Analyzing RF Front-end and Assessment performance

The Low Noise Amplifier (LNA) and mixer are key components in RF systems, particularly in receivers. The LNA amplifies weak signals while introducing minimal noise, improving the signal-to-noise ratio (SNR). Its design considerations include low noise figure, sufficient gain, impedance matching, and proper biasing. On the other hand, the mixer performs frequency translation by mixing the received signal with a local oscillator (LO) signal to produce an intermediate frequency (IF) or baseband signal. Mixer design considerations include high conversion gain, isolation, linearity, spurious response minimization, and impedance matching. Both components are critical for optimal signal processing and performance in RF systems, requiring careful attention to various parameters and advanced design techniques.

In this project, I did not undertake the design of the LNA and Mixer components. Instead, we utilized predefined front-end parameters and evaluated network performance according to the specifications outlined in the project file.

The circuit parameters are outlined as follows:

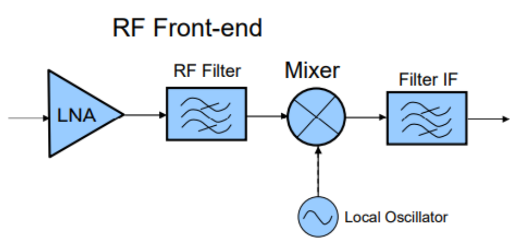


Figure 1. Circuit Schematic

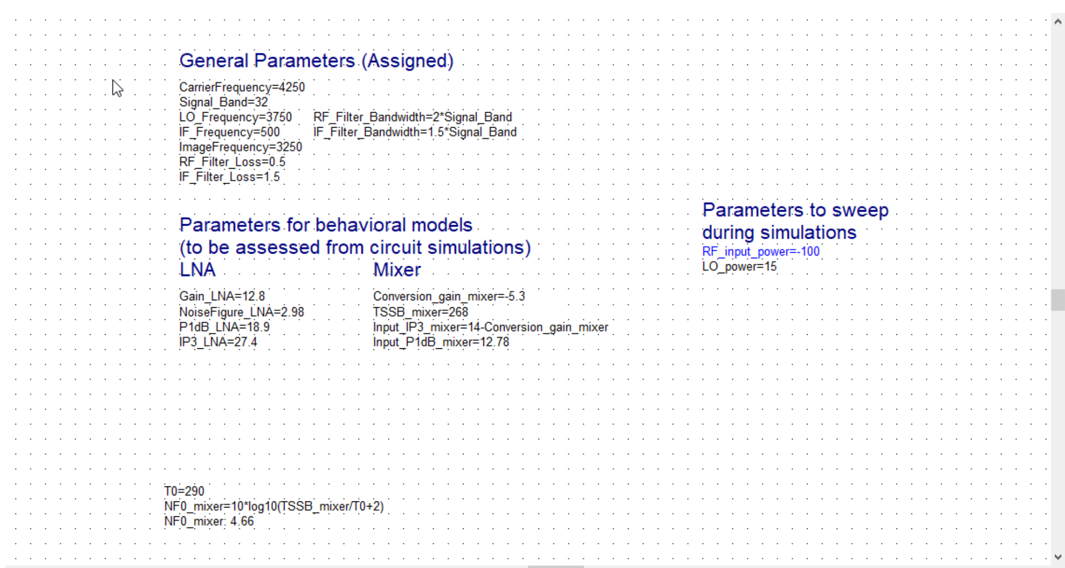


Figure 2. Requested parameter of LNA & Mixer

Measurement of EVM

Measuring Error Vector Magnitude (EVM) in the front-end circuit is vital for assessing signal quality, optimizing performance, detecting interference, and ensuring compliance with communication standards. High EVM values indicate potential issues such as distortion or noise, prompting adjustments to parameters like gain or filtering. Monitoring EVM helps engineers pinpoint problems and implement solutions to enhance system reliability and meet regulatory requirements.

• VSS simulation provides both EVM and Constellation measurements.

• The global variable RF_input_power is adjusted, starting from a very low value (e.g., -100 dB). When EVM reaches 5%, the variable's value reflects the minimum acceptable power level (attributable to noise from LNA, Mixer, and Filters).

• As the input power is further increased, EVM decreases until non-linear effects (from LNA and Mixer) degrade the signal, causing EVM to rise once more. Input power is continuously increased until EVM returns to 5%. The RF_input_power value at this point represents the maximum tolerable power level.

In Simulation

Within the Global definition section, there exists a parameter termed "RF_input_power." This parameter was modified from -100 to reach -73.6, achieving an EVM of approximately 5.2% as required.

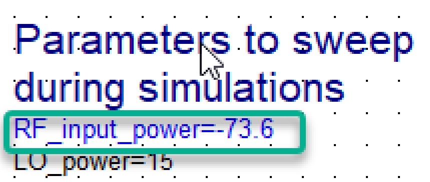


Figure 3. Tunned value of RF to achieve EVM

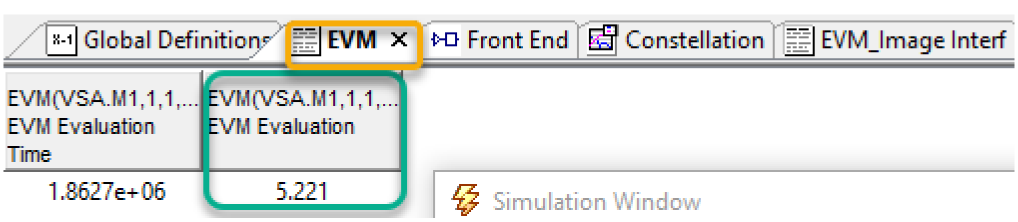


Figure 4. EVM evaluation

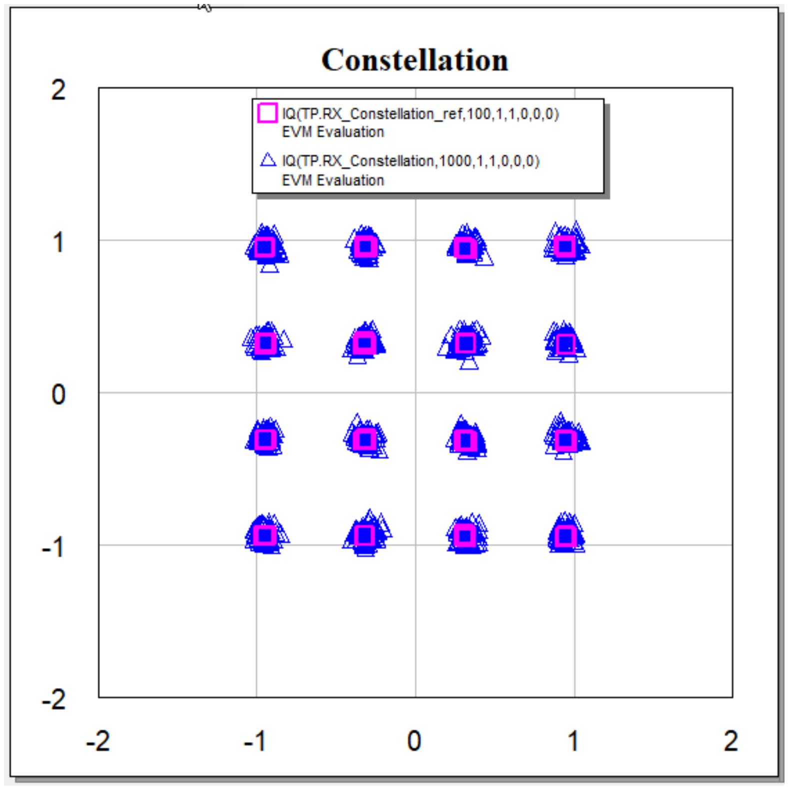


Figure 5. Constellation

Recall of Phase Noise

Phase noise (PN) describes the impact of momentary phase fluctuations, also known as jitter, occurring in the sinusoidal signal generated by an actual oscillator. When an oscillator affected by PN is utilized in a mixer, the random variations in the Local Oscillator (LO) phase get transferred to the carrier frequency of the translated signal. Consequently, during demodulation, the extracted information experiences distortion, leading to degraded quality. The extent of degradation depends on the maximum deviation of the carrier's instantaneous phase, which remains unaffected by the power of the RF signal. In practical terms, phase noise is typically characterized using a mask that represents the relative power density produced by the oscillator at a specified distance (Δf) from the carrier frequency, considering various values of Δf.

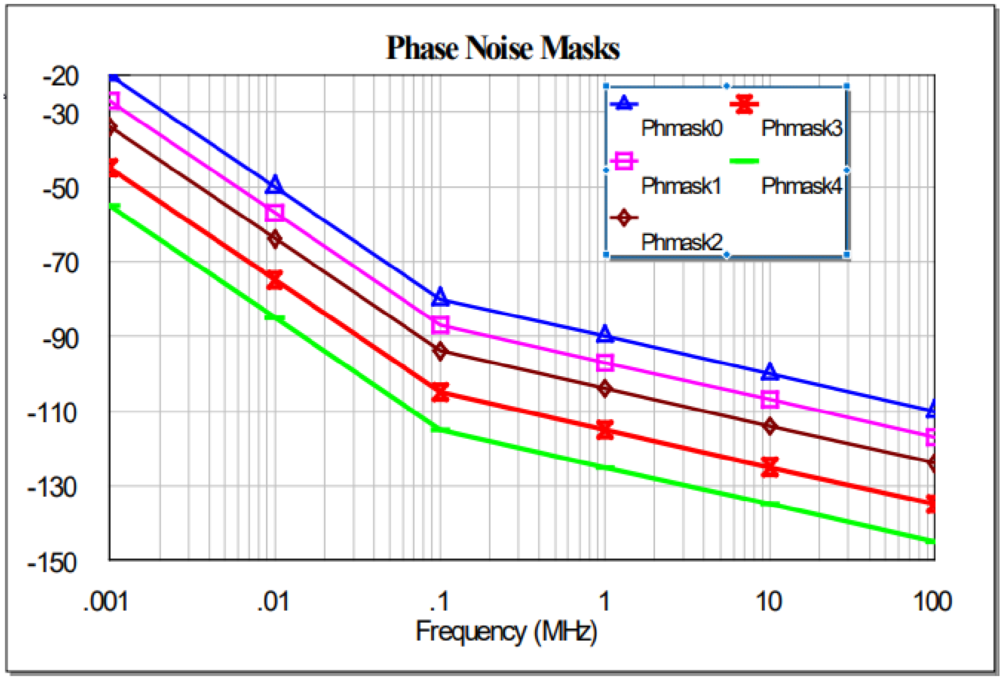


Figure 6. Example pf Noise Masks

In Simulation of phase noise mask

The next stage of the simulation necessitates some modifications. Firstly, we replace "PNOISE" in the local oscillator with "Generate phase noise." Secondly, we select the appropriate "PNMASK" to achieve the desired mask, ensuring the EVM value fluctuates between 5.1% and 5.3%. This step involves testing multiple phase noise masks, and after experimentation, "Phmask3" is determined to be the preferred choice. The following figure displays the resulting outcome.

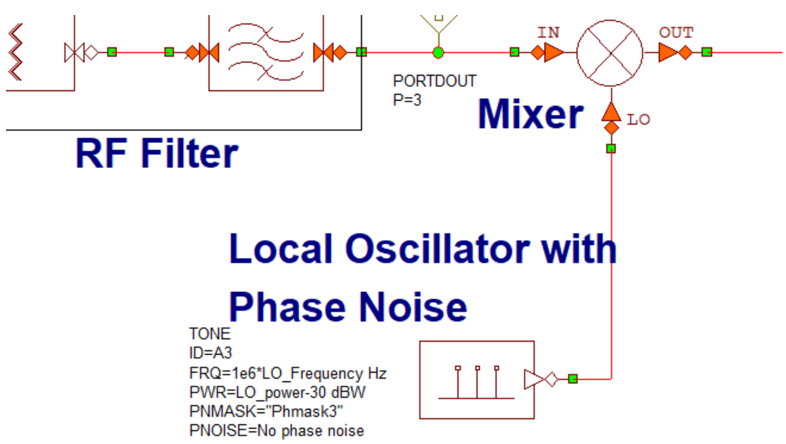


Figure 7. Local Oscillator with Phase Noise

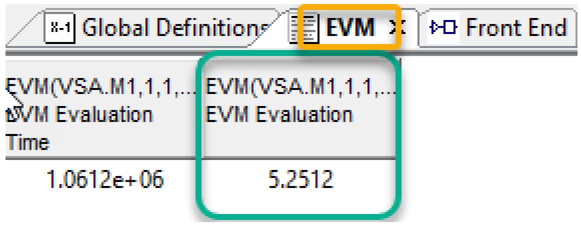


Figure 8. EVM Evaluation after changing PNOISE

In the figure above, the EVM value is observed to be 5.25. Additionally, it's worth noting that the preferred "PNMASK" may not be the final one, given the importance of cost considerations.

Next Step: Degradation due to an image interferer

A signal termed as an image interferer emerges at the input of the RF frontend with a carrier frequency matching the image frequency of the mixer. This interferer ideally gets removed by the image filter. However, in practice, it still persists at the mixer's input, its strength contingent on the filter's selectivity. Even if the image filter effectively attenuates this interferer, if the strength of the received RF signal is significantly lower than that of the interferer, the resulting signal converted at IF undergoes distortion. Consequently, the quality of the demodulated signal at baseband suffers degradation.

Evaluation of the interferer maximum power

The interfering signal is represented as a single tone, with its power controlled by the variable ImagePower, as defined in the diagram.

Initially, the power level is set to -100 dBm, while RF_signal_power is adjusted to the previously determined minimum value. This setup is designed to produce an EVM of about 5%.

The objective is to determine the highest permissible value of ImagePower that results in an EVM of approximately 5.2%, considering the Phase Noise effects originating from the Local Oscillator (LO).

In Simulation

Initially, activate the measurements in the graphs for both "EVM_Image Interf" and "Constellation_Image Interf". Additionally, include a second row in this illustration.

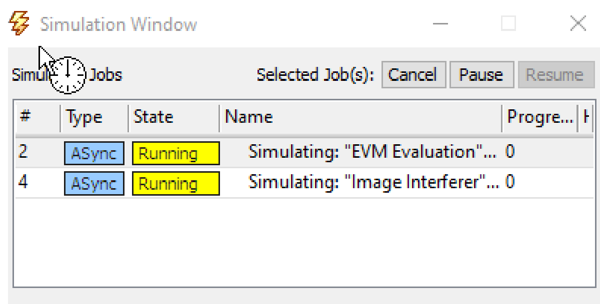


Figure 9. Simulation Window

Next, we start with ImagePower to -140 and gradually raise it until the EVM reaches approximately 5.2%. At firist this value is about 80% and by setting ImagePower to -40, I received EVM about 5.2%.

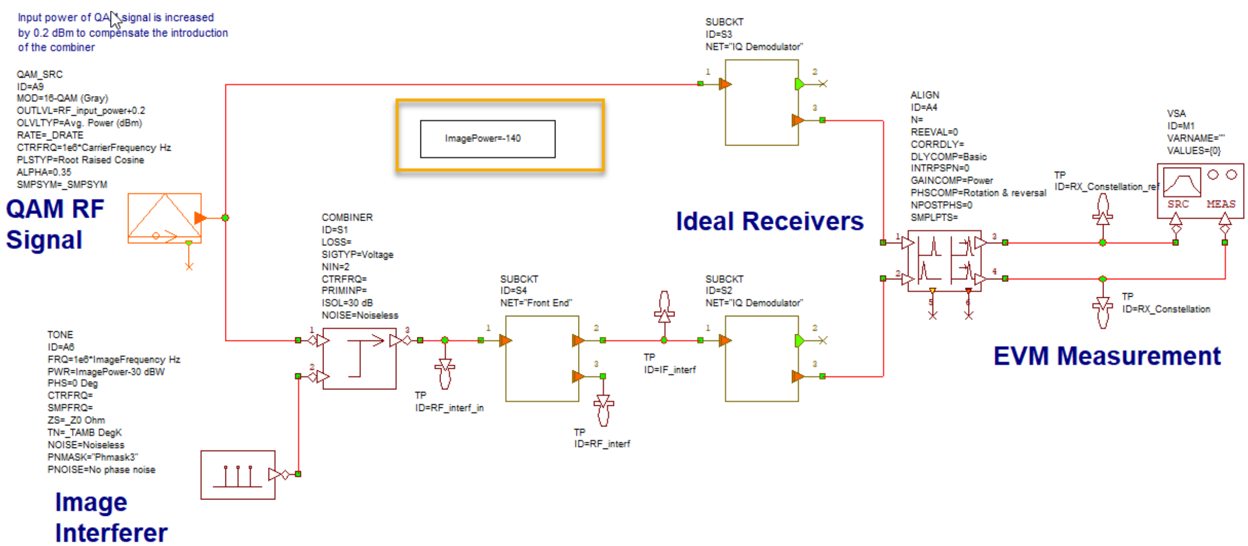


Figure 10. Image Power Schematic_with ImagePower -140

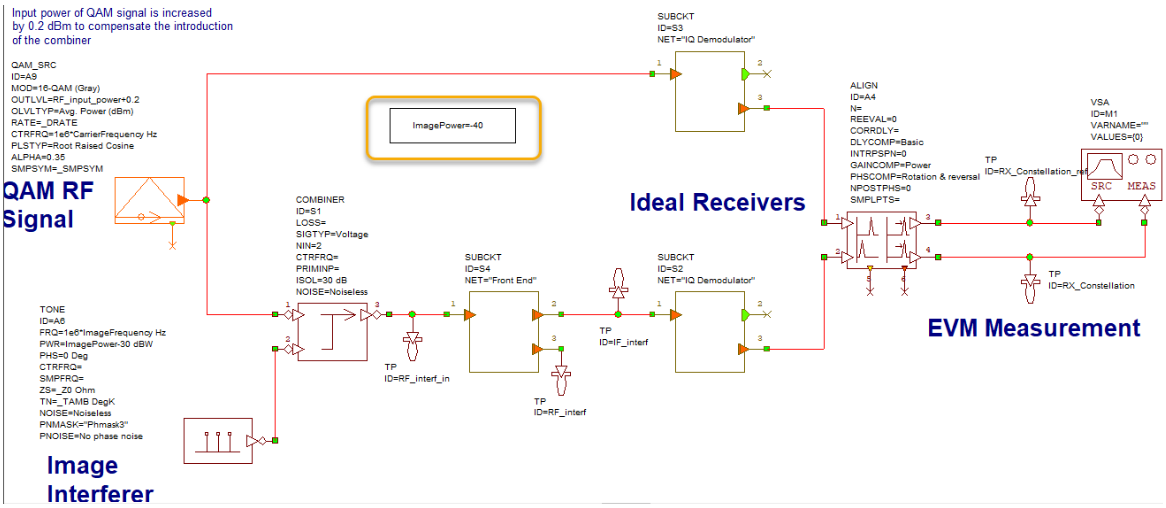


Figure 11. Image Power Schematic_with ImagePower -40

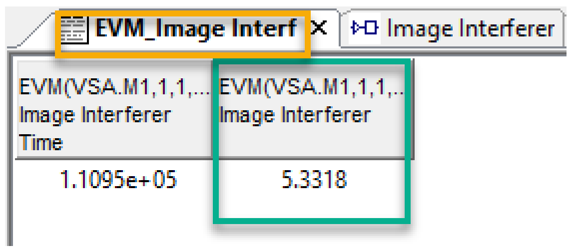


Figure 12. EVM_Image_Interf

RF Spectrum

To facilitate a more comprehensive comparison, the RF Spectrum has also been illustrated in the subsequent section.

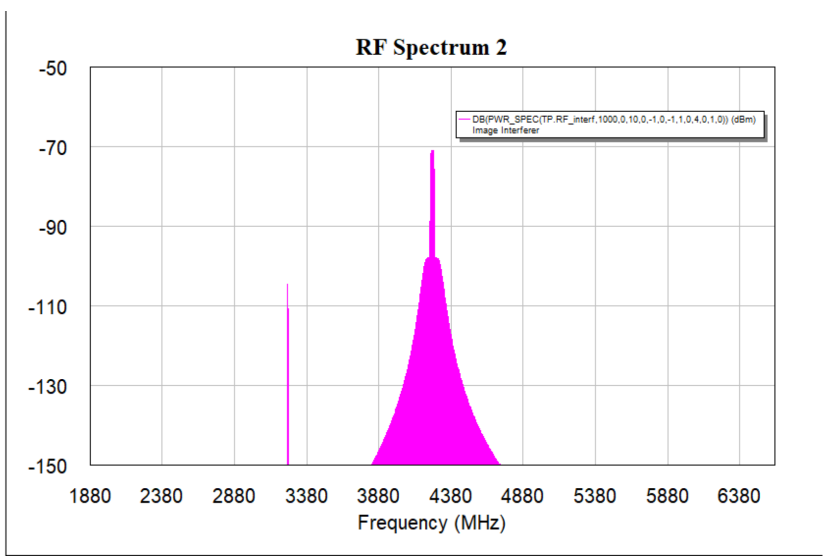


Figure 13. RF Spectrum

Data Range

To determine the data range, we start by adjusting the RF_Input_Power from -100 as the initial value, then identifying -73.6 as the optimal value to maintain the EVM within the desired range (5.2%). Subsequently, we fine-tune it to find 0.5 as the most suitable value to fulfill this condition, resulting in an EVM of approximately 5, which is deemed acceptable. Hence, the data range can be calculated using the formula below:

DR = Pmax – Pmin= 0.5-(-73.6)=74.1

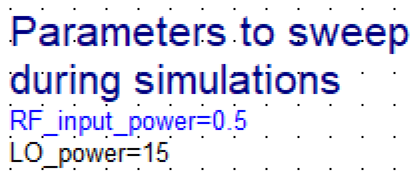
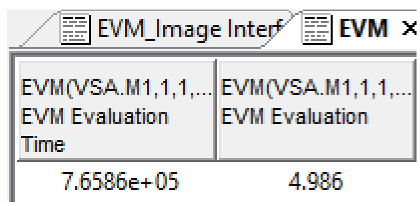


Figure 14. RF Input Tunning



EVM(VSA.M1,1,1,... EVM Evaluation Time	EVM(VSA.M1,1,1,... EVM Evaluation
7.6586e+05	4.986

Figure 15. EVM

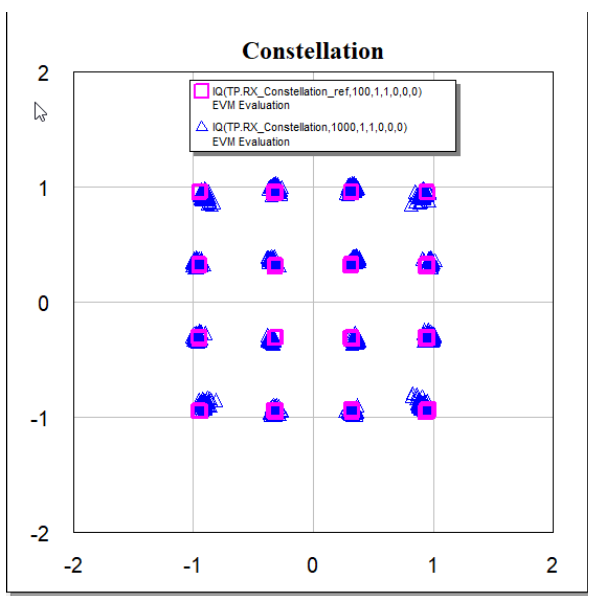


Figure 16. Constellation