THE ZGS INJECTOR

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The ZGS proton linear accelerator injector is a copy of the Brookhaven AGS injector. Discussion will therefore be limited to areas where significant differences exist.

This machine is nearing its operational status. At this time the tank is being evacuated.

In order to obtain preliminary tuning of the cavity, rf power has been applied at 1 atm. pressure in the tank. Power levels were increased until sparking occurred. To tune, it was necessary to turn off the final amplifier and to drive through with only the driver amplifier. These experiments resulted also in preliminary measurements of waveguide and coaxial line tuning. Fig. 1 shows a sketch of the waveguide and linac arrangement. Initial tuning was tried with the dummy load removed and other equipment installed, but not connected to the linac tank. First indications are that the coaxial section may be too short. It was also felt that the iris is too close to the transition section, and this may have to be moved back. The irises seemed to function well in the initial attempts at matching.

Recently efforts have been concentrated on tank flattening. A number of approaches used elsewhere, such as "glo-balls" and "bead pulling" have been considered and it was decided to use a sophisticated bead pulling method. The improvement in method of measurement has yielded valuable information in connection with tank "flattening". It seems useful therefore to describe the method in more detail. A block diagram is shown in Fig.2.

The bead pulling method is based on the fact that when a cavity is perturbed locally with a small perturbation in the form of a metallic bead, the resonant frequency change is given by:

$$d\upsilon \sim -E_z^2 \, dV_{bead}.$$

The bead is pulled with a string along the axis of the tank. To prevent damage to the drift tubes it is supported in the center part of the drift tubes by Teflon supports. The motion due to these supports does not seem to disturb the observed field patterns. Field patterns are obtained by exciting the cavity with a lock-on oscillator, its frequency is compared with a reference oscillator and the resulting frequency difference is converted into $\int E dt$. Because of the uniform bead speed used this is equivalent to $\int E dz$ and can be converted into a voltage which is read by a digital voltmeter. A complete bead pulling measurement can be done in 3 minutes during which time the reference oscillator must be stable. An example of some results is given in Fig.3. It is interesting to note the double peaks occurring in the longer drift tubes. Calculations done at MURA seem to confirm these results. Apparently axial fields are somewhat larger at the face of the drift tube as compared with the gap center location.

To interpret the results $\int E_z dz$ values are plotted versus drift tube number and compared with normalized gap voltages calculated before at BNL. This is shown in Fig.4.

Experimental observations at low drift tube numbers differ from theoretical values as shown. This is due to the size of the bead used (3/8" diameter) compared with drift tube bore at these locations (1/2" diameter). The larger drift tubes have a 1¼ inches diameter bore. Different bead sizes have been used and at present an attempt is being made to extrapolate the results to zero bead diameter. The results shown in Fig. 4 were obtained without loop connection. With the loop connected pronounced changes were observed, as shown in Fig. 5. These can be corrected, however, with the ball tuners. The observed fact that one ball tuner is quite effective in one gap, but less so in another, suggests that it might have been attractive to have more ball tuners. The pronounced changes observed by connecting the loop suggest that tank "flatness" may suffer from relative small tuner adjustments. This should be investigated further.

With the bead pulling method it is simple to distinguish between the lowest mode and higher possible modes. In the first case the graphical result of gap voltage pulses shows a flat envelope in contrast to the case of higher modes. The present quadrupole configuration is NSNS---. It was felt that this mode should be tried first before falling back on the more conventional NSSNNSSN--- arrangement. Power consumption in the first case is higher but the advantage exists of higher linac acceptance values.

With respect to the rf system more should be known before long concerning the matching situation. The power amplifier has given 6 Mw into a dummy load, but, so far, has never been operated with a reactive load. The pulse width up until now has been 500 μsec; it is variable and it is thought that this could be increased to 1 msec. An rf pulse, observed at low power level, is indicated in Fig. 6. The double decay noted is because the driver amplifier cuts off after the power amplifier, thus some driver power is seen in the cavity.

A block diagram of the rf system is shown in Fig. 7. The frequency of 200 Mc/s is obtained in 3 stages; by doubling, tripling and doubling again 15 Mc/s. The low level exciter output at 200 Mc/s is approximately 1 watt.

The crowbar, as shown, dumps the 50 kv supply in the event of a pulse modulator input over current. The modulator incorporates a hard tube and ordinarily maintains constant voltage on the power amplifier regardless of the voltage droop across the 32 pF storage capacitor. In addition, it may be programmed to give a rising pulse, if desired. In the event of a fault in the power amplifier a signal is fed back to block the modulator.

As far as the "Continental" system performance goes, except for the usual small failures, performance has been quite satisfactory. On the other hand, it was felt that the pulse modulator could be improved. At present four tubes are used in series-parallel, in a "two-deck" arrangement. Some difficulty has been experienced in maintaining balance between the two. Part of this trouble was due to difficulty in regulation of the ac mains, which has been corrected by going to better regulated lines.

There is some thought that the pulse modulator may be replaced by a single tube capable of handling the voltage and current. It is good to remove complexity and improve reliability in this circuit, since it forms the first line of protection in the event of a power amplifier failure.

There has been some concern about possible damage to the power amplifier in the event of severe sparking in the linac. The energy storage of the linear accelerator tank is 125 joules. It is intended to incorporate an rf crowbar system. This will serve to "dump" the cavity in the case of a fault, preventing power from being fed back to the power amplifier. This system is not complete yet; it will be installed, however, before the linac becomes operational.

Discussion

J.P. Blewett (BNL): Do you have only one loop size available?

R. Perry (ANL): Yes, only one has been tried so far. This has adjustable penetration, which has been optimized. It turns out that the optimum location was just about flush with the cavity; just a small fraction of an inch penetration.

I.J. Polk (BNL): What is the average power loss in the tank?

R. Perry (ANL): The system was designed for 25 kw average power from the transmitter. What it actually will be, is not known at present.

I.J. Polk (BNL): Did you check the Q value of the tank?

R. Perry (ANL): Yes. From preliminary measurements it seems to be approximately 70,000. These measurements yielded preliminary values only and should be repeated. It may be less than 70,000. Say 60,000 to 70,000, from a quick look at the decay of the pulse. This implies a power loss of 3.5 Mw.

R.L. Gluckstern (Yale): How "flat" is your tank?

R. Perry (ANL): During the last run, about 6 - 8% for the worst deviations. We expect to be able to "flatten" to about 1 or 2%.

R. Beringer (Yale): Does your tank have end tuners, as distinguished from the ball tuners?

R. Perry (ANL): Yes, we also have end tuners.

R.P. Featherstone (Minnesota): When you speak of the effect of the loop in distorting the axial field distribution, was it disconnected or mistuned?

R. Perry (ANL): It was connected, but we checked the distribution after tuning adjustments were made.

R.P. Featherstone (Minnesota): Then the loop was tightly coupled to the driving tube?

R. Perry (ANL): Yes.

K. Batchelor (Rutherford): Did the frequency change when the loop was put in?

R. Perry (ANL): Yes. I do not think we brought it back to the same value with the ball tuners.

G.K. Green (BNL): How do you dump the cavity?

R. Perry (ANL): We have a spark gap in one end wall. Sufficient voltage is applied to initiate a spark, producing ions, with consequent breakdown of the cavity over its entire length. This is also done on the Hilac.

R.H. Rheaume (BNL): You said 125 joules are stored in the cavity?

R. Perry (ANL): Yes.

R.H. Rheaume (BNL): That seems rather small. Why should that hurt the 7835 tube?

M.V. Hoover (RCA): The possibility exists that in the event of protection failure of the modulator, power could come from two directions resulting in possible damage to the power amplifier tube.

K. Batchelor (Rutherford): What is your rf pulse repetition rate?

R. Perry (ANL): 10 pulses per second, 500 μsec pulses. Of course when running with the ZGS, we will not keep this rate, probably just 2 or 3 pulses per second.

R.B. R-Shersby-Harvie (CERN): How much did the rf power supply cost?

R. Perry (ANL): The rf supply was about $350,000, installed. Added to this should be the cost of the 7835 power amplifier tube, which is $55,000.

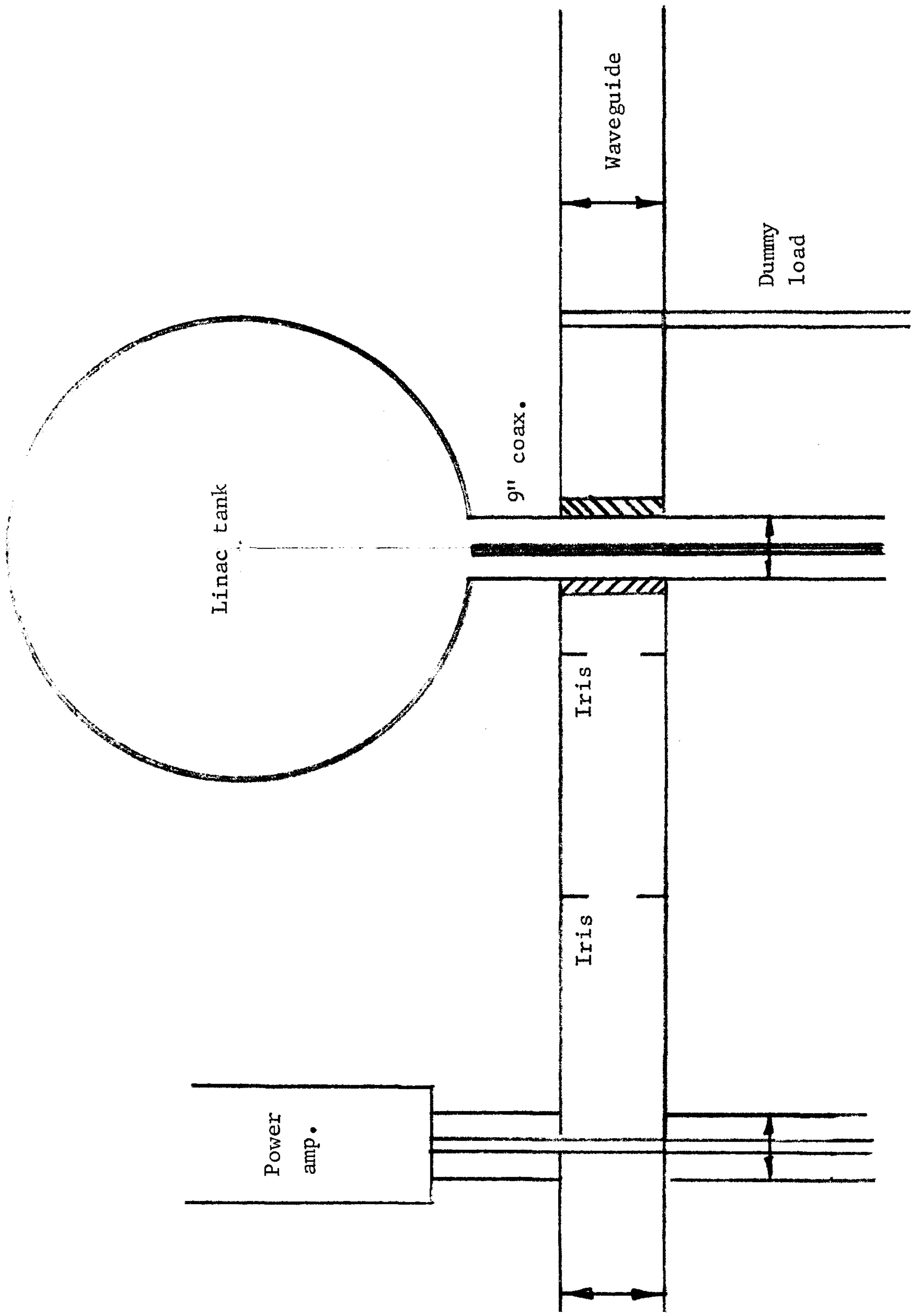

Fig. 1

Waveguide and linac connection

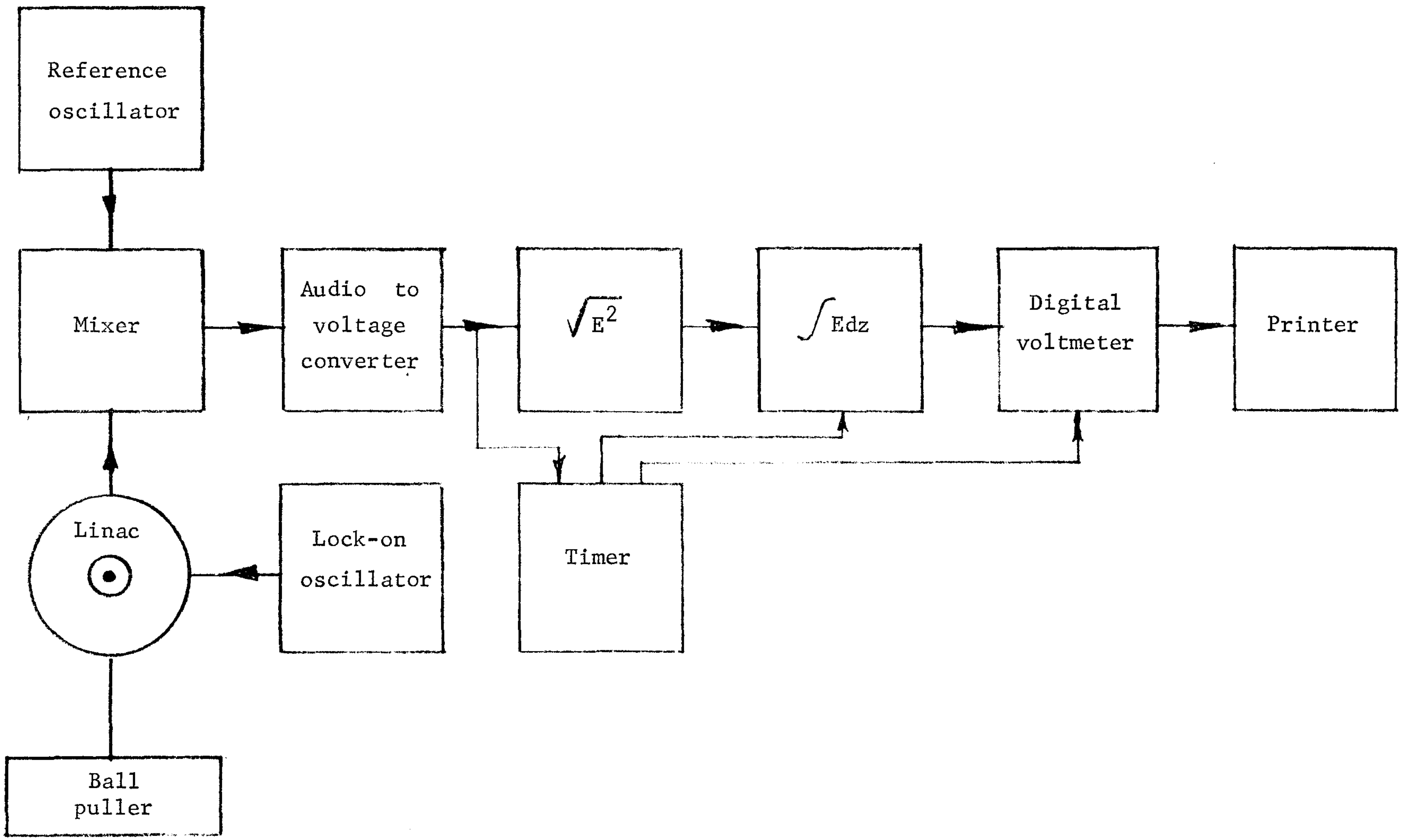

Fig. 2

Block diagram of system for measurement of linac field distribution

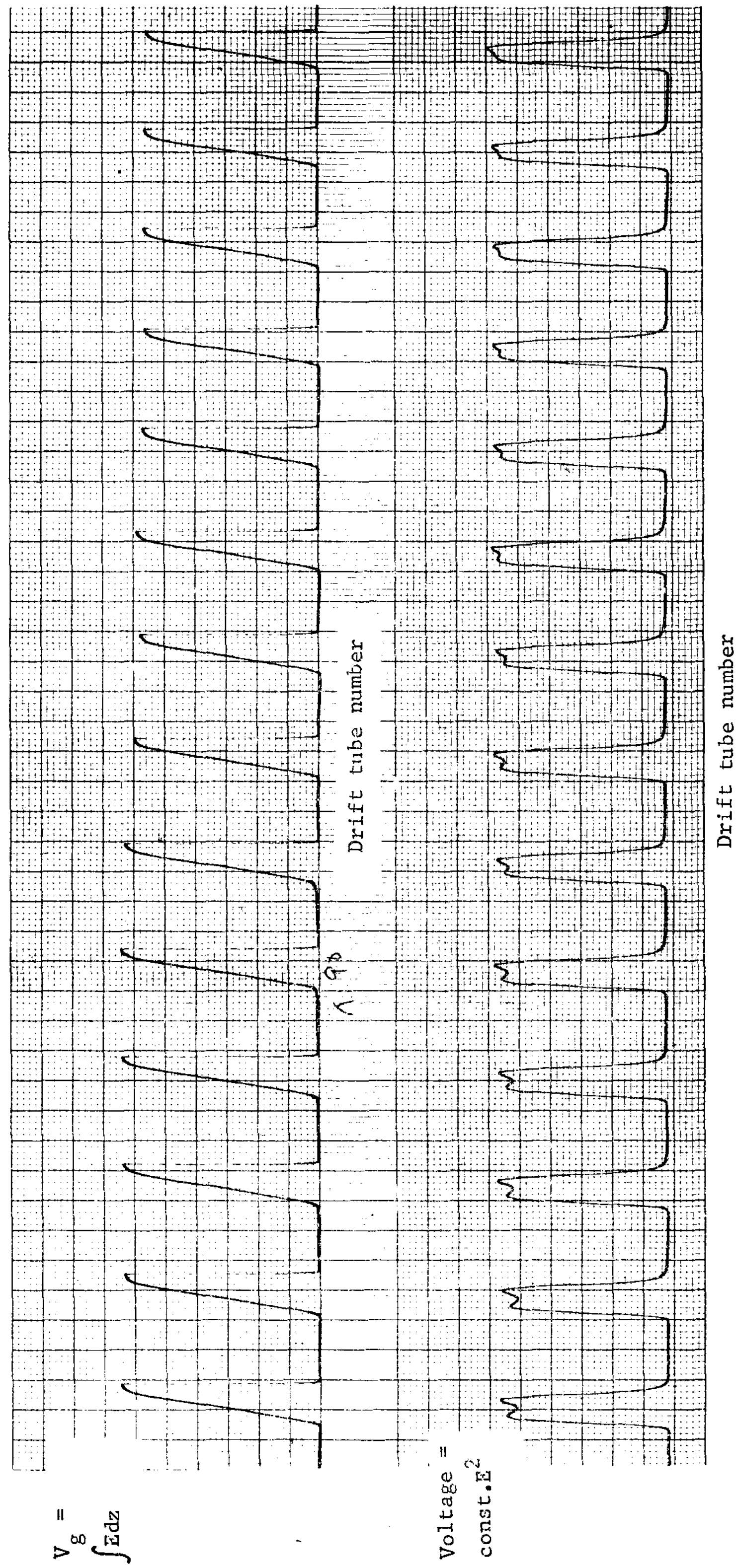
$V_g = \int Edz$
Voltage = $const.E^2$
Drift tube number
Drift tube number

Fig. 3

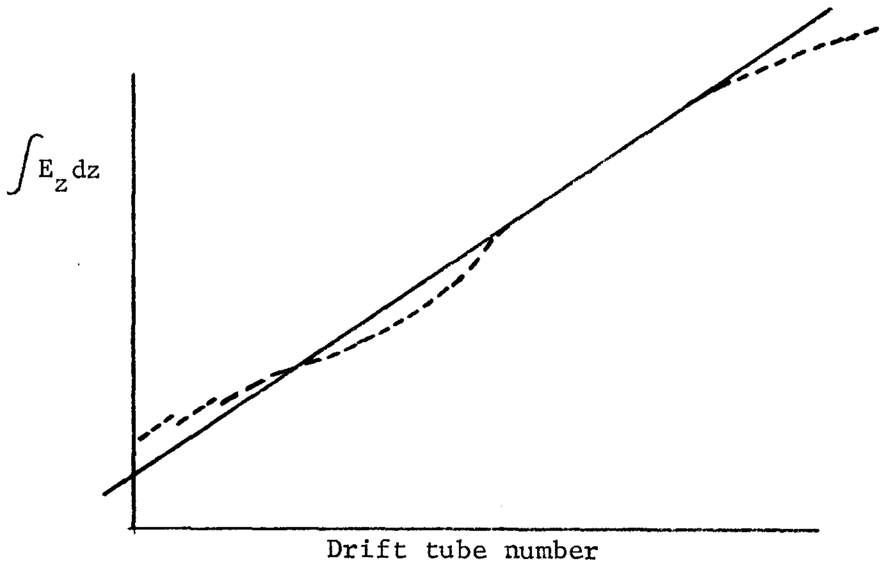

Fig. 4

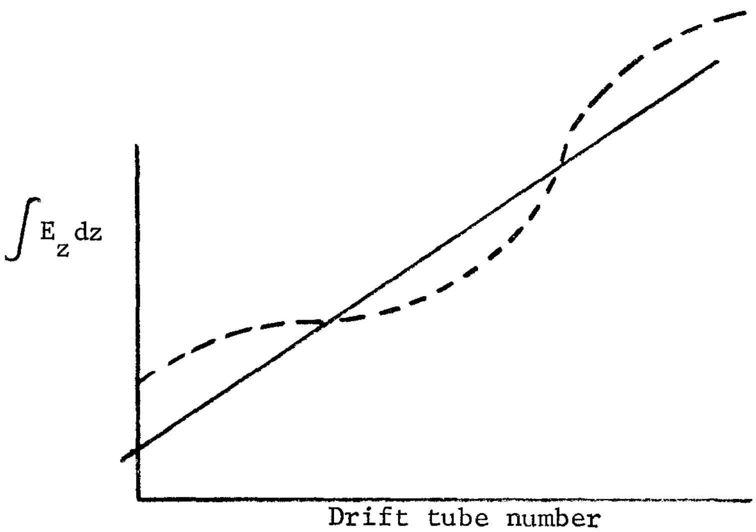

Fig. 5

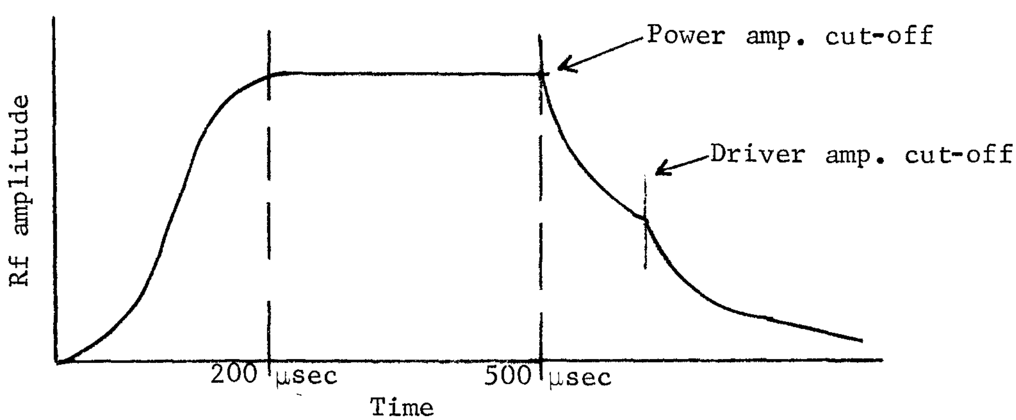

Fig. 6

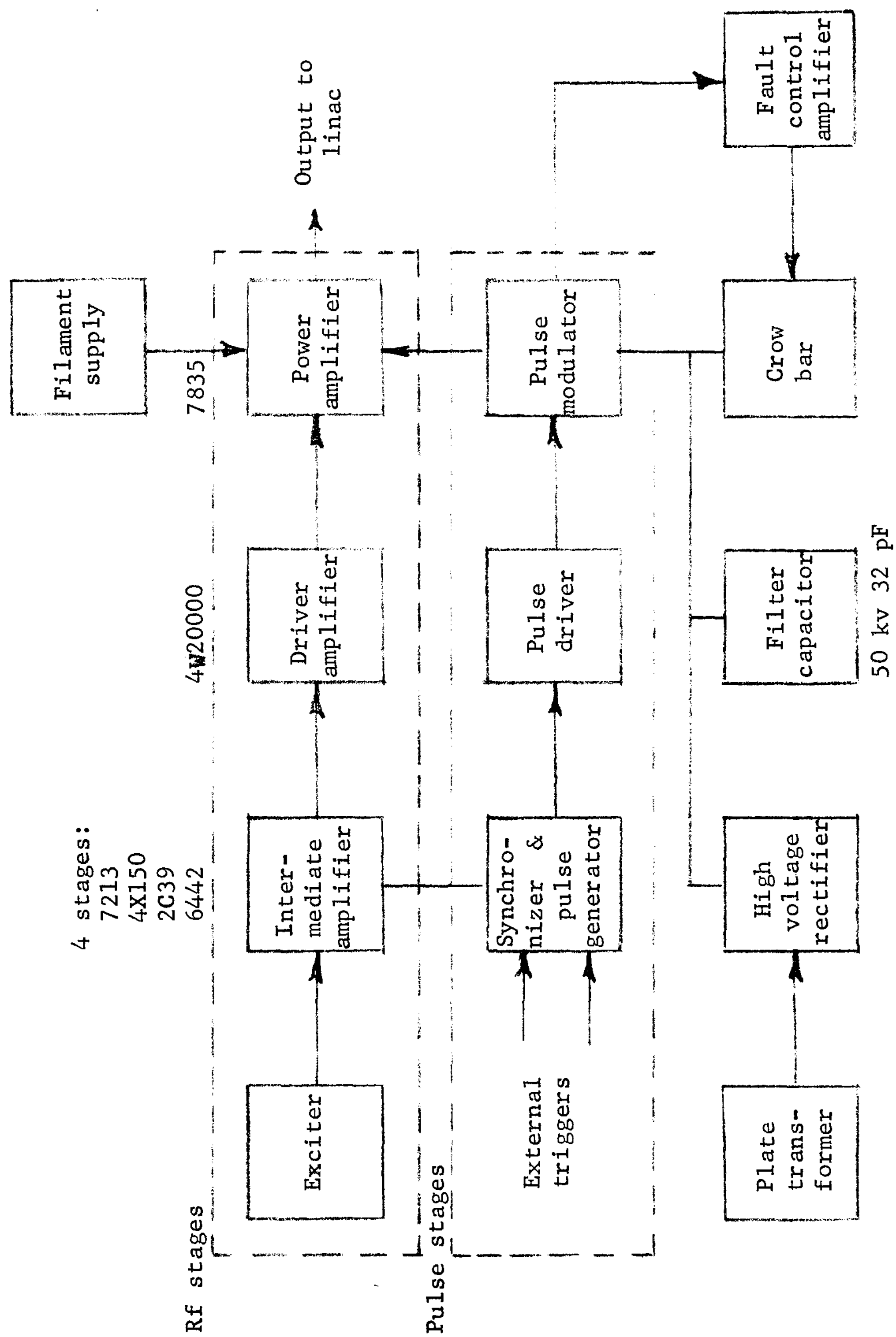

Fig. 7
Block diagram
Linear accelerator radiofrequency system