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Department of Electrical Engineering and Computer Science

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Section: BEE 12C

EE-351 Communication Systems

Lab 7: SSB Transmission

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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1 Table of Contents

2 SSB Transmission

2.1 Objectives

- You will be able to describe that how a balanced modulator is used to generate DSB signal, explain how the SSB is output from LSB filter. And explain how an SSB have low power consumption and narrow bandwidth.

2.2 Introduction

Balanced modulators are used to generate DSB signals by multiplying a carrier signal with the modulating signal. The modulating signal can either be an analog or digital signal. The balanced modulator produces two sidebands, upper and lower, which are symmetrically placed around the carrier frequency. To extract SSB signals from the DSB signal, a filtering process is required. The LSB filter can be used to remove the unwanted sideband, leaving only the desired SSB signal.

SSB signals have several advantages over DSB signals. They have lower power consumption and require less bandwidth, making them ideal for long-distance communication. Moreover, SSB signals can be easily demodulated using simple envelope detection circuits.

2.3 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

3 Exercise 1

3.1 Introduction

The first section of an SSB transmitter includes a balanced modulator and an LSB filter. The balanced modulator converts the message and carrier signals to a DSB signal. The LSB filter then removes one of the sidebands from the DSB to produce an SSB (Figure 4-3).

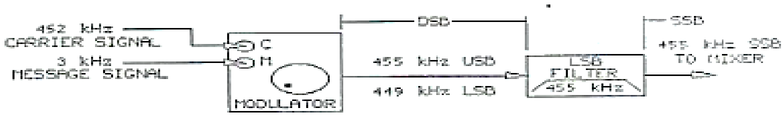

Figure 4-3.

The balanced modulator frequency translates a message signal to two sidebands and suppresses the carrier signal frequency to produce a DSB signal. To make filtering of a sideband easier, the carrier frequency (f_c) is relatively low (452 kHz). A low f_c provides a higher percentage of difference between upper and lower sideband frequencies than a high f_c would provide.

To produce an SSB signal from the DSB signal, a ceramic band pass filter with a narrow 4 kHz bandwidth removes the 449 kHz LSB signal. The 455 kHz USB signal is output from the filter and contains all of the 3 kHz message signal intelligence (Figure 4-4).

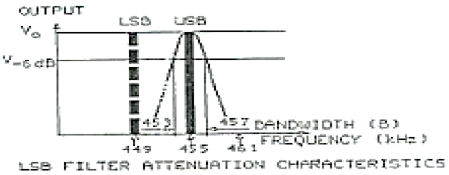

Figure 4-4.

4-5

A filter with a narrow bandwidth is necessary because the USB and the LSB are only 6 kHz apart; the SSB signal is the 455 kHz USB. Because of the narrow bandwidth of the filter, the carrier signal has to be exactly 452 kHz so that a 455 kHz USB frequency is present.

The advantages of SSB transmission are that:

1. Only 16.5% of the total 100% modulated AM signal power is required, because the carrier and one of the sidebands are not present.
2. The SSB bandwidth is less than half of the AM bandwidth.

These advantages are offset, however, because more components are required for an SSB transmitter than for an AM transmitter.

3.2 Procedure A: Balanced Modulator

1. Locate the AM/SSB TRANSMITTER and VCO-LO circuit blocks on the ANALOG COMMUNICATIONS circuit board, and connect the circuit shown (Figure 4-6). Be sure to place a two-post connector in the 452 kHz position on the VCO-LO circuit block. VCO-LO connects to the MODULATOR'S carrier signal input (C), and the SIGNAL GENERATOR connects to the MODULATOR'S message signal input (M).

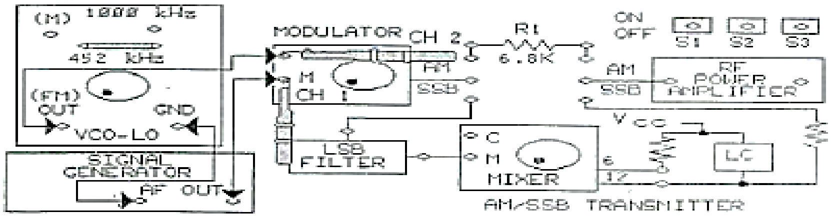

Figure 4-6.

2. Connect the oscilloscope channel 1 probe to the message signal input (M). While observing the signal on channel 1, adjust the signal generator for a 300 $mV_{pk\text{-}pk}$, 3 kHz sine wave (message signal) at M.
3. Connect the oscilloscope channel 2 probe to the carrier signal input (C). While observing the signal on channel 2, adjust the amplitude knob on VCO-LO for a 100 $mV_{pk\text{-}pk}$ carrier signal at C.
4. Turn the NEGATIVE SUPPLY knob on the left side of the base unit completely Counterclockwise (CCW) to adjust the VCO-LO frequency to less than 452 kHz.
5. Set switches S1, S2, and S3 to OFF. Adjust the MODULATOR'S potentiometer knob fully CCW.
6. Connect the oscilloscope channel 2 probe to the MODULATOR'S output. Set the oscilloscope vertical mode to channel 2, and trigger on channel 1 (the message signal). Set the channel 2 attenuation to 0.5 V/DIV, and set the oscilloscope sweep to 0.1 ms/DIV.
7. Slowly turn the MODULATOR'S potentiometer knob clockwise (CW) until the AM signal (channel 2) is less than (<) 100% modulated. Continue to turn the knob slowly CW until the AM signal is greater than (>) 100% modulated.
8. Continue to turn the knob slowly CW until the amplitude modulated signal appears, as shown in Figure 4-7. What type of amplitude modulated signal appears on channel 2?

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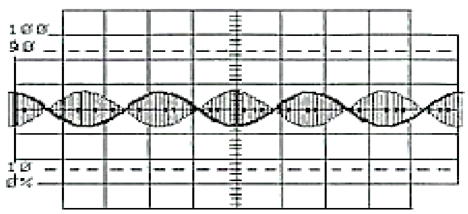

Figure 4-7.

9. The carrier signal frequency (f_c) is 452 kHz, and the message signal frequency (f_m) is 3 kHz. What frequencies are present in the frequency spectrum of the DSB signal?

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3.3 Procedure B: LSB Filter

10. Connect the LSB FILTER to the MODULATOR with a two-post connector, as shown. Set setup switch S1 to ON. Set setup switches S2 and S3 to OFF. In the previous PROCEDURE section, you connected and adjusted the VCO-LO signal for 100 mV_{pk-pk}; you connected and adjusted the SIGNAL GENERATOR for a 300 mV_{pk-pk}, 3 kHz signal.

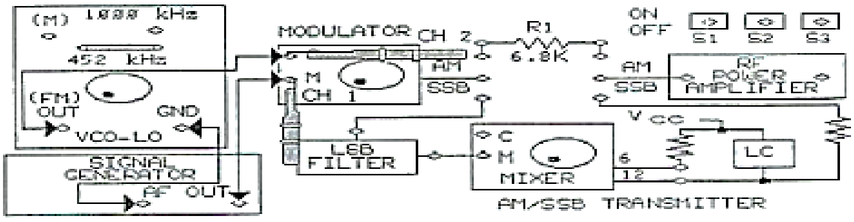

Figure 4-11.

11. Connect the oscilloscope channel 2 probe to the output of the LSB FILTER. Set the channel 2 attenuation to 50 mV/DIV. Connect the channel 1 probe to input M of the MODULATOR. Set the oscilloscope vertical mode to channel 2, trigger on channel 1, and set the sweep to 0.1 ms/DIV. The NEGATIVE SUPPLY knob on the base unit should be fully CCW.

12. A trace like the one in Figure 4-12 (a) appears at the USB FILTER output on channel 2. Increase the VCO-LO's frequency to the MODULATOR by slowly turning the NEGATIVE SUPPLY knob CW until the LSB FILTER'S output appears, as illustrated in Figure 4-12 (b).

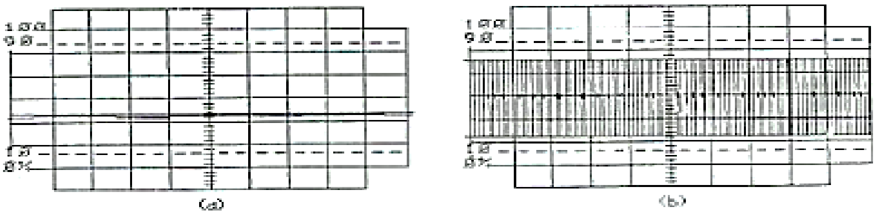

Figure 4-12 (a) and (b).

13. What is the LSB FILTER'S output signal that is shown on channel 2?

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14. Trigger the oscilloscope on channel 2, and set the oscilloscope sweep to 1 μs/DIV so that the channel 2 signal appears, as shown in Figure 4-13.

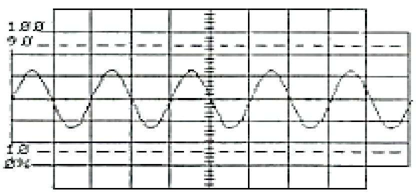

Figure 4-13.

15. While observing the 455 kHz signal at the LSB FILTER's output on channel 2, vary the amplitude of the 3 kHz message signal to the MODULATOR by varying the AF LEVEL knob on the SIGNAL GENERATOR. Does the amplitude of the 455 kHz signal vary with the amplitude of the 3 kHz message signal?

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16. How much of the message signal does the SSB signal contain?

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17. Which graph (Figure 4-14 (a) and (b)) shows the relationship of the filter's attenuation characteristic curve to the present LSB and USB frequencies being input to the USB FILTER?

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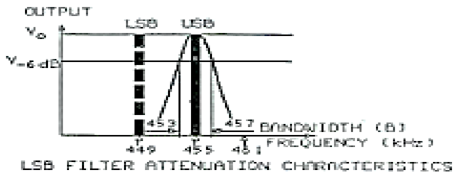

Figure 4-14 (a).

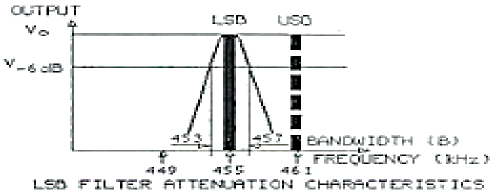

Figure 4-14 (b).

18. Trigger the oscilloscope on channel 1, and set the oscilloscope sweep to 0.1 ms/DIV. Continue to increase the oscillator's frequency by slowly turning the NEGATIVE SUPPLY knob CW until the channel 2 signal appears, as shown in Figure 4-15. What type of signal is the LSB FILTER'S output?

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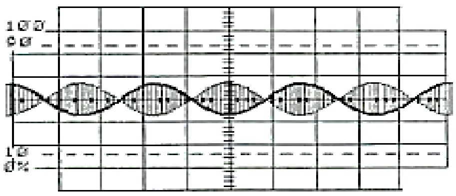

Figure 4-15.

19. What frequencies are in the LSB filter output?

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20. Continue to slowly increase the oscillator's frequency by turning the NEGATIVE SUPPLY knob CW until channel 2 appears, as shown in Figure 4-16. What type of signal is the LSB FILTER'S output?

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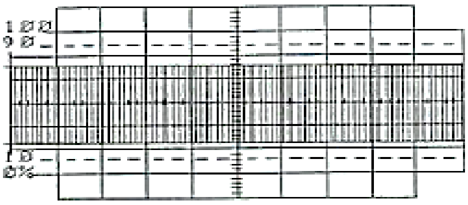

Figure 4-16.

21. Continue to increase the oscillator's frequency by slowly turning the NEGATIVE SUPPLY knob CW until the channel 2 signal is a thick line.

22. Which graph (Figure 4-17 (a) or (b)) represents the sideband frequencies in relationship to the filter's attenuation characteristic curve?

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3.4 Deliverables

- **Step 8**

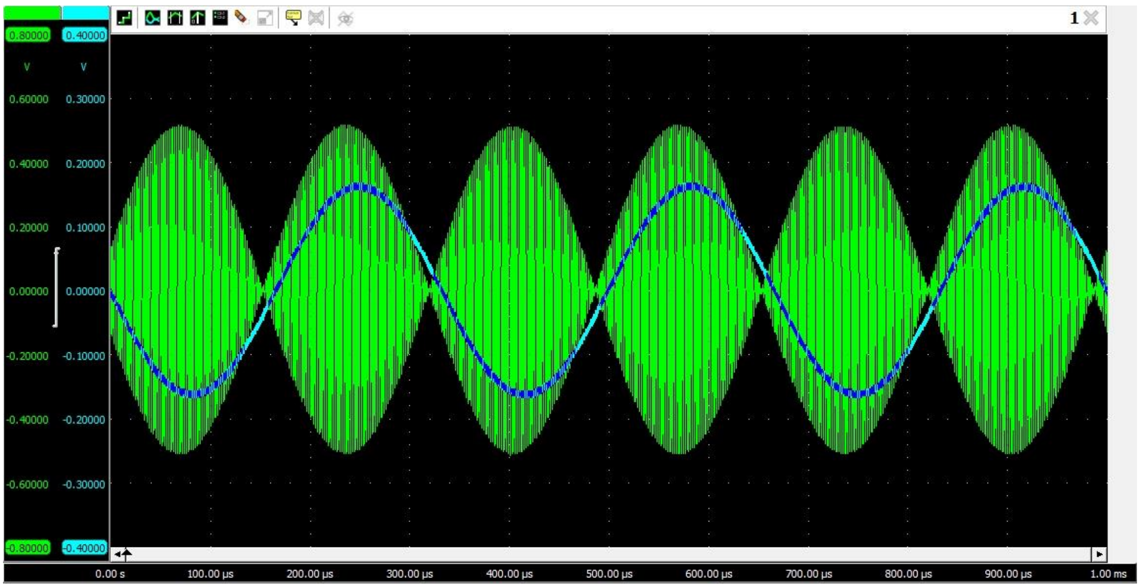


Figure 1: DSB Signal

- **Step 9**

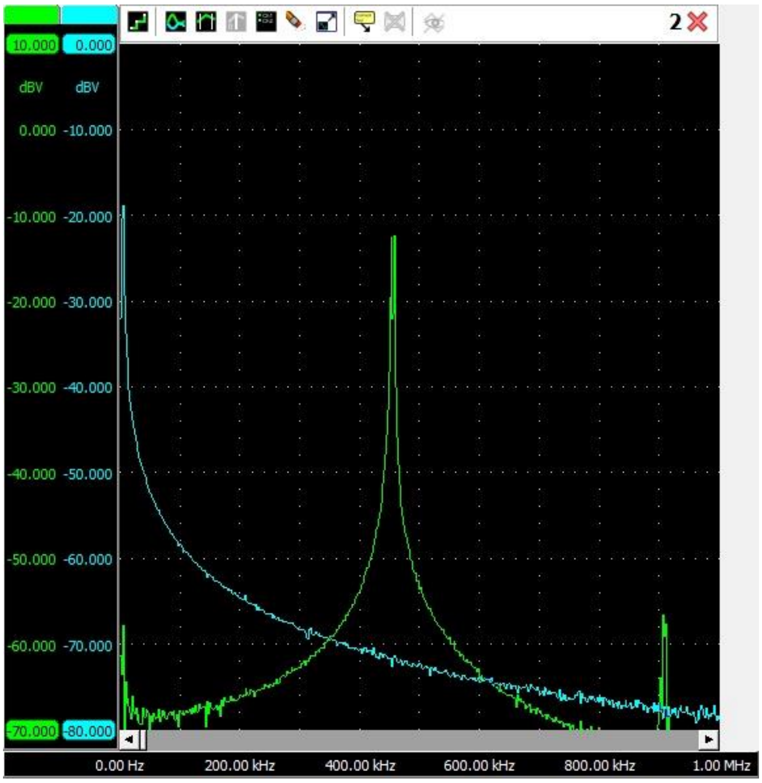


Figure 2: FFT Spectrum

- **Step 12**

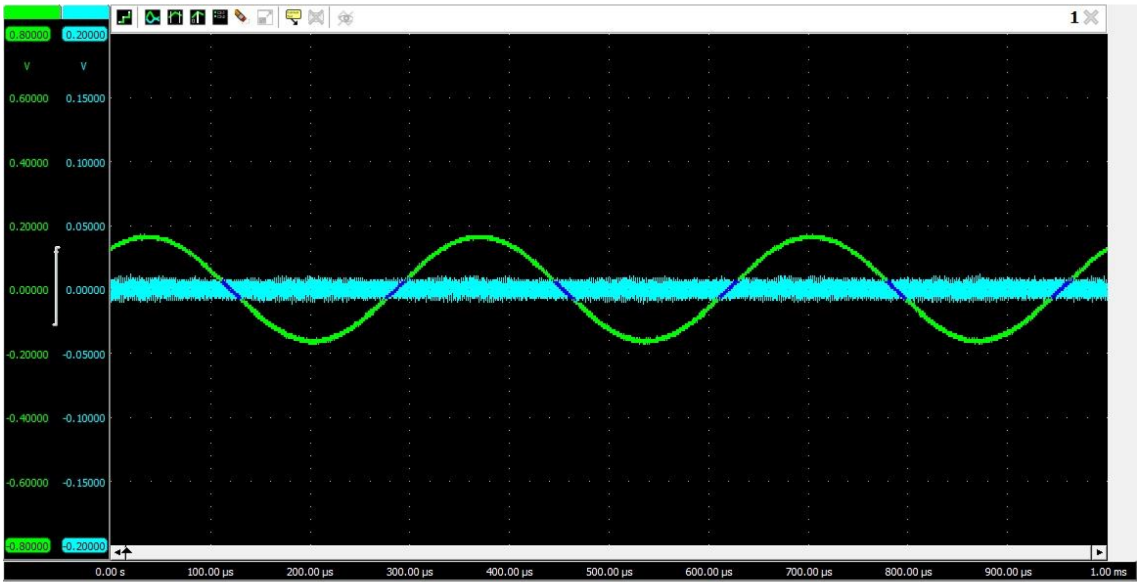
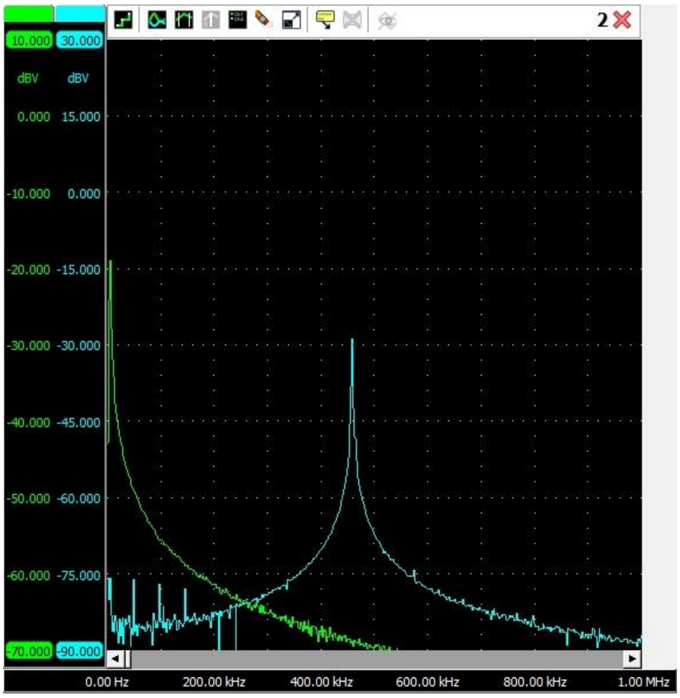


Figure 3: Filtered Output

- **Step 15**

Yes, the amplitude of the 455 kHz signal varies with the amplitude of the message signal.

- **Step 17**



The obtained spectrum possesses the type A attenuation characteristics.

- **Step 18**

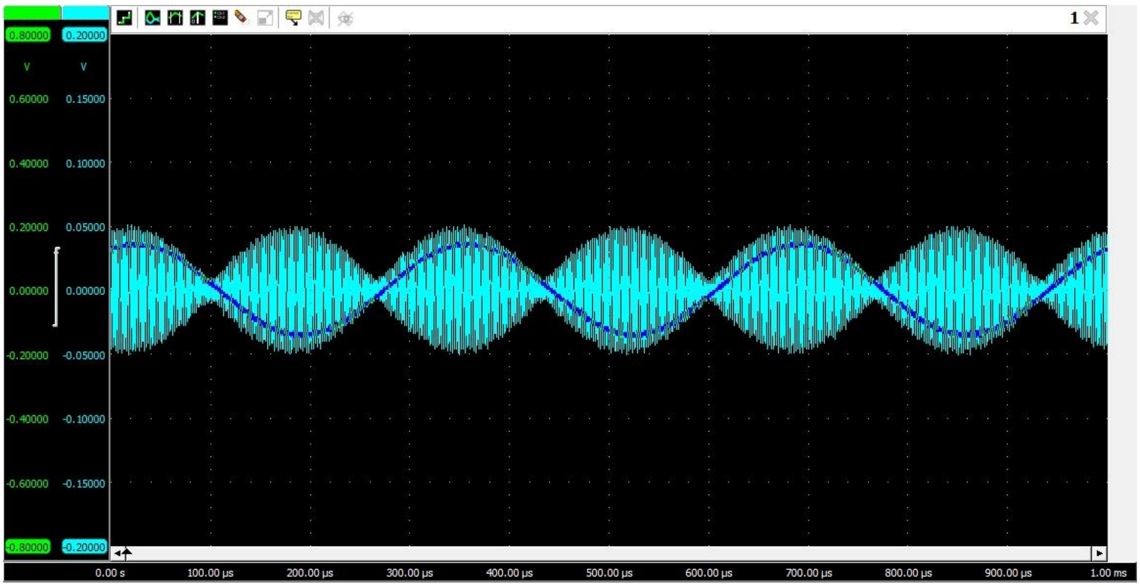


Figure 4: 100% Modulation

- **Step 19**

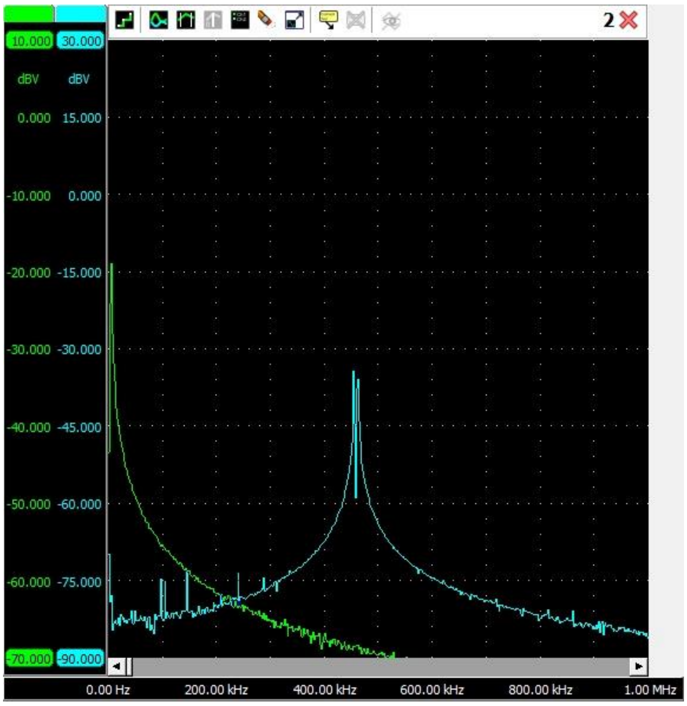


Figure 5: FFT Spectrum

- **Step 21**

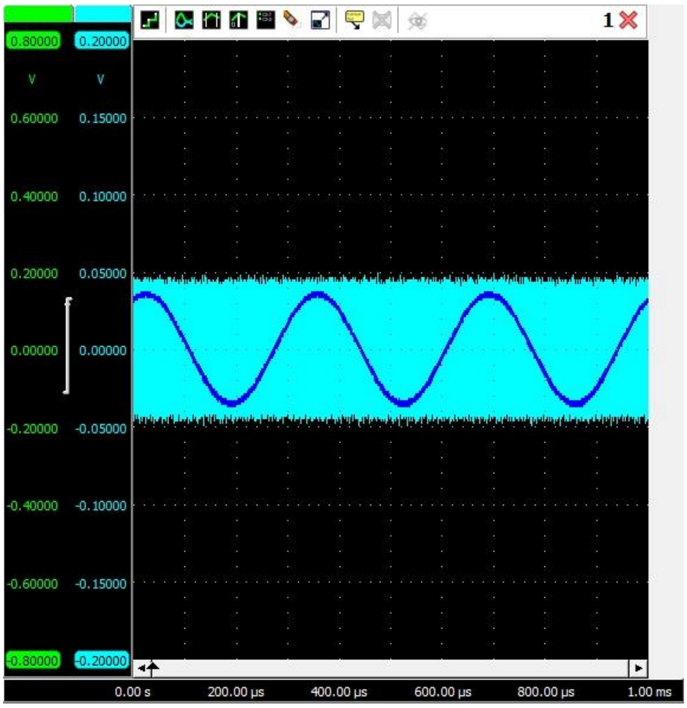


Figure 6: CW NEG Supply Output

- **Step 22**

The obtained spectrum possesses the type B attenuation characteristics

4 Exercise 2: Mixer and RF Amplifier

4.1 Introduction

The second section of the SSB transmitter frequency-translates the 455 kHz SSB to a 1000 kHz SSB and then increases the power of that signal before the antenna transmits the signal. The process of increasing the frequency of the 455 kHz SSB to a higher frequency for transmission is called an up-conversion (Figure 4-19).

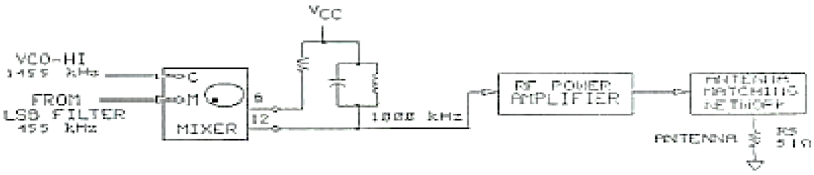


Figure 4-19.

The mixer, which is a balanced modulator, performs the up-conversion. The mixer combines the 455 kHz SSB signal with a 1455 kHz VCO-HI signal from an oscillator to produce a 1000 kHz SSB.

By adjusting the null potentiometer of the mixer until the output signal at pin 6 becomes a DSB, the 1455 kHz VCO-HI frequency in the output is then suppressed. An LC network that is tuned for 1000 kHz connects to the mixer's pin 12. The LC network passes the 1000 kHz SSB frequency to the RF Power Amplifier and filters all other frequencies (Figure 4-20). With the 455 kHz SSB message and 1455 kHz VCO-HI inputs to the balanced mixer, the LC network filters the 455 kHz (input) and 1910 kHz (sum) frequencies.

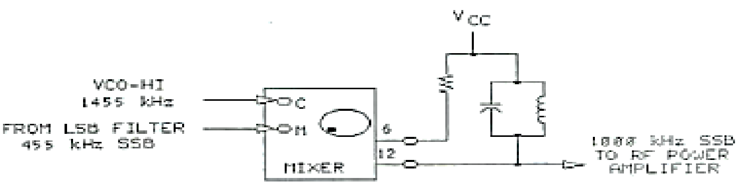


Figure 4-20.

The RF power amplifier has a tuned antenna matching network that increases the power of the 1000 kHz SSB signal radiated by the antenna (R5). The RF power amplifier with its antenna matching network uses the same circuits used in AM transmission.

For transmission of a 100% modulated AM signal, 66.7% of the total signal power (P_T) is required to transmit the carrier frequency, which contains no message signal intelligence; the carrier signal power is wasted. The sideband frequencies, which contain the message intelligence, consume 33.3% of the total power (Figure 4-21).

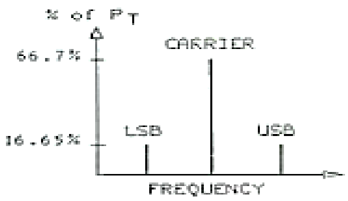


Figure 4-21.

4.2 Procedure A: Adjust the Circuit for a 455 kHz to the MIXER

1. To connect and adjust the SSB TRANSMITTER circuit for an SSB signal to the MIXER, first connect the circuit shown. Be sure to place a two-post connector in the 452 kHz position on the VCO-LO circuit block. The LSB FILTER connects to the MODULATOR with another two-post connector (Figure 4-22).

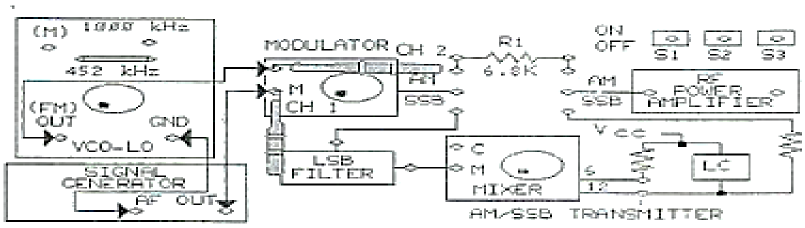


Figure 4-22.

2. Connect the oscilloscope channel 1 probe to the MODULATOR'S M input. While observing the signal on channel 1, adjust the signal generator for a 300 mV_{pk-pk}, 3 kHz sine wave (message signal) at M.
3. Turn the NEGATIVE SUPPLY knob on the left side of the base unit fully CCW to set the VCO-LO frequency less than 452 kHz.
4. Connect the channel 2 probe to the MODULATOR'S C input. While observing the signal on channel 2, adjust the amplitude knob on VCO-LO for a 100 mV_{pk-pk} carrier signal at C.
5. Set switch S1 to ON to automatically output a DSB from the MODULATOR. Set S2 and S3 to OFF.
6. Connect the channel 2 probe to the M input of the MIXER. Set the oscilloscope channel 2 attenuation to 50 mV/DiV, set the vertical mode to channel 2, trigger on channel 1, and set the sweep to 0.1 ms/DIV.

7. A trace appears at the LSB FILTER output on channel 2 (Figure 4-23 (a)). Slowly increase the VCO-LO's frequency to the MODULATOR by turning the NEGATIVE SUPPLY knob CW until the LSB FILTER'S output amplitude is maximum (Figure 4-23 (b)). This output is an SSB signal.

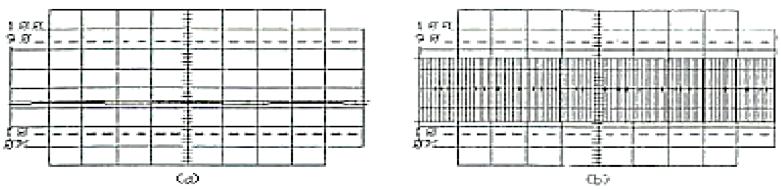


Figure 4-23 (a) and (b).

4.3 Procedure B: Convert the 455 kHz SSB to a 1000 kHz SSB

8. Connect the output of the VCO-HI circuit block to input C of the MIXER (Figure 4-25).

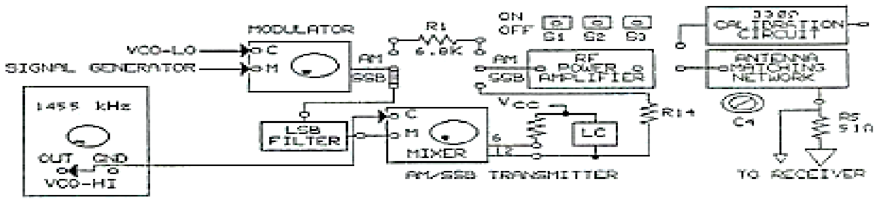


Figure 4-25.

9. Set S1 to ON to automatically output a DSB from the MODULATOR. Set S2 and S3 to OFF.
10. Connect the channel 2 probe to the MIXER'S C input. Adjust the VCO-HI signal to 100 mV_{pk-pk} with the VCO-HI potentiometer knob.
11. Set the VCO-HI frequency to approximately 1455 kHz by adjusting the POSITIVE SUPPLY knob on the base unit.
12. Connect channel 1 to the filter's output, and trigger on channel 1.
13. Connect channel 2 to the MIXER'S pin 6 output. Adjust the MIXER'S potentiometer knob for a DSB signal at pin 6.
14. Connect channel 2 to the MIXER'S pin 12 output. Fine tune the 1455 kHz VCO-HI frequency by adjusting the POSITIVE SUPPLY knob on the base unit for the maximum SSB signal at pin 12.
15. Trigger on channel 2. Set the oscilloscope sweep to 0.5 µs/DIV. The signal at pin 12 should appear as shown. If it does not, slightly adjust the MIXER'S potentiometer knob so that the signal appears .
16. Measure and record the period (T) between peaks of the waveform (Figure 4-23). Each horizontal division is 0.5 µs.

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17. What is the output signal's frequency at pin 12 ?(Calculate the answer from the time period.)

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18. While observing the 1000 kHz SSB signal at the MIXER'S pin 12, vary the amplitude of the 3 kHz message signal to the MODULATOR by varying the AF LEVEL knob on the SIGNAL GENERATOR. Does the amplitude of the 1000 kHz signal at pin 12 vary with the changing amplitude of the 3 kHz message signal?

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19. Connect the channel 2 probe to M of the MODULATOR, and adjust the SIGNAL GENERATOR for a 300 mV_{pk-pk}, 3 kHz message signal (the original setting).

4.4 Procedure C: RF Power Amplifier and Antenna Matching Network

20. With two-post connectors, connect the RF POWER AMPLIFIER to the MIXER and the ANTENNA MATCHING NETWORK (Figure 4-27).

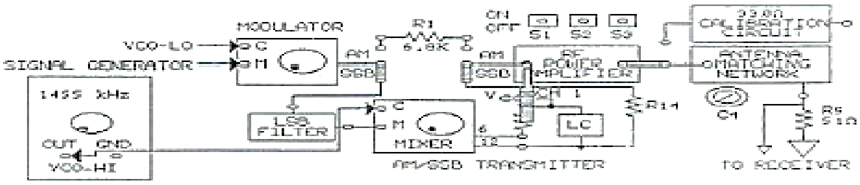

Figure 4-27.

21. Set S1, S2, and S3 to ON. When S1 and S2 are on, they automatically balance the MODULATOR and MIXER, respectively, for DSB signals. When S3 is on, the ANTENNA MATCHING NETWORK impedance is automatically set to 330Ω.

22. Connect the channel 1 probe to the input of the RF POWER AMPLIFIER. Measure and record the peak-to-peak voltage.

23. With the existing circuit conditions, the input current (I_i) to the RF POWER AMPLIFIER is about 26 μArms. Using the V_i value of 23.7 mVrms, calculate the input power ($P_i = V_i \times I_i$).

24. Connect the channel 2 probe to the output of the ANTENNA MATCHING NETWORK. Measure and record the peak-to-peak output voltage across R5 (Vo). This resistor simulates the impedance of the transmitting antenna.

25. Calculate the rms power dissipated by R5 (P_o). $((.353\ P_o)^2/51)$

23. With the existing circuit conditions, the input current (I_i) to the RF POWER AMPLIFIER is about 26 μArms. Using the V_i value of 23.7 mVrms, calculate the input power ($P_i = V_i \times I_i$).

24. Connect the channel 2 probe to the output of the ANTENNA MATCHING NETWORK. Measure and record the peak-to-peak output voltage across R5 (Vo). This resistor simulates the impedance of the transmitting antenna.

25. Calculate the rms power dissipated by R5 (P_o). $((.353\ P_o)^2/51)$

26. Calculate the power gain (Ap) across the RF POWER AMPLIFIER and the ANTENNA MATCHING NETWORK. ($A_p = P_o/P_i$)

27. In a 100% modulated AM signal, the USB accounts for 16 65% of the total signal power. If the SSB power that you measured across R5 was part of the 100% modulated AM signal's power, what is the total signal power (P_T) of the 100% modulated AM signal? ($P_T = P_o/0.1665$)

28. If you were using a message signal that contained frequencies from 1 kHz to 3 kHz, the SSB signal would have a 2 kHz bandwidth (from 1001 kHz to 1003 kHz). What is the bandwidth (B) of a 100% modulated signal containing a message signal with frequencies between 1 kHz and 3 kHz?

4.5 Deliverables

- **Step 7**

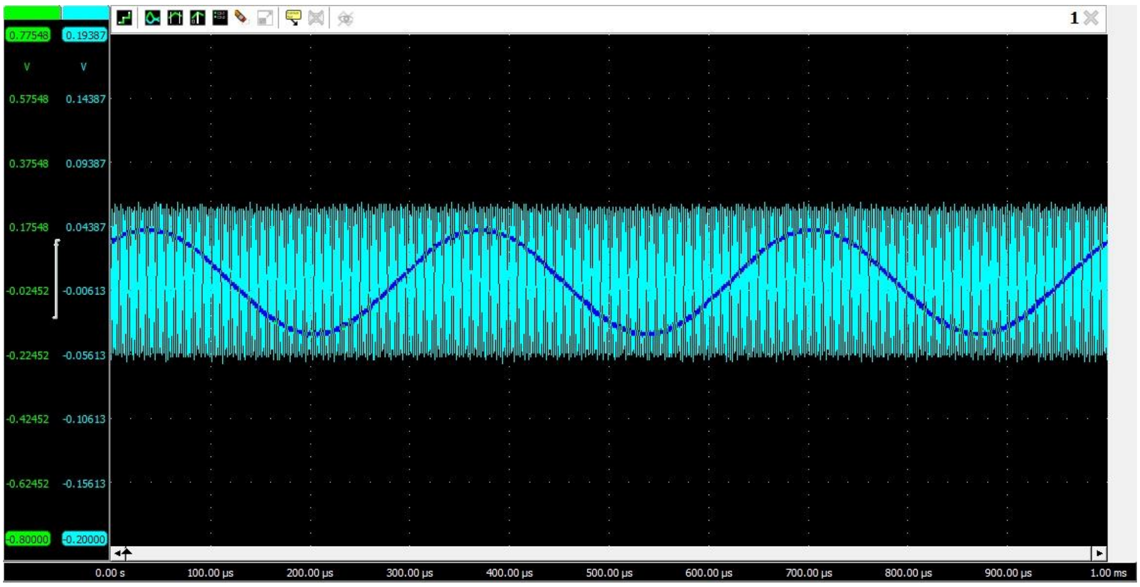

Figure 7: LSB Filter Output Trace

- **Step 13**

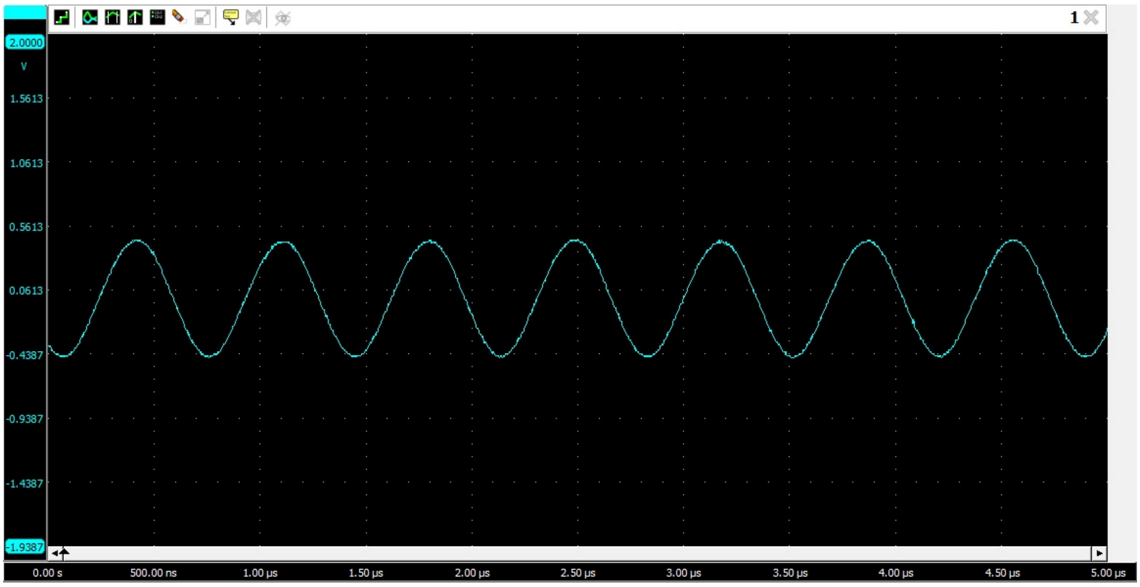

Figure 8: DSB Signal

- **Step 16**

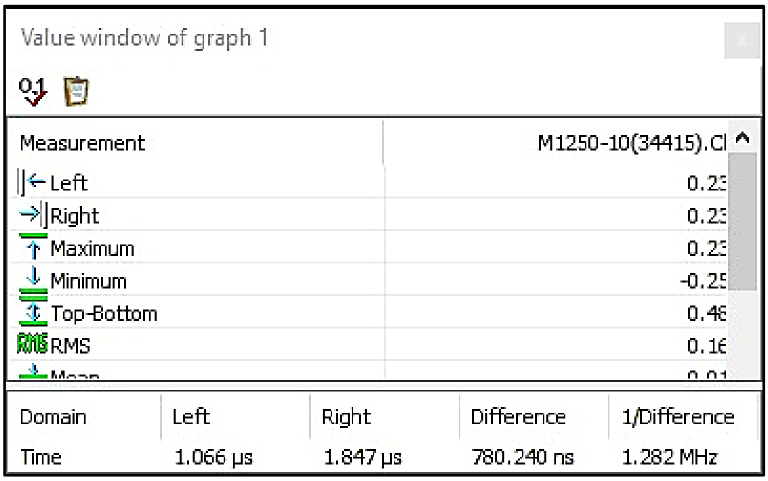

Figure 9: Period T Calculation

T = $780.240\ ns$

- **Step 17**

f = $1.282\ MHz$

- **Step 18**

No, the amplitude of the 1000 kHz signal does not vary with the amplitude of the message signal.

- **Step 22**

$V_{p\text{-}p} = 60\ mV$

- **Step 23**

$P_i = 0.312\ uV$

- **Step 24**

$V_o = 210\ mV$

- **Step 25**

$P_o = 107\ \mu W$

- **Step 26**

$A_p = 343$

- **Step 27**

$P_t = 647\ \mu W$

- **Step 28**

$BW = 4\ kHz$

5 Conclusion

In conclusion, the use of a balanced modulator to generate DSB signals and the extraction of SSB signals from them using a LSB filter have been discussed in this report. SSB signals offer several advantages over DSB signals, such as low power consumption and narrow bandwidth. The practical applications of these modulation techniques are widespread, and they are commonly used in radio communication and signal processing.