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Potential Upgrade of the CMS Tracker Analogue Readout Optical Links using Bandwidth Efficient Digital Modulation

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The potential application of advanced digital communication schemes in a future upgrade of the CMS Tracker readout optical links is currently being investigated at CERN. We show experimentally that multi-Gbit/s data rates are possible over the current 40 MSamples/s analogue optical links by employing techniques similar to those used in ADSL. The concept involves using digitally-modulated radio frequency (RF) sinusoidal carriers in order to make efficient use of the available bandwidth.

Summary

Approximately 40 000 analogue readout optical links are being installed in the CMS Tracker sub-detector for operation in the LHC. Each readout link transmits data using analogue Pulse Amplitude Modulation (PAM) and has been specified to be equivalent to a baseband digital PAM system conveying 8 bits of information at 40 MSamples/s. Hence the equivalent digital data rate for the analogue optical links is 320Mbit/s. The next iteration of the CMS Tracker will be operated in the Super LHC (SLHC) environment and will have to cope with significantly increased data rates due to the foreseen tenfold increase in luminosity. The cost of the optoelectronic components represents a large fraction of the CMS Tracker electronics budget. Hence, a digital system reusing the existing components while delivering sufficient performance for SLHC operation could potentially be a cost-effective alternative to a full replacement of the installed links. The feasibility of such a conversion must therefore be explored in terms of performance that can be achieved and implementation complexity.

The theoretically achievable data rate over the existing analogue link has previously been investigated using established communication theory. This theoretical estimate has now been augmented with experimental results from characterization tests performed in the laboratory. An Agilent 4438C Vector Signal Generator was used to transmit randomly generated data through an analogue optical link, using Quadrature Amplitude Modulated (QAM) RF carriers. At the output of the optical link, an Agilent 4440A Spectrum Analyzer demodulated the signals obtained, allowing a detailed analysis of the link's bandwidth and noise characteristics. The experimental setup and method for determining the capacity of the optical link will be described.

RF digital modulation over fiber has been experimentally proven to be a candidate for a future readout link system operating in the SLHC environment and future experiments. The first estimate of the achievable data rate based upon detailed experimental measurements will be presented, along with potential hardware implementation options for a prototype of the proposed system. Also, the difficulties associated with the proposed upgrade scheme will be reviewed and compared to the expected benefits.

The performance of future detectors will impose even greater requirements on the readout systems, with large amounts of data having to be collected and transmitted over optical fiber. Achieving higher data rates will undoubtedly require employing novel techniques derived from communication engineering and information theory. The current work represents a stepping stone to understanding the benefits –as well as limitations –of the application of such a novel data transmission concept in the context of HEP instrumentation.

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