SLC INTERFEROMETER SYSTEM AND PHASE DISTRIBUTION UPGRADES

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Abstract

Many of the components used in the Stanford Linear Collider (SLC) phasing system date back 30 years to the construction of SLAC. At the start of SLC the phase reference system was upgraded with many of the original components remaining. The R.F. drive system phase stability requirements became tighter with operation and optimization of the SLC. This paper describes analysis done on the R.F. drive system and interferometer system during the 1996 run and down time, modifications to the systems during the 1996-97 down time, and the improvements in stability from the modifications.

1 INTRODUCTION

The sun coming up in the morning on a beautiful sunny day for someone in Stanford, California is not such a nice experience if one is an operator of the Stanford Linear Collider (SLC) trying to maintain luminosity. The improvements on the SLC the past decade have decreased the emittance of the beam to a point where the existing phase variations in the RF, due to diurnal temperature changes, significantly effect luminosity. The effects are greatest at sunrise when the temperature gradient with respect to time is the largest.

During the 1996-97 down time the front end phase distribution system was reconfigured. The phase critical path was moved from the low level RF system before the high powered amplifier which drives the Main Drive Line (MDL) to the front of the MDL. The phase distribution system is described in reference [1]. Time Delay Reflectometry (TDR) measurements on the MDL showed problem areas which were rebuilt.

2 FRONT END PHASING CHANGES

The front end phase distribution of the SLC has been upgraded to move temperature sensitive devices out of the phase critical path. The phase critical path begins where the RF reference signal is first split to feed more than one device of which relative phase is critical. Figure 1 shows that the point at which the phase from the master oscillator splits to feed different areas was in the distribution chassis. RF outputs of this chassis feed Sector 0 and 1, CID and Damping Rings, and the Linac. The items of interest to remove from the phase critical path were the Master Amplifiers and Switch, the Fiducial Generator, and about 60 feet of cable. The Master Amplifiers are used to increase the RF power level to 30 watts. The Fiducial Generator puts a 120 watt 1/2 cycle timing pulse on the RF before it is sent into the MDL for distribution of RF, timing and phase information in the linac.

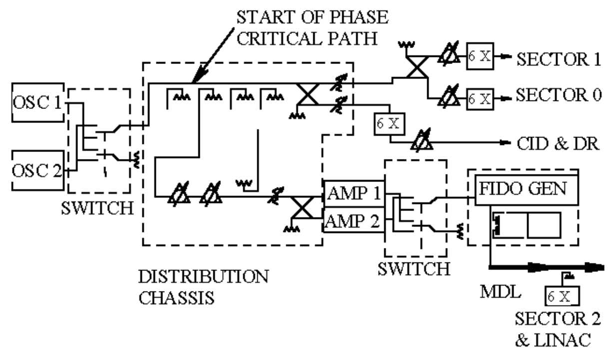

Figure: 1 SLC Old Front End Phase Distribution

2.1 Motivation for Changes

Operators constantly adjust phase to maintain luminosity during times of large outside temperature changes. The most common adjustments are the injection phase from the damping rings to the linac and injection phase of positrons entering sector 1.

In order to verify that the suspected area of RF phase shifts was the section from the distribution chassis to the MDL, an 80k BTU heater was placed in the sector 0 alcove where these electronics and cables are located. The heater was turned on at 04:20AM on June 20, 1996 to simulate the sun coming up. The temperature in the rear of the RF components rack rose from 65°F to 87°F at 06:00AM at which time the heater was turned off. Figure 2 is a plot of the phase difference between sector 2 in the linac and sector 1 from 18-June-1996 at 01:20 to 20-June-1996 at 07:20.

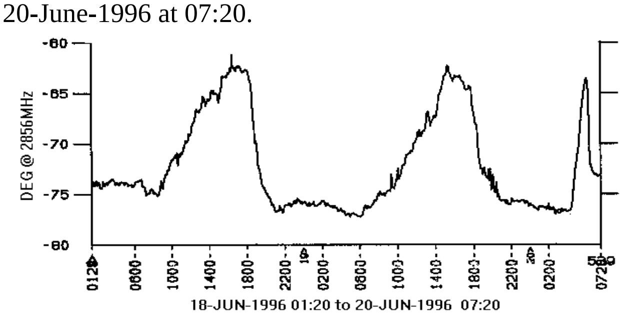

Figure: 2 Sector 1 to Sector 2 Phase Variations

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The sharp rise and fall at the end of the graph is the heater turning on and then off. Normal diurnal phase variations are about 15° @ 2856 MHz with outside temperature changes of 30° F. With the injection phase tolerance into the linac being much less than 1° @ 2856 MHz, the phase variations observed in the RF would cause difficulty in maintaining luminosity.

2.2 Changes to the SLC Front End Phase Distribution

The phase distribution system was changed to the configuration shown in figure 3.

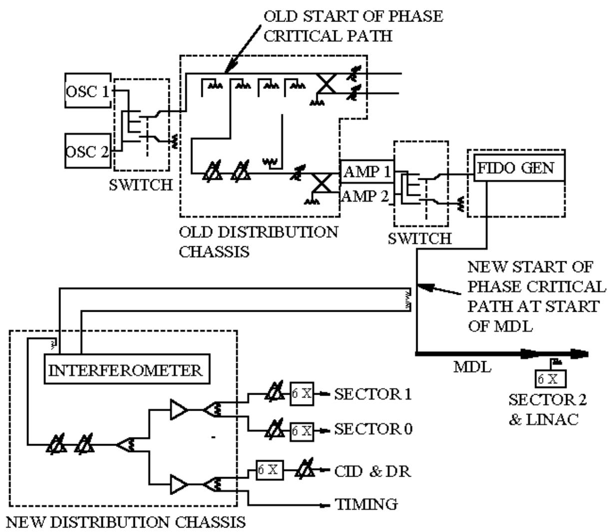

Figure 3. SLC Front End RF Distribution

The phase critical path now starts after the old distribution chassis, the power amplifiers, the power amplifier switch, the fiducial generator and many connectors and cables. The phase critical path now starts at the front of the MDL where the distribution chassis is a 6 foot Heliax cable away. The distribution chassis contains on a single FR4 circuit board the phase sensitive interferometer components and amplifier, two wide band tuning diode phase shifters, splitters and amplifiers. N-type connectors mount to an aluminum housing which supports the board. The aluminum housing is then mounted on a water temperature stabilized plate. A 5.25-19 inch rack mount chassis, 8 inches deep, houses the unit, figure 4.

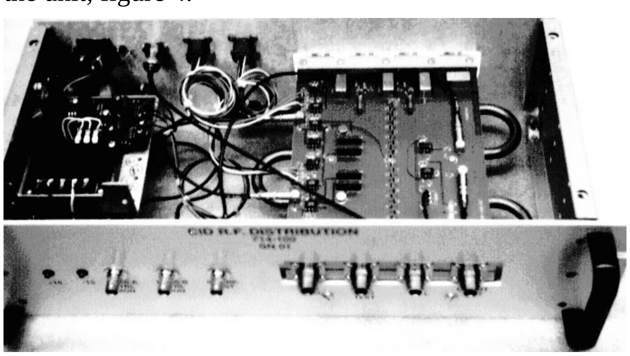

Figure 4. RF Distribution Chassis

2.3 Diode Delay Line Phase Shifters

In order to make the changes to the front end phasing it was necessary to develop a wide band phase shifter which would be able to shift the phase of the 476MHz by 60° which shifts the 2856MHz by 360°. The phase shifter would need to change and stabilize phase between pulses, at 120 rep rate, within 8mS. The phase shifter must also be able to transmit the timing pulse which contains components much higher in frequency. A series of tuning diodes was connected to a microstrip structure in a three layer FR4 board. Figure 5 is a scope image of the timing pulse into and out of the phase shifter. The pulse out has been scaled to the same height as the pulse in, to better see any distortion. Loss through the phase shifter is 6dB.

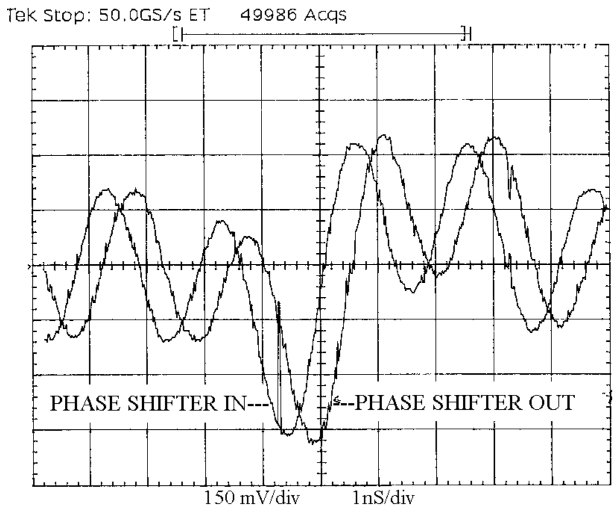

Figure 5. Fiducial Pulse Through the Phase Shifter.

2.4 Phase Variations After Changes

The variation in phase as seen by the sector 2 to sector 1 phase monitor has significantly decreased since the upgrade. Diurnal variations which would cause 15° phase variation at 2856MHz now only cause 3° phase variation.

3 INTERFEROMETER UPGRADES

The interferometer system is used to measure the electrical length of the MDL. Variations in the electrical length of the MDL to each sector from sector 2 are calculated assuming that the variation is distributed uniformly. The calculated phase variation is then used to correct the phase of the sector.

3.1 Interferometer System

The interferometer system, figure 6, uses a dual directional coupler at the front of the MDL to measure RF into and out of the MDL. At sector 30, about 9700 ft later, the RF is coupled off, phase modulated by 180° at 750Hz, run through a nulling phase shifter, amplified and sent back through the MDL to the front. A vector sum of the modulated 750Hz signal from sector 30 and the forward RF into the MDL is run through a 750Hz bandpass filter and feedback amplifiers. The output is used to adjust the nulling phase shifter in sector 30. The variation in MDL phase is measured by 1/2 the amount the nulling phase shifter must move to adjust for the electrical length of the RF path up and back the MDL.

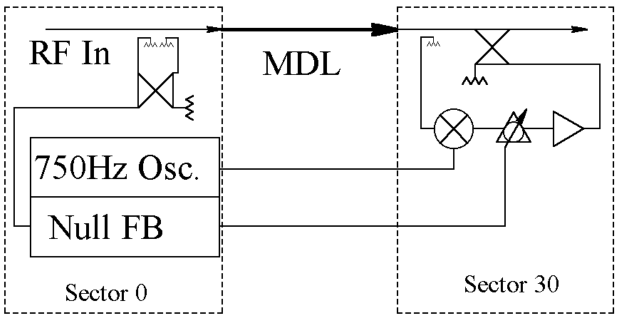

Figure 6 Interferometer System

Matches throughout the system are critical if phase errors are to be kept to levels of 1° 2856MHz or 0.17° 476MHz. The amount of power required to change the phase of an RF signal by 0.17° is -50dB relative to the RF signal, if the phase is off by 90°. A fixed reflection would just add an offset and not effect the relative phase measurement, but in a system which is changing up to 4° diurnally a reflection of -14dB could cause a phase change of 0.17°, which would be 1° of the frequency multiplied by 6.

To reduce some errors in the interferometer system, the MDL input dual coupler and phase sensitive electronics were moved from the sector 0 alcove, about 50 feet of Heliax away to the input of the MDL. The phase sensitive electronics were made part of the temperature stable CID RF Distribution chassis.

3.2 Main Drive Line Maintenance

The MDL is almost about the same as it was 30 years ago as described in reference [2]. Figure 7 shows a TDR measurement from sector 30 to sector 21. The TDR was done using an HP 215A pulse generator with a 60nS wide, 10 volt, 0.5nS rise and fall time pulse. The scope used to collect the data was a Tektronix 544A, 1GS/Sec, 500MHz, 64kB buffer. The expansion joints and couplers stand out in the measurement. The center conductor of the expansion joints at sector 24 and sector 22 appear at 4.2µS and 5.5µS respectively.

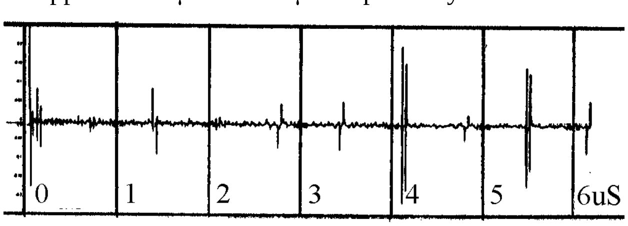

Figure 7. TDR from Sector 30 to Sector 21.

These expansion joints when examined were found to have a reversed center conductor. The outer diameter of the center conductor is matched to the inner diameter of the outer conductor to maintain a 50 ohm line. Figure 8 shows the construction of the expansion joint. The joints exhibited reflection of -11dB when tested on the bench. With the expansion joints expanding and contracting about 1 cm diurnally, the phase of the reflection could change by 10°. This could cause a 4° phase change at 2856MHz. Expansion joints in sectors 2 to 9, 17, 21, 22, and 24 were rebuilt during the down time.

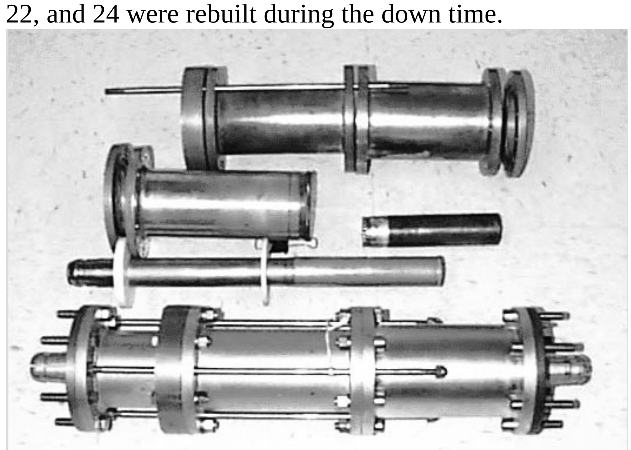

Figure 8. SLC MDL Expansion Joint.

4 PROSPECTS

Beam based phase measurements showed signs of phase variation in the phase reference system, reference [3]. With refinement of beam based phase measurements, locations of phase instabilities may become more apparent. The work done so far should increase stability and will be most noticed with the startup of SLC in June of 1997. We expect to see significant improvements in the positron injection phase stability.

5 ACKNOWLEDGMENTS

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REFERENCES

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[3] F.-J. Decker, R.W. Assmann, M.G. Minty, N.Phinney, W.L. Spence (SLAC), "Beam-Based Analysis of Day-Night Performance Variations at the SLC Linac" Presented at PAC 1997