An American Viewpoint of the EC Directive on EMC

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INTRODUCTION

The years 1976, 1982, 1989, 1992, and 1996 or perhaps 2000 are the past and expected future dates of European Community (EC) attempts to require electronic products to simultaneously comply with both electromagnetic disturbance and immunity requirements. Regulations to control disturbance (previously defined as radio interference) from household and other electronic equipment became effective in 1976 and 1982 and was relatively straightforward.

Publication of the EMC Directive in 1989 caused considerable confusion because it was one of the first "new approach" Directives. This new approach was to legislate electromagnetic compatibility (EMC) without being specific about it. The directive also included a transition period until 1993. This period was later extended until 1996.

The immunity portion of the EMC Directive remains a confusing issue since only "generic" requirements were published prior to 1994 while the European Committee for Electrotechnical Standardization (CENELEC) and others continued to work on product standards. The immunity stress levels appear to be quite onerous since they were originally derived from the environment of process control and power plant equipment.

This article compares the EC and USA disturbance limits, reviews the EC generic immunity limits, analyzes the EC administrative procedures and presents conclusions for the gradual phasing in of the requirements.

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THE DEVELOPMENTS LEADING TO THE EMC DIRECTIVE

The interference protection of the radio services before 1970 were primarily concerned with harmonic emissions from transmitters (including transmitters used for industrial, scientific and medical (ISM) equipment) and emissions from switching and commutation operations in electrical equipment. To control this interference, the International Special Committee for Radio Interference (CISPR) prepared CISPR 11 (ISM), CISPR 14 (Electrical Equipment) and CISPR 15 (Fluorescent Fixtures). The first EC emission control documents, based on CISPR 14 and 15, were Directives 76/889/EEC, 76/890/EEC, 82/499/EEC and 82/499/EEC. These Directives were enforced from June 1978, primarily via manufacturers' declarations of compliance.[1,2,3,4]

From 1970 onward, the ever-increasing use of digital devices such as switching power supplies, monitors, microprocessors, central processors, etc., and their use of specific clock frequencies, set the stage for today's emission control requirements of EN 55022. Originally, national specifications derived from CISPR 11 were used to control emissions from digital devices. Notably, Germany had a stringent emission control law; this law became the de facto standard for emission control of an international digital device. Initially, the emission limit compliance tests needed to be witnessed by (or performed by) the German VDE Testing and Certification Institute.[5,6,7]

The development of a CISPR specification for Information Technology Equipment (ITE) was delayed by two years because some countries required more stringent limits. However, in 1984 the limits were accepted by all CISPR member countries and CISPR 22 was published in 1985.[8] This became European Norm (EN) 55022 in 1987.

The control of emissions is generally well-understood and a sufficient body of expertise exists. However, the immunity requirements are much less understood. Originally, the CISPR prepared an immunity specification for radio and television receivers for immunity to signals on the mains lead.[9] This requirement was extended to include immunity to conducted currents, conducted voltages and radiated fields.[10] Subsequently, problems occurred with susceptibility of digital telecom equipment and national Post Telegraph and Telecommunication agencies (PTTs) prepared immunity specifications. Two other International Electrotechnical Commission (IEC) committees were also concerned with immunity for their equipment:

- IEC TC 65 for Industrial Process Control Equipment covered equipment used in an industrial environment.
- IEC TC 77 for Electric Utility Networks, covered power line

harmonic disturbances up to 10 kHz and in an electric power plant environment.

The original series of IEC 801-1, -2, -3, -4, -5 and -6 immunity documents was prepared for those oppressive environments and was later applied to equipment in any environment.

The EC EMC Directive 89/336/EEC[11,12,13,14] was intended to clarify the EMC situation by mandating that all equipment comply with the "requirements." Unfortunately, the requirements of this new approach Directive had no specific technical criteria or limits but instead established an initial compliance date of 1 January 1993 and also established an administrative juggernaut for national bureaucrats who seldom had any practical EMC experience. The task of preparing the technical EMC requirements was assigned to CENELEC Technical Committee (TC) 110. This committee was moderately fast in regurgitating the CISPR emission specifications but was very slow in creating the required immunity specifications. Instead, CENELEC repeated the immunity limits for industrial and power plant environments in a generic specification.[15] However, these limits do not necessarily apply to an environment where the emission levels are stringently enforced.

The EMC Directive prevented EMC engineering progress by imposing an administrative Trojan horse filled with requirements for paperwork for the CE mark, notified bodies, competent bodies, quality assessment modules, quality assurance per ISO 9000, laboratory accreditation, and certificates of compliance, etc. Each EC member country set up huge EMC administrative offices to analyze, publish, interpret, and re-interpret the balderdash of the EMC Directive. Consequently, real engineering progress was impossible and the original compliance date of January 1993 was extended until January 1996 and more than likely will be extended again. In the meantime it was stated that national EMC requirements prevail until 1996. Since few EC countries have any requirements, no significant EMC control work is carried out unless the product is marketed in the USA, Germany or Denmark.

COMPARISON OF DISTURBANCE LIMITS

There are numerous specifications in existence to limit the emissions from electrical/electronic equipment. These limits are summarized in Table 1. A cursory review of this table shows that all Class B limits are nearly the same and that the Class A limits relax the Class B limits (higher) by 10 to 13 dB. One might ask: "If the limits are the same, why have a multitude of specifications?" The answer is related to the parochial attitude of the committees developing the specifications.

Encouraging developments are the "Generic Limits" of EN 50081-1 and EN 50081-2. Table 1 shows that there is only a need for three types of emission (i.e., disturbance) specifications:

- emission limit specifications for industrial equipment locations
- emission limit specifications for residential equipment locations
- test procedure specifications for each equipment or equipment family.

This consolidation will eliminate the presently required dowsing for the applicable limit and test procedure.

The prime movers in this unifying effort are the national delegates to the CISPR who take the uniform standards initiatives back to their own countries and advocate the use of one specification in place of the present cavalcade of specifications. This trend of consolidation was set by the work on the ITE Specification CISPR22. Since ITE, or computers in general, were the most widely traded technology product in the 1980s, the emission limits of CISPR 22 are consensus limits.

The present CENELEC Class B definition includes residential, commercial and light-industry locations. However, the commercial and light-industry equipment should be Class A equipment. Therefore, the CENELEC definitions for Class A and Class B should be aligned with CISPR 22, 2nd edition as follows.

Class B equipment is intended primarily for use in the domestic environment, an environment where the use of broadcast radio and television receivers may be expected within a 10-meter distance of the apparatus concerned. It may include:

- equipment with no fixed place of use; for example, portable equipment powered by built-in batteries
- telecommunication terminal equipment powered by a telecommunication network
- personal computers and auxiliary connected equipment.

Class A equipment is a category of all other equipment which satisfies the Class A limits but not the Class B limits. Sales of such equipment should not be restricted but the following warning should be included in the instructions for use:

Warning *- This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.*

ANALYSIS OF EC IMMUNITY LIMITS

The 1980s are known as the years when electromagnetic emission control became a requirement for electronic equipment. The 1990s will become known as the years of

Part 1, Class B Limits for Primarily Residential Areas									
Frequency Range, MHz	0.15 → 0.5		0.5 → 5		5 → 30		30 → 230	230 → 1,000	
SPECIFICATIONS	dBμV		dBμV		dBμV		dBμV/m	dBμV/m	NOTES
	QP (1)	AVG (1)	QP	AVG	QP	AVG	QP	QP	
EN 50081-1, "B"	66-56	56-46	56	46	60	50	30	37	@10 m, B Limit
EN 55011 "B"	66-56	56-46	56	46	60	50	30	37	@10 m, B Limit
EN 55013, (2)	66-56	56-46	56	46	60	50	45-55 (3)	-	dBpW, Absorbing Clamp
EN 55014	66-56	56-46	56	46	60	50	45-55 (3)	-	dBpW, Absorbing Clamp
EN 55022, "B"	66-56	56-46	56	46	60	50	30	37	@ 10 m
Vfg 243, "B"	66-56	56-46	56	46	60	50	34	37	@ 10 m (7)
FCC Part 15, "B"	-	(6)	61	48	61	48	40(6)	46	@ 3 m (6)
Part 2, Class A Limits for Industrial Areas									
EN 50081-2, "A"	79	66	73	60	73	60	30	37	@ 30 m, A Limit
EN 55011, "A"	79	66	73	60	73	60	30	37	@ 30 m, A Limit
EN 55022, "A"	79	66	79	66	73	60	30	37	@ 30 m
Vfg 251, Group "1A"	79 (4)	66	73	60	73	60	30 (5)	37 (5)	@ 30 m (7)
FCC Part 15, "A"	-	(6)	73	60	83	70	40 (6)	46	@ 10 m (6)

NOTES:
(1) The dash between two numbers (e.g., 66-56) indicates that the limit decreases with the logarithm of frequency. The limits are plotted on semi-log paper, the vertical scale being the limit and the horizontal scale being the frequency. The two points shown are plotted and a straight line is drawn between them.
(2) EN 55013 also has other limits for antenna emissions from receivers and televisions.
(3) The absorbing clamp measurement is performed from 30-300 MHz.
(4) Vfg 251 is primarily intended for equipment utilized in industrially zoned areas. It is based on EN 55011.
(5) For Class A equipment on a test site.
(6) The FCC Class A and B Limits are as follows:

FREQUENCY	B LIMIT	A LIMIT
0.45 - 1.705	48 dBμV*	60 dBμV*
1.705 - 30 MHz	48 dBμV*	70 dBμV*
30 - 88 MHz	40 dBμV @ 3 m	40 dBμV @ 10 m
88 - 216 MHz	43 dBμV @ 3 m	43 dBμV @ 10 m
216 - 960 MHz	46 dBμV @ 3 m	46 dBμV @ 10 m
>960 MHz	54 dBμV @ 3 m	50 dBμV @ 10 m

* Narrowband Limit; Broadband Limit is 13 dB higher.

(7) The German Vfg 243 and Vfg 251 also have low frequency powerline and radiated magnetic emissions limits.

Table 1. *Limit Comparison of Various RFI Specifications.*

ensuring electromagnetic immunity of products by requiring extensive design and tests that will be at least twice as expensive as those for emission control. The primary driving force is the EMC Directive and to a lesser degree individual national requirements.

The present trend in the EC to require immunity testing for all products must be discouraged. Equipment that could cause great damage when it malfunctions requires immunity to electromagnetic fields. Non-vital equipment should not require immunity testing since this immunity design and test will increase the price to a level that will make many electrical/electronic appliances undesirable.

Table 2 shows some of the immunity levels proposed by CENELEC. In early 1984, only EN 50082-1[15] is referenced by the EC. The EN 50082-2 is not yet official and EN 55024 may become EN 50101 for ITE. The following discussion refers to EN 50082-1, "The Generic Immunity Limits."

The radiated RF immunity limit of 3 V/m from 27 to 500 MHz is a practical limit. However, the tolerance of +6 dB and -0 dB for the uniformity of the field should be changed to ±3 dB. The +6 dB tolerance causes overtesting at 6 V/m. Normally, testing is performed at a higher level. When a susceptibility is observed, the threshold of susceptibility is measured by decreasing the power. At this threshold the field should be measured to determine if the equipment complies with

SPECIFICATIONS	Radiated RF Immunity	Electrostatic Discharge	Transients AC Power	Transients Signal Leads	Transients DC Power	Conducted RF Immunity
EN 50082-1 Generic Limit Residential	3 V/m 27-500 MHz	8 kV (Air)	500 V 5/50 ns 5 kHz	500 V 5/50 ns 5 kHz	500 V 5/50 ns 5 kHz	0.15-100 MHz 3V (Proposed)
EN 50082-2 Generic Limit Industrial	3 V/m 27-500 MHz	8 kV (Air) 3 kV (Direct)	2,000 V 5/50 ns 5 kHz	1,000 V 5/50 ns 5 kHz	2,000 V 5/50 ns 5 kHz	0.15-80 MHz 3V
EN 55024 Limit for ITE	3 V/m 30-1,000 MHz	3 kV (Air) 8 kV (Direct)	500 V 5/50 ns 5 kHz	500 V 5/50 ns 5 kHz	500 V 5/50 ns 5 kHz	20 mA 0.15-80 MHz
Test Procedure	IEC 801-3	IEC 801-2	IEC 801-4	IEC 801-4	IEC 801-4	IEC 801-6

NOTE: Severity levels and frequency ranges are subject to change. Consult specifications for contractual values.

Table 2. *Tabulation of Some European Immunity Limits.*

the field of 3 V/m. The present antenna-to-equipment distance is 3 meters. Optional testing at a distance of 1 meter should also be allowed with the antenna placed to ensure that all parts of the equipment are illuminated. The 3-meter test distance requires a power amplifier with 10 times as much power output as at a measurement distance of 1 meter. Consequently, the test equipment cost becomes very high when only the 3-meter test distance is specified.

The electrostatic discharge test of 8 kV for the air discharge (indirect) and of 3 kV for the direct discharge are reasonable values.

The electrical fast transient test with a voltage of 500 volts and a risetime of 5 ns and a duration of 50 ns are reasonable values. However, a repetition rate of 5,000 per second is unrealistic. Typical arcing phenomena in air have a voltage of 300 V which could double to 600 V because of resonances. The repetition rate is random but seldom exceeds a value which is twice the power frequency. Therefore, the maximum rate specified should be 100 pulses per second.

The conducted RF immunity test of 3 volts over the frequency range of 150 kHz to 100 MHz is a reasonable value. However, since this test via direct (i.e., capacitor) coupling is difficult to monitor, the bulk current injection via a current probe should be used. IEC 801-4, Draft 4, April 1990 related the voltage to the current by 150 ohms; therefore, the current injection would be 3 V/150 ohms = 20 mA. The subsequent Draft 5 and Draft 6 became much too complicated for such a simple immunity test. For guidance, the aircraft equipment immunity test procedures should be consulted to establish a simplified procedure.[16,17,18,19,20]

ANALYSIS OF ADMINISTRATIVE PROCEDURES FOR EMC

The EC EMC Directive established an entirely new industry that produces only paper reports stating that an EMC laboratory is qualified to do the work if it is located in one of the EC member countries.

The EC EMC Directive is converted into national law by analysis and correlation to each country's existing law on EMC. Consequently, each national EMC Directive is different and must be analyzed again by the user. It would have been much simpler to mandate exact translation of the EC EMC Directive for use in each EC member country.

A prerequisite for EMC testing is compliance of the EMC laboratory with the quality requirements of ISO 9000/EN 29000 coupled with the EC Conformity Assessment Directive (90/683/EEC). For EMC laboratories this means compliance and/or awareness of the following European Norms:

EN 45001 General Criteria for the Operation of Testing Laboratories.

EN 45002 General Criteria for the Assessment of Testing Laboratories.

EN 45003 General Criteria for Laboratory Accreditation Bodies.

EN 45011 General Criteria for Certification Bodies Operating Product Certification.

EN 45012 General Criteria for Certification Bodies Operating Quality System Certification.

EN 45013 General Criteria for Certification Bodies Operating Certification of Personnel.

EN 45014 General Criteria for Supplier's Declaration of Conformity.

EN 45019 Guidance on Specific (Draft) Aspects of Testing and Certification.

EN 45020 General Terms and Their Definitions Concerning Standardization and Related Activities.

The inspection of the quality systems requires assessors and auditors which need to be accredited by national accreditation bodies.

Once the laboratory has prepared the quality documents it can apply for accreditation to a competent authority to become a competent body. This requires a quality audit by a lead auditor and assistants. Since U.S. labs may not be directly designated as competent bodies, several EC competent bodies have found a new source of revenue: "Sub-competent" bodies. Typical accreditation fees are US $10,000; an approval of each test report by the EC parent costs US $1,000.00.

This entire effort is a waste of time. EMC is achieved by design and test and not by paper shuffling. The EMC test must be performed by a qualified engineer with at least one year of specific design and test experience. Besides these requirements for competent bodies, there are also the issues of the "notified bodies" and the use of the CE mark which further complicates the EMC engineer's task.

CONCLUSIONS

The demonstration of electromagnetic compatibility requires the accurate measurement of voltages in the frequency domain and time domain. Since these measurements range from 9,000 Hz to 40,000,000,000 Hz, the test personnel must have training and experience in performing these measurements. Mistakes are easily made. The recognition of these mistakes comes from experience with the test setups and the instrumentation. The primary quality assurance comes from the test personnel and not from the paper documentation required by the EC EMC Directive. The quality auditors seldom have any experience in EMC. Therefore, the EN 45000 series of documentation for EMC laboratories is a waste of time and money.

The acceptance of the EC EMC Directive and the ENs for EMC would have been much easier if the requirements had been gradually phased in. Initially, the emission tests should have been required for all equipment. The by-product of emission control is also greater radio frequency hardness to external fields from intentional transmitters and transients.

After emission control is achieved, a gradual phasing-in of the immunity requirements should occur, but for critical equipment only. First, the electrostatic discharge (ESD) requirements should be imposed since the ESD event also generates RF fields and transients. This should be followed by the radiated RF immunity test. Non-critical equipment such as toasters, washing machines, vacuum cleaners, etc. should not be required to have the immunity testing performed. The immunity (i.e., quality) of these products should be market-driven. The user will return the product if it is not compatible. The result is that the manufacturer will ensure immunity of the product voluntarily.

By mandating the all-or-nothing approach of the EMC Directive, nothing was achieved by setting the initial deadline of 1993 and nothing will be achieved with the next deadline of 1996.

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