§6. Measurement and Analysis of Burst Electromagnetic Fields in Fusion Facilities

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Introduction

This study aims to clarify the irregular and burst characteristics of leaked electromagnetic (EM) fields through a simultaneous measurement in both spectrum domain and time domain, and to evaluate the safety for workers in fusion facilities. We focus the measurement on the EM fields leaked from a heating device in the ion cyclotron range of frequency (ICRF) because it is known as one of the strongest EM leakages in the fusion facility. The simultaneous measurement and corresponding statistical analysis provide an effective means to establish an appropriate evaluation method for the leaked EM fields in actual fusion facilities for securing the workers' safety.

Measurement Results and Discussion

The signal from the ion cyclotron heating device is amplified with a two-stage amplifier at the center frequency of 38.5 MHz, and is sent to a plasma load through a waveguide. Last year we have constructed the simultaneous measurement system with a real-time spectrum analyzer (Tektronix RSA3308B), which can measure the leaked EM fields in both the time domain and the frequency domain at the same time. With this system, in this year we conducted the measurement in the vicinity of the amplifiers of the ICRF heating device with actual plasma loads. Fig. 1 shows an example of measured spectrum and spectrogram of the leaked EM fields[1]. The spectrogram is actually a time-varying spectral representation which shows how the spectral density of the leaked EM field varies with time. In the spectrogram, the horizontal axis denotes the frequency and the vertical axis denotes the time. The color denotes the magnitude of the leaked electric fields. It is found that the peak of the leaked high-frequency electric field locates at 38.5 MHz but has a bandwidth of plus/minus 2 MHz. This means that the leaked EM field waveform is not a simple sin wave. But in view of that the bandwidth ranges between plus/minus 5% only with respect to the central frequency, the leaked EM field is also not a wideband signal, and should still be considered as a narrow band one.

In addition, based on a statistical analysis for the time variations of the leaked EM fields, it is found that the varying EM fields do not follow a normal distribution. The derived cumulative probability distributions exhibit a more complicated feature. Table 1 shows the extracted mean value, median value and mode value from the measured leaked electric fields. The median value indicates the value which separates the higher half of the measured leaked electric fields from the lower ones, and the mode value indicates the leaked electric fields value which is observed with a highest probability. For comparison, we also show in Table 1 the measured result for a dummy load of the ICRF heating device. As can be seen from Table 1, the short pulse signal produces a leaked high-frequency electric field level being twice as large as the long pulse signal. However, for either the short pulse or the long pulse, the differences among the mean value, median value and mode value are insignificant.

A major biological effect in ICRF band is known as the thermal effect resulting from a significant temperature rise in human tissue. An average time of six minutes is usually used in the safety evaluation on such thermal effects. For the time-varying leaked EM fields, therefore, the measured statistical mean value of EM fields should be a useful index in safety evaluation. With respect to the ICNIRP safety guidelines, it is obvious from Table 1 that the mean value of the leaked EM field in the vicinity of the ICRF heating device is much lower than the safety limit of 61.4 V/m for occupational exposure.

Conclusion

Simultaneous frequency-domain and time-domain measurement was conducted for the leaked high-frequency electric fields from an ICRF heating device in the fusion facility. Based on statistical analyses of the measured results, it has been shown that the statistical mean value can be used as an index in actual safety evaluation.

1). Yamanaka, Y., et al., IEEJ Trans. FM, **132**, (2012), 356-361.

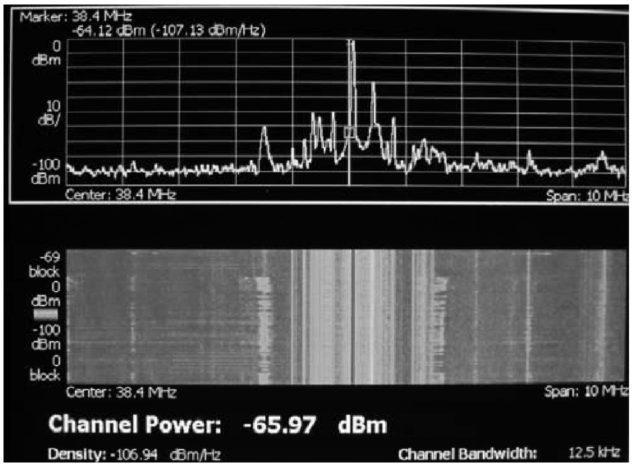

Fig.1 Example of simultaneous measurement results.
Above: spectrum of leaked electric field
Below: spectrogram of leaked electric field

Table 1 Statistical values of measured leaked electric fields

	Dummy load	Plasma load	
		Long pulse	Short pulse
Mean	0.60	0.51	1.08
Median	0.62	0.54	1.15
Mode	0.70	0.60	1.24