IBERCHIP 2010 - XVI Workshop, Iguazu Falls, Brazil - February 23 to 25, 2010

Using Statistical Simulations for Improving IIP2 in Direct Conversion Receiver

Antonio Felipe de Freitas Silva
Microelectronics and Embedded Systems Laboratory
Federal University of Rio Grande do Norte
Natal - RN/Brazil, antonio.felipe.rn@gmail.com

Fernando Rangel de Sousa
Integrated Circuits Laboratory
Federal University of Santa Catarina
Florianopolis-SC/Brazil, rangel@ieee.org

Sebastian Yuri Catunda
Federal University of Maranhão
Belm - MA,Brazil, catunda@dee.ufma.br

Abstract

The direct conversion receivers have widely been used because the possibility of higher integration. However, this architecture presents high intolerance to even-order distortion, DC offset and 1/f noise. In this paper we present the use of statistical simulations for predicting and further improving the Second Order Intermodulation Interception Point (IIP2) of homodyne down-converter. The improvement is achieved by using a circuit based on the use of three instead of two mixers for recovering the in-phase and quadrature components of bidimensional modulated signals. We present results obtained from simulations in a circuit designed on the 130 nm IBM RF technology. At the worst case, the improvement archived is higher than 20 dB.

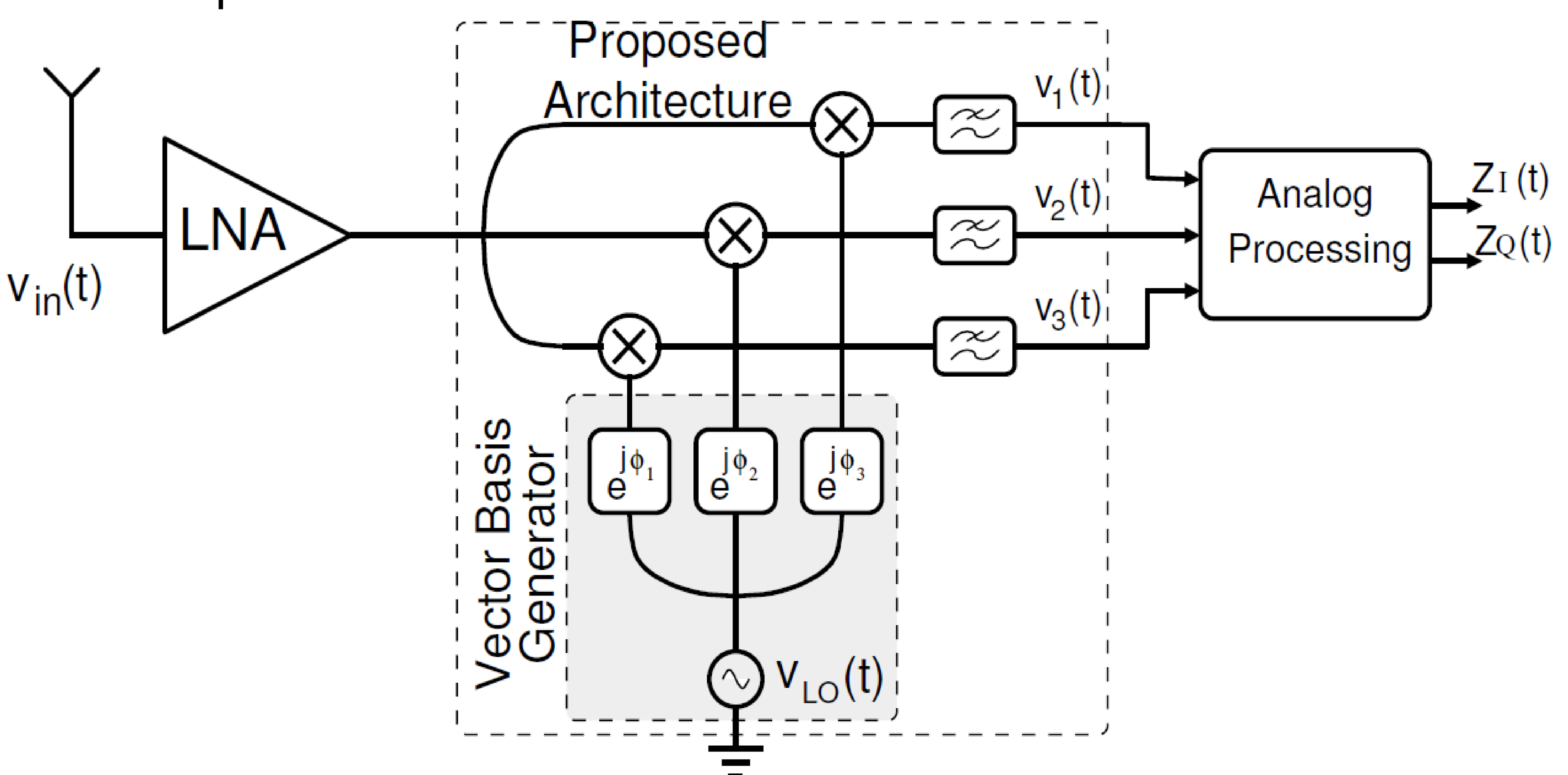
PROPOSED DCR ARCHITECTURE

Many methods for reducing the effects of second order distortion have been proposed, most of them are founded on post digital signal processing. If the distortion component is high enough to block the desired signal or to saturate the baseband amplifiers, these methods just do not work. From this observation, we propose the architecture solution illustrated in the figure below.

From the figure, a straight-forward analysis can be derived [7]. The baseband voltages before analog processing may be given,taking into account the second order effects, by:

$$v_i(t) = A_i a(t)\cos(\theta(t) - \phi_i) + B_i a^2(t) \qquad i = 1,2,3$$

where A_i and B_i are respectively the first and second order gains from the down-conversion path, including the local oscillator's amplitude, mixer's conversion gain and filter's loss. ϕ_i is baseband relative phase shift.



Then, a linear system is set with three equations and three variables, so a(t) and θ(t) can be encountered without being influenced by the squared envelope. In the rectangular form, a(t) and θ(t) becomes:

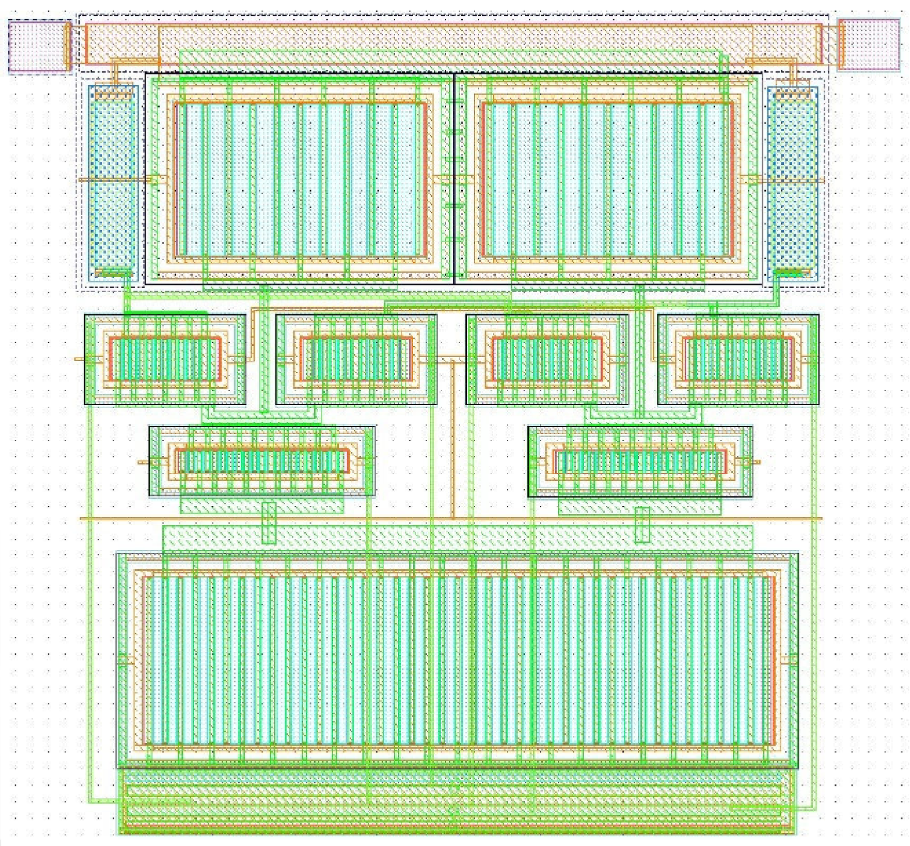
$$Z_I(t) = r_I v_1(t) + s_I v_2(t) + t_I v_3(t)$$

$$Z_Q(t) = r_Q v_1(t) + s_Q v_2(t) + t_Q v_3(t)$$

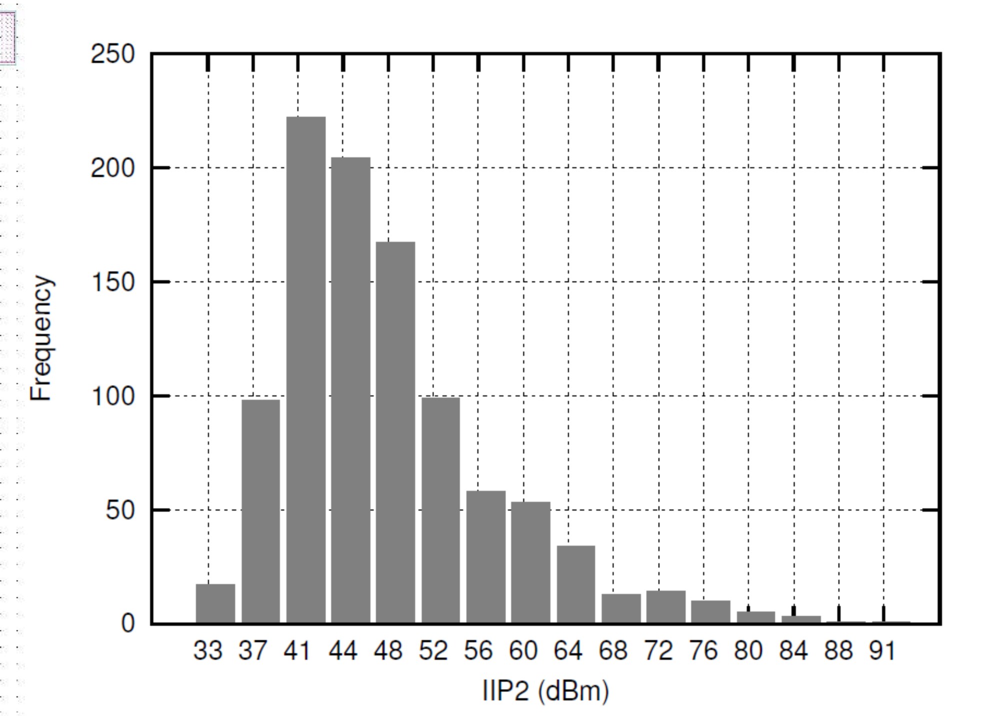
r(I,Q), s(I,Q), t(I,Q) are weighting constants dependent on A_i, B_i and ϕ_i [7].

CMOS Prototype

The main purpose of our research is to build a wideband front-end for a software defined radio platform to be used in a cognitive radio. We have designed a mixer in the IBM 0.13 μm technology. The topology chosen was the based on the Gilbert cell, since its differential characteristic minimizes the even order nonlinearities. However, component dimensions and process parameters vary during circuit fabrication.The mismatch resulted will cause residual second order nonlinearities. The following figures show the layout of the designed mixer and a histogram of the Second Order Input Interception Point (IIP2). It was obtained from Monte Carlo simulations considering only component dimension mismatches.



Layout of the designed CMOS Gilbert cell mixer



Histogram of the IIP2 resulted from the mixer's Monte Carlo analysis when components parameters are varied

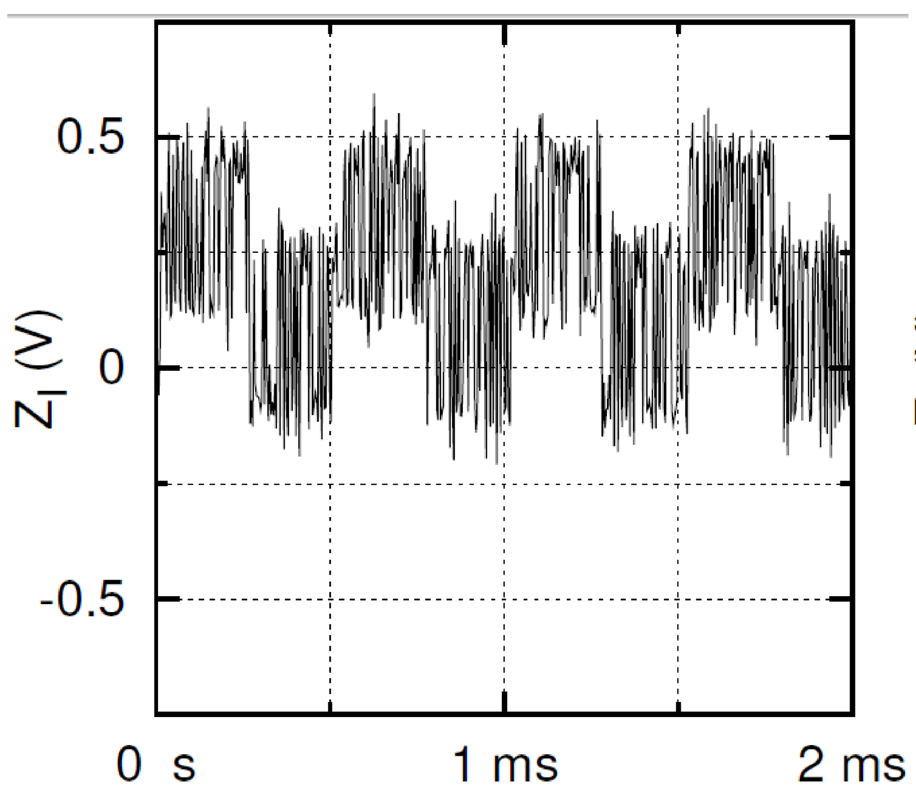
Simulation Results

We did simulations in a receiver based on the Gilbert cell mixer. Using Monte Carlo analysis over Harmonic Balance simulations in the Agilent ADS environment, we obtained the individuals mixer's IIP2 and then the effective system's IIP2. The results are compiled in Table I.

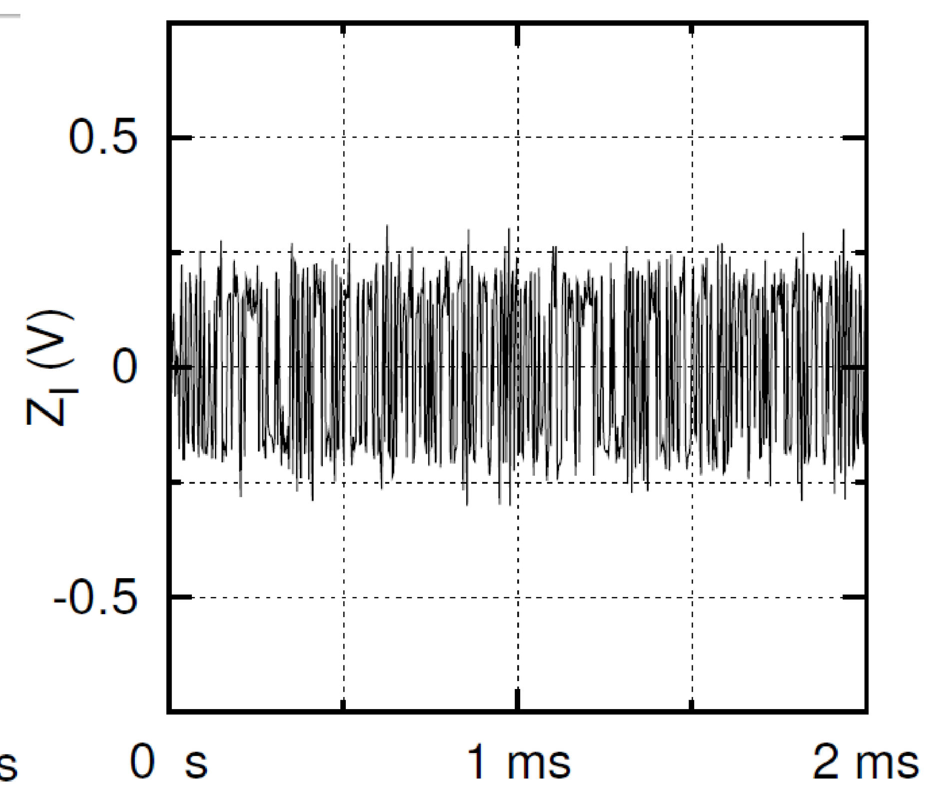
TABLE I
MIXER'S AND EFFECTIVE SYSTEM'S IIP2

Individual mixer's IIP2 (dBm)			Effective system's IIP2 (dBm)	
Mixer 1	Mixer 2	Mixer 3	Z_I	Z_Q
43.5	51.8	50.0	74.9	95.8
40.7	70.6	43.6	74.9	95.8
47.2	52.2	47.5	95.5	95.061

One important testbench was to expose the conventional and the proposed DCRs to a QPSK modulated signal in presence of an AM modulated interferer. The envelop of the interferer was modulated by a 2 kHz square wave signal. The results can bee seen in the figures below.



Conventional Architecture



Proposed Architecture

References

[1] S. Haykin, "Cognitive Radio: Brain-empowered wireless communications", in IEEE Journal on Selected Areas in Communication, vol.23, no.2, pp.201-220, February 2005.
[2] Behzad Razavi, RF Microelectronics, Prentice Hall PTR, 1998.
[3] B. Razavi, "Design Considerations for Direct-Conversion Receivers", in IEEE Transactions on Circuits and Systems, Part II, vol.44, pp.428-435, June 1997.
[4] Faulkner, M., "DC offset and IM2 removal in direct conversion receivers", in IEE Proceedings on Communications , vol.143, pp.179-184, 2002.
[5] F. R. Sousa and B. Huyart, "Five-port receiver with improved sensitivity", in Microwave and Optical Technology Letters, vol.50, no.11, pp.2945- 2947, November 2008.
[6] G. Neveux, B. Huyart and G. J. Rodriguez-Guisantes, "Wide-Band RF Receiver Using the "Five-Port" Technology", in IEEE Transactions on Vehicular Technology, vol.53, no.5, pp.1441-1451, September 2004.
[7] F. R. Sousa, B. Huyart and R. N. Lima, "A new-method for automatic calibration of 5-port reflectometers", in Journal of Microwave and Optoelectronics, vol.3, no.5, pp.135-144, July 2004.

CNPq