3D Vision of Electromagnetic Fields in Antenna and Microwave Technique

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Abstract. *Two approaches, Virtual Reality Modeling Language (VRML) and graphic library OpenGL, are used for active stereoscopic vision of electromagnetic fields surrounding selected antenna or microwave elements. Input data are generated by analytical relations or acquired by electromagnetic field simulators and visualized in the form of vector fields and field lines by active stereoscopy. In case of VRML freeware Quadroview and GeForce 3D Vision package from nVidia is used to acquire stereoscopic vision. In case of OpenGL implementation own stereo browser StereoEMview has been developed. Both approaches require a little bit different initial sources, knowledge of implementation tools and solution procedures. However resulting output is the same. Thus authors can choose which implementation is more suitable for their nature and available sources.*

Keywords

Active stereoscopy, electromagnetic field, field line, OpenGL, stereoscopic vision, stereoscopy, vector field, VRML.

1. Introduction

Electromagnetics is an interesting and rewarding topic on one hand. Except for a short range of wavelengths or extreme intensities, electromagnetic fields and waves are not sensed by humans. That is why understanding electromagnetics may be hard for students as well as for engineers designing unusual components.

In order to enable people to understand electromagnetics, different graphic techniques have been developed to describe fields and waves, such as equipotential plots, vector plots and other. These are quite suitable for 2-D fields, on the other hand describing 3-D fields using 2-D plots is difficult and may result in a plot that can be understood only if the observer knows the particular field.

Recently, 3D vision techniques have reached its maturity [1]. A number of devices available at affordable prices is expected to reach the market this year. Adding one more dimension can dramatically increase the value of vector field plots. Simultaneously, numerical electromagnetics has advanced so much that a number of powerful field simulators are available on the market.

While the techniques using 2-D plots are mature, 3-D vision used in field description is quite new. New approaches should be introduced. This paper describes our approaches and results using Virtual Reality Modeling Language (VRML), graphic library OpenGL, and nVidia commercial solution for stereoscopic vision GeForce 3D Vision® [2].

2. 3D Vision Technology

The illusion of 3D scene is created by human brain when each eye receives its own picture of the observed object. Both pictures are slightly shifted because the eyes are spaced of about 7 cm.

Systems for 3D vision of scene enable perceive the illusion of the third dimension of the picture which is not presented in the original 2D scene. This is done by creation of two shifted pictures each of which is forwarded to proper eye by special method, see Fig. 1. The methods to do this can be classified to stereoscopic and autostereoscopic. The first one uses special glasses which mediate each picture for each eye while the later one does not uses any special glasses or any other special optical devices.

One of the simplest methods to provide different picture for each eye is a method called anaglyph. It uses two shifted pictures for illusion of scene depth each of which is usually in color from opposite parts of visible spectrum, for example in red and cyan. The glasses have one glass in red and the second in cyan. Each glass let in complementary picture so one eye receive red and the other cyan picture. The drawback of this method is that not all the colors are carefully represented. This is a passive 3D vision system.

The active stereoscopic system alternates pictures for left and right eyes. It is based on the physiological properties of eyes. The human brain perceive the stimulation with the delay of about 20 ms. The pictures changing with the frequency at least 50 Hz are perceived by brain as continuous perception. In experience a small

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reserve is used and the repeater frequency of 60 Hz is used per each eye which represents total 120 Hz for both eyes. Shuttered or active LCD glasses are used to alternatively switch on/off of both pictures. The switching of glasses is synchronized with the switching of pictures on PC monitor by infrared (IR) emitter.

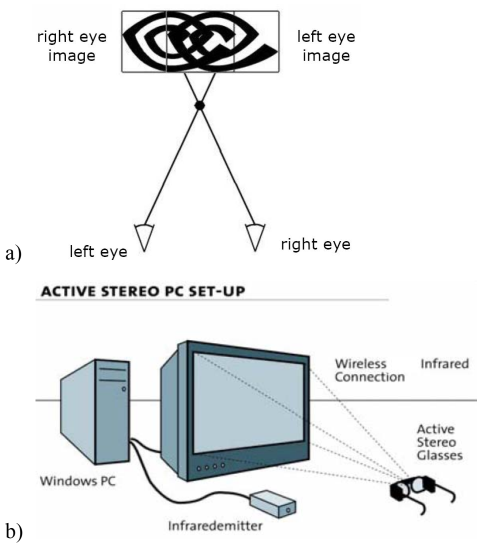

Fig. 1. Schematic view of a) stereoscopic picture which is decomposed into two pictures each for individual eye, and b) view of active stereo PC setup (courtesy of Bitmanagement Software).

3. Implementation of 3D Vision of Electromagnetic Fields

The 3D system used is based on commercial product nVidia GeForce 3D Vision® package [2] composed of 120 Hz 3D monitor Samsung SyncMaster 2233, active (shutter) glasses, IR synchronizer. Graphic cards Quadro FX 3700 and FX 580, and freeware nVidia QuadroView enabling stereoscopic vision is used as a viewer. Following representation of vector fields and field lines has been implemented partially in the frame of diploma thesis [3].

3.1 Input Data

For 3D vision of electromagnetic field in the close vicinity of an antenna or inside microwave elements field components, both electric and magnetic, together with grid position of each component and can be generally acquired either from analytical relation or numerically from electromagnetic simulators. The form of output data is usually text file with data in the following format

$$[x \quad y \quad z \quad \mathrm{Re}\{\mathbf{V}_x\} \quad \mathrm{Re}\{\mathbf{V}_y\} \quad \mathrm{Re}\{\mathbf{V}_z\} \quad \mathrm{Im}\{\mathbf{V}_x\} \quad \mathrm{Im}\{\mathbf{V}_y\} \quad \mathrm{Im}\{\mathbf{V}_z\}] \tag{1}$$

where x, y, z are coordinates of mesh points, and $\mathrm{Re}\{\mathbf{V}_x\}$, $\mathrm{Re}\{\mathbf{V}_y\}$, $\mathrm{Re}\{\mathbf{V}_z\}$, $\mathrm{Im}\{\mathbf{V}_x\}$, $\mathrm{Im}\{\mathbf{V}_y\}$, $\mathrm{Im}\{\mathbf{V}_z\}$ are real and imaginary coordinate components of complex vector (phasor) $\mathbf{V} = \mathbf{V}_{\mathrm{Re}} + j\mathbf{V}_{\mathrm{Im}}$ representing electric or magnetic field intensity or power flow density. The field components are then used to display electromagnetic field in the form of vector field and/or field lines.

3.2 Vector Fields and Field Lines Representation

The vector field is usually represented by an array of arrows or cones. Their orientation in the space is done by their coordinate components. The arrow length or cone height represents the magnitude of displayed field quantity. Color scale to boost the magnitude differences is used. If the field vector is known in common point one can derive the field line. From Fig. 2 it is evident that

Fig. 2. Representation of the common field line.

$$d\vec{l} \parallel \vec{E} \tag{2}$$

that implies

$$d\vec{l} \times \vec{E} = 0 \tag{3}$$

Eq. (3) can be expanded into

$$dy \cdot E_z - dz \cdot E_y = 0 \tag{4a}$$
$$dz \cdot E_x - dx \cdot E_z = 0 \tag{4b}$$
$$dx \cdot E_y - dy \cdot E_x = 0 \tag{4c}$$

Eq. (4a) – (4c) can be combined and expressed in the following form which represent equation of field lines

$$\frac{dx}{E_x} = \frac{dy}{E_y} = \frac{dz}{E_z} \tag{5}$$

This equation can be solved for example by Euler method, see details in [3]. By discretization of eq. (5) after some algebraic modification we find the coordinates of n-points of the field line as

$$x_{n+1} = x_n + E_x \Delta n \tag{6a}$$
$$y_{n+1} = y_n + E_y \Delta n \tag{6b}$$
$$z_{n+1} = z_n + E_z \Delta n \tag{6c}$$

An algorithm for implementation of eq. (6a) – (6c) can be found in [4]. Here described method has a drawback concerning continuity of the field line curve. Precision of the method depends on the chosen approximation step Δn. In case the step is not small enough the field lines always forming closed curves (such as magnetic field lines) would form non-closed curves – initial and end point would be different. To eliminate the problem more precise method (e.g. Runde - Kutta) have to be used. Here we applied the simpler Euler method with randomly generated initial points with shorter line length so that the precision of drawing lines is sufficient.

3.3 Animation of Fields

The animation of fields is based on the mapping of complex vector $\mathbf{V}$ onto time-harmonic vector $\mathrm{V}(t)$ by relation

$$\mathrm{V}(t) = \mathrm{Re}\left\{\mathbf{V} e^{j\omega t}\right\} = \mathbf{V}_{\mathrm{Re}} \cos(\omega t) - \mathbf{V}_{\mathrm{Im}} \sin(\omega t) \qquad (7)$$

The orientation of vector during period T is done by immediate value of the argument from the period $\omega t \in (0, 2\pi)$.

3.4 Comments on VRML and OpenGL Implementation

The VRML [5], text oriented language used for modeling of real scenes in computer graphics, represents a high level programming language supporting such features as e.g. JAVA scripting. Yet the OpenGL is deemed a low level programming language, implemented and supported by many programming languages, for instance by C++, C#, etc. In addition, the VRML can be accelerated by the OpenGL, Direct X, etc. Both aforementioned languages are suitable for the stereoscopic projection of any 3D environment, since they offer very similar advantages. In order to exploit both approaches, it is necessary to provide input data from the electromagnetic field simulators. On the other hand, the OpenGL solution produces the executable application programmed in any language (in our case in Borland Builder C++). Because of the used universal programming language, the final application can provide more functions. Contrary to it, the VRML should be interpreted and the VRML file should be prepared in advance from the data obtained by the electromagnetic field simulator. The VRML file interpreting have higher demands on the computer hardware. Moreover, the stereoscopic VRML projection is possible using the commercially available application.

In case of the OpenGL implementation, after the data obtained from the electromagnetic field simulator are opened, they are immediately stereoscopically projected. The projected model can be viewed from any point outside or inside the model. The model can be rotated, scaled or moved. The electromagnetic field (vectors of either electric intensity or magnetic intensity and the Pointing vector) is drawn using the cones. The color and size of the latter represent the absolute module of the selected electromagnetic field vector. In addition, the cones are rotated in order to display the vectors in the appropriate direction. During the model projection, the following parameters can be selected or changed:

- animation of cones (selected vectors of electromagnetic field) in time;
- animation speed;
- continuous or stepped animation;
- ratio of cones dimensions to the model overall dimensions;
- stereoscopic effect – the shift of the projected scenes for each eye of the observer;
- linear or logarithmic representation of vector intensities;
- color palette representing the vector intensity;
- overall model scale;
- position of the observer;
- direction of a view.

3.5 Anaglyph and Active Stereo 3D Pictures

For the purpose of color version of this paper we provide red-cyan anaglyph picture (red and cyan colored pictures are slightly shifted in opposite directions) to create 3D illusion of the picture of vector fields surrounding half-wavelength dipole, see Fig. 3. Interested reader needs to use simple red-cyan glasses. The difference between simple 2D and active stereo 3D picture is indicated in Fig. 4. The latter, consists of two shifted pictures for left and right eye which are displayed at the 120 Hz monitor alternately (each with repeater frequency 60 Hz) as explained in Section 2. The one 3D picture is then formed in a brain when shutter/LCD glasses are used.

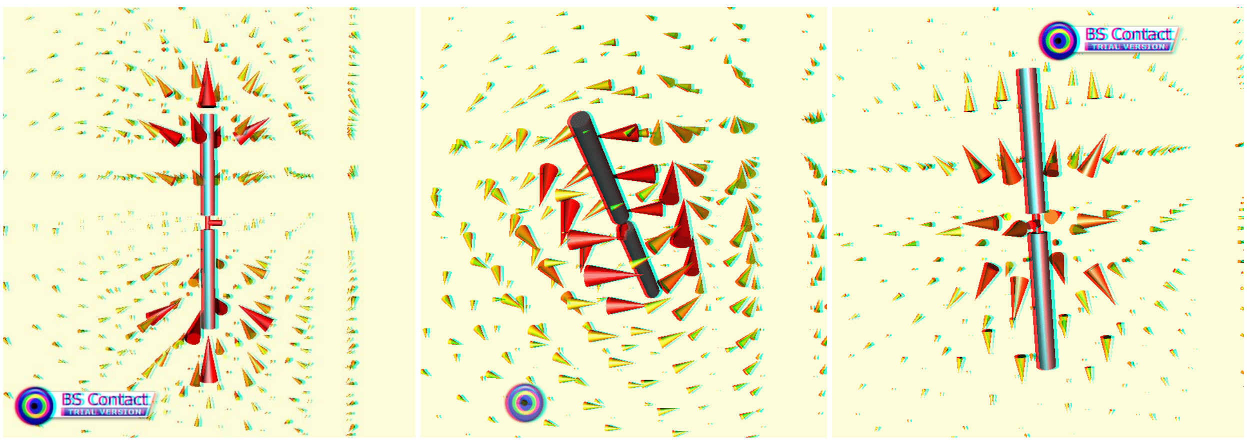

Fig. 3. Red-cyan anaglyph picture of vector E-, H- and S-fields of half-wavelength dipole (red and cyan colored pictures are slightly shifted).

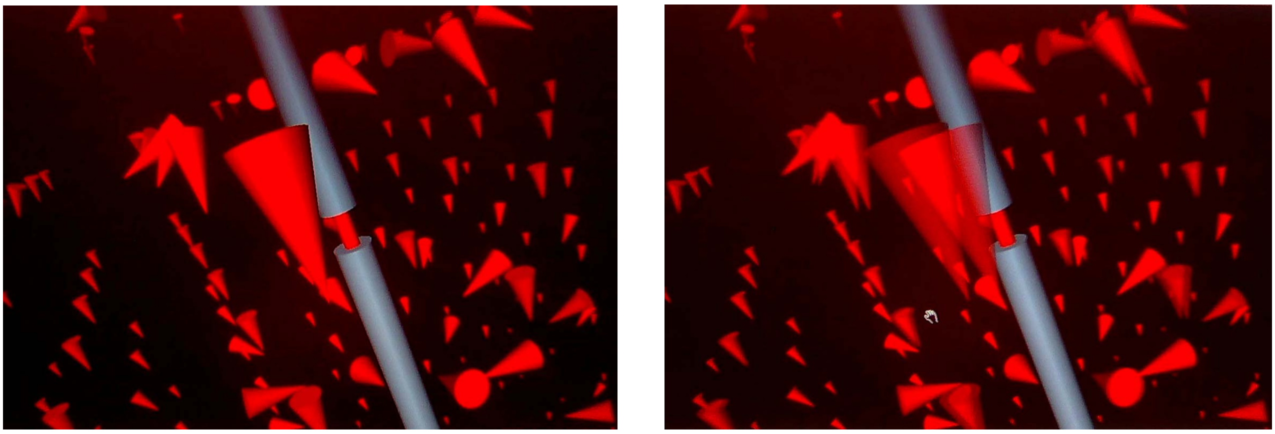

Fig. 4. Detail picture of vector E-field of half-wavelength dipole demonstrating the difference between: a) simple 2D picture (left), b) stereo 3D picture (right, both left and right eye pictures are visible) as seen without shutter glasses (captured with time > 1/60 s).

4. Discussion

Summarizing the characteristics of each implementation, VRML and OpenGL, we find following.

Matlab/VRML:

- *.wrl files for VRML viewer are generated by Matlab
- input data, scene parameters have to be preprocessed by Matlab, or by other math tool before generating *.wrl files
- availability of plenty of VRML display functions (transparency, illumination, ..)
- possible slower display of demanding scenes
- paid animation stereo display when Java scripts are used for animation in VRML (e.g. BS ContactStereo)
- free static stereo display (e.g. QuadroView, interpretation of Java scripts for animation not supported)

OpenGL:

- application of programming language (such as C++, C#, Pascal, etc.), all the numerical calculation and graphic commands are implemented thereby
- executable stereo viewer, input data in format of eq. (1) directly readable
- scene parameters (animation speed, magnitude scale change, step-by-step movement of the animation) can be set instantaneously during displaying scene
- fast display of demanding scenes (processed by graphic card), however specialized graphic card(s) necessary (e.g. Quadro FX series)
- free both static and animation stereo display in own viewer StereoEMview

Both approaches, Matlab/VRML and OpenGL, require a little bit different initial sources, knowledge of implementation tools and solution procedures. However resulting output is the same. Thus authors can choose which implementation is more suitable for their nature and available sources.

Acknowledgements

The authors would like to thank you prof. Ing. Jiří Žára, CSc. and Prof. RNDr. Petr Kulhánek, CSc. from Czech Technical University in Prague, Faculty of Electrical Engineering for their consultation on implementation of animation in VRML and drawing the field lines, respectively.

Research described in the paper was financially supported by the Ministry of education, youth, and sports under grant No. 2359/2009/F1/a and by the research project in the Area of the Prospective Information and Navigation Technologies MSM 6840770014.

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