Short-Term Educational Experiential Project on Microwave Communication Channel for borehole Telemetry

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***Abstract* — Major changes are occurring in introductory microwave engineering to geophysics. The paper describes a short-term undergraduate course on microwave communication in the new propagation channel at S. Seifullin Kazakh Agro Technical University (KATU), Kazakhstan. Along with the continuously evolving curriculum of microwave engineering education, there remains a constant issue - the recognized of obligatory laboratory experience. Characterization of telemetry channel was offered to undergraduate students in the framework of research course on communications. It helps students to familiarize with specific application of microwaves in X-band. The main attention is focused on microwave measurements and its limitations, like in industry, different effects at high frequencies (higher order modes, radiation, coupling etc.), influence of scattering etc. Investigations in the new channel of geophysical information transfer became the educational project arise from opportunity given to undergraduates to receive some practice in the microwaves in very short time. It is one more unique opportunity enough to inflame interest of undergraduate students in their possible future career in urgent growing area between geophysics and microwave communications.**

***Keywords* — Engineering facilities, microwave geophysics, microwave measurement, propagation, telemetry communication channel, logging-while-drilling systems, undergraduate course.**

I. INTRODUCTION

The European natural resources will finish soon. Investigation of new mineral deposits is impossible without new technologies of data transfer from drilling tools upon surface. In logging-while-drilling systems some sensors are usually located in the drilling tool. In the drilling process these sensors periodically control geophysical parameters of drilling and transfer information to surface by telemetry equipment.

The cable telesystems were widely applied all over the world for this purpose. But deep drilling does impossible application of such systems. Existing methods of communication has low transfer rate, and channel capacity is limited. Meanwhile, continuous monitoring of boreholes is necessary that is goal of some European projects. In recent years, a microwave without-cable of system has attracted significant research interest. But success of such projects based on education both in geophysics and electronics [1].

Education in the field of microwave communications at S. Seifullin Kazakh Agro Technical University (KATU), Kazakhstan is not exhaustively covered, mainly due to historical background and to the lack of enterprises in this area able to offer to the young engineers a suitable job opportunity. However, microwave context is nowadays required for engineers that can compete with education levels offered in Universities in most advanced European countries.

The basic goal of the engineering education is training of the competent engineer, responsible in profession, qualified, oriented at job market, and focused on specific activity. So from the academic point of view, the subject of microwave communication in geophysics is very well suited to make students think at a system approach.

Undergraduate students work in conditions of rapid development of modern technique, so high school must continuously adapt it curriculumum for industry inquiries. Traditional training laboratory and experimental base do not support modern educational process. In contrast to academic simulation set-ups, the use of real experimental equipment represents a suitable way to reveal the teen differences between the usually taught idealized systems and strange behaviour of industrial tools.

Nowadays achievements become in multi-disciplinary fields. Therefore it is important to create an environment for studying of phenomena that microwaves plays the leading role. We trust that data transfer from geophysical equipment to operator through a borehole channel belongs to such area. Because in some cases the cable channel is impossible, the propagation channel near microwave band is often used. Thus for student it is important to understand both physical processes in the communication channel and principles of microwave equipment operation.

This paper has presented the undergraduate program for the microwave communication in geophysics channel in KATU. The program not only carried out wide research on microwave communication, but also offers an interdisciplinary number of courses for undergraduate students.

In the paper, laboratory setup of microwave communication in the geophysics carried out with *National Instruments* technologies is considered. Actually this technology is one of the international industrial standards in the field of modern hardware-software complexes of mathematical and physical modeling and design of the automated measurement systems.

II. Fields of Interest

Since 2014 in KATU the large project is carried out on investigations of a new communication channel for telemetry transfer in microwaves for design new logging-while-drilling systems. Because it is of key interest for microwave undergraduate students to be involved in the project, it have been introduced in educational activities [2].

The aim of this course is to give complete knowledge on wave propagation directly from the Maxwell's equations but avoiding long analytical work. The project illustrates the educational features specific to microwaves at KATU.

The study of microwave communications in geophysics requires interdisciplinary knowledge of signal processing, communication systems, electromagnetic scattering, theory of coding, logging, antenna design etc. Helping students to learn about electromagnetics has been an area of center for many years, as demonstrated by many papers, including [3–7].

The student is considered as a member of research team during the project fulfilment. He uses benefits from the most recent experience in the topic and appropriate software. The questions arisen by the undergraduate students help researchers to improve their outcomes, so that the project is productive for all partners. The facilities for the behavioral modeling in laboratory and power transmitters for natural boreholes have been developed [7].

III. Hardware and Software Maintenance

A laboratory plays an important role in teaching engineering skills especially in the fields of microwaves. "From the earliest days of engineering education, instructional laboratories have been an essential part of undergraduate and graduate programs. Indeed prior to the emphasis on engineering science, it could be said that most engineering instruction took place in the laboratory" [8]. Developing practical skills is important for the future engineers. Therefore, the laboratory plays a critical role for introducing student into profession and must be of the highest quality.

Full integration of the experimental equipment is presented in Fig. 1.

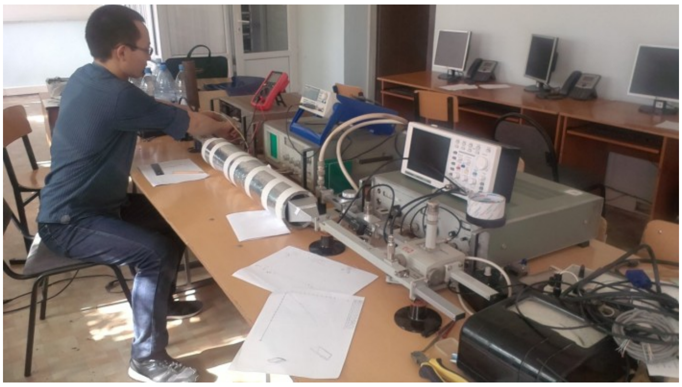

Fig. 1. Student's experimental setup

Experimental activity is performed with teacher and students are free to try their own measurements with the network analyzer and the spectrum analyzer on the transfer channel. It is possible to measure noise and scattering characteristics, VSWR and S-parameters. Setup allows to show the students how each system element affects the performance of a given scattering or noise parameter.

NI ELVIS, National Instruments Educational Laboratory Virtual Instrumentation Suite laboratory educational station is used as measuring system.

The software basis of *NI* technologies is *LabVIEW* environment of graphic programming [9]. By means of *LabVIEW* it is possible to create the so called virtual tools (*VI - Virtual Instrument*).

Researches of the communication system have been carried out in the NI LabVIEW 2013 environment with industrial measurement station NI PXI-1044. Research versions of transmitter part, the communication channel, and receiver have been created.

Interface of transmitter is presented in Fig. 2. It is possible to adjust the modulation rate phase, synchronizing pulse amplitude, carrier frequency and other parameters by means of the interface panel. In the block diagram (Fig. 3) it is possible to track program performance step by step.

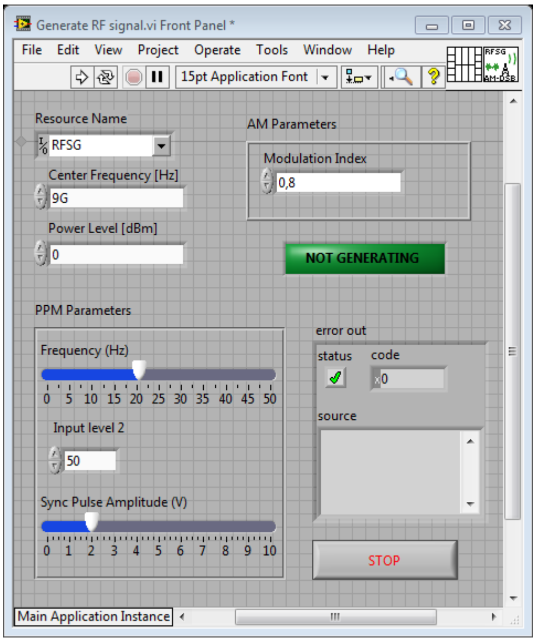

Fig. 2. The transmitter interface

Following stages of operating are shown in the block diagram:

1) Opening of NI-RFSG session;

2) Adjustment of carrier frequency;

3) Generation I/Q switch-on: in this block it is possible to choose the mode of generation of signal of the necessary form (in this case phase-pulse modulation) instead of the constant sinusoid generation;

4) Terminal of the input signal;

5) Coding of a message by Hamming code (7, 4). A coder

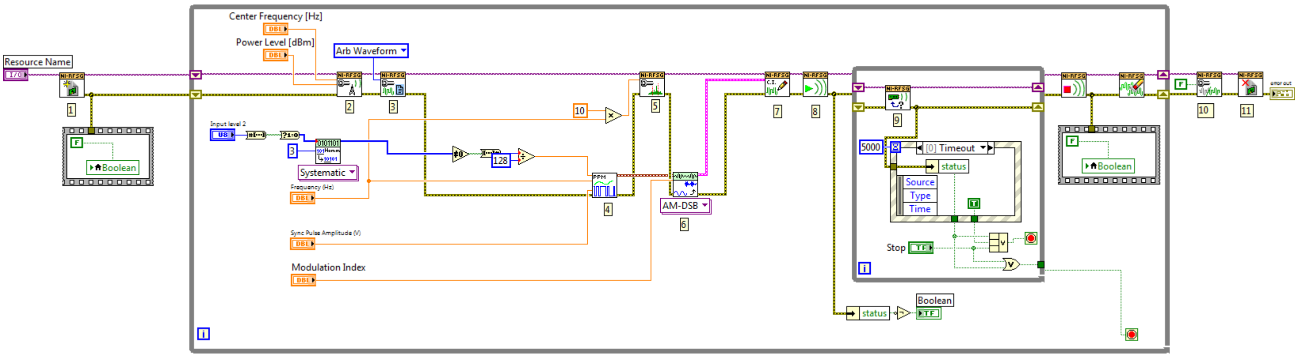

Fig. 3. The transmitter block diagram

from the NI Modulation Toolkit has been used in this step;

6) Generation of the phase-pulse modulation of signal. The modulator has been designed using of two generators of rectangular pulses. One of them generates synchronizing pulse, and the second generates an information pulse. Then two signals are summarised;

7) Adjustment of the spectrum width of the generated signal;

8) Generation of the amplitude-modulation signal;

9) Recording of the signal in the device buffer;

10) Start of generation according to options;

11) Check of the generation status and exit by error or time out;

12) Output exit;

13) Closing of NI-RFSG session.

The eight-digit sequence is accepted from sensor. This sequence split in two equal messages. The messages are coded by Hamming (7, 4) code. As a result we have two 7-bit codewords. It is united in one sequence from 14 digit lengths. This long sequence is connected to the pulse-phase modulator.

Process of the signal receiving can be divided into three stages. The first stage is demodulation of the amplitude-pulse signal. Then demodulation of the pulse-phase is carried out. Pulse-phase demodulator works as a finite automat. When demodulation is finished, the accepted data is decoded. The receiver interface (Fig. 4) is appropriate to its fine tuning on the receiving signal. With the interface it is possible to adjust of the carrier frequency, parameters of speed rate and volume of the recorded data. The numerical indicators on the front panel display the received signal and mode of ten measured values.

In the block diagram (Fig. 5) are shown:

1) Opening of NI-RFSA session;

2) Definition of the synchronisation source;

3) Configuration of I/Q data record;

4) Configuration of the prospective level of signal;

5) Choice of the central frequency;

6) Choice of speed rate for the data recording;

7) Choice of sampling quantity for the one cycle of recording;

8) Demodulation of the amplitude-modulated signal and transfer data to queue;

9) Closing of NI-RFSA session.

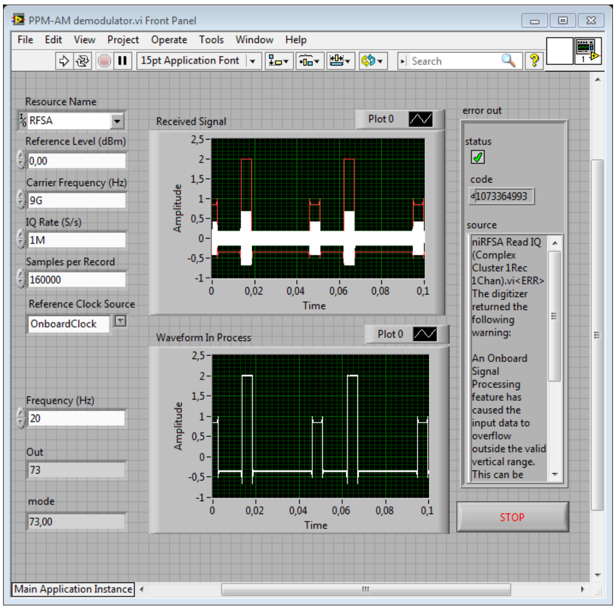

Fig. 4. The block diagram of generator of the rectangular signal

IV. Description of Students' Work

This 72-hours course is offered in both semesters with a standard length of 18 weeks. Each laboratory work is carried out in three stages. As a rule, the first stage is preparation for laboratory work. It assumes studying of theoretical issues of microwave technique and previous disciplines necessary for the experimental work. The stage is finished when a student is completely understand the technology of experiment and expected results on each issue of laboratory work. At the first stage the student is reading a textbook and answers some self-checking questions.

The second stage is directly laboratory work. It includes an assessment of preparation to the laboratory work and its admission to laboratory experiment, researches and record of experiment results. Comparison of the received experimental data with expected result is carried out during all laboratory experiment. Students try to explain the differences observed on attenuation, bandwidth, and all high-frequency behaviour. Radiation losses, unwanted reactive behaviour due to higher order modes generation, and impact of loads are usually presented as main causes of discrepancy. As a rule, experiment must be reiterated many times. This stage is finished if experimental data have coincided with expected result in some interval of time.

The third stage is data processing for experiment, registration and presentation of a report. Students report on simulated and measured results and their noncompliance analysis.

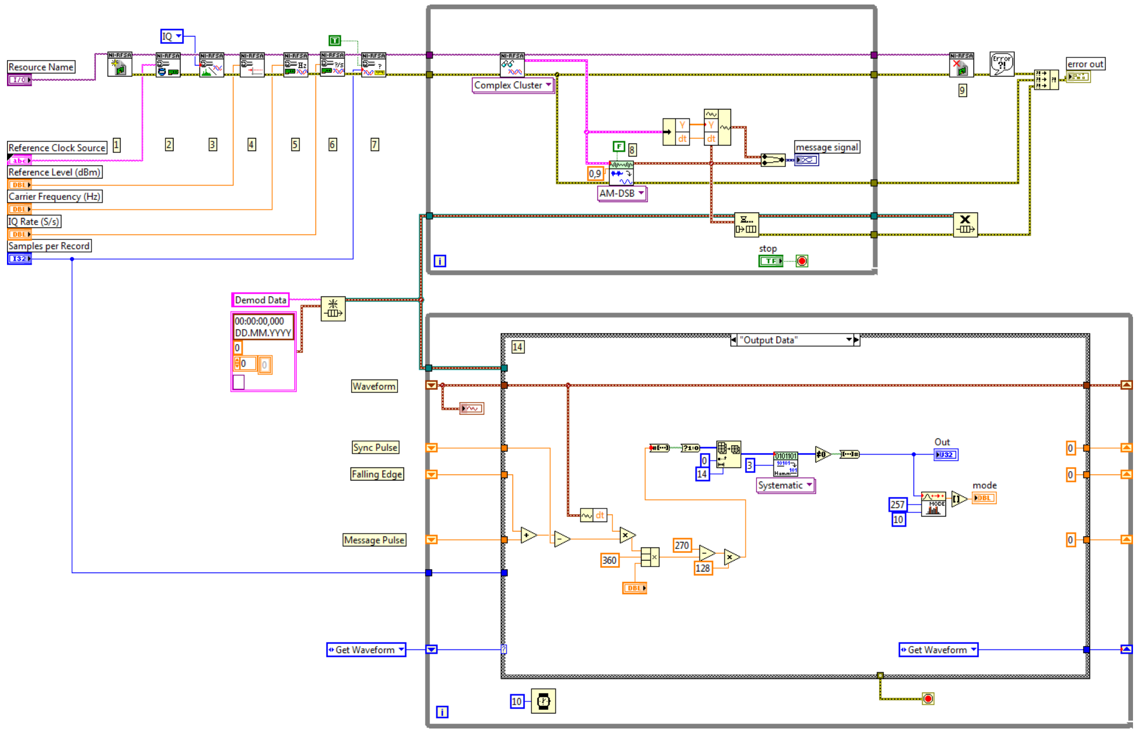

Fig. 5. The block diagram of the receiver

V. Conclusion

Growing microwave applications demand increasing number of academia to include the microwave technical courses in their educational program. The project for basic microwave communication is a good example of communication education at KATU.

The positive experience of the laboratory practical works described above confirms essential increase of the learning efficiency and allows growing quality of training to the international level.

We have some interested undergraduate students who decide to perform their thesis in the microwave communications. Moreover, in Conference on Control and Communications students working in this subject presented good papers in the industry microwave applications [2].

The laboratory will play an important role in engineering education well into the future. This research indicates that integration of microwave communication into a student's curriculum may provide the greatest influence on improving attitudes to profession.

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