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EMC MEASUREMENT FEASIBILITY STUDY FOR AUTOMATED TEST SYSTEM

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Bachelor's Thesis
Spring 2022
Information Technology
Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
Degree Programme in Information Technology, Option of Device and Product Design

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Title of thesis: EMC Measurement Feasibility Study for Automated Test System
Supervisor: Kari Jyrkkä
Term and year when the thesis was submitted: Spring 2022 Number of pages: 37

The objective of this thesis was to study and test the possibility of performing electromagnetic compatibility measurements with an automated test system. This thesis starts with theory part of the electromagnetic compatibility and presenting the spectrum analyzer and accessories needed for the measurements. The measurements were performed at the automated test systems location, to get the interferences from the devices in the same environment.

H-field probes were used for the measurements in this thesis. Larger diameter of the probe has big impact on the measurement results due to its higher sensitivity, which causes ambient interferences to appear much higher compared to a probe with smaller diameter.

Based on the measurements in this thesis, electromagnetic compatibility measurements can be performed with the automated test system. The results concluded that the ambient interferences appear on certain frequency ranges, which can cause the measurement results to disappear under the interferences on specific measurements if the desired measurement frequency range overlaps the ambient interferences.

The automated test systems changing surroundings need to be acknowledged, because some devices around the automated test system might cause interferences on frequency ranges which were not visible in the measurements performed during this thesis.

Keywords: EMC, EMI, Coupling Paths, Wave Impedance, Spectrum analyzer

ABBREVIATIONS

EM	Electromagnetic
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
RF	Radio frequency
RFI	Radio frequency interference
EMP	Electromagnetic pulse
ESD	Electrostatic discharge
DUT	Device under test
PCB	Printed circuit board
ASIC	Application-specific integrated circuit
IC	Integrated circuit
LPF	Low pass filter
IF	Intermediate frequency
RBW	Resolution bandwidth
VBW	Video bandwidth

CONTENTS

1 INTRODUCTION

The purpose of this thesis was to study and test the possibility of performing EMC measurements with an automated test system. The aim was that the results concluded from this thesis would determine if the measurement results would be reliable and their quality high enough in the systems current surroundings to implement them properly.

Performing the measurements with the test system for every product automatically throughout their product development stages, would improve test coverage of all products, and increase the chance of finding possible problem areas on even earlier stages. This would increase quality of the products and shorten product development time considerably.

The thesis included studying theory of electromagnetic disturbances and their coupling methods, determing measurement devices and accessories to be used in the test system, and performing the measurements to ensure quality and reliability of measurements performed in the test systems surroundings.

Initially, the plan was to perform reference measurements at the EMC laboratory in controlled surroundings, to indicate how the measurement results should look like without any excess ambient interferences. Those results would have been compared to the measurement results performed exactly the same way, except at the automated test systems location. However, replicating the probe movements and rotations for the measurements to be comparable would have been very difficult to perform, so the ambient interferences were measured at the test system location for verifying if the EMC measurements would be possible to be performed with the test system.

2 ELECTROMAGNETIC COMPATIBILITY

In every EMC related issue, a source and a victim for the interference emissions are required. If there is no susceptible victim, source of interference or coupling path between them, there is no EMC problem. A single product can be a source of interference and a victim in different situations. (1, chapter 11.1.)

Every new electronic product must be electromagnetic compatibility (EMC) compliant, which means that it should be tested for electromagnetic interferences (EMI) throughout its product development. EMC compliant products should not have any EMI issues anymore, because the products already proved that their electromagnetic (EM) emissions are low enough and EM immunity for emissions from other devices to be high enough in their intended environment (2).

All electronic devices in Europe are subjects of EMC Directive. It determines requirements for the devices, which they must fulfil. Essential requirements from it are that devices need to be designed and manufactured so, that the emissions generated by the device do not exceed a level above which prevents radio and telecommunications devices or other devices from operating properly. Also, the device must have a level of immunity to EM disturbance expected in its intended environment to ensure the devices proper operation without unacceptable degradation of its performance (Figure 1). (1, chapter 2.2.2.1.)

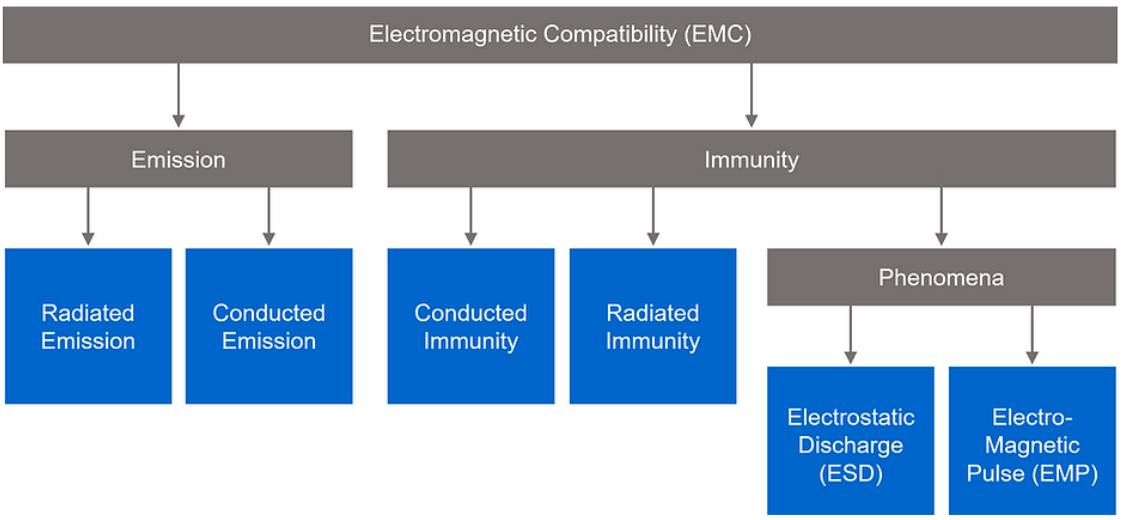

FIGURE 1. Structure of EMC (2).

This chapter focuses on electromagnetic interferences, generation of electric (E-field) and magnetic (H-field) fields and electromagnetic wave, and their coupling methods. It is essential to understand at least the basics of EMC before performing tests or measurements.

2.1 Electromagnetic Interferences

EMI is unwanted electromagnetic energy, which designers must manage and mitigate it within their own designs and protect from other interference sources (3). Any electromagnetic phenomenon that can be the cause of devices worse performance regardless of frequency or coupling path is called electromagnetic interference. Radiated emissions and emissions conducted in cables, conducted pulses/transients and radio frequency (RF), electrostatic discharge (ESD) and lightning surges, disturbances in mains, and electromagnetic field immunity are all covered in the EMC Directive. (1, chapter 2.2.2.)

Damaged components from electrostatic discharge (ESD) are not a concern directly for EMC, it is mostly problematic for electronic production. From EMC point of view, an ESD pulse can affect the functioning of a microprocessor or clocked circuit by corrupting it, like a transient coupled into supply or signal ports would. (1, chapter 1.3.1.1)

Continuous interferences might not have any effect on the operation of solid state and processor-based control systems if the interference stays below logic threshold. If the interference exceeds the logic threshold, operation of the processor will be disrupted entirely. (1, chapter 1.3.1.)

2.1.1 Generation of fields

Different potentials between two conductors generate electric field (E-field). It is measured in volts per metre, and it is proportional to the applied voltage divided by the distance between the conductors (Figure 2). (1, chapter 11.1.4.1)

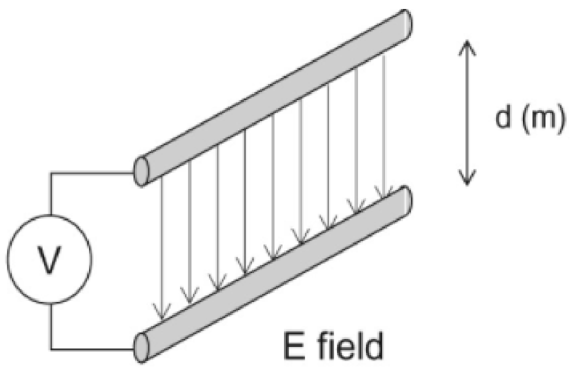

FIGURE 2. Electric field (E-field) (1, chapter 11.1.4.1).

A conductor carrying current generates a magnetic field (H-field) around itself. It is measured in amps per metre, and it is proportional to the current divided by the distance from the conductor (Figure 3). (1, chapter 11.1.4.1)

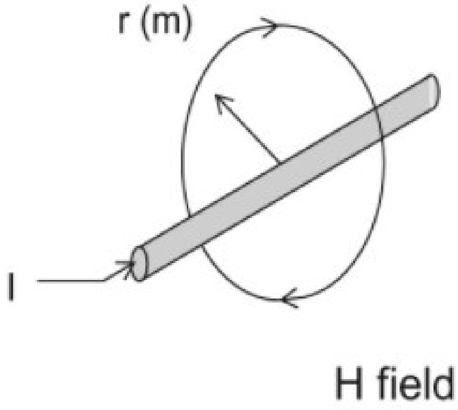

FIGURE 3. Magnetic field (H-field) (1, chapter 11.1.4.1).

When alternating current is generated by an alternating voltage in any electronic circuits network of conductors, an electromagnetic (EM) wave is generated. Its propagation speed is depending on the medium, in free space its speed of light, $3 \cdot 10^8$m/s. As displayed in figure 4, the EM wave propagates as a combination of both, electric and magnetic fields. (1, chapter 11.1.4.1)

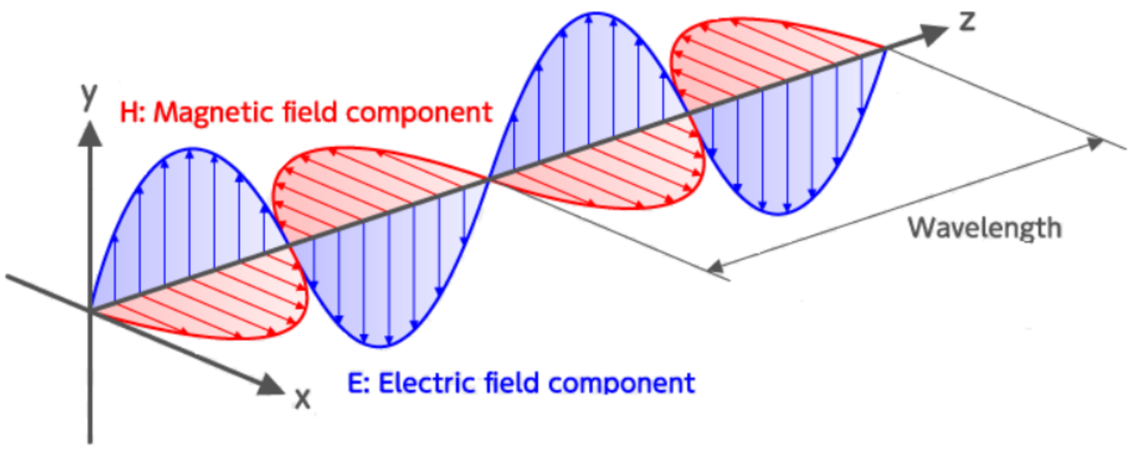

FIGURE 4. Propagation of the E and H fields associated with an EM wave (4).

Close to the radiating source, the fields strength and geometry depend on the source's characteristics. An E-field will be mostly generated on a circuit node with high $\frac{dU}{dt}$, and a H-field will be mostly generated on a conductor carrying a significant $\frac{dI}{dt}$. The physical layout of the conductors, dielectrics and permeable materials close by determine the structure of the E- and H-fields. As distance from the source increases, the complex three-dimensional field structure degrades. The field is still present only in components, which are located orthogonal to each other and propagation direction (Figure 5). (1, chapter 11.1.4.1)

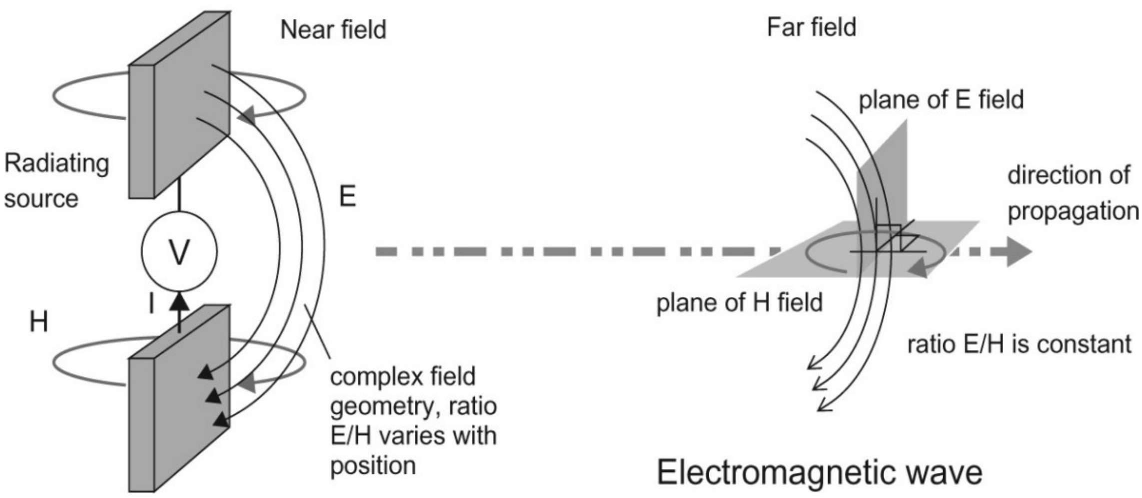

FIGURE 5. (1, chapter 11.1.4.1).

2.1.2 Wave impedance

Wave impedance is the ratio of electric field to magnetic field strengths E/H (Figure 6). To any given wave, it is a key parameter because the coupling efficiency with another conducting structure is determined by it, and the effectiveness of any conducting screen designed to stop it. (1, chapter 11.1.4.2)

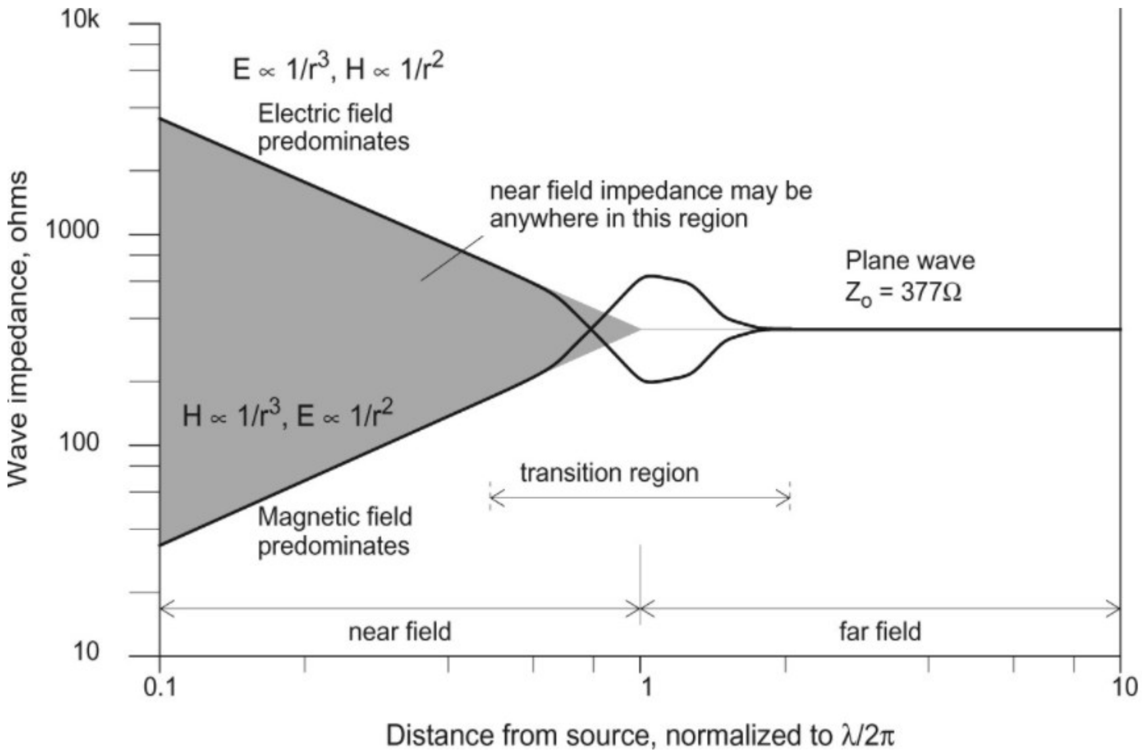

FIGURE 6. Wave impedance for electric and magnetic field sources (1, chapter 11.1.4.2).

When distance from the source is under $\lambda/2\pi$ (near-field), the impedance of the wave depends on the source's characteristics. E-field of high impedance is mainly generated by a low current and high-voltage radiator (e.g. dipole). A low impedance H-field is mainly generated by a high current, low-voltage radiator (e.g. loop). (1, chapter 11.1.4.2)

After distance from source is over $\lambda/2\pi$ (far-field), the wave is called plane wave. As distance increases, E- and H-field degrade simultaneously. And so, the impedance of the wave stays the same. It equals to the impedance of free space, displayed in Equation 1. (1, chapter 11.1.4.2)

EQUATION 1

$$Z_o = \sqrt{(\mu_o/\varepsilon_o)} = 120\pi = 377\Omega$$

$\mu_o = 4\pi * 10^{-7}\ H/m$, permeability of free space

$\varepsilon_o = 8.851 * 10^{-12}\ F/m$, permittivity of free space

The transitioning area from near to far field is when distance from source is around $\lambda/2\pi$ (roughly one sixth of a wavelength). It indicates the area where the complex field structure transforms to simple. Individual electric and magnetic fields must be considered separately in the near field, while plane waves are in the far field always. (1, chapter 11.1.4.2)

2.2 Coupling paths

There are four EMI coupling paths between the system causing the interference (source), and the system being affected (victim): radiative, inductive, capacitive, and conductive (Figure 7). The interference can be coupled through any of the paths, or any combination of the four. (3.)

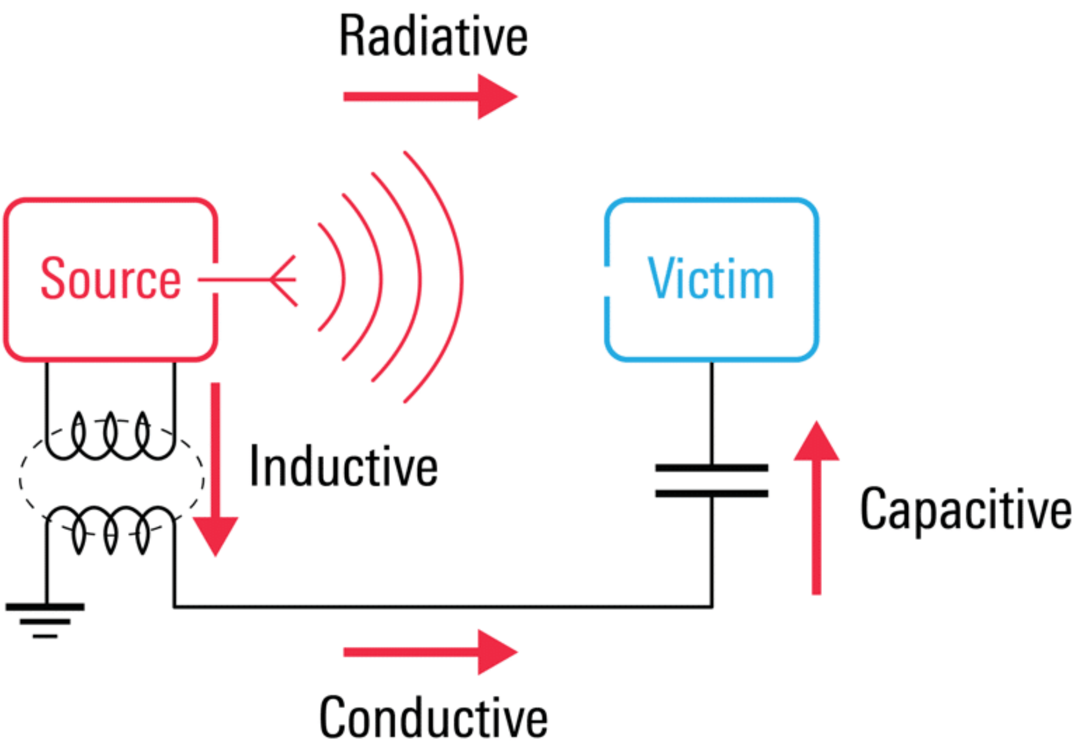

FIGURE 7. EMI coupling paths (3).

EMI is present in all areas of electronics. On top of understanding the source of the interference and the victim affected by it, the coupling paths are just as important to reduce the level of EMI that it does not cause any downgrading in the victim's performance. Determing which coupling path transfers the interference to the victim is key for the ability to address the problem. (5.)

Understanding by which coupling path the source interferences are transferred to the victim is essential, because lowering the coupling factor is in many cases the only way to reduce interference effects, to maintain fulfilling performance specifications of the product. (1, chapter 11.1)

2.2.1 Conductive coupling

Conductive coupling, or common impedance coupling paths are those which occur when the source and the victim have circuit impedance in common. Common impedances, where it is physically present through a shared conductor, are the most obvious ones. (1, chapter 11.1.1)

It becomes an EMC issue when at least two circuits have a common return path, and at least one of the listed cases occurs: (6.)

- High impedance ground (high inductance at high frequency, high resistance at low frequency)
- Large ground current
- Many circuits share ground with a very sensitive, low-noise margin circuit (6.)

Consider the circuits displayed in Figure 8, where a non-zero impedance ground return path is shared between two circuits. The voltage loads are:

$$V_{L1} = R_{L1}I_1 + Z_G(I_1 + I_2)$$
$$V_{L2} = R_{L2}I_2 + Z_G(I_1 + I_2)$$

The first circuits load voltage V_{L1} is influenced by the second circuits return current I_2, as well as second circuits load voltage V_{L2} is influenced by the first circuits return current I_1. (7, p. 451)

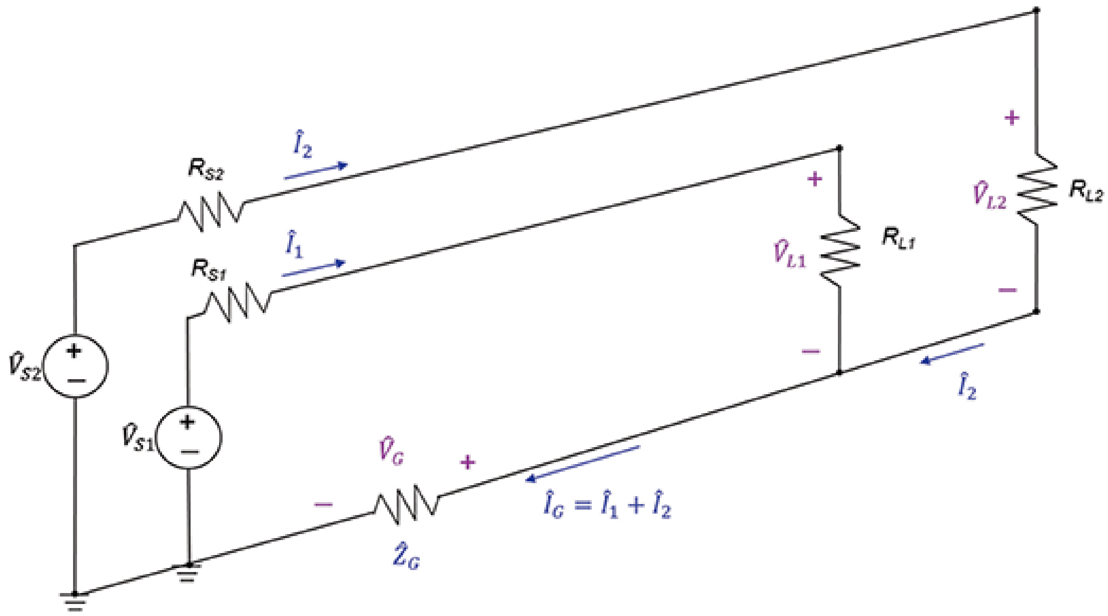

FIGURE 8. Common impedance coupling circuit (7, p. 451).

2.2.2 Inductive coupling

With near field inductive coupling, the field of interest is magnetic field (H-field). Equivalent circuit and physical representation can be seen in Figure 9. The interference source coupling structure and the receiving victim structure are in some way close to each other (e.g. on printed circuit board (PCB) or cable harness), when it is compared to the interference signal wavelength. (2.)

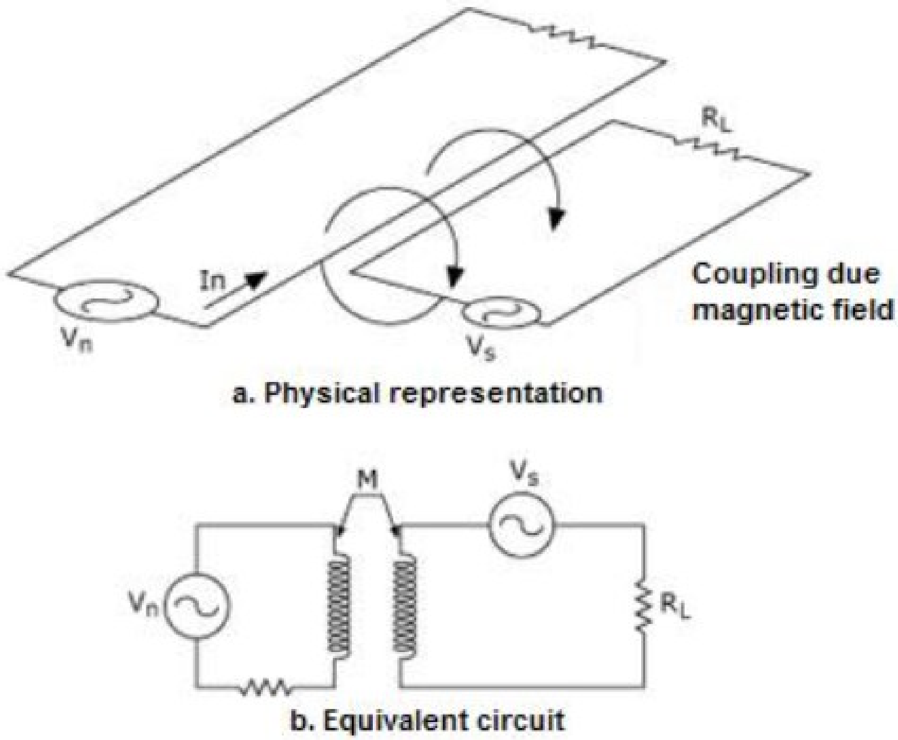

FIGURE 9. Physical representation and equivalent circuit of inductive coupling (8).

Mutual coupling inductance and current variations $\frac{dI}{dt}$ affect the level of interference. Frequency (inductive reactance is directly proportional to it, see equation 2), proximity between source and victim, length of parallel PCB traces or cables, height of the traces or cables with respect to a ground reference plane and interfering circuits load impedance have effect on inductive coupling. (8.)

EQUATION 2

$$X_L = 2\pi f L$$

f = Frequency

L = Inductance

Inductive coupling is a problem, where large loop areas or high-current traces or wires act as the interference sources, and the victims have large loop area structures or low impedance. (2.)

2.2.3 Capacitive coupling

The field of interest for near field capacitive coupling is electric field (E-field). The interference source coupling structure and the receiving victim are positioned near each other in some way (e.g.

on PCB or cable harness), when the distance between them is compared to the interference signal wavelength. (2.) Figure 10 displays equivalent circuit and physical representation of it.

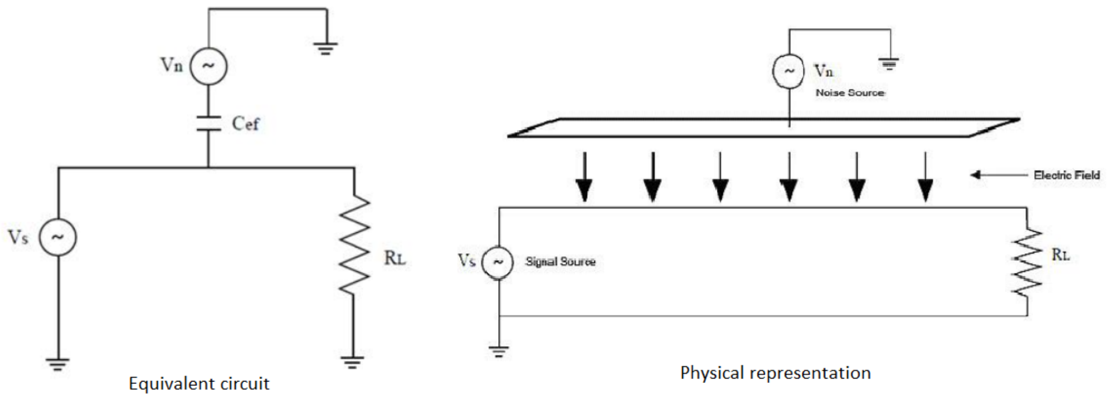

FIGURE 10. Physical representation and equivalent circuit of capacitive coupling (9).

The interference level depends on the coupling capacitance value between the source and victim and voltage variations $\frac{dU}{dt}$. Frequency (capacitive reactance decreases according to frequency, see equation 3), proximity between source and victim, length of parallel PCB traces or cables, height of the traces or cables with respect to a ground reference plane and high input impedance victim circuit and insulation of the cable (ε_r) have effect on capacitive coupling. Figure 11 shows typical capacitive coupling result between two traces or cables. (9.)

EQUATION 3

$$X_C = \frac{1}{2\pi f C}$$

f = Frequency

C = capacitance

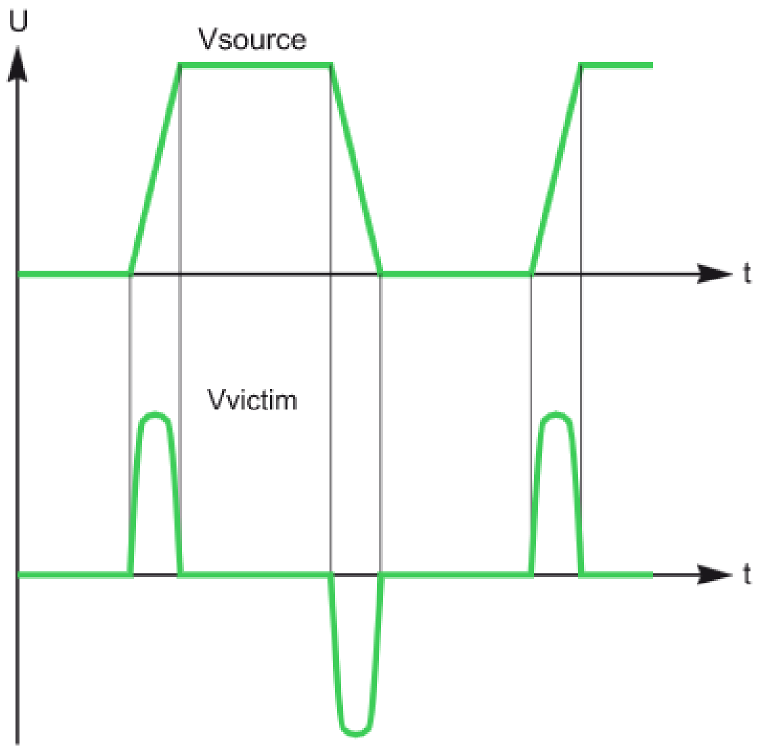

FIGURE 11. Capacitive cross-talk (10).

Basically, capacitive coupling is a problem when you have fast transient signals or high frequency signals typically in cables or PCB traces as the noise source, and high impedance circuits as victims. (2.)

2.2.4 Radiative coupling

In radiative coupling, the distance between noise sources coupling structure and victims receiving structure is far from each other compared to the interference signal wavelength. So, it is far field coupling, and the field of interest is electromagnetic field (EM-field). (2.)

The source and the victim are coupled by a medium (e.g. air). Efficiency of the emitting and receiving antenna, and the power of the radiating source determine the disturbance level. An electromagnetic field includes both E-field and H-field, which are correlated. Analysing the electrical and magnetic components separately is possible. (10.)

When a variable E-field affects a cable, a current is generated to it. This phenomenon is called field-to-cable coupling (Figure 12). When a variable H-field flows through a loop, a counter electromotive force is created which provides a voltage between the two ends of the loop. It is called field-to-loop coupling (Figure 12). (10.)

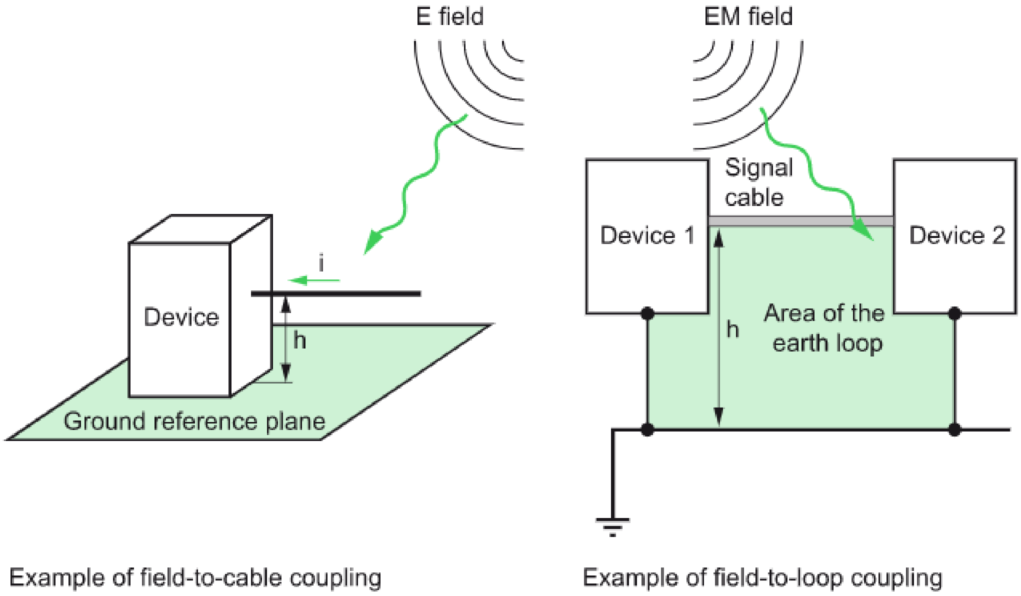

FIGURE 12. Field-to-cable and field-to-loop coupling (10).

Faraday cage principle can be used to block radiated coupling. A shielded cable connected to the devices metal case from both ends of its shielding is one plausible solution. To enhance effectiveness at high frequencies, exposed conductive parts have to be bonded. Symmetrical transmission links and increased distance causes radiated coupling to decrease. (10.)

2.3 Differential- and common-mode noise sources

Differential- and common-mode noises are essential concepts in electromagnetic compatibility. They are always unplanned and undesired. This chapter describes which coupling path usually results into differential- or common-mode noise. Figure 13 shows differential- and common-mode noises of a single current loop. (11.)

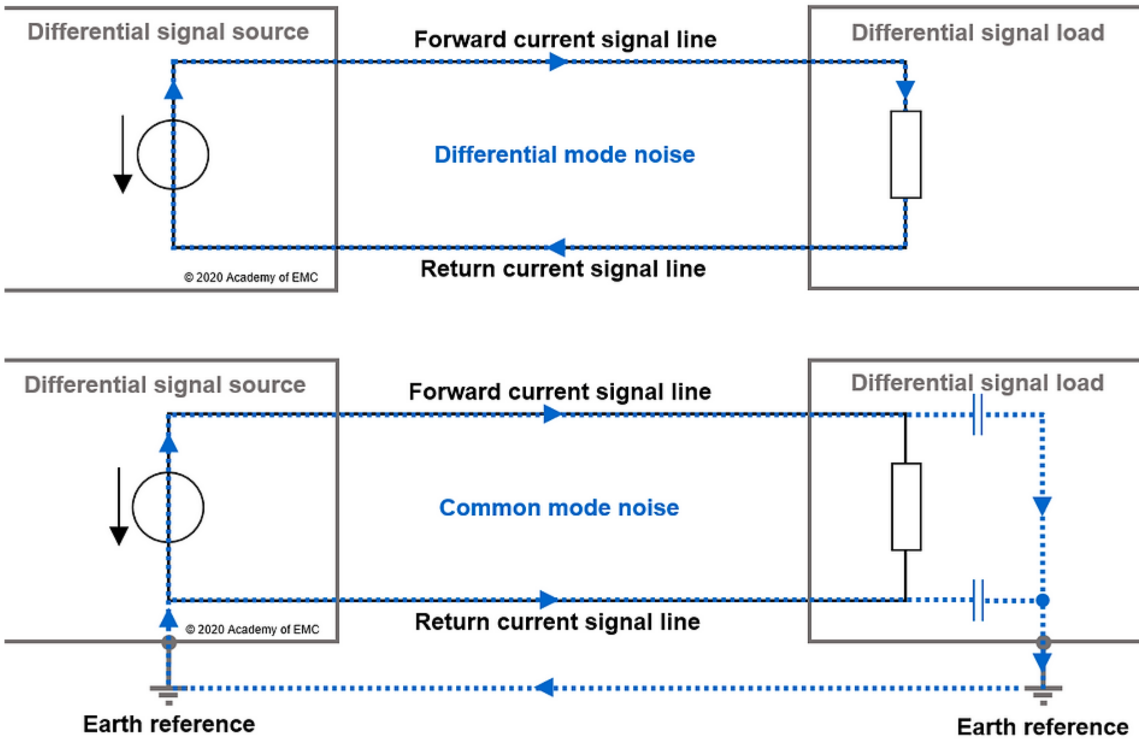

FIGURE 13. Differential mode and common mode of a single current loop (11).

2.3.1 Differential-mode

Consider two devices interconnected with a cable. The signal currents are carried in differential-mode in the two wires near to each other. The differential current will induce a radiated field, and an external radiated field can couple into the system and induce interference between them. (1, chapter 11.1.5.1)

Typical differential-mode noise sources and their physical coupling paths are displayed in more detail below:

- **Inductive coupling.** A noise current induced to a circuit loop by a magnetic field.

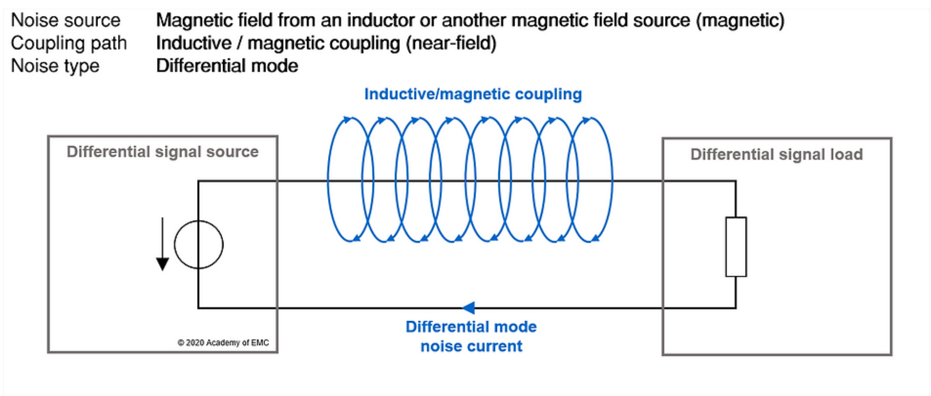

FIGURE 14. Inductive differential-mode noise (11).

- **Impedance coupling.** At least two circuits share a common path.

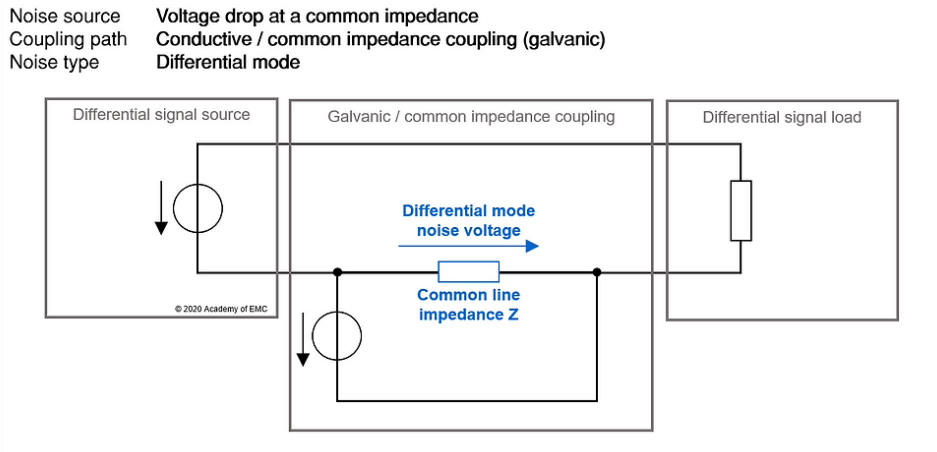

FIGURE 15. Conductive differential-mode noise (11).

- **Common mode to differential mode conversion.** Impedance difference between differential signal forward and return current lines.

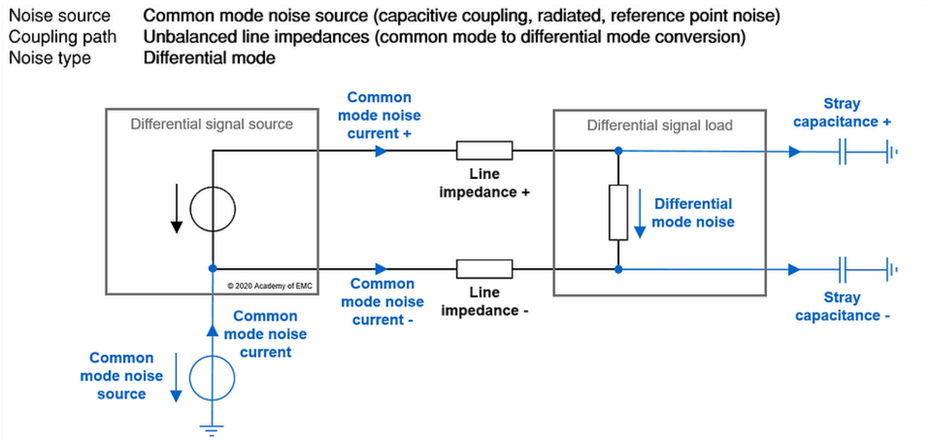

FIGURE 16. Noise from common- to differential-mode conversion (11).

2.3.2 Common-mode

Currents are also carried in common mode, which means that all currents flow in the same direction on the wires. Usually, signal currents have nothing to do with these currents. An external field might induce the currents by coupling to the cable loop, the ground plane and the different impedances connecting the device to the ground, and it might also create differential currents internally to the device which is vulnerable to them. Internal noise voltages between the cable connection and ground reference point could also generate them, and be liable for the emissions. The common mode current amplitude and spectral distribution are determined by stray inductances and capacitances, which are associated with the wiring and enclosure of each unit. (1, chapter 11.1.5.2)

Typical common-mode noise sources and their coupling paths are described in more detail below:

- **Capacitive coupling.** Both lines are coupled with a noise current.

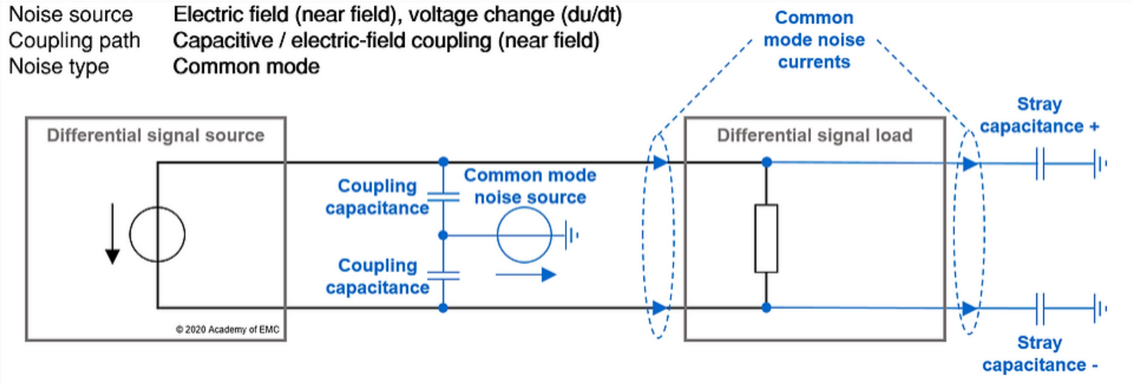

FIGURE 17. Capacitive common-mode noise (11).

- **Electromagnetic coupling.** Wireless radiation coupled into part of an electronic circuit or a cable acting like an antenna.

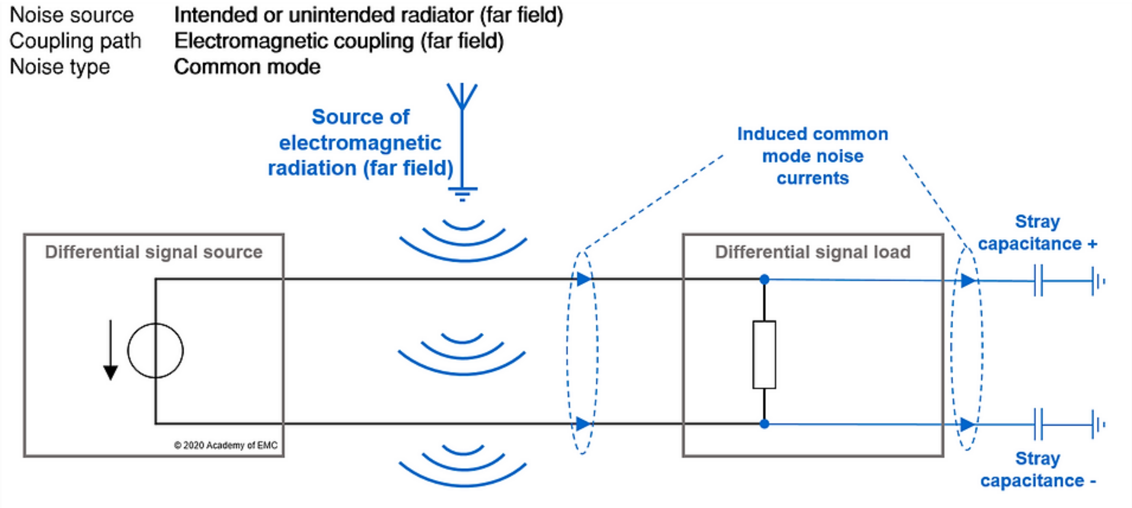

FIGURE 18. Electromagnetic common-mode noise (11).

- **Reference point noise.** Increase or decrease of voltage potential of the circuits reference point (ground) or a voltage potential difference between spatially divided circuits.

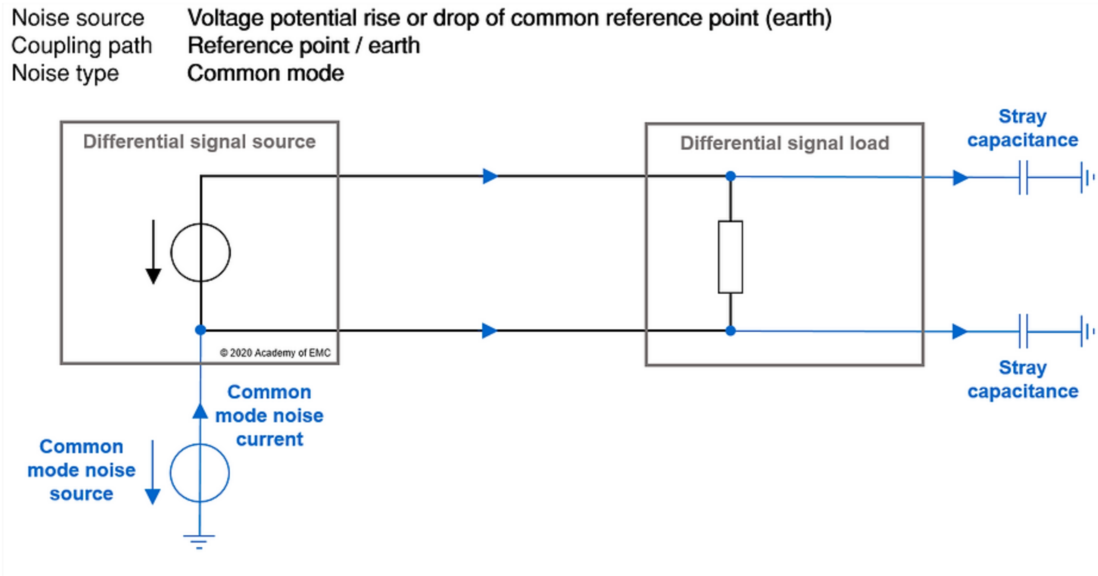

FIGURE 19. Reference point common-mode noise (11).

3 MEASUREMENT DEVICES

This chapter introduces features and functionalities of a spectrum analyzer and near field probes, which were used for the feasibility measurements to verify the EMC measurements at the current location of the automated test system.

After the measurements will be implemented to the automated test system, the measurements will be performed by scanning steadily with a near field probe very close to surface of the products printed circuit board (PCB) on some smaller predefined area, e.g. on top of some integrated circuit (IC). The first scan is performed with the device under test (DUT) turned off to display interferences from surroundings, and the second scan where the device is turned on to add interferences from the device to the measurement results. Subtracting the first scan result from the second scan leaves the interferences from DUT as a result, and excludes the interferences from surroundings. Performing the measurements increases the chance to accurately locate possible emission sources from the DUT, which helps with taking necessary measures to lower the emission levels to acceptable level, that the products are EMC compliant.

3.1 Spectrum analyzer

A spectrum analyzer displays measured input signals in frequency domain (Figure 20), meaning that the signals are displayed graphically with amplitude of the signals vertically on a logarithmic scale and frequency horizontally on logarithmic or normal scale. (12.)

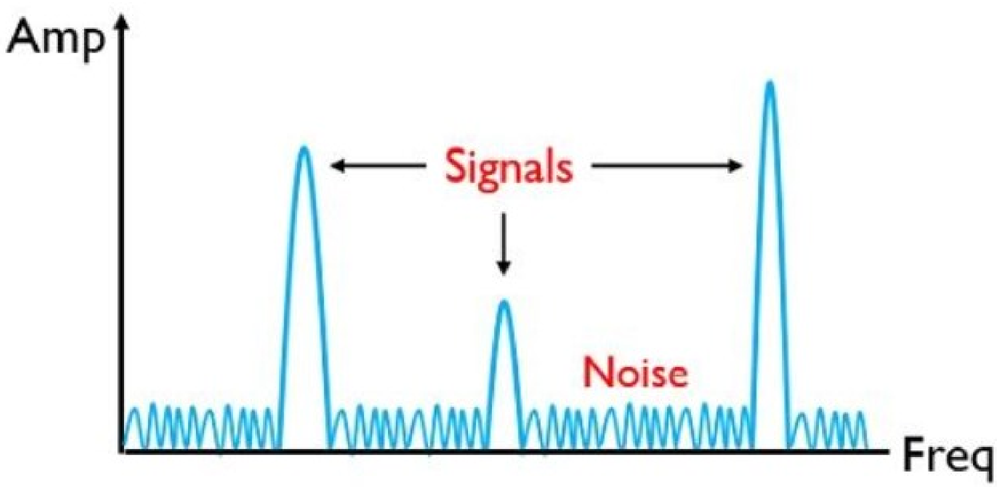

FIGURE 20. Frequency domain display (12).

The most used spectrum analyzer type is swept-tuned receiver. It displays the frequency components of the input signal by sweeping the whole frequency range. Because the device is capable of measuring on a large frequency range, it is suitable for many different applications in various fields. Figure 21 displays the block diagram of the spectrum analyzer. (12.)

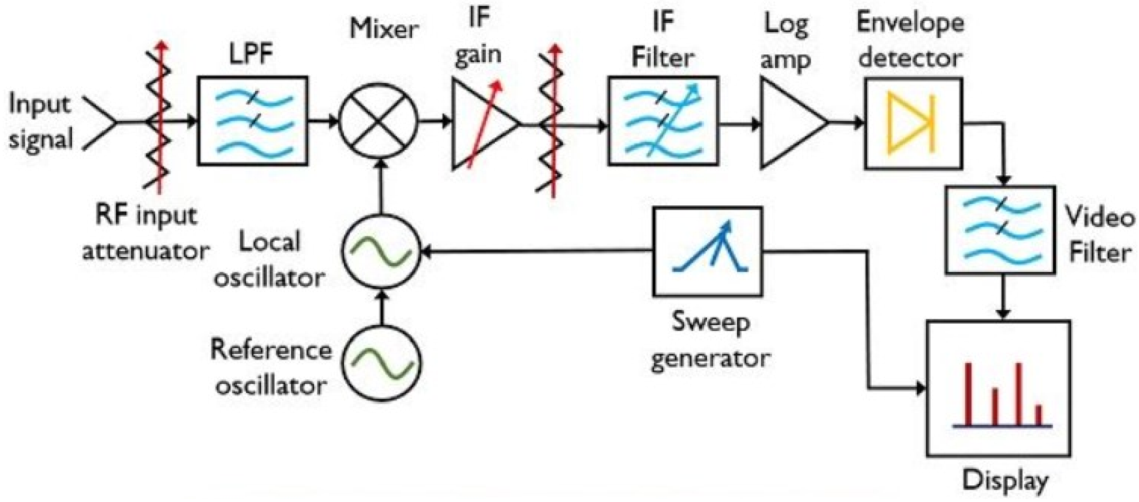

FIGURE 21. Spectrum analyzer block diagram (12).

First, the input signal is attenuated by RF input attenuator, which acts as a protective circuit for the spectrum analyzer by attenuating the signal to appropriate level. The attenuated signal passes through a low pass filter (LPF), which blocks out high-frequency components from the signal. Some spectrum analyzers use a pre-selector instead of low pass filter, which acts as a bandpass filter. The signal is then passed on to mixer, which creates an intermediate frequency (IF) signal by combining the input signal with local oscillator signal. The signal then proceeds to IF filter, which is a bandpass filter centered at the IF, and the adjustable IF filter bandwidth is called resolution bandwidth. The output from IF filter then goes to envelope detector, and its output voltage shows the signals amplitude. It is then smoothened by video filter and further digitized with an ADC before displaying it on the spectrum analyzers screen. (12.)

To perform measurements properly with a spectrum analyzer, measurement settings must be set correctly to get the desired measurement results. Some distortions might occur to the results if the settings are set incorrectly.

The usual measurement settings are listed below with short descriptions:

- **Start and stop frequencies** determines where the frequency range to be measured will begin and end and they must be set separately every time, depending on the desired measurement.
- **Reference level** does not affect measurement results, only determines where the measurements are displayed on the spectrum analyzers screen. This setting is set automatically by the spectrum analyzer but might need some adjusting manually in some cases.
- **Attenuation** setting adds attenuation to the input received from the preamplifier.
- **Sweep time** means how long it takes to do a single sweep through the set frequency range. This setting can be changed manually, but usually the spectrum analyzer will set it correctly automatically.
- **Resolution bandwidth (RBW)** affects accuracy of the measurement. Narrow RBW lowers noise level and increases accuracy but as a downside, increases sweep time. The spectrum analyzer can set the RBW automatically, or it can be changed manually depending on the measurement.
- **Video bandwidth (VBW)** only affects accuracy of the image displayed on the spectrum analyzers screen, automatically set to match RBW.

3.2 Near field probes

Near field probes are used for locating emission sources straight from DUTs, because they detect field strength in the near field. There are two kinds of near field probes for different fields, shorter rod type probe for E-field and a probe with a loop at the end of it for H-field (Figure 22). (1, chapter 7.2.3.)

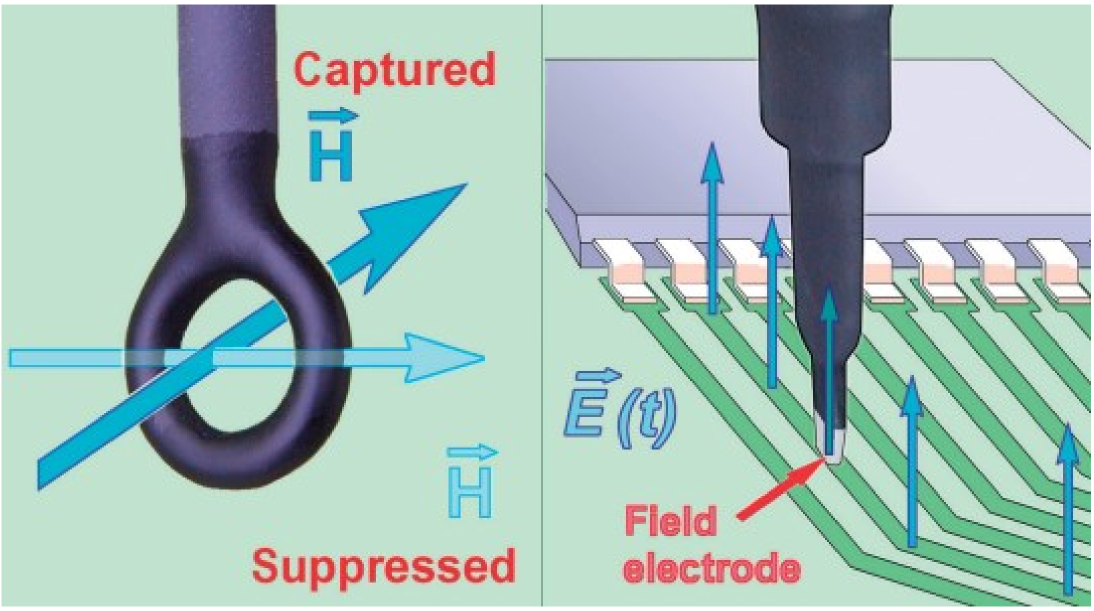

FIGURE 22. H-field loop probe and E-field rod probe (13).

Design of the probe affects sensitivity and spatial accuracy. With smaller probes signal locations can be found more accurately, but it will lose sensitivity. It can be increased with a preamplifier when working with low-power circuits. H-field probes should detect paths of high $\frac{dI}{dt}$, and E-field probes should only detect nodes of high $\frac{dU}{dt}$. (1, chapter 7.2.3)

H-field probe was used for measurements during this thesis, because they are used a lot more frequently in EMC measurements. Test measurements made with E-field probe of the ambient interferences at the automated test system did not show any significant differences compared to the H-field probes. Therefore, the measurements made in this thesis will focus on the H-field probes. Figure 23 displays the difference between measurement results scanned on top of an application specific integrated circuit (ASIC). Yellow trace was scanned with small loop XF-R 3-1 probe, and green trace with big loop RF-R 400-1 probe. The probes were moved around with free hand, so the movements are not exactly the same. Meaning, that because the movements are only roughly the same, they are not really comparable. Displaying how much the probe design affects the measurement results, the rough measurement is fine.

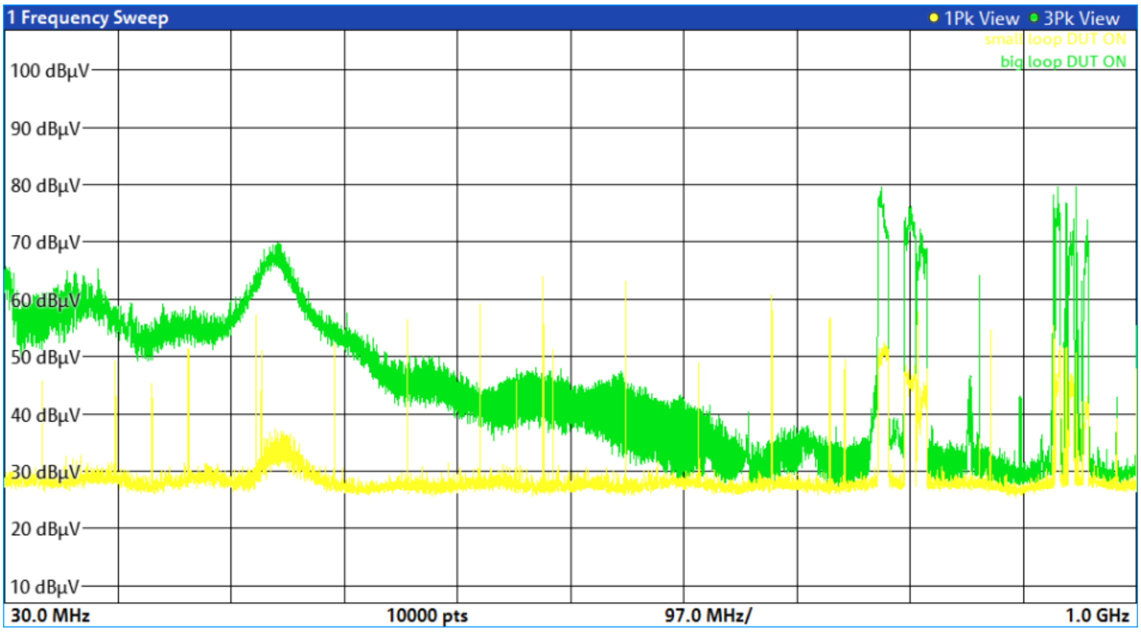

FIGURE 23. Difference between RF-R 400-1 (green) and XF-R 3-1 (yellow) H-field probes.

In the frequency range from 30MHz to about 400MHz, the bigger loop probe picks up interferences from other circuits nearby due to its higher sensitivity. In that range, almost all visible spikes on the yellow trace are hidden under it. Also, on the frequency range between 750MHz to 1GHz, ambient interferences appear roughly 20-30dBµV stronger.

The bigger RF-R 400-1 probe is mostly used for rougher scans over large areas over the DUT for searching the location of the possible interference source and it is not used for small area measurements on top of ICs like this one. Both probes pick up the ambient interferences in the 750MHz to 1GHz range, but the smaller XF-R 3-1 does so significantly less.

Based on the comparison between the probes, the bigger RF-R 400-1 probe should not be used in the automated test system for taking rough scans which would cover the whole DUT. That is because the higher sensitivity of the probe causes a lot more of interferences to appear on the measurement results from surroundings and nearby circuits. Instead, in this current location of the system, the focus should be more on precise measurements on smaller areas on the DUT with less sensitive probes, which have smaller diameter than the RF-R 400-1 probe.

4 MEASUREMENTS

To verify the feasibility of performing EMC measurements with the automated test system, ambient interferences were measured to see, how much they would affect the final results.

Initial plan was to take reference measurements at EMC laboratory and compare them to measurements, which would have been performed exactly the same way at the desired target location. However, for the measurements to be comparable, the probes should have been placed same distance away from the DUT and rotated exactly like in the reference measurements, while sweeping for measurement results. Doing that by placing the probes with free hand would be extremely hard or even impossible, so just measuring the ambient interferences is enough to determine whether the EMC measurements can be performed with the automated test system or not. That is, because if there is too much ambient interference, the interference spikes from the DUT will not be visible from under the ambient interference.

4.1 Measurement setup

The measurements were performed at the location of the automated test system with two different sized probes, RF-R 400-1 with 25mm loop diameter which can be used for measurements at <10cm distance from the DUT, and XF-R 3-1 with 3mm loop diameter which is only used for measuring very close from the DUT. Measurement device was Rohde & Schwarz FSVA3013 spectrum analyzer with a 30dB preamplifier to 3GHz. Figure 24 below displays both probes and preamplifier.

FIGURE 24. RF-R 400-1 and XF-R 3-1 H-field probes, and 30dB preamplifier where the probe was connected.

The measurement parameters used on the spectrum analyzer are listed below:

Frequency ranges: 150kHz to 30MHz(conductive), 30MHz to 1GHz and 1GHz to 6GHz(radiative)

RBW: 100kHz

VBW: 100kHz (set automatically)

Sweep time: 10ms (150kHz to 30MHz and 30MHz to 1GHz), 50ms (1GHz to 6GHz)

Ref level: 107 dBµV (set automatically)

Attenuation: 0dB

Preamplifier: Off (used external 30dB preamplifier)

4.2 Measurement results

The measurements were performed with wide frequency ranges to get understanding of how much of the ambient interferences would the probes pick up, and which frequency areas would be the most troubling ones. The measurements were performed by moving the probes on top of a DUT, trying to repeat exactly the same movements with both probes and different frequency ranges. The results also display how much the loop size of the probe affects the measurement results.

Figures 25, 26 and 27 below display the measurements with the DUT turned off, on different frequency ranges. Blue traces are measured with XF-R 3-1 small loop probe and orange traces with RF-R 400-1 probe.

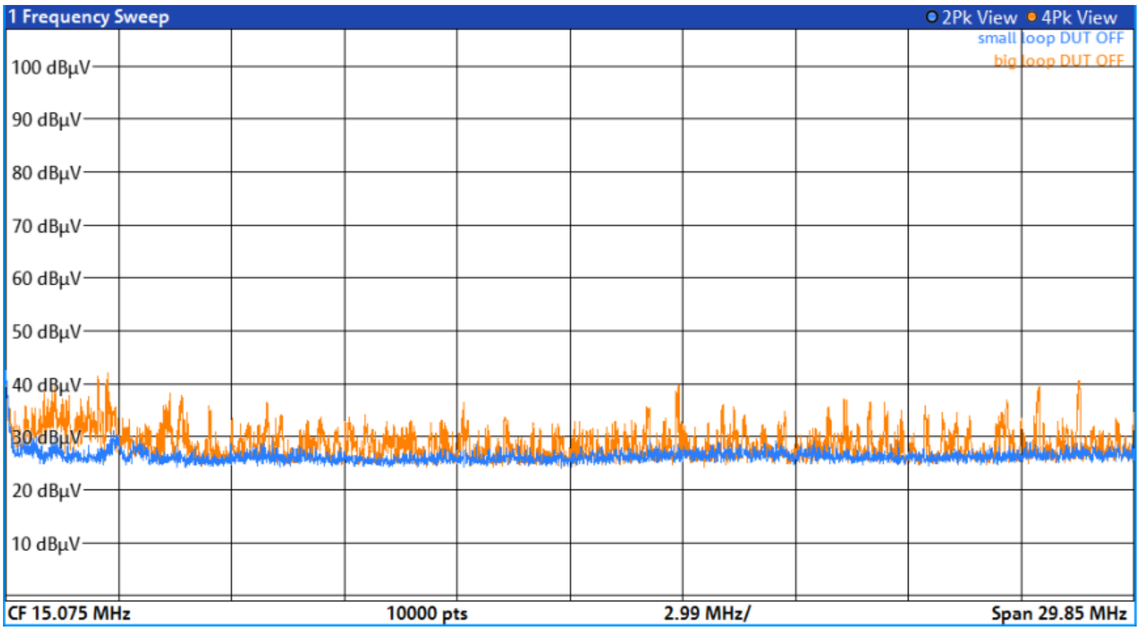

FIGURE 25. Ambient interferences, frequency range from 150kHz to 30MHz.

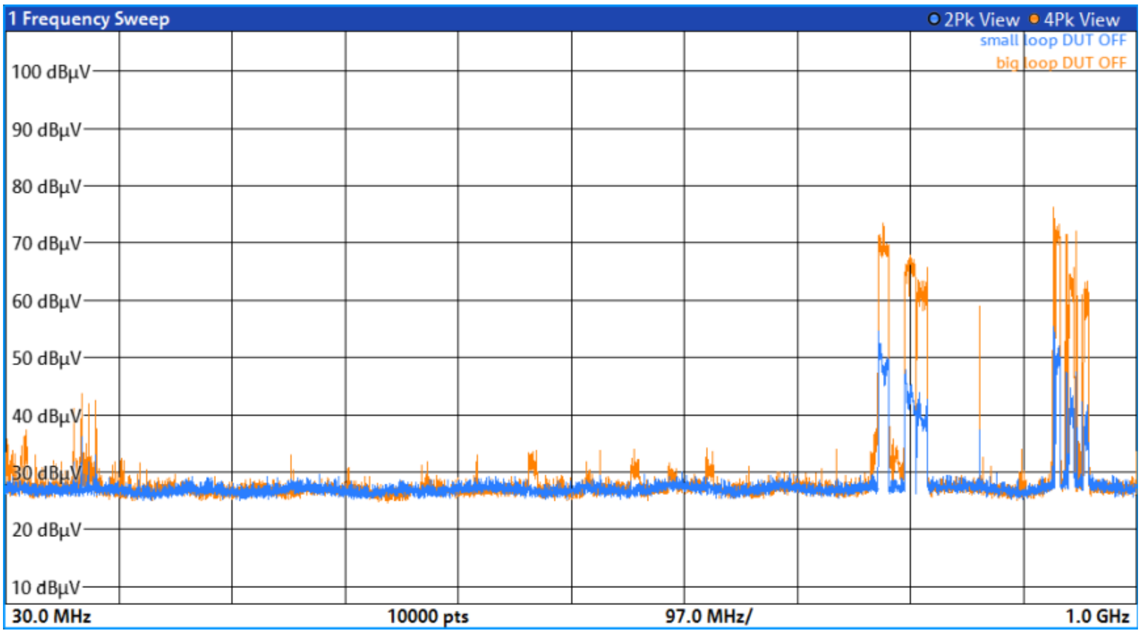

FIGURE 26. Ambient interferences, frequency range from 30MHz to 1GHz.

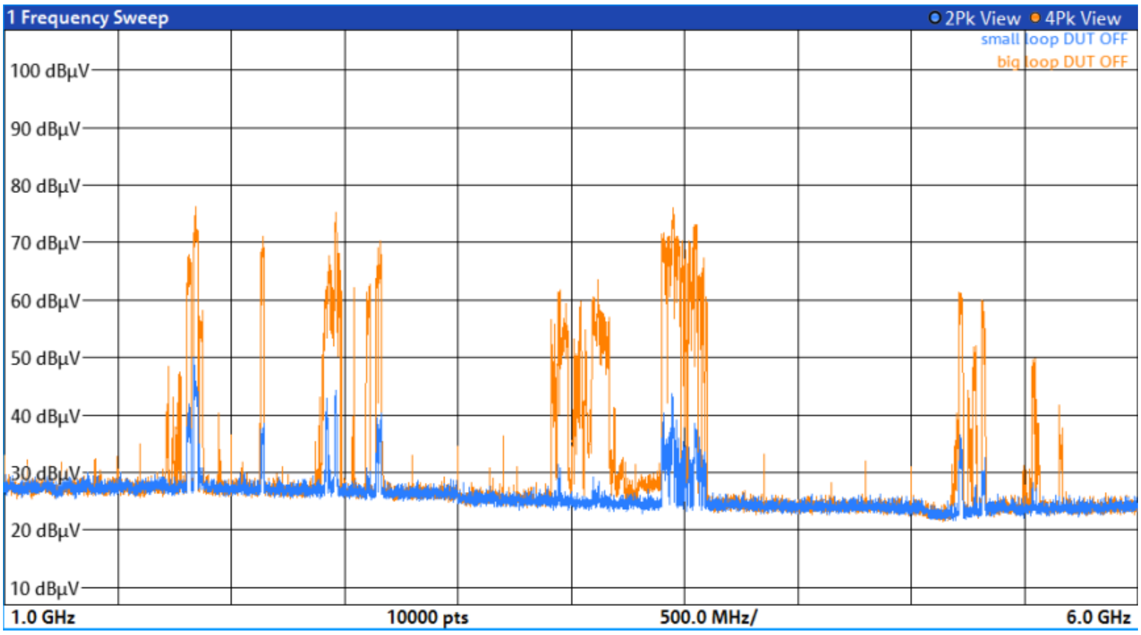

FIGURE 27. Ambient interferences, frequency range from 1GHz to 6GHz.

The ambient interferences begin to appear after 750MHz. The orange trace measured with the bigger probe picked up the interferences a lot stronger compared to the smaller probe displayed on blue trace, and all of the possible spikes to be measured from the DUTs would be hidden under them on these frequencies.

Figures 28, 29 and 30 below display measurements performed on top of an ASIC with the small XF-R 3-1 probe. Blue trace shows the scan while the DUT was turned off, and yellow trace when the DUT was turned on. The spectrum analyzer was set to max hold, and measurements were performed with one continuous scan, moving the probe all around the ASIC to get all of the spikes visible in each figure.

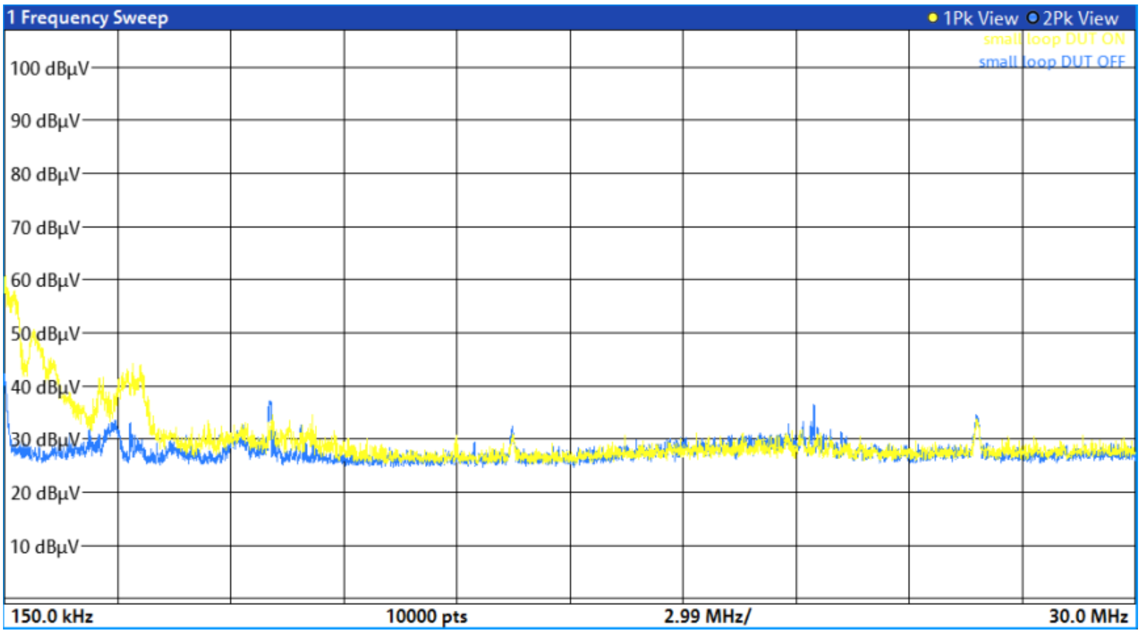

FIGURE 28. Scanned on top of ASIC, frequency range 150kHz to 30MHz.

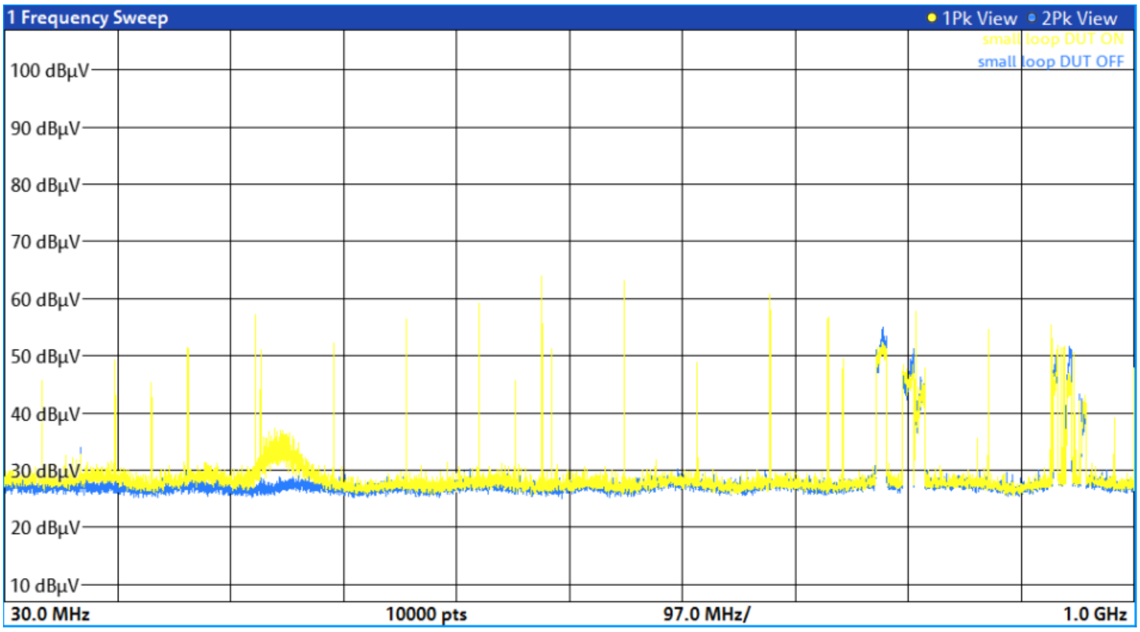

FIGURE 29. Scanned on top of ASIC, frequency range 30MHz to 1GHz.

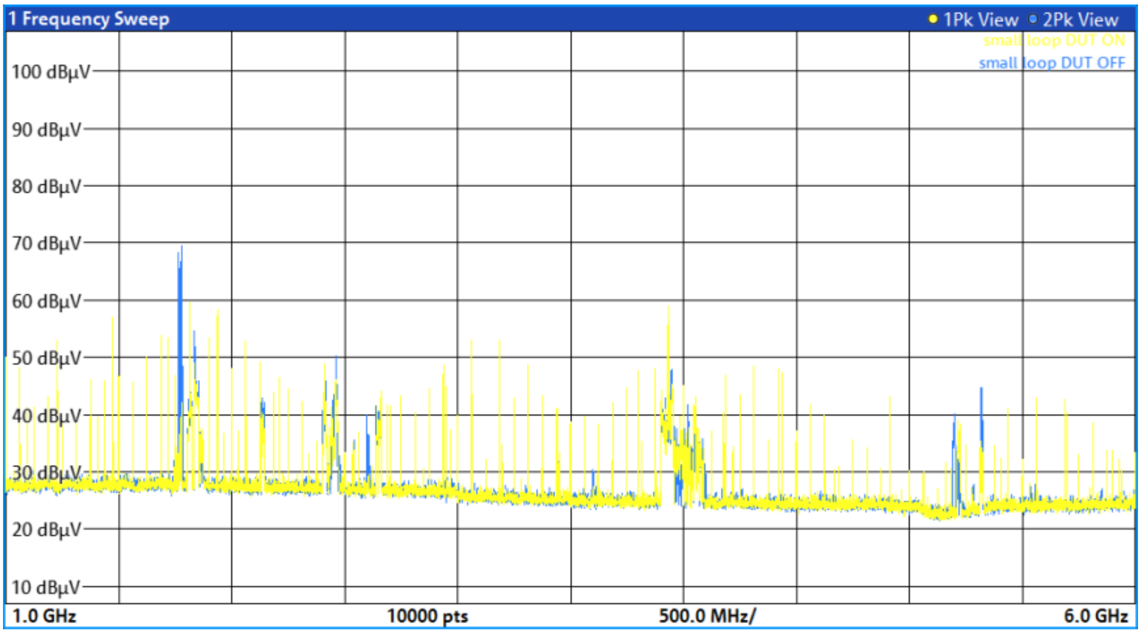

FIGURE 30. Scanned on top of ASIC, frequency range 1GHz to 6GHz.

As shown in the figures above, the ambient interferences are present in the measurements on higher frequencies, but not nearly as much compared to the more sensitive probe. On those areas, some of the measured spikes from DUT are partly or completely hidden under the ambient interference. The blue trace with only the ambient interferences can be subtracted from the yellow trace, leaving only the measurements from DUT as a result. Doing so also subtracts the spikes measured from DUT which are under the ambient interferences, but it will help with post processing the results.

These measurements were performed manually in one continuous measurement by moving the probe around the ASIC. Usually, the area of interest is divided into a test point grid and first measured with wider frequency ranges on each test point with different rotations on the probe to get the strongest results. Based on findings from those measurements, the frequency range will be set precisely to the desired frequencies and then the exact same measurements will be performed again, to get a more accurate look for analyzing the results. As long as the desired frequency range is not on the ambient interference frequencies, the measurements can be analyzed properly.

Based on these measurement results, the EMC measurements can be performed with the automated test system. It needs to be acknowledged, that the ambient interferences will cause some trouble in the specific frequency ranges displayed in figures 25 to 27, which will cause the measured spikes from DUT to remain hidden under them. Fortunately, as the probes loop size decreases which makes it less sensitive and more precise, the ambient interferences appear significantly weaker. The probes used with the automated test system should remain on the smaller end, to minimize the ambient interferences from the desired measurement results.

5 CONCLUSION

The aim of this thesis was to study and verify the feasibility of performing EMC measurements on an automated test system. The main concern was the current location of the system, where is a lot of possible interference sources, which could affect the measurement results.

The measurements were performed manually at the automated test system, to verify the reliability of the results. Based on the measurement results, the automated test system can be used to perform EMC measurements. There is ambient interference at some frequency ranges, beginning after 750MHz, which will affect the results measured from DUTs if the desired measurement frequency range is located in the same range as the ambient interferences. They might make the results from DUTs harder to analyze or cover them completely on some specific cases, but performing the measurements automatically with the system would still be beneficial. Automated test system provides more space to make measurements for different sizes of DUTs compared to some basic EMC scanners and it can automatically turn the DUT around which is efficient when measurements need to be made from both sides of the DUT.

The measurements also clarified that the automated test system should focus on more precise measurements on smaller areas of interest (e.g. on top and around of ICs), instead of scanning the whole product with a rougher scan. The reason for it is that the bigger probe which would be used for the rough scan, is very sensitive and picks up too much of the interferences from surroundings and nearby circuits. In the current location of the automated test system, interferences from surrounding devices can change according to which projects are ongoing and what devices they have to use. Some of the devices might cause permanent or temporary interferences on certain frequency ranges depending on the device, which were not visible on the performed measurements. Therefore, it would be more beneficial to use the smaller probe at the current location of the automated test system to minimize the interferences. The small accurate probes also pick up some of the ambient interferences, but a lot weaker compared to the bigger probe.

The next step is to start implementing the EMC measurements to the automated test system. The first phase is to program the movement of the probes to the system to produce precise and repeatable measurements and create drivers for the measurement devices to operate them automatically.

After implementing those, the next phase is that the measurement results need to be postprocessed into easily understandable and presentable format. Then the results can be automatically reported for the user.

During this thesis, I learned a lot about EMC and how the measurements should be performed. I did not have any previous experience about EMC, the spectrum analyzer and accessories needed for the measurements. It was really interesting to learn about the different interference coupling methods and about the EMC measurement process.

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