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DEVELOPMENT OF RF INTERLOCK AND DIAGNOSTICS SYSTEMS IN SOLARIS STORAGE RING

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Abstract

The RF team in NSRC Solaris is tasked with not only maintaining existing systems, but also developing and introducing new solutions to improve overall performance and reliability of the storage ring. Therefore a number of devices developed and introduced this year are a subject of this paper, including a Cavity tuning protection system, Master Oscillator splitter and Tune excitation network.

CAVITY TUNING PROTECTION

All resonant cavities in the storage ring are fitted with a tuning mechanism that uses a mechanical arm to stress and de-stress one of the cavity walls. During maintenance operations, or simply during some tests with the beam, manual tuning of the cavities is possible. This operation poses a potential risk, of stressing and damaging the cavity walls. The mechanical construction of the tuning arm is equipped with end-switches to detect the outermost safe position of the cavity, however the electrical signal they send is handled only digitally. If the tango device server is not responding the interlock would not function. In order to prevent this an electronic device was built to physically disconnect the power to the tuning motor, as soon as limit switch is reached. The outlook of this device is presented in Fig. 1

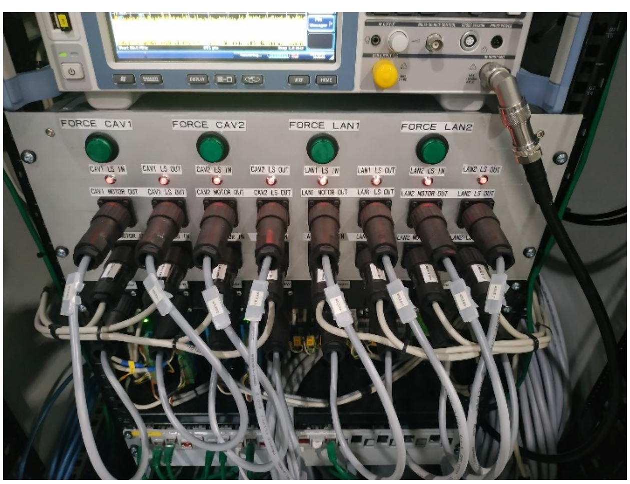

Figure 1: Assembled and running device.

The device handles all four cavities, and disconnects the motor drives with special, industry-grade relays. It is interfaced with PLC systems and can signal an interlock to the outside and also can be potentially remotely reset.

In the case of an interlock, the relays become energised and motor is disconnected. In order to return the motor to a safe position, there is a physical button that needs to be pressed on the front-plate of the device. While the button is pressed, the operator in the control room can move the motor in an opposite direction. After such action, the button can be de-pressed and the system returns to normal operation. The device was tested with all cavities and all possible limit switches and the results were good. So far, after about a year of operation, the device disconnected cavities only once.

MASTER OSCILLATOR DIVIDER NETWORK

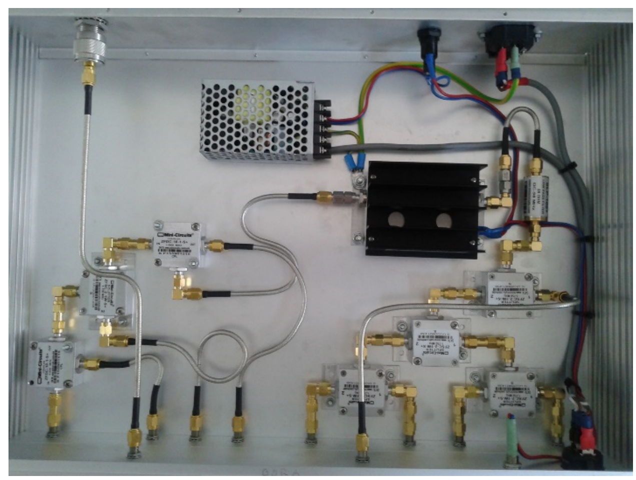

Figure 2: Inside of the MO divider.

Due to development of the storage ring and beamlines, there is an increasing number of devices that require the signal from the Master Oscillator (MO). The signal was usually distributed by cables, from splitters placed directly on the MO output. With every new splitter the signal is attenuated, and new modules would receive signal that could be too weak in power. Therefore a device was constructed, that amplifies the MO signal and then feeds it into a splitter network, providing all output ports with sufficient power rating and matched phase signal. The device consists of an amplifier from Mini-Circuits (ZHL-3A-S+), and an array of splitters that ensure sufficient power levels on every output.

Everything is connected witch semi-rigid cables to provide phase-matching. Inside, the input is also connected to the amplifier via a 100MHz low-pass filter in order to filter out any noise coming from the outside. The device was

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tested with a network analyzer and all functions are working properly. The inside construction of the device is shown in Fig. 2.

STRIPLINE FEEDING AND RECEIEVING NETWORK

In order to measure synchrotron tune in both horizontal and vertical planes, a specific device consisting of two parts was constructed. The first one is a stripline feeding network (TX). This device is connected to stripline installed in the storage ring. A Rohde and Schwarz FSV4 spectrum analyzer is transmitting signal from its tracking generator into four splitters which then feed the signal into individual amplifiers. The amplified signal is then fed via a signal processing network consisting of various phase shifters in order to provide proper phasing, and is fed into the stripline. What is important, is that the signal needs to be fed to each strip in the direction opposite to the beam. This provides electromagnetic excitation and creates betatron oscillations. Additional ports are available if the stripline was needed for some other application such as filling pattern monitoring. All unused signal paths are connected to 50 Ω terminators. A simplified schematic of this device is shown in Fig. 3

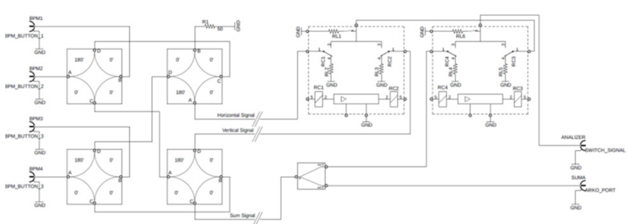

Figure 3: Schematic of the stripline feeding network.

The receiving network (Rx) takes the signal from button BPMs in the storage ring and after passing a pre-selected path, the signal is fed into an input of the aforementioned spectrum analyzer, therefore both devices act as an extension to the spectrum analyzer itself. This enables exciting the beam and measure the synchrotron tune. The performance of the device is limited mostly by the bandwidth of BPMs as they operate mostly at 500MHz. Therefore all the signals coming from the beam can only be observed around this frequency. A simplified schematic of the receiving network is shown in Fig. 4.

In order to measure the tune, the electron beam is excited by the tracking generator in a pre-selected horizontal, vertical or diagonal plane.

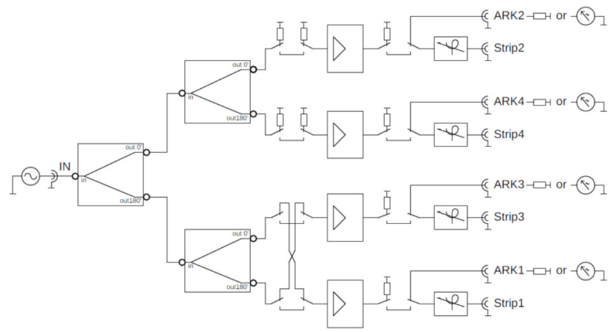

Figure 4: Schematic of the receiving network.

This excitation manifests itself as the betatron tunes and can be observed in form of satellite tune frequencies around the main harmonic frequency. Specific tune frequencies are obtained by measuring the Δf, that is the main harmonic frequency minus the satellite tune frequency. The MO frequency (F_{Mo}) in Solaris is 99.9318 MHz. Since the BPMs have the highest Q-factor around 500MHz the spectrum analyzer is set to a fifth harmonic of the frequency $F_{BPM} = 5 \cdot F_{Mo}$ = 499.659 MHz. For Solaris storage ring, the measured tune frequency values were 499 kHz for vertical plane and 667 kHz for horizontal plane. The sum signal of both tune frequencies is presented in Fig. 5. The fractional tune value is obtained by dividing this tune frequency by the revolution frequency, which in Solaris equals to 3.122 MHz. That results in tune values of 0.159 and 0.213 for vertical and horizontal plane, respectively [1]. The only inconvenience is that the measurement process is quite long (about 1 minute for a single scan across the entire span) as the resolution bandwidth of the spectrum analyzer cannt go down to 30Hz and has to be around 3-5 kHz.

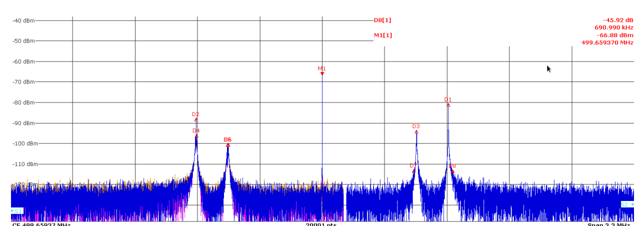

Figure 5: Sum signal of both horizontal and vertical tune frequencies.

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[1] David Olsson, Lars Malmgren, Anders Karlsson, *“Design of Striplines for the MAX IV and SOLARIS Storage Rings”*, in Technical Report LUTEDX/(TEAT-7254)/1-60/(2017), Lund, Sweden, 2017.