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Simulation and Analysis of Frequency Modulation System in MATLAB as Practical Assessment Method for Communication Engineering Course

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Abstract

COVID-19 pandemic hit has raised new challenges for Outcome-Based Education (OBE) system since the normalization of the online education delivery. Still, this era of endemic imposes challenges in satisfying OBE requirements, especially the students' practical assessments. As an essential part of Communication Engineering, Frequency Modulation (FM) fundamental can be theoretically and mathematically explained during the online classes. However, its practical assessment needs to be done experimentally. Since buying the real devices and tools needed to create a complete FM system consumes high cost, software simulation is the best solution to accommodate the learning processes for all students. Hence, aided by the MATLAB simulation and analysis approaches, this paper presents the implementation of FM practical assessment at Universiti Teknologi MARA (UiTM) as an institute of higher education. For this task, students have built the FM system by using both mathematical and Simulink model. The model also emphasized students on the association between FM's important parameters: modulating frequency, modulation index, frequency deviation, and bandwidth, with the type of FM, Narrow Band FM (NBFM) or Wide Band FM (WBFM). Results for all model configurations are recorded and analyzed accordingly. From this practical activity, students have demonstrated a better attainment for this course's Program Outcome (PO) as compared to the conventional assessment methods.

Keywords: Frequency Modulation *(FM),* Outcome-Based Education *(OBE)*

Introduction

The era of COVID-19 pandemic has seen a paradigm-shift of students learning activities due to the closure of all education centers around the world, following the World Health Organization (WHO) instructions (WHO et. al., 2020). As a result, the education system has changed dramatically, with more online classes, e-learning, remote assessments, etc. performed on various digital platforms. Post-pandemic, most of the institutes of higher learning in Malaysia still practicing the hybrid mode, with both online and physical classes (MOHE, 2021). While more university courses have been successfully launched using the online platform, quite of pressure experienced from the Electrical Engineering (EE) department to run their hands-on activities in fulfilling the Outcome-Based Education (OBE) system requirements (WEF, 2020).

In EE UiTM, one of the major courses is Communication Engineering. This course has become the depth and breadth of today's modern communication systems (UiTMCJ, 2021). Thus, to achieve the Communication Engineering Course Objectives (COs) and Program Outcomes (POs) as required by the OBE system, particularly during this post-pandemic working structure, this paper presents a method of the implementation of Frequency Modulation (FM) practical assessment by using the MATLAB simulation and analysis approach. Therefore, Section II firstly introduces the course OBE specifications. Then, Section III elaborates on the paper's main subject. Lastly, Section IV presents the achievement of COs and POs comparing the students' score results before and after the implementations. The comparisons and analysis made in this paper will provide insight to the educators into the attainment of POs with the methodology used.

OBE Requirements for Communication Engineering

The Communication Engineering course in the Diploma of Electrical Engineering (Electronic/Power) program in UiTM has been equipped with OBE elements from a decade ago. In Malaysia, OBE has been made compulsory using signatories of the Dublin Accord (IEA, 2022). This is also to ensure that the accreditation to tertiary education programs qualifies graduates for entry to technical engineering practice. For these purposes, all EE programs are accredited locally by the Engineering Technology Accreditation Council (ETAC) under the Board of Engineers Malaysia (BEM) (BEM, 2022).

Since OBE primarily focuses on skill-based teaching and learning, most of the POs for the EE programs in UiTM are measured through lab-based activities (A. Manaff Ismail et. al., 2010). Hence, during the UiTM closure, shifting to entirely online to achieve the course outcomes was challenging. Since the Communication Engineering course is compulsory for all EE students, applying the online learning mechanism requires proper planning for the tasks' distribution. Initially, the faculty decided to continue with the planned activities and assessment processes for this course. Later for the subsequent semesters, some modifications were made through the Continuous Quality Assurance (CQI) meeting and adopted new methods which are by using the simulation software to assess the COs in attaining the POs. This is also to fulfill the minimum 50% practice-oriented components in the EE program as required by ETAC (HEA UiTM, 2022).

One of the COs for the Communication Engineering course is CO3: *to develop the proper waveform and spectrum of analog and digital transmission techniques based on the applied modulation or multiplexing*. This CO3 is mapped to the PO5 of the EE program which is: *applying an appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations*. In order to achieve these CO-PO necessities, the simulation methodology using MATLAB as a widely available, up-to-date, reliable, and modern engineering tool, was decided (Lawrence & Chibuisi, 2015). For this goal, legacy FM technology was chosen as one of the topics. Until today, FM has been successfully transferring voices and music at its greatest and being applied most in radio and TV broadcasting, radar, telemetry, emergency, and security system (Faruque, 2017). Thus, understanding the fundamental of this FM system through simulation is promising to train students in model development and data analysis.

Conducting a simulation assessment is advantageous. In terms of implementation, this assessment can be done by using both offline and online approaches, anytime and anywhere across UiTM, especially in the engineering campuses. All UiTM campuses are equipped with the MATLAB network-licensed version. The software itself is also installed in each computer in the laboratory, thus students will use this software when they are having the physical class. If students are outside campuses doing online-distance-learning (ODL), they also can make remote access to the laboratory software using any 'remote-desktop' applications.

Frequency Modulation Simulation Model

Theoretically, Frequency Modulation (FM) is the process of varying the frequency of a carrier wave, f_c in proportion to the amplitude of a modulating signal, V_m. As stated in Equ. 1, in FM, the amplitude of the carrier, V_C is kept constant while its frequency changes at the rate equal to the frequency of the modulating signal, f_m (Faruque, 2017).

$$V_{FM} = V_C \, cos \, cos \left[2\pi f_c + m_f \, sin \, sin \, 2\pi f_m(t)\,\right] \qquad (1)$$

Modulation index, m_f is a ratio between the frequency deviation, Δf and the maximum modulating frequency, f_m. It represents a way to express the peak deviation frequency as a multiple of the maximum modulating frequency. Frequency deviation is the maximum change of the instantaneous frequency of FM signal from the center carrier frequency. It is proportional to the amplitude of the modulating signal, V_m. Bandwidth shows the range of frequencies that contains information. Thus, the relationship between the FM bandwidth, B_{FM}, frequency deviation and modulating frequency in Carson's rule is as follows:

$$B_{FM} = 2(\Delta f + f_m)\, Hz \qquad (2)$$

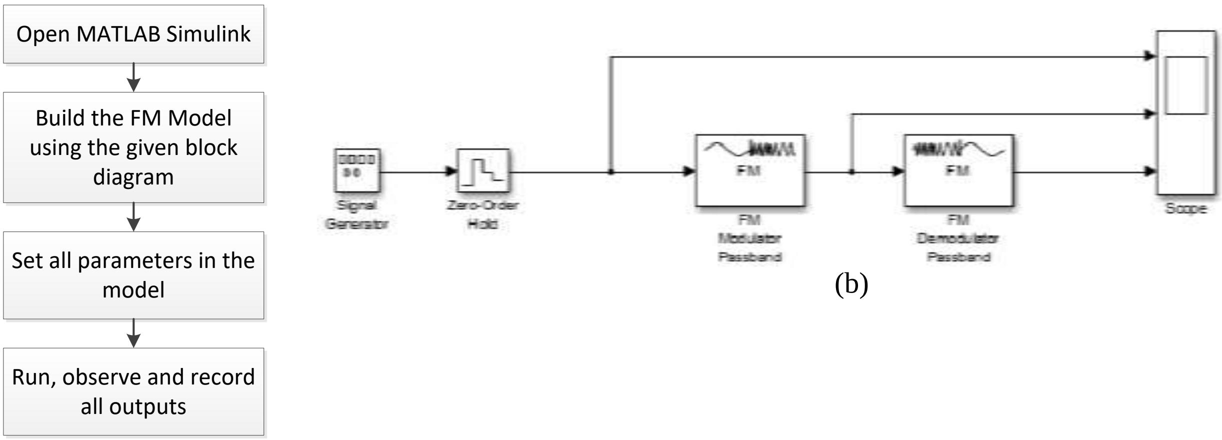
Another relationship between the FM bandwidth, number of pairs of the significant sidebands, n and modulating signal frequency, f_m as stated in Bessel rule is:

$$B_{FM} = 2(n f_m)\, Hz \qquad (3)$$

There are two types of FM which are Narrow Band FM (NBFM) and Wide Band FM (WBFM). The main difference between these two types is the number of sidebands. WBFM produces a greater number of sidebands as compared to NBFM. WBFM has modulation index more than 4, while NBFM has modulation index less than 4.

PART A: FM Output Generation using MATLAB Simulink

This part familiarizes students with the flow of working with the MATLAB Simulink model as described in Fig. 1 (a). By referring to the lab manual, students have built the FM block diagram as depicted in Fig. 1 (b). All model parameters are listed in Table 1. To obtain the results, students run, observed and recorded all required outputs using the *Scope*. Example of recorded results are attached in the Appendix. Students have observed that in FM, the amplitude of the signal is kept constant while the frequency changes linearly with the amplitude of the modulating/information signal. In overall, about 30 minutes were spent on the completion of this part.



(a) (b)

Figure 1: (a) Flow of work using Simulink and (b) The designed FM block diagram

Table 1

FM Simulation Model Parameters

Block	Parameter	Value
Signal generator	Waveform Amplitude Frequency	Sinewave 1.2 V 10 Hz
Zero-Order Hold	Sample time	1/8000
FM Modulator Passband	Carrier Frequency Frequency Deviation	200 Hz 50 Hz
FM Demodulator Passband	Carrier Frequency Frequency Deviation (Hz) Hilbert transform filter order	200 Hz 50 Hz 120

PART B: FM Analysis using MATLAB Editor

This part trains students with MATLAB programming for FM signal analysis by applying the flow of work as depicted in Fig. 2 (a). By referring to the lab manual, students have developed the FM simulation program in MATLAB Editor as shown in Fig 2 (b). Equ. (1) was used in this model. To generate the FM frequency spectrum, Fast-Fourier-Transform (FFT) function was also applied. Equ. (2) and (3) were used for FM bandwidth analysis. The FM parameters are listed in Table 2. Students run, observed and recorded all generated outputs. Example of results are attached in the Appendix. For this part, students have spent approximately 1 hour and 30 minutes.

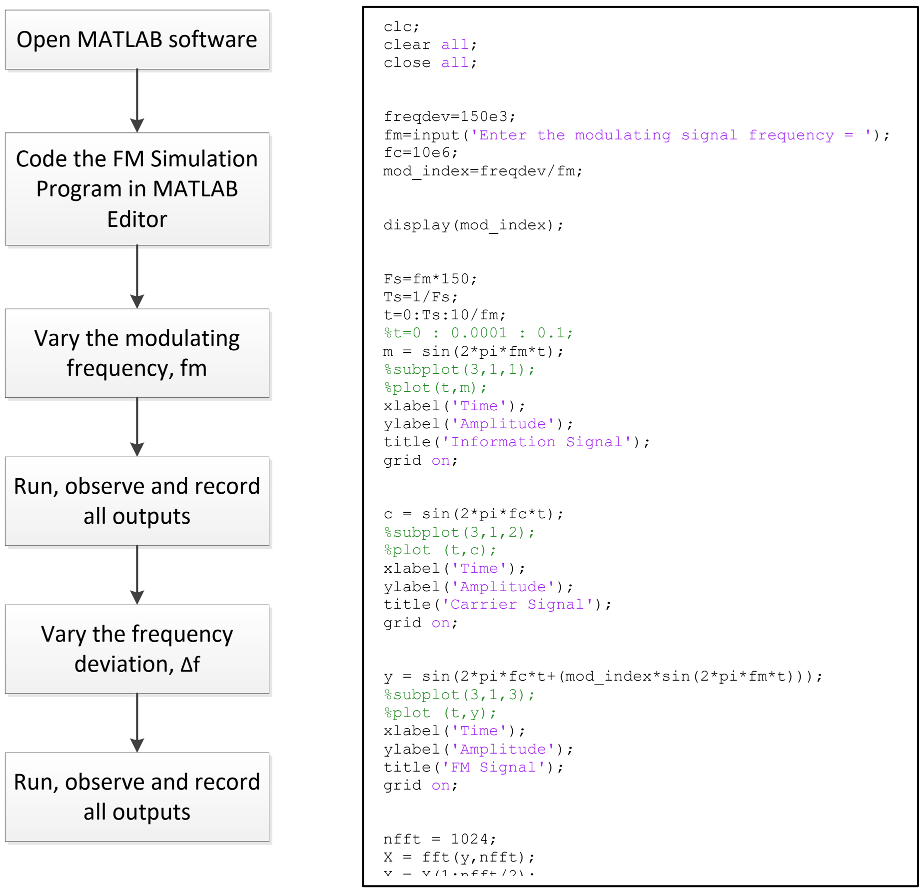
By referring to the attached results, it can be observed that the higher the modulating frequency, f_m the higher the FM bandwidth, B_{FM} computed. This proves the Bessel rule. It also can be observed that the higher the peak frequency deviation, Δf, the higher the FM bandwidth. This proves Carson's rule. The results tabulated in the Appendix also assessed students' ability in the determination whether the configuration is a WBFM or NBFM.

Table 2
FM Simulation Model Parameters

Parameter	Symbol	Value
Frequency deviation	Δf	150 – 270 Hz
Modulating frequency	f_m	30 – 100 kHz
Carrier frequency	f_c	10 MHz

Communication Engineering PO Achievements

As tabulated in Table 3, the average students' achievement marks from the implementation of the FM assessment model presented above were analyzed. A standardized laboratory practical assessment evaluation criteria or rubrics were used. The criteria that were evaluated are applying correct procedures, right software/tools handling, successful model constructions, producing correct outputs, and the ability in performing technical analysis. The results show that most of the students can successfully fulfill Criteria 1, 2 and 3. However, many students produce some errors in demonstrating the correct outputs for all model configurations as required in Criteria 4. Among all, Criteria 5 shows a critical performance where the mark obtained is lower than 50 %. This means many students have difficulties or a low ability to show an exact analysis and discussion of their simulation findings with the FM fundamental.



(a) (b)

Figure 2: (a) Flow of work using MATLAB coding and (b) The FM simulation program

In addition, the CO3-PO5 attainments for the Communication Engineering course in all EE UiTM programs were also evaluated. As it is newly introduced in the EE UiTM syllabus to fulfill the 50 % ETAC lab-based requirements which started last semester (Oct21-Feb22), 6 lab activities were done in total to achieve this PO5 in the Communication Engineering course. Hence, this PO5 attainment was actually contributed by 5 other experiments which are Amplitude Modulation, Pulse Modulation, Pulse Code Modulation, Digital Modulation, and Multiplexing System. Compared with all previous semesters, only 1 lab activity/experiment was assessed to students. Thus, our initial analysis is important to give a brief overview on the impact of applying more laboratory assessments to the EE Program Outcome, particularly by using a simulation approach.

Currently, EE department in UiTMCJ offers 2 programs which are the Diploma of EE-Electronic (EE111) and the Diploma of EE-Power (EE112). The average PO5 attainment of these EE programs is presented in Figure 3. Then, the PO5 attainments for 3 mainstream semesters which are Sept19-Jan20, Oct20-Feb21 and Oct21-Feb22 were analyzed. It can be seen that by applying more laboratory assessments, significant PO5 attainments have been produced. We also compare the method of Teaching and Learning delivery between these semesters. From Sept19-Jan20, all assessments were conducted face-to-face (F2F) which was just before COVID-19 hit. In Oct20-Feb21, all assessments were conducted online (ODL) during COVID-19 with high cases. The students' learning activities in the semester Oct21-Feb22 were conducted during the endemic by using a hybrid mode, with all lab assessments done during the physical classes. As compared to the ODL mode, the PO5 attainment using hybrid is lower due to more laboratory assessments that need to be completed by students. Inadequate preparations of the laboratory facilities after 1.5 years closure period also contributed to the attainment figure. Furthermore, students in this hybrid semester were entering the campus for the first time after 2 semesters of experiencing online learning activities. They were most probably affected physiologically by a changing study routine.

Table 3
Students' achievement marks for each evaluation criteria

No.	Criteria	Full Mark	Average Mark Obtained
1	Ability to follow the procedures completely	10	9.89
2	Ability to handle software /equipment tools efficiently	20	19.86
3	Ability to construct model/circuits/ system/coding using software tools	20	19.79
4	Ability to produce output/result for all tasks using given/dedicated techniques and tools	20	17.28
5	Perform technical analysis using given/dedicated techniques and tools	20	9.92
	Total	90	76.73

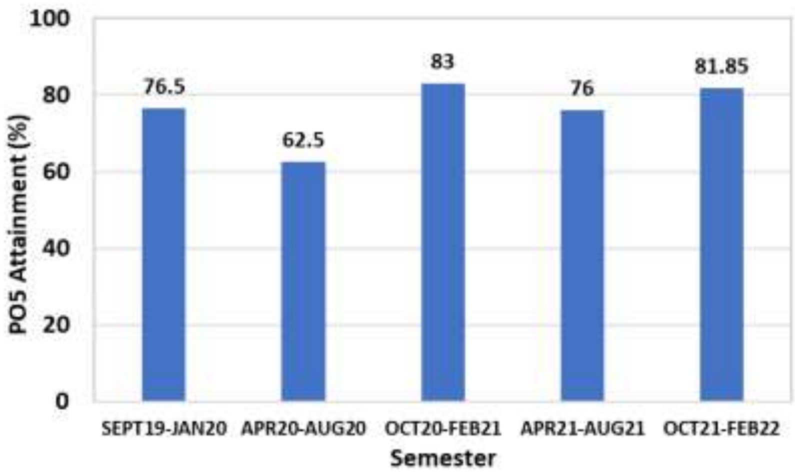


Figure 3: Acheivement of PO5 for 5 semesters

Conclusion

In this paper, we have demonstrated the usage of MATLAB and Simulink as modeling and simulation tools for FM system as a case study. We have presented the students' practical learning methods using these tools. We also found that MATLAB and Simulink have rich libraries and built-in functions that can be used to ease the whole modeling process, especially during the ODL learning phases. By properly guiding the students through an understandable lab manual, they can completely perform the practical assessments using MATLAB simulations or any other modern tool. From our analysis, it is also recommended that instructors and educators engage more with students in the discussion and analysis part of their lab reports. By referring to all presented data, we can conclude that performing laboratory practical assessments have significantly improved the Communication Engineering course's CO-PO attainments. The above comparative analysis of face-to-face, online, and partial-online has given a breakthrough as a new normal for all educational institutions to have a mixture of all delivery methods. Hence, accomplishing the practical assessments using simulation is advantageous since it can be applied in both online and offline learning approaches.

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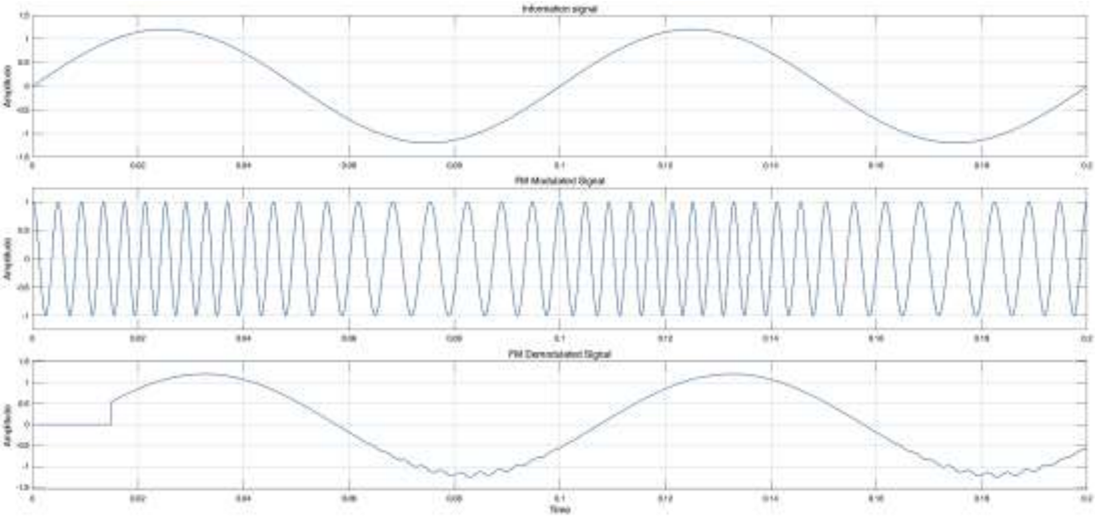
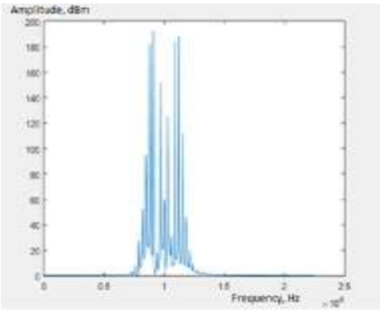
Appendix

Results for PART A

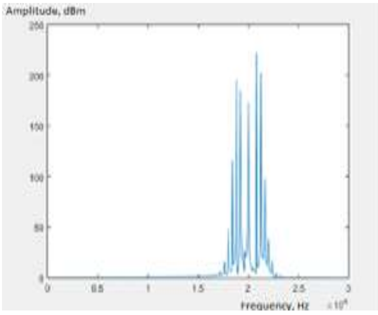


Results for PART B

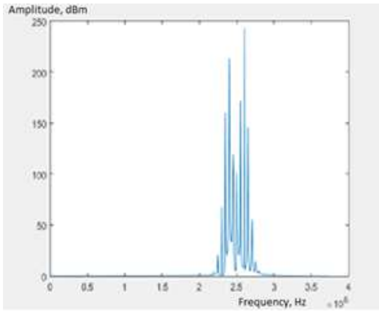
(a) Varying the modulating signal frequency, f_m



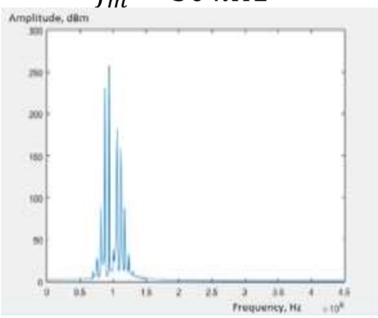
$f_m = 30\ kHz$



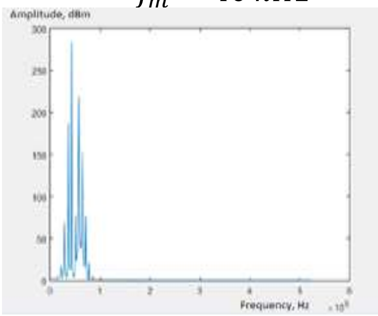
$f_m = 40\ kHz$



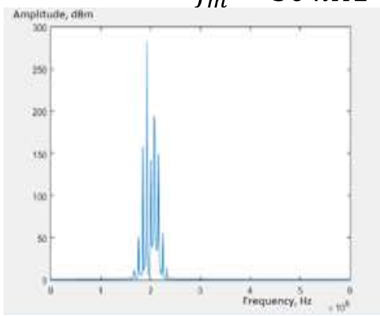
$f_m = 50\ kHz$



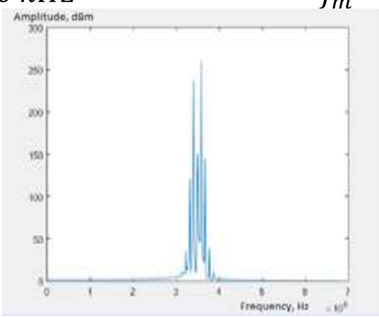
$f_m = 60\ kHz$



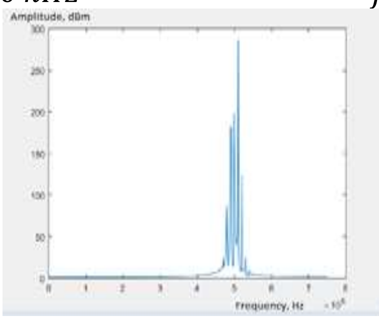
$f_m = 70\ kHz$



$f_m = 80\ kHz$



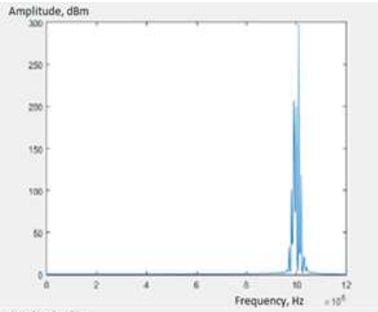
$f_m = 90\ kHz$

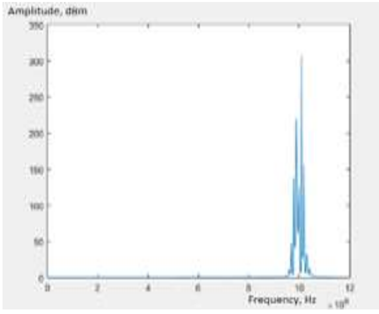


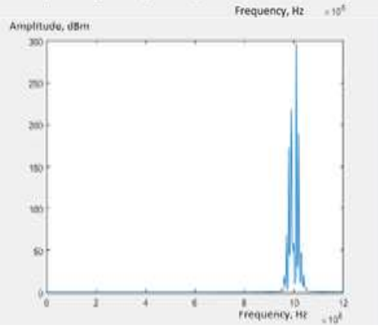
$f_m = 100\ kHz$

f_m (kHz)	BW (kHz)	n	NBFM@WBFM	m_f
30	360.2	6	WBFM	5.00
40	398.0	4.98	NBFM	3.75
50	403.0	4.03	NBFM	3.00
60	483.0	4.03	NBFM	2.50
70	564.0	4.028	NBFM	2.14
80	480.0	3.00	NBFM	1.88
90	541.0	3.01	NBFM	1.64
100	601.0	3.01	NBFM	1.50

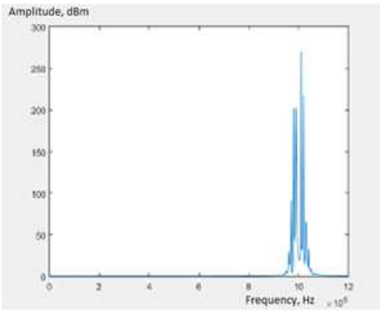
(b) Varying the frequency deviation, Δf

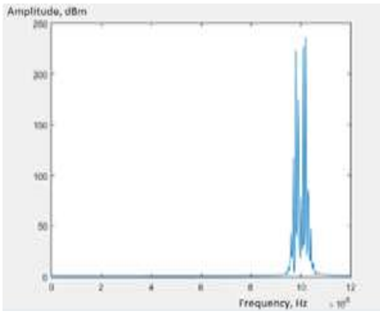






$\Delta f = 150\ kHz$ $\Delta f = 180\ kHz$ $\Delta f = 210\ kHz$





$\Delta f = 240\ kHz$ $\Delta f = 270\ kHz$

Δf (kHz)	n	m_f	BW (kHz)
150	4	1.5	403
180	4	1.8	403
210	4	2.1	403
240	5	2.4	794
270	6	2.7	794