Los Alamos
NATIONAL LABORATORY
memorandum
Spallation Neutron Source Division

To/MS: Don Rej, SNS-DO, H824
Norbert Holtkamp, ASD, ORNL
Thru/MS: Mike Lynch, LANSCE-5/SNS-2
From/MS: Amy Regan, SNS-2, H827
Phone/Fax: 5-0658/Fax 5-2818
Symbol: LANSCE-5/SNS-2:02-011
Date: April 11, 2002

RF Controls Reference Design

The following is an update of an e-mail distributed by Hengjie last month. The original reference design based on distributing a local oscillator signal along a heated coax line in the tunnel has been modified slightly. Instead of distributing the local oscillator (LO) on the heated coax, we will be distributing the RF signal. We will still be sending the cavity field IF signal back to the rack, but through Hengjie's clever design, the performance of the reference system should be better with respect to phase noise, and requires a lot less power for the signals distributed down the coax, when compared to the original design.

The LLRF system consists of the following hardware components

1. electronic control sub-system (comprised of three circuit boards in VXI format - CDM, HPM, and FRCM),
2. reference line sub-system (coax, master oscillators and power amplifiers). The new scheme will continue to use all the hardware components being developed for the previous design, except it will require a new, more simple CDM. The design will only differ from the previous one in the way the system is configured and how the reference frequencies will be generated and distributed. There will be no extra hardware development work. The required new CDM will need some amount of work in prototyping and testing. This work is on-going now. The new CDM is halfway through our ECAD team. Hengjie is working closely with the designer to complete it soon. As a backup, the original CDM, which needs re-work anyway (and hence the overall workload has not been dramatically increased), can be used until the newest design is available.

There are quite a few drawings which have been generated which support this new design. They are not included here but can be provided upon request to me.

1. The new LLRF configuration will use 805MHz / 402.5MHz as the reference frequencies, instead of 352.5MHz/755MHz as in the previous design. The first benefit of doing so is that since 805MHz is the second harmonic frequency of 402.5MHz, generation of the two reference frequencies with a total coherent phase relationship will be easy. Since the reference frequencies will be the same as the RF frequencies in the cavities, the RF phase can now be directly compared with the phase of the reference. We believe this should make initial installation/commissioning easier.
2. The new configuration will globally distribute only two common frequencies - 805MHz reference (402.5MHz in DTL case) through the temperature regulated 3.125" coax line in the tunnel, and the 755MHz LO frequency (352.5MHz in DTL case), through a regular Heliax cable in the Klystron Gallery upstairs to facilitate the signal processing.
3. At each Klystron location, the LO frequency is sent to the tunnel through a 3/8" Heliax cable. The 805MHz cavity RF signal and 805MHz reference are down converted into 50MHz IF cavity signal and 50MHz reference in the tunnel. The down converted cavity signal and reference then come

out of tunnel together through a matched cable pair. The cable pair along with the LO cable are not temperature controlled. Due the nature of balanced circuit topology, any temperature change will equally affect the phase of both the cavity signal cable and the reference cable. So the relative phase relationship between the cavity signal to be measured and the reference will be maintained. A quick calculation has shown that given a 30m distance (from tunnel to rack), and 95% cable length match (which means off by 1.5m!), a 40 deg F temperature swing will only create about 0.1° differential phase error.

   a. Issue: the routing of the cables right now looks like cable length will be longer than our original pessimistic estimates. This will directly affect cavity field control performance. The longer the cable path, the larger the group delay, and the slower your system is. I have asked Ray Fuja and Chip Piller to look into this and see what influence they can have in getting those cable runs shortened.

4. For the same reason, any phase error in LO signal will not affect the phase measurement. In other words, since the 805MHz cavity RF and Reference are converted to 50MHz by a common LO, the phase error in the LO will produce a common-mode phase error in the cavity signal and reference. Therefore, the phase stability (jitters and drift) is not required for the LO frequency.
5. After arriving at the rack, the 50MHz cavity IF goes to FRCM for measurement, while the 50MHz reference goes to CDM. The CDM generates the 40MHz and 10MHz clock for the FRCM from the 50MHz reference. The clock generation is accomplished by first dividing the 50MHz Reference frequency by 5 to get the 10MHz, and then extracting the 4th harmonic frequency of the 10MHz to get the 40MHz clock. The extraction of the 4th harmonic is done with a diode frequency quadrupler. Since the 10MHz and 40MHz clocks are directly derived from the 50MHz reference, they will track the phase movement (it is actually the change of delay time) of the 50MHz reference. That is exactly what we want.
6. Initially there was a concern about the undeterministic initial state of the counter used as the frequency divider here. However, with this system, there is no possibility of multiple results of phase measurement due to the random initial state of the frequency divider after each power-up. Nevertheless, a global 10MHz reset for the counters in all systems has been planned to ensure the synchronism.
7. There are a large number of directional couplers used as the "taps" on the reference line. Due to the longer distance between the cavities in DTL and CCL section, one tap per cavity is planned for the normal conducting cavities. Originally we planned on having one tap shared by two cavities for the superconducting sections. Since then, Dave Thomson has done some layout calculations and has come up with a way to share one tap for every three medium beta cavities, thereby saving even more taps (and hence, money). In the previous design, every cavity required its own tap.
8. The Roscoe RF & Microwaves master oscillator units are still to be used. We originally measured some problems with them, one is back at the manufacturer right now being upgraded. Tests will be conducted to confirm the specs after they come back from the vendor.
   a. Issue and resolution: we have one now in-house that does not work perfectly but will suffice for the first systems until we get the modified one back from the manufacturer. He is waiting for the delivery of a couple of long-lead items in order to complete that fix, and hopes to have the m.o. back to us in June so that this issue should be moot.
9. The changes with the new plan should not have any effect on MEBT, as MEBT LLRF will still get all 352.5, 50, 40 and 10MHz frequencies, and distance from the master oscillator where the LO is originated to the MEBT is short.
10. We have a mockup of the heated reference line built and operating in a long hallway in LAMPF. With this we have proven out the heating control circuitry and performance. We have made measurements with and without flex joints. We have one more flex joint measurement to perform, but we are waiting until we get the "real" heat tape in to re-configure the system. The originally

purchased heat tape was based on a type that would eventually breakdown in a radiation environment.

11. Dave Baca has been working on a layout for the routing of the reference line in the SNS facility. He's done the initial routing. He's now working on getting the two specially made mitred bends to get in and out of the wall chases.

I know that Hengjie gave a talk at Oak Ridge last week describing this system as well as the present status of the overall RF Control System. Basically we have working prototypes of all of the modules except the FRCM motherboard that we can use if the "final" versions are not ready in time. This includes the associated EPICS screens. The motherboard is 60-70% complete in testing right now. The intent is to complete a prototype system and integrate it at LANL, closing the field control loop around a dummy CCL cavity, which will allow us to also modify the resonance frequency and verify our resonance control algorithms. Heliax cabling has been ordered and is due to arrive at ORNL in a few weeks. The racks should be ordered this week. They will be directly shipped to ORNL as well.

Distribution:
Ray Fuja, ORNL
Hengjie Ma, ORNL
Marion White, ORNL