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EE-351 Communication Systems

Lab 5: AM Reception and RF Stage

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 Table of Figures

3 RF Power Amplifier

3.1 Objectives

- When you have completed this exercise, you will be able to calculate the AM signal power at an RF filter input, describe how an RF filter is tuned to filter an AM signal, and calculate the power gain of an RF amplifier. You will use an oscilloscope to make AM signal measurements.

3.2 Introduction

Radio frequency (RF) amplifiers and amplitude modulation (AM) are critical components in modern communication systems. RF amplifiers are used to amplify low power RF signals, while AM is a widely used technique in broadcasting to carry information through radio waves.

The purpose of this lab report is to explore the properties and characteristics of RF amplifiers, including measurements of amplifier gain, and frequency response characteristics. 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

On the circuit board, you will set up the AM transmitter to transmit a 100% modulated AM signal to the AM receiver.

The transmitted AM signal is sent by a direct connection between the transmitter and receiver on your circuit board, not through the airwaves as in regular radio transmission. See Figure 3-3. A 1 MΩ resistor in this connection reduces the AM signal power at the RF filter input.

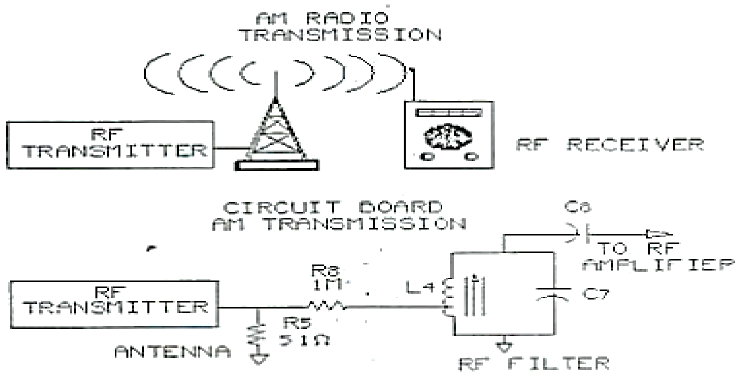

Figure 3-3.

The RF stage in the AM/SSB RECEIVER circuit block contains an RF FILTER and an RF AMPLIFIER. On your circuit board, when you adjust variable inductor L4 for the transmitted 1 MHz AM signal, all frequencies outside the RF filter bandwidth are rejected (attenuated). Refer to Figure 3-4. The RF filter bandwidth is large enough to pass the upper sideband (USB) and lower sideband (LSB) frequencies, which are on each side of the 1000 kHz carrier frequency (f_c). When the filter is tuned, f_c is the filter's resonant frequency.

Remember from Unit 2 that the USB = $f_c + f_m$ and the LSB = $f_c - f_m$. With a 1000 kHz carrier signal (f_c) that contains a 2 kHz message signal (f_m).

the frequency of the USB is 1002 kHz, and the frequency of the LSB is 998 kHz.

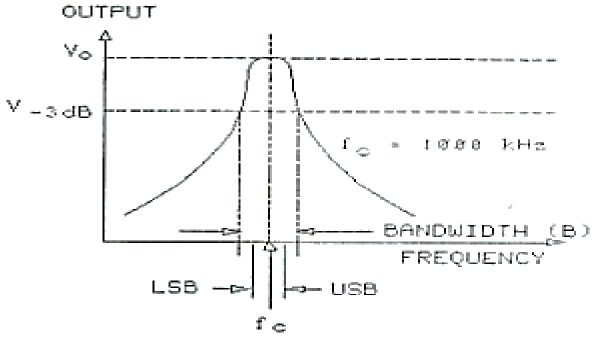

Figure 3-4.

Refer again to the CIRCUIT BOARD AM TRANSMISSION section of Figure 3-3. When you adjust the RF filter to remove undesired frequencies (pass the desired AM signal), the filter provides a 50Ω matching impedance between its inductor (L4) tap and ground for the receiving antenna. On the circuit board, there is no receiving antenna, but the signal at the L4 tap represents a signal received by an antenna.

The RF AMPLIFIER, illustrated in Figure 3-5, is a single-ended differential amplifier composed of two transistors: Q2 and Q3. The input connects to the bases of Q2 and Q3; the base of Q3 is grounded for ac signals. The emitters of Q2 and Q3 connect to the collector of Q4, which functions as a constant-current source. Q3 is a common base amplifier.

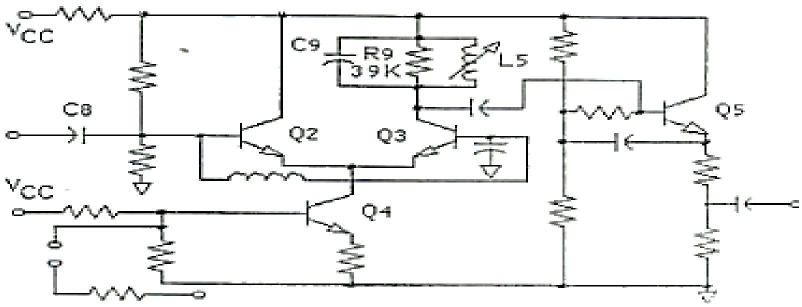

Figure 3-5.

The Q3 collector is connected to an RLC network, which contains a variable inductor (L5). The Q3 collector is coupled to the base of Q5, which functions as an emitter-follower buffer. The RF amplifier output is at C10 in the Q5 emitter circuit. The power gain of the RF amplifier is very high so that the amplifier can greatly increase the power level of the AM signal selected by the RF filter.

4.2 Procedure A: Connect an AM Transmitter Circuit

In this PROCEDURE section, you will connect and adjust the AM transmitter and use the transmitter's output signal as the receiver's input signal.

1. Connect the AM transmitter circuit, as shown in Figure 3-6.

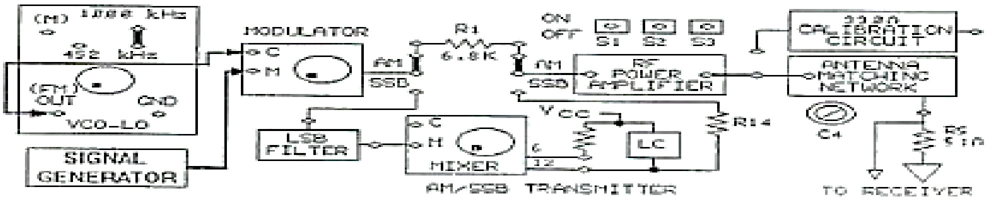

Figure 3-6.

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).

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

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, as shown in Figure 3-7 on the next page.

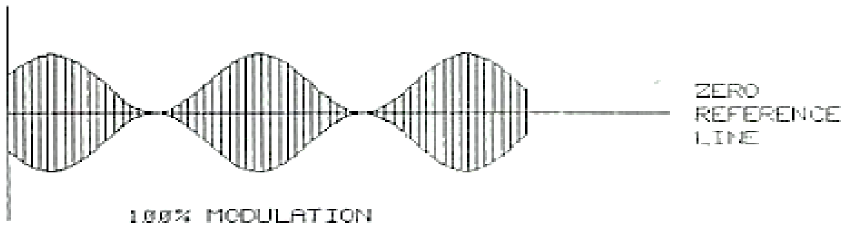

Figure 3-7.

4.3 Procedure B: RF Filter: Input Power

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 3-9). Connect the channel 1 oscilloscope probe to the R8 input. Is the transmitted AM signal at the R8 input?

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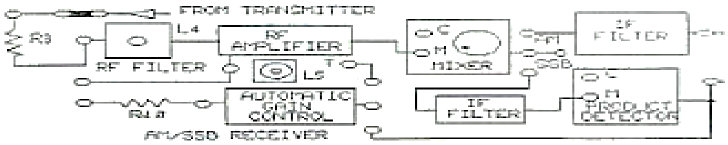

Figure 3-9.

12. To simplify signal observations and adjustments at the RF FILTER and RF AMPLIFIER, use only the 1000 kHz carrier signal as the transmitted signal. On the AM/SSB TRANSMITTER circuit block, disconnect the signal generator from the MODULATOR message signal input (M).

13. On channel 1, measure the peak-to-peak voltage of the carrier signal at the input to R8.

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14. Calculate and record the carrier signal's peak-to-peak voltage at the RF FILTER input. Use the voltage divider equation:

$$[V_{RF(i)} = V_{R8} \times (50/1{,}000{,}050)].$$

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15. Convert the $V_{RF(i)pk\text{-}pk}$ value that you calculated in step 14 to an rms value ($V_{RF(i)rms} = V_{RF(i)pk\text{-}pk} \times 0.3535$). Use your result in the following equation to calculate the carrier signal's rms power using 50Ω as the input impedance. Record your answer in picowatts.

$$P_{RF(i)rms} = (V_{RF(i)rms})^2/50$$

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4.4 Procedure C: RF Filter (Adjust for AM Signal)

16. No connections are necessary in the RF FILTER and RF AMPLIFIER sections of the receiver circuit except for the two-post connector that connects the TRANSMITTER circuit. Figure 3-11 shows the RF FILTER and RF AMPLIFIER schematic.

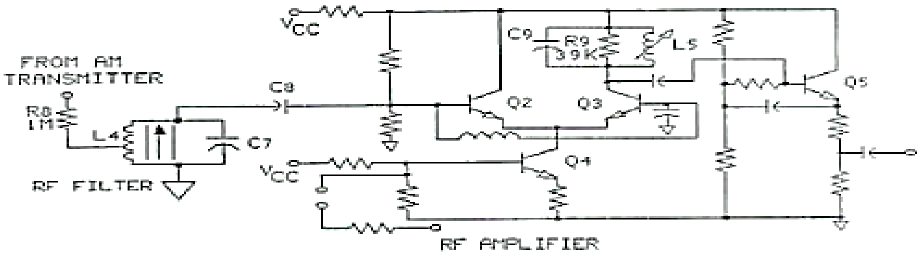

Figure 3-111.

17. Connect the channel 1 oscilloscope probe to the RF AMPLIFIER output. Adjust L5 at about the midpoint so that a signal appears on channel 1.

18. Adjust inductor L4 for the maximum peak-to-peak signal at the RF AMPLIFIER output. What is the resonant frequency (f_r) of the RF FILTER?

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19. With the 1000 kHz carrier signal and a 2 kHz message signal, what is the LSB that the RF filter has to pass?

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20. With a 1000 kHz carrier signal and a 2 kHz message signal, what is the RF FILTER's minimum bandwidth (bw) necessary to pass the received AM signal?

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4.5 Procedure D: RF Power Amplifier (Maximize Gain)

21. While observing the signal on channel 1, adjust variable inductor R5 in the RF AMPLIFIER collector circuit for the maximum peak-to-peak carrier signal at the RF AMPLIFIER output.

22. On channel 1, measure the peak-to-peak voltage of the carrier signal at the RF AMPLIFIER output ($V_{RF(0)}$). Record your result.

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23. Convert the $V_{RF(o)pk\text{-}pk}$ value that you calculated in step 22 to an rms value ($V_{RF(0)rms} = V_{RF(0)pk\text{-}pk}$) x 0.3535). Use your result in the following equation to calculate the carrier signal's rms power at the RF AMPLIFIER output. The RF AMPLIFIER output impedance is 2 kΩ. Record your result in microwatts. $P_{RF(0)} = V_{RF(0)}{}^2/2\ k\Omega$

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24. The carrier signal's input and output power to and from the RF stage (RF FILTER and RF AMPLIFIER) are shown. Calculate and record the input power in decibels with reference to 1 mW (dBm).

$$dBm_{RF(i)} = 10 \times [\log_{10} (P_{RF(i)}/1\ mW)]$$

HINT: *Convert pW and mW to watts before dividing.*

25. Calculate the output power in decibels with reference to 1 mW (dBm).

$$dBm_{RF(0)} = 10 \times [\log_{10} (P_{RF(0)}/1\ mW)]$$

26. From the input and output power in dBms, calculate the power gain of the RF stage in dB.

$$Ap_{RF} = dBm_{RF(o)} - dBm_{RF(i)}$$

4.6 Deliverables

- **Step 9**

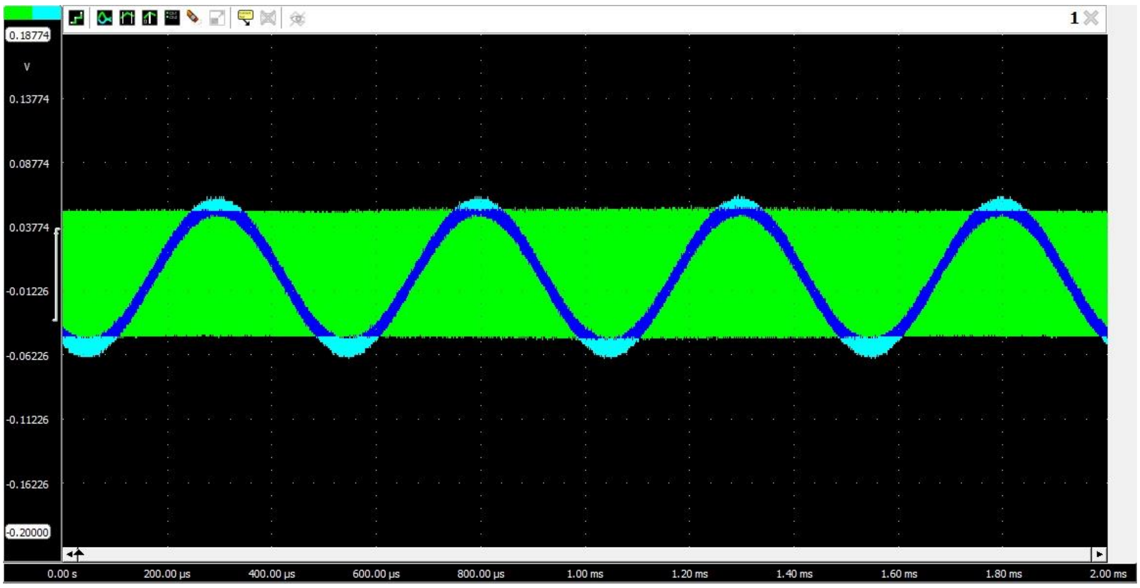

Figure 1: Message (M) and Carrier Signal (C) at MODULATOR Input

- **Step 10**

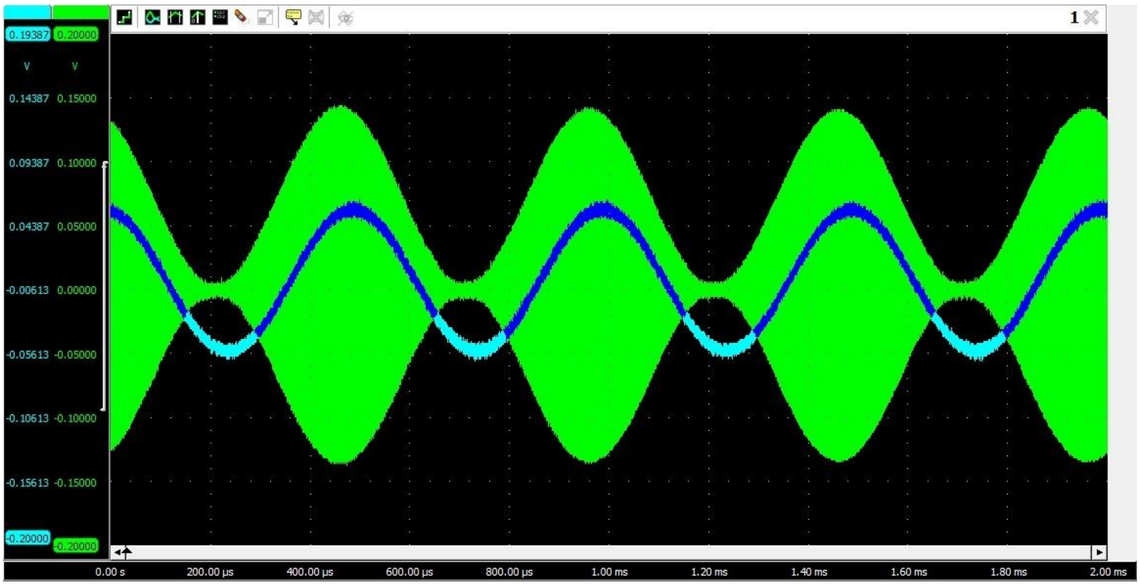

Figure 2: 100% Modulation AM Signal

- **Step 11**

Yes, the transmitted AM signal is at R8 input.

- **Step 13**

Peak to Peak voltage is 223mV.

- **Step 14**

Using the Voltage divider equation, we get 16mV.

- **Step 15**

$\mathbf{P_{RF(i)}} = V^2_{RF(i)\ RMS} / 50 = \mathbf{0.311\ pW}$

- **Step 18**

The Resonant Frequency of the RF Filter came out to be 1MHz

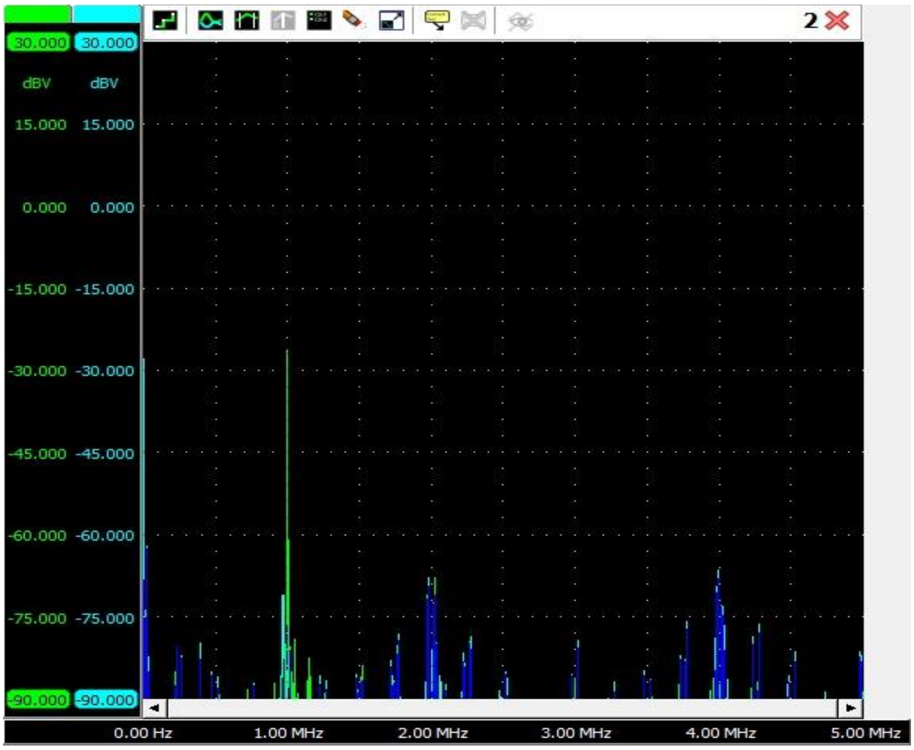

Figure 3: Frequency Spectrum to get Resonant Frequency

- **Step 19**

In this case, the RF stage will pass the lower sideband, which has a frequency of 998 kHz

Measurement	20*Log1(FFT3)	20*Log2(FFT4)
Left	-90.513 dBV	-118.918 dBV
Right	-81.294 dBV	-81.124 dBV
Maximum	-69.597 dBV	-67.890 dBV
Minimum	-100.096 dBV	-130.062 dBV
Top-Bottom	30.500 dBV	62.171 dBV
Mean	-92.052 dBV	-106.770 dBV

Domain	Left	Right	Difference	1/Difference
Frequency	1.015 MHz	1.021 MHz	5.459 kHz	-

Figure 4: Cursors of the Frequency Spectrum

- **Step 20**

With a 1000Hz carrier signal and a 2kHz message signal, the minimum band width will be 1002-998Hz. Which comes out to be **4kHz.**

- **Step 22**

$\mathbf{V_{RF(o)} = 230mV}$

- **Step 23**

$\mathbf{P_{RF(o)}} = V^2_{RF(o)\ RMS} / 2000 = \mathbf{3.3\ \mu W}$

- **Step 24**

$\mathbf{dBm_{RF(i)}} = 10 \times \log (P_{RF(i)} / 1mW) = \mathbf{-95.07\ dBm}$

- **Step 25**

$\mathbf{dBm_{RF(O)}} = 10 \times \log (P_{RF(O)} / 1mW) = \mathbf{-24.8\ dBm}$

- **Step 26**

$\mathbf{Ap_{RF}} = dBm_{RF(O)} - dBm_{RF(i)} = 24.8 - (-95.07) = \mathbf{70.27\ dBm}$

5 Conclusion

In this lab we learned how to calculate the AM signal power gain using the RF amplifier. We further strengthened our concepts on Amplitude modulation, RF filtering, and amplification. Furthermore, by using the signal generator and oscilloscope we measured and analyzed the effects of signal modulation and amplification.

Through the experimental procedures and data analysis, it was observed that the characteristics of the filters and amplitude modulation were consistent with theoretical expectations. The results demonstrated the effectiveness of the filter circuits in attenuating unwanted signals and the capability of amplitude modulation in carrying information with minimal distortion.