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A Multimedia Textbook of EM Theory and Techniques

Teaching university courses, which deal with the phenomena of electromagnetic nature and their application, is rather difficult due to their abstract nature. Therefore, the teaching has to be accompanied by clear explanation, and by simulation illustrating the examined topics. That is why a multimedia textbook was developed, which presents the theoretical description of electromagnetic phenomena, and at the same time, enables to simulate them.

The textbook is of a two-dimensional structure, which enables the book to be used by bachelor's students and master's ones for studying, by users of incorporated programs for guiding, and by programmers for developing their own applications. The textbook is completed by an explanatory indexing mechanism, which makes the book readable even for an inexperienced reader.

Key words: antennas, electromagnetic phenomena, frequency selective surfaces, microwave transmission lines, multimedia textbook, optoelectronics

1 INTRODUCTION

Increasing demands on reliable transmission of information causes shifting communication services to higher and higher frequency bands. Technical universities have to reflect the described situation by educating highly qualified specialists, which are able to design electronic circuits and antennas working on tens of GHz. Since phenomena in this frequency range are of the wave nature, analysis and design have to be based on Maxwell's equations in the integral form or the differential one. Unfortunately, description of studied phenomena exploiting integral equations or differential ones usually cause problems due to the following reasons:

– The phenomena are described by relatively complicated and abstract mathematical expressions, and therefore, imagining physical meaning of the mathematical description is rather difficult.

– Phenomena of wave nature are relatively abstract, and therefore, properties of studied phenomena can be investigated indirectly only.

In the classical education, the above problems are solved by the following way:

– During lectures, a basic theoretical description of studied phenomena and systems is presented to students, and their mathematical formulation based on differential or integral equations is explained to them.

– Next, students pass computer exercises, where they become familiar with basic features of studied structures, with typical values of variables describing the structure of interest, and with basic consequences. Computer exercises are based on simulation's software, which enables empirically study the objectives of interest.

– Finally, students equipped by necessary theoretical knowledge and basic sense for phenomena comes to the laboratory, where they can selected phenomena experimentally test and verify.

In order to accomplish the above three steps as efficiently as possible, new technologies like Internet and multimedia are frequently discussed these days.

The multimedia textbook can associate theoretical descriptions and practical simulation of examined phenomena. Therefore, the textbook can present the basic knowledge in the text form (descriptions, equations, figures), and at the same time, it enables to run simulations of studied phenomena directly from text. Moreover, the textbook can enable to search for additional information via hypertext links. That way, the vertical structure of the textbook has been developed (the upper layer contains a rough description, the lowest layer goes to the tiniest details).

The multimedia textbook was developed in two versions.

The first version of the textbook is written in Czech with a few chapters translated into English, which should help Czech students improve their knowledge of specialized English. The Czech version of the textbook is accessible via

http://www.feec.vutbr.cz/~raida/multimedia

The second version of the textbook is written in English with a few chapters composed in Dutch. The English version of the textbook is accessible via

http://www.feec.vutbr.cz/~raida/multimedia_en

The paper concentrates on the English-Dutch version of the multimedia textbook.

2 OUTLINE OF THE TEXTBOOK

The textbook consists of six chapters covering selected topics of electromagnetic theory and microwave techniques.

The first chapter, Introduction, is devoted to the unification of readers' knowledge, to the introduction of notation used in the textbook, and to the definition of the basic terminology.

The second chapter, Propagation of EM Waves, discusses selected topics from the field of wave propagation in inhomogeneous media (dielectric layers, diffraction on a half-plane or on a cylinder, etc.). The described phenomena are simulated using geometric theory of diffraction in order to illustrate the investigated phenomena [1, 2].

The third chapter, EM Waves on Transmission Lines, is oriented towards investigating wave propagation along selected types of transmission lines. Waveguides and shielded microstrip lines are modeled using the finite-element method [3, 4].

The fourth chapter, Antennas, deals with the wire antennas (symmetric and asymmetric dipoles, Yagi antennas) and with microstrip antennas (microstrip dipoles, patch antennas). The antennas are modeled using the method of moments in order to demonstrate their basic properties [5, 6].

The fifth chapter, Frequency-Selective Surfaces, describes basic types of those reflectors and discusses the way of modeling their behavior by the frequency-domain method of moments [7].

The sixth chapter, Radio-optics, introduces the Gaussian beam and its exploitation for the basic modeling in the area of paraxial optics [8].

The contents of the multimedia textbook is at the reader's disposal in the left-hand frame of the screen during the whole time of reading as shown in the Figure 1.
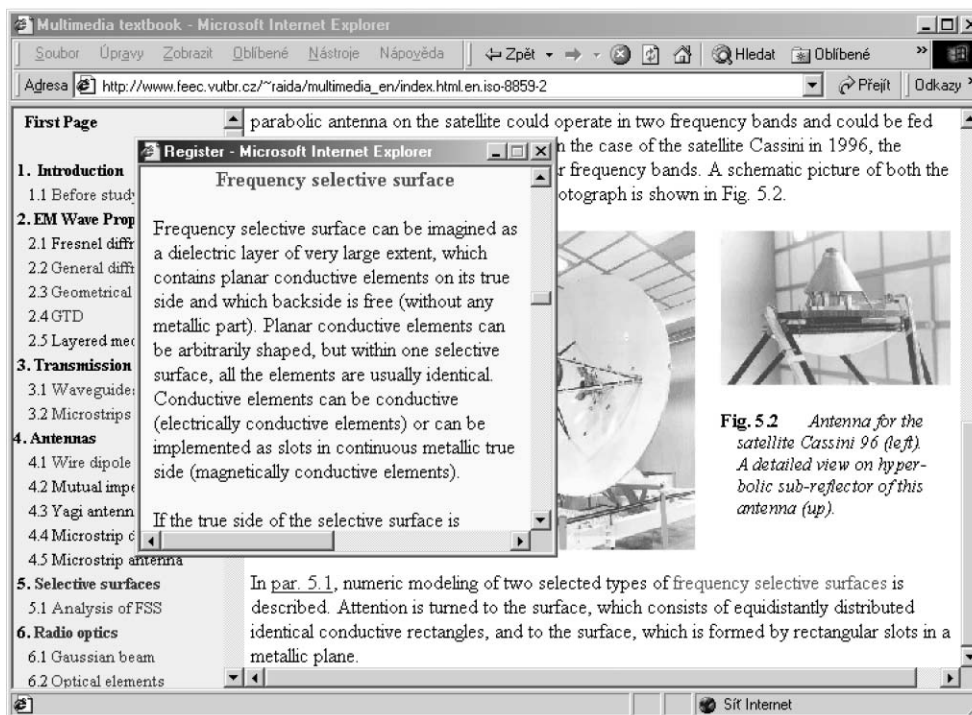

Fig. 1 A brief explanation of the indexed term »frequency selective surface« in the explanatory window in the foreground. The contents of the textbook is perpetually visible in the left-hand frame

The textbook is conceived as a collection of carefully selected topics which the multimedia processing makes sense to. Since the basics of EM theory are not included in it, a special indexing mechanism has been developed in order to explain the basics to the reader. The basic indexed terms are printed in red in the text. Clicking the red basic term, a special explanatory window is opened, whose contents provides a brief explanatory text and graphics (see Figure 1). Clicking elsewhere, the explanatory window is automatically closed. An alphabetical list of indexed terms completed by the explanatory text (and even graphics when needed) is accessible via the menu item »Index« at the bottom of the contents frame.

3 SOFTWARE IMPLEMENTATION

The textbook is basically written in Hypertext Mark-up Language (HTML). Using HTML, the structure of the textbook can be expanded into the second dimension. The first dimension (horizontal one) consists of a continuous text (as a common book). Inserting links into the horizontal structure, an additional dimension (the vertical one) is created. In the vertical dimension, four levels A to D are formed (see Figure 2).
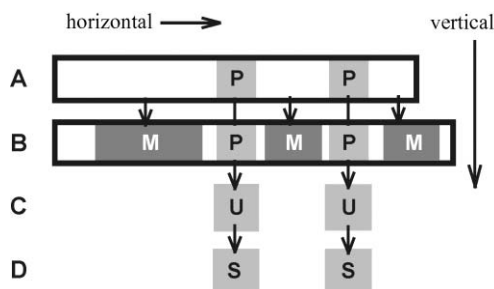

Fig. 2 Two-dimensional structure of the textbook. M: mathematical parts, P: links to simulation programs, U: user's guide of the program, S: programmer's guide

The basic level A of the book is of the form of a clear explanatory text, which brings all the information in very simple way free of any mathematical derivation. The mathematical description is limited to the initial formulation of the problem and to its final solution. The results can be simulated using a respective MATLAB program (P).

The basic level A can be used as a textbook for students of the bachelor study programs, where students are interested in practical results with the basic notion of their theoretical background. Further, the basic level can serve as a manual concentrating the most important formulae.

The second level B of the textbook can be read as a continuous text, which contains all the detailed mathematical derivations presented as results in the level A. Moreover, mathematical parts (M), which were omitted in the level A, can be accessed by links from the basic level. Mathematical passages are joined together by a brief text expecting a more experienced reader.

The second level B can be used as a textbook for students of the master study programs, where students are expected to obtain very good theoretical background. Students, who feel the text too demanding, can access simpler explanations in the layer A via links. Further links are oriented to the layer C, which contains user's description of computer programs.

Layer C is built in the form of the collection of text fragments, which do not create any continuous unit in their whole. Separate segments can contain user's guide of modeling programs (U), e.g.

Finally, the last layer of the textbook (D) contains text segments S, which describe a proper software implementation of simulation programs in MATLAB.

3.1 Simulation programs

All the simulation programs accompanying the textbook are written in MATLAB 5.3. This concept has got its advantages and disadvantages.

The main advantage of the use of MATLAB programs consists in the fact that students can simply observe the way of software implementation of differential equations or integral ones described in the textbook. Therefore, students can better understand rather abstract mathematical description of studied phenomena.

Further, students can modify the source code and can examine changes in the simulation process caused by these modifications. Therefore, students can get better notion of consequences of the matter of those changes.

Moreover, the MATLAB source code is platform-independent, and therefore, the simulation programs can run on a PC under Windows, or on a workstation under Unix.

In order to make the programs user friendly, the shell creating the standard Windows users' interface completed the m-files. Readers, who are not interested in MATLAB, can run the programs as classical Windows applications. The typical users' interface of programs, which are incorporated into the multimedia textbook, is depicted in the Figure 3.
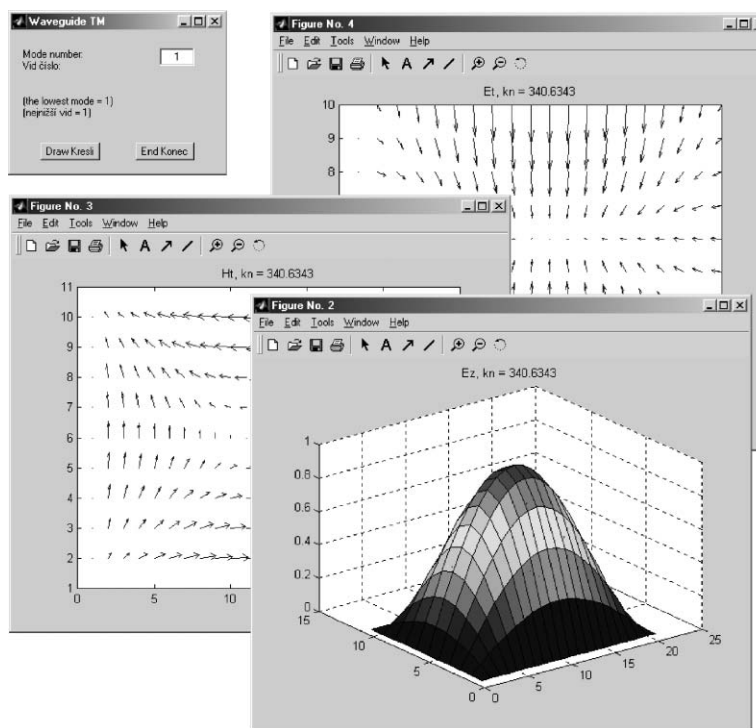
Fig. 3 A standard Windows user's interface of MATLAB programs accompanying the multimedia textbook

On the other hand, the use of the textbook is conditioned by having MATLAB installed on the computer. Further, the reader of the textbook should have open one window for the book and another independent window for the simulation program.

Therefore, we plan to rewrite selected programs to Java in order to have the programs in the platform-independent binary form at the disposal, which might be run directly from the text. These programs can be used by readers, who are not interested in the MATLAB implementation of routines described in the textbook.

4 ADVANTAGES OF THE TEXTBOOK

The textbook was developed in order to make reading and studying easier and more efficient comparing with the standard textbooks. The students can follow the thread of the problem, simply skipping already known things and more deeply investigating problems they are not familiar with. The described personal selection of the way of study can be simply done by clicking a desired link.

Searching in the multimedia textbook is also easier than in the classical textbook. A full-text search machine can find every appearance of the term in

the whole book almost immediately. The result of the search makes clear all the dependencies of the word with the possibility of going to the chapter, where the word is found.

Posting examples and pictures to the textbook supports the theoretical explanation of a phenomena. Compared to the standard textbook, the pictures are of higher resolution, colorful and not static only. Using sequences of a picture, the time dependencies of an examined phenomena can be easily shown (i.e., the time course of electromagnetic field in the wave-guide can be simply illustrated). The examples can be much more extensive. If necessary, source code of simple programs for testing and further developing can be posted on the page and downloaded anytime.

The fact that the updating cycle of the multimedia textbook can be significantly shorter than in the case of the printed book is another advantage. It is quite simple to update the text, example or just add an extra chapter to the electronic version and upload it to the web or release a new CD in comparison to the same process with the paper version.

The standard textbook can be read only by those students, who can buy it in the bookstore. On the other hand, the described multimedia textbook can be even accessed via Internet, which simplifies the

way of students to the desired knowledge (of course, the problem of copyrights has to be properly solved).

Even from the authors' point of view, the electronic publishing brings some extra possibilities. The feedback from the readers can be faster and closer. It is obvious and common that by finding a problem (or even mistake) during reading a text on the network, the user sends an email to the authors' team, asking for explanation or just pointing their attention to the disputable topic. It is up to the publishers if they also can effort kind of discussion forum or on-line support.

Moreover, the multimedia textbook can be conceived as an open publication. Authors from universities and companies all over the world can contribute new chapters of the multimedia textbook in an electronic form (written in a proper word processor). Editors of the textbook convert the text into HTML taking care for the proper structure; incorporate new indexed terms into the existing indexing mechanism; connect new pages by links with the existing parts of the textbook; and build a unified users' interface of simulation programs.

The described version of the multimedia textbook was developed by the above-described way. Chapters of the textbook were created by Ph.D. students of the Czech Technical University in Prague and the Brno University of Technology in Microsoft Word. The chapters were reviewed by professors, were improved and were translated into HTML. Authors verified the result.

5 CONCLUSIONS

In the paper, both the vertical and the horizontal structure of the multimedia textbook of EM theory and techniques was deeply described.

The horizontal structure of the textbook covers topics of the EM theory and their implementation to the antenna techniques, and microwave techniques.

In the vertical structure, a textbook for students of bachelors' study programs, and a textbook for students of masters' programs can be found. Further, the vertical structure continues to the layers of questions and answers, and to the layers of simulation programs.

The multimedia textbook is accompanied by the set of MATLAB programs, which can be used as simulation tools of examined phenomena. These programs are deeply described from the user's point of view and from the programmer's point of view.

The described multimedia textbook is available in the English version and in the Czech one.

The Czech version of the multimedia textbook was tested in teaching regular courses at the Brno University of Technology. A free, instant access to the multimedia textbook and to the accompanying software increased the interest of students in their study of electromagnetics and numerical methods (which are exploited in MATLAB programs), which can be understood as the most important benefit of the multimedia textbook.

ACKNOWLEDGEMENTS

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Multimedijski udžbenik o teoriji i primjeni elektromagnetizma. Podučavanje sveučilišnih kolegija koji se bave fenomenima elektromagnetizma prilično je zahtjevno zbog apstraktnosti gradiva koje se iznosi. Podučavanje stoga valja popratiti jasnim objašnjenjima i simulacijama koje ilustriraju teme koje se obrađuju. Upravo je zato priređen multimedijski udžbenik koji donosi teorijski opis elektromagnetskih fenomena i istodobno omogućava njihovo simuliranje.

Struktura udžbenika je dvodimenzionalna što omogućava njegovu primjenu na dodiplomskom i poslijediplomskom studiju korištenjem gotovih programa koji su dio udžbenika ili izradbom vlastitih programa od strane korisnika. Udžbenik je opremljen sustavom kazala s objašnjenjima, što olakšava korištenje i čitateljima koji ne poznaju područje.

Ključne riječi: antena, elektromagnetizam, frekvencijski selektivne površine, mikrovalne prijenosne linije, multimedijski udžbenik, optoelektronika

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