More Insight into Conducted Immunity Tests and Investigation of Support Influences

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***Abstract*— The conducted immunity test is one of the major EMC tests performed in laboratories in the frequency range 150 kHz - 80 MHz by the use of CDNs in accordance with IEC61000-4-6. In this paper, we investigated the conducted immunity test setup in more detail in terms of loop impedance values to gain more insight and also investigated influences of supports used under EUTs in tests for separation from the metallic plane. For this purpose, we compared various conducted immunity setups installed with a variety of insulation supports including a copper-wrapped one. We also sought a link between them based on the loop impedance values and the injected currents on the test loops. As a result, a further serious step was taken to discover the details of the conducted immunity test, which is based on the impedance measurement of test loops and on support influences.**

Keywords - CDN, Conducted Immunity, EMC, Loop Impedance, Support

I. INTRODUCTION

The conducted immunity test is one of the major EMC immunity tests and widely performed in laboratories in the frequency range 150 kHz - 80 MHz by the use of CDNs in accordance with IEC61000-4-6 [1] and sometimes is extended to 230 MHz. The principle of the test is to induce electric and magnetic disturbance inside the EUT by applying a conducted disturbance signal in Common Mode (CM) on the EUT input and output cables. The disturbance is applied via a defined source impedance of 150 Ω. A piece of good work on deep details of the conducted immunity test and its advantages / disadvantages is perfectly presented in [2]. In addition, pitfalls and practice of conducted immunity testing were very well studied in [3]. There are also a few more researches on application of the standard IEC61000-4-6 in the literature. Some of them give useful information for the enhancement of standard applications such as automation and speeding up of the tests [4-5]. The others focus on investigation and comparison of some conducted immunity test components such as EM and Bulk Current Injection (BCI) clamps in terms of tests and calibrations [6-7]. Practical approach to IEC61000-4-6 and variations in injected currents are studied in [8-9]. Finally, alternative conducted immunity test applications for industry, which are based on loop impedance measurements, were studied and loop impedance measurements were included into conducted immunity researches for the first time in [10,11].

In this paper, we bring the current state-of-the-art research one more step further and investigate details and pitfalls of conducted immunity laboratory setups in more detail by analyzing loop impedance values and injected currents with the inclusion of different supports which are utilized to isolate EUTs from the ground plane as stipulated by the standard. In fact, support effects on radiated emission tests were investigated in several papers such as [12] but it is studied for conducted immunity tests for the first time in this paper. As supports, we included four materials; wood, molding polyamide, styrofoam and copper. For loop impedance measurements, although there are some methods in the literature, we chose the two current probe method introduced in [13] for our research.

II. THEORY AND EXPERIMENTAL SETUP

The deep investigation of the conducted immunity test and support influences on it in our research is completely based on the impedance measurements of loop impedance values from 150 kHz to 230 MHz. The loop impedance measurement method that we used is stated in [13] in detail. This impedance measurement method uses a Vector Network Analyzer (VNA), two current probes and a piece of precision known impedance. It yields the value of the unknown target impedance as well as the overall loop impedance. The standard IEC61000-4-6 requires the test setup presented in Fig.1. As seen in Fig.1, the loop impedance includes two 150 ohm impedance values formed by CDNs and the EUT on the loop [10]. As measured impedance values by the VNA are complex numbers, the correction factor K becomes a complex number. On all the impedance graphs in this paper, we only give the module values of the complex numbers. The injected power is obtained in the calibration phase in a test jig before the test, as stated in IEC61000-4-6.

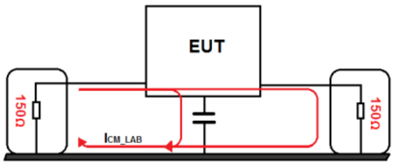
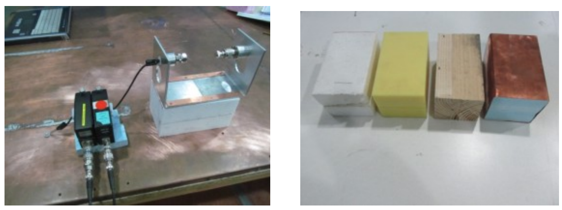


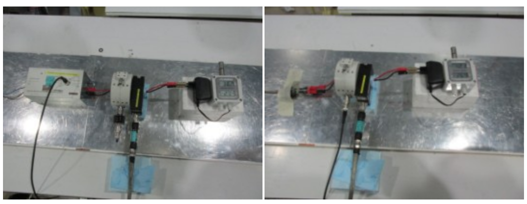
Fig 1. Conducted immunity test setup [10]



(a) (b)

Fig 2. (a) Setup for repeatability verification (b) Supports used in research

After modeling the test setups, as seen in Fig.2(a), we firstly performed some repeatability checks of the loop impedance measurements on a simple setup which was installed with a simple metallic structure and the supports beneath three times per non-conductive support on different occasions. Following the verification of the repeatability, we continued the measurements with the thermo-hygrometer along with the insulation supports under investigation. The thermo-hygrometer was modified and specially made susceptible to RF disturbances. As insulation supports, we utilized four support types with a height of 10 cm and seen in Fig.2(b); styrofoam, molding polyamide, wood and a copper-wrapped one. It must be specially stated here that the metallic supports are not normally required by any standard however the metallic support was used to present the worst case situation and to show the efficiency and performance of the loop impedance measurement in the extreme condition. After the test setup was established, the loop impedance of the setup with each support in turn was measured with a frequency step size of 250 kHz by using the two-probe impedance measurement method. After the measurement of the loop impedance values of the setups, the EUT was actually tested in the laboratory setup with the CDN, which contains each support in turn, as seen in Fig.3(a). The two probes utilized for loop impedance measurement were also kept in place in the test phase in order to maintain consistency between the loop impedance measurement and the test. In addition, the receiving current probe used in the impedance measurement was also used to measure the injected current and the injection probe used in the impedance measurement was terminated with 50 ohm in the test stage. Thereafter the calibrated power level was applied to the RF input port of the CDN of the setup and the current injected into the loop was experimentally measured by the receiving probe. During the tests, the current injected to the setup and the susceptibility of the EUT, which corresponds to the temperature/humidity deviation caused by injected disturbance on its display, were recorded to be compared to each other in an attempt to link the loop impedance measurement results to the susceptibility results of the EUT. The thermo-hygrometer was powered as intended and was connected to the mains through a M2 CDN in the power port as seen in Fig.3(a). The deviation in the laboratory temperature, subsequently in the read value on the display of the thermometer, between the beginning and the end of the measurements in the absence of the disturbance signal was recorded approximately as 0.5^{o}, consequently the effect of the change in the laboratory temperature on the measurement results was assumed to be negligible. On the other hand, it was not easy to control the humidity of the test chamber during a whole long test and we accordingly normalized the natural laboratory humidity deviations which did not result from the disturbance signal.



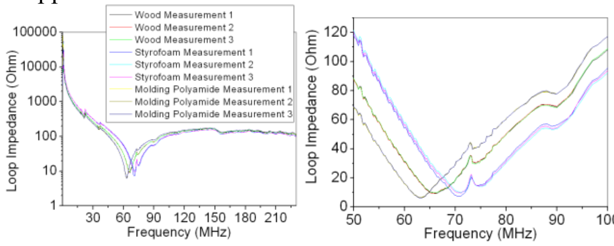
(a) (b)

Fig 3. Conducted immunity test setups of the electronic thermometer (a) with CDN, (b) with mains without CDN

Finally, as it is not always possible to use CDNs due to some limitations such as high supply currents especially in industrial environments, we also studied the support effects for the case without the CDN. In this final step, we tested the EUT connected directly to the mains without the CDN as seen in Fig.3(b) and the injection was performed by means of the BCI clamp, which had been also used for the loop impedance measurement.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The repeatability of the loop impedance results is presented in Fig.4. While Fig.4(a) shows the overall 9 measurements in one graph, Fig.4(b) zooms in on the resonance regions of the curves to show the repeatability in more detail. The repeatability of loop impedance results looks very satisfactory per support within maximum ± 5 ohms.



(a) (b)

Fig 4. Repeatability verification (a) full frequency range, (b) zoomed in

The loop impedance measurement results for the setup with the thermo-hygrometer connected to the CDN and placed on each support in turn are presented in Fig.5(a). As seen in Fig.5(a), the support effects on the loop impedance are clearly noticeable. Although it is not easily observable in the graph due to the large scale of the graph, the loop impedance of the setup with the styrofoam support is generally higher than the setups with the wood and molding polyamide supports in most of the frequency range. On the other hand, the loop impedance values of the setups with the wood and styrofoam supports look similar. The loop impedance values of the setup with the EUT placed on a copper-wrapped support are lower than all the others in most of the frequency range as expected but it is surprisingly higher than the other curves in some small frequency ranges. The graph seen in Fig.5(b) reveals that the current injected into the loop is inversely proportional to the loop impedance as expected. For example, in the frequency range up to 90 MHz, while the loop impedance of the setup with the copper-wrapped support is significantly lower than the others, the consequent current injected to the loop is higher than the others in this lower frequency range. The similar behavior of the current and the loop impedance is easily seen in the other frequency ranges. Regarding the susceptibility, the EUT is affected in different frequency ranges in terms of the temperature and humidity display deviations. For the displayed temperature, the EUT is severely affected by the injected interference in the broad frequency range from 30 MHz to 180 MHz. On the other hand, for the displayed humidity deviations, the frequency range in which the EUT is affected is smaller and concentrated around 160 MHz. Although the frequency ranges are different, there is a reasonably good relation between the injected current level and the susceptibility of the EUT in the frequency ranges where the EUT is affected. Generally, as the injected current increases, the severity of the failure of the EUT increases. In this context, while the copper-wrapped support causes the most severe deviation on the EUT display in most of the effective frequency range, the styrofoam support causes the least effect, which is compatible with the impedance and injected current curves. The molding polyamide and wood supports have similar effects on the test results but their effects on the test results are clearly different from the effects of the styrofoam as seen in Fig.5(c). While the EUT is affected similarly for wood and molding polyamide, the effects on the EUT are markedly reduced with the use of the styrofoam support. This means that any non-conductive support with a higher dielectric constant may result in higher effects on the conducted immunity test results in comparison to the styrofoam support or air. These first results are very essential to show the direct effects of the supports on the loop impedance and test results and to gain more insight into details of conducted immunity tests.

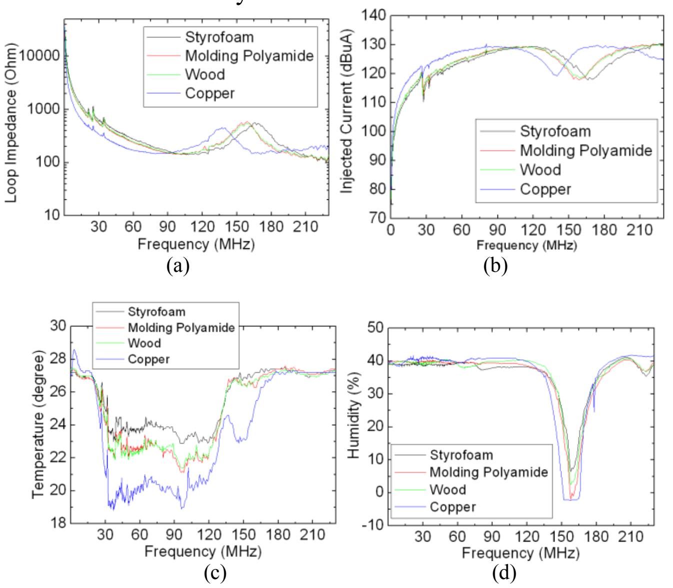


Fig 5. Results of thermo-hygrometer and supports with CDN (a) loop impedance values, (b) injected current, (c) temperature susceptibility level, (d) humidity susceptibility level

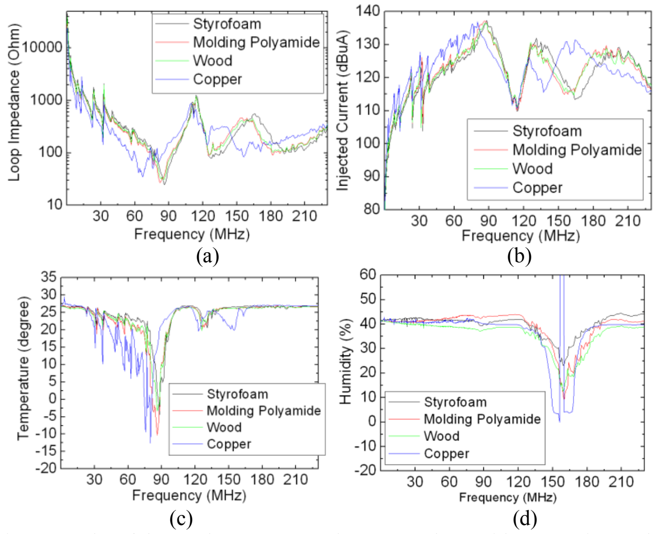


Fig 6. Results of thermo-hygrometer and supports along with connection to the mains without CDN (a) loop impedance values, (b) injected current, (c) temperature susceptibility level, (d) humidity susceptibility level

After the testing with the CDN, finally, the results for the setup, in which the EUT was directly connected to the mains without a CDN, are similarly shown in Fig.6. Due to unpredictable and undulant impedance behavior of the mains, the graphs are different from the graphs of the setup with the CDN. The removal of the CDN from the setup significantly changes the loop impedance and consequently, the injected current and the susceptibility levels. Despite this change, the relation between the loop impedance, the current and the susceptibility level remains consistent like in the case with the CDN. The graphs in Fig.6 also show again that the type of the used support appreciably affects the test results and may lead to variances in test results between laboratories.

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