RF CMOS Sensors for Contactless Health Monitoring

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- **Motivations**
- **Research objectives (overview)**
  - Contactless monitoring
  - System-on-Chip RF sensors
- **SoC CMOS RF sensors: the two cases of study**
  - UWB Radar for cardio-pulmonary monitoring
  - Microwave Radiometer for temperature monitoring
- **Short summary and conclusions**
- **References to some author's publications**

- **Health Care wireless assistance**
  - It is expected to be one of the most important contributions of ICT to reduce the cost of the medical service and contrasting the risks of social exclusions (i.e. aging and chronic diseases)
  - What does “wireless” mean in this context?

- **Wireless Body Area Network**
  - Sensors platform
  - Body area wireless connectivity (i.e. data communication)

- **More than this?**
  - Wireless for contact-less sensing
  - Wireless as enabling technology for wearable (portable) electronics

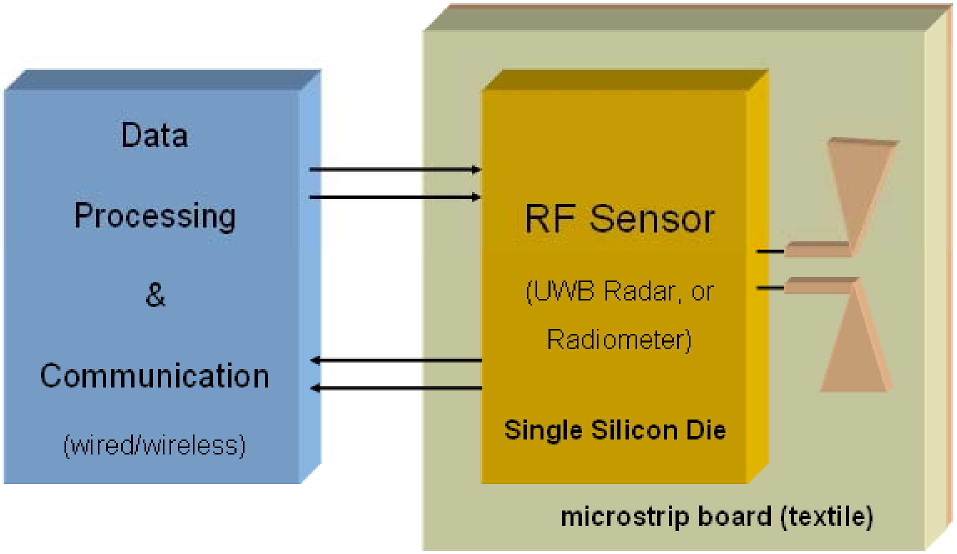
Motivations (2/2)

- **Needs of contact-less sensing**
  - Free on any encumbrance: no gel (e.g. ultrasounds), no electrodes, no wires
  - No (or extremely reduced) artefacts of movement

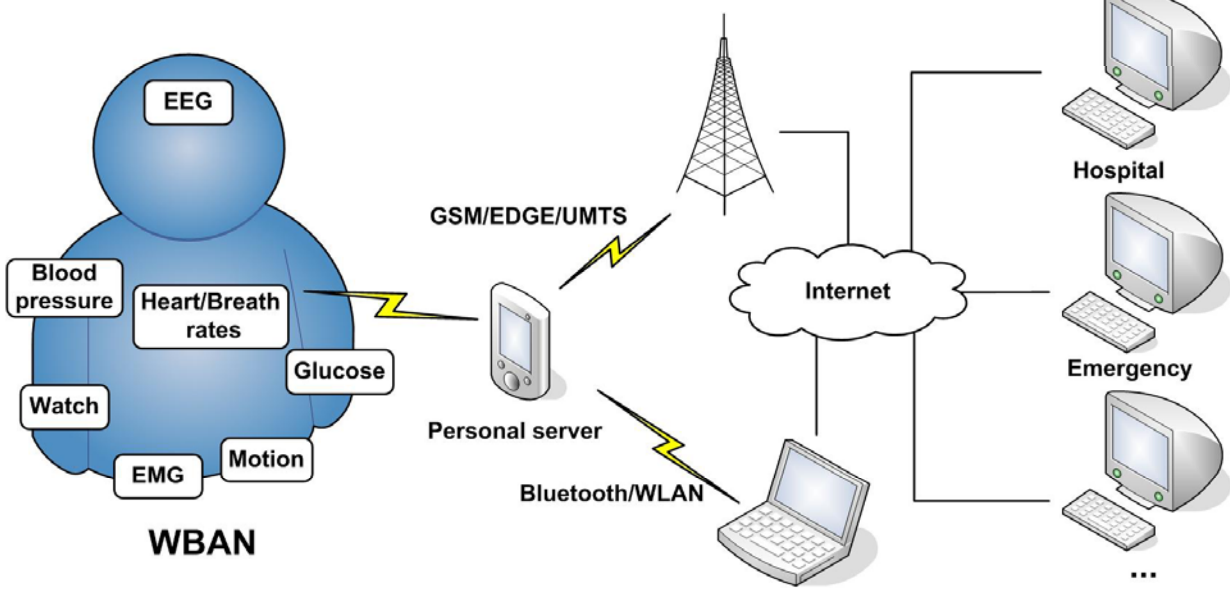
- **RF sensors can be exploited for contact-less detection of vital signs**
  - Microwaves are capable of penetrating dielectric layers
  - Traditional Microwave Integrated Circuits (MICs) make use of hybrid technologies NOT suitable for size and cost reasons
  - System-on-Chip (SoC) approach is required for implementing a new generation of low-cost wearable contact-less sensors for dealing with present and future challenges in modern monitoring of human physiology

- **UWB Radar for cardio-pulmonary monitoring**
  - Feasibility study of a SoC UWB Radar on silicon for contactless detection of heart and breath rates
  - SoC implementation
  - Functional test-chip verification through lab-test
- **Microwave Radiometer for temperature monitoring**
  - Feasibility study of a SoC 13-GHz Radiometer on silicon for remote temperature sensing
  - Building-blocks implementation
  - Verification through equivalent-like discrete-components system
- **EU Project PROeTEX (FP6-2004-IST-4-026987)**
  - Wearable sensor platform for emergency operators (fire fighters, rescuers, etc).
  - Four-year integrated project
  - Additional applications: telemedicine, sport, etc.

- **Objectives at first glance**
  - Wireless (i.e. contactless) sensor
  - Low-power data processing (local/remote) and communication (wired/wireless link)
  - Nano-scale CMOS SoC implementation (analog and digital sections)



- **Future perspective for both sensors**
  - Autonomous fully wireless sensor (i.e. sensing and data communication*)
  - WBAN/WLAN/GSM/EDGE/UMTS communication scenario

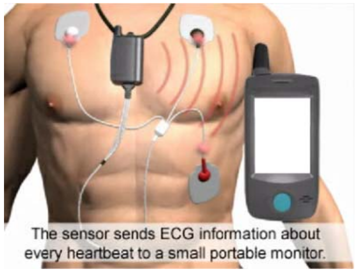


(*) e.g. by using a Zigbee-based low-power radio data link

UWB Radar for cardiopulmonary monitoring: intro (1/4)

- **Heart rate (HR) and HR variability (HRV)**
  - They allow understanding cardiovascular regulation in a range of conditions (heart failure, diabetes, hypertension, and sleep apnea)

- **State of the art for cardiac monitoring**
  - Electrocardiography (ECG)
    - Portable ECG: Holter (since 1960s) [1] (up to 72 hours monitoring)
    - Cardiac Event Monitor [2] (longer time of observation)
  - Echocardiography
    - Ultrasounds (not reported)
  - Pulse oximetry [3]
  - These systems require wires and a direct contact between the sensor and the body
    - commercial versions available today

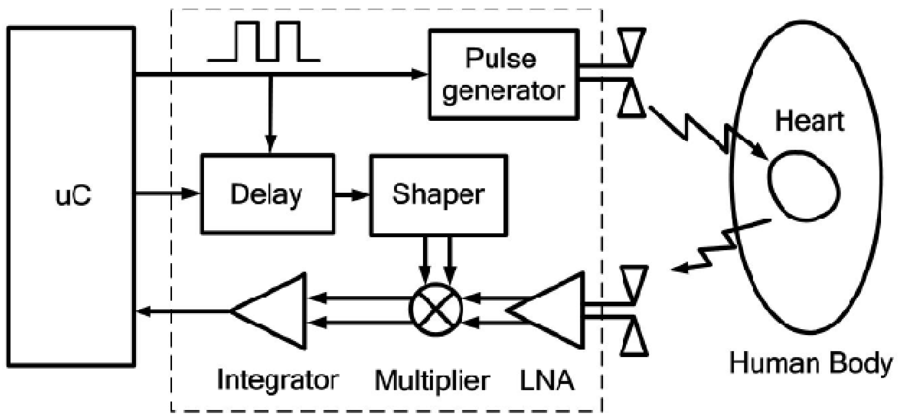


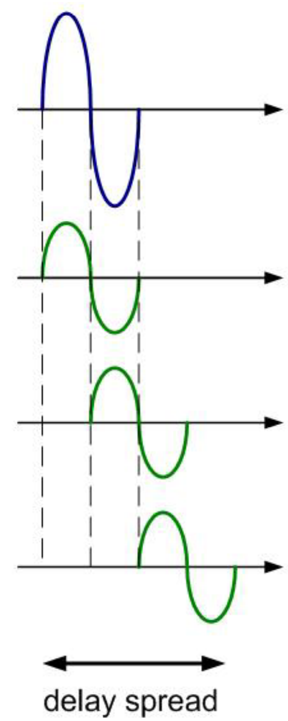
[1] http://www.sads.org.uk/cardiac_test.htm [2] http://www.cardionet.com [3] http://www.contec-oximeter.com

- **Radars for contactless cardiac monitoring: needs and solutions**
  - Radars sense the mechanical activity instead of the electrical activity of the heart (i.e. need of detecting arrhythmias)
  - Radar as enabling technology for contact-less cardio-pulmonary monitoring
    - McEwan(1994) / Immoreev(2002) (range-gated topologies in hybrid technology)
      - NOT suitable for portable/wearable applications (lack of miniaturization)
      - NOT low-cost
    - Droitcour et al. (CW Doppler on silicon in 2004)

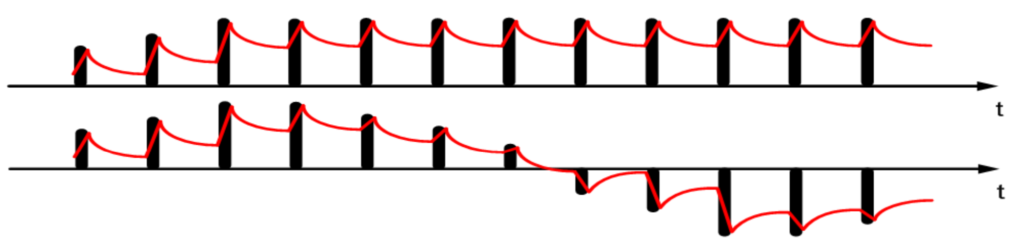
- **Why UWB Pulse Radar?**
  - Benefits of pulse radar technology
    - FCC/ETSI international standard compliance
    - Extremely-low power spectral density (-41.3 dBm/MHz in 3.1-10.6 GHz)
    - Robustness against interference
    - Low-complexity transceiver architecture
    - Very low energy consumption (switched-on in 2% of monitoring time)
  - Drawbacks
    - Lack of circuit solutions for UWB ICs
    - Time-domain tests

- **SoC UWB (3.1-10.6 GHz) Radar**
  - Cross-correlation receiver architecture (best performance against range-gated)
  - The output signal is modulated by the heart wall movement
  - Pulse repetition frequency (1-10MHz)



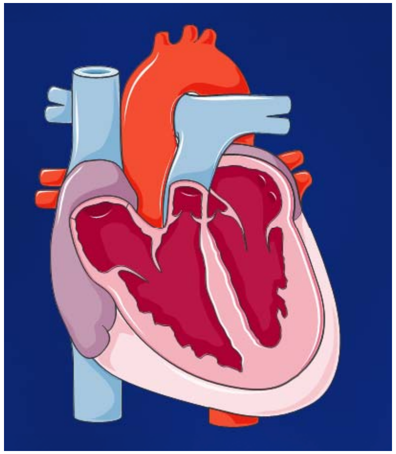


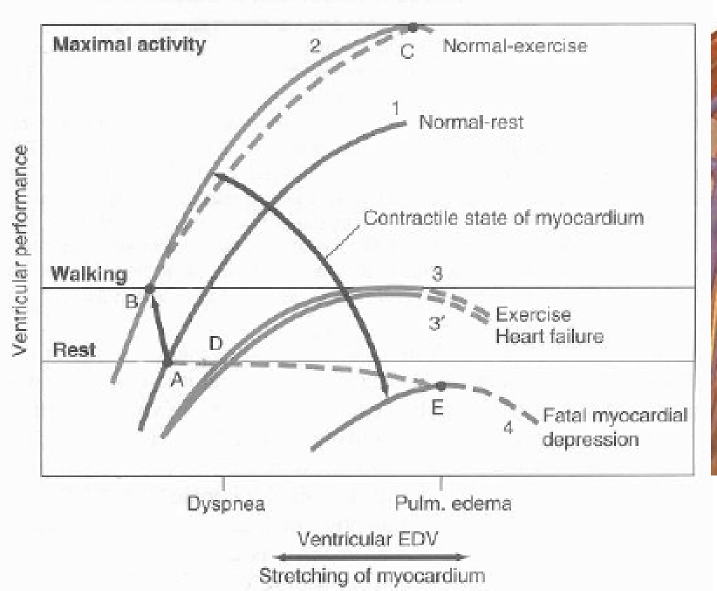
(no movement)
(with movement)

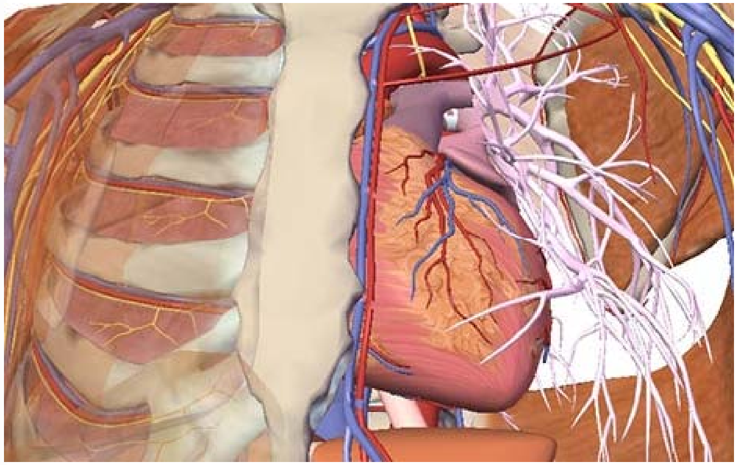


- **Three main steps (stages) of this research**
  - Feasibility study including intra-body channel loss characterization (2006)
  - Design and experimental characterization of the building-blocks in 90nm CMOS technology by ST-Microelectronics (2007-2008)
  - Re-design of building-blocks and SoC integration of the overall radar (2009)
- **Experimental verifications started in Q4/2009**
  - Functional lab-tests on test-chips completed in Q1/2010
- **Field operational tests started in Q3/2010**
  - Experimental setup and design fine tuning of radiant elements

- **System-level feasibility study: heart and chest physiology**
  - Max heart displacement (EDV/ESV) about 1.5 cm (typical, i.e. 400ps)
  - Chest tissues (air, skin, fat, muscle, cartilage, lung, heart, blood) (2cm, 2ns t-o-f)
  - Electromagnetic properties of the tissue layers (Gabriel et al. USAF)





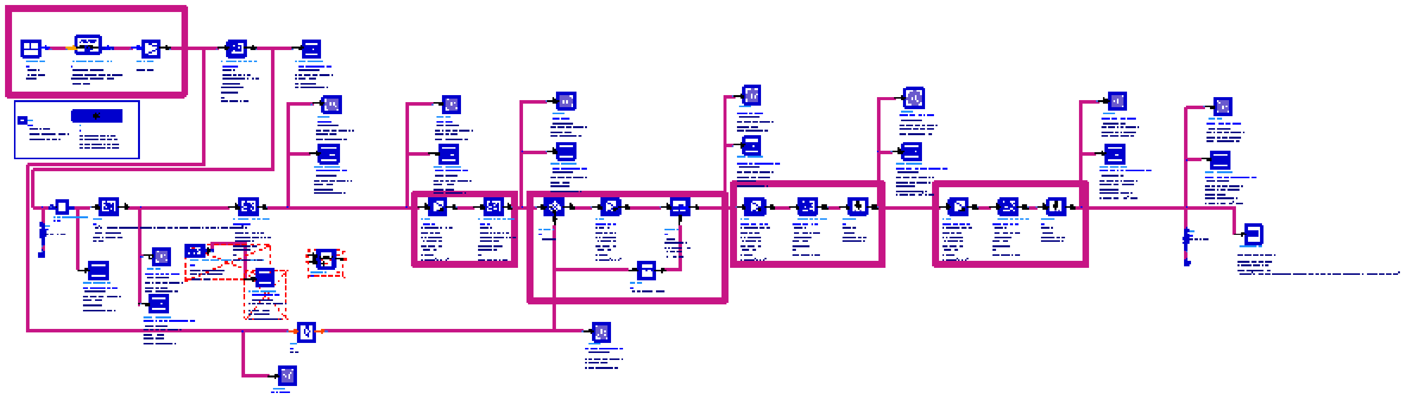


Heart Phisiology Kit
http://www.servier.com

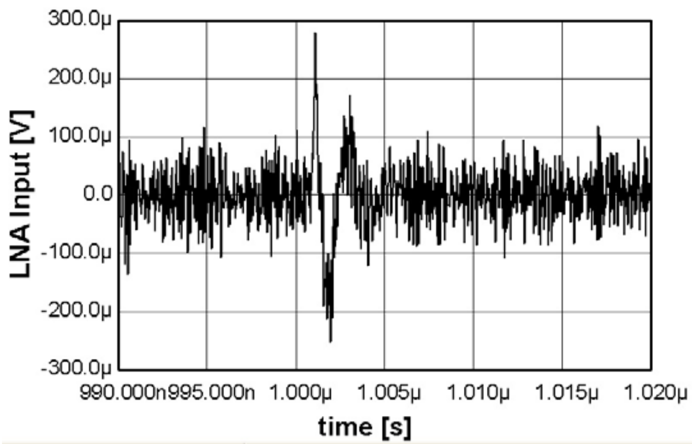
Harrison's Principles of Internal Medicine
D. L. Kasper et al., McGraw-Hill, 2005

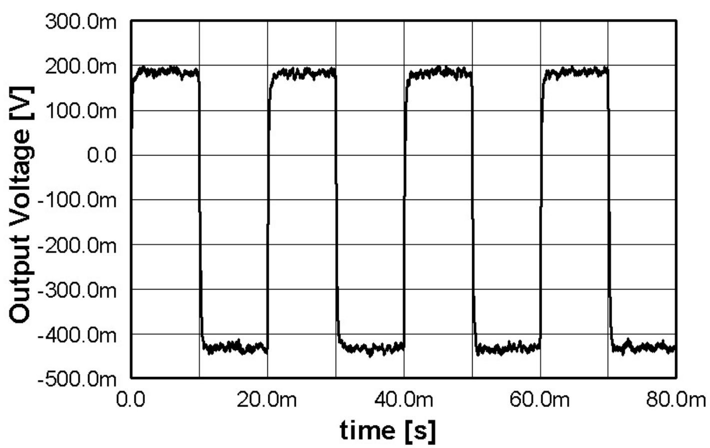
Visible Human Body Model
http://www.visiblebody.com

- **System-level feasibility study: theory and CAD simulation results**
  - Specifications of the building blocks have been derived for 90nm CMOS by STM

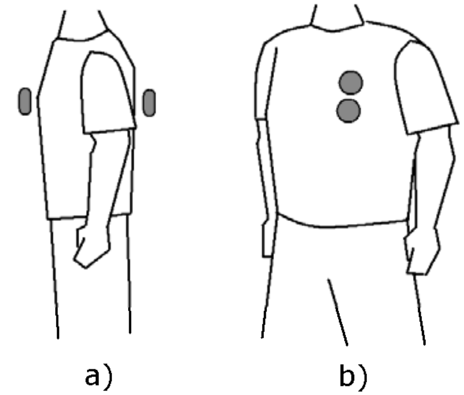


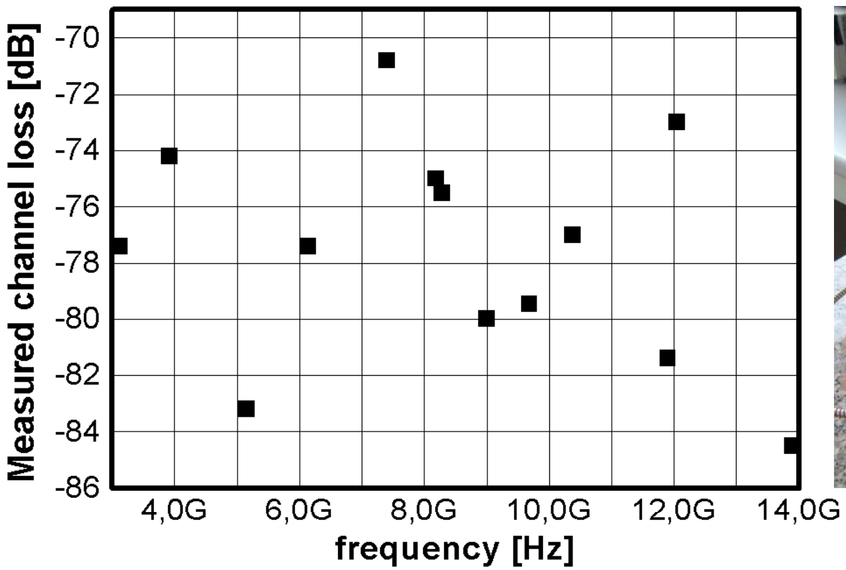
  - LNA input and Integrator output signals

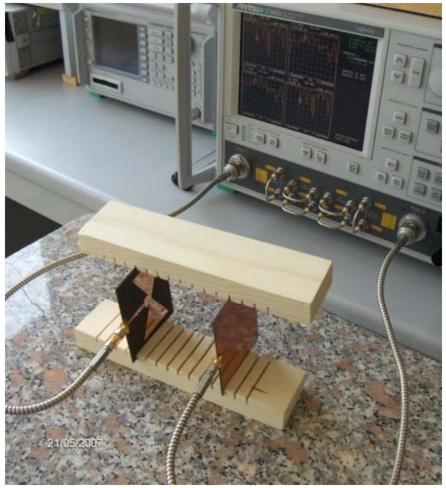




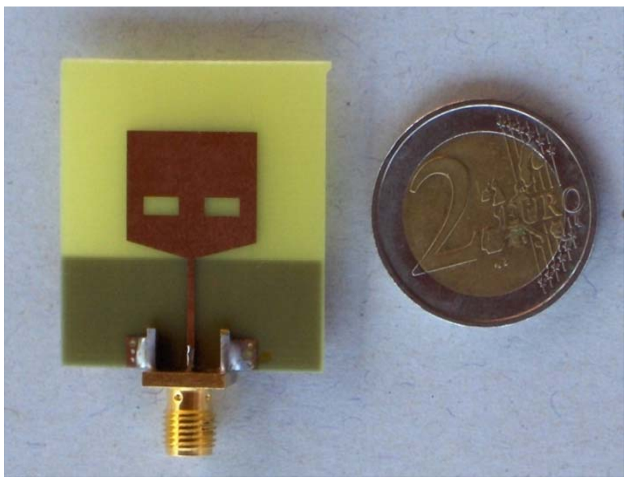
- **Intra-body channel loss: theoretical modelling by near-field equations (not reported) and experimental verification**
  - 80dB average loss in 3.1-10.6 GHz
  - 10 couples of antennas have been realized
  - Confirmation of the theoretical model
  - Invariance up to 5mm from the skin
  - Results confirmed by other parallel researches

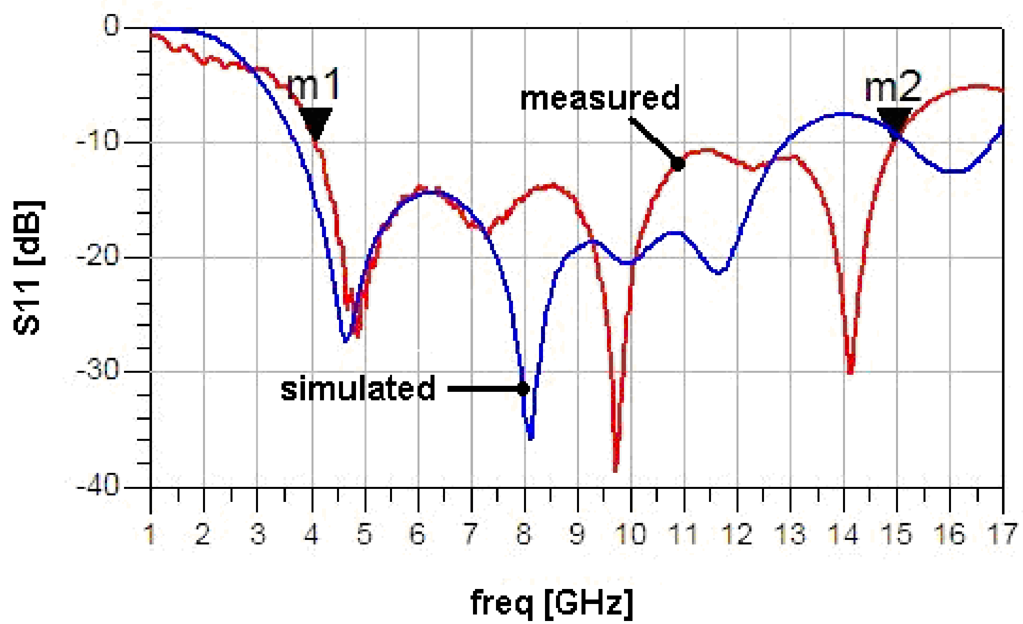




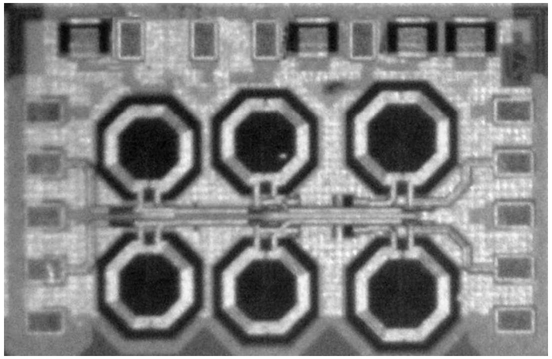


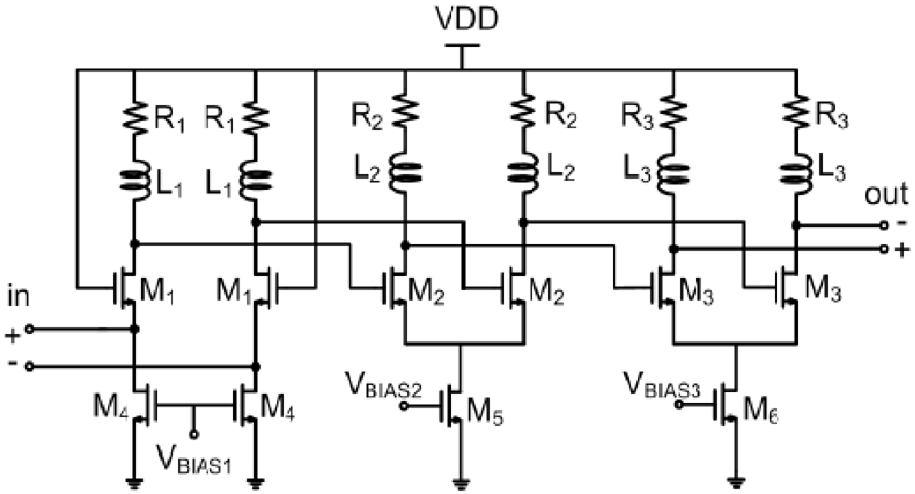
- **UWB Antenna has been realized and measured**
  - S11 < -10 dB in 4-15 GHz band
  - Large bandwidth for microstrip Helm antennas

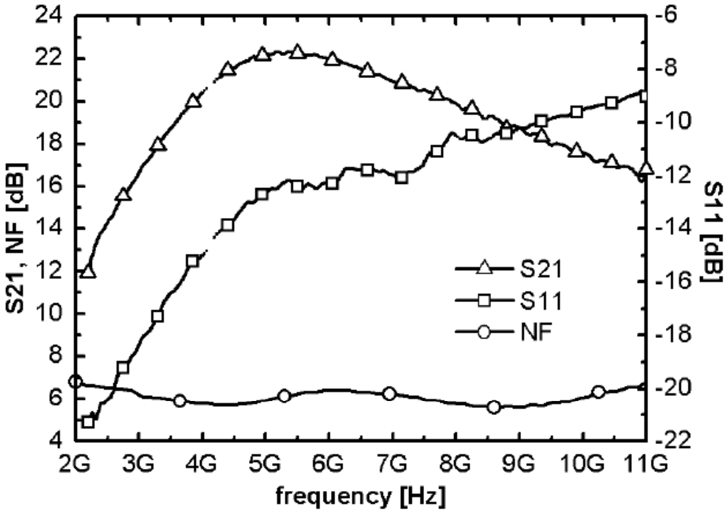




- **Low Noise Amplifier (LNA)**
  - S21=22.7 dB
  - ICP1dB=-19dBm
  - NF=5dB
  - B3dB=4.9 GHz
  - PC=34.8mW
  - Area=0.685mm^2
  - Max Delay Group variations=41ps







- **Pulse Generator**
  - Large-signals approach
  - Scheme of principle

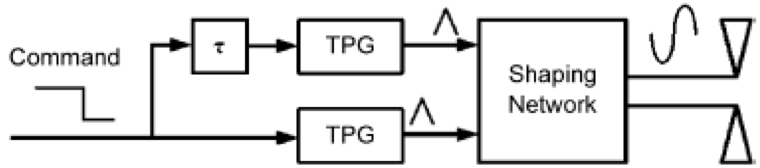
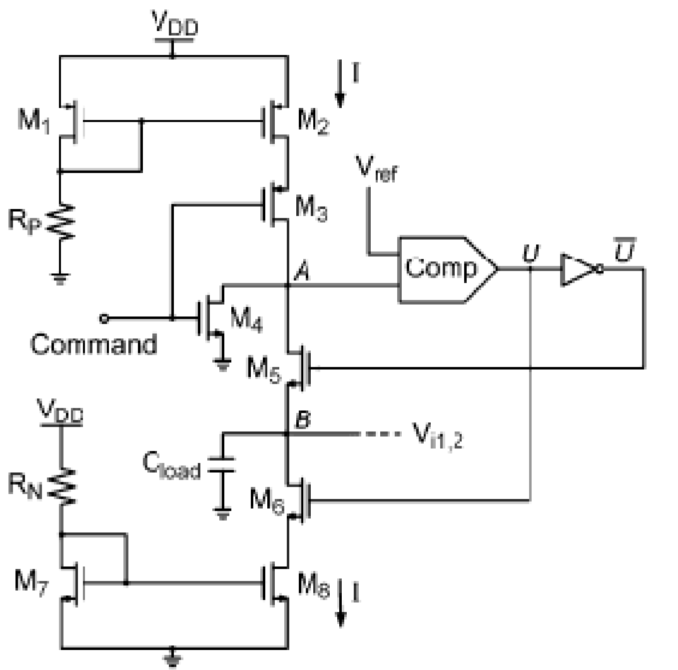
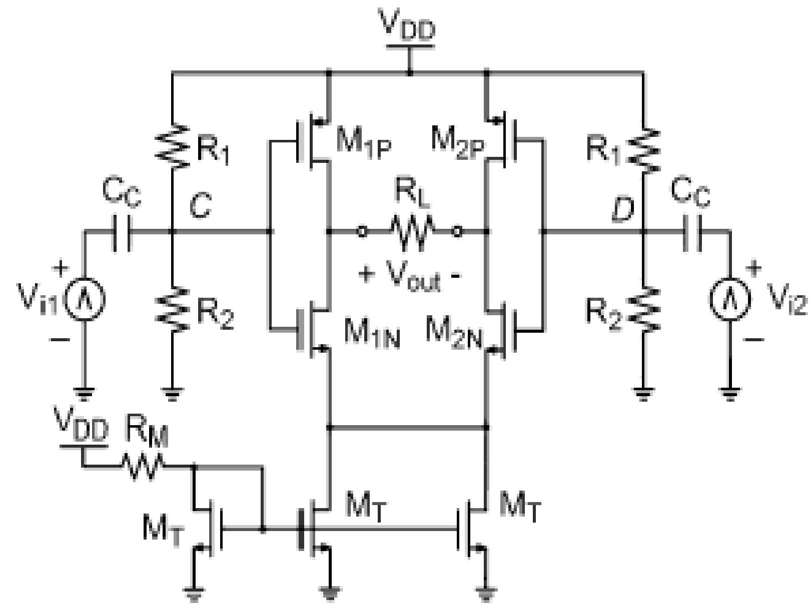


Fig. 1. Block diagram of the novel pulse generator. TPG is the triangular pulse generator, whereas τ is the delay building block.

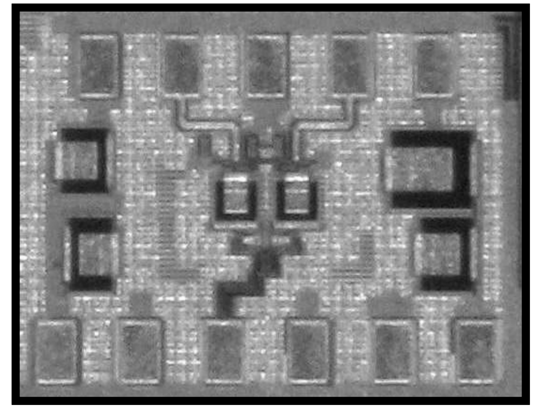
  - Triangular Pulse Generator (TPG) (based on [4]) and Shaping Network

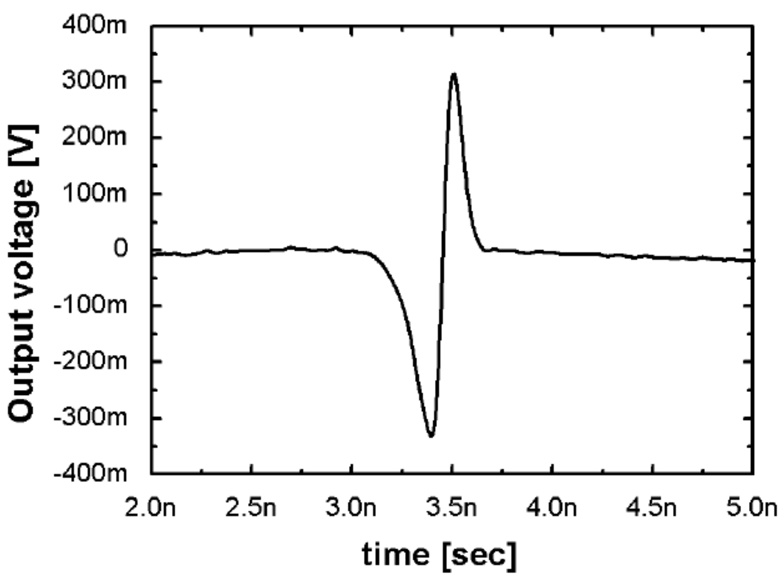


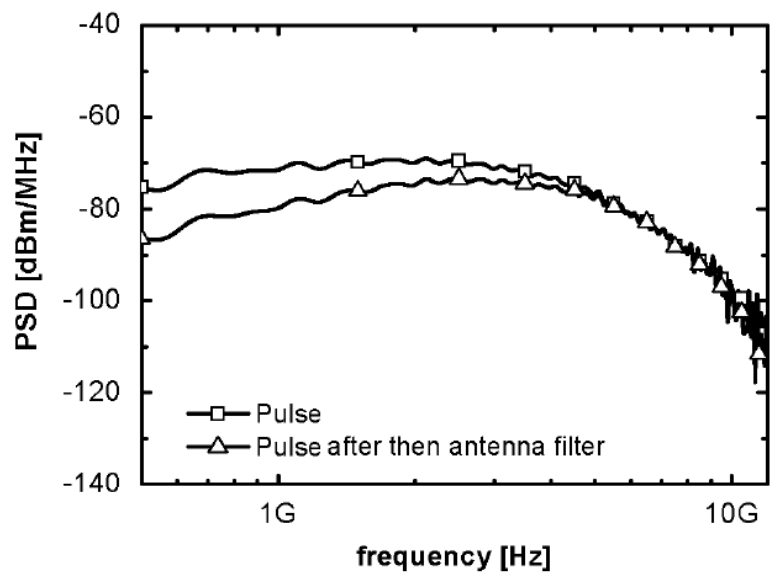


[4] J. Ryckaert et al., “Ultra-wideband transmitter for low-power wireless body area networks: Design and evaluation,” IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 52, no. 12, pp. 2515–2525, Dec. 2005.

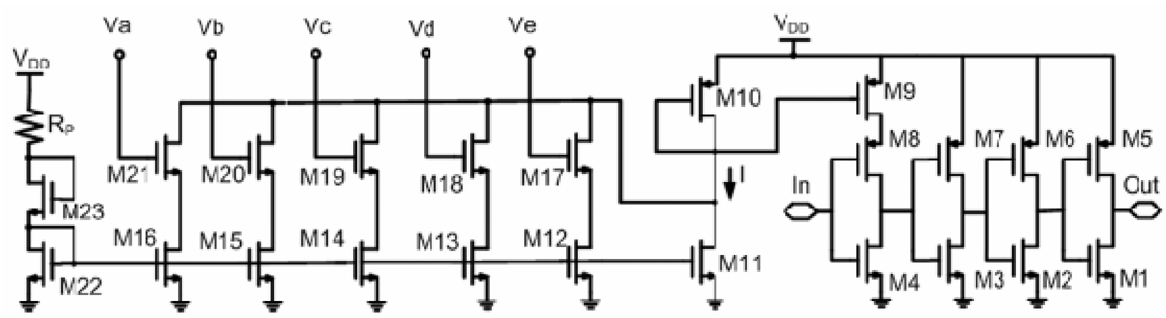
- **Pulse Generator**
  - Vpp=660mV (900mV on-chip)
  - Td=380ps
  - Energy consumption: 8pJ/per pulse
  - Area=0.25mm^2



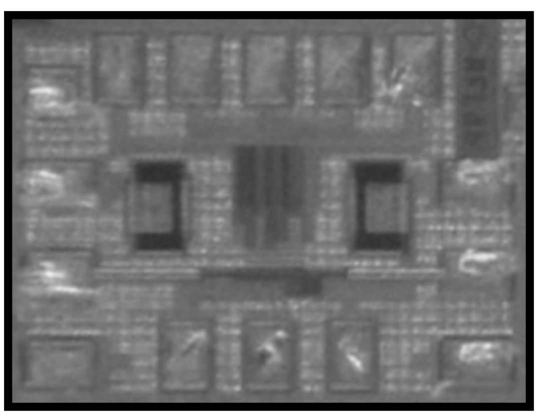


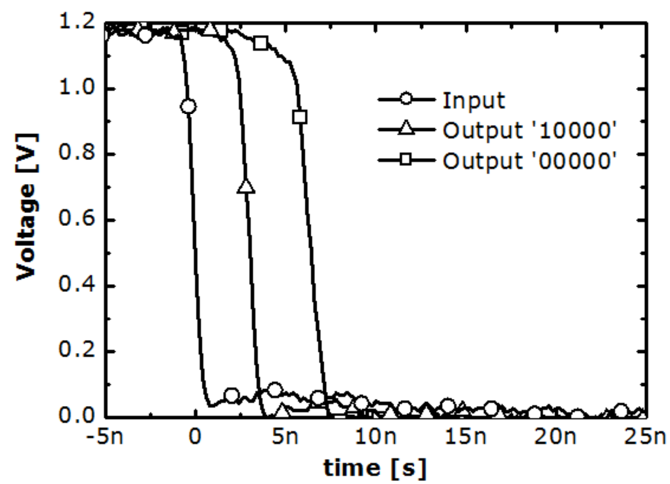


- **Delay Generator (based on [5])**
  - 5-bit programmable delay from 1 to 3ns (typical time-of-flight is 2ns)
  - Measured up to 6ns due to the input capacitance of the oscilloscope
  - Large monotonic delay range
  - Area=0.2mm^2



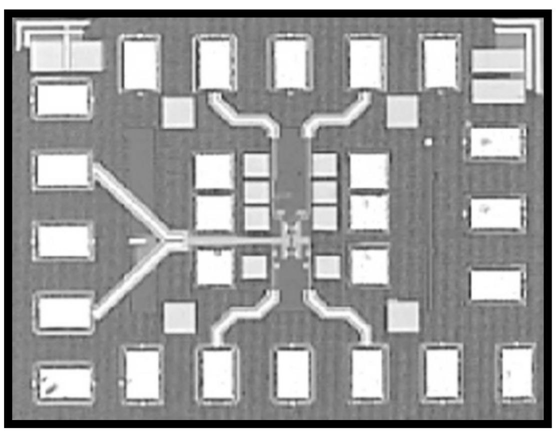
[5] M. Maymandi-Nejad and M. Sachdev, "A digitally programmable delay element: Design and analysis," IEEE Trans. Very Large Scale Integration (VLSI) Syst., vol. 11, no. 5, pp. 871–878, Oct. 2003.

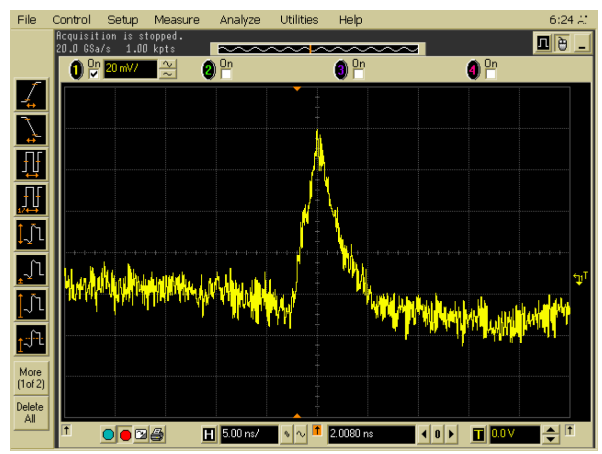




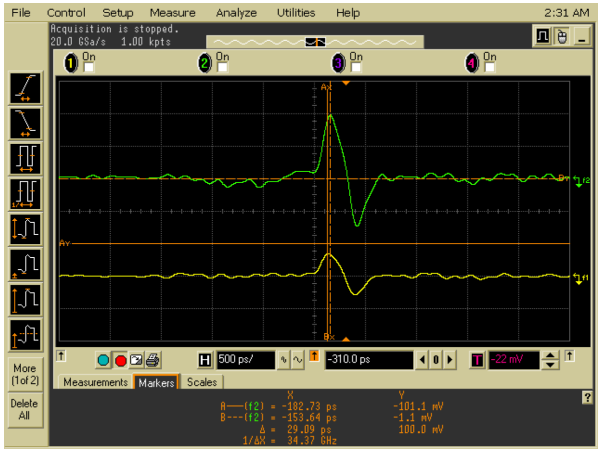
UWB Radar: major achievements (9/14)

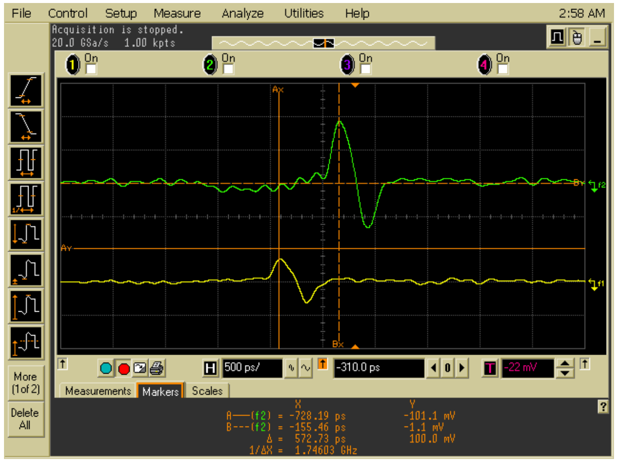
- **UWB Multiplier**
  - Fully differential topology based on Gilbert's multiplier
    - Common-gate differential pair input stage for a low-complexity input impedance matching to the low noise amplifier (LNA) output impedance
    - Paper currently under review
  - PC=0.9mW
  - Area=0.3mm^2
  - Experimental tests
    - Inputs
      - LO: Vpp=800mV
      - RF: Vpp=160mV
    - Output
      - Vmax=40mV

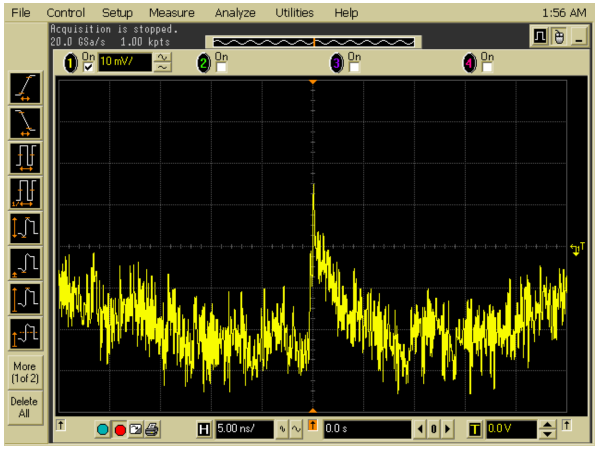


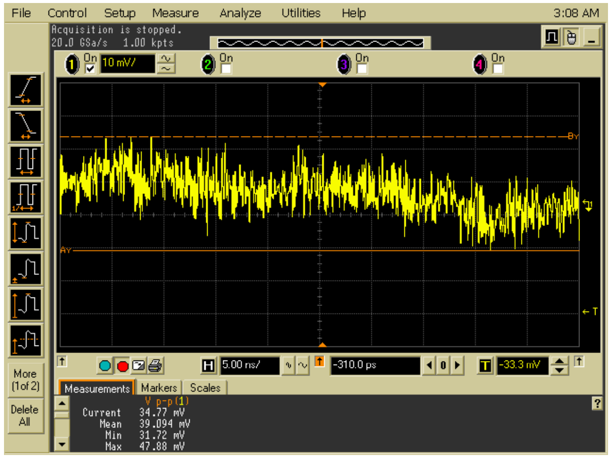


- **UWB Multiplier**
  - Set of experimental results (correlation/no correlation)



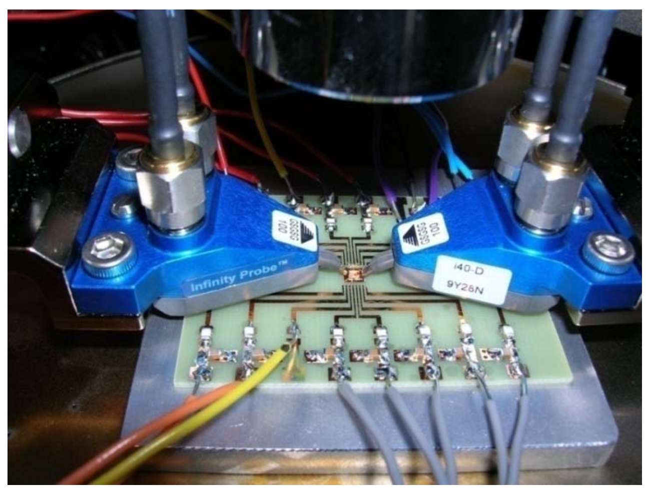




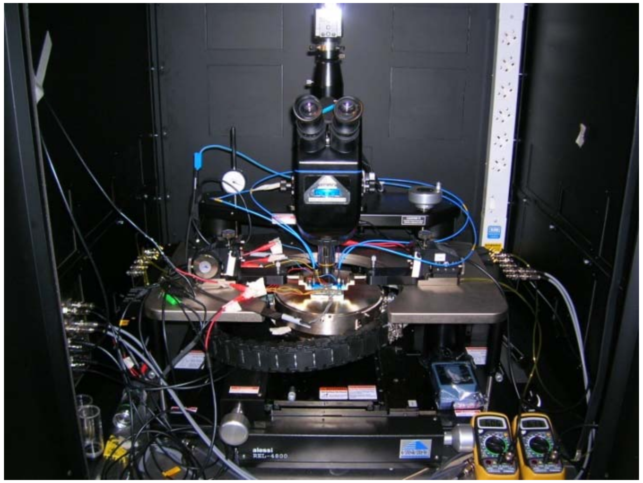


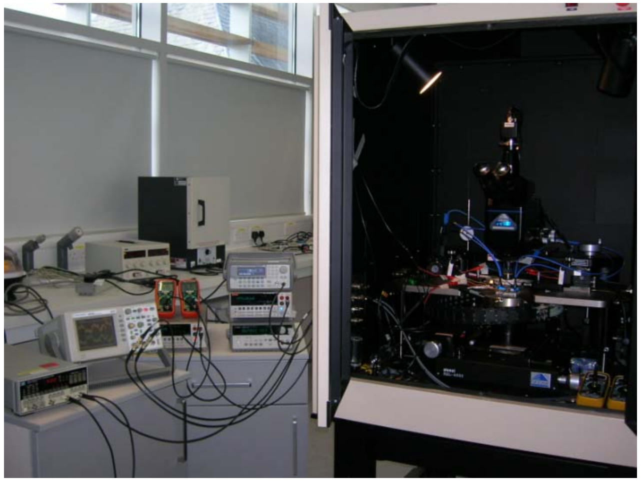
UWB Radar: major achievements (11/14)

- **SoC UWB Radar sensor**
  - Three-stage integrator (not reported) based on gm-C cell with output buffer stage
    - Voltage gain=58dB, cut-off frequency=145Hz, PC=1.1mW
  - Overall radar integration (chip area approx 2 mm^2)
  - Test by means of microprobes (LNA input – Attenuation – Pulse Generator output)

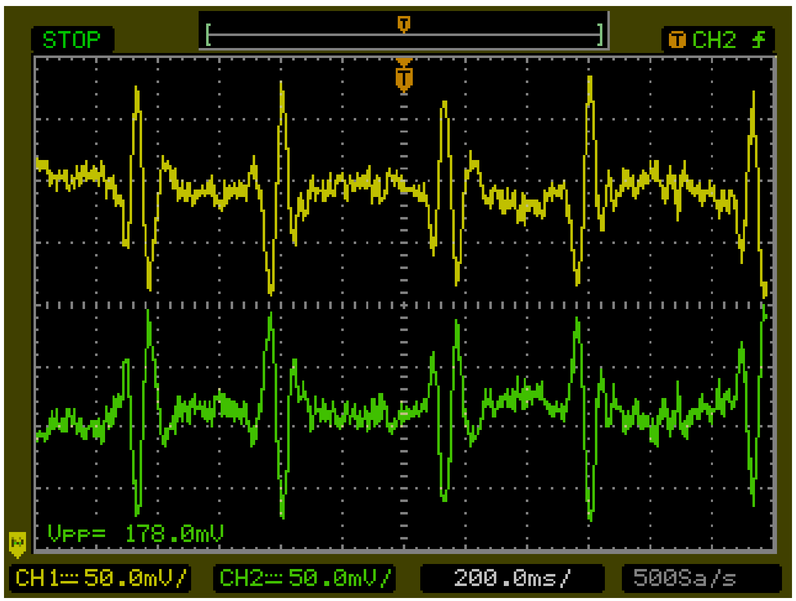


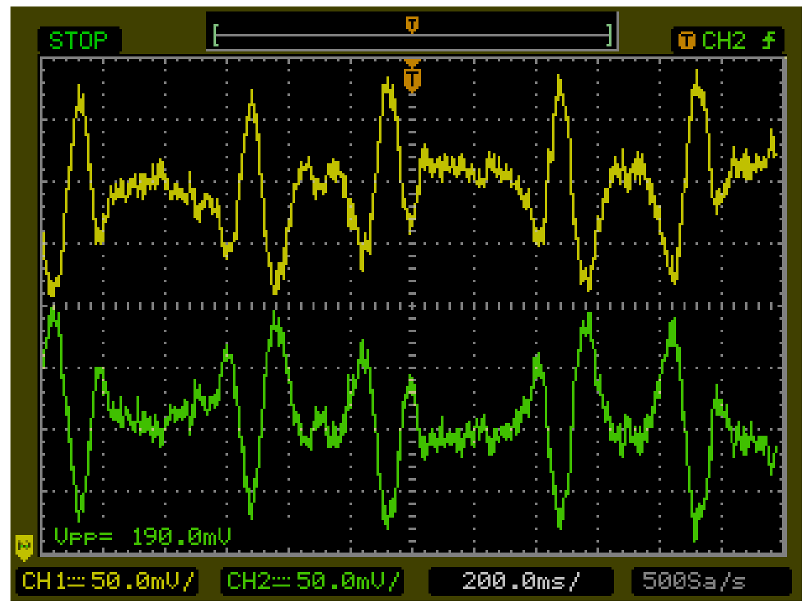
- **SoR UWB Radar sensor**
  - Complete experimental setup



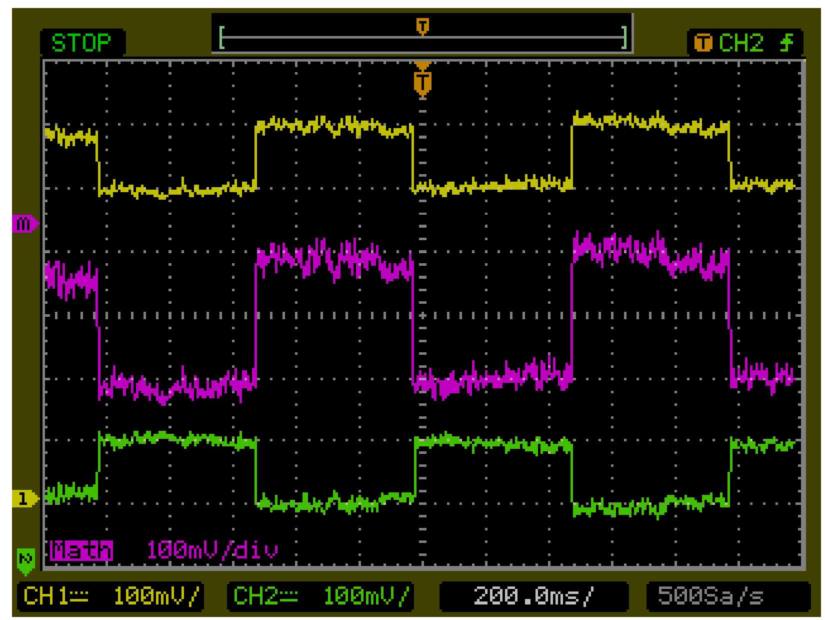


- **SoC UWB Radar sensor**
  - 1-Hz periodic delay (i.e. close to the heart beat frequency)
    - Ramp (50% duty cycle)
    - Sine (very similar to the heart movement)
    - Observation windows of about two periods (2.4s)
  - Overall energy consumption: 180 pJ/pulse





- **SoC UWB Radar sensor**
  - LNA input and Integrator output signals (measured)
    - 1-Hz periodic square delay (on-off correlation)
  - Note the agreement with the results of the CAD system analyses (2006)



- **Radiometer for temperature remote sensing: needs and solutions**
  - Radiometer senses the black-body radiation of a remote warm (with respect to 0K) surface
  - Microwave radiometers can be exploited for contact-less detecting the temperature of internal organs, fire beyond a wall, etc.
  - State of the art for microwave radiometers
    - Hybrid technology (waveguide, MICs, Peltier’s cells)
      - Geo- and Bio-Sciences
      - NOT portable/wearable applications
      - NOT low-cost

http://www.radiometrics.com

- **Why SoC 13-GHz Radiometer?**
  - Benefits
    - Translating calibration in digital domain (impressive miniaturization)
    - “Transmission-free” band in accordance with international standards
    - Trade-off between penetrating capability and spatial resolution
  - Drawbacks
    - Size of the patch antenna array (about 8x8cm^2)

- **13-GHz SoC Radiometer**
  - Ultra-low noise receiver with an internal noise reference
  - Two applicative scenarios
    - Internal temperature (35-50 ˚C, 5cm)
    - Fire beyond walls/doors/etc. (0-850 ˚C, 200m)
  - Direct-Conversion and Direct Detections architectures
    - Direct Detection (DD)
      - No Mixer, No Oscillators (benefits)
      - High-Gain LNA (drawback)

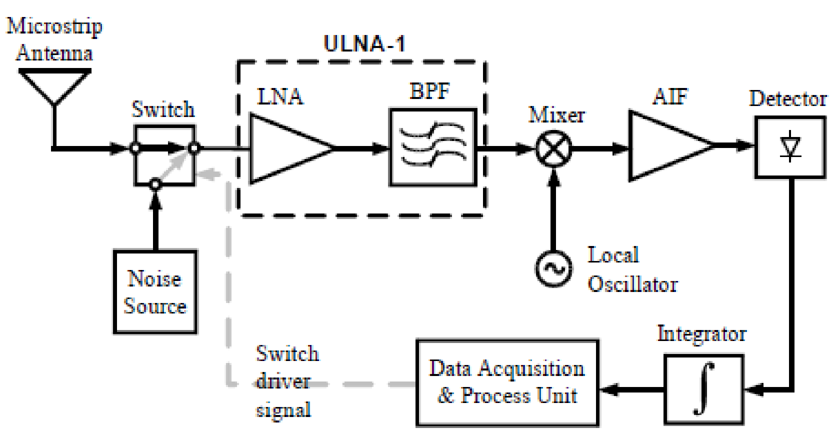


Fig. 1: Block diagram of the Down-Conversion Detection radiometer.

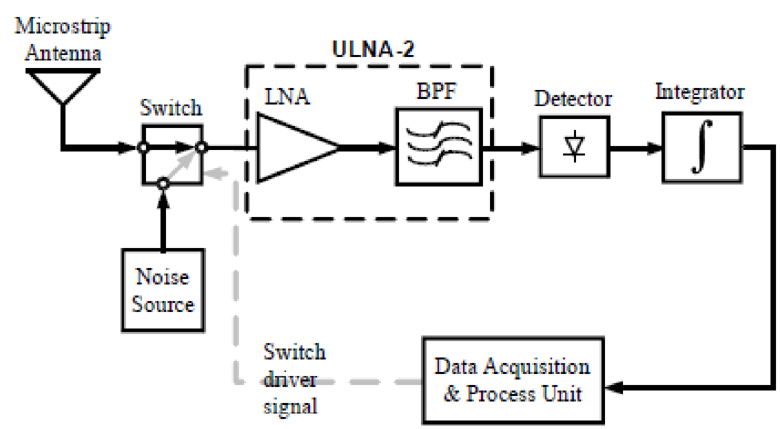
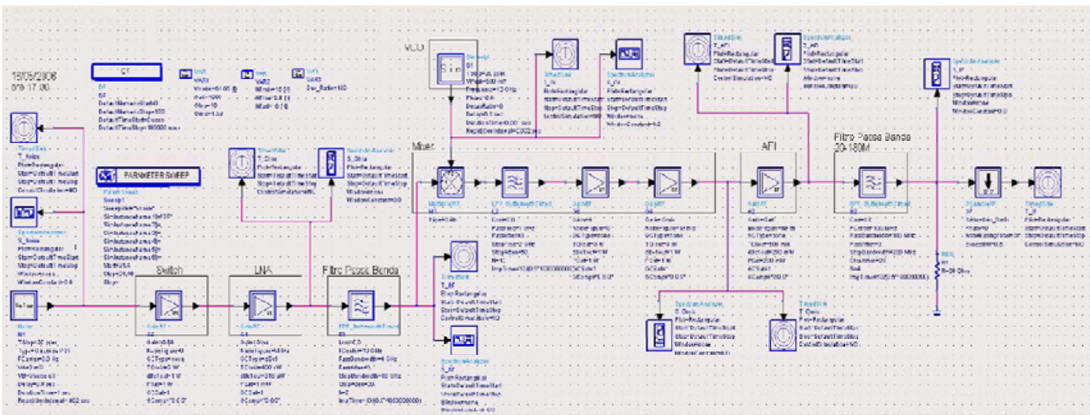
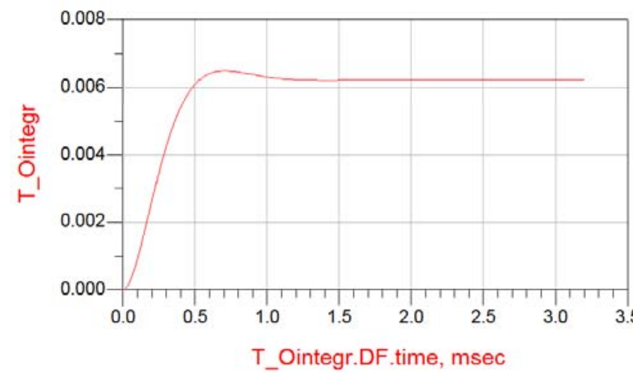


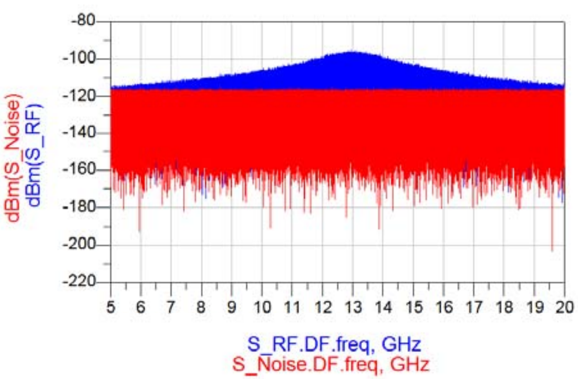
Fig. 2: Block diagram of the Direct Detection radiometer.

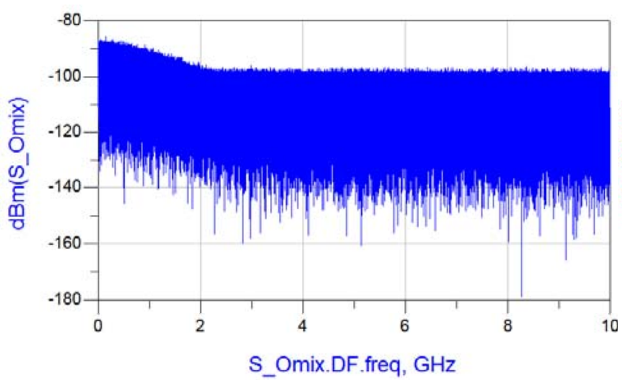
- **13-GHz SoC Radiometer**
  - Feasibility study by means of radiation theory and CAD system-level simulations (2006)
  - Experimental trials through equivalent-like “low-cost” hybrid prototype (2007-2009)
    - Implementation by using components on the shelf (DVB-S receiver, readout and calibration circuitry)
  - Design and experimental verification of the most critical building-blocks in 90nm CMOS technology by ST-Microelectronics (2007-2009)
    - RF Switch, Low Noise Amplifier (LNA), Voltage Controlled Oscillator (VCO), Power Detector
    - High-Gain LNA and Mixer have been designed successfully
      - Satisfactory performance (not fabricated)

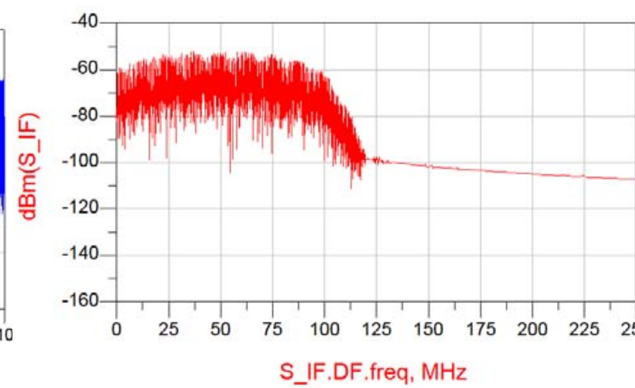
- **System-level feasibility study: theory and CAD simulation results**
  - SoC feasibility demonstrated in 90nm CMOS process
  - Both scenarios: internal temperature and fire detections (sensitivity 0.1K)



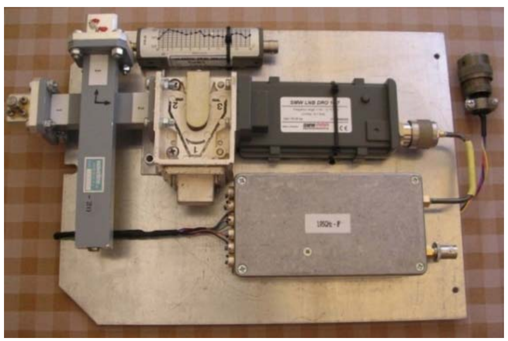


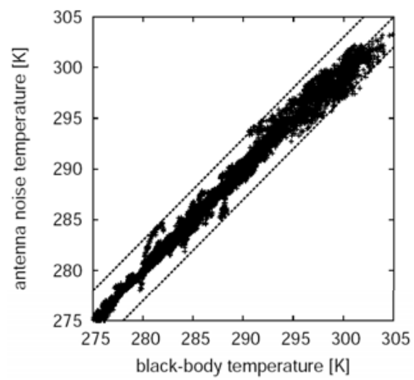


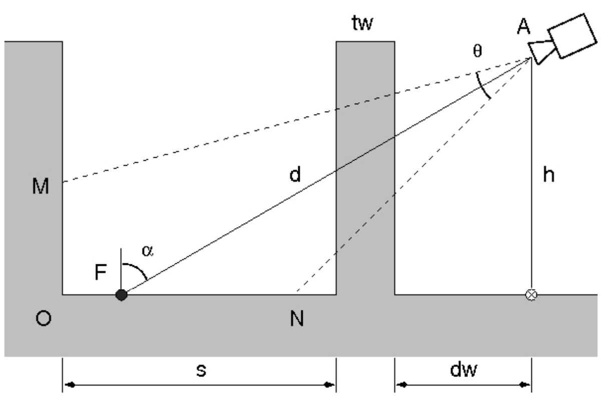


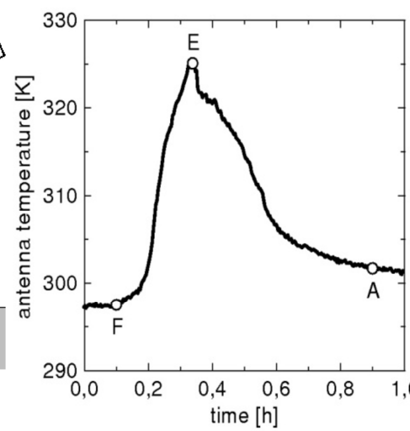


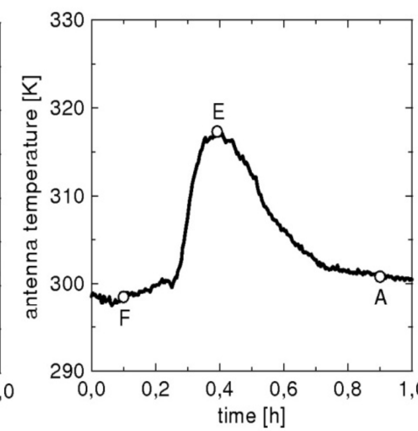
- **Equivalent-like "low-cost" hybrid prototype (in** cooperation with the University of Perugia)
  - Summary of the experimental results
    - Inter-wall (12.5 cm) detection (3K accuracy)
    - Detection demonstrated even against infrared (IR) technology

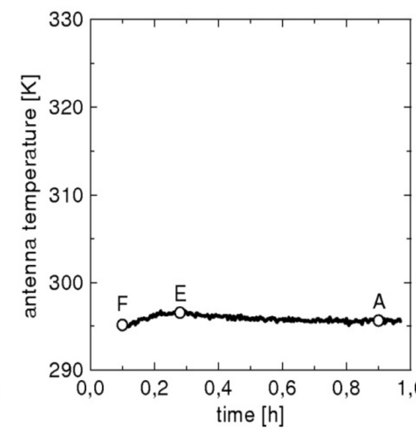












- **Active microwave inductors (e.g. RF switch, LC-active VCO)**
  - Q-factor > 300
  - D-BSI and CCD-BSI

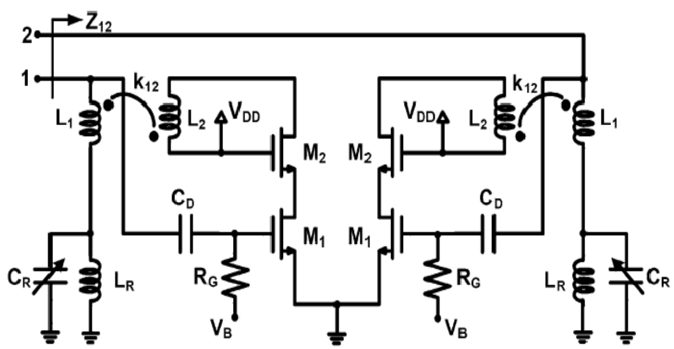


Fig. 1. Schematic of the D-BSI circuit.

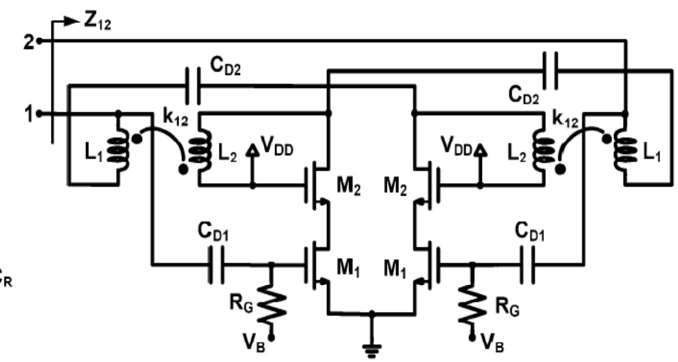
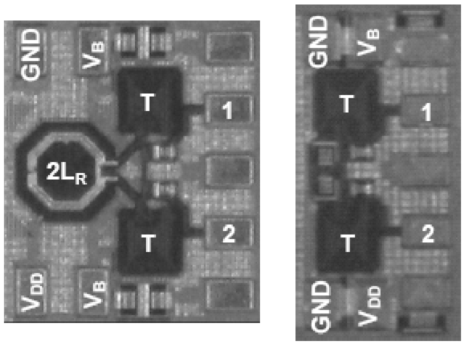
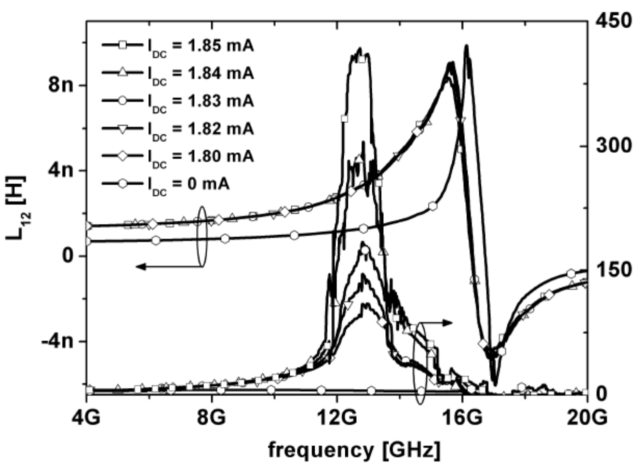
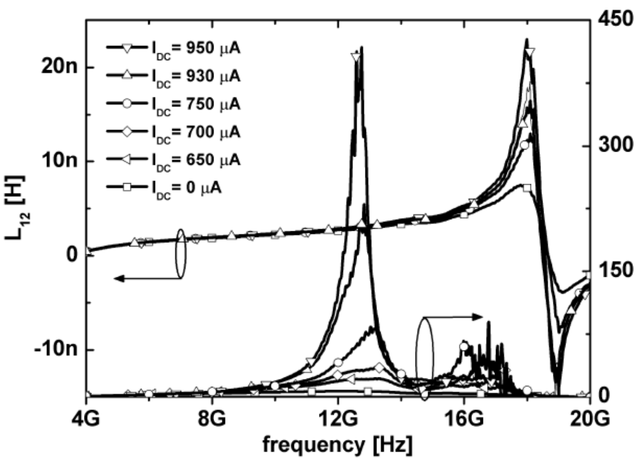
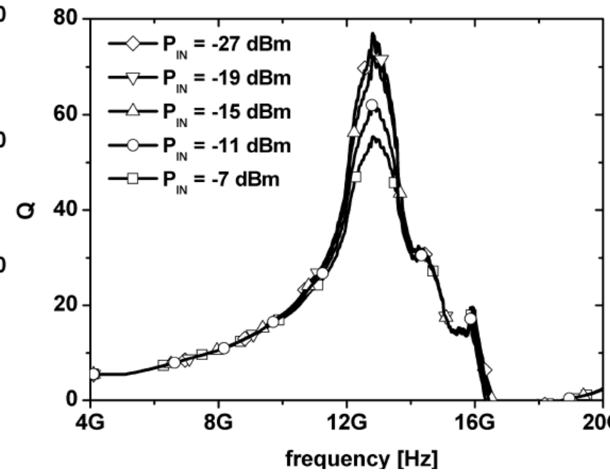


Fig. 2. Schematic of the CCD-BSI circuit.

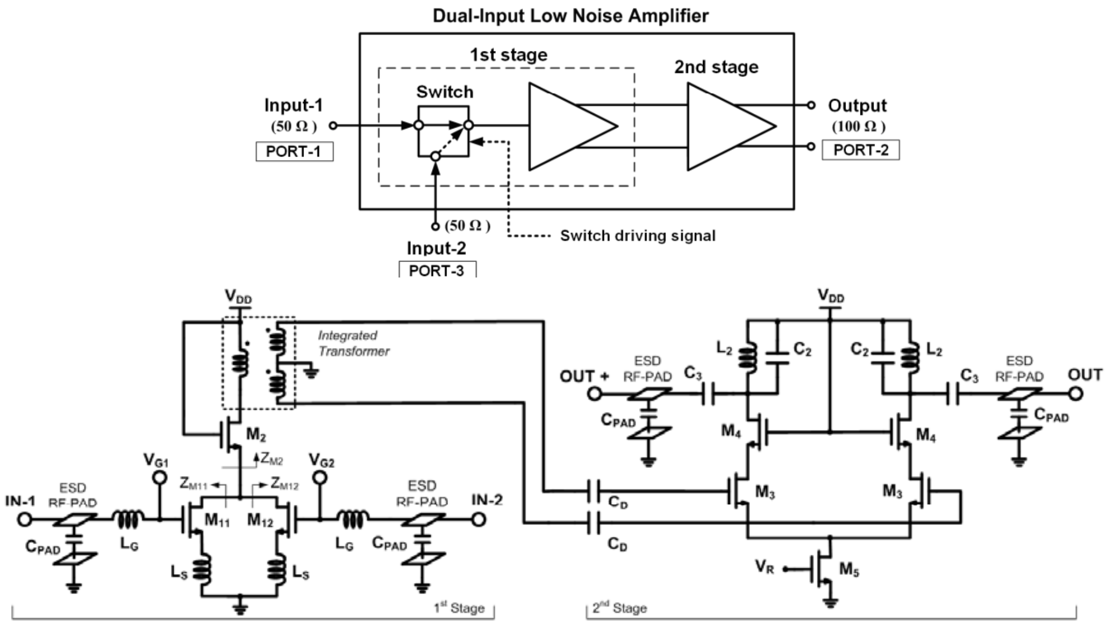


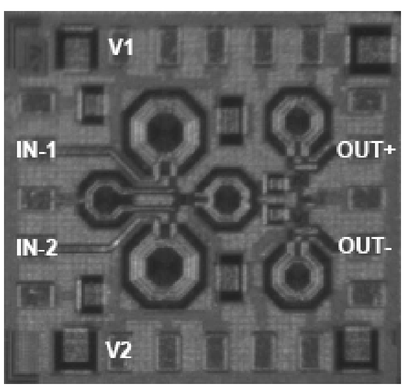


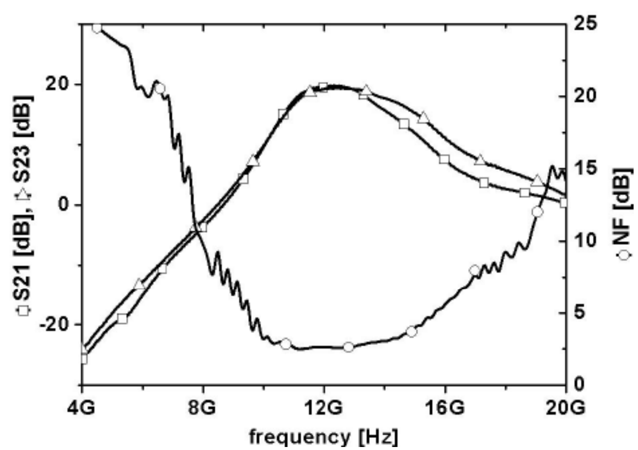


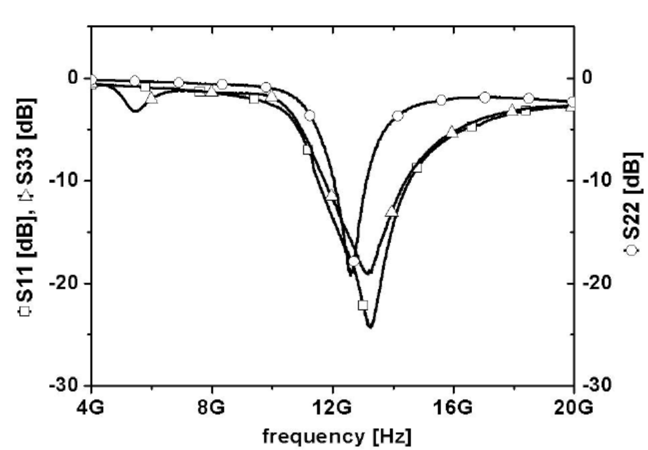


- **Dual-Input Pseudo-Switch RF LNA (for Direct-Conversion Detection)**
  - S21 =19dB
  - ICP1dB = -18dBm
  - NF= 1.6dB
  - S11<-20dB
  - PC=17mW
  - Area=0.51mm^2









- **High-Gain Dual-Input Pseudo-Switch RF LNA (for Direct Detection)**
  - Two additional common-source stages (4 stages in total)
  - S21=50dB
  - NF=1.5dB
  - S11<-30dB
  - PC=32mW
  - Area=$1mm^2$

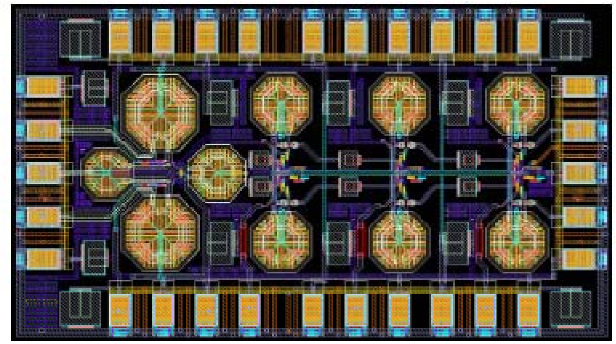


Fig. 8: Layout of the ULNA-2 for Direct Detection radiometer.

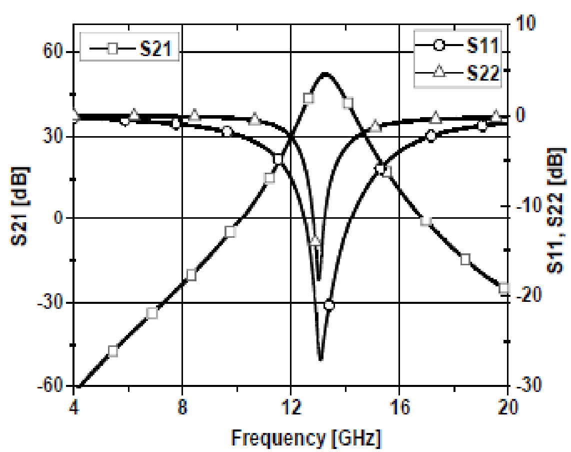


Fig. 9: Post-layout simulations of the power gain (S21) and I/O matching (S11 and S22), respectively, vs. frequency of the ULNA-2.

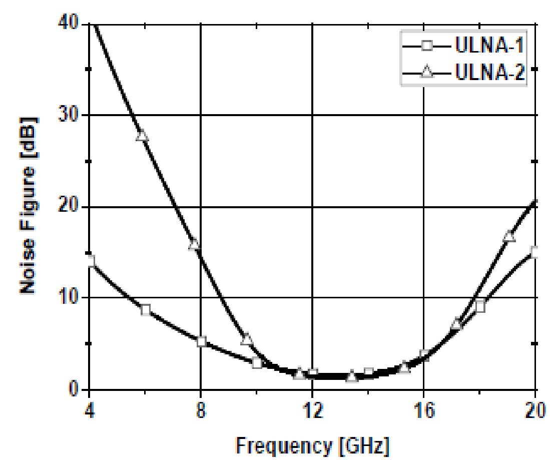
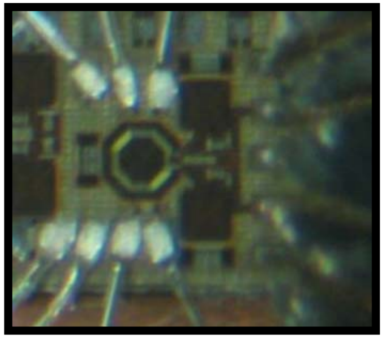
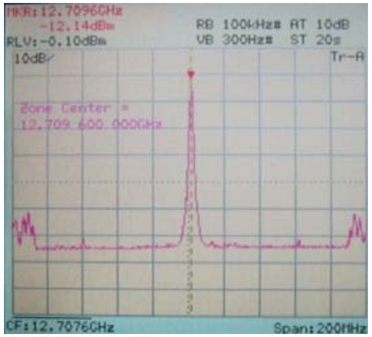


Fig. 10: Noise figure (NF) vs. frequency, by post-layout simulations both for the ULNA-1 and ULNA-2.

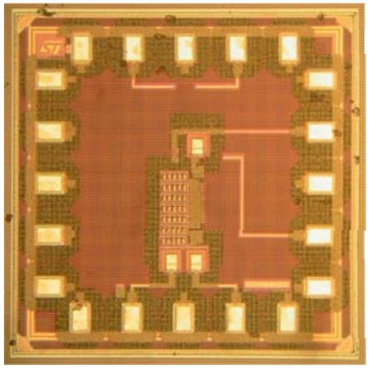
Microwave Radiometer: major achievements (6/6)

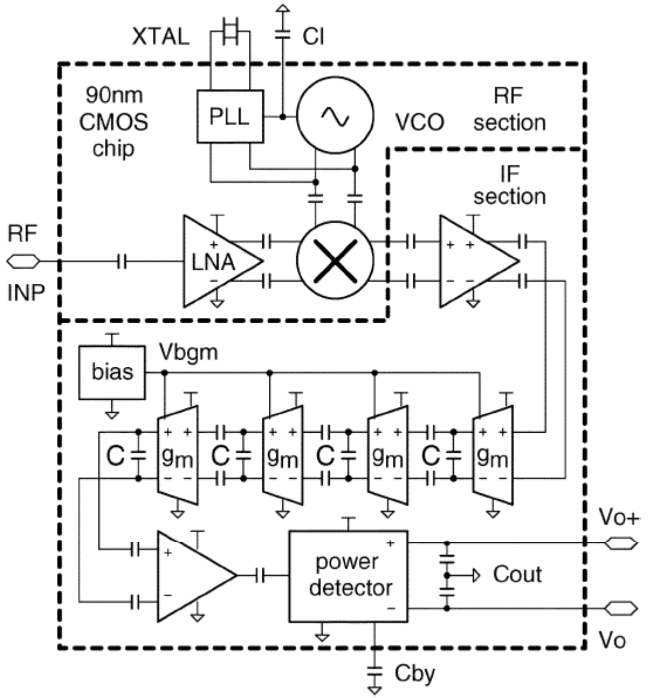
- **Voltage Controlled Oscillator (VC0)**
  - Tuning Range=250 MHz (12.50–12.75 GHz)
  - Phase Noise= -110 dBc/Hz @ 1 MHz
  - Low Phase Noise with 37% SoA PC
  - It is being submitted to IEEE journal

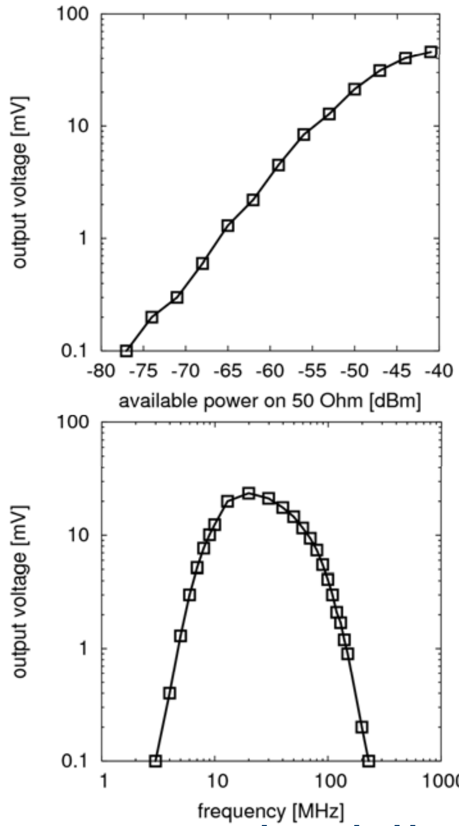




- **Power Detector (in cooperation with University of Perugia)**
  - Sensitivity=3mV/nW
  - Linearity range up to -45dBm
  - PC=2.2mW
  - Area=0.15mm^2







- SoC RF CMOS sensors have strategic relevance for the implementation of next-generation contacless sensors for health monitoring and other emerging wireless applications (e.g. civil and environmental safety, security)
- An innovative SoC UWB (3.1-10.6GHz) Radar for cardio-pulmonary monitoring has been proposed, designed, implemented and characterized experimentally through on-chip measurements for the 1st time in the literature
- An innovative SoC Radiometer for temperature remote sensing has been proposed and its most critical building blocks have been implemented on standard CMOS technology for the 1st time in the literature
- The proof-of-the-concept for inter-wall detection of temperature through 13-GHz Radiometer has been provided by an equivalent-like hybrid prototype, whereas internal temperature detection has been proved by means of simulations
- Several novel IC solutions with the highest figures of merit have been proposed for the implementation of both SoC RF CMOS sensors
- All the circuits have been tested successfully and most of them have been already published in IEEE Journals

References to some author’s publications

Journals

[1] D. Zito, A. Fonte, “Dual-input Pseudo-switch RF Low Noise Amplifier”, IEEE Trans. On Circuits and Systems II-Express Briefs, IEEE Trans. On Circuits and Systems II, Vol. 57, Is. 9, Sept. 2010.

[2] F. Zito, D. Pepe, D. Zito, A. “UWB CMOS Monocycle Pulse Generator”, IEEE Trans. On Circuits and Systems I-Regular Papers, Vol. 57, Is. 11, September 2010.

[3] D. Zito, D. Pepe, “LC-active VCO for Modern Wireless Transceivers”, Int. J. of Circuit Theory and Applications, Wiley, vol. 38, pp.69-84, February 2010.

[4] F. Alimenti, S. Leone, G. Tasselli, V. Palazzari, L. Roselli, D. Zito, “IF Amplifier Section in 90nm CMOS Technology for SoC Microwave Radiometers”, IEEE Microwave and Wireless Components Letters, Vol.19, Is.11, pp. 770-773, Nov 2009.

[5] D. Pepe, D. Zito, “22.7dB gain -19.7dBm ICP1dB UWB CMOS LNA”, IEEE Transactions on Circuits and Systems II, Vol. 56, Is. 9, pp. 689-693, July 2009.

[6] D. Zito, A. Fonte, D. Pepe, “Microwave Active Inductors”, IEEE Microwave and Wireless Components Letters, Vol.19, Is.7, pp. 461-463, June 2009.

[7] D. Zito, “A Novel Low-power Radio Receiver Topology for RF and Microwave Applications”, Int. J. of Circuit Theory and Applications, Wiley, Vol.39, pp.1008-1018, April 2009.

[8] D. Zito, et al., "Feasibility Study and Design of a Wearable System-on-a-Chip Pulse Radar for Contact-less Cardiopulmonary Monitoring", International Journal of Telemedicine and Applications, Special Issue of IEEE workshop on “Smart Home and Tele-health”, Hindawi Publishing Corporation, Vol. 2008, pp.1-10, Jan 2008, *invited paper*.

[9] D. Zito, D. Pepe, B. Neri, “RFID Systems: Passive vs. Active and a Novel Low-Power RF Transceiver for IEEE 802.15.4 (ZigBee) Standard Based Applications", J. of Low Power Electronics, American Scientific Publishers , Vol.3, Is.1, April 2007, pp. 96-105;

Chapter of book

[10] “System-on-Chip RF Sensors for Life and Geo Sciences”, Chapter B-VI of “Principles of Waveform Diversity and Design”, D. Zito, et al., SciTech Publishing (USA), *invited chapter*, ISBN 9781891121951, August 11, 2010.

Conference proceedings (invited papers)

[11] D. Zito, D. Pepe, M. Mincica, D. De Rossi, "Wearable SoC UWB (3.1-10.6 GHz) Radar for Cardiopulmonary Monitoring", IEEE International Conference on VLSI-SoC 2008, Rhodos Island (Greece), pp.382-386, Oct. 2008, *invited paper*.

[12] A. Fonte, D. Zito, F. Alimenti, "CMOS Microwave Radiometer: Experiments on Down-Conversion and Direct Detections", IEEE ICECS 2008, pp.1273-1276, *invited paper*.

[13] D. Zito, "On Exploiting New Circuit Topologies for the Next-Generation Wireless Transceivers at the μ- and mm-Waves", IEEE Conference on Circuits and Systems Conference NEWCAS 2008, Montreal, June 2008, pp. 380-383, *invited paper*.

[14] F. Alimenti, D. Zito, A. Boni, M. Borgarino, A. Fonte, A. Carboni, S. Leone, M. Pifferi, L. Roselli, B. Neri, R. Menozzi, "System-on-Chip Microwave Radiometer for Thermal Remote Sensing and its Application to the Forest Fire Detection", IEEE International Conference on Electronics, Circuits and Systems (ICECS) 2008, Malta, 31 August – 3 September 2008, pp. *invited paper*.

[15] E. P. Scilingo, A. Lanatà, D. Zito, D. Pepe, M. Mincica, F. Zito, D. De Rossi, "Wearable monitoring of cardiopulmonary activity through radiant sensing", IEEE International Workshop on Wearable Micro and Nanosystems for Personalised Health (pHealth) 2008, Valencia (Spain), May 21-23, 2008, *invited paper*.

[16] D. De Rossi, A. Lanata, E.P. Scilingo, D. Zito, D. Pepe, B. Neri, "An ultra wide bandwidth wearable system for cardiopulmonary monitoring", 4th International Conference on Personalised Healthcare (pHeath) , Porto Carras (Greece), 20-22 June 2007, *invited paper*.

Conference proceedings

[17] M. Mincica, D. Pepe, D. Zito, F. Zito, "Advances in CMOS SoC Radar Sensor for Contact-less Cardiac Monitoring", IEEE Proc. Of PhD Research in Electronics and Microelectronics (PRIME) 2010, 18-21 July 2010, Berlin.

[18] M. Mincica, D. Pepe, A. Tognetti, A. Lanata, D. De Rossi, D. Zito, "Enabling technology for heart health wireless assistance", 12th IEEE Int. Conference on E-health Networking, Application and Services (HealthCom) 2010, 1-3 July 2010, Lyon.

Conference proceedings (continued)

[19] M. Mincica, D. Pepe, A. Tognetti, A. Lanata, D. De Rossi, D. Zito, "Contactless Cardiac Monitoring Through Wearable Pulse Radar", URSI one-day Colloquium on "Wireless as Enabling Technology" organized by Royal Irish Academy, Dublin, 22 April 2010

[20] M. Mincica, G. Agnese, D. Pepe, D. Zito, "CMOS Correlation Receiver for UWB Pulse Radar", 5th IEEE Conference on PhD Research in Microelectronics and Electronics, Cork (Ireland), 12-17 July 2009, pp. 382-386.

[21] Fonte and D. Zito, "High-Q Millimeter-wave CMOS Active Inductor", 5th IEEE Conference on PhD Research in Microelectronics and Electronics (PRIME), Cork (Ireland), 12-17 July 2009, pp. 272-275.

[22] F. Alimenti, G. Tasselli, S. Bonafoni, D. Zito, L. Roselli, "Inter-Wall Fire Detection by Low-Cost Microwave Radiometric Sensors", IEEE European Microwave Conference, Amsterdam (NL), pp. , 27-31 Oct. 2008, pp.63-66.

[23] G. Tasselli, F. Alimenti, A. Fonte, D. Zito, L. Roselli, D. De Rossi, A. Lanatà, B. Neri, A. Tognetti, "Wearable Microwave Radiometers for Remote Fire Detection: System-on-Chip (SoC) Design and Proof of the Concept", Int. Conf. of the IEEE Engineering in Medicine and Biology Society, Vancouver, 20-24 August 2008, pp. 981-984.

[24] D. Zito, et al., "Wearable system-on-a-chip UWB radar for contact-less cardiopulmonary monitoring: Present status", Int. Conf. of the IEEE Engineering in Medicine and Biology Society (EMBS), 20-25 Aug. 2008, Vancouver, pp. 5274 – 5277.

[25] D. Zito, A. Fonte, B. Neri, "Advanced Model and RF-CMOS Design of the Boot-Strapped Inductor", IEEE Int. Conf. on Electronics, Circuits and Systems (ICECS) 2007,11-14 December 2007, Marrakech, pp. 613-616;

[26] D. Zito, F. Alimenti, A. Fonte, B. Neri, D. De Rossi, A. Lanata, A. Tognetti, "Wearable System-on-a-Chip Radiometer for Remote Temperature Sensing and its Application to the Safeguard of Emergency Operators", Int. Conf. of the IEEE Engineering in Medicine and Biology Society, Lyon (France), 23 - 26 August 2007, pp. 5751-5754;

[27] D. Zito, et al., "Wearable System-on-a-Chip UWB Radar for Health Care and its Application to the Safety Improvement of Emergency Operators", International Conference of the IEEE Engineering in Medicine and Biology Society, Lyon (France), 23 - 26 August 2007, pp. 2651-2654;

Conference proceedings (continued)

[28] F. Barale and D. Zito, "UWB 3.1-10.6 GHz CMOS LNA", IEEE Proc. of the Int. Conf. on PhD Research in Microelectronics and Electronics, Bordeaux (France), 2-5 July 2007, pp. 45-48;

[29] F. Zito, D. Zito and D. Pepe, "UWB 3.1-10.6 GHz CMOS Transmitter for System-on-a-chip Nano-Power Pulse Radars", IEEE Proc. of the Int. Conf. on PhD Research in Microelectronics and Electronics, Bordeaux, 2-5 July 2007, pp.189-192;

[30] A. Fonte and D. Zito, "1-V 13-GHz Ultra Low Noise Amplifier for System-on-a-Chip Radiometer in CMOS 90 nm", IEEE Proc. of the Int. Conf. on PhD Research in Microelectronics and Electronics, Bordeaux (France), 2-5 July 2007, pp.41-44;

[31] F. Alimenti, A. Fonte, D. Zito, "Feasibility Study and Design of a Low-cost System-on-a-Chip Radiometer on Silicon", IEEE Int. Waveform Diversity & Design (WDD) Conference, 4-8 June 2007, Pisa (Italy), pp. 37-41;

[32] D. Zito, D. Pepe, B. Neri, D. De Rossi, "Feasibility Study of a Low-cost System-on-a-Chip UWB Pulse Radar on Silicon for Heart Monitoring", IEEE Int. Waveform Diversity & Design (WDD) Conference 2007, 4-8 June 2007, Pisa, Italy, pp. 32-36;

[33] D. Zito, D. Pepe, B. Neri, D. De Rossi, A. Lanatà, "Wearable System-on-a-Chip Pulse Radar Sensors for the Health Care: System Overview", IEEE Int. Conf. on Advanced Information Networking and Applications (Int. Workshop on Smart Homes and Tele-Health), Niagara Falls (Canada), May 21th-23rd, 2007, pp. 766-769.

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Prior to joining UCC/Tyndall, he worked with the RF Advanced Design Center of the University of Catania (Italy) within STMicroelectronics in Spring 2001, and the RFIC design team within the Drive Unit of Austriamicrosystems, Graz (Austria) in 2002. In 2005, he became an Assistant Professor of Electronics at University of Pisa (Italy). He is co-author/author of more than seventy papers in peer-reviewed international journals and conference proceedings (six invited papers), one chapter of book, one book edited and two patents. His primary interests relate the design of radio-frequency, microwave and millimetre-wave front-ends on standard CMOS and Bi-CMOS technologies. He had the responsibility of about ten EU and National projects, 36 test-chip designs (96% passed at 1st foundry-run). He is the National Coordinator for Ireland of the EU COST Action IC803 on Emerging Wireless Applications. He is leading a EU cluster on innovative systems for biomedical applications.

Domenico Zito received three reasearch awards at IEEE conferences, two best paper award nominations (IEEE EuMIC 2006 and IEEE BCTM 2006), and the "First Price" (10KE) at European Wireless Business Idea "Mario Boella" Competition in December 2005.

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