Methods for Investigating Influence Parameters in the Measurement Setup for Radiated Emissions according to CISPR 25

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***Abstract*—This work examines methods to evaluate the impact of different measurement setups on the radiated emissions measurement according to CISPR 25. Besides using a real device under test, swept measurements with a vector network analyzer and the artificial excitation of the wiring harness with a broadband impulse are discussed. The investigations evaluate the reproducibility of measurements using CISPR 25 setup. This paper concludes that of the methods investigated, the most suitable is the one in which the wiring harness is excited with a broadband impulse.**

Keywords—CISPR 25, ALSE, Reproducibility, Radiated Emissions, Broadband Impulse Excitation

I. INTRODUCTION

Since the introduction of the CISPR 25 standard in 1995 the complexity of electronic control units (ECUs) and wiring harnesses increased significantly. Today's ECUs not only use several different bus systems but also several of the same type in parallel. But the measurement setup specified in the standard remained largely unchanged.

CISPR 25 defines for the radiated emissions measurement of a component, that it is connected via a cable (test harness) to a load simulator [1]. The device under test (DUT) can only be properly tested, when all connections necessary for operation are available. Therefore, active communication must be possible for DUTs with bus systems. Since the periphery cannot be placed inside the absorber lined shielded enclosure (ALSE), the bus signals are usually transmitted via an optical link outside the chamber. For each bus to be transmitted a separate optical converter inside and a counterpart outside the chamber is required. For this purpose, the wiring harness must be adapted, so that all required transceivers can be connected on the load simulation side. A large number of possible set-up variants are imaginable, which are potentially accompanied with different measurement results. In addition, the positioning of the individual devices on the ground plane also has a partly unknown influence on larger setups. For comparative measurements, different measurement setups are to be investigated with regard to the radiated emissions.

The aim of this work is to find a measuring method which can reliably characterize the influence of different measurement setup variations on the radiated emissions. These methods shall meet the following requirements:

- a sufficient bandwidth so that resonances and the damping curve can be evaluated over the entire frequency range demanded by CISPR 25
- the reproducibility of the signal excitation in order to achieve general comparability
- a high dynamic range to be able to evaluate variants of the setup with sufficient accuracy

II. MEASUREMENT METHODS

Three different measurement methods are evaluated in the following below: a) The measurement of emissions driven from a real DUT; b) The measurement of radiated emissions when the wiring harness is excited using a broadband impulse; c) the measurement of the transfer behavior between the wiring harness and the measuring antenna with a vector network analyzer (VNA).

A. Measurements with a real DUT

First, measurements are carried out with a real DUT. Therefore, automotive ethernet, according to the 100 BASE-T1 standard, is used as test bus. For both, the DUT and the load simulation a fiber optical media converter is used. For the purpose of this test the media converters are modified to produce high and reproducible emissions.

Fig. 1 shows the setup for measuring the radiated emissions in an ALSE according to CISPR 25. Both fiber optical converters are connected to an opposing converter outside the chamber. Each of them is connected to a PC. Those ensure a constant data traffic over the link. Both media converters in the ALSE are connected together via an unshielded twisted pair cable (UTP) of type "KROCAR 64996795." The test harness has a length of 1700 mm. Both devices are placed on a non-conductive material, 50 mm above the ground plane according to CISPR 25. The media converter on the right is connected to the reference ground plane. This grounding setup is also used for the measurements with the VNA and the impulse excitation method later on.

The measurements are made in the CISPR 25 frequency range between 30 MHz and 1 GHz [1]. For this range, the antenna is directed towards the wire harness. The frequency range above 1GHz is not considered, since the reproducibility is worse, as shown in Section II part C. The parameters of the scanning receiver are:

- Step size: 50 kHz
- Resolution bandwidth: 120 kHz
- Dwell time: 5 ms

One hybrid antenna (ultralog) is used to cover the entire frequency range in order to avoid measurement inaccuracies caused by changing the antenna.

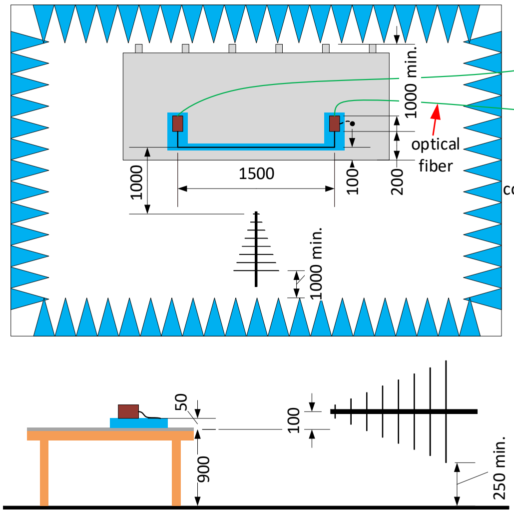

Fig. 1. Test setup according to CISPR 25 for the real DUT, for the radiated emissions from 30 MHz to 1 GHz

The radiated emissions of this setup are shown in Fig. 2. The blue line represents the values of the average detector, whereas the orange line represents the peak detector measurement. The DUT emits narrowband emissions which only occasionally emerge from the noise floor. The trace of the average detector shows the carrier of the Ethernet-signal at 33.3 MHz and its second harmonic at 66.6 MHz. At 50 MHz the second harmonic of an internal clock signal of the DUT media converter occurs (25 MHz fundamental frequency). The harmonics continue over the entire frequency range.

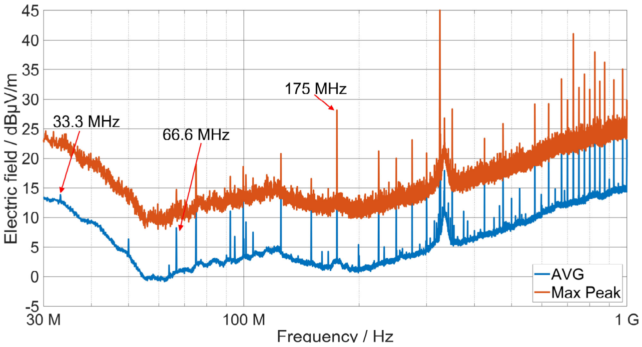

Fig. 2. Radiated emissions of the modified media converter link

Due to the insufficient number of excitation frequencies in this measurement method, it can not be used to obtain general statements about the influence of the measurement setup on the radiated emissions. This illustrates the necessity to provide a broadband excitation which covers the entire frequency range.

B. *Broadband excitation of the wiring harness with an impulse*

To achieve broadband excitation of the wiring harness a fast impulse can be used. The used cable impulse generator works by charging a short piece of coaxial cable with twice the impulse voltage. The charged cable gets connected with the output, via a bounce-free, coaxial switch. During switching, a traveling wave occurs at the generator's output with steep rise times. The duration of the impulse depends on the length of the charged coaxial cable [2].

The used impulse is shown in Fig. 3 in time domain. Fig. 4 shows the corresponding broadband frequency domain [3]. The used impulse has a rise time of less than 100 ps (10% - 90%) and a width of 200 ps (50% - 50%). This results in a 3 dB corner frequency of approximately $f_{3dB} = 1.5$ GHz and a signal power variation of less than 1 dB under 1 GHz.

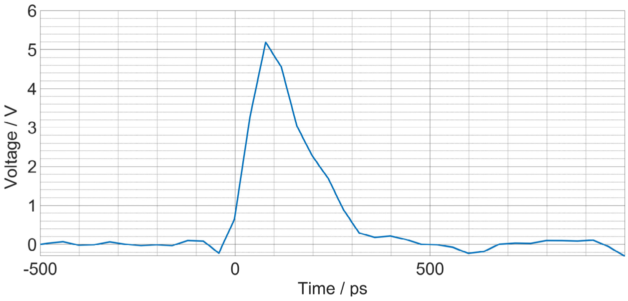

Fig. 3. Impulse for wiring harness excitation in time domain

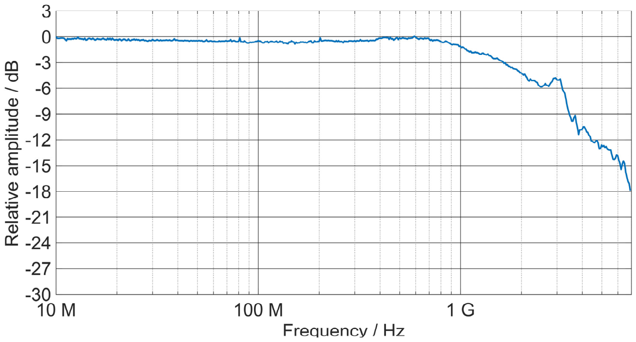

Fig. 4. Impulse for wiring harness excitation in frequency domain (normalized)

The entire setup is shown in Fig. 5. The impulse generator housing is connected to the ground plane. The impulse generator output is connected to an attenuator. For DUT configurations without galvanic connection to the ground plane, the attenuator dissipates the charge on the wiring harness, caused by the impulse. The attenuator is attached to an injection adapter, which serves an adaption to connect the M12 connector of the harness. The impulse is applied as a common mode signal (CM) to both conductors and has a repetition rate of 100 impulses/second. On the other end of the harness, a shielded enclosure is connected, in which the same printed circuit board from the actual DUT is located as termination. In order to provide comparability, the same cable harness is used as for the measurement of the real DUT.

The measurements are taken between 30 MHz and 1 GHz. Due to the excitation by impulses, only the peak detector of the test receiver can be used. The selected dwell time is 15 ms, so that at least one pulse is recorded in each measuring interval.

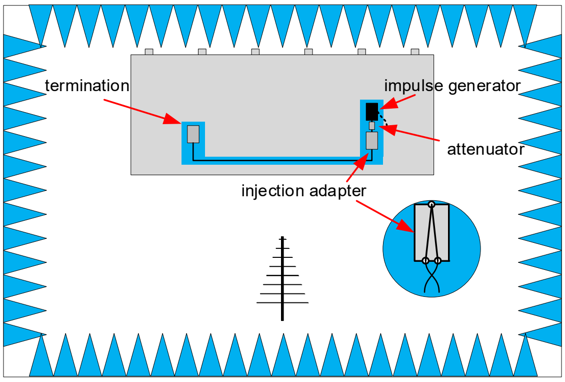

Fig. 5. Test setup for the measurement of radiated emissions with impulse excitation of wiring harness

The other settings of the test receiver are not changed:

- Step size: 50 kHz
- Resolution bandwidth: 120 kHz

Fig. 6 shows the radiated emissions of the impulse method compared to those from the real DUT. The plot shows, that resonances of the setup can be clearly seen if impulse excitation is used: Almost over the entire frequency range the signal is above the noise floor. The resonance at 179 MHz is where the wavelength equals the length of the cable. For the CM-excitation the propagation of the electric field takes place between cable and ground plane. The relative permittivity on which the velocity factor is based is approximately $\varepsilon_r = 1$ in this case. The effect of this resonance may be recognized to some extent in the measurement with the real DUT, but due to its narrowband excitation frequencies the apparent resonance frequency seems to be shifted to 175 MHz because the excitation frequency does not match the resonance frequency. The same can be seen for other frequencies too, where the resonances are caused by the dimensions of the setup.

Excitation with the impulse generator provides the advantage that a floating measurement setup is also possible, where there is no galvanic connection with the ground plane. The impulse voltage can be freely selected between 1 V and 600 V. Therefore it is possible to utilize the entire dynamic range of the test receiver.

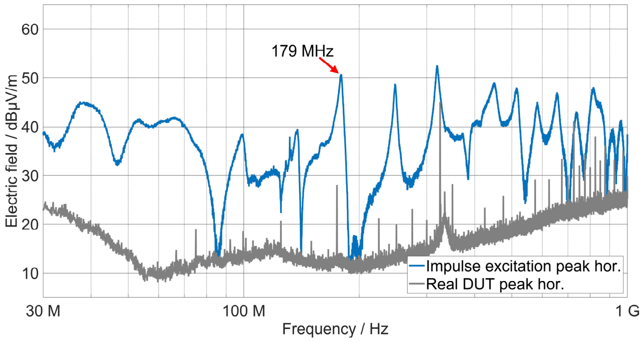

Fig. 6. Radiated emissions with impulse excitation of wiring harness (impulse generator grounded)

To investigate the general reproducibility, identical measurements are carried out on different days using the setup shown in Fig. 5. For this test series the impulse generator housing is not connected to ground, and the frequency range is extended to 3 GHz. Between each measurement the setup on the table was entirely disassembled and rebuilt. Also, the antenna and the table are removed from the ALSE and then repositioned.

Reproducibility is evaluated using four of these measurements, see Fig. 7. Three of the shown traces do not have a significant deviation.

Only measurement one shows some deviations e.g. at 110 MHz with approx. 4.5 dB. Since comparisons between different laboratories like in [4] show similar differences in level, the deviations of measurement one compared to the others is too high.

In conclusion, a carefully assembled setup provides sufficient reproducibility up to 1 GHz. However, in spite of a comprehensive documentation of every rebuilt test run, it was not possible to identify the cause of the 4.5 dB deviation from measurement 1 in retrospect. In the frequency range from 1 GHz to 3 GHz, where the length of the test harness corresponds to multiple wavelengths, a sufficient repeatability between the measurements cannot be achieved. Small changes in the cable position can lead to high deviations in amplitude [5].

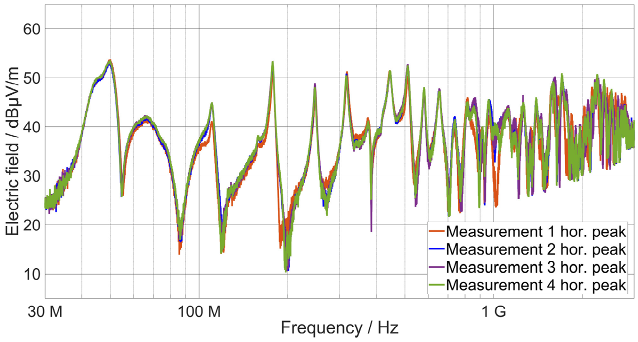

Fig. 7. Evaluation of the reproducibility of the radiated emissions (impulse generator floating)

C. Measurement of the transfer behavior between wiring harness and antenna

For the third approach the excitation (and the measurement) is done by a frequency sweep using a VNA. Two measuring methods are possible. Either the measurement of conventional scattering parameters or the measurement as mixed-mode scattering parameters [6]. The latter provides the advantage, that the response of both, CM and differential mode (DM) excitation can be investigated with the same measurement setup. Compared to the impulse method from the previous chapter the VNA measurements always requires a connection to ground, meaning no isolated measurements are possible.

The setup for the conventional scattering parameter measurement (Fig. 8) is similar to the previous setup with impulse excitation. One port of the VNA is connected to the CM injection adapter. The other port is connected to the antenna. In this arrangement the test harness connected to the VNA sees a differential impedance of about 0 Ω and a CM impedance to ground of 50 Ω. The other end of the wiring harness is terminated in the same way it is for the measurement with the impulse excitation

The setup for the mixed-mode scattering parameter measurement is shown in Fig. 9. Again, one port of the VNA is connected to the antenna. Instead of directly connecting both wires of the twisted pair cable together, this time both are feed to their own connector representing port 2 and 3. Since a 2-port VNA is used for the measurement, the respective unused port remains terminated with 50 Ω and the scattering matrix is composed of three measurements. In this arrangement the test harness to which the VNA is connected sees a differential impedance of about 100 Ω and a CM impedance of 25 Ω. The mixed mode parameters are calculated from the resulting 3x3 scattering matrix [6].

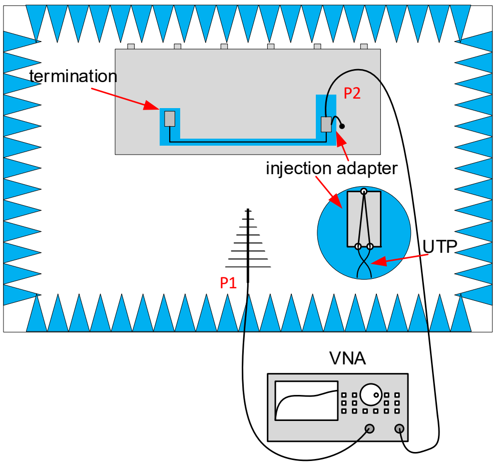

Fig. 8. Setup for conventional scattering parameter measurement

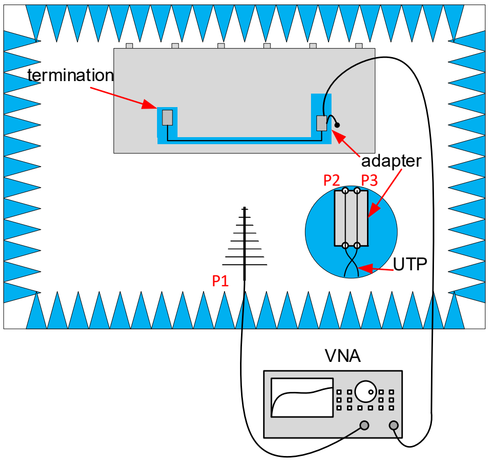

Fig. 9. Setup for mixed-mode scattering parameter measurement

The results can be seen in Fig. 10. The blue trace represents the S_{12}-Parameter and the red trace the mixed mode S_{1C2}-Parameter which is the response at the antenna, to a common mode excitation of the test cable. The gray trace shows the voltage transfer function of the impulse excitation setup.

The comparison of the conventional and mixed-mode transfer function reveals only a rough similarity. Up to a frequency of around 200 MHz the same resonances can be seen, but partly shifted in frequency and with deviations in level. These deviations can be partially caused by the different impedances on the end of the cable, where the VNA is connected. This results in different reflection coefficients, which can significantly influence the resonance behavior.

The comparison to the transfer function of the impulse excitation also shows limited comparability. Within a limited frequency range, e.g. from 60 MHz to 80 MHz and to some extend from 500 MHz to 1 GHz the results of the S_{12} and the impulse setup are similar. Overall, the impulse method is considered the best approach so far due to the following reasons.

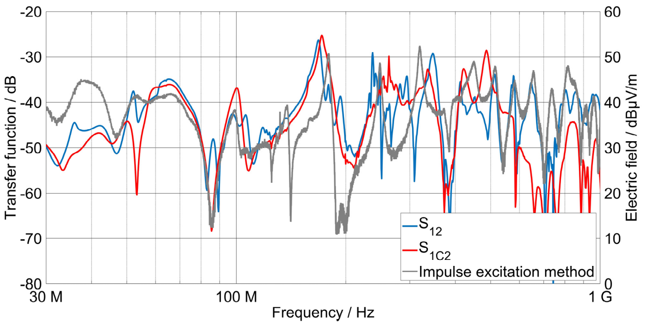

Fig. 10. Measurement of the transfer function compared to the impulse method

In general, reproducible results are difficult to achieve with the transfer function method. E.g. one significant impact factor is the position of the shielded measuring cable (type RG214) on the ground plane (on the table) used to connect the VNA outside the ALSE and the harness on the CIPSR 25 table. Changing the position of the auxiliary cables even only by a few centimeters results in a deviation of several dB in the measurement. Also, the main cable resonance is shifted to 170 MHz instead of 179 MHz. The reason for this seems to be the missing impedance matching between the wiring harness and the shielded cable.

III. CONCLUSIONS

In the context of this paper three different methods are examined, to evaluate the influence of the measurement setup on the radiated emissions in a CISPR 25 component test in a frequency range from 30 MHz to 1 GHz. Used sources for excitation are a real DUT, a broadband impulse generator and a VNA swept measurement. The narrow band emissions of a real DUT cannot be used to evaluate the entire frequency range. Using a network analyzer to measure the transfer function between test harness and antenna offers the advantage of a high dynamic range and the possibility to examine CM and DM separately. However, the VNA method has its restrictions regarding the reproducibility. The measurement of the radiated emissions with an impulse excitation of the wiring harness provides the best results of the described methods. It provides a high dynamic range for the measurements. The method is versatile providing both, excitations with ground reference and isolated excitation with no connection to the ground plane. Within the determined frequency range up to 1 GHz a high reproducibility can be achieved with this method.

OUTLOOK

In future work the impulse excitation method will be used to determine the influence of the measurement setup for measurements with complex wiring harnesses. The first step is to build an impulse generator with multiple outputs to use with a wiring harness with several cables.

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