Research on Indoor EM Radiation Intensity for Control of Intelligent Devices in Architecture

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Abstract. In an indoor environment, electromagnetic (EM) radiation exceeding a certain threshold can potentially harm organisms, however, electromagnetic signals below a certain threshold value cannot make the device work properly. Therefore, how to choose a reasonable antenna radiation intensity is a problem worth studying. This paper calculates the intensity of electromagnetic radiation received in different rooms when the antenna is placed at the ceiling of the living room in a general house structure. Accordance to the limits in the environmental radiation evaluation standards, the radiation power of the antenna is controlled to get appropriate radiation intensity in different rooms. The results in this paper is helpful for the researches about indoor electromagnetic radiation.

1. Introduction

In recent years, home intelligent devices have been greatly developed, and many of these are working by using wireless communication functions\(^{[1-2]}\). In this process, a large amount of electromagnetic waves are radiated. Electromagnetic radiation that exceeds a certain threshold can have potentially adverse effects on living organisms. However, when the intensity of electromagnetic radiation is too low, the equipment cannot work properly. So it is a question worth studying to control radiation intensity at a reasonable level.

According to the environmental radiation evaluation standard\(^{[3]}\), the limit values of the electromagnetic radiation for public exposure are shown in Table 1. * is the plane wave equivalent value for reference. ** is just for reference, not as a limit value, \(f\) is the frequency in MHz. The data in Table 1 are rounded.

| Frequency (MHz) | Electric field strength (V/m) | Power density (\(\mu W/cm^2\)) |
|----------------|-------------------------------|-------------------------------|
| 0.1–3         | 40                            | 400**                         |
| 3–30          | 67/\(\sqrt{f}\)               | 1200/\(f\)                   |
| 30–3000       | 12**                          | 40                            |
| 3000–15000    | 0.22\(\sqrt{f}\)             | \(f/75\)                     |

According to "Guidelines for the management of radiation environmental protection - Electromagnetic radiation environmental impact assessment methods and standards" (HJ/T0.3-1996)\(^{[4]}\), the electromagnetic radiation control of a single project should follow the following principles:
(1) In order for the public to receive the electromagnetic radiation lower than the provisions of GB8702-88, electromagnetic radiation intensity must be limited to a fraction of the specified limit.

(2) For large projects that are subject to examination and approval by the National Environmental Protection Agency, the electric field strength can be \(1/\sqrt{2}\) of GB8702-88 limit, or power density can be 1/2 of the limit.

(3) For other projects, the electric field strength can be \(1/\sqrt{5}\) of GB8702-88 limit, or power density can be 1/5 of the limit.

The study in this paper does not belong to the "large electromagnetic radiation launch facility" mentioned above, so the electric field strength can be \(1/\sqrt{5}\) of the limit, or power density can be 1/5 of the limit, which are 5.4 V/m or 8\( \mu\)W/cm\(^2\), respectively.

2. Model and analyse

In this work, the antenna, which is used to transmit electromagnetic waves to all corners of the house, is placed at the center of the room's living room ceiling\(^5\). The house and the location of the antenna are shown in Figure 1. The thickness of the wall is 24 cm. The goal of this section is to calculate the electromagnetic field strength at the center of each room of the house. (1) – (8) is living room, balcony, bathroom, kitchen and 4 bedrooms. The location of the antenna is the “•” shown in Figure 1.

![Figure 1. The house and the location of the antenna.](image)

The electromagnetic waves in the room reflect and attenuate after passing through the concrete wall. As a non-magnetic medium, the concrete has a permeability of 1 and its relative permittivity can be calculated by the formula\(^6\):

\[
\varepsilon(w) = \varepsilon' + j\varepsilon'' = \varepsilon_{\infty} + \frac{\varepsilon_s - \varepsilon_{\infty}}{1 + (jwt)^{-\eta}}
\]

The real part \(\varepsilon'\) and the imaginary part \(\varepsilon''\) are

\[
\varepsilon' = \varepsilon_{\infty} + \frac{\varepsilon_s - \varepsilon_{\infty} \left[1 + (jwt)^{-\eta} \sin \left(\frac{\pi \eta}{2}\right)\right]}{1 + 2(wt)^{1-\eta} \sin \left(\frac{\pi \eta}{2}\right) + (wt)^{2(1-\eta)}}
\]

\[
\varepsilon'' = \varepsilon_{\infty} + \frac{(\varepsilon_s - \varepsilon_{\infty})(wt)^{1-\eta} \sin \left(\frac{\pi \eta}{2}\right)}{1 + 2(wt)^{1-\eta} \sin \left(\frac{\pi \eta}{2}\right) + (wt)^{2(1-\eta)}}
\]

where \(j\) is the imaginary unit, \(\varepsilon_{\infty}\) is the dielectric constant under the optical frequency, \(w\) is the angular frequency, and \(\eta\) is a parameter of the degree of dispersion of the relaxation time.

In this work, the operating frequency of the antenna is 300 MHz so the relative dielectric constant of the concrete is 5.
The antenna radiation power is first set to 0.5 W for calculation. In order to make all rooms in the house receive electromagnetic signals, the radiation pattern of the antenna should not be too narrow. The antenna radiation pattern selected in this paper is shown in Figure 2[7-9].

![Figure 2. The radiation pattern.](image)

3. Results

After the calculation, the electric field strengths of different rooms are shown in Table 2. It can be seen that the electromagnetic field radiation intensity of each room is far below the limit value 5.4 V/m. In this case, the electromagnetic radiation of the indoor antenna does not have a potential negative effect on the human body.

| Room (number) | Calculated electric field strength (V/m) |
|---------------|------------------------------------------|
| (1) Living room | 0.375                                    |
| (2) Balcony    | 0.405                                    |
| (3) Bathroom   | 1                                        |
| (4) Kitchen    | 0.240                                    |
| (5) Bedroom1   | 0.480                                    |
| (6) Bedroom2   | 0.260                                    |
| (7) Bedroom3   | 0.610                                    |
| (8) Bedroom4   | 0.251                                    |

In order to ensure that the intelligent device can receive sufficiently strong electromagnetic wave radiation and work normally, the radiation intensity of the antenna should be increased. Besides, the electromagnetic radiation intensity of each room should not exceed the limit value of 5.4 V/m. From Table 2, it can be seen that the radiation intensity of the electromagnetic wave in the bathroom is the largest, which is 1 V/m.

![Figure 3. Comparison of limit value and radiation intensity.](image)

Therefore, setting the antenna's radiated power to 12.5W is a good choice. In this case, the electric field strength of each room is expanded to five times the original. Although the electric field strength
in the bathroom is the maximum, the radiation intensity is also lower than the limit value 5.4 V/m. The radiation intensity and limit values of each room are compared in Figure 3.

4. Conclusion
In this paper, we calculate the radiation levels of different rooms in a house where an antenna can be used to transmit signals with intelligent devices. From the results, it can be seen that the radiation intensity received by different rooms in the house is different, so the housing structure, location and radiation source are the main factors that affect the radiation intensity at different locations in the room. According to the Electromagnetic Radiation Protection Regulations [2,3], in order to prevent electromagnetic radiation from adversely affecting the human body and the radiation intensity is sufficient to make the device work normally, the antenna radiation power can be controlled at about 12.5 W in a typical house structure.

This work is helpful to evaluate the electromagnetic environment in a building. The research methods used in this paper are also useful to the research about electromagnetic environment and interior architecture.

References
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