Microwave System Calculator: Tutorial #1
Quickly change system performances

We start this short demo on MwSC looking at one of the Maxim Application Note you may find at http://www.maxim-ic.com/an2371 :
AN2371: Consider Overall Cascaded Performance When Comparing Integrated RF Frequency Mixers to Passive Mixer.

Extracted from the Application Note, <<... *the following application note compares the features of an integrated RF and passive mixer solution. It discusses the main features of both solutions and shows the main advantages of an integrated over a passive solution ...*>>

OK, but what happens if we still need of a discrete solution and we want the performances of the integrated one?
Let's see what we can do using MwSC.

Let's summarize the characteristics of the integrated solution (MAX9993), we assume them as the required specifications for the system we would like to design (frequency band – PCS and UMTS: 1850 – 1910 MHz):

Conversion Gain	8.5 dB
Noise Figure	9.5 dB
IIP3	23.5 dBm
OIP3	32 dBm

First of all, let's verify the conclusion on the discrete solution shown on the Application Note:

MwSC output (data1.txt): discrete solution presented in AN2371
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Input chain:

Stage	Gain[dB]	NF[dB]	IIP3[dBm]	P1dB[dBm]	Psat[dBm]
HJK-19MH	-7.50	7.50	29.00	16.00	
Needed PreAmp to get required specification	16.00	2.00	17.50	13.20	

Result of calculation (by stage):

Stage	Pin[dBm]	Gain[dB]	NF[dB]	IIP3[dBm]	Pout[dBm]
HJK-19MH	-20.00	-7.50	7.50	29.00	-27.50
PreAmp	-27.50	8.50	9.50	23.54	-11.50

Result of calculation (system level):

Pin[dBm] = -20.00	**IM3[dBc]** = -87.09	**NF[dB]** = 9.50
Gain[dB] = 8.50	**IIM3[dBm]** = -107.09	
Pout[dBm] = -11.50	**OIM3[dBm]** = -98.59	
	IIP3[dBm] = 23.54	
	OIP3[dBm] = 32.04	

So to be able to get required performances, we would need of a not realizable IF amplifier as it is correctly stated in the Application Note.
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But is what we can do with some commercial amplifier still very far from what we need?
Let's try using the Minicircuits amplifier PHA-1+.

MwSC output(data2.txt): using Minicircuits PHA-1+
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Input chain:

Stage	Gain[dB]	NF[dB]	IIP3[dBm]	P1dB[dBm]	Psat[dBm]
HJK-19MH	-7.50	7.50	29.00	16.00	
PHA-1+	13.00	2.60	29.00	22.40	

Result of calculation (by stage):

Stage	Pin[dBm]	Gain[dB]	NF[dB]	IIP3[dBm]	Pout[dBm]
HJK-19MH	-20.00	-7.50	7.50	29.00	-27.50
PHA-1+	-27.50	5.50	10.10	28.29	-14,50

Result of calculation (system level):

Pin[dBm] = -20.00	**IM3[dBc]** = -96.58	**NF[dB]** = 10.10
Gain[dB] = 5.50	**IIM3[dBm]** = -116.58	
Pout[dBm] = -14.50	**OIM3[dBm]** = -111.08	
	IIP3[dBm] = 28.29	
	OIP3[dBm] = 33.79	

and so here is what we get:

Conversion Gain	5.5 dB [**-3.0 dB**]
Noise Figure	10.1 dB [**+0.6 dB**]
IIP3	28.29 dBm [**+4.79 dBm**]
OIP3	33.79 dBm [**+1.79 dBm**]

we got better linearity performances losing something on noise figure and something more on conversion gain.
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Is this still not acceptable? Do you prefer to lose something on linearity and have a better noise figure?
Let's go for a third solution adding a pre-amplifier (GALI5):

MwSC output(data3.txt): using Minicircuits Gali5 and PHA-1+
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Input chain:

Stage	Gain[dB]	NF[dB]	IIP3[dBm]	P1dB[dBm]	Psat[dBm]
GALI5	18.63	3.61	11.52	16.83	
HJK-19MH	-7.50	7.50	29.00	16.00	
PHA-1+	13.00	2.60	29.00	22.40	

Result of calculation (by stage):

Stage	Pin[dBm]	Gain[dB]	NF[dB]	IIP3[dBm]	Pout[dBm]
GALI5	-20.00	18.63	3.61	11.52	-1.37
HJK-19MH	-1.37	11.13	3.73	7.90	-8.87
PHA-1+	-8.87	24.13	3.84	7.48	4.13

Result of calculation (system level):

Pin[dBm] = -20.00	**IM3[dBc]** = -54.96	**NF[dB]** = 3.84
Gain[dB] = 24.13	**IIM3[dBm]** = -74.96	
Pout[dBm] = 4.13	**OIM3[dBm]** = -50.83	
	IIP3[dBm] = 7.48	
	OIP3[dBm] = 31.61	

and we finally get:

Conversion Gain	24.13 dB [**+15.63 dB**]
Noise Figure	3.84 dB [**-5.66 dB**]
IIP3	7.48 dBm [**-16.02 dBm**]
OIP3	31.61 dBm [**-0.39 dBm**]

That is another solution with enhanced conversion gain and noise figure but losing on input linearity.
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Finally let's compare the costs of the 3 solutions (stock > 50):

solution1	8.6$ (MAX9993)	8.6 $	Cheapest
solution2	13.15$ (HJK-19MH) + 1.49$ (PHA-1+)	14.64 $	Best linearity
solution3	1.49$ (Gali5+) + 13.15$ (HJK-19MH) + 1.49$ (PHA-1+)	16.13 $	Best Conversion Gain / Noise Figure

So we have a cheap, a linear and a CG/NF optimized solution to choose from.

We have shown how simple, fast and useful could be MwSC to guide you towards the right system decisions.

Useful links:
http://www.maxim-ic.com/an2371 (Maxim Application Note)
http://www.minicircuits.com/products/fm_sm_hi_ip3_1.html (HJK-19MH)
http://www.minicircuits.com/products/amplifiers_monolithic.html (PHA-1+, GALI5+)

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2010/04/24
http://www.microwave-system-calculator.com