POST COUPLER STUDIES FOR ALVAREZ TANKS TO BE USED FOR HIGH POWER OR VARIABLE ENERGY

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Summary

The on-axis electric field in a 22 cell Alvarez tank that models the 0.8 MeV to 2.8 MeV section of a 268 MHz linac has been stabilized with post-couplers at a constant spacing from the drift-tube. Measurements on field shaping with post-couplers show that a step function in the on-axis field can be produced by introducing post-coupler asymmetries. This field shaping which can be used to allow a wide range of output energy variability from an Alvarez linac can be produced with post-couplers on each drift-tube or on every second drift-tube.

Introduction

Post-couplers in a drift-tube linac are important in stabilizing the on-axis electric fields against tilts produced by mechanical errors[1,2]. Recently it has been proposed[3,4] that post-couplers could also be used to shape the on-axis fields along the linac length in a manner that would allow a wide range of energy variability for the output beam. Drift-tube linacs normally have a very narrow range for the output energy.

The long range goal for accelerator development at the Chalk River Nuclear Laboratories is the development of high current cw linacs suitable for electronuclear fuel breeding. Large frequency shifts can occur in such accelerator structures operated in the cw mode (100% duty factor) because of the high average power dissipated in the structure walls. One or more mechanical tuners are required in each accelerator structure to correct for frequency shifts and to ensure that each structure operates at the same frequency. On-axis fields were measured in a low power drift-tube linac model to determine optimum post-coupler dimensions that stabilize the structure against tilts introduced by adjustable tuners. During the course of these measurements, on-axis field shaping with post-couplers was investigated.

Experimental Model

On-axis fields were measured on a 22 cell aluminum Alvarez drifttube tank that was available from a previous experiment. Figure 1 shows a photograph of the 50 cm diameter 372 MHz tank, a 0.72 scale model of the 0.8 MeV to 2.8 MeV section of the 3 MeV High Current Test Facility linac[5]. Drift-tubes were 98 mm diameter with a 11 mm diameter bore hole. The first and last full drift-tubes were 26.6 mm and 44.6 mm in length respectively. Field perturbations were introduced by adjusting the tank end plates to give a field tilt while maintaining a fixed resonant frequency.

Initial experiments on field stabilization used 19 mm (nominal 3/4 inch) diameter rods for post-couplers. This diameter was chosen to be equal to that of the drift-tube stems. Eccentric tabs with total areas 1.85 and 5.69 times the post-coupler cross-section were used for measurements involving field shaping. Three post-couplers showing the different end arrangements are shown in Fig. 2 together with the first drift tube.

Field Stabilization

Field tilt is defined as the difference in the on-axis electric field from one end of a tank to the other end divided by the average on- axis electric field. Adjustments of field tilt for the model tank were made by increasing or decreasing the length of the first cell by 2 mm or 3 mm with a movable end plate. Shifts of +1.0 MHz to -0.5 MHz in tank frequency were introduced by these adjustments. Since tilt measurements must be made at a fixed frequency the length of the final cell was adjusted to maintain a fixed frequency. The end plate shifts introduce severe distortions in the first and last cell lengths. Experimentally the tilt was found by averaging over the three cells next to the end ones.

Standard bead perturbation methods were used to sample the on-axis electric fields. First measurements made without post-couplers showed a linear dependence of the tilt on end plate frequency shift, with a slope of 57%/MHz. Ten 19 mm diameter post-couplers were then installed and located opposite the even numbered drift tubes, alternating from side to side of the tank.

Since the model represents the low energy section of a linac, cell lengths change fairly rapidly. The last drift-tube is almost a factor of two longer than the first drift-tube. Initial measurements of tilt stabilization were therefore made with a smaller post-coupler-to-drift-tube spacing at the low energy end than at the high energy end in an attempt to equalize the couplings. This approach results in the variation of two parameters namely the post-coupler-drift-tube spacing and the spacing increase along the tank length - making data analysis more complicated than necessary. An attempt was then made to stabilize the fields with a constant post-coupler-to-drift-tube gap. At a spacing of 26.5 mm a tilt stability of less than 1%/MHz was achieved corresponding to a stability improvement by a factor of 57. Individually adjusting the spacing for each post-coupler did not lead to a significant improvement in tilt stability.

Tilt stability is only one parameter that determines optimum post-coupler positions. The ratio of fields in all cells with and without post-couplers serves as a second parameter. Tilt stability may be improved by large post-coupler-to-drift-tube spacings but severe oscillations in the field amplitude can result along the tank. At the optimum 26.5 mm spacing the ratio of fields without post-couplers to the fields with couplers is constant within 2%.

Tilt stability measurements were also made with the two different sizes of eccentric tabs. Shifts of less than 1%/MHz were achieved in each case. The post-coupler-to-drift-tube spacing required increased from 26.5 mm to 34.2 mm for the small tabs and to 54.2 mm for the large tabs. The tabs showed minor improvements in field smoothness.

Field Shaping

A perturbation of the symmetry of a post-coupler-drift-tube geometry such as tab rotation can produce changes in the on-axis electric fields along the linac length. Recently Swenson et al.[3,4] have proposed the use of perturbed post-couplers to introduce a sufficiently large step reduction in the on-axis fields that will drop the beam out of synchronism with the field in a programmed manner. This field reduction can give a wide variable-energy capability to a single-tank drift-tube linac.

Experimental measurements were done to produce such a step reduction in the model tank by rotating post-coupler tabs. Initial measurements were made with 10 post-couplers opposite the even numbered drift-tubes, as above, and with the small eccentric tabs. Rotating tabs 90° from the symmetric vertical position resulted in a very small (1%) change per coupler indicating that the tabs were too small. Large tabs were then mounted on the posts; Fig. 3 shows the results of rotating 1, 2 or 4 large tabs 90° towards the high energy or downstream end of the tank. Tabs on the upstream and downstream post-couplers remained unchanged at 0°. The peak on-axis electric field is shown plotted relative to the field with all tabs vertical. Coupler numbering refers to the drift tube opposite which the coupler is mounted. (Coupler 10 therefore is between gap 10 and 11.) The field reduction produced beyond the rotated tabs is 5%, 12% and 22% for 1, 2 or 4 tabs respectively. In addition to the field reduction in the downstream part of the tank, a field increase of about 5% occurs over several cells upstream of the ones containing rotated couplers. Only the number of cells affected changes as the number of rotated tabs increases. Similar results were obtained for the perturbation beginning in an earlier or later cell. This then would be the mechanism to produce a variable energy drift-tube linac. By pre-programming the location of the perturbation, various energies can be achieved. (A step increase can similarly be produced by rotating tabs toward the upstream end of the linac.)

Various schemes of reducing the upstream field increase have been tried without success. Figure 4 shows fields for a gradual rotation of the post-couplers by four successively larger steps (22.5°, 45°, 67.5°, 90°). The net result was to increase the number of cells across the step and to decrease field step from 22% to 16%.

Tilt stability was checked for post-couplers rotated 90° downstream. Rotating 4 tabs 90° introduced a 6%/MHz shift and rotating all 10 tabs 90° introduced a 12%/MHz shift. To stabilize the tilt to < 1%/MHz with 4 tabs rotated 90° as shown in Fig. 3 required an increase in the coupler-to-drift-tube gap from 54.2 mm to 56.2 mm on all couplers. No significant change in the field pattern occurred with this spacing change.

For a second series of measurements post couplers with large tabs were installed opposite each drift-tube. As described before, successive couplers were located at alternate sides of the tank. Tilt stabilization to < 1%/MHz was achieved at a constant spacing of 52.0 mm for all 21 post-couplers. This spacing was 2.2 mm closer than that for the 10 post-coupler measurements associated with post-couplers opposite only even-numbered drift-tubes.

Figure 5 shows normalized peak on-axis electric fields for the 21 post-coupler arrangement with 1, 3 and 6 tabs rotated 90° towards the upstream end. Field reductions of about 2%, 6% and 14% respectively are produced in cells beyond the perturbed tab location. Field perturbation per tab is a factor of two smaller than the case of the same area tabs on 10 post-couplers opposite even-numbered drift-tubes. This is at least partly the result of a compensating effect on the asymmetry by the tab from the adjacent cell. Again, similar results are obtained if the location of tab perturbations is centred about different cells than shown in Fig. 5.

A field increase is again evident in gaps upstream of the rotated couplers but the number of gaps affected is less. The magnitude of the increase depends on the number of rotated couplers - an effect not observed in the 10 post-coupler measurements.

Figure 6 shows the field step produced by 6 couplers all rotated 90° compared in four successively larger 22.5° steps with the last two tabs at 90° and compared to six tabs rotated by successively larger 15° steps. Field reduction downstream of the rotated couplers is largely unchanged while the field increase upstream can be reduced by a factor of 3 using this procedure. No such reduction was observed in the 10 post coupler case.

Figure 7 shows the normalized field produced by six successively larger 15° step tab rotations beginning at drift tubes 7, 10 and 14. Slightly larger steps are produced as the starting location moves downstream. This effect is likely the result of increased perturbation with increasing drift-tube length.

As a final confirmation of the procedure, tilt stability with the case of six couplers rotated 90° was found to be essentially unchanged from the 1%/MHz value observed with all tabs vertical.

Conclusions

In addition to their usual function of providing field stability, post-couplers can be used to introduce a step reduction in the on-axis electric field along a drift-tube linac. Unfortunately a field increase is also introduced in cells upstream of the perturbed cells. The magnitude of this upstream perturbation can be reduced by introducing a gradual cell-to-cell tab rotation for the case with post-couplers adjacent to each drift-tube but remains unchanged for the case with couplers on every second drift tube. With post couplers on each drift tube, tilt stability is not disturbed by tab rotation. This stability is partially destroyed with tab rotation when post-couplers are placed opposite every second drift-tube but can be regained by a small increase in the post-coupler-to-drift-tube spacing.

Measurements on stable field steps reported here are only associated with a rotation of the eccentric tab on the end of the post-coupler because this was the easiest procedure to perform in the laboratory. Obviously many other schemes can be employed such as movement of the post-coupler to an asymmetric location or the extension of the end of the post-coupler in an asymmetric manner. The effects the introduction of a step has on drift-tube and post-coupler stem currents and the associated consequences they have on the cylindrical outer wall joint have not been investigated. Such measurements would be difficult for low-power rf systems and would best be done on high-power rf systems that are properly instrumented.

References

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2. C.W. Owen and J.D. Wildenradt, "Experiences with Post Coupler Stabilized Structures in the NAL Linac", Proc. 1970 Proton LInac Conference, Batavia (1970).
3. D.A. Swenson, T.J. Boyd, Jr., J.M. Potter and J.E. Stovall, unpublished Los Alamos Scientific Report AT-1-81-69.
4. D.A. Swenson and J.E. Stovall, "A Continuously Variable Energy Drift Tube Linac", proceedings of this conference.
5. J. Ungrin, J.C. Brown, B.G. Chidley, G.E. McMichael and S.O. Schriber, "Initial Operation of a 100% Duty Factor 3 MeV Alvarez Linac", IEEE Trans. Nucl. Sci., NS-28 (3), 3495 (1981).

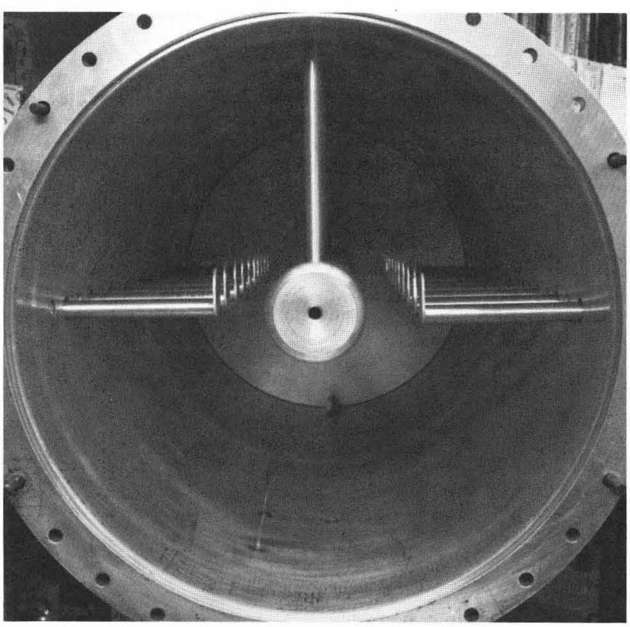

Fig. 1 372 MHz aluminum Alvarez model.

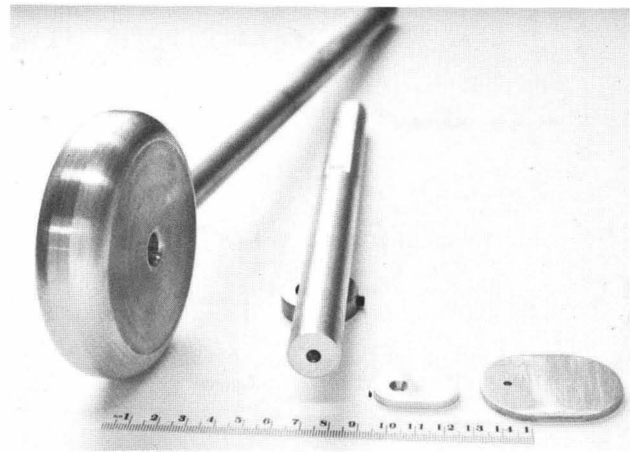

Fig. 2 Post couplers and tabs shown with drift tube number 1.

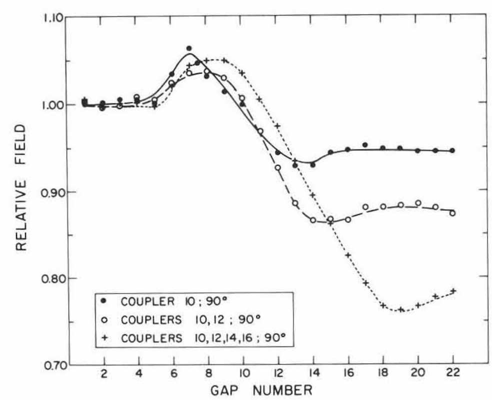

Fig. 3 Normalized on-axis field with one, two, or four large tabs rotated 90° downstream. Post-couplers on even drift-tubes only.

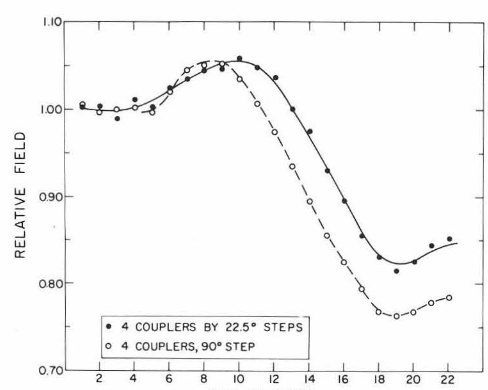

Fig. 4 , Comparison of four tab case of Fig. 3 with case of four successive 22.5° steps.

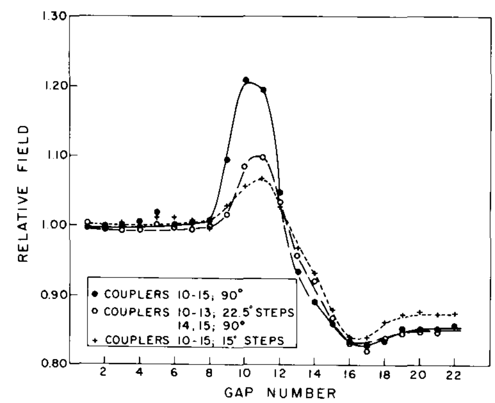

Fig. 6 Reduction of upstream perturbation with gradual tab rotation. Geometry as in Fig. 5.

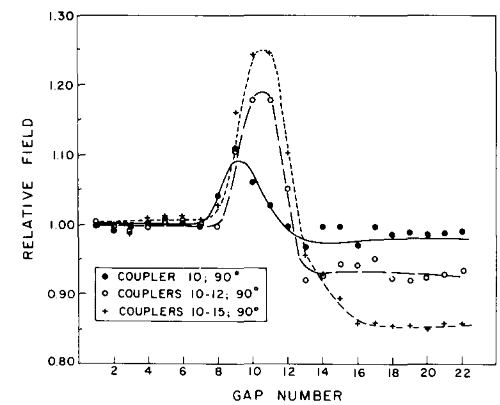

Fig. 5 Normalized on-axis field with one, three or six large tabs rotated 90°. Post-couplers opposite all drift tubes.

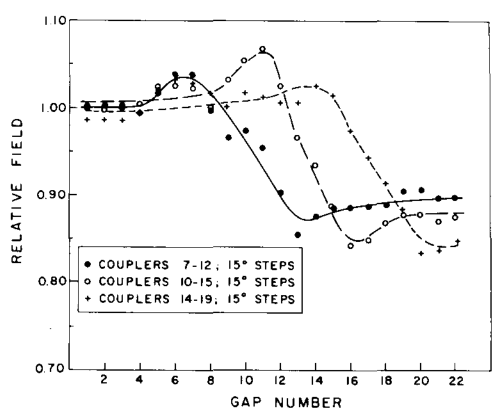

Fig. 7 Step produced by six successive 15° steps started at drift-tubes 7, 10 and 14.