Teaching Fundamentals of Telecommunications Technology

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Abstract— **This article is about the laboratory stands and teaching program of telecommunications technology allowing our third-year students (from Electrical Engineering Department) to know the operation principles of basic telecommunication schemes.**

Telecommunication plays an increasingly important role in many fields of technology, as a tool to meet specific targets. This situation forces specialists in different fields to acquire the basic knowledge about the functioning, possibilities and limitations of telecommunication. Telecommunication technology is an important part of education of electrical engineering students. Future electrical engineer will have to deal with different data systems, starting with communication systems realized in the workplace and ending up with transferring data to supervisory units in electric power systems.

The laboratory of fundamentals of telecommunications technology enables students to realize schemes using virtual and real devices. During first exercises students simulate various systems using LVSIM®-COM and LVSIM®-ACOM programs. Students begin from familiarizing themselves with basic devices, such as: signal generator, oscilloscope. During the last exercise they are using Binary Phase Shift Keying (BPSK).

Then, students become familiar with the real network devices. They create and configure wired and wireless networks, examine the capacity of each connection and analyze the network using sniffer-type programs.

Keywords - Engineering education, fundamentals of Telecommunications Technology, LVSIM®-COM

I. INTRODUCTION

The laboratory is located in one building in three different rooms. The first room is equipped with six sets of PC with relevant software. On two of them two different simulation software from LabVolt company are installed. First simulation program LVSIM®-COM is used to familiarize students with the functions of oscillators, filters, amplifiers, LC networks, modulators, limiters, mixers, and detectors in AM, FM, PM, SSB, and PLL circuits. In the program all the standard Analog Communications laboratory equipment is replaced by images of modules that students can manipulate on the computer screen. Using the mouse, students can identify and set up equipment for a given exercise, make the necessary connections between modules, and verify the connections made. The LVSIM®-ACOM software familiarizes students with activities related to Amplitude and Frequency Modulation, including waveform and spectral analysis; power and frequency measurements; baseband signal generation and reception; modulation and demodulation principles; using filters, mixers, oscillators, IF and RF amplifiers; automatic gain control (AGC); voltage control oscillators (VCO); and phase locked loops (PLL). Second simulation program LVSIM®-DCOM software is used to familiarizes students with activities related to Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), Pulse Position Modulation (PPM), Analog-to-Digital and Digital-to-Analog conversions, Pulse Code Modulation (PCM), Differential Pulse Code Modulation (DPCM), Delta Modulation (DM), Amplitude-Shift Keying (ASK), Frequency-Shift Keying (FSK).

The other five laboratory stands are located in two additional rooms. Third laboratory stand is composed of three computers connected together by modems and telephone exchange. The stand is showing the use of telephone systems and modems links for remote monitoring and setting of digital protection devices (7SJ produced by Siemens is used).

Fourth laboratory stand is used to familiarize students with the principle of work and settings of local area networks on the base of Ethernet standard, NetBEUI protocol, IP protocol. Students learn the working principle of Ethernet and IP protocols, switches, hubs, routers, use of modems for dial up connections. In the fifth laboratory stand students learn the working principle of WiFi networks in Ad-hoc and Infrastructure model. They are using the stand composed of four different PC computers equipped with access points (AP). In one of the exercises students are learning how to use the program like Commview to investigate the network traffic. In the article, we would like to show our laboratory stands together with the process scope of learning program and grading system.

II. EXERCISES

In the laboratory, which takes place in three rooms, the following exercises are carried out.

First room - LVSIM®-COM, LVSIM®-ACOM,
- two-channel function generator,
- RMS voltmeter and spectrum analyzer,
- basic principles of amplitude modulation on the example of double sideband modulation DSB,
- basic principles of frequency modulation (FM),
- telecommunication system using amplitude modulation (AM),

- principles of operation of devices used in a AM communication systems,
- mechanism for shifting the frequency of primary band used in AM communication,
- principles of generating modulated signals by AM modulation,
- determining the percentage of modulation of amplitude modulated signal,
- reception of AM signals – frequency response RF,
- principles of operation of mixer,
- demodulating of AM signal,
- generating SSB signals using filter method,
- Frequency Shift Keying (FSK),
- the impact of noise on frequency shift keying,
- FSK communication standards,
- mode 2 of modem CCITT V.23 (1200 b/s)
- Binary Phase Shift Keying (BPSK),
- the impact of noise on Binary Phase Shift Keying (BPSK).

Second room
- selected communication standards used in power engineering – LAN,
- selected communication standards used in power engineering – modems,
- LAN network – protokół NetBEUI protocol,
- LAN network – protokół TCP/IP protocol,
- LAN/WAN network – routers,
- WAN network – Dial-Up and modems,

Third room
- WiFi 802.11a network – Ad-hoc model,
- sieć WiFi 802.11a – Infrastructure model,
- analysis of the WiFi network traffic–Commview program.

Description of classes are divided according to the room where the exercise is taking place.

III. FIRST ROOM

LVSIM®-COM is a main program used in exercises which are realized in the first room. The program enables to simulate operation of real devices on a computer monitor. Students have to select appropriate elements of a system, make connections between them and then configure devices to obtain proper results.

The following chapters briefly describe the exercises which are carried out during classes.

A. *Two-channel function generator*

The exercise enables students to use a two-channel function generator and observe simulated signals on the oscilloscope.

B. *RMS voltmeter and spectrum analyzer*

During this exercise, in the initial phase, students measure amplitude of different electrical signals (with different shape) and examine the relationship between the peak amplitude and RMS values of signals. The spectrum analyzer enables to observe signals in frequency domain.

C. *Basic principles of amplitude modulation on the example of double sideband modulation DSB*

The exercise aims to familiarize students with characteristic features of amplitude modulation with the use of spectrum analyzer, oscilloscope, RF generator and other devices.

D. *Basic principles of frequency modulation (FM)*

The exercise aims to familiarize students with principles of generating frequency modulated carrier wave with the use of spectrum analyzer and oscilloscope.

E. *Telecommunication system using amplitude modulation (AM)*

The exercise aims to familiarize students with principles of operation of telecommunication system using amplitude modulation, including AM/DSB/SSB transmitter and AM/DSB receiver. By connecting AM/DSB/SSB generator with two-channel function generator students can realize the transmitter scheme. The function of receiving is fulfilled by AM/DSB receiver. By creating connection between transmitter and receiver students can realize a basic telecommunication system, which consists of transmitter, telecommunication line and receiver.

F. *Principles of operation of devices used in a AM communication systems*

The exercise aims to familiarize students with principles of operation of the AM / DSB/SSB generator and AM / DSB receiver. This exercise is divided into two parts. In the first part students observe information signal in time domain and in the second in frequency domain. The observation of the signal results in answering the question: which parameters and how they affect the shape of the amplitude modulated signal?

G. *Mechanism for shifting the frequency of primary band used in AM communication*

The exercise enables to understand the principle of shifting signal carrying information, to higher frequencies. This operation is done using a mixer, which mixes frequency of data signal (low frequency) with carrier frequency (high frequency). Result values on the outputs of mixer are: sum and subtraction of input frequencies (low and high frequencies). As a result of such operation students get frequency band with LSB or USB and with carrier frequency.

H. *Principles of generating modulated signals by AM modulation*

The aim of the exercise is to familiarize students with principles of describing AM modulated signal in time and frequency domain with the use of AM/DSB/SSB

generator and observation of AM signals using oscilloscope and spectrum analyzer. During realization of the exercise students analyze the impact of changing amplitude, frequency, modulating index, and shape of the modulating signal on the shape of modulated signal.

I. Determination of the percentage of modulation of amplitude modulated signal

The aim of the exercise is to familiarize students with the phenomenon of frequency shifting of primary band. Students learn methods determining the percentage of modulation and observe effects of its change.

J. Reception of AM signals – frequency response RF

The exercise aims to familiarize students with the principle of operations of RF filter, by creating simple telecommunication system and by using spectrum analyzer to observe frequency response of a filter.

K. Principles of operation of mixer

The aim of the exercise is to familiarize students with principle of operation of super heterodyne receiver which uses frequency mixing to convert a received signal to a fixed intermediate frequency, which can be more conveniently processed than the original carrier frequency.

L. Demodulating of AM signal

The exercise aims to familiarize students with demodulation process of AM signal with use of envelope demodulator which is located in AM/DSB receiver.

M. Generating SSB signals using filter method

The special type of AM modulation is a Single Side Band modulation. There are several varieties of this modulation, which have the same feature of reducing necessary emission bandwidth due to removing one sideband and carrier wave. The aim of the exercise is to familiarize students with principles of filter method of signal generation using AM/DSB/ SSB generator.

N. Frequency Shift Keying (FSK)

During this exercise, in the initial phase, students observe a process of generating and receiving FSK signal with the use of FSK modem. Students analyze the operation of analog and digital loopback. The test of loopback consists of test procedure, in which signals from output are sent to the place of their origin. Analog loopback enables to check single modem. That's why FSK signal is sent from modulator output to demodulator input of the same modem. Students use FSK modem and can observe spectral effects by changing the relation $\Delta f/R_b$, where Δf is a frequency deviation and R_b is a data transmission speed.

O. The impact of noise on frequency shift keying

The aim of the exercise is to check whether FSK modem compares the levels of frequency bands f_m i f_s to determine whether the receiver received high or low logic state and whether the subtraction of levels is a result of carrier signal, noise signal or combination of these signals.

P. FSK communication standards

The aim of this exercise is to familiarize students with principle of operation of CCITT V.21 and Bell 103 modems during static mode of operation. Students observe relations between control signals, data and carrier signal.

Q. Mode 2 of modem CCITT V.23 (1200 b/s)

The exercise enables to familiarize students with principles of operation of CCITT V.23 modem in mode 2 using static mode of operations. Students observe relations between control signals, data and carrier signal, with an emphasis on the control signals used in the return channel.

R. Binary Phase Shift Keying (BPSK)

During the exercise, students observe generation and demodulation of BPSK signals. Initially, students are familiarized with BPSK modulation process and with features of BPSK signals in time domain. In next tasks students observe the operation of Phase-locked loop (PLL) in BPSK demodulator. Last part of the exercise, aims to present students features of BPSK signals in frequency domain.

S. The impact of noise on Binary Phase Shift Keying (BPSK)

The exercise aims to present the impact of noise on binary phase shift keying and the difference of BPSK, ASK and FSK signals in response to noise.

IV.   .SECOND ROOM

A. Selected communication standards used in power engineering – LAN and modems

presents connections between computer and other devices used in the laboratory stand. To realize the exercise students use two computers and connections, such as: modem – leased line, RS485, RS232. Local area connections are made in Ethernet 10Base2 standard as 50 Ω coaxial cable, which is placed in a plastic insulated tube and using BNC sockets. Termination resistors (50 Ω) are installed on the ends of network and they are necessary for proper operation of the network.

By correctly configuring the scheme, students realize signal transmission in RS232C standard and observe control signals and data frames on oscilloscope.

Next task is to visualize signals which are transmitted in RS485 standard, configure transmission and analyze voltage levels on transfer link.

Then students have to visualize modulated signals which are transmitted by modem in switched and leased telephone line and in Ethernet 10Base standard.
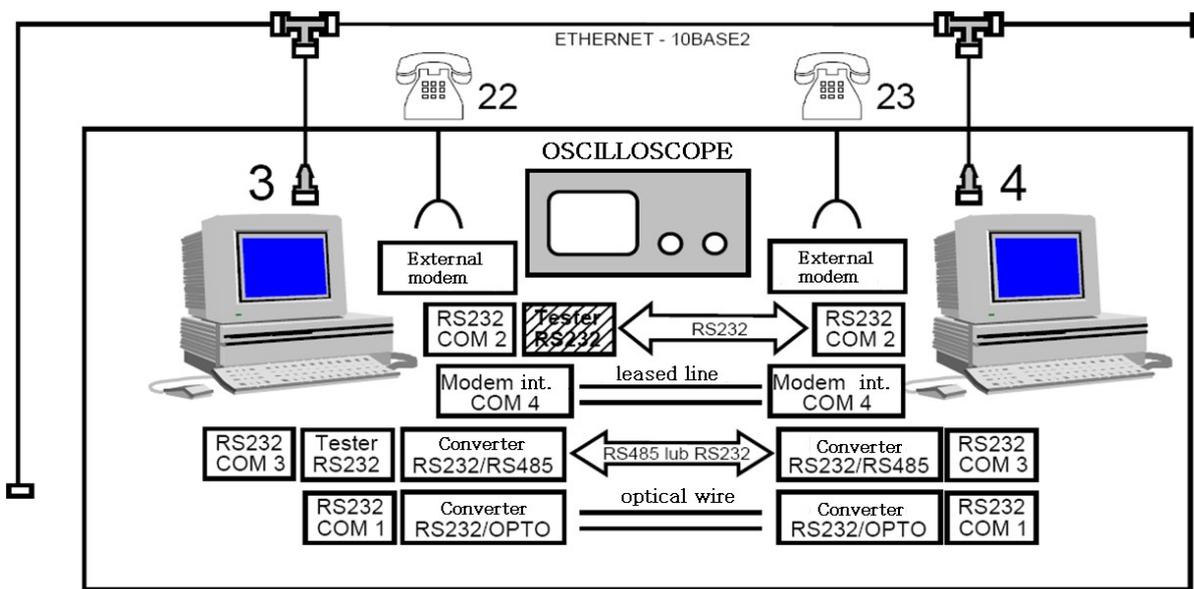

Fig. 1 Block diagram of the laboratory stand – LAN and modems

B. LAN network –NetBEUI protocol

Students are familiarized with a reference structure of OSI model and with issues associated with each layer: physical layer (Ethernet 10/100 Base-T, encoding bit stream, electrical signals in twisted pair wire), data link layer (CSMA/CD, full-duplex, MAC control, auto-negotiation), Ethernet data frame (LLC protocol), network layer and transport layer (NetBEUI), session layer, presentation and application layer (SMB).

C. LAN network –TCP/IP protocol

The exercise aims to familiarize students with data link layer (Ethernet frame, IP addresses), network layer (internet protocol, IP datagram, ICMP), transport layer (TCP protocol, UDP protocol), application layer (FTP, http,POP, DNS, DHCP, SNMP, SMTP, TFTP) and subnet.

V. THIRD ROOM

A. WiFi 802.11 network –Ad-hoc model

Fig. 2 presents the laboratory stand, which consists of three PC computers with Windows 2000 Professional operating system and with external Wi-Fi cards (Linksys) with USB 1.1. interface.
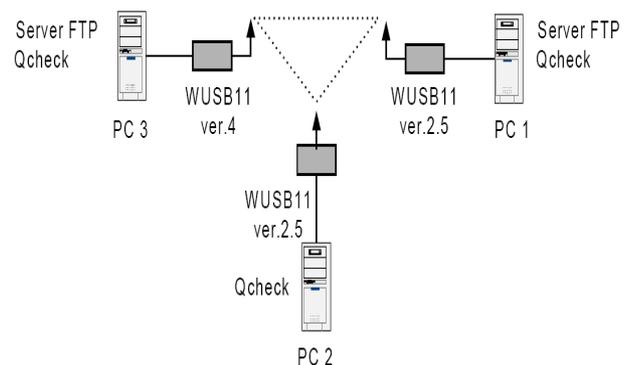

Fig. 2 The scheme of network in Ad-hoc model

Students have to perform following tasks for relation between System-1 and System-2:
– install Linksys WUSB 11 (ver. 2.5) cards in Windows operating system,
– configure parameters of wireless network,
– configure Q-check program, which is used to measure performance and capacity of wireless network interfaces,
– measure delays for different sizes of transmitted packets,
– measure capacities of transmission (using TCP and UDP protocols),
– measure capacities for Audio-Video applications (UDP protocol),
– measure network parameters with enabled WEP encryption.

Next, students perform this procedure for the relation between System 1 - System 3.

B. WiFi 802.11a network – Infrastructure model

The laboratory stand presented in Fig. 3 is equipped with Wi-Fi external cards Linksys WUSB 11 ver. 2.5. Additionally, Q-check 2.1 program is installed on PC computers and it is used to evaluate performance of the network. The station System-3 is equipped with standard Realtek network card and with wireless D-link card, which is working as a wireless sniffer. Fig. 3 presents the scheme of tested network.

The exercise is divided into two parts. In the first part students have to set a connection using D-Link 713 Access Point and measure capacity of the network with use of Q-check. In the second part students have to analyze network security options which are available by Access Point. During the exercise students will use the access point which plays role of wireless gateway.

Students in order to properly set up connections use DI-713P. It is a wireless, wideband router, which enables to share Internet access to users with a wired (Ethernet) and wireless (802.11b) data transmission technology. The device has a built-in firewall, which allows controlling traffic to/from the Internet.
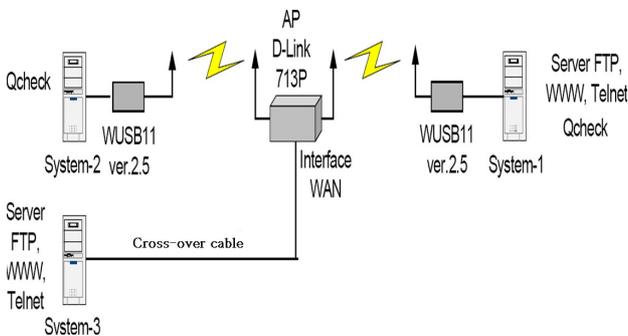

Fig. 3 The scheme of network in Infrastructure model

Internal network users have access to a built-in DHCP server that provides dynamic IP addresses downloading by stations. Managing of operation principles of router can be done by a simple WWW interface.

Students have to:
− measure time delay for different size of data packets (Q-ckeck),
− measure frequencies (Q-check),
− measure frequencies for Audio-Video application (Q-check).

Next, students have to configure Virtual Server in Access Point according to Fig. 4. Access Point has to be configured in such a way so the access to particular services has to be available from Internet, not only from local area network. Station System-3 is a client which simulates connections from Internet and is connected to AP by cross-over network cable to WAN port. Stations System-1 and System-2 connect with AP using wireless interfaces.
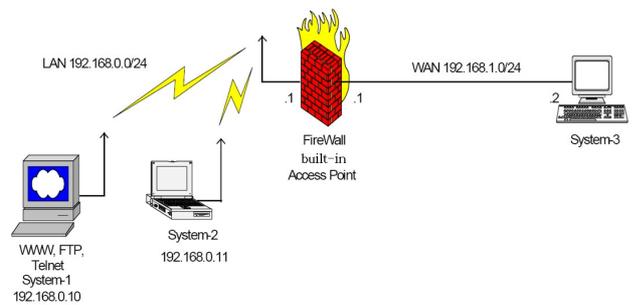

Fig. 4. Scheme of network configuration

Students have to check:
− communication between the various stations System-1 – System-2; System-1 – System-3;
− possibility to connect for any service to System-1 station,
− availability of services from System-2 station,
− possibility to view websites using web browser running on station System-2.

Then students learn to configure access control lists (which work in third and fourth layer of OSI model) and they configure security options of AP.

In order to realize this task there is another option created in access point – Mac Access Control, which uses mainly MAC addresses of devices in wire and wireless network. In the exercise students have to configure the following security mechanism, according to the following guidelines:
− station System-2 has to have the possibility to configure AP using www interface and to connect with services in Internet (in this example to data at the station System-3),
− station System-1 has to have the possibility to communicate only in LAN (both for wired and wireless hosts), but it cannot control AP through www and connect to the Internet.

C. Analysis of the WiFi network traffic–Commview program

Analysis of computer networks is one of the most important tasks, which is daily routine of the network administrators. In addition to checking the configuration of active devices, it is equally important to analyze the traffic generated by the client and server stations. Indeed an invaluable tool is the network analyzer (also known as a sniffer). As a rule, it is software acting on a PC station with a dedicated network interface. Simple analyzers can decode only a few layers of ISO / OSI model (they are generally layer 1-3), more complex are capable of decoding all layers of the model, starting from the application layer and ending at the physical layer.

Main features of good analyzer are: possibility to handle different network technologies (LAN, WAN), the speed of analysis and packages processing, ability to decode a large number of network and application protocols (POP3, SMTP, HTTP), simple and user-friendly interface.

CommView for Wifi is a special edition of CommView software designed to capture and analyze packets in the currently used wireless networking

technologies 802.11 a / b / g. CommView for Wifi collects information from the wireless adapter and decodes the captured data. With it, user can view the network connections and process individual packets.

The software also allows you to decrypt the encoded data traffic through WEP technology and also WPA-PSK, until all network layers. Entire sessions or individual frames can be saved for later analysis, it is also possible to export stored data to a format supported by other network analyzers such as Ethereal.

Studenci podczas zajęć poznają program Commview poprzez wykorzystywanie licznych opcji programu do analizy sieci.

Students learn in the classroom through the use of the program Commview many program options for network analysis.

VI.   CONCLUSIONS

Teaching of fundamentals of telecommunications technology prepares future electrical engineers for solving problems, which they can encounter during their professional career. By participating in laboratory classes students are familiarizing themselves with methods, which are used for data transmitting in analog systems (amplitude modulation, frequency modulation etc.) and digital (frequency shift keying etc.), selected standards of asynchronous data transmission used in power engineering in local connections (RS232, RS422, optical wires) and in wide area networks (modem connections using switched and leased lines). Students then create network schemes, which enable to learn principles of transmitting data in local computer network LAN and wide network WAN using TCP/IP (configuration of active elements such as: hub, switch and router).

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