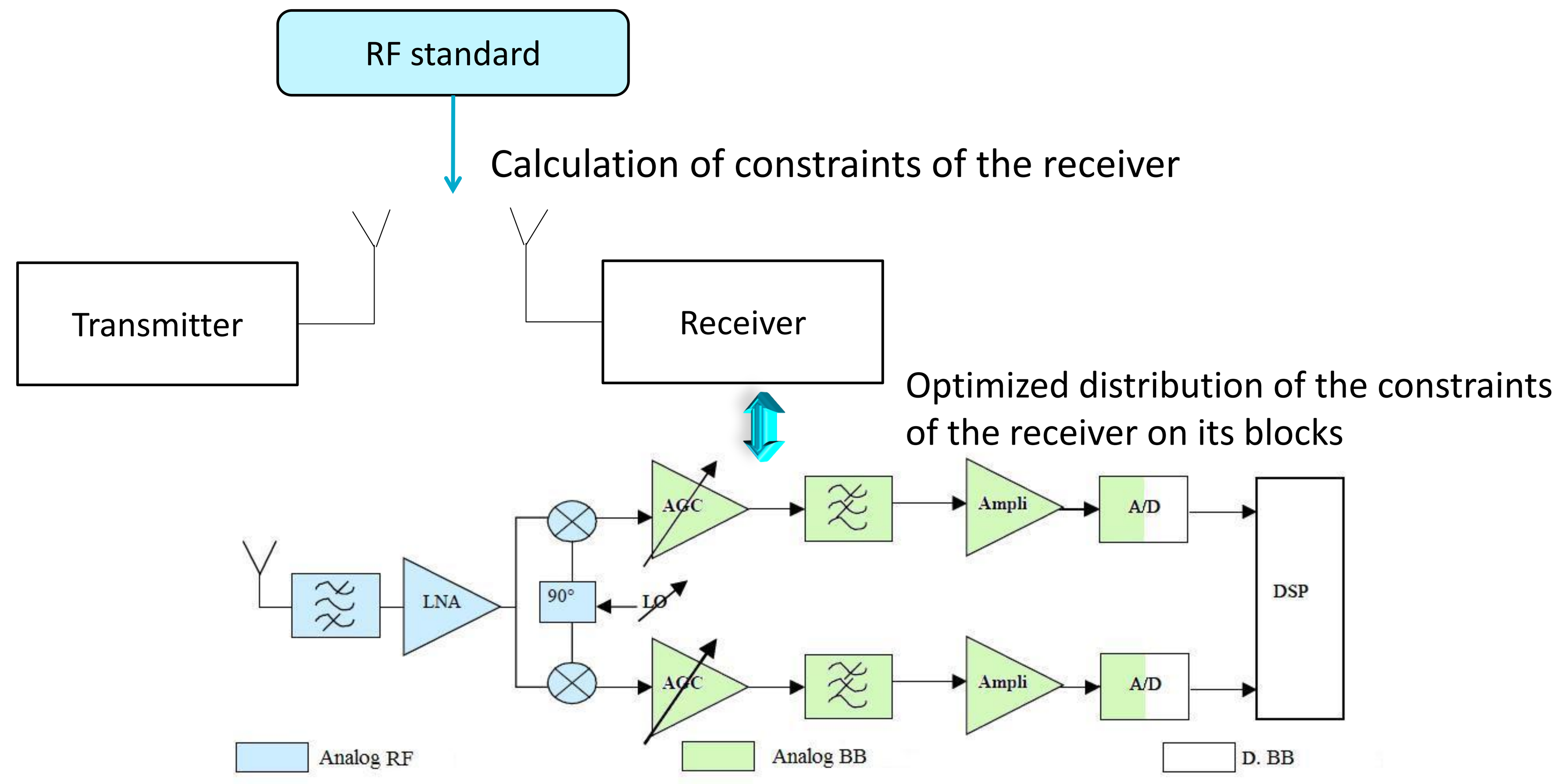
Optimal specification of a receiver blocks from global specifications

Example of IEEE 802.15.4

Papy Ndungidi, Ursula Dongmo, Fortunato Dualibe, Carlos Valderrama, *Member, IEEE*
Electronics and Microelectronics Department – Faculty of Engineering, Mons (FPMs)
University of Mons (UMONS) – Mons – Belgium
First_name.Name@umons.ac.be

Introduction

This poster presents a novel method for calculating optimal specifications of the blocks of a RF receiver from the constraints of a standard and architecture. An application of the method is made for the standard IEEE 802.15.4. The novelty of this method is to offer optimal and realistic solutions, thanks to a nonlinear constrained optimization.



RF Filter	LNA	Mixer	Channel Filter	AGC	AA Filter	ADC
Gain NF Rec. Band Order	Gain NF IIP3 IIP2	Gain NF IIP3	Gain NF Band width Order	NF IIP3 $Gain_{Max}$ $Gain_{min}$	Gain NF $f_{sampling}$	Dynamic Order Resolution IIP3, …

Tools and methods

Parameters	IEEE 802.15.4 for PHY 2450 MHz
Frequency Band	2400-2483.5 MHz
Channel Bandwidth	2 MHz
Channel spacing	5 MHz
Coverage	Worldwide
Spread Spectrum Technique	DSSS
Modulation	O-QPSQ with MSK
Bit Rate	250 kbit/s
Symbol Rate	62.5 ksymbol/s
Number of channels	16
Receiver Sensitivity	-85 dBm
Receiver Maximum Input Level	-20 dBm
PER	1%
Adjacent channel rejection	0 dB
Alternate channel rejection	30 dB

IEEE 802.15.4 standard specifications

Calculation of the global specifications of the receiver

E_b/N_o = **7.78 dB**
SNR_{out} = **-1.14 dB**
SNR_{in} = **25.82 dB**
NF = **26.96 dB**
DR_{in} = **65 dBm**
DR_r = **63.6 dB**
S_{fs} = **13 dBm** (equivalent to 1 V under a 50 Ω load)
G_{min} = **33 dB**
G_{max} = **100.24 dB**

Choice of an homodyne architecture

$$F = 1 + (F_{RF} - 1) + \frac{F_{LNA} - 1}{G_{RF}} + \frac{F_{MIX} - 1}{G_{RF}G_{LNA}} + \frac{F_{FC} - 1}{G_{RF}G_{LNA}G_{MIX}} + \frac{F_{CAG} - 1}{G_{RF}G_{LNA}G_{MIX}G_{FC}} + \frac{F_{FAA} - 1}{G_{RF}G_{LNA}G_{MIX}G_{FC}G_{CAG}}$$

$$\frac{1}{IIP3^2_{total}} = \frac{1}{IIP3^2_{RF}} + \frac{G_{RF}}{IIP3^2_{LNA}} + \frac{G_{RF}G_{LNA}}{IIP3^2_{MIX}} + \frac{G_{RF}G_{LNA}G_{MIX}}{IIP3^2_{FC}} + \frac{G_{RF}G_{LNA}G_{MIX}G_{FC}}{IIP3^2_{CAG}} + \frac{G_{RF}G_{LNA}G_{MIX}G_{FC}G_{CAG}}{IIP3^2_{FAA}}$$

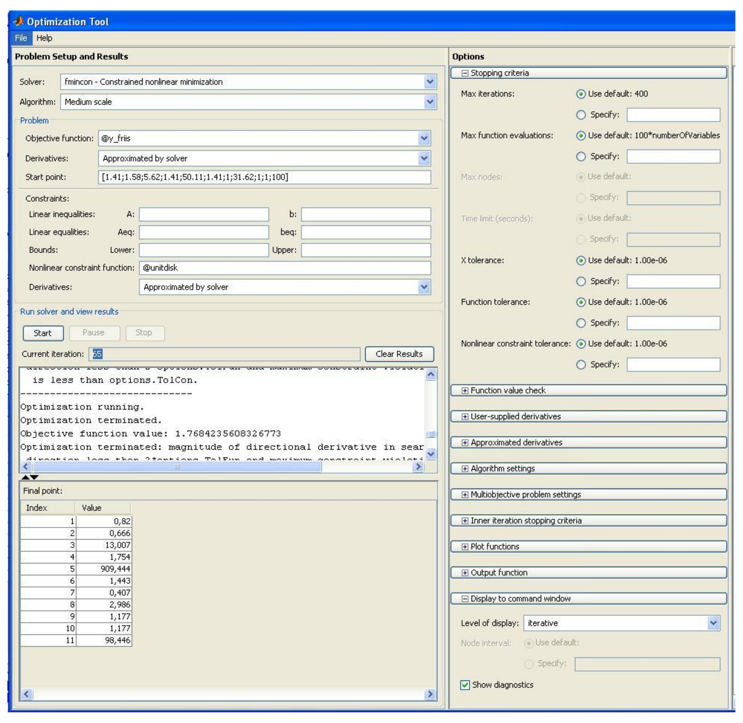
Constrained nonlinear optimization problem.

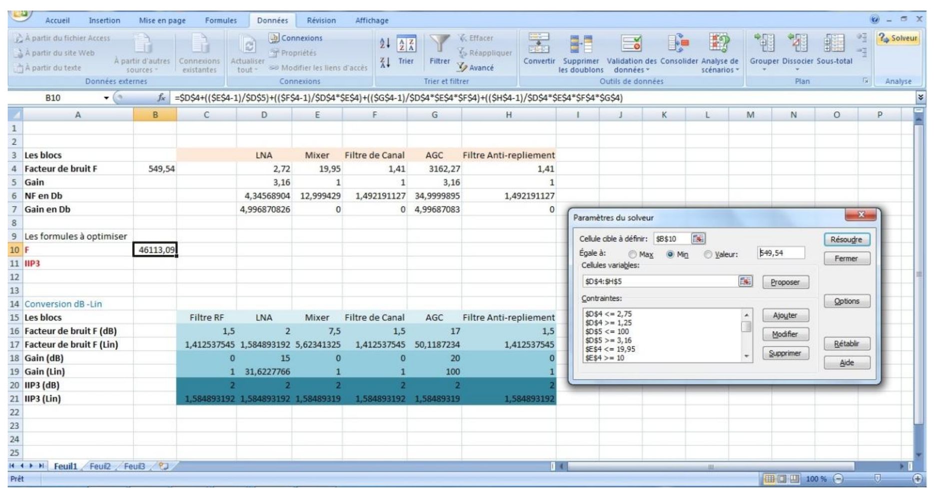
The problem can be summarized in the minimization of a cost function (F(=*nf*) or *IIP3*), under two types of constraints:

1. the sum of the gains of all blocks in the chain must be between $Gain_{Max}$ and $Gain_{min}$
2. the possible values of solutions are either fixed or within a certain range (see Table: Realistic values)

Realistic values

Blocs	Gain (dB)	NF (dB)	IIP3 (dBm)
Filtre RF	0	1.5	13.42
LNA	5 à 20	1 à 4.4	-22 à 15.8
Mixer	0 à 17.5	10 à 13	-12 à 24
Filtre de canal	0	1.5	13.42
CAG	5 à 40	5 à 35	4.38 à 20
FAA	0	1.5	13.42



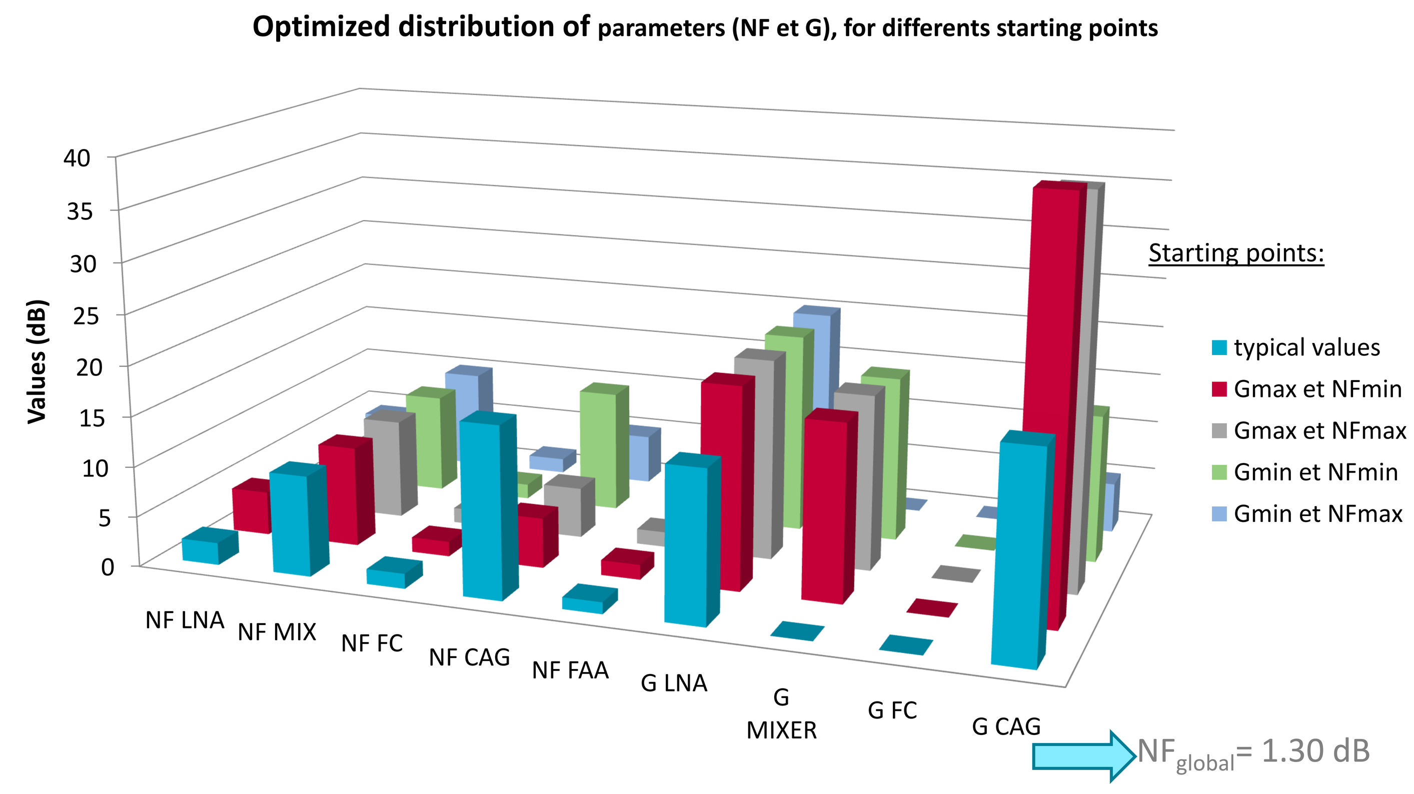


Generalized Reduced Gradient (**GRG**) with the solver of MS Excel

Sequential Quadratic Programming (**SQP**) with the optimization tool of Matlab

Results

Examples of result



[dB]	Typical values	G_{max} NF_{min}	G_{max} NF_{max}	G_{min} NF_{min}	G_{min} NF_{max}
$NF_{LNA} \in [1, 4.4]$	2.22	4.39	1	1	4.39
$NF_{MIX} \in [10, 13]$	10.00	10	10.000	10.0007	10
$NF_{FC} = 1.5$	1.49	1.49	1.501	1.5001	1.49
$NF_{CAG} \in [5, 35]$	16.99	4.99	5.048	12.248	4.99
$NF_{FAA} = 1.5$	1.16	1.49	1.501	1.5	1.49
$G_{LNA} \in [5, 20]$	14.99	20	19.99	19.99	20
$G_{MIX} \in [0, 17.5]$	0	17.49	17.44	16.60	0
$G_{FC} = 0$	0	0	0	0	0
$G_{CAG} \in [5, 40]$	20	40	38.406	14.6905	4.99
Min NF_{Total}	1.30	1.30	1.30	1.30	1.30

33 dB < $[G_{LNA}+G_{MIX}+G_{FC}+G_{CAG}+G_{FAA}]_{Opt.}$ < 100.24 dB

Conclusion

We have proposed an optimization method that suggests an optimal distribution of the parameters of specification on the various blocks of the system, according to the constraints of each block, and minimizes system constraints such as noise figure and total distortion of 3rd order.
Once we put minimization problem in its general form, we applied two algorithms for optimization: the GRG and SQP.

Another way to do it would use the multi-objective optimization that would give optimum gain values for both cost functions together, not separately.