Field Strength Estimation through a Vehicle Structure using Topological Model and PWB Method

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***Abstract* – In this article, an averaged field strength estimation with small time consumption is carried out in a commercial vehicle structure modelled as an enclosed large cavity with several apertures. Well-known commercially available software employing full EM-based algorithms such as FDTE, FEM, and MoM require a lot of resource and much time consumption. However, a topological modeling and PWB(PoWer Balance) method based on statistical theory are introduced and employed to give a reasonably good trend in the field strength estimation inside vehicle structure.**

***Index Terms* —, Power Balance (PWB) Method, Topological Modeling, Vehicle structure, Large-scaled structure.**

1. Introduction

As the cutting-edged electrical equipment is installed inside automotive vehicles with the help of technical development, the safety technologies protecting malfunction and electrically critical damages becomes more and more important. These damages inside automotive vehicles caused by high-powered electromagnetic wave may have a possibility of casualty and harm to human life. Hence, the importance of estimation of field distribution into automotive vehicle from the high power increases gradually.

2. Power Distribution Analysis and Geometrical Structure

(1) Automotive Vehicle Model

The target structure for power distribution analysis is mainly composed of three parts.; 1) Bonnet/Hood, 2)Main Body, 3) Trunk/Tail. The size of bonnet/hood in front of vehicle is assumed to be 180(a)x150(b)x110(c) cm^3 and the radiator has been modelled as an aperture having 100x20 cm^2. In addition, the front/rear windshield glass are modelled as apertures of 170x45 cm^2 and the glasses on the side front/rear doors are modelled as 100x45 cm^2. As shown in Fig.1, the trunk part has been modelled as a metallic cavity with a cube of 180x90x110 cm^3 and the connecting aperture between hood and main body has been modelled as a circular opening of 1.2 cm. Fig.2 shows topological graph of three main parts suggested in this article. Each part of three main parts has been represented as an ideal junction and the losses existing in each part have been modelled as nodes, respectively.

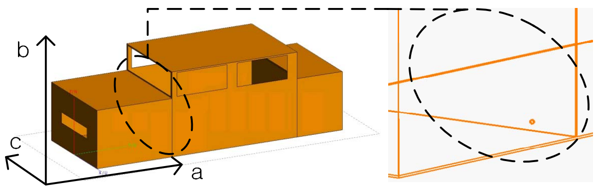

Fig. 1. Vehicle structure.

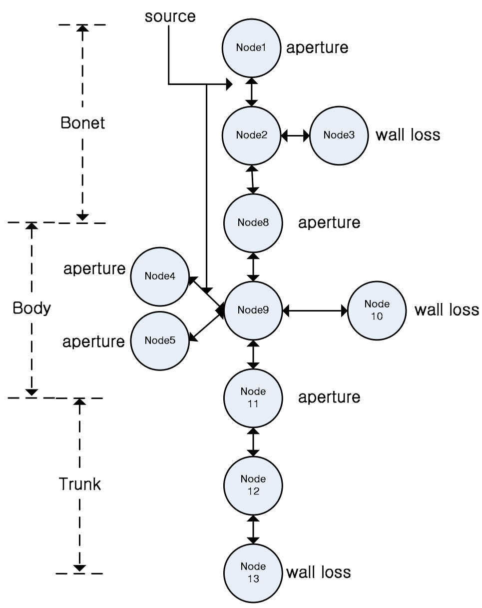

Fig. 2. Topological modelling.

(2) Power Estimation using PWB Method

This method is mainly used in the field strength estimation inside an electrically large cavity, especially focused on the high frequency regime. In general, the electromagnetic field phenomena in an electrically large cavity can be considered as MSRC(Mode-stirred Reveberation Chamber) environment which results in an averaged field strength distribution. In order to verify the electromagnetic field effects inside an automotive vehicle from the external high-powered wave, the definition of quality factor Q and the relationship between the quality factor and power losses P_d dissipated at wall, glass and apertures should be introduced and evaluated for the field estimation. The detailed expressions are as follows [1].

$$Q = 2\pi f \frac{W}{P_d} \qquad (1)$$

$$Q_{ap} = \frac{2\pi V}{\lambda < \sigma_{ap} >},\ < \sigma_{ap} > = \frac{16}{9\pi} \cdot \left(\frac{2\pi}{\lambda}\right)^4 \cdot a^6 \quad for \quad f \le \frac{1.3c}{2\pi a}; \qquad (2)$$
$$< \sigma_{ap} > = \frac{\pi a^2}{2} \quad for \quad f \ge \frac{1.3c}{2\pi a};$$

$$Q_{wall} = \frac{2\pi V}{\lambda < \sigma_{wall} >},\ < \sigma_{wall} > = \frac{4S \cdot R_S}{3c \cdot \mu_0} = \frac{4\pi S_{surface}}{3\lambda} \cdot \sqrt{\frac{\mu_r}{\pi f \mu_0 \sigma}} \qquad (3)$$

The total Q can be represented as a function of Q_{ap} and Q_{wall} inside cavity. By employing the Q-factors described previously and the averaged energy density S through the volume, the power response inside bonnet/hood and main body of vehicle structure can be evaluated as eqs. (4) and (5).

$$P_{bon} = \frac{2\pi \cdot V_{bon}}{\lambda \cdot Q^{bon}_{tatal}} \cdot S_{bon},\ S_{bon} = \frac{\lambda \cdot P_t}{2\pi \cdot V_{bon} \cdot \left(\frac{1}{Q^{bon}_{wall}} + \frac{1}{Q^{bon}_{ap}} + \frac{1}{Q^{bon}_{h}} \right)} \qquad (4)$$

$$P_{bod} = \frac{2\pi \cdot V_{bod}}{\lambda \cdot Q^{bod}_{tatal}} \cdot S_{bod},\ S_{bod} = \frac{\lambda \cdot \frac{\sigma_h}{2} \cdot S_{bon}}{2\pi \cdot V_{bod} \cdot \left(\frac{1}{Q^{bod}_{wall}} + \frac{1}{Q^{bod}_{fbwin}} + \frac{1}{Q^{bod}_{swin}} + \frac{1}{Q^{bod}_{h}} \right)} \qquad (5)$$

3. Simulation Results

It is assumed that the plane wave with 0-degree angle is incident from the external environment. The commercially available full-EM software FEKO has been employed to investigate rigorously the field distributions and the results have been compared with those obtained from the dissipated power based on eqs. (4) and (5). As shown in Figs. 3 and 4. Figs. 3and 4 show good agreements among the results obtained from a variety of analysis method in the region of high frequency.

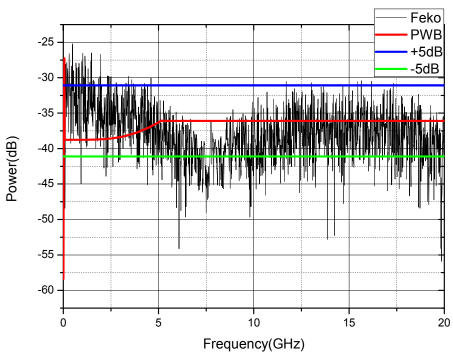

Fig. 3. Bonnet power distribution.

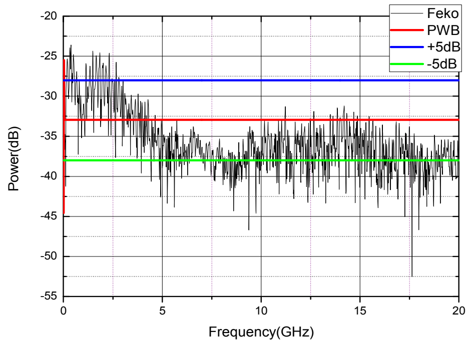

Fig. 4. Main body power distribution.

TABLE I

	Required Memory(Mbytes)	Time-consumption(s)
FEKO (bonnet)	1350	145427.812 (40.4h)
FEKO (main body)	1350	140338.704 (38.9h)
PWB Method (total)	0.624	1.022

4. Conclusion

A simple estimation method of field strength inside automotive vehicle from an externally high-powered field has been introduced and verified with other methods. By comparing with a commercially available software, it can be ensured that a reasonably good agreements have been achieved among the results in the viewpoint of statistically-based average value. Moreover, it is seen that the proposed method becomes more easily performed and very helpful in terms of saving the computer resources and much time consumption

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