# RF-TUNING OF THE HERA LINAC 3 ALVAREZ STRUCTURES

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## Abstract

For the RF-tuning of the HERA Alvarez linac 77 postcouplers have to be adjusted in length and angle in addition to the usual rf resonator measurements; this tuning was done in a straightforward way:
For each tank the passband modes were first identified. After inserting the postcouplers, the mapping of the postcoupler and drifttube passbands and a stabilisation measurement were made by varying only the coupler length. The quality of the stabilisation was checked by computer with endcell plungers specially inserted and controlled for this purpose.
As a final step the tabs of the postcouplers were adjusted.

## Introduction

The HERA LINAC 3 Alvarez structure consists of three tanks. It is a copy of the CERN Proton Linac II. As the tanks will be loaded with only 20 mA $H^-$-ions, the necessary number of feeders is reduced to one per tank.
Table 1 gives some parameters:

Table 1 - Tank Parameters -

| | | Tank 1 | Tank 2 | Tank 3 | |
|---|---|---|---|---|---|
| Input energy | | 0.75 | 10.35 | 30.48 | MeV |
| Output energy | | 10.35 | 30.48 | 50.00 | MeV |
| Cavity length | | 6.94 | 12.96 | 13.36 | m |
| Nos. of unit cells | | 52 | 44 | 32 | |
| Nos. of postcouplers | | 25 | 21 | 31 | |
| Cavity diameter = D (ID) | | 94 | 90 | 86 | cm |
| Drifttube diameter = d (OD) | | 18 | 16 | 16 | cm |
| (D - d)/2 λ | | .256 | .25 | .236 | |
| Group velocities / length | | | | | |
| driftt.0- 1 | (146) | 160 | 88 | 77 | MHz |
| postc. 1- 3 | ( 22) | 50 | 25 | 43 | MHz |
| postc. 1-10 | ( 18) | 60 | 55 | 43 | MHz |
| Destabilisation | ( 5) | 4.0 | 5.4 | 2.2 | us |
| Δ f unstab.- stab. | | 40 | 50 | 120 | kHz |

One postcoupler is mounted per two full drifttubes in tank 1 and tank 2 and one per full drifttube in tank 3, their tabs are 25 mm by 45 mm.

The postcoupler position must be fixed after its adjustment in length and angle. The length was varied with an accuracy of 0.1 mm, the angle in 0.5° steps. As the rf connection is done by the same finger contacts before and after fixing there is no change except for errors due to the reassembly of the couplers.

## Measurement Set-Up

All measurements were done completely by computer. The principal set-up is shown in Fig.1. Tank field measurements were realized by perturbation with a slim ceramic bead. For this purpose step motor units were mounted on the ends in order to pull beads over the different tank distances (see Fig. 2).
The position of the bead and the tension of the string were checked automatically by a light and a tension sensor. A bead of 1 gram was 2 mm off center when pulled by a 14 m long string with a tension of 20 N.

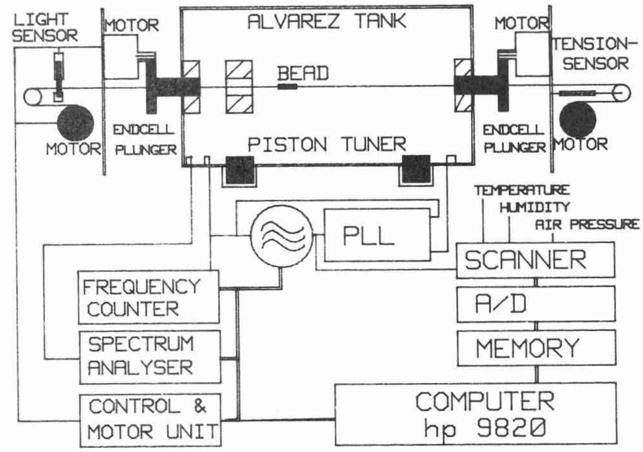


Fig. 1 Block diagram of the measurement set-up

An endcell plunger on each side of the cavity made it possible to produce field tilts. With computer controlled data aquisition it was possible to speed the bead up to the mechanical limits. Push button menue computer software was made for quick measurements, analysis and prediction. Q measurements, frequency scans and brillion diagrams were also controlled by software.

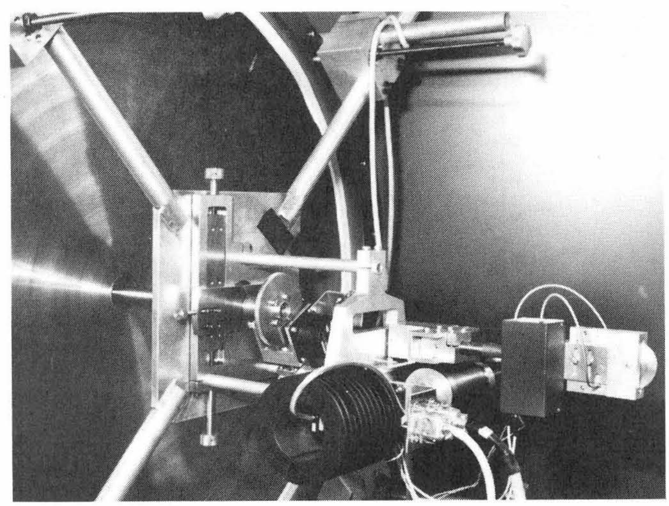

Fig. 2 Step motor unit with light sensor and endcell plunger

## Frequency Tuning

The fine tuning range of all tanks is about 60 kHz, it is realized by up to four piston tuners.
Bulk tuning is done by a T shaped bar. Model measurements showed a good agreement with estimates given by Wheeler[1] for a rectangular bar. The right frequency range was reached in one tuning step. Humidity and air pressure were taken into account.

## Q - Values

The inner surface of the tanks was produced by electroplating. Aluminum wire joints are used for rf and vacuum. The reductions of the unloaded Q during assembly of components are given for tank 1. The final Q values of all tanks are listed also.

Table 2 - Q Values during assembly and final results (in thousands) -

| | Q | ΔQ |
|---|---|---|
| Tank 1 | | |
| as a cylindrical cavity (theory) | 104 | |
| | | 41 |
| measured with bulk tuner | 63 | |
| | | 4.7 |
| as an Alvarez resonator (measured) | | |
| with stems and drifttubes | 58.3 | |
| with two piston tuners: | | |
| in lowest penetration | 58.3 | |
| | | 1.7 |
| in highest penetration | 56.6 | |
| decrease by postcouplers | | 3 |
| Tank 1 all components mounted | | |
| feeder loop shorted | 55 | |
| ====== | | |
| Tank 2 " " " | 49 | |
| ====== | | |
| Tank 3 " " " | 60 | |

## Tuning and Stabilisation Strategy

First the drifttube passbands were measured without postcouplers in the frequency domain. Then all postcouplers were moved by equal distances into the tank until the confluence of the drifttubes and postcoupler passbands was reached (see Fig. 3). All tabs were vertical and pointed down.

In order to fine tune the postcoupler length a stabilisation measurement was done by minimising the effect of endcell detuning.

The tabs were then turned for the first time in order to reach the theoretical field profile calculated by SUPERFISH.

In the next step the upper plate of the T - shaped bulk tuner was removed and the new size of the tuner was calculated.

Finally with the new bulk tuner size the stabilization was checked again and then the tabs were turned. This was done until the differences between theoretical and measured values were better than 2% for tank 1 and 1% for tank 2 and tank 3.

## Drifttube and Postcoupler Passbands

The drifttube passbands of the tanks were identified by field measurements without postcouplers and were checked when the posts were moved in.
The postcoupler passband and part of the drifttube passband at confluence are shown in Fig. 3.

The group velocities of the first part of the drifttube passband (mode 0 and mode 1) and of the postcoupler passbands are given in Table 1.

The velocities of the postcoupler passbands were calculated between mode 1 and mode 3 and between mode 1 and mode 10 from

$$vg = 2 N L (fi-fj)/(ni-nj)$$

where:
f = frequency, n = mode number, L = cell length, N = number of modes in the passband.

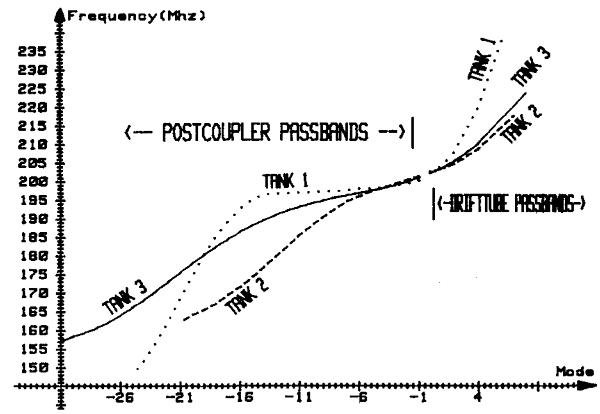


Fig. 3 Postcoupler and drifttube passbands

When all postcouplers of tank 1 have the same length then the group velocity in the range of mode one to ten is reduced compared to the other tanks.
The values for this case are given in parentheses for tank 1. For this reason several investigations (which are described later) were made with tank 1.

## Stabilisation Measurements by Endcell Detuning

Special plungers were used in order to make an endcell detuning possible (see Fig. 1 and 2). The frequency change by one endcell plunger of about 5 kHz was compensated by the piston tuner which was nearest to the opposite endcell. This produced the highest tilt. The normalized field midgap values ei,a and ei,b for the detunings of the two endcells were stored in the computer and the quotient eia/eib was displayed for analysis together with ei,a and ei,b.
A measure for the destabilisation was calculated by the relation:

$$\text{destabilisation} = \sum_i (|ei,a/ei,b|-1)/(N\ dF);$$

where:
i = cell number, dF = endcell detuning and N = number of cells.

The optimized destabilisation values for all tanks are given in Table 1.
A typical plot of destabilisation values dependent on postcoupler length is given in Fig. 4.

The accelerating frequency rises when the postcouplers are in stabilizing position (see Δf unstab.-stab. in Table 1).

## Problems with Tank 1

As mentioned before, the group velocity in the upper postcoupler passband of tank 1 was reduced. This effect is worst at passband confluence due to the lower capacity between postcouplers and drifttubes. At confluence the distance between postcouplers and drifttubes is 4(2) cm greater compared to tank 3 (2). This is due to the designed tank dimensions and leads to a reduced postcoupler mode spread at confluence.

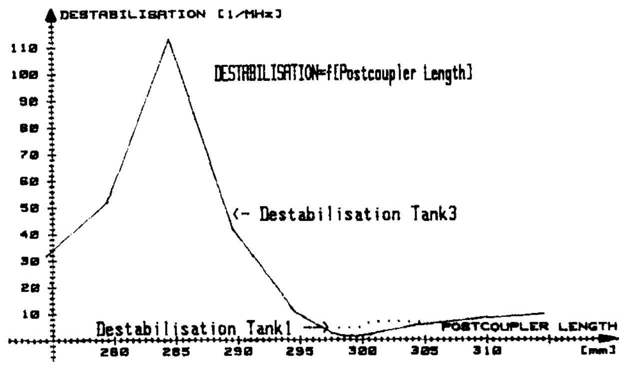


Fig. 4 Destabilisation as function of postcoupler length for tank 1 and tank 3

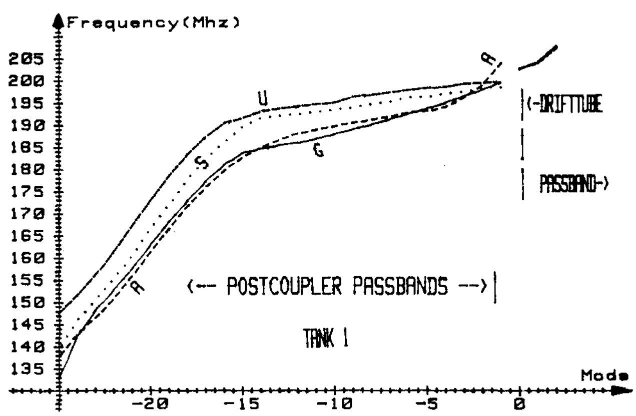


Fig. 5 Postcoupler passbands for different postcoupler settings which are shown in Fig. 6

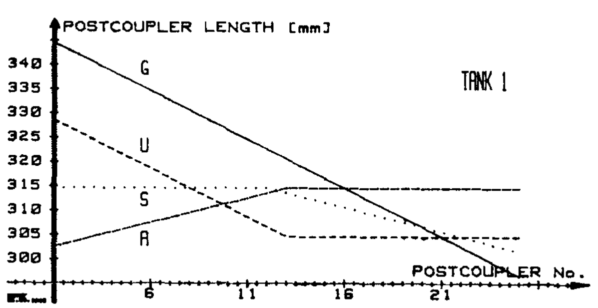


Fig. 6 Postcoupler settings in order to investigate the effect on the passbands

In addition the distance of adjacent posts is three times smaller in the low energy part of tank 1 compared to tank 2 and tank 3. The stroger inductive coupling gives an increased mode spread which can be seen in the lower part of the postcoupler passband (Fig. 5).

In tank 1 the drifttube length also increases by a factor three from the beginning to the end thus improving the capacitative coupling of the postcouplers in the high energy part of the tank. In order to raise the postcoupler frequency and improve coupling a postcoupler length which is reduced to the end of the tank is the best solution (see Fig. 5 and 6, curve G).
This is confirmed by a high group velocity in the drifttube passband and high velocities in the postcoupler passband as well.
The destabilisation curve of tank 1 under these conditions showed no minimum like tank 2 or tank 3. The curve dropped just before the point where the difference between the accelerating mode and the highest postcoupler mode was equal to the difference of the two lowest accelerating passband modes.

For investigations with larger tabs and interpretations of the curves of Fig. 5 and 6 and lumped circuit calculations see [4].

## Conclusion

The stabilisation of Alvarez tanks can be done in a straightforward way. After reaching passband confluence in the frequency domain, the postcoupler length can be optimized by reducing the effect of endcell detuning. If the coupling of the posts is sufficient then all posts can have the same length.

Only in the final step are the tabs adjusted for the required field.

## Acknowledgements

The author gratefully acknowledges the help of L. Becker +, U. Timm +, S.H. Wang *, G. Sandels ++, D. Warner ** and the HERA LINAC 3 team.
+ DESY, ** CERN, ++ Rutherford Institute,
* Institute of High Energy Physics, Beijing.

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