PCM based digital communication system using LabVIEW

Habibur Rahman, Mehadi Hassan, Faruque Hossain

Department of Electronics and Communication Engineering,

Khulna University of Engineering & Technology, Khulna, Bangladesh
Email address: habibkuet@outlook.com, munna.orb@gmail.com, fhossain97@yahoo.com

Abstract— **This work presents the design and performance evaluation of Digital Communication System based on Pulse Code Modulation (PCM) virtually. LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is often a system as well as development atmosphere for the graphical programming language from National Instruments. This system is helpful for researchers and students to understand the process of digitizing the analog signal and the digital communication procedure with the help of Virtual Instrument Technology. The simulation results are presented to compare the system performance in Virtual Laboratory interface with Real Laboratory. This paper provides an example of designing a communication system virtually in terms of evaluating the performances in a flexible way.**

Keywords—**LabVIEW, Vitual instrumentation, Sub VI , Digital Communication system, PCM**

I. INTRODUCTION

Electronic communication is a form of communication that is used for the transfer of data, images, and signals, etc. through wire, electromagnetic energy, radio, photo-electronic or photo-optical system [1]. The electronic communication systems are playing a great role in the field of communication. For this growing field the design and performances evaluation of a specific requirement is must for successful achievement [2]. Changing or improving the performance vary rapidly.

Such development works typically involve the design of a new system based on the specific requirements and the performance evaluation of the implemented system. However these process are costly, time consuming, complex etc. For example the design of a transmitter includes the high speed components, VLSI (Very Large Scale Integration) design, advanced semiconductor facsimile etc [3].

To solve these existing problem, it is necessary to design the system virtually or computer based techniques to interface the students with the physical world, with suitable front end design to provide increasing sophistication and increased flexibility [4].

LabVIEW is such a platform which provides the opportunity of designing the systems virtually. Comparing with other simulation tools e.g. MATLAB (Matrix Laboratory) cannot be interfaced for the real time application and required skilled coding technique. On the other hand, LabVIEW provides the flexibility of designing of the systems in block representation, easy to understand and helpful for researcher and industrial people. At the same time teachers and students can demonstrate the systems in the classroom.

This work presents the detail implementation of a PCM based digital communication system in LabVIEW. For the demonstration, this system considers PCM techniques with both uniform and non-uniform quantization. It also includes the design of transmission medium including channel noise and the elimination of channel error in the receiving side. The system performances are shown and analyzed in term of SNR as a function of various parameters.

Fig. 1 is the block diagram of the complete digital communication system based on PCM. This communicational system is designed in LabVIEW and presented in Fig. 6. The front panel of the LabVIEW gives the user interface and the block diagram is for designing the system.

II. THEORITICAL BACKGROUND

PCM modulation is a kind of source coding. The meaning of source coding is the conversion from analog signal to digital signal. After converting to digital signal, it is easy to process the signal such as encoding, filtering the unwanted signal and so on.
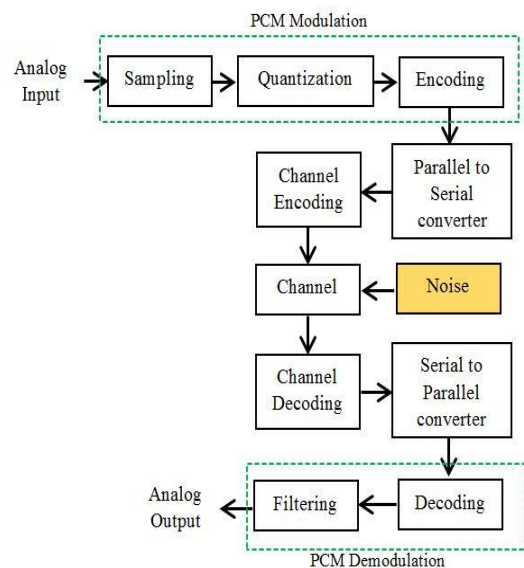

Fig. 1 Block diagram of complete PCM communication system [2].

An operation that is basic to digital signal processing and digital communications is the Sampling process, whereby an analog signal is converted into a corresponding sequence of samples that are usually spaced uniformly in time [2]. Any human sense (the ear or the eye), as ultimate receiver, can only detect finite intensity differences. This means that the original continuous signal may be approximated by a signal constructed of discrete amplitudes selected on a minimum error basis from an available set. This is known as Quantizing. In other words the conversion of an analog (continuous) sample of the signal into a digital (discrete) form is called the Quantizing process [2].

In combining the processes of Sampling and Quantizing, the specification of a continuous base band signal becomes limited to a discrete set of values, but not in the form best suited for transmission over a line, radio path, or optical fiber. Encoding is the process of translating the discrete set of sample values to a more appropriate form of signal. Any plan for representing each member of this discrete set of values as a particular arrangement of discrete events is called a code. One of the discrete events in a code is called a code element or symbol. Decoding is the reverse process of Encoding. It is used in the receiver to regenerate the received pulses. These clean pulses are then regrouped into code-words and decoded into a quantized PAM (Pulse Amplitude Modulation) signal.

Channel encoding is the signal processing operation which is used to provide for the reliable transmission of digital information over the channel and as the title channel decoding is the reverse process of channel coding. There are many types of channel encoding technique, but in this work hamming code is used as channel encoding technique [7]. In parallel transmission there is some complexity. Because in that type of transmission inter symbol interference may occur between two parallel lines, for this purpose different carrier will be required for modulating different parallel lines. So, serial transmission is necessary through the channel [1].

In PCM, a signal sample 'm' is transmitted as a quantized sample 'm', causing a detector error $q = (m - m_q)$. Because of channel noise, the transmitted sample m_q is read as m_i, causing a detector error $\varepsilon = (m_q - m_i)$. Hence, the actual signal sample m is received as m_i with total error [1] [2].

$$m - m_i = (m - m_q) + (m_q - m_i) = q + \varepsilon \qquad (1)$$

Where both q and ε are the zero mean RVs, because the quantization error q and the channel-noise error ε are independent. Total noise power is equal to quantization noise power plus channel noise power [1] [2]

$$(m - m_i)^2 = q^2 + \varepsilon^2$$
$$= \frac{1}{3}\left(\frac{m_p}{L}\right)^2 + \frac{4m_p^2 p_\varepsilon * (2^{2n} - 1)}{3*2^{2n}} \qquad (2)$$

III. VIRTUAL ENVIRONMENT

An environment where real environmental system is developed virtually in Laboratory is known as (virtual environment) VI [8]. The particular ending item of this development is known as virtual instrumentation, since having its components and also activities the item commemorates an environment in the physical shape. The environment will serve for the progress of your comprehensive technique, being sure command from the total process of your calculated information variety, their analysis and also visual demonstration [9].

VI can be last merchandise and also a basic system regarding application in this development environment LabVIEW. Every VI may be used being an impartial application, or maybe in the form of new Subordinated virtual equipment, the particular so-called Sub VI, which may be realized by simply example as being a Subprogram inside text-oriented coding. Originator on the program can thus try to portion his/her application in individual parts, which is why he/she produces the actual Sub VIs. Through joining these personal Sub VIs at this time there presents the particular VI [10].

IV. DEVOLOPEMENT OF PULSE CODE MODULATION SYSTEM

In this work all blocks shown in Fig. 1 are individually implemented in LabVIEW as a Sub VI then all are combined to make complete digital communication system.
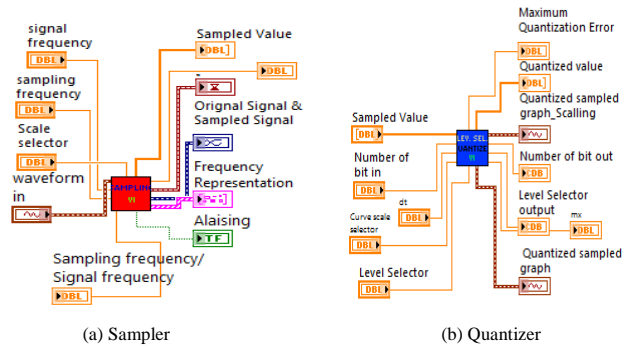

(a) Sampler   (b) Quantizer

Fig. 2 A Pictorial view of (a) "Sampler" and (b) Quantizer Sub VI.

Fig. 2(a) represents the simple block diagram of "Sampler" Sub VI and Fig. 2(b) represents "Quantizer" Sub VI with input and output Block. First block serves the Sampling operation of the pulse code modulation technique. The signal output of "Simulate signal" block which is a built in block of LabVIEW is inputted to the "Waveform in" input block of "Sampler Sub VI". Then it is needed that all sampled value is quantized to the nearest quantization level. Second block serves that purpose, according to the level of quantization selected.
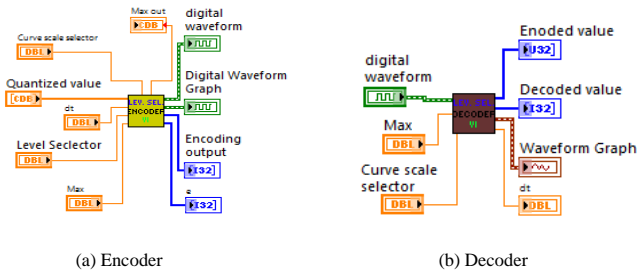
(a) Encoder   (b) Decoder

Fig. 3 A pictorial view of (a) "Encoder" and (b) "Decoder" Sub VI.

Fig. 3(a) represents the simple block diagram of "Encoder" Sub VI and Fig. 3(b) represents "Decoder" Sub VI with input and output block. By the first block all quantized sampled value are encoded according to the condition which is made in the math script node of LabVIEW and by the second block these encoded value are decoded in the receiver section.
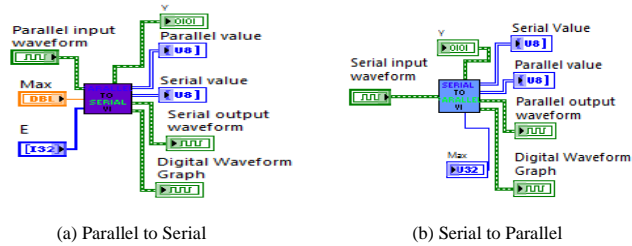

(a) Parallel to Serial   (b) Serial to Parallel

Fig. 4 A pictorial view of (a) "Parallel to Serial Converter" and (b) "Serial to Parallel Converter" Sub VI.

Fig. 4 represents the simple block diagram of "Parallel to Serial Converter" Sub VI and "Serial to Parallel Converter" Sub VI with input and output block. First block serves the

operation, according to the title. After the encoding section parallel output will be got. But serial output is needed to transmit through the single channel and this block serves that purpose. Second block are used to revers these serial data into parallel after receiving in the receiver section.
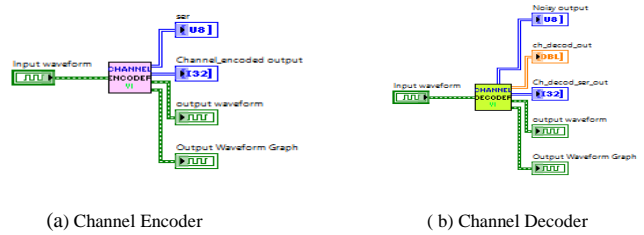

(a) Channel Encoder   (b) Channel Decoder

Fig. 5 A pictorial view of (a) "Channel Encoder" and (b) "Channel Decoder"

Fig. 5 represents the simple block diagrams of "Channel Encoder" Sub VI and "Channel Decoder" Sub VI with input and output block. For every four message bit, three Parity bit is mixed by the first block and by the second block bit error is detected and inverted to eliminate error in the demodulation and restoration part. After that task a Low Pass Filter (LPF) is used to cut off high frequency signal.

At first all elementary Sub VI block are implemented in LabVIEW by using MathScript Node. MathScript Node is the MATLAB like platform where line by line code can be implemented. But it consumes more time that"s why array function blocks are used to implement these elementary Sub VI. It takes lesser time than MathScript Node. It is less time consuming.
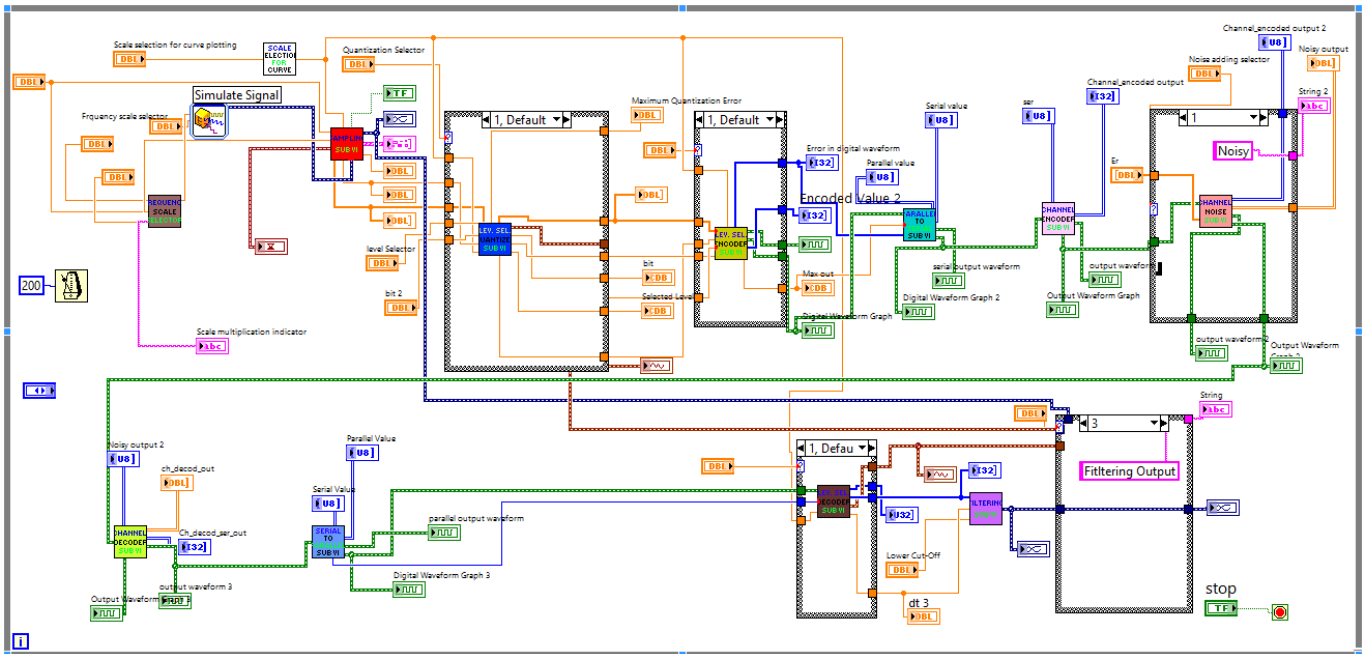

Fig. 6 Block diagram of PCM based complete digital communication system in LabVIEW
.

98

Fig. 6 represents the combinational block diagram of all block which are discussed in previous. This combination makes total PCM based communication system through the channel, which can detect the one bit error for every seven bit, these seven bit includes four message bit and three parity bit.

Previously discussed block Sampler, Quantizer, Enoder Sub VI are used to implement pulse code modulation Sub VI and Decoder, Filtering are used to implement pulse code demodulation Sub VI. Pulse code modulation Sub VI and Pulse code demodulation Sub VI can be used in different purpose such as implementing different type of multiplexing, de-multiplexing and so on.

V. SUB VI OUTPUT AND EXPLANATION

This section presents input controlling parameter and most of the Sub VI block's output with necessary explanation. At first three input parameter followed by sampling output, bit error and bit error removing process output, filtering output are presented one by one.
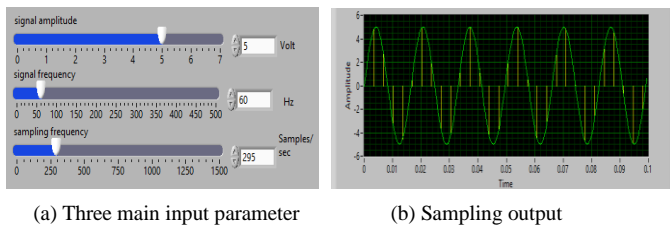

(a) Three main input parameter   (b) Sampling output

Fig. 7 (a) Three main input parameter of Sub VI "Sampler" and (b) Sampling output

Fig. 7(a) represents three main input parameter of Sub VI "Sampler". These are Signal frequency, Signal amplitude and sampling frequency. Output parameter of this module are aliasing indicator, original and sampled signal graph and it's frequency representation. Original and sampled signal graph are highlighted in Fig. 8 (b).

Previously discussed all Sub VI have a similar output window in where users or students can change the input parameter of those blocks and see the response of each block by output parameter. Here, only channel decoder output window is described in the following Figure.
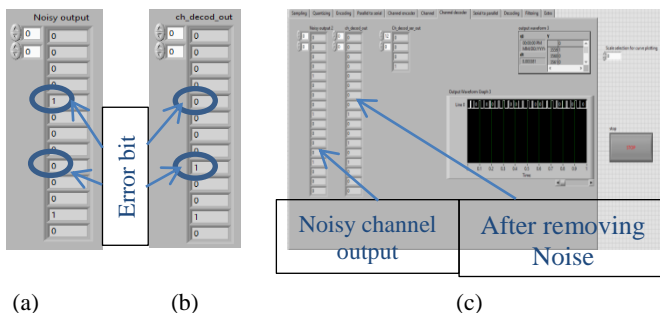

(a)   (b)   (c)

Fig. 8 a) Channel output bit pattern with bit error; b) After removing error and c) Sub VI "Channel Decoder" output.

Fig. 8 represents output window of "Channel Decoder" Sub VI, Received bit pattern before removing bit error and after removing bit error. Transmitted bit pattern at any instant is '00000000100100' and Received bit pattern with bit error is '00001000000100' as shown in Fig. 8(a). In the Received bit pattern it is clear that bit number 5, 9 are affected by the noise. Received bit pattern after removing bit error is shown in Fig. 8(b). Channel decoder detects these error bit and eliminates these error.
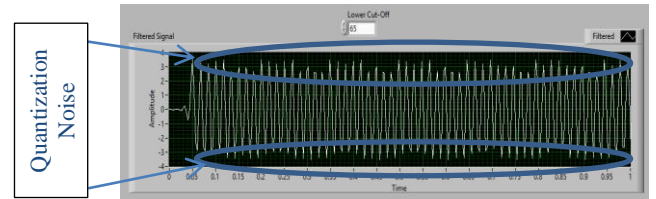

Fig. 9 Output of Sub VI "Filtering" (uniform quantization).

Fig. 9 represents the Sub VI "Filtering" output. It is the filtered output of the decoded signal. After this module operation message signal will be get but there exists some quantization noise. To reduce quantization noise in PCM system large quantization level or non-uniform quantizer are used in the quantization process. In this work uniform quantizer is used and quantization level is taken as 256. There exists some quantization noise too, but the output of this module is comparable with the input message signal.
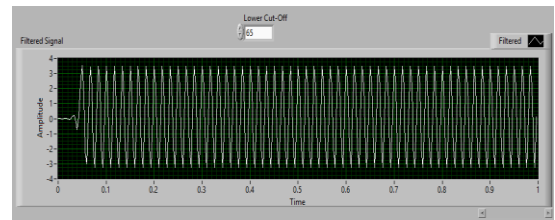

Fig. 10 Output of Sub VI "Filtering" (Non-uniform quantization)

Fig. 10 represents Sub VI "Filtering" output using Non-uniform quantization. From this figure it is cleared that quantization noise can be greatly reduced by using Non-uniform quantization.

VI. RESULT ANALYSIS

Fig. 11 to Fig. 13 shows the performance of the system in terms of SNR (Signal to Noise Ratio) for various parameters.

TABLE I: THE INPUT PARAMETERS.

Input	Value
Signal Amplitude	5V
Signal Frequency	60 Hz
Sampling Frequency	295 Sample/s
Cut off frequency	65 Hz
Quantization Level / Bit per sample	256 Level / 8 bit

Output	Value
Level difference	0.0390625 V
Maximum Quantization Error	0.0196078V
Bit per sample / Quantization Level	8 bit / 256 Level
Signaling Rate	8*295=2360
Signal power	2.153 dB
Quantization Noise power	-89.7009 dB
Channel Noise power	-80.0638 dB
SNR	78.9853 dB

Table I shows the input parameter of overall combination block diagram of the PCM system which is presented in the Fig. 6 and Table II shows the output parameter of that. In Table I and Table II "Quantization Level/Bit per sample" means that one of those will be used as input parameter and in that time other will be got as output parameter. The SNR variation of that system with respect to peak signal amplitude is shown graphically in the following graph.
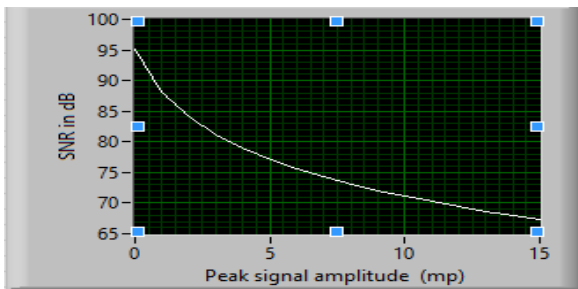

Fig. 11 SNR vs Peak signal amplitude

Fig. 11 represents the Variation of SNR in dB with respect of peak signal amplitude in Volt. SNR is inversely related to the peak signal level. It means that if quantization level L is fixed then SNR will be increased with the decreasing of peak signal level, similarly SNR will be increased with the increasing of peak signal level, in that case quantization level L is taken as 256. SNR will also be varied with respect to the variation of Quantization Level.
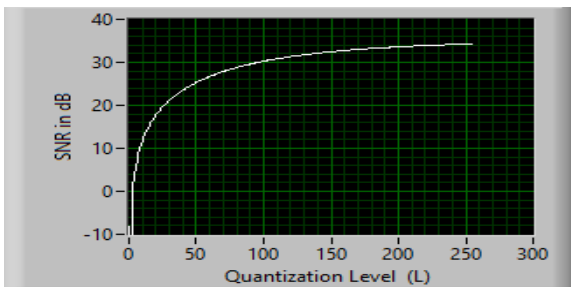

Fig. 12 SNR vs Quantization Level

Fig. 12 represents the variation of SNR with respect to Quantization Level where peak amplitude level and probability of error are taken as fixed. In that case peak amplitude level m_p is 5mv and error probability is 10E-6
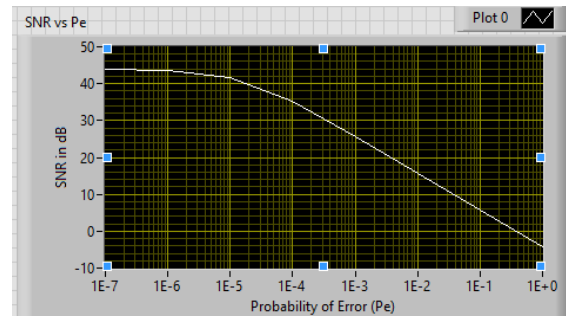

Fig. 13 SNR vs Error Probability (P_e)

Fig. 13 represents the Variation of SNR in dB with respect to the error probability where quantization level, peak amplitude level is taken as fixed. In that case quantization level is taken as 256 and peak amplitude level is taken as 5mV.

VII.   CONCLUTION

In this work, according the basic of PCM system, every block is implemented sequentially in LabVIEW. Input parameter can be changed from the front panel of the LabVIEW according to the user's requirement. Changing the parameters also varies the performance curves according to the theory. In this system large number of quantization level and non-uniform quantization process are implemented individually to see the change of quantization error. As every function of PCM system is included in a single panel, it will be very helpful for the researchers and students to understand the whole PCM system.

REFERENCES

[1]   B. P. Lathi, *Modern Digital and Analog Communication Systems* 3e Osece. Oxford university press, 1998.

[2]   S. S. Haykin, M. Moher, and T. Song, *An introduction to analog and digital communications* (Vol. 1). New York: Wiley, 1989.

[3]   L. Yitong, S. Lei, F. Lan and W. Jianwei, "A virtual telephone communication system based on LabVIEW". In 2010 *International Conference on Audio, Language and Image Processing*, 2010, pp. 950-954.

[4]   N. Ertugrul, "Towards virtual laboratories: a survey of LabVIEW-based teaching/learning tools and future trends". *International Journal of Engineering Education,* 16(3), 2000, pp. 171-180.

[5]   Z. Yi, J. Jian-Jun and F. Shao-Chun, "A LabVIEW-based, interactive virtual laboratory for electronic engineering education". *International Journal of Engineering Education*, 21(1), 2005, pp. 94-102.

[6]   R. Bitter, T. Mohiuddin, M. Nawrock. *LabVIEW Avanced Programming Techniques,* 2nd Eddition, Motorola, Taylor & France Group, 2007,

[7]   J. G. Proakis, M. Salehi, N. Zhou and X. Li, *Communication systems engineering* (Vol. 2). Englewood Cliffs: Prentice-hall, 1994.

[8]   National Instruments Corporation, *LabVIEW User Manual*, Austin, Texas 2003.

[9]   C. Elliott, V. Vijayakumar, W. Zink and R. Hansen, "National instruments LabVIEW: a programming environment for laboratory automation and measurement". *Journal of the Association for Laboratory Automation,* 12(1), 2007, pp. 17-24.

[10] S. Koprda, M. Turcani and Z. Balogh, "Modelling, simulation and monitoring the use of LabVIEW". *In Application of Information and Communication Technologies (AICT),* 6th International Conference (pp. 1-5). IEEE, Oct. 2012.