A Brief History of EMC Education

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Abstract — **This paper provides a brief review of events that have had an impact on EMC education, primarily in the U.S. and Europe. The authors are continuing to collect information on this topic and invite contributions. We are particularly interested in obtaining more information on the history of EMC education in Asia and other parts of the world.**

I. Introduction

Electromagnetic compatibility problems date back to the days when mankind first learned to generate and use electricity. The earliest power generation plants were susceptible to lightning, the earliest electric appliances had to deal with power line disturbances and even the telegraph was not immune to crosstalk. With the invention of the telephone, electrical noise suppression took on a new level of importance. Engineers in the telephone industry began to study sources of noise and noise coupling mechanisms. Special components and circuits were developed to attenuate crosstalk and protect against transients. Around the turn of the century, when Marconi demonstrated his "wireless telegraph", a whole new class of electromagnetic compatibility problems was introduced. Radio technology made it possible for electronic devices to interfere with each other even when they were located miles apart.

The earliest wireless telegraphs were broadband devices making it difficult to pick up a clear signal if there were more than one transmitter operating within range of the receiver. The introduction of the vacuum tube oscillator in 1912, made narrow-band radio communications possible and greatly reduced instances of unintentional interference between radio transmitters. However, narrow-band radio transmitters enabled the transmission of voice communication resulting in the proliferation of commercial radio stations. Commercial radio stations generated revenue, which fueled the rapid development of radio technology and also, predictably, the first widespread examples of a new phenomenon known as "intentional electromagnetic interference".

As more commercial radio stations began to appear in populated areas, the competition for listeners became fierce. One way to increase market share was to improve the content of radio broadcasts. Another way was to transmit a strong RF signal to block reception of a competitor's broadcast.

As this phenomenon became more common, different countries established entities to regulate intentional radio frequency transmissions. In Europe, CISPR was established in 1933 and in the U.S., the Federal Communications Commission was established in 1934.

World War II encouraged the rapid development of RF and microwave technology. Radio communications and both intentional and unintentional radio frequency interference played a major role in the war. After the war, military organizations around the world recognized the importance of measuring, analyzing and preventing potential electromagnetic compatibility problems. Test procedures and standards were developed for evaluating the ability of military hardware to operate in harsh electromagnetic environments including a relatively new threat called Nuclear Electromagnetic Pulse (NEMP). Driven primarily by the needs of the military, a new engineering specialization was born as many engineers began devoting more and more of their time to diagnosing, solving or preventing electromagnetic compatibility problems.

In the 1960s and 1970s as electric and electronic devices proliferated, EMC became more of a factor in the design of new products. Nevertheless, most of the engineers who specialized in EMC were still working on military problems. This changed rather suddenly in the 1980s however as governments began introducing EMC requirements for commercial products. As the number of EMC engineers grew, so did the demand for EMC education.

II. Conferences

Perhaps the first conferences devoted to EMC were a series of conferences held at the Armour Research Foundation between 1954 and 1957 sponsored by the U.S. military. This successful series set the stage for a group of engineers interested in EMC to petition the *Institute of Radio Engineers* (IRE) to establish a *Professional Group on Radio Frequency Interference* (PGRFI). The PGRFI, which later evolved to become the IEEE EMC Society, has been holding annual conferences devoted to EMC ever since.

In 1972, an EMC Conference was organized at the Wrocław University of Technology, in Wroclaw, Poland. The conference was held again in 1976 and biannually ever since. In 1975, Prof. T. J. Dvorak and colleagues at

the Swiss Federal Institute of Technology organized a conference on EMC in Montreux. This bi-annual conference eventually became known as EMC Zurich and is currently in its 16th edition. In 1994, Prof. Marcello D'Amore and his colleagues at the University of Rome, La Sapienza organized a conference known as EMC ROMA. This conference was held again in 1996 and 1998 before moving to Brugge, Belgium and being renamed EMC EUROPE. The first national German congress on EMC was in Karlsruhe 1988 (EMV'88), held in German language.

A primary goal of these conferences has been the exchange of information relevant to EMC engineers. In addition to regular technical sessions devoted to the presentation of new information, the conferences above also feature workshops and sessions dedicated to the presentation of tutorial information for engineers that are new to the field.

III. SHORT COURSES

Most electrical engineers receive little or no EMC training as university students. Therefore, many of them rely on short courses to supplement the knowledge they obtain from technical presentations, publications and experience. Although short courses and seminars on EMC-related topics were offered by various individuals in the 1960s and 1970s, the short course business increased sharply in the 1980s after the FCC began regulating unintentional radiated emissions.

Early pioneers in the short course business included Don White (Don White Consultants) and Ken Keenan (The Keenan Corporation). Don White's business grew to a point where he employed several instructors with individual specialties who traveled the world teaching EMC. Some of the instructors who worked for Don White Consultants included Bill Duff, Dick Ford and Michel Mardiguian. Don White Consultants published a trade magazine for EMC engineers called *EMC Technology and Interference Control News*. They also published a popular series of handbooks on various EMC-related topics and sponsored an EMC conference/exhibition.

Henry Ott was teaching an out-of-hours EMC course to his colleagues at Bell Laboratories in the early 1970s. In 1976, he published a book titled *Noise Reduction Techniques in Electronic Systems* that quickly became a popular resource for EMC engineers. A second edition was published in 1988. Towards the end of his career at AT&T Bell Labs, he formed Henry Ott Consultants and took his short course business on the road. Today, nearly twenty years later, Henry's courses and his book continue to be useful resources for new EMC engineers.

Another popular EMC short course instructor in the mid-1980s was Tom Van Doren, a professor at the University of Missouri-Rolla (UMR), who had developed an interest in EMC while working on various EMC-related problems for the military. Tom began teaching short courses independently in 1983 and then through the UMR department of continuing education a few years later.

Although it is not possible to cite all of the people who developed EMC short courses and educational materials during the 1980s and 1990s, some of the major contributors that haven't already been mentioned include; Bernhard Keiser, Al Smith, Fred Tesche, Bill Kimmel, and Daryl Gerke.

IV. UNIVERSITY COURSES

During our initial queries, we were made aware of courses with significant EMC content at the Uppsala University (Sweden), the Politecnico di Torino (Italy) and the Federal Armed Forces University in Hamburg (Germany) dating back to the 1970s. However, the first well documented university course dedicated to EMC that we were able to find was a course offered at the University of York in Great Britain [1]. This course has been offered by Professor Andy Marvin and his colleagues at York since 1982. In 1985, Prof. Marvin was traveled to Concordia University in Montreal, Canada for an extended visit with Prof. Stanley J. Kubina. There Prof. Marvin taught a course titled *Techniques in EMC* [2]. Concordia University has continued to offer EMC courses ever since, including an electromagnetics course in EMC applications for computer engineering students [3].

Also in 1985, Prof. Tom Van Doren offered the first EMC course at the University of Missouri-Rolla. The course was titled *Grounding and Shielding*, because Tom was concerned that any course with the term "electromagnetic" in its name was not likely to draw many students. Grounding and Shielding is still offered at UMR and with ~50 students per year, it is one of the most popular senior technical electives in the electrical engineering department.

Other universities offering EMC courses in the 1980s included the Swiss Federal Institute of Technology (both Lausanne and Zurich, Switzerland), the Technical University at Eindhoven (Netherlands), The Royal Institute of Technology (Sweden), the University of Florence (Italy), the Technical University of Turin (Italy), the University of Cassino (Italy), the University of Rome "La Sapienza" (Italy), the Royal Melbourne Institute of Technology (Australia), North Carolina State University (USA), the University of Kansas (USA), the University of California-Berkeley (USA), Florida Atlantic University (USA) and the University of Kentucky (USA). Professor Clayton R. Paul, at the University of Kentucky, had obtained a considerable amount of experience in EMC working with companies such as Ford Motor Company and IBM. In 1986, he introduced an EMC course that included a project, where students built a device that transmitted a 10-MHz signal over a three-foot ribbon cable. Students then measured the conducted and radiated emissions from these devices.

Bench top measurements were made at the university and radiated measurements were made at a local IBM facility with the help of Don Bush and his colleagues at IBM.

At the time, Henry Ott and Clayton Paul were both members of the IEEE EMC Society Education Committee. Henry Ott chaired this committee until 1988 and Clayton Paul chaired the committee from 1989 to 1992. The committee was very interested in promoting EMC education at the university level and was looking for ways to promote the development of courses at more universities. One of the projects that they coordinated was the development of a manual describing 11 simple experiments that could be used as demonstrations or laboratory exercises in a university course. In 1990, Clayton Paul published a paper titled "Establishment of a University Course in Electromagnetic Compatibility (EMC)" in the *IEEE Transactions on Education* that provided detailed information for faculty who were considering developing their own EMC course [4]. Two years later, Dr. Paul published a book titled *Introduction to Electromagnetic Compatibility* [5]. This was the first EMC book that was specifically written to be a text for a university course.

Many of the existing university EMC courses adopted Dr. Paul's book and the availability of the book helped to encourage the development of new courses. Don Weiner at Syracuse University was one of the people who reviewed the manuscript for this text. He credits Clayton Paul's 1990 paper and the manuscript as being the impetus for their first EMC course, which was offered the year that Dr. Paul's book was released [6].

Other universities that established EMC courses in the 1990s include the universities at Ancona, Bari, Bologna, Naples, Pavia, and Vercelli in Italy; the universities at Berlin, Dortmund, Dresden, Hamburg-Harburg, Hannover, Karlsruhe, Magdeburg, Munich, Paderborn, and Stuttgart in Germany; the Technical University at Delfte (Netherlands); University of Twente (Netherlands); Universitat Politècnica de Catalunya (Spain); Universidad Politécnica de Madrid (Spain); Universidad Politecnica de Valencia (Spain); Universidad de Sevilla (Spain); the University of Toronto (Canada); Washington State University (USA); North Dakota State University (USA) and San Francisco State University (USA). The course at San Francisco State was established by Prof. Zorica Pantic-Tanner with some financial support from the Santa Clara Valley Chapter of the IEEE EMC Society. This program was so successful that the chapter brought a proposal to the IEEE EMC Society to establish a mechanism for providing financial incentives for faculty to establish EMC courses at universities. This effort evolved into the University Grant program, which annually awards a specified amount to a deserving faculty member for the purpose of establishing a new university EMC course. Universities that have developed EMC courses with the help of the University Grant program are listed below:

1997- Northern Illinois University
1998- University of Nevada-Reno
1999- University of Michigan-Dearborn
2000- University of L'Aquila, Italy
2001- Utah State University
2002- Clemson University
2003- The Citadel.

V. What we have missed

The information above was collected by the authors from literature searches and questionnaires distributed by email. We realize that there are many universities and individuals that we have neglected to mention and we apologize in advance for the omissions. We are continuing to compile historical information for a future publication. If you have information related to the history of EMC education that you would like to contribute, we are very interested in hearing from you. Information can be provided by responding to a web-based survey accessible at accessible at http://dau.ing.univaq.it/art/.

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