High-speed Links with Copper Cables

Introduction

Communication system complexity continues to rise due to increased port densities and their associated higher bandwidth requirements. Backplanes have been the major link medium between different cards in multi-blade systems that have been addressing these needs. New transceiver technology has been developed to address backplane performance, density, and link distances. This same transceiver technology is also enabling cost effective, high-speed box-to-box connections on copper cable links without the need for elaborate protocols.

The maximum link distance for a copper cable link is determined by the cable attenuation. The link distance performance can be improved by utilizing both transmit pre-emphasis and receive equalization which are provided by the transceivers, where boosting the gain at higher frequencies compensates cable attenuation. Backplanes are typically made from FR-4 materials that have similar frequency response as most copper cables. The signal loss is mainly due to skin effect at signal rates lower than 3Gbps. Therefore, signal improvement techniques that can be applied to one interconnect can be applied to the other. Backplane extensions and stackable links can now be implemented using very low cost, standard copper cables that exhibit some of the same transmission properties as FR-4 backplane material. Figure 1 shows an inexpensive high-speed copper link adapter used in stackable switches. This paper describes the link performance of the three different copper cables that benefited from receive equalization and transmit pre-emphasis functions of a transceiver at 3.125Gbps data rate.

Figure 1: PC boards with copper cables

Test Setup

Figure 2 describes the test setup that was used for the evaluation of the different copper cables. A commercially available Quad 8bit/10bit parallel-to-serial and serial-to-parallel 3.125Gbps XAUI transceiver device, the BBT3410 from BitBlitz

Communication, was used in this evaluation. The device has 4-levels of programmable transmit pre-emphasis and 16-levels of receive equalization. In this test setup, the transceiver was set to internal loopback mode where the high speed receive signals are looped back directly to the corresponding transmit terminals.

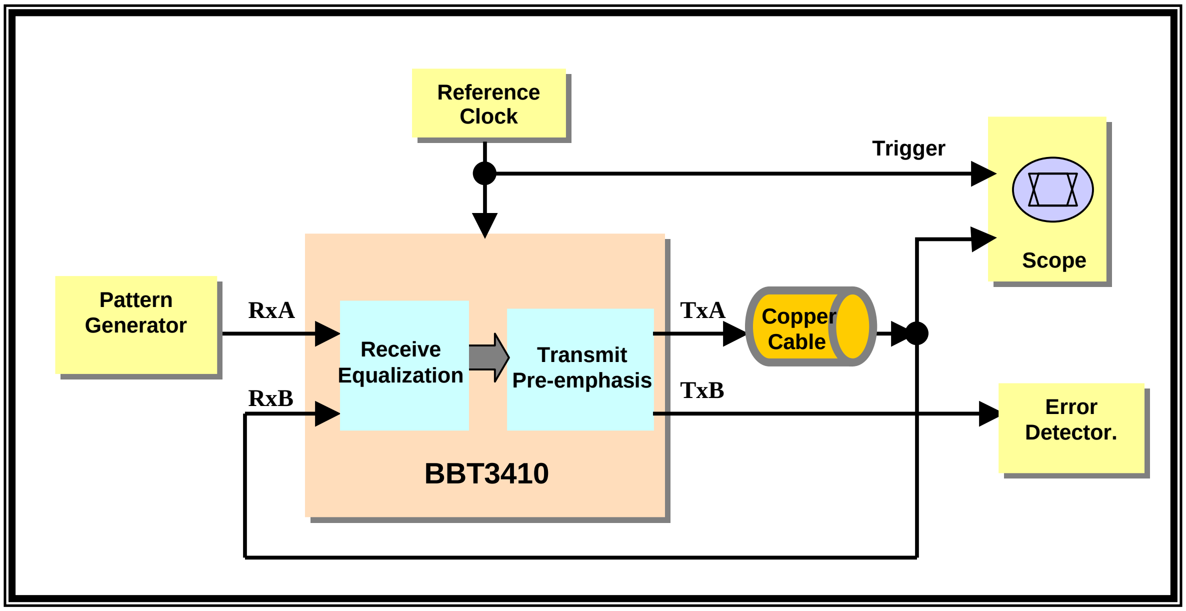

Figure 2: Copper cable link test setup

The output of the test pattern generator connects to the RxA input of the Channel A transceiver. And the internal loopback signal of this channel is then connected through the TxA output port of the transceiver to the cable under test, which then connects to a digital sampling oscilloscope for observation and the RxB input of the Channel B transceiver for data recovery. The recovered data is then connected to an error detector counter for Bit Error Rate (BER) measurement via the TxB output of the Channel B transceiver.

Test Results

The three cables referenced in this paper are the Infiniband, the Twin-Ax, and the IEEE 1394, cables. Figure 3 describes the data eye of the input signal to each of the cables under test at TxA output of the transceiver without pre-emphasis.

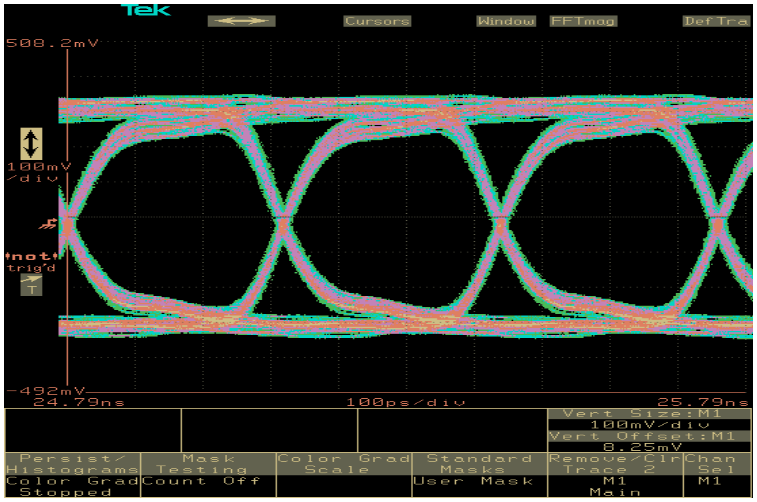

Figure 3: Transmit TxA output data eye

1. Infiniband cable

A 10m long 26 AWG 4X Infiniband cable from Spectra Strip was used in this test. Since the test setup only utilized SMA connectors, a converting PCB was used to convert the Infiniband connectors to SMA connectors for this test. In effect, a total of 10in. of FR-4 traces were present in addition to the Infiniband cable and connectors for the connector conversion and the traces on the transmission and the receiver ends. Figure 4 shows the output data eye at RxB after 10m of Infiniband cable and connectors in addition to the FR-4 traces. Error free operation was achieved with equalization set to 0A'h without pre-emphasis. The link distance performance can further be improved by boosting the pre-emphasis and equalization levels.

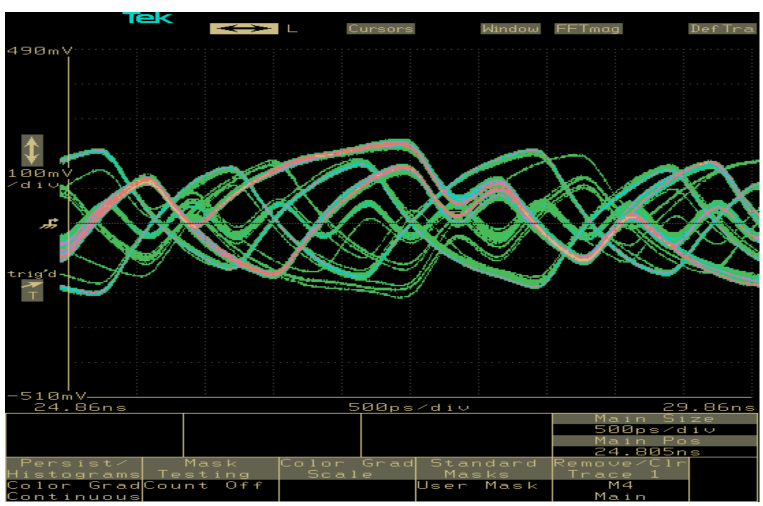

Figure 4:Transmit RxB data after 10m Infiniband cable.

(No transmit pre-emphasis, IEEE specified CJPAT pattern)

2. Twin-Ax cable

For this test a 30m long Twin-Ax cable with direct SMA connectors on both ends were used. The cable was IBM standard 20 AWG cable manufactured by Madison Cable. In addition to the cable and connectors, there were 7in. of FR-4 traces on both the receive and transmit sides for the connection to the BBT3410 device. Error free operation was achieved with equalization set to 07'h without pre-emphasis. Figure 5 shows the output data eye for this test setup. The link distance performance can also be further improved by boosting the pre-emphasis and the equalization levels.

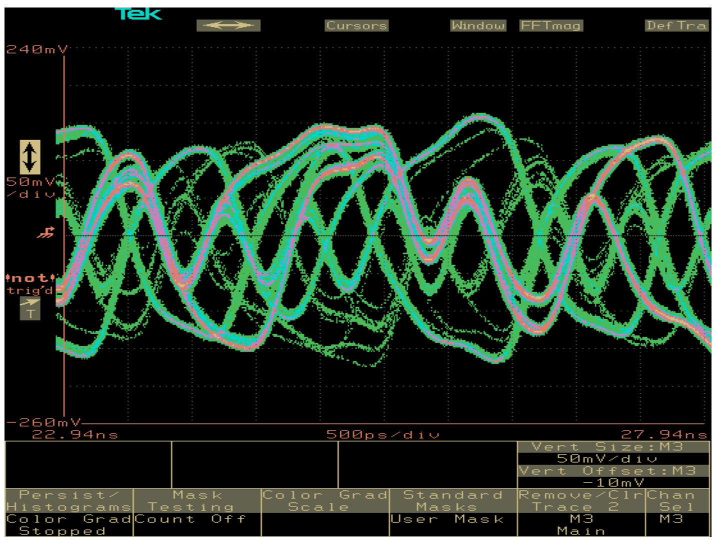

Figure 5: Transmit RxB data after 30m Twin-ax cable
(No transmit pre-emphasis, CJPAT pattern)

3. IEEE1394 cable

An IEEE 1394a cable, also known as a FireWire[i] cable that is used as a high-speed serial bus for personal computers, was the connector for this link test. The IEEE 1394a only specifies 400Mbps data transfer rate for this cable, but by utilizing the receive equalization, this low cost cable can transmit at 3.125Gbps data rate for short distances error free. In this test the cable used was a 10ft. IEEE 13946-10 (IOGEAR's Model G2L) cable that was attached to two SMA connectors on each end. In addition to the cable and connectors, there were also 7in. of FR-4 traces on both the receive and the transmit sides for connection to the transceiver. Figure 6 shows the output data eye without pre-emphasis. This required an equalization level of 08'h for error free operation. Similar to the last two cables, the cable distance performance can still be improved by boosting the pre-emphasis and the equalization levels.

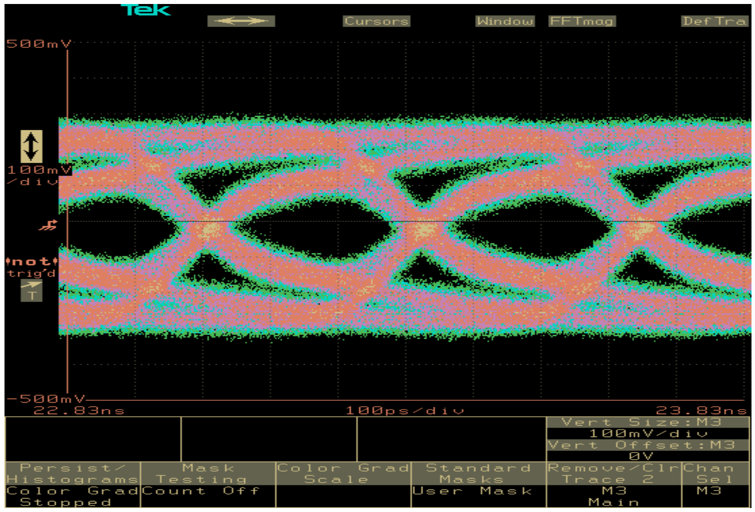

Figure 6: BBT3410 Transmit TxA data after 3m (10-foot) IEEE 1394 cable
(No transmit pre-emphasis, PRBS-31 pattern)

Summary

This paper has described the performance of three different copper cables with various lengths at 3.125Gbps data rate. Even though these cables were not previously designed to drive 3.125Gbps data rates over long distances, by using integrated transmit pre-emphasis and receive equalization in BBT3410 transceiver it was possible to extend the performance of each of the cables for a longer distance with less than 10^{-15} BER.

In most cases, though the receive data eyes appeared closed, correct data was recovered because of the clock and data recovery circuitry and receive equalization. Increasing both transmit pre-emphasis and receive equalization boost could further increase the link distances for each of the copper cables. This paper expands transceiver applications from backplane to other copper based transmission media, giving system designers more flexibility and choices in selecting link media and therefore potentially reducing the total overall system cost.

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[i] FireWire is a trademark of Apple Computer Inc.