SPEAR-148
A. P. Sabersky
November 1972

MEASURING TUNES WITH A PHASE-LOCKED LOOP

Introduction

We measure beam tunes, tune widths, and tune shifts by exciting the stored beam through the gated amplifiers of the fast-feedback system, then observing beam enlargement on the synchrotron-light monitors. Pure horizontal and vertical position signals could be used to observe beam excitation, and the sensitivity of this method would be limited by the sensitivity of the beam-position measuring system.

Most storage-ring parameters, for example magnet settings and stored currents, are directly read out to the operators and experimenters, in contrast with the values of tunes and tune shifts, which must be rather laboriously measured. A monitor which automatically followed the tune frequencies and read them out continually to the experimenters and the control computer would be a timesaving convenience as well as an effective alarm in case of undetected changes in operating conditions.

The Phase-Locked Loop[1]

The phase-locked loop (PLL) is a circuit which has such wide use that a it is customarily treated as a "black box" and is applied almost as a single component, much like the operational amplifier. The PLL contains a voltage-controlled oscillator (VCO) which locks onto an external reference frequency or an external reference device, e. g., a tuning fork. A good example of a PLL is the oscillator which drives the horizontal sweep in a television receiver. Rather than deriving the starting time for each horizontal line

[1]Floyd M. Gardner, Phaselock Techniques

from the composite video information, the receiver has its own oscillator, locked to an external reference frequency.

A block diagram of a PLL is shown in Fig. 1. The phase detector produces a dc voltage output proportional to the phase difference between the input signal and the VCO frequency. This voltage, which is the error signal in the feedback loop, alters the VCO frequency until it exactly matches the input frequency. There is a residual phase error between the input signal and the VCO signal. The loop filter modifies the error signal to give the feedback system the required characteristics for stability, tracking, etc.

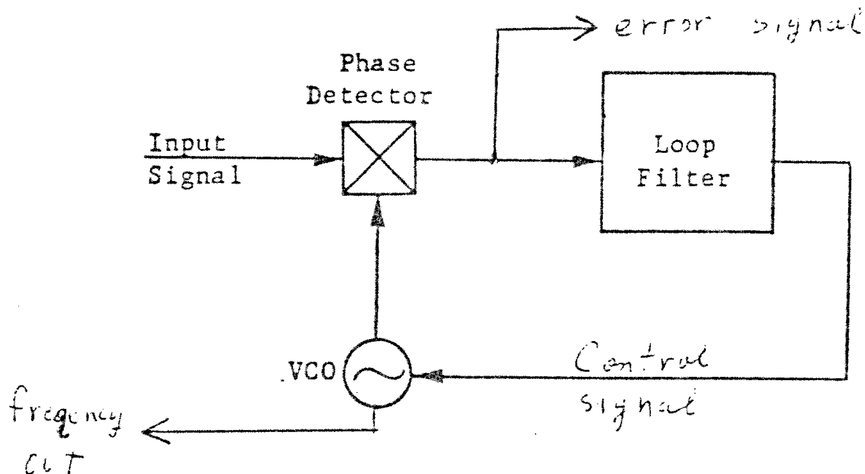

FIGURE 1 BASIC PHASELOCK LOOP

If the input signal is frequency-modulated, the PLL will act as an FM detector. The VCO cannot follow the input signal frequency instantaneously and the phase lag of the VCO appears on the error signal. If we use a low-pass filter with a cutoff frequency below the modulating frequency, the VCO will stay at the central frequency and the demodulated FM will appear on the error signal.

Measuring Tunes

If there are residual coherent betatron oscillations and the detection system is sensitive enough to observe them, the PLL is locked onto the frequency of interest and its output connected to a frequency counter. If it is necessary to excite betatron oscillations in order to observe them clearly, the output of the PLL is connected to the pulsed-beam excitation system in the same manner that the precision oscillator is now used. The output amplitude of the VCO is independent of input-signal amplitude and frequency, and the loop will stay locked on over a wide range of input-signal strength.

If the beam is executing coupled betatron-synchrotron oscillations, the PLL will lock onto the main line, rejecting the amplitude-modulated sidebands. In case of any line-splitting due to frequency modulation, the error signal will give a measure of modulation depth and frequency while the PLL output stays at the average frequency.