

Development of a simulation program for Smith chart education

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Abstract

The research in this paper describes the development of simulation program for Smith chart education which was designed to be as an instructional media in telecommunication engineering course. The simulation that was developed is based on the GUI-MATLAB program. It consists of a GUI (Graphical User Interface) input parameter window, a calculating menu, and a graphical display window for use of Smith chart in transmission line. The performance of the simulation that was developed was evaluated by 5 experts. They found it to be at appropriated level for the students it was aimed at (mean equaled to 4.21 and S.D. equaled to 0.08). After implementing use of the simulation software in classroom at department of teacher training in electrical engineering, faculty of technical education, King Mongkut's University of Technology North Bangkok, the students' satisfaction to towards using the simulation as assessed. It was found to be at a high level giving an average result of 4.18 of the maximum 5 points. The simulation program was found to have an efficiency equal to 1.02 which is in agreement with the standard criteria of Meguigans's formula [8]. In conclusion, the simulation can be used appropriately in the teaching of transmission line course. Moreover, as well as meeting its teaching aims it helps the learner to develop wider learning skills such as understanding and analyzing.

Keywords: GUI-MATLAB, simulation program, Smith chart

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1. Introduction

In the era of Education 4.0, the management of Thai education institutions are becoming increasingly focused on producing graduates who are able to create innovation. Thus, 21st century skills are essential to learning and teaching in universities as well as in real life. According to the Bloom's taxonomy of learning theory, in the field of Engineering, the skills that are required by learners are analyzing, applying, evaluating and creating [1] according to. Moreover, STEM education that was initiated when there was a shortage of engineers and scientists in the United States, is a guide line that can be used to develop knowledge, skills and attitudes in Thailand using integrated Science, Technology, Engineering and Mathematics. [2] Thus, in the managing of STEM teaching at each education level, the instructional model and teaching media must be appropriate for the students to gain performance when learning.

Several recent studies have proposed that active learning can be successfully implemented in higher

education [3–5]. These studies show that skills can be developed in projects, problem solving, and research. Various learning activities will be used in teaching within classroom using modern technological teaching aids such as simulation program, demonstration and experimental set to promote and support students to have the achieve their highest learning potential. The development of simulation program must be consistent with users' requirements. It must transfer knowledge to users correctly, must not have limitations of use and the operating structure must be understood easily.

This paper presents, the development instructional media the teaching and learning of telecommunication engineering by developed the using GUI (Graphic User Interface) function of the MATLAB program. In order to encourage new learning skills of students, establish motivate in learning, manage various activity and learners will be able have enthusiastic affects to higher academic achievement.

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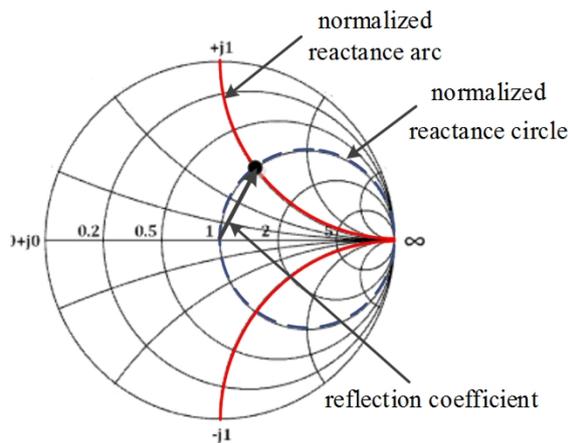


Figure 1: Smith chart.

2. Purpose of The Research

1. To develop an instructional media for Smith Chart education.
2. To evaluate the efficiency of the instructional media that was developed for Smith Chart education.
3. To evaluate the students' satisfaction towards using the instruction media.

3. Theory

3.1. Smith chart

The calculations for transmission line circuits, can be complex, and difficult to solve the various solutions. A Smith chart is a graphical tool that is a circular plot. When used correctly, matching impedances, with complicated structures, can be done without any computation. The only effort required is the reading and following of values along the circles. The Smith chart is a polar plot of the complex reflection coefficients and impedance or admittance of transmission line circuits. [6]

A Smith chart is developed by examining the load where the impedance must be matched. Instead of considering its impedance directly, the reflection coefficient that is used to characterize a load such as admittance, gain, and trans-conductance, will be presented. The advantages of Smith chart in transmission line education are that they remove the need for difficulty calculations and learners can understand the contents quickly. The component of the smith chart are: a normalized reactance arc that is show imaginary values, the normalized reactance circle which is shown in real values and the vector of the reflection coefficient which is expressed in magnitude and angle form on a polar diagram. An example Smith Chart is show in Figure 1.

The expression of the impedance and admittance terminology can be written as,

$$\text{Impedance } (Z) = \text{Resistance } (R) + j \text{ Reactance } (jX)$$

Admittance $(Y) = \text{Conductance } (G) + j \text{ Susceptance } (jB)$

The equation of normalized impedance (z_L) is shown as follows,

$$z_L = \frac{Z_L}{Z_0} = \frac{R}{Z_0} + j \frac{X}{Z_0} = r + jX \quad (1)$$

The equation of reflection coefficient at load, (Γ_L) can be written as,

$$\Gamma_L = \frac{z_L - 1}{z_L + 1} = |\Gamma_L| e^{+j\theta} \quad (2)$$

3.2. The MATLAB program

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. Although MATLAB is intended primarily for numerical computing, an optional toolbox, Simulink [7], GUI (Graphical User Interfaces) that is a component of the MATLAB program that helps the instructor and learner to design a graphical structure and create innovation easy to use contents. This is especially useful for mathematical simulation program which can be complicated and easy to make error when calculating. The MATLAB program is suitable for people who want to develop and solve complex mathematical problems.

A GUI simulation covering the user's objectives was constructed by using GUI function and m-file coding from the MATLAB software. The user interface includes controls that use GUI function. These as shown in figure 2 and consist of push buttons, radio buttons, edit text, static text, and graphical windows. In this paper, the simulation program that supports the use of Smith chart when calculating transmission line is presented. It consists of 3 main parts including 1) menu part, 2) processing part, and 3) graphical display part.

4. Research Methodology

The process of research methodology, as shown in Figure 3 are as follows,

1. The first task was to analyze the course curriculum of communication networks and transmission lines in Bachelor of Science in technical education, program in electrical engineering at King Mongkut's University of Technology North Bangkok. The course topics consisted of basic high-frequency transmission lines, equations of transmission lines and standing waves, Smith chart and applications and microstrip lines and applications.

2. The next task was to determine the behavioral objectives of selected course content that supports a

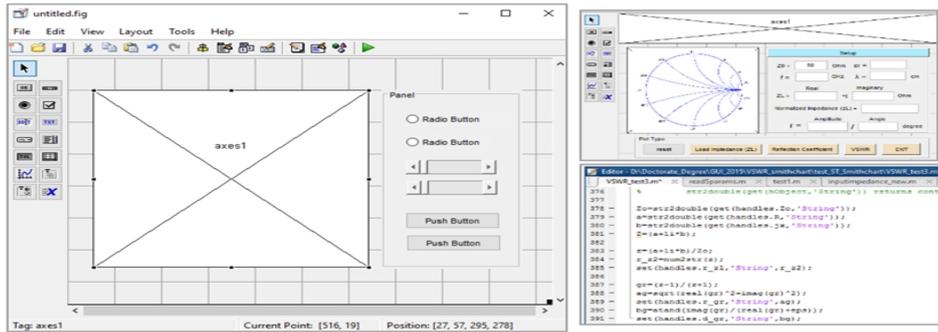


Figure 2: The developed GUI simulation.

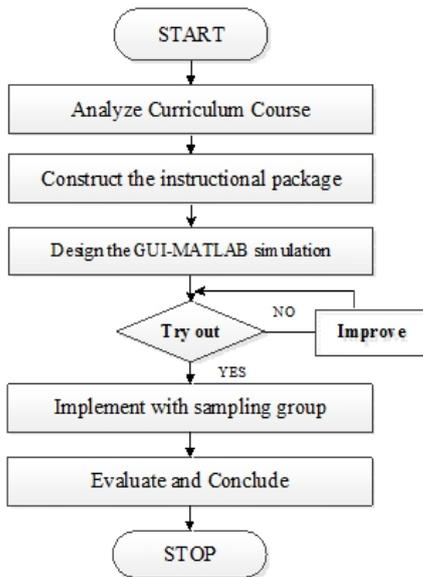


Figure 3: Process of research methodology.

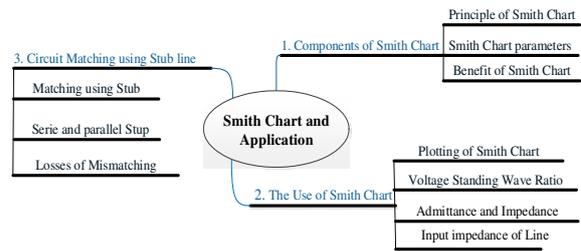


Figure 4: The coral pattern of smith chart.

framework in learning and teaching in the topic of Smith chart and application, as shown in Figure 4.

3. Following this the research instruments were developed which included the development of a GUI simulation program, PowerPoint presentation, achievement test and the questionnaire with a 5-level scale of likert technique, as shown in Figure 5.

4. Next the population and sample were defined. The population used in this research, was bachelor students who are in the electrical engineering program at the Faculty of Technical Education at King Mongkut’s University of Technology North Bangkok, King Mongkut’s Institute of Technology Ladkrabang and Rajamangala University of Technology. The sampling group was 20 bachelor students who studied in electrical engineering major in semester of 2/2016 at King Mongkut’s University of Technology North Bangkok.

5. Finally, in order to accumulate and analyze research data, the research data was collected. It was analyzed for mean value, standard deviation and per-

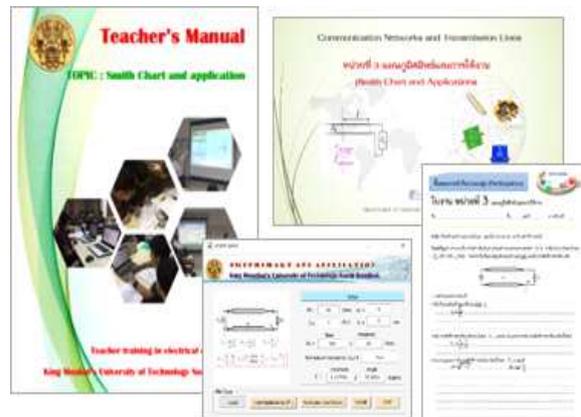


Figure 5: The research instruments for smith chart education.

centage. Data was collected using the questionnaire, qualitative data and interview.

5. The simulation Program Design

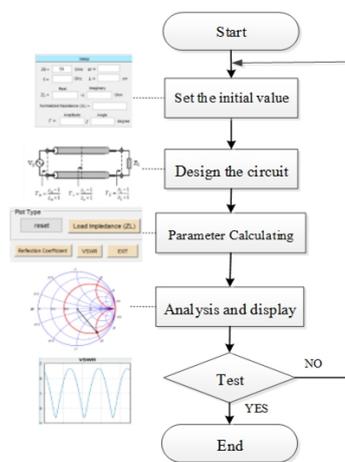
The process that was used to designing a GUI simulation to be used with a Smith chart and applied to teach the principle of telecommunication systems now follows. The MATLAB based simulation program consists of 3 parts: 1) the initial parameter setup window which inputs parameter values such as frequency, relative permeability, wavelength, characteristic impedance and load impedance, 2) the calculat-

Table 1. The results of the quality evaluation from the simulation program (N = 5)

Evaluated topics	Mean.	S.D.	Interpret
1. Design of simulation program	4.12	0.18	high
2. Accuracy of simulation program	4.16	0.26	high
3. Ease to use	4.44	0.09	high
4. Relevance of content and design	4.12	0.18	high
5. Likelihood that simulation will encourage student to understand knowledge	4.20	0.32	high
Overall score	4.21	0.08	high

Table 2. The efficiency of simulation program (N = 20, level of significance is 0.05)

Test	t-test for equality of Means					Meguigans's theory
	Mean	S.D	df	t	P	
Pre-test	3.05	1.15	19	12.17	0.000	1.02
Post-test	12.45	2.98				

**Figure 6:** The developed simulation program.

ing menus which support the analysis of transmission line parameters such as normalized impedance or admittance and reflection coefficient and 3) the graphical display window which shows the results from the calculations such as impedance or admittance, reflection coefficient, VSWR and matching ratio of transmission line circuit. The process of development is illustrated in Figure 6 and the resulting simulation window is shown in Figure 7.

6. Implementation and Research Results

The implementation of this simulation program with a sampling group is shown in Figure 8. The teaching process was as follows; first the teaching plan was explained. Next, the basic knowledge of the students was evaluated using the pretest. Following this the course content was provided based on the STEM education using the instructional package such as content sheets. The next stage was for the students to work with the GUI simulation program and to be shown the

associated PowerPoint presentations. After finishing all of the lessons, the students took an achievement test to assess how much they had learnt.

The results of the research presented in 4 sections as follows 1) the simulation program that was developed 2) an evaluation of the quality of the design of the simulation program, 3) the efficiency of simulation program and 4) the student's satisfaction with the simulation. The findings were as follows,

6.1. The GUI simulation tool

The simulated results were similar to the theoretical results that were calculated. It was found that the calculated values agreed with the transmission and line theories. It was therefore concluded that the GUI simulation program that was developed could be used efficiently and correctly as a teaching aid. An example of the transmission line calculation is show in Figure 8. For this example the characteristic impedance (Z_0) equaled 50 ohm and the load impedance (Z_L) equaled to $100 + j50$ ohm. The GUI simulation program that was developed is able to can analyze the impedance, admittance, reflection coefficient and voltage standing wave ratio (VSWR) of transmission line circuits and more.

6.2. The evaluation of the quality of the simulation program that was developed

The GUI-MATLAB based simulation program was evaluated by 5 experts who have experience in the teaching of telecommunication engineering or related subjects. The topics that were evaluated included the design of the simulation program, the accuracy of the simulation program, its ease of use, the content relevance and design, and how likely it was to encourage student understanding of knowledge of the subject. In Table 2, it was found that quality evaluation of the simulation program had the mean appropriate level equaled 4.21 from a maximum of 5 points, and S.D. equaled 0.08. The developed GUI-MATLAB program

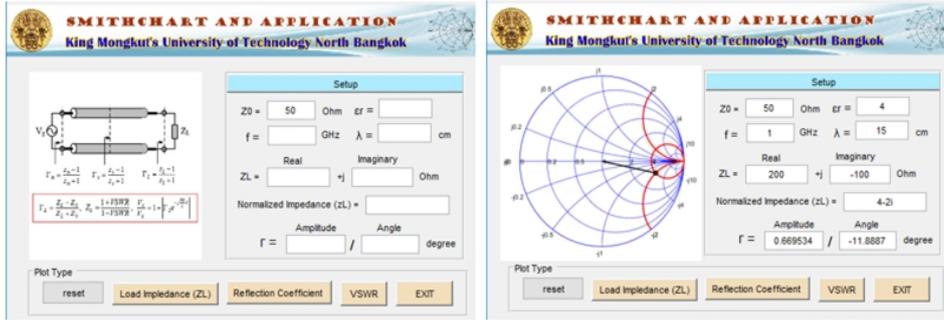


Figure 7: Simulation program for smith chart education.

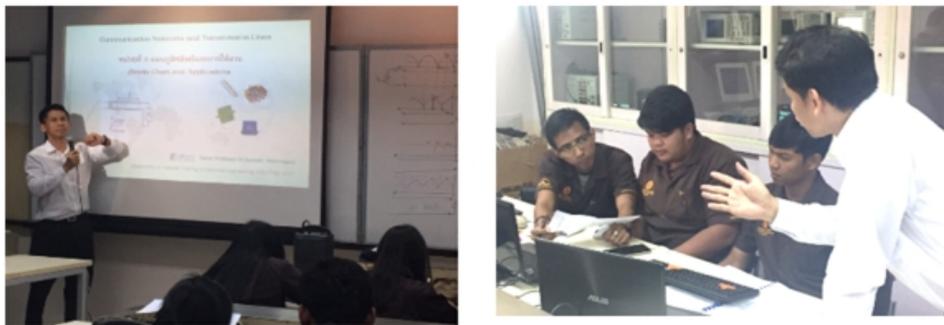


Figure 8: The teaching and learning in a classroom.

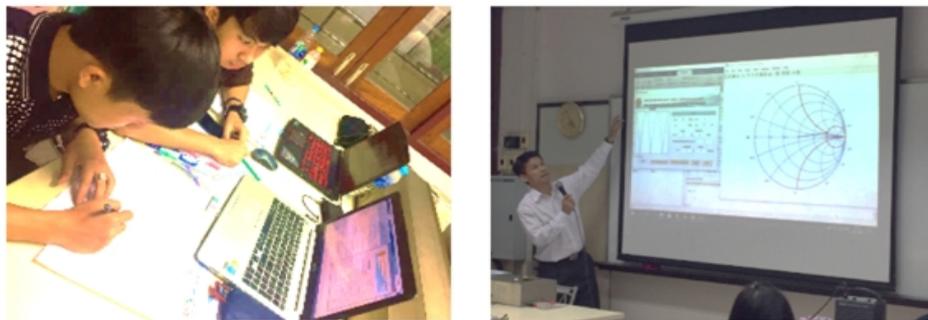


Figure 9: The learning and teaching activities.

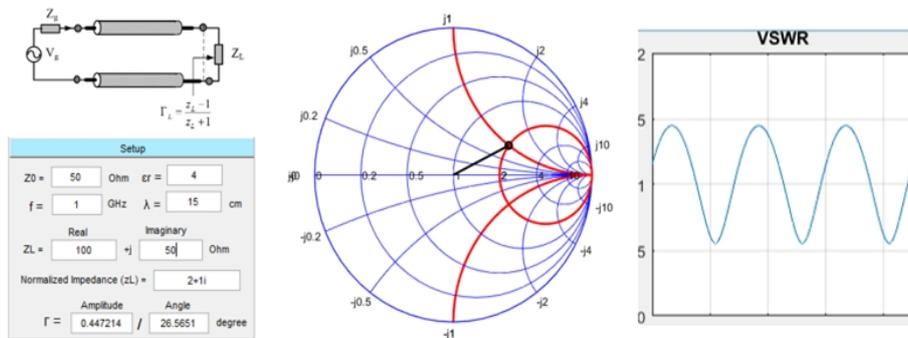


Figure 10: Results of a Smith chart simulation.



Figure 11: Implementation with the sampling group.

Table 3. The students' satisfaction results of the simulation program (N=20)

Evaluated topics	Mean.	S.D.	Interpret
1. Design of simulation program	4.20	0.37	high
2. Accurate simulation results	4.17	0.44	high
3. Ease of use	4.21	0.32	high
4. Relevance of content and purpose	4.18	0.43	high
5. Encourage students to learn	4.15	0.17	high
Overall score	4.18	0.27	high

was highly appropriate (mean equaled 4.44 and S.D. equaled 0.09).

6.3. Evaluation of the results of efficiency from the simulation program

The simulation program that was developed was tried out by a sampling group of 20 bachelor degree students registered in the transmission line course, faculty of technical education at King Mongkut's University of Technology North Bangkok (KMUTNB). For learning and teaching activities, the students were given a pretest before participating in the Smith chart lesson. Following this the GUI-MATLAB based simulation program was implemented as shown in Figure 11. The learning outcomes were evaluated using a student posttest after finishing the lesson.

The data that was collected was analyzed to validate the efficiency of simulation program using Meguigans's theory. Table 3 shows the mean standard deviations and t-test value from this analysis. It was found that the mean scores of the post lesson test (mean equaled 12.45) in the teaching of Smith chart was higher than the pre lesson test score (mean equaled 3.05). It was also found that the simulation program was an efficient tool according to the standard critical of Meguigans's formula (more than 1.0) [8]. The learning achievement comparison between the pre lesson test and post lesson test found that it was statistically different at the .05 level.

It can therefore be concluded that the GUI-MATLAB simulation program that was developed can be used effectively in the learning and teaching of telecommunication engineering courses.

6.4. Student satisfaction

The GUI-MATLAB based simulation program was with 20 students who were registered in the transmission line course, at the faculty of technical education at King Mongkut's University of Technology North Bangkok (KMUTNB). The sampling group was taught using the simulation program. After participating in all lessons, the students' satisfaction was evaluated using a 5-scale rating system with questionnaires [9]. The results of this can be seen in Table 4.

The topics that were evaluated in the questionnaire can be seen in Table 4. It was found that the student satisfaction was at a high level with a low standard deviation (mean value equaled to 4.18 and S.D. equaled to 0.27). In summary, the students reported that the GUI-MATLAB program was easy to use for learning the Smith chart and its applications.

7. Conclusions

This research has presented the development of a MATLAB simulation program with a Smith chart for learning and teaching of telecommunication engineering. The simulation was able to present the parameters of transmission line circuits such as, impedance, admittance, reflection coefficient and voltage standing wave ratio (VSWR) in a clear and easy to understand way.

The simulation program that was developed was found to be efficient and consistent with theory. An evaluation of students' satisfaction when using the simulation program was carried out. It found that they

were satisfied with it. The efficiency of the simulation program as a teaching aid was found to be within the standard criteria of Meguigans's formula (equal to 1.02), this was consistent with research results of W. Weerasin [10]. In conclusion, the simulation program that was developed can be used as instructional media to help students to learn theoretical and practical skills which will be useful for their careers as Engineers.

8. Suggestions for Research

Suggestions for further research are to develop a novel learning model based on STEM education and an instructional package with various teaching activities using several teaching aids according to different competences of learners. In addition to this the simulation program for the Smith chart education that has been developed should be evaluated using various sampling groups and universities to further evaluate its effectiveness.

In order to develop the learning model, researchers should focus on student centered learning and active learning, such as project based learning, problem based learning and research based learning.

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