

Simulating a Laboratory Experience for an On-Line EMC Course

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Abstract

At Utah State University we have begun developing an on-line version of our EMC course, to be made available to our Distance Education students. Because a "laboratory experience" is very important to help reinforce the lecture material, we have tried to replicate the laboratory experience with virtual instruments, components and exercises. To do this, we are developing a series of laboratory modules using the programs LabVIEW and MATLAB. The combination of these two programs allows us to develop and use laboratory modules that give the student a virtual laboratory experience that closely approximates what he or she would see in the real laboratory environment. This paper will report on the design, development and implementation of laboratory modules suitable for use with an on-line EMC course.

Keywords

EMC Education, EMC Simulation, MATLAB, LabVIEW

INTRODUCTION

With the desire for constantly increasing speeds from today's circuits, both digital and analog, the need for an understanding of the basic concepts of Electromagnetic Compatibility (EMC) becomes more critical for graduates of electrical engineering curricula. Today's digital and analog circuits often operate at speeds that are considered to be part of the microwave spectrum. Additionally, with the increase of wireless communications and networking, and the low power devices that make this possible, the possibilities of an engineer having to deal with unwanted interference between electronic systems grow greater each day. Yet, despite the increasing importance of EMC, many schools do not offer a course in EMC or include relevant EMC topics into their curriculum. Those that are interested in teaching such a course often do not know where or how to begin such an endeavor. Also, there is usually a reluctance to add one more classes to an already crowded curriculum, since there is a fear that something else will have to be eliminated, or that there will be an additional drain on existing or even ever decreasing resources.

One way that departments have sought to overcome some of these resource problems is to offer some courses in an on-line format. Most universities now offer on-line courses in many areas, including engineering. At Utah State University, we have begun developing an on-line version of his EMC course that will be made available to students off campus, as well as others who are interested in distance education. This course

will be identical to the class taught on campus, has the same prerequisites and follows the same sequence of material.

In a previous paper [1], sources of information for developing an EMC course were provided. Key among these is the EMC Education Manual [2], freely available from the web page of the education committee of the EMC society [3]. It provides a suggested course outline, some demonstrations and laboratory experiments that can be used to emphasize various EMC concepts, and a substantial bibliography of documents for additional references.

However, one of the issues with on-line engineering courses is that the distance education student does not always have access to the laboratory equipment that often helps illustrate the theoretical concepts being taught in the classroom. Because a "laboratory experience" is very important to help reinforce the lecture material, we have tried to replicate the laboratory experience with virtual instruments, components and exercises.

This paper will discuss ways to achieve a "laboratory experience" for a course and report on the design, development and implementation of laboratory modules suitable for use with an on-line EMC course. Results of this development will be made available to the EMC education community for use by other schools and instructors.

DEFINING THE LABORATORY EXPERIENCE

When determining how to simulate a laboratory experience, the first thing to understand the **purpose** of the lab experience. The main purpose of the lab experience is to take the concepts, theoretical or otherwise, that are taught in the class and make them better understood and more real to the student. Additional benefits include the opportunity to explore the concepts under review, to use the tools of the profession, and to develop the skills of observation, analysis, synthesis, and design.

In trying to gain these benefits, many approaches have been used to achieve the laboratory experience. These include traditional laboratory-based experiments, individual or team projects, software and hardware based simulations of real world situations, or combinations and variations of the above. Given the purposes stated above, the experiments chosen for the EMC laboratory experience should clarify and illuminate difficult to explain or hard to understand concepts that are still basic to the EMC field.

In the IEEE EMC Education Manual, the eleven demonstrations and laboratory experiments listed center mainly on the concepts of 1) radiated and conducted noise, and 2) the coupling of electric and magnetic fields onto cables and into en-

closures. Because these are core concepts to understand, we have developed some laboratory experiences oriented around transmission lines, antennas and electromagnetic shielding.

In the ideal world, we would have enough equipment available to the student for them to conduct experiments on real components and systems. Unfortunately, we live in the real world, where we are resource constrained, be it in terms of dollars, time and space. Because of this, we are forced to simulate some experiments to handle the number of students we have, versus the amount of equipment we have. To insure that the students get the benefit of hands on experience in EMC problems with real equipment and components, we have our students participate in an EMC build and test project, which gives them experience in construction, measurement, analysis and mitigation approaches to an EMC challenge. We have had our students replicate the EMC Society's design competition [2] locally during the course of the class, and the students always walk away from the experience with a greater appreciation of the fact that EMC is as much an art as a science.

However, this is much more difficult for distance education students to do. Thus, we have incorporated into our course a software project to go along with the hardware project. Students in the classroom are tasked to develop realistic simulations of EMC related phenomena, and then required to explore the limits of the simulation and discover what principles can be deduced from the virtual experiments [4]. Distance education students that do not have the capability of carrying out the hardware project in the course can substitute a second software project to compensate for the lack of available equipment.

SIMULATING THE LABORATORY EXPERIENCE

One of the key things that students need to carry away from their software simulations is that the results are only as valid as the accuracy of the model they use to replicate the physical situation they are trying to simulate, and that the accuracy of this model is also affected by the ability of the software to accurately represent the model. Thus, in one sense, the students' results are twice removed from the real world. However, this also provides an opportunity to remind the students that the results they obtain from "real" measurements on components and systems are also affected by how accurately their instrumentation can make a measurement, as well as how many other mediating factors are affecting their results. Since our department building is across the street from the university's NPR station, students soon learn why measurements of RF circuitry operating at low power levels are best made in a shielded chamber.

One of the laboratory simulations that is often chosen by students is a module to simulate and characterize different types of transmission lines. When simulating microstrip lines, which can be used to understand the operation of a PCB land above a ground plane, they have to recognize the fact that there is no one equation for microstrip which will serve them in all circumstances. Thus, we have the opportunity to talk about coupling concepts in terms of bandwidth, effective di-

electric constants, and a number of other principles. While students obtain much of their information from the course text [5], they are also encouraged to research the literature to see how their simulations match up with measurements reported in the literature. This has several benefits. Not only do they get an independent check on the validity of their models and simulations, they also become familiar with the literature in the field. As most of my students are seniors or beginning graduate students, this is an experience that will assist them as they move forward in school or at work. Student

SIMULATION SOFTWARE

While there are many approaches we could have chosen to simulate the laboratory experience, we focused on two main software packages – MATLAB and LabVIEW. These were chosen because of their common presence in most educational environments, as well as their common usage in industrial settings. By familiarizing themselves with these tools, the students not only improve their educational experience, they also gain valuable skills that will enhance their capabilities in the workplace.

MATLAB [6] is a software package that provides mathematical computation and visualization capabilities, along with a flexible programming and development environment, to include the capability to easily build Graphical User Interfaces for simplifying numerical modeling and simulation problems. By using MATLAB along with the accompanying program Simulink, the student can model and simulate laboratory experiments, again providing a laboratory related experience.

LabVIEW [7] is a widely available software package used for test, measurement and control purposes, and has very useful simulation capabilities built into it also. With the many virtual instruments that are built into LabVIEW, students can conduct realistic experiments, even if they do not have access to the actual instrumentation. LabVIEW also has the built-in capability to control real instrumentation remotely, via the Internet. This allows a student to control laboratory instrumentation in a central location from many remote sites, as well as reviewing the results of carrying out remotely controlled experiments. Thus, one way to provide an on-line student a laboratory experience is to provide them access to laboratory equipment and experiments remotely.

The combination of these two programs allows us to develop and use laboratory modules that give the student a virtual laboratory experience that closely approximates what he or she would see in the real laboratory environment. Because there is also the capability to tie these two packages together through an interface toolkit, the modeling sophistication of MATLAB can be harnessed to the virtual measurement environment that can be built in LabVIEW, resulting in very sophisticated and accurate models and simulations. In fact, by combining these modules with real world instrumentation, the student gains an opportunity to compare theory, modeling & simulation, and measurements, and understand the strengths and weaknesses of these different approaches to understanding EMC concepts. While we have concentrated on the virtual instrumentation capability in the short run, our eventual

goal is to have a dedicated set of instrumentation available for distance students to control from their remote sites.

EXAMPLE MODULES

While many different types of simulation modules have been built by our students, the results of only two will be presented here. In the both cases, the students chose to develop a transmission line simulator, one done primarily in LabVIEW and one in MATLAB. In fig. 1, the student has developed a LabVIEW simulation that can calculate the parameters of various types of transmission lines, in this case a microstrip line. Notice that the error window to the right side of the interface is indicating that there is a problem with the values chosen here. Worrying about error checking helps the student, and any other user be aware of the fact that the results of a model or simulation are only as good as the data use.

In the other example, the student has developed a MATLAB based toolbox for EMC calculations with a very simple top level interface shown in fig. 2. From here, one can select a calculator for per-unit values of transmission line parameters, fig. 3, or a calculator to simulate reflections on a transmission line, fig.4.

Other laboratory modules that have been developed include simulations for waveguides, antennas, and shielding experiments.

LESSONS LEARNED

In the process of having the students develop these simulations and modules, several lessons learned become apparent. First, even if the student has no experience in using either MATLAB or LabVIEW, we have found that most students can complete a reasonably accurate simulation, including the GUI and input/output sections before the semester is over. Because most of our students use at least one of these packages in their other classes, many develop very intricate modules as part of the class, mainly because they enjoy the project and don't realize how much they are learning while having fun.

Second, it takes as much time for the students to validate and "bullet-proof" their simulations as it takes to develop them in the first place. Thus, it is important to give the students a clear time line to work too, as they often forget that a simulation that gives bad results is often worse than no simulation at all.

Third, we require that the students document their work with help files and references. Again, this takes more time than most students realize, so we build that aspect of the project into the timeline.

To date, student response has been overwhelmingly positive. Many feel they learn as much wrestling with the simulations

as they do with the actual measurements. Once they "get it right", they are able to go in and rapidly try different configurations, gaining additional insight, with very repeatable results.

SUMMARY

Because of lack in equipment availability, especially those students who are distance education students, we desired to provide a laboratory like experience with software-based simulation modules. These modules are developed from readily available software and provide a surprisingly accurate, repeatable and interactive experience for the students. With the low cost of student versions of LabVIEW and MATLAB, even students that are off-site and have no access to laboratory equipment can have the chance to develop a greater physical intuition as to what happens in EM interaction situations with transmission lines, waveguides, and antennas. Because of capabilities that are inherent in these packages, it is hoped that an interactive experience with real equipment can be developed in time. For more information about these simulations or copies of the software, contact the author.

REFERENCES

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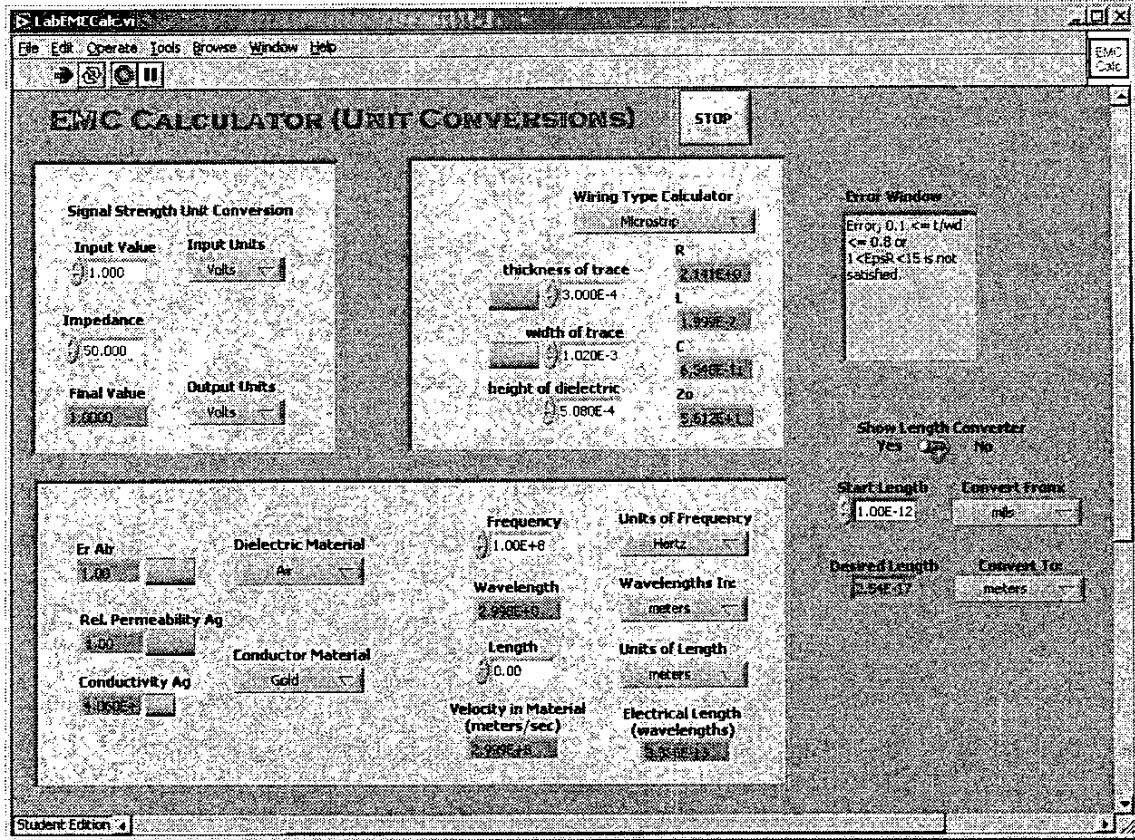


Fig. 1 LabVIEW-based EMC calculator.

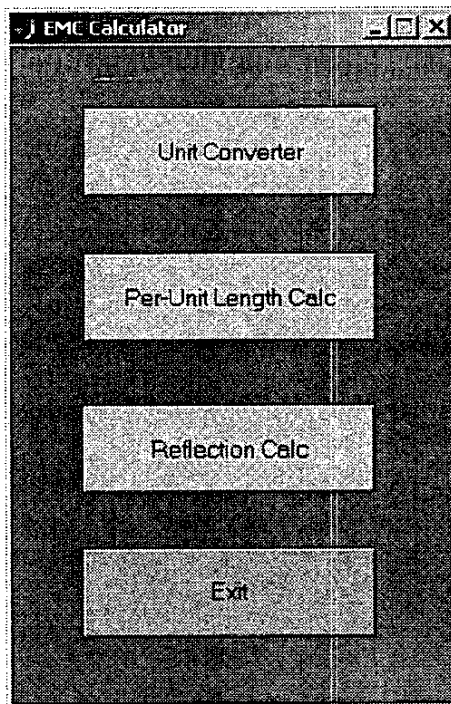


Fig 2. Top level MATLAB interface for EMC Toolbox.

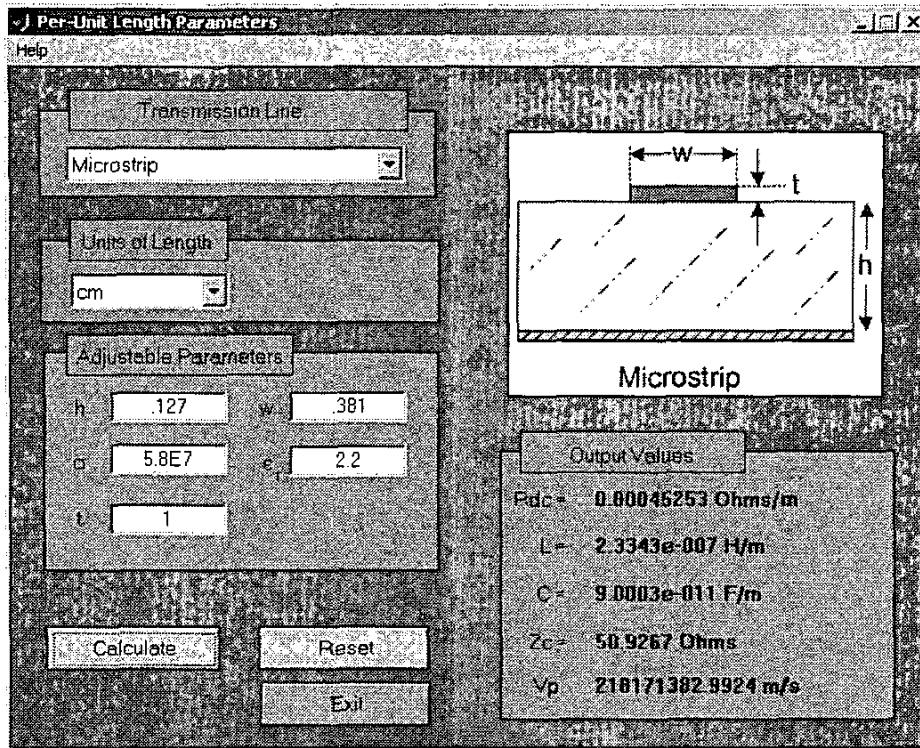


Fig 3. Per Unit Length Parameter calculator in MATLAB.

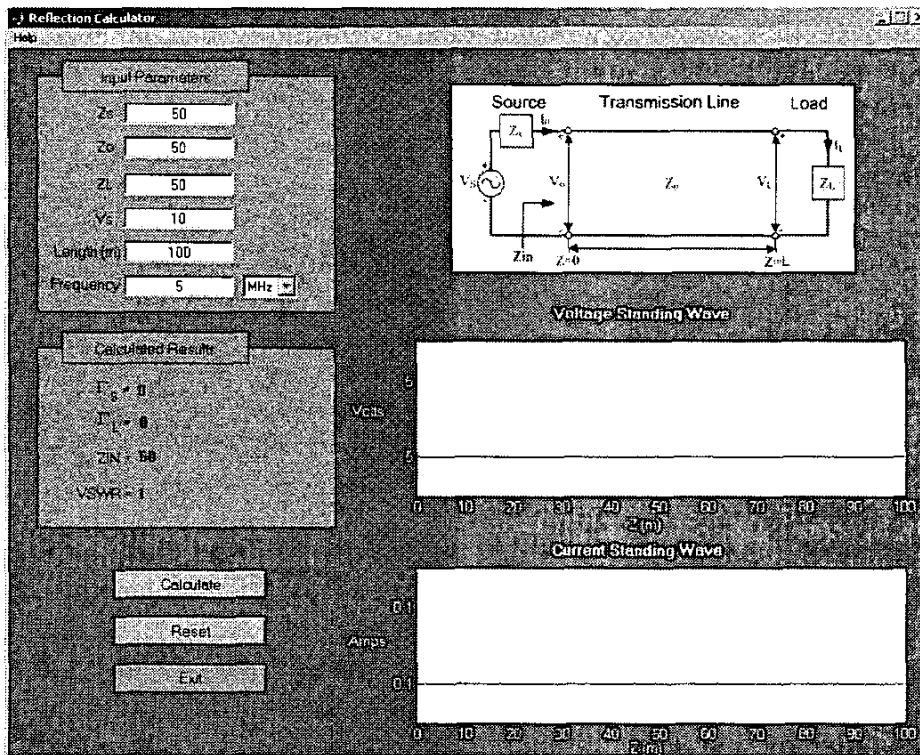


Fig. 4. Reflection Coefficient calculator in MATLAB.