ELEC 240
Final Project - RF Transceiver System

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1 Objective

Our goal in this project is to construct an RF transceiver system that can transmit and receive audio signals across the 160-190kHz band. There are three major components to the **transmitter**: the analog input circuitry, the digital signal processing component where we modulate the signal with a higher carrier frequency sine wave, and then the RF breadboard module that bandpass filters and amplifies the signal. There are also three major components to the **receiver**: the RF breadboard module that receives the signal and bandpass filters it, the signal processing component in LabView that demodulates the signal, and the speaker driver circuit that converts the processed signal into an audio signal via the carbon handset.

2 Materials

2.1 RF Receiver

Specifically for the analog input mixer circuit, we need the following components:

- test board
- 2 $3.3k\Omega$ resistors
- 1 $10k\Omega$ resistor
- 1 $100k\Omega$ resistor
- Carbon telephone handset
- 1 $1\mu F$ capacitor
- 1 741 op-amp
- 1 Dynamic microphone
- 15 V power supply
- red, green, black, and yellow wires

For the rest of the receiver components, we need:

- Labview program
- RF Breadboard module
- NI Virtual Bench
- BNC cords
- BNC T-connector

2.2 RF Transmitter

For the speaker driver circuit, we need:

- 1 $8.2k\Omega$ resistor
- 1 $1k\Omega$ resistor
- 741 op-amp
- carbon microphone headset

For the rest of the transmitter components, we need:

- Labview program

- RF Breadboard module

- NI Virtual Bench

- BNC cords

- BNC T-connector

3 Test Description

As outlined in the *Objectives* section, there are 2 major components to the lab: the RF Receiver and the RF Transmitter.

3.1 RF Receiver

Within the RF Receiver section, there are three subcomponents.

The first component is the RF breadboard module(set to receive mode). This module will take the received signal from the antenna and bandpass filter out noise. We obtained an RF module from the lab room and screwed it into the testboard.

The second component is the Labview receiver program that performs an analog to digital conversion on the signal received from the RF Breadboard module, demodulates it by multiplying by a sine wave of the same predetermined carrier frequencies, then reconverts the signal back to analog.

The third component is the analog speaker driver circuit that takes the analog signal from the Labview receiver program and amplifies it via a 741 op-amp so that we can hear it through the carbon handset.

3.2 RF Transmitter

Within the RF Transmitter section, there are three subcomponents.

The first component is the analog mixer circuit that turns audio from the microphone and carbon handset into an electrical signal. We replicated the analog mixer circuit from Experiment 4.3: Transducer Amplifiers. In this circuit, we are able to simultaneously take inputs from both the microphone component of the carbon handset as well as the dynamic microphone and amplify them using the 741 op-amp.

The second component is the Labview transmitter program that converts the analog input from the mixer circuit to a digital signal, low-pass filters the message signal, and modulates it to approximately 200 kHz range by multiplying the message signal by a sine wave.

The third component is the RF breadboard module that must be set to transmit mode. This module will amplify the output of the Labview transmit program and send this signal to the antenna to be transmitted wirelessly.

3.3 Pre-Lab Calculations and Schematics

For the transmission and reception of a signal, we used amplitude modulation. Let $s(t)$ denote the time representation of the message signal (i.e. the audio signal that we speak into the microphone). The following diagram in Fig 1 depicts the overall setup of the RF Transceiver system.
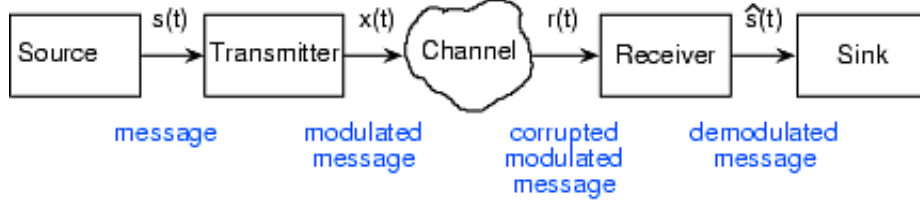
Figure 1: Overall Configuration of RF Transceiver

The transformation from $s(t)$ to $x(t)$ via the transmitter occurs by modulating the message signal by a cosine of the carrier frequency f_c and amplifying the signal as follows:

$$x(t) = A(1 + s(t))cos(2\pi f_c t)$$

This can also be viewed in the frequency domain (via the Fourier Transform) as:

$$X(f) = A(S(f - f_c) + S(f + f_c))$$

Note that $f_c >> W$, the bandwidth of the message signal $s(t)$.

To demodulate the signal, we multiply the signal by a sine wave of the frequency f_c and same phase to achieve the following expression in the time domain:

$$x(t) = A(1 + s(t))cos(2\pi f_c t)cos(2\pi f_c t)$$
$$= A(1 + s(t))cos^2(2\pi f_c t)$$
$$= A(1 + s(t)) * (1 + sin(2f_c))/2$$
$$= \frac{A}{2}(1 + s(t)) + \frac{A}{2}(1 + s(t))sin(2f_c)$$

By low-pass filtering the signal, we obtain $\frac{A}{2}(1 + s(t))$, which we can then remove the DC gain to obtain a signal proportional to the original $s(t)$. Note that in our system, we perform a digital to analog conversion (because it is easier to multiply by a sine wave in discrete time rather than in continuous time) and then convert back to analog once we are done with processing.

For the analog mixer circuit for the RF Transmitter, we used the analog mixer circuit from Experiment 4.3: Transducers Amplifiers as depicted below in Fig 2
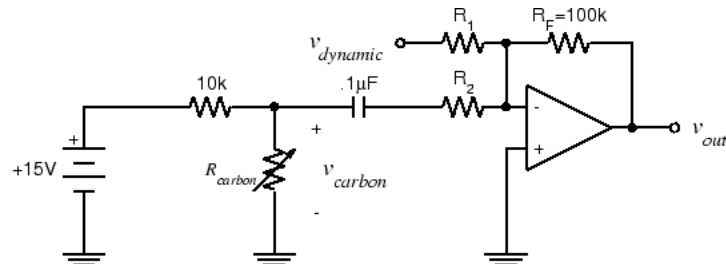

Figure 2: Analog Mixer Circuit from Lab 4.3: Transducer Amplifiers

4   Results and Discussion

Your text here

Note (To be deleted): The heart of your report is the presentation of your results and a discussion of those results. In your discussion, you should not only analyze your results, but also discuss the implications of those results.

5   References

- https://www.ece.rice.edu/~dpr2/elec240/final-lab/

6   Conclusion

Your text heres

7   Errors

- *Handset microphone had excessive feedback:* Our handset, when placed facedown on a table or held in a certain position, would have excessive feedback, which would cause it to magnify the noise that it was producing. Thus, we would sometimes have to cover the earpiece so that we could speak into the microphone of the handset without introducing significant external noise into the transmitted audio signal. In the future, use a higher quality/fully functional handset.

- *SNR ratios of our partner group were slightly higher than our ratios* This error was likely due to the fact that many different lab groups were trying to test their own RF Transceiver performance at the same time we were testing ours, potentially at the same frequency. Therefore, our partner group may have been receiving other groups transmitted signals while we did not when we switched to receiving. This would explain why the SNR ratios of our partner group were slightly higher than our ratios.