Software Defined Radio

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Outline

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What?

”…a radio that includes a transmitter in which the operationg parameters of the transmitter, including the frequency range, modulation type or maximum radiated or conducted output power can be altered by making a change in software without making any hardware changes”

-FCC definition

FCC, federal communications commission

Motivation (1/2)

- Continuous transition from analog to digital
  - software defines waveforms
  - analog signal processing is replaced with DSP
- Evolving technologies
  - NMT >> GSM >> UMTS >> ???
  - infrastructure upgrades
- Multimode devices
  - 4G devices
  - legacy devices
  - same device for different networks

Motivation (2/2)

- Reusable devices
  - devices can be upgraded
  - software update
- Increasing DSP capabilities
  - computational power increases
  - power consumption decreases
- Money

Concept

- Software replaces hardware as much as possible
  - reduces costs
  - increases versability
- Equipment/infrastructure ’recycling’
  - by software updates
- Anything is possible
  - within the current limits

Applications

- Military
  - real-time flexibility
  - secure
- Commercial
  - international connectivity
- Civilian
  - portable command for crisis management

- Bluetooth, WLAN, GPS, Radar, WCDMA, GPRS, GSM, PCS, DECT, AM, FM, etc.

Features (1/3)

- Reconfigurability
  - co-existence of multiple software modules implementing different standards
  - dynamic configuration both in terminals and in infrastructure equipment
  - future-proof, multi-service, multi-mode, multi-band, multi-standard terminals and infrastructure equipment

Features (2/3)

- Ubiquitous Connectivity
  - if the terminal is incompatible with the network technology, an appropriate software module is installed (over-the-air)
  - the infrastructure equipment can adjust to the legacy terminals

Features (3/3)

- Interoperability
  - SDR facilitates implementation of open architecture radio systems
  - End-users can use third-party applications seamlessly

Programmability (1/2)

- Hardware radio
  - no software changes
- Software controlled radio
  - in PDR, BB operations and link layer protocols are implemented in software.
- Software defined radio
  - SDR system is one in which the BB processing as well as DDC/DUC modules are programmable.

BB, baseband

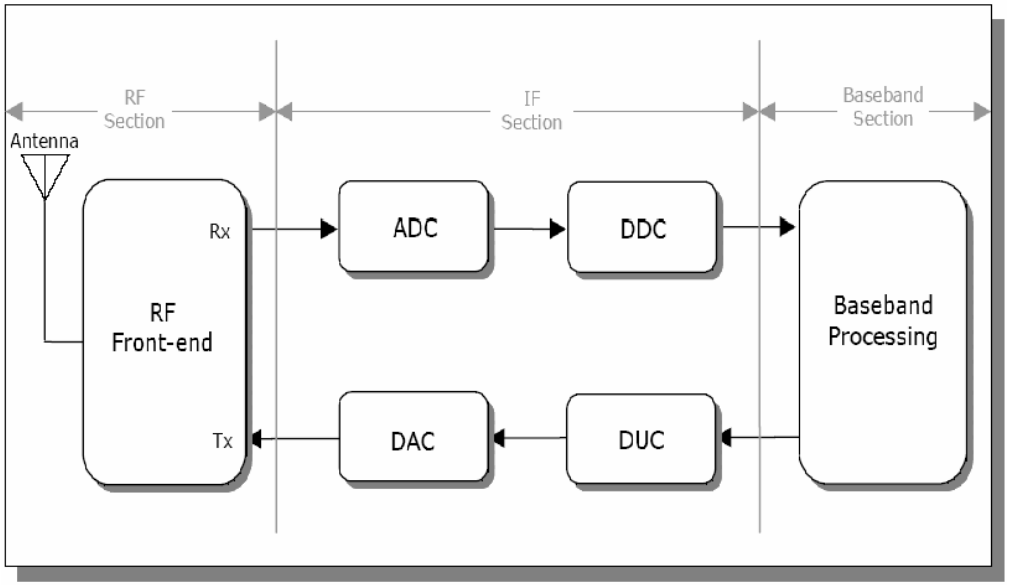
PDR, programmable digital radio
DDC/DUC, digital down/up converter

Programmability (2/2)

- Ideal software radio
  - programmability is extended to the RF section
- Ultimate software radio
  - in a single chip, no external antenna and no restrictions on operating frequency
  - intended for comparison purposes only

Architecture (1/3)

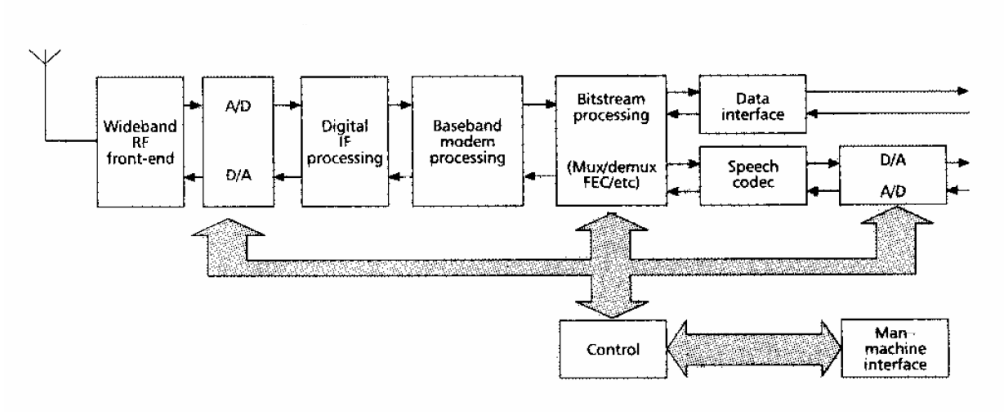
- The digital radio system consists of three main functional blocks
  - RF section
  - IF section
  - BB section
- RF section is essentially analog hardware
- IF and BB are digital



RF, radio frequency
IF, intermediate frequency

Architecture (2/3)

- BB operations include
  - channel coding
  - source coding
  - control functionality
- BB modem functionality
  - new and adaptive modulation schemes
  - self-adaptive or download control
- IF signal processing
  - terminal capable to adapt to multiple radio interface standards



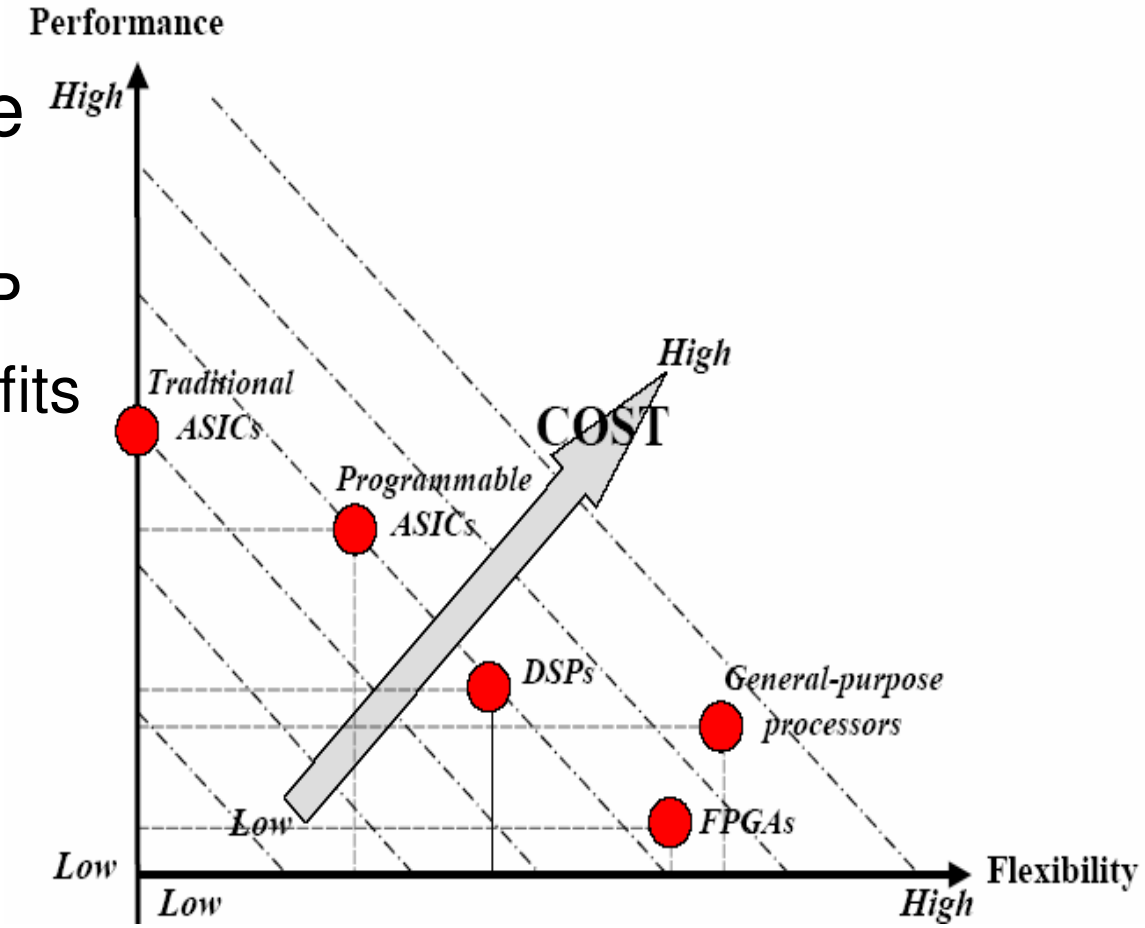
Architechture (3/3)

- Object-oriented approach
  - hardware abstraction
  - SW portability
  - definition of interfaces (API)
- Parameter approach
  - general structure is the same
  - modules configured by changing parameters

API, application programming interface

Implementation (1/2)

- Operations can be implemented with
  - ASIC, FPGA, DSP
  - each has its benefits and drawbacks



ASIC, application specific IC
FPGA, field programmable gate array
DSP, digital signal processor

Implementation (1/2)

	FPGA	DSP
Programming language	VHDL, Verilog	C, Assembly
Performance	Can be very fast	DSP chip clock speed
Reconfigurability	SRAM-type FPGAs: infinite	Changing the program
Advantages against the other	FIR & IIR filters, correlator, convolver, FFT, etc…	Signal processing program of sequential nature
Parallelism	Can be parallized to achieve high performance	Sequential, cannot be parallized.

- Multiantenna systems

Drawbacks (1/2)

- Wide instantaneous bandwidth and high dynamic range both in analog and digital domains required.
- As the receiver bandwidth increases, it becomes more susceptible to more interferes
- Support for multiple channels/modes simultaneously?

Drawbacks (2/2)

Multimode

- e.g. transceiver should support WCDMA, CDMA-2000, GSM, D-AMPS etc…

- Spectrum allocations
  - bands from 400 MHz to more than 2,2 GHz
  - SDR front end should be capable to cover wide range with high dynamic range

Conclusions (pro)

- With SDR anything is possible
  - within the current limits
- From hardware desing to software desing
- Reusability, reconfigurability, recycling
- Multimode devices
  - single device is adequate
- Cheaper

Conclusions (con)

- Large computational power is needed
  - especially IF section (modem, DDC/DUC)
- Power consumption
  - battery sizes
- Complexity
  - multimode devices
- A/D performance
  - accuracy, linearity, sampling rate, resolution
- Higher initial costs

Homework

- What is Software Defined Radio?
  (FCC definition is not accepted)

References

- Software-Defined Radio, White Paper, Wipro Technologies
- Software-Defined Radio: Facets of a Developing Technology, IEEE Personal Communications, April 1999
- PG seminar course: Software Radios, Fall 2004, University of Oulu. http://www.ee.oulu.fi/~juntti/sdr.html