Lab 3 – Exploring the diode-ring mixer

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Abstract

1 Introduction

Mixers are three-port devices (Figure 1) that produce sum and difference frequencies of the two supplied input frequencies. They have wide applications including use as modulators, phase detectors, and product detectors.

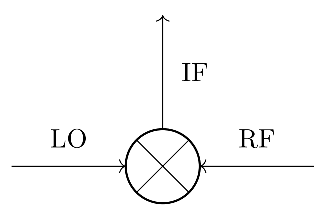

Figure 1: Mixer

Typically, one of the inputs to the mixer is a local oscillator (LO), and for down conversion, the other input signal is called RF, and the output is called IF (intermediate frequency).

In this lab we build a diode-ring mixer, and test its various characteristics. The diode-ring mixer is a passive, double balanced mixer. The passive design allows for greater bandwidth, at the cost of greater conversion loss; and the double balanced design provides great RF and LO suppression.

2 Experimental Setup

We build the double balanced diode ring mixer according to Figure 2. It consists of two transformers and a diode ring. The ring diode used is BAT15-099R, which can be used in these mixers for up to 12GHz in frequency. The RF transformers are ADT4-1WT+, which work from 2 to 775 MHz. Here, the transformers are used as baluns, which convert between balanced and unbalanced signals.

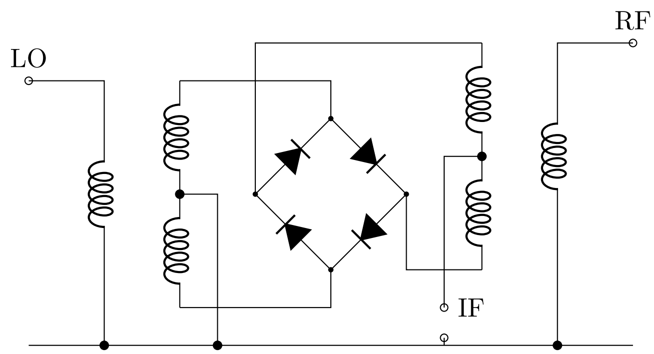

Figure 2: Circuit of Double Balanced Diode Ring Mixer

3 Results and Discussion

3.1 Overall Performance

To test our mixer, we drove both the LO and RF inputs at 0dBm, and set RF frequency to 10MHz, and LO frequency to 7.1MHz. The output spectrum from 0Hz to 40MHz is shown in Figure 3, where the sum and difference frequencies, as well as the most prominent intermodulation distortions are marked by texts.

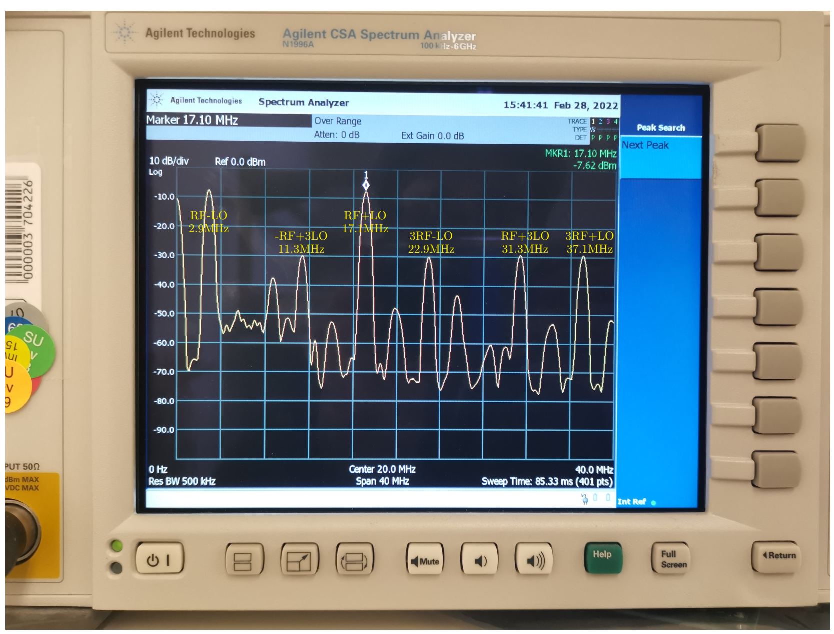

Figure 3: Spectrum of Mixer Output. LO=RF=0dBm.

From the figure, we can see that both the sum (17.1MHz) and different (2.9MHz) frequencies are at least 20dB above the intermodulation distortions, which means our mixer mixes the two inputs pretty well. In addition, the LO leakage is virtually non-existent – well below -50dB at 7.1MHz.

Interestingly, at this level of input, the highest spurs occur at $3RF \pm LO$ and $3LO \pm RF$. These are all fourth-order intermodulations, with odd orders for both the RF and the LO components. We hypothesize that this particular diode-ring mixer network suppresses intermodulations when either the RF or the LO has even orders. To validate this hypothesis, we lowered RF to -10dBm, while keeping LO at 0dBm. The results are shown in Figure 4.

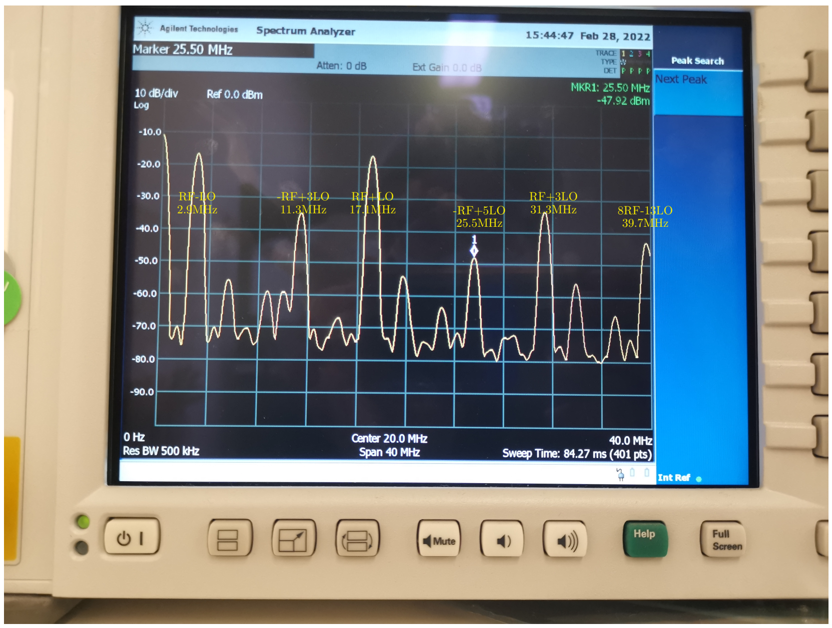

Figure 4: Spectrum of Mixer Output. LO=0dBm, RF=-10dBm.

In this case, the biggest intermodulations are at $3LO \pm RF$, $5LO - RF$, and something at 39.7MHz, which seems to be $8RF - 13LO$. The $5LO - RF$ still confirms our hypothesis of the mixer suppressing even orders of LO and RF. The component at 39.7MHz is quite weird, and we have no idea why this intermodulation would be so big.

3.2 Conversion Gain and 1dB Compression Point

An important performance metric of mixers is the conversion gain, defined as the power level of the IF output minus the power level of the RF input in dBs. Ideally, the conversion gain would be constant at all RF input levels. However, for real mixers, as the RF input power increases, the IF output power cannot keep up with the increase in input. The point where the ideal output power is 1dB lower than the actual output power is called the 1dB compression point. Operating below the 1dB compression point guarantees good linearity between the input and the output of the mixer; so little distortion is introduced to the signal.

We measured the 1dB compression point and gain when LO=0dBm by stepping the RF input power from -10dBm to 0dBm. The results are plotted in Figure 5.

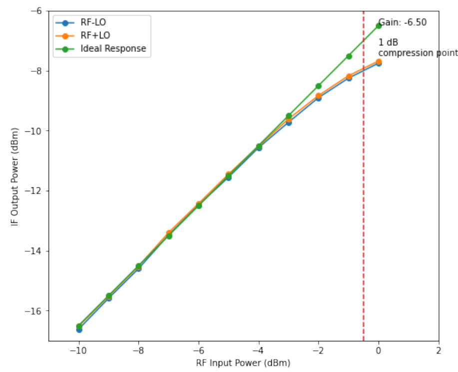

Figure 5: RF Input Power vs IF Output Power (LO=0dBm)

From the figure, we can see that under -4dBm, the relationship between input power and output power (in dBs) is very linear, with gain around $-6.5dB$. Ideally, the diode ring passive mixer would equally divide all the input power between the sum and the difference frequencies in the output. So we would expect to see a gain of $-6dB$ for both. The $0.5dB$ discrepancy between the measured $-6.5dB$ and the theoretical $0.5dB$ is probably due to non-ideal componenents.

However, above $-4dBm$, the ideal response and actual response start to differ, and we reach the 1dB compression point around $-0.5dBm$.

3.3 Conversion Gain vs LO Drive Level

To measure the dependance of conversion gain on LO Drive Level, we measured the conversion gain with LO drive level from -5dBm to 3dBm. Since the conversion gain is more actually measured at low RF levels, we kept RF input at -10dBm, and calculated the gain as

$$\text{IF output level} + 10dBm.$$

The results are plotted in Figure 6.

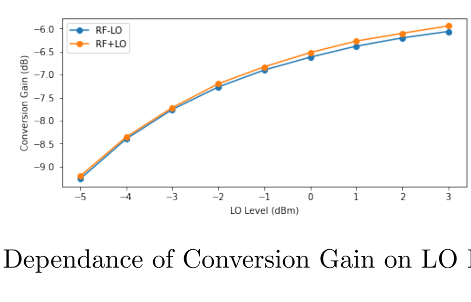

Figure 6: Dependance of Conversion Gain on LO Drive Level

From the plot, we can see that at low LO levels, the gain increases by almost 1dB for every 1dB increase in LO level. At high LO levels, the conversion gain becomes insensitive to the LO level, and almost reaches the theoretical -6dBm.

This behavior is both expected and desired. Since the LO just serves to switch RF on and off, when it is high enough, the output should be independent of its value. In addition, the relative independence of conversion gain on LO drive level allows us to choose a wide range of LO drive levels.

3.4 Third-Order Intercept

3.5 Port Isolation

4 Conclusions

Learn more about why some harmonics are more prominent