RF System of the Grenoble 85-inch Cyclotron

by

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Abstract

The Grenoble RF system has been designed to provide the possibility of varying the frequency and energy of the cyclotron in operation. Two dees are used with two resonant cavities of a new conception. Tuning is achieved by displacement of a panel without sliding contacts. The RF energy is supplied by two power amplifiers built on top of these cavities and driven by a stable frequency synthetizer followed by a wide band distributed amplifier. Automatic tuning and voltage stabilization will be provided for ease of operation.

Description

From the physicists' point of view it is of paramount importance to be able to modify the energy of the beam of particles accelerated in a cyclotron without interrupting the experiments. This is impossible with conventional quarter-wave coaxial cavities where the sliding contacts exert high pressure on the walls of the cavities. Variable tuning has been achieved with the movable panel cavities of the Berkeley 88" cyclotron, but the whole of the frequency band cannot be covered in this machine due to long line effects in the driving circuit.

For Grenoble, we have tried to build an RF system tunable in operation at maximum power for all the frequency band and with the possibility of remote control with as few tuning adjustments as possible. In this respect, it seems important to use a multiple dee system since it is easier to reach high frequencies with low capacity dees and less power is required for a given energy gain per turn. For these reasons among others we have chosen a two-dee system which leaves available space for the extraction system. The frequency bandwidth to be covered is only one octave and can be achieved by a simple cavity tuning mechanism.

The cavities, one on each side of the magnet, are tuned by a rotating member capacitively coupled to avoid sliding contacts to a cylindrical wall of the cavity (fig. 1 and 2). In this way, there is only one electrical contact carrying RF currents, on the axis of the rotating member. In the lower position, the dee stem forms a coaxial line resonant with the dee capacity. In the upper position the dee stem and the rotating member form a shielded pair line of low inductance compared to a coaxial line and the resonant frequency is high. This design with only one moving part is of very simple construction and avoids the need of flexible couplings for the water cooling system. It leaves a wide available space in the upper part of the cavity so that the power amplifier can be placed on top of the cavity, with direct coupling of the power tube amplifier to the cavity by a loop and there is no problem of line coupling at variable frequency. The dee stem is supported at the rear of the cavity by a mechanism for adjusting the dee position inside the cyclotron (fig. 3). The dee stem is of short length and the dee is stable in position. In the rear part of the cavity, the vacuum wall is separated from the cavity wall and a number of holes are provided for water connections and for introducing a probe. The dee, dee stem, the cylindrical wall of the cavity and the rotary parts, carrying most of the RF current, are of copper. The remaining parts of the cavity are of pure aluminum. On each side of the cavity, holes are provided for the diffusion pump and for a window. On top of the cavity is the tuning mechanism with a differential gear system giving two speeds of frequency variation. A linkage has been introduced between this driving mechanism and the rotating member of the cavity and achieves a nearly linear frequency variation in time.

Amplifier

The amplifier takes its signal from a master oscillator of the frequency synthetizer type giving a stability better than 10^{-7} per day. The output of this master oscillator is amplified by a wide band distributed Marconi amplifier giving an output power of 1 kw from 2 to 24 Mc/s without tuning adjustment. This preamplifier drives the two power amplifiers which are RS 1082 Siemens tetrodes, either in phase or in opposite phases. The grid circuits of these tubes are tuned by coaxial stubs whose tuning adjustment we intend to couple to the resonant cavities' tuning mechanism since the preamplifier is quite insensitive to relatively large standing wave ratio.

The control circuits consist of a phase locking system using a phase discriminator to compare the RF phase on the two dees. It seems possible to control the phase relationship between the two dees, whether in phase or in opposite phase within one degree. The voltage of the dees will be stabilized with a feedback loop controlling the RF driver amplitude or the screen grid voltage of the power amplifiers. An automatic tuning system based on the comparison of phases in the amplifier and the cavities will also be provided.

Results

The RF system has been tested on 1/5 scale models from which the dimensions of the full scale cavities have been obtained. It has also been possible to estimate the main parameters: frequency tuning, Q factor, impedance, electric and magnetic field maps on the dee stems and the dees, and elements for the coupling loop.

The first cavity, built from these experiments, has given the predicted results. The Q factor variation as a function of frequency is shown on fig. 4 with the distance between the two cylindrical panels of the movable capacitor as a parameter. The best results are obtained with a space of 16 mm. The same applied for the product $QL\omega$ (fig. 5) with which one can compute the power necessary for a given dee voltage. For the intended dee voltage of 50 kV, this power reaches a maximum value of 42 kW at 23 MHz, a value which is very low compared to the powers usually needed for cyclotrons of the same size. All these measurements have been conducted with an aluminum box around the dee (fig. 6) in lieu of the cyclotron vacuum box and we hope to achieve higher Q values with the complete equipment comprising a copper liner and provision for better contacts.

In conclusion it can be said that this system seems to provide very flexible tuning of the RF of a cyclotron and we expect the servo systems, now under development, will reduce the operators' tasks to simple controls of frequency and power.

References:

1) M.J. Jakobson, F.H. Schmidt - Phys. Rev. 83 N° 2 (1954) p. 303.

2) Rapport interne CSF 1024.

3) French patents N° 957,393 dated 12/17/63 and N° 957,735 dated 12/19/63.

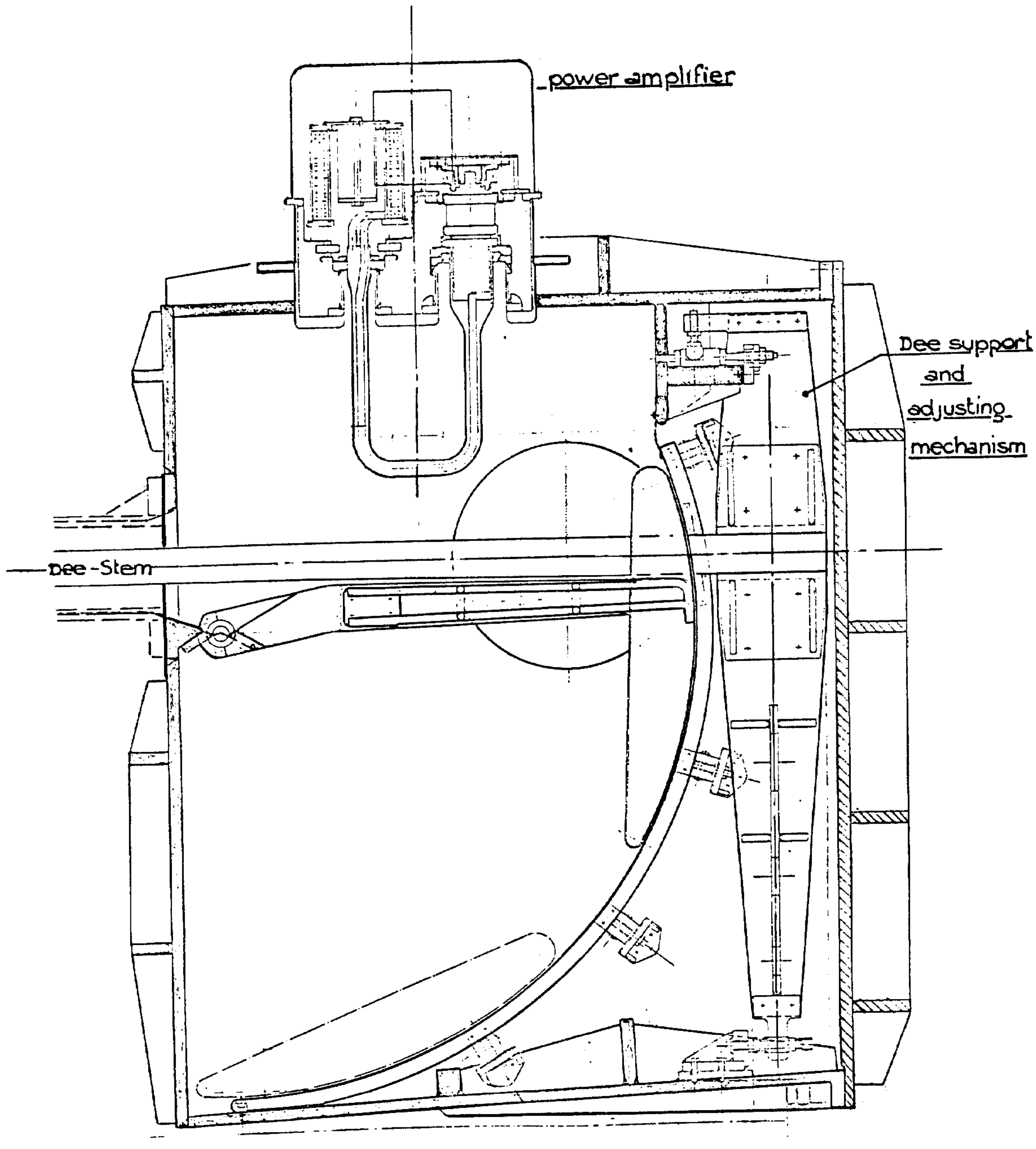
power amplifier
Dee support and adjusting mechanism
Dee-Stem

Figure 1.

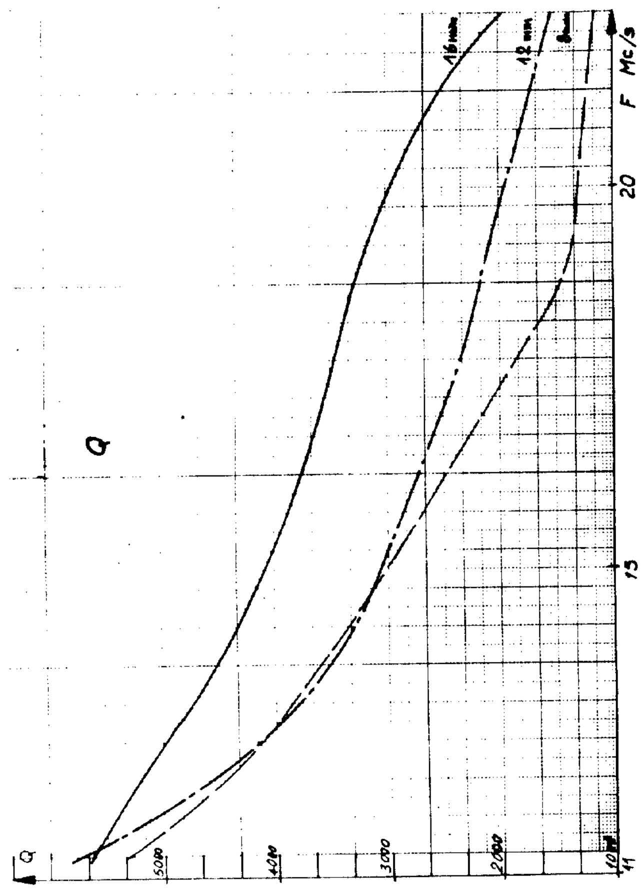

Figure 4.

Fig. 2. Rotating capacitive panel.

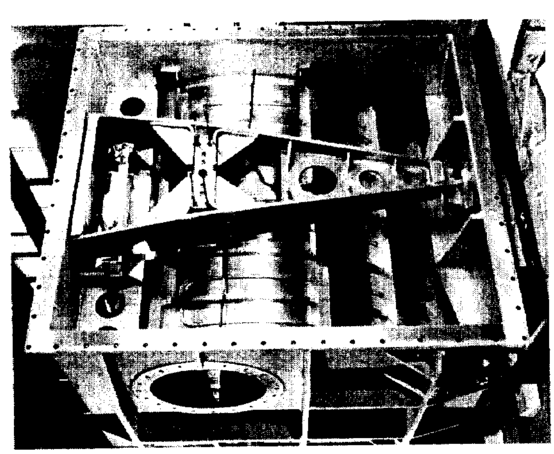

Fig. 3. Dee adjusting mechanism.

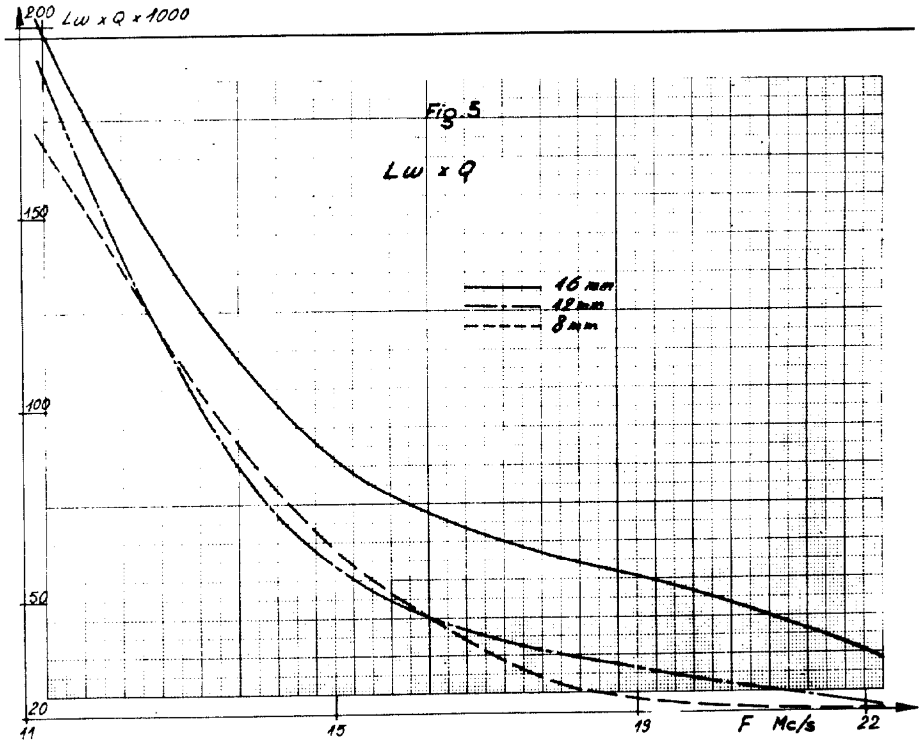

Figure 5.

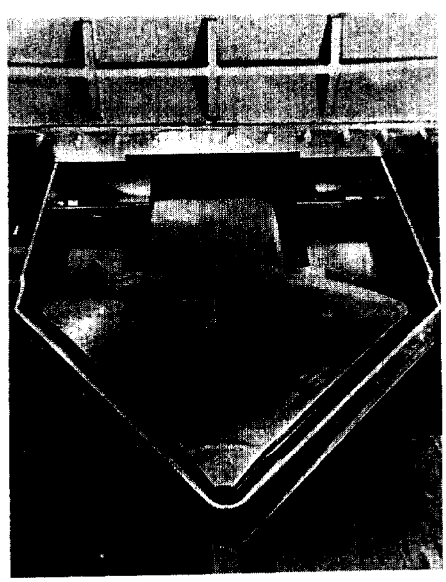

Fig. 6. Dee.