Fiber Optic Communications Educational Toolkit

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Introduction

- The main motive for this work was the need for a low cost laboratory alternative for schools teaching Fiber Optic Communications (FOC) to supplement courses offered in this field.

- This FOC educational toolkit (ETK) provides both undergraduate and graduate students with a new way to study the physical layer of high speed fiber optic communications systems.
The Fiber Optic Communications educational toolkit (FOC ETK) provides undergraduate and graduate students with a low cost and flexible tool to study high speed fiber optic communication systems.

As an introductory tool, the FOC ETK allows for deductive approach, to investigate existing systems. Advanced students ready for an inductive approach can use the toolkit in their own projects.
FOC ETC Design Rationale

To design a fiber optic toolkit that is:

- Able to demonstrate phenomena related to high speed data communications; issues involve bandwidth, dispersion, rise and fall time, synchronous communications involving coding and retiming with phase-lock loop
- Uses inexpensive plastic fiber, no longer than 25m
- Inexpensive high speed, at least 1Mb/s set-up
Fiber Optic Communications Educational Toolkit

- The FOC educational Toolkit can be used to develop low cost fiber optic communications teaching laboratories.

- It is a tool that can be used to supplement courses offered in this field.
Several Experiments were developed and implemented using the educational FOC toolkit. These experiments include:

- Fiber Optic Link Linearity.
- FOC Link Attenuation
- FOC Link Dispersion
- Data transmission

The following slides cover those experiments.
Basic Fiber Optic Link

The circuit below is used to test fiber optic link linearity and attenuation in optical fiber data links.

The LED load resistor is selected to adjust the LED current, and the photo diode load resistor sets the sensitivity of the receiver.
Fiber Optic Link Linearity

- Using the basic fiber optic link circuit given in the previous slide, several Experiments were developed to test the source and link linearity and fiber optic link attenuation.

- Given that the LED forward voltage is nearly constant, we expect to see a linear relationship between the transmitter and the receiver currents.
Fiber Optic Link Linearity

Receiver detector resistor voltage vs. LED current

Detector resistor voltage vs. LED current in mA
Attenuation and Power Budget

- The power budget is a useful tool for considering how optical power can be a constraining factor.
- The FOCETK can be used for Attenuation Experiments
- The difference between the transmitter power and the minimum required power at the receiver is the amount of power available to the link, which comprises the sum of all the losses and margin.

\[ P_{tx} - P_{rx} = \sum P_{loss} + P_m \]
Attenuation and Power Budget

Attenuation normalized to 1.0 meter length

- IFE91D - 870nm
- IFE97 - 660nm

Fiber length in meters

Attenuation in dB
Fiber Optic Communications

**FOC Involves the following:**

- High speed data Transmitter
- Receiver, detector and slicer
- Dispersion & rise & fall time
- Data Encoding & decoding
- Retiming, phase-lock loop
FOC ETC Transmitter

In this data transmitter circuit, the FPGA forms a low voltage differential drive signal (LVDS)

FOC Toolkit transmitter
A large resistance is selected to provide the required sensitivity. The amplifier uses negative feedback in such a way that from the photo detector the effective resistance appears very small, which allows the bandwidth and data rate to be large.
The output of the trans-impedance amplifier is very analog and will not comply with any given logic signal standard.

The circuit below converts such a signal to digital values. Such action is called *slicing* the signal.

![FOC Toolkit Data slicing circuit](image)
Dispersion in Optical Fiber

Optical dispersion is the spreading that occurs to a light pulse as it travels along an optical fiber.

\[ T_o = \sqrt{T_{tx}^2 + T_f^2 + T_{rx}^2} \]

Pulse dispersion in optical fiber
Bandwidth and Rise time

A relationship between rise time and bandwidth is particularly useful. In considering the time to rise from 10\% to 90\% of the final value, we solve for $H(s)$ and $h(t)$ to find $t_r$.

$$H(s) = \frac{K}{1 + \tau s} \quad \text{where} \quad F_c = \frac{1}{2\pi \tau}$$

$$h(t) = K \left(1 - e^{-t/\tau}\right)$$

$$t_r = \frac{-\ln(0.1) + \ln(0.9)}{2\pi F_c} \approx \frac{0.35}{F_c} \text{sec}$$
Synchronous serial communications is a widely used technique whereby the transmitter uses an encoding to convey the data and clock together.

Manchester coded data

Beginning of a message
Symbol Retiming

It is common practice in communications to use a phase-lock loop to track a Manchester coded signal. The FOC ETK can produce a preamble waveform and provides a discrete time phase-lock loop for retiming.
Conclusion

- The FOC toolkit presents a low cost alternative for educators to teach the physical layer of FOC data links.

- A field programmable gate array (FPGA) is used to generate the transmit data signal and also retime received signals.

- Other than the flexibility afforded by an FPGA, the accompanying development board should be particularly flexible in the discretion afforded to the instructor.