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Research Article

Isotropic Broadband E-Field Probe

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Abstract

An E-field probe has been developed for EMC immunity tests performed in closed space. The leads are flexible resistive transmission lines. Their influence on the field distribution is negligible. The probe has an isotropic reception from 100 MHz to 18 GHz; the sensitivity is in the 3 V/m–10 V/m range. The device is an accessory of the EMC test chamber. The readout of the field magnitude is carried out by personal computer, which fulfils also the required corrections of the raw data.

1. Introduction

The generation and measurement of defined electromagnetic fields for radiated immunity test on open-area test site are rather expensive and time-consuming. Further the environmental, meteorological conditions strongly influence the measurements. Therefore, there is a real need for performing the investigations in closed measuring chambers built in laboratory rooms. Different methods have been proposed in the literature as anechoic chambers, reverberation boxes or TEM cells [1, 2]. In all cases, there is a chance for the resonance in the chamber and/or the appearance of spurious modes and therefore the exposed electric field can differ from the expected one. The purpose of this work was the development of an E-field probe for the independent control of the actual value of the microwave field. There are field measuring devices in the trade; however, they are hardly suitable for building in the measuring chamber as a remote controlled accessory. Further, because they are intended to be used in free space or in large anechoic rooms, there is no special attention on the reflections from the equipment, which can disturb the distribution of the field in small chambers. In this paper, a device is described which overcomes these limitations; it can be mounted in the measuring chamber, and it has only minimal effect on the field distribution; and the readout is performed outside the measuring chamber.

The device is made up of a field sensor and a 2 m-long flexible cable delivering the signal to the connector on the wall of the chamber. It is important that the probe and its cable do not alter the field distribution in greater extent than 1 dB. The sensitivity of the probe should be isotropic because the test is made at all degrees of polarization. There is even a test method which applies rotating polarization [3]. Further the sensitivity should be high enough for measuring the field strength of 3 V/m, which is the lowest specified value by the IEC-ETSI in the frequency range of 30 MHz–18 GHz. We remind here that there are a great variety of prescribed field values in the different standards, starting from the mentioned lowest up to 200 V/m (MIL-STD-461E). The aim of this work was the development of a field probe for intensities from 3 V/m up to 10 V/m. The relative distribution of the electric field is determined by the testing arrangements; the magnitude of the electric field at each point in the measuring box is proportional to the square root of input power. This is why the limited sensitivity range of the probe does not affect significantly the application; the actual value of the field can be easily tuned in the range, where the measurement can be performed. However, the sensor should take even higher fields without degradation because it remains on the place during the test.

2. The Construction and Features

The traditional isotropic E-field probe construction, with three mutually orthogonal short dipole antenna was applied [4, 5] as it is shown in Figure 1. The sensing dipoles were fabricated by painting with silver paste through a mask. The three antennas were arranged along the faces of the cube fabricated from a styrofoam. The zero-bias detector diodes were mounted in the gap of the antennas also by silver paste. The connections between the sensors and the amplifier are 2-m-long flexible resistive transmission lines fabricated by screen printing from resistive carbon paste on 0.125 mm thick polyester foil [6, 7]. The 7mm-long dipoles are perpendicular to the resistive lines. Therefore, any field component parallel to the carbon wires results in only common-mode signal on the diode. The end of the resistive line is mounted in a DS type connector; it fits into the socket mounted on the inner wall of the measuring chamber. Facing to it on the outer wall of the chamber there is the equivalent socket into which the amplifier is connected.

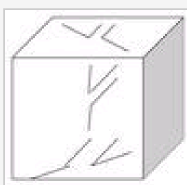

Figure 1: The draft of the sensing head.

The effect of the resistive transmission lines on the microwave field distribution was checked first in the GTEM cell [8]. A monopole antenna was fabricated from a semirigid cable by removing the outer conductor at the 12-mm-long end part. This antenna was fixed in the GTEM cell and the transmission was measured and saved between the feed point of the cell and this antenna in the case when the cell was empty. Then the resistive transmission line was placed into the GTEM cell and the transmission measurement was performed again. The difference of the first and the second transmission spectra was registered. The measurements were made by placing the sensing monopole in 5 measuring points within a $0.5 \times 0.5\,\text{m}^2$ square and orienting it to 3 mutually orthogonal directions in each measuring position (IEC 61000-4-20); Figure 2 shows one typical measurement.

Figure 2: The difference in the transmission of the GTEM cell with and without loading in the screen printed resistive lines.

The conclusion of the numerous investigations was that the difference in the transmission was always less than 1 dB in the case of the resistive lines, even when they were arranged in very different ways. On the other hand, any other conductive wires or coaxial cables resulted in significantly greater effects, at least at one frequency the difference exceeds the 6 dB. It happened also in the case of the thinnest available coaxial cable having only an outer diameter of 1.8 mm. Objects having dimensions much smaller than the wavelength as small metal boxes, or coaxial adapters, and so forth showed also small effect on the field, except when they were placed in the immediate vicinity of the monopole.

The resistive line is a lowpass filter as it is shown in Figure 3. The cut-off frequency is about 800 Hz. This is the reason for the application of the simple envelop detector only, having direct DC output. This is the price for the nondisturbing character of the probe.

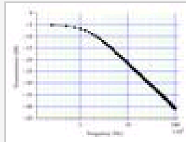

Figure 3: The measured transmission of the 2 m-long resistive wire pair.

At low levels, the output of the detectors are proportional to the square of the electric field. Therefore, the sum of the three signals will be the correct vectorial sum of the square of the total field strength, its square root is the effective value of the field, independent from the polarization. At higher levels, the output flattens down as the diode impedance lowers at higher biases. This effect was investigated by placing the detector in front of an antenna feed with variable powers. The situation is shown in Figure 4(a), where the detector output is depicted in the function of the power. In the saturation region, where the sensitivity of the detector decreases, the output signal will not proportion to the square of the field, therefore the sum of the three signals will not result the correct value of the total field. A possible normalization method is shown in Figure 4(b). It can be seen measured point pairs of the Figure 4(a) fit rather well to the exponential function, that is, the detector DC output power characteristic will be linear in log-log scale. This observation offers a method of normalization: the components of the E^2 can be determined from the logarithm of the DC signal. The other method is the regulation of the radiated power and keeping the detector always in the low-level range.

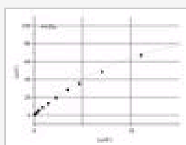

Figure 4: (a) The detector output voltage in the function of the power feed in the calibrated antenna. The doted line is the exponential fit. (b) The same curve plotted in log-log scale.

The sensitivity of the probe was calibrated in free space in an anechoic chamber with the help of calibrated antennas [9]. Figure 5 shows the normalized output voltage of one sensor at 10 V/m field strength. The normalization was done according to the second method: the power was regulated in such a way that the output was always lower than 25 mV. This value is within the square-law region with an accuracy of about 8%. In cases when this power was less than necessary for producing the 10 V/m, the measured DC values were multiplied by the ratio of the necessary power and the actual power. The structure has a resonance at around 13 GHz. This resonance can be hardly tuned by the length of the dipole; we suppose that it is linked to the diode.

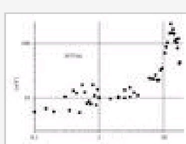

Figure 5: The diode DC output normalized to 10 V/m field strength.

The directional sensitivity can be characterized by the ratio of the outputs at parallel and perpendicular polarizations. It is better than 1 : 100. The immunity of the probe against high electric fields was also checked. The 210 V/m field at the resonance frequency did not induced any observable degradation. Therefore, the probe should not be removed from the measuring chamber even at high field tests.

The DC output signals of the three detectors are individually amplified and digitalized with a resolution of 12 bit. The bit values of the voltage (LSBs) are feed to a personal computer via the serial port. A special program has been written in Windows environment which reads in and displays on the monitor the LSB values. The observer can save the actual data by mouse click in dedicated dat files. Each file contains three LSB values, respectively, the three detectors. The syntax of the file name is: xxxx*****n.dat. The first four characters are the frequency of the measurement in GHz. The next characters are the identification of the investigation. The numeric character in the last position is the number of successive measurements under equivalent circumstances, it counts automatically. The processing of the raw data is carried out by a macro written in Excel. At first the values obtained from identical measurements are averaged, after that the zero shifts are corrected. Namely, the zero levels of the of the amplifiers are shifted in the positive direction, therefore any accidental temperature drift will not suppress them to negative voltage and even the smallest input equal only to 1 LSB can be detected. The actual value of the shift is measured at zero field and this value—usually less than 10 LSBs—is subtracted from the average of the measured data. The next step is the multiplication by the individual frequency dependent sensitivities of the three detectors. The macro program reads out from the file name the frequency and applies the belonging sensitivity values. After that, the program sums the three components and calculates the square root too.

The basic realization of the device work according to the mentioned second method, and the detected signals can be observed only in the square-law region of the diodes. For this the amplification is set for 1 LSB = 6 μV, that is, the maximum of the scale is $4096*6\mu V = 24.5$ mV. However, the Excel macro can evaluate the E^2 values from the logarithmic calibration too. Of course the amplification factor should be decreased in this case.

3. Conclusions

A microwave E-field probe has been developed for measuring the field distribution in chambers used for radiated immunity test. The device is an accessory of the measuring chamber, it is connected to the connector mounted on the inner wall of the chamber by a 2 m-long flexible resistive cable, which does not perturb significantly (less than 1 dB) the field distribution. The sensitivity is frequency dependent. The measured data are digitalized and feed into personal computer for further processing, which is performed expediently by special Microsoft Excel macro.

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