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E157 RF Design
Lab Partner: Zoe Worrall
Design Project 2
December 13, 2024

1 Summary Information

The secret message is “HMC”. The maximum range that we predicted our receiver would work at was XX m. The maximum range we were able to test was 72.3 m due to running out of cable length in the hallway. The analytical system temperature was 8.22E+10 K and the measured temperature was 7.13E+07 K. The analytical receiver IIP3 was 7.53 dBm and the measured one was XX dBm.

2 Pictures of Received Data

Figure 1: Picture of setup at 3 m range

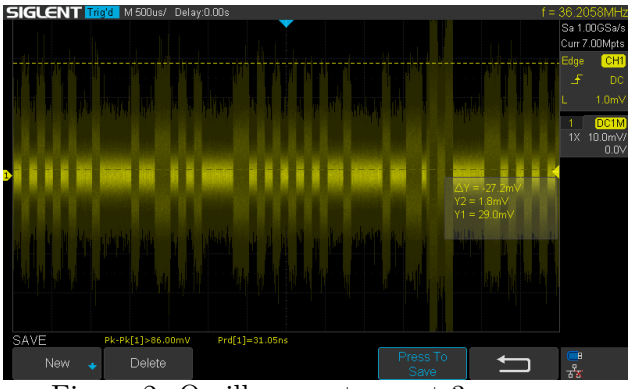


Figure 2: Oscilloscope trace at 3 m range

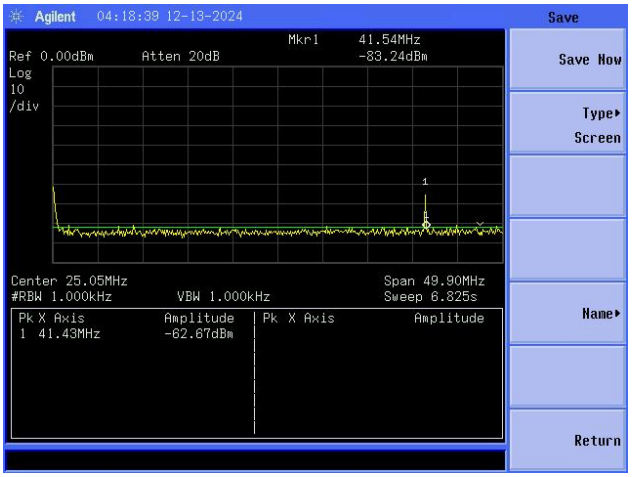


Figure 3: Spectrum at 3 m range


Figure 4: Picture of setup at max range

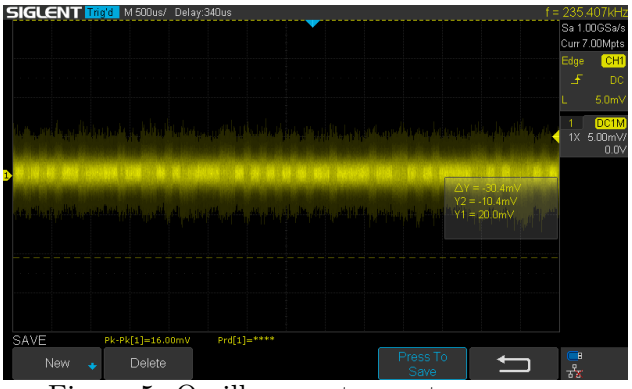


Figure 5: Oscilloscope trace at max range

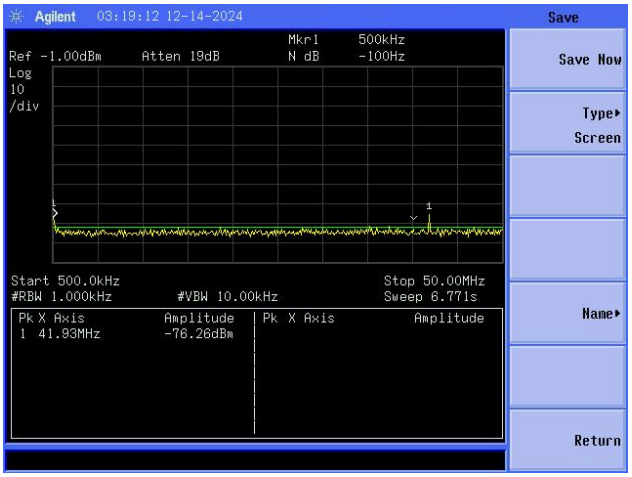


Figure 6: Spectrum at max range

3 Oscilloscope Trace Decoding

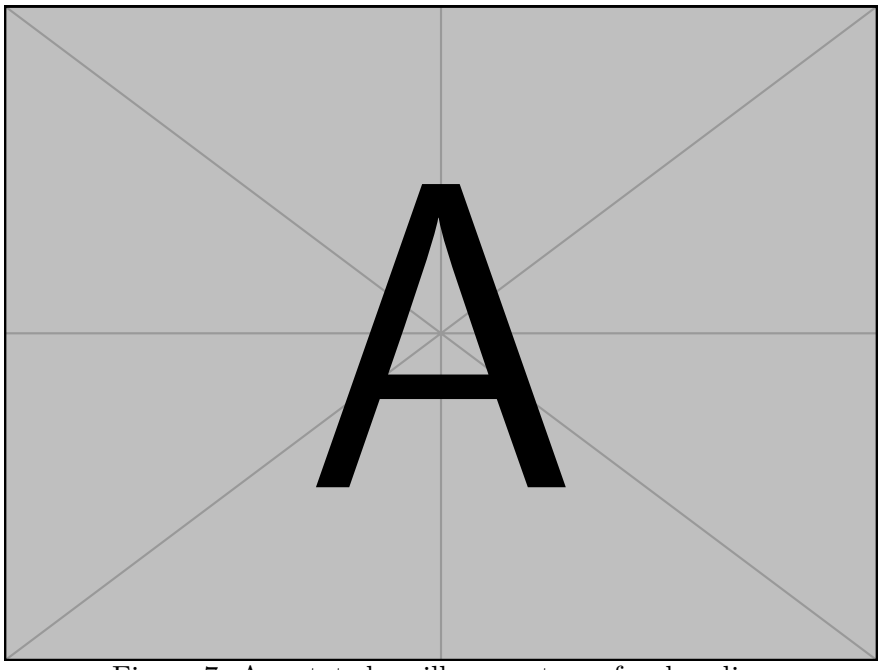


Figure 7: Annotated oscilloscope trace for decoding

4 Antenna Information

Figure 8: Hawking H-A16SD Antenna

5 Receiver Schematic

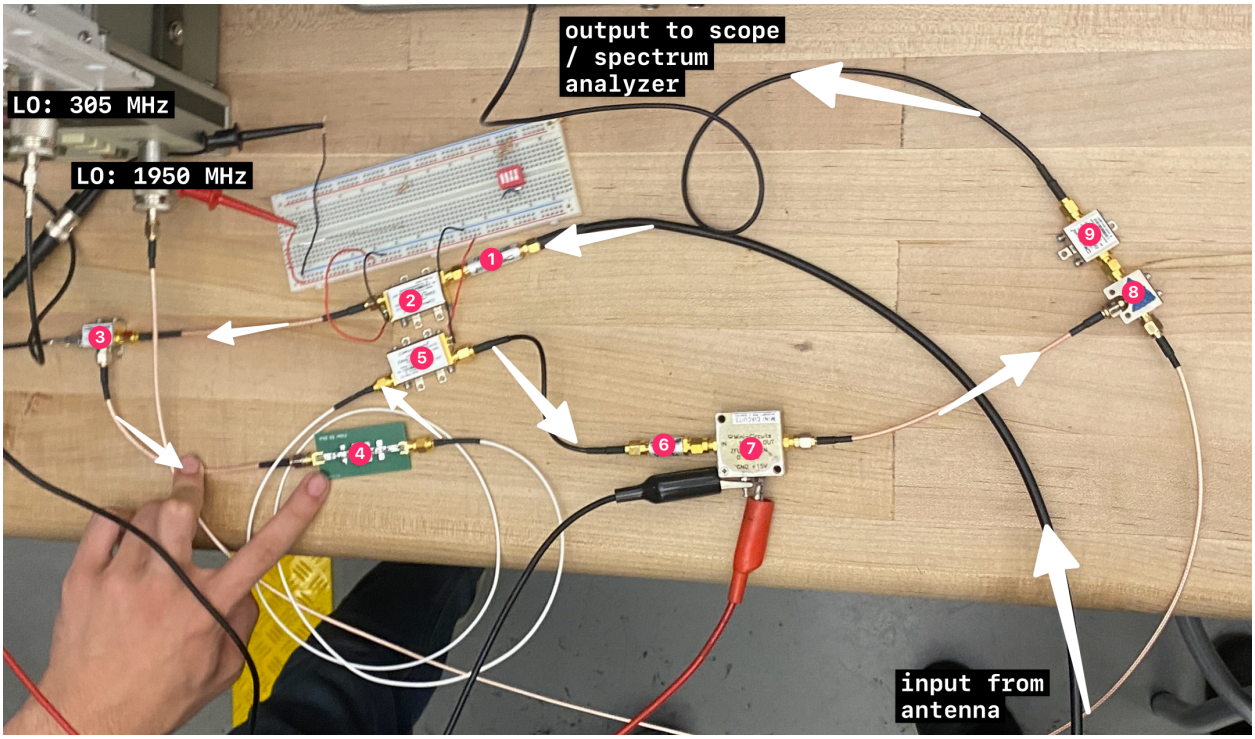


Figure 9: Picture of Receiver

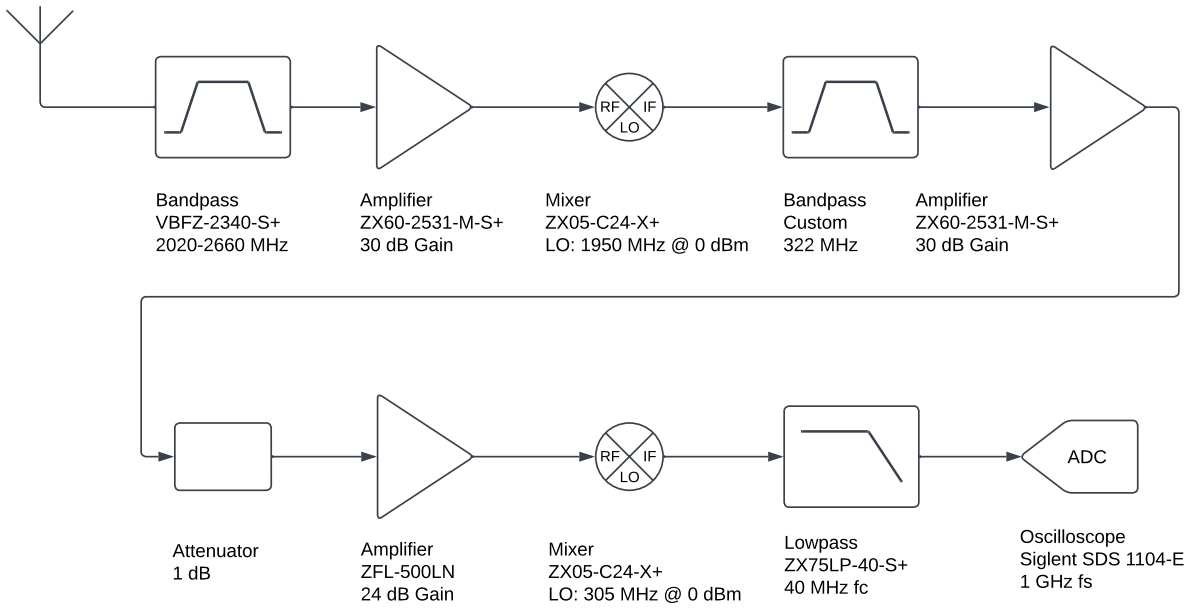


Figure 10: Receiver Schematic

The custom bandpass filter was built as a 2nd order chebyshev filter designed using Marki LC Filter Design Tool. The S21 log magnitude is provided below for reference

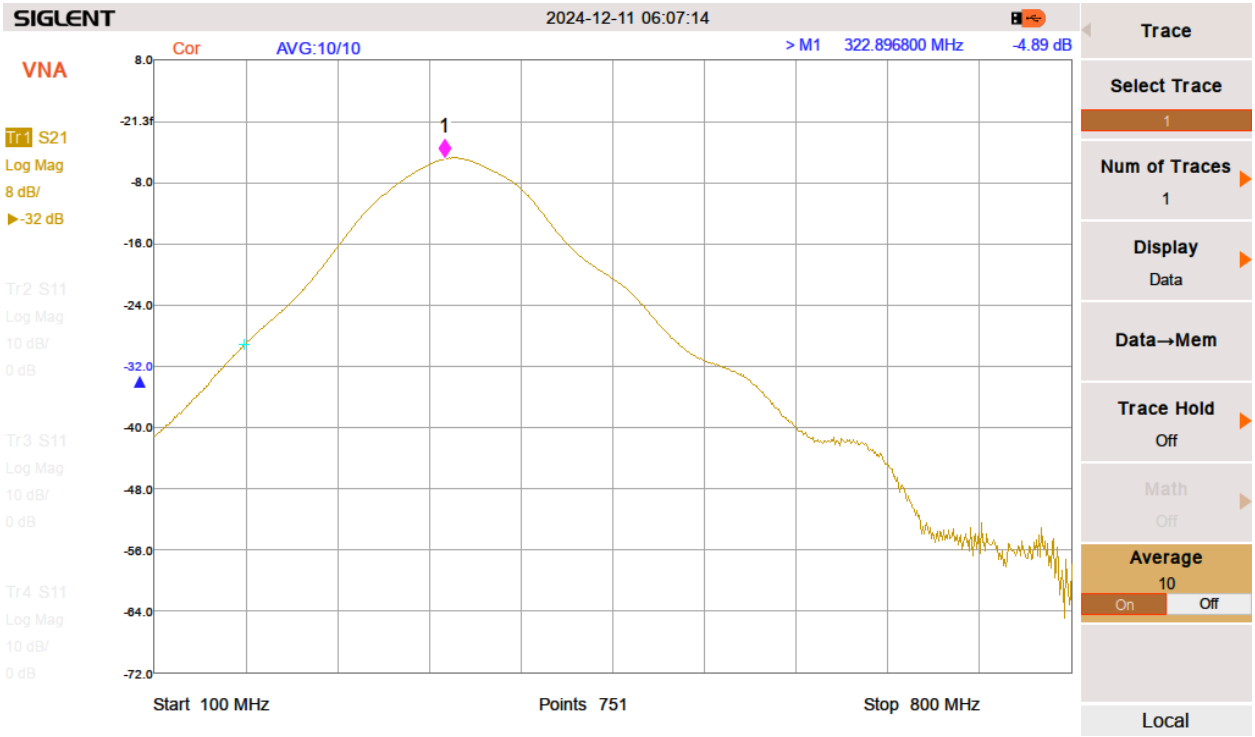


Figure 11: Custom Bandpass filter S21

6 Receiver Spectra

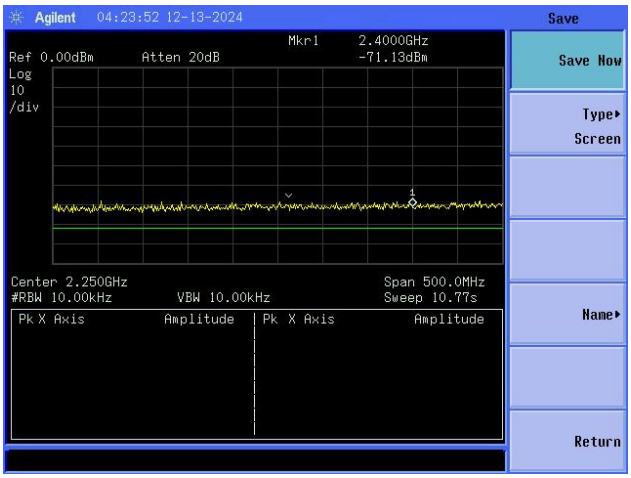


Figure 12: Stage 0: Raw antenna spectra

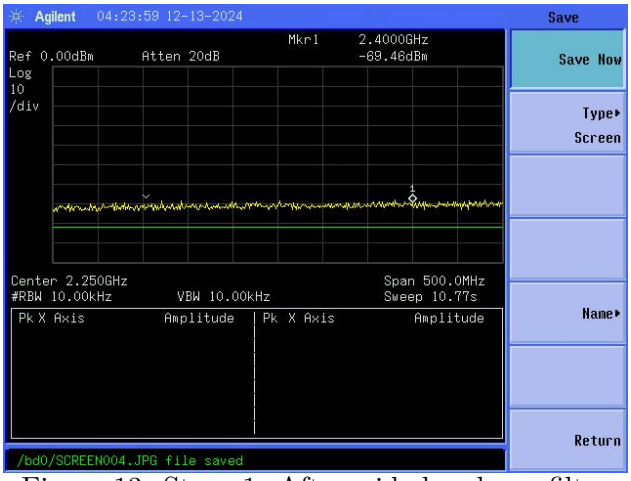


Figure 13: Stage 1: After wide bandpass filter

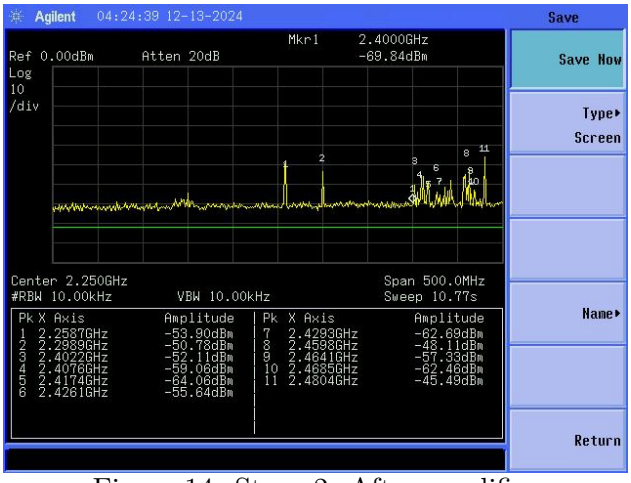
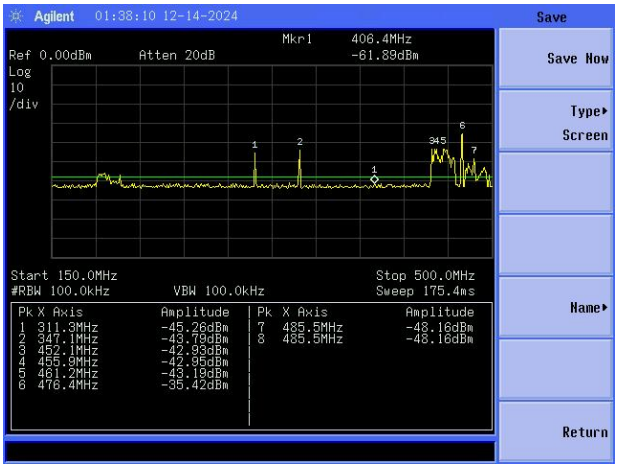
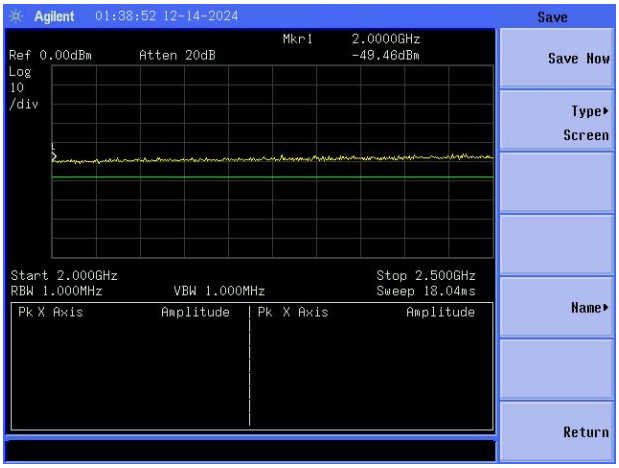


Figure 14: Stage 2: After amplifier



(a) IF Spectra



(b) RF Spectra

Figure 15: Stage 3: After mixer (LO = 1950 MHz)

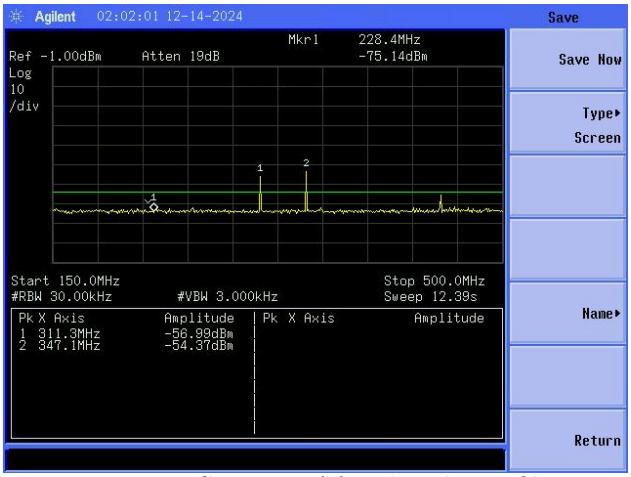


Figure 16: Stage 4: After bandpass filter

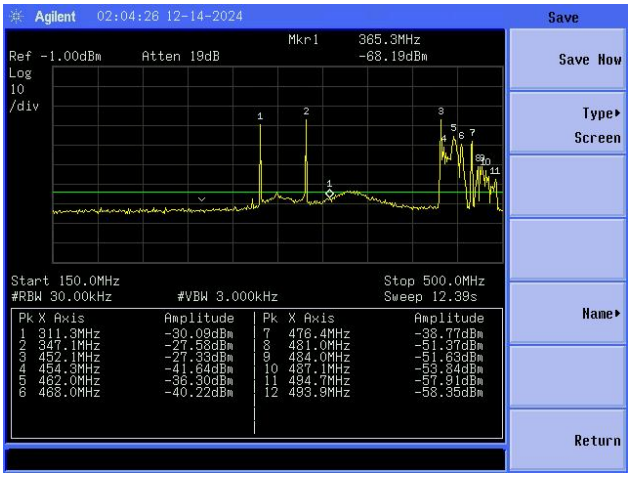


Figure 17: Stage 5: After amplifier

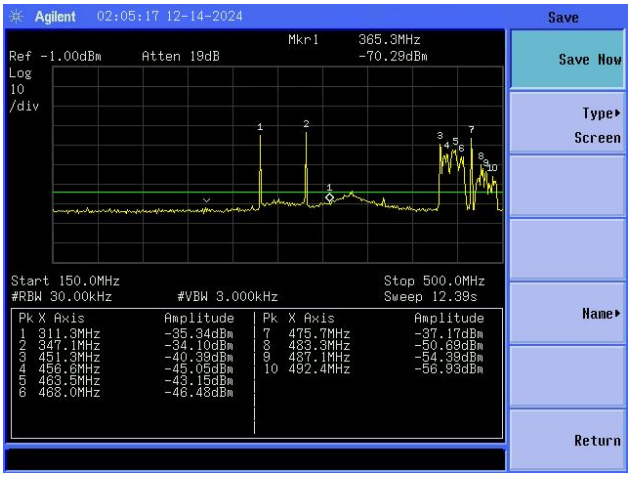


Figure 18: Stage 6: After attenuator

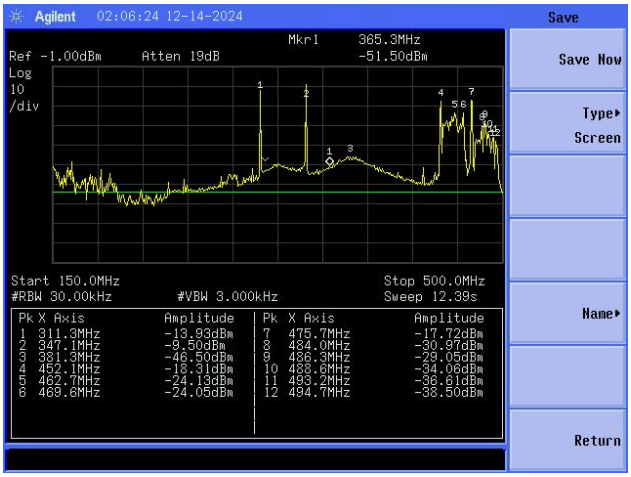
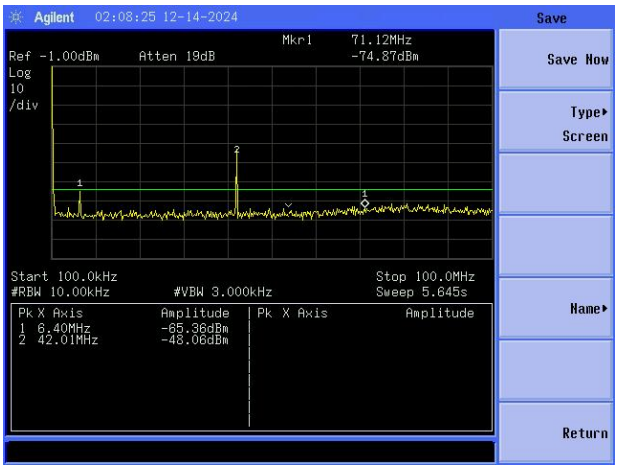
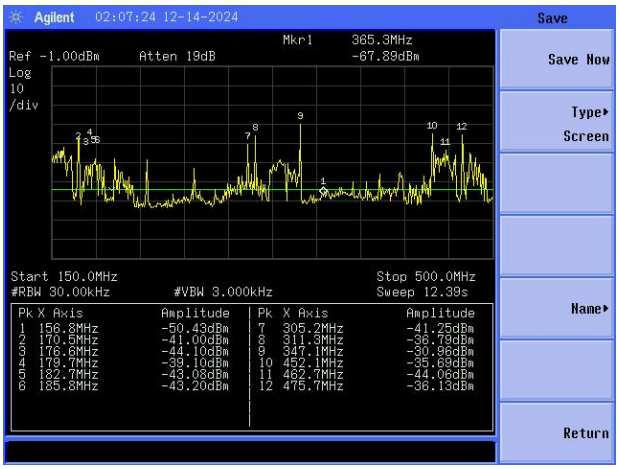


Figure 19: Stage 7: After amplifier

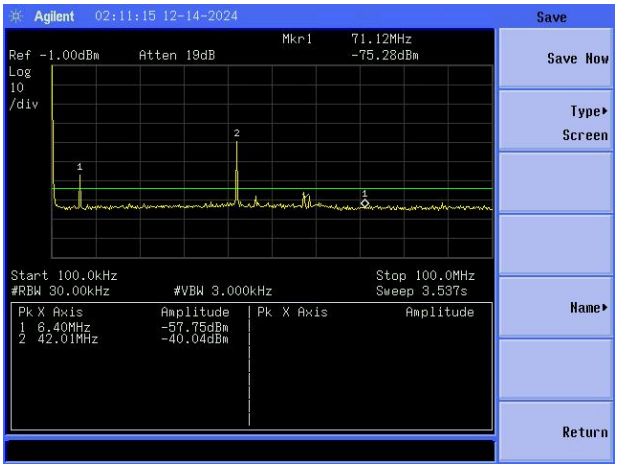


(a) IF Spectra

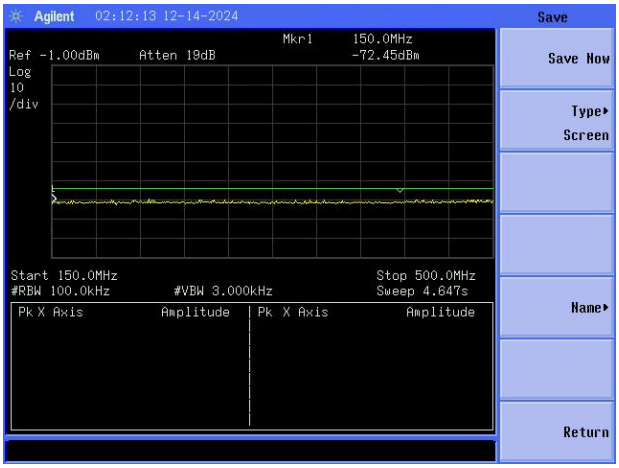


(b) RF Spectra

Figure 20: Stage 8: After mixer



(a) IF Spectra



(b) RF Spectra

Figure 21: Stage 9: After lowpass filter

7 Theoretical Signal and Noise Levels

8 IP3 Distortion Characterization

To measure the IIP3 of our amplifier we replaced the antenna with a two tone signal generator. We tested a range of input powers and measured the output power of the fundamental and the IM3 terms to make the following plot.

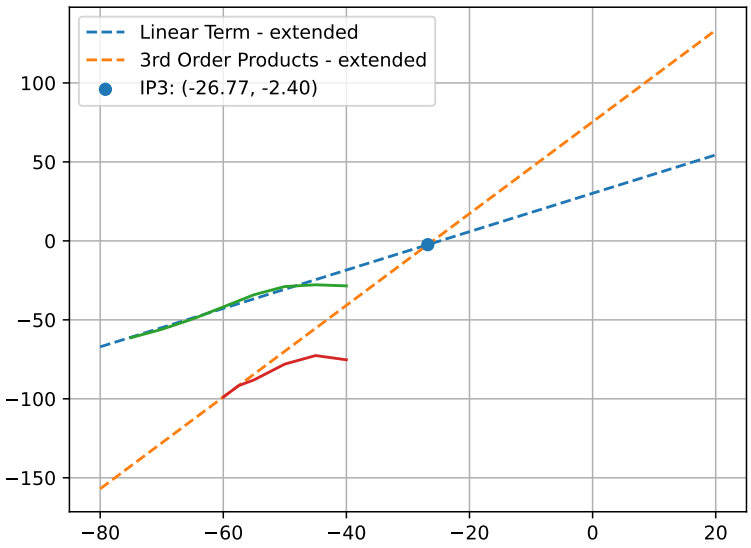


Figure 22: Analytical and measured IIP3

Running a linear regression we get:

Term	Slope	Intercept
Linear	1.21	30.12
3rd Order	2.9	75.34

To calculate the analytical IP3 point we used the following logic. We only need to consider the IM3 components generated by the last amplifier because they are orders of magnitude larger than the earlier ones. This allows us to simplify the receiver chain into gain → amplifier → attenuation.

Adding additional (assumed perfectly linear) gain G before the final amplifier reduces the input power needed to achieve the same output power. In other words reduces $IIP3$ to $IIP3_{combined} = IIP3_{amplifier} - G$ while keeping the same $OIP3$. Adding additional attenuation L after the final amplifier reduces the total output, keeping $IIP3$ the same and reducing $OIP3$ to $OIP3_{combined} = OIP3_{amplifier} - L$.

Our final amplifier (stage 7) is the ZFL-1000LN which has an $IIP3$ of -6.4 dBm and $OIP3$ of 14 dBm. Adding up all the amplification and attenuation from stages 1-6, we get $G =$

56.1 dBm and addding up the attenuation from stages 8-9 we get L = -7 dBm. This results in analytical $IIP3$ = -62.5 and $OIP3$ = 7 dBm.

9 Additional Notes

All of the data, code, and figures are available in this github repo: github.com/kavidey/e157/tree/main/dp_02.

1. `schematics/` has the pretty display schematics made in Altium