AC 2008-937: INCORPORATION OF BROADBAND ACCESS TECHNOLOGY IN A TELECOMMUNICATIONS ENGINEERING TECHNOLOGY PROGRAM

Warren Koontz, Rochester Institute of Technology

Warren is currently a professor in the College of Applied Science and Technology at RIT and chair of the Telecommunications Engineering Technology program. He joined RIT in December 2000 after retiring from Bell Laboratories. He began his thirty two year career at Bell Labs as a member of technical staff in the Electronic Switching Division in Naperville Illinois. He was involved in a variety of projects at a variety of Bell Labs locations, including international assignments in The Netherlands and Germany. At the time of his retirement, he was a director in the Optical Networking Group in Nuremberg.

Warren holds a BSEE from the University of Maryland, a MSEE from MIT and a PhD from Purdue University. He is currently a student in the Community Education Division of Eastman School of Music. He is a senior member of the Institute of Electrical and Electronics Engineers.

Chance Glenn, Rochester Institute of Technology

Chance Glenn is an associate professor in the ECTET department at Rochester Institute of Technology. He received his undergraduate degree in electrical engineering from the University of Maryland at College Park. He received his Master's Degree and Ph.D. in electrical engineering from the Johns Hopkins University in Baltimore, Maryland. His primary research area is in the application of nonlinear dynamical systems theory to the development of advanced communications technology.

As director of the William G. McGowan Center for Telecommunications Innovation and Collaborative Research, Dr. Glenn has developed a new signal transform algorithm for the compression and encryption of digital audio, video, and image data utilizing his understanding of chaotic and nonlinear dynamics. He has developed a new digital modulation technique, called Fourier Series Waveform Modulation, which shows significant performance improvements over conventional techniques. He is also pioneering new image processing technology for the translation of American Sign Language to digital text and audio.

Mark Indelicato, Rochester Institute of Technology

Mark J. Indelicato graduated from Manhattan College with a Bachelor of Engineering in Electrical Engineering. Immediately following graduation he worked for Nippon Electric Corporation (NEC) as a Large Business Communications Systems Engineer. He traveled extensively throughout the United States and Puerto Rico designing, managing and troubleshooting voice and data communications systems. While at NEC, Professor Indelicato earned his Masters in Information Systems Engineering at Brooklyn Polytechnic University. He then was hired as the first faculty in the then newly formed Undergraduate Telecommunications Engineering Technology where he served as instructor and Program Chair. He now teaches in both the Graduate and Undergraduate telecom programs and has research interests in IP Multimedia Subsystems and VoIP Security.

Incorporation of Broadband Access Technology in a Telecommunications Engineering Technology Program

Warren L. G. Koontz, Professor, Chance Glenn, Associate Professor and Mark Indelicato, Associate Professor

College of Applied Science and Technology

Rochester Institute of Technology

Abstract

The so-called "last mile" of the telecommunications network, which links residences and business locations to the network, has traditionally been the last bastion of old technology. Residential voice service is still mostly provided via an analog signal over a pair of copper wires that connects the telephone to a switching system in a central office. The high-speed digital technology employed by modern switching systems and inter-office transmission systems does not extend to most residences. The local access network is a landscape of copper wires bound into large cables, splices, cross-boxes and other equipment that has provided voice-grade service over the years. However, the landscape is changing dramatically as both residential and business customers demand more and more bandwidth for a growing number of services including high-speed Internet access and video as well as voice. Telcos such as AT&T and Verizon as well as Multi-Service Operators (MSOs) are both vying to provide the "triple play" (voice, data and video) to these customers. In order to provide the triple play, service providers are introducing digital transmission and optical fiber, which have revolutionized long-haul communication, to the local access network.

The Telecommunication Engineering Technology program at RIT is responding to this trend by providing courses and laboratory facilities to introduce students to the associated technology. Our Telecommunication Systems Laboratory now features both passive optical network (PON) and hybrid fiber/coax (HFC) technology. These are two leading approaches to provide broadband access to support the triple play. In addition, we are developing new courses to cover topics such as video transmission and broadband network engineering. This paper presents the current status of our laboratory and course development along with our plans for future enhancements.

Introduction

This paper consists of two parts: a review of communication requirements and technology in the local access network and a report on how this area is being addressed by the Telecommunication Engineering Technology Program and Rochester Institute of Technology.

The Local Access Network

The local access network is sometimes referred to as the "last mile" of the information highway. It has also been known as the local loop network or the "outside plant". It is the part of the telecommunications network that connects individual subscribers (residential and business) to a network node (e.g., a telco central office). The local access network was originally designed to provide analog voice service. It was required to transmit a limited range of audio signals (up to about 4000 Hz), DC control signals (on/off hook and dial pulses) and ringing voltage (about 90 VAC @ 20 Hz) over a distance that normally ranged up to about 13 miles (1). The traditional medium of choice has been twisted pairs of copper wire, supplemented with load coils for distances (i.e., loop lengths) exceeding 18000 feet. Even as long-distance networks migrated to microwave radio, then to coaxial cable and finally to optical fiber, the twisted pair continued to rule the local access network.

In the 1970s, broadcast television service providers began installing coaxial cable systems to distribute television from centralized "head ends" to individual subscribers. These systems, which consist of coaxial cable and broadband RF amplifiers, could carry both VHF and UHF television signals and for many subscribers offered superior quality compared to over-the-air broadcast.

Thus many communities were served by two separate local access networks providing two different services and run by two different types of business. However, changes in both technology and the regulatory environment soon began to blur the distinctions, especially with regard to services offered. Both the telcos and the cable TV service providers began to offer Internet access with steadily increasing bandwidth. The multi-service operators (or MSOs, as the cable TV service providers are now called) had the advantage of having a broadband network in place and could use this bandwidth for downstream video, two-way data and even two-way voice. The concept of "triple-play" service (voice, data and video from a single service provider) was born. At the same time, the MSOs were converting their coax networks to hybrid fiber/coax (HFC) networks that use optical fiber to deliver service to points near the subscribers and coax for the final distribution network. The addition of optical fiber improved signal quality while significantly reducing the number of broadband amplifiers in the network.

In order to compete, telcos had to upgrade their access networks. Digital Subscriber Line (DSL) technology can squeeze more bandwidth out of twisted pairs, but not enough for a triple play. While some telcos are patching together a triple play by bundling satellite service, others, such as Verizon and AT&T, are investing heavily to upgrade their local access networks. Verizon is making perhaps the most radical change by converting to all-fiber local access networks (fiber to the home or FTTH) using passive optical network (PON) technology. As of October 2007, Verizon's FTTH service, which they call FiOS, was available to 8.5 million households and FiOS TV service was available to 4.7 million households (2).

Thus today we have both telcos and MSOs building broadband access networks and offering triple-play services. And both of these industries require engineers who understand broadband technology, service and standards.

The RIT Telecommunication Engineering Technology Program

The College of Applied Science and Technology at RIT has introduced a BS program in Telecommunications Engineering Technology in the early 1990s and added an MS program in 2002 (3). The BSTET program is derived from an electrical engineering technology program and the programs are nearly identical for the first two years. Upper level undergraduate students and graduate students take specialized courses in telecommunications, including voice and data transmission, switching and signaling technology, network planning and management and telecommunication policy and regulation.

Until recently the program has had little emphasis on broadband transmission in general and video transmission in particular. Whether students study electronics, transmission lines, antennas or even fiber optics, they normally learn to address the amplification, transmission or propagation of single sinusoidal signals or single modulated sinusoidal carriers. In June 2006 the Society of Cable Telecommunications Engineers (SCTE) announced the formation of the SCTE Cable College at RIT (4) to "deliver a comprehensive cable-centric educational program for telecom technicians and engineers in the cable industry". This partnership between RIT and the SCTE, together with the general developments in broadband technology outlined above, has led to an increasing emphasis on video and broadband technology in the Telecommunications Engineering Technology program.

In the sections that follow, we present descriptions of the first two new courses to address this technology and the laboratory facilities that have been acquired and installed to support classroom learning with hands-on experience.

Courses

Courses have been selected based on a number of inputs, including

- Specific requests from representatives of SCTE, as reflected in their proposed curriculum
- Meetings with the Industrial Advisory Board for the Telecommunications Engineering Technology program
- The background and expertise of the Telecommunications Engineering Technology faculty
- The overall goals of the Telecommunications Engineering Technology program

With regard to the last point, courses outside the scope of engineering technology (e.g., cable installation) were referred to other departments in RIT.

The initial courses are introductory with regard to video and broadband, but build on a basic background of most telecommunications or electrical engineering technology students. They also supplement existing courses that have been deemed important by the SCTE, such as transmission systems, communication systems and fiber optic technology.

In addition to traditional students, RIT in general and the TET program in particular address the needs of students who are working in industry and/or are distant from the RIT campus. Most courses are available in the evening or online (online courses may require an on-campus weekend for laboratory practice).

Principles of Digital Video

This course explores the creation, processing, and distribution of raw and compressed digital video formats over different communication networks such as wireless, cable, and fiber. The course has a special emphasis on digital television applications such DTV, HDTV, and IPTV. The course also explores different video distribution network topologies and protocols for the Internet, cable, and enterprise networks for video conferencing.

This course is a foundation course for the knowledge of digital video, digital video processing, and distribution of digital video over a variety of networks. The student will be prepared to take advanced courses in digital video processing after taking this course.

The purpose of the course is to enable students to:

- Demonstrate a knowledge of the basic terminology in digital processing
- Understand basic concepts of video formats
- Demonstrate a knowledge of various coding and compression techniques
- Demonstrate understanding knowledge of digital video processing and its use in industry
- Demonstrate knowledge of issues of synchronous and asynchronous distribution of video over the internet and other networks.
- Perform digital processing activities on video streams.
- Perform networking processes on digital video
- Demonstrate knowledge of the impact of standards on the digital video industry.

The course is divided into the following topics:

- Digital Basics
- Digital Video Formats (DTV, HDTV)
- Compression of Digital Video (MPEG, MPEG2, MPEG4)
- Modulation Techniques (QAM, QPSK)
- Network Distribution (Cable, IP, Wireless, streaming, topologies)
- State of Art Technology Issues
- Industry Issues

A key component of this course is a group project that incorporates learning in the technical aspects of video processing, network delivery of content, and in business analysis. We've derived a new concept in video delivery, and the students are developing a first-level prototype to demonstrate it. They learn cross-disciplinary team-work in the process. In addition to the prototype, they are tasked with developing a report and a presentation to describe and defend their work. This is the first run of this course, which is delivered online exclusively. There will be an opportunity to gain valuable feedback from these first students.

Introduction to Cable Networks and Technology

This course provides a technical overview of the architectures and technologies that have been employed from the first days of Community Access Television (CATV) to those used by the Cable Television (CATV) and Multiple Service Operators (MSOs) of today to offer voice, data, video and wireless services.

The purpose of the course is to enable students to:

- Identify, list and describe the basic network signaling and protocol requirements of broadcast RF TV
- Identify, list and describe the basic network signaling and protocol requirements of broadcast Cable RF TV
- Identify, list and describe the basic network signaling and protocol requirements of broadcast Digital Cable TV
- Identify, list and describe the basic network signaling and protocol requirements of broadcast IPTV
- Identify, list and describe the basic network signaling and protocol requirements of DOCSIS (Data Over Cable Service Interface Specifications)

The course is divided into the following topics:

- Radio Frequency Transmission Basics
- RF Broadcast CATV Network Architecture
- RF Broadcast coaxial CATV Network Architecture
- Digital CATV Network Architecture and Technology
- HFC Transport Systems
- DOCSIS Network Architecture and Services
- VoIP Network Architecture
- Signaling and protocol requirements for MSO services – voice video and data

The use of a hybrid fiber/coax system augments the lecture and project work required of this course. The components of this system are actual equipment used in the MSO head end and outside plant environments and it part of the Telecommunications Systems Laboratory (TSL) in the McGowan Center for Telecommunications.

HFC Network Capabilities include:

- Local channel insertion - Content that has been modulated by proprietary schemes can be inserted into the RF stream. Error performance with respect to various transmission impairments can be measured to find probabilities of error and bandwidth efficiencies.
- Analog FM/AM and digital (QAM) channel transmission
- Provision of DOCSIS carriers for IP services accessed by customer premise cable modems and set top boxes.

The feed to the HFC is like the feed from a Local Hub Site (LHS). The LHS converts the RF feed to 1310 nm fiber for delivery to the HFC node. At the LHS, local content is added on specific channels. Cable modem services are activated with the Cable Modem Telecommunications Services (CMTS) equipment that originates and terminates the DOCSIS signals. Also, Video-on-Demand (VOD) capability is activated here. The HFC node provides a return channel for latter two services.

Laboratory Facilities

The Telecommunication Systems Laboratory (TSL) was established during the early years of the BSTET program and has been under constant development since that time. In March 2008 the TSL will be moved into the newly constructed William G. McGowan Center for Telecommunications Innovation and Collaborative Research at RIT. The original intent of the laboratory was to provide a small-scale version of the public switched telephone network (PSTN). The basic equipment in the laboratory, which has been in place since its beginning, includes the following

- Two switching systems, which serve as local (Class 5) switches
- Inter-office transmission systems including four-wire analog and digital (T1)
- Local access networks connected to each switch (twisted pair cable)
- Customer premises equipment including telephones and private branch exchanges (PBX)

Typical laboratory exercises that make use of this equipment include

- Tracing a voice circuit through the network and identifying all of the elements of the circuit
- Making measurements to observe the signaling protocols used to set up and take down voice circuits
- Establishing complex circuits such as foreign exchange (FX) lines
- Using a T1 analyzer to observe and troubleshoot a digital circuit

The ongoing addition of new equipment has expanded the capability of the laboratory. Some significant recent additions include

- Fiber optic inter-office transmission gear that can transport T1 or Ethernet signals using a SONET (Synchronous Optical Network) OC-3 (155 Mb/s) carrier. The SONET gear supports a ring network with protection switching.
- Data networking equipment (routers, switches, patch panels and cable) to give students access to the IP world
- Voice over IP equipment, including VoIP telephones and soft switches

But the most significant additions with regard to the topic of this paper are (1) a passive optical network (PON) fiber to the home (FTTH) system and (2) a hybrid fiber/coax (HFC) system. These systems provide students with hands-on access to the two major broadband technologies for the local access network.

PON Fiber to the Home System

This system is described in a previous paper (5) and will only be mentioned briefly here.

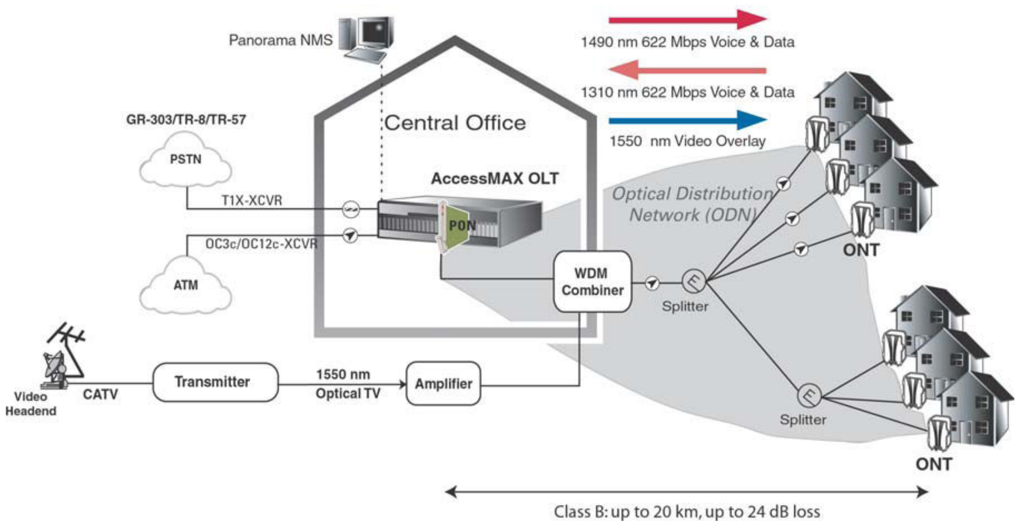

Figure 1 - Passive Optical Network

Figure 1 (6) illustrates the structure of a passive optical network (PON). The optical line terminal (OLT) located in the central office provides links to the public switched telephone network (PSTN) for switched voice service and to an asynchronous transfer mode (ATM) network for data transmission. A wavelength-division multiplexer (WDM) combiner merges broadcast TV service into the fiber network leaving the central office. The PON itself provides two-way transmission between the central office and individual optical network terminations (ONT) located at subscribers' homes. The PON contains one or more optical splitter/combiners located at fiber distribution hubs so that each fiber leaving the central office can serve more than one subscriber. The network is called *passive* because power is only required at the ends of the network (for the OLT and ONT).

Figure 2 Optical Line Terminal

Figure 2 shows the OLT, which is an implementation of the Tellabs AccessMax channel bank assembly, installed in the TSL. The left-most two cards in the shelf are PON cards and the left-most card is connected to an outgoing fiber. The other cards include a controller, interfaces to the PSTN and interfaces to the ATM network.

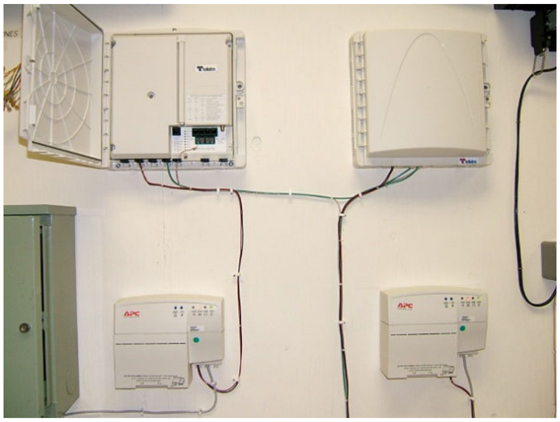

Figure 3 - Optical Network Terminations

Figure 3 shows two ONTs with associated power supplies below them. Each ONT terminates a fiber and provides interfaces for switched voice (RJ-11), Internet access (RJ-45) and TV (coax).

The system is currently limited to switched voice service only, but a WDM combiner has recently been added and TV will be overlaid in the near future.

The system was installed by students as part of a course in fiber optic telecommunication systems. Laboratory exercises have been developed to provide students the experience of working with the craft interface to configure voice service.

Hybrid Fiber/Coax System(HFC)

The HFC system is a new addition to the TSL which consists of a Cableoptics Omnistar broadband transmission platform, a Motorola optical node, broadband RF amplifiers, optical fiber and coaxial cable.

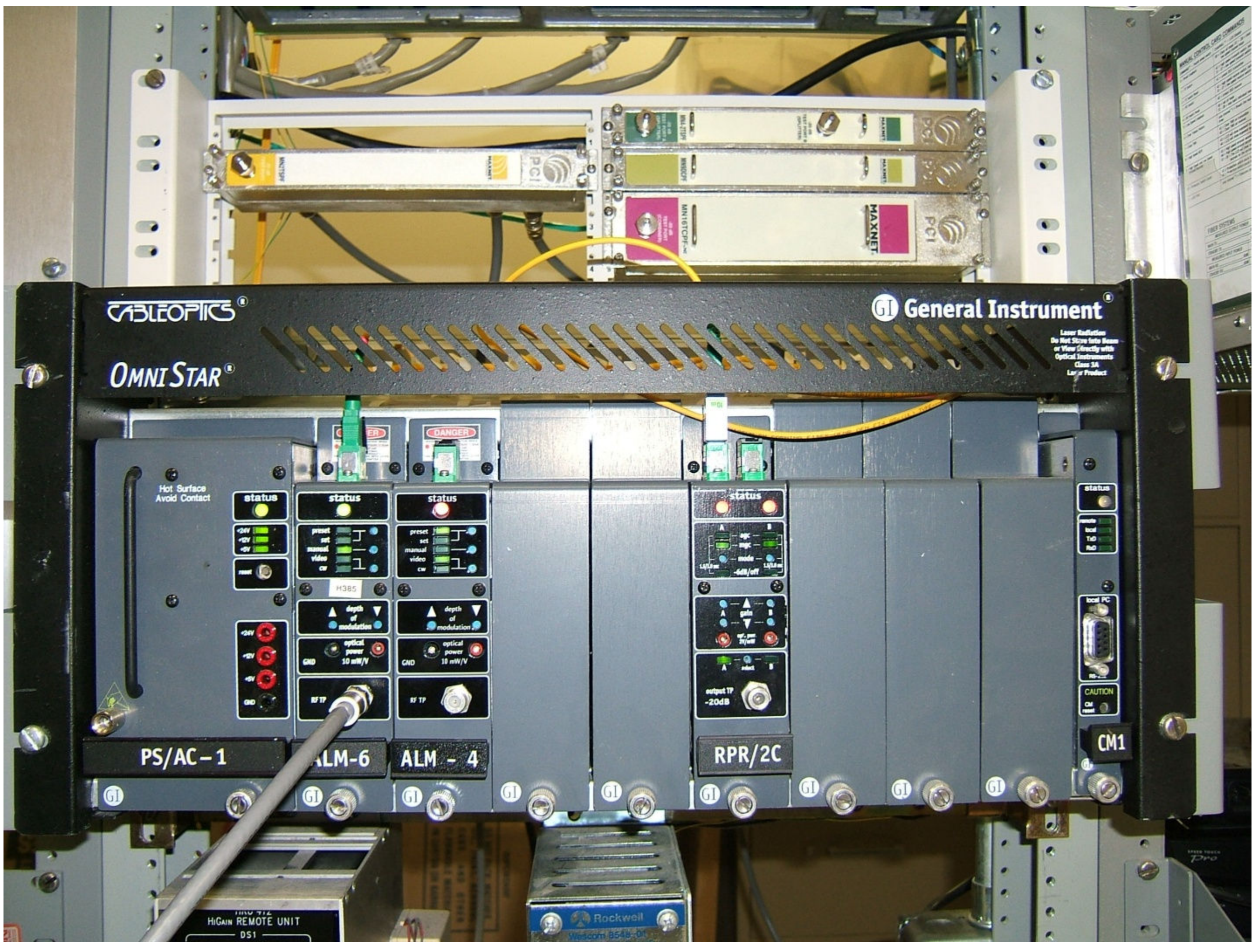

Figure 4 - OmniStar Transmission Platform

Figure 4 shows the transmission platform. The unit labeled ALM-6 is an optical transmitter that is driven by a local TV feed over coax. Note the fiber connection at the top of the unit.

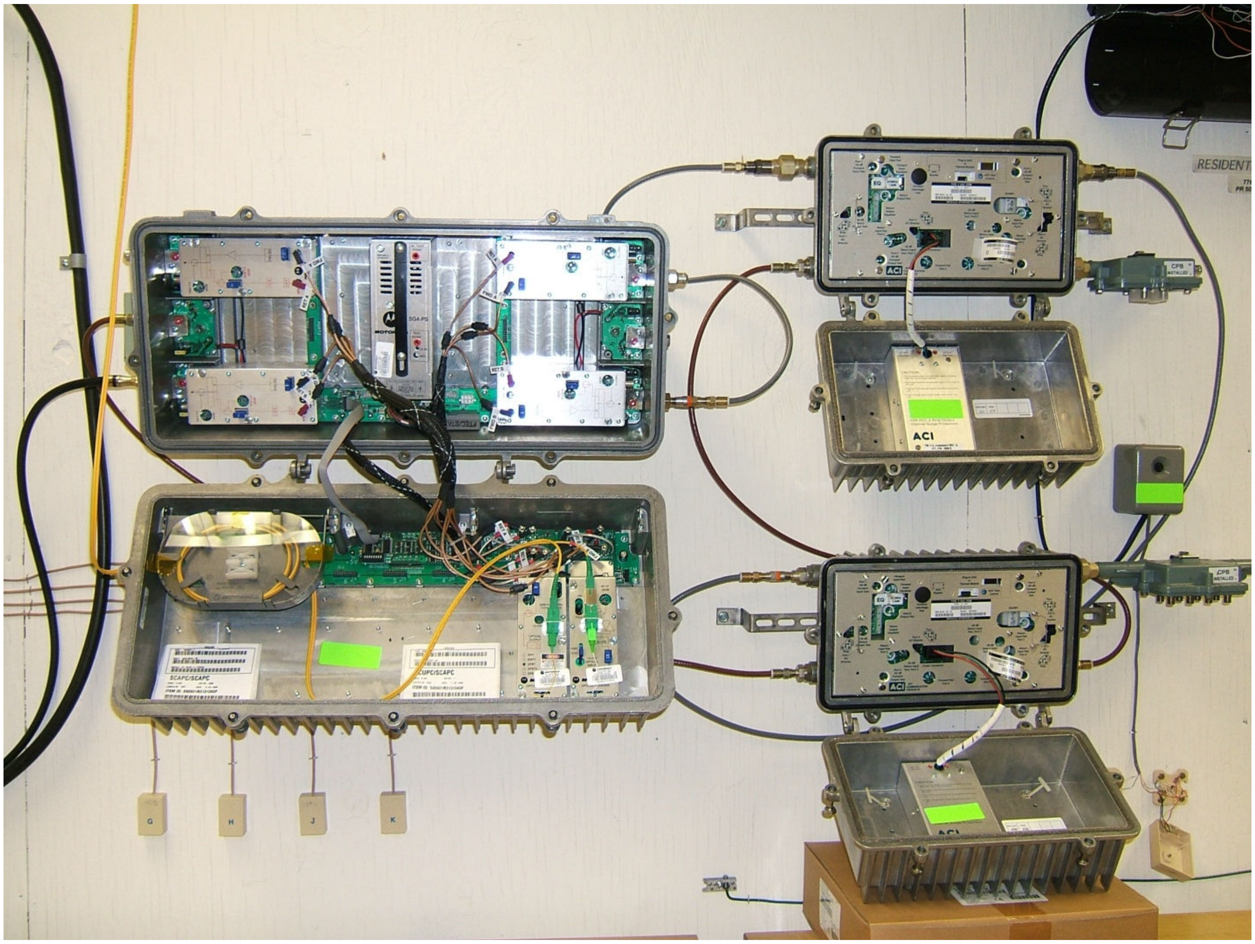

Figure 5 - Fiber Node and Amplifiers

Figure 5 shows the fiber node (left), which converts the optical signal from the transmission platform to RF for further transmission over coax, and two broadband amplifiers (right). The upper amplifier connects to the fiber node and is in cascade with the lower amplifier. The coax links include attenuators to simulate longer cable spans.

Like the PON system, the HFC system in the TSL is not yet fully operational and work is on hold pending the move to the McGowan center, which is scheduled for March 2008. Nevertheless, some students have already had the opportunity to participate in the installation of this equipment and become familiar with its operation.

In summary, the PON and HFC systems in the TSL are a vital part of RIT's growing program in broadband access network technology.

Summary

The Telecommunications Engineering Technology program at RIT is responding to the need for engineers who can provide technical leadership to telecommunication equipment and service providers as they respond to the growing demand for broadband "triple-play" services. We plan to expand our course offerings and our laboratory facilities based on close examination of the industry and input from partners such as the SCTE.

Bibliography

1. **AT&T.** BSP 901-350-202.

2. **Spangler, Todd.** *Multichannel News.* [Online] October 29, 2007. www.multichannel.com/article/CA6495162.

3. *A Master of Science Program in Telecommunications Engineering Technology.* **Koontz, Warren L. G.** Salt Lake City, UT : s.n., 2004. ASEE Annual Conference.

4. *Society of Cable Telecommunications Engineers - Education.* [Online] http://www.scte.org/content/index.cfm?pID=1162.

5. *Implementation of Fiber to the Home in the RIT Telecommunications Systems Laboratory.* **Koontz, Warren L. G., Kim, Doyoub and Jorgensen, David.** Louisville, KY : s.n., 2007.

6. Tellabs. *AccessMAXTM Release 9.2.1 FiberDirect Application Guide, Revision 4.* November 16, 2005.