

# Experiment Results of the Unwanted Influence of a Probe Fixture in Transient Electromagnetic Field

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## Abstract

Field probes are used extensively in electromagnetic compatibility tests to measure magnitudes of electromagnetic field strength. To achieve accurate measurements in a certain space position, a probe (mounting) fixture or probe stand is always utilized to hold the field probe. The unwanted influence of a probe fixture in transient electromagnetic field is investigated by experiment in this paper. Considering the measurement uncertainty of measuring system, the preliminary experiment results are in accordance with the assessment by finite integration technique which has been carried out.

## 1. Introduction

Field probes are used extensively in electromagnetic compatibility (EMC) tests to measure magnitudes of electromagnetic field strength. To achieve accurate measurements in a certain space position, a probe (mounting) fixture or probe stand is always utilized to hold the field probe. With regard to field uniformity tests (also called as field calibration in some standards), which assure the validity of the test results of equipments under test (EUT) in electromagnetic field facilities, several measurement positions are normally needed [1]-[6]. MIL-STD-461F, taken as an example, requires five positions to calibrate the transient electromagnetic field [4]. Therefore, a precise-positioning and fast-changeable-measurement-positions probe fixture is necessary for such field uniformity calibrations.

Meanwhile it's noted that the probe fixture is required to be non-reflecting, non-conducting and low-permittivity to avoid field perturbation [2] [6]. Thus the unwanted influence of a probe fixture in the transient electromagnetic field has been calculated by finite integration technique [7]. This paper focuses on the experiment results of the unwanted effects due to field perturbations by the designed probe fixture.

## 2. MEASUREMENT METHOD

The measurement procedure to qualify the unwanted effects due to field distortions is similar to the probe fixture validation method illustrated in [6].

Firstly, put the field probe on a low-loss (loss tangent less than 0.005), low-permittivity (relative permittivity less than 1.2) dielectric support. Then generate a standard field and record the measured value  $U_0$  (oscilloscope reading). The electric field  $E_0$  can be obtained in kV/m by

$$E(\text{kV/m}) = \frac{U(\text{mV})}{C[\text{mV/(kV/m)}]} \quad (1)$$

where  $C$  is the correction factor of the sensor [8].

Secondly, remove the dielectric support and place the probe fixture under validation at the location to support the field probe and keep it in the same position as that in the first step. Then generate the constant field once again. Record the measured value  $U_1$  and compute the electric field  $E_1$  in kV/m.

Lastly, the unwanted influence factor  $k$  of the probe fixture can be expressed as

$$k = E_1 - E_0 \quad (2)$$

where  $k$  is denoted as the influence factor of the intended probe fixture, dB;  $E_1$  is the measured field with the intended probe fixture, dBV/m;  $E_0$  is the measured field in dBV/m with a low-loss, low-permittivity, dielectric support in the same place.

The unwanted influence factor for the same probe orientation shall be less than 0.5 dB [6].

### 3. MEASUREMENT CONFIGURATION

The constant transient electromagnetic field is set up in a guided wave electromagnetic pulse (EMP) simulator in the lab of Beijing Institute of Radio Metrology and Measurement (BIRMM), which is also called as conical transmission line, as shown in Fig. 1.

The standard defined EMP is applied. Its mathematical expression can be given as [4]

$$E(t) = \begin{cases} 0 & \text{when } t \leq 0 \\ E_0 \cdot d(e^{-at} - e^{-bt}) & \text{when } t > 0 \end{cases} \quad (3)$$

with  $E_0 = 5 \times 10^4$  V/m,  $a = 4 \times 10^7$  s<sup>-1</sup>,  $b = 6 \times 10^8$  s<sup>-1</sup> and  $d = 1.3$ .

The intended probe fixture is made of Polyoxymethylene for its good mechanical property and Teflon for its low permittivity. The relative permittivity of them is 3.7 and 2.08, respectively. And the loss tangent is normally 0.004 and 0.00037, respectively. Fig.2 shows the photo of the designed probe fixture.



Fig. 1 The conical EMP simulator in BIRMM lab



Fig. 2 The designed probe fixture

From Fig.2 it can be seen that one more ground field probe is used in the validation test. The reason to employ it is to keep the standard field under surveillance because the pulser to excite the transient electromagnetic field cannot always maintain same output when displaying same output value. Therefore, the electric field  $E$  is normalized by

$$E = \frac{U \text{ (mV)}}{C \text{ [mV/(kV/m)]}} \left/ \left\{ \frac{U_G \text{ (mV)}}{C_G \text{ [mV/(kV/m)]}} \right\} \right. \quad (4)$$

where  $U_G$  is the measured value (oscilloscope reading) of the ground field probe and  $C_G$  is its correction factor.

Five blocks of foamed polystyrene (see Fig. 3) is selected in the validation test with different heights, i.e. 0.2 m (2 blocks, one block is not shown in Fig.3), 0.34 m, 0.16 m and 0.3 m respectively. The relative permittivity of this dielectric material is 1.05 and its loss tangent is normally 0.00003 at 3 GHz.

## 4. Measurement Results

The validation test is conducted in 24 positions, which coordinates are shown in Fig. 4. The experiment results are listed in Table I.



Fig. 3 Foamed polystyrene blocks

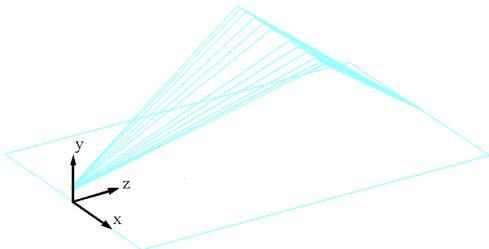


Fig. 4 The coordinates of the conical EMP simulator

Because  $C$  and  $C_G$  can be counteracted by using (4) and (2) when calculating the influence factor  $k$ , they are not taken into account in the validation for the sake of convenience.

TABLE I EXPERIMENT RESULTS OF INFLUENCE FACTOR

No.	Position Coordinates /m			Foamed Polystyrene Blocks			Probe Fixture			$k$ /dB	$k'$ /dB
	$x$	$y$	$z$	$U_0$ /mV	$U_{0G}$ /mV	$E_0$ /dB	$U_1$ /mV	$U_{1G}$ /mV	$E_1$ /dB		
1	-0.5	0.4	1.9	121.5	136.8	-1.03	110.0	133.6	-1.69	-0.66	-0.86
2		0.5		123.3	130.5	-0.49	119.5	135.2	-1.07	-0.58	-0.27
3		0.8		132.0	135.4	-0.22	150.4	146.6	0.22	0.44	1.13
4		1		138.0	137.0	0.06	145.5	140.2	0.32	0.26	0.46
5	0	0.4	2.2	120.9	136.9	-1.08	119.4	130.5	-0.77	0.31	-0.11
6		0.5		133.2	130.6	0.17	140.0	132.0	0.51	0.34	0.43
7		0.8		131.5	128.9	0.17	151.4	150.0	0.08	-0.09	1.22
8		1		133.7	133.7	0.00	135.4	144.9	-0.59	-0.59	0.11
9	0.5	0.4	1.9	122.2	138.6	-1.09	112.6	135.3	-1.60	-0.50	-0.71
10		0.5		124.0	133.6	-0.65	134.3	140.1	-0.37	0.28	0.69
11		0.8		131.0	136.9	-0.38	135.8	137.1	-0.08	0.30	0.31
12		1		141.4	138.4	0.19	137.0	129.0	0.52	0.34	-0.27
13	-0.5	0.4	2.2	118.0	141.6	-1.58	112.2	129.0	-1.21	0.37	-0.44
14		0.5		110.1	135.2	-1.78	113.5	137.0	-1.63	0.15	0.26
15		0.8		131.0	138.4	-0.48	130.8	148.1	-1.08	-0.60	-0.01
16		1		110.0	133.9	-1.71	125.8	151.3	-1.60	0.10	1.17
17	0	0.4	1.9	107.9	133.8	-1.87	108.6	132.3	-1.71	0.15	0.06
18		0.5		107.3	132.1	-1.81	121.0	141.8	-1.38	0.43	1.04
19		0.8		129.1	138.6	-0.62	131.8	143.3	-0.73	-0.11	0.18
20		1		130.6	140.0	-0.60	126.7	136.8	-0.67	-0.06	-0.26
21	0.5	0.4	2.2	109.2	132.2	-1.66	112.6	135.5	-1.61	0.05	0.27
22		0.5		115.1	138.5	-1.61	120.3	136.9	-1.12	0.48	0.38
23		0.8		121.4	136.8	-1.04	132.0	146.4	-0.90	0.14	0.73
24		1		127.0	140.0	-0.85	117.6	143.2	-1.71	-0.86	-0.67

For better illustration, Fig. 5 is drawn to investigate the unwanted influence factor  $k$ . It can be found that a majority of  $k$  values are fallen into the range [-0.5 dB, 0.5 dB]. Only 21% ( $\approx 5/24$ ) values are in the range [-1.0 dB, -0.5 dB].

In the last column of Table I are also listed the influence results without normalization by using (4), which is designated as  $k'$  for comparison. Fig. 6 shows its graph. In this figure the influence factors  $k'$  values are mostly fallen into the range [-1.0 dB, 1.0 dB]. And 29% ( $\approx 7/24$ ) values are in the range [1.0 dB, 1.5 dB] and [-1.5 dB, -1.0 dB]. Hence it can be estimated that the normalization data process eliminates the unsteadiness effect of the pulser for about 0.5 dB.

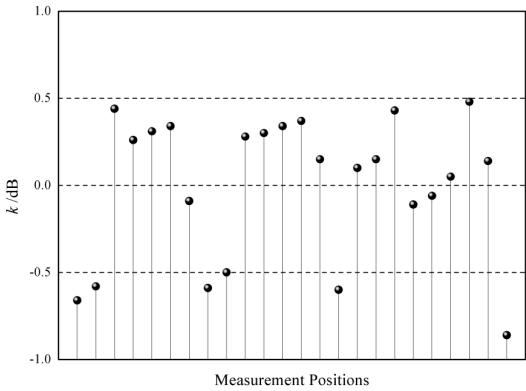


Fig. 5 Normalized influence factor  $k$  in various measurement positions

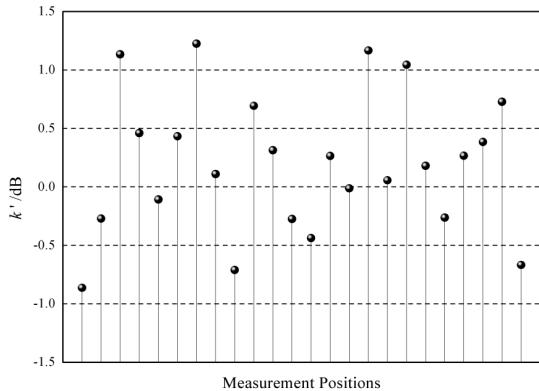


Fig. 6 Influence factor  $k'$  without normalization

Considering the measurement uncertainty of field probe measuring system is 1 dB or so, it can be roughly deemed that the unwanted influence due to the probe fixture under validation is acceptable. The measurement results are also in accordance with the assessment by finite integration technique [7].

However, the field probe measuring system with about 1 dB measurement uncertainty is not capable strictly to perform the validation because the unwanted influence factor shall be less than 0.5 dB. So this presented experiment is only a preliminary validation. Future work should be carried out to increase the accuracy of the probe measuring system and then give more determinate conclusion.

## 5. Conclusion

The unwanted influence of a probe fixture in transient electromagnetic field is investigated by an experiment in this paper. Considering the measurement uncertainty of measuring system, the preliminary experiment results are in accordance with the assessment by finite integration technique which has been carried out before.

## 6. References

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