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5G mm-Wave Technological Prototype Demonstrators for Wireless Communication between Connected Objects: Toward Energy-aware MIMO and Configurable Phased Array solutions

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Abstract — ***This contribution deals with 5G and mm-Wave Technological platform and prototype demonstrators with emphasis on the following driving enablers:***

- ***Smart 3D antenna solutions for MIMO and mMIMO (massive MIMO)***
- ***Point-to-Point Spectrum sensing for evaluating energy efficiency & cost of communication***
- ***Switched Phased-Arrays design solutions for Beamforming and Beam steering***
- ***Unified Time-Domain and Frequency-Domain Technological platform toward standardization of Near-Field sensing***

The proposed platform and prototype demonstrators are developed based on Energy-aware Chip-Package-PCB [including antennas] Co-Design* [1] *of emerging technologies including 5G and mm-Wave wireless applications addressing the challenges: Any-Device, Any- Network, Any-Where, Any-Time with Seamless Connectivity.

MAIN RESULTS, ANALYSIS AND DISCUSSIONS

Wireless-Link demonstrators with MIMO functionality is built using NXP circuit design solutions combined with innovative 3D Smart Antenna Solutions. This is the world's most integrated Ku band down-converter solution for Quadrature Channel (QUAD) applications. NXP's unique SiGe process has enabled this unrivalled level of Ku band integration, with the bias function, as well as the full matrix for selecting one of the four incoming channels to any of the outputs, combined in one device. Reliable and easy to implement modular approach is proposed enabling various configurations which offer real benefits over typical discrete solutions. Innovative 3D Smart Antenna Solutions suitable for Near-Field/Far-Field Communications [2-5] are evaluated for MIMO/mMIMO and configurable phased-array applications.

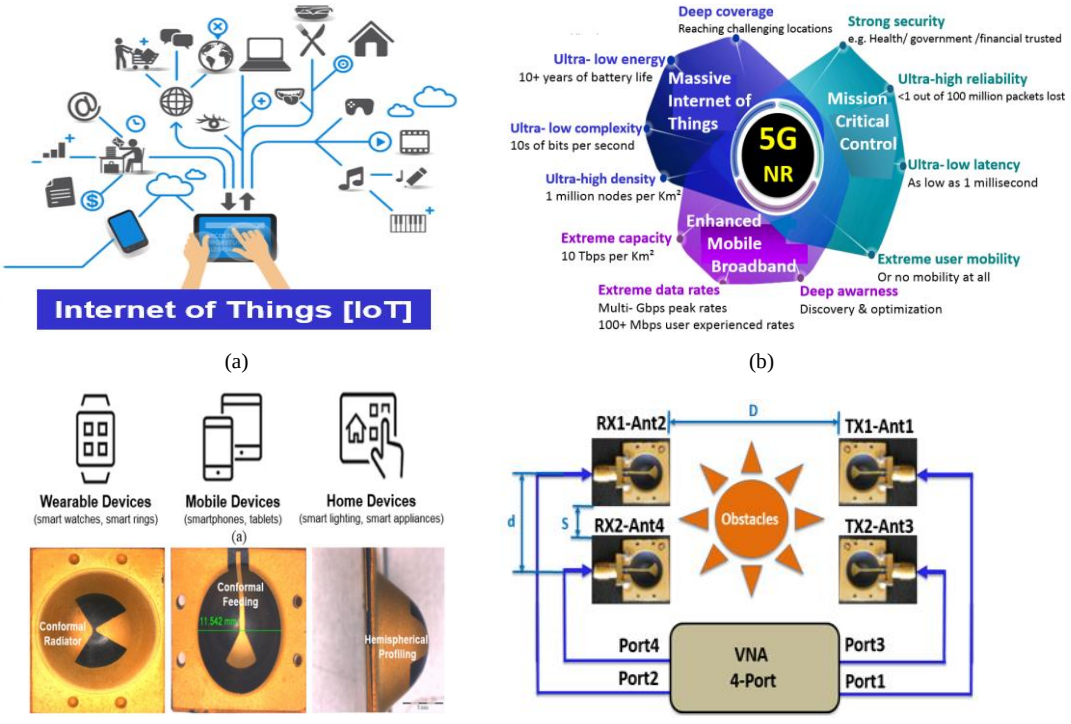
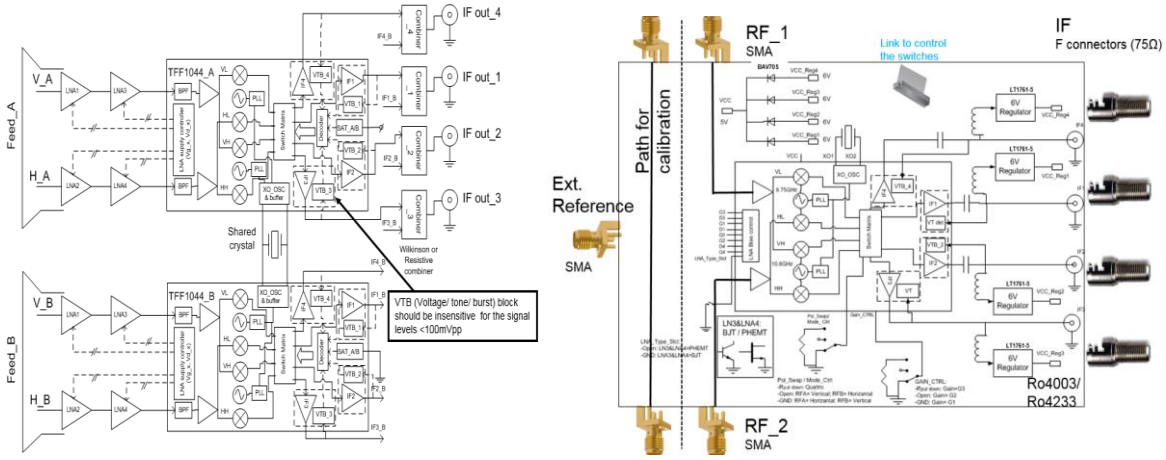


Fig.1: Connected (wearable, mobile, home devices) in the perspectives of Internet-of-Things [IoT] (a) and 5G applications (b): Making 5G NR a reality leading the technology innovations for a unified, more capable 5G air interface, CTIA Super Mobility 2016-5G Technical Workshop Qualcomm Technologies, Sep. 2016. Designed and fabricated 3D conformal (c) antenna for MIMO applications (d).

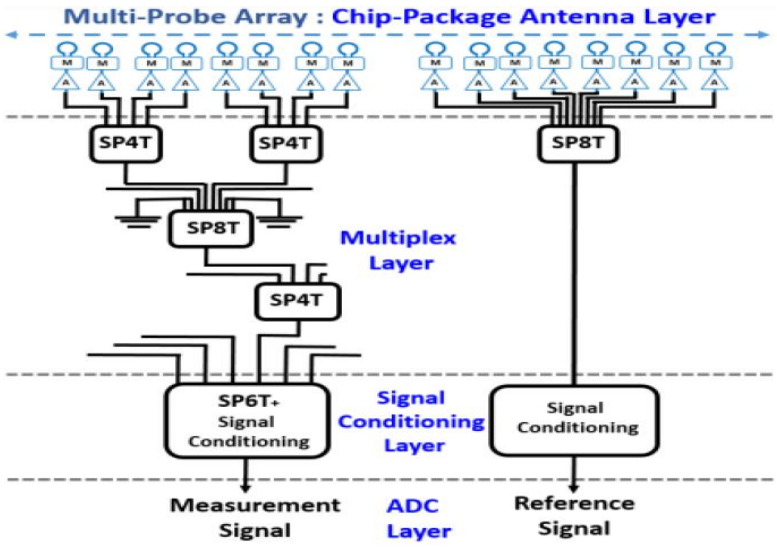
An important attention is directed towards the following requirements:

- Energy-aware Chip-Package-PCB-Antenna co-design [1] accounting for proper transitions at different sub-domain interfaces
- Stochastic signal-processing approach for optimal monitoring of Signal-to-Noise (SNR) ratio accounting for waveform shaping and energy-efficient modulation schemes.
- System-level test/calibration and validation for proper deployment of 5G and mm-Wave [1]-[7] technological platform accounting for Multi-Physics [1] reliability constraints.

Fig.2 shows the block diagram of developped 4-Channel single Chip solution realized using NXP SiGe technology in WLCSP packaging. Dedicated application boards and smart MIMO antenna solutions [8] are proposed to evaluate loss path and Signal-to-Noise ratio as function of coupings and interferences.



(a) (b)



(c)

Fig.2: MIMO Multi-Channel single Chip solution realized using NXP SiGe technology in WLCSP packaging (a) including calibration path (b). Principle of used Near-Field scanner based on switched probe arrays (c).

The 4-channel demonstrator includes the following elements:

- Quad RF downconverter: 2 RF inputs, 4 IF outputs
  - Single-ended RF inputs / IF outputs
  - Programmable conversion gain
- 4x4 IF switch: allows all polar/band combinations at any IF output
  - Reduced power drop when same polar/band distributed to multiple outputs
- Dual LO PLL frequency synthesizer
  - Integrated loop filter
  - Integrated reference clock crystal oscillator (off chip reference clock)
- Voltage & tone detection: for selection of polar/band

  - IF path switched off when no user connected (power saving mode)
- Quad LNA controller: for control of 4 external low noise transistors
  - Compatible with BJT/pHEMT transistor control
- Digital control bus: for debug and test
- 5V supply: single pin

Fig.2(c) illustrates distributed Chip-Package-PCB Co-design of switched probe arrays for Near-Field scanning systems considering the following aspects:

- The probing sensors are implemented at the interface of the chip and package domains so that the probe itself is realized on package and the pre-amplifiers are implemented on chip.
- The signal processing controls integrate calibration and deembedding procedures properly accounting for probe compensation (including mutual couplings)
- The concept of Built-In-Self-Test (BIST) is introduced for broadband matching, power calibration (including nonlinearities, modulation effects), and probe arrays compensation (multi-Physics).

The inherent topology architecture of probe arrays [2-3] systems requires innovative deembedding and compensation (load modulation-aware) procedures tightly combined with signal processing techniques for accurate extraction of Near-Field amplitude and phase information with controlled noise uncertainties [9].

CONCLUDING REMARKS

Stochastic approaches based on Energy oriented metrics such as Power Spectral Density [10] and Entropy [11] are proposed for the modeling and experimental verification of emerging technologies including 5G/mm-Wave MIMO/mMIMO and Phased-Array applications. Use of BIST (Built-In-Self-Test) solutions for real-time monitoring of system-level performances including power/energy level and Signal-to-Noise ratio tracking and optimization will open further possibilities.

ACKNOWLEDGMENT

The author is grateful to National Instruments, Keysight, Rohde & Schwarz, AR-France and EMSCAN for their collaborations and partnership. This work was supported in part by COST ACTION IC1407, and by the European Union's Horizon 2020 research and innovation programme under grant no. 664828 (NEMF21).

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