



Characterization of Direct Conversion Software Defined Radios for Use in Broadband Spectrum Measurements

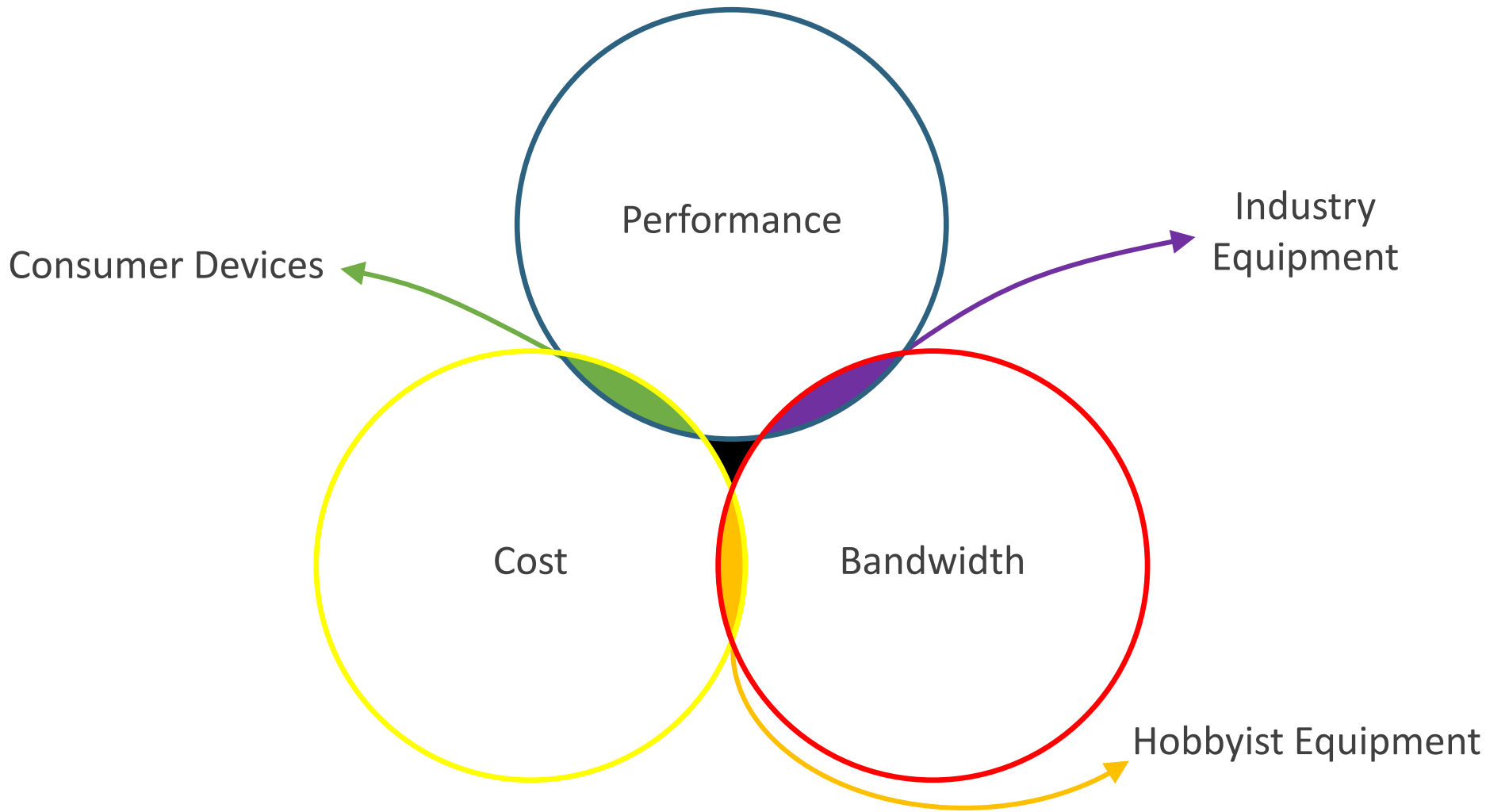
Architecture, performance, and non-idealities

Todd Schumann, Jeffrey Wepman, and Michael Cotton

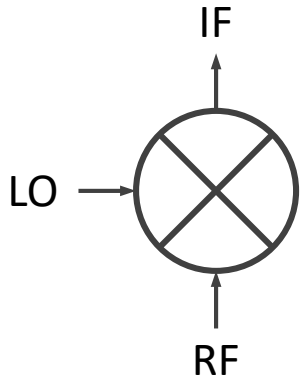
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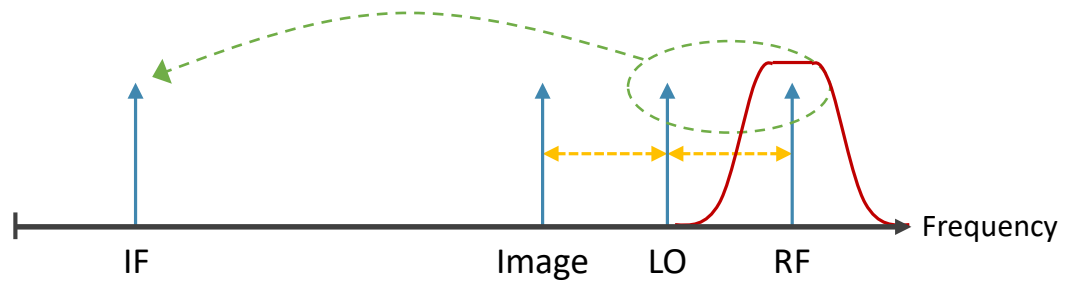
RF Device Tradeoffs



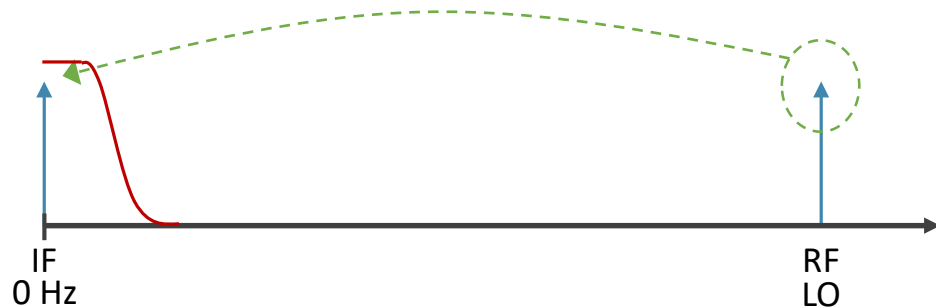
RF Mixing Schemes



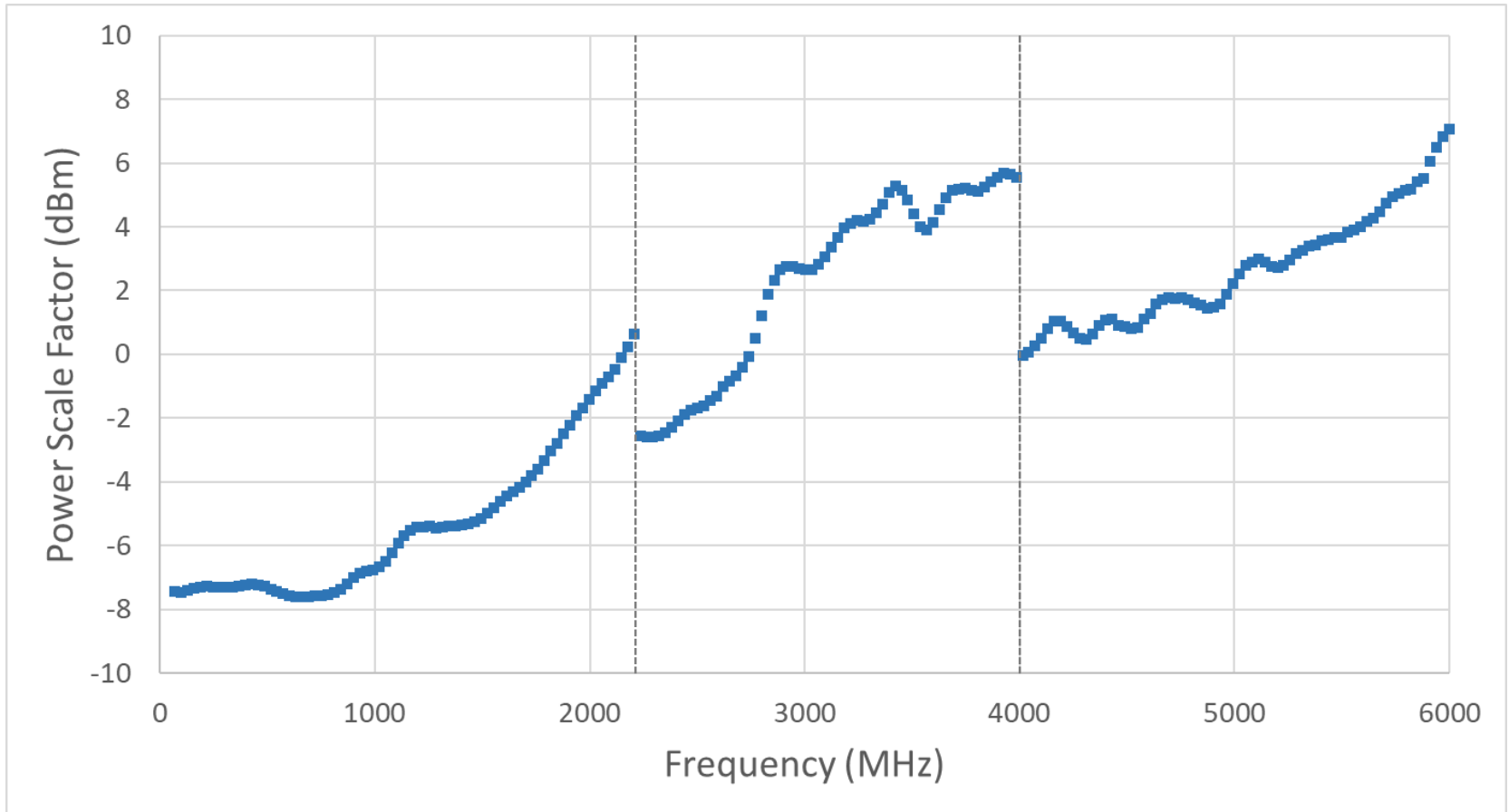
Heterodyne Mixing



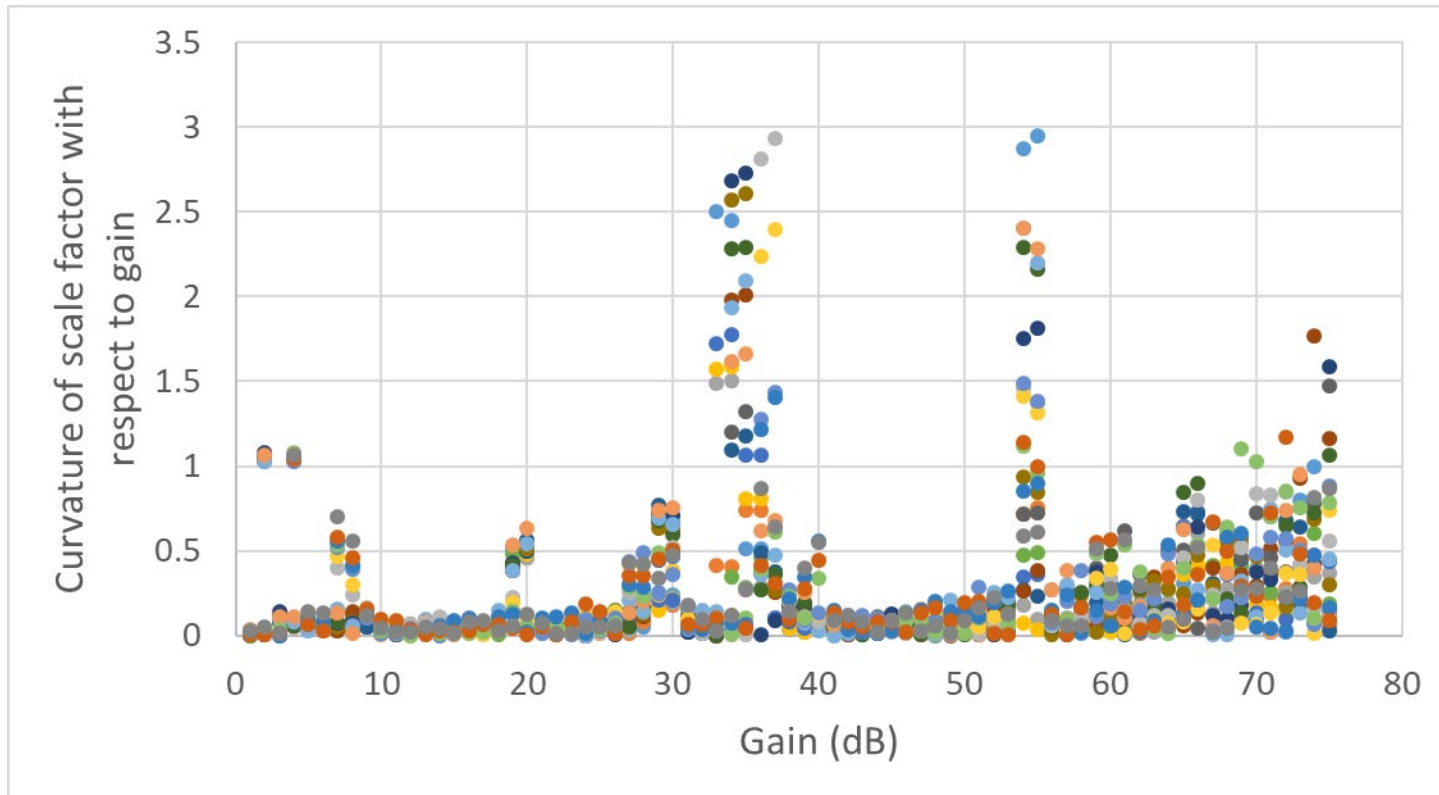
Homodyne Mixing (Direct Conversion)



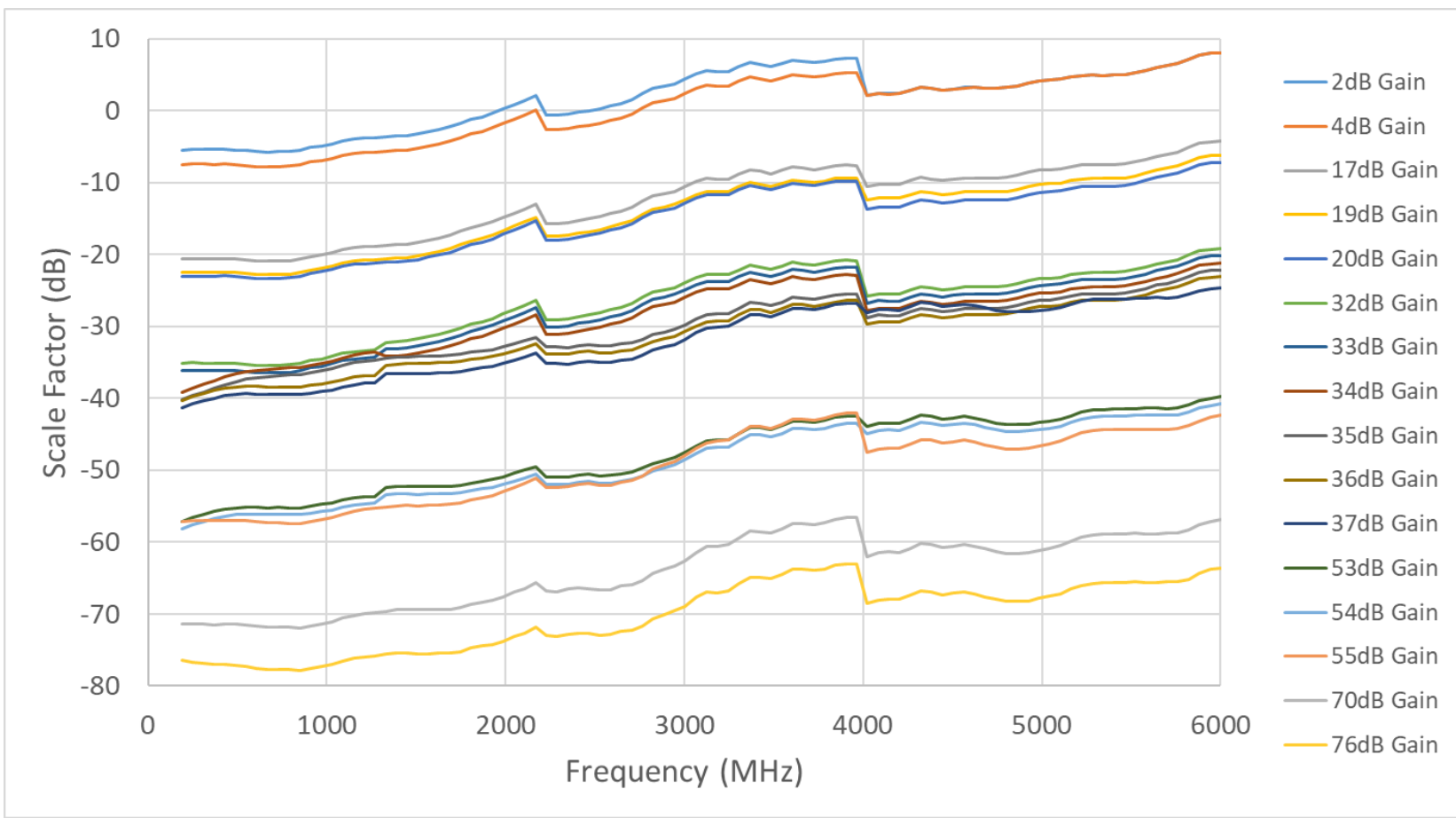
Scale Factor Measurement



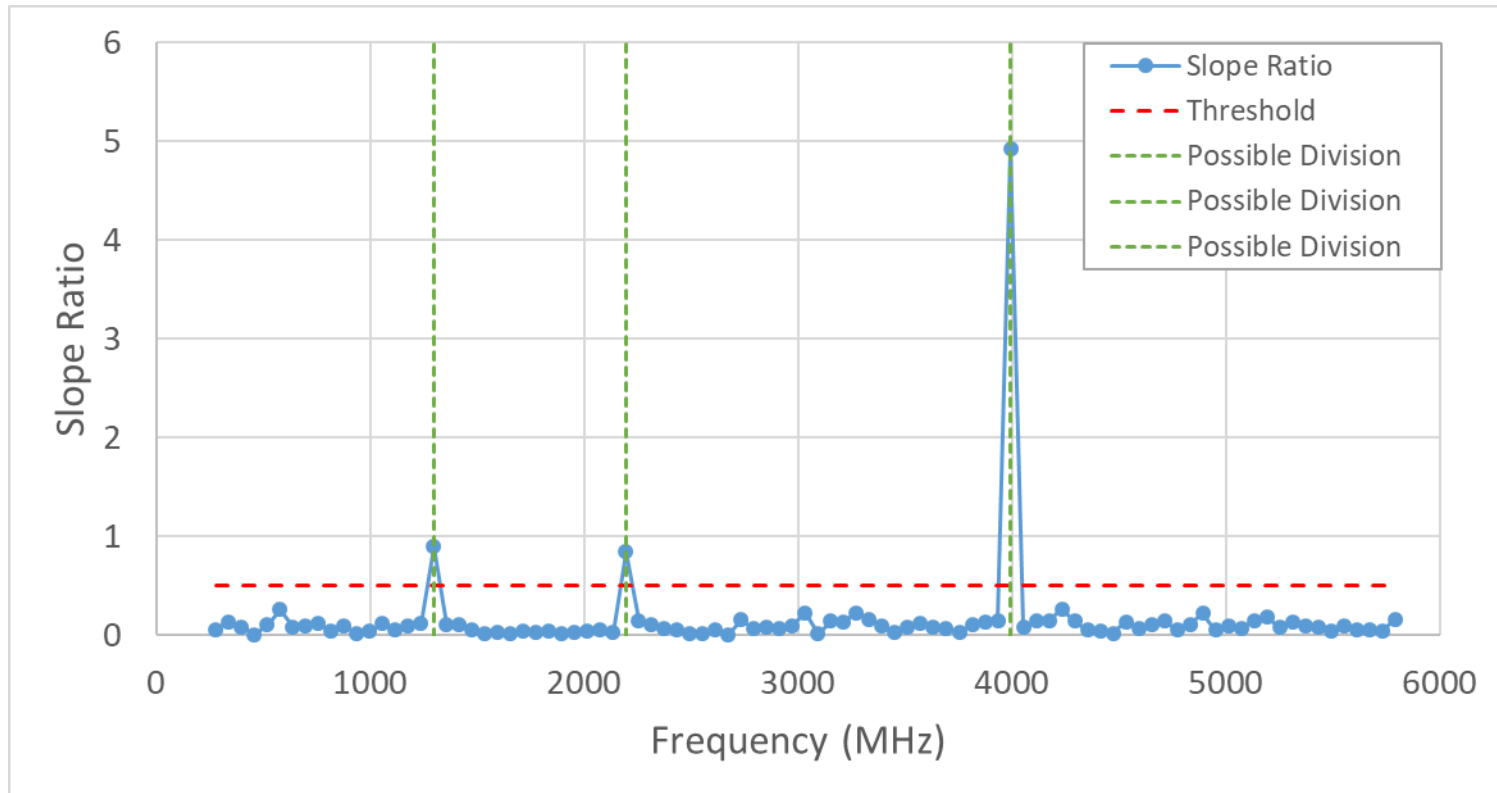
Curvature of Scale Factor vs Gain



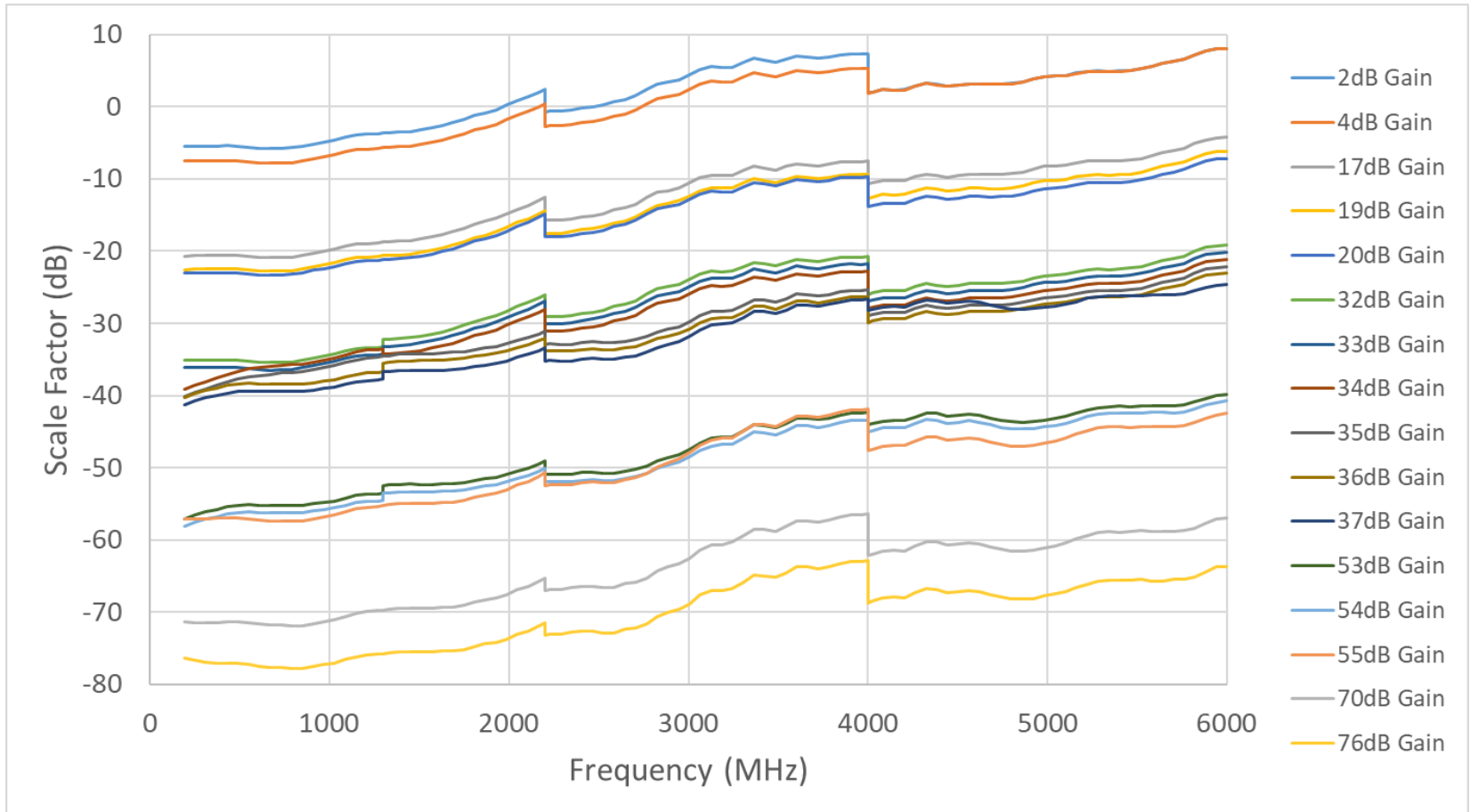
Determining Scale Factor Divisions in Frequency



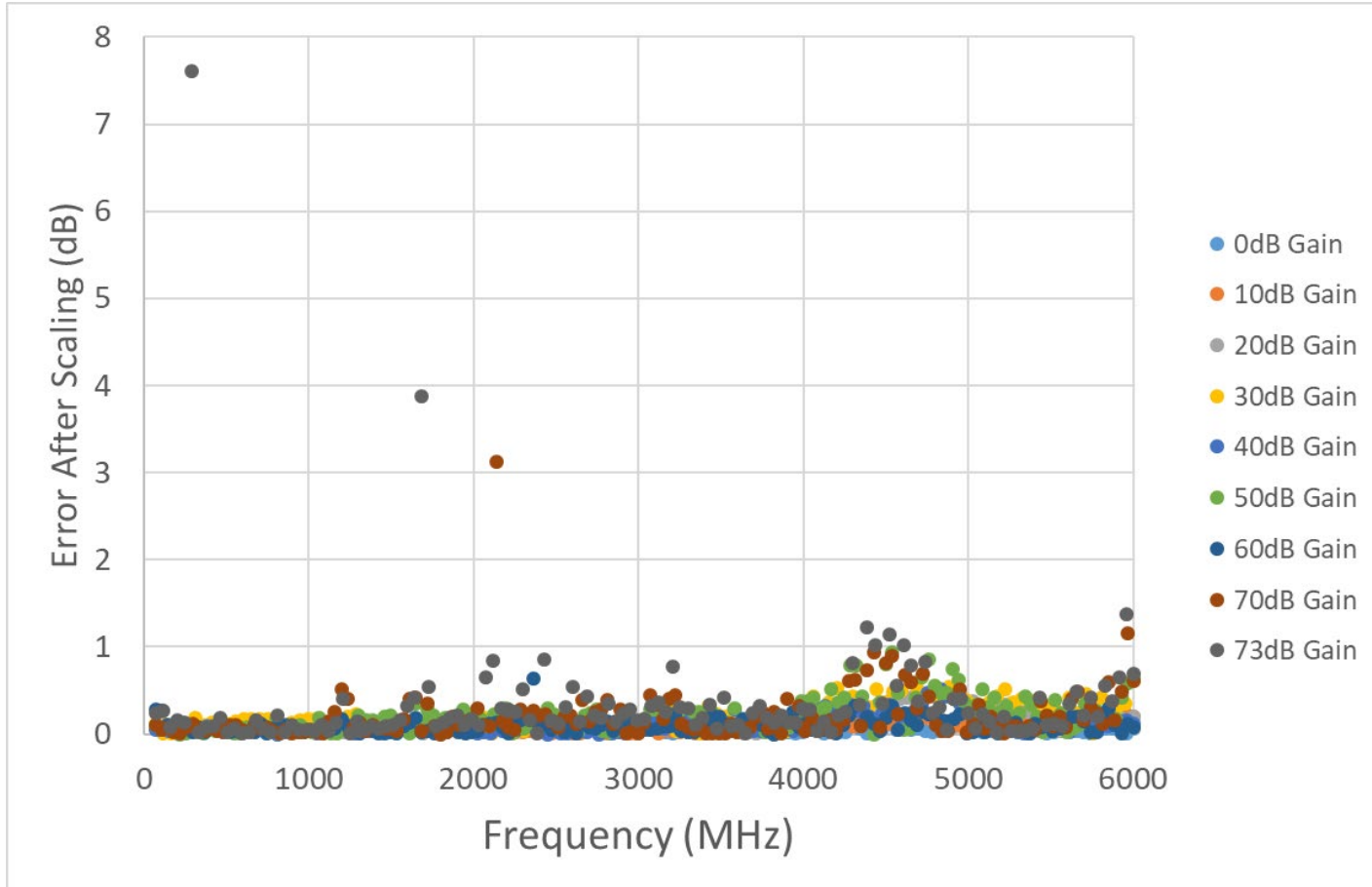
Division Finding Algorithm



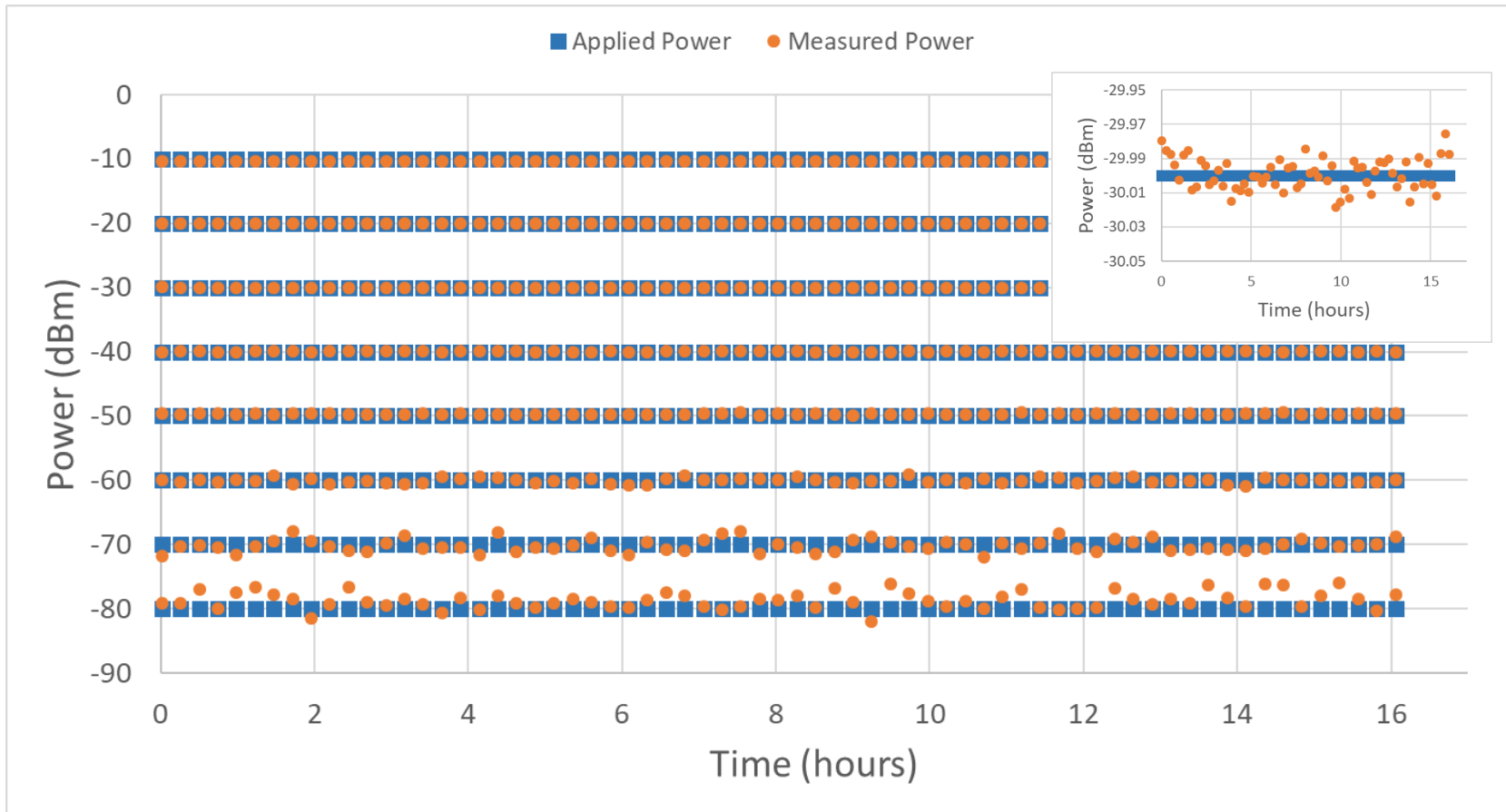
Final Scale Factor Determination



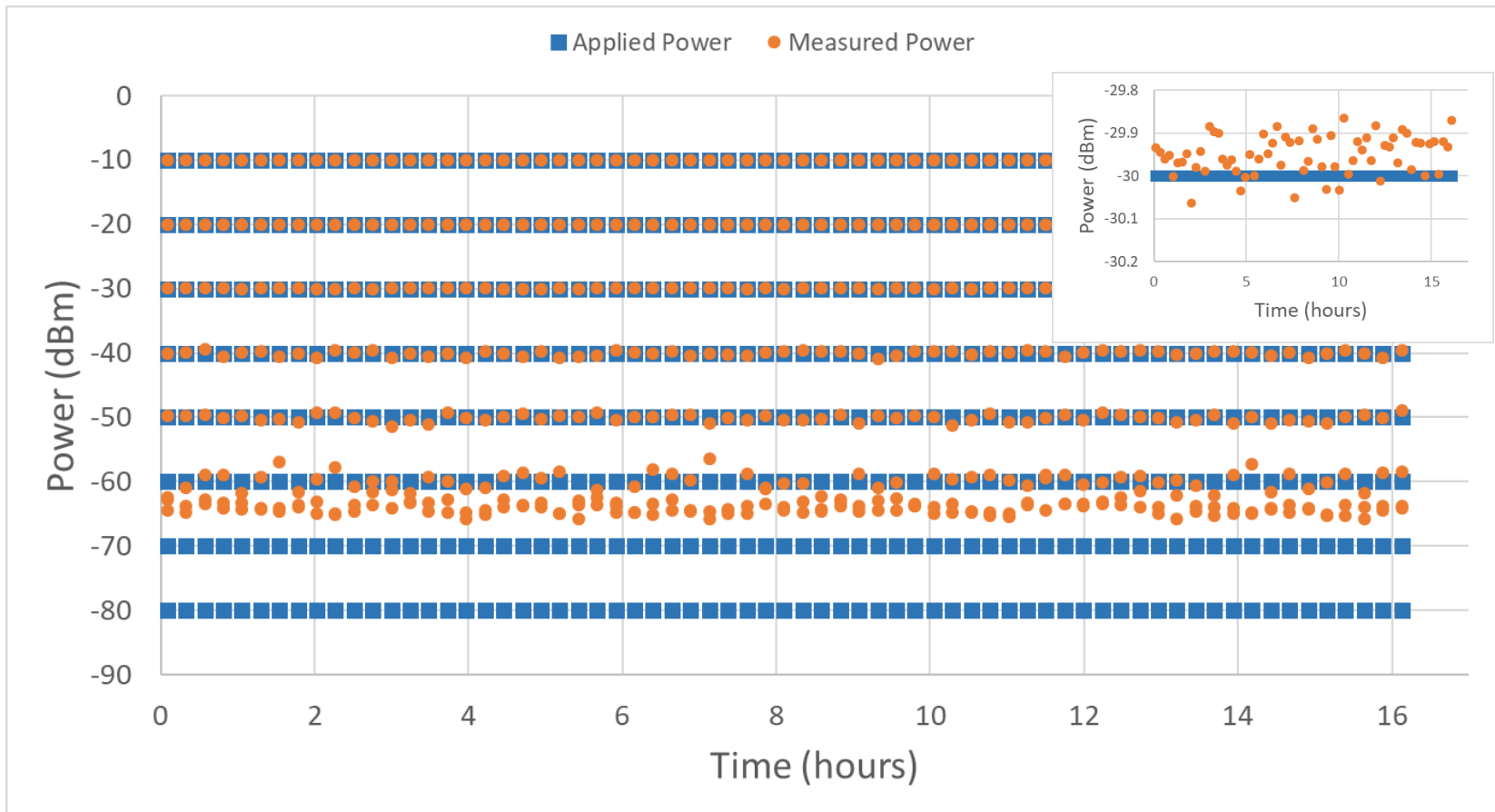
Testing Accuracy



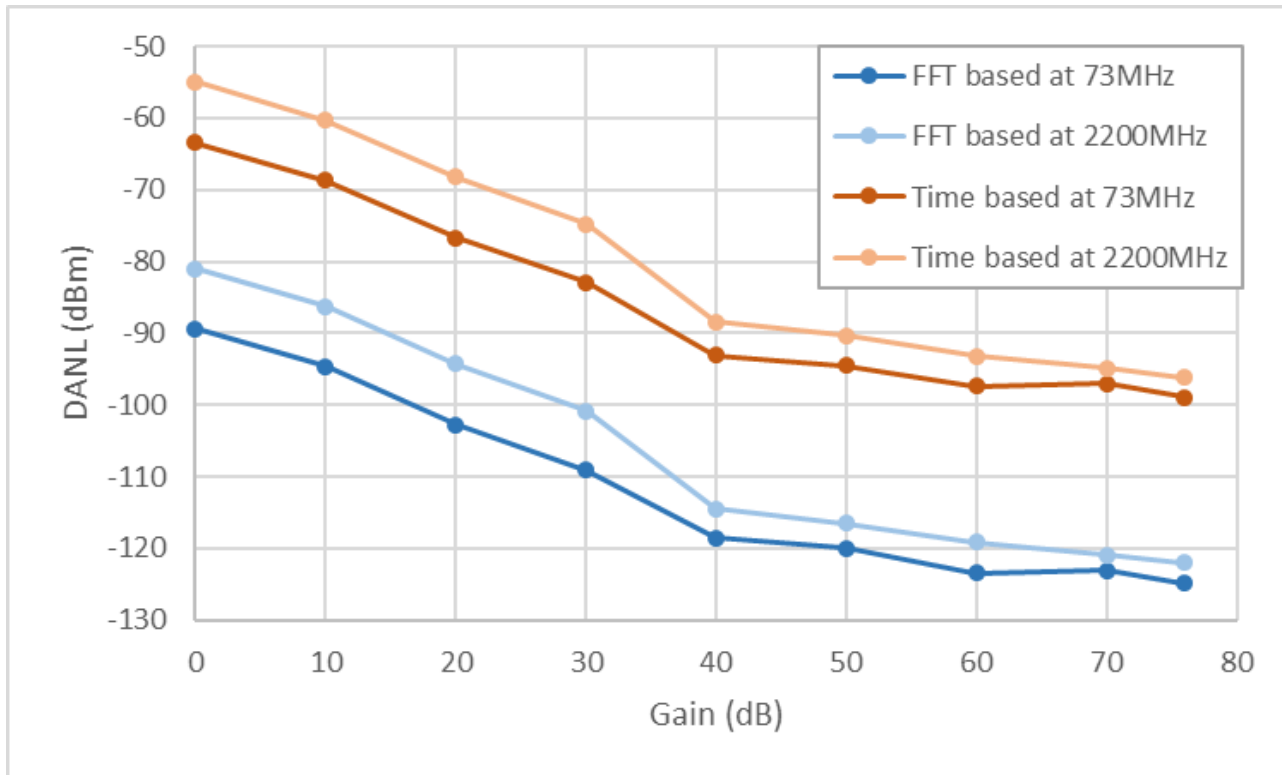
Long Term Stability ($f_0 = 70$ MHz)



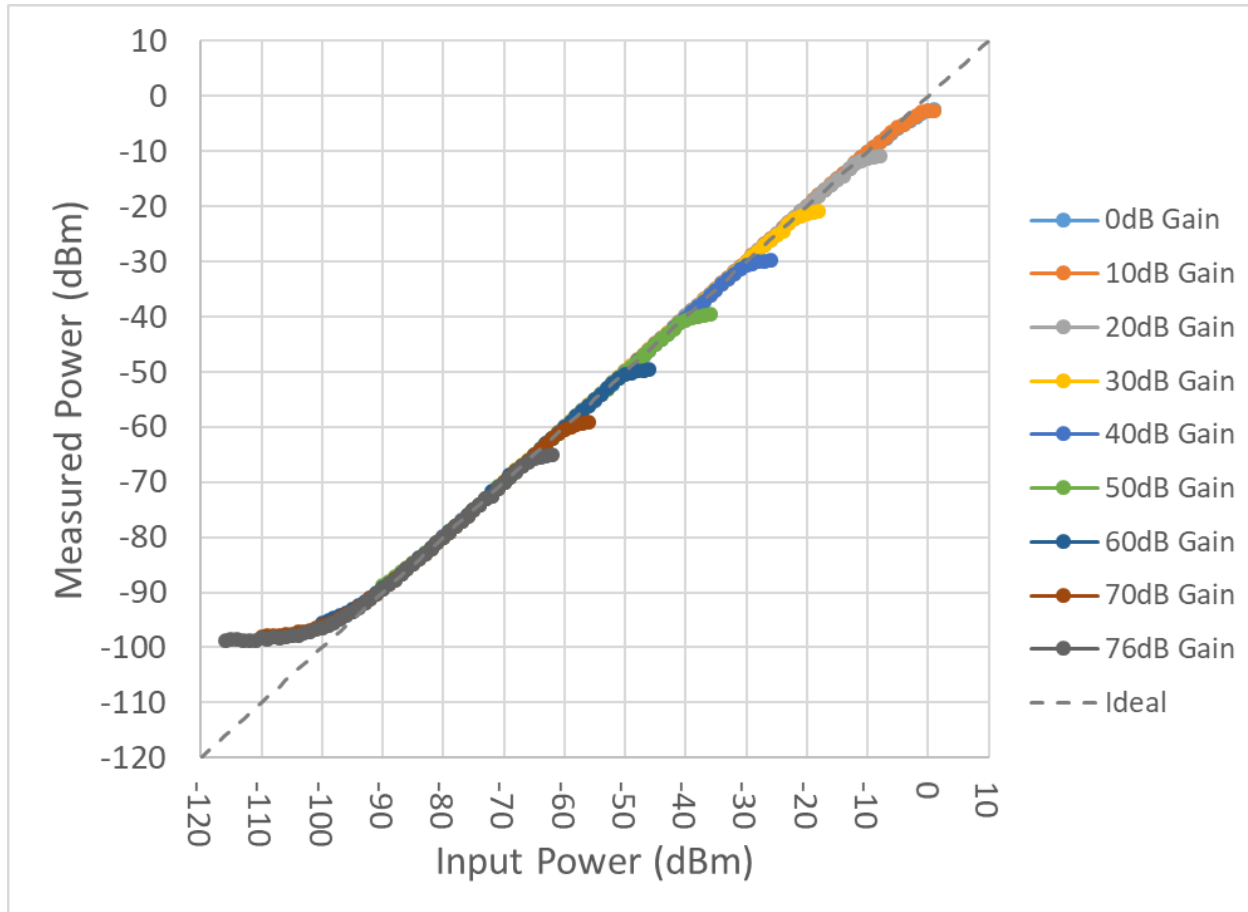
Long Term Stability ($f_0 = 6\text{GHz}$)



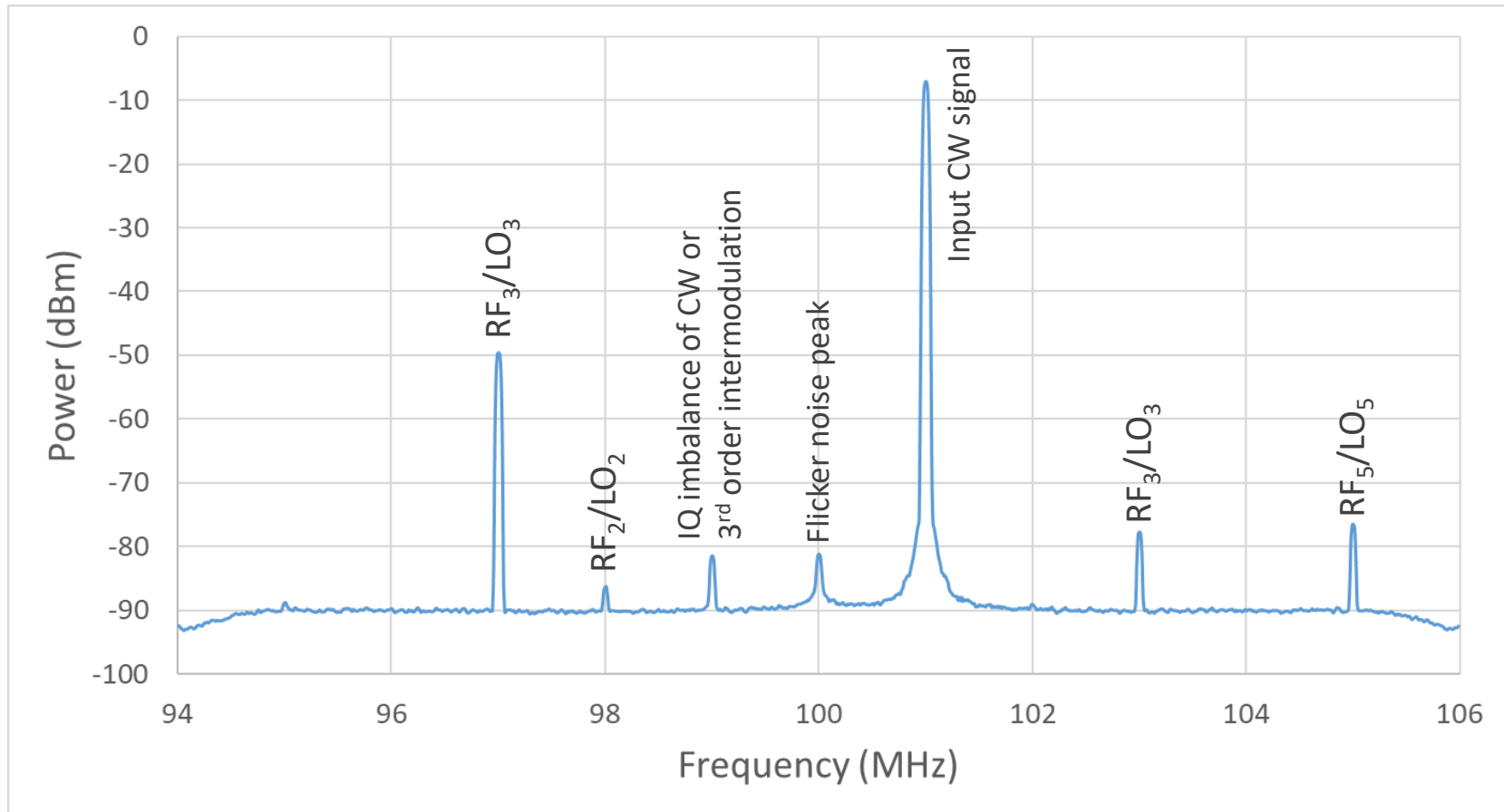
Determining the Lower Range (DANL)



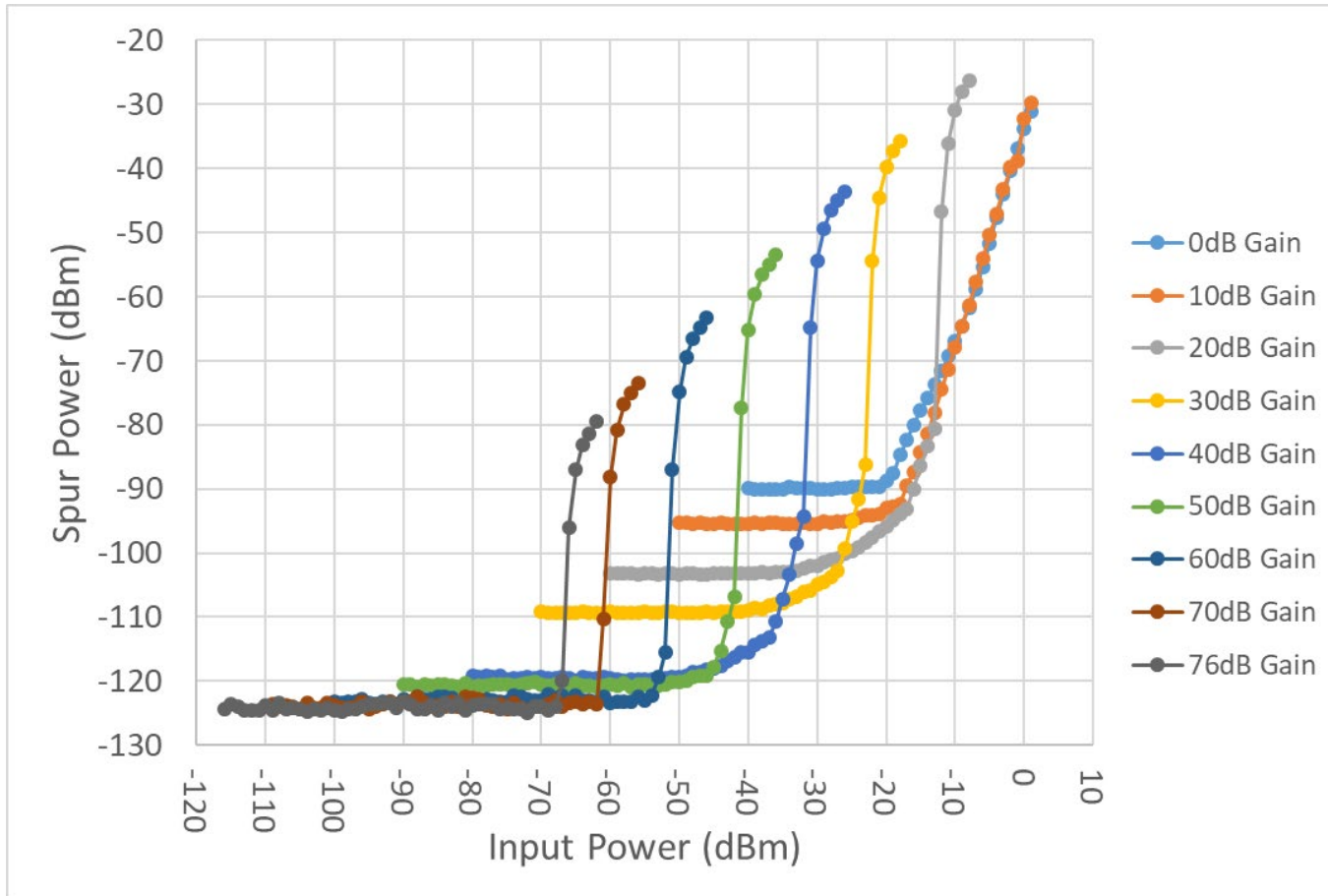
Determining the Upper Range (Compression)



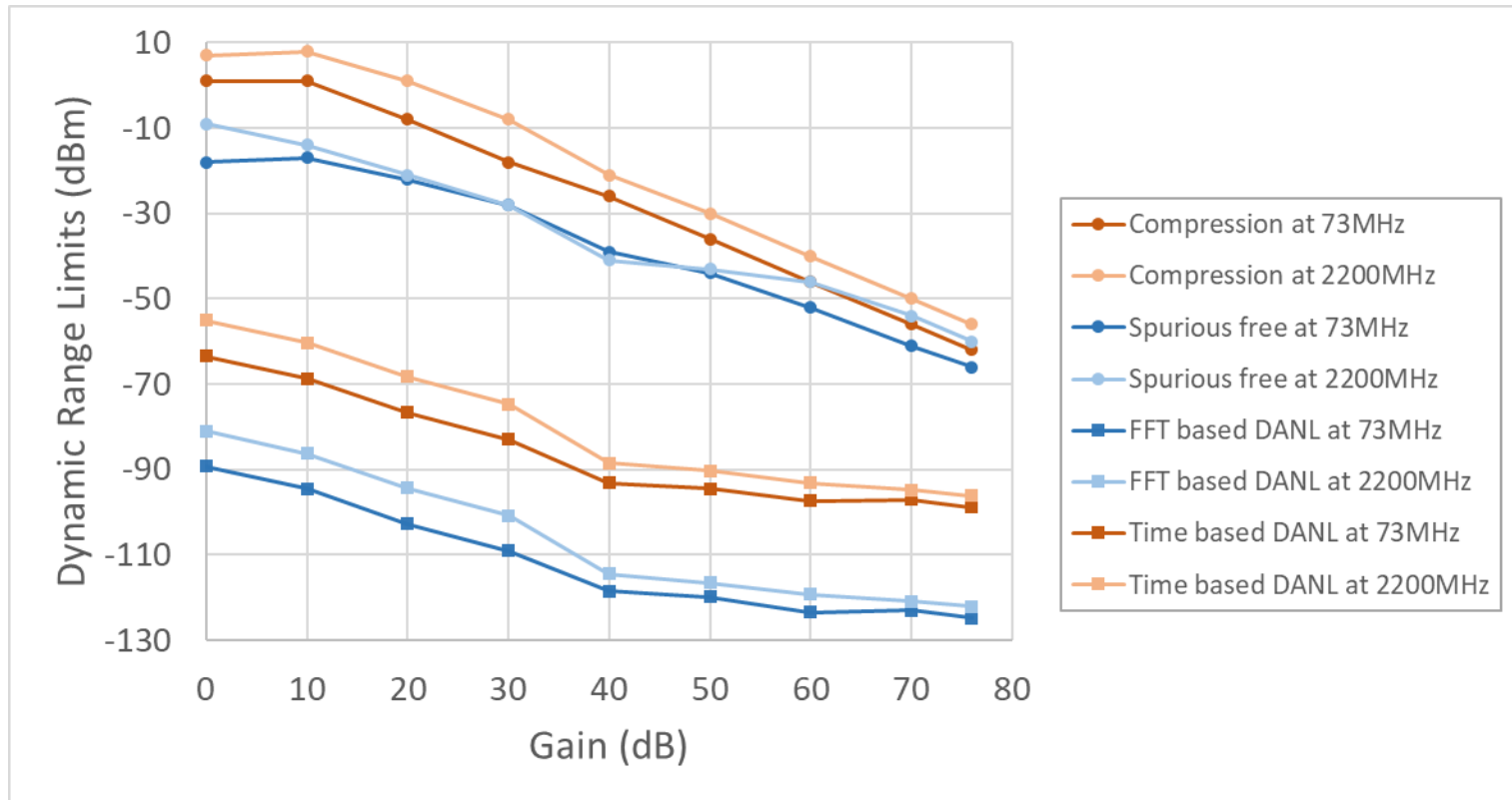
LO Harmonic Intermodulation at Compression



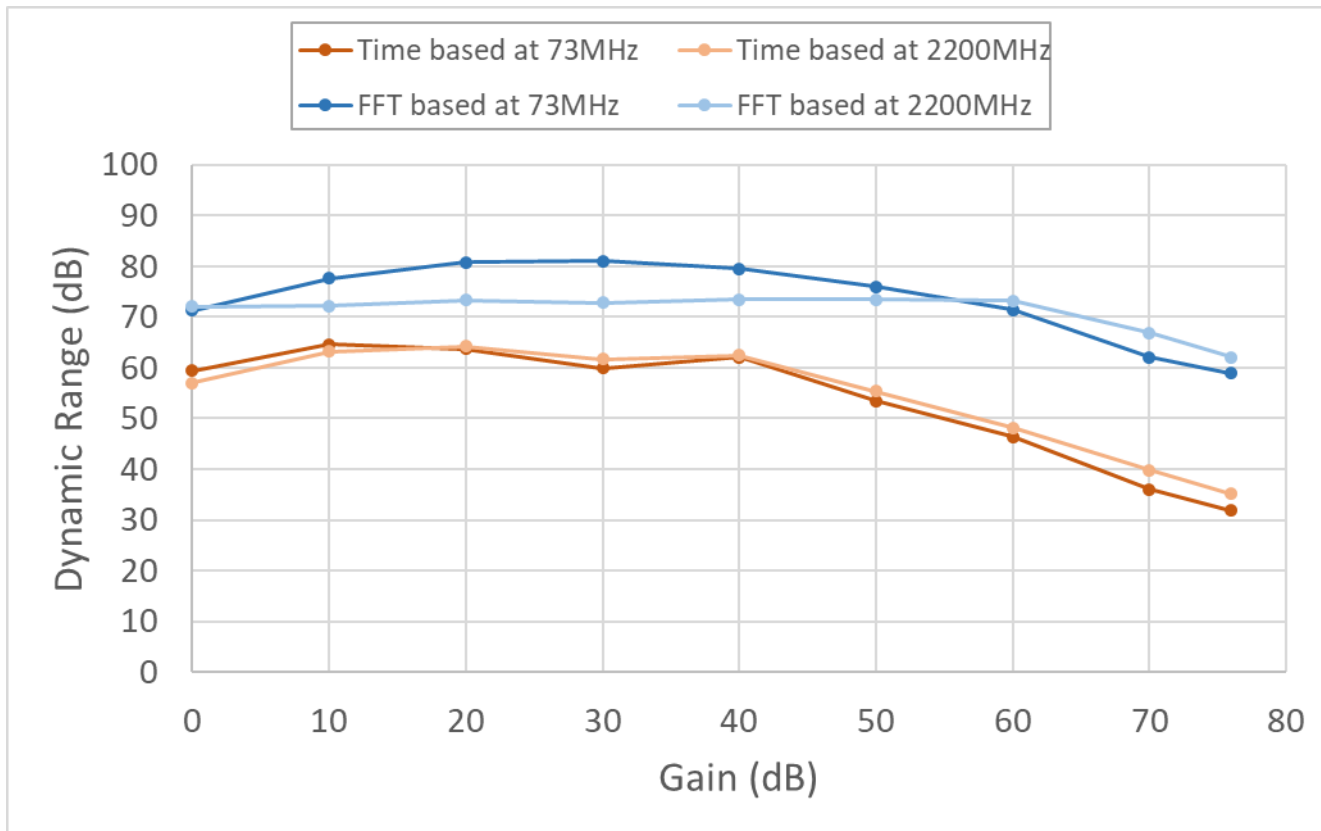
Determining the Upper Range (Spurious Free)



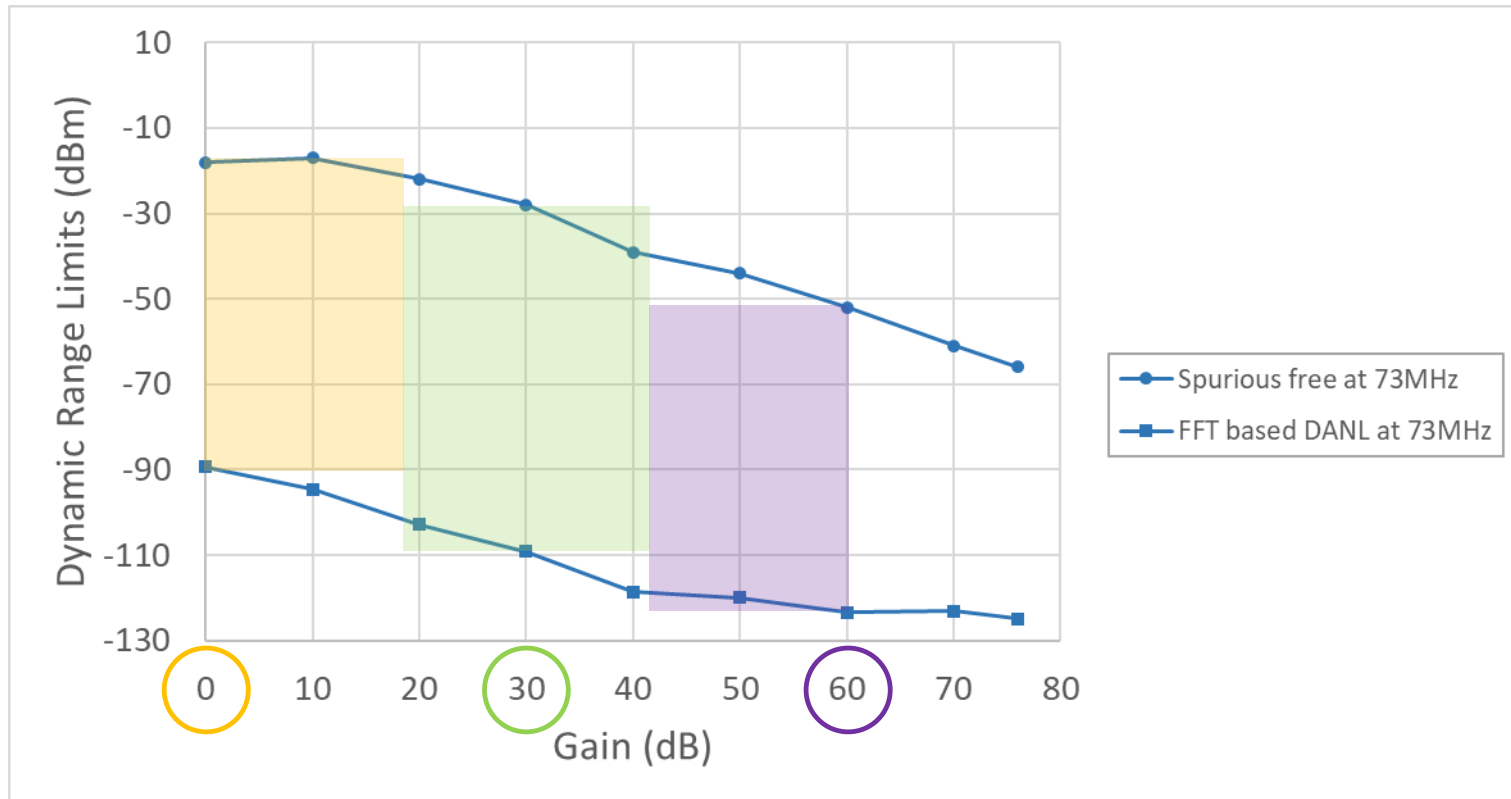
Dynamic Range Limits



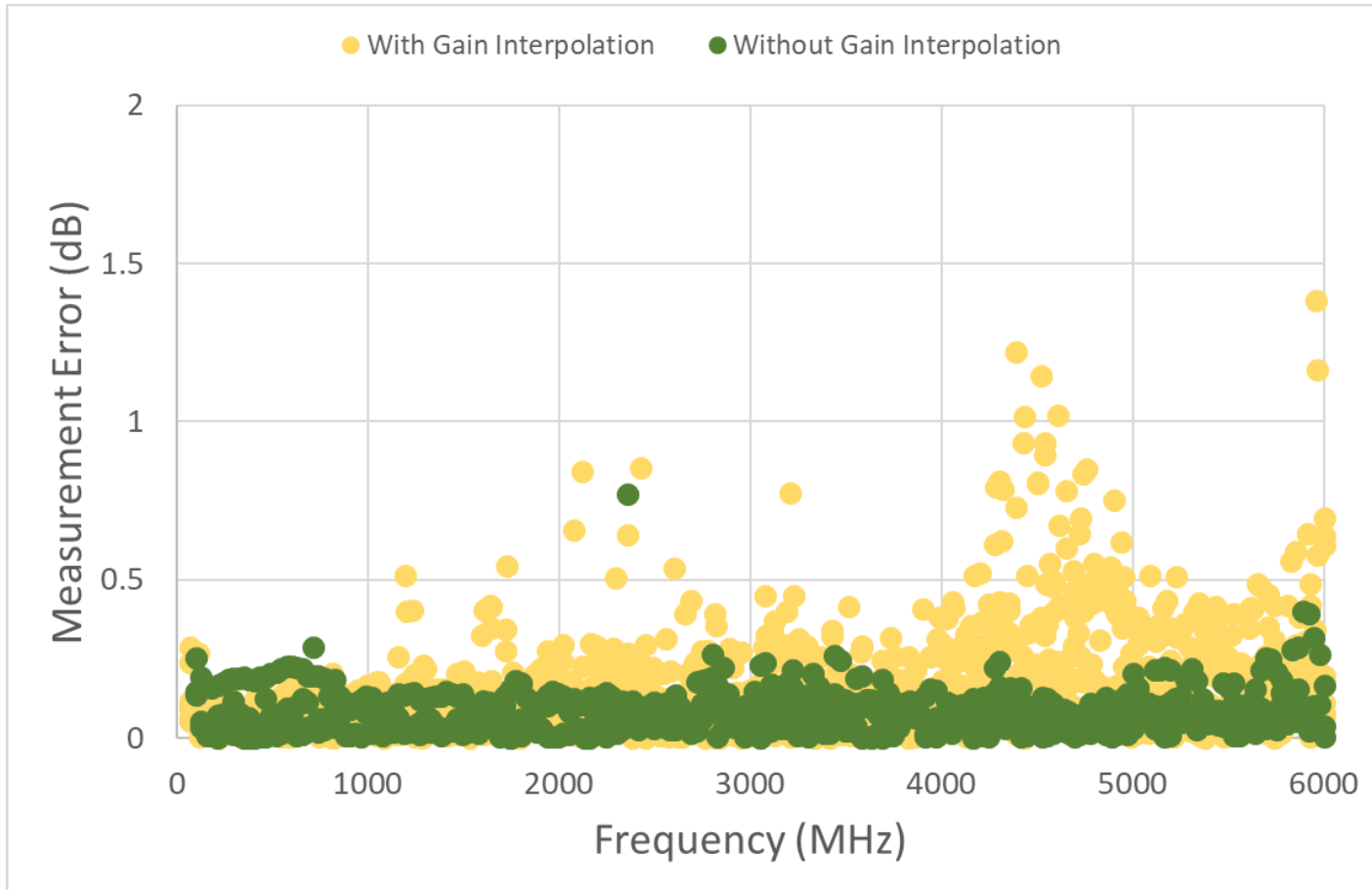
Dynamic Range



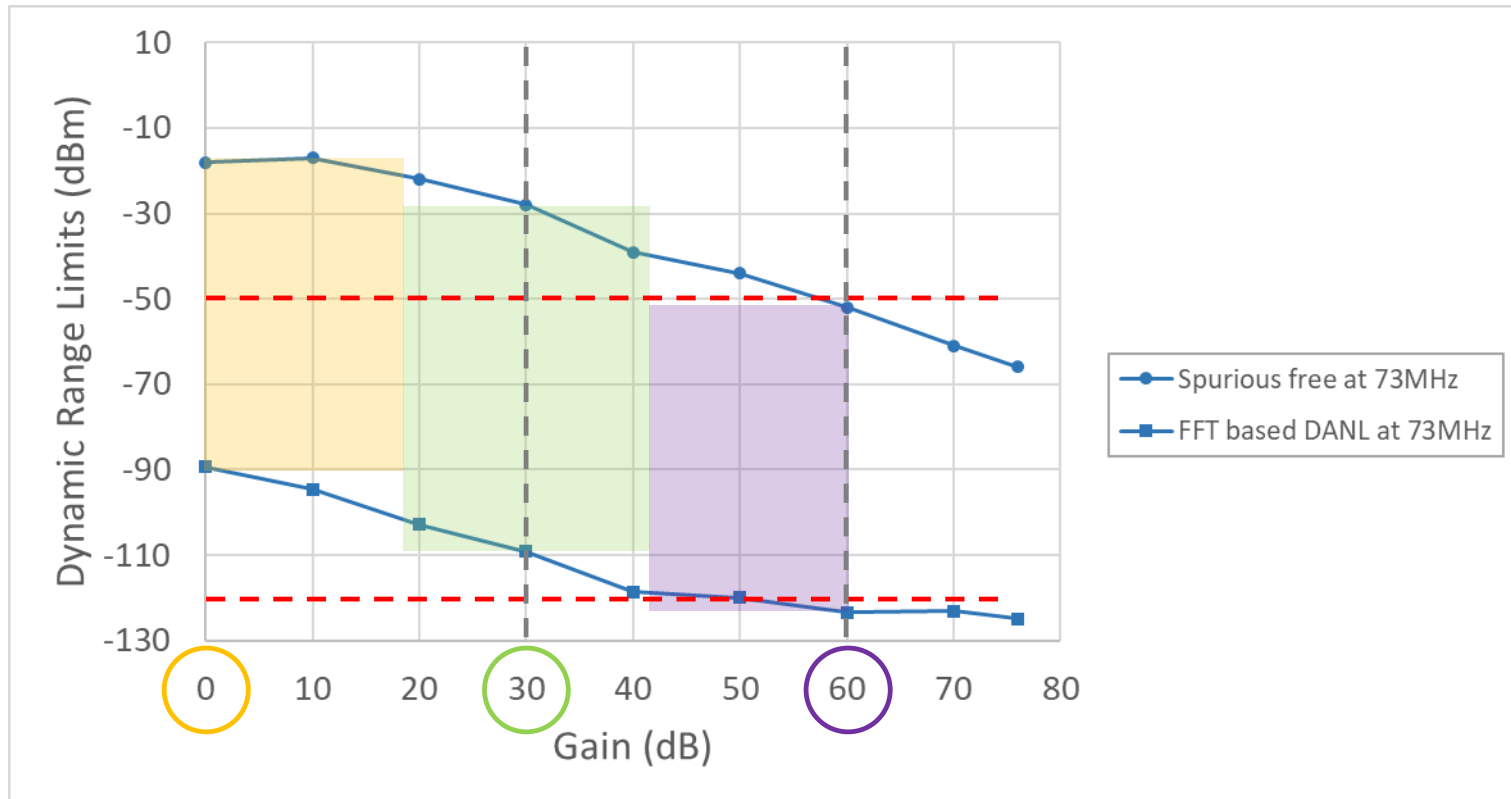
Optimal Gain Selection



Errors without Gain Interpolation

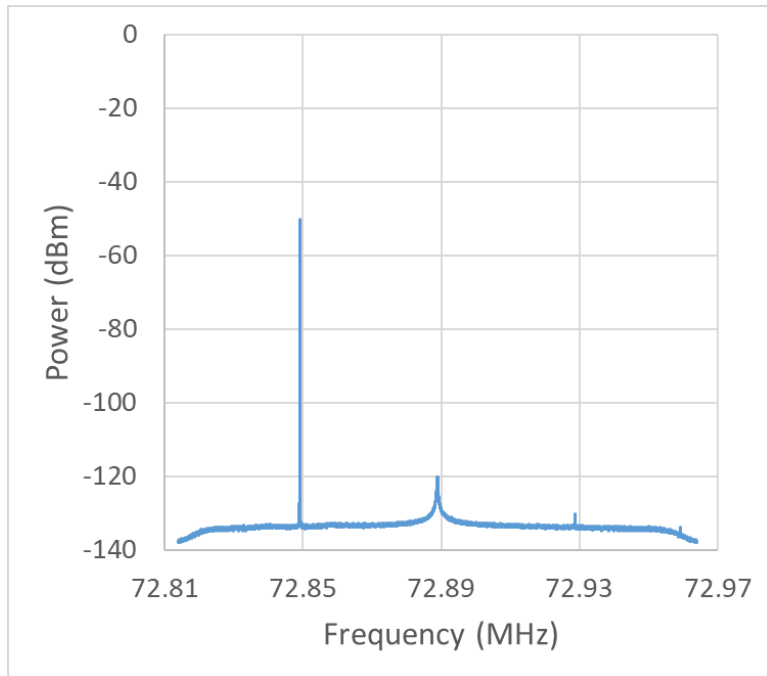


Special Case: Low and High Level Signals

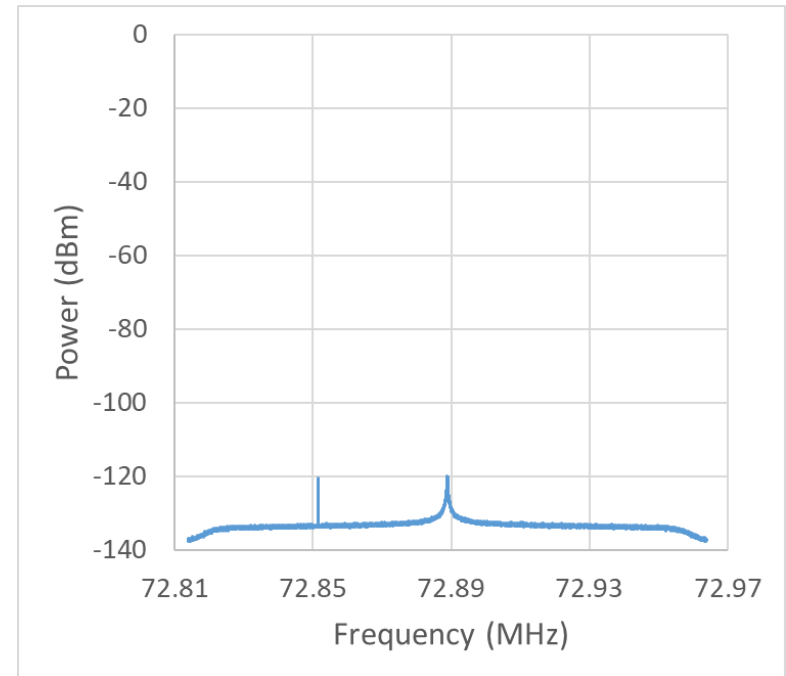


Boost Dynamic Range with More Points

-50dBm signal at 30dB gain

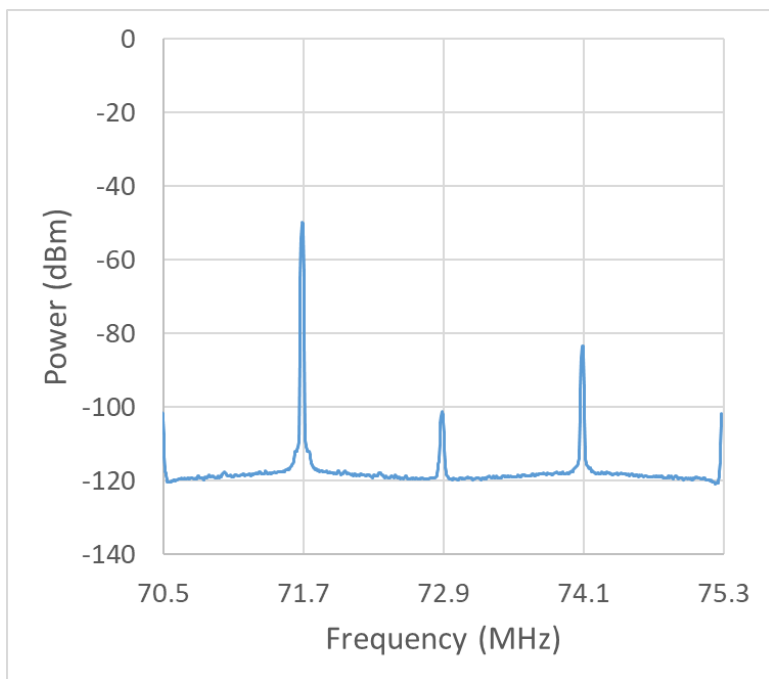


-120dBm signal at 30dB gain

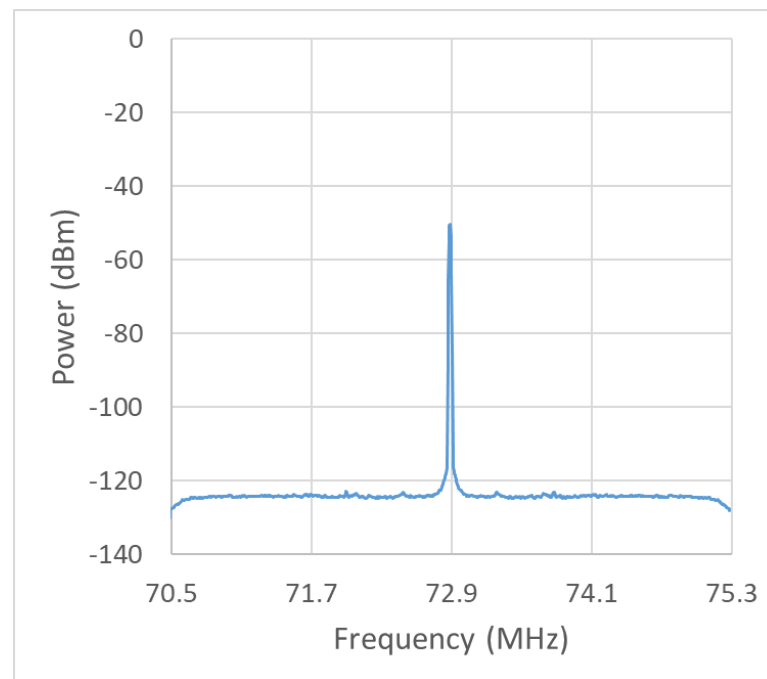


Center the Overly Strong Signal

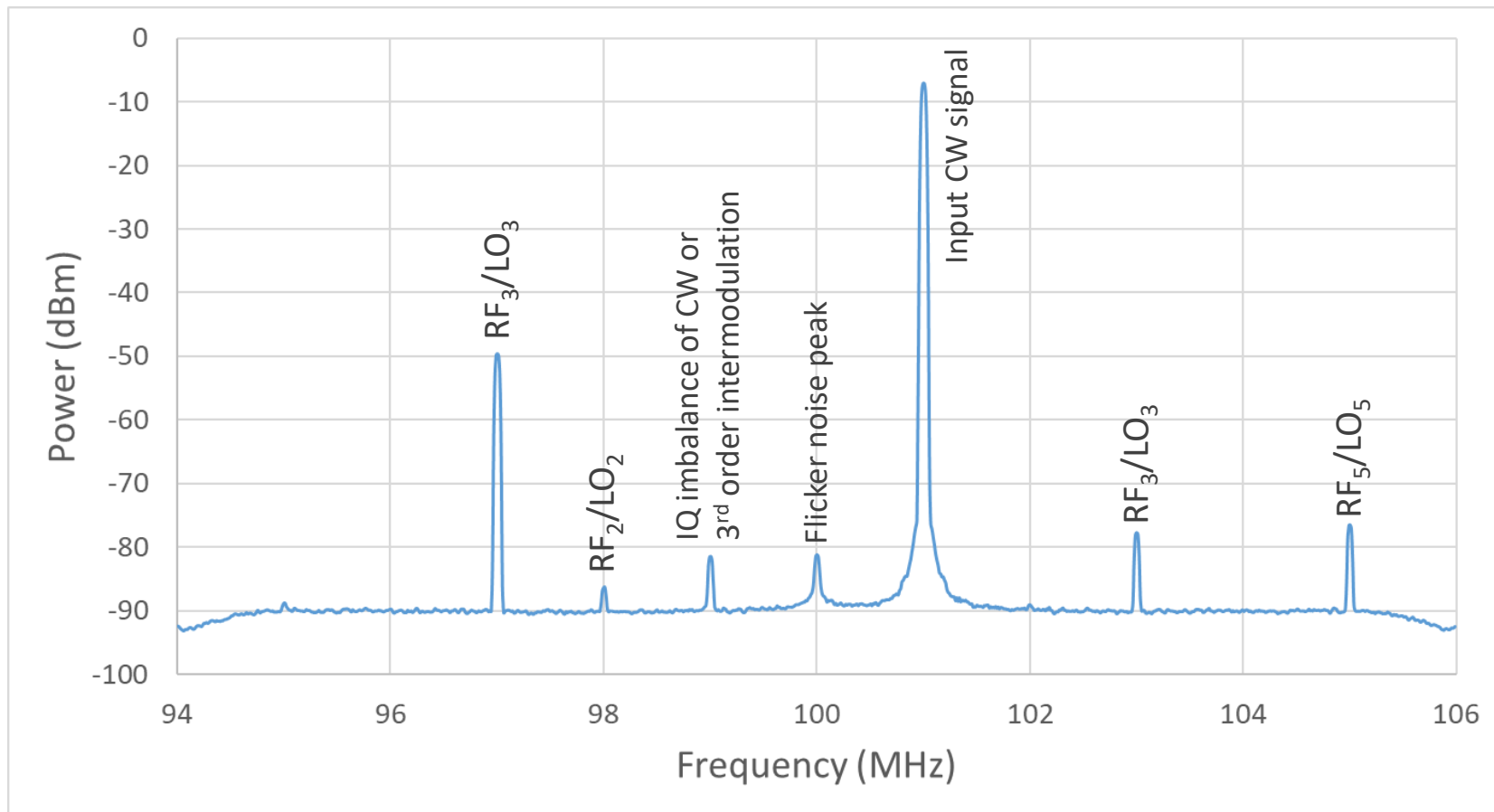
Strong uncentered signal



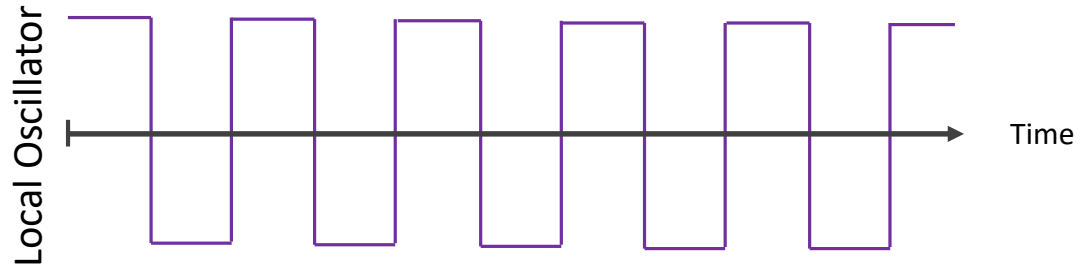
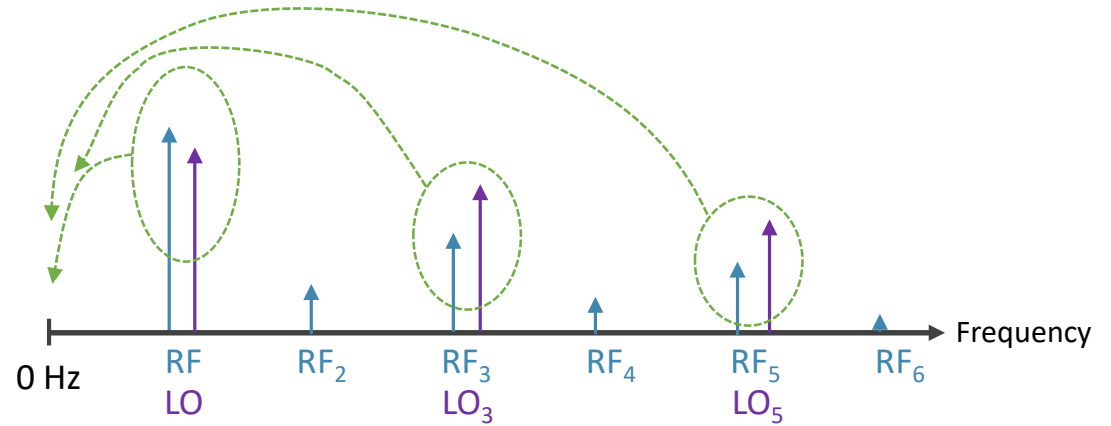
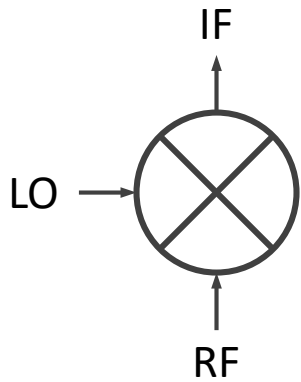
Strong centered signal



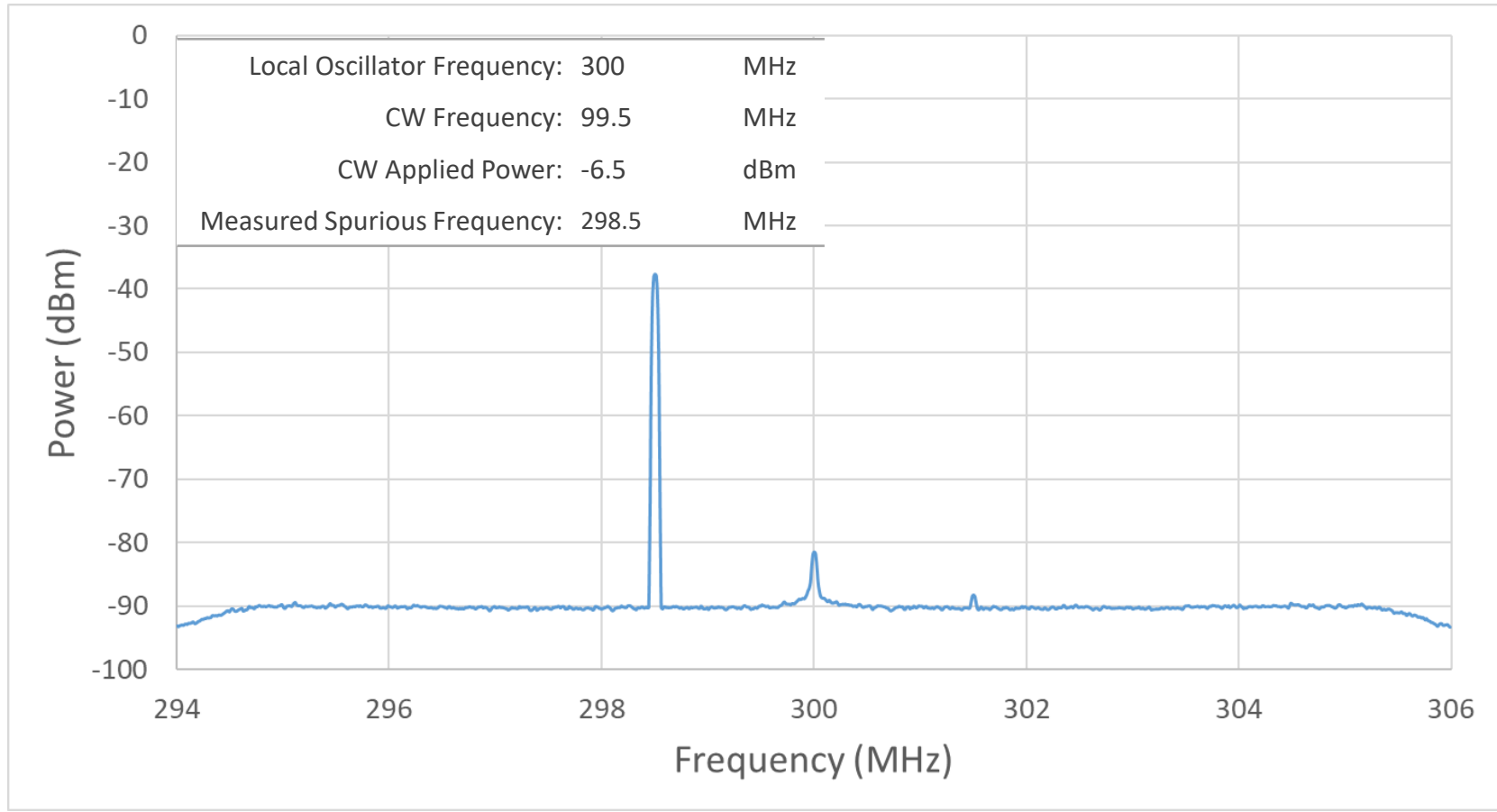
LO Harmonic Intermodulation at Compression



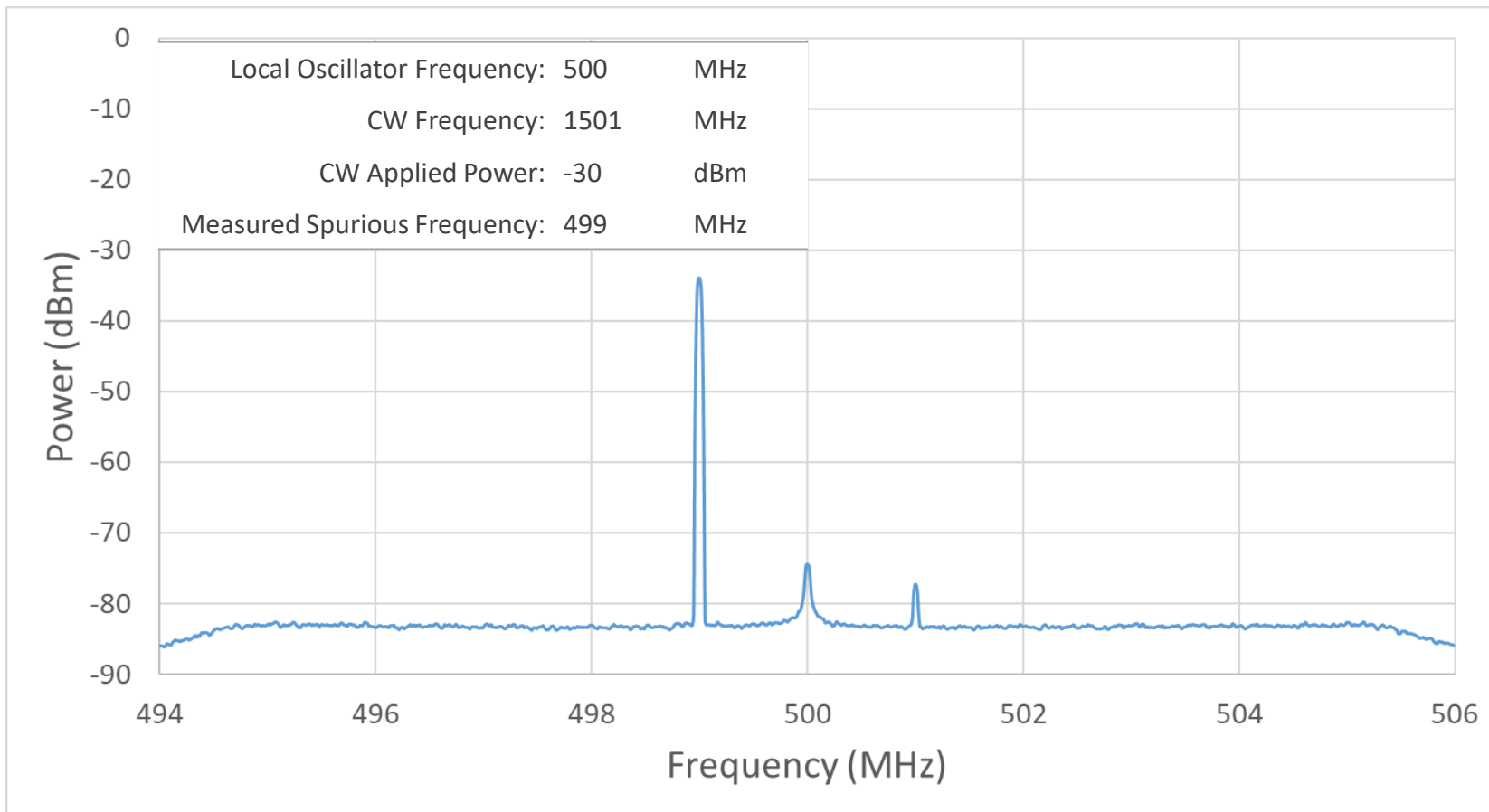
Local Oscillator Properties



Out-of-Band Odd Harmonic Injection



Local Oscillator Harmonic Mixing

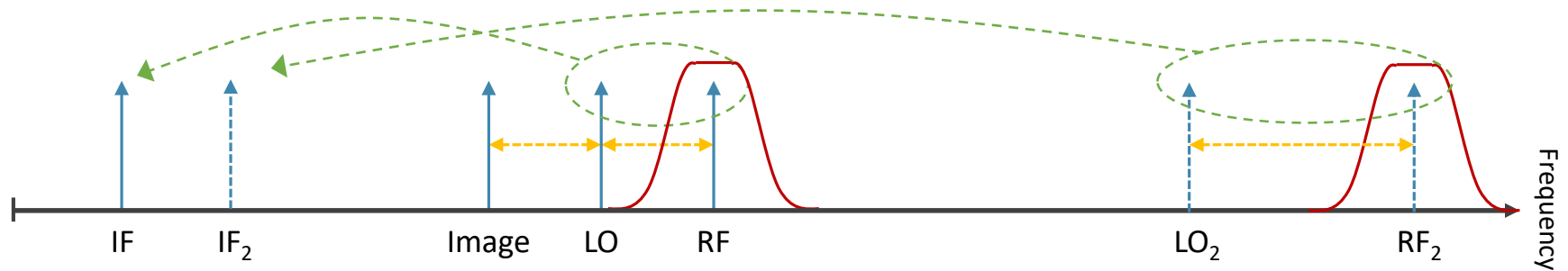


Local Oscillator Harmonic Mixing

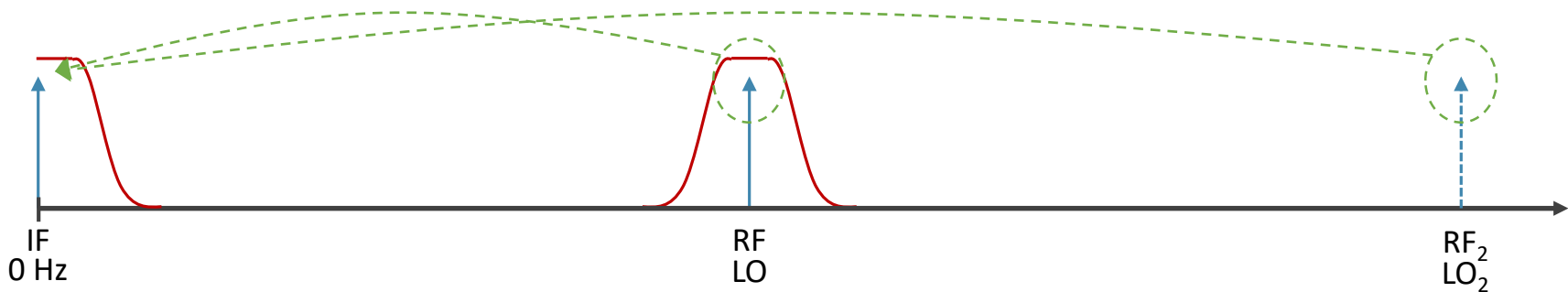
Harmonic #	$P_{\text{difference}}$ (dB)	LO (MHz)	Spur (MHz)	P_{expected} (dBm)	P_{measured} (dBm)
1	0	1500	1501	NA (Base)	-10
3	-9.5	500	499	-19.5	-19.1
5	-14	300	301	-24	-23.5
7	-16.9	214	211	-26.9	-26.5
9	-19.1	167	165	-29.1	-28.9
11	-20.8	136.5	137	-30.8	-30.7
13	-22.3	115.5	115	-32.3	-32.2
15	-23.5	100	99	-33.5	-33.4
17	-24.6	88.1	91.4	-34.6	-34.5
19	-25.6	79.1	81	-35.6	-35.4
21	-26.4	71.4	73	-36.4	-36.3

Nonidealities in Different Mixing Schemes

Heterodyne Mixing



Homodyne Mixing (Direct Conversion)



Final Wrap Up

- Direct conversion software defined radios can be calibrated to serve as low cost spectrum analyzers
 - Stability error is well within 1dB
 - Scale factor can be interpolated across gain and frequency to within 1 dB of error
 - This can be further enhanced by limiting gain values
- Dynamic range characterized for both time- and FFT- based measurements
 - Limiting gain selection can still measure the full range and ease calibration
 - Strategies exist for dealing with simultaneous strong and weak signals
- Direct conversion receivers suffer from harmonic mixing problems
 - Requires the use of a preselector, even with a judicious choice of antenna



Thank you for your
attention!

Questions?

Power Measurement

