Gaps in the Application of the EMC Directive Due to Inadequate Harmonized Product Standards

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Abstract—For planning wireless communication systems the noise levels outside buildings have been used. The ITU (International Telecommunication Union) man-made noise levels are based on measurements performed in the 1970s. Measurements carried out since then showed that the noise caused by ignition systems reduced, but man-made noise in business areas and city centers increased. But the interference scenario changed: from analog communication systems in relatively free space to digital systems in living areas, often semi-enclosed such as offices, industrial production areas, and even cars and trains. Measurements in these semi-enclosed environments show a much higher, up to 60dB, man-made noise level. The higher noise level is not only due to a shorter distance to the source of emission, but mainly due to mistakenly assumption that compliance with a harmonized product standard is sufficient evidence of compliance with the European EMC directive. This is an incorrect and a wrong assumption. The EMC directive gives essential requirements to comply with. The use of harmonized product standards only gives a presumption of conformity. In a court case in a dispute on EMC of an electrical wheelchair, the key reference was the essential requirements and not the harmonized product standards. Several product standards have been developed with relaxed, or sometimes even no requirements. Some allow unlimited emission levels while others restricted the frequency range. These standards, although harmonized, are not in line with the essential protection requirements of the EMC directive.

Man-Made Noise

The knowledge of the electromagnetic ambient, or radio, noise is of particular interest in planning and setting up wireless systems, and as such to estimate the risk and impact of electromagnetic interference (EMI). Radio noise external to the radio receiving system derives from either natural, such as atmospheric and galactic noise and lightning, or unintended radiation from electrical and electronic equipment, power transmission lines, including railway systems, and internal combustion engines. This unintended radiation is called man-made noise (MMN) and is assumed to comprise two dominant and distinct components: white Gaussian noise (WGN) and impulsive noise (IN).

The levels for radio, including man-made, noise are usually taken from the ITU-R 372-8 [1]. The levels in that document are based on measurements made in the 60s and 70s in the United States [2].

The noise power in an equivalent lossless antenna can be replaced by the man-made noise, where the measured field strength, using an isotropic antenna with gain 1 and no losses, in a measuring bandwidth b is converted to the noise figure F_a. In logarithmic units this becomes

$$F_{aM} = E_n + 95 - 20\log f_{MHz} - 10\log b \text{ [dB]} \qquad (1)$$

Probabilistic descriptions of the received noise waveform are required to determine system performance and the amplitude probability distribution (APD) (exceedance probability) of the received envelope is used. The most important minimum expected median values of F_a is shown in Figure 1, taken from [1].

Technology changed considerably in the last decades, as well as the use of wireless systems. Some measurement campaigns have been carried out to update the man-made noise levels [3, 4, 5, 6, 7, 8, 9, 10, 11]. In [3] measurements performed in business areas of Montreal and Ottawa, and in residential Ottawa are described showing that there has been no significant increase of the MMN, but even a decrease in noise level, caused in part by the practice of using buried power lines rather than overhead power lines.

In 1970s, a significant component of man-made noise in VHF (30–300MHz) is due to ignition impulses from motor vehicles. Measurements show now that this automobile noise is no longer a significant VHF noise source, but that now computers were found to be capable of generating a significant amount of noise [6]. A follow-up report on Man-Made Noise power measurements at VHF and UHF frequencies [7] concluded that 402.5 MHz UHF noise levels in business areas were high enough to adversely affect communication system performance some of the time. The communication office in the United Kingdom awarded a contract in 2001 for setting up a measurement facility for measuring the man-made noise in various areas and measurement results have been published in 2003 [8]. MMN data has been collected in 8 locations: (large) city centre, factory estate, business centre, town centre, shopping centre/mall, major highway, suburban, and rural, at mid-morning, evening, and the rush hour. The study concludes that the decreasing level with frequency is as in the ITU report [1], but that the overall level is substantially higher. The highest MMN levels were found at the city centre, the factory estate and at the business centre. The road junction showed lower results, which again shows the effectiveness of measures taken via European legislation to reduce the automobile ignition noise. Measurements in Sweden [9] show lower noise levels than the ITU levels, except

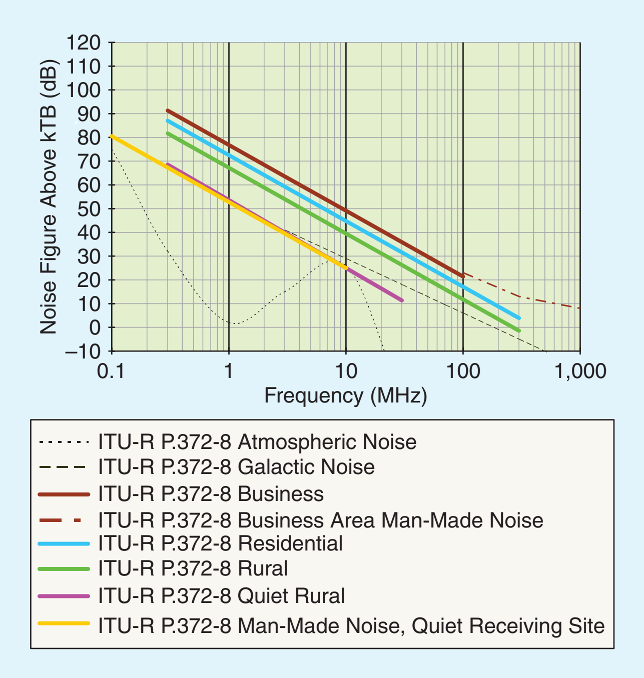

Fig. 1. Minimum expected median values of F_a.

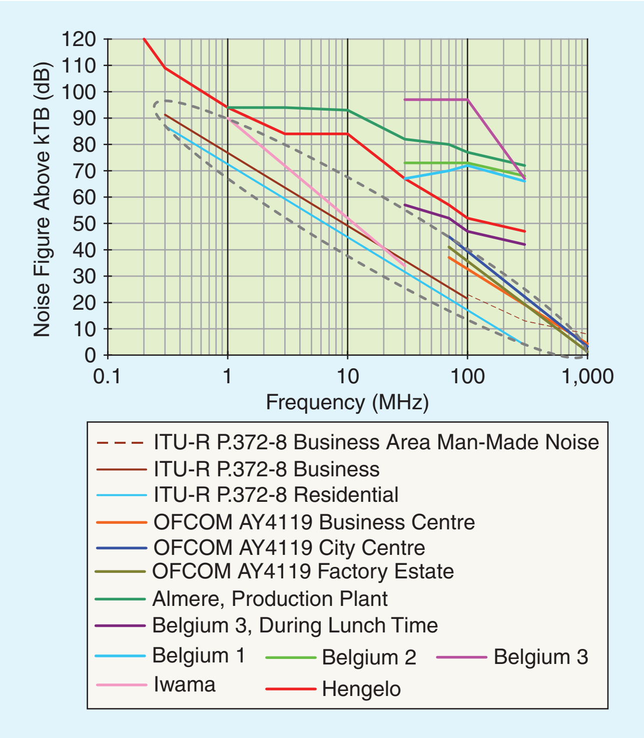

Fig. 2. Noise levels outside buildings and in semi-enclosed, industrial, environments. The lines within the ellipsoid are the noise levels outside buildings.

for urban areas and the city of Stockholm where the MMN was up to 15dB higher. Iwama [10] showed a much higher MMN at the lower frequencies, in the HF region, decreasing faster in UHF region.

Figure 2 gives the values for F_a for man-made noise as collected in the last decade.

It is remarkable that nearly to no data is available on the EM ambient in living, often semi-enclosed, environments. Semi-enclosed

Fig. 3. Some of the semi-enclosed, industrial, environments where EM ambient surveys have been performed.

environments are sites such as production plants, offices, houses and even include cars, trains or planes. Wireless communication systems are being used more and more in these semi-enclosed environments, while the interference model is based on the conventional assumption that free-space radio communication systems has to be protected. An additional issue is the multiple reflections inside semi-enclosed environments at VHF and UHF, where the wavelength of the noise is smaller than the dimension of the semi-enclosed environment. These multiple reflections are scattering MMN and radio waves erratically, and interfering with or blocking wireless transmissions [12]. EN 61000-2-5 [13] provides some guidance for the characterization of the electromagnetic ambient levels under different circumstances. However, the electromagnetic environment inside transportation equipment, vehicles, traction, ships & aircraft, is not described. A guide to establish the EM ambient is given in [14]. NIST (National Institute Science Technology, Boulder, USA) performed tests (*no reference, data taken from press news*) in manufacturing plants crowded with stationary and mobile metal structures, such as fabrication and testing machinery, platforms, fences, beams, conveyors, mobile forklifts, maintenance vehicles and automobiles in various stages of production. The survey showed that interference from heavy equipment can impair wireless communication signals such as those used in some controllers on the production floor.

Within the frame of COST 286, several institutes performed site surveys in industrial environments [11], including KHBO Brugge-Oostende, University of Liege (both Belgium), University of Catalunya (Spain), University of Hannover (Germany), University of Twente (Netherlands). Measurements have been performed in HF, VHF and UHF bands. Based on these surveys noise figure curves have been added, as shown in Figure 2. Pictures of some of the environments are shown in Figure 3.

The difference in man-made noise level looks enormous, and it is. The large increase is due to the high emission level of machinery controlled by computers, frequency converters and valves. These machines have to fulfill rather relaxed and high radiated emission levels at a distance of 10 m to 30 m. In the survey we investigated the emission levels around these machines with measuring distances sometimes less than 2 m. One measurement was performed during lunch time. Comparing the results on average the MMN decreased by 40dB during this break, proving that the electrical and electronic equipment was the source.

Interference Case

In the 1970s the then man-made noise is mainly due to ignition impulses from motor vehicles. This has changed to MMN due to the use of electrical equipment [6], sometimes high enough to adversely affect communication system performance [7].

Most existing radio receivers are designed for the case of additive white Gaussian noise (WGN), and their performance may deteriorate in other scenarios, for example when subjected to impulsive noise [9]. In rural environments the man-made noise can be approximated as WGN, but in urban and sub-urban environments the man-made noise is often impulsive noise (IN). For digital communication systems, WGN does not represent a major problem as long as the mean power of the desired received signal is high enough.

The IN is harmful for digital communication because each pulse may cause bursts of bit errors and loss of synchronization. An extreme example of underestimating the MMN is the German Toll project [15, 16]. Several billions of euros were lost due to interference in GPS receivers in industrial areas and city centers, and the system had to be redesigned causing a long delay without income (of toll).

Another key issue is the classic interference case. This assumes a source of noise, on the road or from a neighbor, which is interacting with the wanted signal received with an antenna placed on the rooftop of a building, as shown in Figure 4 and 5.

In our modern living environment many electronic systems are used, including wireless communication systems. Especially in the transport sector a huge increase of wireless control systems can be observed, from the wireless bridge control systems on large cruise-liners, to the next generation passenger planes. This interference case, where many systems are packed in semi-enclosed environments, is not taken into account by most standards. In industrial production plants many wireless systems are already in use and many interference problems had to be solved, such as disturbed wireless data transmission in the 433 MHz band.

European Emission Standards

In the last decade a plethora of new product standards have been published, especially (driven) by European companies. Due to a lack of a generic standard, based on a proper description of the electromagnetic environment in which the product would be used, two product standards have been selected as 'generic' standard: the EN55022 for household and office environments, and the EN55011 for the industrial environment. Parallel to these generic standards, product standards have been developed. As an example, the EN55015 is the product family standard for electrical lighting and similar equipment. The frequency range covered is 9 kHz to 400 GHz, but the 1996 version contains no requirements for radiated emissions from 30 MHz and above. The Swedish Authority has found that some halogen lighting sets which are powered by an electronic transformer cause radiated emissions in frequencies not covered by EN 55015 [19]. When they tested it against the generic standards they found that the apparatus exceeded the limit by 30 dB and 31 dB at 30.72 MHz, and the disturbance level was extensive up to 50 MHz. The EN 55015 has been upgraded and now contains requirements up to 300 MHz [20].

The manufacturers of frequency converters had problems to fulfill the generic standards and used the same trick: they developed the IEC 61800-3 and EN 61800-3 on EMC for Adjustable Speed Electrical Power Drive Systems (PDS) [21]. Instead of leaving out a frequency range, complete categories were excluded. In the standard it is written '*Where a PDS does not comply with the limits of category C1, the following warning shall be included in the instructions for use: Warning: In a domestic environment, this product may cause radio interference, in which case supplementary mitigation measures may be required*'. Does such a product not produce interference in other environments than the domestic environment? For equipment of category C2 an 'information requirement' has been added: '*If a PDS does not meet the limits of category C1 or C2, a warning shall be included in the instructions for use stating that: this type of PDS is not intended to be used on a low-voltage public network which supplied domestic premises; radio frequency interference is expected if used on such a network. The manufacturer shall provide a guide for installation and use, including recommended mitigation devices*'. We asked a manufacturer for the recommended mitigation devices. The answer was that such a filter did not exist…. In one case we asked for measurement results of a PDS, in this case conducted emission. After several months and many repeated requests we received the data, showing compliance with the standard, and an overall emission level of 45 dBμV. But the equipment caused interference problems so we performed measurements. The emission level was 130 dBμV, 75 dB above the limit of the generic standard, and 85 dB above the level stated by the manufacturer. When confronted with this huge difference the manufacturer did not respond for 6 months, and finally replied with the statement that the wrong data had been sent erroneously…. The PDS appeared to be a C2 type, which actually means that the emission level is unlimited. Because the EN 61800-3 is a harmonized standard, a presumption of conformity with the EMC Directive [17] exists, and therefore a CE mark is affixed, even on equipment generating over 130 dBμV conducted emission. But is this approach in line with the essential requirements of the directive?

European EMC Directive

The EMC Directive [17] limits electromagnetic emissions of equipment in order to ensure that such equipment does not disturb radio and telecommunication [18]. This EMC Directive is a so-called EC New Approach directive, and does not exactly specify what requirements are to be met, but the goal of the directive has been specified in terms of "essential requirements".

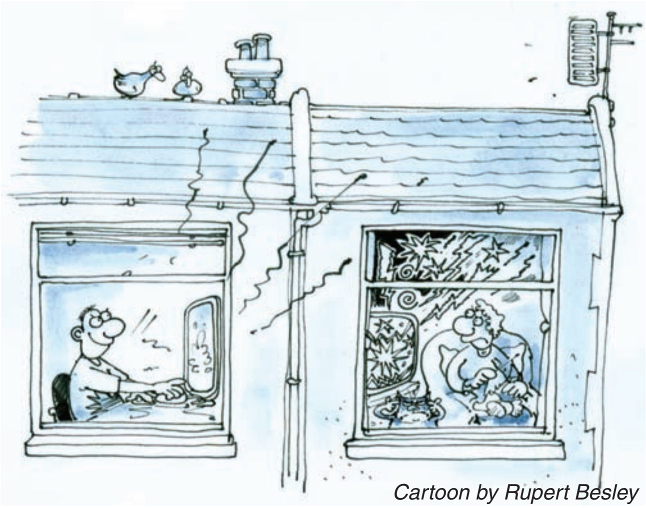

Fig. 4. Classic interference case, from neighbour to your aerial.

Fig. 5. Classic interference case, from environment.

The essential requirements for apparatus are protection requirements:

'*Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:*

a) *the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;*
b) *it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use.'*

By mandate from the European Commission, European Standardization Bodies such as CENELEC have been granted permission to autonomously declare EMC standards as being suitable for obtaining a "Presumption of Conformity" with the Essential Requirements. The common approach is that if a product fulfills the requirements of a harmonized standard, the CE mark is put on the product, the Declaration of Conformity is signed by the responsible manager, and that is it.

The EMC-directive covers the frequency range up to 400 GHz. If a harmonized standard is limiting the frequency range, the presumption of conformity using harmonized standards still applies. But, the presumption of conformity is a presumption, and not proof that the essential requirements of the directive are fulfilled. A well known case is the jammed wheelchair [22], where an accident with an electric wheelchair is described. The culprit was a GSM-phone booster operating above 1 GHz. Although the wheelchair did meet the relevant harmonized product standard for electric wheelchairs, which was up to 1 GHz, the manufacturer was sentenced by court because the product did not fulfill the essential requirements of the EMC Directive.

Maybe we need lawyers to explain engineers that the EMC Directive is the Law. And the Law states the essential requirements. Harmonized standards are just useful to declare a presumption of conformity with the essential requirements. Creating harmonized standards which exclude frequency ranges, such as the EN 55015, or allow essentially unlimited emission levels such as the IEC 61800-3, are in this way not useful. However, these lightning and PDS systems are being applied in our living environments in huge numbers causing a very high noise level, as shown in Figure 2.

A court case could be very useful in sparking interest in this issue. Most national authorities do however not have sufficient means to carry out proper market surveillance and most are acting on a complaint basis only. A nice example is a case in Germany where a flat screen television set was causing interference in the HF (high frequency) radio band, around 3.6 MHz [23]. The German national authority checked and confirmed the interference, and concluded that the owner of the television is not allowed to switch on the television anymore, and if he would switch it on, then he would be charged because of offending the law. The supplier of the television repeated the EMC measurements at an accredited laboratory showing that the television was fulfilling the harmonized product standards. These standards however only consider conducted emission in the HF band, and no radiated emission. The television set fulfills the requirements of the harmonized product standard, but not the essential requirements which are stated in the EMC Directive. But instead of challenging the supplier in a court case the national authority followed the easy route by asking the consumer to switch off the television.

Conclusion

Man-made noise has changed in the last decades. Noise from automotive ignition reduced, but the man-made noise caused by electrical and electronic equipment increased in the conventional outside areas. Inside semi-enclosed living environments the man-made noise is much higher, 20 dB to sometimes more than 40 dB, than the free space noise levels described in ITU-R P.372. If new services are introduced in these environments, assuming the old man-made noise levels, then serious link problems are occurring: many examples of EMI after the introduction of new services have been reported.

The main cause of the high man-made noise level is the conventional interference case founding the current electromagnetic compatibility standards, which do not consider wireless communication systems operated in semi-enclosed environments. As a result, high emission levels in the standards for industrial environments have been allowed. A more critical issue is the wrong interpretation of the European EMC Directive by many people. This new-approach EMC directive states the essential requirements. Compliance with harmonized standards is only a presumption of conformity with the Directive. However, immoral harmonized standards resulted in a huge increase of man-made noise in our living environments, resulting in many EMI problems.

References

[1] ITU-R P.372-8, Radio Noise, 2003.
[2] A.D. Spaulding, R.T. Disney, Man-Made Noise: Estimates for Business, Residential and Rural Areas, NTIA 74–38, 1974.
[3] W.R. Lauber, J.M. Bertrand, P.R. Bouliane, An update of CCIR business and residential noise levels, IEEE International Symposium on Electromagnetic Compatibility, 1994, page 348–353.
[4] F.H. Sanders and V.S. Lawrence, Broadband Spectrum Survey at Denver, Colorado, NTIA Report 95–321, Sept. 1995.
[5] A.D. Spaulding, "The natural and man-made noise environment in personal communications services bands," NTIA Report 96–330, May 1996.
[6] R.J. Achatz, Y. Lo, P. Papazian, R.A. Dalke, G. Hufford, Man-made noise in the 136-138 MHz VHF meteorological satellite band, NTIA Report 98–355, 1998.
[7] R.J. Achatz, R.A. Dalke, NTIA Report 02-390, Man-Made Noise Power Measurements at VHF and UHF Frequencies, 2001.
[8] RA(OfCom) AY4119: Man-Made Noise Measurement Programme (2003).
[9] J. Rantakko, E. Lofsved, M. Alexandersson, Measurements of Man-Made Noise at VHF, EMC Europe Workshop 2005.
[10] M. Iwama, Estimation of Background Noise in HF-band, 2008 Asia-Pacific Symposium on Electromagnetic Compatibility & 19th International Zurich Symposium on Electromagnetic Compatibility, 19-22 may 2008, Singapore, pp. 478–481.
[11] F. Leferink, F. Silva, J. Catrysse, S. Battermann, V. Beauvois, A. Roc'h, Man-Made noise in our living environments, accepted for publication URSI Radio Science Bulletin, 2010.
[12] F. Leferink, W. van der Wurff, Wireless communication systems: the impact on throughput in highly reflecting environments, EMC Europe 2004, Eindhoven, pp. 211–215.
[13] IEC 61000-2-5, Technical Report, Part 2-Environment, Section 5 - Classification of electromagnetic environments. Basic EMC publication, 1995.
[14] CENELEC CLC/TS 50217: Guide for in situ measurements – In situ measurement of disturbance emission, draft.
[15] Volpe GPS Vulnerability Report, Recommendations and FAA response, 10 September 2001.
[16] Die Maut, die Macht und die Manager; Der grosse Flop von Toll Collect, ZDF, 30 Jan. 2004.
[17] Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004, on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC.
[18] http://ec.europa.eu/enterprise/sectors/electrical/emc/.
[19] J. Rajamaku, A. Kasanen, An EMC market surveillance project on energy-saving lamps in Finland, EMC2002, International Wroclaw Symposium and Exhibition on Electromagnetic Compatibility.
[20] EN 55015, Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment, 2006.
[21] EN 61800-3 (or IEC 61800-3), Adjustable Speed Electrical Power Drive Systems - Part 3: EMC requirements and specific test methods, 2004.
[22] D. Groot Boerle, F. Leferink, The Jammed Wheelchair: a case study of EMC and functional safety, EMC Society Newsletter, Fall 2004, page 61-65, http://www.emcs.org/acstrial/newsletters/fall04/63_67.pdf.
[23] http://www.youtube.com/watch?v=-BZSXKxyJn0.

Biography

Frank Leferink *received his B.Sc in 1984, M.Sc. in 1992, his PhD in 2001 and became a Professor in 2003. Since 1984, he has been an employee of THALES in the Netherlands; he is now the Technical Authority and responsible for the EMC activities within THALES Netherlands. He is the manager of the (virtual) Center of Excellence on EMC, comprising a group of more than 100 EMC engineers within the THALES group located at approximately 30 sites in France, United Kingdom, The Netherlands, Italy and Germany. Since 2003, he is a (part-time, full-) Professor EMC at the University of Twente. He is acting chair of the Telecommunication and EMC group, with six staff and 12 PhD researchers; seven of them are involved in EMC research. He has published over 150 papers. He is teaching EMC and Transmission Media courses, and is involved in training activities towards professionals. He is chair of the IEEE EMC Benelux Chapter, a member of ISC EMC Europe, and associate editor of the IEEE Transactions on EMC. His main interest areas are EMI at the PCB and IC level and innovative test techniques, such as reverberation chambers.*