LAB 3 – Mixers: practical usage of a passive diode ring mixer

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Lab 3 of EE 133 investigates the uses and limitations of mixers. We discuss different constructions of passive mixers and kind of conversions. Then we build a diode ring mixer and measure the frequency and waveform properties of the diode ring mixer that we built.

I. THEORETICAL BACKGROUND

Mixers are non linear components that take in two signals and output their sum and difference frequencies at the third port. Mixers can be passive or active and can be used to modulate and demodulate signals, detect phase, and is the key component superheterodyne receiver.

We can consider the basic trigonometric property that given two waves:

$$cos(\alpha)cos(\beta) = \frac{cos(\alpha+\beta) + cos(\alpha-\beta)}{2}.$$

Therefore, when multiplying two waves, the output contains both the sum and difference of the input frequencies. In practice, we find that there are many more frequency components to the output signal.

To begin, for this lab, we consider two passive configurations for a mixer: the fet and diode rings as seen in FIG. 1.

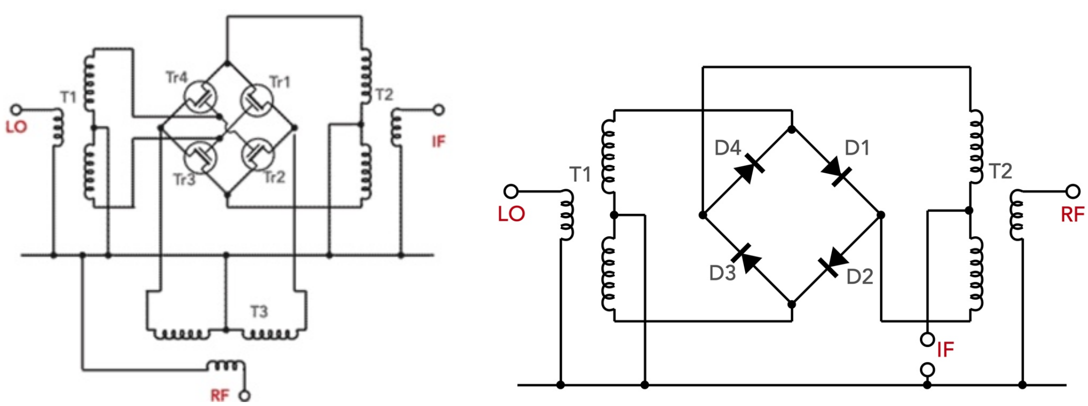

FIG. 1. **Fet ring (Left) and diode ring (right) mixer configurations.**

Both of these configurations use switching defined by the local oscillator (LO) to modulate the signal from the radio frequency (RF) port. In addition both rings are run deferentially, requiring transformers at the input (and on the output of the intermediate frequency (IF) for the fet ring).

By convention we will will label the input ports of the mixer RF if it is at a higher frequency than the output IF. Otherwise, if the input frequency is lower than the output, we will refer to the input as IF and the output as RF. The LO port will be considered a constant about which we modulate (or demodulate) our signal.

Because these devices are non ideal and because our input signals are not pure signals, leakage and harmonics become non-insignificant components of our output frequency spectrum.

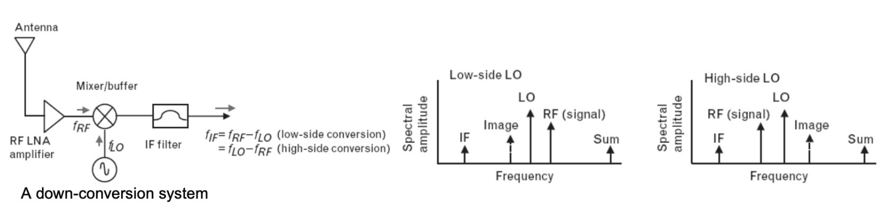

FIG. 2. **System modeling down conversion of a signal from a receiving antenna to an intermediate frequency.**

Looking at FIG. 2, if we first consider the down conversion case (where we label the input RF and output IF), we can see the sum and difference components of our spectrum. Because this is a down converter, we add a filter on the output to isolate the difference component and call it the IF. In addition, we see both the LO and RF signals on the output of the mixer. Next, we also see the frequency of $f_{\mathrm{LO}} \pm f_{\mathrm{diff}}$. Finally, we expect to see the harmonics of all of the above signals.

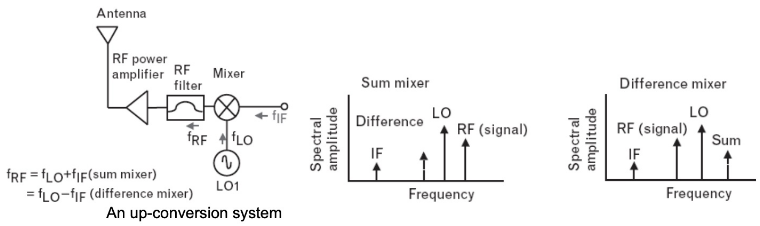

FIG. 3. **System modeling up conversion of a signal from an IF source to a transmitting antenna.**

FIG. 3 displays the case of up conversion (where our output (labeled RF) is at a higher frequency than our input (labeled IF)). The major components are largely the same. We have the input LO and IF frequencies appearing on the output. In addition we have their sum and difference frequencies present as well.

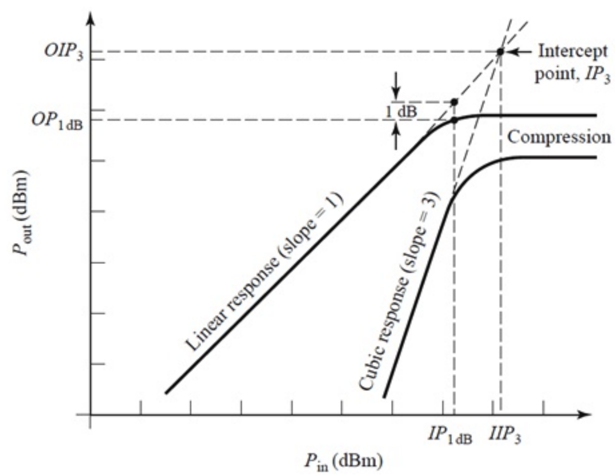

FIG. 4. **Graph displaying the dynamic range of a mixer, its linear region, and its compression point.**

The final point to consider is that our mixer is practically a non-linear device. This means that there is a limit to the amount of power that we can send to our input where we would can expect to see a proportional increase to power at the output. In FIG. 4. we see that the 1 dB compression point is defined by the point when the gain of our mixer is decreased by 1 dB.

II. LAB PROCEDURE

In lab, we constructed both a double balanced diode ring mixer and a fet ring mixer. The rings for both components were held in SMD packages and required transformers that operated within our frequency range of interest.

Generating our LO and RF signals with a frequency generator, we then tested our mixers at a variety of frequencies, both at high-side and low-side, analyzing the output on a spectrum analyzer. Using our oscilloscope, we then inspected the amplitudes of the output signal as we varied the frequency of the RF. Finally, we attempted to estimate the 1 dB compression point at 3 MHz by simply stepping up our RF input by 1 dBm until we no longer saw an increase in power in our spectrum analyzer.

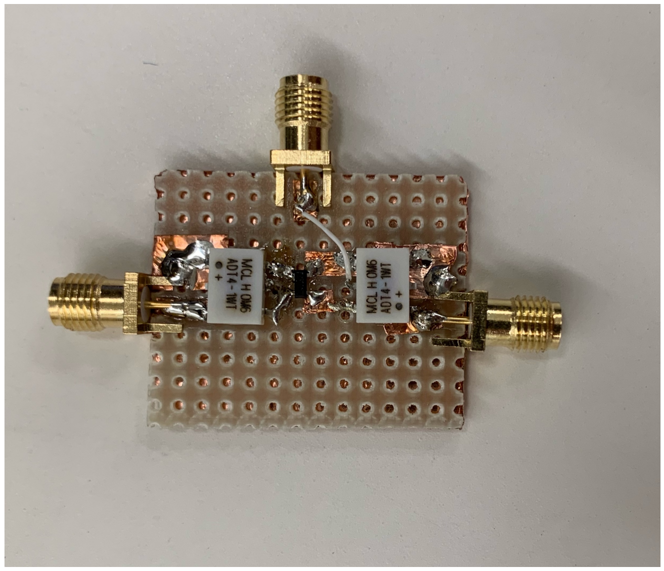

FIG. 5. **Construction of our diode ring with copper tape, terminating at 50 ohm SMA connectors.**

III. DISCUSSION

In this section, we will be discussion a low-side mixer and our findings.

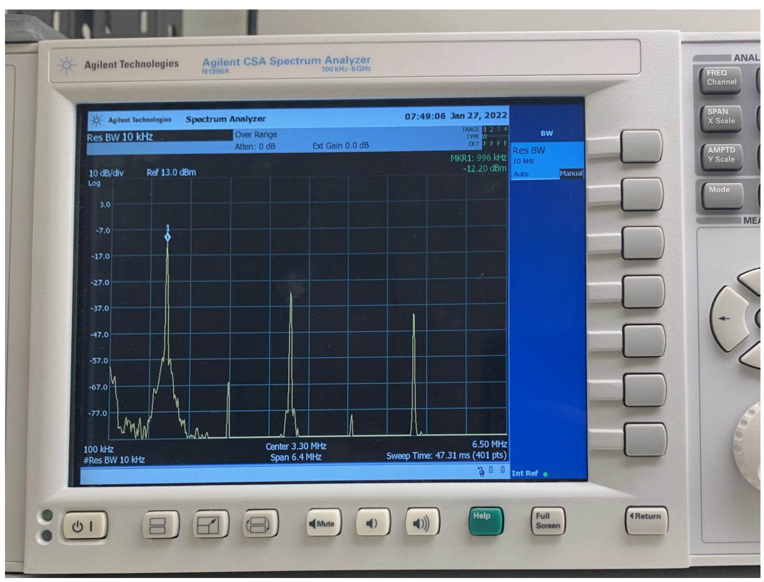

FIG. 6. **Spectrum analyzer reading from IF port of diode ring mixer with RF = 2 MHz and LO = 3 MHz.**

As seen in FIG. 6, the LO is seen at 3 MHz and the RF at 2 MHz. In addition we see the sum at 3 MHz and difference frequency at 1 MHz. As a down converter we see that we get an output of -7 dBm.

Virtue of not having any filtering, we have the potential of using our mixer both as a down converter (if we choose the difference) or an up converter (if we choose the sum).

For our diode ring we approximated our gain to be about 1 and our 1 dB compression point to be -3dBm. For our fet ring we approximated our gain to be about 1 and our 1 dB compression point to be about 2 dBm.

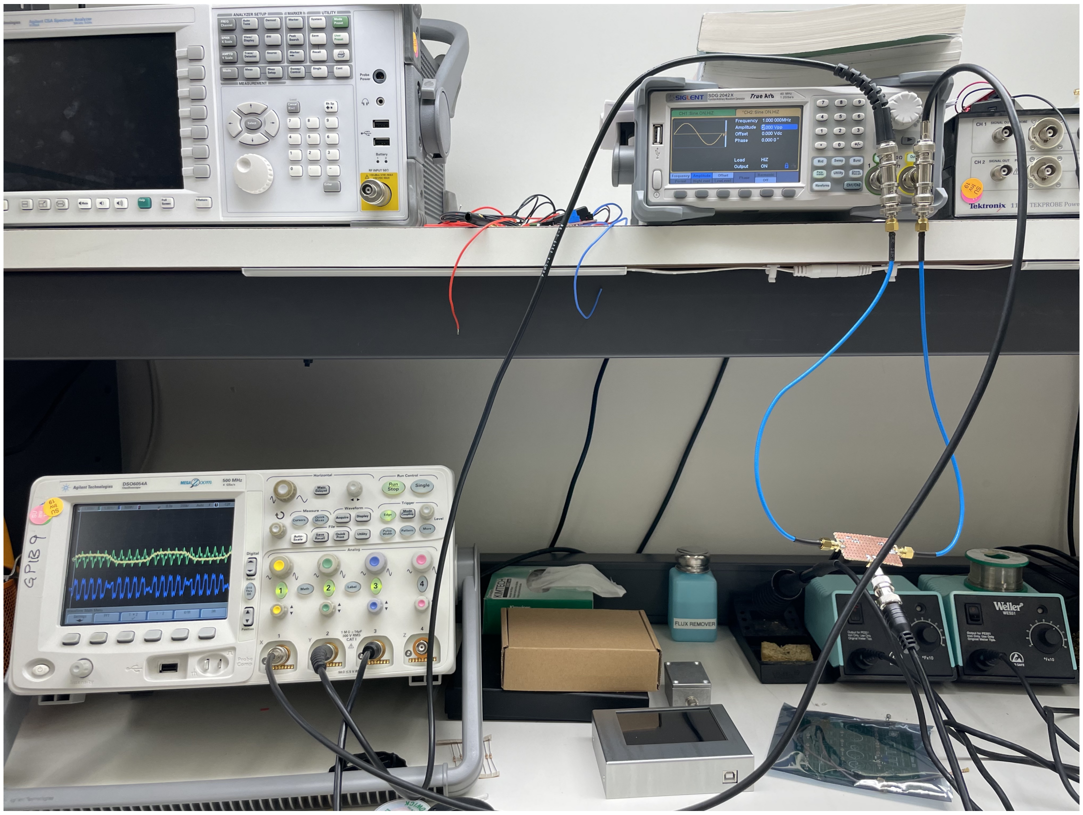

FIG. 7. **Oscilloscope reading demonstrating AM modulation at 4 MHz carrier 1 MHz AM.**

Finally, we demonstrated that, indeed the amplitude of the IF wave is modulated by that of the RF signal. In the construction we used for this lab, neither the signal from the fet ring, nor that from the diode ring, would be consider an ”amplitude modulated” signal but instead would be considered double-sideband (DSB) modulated signals.