EE 8114 Fall 2004: Suggested Project Titles

(You may also suggest your own topic provided the project is exclusively done for the course EE 8114)

For all these projects, students are expected to search and find the relevant reference material. The given references are just examples. References can be obtained by searching research databases available from the Ryerson University Library web site. Most important ones are: **IEEE Explore** and **Engineering Village 2**. Example, [1]

Experimental Characterization of EDFA [2] Erbium doped fiber amplifiers (EDFA) play a significant role in optical amplification at 1550 nm wavelength window. Therefore, they are widely used in wavelength division multiplexed (WDM) systems. However, one significant shortcoming of EDFA is the non-uniform gain spectrum. This causes different wavelength signals to experience different gain which in turn causes different signal to noise ratio (SNR). In this project, you will perform measurements to find the gain characteristics of an EDFA under different operating conditions.

Ref: Gerd Keiser, 'Optical Fiber Communications' third edition, McGraw-Hill (2000), Section 11.3, S. Novak and R. Gieske, 'Simulink Model for EDFA Dynamics Applied to Gain Modulation', Journal of Lightwave Technology, Vol. 20, No. 6, pp. 986-992, June 2002

Enhancing the Simulink Model of EDFA [2] Erbium doped fiber amplifiers (EDFA) play a significant role in optical amplification at 1550 nm wavelength window. Therefore, they are widely used in wavelength division multiplexed (WDM) systems. The dynamic characteristics of an EDFA are important. A Simulink based simulation model has been developed by former EE8114 Ryerson students. In this project, you will apply different inputs to the model and for characterization and enhance the model.

Gain Compensation of EDFA [2] Erbium doped fiber amplifiers (EDFA) play a significant role in optical amplification at 1550 nm wavelength window. Therefore, they are widely used in wavelength division multiplexed systems. However, one significant shortcoming of EDFA is the non-uniform gain spectrum which, in turn causes different signal to noise ratio (SNR) to signals of different wavelengths. It is an important task to compensate for the non-uniform gain spectrum. One way to accomplish this is to use an EDFA in conjunction with an optical filter that has a transfer function that is opposite to the EDFA gain spectrum, to the first order. In this project, you will simulate and evaluate such a gain flattening filter.

Simulink Model for Mach-Zehnder Interferometer (MZI) Direct modulation of laser diode is not possible at very high bit rates because of the laser chirp and resonance frequency. Therefore, external modulation is used instead of direct modulation. In this case, the laser is driven by a constant driving current and acts as a constant optical source. The optical signal is modulated by an external modulator. Mach-Zehnder interferometer is a widely used optical modulator that can modulate the optical signal up to several Gb/s. The MZI splits the optical signal into two paths (called the arms of MZI) and apply a relative phase shift between the signals in those two arms by applying an electric or magnetic field. When these two signals are summed, depending on the delay they interfere with each other either constructively or destructively. This way the modulation is achieved. In this project, we will develop a Simulink model for the MZI and investigate how high speed modulation is achieved and to find out the practical limitations of this approach.

Ref: Section 10.2.5, Gerd Keiser

Experimental Characterization of MZI Please read above for MZI description. We have MZI interferometer available in the lab. In this project, you will characterize the MZI experimentally. Talk to me for details

Fiber Bragg Gratings for DWDM The fiber Bragg grating (FBG) is a special in fiber filtering device. Similar to electrical filters that reject or pass only certain frequencies, FBGs can be designed to reflect or transmit only a specific wavelength. Therefore, FBGs play an important role in WDM (Wavelength Division Multiplexed) systems. At Ryerson University, we have the facility to actually write Bragg gratings. In this project, we will design and build a Bragg grating filter.

Ref: Gerd Keiser, 'Optical Fiber Communications' third edition, McGraw-Hill (2000), Section 10.2.6

K. O. Hill and Gerald Meltz, 'Fiber Bragg Grating Technology: Fundamentals and Overview', Journal of Lightwave Technology 1997

Noise Cancellation in Analog Fiber-Optic Receivers [3]: There are three dominant noise mechanisms in an analog optical fiber link. These are: shot noise that is proportional to the mean optical power, relative intensity noise (RIN) that is proportional to the square of the instantaneous optical power and thermal noise that is a function of absolute temperature and independent of the optical power. In this project, we investigate how an adaptive filter can be used to cancel these noise processes.

Ref: Gerd Keiser, 'Optical Fiber Communications' third edition, McGraw-Hill (2000), Sections 7.5 and 9.2

Modal Dispersion in Step Index Multimode Fibers Model dispersion is the dominant dispersion mechanism in multimode fibers. Number of sustaining modes can be deduced from the fiber parameters. Each mode has a different velocity. These are described in section 2.4 of Keiser. In this project, we need to derive a mathematical expression for the impulse response for the multimode step index fiber in terms of the fiber parameters. The impulse response will enable a quantitative estimation of the modal dispersion. Then an equalizer can be devised to overcome the inter symbol interference due the multimode dispersion. There has been some work done on this project. The student can continue on the project.

Simulink based Predistortion Module for Semiconductor Laser In the small signal region, the operating characteristics of a semiconductor laser are described by a set of equations that govern the interaction between electrons and photons in the active region. These are called laser rate equations and given in equations (4.30) and (4.31) of [Keiser]. A simulation model running on Simulink has been developed for the laser based on the rate equations previously and available from the course instructor. The objective of the project is to develop a Simulink model that pre distorts the modulating signal x(t) under analog direct modulation conditions so that, the output of the laser z(t) is linear with respect to the input of the predistortion unit x(t). Note that z(t) will not be linear with respect to y(t). Note that the compensation can be done either prior to the system (pre-compensation) or after the system (post-compensation).

Reference: Gerd Keiser, 'Optical Fiber Communications' third edition, McGraw-Hill (2000), Sections 4.3 and 4.4

Rodney S. Tucker, 'High speed Modulation of Semiconductor Lasers', invited paper, Journal of Lightwave Technology

Caludio F. De Meto et. al. 'Simulink blocks for simulation of light sources' Proceedings of IEEE MTT-S IMOC 99 More papers on predistortion for RF amplifiers such as [4], citedavis, citefaulkener

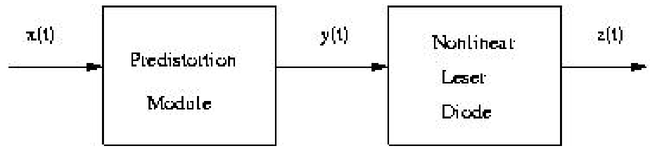

Figure 1: Predistortion Arrangement for a Nonlinear Device

Adaptive Modeling/Compensation of the Laser Diode Adaptive filters learn a system to either model or inverse model them. Channel estimation is a good example of modelling a communication channel in time domain. Similarly, an adaptive filter can be trained to model a nonlinear system such as the laser diode. Adaptive approach has several advantages over fixed approaches. With an adaptive approach, the laser parameters need not to be precisely measured. Furthermore, the adaptive filter can track the changes in the laser characteristics. In this project, the student will build a baseband nonlinear adaptive filter to model/compensate nonlinear characteristics of the laser diode.

Ref: Xavier N. Fernando and Abu B. Sesay, 'Higher order Adaptive Filter Characterization of Microwave Fiber Optic Link Nonlinearity', Proceedings of the SPIE, Photonic west 2000, Vol. 3927-06, pp. 39-49, San Jose, CA, Jan 2000.

Xavier N. Fernando and Abu B. Sesay, 'Higher order Adaptive Filter based Predistortion for Nonlinear Distortion Compensation of Radio over Fiber links' Proceedings of the International Conference on Communications (ICC 2000), Vol. 1/3, pp. 367-71, New Orleans, LA, June 2000.

Investigation of the Laser Chirp Consider a laser that emits a single longitudinal mode. That means the output signal has a single frequency similar to an electronic oscillator. During direct modulation, only the amplitude of the output power supposed to change depending on the driving current. However, the output may experience a frequency change as well. That means the instantaneous frequency of the emitted optical signal may also change with time. This unwanted frequency modulation is called laser chirp. The effect of chirp is detrimental in a fiber optic communication link when it is combined with fiber dispersion, because dispersion is a function of line width. On the other hand, the chirp may also bring some benefits (can you think of any?). In this project, we will find a way to measure the laser chirp and then investigate it.

Ref: Gerd Keiser, 'Optical Fiber Communications' third edition, McGraw-Hill (2000), Section 8.4.3 R. A. Linke, 'Modulation induced transient chirping in single frequency lasers' IEEE J Quantum Electronics, vol. QE 21, pp. 593-597, June 1985

Henry A. Blauvelt et. al. 'Optimum range of DFB Laser Chirp for Fiber Optic AM Video Transmission', J of Lightwave Technology

Application of laser Chirp on Spread Spectrum Communications In spread spectrum communications, the information is spread in frequency according to known law. At the receiving end, a de-spreading is done to recover the original signal. There are several advantages in this approach including noise and multipath and multi-user rejection. A PN sequence is widely used for spreading. However, other spreading phenomena such as chirp can be used for spreading before transmission. The important issue is that we should be able to de-spread at the receiving end. For this we should know the spreading law. This project involves with investigating whether laser chirp can be used for spread spectrum applications. How it can be practically de-spread? What are the pros and cons in this approach?

Investigation of Clipping Noise In Fiber-Radio Systems: In a directly modulated analog system, the output optical power is clipped when the modulating current goes below the threshold level required for lasing. The clipping noise is one of the major concerns in analog optical communications especially, in fiber-wireless systems. Clipping is an impulsive type of noise and can be statistically characterized. In this project, we will evaluate the mathematical model for clipping noise and investigate the performance of a fiber-wireless system under clipping condition. Then an adaptive noise cancellation technique will be investigated.

Multimode Fibers for Fiber-Wireless Systems Multimode fibers exhibit modal dispersion. When radio signal is transmitted over a multimode fiber, the output radio signal would be distorted due to modal dispersion. Consider a vector-modulated signal. Due to the distortion of the radio signal the constellation of the vector-modulated symbols would be distorted too. In the project, we like to develop a relationship between the parameters of the multimode fiber and the distortion of the vector modulated symbols assuming a QAM modulation scheme for the radio and direct intensity modulation for optical.

Radio-over Fiber as an Optical Sensor When the optical fiber is exposed to high electric or magnetic fields, the optical carrier experiences a phase shift referred to as Faraday's rotation. This phenomenon is used in optical fiber sensors. In the project, we will investigate fiber sensors in-detail and find a novel way to deduce the electric field using fiber sensors. When the vector modulated radio signal is transmitted over fiber, how Faraday's rotation will reflect on the phase and amplitude of the vector modulated symbols? Detecting the phase and amplitude of vector-modulated symbols is much easier than detecting the phase of the optical carrier itself.

PSpice based Predistortion Module for the Semiconductor Laser In the large signal region, since the rate equation description is not quite accurate; an equivalent circuit model is used to describe the dynamic behavior of a laser diode. This equivalent circuit model and its parameters are described in [Tucker]. In this project, we first understand and reproduce a PSpice model for the laser from the previous students' work. Then we will focus on developing a SPICE model that pre distorts the modulating current so that, the output of the laser is linear with respect to the input of the predistortion unit under analog direct modulation conditions. That is z(t) is linear with respect to x(t) in the above figure. Note that the compensation can be done either prior to the system (pre-compensation) or after the system (post-compensation). This is an excellent project for your, if you also take EE8502 or EE8504.

Reference: Gerd Keiser, Sections 4.3 and 4.4, Rodney S. Tucker, 'High speed Modulation of Semiconductor Lasers', invited paper, Journal of Lightwave Technology, Benjamin Tsou et al. 'A Versatile SPICE Model for Quantum Well Lasers'

Simulation Model for Fiber-Radio System In fiber-radio systems, the portable unit is same as existing wireless portable devices. They receive and transmit radio signals. However, the radio signal is transmitted over an optical fiber from the antenna to the central base station. Therefore, we have a two-stage modulation. This is an emerging technology to boost the capacity of wireless networks. The problems associated with fiber-radio systems are unique. In this scenario, the baseband digital data is vector modulated on a radio carrier and this radio carrier modulates the optical signal. Therefore, all the impairments of the optical channel will be reflected on vector modulated baseband symbols. Please see more information on http://www.ee.ryerson.ca/wincore/adroit.html to read more about the fiber-radio systems and to see a power point presentation on fiber-radio systems, also see [5] and [6]

Dispersion in Single Mode Fibers Fiber dispersion limits the maximum bit rate that can be transmitted via a fiber in digital systems because, the optical pulses get smear and overlap with each other after some distance. For a single mode fiber material dispersion and waveguide dispersion are the two predominant dispersion mechanisms. Modal dispersion is dominant in Multimode fibers. Section 3.2 of [Keiser] gives a good overview of these dispersion mechanisms.

The dispersion can be overcome by various methods. The idea is to have a device that has an inverse operation to dispersion. In this project, a simulation model will be developed to represent the dispersive fiber. Then the dispersion will be anayzed under different conditions.

Electro Absorption Modulator (EAM) Direct modulation of laser diode is not possible at very high bit rates because of the laser chirp and resonance frequency. Therefore, in high speed links external modulation is used instead of direct modulation. In this case, the laser is driven by a constant driving current and acts as a constant optical source. The optical signal is modulated by an external modulator. EAM can be used as an external modulator because it modifies the phase of an optical carrier according the applied electric field. Some people from British Telecom (Dave Wake) recently improved the EAM so that it can also be used as an optical detector. In this case, the output current is proportional to the input optical power. In this project, we will evaluate an EAM and see how it can be used as both an optical detector as well as a modulator.

Optical-Wireless (Free Space Optical) Systems

High-speed optical wireless (Infrared) links have become popular in indoor applications. These infrared (IR) wireless links have several advantages over their radio counterparts. Namely, in the IR band, abundant unregulated bandwidth is available and IR systems are immune to electromagnetic interference. Intensity modulated optical wireless systems do not have multipath fading and they are immune to eavesdropping. These advantages promise a bright future for IR wireless systems, [7], [8], [9], [10], [11], [12].

Investigation of Infrared Wireless System When the infrared signal is emitted into the free space, there will be multipath dispersion. Under line of sight conditions, the optical wireless channel can be modelled as an exponentially decaying model [13]. When the optical signal is radiated towards the ceiling and the reflected signal is detected by the receivers the impulse response of the channel is given by a different function. This project is involved with developing a simulation model to represent the optical wireless channel under both the line of sight and ceiling reflected cases, using a certain scheme. Then, we need to investigate suitable equalizer architectures so that the bit error rate is minimized.

Noise Cancellation of an Infrared Receiver [3], citenarasimhan: Ambient noise is the biggest concern in an Infrared wireless channel. The ambient noise mainly comes from the fluorescent lighting and sunlight. This ambient noise when received by an Infrared receiver will generate an excessive shot noise that is proportional to the mean optical power. Depending on the light source the spectral characteristics of the ambient noise varies. We are only concerned with the wavelength range in which the photo detector is sensitive. Furthermore, due the ballast flickering, which is several kilohertz, there would be an electrical noise superimposed with fluorescent lighting. In this project, we will develop a noise cancellation technique to remove the ambient noise in an IR communication link.

Design of an IR Wireless Transmission Link If you are good in electronic circuit design and like build something to get hands-on experience, this is for you. In this project, we will build an Infrared digital transmitter and receiver to analyze the performance of the communication link. Either this can be done using discrete components on a PCB or if you are familiar with Cadence environment, then you can first create the circuit in the computer, get simulation results and then actually build it. This is an excellent project for your, if you also take EE8502 or EE8504 (search the CCECE 2004 for a good paper on this).

Simulation Environment

Preferred simulation environment for all these projects is SIMULINK environment running on MATLABTM platform. Students may also use other software, if they find it more flexible. However, the results should be transparent to the software used for simulation. Ref: Claudio F. de Melo et al. 'Simulink Blocks for Simulation of Light Sources' IEEE MTT-S IMOC'99 Proceedings, Ref: Mastering Simulink 4, Dabney Harman, available from me http://www.mathworks.com

References

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