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Paper Session III-B - Wavelength- Division Multiplex of Bipolar Digital Signals for Digital Fiber Optic Transmission

Kent Lindberg
Lockheed Space Operations Company Kennedy Space Center,

Ronnie D. Gibbons
Lockheed Space Operations Company Kennedy Space Center,

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Ronnie D. Gibbons
Lockheed Space Operations Company
Kennedy Space Center, Florida

ABSTRACT

Deterioration of the Kennedy Space Center Launch Processing System copper data bus cables over time, combined with the unavailability of replacement cabling and the transmission distances of 10 kilometers, resulted in the decision to replace the copper cable system with a fiber optic version. The replacement system is referred to as the Digital Fiber Optic Transmission Equipment. The distinguishing aspect of the digital Fiber Optic Transmission Equipment is the use of Wavelength Division Multiplexing fiber optic technology. This design allows the transmission of digital bipolar data on a single fiber optic cable. This paper describes the system requirements and design characteristics of Digital Fiber Optic Transmission Equipment using Wavelength Division Multiplexing technology for the transmission of digital bipolar data on a single fiber optic cable.

Introduction

The Kennedy Space Center Launch Processing System (LPS) provides the software and hardware required to process and launch NASA's Space Transportation System. Much of the LPS hardware has been in operation since the late 1970s and continues to support processing and launch today. The LPS utilizes copper data buses equipped with analog transmitters, receivers and equalizers to provide data communications between the orbiter and Ground Support Equipment (GSE) and the Launch Control Center (LCC). Deterioration of the cables over time, combined with the unavailability of replacement cabling and the relatively long transmission distances involved, resulted in the decision to replace the copper cable system with a fiber optic version. Started in 1991, this replacement project is scheduled to be completed this year.

System Requirements

Optical transmitters and receivers were required to support the new fiber optic cable plant. Due to performance and system requirements unique to LPS, commercial off-the-shelf (COTS) products were unacceptable, dictating a custom design. These performance and system requirements included: a digital system with the ability to transmit burst Manchester Biphase-L (tri-state) data; a bit error rate less than or equal to $1x10^{-12}$; and a 10 kilometer transmission requirement over multimode fiber optic cable. Of these requirements, the ability to transmit burst-mode Manchester Biphase-L data on a digital fiber optic link was the most significant.

Electrically, Manchester Biphase-L data is identical to MIL-STD-1553 data. It has the same tri-state electrical signal characteristics consisting of positive, zero, and negative as depicted in Figure 1. Because light-emitting diodes (LEDs) that perform the electrical to optical conversion can represent only two of the three required electrical signal levels, it is impossible to transmit Manchester Biphase-L data on a conventional (bi-state) digital fiber optic cable. The transmission of Manchester Biphase-L burst-mode data on a conventional fiber optic link will cause errors, as depicted in Figure 2.

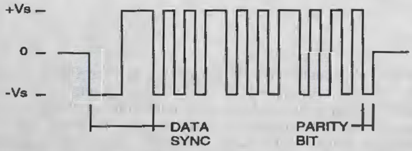

Figure 1. Typical Manchester Biphase-L Data Word

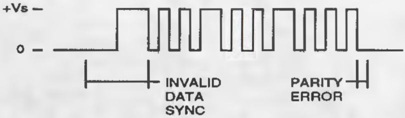

Figure 2. Data Errors Resulting From The Transmission Of Manchester Biphase-L Data On A Conventional Bi-State Fiber Optic Link

Design Characteristics

The LPS fiber optic transmitter and receiver designs solve this problem by using Wavelength Division Multiplexing (WDM) technology to allow the transmission of Manchester Biphase-L data on a single fiber optic link. In this system, two LEDs of different wavelengths are used. An energized 1300 nm LED is used to transmit the positive component of the waveform and an energized 1550 nm LED is used to transmit the negative component of the waveform. The zero level component of the waveform is represented by neither of the LEDs being energized. The 1300 nm and 1550 nm wavelengths are optically combined using a wavelength division multiplexer onto a single fiber optic cable for transmission. The unidirectional optical isolation between the two wavelengths is greater than 35 decibels.

The transmitter uses analog circuitry to receive the differential Manchester Biphase-L baseband data (See fig. 3.). This data is converted to a single-ended bipolar analog signal and applied to a comparator circuit. The comparator circuit converts the positive and negative portions of the data into two separate Transistor-Transistor Logic (TTL) signals. The positive comparator circuit drives a 1300 nm wavelength LED and the negative comparator circuit drives a 1550 nm wavelength LED.

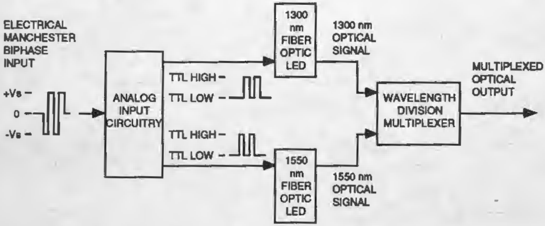

Figure 3. WDM Transmitter Module Block Diagram

At the receiver, the optical signals enter a wavelength division demultiplexer, where the two optical wavelengths are separated and routed to their respective optical receivers (See fig. 4.). Each optical receiver converts its optical signal into a TTL electrical signal. The TTL outputs of the two optical receivers are then combined using analog circuitry to reconstruct the original bipolar signal. The analog bipolar signal is then converted to differential Manchester Biphase-L data and transmitted on copper cabling to its final destination.

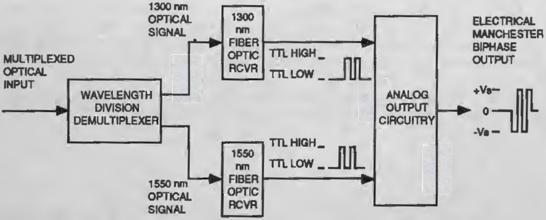

Figure 4. WDM Receiver Module Block Diagram

Kennedy Space Center is unique in that the fiber optic cable system was intended to support transmission of the 1550 nm wavelength on graded-index multimode fiber. For this reason, the WDM design posed the following technical concerns: 'What would the magnitude of the pulse width distortion be due to the different propagation speeds (i.e. chromatic dispersion) of the two wavelengths in the fiber?'; or 'What was the maximum allowable spectral width needed to maintain the optical isolation of the 1300 nm and 1550 nm wavelengths in the optic fiber?' With respect to these concerns, no published data was available to support the optical transmission and multiplexing of 1300nm and 1550 nm wavelengths onto a single multimode fiber.

A laser diode-based design would have solved all of the above issues. However, no lasers were allowed for several reasons - the most important being safety. The most significant system design constraint was that the fiber optic cable system had already been installed at KSC and was comprised almost exclusively of multimode fiber.

The selection of the digital fiber optic receiver was a difficult process. An Automatic Gain Control (AGC) type receiver would have been preferred in terms of reducing pulse width distortion and having the best dynamic range. But, since KSC's Manchester biphase-L data has burst-mode requirements and a non-50% duty cycle, an AGC receiver could not be utilized. The WDM design uses an Edge Detecting-type receiver which supports the burst-mode data requirements and has the required 18 dB of dynamic range. This type of receiver operates by differentiating the electrical signal out of the optical receiver (PINFET-type) and uses a fixed threshold comparator for signal detection of both the positive and negative edges of the signal. These edges are then used to set/reset a flip flop circuit, which is the final data transition. This type of receiver detects changes, not data levels, and therefore its output has memory or latches to the last data bit state received. A data error will occur with burst-mode data if the logic state of the first bit of the next word is received at the same logic state as the latched output of the edge detector.

Conclusion

The WDM design demonstrates the feasibility of digital tri-state data transmission on a single fiber optic cable. The WDM fiber optic transmission hardware is currently supporting Space Shuttle processing and launch operations at KSC.