

# The Development of Instructional Tools for Analog and Digital Modulation in Communication Systems

Kanokwan Ruangsiri<sup>1</sup>, Pinit Nuangpirom<sup>2</sup> and Somsak Akatimagool<sup>3</sup>

<sup>1</sup>Chitralada Technology College,

<sup>2</sup>Rajamangala University of Technology Lanna,

<sup>3</sup>King Mongkut's University of Technology North Bangkok.

**Abstract-** This dissertation aims to develop the instructional tools for communication systems. The research tools were the content sheet, experiment set and simulation program. The performance of research tools was the expert's evaluation and the student's satisfaction. Samples were 20 students who registered in electronic circuits design courses of Chitralada technology college. The research results were as follows, the appropriation of developed instructional tools by 7 experts was high level and the satisfaction of the sampling group was high level. Therefore, the instructional tools can be applied and developed for learning in electronic and telecommunication engineering course and related.

## I. INTRODUCTION

Considering many courses in electronic engineering education, especially electronic circuit design subject has a difficult to learn because the nature of subject is usually taught informing an abstract concepts and the mathematical model which is hard to understand [1]. This problem has been found in many universities by lacking integration of modern instructional media [2-4].

For several years, few instructional tools were utilized in teaching to design and construct electronic circuits. Typically, an experiment set, an oscilloscope, and a signal generator were not enough and had expensive. Nowadays, educational simulation development is necessary to use in the engineering education [5] such as, IE3D, Sonnet, Computer Simulation Technology (CST) simulation tools, Pspice for circuit design and analysis in communication and electronic engineering courses [6]. However, most universities have insufficient educational tool, students will cannot to learn in complex contents to be easy and efficiently within a classroom. Thus, in this paper, the instructional tools in the teaching of analog and digital modulation in communication systems were developed.

## II. THEORIES

Analog modulation [7] is a process of varying one of the characteristics of high frequency sinusoidal (the carrier) in accordance with the instantaneous values of the modulating (the information) signal. The high frequency carrier signal is mathematically represented by the equation (1).

$$c(t) = A_c \cos(2\pi f_c t + \phi) \quad (1)$$

Where  $c(t)$  means instantaneous values of the cosine wave.

$A_c$  means its maximum value.

$f_c$  means carrier frequency.

$\phi$  means phase relation with respect to reference.

Any of the last three characteristics or parameters of the carrier can be varied by the modulating (message) signal, giving rise to amplitude, frequency or phase modulation respectively.

### A. Amplitude Modulation (AM)

The amplitude of the carrier signal in amplitude modulation is varied by the modulating/message/information/base-band signal, in accordance with the instantaneous values of the message signal. Similarly, the amplitude of the carrier is made proportional to the instantaneous values (amplitude) of the modulating signal. The peak amplitude of carrier after modulation at any instant is represent by the equation (2).

$$s(t) = [A_c + m(t)] \cos(2\pi f_c t + \phi) \quad (2)$$

$$s(t) = A_c [1 + k_a m(t)] \cos(2\pi f_c t + \phi) \quad (3)$$

Where  $k_a = 1/A_c$  is called amplitude sensitivity of the modulator and  $m(t)$ .

The equation (3) is the standard expression for amplitude modulated signal. Let  $m(t) = A_m \cos(2\pi f_m t)$  be the message signal of frequency  $f_m$  and peak amplitude  $A_m$ . Then single tone modulated signal is given by the equation (4).

$$s(t) = A_c [1 + k_a A_m \cos(2\pi f_m t)] \cos(2\pi f_c t + \phi)$$

$$s(t) = A_c [1 + (A_m / A_c) \cos(2\pi f_m t)] \cos(2\pi f_c t + \phi)$$

$$s(t) = A_c [1 + m \cos(2\pi f_m t)] \cos(2\pi f_c t + \phi) \quad (4)$$

Where  $m = A_m / A_c$  is modulation index.

### B. Frequency Modulation (FM)

Frequency modulation is a variation of angle modulation where instead of phase, we change the frequency of the carrier in response to the message signal. Vary the frequency by adding a time varying component to the carrier frequency.

$$f(t) = f_c + k_f m(t) \quad (5)$$

Where  $f_c$  is the frequency of the carrier signal, and  $k_f$  a scaling factor, and  $m(t)$ , the message signal. The term  $k_f$  and  $m(t)$  can called a deviation from the carrier frequency. The frequency modulated signal is given by the equation (6)

$$s(t) = A \cos(2\pi[f_c + k_f m(t)]t). \quad (6)$$

### C. Phase Modulation (PM)

Phase modulation is widely used for transmitting radio waves and is an integral part of many digital transmission coding schemes that underlie a wide range of technologies like WiFi, GSM and satellite television.

Phase modulation changes the phase angle of the complex envelope in direct proportion to the message signal. Suppose that the signal to be sent is  $m(t)$  and the carrier onto which the signal is to be modulated is

$$c(t) = A \cos(2\pi f_c t + \phi(t)). \quad (7)$$

We can phase modulate this carrier by changing the phase in response to the message signal.

$$\phi_i(t) = k_p m(t)$$

Now we can write the equation for the carrier with a changing phase as

$$s(t) = A_c \cos(2\pi f_c t + k_p m(t)). \quad (8)$$

The factor  $k_p$  is called the phase sensitivity factor or the modulation index of the message signal.

## III. RESEARCH METHODOLOGY

The research process consisted of analyzing the course curriculum of electronics circuit design subject, to determine the topic of teaching content, and to define the behavioral objectives that provides a framework for the teaching [1]-[3]. However, presently the most instructional set in the classroom, has various problems, such as limitation of use, not cover the theory, teaching aids not sufficient and not diverse, ect. Thus, in this research, we develop the research tools by analyzing the behavioral objectives that consist of the content sheets, simulation program using GUI function of MATLAB, experimental set, PPT presentation and tests. The detail of research tools is below.

### A. Simulation program development

The process of designing a simulation program is shown in Figure 1. We can select the desired circuits or modulating type. Next, the initial calculating values are set up. The program will calculated and processed according to various modulating types and will show the modulating results.

The simulation tool development using the graphical user interface (GUI) function of MATLAB software is illustrated in Figure 2. The developed program can simulate both analog and digital modulation systems, as amplitude modulation, frequency modulation, phase modulation, amplitude-shift keying, frequency-shift keying, phase-shift keying, pulse width modulation and pulse amplitude modulation.

### B. Experimental set of communications systems

The experimental sets of communication system were developed using defined behavioral objectives. These consist of amplitude modulation, frequency modulation, phase modulation, amplitude-shift keying, frequency-shift keying, phase-shift keying, pulse width modulation and pulse amplitude modulation, as shown in Figure 3.

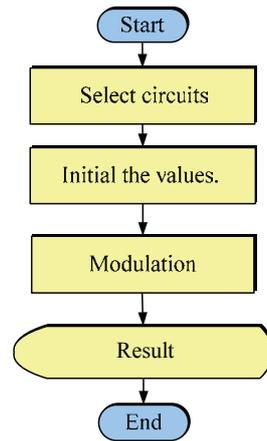


Figure 1. Flowchart of simulation tool

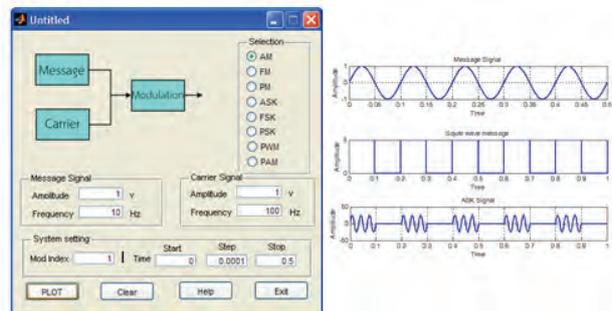


Figure 2. The modulating simulation tool



Figure 3. The developed experimental set

#### IV. RESEARCH RESULTS

The research has been presented in four sections: 1) the results of simulation program, 2) the results of experimental set, 3) the quality of instructional tools by expert's evaluation, and 4) the student's satisfaction.

##### A. The simulated results of program tool

The simulation tool can be analyzed in 8 circuits, including Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), Amplitude-shift keying (ASK), Frequency-shift keying (FSK), Phase-shift keying (PSK), Pulse Width Modulation (PWM) and Pulse Amplitude Modulation (PAM). In this research, we present the example for amplitude modulation, as shown in Figure 4.

Figure 4 presents a diagram of amplitude modulation that define the peak amplitude of message signal is 5 V and the frequency of message signal is 100 Hz. For the carrier signal, we set the peak amplitude is 5 V and frequency is 1 kHz. The results of simulation tool were shown in Figure 5.

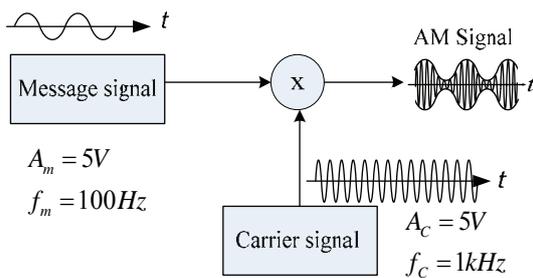


Figure 4. Diagram of amplitude modulation

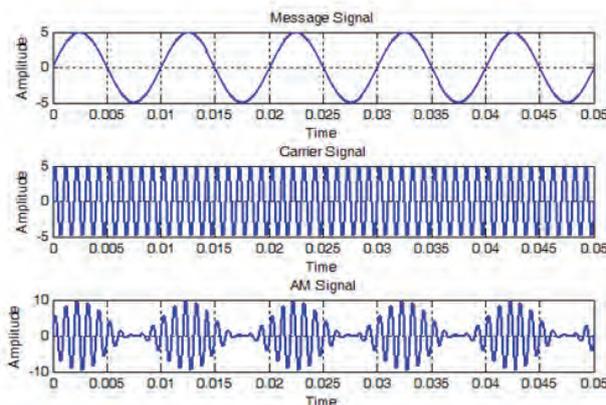


Figure 5. The result of AM using developed simulation tool

Figure 5 presents the result of amplitude modulation, we observed that the amplitude of carrier signal varies depending on the message signal. The analyzed result is consistent with the properties of amplitude modulation [7].

##### B. The results of experimental set

The experimental set consists of 8 sets, such as AM, FM, PM, ASK, FSK, PSK, PAM and PWM and we present an example of pulse width modulation (PWM). The developed experimental set includes the pulse width modulation and demodulation set, DC Power supply, function generator and oscilloscope as shown in Figure 6.

Figure 7 present the results of PWM experimental set, we can control the width of pulse by adjust the referent voltage. The analyzed results are consistent with theory [7].

##### C. The quality of instructional tools

The developed instructional tools for teaching in electronics circuit design course were evaluated by 7 experts whom have experience in the teaching on electronic engineering. The findings related to the simulation tool topic had a mean value of 4.47, and S.D. equal to 0.35, thus the quality of simulation tool was more appropriate. The quality of the experimental set found that the mean value is 4.36, and S.D. is 0.34, thus the quality of experimental set was more appropriate. The quality of the developed instructional tools had mean value of 4.41 and S.D. equal to 0.27, the quality of developed instructional tools was more appropriate, as shown in table 1.

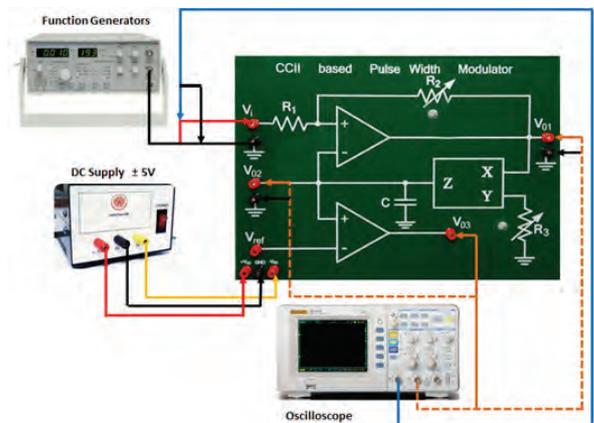


Figure 6. The Pulse Width Modulation (PWM) testing

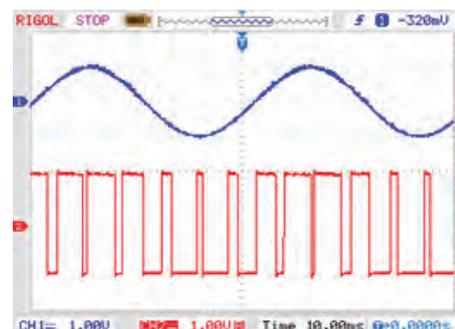


Figure 7. The measured results of PWM.

**TABLE I.** The results of the quality of instructional tools by 7 experts

List	$\bar{X}$	S.D.
<b>1. Simulation tool</b>		
1.1 Appropriate for students	4.56	0.73
1.2 Accurate results	4.44	0.73
1.3 Easy to use	4.22	0.67
1.4 Appropriate for content and purpose	4.44	0.53
1.5 Encourage student to learn	4.67	0.50
Average	4.47	0.35
<b>2. Experimental set</b>		
2.1 Appropriate for students	4.22	0.67
2.2 Accurate results	4.44	0.53
2.3 Easy to use	4.33	0.71
2.4 Appropriate for content and purpose	4.11	0.60
2.5 Encourage student to learn	4.67	0.50
Average	4.36	0.34
<b>Total</b>	<b>4.41</b>	<b>0.27</b>

**TABLE II.** The students' satisfaction of usage of developed instructional tools

List	$\bar{X}$	S.D.
<b>1. Simulation tool</b>		
1.1 Appropriate for students	4.24	0.66
1.2 Accurate results	4.40	0.50
1.3 Easy to use	4.40	0.58
1.4 Appropriate for content and purpose	4.40	0.65
1.5 Encourage student to learning	4.48	0.51
Average	4.38	0.32
<b>2. Experimental set</b>		
2.1 Appropriate for students	4.08	0.64
2.2 Accurate results	4.36	0.57
2.3 Easy to use	4.28	0.68
2.4 Appropriate for content and purpose	4.00	0.76
2.5 Encourage student to learning	4.44	0.58
Average	4.23	0.33
<b>Total</b>	<b>4.31</b>	<b>0.28</b>

#### D The student's satisfaction

The developed instructional tools was experimented by using 20 students who registered in electronics circuit design course at Chitralada technology college, as shown in Figure 8. The sample group was taught by using the developed instructional tools in electronic circuit design subject. After learning all lessons, we measured students' satisfaction of usage of developed instructional tools using questionnaire.



Figure 8. The experiment of instructional package

The findings after learning and teaching using the developed instructional tools are that the students have more knowledge and understanding of the course contents. Also the satisfaction of the students to developed instructional tools had mean value of 4.31 and S.D. equal to 0.28, as shown in table 2. Thus the developed instructional package has good quality to use in the teaching of electronic engineering of bachelor degree.

#### V. CONCLUSIONS

This research has been presented the development of the instructional tools for analog and digital modulation in communication systems of electronic circuit design subject which consists of simulation program and experiment set. The conclusion of the findings is as following.

1) The developed simulation tool using the graphical user interface (GUI) function of MATLAB software, is able to analyze modulation in communication systems correctly and consistent with the theory.

2) The developed experimental set can be used efficiently in the teaching of electronic circuit design subject. The measured results are correctly and consistent with the theory.

Overall the developed instructional tools were evaluated for efficiency of learning usage to accord engineering standard, therefore they may be used both theoretical and practical teaching.

#### VI. REFERENCES

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