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A RADIAL SIGNAL PROCESS METHOD FOR THE BPS BOOSTER LLRF CONTROL SYSTEM

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Summary

The function of the Radial Position Processor is to convert rf fundamental frequency components induced by circulating bunches in a Position Pick-up Unit into an analog voltage proportional to the average beam transverse deviation from the synchronous orbit position. Because of the relatively large frequency swing, (2.76-6.31 MHz), some second harmonic components of lower frequencies would be passed by a broad-band system capable of covering the entire frequency range. Because of this, and because of the relatively high signal to noise ratio inherent in swept narrow-band channels, the superheterodyne principle has been chosen for this system. Position error discrimination is developed by amplitude to phase conversion following frequency conversion to 10 MHz. This technique results in high precision radial position error discrimination over a 52 db dynamic range of input signals. The system can, therefore, operate without readjustment over a large range of beam intensity and bunching factor.

Detailed system design and test results are described. Since the BPS booster synchrotron is not yet completed, no actual performance details are available.

Introduction

The BPS booster synchrotron will operate at harmonic number 3 with an rf frequency range 2.76-6.31 MHz. The beam radial position pick-ups will be ferrite loaded broad-band devices capable of delivering beam-bunch fundamental and lower harmonic rf signals to a signal processor. The function of the Radial Position Processor is to convert those signals into low frequency analog signals representing the equilibrium radius at all times during the acceleration cycle.

Several techniques have been developed to do this processing[1,2,3]. The techniques most applicable to our needs would be direct detection of the wide-band signals containing the radial error information, or, using a swept local oscillator, converting the swept signals into narrow band (Intermediate Frequency) signals by the superheterodyne technique and processing the narrow band IF signals. We have chosen the superheterodyne technique, primarily because of the noise immunity and improved signal to noise ratio achievable with such a technique.

Following frequency conversion of the two signal channels (inside and outside) there is again a choice of several methods for extracting position information from the two IF signals. We have chosen to process the signals by detecting their relative phase[3].

For BPS Booster Radial Position Processor, the amplitude/phase converter had been completed after the frequency mixing. The test results show that a radial signal processor method like this, combined with the appropriate selection of the IF value, and the precise design and fabrication of channels with extremely well-matched phase characteristic, enable the processor to have stationary phase shift within an error of $\pm 3^{\circ}$ while the swept signal dynamic range varies 52 db. So this can be made to work well over a large range of beam intensity and bunching factor. A block diagram of the processor is shown in Figure 1.

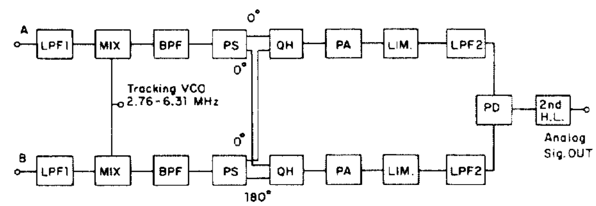

Figure 1 Block Diagram of Radial Position Processor for BPS

Several Remarks

1. For reducing the 2nd harmonics, a high mixed frequency f_o must be chosen. Because the radial position signal has a rise time as short as 0.5 µs, an appropriate pass band (2 MHz) for the band pass filter is necessary. This also forces an increase in f_o. It is clear that the processor works as a high frequency phase discriminator. On the other hand, the upper limit on f_o is limited by HF phase detection technology. A 10 MHz mixed frequency was chosen to meet the requirements. The signal frequency band, the tracking frequency band and the different filter frequency bands are illustrated in Figure 2.

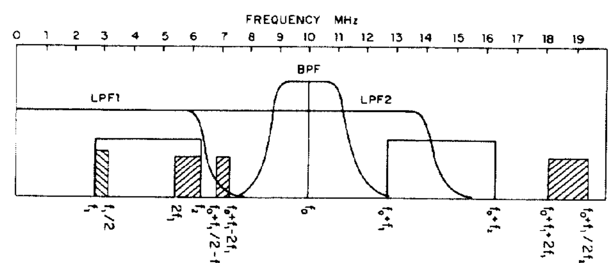

Figure 2 Frequency Bands for Signals and Filters

It is obvious that the 2nd harmonics of the lower frequency band (2.7-3.15 MHz) have the possibility of passing through the LPF, but they are rejected by the following BPF.

2. Precise design of the different filters is necessary[4].

For the LPF, Chebyshev filters with equal ripple in the passband and relatively narrow transition band were chosen. The maximum decay in passband is $A_p<0.1$ db, the minimum stopband decay is $A_s>35$ db, the band width ratio is y=1.5, the cutoff frequency is $F_c=6.31$ MHz and the order of the filters is n=7. For the BPF we choose Butterworth polynominal filters with equal inductance which were designed like the narrowband filters. We have $A_p\leq 1$ db, $A_s\geq 35$ db, $F_{1db}=2$MHz, $F_{35db}=6$MHz, $F_{35db}=6$MHz, $f_o=10$MHz, and n=5.

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The tolerance of inductive parts between their required designed values and actual values must be within 2%, and the parameters of the parts in the corresponding channels must keep equal within 0.2%. In addition to this, the physical construction of the two channels must be as identical as possible.

3. The trim capacitors in the HF preamplifiers of two channels must be carefully tuned to compensate the unavoidable phase error in all commercial parts, for example, the QH has a phase error of about 2^{o}.

4. Impedance matching between stages and the maintaining of reasonable signal levels in all stages was kept in mind throughout the entire work.

Test Results

Figure 3 shows the two 10MHz channels phase error due to the beam intensity variation. Phase erors within $\pm 3^{o}$ were obtained within the dynamic range of 52 db and the 56 db decay of the sum signal results in a phase shift error of 6^{o}.

The amplitude to phase conversion curve is shown in Figure 4(a). The sensitivity is 6^{o}/1db. The curve (b) shows the phase detector output characteristics. The sensitivity is 1v/2db.

Figure 5(a) and (b) shows the radial position output waveforms for different input conditions.

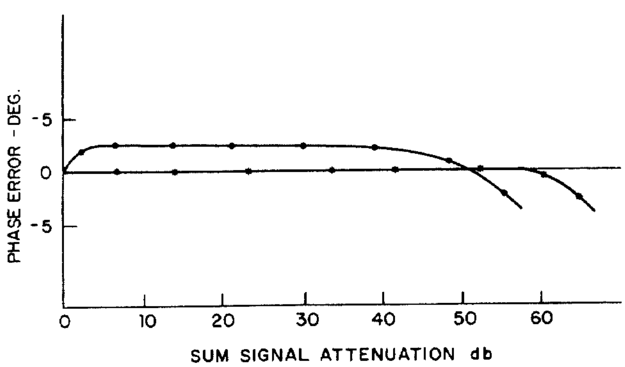

Figure 3 Phase Errors Introduced in Each Channel for A Large Range of Beam Intensity

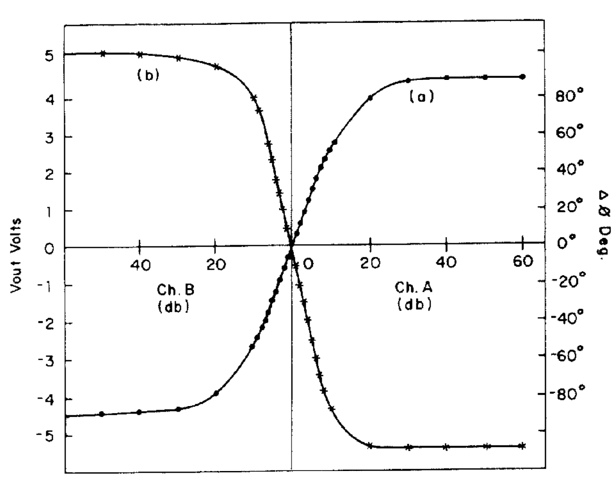

Figure 4(a)Amplitude/Phase Curves
(b)Phase Detector Output Characteristics

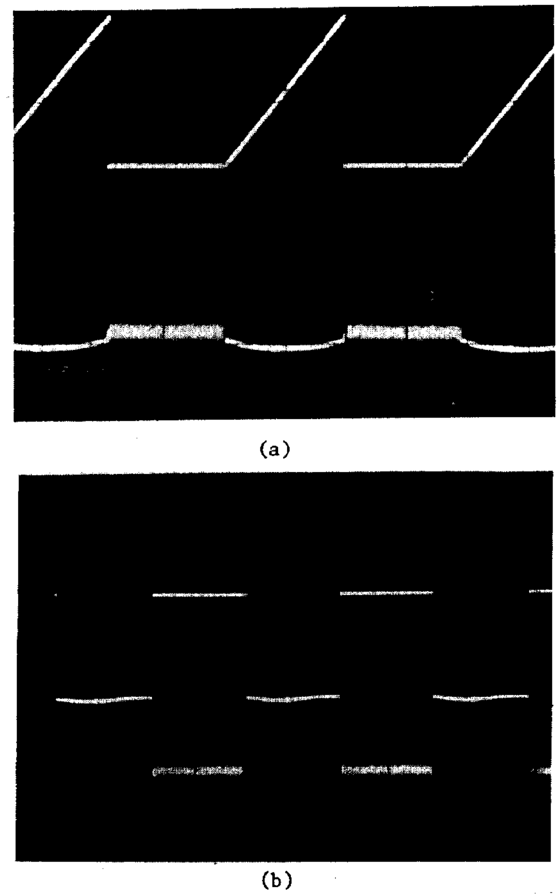

Figure 5 Radial Position Output Waveforms. a) Both beam detectors at 0 db. Upper trace is frequency program driving the frequency from 2.63 to 6.31 MHz during a 4 msec sweep time. Lower trace is the analog position signal output from the processor. b) The frequency is being swept over the same range as in a but input b is 12 db lower than input a. The upper trace is the swept rf input to channel B.

Acknowledgements

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