Reproducibility of Long Cable Test-Setup of EMC Measurements

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Abstract. *This paper deals with an analysis of influence of geometrical arrangement of cables at immunity test against rf electromagnetic field. The effect of a length of the single-wire cable shortened into a bundle upon frequency dependence of induced current, which flows through the wire, is analyzed using numerical simulations. Results obtained by numerical simulations are verified by measurement of real electrical structure.*

Keywords: Immunity Testing, Transmission Lines, Influence of Electromagnetic Field, Nondestructive Shortening of Single-Wire Line

1. Introduction

Many of electrical systems contain cablings, which ensure their contact with a surrounding environment. The arrangement of such a cabling is a determining factor of a validity of electromagnetic compatibility (EMC) tests. One of EMC tests, which may be affected by cabling arrangement, is test of immunity against rf electromagnetic (EM) field [1]. A methodology of the test, according to the standard, requires an assurance of homogeneity of EM field within test area and a compliance with specified configuration of a test site.

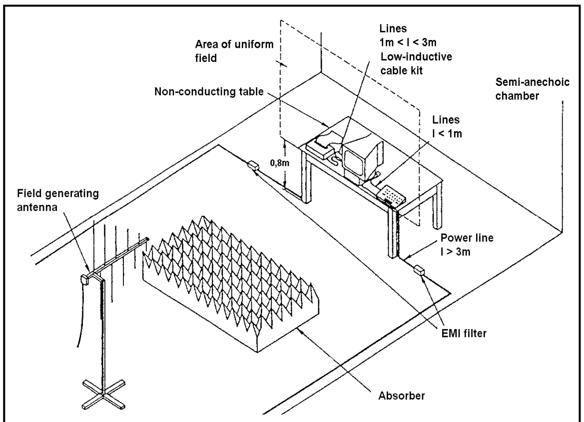

Fig. 1. Test place for immunity test against rf electromagnetic field (EN 61000-4-3) [1]

A configuration of test place for a table-top equipment under test (EUT) represents a basic arrangement of the test place. A problem occurs if equipment's cabling, which is arranged freely on the test table, does not have the specified length of 1 m and it is not possible to shorten it simply to that length. In the case of cables with length between 1 and 3 m, the standard [1] specifies nondestructive shortening into the bundle. This bundle should consist from unbounded loops [2], [3].

A change of geometrical arrangement of the EUT's cabling causes a change of its electrical properties. If this change is significant, the induced currents at the ends of the cable, which is situated in EM field, will be dependant on current cabling configuration. Such situation should not happen according to recommended technical standard. A signification of this effect is given by the fact that almost no external cabling of EUT has necessary length of 1 m. Nondestructive shortening of illuminated cable lengths belongs to frequently performed activities of test engineers. The aim of this paper is qualify a signification of this effect.

2. Creation of test configuration model

The cabling of EUT was replaced by transmission line (TML) to simplify a model. Effect of the EM field to TML was a topic of several works [4], [5]. Their aim was analytical determination of currents flowing through impedances of the cable interfaces. In case of analysis of more complicated shapes of TML, it is more suitable to use the numerical simulation methods. The numerical simulator FEKO, based on method of moments, was used in our analysis.

The situation, that really occurs by TML irradiated by EM field, may be analyzed using common mode (CM) model of the line. The disturbing common mode voltage is generated between wires of the cabling and conducting reference plane. Coupling between cabling and reference plane is accomplished via cable terminating impedances or via parasitic impedances between them. The latter is dominant in case of tested devices with large cablings.

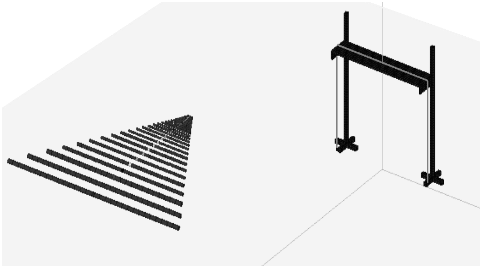

Fig. 2 Model of test place with CM lines

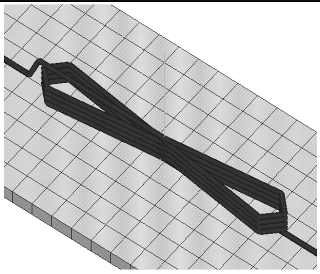

Fig. 3 Model of cable bundle

Single-wire cable long 1m situated in 80 cm height over the plane was considered in our analysis. This cable was terminated by 50 Ω impedances to the reference plane and was irradiated by plane EM wave. Such a simple model of the test place may be extended to more complex one, which describes better a behavior of the real system. Then some other parts should be added into the model. Those could be supporting elements from dielectric materials and also dielectric insulation of the wire. The model of log-periodic dipole array is used to simulate the real field source truly.

Only the ground plane was included into the model of anechoic-shielded chamber. Omission of absorbers, which are during the test situated between the antenna and EUT, within the model deteriorated a homogeneity of EM field in vertical direction due to reflections from the ground plane. However, the irradiated cables were in constant height over the plane, so an absence of the absorbers is acceptable. The transmitting antenna was excited by a voltage levels, which ensured EM field according to standard requirements [6]. The model created in FEKO simulator is shown in Fig. 2.

In case of longer cables, which are shortened to 1 m length by nondestructive shortening, the model shall contain also the cable bundles (Fig. 3).

3. Measurement setup

A complex system for testing immunity of EUT against rf field was used to verify obtained results of previous analysis. Stabilized power supply BK 127 was used as EUT. It is a simple regulated analogue voltage source based on integrated circuit μA723 and realized without considering EMC properties. The complex testing system allows measuring of EUT output voltage during the test, so it is possible to measure frequency dependences of output voltages of the tested power supply on disturbing EM field. Also dependences of absolute additional error may be calculated from the measured values of output voltage.

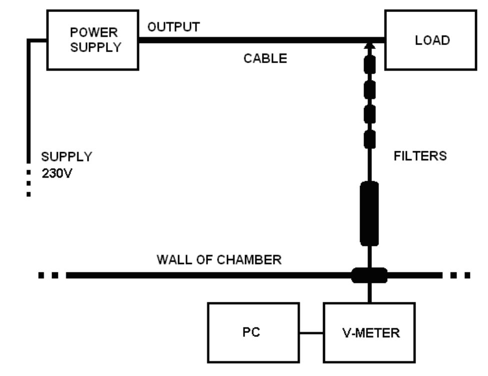

Fig. 4 Configuration of measuring chain to test power supply

A configuration of measuring place is shown in Fig. 4. The EM field was generated according to the standard EN 61000-4-3 [1]. The tested power supply was placed on a wooden board 80 cm over the ground plane. Output cables of voltage source were shortened by the bundle and were situated on the table perpendicularly to EM wave propagation direction. The cables were terminated by resistive load. Measuring cable was connected into the load to monitoring the output voltage. Additional filters, which ensure rf isolation from the tested source, were added to the measuring cable and this cable was connected to a voltmeter, situated outside the chamber. Measured data acquisition from the voltmeter as well as generating of required EM field was controlled by a computer.

4. Simulated and measured results

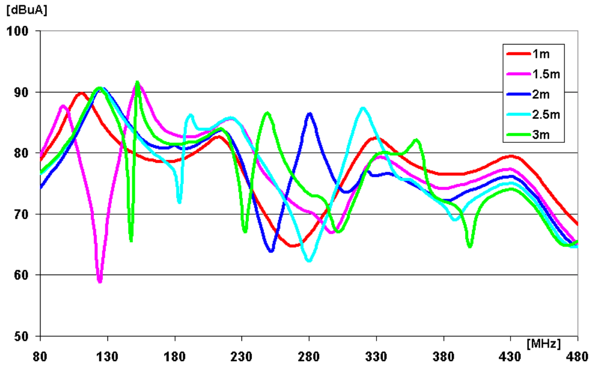

Fig. 5 Frequency dependence of current flowing via cable arranged into bundles for different cable lengths

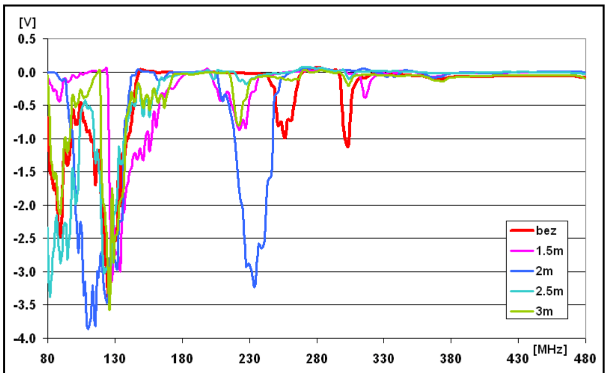

Fig. 6 Frequency dependence of absolute additional error for different cable lengths

Analysis of cable length effect: A model of cable bundles was used as a consideration of shortened cable with length of 1.5, 2, 2.5 or 3 m to the length of 1 m. Longer cables were arranged into more bundle loops with constant geometrical parameters. The length of the bundle loops was 250 mm, their diameter of bending 10 mm, diameter of the wire was 1 mm and a distance between the loops was 2 mm. The cable bundle was situated at the center of the cable. Such cable was irradiated by horizontally polarized log-periodic antenna and the intensity of EM field in the place, where the tested cable was situated, was 10 V/m.

Frequency dependences of induced current for shortened cables of different lengths, which were obtained using numerical simulations, are shown in Fig. 5. Even if maximal values of the induced current are very similar (maximal difference is less then 1.5 dB), an use of bundles increases a probability of high current zone appearance (the frequency dependence has three or four current peaks). Hence it may influences the test validity.

Similarly, if same test was realized using the real measurement of the power supply, the maximal error of the output voltage (for different lengths of the cable) varies from 3.14 to 3.86 V, if nominal value of the supply voltage was 10 V(see Fig. 6).

Analysis of bundle positions: The similar three-meter long cable shortened using the cable bundle was used as in previous case. The bundle position was changed. At first it was situated at the center of a horizontal part of the cable, then in near end (from a view of the induced current) and finally in the far end of the cable horizontal part.

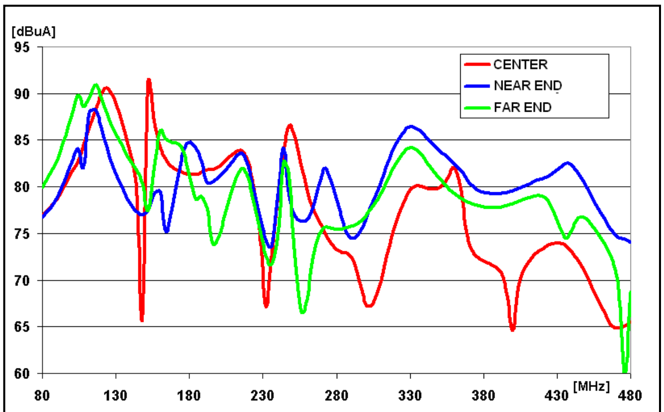

Fig. 7 Frequency dependence of current flowing via cable arranged into bundles for different bundle positions

In Fig. 7, one can see simulated frequency dependences of induced current on the cables shortened using the cable bundle for different position of the bundle in a horizontal part of the cable. Maximal values of the current differ no more than 3 dB. Moreover, the various shape of frequency dependences, similarly to the previous analysis, shows evidence of an influence of the cable bundle position upon the induced current value.

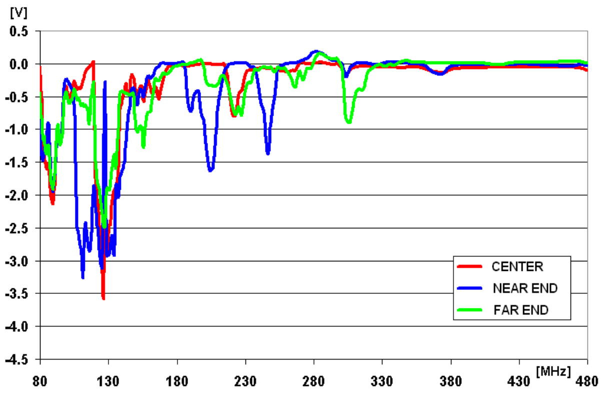

Fig. 8 Frequency dependence of absolute additional error for different bundle positions

Also an experiment with changing the bundle positions was performed with output cable of the power supply. Maximal absolute errors are in interval from 2.49 to 3.53 V. Evident change of shape of the frequency dependence may be seen in Fig. 8 as well as the change of the maximal error of the power supply output voltage.

5. Conclusions

The standard EN 61000-4-3 allows shortening of cables with length from 1 to 3 m into the bundles. However, as it was shown in this paper, such bundles affect the shape of the frequency dependence of induced current due to their position and arrangement. Even if differences between maximal values of the currents are not so evident (maximally 3 dB), frequencies of such maxims change and also there are more local maxims of the induced current in the analyzed frequency range. It may affect validity and also reproducibility of the immunity test. Therefore it is advisable to avoid such a cable shortening in an EMC testing practice.

Acknowledgements

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