

Accurate Mixer Measurements Using Multi-tone X-parameter - Models

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What We Will Talk About

This presentation focuses on the applicability of X-parameter* technology to mixers.

System-level models need to protect the manufacturer IP and to accurately predict the HW nonlinear behavior in the simulation environment.

X-parameter models have this unique capability.

Their applicability to mixers is demonstrated and the accuracy is shown based on some fundamental measurements, such as compression and LO-starvation.

* "X-parameters" is a registered trademark of Agilent Technologies.
The X-parameter format and underlying equations are open and documented.
For more information visit <http://www.agilent.com/find/eesof-x-parameters-info>

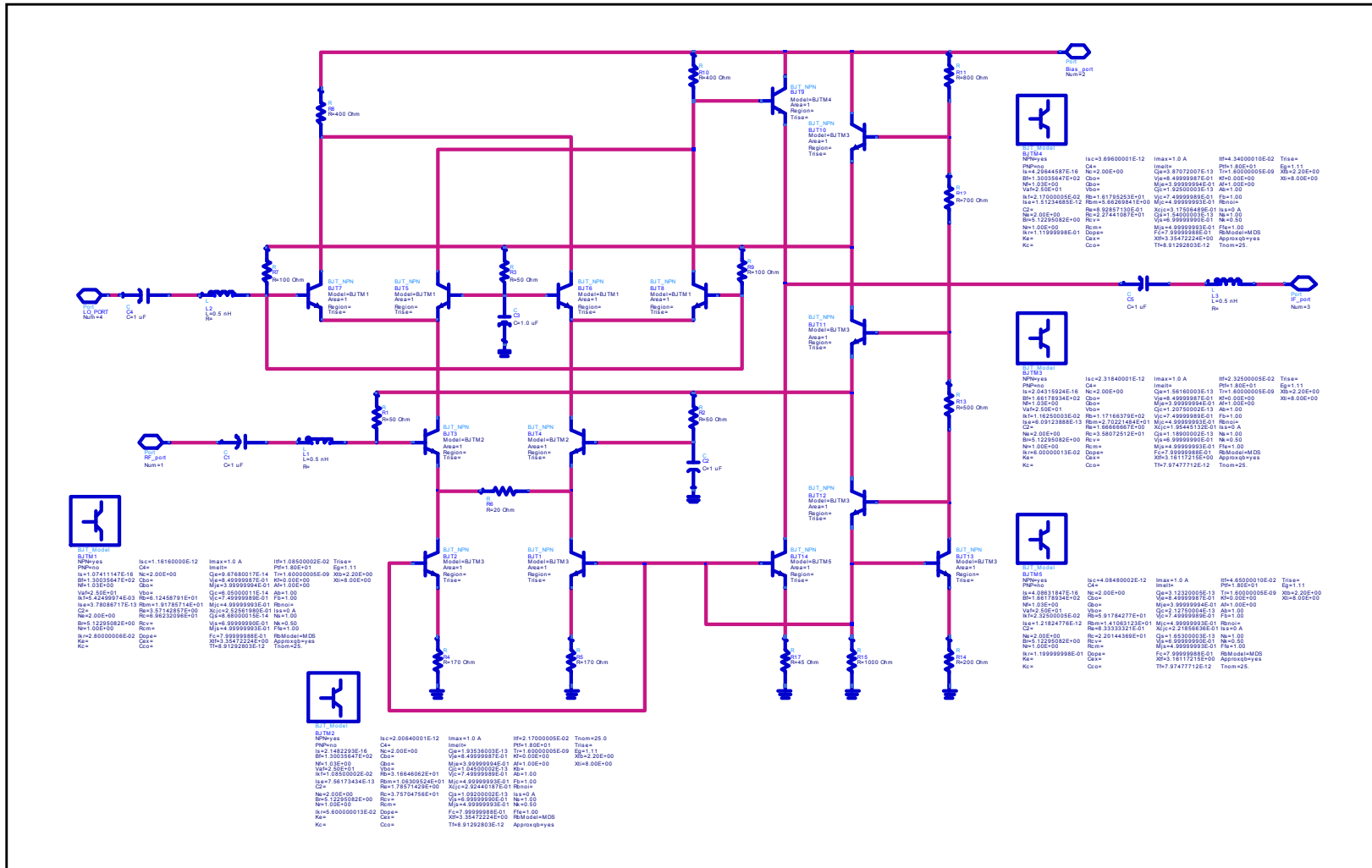
Mixer X-Parameter Models

Accuracy of X-parameter models for mixer is evaluated for several practical scenarios:

- multi-tone
- multi-port
- swept RF level
- swept LO level
- swept RF frequency
- mixer sub-system = mixer + Band Pass Filter (BPF)

Mixer Circuit

- standard Gilbert-cell mixer



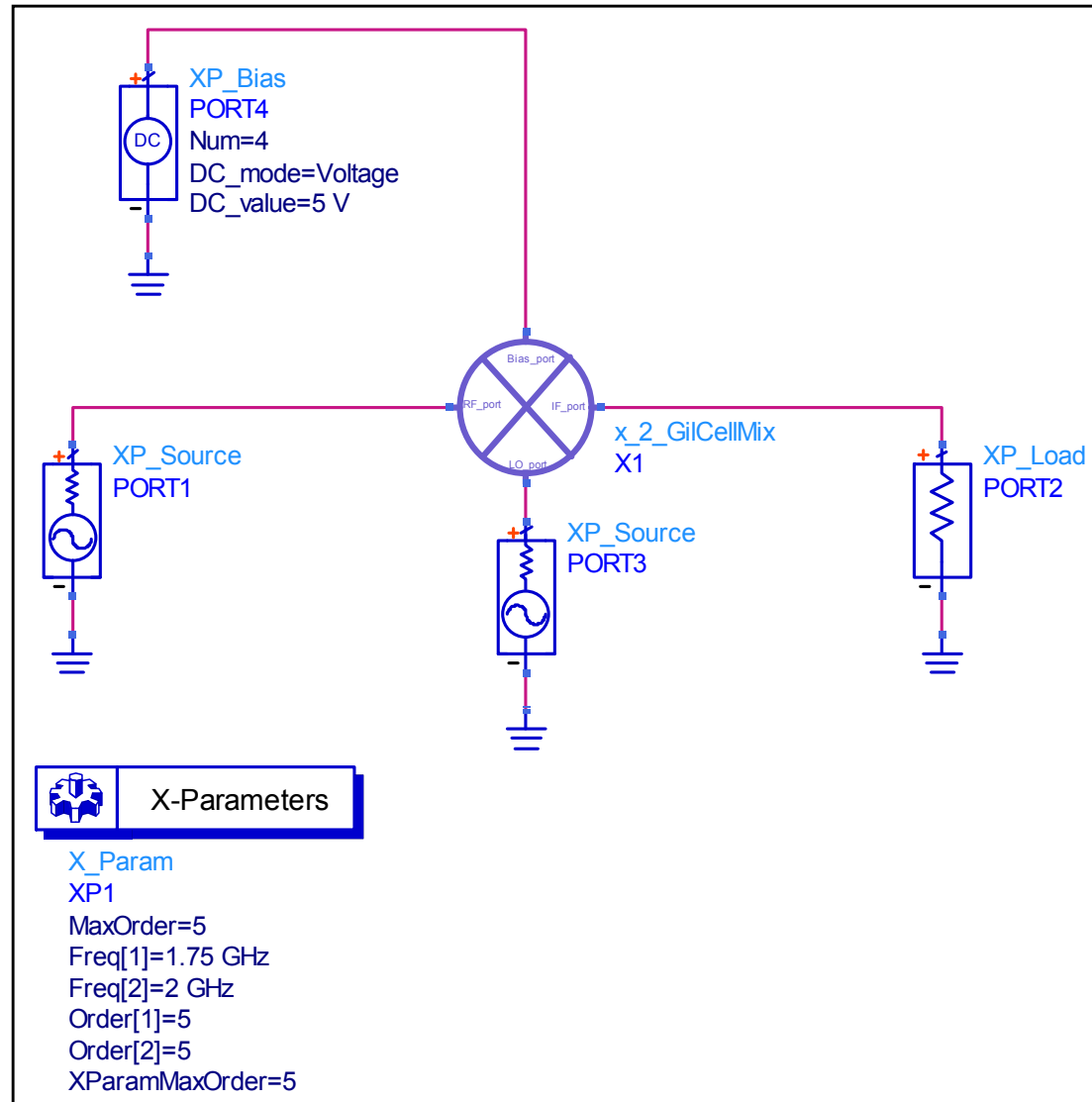
Performance to Be Measured

- spectral content – magnitude and phase
- compression curve
- LO starvation curve
- leakage: LO-to-RF, LO-to-IF, RF-to-IF
- frequency response

X-Parameter Model Extraction

X-parameter model is extracted using multiport, multi-tone ADS-simulation.

- RFfreq = 2 GHz
- LOfreq = 1.75 GHz
- IFfreq = 250 MHz
- RF-power sweep: -30 dBm to 0 dBm
- LO-power sweep: -25 dB to 0 dBm
- power supply – one point: 5 V

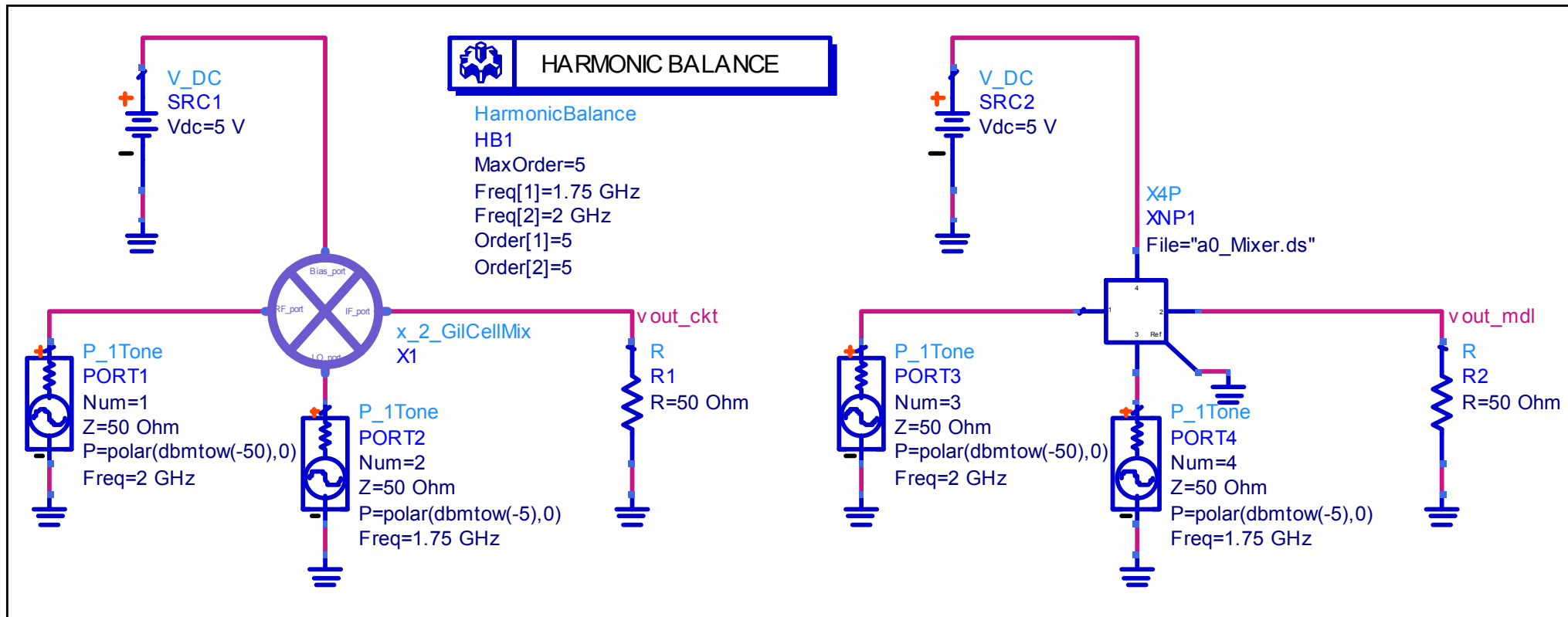


Spectral Content

- measurement made at single LO and RF power levels
- magnitude and phase of output signal at all frequencies monitored at the output port

Spectral Content Measurement Setup

- RFpwr = -50 dBm
- LOpwr = -5 dBm



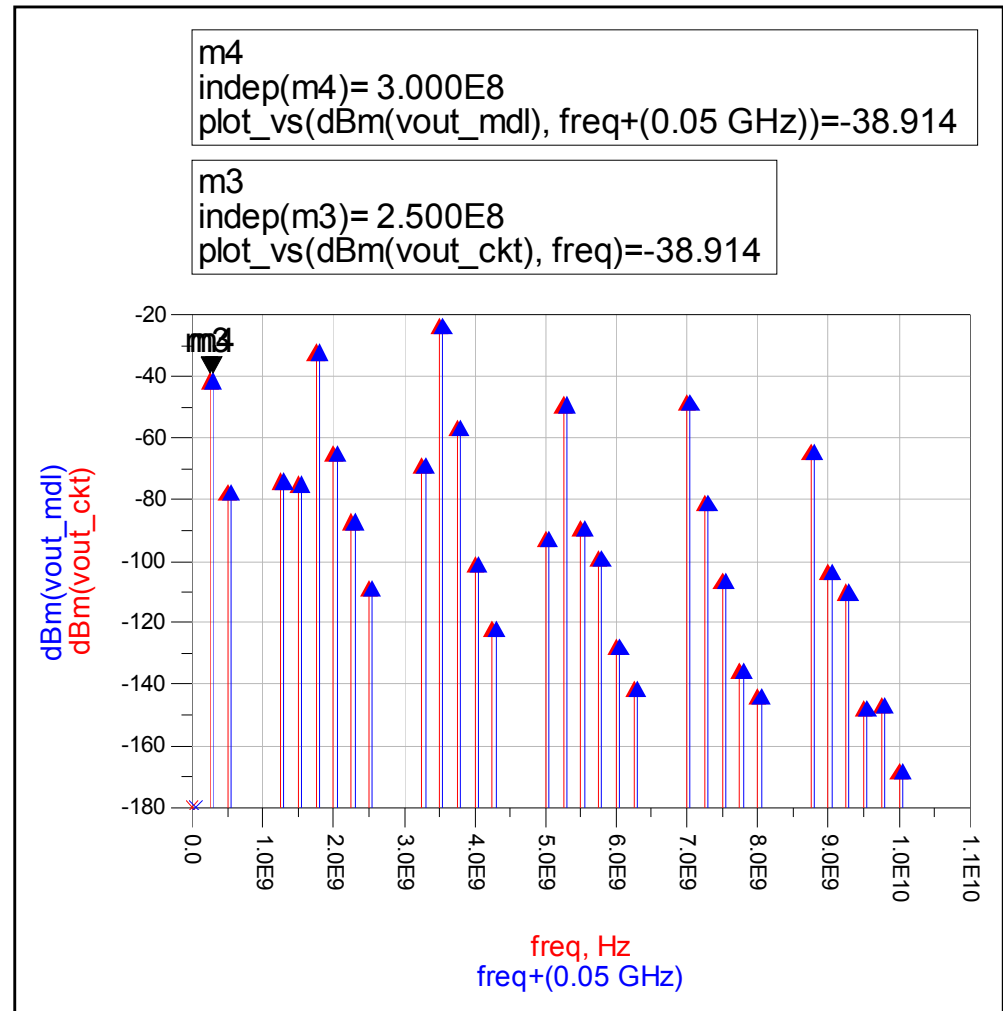
Spectral Content

Measurement Results - Magnitude

- RFpwr = -50 dBm
- LOpwr = -5 dBm

Small display offset

Ckt
Xpar



- intentional display offset of 50 MHz – to distinguish the traces

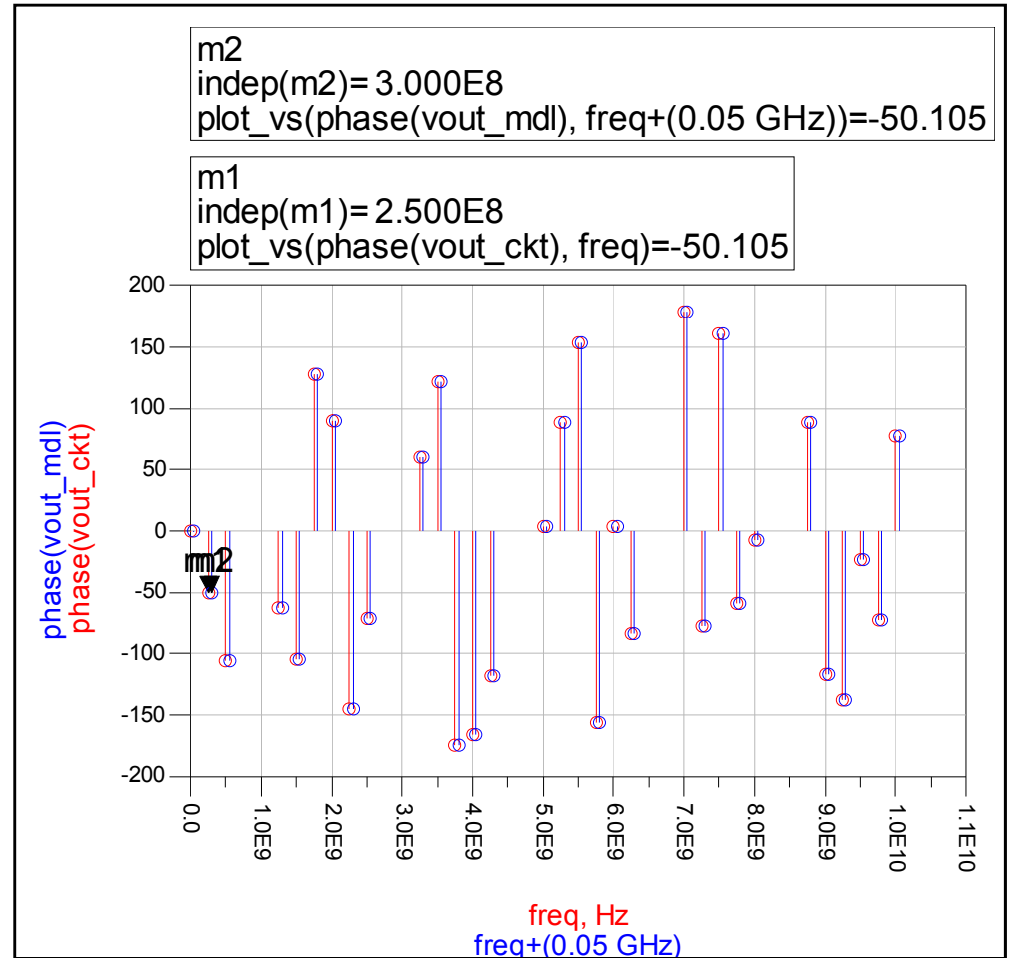
Spectral Content

Measurement Results - Phase

- RFpwr = -50 dBm
- LOpwr = -5 dBm

Small display offset

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Xpar



- intentional display offset of 50 MHz – to distinguish the traces

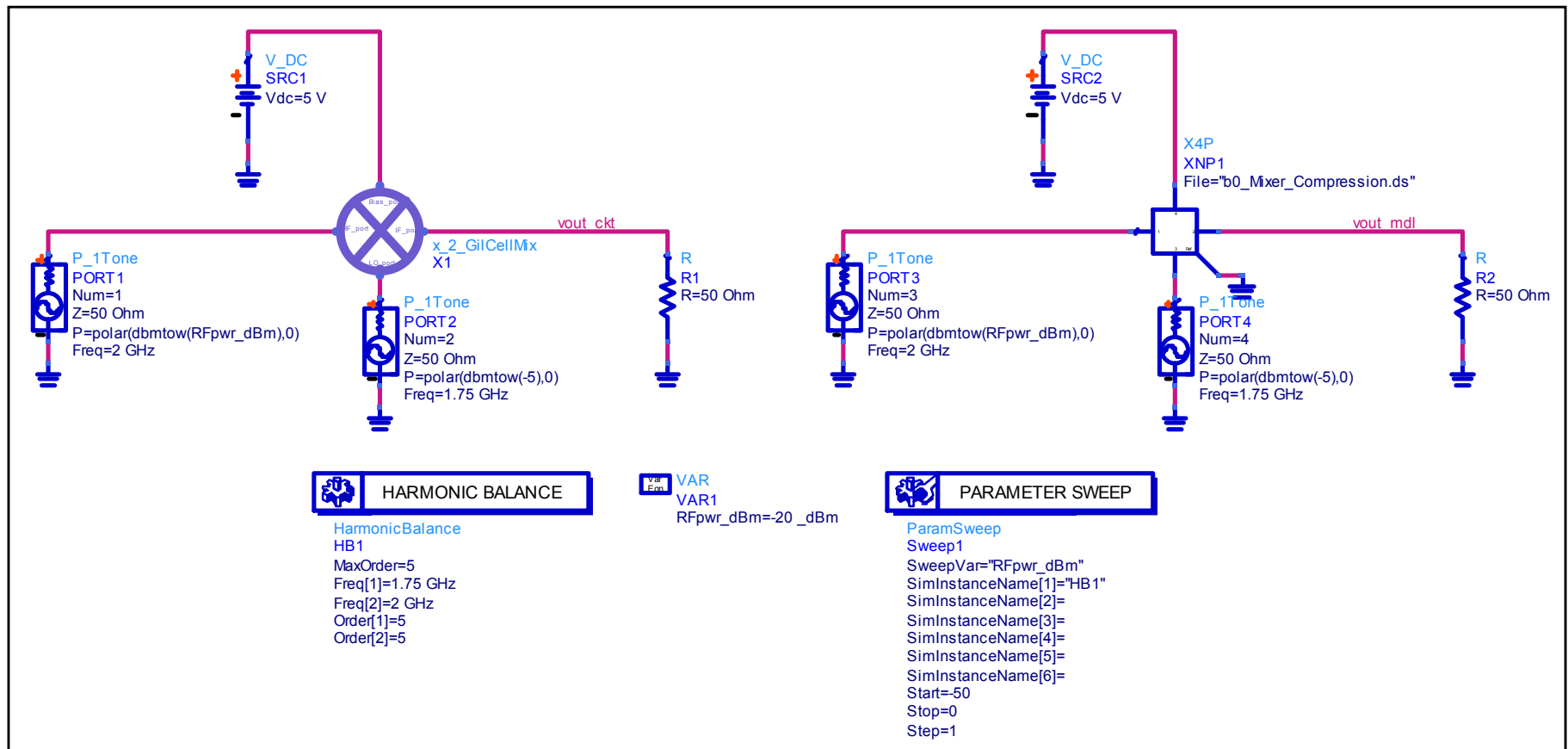
Compression Curve

- compression curve measured by maintaining a constant LO power and sweeping the RF power level
- magnitude and phase of output signal at the IF frequency monitored at the output port

Compression Curve

Measurement Setup

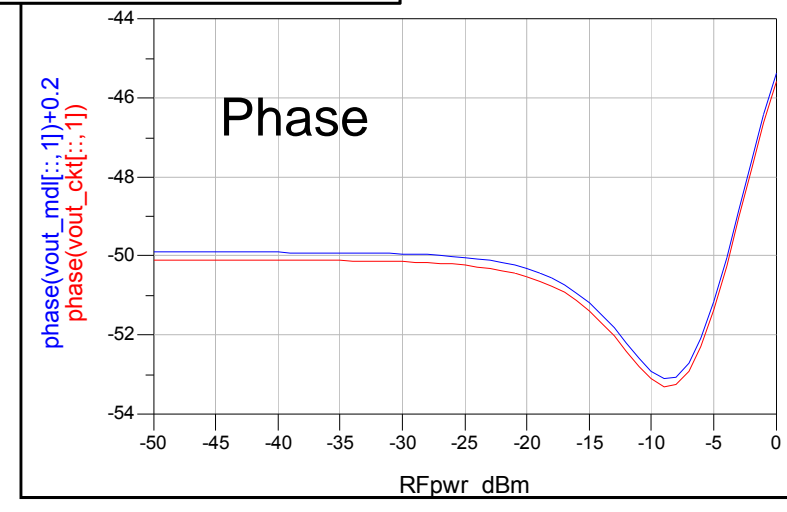
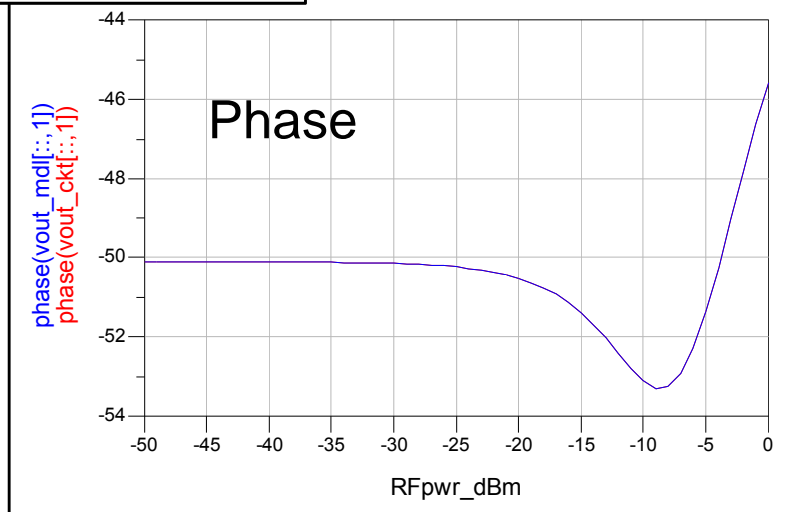
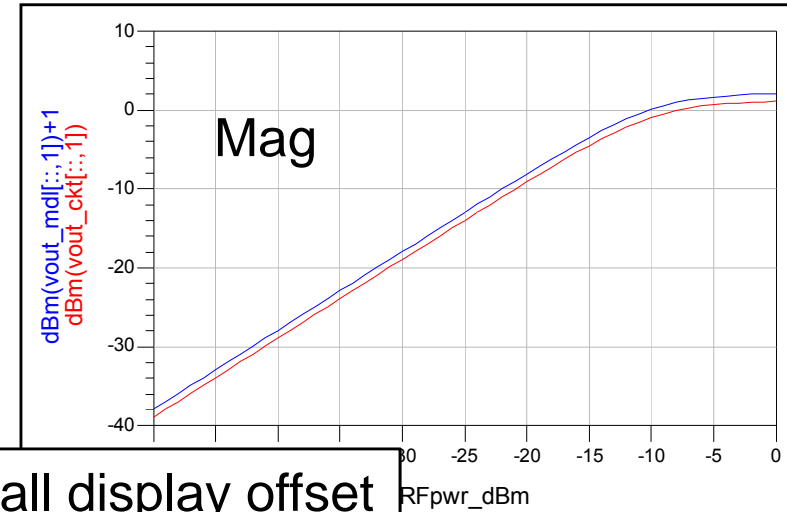
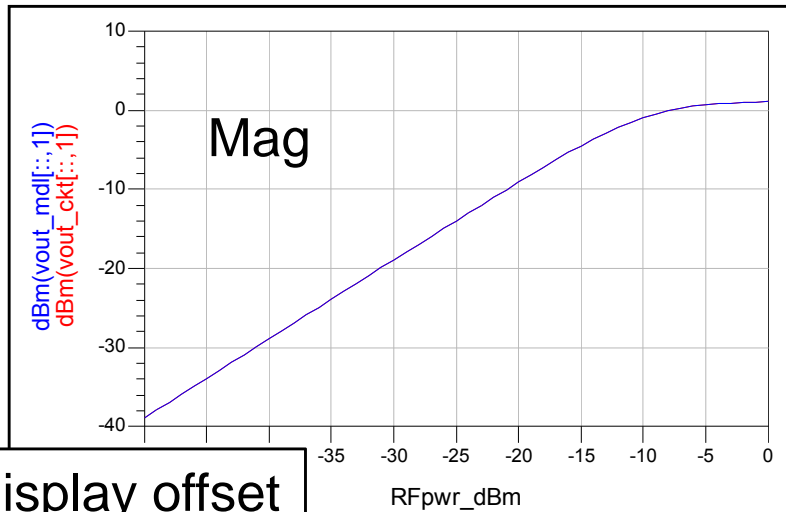
- $RF_{pwr} = -50 \text{ dBm}$ to 0 dBm
- $LO_{pwr} = -5 \text{ dBm}$



Compression Curve

Measurement Results

- small intentional display offset – to distinguish traces



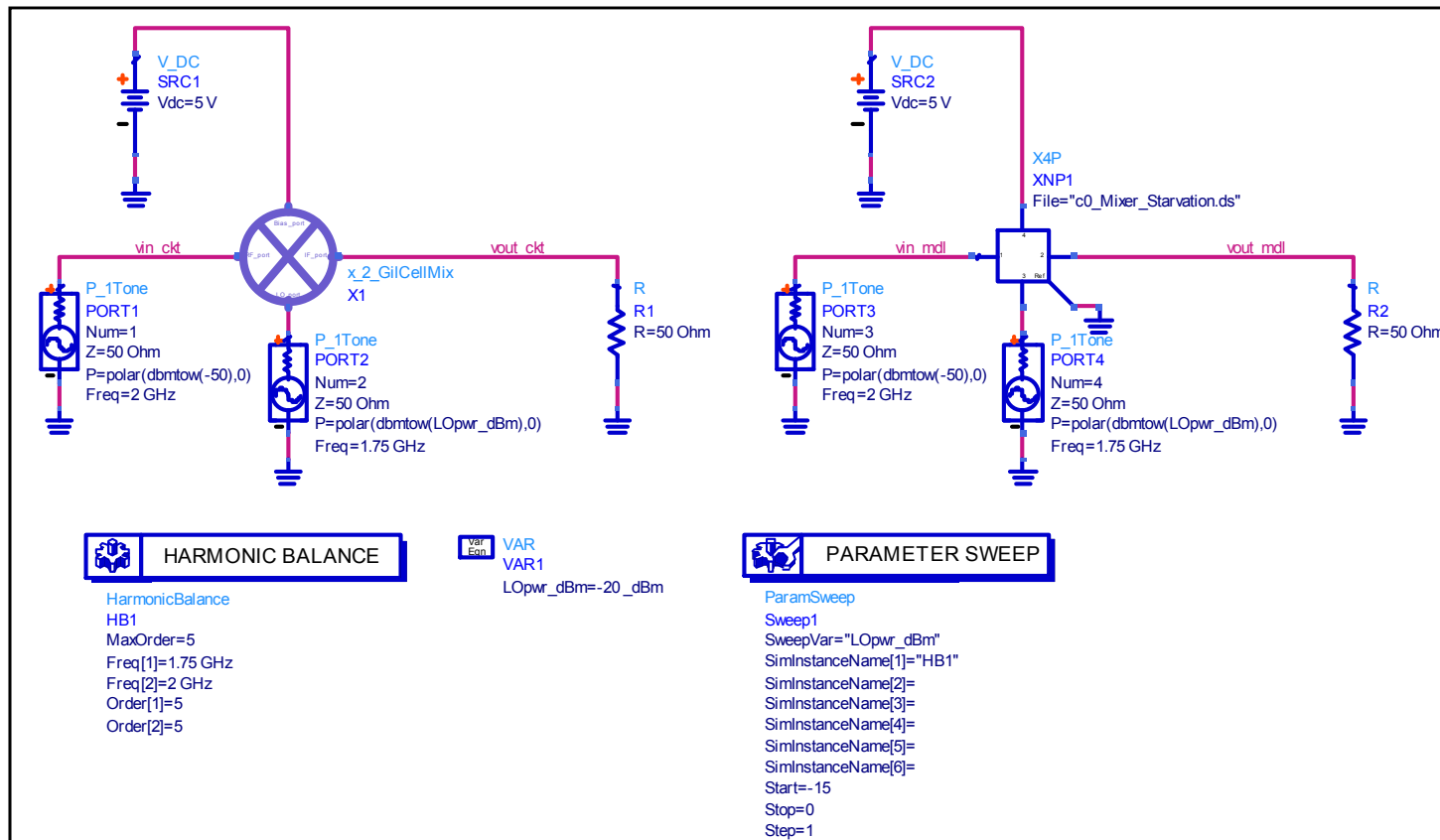
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LO Starvation Curve

- starvation curve measured by maintaining a constant RF power and sweeping the LO power level
- magnitude and phase of output signal at the IF frequency monitored at the output port

LO Starvation Curve Measurement Setup

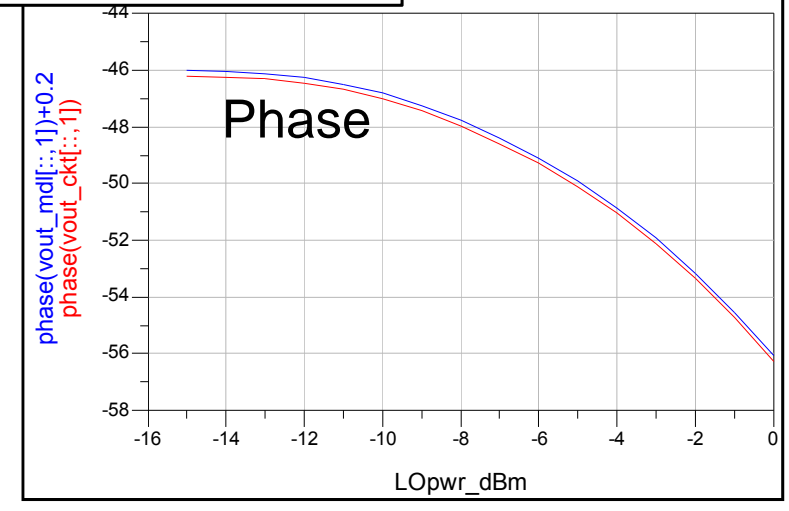
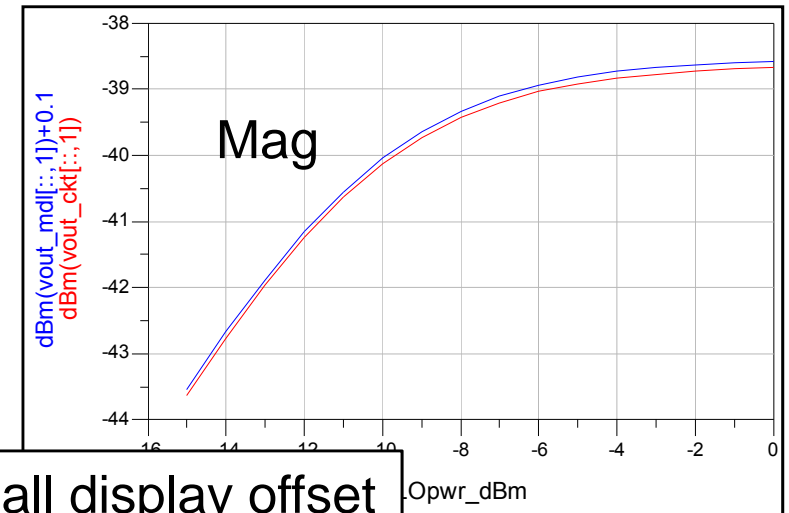
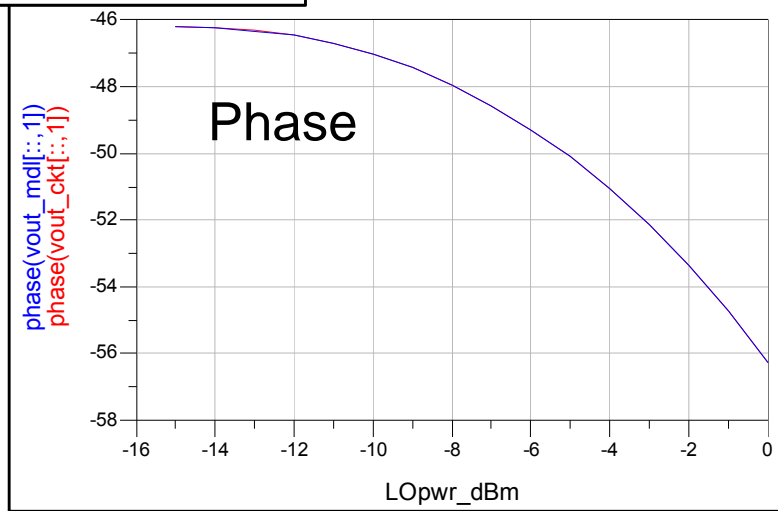
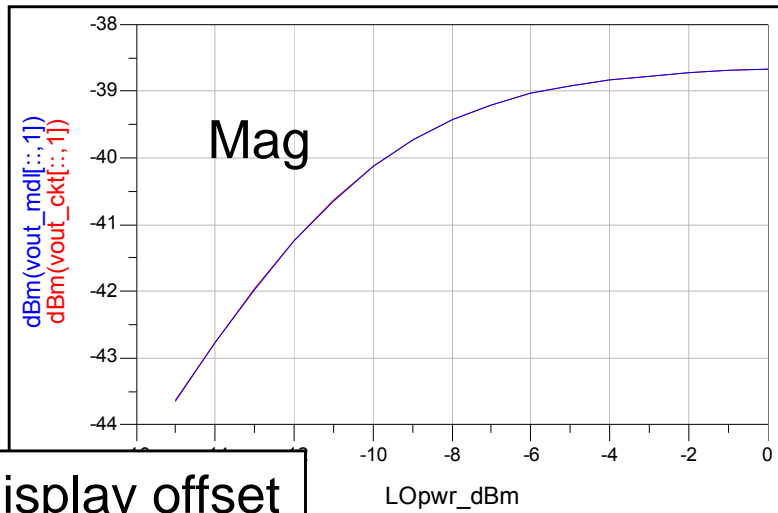
- RFpwr = -50 dBm
- LOpwr = -15 dBm to 0 dBm



LO Starvation Curve

Measurement Results

- small intentional display offset – to distinguish traces



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LO to RF and LO to IF Leakage

- LO to RF and LO to IF leakage measured by maintaining a constant RF power and sweeping the LO power level
- magnitude and phase of output signal at the LO frequency monitored at both the input and output ports

LO to RF and LO to IF Leakage

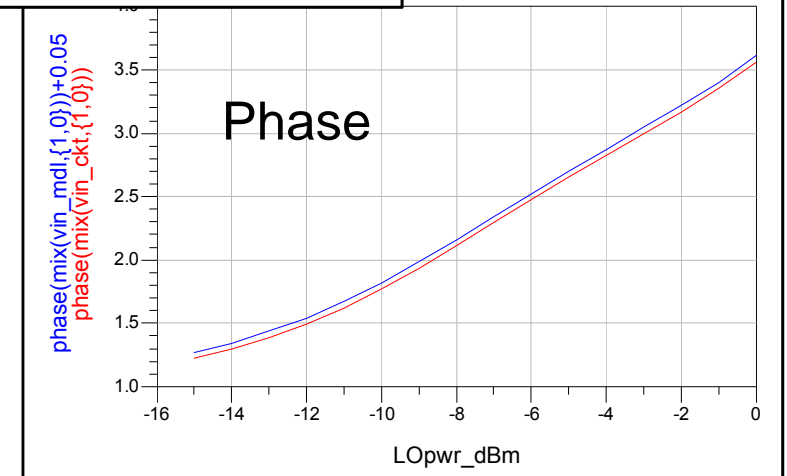
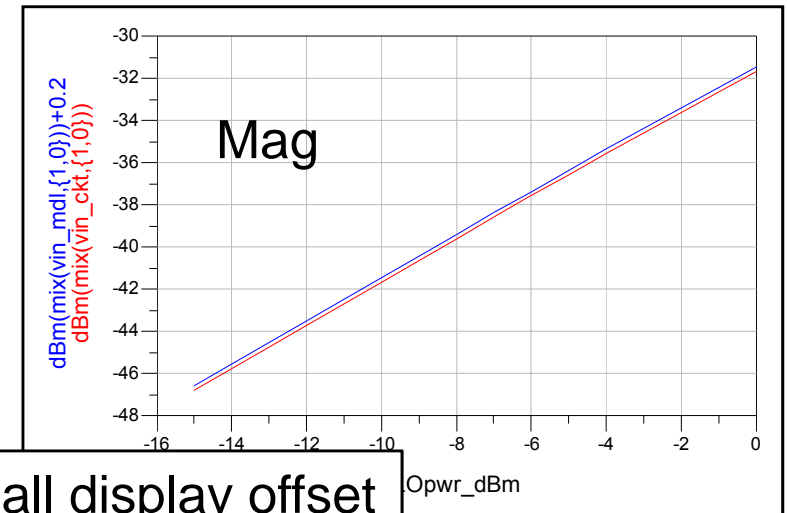
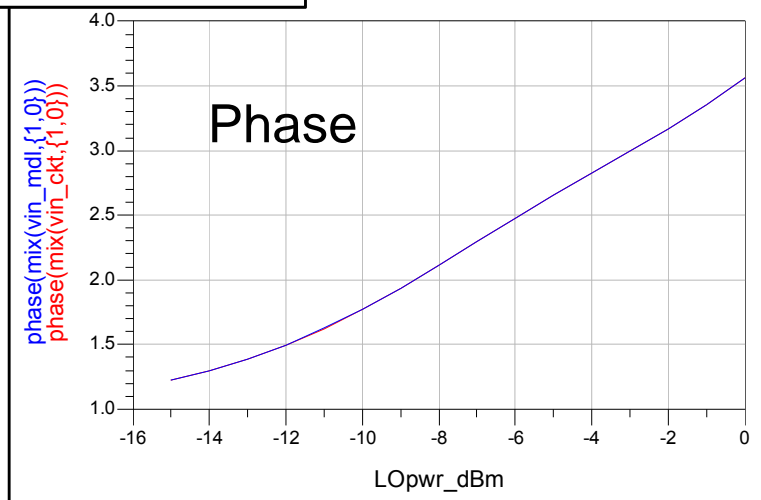
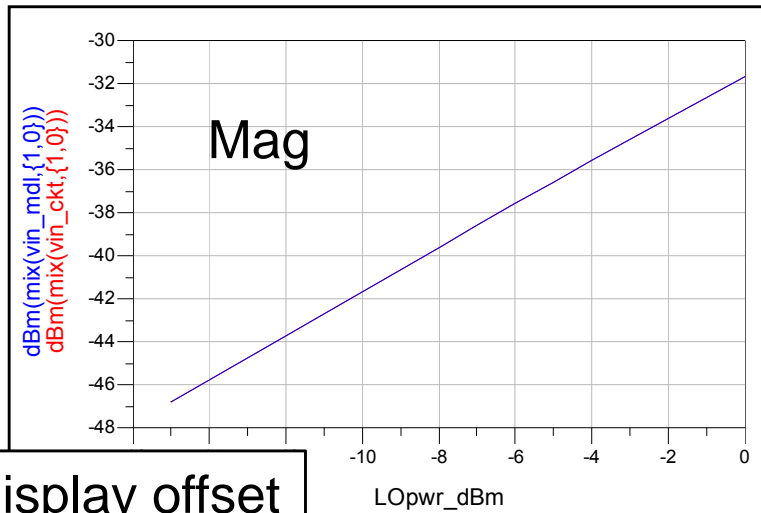
Measurement Setup

- same as LO starvation curve
- RFpwr = -50 dBm
- LOpwr = -15 dBm to 0 dBm

LO to RF Leakage

Measurement Results

- small intentional display offset – to distinguish traces

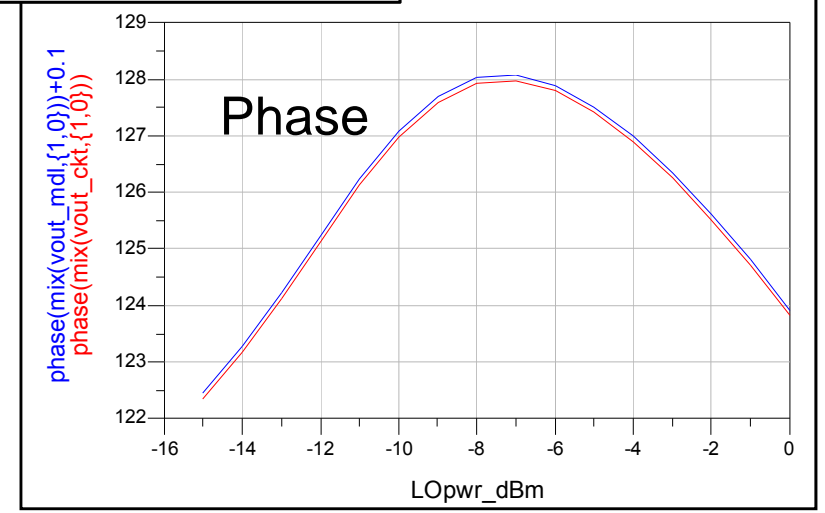
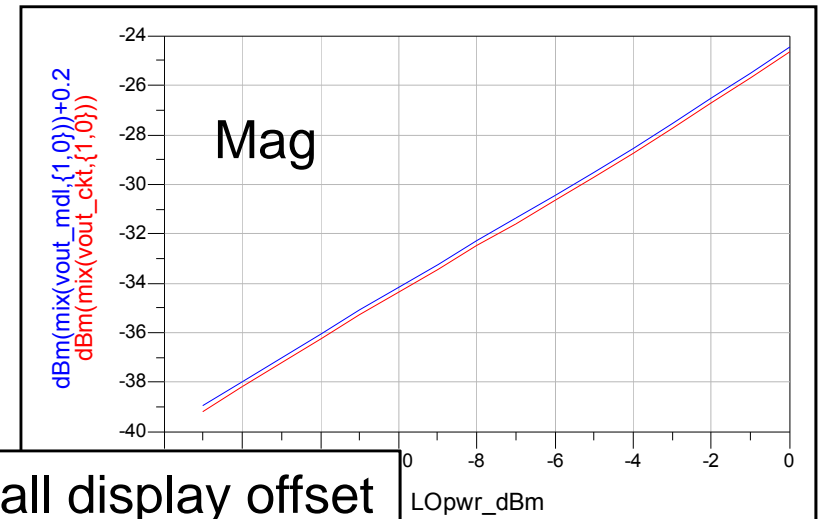
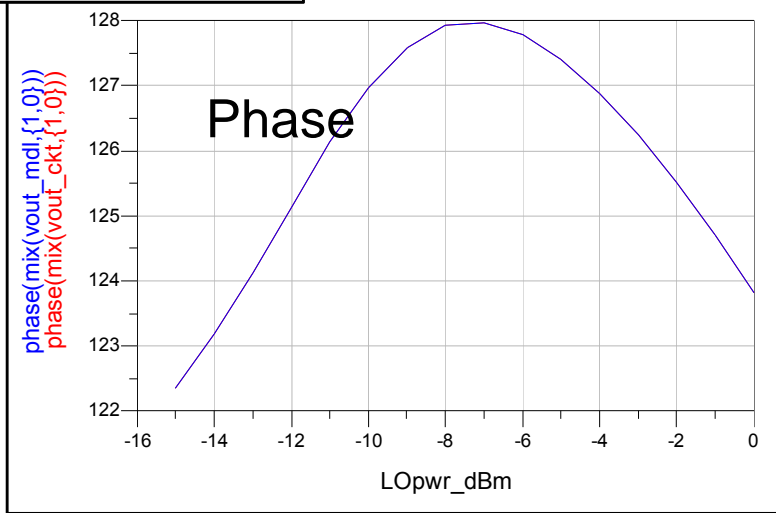
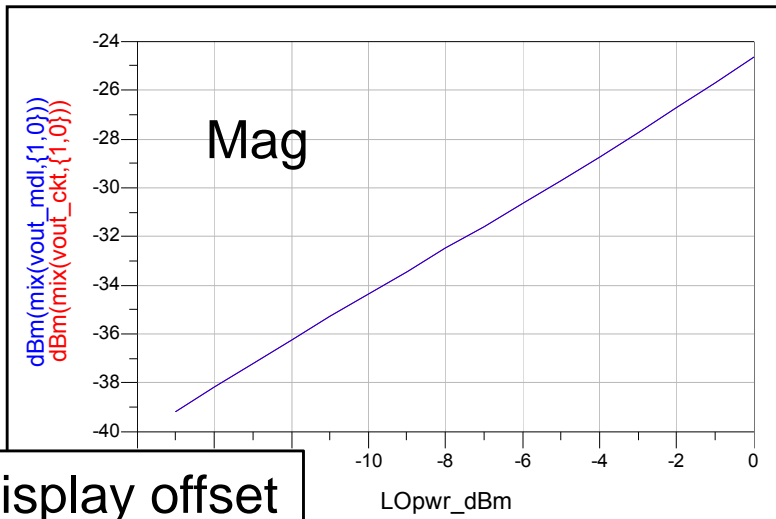


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LO to IF Leakage

Measurement Results

- small intentional display offset – to distinguish traces



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RF to IF Leakage

- RF to IF leakage measured by maintaining a constant LO power and sweeping the RF power level
- magnitude and phase of output signal at the RF frequency monitored at the output port

RF to IF Leakage

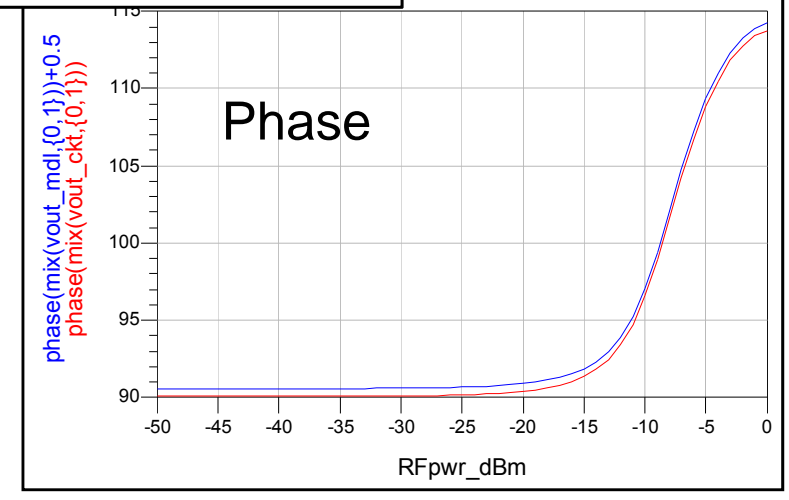
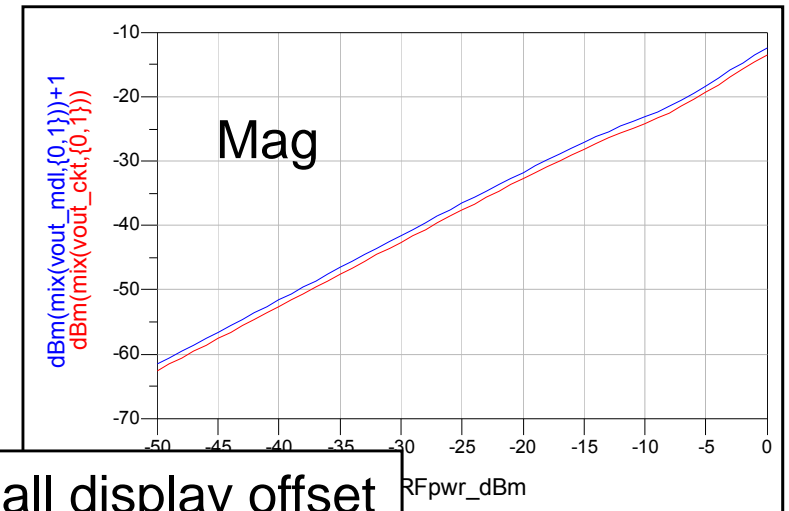
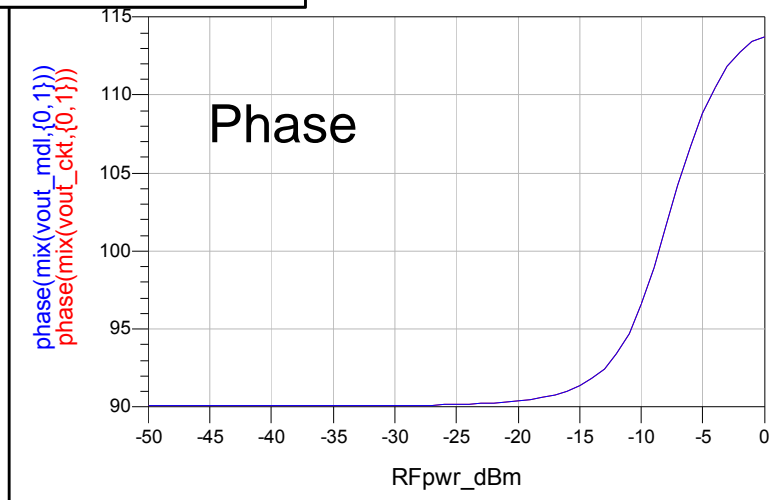
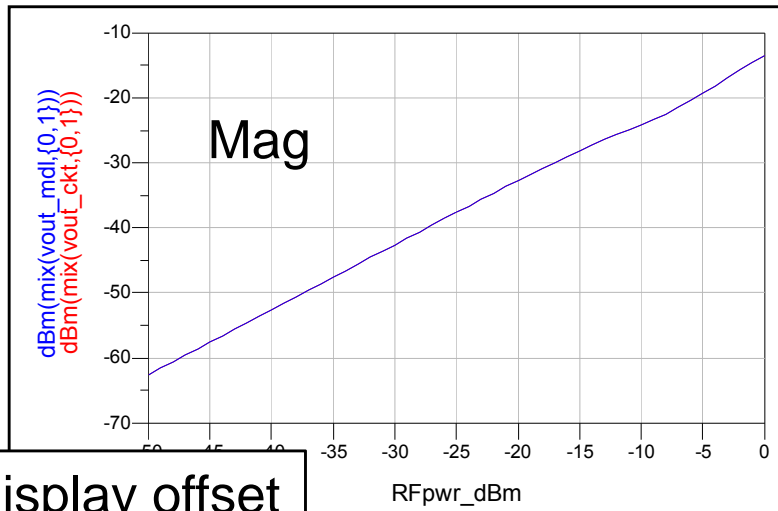
Measurement Setup

- same as compression curve
- RFpwr = -50 dBm to 0 dBm
- LOpwr = -5 dBm

RF to IF Leakage

Measurement Results

- small intentional display offset – to distinguish traces



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Modeling a Mixer Sub-System

The X-parameters may be used to model more than just the mixer itself.

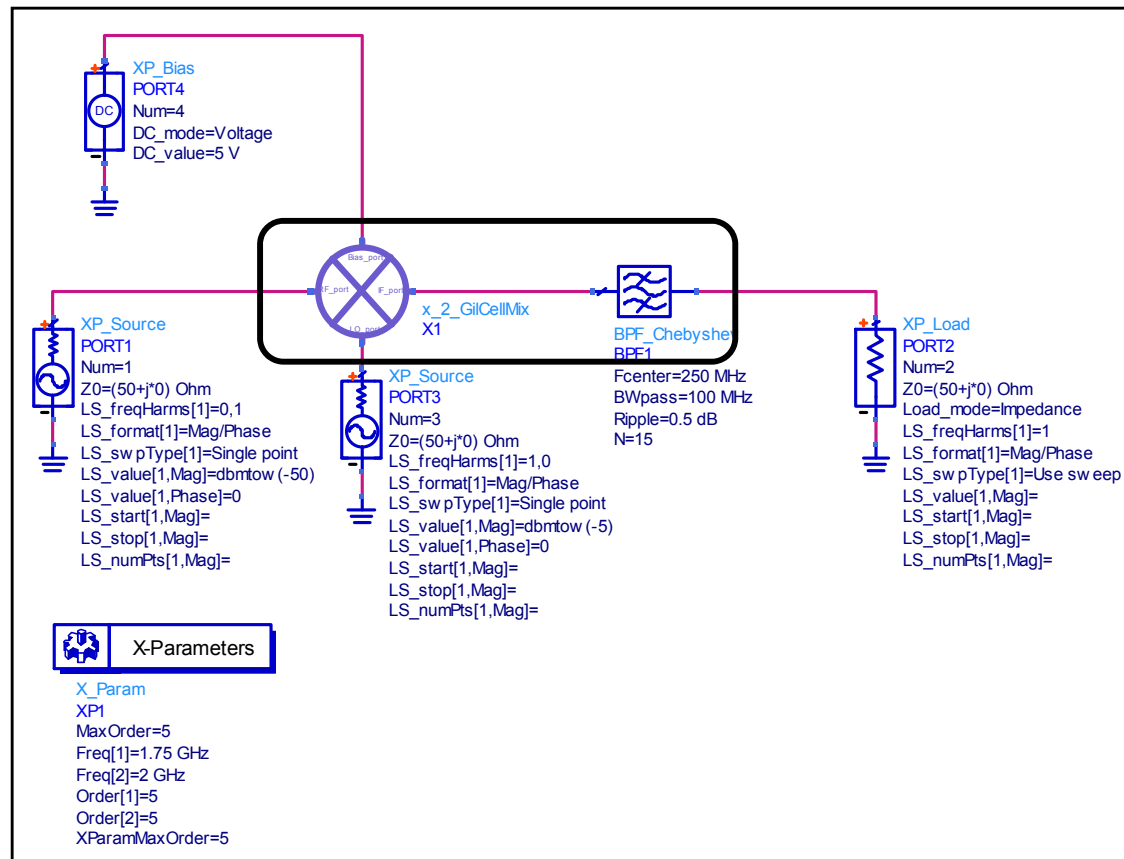
The following example is a simple system where the mixer is cascaded with a band-pass filter.

The X-parameters are extracted for the entire cascade encompassing both the mixer and the band-pass filter.

Mixer Sub-System – X-Parameter Extraction

Mixer and Band-Pass Filter

- one set of power levels is verified
- similar tests as for the single mixer could be configured



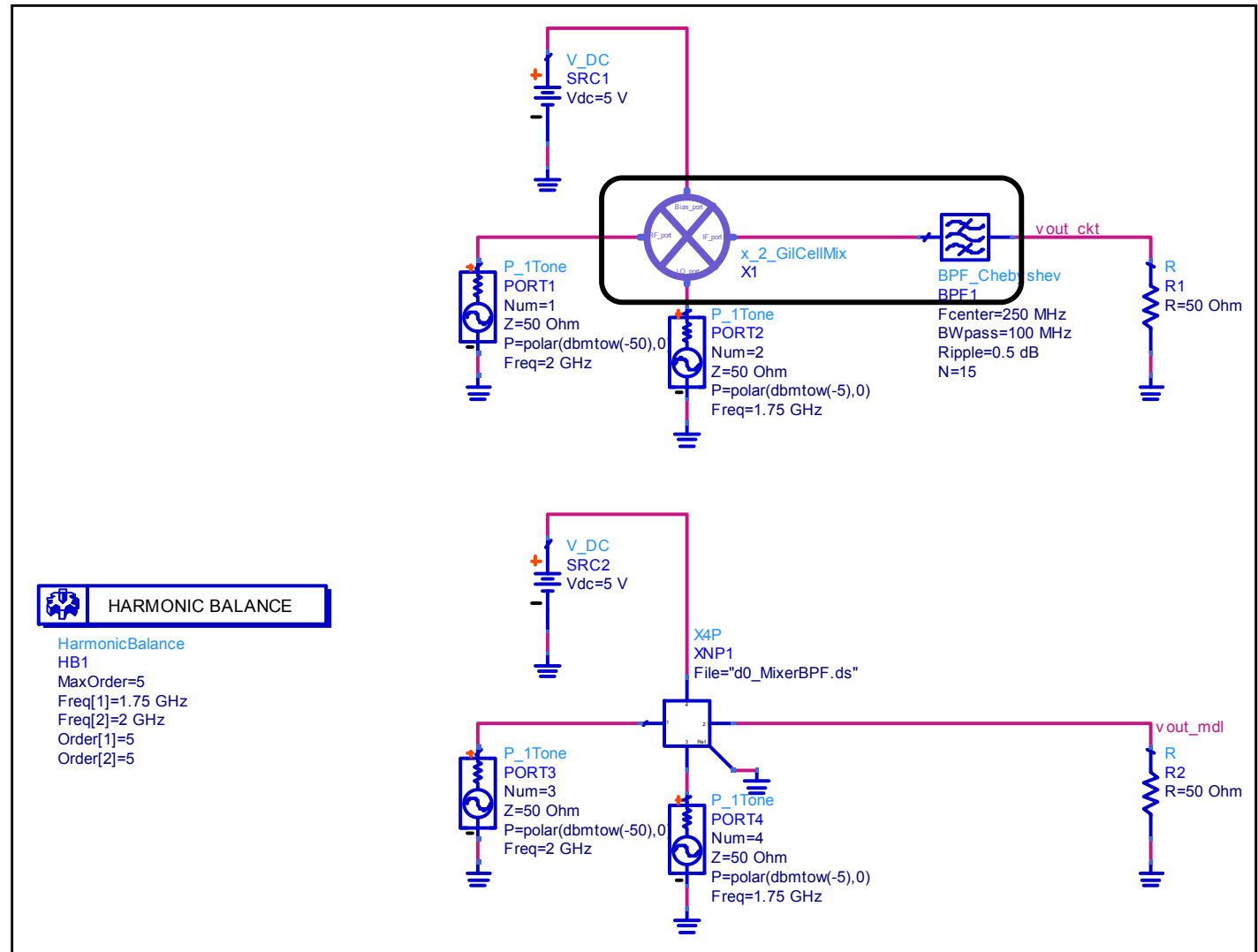
Mixer Sub-System Spectrum Measurement

- output port now located after the BPF
- measurement made at single LO and RF power levels
- magnitude and phase of output signal at all frequencies monitored at the output port

Mixer Sub-System

Spectrum Measurement Setup

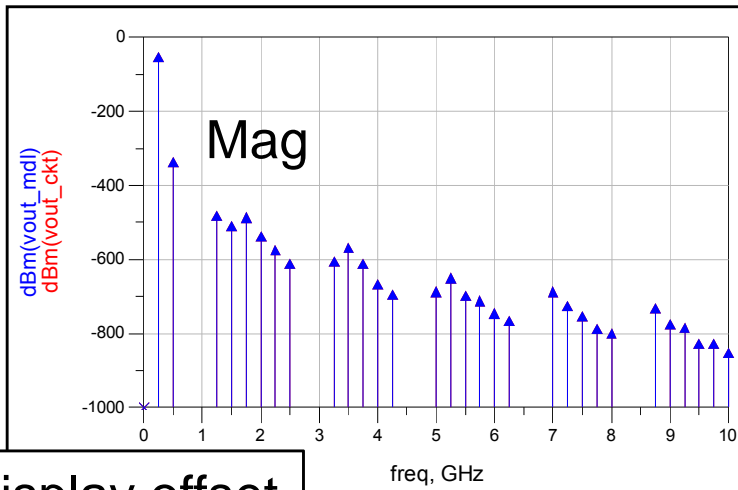
- RFpwr = -50
- LOpwr = -5 dBm



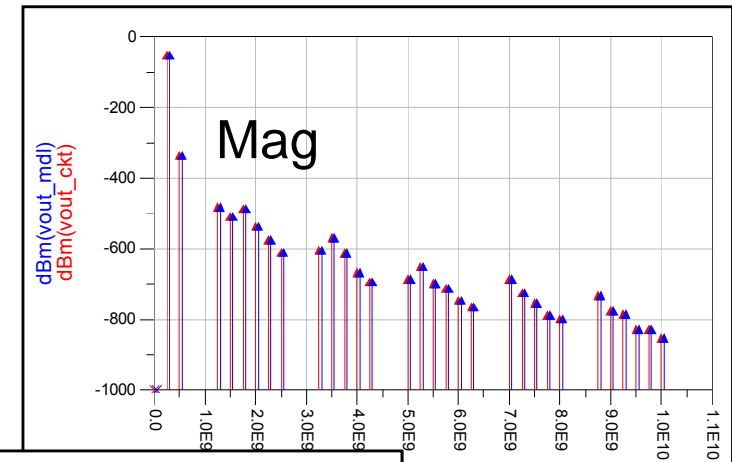
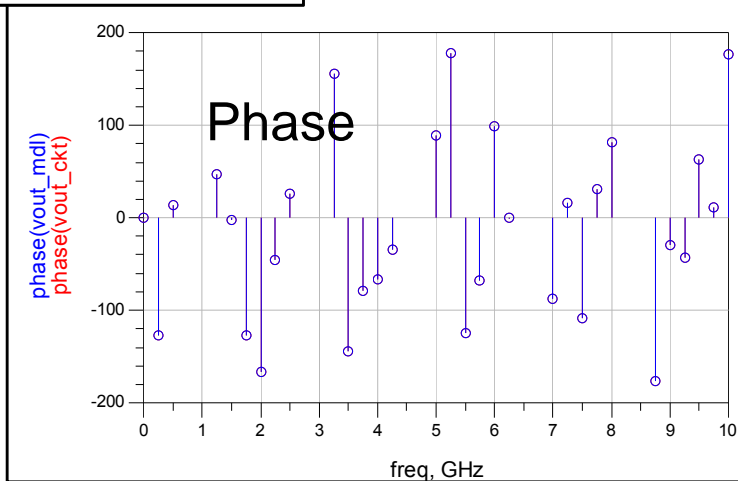
Mixer Sub-System

Spectrum Measurement Results

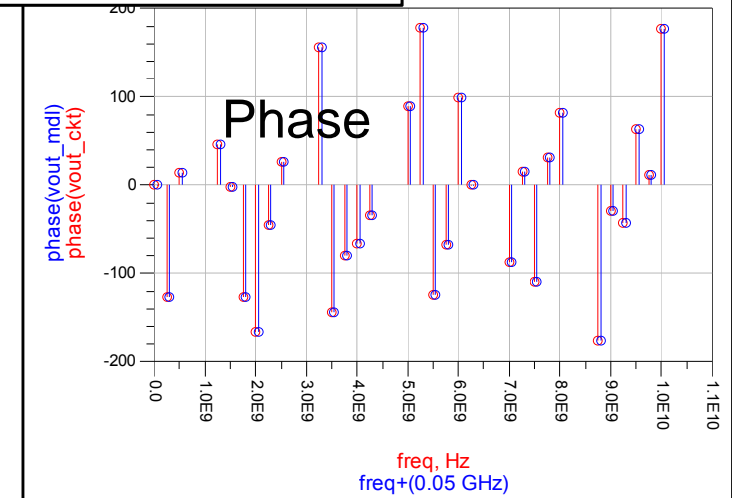
- small intentional display offset – to distinguish traces



No display offset



Small display offset



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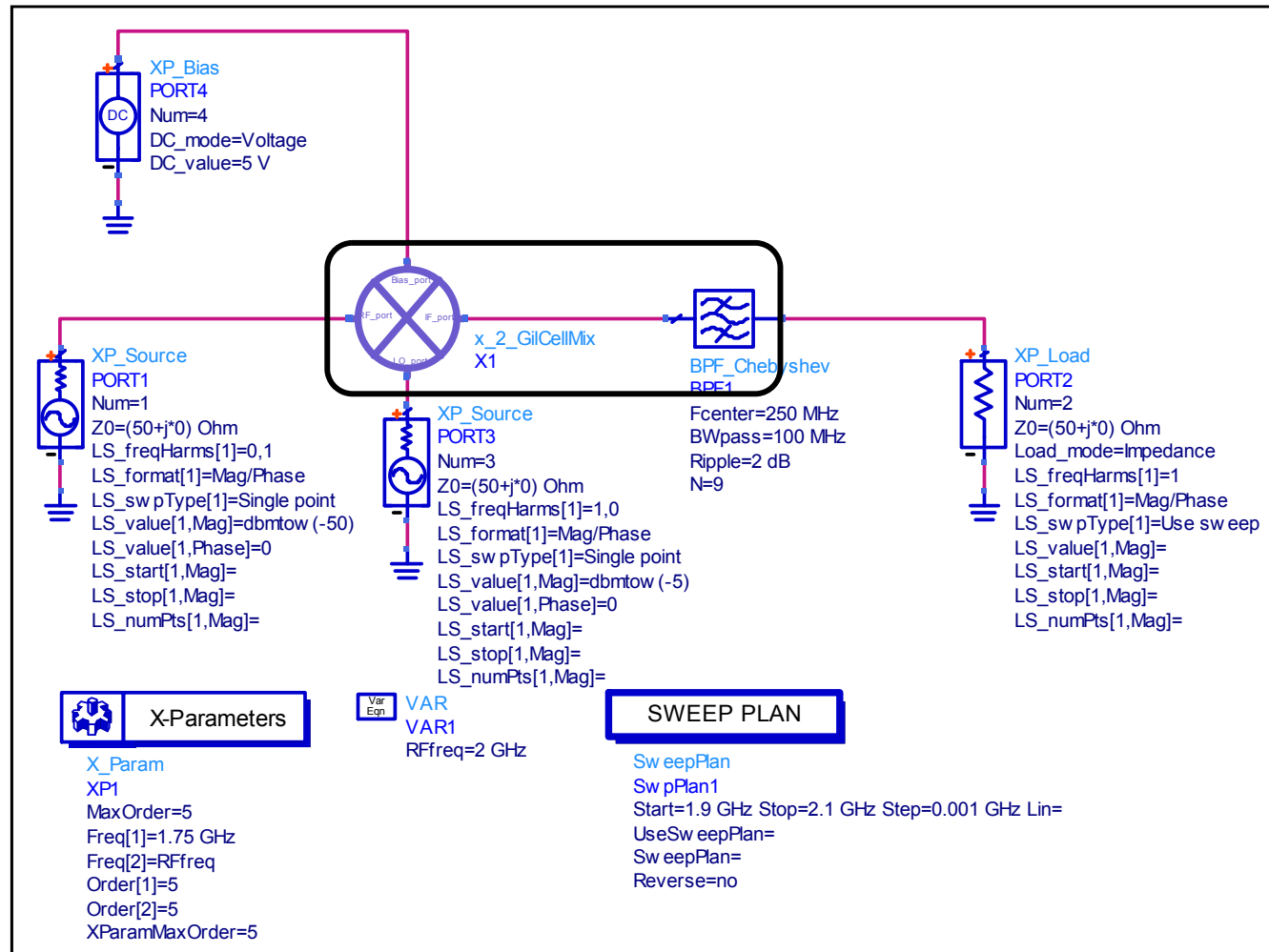
Mixer Sub-System Frequency Response

- output port now located after the BPF (BW = 100 MHz)
- measurement made at single LO and RF power levels
- RF frequency swept from 1.9 GHz to 2.1 GHz
- magnitude and phase of output signal at all frequencies monitored at the output port

Mixer Sub-System – Frequency Sweep

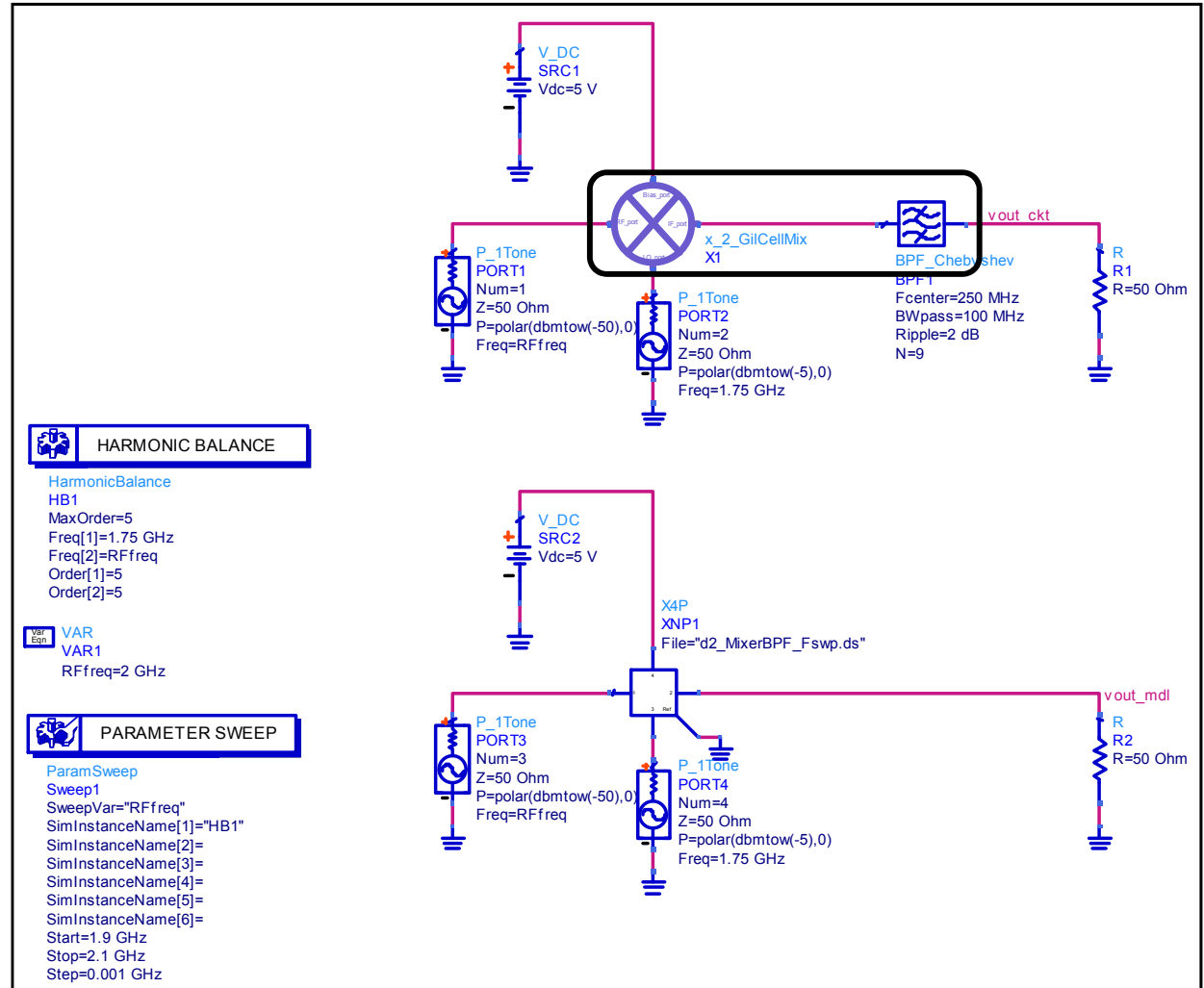
Mixer and Band-Pass Filter X-Parameter Extraction

- cross-frequency non-linear response



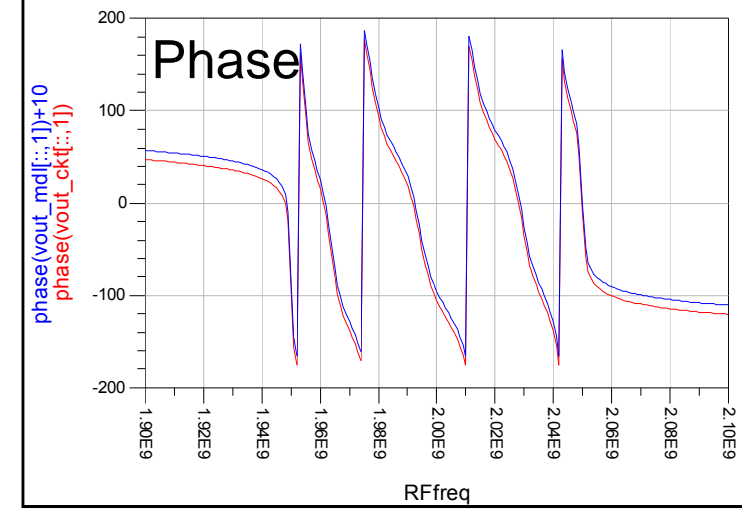
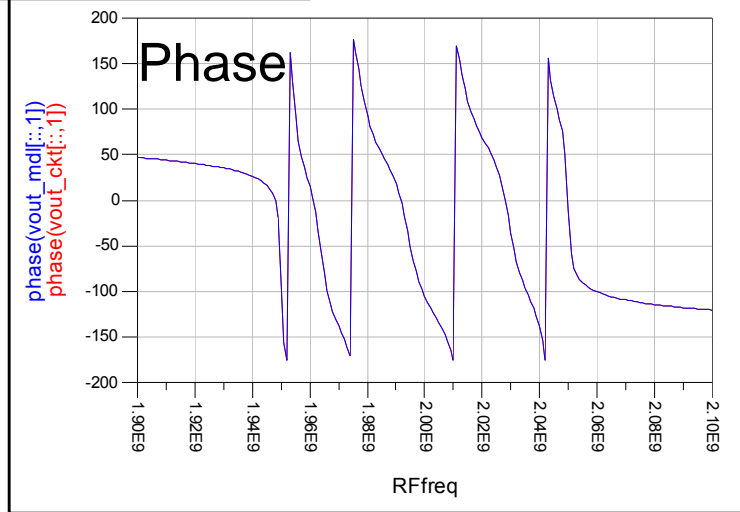
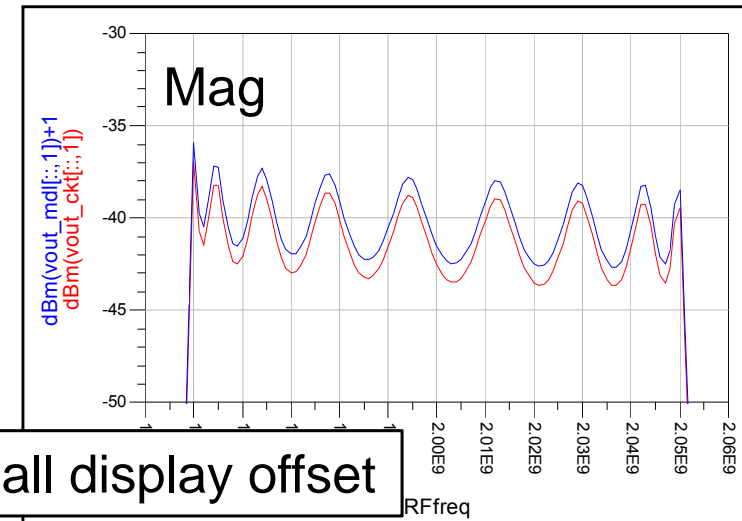
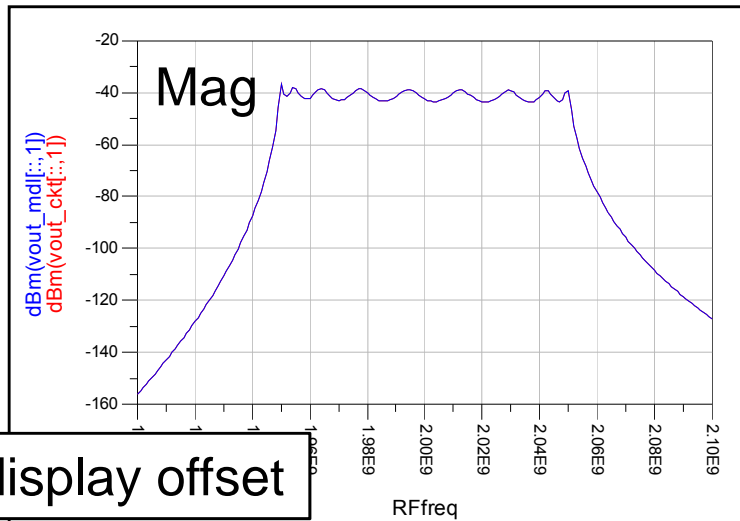
Mixer Sub-System – Frequency Sweep Measurement Setup

- RFfreq = 1.9 GHz to 2.1 GHz
- RFpwr = -50 dBm
- LOpwr = -5 dBm



Mixer Sub-System – Frequency Sweep Measurement Results

- small intentional display offset – to distinguish traces



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Conclusions

We have demonstrated excellent accuracy of X-parameter models in mixer applications: spectrum, compression, starvation, leakage, frequency response.

It is important to understand the X-parameter model needs to have a proper coverage for the operating conditions under which it is going to be used (power levels, frequencies, loading, biasing).

X-parameter models may simulate significantly faster than the transistor level circuits.

X-parameter models provide the IP-protection of the circuit level designs.