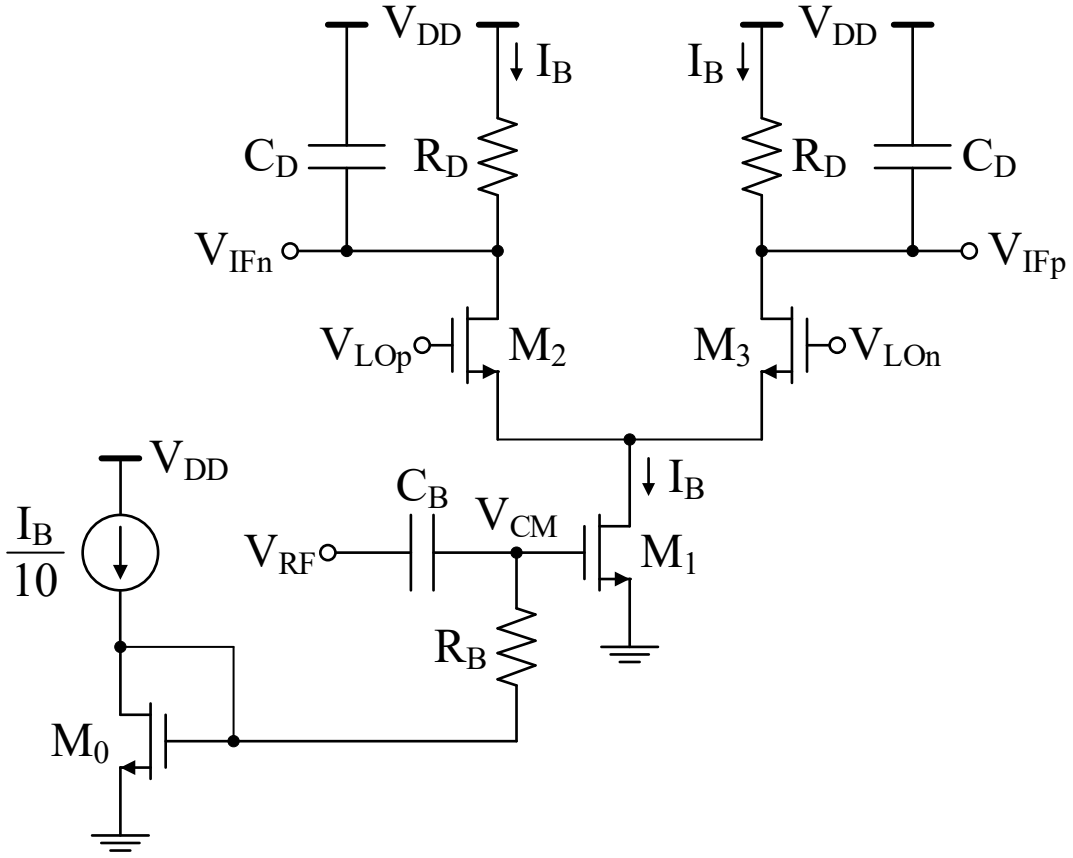
Circuits and Systems for Radio Frequency

Single Balanced Mixer Simulation

2025/2026

Single balanced mixer – Design example and testbench

- Only one branch is active at any given time
- Simulate circuit without and with capacitor C_D



Design:

- nch_lvt
- V_{DD} = 1.2 V and V_{CM} = 0.475 V
- W_F = Width per finger and W_T = Total width

	W_F [µm]	W_T [µm]	Fingers	L [µm]
M_0	0.44	3.52	8	0.06
M_1	3.88	31.04	8	0.06
$M_{2,3}$	2.10	4.20	2	0.06

I_B [mA]	R_D [kΩ]	R_B [kΩ]	C_B [pF]	C_D [pF]
1.0	0.5	10.0	1.0	50.0

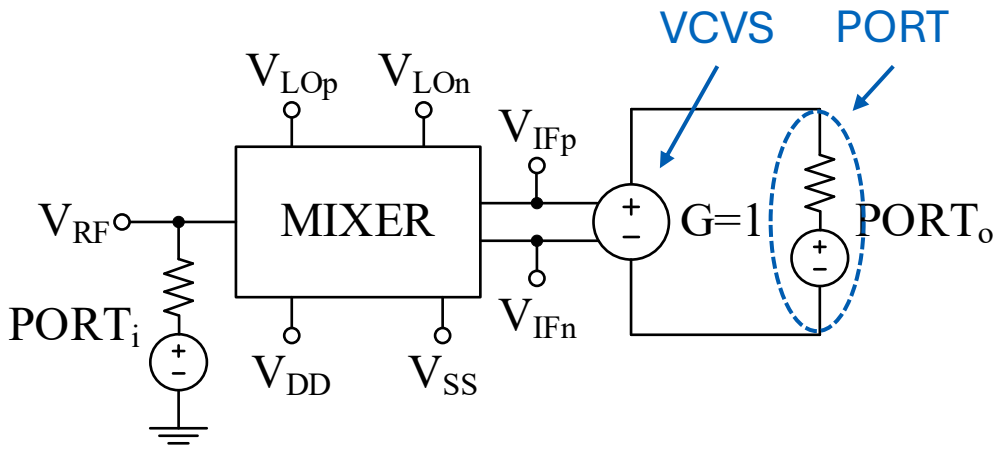
f_{RF} [MHz]	f_{LO} [MHz]	V_{amp} [dBm]
90.0~99.0	100.0	-30

Single balanced mixer – Design example and testbench

Procedure for PSS only simulations:

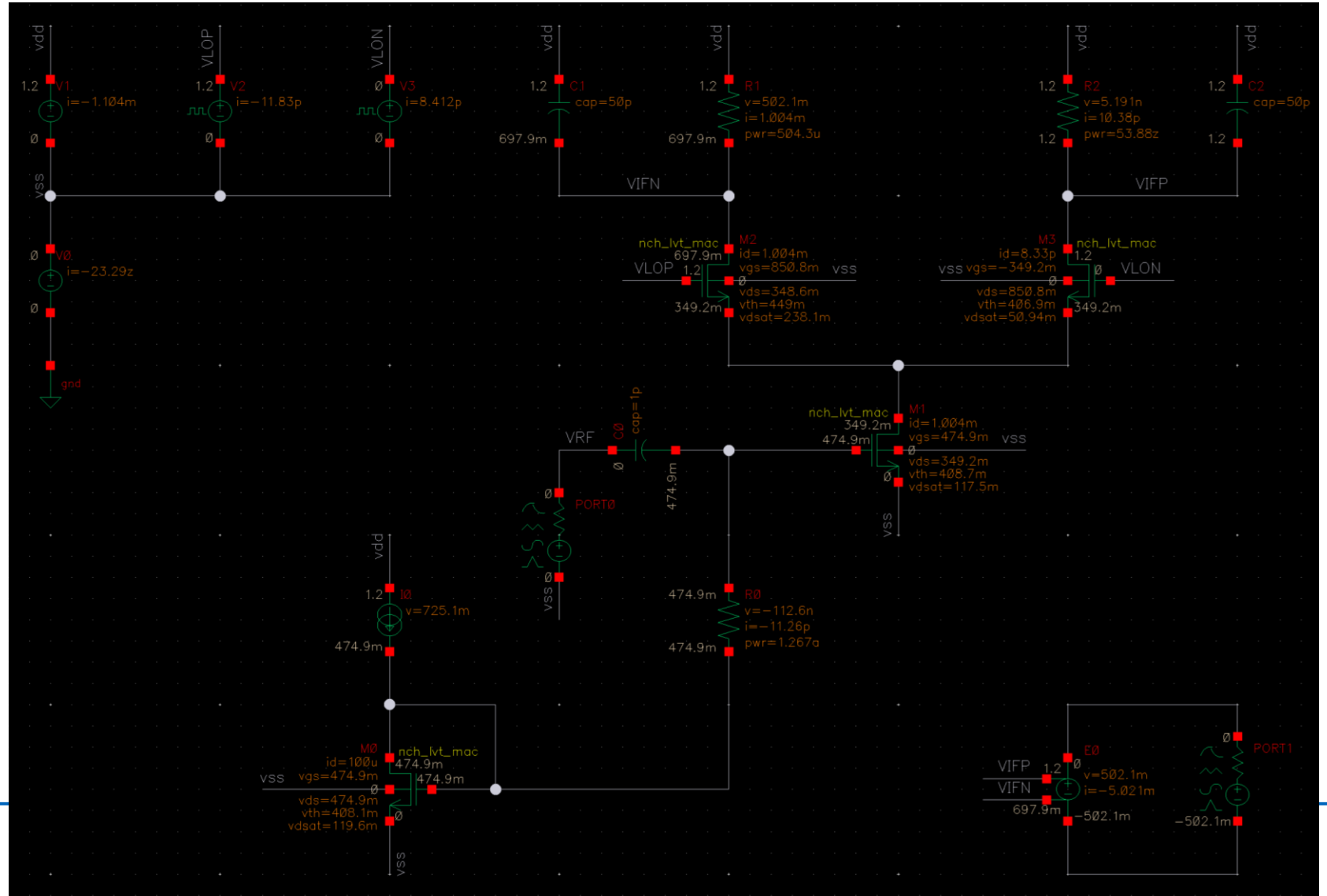
- Input port ($PORT_i$) – Simulate circuit for different port resistances (50 and 1000 Ω)
  - Define port as a sine signal with a given frequency and amplitude
- Output port ($PORT_o$) with 100 Ω

- **PSS simulation:**
  - Beat frequency = f_{LO}- f_{RF}
  - Number of harmonics = 100

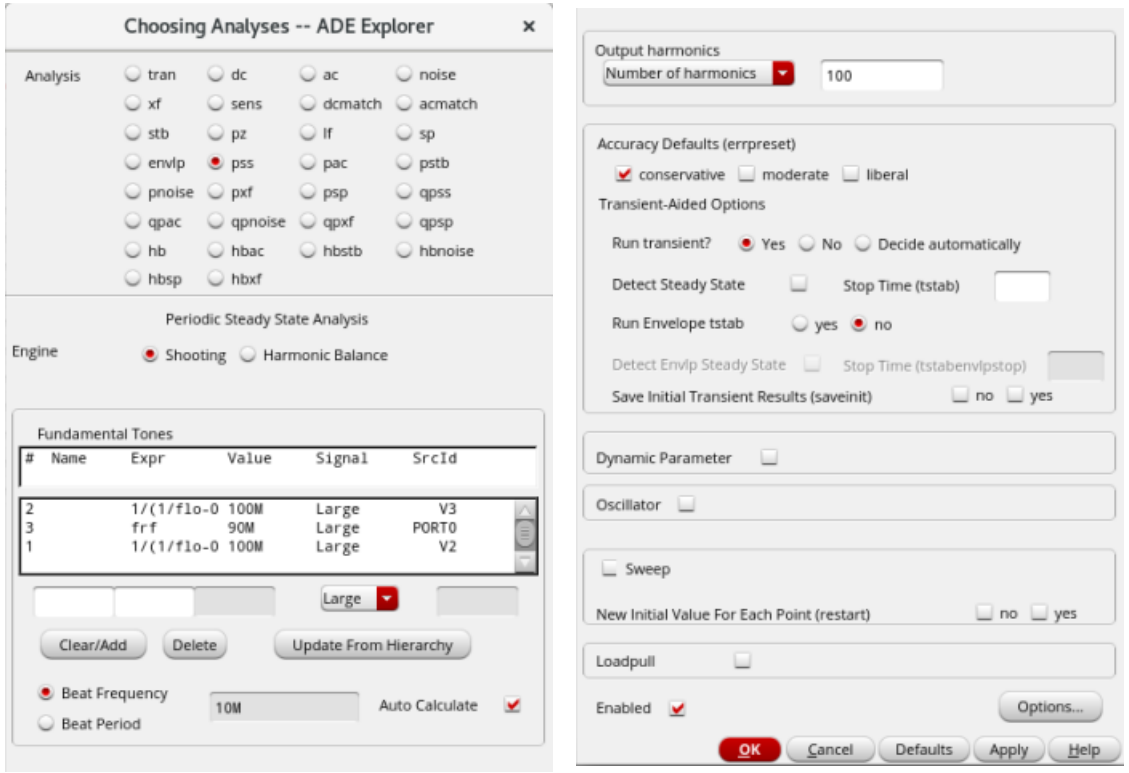


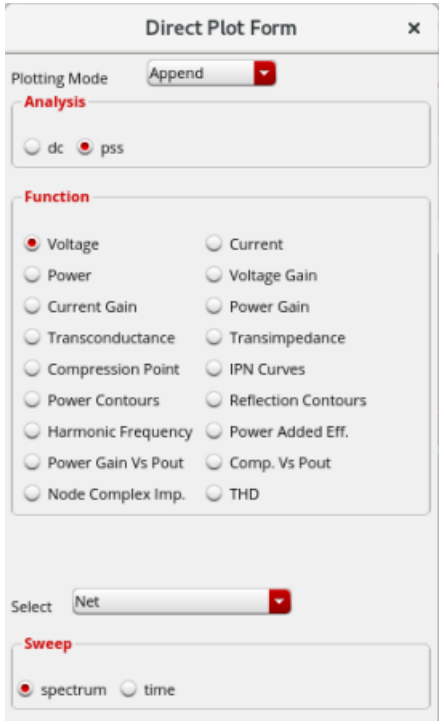
Single balanced mixer – Flat schematic example

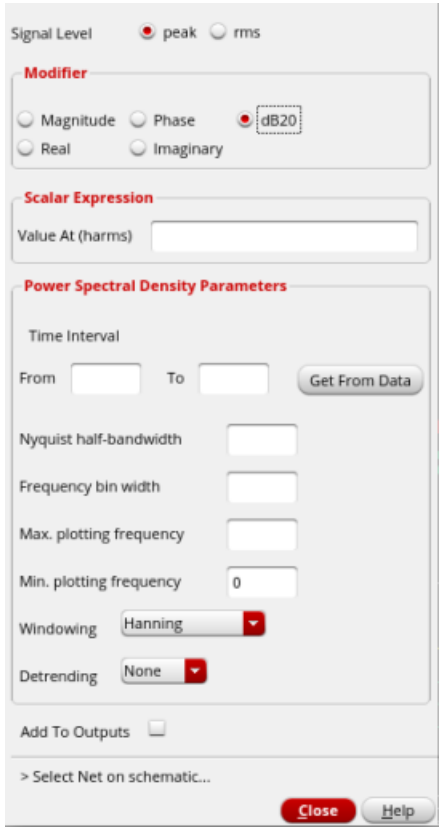
- Check PFR to make sure design is correct



Simulation window/result plotting for PSS only simulation



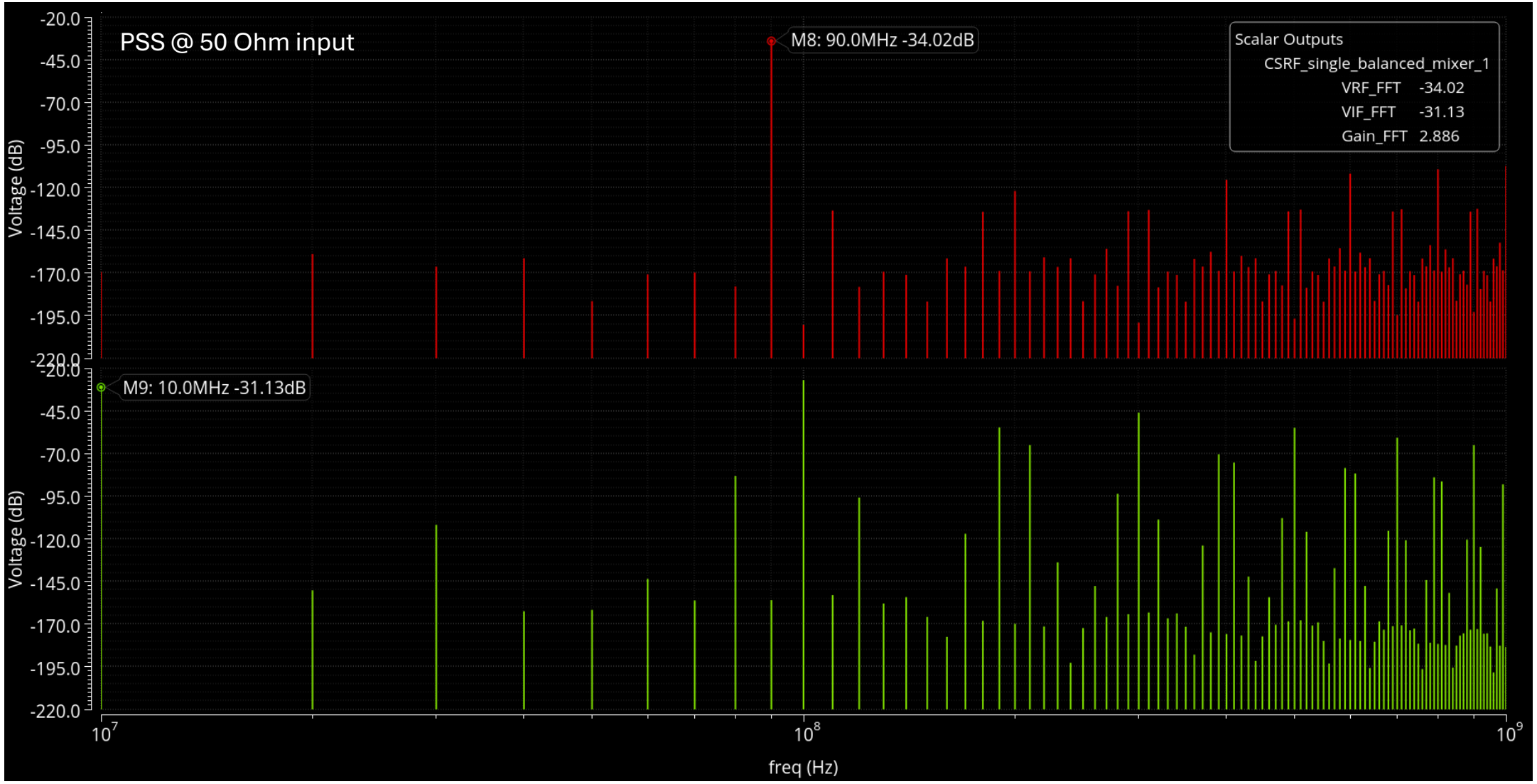




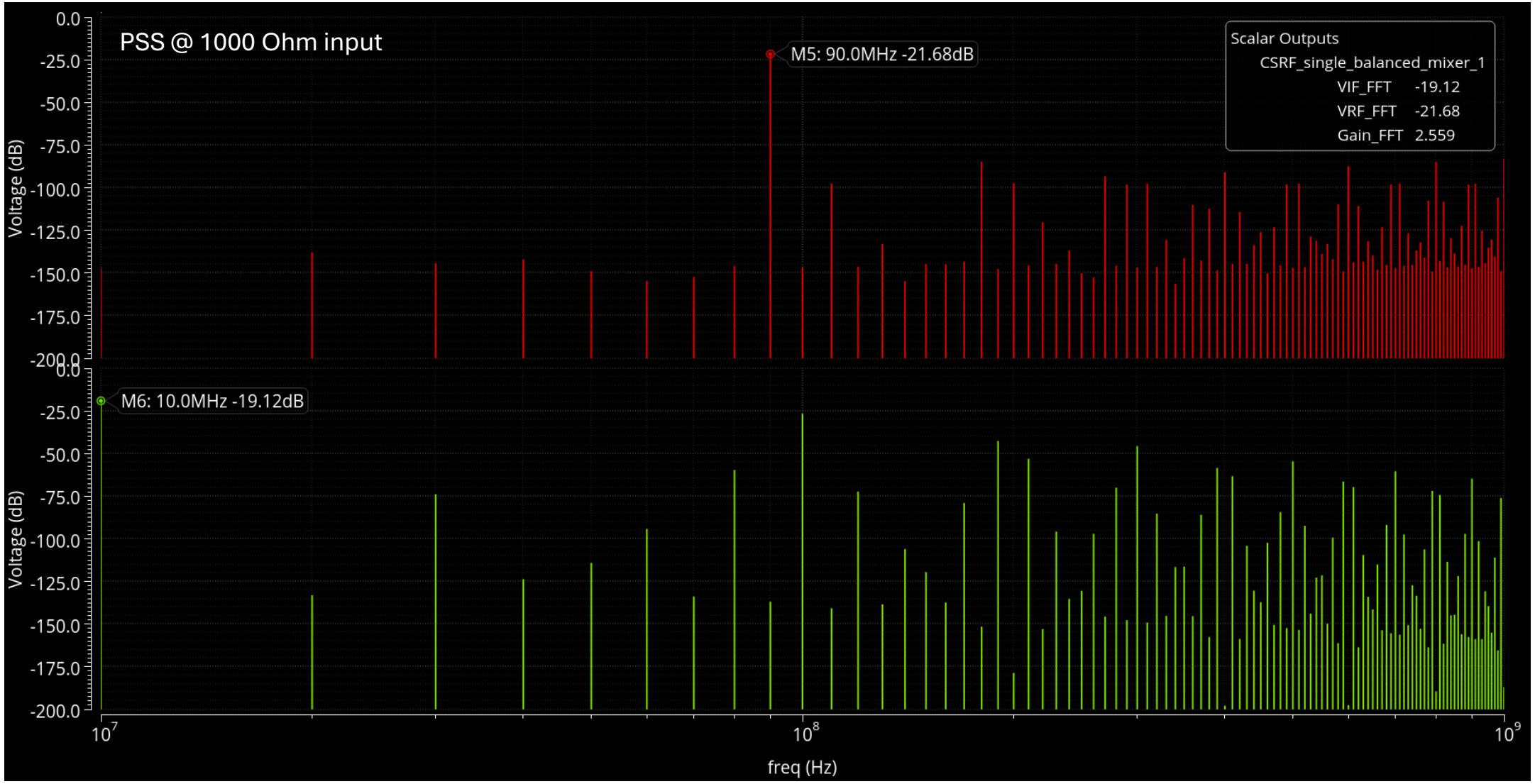
PSS simulation configurations

Direct plot configurations

Single balanced mixer – Simulation results (PSS)



Single balanced mixer – Simulation results (PSS)

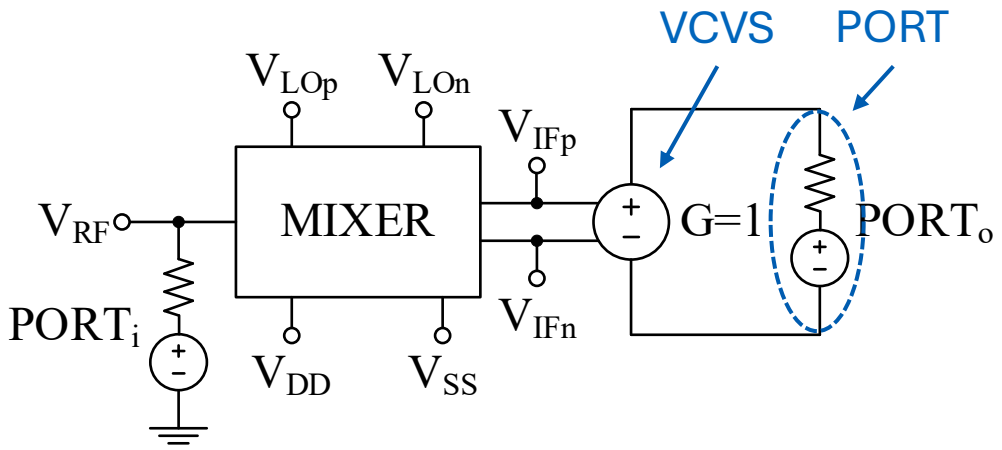


Single balanced mixer – Design example and testbench

Procedure for PSS+(PAC/PNOISE) simulations:

- Input port ($PORT_i$) – Simulate circuit for different port resistances (50 and 1000 Ω) and PAC magnitude = 1
  - For frequency simulations input port must be configured to a DC source
- Output port ($PORT_o$) with 100 Ω

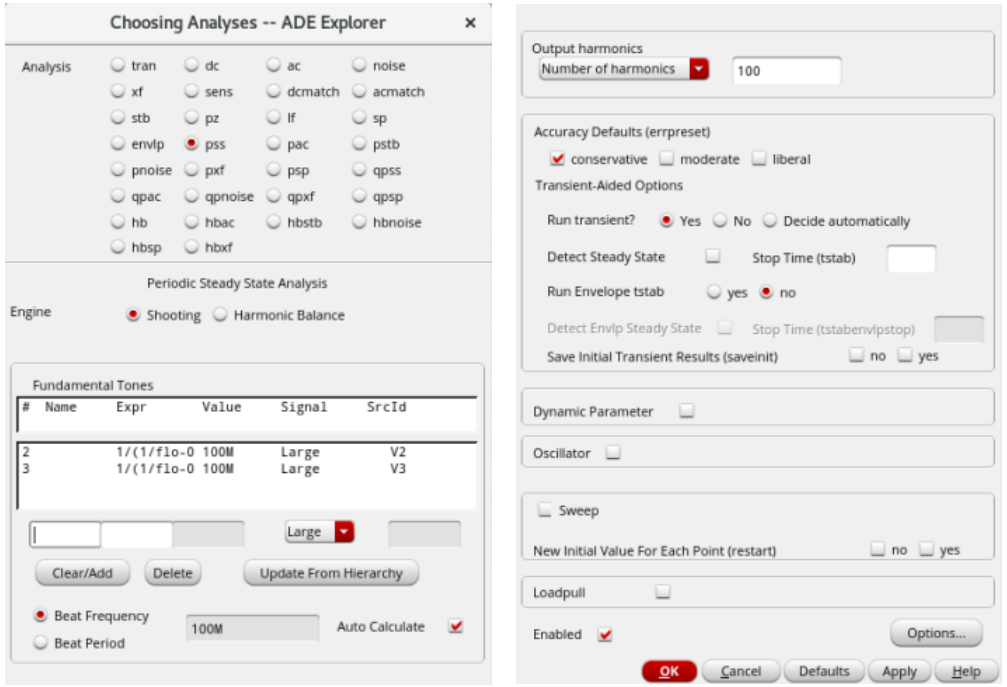
- **PSS simulation:**
  - Beat frequency = f_{LO}
  - Number of harmonics = 100

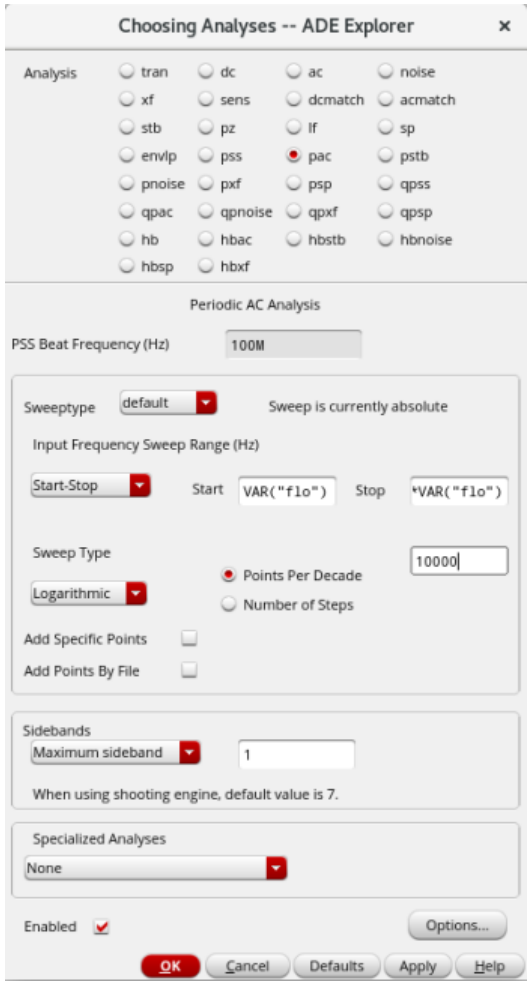


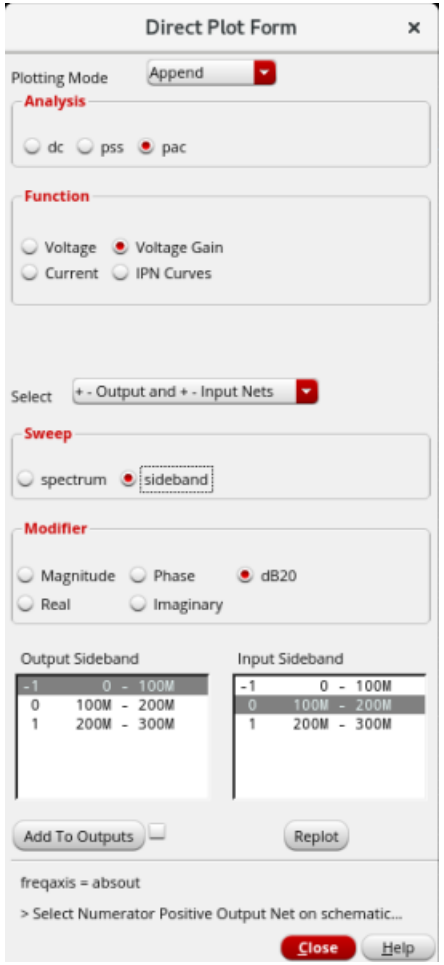
- **PAC simulation for conversion gain simulation:**
  - Start Frequency = f_{LO}
  - Stop Frequency = $2 \times f_{LO}$
  - Maximum sidebands = 1
  - Use a high number of points (>1000)
  - To plot, select “Voltage Gain”, and the “sideband” sweep option with output sideband = -1 and input = 0

Important note: The voltage gain option is necessary because, even with PAC magnitude = 1, the input magnitude is dependent on the circuits input impedance

Simulation window/result plotting for PSS+PAC simulation



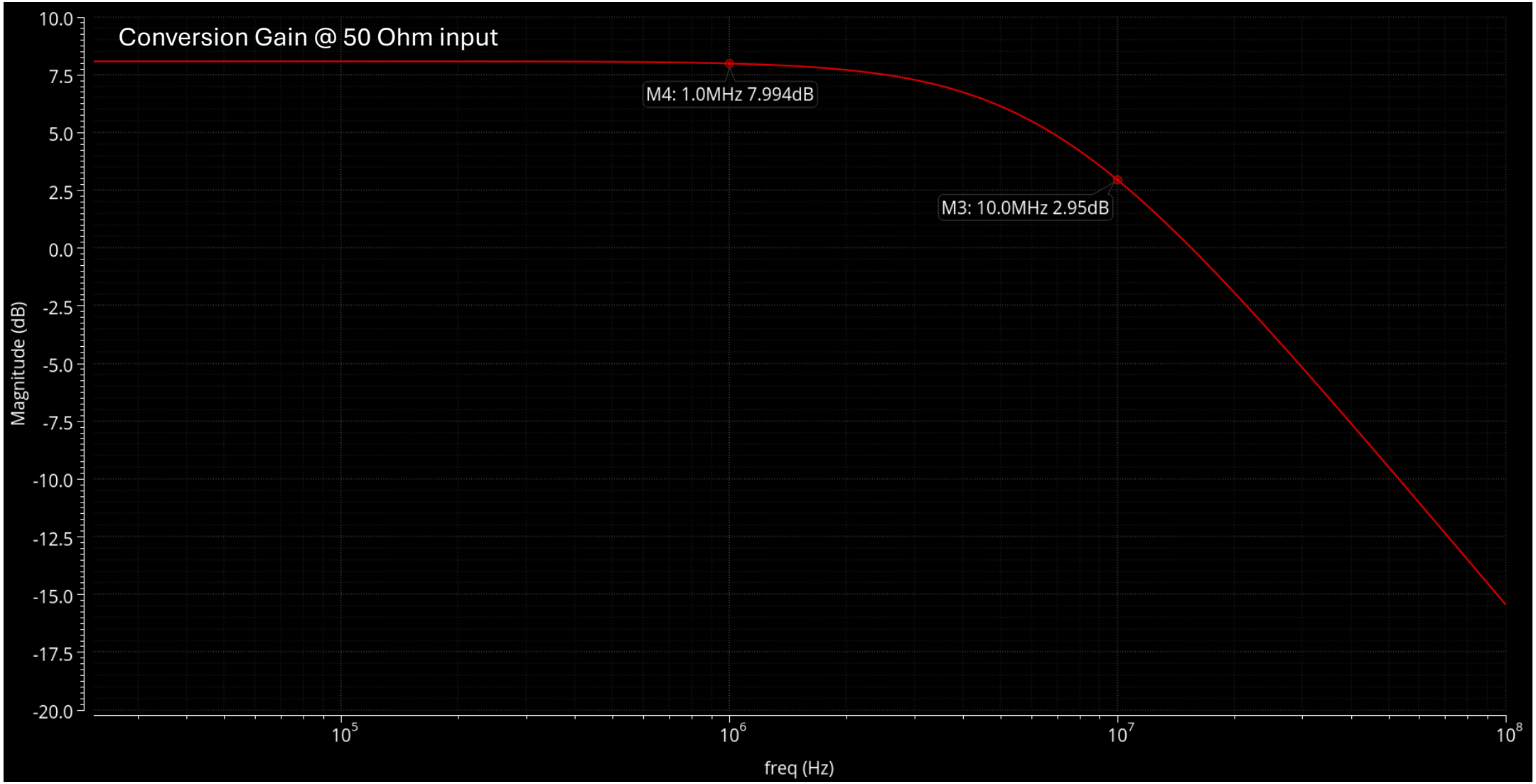




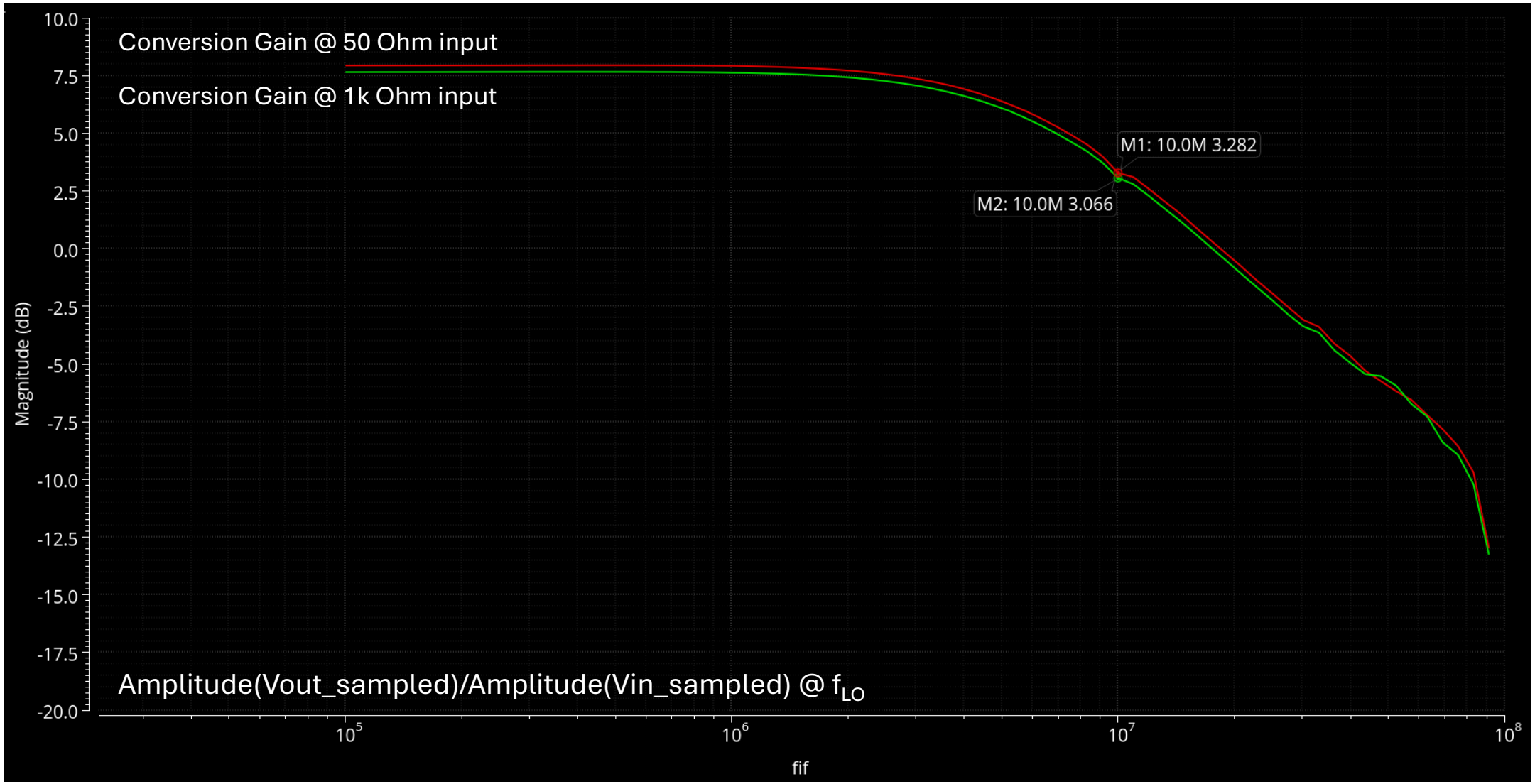
PSS+PAC simulation configurations

Direct plot configurations

Single balanced mixer – Simulation results (PSS+PAC)



Single balanced mixer – Simulation results
(obtained from a transient simulation)



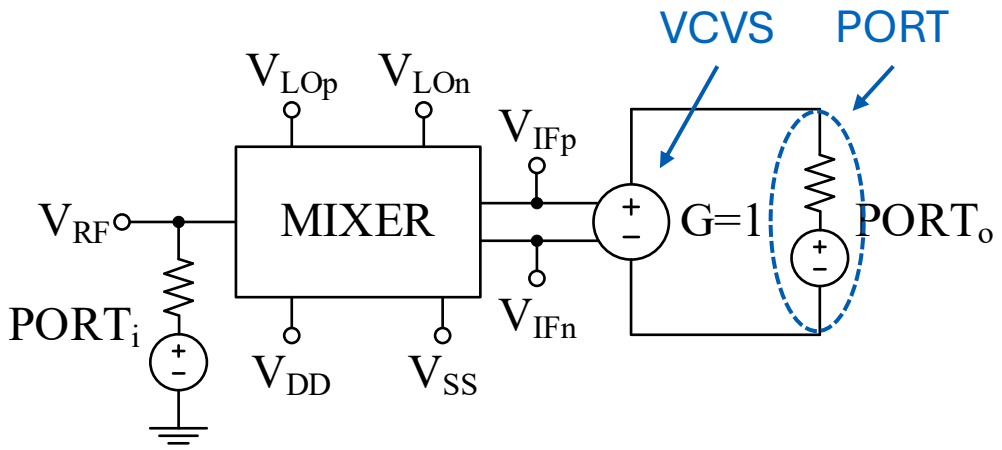
Single balanced mixer – Design example and testbench

Procedure for PSS+(PAC/PNOISE) simulations:

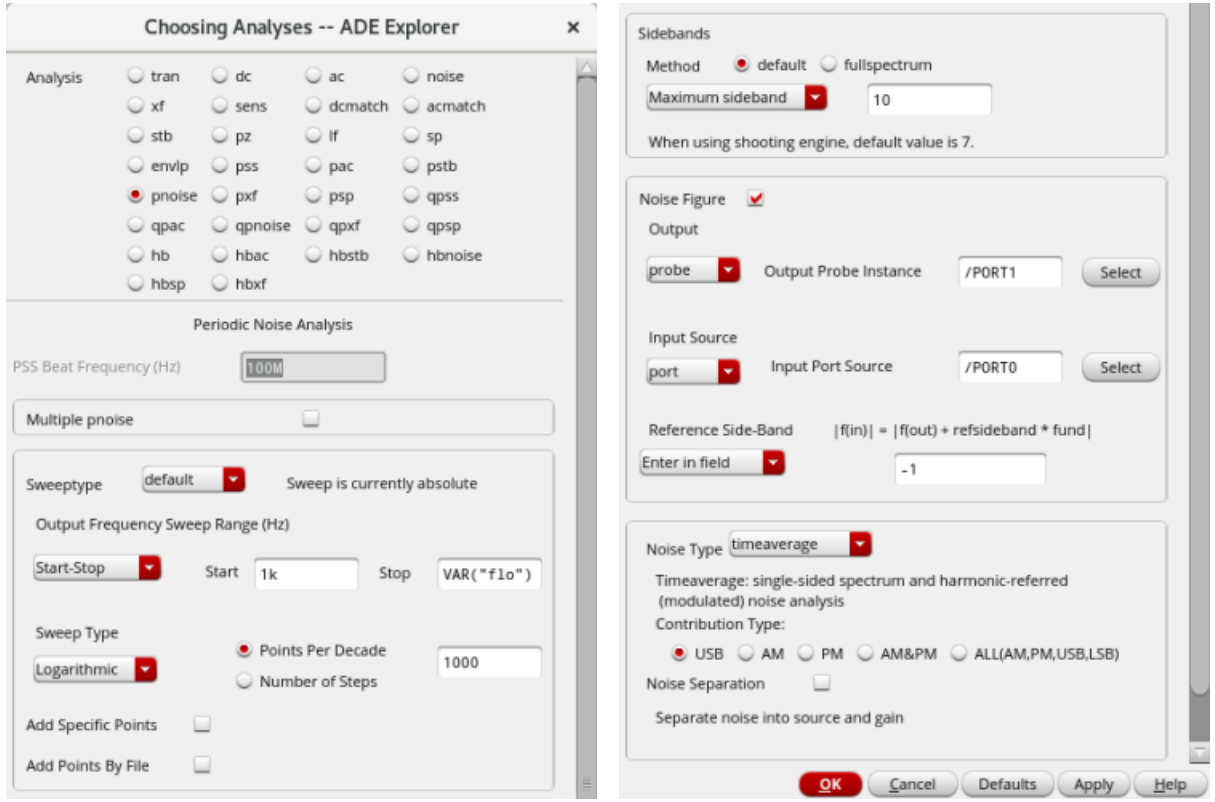
- Input port ($PORT_i$) – Simulate circuit for different port resistances (50 and 1000 Ω) and PAC magnitude = 1
  - For frequency simulations input port must be configured to a DC source
- Output port ($PORT_o$) with 100 Ω

- **PSS simulation:**
  - Beat frequency = f_{LO}
  - Number of harmonics = 100

- **PNOISE simulation for noise figure simulation:**
  - Start Frequency = 1
  - Stop Frequency = f_{LO}
  - Maximum sidebands = 10
  - Reference sideband = -1
  - Select output and input ports

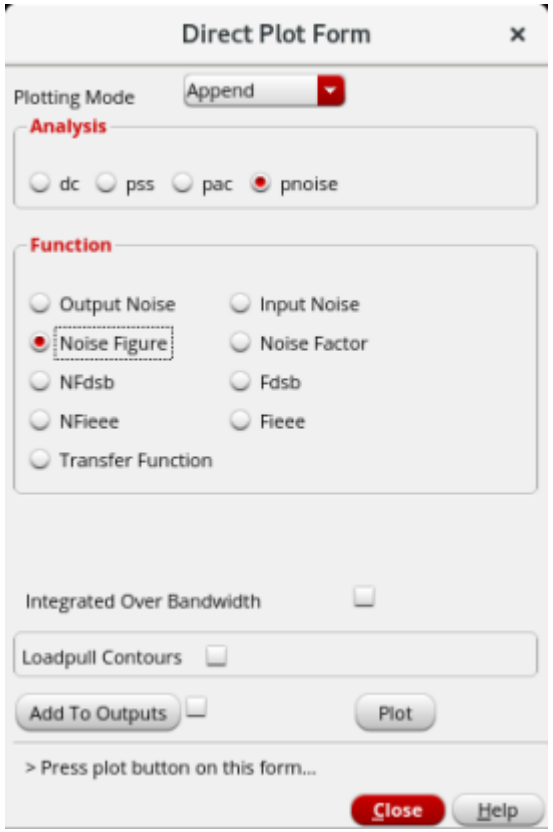


Simulation window/result plotting for PSS+PNOISE simulation



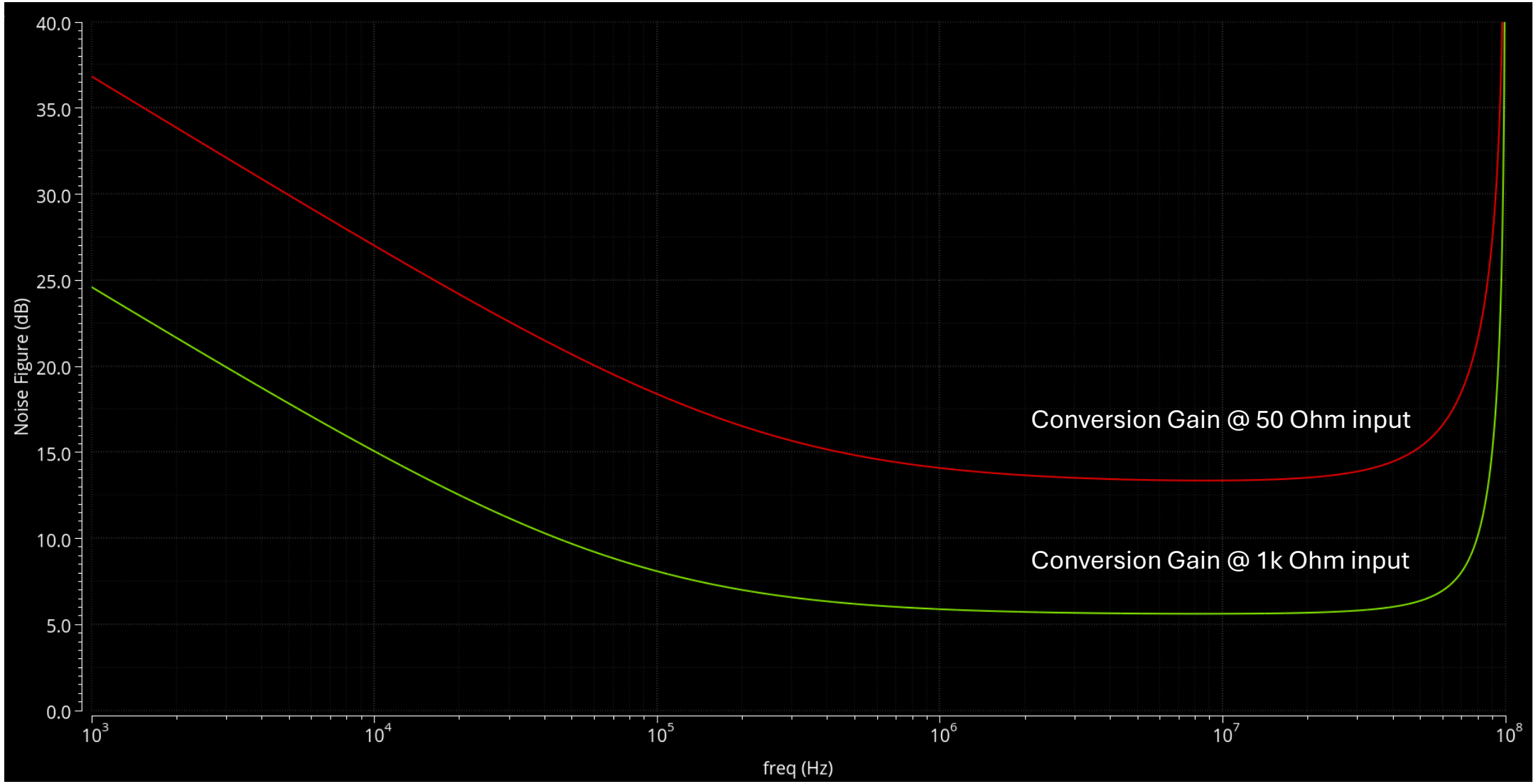
PNOISE simulation configuration

(see slide 9 for PSS simulation configuration)



Direct plot configurations

Single balanced mixer – Simulation results (PSS+PNOISE)

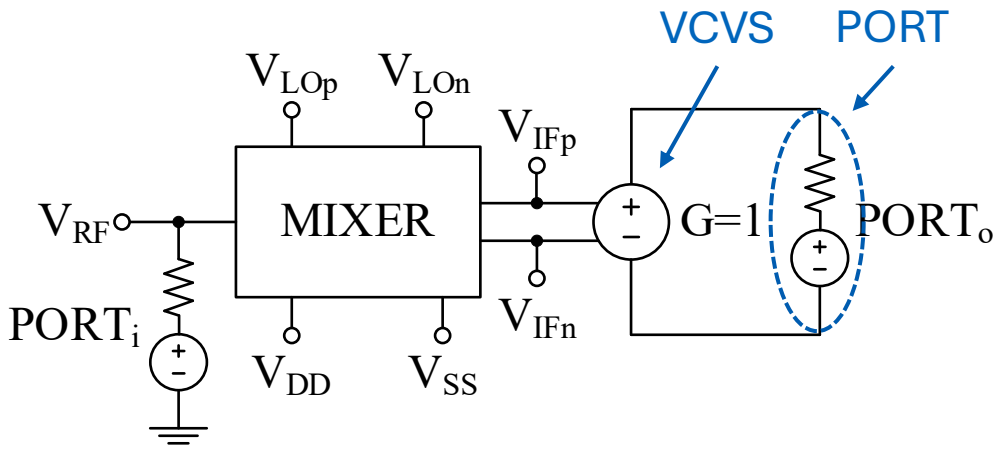


Single balanced mixer – Design example and testbench

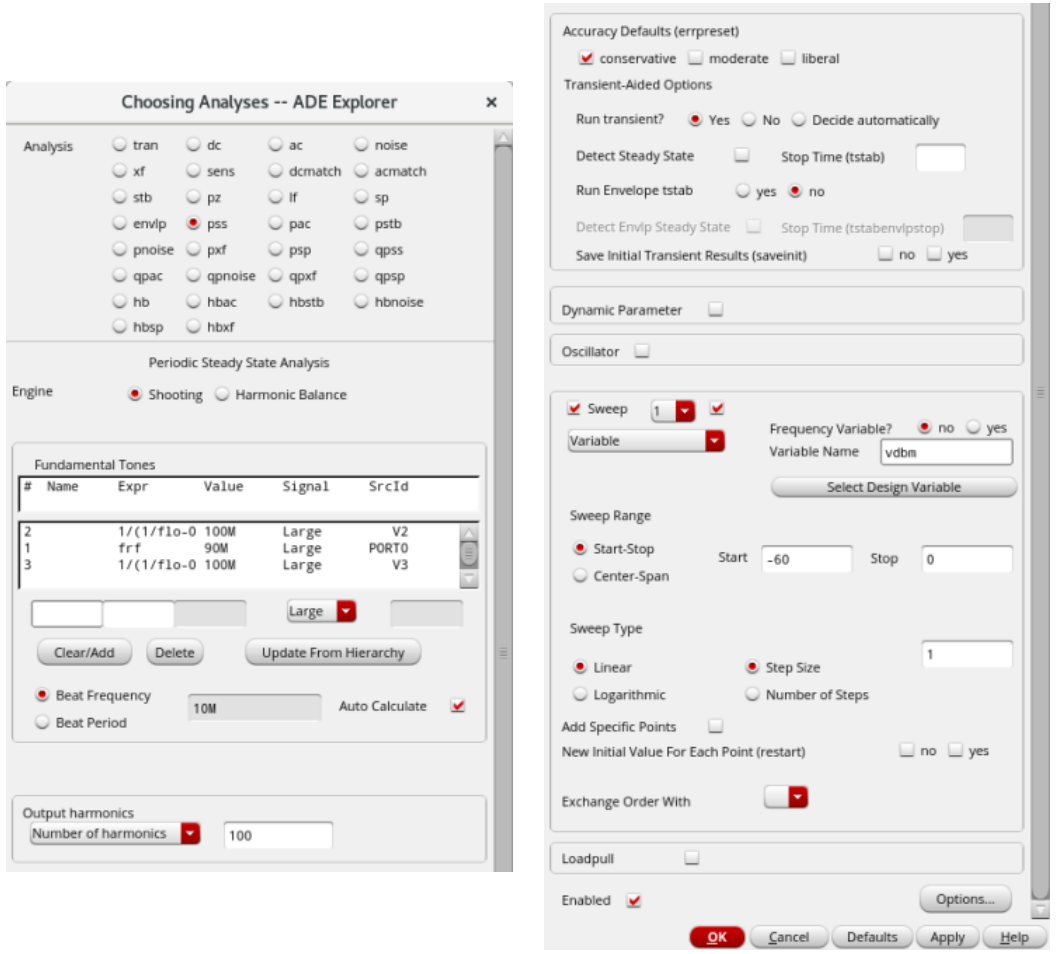
Procedure for 1dB compression point simulation using PSS:

- Input port ($PORT_i$) – Simulate circuit for different port resistances (50 and 1000 Ω)
  - Define port as a sine signal with a given frequency and amplitude
- Output port ($PORT_o$) with 100 Ω

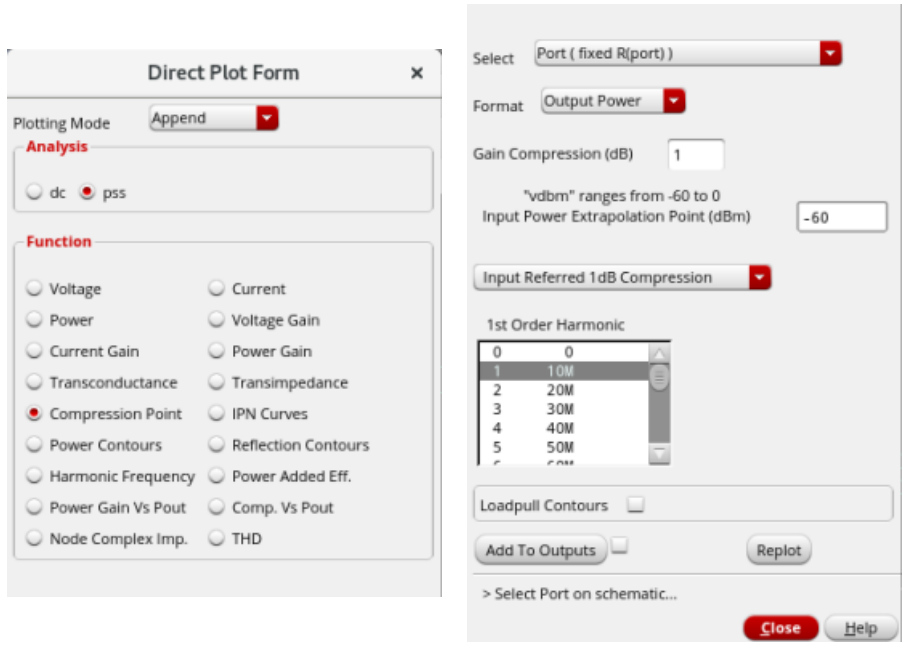
- **PSS simulation:**
  - Beat frequency = f_{LO}- f_{RF}
  - Number of harmonics = 100
  - Activate the sweep box
  - Define design variable that controls input amplitude
  - Define sweep range from -60 to 0 and define step
  - To plot select “Compression Point”, an “Input Power Extrapolation Point” inside the linear region and the f_{IF} frequency in the “1st Order Harmonic” table



Simulation window/result plotting for PSS only simulation

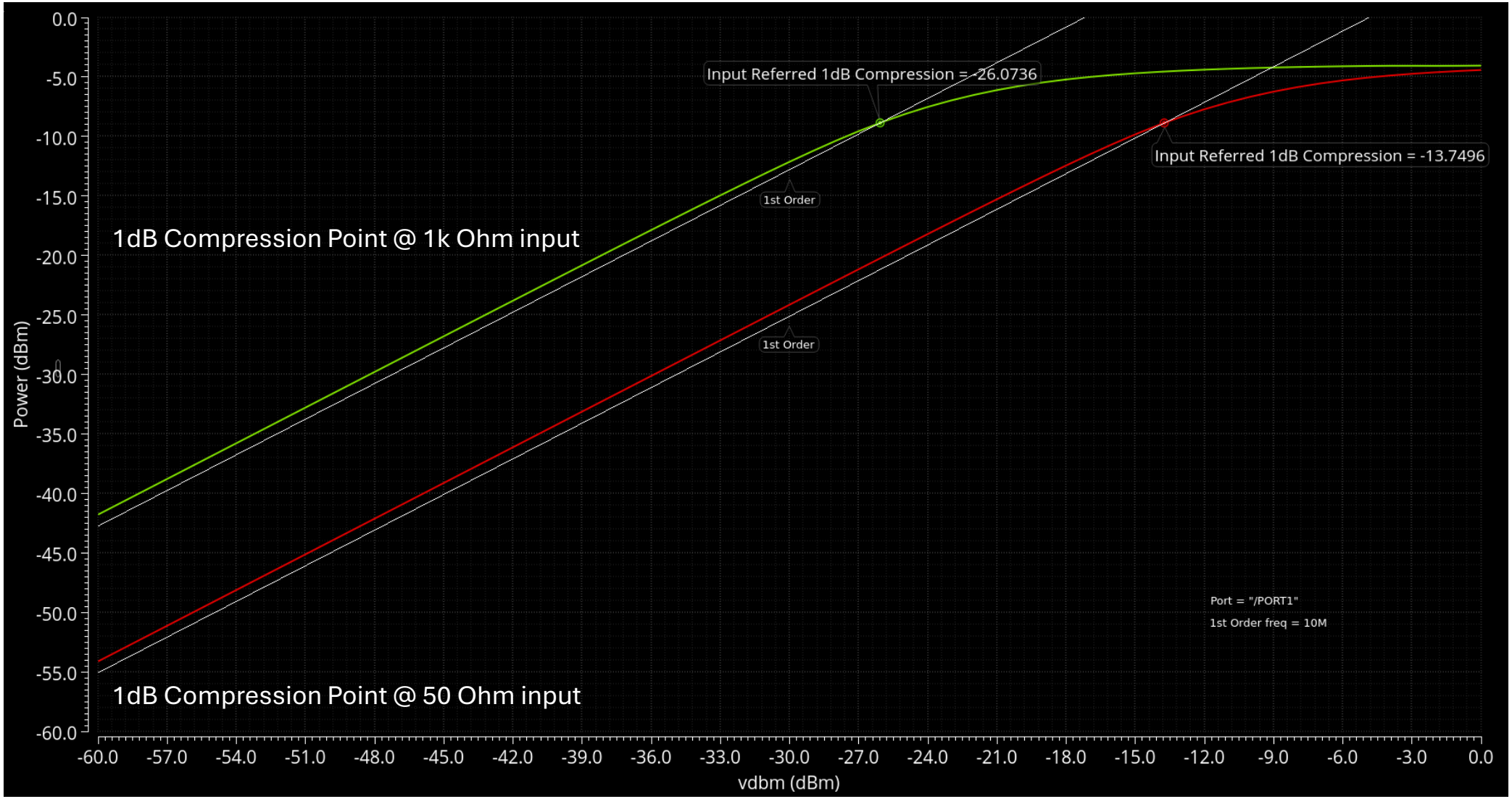


PSS simulation configuration for 1dB CP

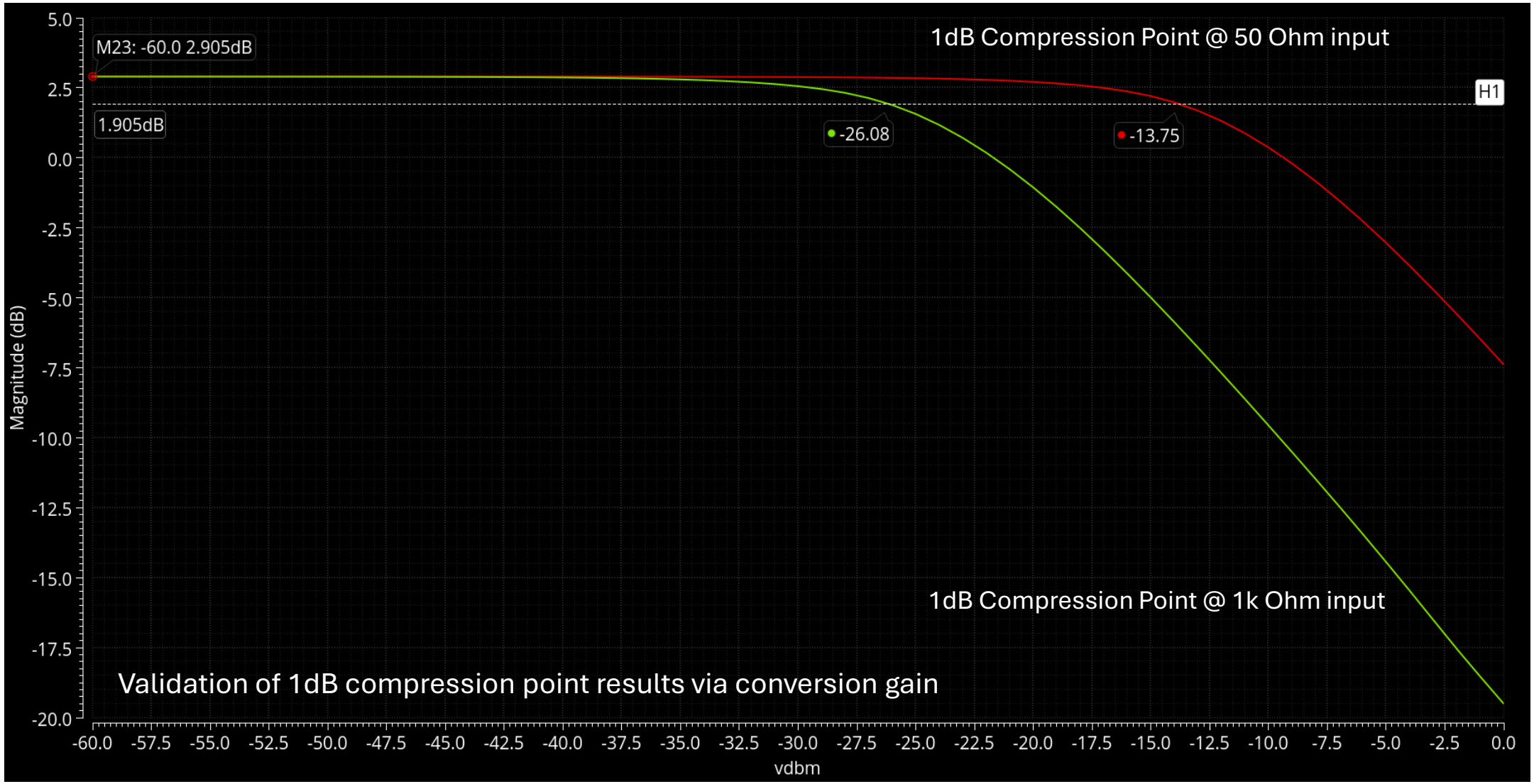


Direct plot configurations

Single balanced mixer – Simulation results (PSS)



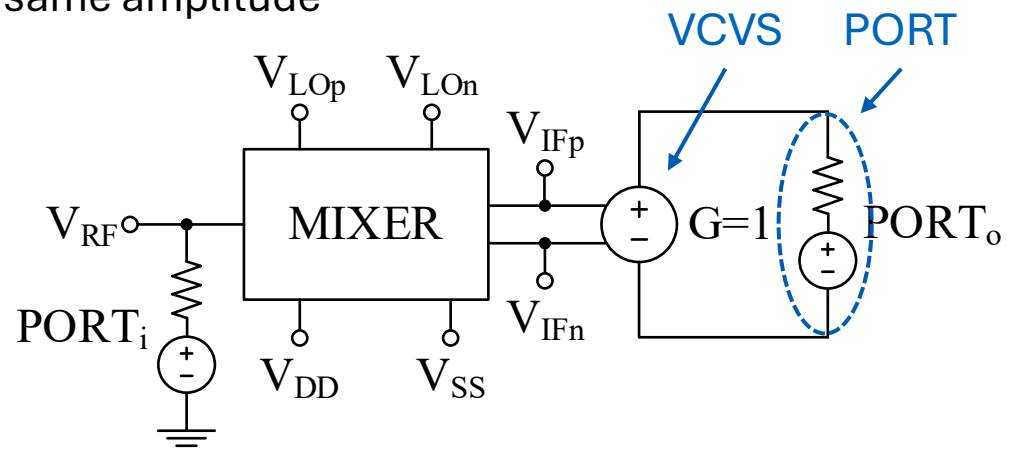
Single balanced mixer – Simulation results (PSS)



Single balanced mixer – Design example and testbench

Procedure for IIP3 simulation using PSS:

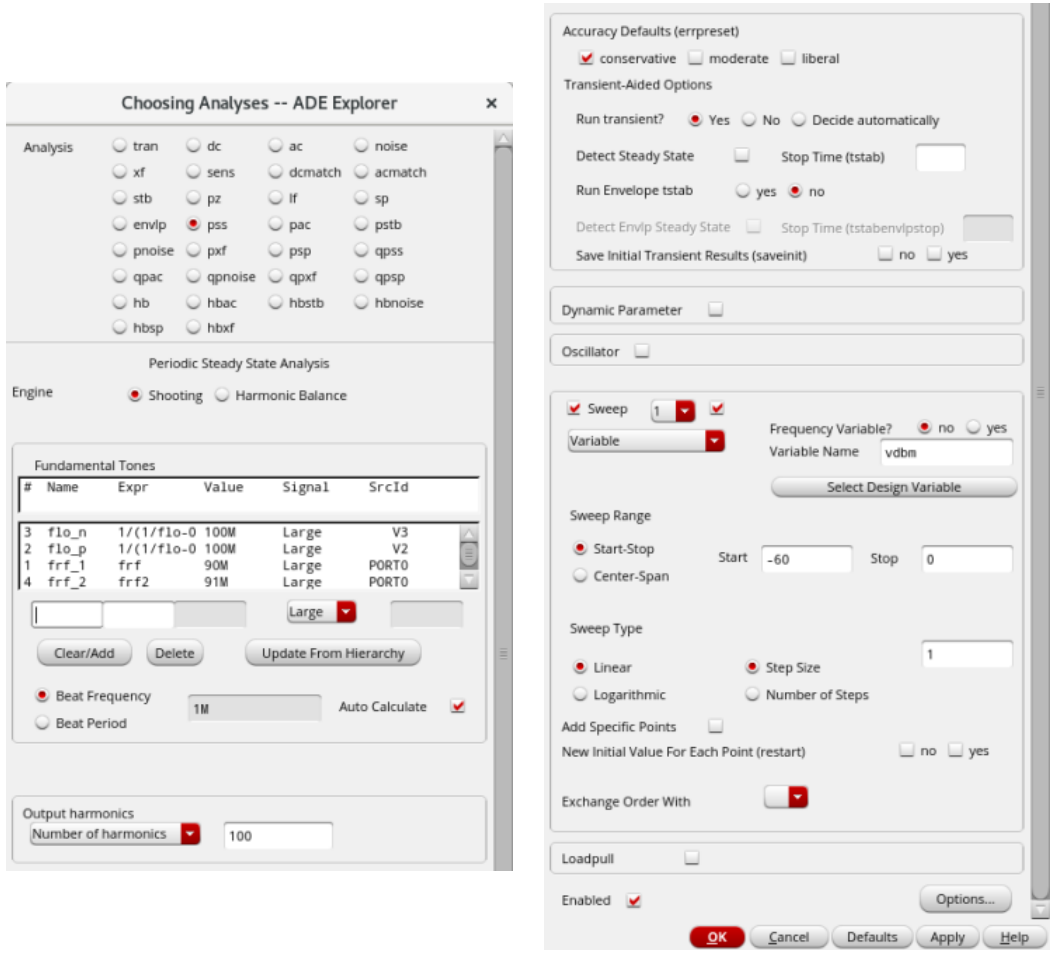
- Input port ($PORT_i$) – Simulate circuit for different port resistances (50 and 1000 Ω)
  - Define port as a sine signal with two tones (f_{RF} and f_{RF2}) and same amplitude
- Output port ($PORT_o$) with 100 Ω

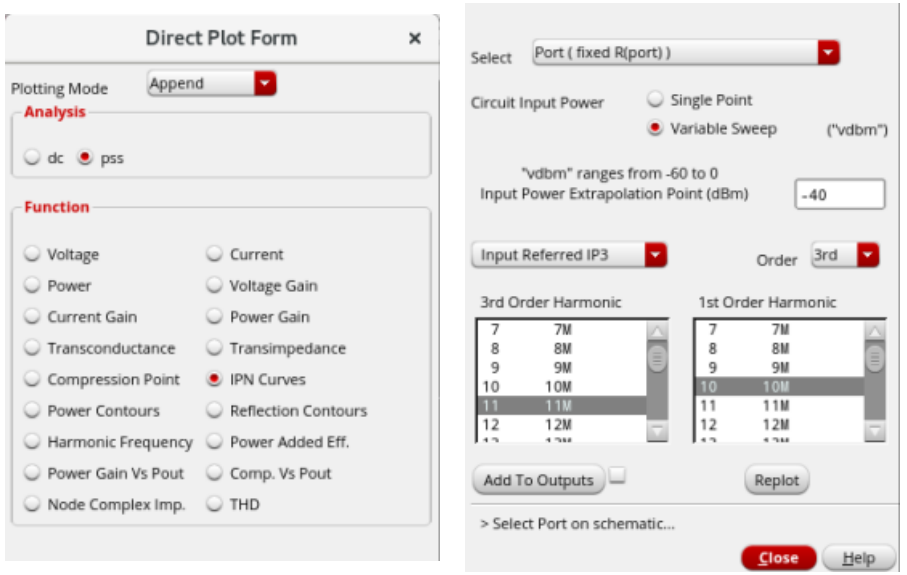


- **PSS simulation:**
  - Beat frequency = f_{RF2}- f_{RF}
  - Number of harmonics = 100
  - Activate the sweep box and
  - Define design variable that controls input amplitude
  - Define sweep range from -60 to 0 and define step
  - To plot select "IPN Curves", choose "Variable Sweep" in "Circuit Input Power" and an "Input Power Extrapolation Point" inside the linear region. In the "1st Order Harmonic", choose f_{IF} (considering there is no second tone). In the "3rd Order Harmonic", choose f_{IFx} or f_{IFy} (see below), whichever is closer to f_{IF}

- **Frequency examples:**
  - f_{RF} = 90 MHz and f_{RF2} = 91 MHz
  - Calculate $f_x = 2 \times f_{RF} - f_{RF2}$ = 89 MHz and $f_y = 2 \times f_{RF2} - f_{RF}$ = 92MHz
  - Perform down-conversion: $f_{IFx} = f_x - f_{LO}$ = 11 MHz and $f_{IFy} = f_y - f_{LO}$ = 8 MHz

Simulation window/result plotting for PSS only simulation

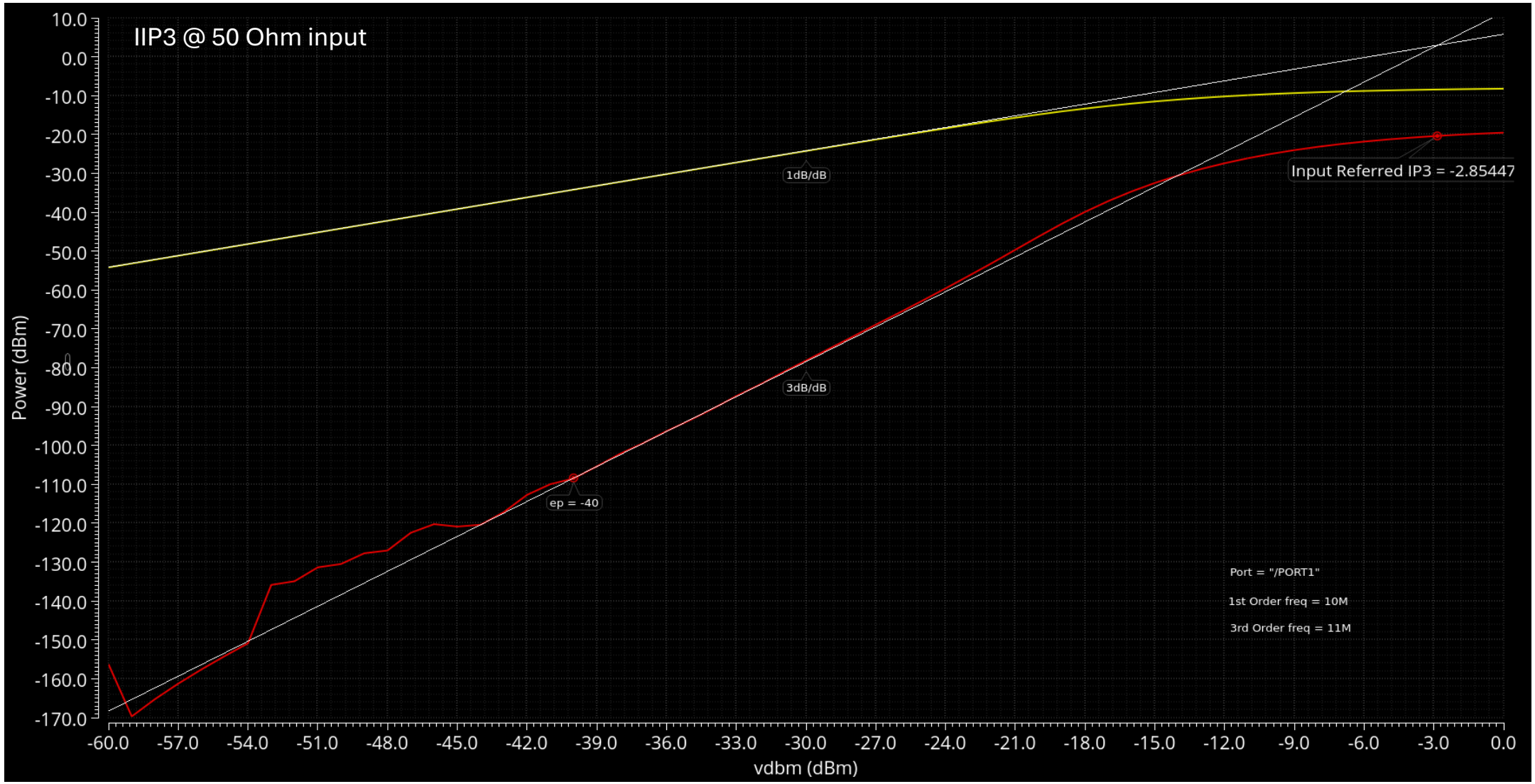




PSS simulation configuration for IIP3

Direct plot configurations

Single balanced mixer – Simulation results (PSS)



Single balanced mixer – Simulation results (PSS)