Rf/Microwave and Lightwave Engineering Laboratory

Edip Niver
Electrical and Computer Engineering Department
New Jersey Institute of Technology
Newark, NJ 07102 USA
Telephone: (973) 596-3542, Fax: (973) 596-5709 e-mail : niver@njit.edu

Abstract: Rapid implementation of practical wireless and fiber optic communication systems require training of future generation of engineers not only in theoretical aspects but it also have to be complemented with laboratory skills. The multidisciplinary nature requires background in courses diverse as rf/microwaves, fiber optics, communication systems and semiconductors. Although there are conceptual similarities between rf/microwave and optical signals, there also exist major differences with respect to components including sources, detectors and transmission media, and their experimental characterization. The laboratory course emphasizes measurements in rf/microwave spectrum up to 10 GHz and in the lightwave spectrum from 600 to 1600 nm. The laboratory experiments are based on utilization of research quality state-of-the art equipment to carry out input/output relations: *Electrical/Electrical* measurements include characterization of sources, detectors and various components; *Electrical/Optical* measurements include characterization of light emitting diodes and laser diodes, their spectral outputs and biasing characteristics, etc.; *Optical/ Electrical* measurements include characterization photodetectors and optical receivers; *Optical/ Optical* measurements include characterization of spectral attenuation and dispersion in single and multimode optical fibers, optical couplers, coupling of light into fiber and OTDR measurements. Additional experiments carried out include the characterization of a microwave and fiber optic links. Most of the equipment is interfaced to the IEEE-488 bus to perform automated measurements; the measured results can either be stored electronically for further processing. Software tools are utilized whenever it is possible to simulate the actual experiments prior to laboratory sessions or to compare the experimental data with equivalent synthetic data. Due to extensive cost of the equipment, the laboratory equipment is also used extensively for classroom demonstrations, senior projects, and graduate dissertations. The funding to establish such a laboratory is provided by grants from federal (NSF) and state (NJ Commission on Science and Technology/American Electronic Association) agencies, corporate donations and NJIT contributions.

Keywords: radio frequencies, microwave, fiber optics, laboratory

1. Introduction

In the Electrical and Computer Engineering (ECE) Department at the New Jersey Institute of Technology (NJIT) the rf/microwave and lightwave engineering education and research program is a major option. Students can specialize in this field from the baccalaureate through the doctoral level. Because of the rapid implementation of related new technologies, the program is interdisciplinary involving rf/microwaves, fiber optics, communication systems and semiconductors. Consequently, new course including laboratory [1] has been introduced into the curriculum at the undergraduate and graduate levels.

Lightwave communication systems utilize radio frequency or microwave signals to modulate on optical carrier, which is then transmitted through an optical fiber. Although there are conceptual similarities between rf/and optical signals, there also exist major differences with respect to components including sources, detectors and transmission media, and their experimental characterizations. In general, laboratory measurements are performed at radio frequencies in the microwave spectrum up to 10 GHz and in the lightwave spectrum from 600 to 1600 nm.

The emphasis on research quality state-of-the-art instrumentation for the rf/microwave and lightwave laboratory at NJIT for undergraduate training is warranted because:

- fiber optic communication systems as a discipline has a novel aspect and requires contemporary hardware,

- industry prefers to hire graduating engineers who have been exposed to state-of-the-art instrumentation and can perform in the workplace with minimal inhouse training,

- the utilization of the same equipment in teaching as in research avoids duplication and additional costs; low cost kits are very limited in scope and are not adequate to address the issues related to fundamental concepts.

2. Undergraduate Program

The laboratory course is a major part of comprehensive undergraduate curriculum which consists of the following senior courses:

Fall Semester

EE 457 Microwaves and Integrates Optics,
EE 463 Semiconductor Devices,

Spring Semester

EE 484 Fiber Optic Systems,
EE 493 Rf/Microwave / Fiber Optics Laboratory,
EE 416 Senior Project

The existing equipment is used for demonstration in lecture based courses and extensively utilized in the laboratory course as well as in senior projects. Furthermore, students are exposed to advanced research seminars as well as to invited speakers from the industry.

3. Equipment

The sources of funding for the Rf/ Microwave and Lightwave Engineering Laboratory were derived from the grants from federal (NSF) and state (NJ Commission on Science and Technology/ AEA) agencies, donations by members of the New Jersey Rf/ Microwave Industries Association, corporate gifts and NJIT contributions. Due to the high cost of instrumentation in rf/ microwave and lightwave regions of the spectrum, the established laboratory for educational purposes consists of three identical arrangements of major instruments and one set of specialized instruments.

The established prototype bench consists of

- Vector Network Analyzer (300kH - 3 GHz),
- Optical Transmitter (1300 nm laser diode with modulation BW 3 GHz),
- Optical Receiver,
- Optical Coupler,
- Digitizing Oscilloscope with Time Domain Reflectometry Sampling Head,
- Optical Power meter with proper sensors,
- Rf/Microwave power meter with sensor,
- He- Ne laser with miscellaneous optical hardware,
- Bit error test set (155 Mbps),
- Constant Current Source and a multimeter.

The specialized instruments are,

- Vector Network Analyzer (0.045-50 GHz),

- Optical Time Domain Reflectometer with 1300 and 1550 nm plug-ins,
- Optical Spectrum Analyzer (600 – 1750nm),
- Optical Monochromator with white light source (400-1800nm),
- Rf / Microwave spectrum analyzers with sweep generators,
- Solid state sources (Gunn diode oscillators,laser diode and light emitting diodes,etc.)

Most of the above instruments are interfaced to the IEEE-488 bus to perform automated measurements; the measured results can either be stored in data files for futher processing of plotted on an external printer or plotter. This equipment is also being used in various classroom demonstrations, senior projects and in graduate research.

4. Measurements

The establishment of the state-of the-art laboratory permits us to implement the program in a realistic environment, covering the rf/microwave spectrum up to 50 GHz and lightwave spectrum in the 400-1800nm region . Typical characterizations carried out in the laboratory employing the available equipment include,

- Electrical/Electrical measurements on devices in which input and output signals are electrical in character. These involve rf/microwave characterization of passive and active microwave components, such as, various transmission lines (microstrip, coax,etc.), waveguides, attenuators, filters, sources and detectors. Typical measurements are bandwidth, insertion loss/gain, phase, impedance, cross-talk and group delay.

- Electrical/Optical measurements using electrical input and optical output include characterization of laser diodes (LD), light emitting diode (LED), optical sources and optical modulators . The key characterization parameters are sensitivity, modulation bandwidth, dynamic range and linearity.

- Optical/Electrical measurements utilizing optical input and electrical output include PIN and Avalanche photodiodes and optical receivers. Characteristics measured are similar to ones mentioned in electrical / optical measurements, except that the independent and dependent variables are reversed.

- Optical/Optical measurements such as optical fibers (single and multimodes), switches, splitters, attenuators, connectors and optical modulators. The key parameters measured are spectral attenuation, optical delay, dispersion and optical return loss.

After characterization of individual components, optical communication system concepts are investigated using bit-error test sets and other available equipment. Software tools are also being emphasized in the above measurements prior to or after the experiments.

5. Experiments

The available equipment is shared among the students who are carrying out their undergraduate and graduate projects and those who perform the following laboratory course experiments:

Basic rf / microwave measurements

Includes familiarization with various components, characterization of waveguides, Gunn diode oscillator and linearity of the detector. Emphasizes the use of power meter and the frequency counter.

Light Coupling into Fiber

A He-Ne laser beam is coupled into multimode fiber. Horizontal and vertical offsets are characterized by monitoring output power with an optical power meter.

Spectral Attenuation of Multimode Fibers

A white light source is coupled to a 1 km multimode fiber via a monochromator in the 900 - 1700 nm range. The fiber is then replaced by a 2 km one, and then resulting attenuation for a 1km fiber is determined.

Time Domain Reflectometry

Various cable and terminations are investigated using a high bandwidth digital sampling oscilloscopes and sampling head. Coupling between two lines is examined experimentally.

Optical Time Domain Reflectometer

Attenuation along an optical fiber and losses due to splices and connectors are characterized at 1300 and 1550 nm.

Microwave Spectrum Analyzer

Spectral characterization of various components is carried using the scalar spectrum analyzer and sweep oscillator. Experimental results are compared with theory.

Vector Network Analyzer

Vector measurements of S-parameters for one and two components are performed using various network analyzers. Measurement data is compared with numerical simulations.

Optical Pulse Dispersion

Pulse broadening in a long optical fiber is measured by modulating a laser with an rf signal. The received signal is converted to the time domain and is compared with the one received at the end of a short fiber.

Microwave Link

A microwave carrier is modulated and radiated from a horn antenna. Receiving antenna placed a few meter away picks up the signal and the signal is demodulated. Link performance is investigated for various analog and digital signals.

Fiber Optic Link

Various rf and optical characterizations of an optical data link consisting of an optical transmitter, fiber and optical receiver, is carried out.

Automated Measurements on IEEE – 488 Bus

Students carry out automated measurements via controlling instruments using a computer. They have to change the program statements written in BASIC to accommodate the device under test.

Optical reflection measurements

Return Loss of an optical port is characterized using the optical coupler in a lightwave component analyzer system.

The laboratory is also being used for various projects; some of the senior projects completed are:

- ECL Line Drivers and Receivers,
- LED Optical Link,
- Laser Diode Link,
- Fixture for Measurements of Thin Films,
- Microstrip Impedance Characterization,
- Phased Array Antenna Feed Network,
- Radiation from Optical Tapers,
- Tapered Dielectric Rod Antenna,

- Pin Diode Microwave Switch,
- Single Sideband Mixer,
- Prototype Board for TDR Measurements,
- Mode Converter.

6. Conclusions

A laboratory equipped with state-of-the-art instruments in rf/microwave and fiber optics results in a comprehensive training when combined with theory and software simulations. Complex fundamentals verified by experiments are no longer abstract concepts but became realities when a student perform physical measurements. Such an educational experience effectively prepares a student for the industrial workplace and gives him/her self-confidence and minimizes the need for inhouse training.

7. References

[1] Niver, E., "RF/Microwave and Lightwave Engineering Laboratory," 1991 ASEE Annual Conference Proceedings, pp.463-6. New Orleans, June 16-19, 1991.