TESLA TEST FACILITY STRIPLINE READOUT SYSTEM

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Abstract

The elaboration of the signals provided by the four-stripline Beam Position Monitors (BPM) on the superconducting linac TTF will be accomplished by parallel rf circuits, giving a signal of ~1 V /cm, independent of beam current, for both horizontal and vertical beam positions with time response ~1µs. and useful range > ±1 cm The performances with respect to thermal drifts and input dynamics are presented.

1 INTRODUCTION

Beam diagnostics for a superconducting linac asks for special features with respect to those for standard linacs. Beam stability all along the long macropulse, a peculiar feature of a sc linac, is a crucial issue for linear collider operation to avoid luminosity losses at the interaction point. Therefore the transverse beam position monitor system must be able to perform time resolved measurements on a time scale comparable with that characteristic of instability risetime in the range of a few microseconds. This rules out any multiplexing between the striplines and a single elaboration circuit, as is commonly used for BPM on storage rings. The circuit realized in the LNF for the stripline BPM of the TESLA Test Facility (TTF) in DESY uses a pair of matched channels for signal conditioning and position measurement from each pair of striplines. It exploits the experience gained on a similar circuit developed [1] for the 25 MeV superconducting linac LISA of LNF [2].

Relevant changes and improvements have been carried out in nearly every functional block, to reduce noise and simplify tune up. The TTF beam parameters of interest for the BPM operation, and the required performances are listed in table 1. Operation with both the injector in construction (Injector I) and a new one in development (Injector II) is considered.

Table 1 - TTF beam parameters

Parameter	Inject. I	Inject. II
$\langle I\rangle_{macropulse}$ [mA]	8	8
Charge per bunch [pC]	40	8640
pulse rep. rate [MHz]	216.7	1.003
Input @ 216 MHz [mVpp]	20	
Resolution [µm]	±100	
Time response [µs]	1	
Output [V/50Ω]	±1	

2 THE CIRCUIT

The block scheme of the circuit is shown in Fig. 1. Since the LISA micropulse frequency is 50 MHz, the previous circuit operated directly at this frequency, avoiding the complicaton of a down conversion. Therefore we chose 50 MHz as the intermediate frequency in down conversion from the induced signal component of 216.7 MHz. The latter corresponds to the fundamental pulse frequency with the injector I, and to the 216th harmonic with the injector II; nonetheless, their amplitude is nearly equal due to the very low micropulse duty cycle in both cases.

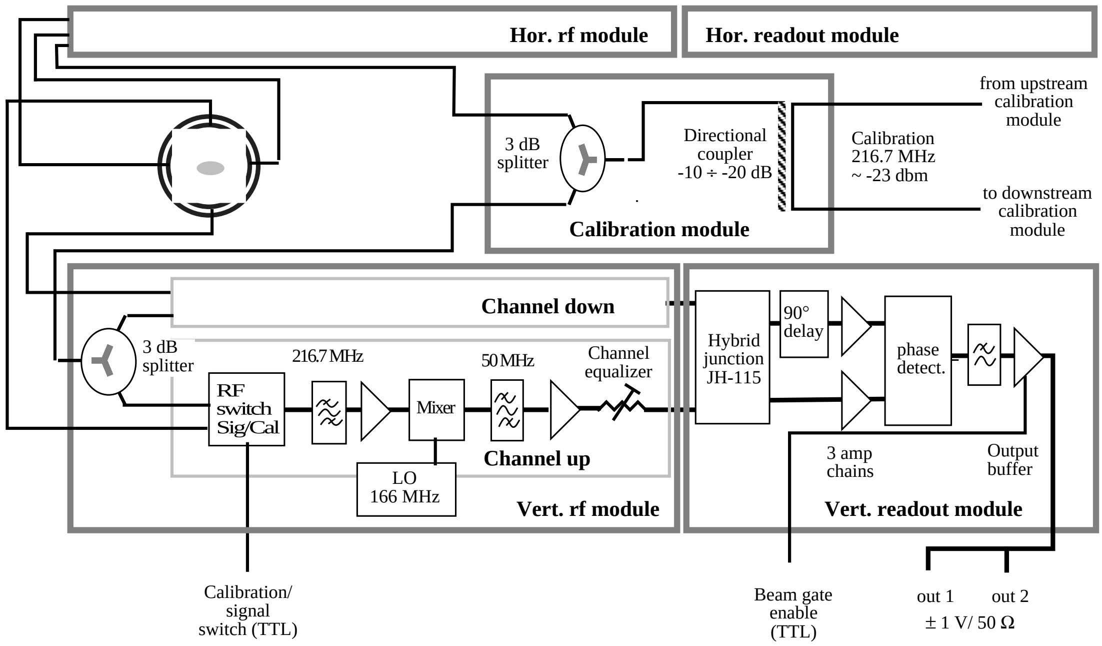

Figure 1 - Block schematic of the circuit

The circuit for each parallel pair of striplines (horizontal or vertical) is splitted in two modules, as shown by segmention in the scheme. Each module is housed in a bulk aluminium case, with input and calibration connectors in the front panel of the 'rf module'; signals at intermediate frequency are fed to the 'readout module' through coaxial connectors and semirigid cables on the backplane; quasi-DC voltage, giving the beam position, is available on output connectors in the front of the readout module. Control signals (Beam Gate and Calibrate) are distributed through the backplane. This layout allowed an easy step by step channel equalization.

The front-end includes a robust helical filter of ~10 MHz bandwidth to select the 216.7 MHz component and adiacent sidebands from the spiking signals from the striplines. A rf relais selects the input signal from the stripline or a calibration input before the front-end filter, so that as far as possible the same signal path is used. The local oscillator is not locked to the linac master oscillator since any drift would affect in the same way both channels and would be cancelled in the following phase difference measuring circuit. The downstream 50 MHz filter reduces the bandwidth to ~ 5 MHZ. Its tuning is crucial for channel equalization; moreover it resulted to be the most temperature sensitive part of the whole circuits.

In the readout module the signals go through a quadrature hybrid junction which realizes an amplitude-to-phase conversion. This technique gives an intensity indipendent measurement of the amplitude ratio of two phase-related signals [3]. A chain of three amplifiers with low phase error raises each signal to a level suitable for phase detector operation. The major improvement in the IF section with respect to the LISA circuit is the phase detector, realized with a double balanced mixer, instead of the previous ECL exclusive-or circuit. This radically eliminates a number of related problems (separate supply lines, heat dissipation, digital noise and critical setting of the comparator thresholds).

3 MODULE TESTING

3.1 CW response test

The prototype performances were first measured using signals from bench generators (both sinusoidal rf and pulse generators) to simulate as far as possible in a pratical way the beam induced signals. A further test has been carried out simulating the beam with a movable, ac excited straight wire inside the BPM. The output from the elaboration of signals from each pair of striplines is a bipolar dc voltage, depending on the amplitude ratio, with a slope of ~ 90 mV/dB around the origin and an offset of a few millivolt; since the linearity range is limited to unbalance of very few dB a calibration curve must be used to precisely measure off-axis displacements greater than a few millimeters. A fine wire scanning of ± 500 µm around the central position is shown in Fig. 2. Peak to peak noise was measured with a digital oscilloscope bandwidth limited to 20 MHz. The measured noise is < 4 mV_{pp}, corresponding to a position resolution better then 40 µm. The output vs. dephasing channels each others is ~ 80 mV/rad; this limits the cable length matching tolerance to less than 1 cm.

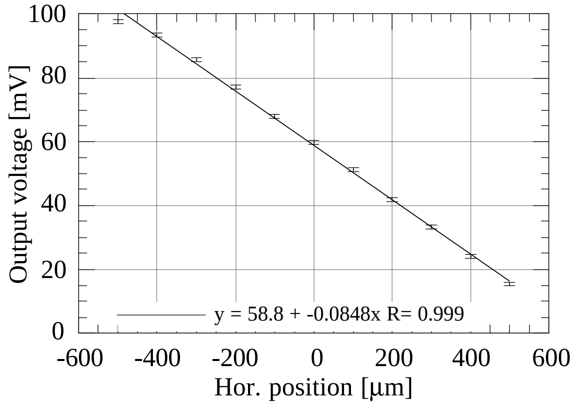

Figure 2 - Output vs wire displacement in 100 µm steps.

It is a common practice not to rely on analytical calculation to relate the output from unbalanced signals to displacement. When mapping the response with a movable wire a calibration is obtained as much as possible nearest to the real operating conditions, taking into accont all mechanical imperfections; this allows also a previous estimate of the repetibility of the response when BPM's are dissassembled for cleaning and reassembled on the machine without further characterization. Sistematic mappings were carried out at DESY-Zeuthen and will be used for off center position reconstruction. Wide wire scanning shows that signal compression starts with displacement >5 mm as shown in Fig. 3.

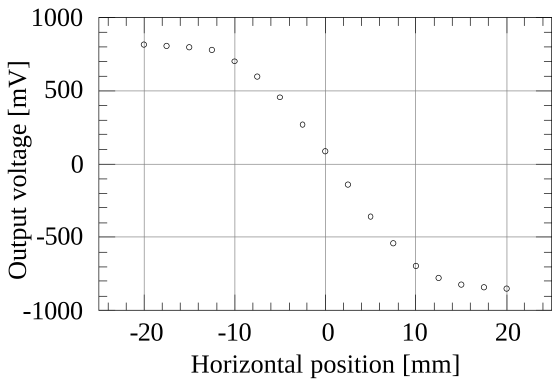

Figure 3 - Response of electronics to wire displacement in a BPM symmetry plane.

Most of time BPM's will operate with centered beam, i.e. equal signals from striplines; moreover, the calibration signal just simulates this case with an externally injected signal. The offset voltage and its temperature drift in this condition are of outstanding interest for on line check of performance. Measurements on the prototype in thermostatic room showed a strong correlation between offset and temperature, as shown in fig 4. Sistematic measurements of thermal coefficient on every module give coefficient in the range 0 to -2 mV/°C, setting un upper limit < ±5 °C to the ambient temperature variation. Further tests are planned after installation on site. The offset measured on line in calibration mode could provide the correction factor to take into account the thermal drift, if required for high precision measurements.

The dynamic range is not of primary concern, since TTF is expected to operate at constant average current. Therefore the electronic performances have been optimized and characterized at high signal level, a few dB below the onset of phase distortion in the amplifier-limiter chain, as shown in Fig. 5.

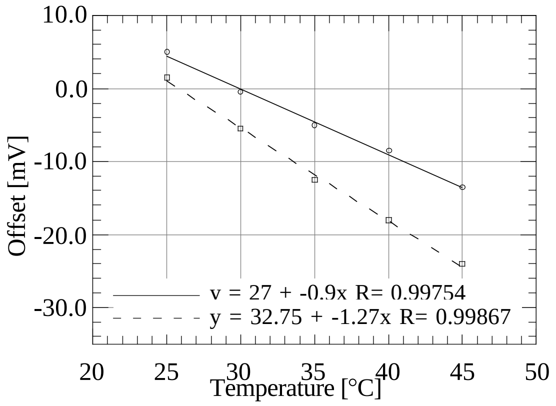

Figure 4 - Offset drift vs ambient temperature

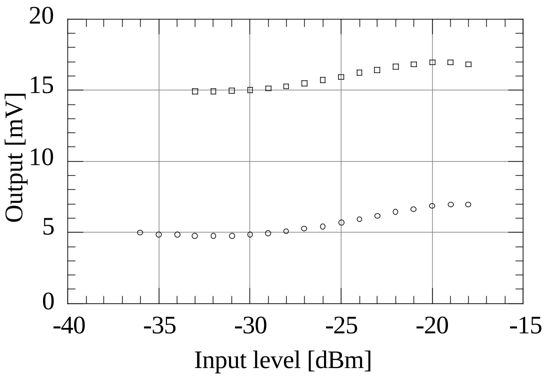

Figure 5 - Offset change vs input level for balanced input (dots) and calibration (squares).

This ensures the best signal-to-noise ratio and leaves margins of usability at lower current, if it were required; on the other side, higher current would ask for an adjustment of the output level from the rf modules to avoid overload of the following stages.

3.2 Pulse response test

We carried out a few tests of the response to sudden signal unbalancing to measure the risetime. In a preliminary attempt we inserted a double balanced mixer, operating as a modulator, in one of the 216.7 MHz input signal path. The output of BPM electronics followed the modulating signal shape with a risetime < 1 μs. However, the envelope of the modulated rf signal could not simulate the signal that will be injected by Injector II due to the amplitude limit of the rf generator. To test the single pulse rsponse we created a bipolar doublet pulse burst using a four channels Stimulus Generator Textronix 9000, summing two phase shifted pulse trains with opposite polarity; we simulated the expected signal after the front end filters injecting short bursts of pulses at 216 MHz of different amplitude in the rf module inputs; ideally just one pulse would be enough, but again amplitude limitation forced us to use tens of ns long train to reach a stable amplitude.of the output signal. The spurious peaks at the end of the pulses are probably due to unproper operation of the phase detector when signals at its inputs are no longer limited by one or both of the amplifier chains.

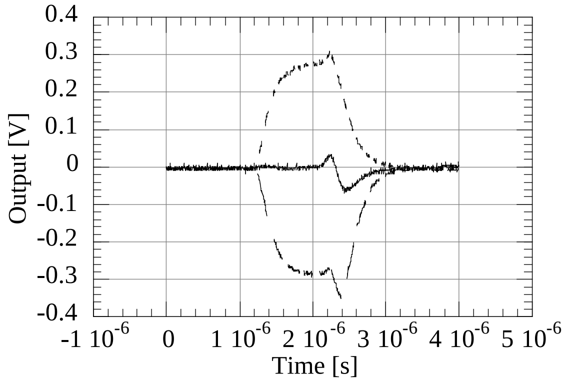

Fig. 6 - Time response to short rf bursts of balanced and unbalanced signals

4 THE CALIBRATION SYSTEM

Since the position measurement is critically depending on matching between each pair of electronic channels, from the stripline pick ups to the phase detector, a calibration system is in contruction to check periodically the module performances. The schematic of the 'calibration module' is shown in the Fig. 1; a single cable feeds all calibrators via feedthrough directional couplers. The insertion losses and cable attenuation along the linac, due to variing distances from the generator, are largely compensated choosing a different coupling factor in each directional coupler, so as to have nearly a constant level at each calibrator input. Moreover, as part of the first calibration of the offset of the modules, a spare BPM equipped with a coaxial rod and rf excitation will be used to simulate a centered beam and will allow to check the unbalances due to connector/adapter losses. This check could be repeated periodically to bring out the effects of ageing and damage of cables and connectors.

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