Industry-Academia Collaboration
Supporting EMC Education

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Abstract

This paper provides an overview of the projects and industry collaboration with students that are involved with the activities at the Grand Valley State University (GVSU) Electromagnetic Compatibility (EMC) Center. This facility provides high speed & EMC design, simulation and test services for industry as well as educational activities for undergraduate and graduate level students. Several collaborative projects and activities between industry and students are described.

Introduction

The objective of the EMC Center is to provide a venue where industry and academia can interact for mutual benefit. Students are exposed to product technology and how to design and test electronics preparing them for careers in related fields. Industry gains access to a unique combination of expertise, technical services and an introduction to future engineers entering the job market. The EMC Center educational activities fall into several categories. Concepts and theory are taught in junior, senior and graduate level classes while laboratory measurements reinforce the practical applications. Laboratory measurements are made to quantify and document EMC principles. Senior design projects involve multi-disciplinary teams that create specific mechanical and electrical automation fixtures that complement the existing test capabilities. Examples include a radiated immunity test chamber, radiated emissions antenna positioner, a near-field emissions scanner and precision probe manipulators for characterizing high-speed interconnects. Graduate level projects involve the analysis of EMC design concepts by creating printed circuit boards for defining best design practices, teaching university classes and training seminars. The various boards focus on understanding how to address common EMC & high-speed design issues with meeting requirements. In addition to student projects, the EMC Center employs co-op students who are involved in running simulations, testing, lab maintenance and building new capabilities to serve industry and academia. Product development from various industries is supported at the EMC Center including medical, automotive, commercial, aerospace, defense and appliance. This variety exposes students to cutting edge technology and gives them an advantage when they graduate and seek employment. It also provides networking opportunities with staff from visiting industrial clients, preparing them for the next steps in their career.

This paper is organized as follows Section 1 describes the ElectroMagnetics (EM) and ElectroMagnetic Compatibility (EMC) courses at GVSU. Section 2 is devoted to the senior projects supported by the EMC Center, while Section 3 focuses on the graduate projects. In Section 4, the students' collaborative education at the EMC Center is discussed. EMC testing and product development support are the subject of Section 5. Finally, Section 6 contains the summary and conclusions.

Section 1 EM/EMC Courses at GVSU

EMC education at GVSU is supported by the junior, senior and graduate courses, as well as senior and graduate capstone projects.

EGR 343 – Applied Electromagnetics - Review of vector calculus, Maxwell's equations, electromagnetic waves, transmission lines and antennas. EMC topics: signal spectra, signal integrity, crosstalk [1], overview of standard EMC tests and regulations. Laboratory measurements.

EGR 443 – Electromagnetic Compatibility - Conducted emissions and power supply filters, conducted susceptibility [2], radiated emissions [3], radiated susceptibility, electrostatic discharge, inductive, capacitive, conducted and radiated coupling mechanisms, electromagnetic shielding, common-mode and differential-mode currents. EMC test procedures. EMC precompliance lab measurements. Design project – SMPS for minimal conducted and radiated emissions.

EGR 643 – PCB Design and EMC - Current distribution and current return path [4], decoupling capacitors and embedded capacitance, ground bounce and power rail collapse, PCB layout and stack-up, differential signaling, Design project - PCB design for EMC compliance.

Section 2 Senior Projects

As part of students' requirements to graduate from the engineering program at GVSU, they must complete a Senior Design Project. The project team involves members from different disciplines including mechanical, electrical, computer engineering and project engineering. They form a team and take spend two semesters to work on developing a sponsored project from industry. These projects allow students to learn how to collaborate as a team, how to capture and design to requirements. It also teaches them how to validate their designs and confirm requirements are met. It is also a requirement for the students to develop a bill of materials and optimize the cost of each item in order to stay in budget. Since inception a few years ago, the EMC Center has sponsored 4 graduate projects, 5 senior design projects and 2 mechanical based projects. Some of these projects are showcased in this paper.

The students that have been sponsored by the EMC Center to complete their projects have gained unique experiences that set them apart from their peers. This was evident when the students began interviewing ahead of their graduation and readily secured engineering jobs in their field of study. A number of students and employers commented during and after the process of seeking employment that the students' skills and experience made them unique and sought after.

2.1 Radiated immunity chamber - Industries that develop and produce electronic products must verify the electromagnetic performance of their product prior to producing and selling it in the market place. The testing used to verify the performance is defined in government regulations such as FCC and CE mark as well as industry specific regulations and standards. The EMC reverberation chamber test is designed to reproduce the test environment as required by the standards.

The purpose of this design project was to take an existing empty reverberation chamber and to design a conductive tuner, a motor interface, as well as a system integration process to build a fully functional chamber for use in pre-compliance testing. The testing would be a radiated immunity capability that can expose electronics to a radio frequency field of up to 200V/m.

The interior of the fully designed and equipped chamber is shown in Fig. 1.

Figure 1: Interior of the reverberation chamber

2.2 Radiated emissions antenna positioner - The purpose of this project was to automate the position of the measurement antennas during EMC radiated emissions testing. The automation fixtures are typically made of non-metallic structures and make use of pneumatic drive to avoid adding unwanted noise to sensitive RF measurements.

The antenna automation fixtures would serve two primary purposes:

1) Setup an automated movement for two different antennas according to the FCC Part 15 emissions testing. The movements include a) a height scan, b) rotating the antennas in two polarizations (horizontal and vertical), c) maintain an antenna angle that keeps it

pointed toward the product under test regardless of the other movements for height scan and polarization change (known as boresight control).

2) Setup an automated movement for two different antennas according to the CISPR 25 radiated emissions testing. The movements include a) shifting the antennas side to side while maintaining a parallel relationship to the product/wire harness being testing. The side to side movement shall target two primary locations: antennas in front of device under test and antennas centered in front of harness, b) rotating the antennas in two polarizations (horizontal and vertical).

The fixtures are to be located inside faraday cages (EMC chambers) and shall be controlled externally by the user. Compressed air was the preferred method to operate the fixtures. Fixtures must have mobility for movement in and out of test chambers.

The final functional positioner is shown in Fig. 2.

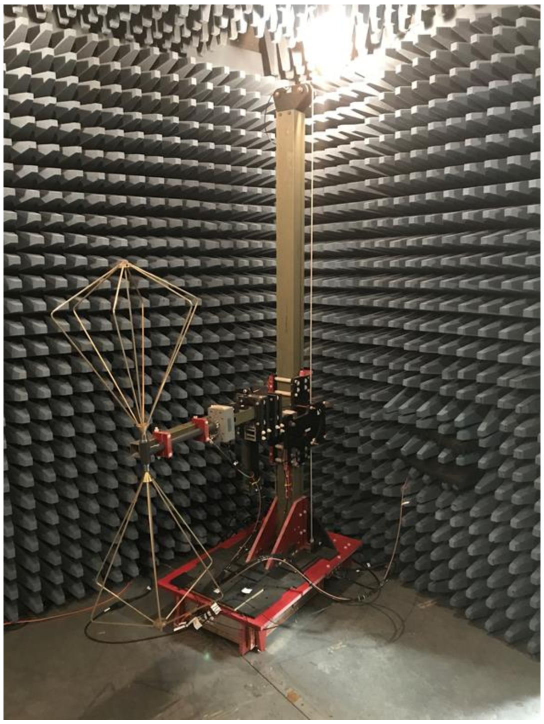

Figure 2: Antenna positioning system

2.3 Near-field emissions scanner - Computer controlled, automated XYZ axis measurement system for electromagnetic interference characterization. This system utilizes an Asymtek 3 axis control fixture. Axis manipulation is executed through RS 232 commands. Actual detection of electromagnetic interference sources is measured with a spectrum analyzer. The Asymtek unit provides the mechanical control for positioning a detection device referred to as a near field sniffer probe. The sniffer probe is indexed across a predetermined area of a device such as a printed circuit board to measure near field emissions. The emissions amplitudes are displayed in a color intensity format to graphical display hotspots of printed circuit boards. An image overlay of the circuit board is required to identify locations of emissions hotspots.

The final functional positioner and its output are shown in Fig. 3

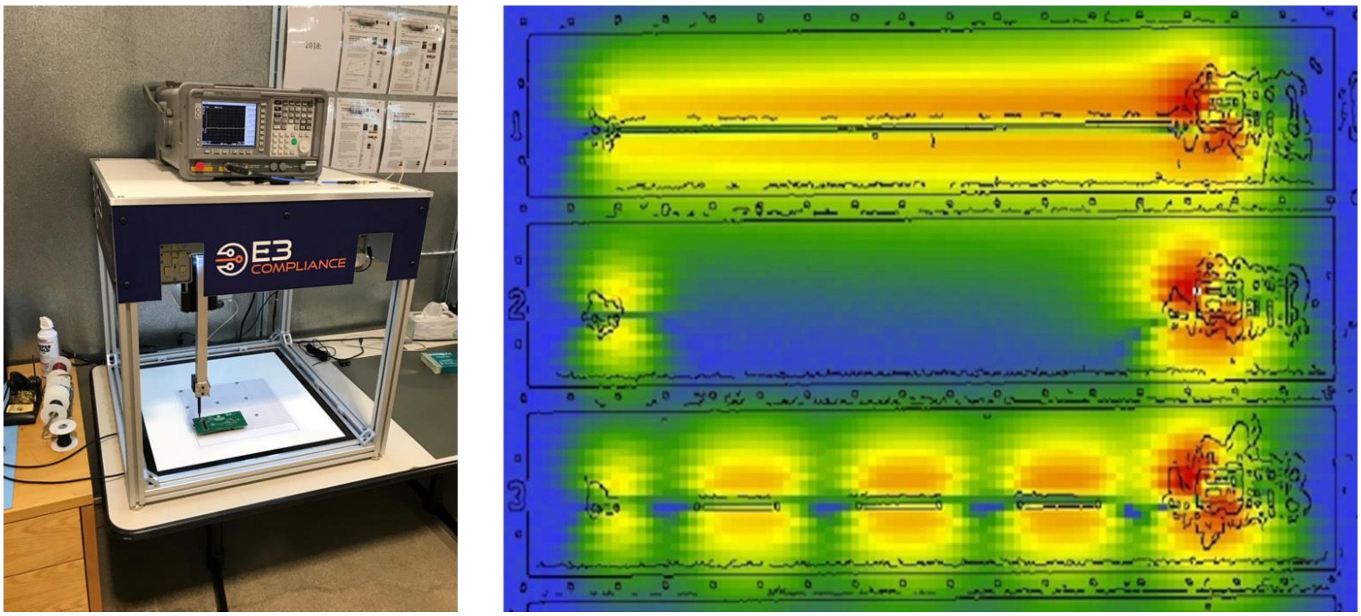

Figure 3: Near-field scanner and its output

2.4 Precision probe manipulators for characterizing high-speed interconnects - Micro probe positioners are designed to place probe tips at test points on PCBs. The PCB test points can be in close proximity to each other and electrical components. With that in mind, the movement of each probe positioner must have fine resolution. In addition, the current design allows for the operator to encounter situations where only one of two probe tips contact the testing surface. The goal of this project is to modify existing probe positioners to provide two additional axis of motion: roll and tilt. With the addition of these two degrees of freedom, the user will be able to ensure all probe tips make contact. In addition, the existing probe positioner will be redesigned to minimize the effects of cable torque and allow for different probe tip attachments.

The designed precision probe manipulators are shown in Fig. 4.

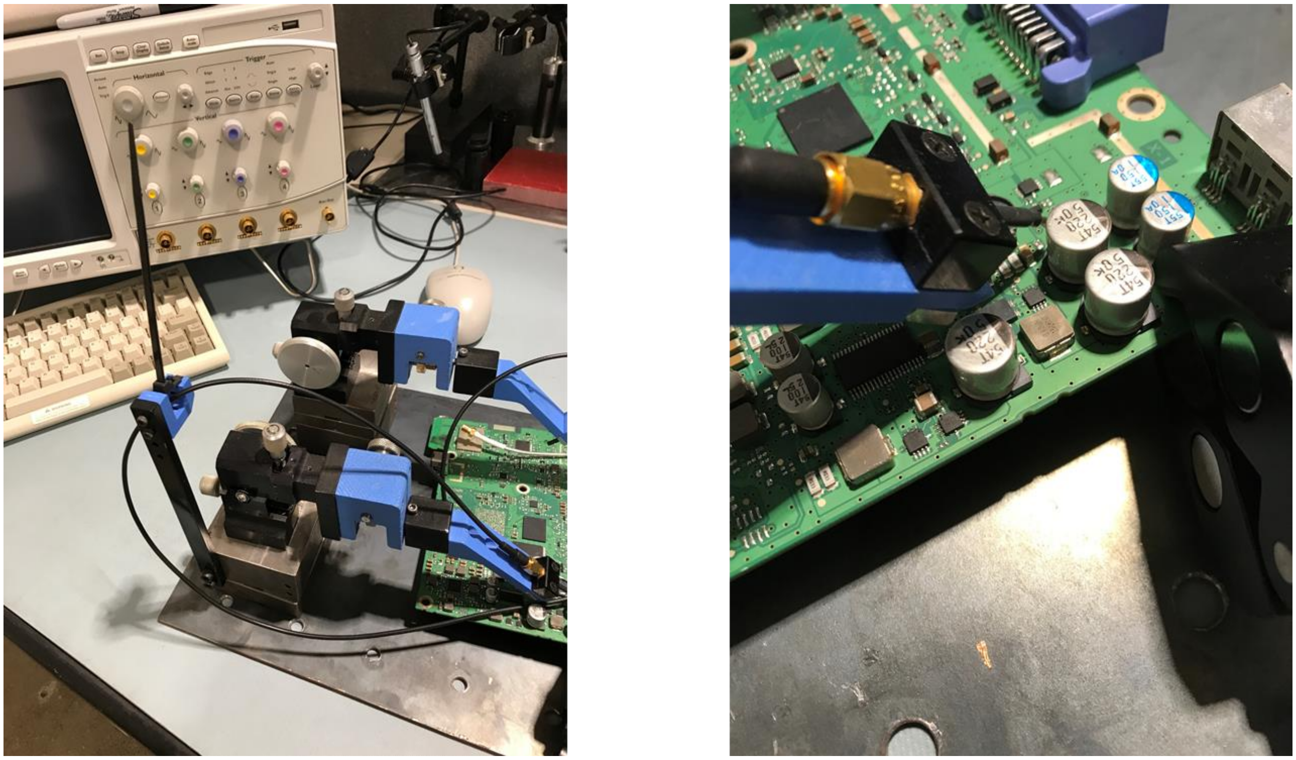

Figure 4: Precision probe manipulators

2.5 Antenna Characterization Turntable is an integrated antenna characterization scanner system that can take measurements of antenna radiation patterns and automatically generate the RF antenna characterization for the industrial sponsor – E3 Compliance. This scanner system is resided in the GVSU EMC Center and can be used for GVSU educational and industrial purposes.

The integrated antenna characterization scanner system is used for capturing RF antenna characterization and measuring radiation transmitting antenna pattern. The design is primarily consisted of an anechoic chamber with absorption foams, a 2 DOF rotary platform, and an installed antenna. EMI test receiver is used for measuring the amplitude of the radiated RF energy and a signal generator can be used optionally as a signal source for igniting either an installed antenna or the antenna under test. Installed antenna can be transmitting and as well as receiving RF signals.

After the equipment is installed, measurements of an AUT (Antenna Under Test) need to be taken by varying the theta and phi rotations in spherical coordinate system while keeping the distance (rho) between AUT and the installed antenna constant.

The designed antenna turntable is shown in Fig. 5.

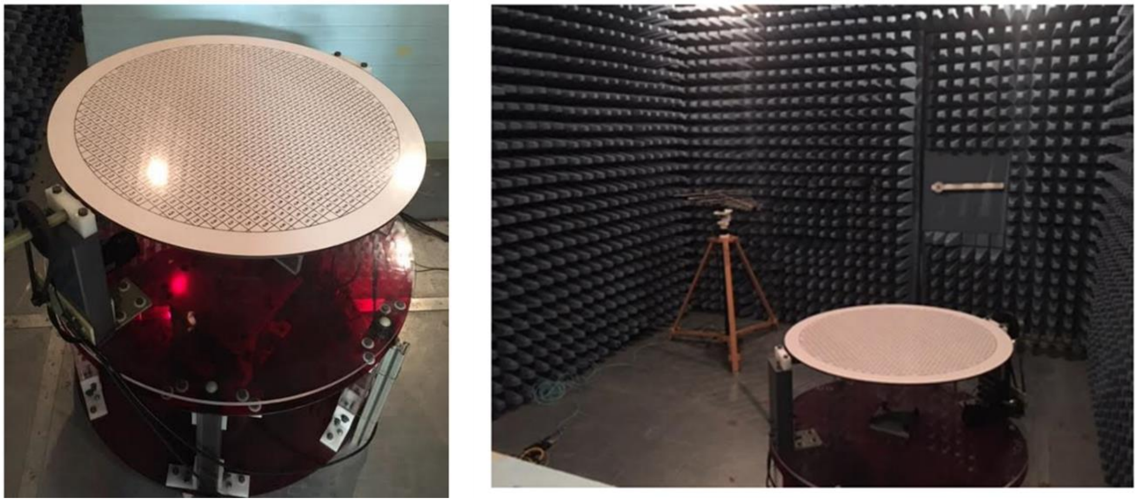

Figure 5: Antenna turntable

Section 3 Graduate Projects

This section describes four recent graduate projects supported by the EMC Center:

- Impact of Decoupling Capacitors,
- Embedded Capacitance and Impedance,
- EMC Filters, and
- Antenna Matching Networks

3.1 Impact of Decoupling Capacitors

This project investigates the impact of decupling capacitors on power distribution network integrity and emissions. Two different placement strategies were investigated using both the four-layer and six-layer boards, shown in Fig. 6.

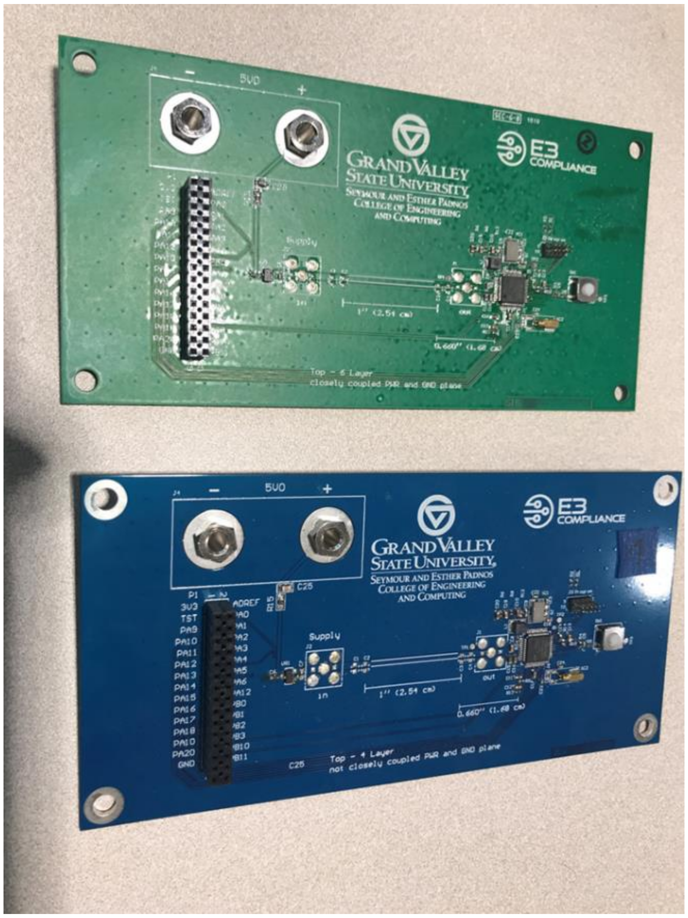

Figure 6: Four- and six-layer boards for decoupling capacitor study

In the first strategy the decoupling capacitors were place near the power and ground pins of the switching IC while in the second strategy, the capacitors were pace in the vicinity (not very close) of the switching device. The four-layer board had power and ground plane not closely spaced, while the six layers geometry provided closely spaced planes. The measurements on both board will be performed in time domain and will serve the purpose of establishing the proper design practices for decoupling capacitor placement.

3.2 Embedded Capacitance and Impedance

This project investigates the impact of embedded capacitance geometries on the power distribution network impedance. Two same two placement strategies were investigated, again using both the four-layer and six-layer boards, shown in Fig. 7.

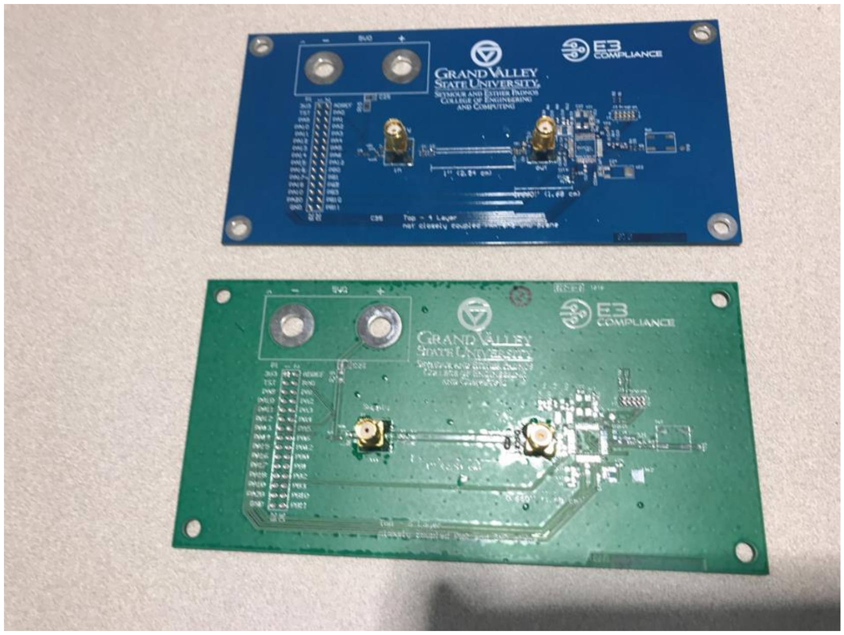

Figure 7: Four- and six-layer boards for impedance study

This time the measurements were performed in frequency domain and illustrated the impact of capacitor placement and board geometry on the impedance curves.

3.3 EMC Filters

In this project several EMC filter topologies are investigated and their performance is characterized through a network analyzer measurements. PCB designed for this study is shown in Fig. 8.

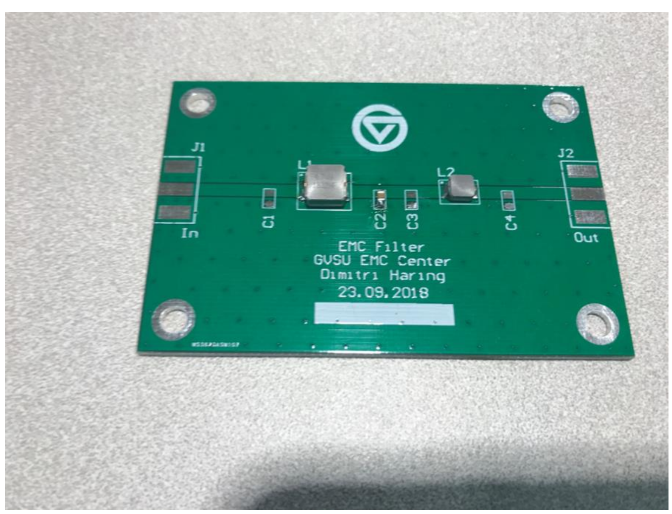

Figure 8: PCB for EMC filter study

The board could be populated to result in a low-pass single element filter (L or C), second order filters (LC or CL), or a third order PI or T filters. The filter performance is evaluated with different source and load impedances to determine the optimal filter configuration for a particular application.

3.4 Antenna matching networks

This project focuses on the design of a LC, Pi, and T antenna matching network. The log-periodic antenna used in this project is shown in Fig. 9.

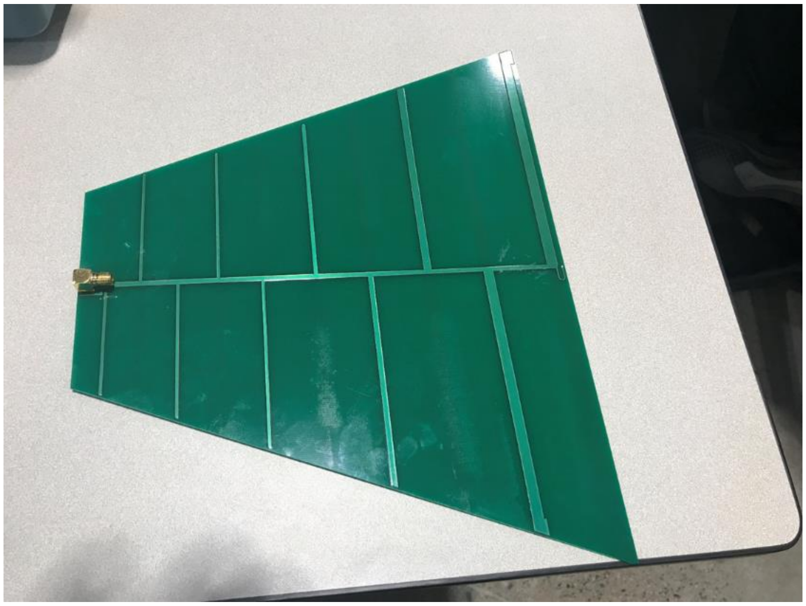

Figure 9: PCB log-periodic antenna

The object of this study is to select the best matching network at achieve an antenna resonance at a specified frequency. The study makes an extensive use of the Smith chart technique to make the design process easier while at the same time showing the practical application of the Smith chart approach.

Section 4 - Co-op Student Involvement

One of the primary missions of the EMC Center is to engage students in learning about EMC aspects of product design and testing. Each year the EMC Center employs 2 co-op students each of the 3 semesters (Winter, Summer, Fall). They spend three rotations that are each 3 months long over the course of their cooperative experience. They start out by learning EMC fundamentals of equipment like spectrum analyzers, vector network analyzers, oscilloscopes, signal generators, couplers, power meters, sensors and antennas. Students spend time measuring EMC phenomena of electronic devices from industry according to governmental and industry specific standards. Through the process of testing, they gain knowledge and experience on the technology built into the products and how to evaluate product performance with monitoring tools. In addition to testing, the students also maintain lab equipment, build new test capability and improve the automation test software used for testing.

During the students' 2^{nd} and 3^{rd} rotations they get involved in more advanced EMC topics. They include EMC design reviews, modeling & simulations and constructing new antennas and test fixtures. Design reviews help the students understand how to take an existing circuit that is designed to achieve product functionality and protect it from EMC/EMI issues. They learn during modeling and simulation projects how to construct physical and electrical models that can be used to understand and predict EMC issues. When building new antennas and test fixtures they learn how to build lab equipment that can perform as intended in specifications during EMC/EMI exposure.

While the students are exposed to and learn a great deal about industry knowledge, it is important to note that any student that is engaged at the EMC Center is under a non-disclosure agreement as well. This ensures protection of any industry intellectual property that may be disclosed in the course of doing business.

Section 5 - Testing and Product Development Support

The EMC Center provides a number of services to industry that fall into different parts of a product development life-cycle. Early engagement provides the best value and prevents EMC issues further down the road. The engagement starts with a concept or architectural review to identify flaws that may lead to a product's inability to meet EMC requirements. We answer questions like: 1) does the enclosure protect from electrostatic discharge, 2) do the cables have appropriate ground wiring and connections, 3) does the printed circuit board have enough layers, etc… Then we move on to a detailed schematic and PCB layout review. During these reviews each component and connection are examined in 3D to understand what improvements can be made to meet the target EMC requirements. Most products that fail EMC requirements have either a flaw in the schematic or layout design that could have been prevented from an experienced person reviewing the design.

After the prototype design has been reviewed and updated, typically the first prototypes are then tested in the key EMC risk areas. The risk areas are identified through a combination of EMC requirements, product technology and the limitations or compromises resulting in the actual released design. The risk areas drive which tests are performed and to what level they are performed. Typically, within one to two weeks of testing, the design flaws are identified where

EMC performance does not meet the intended requirements. The EMC Center then engages to identify the root cause(s) linked to the EMC performance issues and design improvements are identified and re-tested in the EMC Chambers.

The goal if testing, finding root-cause, improving issues and re-testing is to ensure that when the prototype design is updated, it has a high confidence of passing compliance testing. The EMC Center uses a combination of design reviews, simulation and pre-compliance testing to address all of the risk areas and ensure a high confidence product design. This allows clients of the EMC Center to introduce their product into the market place on-time or ahead of schedule without the impact of unforeseen failures in EMC testing and not meeting regulations.

Section 6 – Summary and Conclusions

This paper described several outcomes of the industry academia collaboration supported by the GVSU EMC Center. This collaboration has a positive impact on the content of the junior, senior and graduate level EMC courses, as well as the senior and graduate design projects. In addition to student projects, the EMC Center employs co-op students who are involved in running simulations and testing electronic products. The EMC Center also provides product design support and testing for industry.

As for student impact, they leave with a deeper understanding of electromagnetic compatibility that will enhance their career no matter what role in electrical engineering they choose. Their experience in the EMC Center will help them recognize, diagnose and resolve radio interference issues that occur at all stages of electronic product development. This is a unique skillset provided by this collaborative relationship.

In the past few years, since the inception of the GVSU E3 Compliance educational collaboration, two students have been hired by E3 Compliance and one student has been hired by an industrial client of the EMC Center. In that same time, a number of other students have graduated and become employed as electrical engineers in the automotive, aerospace, medical and consumer electronics industries. They have provided feedback that the exposure and training on EMC they received while studying at GVSU helped them successfully anticipate EMC requirements. This provides a tangible benefit to their employers as they design products with EMC in mind and prevent unneeded circuit board design iterations. Some of the engineers who first learned about EMC at GVSU have returned as clients to get assistance in addressing challenging EMC problems with new technology and became clients of the EMC Center. These trends are growing with each passing year and are expected to have a greater impact over time. Especially as students' exposure to EMC at the University continues to expand and a great number of manufacturers become equipped with engineers knowledgeable about EMC.

References

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