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RF Reference Distribution System for the RISP Linac

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1. Introduction

The heavy-ion accelerator of the Rare Isotope Science Project (RISP) in Korea has been developed [1-2]. The RF reference distribution system must deliver a phase reference signals to all low-level RF (LLRF) systems and BPM systems with low phase noise and low phase drift. The frequencies of RISP linac are 81.25MHz, 162.5MHz and 325MHz, and there are 130 LLRF systems and 60 BPMs respectively for SCL3, and 210 LLRF systems and 60 BPMs for SCL2. 81.25 MHz signal is chosen as an reference frequency, and 1-5/8" rigid coaxial line is installed with temperature control. This paper describes the design for the RF reference distribution system such as reference frequency, phase noise on master oscillator, phase stability and temperature influence, and reference line attenuation.

2. RF reference distribution

2.1 Conceptual Design

There are a variety of approaches to distribute the RF reference signals and many new technologies are being applied worldwide [3-5]. As coaxial-cable-based distribution and optical-fiber-based distribution are the two most commonly used solutions for RF reference distribution in Linac. Coaxial cable is a very conventional medium to distribute the RF reference signal, by which RF signal can be transmitted directly from source to destinations [6]. For a linac with multiple LLRF systems, a bus-like topology is preferred with a main cable line running the RF power and many tap points along the line delivering required signals to each of LLRF systems. The bus-like topology distribution has the advantage of less volume, less power attenuation and easier to implement compared to star topology.

The requirements of the RF phase stability is ±1° in RF control system, and phase stability in RF reference should be within ±0.3° commonly to satisfy the requirements. Fig.1 shows the synchronous phase deviations depending on RF phase shift in the case of the long length for SCL2. This calculation means that the phase shifts in RF reference line should be controlled within about ±2.5° to maintain the phase stability within ±0.3°.

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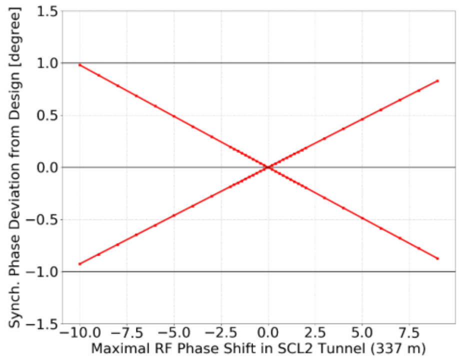


Fig. 1. Synchronous phase deviation due to RF phase shift in SCL2 tunnel.

2.2 RF Reference Line

As phase drift in cable is mainly caused by temperature change, an obvious way to reduce phase drift is to make the cable shorter and to control the temperature around cable within a small range. Fig.2 shows the schematic layout of the RF reference line for RISP Linac. To minimize the temperature related phase change, the reference clock is fed from the center of the SCL2 tunnel into three RF distribution lines through a 4-way splitter, as shown in Fig.2, which are Ref.line#1, Ref.line#2 and Ref.line#3. The construction of SCL1 (Ref.line#4) was pended. Exception for extension in the SCL2, each RF reference line is about 120m. In addition, low loss, temperature-controlled 1-5/8" rigid coaxial line is selected for the RF reference lines. Phase change due to temperature change was calculated for each of the cavity along the linac, as shown in Fig.3. Foam polyethylene instead of Teflon is used as the insulating material in the cable to avoid the so-called teflon "knee" induced phase instability problem [7].

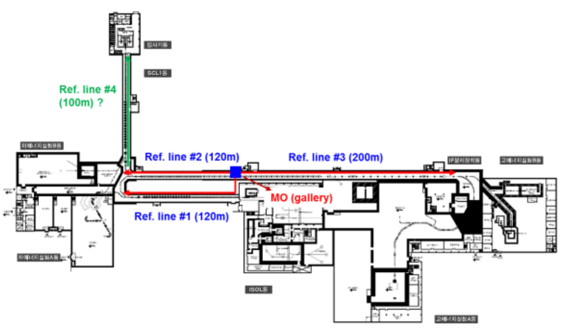


Fig. 2. Schematic layout of the reference lines and the reference-feed in the linac tunnel

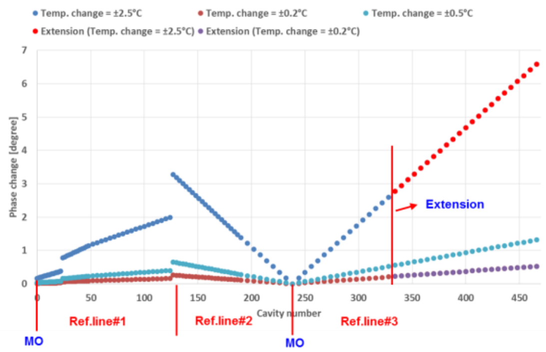


Fig. 3. Phase change ("degree" corresponds to the cavity RF frequency) due to temperature change for each of the cavity along the linac.

The main line is designed to have dry air inside during operation, to avoid phase drift caused by humidity changes. Dry air expects to be pressurized to a couple of psi above atmospheric pressure.

The reference rigid line for the SCL3 was installed in the SCL3 tunnel as shown in Fig. 4.

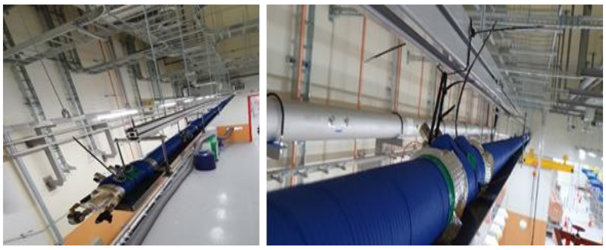


Fig. 4. RF reference rigid line installed in the SCL3 tunnel

2.3 Master Oscillator

81.25 MHz signal is chosen as the reference frequency. Fig.5 shows the block diagram of master oscillator for RF reference clock generation. 10MHz rubidium generator is used and is synchronized with 1 pps signal of timing system. 81.25MHz reference signal is generated in a phased-lock oscillator (Wenzel), and is amplified in a solid-state amplifier with a low phase noise.

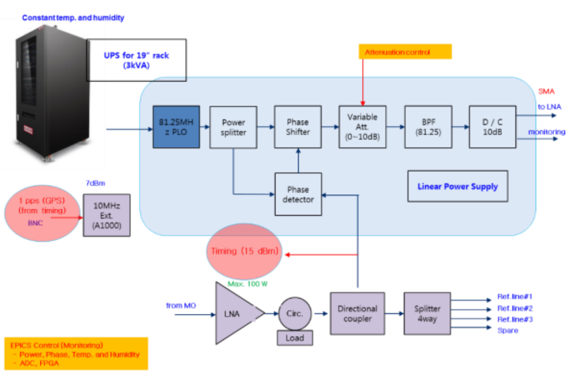
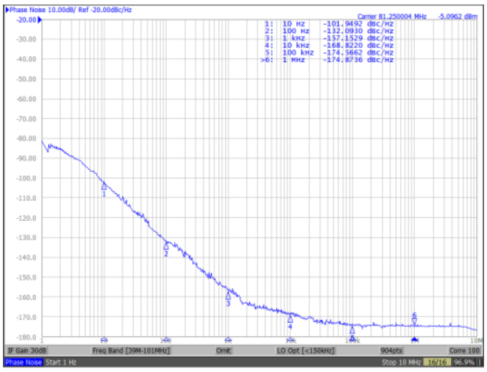
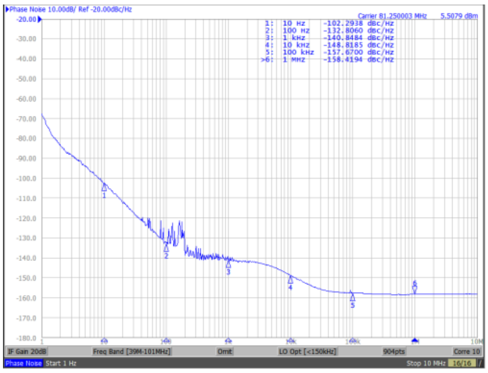


Fig. 5. Block diagram of master oscillator for RF reference clock generation.

A phase noise of 81.25MHz was measured as shown Fig.6, and the measured results are summarized in Table 1. RMS jitter of the LNA output was about 588 fs, and phase error was 0.0172°. All components of the master oscillator are installed in a constant temperature and humidity rack.



(a) phase noise at the 81.25 MHz PLO with an input from the 10 MHz rubidium frequency generator (A1000)



(b) phase noise at the high-power LNA with an input from the A1000 and the 81.25 MHz PLO.

Fig. 6. Measured phase noise of the 81.25 MHz reference signal

Table 1. Measured phase noise and calculated phase error of the reference clock.

Frequency offset	10 MHz Rubidium Frequency (A1000)	81.25 MHz PLO with A1000	81.25 MHz LNA with A1000 and PLO
1 Hz (dBc/Hz) 10 Hz (dBc/Hz) 100 Hz (dBc/Hz) 1 kHz (dBc/Hz) 10 kHz (dBc/Hz) 100 kHz (dBc/Hz) 1 MHz (dBc/Hz)	-116 -140 -158 -164 -170 -170 -	- -101.9 -132.1 -157.1 -168.8 -174.5 -174.8	- -102.3 -132.8 -140.8 -148.8 -157.7 -158.4
Calculated jitter	70 fs	200 fs	588 fs
Calculated phase error	0.00025°	0.0058°	0.0172°

3. Conclusions

The reference distribution system for RISP Linac has been developed. Master oscillator has been designed to generate 81.25MHz reference signal. To minimize the temperature related phase change, the reference clock is fed from the center of the SCL2 tunnel into three RF distribution lines. Low loss, temperature-controlled 1-5/8" rigid coaxial line is selected for the RF reference lines. The main line is designed to have dry air inside during operation, to avoid phase drift caused by humidity changes. The reference rigid line for the SCL3 was installed in the tunnel. The master oscillator was installed, and phase noise was measured.

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