

RADIATED IMMUNITY/SUSCEPTIBILITY TEST METHOD USING SLOWLY ROTATING ELECTROMAGNETIC WAVE

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Abstract: Authors have proposed a new immunity/susceptibility test method. The paper describes an overview of the proposed method and some estimation results. In the method, electromagnetic fields of low-rate-rotating polarization controlled electrically and continuously in a two-dimensional plane, so that radiated immunity/susceptibility characteristics depicted three-dimensionally can be obtained by using a turntable together with. The experimental results show the effectiveness of the method for quickly visualizing the weak and strong directions.

Key words: Immunity test, susceptibility test, rotating-EM field, three-dimensional map.

1 Introduction

According as electronics equipment becomes smaller and thus more sensitive, it is increasingly necessary for manufacturers to determine a product's immunity against strong and unintentional electromagnetic (EM) fields, and/or the product's susceptibility to interfering EM fields. The immunity test method is prescribed in the International Standard of the International Electrotechnical Commission (IEC) [1]. For a radio frequency (RF) radiated immunity test, it is required to be conducted by applying EM fields of horizontal and/or vertical polarizations to equipment under test (EUT) in an anechoic chamber. Transverse Electromagnetic (TEM) wave guides such as TEM [2] and GTEM [3] cells are also used under a specific direction of polarization. On the other hand, a reverberation chamber [4] is for unspecific directions. These conventional methods cannot be used to generate fields in an arbitrary and known direction. Since the radiated immunity/susceptibility characteristics of EUT highly depend on the direction of field polarization, it is necessary to know the dependence. If EM fields of a controlled direction can be generated, more detailed characteristics may be obtained.

In this paper, we take an overview of a proposed RF immunity/susceptibility test method. The method generates the slowly rotating fields electronically so that the direction of the field polarization can be known easily and the characteristics are obtained differently than with the conventional method. Moreover, by using a turntable we can depict the characteristics three-dimensionally, a 3D map, regarding the directions of polarization and of the turntable rotation. Thus, we can visually determine the characteristics in an instant. Since the polarization is controlled electrically, the measurement time mainly depends on one-rotation time of the turntable. We have concerned on an un-modulated and amplitude-modulated (AM) RF signals which are recommended in [1]. To verify our method both experimentally and quantitatively, we have discussed the characteristics of a shielded enclosure with a slot and an actual chassis of a tower-type personal computer under un-modulated fields. For an AM RF signal, we will show the results for an amplifier/speaker unit.

2 Slowly Rotating Field

Term of *Rotating EM Field* signifies an electromagnetic field whose polarization rotates very slowly (i.e., at less than 1 Hz) in a two-dimensional plane. The rotation frequency in the EM field's polarization plane is thus much lower than the field's carrier frequency. This is the significant difference from a circularly polarized field.

Let consider an EM field of angular frequency ω slowly rotating at an angular frequency Ω in the x - y plane, where Ω is much smaller than ω [5]. Then the components of the field vector \vec{E} of unit amplitude are written as

$$\left. \begin{aligned} E_x &= \sin \omega t \cos \Omega t \\ E_y &= \sin \omega t \sin \Omega t \end{aligned} \right\} \quad (1)$$

At a glance of the above, we notice that the components are mathematically equivalent to

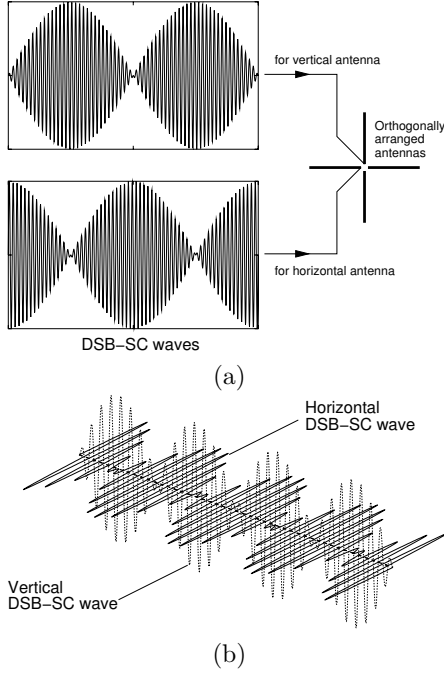


Fig. 1 DSB-SC waves in the time domain: two DSB-SC waves exciting a set of orthogonal antennas (a) and the respective radiated fields (b).

double-sideband suppressed-carrier (DSB-SC) signals. This suggests that we could generate the rotating fields by applying the DSB-SC signals to a set of orthogonally arranged antennas as shown in Fig. 1. In this case, it is difficult to generate DSB-SC signals by using multipliers as mixers, so that we proposed the following scheme. We rewrite (1) into

$$\left. \begin{aligned} E_x &= \frac{1}{2} \{ \sin(\omega + \Omega)t + \sin(\omega - \Omega)t \} \\ E_y &= \frac{1}{2} [\sin\{(\omega + \Omega)t - \pi/2\} \\ &\quad + \sin\{(\omega - \Omega)t + \pi/2\}] \end{aligned} \right\} \quad (2)$$

Equation (2) denotes that the two DSB-SC signals, E_x and E_y , could be composed of four signal components. Practically we manufactured the experimental setup based on the above equations. Next, we show a system for an amplitude-modulated electromagnetic (AM-EM) field. Similar to the aforementioned, rotating AM-EM fields can also be generated using the following two signals,

$$\left. \begin{aligned} E_x &= (1 + m \sin pt) \sin \omega t \cos \Omega t \\ E_y &= (1 + m \sin pt) \sin \omega t \sin \Omega t \end{aligned} \right\} \quad (3)$$

where m and p are, respectively, the modulation index and the angular frequency of the modulating

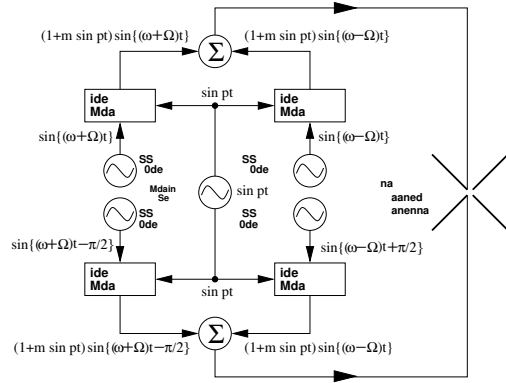


Fig. 2 Block diagram for rotating AM-DSB-SC signal generator

signal. Equations (3) can also be rewritten into

$$\left. \begin{aligned} E_x &= \frac{1}{2} \left[(1 + m \sin pt) \sin\{(\omega + \Omega)t\} + \right. \\ &\quad \left. (1 + m \sin pt) \sin\{(\omega - \Omega)t\} \right] \\ E_y &= \frac{1}{2} \left[(1 + m \sin pt) \sin\{(\omega + \Omega)t - \pi/2\} + \right. \\ &\quad \left. (1 + m \sin pt) \sin\{(\omega - \Omega)t + \pi/2\} \right] \end{aligned} \right\} \quad (4)$$

Using four AM signals, we can generate the two AM-DSB-SC signals. Figure 2 shows our system for generating AM-DSB-SC signals based on (4).

3 Susceptibility Characteristics

We checked whether our system works as expected in practical cases. We show some results for electronics enclosures against radio-frequency sinusoidal waves and for a practical amplifier against amplitude-modulation waves.

3.1 RF Sinusoidal Wave

Figure 3 (a) show the experimental results for the enclosure with a slot as an example. Here we defined susceptibility as the induced power in a probe inside EUT. The enclosure inherently resonates at 492 MHz for the dominant TE_{101} . In this experiment, a 492-MHz signal rotating at 1 Hz excited the EUT on the turntable.

We compared the characteristics with computed results obtained using the finite-difference time-domain (FDTD) method [6]. Figures 3 (b) and (c) show the 3D map results in a horizontal position by an experiment and a finite-difference time-domain (FDTD) method, respectively. These maps agree well with each other. In further detail, Fig. 4 shows the comparisons for two special states: (a) for vertical polarization and (b) for a zero-azimuth angle. These were also in good agreement. For other frequencies, except resonance frequencies,

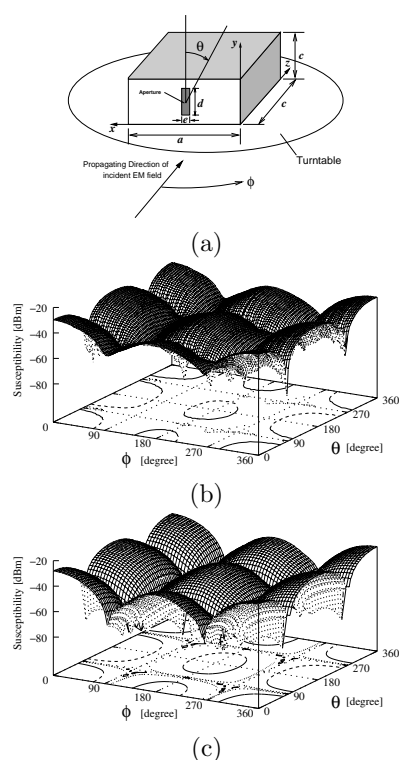


Fig. 3 Three-dimensional maps for an enclosure with a slot: enclosure model in a horizontal position (a), the experimental map (b), and the computed map (c).

the probe output was very low because almost no field impinged to the enclosure.

The next model is a chassis actually used for a tower-type personal computer (see Fig. 5 (a)). Such model is too hard to be characterized numerically. The experimental setup is shown in Fig. 5 (b). In our experiment, the chassis was set upright on the turntable, and the monopole probe at the center of the sidewall detected the impinging fields. We did not observe any apparent resonance of this chassis in the frequency region below 1000 MHz. Figure 6 shows the measured results for frequencies of 550MHz and 930MHz. There are remarkable differences in Figs. 6 (a) and (b). The most significant difference can be seen when the rear side is excited. The susceptibility level at 930 MHz was much higher than that at 550 MHz.

3.2 Amplitude-Modulation Wave

Next, we show an example when the rotating AM-DSB-SC wave was applied to an AF amplifier built into a speaker unit of a personal computer (see Fig. 7 (a)). The experimental setup is shown in Fig. 7 (b). The output voltages at the speaker terminal were estimated as the immunity levels of the EUT when no audio signal was supplied to the

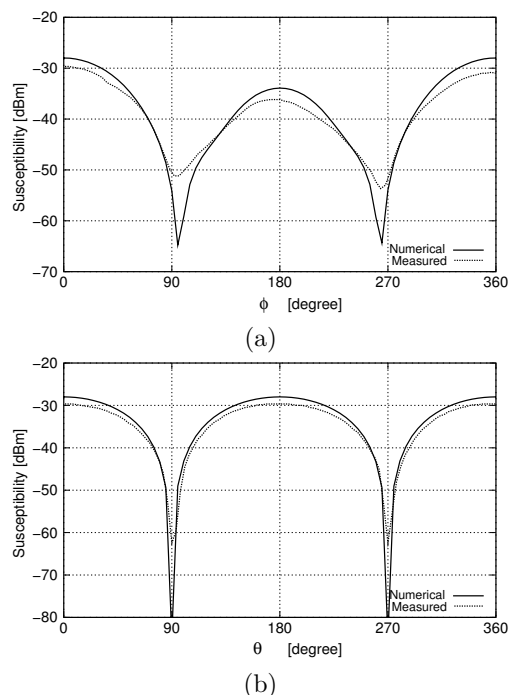


Fig. 4 Comparison of measured and computed results for vertical polarization, $\theta = 0$, (a) and for zero-azimuth angle, $\phi = 0$, (b).

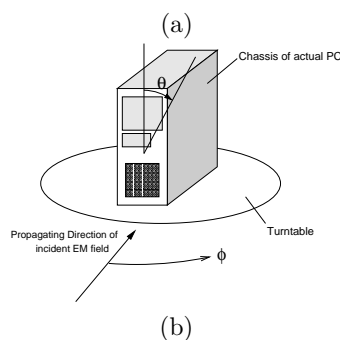


Fig. 5 Actual personal-computer chassis (a), and test-site coordinates (b).

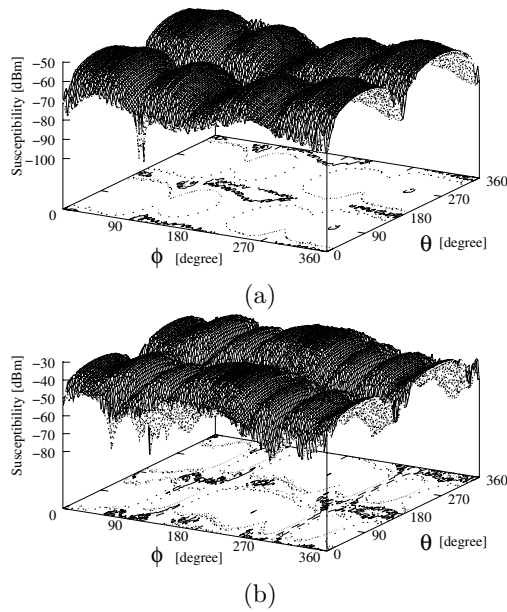


Fig. 6 Three-dimensional map for a tower-type personal computer:(a) for 550 MHz, and (b) for 930 MHz.

amplifier; the results are shown in Fig. 8.

Figure 8 shows a 3D map for a 400-MHz field of 1-kHz 80%-AM. The radiated immunity/susceptibility characteristics of the EUT depended greatly on the incident angle and the polarization direction of the EM fields.

4 Conclusion

We showed a new radiated immunity and susceptibility test method using a slowly rotating EM field. The experimental results showed that the proposed method was a useful technique for clearly revealing the detailed characteristics of EUT visually in a three-dimensional map. In spite of such detailed picture, measurement time is so short that it would be advantageous for trial phase of manufactured products.

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References

[1] "Radiated, Radio-Frequency, Electromagnetic Field Immunity Test", International Standard, Standard IEC 61000-4-3, 1995.
 [2] M. L. Crawford, "Generation of standard fields in a TEM transmission cell," *IEEE Trans. Electromagn. Compat.*, vol. EMC-16, no. 4, pp. 189-196, Nov. 1974.

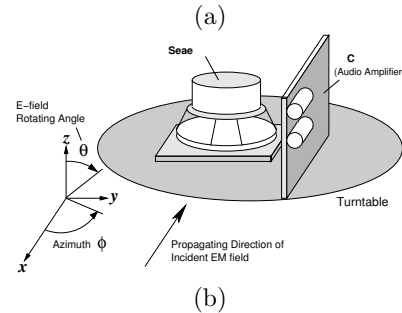


Fig. 7 Audio amplifier/speaker (a), and test-site coordinates (b).

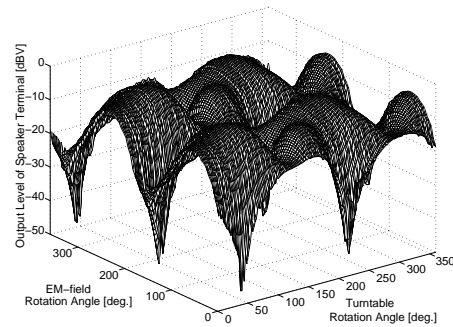


Fig. 8 Three-dimensional map of audio amplifier and speaker unit for a 400-MHz field of 1-kHz, 80%-AM.

[3] D. Hansen and D. Rristau, "Source of problems in the GTEM field structure and recommended solutions," *Proc 1996 Int. Symp. Electromagn. Compat.*, Santa Clara, pp. 48-51, Aug. 1996.
 [4] M. L. Crawford and G. H. Koepke, "Design, evaluation and use of a reverberation chamber for performing electromagnetic susceptibility / vulnerability measurements," *NBS Technical Rept.* 1092, Apr. 1986.
 [5] K. Murano and Y. Kami, "A New Immunity Test Method," *IEEE Trans. Electromagn. Compat.*, vol. 44, pp. 119-124, Feb. 2002.
 [6] K. Murano, T. Snpei, F. Xiao, Y. Kami, F. Centola, and J. L. Drewniak, "Evaluation of 3D radiated immunity characteristics of cavities with apertures," in *Proc. of Europe Intn. Symp. Electromagn. Compat.*, pp.907-911, Sept. 2002.