

RF Cascade Workbook 2003

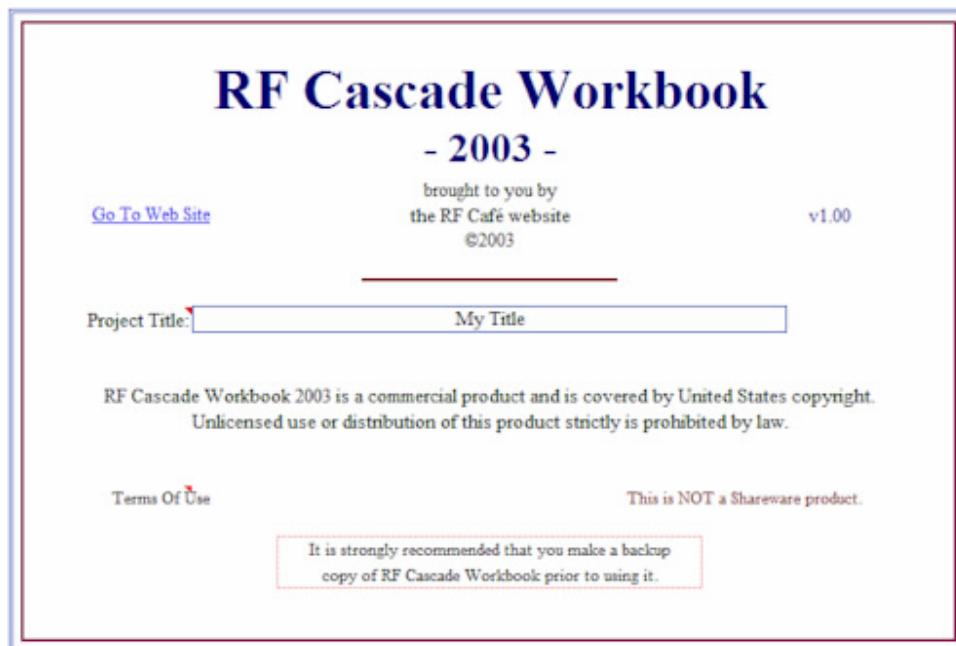
User's Guide[©]

Revision -

by Kirt Blattenberger

RF Café Website
(www.rfcafe.com)

Important: You must select “**Enable Macros**” when opening RF Cascade Workbook 2003, or the VBA code will not function.



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1 Introduction

RF Cascade Workbook 2003 incorporates many features requested by users over the last year. While automated program features and multi-page displays are useful, it seems most users would rather have the convenience and ease of all input and output cells being on a single worksheet, and have most of the formulas in a VBA¹ routine to maintain uncluttered cells and simple manipulation. Another concern is the rather large size of the basic workbook, since every system saved creates a file the size of the entire workbook. Here is brief list of changes for RF Cascade Workbook 2003:

- All input/output cells located on a single worksheet (makes inserting/deleting rows simpler)
- Removed pop-up calculators since they just make the workbook larger
- Put the vast majority of cell formulas in VBA code for easy manipulation
- Added the ability to specify individual device IP2 and IP3 as input or output referenced
- Provided this user's guide, and eliminated the online help (smaller workbook file size)
- Put device tolerance and Min/Max cells next to Nominal parameters
- Modified formulas to reflect gain min/max values in addition to device min/max variations
- Added a minimum system SNR value for use in calculating dynamic range
- Employed Excel's outline feature to easily show/hide Min/Max values
- Reduced the number of default graphs (smaller workbook file size)
- Reduced the overall file size to under 200 kBytes

All of the formulas used in RF Cascade Workbook 2003 are presented in the following paragraphs to assist in understanding the operation of the spreadsheet. Most calculations are implemented in VBA code, which makes customization more convenient and keeps clutter out of the cells. This is especially helpful in the case of conditional formulas. Expansion of the workbook to include custom calculations is a simple matter. Excel has a very extensive Help section for VBA code writing.

1.1 Terms of Use

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Your use of RF Cascade Workbook 2003 attests to your agreement to hold harmless Kirt Blattenberger and his assigns for any losses that may occur as a result of the use of RF Cascade Workbook 2003. Every iota of code is available for review and discernment by the user, who is consequently solely responsible for all results. RF Cascade Workbook 2003 has been tested and is believed to be free of errors upon release. Formulas used in RF Cascade Workbook 2003 are not proprietary and have been obtained from multiple sources.

Prior to using this workbook for the first time, please be sure to create a backup copy so the original version is always accessible. If you loose track of the original and I have your name on file as a legal licensee, I will gladly e-mail a replacement version upon request (I've done that sort of thing, too).

1.2 VBA Code Access

Access to the VBA code is made using the "Tools→Macro→Visual Basic Editor" menu selection (Figure 1), and choosing the relevant page. Note that different versions of Excel might have slightly different menu structures, so your menu might look different from Figure 1.

¹ Visual Basic for Applications

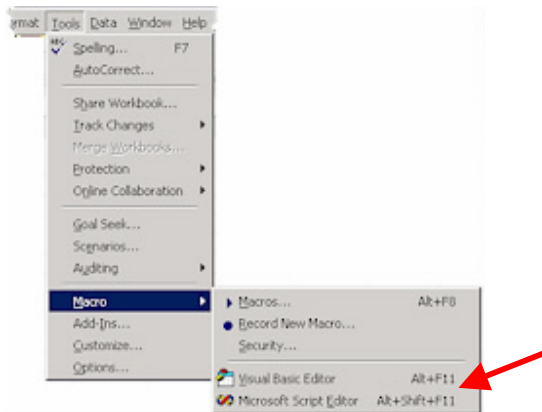


Figure 1 VBA Menu Access

Figure 2 shows a portion of the VBA code window, where you can make changes to existing functions, or add new ones of your own. The “Option Explicit” directive forces the declaration of all variables, which aids during the debug process by eliminating the difficult to find misspelled variable or constant that is so easy to have in VB.

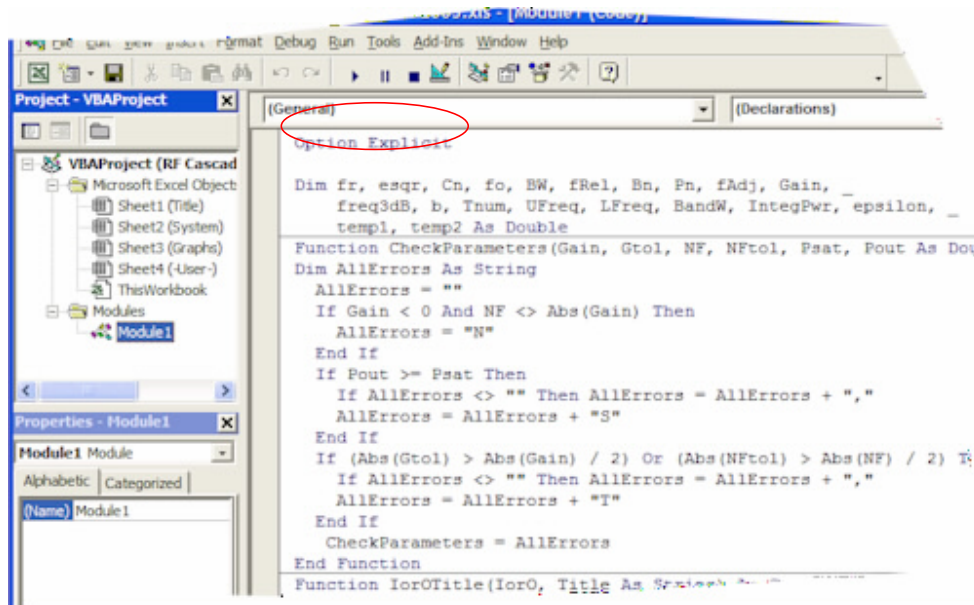


Figure 2 VBA Code Window

2 Adding Or Deleting Rows

Adding or deleting a row (or rows) is a simple process, but care must be taken to be certain that the cascaded formula sequences are not lost. Here is a step-by-step method that assures cascade integrity. One simple rule applies to adding and deleting rows:

Never Select the First Two Rows Or the Last Two Rows

There are other methods of adding or deleting rows, but this one seems to be the most foolproof.

2.1 Adding Rows

Highlight the rows where you want to insert the new rows.

25	13	Comp13	0.00	0.00	999.00	999.00	999.00
26	14	Comp14	0.00	0.00	999.00	999.00	999.00
27	15	Comp15	0.00	0.00	999.00	999.00	999.00
28	16	Comp16	0.00	0.00	999.00	999.00	999.00
29	17	Comp17	0.00	0.00	999.00	999.00	999.00
30	18	Comp18	0.00	0.00	999.00	999.00	999.00

Click the cursor on the Insert→Rows menu item.

Go back and highlight the row just above the newly inserted rows.

24	12	Comp12	0.00	0.00	999.00	999.00	999.00
25	13	Comp13	0.00	0.00	999.00	999.00	999.00
26							
27							
28							
29	14	Comp14	0.00	0.00	999.00	999.00	999.00
30	15	Comp15	0.00	0.00	999.00	999.00	999.00

-- Use the Ctrl+C keyboard combination to copy the rows to the Windows clipboard.

Highlight the newly inserted rows PLUS the one immediately below it.

24	12	Comp12	0.00	0.00	999.00	999.00	999.00
25	13	Comp13	0.00	0.00	999.00	999.00	999.00
26							
27							
28							
29	14	Comp14	0.00	0.00	999.00	999.00	999.00
30	15	Comp15	0.00	0.00	999.00	999.00	999.00

-- Use the Ctrl+V keyboard combination to paste the rows into the worksheet from the Windows clipboard.

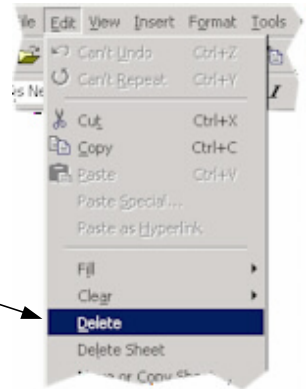
Resulting new rows that maintain continuity of cascaded formulas.
Done!

25	13	Comp13	0.00	0.00	999.00	999.00	999.00
26	13	Comp13	0.00	0.00	999.00	999.00	999.00
27	13	Comp13	0.00	0.00	999.00	999.00	999.00
28	13	Comp13	0.00	0.00	999.00	999.00	999.00
29	13	Comp13	0.00	0.00	999.00	999.00	999.00
30	15	Comp15	0.00	0.00	999.00	999.00	999.00

2.2 Deleting Rows

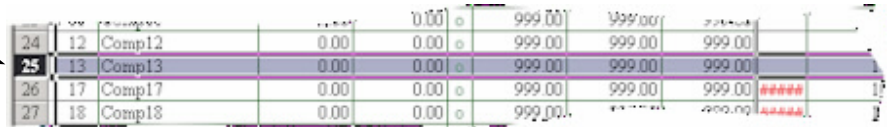
Highlight the rows where you want to delete existing rows.

25	13	Comp13	0.00	0.00	999.00	999.00	999.00
26	14	Comp14	0.00	0.00	999.00	999.00	999.00
27	15	Comp15	0.00	0.00	999.00	999.00	999.00
28	16	Comp16	0.00	0.00	999.00	999.00	999.00
29	17	Comp17	0.00	0.00	999.00	999.00	999.00
30	18	Comp18	0.00	0.00	999.00	999.00	999.00



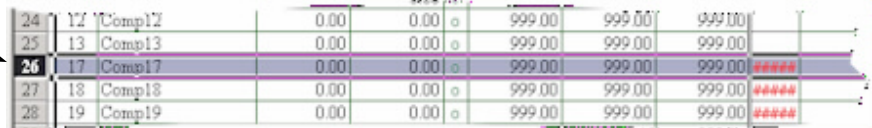
Click the cursor on the Edit→Delete menu item.

Go back and highlight the row just above the newly deleted rows.



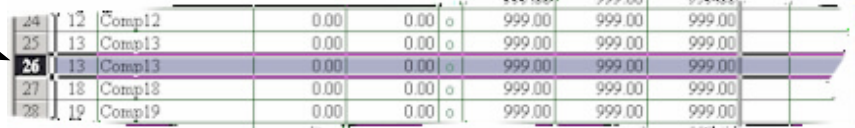
-- Use the Ctrl+C keyboard combination to copy the rows to the Windows clipboard.

Highlight the first row where the deleted rows used to be (this will be the first row where the red #### characters appear).



-- Use the Ctrl+V keyboard combination to paste the rows into the worksheet from the Windows clipboard.

Done!



3 System Specification

System parameter specifications are located in the upper left region of the worksheet as shown in Figure 3. A brief explanation of each parameter is given in Table 1. All cell input data is validated for correctness.

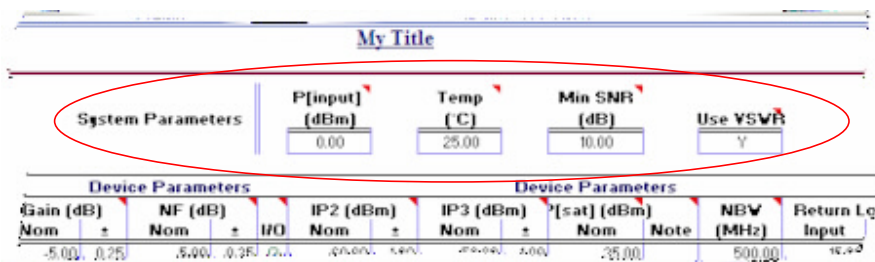


Figure 3 System Specification Input Area

Parameter	Description	Range	Tolerance	Units
P[input]	Signal power level at system input	-1000 to +1000	-	dBm
Temp	System reference temperature – used for noise power calculations. (-273.15 is absolute zero)	-273.14 to +1000	-	°C
Min SNR	Minimum system SNR used to calculate the dynamic range (SDR)	-100 to +100	-	dB

Parameter	Description	Range	Tolerance	Units
Use VSWR	Determines whether the interface VSWR mismatch errors are included in the cascaded Gain equation, which in turn affects every other equation in the system.	“y” or “Y” to include “n” or “N” to exclude	-	-

Table 1 System Input Parameters

4 Device Specification

Each device is specified similar to what is shown in Table 2. Figure 4 identifies each of the special features in the worksheet, so please review it carefully before proceeding. Note that due to the new layout of the device parameter input cells, it is not possible to simply copy and paste from a previous version or RF Cascade Workbook into this one. It will be necessary to retrieve the tolerance values from the “Min-Max 1” worksheet of previous versions. All cell input data is validated for correctness.

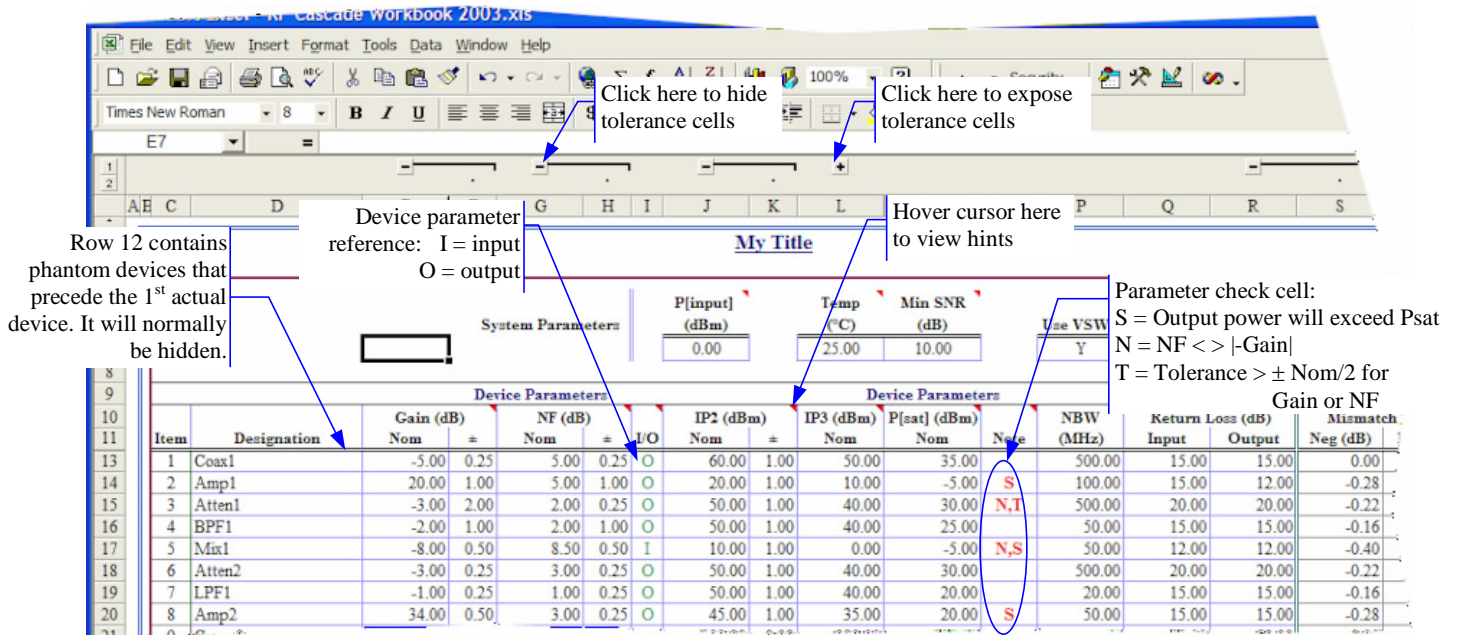


Figure 4 Device Specification Input Area

A description of and allowable input range for each device parameter is given in Table 2. Limits have been set using the “Data→Validation” menu selection (Figure 5), and may be changed by the user. Keep in mind if you decide to increase the limits on dB values (although it is hard to imagine why the need would arise) that the VBA functions use double precision numbers with a maximum value of around 10^{308} , so values like NF, IP2 and IP3 that need to be converted from decibels to linear numbers during calculation could exceed the limit and cause an error to display in the cells. Cell contents are validated using the built-in Excel data validation feature (use ... menu for modify).

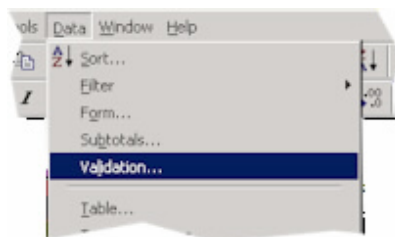


Figure 5 Data Validation Menu Access

Parameter	Description	Range	Tolerance	Units
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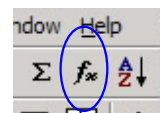
Parameter	Description	Range	Tolerance	Units
Device Designation	Descriptive name	-	-	-
Gain	Linear power Gain	-1000 to +1000	-1000 to +1000	dB
NF	Noise Figure	0 to +1000	0 to +1000	dB
I/O	Input/Output parameter reference – applies only to IP2 and IP3. Conversion of the input value is not made automatically by switching between “I” and “O,” so entering +20 dBm as the IIP3 (with an “I” in the “I/O” cell) and then changing to an “O” will result in the +20 dBm being interpreted as the OIP3. Make the conversions as follows: OIP2(3) = IIP2(3) + Gain IIP2(3) = OIP2(3) - Gain	“i” or “I” for input “o” or “O” for output	-	-
IP2	2 nd -Order Intercept Point	-1000 to +1000	-1000 to +1000	dBm
IP3	3 rd -Order Intercept Point	-1000 to +1000	-1000 to +1000	dBm
P[sat]	Saturated Power	-1000 to +1000	-1000 to +1000	dBm
Note (this is not an input)	Displays alert for the following conditions: N = A negative value is entered in the Gain cell, but the NF is not equal to the absolute value of the Gain. S = The input power plus linear Gain results in an output power greater than the saturated power for the device. T = Tolerance is greater than ±Gain/2 or ±NF/2	-	-	-
NBW	Noise Bandwidth	10 ⁻⁶ to 10 ⁶	-	MHz
Input Return Loss	$RL = 20 * \log_{10} \frac{VSWR + 1}{VSWR - 1}$	10 ⁻³ to 100	-	dB
Output Return Loss	$RL = 20 * \log_{10} \frac{VSWR + 1}{VSWR - 1}$	10 ⁻³ to 100	-	dB

Table 2 Device Input Parameters

5 Output (Calculated) Parameters

Although the definitions of system cascaded parameters are pretty much standard throughout the industry, all of the formulas and assumptions used in RF Cascade Workbook 2003 are presented here in order to eliminate any ambiguity. Since formulas are contained in VBA code, you may easily modify them to suit your individual preferences without having to edit sometimes lengthy formulas in the directly cell.

One tip when viewing the cell formulas is to initially place the cursor in the cell, then click the “fx” icon on the tool bar. This will call up the function dialog box as shown in make modification and evaluation of the function output simpler because the result will be displayed as parameters are changed.



This section presents all of the formulas used in the VBA functions to calculate system cascade parameters. In the following equations, the subscript “N” refers to the current stage device parameter, while “N-1” refers to the cascaded system parameters up through and including the previous stage. Use Figure 6 as a reference when interpreting the formulas. For example, Gain_N refers to the gain of the current stage’s device. Gain_{N-1}

refers to the cascaded gain of all stages preceding the current stage. So referring to Figure 6, for N=3, DeviceGain_N = 20 dB, and NomGain_{N-1} = -5 dB. Finally, upper case names refer to decibel values (e.g., 20 dB or 20 dBm), while lower case names refer to linear values (e.g., x100 or 100 mW).

Min/max formulas are constructed using only combinations that can occur based on the available combinations of parameters, rather than just those combinations that yield absolutely the largest and smallest values. For instance, the maximum IMD3 value uses the cascaded values of MaxP[sig] and MaxIP3 because both use MaxGain.

Item	Designation	Gain (dB) Nom	NF (dB) ±	IP2 (dBm) I/O	IP3 (dBm) Nom	[sat] (dBm) Nom	Note	NBW (MHz)	Return Loss (dB) Input	Return Loss (dB) Output	Mismatch Error Neg (dB)	Mismatch Error Pos (dB)	Gain (dB) Min	Gain (dB) Max	N
1	Coax1	-5.00	0.25	5.00	60.00	50.00	35.00	500.00	15.00	15.00	0.00	0.00	-5.00	5.25	4.75
2	Amp1	20.00	0.00	5.00	20.00	10.00	-5.00	100.00	15.00	12.00	-0.28	0.27	15.00	8.47	16.52
3	Atten1	-3.00	2.00	2.00	50.00	40.00	30.00	500.00	20.00	20.00	-0.22	0.22	12.00	8.25	15.74
4	BPF1	-2.00	1.00	2.00	50.00	40.00	25.00	50.00	15.00	15.00	-0.16	0.15	10.00	5.09	14.89
5	Mix1	-8.00	0.50	8.50	10.00	0.00	-5.00	50.00	12.00	12.00	-0.40	0.38	2.00	-3.80	7.77
6	Atten2	-3.00	0.25	3.00	50.00	40.00	30.00	500.00	20.00	20.00	-0.22	0.22	-1.00	-7.27	5.23
7	LPF1	-1.00	0.25	1.00	50.00	40.00	20.00	20.00	15.00	15.00	-0.16	0.15	-2.00	-8.68	4.64
8	Amp2	34.00	0.50	3.00	45.00	35.00	20.00	50.00	15.00	15.00	-0.28	0.27	32.00	24.54	39.41

Figure 6 Formula Reference Designations

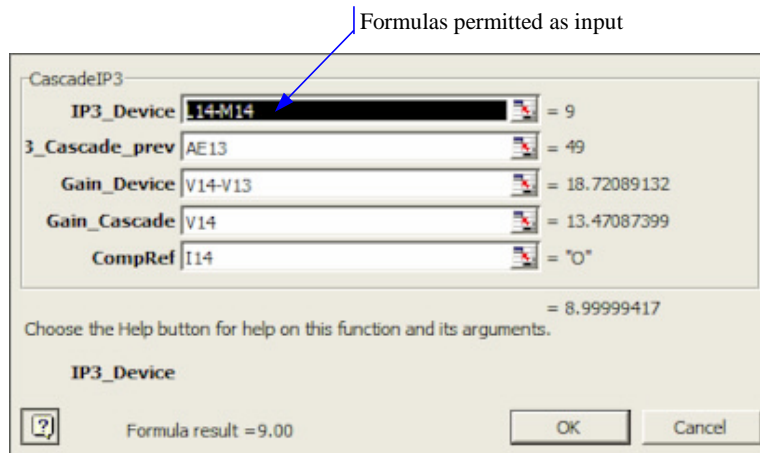


Figure 7 Function (fx) Dialog Box

Convert between decibels and non-decibels as follows:

$$P(dB) = 10 * \log_{10}(p), \quad p = 10^{\frac{P(dB)}{10}}$$

5.1 Interstage VSWR Mismatch Error (dB)

VSWR mismatch errors are caused by constructive and destructive interference of the voltage standing waves at device interfaces due to impedance mismatches. This is NOT the sum of all VSWR errors (see VSWR Mismatch column and right end of worksheet for cumulative). It is assumed that there is infinite isolation between the device's input and output ports. These equations deal with voltage, so the "20*log₁₀(v)" decibel form is used.

- Neg -

$$\begin{aligned} NegError_N &= 20 * \log_{10} [1 - |\Gamma_1| * |\Gamma_2|] \\ &= 20 * \log_{10} \left[1 - \left(10^{\frac{-DeviceVSWR_Out_{N-1}}{20}} * 10^{\frac{-DeviceVSWR_In_N}{20}} \right) \right] \end{aligned}$$

- Pos -

$$\begin{aligned} PosError_N &= 20 * \log_{10} [1 + |\Gamma_1| * |\Gamma_2|] \\ &= 20 * \log_{10} \left[1 + \left(10^{\frac{-DeviceVSWR_Out_{N-1}}{20}} * 10^{\frac{-DeviceVSWR_In_N}{20}} \right) \right] \end{aligned}$$

5.2 Gain (dB)

Gain values expressed in decibels add arithmetically for the linear operating region (potential output compression is ignored) If the “Use VSWR” cell is set to “Y,” then the interstage VSWR mismatch values are added to the total gain for Min and Max values. Gain is used in all equations except for VSWR.

- Nom -

Nominal cascaded gain uses the sum of the nominal gains for each of the stages.

$$NomGain_N = NomGain_{N-1} + DeviceGain_N$$

- Min -

Minimum cascaded gain uses the sum of the minimum gains for each of the stages.

$$MinGain_N = \begin{cases} for\ UseVSWR="Y", & MinGain_{N-1} + (DeviceGain_N - TolGain_N) + NegVSWR_N \\ for\ UseVSWR="N", & MinGain_{N-1} + (DeviceGain_N - TolGain_N) \end{cases}$$

- Max -

Maximum cascaded gain uses the sum of the maximum gains of each of the stages.

$$MaxGain_N = \begin{cases} for\ UseVSWR="Y", & MaxGain_{N-1} + (DeviceGain_N + TolGain_N) + PosVSWR_N \\ for\ UseVSWR="N", & MaxGain_{N-1} + (DeviceGain_N + TolGain_N) \end{cases}$$

5.3 Noise Figure, NF (dB)

Noise figure is effectively the reduction of signal-to-noise ratio from the cascade input to the output. Noise figure must be calculated using the non-decibel forms of gain and noise figure, and then converted in decibel. These equations deal with power, so the “ $10 * \log_{10}(v)$ ” decibel form is used.

- Nom -

Nominal cascaded noise figure uses the nominal gains and noise figures of each of the stages.

$$NomNF_N = 10 * \log_{10} (nom_nf_N)$$

$$nom_nf_N = nom_nf_{N-1} + \frac{device_nf_N - 1}{nom_gain_{N-1}}$$

- Min -

Minimum cascaded noise figure uses the maximum gains and minimum noise figures of each of the stages.

$$MinNF_N = 10 * \log_{10}(\min_nf_N)$$

$$\min_nf_N = \min_nf_{N-1} + \frac{(device_nf_N - tol_nf_N) - 1}{\max_gain_{N-1}}$$

- Max -

Maximum cascaded noise figure uses the minimum gains and maximum noise figures of each of the stages.

$$MaxNF_N = 10 * \log_{10}(\max_nf_N)$$

$$\max_nf_N = \max_nf_{N-1} + \frac{(device_nf_N + tol_nf_N) - 1}{\min_gain_{N-1}}$$

5.4 2-Tone, 2nd-Order Intercept Point, IP2 (dBm)

IP2 is the theoretical power at which the 2nd-order intermodulation products would intersect the power of the original tones (CW) the when input/output power slopes are plotted. In the linear region of operation, the original tones plot on a 1:1 (normalized) slope, while the 2nd-order products plot on a 2:1 (normalized) slope. Therefore, the product tones increase at twice the rate of the original tones, and the lines cross at the IP2 point.

- Nom -

Nominal cascaded 2nd-order intercept point. Uses the nominal gains and IP2s of each of the stages. If device input values are specified, then a conversion is first made to equivalent output IP2. The final displayed value depends on whether the system is specified for input or for output values.

$$NomIP2_N = 20 * \log_{10}(nom_ip2_N)$$

$$\frac{1}{nom_ip2_N} = \frac{1}{10^{\frac{DeviceIP2_N}{20}}} + \frac{1}{10^{\frac{NomIP2_{N-1}}{20}} * 10^{\frac{DeviceGain_N}{20}}}$$

$$I/O \text{ Conversion : } Nom \ OIP2_N = Nom \ IIP2_N + Nom \ Gain_N$$

- Min -

Minimum cascaded 2nd-order intercept point. Uses the minimum gains and minimum IP2s of each of the stages. If device input values are specified, then a conversion is first made to equivalent output IP2. The final displayed value depends on whether the system is specified for input or for output values.

$$MinIP2_N = 20 * \log_{10}(\min_ip2_N)$$

$$\frac{1}{\min_ip2_N} = \frac{1}{10^{\frac{DeviceIP2_N - TolIP2_N}{20}}} + \frac{1}{10^{\frac{MinIP2_{N-1}}{20}} * 10^{\frac{DeviceGain_N - TolGain_N}{20}}}$$

$$I/O \text{ Conversion : } Min \ OIP2_N = Min \ IIP2_N + Min \ Gain_N$$

- Max -

Maximum cascaded 2nd-order intercept point. Uses the maximum gains and maximum IP2s of each of the stages. If device input values are specified, then a conversion is first made to equivalent output IP2. The final displayed value depends on whether the system is specified for input or for output values.

$$MaxIP2_N = 20 * \log_{10}(\max_ip2_N)$$

$$\frac{1}{\max_ip2_N} = \frac{1}{10^{\frac{DeviceIP2_N + TolIP2_N}{20}}} + \frac{1}{10^{\frac{MaxIP2_{N-1}}{20}} * 10^{\frac{DeviceGain_N + TolGain_N}{20}}}$$

$$I/O \text{ Conversion : } MaxOIP2_N = MaxIIP2_N + MaxGain_N$$

5.5 2-Tone, 3rd-Order Intercept Point, IP3 (dBm)

IP3 is the theoretical power at which the 3rd-order intermodulation products would intersect the power of the original tones (CW) the when input/output power slopes are plotted. In the linear region of operation, the original tones plot on a 1:1 (normalized) slope, while the 3rd-order products plot on a 3:1 (normalized) slope. Therefore, the product tones increase at three times the rate of the original tones, and the lines cross at the IP3 point.

- Nom -

Nominal cascaded 3rd-order intercept point. Uses the nominal gains and IP3s of each of the stages. If device input values are specified, then a conversion is first made to equivalent output IP3. The final displayed value depends on whether the system is specified for input or for output values.

$$NomIP3_N = 10 * \log_{10}(\text{nom_ip3}_N)$$

$$\frac{1}{\text{nom_ip3}_N} = \frac{1}{10^{\frac{DeviceIP3_N}{10}}} + \frac{1}{10^{\frac{IP3_{N-1}}{10}} * 10^{\frac{DeviceGain_N}{10}}}$$

$$I/O \text{ Conversion : } NomOIP3_N = NomIIP3_N + NomGain_N$$

- Min -

Minimum cascaded 3rd-order intercept point. Uses the minimum gains and minimum IP3s of each of the stages. If device input values are specified, then a conversion is first made to equivalent output IP3. The final displayed value depends on whether the system is specified for input or for output values.

$$MinIP3_N = 10 * \log_{10}(\min_ip3_N)$$

$$\frac{1}{\min_ip3_N} = \frac{1}{10^{\frac{DeviceIP3_N - TolIP3_N}{10}}} + \frac{1}{10^{\frac{MinIP3_{N-1}}{10}} * 10^{\frac{DeviceGain_N - TolGain_N}{10}}}$$

$$I/O \text{ Conversion : } MinOIP3_N = MinIIP3_N + MinGain_N$$

- Max -

Maximum cascaded 3rd-order intercept point. Uses the maximum gains and maximum IP3s of each of the stages. If device input values are specified, then a conversion is first made to equivalent output IP3. The final displayed value depends on whether the system is specified for input or for output values.

$$MaxIP3_N = 10 * \log_{10}(\max_ip3_N)$$

$$\frac{1}{\max_ip3_N} = \frac{1}{10^{\frac{DeviceIP3_N + TolIP3_N}{10}}} + \frac{1}{10^{\frac{MaxIP3_{N-1}}{10}} * 10^{\frac{DeviceGain_N + TolGain_N}{10}}}$$

$$I/O \text{ Conversion: } MaxOIP3_N = MaxIIP3_N + MaxGain_N$$

5.6 Saturated Power, P[sat] (dBm)

P[sat] is the output power at which no further increase in the input power will result in an increase at the output. This is an extremely nonlinear region of operation and can only be modeled by sophisticated transfer functions that are unique to each device. Therefore, no attempt is made to model it here. Instead, the P[sat] value is used as a monitor for the power level in the system to alert the user to a potential problem. A check is made to determine whether the power level at the device input, plus the linear gain of the device, results in a power level equal to or greater than the P[sat] of the device. If so, then the output power is limited to the device's P[sat] power level. No tolerance input parameter is provided for P[sat] because it normally is not an intentional design parameter.

- Nom -

Nominal gain and P[sat] values are used per the following equation.

$$NomP[sat]_N = \begin{cases} DeviceP[sat]_N & , \text{if } P[sat]_{N-1} + DeviceGain_N > DeviceP[sat]_N \\ P[sat]_{N-1} + DeviceGain_N & , \text{if } P[sat]_{N-1} + DeviceGain_N \leq DeviceP[sat]_N \end{cases}$$

- Min -

Same as Nominal, except the MinGain value is used since it results in a lower power through the cascade.

$$MinP[sat]_N = \begin{cases} DeviceP[sat]_N & , \text{if } P[sat]_{N-1} + DeviceGain_N - TolGain_N > DeviceP[sat]_N \\ MinP[sat]_{N-1} + DeviceGain_N - TolGain_N & , \text{if } P[sat]_{N-1} + DeviceGain_N - TolGain_N \leq DeviceP[sat]_N \end{cases}$$

- Max -

Same as Nominal except the MaxGain value is used since it results in a higher power through the cascade.

$$MaxP[sat]_N = \begin{cases} DeviceP[sat]_N & , \text{if } P[sat]_{N-1} + DeviceGain_N + TolGain_N > DeviceP[sat]_N \\ MaxP[sat]_{N-1} + DeviceGain_N + TolGain_N & , \text{if } P[sat]_{N-1} + DeviceGain_N + TolGain_N \leq DeviceP[sat]_N \end{cases}$$

5.7 Signal Power, P[sig] (dBm)

P[sig] is the power of the signal as it propagates through the cascade, and is increased or decreased by the linear gain of each stage. Note that it is possible for the calculated value to exceed the P[sat] value, because no adjustment is made. This is done to prevent the annoying case where all of the other power dependant values are thrown off by an adjusted output power value. There is an indication of a saturated condition given in the alert column labeled "Note."

- Nom -

$$NomP[sig]_N = P[sig]_{N-1} + DeviceGain_N$$

- *Min* -

$$MinP[sig]_N = P[sig]_{N-1} + DeviceGain_N - TolGain_N$$

- *Max* -

$$MaxP[sig]_N = P[sig]_{N-1} + DeviceGain_N - TolGain_N$$

5.8 Noise Bandwidth, NBW (MHz)

Cascaded noise bandwidth merely checks the NBW of the current device, and sets the system NBW to the lesser of either the device NBW or the system's previous NBW. Only a nominal value is calculated.

$$NBW_N = \begin{cases} DeviceNBW_N & ,if \ DeviceNBW_N < NBW_N \\ NBW_N & ,if \ DeviceNBW_N \geq NBW_N \end{cases}$$

5.9 Noise Power, P[n] (dBm)

P[n] is the power of the noise as it propagates through the cascade, and is increased or decreased by the gain noise figure and NBW of each stage. Since the system temperature is given in Celsius degrees, 273.15 is added to get equivalent Kelvin degrees. NBW is given in MHz, so a multiplication by 10^6 is done. Note that MaxGain corresponds to MinNF in the cascaded results, and vice versa.

- *Nom* -

$$P[n]_N = 10 * \log_{10} \left\{ (SystemTemperature + 273.15) * NBW_N * 10^6 + Gain_N + NF_N \right\}$$

- *Min* -

$$MinP[n]_N = 10 * \log_{10} \left\{ (SystemTemperature + 273.15) * NBW_N * 10^6 + MinGain_N + MaxNF_N \right\}$$

- *Max* -

$$MaxP[n]_N = 10 * \log_{10} \left\{ (SystemTemperature + 273.15) * NBW_N * 10^6 + MaxGain_N + MinNF_N \right\}$$

5.10 Signal to Noise Ratio, SNR (dB)

SNR is the difference between the noise power level and the signal power level.

- *Nom* -

$$NomSNR_N = NomP[sig]_N - NomP[n]_N$$

- *Min* -

$$MinSNR_N = MinP[sig]_N - MaxP[n]_N$$

- *Max* -

$$MaxSNR_N = MaxP[sig]_N - MinP[n]_N$$

5.11 Saturated Dynamic Range, SDR (dB)

SDR is the difference between the saturated power level and the noise power level, minus the minimum system SNR. This is different than the standard dynamic range (DR), which references the 1 dB compression point (P1dB), since RF Cascade Workbook 2003 does not calculate P1dB.

- *Nom* -

$$NomSDR_N = NomP[sat]_N - NomP[n]_N - MinSystemSNR$$

- *Min* -

$$MinSDR_N = MinP[sat]_N - MaxP[n]_N - MinSystemSNR$$

- *Max* -

$$MaxSDR_N = MaxP[sat]_N - MinP[n]_N - MinSystemSNR$$

5.12 Spurious-Free Dynamic Range, SFDR (dB)

SFDR is the theoretical power of two tones at the system input that would generate 3rd-order products at the output with a power just equal to the noise power at the output.

- *Nom* -

$$NomSFDR_N = \frac{2}{3} * (NomIP3_N - NomP[n]_N)$$

- *Min* -

$$MinSFDR_N = \frac{2}{3} * (MinIP3_N - MaxP[n]_N)$$

- *Max* -

$$MaxSFDR_N = \frac{2}{3} * (MaxIP3_N - MinP[n]_N)$$

5.13 3rd -Order Intermodulation Product Power, IMD3 (dBm)

IMD3 intermod products are caused by the nonlinear mixing of two input tones of equal amplitude. It is essentially the same process as in a mixer for frequency conversion, where an infinite series is produced that consists every possible frequency according to $\pm j * \text{Tone1} \pm k * \text{Tone2}$. The 3rd -order products that most likely fall inband at the output are $\pm 2 * \text{Tone1} \pm \text{Tone2}$ and $\pm \text{Tone1} \pm 2 * \text{Tone2}$. In reality, the powers of most products are below the noise power. A smaller (minimum) IMD3 is better.

- *Nom* -

$$NomIMD3_N = NomP[sig]_N - 2 * (NomIP3_N - NomP[sig]_N)$$

- *Min* -

$$MinIMD3_N = MaxP[sig]_N - 2 * (MaxIP3_N - MaxP[sig]_N)$$

- *Max* -

$$MaxIMD3_N = MinP[sig]_N - 2 * (MinIP3_N - MinP[sig]_N)$$

5.14 Delta 3rd -Order Intermodulation Products, Δ IMD3 (dB)

Delta IMD3 intermod is the difference between the IMD3 product power, IMD3, and the signal power, P[sig].

- *Nom* -

$$Nom\Delta IMD3_N = NomP[sig]_N - NomIMD3$$

- *Min* -

$$Min\Delta IMD3_N = MinP[sig]_N - MaxIMD3$$

- *Max* -

$$Max\Delta IMD3_N = MaxP[sig]_N - MinIMD3$$

6 Graphs

Two worksheets with graphs are provided by default. You may, of course, add as many graphs as necessary to plot parameters. Each graph adds about 10 kBytes to the file size. A lot of online help is available through Excel for working with graphs. Most parameters can be modified by double-clicking on the item you want to change. When a graph is selected, the “Chart” menu item appears on the main menu bar (see Figure 9). From there, you can access all of the graph setup parameters.

If you want to add another graph worksheet, the simplest way is to right-click on the bottom worksheet tab and select the “Move or copy...” menu item, and instruct Excel to make a copy per Figure 8

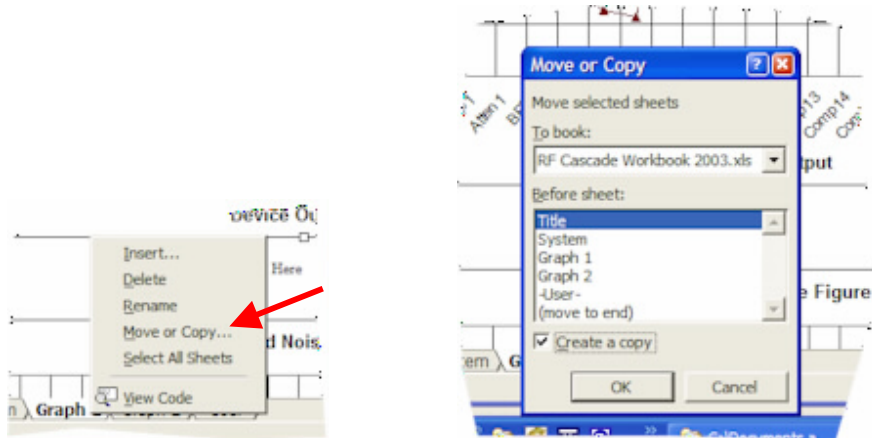


Figure 8 Copying A Graph Worksheet

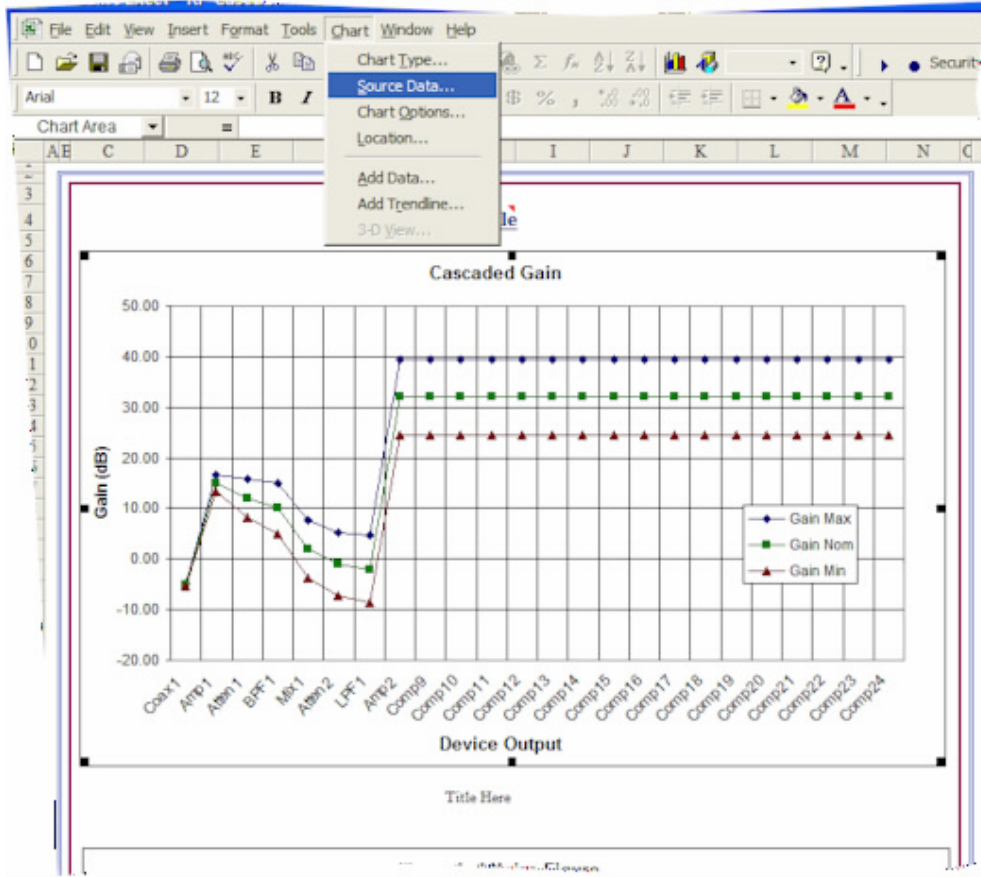


Figure 9 Graph

7 Conversion Formulas

These formulas were implemented in previous version of RF Cascade Workbook as popup windows, but are instead supplied here. This reduces the size of every new workbook.

7.1 Noise Temperature – to – Noise Figure

$$\text{Noise Temperature (K)} = 290 * \left(10^{\frac{\text{Noise Figure (dB)}}{10}} - 1 \right)$$

$$\text{Noise Figure (dB)} = 10 * \log_{10} \left(\frac{\text{Noise Temperature (K)}}{290} + 1 \right)$$

7.2 VSWR – to – Return Loss

$$\text{VSWR (:1)} = \frac{10^{\frac{\text{ReturnLoss (dB)}}{20}} + 1}{10^{\frac{\text{ReturnLoss (dB)}}{20}} - 1}$$

$$\text{Return Loss (dB)} = 20 * \log_{10} \left(\frac{\text{VSWR} + 1}{\text{VSWR} - 1} \right)$$