DEBUNCHERS

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There is some question as to the need of a debuncher for a high energy proton linear accelerator. Considering a 3 Bev linac with parameters as given by L. Smith, a momentum spread given by $\Delta p/p \cong 0.001$ is to be expected. Combined with this, for an operating frequency of 1000 Mc/s, the spread in phase angle would be $\Delta\theta \cong \pm 2.5^{\circ}$. At 200 Mc/s this would be $\Delta\theta \cong \pm 0.5^{\circ}$. These results hardly indicate the need for a debuncher. However, similar arguments existed before in connection with the CERN PS injector. A debuncher was nevertheless built and installed at the 50 Mev linac end. Its effect on energy spread was negligible because this was already small. It did, however, produce the effect of smoothing out the results of rf instabilities in the linac tanks. Also, it had a tendency of reducing momentum errors.

In the light of this, it was decided to incorporate a debuncher in the study for a high energy linac because it is useful in reducing the effect of irregularities in the machine.

The simplest debuncher is, of course, an inverted single gap buncher with drift space. This is practical at low energies. For example, at 50 Mev, an rf voltage of 600 kv plus drift space of 15 meters is needed, as in the CERN PS. At relativistic energies, this method is useless because of the impractical drift length required.

The obvious way of debunching relativistic particles is to use a magnetic debuncher, which consists of a series of magnetic prisms followed by an accelerator cavity. Particles of different momenta travel different distances through the magnetic system and arrive at the accelerator gap at different times. A system of this sort has been studied by J. Parain*. After having evaluated a few simple arrangements with only a few magnets, the system shown in Fig. 1 was arrived at. This would be followed by an rf cavity, which is not shown. One advantage here is that this provides the possibility of putting in higher harmonics in the accelerator section which would reduce the nonlinearities. For the parameters considered, these can be quite serious. This type of debuncher becomes rather impractical if particle energies in the Bev region are considered. At 3 Bev, the over-all length required for this system is approximately 100 m, requiring 90^{o} bending magnets in which the beam radius of curvature would be of the order of 6.5 meters.

Another method to obtain particle debunching is to make use of the linac itself by adjusting the phase in certain sections such that a shift back and forth takes place from the area near the stable point in a $\Delta\gamma$-$\Delta\varphi$ plot to the area near the unstable point. In its essence, this method was used several years ago by Professor Hein to reduce the rf structure on the PS by switching over to the unstable point after transition, then letting the beam drift a certain time and following this to manipulate it back to the stable point. For matching the linac to the synchrotron this method was first proposed by L. C. Teng.** The usual method of matching linac to synchrotron is illustrated in Fig. 2a.

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*AR/Int SG/62-3

**L. C. Teng, IA LCT-3, April 1961; also "Linear Accelerator Conference Report", IA AvS-1, 1961

The method, as proposed, would require now a transition of boundary 1 from the stable point to boundary 1' around the unstable point, as shown in Fig. 2b. After some drift space the particles would be represented by boundary 2 around the unstable point, which would be transferred back to the stable point, becoming boundary 2', which finally ends up as boundary 3, as desired. By judicially adjusting the durations of operation near stable point and near unstable point, it is possible to manipulate the original phase space boundary to the desired shape for acceptance in the synchrotron. This method has been further considered by J. Parain* and applied to the practical case of a 3 Bev linac. From this it became evident that nonlinearities would limit the extent of debunching possible. This actually applies equally so to the magnetic debuncher. Four cases were considered and the results obtained for these are enumerated in Table 1. The values listed indicate maximum possible debunching factors as limited by nonlinearities. In the last case mentioned, a debunching factor of 28 is obtained; however, this is at the cost of a substantial extension in over-all linac length.

The rather strict criterion of avoiding nonlinearities was applied not only because it was a convenient mathematical criterion but also because in the course of higher energy machine studies, beam stacking of linac pulses before acceleration was considered. In that case, a near "adiabatic" beam is required. Disregarding this particular case, the criterion of avoiding nonlinearities might be too stringent and better debunching factors could be obtained if a certain amount of nonlinearities is tolerable. This is really determined by the bucket height available in the synchrotron. Nevertheless, the boundary 3 as

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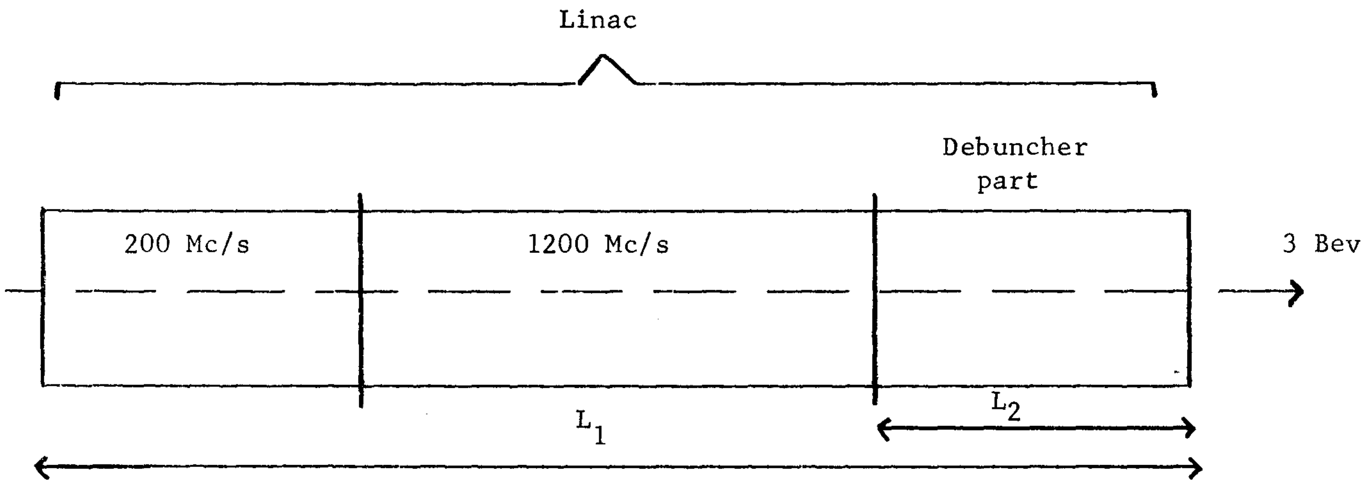
*AR/Int. SG/62-9, August 1962

Table 1



	No debunching in linac	Debunching during acceleration using 1200 Mc/s sections	Debunching during acceleration using 200 Mc/s sections	Debunching without acceleration using 200 Mc/s sections
field strength - 10^6 (V/m)	6	6	4	4
freq. (Mc/s)	1200	1200	200	200
φ_s (o)	60	60	60	0
$\Delta\varphi$ (o) as limited by nonlinearities	±3	±8	±8	±14
$\Delta\varphi'$ (o) considering acceptance of synchrotron using 200 Mc/s	±0.5	±1.3	±8	±14
L_2 (meters)	0	52	312	254
L_1 (meters)	656	656	768	910

shown in Fig. 2b might end up distorted to such an extent that in essence, the over-all energy spread is not improved if compared with boundary 1. This is indicated by boundary 3* in Fig. 2b. It should be stressed again that the need of a debuncher depends to a great extent on how stable linac performance can be made with regard to phase, rf level, and so on.

Discussion

L.C. Teng (ANL): The side lobes in the distorted phase space boundary due to nonlinearities do not contain a substantial fraction of the beam; one might be willing to sacrifice these.

K. Johnsen (CERN): As said, avoiding nonlinearities is a convenient mathematical criterion and it should be used judicially. Nevertheless, it provides a good approximation of optimum debunching possible with this method. In a first approach, however, it is more important to make sure that all particles are acceptable to the synchrotron bucket rather than asking for a near adiabatic beam required for the more futuristic application of beam stacking, which would probably not be done until a long time after the machine has been built.

J.P. Blewett (BNL): Another place where it would be useful to have a 100% efficient debuncher and buncher might be at the point where one changes frequency in the linac. If this linac serves as an injector for a larger machine, it would be attractive to have all of the buckets filled at injection into the synchrotron rather than just every other one or every sixth one.

K. Johnsen (CERN): A similar situation exists when a booster ring is introduced between linac and final accelerator, as has been considered at CERN for higher energy machines.

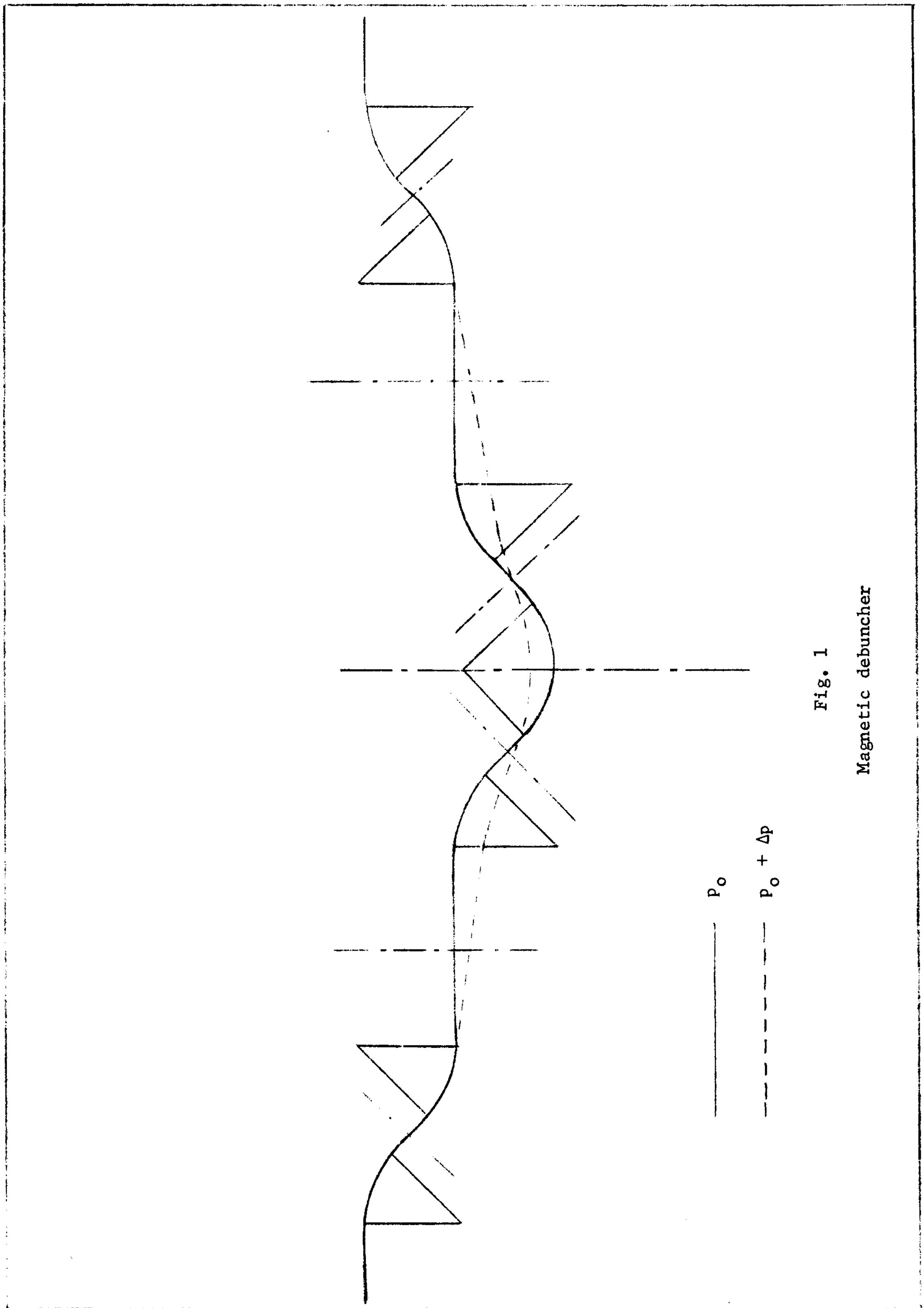


Fig. 1

Magnetic debuncher

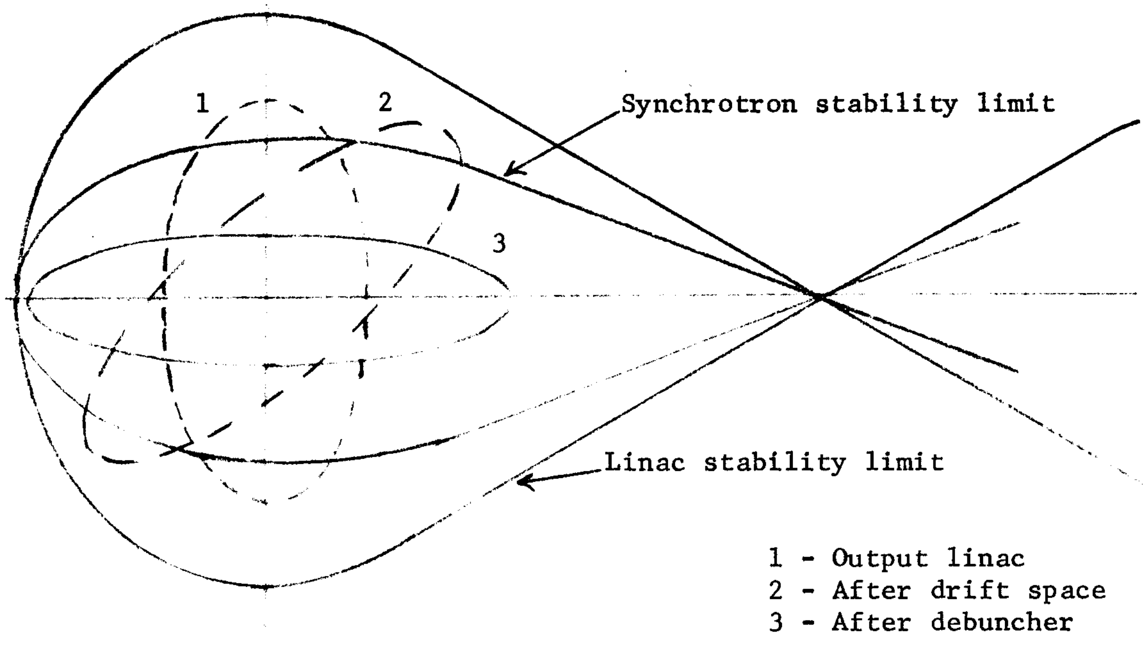

1
2
3
Synchrotron stability limit
Linac stability limit
1 - Output linac
2 - After drift space
3 - After debuncher

Fig. 2a

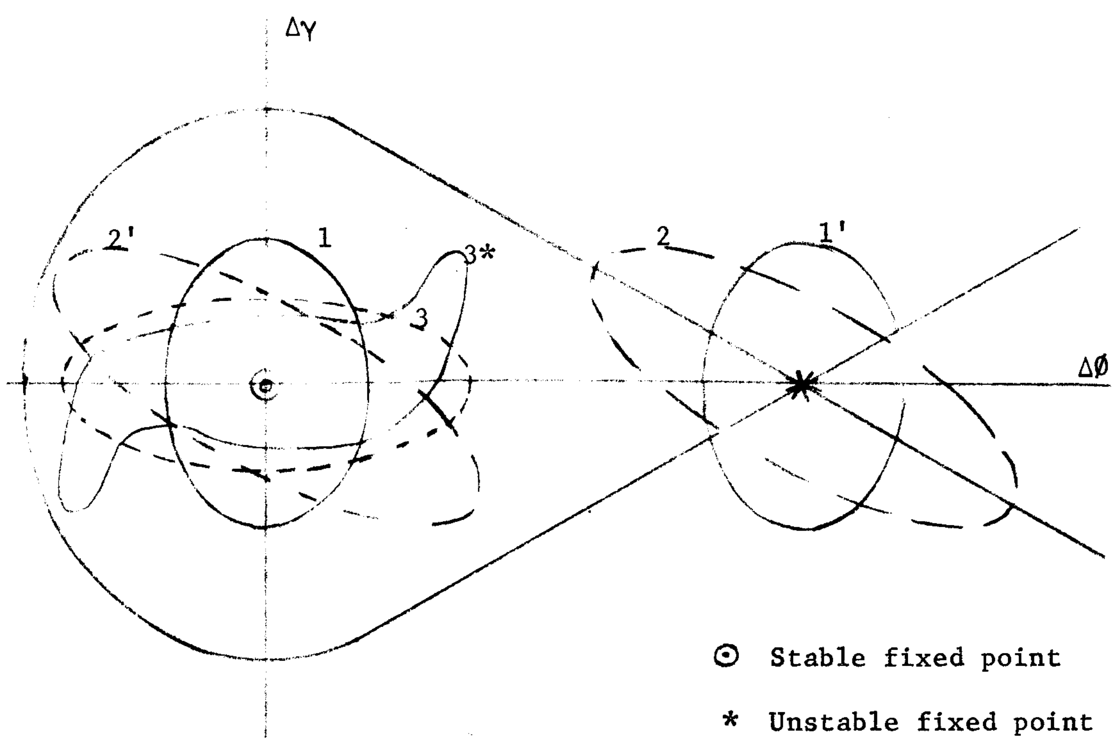

ΔY
2'
1
3*
3
2
1'
ΔØ
⊙ Stable fixed point
* Unstable fixed point

Fig. 2b