SWITCHED DETECTOR FOR BEAM POSITION MONITOR*

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Abstract

The NSLS storage rings use sets of four button electrodes to determine the transverse position of the stored electron beam in the vacuum chamber. By means of GaAs switches, the 211 MHz component of the induced signals on each of the four buttons is measured in turn by a single amplifier/detector channel. These signals are then stored in four sample and hold circuits. The measurement cycle is repeated at a rate of 40 KHz. The required sums and difference of these signals are obtained by analog means. The results are normalized with respect to beam intensity by "servoing" the gain of the amplifier/detector channel such that the sum of the signals from the four buttons is maintained at a fixed value.

Introduction

To meet the increased requirements of the experiments being performed at the NSLS, the present beam position monitoring system must be updated. The new system must provide greater accuracy and a wider bandwidth than the present system. Increasing the bandwidth of the system will allow global[1] and local[2] position feedback systems to be implemented. The design goal of the system is to provide ± 10 micrometer accuracy within a 300 Hz bandwidth, over a 30 dB dynamic range.

For this purpose, new switched RF receivers have been developed. These receivers will each process RF signals from a single set of existing pick-up electrodes (pues). Thus, twenty-four and fourty-eight receivers will be required for the vacuum ultra-violet and x-ray rings respectively.

From a set of four pues presently installed at the NSLS (Fig. 1) the transverse position of the beam may be determined by:

$$X_{pos} = K_x \frac{V_A - V_B + V_C - V_D}{V_A + V_B + V_C + V_D} \text{ (mm)},$$

$$Y_{pos} = K_y \frac{V_A + V_B - V_C - V_D}{V_A + V_B + V_C + V_D} \text{ (mm)}$$

where V_A, V_B, V_C, V_D are the RF signals induced by the electron beam on the pues. For beam motions close to the center of the beampipe K_x and K_y are relatively constant. A method of compensating for variations in K with beam position is discussed in Ref. 3.

From the above formulas it can be shown that a relative difference in RF signals from the pues of 10 db translates to a position of approximately 10 mm from center. The receiver has to be linear over a 10 dB range to accurately measure beam position over ± 10 mm for a given beam current.

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There are two basic methods of processing the pulse signals from capacitive pickups. The signals can be processed in the time domain by peak detection, or in the frequency domain by detecting one Fourier component of the pulse train by means of a tuned receiver. Each of the signals may be processed in parallel, or multiplexed through one channel. An overview of such RF detector systems as well as synchrotron light detectors is given by Billing.[4] The receiver discussed in this paper multiplexes the four electrode signals from one pue station through a single tuned amplifier/detector channel.

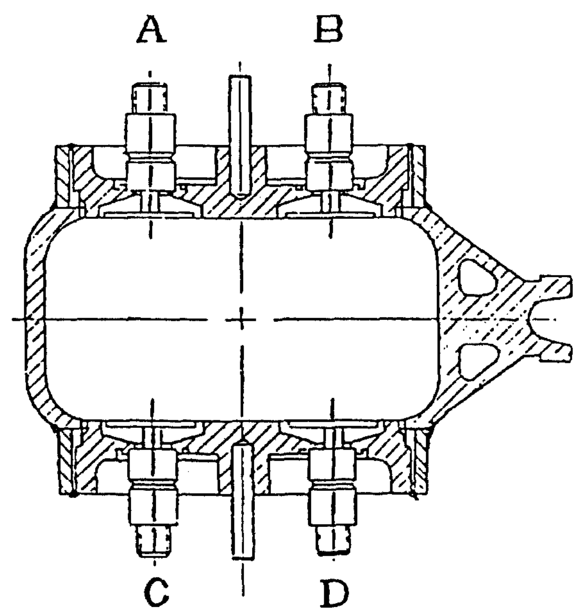

Fig. 1. A set of four PUEs mounted in the vacuum châmber

Receiver Description

Figure 2 shows a block diagram of the receiver. The induced signals from the pue electrodes are first filtered to remove frequency components above 300 MHz. These filtered signals are then multiplexed using a gallium arsenide FET (GaAs) 4-pole switch. A five section helical bandpass filter (1 MHz 3 dB bandwidth) is used to select the fourth RF harmonic (211.54 MHz) as the Fourier component to be detected. The multiplexed signals are then mixed down to 10.7 MHz where a single IF amplifier/detector channel is used to detect the amplitude of each signal. Integrating sample and hold circuits are used to store the information. The measurement cycle is repeated at a rate of 40 KHz. To produce the position voltages, the sums and differences of the stored signals must be obtained. These position signals are derived using simple

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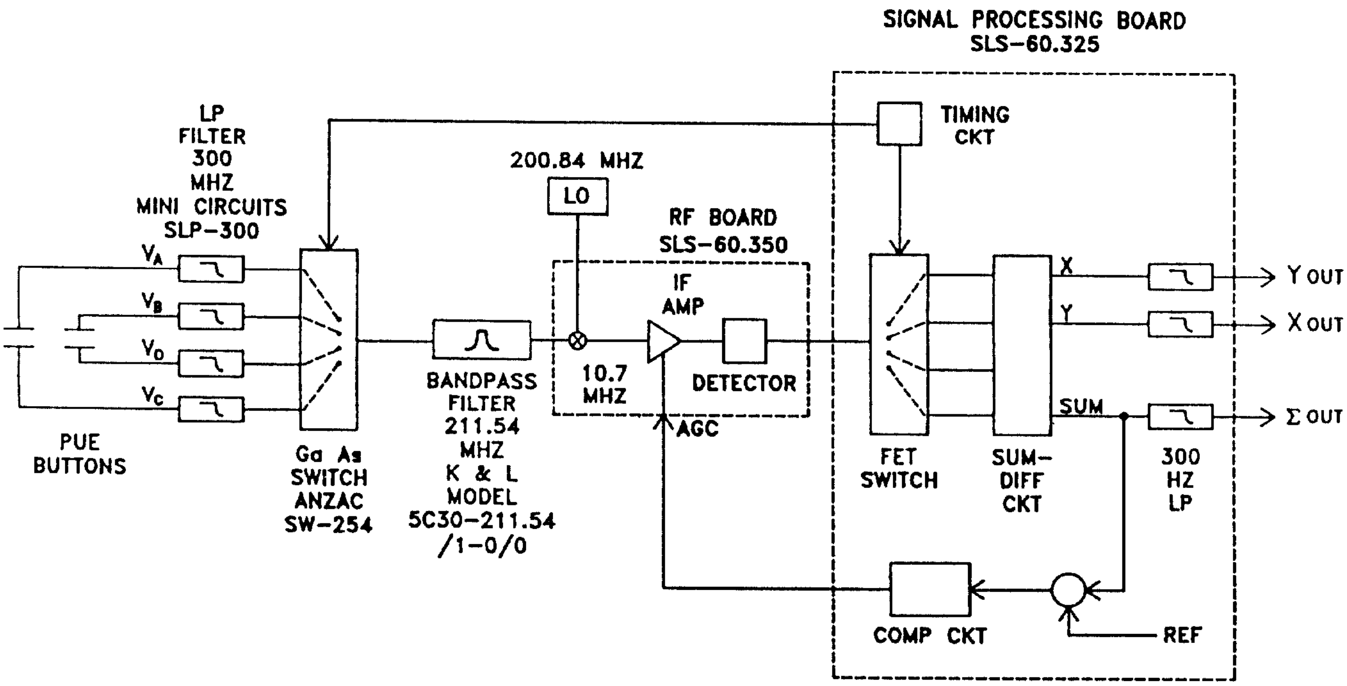

Fig. 2. Block diagram of the switched PUE receiver

integrated circuits at baseband frequencies. The results are normalized with respect to beam current by means of a servo amp. This servo adjusts the gain of the IF amplifier to keep constant the sum of the 4 stored signals. Low pass filters limit the three output signals (vertical position, horizontal position, and sum) to 300 Hz.

Advantages

Detecting the four pue position signals with one amplifier/detector channel eliminates the need to match separate RF detector channels. This matching would be difficult and costly since the detectors would have to be matched better than 0.02 dB over the entire 40 dB dynamic range for a position resolution of 10 micrometers.

In the switched receiver, the components which must be matched are the input 300 MHz low pass filters and the GaAs switch. Extensive testing of these components with regard to input power, temperature and day-to-day drift has been performed. Relative differences in the insertion loss of these components track to within 0.03 dB over input power ranges of -40 dBm to 0 dBm and temperature ranges of 10 to 50 degrees celsius. Over all ranges the switch module has typically 1 dB insertion loss and better than 60 dB isolation at 211.54 MHz.

There are two advantages to the method of normalization utilized in this design. The necessity of dividing one analog signal by another is avoided. Also, variations in the amplitude of the four position signals at the input of the detector do not depend upon the intensity of the stored electron beam. Therefore, the linearity of the detector needs to extend only over a range of 10 dB and not the full dynamic range of the receiver. The amplifier/detector section of the receiver uses two integrated circuits intended for use in television applications (a Motorola 1349 IF amplifier and a Motorola 1330 synchronous detector).

Other Considerations

If the transverse motion of the beam has appreciable Fourier components higher than half the switching frequency, aliasing will occur. The input signal is averaged over one fourth of the sampling period. Thus, each frequency component present at the input of the switch will be convoluted in the frequency domain with a function of the form:

$$\frac{(\sin N\pi \frac{t}{T})}{N\pi \frac{t}{T}} .$$

Where $1/T = 40$ KHz and $t/T = 1/4$.

A spectrum of frequency components will be created for each frequency at the input. Should a created component fall into the passband of the helical filter it will be detected. If the detected signal is within the passband of the output low pass filters, it will give erroneous position information. For this reason, a switching frequency is chosen to avoid the creation of aliasing components within 300 Hz of 211.54 MHz.

Evaluation

The prototype receiver was evaluated on a test set consisting of a probe inserted into a section of vacuum chamber. A slide mount allows the probe to be moved throughout the cross section of the vacuum chamber with a repeatability of 10 micrometers. A 211.54 MHz RF signal is fed to the probe. The field from the probe induces a signal on a set of 4 pues mounted on the test chamber. These induced signals from the probe may be processed in the same manner as the induced signals from an electron beam in a storage ring. The values of K_x

and K_y mentioned earlier are equal to 18 mm and 21 mm respectively for position changes close to center. Using the above test set the prototype receiver was evaluated. Figure 3 is a plot of vertical position error vs transverse position of the probe.

The dynamic range of the receiver was tested by varying the drive to the probe. Since the gain of the IF amp is controlled by beam intensity (sum voltage), output noise is also a function of beam intensity. As beam current drops, the gain of the IF amp is increased. Thus, the signal to noise ratio is decreased. The lower end of the dynamic range is set to a value where the noise at the output is equivalent to a 10 micrometer beam motion. The upper end of the dynamic range is limited by saturation of the AGC loop.

For the prototype receiver, the dynamic range is -30 dBm to 0 dBm. The 211.54 MHz component of the signal from a pue in the x-ray ring is approximately -24 dBm with 20 milliamps stored beam. Thus, the dynamic range of the detector is appropriate for the signals for the pues in the x-ray ring.

Summary

This receiver provides a relatively simple means to obtain accurate transverse position measurements. By using one amplifier/detector channel, the need to match RF components is minimized. The method of normalization greatly reduces the dynamic range requirements on the detector. The prototype receiver provides ± 20 micrometer resolution within a 300 Hz bandwidth over a 30 dB dynamic range. The receiver is relatively insensitive to the number of bunches stored in the machine and beam energy. Although aliasing is possible, with knowledge of the frequency components contained in the input signal, the possibility can be minimized.

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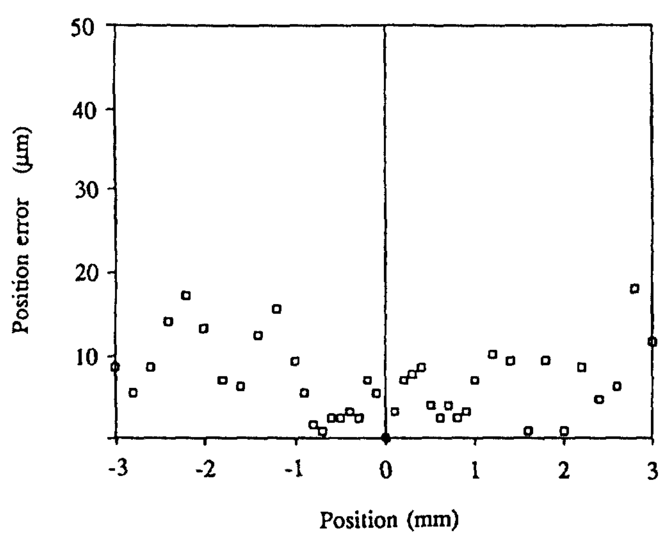

Fig. 3. Position error vs. transverse probe position (prototype)

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