Development of Low Cost Radiated Emission Measurement System

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***Abstract*- A novel low cost radiated emission measurement system by using current probe has been proposed in this paper. Compared with conventional anechoic chamber measurement method, this new method could reduce test cost and save developing time efficiently. In order to improve the accuracy, a transfer function has been built for mapping the relationship between current probe method and anechoic chamber method. By using the interpolation, the final estimated radiation emission has been validated and agreed well with the experimental results in anechoic chamber.**

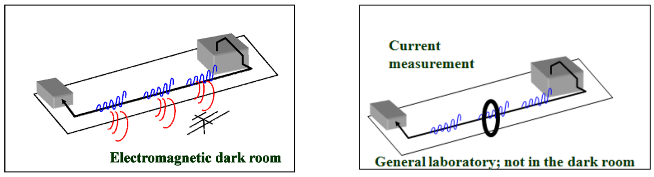
***Key Words*-radiated emission, transfer function, Taguchi method**

I.INTRODUCTION

Experts predict that by 2010, 30% of an automobile's cost will be in electronic components, thus electromagnetic compatibility (EMC) will become a more critical aspect of the automotive design [1-3]. Predicting EMC performance via modeling and simulation will allow for further cuts in design cost and time. The standard IEC/CISPR 25 is an international standard containing limits and procedures for the measurement of radio disturbances, which is designed to protect receivers from disturbances produced by conducted and radiated emissions arising in a vehicle.

Absorber-lined shielded enclosure (ALSE) method is one method used for the measurement of radiated emissions from components/modules. Fig.1 (a) illustrated the test setup that was stated in IEC/CSIRP 25, which consists of the power supplier, harnesses, artificial network, circuit board installed in shielding box, related ground plane and receiving antenna. As shown in the figure, all the equipments should be put into anechoic box for shielding noise source from outside. Generally, the fee for building or ordering an anechoic box is too expensive, so we should look for some cheap measurement methods, especially in production developing stage.

In order to reduce measurement cost, current measurement method might be a replacement by using current probe. Since the detected signal of current probe is caused by near-field coupling, the noise source in surrounding environment will be much lower than the detected signal, the test equipments should not be involved in anechoic box. Consequently the measurement cost could be reduced drastically. As depicted in Fig.1 (b), the current probe is located in the center of the measured harness, and it is connected with a spectrum analyzer. By comparing the results obtained by anechoic chamber and current probe, we can get a transfer function to transform the result tested by current probe to the real result. As a result, the measurement accuracy of current probe method depends on the transfer function.



(a) (b)

Fig.1 Measurement methods of radiated emission from circuit board

Due to the current distribution along the harness, the signal detected by the current probe is very sensitive to the location and frequency. At some resonant frequency, the distribution is a standing wave along the harness, thus the current magnitude is very low at some standing wave node. This phenomenon will lead to much error in radiation emission measurement including the noise level and peak frequency. For the sake of the measurement with high accuracy and low cost, we should propose some novel method in this study.

II. TECHNICAL APPROACH AND SCHEME

A. Novel multiple current probes method for accuracy improvement

Due to the disadvantage of single current probe method, a novel multiple current probes method has been proposed in this study. As shown in Fig.3, three current probes have been put along the harness in parallel. The detected signals by three probes are summed together and then imported into spectrum analyzer. Compared with single current probe method, multiple current probes detector can avoid standing wave node.

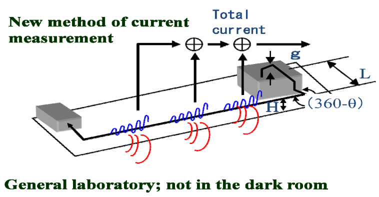


Fig.2 Multiple current probes method

The main task is to determine the locations of multiple current probes and how to combine the signals from different paths. Since the phase distribution of the current along the harness is diversified, we can't sum the three ways signal directly. For example, if the phase at two probes is out of phase, the summation will be zero. Furthermore, the phase shift at different frequencies is not same. To prevent this error in summation, a switching unit is invented to the multiple current probes method, as illustrated in Fig.4. As the measured result at each probe is obtained respectively, the average spectrum can be calculated, and signal cancelling in different probes can be eliminated effectively.

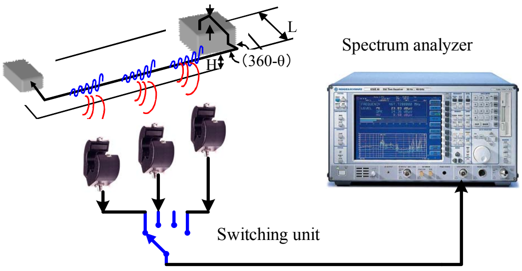


Fig.3 Switch unit for multiple probes

As the noise source is determined, the magnitude of current distribution will be invariant in time. Based on this principle, actually, we use one current probe and place it at different positions of the cable, then treat the max of the three as the peak of standing wave. The effect is the same.

B. Parametric study and transfer function

Based on primary experiments, four parameters such as L (harness length), H (harness height over ground plane), g (gap between harness and supporter) and θ (bend angle of harness) will have effects on the results. As shown in Fig.4,the value of four parameters is J: L=500mm, H=55mm, θ=135, g=20mm I: L=500mm, H=55mm, θ=135, g=10mm, as we can see, the peaks change when the parameters are changed.

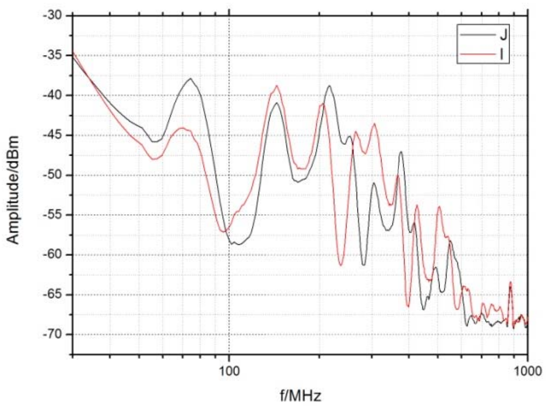


Fig.4 Parametric study for sensitivity analysis

Our objective is to get the conversion formula between the current spectrum and the Radiated spectrum. As we can get some sets of accurate data from the darkroom , we will do the experiments in lab with the same setting of parameters. And get the difference between the two sets of data as shown in the formula, it is K.

$$K[dB] = S_{Darkroom}[dB] - S_{Probe}[dB] \qquad (1)$$

Figure.5 illustrates the transfer function which is the relationship between the K and the four parameters.

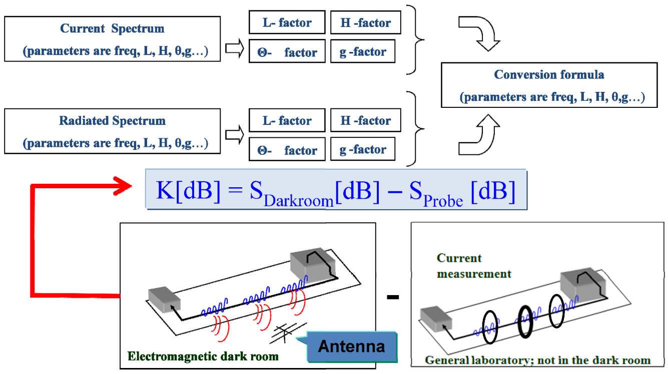


Fig.5 Transfer function

Based on the above parametric study, the accuracy of transfer function can be verified. For example, the measured data can be divided into two parts. One part can be used for transfer function derivation, and the other part can be used for its verification. Figure.6 shows the flow chart of parametric study.

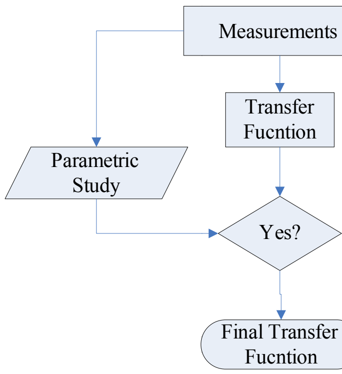


Fig.6 Flow chart for parametric study

C. Taguchi method

The objective of Taguchi method [4] is to get as much information, usually the whole, as possible with least cost. The method is especially useful in the study of parametric performance.

The main work is to design a set of arrays which are orthogonal, and the following experiments will be carried out based on the set of arrays.

The general steps are as follows:

1) Determine the parameters which are to be study. The

number of parameters is denoted by p .

2) Determine the levels of each parameter, the number of levels is denoted by s .
3) Design the orthogonal arrays
4) Do the experiment according to the set of arrays.
5) Analyze the results.

The set of orthogonal arrays is denoted by $L_n\left(s^p\right)$, L represents the orthogonal table, s and p are as explained in step 1) and 2) respectively, n is the number of the orthogonal table rows, which is also called the number of the experiments. To determined s and p , n can be got according to orthogonal of Taguchi method.

For example , $p=4$, $s=3$,if we do the experiments by conventional method, the total number of experiment should be $3^4=81$, if we use Taguchi method, the number will be reduced to 9, which is denoted by $L_9\left(3^4\right)$.[5]

In our study, there are four parameters, and we choose three levels for each factor. $L:(600,550,500)$, $H(55,50,45)$, $\theta=(90,110,135)$, $g=(20,10,5)$, The dimension of the four factors is mm.

The four parameters are independent, and arbitrary two columns are orthogonal, the order should not be changed, each row is a specific combination. The information involved in the table are dispersed equally, so it already contain the whole information of 81 sets of data.

D. Transfer function and evaluation

In the actual measurement, we use one current probe in lab, and current probe position is determined as follows: we use S21 mode of the vector network analyzer, then move the current probe to find the points where the performance of the coupling curves is well. This method is fast. The coupling curves are as Figure.7 shows.

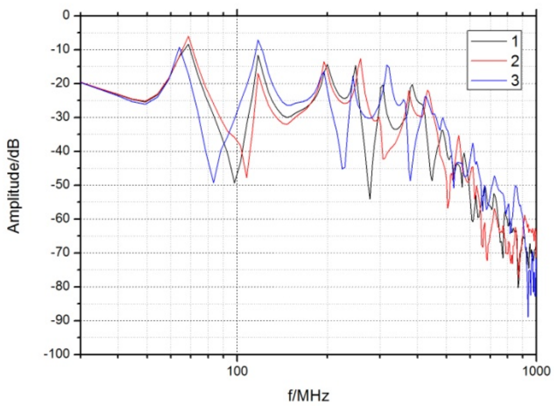


Figure.7 the coupling curves in the vector network analyzer

The three curves are got at different position. From Figure.7, we can see the curve-2 and curve-3 are better and curve-2 is not good at 130MHz,330MHz,480MHz but other frequencies are good, curve-3 is not good at 70MHz,380MHz ,but other frequencies are good, so we can use position-2+position-3 to supplement each other. In the actual operation, we measure at position-2 and position-3, and treat the average value as the result.

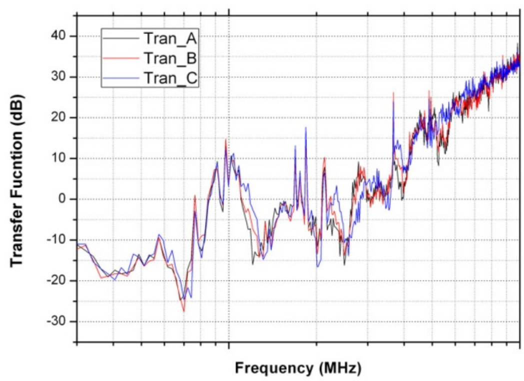
When we got the transfer function data, we also should do the evaluation. So we choose one case as shown in the Table.1, the Cases from A to I is used for get the transfer function, and Case J is for evaluation.

Case	L(mm)	H(mm)	Θ(degree)	g(mm)
A	600	45	135	5
B	600	50	110	10
C	600	55	90	20
D	550	45	90	10
E	550	50	135	20
F	550	55	110	5
G	500	45	110	20
H	500	50	90	5
I	500	55	135	10
J(Evaluation)	500	55	135	20

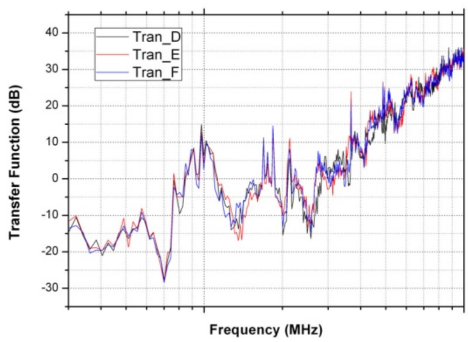
Table.1 the experiment cases

III. ANALYSIS AND RESULTS

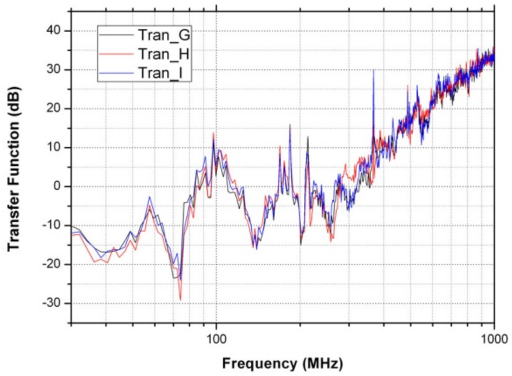
Firgure.8 shows the transfer function data, which is the difference between the results in darkroom and in lab. There are nine curves corresponding to the nine Cases from A to G.



(a) Transfer function data of Case A to C



(b) Transfer function data of Case D to F



(c) Transfer function data of Case G to I

Figure.8 transfer function data

Case J is for evaluation, owing to the setting is similar to Case G and I, so we use G and I to get transfer function for Case J, as shown in Figure.9.

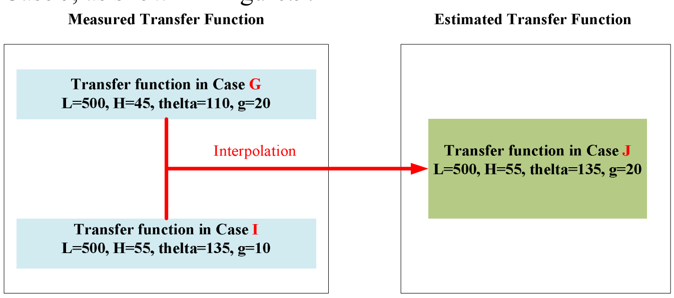


Figure.9 the transfer function for Case J

Then we use the transfer function data for J to get the estimated results, from Figure.10 we can see the estimated results by current probe is similar to the exact results in darkroom, the peak is approximately the same.

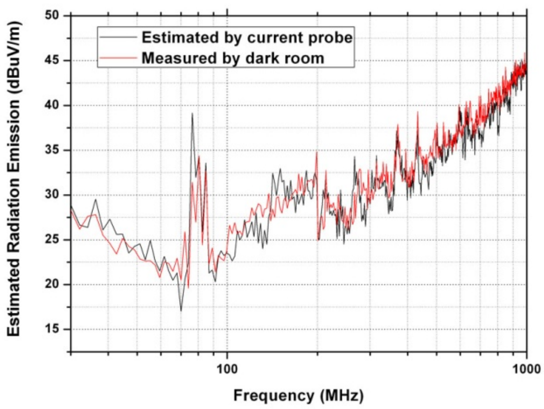


Figure.10 the comparison of results by current probe and by darkroom

IV. CONCLUSION

This paper proposed a development of radiated emission measuring system based on Taguchi method. Taguchi method is a good principle for design an experiment with lowest cost, which can reduce the complexity. Some numerical method can be used to get the transfer function, the estimated results got in lab can be approximately accurate as in darkroom, so the contradiction between accuracy and low cost has been solved.

V. ACKNOWLEDGMENT

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XI. REFERENCES

[1] KUMAR Rajeev MISRA Ashok "Effect of processing parameters on the electromagnetic radiation emission during plastic deformation and crack propagation in copper-zinc alloys" *JOURNAL OF ZHEJIANG UNIVERSITY SCIENCE A 2006 7(11)*

[2] Colotti, J. "EMC DESIGN FUNDAMENTALS" *Systems, Applications and Technology Conference, 2006. LISAT 2006. IEEE Long Island 5-5 May 2006*

[3] Goedbloed, J.J; "Uncertainties in EMC compliance testing" *Implication of measurement Uncertainties for EMC Testing(Digest No.1997/116), IEEE Colloquium on the 11 June 1997*

[4] Yiming Man Jiangwei Gong Huiyan Chen Yanhua Jiang Yuwen Hu "Design optimization of control parameters for strapdown line-of-sight stable tracking platform based on the Taguchi method " *2009 Chinese Control and Decision Conference(CCDC2009)*

[5] Peace Glen Stuart "Taguchi methods: a hands-on approach to Quality Engineering", *Fourth printing March 1995*