

A PROBLEM IN RF SWITCHES OF MULTIPLEXING BPM SYSTEM

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Abstract

At SPring-8, we have been developing a new detection circuit for beam position measurement with a resolution of submicron and a measuring interval of a few milliseconds with high stability. In the circuit, a multiplexing method using RF switches is employed in order for a drift of the circuit to be canceled. To achieve design performance, the switches must have following properties: a short switching time, high repeatability and long lifetime. During the evaluation of components for the new detection circuit, we found that some RF switches made of GaAs had a problem that the output signal changed for a few m dB for seconds after the switches were turned on. A few m dB, which is 1/10000 in voltage ratio, corresponds to a beam position error of a few microns in SPring-8. Such position error is out of the required specifications. We investigated several kinds of RF switches and decided to adopt a CMOS RF switches as the multiplexer. In this paper, we report switching properties of several RF switches and demonstration of beam position measurement using the switches.

INTRODUCTION

We have been developing new detection circuit for COD measurement. The position resolution and the repetition rate of measurement required for the circuit is submicron and hundreds of cycles per second, respectively. Furthermore, a long-term stability of the micron to sub-micron is required. Recently, parallel processing circuits for COD measurement for the sake of high measurement repetition tend to be employed [1, 2, 3], however, we have adopt a multiplexing method, in which four beam signals from one BPM head are multiplexed with RF switches and detected with one detection circuit, in order to increase the long term stability and to reduce the signal amplitude dependence of the detection circuit.

In order to achieve fast repetition of measurement with the multiplexing method, short switching time is required for RF switches. In addition, for the purpose of high stability on beam position measurement, high repeatability of RF switches is required.

Now, we are checking performance of prototype of the circuit. Total performance and that of the circuit downstream of the RF switches will be reported after installation and commissioning. In this paper, we report effect which arises from characteristics of RF switches.

PROTOTYPE

Fig. 1 is a block diagram of prototype of the developing circuit. Three BPMs (total twelve beam signals) are mul-

tiplexed with a 12:1 RF switch. After a frequency component of acceleration frequency, which is 508.58 MHz at SPring-8, in the pick-up signals is down-converted to 250 kHz IF frequency, the down-converted signal is digitized with 1MSPS-ADC for 1 ms. The digitized signal is processed with DSP and sent to control system. Thus three BPM data can be obtained every 12ms. When signal from a signal generator of 508.58 MHz is fed to the circuit without RF switches, i.e. BPMs and RF switches in Fig. 1 are replaced with signal generator and power divider, we can obtain the position resolution of 0.2 μ m in standard deviation.

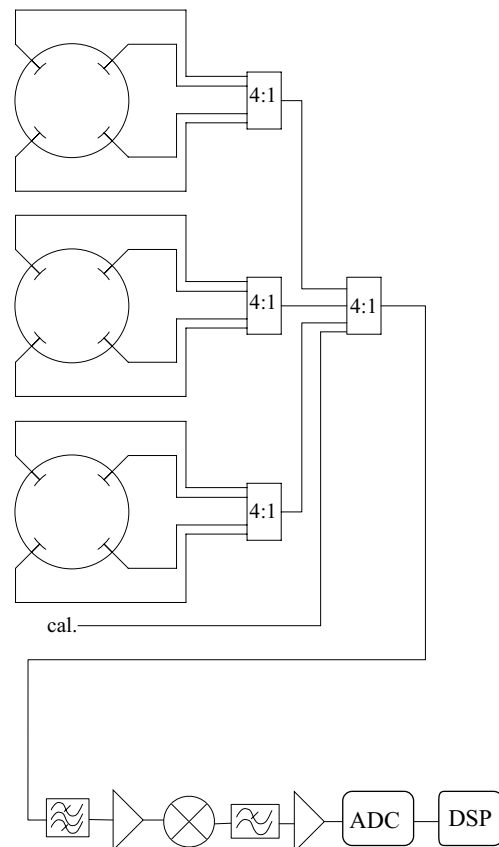


Figure 1: Block diagram of the developing circuit.

SWITCHING TIME

During initial phase of the circuit design, we planned to adopt RF switches made of GaAs. When we measured signal from signal generator with a prototype of the detection circuit equipped with GaAs multiplexer, we observed an unexpected behavior. As shown in Fig. 2, obtained beam position changes asymptotically for a second after

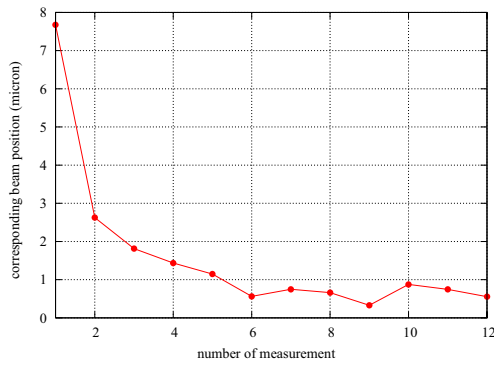


Figure 2: Corresponding beam position obtained with GaAs multiplexer.

the switch was turned on.

The beam position measured with multiplexer depends on the switching pattern, such as the order of the switching the channels and switching rate. We have to eliminate this kind of dependence to obtain the correct beam position data.

We measured switching time of two types of GaAs switches and CMOS type switches using spectrum analyzer (Rohde& Schwartz FSU08) of zero-span mode with its resolution bandwidth set to 100 kHz (Fig. 3). In the figure, absolute RF power is normalized with their final values. The output signal from GaAs switches reached the final values very slowly; it took several hundred milliseconds to read the final values. We did not observe such kind of behavior in the CMOS switch.

The observation of the switching behavior with an oscilloscope cannot recognize this kind of slow ramp of the signal, because the range of the variation is too small to be measured with 8-bit resolution, which correspond to 4×10^{-3} . Although the range of the signal variation is small for normal measurement instruments, the effect of the signal variation to the position values are significant for a beam position measurement with micron to sub-micron resolution.

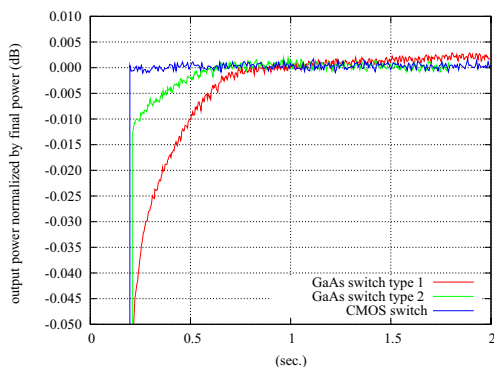


Figure 3: switching behavior observed with spectrum analyzer.

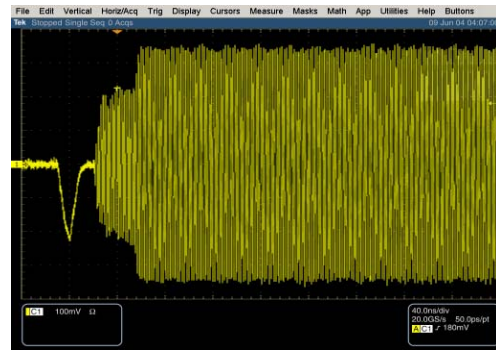


Figure 4: Switching behavior observed with 8bit oscilloscope.

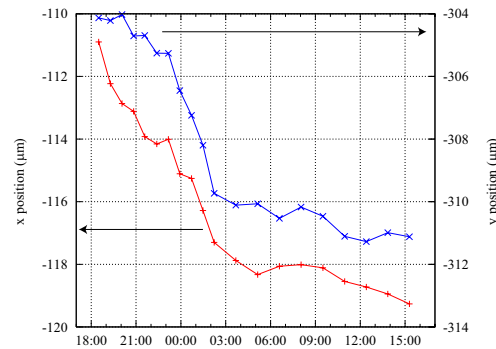


Figure 5: Long time measurement.

REPEATABILITY

For a test of repeatability of CMOS switch, we measured signal from signal generator for about 24 hours. During the measurement, a standard deviation of the calculated x/y position was $0.3 \mu\text{m}$. As shown in Fig 5, horizontal and vertical positions drift about $10 \mu\text{m}$ with 24 hours. The drift of the position might suggest that RF switches drift independently.

MEASUREMENT WITH BEAM

We measured actual beam signal for 15 minutes during user operation at the beam current of 100 mA with top-up operation. Fig 6 is the result of the measurement. As can be seen in the figure, vertical beam position jumped about $2 \mu\text{m}$. This jump was also observed with current BPM monitor.

The position resolution observed with actual beam (5.2 and $2.0 \mu\text{m}$ for horizontal and vertical direction, respectively) is larger than that with signal generator. The source of this deviation might come from a vibration of beam duct and ripple of magnet power supplies[4]. We have to point out the cause of this deviation to take full performance of the circuit.

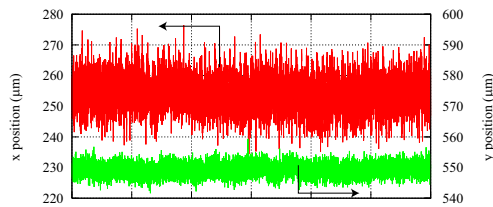


Figure 6: Measurement of actual beam signal.

SUMMARY

In this paper, we reported the problem on RF switches used in multiplexing BPM system. While, RF switches made of GaAs were not appropriate for the multiplexer, as to the switch with CMOS process, switching properties of CMOS process such as switching time and repeatability were suitable. Newly developing BPM circuit with multiplexer was demonstrated briefly with signal generator and actual beam signal.

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