Implementation of the Low Level RF System at PLS Storage Ring

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Abstract

The RF system in the storage ring of the Pohang Light Source (PLS) consists of four independent RF station and its total RF power of 240 kW (500 MHz) can support the storage ring operation up to 400 mA at 2 GeV. Continuous variation of power levels from the klystron amplifier is demanded to accommodate the signal phase and amplitude changes to each RF cavity during beam stacking and decaying. The signal amplitude control, the forward path phase control, and the tuner control are used to achieve this demand and, thus, to keep the RF cavity on tune. We have improved beam operation properties by improving circuits in the low level RF system. We can now understand the main causes of beam instabilities better in various conditions.

1 Introduction

Low level RF system at PLS storage ring consists of 3 independent feedback control circuits such as forward path phase control, automatic gain control, and tuner control circuit. These circuits will ensure the required stability condition for the PLS RF cavities operation. Fig. 1 shows a simplified block diagram of the low level RF system of the storage ring RF system.

The RF power for four cavities is provided by four independent RF stations with a 60kW klystron amplifier system per each station. The output power from each RF station is fed via high power circulator to drive the RF cavity. In the 2.0 GeV operation, the dissipation of the RF cavity is 20kW for 400 kV of accelerating voltage with a coupling factor of 1.8. The RF cavity dissipation should remain constant through the entire range of operating beam current zero to 400mA.

When the beam is demanding more power from the RF cavities, the automatic gain control loop should adjust the drive signal of the RF system providing more power for the beam and keeping the RF cavities voltage constant. As the RF signal must go through the low level RF system including three automatic control circuits and finally the klystron amplifier system, the phase of RF signal will vary with the RF output power level. Since the phase variation may give some effects on beam stacking, the phase control circuit has to correct it precisely to keep the phase constant throughout the whole range of the operating power. In order to keep the four RF cavities on-tune during the operation, each RF cavity tuner control loop controls a stepping motor to move the plunger in and out of the RF cavity to keep it on tune.

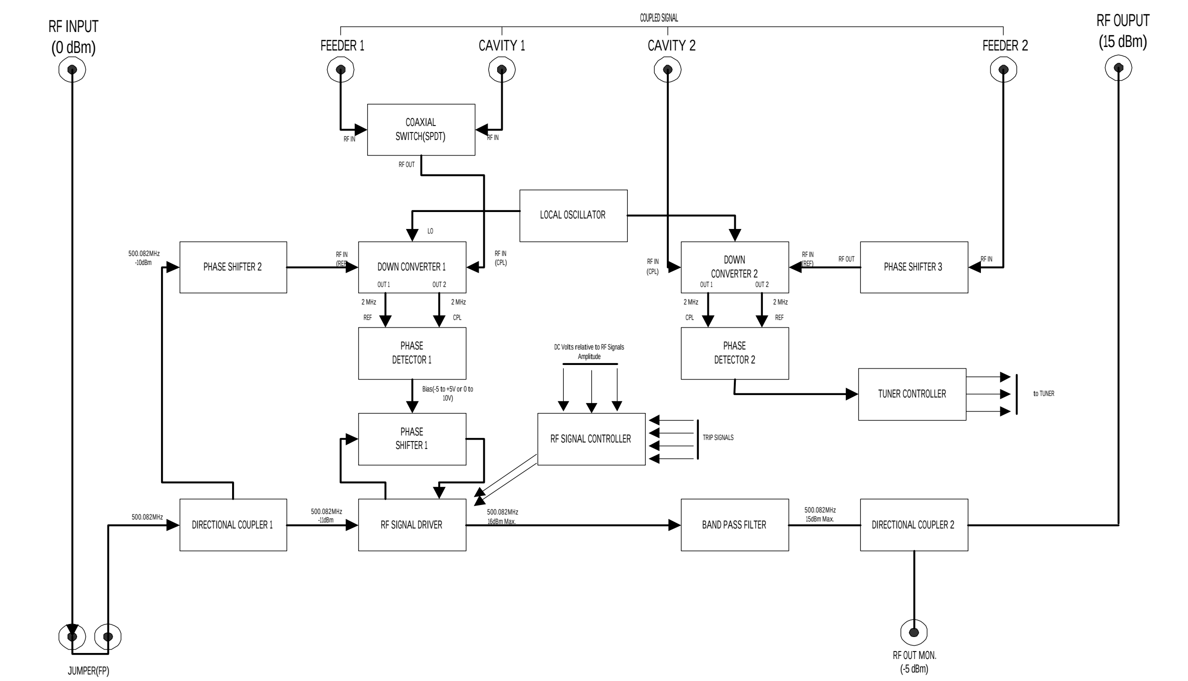

Fig. 1: A simplified block diagram of the low level RF system of the PLS storage ring

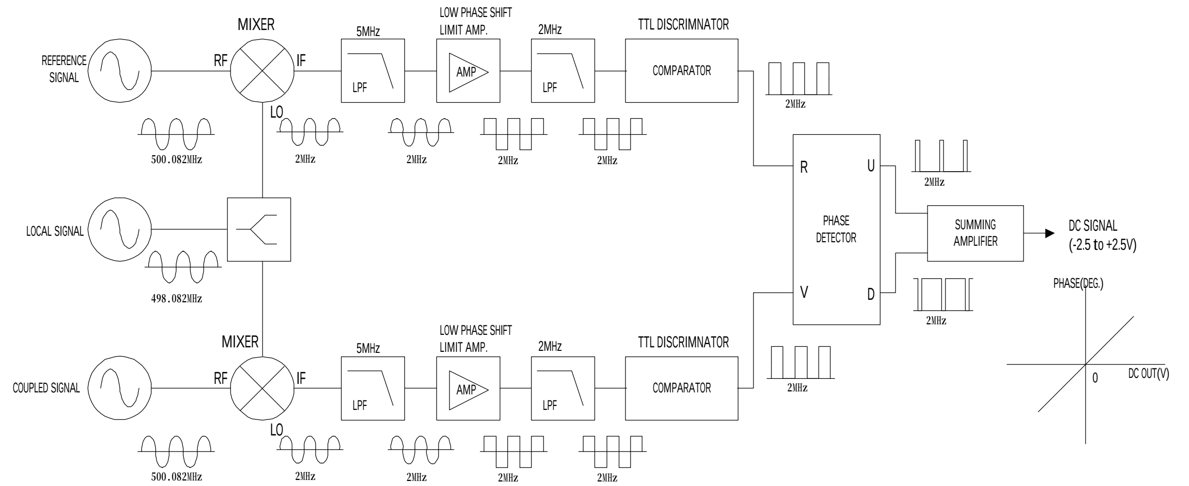

Fig. 2: Phase detection circuit diagram & output waveform of each stage

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The intermediate frequency (IF) output signal of the mixer is filtered and amplified and fed back to the electronic phase shifter to compensate for the phase error in the RF signal path.

Fig. 2 shows the phase detection circuit diagram and output waveform of each stage. In late 1996, an upgrade was pursued to improve dynamic range of phase detection by separating the low frequency signal from the high frequency signal to isolate interference between them and by strengthening and shielding the high frequency circuit with a down converter.

The master oscillator signal goes through an electronic phase shifter to a phase detector as the station phase reference signal. A directional coupler in the feeder of the RF cavity picks up a portion of the RF signal and feeds it back to the RF port of the phase detector.

The intermediate frequency (IF) output signal of the mixer is filtered and amplified and fed back to the electronic phase shifter to compensate for the phase error in the RF signal path.

This phase detector has shown a satisfactory dynamic range in the input range of -40dBm to 0dBm as shown in Fig. 3. We have designed and produced them for reliability using improved EPLD (Erased programmable logic device) in the automatic gain control and the tuner control circuits, compared with the old version of low level RF system. As a result, we have less possible errors in normal operations. The new system produces better reliability and the fast response time. Table 1 shows the performance comparison between EP910 and EPM7064LC.

During the test without beam, the amount of phase variation of the system is more than 30 degrees between operating power level of 6kW and 60kW. With the forward path phase loop, the phase variation is reduced to less than ±0.3 degree. With an automatic gain controlfeedback loop, the amplitude variation of RF power into the RF cavity is measured to be less than ±0.5% (0.039dB). At the initial phase, the operating power for the four cavities is 80 kW without beam. With beam current of 200mA at 2.0GeV, the total RF power required is about 120kW. With the forward path phase control loop the phase variations reduced to be less than 0.3 degrees.

Table1: EPLD (EP910 and EPM7064LC) performancec omparison

Feature	EP910	EPM7064
Available Gates	Over 900	2500
Usable Gates	750	1250
Macrocells	24	64
Max. User I/O	24	68
Fmax	41.7MHz	125MHz
Icc(mA)	20.0	
Standby Icc(mA)	0.1	
TPD	30nS	12nS
Package	CerDIP 40pins	PLCC84pins

3 The purity of RF signal

By comparing with result of theoretical calculation, we adjust the forward path phase of each RF stations to the optimum point. Fig. 4 shows a spectrum of RF signal measured at the RF cavity input port without beam. Fig. 5 shows a spectrum of RF signal with beam of 140mA. In the injection stage, as the current reaches a threshold level, the revolution frequency (1.06855MHz) appears as a side band periodically back to the RF port of the phase detector.

4 Station phase tuning

Information of the synchrotron oscillation frequency is used for tuning the station phase. The synchrotron oscillation frequency is given as

$$fs = \frac{1}{2\pi}\left(\frac{\alpha h \omega_0^2 eV\cos(\phi_0)}{2\pi E}\right)^{1/2}$$

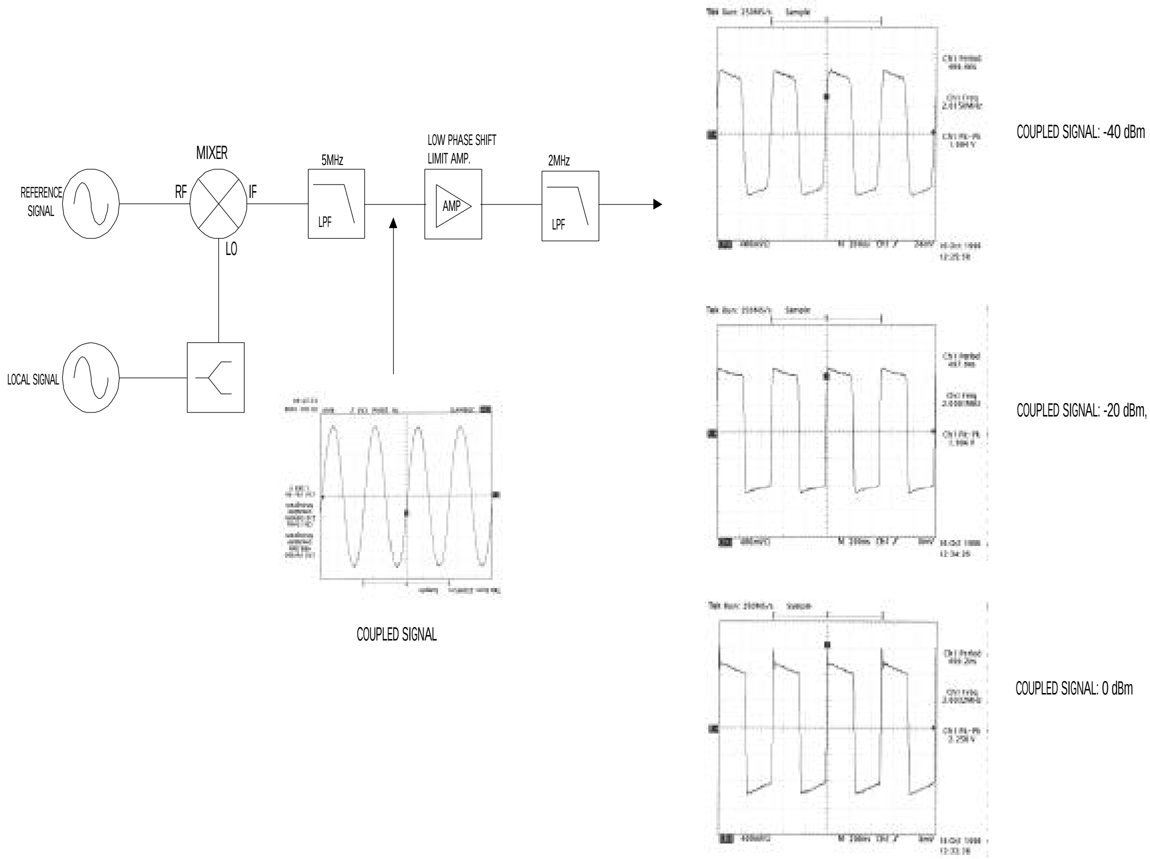

Fig. 3: Characteristics of phase detection and amplification of phase detector

where the momentum compaction α is 0.001809, the harmonic number h is 468, the revolution angular frequency ω_0 is $2\pi \times 1.06855 MHz$, and the RF voltage eV is 1.6 MV. The synchronous phase angle ϕ_0 is determined by

$$\cos\phi_0 = [1 - (\frac{U_0}{eV})^2]^{\frac{1}{2}}$$

where the synchrotron radiation loss per turn at 100 mA U_0 is 225 keV, and the electron energy E is 2 GeV, producing the synchrotron oscillation frequency of 11.4 kHz. We adjusted the forward phase of four RF stations to a correct value, then we could obtained maximum synchrotron frequency as the theoretical one. Fig. 6 shows the spectrum of the measured synchrotron oscillation frequency.

5 Summary

A new low level RF system has been implemented for the PLS storage ring RF system in late 1996. Each of the three feedback circuits shows a good performance. With the electron beam, however, some minor problems have been noticed such as slow drift of the phase reference and reduced dynamic range. With an extensive study and measurements with beam, we anticipate a better system to be ready very soon.

Acknowledgments

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References

[1] PLS Conceptual Design Report, PAL (1992).

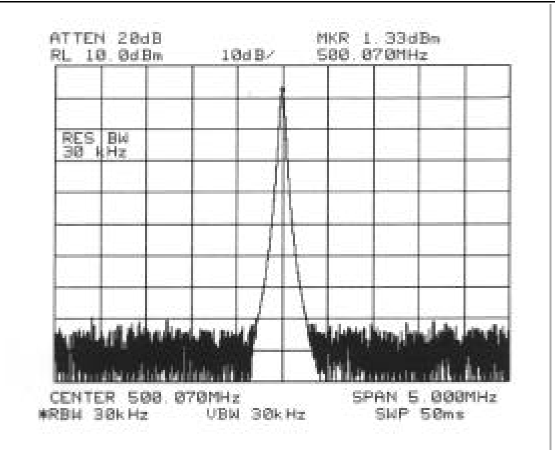

Fig. 4: A spectrum of RF signal from the RF cavity input without beam

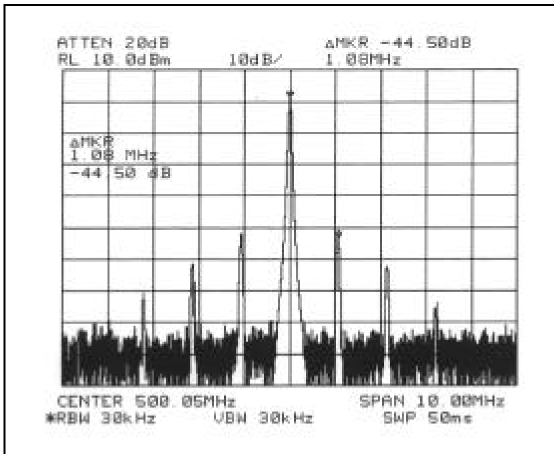

Fig. 5: A spectrum of RF signal from the cavity input with beam (beam current 140mA**)**

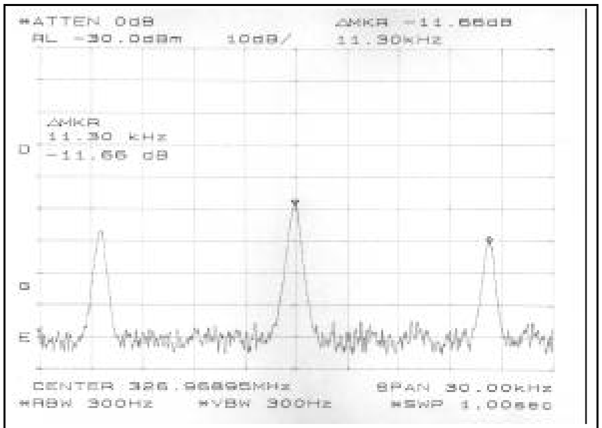

Fig. 6: The spectrum of the synchrotron oscillation frequency