CE Requirements for Modern Television Receivers

Meeting EMC requirements for TVs poses a challenge due to mass production processes and the ever-growing density of entertainment and communication electronics in the home.

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INTRODUCTION

Since January 1, 1996, each and every apparatus which is placed on the European market and put into service must comply with the conformity requirements of the applicable EU directives. The manufacturer, a representative within the EU, or the importer has to declare conformity and affix the CE Mark. Emissions and immunity tests for televisions and videos have to be performed according to the harmonized European norms EN 55013/A12 and EN 55020. This article introduces these tests and reports on the measurement experience gathered in an accredited EMC test lab for this product type.

NORMS

The following harmonized standards for reaching the CE conformity are presently applicable: EN 55013:0690/A12:08.94 for emissions and EN 55020:12.94 for immunity. Both standards are published in the Official Journal of the European Union.

In the near future we can expect publication of Amendment A13 to EN 55013 and A11 to EN 55020. These changes have already been ratified but are not yet harmonized by CENELEC. They describe the requirements for the operation of satellite receivers. This means that they can be used on a worldwide basis by any manufacturer following the self-certification procedure. They do not necessarily require the involvement of any EU accredited test lab or any Competent Body (Art. 10.2:89/336/EEC) but rather require using the compliance route according to Article 10.1 of the EMC Directive, which is not restricted in application to the EU.

The *emission* amendment A14 is undergoing preparation. This document will specify additional requirements for digital signal processors (DSPs) in TVs and VCRs. Also covered are PC plug-in cards with TV receiver functions, infrared remote controls, IR headphones, etc.

Amendment A12 contains requirements for DSPs, PC plug-in cards and IR equipment for *immunity*. Furthermore, there will be requirements specifying the applicable tests for fast transients (burst) electrostatic discharge (ESD) and pulse modulated RF fields (GSM). Those requirements have not yet been included as amendments in conformity tests for TVs.

TEST EQUIPMENT

TV testing and measurements according to EN 55013 and 55020 require specific test setups and equipment. While most of the equipment can be found in an ordinary EMC test lab, special coupling networks and signal generators may not be readily available. Based on the cost of a standard well-equipped EMC laboratory, the additional investment necessary to expand into the TV product area is between $30,000 and $60,000. Table 1 shows a comprehensive list of the typical test equipment needed and estimates the total financial investment.

No.	Test Equipment	Features, Comments
1	TV-generator	NTSC, PAL, SECAM, PAL+, etc. band I-IV, hyperband
2	Luminance meter	according to CCIR 471
3	EM-anechoic chamber	Frequency range ≥ 1GHz, turntable, antenna lift
4	Jacky	150 Ω, size 2 x 1 x 1m
5	Sound deadening room	min. 4x4x2m
6	Coupling/decouplingnetworkM	AC power port
7	EMI receiver or analyzer	150 kHz - 1.75 GHz
8	Power divider	75 Ω
9	Matching network	50 Ω⇳ 75 Ω
10	EMI antenna	80-1000 MHz
11	Harmonics meter	until 40. harmonics, incl. 50/60 Hz power supply
12	2 Disturbance generators	f =150 kHz - 150 MHz; 2 W
13	Power meter	Disturbance level control
14	Microphone	EMI-proof, dynamic range >60dB
15	Audiometer	Dynamic range >60dB
16	Bandpass filters	1 kHz according to EN 55020 App. B.2
17	Lowpass filters	fg = 15 kHz according to EN55020 App. B.1
18	3 networks, Sr = 47 kΩ	Scart terminator
19	Input networks, RCI	for TV audio inputs current injection
20	Output networks, RCO	for TV audio outputs current injection
21	Scart adaptors	Scart ⇳ BNC
22	Antenna network A	for antenna current injection
23	50 Ω and 75 Ω coax lines	
	Cost: > $ 1,000,000 U.S.	

Table 1. *Equipment and Associated Costs for a Full-service Laboratory which Tests for TV Emissions and Immunity Measurements.*

Aside from the specialized test equipment, a lot of know-how in standardization is needed, e. g., knowledge of how to correctly apply the input test signal to the TV receiver.

INPUT TEST SIGNAL

The input test signal to the TV is well-defined in the standards. In order to comply with these specifications for the sound and video signal, a specialized TV test generator is needed.

PICTURE GENERATION

The color bar patterns shall be in accordance with CCIR Recommendation 471, 100/0/75/0, f_C level at the antenna input of 70 or 74 dB (µV). The picture brightness should be set at: black bar 2 cd/m2, magenta bar 30 cd/m2, white bar 80 cd/m2. The exact setting of the brightness of the picture is very important for the reproducibility of the test results. Extreme deviations can result in as high as 12 dB for emissions.

SOUND GENERATION

Sound generation should be through an unmodulated sound carrier, stereo if applicable. The volume control will be set to 50 mW. This volume setting will remain unchanged during the measurement. However, the sound modulation will be switched off at the TV test generator.

Caution must be exercised when purchasing a TV test generator. Aside from the costs, the available functions like NTSC, PAL, SECAM, PAL+ or NICAM have to be considered. Other questions include "Are worldwide channel tables available?" and "Is the carrier level adequately adjustable for picture, sound and chroma?". The power dividers and matching networks cause signal losses. They have to be compensated to achieve 70/74 dB(µV) at the antenna terminal of the TV. In all cases a detailed investigation of the generated input signal against undesirable deviations must be performed. Not having expensive tunable filters available leads to the existence of the two sidebands at the RF output terminal of the TV signal generator (Figure 1).

PERFORMANCE CRITERIA FOR IMMUNITY

PICTURE

The standard recommends a subjective judgement of the picture quality at a distance of 6 times the screen diagonal. No visible picture degradation may occur (change in brightness, color saturation, bars, patterns, etc.). This is a simple way of judging quality but it nicely matches the vision of the human eyes and their adaptive ability. Nevertheless, a number of problems still exist:

- The recognition is subjective and may lead to errors which could result in different judgments by different test personnel.
- Automation is difficult to achieve; a test engineer must permanently eyewitness the process. This is tiring and not cost-effective.

However, we still prefer this procedure because of the higher level of judgment in achievable quality. All other attempts have been unsatisfactory or financially unfeasible. This includes monitoring the cathode voltage, composite color picture signal or any other camera-related analysis.

SOUND

In this case the standard calls for an objective judgment by means of an audiometer. The input signal to the TV at 1 kHz with a frequency shift of 30 kHz will be adjusted before the measurement to result in 50 mW output power at the speaker. This forms the 0 dB reference. The actual analysis will be performed with a audiometer including a 1-kHz bandpass filter. The 1-kHz modulation has to be switched off for this measurement. For a serious analysis, the remaining noise signal of the TV receiver has to be clearly under the -40 dB limit (S/N ratio). If we turn on a 1-kHz modulated interference frequency, the maximum allowable interfering signal at the speaker may be 50 mW - 40 dB =

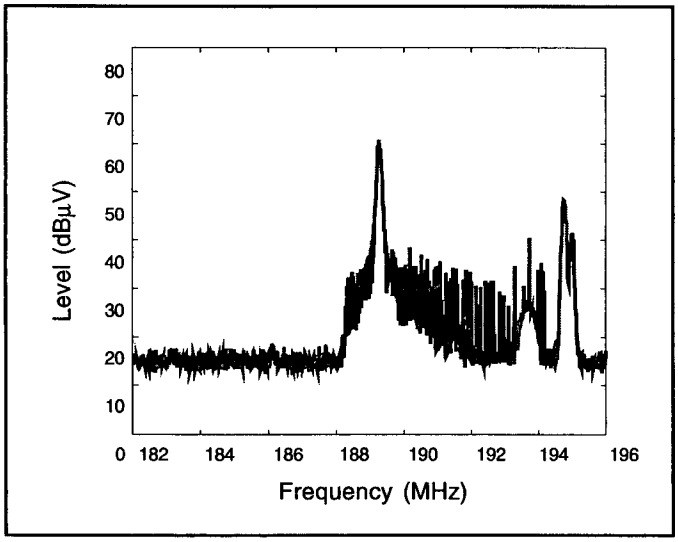

Figure 1A. *Terrestrial TV Signal Received via Aerial Tuned to Channel 7 - Only Upper Side Band.*

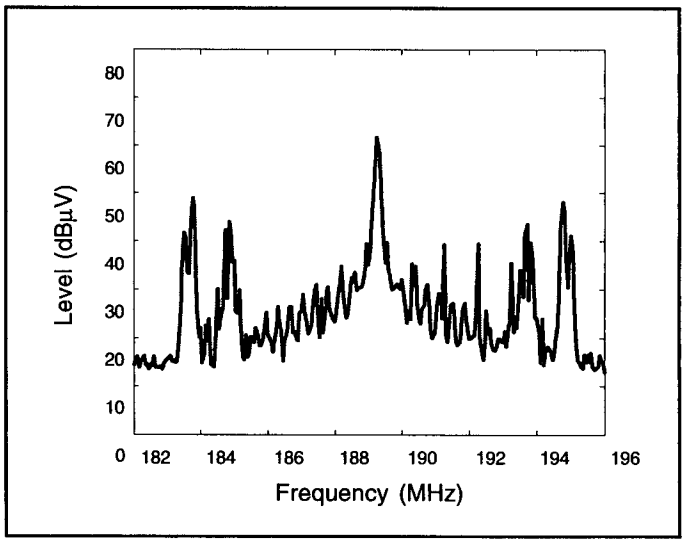

Figure 1B. *TV Generator Applied Signal for Channel 7 - Both Side Bands Existing.*

0.05 mW. A word of caution when purchasing the audiometer system is warranted: the system must demonstrate a 60-dB dynamic range. If the speaker of the TV set is not accessible for measuring the direct audio voltage, a microphone may be used. The disadvantage of this measurement is the sensitivity to background noise, virtually requiring an acoustic anechoic chamber. The advantage is not having to cope with the direct coupling effects of RF to the measurement set.

Very helpful for design engineers and production monitoring is the step-by-step documentation of the test results. Test software for the audiometer can be used which reads the 1-kHz level of the audiometer after each frequency step. This results in a quick overview of the critical interfering frequencies and the final pass or fail judgment of the overall test (Figure 2).

INDIVIDUAL EMC TESTS

EMISSIONS

Conducted emissions on the mains (0.15 - 30 MHz)

This measurement follows the well-known CISPR 16-2:1996 procedure with practically identical limits as ITE standard EN 55022/B. The test setup, however, is slightly different. The special line stabilization networks (LISNs) are to be placed under the 0.8-m high nonmetallic table. Testing is done with and without a low impedance bonding between the LISN and the ground of the coaxial antenna input according to the chosen interference model. This results in twice the measurement time! This measurement analyzes the effectiveness of the mains input filters. EMI problems result typically from incorrectly placed input filters with unfavorable grounding or inadequately compensated overshoots of the switched mode power supplies (SMPS). Routing the mains power cord diagonally via the printed circuit board practically wipes out the effectiveness of the filters due to RF short circuiting.

Conducted emission testing on the antenna port (30 - 1750 MHz): TV tuned to channel 21 (471.25 MHz)

The TV acts as a source for EMI frequencies which can spread via the coaxial input of the tuner to the antenna cable. This may result in EMI to adjacent electronic victims and potential radiated interference via the antenna, resulting in radio and television interference. The 50-ohm EMI test receiver input and the 75-ohm TV input and generator output have to be matched correctly, and have to include the necessary compensation for eventual losses by the power divider. As shown in Figure 3, in the course of the test result, the TV input signal must be visible, as should the first and second harmonics of the signal input. This rarely leads to any severe problems because modern tuner constructions are typically engineered by RF experts with a minimal amount of leakage.

Despite some signals exceeding the limits, this test was passed anyway because the standard permits excessive emissions at the input frequency and its harmonics. Switching on and off the TV test generator can demonstrate that the reason for exceeding the limits is this very generator.

Radiated emissions (80 - 1000 MHz)

This test is related to CISPR 16-2. Vertically and horizontally polarized electromagnetic fields are tested at a 3-m distance (Figure 4). These originate from high clock microprocessors and controllers supporting functions like remote control and monitoring. EMI and the typical needle spectrum is freely propagating over all PCBs and connected cables. No help can be expected from the plastic housing of the TV because this is electromagnetically almost transparent. The major spread and occurrence of EMI is traveling towards the IF. This dual layer circuitry, as well as the digital controls, are very often designed by software engineers with no experience in EMC. Interestingly, the tuners are much better. Aside from RF phenomena, low frequency effects have to be considered, too.

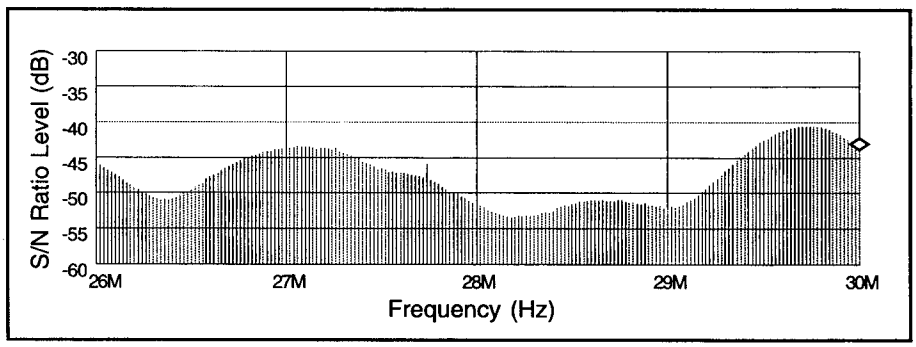

Figure 2. *Documentation of Test Results for the Development and Quality Control of the 1-kHz EMI Signal Versus Frequency.*

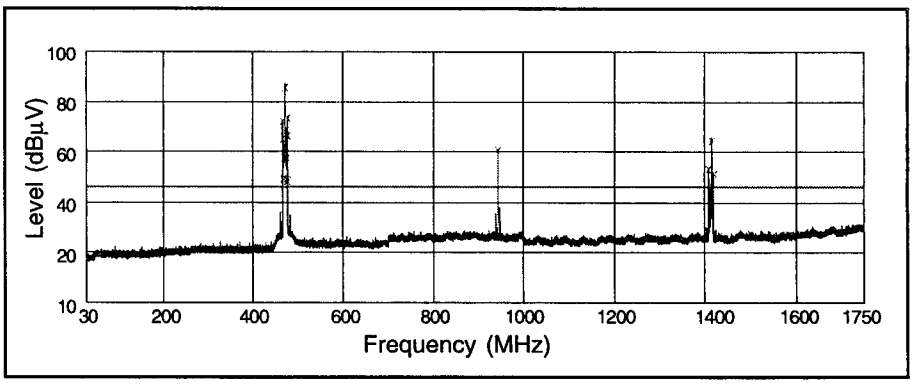

Figure 3. *Conducted Emissions at Antenna Port - TV Tuned to Channel 21, Acceptable. Test Result: Passed.*

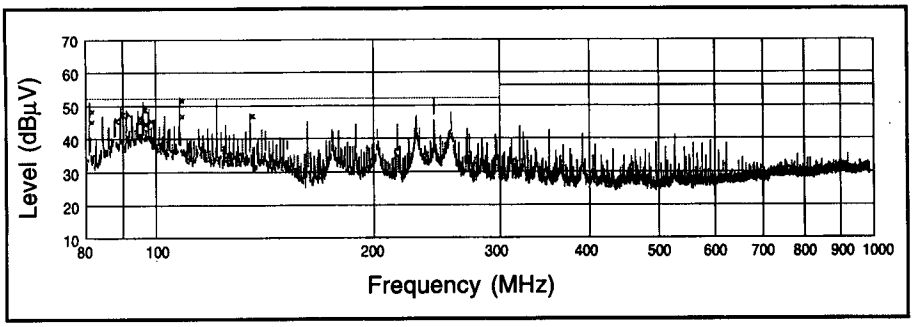

Figure 4. *Typical Measurement Result of a TV Radiated Emission Test Including Visible Harmonics of the Microprocessor.*

Harmonics (50 - 2000 Hz)

Since EN 60555 part 2:87 "Disturbances in supply systems caused by household appliances and similar electrical equipment," has become effective, TVs have their own class of limits. This step was necessary in order to protect the power lines of the low voltage distribution systems against injected harmonics. It leads to uncontrolled degradation of the guaranteed quality of the supplied voltage. Harmonics may result in performance degradation or even losses of adjacently connected equipment. The level of brightness as specified by the input signal definition strongly affects the harmonics content. Figure 5 is a bar chart which accompanies harmonic table presentations. It supports a qualitative analysis for the development of power supplies.

Normative and regulatory hints for emissions

The EU legally requires meeting the protective requirements of the EMC directive in terms of emissions *and* immunity. However, in North America immunity requirements are voluntary. In Asia, Australia and New Zealand, only EMC emission laws have been established to control the radio frequency spectrum. In the future, we might see other immunity requirements amended. This is a logical consequence which keeps up trade and does not impose unnecessary trade barriers in relationships with the EU.

IMMUNITY

RF field immunity (150 kHz - 150 MHz)

This type of measurement is usually performed in a 150-ohm strip line called a Jacky. This requires considerable space to accommodate its physical dimensions of about 2 x 1 x 1 m. Placing this into a shielded room may require additional absorbers to prevent moding and uncontrolled room resonances affecting the generated working field between the plates of the strip line. The required field strength for such a test is typically

Continued on page 85

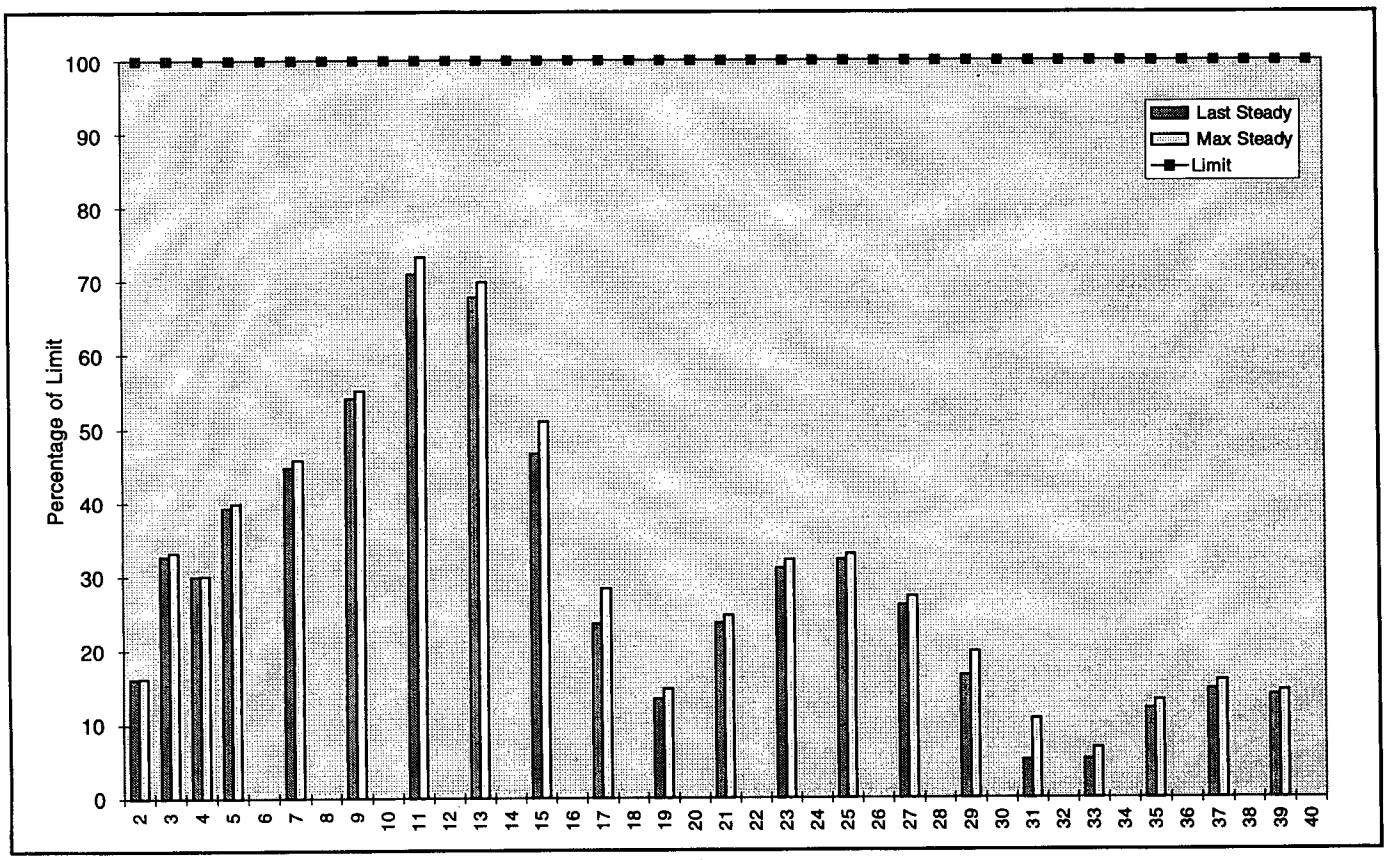

Figure 5. *Power Line Harmonics for a TV with the Following Brightness Settings: Black Bar 2 cd/m², Magenta Bar 30 cd/m², White Bar 80 cd/m².*

CE REQUIREMENTS FOR MODERN TELEVISION RECEIVERS . . . *Continued from page 29*

in the range of 1.5 V/m. AM modulation of 80 % and 1 kHz is used. However, criticism is very much justified because the TV on the test occupies almost 70 to 80 % of the total height within the strip line. Using this type of standardized test facility may result in strong deviations of test results among test labs around the world. Therefore, interconnecting lines and the immediate environment around the Jacky have to be very well-controlled. For a successful acoustical assessment of the TV performance, the microphone has to be EMI hardened.

Experience indicates that this measurement is highly critical in spite of a fairly low field strength being applied. One typical potential victim is the final audio stage. The RF will couple into long speaker lines right through the TV plastic housing and thus cause demodulation in the audio stage. A toroidal ferrite core has often been the solution to EMI. A final comment regarding the process of harmonization in standards is targeted at normal CE testing against fields of up to 1000 MHz. This is physically impossible within a Jacky due to higher order modes which will sooner or later eliminate this equipment in favor of more broadband TEM cells.

Current Injection into Audio and Mains Ports (150 kHz - 150 MHz)

This test checks immunity against EM fields which can degrade the picture and sound quality of the TV via cables. A large variety of coupling networks is needed to match the various impedances of audio in- and outputs, mains, and the 50-ohm injection generator. These coupling networks are explicitly described in the annex of EN 55020. It is important to control the proper bonding of the coupling networks and the TV generator to arrive at reproducible test results. The TV set is placed 100 mm above a large ground plane with the dimensions 1 x 2 m. All further ground potentials are referenced to this plane. Extreme care must be taken not to create ground loops. The construction of the typical TV power supply dictates special measures due to functional and safety aspects in operations.

The required measurement time strongly depends on the number and type of the external ports and modes of operation. This includes all different receiving and monitoring functions. A quickly growing matrix of tests results from these different operational modes and external ports to be tested. Assuming 20 minutes per measurement run can easily result in several hours total testing time (Table 2).

Symmetrical injection into the coax center pin of the antenna port

This test investigates the EMI suppression of signals next to the tuned TV reception channel. The EMI signal and the TV input signal are simultaneously applied to the antenna input via a power divider. The EMI signal will be applied to the picture and sound frequencies of adjacent channels. The level of EMI is dependent on the specific TV system and is specified in a table of levels. There are six different immunity checks to be performed for the particular neighboring channel:

A: Apply unmodulated signal to the video carrier

B: Apply *two* unmodulated signals ±0.5 MHz apart from the video carrier

C1: Apply an unmodulated signal to the equivalent frequency of the first sound carrier 1 kHz FM, 30 kHz frequency shift

C2: Apply an unmodulated signal to the equivalent frequency of the second sound carrier 1 kHz FM, 30 kHz frequency shift

D: Apply a modulated signal to the video carrier of 1 kHz AM and 80 % modulation

E: Apply a modulated signal of 1 kHz AM and 80 % modulation within the frequency range 26 to 30 MHz

This test directly specifies the TV quality with respect to the input front end selection.

Asymmetrical injection into the antenna port onto the coax braid

The amplitude modulated EMI current (80 %, 1 kHz) is injected into the shield of the antenna cable via a 100-ohm resistor. This simulates EMI coupling to a long antenna cable. In particular, in a frequency range of nearby CB, radio controlled toys, and amateur radio stations operating between 26 and 30 MHz (10 m band), this test becomes important.

If this disturbance occurs, the reason is a faulty ground concept. Often the tuner chassis is bonded via a large impedance to the ground of the TV boards. Coupling can now easily take place to sensitive components of the TV.

TV-Mode \ Network Input		1 AC-Power Port	2 Head-Phones	3 External Speakers	4 Audio Inputs SCART	5 Audio Inputs Front	6 Audio outputs SCART	7 S-Video	
1	ANTENNA BAND I/PAL	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	→
2	ANTENNA BAND III/PAL	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	
3	ANTENNA BAND IV/PAL	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	
4	ANTENNA BAND V/PAL	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	
5	AV 1	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	
6	AV 2	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	
7	FRONT	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	Picture: Sound:	
↓									Test Result

Table 2. *Test Matrix of a Sample TV with a Higher Order of Operational Modes and Ports. The test time needed for a complete run of this 7 x 7 matrix is 16.5 hours.*

PRACTICAL EXPERIENCE

With the ever-growing proliferation of digital technology in TVs, a decrease of immunity problems compared to the old analogue technique has been noticed. This is caused by the threshold in digital technology which the interfering signal has to overcome to trigger malfunctions. Emissions, however, are rising due to faster clocks and processors occupying a broader spectrum range.

These factors may even introduce a functional problem within the TV set itself. Technologically speaking, mass-produced items like TV sets are very cost-sensitive, in many cases leading the manufacturers to use dual-layer printed circuit boards. Multilayer boards, however, may save up to 20 dB in emissions. Being more expensive themselves, they add little cost from a global production perspective. Unshielded connectors and cables within the set also contribute to emissions.

As far as immunity is concerned, the selectivity of the various boards of the TV is important. Strong coupling will normally take place in fairly narrow frequency bands. In order to precisely locate these spots, the test house has to sweep through in small frequency steps, resulting in considerably increased test time and consequently, costs. One gets a general idea of the immunity behavior of a TV test at those critical frequencies by

1. Applying the harmonics of the first input frequency of the video, first and second sound and chroma carrier,
2. Applying the harmonics of the video and sound IF frequencies
3. Testing the interaction with frequencies of short wave, FM, UHF, and mobile telephone frequencies up into the GHz range.

Additionally, the importance of a high quality test report should not be underestimated! The test report serves as a CE compliance indication and is a valuable tool and reference for the design engineer. The report should include test specifications, setups, equipment, documented test results from automated procedures, etc.

A legal requirement in Europe for demonstrating compliance in the production process is the 80/80 rule for emissions. This means that 80% of a production lot must meet the emission limits with an 80 % degree of probability. The statistical sampling must be performed very carefully because of the enormous costs involved. Many large TV manufacturers produce several millions of TV sets a year.

CONCLUSIONS

EMC testing according to the present legislation and CE requirements are sometimes very time-consuming and tedious. The standardization process is moving towards including additional immunity requirements like ESD and BURST. The old and well-known emissions testing to protect a radio frequency spectrum is still important because modern digital technology interferes with a wider spectrum range.

The immunity of TVs as a central element in modern entertainment electronics in the living room can account for typical EMI phenomena, particularly with the proliferation of mobile phones (GSM, DECT etc.). For TV manufacturers and distributors, as well as for the few specialized (accredited) EMC test labs, it is not only the specific EMC test equipment which is important but rather the know-how of the EMC test engineer. To maintain an attractive external test service, the organization must be capable of providing immediate retrofits and qualification solutions for problematic circuit boards with due consideration to cost and production.

The typical time needed to perform TV emission testing amounts to between five and six hours. Immunity, however, requires 28 hours for a typical TV according to the 7 x 7 matrix. This time does not include the preparation of the test report.

This information explains why the non-EU member states and industries are reluctant to implement legal immunity requirements for TVs. In the long run, however, there is no choice because modern technology calls for additional protective measures. Furthermore, it does not make sense to put up trade barriers and run different production lines to service diverse international markets and clients.

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