

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

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Introduction

In the 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. In this study, we measured the time variation of electric field leaked from a heating device in the ion cyclotron range of high-frequency in a fusion facility, and analyzed the statistical characteristics. In addition, we also evaluated the possibility of EM interference to an implanted cardiac pacemaker in the measured EM environment. It is found that even in the worst case the interference voltage induced in the output of the pacemaker sensing circuit does still not exceed the threshold of malfunction.

Measurement Method and Results

The EM field leaked from the heating device in the ion cyclotron range of frequencies is chosen as the major target of study because it is known as one of the strongest EM leakages in the fusion facility. The signal from the ion cyclotron heating device is amplified with a two-stage amplifier at the center frequency of 64.9 MHz, and is then sent to the plasma load through a waveguide. The leaked EM field in the vicinity of the second-stage amplifier was found to be the strongest one and was measured using a real-time spectrum analyzers (Tektronix RSA3308B). Since the leaked EM field occurred in a burst form and has a varying field level, the real-time spectrum analyzer provided the measurement data in both the time domain and the frequency domain. For these measured data we made a statistical analysis to extract the leaked field feature such as frequency band, amplitude distribution and intersection rate distribution. As a result, we found that the electric field variation with time was very small and the maximum electric field level, i.e., 1.8 V/m, was only 1/30 of the ICNIRP safety guideline. However, the instantaneous field variation was very violent so that it

reached 140,000 times in one second to cross some field level, although the range of variation with time was within 0.05 V/m.

EM Interference Evaluation

It is necessary to evaluate the EM interference to various implanted medical devices in order to secure worker's safety. In the present study, the cardiac pacemaker was taken up, and the influence by the leaked electric field from the ion cyclotron heating device was evaluated quantitatively. The cardiac pacemaker consists of a shielded housing with electronic circuits inside and an electrode. It is connected to the heart by an electrode to read the electrocardiogram (ECG) and to simulate the heart beat by voltage pulses if necessary. The leaked EM fields can couple into the pacemaker to cause an interference voltage at the input of the internal sensing circuit. The induced interference voltage at the input of the sensing circuit of pacemaker will be amplified and low-pass filtered. When the output voltage of the amplifier and low-pass filter exceeds a threshold, the pulse voltage to simulate the heart beat may be triggered and a malfunction of cardiac pacemaker may occur. In principle, the leaked EM field is difficult to pass through the low-pass filter (cut-off frequency: 1 kHz) because the center frequency of the ion cyclotron heating device is 64.9 MHz. However, the second power component of the input signal may be generated by the nonlinearity in the amplifier circuit, and there is a possibility of the EM interference appears in the output of the low-pass filter as a direct-current component. Through a worst-case analysis using a nonlinear analytical technique, we found that the maximum interference voltage was about 1.4 mV for the EM field leaked from the ion cyclotron heating device. This value did not to exceed the malfunction threshold voltage (about 2 mV) for malfunction of cardiac pacemaker.

Conclusion

A statistical measurement was made for the leaked electric field from an ion cyclotron heating device in the fusion facility. The EM interference to a cardiac pacemaker by the leaked electric field was also quantitatively evaluated. Since the present measurement was made for a dummy plasma load, the measurement for actual plasma loads and the derivation of statistical characteristics for the measured leaked EM fields will be the future subject.