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Electromagnetic Field Distributions of Open Cabinet in Nuclear Power Plants

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***Abstract* - We investigate the scattering characteristics of periodic open cabinet in nuclear power plants by using mode matching technique. The power conservations for all propagation modes are validated and then the field distributions in the cabinet are clearly derived.**

***Index Terms* — Mode matching technique, electromagnetic compatibility, electromagnetic scattering.**

1. Introduction

Wireless communication technologies have been considered to be applied in nuclear power plants (NPPs) since there are advantages such as easy mobility, low wiring costs, etc. Before applying the technologies, however, electromagnetic interference test for a cabinet with digital modules should be examined. So, it is important to investigate the scattered field distributions, when arbitrary electromagnetic field is incident into the cabinet where instrumentation and control (I&C) equipments are installed. Mode matching technique (MMT) can be a good candidate to solve the scattered field [1]. In this paper, we investigate modal scattered fields and the power conservation for the cabinet and finally obtain field distributions inside the cabinet.

2. Cabinet Geometry and Formulations

Fig. 1 shows top view of the cabinet geometry which similarly describes the I&C equipment in the NPP. The sides represented by $2x_1$ and $2x_2$ stand for an open door and inner conducting walls, respectively. We assume that there is a central metallic frame including digital modules inside the cabinet and the height of the cabinet and the central frame along the y-axis are infinite because the height is long enough compared with the wavelength at 5 GHz, which is one of the application frequencies in wireless local area network (WLAN). The specific dimensions are listed in Table 1 and similar to practical dimensions. As described in Fig. 1, Regions are separated into five and each Region can be considered as a parallel plate waveguide with different spacings.

The n^{th} order transverse magnetic (TM$_n$) H_y-field in a parallel plate waveguide is as follows

$$H_y = \cos(\gamma_n x)e^{-jk_n z} \tag{1}$$

$$\gamma_n = n\pi/x_p \text{ and } (k_n)^2 = (\gamma_n)^2 - \omega^2\mu_0\varepsilon_0. \tag{2}$$

γ_n and k_n are the n^{th} eigenvalue and propagation constant of the waveguide, respectively, and $2x_p$ is the spacing in the cabinet (for example, p = 1 or 2). Corresponding E-fields are obtained from the Maxwell's equation.

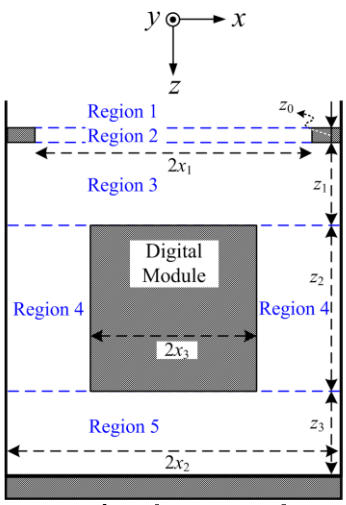

Fig. 1. Configuration of a cabinet in nuclear power plants.

TABLE I
Dimensions of the Cabinet in Fig. 1.

Dimensions	Physical length
x_1	300 mm
x_2	360 mm
x_3	180 mm
z_0	30 mm
z_1	180 mm
z_2	360 mm
z_3	180 mm

3. Modal Transmission and Power Conservations

Fig. 2(a) shows the Regions 3 and 4 and Junction between two Regions. When an arbitrary mode in Region 3 is transmitted into Region 4, the reflection and transmission coefficients depending on the modes can be systematically obtained by using MMT [2], [3]. The power summations of the reflected and transmitted modes can be solved and are plotted versus incident modes as shown in Fig. 2(b). Power conservations by the summations are satisfied for all modes, and the transmitted and reflected powers from 3rd to 23rd modes are similarly split into around 0.5. In the same way, the reflection and transmission coefficients at other junctions are obtained, and we apply the multi-region problem [4], then entire scattering characteristics are solved.

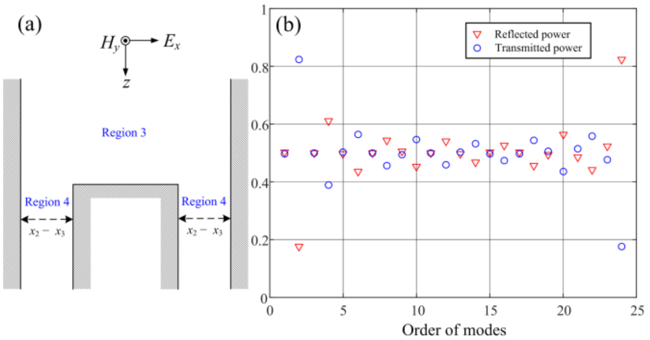

Fig. 2. Modal reflected and transmitted powers at junction between Regions 3 and 4.

4. Field Distributions in the Cabinet

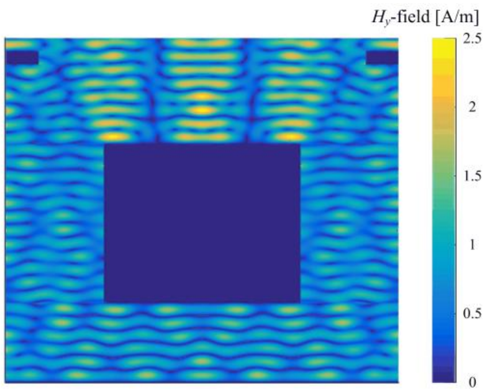

Fig. 3. Strength of the H_y-field distribution according to the TM_4 mode from Region 1.

Fig. 3 shows strength of the H_y-field distributions in the cabinet when a TM_4 mode is incident from the outside and multi-region problems [4] is applied. The scattered electromagnetic fields in front of the digital module is stronger than those in other areas since the incident wave is mainly reflected against the digital module. In a similar way, we can obtain the field distributions for the other incident modes, and it is found that slightly stronger fields are observed between the digital module and inner wall (Region 4) as the higher order modes are incident.

5. Conclusion

We have investigated the scattering characteristics of the periodic open cabinet in NPP by MMT. The power conservations for all propagation modes were satisfied and corresponding field distributions in the cabinet were fully described.

Acknowledgment

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References

[1] Jaeyul Choo, Choongheui Jeong, and Jaegul Choo, "Transverse electric scattering of open cabinet in nuclear power plants," *IEEE Antennas Wirel. Propag. Lett.*, vol. 15, pp. 1204-1207, 2016.

[2] J.-E. Park, F. L. Teixeira, and B.-H. V. Borges, "Analysis of deep-subwavelength Au and Ag slit transmittances at terahertz frequencies," *J. Opt. Soc. Am. B*, vol. 33, pp. 1355-1364, Jul. 2016.

[3] A. Wexler, "Solution of waveguide discontinuities by modal analysis," *IEEE Trans. Microw. Theory Tech.*, vol. 15, pp. 508-517, 1967.

[4] W. C. Chew, *Waves and Fields in Inhomogeneous Media*, Wiley: New York, 1999, pp. 360-365.