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RF Systems for the NLCTA*

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Abstract

This paper describes an X-Band RF system for the Next Linear Collider Test Accelerator.[1] The RF system consists of a 90 MeV injector and a 540 MeV linac. The main components of the injector are two low-Q single-cavity prebunchers and two 0.9-m-long detuned accelerator sections. The linac system consists of six 1.8-m-long detuned and damped detuned accelerator sections powered in pairs. The rf power generation, compression, delivery, distribution and measurement systems consist of klystrons, SLED-II energy compression systems, rectangular waveguides, magic-T's, and directional couplers. The phase and amplitude for each prebuncher is adjusted via a magic-T type phase shifter/attenuator. Correct phasing between the two 0.9 m accelerator sections is obtained by properly aligning the sections and adjusting two squeeze type phase shifters. Bunch phase and bunch length can be monitored with special microwave cavities and measurement systems. The design, fabrication, microwave measurement, calibration, and operation of the sub-systems and their components are briefly presented.

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Abstract

This paper describes an X-Band RF system for the Next Linear Collider Test Accelerator.[1] The RF system consists of a 90 MeV injector and a 540 MeV linac. The main components of the injector are two low-Q single-cavity prebunchers and two 0.9-m-long detuned accelerator sections. The linac system consists of six 1.8-m-long detuned and damped detuned accelerator sections powered in pairs. The rf power generation, compression, delivery, distribution and measurement systems consist of klystrons, SLED-II energy compression systems, rectangular waveguides, magic-T's, and directional couplers. The phase and amplitude for each prebuncher is adjusted via a magic-T type phase shifter/attenuator. Correct phasing between the two 0.9 m accelerator sections is obtained by properly aligning the sections and adjusting two squeeze type phase shifters. Bunch phase and bunch length can be monitored with special microwave cavities and measurement systems. The design, fabrication, microwave measurement, calibration, and operation of the sub-systems and their components are briefly presented.

1 INTRODUCTION

There are four RF stations in the first stage of the NLCTA project. One station is dedicated to the injector. Each of three stations feeds a pair of 1.8 m accelerator sections. This paper will focus mainly on the injector RF system since it is more complex than other three, using both general and special microwave components. The injector RF system is comprised of the following components:

- An RF pulse compression system.
- Two X-Band prebunchers for velocity modulation.
- A 0.9 m detuned accelerator section with capture cavities in its front end.
- A 0.9 m detuned accelerator section.
- Two magic-T type phase shifter/attenuators for RF feeds of the prebunchers.
- Two squeeze type phase shifters for RF feed of the second 0.9 m accelerator section.
- A bunch length monitor for injector tuning.
- A beam phase monitor for beam phase analysis.

Fig. 1 shows schematically the RF system for the injector. An XL-4 75 MW X-Band klystron is used as a single source to power the system. All components are monitored or controlled in a nearby control room. The system has been successfully operating since the summer of 1996.

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2 RF PULSE COMPRESSION SYSTEM

The RF source for each RF system is a 75 MW klystron. Each klystron feeds a SLED-II RF pulse compression system,[2] which compresses the 50 MW, 1.5 μs klystron pulse by a factor of six in time and multiplies the peak power by factor of four. The 200 MW output of the SLED-II pulse compressor is transmitted in low-loss oversized circular waveguides, which enter a shielded accelerator vault. structures. The overall efficiency of the operating RF systems exceeded our expectation.

3 ACCELERATOR STRUCTURES

In order to achieve the desired luminosity and suppress the long range transverse wakefields for multi-bunches, we have developed several types accelerator structures.[3] The two 0.9 m injector structures were constructed by using even number cells (for 1st section) and odd number cells (for 2nd section) of the 1.8 m detuned structure. The first three cavities of the first section have an RF phase velocity of 0.6c, 0.7c and 0.9c respectively. This design preserves the detuning characteristics for HOM (High Order Modes) and has a flat accelerating field distribution along the axis while beam loading is present. Two all-metal RF loads, capable of handling 100 MW RF power are connected to each accelerator output coupler.[4]

4 PREBUNCHERS AND BEAM PHASE MONITOR

The two standing wave single-cavity type prebunchers require 0.25 KW and 4 KW respectively, for optimum bunching. The second prebuncher is driven by the output from a 25 db coupler in the WR 90 feed line to the first 0.9 m section. The first prebuncher is driven by the output of the 10 db coupler in the WR 90 feed line of the second prebuncher. In order to reduce the transient beam loading effect on bunching, both prebunchers were designed to be over-coupled with a coupling coefficient β ~100 and time constant ~1.1 ns. Each prebuncher cavity consists of a copper body with two nose-pieces and a WR 90 feed (see Fig 2). The drift distance between the second prebuncher and the bunching section in the front of the first 0.9 m section is 5.9 cm. This minimizes the debunching due to space charge effects. This small distance required the second prebuncher to be an integrated part of the second 0.9 m ac-

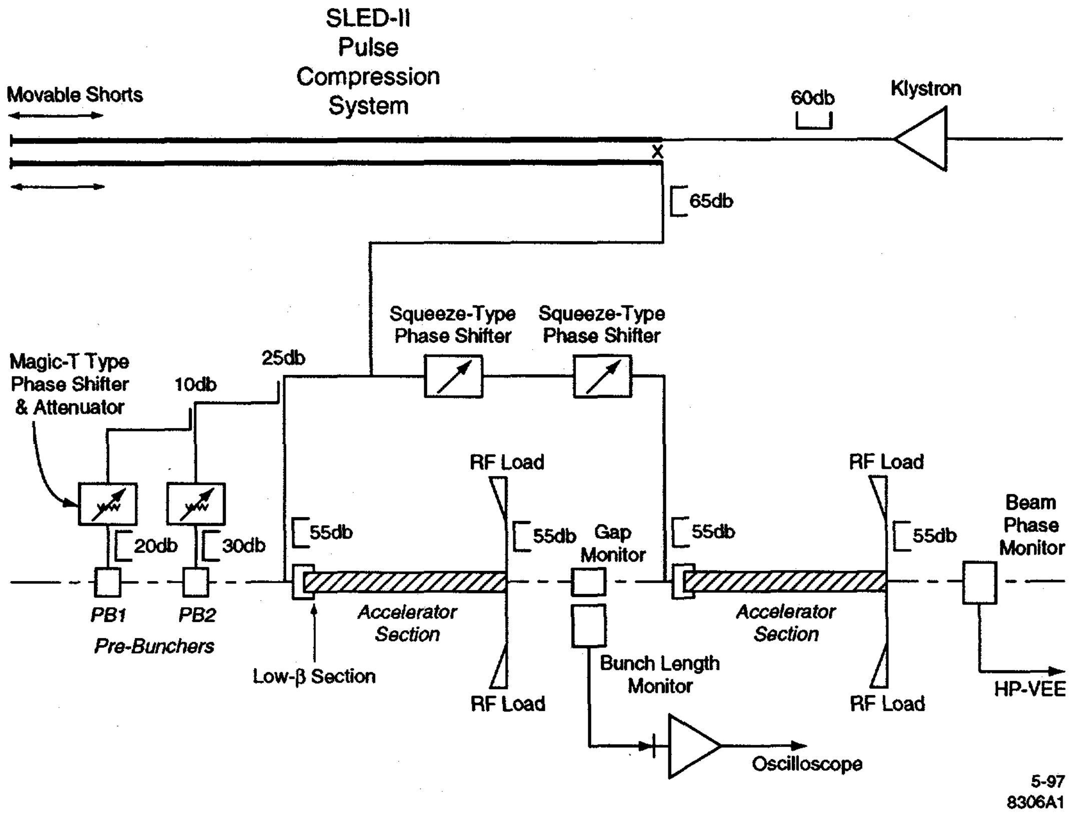

Figure 1: NLCTA Injector RF System Layout

celerator section. The beam phase monitor uses the same design as the first prebuncher assembly. The beam excited signal is sent to an HP VEE (Virtual Engineering Environment) system for data analysis.

5 MAGIC-T TYPE PHASE SHIFTER/ATTENUATOR

Electrons from a 150 KeV thermionic-cathode gun are velocity modulated in each prebuncher. These are followed by drift sections in which the bunching occurs. In order to obtain the best bunching, both the RF phase and amplitude of each prebuncher need to be accurately and independently adjusted. To accomplish this we have inserted a magic-T type phase shifter/attenuator in each RF feed. As shown in Fig 3, this device has non-contacting movable shorts on two collinear arms which are driven by mover mechanisms. The two remaining arms are input and output ports. Keeping the RF amplitude of the output port constant, the RF phase can be changed by moving both shorts equal distances either toward or away from the junction. Keeping the RF phase of the output port constant, the RF amplitude can be changed by moving the shorts equal distances, but opposite in direction relative to the junction. Microwave measurements show the orthogonality of the RF phase and amplitude adjustments. The top plot of Fig 3 shows that the RF phase can be changed 360° without changing the amplitude by more than 0.05 db. The bottom plot of Fig 3 shows that the RF amplitude can be changed by -40 db without changing the phase by more than 5°. Precision linear actuators are attached to the movable shorts, and LVDT's (Linear-Variable Differential Transformer) give signals for RF phase and amplitude calibration.

6 SQUEEZE TYPE PHASE SHIFTER

Two squeeze type phase shifters[5] allow us to optimize the beam RF phase for the second 0.9 m accelerator section in order to obtain the minimum energy spread within the individual bunches. They have 18 in. long slots centered in the broad wall of copper WR 90 waveguide, with vacuum pumping on both sides of each slot. The slotted vacuum chambers are designed so that they are anti-resonant to unwanted RF coupled through the slots. The slot width is adjusted using a stepper motor driven differential screw system, and its position is monitored with an LVDT. The slot width is adjustable from 0.030 in to 0.090 in. and results in a phase change over a range of ±30°.

7 BUNCH LENGTH MONITOR

The principle of non-intercepting RF bunch length measurement was proposed and experimentally tested at SLAC.[6],[7] As shown in Fig. 1, a bunch length monitor cavity is installed adjacent to the beam line between the two injector sections. The fields radiated from the beam

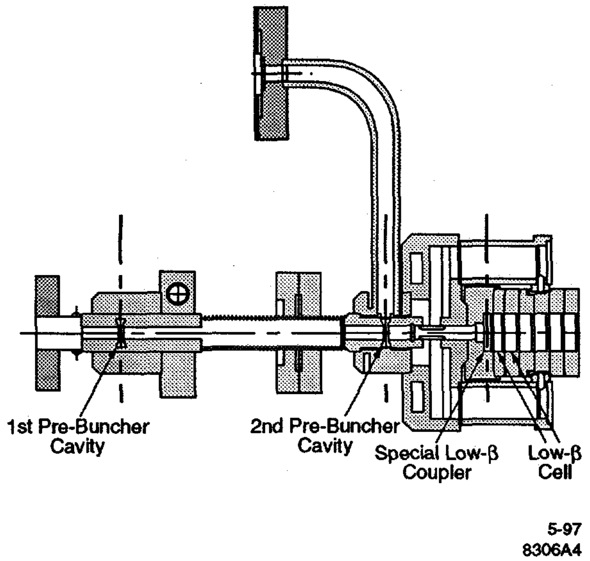

Figure 2: Prebunchers and Front End of 1st 0.9 m Accelerator Section

traversing a ceramic gap enter the bunch length monitor cavity and excite a resonant mode. The radiated power is proportional to $exp(-\omega^2{\sigma_z}^2/c^2)$, where σ_z is the standard deviation for a Gaussian bunch. Fig. 4 shows the theoretical beam power spectra for three different bunch lengths with σ_z equal to 0.5 mm, 1.0 mm, and 1.5 mm respectively. For the first stage of the NLCTA project, the injector delivers a 140 ns pulsed beam, consisting of bunch trains of 1600 micro-bunches. They are 0.4 mm (RMS) in length and 88 ps apart. A TM_{020} mode cylindrical copper cavity was designed to resonate at 34.272 GHz, the 3rd harmonic of the micro-bunch frequency. The cavity signal is transmitted through WR 22 rectangular waveguide to a crystal detector and an amplifier. In the NLCTA control room a 600 mV signal was observed for 0.5 A accelerating currents. The bunch length monitor has been a powerful tool for injector tuning.

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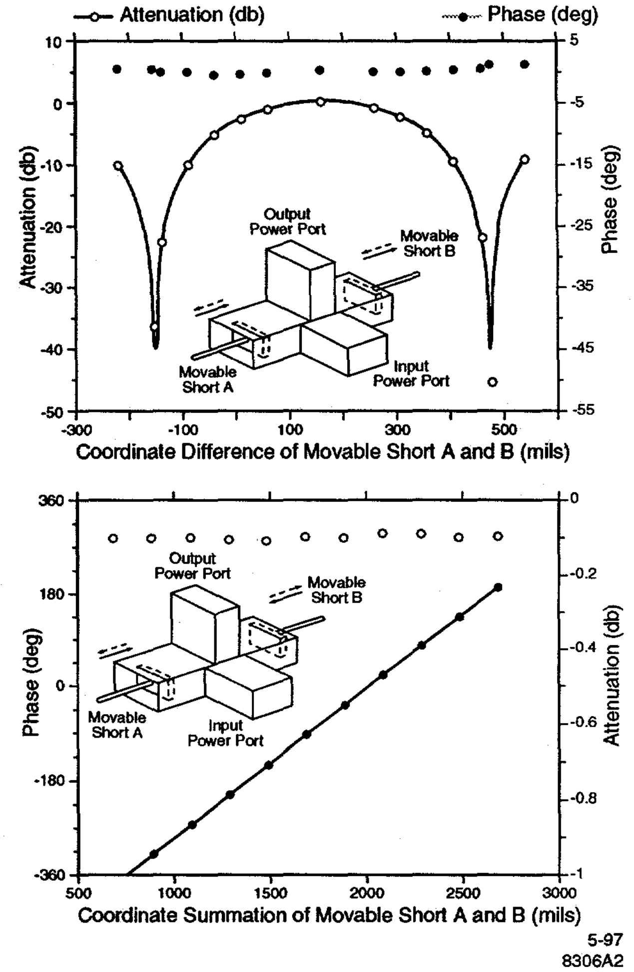

Figure 3: Calibration curves for Magic-T Type Phase Shifter and Attenuator

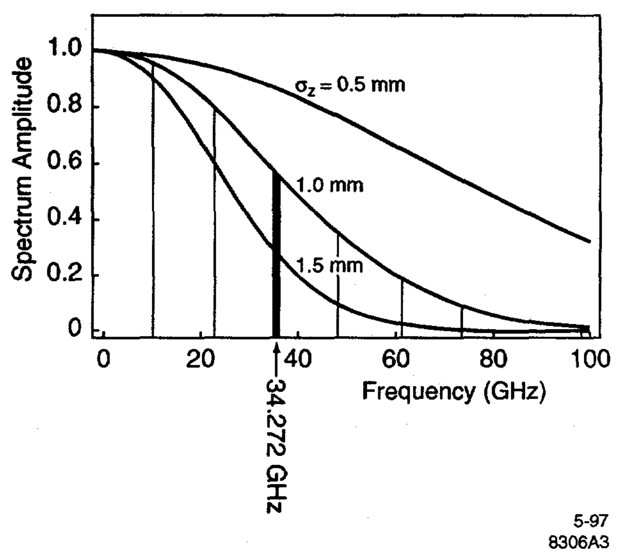

Figure 4: Theoretical Beam Power Spectra for Three Different Bunch Distributions

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