Analysis of EMP Penetration into an Enclosure with Electromagnetic Shielding Material

Hyeong-Rae Im, In-Kyun Jung, and Jong-Gwan Yook
Dept. Electrical and Electronic Engineering, Yonsei University
Seoul, South Korea
ihr3021@yonsei.ac.kr, jgyook@yonsei.ac.kr

Hong-Ryeol Song
Samjin Elex Co., Ltd
Seoul, South Korea
hysong@samjinelex.com

***Abstract*—To reduce the intensity of EMP penetrated to the electronic devices mounted in an enclosure, some electromagnetic shielding structure are required. In this paper, EMP penetration through the slots and glass aperture at a simple rack are considered. In addition, the effect of shielding film applied to these parts are analyzed so that a shielding guideline for a simple rack structure can be proposed from further case study.**

***Keywords*—Electromagnetic pulse (EMP); Enclosure; Electromagetic Shielding;**

I. Introduction

Electromagnetic pulse (EMP) is one of the representative technology of the modern military weapons. As one of many types of EMP, High-Altitude Electromagnetic pulse (HEMP) is occurred from the nuclear explosion at an altitude of tens of kilometers, and it causes serious malfunctions in electronic devices for power supply and control systems [1]. A metal enclosure, such as commercial rack, are used to mount electronic devices, but there are some narrow slots and apertures at the enclosure for the use of the devices inside the rack. The field penetration through the slots and apertures have been analyzed in many researches [2]–[5]. Because of the weakness of these parts to EMP penetration, some electromagnetic shielding structures are needed to protect the electronic systems. In this paper, the field penetration through narrow slots and apertures with a electromagnetic shielding material are studied.

II. Conditions for analysis

A. Structure of Enclosure

A simple rack which satisfies IEC 297 standard is modeled and analyzed as enclosure. To show the effect of electromagnetic shielding, a shielding material is applied to each part. A shielding material is filled at the narrow slots of the rack. To analyze the field penetration through the aperture, an effective medium which is equivalent to a glass aperture with a shielding film is used.

B. Shielding Material and Effective Medium

To consider the effect of shielding materials applied to narrow slots and glass aperture, the permittivity and permeability of materials are needed first, and it can be done by calculating equivalent conductivity of them. Two samples of materials which have different shielding effectivenesses, 20 dB and 30 dB, are used. Equivalent conductivity can be calculated from shielding effectiveness and thickness of them.

A glass aperture with shielding film is a multi-layered dielectric structure. The numerical analysis of transmission and reflection characteristic of this multi-layered dielectric containing thin dielectric has higher computational cost than that of single-layered dielectric. Therefore, an effective medium which has same transmission and reflection characteristics with the original structure can be used. The permittivity and permeability of effective medium can be derived by using Nicolson-Ross-Weir (NRW) method [6]–[8]. The S-parameter can be calculated from the boundary value problem of the multi-layered dielectric.

III. Result and discusion

To analyze the field penetration into an enclosure, a commercial time-domain solver was used. A simple rack structure is modeled, and the detailed model of the rack for the field simulation is shown in Fig. 1. The width of narrow slots are 2 mm, and the overall structure of the rack is assumed as perfect electric conductor except the narrow slots and glass apertures in front of the rack. E1 pulse which has a shape of double exponential pulse is applied as incident field [1]. The polarization of incident field is assumed as y-axis in order to set the worst condition for the field penetration.

The electric field distribution in dB scale compared to the incident field is shown in Fig. 2. The observation plane is

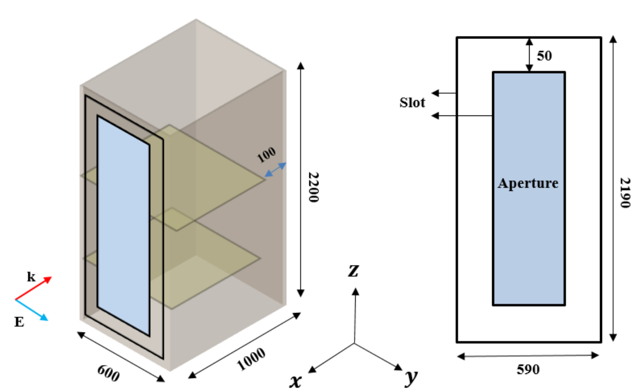

Fig. 1: **Structure of a simple rack model (unit : mm).**

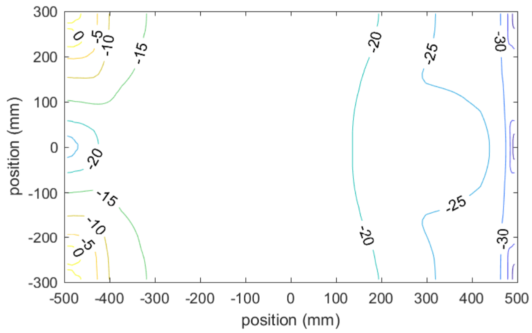

Fig. 2: **E-field distribution inside the rack (no shielding material).**

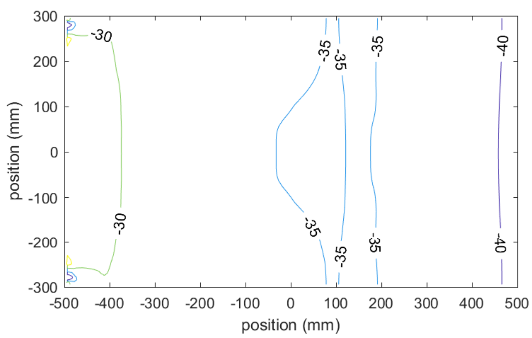

Fig. 3: **E-field distribution inside the rack (20 dB shielding material at the slots).**

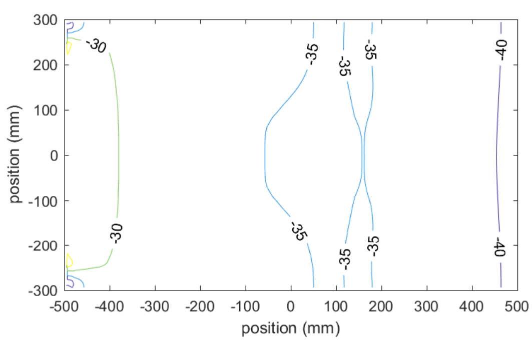

Fig. 4: **E-field distribution inside the rack (30 dB shielding material at the slots).**

cross-section at 1100 mm height. It can be found that electric field penetrated through the slots has dominant strength. This is because half-wavelength resonance is occurred at the slots. Therefore, it is expected that narrow slots are weaker parts than glass aperture with respect to EMP penetration. As another case, shielding material is applied to the slots. In the case of shielding material which has 20 dB of shielding effectiveness, the amplitude of penetrated field is decreased, as shown in Fig. 3. However, there is no meaningful difference between

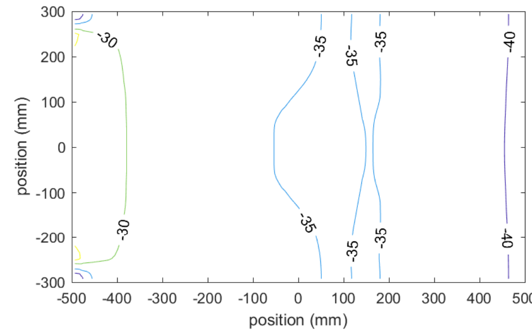

Fig. 5: **E-field distribution inside the rack without the slots (20 dB shielding material at the aperture).**

the result of 20 dB and 30 dB shielding material as shown in Fig. 4. This is because electric field penetrated through the aperture becomes dominant as the shielding effectiveness of the material applied to the slot becomes increased. As the third case, Fig. 5 shows the result for a rack which only has glass aperture with 20 dB shielding film. The amplitude of the penetrated field through the aperture becomes decreased.

IV. Conclusion

For the analysis of EMP penetration into a simple rack structure, narrow slots and glass aperture are considered. In addition, electromagnetic shielding materials are applied to the narrow slots and aperture respectively. For the glass aperture, an effective medium is used to decrease computational cost. From further study, a guideline for electromagnetic shielding can be proposed in order to satisfy the specific value of shielding effectiveness required for an enclosure like a simple rack.

Acknowledgment

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References

[1] IEC 61000-4-36 (2014-11) : Electromagnetic compatibility (EMC) - Part 4-36: Testing and measurement techniques IEMI immunity test methods for equipment and systems.

[2] Y. Rahmat-Samii and R. Mittra, "Electromagnetic coupling through small apertures in a conducting screen," *IEEE Transactions on Antennas and Propagation*, vol. 25, no. 2, pp. 180–187, 1977.

[3] A. Taflove, K. R. Umashankar, B. Beker, F. Harfoush, and K. S. Yee, "Detailed fd-td analysis of electromagnetic fields penetrating narrow slots and lapped joints in thick conducting screens," *IEEE Transactions on Antennas and Propagation*, vol. 36, no. 2, pp. 247–257, 1988.

[4] "An efficient mom formulation for the evaluation of the shielding effectiveness of rectangular enclosures with thin and thick apertures."

[5] R. Xiong, B. Chen, Q. Yin, and Z.-Y. Cai, "Improved formalism for the fdtd analysis of thin-slot penetration by equivalence principle," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 655–657, 2011.

[6] A. Nicolson and G. Ross, "Measurement of the intrinsic properties of materials by time-domain techniques," *IEEE Transactions on instrumentation and measurement*, vol. 19, no. 4, pp. 377–382, 1970.

[7] W. B. Weir, "Automatic measurement of complex dielectric constant and permeability at microwave frequencies," *Proceedings of the IEEE*, vol. 62, no. 1, pp. 33–36, 1974.

[8] T. L. Blakney and W. Weir, "Comments on" automatic measurement of complex dielectric constant and permeability at microwave frequencies"," *Proceedings of the IEEE*, vol. 63, no. 1, pp. 203–205, 1975.