Receiver Design Worksheet

▸ useful functions and identities
▸ Units
▸ Constants

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Introduction

Receiver and transmitter design calculations are usually done on an Excel spreadsheet. An excel spreadsheet has the advantage that it maximizes the number of parameters that can be displayed on a signal sheet simultaneously. On the other hand, it has the disadvantages of a very difficult to read format (e.g. A126 in instead of IP3), which is error prone and difficult to update or explain to others. An Excel spreadsheet should be accompanied with documentation from a word processor, but it never seen.

This report is a simplified version of detailed Mathcad worksheet used for receiver calculations. All of the user inputs to the system are highlighted. The worksheet can be considerably cleaner, when the regions with equations are collapsed. There are left open here so the reader can read the equations.

Cascaded Receiver Block Equations

Cascaded Gain Equation

$$\mathrm{Gain_{cas}}(\mathrm{Gain}, N) := \mathrm{Gain}_0 + \mathrm{if}\left(N > 0, \sum_{i=1}^{N} \mathrm{Gain}_i, 0\right)$$

Cascaded IP_3 Equation

$$\mathrm{IP3_{cascade}}\left(G_{jam}, G_{jam2}, \mathrm{Gain}, IP_3, N\right) := -10 \cdot \log\left(10^{\frac{-IP_{3_0}}{10}} + \mathrm{if}\left(N > 0, \sum_{i=1}^{N} 10^{\frac{\mathrm{Gain_{cas}}\left(G_{jam}, i-1\right) + 2 \cdot \mathrm{Gain_{cas}}\left(G_{jam2}, i-1\right) - \mathrm{Gain_{cas}}(}{20}}\right.\right.$$

Cascaded IP_2 Equation

$$\mathrm{IP2_{cascade}}\left(G_{jam3}, G_{jam4}, G, IP_2, N\right) := -20 \cdot \log\left[\sum_{i=0}^{N} \mathrm{if}\left[i = 0, 10^{-\frac{IP_{2_i}}{20}}, 10^{-\frac{IP_{2_i} - \sum_{j=0}^{i-1}\left(G_{jam3_j} + G_{jam4_j} - G_j\right)}{20}}\right]\right]$$

Reverse Cascaded IP_3 Equation

$$\mathrm{IP3_{reverse}}\left(G_{jam}, G_{jam2}, G, IP_3, n, N\right) := -10 \cdot \log\left(10^{\frac{-IP_{3_n}}{10}} + \sum_{i=n}^{N} \mathrm{if}\left(i > n, 10^{\frac{\sum_{j=n}^{i-1} G_{jam_j} + 2 \cdot \sum_{j=n}^{i-1} G_{jam2_j} - \sum_{j=n}^{i-1} G_j - 2 \cdot IP_{3_i}}{20}}, 0\right)\right)$$

Cascaded Signal Power Equation

$$S_{cascade}\left(\mathrm{Gain}, P_{signal}, N\right) := P_{signal} + \sum_{i=0}^{N} \mathrm{Gain}_i$$

Cascaded Noise Figure Equation

$$\mathrm{NoiseFig_{cas}}(\mathrm{Gain}, NF, N) := 10 \cdot \log\left(10^{\frac{NF_0}{10}} + \mathrm{if}\left(N > 0, \mathrm{if}\left(N > 1, \sum_{i=1}^{N} \frac{10^{\frac{NF_i}{10}} - 1}{10^{\frac{\sum_{j=0}^{i-1} \mathrm{Gain}_j}{10}}}, \frac{10^{\frac{NF_1}{10}} - 1}{10^{\frac{\mathrm{Gain}_0}{10}}}\right), 0\right)\right)$$

Reverse Cascaded Noise Figure

$$\mathrm{NoiseFig_{rev}}(\mathrm{Gain}, NF, n, N) := 10 \cdot \log\left(10^{\frac{NF_n}{10}} + \sum_{i=n}^{N} \mathrm{if}\left(i > n, \frac{10^{\frac{NF_i}{10}} - 1}{10^{\frac{\sum_{j=n}^{i-1} \mathrm{Gain}_j}{10}}}, 0\right)\right)$$

Cascaded 3rd Order Intermodulation Power

Equation

$Intermod_{cas}\left(G_{jam}, G_{jam2}, Gain, IP_3, P_{jam1}, P_{jam2}, N\right) := P_{jam1} + 2\cdot P_{jam2} + Gain_{cas}(Gain, N) - 2\cdot IP_{3cascade}\left(G_{jam}, G_{jam2}, Gain, I\right.$

Cascaded 2nd Order Intermodulation Power

Equation

$Intermod2_{cas}\left(G_{jam3}, G_{jam4}, G, IP_2, P_{jam3}, P_{jam4}, N\right) := P_{jam3} + 2\cdot P_{jam4} + Gain_{cas}(G, N) - IP_{2cascade}\left(G_{jam3}, G_{jam4}, G, IP_2, N\right)$

Cascaded Output Referred Noise Power

$$N_{powercas}(Gain, NF, BW, N) := N_{floor} + 10\cdot\log\left(\frac{BW_N}{Hz}\right) + NoiseFig_{cas}(Gain, NF, N) + Gain_{cas}(Gain, N)$$

Change in System Noise Figure due to Noise of Element N

$$DeltaNF(G, NF, i, N) := \frac{10^{\frac{NF_i}{10}} - 1}{\left(\text{if}\left(i = 0, 1, 10^{\frac{\sum_{j=0}^{i-1} G_j}{10}}\right)\right)\cdot\left(10^{\frac{NoiseFig_{cas}(G, NF, N)}{10}} - 1\right)}\cdot NoiseFig_{cas}(G, NF, N)$$

Cascaded Carrier to Noise Ratio

$Carrier\_Noise\left(G, P_{sig}, NF, BW, N\right) := S_{cascade}\left(G, P_{sig}, N\right) - N_{powercas}(G, NF, BW, N)$

Cascaded Carrier to 3rd Order Interference Ratio

$Carrier\_Int\left(G_{jam}, G_{jam2}, G, IP_3, P_{sig}, P_{jam1}, P_{jam2}, N\right) := S_{cascade}\left(G, P_{sig}, N\right) - Intermod_{cas}\left(G_{jam}, G_{jam2}, G, IP_3, P_{jam1}, P_{jam2}, N\right.$

Cascaded Carrier to 2nd Order Interference Ratio

$Carrier\_Int2\left(G_{jam3}, G_{jam4}, G, G_{IF}, IP_2, P_{sig}, P_{jam3}, P_{jam4}, N\right) := S_{cascade}\left(G, P_{sig}, N\right) - Intermod2_{cas}\left(G_{jam3}, G_{jam4}, G_{IF}, IP_2, P_{jam}\right.$

Cascaded Carrier to Noise plus Interference Ratio

$$Carrier\_NoiseInt\left(G_{jam}, G_{jam2}, G, IP_3, P_{sig}, P_{jam1}, P_{jam2}, NF, BW, N\right) := S_{cascade}\left(G, P_{sig}, N\right) - 10\cdot\log\left(10^{\frac{N_{powercas}(G, NF, BW, N}{10}} + 10^{\frac{Intermod_{cas}\left(G_{jam}, G_{ja}\right.}{}}\right.$$

Cascaded Carrier to (Noise + Interference + Phase Noise) Ratio

$$Carrier\_NoiseIntPN\left(G_{jam}, G_{jam2}, G, IP_3, P_{sig}, P_{jam1}, P_{jam2}, NF, BW, PN_{jam}, N\right) := S_{cascade}\left(G, P_{sig}, N\right) \ldots$$

$$+ -10\cdot\log\left(10^{\frac{PN_{jam_N}}{10}} \ldots + 10^{\frac{N_{powercas}(G, NF, BW, N)}{10}} \ldots + 10^{\frac{Intermod_{cas}\left(G_{jam}, G_{jam2}, G, IP_3\right.}{10}}\right.$$

Cascaded Carrier to Everything Ratio

$Carrier\_Everything\left(G_{jam}, G_{jam2}, G_{jam3}, G_{jam4}, G_{TX}, G_{imag}, G, IP_2, IP_3, P_{sig}, P_{jam1}, P_{jam2}, P_{jam3}, P_{jam4}, P_{image}, NF, BW, PN_{jam}\right.$

Cascaded Carrier to Phase Noise Ratio

$$\text{Carrier\_PN}(G, P_{sig}, PN_{jam}, N) := S_{cascade}(G, P_{sig}, N) - PN_{jam_N}$$

Cascaded Carrier to Image Noise Ratio

$$\text{Carrier\_Image}(G, G_{imag}, P_{sig}, P_{imag}, N) := S_{cascade}(G, P_{sig}, N) - S_{cascade}(G_{imag}, P_{imag}, N)$$

Cascaded Bias Currents

$$I_{cas}(I_{BIAS}, N) := \sum_{i=0}^{N} I_{BIAS_i}$$

Cascaded Power Dissipation

$$P_{cas}(I_{BIAS}, V_{DD}, N) := I_{cas}(I_{BIAS}, N) \cdot V_{DD}$$

Peak to Peak Output Voltage at Output Node

$$V_{outp\_p}(G_{jam1}, G_{jam2}, G, P_{sig}, P_{jam1}, P_{jam2}, R_{out}, N) := \sqrt{1mW \cdot R_{out_N} \cdot \left(10^{\frac{S_{cascade}(G, P_{sig}, N)}{10}} + 10^{\frac{S_{cascade}(G_{jam1}, P_{jam1}, N)}{10}} + 1\right.}$$

Cascaded Receiver Equations

Receiver Architecture with Two LNA's and a Passive Mixer

$P_{sig} := -100dBm$ $BW_{sig} := 1MHz$ — Power of Signal

$P_{min} := -103dBm$ — Minimum Signal Power

$N := 11$ — Number of Blocks

$i := 0..\ N-1$ — Index Vector

$f_{jam1} := 900 \cdot kHz$ — Frequency offset of Jammer that is Farthes

$f_{jam2} := 1.8 \cdot MHz$ — Frequency offset of Jammer that is Cosest

$P_{jamMax} := -21dBm$ — Maximum Jammer Power

$P_{jam1} := if\left(P_{sig} + 58dB < P_{jamMax}, P_{sig} + 58dB, P_{jamMax}\right)$ — Power of Jammer that is farthest from the d

$P_{jam2} := if\left(P_{sig} + 58dB < P_{jamMax}, P_{sig} + 58dB, P_{jamMax}\right)$ — Power of Jammer that is closest to desired

$P_{jam3} := if\left(P_{sig} + 58dB < P_{jamMax}, P_{sig} + 58dB, P_{jamMax}\right)$ — Power of Jammer that $f_{IF}/2$ above the desi

$P_{jam4} := if\left(P_{sig} + 58dB < P_{jamMax}, P_{sig} + 58dB, P_{jamMax}\right)$ — Power of Jammer that $f_{IF}/2$ below the desi

$P_{image} := if\left(P_{sig} + 58dB < P_{jamMax}, P_{sig} + 58dB, P_{jamMax}\right)$ — Power of Signal in the Image Band

$V_{DD} := 3V$ — Power Supply Voltage

A/D and Filter: Noise Figure, Gain, and Intercept Point Parameters

$Atten := 65dB$ — Baseband Filter Attenuation

$NF_{AGCmin} := 10dB$ — AGC Noise Figure at Minimum Input Pow

$Gain_{AGCmax} := 65dB$ — AGC Gain at Minimum Input Power Level

$Slope_{AGC} := 1\frac{dB}{dB}$ — AGC Gain Slope

$NF_{10} := 10 \cdot \log\left[10^{\frac{NF_{AGCmin}-3}{10}} \cdot \left(1 + 10^{\frac{P_{sig}-P_{min}}{10}}\right)\right]$ $NF_{10} = 11.764$ — AGC Noise Figure

$IP3_{10} := 6$ — AGC 3rd Order Intercept Point

$IP2_{10} := 6$ — AGC 2nd Order Intercept Point

$G_{10} := Gain_{AGCmax} + Slope_{AGC} \cdot \left(P_{sig} - P_{min}\right)$ $G_{10} = 68$ — AGC Gain

$G_{jam1_{10}} := G_{10} - Atten$ $G_{jam2_{10}} := G_{10} - Atten$ — Adjacent and Alternate Adjacent Channel (

$G_{TX_{10}} := G_{10} - Atten$ $G_{imag_{10}} := G_{10}$ — Gains for Signals at Image and Transmit Fr

$G_{IF_{10}} := G_{10}$ — Gains for Signal at Intermediate Frequency

Stepped Gain LNA #1 Noise Figure, Gain, and Intercept Point Parameters

$G_{LNAGmax} := 13dB$ $G_{LNAGmin} := -5dB$ Maximum and Minimum LNA Gain

$IP_{3LNAGmax} := 6dB$ $IP_{3LNAGmin} := 10dB$ IP_3 at Maximum and Minimum Gain

$IP_{2LNAGmax} := 6dB$ $IP_{2LNAGmin} := 10dB$ IP_2 at Maximum and Minimum Gain

$NF_{LNAGmax} := 1.8dB$ $NF_{LNAGmin} := 3dB$ Noise Figure at Maximum and Minimum G

$P_{LNASwitch} := -90dBm$ LNA #1 Bypass Switching Threshold

$G_3 := if(P_{sig} < P_{LNASwitch}, G_{LNAGmax}, G_{LNAGmin})$ LNA #1 Gain

$G_{jam1_3} := G_3$ $G_{jam2_3} := G_3$ Adjacent and Alternate Adjacent Channel (

$G_{imag_3} := G_3$ Gains for Signals at Image Frequency

$G_{IF_3} := G_3 - 20$

$IP_{3_3} := if(P_{sig} < P_{LNASwitch}, IP_{3LNAGmax}, IP_{3LNAGmin})$ LNA #1 IP_3

$IP_{2_3} := if(P_{sig} < P_{LNASwitch}, IP_{2LNAGmax}, IP_{2LNAGmin})$ LNA #1 IP_2

$NF_3 := if(P_{sig} < P_{LNASwitch}, NF_{LNAGmax}, NF_{LNAGmin})$ LNA #1 NF

$I_{BIAS_3} := if(P_{sig} < P_{LNASwitch}, 6mA, 0mA)$ LNA #1 Bias Current

Stepped Gain LNA #2 Noise Figure, Gain, and Intercept Point Parameters

$G_{LNAGmax} := 12dB$ $G_{LNAGmin} := -3dB$ Maximum and Minimum LNA Gain

$IP_{3LNAGmax} := 6dB$ $IP_{3LNAGmin} := 10dB$ IP_3 at Maximum and Minimum Gain

$IP_{2LNAGmax} := 6dB$ $IP_{2LNAGmin} := 10dB$ IP_2 at Maximum and Minimum Gain

$NF_{LNAGmax} := 2dB$ $NF_{LNAGmin} := 3dB$ Noise Figure at Maximum and Minimum G

$P_{LNASwitch} := -90dBm$ LNA #2 Bypass Switching Threshold

$G_5 := if(P_{sig} < P_{LNASwitch}, G_{LNAGmax}, G_{LNAGmin})$ LNA #2 Gain

$G_{jam1_5} := G_5$ $G_{jam2_3} := G_5$ Adjacent and Alternate Adjacent Channel (

$G_{imag_3} := G_5$ Gains for Signals at Image Frequency

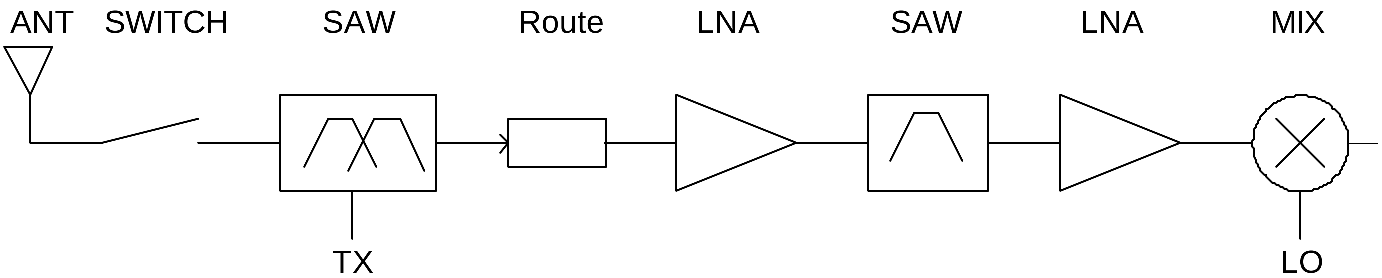
$G_{jam3_5} := G_5$ $G_{jam4_5} := G_5$ Gains for Signals at Half-IF Frequencies

$G_{IF_5} := G_5 - 20dB$ Gains for Signals at Intermediate Frequenc

$IP_{3_5} := if(P_{sig} < P_{LNASwitch}, IP_{3LNAGmax}, IP_{3LNAGmin})$ LNA #2 IP_3

$IP_{2_5} := if(P_{sig} < P_{LNASwitch}, IP_{2LNAGmax}, IP_{2LNAGmin})$ LNA #2 IP_2

$NF_5 := if(P_{sig} < P_{LNASwitch}, NF_{LNAGmax}, NF_{LNAGmin})$ LNA #2 NF



Switch	SAW	Route	LNA #1	SAW	LNA #2	Mixer
$G_0 := -0.3dB$	$G_1 := -2dB$	$G_2 := -0.1dB$	$G_3 = 13$	$G_4 := -3dB$	$G_5 = 12$	$G_6 := -6dB$
$Gjam1_0 := -0.3dB$	$Gjam1_1 := -2dB$	$Gjam1_2 := -0.1dB$	$Gjam1_3 = 13$	$Gjam1_4 := -3dB$	$Gjam1_5 = 12$	$Gjam1_6 := -6d$
$Gjam2_0 := -0.3dB$	$Gjam2_1 := -2dB$	$Gjam2_2 := -0.1dB$	$Gjam2_3 = 12$	$Gjam2_4 := -3dB$	$Gjam2_5 = 0$	$Gjam2_6 := -6d$
$Gjam3_0 := -0.3dB$	$Gjam3_1 := -10dB$	$Gjam3_2 := -0.1dB$	$Gjam3_3 = 0$	$Gjam3_4 := -13dB$	$Gjam3_5 = 12$	$Gjam3_6 := -3d$
$Gjam4_0 := -0.3dB$	$Gjam4_1 := -10dB$	$Gjam4_2 := -0.1dB$	$Gjam4_3 = 0$	$Gjam4_4 := -13dB$	$Gjam4_5 = 12$	$Gjam4_6 := -3d$
$Gimag_0 := -0.3dB$	$Gimag_1 := -25dB$	$Gimag_2 := -0.1dB$	$Gimag_3 = 12$	$Gimag_4 := -13dB$	$Gimag_5 = 0$	$Gimag_6 := -3d$
$GIF_0 := -0.3dB$	$GIF_1 := -25dB$	$GIF_2 := -0.1dB$	$GIF_3 = -7$	$GIF_4 := -20dB$	$GIF_5 = -8$	$GIF_6 := -6dB$
$NF_0 := 0.3dB$	$NF_1 := 3dB$	$NF_2 := 0.1dB$	$NF_3 = 1.8$	$NF_4 := 3dB$	$NF_5 = 2$	$NF_6 := 8dB$
$IP2_0 := 1000dBm$	$IP2_1 := 1000dBm$	$IP2_2 := 1000dBm$	$IP2_3 = 6$	$IP2_4 := 1000dBm$	$IP2_5 = 6$	$IP2_6 := 10dBm$
$IP3_0 := 1000dBm$	$IP3_1 := 1000dBm$	$IP3_2 := 1000dBm$	$IP3_3 = 6$	$IP3_4 := 1000dBm$	$IP3_5 = 6$	$IP3_6 := 10dBm$
$Rin_0 := 50\Omega$	$Rin_1 := 50\Omega$	$Rin_2 := 50\Omega$	$Rin_3 := 50\Omega$	$Rin_4 := 50\Omega$	$Rin_5 := 50\Omega$	$Rin_6 := 50\Omega$
$Rout_0 := 50\Omega$	$Rout_1 := 50\Omega$	$Rout_2 := 50\Omega$	$Rout_3 := 50\Omega$	$Rout_4 := 50\Omega$	$Rout_5 := 50\Omega$	$Rout_6 := 500$
$BW_0 := 1\cdot10^6 Hz$	$BW_1 := 1\cdot10^6 Hz$	$BW_2 := 1\cdot10^6 Hz$	$BW_3 := 1\cdot10^6 Hz$	$BW_4 := 1\cdot10^6 Hz$	$BW_5 := 1\cdot10^6 Hz$	$BW_6 := 1\cdot10^6$
$IBIAS_0 := 0mA$	$IBIAS_1 := 0mA$	$IBIAS_2 := 0mA$	$IBIAS_3 = 6\,mA$	$IBIAS_4 := 0mA$	$IBIAS_5 := 10mA$	$IBIAS_6 := 10m$

Image Noise

$$P_{imag_i} := P_{image} + Gain_{cas}(G_{imag}, N-1) - Gain_{cas}(G, N-1) + Gain_{cas}(G, i)$$

RF VCO Phase Noise

$$L(f) := -110dBC\_Hz - 20\cdot\log\left(\frac{f}{100\cdot kHz}\right)dBC\_Hz$$

RF Phase Noise Equation

$$P(f_1, f_2, P_{jam}) := 10\cdot\log\left(\frac{\int_{f_1}^{f_2} 10^{\frac{L(f)}{10}}\,df}{Hz}\right) + P_{jam}$$

Integrated Phase Noise Power

$L_{RFjam1} := L(f_{jam1})$ $\quad L_{RFjam1} = -129.085\,dBC\_Hz$ Phase Noise of Local Oscillator at

$L_{RFjam2} := L(f_{jam2})$ $\quad L_{RFjam2} = -135.105\,dBC\_Hz$ Phase Noise of Local Oscillator at

$$PN_{jam_i} := 10\cdot\log\left(10^{\frac{P\left(f_{jam1}-\frac{BW_{sig}}{2},\, f_{jam1}+\frac{BW_{sig}}{2},\, P_{jam1}\right)}{10}} + 10^{\frac{P\left(f_{jam2}-\frac{BW_{sig}}{2},\, f_{jam2}+\frac{BW_{sig}}{2},\, P_{jam2}\right)}{10}}\right) + Gain_{cas}(G, i)$$

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$PN := P\left(1kHz, \frac{BW_{sig}}{2}, 0\right) + 3 + S_{cascade}(G, P_{sig}, 7)$ $\quad PN = -123.409$ Noise Power at the Mixer Output

$$NF_7 := 10\cdot\log\left[1 + 10^{\frac{PN-\left(N_{floor}+10\cdot\log\left(\frac{BW_{sig}}{Hz}\right)\right)}{10}}\right]$$

$NF_7 = 0.506$ Effective NF due to In-Band Phas

Calculations

$NF_{cas_i} := NoiseFig_{cas}(G, NF, i)$

$S_{cas_i} := S_{cascade}(G, P_{sig}, i)$

$C\_N_{cas_i} := Carrier\_Noise(G, P_{sig}, NF, BW, i)$

$V_{p\_p_i} := V_{outp\_p}(G_{jam1}, G_{jam2}, G, P_{sig}, P_{jam1}, P_{jam2}, R_{out}, i)$

$IP_{3CMr_i} := IP_{3reverse}(G_{jam1}, G_{TX}, G, IP_3, i, N - 1)$

$I_{mod_i} := Intermod_{cas}(G_{jam1}, G_{jam2}, G, IP_3, P_{jam1}, P_{jam2}, i)$

$G_{cas_i} := Gain_{cas}(G, i)$

$C\_PN_i := Carrier\_PN(G, P_{sig}, PN_{jam}, i)$

$\Delta NF_i := DeltaNF(G, NF, i, N - 1)$

$G_{icas_i} := Gain_{cas}(G_{imag}, i)$

$C\_I2_{cas_i} := Carrier\_Int2(G_{jam3}, G_{jam4}, G, G_{IF}, IP_2, P_{sig}, P_{jam3}, P_{jam4}, i)$

$C\_E_i := Carrier\_Everything(G_{jam1}, G_{jam2}, G_{jam3}, G_{jam4}, G_{TX}, G_{imag}, G, IP_2, IP_3, P_{sig}, P_{jam1}, P_{jam2}, P_{jam3}, P_{jam4}, P_{imag}, NF, BW$

$IP_{3cas_i} := IP_{3cascade}(G_{jam1}, G_{jam2}, G, IP_3, i)$

$C\_I_{cas_i} := Carrier\_Int(G_{jam1}, G_{jam2}, G, IP_3, P_{sig}, P_{jam}$

$NF_{rev_i} := NoiseFig_{rev}(G, NF, i, N - 1)$

$C\_NI_{cas_i} := Carrier\_NoiseInt(G_{jam1}, G_{jam2}, G, IP_3, P_s$

$IP_{3rev_i} := IP_{3reverse}(G_{jam1}, G_{jam2}, G, IP_3, i, N - 1)$

$N_{p_i} := N_{powercas}(G, NF, BW, i)$

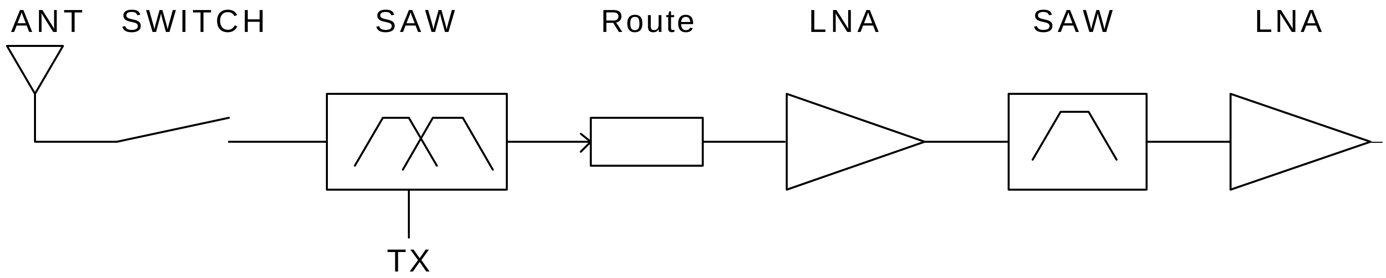
$C\_NIPN_i := Carrier\_NoiseIntPN(G_{jam1}, G_{jam2}, G, IP_3$

$IP_{2cas_i} := IP_{2cascade}(G_{jam3}, G_{jam4}, G, IP_2, i)$

$I_{mod2_i} := Intermod2_{cas}(G_{jam3}, G_{jam4}, G, IP_2, P_{jam3}, P$

$C\_Imag_i := Carrier\_Image(G, G_{imag}, P_{sig}, P_{image}, N -$

Block Output Parameters



$G_{cas_0} = -0.3\,dB$	$G_{cas_1} = -2.3\,dB$	$G_{cas_2} = -2.4\,dB$	$G_{cas_3} = 10.6\,dB$	$G_{cas_4} = 7.6\,dB$	$G_{cas_5} = 19.6\,dE$
$G_{icas_0} = -0.3\,dB$	$G_{icas_1} = -25.3\,dB$	$G_{icas_2} = -25.4\,dB$	$G_{icas_3} = -13.4\,dB$	$G_{icas_4} = -26.4\,dB$	$G_{icas_5} = -26.4$
$NF_{cas_0} = 0.3\,dB$	$NF_{cas_1} = 3.3\,dB$	$NF_{cas_2} = 3.38\,dB$	$NF_{cas_3} = 4.871\,dB$	$NF_{cas_4} = 4.992\,dB$	$NF_{cas_5} = 5.13$
$NF_{rev_0} = 5.616\,dB$	$NF_{rev_1} = 5.316\,dB$	$NF_{rev_2} = 2.758\,dB$	$NF_{rev_3} = 2.658\,dB$	$NF_{rev_4} = 8.806\,dB$	$NF_{rev_5} = 5.806$
$\Delta NF_0 = 0.15\,dB$	$\Delta NF_1 = 2.26\,dB$	$\Delta NF_2 = 0.08\,dB$	$\Delta NF_3 = 1.9\,dB$	$\Delta NF_4 = 0.18\,dB$	$\Delta NF_5 = 0.22\,dI$
$N_{p_0} = -114.3\,dBm$	$N_{p_1} = -113.33\,dBm$	$N_{p_2} = -113.35\,dBm$	$N_{p_3} = -98.858\,dBm$	$N_{p_4} = -101.737\,dBm$	$N_{p_5} = -89.6\,dE$
$IP_{3cas_0} = 1\times 10^3\,dBm$	$IP_{3cas_1} = 997.137\,dBm$	$IP_{3cas_2} = 995.982\,dB$	$IP_{3cas_3} = 8.4\,dBm$	$IP_{3cas_4} = 8.4\,dBm$	$IP_{3cas_5} = -1.11$
$IP_{2cas_0} = 1\times 10^3\,dBm$	$IP_{2cas_1} = 994.128\,dBm$	$IP_{2cas_2} = 993.607\,dB$	$IP_{2cas_3} = 24.4\,dBm$	$IP_{2cas_4} = 24.4\,dBm$	$IP_{2cas_5} = 24.26$
$IP_{3rev_0} = -2.459\,dBm$	$IP_{3rev_1} = -2.759\,dBm$	$IP_{3rev_2} = -4.759\,dBm$	$IP_{3rev_3} = -4.859\,dBm$	$IP_{3rev_4} = 7.513\,dBm$	$IP_{3rev_5} = 4.513$
$S_{cas_0} = -100.3\,dBm$	$S_{cas_1} = -102.3\,dBm$	$S_{cas_2} = -102.4\,dBm$	$S_{cas_3} = -89.4\,dBm$	$S_{cas_4} = -92.4\,dBm$	$S_{cas_5} = -80.4\,d$
$V_{p\_p_0} = 0.858\,mVpk\_pk$	$V_{p\_p_1} = 0.681\,mVpk\_pk$	$V_{p\_p_2} = 0.674\,mVpk\_pk$	$V_{p\_p_3} = 2.85\,mVpk\_pk$	$V_{p\_p_4} = 2.018\,mVpk\_pk$	$V_{p\_p_5} = 6.146$
$I_{mod_0} = -2.126\times 10^3\,dBm$	$I_{mod_1} = -2.123\times 10^3\,dBm$	$I_{mod_2} = -2.12\times 10^3\,dBm$	$I_{mod_3} = -132.2\,dBm$	$I_{mod_4} = -135.2\,dBm$	$I_{mod_5} = -104.1$
$I_{mod2_0} = -1.126\times 10^3\,dBm$	$I_{mod2_1} = -1.122\times 10^3\,dBm$	$I_{mod2_2} = -1.122\times 10^3\,dBm$	$I_{mod2_3} = -139.8\,dBm$	$I_{mod2_4} = -142.8\,dBm$	$I_{mod2_5} = -130.$
$C\_N_{cas_0} = 14.03\,dB$	$C\_N_{cas_1} = 11.03\,dB$	$C\_N_{cas_2} = 10.95\,dB$	$C\_N_{cas_3} = 9.458\,dB$	$C\_N_{cas_4} = 9.337\,dB$	$C\_N_{cas_5} = 9.2$
$C\_I_{cas_0} = 2.026\times 10^3\,dB$	$C\_I_{cas_1} = 2.02\times 10^3\,dB$	$C\_I_{cas_2} = 2.018\times 10^3\,dB$	$C\_I_{cas_3} = 42.8\,dB$	$C\_I_{cas_4} = 42.8\,dB$	$C\_I_{cas_5} = 23.77$
$C\_I2_{cas_0} = 1.026\times 10^3\,dB$	$C\_I2_{cas_1} = 1.043\times 10^3\,dB$	$C\_I2_{cas_2} = 1.038\times 10^3\,dB$	$C\_I2_{cas_3} = 70.4\,dB$	$C\_I2_{cas_4} = 87.4\,dB$	$C\_I2_{cas_5} = 100$
$C\_NI_{cas_0} = 14.03\,dB$	$C\_NI_{cas_1} = 11.03\,dB$	$C\_NI_{cas_2} = 10.95\,dB$	$C\_NI_{cas_3} = 9.456\,dB$	$C\_NI_{cas_4} = 9.335\,dB$	$C\_NI_{cas_5} = 9.0$
$C\_NIPN_0 = 7.612\,dB$	$C\_NIPN_1 = 6.723\,dB$	$C\_NIPN_2 = 6.693\,dB$	$C\_NIPN_3 = 6.071\,dB$	$C\_NIPN_4 = 6.015\,dB$	$C\_NIPN_5 = 5.8$
$C\_PN_0 = 8.736\,dB$	$C\_PN_1 = 8.736\,dB$	$C\_PN_2 = 8.736\,dB$	$C\_PN_3 = 8.736\,dB$	$C\_PN_4 = 8.736\,dB$	$C\_PN_5 = 8.736$
$C\_Imag_0 = -6\,dB$	$C\_Imag_1 = -6\,dB$	$C\_Imag_2 = -6\,dB$	$C\_Imag_3 = -6\,dB$	$C\_Imag_4 = -6\,dB$	$C\_Imag_5 = -6$
$C\_E_0 = -6.185\,dB$	$C\_E_1 = -6.226\,dB$	$C\_E_2 = -6.228\,dB$	$C\_E_3 = -6.262\,dB$	$C\_E_4 = -6.265\,dB$	$C\_E_5 = -6.273$

System Output Parameters

$\mathrm{NoiseFig}_{cas}(G, NF, N-1) = 5.616\,\mathrm{dB}$ — Cascaded Noise Figure E

$\mathrm{Gain}_{cas}(G, N-1) = 85.6\,\mathrm{dB}$ — Cascaded Gain Equation

$\mathrm{IP}_{3cascade}(G_{jam1}, G_{jam2}, G, IP_3, N-1) = -2.459\,\mathrm{dBm}$ — Cascaded Two Tone IP_3

$\mathrm{IP}_{2cascade}(G_{jam3}, G_{jam4}, G, IP_2, N-1) = 23.298\,\mathrm{dBm}$ — Cascaded Two Tone IP_2

$S_{cascade}(G, P_{sig}, N-1) = -14.4\,\mathrm{dBm}$ — Output Signal Power (dB

$\mathrm{Intermod}_{cas}(G_{jam1}, G_{jam2}, G, IP_3, P_{jam1}, P_{jam2}, N-1) = -35.483\,\mathrm{dBm}$ — Output 3rd Order Intermo

$\mathrm{Intermod2}_{cas}(G_{jam3}, G_{jam4}, G, IP_2, P_{jam3}, P_{jam4}, N-1) = -63.698$ — Output 2nd Order Interm

$N_{powercas}(G, NF, BW, N-1) = -23.113\,\mathrm{dBm}$ — Output Noise Power (dB

$\mathrm{Carrier\_Noise}(G, P_{sig}, NF, BW, N-1) = 8.713\,\mathrm{dB}$ — Carrier to Noise Ratio

$\mathrm{Carrier\_Int}(G_{jam1}, G_{jam2}, G, IP_3, P_{sig}, P_{jam1}, P_{jam2}, N-1) = 21.083\,\mathrm{dB}$ — Carrier to 3rd Order Inter

$\mathrm{Carrier\_Int2}(G_{jam3}, G_{jam4}, G, G_{IF}, IP_2, P_{sig}, P_{jam3}, P_{jam4}, N-1) = 73.607\,\mathrm{dB}$ — Carrier to 2nd Order Inte

$\mathrm{Carrier\_Image}(G, G_{imag}, P_{sig}, P_{image}, N-1) = -6$ — Carrier to Image Noise R

$\mathrm{Carrier\_PN}(G, P_{sig}, PN_{jam}, N-1) = 8.736\,\mathrm{dB}$ — Carrier to Phase Noise R

$\mathrm{Carrier\_NoiseInt}(G_{jam1}, G_{jam2}, G, IP_3, P_{sig}, P_{jam1}, P_{jam2}, NF, BW, N-1) = 8.47\,\mathrm{dB}$ — Carrier to (Noise + Interfe

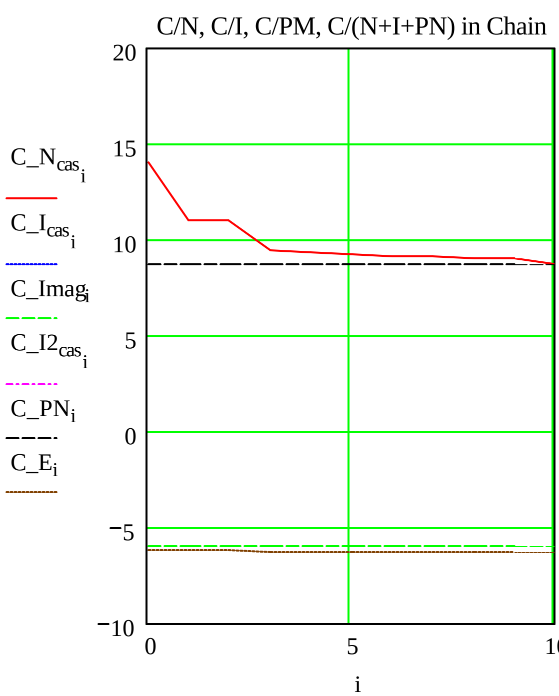
$\mathrm{Carrier\_NoiseIntPN}(G_{jam1}, G_{jam2}, G, IP_3, P_{sig}, P_{jam1}, P_{jam2}, NF, BW, PN_{jam}, N-1) = 5.59\,\mathrm{dB}$ — Carrier to (Noise + Interfe

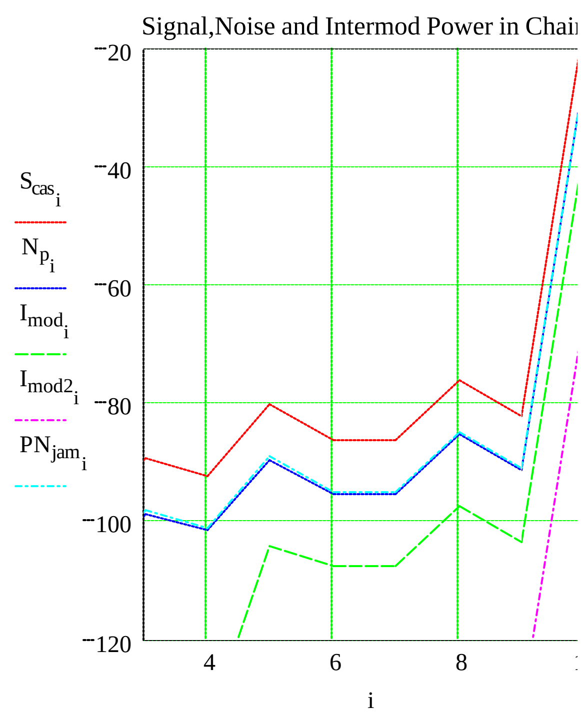
$\mathrm{Carrier\_Everything}(G_{jam1}, G_{jam2}, G_{jam3}, G_{jam4}, G_{TX}, G_{imag}, G, IP_2, IP_3, P_{sig}, P_{jam1}, P_{jam2}, P_{jam3}, P_{jam4}, P_{imag}, NF, BW, PN_{jam}$

Carrier to Everything Rati

$I_{cas}(I_{BIAS}, N-1) = 46\,\mathrm{mA}$ — Total Bias Current

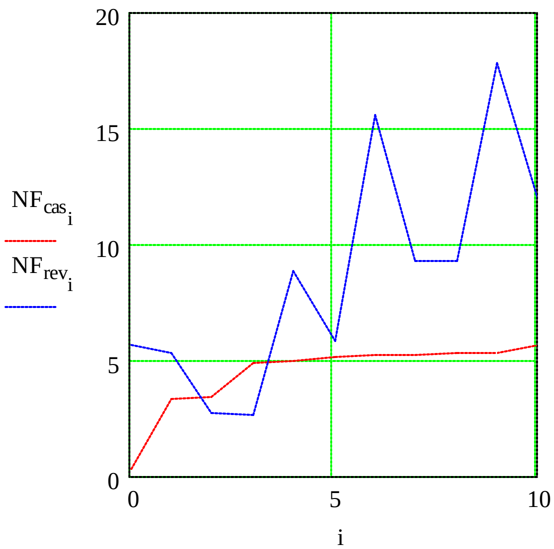
$P_{cas}(I_{BIAS}, V_{DD}, N-1) = 138\,\mathrm{mW}$ — Total Power Dissipation



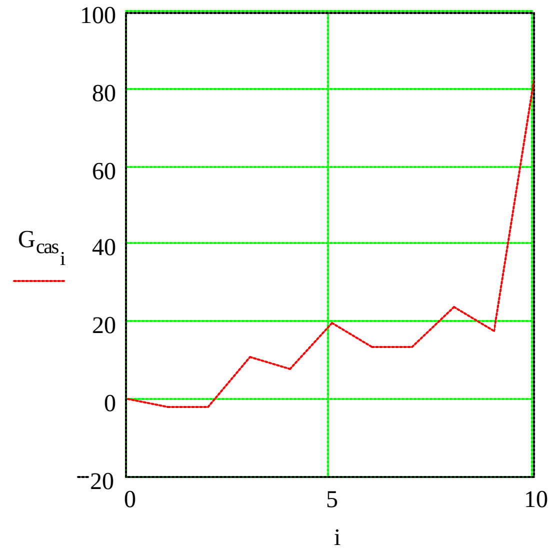


0:Switch 1:SAW 2:Route 3:LNA 4:SAW 5:LNA 6:Mixer 7:Phase Noise 8:IF AMP 9:SAW 10:Baseban

Noise Figure Through Receiver Chain



Gain Through Chain



Two Tone IP_3 Through Chain