The operating parameters for Brookhaven National Laboratory’s Low Energy RHIC Electron Cooling (LEReC) project create a unique challenge. To ensure proper beam trajectories for cooling, the relative position between the electron and the ion beam needs to be known to within 50 μm. In addition, time of flight needs to be provided for electron beam energy measurement. Various issues have become apparent as testing has progressed, such as mismatches in cable impedance and drifts due to temperature sensitivity. This paper will explore the difficulties related to achieving the level of accuracy required for this system, as well as the potential solutions for these problems.

**Position Measurements**

To ensure sufficient cooling, the position of the electron beam with has to be measured with 50 μm accuracy with respect to the ion beam. The challenge with this level of accuracy is the vast difference between the repetition rates of the two beams. The ion beam has a repetition rate of 9 MHz and the electron beam has a repetition rate of 704 MHz. This large difference in frequencies creates disparate responses between the two sets of electronics that are designed to handle the signals from each beam. To ensure that the beam positions are close enough to each other, a relationship must be established during calibration between the two sets of electronics, or the position measurement must be absolute (from the center of the beam pipe).

Physical implementation of the switch and amplifier circuit. The perpendicular circuit board contains the switches which are oriented so that the different signal paths are nearly identical to each other.

Switch configuration used to eliminate temperature drifts in cables downstream. Amplitude imbalances present in a pair of cables can be detected when the inputs to the cables are swapped.

The blue signal is the position calculated from a simulated signal. The signal goes through a switch similar to the one shown to the left. There are several hundred feet of cable between the switch and the rest of the electronics. The scale of the y-axis is measured in microns. Variations in cable losses due to temperature changes can be seen in the envelope of the blue signal. The green signal is a running average of the blue. These results illustrate the effectiveness of including switches as far upstream as possible.

**Phase Measurements**

Energy measurements are also necessary for LEReC and will be calculated from the time of flight of the electron beam. Time of flight measurements will be achieved by sampling with a clock locked to the global RF clock that is used to generate the 704 MHz clock. The signal will then be digitally down-converted with a digitally synthesized 704 MHz clock to calculate the phase at each BPM.

A simple representation of the digital quadrature demodulation that is performed after the signal is sampled. The clock used to down convert the signal is a 400 MHz clock that is generated from the 10 MHz reference output of the signal generator that was used to create the 700 MHz clock. The cascaded integrator comb filters (CIC) low pass the in phase and quadrature signals while also reducing the data rate by a factor of 512. This gives a bandwidth of about 390 KHz which should be sufficient for measuring power supply ripple. The phase can be calculated by taking the inverse tangent of the i and q outputs.

As an initial test, the phase was varied using the phase shifter with steps of 0.6 degrees, 1.2 degrees, and 2.4 degrees. The results are not exact however as a noticeable shift was created when the screwdriver came into contact with the coaxial phase shifter. This created the dips shown on the chart preceding each increase in phase.

**References**

