AMWC Lab 2 - Part I: Receiver Characterization

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***Abstract*—We designed the RF receiver till IF part and characterized by measuring the performance metrics. The measured values are compared with SystemVue simulations. We measured the key parameters like Cascaded Gain,noise performance, IIP3, IP1dB. We measured the receiver performance with 2-tone test mainly the inter-modulations and sensitivity of the receiver.**

I. Introduction

We build the RF receiver with X-wave components till the IF section and measured the RF performance.The performance metrics are compared with the SystemVue design and explained why the difference is observed between them.

We use the X-wave components with the parameters of the components are given below. The key points in the design are the Local Oscillator is driving the 15.4dBm power which is fed to the mixer. The DC power supplies are limited by current. The current from 8V is limited by 203mA and 4V supply is limited by 80A.

1) BPF
   a) IL=1.13dB (gain= -1.13 dB)
   b) NF=1.13dB
2) LNA
   a) NF=0.35 (at 2.4GHz)
   b) Gain=23dB
   c) OIP3 =33dBm
3) Gain block
   a) Gain = 21dB
   b) P1dB = 16dBm
   c) OIP3=35dBm
   d) NF=3.7dB
4) Mixer
   a) Conversion gain = -7dB
   b) IIP3 = 23dBm
   c) IIP1dB = 17dBm
   d) LO power = +15.4dBm
5) Channel Select Filter
   a) IF Centre frequency= 168.5MHz
   b) IL=8dB
6) IF amplifier
   a) NF=1.25dB
   b) Gain = 26dB
   c) OIP3=34dBm
   d) P1dB = 19dB
7) Local Oscillator (LO)
   a) Frequency=2.2435GHz
   b) Power=15.4dBm
8) LO attenuation Attenuation of 15.4dB
9) LO gain
   a) NF=3.7dB
   b) Gain=15.4dB

These are the power supplies used for the LNA, Gain block and IF amplifiers. These power supplies used here provide the dc supply required for the amplifiers (LNA and gain blocks).

1) LNA power supply
   a) Regulated Voltage = 5V
   b) power module Input Voltage = 8V
2) Gain block power supply
   a) Regulated Voltage = 7V
   b) power module Input Voltage = 8V
3) First IF amplifier power supply
   a) Regulated Voltage = 3V
   b) power module Input Voltage = 4V
4) Second IF amplifier power supply
   a) Regulated Voltage = 7V
   b) power module Input Voltage = 8V

Note: In the given design we didn't use the Image Rejection(IR) filter. So Image rejection is less compared to SystemVue measurements.

II. Receiver Characterization

A. Receiver Metrics

We connected the receiver kit with dc power supply and signal generator. We used a LO source directly to feed the mixer block. The IF-output is connected to VSA (vector Signal Analyzer) to measure the output power from IF section.

We designed the RF receiver using SystemVue and got the measured results using the equations.

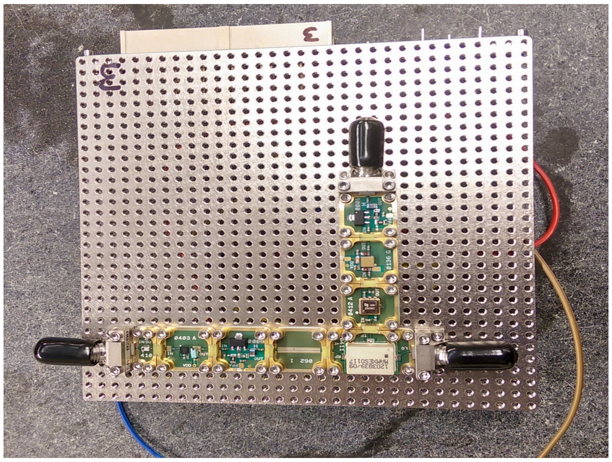
These are the receiver measurements taken from the VSA:

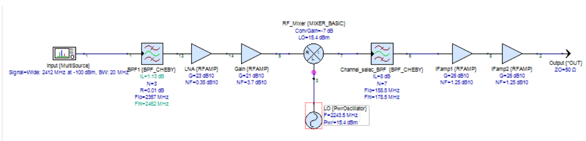
1) Overall gain

B. Measurement setup

   a) Measured the loss due to cables, connectors and alternators with out our kit. Here measured loss is 17.4dB, out of which 10dB from the analysis side and 7.4dB due to generation side.

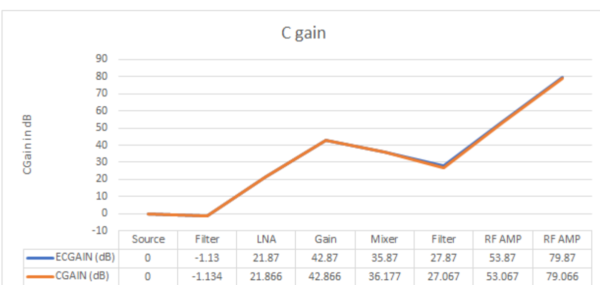
   b) Connected the RF kit, gave DC power supplies and gave the RF signal with amplitude -100dBm, we measured the RF signal in VSA and measured





as -51.5dBm. So the gain including the losses is 68.5dBm.

c) Measured the cascaded gain using SystemVue, it results as 79.0dB which is different than the measured value.



2) IP1dB

C. Measurement setup

a) Slowly increased the RF input power in steps of 10dB from -100dBm and measured the output power for each step. We expect at each Input power, the output should be increased by the cascaded gain times when the receiver is in linear region or not in compression region.

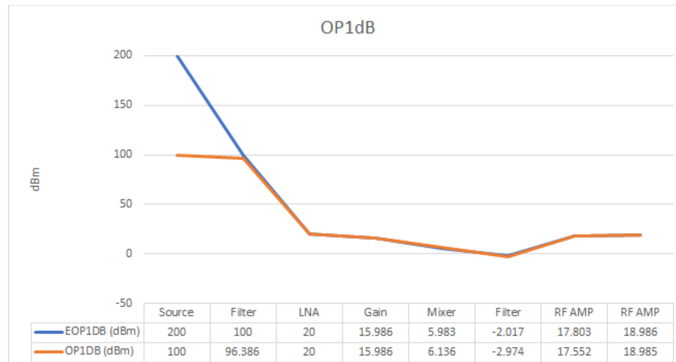
b) When the input power is close to compression region, we incremented in steps of 1dB to find the 1-dB output compression point.

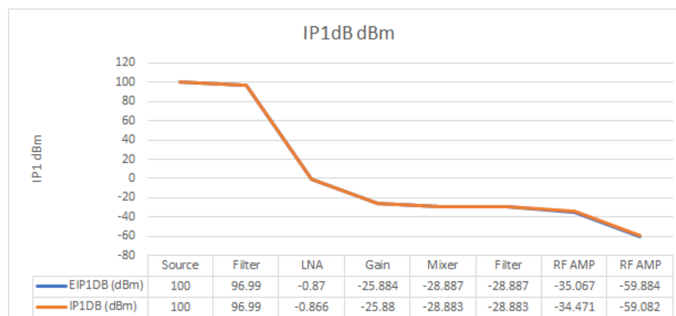
c) The 1dB compression point is 7.5dBm, including losses it is 17.5dBm.

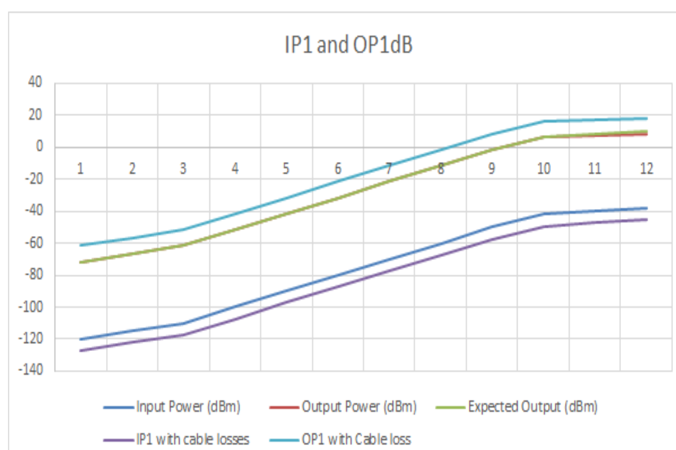
d) From this, we can see the IP1 dB point where the output is compressed by 1dB, which is -40dBm. Including losses it results to -47dBm.

e) Measured the OP1dB point using SystemVue, it results as 18dBm which is closely matched with the measured value.

f) Measured IIP1dB using SystemVue is -59.089dBm. The difference is due to the measured gain is different using SystemVue and RF kit measured with VSA.



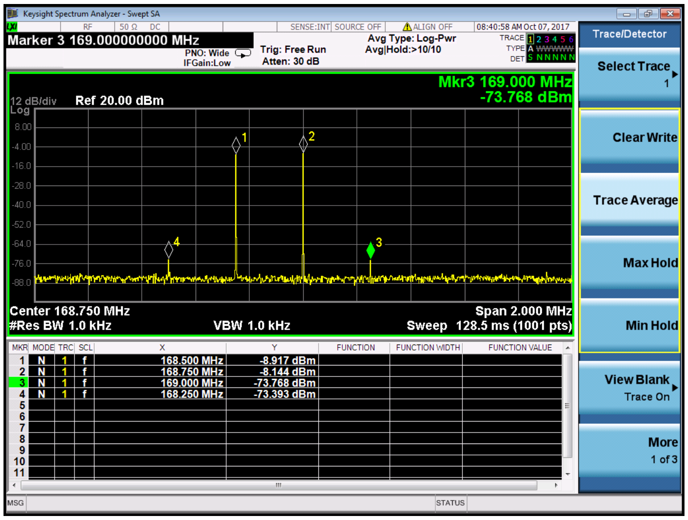




3) IIP3

a) Now Two-tone test is enabled, where there is a signal at desired frequency and another tone at different frequency so that we can see both the signals in IF section. Lets take f2 is 250k away from desired signal (f1).

b) both set to same level at first, we can see both tone in VSA.



c) Now slowly increase the power of both signals.

d) we can see after certain power level the third order components increase by 3dB, where as fundamental components will be increased by 1dB. This is due to non-linear components of the receiver.

e) Slowly increased the RF input power in steps of 1dB from -60dBm and measured the output power for each step. We expect at each Input power, the output should be increased by the 1dB at fundamental frequency and by 3dB at third order frequency components.

Input power (dBm)	Output Power at F1 (dBm)	Output power at 3rd intercepts (dBm)
-100	-51.5	-100
-49	-0.5	-47
-50	-1.5	-51
-51	-2.5	-54.5
-52	-3.5	-58
-53	-4.5	-61.5
-54	-5.5	-64.5
-55	-6.5	-67.5
-56	-7.5	-70
-57	-8.5	-74

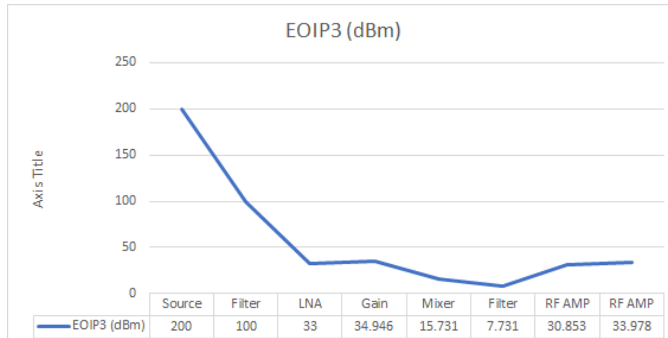
f) When the input power is -53dBm, the Output at fundamental is -4.5dBm and 3rd order harmonic is at -61.5dBm. To reach 3rd point fundamental need 28.5 steps. So IIP3 is 28.5+ input power which is 28.5-53 = -24.5dBm.

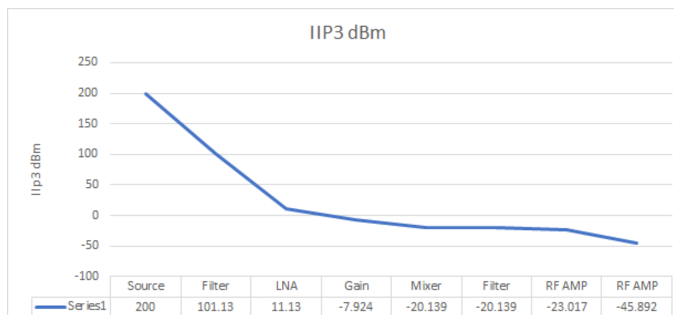
g) The OIP3 is defined as the power of output at which input power is IIP3 point. So OIP3 is computed as 28.5+ (-4.5) = 24dBm.

h) With losses included, IIP3 is 7dB below -24.5dBm which is -31.5dBm and OIP3 is 10dB above 24dBm which is 34dBm.

i) Measured the OIP3 point using SystemVue, it results as 34dBm which is closely matched with the measured value.

j) Measured IIP3 using SystemVue is -45.89dBm. The difference is due to the measured gain is different using SystemVue and RF kit measured with VSA.





4) Noise Figure

D. Measurement setup

Since we don't have direct way to compute the Noise Figure, we can compute the same from noise power measured at desired channel to out-of band channel.

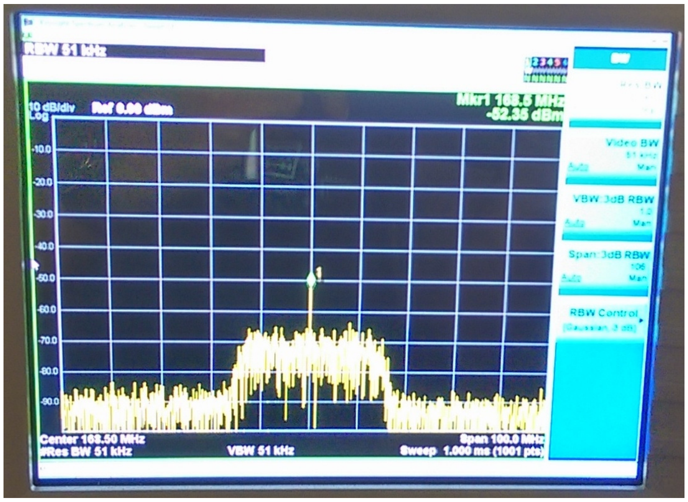
a) Measure the average noise power in desired band.

b) Measure the average channel power above/below the desired band.

c) When the receiver is ideal, NF=0dB, so receiver will not introduce any extra noise.

d) When there is a Noise figure of receiver other than zero, then noise at the IF out is defined as Noise at input *cascaded gain + Noise Figure of receiver.

e) The 1dB compression point is 7.5dBm, including losses it is 17.5dBm



f) From this, we can see in the desired channel we can see the noise as input noise * gain of cascade + NF of the receiver.
g) Measured Noise figure using SystemVue, it results as 1.513dB.

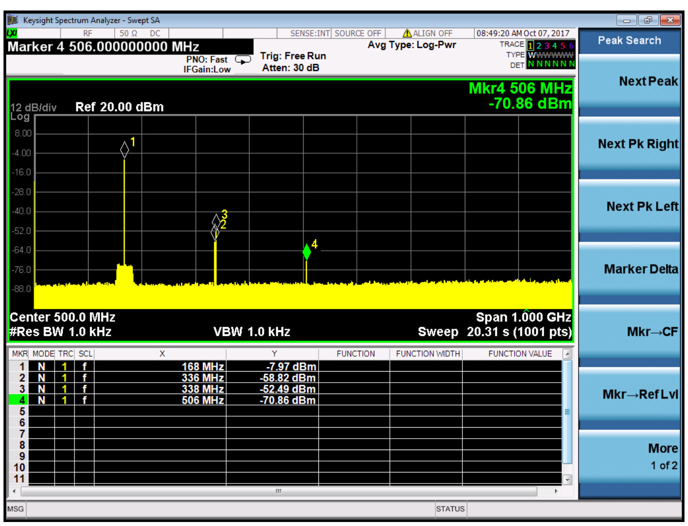
E. Spectrum Plots

The spectrum of IF signal with its harmonics is captured using the VSA.

F. Measurement setup

Input is a two-tone frequency signal and observed the harmonics using VSA.

1) Measure the IF spectrum in the desired band and its harmonics.
2) Set the span to large enough to capture the fundamental and harmonics.



3) Clearly we can see the fundamental and 2nd harmonic of the signal and 3rd order harmonic frequencies.
4) After 3rd order harmonic the power level of the harmonic is too low and we need large bandwidth to capture the other harmonics.

G. Image Rejection of the receiver

The RF kit, we build don't have the Image rejection filter. We used only transmission line instead of the IR filter.

H. Measurement setup

1) This is a one-tone test with the frequency is at Image frequency of the receiver instead of the fundamental frequency.

2) We measured the output power at IF band.
3) Here Image frequency is mapped to IF center freq of the receiver.
4) Image frequency is 2.412GHz-(2*168.5MHz) which is 2.075GHz
5) Tone power at Image frequency is -100dBm, and measured the output as -53.5dB.
6) but if signal at F1=2.412GHz with -100dBm is power level, then IF output is -51.5dBm.
7) IRR is defined as the ration of input frequency power to image frequency power.
8) Here IRR is measured as 2dB. but we don't have any Image rejection filter.
9) This 2dB is observed due to the Filter roll-off.

I. Receiver Desensitization

The receiver desensitization is due to strong interference signal in the same IF band. This is how the fundamental (main) signal is deteriorated due to mixing of actual signal and strong interfere in mixer.

J. Measurement setup

This is same as two-tone test, where there is fundamental frequency is generated using generator1 and interference signal is generated using generator2. We measure the IF output power using VSA.

1) generate the fundamental signal using generator1 with frequency 2.412GHz and power level is -100 dBm.

2) Measure the IF output power using VSA.
3) Now feed the another signal (interference signal) with frequency 2.462GHz and power level is set to -100dBm.
4) Now measure the IF output power level.
5) We can see the IF output is decreased or not due to stron interference.
6) Now increase the interference power level in steps of 10dBm and observe the IF power level.
7) When there is a change in output power, vary the interference insteps of 1dB to find the exactly at which power, the interference can cause degradation in main signal.

Input power of Main signal (dBm): F1=2.412GHz	Input power of interference signal (dBm), F2=2.462GHz	Output of IF signal (dBm), Fif=168.5MHz
-100	-100	-51.5
-100	-90	-51.5
-100	-80	-51.5
-100	-70	-51.5
-100	-60	-51.5
-100	-50	-51.5
-100	-40	-51.5
-100	-30	-51.5
-100	-20	changed

From this we can say, due to strong interference in near fundamental can cause the degradation in SNR and difficult to demodulate.

8) From the table, it is -20dBm of interference signal power can cause desensitization.
9) Including the cables loss it is -27.3dBm is the interference power.

III. SystemVue Additional graphs

Cascade analysis using Systemvue is performed and plots are obtained from that are provided here.

Main parameters of the receiver design is:

1) Cascaded Noise Figure
2) SFDR
3) Compression Curve

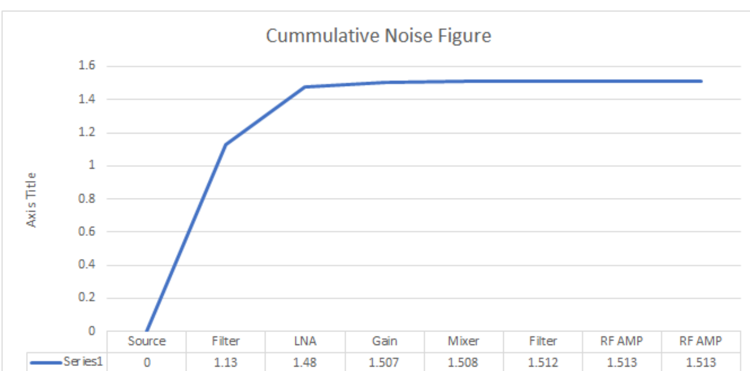


Fig. 1. Cascaded Noise Figure (dB)

This is the compression curve using Systemvue.

IV. Conclusion

We designed the receiver and understood the linearity of the receiver and its dependent factors. We understood the importance of the image rejection filter before Mixer. We understood how to perform the 2-tone test and how to measure the receiver sensitivity and selectivity. We compared the measured results with SystemVue simulation results.

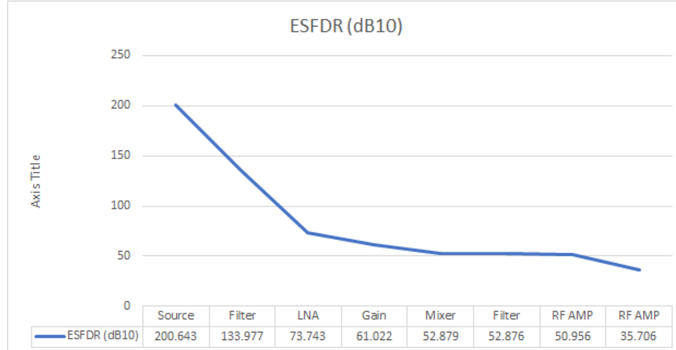


Fig. 2. SFDR (dB)

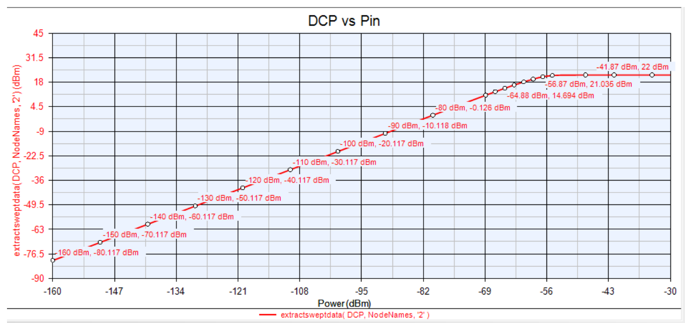


Fig. 3. Compression Curve (Pin vs Pout) (dBm)

References