§12. Measurement and Wideband Exposure Evaluation of Environmental Electromagnetic Fields

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Introduction

In the experimental fusion facility, in addition to static magnetic fields for confining plasma, many devices such as plasma heating and discharge cleaning also leak electromagnetic (EM) fields with an irregular variation ranging from several MHz to several hundred GHz. This kind of wideband and irregularly varying EM field is very special, and no evaluation method has been well defined with respect to various safety guidelines issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) or the Ministry of Internal Affairs and Communications, Japan. The objective of our study is to develop a method for the safety evaluation of such kind of special EM environment in the fusion facility.

Measurement Method

The leaked EM field from the heating device in the ion cyclotron range of frequencies (ICRF) is chosen as the major target of study because it is known as one of strong EM leakages in the fusion facility. This EM field occurs in a burst form and has a varying field level. In order to master the time-varying EM field for both the frequency and the field intensity at the same time, we propose to use a real time spectrum analyzer in the measurement. The basic idea is to measure the electric field with a wideband antenna in the time domain, and then transfer each time frame data to the frequency domain via the Fourier transform to obtain the frequency domain electric field data. The real time spectrum analyzer provides the possibility for such type same-time measurement in both the time domain and the frequency domain. For the measured field data at both the time domain and the frequency domain, we make statistical analysis to extract the leaked field feature such as frequency band, amplitude distribution, and so on. The validity of this idea has been confirmed in an ordinary room environment. Its application and validation to ICRF leakage is planed in 2009 after the ICRF device starts to work.

Calculation Method

The specific absorption rate (SAR), i.e., the power absorbed in unit mass is generally used for the safety evaluation of EM field exposure to the human body. However, for a wideband EM field, the specific energy rate (SA), i.e., the energy absorbed in unit mass is more practical. Here we develop a calculation method for the SA. The SAR can be easily derived as long as we know the SA and the time feature of the EM field waveform. We employ a frequency-dependent finite difference time domain (FDTD) method as the numerical tool of EM field calculation inside the human body. The Debye approximation is used to represent the frequency-dependent complex relative permittivity of the human body in the wide frequency band, that is

$$\varepsilon_r(\omega) = \varepsilon_\infty + \chi(\omega) + \frac{\sigma_0}{j\omega\varepsilon_0}$$

where ε_∞ is the relative permittivity at infinite frequency, $\chi(\omega)$ is the frequency domain susceptibility, and σ_0 is the static electric conductivity. The average difference is found to be within 10% between the one-relaxation Debye approximation and the measurement-based data for the dielectric tissue properties in the frequency band from dozens of MHz to 10 GHz. This finding indicates that the one-relaxation Debye approximation has a reasonable accuracy in the frequency-dependent FDTD calculation. The SA is then obtained from the time integration of the electric field $E(t)$ and the current density $J(t)$, and divided by the mass density ρ of human tissue, i.e.,

$$SA = \int_0^T J(t)E(t)/\rho \cdot dt$$

where T is burst time duration. The lower-right figure shows an example of SA distribution on the human body surface with a wideband EM radiation device in the neighbor of the waist. The SAR can be then obtained from the time average of SA over the burst duration.

Conclusion

In this study, a measurement and calculation method for the safety evaluation of human body exposed to wideband and time-varying EM field have been developed in the fusion facility environment. Their application to actual ICRF leakage EM field is the future subject.