CHARACTERISTIS OF RADIATED-EMISSION FROM SLOTS ON A PERSONAL COMPUTER ABOVE 1 GHz

Ki-Bum Jung
Div. of Electrical and Computer, Hanyang University
E-mail: kbjung@ihanyang.ac.kr
Kyung-Bae Ko
Div. of Electrical and Computer, Hanyang University
E-mail: kkb815@ihanyang.ac.kr
Sung-Min Han
Advanced Materials & Integration Co., Ltd. EMC Division, R&D Center
E-mail: han-ba-da@amic.co.kr
Yeon-Choon Chung
Department of Information and Communication Engineering, Seokyeong University
E-mail: ycchung@skuniv.ac.kr
Jae-Hoon Choi
Div. of Electrical and Computer, Hanyang University
E-mail: choijh@hanyang.ac.kr

Abstract: Many problems of EMC and EMI require a detailed knowledge of the polarization status of radiated emission caused by EUT. The topic of wave polarization is a classic one. The characteristics of emission from EUTs at frequencies in excess of 1 GHz have been examined by a combination of numerical modeling techniques and measurement of radiated field patterns and magnitudes. The result shows that for real EUTs, the maximum emission may occur in any direction. The reason for the uncertainty in emission direction is the fact that a typical EUT has the dimension of several wavelengths at microwave frequencies. In general, the polarization of the Rx antenna will not be the same as the polarization of the incident wave. This is commonly stated as "polarization mismatch". The amount of power extracted by the antenna from the incident signal will not be maximum because of the polarization loss. The uncertainty due to the polarization mismatch between the EUT and receiving antenna by measurement at frequency above 1 GHz will be evaluated by polarization loss factor(PLF).
Key words: EMC, EMI, PLF, Uncertainty, Above 1 GHz.

1. Introduction

Many problems of EMC and EMI require a detailed knowledge of the polarization status of field caused by radiated emission from EUT. The need for serious consideration on polarization status at higher frequencies has arisen because of the increasing use of the radio spectrum at microwave frequencies for various services. At microwave frequencies a typical piece of consumer equipment may be several wavelengths to several tens of wavelengths in size. This means that as a radiating structure, its properties are rather more complex than at lower frequencies. This makes it difficult to predict the direction of maximum radiation from the equipment. In this paper, we studied uncertainty of amount of power extracted by the antenna from the incident signal by radiation patterns of radiated emission through cavity-backed apertures above 1 GHz.

2. Radiation pattern above 1 GHz

An EUT(Equipment under Test) , in general, has dimension that is typically between half and thirty three wavelengths at frequency range from 1 GHz to 10 GHz. In this paper, the radiated emission from the slots on a front panel of a personal computer is investigated. The front of the PC(EUTs) is shown in Fig. 3. Each of the slots indicated in Fig. 3 is regarded as a possible source antenna. The slots on PC panel can be modeled as an array antenna. The modeling of array antenna is normally undertaken by summing the field contributions from all part of the aperture antenna. Each element in the array is treat as an isotropic point source and the contributions are summed from each element. This is the approach that has been taken for the model of emissions from the EUTs. In the analysis, the EUT is modeled in two dimensional array. This model was used to investigate the field patterns that might be expected from radiating structures of a typical personal computer enclosure. Also, slot structure of a personal computer is simplified by rectangular aperture antenna.

2.1 Beam steered sources

Arrays offer the unique capability of electronic beam scanning of the main beam. By changing the phase of the exciting currents in each element of the array, the radiation pattern can be scanned through space[1~2]. The equation for phase difference, ψ of radiated field is given as:

$$\psi = \frac{2\pi d}{\lambda}\cos\theta + \delta \qquad (1)$$

Where d is the spacing between sources, θ is the angle of the field relative to the adjacent sources, δ is the phase difference between adjacent sources. For a maximum field $\psi = 0$, as the sources must be in phase. Also for a single lobe beam steered antenna the spacing between sources must be $\lambda/2$. Spacing greater than $\lambda/2$ lead to multi-lobed antenna patterns and spacing less than $\lambda/2$ make the points behave as a single source. For a maximum field, the wave from two sources must be in phase. To determine these direction, substituting ψ =0 and $d = \lambda/2$ into eq.(1) gives an equation for phase difference for required beam steer, where θ is the required beam steer and δ is the necessary source phase difference

$$\delta = -\pi\cos(\theta), \quad \theta = \cos^{-1}\left(-\frac{\delta}{\pi}\right) \qquad (2)$$

The beam steer angle relative to two sources point is shown as Fig. 1.

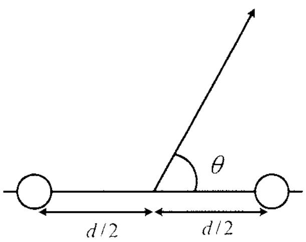


Fig. 1. Beam steer angle relative to two point sources.

2.2 Polarization Loss Factor and Efficiency

In general, the polarization of the receiving antenna will not be the same as the polarization of the incident wave. This is commonly stated as "polarization mismatch." The amount of power extracted by the antenna from the incident signal will not be maximum because of the polarization loss. Assuming that the electric field of the incident wave can be written as[3]

$$\hat{E}_i = \hat{\rho}_w E_i \qquad (3)$$

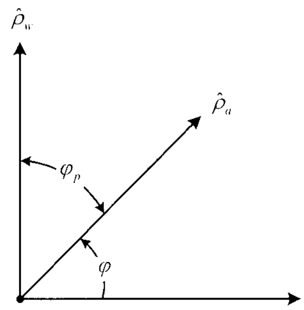
where $\hat{\rho}_w$ is the unit vector of the wave, and polarization of the electric field of the receiving antenna can be express as

$$\hat{E}_a = \hat{\rho}_a E_a \qquad (4)$$

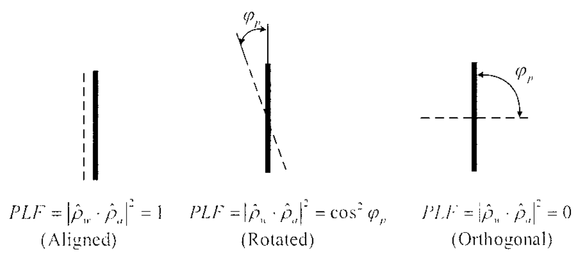
where $\hat{\rho}_a$ is its unit vector(polarization vector), the polarization loss can be taken into account by introducing a polarization loss factor(PLF). It is defined, based on the polarization of the antenna in its antenna in its transmitting mode, as

$$PLF = |\hat{\rho}_w \cdot \hat{\rho}_a|^2 = |\cos\varphi_p|^2 \,(demensionless) \qquad (5)$$

where φ_p is the angle between the two unit vector. The relative alignment of the polarization of the incident wave and of the antenna is shown in Fig. 2. If the antenna is polarization matched, its PLF will be unity and the antenna will extract maximum power from the incident wave.



(a) Polarization unit vectors of incident wave($\hat{\rho}_w$) and antenna($\hat{\rho}_a$)



(b) PLF for transmitting and receiving aperture antennas

Fig. 2. Polarization Loss Factor(PLF) for linear wire antenna.

In general then, the maximum effective aperture(A_{em}) of any antenna is related to its maximum directivity(D_0) by

$$A_{em} = \frac{\lambda^2}{4\pi} D_0 \qquad (6)$$

If reflection and polarization losses are include, then the maximum effective area of eq.(6) is represented by

$$A_{em} = e_t \left(\frac{\lambda^2}{4\pi} \right) D_0 \left| \hat{\rho}_w \cdot \hat{\rho}_a \right|^2$$
$$= e_{cd} \left(1 - |\Gamma|^2 \right) \left(\frac{\lambda^2}{4\pi} \right) D_0 \left| \hat{\rho}_w \cdot \hat{\rho}_a \right|^2 \quad (7)$$

2.3 The PC model

The work presented in the previous section has suggested that only sure method of testing an EUT for maximum emissions is to fully profile the emission in all possible directions. A typical PC has been modeled and examined. The design of PC is shown in Fig. 3.

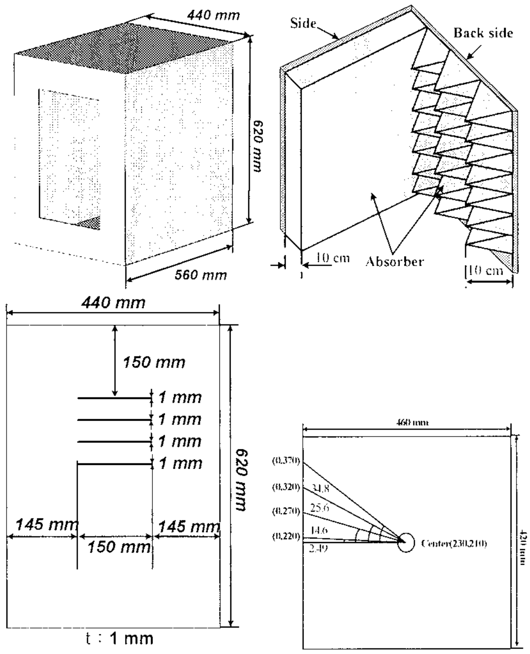


Fig. 3. The PC model construction and design.

Each of the slots indicated in the Fig. 3 is regarded as a possible source antenna(CGE02). Phase differences between the slots can then be calculated for various frequencies. The phase differences associated with several frequencies are tabulated in Table I.

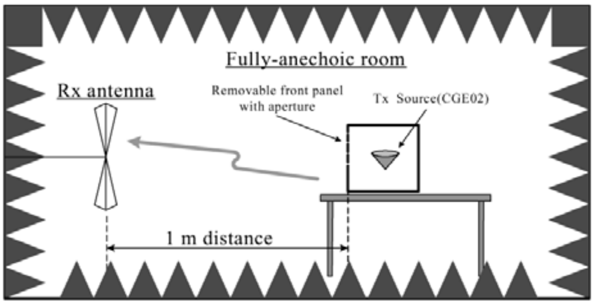
Table I Phase calculated for various frequencies following path length as indicated in Fig. 3.

slot	Angle (Degree)	Phase 1GHz	Phase 2GHz	Phase 3GHz	Phase 4GHz	Phase 5GHz
1	2.49	276.26	192.52	108.78	25.04	301.30
2	14.60	285.24	210.47	135.71	60.95	346.18
3	25.60	305.94	251.88	197.82	143.76	89.71
4	34.80	336.21	312.42	288.64	264.86	241.07

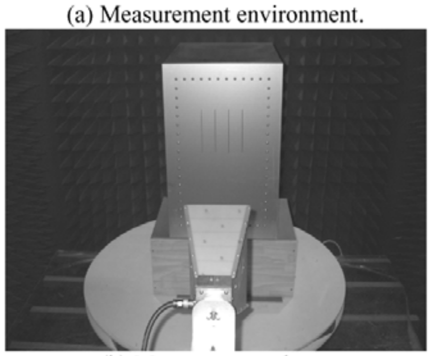
To test whether beam steering occurs for the four slots at various frequencies the geometry and phase differences were set up and simulation.

2.3 Experiment result of the PC model

The measurement set up are shown Fig. 4. It is measurement condition to fully anechoic room.



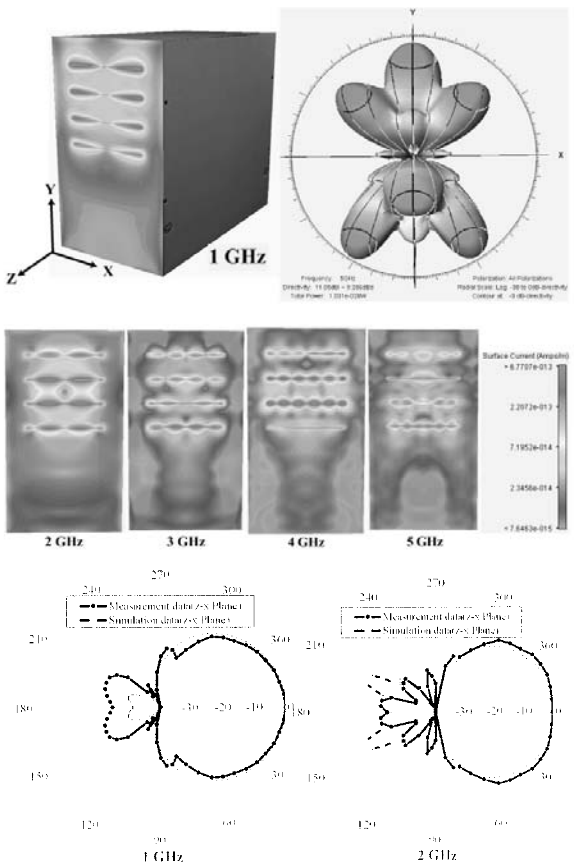
(a) Measurement environment.



(b) Measurement photo.

Fig. 4. Measurement set up of cavity-baked aperture.

Fully direction profiled the emission in all direction of 1 GHz ~ 5 GHz is shown Fig. 5[4]. Also, measured and simulated data is included. Its results are a very similar.



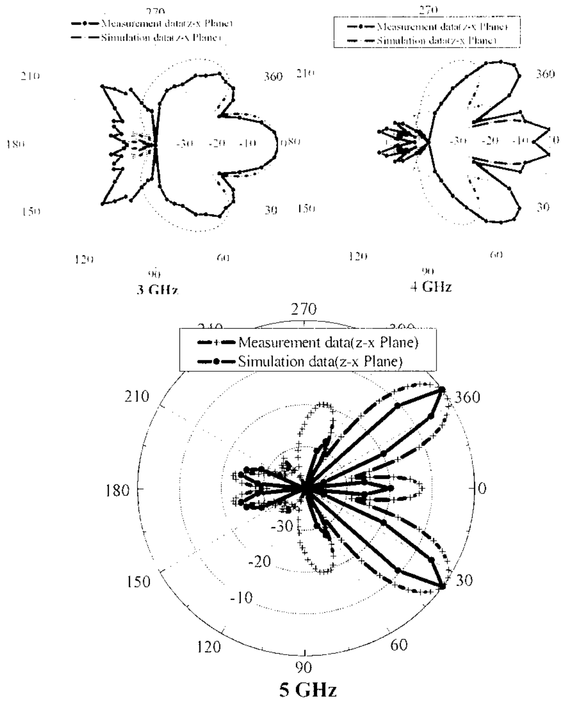


Fig. 5. Fully profile the emission in all direction of PC model by 1 ~ 5 GHz.

Uncertainty of maximum field PLF is shown Fig. 6. The result is an effect of by beam steered sources.

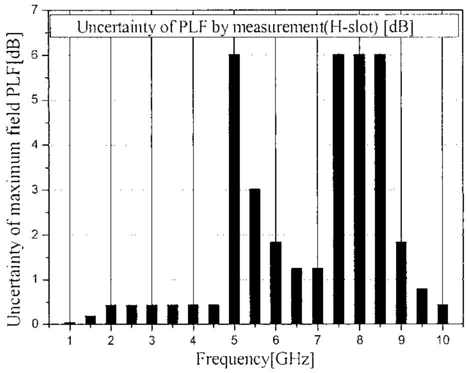


Fig. 6. PLF Uncertainty of maximum profile data.

It is structure of horizontal slot. EUT target plane is shown Fig. 7. E-field is only detected in target plane. If Maximum field is out of this region, we can't measure maximum field.

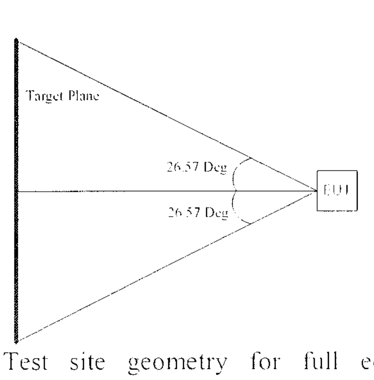


Fig. 7. Test site geometry for full equipment coverage.

E-fields profiled of EUTs at the 5 GHz by changing angle are shown Fig. 8. If measurement distance is 3 m and target plane is 3 m × 3 m, scan is done from -26.57° to 26.57°. However, if the maximum is outside of this region, the maximum beam point can be missed owing to the limited scan.

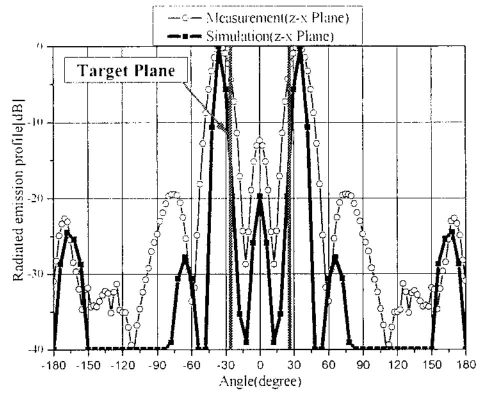


Fig. 8. Target plane and far field fully profiled emission data.

3. Conclusion

Various models to analyze the radiated emission from slots on a PC panel at frequencies above 1 GHz have been developed. It has been shown that the peak of emissions could be in any direction from the EUT due to beam steering effects. It has been shown that for most of the frequencies investigated beam steering effects were occurring. If measurement distance is 3 m and target plane is 3 by 3 m, scan is done from –26.57° ~ 26.57°. However, if the maximum is outside of this region, the maximum beam point can be missed owing to the limited scan. From the results presented it seems reasonable to conclude that the only sure method of testing the EUT for maximum emissions is to investigate the full emission profile in all possible direction. Due to the possible uncertainty increase caused by polarization mismatch at frequencies above 1 GHz, it is recommended that the measurement method used below 1 GHz needs modification.

References

[1] A.J. Rowell, D W Welsh & A D Papatsoris, "Practical Limits for EMC Emission Testing at Frequencies Above 1 GHz Final Report(AY3601) For the Radio Communications Agency", York EMC Services Ltd.

[2] C.R. Paul, "Introduction to Electromagnetic Compatibility", New York: Wiley-Intersciences, 1992.

[3] Constantine A. Balanis, "Antenna theory analysis and Design Second Edition", John Wiely & Sons, Inc

[4] R.D. sm edt, K. Vervoort, E.V. Oerle, D.V. Ttoy, "Effect of a Board on the shielding effectiveness of a Box", EMC Europe 2002, Sep. 9-13, 2002.