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Building the bridge between engineering and engineering technology schools in a telecommunications program

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Abstract

There is a traditional contradiction between engineering and engineering technology schools. The former are more theoretically oriented; engineering courses taught at engineering schools rely heavily on the student's strong background in physics and mathematics. The graduates of engineering schools traditionally work as researchers, developers, and designers of new devices and technologies. Engineering-technology school graduates are more practical-oriented; the courses require less theory and are more descriptive. Engineering technology education emphasizes extensive laboratory work. Graduates of such schools work primarily as maintenance and control personnel, operating with existing equipment rather than creating new equipment.

However, today industry has changed the traditional approach to design and maintenance. These changes are characterized by a dramatic shortening of the design stage and, more important, by a consideration of the maintenance requirements of new equipment at the design stage. Consider, for example, the telecommunications industry. Indeed, reliability, protection and restoration ability, and the ease of managing telecommunications networks are as important as their transmission speed and security. But all these properties have to be built in before the networks come into operation. All this implies that engineers responsible for maintenance and control—engineering technology graduates, that is—have to be involved in the design of new systems and technologies. The point is that engineering technology graduates have to be able to speak the same language as design engineers. It follows, then, that engineering technology students must be familiar with the type of academic training engineers receive. This is why teaching engineering-level courses at an engineering technology school represent an important approach to meeting the new challenge posed by industry.

This paper discusses the major features of engineering-technology programs and a possible way to teach engineering-level courses in such programs. As an example, we will consider the practice of teaching a fiber-optic communications course in a baccalaureate program for telecommunications technology majors, a course based on our textbook[1]. Several practical illustrations support the thesis of this paper.

Main features of engineering technology schools and fiber-optic communications courses

When teaching in an engineering technology program, the instructor must address two critical issues: The first is the nature of the future work and potential responsibilities of the graduates. They are trained to work as technologists, which means their major responsibilities lie mostly in maintenance; however, the tendency is to involve them in design, development, and research. Thus, their academic training has to provide them with a deep knowledge of technology coupled with a sound general education.

The second feature is the background in the basic sciences of students in engineering-technology programs. Typically, their mathematical education doesn't include courses beyond Calculus II, and their education in the physical sciences doesn't exceed two courses in non-calculus physics. On the other hand, the scientific description of processes, devices, and systems that has to be learned requires a thorough grounding in the fundamentals of mathematics, physics, and other disciplines. Thus, some compromise should be reached between the need to deliver the full range of the required knowledge and above-described restrictions in the tools that could be used for delivery of this knowledge.

A fiber-optic communications course is particularly challenging because it relies heavily on a deep understanding of the physical processes that control the behavior of the components and systems constituting this technology. Optical fiber itself, light sources, photodiodes, and all the passive and active components of fiber-optic networks demand an in-depth knowledge of classical optics, semiconductor materials, micro-mechanical and micro-optical processes, and many aspects of modern science.

The importance of teaching a fiber-optic communications course in both engineering and engineering technology programs can't be overestimated. In 1998 digital technology--computers, telecommunications, and consumer electronics--became the largest sector of the economy of the United States, even bigger than the automotive and food industries. Telecommunications itself makes up more than one sixth of the American economy, and modern telecommunications is based on fiber-optic communications technology. In fact, 98% of domestic traffic is carried by fiber-optic communications systems. Fiber optics continues to grow at an exponential rate. This is why we call it the technology of the future and why many curriculums for electrical and telecommunications technology majors include a course in fiber-optic communications[2].

This paper concentrates on how to deliver engineering knowledge to engineering-technology students. In particular, we will discuss how to train the future technologists to make them able to design modern telecommunications systems, understand the scientific foundation of technical documentation, and work independently in a modern technological environment. Examples drawn from teaching a fiber-optic communications course at New York City Technical College will illustrate the thesis of this paper.

Ability to design

Among myriad aspects of design work, we will focus on the ability of an engineer to choose the appropriate components and modules for constructing the correct system. Consider, for example, designing a local area network (LAN). After gathering all the necessary information about the number of sites, locations, distances, required bandwidth, and other factors and devising the type of network, the designer has to choose the right components of the network. (Some recommendations on the design of LANs can be found in our textbook[1].) The designer needs to start with a transmission medium, that is, to choose between copper wire and optical fiber. To make a right choice, a designer has to weigh cost, transmission capacity, reliability, security, and installation and maintenance expenses associated with its medium. He or she has to take into account also the performance characteristics of the network that can be achieved with a specific medium. What's more, the designer has to take into consideration the ability of the transmission medium to meet the needs of the network at a time when it might have to be expanded.

It would seem that optical fiber is the clear choice in all cases; however, recent impressive developments in copper-wire technology, such as Category 6 or Category 7 cable, present the designer with something of a dilemma. Nevertheless, in most cases optical fiber is the only transmission medium that meets all the requirements for LANs.

The next step in designing a LAN is the selection of a specific fiber-optic cable. The heart of the cable is an optical fiber itself; thus, we depend completely on the designer's ability to choose the proper optical fiber. This ability boils down to his or her proficiency in reading technical documentation, specifically, the manufacturer's specifications (data) sheets. This is why we devote considerable time during lectures and in laboratory exercises to have students become familiar with specifications sheets. In our classroom, we conclude theoretical discussions of what makes optical fiber a perfect light conductor with a detailed review of a manufacturer's data sheet[1]. In our laboratory, we measure the basic characteristics of an optical fiber and students must compare the figures obtained in their experiments with those presented in the specifications sheets.

Let me now give an example, one in which students have to work with bandwidth specification of a multimode fiber found in a manufacturer's data sheet.

First, the students are asked to discover what phenomenon underlies this specification. Secondly, the bandwidth of this type of fiber is specified in this data sheet even without mentioning its units. This fact raises the question of how manufacturers measure the fiber bandwidth and why they use MHz-km rather than just MHz. Thus, the students reach the conclusion that manufacturers specify bandwidth-length product rather than pure bandwidth.

Third, we encourage our students to question why the manufacturer needs to specify bandwidth as two numbers, such as 160/200 at 850/1300 nm. This discussion turns invariably to the question of what essentially changes in the optical fiber with a change in operating wavelength. Students have to recall that the number of modes, N, can be computed through the following formulas:

$$N = V^2/2 \text{ or } N = V^2/4, \qquad (1)$$

where

$$V = (\pi dNA)/\lambda \qquad (2)$$

Here d is the core diameter, NA is the numerical aperture, and λ is the operating wavelength[1]. From calculations using these formulas, which were explained to them in preceding class sessions, students already know that the number of modes depends on a wavelength; therefore, they come to the conclusion that the shorter the wavelength, the greater the number of modes that exist within a fiber, and the greater the number of modes, the lower the bandwidth.

The discussion of other specifications is carried out in a similar way.

Understanding the scientific keys to technical documentation

The difference between vocational and academic training is that higher education should provide an understanding of how the pure science underpin technology used in practical everyday work. The scientific basis of technology is always the prime concern in engineering schools but such subject matter is often given short shrift in engineering technology schools. This is why in our telecommunications program we pay particular attention to the scientific foundation for phenomena and devices we study.

Here is how we discuss the phenomenon restricting the bandwidth of singlemode optical fiber, namely, chromatic dispersion. Students will find a formula for a chromatic-dispersion parameter in a data sheet, but they won't know where this formula comes from. Thus, the problem is to introduce the scientific basis for this formula.

Our students are taught from the outset that the key point in the study of chromatic dispersion is that the core's refractive index depends on wavelength; thus, $n = n(\lambda)$. Since the velocity of light, v, within a material is given by $v = c/n$, where c is the speed of light in a vacuum, then light of different wavelengths travels along the fiber at different velocities. Even if all of these beams propagate along the same path, they will arrive at the receiver end at different times. This results in the spreading of the output light pulse. This phenomenon is referred to as chromatic dispersion.

An understanding of this physical mechanism enables students to derive the basic formulas that govern chromatic dispersion. The following is the course of derivation of these formulas that we reach to our students. The reason for presenting this example here is to show that our engineering technology students have sufficient background in mathematics and physics to understand the scientific basis of technical documentation that they will meet in the workplace.

Pulse spreading caused by chromatic dispersion can be calculated as follows:

$$\Delta t_{chrom} = D(\lambda)\Delta\lambda\, L, \qquad (3)$$

where $D(\lambda)$ is the chromatic-dispersion parameter measured in picoseconds (ps) per nanometer (nm) times kilometer (km), L is the transmission length in km, and $\Delta\lambda$ is the spectral width of a light source in nm. Given the spectral width of a light source and the transmission length, a chromatic dispersion parameter becomes the critical characteristic of an optical fiber that determines chromatic dispersion.

Manufacturers specify the chromatic-dispersion parameter for optical fibers either by giving its value or by the formula

$$D(\lambda) = (S_0/4)\lambda[1 - (\lambda_0/\lambda)^4], \qquad (4)$$

where S_0 is the zero-dispersion slope in ps/(nm^2-km), λ_0 is the zero-dispersion wavelength, and λ is the operating wavelength.

Students have to understand the structure of Equation 4 and the origin and meaning of each term involved in this formula. The best way for them to gain such an understanding is by deriving the formula. In our lecture, we derive Equation 4 based on the group velocity concept. The derivation relies on expansion of group velocity function into the Taylor series, taking simple derivatives, and separating the linear and nonlinear terms of the equation[1]. All these operations are well within the mathematical background of engineering technology students.

To obtain Equation 4 explicitly, students have to become familiar with another technique employed in engineering practice: the use of an experimentally obtained graph that shows how group velocity depends on the refractive index of an optical fiber. To complete the derivation, students must use the mathematical expression describing the experimental graph. In our example, such a formula is known as a Sellmeier equation, which is an industry standard.

By deriving Equation 4, students gain information necessary to an understanding of the origin and nature of chromatic dispersion and, therefore, the bandwidth of optical fiber.

Ability to work independently

An ability to work independently is very important for a practicing engineer. For engineering technology graduates, this ability is also a great advantage. However, the teaching method in engineering-technology schools generally consists of giving step-by-step instructions. While this approach helps to better explain the material, it precludes the student's developing the ability to work without close supervision. In our college, we have taken a new approach to assigning laboratory exercises in order to encourage students to work independently.

Let's consider the method of conducting laboratory exercises in a typical fiber-optic communications course. This segment of the course is taught as a set of small technical projects that include both hands-on experiments and computer simulations.

Each experiment is designed as a real-life workplace assignment. The student is given no detailed step-by-step instructions. Using his or her knowledge of the topic obtained in the classroom and from the textbook[1], the student has to devise the arrangement and the procedure of the measurement and determine what data are to be gathered and how that data must be processed. The student has to build the setup of the experiment and the necessary circuitry and perform the measurements.

The objectives of our approach are:

- To prepare students to work independently in a manner that simulates the way they will work in industry.
- To encourage the study of new material by stimulating their interest through the practical application of their knowledge.
- To integrate their knowledge they've acquired in different areas, such as engineering technology, mathematics, physics, chemistry, English, and other subjects.
- To equip the students with the skills for building experimental arrangements and performing professional measurements.

To show how we implement this approach, let's consider the laboratory exercise of measuring attenuation in optical fibers. Students receive an assignment to evaluate attenuation of different types of optical fibers. It is expected that the students will reason as follows:

Attenuation is given by[1]

i. A (dB/km) = - Loss (dB) / Fiber length (km)

ii. Loss (dB) = 10 log P_{out} (mW)/P_{in} (mW) = P_{out} (dBm) - P_{in} (dBm)

Therefore, to obtain the attenuation figure, we need to measure output and input power. Input power, P_{in}, is not the power radiated by a light source, but it is the power launched into an optical fiber. Therefore, if we measure the light power emerging from a short piece of optical fiber, we will obtain the desired quantity, P_{in}. This is because the losses introduced by this short piece are negligible. Output power, P_{out}, is the light power emerging from an optical fiber under test. It follows from the definition of attenuation that A (dB/km) should be independent of fiber length. To verify this, we need to make these measurements with fiber cable of various lengths.

Theory predicts that attenuation depends on the wavelength of the transmitted signal. To verify this, we need to use the light sources that radiate different wavelengths.

Our laboratory manual[3] includes guidelines and requirements for the report the students must write when they've completed their work. These requirements emphasize that a laboratory report must provide enough information to enable anyone to reproduce the measurements reported. A theory component must be included in the report and must predict the expected results of the measurements. Another important factor that we emphasize to the students is the analysis of the results. In doing the analysis, a student must compare the obtained results with the theoretical predictions and with characteristics given in the manufacturer's data sheet. All manufacturers' data sheets that are necessary for the laboratory work are appended to our laboratory manual[3]. The analysis must also include a discussion of any discrepancies among theory predictions, the manufacturer's data, and the results of the actual measurements.

References:

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Biography

DJAFAR K. MYNBAEV graduated from Leningrad Electrical Engineering Institute, USSR, with MS (1963) and Ph.D. (1969) degrees, both in electrical engineering. He worked for over twenty years for industrial, research, and academic institutions in the former Soviet Union. He moved to the United States in 1991. He has taught electrical engineering and electrical engineering technology courses at the New York Institute of Technology and physics at Fordham University. He also worked for Bellcore (Bell Communication Research), where he performed research in the area of broadband access networks. In 1996 he joined New York City Technical College of the City University of New York, where he is currently an associate professor in the Department of Electrical Engineering Technology and Telecommunications. He is director of the school's telecommunications program. His current research is concentrated on the testing, measurement, and troubleshooting of fiber-optic communications systems. He holds 26 patents and has published more than 85 technical papers. His latest publication (with Lowell L. Scheiner) is the textbook *Fiber-Optic Communications Technology*.