LABORATORY REPORT - CHAPTER 9

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Total Grade	/100

Remarks: Record all your measurements and write all your answers in the boxes provided.

Preliminary Work

1. Monopole Antenna

1. TRC-11 emits radio waves at 27.00 MHz. The wavelength of these waves is approximately λ=11 m.

2. Estimate the series capacitance, C_{mr}, and radiation resistance, R_{rr}, of your monopole antenna when it is fully extended using

$$C_{mr} \approx 2\pi\epsilon_o \frac{l}{\ln(l/a) - 1} \quad \text{for} \quad \frac{l}{\lambda} < 0.1 \tag{1}$$

and

$$R_{rr} \approx 40\pi^2 \left(\frac{l}{\lambda}\right)^2 \quad \text{for} \quad \frac{l}{\lambda} < 0.1 \tag{2}$$

or from the graph in Fig. 1.

C_{mr}= 8pF R_{rr}= 0.8Ω

1.2. GRADE:

3. The series capacitance of the antenna can be tuned out using a series inductance. Find the value of the series inductance, L_s, to tune out the series capacitance, C_{mr}, of the antenna at 27 MHz.

L_s= 4.34uH

1.3. GRADE:

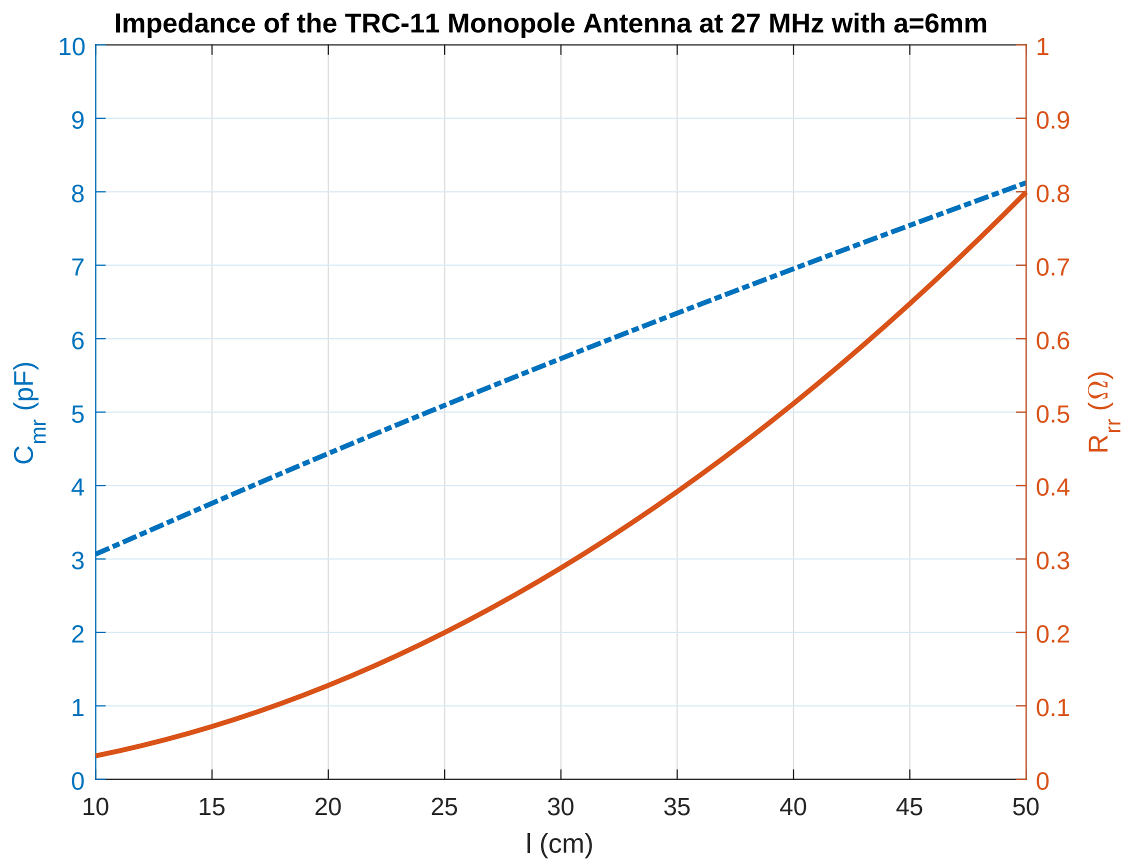

Figure 1: Calculated series resistance (solid) and series reactance (dash-dot) of the TRC-11 monopole antenna at 27 MHz as a function of its length with a=6 mm.

Experimental Work

1. Tuning the monopole antenna

1. Using about 30 cm of 0.35 mm enamelled wire, wind 31 tight turns on T37-7 core to generate the series antenna tuning inductance, L31. Leave about 1 cm of wire at both ends. Strip the ends of the wire. Mount and solder the inductance with its core placed perpendicularly.

2. Mount and solder the SMA connector, P30.

3. Cut the jumper, JP30, connecting the dummy load to the relay output.

4. Cut the jumper, JP81, connecting the antenna to receiver for tuning purposes. You need to reconnect this jumper later, when the testing is finished.

5. Connect the antenna to the SMA connector, P30, and extend the antenna to its full length. Let the antenna stand perpendicular to the board surface.

6. With no power connected, the relay connects the antenna and its tuning inductance (see Fig. 2) (through DC block capacitance C31) to TP82. Connect the signal generator

leads between TP82 and GND. Set the signal generator to 27 MHz and 5 Vpp. Connect the oscilloscope probe also between TP82 and GND. Change the frequency in 0.1 MHz steps to determine the dip in the signal. Find the resonance frequency where the signal is minimized. If the dip frequency is lower than 27 MHz, spread the turns of L31, to increase the resonance frequency. If the dip frequency is higher than 27 MHz, tighten the turns to decrease the resonance frequency. If you cannot achieve the resonance at 27 MHz, you may need to decrease or increase the number of turns of L31. Record the dip frequency, f_r, and the value of the peak-to-peak voltage, v_{minpp}, at the dip. Note that if you bring your hands closer to the antenna, the capacitance of the antenna increases and the resonance shifts to smaller frequencies.

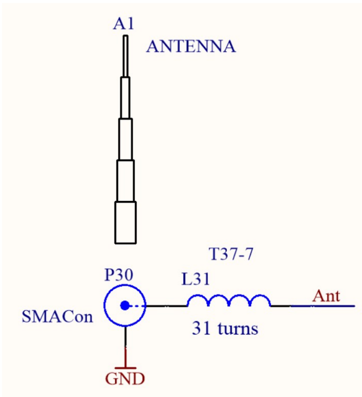

Figure 2: Short monopole antenna and its series tuning inductance.

7. Calculate the series resistance of the antenna from the peak-to-peak voltage, v_{minpp}, at the dip. Note that the signal generator has a series resistance of 50 Ω and its open-circuit voltage is 10 Vpp when its amplitude is set at 5 Vpp. At the resonance the impedance between TP82 and GND is purely real and its value can be found from the resistive voltage division:

$$R_A = \frac{v_{minpp}}{10 - v_{minpp}} 50\ \Omega \tag{3}$$

For example, if v_{minpp}=2 Vpp, we find R_A=12.5 Ω. The value of R_A, is typically higher than the predicted value of the series antenna resistance, R_{rr}, since the measured value of R_A also includes the losses in the series resonant circuit, such as the series resistance of the tuning coil. Note that the value of the dummy load, R33, should be nearly equal to R_A for accurate tuning of the receiver and transmitter.

f_r= 26.700MHz	v_{minpp}= 2.20V	R_A= 13.9Ω

1.7. GRADE:

2. On the Air

1. The receiver monopole antenna picks up the 27.00 MHz electromagnetic wave. The signal is amplified and down-converted by the receiver mixer to 15 MHz. The signal passes through the narrow-band crystal IF filter at 15 MHz. The first and second IF amplifiers

amplify the signal. The envelope detector recovers the audio modulation signal. The signal is fed to loudspeaker amplifier. The earphones convert the electrical signal to sound waves to be transmitted to your ears.

Apply power to TRC-11. Adjust the volume knob all the way counterclockwise. Plug the earphone into its socket. Increase the volume until you hear the *atmospheric noise*. Atmospheric noise is radio noise caused primarily by lightning discharges in thunderstorms in different parts of the world. Since there are on the average 40 cloud-to-cloud or cloud-to-ground lightning flashes per second, you can hear them through the earphone in the form of an impulse noise. Its amplitude may depend on local weather conditions and the time of the day. At 27 MHz atmospheric noise dominates.* You should hear a lot of noise if there is no one transmitting at 27 MHz nearby. If there is a nearby 27 MHz transmitter, the automatic gain control circuit reduces the gain of the receiver amplifier. In that case, you do not hear the atmospheric noise.

2. Your receiver with the fully extended receiver antenna should be so sensitive that you should be able to receive the 27.00 MHz signal without a direct connection of the signal generator. Leave the signal generator leads about 1 m away from your monopole antenna. Set the frequency of the signal generator to 27.000 MHz. Set the amplitude to 1 V_{pp}. Set the modulation frequency to 600 Hz. Set the modulation index to 50%. Connect the power adaptor to TRC-11. Plug the earphone into its socket. Adjust the volume knob all the way counterclockwise. Increase the volume until you can hear the sound of the modulation frequency from the earphone. Does the signal LED turn on, indicating a strong signal? LED must turn on, when the signal generator leads are sufficiently close to your short antenna. Connect the oscilloscope probe to TP70, AGC amplifier output signal. Make sure that your oscilloscope coupling is DC. This voltage shows the strength of the incoming signal. Change the frequency in 1 KHz steps to find the center frequency. Record the center frequency. Reduce the amplitude of the signal generator until you can no longer hear the 600 Hz. Record this amplitude (V_s) of the signal generator and the measured voltage at TP70. With a well-tuned TRC-11, the LED turns on with a 10 mVpp signal source nearby.

Heard the atmospheric noise? Yes

f(MHz)= 27.0MHz V_s= 20mV

Voltage at TP70= 540mV

2.2. GRADE:

3. When you press the push-to-talk switch, the transmitter oscillator generates a sinusoidal signal at 27 MHz. This signal is fed to transmitter amplifier to amplify it. With the PTT switch pressed the relay connects the antenna to the output of the amplifier, hence a 27 MHz signal is transmitted to air. Press the push-button switch, S90. The red LED

*At higher frequencies *galactic noise* may become important. It is much weaker and it is coming from the center of the Milky Way.

should turn on indicating the presence of a nearby 27 MHz transmitter. The LED turns on even when the receiver is not connected to the antenna, indicating the presence of a very strong signal in the vicinity. Measure the DC voltage at TP70, while transmitting. Note that nearby TRC-11s transmitting may also cause the red LED to turn on.

4. Your transmitter is ready to transmit an audio signal. Turn down the volume knob counterclockwise to reduce the volume. Connect the earpieces and whisper into the microphone. You should be able to hear your own voice and surrounding sounds. Note that if other students are transmitting at the same time you may hear their transmissions as well. A low frequency whistle sound may also be present due to interference of two or more transmissions.

5. From the peak-to-peak transmitter output voltage at TP36 you calculated earlier, estimate the power transmitted, P_o, into air by calculating the power dissipated in the antenna resistance. Note that it is a very small power, well below the allowed transmission power at this frequency without a license. We keep the output power level intentionally low, to be able to the experiment without a radio amateur license. We note that the peak transmitting power of a typical mobile phone is about 1 W. Mobile operators pay hundreds of millions of dollars of license fees to be able to use the frequency bands at that power level.

RF power transmitted, P_o (μW)= 47.987mW

2.5. GRADE:

Voltage at TP70= 834mV

2.5. GRADE:

6. Estimate the magnitude of E field at a receiver location $r = 20$ meters away from the transmitter. If P_o is the transmitted power in watts, E field in V/m is given by

$$|E_x(r)| = \frac{\sqrt{120P_o}}{r}$$

Calculate the open circuit antenna voltage using $V_r = l|E_x|/2$ (true if $l < \lambda/8$) where l is the length of your monopole antenna in meters.

Estimated $|E_x(r)|$ (V/m) (at $r = 20$ m) = 0.119 V/m

Estimated V_r (at $r = 20$ m) = 0.03V

2.6. GRADE:

7. Find a partner with a completed TRC-11. Try to listen to the partner's TRC-11 at a distance. Find the maximum distance that two TRC-11's can communicate. From this measurement find the minimum detectable E field magnitude using the formula $|E_x(r)| = \sqrt{120 P_o}/r$

Measured maximum distance of communication r (m)= 25m
Minimum detectable $|E_x(r)|$ (V/m)= 0.083 (V/m)

2.7. GRADE:

8. Using the maximum detection distance that you measured in the previous step, estimate the maximum distance of communication if the transmitter power were 1 W.

With $P_o = 1$ W, the estimated maximum distance r (m)= 115.3m

2.8. GRADE:

9. Enjoy your TRC-11...