Delta-T Phase Scan Simulations for the SNS CCL

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Introduction

During the initial operation of the SNS linac (commissioning), it will be necessary to establish the optimum settings for the phase and amplitude of the RF fields in each of the 4 modules of the coupled cavity linac (CCL). It is unlikely that these 8 quantities can be set close enough to their design values by direct field measurements alone to provide satisfactory performance. This note explores the suitability of using the delta-t method, developed at LAMPF [1,2] and widely used elsewhere, to empirically determine the optimum settings for the SNS CCL.

. The purpose of this note is to simulate delta-t commissioning measurements on CCL modules #1 through #4. For details on the delta-t method, see [1,2]. The delta-t method uses the beam-off minus beam-on time delay differences for two beam RF phase pickups, labeled *B* and *C*, at the end of the module being commissioned, and a few meters downstream of the end of the module respectively, to determine the optimum settings of the module RF phase and amplitude. The equations for the time delays (delta-t's) as a function of RF phase, RF amplitude and input energy variations are derived in the references [3].

Simulation Model

SNS CCL modules are all 12-segment, 8-cell side-coupled structures, with a center-to center spacing of 6.5 $\beta\lambda$ at 805 MHz. The specific parameters used for modeling each module are

Module number	Input energy (MeV)	Output energy (MeV)	Phi-s (degrees)	*L AB* (meters)	*L BC* (meters)
1	86.8277	107.1613	-30	12.264	13.35
2	107.1613	131.1402	-30	13.382	14.45
3	131.1402	157.2143	-29	14.472	14.77
4	157.2143	185.6266	-28	15.498	16.00

L AB is the accelerating structure length, and *L BC* is the separation of the two pickups used for the delta-t scan. In the case of CCL module #4, the 16 meters represents the drift length to the phase pickup between cryomodules #2 and #3. In the simulation, each CCL segment is modeled as a single RF cell, rather than 8, and all 12 segments are assumed to have the same synchronous phase and energy gain.

Figures 1 through 4 show delta-t variable phase scans of CCL modules 1 through 4 respectively. The x axis is *dTB*, the time delay deviation from the design time delay at pickup *B* for a synchronous particle with the design input energy, phase, and RF amplitude. The y axis is *dTC*, the corresponding delay deviation at pickup *C*. Each red line represents a phase scan from Phis-5 degrees to phis + 5 degrees at constant RF amplitude and input beam energy. The cluster of 3 red phase scans represents phase scans at 0.98, 1.00, and 1.02 times the design RF amplitude. The 5 clusters represent 5 different input beam energies, ranging from Ws – 0.1 MeV to Ws + 0.1 MeV. The 3 blue lines

represent the locus of points for phis ±2 degrees for various input energies. The design requirements for setting the static amplitude and phase are ±2% and ±2 degrees, represented by the red and blue lines respectively.

The intercept of the phase-scan line with the center blue line represents the input beam energy offset from the synchronous energy. For a cluster of phase scan lines at this offset energy, the amplitude is set by requiring the *slope* of the phase scan to be inside the *slopes* for the phase scans for A=0.98 and A=1.02, and the setpoints *dTB* and *dTC* must be within the box defined by the corresponding red and blue lines.

Visual inspection of the 4 plots indicates that a time resolution of ±5 ps is probably adequate for measuring *dTB* in all cases. For *dTC*, especially for modules #1 and #2, the resolution may have to be somewhat better. However, in both cases, the B-C pickup separation can easily be doubled by using the pickup two modules downstream of the module being commissioned. Plots of *dTC-dTB* vs. *dTB* did not appear to be any better.

Conclusion.

The RF phase and amplitude of CCL modules 1 through 4 can be adequately set using the delta-t method and with phase resolution of ±5 ps, provided the B-C phase pickup separations are at least 15 meters.

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[1] K. R. Crandall and D. A. Swenson, “Side-Coupled cavity Turn-On Problem”, MP-3-98 (February 9, 1970).

[2] K. R. Crandall, “The Delta-t Tuneup Procedure for the LAMPF 805-MHz Linac”,LA-6374-MS (UC-28) (May 1976).

[3] See for example, ref[2], Eqns (8) and (9).

[4] This description is based on the *slope method* for setting amplitude and phase, described in [2]. The other method described in [2] is the *output energy change method*. Both methods have essentially the same time resolution requirements.

Figure 1. Simulation of variable phase delta-T curves for CCL module #1

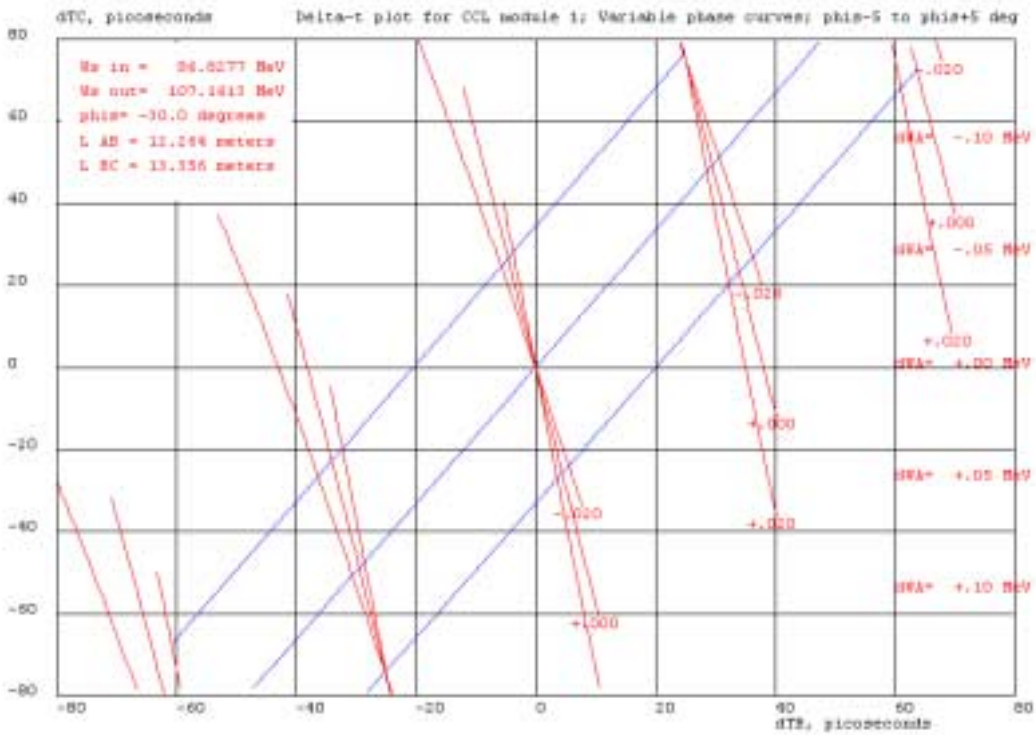

Figure 2. Simulation of variable phase delta-T curves for CCL module #2

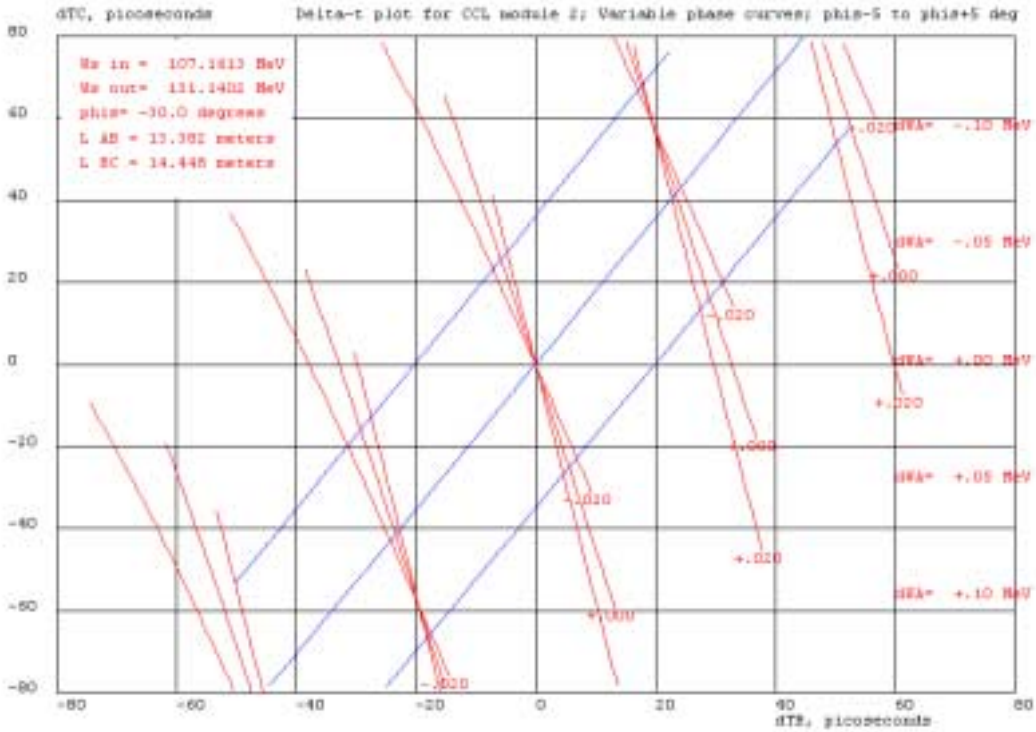

Figure 3. Simulation of variable phase delta-T curves for CCL module #3

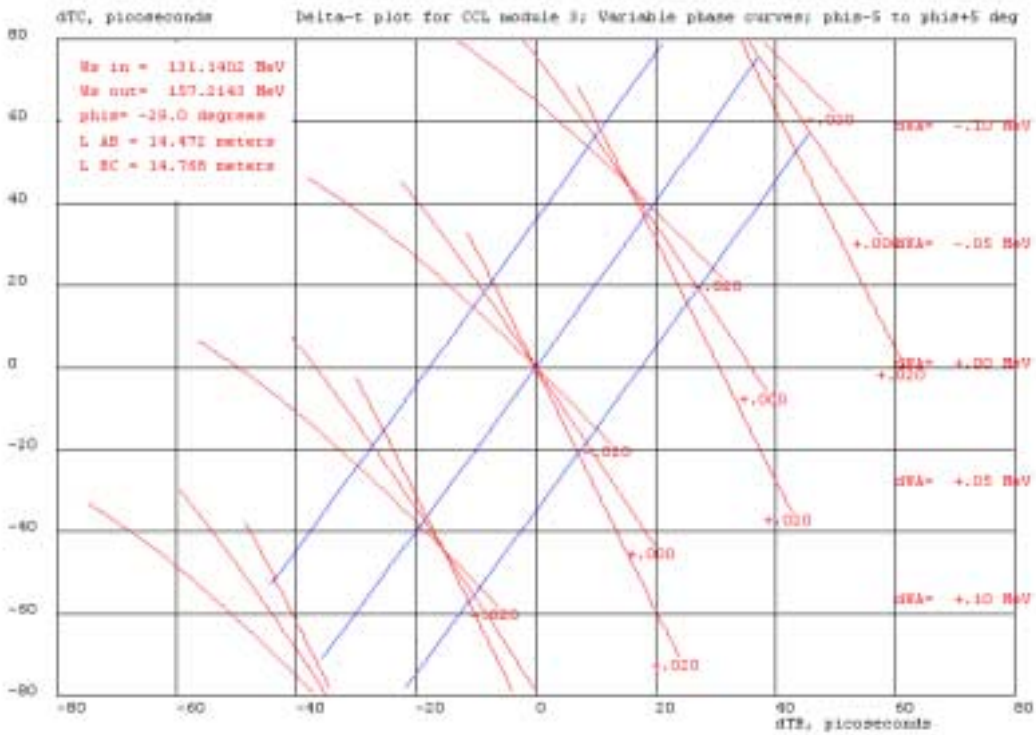
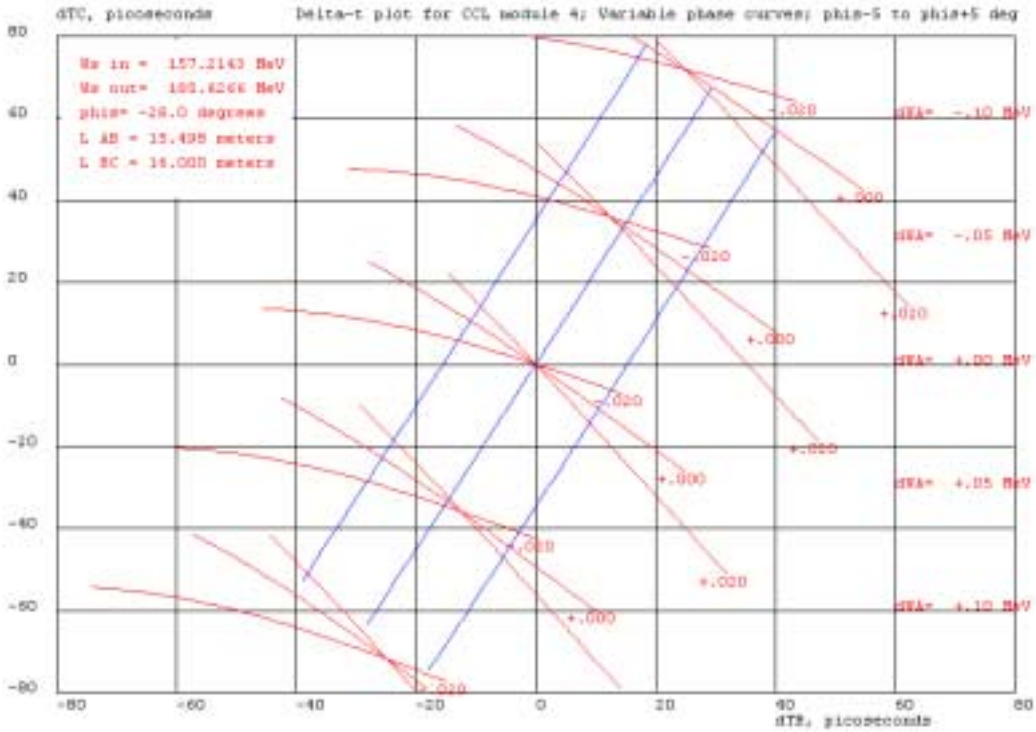
Figure 4. Simulation of variable phase delta-T curves for CCL module #4