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Assessing the performance of future White-Rabbit RF and Timing distribution system for LHC under real conditions

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To meet the High-Luminosity LHC demand for enhanced phase stability and replace the outdated RF and timing distribution system (called TTC backbone), an upgrade to a White Rabbit-based system is planned. A compliance test showed a phase variation of less than 30 ps in a proof-of-concept system. In order to assess the quality of the new system in real conditions a test campaign was started in several points of LHC monitoring its phase stability with respect to the RF-master frequency and comparing it to the TTC backbone currently in operation. The test campaign will be described and results presented.

Summary (500 words)

The timing distribution of the LHC is based on obsolete components and the High-Luminosity (HL) upgrade of the LHC requires a higher phase stability, of the order of 10s of picoseconds. Therefore it will be replaced by a White Rabbit (WR) based network, similar to the one employed at SPS. This has the advantage of being scalable due to its Ethernet topology and providing high phase stability even under temperature fluctuations and different operating modes.

A preliminary compliance test was done on a proof-of-concept system realized in a lab by a cascade of switches and White-Rabbit to RF (WR2RF) boards developed for the SPS RF frequency of 200 MHz. It revealed a peak-peak phase stability of less than 28 ps under normal operation and with network disturbances, suitable for the timing requirements of the HL-LHC experiments.

In SR4 where the LHC RF control system is located, the RF frequency is encoded in binary format and sent to the master switch of the WR timing network in the form of a Frequency Tuning Word (FTW). This master switch is located 7km away in CCR, close to the CERN Control Center. It distributes the FTW through the WR network to the experiments, where a WR2RF board recovers the bunch clock (one tenth of the RF frequency) and orbit from the FTW with very low jitter (< 3 ps rms) and high phase stability (< 30 ps).

The planned tests involve acquiring phase measurements at two locations. One location is SR4, where it is possible to measure the phase variation between the original master RF frequency and the bunch clock recovered from the FTW of two different WR networks: a reference network, fully located in SR4, consisting of one WR switch (WRS) and a WR2RF board which regenerates the bunch clock from the FTW; and a realistic WR timing network in the form of a second WR2RF board (located in SR4) connected to the master switch of the WR timing network (in CCR) through a cascade of 5 WRS, to mimic the network connection to the experiments.

The second part of the test takes place at the CMS experiment. There a third WR2RF board also connected to the WR timing network through five

layers of switches retrieves the bunch clock and orbit from the FTW send by the frequency master in SR4. The phase between these clocks and their counter parts from the original TTC backbone is measured.

This new WR-based architecture is analyzed, characterized, and compared with the legacy architecture, aiming to assess its quality in terms of phase stability for the HL-LHC requirements.

Author: KAFFKA, Lilith (CERN)

Co-authors: SPIERER, Arthur (CERN); GOUJON, Audrey; GOUSIOU, Evangelia (CERN); HAGMANN, Gregoire (CERN); KOZSAR, Ioan (CERN); TROSKA, Jan (CERN); HEGEMAN, Jeroen (CERN); PALLUEL, Julien (CERN); LIPINSKI, Maciej Marek (CERN); BARON, Sophie (CERN); GINGOLD, Tristan (CERN)

Presenter: KAFFKA, Lilith (CERN)

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