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White Rabbit-based LLRF upgrade for CERN's SPS

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The Super Proton Synchrotron (SPS) Digital LLRF 200 MHz system at CERN was redesigned in 2020, using a fixed-frequency clock provided by the White Rabbit network instead of the usual RF clock. This triggered the development of WR hardware with sufficient performance (approx. 100 fs rms jitter above 100 Hz and 13 ps/1 degree end-to-end phase stability). WR is also used in the SPS to distribute the revolution frequency across large distances in the form of Frequency Tuning Words encapsulated in Ethernet frames, which drive an RF Numerically Controller Oscillator (RFNCO). The reconstructed RF is used for synchronization with other machines and systems.

This paper describes the developments that made the WR-based LLRF possible: the MTCA.4 eRTM14/15 Timing Receiver board which generates the clocks and Local Oscillator signals for the Cavity and Beam Controllers and the WR2RF-VME board, which reproduces the RF-synchronous signals and pulse patterns from the data streams received from the WR network. We also describe the phase noise and transceiver stability optimizations used in the components of the WR network, which enabled WR operation with the performance necessary for the SPS LLRF.

Primary author: WŁOSTOWSKI, Tomasz (CERN)

Co-authors: Mr LIPIŃSKI, Maciej (CERN); RIZZI, Mattia (PSI - Paul Scherrer Institut); Mr SUMIŃSKI, Maciej (CERN); Mr ADRIANEK, Karol (CERN); EGLI, Julien (CERN); Mr WUJEK, Adam; HAGMANN, Gregoire (CERN); Mr GILL, John Robert (CERN); ARRUAT, Michel (CERN); BAUDRENGHIEN, Philippe (CERN); Mr KUZMANOVIĆ, Predrag; NOVEL GONZALEZ, Saul (CERN); Mr GONZALEZ COBAS, Juan David (CERN); Mr DANILUK, Grzegorz (CERN); Mr GINGOLD, Tristan (CERN); SPIERER, Arthur (CERN); Mr LAMPRIDIS, Dimitrios (CERN)

Presenter: WŁOSTOWSKI, Tomasz (CERN)

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