Lessons Learned in High Frequency Data Transmission Design: ATLAS Strips Bus Tape

*University of Oxford, †University of California Santa Cruz, ‡Rutherford Appleton Laboratory

ABSTRACT

The strip bus taps will be located in the sectional inner boundary of the outer shell of the ATLAS detector at the Large Hadron Collider. Due to the location there are unique challenges, material, space, and radiation hardness constraints. The 1.4-m taps must transmit data at 650 Mbps point to point links and 155 Mbps multi-drop links. This paper studies the trade-offs between optimization to satisfy the constraints and signal integrity in a HERP environment environment.

INTRODUCTION

Transmission Line Theory

- Line definition and properties
- Line equations
- Time domain characterization
- Frequency domain characterization

Bus Tape Construction

- Material selection
- Design considerations
- Fabrication process

Multi-Drop Lines

- Design considerations
- Performance analysis

Carbon Fiber in Transmission Lines

- Material properties
- Applications

CONCLUSIONS

- Summary of findings
- Future work

REFERENCES

- Literature review
- Conclusion

MEASUREMENT TECHNIQUES

- Point-to-point lines can be measured either using an offline analyzer or TDR. Both instruments can produce S-Parameters. See [3] for detailed instructions on measurement techniques. Signals can be transmitted on both point-to-point and multi-drop lines to measure eye diagrams and bit error rate.

S-Parameters

- S-Parameters are a set of plots showing transmission, reflection and cross-talk at a range of frequencies. S-Parameters can be interpreted directly, converted to time domain impedance plots or used to simulate eye diagrams. S-Parameters are most useful for quick assessing potential to operate at different frequencies.

BERT

- Bit-error rate test (BERT) evaluates the number of errors transmitted through a cable for a given bit sequence, transmission speed, and signaling standard. The primary objective is to verify that the error rate is low enough to satisfy the experiment's requirements. A scan of the transmission speed gives the cable bandwidth for a given error rate. Effects of the transmission parameters, such as amplitude, pre-emphasis level, and encoding techniques (8T0B, 64QAM, etc.) on the bandwidth can be studied.

RESULTS

- Point-to-Point
  - Point-to-point lines were studied to determine the optimal tape material stack-up. An earlier tape design had a carbon fiber layer too close to the data tracks, resulting in very poor signal quality. The following generation of tapes had a mechanism/polyimide and a bottom copper shield underneath data lines screening the lossy influence of the carbon fiber. We studied data transmission on this tape for different shielding configurations. We found that a single layer of shield with eye diagrams of 900 Mbit/s and BER tests of 8700 encoding was assessed as well. No errors were observed despite running tests for between 3 and 9 hours. The measured bandwidth is in excess of the required 640 Mbit/s transmission.

- Multi-Drop
  - For multi-drop transmission of the TTC data we instrumented the test tape without loss shield in the configuration for the longest such line on the tape: 1) 100 Mbit/s line. 2) The last 10 hybrid location (out of 28) had capacitive loads indicating the line loading with the receiver. 3) The run of the line before the loads was covered with silicon sensors to simulate the effect of the modules loaded on top of the tape. We anticipated the loading of less than 3 pF and the operational speed of 10 Mbit/s. The performance of cables up to 360 Mbit/s was observed.

CONCLUSIONS

- When data transmission speeds were slower, basic DC electrical design practices could be used to design a data transmission line. As speeds increase, proper transmission line design techniques become vitally important. Many simulation software packages are available to simulate transmission line performance. These simulations should be used early in the design process to study options and immediately before production to identify unexpected issues.

- Both simulations and lab testing showed that the initial design of the bus tapes were unlikely to perform well at the desired speeds. By adjusting appropriate insulation above and below the transmission lines, the modified bus tape increased the transmission speed at 640 Mbps and multi-drop at 160 Mbit/s with realistic capacitive loading. The worst eye diagrams on multi-drop lines were in the middle of the tape, which was unexpected.

- Carbon fiber is a poor conductor. It is difficult to model the electrical properties due to the variations in fibers, resins and build processes. For the purposes of the strip bus taps, the recommended option is to avoid the use of carbon fiber for AC grounding.

FUTURE WORK

- Future tapes will be built with a new stackup as shown in Figure 13. This design should be an appropriate balance of signal integrity and material budget for the intended transmission speeds. It has the ground layer on the bottom separating the data transmission from the dissipative effect of the carbon fiber.

REFERENCES


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