Teaching Frequency Modulation to Undergraduate Electrical and Electronics Engineering Students Using MATLAB/SIMULINK

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***Abstract*— Teaching scientific concepts to undergraduate students is quite difficult sometimes especially when lots of mathematical terms are involved in the teaching process. Frequency modulation is one of these concepts. With the aid of MATLAB/SIMULINK toolbox it becomes much easier to realize this concept (FM Modulation) whether in time domain or in frequency domain. In doing so, the students will grasp the concept of Frequency Modulation faster and easier. The present paper tackles the task of explaining the FM modulation concept in a simple and straightforward way. That is done by using MATLAB/SIMULINK tool box in both possible domains: time domain and frequency domain. The simulation results obtained by such simple system is validated by a counterpart experimental investigation. Quite satisfactory agreements are reached when comparing the simulation results with that of practical counterpart.**

Key world: Education, Engineering, Frequency Modulation, MATLAB/SIMULINK

I. INTRODUCTION

All modulations whether 'Amplitude', 'Frequency' or 'Phase' (AM, FM or PM) are 'analog' but can be made 'discrete' for digital modulation systems. In fact FM & PM are the same, because phase is the time integral of frequency. Any ' discretization ' adds very high frequency components needing higher band-widths but in data transmission systems where the criterion is presence or absence of a 'pulse' this can be avoided and large distortions (due to limited band-width) can be tolerated.

In simple AM at least half the power is concentrated in the 'Carrier' that has no information in it, leaving less than half in the 'information bearing' side bands. In FM by suitable choice of 'modulation index' one can achieve Carrier power of 'zero putting all information power in side band pairs [1]. To achieve improved understanding to FM modulation, the MATLAB is utilized in this regard. MATLAB is a computational software which provides the easiest and quickest solution to scientific and technical problems. SIMULINK is an additional part of MATLAB to model, simulate, and analyze many dynamic systems but cannot operate separately [2]. Yet, an efficient and effective method for teaching analog and digital modulation to undergraduate students and to minimize, to a great extent, mathematical terms SIMULINK was utilized [3]. A software package which is designed using MATLAB's Graphical User Interface (GUI) was used to model some form of modulation called "Chaos-Based Digital Communication System Simulation Package (CDCSSP)" demonstrates how successful it is in terms of enhancing student learning [4]. In addition, to make the students better understand some complex circuits MATLAB /SIMULINK was used in different courses dealing with circuits and systems for wireless telecom applications. It shows well appreciation by majority of students involved [5]. For instance, Gohokar [6] has developed a SIMULINK models for ASK, FSK, and PSK modulators where the user can easily change the parameters and immediately see the results. Moreover, Individuals can teach themselves communications in a more easy manner, they can use MATLAB and SIMULINK as a platform for testing and verifying their ideas [7] . However, a comparison between real laboratories and simulation ones is still a debatable issue. In their findings Krishnan and Woods [8] argue that practical laboratory and simulation laboratory exercises do not compete against each other, but rather support and complement each other. Increasingly, virtual laboratories is fast becoming reality nowadays. Admittedly some in depth attempts in teaching FM have been done by researchers [9] [10]. For instance, a web-based laboratory [9] to conduct a frequency modulation experiments for students taking communication principles course was developed in the National University of Singapore(NUS), It provides a solution for distance learning. Another virtual lab was developed to be used to teach communication for a post-graduate students using GUI software packages to address several topics in audio, image, and video compression [10]. In addition, an inverting

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classroom can play an important role in contemporary engineering education by imposing learner or student-centered activities and giving them the opportunity to become independent learners [11].

In summary, MATLAB/SIMULINK can be utilized in the following:

1. To ease and simplify many engineering concepts. FM Modulation is one of them.
2. To make distance learning possible even for engineering fields where the practical is crucial in such specialization.
3. Virtual Laboratories in communication give as good result as the practical with lesser effort.

The merits or goals that are targeted behind the work reported in the present paper is to use MATLAB/ SIMULINK to provide better understanding in teaching frequency modulation to undergraduate students.

II.Problem Statement

This study is dedicated to answer the following research question: How can someone (lecturer) explain the Frequency Modulation concept to the electrical and electronics engineering undergraduate students using MATLAB/SIMULINK?

It is quite difficult for the students to realize FM Modulation concept theoretically unless there is a tool to make it easy. With the aid of MATLAB/ SIMULINK tool, the lecturer can display the Bessel functions for different values of Beta (β) (modulation index). In other word, if Beta changed it will eventually lead to a change in the number of Bessel functions, the level of the Bessel functions (sidebands), and the direction. However, the direction is hard to be seen in the power spectral density because the magnitude is taking only the absolute values of the Bessel functions. That's why negation is impossible.

Hence, the core subject of this paper is to demonstrate in an understandable way the concept of Frequency Modulation (FM). SIMULINK is a good tool to achieve this concept very clearly. Most of the previous work emphasized on time domain in relation to increasing the modulation index (β), however, the frequency domain plot is equivalently important as well, if not more. The previous work addressed the discrete functions rather than continuous functions unlike this paper which consider the continuous functions for both time domain and frequency domain plots. Moreover, the simplicity of this realization makes it easy for the lecturer to show the students everything related to FM Modulation using desktop/laptop facility containing MATLAB/SIMU-LINK software installed.

III.Idea Approach

Angle modulation is resulted by changing the phase(ϕ) or (ωt) of equation**Error! Reference source not found.** below**Error! Reference source not found.**:

[12] $$s(t) = A\cos\ (\omega t + \phi) \qquad (1)$$

where either the angle ϕ or the angle ωt is varied. If ϕ is varied by the information signal, the result is called Phase Modulation. But if ϕ is kept constant and ωt is varied by the information signal to deviate the carrier frequency, the result is called FM Modulation [12].

The form of angle modulation known as frequency modulation [13] is written as in equation(2) below:**Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.**

[13] $$S_{FM}(t) = Ec * \cos(\omega_c t + k_f \int_0^t m(\tau)d\tau) \qquad (2)$$

Frequency Modulation formula can be expressed by a function (fcn) block as shown in

Fig-1: FM Modulation Using SIMULINK. Any input will be given the name (u) and if more than one input as the case of **Fig-1** will be given the names u(1), u(2), … u(n) successively. Hence the clock (t) will be u(1) and the modulation index Beta (β) will be u(2) and so on.

Assuming the modulating frequency or the inform-ation signal is represented by a sinusoidal function then the formula(3) is FM modulation formula to be used in the simulation.

$$s_{FM} = Ec\cos(2 * pi * 25000 * t + \beta * \cos(2 * pi * 2000 * t)) \qquad (3)$$

Where $\beta = \frac{\Delta fc}{fm}$, and $\Delta fc = ko.Em$. Where ko is the modulator sensitivity and Em is the modulating amplitude Therefore $\beta = \frac{ko.Em}{fm}$. Note β represents the FM modulation index.

The carrier frequency (fc) is chosen arbitrarily to be fc=25k Hz, and the modulating frequency (fm) or information signal is set to (fi)=2kHz.

Fig-1: FM Modulation Using SIMULINK

Beta(β) needs to be changed each time to increase the frequency deviation and observe the waveforms in both time domain and frequency domain. The bandwidth is directly proportional with β. When β=5.53, the time domain plot and frequency domain plot are shown in

Fig .2 and Fig-3 respectively.

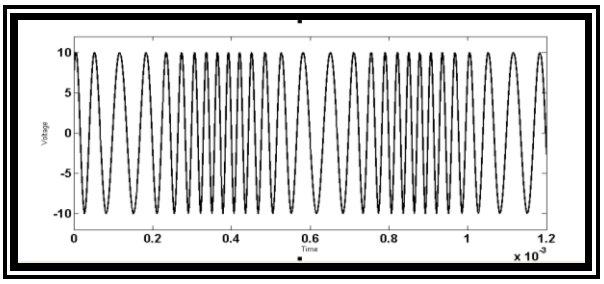

Fig .2: FM Time Domain Plot

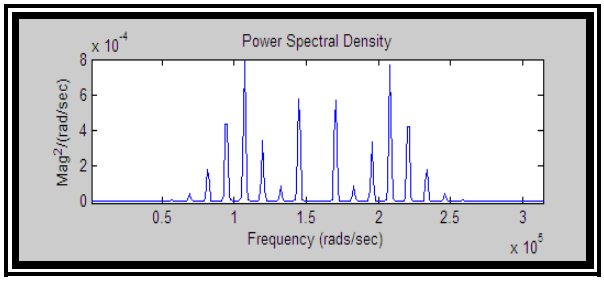

Fig-3: FM Frequency Domain Plot

It is quite obvious from the Bessel Functions of

Fig-1 and the numerical values shown in

Table 1, the carrier (Jo) becomes equal to zero when Beta (β) takes 2.41 and 5.53 values respectively. Therefore, when Beta (β) is given the value 5.53 as shown in

Fig-1 the resulted power spectral density shown in Fig-3 shows zero carrier (J0=0) as well and 8 significant sidebands are there, where the 9th component is disregarded because it is very small. Furthermore, the negative values of the sidebands in

Table 1 will turn to be positive in Fig-3 since the power spectral density takes the magnitude, which is the absolute value.

IV. Results and Discussion

a) Simulation Results

As a matter of fact Beta (β) was chosen purposefully to make the carrier (Jo) zero in all the proceeding figures. The bandwidth is directly proportional with Beta (β) as it is quite clear from the frequency domain plots. Carson's rule states that nearly all (~98 percent) of the power of a frequency-modulated signal lies within a bandwidth BW_{FM} as a rule of thumb of(see equation(4) and(5)):

[12] $$\mathbf{BW_{FM} = 2(f_m + \Delta f_c)} \quad (4)$$

[12] $$BW_{FM} = 2f_m(1 + \beta) \quad (5)$$

Where Δf_c is the peak deviation of the instantaneous frequency f_m from the center carrier frequency [14].

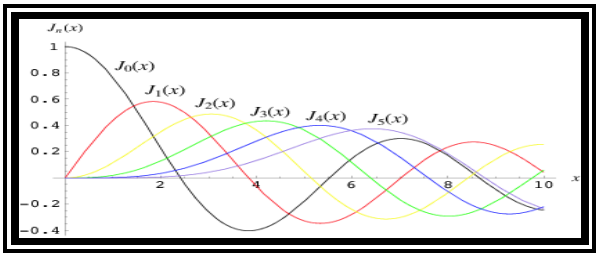

Fig-1: FM Bessel Functions, source [15]

Table 1: FM Bessel Function Table

Modulation index(β)	Sideband Carrier	1	2	3	4	5	6	7	8	9
0.00	1.00									
0.25	0.98	0.12								
0.5	0.94	0.24	0.03							
1.0	0.77	0.44	0.11	0.02						
1.5	0.51	0.56	0.23	0.06	0.01					
2.0	0.22	0.58	0.35	0.13	0.03					
2.41	0	0.52	0.43	0.20	0.06	0.02				
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	0.01			
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01			
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02		
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	
5.53	0	−0.34	−0.13	0.25	0.40	0.32	0.19	0.09	0.03	0.01

6.0	0.15	−0.28	−0.24	0.1 1	0.3 6	0.3 6	0.2 5	0.1 3	0.0 6	0.0 2

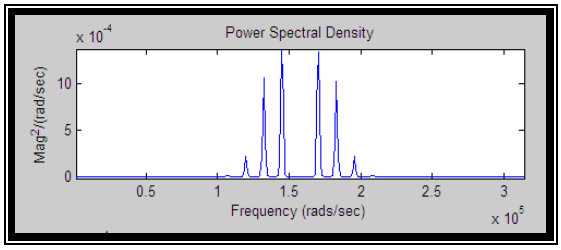

Fig-2: FM Frequency domain plot for β =2.41

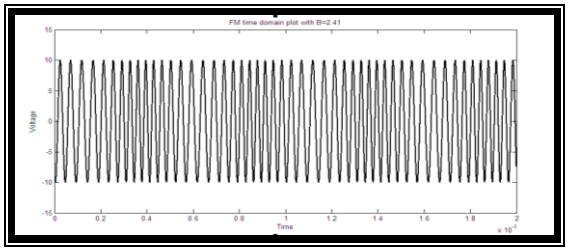

Fig-3: FM Time domain plot for β =2.41

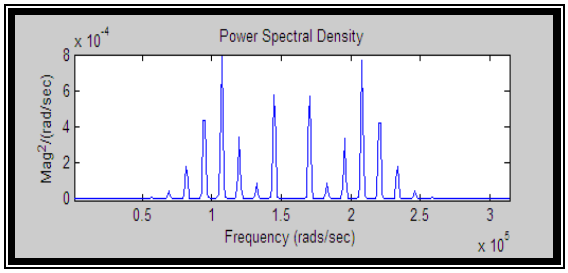

Fig-4: FM Frequency domain for β =5.53

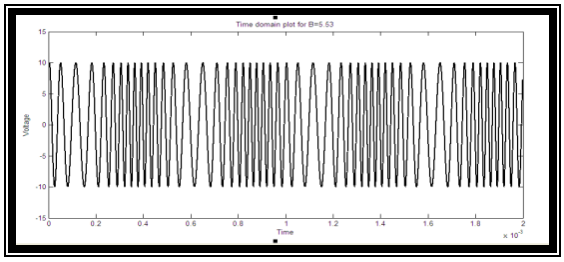

Fig-5: FM Time domain for β =5.53

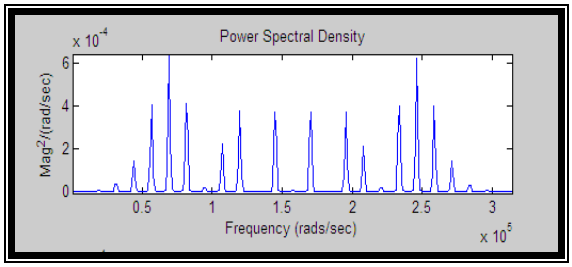

Fig-6: FM Frequency domain for β =8.5

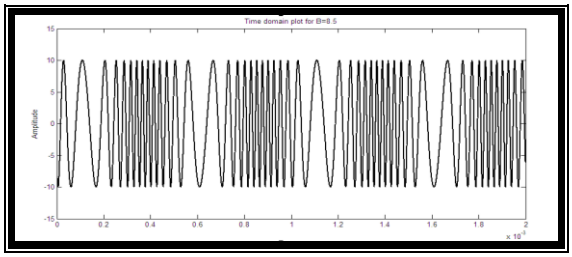

Fig-7: FM Time domain for β =8.5

V. CONCLUSIONS

Using MATLAB/SIMULINK as a tool to simulate FM Modulation technique has been investigated in this paper. The intention behind such investigation is to help the undergraduate students in electrical and electronics engineering field grasp this topic easier and faster. A great compatibility between simulation and practical results has been encountered.

The success behind reaching satisfactory comparison between the practice and simulation studies can be extended to investigations dealing with FM demodulation and that to say extracting information signal from RF signal.

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