A MEASUREMENT SYSTEM USING GP-IB FOR A MAGNETIC CORE TEST CAVITY

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Abstract

It is necessary to understand the characteristics of magnetic cores in order to design the RF system of the JHF proton synchrotrons. We have developed a measurement system using the GP-IB for a test cavity to measure the characteristics of the magnetic cores. This system also enables us to control the most of measurement devices and to take measured results by a PC.

1 INTRODUCTION

In the design of the RF system of the JHF (Japan Hadron Facility) proton synchrotrons, it is very important to find a magnetic core to which satisfies the required condition of the JHF accelerators[1]. Ferrite cores are usually used for the magnetic core of the proton synchrotron, however there are some problems. Generally, some ferrite cores have non-linear characteristics which depend on the RF magnetic field. And, there is a size-dependence of the characteristics. Thus, it is required to measure the characteristics of large size magnetic cores. To measure characteristics of the magnetic cores, we have developed a test cavity which is capable of measuring an actual size one, and measurement system using software 'HP-VEE'[2,3] which is possible to control the measurement devices by using a GP-IB command directly. In this measuring system, the acquisition of data and calculation of the characteristics of the magnetic cores are automatically processed.

2 TEST CAVITY

Figure 1 is a photograph of the test cavity, and Figure 2 shows a cross section of the test cavity. It is possible to measure one or more magnetic cores using the cavity. The cavity has a co-axial structure, and magnetic cores are put between water cooling plates. The RF power was supplied to the cavity through the RF feeder, and also matching circuit was used unless the core impedance is about 50 Ω. The input RF power is limited to 1kW by the power amplifier. In the cavity, there are 16nF variable capacitors, and 8 pieces of the fixed capacitance (2nF each) can be installed. The resonant frequency can be changed. And a bias power supply provides the direct current and 0-100Hz alternating current up to 1000A for testing the effects of biasing magnetic field. We picked up a voltage and current by a high voltage probe and current transformer, respectively. We also measured the phase difference between the voltage and current.

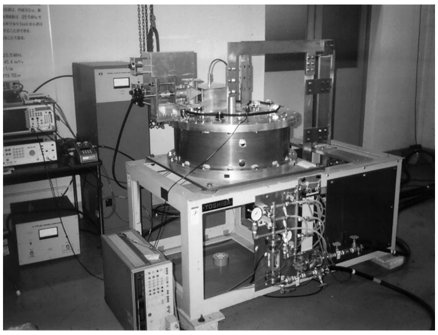

Figure 1: Photograph of the test cavity.

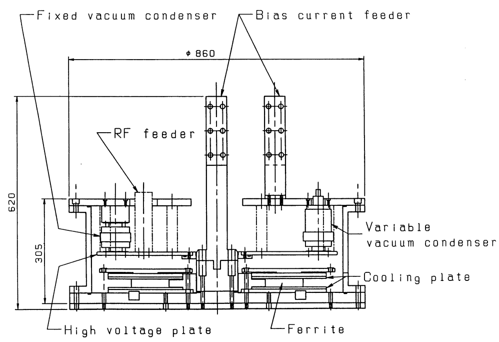

Figure 2: Cross section of the test cavity.

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3 DERIVATION OF MAGNETIC CORE'S CHARACTERISTICS

3.1 Basic Characteristics of Magnetic Core

The complex permeability μ can be defined by series expression,

$$\mu=\mu_s'-j\mu_s'' \quad (1)$$

and parallel one,

$$1/\mu=1/\mu_p'-1/j\mu_p''. \quad (2)$$

Suffixes s and p mean series and parallel, respectively. The inductance, L and resistance, R can be expressed as;

$$L_p=\mu_p'\mu_0(\ln(b/a))t/(2\pi) \quad (3)$$

$$R_p=\mu_p''\mu_0(\ln(b/a))\omega t/(2\pi) \quad (4)$$

$$L_s=L_pR_p^2/(R_p^2+\omega^2L_p^2) \quad (5)$$

$$R_s=\omega^2L_p^2R_p/(R_p^2+\omega^2L_p^2)\ , \quad (6)$$

where a, b and t are, inner diameter, outer diameter and thickness of a magnetic core, respectively.
The Q value of the core is;

$$Q=R_p/(\omega L_p)=\ \mu_p''/\mu_p'=\omega L_s/R_s=\mu_s'/\mu_s''\ . \quad (7)$$

The relations between parallel and series permeability are given by;

$$\mu_p'=\mu_s'(1+1/Q^2) \quad (8)$$

$$\mu_s''=\mu_p''(1+Q^2)\ . \quad (9)$$

We should note that μ_s' is not equal to μ_p' in the case of small Q value.

3.2 Derivation and Correction of Characteristics of Magnetic Core

Figure 3 shows the equivalent circuit of the cavity. A magnetic core can be replaced by a parallel circuit which composes of the inductance, L and resistance, R. The impedance of the core is given by;

$$Z=V/Ie^{j\phi}\ , \quad (10)$$

where, V and I are effective values and ϕ is the phase difference of them. We measured the voltage, current and these phase difference. The resistance is;

$$R_p=|Z|/\cos\phi\ . \quad (11)$$

The power dissipation and RF magnetic field in core are given by;

$$P_{in}=VI\cos\phi \quad (12)$$

$$B_{rf}=V_{peak}/(\omega S)\ , \quad (13)$$

where, V_{peak} is the peak value of the voltage and S is the cross section of a magnetic core. The inductance is calculated by the resonant frequency, f, and the resonant capacitance, C.

In the real circuit, we need some corrections because the choke coil L_{ch} and bypass capacitance C_b and straying capacitance C_s exist. The admittance is;

$$Y=1/R+1/(j\omega L)+j\omega(C+C_s)+1/(j\omega L_{ch}+1/(j\omega C_b))\ . \quad (14)$$

The inductance, L is obtained by;

$$L=(L_{ch}C_b\omega^2-1)/(\omega^2((C+C_s)C_bL_{ch}\omega^2-C_b-(C+C_s)))\ . \quad (15)$$

We have measured the characteristics of magnetic cores using these equations[4]-[7].

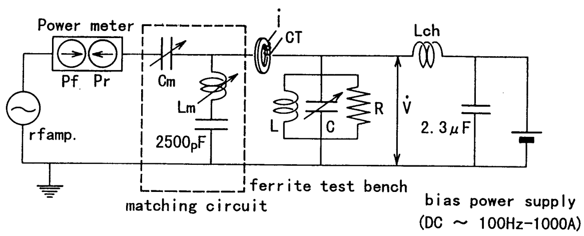

Figure 3: Equivalent circuit of the test cavity.

4 MEASUREMENT SYSTEM

Figure 4 shows the block diagram of the measurement system. A signal from the synthesizer, HP3326A is used as an input signal for a bias power supply and as a trigger signal to synchronize the arbitrary wave form generator, WAVETEK395. The RF amplifier, ENI A1000 amplifies the signal generated from wave form generator and provides to the cavity through the power meter, Bird4391. And the RF current is measured by the current transformer, Pearson411. The wave form measured by the oscilloscope, HP54520A is transmitted to the PC with the GP-IB. The data are processed and characteristics of magnetic cores are calculated immediately and saved. An error and a standard deviation about Z, V, I and ϕ are calculated to check whether the measurement is performed correctly or not.

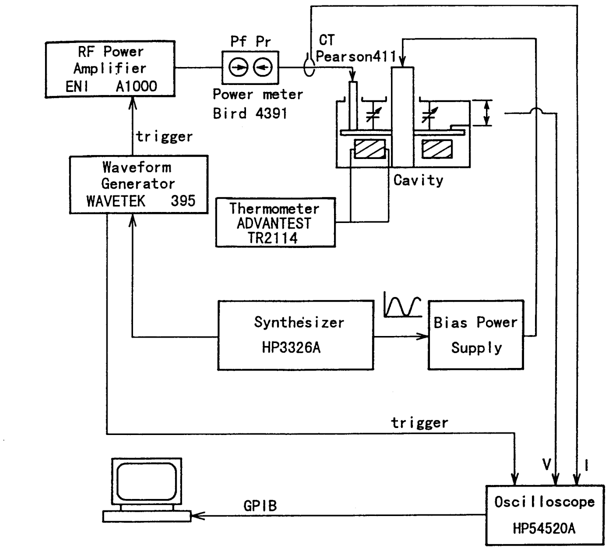

Figure 4: Block diagram of the measurement system.

5 GP-IB CONTROL ON HP-VEE

Figure 5 shows a display of HP-VEE to control oscilloscope HP54520A. We can develop a program visually. It is also possible to use the GP-IB command and to control a measurement device directly. If there is not a device component, we must control a measurement device using a GP-IB command or unique command for each device directly. In this way, we have developed several programs to control the measurement device, for example, the digital multi-thermometer, TR2114, network analyzer MS3401 and arbitrary wave form generator, WAVETEK395 .

6 CONCLUSION

We have developed the measurement system using the GP-IB for the magnetic core test cavity. In this system, the characteristics of the magnetic core can be measured. In addition to this, we developed several programs using GP-IB to control the measurement devices which is very useful for the experiments.

7 REFERENCES

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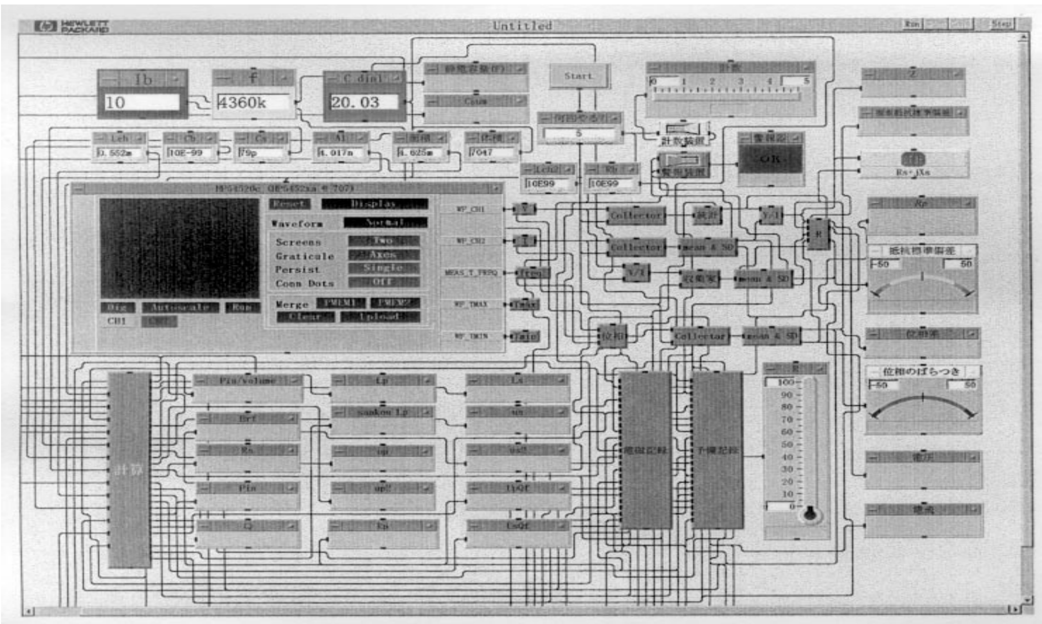

Figure 5: Program of HP-VEE.