THE RF SYSTEMS OF THE MSU K500 AND K800 CYCLOTRON*

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Abstract

Modifications to the initial design, and present performance of the K500 R.F. system will be described. In addition, plans for the K800 R.F. will be delineated.

At the 1979 International Cyclotron Conference held at the University of Indiana the proposed design for the K500 RF system of the Michigan State University superconducting cyclotron was described[1].

The rf system first tried to accelerate beam in November 1981. The problems with three phase operation have been described in a paper delivered at the 1983 National Accelerator Conference[2]. Suffice it to say that by January 1982 we had installed neutralizing loops between A-B and A-C stems and because the ion source quite effectively shielded B dee from C dee, we had three independent rf systems.

We were now able to accelerate beam in a routine way for experiments. For days at a time the rf system would behave nicely. However, especially in the beginning, and although less often later but still too often, various problems would develop that resulted in downtime and interference with the experimental schedule.

Because of the possible interest to others, we will list the various kinds of problems that have caused downtime.

1. Output coupler. The original design used loop coupling out of the transmitter that was supposed to require no adjustment over the 9 to 30 MHz frequency range because the loop penetrated the moving short in such a manner as to induce 1/5th of the anode voltage into it. However, when testing the transmitter into a dummy load, it was realized that the self inductance of this loop had to be resonated out with a series capacitor, which had to be varied as a function of frequency. Into a dummy load this worked fine, but into the dee it didn't. When the dee was mistuned, or when it sparked, the series resonant transmitter output circuit saw a short, and huge voltages could and did appear across the capacitor resulting in its destruction. Very early we changed to the simple capacitor output coupling scheme as used at the Riken SSC. Since then (September 1980) this problem has disappeared.

2. Input coupler. The "window" or insulator, that makes the penetration from air to vacuum for the purpose of coupling power to the dee has been a continuous source of trouble. To date 15 of these have been destroyed, resulting in one day downtime each time. The obvious mechanism of destruction is persistent arcing on the air side. The air side can hold 20 KV, so apparently what happens is that when a dee to coupler spark occurs, within a namosecond or so 20 KV exceeded, a spark occurs, and we haven't been smart enough to turn the rf drive off to prevent damage. We think we will eventually solve this problem.

3. Burnt fingers. The moving shorts of the transmitter stems, and the outer conductor of the dee stem shorts employ standard silver plated BeCu finger stock with goldplated contips. These burn out regularly. Excessive damage is avoided because we have 24 photo-sensitive transistors looking for sparks on each short and we shut the rf off when a spark occurs. It is apparent, via microscopic observation, that after the fingers have travelled enough to wear off the gold contips, sparking and self destruction will occur. This has not been a big problem with us because only about 2 hours downtime results from each failure. But one time we failed to see the sparking, and one of the 4 inch diameter transmitter stems was burned in two resulting in a week downtime.

   We believe that these problems can be solved by, on the one hand, using more sophisticated electronic monitoring techniques to prevent damage when sparking occurs, and on the other to install a different type of finger. The new fingers will use silver graphite contips of sufficient size (1/8") such that it will take years to wear them out.

4. Power supplies. Thirty years ago one could buy power supplies with crowbars from industry that worked. No more. We have a continuous upgrading fight with our power supplies to keep them from self destructing.

5. Hydraulics. We use MOOG hydraulic valves for our dee fine tuner servoes and the input coupler positioners. Initially they worked satisfactorily, but with time their performance deteriorated. The problem is that our oil gets contaminated with particles that plug up the one micron filters in the valves. The solution is to prefilter the oil better, and to switch to using Atchley valves which can tolerate 10 micron size particles.

6. Dee sparking. Initially, and on a few occasions since then, the dees could run at 100 KV peak without excessive sparking. However, they would prefer to run at a maximum of about 80 KV. The dee puller to ion source has a 1 cm spacing.

7. Electronics. The phase detectors have good short time stability of ± .1° but their long

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time stability is only about ± 2°. In the beginning we had the usual problem with the infant mortality of various chips, but by now the reliability seems adequate.

8. Neutralizing. The neutralizing loops are capable of neutralizing over the frequency range 12 to 28 MHz. Although the loops are not big enough to achieve complete neutralization below 12 MHz, sufficient neutralization exists to permit satisfactory three phase operation there. However, the loops, beside restricting the upper frequency to 27.5 MHz, also limit the dee voltage for frequencies below 15 MHz to about 70 KV due to sparking to them from the stem. For these reasons we are considering changing to capacitor pick ups at the insulator plus a variable length λ/2 transmission line between adjacent stems.

Things that worked well with the K500 RF System

1. The inner conductor stem shorts have not had a single failure.

2. The amplitude servoes work well.

3. The phase servoes work well.

4. The three phase digital phase meter works well.

During normal running the rf balcony does not need to be attended.

Future plans are to incorporate computer monitoring and to provide alarms for some 130 analog inputs and some 200 one bit digital inputs. Then we propose to substitute computer control for the present some 30 knob settings necessary to tune up to a new frequency.

K800 RF Systems

Whenever possible the plan is to copy the K500 R.F. system. There are some differences imposed by the fact that the dees are almost twice as big, and the design goal is to achieve 200 KV instead of the 100 KV requirement for the K500. The RF power will be about 210 KW and the stem currents almost double the K500's.

The resonator design will be very similar to that of the K500, but bigger. We will use the same dee stem insulator, achieving a vacuum seal using indium wire. The moving short region will have a six inch diameter inner conductor and a twelve sided polygon outer conductor about thirty inches in diameter. The contacts will be copies of the K500, the current density on the inner conductor being only slightly higher (84 amps/cm).

The neutralizing loops will also be copies of the K500 scheme. When the K500 is used as an injector into the K800, presumably we will not need neutralizing, as the dees can be shielded from each other.

K800 Transmitter

We will use the RCA 4648 tetrode for the power source. We have already tested a prototype transmitter into a dummy lead at 350 KW delivered. The anode circuit is a copy of the K500 but, because of the large grid capacity of 1200 rf, the grid circuit is different. We have tested the grid circuit over the entire frequency range and it performs satisfactorily at all frequencies.

The 90 some modules for regulation and control will be exact copies of those used in the K500 system. We have already manufactured about 15% of them.

References

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1. RF System. J. Riedel, IEEE Transactions on Nuclear Science, Vol. NS-26, No. 2, April, 1979, p. 2133.

2. Three Phase RF Systems for Superconducting Cyclotrons, by J. Riedel, IEEE Transactions on Nuclear Science, August, 1983, Vol. NS-30, No. 4.