National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

Department of Electrical Engineering and Computer Science

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Semester: 6th Section: BEE 12C

EE-351 Communication Systems

Lab 6: Mixer, IF Filter and Envelope Detector

Group Members

Name	Reg. No	Viva / Quiz / Lab Performance	Teamwork	Ethics	Software Tool Usage	Analysis of data in Lab Report
		5 Marks	5 Marks	5 Marks	5 Marks	5 Marks
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3 RF Power Amplifier

3.1 Objectives

- When you have completed this exercise, you will be able to explain the operation of the mixer, describe the function of IF filter and describe how the envelope detector converts a 455kHz signal to the message signal. You will use an oscilloscope to make AM signal measurements.

3.2 Introduction

The purpose of this lab report is to explore the properties and characteristics of RF Mixer, IF filter and envelope detector. Overall, the lab report aims to provide a comprehensive understanding of the fundamental concepts and practical applications of RF amplifiers and AM.

3.3 Lab Report Instructions

All questions should be answered precisely to get maximum credit. Lab report must ensure following items:

- Lab objective
- Results (screen shots) duly commented and discussed.
- Conclusion

4 Lab Procedure

4.1 Introduction

The basic sections of the AM receiver shown in Figure 3-2 are shown again in Figure 3-13. Refer to this figure as necessary to follow along with the general path of the transmitted AM signal.

NOTE: *The IF amplifier is not included on the circuit board.*

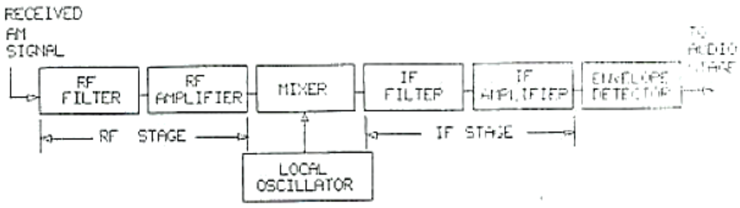

Figure 3-13.

Refer to Figure 3-14. The role of the mixer is to join the RF stage to the IF stage. The mixer combines the 1000 kHz AM signal from the RF stage with a 1455 kHz LO signal to produce a 455 kHz difference signal for the IF stage. Besides the 455 kHz difference frequency, the sum frequency (2455 kHz) of the AM signal and the local oscillator signal is also output from the mixer.

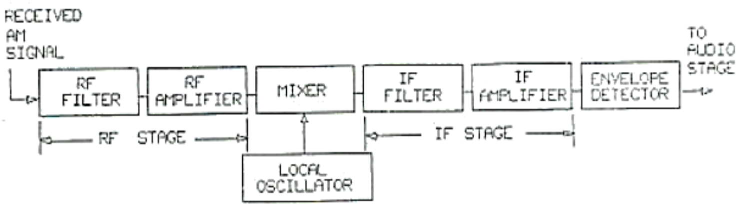

Figure 3-14.

The IF filter in the IF stage is a ceramic filter, which has a higher attenuation outside of the filter's bandwidth than LC filters do. See Figure 3-15 (next page). The equivalent circuit of the ceramic and

ceramic holder is shown. The components L_S, C_S, and R_S represent the series resonant circuit of the crystal. C_P represents the parallel capacitance of the ceramic holder.

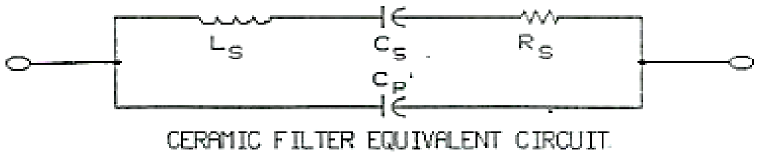

Figure 3-15.

See Figure 3-16. The IF filter is designed to pass a 455 kHz signal with a bandwidth that includes the AM sidebands: the LSB at 445 kHz and the USB at 465 kHz. The bandwidth is therefore 20 kHz. Frequencies outside of this range are greatly attenuated.

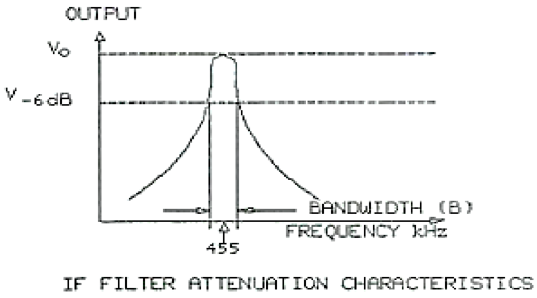

Figure 3-16.

As shown in Figure 3-17, a simple message signal detector is the nonlinear charging circuit formed by a diode in series with the parallel RC network. This kind of envelope detector is also known as a diode (CR1) detector. The circuit is designed to have a fast charge time and a slow discharge time, with the resistor (R12) controlling the discharge time constant (Figure 3-18, next page). There is an optimum value for the RC circuit discharge time constant.

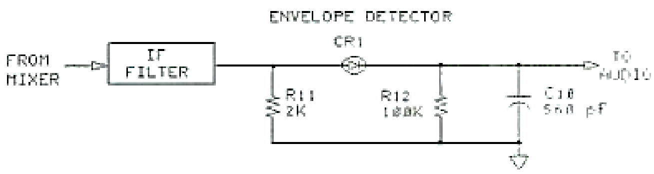

Figure 3-17.

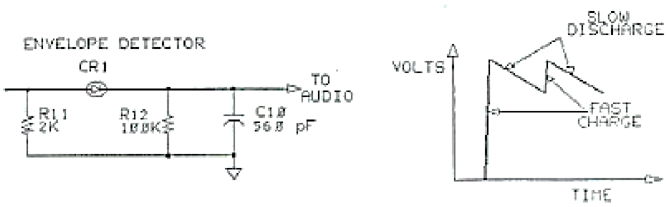

Figure 3-18.

When an AM signal is applied to the envelope detector circuit input, the diode conducts only during the positive portion of the AM. The charging and discharging output signal of the envelope detector RC circuit closely follows the positive envelope of the AM signal that is equivalent to the message signal, as Figure 3-19 shows.

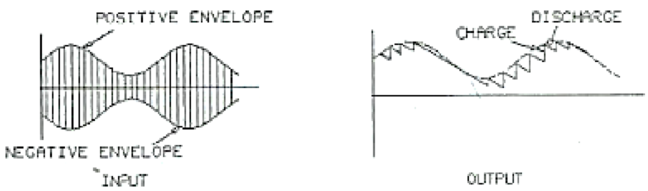

Figure 3-19.

4.2 Procedure A: Connect the AM Transmitter and Set the RF Stage

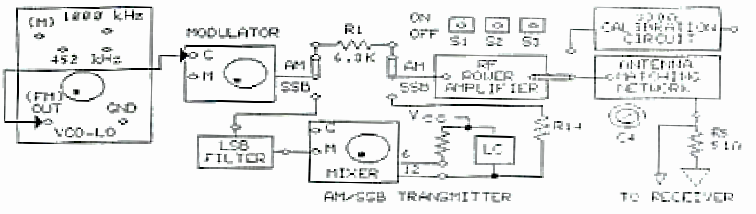

Figure 3-20.

2. On the VCO-LO circuit block, insert the two-post connector in the 1000 kHz position.
3. Set switches S1 and S2 to OFF.
4. Set S3 to ON. When S3 is on, the ANTENNA MATCHING IMPEDANCE is automatically set to 330Ω.
5. Connect the oscilloscope channel 1 probe to the MODULATOR's carrier signal input (C).
6. While observing the signal on channel 1, set the carrier signal amplitude to 0.1 $V_{pk\text{-}pk}$ by adjusting the knob on the VCO-LO circuit block.
7. While observing the signal on channel 1, set the carrier signal frequency to 1000 kHz by adjusting the NEGATIVE SUPPLY knob on the base unit.
8. Connect the oscilloscope channel 2 probe to the MODULATOR message signal input (M).
9. While observing the signal on oscilloscope channel 2, adjust the signal generator for a 0.1 $V_{pk\text{-}pk}$, 2 kHz sine wave signal at the message input of the MODULATOR.
10. Connect the channel 1 oscilloscope probe to the output of the antenna (R5). Set the sweep to 0.1 ms/DIV, and trigger on channel 2. Adjust the MODULATOR potentiometer knob so that the AM waveform is 100% modulated (see Figure 3-7).
11. With a two-post connector, connect the TRANSMITTER to the 1 M Ω resistor (R8) at the AM/SSB RECEIVER circuit block input (Figure 3-21).

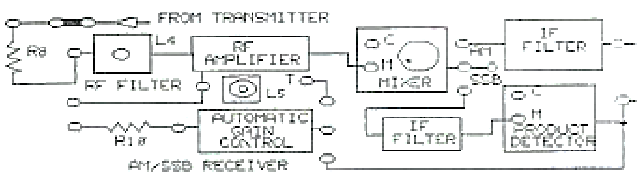

Figure 3-21.

12. Connect the channel 1 oscilloscope probe to M at the MIXER. Adjust L5 at about the midpoint so that a signal appears on channel 1.
13. Tune inductor L4 for the maximum peak-to-peak AM signal at the RF AMPLIFIER output.
14. Adjust the variable inductor (L5) in the RF AMPLIFIER collector circuit for the maximum peak-to-peak AM signal at the RF AMPLIFIER output.

4.3 Procedure B: Mixer

15. As shown in Figure 3-23, connect the output of the 1455 kHz VCO-HI circuit block to the local oscillator (C) input of the MIXER. Set the VCO-HI potentiometer knob fully CW. Connect the MIXER to the IF FILTER with a two-post connector.

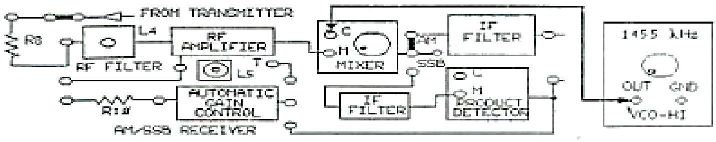

Figure 3-23.

16. Connect the oscilloscope channel 2 probe to the MIXER'S output. Adjust the MIXER'S balanced potentiometer knob until the output signal appears, as shown in Figure 3-24. This adjustment suppresses the 1455 kHz VCO-LO frequency in the output signal.

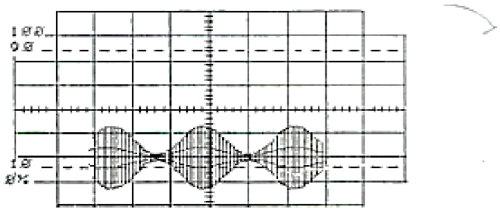

Figure 3-24.

17. Connect the oscilloscope channel 2 probe to the output of the IF FILTER. While observing the IF FILTER output, set the 1455 kHz VCO-HI frequency by adjusting the POSITIVE SUPPLY knob on the base unit for the maximum peak-to-peak signal. If this signal is not exact, the AM signal will not appear. Connect the oscilloscope channel 2 probe to the MIXER'S output, and connect the channel 1 probe to the MIXER'S M input.

18. Adjust the MIXER'S potentiometer for a clear, sharp output signal. Compare the output signal on channel 2 with the MIXER'S input signal on channel 1. Is there another modulation envelope, similar to the signal shown in Figure 3-25, within the AM signal at the MIXER output?

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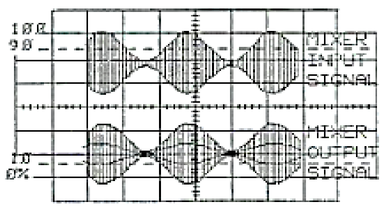

Figure 3-25.

19. Set the oscilloscope sweep to 1 µs/DIV, and trigger on channel 2. The MIXER'S output signal should be similar to the complex signal shown in Figure 3-26. Measure the time between peaks of the complex waveform, which is an approximate measure of the period (T). Each horizontal division is 1 µs.

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21. To determine that frequencies in the range of 2455 kHz are present, set the oscilloscope sweep to 0.2 μs/DIV. The signal on channel 2 should appear, as shown in Figure 3-27. Measure and record the period (T). Each horizontal division is 0.2 μs

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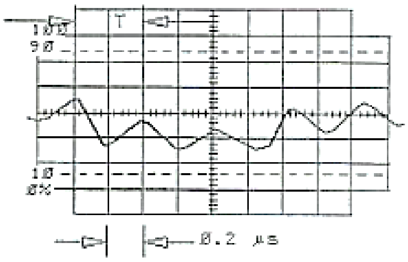

Figure 3-27.

22. From the period (T), calculate the frequency of the complex waveform. Record your answer in kilohertz.

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4.4 Procedure C: IF Filter

23. Connect the channel 1 oscilloscope probe to the IF FILTER output. Channel 2 should be connected to the IF FILTER input. Set the oscilloscope sweep to 0.2 ms/DIV. Trigger on channel 2.

24. Compare the IF FILTER output on channel 1 with the IF FILTER input on channel 2. Is there another modulation envelope within the signal at the IF FILTER output?

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25. While observing the IF FILTER output signal on channel 1, slightly vary the frequency of the 1455 kHz signal to the MIXER by adjusting the POSITIVE SUPPLY fine tune knob on the base unit.

26. Why does the IF FILTER output signal disappear when the frequency of the 1455 kHz signal to the MIXER is slightly increased or decreased?

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4.5 Procedure D: Envelope Detector

27. Connect the oscilloscope channel 1 probe to the MODULATOR message signal input on the AM/SSB TRANSMITTER circuit block, and connect the channel 2 probe to the ENVELOPE DETECTOR output.
28. Does the signal at the ENVELOPE DETECTOR output have the same frequency as the message signal?

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29. At the signal generator, vary the frequency of the 2 kHz message signal. Did the ENVELOPE DETECTOR output frequency vary with the frequency of the message signal?

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4.6 Deliverables

- **Step 9**

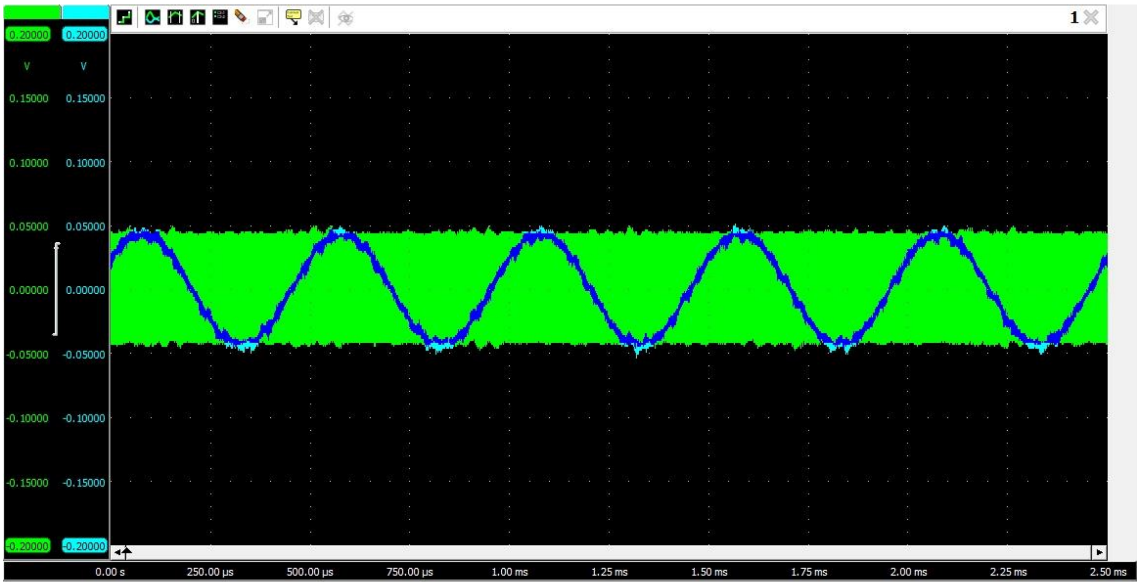

Figure 1: Message (M) and Carrier Signal (C) at MODULATOR Input

- **Step 11**

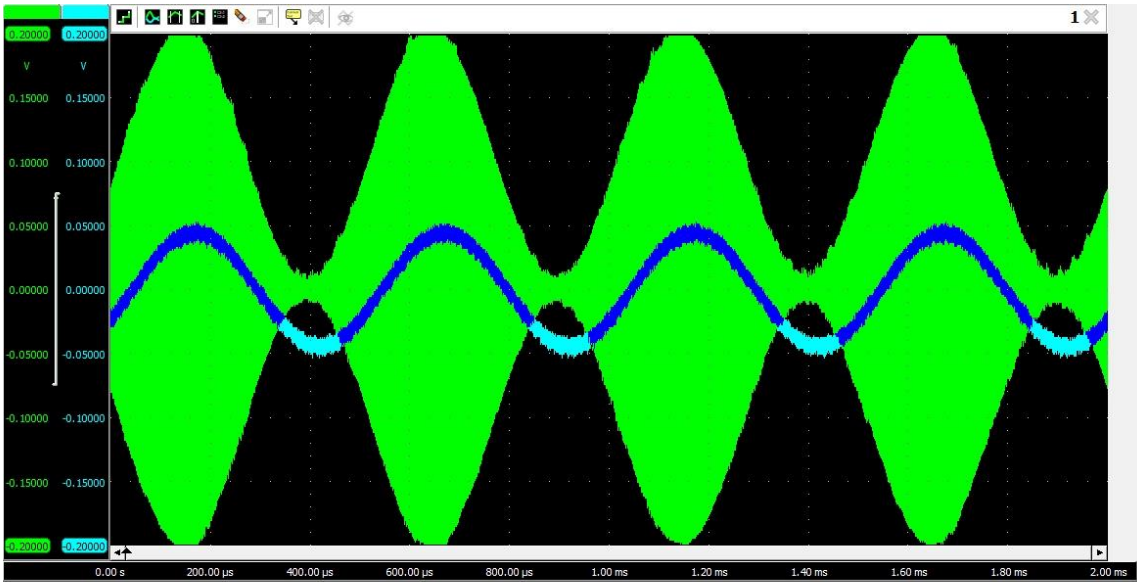

Figure 2: 100% Modulation AM Signal

- **Step 17**

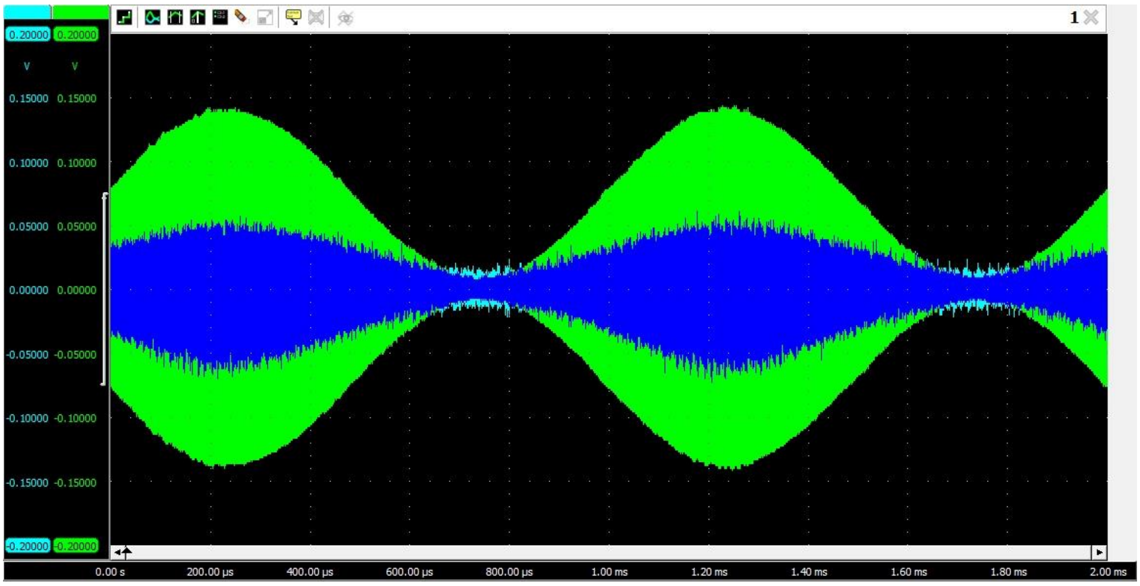

Figure 3: VCO-HI and AM signal

- **Step 18**

Yes, the presence of another modulation envelope is observed.

- **Step 19**

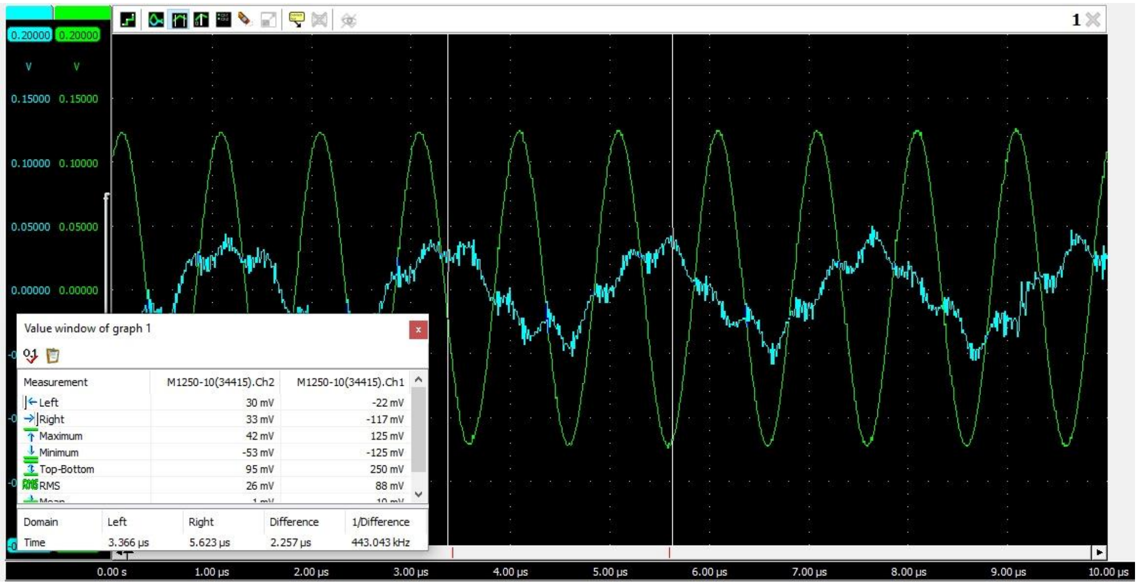

Figure 4: Period Calculation

T = 2.25 μs

- **Step 20**

$f = 444.44\ kHz$

- **Step 21**

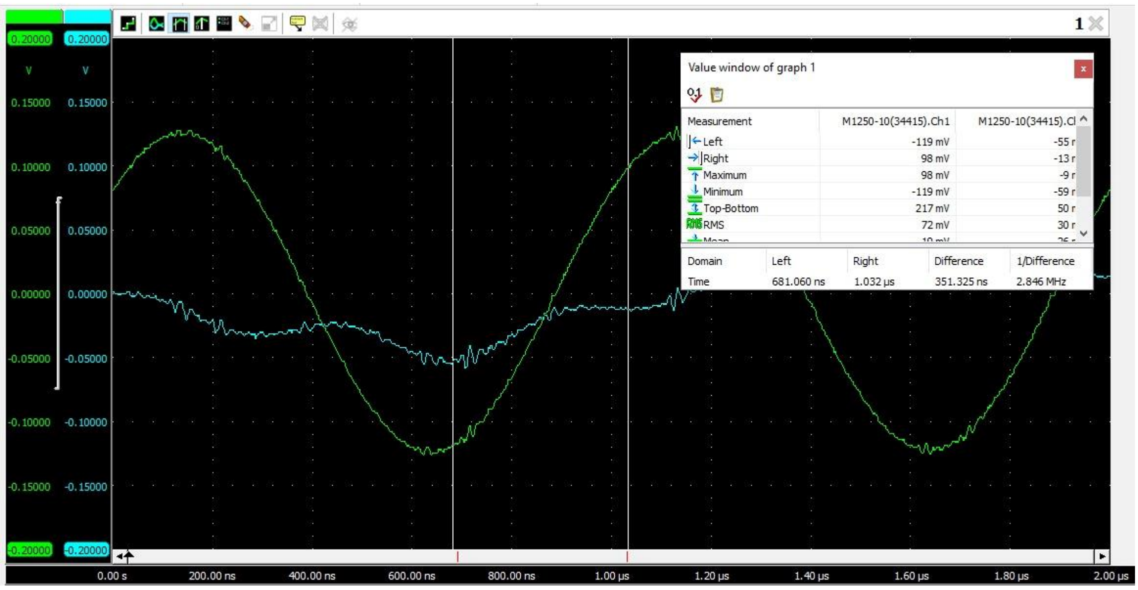

Figure 5: Period Calculation

T = 351 ns

- **Step 22**

$$f = 1/351\ Hz$$

- **Step 24**

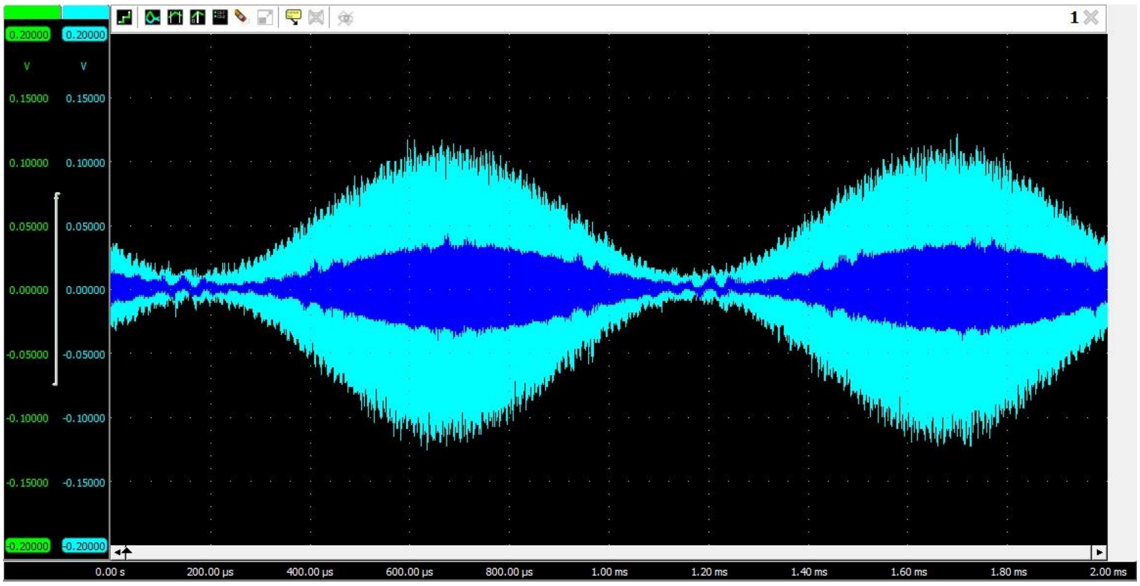

Figure 6: Presence of Modulation Envelope

- **Step 25**

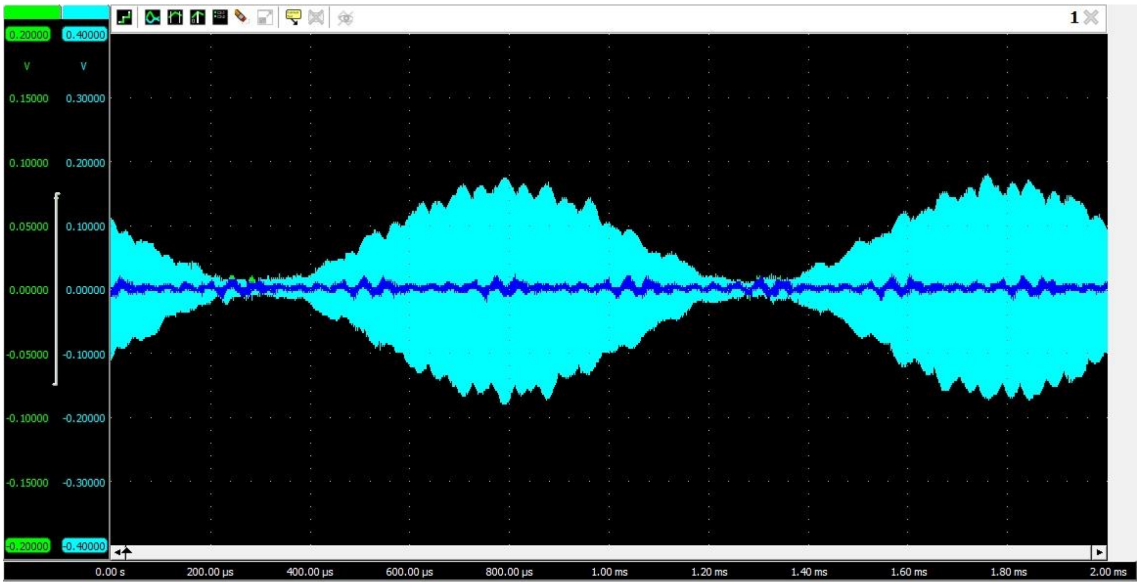

Figure 7: IF Filter Output

- **Step 28**

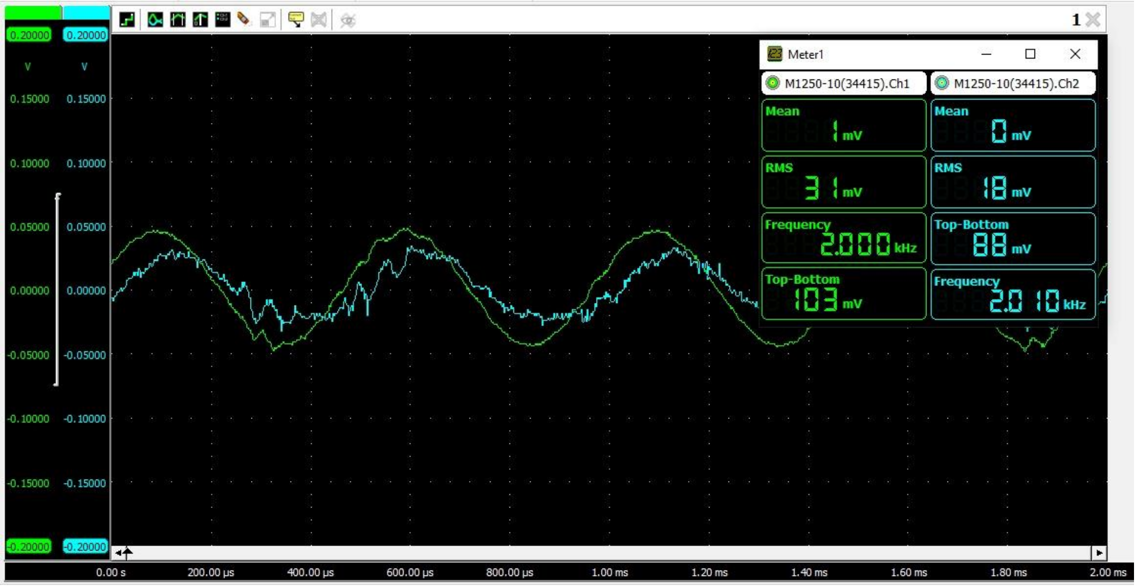

Figure 8: Envelope Detector Output

- **Step 29**

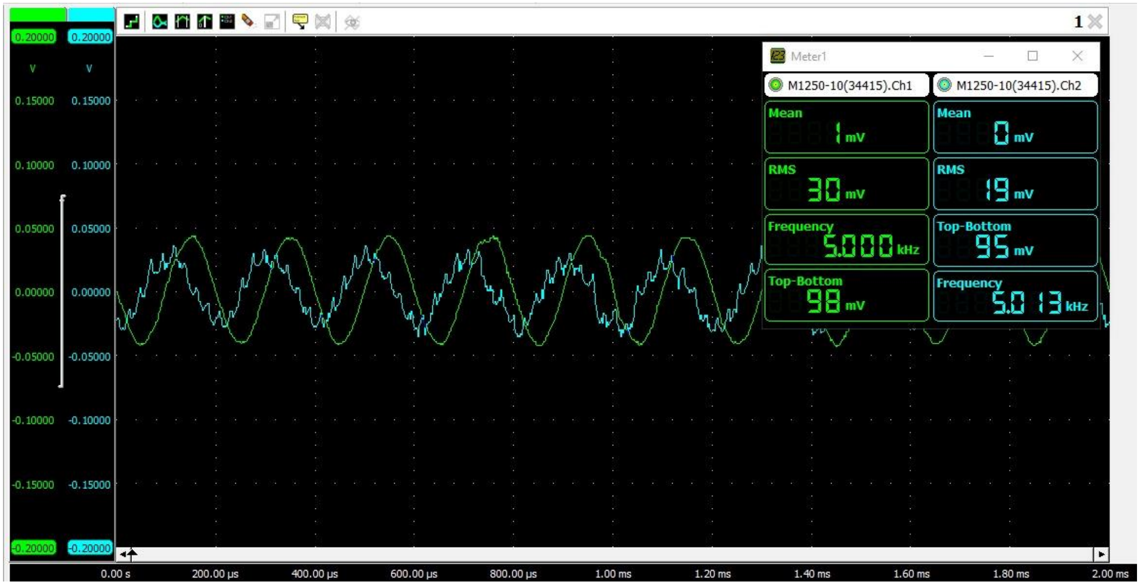

Figure 9: Frequency Variation

5 Conclusion

We completed the lab exercise and gained practical knowledge and hands-on experience in understanding the fundamentals of communication systems. By the end of this lab, we had a better understanding of the mixer, IF filter, and envelope detector, as well as their individual functions in the context of modulation in a communication system.