## 2· 項目簡介

(*項目所屬科學技術領域、主要技術內容、授權專利情況、技術經濟指標及應用推廣情況*)

The wireless and semiconductor industries fast progress has raised the perspective of fully autonomous and seamless wireless connectivity in the near future, via combining advanced CMOS technologies with innovative hybrid-domain circuits and systems solutions. One aim inside this immense scope is to develop a smart-mobile-companion device with high performance, adaptive connectivity and high power efficiency. High performance is the essential ingredient to cope with the ever increasing number of add-on functionalities in small handheld devices, like the smart phones, which can potentially integrate the cellular, WiFi, energy-harvesting ZigBee/Bluetooth units, Global Positioning System and mobile TV, etc. All of them open tremendous opportunities for furthering the horizons of radio frequency integrated circuits (RFICs) in the years to come.

The technical challenges of RFIC development can be classified as ultra-low-power (ULP) and wideband electronic solutions that are capable of handling multiple wireless standards in a small die area and with a long battery life, while minimizing the manufacturing costs. Yet, in China nowadays, still most of the advanced microelectronics are imported including those turn-key intelligent solutions for the huge market of smart phones, although China consumes close to 50% of world electronics, thus implying a strong lack of pioneering innovations from our fast-growing country that is the 2nd-largest world economy. According to recent reports "China spends a lot more on importing chips than oil and last year imported $192 billion in integrated chips and a mere $120 billion in oil. This matters in China - and in the telecom sector in particular - because despite tipping all of that cash into semiconductor industry's pockets, domestic handset firms are well back in the queue for the US Qualcomm and ARM chips that power top-range devices. A paper by State Council Research Office a month ago said 80% of China's chips come from abroad, namely, according to a sour China Business News report: China in one year produces 1.18b handsets, 350m computers and 130m color TVs - all No. 1 worldwide. But the high-end patent fees embedded in these reduce all of us to manual workers for the international vendors. In truth China industry lacks the scale as well as the expertise of the big US, Korean and Taiwan chip players."

Driven by these crucial facts, circuits and systems innovations become decisive and will be exorbitantly demanded for the growth of our information technology sectors in the future. Then, our main objective for development should be to contribute for the invention of sustainable turn-key wireless interfaces capable of surpassing the constraints of CMOS technologies and addressing the key technical challenges of existing designs. With all this in mind our strategy in this area led recently to three main technology breakthroughs in:

i) ULP Short-Range Radios;
ii) Wideband Cognitive Radios;
iii) ULP Analog-Baseband Circuitry.

i) ULP radios have essentially underpinned the development of short-range wireless technologies such as personal/body-area networks (IEEE 802.15.4 standard) and Internet of Things. The main challenges present are the stringent power and area budgets, and the pressure for minimum external components to save cost and reduce system dimensions. Balancing them with the performance metrics such as noise figure, linearity and input matching involves many design tradeoffs at both architecture and circuit levels. There are numerous architectures reported. Ultra-low-voltage receivers have been extensively studied for short-range ZigBee, Bluetooth and energy-harvesting applications. Yet, the lack of voltage headroom (below 1V) will limit the signal swing and transistor's fT, imposing the need of bulky inductors or transformers, thus, easily penalizing die area. Our inventions, now with world recognition and being at the forefront of the state-of-the-art, were based on innovative and ingenious ULP receiver topologies addressing the challenges and optimizing the performances, in advanced process nodes such as 65-nm CMOS featuring sufficiently high-fT and low-VT transistors for GHz circuits to operate at very small bias currents.

ii) Wideband cognitive radios are targeted for the 4th-generation (4G) communication and beyond, with the scope of sharing the geographically unused white spaces in the TV band (54 to 864MHz) which has led to the appearance of the wideband wireless receiver and transmitter for the IEEE 802.22 standard, embodying the cognitive radio technique to enable an opportunistic share of the spectrum. To avoid causing detrimental interference to the incumbent primary users, one key challenge of such a TV-band transmitter lies on managing the unwanted harmonic emission without pricy or complicated filtering modules. For the TV-band receiver, as the sensitivity is mainly limited by its noise figure, the forefront low-noise amplifier and mixers should feature high-gain and low-noise. These requests promote the use of an active mixer driven by an adequately large local oscillator for hard-switching mixing. Our innovations in this area have focused on multi-path mixing and sinewave mixing to enhance the harmonic rejection ratio, and on the utilization of passive-intensive filter to suppress skilfully the non-cancelled harmonics without degrading the linearity.

iii) ULP Analog-Baseband circuitry in modern wireless devices suffer from one energy problem which is the need to drive up the high-color-depth LCD display, involving an extensive number of amplifiers to buffer the reference voltages, which have to be stabilized by nF-range capacitors to handle the glitch energy during the digital-to-analog conversion. To deal with such a large capacitive load (CL), most commercial buffer amplifiers will require an external resistor in series with the output for ringing reduction. This regrettably penalizes the cost, settling time and high-frequency gain droop. Our innovation in this case focuses on advanced micro-power single- and multi-stage amplifiers for its capability of precision buffering, balanced speed, power and area efficiencies at low voltage. Then, our successful research work led to the development of micro-power amplifiers managed to afford particularly large and wide range of CL with optimized power and die size, being particularly suitable for compact LCD drivers with different resolution targets.

The associated sub-projects have trained or are training 10 Ph.D., 4 M.Sc. and 4 B.Sc. students. Totally, 4 US Patents were applied, 1 book chapter, 13 international journal publications including the prestigious IEEE Journal of Solid-State Circuits, and 10 international conference papers were published. From these, 4 of the conference papers were published in the World Electronics Chip Olympics - International Solid State Circuits Conference (ISSCC) that takes place every year in San Francisco, USA. The 4 Ph.D. students able to publish in this world top conference in 2014 are from mainland China and before joining our laboratory and project had only experience of working in Chinese companies performing "electronics reverse-engineering" without knowing the technology. But, with the solid and sound coordination of our research team, in 3 to 4 years, and also with their hard work and acquired knowledge, they were catapulted to the world-stage of electronics. A technical industry source, from a world-leading company in the field, mentioned above, after being aware of our results in ISSCC 2014 stated: "I was not previously aware of UM's prevalence in the area of RF/Mixed-signal but considering your success at publishing at ISSCC this year something tells me I will soon start seeing UM everywhere."

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