A Remote Monitoring System of High Frequency Electromagnetic Field in a Magnetic Confinement Fusion Test Facility

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***Abstract*— A remote and continuous high frequency electromagnetic-field monitoring system using EMC-300EPs with 3-axes probes in a magnetic confinement fusion test facility is developed. The required frequency range of the measurement system is from 25 MHz to 100 MHz. The outputs of each measurement instrument received with the probes are measured simultaneously by original software using a laptop type personal computer connected with a local area network. The measurement values of the electromagnetic-field strength can be transferred using local area network system and are monitored in fusion device control room a point about 200 m far from a fusion device building. The example of the measurement data on the periphery of a high-frequency generator and amplifier used as an auxiliary heating system for a magnetic confinement fusion test device using this monitoring system is shown.**

Key words: remote monitoring system, local area network, high frequency electromagnetic field, magnetic confinement fusion test facility, ion cyclotron range of frequency heating.

I. Introduction

New energy sources will be required for providing an answer to both the energy demand and the global warming problems. A study of fusion energy, which would be one of new energy sources, has made remarkable progress using fusion test devices over the last decades. The main objectives of fusion test device are the study of the control and the confinement of high performance plasma with high temperature and high density. In order to generate high temperature plasma, a magnetic confinement type fusion test device has mainly three types of auxiliary heating system: Neutral Beam Injection (NBI) system, Electron Cyclotron resonance Heating (ECH) system and Ion Cyclotron Range of Frequencies (ICRF) heating system.

A plasma is a quasineutral gas of charged and neutral particles which exhibits collective behavior. In the magnetic confinement fusion device, plasma is immersed in externally imposed magnetic field. In the presence of a uniform magnetic field, it is known that a charged particle has a cyclotron gyration with a cyclotron frequency. The dynamical effect such as the cyclotron gyration creates the possibilities of wave resonances as well as cutoff as a consequence of collective behavior [2, 3]. Therefore, in order to heat the plasma, the resonance heating methods are proposed in a magnetic confinement fusion study. The resonance heating frequencies of electron and ion, which depend on magnetic field strength, plasma density and mass of particles etc, are estimated to several hundred GHz and several hundred MHz, respectively, in a future nuclear fusion reactor.

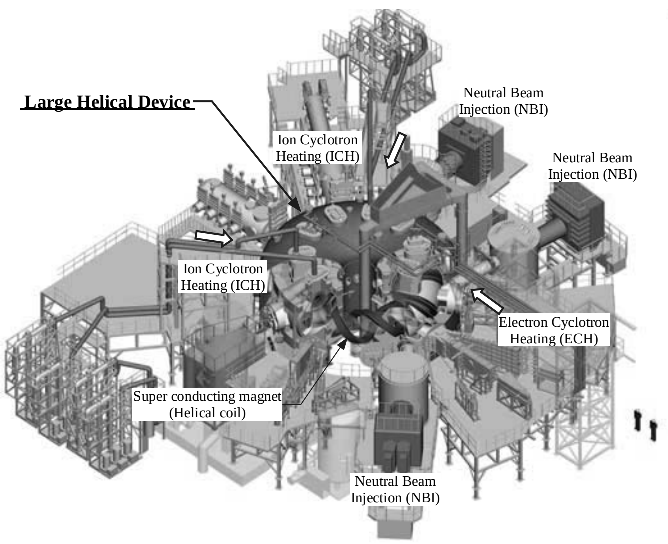

Fig. 1 A bird's-eye view of the LHD

The Large Helical Device (LHD) of the National Institute for Fusion Science, which is one of the magnetic confinement fusion test devices, has the largest superconducting helical and poloidal coil system in the world [1]. A bird's-eye view of the LHD is shown in Fig. 1. LHD started to conduct plasma experiments in March 1998. Since then, it has successfully performed plasma experiments in annual cycles.

In the building of LHD, safety issues are related to the leakage of not only the static magnetic field but also various frequencies of electromagnetic fields, which range from the extremely low frequency (ELF) of 60 Hz to the extremely high frequency of 168 GHz. Except for the superconducting magnet coil system, the major electric devices are the coil power supply and motor generator, which comprises the power supply to the neutral beam injection of ELF, a microwave generator of 2.45 GHz for discharge cleaning of first wall and plasma facing components, plasma heating devices such as the ion cyclotron range of frequency of 25-100 MHz, and the electron cyclotron resonance heating of 77, 84 and 168 GHz.

Although the structural materials of the LHD and related devices absorb high-frequency electromagnetic waves, leakage of various frequencies of electromagnetic fields is a concern. Considering the safety for workers, we measured the electromagnetic fields around the LHD and heating devices. The test of monitoring instruments and safety protection for electromagnetic fields have already been examined [4-8]. As for the leakage of the static magnetic field, we have already been constructed the monitoring system using original software. A previous study of safety guidelines applying to the NIFS referred to the recommendations and guidelines of the World Health Organization (WHO) and the International Committee of Non-Ionizing Radiation Protection (ICNIRP) [9-12].

The objectives of this study are construction of a remote electromagnetic field monitoring system for the safety management. We introduce the system and the software for data acquisition and analysis, and report the example of measurement results on the periphery of a high-frequency generator and amplifier used as an auxiliary heating system for a magnetic confinement fusion test device.

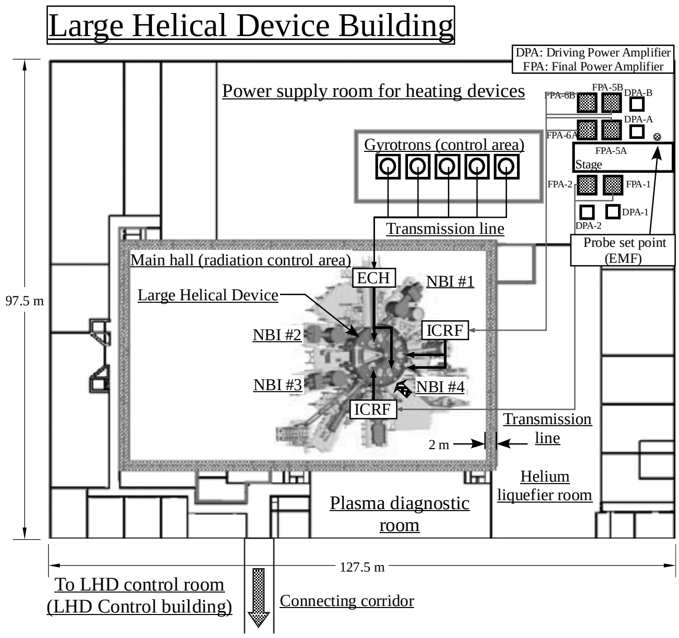

Fig. 2 Layout of the LHD and plasma heating electric devices

II. Remote Monitoring System

A. Instruments Layout

The layout of the LHD and high frequency generating devices for plasma heating in the LHD building is shown in Fig. 2. There is a distance of about 200 m between the LHD building and the LHD control room.

In the LHD building, there are two types of high frequency generating devices. One is a gyrotron which generates the high frequency electromagnetic wave in order of several ten or hundred GHz for ECH. Other is an oscillator that generates in order of several ten MHz for ICRF. Although the gyrotrons might have a leakage of the high frequency electromagnetic field, they emit X-rays in the term of operation of the device, so that, workers are barred at a distance of more than several meters from the ECH sources. As the results, it is requirement to monitor only the amplifiers of oscillator for ICRF. The measuring objects are few final power amplifiers and driving power amplifiers as shown in Fig. 2.

B. Measurement Instruments

A high frequency of the electromagnetic field was measured near the ICRF wave source devices using two EMC-300EPs with three-axis probe (Narda S.T.S.). They were set at a distance of several meters from the ICRF wave sources. The specification of measurement instruments are summarized in Table I and II. Considering the ICRF heating operation for few seconds, the sampling rate is sufficient time resolution [8].

TABLE I
Specifications of Measurement Instrument

Instrument model	EMC-300EP
Sampling rate	5 Hz
Interface	Serial communication (RS-232C) with a optical cable

The electric field probe "Type 18c" and the magnetic field probe "Type 10c" as the measurement probes were used. These probes are set up near the stage toward the final power amplifier (FPA-5A, 5B) and the driving power amplifier (DPA-A, B) as shown in Fig. 2. The measured frequencies are sufficient range for ICRF in the experimental conditions.

TABLE II
Probe Specification

Probe model	Axes	Frequency	Measurement range
type18c	3	100 kHz - 3 GHz	0.2 - 320 V/m
type10c	3	27 MHz - 1 GHz	0.025 - 16 A/m

C. Measurement System and Software Applications

A schematic diagram of the real time measurement and monitoring network system is shown in Fig.3. EMC-300EP has a serial interface of RS-232C communication system using an optical fiber cable. Then, the optical fiber cable is converted to USB cable for connecting with a personal computer (PC). The measurement data of EMC-300EPs are transferred to the PC. The specifications of the PC are summarized in Table III.

TABLE III
SPECIFICATIONS OF PERSONAL COMPUTER USED IN DATA ACQUISITION

Type of PC	Laptop type
CPU	Intel® Pentium®M, 1.86 GHz
OS	Windows XP™ Professional
Memory	1 GB
Hard disk	60 GB
Network adaptor	100 Mbps

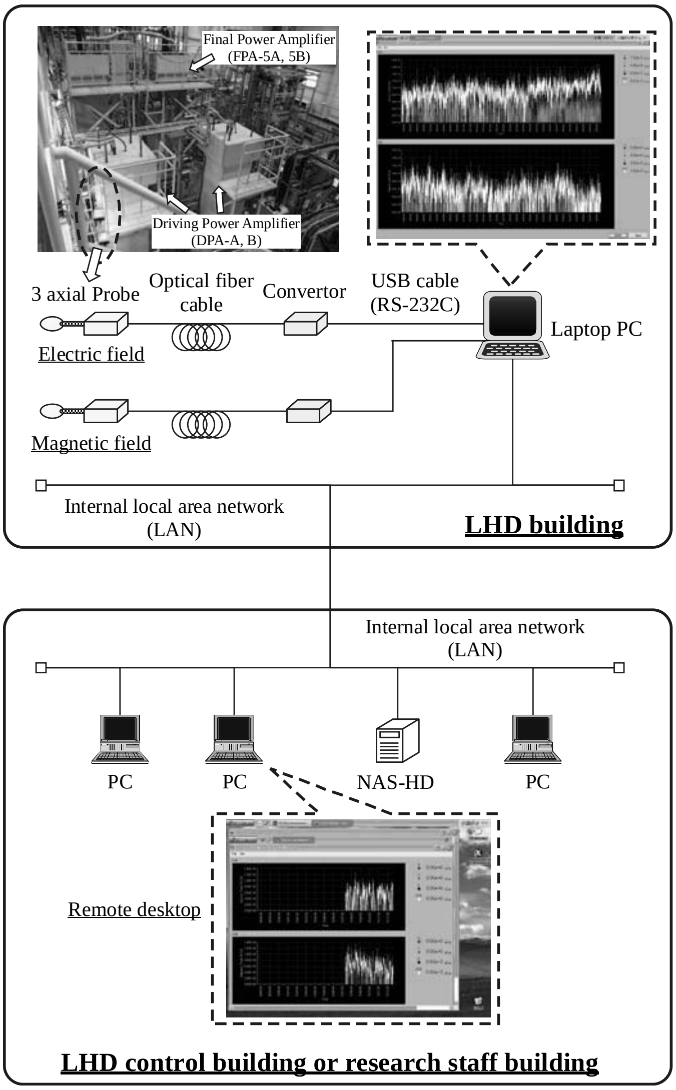

Fig. 3 Remote measurement and real time monitoring network system

The data acquisition software is made using Visual Basic™ programming language. The software acquires data through RS-232C serial interfaces and calculates the mean square values of each data. The data is displayed on the graph as shown in Fig. 3 and three data files of acquired data file, average data files at interval of 1 second and 6 minutes are created and stored on the real time. The PC for the data acquisition is connected with an internal local area network and can be monitored from LHD control room using “Remote Desktop” application including accessory software in Windows XP™. A time in the PC is synchronized with a NTP (Network Time Protocol) server in the institute once a day. The data files are transferred and stored in a NAS (Network Attached Storage) type hard disk at a staff room in the research staff building once a day. Using the existing LAN system and accessory software saved the capital cost and shortened the system development period.

Since the measurement data file is too large to open by spreadsheets program, a specially designed data analysis program is made using LabVIEW™ programming language. This program can display all the data in a day and extract the data within the time specified. It also extracts the value of maximum in a day and background level at 0:00 within the term specified. The extracted data is automatically saved on a hard disk drive in PC.

III. MEASUREMENT RESULTS

The operation of LHD is conducted from 9:00 to 18:45. A plasma shot is normally made every three minutes and ICRF heating is also made at the same time period if required. The ICRF devices are operated in bursts for a short time to a long time, such as one hour. Figure 4 shows an example of the electric and magnetic fields observed around the ICRF sources in a day using the analysis program.

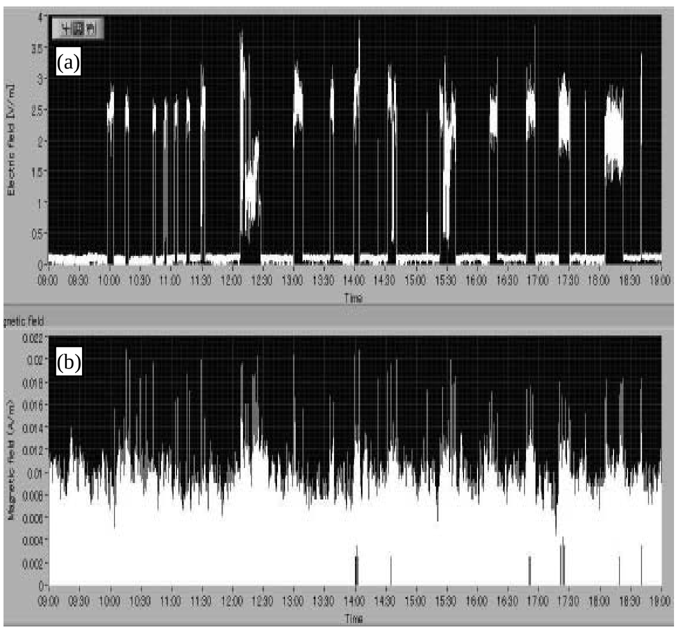

Fig. 4 An example of measurement data in a day [Feb. 15. 2007]: (a) Electric field, (b) Magnetic field

The frequency and the power of ICRF were 38.47 MHz and 0.6-1 MW, respectively. Many peaks are observed according to the plasma shots. In these experiments, the maximum electric field in each pulse was approximately 4 V/m. In addition, the measured maximum values of the magnetic field were approximately 0.02 A/m, which is the same level of detection limit of the instrument. It was difficult to detect the leakage of high frequency magnetic field under this frequency and power of ICRF.

The mean data of electric and magnetic fields for 6 minutes of Fig.4 is shown in Fig.5. Each mean data is calculated by the data acquisition software at intervals of 6 minutes starting from 0:00. All the data, not only electric field but also magnetic field, were less than the occupational guideline levels proposed by the ICNIRP. The mean data for 6 minutes are useful for safety management by making the self-regulation rules refer to the recommendations of the WHO and the ICNIRP.

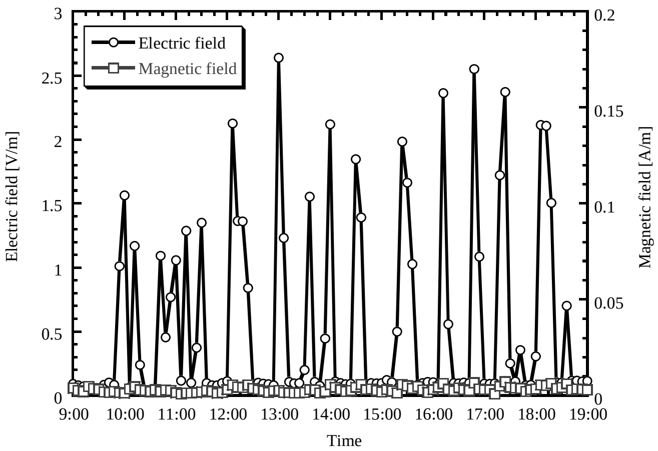

Fig. 5 Mean electric and magnetic fields data at intervals of 6 minutes

The LHD project has a plan to increase the heating power of the ICRF, ECH and NBI, and then a long heating mode of more than 1 hour will be performed. Thus, the monitoring of electromagnetic fields around the plasma heating devices will become more important from the viewpoint of occupational protection. For the advanced monitoring system, we are preparing with setting few RF personal monitors, which contain both electric and magnetic field sensors and support all major standards, up near the ICRF devices as a multi-point area monitoring system. Since the personal monitor also equips with a serial interface, we will construct a monitoring system as a set of simultaneous measurement using original software.

IV. Conclusion

We developed the remote electromagnetic field monitoring system for a magnetic confinement fusion test facility. In the monitoring system, the high frequency electric and magnetic field from 25 MHz to100 MHz was measured using two EMC-300EPs, simultaneously and the outputs of instruments are acquired and displayed on the graphs using original software. Then, the measurement results of the electromagnetic field strength were monitored in the magnetic confinement fusion device control room a point about 200 m far from a fusion device building through the local area network system. An example of the measurement data in a day on the periphery of a high-frequency generator and amplifier used as an auxiliary heating system for a magnetic confinement fusion test device using this monitoring system is shown. Although all the measured data are less than the occupational guideline levels, in order to deal with increasing ICRF devices for future study, we would construct a multi-point area monitoring system using few RF personal monitors and original data acquisition software.

Acknowledgments

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