Experiences and the History of Generating IEEE EMC Society Standards

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Abstract—This paper reviews the many facets of developing IEEE EMC Society standards from the first one on record in 1950, before the Society was founded, to the ones that have launched new technology and a whole array of volunteers who are now involved beyond the handful involved over 50 years ago. The experiences in the past 50 or so years have been challenging and in some cases momentous, continuing a rich tradition of standards activity on electromagnetic compatibility.

Index Terms—Electromagnetic compatibility, standards, standards study questions

I. INTRODUCTION

Industry, academia, and those simply interested in standardizing key concepts and principles of EMC have used EMC standards. While the focus for years has been on test instrumentation and measurement techniques, in recent years the focus has been expanded to include spectrum usage and intersystem compatibility. There have been papers published in the recent past on various stages of the EMC Society and other standards developer-sponsored standards [1], [2], and [3]. This paper focuses only on the EMC Society standards history.

The author got involved in the work of the standards committees in the late 1970's. At that time, there were only a little over a half dozen standards that were developed. The chairman of the EMC Society Standards Committee at that time was Bud Taggart of NBS (long before the name change to NIST). He had kept after the developers to maintain the few EMC standards, but it was not easy even then to get volunteers. I vividly recall his telling me as I took over the chairmanship in 1983 that it was as difficult as "pulling hen's teeth" to get activity going. Maybe I was too eager to help that not only did I take over the chairmanship, but had it for the next 17 years until I relinquished it to the present chair, Stephen Berger, in 2000. What happened in my years of work closely follows the standards development of updating the old standards and introducing new ones described below. I want to thank the many volunteers who worked on the standards development. The names are fortunately retained in the forewords of the EMC Society standards for all to see and to give our thanks for their efforts.

II. History of EMC Standards Developed by the EMC Society

For over 50 years, there have been EMC standards associated with the IEEE, even before the IEEE was established in 1963.

Table 1 summarizes the standards activity of the EMC Society that is now further elaborated [1]. Earliest records show that the first EMC standard, which became the responsibility of the IEEE EMC Society, was IEEE Standard 140, which was released in 1950. The subject was a Recommended Practice for minimization of interference from radio-frequency heating equipment. This document recommended ways to minimize emissions from RF heating equipment by providing procedures to be used when interference is encountered, locating the sources of the interference and then applying corrective measures such as source frequency shifting, automatic frequency control, and improving source shielding including tightening of shielding fasteners around the heating equipment doors. This landmark standard was so useful that it was in place for 40 years before it needed updating, leading to the next edition in 1990. The chair of this work was Jim Maw and the secretary was Stephen Berger. There were eight members of the working group which many might remember as it included a future EMC Society president, Gene Knowles.

In 1952, a companion Recommended Practice was published as Standard 139 on in-situ measurements of RF from industrial, scientific and medical equipment. This was a continuation of the work in IEEE Standard 140, but more specifically addressed in-situ measurements of the emissions from the ISM equipment on the user's premises. It includes the effects of nearby RF sources for which its emissions may interact with the ISM emissions to create harmonically related spurious frequencies. The working group chair was Dan Weinberg and six others, which included another future EMC Society president, Ed Bronaugh.

In 1951, there was concern for determining the interference potential of spurious emissions from FM and TV broadcasting receivers creating interference. These sources included local oscillator circuits, intermediate frequency amplifiers, oscillators associated with cathode-ray-tube operation, TV sweep circuits, etc. IEEE Standard 187 provided a way to measure these spurious emissions at an open field test site. This standard also withstood the test of time, as it was not revised until 1990. There was urgency for this standard and surprisingly we were asked by the IEEE EMC Society Chapter in Tokyo to undertake this revision. Dr. Risaburo Sato chaired the working group with 10 members, eight of whom were from the Tokyo Chapter. The work was so focused that the revision was done in less than three months; clearly, this was a record as no other standard revision has taken so short a period before then and after then.

By 1961, there was a need to have a common repeatable way to measure conducted emissions into the power line from the same FM and TV broadcasting receivers. This lead to IEEE Standard 213 which provided the measurement procedure in the frequency range 300 kHz to 25 MHz using a Line Impedance Stabilization Network (LISN) with a 5 uH, 50 ohm system. A companion standard containing the construction details for this LISN was published the same year as IEEE Standard 214. By 1987, both standards were included in the revised IEEE Standard 213. That work was chaired by Mike Hart and had 13 members and by that time, the author was the chairman of the standards committee itself.

In 1969, there was a significant standard introduced. It was Standard 299, which provided a method for measuring the effectiveness of large electromagnetic shielded enclosures. The applicable frequency range was 14 kHz to 18 GHz, but included suggestions to extend the range down to 50 Hz and up to 100 GHz. This standard had more applicability than MIL STD 285, which had been the referenced standard for military use for years. For example, IEEE Standard 299 introduced the use of a test plan prior to starting the effectiveness measurements. It also provided guidance on frequencies to test other than those at the lowest natural resonant frequency of the enclosure. The working group chair was split between Gene Knowles, who chaired the group after April 1988, and Richard Schulz (past editor of the EMC Transactions, including the 25th anniversary edition in 1982) prior to April 1988. Their joint effort led to the group comprised of eight members who published the next revision in 1991.

Going into the 1970's, the EMC Society standards committee started work on other EMC measurement standards in particular. At the end of 1974 and into 1975, the next standard developed by the IEEE EMC Society dealt with the use of an impulse generator to calibrate automatic spectrum scanning instrumentation of the day. Interestingly, the use of impulse bandwidth, the subject of IEEE Standard 376, even today is being accepted for calibration of spectrum analyzers. So, this ground breaking standard drafted over a quarter of a century ago is still of interest even today. The working group chair for the inaugural edition of this standard was Dr. Ralph Showers who led a group of five members, including the standards committee chair, Bud Taggart.

In 1971, work began with the IEEE Vehicular Society (then called Group as was the EMC Society), the Electronics Industries Association (now an Alliance), and the IEC to establish a standard to measure the spurious emissions from land-mobile communication transmitters primarily in the 25 MHz to 1000 MHz band. This work was published in 1980 as Standard 377. The chairman of the working group, which at the time was called Subcommittee 27.7, was John Neubauer. The subcommittee had four members including a past president of the EMC Society, Dr. Ralph Showers.

In 1985, the EMC Society standards committee published a Recommended Practice for site survey measurements in the range of 10 kHz to 10 GHz. This document was published as Recommended Practice 473. This Recommended Practice introduced one of the first approaches to measuring RF ambient inside buildings as well as in obstruction free areas outside. The chair of the working group was Ed Skomal who had seven people in his group. It is also interesting to note that one of the members was Al Smith, who contributed his expertise based mainly on his work in radiated emission test site validation following his landmark work on the use of normalized site attenuation (NSA) for open area test site validation. The standard was reaffirmed in 1991. Work is now underway on the next edition of the document.

In 1983, the work shifted to developing measurement procedures for field disturbance sensors and RF intrusion alarms as IEEE Standard 475. The radiated emission procedures covered the range of 300 MHz to 40 GHz while the power line conducted emission procedures addressed the 30 to 300 MHz range. Ralph Taylor chaired the project. The standard was revised in 1994 and is still being applied today.

The 1990's produced the next EMC Society standard that addressed simpler measurements of electric and magnetic emissions from video display units in the frequency range 5 Hz to 400 kHz. The chair of the 14 member working group was Dheena Moongilan. This IEEE Standard 1140 published in

1994 was similar to one published in Sweden at the time, but used a lesser set of measurement points [4]. This generated the first real contentious issues as there was at the time scares that a person sitting in front of a CRT (cathode ray tube) would be adversely affected health-wise from these fields. This got the attention of the US Food and Drug Administration and in particular the manufacturers of PC monitors for obvious reasons. A rash of challenges to the work ensued with many wanting to contribute their "view" to the way the measurements were to be made and why the lessening of the number of measurement points was justified. From the author's perspective, this was an indication of the importance of these types of standards to government regulators in the US and to manufacturers of PC monitors in particular. We needed this "wake up call" to improve our process to get more inputs beyond that of our EMC Society committee and limited other volunteers from our Society. The standard remains active and was reaffirmed in 1999 with no changes.

In 1996, the first IEEE standard on calibrations of field probes, excluding antennas, in the frequency range 9 kHz to 40 GHz was published as IEEE Standard 1309. It included the use of TEM cells, Helmholtz coils, open-ended waveguides, pyramidal horns and other techniques for generating the calibration field. In 1998, the first guide to address the RF characteristics of conductive gaskets in the frequency range DC to 18 GHz was published as IEEE Standard 1302. It contained several techniques and provided a guide to selecting the best method depending upon the application. John Kraemer chaired this working group of 21 members. The standard was updated in 2005 to include measurement uncertainty and additional technical background.

In 1998, the first guide to characterize the RF characteristics of conductive gaskets in the frequency range DC to 18 GHz was published as Guide 1302. This work was started before 1996 and hence has a lower number than standard 1309. By this time, the standards work of the Society was becoming much more active as is shown with the large number of working group members on the standard 1309 work as well as this work in that there were 30 members on the working group including the chair, Hugh Denny. Working group members included companies producing conductive gasket as one might expect. It was interesting to see how each of the manufacturers viewed the work as each used different techniques in formulating their specification sheets. The document contained several techniques including classical transfer impedance and provided guidance on selecting the best method depending upon the application.

In 1998, work started on a recommended practice on test fixtures to determine the shielding characteristics of connectors and cabling, i.e. P1530. The work did not mature enough to be published and hence was terminated by the IEEE Standards Board in 2002 after the EMC Society Standards Development Committee agreed to that action. The work may be revisited in the future if there is any interest in reactivating the project.

Starting in about 2000, there was a new round of standards activity. The first to be published in 2005 was standard 1560. This brought out the need for measuring RF filter performance not in matched loads or at low frequencies, but instead as the filter would be used by the end user. This was an improvement over existing filter performance specifications, such as MIL-STD-220B [5], which used the match load approach that is not likely in an actual installation of the filter. The discussion that led to this work was very interesting. The example given needing this in-situ characterization was that associated with filters installed in large shopping centers. These filters had high currents and power loads, which was different than the "normal" use. Kermit Phipps chaired the working group. The group had 25 members and continues to show a large turnout for the Society's standards activity. In addition, it had a graphics designer to make the figures easier to read and use in the future. Talk about going high tech!

The other projects, which are contained in Table 1, are preceded by the letter "P" which shows that these are still projects and not yet published standards. Since they will provide an introduction to our future standards history, we now will provide a short summary of the work with the name of the project leader or chair of the working group. For those interested in seeing how these projects are posted on the IEEE Standards Association web site, use the following URL: www.standards.org. Click on "enter here" under "Standards Development". Under "Standards Projects" click on "Listing of projects since 1998". That page will have the listing of projects. Using the project number in Table 1, scroll to the number of interest and click on it to gain further information including the scope and purpose as well as the chair of the working group of record.

Following is a summary of the present standards activity as of the start of 2007 for all projects in Table 1 starting with P1597, which was initiated in 2001. Here we enter into a new area of EMC Society standardization work away from the historical measurement procedure activities and into the world of electromagnetic computations and modeling. The work is divided into two parts with the numbers assigned as P1597.1 and P1597.2. Both of these projects are chaired by our current EMC Society President, Andy Drozd, and have considerable membership from organizations that are dealing with computational electromagnetic (CEM) code. P1571 is a standard to validate the CEM application models as concerns persist that there are no well-defined methodologies to achieve code to code or simulation to measurement validation with a consistent level of accuracy. P1597.2 on the other hand is to aid modelers and analysts in the selection and application of appropriate modeling and simulation methodologies, etc.

P1642 was initiated in 2002. Here again the activity of the EMC Society standards work moved into new territory with a recommended practice that will provide users of computers with guidance on threat levels (levels of interference that is extraordinarily high), protection methods (mitigation or immunity guidance), monitoring of the interference levels and finally testing the computers for its immunity to the high levels of RFI. In this day of such potential threats, the need for such recommendations is apparent. Bill Radasky is the chair of this working group (Bill is also chair of EMC Society Technical Committee 5 on high power electromagnetics; this is a most appropriate background for this work). A companion recommended practice is P1643, which also was started in 2002. It covers virtually the same scope of P1642 except it is focused on electronic voting machines, not computers. This in fact is a highly sensitive area as not having a voting system that is robust against EMI threats is not acceptable. Bill Radasky also chairs this working group.

In 2005, P1688 was initiated. The purpose of this project is to provide EMI test levels and test methods at the replaceable electronic module of a larger system to assess or qualify that such modules meet applicable emission limits and immunity protection

levels and that they in turn will keep the overall host system under test in compliance with regulatory limits and customer required immunity levels. Any design change of a module can thus be tested for acceptance for use in a system without the need for performing a costly system level test. The discussion of predicting system level EMC compliance with module level test results led to many discussions in the standards development committee as this has been attempted before even using modeling techniques. In the end, it was felt that this work if successful will be a major contribution to our discipline and hence the work is progressing at a rather fast pace. Fred Heather is the chair of the working group.

In early 2005, and carrying over into the last quarter of 2006, a new challenge emerged for the EMC Society standards development committee as well as for the Society as a whole. This was the major effort to extend the usage of the radio spectrum using a variety of techniques centered on the use of software or policy defined processing of information on the transmission path. Part of this activity is to ensure that EMC also includes spectrum management. There were those when this subject came up that did not believe that the scope of our Society should include spectrum management. But a review of the latest version of the scope indeed does include this and hence those arguments against getting into spectrum management issues have been answered. So with that as a preface, following is the latest exciting spectrum usage activity in which the Society's standards development committee is now involved. Further, since the issues cross over into the scope of the IEEE Communications Society, you will see that the EMC Society is a co-sponsor on the four standards projects starting with P1900.1. That standard provides the basic building blocks for the other three in the P1900 series. It provides terms and definitions that clarify what is meant by the key words such as software defined radio, policy defined radio, adaptive radio, cognitive radio and so on. These technologies cannot flourish if the terms used are not understood and hence the importance of this particular standard. Next comes P1900.2, which is a recommended practice that provides guidance for the analysis of coexistence, and interference between various radio services in order to produce spectral efficiency, i.e. more and better use of the spectrum. P1900.3 moved on to the use of mathematical concepts and methods to assure compliance with established requirements for spectrum use stemming from the types of defined radio methods noted above. This recommended practice would then provide guidance for the validity analysis of proposed software defined radio (SDR) software prior to programming and activation of an SDR terminal or SDR components. Finally, P1900.4 which is was approved as a project in late 2006 gets into recommending ways of defining appropriate system architecture and protocols which will facilitate the optimization of radio resource usage, in particular, by exploiting information exchanged between network and mobile terminals, whether or not they support multiple simultaneous links and dynamic spectrum access. There is a significant amount of work on all these standards in this new technology challenge for our Society. The doors are open to those who want to participate, as more volunteers are needed on the various projects. The EMC co-sponsor point of contact for this work is Steve Berger who is the chairman of the EMC Society Standards Development Committee.

Table 1 summarizes the status as of January 2007 of each of the standards that have been addressed in this paper.

Note: P indicates a project is underway and is not yet a standard or recommended practice.

There were many more clarifications that can be further summarized in reference [3].

Table 1: IEEE EMC Society Standards

139-1988 Recommended Practice	Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises
187-2003 Standard	Radio Receivers: Open Field Method of Measurement of Spurious Radiation from FM and Television Broadcast Receivers
213-1987 (R1993, 1998) Standard	Measuring Conducted Emissions in the Range of 300 kHz to 25 MHz from Television and FM Broadcast Receivers to Power Lines
299-1997 Standard	Measuring the Effectiveness of the Electromagnetic Shielding Enclosure
377-1980 (R1991, 2003) Recommended Practice	Measurement of Spurious Emission from Land-Mobile Communication Transmitters
473-1985(R1991) Recommended Practice	Electromagnetic Site Survey (10 kHz to 10 GHz)
475-2000 Standard	Measurement Procedure for Field-Disturbance Sensors, 300 MHz to 40 GHz
1140-1994 (R1999) Standard	Test Procedures for the Measurement of Electric and Magnetic Fields from Video Display Terminals (VDTs) from 5 Hz to 400 kHz
1302-1998 Guide	Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz
1309-1996 Standard	Calibration of Electromagnetic Field Sensors and Probes Excluding Antennas from 9 kHz to 40 GHz
P1530 Recommended Practice	Design and Construction of Calibration Artifacts for Cable and Connector Shielding Test Fixtures for Frequencies from 1 Hz to 10 GHz
P1560 Standard	Methods of Measurement of Radio Frequency Interference Filter Suppression Capability in the Range of 100 Hz to 40 GHz
P1597.1 Standard	Validation of Computational Electromagnetics (CEM) Computer Modeling and Simulation
IEEE P1597.2 Recommended Practice	Computational Electromagnetics (CEM) Computer Modeling and Simulation Applications
IEEE P1642 Recommended Practice	Protecting Public Accessible Computer Systems from Intentional EMI
IEEE P1688 Standard	Module Electromagnetic Interference (EMI) Testing
IEEE P1900 series Standards	Policy on software defined and adaptive radio P1900.2 Interference and Co-Existence Aspects (EMC Society leads) P1900.3 Evaluation of Software-Defined Radio Software Modules (EMC Society leads)

III. CONCLUSIONS/SUMMARY

This paper gives a short summary of the history of EMC standards, which have been developed and/or sponsored by the IEEE EMC Society over its 50-year history. Also included were some of the experiences in the development of the standards and the names of those who led the working groups in the past and in the present. Rather than list in the references a repeat of the standards as indicated in Table 1, the URL to find further information on these standards was given above in Section II instead. The names and contact information of those who are chairing the present work are contained on the EMC Society web site (www.emcs.org) under the "Standards" button on the home page. In summary, there is a rich heritage of EMC standards with more to come. The author encourages the reader to join in the fun and rewarding experience of contributing to our standards and hopes that contact will be made with the chair of the standard in your area of expertise. In this way, our next 50 years will be as successful as the past 50.

REFERENCES

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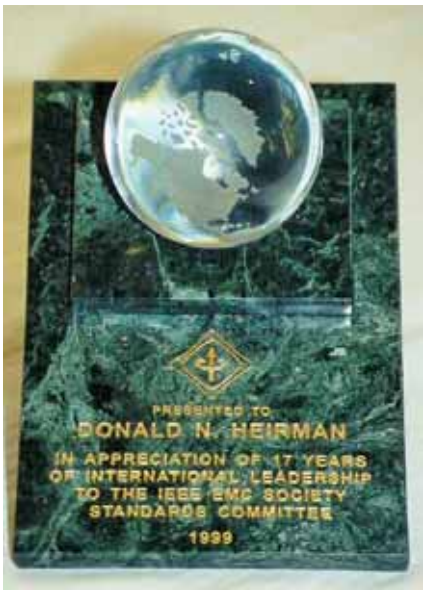
[3] D. N. Heirman, "A History of the Evolution of EMC Regulatory Bodies and Standards", 16th International Zurich Symposium on Electromagnetic Compatibility, February 2005.

[4] MPR (Matoch Provstyrelse), Swedish National Metrology and Testing Council 1990:10, "Test Methods for Visual Display Units"

[5] MIL-STD-220B, "Method of Insertion Loss Measurement"

Donald Heirman is president of Don HEIRMAN Consultants, training, standards, and educational electromagnetic compatibility (EMC) Consultation Corporation that was established after he retired from AT&T Bell Laboratories in 1997 after 34 years of service as manager of its global product compliance laboratory. He received his BSEE and MSEE from Purdue University. Mr. Heirman is a member of the IEEE EMC Society Board of Directors, its Vice President for Standards, chair of the technical committee on EMC measurements (TC2), past Society president and past chair of its standards development committee (1982-1999). He is also the immediate past president of the IEEE Standards Association (SA) serving in 2005 and 2006, present member of the SA Board of Governors and member of the 2005 and 2006 IEEE Board of Directors and Executive Committee. Mr. Heirman is a Fellow of the IEEE, life member of the EMC Society, and recipient of numerous IEEE and EMC Society awards including the Steinmetz, Cumming, Stoddart, Centennial and Millennium awards. He is also the Associate Director for Wireless EMC at the University of Oklahoma Center for the Study of Wireless EMC. He has presented numerous workshops, tutorials, and technical papers internationally and is listed in several Who's Who publications. He is a retired Commander in the US Navy Reserves.



A photo of the 1999 IEEE award received by Don Heirman "In appreciation of 17 years of international leadership to the IEEE EMC Society standards committee."

PHOTO BY DAN F. MARTIN PHOTOGRAPHY & GRAPHICS

Don Heirman (left) is shown with IEEE Immediate Past President Wallace Read at the 1997 IEEE International Symposium on EMC held in Austin, Texas, where Mr. Heirman received the IEEE Charles Proteus Steinmetz Award. This award is sponsored by the IEEE Standards Board and presented annually to an individual in recognition of major contributions to the development of standards in the field of electrical and electronic engineering.