BEAD PERTURBATION MEASUREMENT*

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ABSTRACT

A common method of determining the fields in a linear accelerator tank is to measure the change in the tank resonant frequency when a small metallic bead is pulled through the accelerating gaps along the tank axis. A system for detecting and measuring these small frequency changes is described. The period of each cycle of a low beat frequency signal is accurately determined by means of a zero crossing detector and a digital timer. This data is collected and processed by a small digital computer and the results are displayed at the end of each run.

Introduction

To determine the magnitude of the electric fields in a linear accelerator tank it is common practice to set the tank up as a self excited oscillator and to then introduce a perturbation in the form of a small metallic bead which is pulled through the accelerating gaps along the tank axis. This produces small changes in the resonant frequency of the tank as the bead passes through the gaps; the measurement of these frequency changes will yield the value of the electric fields in the accelerating gaps. Since the tank resonant frequency is on the order of 201-MHz, and frequency changes caused by the bead are typically 100 to 200-Hz, it is necessary to translate the tank signal to a low frequency where these small changes can be measured. This is accomplished by heterodyning the tank signal with a stable local oscillator signal to produce a beat frequency of approximately 200-Hz. The changes in tank resonant frequency as the bead is pulled will then show up as large changes in beat frequency signal which are easily measured.

Description and Operation

As shown in Fig. 1 the tank, a phase shifter, and two power amplifiers constitute a resonant system whose frequency is determined by the tank. Although the tank frequency is quite stable in the short term it will tend to drift as the temperature of the tank wall changes, which implies that the local oscillator be adjustable in frequency yet extremely stable once set. The Gertch Model SSG-1 signal generator has these characteristics but its output contains many side bands and some line related modulation which adversely affect the 200-Hz beat frequency signal. To overcome this problem a battery operated crystal oscillator-multiplier chain is used as the 201-MHz local oscillator. This signal is nearly free of power

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line modulation and provides a clean 200-Hz signal when mixed with the 201-MHz tank signal. The oscillator-multiplier is phase-locked to the Gertch signal generator through a narrow band width loop to provide long term stability and fine tuning capability (10-Hz steps). The narrow band width filter prevents the line modulation of the Gertch signal from affecting the crystal oscillator frequency.

The period of each cycle of the 200-Hz signal is measured by the digital timer with a resolution of 1-μsec. At the end of each period determined by a zero crossing detector the count accumulated by the timer is transferred to a storage register, the counter is reset to zero, and an interrupt signal is sent to the computer. Before the end of the next period the computer has read the contents of the storage register through a prototype of the LAMPF Data Acquisition and Control Terminal (DACT).[1]

The computer program calculates a base line frequency from this data and looks for a significant change in the beat frequency as the bead approaches an accelerating gap. When this condition is detected, the program stores the values of each period of the 200-Hz signal as the bead progresses through the gap. From this data the fields in the gap are calculated. The process is repeated for each gap in the tank and the results are displayed in graphical and tabular form on a storage oscilloscope and teletype.

Optimum running conditions are found at night when the building is electrically quiet. All water must be turned off on the tank to reduce vibration, and the tank must be at ambient temperature to reduce base line drift.

At present, the system has been used to measure and set the field distribution in the first tank of the drift-tube portion of LAMPF. In the near future, the system will be used to facilitate the adjustment of the post-couplers in Tanks 2, 3 and 4 of the same linac. In this application the accuracy and speed inherent to this measurement technique will be of utmost importance since the technique for adjustment of the post-couplers is based on the detection of small changes in field distributions resulting from small frequency perturbations in the end cells.

Results

Figures 2 and 3 show the results from a single run and from an average of six runs all taken under the same conditions. The points are proportional to the measured field levels at each cell of the 31-cell first tank at LAMPF. The vertical scale is in arbitrary units running from 100 to 324 full scale. Each point is found by taking the integral of E·dL through a cell divided by the total length of the cell; this length is the distance between centers of drift-tubes. The solid line is the design field distribution normalized to have average value equal to the average of the 31 data points.

The scatter in the data points is primarily systematic and not due to random errors in the measurement; averaging of runs does not significantly reduce the point to point differences observed on the pictures. An estimate of the fluctuation from run to run is the rms of the percent differences between corresponding cells of any two runs taken under the same conditions. The two runs are first normalized to have the same average value. Four different pairs of runs from the set of runs in Fig. 3 have the following rms percent differences: 1.1%, 0.8%, 1.2% and 1.1%. Using the average of these pairs as representative, the rms fluctuation in any one run is 0.7%. The rms deviation of the six run average is 1.4%. Noise is only contributing 0.3% rms for an average of six runs.

The integral field values calculated by computer agree to 1.0% rms of the values found by using a chart recorder. This method measures the fields in the centers of the gaps and uses the known theoretical field distributions for each gap. This technique is described elsewhere.[2]

Conclusion

The instrumentation described here provides an accurate, rapid and graphic means for measuring the field distribution in a linac tank. The speed and accuracy of the technique and the fact that the data can be manipulated by the small on-line digital computer, will greatly facilitate the adjustments required for optimum performance of the new generation of resonantly coupled linear accelerators.

Acknowledgements

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References

[1] D. R. Machen, R. A. Gore, and D. W. Weber, "A Compact Data Acquisition and Control Terminal for Particle Accelerators," Proceedings of the 1969 Particle Accelerator Conference, IEEE Transactions on Nuclear Science, Vol. NS-16, No. 3, p. 883.

[2] "Quarterly Status Report on the Medium-Energy Physics Program for the Period Ending July 31, 1967," Los Alamos Scientific Laboratory, LA-3772-MS, Experimental Results on the 35-cell Model, p. 15.

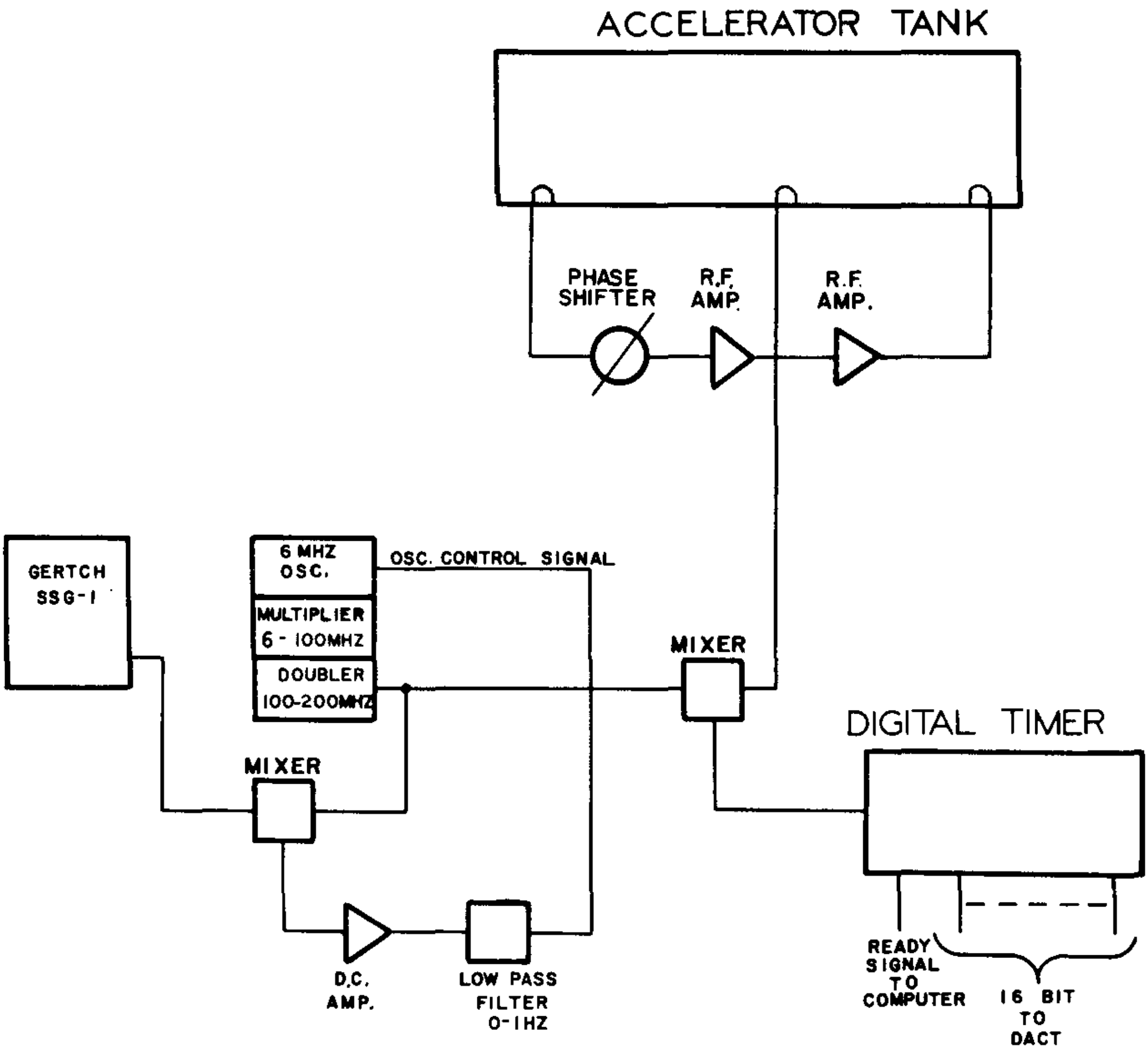

Fig. 1. Tank frequency measurement system.

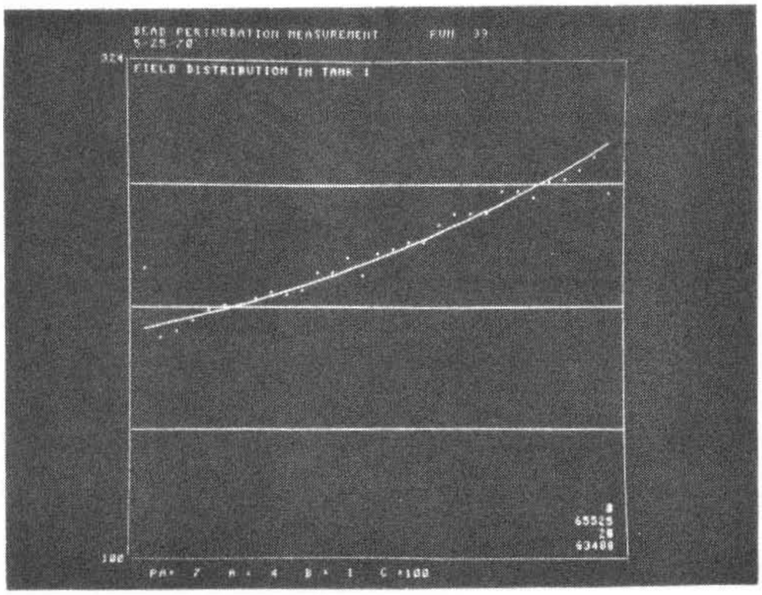

Fig. 2 Bead perturbation measurement. Field distribution in Tank 1.

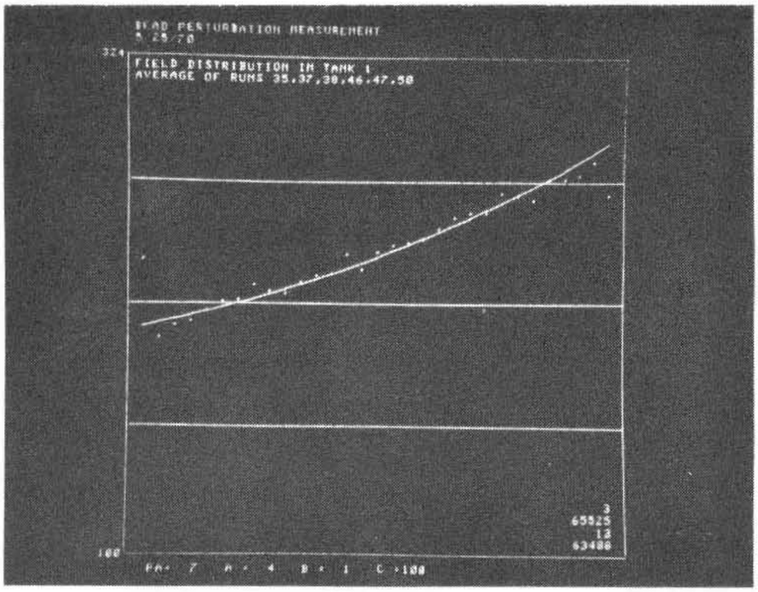

Fig. 3 Bead perturbation measurement. Field distribution in Tank 1, average of runs 35, 37, 46, 47, 50.