RF POWER DEVELOPMENTS

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Considering long linacs, perhaps the most troublesome and costly engineering aspect is that of supplying rf power to the accelerator. The frequency ranges that seem to be of interest are mentioned first.

Clearly, 200 Mc/s will be used for the low energy end of these machines. At the intermediate or higher energies, 400 Mc/s might be used with some saving in cost, either in a large iris-loaded guide, or a drift tube structure. Of course, the higher frequencies are more desirable, since the shunt impedance increases with higher frequency. So far, thoughts about iris-loaded guides have centered about 1200 Mc/s. This seems to be the highest practical frequency due to the aperture size. However, if practical power sources are available at 800 Mc/s, this frequency might be a possibility.

At 200 Mc/s, gridded tubes appear to present the best solution. Both the Yale and MURA designs, as well as the existing Argonne machine, use the tube, RCA 7835, capable of 5 Mw. Klystrons are feasible at 400 Mc/s, although presumably the tube, RCA 2054, capable of 5 Mw would be favored here. Presently, the feeling is that klystrons are the only solution at 1200 Mc/s. At 800 Mc/s, either triode or klystron may be used.

Two classes of linear accelerator service should be distinguished. The first is injector service for high energy synchrotrons, where, even with multi-turn injection, the maximum pulse length is about 500 μsec, and the maximum duty cycle is about 1%. The second class is the physics machine, where the longest pulse lengths and duty cycles are desirable. The results of the Yale design study indicate that a 2 millisec pulse with a 6% rf duty cycle is a reasonable maximum for economic reasons. Economic considerations dictate lower gradients for higher duty cycle machines, resulting in longer, lower power structures.

Several factors must be considered in the preliminary design of rf power systems for long linacs. Perhaps the first of these is the reliability of individual components. Since the long accelerators under consideration here require a large number, perhaps even up to one hundred tanks, reliability of an order of magnitude greater than available at the present time is required to maintain the same overall machine reliability. Secondly, it is necessary to have independent control of the voltage level and phase of each tank. Considerations of length, gradient, and peak field set certain limits on the power requirements of each tank. Finally, rf power generally costs less per watt for the higher power tubes.

These thoughts lead to several desirable design principles. One would always like to use the highest power tube available. Presently, this means about 5 Mw of rf power per tube. However, individual sections of accelerator operate more typically at 1/2 to 1 Mw each, dictated by machine design. Thus, the use of a 5 Mw tube requires power splitting at high power level, as well as severe problems in obtaining independent level and phase control on the individual tanks. It may well be better to use single lower power tubes feeding each section.

When using a klystron to drive a high Q load, the klystron is mismatched during some part of the pulse, normally on the leading edge during the build-up period. Thus, one has to use a large and expensive isolator, or devise some other method of matching a klystron to a standing waveload. Another problem with klystrons is the control of beam voltage in situations where accurate level and phase control on the sections must be maintained.

Discussion

R. P. Featherstone (Minnesota): Are there compelling reasons not to make the sections twice as long?

G. W. Wheeler (Yale): Yes, there are. The reason here in the standing wave type of machine is that you are limited in maximum length because of tuning the sections. This problem becomes particularly vexing to me, because in the high duty cycle machine, we are looking at considerably lower gradients than one considers for the injector, but still you are fixed in maximum length, and this means that with lower gradients, you are running lower powers per section.

R. B. Neal (Stanford): Just to add a note; in the traveling wave machine you lose shunt impedance as you increase the length, keeping the attenuation constant.

G. W. Wheeler (Yale): Yes, so this is the same type of consideration. Whether these sections come out requiring 1/2 Mw or 1-1/2 Mw is not clear, but the problem still exists, if you start thinking in terms of the largest klystrons available, or possibly the largest tubes. At this point, at least, it is a problem of philosophy, as to whether one uses individual tubes on the sections, to buy what I think is reliability, and certainly ease of adjustment.