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MSU RF System

Note #4

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Measurements on Cyclotron r.f. System

Introd. The MSU cyclotron works very well. However, experimenters will always like to have a given cyclotron operate even better than it is. At present emergent beam is momentum modulated predominantly by 360 Hz, this modulation being measured as the differential current delivered to a pair of slits which intercept part of the beam. In addition it is suspected that there is other modulation at low frequencies (between .1 and 10 Hz) due to mechanical vibrations of the r.f. structure. This note documents the results of certain measurements made on the system, and recommends further measurements and corrective action.

Voltage Regulation. The signal source for voltage monitoring is a loop coupled into the dee stem fed unterminated via a 3ft 50Ω cable to a vacuum tube rectifier, and then a vacuum tube cathode follower and then the long cable to the control room. Signals from each dee stem are added or subtracted at the scope to display the net accelerating voltage. The observed ripple is .025% peak to peak, mostly 360 Hz. For voltage regulation, small capacitors looking at the dees provide a dV/dt signal into terminated cables whose r.f. output in the control room are rectified and mulled by a d.c. command signal and fed to the voltage servo. This error signal was measured and agreed perfectly with the monitoring signal mentioned above. The servoe gain at 360 Hz was measured to be 7. This means that the servo is reducing the unregulated 360 Hz ripple by a factor of 7. The d.c. gain of the servo was calculated to be about 1000.

Displaying the error signal on the Esterline Angus chart recorder showed that the dc stability over one hour was about 2 parts in 10^5. There was amplitude modulation of 2 PPM at frequencies from .1 Hz to 2 Hz, but whether this was noise or coherent modulation was undetermined due to the unknown response of the recorder.

Since there was a suspicion that perhaps spurious 360 Hz signals were adding to the error signal, the rf from a capacitive dee signal was fed directly to the control room, peak detected and monitored. The 360 Hz ripple appeared to be smaller than that observed on the other monitors.

Phase Measurement

Since tuning errors due to vibrations will cause larger phase modulation than amplitude modulation ($\Delta \sin\theta$ vs $\Delta \cos\theta$ for θ near 0), the output of the phase detector, nulled by the dc command signal, was displayed on the chart recorder. Oscilloscope display of this signal was useless because of a very large 60 Hz signal added to it, spurious, no doubt. The chart recorder signal was very similar to the voltage signal, again with uncertainty about whether the observed modulation was a low frequency coherent signal, noise, or due to the chart recorder.

Conclusions to be drawn from the measurements

Clearly, the 360 Hz ripple can be further reduced by providing for more gain at 360 Hz. There is no good reason not to have unity gain at 50 KHz, thus a servo gain at 360 Hz of 100. However greater attention to monitoring the true dee voltage would be necessary, otherwise the servo can equally well increase the 360 Hz modulation. As for the measurements; the conclusion is that they must be made in a more sophisticated manner. There exist instruments capable of displaying

carry coherent signals even when immersed in a sea of noise. Such an instrument is the Lock in Amplifier, manufactured by a number of companies including Princeton Applied Research. This instrument uses a sampling technique to obtain an arbitrarily small bandwidth centered about a selected frequency and it is recommended that MSU obtain one (with a dual channel) so that precise measurements can be made. To use this instrument a low frequency signal generator will also be necessary (.001 to 1 KHz).

With these instrument it will be possible to measure the open loop transfer functions of the amplitude and phase servos with the loops closed and thus determine what corrective action is necessary.