EM field measurement aspects for electromagnetic compatibility purposes

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Abstract. *EM field measurement is just one of many necessary rf measurements in area of electromagnetic compatibility (EMC). Therefore it is important to know all of possible problems regarding of this process. This paper deals with influence of the field probe to the field distribution and to the final measured results.*

Keywords: electromagnetic compatibility, EM field measurement, method of moment

1. Introduction

No doubt that beginning of electrical devices disturbance problems by natural as well as artificial sources are related to broadcast origin. Due to increase of electric devices density the disturbance became intolerable because it exceeded the level of rf signal transmission. During last two decades there originated problems from devices interference, even the devices threatened the human life due to undesired disturbance. Therefore, European union published the European Directive 89/336/EEC [1] called Approximation of the laws of the member states relating to electromagnetic compatibility, which became the headstone of fight against electromagnetic (EM) smog and disturbances at all. This direction gave the legislative base for the new scientific area – Electromagnetic Compatibility (EMC). One of possible problems of every EMC engineers is measuring of field strength, which is necessary during measurement of electrical devices EMC properties. One of possible problem regarding EM field measurement is described in this paper.

2. Problem description

Standard requirements

The task of EM fields measuring we can find in international EMC standard EN 61000-4-3, which describes measurement of electric devices immunity against rf fields. The electromagnetic environment is determined by the strength of the electromagnetic field, is not easily measured without sophisticated instrumentation nor is it easily calculated by classical equations and formulae because of the effect of surrounding structures or the proximity of other equipment that will distort and/or reflect electromagnetic waves. Tested equipment is subjected to field strength of 3 V/m or 10 V/m with homogeneity – 0dB/+6dB from 80 MHz to 1000 MHz. This frequency range is 80% amplitude modulated with a 1 kHz sine wave. The signal generator provides the modulated frequency at a step rate of 1% of fundamental to the RF amplifier. The RF amplifier provides the necessary power to the antenna to establish the field levels as monitored by the field probe. The anechoic chamber, where the test is performed, is calibrated according to the criteria as per EN 61000-4-3 for 16 points given by geometrical arrangement in Fig. 1 [2].

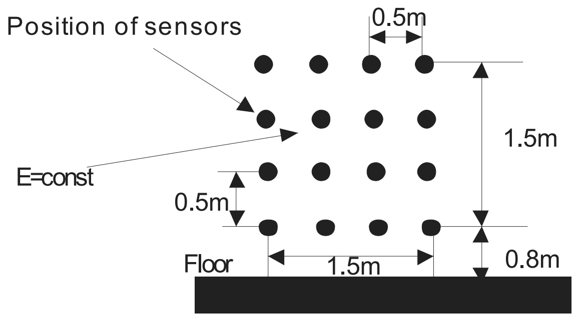

Fig. 1. Geometrical arrangement of measuring points

Then main task is setting the proper value of field strength at the place of tested device; or measuring of EM field. Because field strength is monitored by probe without tested device at test place result of measurement is influenced only by the presence of the probe. So this process is not very easy and quality of evaluation depends just on the field probe.

EM field probe

The task of field probe is to transform the electrical field into directly measurable quantity as e.g. DC voltage is. The heart of probe is sensor, which is often realized as a dipole with travelling wave. This sensor works in a ultra-wide frequency range, it has a sufficient sensitivity and its producing is not very difficult [3]. Voltage induced on a dipole is directly proportional to strength of incident EM field. This voltage is rectified and transferred via resistive wires to electronic interpretation unit (EIU) that is located in a sufficient distance from sensor. Scheme of sensor can be seen in Fig. 2, to the golden contact we connect EIU, it converts signal into digital form and transfers it to the controlling computer. In fact, probe consists of three independent sensors due to isotropic properties of the whole probe [4]. In term of measurement the field around sensors is interested for us. This field can be affected by metal parts of probe as enclosure of EIU or sensors are.

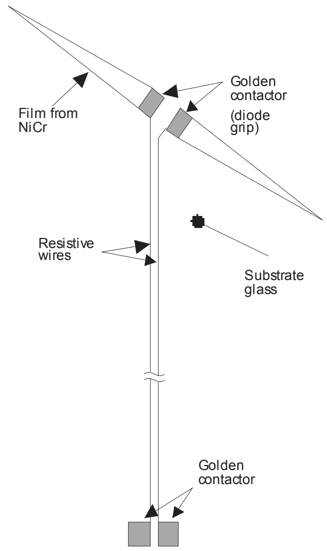

Fig. 2. Measuring resistive dipole

Model of the probe

It is necessary to know how can be the EM field influenced by presence of the probe during the measurement. To solve this problem, we have to design such a model, which can represent real behaviour of the probe and is also designed regarding to the used method. In our case EM field is excited by point source and waves propagate to surroundings and the main task is to calculate the strength of EM field, or current distribution on attendant structures in analysed area eventually. Such problem leads to integral equation that can be described formally

$$\iiint_V \nabla X \; dx\,dy\,dz = Y \tag{1}$$

where Y is source and X unknown function, V analysed area and ∇ is the Hamiltonian operator.

It means that using (1) unknown function X can be solved, which in our case represents EM field distribution in V and Y is the feed of EM field source. Solution of (1) leads to integral equation of first kind, which has not any analytical solution. Hence, we can transform it to integral equation of second kind or solve this equation numerically. However transformation to the integral equation of second kind is very difficult, complex and just approximate, so numerical solution, which is quite accurate, is preferred. One of the most popular methods is method of moments that is based on transformation of integral equation to system of linear equations – matrix equation and it can be solved easily using computer [5]. This principle is used by many commercial software that solve EM problems, e.g. FEKO, NEC, etc.

Method of moment's principle is based on dividing analysed structures to the small parts, called segments. If one has more segments it means that one needs more long time calculation, but has more accurate results. So it is necessary to strike a balance between number of segments and calculation accuracy [5]. To get the model of probe all the metal parts (case of EIU and sensors) were replaced with segments with properties (dimensions, electrical properties) as real probe has (see Fig. 3). We consider that probe is situated in infinitely large space without any scatterers and it is incident by plane wave with linear polarisation. The distance between sensors and case of EIU can be changed, in case of our probe [4] the distance is h = 30cm.

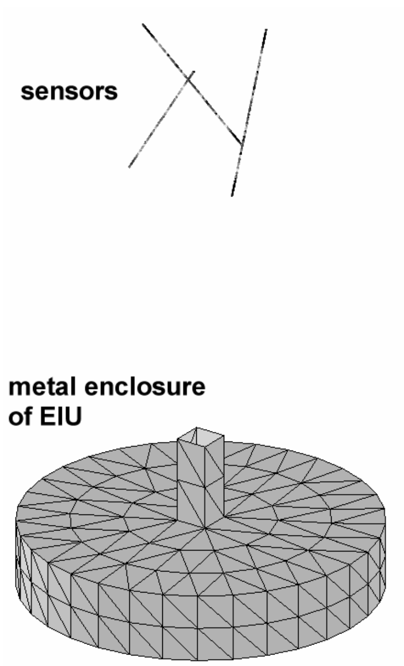

Fig. 3. The model of the probe in simulation

3. Results

The only possible way how to examine the probe influence to EM field homogeneity is numerical calculation – simulation, so we use the software product FEKO [6]. In the whole analysed area we ensured constant EM field with strength of electric field E=10V/m without probe and linear polarisation of EM waves – horizontal or vertical in the frequency range 80MHz to 1GHz. Then we added model of the probe described above and surveyed the field strength changes in different distances between sensors and EIU with step 10cm. The results of simulation for horizontally polarised waves are in Fig. 4.

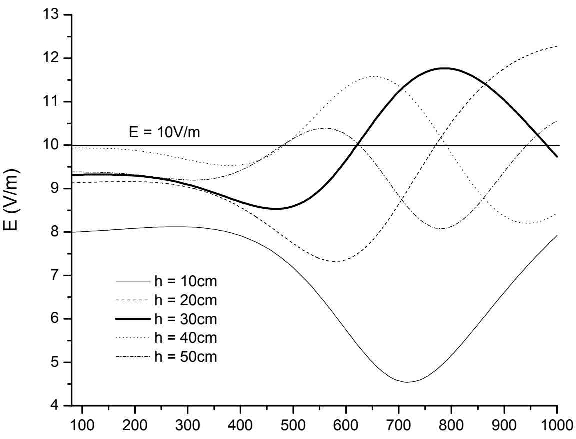

Fig. 4. Frequency dependence of field strength at different distances between sensors and EIU – horizontal polarisation

As we can see in Fig. 4 the probe changes the field distribution around itself. It is remarkable that taking away sensors from EIU unit the variation of field strength around sensors decreases. At distance h=30cm from the EIU the value of field strength is lower than required 10V/m up to 620MHz, the minimal value is 8.5V/m at 460MHz. At higher frequencies the field is increased, maximal value of strength is 11.8V/m at 785MHz, at these frequencies the metal case does not shield the EM field but boost it. Expressing in dB units, the field variation due to probe is in interval from –1.4dB to +1.4dB. It means that at higher frequency we have to set up the field strength approximately 1.5dB higher than the result obtained by calibration is, if we want to fulfil the standard requirements. At lower frequencies there is no problem, because standard allow us to vary field strength in interval –0dB to +6dB. So we know that field variation decreases with increasing distance between sensors and EIU and the average value is below required field strength 10V/m. Mentioned decline has exponential character, therefore there is no reason to retreat the sensor from EIU too much especially if there could be a problem with voltage transfer from sensors to EIU.

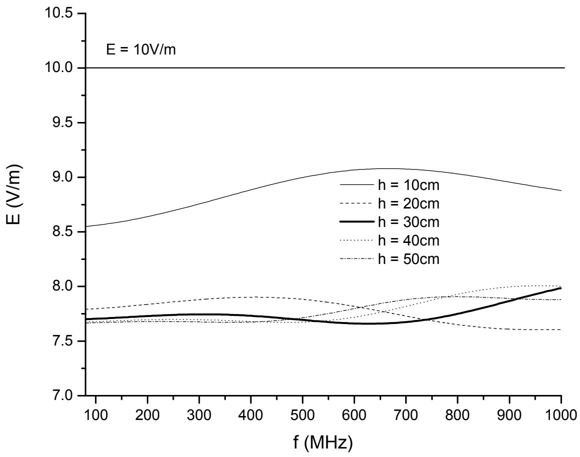

Fig. 5. Frequency dependence of field strength at different distances between sensors and EIU – vertical polarisation

Similar analysis was performed also for vertically polarized EM waves; the results are shown in Fig. 5. In comparison with previous analysis, the variation of EM field is less in the given frequency range. On the other hand, average difference between required and obtained value of field strength is bigger; it is -2.3dB. It means that during measurement our field is approximately 2dB higher than required one, but it fulfils the standard requirements. This decline of measured value is caused by sensors, metal case of EIU causes just a little variation of the field in a frequency range.

4. Discussion

The paper showed a problem of measuring EM field for EN 61000-4-3 standard purposes. As it is evident from achieved results, we could measure the accurate values of field strength using the probe, but this field is influenced by the probe. So the field changes if the probe is not present. However, this change is not so cardinal because the standard allow us keep field strength in interval –0dB/+6dB and this requirement is fulfilled. Also we can minimize the influence of metal case of EIU to field distribution taking sensors away from EIU and this information could help producer to improve probe properties.

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