Presented at 5th European Particle Accelerator Conference (EPAC 96), 6/10/1996-6/14/1996, Sitges, Spain SLAC-PUB-9901

Microwave Cold-Testing Techniques for the NLC*

S. M. Hanna, G. B. Bowden, H. A. Hoag, R. J. Loewen, R. L. Miller, R. D. Ruth, J. W. Wang.
Stanford Linear Accelerator Center, Stanford, CA 94309, USA.

Abstract

The R & D program for the Next Linear Collider Test Accelerator (NLCTA) includes the development of microwave techniques for testing X-band accelerating structures at different stages of design, manufacturing and assembly. During the design phase, short stacks were built and tested to finalize dimensions. Cell by cell measurements were performed on the NLCTA injector cells as a micro-wave quality control (QC) after manufacturing. The two injector sections were tuned using a moveable plunger and tested using a semiautomated system of bead-pull. Using this perturbation technique, we were able to map the amplitude and phase of the electric field on the axis throughout the assembled structures under traveling-wave conditions.

1 INTRODUCTION

The development of high-gradient X-band accelerator sections for the Next Linear Collider (NLC), requires low power rf testing techniques that ensure the precise and reliable performance of these sections. For this reason, the NLC Test Accelerator (NLCTA) project [1] provides for an R & D program to develop the low-power testing techniques. These characterizing techniques are aimed at supporting different development phases of the accelerator sections; from the design, through manufacturing, and finally testing of the complete accelerator section. In Fig. 1 we summarize the series of tests that can be used through the development phases of an accelerator section.

In this paper, we will outline some of the above testing techniques. Results of measurements performed on the two NLCTA injector sections are presented as examples of the implementation of these testing techniques.

2 MICROWAVE QC

In the Detuned Structure (DS) used for the NLCTA injector sections, the diameter of each cell (2b), the thickness of its iris (t) and the diameter of its aperture (2a), all vary progressively from cell to cell. The goal is to detune the dipole modes and prevent short range cumulative build up of wake fields, while maintaining quasi-constant gradient characteristics of the fundamental accelerating mode.

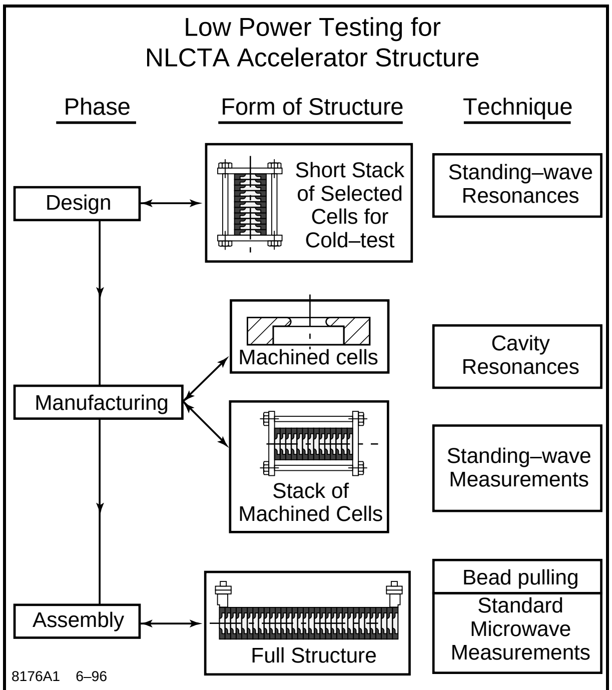

Figure: 1 Outline of different low-power microwave tests performed on NLCTA structures during the phases of design, manufacturing, and assembly.

To verify the regularity of machining of successive cells we measured the resonant frequency of the individual cells in the configuration shown in Fig. 2. The results of the measurement for the 204 cells of the two injector sections are plotted in Fig. 3. By plotting the inverse of the measured frequency versus the cell radius b, one obtains a straight line fit which is a convenient way of verifying the (2b) dimension.

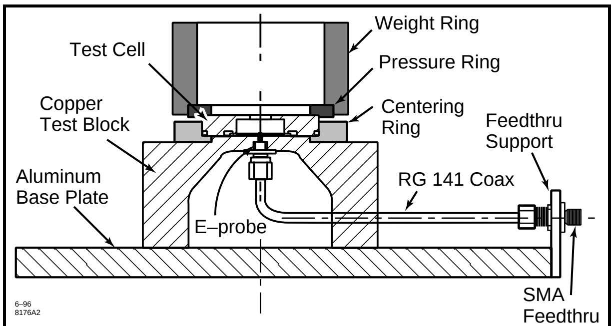

Figure: 2 Setup for microwave QC testing of individual cells of the two Detuned Structures (DS) of the NLCTA injector.

*Work supported by Department of Energy contract DE–AC03–76SF00515.

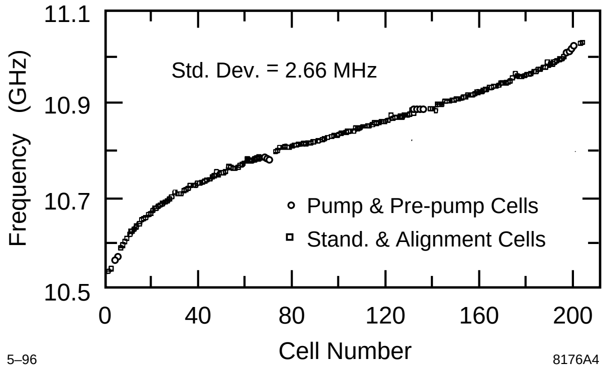

Figure: 3 Results of cell testing of the injector sections

3 TUNING AND TESTING INJECTOR SECTIONS

The use of brazing in the assembly of an accelerator section can result in deviations in the volume of the constituent cavities (cells). Thus it was required to tune individual cells in the injector sections. A stainless steel plunger was progressively pulled through the structure from the center of one cell to the next. The resulting phase shift was measured on a network analyzer at a frequency corresponding to the operating frequency 11.424 GHz and corrected for room temperature and dry N_2 under atmospheric pressure. In the two injector sections we tuned, the majority of the cells needed to be tuned by pulling their cylindrical walls outward to make up for the volume of the brazing fillet. The completed structure was finally checked using the bead-pull technique.

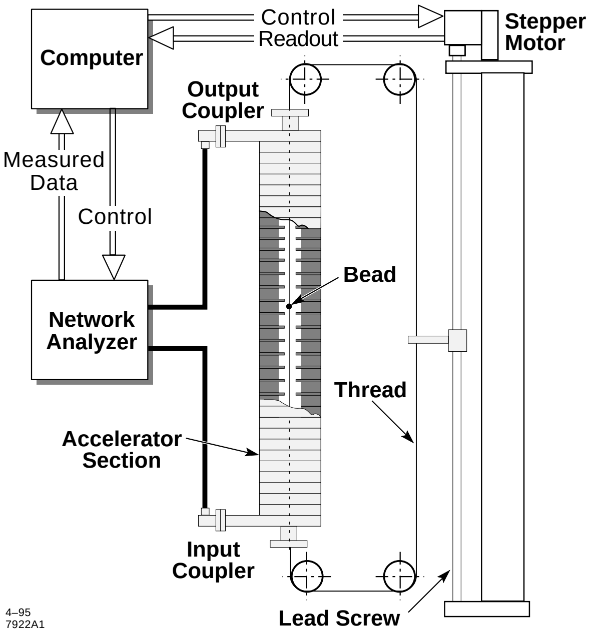

Figure: 4 Schematic diagram for the semiautomated bead-pull test setup

A. TW Perturbation Technique:

Mallory and Miller [2] were the first to use the bead-pull technique under traveling-wave conditions to measure the phase and field strength in accelerator structures. Steele [3] formulated the theoretical basis for the technique. We have built a semi-automated system [4] based on this technique to evaluate the tuning of X-band accelerators. Fig. 4 shows a schematic for our bead-pull system. A small metallic cylindrical bead is attached to a thin nylon string along the axis of the vertically-mounted accelerator section. The position of the bead is determined by the position of the carriage moving on a lead screw driven by a stepper motor. The computer which controls the motor also collects and processes the reflection coefficient data (S_{11}) from the microwave network analyzer. The field perturbation introduced by the bead located at a

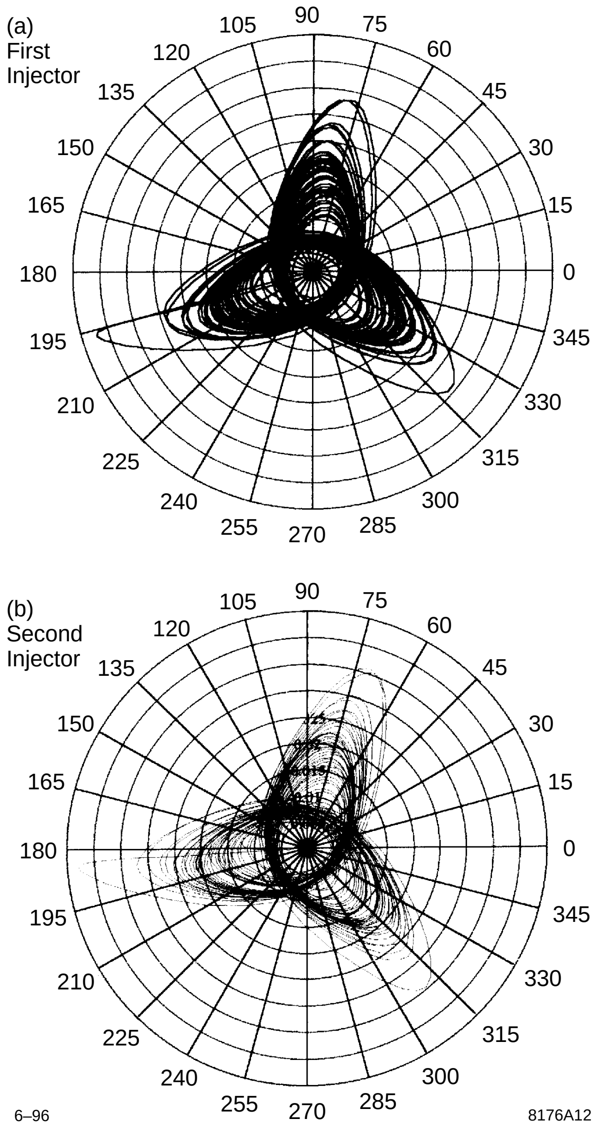

Figure: 5 Results of bead-pull measurements for the two NLCTA injector sections.

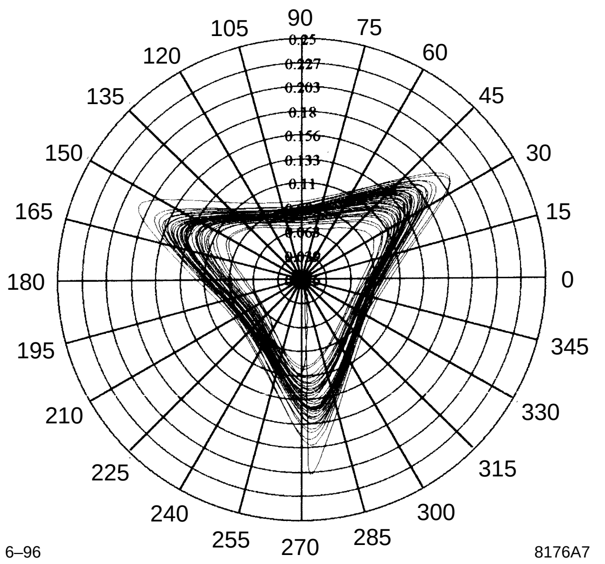

Figure: 6 Phasor of the electric field along the axis of the second injector section.

position z can be modeled as a reactive discontinuity in a transmission line. The susceptance associated with this disconti-nuity is proportional to the energy perturbation; and hence to the square of the field at this location. For a small needle-like bead located on the axis of the accelerator structure the field that is perturbed is the electric field of the 2π/3 mode.

$$E_z(z) = |E(z)|e^{-j\Theta_E(z)}$$

The difference between the unperturbed input reflection S_{11}^u and the perturbed reflection S_{11}^p is then proportional to the square of the field as follows:

$$\Delta S_{11}(z) = S_{11}^p(z) - S_{11}^u(z) = c|E(z)|^2 e^{-2j\Theta_E(z)} \qquad (1)$$

where c is a constant which depends on the input power and the bead characteristics (material, shape, and volume).

B. Results of Characterization of NLCTA Intector Sections

Using the bead-pull system shown schematically in Fig. 4, we tested both sections of the NLCTA injector. We used a stainless steel cylindrical bead of diameter d_b=0.625 mm and a length l_b=1mm supported on a monofiliment nylon string of diameter d_s = 0.145mm. The bead was moved along the structure in steps of 0.5mm (approximately 17 steps per cell). At each bead position, the S_{11} value used was the average of 256 measurements. The measurement time for the 90-cm structure was 90 minutes. The measurements were made at frequency corrected for the nylon string, the room temperature and dry N_2. The results of these measurements on both injector sections are shown in Fig. 5.

The three-fold symmetry of the accelerating 2π/3 mode is manifested clearly. The variation in the reflection from the bead as it is pulled along the axis of each structure traces the hypotrochoid function. This trace can be predicted theoretically for a given longitudinal electric field, Ez based on its space harmonics. Our previous work, [4] showed good agreement between theory and experiment. It is to be noted that the data shown in Fig. 5 represents the measured reflection after centering by subtracting a phasor corresponding to the reflection from the unperturbed structure, S_{11}^u according to Eq. (1). The amount of centering ($|S_{11}^u|$=0.02) for both sections was consistent with the VSWR=1.04 measured for both of them.

The electric field Ez can be obtained from the measured reflection (after centering) using Eq. (1). Ez for the second injector section is plotted as (a phasor) in Fig. 6. In Fig. 7 we show phase variations of Ez for the same the same section for the first eleven cells.

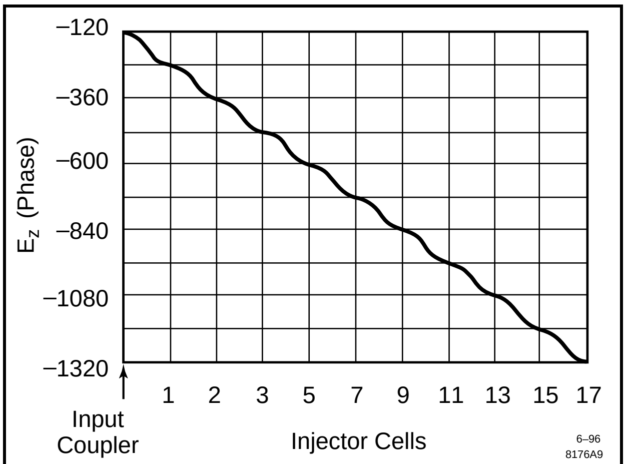

Figure: 7 Phase of the electric field along the axis of the NLCTA second injector section.

REFERENCES

[1] R. D. Ruth, "The Next Linear Collider Test Accelerator," in these proceedings.

[2] K. B. Mallory and R. H. Miller "On Nonresonant Perturbation Measurements," IEEE Trans. On Microwave Theory and Techniques, Vol. MTT-14, No. 1966, pp 99-100.

[3] C. W. Steele, "Nonresonant Perturbation Theory," IEEE Trans. on Microwave Theory and Techniques, Vol. MTT-14, No. 2, 1966, pp.70-74.

[4] S. M. Hanna, et al. "A Semi-Automated System for the characterization of NLC Accelerating Structures," Proceeding of the 1995 Particle Accelerator Conf., pp 1108-1110.