Boston University

Electrical & Computer Engineering

Second Prototype Testing Report

Better Bot

by

Team #15

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Introduction

The primary objective of AM Radio Localization system is to accurately determine the location of AM radio sources in a given area. During our second prototype testing, we examined three subsequent circuits: active antenna, isolation amplifier, and tracking filter. The active antenna amplifies the radio signals, while the isolation amplifier ensures that the amplified signals are isolated from the noise in the range of 100kHz to 10MHz. The tracking filter then applies a filter to the enhanced signals to eliminate any unwanted interference and improve the signal quality. The report details the design and implementation of the three main circuits of the system, including the circuit diagrams, testing procedure, and performance evaluation.

Active Antenna

Set Up

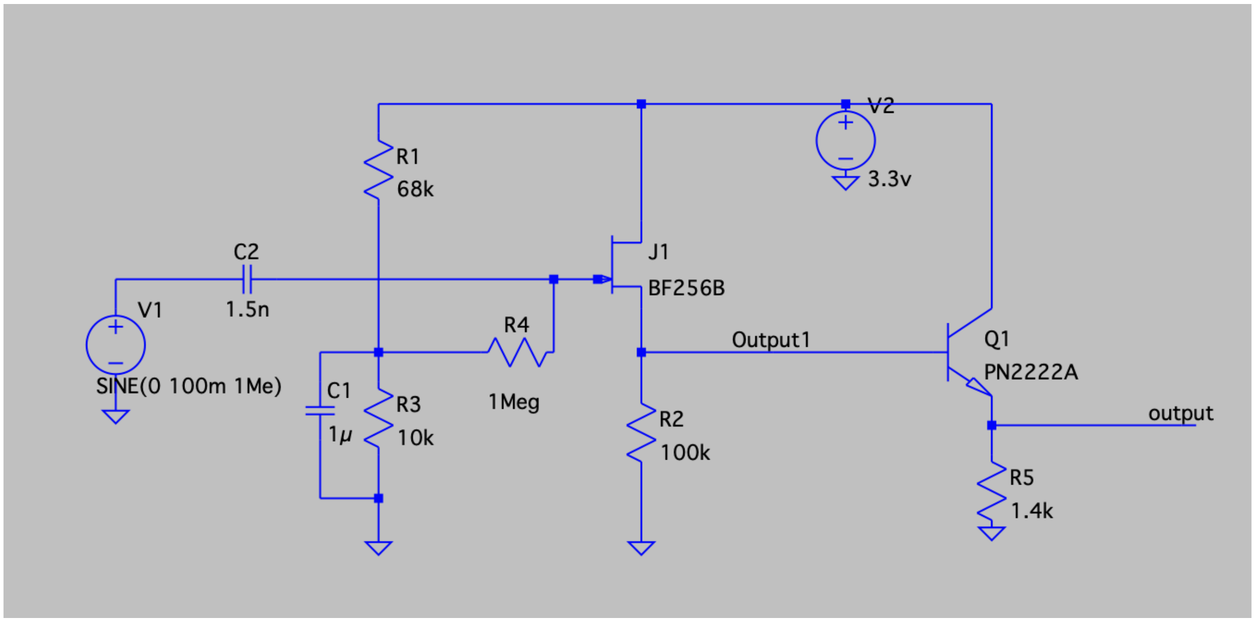

Fig 1. Schematic of Active Antenna

Fig1 shows the schematic of the active antenna which is powered up by a 3.3V dc source. This circuit is made up of two stages. The first stage is made up of a BF256B JFET emitter follower. A voltage divider is connected to the base of the JFET to regulate the voltage at Output1 and prevent the JFET from saturating. The second stage of the circuit is a PN2222A BJT emitter follower to achieve a high output impedance . Since we will use a spectrum analyzer for analyzing the output signal and it has a really small input impedance (50 ohm), a huge output impedance is added between the circuit and spectrum analyzer in order to avoid breaking the device.

Testing Procedure

We first powered up the antenna with a 3.3V DC voltage source. Then, we connected a 10 feet 28 gauge wire to collect the surrounding AM radios. Next, we connected the spectrum analyzer to the output. On the spectrum analyzer, we set the range of frequency to be 500kHz to 1.8Mhz which is a typical frequency range for the AM radio. We also set the resolution bandwidth (RBW) to be 1kHz to get a better frequency resolution and video bandwidth (VBW) to be 300 Hz in order to get less noise at the output.

Test Output

Fig 2. Output of Active Antenna

Fig2 shows the output from the active antenna on the spectrum analyzer. From the graph we can see that the range of AM radio inside the Photonics Building room 113 is 500kHz to 1.6MHz. For our next step, we will use of the pulses as a reference frequency for subsequent circuits.

Tracking filter

Equipment and Setup:

As per the procedure outlined in the testing plan, the breadboard prototype of the tracking filter was set up by connecting its power rails to a DC power supply delivering 3.3V and 6V. After which two BNC cables were connected in parallel from the function generator, one to the input node of the tracking filter and the other to one of the four oscilloscope channels. Lastly, the output node of the tracking filter was connected to the spectrum analyzer. All connections were measured relative to the DC power supply's ground.

Measurements Taken:

After the connections for the tracking filter were made and the power supply was powered we failed to get a response. There was no amplification of the signal and the power supply seemed to draw no current. Any possible filtering that was observed was most likely caused by the LC tank that was already part of the circuit.

We expected to observe the same behavior witnessed on the previously conducted 'preparatory' testing (Fig. 4), a frequency response spike visible on the target frequency accompanied by another spike at the first harmonic (or half the target frequency). Although far from ideal, the amplification of the desired frequency is such that there is a 'practical' clearance of 0.78 MHz.

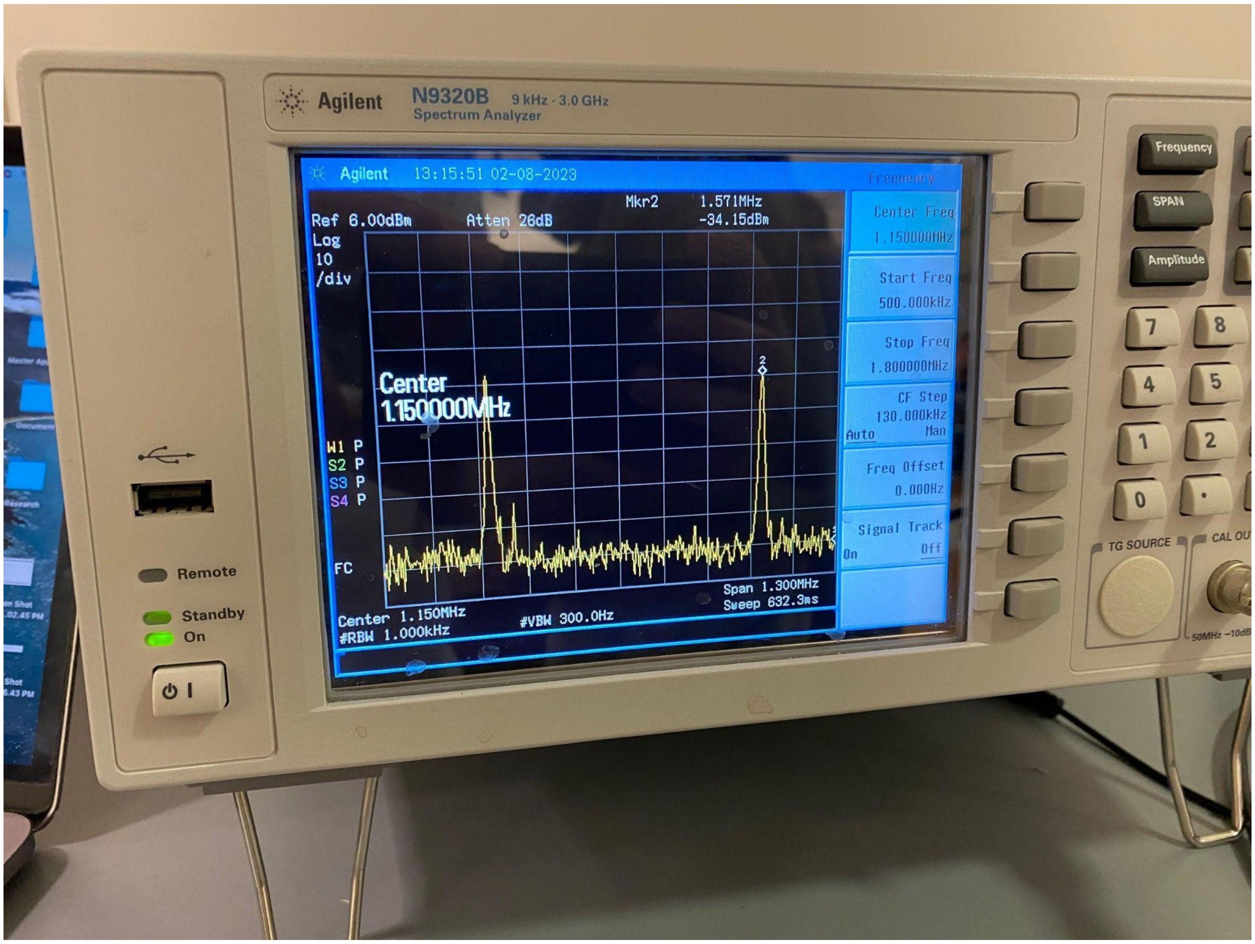

Fig. 3 Expected behavior of the tracking filter

Discussion:

Not getting any response from the filter was short of frustrating. The circuit had not experienced any changes since the preparatory testing, which the team and client deemed successful. As to have some positive feedback from the unsuccessful testing, the results from the preparatory stage were presented to Professor Hirsch. He explained that the second peak of half the frequency of the desired target was most likely caused by the cables used for the construction of the filter acting as an antenna that was receiving unwanted signals. These wires might have also caused a faulty connection which made the filter faulty without apparent cause.

In order to solve the problems observed during this stage of testing Professor Hirsch advised changing the way the prototype was assembled. Instead of using wires and a breadboard we are now prototyping by soldering the components into a prototyping board, avoiding most interference caused by the possible detection of unwanted signals.

Isolation Amplifier

Overview:

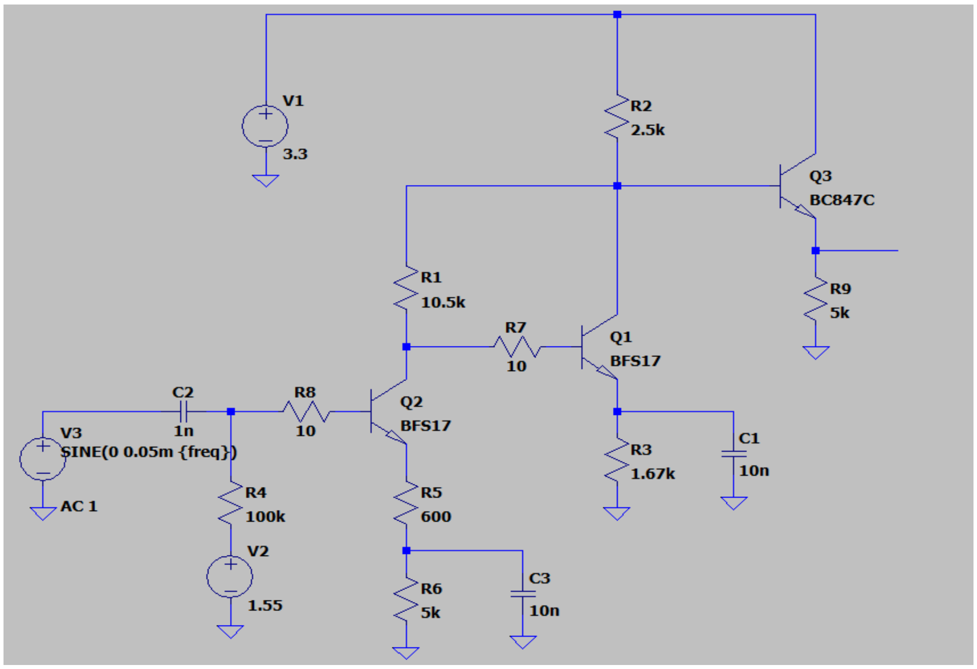

Fig. 4 Circuit Diagram of INA

The purpose of the isolation amplifier is to amplify the active antenna signal output and reduce negative feedback signal. The implementation of this circuit uses only discrete components. A small value of resistor R8 will keep the transistor stable. Q2 will drive low impedance to Q1 this will eliminate the noise and generate high frequency response. Another important factor of an isolation amplifier is to amplify voltage gains. Q3 reduces the output impedance, which is required/recommended for signal amplification. This step is important because high output impedance will tend to result in loss of the signal and distortion.

Procedure:

To complete powering up and measure the output gain of the isolation amplifier requires a power supply, function generator, and oscilloscope. The AC input is connected to the function generator with frequency of 1MHz and 50mVpp. The two DC inputs are connected to the power supply with 1.5V and 3.3V. Then we can check the gain by measuring the output voltage signal with an oscilloscope hooked up to the output ends.

Test Output:

Fig. 5 Output voltage of LNA

The output generated by the isolation amplifier is within the range of our expected output. In Fig. 5 is the Voltage output from INA, we can see that the output with Pk-to-Pk of 880mV, and our input amplitude is set to 50mVpp, this indicates the gain is around 8-9. The expected gain range for our test plan is from 5-10. The isolation amplifier is working properly.

Triode Mixer

Overview:

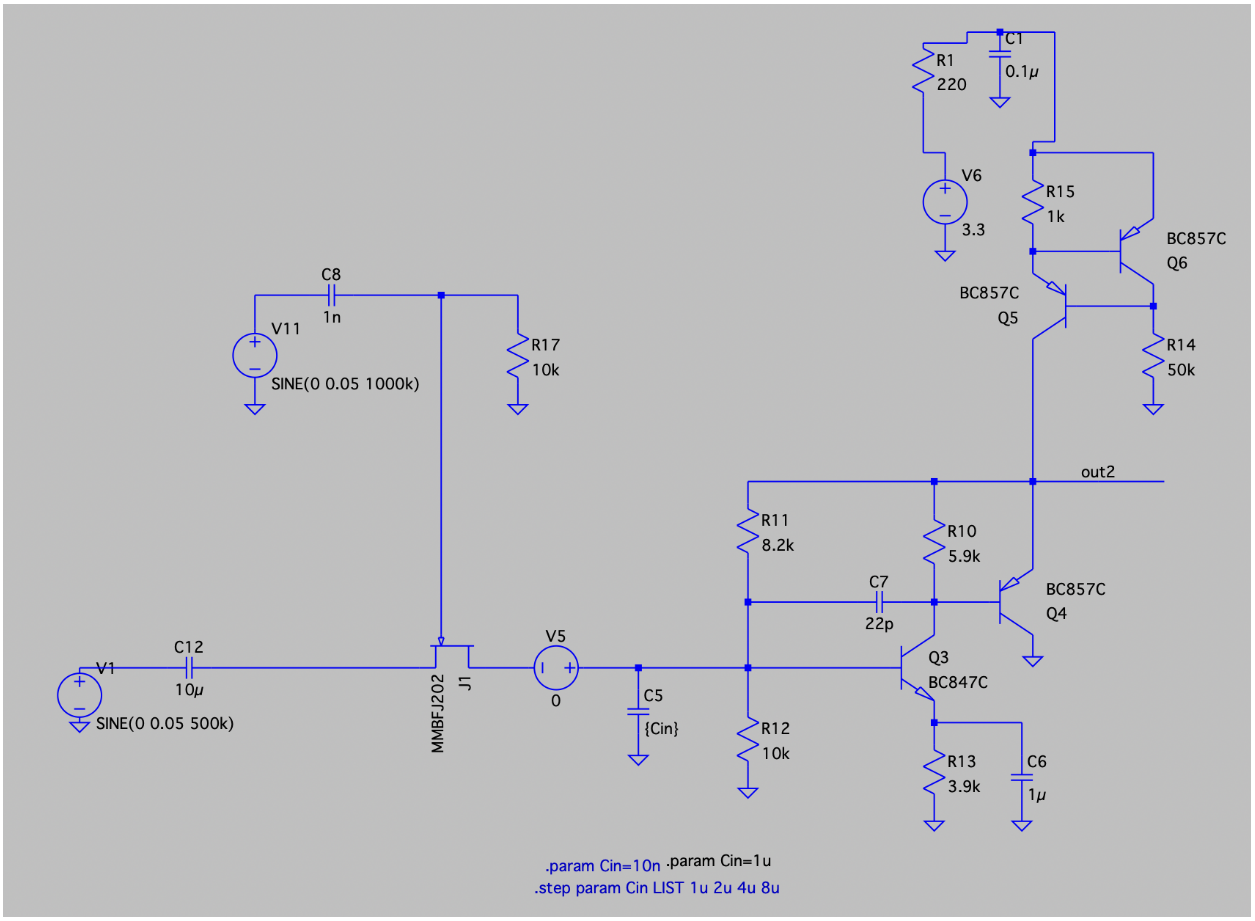

Fig. 6 Circuit diagram of Triode Mixer

The triode mixer circuit is a key component of the AM radio localization system. The circuit uses a mixer to generate intermediate frequency (IF) signals by multiplying the radio frequency (RF) signal with a local oscillator (LO) signal. For example, the mixer used in this circuit produces two new frequencies: RF-LO and RF+LO, which are separated by a constant 5 kHz offset. These new frequencies produce IF signals of 5kHz and 2MHz. The 2MHz IF signal can be easily removed with a low-pass filter, leaving only the 5kHz IF signal.

This mixer circuit is essential for heterodyne systems, which use mixing to produce a constant-frequency IF that can be filtered with a single-frequency bandpass. The mixer also keeps the phase, which makes it possible to measure the phase of high-frequency signals with great accuracy.

Procedure:

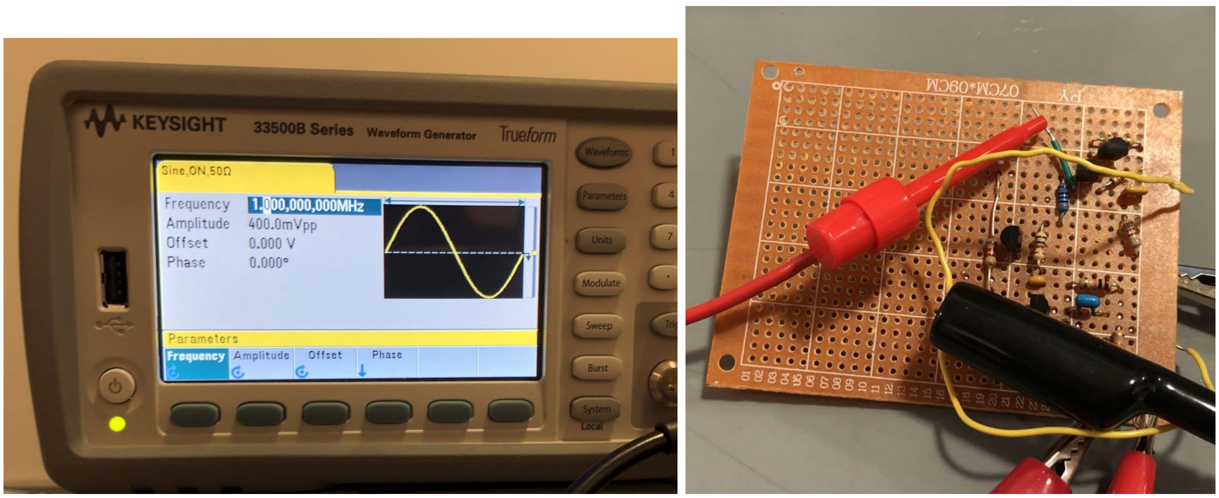

Fig. 7 Input from Function Generator and Prototype Triode Mixer

A function generator stands in for the LO and RF waves during our testing process. Due to hardware limitations, the input frequency for LO and RF is the same at 1 MHz. The output IF frequency from simulation and the actual output displayed in the frequency domain are posted below in the test output section.

Test Output:

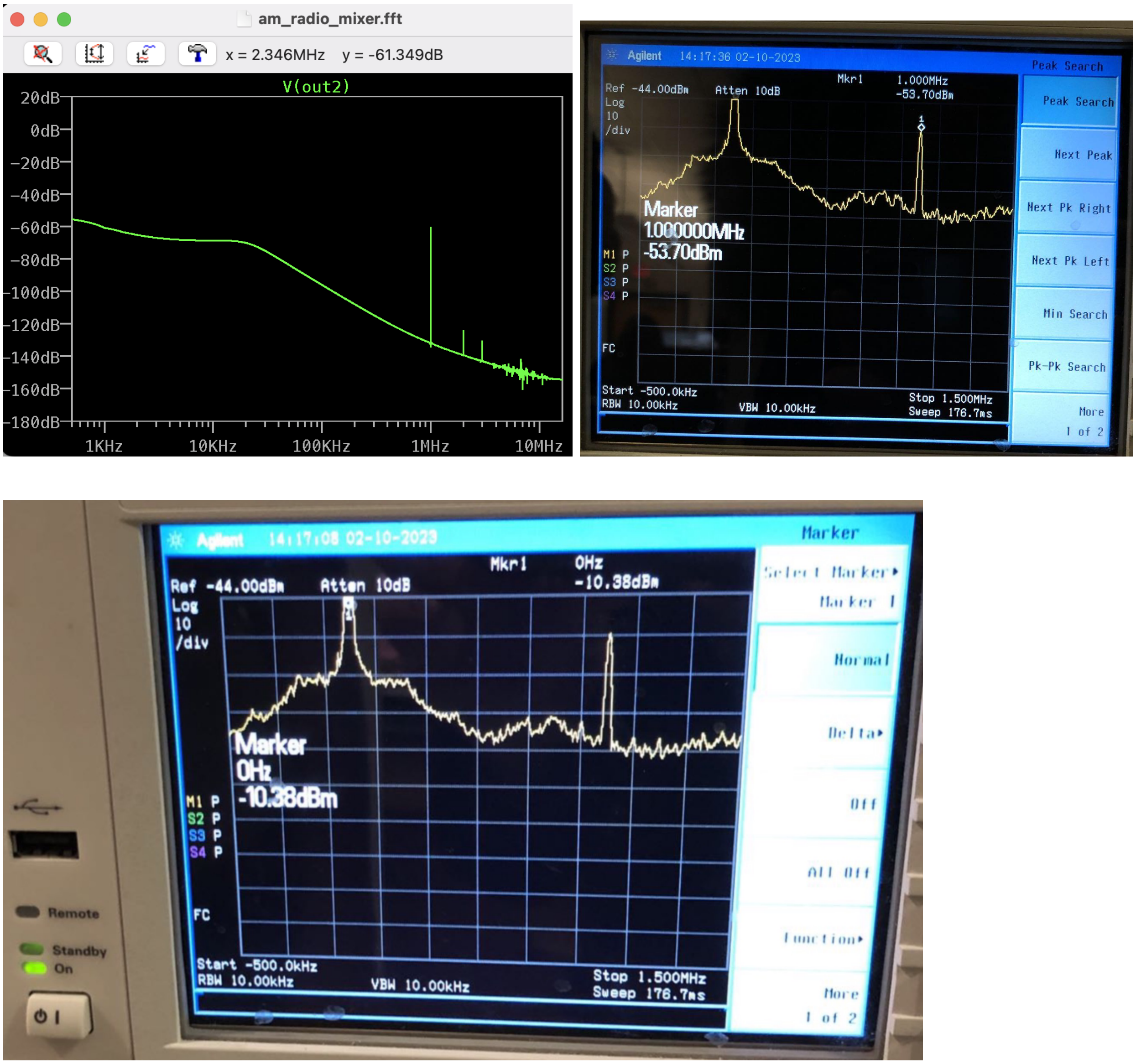

Fig. 8 Simulation and Testing Output of Triode Mixer

The output has two peaks, one at 0 Hz and one at 1 MHz, which is similar to the simulation result.

Future Plan:

The common way to improve a mixer is to improve its conversion gain, which is the ratio of the IF output power to the RF input power. There are two critical factors affecting its conversion gain. One is the power output from LO (Local Oscillator) and RF (Tracking Filter). The other one is the linear operation range of the JFET used in the mixer. I plan to investigate more on the JFET operation range. I could also design and add a power amplifier between the tracking filter and the triode mixer. Either way, they will be presented on a breadboard before the final prototype test.