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EMISSION TEST SOLUTION DEVELOPMENT FOR TABLET COMPUTERS

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ABSTRACT

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The objective of this master's thesis was to study authority requirements of a tablet computer, and find out a method which can be used for measuring electromagnetic interference in a research and development environment. This master's thesis was commissioned by Aava Mobile Ltd.

The thesis covers electromagnetic compatibility authority requirements. First generally global and country specific compliance for requirements, then focusing particularly on Tablet Computer related requirements of dedicated operating environment. The arrangement of a pre-compliance test site covers the radiated and conducted interference measurements for information technology, industrial, science & medical, and vehicle emission requirements.

The test site of radiated emissions was built by applying the CISPR standard. Because the measurement distance was different than the standards requires, the measurement uncertainty was eliminated by the calibration. The test arrangement for conducted emissions from AC –mains and from telecommunication ports were carried out according to the official standards and methods.

In both measurements, radiated and conducted emissions, a spectrum analyzer was used as a test receiver. The measurement data was collected by the test software from the spectrum analyzer, then the test data was calculated with the required calibration values, and finally, the emission data was converted to correspond to the official test results

The achieved pre-compliance test arrangement gives a quick response for finding emission problems of a product in an early phase of a developing process. When the test set up is properly built, the pre-compliance testing reduces the risk of failing the official country certification tests.

Keywords:

EMC, Radiated Emissions, Conducted emissions, Pre-compliance testing, Type approval tests

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TERMS AND ABREVIATIONS

Antenna Factor	Ratio of the electric field strength induced to the terminals of antenna
Bi-conical antenna	A broadband dipole antenna made of two conical conductive objects
Conducted Interference	Interference resulting from conducted noise or unwanted signals entering a transducer or receiver by direct coupling
Coupling /Decoupling Network (CDN)	A decoupling network is used to measure RF emission of transmission line. Commonly used also for immunity testing.
Electromagnetic interference	Electromagnetic energy from sources external or from electrical equipment that adversely affects equipment by creating undesirable responses.
Far Field	The regions in space where the power flux density from an antenna obey an inverse square law of the distance.
Immunity	The property of a receiver or any other equipment or system enabling it to reject a radio disturbance.
OATS	A test facility located outdoors used for radiated emissions testing.
VCCI	Voluntary Control Council for Interference by Information Technology Equipment and Electronic Office Machines.

1 INTRODUCTION

The information technology has revolutionized products. The products have become complex systems which combine hardware with different sensors, data processing and storage, and connectivity to other devices in different ways.
The competition in information technology industry has caused an increasing demand and dependence to use on the use of high speed transmission technologies in applications and computer networks. As the number of these applications and amount of devices increases, there is an increase in electromagnetic radiation of the electromagnetic spectrum in which these systems operates.

The tablet computer contains the newest technology of a cellular modem for radio communication and in addition, it includes all short range radio options, like WLAN, Bluetooth radio, and Near Field Communication (NFC). The device can also be connected to an Ethernet network, or to an external monitor through the high speed interface. This transmission and communication have potential to interfere other electronic devices or systems. Because of the development, the testing of electromagnetic emissions has an increasingly important role in product development of mobile devices.

In the whole product development process the significant bottleneck has been a verification of Electromagnetic Compatibility (EMC). Since the EMC problems are difficult to find and identify, the EMC related problems often appear too late, in the worst case during official type approval tests, when the company is already in the critical path with product launch and customer deliveries. In this phase product changes are time-consuming, and expensive. The product change usually causes extra layout rounds or the process of a new component approval and it might be affect mechanical design as well. These operations will show as delays in product releases. The extra production rounds will increase costs and decrease the sales margin of the product respectively. Thus, the focus of the emission measurements should be set in the beginning of the product development phase. When potential interference problems have been detected in the early stage, the problems can be fixed properly and the delays in the product development process can be avoided. Then the product will come on the market in the planned schedule.

Small or middle-sized product developers do not necessarily have the test facilities to execute an electromagnetic interference testing according to the official standards. In this master's thesis the aim was to find a cost effective way for verification of electromagnetic interference.

2 ELECTROMAGNETIC INTERFERENCE

Electrical device produces unwanted radio-frequency energy. Every digital device has the potential of causing interference to other electrical devices. There are two basic types of fields: electric and magnetic. Actually, the word electromagnetic consists of two those root words. According to Maxwell's equations,*" a time variant within a transmission line develops a time varying magnetic field, which gives rise to an electric field. These two fields are related to each other mathematically. Time – varying current exists in two configurations, magnetic sources and electric sources"* [1].

An example of a magnetic source configuration is shown in figure1.Current is flowing in this circuit around the closed loop, the signal trace and the return loop

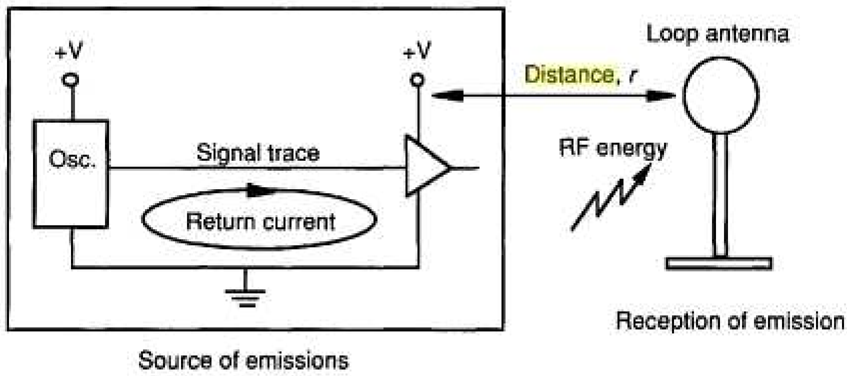


FIGURE1. *RF transmission of magnetic field [1]:*

The fields produced by the loops are a function of four variables [1]:

1. Current Amplitude loop; the field is proportional to the current.
2. Orientation of the loop antenna; for a signal to be observed, polarization of the source loop current should match that of the measuring device
3. The size of the loop; if the loop is smaller than the wavelength of the generated signal, the field strength will be proportional to the area of the loop. The larger the loop, the lower the frequency observed at the terminals of the antenna.

4. Distance. The distance determines whether the field created is magnetic or electric dominant. When the distance is electrically close to the loop source, the magnetic field falls off the square of the distance. When the distance is far the plane wave is observed. This plane wave falls off inversely with an increasing distance (1/r).

The electronic source is modeled by a time –varying electric dipole. This means that two separate, time-varying point charges of opposite polarity exist in close proximity. The ends of the dipole contain change in electronic charge [3].

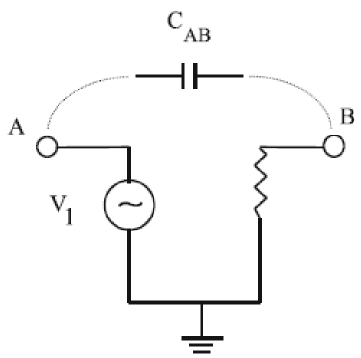


FIGURE2. *Electric field (dipole antenna);*

The fields created by this electric source are a function of four variables:

1. Current amplitudes in the loop; The fields are proportional to the amount of current flowing in the dipole
2. Orientation of the dipole relative to the measuring device. This is equivalent to the magnetic source described above.
3. Size of dipole. The fields created are proportional to the length of the current element. For a specific physical dimension the antenna will be resonant to a particular frequency.
4. Distance; Electronic and magnetic fields are related to each other. Both field strengths fall off inversely with distance. In the far field behavior is similar to that of the loop source.

The relationship between near field and far field, also magnetic and electric components, is illustrated in figure 3.

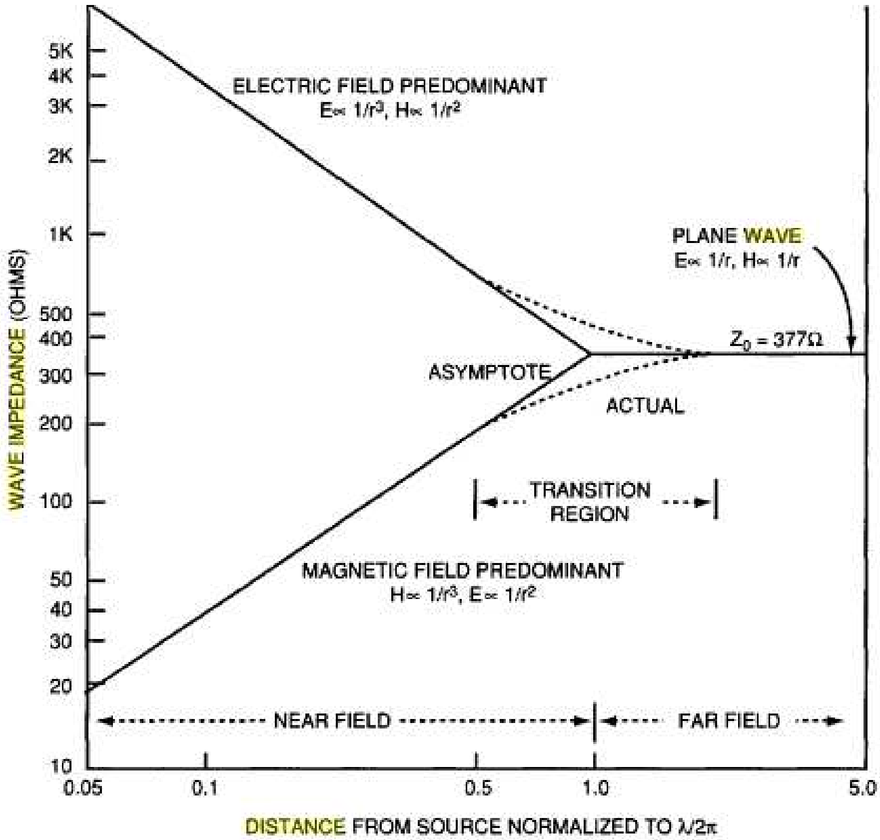


FIGURE3. *Wave impedance versus distance from E and H sources [1]*

All waves are a combination of electric and magnetic field components. The ratio of the electric to magnetic field strengths (E/H) is called wave impedance. The wave impedance is a key parameter of any given wave as it determines the efficiency of coupling with another conducting structure. In a far field (d> λ /2π) the wave is called as a plane wave and the E and H field decay with distance at the same rate. Therefore the impedance Zo is constant, and it is equal to the impedance of free space given by equation 1.

EQUATION1

$$Z_o = E/H = \sqrt{\mu_o/\varepsilon_o} = \sqrt{\frac{4\pi 10^{-7}\ \mathrm{H/m}}{\frac{1}{36\pi}(10^{-9})\ \mathrm{F/m}}} = 120\pi \text{ or } 377\text{ohm}$$

In the near field, (d < λ /2π), the wave impedance is determined by the characteristics of the source. A low frequency, high voltage radiator will mainly generate an electronic field of high impedance, while a high current, low voltage radiator will mainly generate a magnetic field of low impedance. [1]

2.1 Emission

Emission is every electromagnetic disturbance that is produced by the electrical device to the environment. For example, the tablet computer emits the communication signal and the WLAN router receives it. This kind of emission is needed for the correct operation between devices. However, most electronic devices also produce a lot of emissions that are not necessary for the operation. These emissions may disturb the normal operation of another electronic device.

This unintended emission can spread over a whole frequency range, starting from the power network frequency 50Hz up to several GHz. The signals can be radiated when the signals are transmitted thought the air. The other way is conducted emission when the signals are transmitted along cables.

Every government and the industry bodies control these unwanted emissions. To guarantee the proper operation of other equipment, the conducted and radiated emissions must be limited.

2.2 Immunity

With the increasing popularity of broadcasting, rules to prevent radio interference and equipment malfunctions have become necessary. Because the functionality of electronic devices has become more complex, the likelihood of unexpected system failures increases. In some cases disturbance may be no more than nuisance, in others it may be economically damaging or even life threatening.

Electronic devices will be susceptible to environmental electromagnetic fields and to disturbances coupled along cables. The potential threads are magnetic or radiated fields, conducted transients, electrostatic discharge and disturbances that are connected to supply voltage or connected cables. When these effects are recognized in the early phase of a product design, the needed modifications can be done in a cost-optimized way. Then the reliability will be improved and the field returns will be reduced.

3 REQUIREMENTS

The term EMC has two complementary aspects. First, it describes the ability of electrical system to operate without interfering with other systems and second it describes the ability to operate within a specified electromagnetic environment

“EMC standards have been created to facilitate the industry, consumers and the authorities by defining common rules for the products. Standardization creates a better compatibility and safety for products, while it protects users and the environment. EMC Directive defines the requirements for the product which must be met before the product is placed on the market” (Siira, 2014)

Depending on the user environment, the EMC Directives order what standard the device should follow. Thus, requirements for industrial environment are different for the ones for the hospital environment. There are also specific requirements for electronic equipment in vehicles. The classification of the product is defined in product standards.

3.1 International EMC standards

The leading electro-technical global standardization organization is the IEC (International Electro-technical Commission). The IEC prepares and publishes for all electrical, electronic and related technologies. It also promotes international cooperation related matters of electro-technical standardization [5].

The EMC standards are defined in the technical committees of IEC / CISPR and IEC/ TC77. CISPR (International Special committee for radio Interference) is mainly focused on measuring emissions and the Technical committee 77 (*TC77),* is focused on the immunity test standards and requirements There is also the Advisory Committee on EMC (ADEC), whose task is to prevent the development of conflicting standards[5].

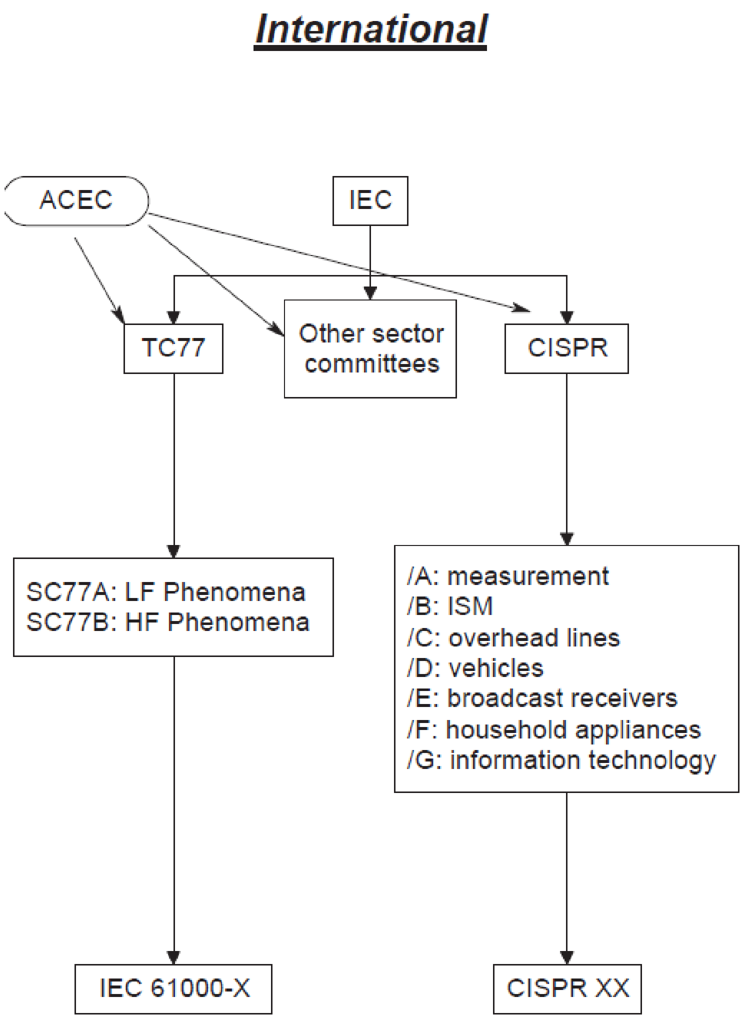


FIGURE4. *International EMC standards structure [4]*

3.1.1 TC77

The main task of TC77 is to prepare Basic and Generic EMC publications specifying electromagnetic environments, emissions, immunity, test procedures and measuring techniques. The major output of TC77 is the various parts of the IEC publication 61000 which is described in table 1 [4].

TABLE 1. *IEC 61000 publications*

IEC 61000-1	GENERAL General considerations (introduction, fundamental principles, functional safety) Definitions, Terminology
IEC 61000-2	ENVIRONMENT Description of the environment, Classification of the environment Compatibility level
IEC 61000-3	LIMITS Emission limits Immunity limits
IEC 61000-4	Testing and measurement techniques
IEC 61000-5	Installations and mitigation guidelines, mitigation methods and devices
IEC 61000-6	Generic standards
IEC 61000-9	Miscellaneous

3.1.2 CISPR

The CISPR publications (International Special Committee on Radio Interference) deal with the limits and measurement of the radio interference characteristics of potentially disturbing sources. There are a number of subcommittees as shown in table 2. Although all the output of CISPR subcommittees is nominally product related, several of the emissions standards –particularly CISPR11, -14 and -22 have assumed wider importance since their limits and the methods are referred to many more product standards [5].

TABLE2*.Structure of CISPR [4]*

Committee	Title	Main Publications
CISPR/ A	Radio-interference measurements and statistical Methods	CISPR 16, CISPR17
CISPR/ B	Industrial, Scientific and Medical radio-frequency apparatus	CISPR 11, CISPR19 CISPR23, CISPR28
CISPR/ C	Overhead power lines, high voltage equipment and electric traction systems	CISPR 18
CISPR/ D	EM disturbances related to electric and electronic equipment on vehicles and devices powered by internal-combustion engines	CISPR12, CISPR21, CISPR25
CISPR/E	Broadcast receivers	CISPR 13, CISPR20
CISPR/ F	Interference relating to household appliances, tools, lighting and similar equipment	CISPR 14, CISPR15
CISPR/ G	Information technology	CISPR 22, CISPR24
CISPR/ H	Limits for the protection of radio services	

The product standards include the limits and methods of measurements. The product classification is shown in the table below.

TABLE3. Product classification

Type of Electronic equipment	Product standard EU	US
Information technology equipment (ITE)	EN55022. EN55024	FCC CFR47, Part 15
Industrial, Scientific, Medical electrical equipment (ISM)	EN55011, EN60601-1.2	FCC CFR47, Part 18
Broadcast Receivers	EN55013, EN55020	15.117, FCC 05-190
Household, Appliances, Tools	EN55014-1, EN55014-2	FCC CRF47, Part 15.103
Radio Equipment	EN 301489-1	FCC 47CFR Part15 "Radio frequency devices
Automotive equipment ISO-7637, ISO-11451-x, ISO-11452-x	95/54/EC	SAEJ1113
Military equipment	MIL-STD-461	MIL-STD-461

3.1.3 Generic Standards

In the early days of the EMC directive, there were many industries where no product specific standards had been developed. The General Standards were created to cover this lack of standards. These standards are not related to any particular product or product family. Where a relevant product-specific standard exists, this takes precedence over the generic standard. IEC has issued four generic standards: IEC 61000-6-1, 2, 3, and 4, which specify emission and immunity requirements for two classes of equipment: “industrial” or “residential, commercial, and light industrial.” [13].

TABLE4. *IEC Generic Radiated Emissions Requirements (Electric Field).*

Standard	Frequency	Environment	Limit	Distance	Reference Standard
IEC 61000-6-3	30 – 230Mhz	Residential	30 dB µV/m	10m	CISPR 22
	230- 1000Mhz		37 dBµV/m	10m	
IEC 61000-6-4	30 – 230Mhz	Industrial	30 dBµV/m	30m	CISPR 11
	230- 1000Mhz		37 dBµV/m	30m	

The emission limits are defined separately for residential areas and industrial areas. These two areas have different classes of limits: class A represents the industrial environment; class B defines the limits for residential commercial or light industry areas. [13]

3.2 EMC requirements in European Union

The governing bodies in the European Union with respect to EMC include the IEC, CISPR, and the European Committee for Electro technical Standardization (CENELEC). The IEC coordinates international standardization and related matters, while CENELEC and CISPR are largely responsible for approving detailed EMC standards to demonstrate compliance with the EMC Directive. [6]

If a product is sold in the European Union, it must be in compliance with the EMC Directive, 89/392/EEC. Products that meet the EMC directive carry the “CE” marking that signifies the manufacturer’s assertion of compliance (Figure 5). The CE is an acronym for the French “Conformité Européenne.”

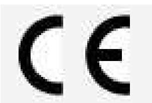


FIGURE5. *European Union “CE” Compliance Marking*

3.2.1 R&TTE Directive

All telecom terminal equipment (TTE) and all radio equipment are included in The Radio &Telecommunication Terminal Equipment Directive (99/5/EC) and it displays the EMC directive for this equipment. This R&TTE directive establishes a regulatory framework for the placing on the market, free movement and putting into service in the Community of radio equipment and telecommunications terminal equipment.
In R&TTE directive the following essential requirements are applicable to all apparatus [14]:

1. The protection of the health and safety of the user and any person, including the objectives with respect to safety requirements contained in directive 73/23/EEC
2. The protection requirements with respect to electromagnetic compatibility contained in directive 89/336/EEC

The R&TTE directive (article3) identifies the essential requirements when the apparatus is placed on the market. The CE mark indicates the conformity of the apparatus with all provisions of the directive, including the conformity assessment procedures [14]

Countries not belonging to the EU are divided into those that follow the same rules as EU member states and those with a completely different legislation [16]. The restrictive countries in Europe are Russia, Ukraine and Moldova. In these countries it requires a close cooperation between manufacturers and a local importer. The factory inspections are requested, and manufacturers and exporters have to submit samples for in-country testing. In these countries the regulations are similar to EU directives and the European standards are generally accepted.

3.3.2 Low voltage directive (LVD)

As a part of the emission and immunity requirements, there are mandatory requirements for safety. The safety standards have been designed to assure the component or equipment safety. The objective of the Low Voltage Directive 2006/95/EC (LVD) is to guarantee that electrical equipment in the EU market does not endanger the safety of persons, domestic animals or property when properly used, installed and maintained. The directive is applied to all risks caused by the use of electrical equipment. The directive presents the essential safety goals that all electrical equipment must meet in order to be placed in the EU market. In accordance with the EU's harmonization legislation, the directive also ensures the free movement of compliant electrical equipment [7].

3.3. United States & Canada

In the United States radio frequency interference requirements are controlled by the FCC (Federal Communications Commission) [11]. The FCC imposed legal limits on electromagnetic emissions produced by commercial digital equipment in response to the increased number of systems that were interfering with wired and radio communications. The requirements for radiation devices are detailed in CFR 47, (Code of Federal requirements) part 15. There are two sets of limits, one for residential areas and a second for industrial areas. The industrial, scientific, and medical (ISM) devices are detailed in CFR 47, Part 18. [11].

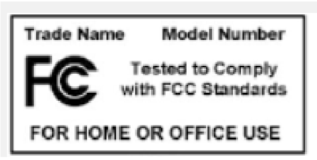


FIGURE6. *example of of FCC type label*

The safety requirements

In North America the safety certification organization is US Underwriters Laboratories Inc. (UL). Most UL's safety standards are IEC based and as a result closely adhere to international requirements as well as meeting United States and Canada (CSA) requirements. The applicable safety standard depends on the product classification. The equipment that is used as an information technology device is applicable with in UL 60950-1 standard. It covers also equipment which are designed for use as telecommunication terminal equipment and network infrastructure equipment, regardless of the source of power.

"The UL 60950-1 standard and tests take into account not only normal operating conditions of the equipment, but also likely fault conditions, consequential faults, foreseeable misuse and external influences such as temperature, altitude, pollution, moisture, as well as over-voltages on a mains supply, telecom network, or cable network" [12].

UL certification mark [12]

CSA certification mark

3.4 EMC framework in Australia/New Zealand

The EMC requirements in Australia and New Zeeland have a very similar approach to Europe, giving manufacturers more responsibility in the marketing of their products. The authority for all related matters is the Australian Communication Authority (ACA). All standards for Australia are based on international or European standards. Unlike the requirement in Europe, the immunity testing is required only for radio and broadcast devices. For another electrical devises only emission requirement is applied. The ACA introduced the C-tick mark as its conformity mark. The C-tick mark shows compliance with regulations for all electronic devices that are sold in Australia or New Zeeland [13]

C-tick mark

3.5 China Compulsory Certification CCC

In China the national standard is called Guobiao,(GB). Most of the GB- standards are harmonized to an IEC standard. In the Information Technology area GB4943 is harmonized to IEC60950 in product safety and GB9254 is harmonized to IEC/CISPR 22 for electromagnetic emissions [23].

Generally, if the IEC tests are passed, the CCC requirements should be fulfilled too. The manufacturers often save time and costs by transferring a CB report to a CCC report. An application is submitted to certification bodies. Once the application is accepted, the manufacturer has samples tested at an accredited lab in China

.

China approval mark

3.5.1 CB- EMC certificate

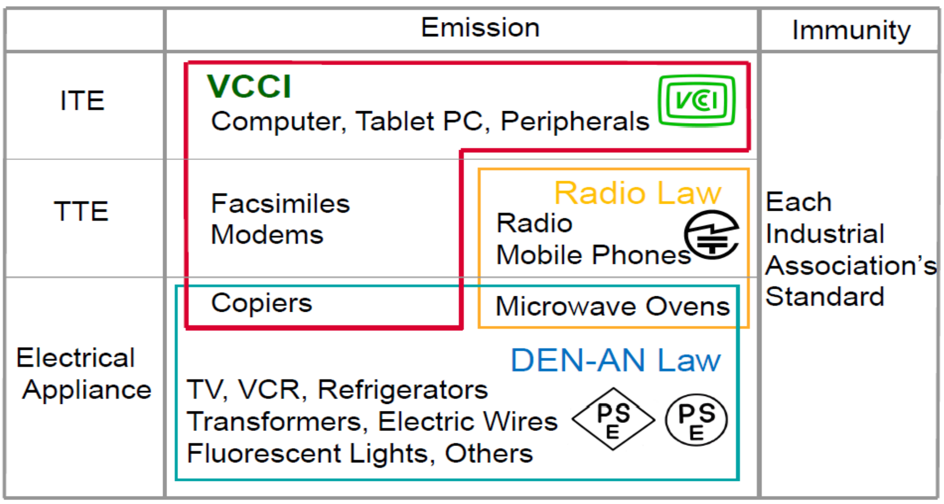
Authorities in different countries have made a reciprocity agreement with the procedures for product testing and certification. The manufacturer can apply the CB EMC approval for the device. When the tests have been completed and passed in the CB-EMC approved laboratory, the same tests need not be repeated, but they are recognized in other countries too.

3.6 Requirements in Japan

The EMC requirements in Japan are quite different. In Japan the government does not set rules for Electromagnetic compatibility. Instead, a private sector has been set the requirements called Voluntary Control Council for Interference (VCCI).

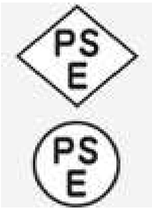
The VCCI applies to Information technology equipment (ITE) or Telecom technology equipment (TTE) [9]. The system is completely voluntary, but strongly supported in Japan. Selling equipment without VCCI registration and the VCCI mark is legally possible, but the product will fail from a marketing point of view. The VCCI standards are largely based on CISPR 22.

TABLE5. *EMC related requirements in Japan [9]*



VCCI mark

The safety issues are controlled in Japan by the PSE law. The purpose of the Electrical Appliance and Material Safety Law is to prevent hazards and disturbances resulting from electrical appliances. There are mandatory technical requirements that must be fulfilled before a company has a right to attach the PSE mark to the product.



PSE mark

4 EMISSION REQUIREMENTS FOR TABLET COMPUTER

A tablet computer contains almost the same features that smart phone provides today. It uses the same operating system than desktops, and because of versatile interfaces and accessories, it provides practically the same user interface and user convenience than desktop computers. The desired communication signals and the potential unwanted emissions are shown in figure7 below.

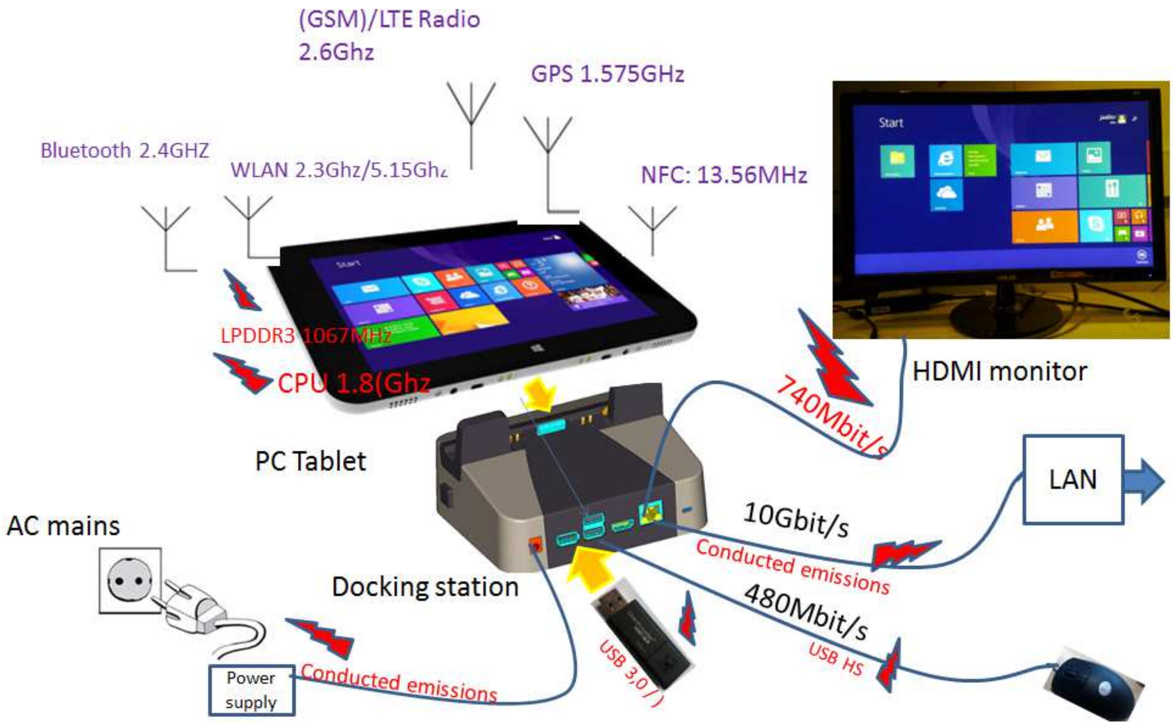


FIGURE7. *Radiated & conducted signals of PC tablet*

Based on the typical mode of operation and the operation environment, the tablet computer belongs to a category of Information technology equipment. So the device has to be compliant with the requirements of information technology equipment. In Europe the limits for radiated and conducted emissions are defined in EN55022 and also most of the countries outside of Europe have harmonized same limits and method according to the CISPR22, CISPR16, and EN55022. The conducted emission vales are measured according to a CISPR 16 quasi peak detector, but the standard requires the conducted emissions to be measured also with an average detector. The limit for the average measurements is 10dB below the quasi-peak limits.

TABLE6. Conducted disturbance at AC mains according EN55022 *[3]*

Frequency range MHz	Limits dB(μV)	
	Quasi-peak	Average
0,15 to 0,50	66 to 56	56 to 46
0,50 to 5	56	46
5 to 30	60	50

NOTE 1 The lower limit shall apply at the transition frequencies.

NOTE 2 The limit decreases linearly with the logarithm of the frequency in the range 0,15 MHz to 0,50 MHz.

TABLE7. Conducted disturbance at telecommunication ports according EN55022 *[3]*

Frequency range MHz	Voltage limits dB(μV)		Current limits dB(μA)	
	Quasi-peak	Average	Quasi-peak	Average
0,15 to 0,5	84 to 74	74 to 64	40 to 30	30 to 20
0,5 to 30	74	64	30	20

NOTE 1 The limits decrease linearly with the logarithm of the frequency in the range 0,15 MHz to 0,5 MHz.

NOTE 2 The current and voltage disturbance limits are derived for use with an impedance stabilization network (ISN) which presents a common mode (asymmetric mode) impedance of 150 Ω to the telecommunication port under test (conversion factor is 20 $\log_{10}$ 150 / I = 44 dB).

In the United States the radiated emission measurement is also done according to the CISPR22 and EN55022 but the limits are different in the United States (FCC47 part 15). The upper frequency limit is extended to a possible maximum of 40Ghz depending on the frequencies used within the device. The relationship between internal clock frequencies and the maximum measurement is shown the table 8 [4].

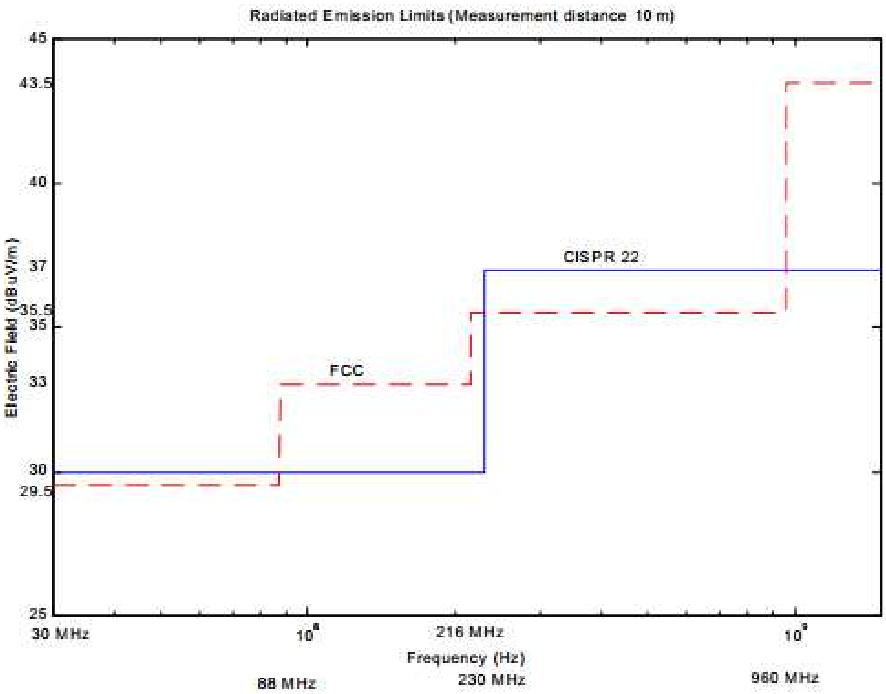


FIGURE8. *CISPR22 and FCC limits*

TABLE8. *Maximum measurement frequency FCC Rules part 15 [11]*

Highest frequency generated or used in the device (MHz)	**Upper frequency of measurement range (MHz)**
Below 1.705	30
1.705-108	1000
108-500	2000
Above 1000	5^{th} harmonic or 40Ghz whichever is lower

4.1 Radio Standards

Because the tablet computer involves a radio device, In Europe ETSI Radio standards should be applied. ETSI Radio standards cover the particular issues such as exclusion band, and arise when a general EMC requirement is applied to a radio receiver or transmitter. The EN 301-489 series of standards for radio equipment includes 29 different radio systems. The following table shows all radio standards, which are related to a tablet computer.

TABLE9. *Radio standards related to tablet computer requirements*

Device	*EMC standard (ETSI)*	*Applicable Radio Standard*	
		EU area	*United states*
Bluetooth		*EN 300 328, EN 300 328,*	*FCC 15.247, RSS-210*
WLAN / WiFi Devices	*EN 301 489-17*	*EN 300 328, EN 301 893,*	*FCC 15.247 [2.4 GHz]FCC 15.407 [5 GHz]*
GSM/UMTS Devices	*EN 301 489-7*	*EN 301 511 (GSM), EN 301 908 (UMTS)*	*FCC part 22/24*
GPS Devices	EN 301 489-3	*EN 300 440*	FCC 47 C.F.R.(2.1, 2.106)
(RFID) Devices	*EN 301 489- 3*	EN 302 291-2	*FCC 15.231 (125 kHz), FCC 15.225 (RFID)*
CDMA mobile portable devices	*EN 301- 489-24*		*FCC part 22/24*

4.2 Requirements for healtcare environment

When the electrical device is used for health care purposes, it must follow the IEC 60601-1-2, EN 55011, EN 61000-3-2, EN 61000-3-3 standards [21]. Typically the test data in European Union is accepted as an evidence that product complies with the EMC standards in the United States

EN55011 covers radiated and conducted emissions of industrial, scientific and medical appliances. The limits of the emissions are shown in figures 9 and 10. Boundary values are:

Class A: for application in an industrial field
Class B: for household and medical applications

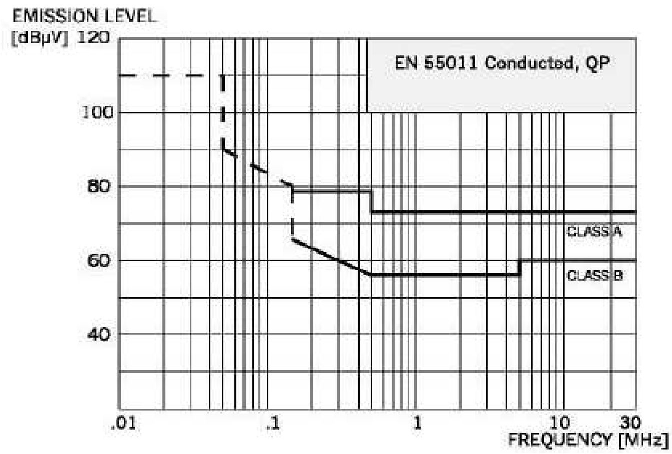


FIGURE9. *Limits for conducted emissions according EN55011*

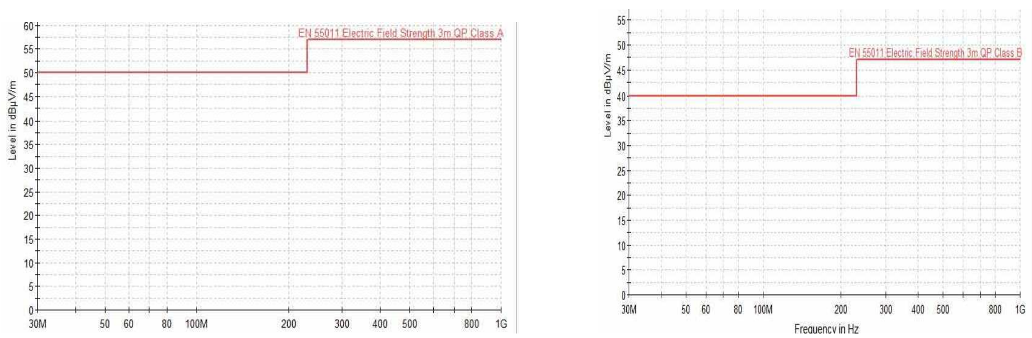


FIGURE10. *Limits for radiated emissions according EN55011 class A and class B*

4.3 EMC requirements for Vehicles

The tablet computer may also be used in vehicles. In this case, the EMC requirements for vehicle environments must be fulfilled. The International standard to be applied is CISPR 25. If the product is sold in the United States, the requirements of SAEJ1113 must be fulfilled [19]

CISPR-25 covers a wider frequency range (150 kHz to 960MHz) and has broadband and narrowband limits. The broadband limits are for measurement when the quasi-peak detector of test receiver is used (figure11). The narrowband measurement is done with an average detector (figure12). The function of detectors will be discussed in more detail in chapter 6.1.3.

The test levels are not continuous across this frequency range. Instead of being applied only to utilized radio frequency bands In CISPR-25, there are five classes of limits that can be applied. Often the customer will specify these classes.

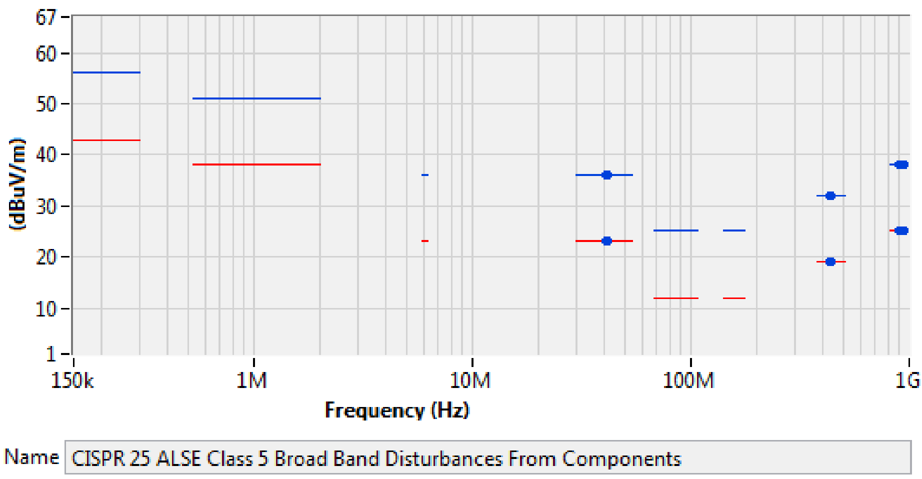


FIGURE11. *Broadband limits for emission measurements*

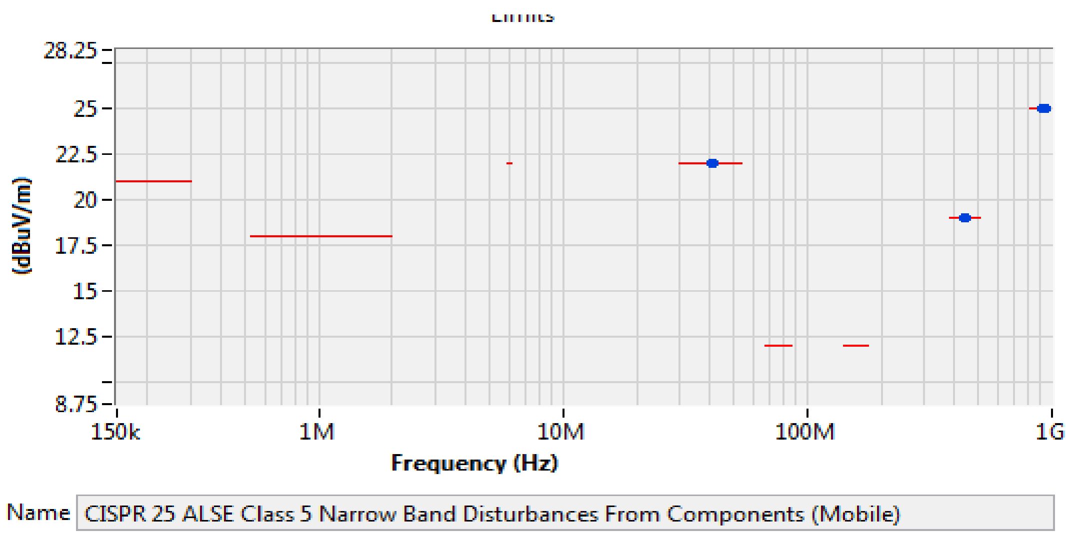


FIGURE12 *Narrowband limits for emission measurements*

5 EMC DESIGN VERIFICATION IN R&D PROCESS

5.1 Development process

The design of an electronic product should start with a thorough system design, based on the product specification. The product specifications determine features of the product under development. Each product is subject to authority regulations and standards, which are also market area specific. The use of the product defines the standards for the product, especially the safety and environmental impact.

Product regulations are constantly strained, and upon going to limit competitors' patenting of the solutions. These factors must be taken into the design boundary conditions from the start

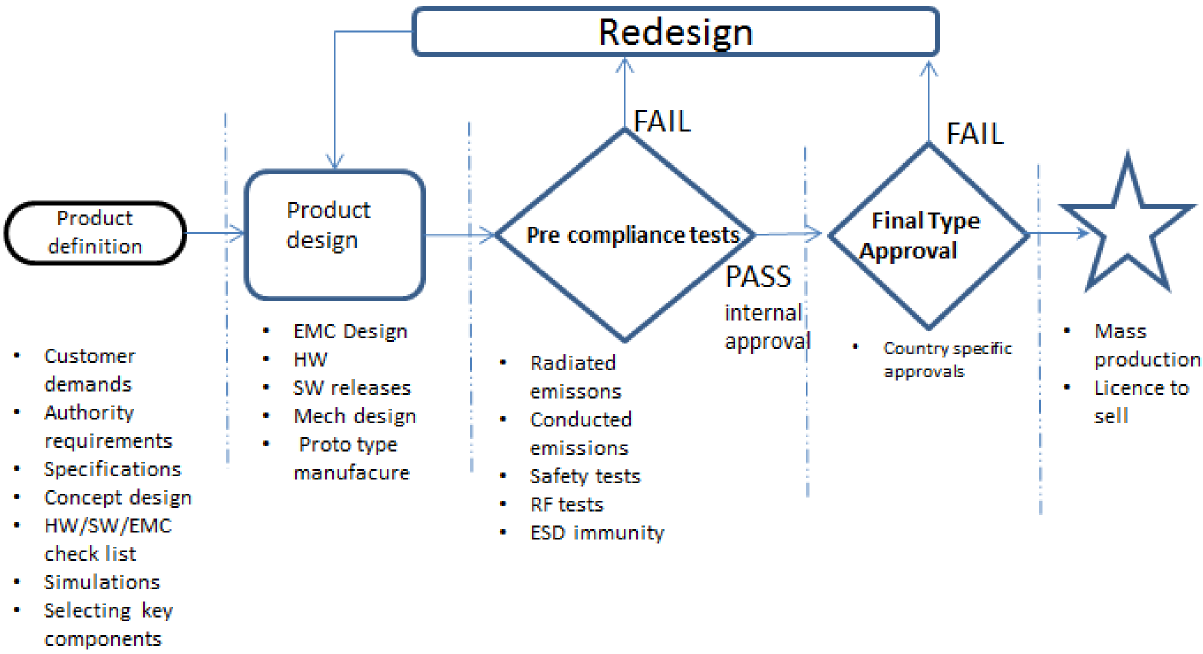


FIGURE 13. *Product development diagram*

5.2 Product Definition

The analysis during the development cycle is performed the carefully by the product designers. The analysis includes functionality, manufacturability, and compliance with various regulatory requirements, including electromagnetic interference and immunity. During the design cycle, when the hardware does not exist, the use of simulation tools is one alternative way of analysis.

The advantage of using the EMC simulation is a better predictability of failure estimations. What-if analysis is the typical way of working. It is inexpensive to make minor changes to the design just in the simulation tool and to report how the performance could be improved. This way of working is very competitive both in time and costs compared to manual laboratory work (figure14). When the bugs or poor performance issues are discovered using simulations, the design cycle may be shorten.

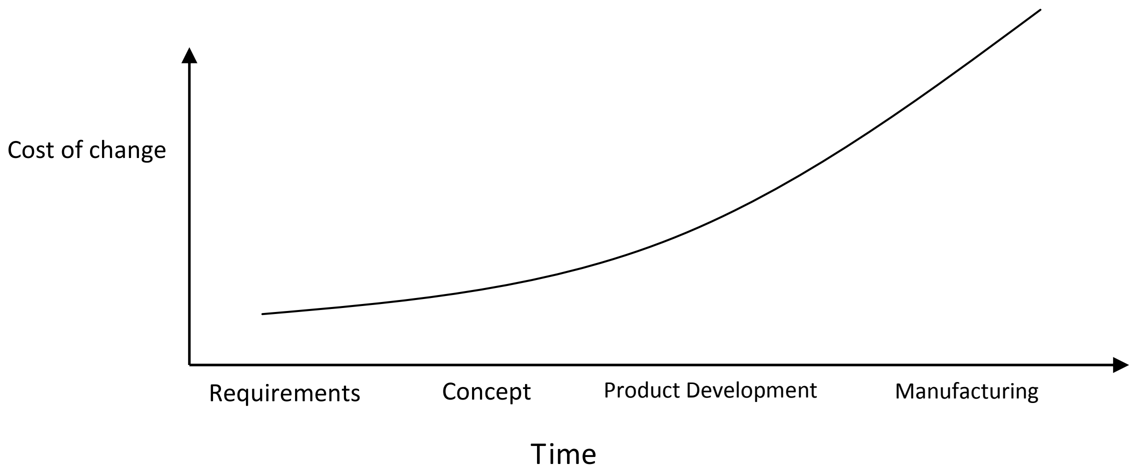


FIGURE14. *Cost of change*

5.3 EMC design

Many factors must be considered in the EMC aspects of the design. It is important that the EMC aspects are taken into account in early phase of the development process. Decisions about the product enclosure are usually the first to be made and they can dramatically impact on the success of the EMC design.

The printed Circuit Board (PCB) layout and design may be the most important factor in the ability of an electronic product to comply with the regulations on radiated and conducted emission. To avoid the loop radiation, the signal returns must ensure properly. The interference path should be kept away from sensitive circuits, and the ground impedances should be minimalized, it might be preferable to use more than one ground plane to prevent unwanted emissions. The minimization of enclosed loop area is critical especially in high currents and fast rise time of the digital signals.

The cables, inside and outside of the device may cause severe radiated emission problems. These common mode currents tend to be driven by a voltage difference on the PCB. Hence, the cable acts like an antenna and the common mode currents return to their source on the PCB. To reduce these problems the return current is isolated to the noisy ground. If the problem is a differential mode interference, the RC filter blocks high-frequency differential mode noise. Another solution to reduce electromagnetic interference is to use grounded conductive shielings to block the radiation of energy to the outside. The use of solid ground is not only reduces emissions, but also improves the signal integrity of high speed signal paths.

Electronic products today are so complex that is virtually impossible to consider all EMC issues in the design. However if attention is paid to EMC throughout the design, the major problem will be prevented. In designing there should be left options on the PCB to fix possible problems. The optional solutions should be done with a minimal impact on product cost and schedule.

5.4 EMC Verification / Precompliance Testing

The pre-compliance test discovers whether there is a concern of emission issues before the mass production phase. When the EMC verification is done during the design phase, the optimal solutions of product can be found in an effective manner. The pre-compliance tests reduce risks of failing the formal certification tests.

Pre compliance testing utilizes a full-compliance relevant method and the EMC standards, but the test procedures are less strict than in the full-compliance phase. Not testing strictly to formal test standards can save money and test time, but it is important to understand all the procedures and what errors can be introduced when not performing the tests “by the book”.

5.5 Type approval

The tablet computer has to comply with country specific requirements to obtain a regulatory of type approval. Depending on the country in which the products will be sold, the necessary processes can vary considerably and the procedure may depend on the product type.

5.5.1 Self declaration of conformity

Self-declaration is the most convenient way to handle a type approval of information technology device, radio products and short range devices. The self-declaration route is a way for manufacturers to take care of their approvals without involving any third parties. The full legal responsibility for the correctness of their statements lies with the manufacturer or the person placing a product with a wireless connectivity on the market. In order to make sure that the statements you are making are really correct, testing in an accredited laboratory might be advisable.

Self-declaration is possible in the European Union and EFTA countries, Australian and New Zeeland. [17]

Since in this case no certificates are being issued, the involvement of a certification body is not required. However the company policy of quality management leads to different interpretations of the applicable regulations and standards.

5.3.2. Classical type approval

The Classical type approval is required for certification in the USA and Canada. Testing in an accredited test laboratory is always mandatory. The product is tested to the applicable EMC standards and brought into the market with appropriate regulatory marks and statements under the vendor's or importer's authority. [10]

A classical type approval allows for less flexibility than self-declaration. Re-certification is required even for minor product changes, and demands the involvement of local authorities

6 EMISSION TEST SITE IN R&D ENVIRONMENT

It is obvious that EMC measurements are required in the research and development phase. In practice is has meant that the verification service must be ordered from on the external test house. The verification service has increased external costs of the company, and the problems have also caused the scheduling of the testing. It is often necessary to book the testing service many weeks in advance from the test house. By the ordering time there is not necessarily a clear vision, which tests in particular are needed. It is not known what is the critical test case or a combination of the accessory devices. There might also be uncertainties of software maturity. It is important to drive the critical use cases by the software when executing an emission measurement, because only this way is possible to point out the potential emission problems in the early phase of development.

To ensure the performance of the field tests the worst case situation should be tested in the pre-compliance phase. Before the measurements the dedicated applications were installed to the device for these purposes. For example, The Heavy Load" application drives the CPU to a maximum load condition. The traffic in USB bus is kept on continuous traffic between USB memory stick and the device.
The short range radios of the device are controlled with dedicated software. Bluetooth, WLAN, NFC and GPS modules transmitters can be switched on using the special application. The measurements are also done with voice or data call. The call is established by the communication tester. In a typical case the maximum power of the carrier is used.

In this thesis the target was to build the test arrangements of radiated and conducted emission measuring in a research and development environment. The purpose of test arrangements was to improve the pre-compliance process avoiding unpleasant surprises at the final compliance tests.

There were two ways to determine the errors in a pre-compliance test set up. One is to follow the same procedure as for a full-compliance test. This includes measuring the normalized site attenuation (NSA) obtaining calibration data for all equipment, cables, and antennas, and working out the measurement uncertainty calculations prescribed by appropriate test procedures. This method was used in the radiated emission measurement.

The second method was to compare test results with a known product that has been fully evaluated. The compliant system is taken from the test laboratory after the formal EMC testing, never opened or modified. This system is generally called a “golden” (reference) unit. According to the test data of formal EMC testing, the correction factor can be added to measurement results on the pre-compliance site.

6.1 Radiated emission testing

According to the official EMC regulations, the radiated emissions compliance test has been done for many years in an open area test site (OATS). In order to achieve the requirements set to the measurements, the environment must be free from obstacles and reflecting objects [25]. Both FCC and EN regulatory documents presume the use of an open-area test site (OATS) for measurements. Alternative testing facilities are acceptable providing that the data taken at such can be correlated with the data taken at an OATS.

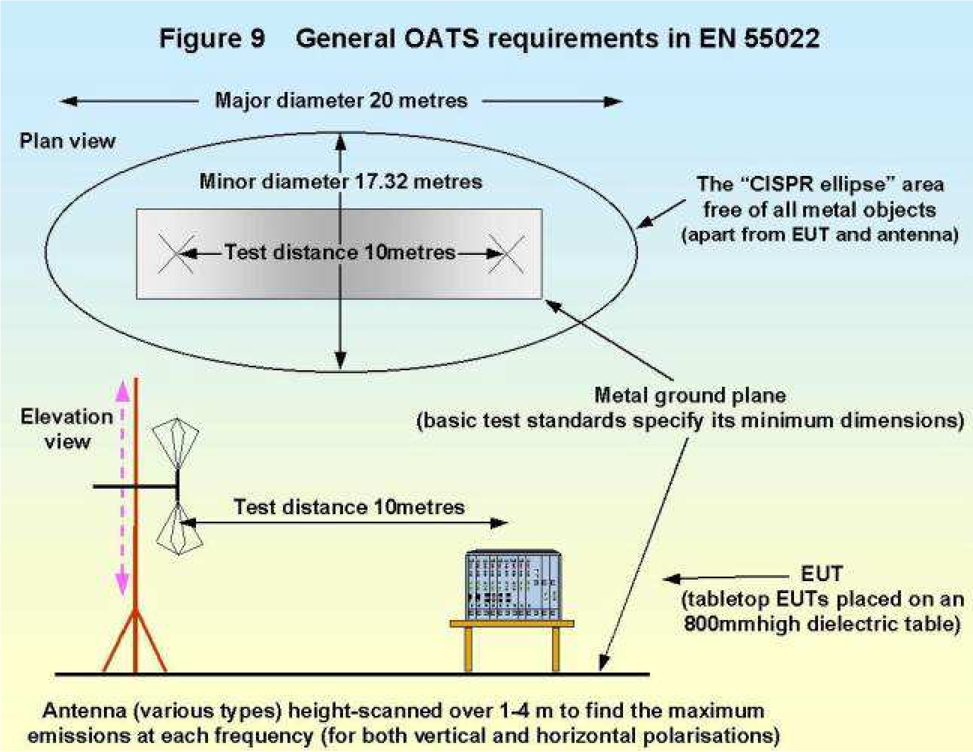


FIGURE15. *Measurement distance of OATS [3]*

In the research and development environment facilities are often limited, so there were no possibilities to build the OATS. On the other hand on investment in an anechoic chamber was not economically profitable.

6.1.1 Radiated emission test setup

The first task was to define an appropriate distance and space for the radiated emission measurement. Radio transmission needs enough space to proceed. The space depends on the wavelength. Most of the energy transmitter and the receiver proceed to an antenna formed between the ellipsoid, called the Fresnel's first zone (Figure16). When designing the radiated measuring, this zone should be kept free from obstacles. The existence of the Fresnel zone awareness is important because accessibility is a prerequisite for the unhindered propagation of radiated signals.

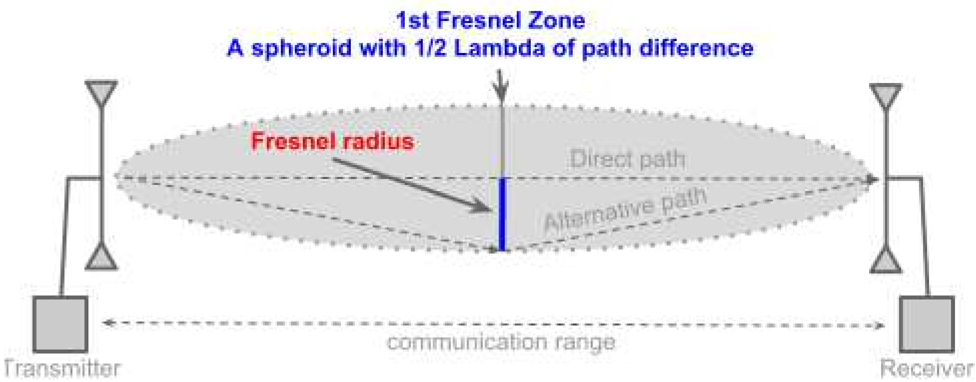


FIGURE16. *Fresnel's first zone*

The Fresnel radius can be calculated with following equation [8]:

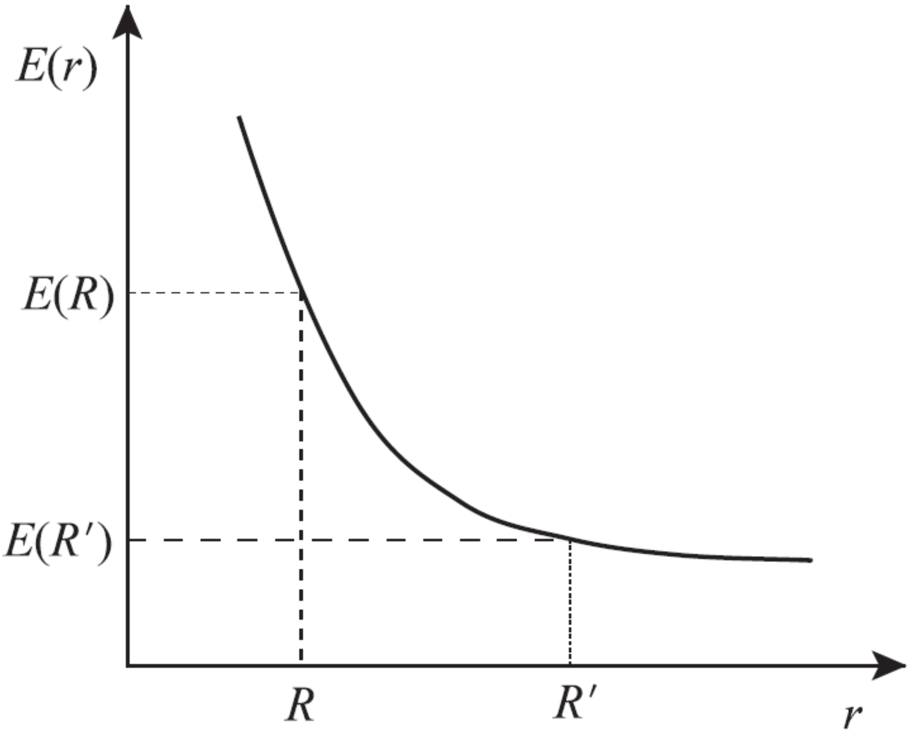
$$h_r = \frac{\sqrt{D\lambda}}{2}$$

EQUATION 1

In test laboratory conditions the suitable measurement distance is 2 meters, the required frequency ranges from 30Mhz to 1000MHz. The calculation of Fresnel radius in the lowest frequency point gives a minimum height of 4,47meters. The conclusion was to limit the range of the radiated emission starting with 100Mz, where the minimum height was suitable for a laboratory environment.

Because the distance between the product and the receiving antenna is different than the official test site, the emission levels should be converted to correspond to the official test results. This conversion is done by Inverse Distance Method.

Inverse Distance Method - an approximate technique used to translate emissions levels (or emissions limits) from one value of R to another. The far-field approximation, which states that radiated far fields decay as 1/R, is assumed in the inverse distance method [18].



$$\frac{E(R)}{E(R')} = \frac{1/R}{1/R'} = \frac{R'}{R} \qquad \Rightarrow \qquad E(R') = \frac{R}{R'}E(R)$$

EQUATION 2

$$[E(R')]_{dB} = [E(R)]_{dB} + 20\log_{10}\left(\frac{R}{R'}\right)$$

EQUATION 3

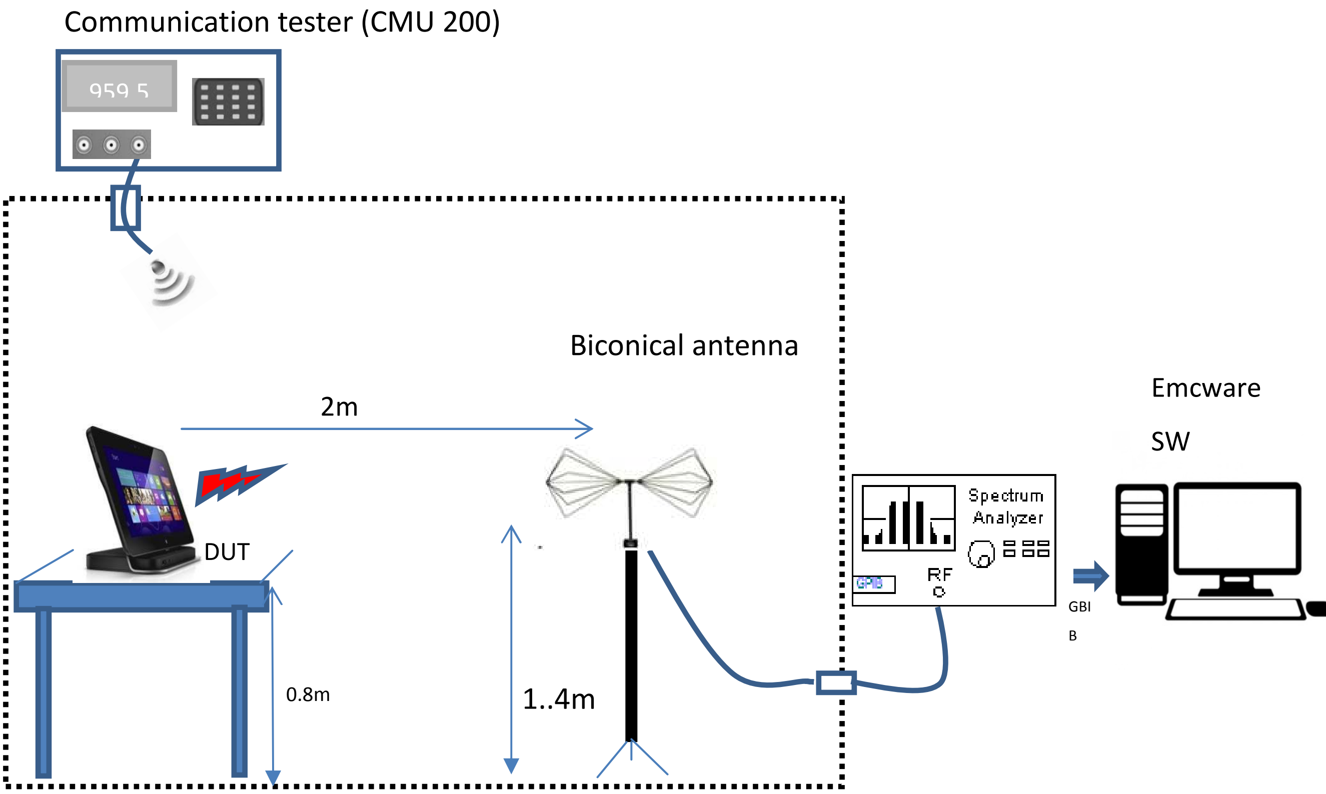


FIGURE17. *Test set up for Radiated emissions*

6.1.2 Spectrum analyzer

To measure emissions the spectrum analyzer was used as a test receiver.

The primary advantage of using a spectrum analyzer for development and product verification is that it much easier to correlate the measured results from pre-qualification analysis with those of a formal EMC test. Making the frequency domain visible enhances the ability of a design, and enables to understand what is happening and where it is occurring. The spectrum analyzer displays a spectral distribution of Radio Frequency energy.   The signal is received from a transducer, such as an antenna or probe. Figure18 shows the block diagram of the spectrum analyzer.

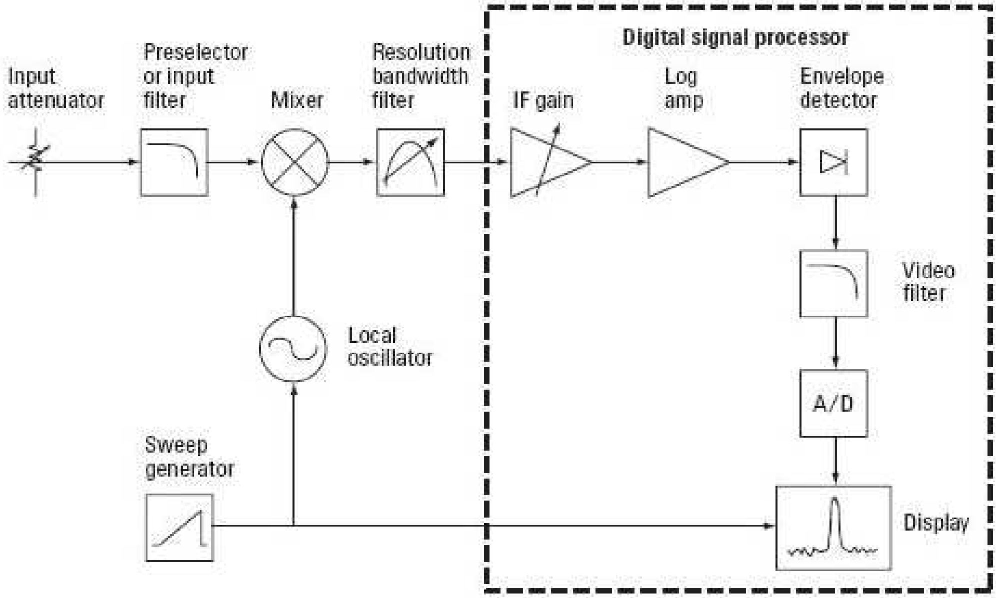


FIGURE18. *Block diagram of spectrum analyzer*

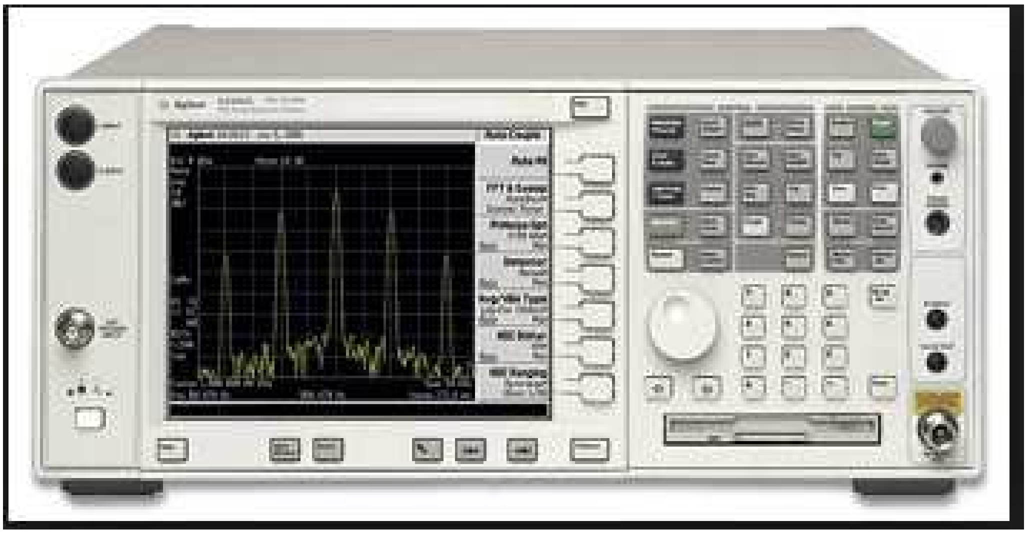


FIGURE19 *E4445 spectrum analyzer*

The parameters of the receiver bandwidth and detector response at given frequency are defined in a separated standard that is referenced by all the commercial emissions standards that are based on CISPR, Notably EN55011, EN55013, EN55014, and EN55022.

The spectrum analyzer contains three kinds of detectors in RF emission measurements: peak, quasi peak and average. The characteristics are defined in CISPR 16-1 and are different for different frequency bands.

6.1.2.1 Peak Detector

Since the signals are measured in spectrum analyses in a peak detection mode, the amplitude values are equal or higher than quasi-peak or average modes. In the development phase it is an easy process to take a sweep from the desired frequency area, and compare the results to a limit line..

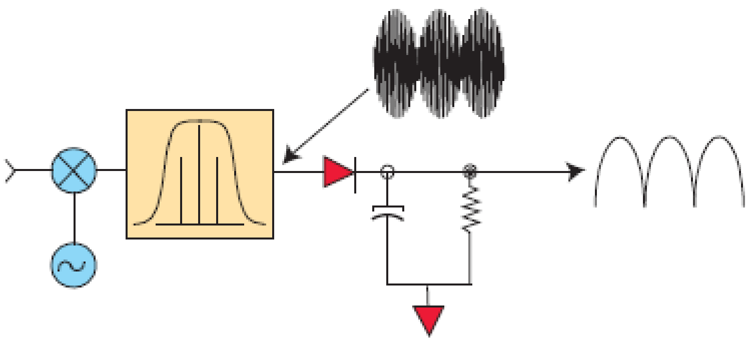


FIGURE20 *Peak detector diagram [22]*

6.1.2.2 Quasi-peak Detector

Quasi -peak measurement is a measurement technique that is used to reference heard by human interference. It is a CISPR standard technique recommended measurement, but it has a drawback of long measurement time. The Quasi-peak detector does not measure directly an average but rather a peak value The charging time constant of a Quasi -peak detector is 1ms, and the discharge time constant of 160ms. The quasi -peak detector ratio of the actual peak value response is as follows: [22]

EQUATION 4

$$\propto = \frac{\pi B_6 R_1}{F_Y R_2}$$

Where R1 is the charging resistance [Ω] ; R2 is the discharge resistance [Ω] ; B6 is a 6 dB bandwidth of approximately 0.95 * Bi , where Bi is the bandwidth of the impulse [Hz]; Fr is the impulse sets the playback speed .

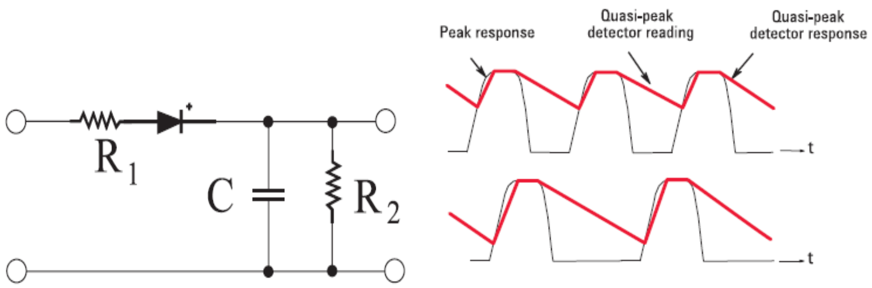


FIGURE21. *Quasi-peak detector response diagram* [22]

6.1.2.3 Average Detector

The average detector measures the average value of the signal. For a continuous signal this will be the same as its peak value, but a pulsed or modulated signal will have an average level lower than the peak. Figure 22 shows a signal that has just passed through the filter and is about to be detected. The filter averages the higher frequency components, such as a noise, at the output of the envelope detector [22].

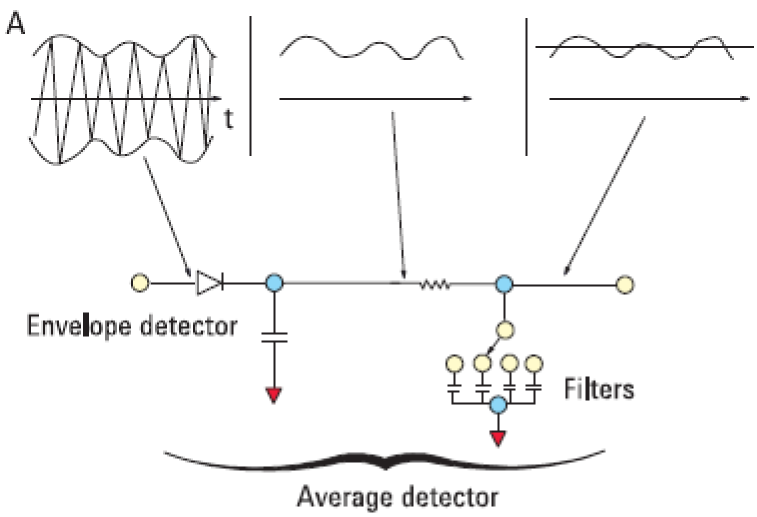


FIGURE22. *Average detection response diagram. [22]*

6.1.3 Transducers and Antennas

For radiated and conducted emission measurements, the device is needed to convert the measured variable into the input of a spectrum analyzer. Measured variables take one of the three forms, radiated electromagnetic field, conducted cable voltage, or conducted cable current. The radiated field measurements can be made either by electric (E) or magnetic (H) field components In the far field the two are equivalent, and related by the impedance of free space:

$$Z_o = E/H = \sqrt{\mu_o/\varepsilon_o} = 377\text{ohm} \qquad \text{EQUATION 5}$$

In this thesis the radiated emissions of a product are measured with a bi-conical antenna. The electric emission on the measurement antenna produces at the antenna terminals a voltage which is fed to a spectrum analyzer through the co-axial cable. The ratio of the electric field at the antenna to the bi-conical antenna is defined as the antenna factor af. [18]

$$af = \frac{\tilde{E}_{inc}}{\tilde{V}_{ant}} \qquad \text{EQUATION 6}$$

$\tilde{E}_{inc}$ – incident electric field magnitude at the antenna (V/m)

$\tilde{V}_{ant}$ – received voltage magnitude at the antenna terminals (V)

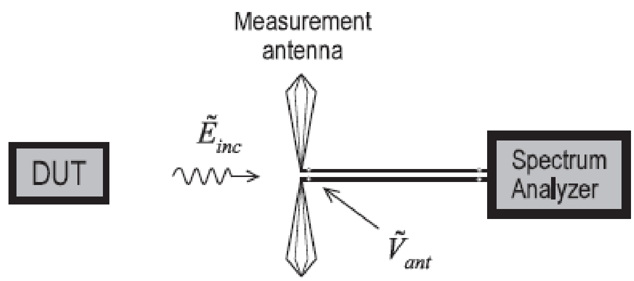


FIGURE23. *Antenna measurement*

As a ratio of the electric field to voltage, the antenna has units of /m and is normally expressed in units of [dB]. The incident electric field is referenced to 1µV/m while the received voltage is referenced to 1µV, the antenna factor can be written as:

$$af = \frac{\tilde{E}_{inc} / 10^{-6}}{\tilde{V}_{ant} / 10^{-6}}$$

EQUATION 7

The antenna factor is a function of frequency and must be known over the entire frequency range of interest. Figure24 show the Antenna factor of the bi-conical antenna which is used in the test arrangement.

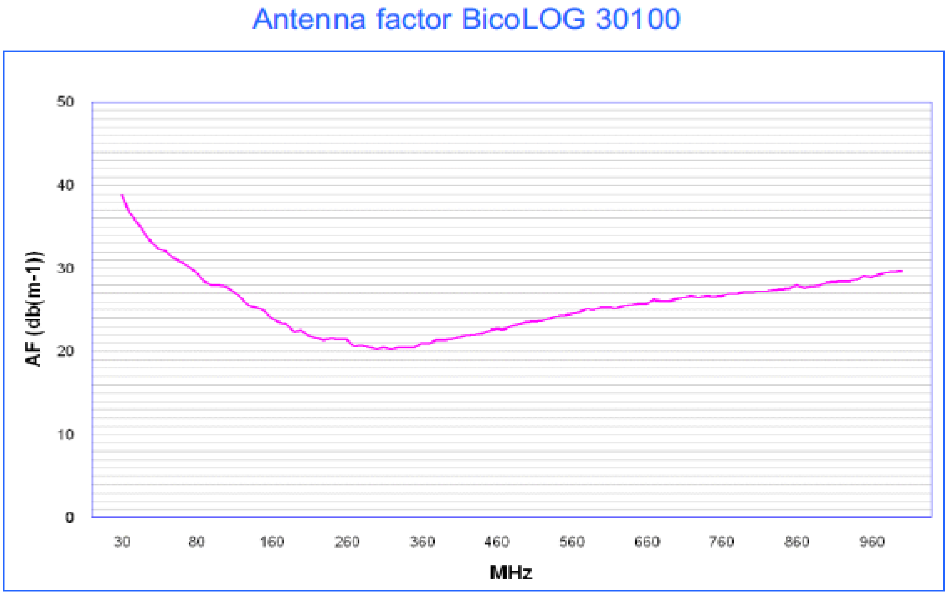


FIGURE24. *Antenna Factor*

6.1.4 Cable calibration

The cable loss was measured by a network analyzer. At first a 2- Port calibration was done. In full 2-port calibration, calibration data is measured by connecting an OPEN standard, a SHORT standard, or a LOAD standard to two desired test ports (or a THRU standard between two ports).This calibration effectively eliminates the directivity error, crosstalk, source match error, frequency response reflection tracking error, and frequency response transmission tracking error from the test setup in a transmission or reflection test using those ports. This calibration makes it possible to perform measurements with the highest possible accuracy. A total of twelve error terms, six each in the forward direction and the reverse direction, are used in a calibration [22].

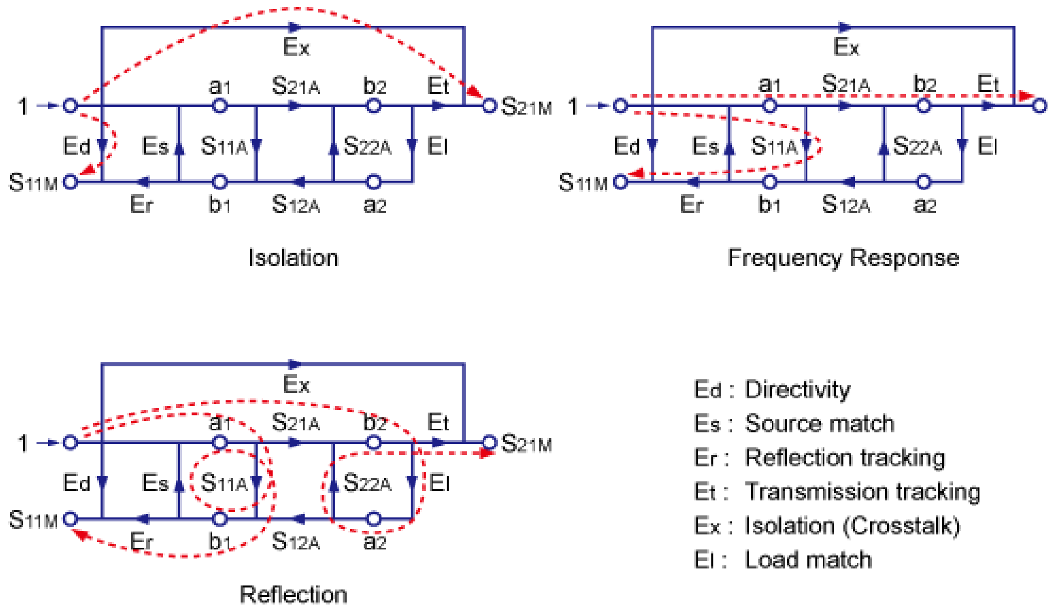


FIGURE25. *Full 2-port calibration [22]*

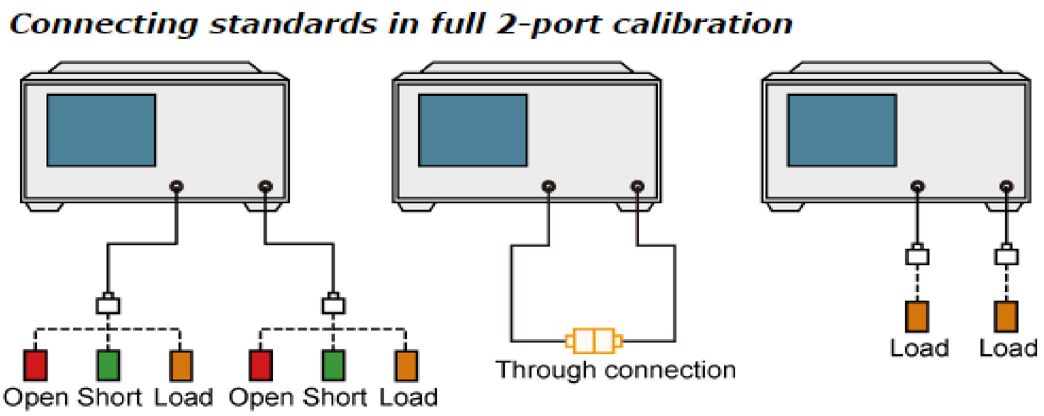


FIGURE26. *The calibration of Network Analyzer*

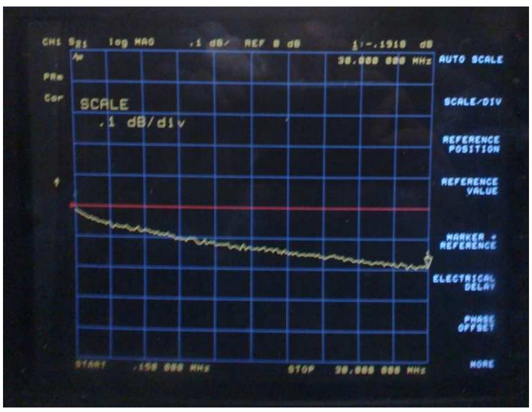


FIGURE27. *Result of cable attenuation 150khz….30Mhz*

6.1.5 Free space loss calculations

The free space loss in the desired frequency point can be calculated by the following equation:

L(dB) = 32,4dB+20logD +20log EQUATION 8

Then the signal level in the spectrum analyzer input is calculated. The gain of reference antenna in the desired frequency point is specified in the manufacturer datasheet. The antenna gain of the receiver antenna is also shown in the manufacturer data.

The results of the calculations are shown in table10 below. The completed table of the calculations is shown in Appendix 1

TABLE10 *Calculations for calibration*

Frequency	Signal Generator Level: [dBuV]	Ref antenna gain [dBd]	Free space loss L(dB) 2m distance	Receiver antenna gain dBd	Cable loss	Spectrum analyzer level CALCULATED [dBuV]
100	70	-2	**12,4**	-19,8	-0,52	**35,3**
110	70	-3	**10,5**	-18,6	-0,55	**34,8**
.						
.						
.						
. 1000	80	1	**38,4**	-1,40	-1,94	**40,15**

6.1.6 Calibration measurement with reference antenna

Calibration measurement is performed so that the known signal level of the generator is driven to a reference antenna. The reading of a spectrum analyzer over the entire frequency band is recorded. The difference values between the calculated and measured results in each frequency point are stored in the correction database. That database is used in the EMC test software as a correction factor table (table 6.15)

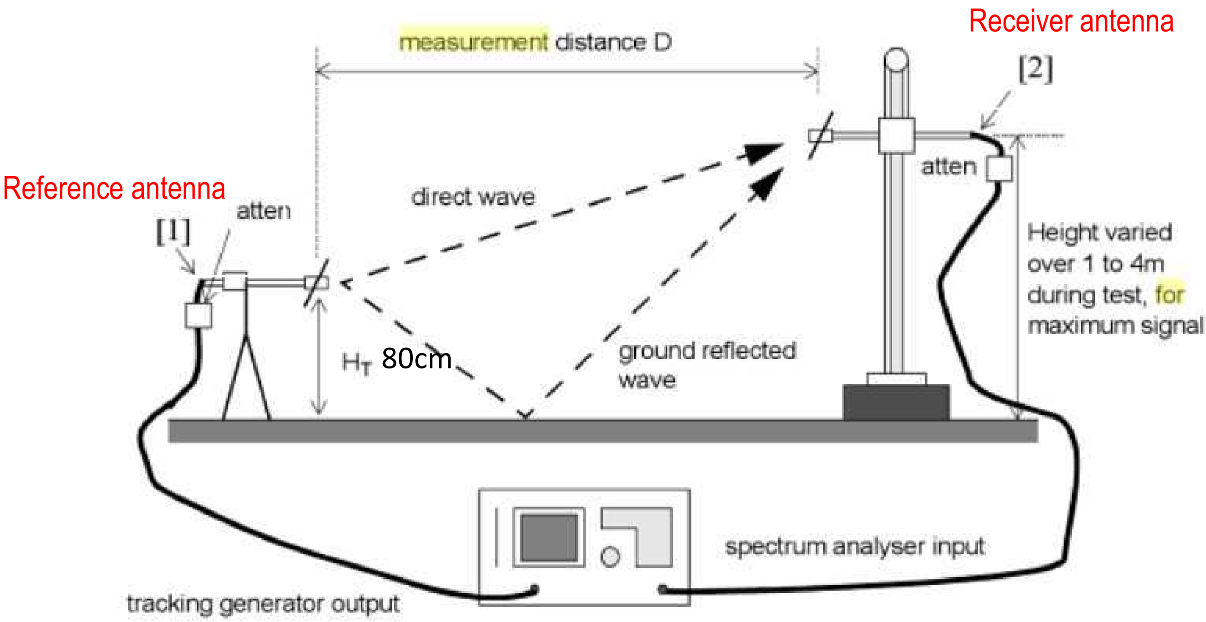


FIGURE28. *Calibration of radiated emission test site*

TABLE10. *Calibration test results*

Freq.[Mhz]	RF Generator Level [dBuV]	Ref antenna gain [dBd]	Free space Loss [dB] (2m distance)	receiver ant. Gain [dBd]	Cable loss [dB]	Spectrum analyzer Level CALCULATED [dBuV]	Test result [dBuV]	Error [dB]
100	70	-2	18,4	-19,8	-0,53	29,3	**48**	**18,7**
110	70	-3	19,2	-18,6	-0,55	28,6	**46**	**17.4**
120	70	-0	10,5	-16,7	-0,58	32,8	**45**	**-12,2**
.								
.								
1000	80	1	37,5	-1,40	-1,94	40,15	**42,00**	**1,85**

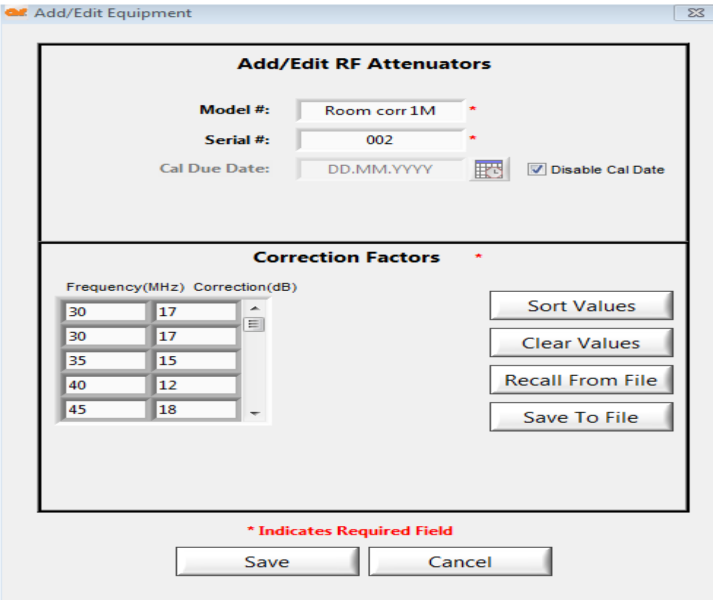


FIGURE29. *Correction factor values of EMC test software*

6.1.7 Radiated emission limits

After the correct calibration values and correlation calculation in each measurement point are put into the test software the measurement can be started. The reported measurement values are always correlated with OATS values and the results are compared with the official limits of OATS. TABLE11 presents the official limits of Information technology equipment (FCC15 and EN55022). The same correction factors can also be used when the measurement is done against the Industrial and Medical standards EN55011.

When it is measured according to the vehicle standard CIPR25, the calibration must be done separately from beginning because the measurement distance is different from the above mentioned cases.

TABLE11 *The official limits of radiated emissions*

FCC Part 15 Radiated Emissions Limits

Frequency (MHz)	Class A (*R* = 10m)		Class B (*R* = 3m)	
	µV/m	dBµV/m	µV/m	dBµV/m
30-88	90	39.1	100	40.0
88-216	150	43.5	150	43.5
216-960	210	46.4	200	46.0
> 960	300	49.5	500	54.0

CISPR 22 Radiated Emissions Limits

Frequency (MHz)	Class A (*R* = 30m)		Class B (*R* = 10m)	
	µV/m	dBµV/m	µV/m	dBµV/m
30-230	31.6	30.0	31.6	30.0
230-1000	71.8	37.0	71.8	37.0

6.1.8 Running the radiated emission tests

The test settings according to the correct standards are saved to the database of the EMC software. Pre-defined setup files contain limits of the dedicated standards, settings of the receiver bandwidth, measurement time, and used detectors. The view of the pre- defined set up is shown in figure 30.

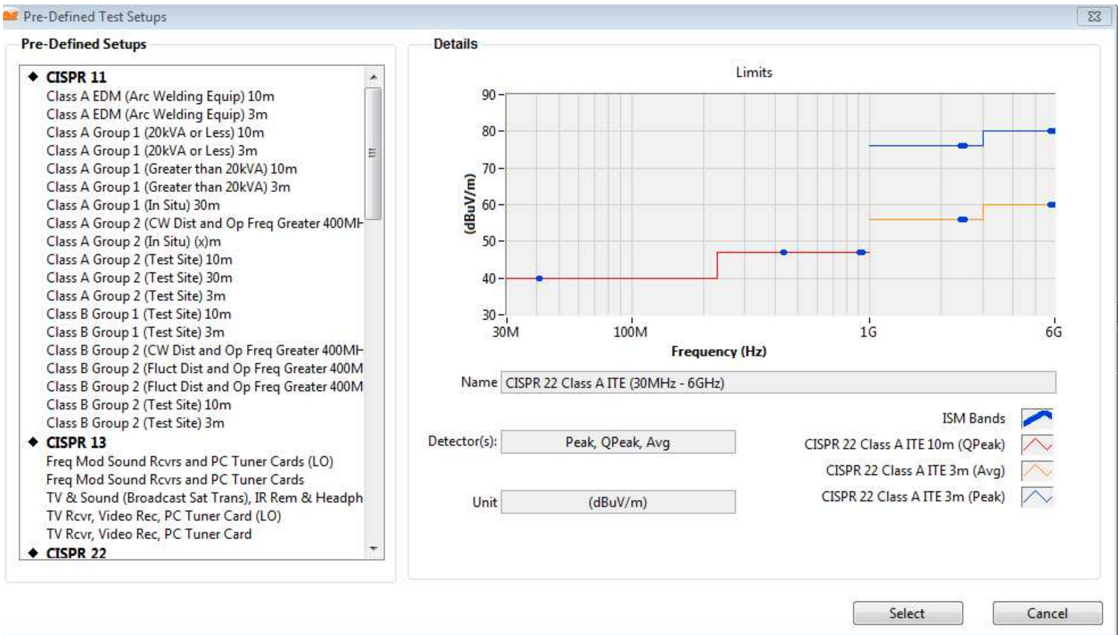


FIGURE30. *Selection of pre-defined test set up*

Pre scan:

When measuring for the first proto version of the device or hardware, it is important that the pre -scan measurement is comprehensive enough. The angle of the device towards to the measurement antenna may have very significant impact on levels of the radiated emissions. The pre-scan measurement was made so that the equipment was rotated 45 degrees at a time followed by scanning the entire frequency range. The height of the measurement antenna during the first pre scan was 100cm. Then the worst values of frequency points were measured in different antenna heights. The highest emission value was saved to the database by testing software.

Typically, in the product development phase when the device is modified continuously to get the optimal solution the verification is done on a narrower frequency band, and only at the worst case position of the measurement antenna.

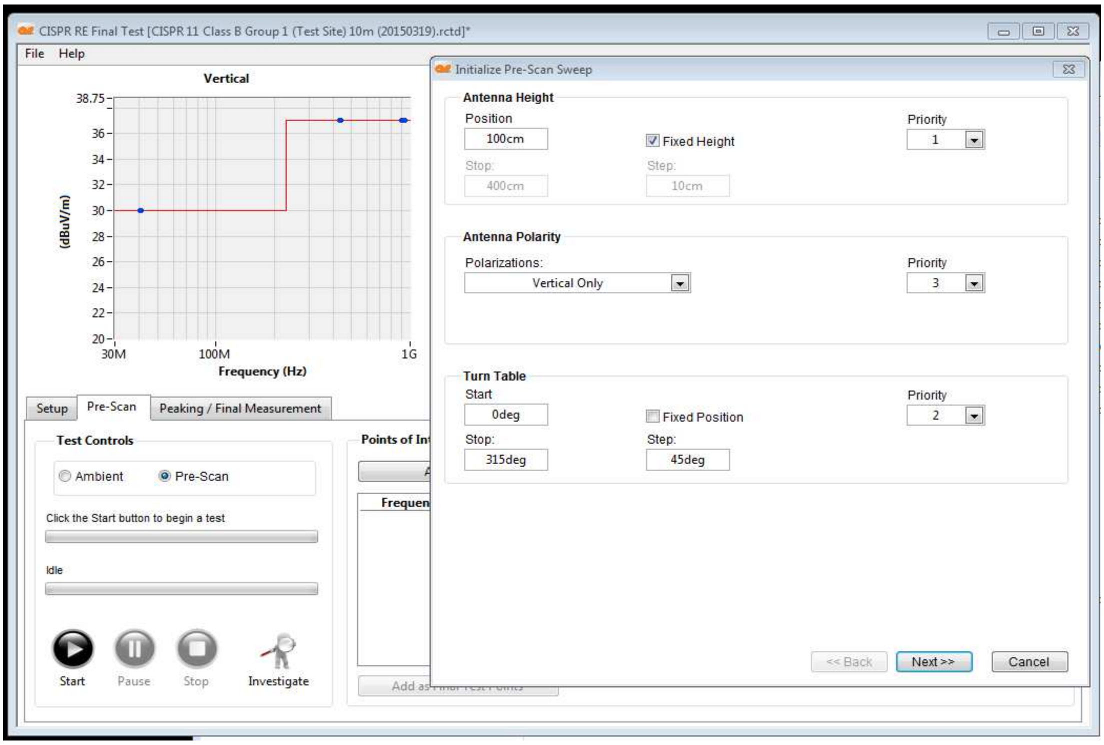


FIGURE31. Initialize pre- scan sweep

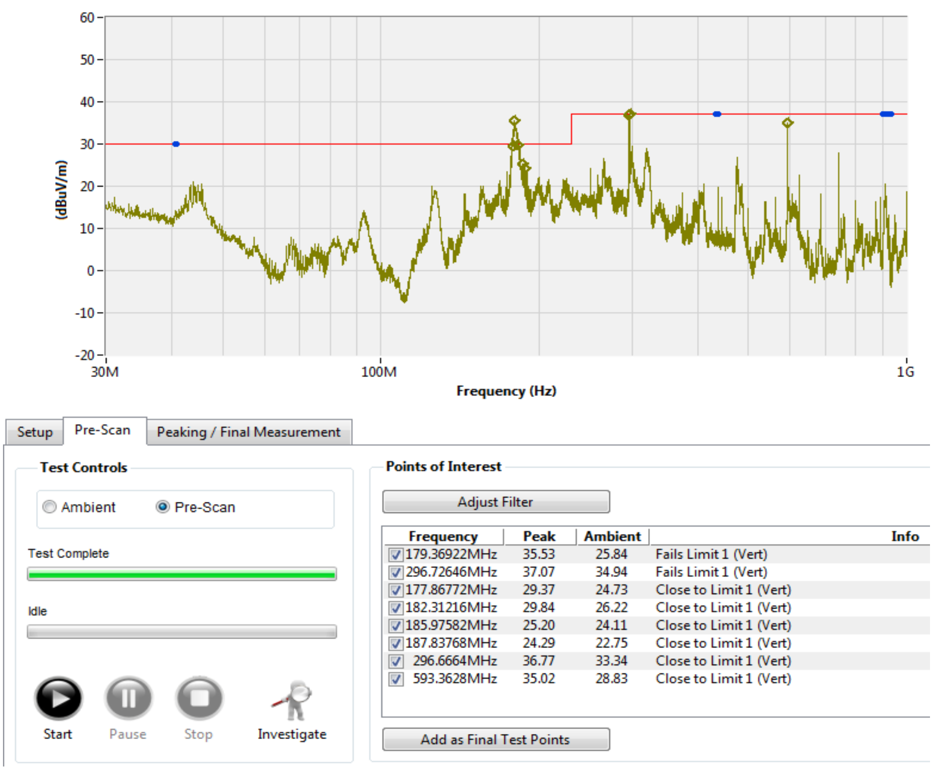
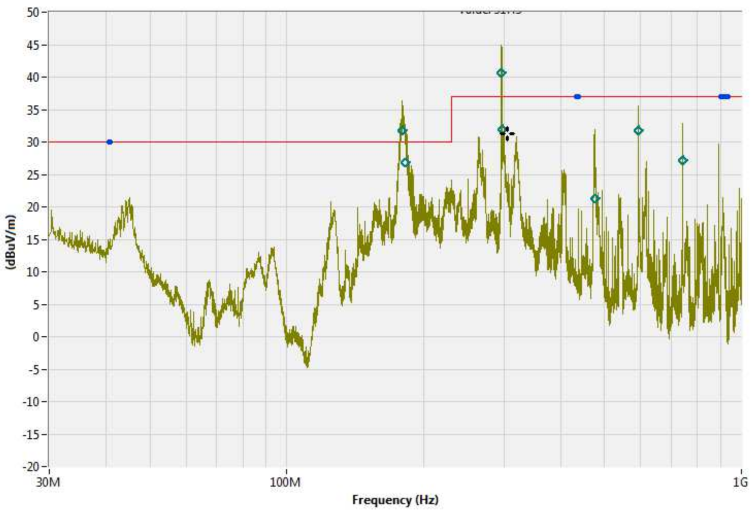


FIGURE32. Test result of pre- scan sweep

After the pre-scan measurement was done the worst emission peak points of the pre scan measurements were selected. The 6dB margin to the limit is a typical criteria for the final measurements. The EMC software generated the list of the highest emission points according selected criteria.

Final measurement

The final measurement is done in the list order. The maximum value has been selected by the EMC software and saved to the database. The information of each angle position in the pre scan phase is included in the database so the final measurement is done in one direction of each frequency point. The final measurement is done by a Quasi -peak detector with the bandwidth settings that are defined the CISPR 16.



Setup | Pre-Scan | Peaking / Final Measurement

Frequency	Status	Peak	QPeak	Amb (V)	Amb (H)	Description
296.6664MHz	Failed	44.912	40.624	33.34	26.74	
296.90664MHz	Passed	36.694	31.926	33.17	28.79	
475.10466MHz	Passed	31.959	21.271	24.97	35.08	
593.42286MHz	Passed	35.522	31.718	30.29	18.17	
741.77106MHz	Passed	32.899	27.172	19.76	11.85	

Test Point Details

Passed

Peaking | Edit History | Edit Status/Description

Highest Measurment

	Highest	Limit	Turn Table	Ante
Peak	32.8987	--	45 deg	100 cr
QPeak	27.1717	37	45 deg	100 cr

FIGURE33.*Results of final measurements*

6.1.9 Test results of radiated emissions

The same specimen that was tested first in pre-compliance test laboratory was sent to a certification test laboratory for a full compliance testing. As was studied before in this thesis, the most significant difference was the different distance between the antenna and the device. As it can be seen on the pictures below, due to the poor antenna performance in a lower frequency, the results were 15 dB lower than the emission levels in the certification test laboratory. There were also differences between narrow spikes of 594MHz and 296MHz. These interferences were caused by electromagnetic energy of clock harmonics. The harmonic signals coupled to the external cables causing the radiated emission. Because the distance differences between the test sites, the phenomenon of the clock harmonic emission occurs in a different way. The other possible reason for different levels was that the external cables were not set exactly to the same positions in the test sites.

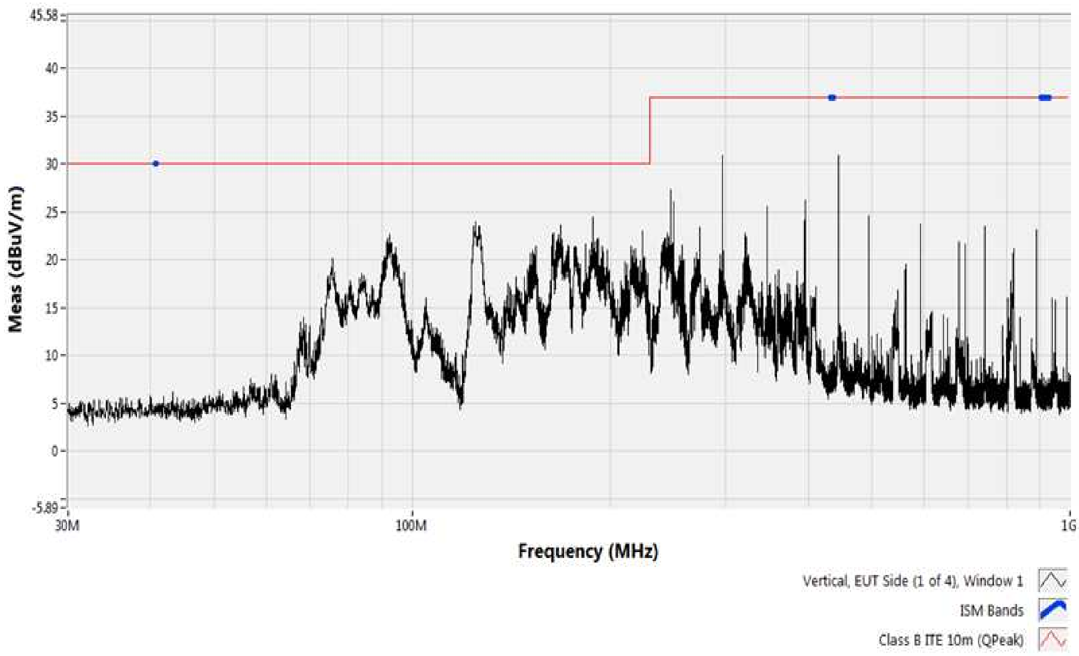
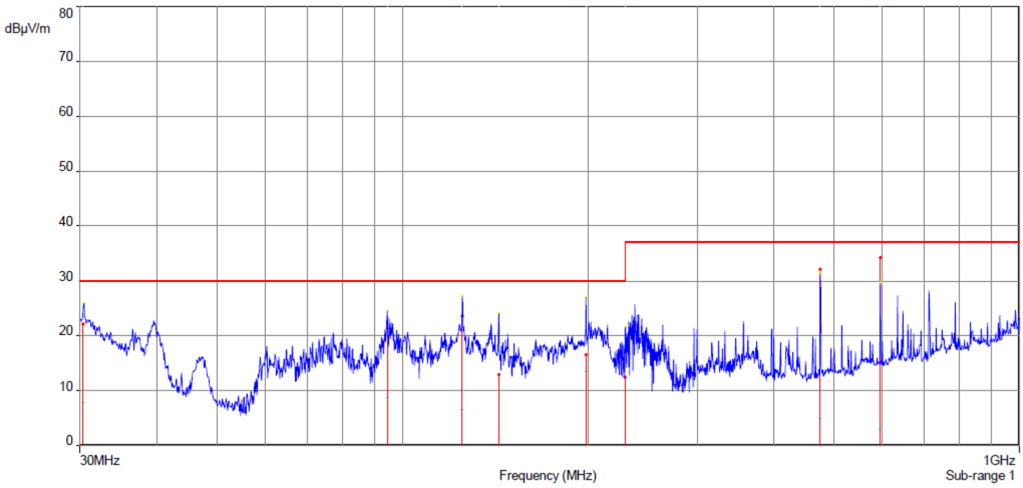


FIGURE34. *Radiated emission measurement, Pre- compliance test site*



Frequency (MHz)	QuasiPeak (dBµV/m)	Abstand (dBµV/m)	Average (dBµV/m)	Winkel	Höhe	Polarisation (dBµV/m)
30.37	22.14	7.86	16.44	239.2	1.19	Vertical
94.38	21.32	8.68	14.56	31	1.51	Vertical
125.01	23.55	6.45	20.83	327.7	1.04	Vertical
143.305	12.87	17.13	9.01	62.1	1	Vertical
198.38	16.5	13.5	8.79	120.1	1.53	Vertical
229.46	12.43	17.57	2.48	231	1	Vertical
476.01	32.09	4.91	20.13	23.8	1	Vertical
594.965	34.19	2.81	18.52	330.6	3.09	Vertical

FIGURE35. *Radiated emissions, full compliance measurement,*

6.2. Conducted emission testing, AC mains port

Conducted emission measurement is not as sensitive to EMI as radiated emission measurements, but it is recommended to use a screened metal room to avoid unwanted signals to interfere with real ones. The conducted emission test uses an artificial main Network (AMN), also known as a line impedance stabilizing Network (LISN) , which acts like a transducer between AC , DC- mains port of the EUT and the measurement receiver. The LISN provides a stable, defined RF impedance equivalent to 50ohm in parallel with 50uH between the point of measurement and the ground reference plane (figure36)

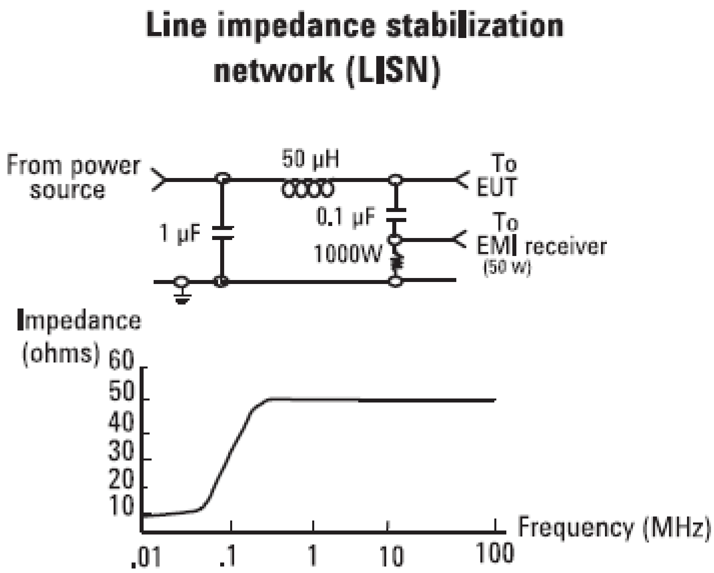


FIGURE36. *Line Impedance stabilization network*

6.2.1 Conducted emission Test setup

The information technology equipment is referred to according to EN 55022 as tabletop apparatuses. A basic setup for conducted emissions measurement is a non-metallic table, wooden table and a ground reference plane. The surface of the table should be 80 cm from the ground reference plane which is located under the table [EN 55022 2006]

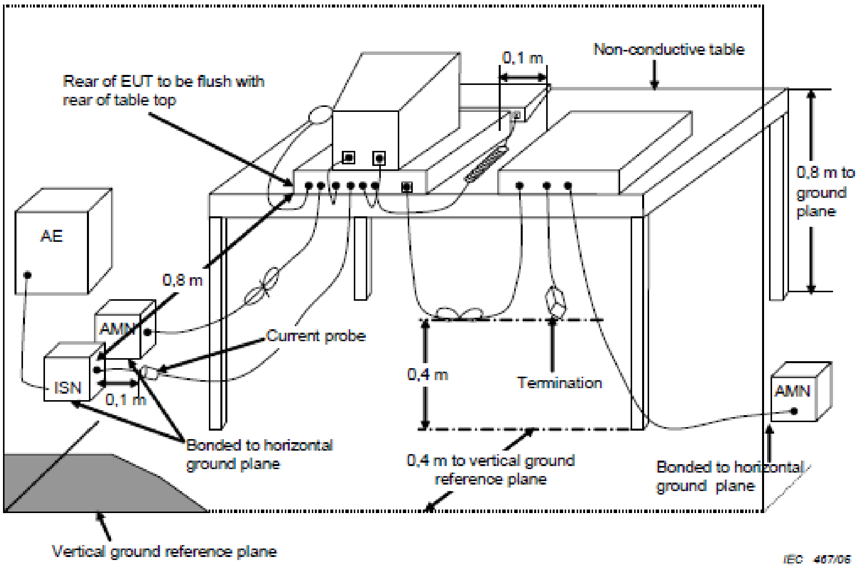


FIGURE37. Test configuration according to the EN 55022 (2006)

The manufacturer of LISN has provided the table with transducers. (appendix 4) The transducers correct the values of measuring frequency band 150khz to 30MHz. The transducer values and measured cable attenuators were input to the measurement software as correction factors. The test set up with the correction factors are shown in diagram of Test set-up signal routings FIGURE38.

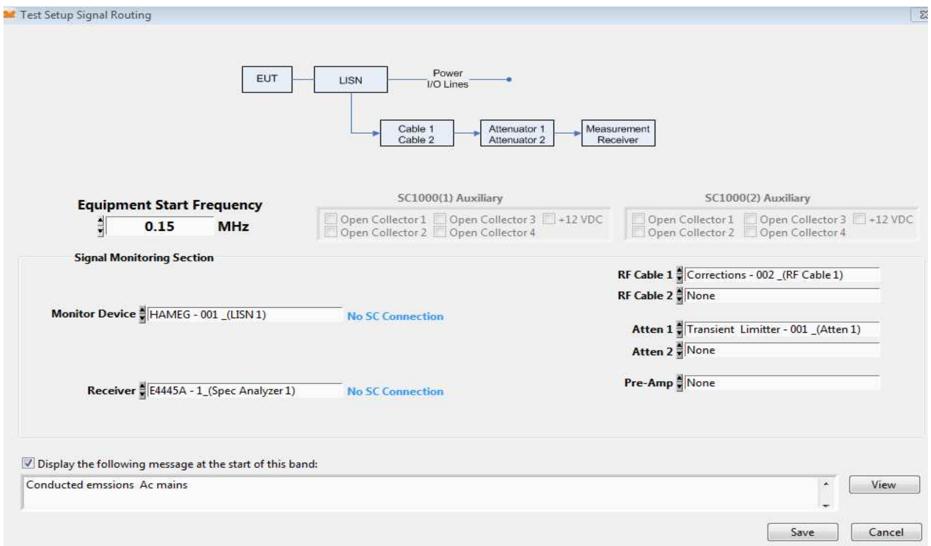


FIGURE 38. *Test setup Signal routings*

6.2.2 Running the conducted emission tests

The test settings according to correct standards are saved to the EMC software. The pre-defined setup files are contained limits of the dedicated standard and settings of the receiver bandwidth, measurement time and used detector. The view of the pre- defined set up is shown in figure 39.

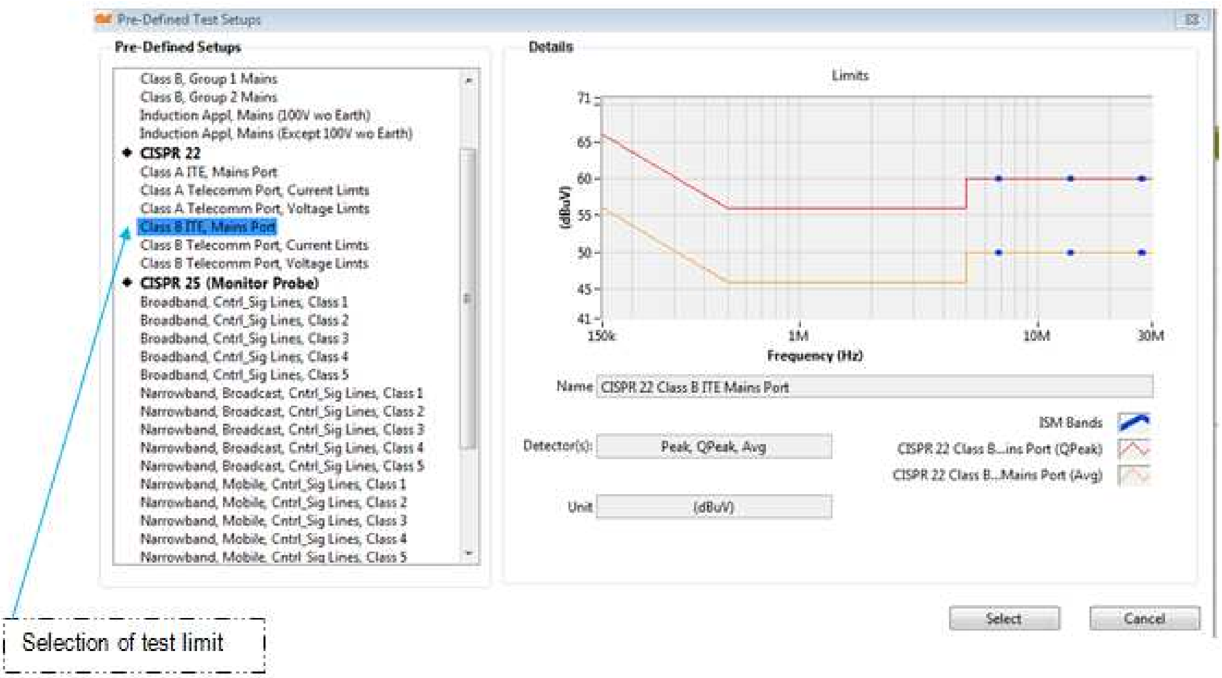


FIGURE39. *Pre- defined test set up for conducted emission of AC mains*

The pre-scan is swept with a peak detector for both AC- cable lines; L1 and N After the pre-scan measurement has been done the worst Emi peak of points the pre scan measurements were selected. The 6dB margin to the average limit is a typical criteria for the final measurements. The EMC software generated the list of the highest emission points according to the selected criteria.

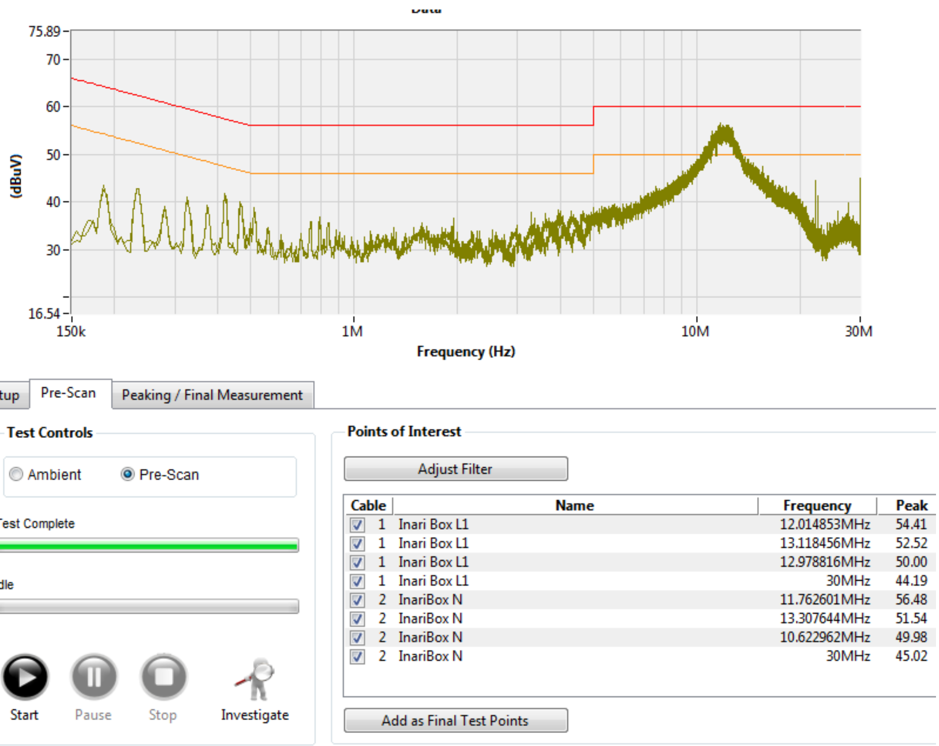


FIGURE40. *Pre scan test result of conducted emission of AC mains*

Final measurement

The final measurement is done in the list order. The final measurement is done separately by Average and Quasi –peak detectors with the bandwidth settings that are defined in the CISPR 16.

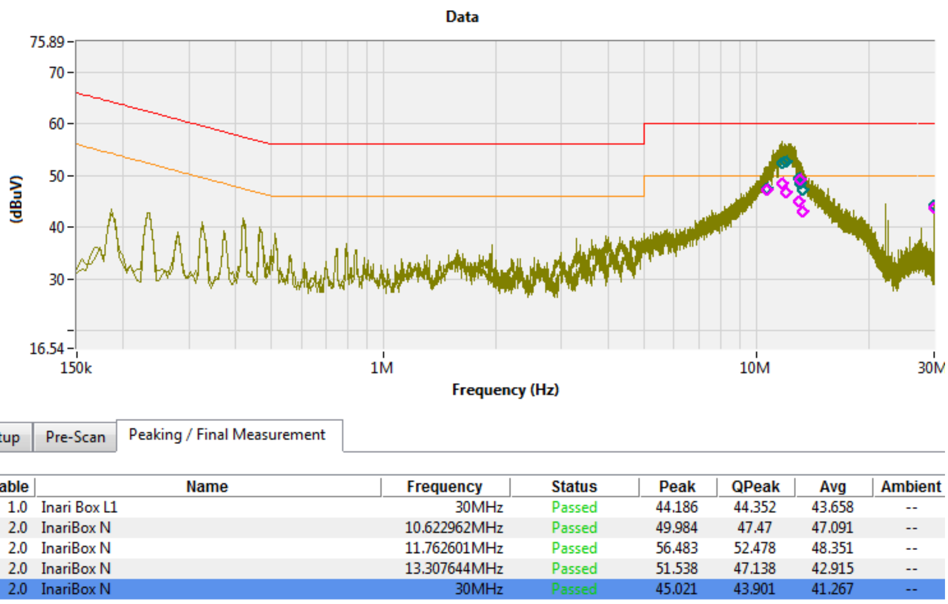


FIGURE41. *Final test result of conducted emission of AC main*

6.2.3 Test results of Conducted emissions from the AC mains

Comparing the results between the pre-compliance test laboratory and the certification test laboratory shows that the measurement accuracy in the pre compliance test site was in a sufficient level in the pre-compliance test site. The levels of emissions throughout the frequency area were approximately 4dB higher than in the full compliance measurement. Based on this comparison, it can be concluded that when the conducted emission levels are below the limits, then they will probably pass also the certification tests.

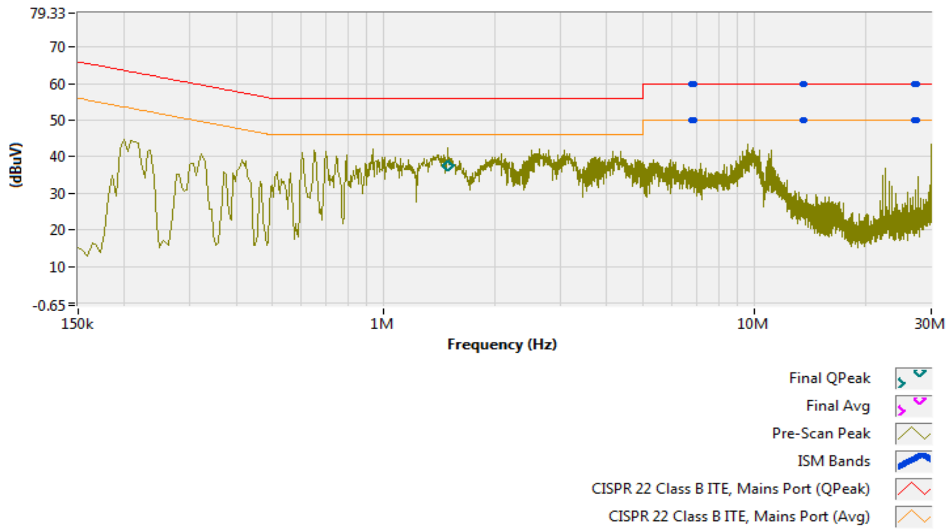


FIGURE42. *Conducted emission measurement, Pre- compliance test site*

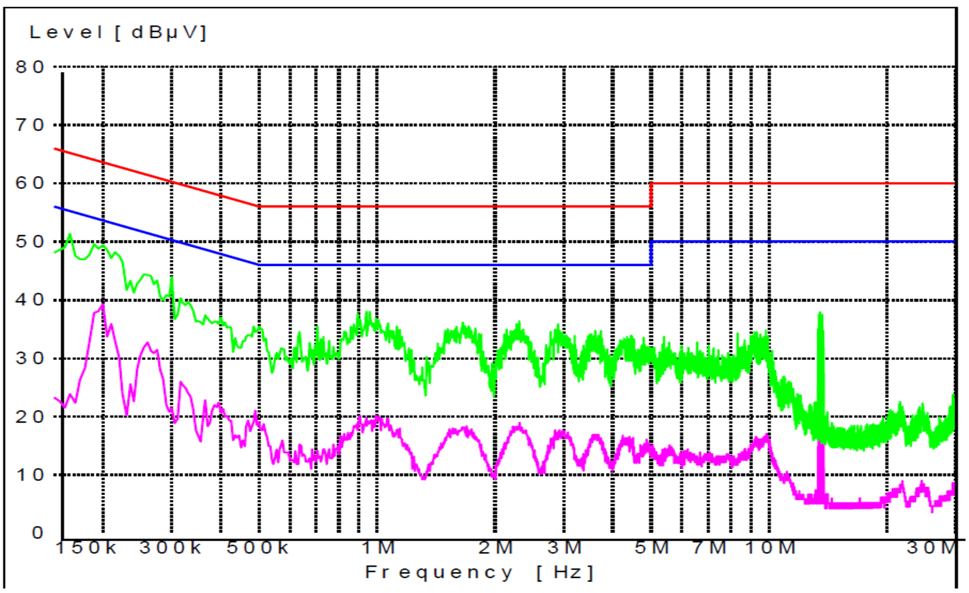


FIGURE43. *Conducted emission measurement full compliance measurement,*

6.3 Conducted emissions of telecommunication ports

The EN55022 requires that for all telecommunication ports on IT, the equipment is tested for RF emissions in the frequency range 150kHz to 30Mhz [3]. The test method where the RF measurement is measured with CDN (Coupling /Decoupling Network) is used in this test arrangement. This method provides the better measurement certainty and the repeatability comparing the RF clamp method with current probe.

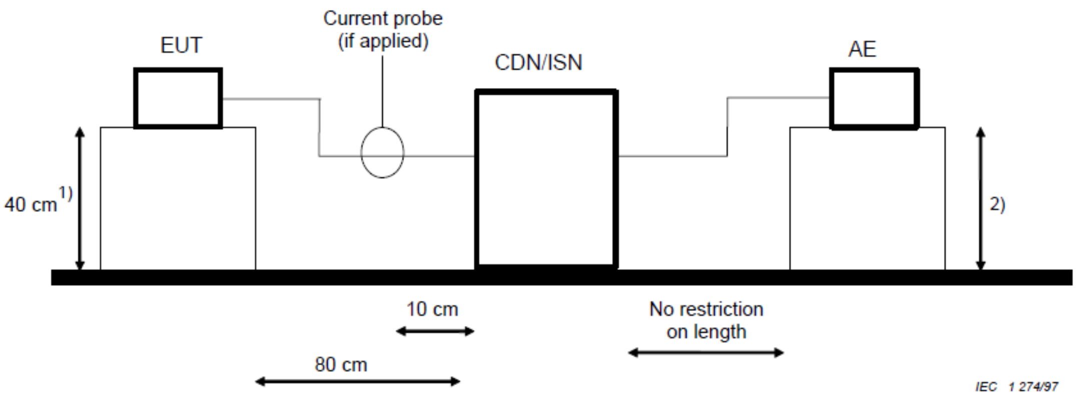


FIGURE44. Test arrangement according EN55022

The CDN was built on own test laboratory. The transducer of the equipment is not yet known. Because of that, the calibration of the conducted emission measurement of telecommunication port is done by a reference product that has been fully evaluated in the formal test laboratory. The correction table is defined based on the measurement results of the official test site.

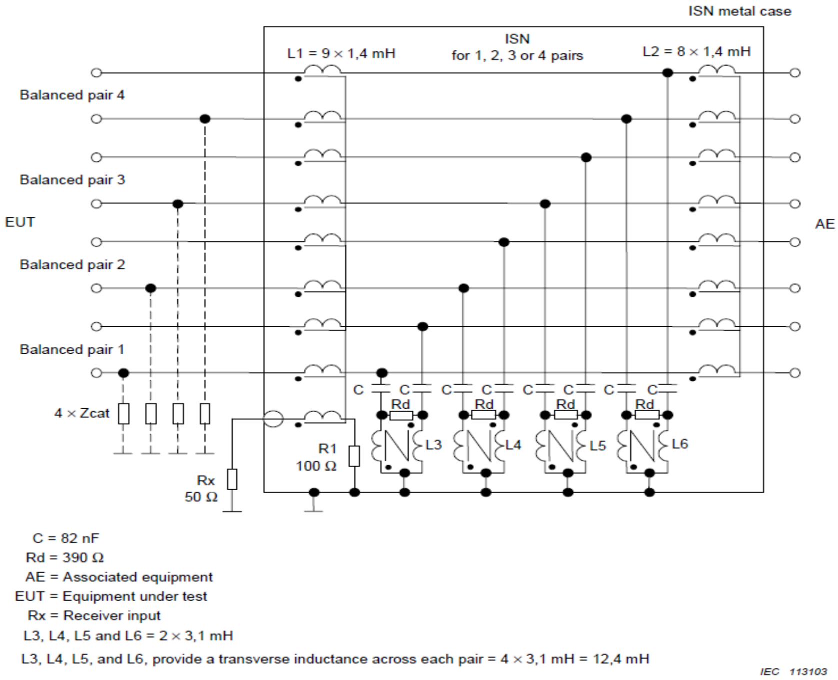
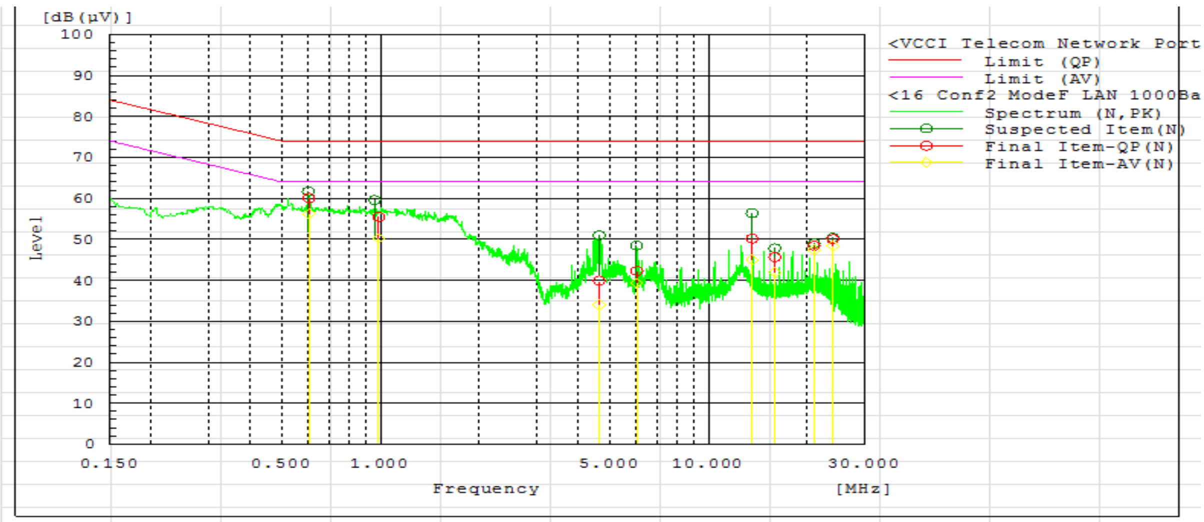


FIGURE45. Schematic of ISN /CDN according EN55022



Final Result

--- N Phase ---

No.	Frequency [MHz]	Reading QP [dB(µV)]	Reading AV [dB(µV)]	c.f [dB]	Result QP [dB(µV)]	Result AV [dB(µV)]	Limit QP [dB(µV)]	Limit AV [dB(µV)]	Margin QP [dB]	Margin AV [dB]	Remark
1	0.60415	50.4	46.6	9.7	60.1	56.3	74.0	64.0	13.9	7.7	
2	0.98652	45.8	40.5	9.7	55.5	50.2	74.0	64.0	18.5	13.8	
3	4.64004	29.9	24.1	9.9	39.8	34.0	74.0	64.0	34.2	30.0	
4	6.03167	32.4	29.4	9.9	42.3	39.3	74.0	64.0	31.7	24.7	
5	13.5604	40.1	34.9	10.1	50.2	45.0	74.0	64.0	23.8	19.0	
6	15.90055	35.5	31.8	10.1	45.6	41.9	74.0	64.0	28.4	22.1	
7	20.92955	38.3	37.2	10.2	48.5	47.4	74.0	64.0	25.5	16.6	
8	23.91985	39.8	38.0	10.3	50.1	48.3	74.0	64.0	23.9	15.7	

FIGURE46. *Measurement result of the formal test laboratory, reference unit*

6.3.1 Test results of conducted emissions of telecommunication ports

Based on reference measurement above, the calibration values has been input to the test software. The testing procedure itself is quite similar that in the Conducted emissions of the AC Mains case. After the correct limits (EN55022 Telecom port)   had been selected the Pre-scan measurement was started. The final measurement was also done same way than in AC mains. The measurements with Average and Quasi-peak detectors were done for a critical frequency point of the pre-scan results.

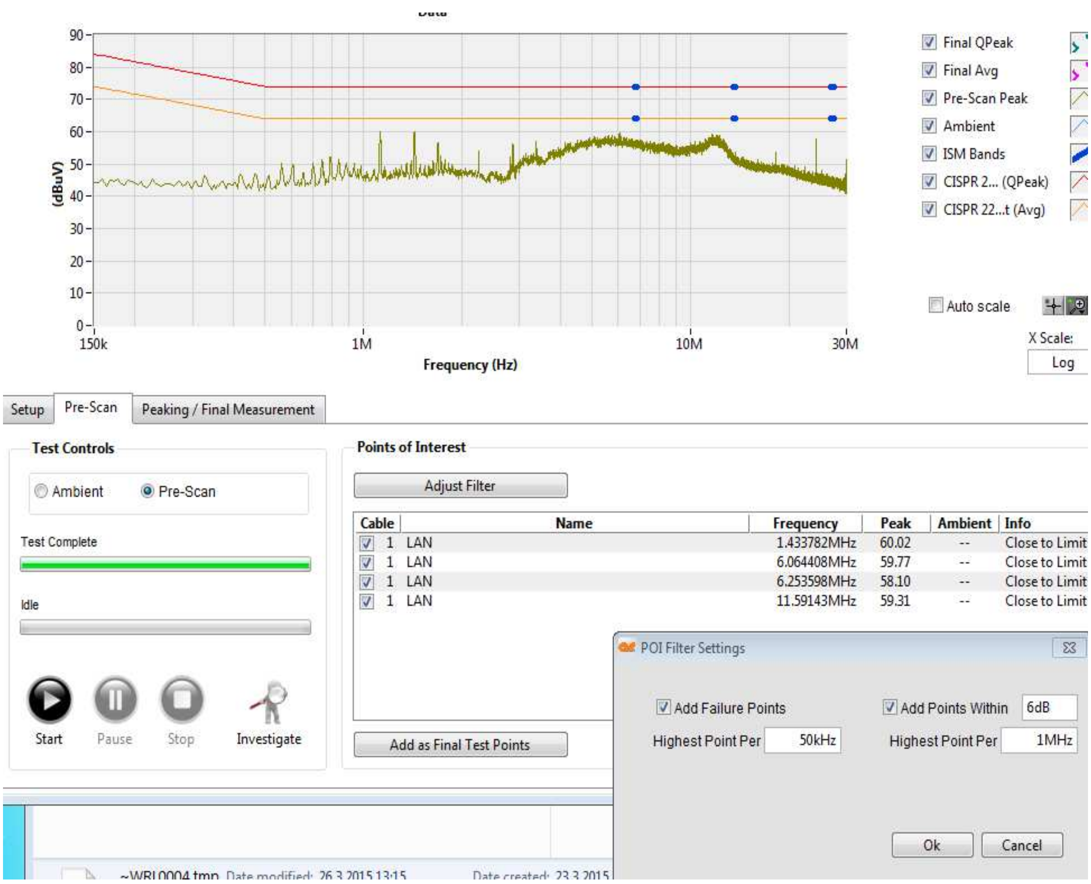
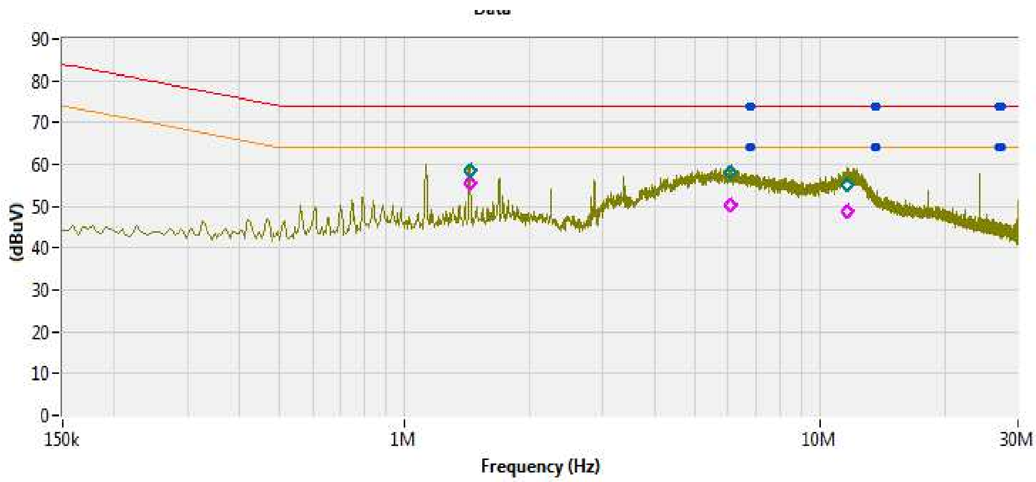


FIGURE47. *Pre scan test result of conducted emission of telecom port*



Setup | Pre-Scan | Peaking / Final Measurement

Cable	Name	Frequency	Status	Peak	QPeak	Avg	Ambient
1.0	LAN	1.433782MHz	Passed	60.02	58.415	55.324	--
1.0	LAN	6.064408MHz	Passed	59.775	58.191	50.311	--
1.0	LAN	11.59143MHz	Passed	59.31	55.056	48.673	--

Test Point Details

Passed

Final Measurement | Edit History | Edit Status/Description

Highest Measurment

	Highest	Limit	Time Stamp
Peak	59.3097	--	03:09:24
QPeak	55.0557	74	03:27:16
Avg	48.6727	64	03:25:52

FIGURE48. *Test result of conducted emission of telecom port*

7 CONCLUSIONS

The objectives of the work were achieved. The completed pre-compliance test site was suitable for the use of product developing phase verification. The pre-compliance test site provides immediate responses to the cases with the aim of improving the disturbance levels, or to test the new features of the device. Also, in the case of the testing of different components, like accessories, the testing arrangement provides valuable support for decisions to select optimal solutions for the product.

The conducted emission test site achieved almost the same reliability level and reparability than the official test laboratory. But what becomes to the test site for radiated emissions, the testing environment was totally different from the conditions of full compliance test sites. It was not possible to use the space of the OATS that was defined in applicable standard; secondly there were no resources to build a fully anechoic chamber . So the testing condition should be applied for the laboratory conditions. The original target was to cover the frequency area from 30MHz to 1000MHz. However, it was observed that in measurements with low frequencies (30MHz to 70Mhz) the receiver antenna performance was worse than it was expected. Otherwise, the lower frequency measurements should be required more space, which could not be implemented in ordinary research and development conditions. Because of that, the frequency area of the radiated emission measurement was changed to 100Mz to1000Mhz.

Unlike the full-compliance measurements the area is not characterized and could have reflections that cause amplitude errors. The calibration measurement eliminates these errors, but because of different set up the sufficient safety marginal should be added to measurement values, so that the device would certainly meet regulatory requirements.

The EMC phenomenon is hard to predict. Because a modern mobile device, like a tablet computer today, is a multipurpose device, the solution of a well-designed device may affect problems in another use case. When the Pre-compliance test setup is built properly in the early phase of product developing process, the anticipate surprises at the final compliance test can be avoided.

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APPENDICES

APPENDIX 1	Calibration table for radiated emissions
APPENDIX 2	The start menu of EMC measuring software
APPENDIX 3	Selection of measuring equipment
APPENDIX 4	Pre compliance test set up for radiated emissions
APPENDIX 5	Pre compliance test set up for radiated emissions
APPENDIX 6	Pre compliance set up for conducted emissions

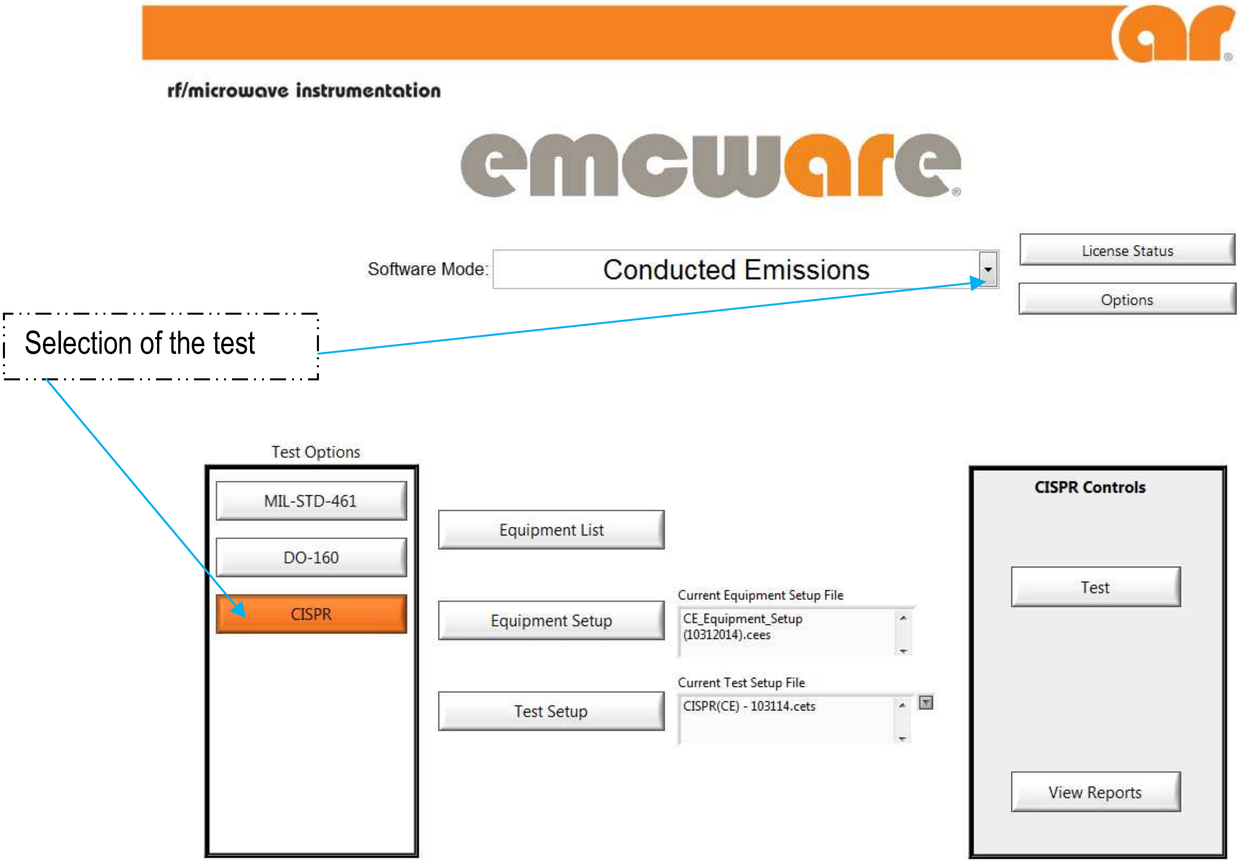
Calibration table for Radiated emissions APPENDIX 1/1

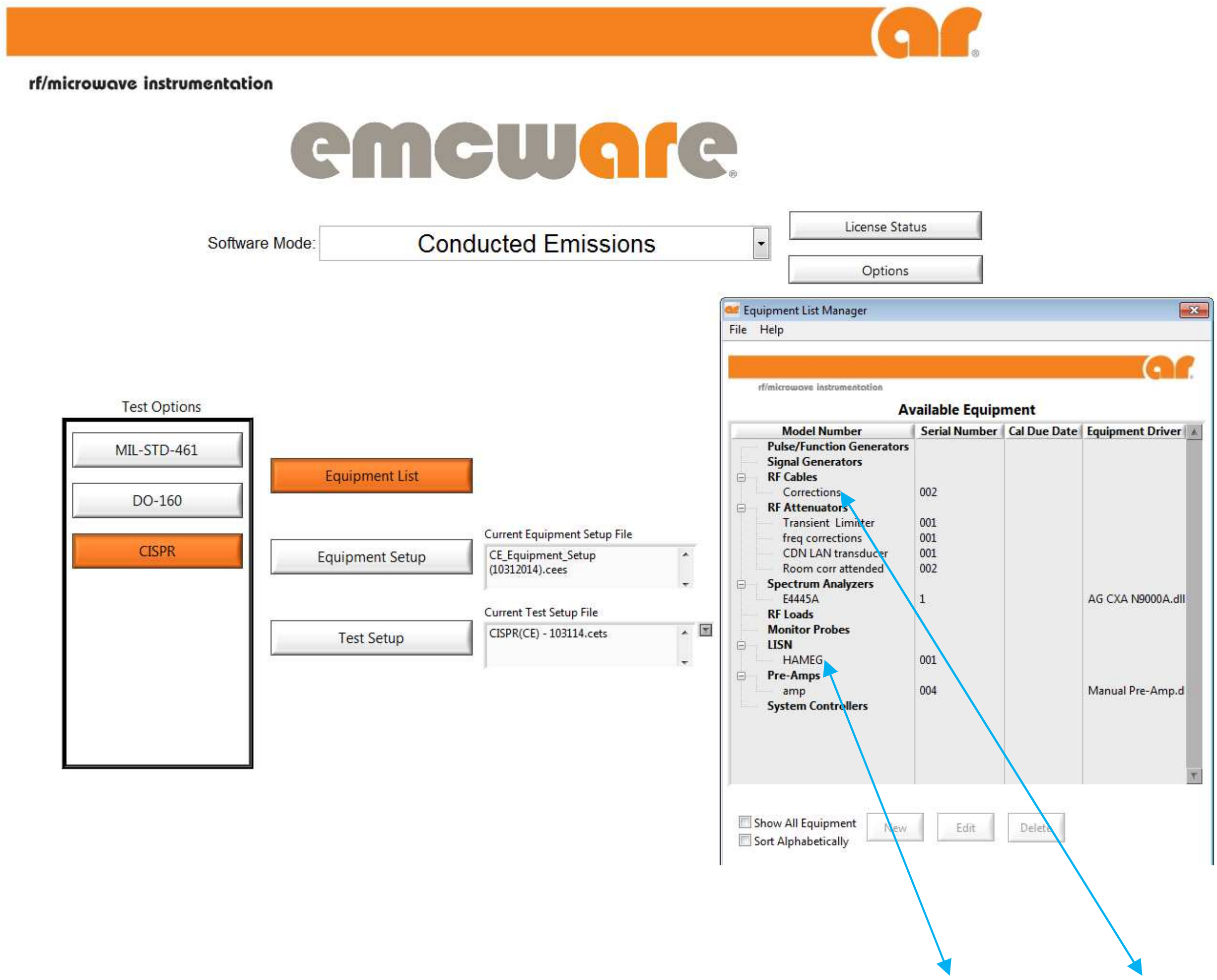
Freq.	RF Generator Level [dBuV]	Ref antenna gain [dB d]	Free space loss 2m distance	receiver ant. Gain dBd	Cable loss	Spectrum analyzer Level CALCULATED [dBuV]	Test result [dBuV]	Error dB
30	110	-20	8,0	-40,88	-0,28	40,88	29,00	-11,88
35	100	-17	9,3	-37,46	-0,30	35,94	26,00	-9,94
40	100	-15	10,5	-35,13	-0,32	39,09	33,00	-6,09
45	100	-10	11,5	-32,52	-0,34	45,65	33,00	-12,65
50	100	-5	12,4	-30,51	-0,36	51,73	48,00	-3,73
55	100	-3	13,2	-29,14	-0,38	54,25	56,00	1,75
60	70	0	14,0	-28,07	-0,40	27,55	36,00	8,45
65	70	-1	14,7	-26,92	-0,42	26,98	42,00	15,02
70	70	-1	15,3	-26,15	-0,44	27,09	43,00	15,91
75	70	-1	15,9	-24,75	-0,45	27,88	39,00	11,12
80	70	-1	16,5	-23,32	-0,47	28,73	43,90	15,17
85	70	-1	17,0	-22,18	-0,48	29,33	43,00	13,67
90	70	-1	17,5	-21,11	-0,49	29,90	47,00	17,10
95	70	-1	18,0	-20,37	-0,51	30,15	48,00	17,85
100	70	-2	18,4	-19,75	-0,53	29,31	48,00	18,69
110	70	-3	19,2	-18,63	-0,55	28,57	46,00	17,43
120	70	0	20,0	-16,66	-0,58	32,76	45,00	12,24
130	70	1	20,7	-15,06	-0,61	34,63	47,00	12,37
140	70	2	21,3	-13,69	-0,64	36,33	45,00	8,67
150	70	3	21,9	-12,79	-0,66	37,61	43,00	5,39
160	70	4	22,5	-11,76	-0,68	39,06	47,00	7,94
170	70	4	23,0	-10,94	-0,71	39,31	49,00	9,69
180	70	5	23,5	-9,44	-0,75	41,28	33,00	-8,28
190	70	5	24,0	-8,94	-0,77	41,30	49,00	7,70
200	70	6	24,4	-8,56	-0,79	42,21	47,00	4,79
210	70	6	24,9	-8,23	-0,82	42,09	46,10	4,01
220	70	6	25,3	-6,65	-0,83	43,25	53,60	10,35
230	70	5	25,7	-6,03	-0,85	42,46	42,00	-0,46
240	70	5	26,0	-5,52	-0,88	42,58	48,20	5,62
250	70	5	26,4	-5,27	-0,90	42,46	53,20	10,74
260	70	5	26,7	-4,05	-0,91	43,32	46,90	3,58
265	70	5	26,9	-4,05	-0,91	43,15	34,00	-9,15
270	70	5	27,0	-3,58	-0,93	43,43	47,30	3,87
280	70	5	27,4	-3,63	-0,95	43,06	52,80	9,74
290	70	6	27,7	-3,47	-0,97	43,89	51,60	7,71
300	70	6	28,0	-2,83	-0,98	44,23	39,20	-5,03
310	70	6	28,2	-2,48	-1,01	44,26	50,20	5,94
320	70	6	28,5	-2,35	-1,02	44,11	40,00	-4,11

330	70	6	28,8	-2,41	-1,04	43,76	48,00	4,24
340	70	6	29,1	-2,33	-1,05	43,56	37,50	-6,06
350	70	6	29,3	-1,61	-1,07	44,02	50,70	6,68
360	70	6	29,5	-1,43	-1,08	43,94	47,00	3,06
370	70	6	29,8	-1,52	-1,11	43,59	49,80	6,21
380	70	6	30,0	-1,50	-1,12	43,36	52,80	9,44
390	70	6	30,2	-1,21	-1,14	43,41	47,30	3,89
400	70	6	30,5	-0,93	-1,16	43,45	47,70	4,25
410	70	6	30,7	-0,89	-1,17	43,26	50,00	6,74
420	70	6	30,9	-1,22	-1,19	42,71	41,50	-1,21
430	70	6	31,1	-1,41	-1,21	42,29	47,40	5,11
440	70	6	31,3	-1,36	-1,22	42,13	46,60	4,47
450	70	6	31,5	-1,22	-1,24	42,06	47,00	4,94
460	70	6	31,7	-1,57	-1,25	41,51	45,20	3,69
470	70	6	31,9	-1,28	-1,26	41,60	42,00	0,40
475	70	6	32,0	-1,28	-1,26	41,50	29,00	-12,50
480	70	6	32,0	-1,39	-1,28	41,29	39,90	-1,39
485	70	6	32,1	-1,39	-1,28	41,20	33,50	-7,70
490	70	6	32,2	-1,30	-1,29	41,19	44,40	3,21
500	70	6	32,4	-1,26	-1,31	41,03	47,70	6,67
510	70	5	32,6	-1,42	-1,32	39,68	51,60	11,92
515	70	5	32,7	-1,42	-1,32	39,60	53,50	13,90
520	70	6	32,7	-1,39	-1,34	40,54	49,50	8,96
530	70	6	32,9	-1,45	-1,34	40,29	49,00	8,71
540	70	6	33,1	-1,17	-1,36	40,40	46,60	6,20
550	70	6	33,2	-1,59	-1,38	39,80	47,30	7,50
560	70	6	33,4	-1,57	-1,39	39,66	41,00	1,34
570	70	6	33,5	-1,64	-1,41	39,41	41,50	2,09
580	70	6	33,7	-1,31	-1,42	39,58	45,10	5,52
590	70	6	33,8	-1,59	-1,43	39,14	39,90	0,76
595	70	6	33,9	-1,59	-1,43	39,07	35,00	-4,07
600	70	6	34,0	-1,27	-1,44	39,31	40,60	1,29
610	70	6	34,1	-1,59	-1,46	38,82	44,90	6,08
620	70	6	34,3	-1,12	-1,48	39,13	40,10	0,97
630	70	6	34,4	-1,55	-1,48	38,55	43,60	5,05
640	70	6	34,5	-1,16	-1,51	38,79	42,20	3,41
650	70	6	34,7	-1,57	-1,52	38,23	40,00	1,77
660	70	6	34,8	-1,55	-1,52	38,12	47,80	9,68
670	70	6	34,9	-1,64	-1,55	37,87	48,80	10,93
680	70	6	35,1	-1,27	-1,56	38,10	48,70	10,60
690	70	6	35,2	-1,71	-1,56	37,53	47,30	9,77
700	80	0	35,3	-1,35	-1,58	41,75	48,90	7,15
710	80	0	35,4	-1,34	-1,60	41,62	44,53	2,91
720	80	0	35,6	-1,12	-1,60	41,70	44,80	3,10

730	80	0	35,7	-1,21	-1,60	41,49	44,36	2,87
740	80	0	35,8	-1,31	-1,64	41,25	46,30	5,05
750	80	0	35,9	-1,25	-1,64	41,19	41,60	0,41
760	80	0	36,0	-1,24	-1,66	41,06	35,50	-5,56
770	80	0	36,2	-1,13	-1,67	41,05	49,90	8,85
780	80	-0,04	36,3	-1,33	-1,69	40,68	44,15	3,47
790	80	0,2	36,4	-1,22	-1,69	40,92	48,00	7,08
800	80	0,52	36,5	-1,47	-1,70	40,87	40,90	0,03
810	80	1	36,6	-0,91	-1,72	41,78	46,32	4,54
820	80	1,12	36,7	-1,11	-1,73	41,58	45,30	3,72
830	80	1,35	36,8	-0,91	-1,74	41,90	50,40	8,50
840	80	1,47	36,9	-1,10	-1,76	41,70	54,70	13,00
850	80	1,57	37,0	-0,80	-1,76	41,99	50,20	8,21
860	80	1,59	37,1	-1,00	-1,78	41,70	51,80	10,10
870	80	1,6	37,2	-0,75	-1,79	41,85	48,80	6,95
880	80	1,62	37,3	-1,15	-1,79	41,36	48,90	7,54
890	80	1,67	37,4	-1,15	-1,82	41,29	46,10	4,81
900	80	1,68	37,5	-1,11	-1,82	41,25	48,50	7,25
910	80	1,63	37,6	-1,06	-1,83	41,14	28,40	-12,74
920	80	1,54	37,7	-1,01	-1,85	40,99	40,20	-0,79
930	80	1,45	37,8	-1,11	-1,85	40,70	50,10	9,40
940	80	1,35	37,9	-1,02	-1,88	40,57	50,40	9,83
950	80	1,26	38,0	-1,12	-1,89	40,28	46,10	5,82
960	80	1,18	38,1	-0,97	-1,90	40,24	44,26	4,02
970	80	1,13	38,2	-1,13	-1,90	39,94	48,60	8,66
980	80	1,07	38,2	-1,19	-1,91	39,73	42,70	2,97
990	80	1	37,4	-1,44	-1,93	40,21	36,60	-3,61
1000	80	1	37,5	-1,40	-1,94	40,15	42,00	1,85

The start menu of the EMC measuring software



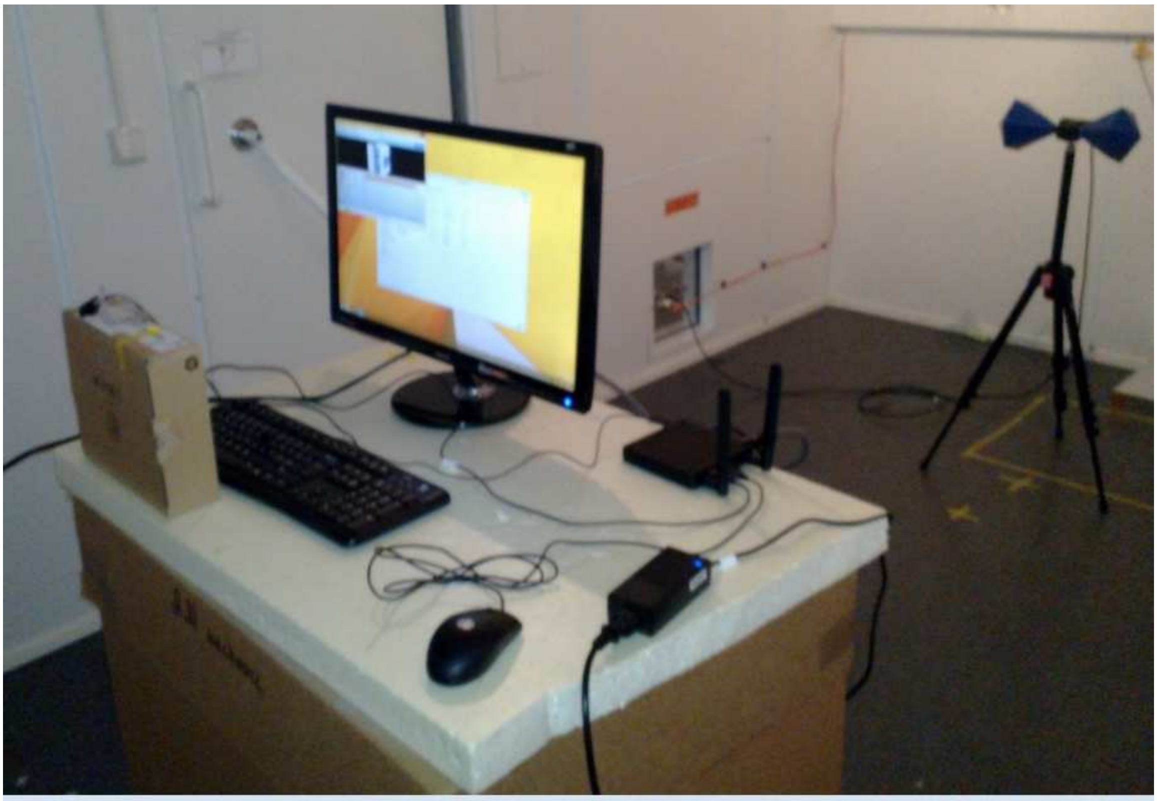


- Cabel corrections
- Insertion loss

	HM6050-2		HM6050-2		HM6050-2	
frequency	with limiter (valid for L1 and N measurements)		without limiter "N"		witout limiter "L1"	
kHz	dB	dB (-10)	dB	dB (-10)	dB	dB (-10)
150	-11,8	-1,8	-11,5	-1,5	-11,5	-1,5
200	-11,2	-1,2	-11,2	-1,2	-11,2	-1,2
250	-10,9	-0,9	-10,9	-0,9	-11,0	-1,0
300	-10,7	-0,7	-10,8	-0,8	-10,8	-0,8
350	-10,6	-0,6	-10,7	-0,7	-10,7	-0,7
400	-10,6	-0,6	-10,6	-0,6	-10,6	-0,6
450	-10,5	-0,5	-10,5	-0,5	-10,5	-0,5
500	-10,5	-0,5	-10,5	-0,5	-10,5	-0,5
550	-10,5	-0,4	-10,4	-0,4	-10,4	-0,4
600	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
650	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
700	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
750	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
800	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
850	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
900	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
950	-10,4	-0,4	-10,3	-0,3	-10,4	-0,4
1.000	-10,4	-0,4	-10,3	-0,3	-10,4	-0,4
2.000	-10,4	-0,4	-10,4	-0,4	-10,4	-0,4
3.000	-10,5	-0,5	-10,5	-0,5	-10,5	-0,5
4.000	-10,6	-0,6	-10,5	-0,5	-10,6	-0,6
5.000	-10,7	-0,7	-10,6	-0,6	-10,7	-0,7
6.000	-10,8	-0,8	-10,7	-0,7	-10,7	-0,7
7.000	-10,9	-0,9	-10,7	-0,7	-10,7	-0,7
8.000	-10,9	-0,9	-10,7	-0,7	-10,8	-0,8
9.000	-11,0	-1,0	-10,8	-0,8	-10,8	-0,8
10.000	-11,0	-1,0	-10,8	-0,8	-10,8	-0,8
11.000	-11,1	-1,1	-10,8	-0,8	-10,8	-0,8
12.000	-11,2	-1,2	-10,9	-0,9	-10,9	-0,9
13.000	-11,2	-1,2	-10,9	-0,9	-10,9	-0,9
14.000	-11,3	-1,3	-11,0	-1,0	-10,9	-0,9
15.000	-11,5	-1,5	-11,1	-1,1	-11,1	-1,1
16.000	-11,6	-1,6	-11,2	-1,2	-11,2	-1,2
17.000	-11,6	-1,6	-11,1	-1,1	-11,2	-1,2
18.000	-11,5	-1,5	-11,0	-1,0	-11,0	-1,0
19.000	-11,5	-1,5	-10,9	-0,9	-11,0	-1,0
20.000	-11,6	-1,6	-11,0	-1,0	-11,1	-1,1
21.000	-11,8	-1,8	-11,0	-1,0	-11,2	-1,2
22.000	-11,9	-1,9	-11,1	-1,1	-11,2	-1,2
22.200	-11,9	-1,9	-11,1	-1,1	-11,3	-1,3
22.400	-12,0	-2,0	-11,2	-1,2	-11,4	-1,4
22.600	-12,3	-2,3	-11,4	-1,4	-11,6	-1,6
22.800	-12,6	-2,6	-11,7	-1,7	-11,9	-1,9
22.900	-12,6	-2,6	-11,7	-1,7	-11,8	-1,8
23.000	-12,4	-2,4	-11,5	-1,5	-11,7	-1,7
23.200	-12,2	-2,2	-11,3	-1,3	-11,5	-1,5
23.400	-12,2	-2,2	-11,3	-1,3	-11,4	-1,4
23.600	-12,2	-2,2	-11,3	-1,3	-11,5	-1,5
23.800	-12,4	-2,4	-11,4	-1,4	-11,6	-1,6
24.000	-12,7	-2,7	-11,6	-1,6	-11,9	-1,9
24.200	-12,6	-2,6	-11,5	-1,5	-11,8	-1,8
24.400	-12,5	-2,5	-11,4	-1,4	-11,7	-1,7
24.600	-12,4	-2,4	-11,4	-1,4	-11,6	-1,6
24.800	-12,4	-2,4	-11,4	-1,4	-11,6	-1,6
25.000	-12,5	-2,5	-11,4	-1,4	-11,6	-1,6
26.000	-12,7	-2,7	-11,4	-1,4	-11,8	-1,8
27.000	-13,0	-3,0	-11,6	-1,6	-12,0	-2,0
28.000	-13,2	-3,2	-11,7	-1,7	-12,1	-2,1
29.000	-13,4	-3,4	-11,8	-1,8	-12,1	-2,1
30.000	-13,5	-3,5	-11,8	-1,8	-12,1	-2,1

APPENDIX 5

Pre compliance Test set up for Radiated emissions



Pre compliance Test set up for Conducted emissions. APPENDIX 6

Test set up for Conducted emissions/ AC mains.

Test set up for Conducted emissions Telecommunication port: