Exclusion zone comparison between in free space and nuclear power plant environment

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***Abstract* - We analyze exclusion zones (EZs) for indoor environments in nuclear power plants and compare them with the EZ in free space. When an indoor environment is considered, the lower transmitted power is recommended since multiple reflections increases stronger scattered power. The EZ area is the widest when the transmitter is at the center of the I&C room.**

***Index Terms* — Indoor exclusion zone, field strength, nuclear power plant.**

1. Introduction

Wireless communication technologies are widely used in industry and this trend is also expected to grow in nuclear power plants (NPPs) [1]. When wireless devices are utilized in the NPP, it is important to analyze whether the electromagnetic field distribution does not exceed the limits allowed by the nuclear power plant. However, researches on field analysis for using wireless devices in the NPP have not been fully investigated yet.

In this paper, we investigate an exclusion zone (EZ) [2], [3] when the indoor environment in NPP is considered and compare the results with the EZ in free space. By using Wireless InSite commercial electromagnetic simulation software [4] that is effective for estimating indoor propagation characteristics by a ray-tracing method, EZs are analyzed according to the transmitter positions.

2. Indoor Geometry and 3D Modeling

Minimum distance d in EZ [2] derived from the free space propagation model is $d = \sqrt{30P_tG_t}/E$, where P_t and G_t are the radiated power and antenna gain of the emitter, respectively. E is the allowable radiated electric field strength of the receiving antenna at the point of installation. The EZ is then defined as the allowed minimum distance d from the emitter position.

Fig. 1(a) shows a proposed hexahedral indoor geometry, which roughly describes the instrumentation and control (I&C) equipment room in NPPs, to observe electromagnetic scattering characteristics and corresponding indoor EZs. The side represented by x_2 consists of glass windows and metallic frames, and the other sides are surrounded by concrete walls. There are two pillars with $p_1 \times p_2$ in the upper region, and a large metallic cabinet with $y_1 \times y_2$ is placed in the upper right corner. The height of the room is 2.74 m and other specific dimensions are listed in Table I. Fig. 1(b) shows the indoor geometry description using Wireless InSite EM software [4]. The transmitter is assumed to emit a signal of 2.4 GHz, which considers a measuring equipment for WirelessHART communications. A vertically polarized antenna is applied, and the antenna is located at 1.4 m from the floor.

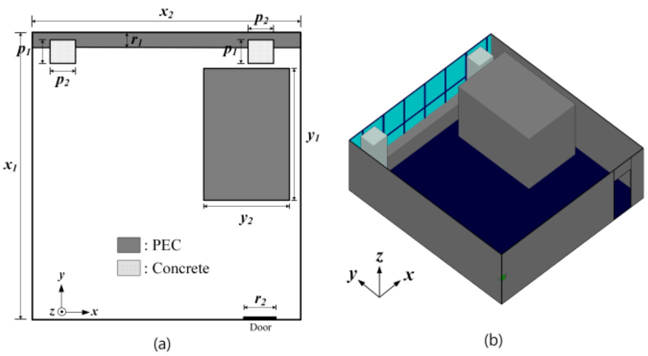

Fig. 1. (a) Configuration of indoor geometry and (b) 3D electromagnetic modeling of the indoor geometry.

TABLE I
Dimensions of Indoor Geometry.

Dimensions	Length
x_1	8.92 m
x_2	8.3 m
y_1	4.13 m
y_2	2.7 m
p_1	0.74 m
p_2	0.8 m
r_1	0.44 m
r_2	1 m

3. Power Strength in Indoor Geometry

Fig. 2 shows the electromagnetic power strengths along the blue line of the inset when the transmitter is activated at (x, y) = (5.175 m, 3.565 m). It is assumed that the transmitter sends -10.0 dBm of 2.4 GHz signal, which is the application frequency of IEEE 802.11 protocols. Transmitting and receiving half wavelength dipole antennas have 0 dBi antenna gains. In the free space case with the solid line, the power strength is inversely proportional, as the distance increases. In the indoor environment case with dashed line, however, the strength decreases but include fluctuations due to the multiple reflections and diffractions. In the case of 1.65 m away from the transmitter, the power strength difference between two cases is observed roughly 5 dB, hence, lower transmitted power is recommended in the indoor geometry.

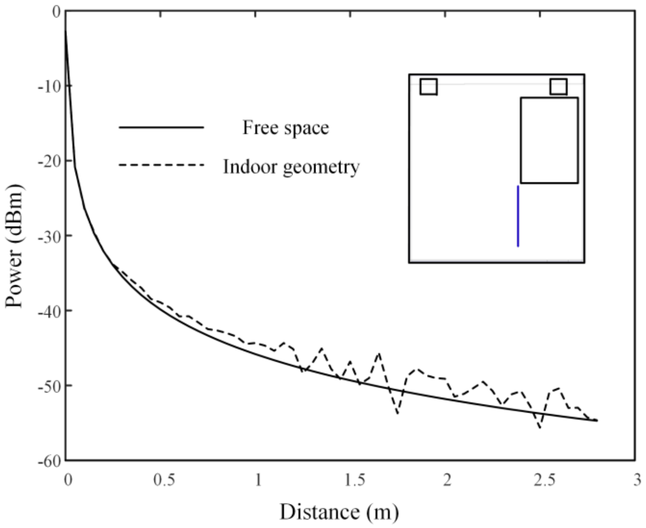

Fig. 2. Power strength in accordance with the distances from the transmitter near a large cabinet.

4. Exclusion Zones according to Transmitter Locations

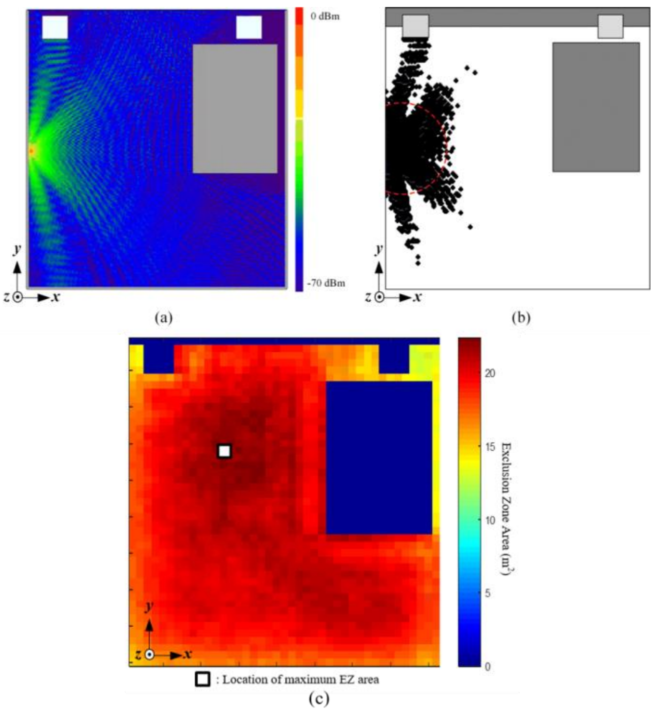

Fig. 3. (a) Simulated power strength, (b) Indoor EZ and free space EZ, and (c) Indoor EZ area depending on the transmitter locations.

Fig. 3(a) describes the electromagnetic power strengths in *xy*-plane when the transmitter is activated at $(x, y) = (0.125$ m, 4.4 m). The scattered field patterns are non-uniformly distributed with respect to the angle of the radiation. This indicates that the EZ of the indoor environments should be more carefully investigated since the scattered field distributions are not uniform as the radiation angle varies. Assuming G_t = 0.792 dBi and P_t = 1.0 W, the EZ corresponding the Tx location is obtained as depicted in Fig. 3(b) as well as free space EZs (red dashed line). The indoor EZs represented by the black area, however, are irregularly distributed due to the scattered *E*-field in the indoor environment.

Fig. 3(c) describes a contour plot for area of the EZ with regards to the transmitter locations, which are located at intervals with 0.2 m × 0.2 m in *xy*-plane with the height of 1.4 m. The EZ area is wider when the transmitter is near the center of the room, while the area is narrower when the transmitter is near corners. The maximum EZ area with the square mark in Fig. 3(c) is 22.37 m^2. These results can be a good reference for installation of the I&C equipment in NPP.

5. Conclusion

In this research, we investigated the EZs for indoor environments by modeling the I&C equipment room in the NPP and compared them with the free space case. The field strengths for indoor environment were stronger than those for free space case, and corresponding EZs were wider. The widest EZ area of 22.37 m^2 was observed when the transmitter was located at the center of the I&C room.

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