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THE RF SYSTEM FOR THE IPCR SSC

M. Hara, T. Fujisawa and K. Ogiwara

The Institute of Physical and Chemical Research, Wako, Saitama 351, Japan

Abstract.- The RF system for the IPCR SSC is designed. Half-wavelength resonator is selected from various types of resonators. Power amplifier, coupling system between resonator and power amplifier, grid tuning system, and phase and voltage stabilizing circuits are also investigated.

1. Introduction.- The RF system for the IPCR SSC is required to satisfy the following conditions[1]:

(1) The frequency range is 17 to 45 MHz for the synchronous operation with the injectors.
(2) Maximum energy gain is 1 MeV per turn per unit charge.
(3) Harmonic numbers are 9, 6, and 4.
(4) The voltage distribution along the accelerating gap should be flat or radially increasing.
(5) Radial length of the accelerating gap should be longer than 2.6 m corresponding to the distance between injection and extraction radii.

According to these conditions, the characteristics of various types of resonators have been studied and compared to select a suitable one[1,2]. A half-wave resonator was chosen and detailed measurements with half scale model were done. Main amplifier, impedance matching schemes, and stabilizing circuits were also discussed.

2. Resonator.- In designing, resonators of three types were investigated. These were resonators of a single gap type, a quarter-wave type with single vertical stem, and a half-wave type with two vertical stems in opposite sides.

The first one is expected to have a simple structure, high Q value, and good voltage distribution. In our case, however, it is difficult to realize because of the following reasons: Injection radius is so small that the spatial restriction near the central region makes the voltage at the dee gap low near the injection orbit(less than a half of the maximum at most). Moreover, compared with the other types, a voltage twice as high is needed to keep the same energy gain per turn, and this demands wide gaps. Transit time effects also become severe.

As for the second one, it was found from model study that it has a large RF electric field even inside the dee. Therefore, we have to employ the third one and extensive studies have been done.

Calculations based on the distributed parameter theory were also done to determine the shapes of the stem. Stems having a cross sectional shape of racetrack seem to have a good characteristics. A half scale model resonator was constructed to investigate

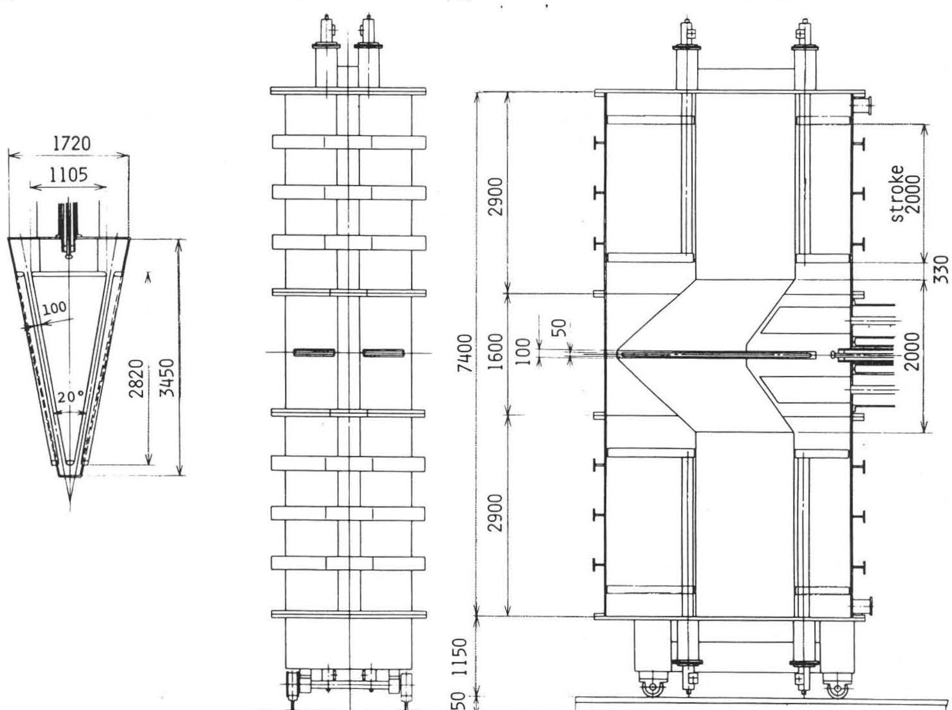

Fig. 1 : Schematic drawing of half wave resonator.

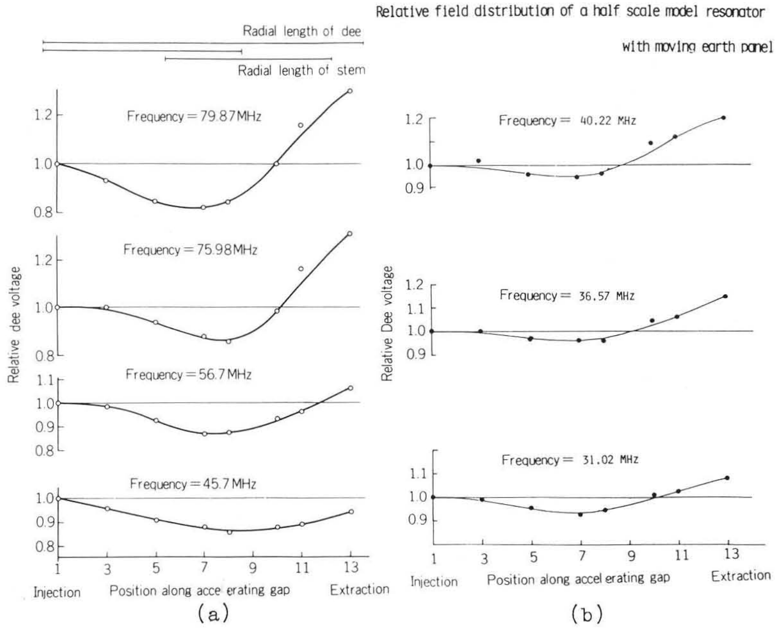

Fig. 2 : Relative distribution of RF electric field along the dee edge of half scale model resonator.
(a) without moving panel (b) with moving panel
Measurements were done by perturbation method using ceramic block.

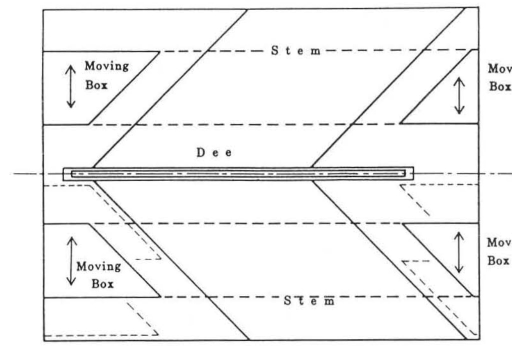

Fig. 3 :Schematic drawing of new type frequency varying method.

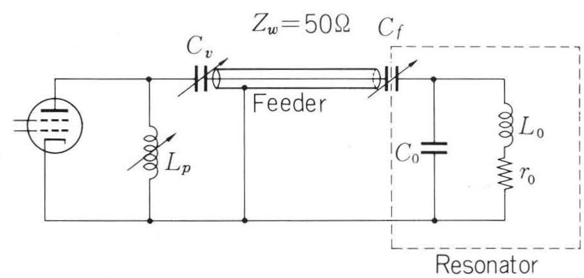

Fig. 4 : RF power feeder line and impedance matching circuit for the SSC.

RF characteristics. Resonance frequencies, Q values, and voltage distributions were measured. After some cut-and-try modifications, the resonators shown in figure 1 is designed. This has 20° delta shaped dees. Sliding shorts are used to change frequency and moving panels are also used at low frequencies. The measured voltage distributions of half scale model are shown in figure 2. At this time, this type of resonator is chosen, and the structural analysis using finite element method (SAP) is in progress. But this type has some disadvantages:

(1) The vertical length is long. Considering the driving length(2m), this amounts to about 11 m.
(2) Maximum current density at sliding short fingers amounts to 70 A/cm at 45 MHz and at 250 kV. It is difficult to design short fingers bearable to that high current density.

Therefore, in parallel with this resonator, new method to vary frequency is planned and under investigation. As is shown in figure 3, shorting parts are limitted to the external liner. Frequency is varied by lifting the "MOVING BOX"(the height is 0.6 m and the gap between stem and box is 4 cm) which surrounds the stem and is not contact with it. New method has the following characteristics:

(1) The height is less than 3 m.
(2) Driving length of "MOVING BOX" is about 0.6 m.
(3) The point where the current density is maximum is fixed.

One of the disadvantages is in the power losses. The power loss is estimated to be about 400 kW at 17 MHz and at 250 kV (less than 100 kW in case of sliding short method). If high voltage such as 250 kV is not needed at low frequencies, this method is applicable.

3. Power Amplifier and Coupling System.- For RF oscillation system, MOPA (master oscillator and power amplifier) system is employed because of the necessity of synchronous operation with the injectors(linac and AVF cyclotron). Maximum output power of the amplifier is to be 300 kW. An RCA 4648 tetrode will be used for the final amplifier at the following operating conditions:

(1) $I_{g1} \simeq 0$.
(2) $E_p < 1.7$ kV.
(3) $E_{g2} = 1.0 - 1.4$ kV.
(4) $R_p = 200 - 600\ \Omega$.
(5) Plate Efficiency = 55 - 65 %.

Length of the feeder line between the power amplifier and the resonator is more than 2 m. Only a travelling wave should be excited on the feeder line because frequency must be varied in the wide range and feeder line is long. The impedance matching system between the resonator and the main amplifier is schematically shown in figure 4. The impedance of the feeder line is fixed to 50 Ω for convenience' sake. A variable capacitor (C_f) is using for the coupling and impedance matching between the resonator and the feeder line. Impedance matching between the main amplifier and the feeder line can be realized by a variable capacitor(C_v). The tuning of plate circuit is done by

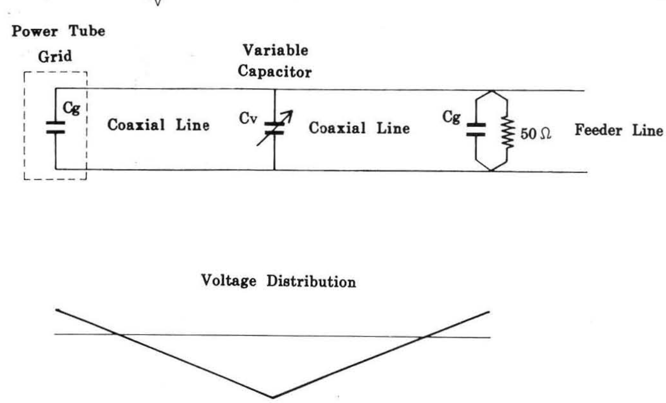

Fig. 5 : Grid tuning circuit and standing wave voltage distribution.

a tuning stub (L_p).

RF input circuit for the final amplifier is schematically shown in figure 5. As the RCA 4648 tetrode has large grid capacitance (C_g), it is difficult to operate without having nodes at this frequency range. Therefore, input circuit is designed to operate in single wavelength mode. Tuning can be obtained easily by adjusting a variable capacitance(C_v). Because this circuit has a symmetry, the input RF voltage can easily be monitored at the 50 Ω resister. From preliminary calculations, for 1.6 m total length of 50 Ω impedance coaxial line, tuning can be obtained by varying C_v from 170 to 2900 pF.

For the coupling system between the resonator and power amplifier and grid tuning circuit, models have been made and RF characteristics are under investigation.

4. Phase and amplitude stabilizing.- Schematic diagram of RF system is shown in figure 6. Frequency tuning of the resonator is done by three devices. Shorting plates and moving panels are used for coarse tuning, and another small capacitive trimmer is for fine tuning. Fine tuning has an auto-tuning loop which uses the phases from the feeder line and the resonator and fixes the difference of them. Figure 7 shows the phase and amplitude stabilizer circuits which are inserted between master oscillator and the pre-amplifier. Double balanced mixers are used to convert the input signals into intermediate frequency of 500 kHz at which frequency the phase comparator is used.

References :

1) M. Hara et al.: IPCR Cyclotron Progr. Rep.,14 (1980),182.
2) K. Ogiwara et al.: ibid.,187.

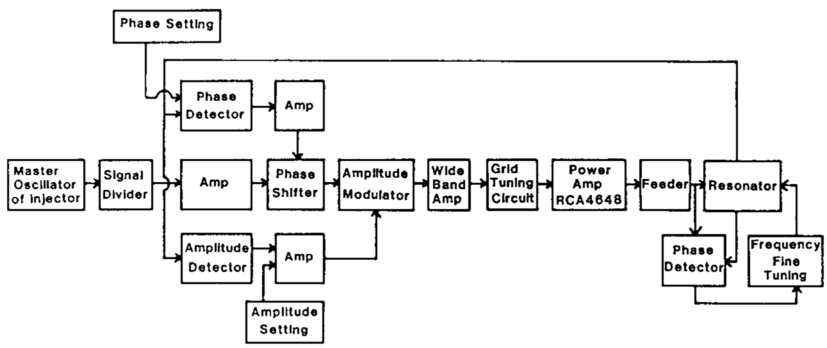

Fig. 6 : Schematic diagram of RF system for the SSC

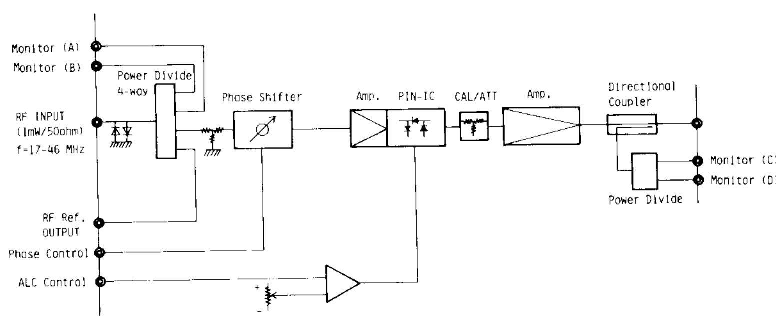

Fig 7 (a)

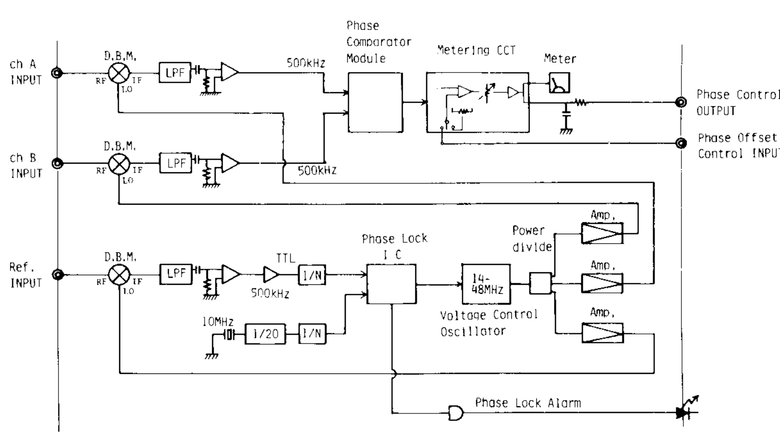

Fig 7 (b)

Fig. 7 : Schematic diagram of phase and amplitude stabilizing circuits.

(a) automatic pase and level modulator.
(b) phase lock circuit.