§12. Study on EM Coupling between EM Fields and Electronic Circuits in Plasma Experimental Environment

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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 may also leak electromagnetic (EM) fields ranged from several MHz to several hundred GHz. The complex EM environment may yield a malfunction or misreading of the electronic personal dosimeter for radiation monitoring. The present study aims to model the EM environment in the fusion facility and derive a circuit model for the personal dosimeter from the view-point of EM coupling in order to clarify the mechanism of malfunction.

Measurement of Leaked ELF Magnetic Field

The leakage of ELF (Extremely Low Frequency) magnetic fields from the coil power room has been measured with a 3-axis magnetic-field probe (Norda, ELT-400) and an oscilloscope (Tektronix TDS3034). The maximum leaked magnetic field has been found between the OV and the IS coil power rooms. For the fundamental frequency component (60 Hz), the leaked magnetic field is as high as 110 μT which exceeds 30% of the ICNIRP professional guidelines (83.3 μT). For the harmonic frequency components, especially the second harmonic component (120 Hz), the leaked magnetic field reaches 3 times at maximum of the ICNIRP professional guidelines. The spectrum analysis of the measured magnetic fields has demonstrated that the maximum leaked component is the second harmonic component, i.e., 120 Hz. Based on the characteristics, an EM model for the ELF magnetic fields can be established.

Susceptibility Measurement of Personal Dosimeter

The susceptibility of a personal dosimeter (ALOKA PDM-111) on radiated EM fields has been measured at the ICRF (Ion Cyclotron Range of Frequencies) band (35 MHz) and the cellular phone frequency band (900 MHz), respectively, in an anechoic chamber. The used antenna produces horizontally or vertically polarized field. The exposure to the dosimeter continues 5 minutes and then the reading of the dosimeter is checked. At ICRF band, no misreading is found up to an electric field of 30 V/m. On the other hand, at 900 MHz band, a misreading of 0.07 μSv occurs when the electric field exceeds 60 V/m for the horizontal polarization. Such a field level is possible in the neighbor of a cellular phone. For the vertical polarization, however, no misreading occurs even if the electric field reaches 100 V/m.

Modeling of EM Coupling

The EM coupling of leaked EM fields with the internal circuit of personal dosimeter is considered as a major reason of the misreading. A model of flip/flop circuit mounted on a micro-scrip line has been proposed to model the above-mentioned susceptibility phenomena. Both a magnetic-field coupling (corresponding to the horizontal polarization) and an electric-field coupling (corresponding to the vertical polarization) have been investigated by using a full-wave electromagnetic field simulation tool (FDTD method) and a circuit simulation tool (SPICE). The simulation results show that the horizontal polarization indeed induces larger interference voltage, up to 4 times, at the IC pins compared to the vertical polarization. The finding qualitatively supports the experimental results, and suggests that the proposed coupling model may be useful for explaining the mechanism of misreading of the personal dosimeter, although further quantitative analysis is required.

Conclusion

In this study, the leaked magnetic field from the coil power room has been measured and characterized for modeling the EM environment. On the other hand, the susceptibility of personal dosimeters for radiated ICRF and cellular phone frequency bands has been measured and classified according to the polarization or the coupling mechanism. The future study is the quantitative clarification of the EM coupling in the fusion facility and countermeasure.