PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Gerardo Castellano

XXX Cycle

Training and Research Activities Report – Third Year

Tutor: Davide De Caro

1. Information

I received the M.S. degree cum laude in Electronic Engineering the 26th March 2014 from University of Napoli "Federico II". From June to October 2014 I received a scholarship as part of the research project "VEM, Virtual Energy Management". I belong to XXX cycle of ITEE PhD and Marvell (Italia) - DIETI finance my fellowship in VLSI systems. My tutor is Prof. Davide De Caro.

2. Study and training activities (accounting also the first and second PhD years)

Year	Lecture/Activity	Type	Credits	Certification
1	The Entrepreneurial Analysis of Engineering Research Project	Ad hoc module	3	x
1	Modelli, metodi e software per l'ottimizzazione	Ad hoc module	4	x
1	Designing and writing scientific manuscripts for publication in English language scholarly journals	Ad hoc module	3	x
1	Gruppo Elettronica PhD School – Siena 2015	Doctoral School	4	x
1	Cadence training course - "Analog Modeling with Verilog-A vMMSIM11.1 (iLS)"	External Module	1	x
1	Cadence training course - "Virtuoso AMS for Digital Designers v12.1 (iLS)"	External Module	1	x
1	Smoothed Particle Machine Perception: a proposed method for sensor fusion and physical-spacial perception	Seminar	0,2	x
1	Risk management meets model checking: fault tree analysis and model-based testing via games	Seminar	0,4	x
1	The iCub project: An open platform for research in robotics & artificial intelligence	Seminar	0,3	x
1	A New Look at Electro-Magnetic Induction	Seminar	0,5	x
1	Affidabilità di dispositivi e moduli elettronici di potenza	Seminar	1,2	x
1	Agents with Truly Perfect Recall	Seminar	0,2	x
1	Passivity-based control of nonlinear physical systems: A port-Hamiltonian approach	Seminar	0,4	x
1	Lagrangean relaxation and Set Covering	Seminar	1	x
1	On the complexity of Temporal Equilibrium Logic	Seminar	0,2	x
2	IEEE Circuits and Systems (CAS) Day – Como 2016	Doctoral School	1	x
2	Topics on Microelectronics – Pavia 2016	Doctoral School	4	x
2	Rohde & Schwarz Research & Education Seminar Tour 2016 "New Frontiers in RF Measurements" – Pavia 2016	Doctoral School	1	x
2	Memory technologies for Android based systems	Seminar	0,4	x
2	Test and Diagnosis of Integrated Circuits	Seminar	2,4	x
2	Hardware Security and Trust	Seminar	2,4	x
2	Gallium Nitride for power applications: benefits, challenges, and state of the art	Seminar	0,4	x

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20	0	3	0	7	1	5	**16**	10	0	0	1	5	0	0	**6**	8	0	0	0	0	0	0	**0**	**22**	**30-70**
Seminars	5	0	0,6	2,2	1,4	0	0,2	**4,4**	5	5,6	0	0	0	0	0	**5,6**	0	0	0	0	0	0	0	**0**	**10**	**10-30**
Research	35	10	6	8	2	9	5	**40**	45	5	10	9	5	10	10	**49**	52	10	10	10	10	10	10	**60**	**149**	**80-140**
	60	10	9,6	10	10	10	10	**60**	60	11	10	10	10	10	10	**61**	60	10	10	10	10	10	10	**60**	**181**	**180**

3. Research activity

In this third year, in collaboration with the Microelectronics Lab of University of Pavia, I dealt with the design and testing of a SAW-less digitally-assisted diversity receiver. A typical mobile communication system is made of a main transceiver and one or more diversity receivers (*MIMO* structure). This approach is a way to add redundancy to the reception of the signal, improving the capacity and the quality of the communication channel. Usually the main receiver and transmitter share the same antenna through a SAW-based duplexer, while the diversity receiver has a dedicated antenna. This scenario is particularly critical in a FDD system: due to the proximity of the two antennas, part of the transmitted signal can be coupled to the diversity receiver. The poor linearity of the diversity receiver, the reciprocal mixing of the TX leakage with the phase noise of the local oscillator and the transmitter broadband noise that directly falls into the receiver band could bring the receiver to desensitization. To avoid these drawbacks, off-chip SAW filters are commonly used to filter out the self-interference components as well as unwanted out-of-band interferers coming from the external environment. That we propose to solve all these problems in a SAW-less diversity receiver is a fully integrated mixed-signal system. At the input of the diversity receiver

the small wanted signal comes with out of band blocker and the strong transmitter leakage signal. Therefore, a main canceler is used to reduce the TX leakage power at the beginning of the receiving chain [1], relaxing the linearity requirement of the chain. However, even the transmitter broadband noise that directly falls into the Rx band can degrades the diversity receiver sensitivity. Considering that, in this project, the receiver noise figure is approximatively 5.2 dB, assuming an antenna coupling of 25dB and a transmitter noise power of -155dBc/Hz, in the worst case (transmitter at full power 23dBm) the effective noise figure of the diversity receiver increases to 17 dB, which corresponds to a noise figure degradation of 12 dB. In order to face this problem, an auxiliary receiver [2] is connected at the transmitter output in order to sense the Tx noise in the RX band and provide a baseband copy of this noise to the digital equalizer. Since there is no distinction in frequency domain between noise and desired signal, the standard filters with frequency specifications domain are useless. However, a digital filter based on an adaptive equalizer may reduce this noise and restore the receiver sensitivity without degrading the desired Rx signal. Considering that the auxiliary receiver senses the signal at the output of the transmitter, whereas the diversity path receives the self-interference from the antenna, the digital equalizer should match in baseband the RF coupling between the main and the diversity antenna [3]. An equalizer based on an adaptive LMS FIR filter [4] is a feasible solution to obtain a low-cost digital path; however, the equalizer does not have to process a band-limited signal, but a downconverted RF noise consisting of spurious emissions of the transmitter, and the poor correlation between the input signals limits the system performance. A solution, based on an analog low-pass filtering of the noise before the analog-to-digital conversion, may extend the cross-correlation in discrete time domain between the reference signal provided by the auxiliary receiver and the desired response generated by the diversity, improving the digital noise cancellation over 20MHz of desired bandwidth. The final system is constituted by the diversity receiver [1], the auxiliary receiver [2], analog 4^{th} order Butterworth filters with cut-off frequency at 15MHz, analog-to-digital conversion with sampling frequency of 40MHz and 8bits of dynamic range, and a digital 4^{th} order complex LMS FIR filter. This solution, validated by experimental measurements, ensures more than 28dB of digital noise reduction and restores the diversity receiver sensitivity, ensuring only 1.1 dB of NF degradation and an equivalent -171 dBc/Hz noise-to-carrier ratio. The optimal configuration is reached after a few tens of microseconds, thus ensuring an efficient tracking of the antenna variations that occur during normal functioning of the device.

[1] E. Kargaran, S. Tijani, G. Pini, D. Manstretta and R. Castello, "Low power wideband receiver with RF Self-Interference Cancellation for Full-Duplex and FDD wireless Diversity," *2017 IEEE Radio Frequency Integrated Circuits Symposium (RFIC)*, Honolulu, HI, 2017, pp. 348-351.

[2] D. Montanari, D. Manstretta, R. Castello, G. Castellano, “A 0.7-2 GHz Auxiliary Receiver with Enhanced Compression for SAW-less FDD,” presented at *ESSCIRC 2017 – 43rd European Solid State Circuits Conference (ESSCIRC)*, Leuven, Belgium, 2017.

[3] B. Widrow, J. McCool and M. Ball, "The complex LMS algorithm," in *Proceedings of the IEEE*, vol. 63, no. 4, pp. 719-720, April 1975.

[4] D. Montanari, L. Silvestri, M. Bozzi and D. Manstretta, "Antenna coupling and self-interference cancellation bandwidth in SAW-less diversity receivers," *2016 46th European Microwave Conference (EuMC)*, London, 2016, pp. 731-734.

4. Products (accounting also the first and second PhD years)

a. Journal papers

I. **G. Castellano**, D. Montanari, D. De Caro, D. Manstretta and A. G. M. Strollo, "An Efficient Digital Background Control for Hybrid Transformer-Based Receivers," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. PP, no. 99, pp. 1-13, *early access*.

II. E. Napoli, **G. Castellano**, D. De Caro, D. Esposito, N. Petra and A. G. M. Strollo*, "*A SISO Register Circuit Tailored for Input Data with Low Transition Probability*,"* in *IEEE Transactions on Computers,* vol. 66, no. 1, pp. 45-51, Jan. 1 2017.

III. E. Napoli, **G. Castellano**, D. De Caro, D. Esposito, N. Petra and A. G. M. Strollo, "Single Bit Filtering Circuit Implemented in a System for the Generation of Colored Noise," in *IEEE*

Transactions on Circuits and Systems I: Regular Papers, vol. 64, no. 5, pp. 1040-1050, May 2017.

IV. D. De Caro, E. Napoli, D. Esposito, **G. Castellano**, N. Petra and A. G. M. Strollo, "Minimizing Coefficients Wordlength for Piecewise-Polynomial Hardware Function Evaluation With Exact or Faithful Rounding," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 64, no. 5, pp. 1187-1200, May 2017.

V. D. De Caro, F. Tessitore, G. Vai, **G. Castellano**, E. Napoli, N. Petra, C. Parrella, A. G. M. Strollo, "Single flip-flop driving circuit for glitch-free NAND-based digitally controlled delay-lines", *Springer, Circuits Syst Signal Process (2017)* 36: 1341.

VI. **G. Castellano**, D. De Caro, D. Esposito, P. Bifulco, E. Napoli, N. Petra, M. Romano, M. Cesarelli, A.G.M. Strollo, " A Hardware Oriented Real Time Filter for Poisson Video Denoising with Application to X-ray Fluoroscopy", *submitted to IEEE Transactions on Circuits and Systems for Video Technology.*

b. Conference papers

I. **G. Castellano**, D. De Caro, A. G. M. Strollo and D. Manstretta, "A low power control system for real-time tuning of a hybrid transformer-based receiver," *2016 IEEE International Conference on Electronics, Circuits and Systems (ICECS)*, Monte Carlo, 2016, pp. 328-331.

II. D. Montanari, D. Manstretta, R. Castello, **G. Castellano,** "A 0.7-2 GHz Auxiliary Receiver with Enhanced Compression for SAW-less FDD," *presented at ESSCIRC Conference 2017: 43rd European Solid-State Circuits Conference*, Leuven, 2017.

III. D. Esposito, **G. Castellano**, D. De Caro, E. Napoli, N. Petra and A. G. M. Strollo, "Approximate adder with output correction for error tolerant applications and Gaussian distributed inputs," *2016 IEEE International Symposium on Circuits and Systems (ISCAS)*, Montreal, QC, 2016, pp. 1970-1973.

IV. E. Napoli, **G. Castellano**, D. Esposito and A. G. M. Strollo, "Digital circuit for the generation of colored noise exploiting single bit pseudo random sequence," *2016 IEEE 7th Latin American Symposium on Circuits & Systems (LASCAS)*, Florianopolis, 2016, pp. 23-26.

5. Conferences and Seminars

G. Castellano, D. De Caro, A. G. M. Strollo and D. Manstretta, "A low power control system for real-time tuning of a hybrid transformer-based receiver," *2016 IEEE International Conference on Electronics, Circuits and Systems (ICECS)*, Monte Carlo, 2016, pp. 328-331

6. Activity abroad

No activity abroad has been carried out in this year.

7. Tutorship

No tutorship has been kept in this year.