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Semester: 6th Section: BEE 12C

EE-351 Communication Systems

Lab 8: SSB Reception

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

- At the competition of this lab, you will be able to describe SSB reception circuits and signals by using AM/SSB RECIEVER circuit BLOCK on the ANALOG COMMUNICATION CIRCUIT BOARD.

3.2 Introduction

Analog communication systems have been widely used in the field of telecommunications for several decades. One of the important aspects of analog communication is the reception of Single Sideband (SSB) signals, which is the focus of this lab experiment. At the completion of this lab, the students are expected to have a comprehensive understanding of SSB reception circuits and signals using the AM/SSB receiver circuit block on the Analog Communication Circuit Board.

The AM/SSB receiver circuit block is a critical component in the analog communication system that is responsible for the reception and demodulation of SSB signals. The SSB signal is a complex waveform that contains both upper and lower sidebands, and it requires special circuits to extract the information from the carrier signal.

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

Figure 5-2 shows a simplified block diagram of the SSB receiver. Refer to this figure throughout the DISCUSSION as necessary.

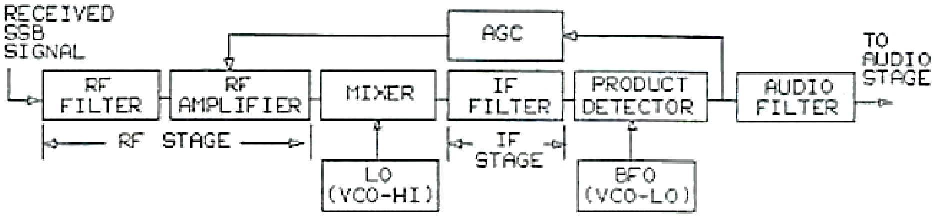

Figure 5- 2.

The RF stage in the AM/SSB RECEPTION circuit block contains an RF filter and an RF amplifier. The mixer in the circuit block is a balanced modulator that converts the 1000 kHz SSB to a 455 kHz SSB IF signal. The IF filter has a narrow bandwidth that removes all frequencies except the 455 kHz. Let's look more closely at each of these components.

The RF filter passes the desired SSB signal and matches the antenna impedance. *(Refer to Figure 5-3.)* On the circuit board, you will set up the SSB transmitter to transmit a 1000 kHz SSB signal to the SSB receiver's RF filter. The transmitted SSB signal is sent by a direct connection between the transmitter and receiver on the circuit board. A 1 MΩ resistor simulates transmission losses by reducing the SSB power at the RF filter input.

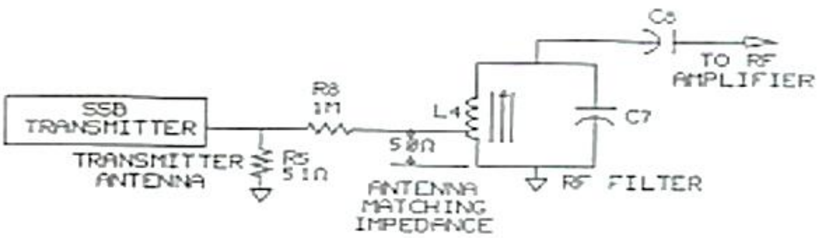

Figure 5-3. SSB transmission path to RF filter

On your circuit board, tune the variable inductor L4 for the transmitted 1000 kHz SSB signal. All frequencies outside the RF filter bandwidth are rejected (attenuated). When the RF filter is tuned for the transmitted signal, the filter provides a 50Ω matching impedance between the inductor (L4) tap and ground for the receiving antenna. On your circuit board, there is no receiving antenna; however, the signal at the L4 tap represents a signal received by an antenna.

The RF amplifier, shown in Figure 5-4, is a single-ended differential amplifier composed of two transistors, Q2 and Q3. The emitters of Q2 and Q3 connect to the collector of Q4, which functions as a constant-current source. The Q3 collector connects to an RLC network, which contains a variable inductor (L5).

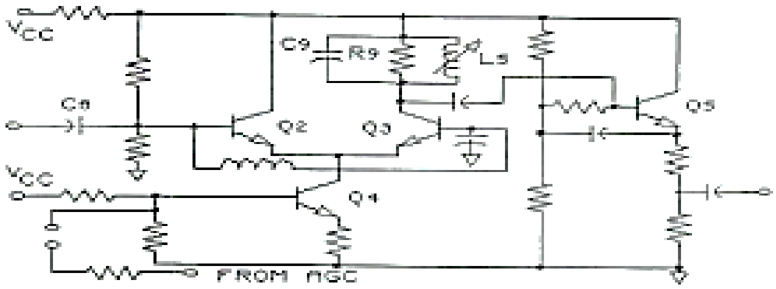

Figure 5-4. RF amplifier.

The Q3 collector is coupled to the base of Q5, which functions as an emitter-follower buffer. The RF amplifier output is at capacitor C10 in the Q5 emitter circuit. The power gain of the RF amplifier is very high: the purpose of the amplifier is to greatly increase the power level of the SSB signal that the RF filter selects.

The mixer, shown in Figure 5-5, joins the RF stage to the IF stage. This balanced mixer is a **down-converter**, because it reduces the SSB frequency from 1000 kHz to 455 kHz for the IF stage. The balanced mixer combines the 1000 kHz SSB signal from the RF stage with a 1455 kHz LO signal to produce a 455 kHz difference signal to the IF stage. The 2455 kHz sum frequency is also in the mixer's output.

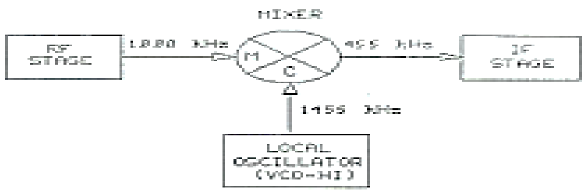

Figure 5-5. Mixer

Figure 5-6 shows the IF filter, which is designed to pass a 455 kHz signal. The IF filter is a ceramic filter. Ceramic filters have a higher attenuation rate outside of their bandwidths than a typical LC filter. The IF filter passes signals with frequencies between 453 kHz to 457 kHz; the bandwith (bw) is 4 kHz. Frequencies outside of the bandwidth are greatly attenuated.

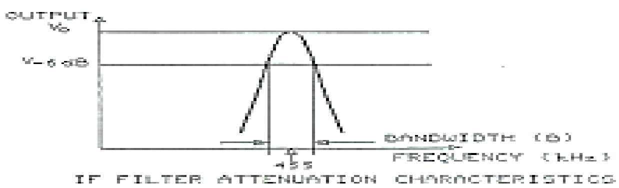

Figure 5-6. IF filter.

4.2 Exercise 1

4.2.1 Procedure A: Connect the SSB Transmitter

1. To generate a 1000 kHz SSB signal from the TRANSMITTER to the receiver's RF STAGE, connect the AM transmitter circuit and the oscilloscope channel 1 and channel 2 probes, as shown in Figure 5-7.

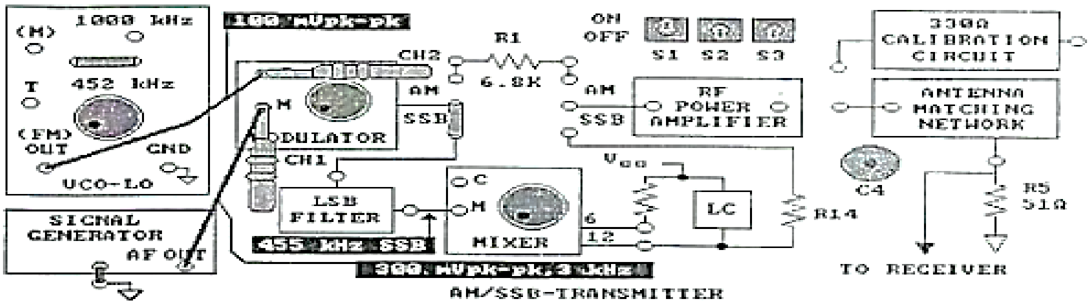

Figure 5-7.

2. Set channel 1 for 100 mV/DIV and the sweep for 0.1ms/DIV
3. While observing the channel 1 signal, adjust the SIGNAL GENERATOR for a 300 m V_{pk-pk}, 3 kHz sinewave message signal at M.

> NOTE: *Make sure each probe is set to the 10X position and that the probe's ground clip is attached to a ground terminal on the circuit board for an accurate measurement.*

4. Set the NEGATIVE SUPPLY knob on the left side of the base unit completely CCW.
5. Connect the oscilloscope channel 2 probe to the MODULATOR's carrier signal input (C). Set channel 2 for 50 mV/DIV.
6. Set the oscilloscope sweep time to 1.0 μs/DIV and observe the signal on Channel 2.
7. While observing the channel 2 signal, set the VCL-LO amplitude to 100 mV_{pk-pk} at C by adjusting the VCO-LO potentiometer knob.
8. Set switch S1 to ON to output a DSB from the MODULATOR.
9. Move the channel 2 probe to the M input at the Mixer.
10. A trace should appear at the LSB FILTER output on channel 2. Slowly increase the VCO-LO frequency by turning the NEGATIVE SUPPLY knob CW until the amplitude of the signal at M on the MIXER is maximum.

11. Connect the circuit and the oscilloscope channel 1 and channel 2 probes, as shown in Figure 5-8.

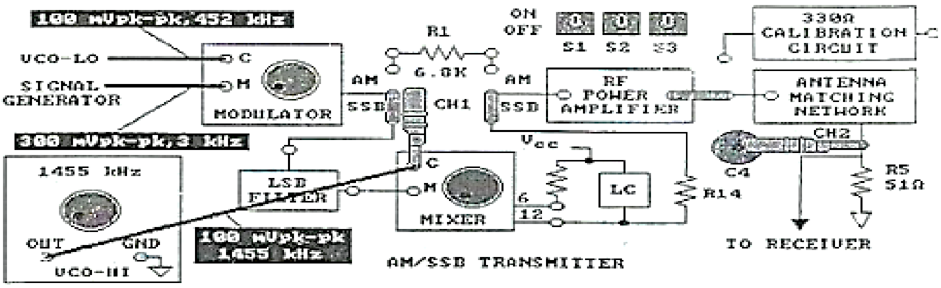

Figure 5-8.

12. Switch S1 should already be ON. Set S2 and S3 to ON.

13. Set channel for 50 mV/DIV and the sweep to 0.5 µs/DIV. Trigger on channel 1.

14. While observing the signal on channel 1, set the VCO-HI amplitude to 100 $mV_{pk\text{-}pk}$ at C on the MIXER by adjusting the potentiometer knob on the VCO-HI circuit block. Set the VCO-HI frequency to greater than 1455 kHz by turning the POSITIVE SUPPLY knob on the base unit completely CCW.

15. Set channel 2 for 200mV/DIV and the sweep for 0.5 µs/DIV. Trigger on channel 2.

16. While observing the output signal on channel 2, adjust the VCO-HI frequency to 1455 kHz by slowly turning the POSITIVE SUPPLY knob CW until the SSB signal's amplitude is maximum.

17. On channel 2, measure the peak-to-peak output voltage across R5. The SSB output should be about 650 $mV_{pk\text{-}pk}$, ± 35% with a 1000 kHz frequency.

4.2.2 Procedure B: RF Filter (Tune in the SSB Signal)

18. With a two-post connector, connect the TRANSMITTER to the 1 M Ω resistor (R8) at the AM/SSB RECEIVER circuit block. *(Refer to Figure 5-10.)*

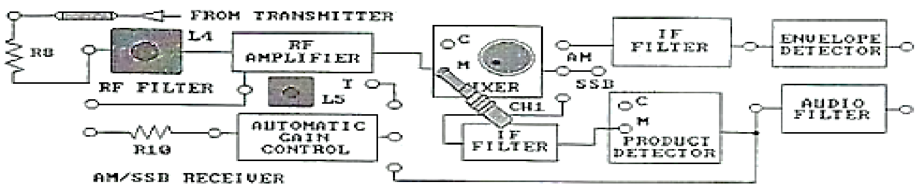

Figure 5-10.

19. Connect the channel 1 oscilloscope probe to the RF AMPLIFIER output.

20. Adjust inductor L5, which is in the RF AMPLIFIER collector circuit, to about the midpoint so that the 1000 kHz SSB signal appears on channel 1.

21. While observing the signal on channel 1, adjust inductor L4 for the maximum peak-to-peak signal at the RF AMPLIFIER output

22. At the 1000 kHz resonant frequency, does the circuit become inductive, capacitive or resistive and why?

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23. When is the input filter impedance at maximum?

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4.2.3 Procedure C: The RF Amplifier (Calculate Power Gain)

24. While observing the signal on channel 1, adjust variable inductor L5 in the RF AMPLIFIER collector circuit for the maximum peak-to-peak carrier signal at the RF AMPLIFIER output.

NOTE: *Whenever you make oscilloscope measurements or observations, be sure to connect the probe's ground clip to a ground terminal on the circuit board.*

25. On channel 1, measure the peak-to-peak voltage of the SSB signal at the RF AMPLIFIER output ($V_{RF(0)}$). Record your answer in millivolts.

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26. Convert the $V_{RF(0)}$ value that you measured in step 8 to an rms value ($V_{RF(0)rms} = V_{RF(0)pk\text{-}pk} \times 0.3535$). Use your result to calculate the SSB signal's rms power at the RF AMPLIFIER output. The RF AMPLIFIER output impedance is 2 kΩ. Record your answer in microwatts. ($P_{RF(0)} = V_{RF}^2/2\ k\Omega$)

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27. Using your $P_{RF(o)}$ from step 9, calculate and record the output power in decibels with reference to 1 mW (dBm). ($dBm_{RF(0)} = 10 \times [\log_{10} (P_{RF(0)}/1\ mW)]$)

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28. The input SSB signal power to the RF stage is typically -85 dBm for the given circuit conditions. From this input power and the output power you calculated in step 10, calculate the power gain of the RF stage in decibels.

(dB). ($Ap_{(RF)} = dBm_{RF(0)} - dBm_{RF(i)}$)

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4.2.4 Procedure D: Mixer and IF Filter (produce a 455KHz SSB)

29. Connect the output of the 1455 kHz VCO-HI circuit block, which also connects to the transmitter's mixer, to the local oscillator input (C) of the mixer. Connect the MIXER to the IF FILTER with a two-post connector, as shown in Figure 5-13.

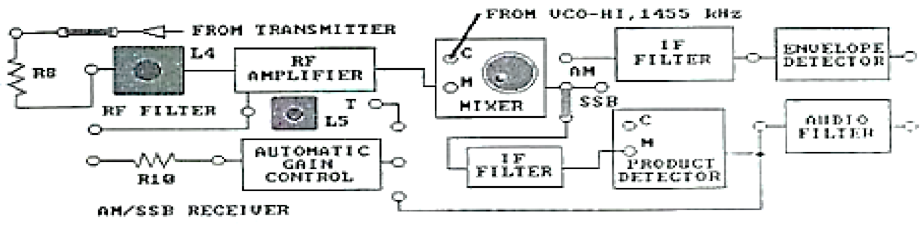

Figure 5-13.

30. Connect the oscilloscope channel 1 probe to the MIXER'S M input, and connect the channel 2 probe to the MIXER'S output. Set channel 2 to 200 mV/DIV and the sweep to 0.5 μs/DIV. Trigger on channel 1.

31. Adjust the MIXER'S null potentiometer so that a DSB signal appears at the mixer's output, as shown in Figure 5-14.

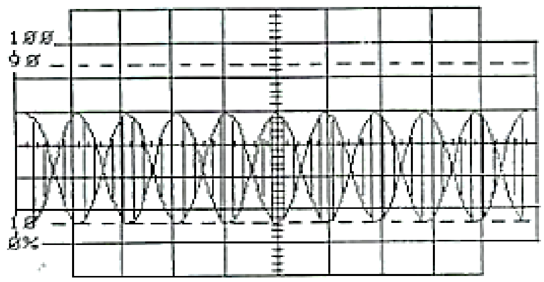

Figure 5-14.

32. What frequencies are present in the DSB from the MIXER?

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33. Connect the oscilloscope channel 2 probe to IF filter output at M on the PRODUCT DETECTOR. Set channel 2 to 100 mV/DIV, set the sweep to 1 μs/DIV, and trigger on channel 2.

34. Measure and record the period (T) between peaks of the SSB waveform at the IF FILTER output. Each vertical division line is 1 μs. *(Refer to Figure 5-15.)*

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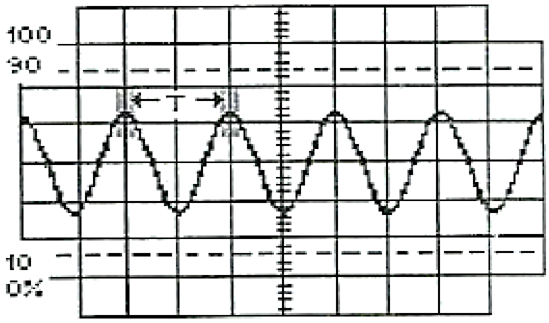

Figure 5-15.

35. From the period (T), calculate the frequency of the SSB waveform. Record your answer in kHz. (f = 1/T)

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4.3 Exercise 2: Product Detector

4.3.1 Procedure A: Connect and Adjust SSB transmitter and Receiver if not done yet.

In this PROCEDURE section, you will connect and adjust the SSB transmitter and receiver to provide a 455 kHz SSB signal to the product detector.

1. If necessary, generate a 1000 kHz SSB signal from the transmitter by performing Procedure A in Exercise 5-1.
2. Connect the circuit and the oscilloscope channel 1 probe, as shown in Figure 5-20.

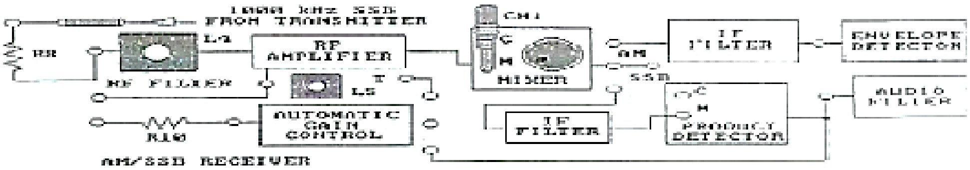

Figure 5-20.

3. Set oscilloscope channel 1 for 200 mV/DIV and the sweep to 0.5 μs/DIV. Trigger on channel 1.
4. While observing the channel 1 signal, adjust the RF AMPLIFIER inductor L5 to about midpoint so that a 1000 kHz SSB signal appears.
5. While observing the signal on channel 1, adjust inductor L4 for the maximum peak-to-peak carrier signal at the RF AMPLIFIER output.
6. While observing the signal on channel 1, adjust the RF AMPLIFIER inductor L5 for the maximum peak-to-peak carrier signal at the RF AMPLIFIER output.
7. On channel 1, measure the RF AMPLIFIER output peak to peak voltage. The RF AMPLIFIER output signal should be about 775 mV_{pk-pk} ± 35% and 1000 kHz.
8. Connect the circuit and the oscilloscope channel 1 and 2 probes, as shown in Figure 5-21.

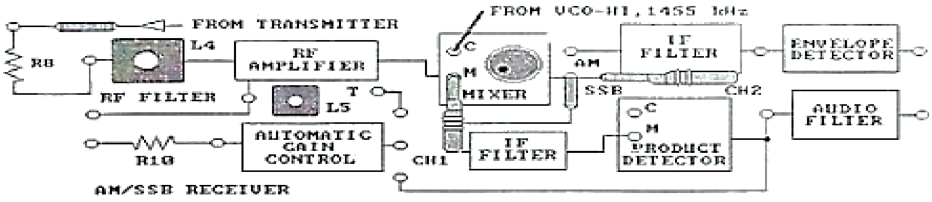

Figure 5-21.

9. The output of the 1455 kHz VCO-HI circuit block (which also connects to the transmitter's mixer) connects to the receiver's MIXER at C.

10. Set channel 1 for 200 mV/DIV and the sweep to 0.5 μs/DIV. Trigger on channel 1. Set oscilloscope channel 2 for 200 mV/DIV

11. On the AM/SSB RECEIVER circuit block, adjust the MIXER's null potentiometer so that a DSB signal appears at the MIXER's output The signal on channel 2 of your oscilloscope should appear, as shown in Figure 5-14.

12. Move the channel 2 probe to IF FILTER output, which is at M on the PRODUCT DETECTOR. Set the sweep to 0.1 μs/DIV and trigger on channel 2.

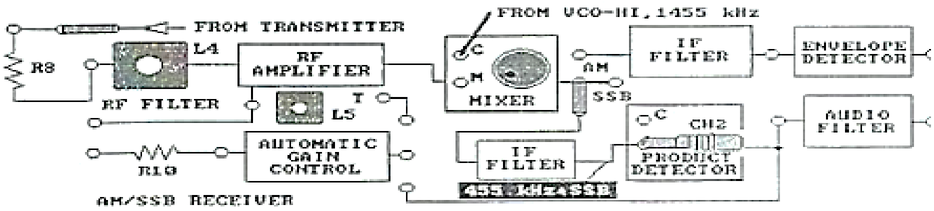

Figure 5-22.

13. On channel 2 measure the IF FILTER output peak-to-peak voltage.The IF FILTER output should be about 300 $mV_{pk\text{-}pk}$ ± 35% and 455 kHz.

4.3.2 Procedure B: Product Detector and Audio Filter(Recover the message Signal)

14. Connect the output of the 452 kHz VCO-LO circuit block (which also connects to the transmitter's modulator) to the BFO input (C) of the PRODUCT DETECTOR, as shown in Figure 5-23.

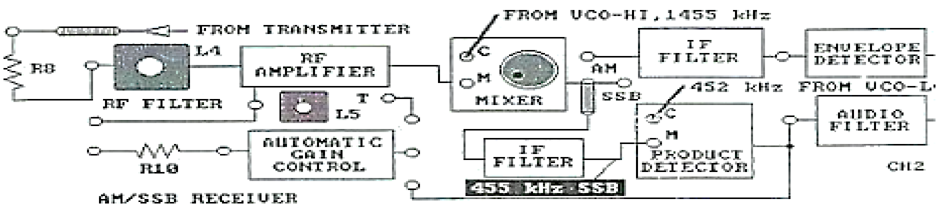

Figure 5-23.

15. Why should the BFO frequency be the same as the carrier frequency (452 kHz) to the transmitter's MODULATOR: to suppress the BFO frequency in the output, to properly recover the message signal, or to enable the audio filter to pass the recovered message signal?

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16. Connect the oscilloscope channel 2 probe to the PRODUCT DETECTOR'S output. Set the sweep to 0.1 ms/DIV and trigger on channel 1.

17. With oscilloscope channel 2 set to 200 mV/DIV and the sweep set to 0.1 ms/DIV, measure the period (T) between the peaks of the signal on channel 2, as shown in Figure 5-24.

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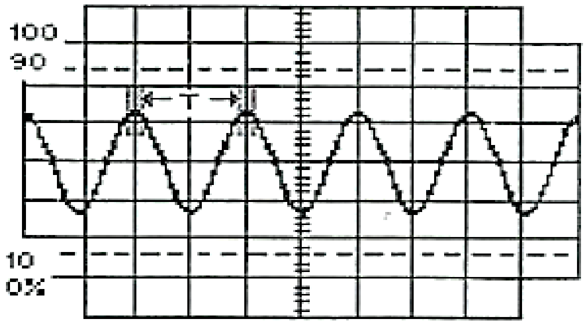

Figure 5-24.

18. Using the value of T that you just measured, calculate the frequency of the signal. Record your answer in kHz. (f = 1/T)

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19. The frequency you just calculated is the LSB signal in the PRODUCT DETECTOR'S output. Is this the frequency of the carrier signal, IF signal, or message signal?

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20. What is the USB frequency (f_{USB}) in the output of the PRODUCT DETECTOR? Record your answer in kHz.

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21. To observe the USB frequency that is very weak, yet still present, set the oscilloscope sweep to 1 μs/DIV and channel 2 to 50 mV/DIV. The signal should appear, as shown in the Figure 5-25. Does the slight waveform on channel 2 have a period of about 1.1 μs, which corresponds to a frequency of 907 kHz?

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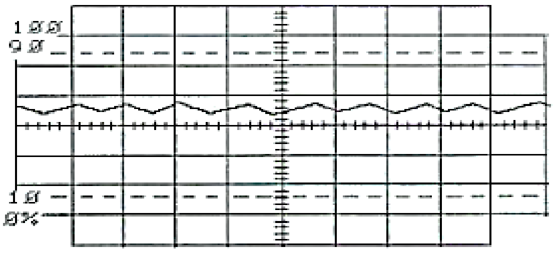

Figure 5-25.

22. Connect the oscilloscope channel 2 probe to the AUDIO FILTER'S output. Set channel 2 to 500 mV/DIV, set the sweep to 0.1 ms/DIV, and trigger on channel 2.

23. Connect the oscilloscope channel 1 probe to the MODULATOR'S message signal input (M) on the AM/SSB TRANSMITTER circuit block. Are the signals on channels 1 and 2 both 3 kHz?

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24. Adjust the AF FREQUENCY knob on the SIGNAL GENERATOR to vary the message signal frequency. Does the recovered message signal frequency at the output of the AUDIO FILTER (channel 2) vary with the changing message signal to the MODULATOR (channel 1)?

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4.4 Deliverables

- **Step 7**

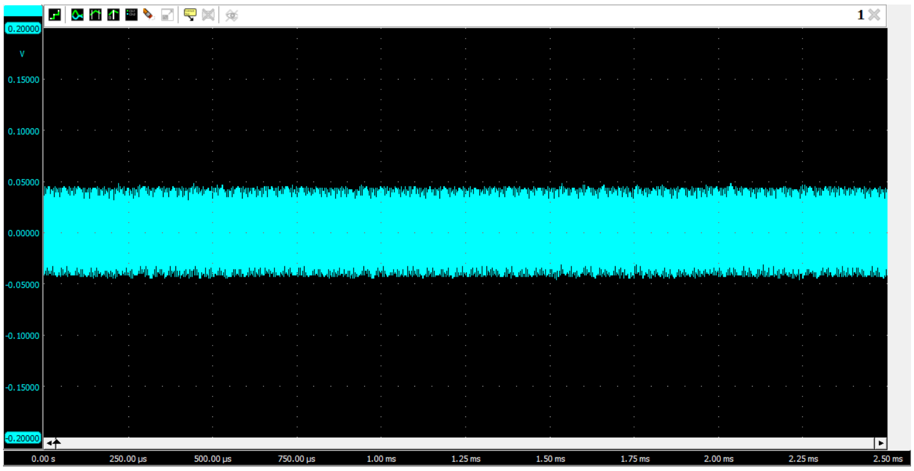


Figure 1: 100mV Peak to Peak Carrier Signal

- **Step 10**

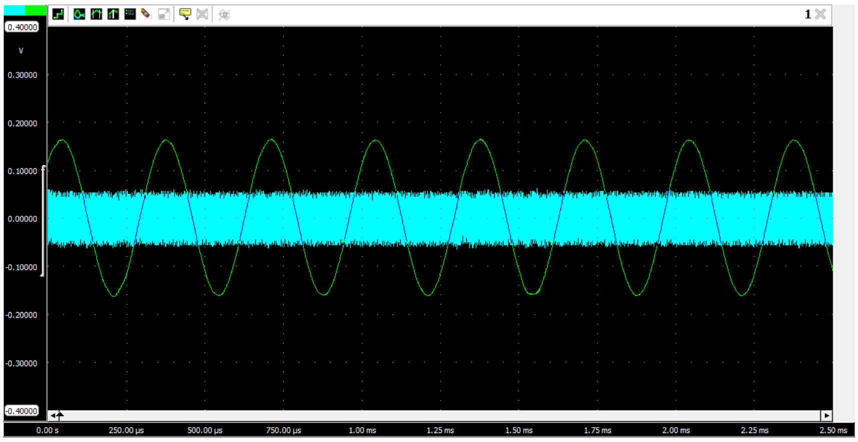


Figure 2: LSB Filter Output

- **Step 16**

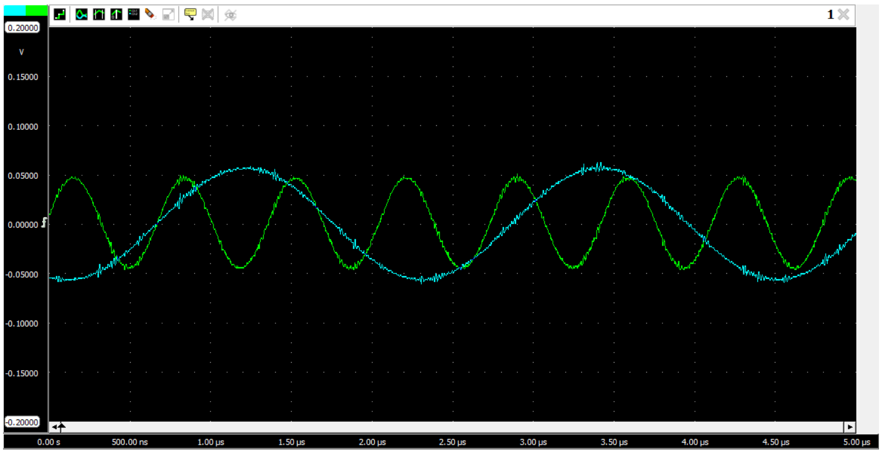


Figure 3: Signal across R5

- **Step 17**

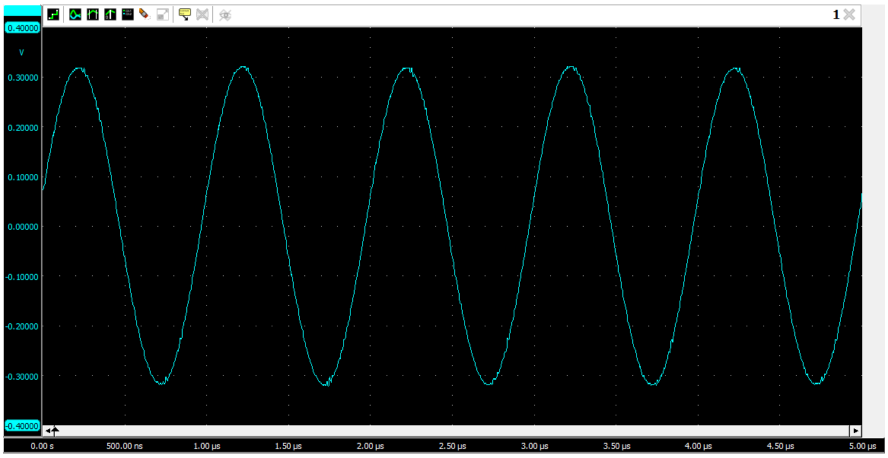


Figure 4: SSB Output

- **Step 18**

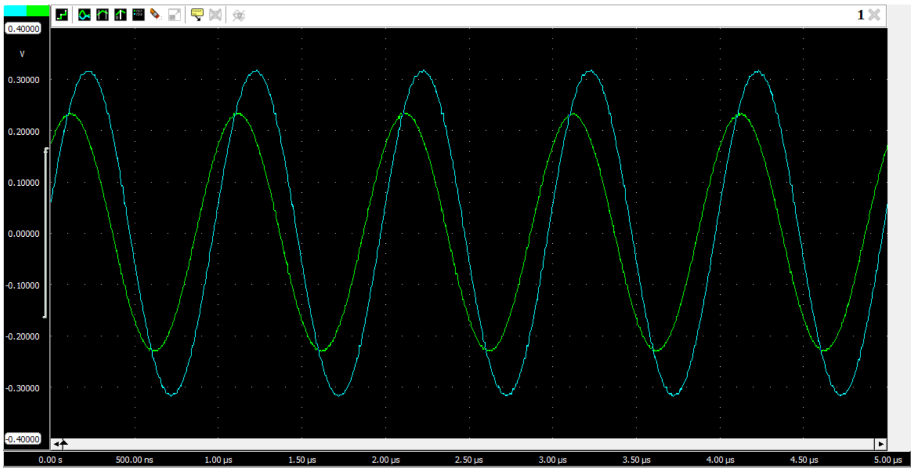


Figure 5: Receiver Block's INPUT

- **Step 25**

$V_{RF0_{P2P}}$ = 360 mV

- **Step 26**

$V_{RF0_{rms}}$ = 127.26 mV $P_{RF_{rms}}$ = 63.63 μW

- **Step 27**

$P_{RF0_{dBm}}$ = -11.96 dBm

- **Step 28**

Ap_{RF} = 73 dBm

- **Step 31**

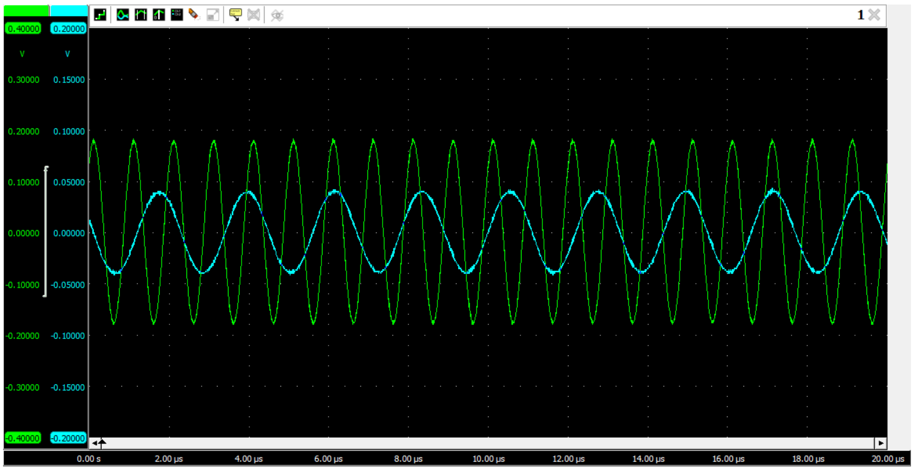
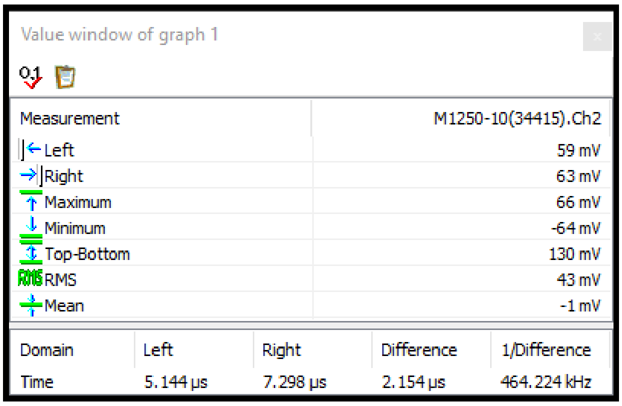


Figure 6: MIXER's Output

- **Step 34**


Value window of graph 1

Measurement	M1250-10(34415).Ch2
Left	59 mV
Right	63 mV
Maximum	66 mV
Minimum	-64 mV
Top-Bottom	130 mV
RMS	43 mV
Mean	-1 mV

Domain	Left	Right	Difference	1/Difference
Time	5.144 µs	7.298 µs	2.154 µs	464.224 kHz

- **Step 35**

f = 464.3 kHz

5 Conclusion

In conclusion, this helped us understand SSB reception circuits and signals by utilizing the AM/SSB RECEIVER circuit block present on the Analog Communication Circuit Board. By completing this lab, we attained knowledge about the different components of the SSB receiver circuit, such as the RF amplifier, mixer, local oscillator, IF amplifier, detector, and how they work together to extract the baseband signal from an SSB modulated RF signal. With this understanding, we will be able to apply this knowledge to design and implement SSB receiver circuits in various communication systems.