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Phase Stability Compliancy Testing of a White Rabbit Based Solution for the LHC RF and Timing Distribution Backbone Upgrade

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The LHC RF and Timing Distribution backbone is being upgraded for the HL-LHC. A White Rabbit technology solution for the generation and the distribution of the RF, similar to the system currently employed in SPS, is being considered. To verify its suitability from a phase stability perspective, an investigation was conducted on a proof-of-concept system. The requirement for the end-nodes is ± 1 degree of the 200 MHz SPS RF frequency. The key figure of merit to check compliancy is peak-peak phase variation which must be < 28 ps. The compliance tests campaign will be described, and results presented.

Summary (500 words)

The LHC RF and Timing Distribution Backbone transmits the crucial Bunch Clocks and Orbit signals from the RF generation system to the experiments. This backbone is being upgraded for the HL-LHC, for which White Rabbit (WR) technology is being considered. The proposed solution provides good phase determinism, despite environmental variations and Bunch Clock operating modes, and is a scalable system thanks to the Ethernet topology. A WR-based solution was also preferred for the HL-LHC Low-Level RF upgrade (which the RF and Timing Distribution Backbone upgrade is also dependent on), along with the event-based timing systems, General Machine Timing (GMT) and Beam Synchronous Timing (BST), that are used by the experiments.

An investigation into the viability of adapting WR-based hardware (currently employed in the SPS RF) is underway. The investigation analyses the performance of a Proof of Concept (PoC) system which comprises cascaded WR switches (WRS) and three WR2RF boards as end-nodes housed in VME crates. One WR2RF board is configured as a master, mimicking the RF frame master, which transmits the RF frequency over the WR network by means of a Frequency Tuning Word (FTW). The two remaining WR2RF cards are configured as receivers, and use the incoming FTWs to locally regenerate the RF, Bunch Clocks and Orbit signals.

The work presented focuses on ensuring compliance with the specification requirement that long term phase stability must be within ± 1 degree of the RF frequency, even after the system or network experiences disturbances. For a 200 MHz RF signal this will be a peak-peak phase variation (θpk-pk) of 28 ps. This θpk-pk over time was the key figure of merit (FoM) employed to confirm whether the PoC system met the phase stability requirement.

To assess the compliancy of the PoC system, two key rounds of testing were performed and were referred to as "Initial Compliance Testing"and "Network Testing". Initial Compliance Testing investigated the phase stability when the PoC system operated normally, as well as after a WR2RF board reset. For this round of testing, all WR2RF boards were connected to the same WRS. The observed performance was satisfactory, with the θpk-pk between like signals generated by the two receiver WR2RF boards consistently within the 28 ps limit.

Network testing is currently underway. The PoC system now employs six cascaded WRSs to better represent the final system potentially being employed in the upgraded RF and Timing Distribution backbone. Once again, the phase stability requirement was assessed after disturbances were introduced in the wider WR network, by temporarily disabling individual ports of a WRS or rebooting a WRS. The phase noise and jitter of

RF and Bunch clock signals generated by a receiver WR2RF, when it was connected to different switches in the cascade, were also assessed.
The WR2RF board's RF signal experienced ≈400 fs increase in rms jitter when the board was connected to the sixth WRS in the cascade versus the third. Regarding phase stability, the initial results look promising and seem likely to meet the θpk-pk specification.

Author: HAZELL, Philippa (CERN)

Co-authors: GOUSIOU, Evangelia (CERN); HAGMANN, Gregoire (CERN); Dr GILL, John (Self-Employed Digital Design Consultant); LIPINSKI, Maciej Marek (CERN); GENOUD, Quentin (CERN); BARON, Sophie (CERN); WLOSTOWSKI, Tomasz (CERN); GINGOLD, Tristan (CERN)

Presenter: HAZELL, Philippa (CERN)

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