PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Gennaro Di Meo

XXIX Cycle

Training and Research Activities Report – First Year

Tutor: Davide De Caro

Add the following items according to the meeting we had today.

Concerning the structure of the document, use the Section number as is. Use the sub-contents indicated with a letter only as a suggestion for your content (a free form text is preferable)

1. Information
    a. Name Surname, MS title – University
    b. XXIX Cycle- ITEE – Università di Napoli Federico II
    c. Fellowship type
    d. Tutor
2. Study and Training activities
    a. Courses
    b. Seminars
    c. External courses
3. Research activity
    a. Title
    b. Study
    c. Research description
    d. Collaborations
4. Products
    a. Publications
        i. Books, Book Chapters, Journal papers, Conference papers (mark international products)ù
        ii. List those in preparation
    b. Patents
5. Conferences and Seminars
    a. Details (Conference name, place, dates, number of papers)
    b. Presentations made
6. Activity abroad
    a. Details (Place, dates, number of papers, contact persons)
7. Tutorship
    a. Type, subjects, hours

Information

Gennaro Di Meo graduated in Electronic Engineering at the University of Naples "Federico II" presenting "Design and Simulation of Adaptive Filters for Full-Duplex Radios in FinFET 14 nm CMOS Technology". Actually, he is a PhD Student (ministerial scholarship) at the "Information Technology and Electrical Engineering" Department of the University of Naples "Federico II" (XXXIV Cycle - ITEE) and he is studying Adaptive Filters for telecommunication applications and approximate adaptive algorithm for low-power implementation under the supervision of Professor Davide De Caro.

Study and Training activities

Courses:

1. How to publish a scientific paper
2. Electromagnetism and relativity
3. Signals Numeric Elaboration
4. Wireless Communication
5. SIE 2019 PhD School (Electronic around the Earth)

Seminars:

1. Matlab Embedded Systems
2. IEEE Explorer Training and Authorship Workshop
3. Robots in medical applications: an overview of current medical robotics market from the industry's point of view
4. Medical Thermal Therapy and Monitoring Using Microwave Inverse Scattering
5. SimScape for Design
6. Distributed Radio System, Virtual RAN and the Path to 5G
7. Designer Matter: Meta-Material Interactions with Light, Radio Waves and Sound
8. Advanced technology at the Service of Visitors to Cultural Heritage Sites

Student: Gennaro Di Meo									Tutor: Davide De Caro								Cycle XXXIV									
gen.dimeo@unina.it									davide.decaro@unina.it																	
	Credits year 1								Credits year 2								Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Total	Check
Modules	20	0,4	5	0	10	6	0	21	10							0								0	21	30-70
Seminars	5	0	0	1,5	1,4	0	0,4	3,3	5							0								0	3,3	10-30
Research	35	9,6	5	8,5	0	4	9,6	37	45							0								0	37	80-140
	60	10	10	10	11	10	10	61	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	180

Fig 1 – Credits Summary, year 1

Research activity

Digital cancellation techniques toward Full-Duplex radios

This research activity is focused on the study of digital cancellation techniques with application for the In-Band Full-Duplex communication. In-band Full-Duplex communication is a challenging technique that provides to transmit and to receive signals using the same bandwidth in the same time, offering the possibility to double the channel capacity. To that purpose, transmission (TX) and reception (RX) paths, connected to the same antenna, should be isolated in a full-duplex transceiver to avoid superimposition of TX signal on the RX one. For this reason, devices as hybrid transformers are employed to achieve the required isolation in the analog domain. Since interference cancellation does not exhibit desired levels (due to impedance balancing and frequency response issues of hybrid transformer) digital cancellation techniques are required to meet desired performances. In particular Adaptive Filters are studied. These circuits are able to adapt their impulse response minimizing the Mean Square Error (MSE) between their outputs and an external solicitation, allowing operations as system identification, channel equalization or noise cancellation (of interest in this case). Among different topologies, Least Mean Square (LMS) filters are surely the most used thanks to their simple hardware structure, but also other variants are implemented according to different requirements. For instance, filtered-x LMS filters are employed to update coefficients in the digital domain and to perform the cancellation in the analog one.

In this first year, important efforts have been dedicated to model the whole Full-Duplex system, composed by Radio Frequency (RF) and baseband digital sections. Collaboration with University of Pavia and University of Milano "Bicocca" has been essential for analog circuits description. RF circuits (as Power Amplifier, Hybrid Transformer, Low Noise Amplifier, mixers) have been simulated in Simulink, while digital algorithms have been described using Matlab scripts. Particular attention was given to description of quantization noise (due to the presence of DAC and ADC in the system) and phase noise (at mixers input), since they limit the cancellation capability of Adaptive Filters. In this version of the system a LMS filter performs the interference cancellation, thus allowing to recognize the weak RX signal from the TX one. In the same time filtered-x LMS filters are employed to ensure a linear behavior of analog circuits in the receiver and to counteract ADC quantization noise. Results, related to a signal bandwidth of 80 MHz, reveal the possibility to achieve target cancellation (about 60 dB). Next goal is to realize a first chip for the In-Band Full-Duplex communication with analog and digital circuits inside in FinFET 16 nm CMOS Technology in the context of PRIN project (next tape-out will be defined by foundry next year).

In the same time important efforts have been dedicated for the development of approximate Adaptive Algorithms for low-power implementations. Indeed the presence of a significant number of multipliers, registers and adders in these circuits enforces a particular attention to power consumption. Approximate Computing is a possible solution offering to trade precision of arithmetic operations for power. Being the filter inherently imprecise (LMS Algorithm is an approximation of Steepest Descent Method and uses the approximate MSE gradient to achieve regime condition), it is possible to introduce some approximations to reduce power with an acceptable impact on regime performances. To that purposes same proposals have been formulated. The first one provides to reduce precision of input samples for coefficients computation when error signal is low. Results showed 1) the possibility to save power consumption reducing the switching activity of multipliers and 2) good regime performances due to a negligible additive approximation error. A second proposal exploits internal signal properties of Adaptive Filters. The point is to use the module of the error signal to compute the MSE gradient estimate. In this way, since error signal becomes low at regime, its most significant bits are stuck at zero and multipliers switching activity is reduced. In addition it is possible to approximate input samples to improve power reduction preserving good regime behavior. This approximate LMS filter was realized in TSMC 28 nm CMOS Technology and a testing phase is provided for next months.

Products

Publications:

1. Variable-Rounded LMS Filter for Low-power Applications, "Application in Electronics Pervading Industry, Environment and Society" Conference, 2019
2. Low-power implementation of LMS Adaptive Filter Using Scalable Rounding, "IEEE International Symposium on Circuits and Systems" Conference, 2020 (submitted)

Conferences

1. 25th International Conference on Electronics, Circuits and Systems, Bordeaux, 9-12 December 2018. Presentation of paper: Quality-Scalable Approximate LMS Filter
2. "Application in Electronics Pervading Industry, Environment and Society" Conference, Pisa, 11-13 September 2018. Presentation of paper: Variable-Rounded LMS Filter for Low-power Applications
3. 51th Annual Meeting of the Associazione Italiana di Elettronica (SIE), Rome, 26-28 June 2019. Poster Session: Design of Adaptive Filters for In-Band Full-Duplex Application

Other Activities

Two weeks at the University of Milano "Bicocca" to begin the design of the chip for Full-Duplex transceiver in the context of PRIN project.

Tutorship

1. Co-supervisor of MSc student (Antonio De Rosa), Thesis title: Design of low-power LMS Filters in 28nm CMOS technology
2. Co-supervisor of MSc student (Salvatore Montella), analysis of Digital Controlled Delay Lines (activity in progress)