ON DETERMINING THE MAXIMUM EMISSIONS OF ENCLOSURES AT FREQUENCIES ABOVE 1GHz

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ABSTRACT

In this paper, we describe a suitable method to determine the maximum radiated electric field of a typical piece of consumer equipment acting as a radiating structure. To ensure that the maximum emission is measured, it is necessary to scan the measurement antenna over a surface surrounding the equipment under test (EUT) at a sufficiently fine scan resolution. Numerical simulations based on the transmission-line matrix (TLM) modeling method are also performed in order to complement the experimental work. So far we can achieve statistical agreement between experiment and simulation results. The statistical analysis on both measurement results and simulation results also indicates that the scan resolution need not fulfill the sub-wavelength resolution criteria at the frequency range from 1GHz to 6 GHz. Examples of the relationship between this uncertainty and coarse scanning resolution and measurement guidelines based on them will be given in the paper.

INTRODUCTION

To test the emissions of a radiating structure is an important step to evaluate the electromagnetic interference generated by this equipment. Although the approach using mode-stirred chambers for EMC emissions testing at microwave frequencies enables the direct measurement of total radiated power, the fields radiated by an equipment enclosure can only be derived by this approach if assumptions are made about the statistical properties of the directivity of the radiating enclosure [1]. Our new work reported here focuses on how to determine the maximum emission of an equipment enclosure in its radiating near field in anechoic chamber.

In this paper, an enclosure electrically large at frequencies in excess of 1GHz is considered. It is assumed that the enclosure contains a source of radiation and that it has the potential to interfere with a low power microwave radio system operated in close proximity to the enclosure. The distance between the enclosure and its victim radio system is likely to be in the order of a few metres and, as such, the enclosure is radiating in its Fresnel diffraction region at a distance R less than $2D^2/\lambda$. Here D is the maximum enclosure dimension and λ is the wavelength.

According to CISPR 16-2-3, during the field strength measurements in the frequency above 1GHz, the 3dB beam width of the measuring antenna should encompass the equipment under test (EUT). Otherwise moving the measurement antenna over the surfaces of the sides of the EUT or another method of scanning of the EUT is required [2]. This implies the direction of the emission from the EUT is along the major pattern robe of the receiving antenna, and the maximum emission can be determined by the result of a single measurement if the beam width of the measuring antenna is big enough to cover the EUT. However, an antenna in the receiving mode is used to capture electromagnetic waves or extract power from its effective area, and it is expected that in the Fresnel region, the radiated field of the enclosure exhibits a rapid spatial variation and the direction of the maximum emission is random. Thus, in order to test the maximum emission accurately, no matter whether the beam width of the receiving antenna is bigger than the EUT, it is necessary to perform the measurement by scanning the receiving antenna around the EUT with enough scan resolution. Consequently, the maximum emission should be determined by the maximum one of all the measurement results from every scan step. Here to test the complex emission of a practical enclosure, the measurement performed in anechoic chamber is accomplished by scanning an antenna over a surface surrounding the enclosure at a sufficiently fine scan resolution which should be less than half wavelength, ideally less than a quarter wavelength [3]. Besides, in order to measure the exact field of every test point, extreme variations of the field along the antenna dimensions should also be avoided. Therefore, during the emission measurement, the dimensions of the measurement antenna should be consequently less than half wavelength at the highest frequency to be tested. In our measurement, for fine detail scans, a

2.5cm dipole equal to half wavelength of 6GHz is employed to avoid smoothing from convolution with the aperture of horn antennas commonly used in this application. Other measurement details will be discussed in the following section of this paper.

However, such measurement is highly time consuming and is therefore undesirable. To achieve data reduction, a statistic method is also introduced to derive the uncertainty of the maximum emission due to coarse scan resolution. Before we use this statistical method to obtain the variation of the maximum emission estimates derived from an emission pattern measured with coarser scan resolution, a reference emission pattern measured with fine scan resolution should be obtained at first. By resorting to numerical modelling technique we can simulate the emission pattern of a radiating enclosure. Because the emission pattern is very sensitive to the exact construction of the EUT, numerical modeling techniques are not expected to predict the emission pattern accurately. However so far we can achieve statistical agreement between experiment and simulation results, for instance, the variation of maximum emission due to coarse scan resolution results from the emission patterns simulated is usually similar to such variation results from measurement results. That is, by combining the numerical modelling technique and the statistic method, we can estimate the relationship between the uncertainty of the maximum emission and scanning resolution before the practical measurement is performed. Here, the measurement results are simulated with the software tool 'HAWK' based on the transmission-line matrix (TLM) modelling method from Department of Electronics, University of York.

In this paper, for convenience, the polarization of the receiving antenna is always vertical in both measurement and simulation.

EXPERIMENT

Configuration of the EUT

Before we test the maximum emission from the new measure, it is necessary to configure an enclosure under test to represent a typical electronic equipment. In the experiments reported here, a comb generator CGE02 from York EMC Services Ltd was used as the emission source inside an enclosure. This source, with a harmonic spacing of 250MHz, can be mounted on a suitable PCB comprising ground and power planes and so could be used inside the enclosure at the various positions to simulate radiation from a processor or other emitting integrated circuit. The different source positions on the PCB are shown in Fig. 1. The dimension of the PCB used in experiment was 300*240mm.

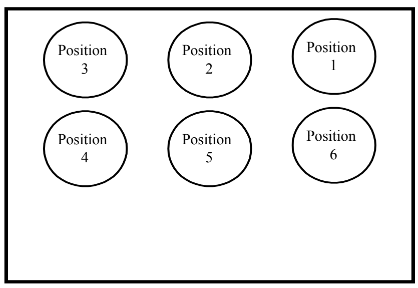

Fig. 1. Different positions of emission source on the PCB.

The enclosure used in the experimental work described here was a copper cuboid of dimensions 480*480*120mm. All outer walls of the box were closed except the front plate, which was interchangeable. Front plates with different slot arrangements were employed. Fig. 2 shows the dimensions of the slots used for the data presented here.

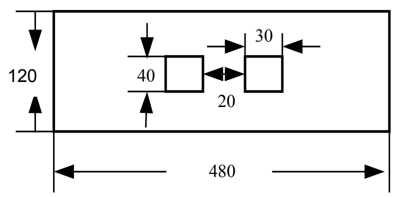

Fig. 2. Geometry of front plate with 2 slots. The slots are same in dimension. All dimensions in millimetres.

Experimental Procedure

Two different kinds of scan were performed. The first was cylindrical scan executed by a repeated rotation of the EUT for each different receiving antenna height over a certain height. The scan range on horizontal direction and vertical direction were $-45^o \sim +45^o$ with 100 steps and –45 ~ +45 centimetres with 60 steps respectively. In order to compare with simulation results, planar scan on a 1m square surface was also executed. The EUT was fixed and the receiving antenna was repeatedly moved horizontally at different heights. The range of planar scan was –50 ~ +50 centimetres on both horizontal and vertical directions and we tested 25 points in each direction. The distance between the receiving antenna and the EUT was 1 meter for these two kinds of scan.

MEASUREMENT AND SIMULATION RESULTS

As the measurement procedure discussed above the emission pattern of the EUT was measured at different frequencies. During the cylindrical scan, the emission pattern was measured at frequencies from 1GHz to 6 GHz with 1GHz interval. For the planar scan, the emission pattern was measured at 1GHz, 2GHz and 3GHz.

Fig. 3 gives two examples of emission patterns measured at two different source positions together with the probability distribution function (PDF) derived from the measurement results respectively. Fig. 3 indicates that the emission pattern of a radiating enclosure is complex and the emission pattern is sensitive to the structure of EUT. The maximum emission can be anywhere in the pattern. Because the dimension of the area of the maximum emission on the emission pattern is more than one wavelength, it seems we can use coarse scan resolution to test the maximum emission. Besides, although the source positions are different, the PDF derived from these two measurements are similar to each other and close to Rayleigh distribution. The study on the mechanism of the PDF of fields is under development.

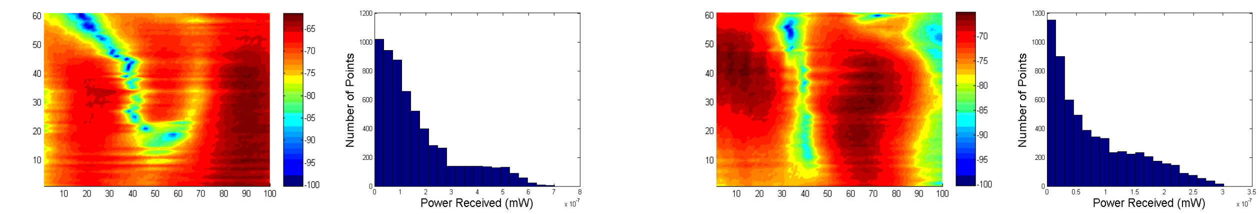

Fig. 3. The emission pattern and the PDF of received power measured as CEG02 at position 6 (left); the emission pattern and the PDF of received power measured as CEG02 at position 3 (right). Cylindrical scan; frequency: 6GHz; colormap unit for received power: dBm; unit for received power in PDF: mW.

An example of the emission pattern measured by planar scan and its PDF are given in Fig. 4 together with the simulation results. The statistic results about the uncertainty of the maximum emission derived from the emission patterns presented in Fig. 4 are shown in Fig. 5. Although Fig. 4 indicates that the emission pattern simulated does not agree well with the emission pattern measured, the PDF derived from measurement results is similar to the PDF derived from the simulation results and these PDF are close to Rayleigh distribution. Fig. 5 indicates that as we reduce the test points, the uncertainty of maximum emission derived from measurement results are similar to that derived from simulation results. Fig. 5 also indicates that the maximum emitted field measured based on a coarse scan resolution was generally within 3dB of the fine scan value even if the scan step was increased to a wavelength scale. For emission pattern at different frequencies, similar statistic results can be also obtained.

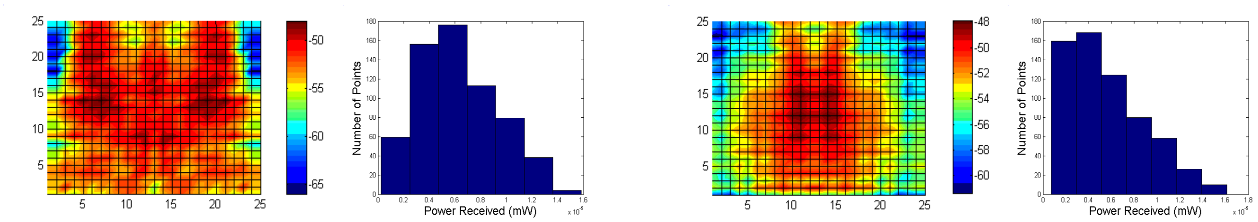

Fig. 4. The emission pattern measured and the PDF of measurement results (left); the emission pattern simulated and the PDF of simulation results (right). Planar scan; frequency: 3GHz; colormap unit for received power: dBm; unit for received power in PDF: mW; source position: 5.

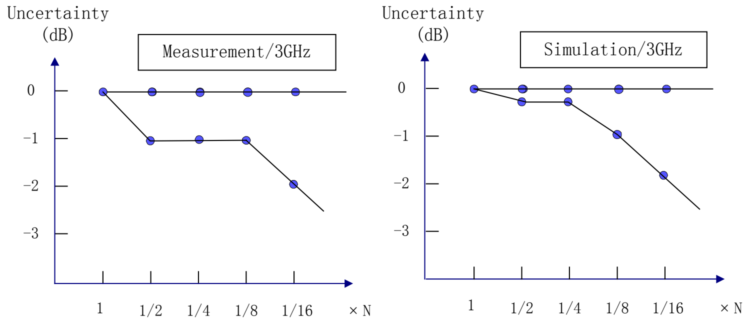

Fig. 5. Divergences of uncertainty derived from the emission patterns presented in Fig. 4. N=25*25 test points.

To get such divergences in Fig. 5, at first both a reference emission pattern measured and a reference emission pattern simulated with fine scan resolution less than half wavelength were obtained, as shown in Fig. 4. In Fig. 4 the scan resolution was 4cm, less than half wavelength of 3GHz. At frequencies below 3 GHz, the maximum emission derived from the emission pattern with such scan resolution should be close to the real value and the difference could be neglected. The number of points 'N' in the reference emission pattern, was consequently equal to 25*25. The emission pattern with coarser scan resolution can be imitated by reducing the rows and columns evenly from the reference emission pattern. For example, the emission pattern with 8cm scan resolution can be obtained by reduced half of the rows and columns with the same interval from the emission pattern with 4cm resolution. Thus, we can get four different patterns imitated. The difference between the smallest maximum emission of all the patterns imitated and the maximum emission of the reference pattern is the uncertainty caused by coarse scan resolution or insufficient test points. The divergence can be obtained by a curve connecting all the minimal maximum emission at different numbers of test points.

CONCLUSION

To measure the maximum emission of a radiating enclosure accurately, the receiving antenna is required to scan around the enclosure with fine scan step less than half wavelength. However, the statistical analyses on measurement results indicate the estimate of the maximum emitted field based on a coarse scan is generally within 3dB of the fine scan value even if the scan step in increased to a wavelength scale.

By combining the statistical method discussed above and the simulation result based on TLM modelling technique, we can estimate the uncertainty of maximum emission results from coarser scan step or insufficient test points before a practical measurement is performed. Thus we can determine the reasonable scan step for a practical measurement of the maximum emission of a radiating enclosure.

REFERENCES

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