409	0.25056	0.71188
0.00000	−0.71188	0.00000	0.20628	0.00000	−0.20628
0.00000	0.28812	0.00000	0.28812	0.00000	0.20628
0.00000	−0.20628	0.00000			
1.50000	0.00000	1.00000	0.47397	0.23646	0.66873
0.00000	0.66873	0.00000	0.04571	0.00000	0.04571
0.00000	0.33127	0.00000	−0.33127	0.00000	0.04571
0.00000	0.04571	0.00000			

Table I. Continued

2.00000	0.00000	1.00000	0.50355	0.20931	0.70975
0.00000	−0.70975	0.00000	0.05812	0.00000	0.05812
0.00000	0.29025	0.00000	0.29025	0.00000	0.05812
0.00000	0.05812	0.00000			
−1.50000	0.00000	1.50000	0.70858	0.09822	0.99244
0.00000	0.99244	0.00000	0.13870	0.00000	−0.13870
0.00000	0.00756	0.00000	−0.00756	0.00000	0.13870
0.00000	−0.13870	0.00000			
−1.00000	0.00000	1.50000	0.59512	0.11341	0.84130
0.00000	−0.84130	0.00000	0.02326	0.00000	0.02326
0.00000	0.15870	0.00000	0.15870	0.00000	0.02326
0.00000	0.02326	0.00000			
−0.50000	0.00000	1.50000	0.76715	0.12622	1.07259
0.00000	1.07259	0.00000	0.16307	0.00000	0.16307
0.00000	0.07259	0.00000	0.07259	0.00000	0.16308
0.00000	0.16308	0.00000			
0.00000	0.00000	1.50000	0.64274	0.12835	0.89664
0.00000	−0.89664	0.00000	0.14921	0.00000	0.14921
0.00000	0.10336	0.00000	0.10336	0.00000	0.14921
0.00000	0.14921	0.00000			
0.50000	0.00000	1.50000	0.82905	0.13348	1.16951
0.00000	1.16951	0.00000	0.08305	0.00000	−0.08305
0.00000	0.16951	0.00000	0.16951	0.00000	0.08305
0.00000	−0.08305	0.00000			
1.00000	0.00000	1.50000	0.83531	0.15090	1.17498
0.00000	−1.17498	0.00000	0.12215	0.00000	−0.12215
0.00000	0.17498	0.00000	−0.17498	0.00000	0.12215
0.00000	−0.12215	0.00000			
1.50000	0.00000	1.50000	0.75417	0.16062	1.04297
0.00000	1.04297	0.00000	0.22305	0.00000	0.22305
0.00000	0.04297	0.00000	0.04297	0.00000	0.22305
0.00000	0.22305	0.00000			
2.00000	0.00000	1.50000	0.66520	0.15770	0.91762
0.00000	−0.91762	0.00000	0.20725	0.00000	−0.20725
0.00000	0.08238	0.00000	0.08238	0.00000	0.20725
0.00000	−0.20725	0.00000			
−1.50000	0.00000	2.00000	0.66647	0.08179	0.93749
0.00000	0.93749	0.00000	0.09732	0.00000	0.09732
0.00000	0.06251	0.00000	−0.06251	0.00000	0.09733
0.00000	0.09733	0.00000			
−1.00000	0.00000	2.00000	0.78853	0.08898	1.11386
0.00000	−1.11386	0.00000	0.05357	0.00000	−0.05357
0.00000	0.11386	0.00000	−0.11386	0.00000	0.05357
0.00000	−0.05357	0.00000			
−0.50000	0.00000	2.00000	0.67907	0.09271	0.95254
0.00000	0.95254	0.00000	0.12222	0.00000	−0.12222
0.00000	0.04746	0.00000	−0.04746	0.00000	0.12222
0.00000	−0.12222	0.00000			

Table I. Concluded

0.00000	0.00000	2.00000	0.75625	0.09200	1.06345
0.00000	−1.06345	0.00000	0.11358	0.00000	−0.11358
0.00000	0.06345	0.00000	−0.06345	0.00000	0.11358
0.00000	−0.11358	0.00000			
0.50000	0.00000	2.00000	0.61385	0.09326	0.86811
0.00000	0.86811	0.00000	0.00013	0.00000	0.00013
0.00000	0.13189	0.00000	−0.13189	0.00000	0.00013
0.00000	0.00013	0.00000			
1.00000	0.00000	2.00000	0.69989	0.10213	0.97942
0.00000	−0.97942	0.00000	0.14296	0.00000	0.14296
0.00000	0.02058	0.00000	0.02058	0.00000	0.14296
0.00000	0.14296	0.00000			
1.50000	0.00000	2.00000	0.79926	0.11243	1.12617
0.00000	1.12617	0.00000	0.09674	0.00000	−0.09674
0.00000	0.12617	0.00000	0.12617	0.00000	0.09674
0.00000	−0.09674	0.00000			
2.00000	0.00000	2.00000	0.82331	0.11749	1.16403
0.00000	−1.16403	0.00000	0.02650	0.00000	−0.02650
0.00000	0.16403	0.00000	−0.16403	0.00000	0.02650
0.00000	−0.02650	0.00000			

Table II. ASCII Current Data File

Card 1:
```
TITLE = "SURFACE CURRENT DATA"
```
Card 2:
```
VARIABLES =
x,y,z,rval,jrms,power,jmagr,utr(1),utr(2),utr(3),jmagi,uti(1),uti(2)
,uti(3)
```
Card 3:
```
ZONE T="Currents", I=   108, J=   160, F=FEPOINT
```
Card Set 4:
```
  -0.50000    0.00000    0.00000    0.00000    0.80820    0.00000
   1.09741    0.00000   -1.00000    0.00000    0.31946    0.00000
   1.00000    0.00000
  -0.50000    0.00000    0.00000    0.00000    0.00000    0.00000
   0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
   0.00000    0.00000
  -0.46194    0.00000   -0.19134    0.00000    1.72683    0.00000
   2.14461    0.00000   -1.00000    0.00000    1.16814    0.00000
   1.00000    0.00000
  -0.46194    0.16571   -0.09567    0.00000    1.06443    0.00000
   1.29295   -0.35430   -0.93494    0.01915    0.77092    0.28817
   0.93775    0.19386
  -0.46194    0.16571    0.09567    0.00000    1.05092    0.00000
   1.27064   -0.35301   -0.93553   -0.01309    0.77093    0.28797
   0.93779   -0.19397
  -0.46194    0.00000    0.19134    0.00000    1.69314    0.00000
   2.08832    0.00000   -1.00000    0.00000    1.17149    0.00000
   1.00000    0.00000
  -0.35355    0.00000   -0.35355    0.00000    0.94776    0.00000
   0.53597    0.00000   -1.00000    0.00000    1.22851    0.00000
   1.00000    0.00000
  -0.35355    0.17678   -0.30619    0.00000    1.20045    0.00000
   0.96819   -0.41572   -0.90949   -0.00135    1.39454    0.40360
   0.91415    0.03776
  -0.35355    0.30619   -0.17678    0.00000    1.30025    0.00000
   0.97393   -0.50267   -0.77897   -0.37488    1.55973    0.59324
   0.78387    0.18332
  -0.35355    0.35355    0.00000    0.00000    1.16799    0.00000
   0.66532   -0.72342   -0.68981    0.02865    1.51187    0.71283
   0.70123    0.01227
  -0.35355    0.30619    0.17678    0.00000    1.29602    0.00000
   0.98829   -0.50910   -0.77973    0.36446    1.54356    0.60163
   0.78196   -0.16301
  -0.35355    0.17678    0.30619    0.00000    1.18367    0.00000
   0.93648   -0.42332   -0.90593   -0.00983    1.38750    0.41011
   0.91159   -0.02842
  -0.35355    0.00000    0.35355    0.00000    0.95377    0.00000
   0.48268    0.00000   -1.00000    0.00000    1.25952    0.00000
   1.00000    0.00000
  -0.19134    0.00000   -0.46194    0.00000    0.57240    0.00000
   0.35765    0.00000    1.00000    0.00000    0.72620    0.00000
   1.00000    0.00000
```

Table II. Continued

−0.19134	0.17678	−0.42678	0.00000	0.74674	0.00000
0.48510	0.50392	0.85408	0.12888	0.93803	0.58657
0.80705	0.06786				
−0.19134	0.32664	−0.32664	0.00000	0.97388	0.00000
0.58787	0.78427	0.59574	0.17325	1.24551	0.85188
0.52070	0.05639				
−0.19134	0.42678	−0.17678	0.00000	1.16861	0.00000
0.71898	0.90601	0.41446	0.08586	1.48808	0.92151
0.38832	0.00472				
−0.19134	0.46194	0.00000	0.00000	1.20724	0.00000
0.81721	0.92792	0.35741	0.10596	1.49900	0.93129
0.35941	−0.05937				
−0.19134	0.42678	0.17678	0.00000	1.17396	0.00000
0.69815	0.93486	0.34609	0.07913	1.50631	0.90227
0.41842	−0.10405				
−0.19134	0.32664	0.32664	0.00000	0.98996	0.00000
0.57155	0.85600	0.51012	−0.08391	1.27804	0.81512
0.56447	−0.13017				
−0.19134	0.17678	0.42678	0.00000	0.77478	0.00000
0.50960	0.59727	0.79555	−0.10185	0.96998	0.57126
0.81569	−0.09117				
−0.19134	0.00000	0.46194	0.00000	0.63599	0.00000
0.51651	0.00000	1.00000	0.00000	0.73632	0.00000
1.00000	0.00000				
0.00000	0.00000	−0.50000	0.00000	0.43209	0.00000
0.58362	0.00000	1.00000	0.00000	0.18106	0.00000
1.00000	0.00000				
0.00000	0.19134	−0.46194	0.00000	0.57256	0.00000
0.80595	0.73863	0.62286	0.25782	0.07807	0.58498
0.72112	0.37119				
0.00000	0.35355	−0.35355	0.00000	0.79794	0.00000
1.12786	0.93524	0.24995	0.25068	0.03672	−0.14598
0.52435	0.83890				
0.00000	0.46194	−0.19134	0.00000	0.96388	0.00000
1.36224	0.98869	0.05697	0.13876	0.04950	−0.76219
0.05915	0.64465				
0.00000	0.50000	0.00000	0.00000	1.00144	0.00000
1.41498	0.99975	−0.00040	−0.02216	0.05989	−0.88975
−0.15236	−0.43027				
0.00000	0.46194	0.19134	0.00000	0.92680	0.00000
1.30699	0.98067	0.07449	−0.18094	0.09849	−0.62318
0.22173	−0.74999				
0.00000	0.35355	0.35355	0.00000	0.74008	0.00000
1.04298	0.91199	0.28997	−0.29016	0.08736	−0.76199
0.40971	−0.50151				
0.00000	0.19134	0.46194	0.00000	0.52085	0.00000
0.73125	0.67368	0.68270	−0.28298	0.08860	−0.93739
0.31087	−0.15704				

Table II. Continued

0.00000	0.00000	0.50000	0.00000	0.40638	0.00000
0.57462	0.00000	1.00000	0.00000	0.00986	0.00000
−1.00000	0.00000				
0.19134	0.00000	−0.46194	0.00000	0.24150	0.00000
0.32116	0.00000	1.00000	0.00000	0.11618	0.00000
−1.00000	0.00000				
0.19134	0.17678	−0.42678	0.00000	0.46961	0.00000
0.32615	0.54312	0.67164	0.50390	0.57853	−0.90569
−0.10048	−0.41186				
0.19134	0.32664	−0.32664	0.00000	0.77087	0.00000
0.32211	0.67902	0.31452	0.66333	1.04150	−0.93063
0.18378	−0.31648				
0.19134	0.42678	−0.17678	0.00000	0.97310	0.00000
0.33566	0.83535	−0.11546	0.53746	1.33461	−0.93106
0.32843	−0.15893				
0.19134	0.46194	0.00000	0.00000	0.97844	0.00000
0.37217	0.93242	−0.35828	0.04710	1.33273	−0.93149
0.35967	0.05450				
0.19134	0.42678	0.17678	0.00000	0.92585	0.00000
0.27813	0.87743	−0.15784	−0.45298	1.27947	−0.92447
0.28791	0.24994				
0.19134	0.32664	0.32664	0.00000	0.69302	0.00000
0.23169	0.75718	0.24573	−0.60522	0.95230	−0.91475
0.10179	0.39099				
0.19134	0.17678	0.42678	0.00000	0.38305	0.00000
0.20909	0.42894	0.77050	−0.47152	0.49973	−0.84299
−0.27954	0.45959				
0.19134	0.00000	0.46194	0.00000	0.21498	0.00000
0.22643	0.00000	1.00000	0.00000	0.20289	0.00000
−1.00000	0.00000				
0.35355	0.00000	−0.35355	0.00000	0.27289	0.00000
0.25319	0.00000	1.00000	0.00000	0.29126	0.00000
−1.00000	0.00000				
0.35355	0.17678	−0.30619	0.00000	0.48895	0.00000
0.45225	−0.60158	0.74069	−0.29912	0.52307	−0.40395
−0.52093	−0.75197				
0.35355	0.30619	−0.17678	0.00000	0.63711	0.00000
0.60823	−0.67582	0.73528	−0.05130	0.66473	−0.62242
0.30174	−0.72218				
0.35355	0.35355	0.00000	0.00000	0.64987	0.00000
0.60425	−0.71712	0.69407	−0.06330	0.69249	−0.71039
0.70377	−0.00720				
0.35355	0.30619	0.17678	0.00000	0.62756	0.00000
0.63538	−0.67432	0.73724	0.04209	0.61965	−0.62767
0.31331	0.71265				
0.35355	0.17678	0.30619	0.00000	0.45876	0.00000
0.42379	−0.62473	0.69822	0.34958	0.49124	−0.38766
−0.54398	0.74418				

Table II. Continued

0.35355	0.00000	0.35355	0.00000	0.27642	0.00000
0.23200	0.00000	1.00000	0.00000	0.31463	0.00000
−1.00000	0.00000				
0.46194	0.00000	−0.19134	0.00000	0.77288	0.00000
0.31284	0.00000	1.00000	0.00000	1.04729	0.00000
−1.00000	0.00000				
0.46194	0.16571	−0.09567	0.00000	0.40588	0.00000
0.30733	−0.32189	0.94228	0.09214	0.48479	0.37520
−0.92180	0.09754				
0.46194	0.16571	0.09567	0.00000	0.38933	0.00000
0.27739	−0.30741	0.94054	−0.14450	0.47561	0.37317
−0.92349	−0.08896				
0.46194	0.00000	0.19134	0.00000	0.74359	0.00000
0.23080	0.00000	1.00000	0.00000	1.02595	0.00000
−1.00000	0.00000				
0.50000	0.00000	0.00000	0.00000	0.46473	0.00000
0.00145	0.00000	1.00000	0.00000	0.65722	0.00000
−1.00000	0.00000				
0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.46194	0.00000	−0.19134	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.46194	−0.16571	−0.09567	0.00000	1.06443	0.00000
1.29295	0.35430	−0.93494	−0.01915	0.77092	−0.28817
0.93775	−0.19386				
−0.46194	−0.16571	0.09567	0.00000	1.05092	0.00000
1.27064	0.35301	−0.93553	0.01309	0.77093	−0.28797
0.93779	0.19397				
−0.46194	0.00000	0.19134	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.35355	0.00000	−0.35355	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.35355	−0.17678	−0.30619	0.00000	1.20045	0.00000
0.96819	0.41572	−0.90949	0.00135	1.39454	−0.40360
0.91415	−0.03776				

Table II. Continued

−0.35355	−0.30619	−0.17678	0.00000	1.30025	0.00000
0.97393	0.50267	−0.77897	0.37488	1.55973	−0.59324
0.78387	−0.18332				
−0.35355	−0.35355	0.00000	0.00000	1.16799	0.00000
0.66532	0.72342	−0.68981	−0.02865	1.51187	−0.71283
0.70123	−0.01227				
−0.35355	−0.30619	0.17678	0.00000	1.29602	0.00000
0.98829	0.50910	−0.77973	−0.36446	1.54356	−0.60163
0.78196	0.16301				
−0.35355	−0.17678	0.30619	0.00000	1.18367	0.00000
0.93648	0.42332	−0.90593	0.00983	1.38750	−0.41011
0.91159	0.02842				
−0.35355	0.00000	0.35355	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.19134	0.00000	−0.46194	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
−0.19134	−0.17678	−0.42678	0.00000	0.74674	0.00000
0.48510	−0.50392	0.85408	−0.12888	0.93803	−0.58657
0.80705	−0.06786				
−0.19134	−0.32664	−0.32664	0.00000	0.97388	0.00000
0.58787	−0.78427	0.59574	−0.17325	1.24551	−0.85188
0.52070	−0.05639				
−0.19134	−0.42678	−0.17678	0.00000	1.16861	0.00000
0.71898	−0.90601	0.41446	−0.08586	1.48808	−0.92151
0.38832	−0.00472				
−0.19134	−0.46194	0.00000	0.00000	1.20724	0.00000
0.81721	−0.92792	0.35741	−0.10596	1.49900	−0.93129
0.35941	0.05937				
−0.19134	−0.42678	0.17678	0.00000	1.17396	0.00000
0.69815	−0.93486	0.34609	−0.07913	1.50631	−0.90227
0.41842	0.10405				
−0.19134	−0.32664	0.32664	0.00000	0.98997	0.00000
0.57155	−0.85600	0.51012	0.08390	1.27804	−0.81512
0.56447	0.13017				
−0.19134	−0.17678	0.42678	0.00000	0.77478	0.00000
0.50960	−0.59727	0.79555	0.10185	0.96998	−0.57126
0.81569	0.09117				
−0.19134	0.00000	0.46194	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.00000	0.00000	−0.50000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.00000	−0.19134	−0.46194	0.00000	0.57256	0.00000
0.80595	−0.73863	0.62286	−0.25782	0.07807	−0.58498
0.72112	−0.37119				

Table II. Continued

0.00000	−0.35355	−0.35355	0.00000	0.79794	0.00000
1.12786	−0.93524	0.24995	−0.25068	0.03672	0.14597
0.52435	−0.83890				
0.00000	−0.46194	−0.19134	0.00000	0.96388	0.00000
1.36224	−0.98869	0.05697	−0.13876	0.04950	0.76218
0.05915	−0.64465				
0.00000	−0.50000	0.00000	0.00000	1.00144	0.00000
1.41498	−0.99975	−0.00040	0.02216	0.05989	0.88974
−0.15236	0.43028				
0.00000	−0.46194	0.19134	0.00000	0.92680	0.00000
1.30699	−0.98067	0.07449	0.18094	0.09849	0.62318
0.22173	0.74999				
0.00000	−0.35355	0.35355	0.00000	0.74008	0.00000
1.04298	−0.91199	0.28997	0.29016	0.08736	0.76199
0.40971	0.50151				
0.00000	−0.19134	0.46194	0.00000	0.52085	0.00000
0.73125	−0.67368	0.68270	0.28298	0.08860	0.93739
0.31087	0.15705				
0.00000	0.00000	0.50000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.19134	0.00000	−0.46194	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.19134	−0.17678	−0.42678	0.00000	0.46961	0.00000
0.32615	−0.54312	0.67164	−0.50390	0.57853	0.90569
−0.10048	0.41186				
0.19134	−0.32664	−0.32664	0.00000	0.77087	0.00000
0.32211	−0.67902	0.31452	−0.66333	1.04150	0.93063
0.18378	0.31648				
0.19134	−0.42678	−0.17678	0.00000	0.97310	0.00000
0.33566	−0.83535	−0.11546	−0.53746	1.33461	0.93106
0.32843	0.15893				
0.19134	−0.46194	0.00000	0.00000	0.97844	0.00000
0.37217	−0.93242	−0.35828	−0.04710	1.33273	0.93149
0.35967	−0.05450				
0.19134	−0.42678	0.17678	0.00000	0.92585	0.00000
0.27813	−0.87743	−0.15784	0.45298	1.27947	0.92447
0.28791	−0.24994				
0.19134	−0.32664	0.32664	0.00000	0.69302	0.00000
0.23169	−0.75718	0.24573	0.60522	0.95230	0.91475
0.10179	−0.39099				
0.19134	−0.17678	0.42678	0.00000	0.38305	0.00000
0.20909	−0.42894	0.77050	0.47152	0.49973	0.84299
−0.27954	−0.45959				
0.19134	0.00000	0.46194	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				

Table II. Continued

0.35355	0.00000	−0.35355	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.35355	−0.17678	−0.30619	0.00000	0.48895	0.00000
0.45225	0.60158	0.74069	0.29912	0.52307	0.40396
−0.52093	0.75197				
0.35355	−0.30619	−0.17678	0.00000	0.63711	0.00000
0.60823	0.67582	0.73528	0.05130	0.66473	0.62242
0.30174	0.72218				
0.35355	−0.35355	0.00000	0.00000	0.64987	0.00000
0.60425	0.71712	0.69407	0.06330	0.69249	0.71039
0.70377	0.00720				
0.35355	−0.30619	0.17678	0.00000	0.62756	0.00000
0.63538	0.67432	0.73724	−0.04209	0.61965	0.62767
0.31331	−0.71265				
0.35355	−0.17678	0.30619	0.00000	0.45876	0.00000
0.42379	0.62473	0.69822	−0.34958	0.49124	0.38766
−0.54398	−0.74418				
0.35355	0.00000	0.35355	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.46194	0.00000	−0.19134	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.46194	−0.16571	−0.09567	0.00000	0.40588	0.00000
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−0.92180	−0.09754				
0.46194	−0.16571	0.09567	0.00000	0.38933	0.00000
0.27739	0.30741	0.94054	0.14450	0.47561	−0.37317
−0.92349	0.08896				
0.46194	0.00000	0.19134	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
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0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				
0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000				

Card Set 5:

1	4	3	3
1	6	5	5
3	8	7	7
3	4	8	8
4	9	8	8
4	10	9	9

Table II. Continued

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5	12	11	11
5	6	12	12
6	13	12	12
7	15	14	14
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8	16	15	15
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9	17	16	16
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26	27	35	35
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27	28	36	36
28	37	36	36
28	29	37	37
29	38	37	37
29	30	38	38
30	39	38	38

Table II. Continued

30	31	39	39
31	40	39	39
32	33	41	41
33	42	41	41
33	34	42	42
34	43	42	42
34	35	43	43
35	44	43	43
35	36	44	44
36	37	44	44
37	45	44	44
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38	46	45	45
38	39	46	46
39	47	46	46
39	40	47	47
41	42	48	48
42	49	48	48
42	43	49	49
43	44	49	49
44	45	50	50
45	46	50	50
46	51	50	50
46	47	51	51
48	49	52	52
50	51	52	52
1	58	3	3
1	6	59	59
3	62	7	7
3	58	62	62
58	63	62	62
58	64	63	63
59	65	64	64
59	66	65	65
59	6	66	66
6	13	66	66
7	69	14	14
7	62	69	69
62	70	69	69
62	63	70	70
63	71	70	70
63	64	71	71
64	72	71	71
64	73	72	72
64	65	73	73
65	74	73	73
65	66	74	74
66	75	74	74

Table II. Continued

66	13	75	75
13	22	75	75
14	69	23	23
69	78	23	23
69	70	78	78
70	79	78	78
70	71	79	79
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83	92	91	91
83	84	92	92
84	93	92	92
84	31	93	93
31	40	93	93
32	87	41	41
87	96	41	41
87	88	96	96
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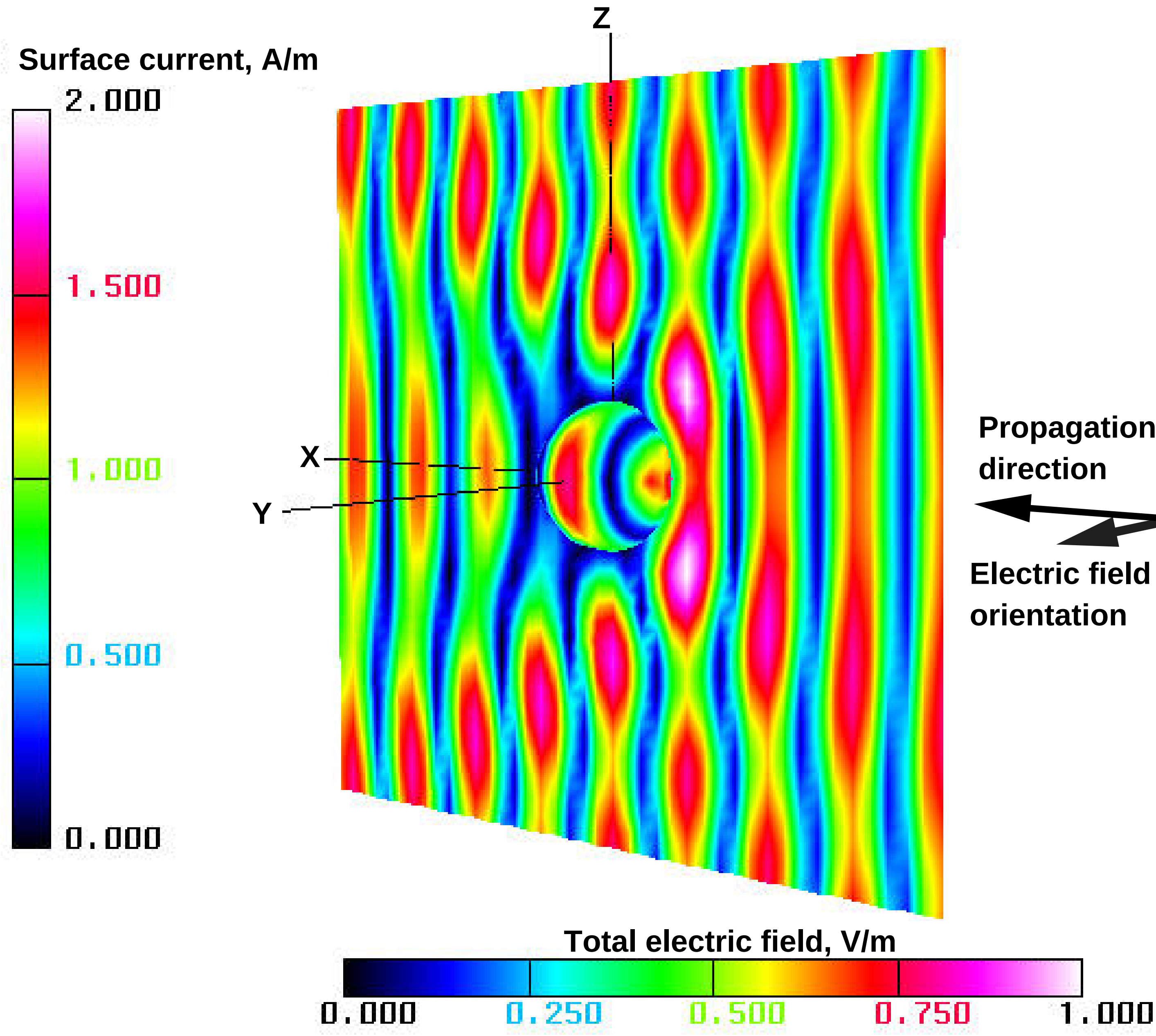
88	89	97	97
89	98	97	97
89	90	98	98
90	91	98	98
91	99	98	98
91	92	99	99
92	100	99	99
92	93	100	100
93	47	100	100
93	40	47	47

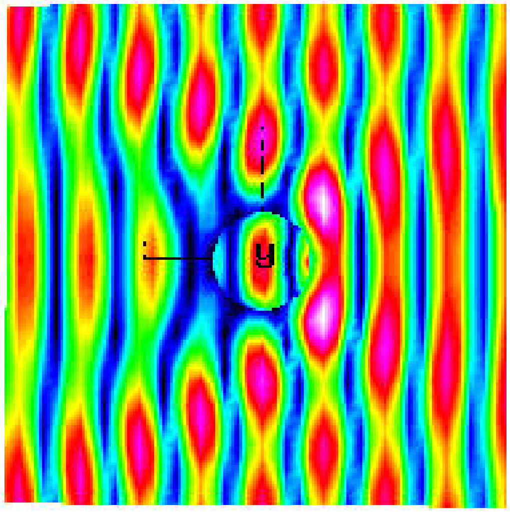
Table II. Concluded

41	96	48	48
96	103	48	48
96	97	103	103
97	98	103	103
98	99	104	104
99	100	104	104
100	51	104	104
100	47	51	51
48	103	52	52
104	51	52	52



(a) ωt = 0

Figure 1. Visualization of magnitude contours of total electric field and surface currents for one−wavelength−diameter sphere.



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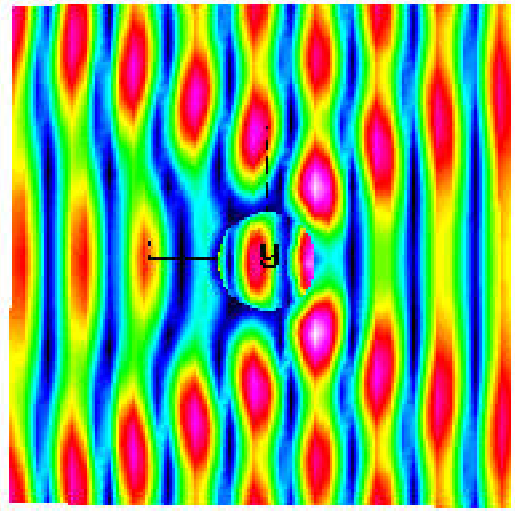
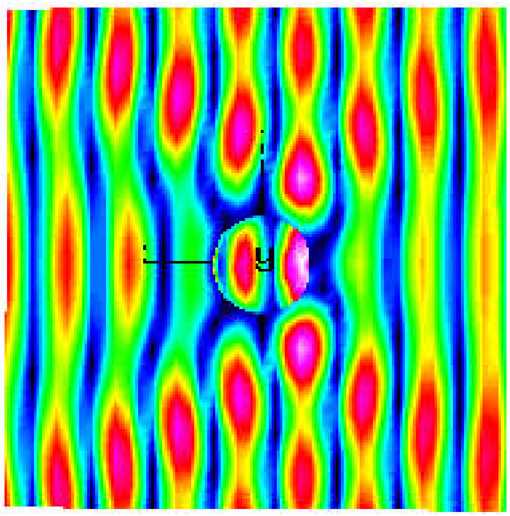
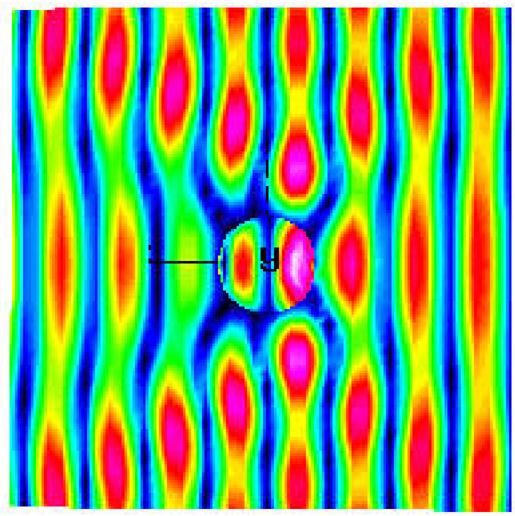


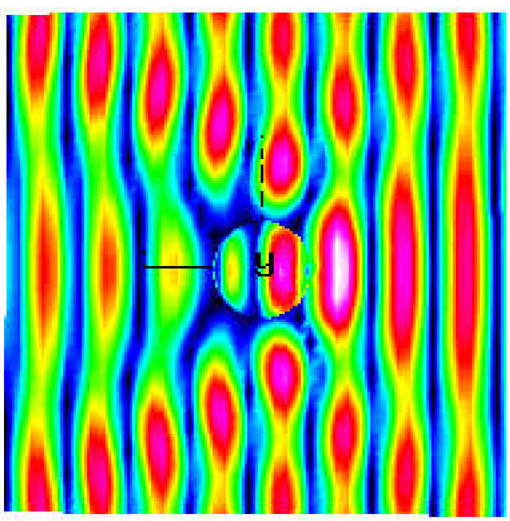
ωt = π/6



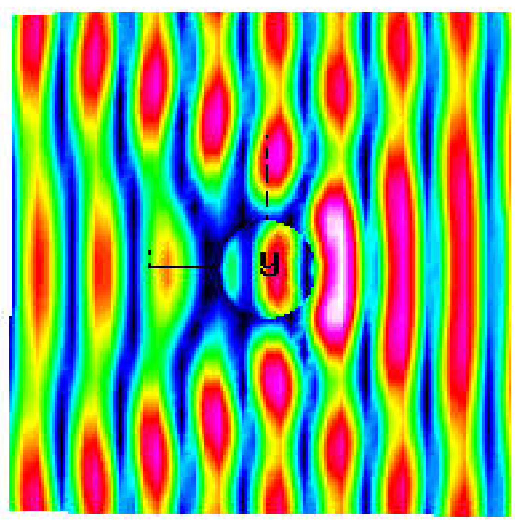
ωt = π/3



ωt = π/2



ωt = 2π/3



ωt = 5π/6

(b) time animation sequence.

Figure 1. Concluded.

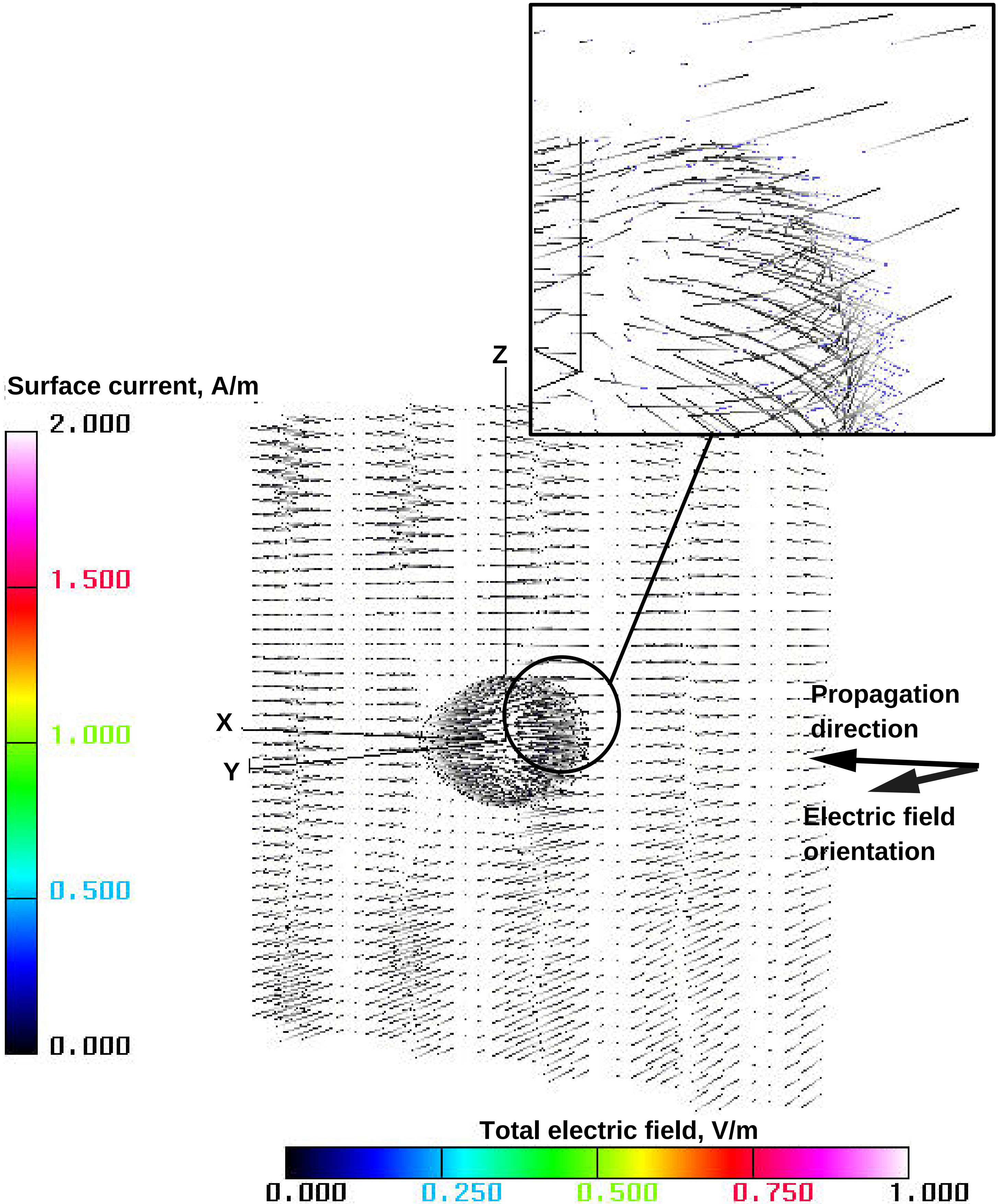


Figure 2. Visualization of total electric field and surface current vectors for one−wavelength−diameter sphere at ωt = 0.

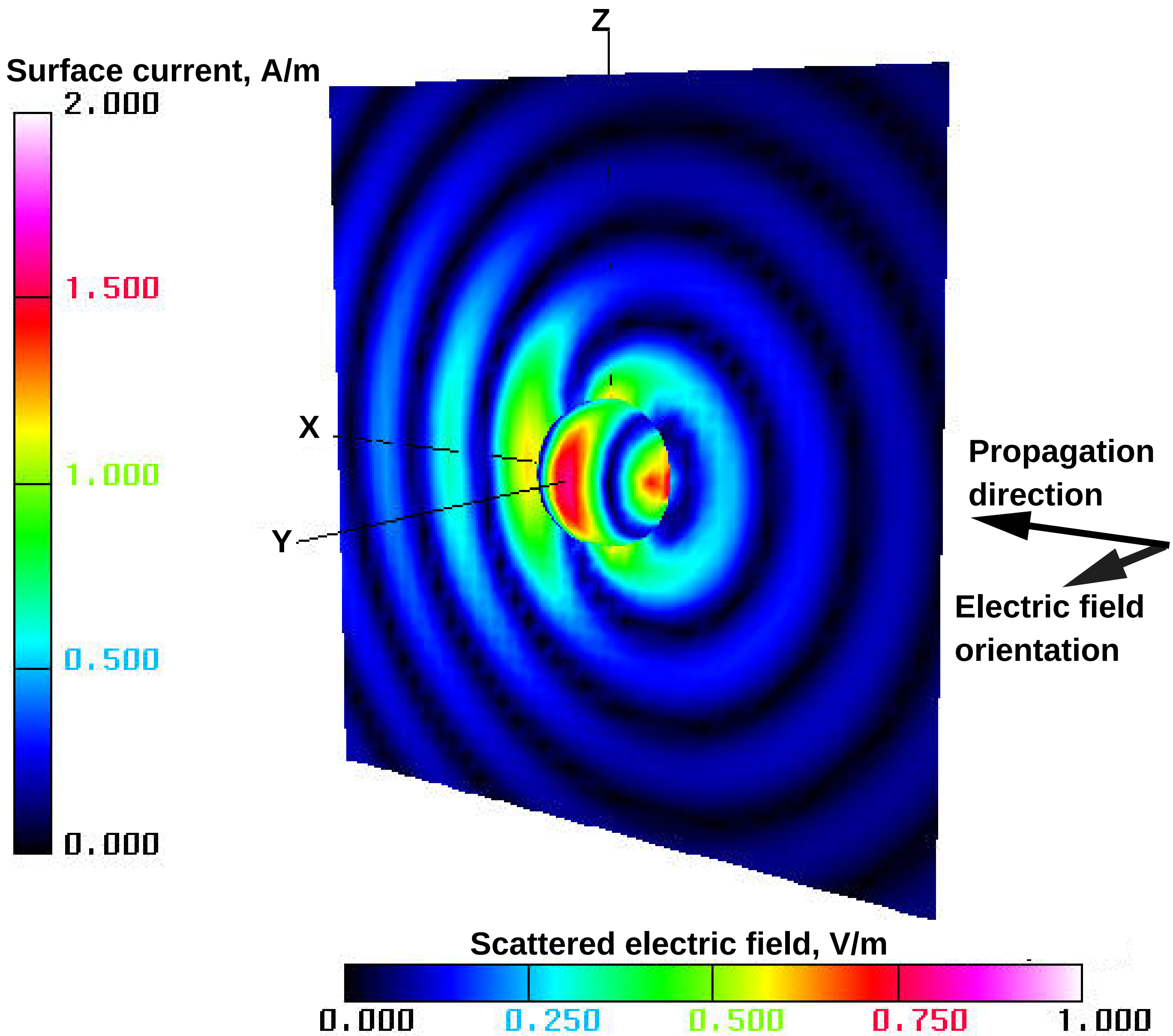
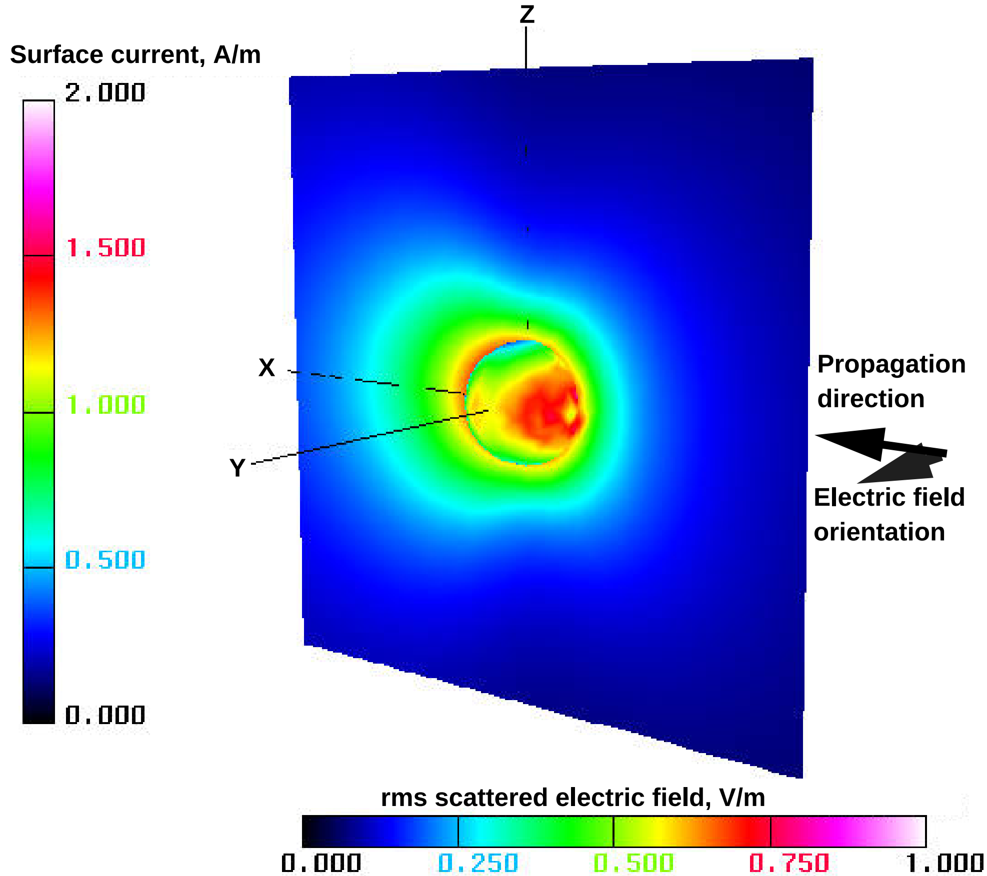
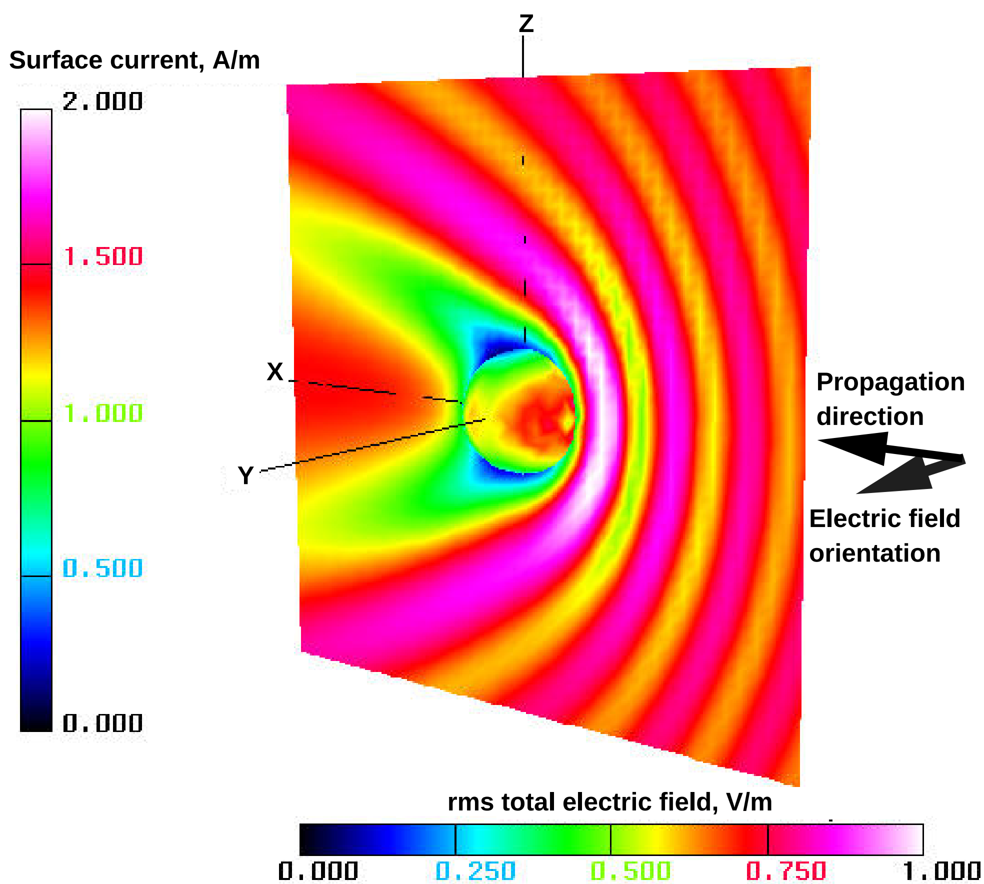


Figure 3. Visualization of magnitude contours of scattered electric field and surface currents for one−wavelength−diameter sphere at $\omega t = 0$.



(a) Scattered field.



(b) Total field.

Figure 4. Visualization of magnitude contours of rms electric field and rms surface currents for one−wavelength−diameter sphere.

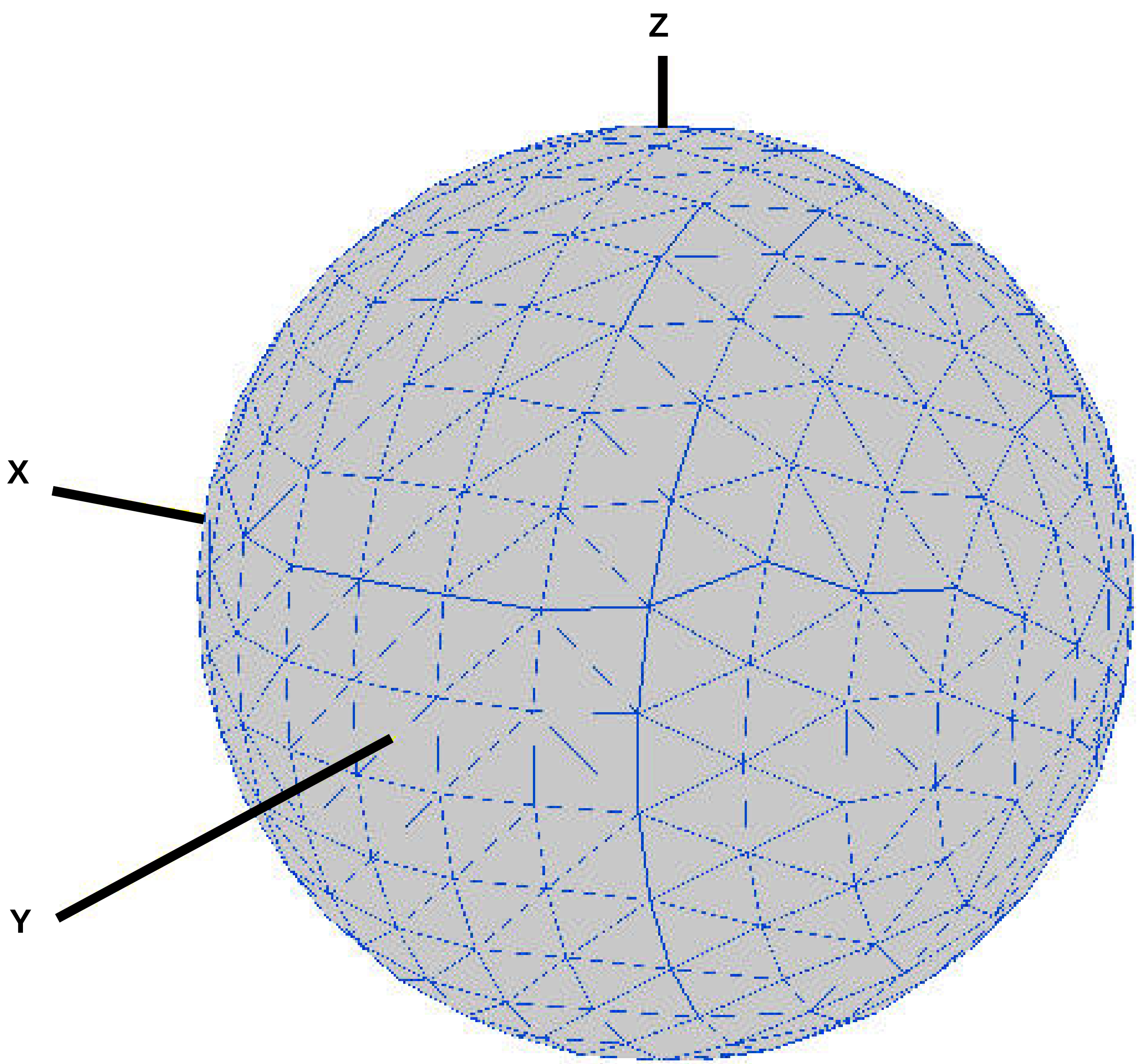
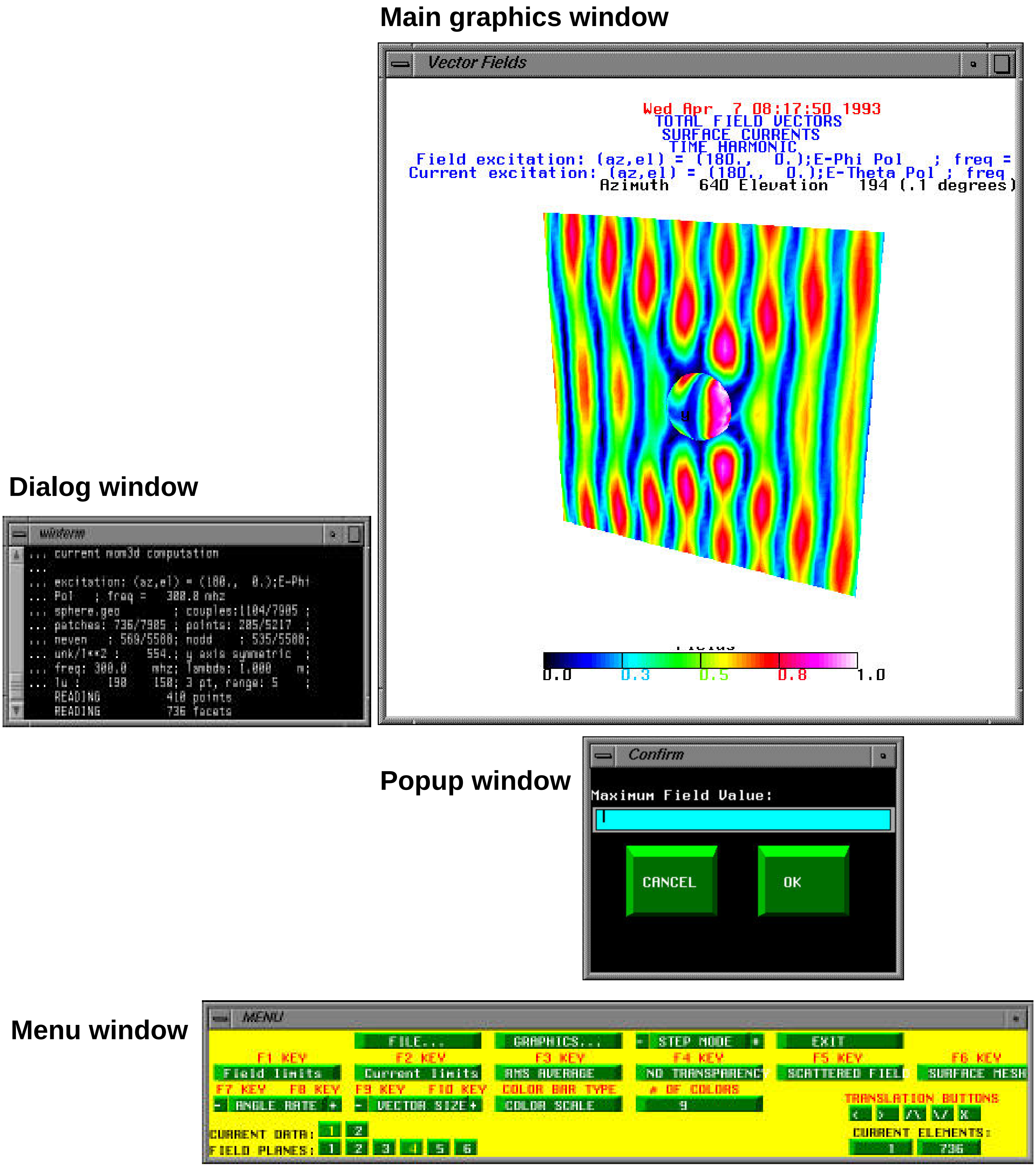
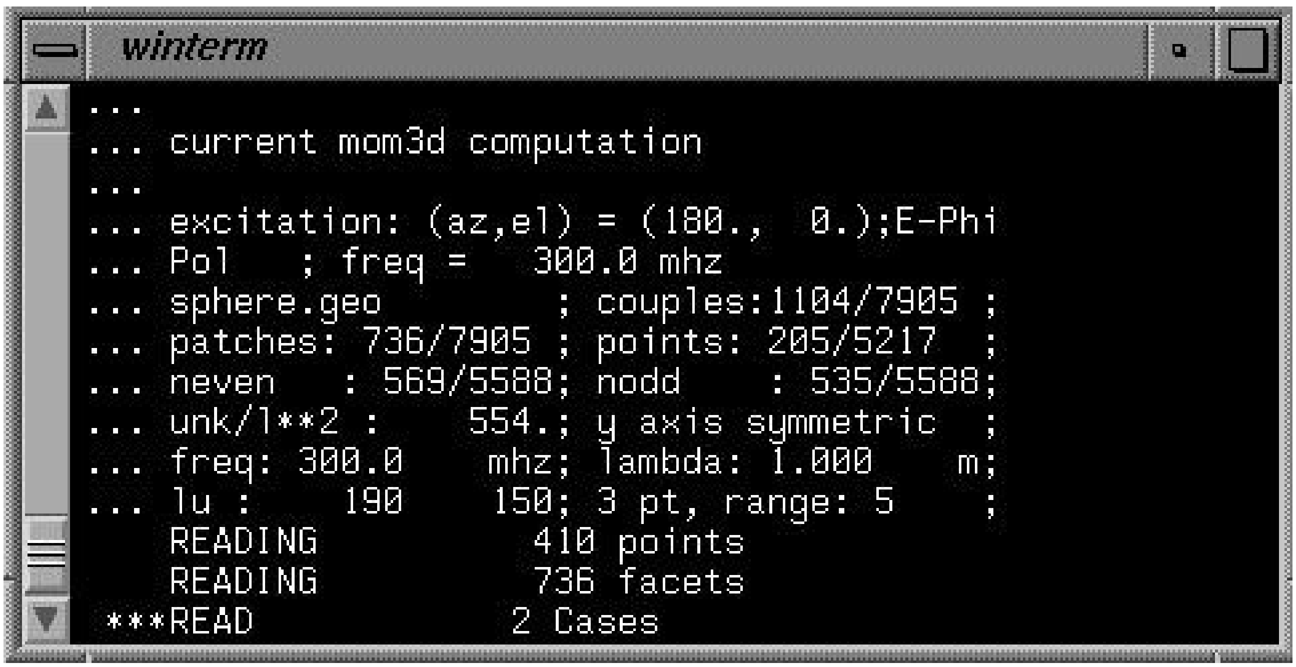


Figure 5. Triangular mesh geometry for one−wavelength−diameter sphere body.



(a) View of all windows.

Figure 6. EM−ANIMATE windows.



(b) Detail view of DIALOG window.

Figure 6. Concluded.

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6. AUTHOR(S)
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13. ABSTRACT *(Maximum 200 words)*
A computer program named EM-ANIMATE has been developed to visualize the electromagnetic properties that are obtained from electromagnetic scattering programs. This program is useful as a diagnostic tool for studying the underlying scattering sources that produce the backscatter or bistatic scattering returns from bodies. For any user view option, this program can calculate and display in real time a time-harmonic animation of the surface currents and the near-field quantities that show field and surface-current magnitudes as well as field and surface-current vector directions and magnitudes. The program, which is designed for easy use, presently runs on a Silicon Graphics, Incorporated, workstation running IRIX 3.0 or higher.

14. SUBJECT TERMS
Electromagnetic fields; Computer graphics; Computerized simulation; Surface properties; Display devices

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