A RF Hardware Abstraction-based Methodology for Front-End Design in Software-Defined Radios

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Outline

• Introduction
• Hardware abstraction
• Our HA-based design approach for RF/MW domain: an overview
• Our HA-based design approach for RF/MW domain: from theory to practice
• Summary
Introduction

1. Communications: a world in turmoil!
2. RF design: a delicate job!
3. Design: which methodology for the future?
Communications: A continuously evolving sector

- Various standards
- Different Quality of Service (QoS) / Applications
- Network convergence

New paradigms:

- Software-Defined Radio (SDR)
- Cognitive Radio (CR)
- End-to-End Reconfigurability (E2R)
  
...
Design Methodology:

- Remarkable advances in digital design
  - Circuit / functionalities’ Synthesis
  - Availability of automation tools / well elaborated design environments
  - Various design approaches, …

- Analog (such as RF / microwave) design stagnates!
  - Design is often manual (/ semi-manual) and handcrafted,
  - RF design is technology-dependent,
  - Designs are generally non adaptive et rarely non reusable, …

⇒ Effective design needs are emerging:

- An agile, flexible and adaptive design approach is needed!
The new design methodology should be:

- **Agile et adaptive** (adaptable to the product line)
  - Mask the design constraints (modeling / functional description)
- **Automated** (enhancing productivity)
  - Masks the technology details,
  - Includes a smart process able to automatically select the implementation
- **Flexible**
  - Allow previous designs reuse, and
  - Capture data all over the design cycle steps (validation)

⇒ A basic concept is needed: Hardware Abstraction
Hardware Abstraction

1. Understand Hardware Abstraction
2. Advantages of Hardware Abstraction
3. Hardware Abstraction in Some Domains
Hardware Abstraction (HA) is a paradigm that consists of masking the physical details of a given platform, allowing the designer to focus on the system’s response details resulting from the direct manipulation of the hardware platform. It is a fashion to describe the functionality without the manipulation of the equipment intrinsic architecture.
Advantages of the hardware Abstraction

- Allows the encapsulation of parts / and details unnecessary for the design
- Enhances the uncoupling of the function from the physical platform
- Allows a multi-level / hierarchical description of the system
- May enhance the design automation and implementation
- Allows the development of standardized interfaces
- Reduces the system complexity (black box concept)
- Allows the clear definition of the specifications of each system component
- Enhances the integration of tiers technologies

⇒ Hardware Abstraction (HA): a useful concept in various domains
Computer Domain:

- Operating Systems
  - Drivers, middleware layers, ...

- Databases
  - Data access logical levels, multi-level databases

- Networking
  - Communication layers and protocols (TCP/IP stack, OSI Model, …)

- Software Design
  - Modular design, Model-driven architecture (MDA), …

⇒ HA has sustained remarkable progress in this domain
Microelectronics Domain:

- VLSI Design
  - Cell concept (behavior defined by formal logical equations, inputs and outputs),
  - A cell captures the functionality defined by the model,
  - Hierarchical design of cells…

- Design of programmable circuits (FPGA, PLA, …)
  - High-level hardware description language (e.g. VHDL / Verilog) ensures the functional description of the system,
  - Then, the circuit is synthesized in an automated fashion.

⇒ HA allowed the development of IP cores, SoCs, …
Hardware Abstraction in some domains (3)

Software-Defined Radio Domain:
- Software Communication Architecture (SCA – JTRS)
  - CORBA / IDL
- Government Reference Architecture
  - Modem Hardware Abstraction Layer (MHAL)
  - Open System Interface (OSI)

Other Initiatives
- Matlab Simulink
- Software-Based Communication Components (OMG)
- Open Wireless Architecture

Radio-frequency (RF) / Microwave (MW): (limited and incomplete initiatives)
- UML Profile for Software Radio – OMG

⇒ Further efforts have to be deployed in order to enhance the contribution of HA in the design schemes of RF/MW systems
The Proposed HA Strategy in RF and Microwave Domain: An overview

1. Model-driven Engineering (MDE)
2. Our HA Strategy: Basic Concepts
3. The Proposed HA-based Design Approach
4. How to enhance the abstraction approach?
5. And if we combine these concepts?
Model-driven Engineering (MDE): a software design approach:
- Platform-Independent Model (PIM)
- Platform-Specific Model (PSM)
- Model Transformations

Model-driven Architecture (MDA): an initiative of the OMG built around several standards
- UML (Unified Modeling Language)
- SysML (Systems Modeling Language)
- OCL (Object-Constraint Language)
- XMI (XML Metadata Interchange)
- ...