RF/RF-SoC
Overview and Challenges

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- **Research Topics in RF**
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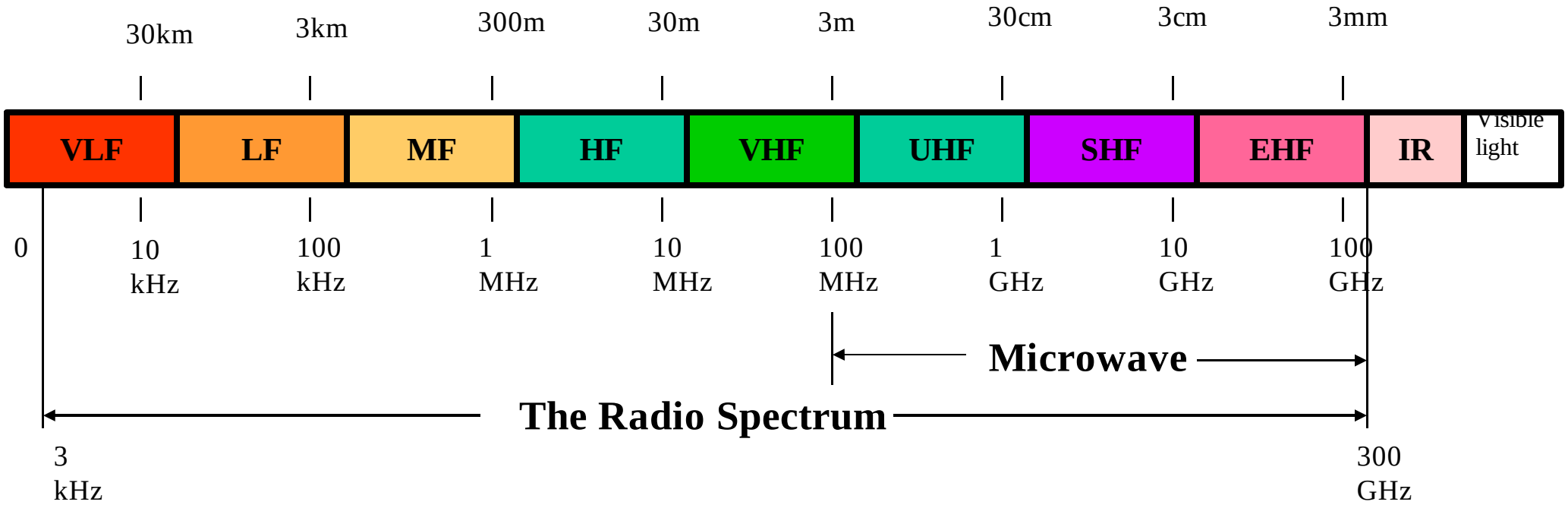
  - RF IC System Design
  - Circuit Implementation
- **What is RF-SoC**
- **Design Methodology**
- **Design Flow**

Allocation of Radio Spectrum in United States

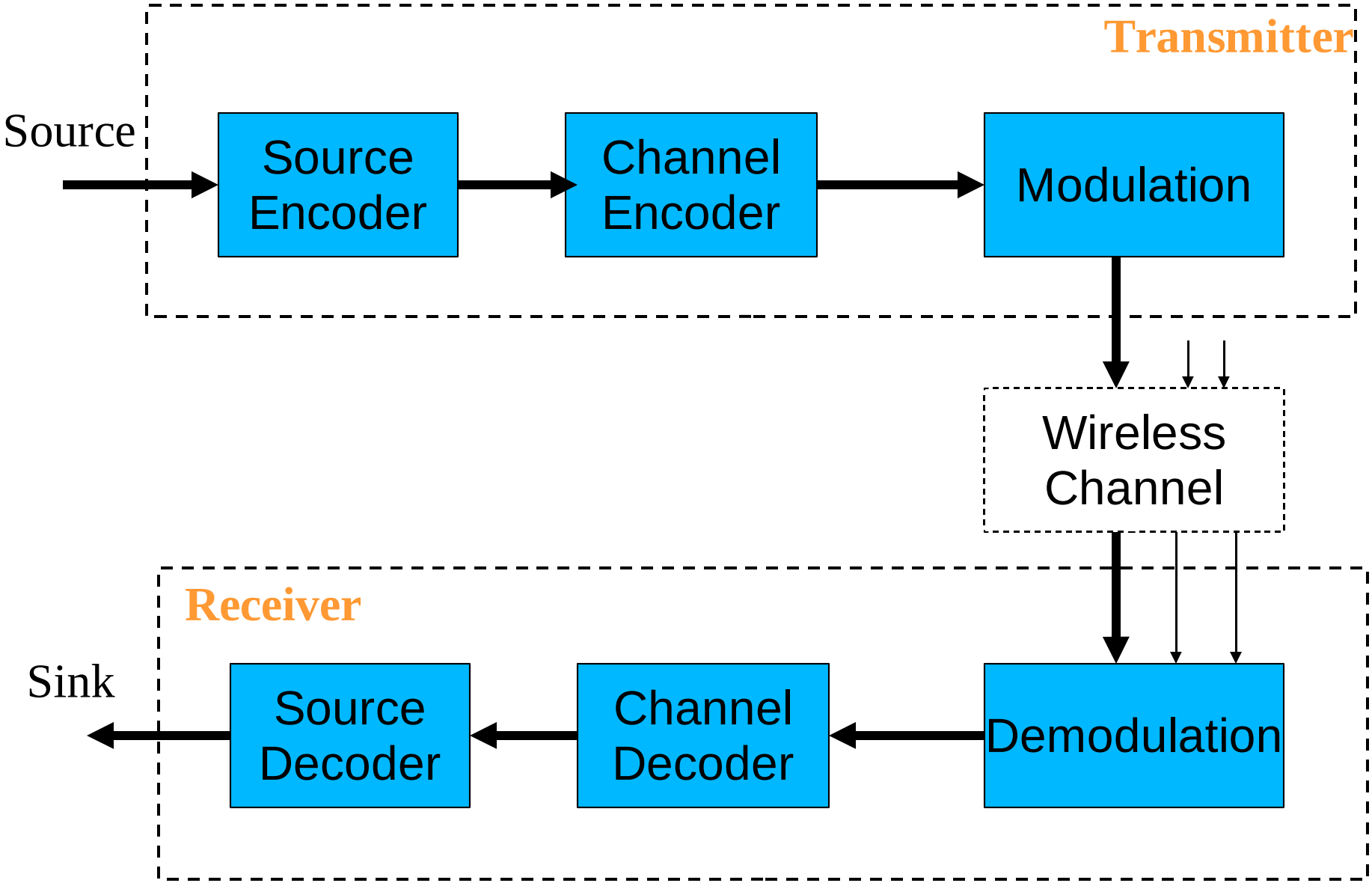


Reference: http://www.ntia.doc.gov/osmhome/allochrt.html April, 2004

What is RF?

- **Bandwidth-based definition:**
  - RF circuits are necessarily narrowband circuits, having bandwidths that are a small fraction of the center frequency.
- **Application-based definition:**
  - For communication system engineers, RF signals are not information but are used as carriers of the information-bearing signals in wireless applications. RF becomes an antonym of the word “based-band”.
- **Size-based Definition:**
  - The size of RF hardware is not negligible compared to the wavelength of the electromagnetic (EM) waves that they process.
- **Definition Used by Electrical Engineers**

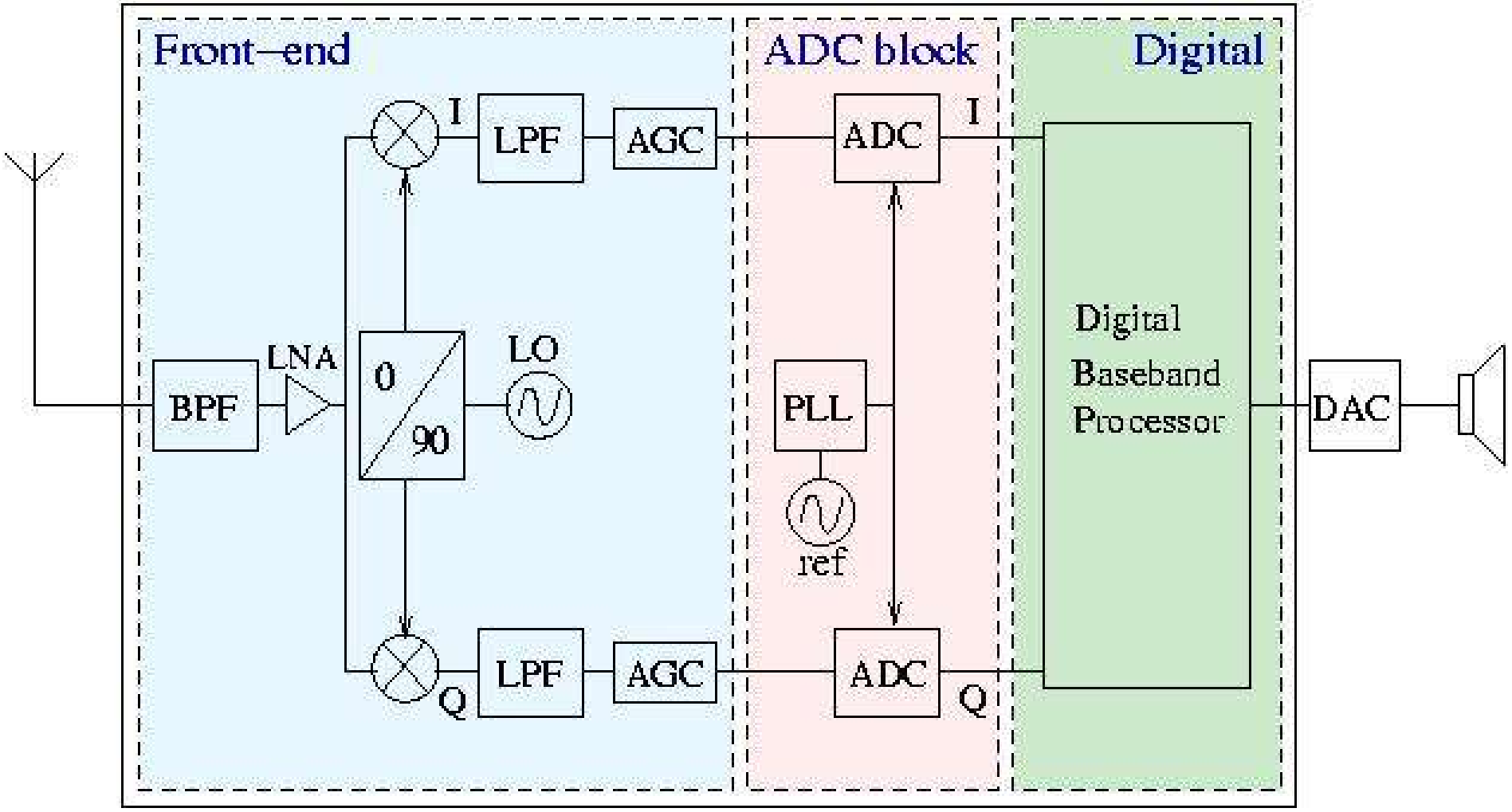
What is RF?
General Digital Communication Diagram



Summary of Different Wireless Standards

Wireless Standard	Access Scheme	Frequency Spectrum(MHz)	Channel Spacing	Modulation Technique	Date Rate
GSM	TDMA/FDD	890-915(Tx) 935-960(Rx)	200kHz	GMSK	270kb/s
UMTS	CDMA/FDD	1920-1980(Tx) 2110-2170(Rx)	5MHz	QPSK	2Mb/s
Bluetooth	CDMA/FH	2400-2480	1MHz	GFSK	1Mb/s

An Example of RF IC
A Receiver System for 3G Mobile



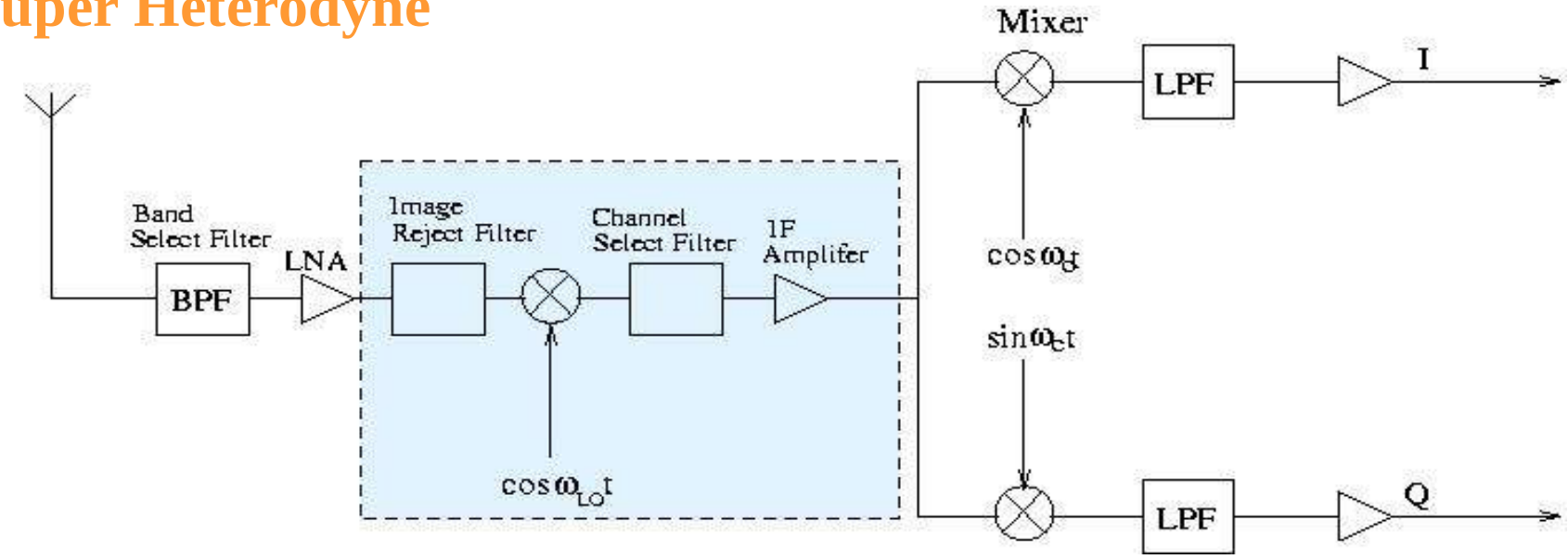
Reference:" A triple-mode continuous-time sigma-delta modulator with switched-capacitor feedback DAC for a GSM-EDGE/CDMA2000/UMTS receive" *IEEE Journal of Solid-state Circuits, Vol. 38, No. 12, Dec. 2003*

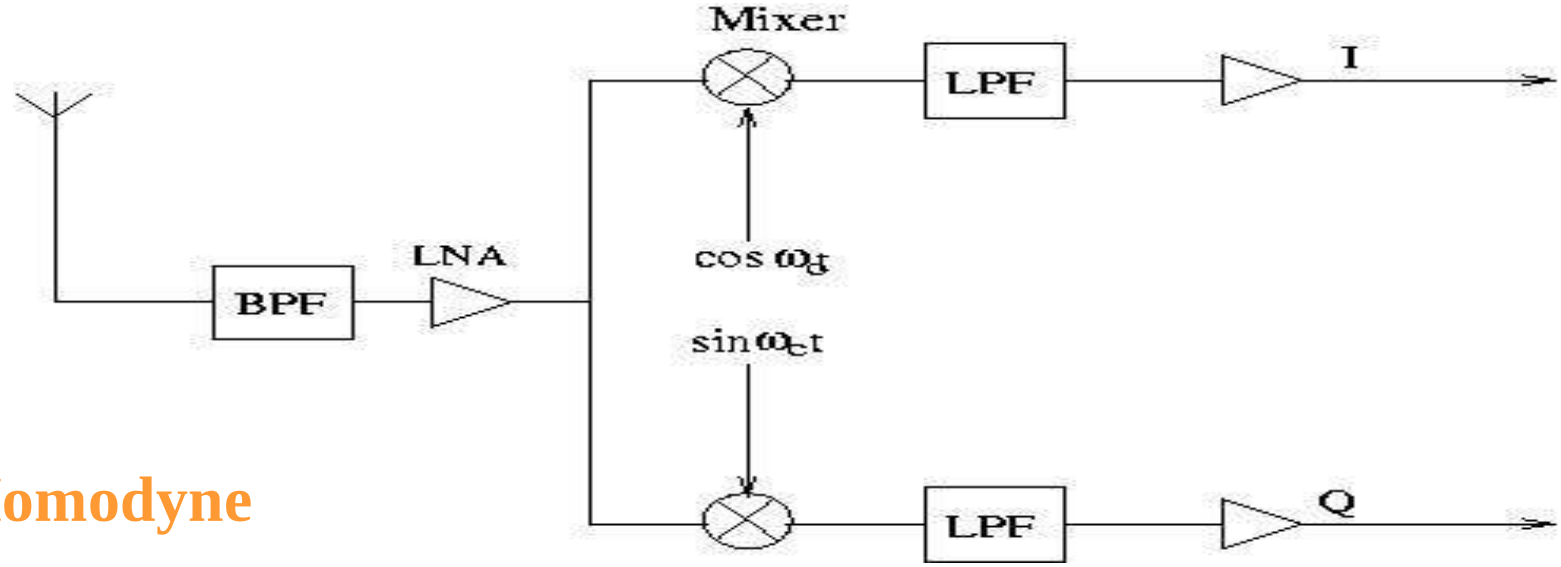
Research Topics in RF IC for 3G Mobile

- **System-level Design**
  - Architecture Design for higher integration of the system.
  - Architecture Exploration for Multi-Standard Receiver.
- **Computer Aided Design**
  - Device Modeling.
  - Simulation Algorithm.
- **Circuit Implementation**
  - Circuit implementation using certain technology for better. performance or higher integration.

System-level:Front-end Architectures

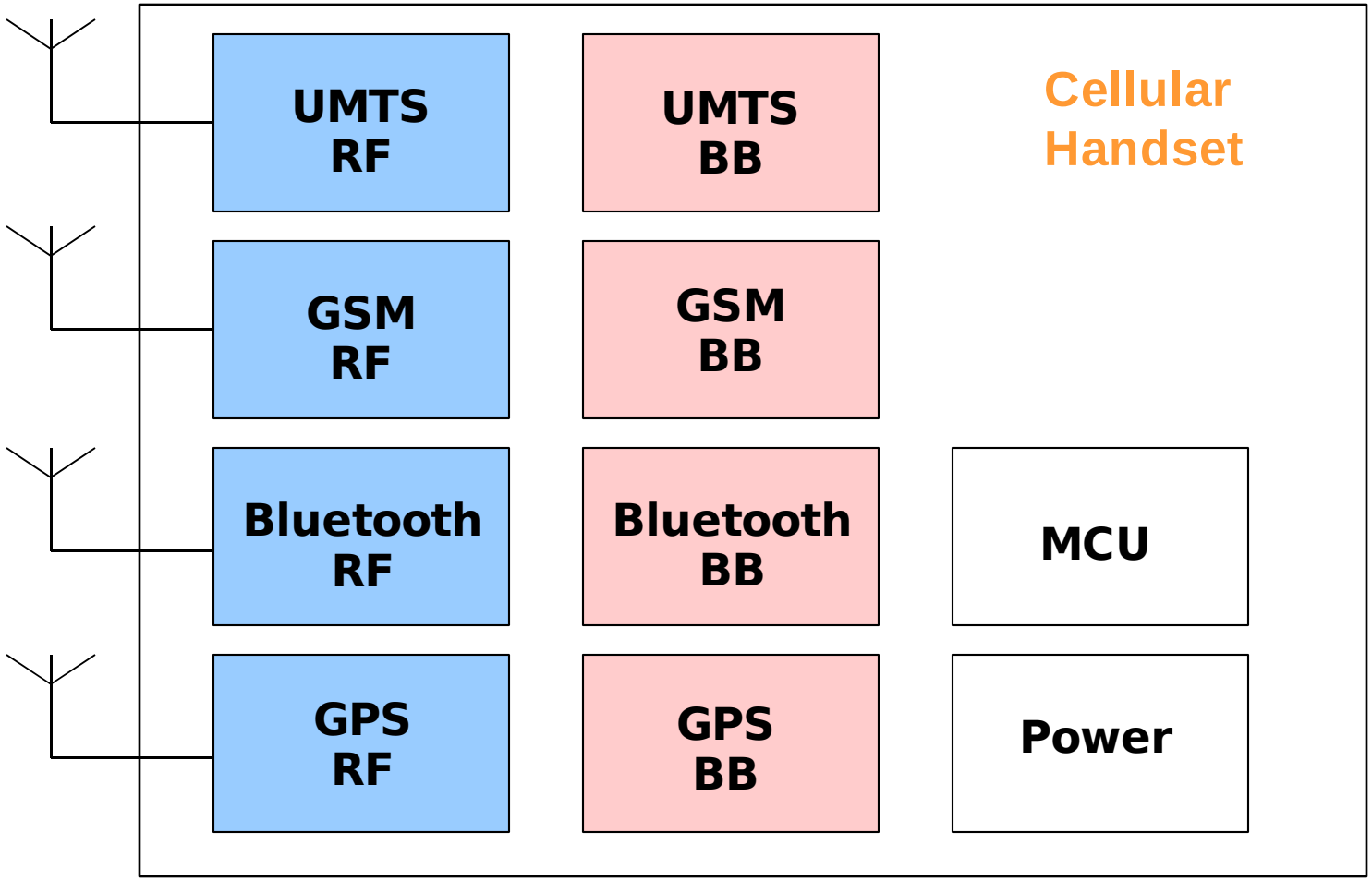
Super Heterodyne



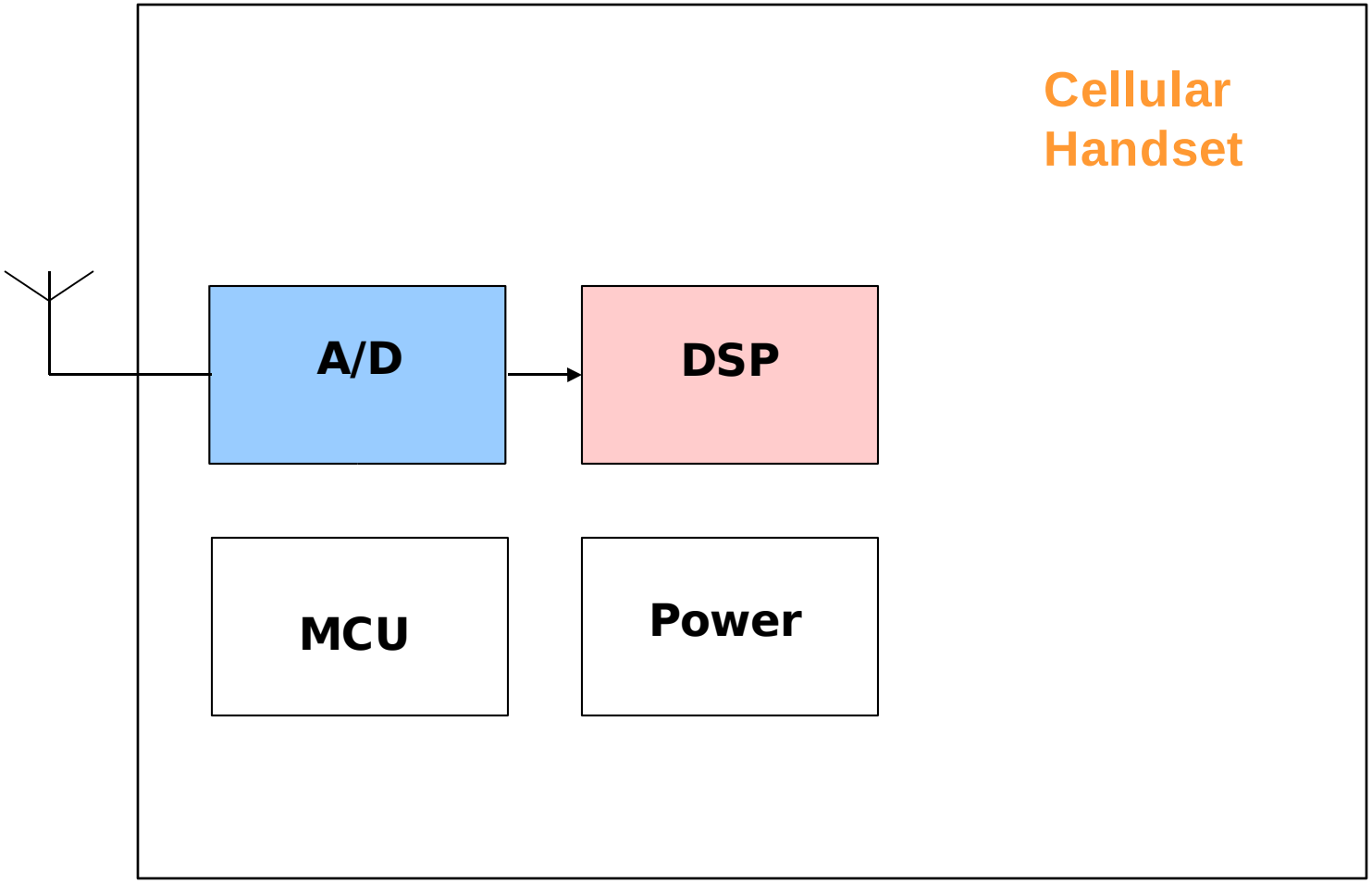


Homodyne

System-level: Multi-Standard Receiver



System-level: Software Radio



Computer Aided Design: RF IC Design

- **Two Circuit Design Methodologies**
  - Digital Design Methodology.
  - Analog/Mixed-signal Design Methodology.

- **RF Design Methodology**
  - Analog/Mixed-signal Design Methodology.

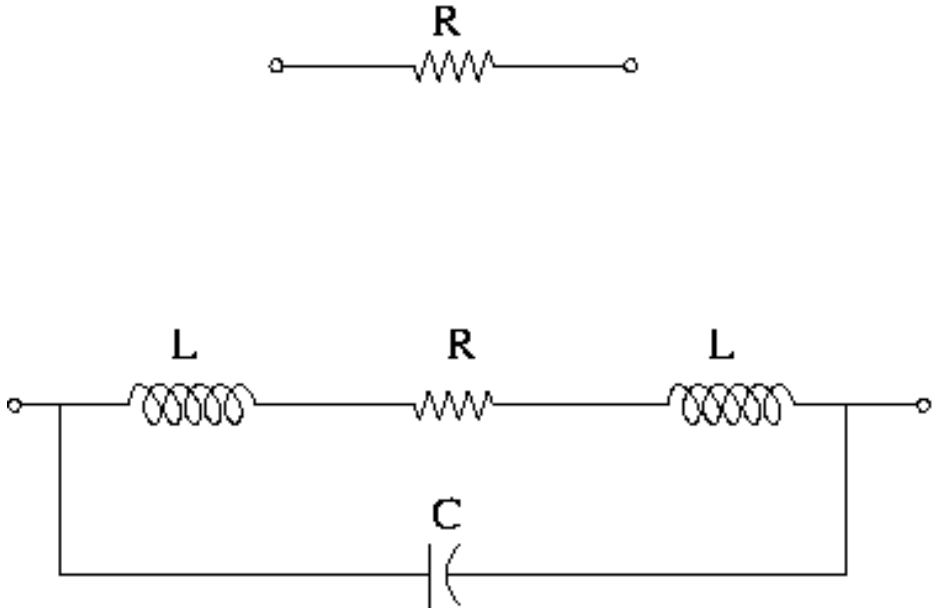
Computer Aided Design: RF IC Verification

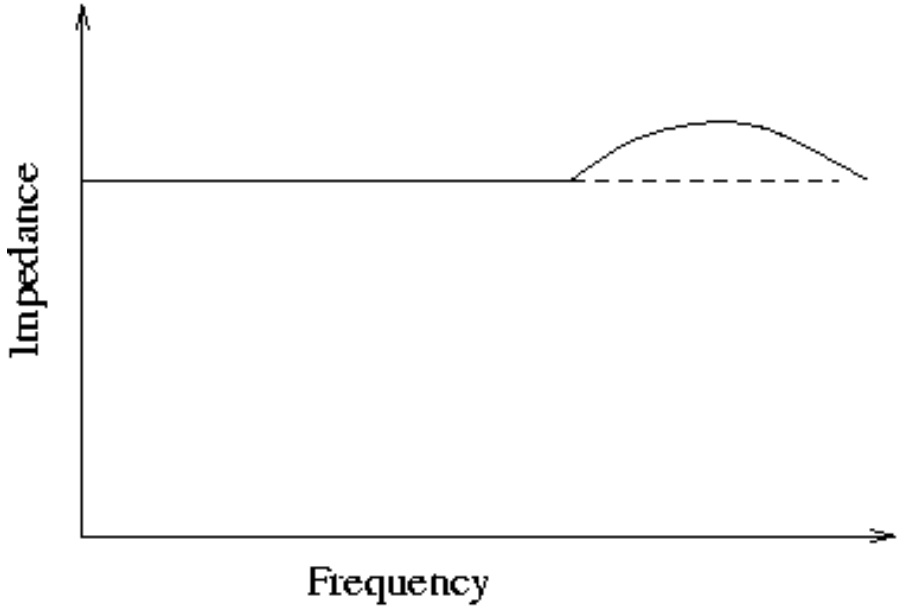
- **SPICE (Simulation Program with Integrated Circuit Emphasis) Simulation Program**
  - Simulator.
  - Device Model.

- **Accuracy and Speed of the Simulation:**
  - Critically dependent on device model and simulation algorithm implemented by the simulator.

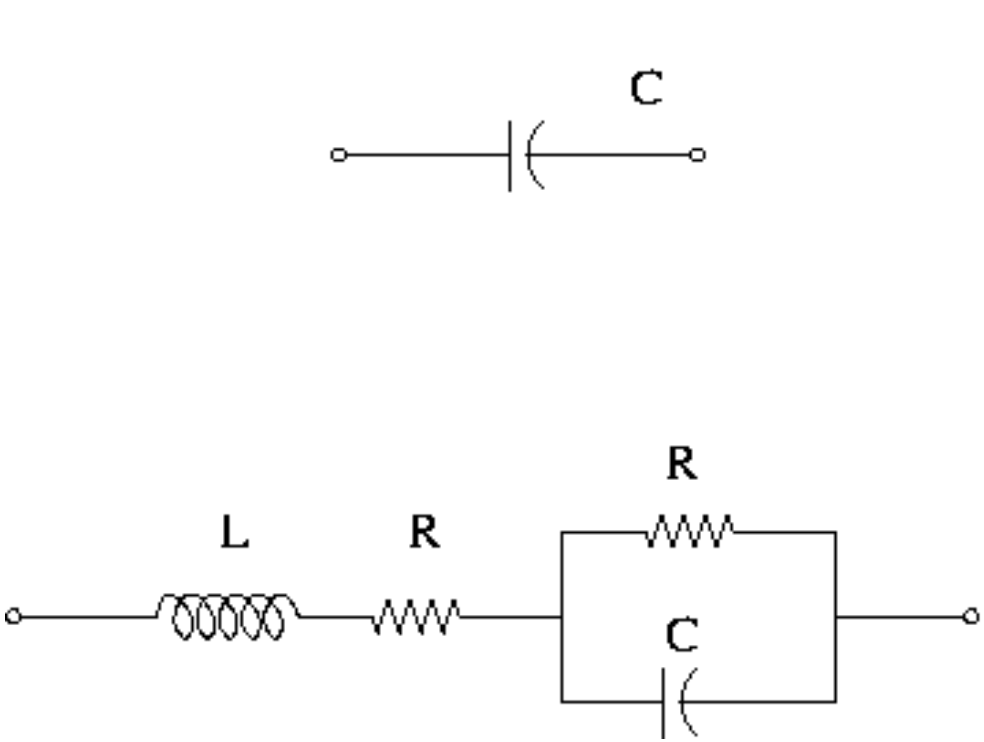
Computer Aided Design: RF IC Verification

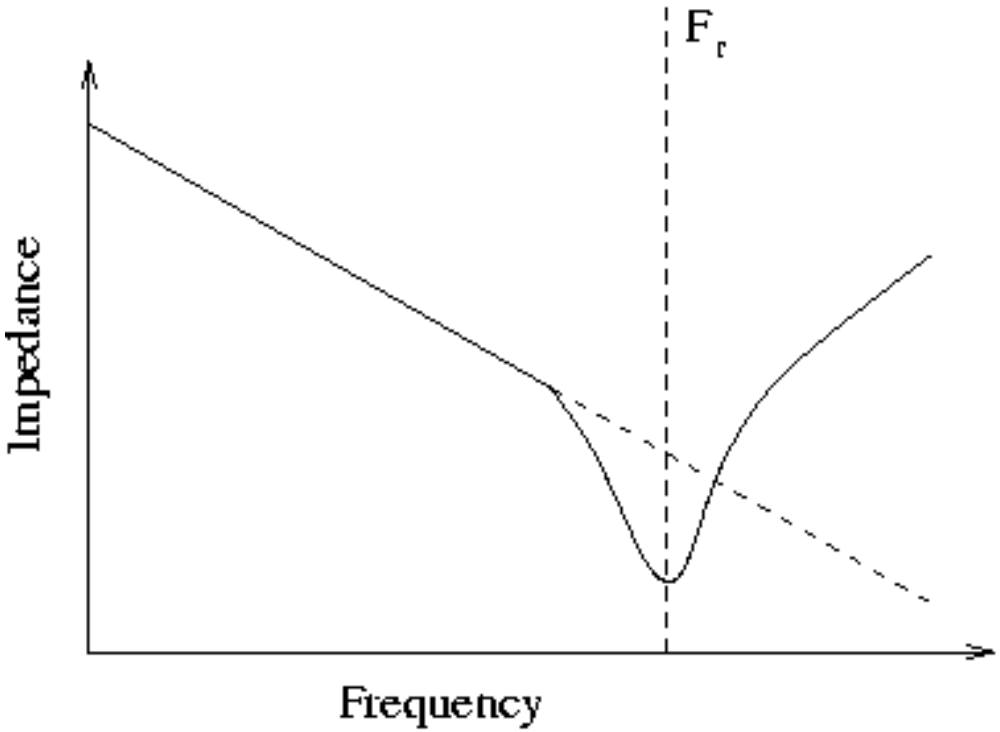
- RF device models are different from analog ones due to the very high operating frequency(1-5GHz).



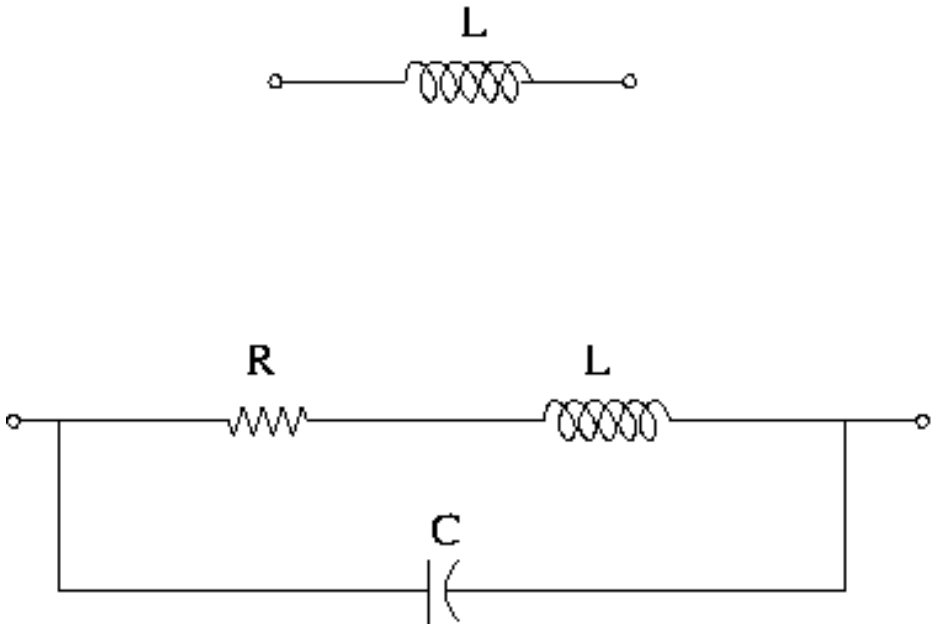


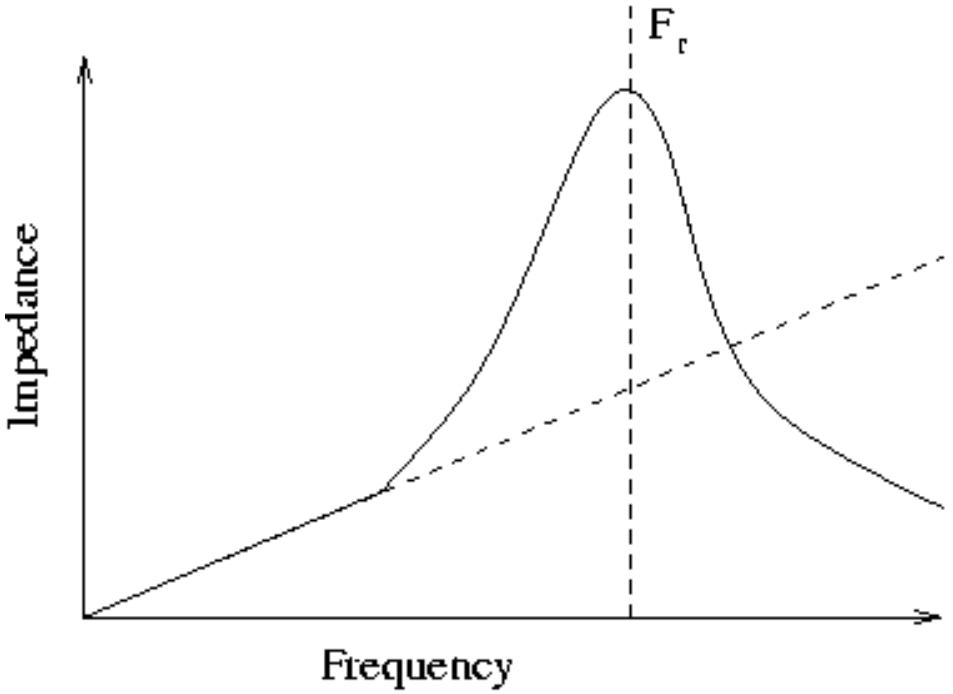
RF IC Verification





RF IC Verification





Computer Aided Design: RF IC Verification

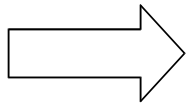
- RF signal: High frequency carrier with relatively low frequency information signal.
- High frequency carrier needs a small time step.
- Low frequency modulation requires a long simulation interval.
- SPICE is not effective and efficient enough for RF circuits.

Circuit Implementation
Comparison of Semiconductor Technologies

GaAs (Gallium-Arsenide)	◆ Highest frequency coverage ◆ **Best RF Performance** ◆ Best passive RF component Integration
SiGe (Silicon-Germanium)	◆ Higher frequency coverage than Si ◆ Better RF performance than Si ◆ Good mixed-signal capability ◆ Higher levels of integration possible ◆ Lower cost than GaAs
Si (Silicon)	◆ **Lowest cost** ◆ **Best mixed-signal capability** ◆ **Highest level of integration possible** ◆ Consistent process

Circuit Implementation

- **Hand-held products demand for**
  - Low power consumption
  - High level of integration
  - Low cost

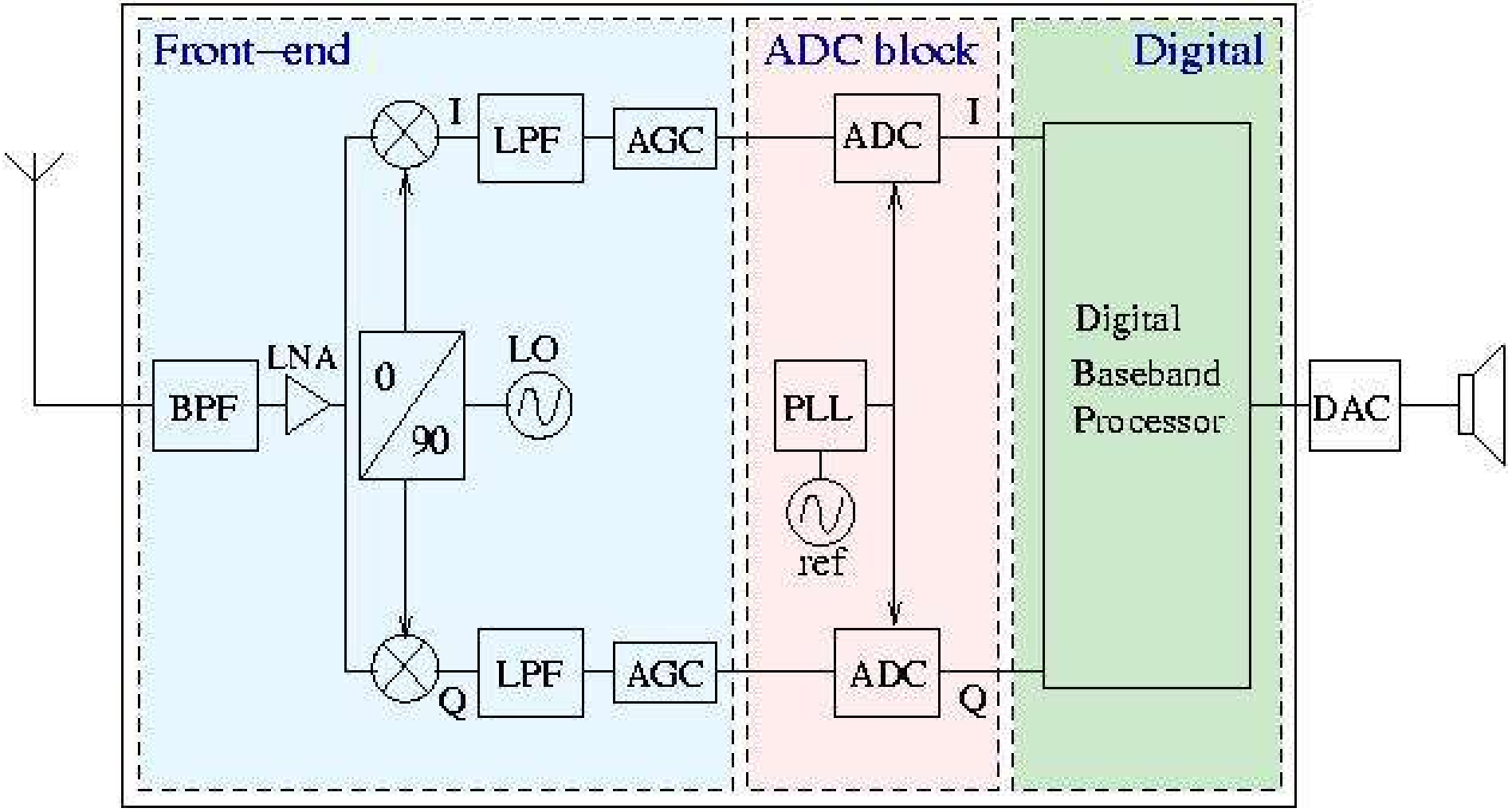


CMOS

- **State-of-the-art CMOS RF IC**
  - A fully integrated 0.18 CMOS direct conversion receiver front-end with on-chip LO for UMTS (published on “IEEE journal of solid-state circuits”, Jan. 2004)

What is RF-SoC ?

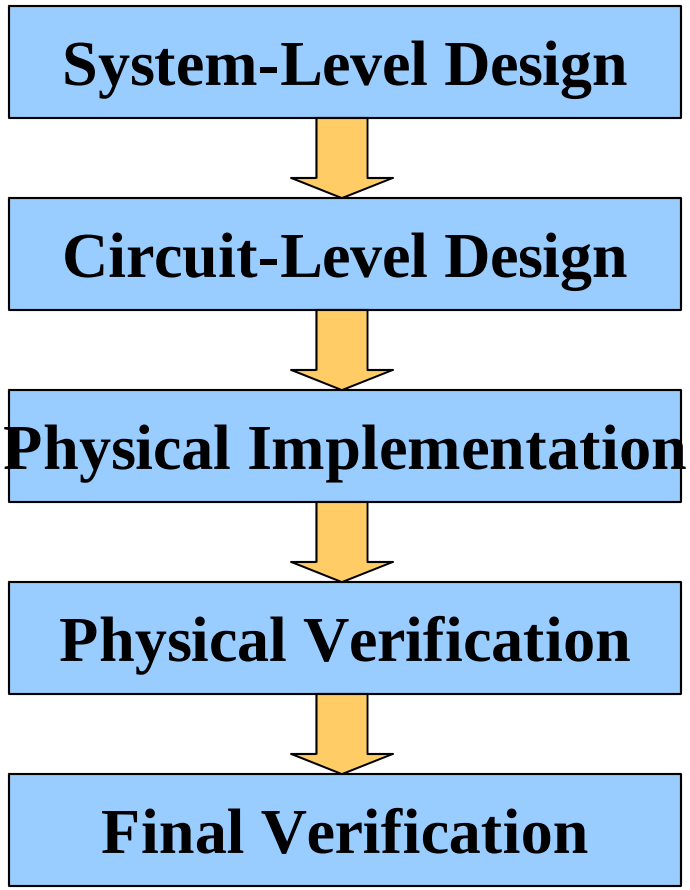
What is RF-SoC ?



Challenges

- Only a single technology can be used.
- RF section can be very sensitive to the interference from digital portion.

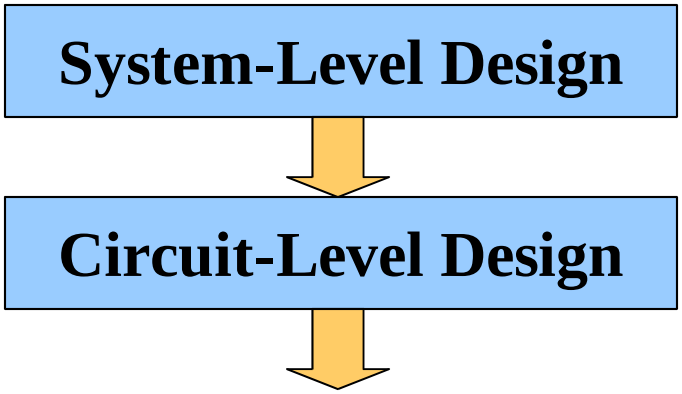
RF-SoC Design Methodology: Top-Down Design, Bottom-up Verification



Basic Idea:

- Architecture of a chip is defined, simulated, and optimized as a block diagram.
- Requirements for the individual blocks are derived.
- Individual blocks are designed and verified against the requirements.
- Entire chip is laid out and verified against the original requirements.

RF-SoC Design Methodology: Top-Down Design, Bottom-up Verification



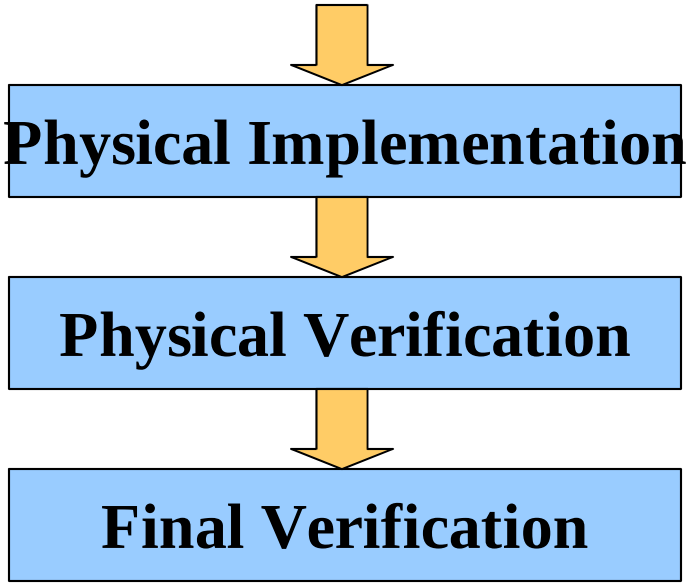
System-Level Design:

- Design is partitioned.
- Circuit blocks and Interfaces are modelled and verified.
- Requirements are derived

Circuit-Level Design:

- Transistor-level circuit of each block is designed.
- Each block is simulated and verified against the specifications.
- Each block is also verified in the context of the entire system (Mixed-level simulation).

RF-SoC Design Methodology: Top-Down Design, Bottom-up Verification



Physical Implementation:

- Architecture is converted to floorplan.
- The blocks are laid-out and routed.

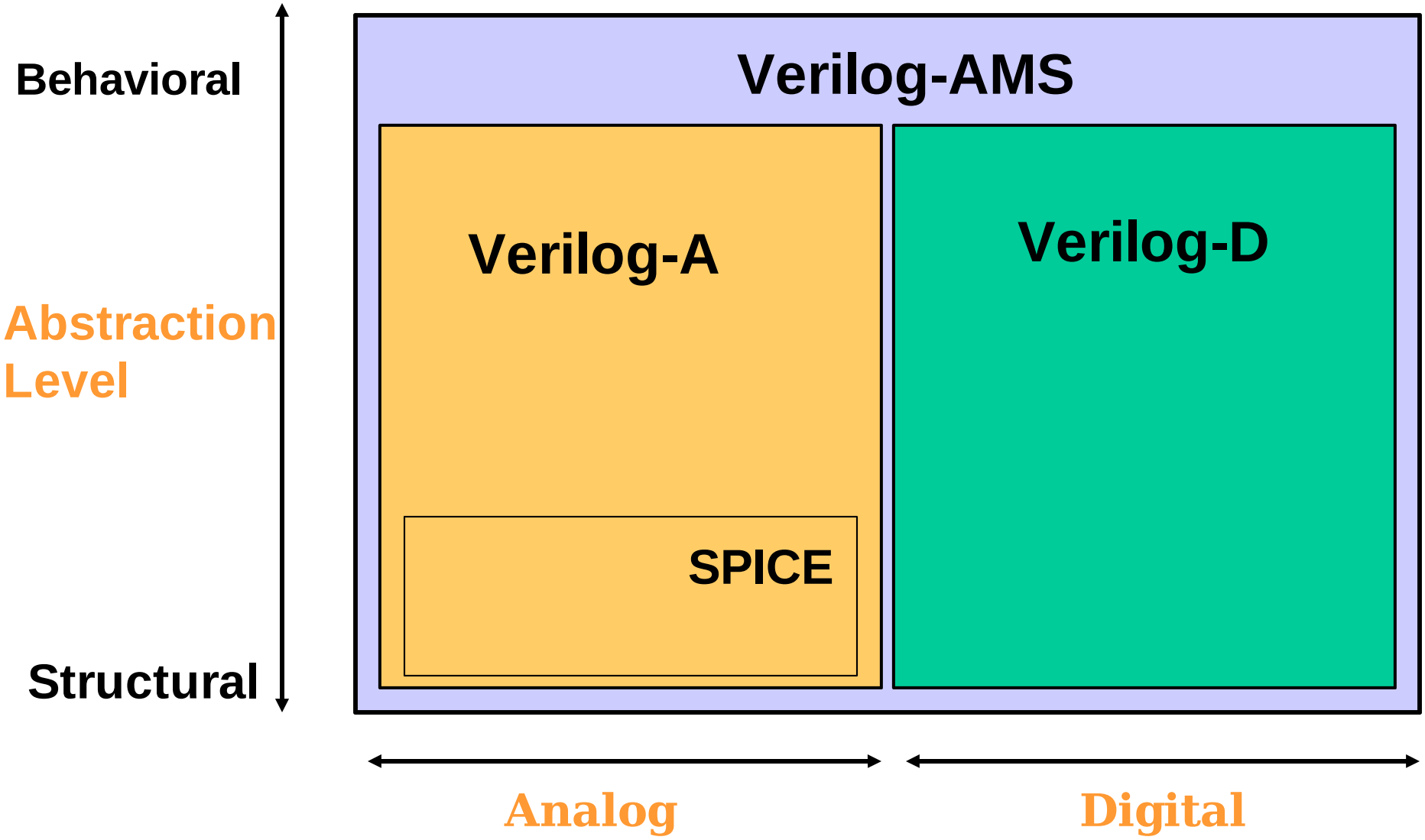
Physical Verification:

- LVS (Lay-out Vs Schematic).
- DRC(Design Rule Check).

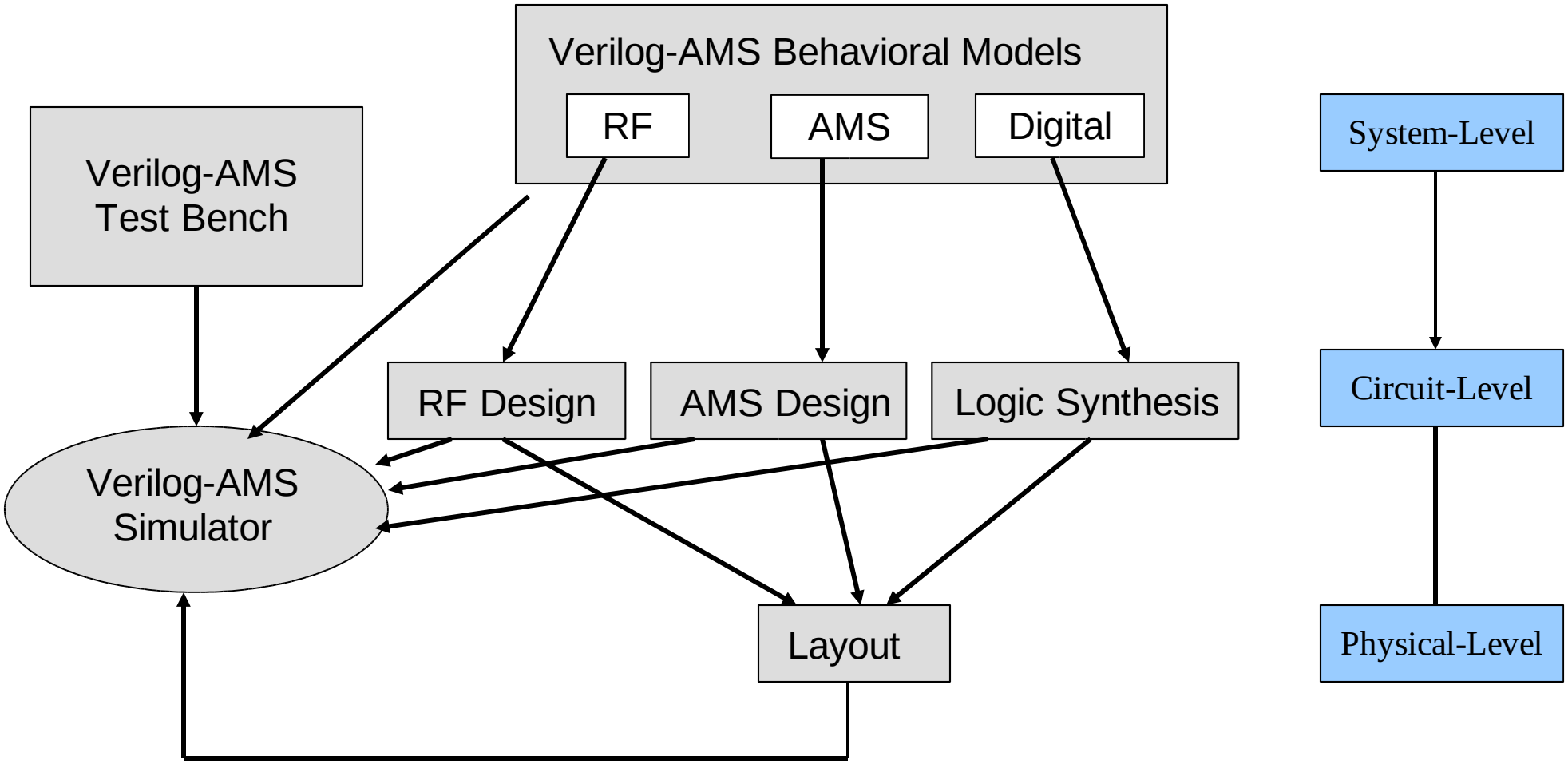
Final Verification:

- Extraction and characterization.
- Macro-models created for a fast high-level simulation.

Scopes of Tools for RF-SoC Design



RF-SoC Design Flow: (Simplified)



References for Receiver Architectures

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Questions?