

EE6320 RF Integrated Circuits

Project: Mixer Design

Mixer Performance Summary Table

	<u>Design Metric</u>	<u>Performance</u>	<u>Specification</u>
<u>Conversion Gain</u>	Minimum Peak Gain in the specified band [$f_{RF} = f_{LO}$]	17.2320 dB	>15 dB
	Maximum Peak Gain in the specified band [$f_{RF} = f_{LO}$]	17.2339 dB	>15 dB
	Peak Gain flatness in specified band [Max-Min Gain]	0.0019 dB	-
	3dB RF Bandwidth [From the plot of $f_{RF} = f_{LO}$]	NA	-
	Minimum Band-Edge Gain in the specified band [$f_{RF} = f_{LO} + 10MHz$]	17.2291 dB	>15 dB
	Maximum Band-Edge Gain in the specified band [$f_{RF} = f_{LO} + 10MHz$]	17.2208 dB	>15 dB
<u>Noise Figure</u>	Maximum SSB Noise Figure for $f_{LO} = 5.17GHz$	6.87 dB	≤ 10 dB
	Maximum SSB Noise Figure for $f_{LO} = 5.245GHz$	6.90 dB	≤ 10 dB
	Maximum SSB Noise Figure for $f_{LO} = 5.32GHz$	6.93 dB	≤ 10 dB
<u>Linearity - IIP₂</u>	Input power used for extrapolation	-50 dB	-
	Power of Fundamental Tone at output (at chosen input power)	-32.70 dB	-
	Power of I _M ₂ Tone at output (at chosen input power)	-118.87 dB	-
	Extrapolated IIP ₂	36.18 dB	$\geq +30dBm$
<u>Linearity - IIP₃</u>	Input power used for extrapolation	-50 dB	-
	Power of Fundamental Tone at output (at chosen input power)	-32.70 dB	-
	Power of I _M ₃ Tone at output (at chosen input power)	-126.28 dB	-
	Extrapolated IIP ₃	-3.20 dB	$\geq -5dBm$
<u>Power</u>	Mixer DC power consumption [Excluding Bias]	1.8204 mW	Minimize
	Bias circuit power consumption	0.53 mW	Minimize
<u>Other</u>	Sum of all resistances [excluding bias]	2050	-
	Sum of biasing resistances	200K	-
	Sum of all capacitances [Including AC coupling]	2n	-
	Sum of all inductances	0	-
	Load chosen (each R_load)	350	-

	Differential Mixer Input Capacitance (C_gs Caps)	0	-
	Simulator Used	NA	-

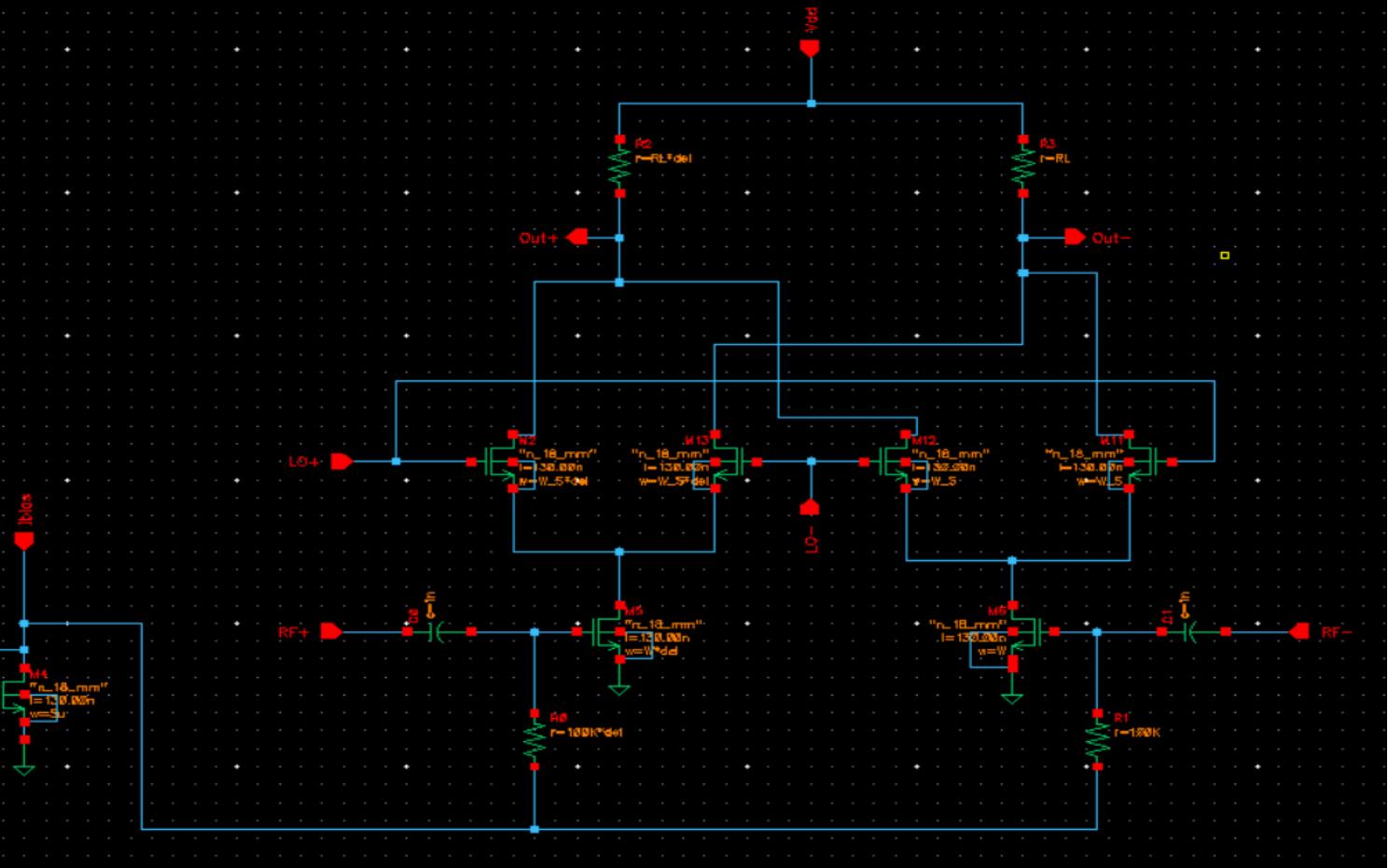
Name: Pragadeeswaran Kannan

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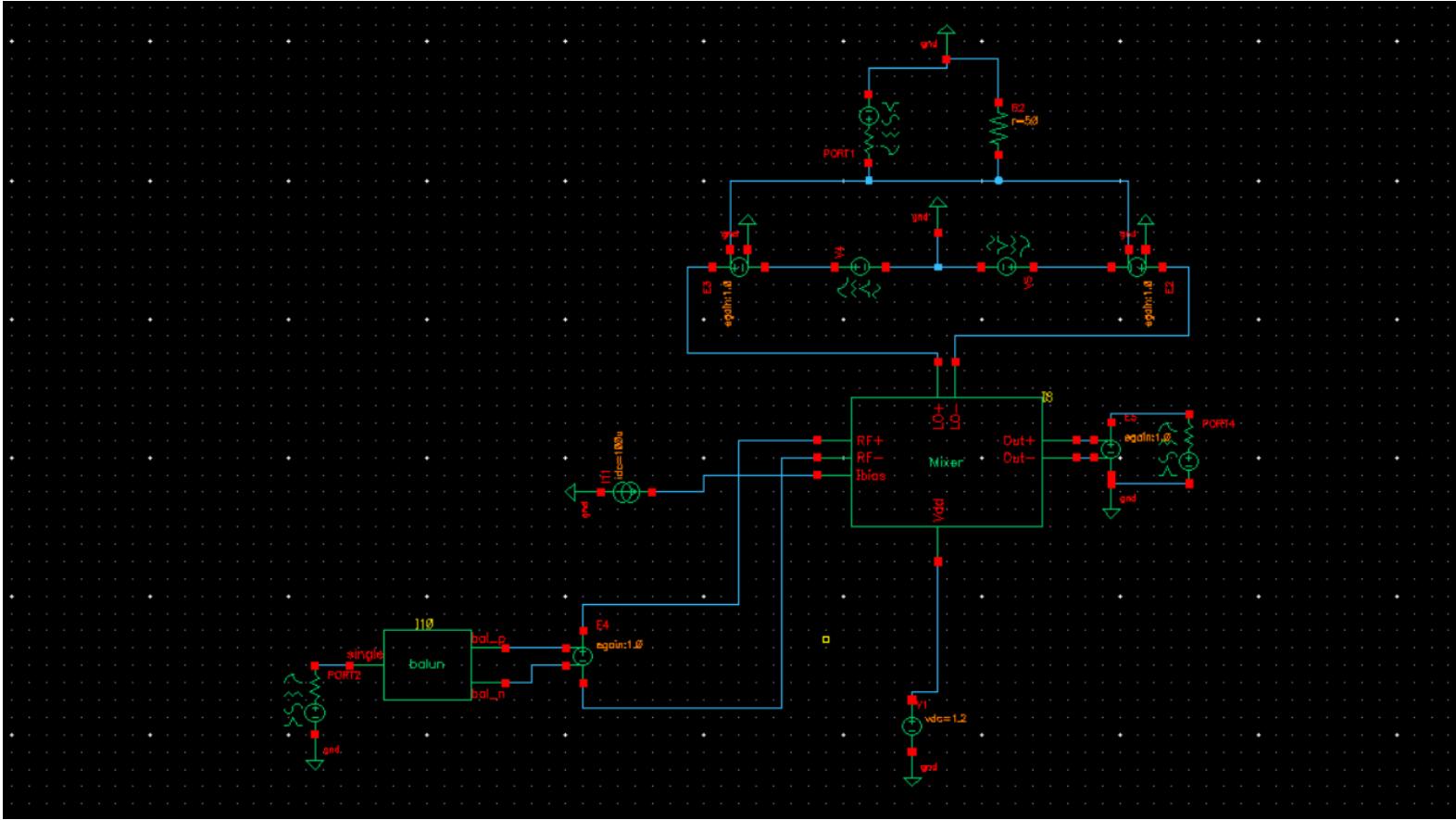
LNA + Mixer Performance Summary Table

	<u>Design Metric</u>	<u>LNA</u>	<u>Mixer</u>	<u>Cascade</u>	
				<u>Expected</u>	<u>Simulated</u>
<u>Conversion Gain</u>	$f_{IN} = f_{LO}, f_{LO} = 5.17\text{GHz}$	32.79 dB	17.2338	50.024	27.01 dB
	$f_{IN} = f_{LO} + 10\text{MHz}, f_{LO} = 5.17\text{GHz}$	32.79 dB	17.2320	50.011	26.92 dB
	$f_{IN} = f_{LO}, f_{LO} = 5.245\text{GHz}$	34.47 dB	17.2338	51.682	26.33 dB
	$f_{IN} = f_{LO} + 10\text{MHz}, f_{LO} = 5.245\text{GHz}$	34.47 dB	17.2320	51.670	26.25 dB
	$f_{IN} = f_{LO}, f_{LO} = 5.32\text{GHz}$	34.02 dB	17.2250	51.245	25.69 dB
	$f_{IN} = f_{LO} + 10\text{MHz}, f_{LO} = 5.32\text{GHz}$	34.02 dB	17.2232	51.223	25.60 dB
<u>Noise Figure</u>	$f_{IN} = f_{LO} + 10\text{MHz}, f_{LO} = 5.17\text{GHz}$	1.557	6.87	1.82 dB	3.32 dB
	$f_{IN} = f_{LO} + 10\text{MHz}, f_{LO} = 5.245\text{GHz}$	1.549	6.90	1.76 dB	3.49 dB
	$f_{IN} = f_{LO} + 10\text{MHz}, f_{LO} = 5.32\text{GHz}$	1.550	6.93	1.78 dB	3.68 dB
<u>Linearity IIP3</u>	Input power used for extrapolation			-	-50 dB
	Power of Fundamental Tone at output (at chosen input power)			-	-24.13 dB
	Power of IM_3 Tone at output (at chosen input power)			-	-86.66 dB
	Extrapolated IIP_3			-	-19.747 dB
<u>Power</u>	Total power consumption [Excluding Bias]				2.13 mW
	Bias circuit power consumption				0.53 mW

Mixer Schematic



Mixer Testbench



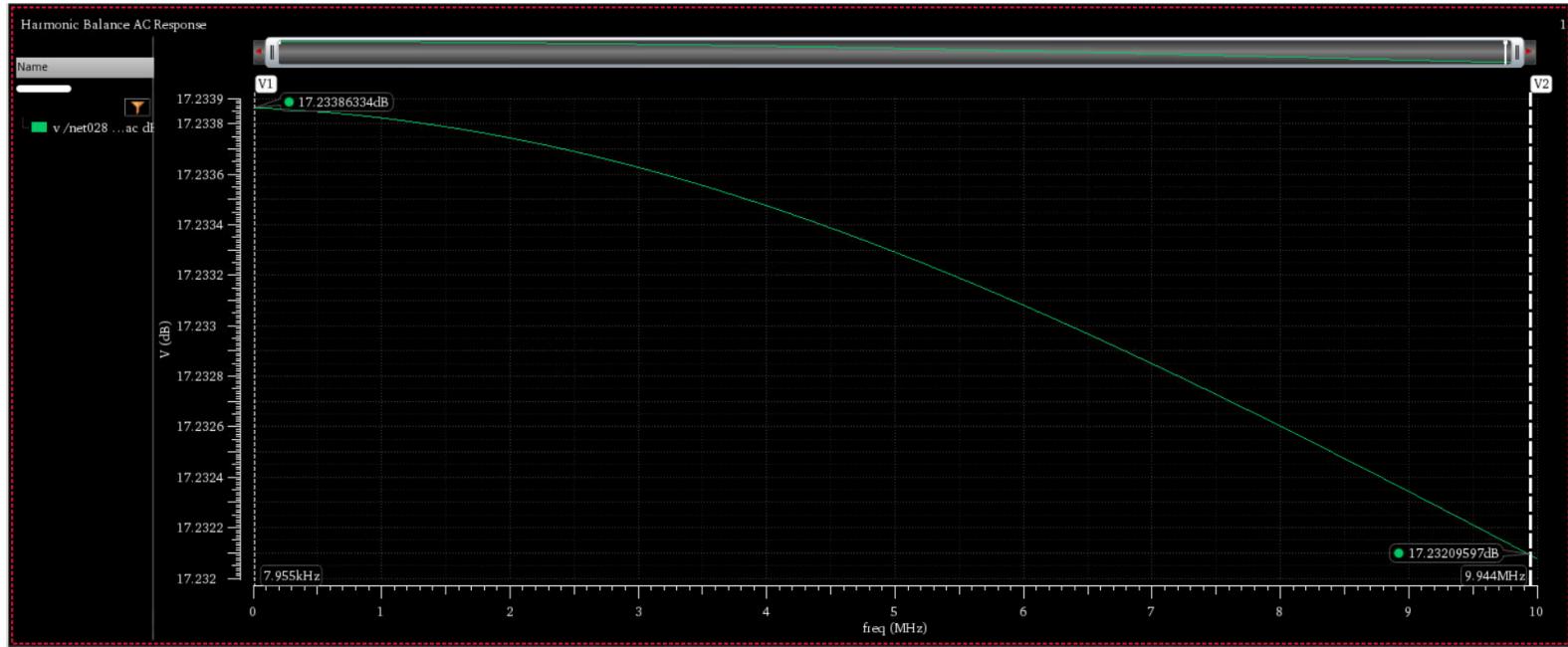
Design Variable Values

<u>Design Variable</u>	<u>Value</u>
Resistance (load, each side)	350 ohms
Length of all MOS	130 nm
Width of Switch MOS (all 4)	20 um
Width of Transconductance MOS (both MOS)	45u
Bias Current	100u
V_LO Amplitude	0.9

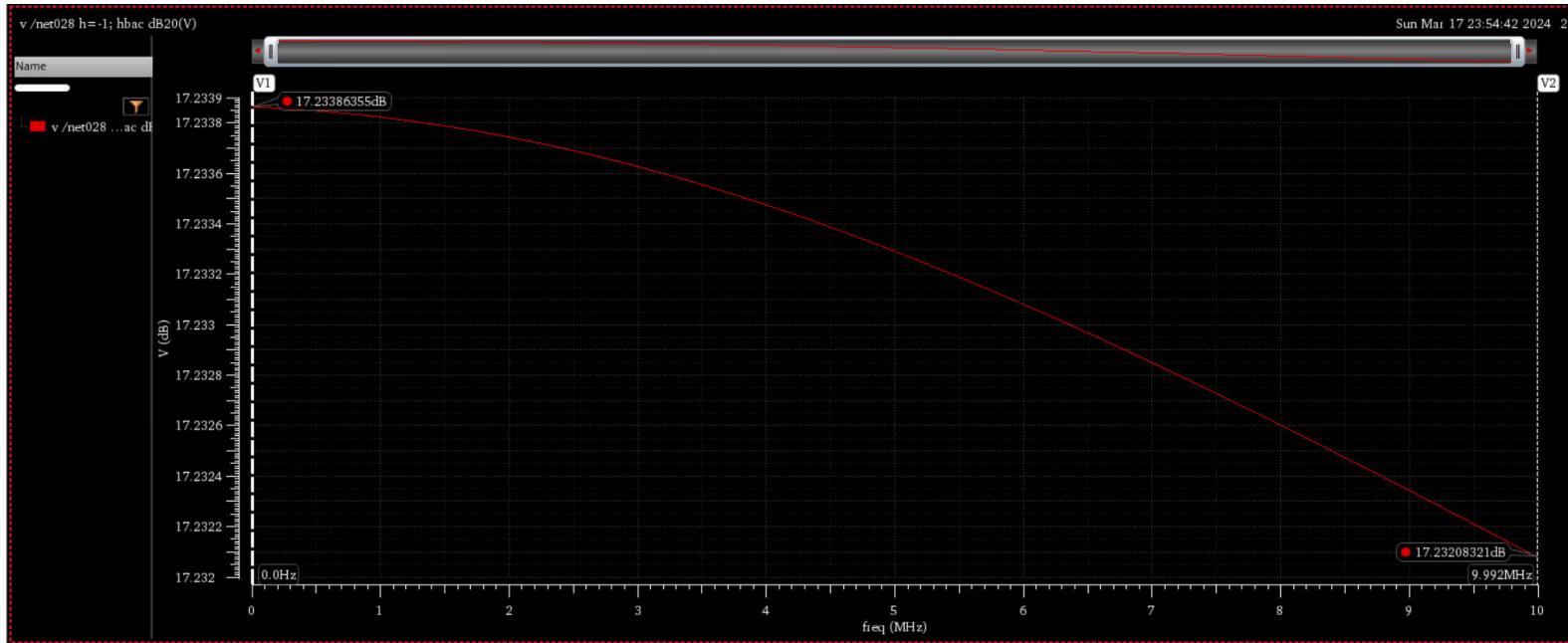
Fixed Constant Parameters

- Transconductance MOS C_gs: -81.99f
- Current Mirror MOS: W = 5u, L = 130n
- Coupling capacitances: 1n (each)
- Bias Resistances: 100K (each)

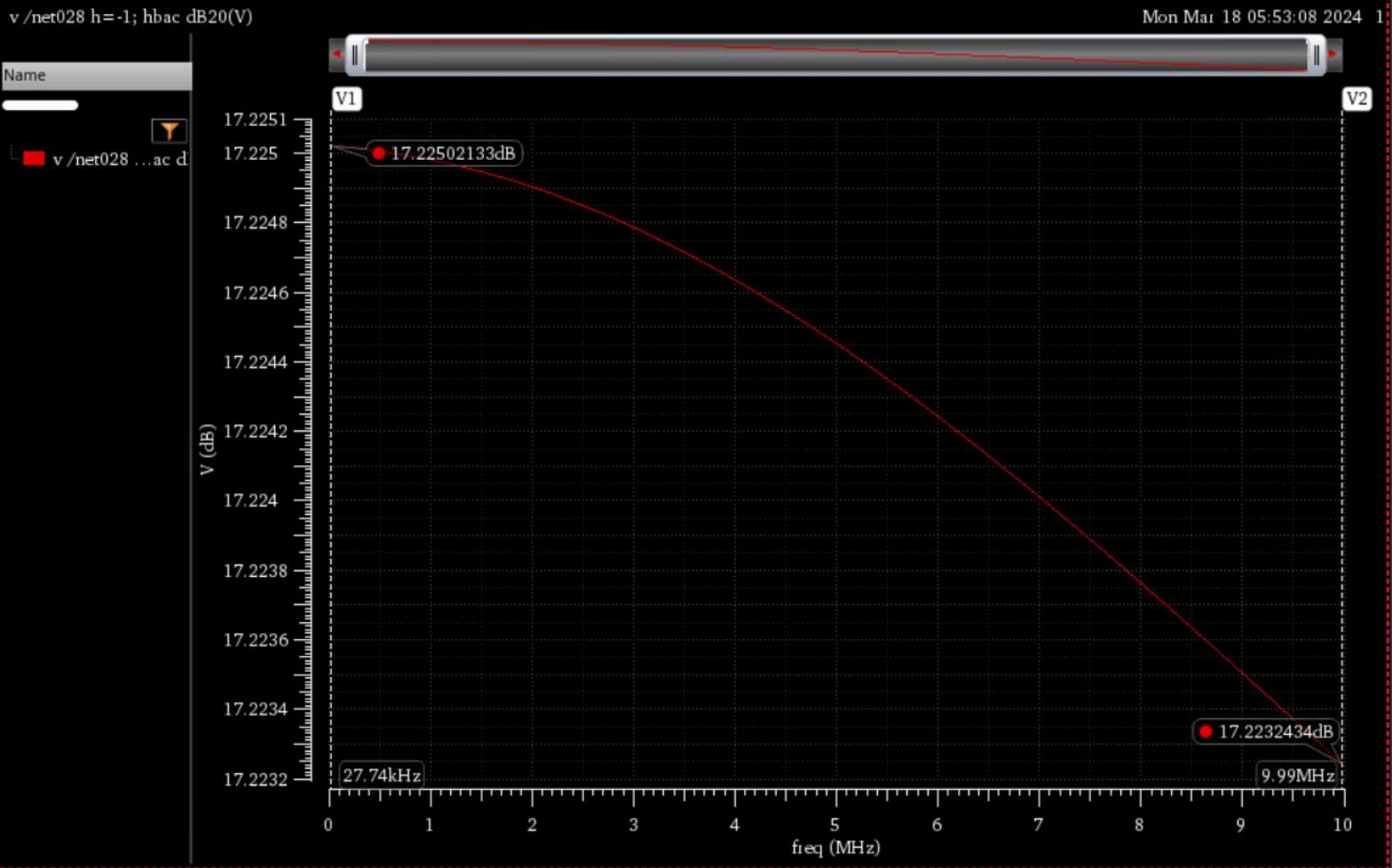
Conversion Gain of Mixer at 5.17GHz



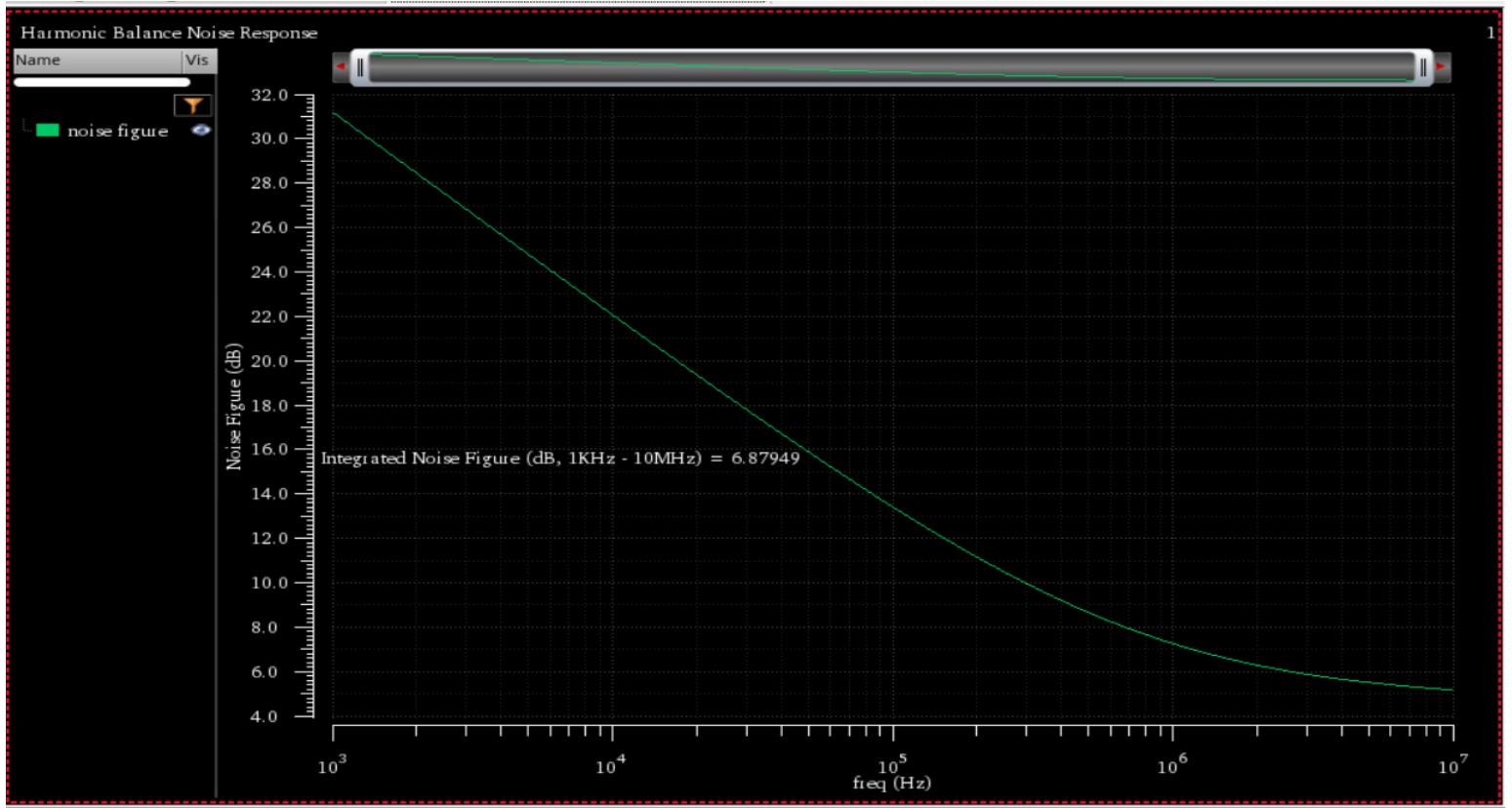
Conversion Gain of Mixer at 5.245GHz



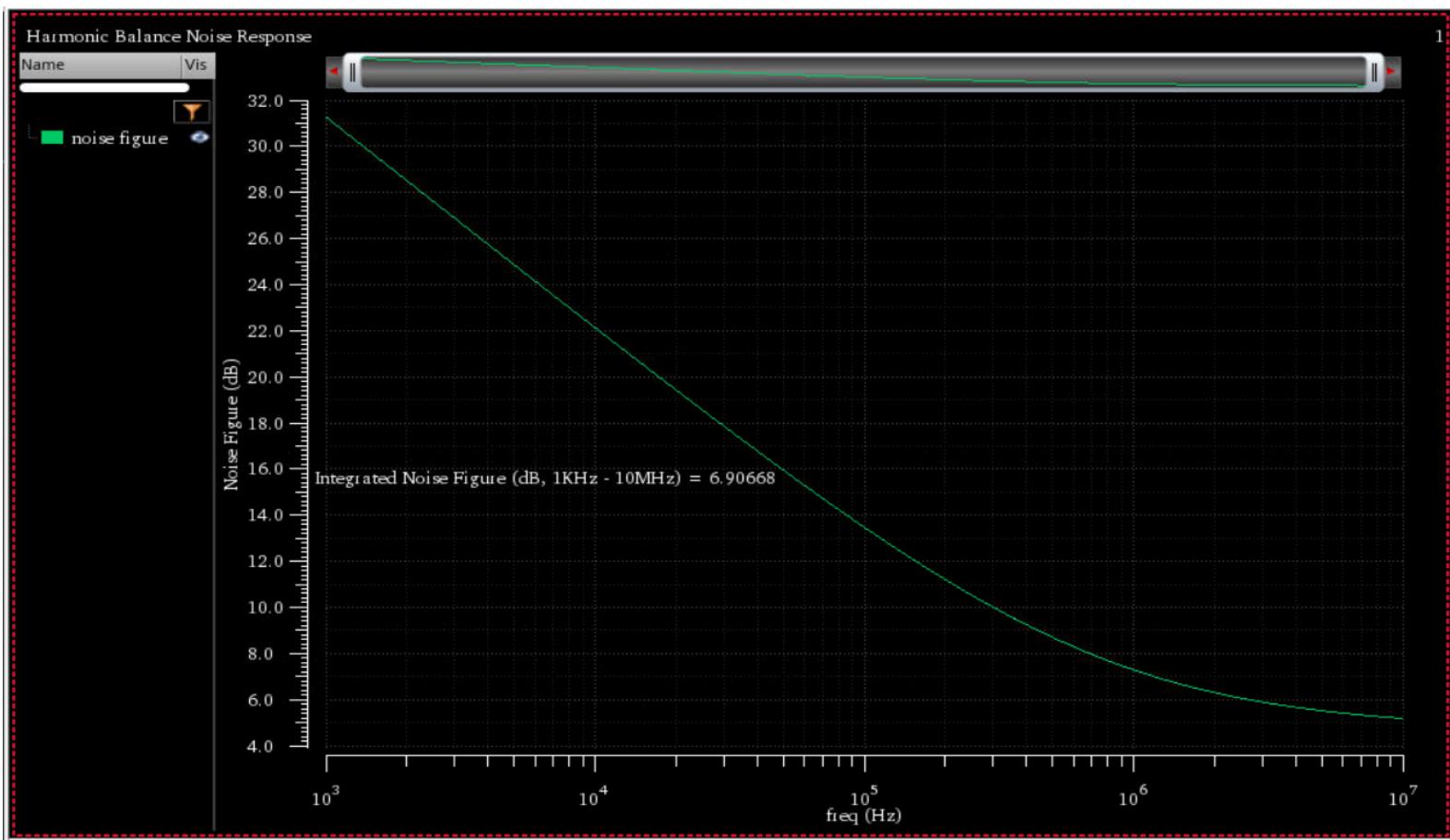
Conversion Gain of Mixer at 5.32GHz



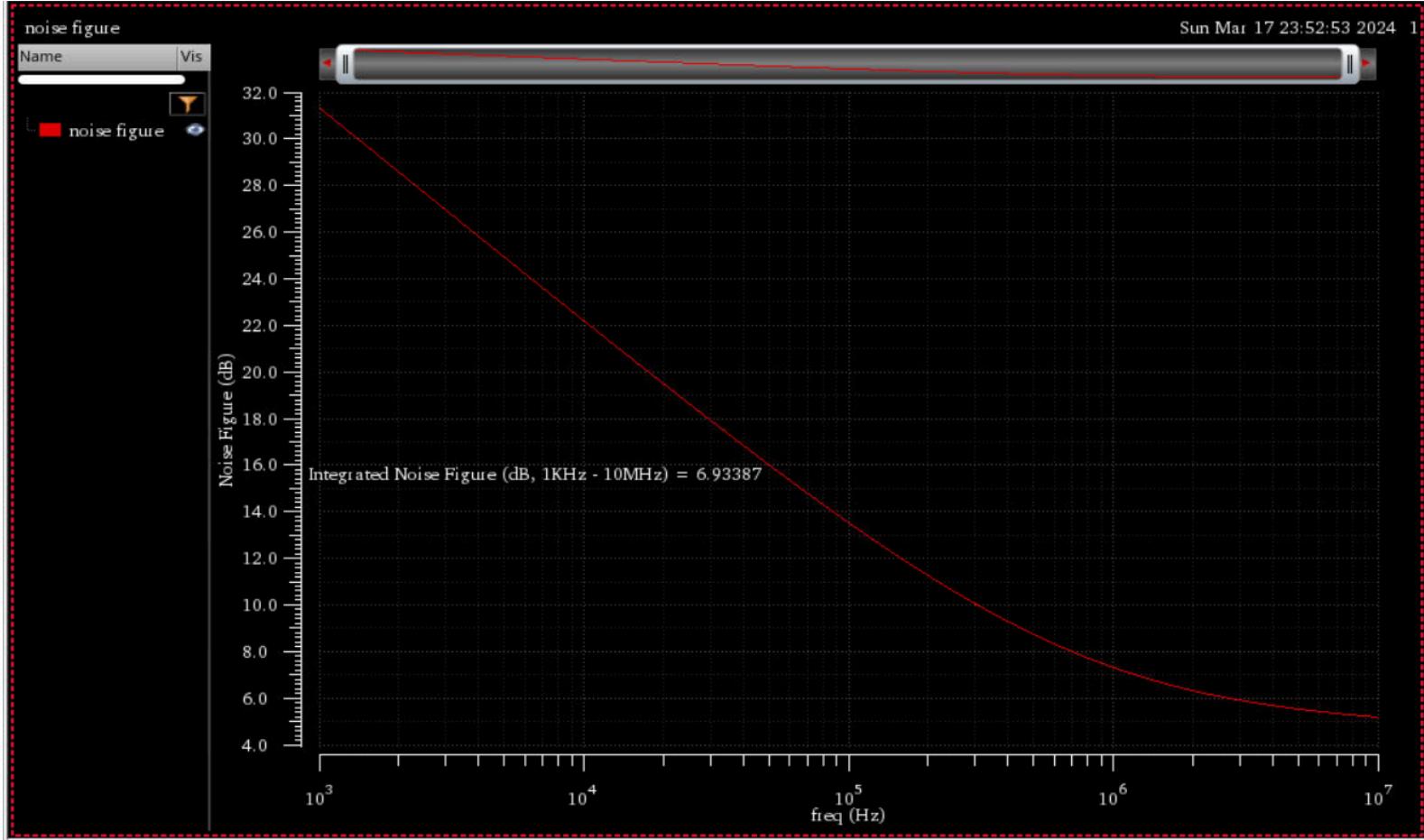
Noise Figure of Mixer at 5.17GHz



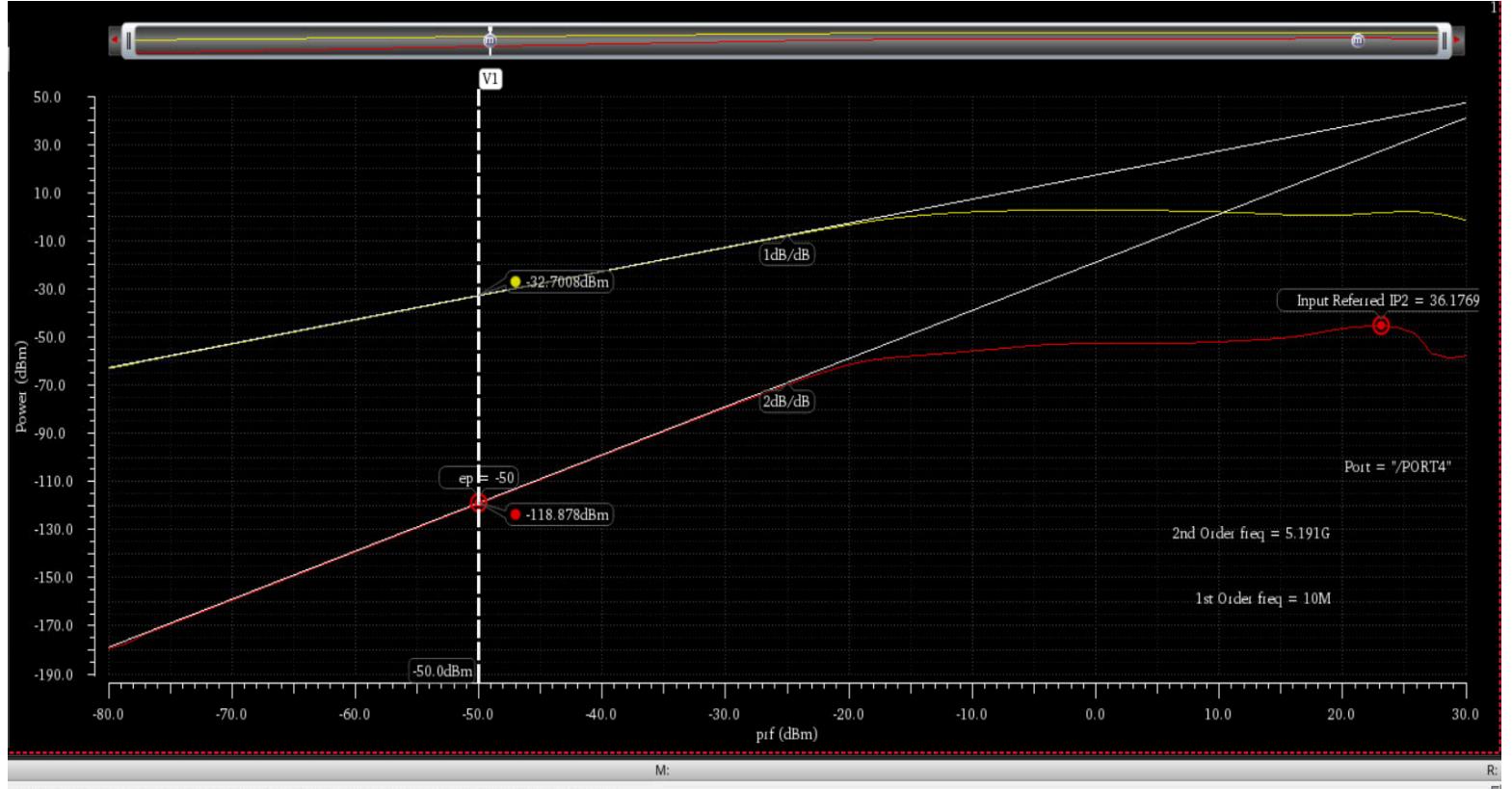
Noise Figure of Mixer at 5.245GHz



Noise Figure of Mixer at 5.32GHz

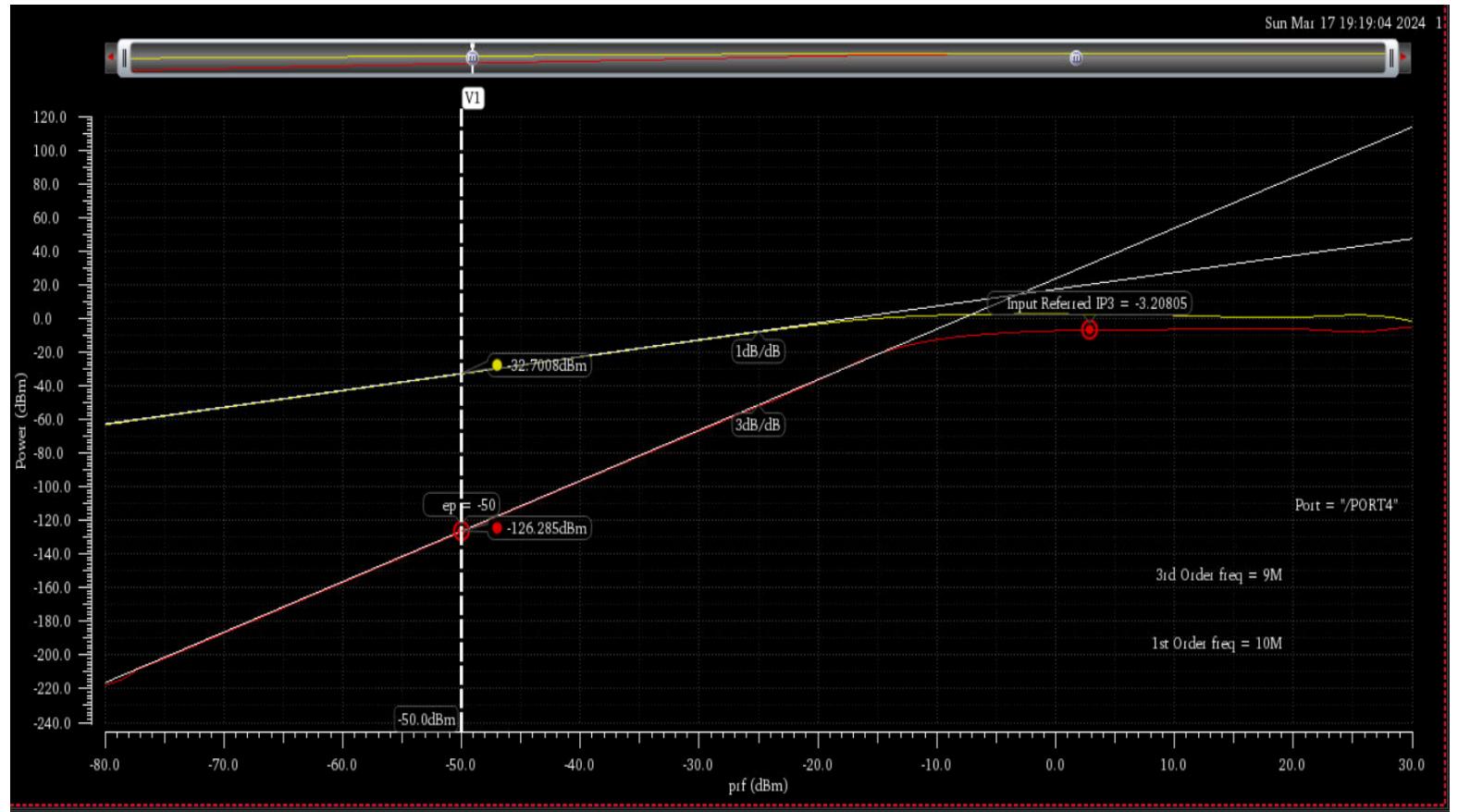


Mixer IIP2 Linearity



Mixer IIP3 Linearity

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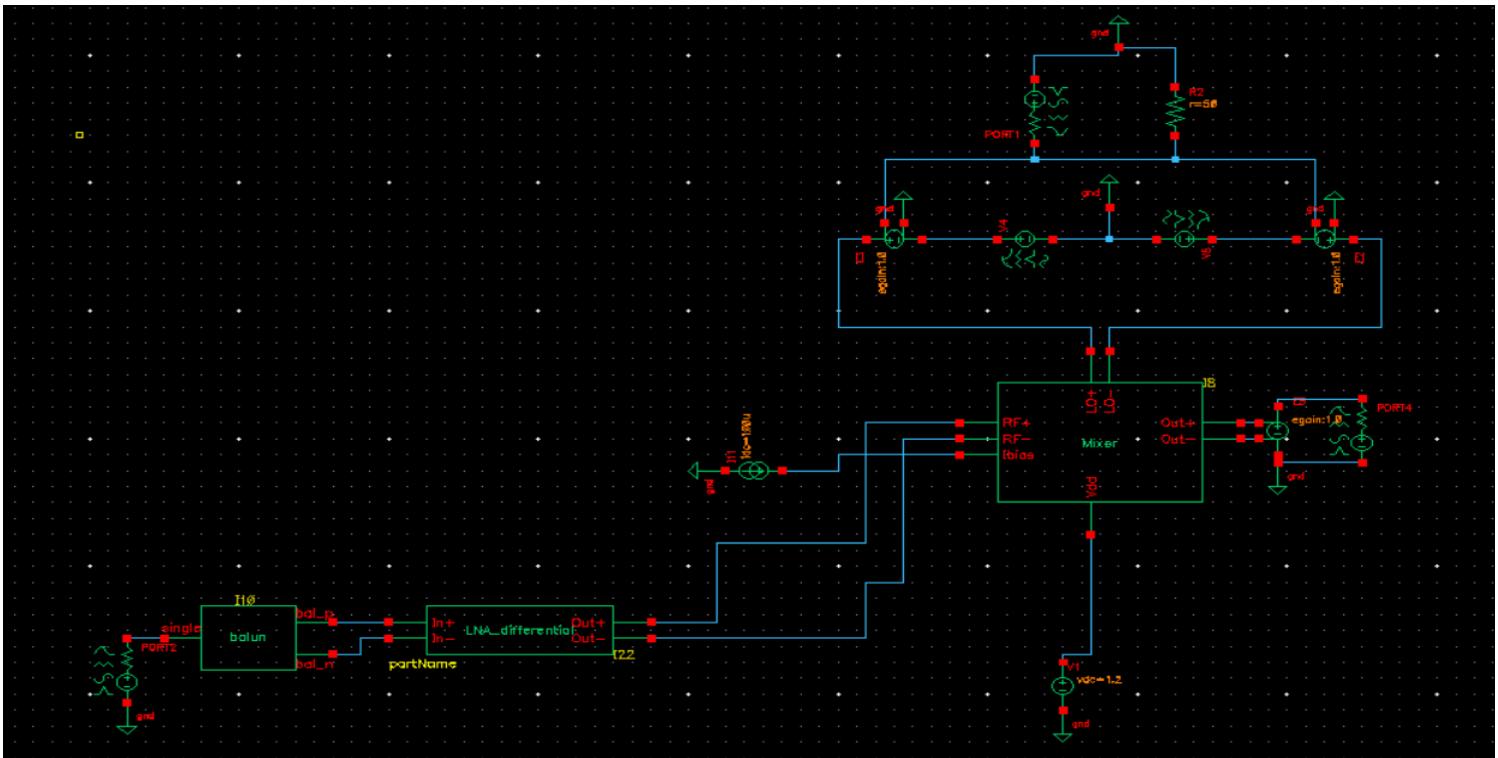


Mixer 3-dB Bandwidth
<put your 3dB BW plot here>

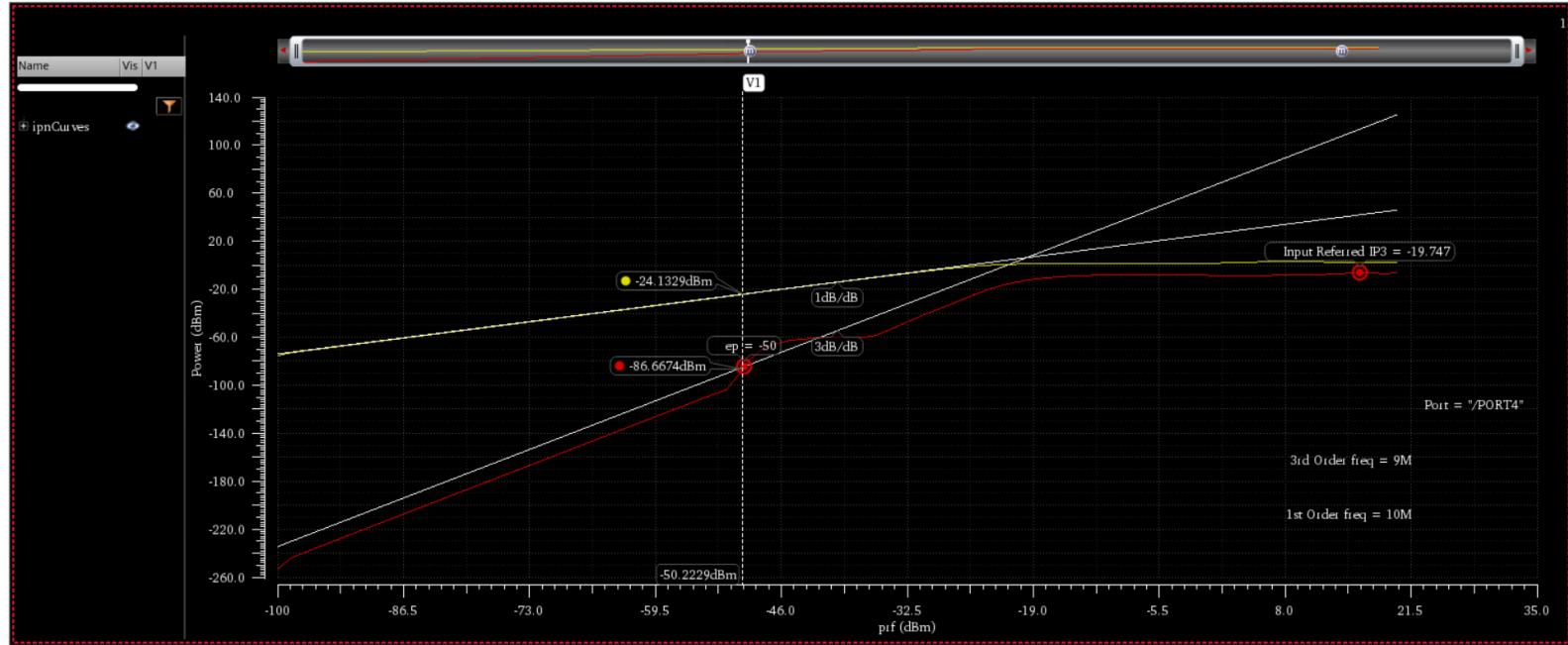
Mixer DC Power Consumption [Excluding Bias]



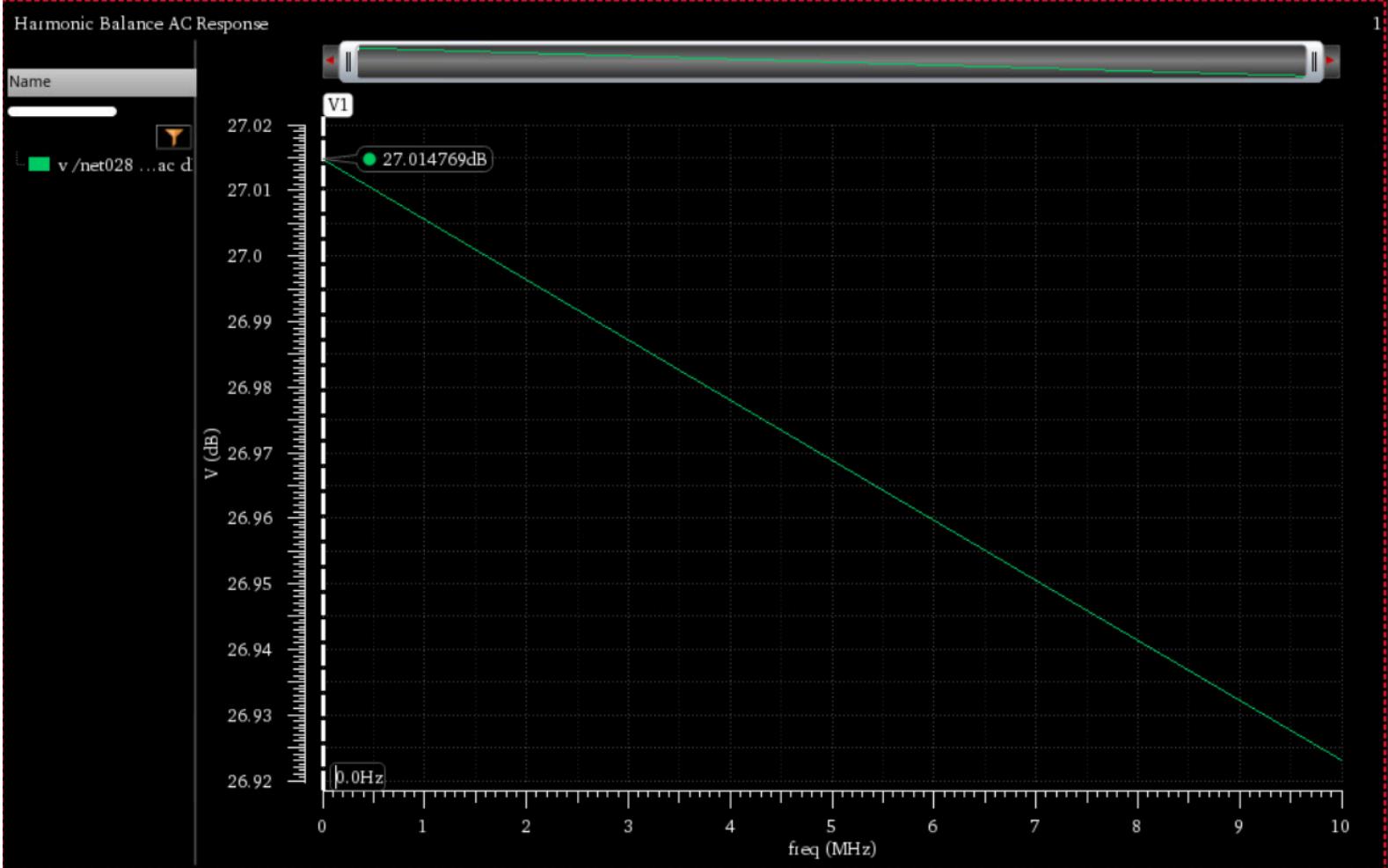
LNA + Mixer Testbench



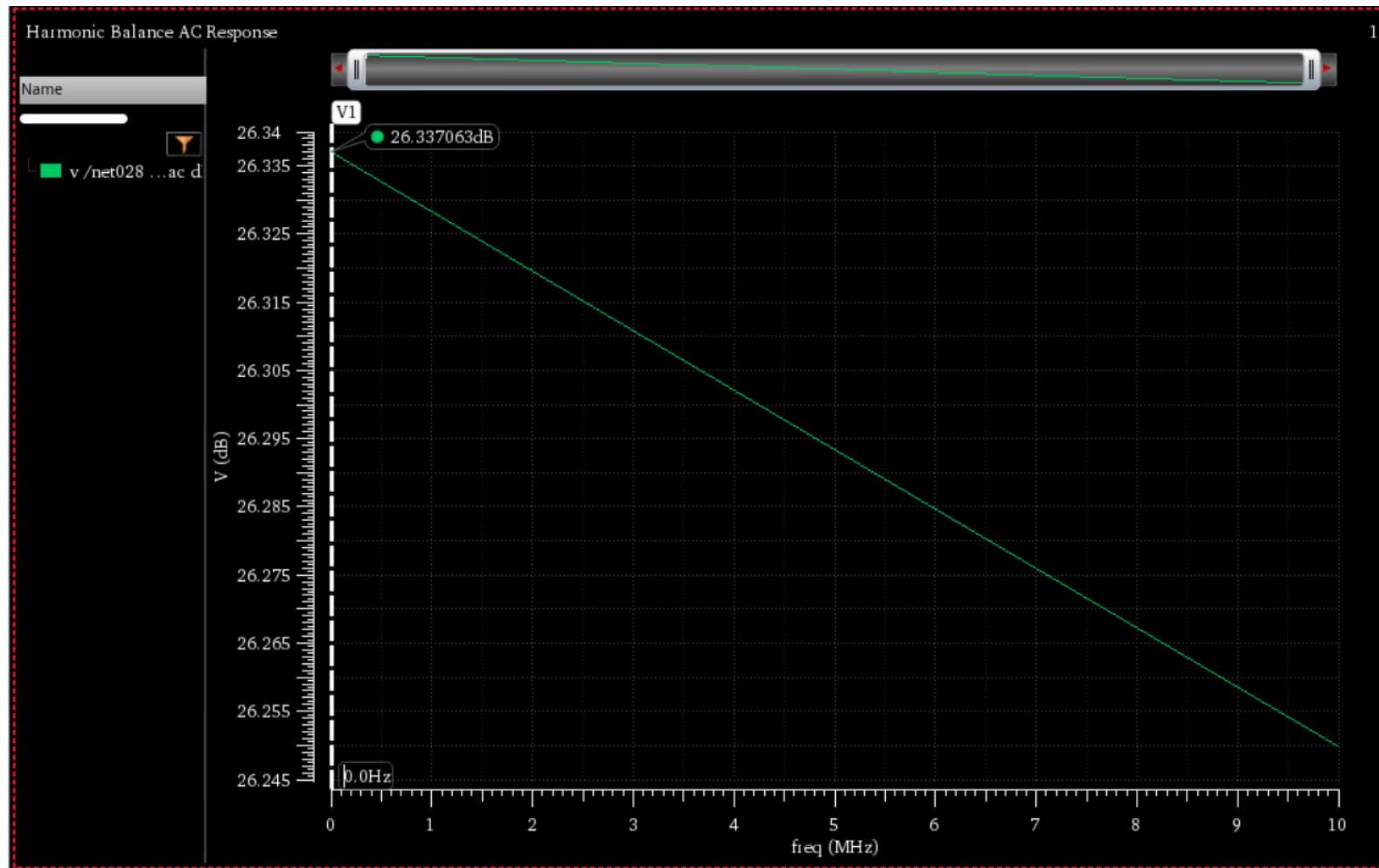
LNA + Mixer IIP3 Linearity



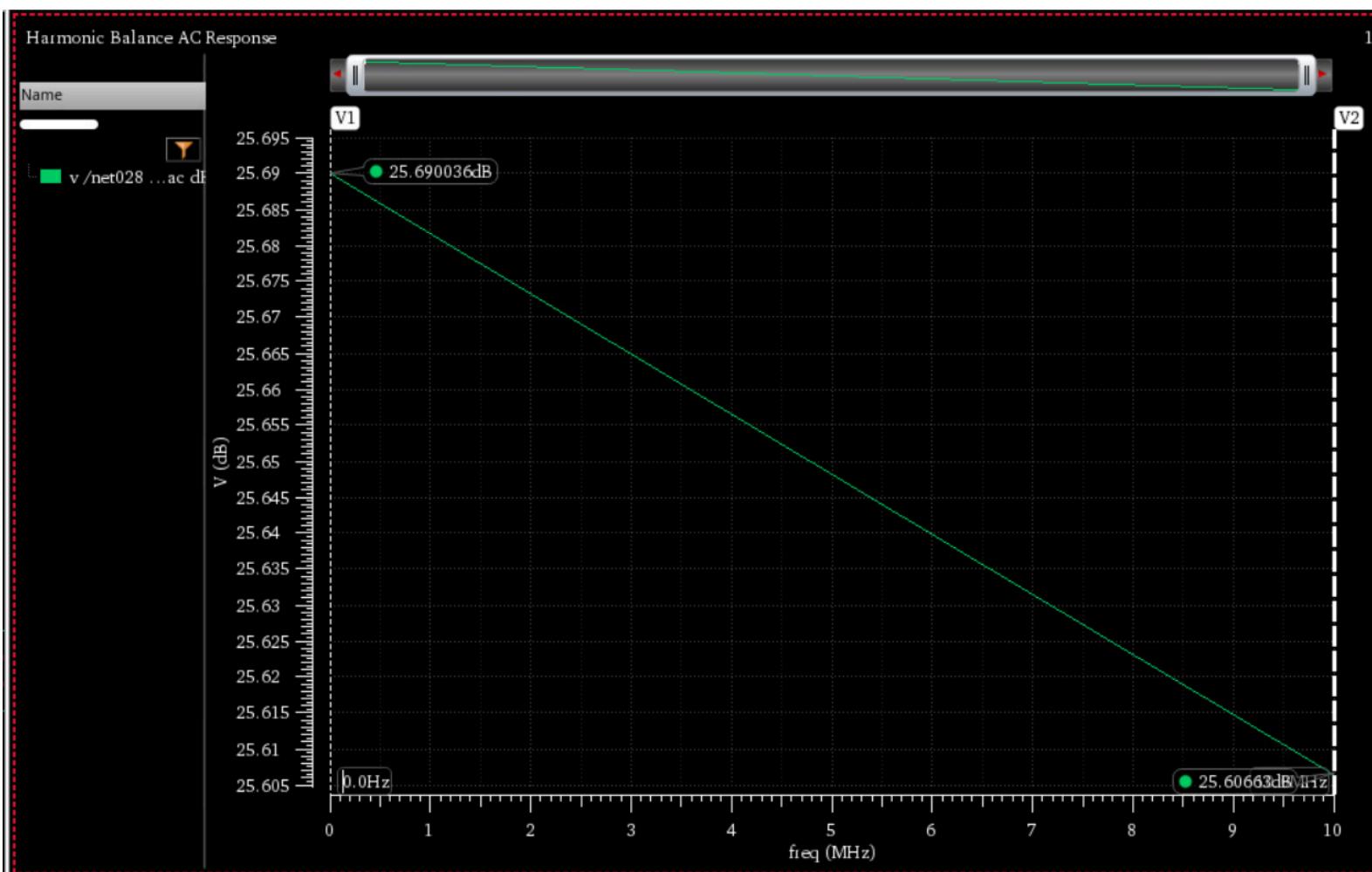
LNA + Mixer Conversion Gain at 5.17GHz



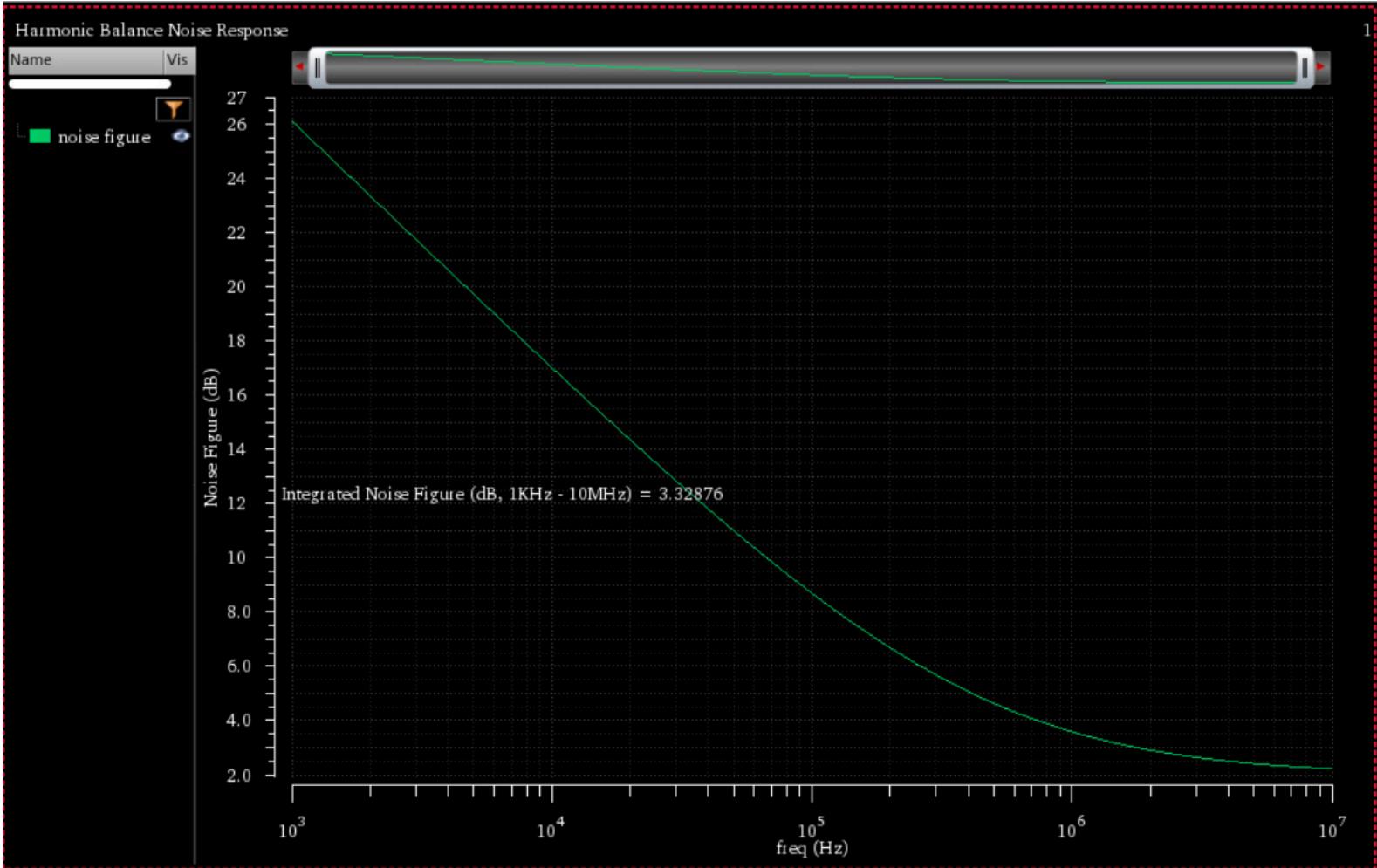
LNA + Mixer Conversion Gain at 5.245GHz



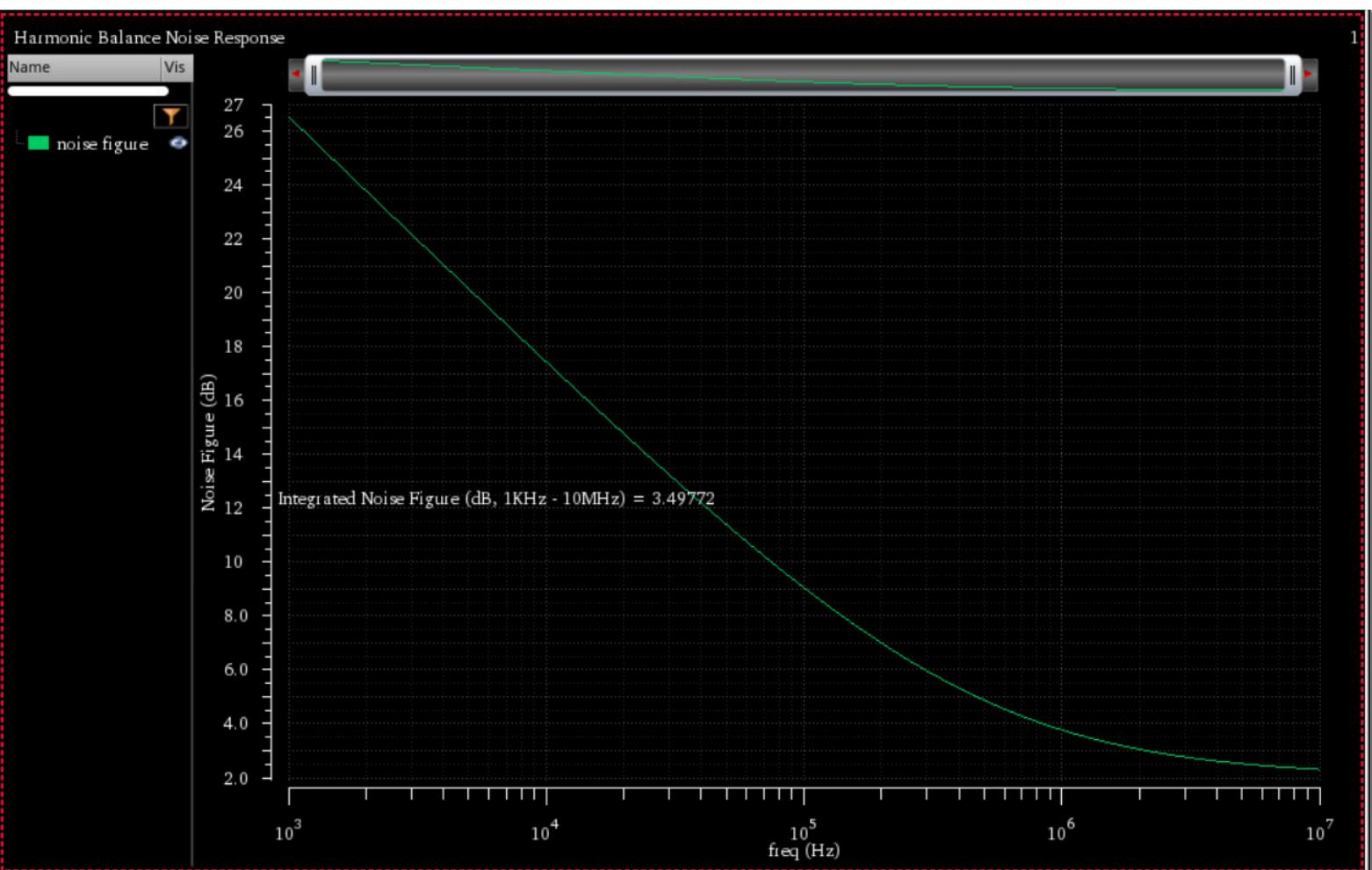
LNA + Mixer Conversion Gain at 5.32GHz



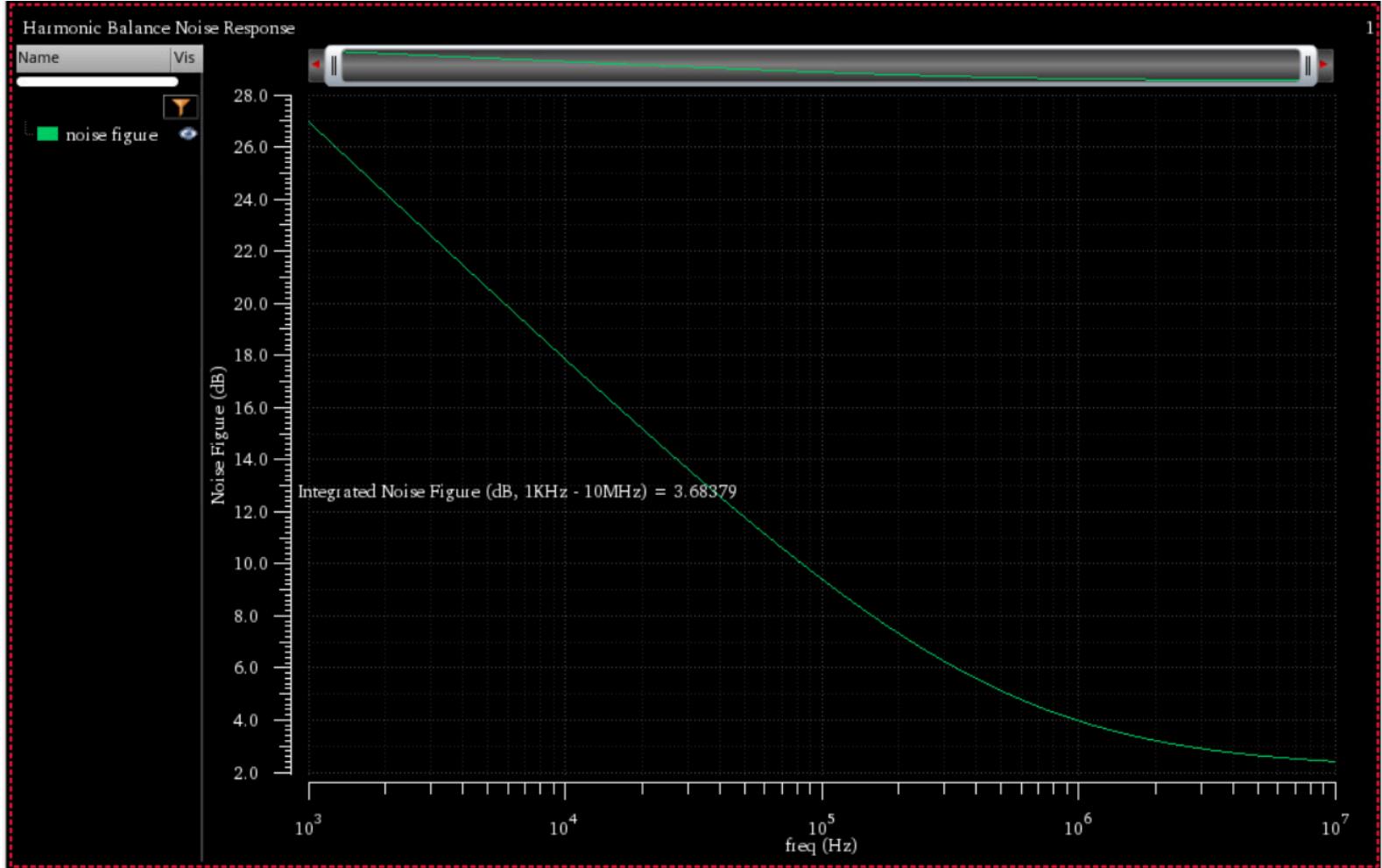
LNA + Mixer Noise Figure at 5.17GHz



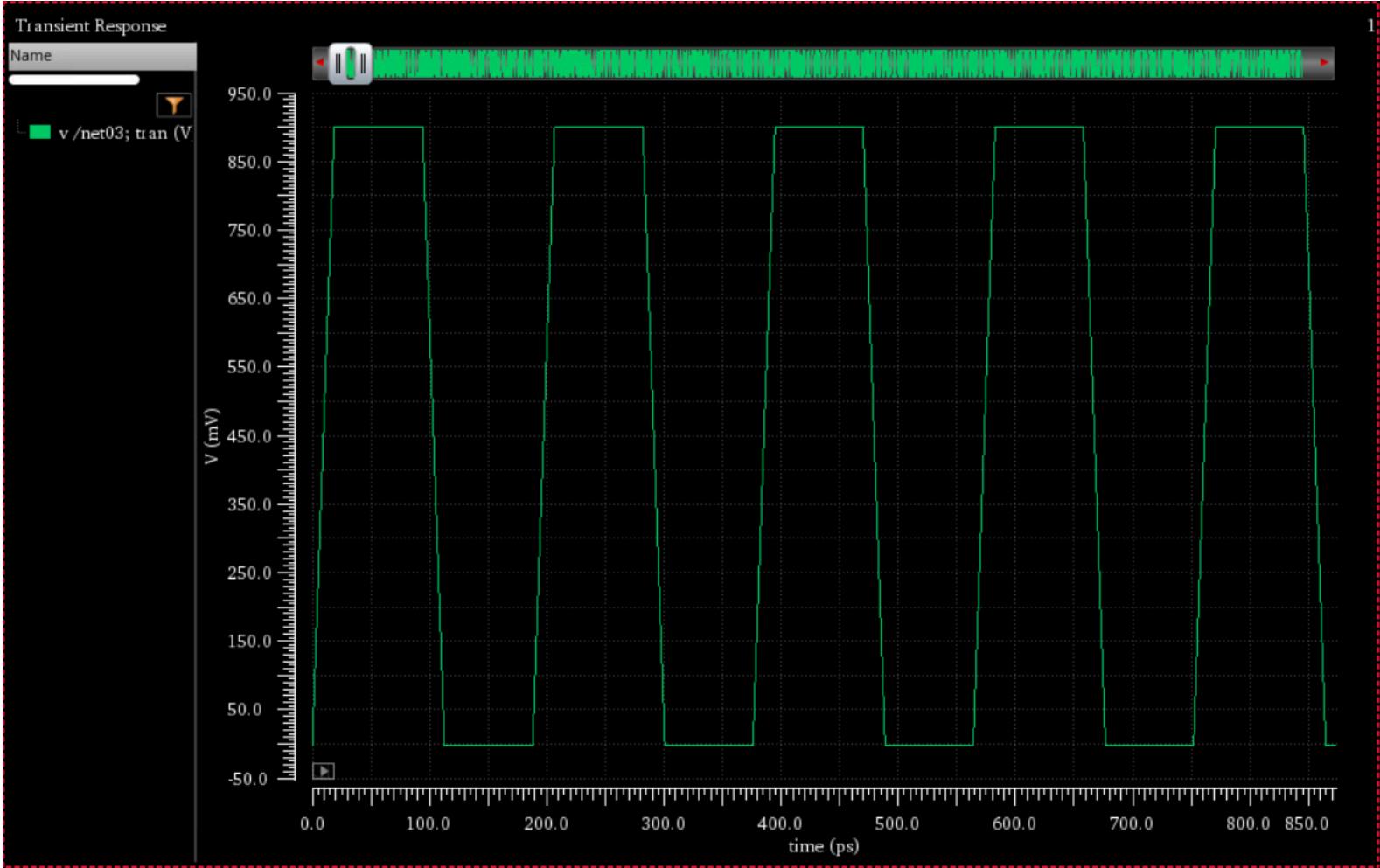
LNA + Mixer Noise Figure at 5.245GHz



LNA + Mixer Noise Figure at 5.32GHz



LO Waveform Characteristics



Characteristics taken are (for generalized manner, as f_{lo} varies for various analysis):

- Frequency: 5.32 GHz
- Time period: 190.6 ps
- Delay time: 0(for I Lo signal), 47.6 ps (for Q Lo signal)
- Pulse Width: 76.2 ps
- Rise/Fall Time: 19 ps

Calculations done for the Project

Gilbert Cell Mixer

i) Gain (Conversion) :-

$$g_m = 13m \quad I_{bias} = 100\mu A$$

$$R_L = 350 \quad I_{DSS} = 764\mu A$$

$$\text{Now, } G_{\text{Gain}} = \frac{2}{\pi} g_m R_L \text{ (formula)}$$

$$\Rightarrow G_{\text{c}} = 20 \log_{10} \left(\frac{2}{\pi} \times 13m \times 350 \right)$$

$$= 9.23 \text{ dB}$$

But ^{nearly} $\approx 7.2 \text{ dB}$ gain is observed.

ii) Noise ~~factor~~ figure (NF) :-

From lectures, we have :

$$\overline{V_{om}^2} = 8kT R_L \left[1 + 8 \frac{g_m R_L}{2} + \frac{8I_T R_L}{\pi V_{io}} \right]$$

$$F = \frac{SNR_{in}}{SNR_{out}} = 1 + \frac{\frac{\overline{V_{om}^2}}{(G_c)^2}}{4kTR_s}$$

$$\Rightarrow F = 1 + \frac{\frac{2\pi^2 k T}{g_m 4 k T R_s R_L}}{\left[1 + \frac{8g_m R_L}{2} + \frac{8I_T R_L}{\pi V_{io}} \right]}$$

$$\Rightarrow F = 1 + \frac{\frac{\pi^2}{2g_m^2 R_s R_L}}{\left[1 + \frac{8g_m R_L}{2} + \frac{8I_T R_L}{\pi V_{io}} \right]}$$

$$NF = 20 \log(F)$$

~~$$= 20 \log \left(1 + \frac{\pi^2}{2} \right)$$~~

$$F = 1 + \frac{\frac{\pi^2}{2(13m)^2 100\mu A \times 350}}{\left[1 + \frac{8(13m)(350)}{2} + \frac{8(764\mu A)(350)}{\pi(0.9)} \right]}$$

~~$$NF = 20 \log(F)$$~~

$$\approx 6.18 \text{ dB}$$

Simulated value was 6.9 dB

LNA Cascade calc.

i) ~~NF~~ at $f_{L0} = 5.17 \text{ GHz}$

$$F = F_1 + \frac{F_2 - 1}{G_1} \rightarrow \text{LNA gain}$$

$$= 10^{\frac{1.55}{10}} + \frac{10^{\frac{6.96}{10}} - 1}{10^{\frac{32.7}{20}}}$$

$$= 1.81 \text{ dB}$$

ii) NF at $f_{L0} = 5.245 \text{ GHz}$

$$\cancel{F} = 10^{\frac{1.549}{10}} + \frac{10^{\frac{6.910}{10}} - 1}{10^{\frac{34.47}{20}}}$$

$$NF = 1.759 \text{ dB}$$

(iii) NF at $f_{L_o} = 5.32G$

$$F = \cancel{10}^{1.55} \cdot 10^{\frac{1.93}{10}} + \frac{10^{\frac{1.93}{10}} - 1}{10^{\frac{34.02}{20}}}$$

$$NF = 1.7816 \text{ dB}$$

Procedure adopted for the Project

- I followed the instructions given in the Help document and set up the analyses
- I varied the parameters based on my intuition and the knowledge about the dependence of the Gain, Nf, etc on the parameters I am setting.
- When I got the necessary specifications except IIP3 point, I varied the parameters by trial and error and finally got the IIP3 point under -5db even though I had to compromise on Gain a little bit.
- After the Standalone mixer was done, I cascaded it with the LNA and did my analyses. I also hand calculated the expected values and compared them with my simulated ones.

Path to the Project Files

- Schematic: `home/ee21b103/cadence_project/Mixer`
- Testbench for mixer gain, NF, IIP points: `home/ee21b103/cadence_project/Mixer_Testbench`
- Testbench for LNA+Mixer gain, NF, IIP points: `home/ee21b103/cadence_project/Mixer_testbench2`