Software Radio: An Enabling Technology for Mobile Communications

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Agenda

- What is software radio?
- The hardware point of view
- The software point of view
- Some relevant experiences

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Some definitions

Software radio

A class of reprogrammable or reconfigurable radios … the same piece of hardware can perform different functions at different times …

A radio that is substantially defined in software and whose physical layer behaviour can be significantly altered through changes to its software

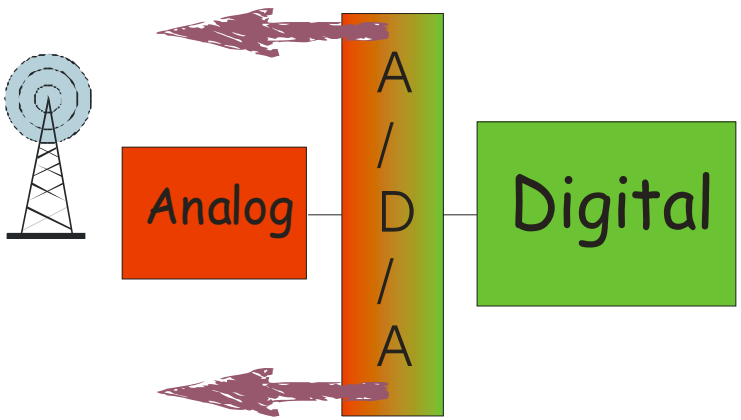
A radio that accepts fully programmable traffic and control information and supports a broad range of frequencies, air-interfaces and applications software

Flexible and all-purpose radios that can implement new and different standards or protocols through reprogramming

Some definitions

Software radio

Emerging and evolving technology enabling flexible radio systems, providing multiple services, multiple band operations, reconfigurability and reprogrammability using software.



Introduction

Low flexibility and capability

High flexibility and capability

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Introduction

Hardware radio (HR): the radio is implemented using hardware components only and cannot be modified except through physical intervention*

Difficult to upgrade, design and manufacture

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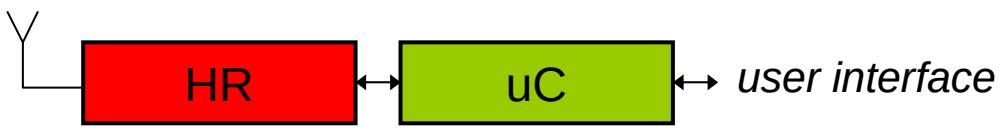
* www.sdrforum.org

Introduction

Software controlled radio (SCR). Only the control functions of an SCR are implemented in software. Thus only limited functions are changeable using software. Typically this extends to inter-connects, power levels etc. but not to frequency bands and/or modulation types etc. *



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* www.sdrforum.org

Introduction

Software defined radio (SDR) provide software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (such as hopping), and waveform requirements of current and evolving standards over a broad frequency range. The frequency bands covered may still be constrained at the front-end requiring a switch in the antenna system. *

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* www.sdrforum.org

Introduction

Ideal software radio (ISR) provide dramatic improvement over an SDR by eliminating the analog amplification or heterodyne mixing prior to digital-analog conversion. Programmability extends to the entire system with analog conversion only at the antenna, speaker and microphones.*

Ultimate software radio (USR). It accepts fully programmable traffic and control information and supports a broad range of frequencies, air-interfaces & applications software. It can switch from one air interface format to another in milliseconds, use GPS to track the users location, store money using smartcard technology, or provide video so that the user can watch a local broadcast station or receive a satellite transmission.*

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* www.sdrforum.org

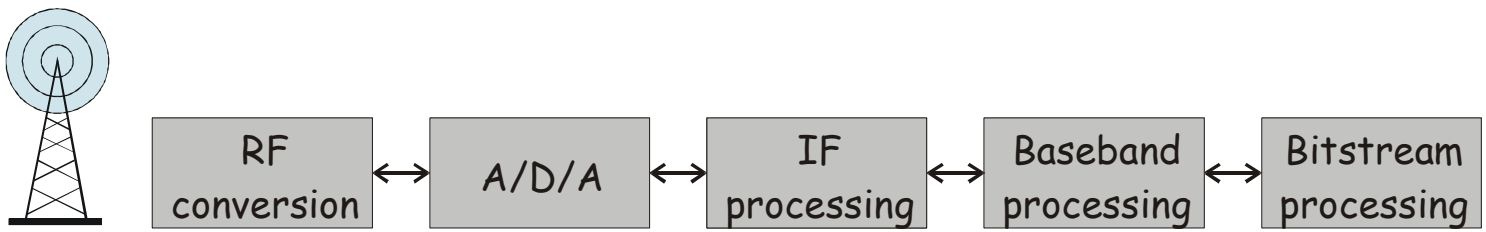
Introduction

Benefits from software radio

- Multi-functionality
- Global mobility
- Compactness and power efficiency
- Ease of manufacture
- Ease of upgrades, runtime reconfiguration and over-the-air updates.

Introduction

Typical block diagram of a software radio*



Criterions:

- Cohesion among functions within a segment
- Changes in bandwidth and sampling rate
- Mapping to hardware

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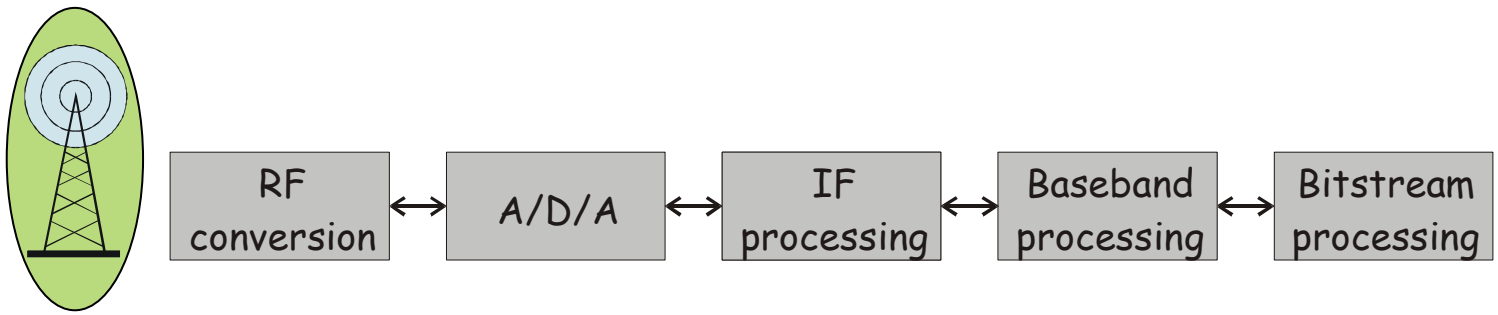
** suggested by Joe Mitola*

Introduction

Typical block diagram of a software radio

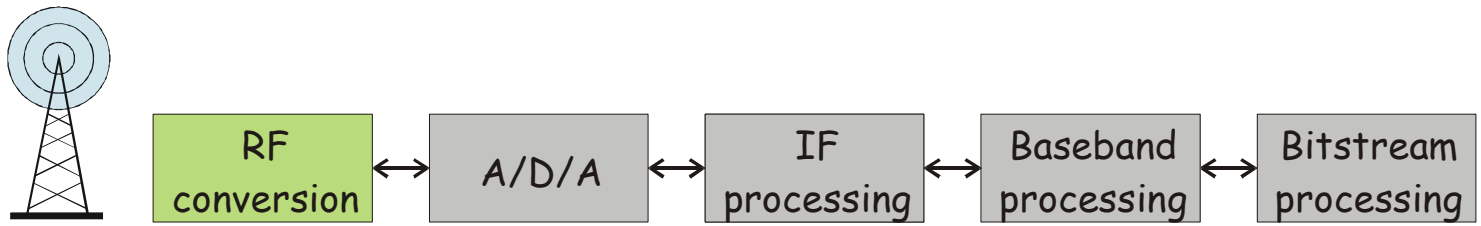


Antenna

- Trade-off
  - Directional selectivity
  - Wideband, low loss
  - Cost

Introduction

Typical block diagram of a software radio

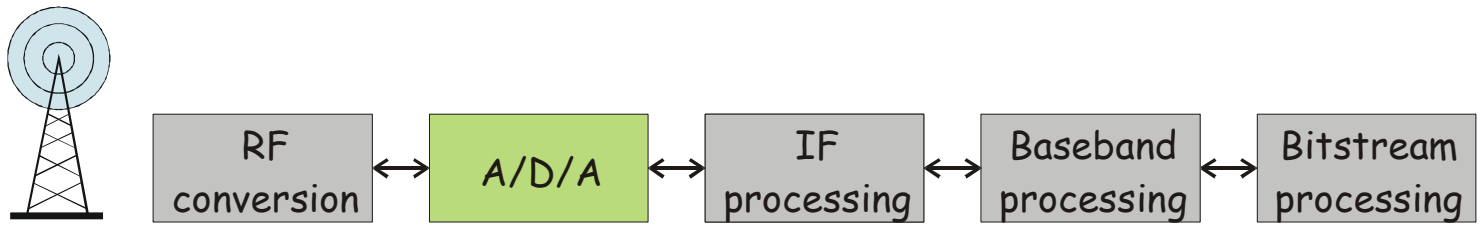


RF conversion

- Amplification (LNA and power) and some filtering
- Conversion from / to RF to / from standard IF
- In most bands, it must be implemented with analog components

Introduction

Typical block diagram of a software radio



Wideband A/D/A

- A/D conversion is the major bottleneck
- Aperture uncertainly, linearity and noise limits performance

$$Dynamic\ range \cdot Sampling\ \ frequency = ctant.$$

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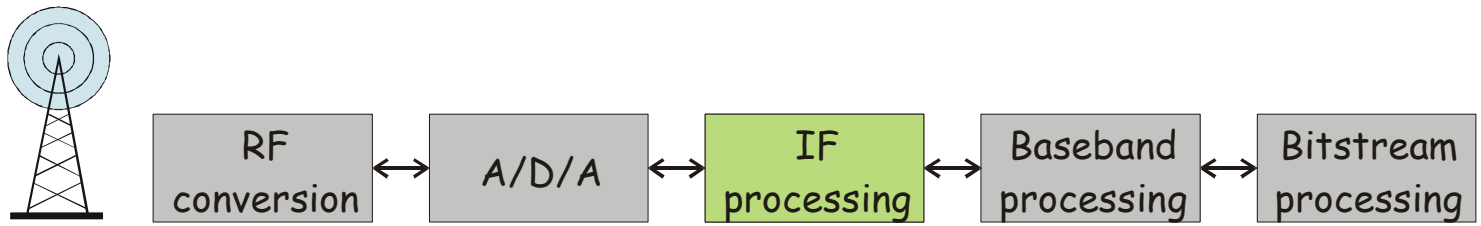
Introduction

Typical block diagram of a software radio

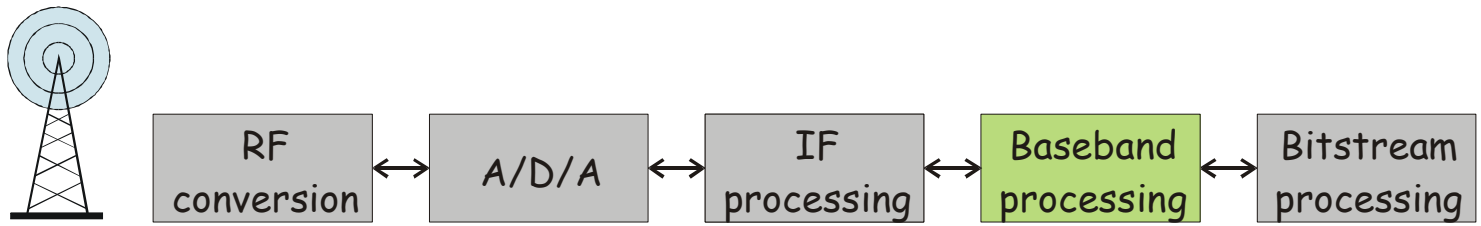


IF processing

- Conversion from / to IF to / from modulated baseband
- Complexity depends on IF and IF bandwidth
- Normally implemented with ASIC (DDC i DUC)

Introduction

Typical block diagram of a software radio

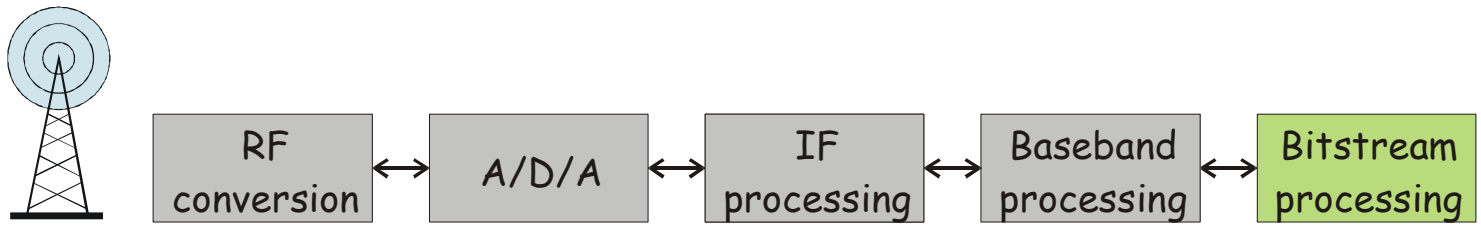


Baseband processing

- Modulation, equalization, timing recovery, synchronization, ... soft decision processing
- Complexity depends on baseband bandwidth and oversampling factor

Introduction

Typical block diagram of a software radio



Bitstream processing

- Multiplexing, interleaving, error correction, encryption, signalling, …
- Typically demands an order of magnitude less computational cost than baseband processing

HW perspective

Digital hardware devices to build a reconfigurable platform

A/D/A

Digital Hardware

Flexibility

Efficiency

ASIC

PLD

DSP

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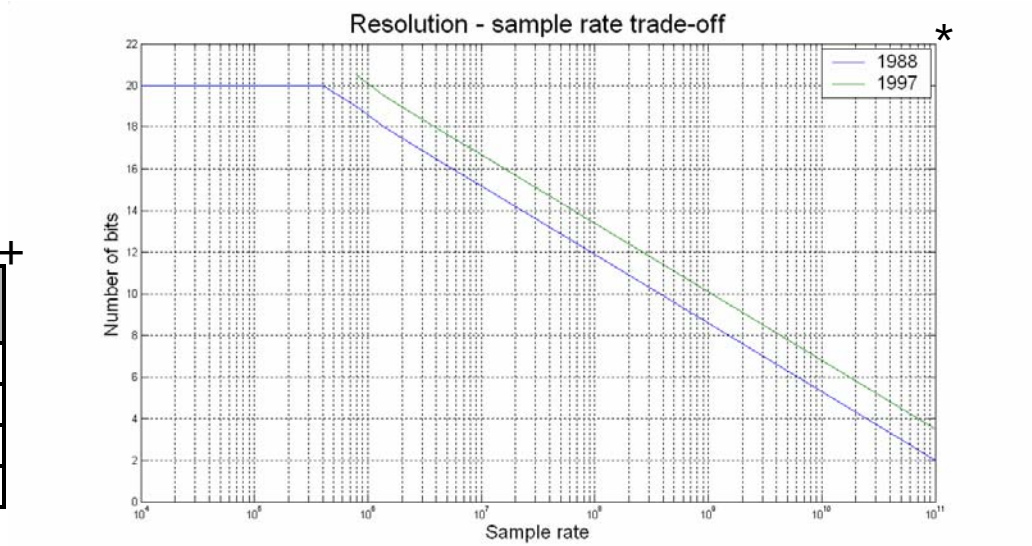
A/D/A

+

SDR	Sampling rate	Dynamic range (dB)
Music	20 – 100 Khz	60 – 96
HF – RF	75 Mhz	130
VHF – RF	650 Mhz	96
UHF – RF	5.4 – 10 GHz	48 - 90



*

Related topics

- SNR, SFDR, NPR, linearity, DNL, INL, aperture uncertainly, …
- Bandpass sampling, oversampling, quadrature sampling, dithering, …

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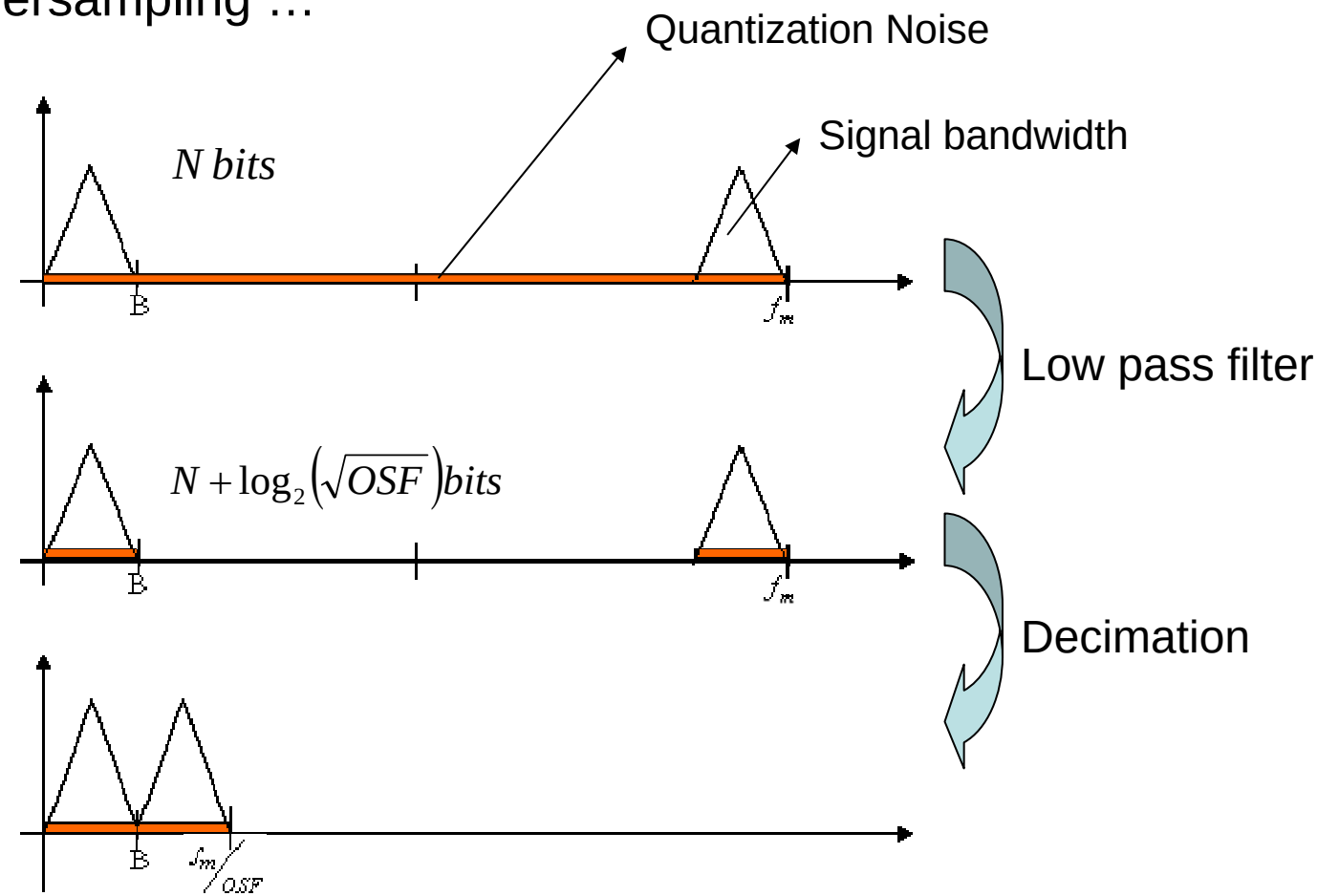
** R.H. Walden, A/D converter survey and analysis*

+ J. Mitola III, Software radios. Survey, critical …

A/D/A

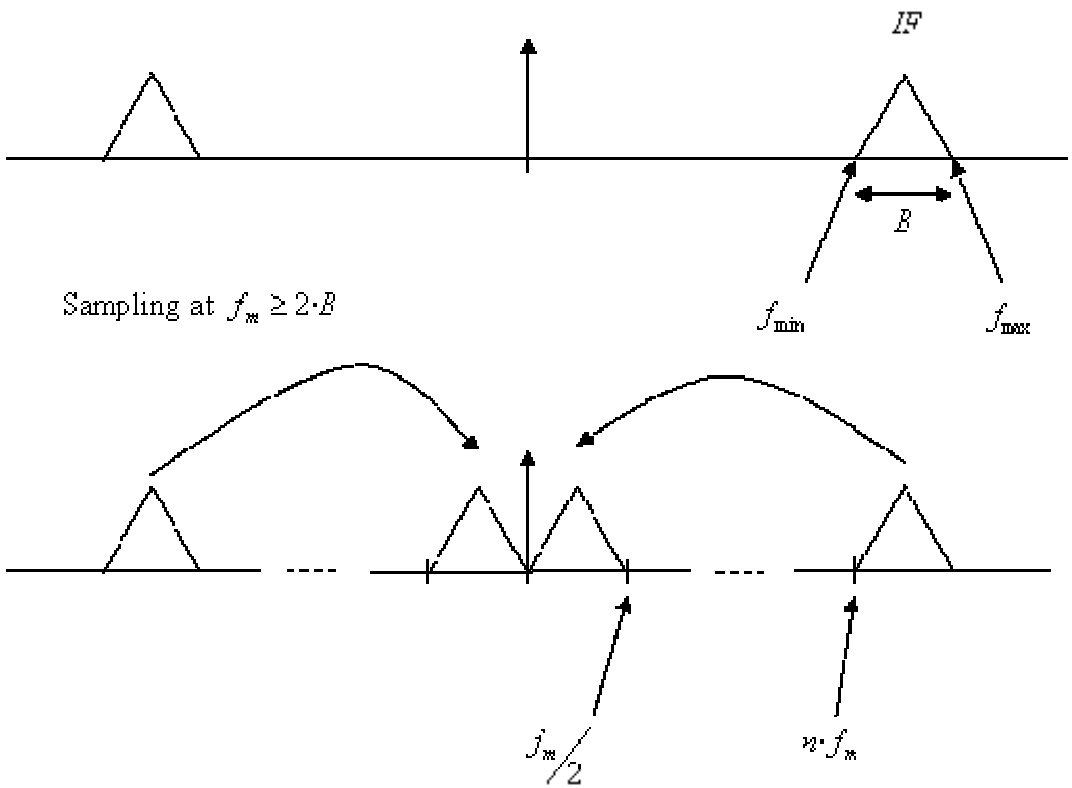
Oversampling …



OSF: oversampling factor

A/D/A

Bandpass sampling …



$$f_m' \geq 2 \cdot B$$

$$n \cdot f_m' + \frac{f_m'}{4} = IF \rightarrow n$$

$$n \rightarrow \bar{n}$$

$$\bar{n} \cdot f_m + \frac{f_m}{4} = IF \rightarrow f_m$$

High filter requirements

Low dynamic range

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ASIC / DSP / PLD

ASIC (*Application Specific Integrated Circuit*)

- High speed, low power consumption
- Low flexibility

→ **IF processing**

- DDC, RSP
- DUC, TSP

DSP (*Digital Signal Processor*)

- High flexibility, low cost / MIP, fast time-to-market
- Low bandwith, high power consumption

→ **Baseband processing**

PLD (*Programmable Logic Device*)

- High flexibility and speed, moderate power consumption
- Difficult to develop applications with

→ **IF, baseband, processing**

- FPGA, CPLD

PLD vs DSP

DSP is better when …

- the algorithm exhibits a complicated sequential structure
- the algorithm needs floating point arithmetic
- very fast time-to-market is required
- power consumption is not a big problem

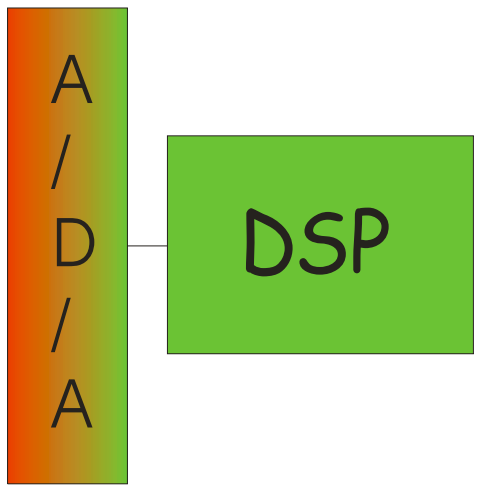
PLD is better when the algorithm is …

- deeply pipelined
- highly parallel
- integer arithmetic

HW strategies

Hardware strategies to implement a software radio*

1. **DSP based**

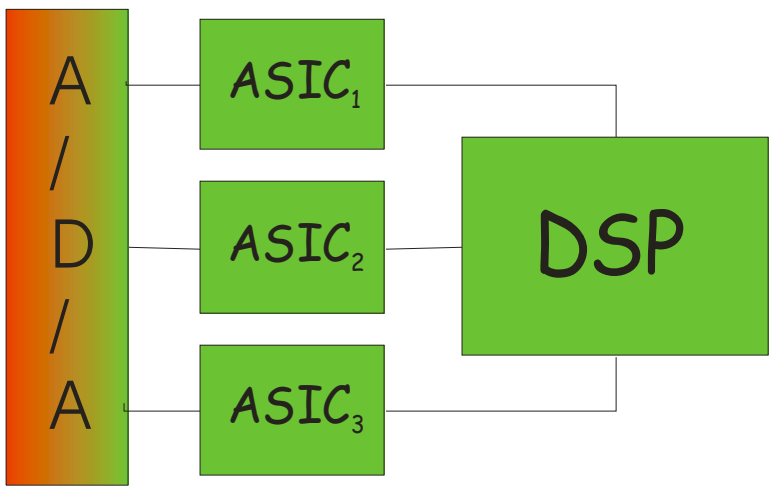


* *Mark Cummings et al, FPGA in the Soft. Radio*

HW perspective

Hardware strategies to implement a software radio

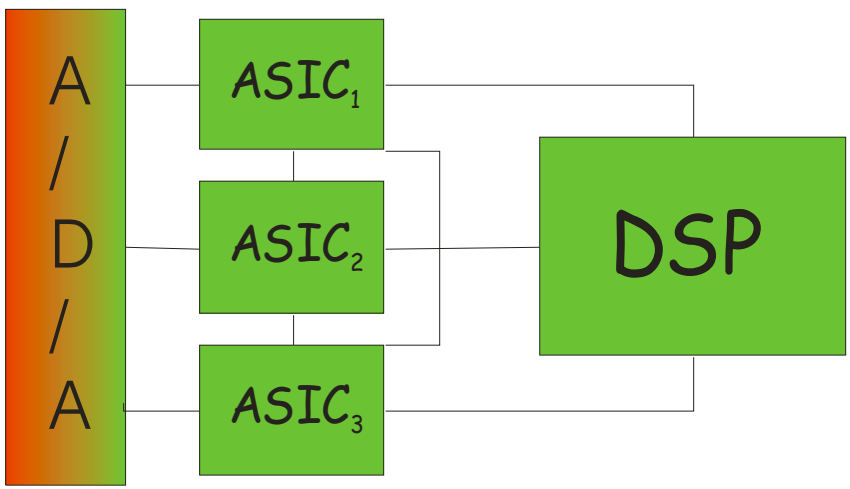
1. **DSP based**
2. **DSP + multiple ASIC**



HW perspective

Hardware strategies to implement a software radio

1. **DSP based**
2. **DSP + multiple ASIC**
3. **Parameterized hardware**



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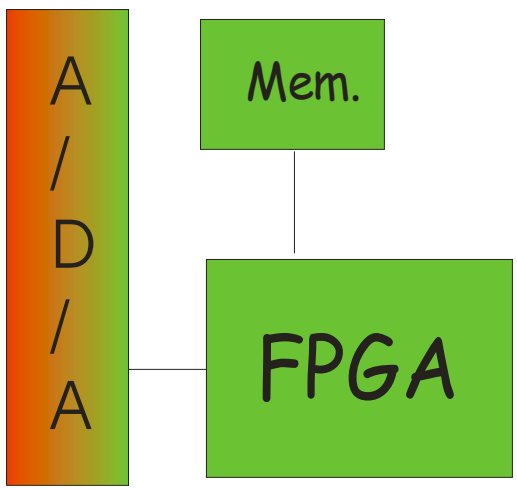
HW perspective

Hardware strategies to implement a software radio

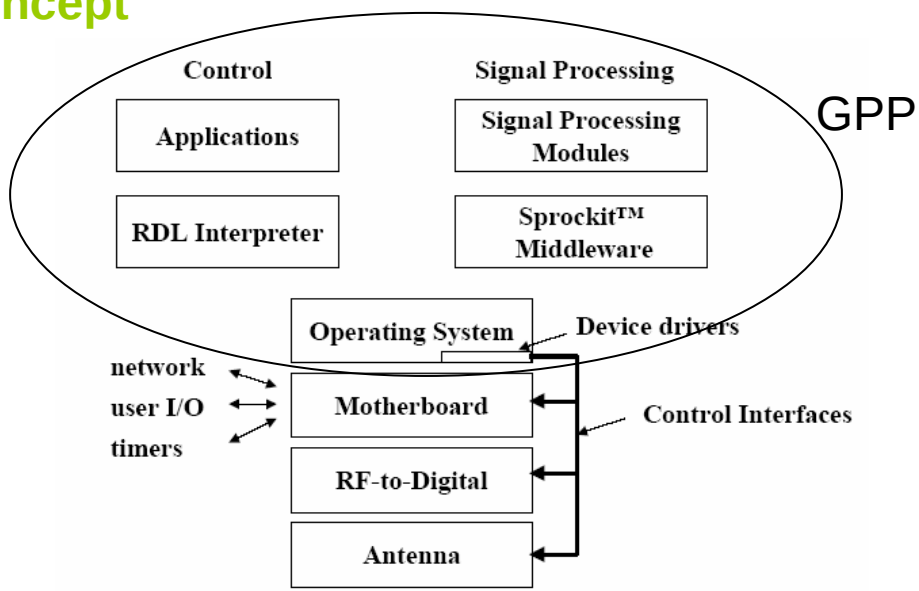
1. **DSP based**
2. **DSP + multiple ASIC**
3. **Parameterized hardware**
4. **Dynamically reconfigurable FPGA**



HW perspective

Hardware strategies to implement a software radio*

1. **DSP based**
2. **DSP + multiple ASIC**
3. **Parameterized hardware**
4. **Dynamically reconfigurable FPGA**
5. **Vanu concept**



* *www.vanu.com*

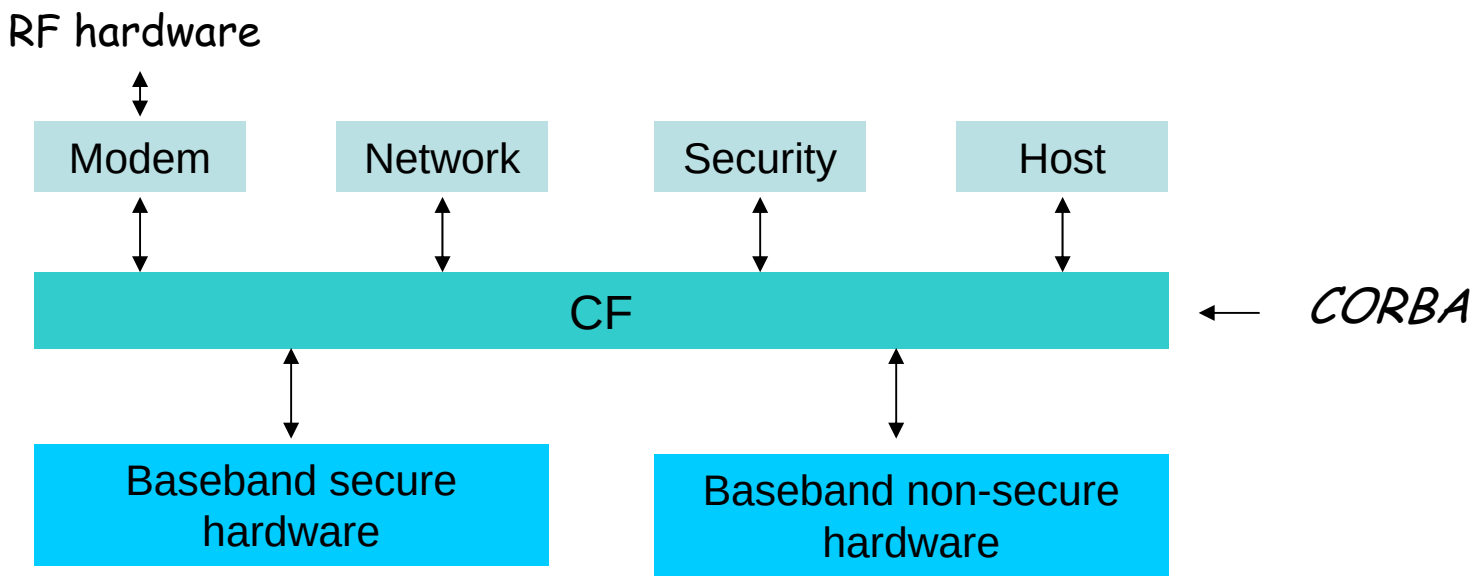
Introduction

Formal design methodologies that can be used to design and implement software radios in a reconfigurable platform

Introduction

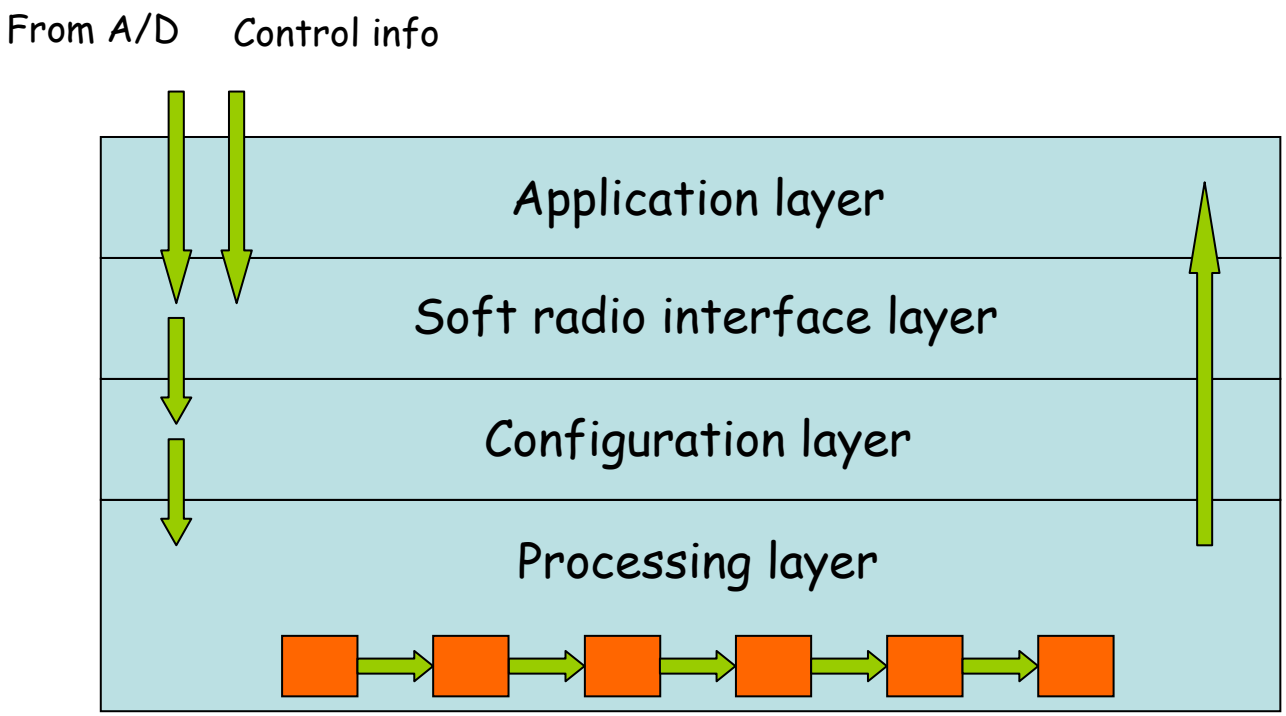
SCA (software communication architecture)

Defines the operating environment for the radio system, including systems and interfaces



The layered radio architecture*

Layered architecture

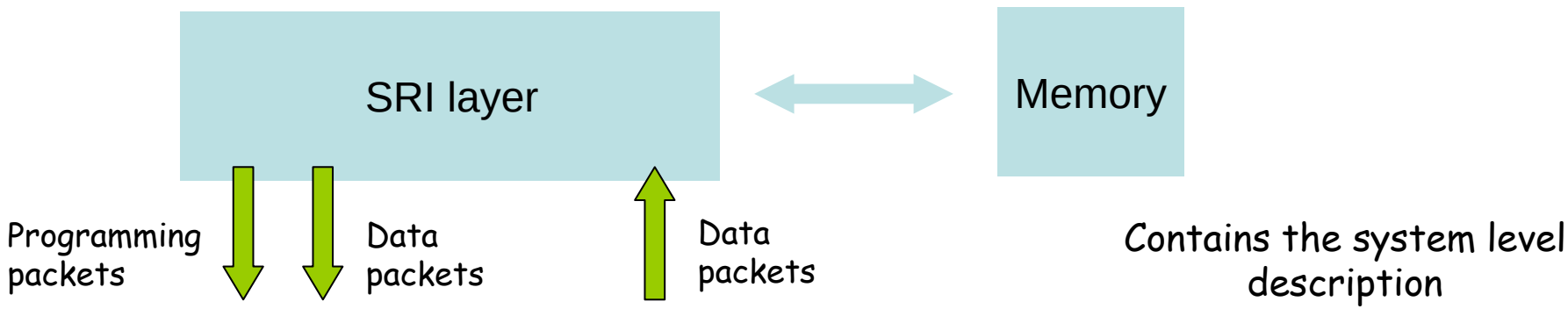


* *Srikathyayani Srikanteswara et al, A Soft Radio Architecture for Reconfigurable Platforms*

The layered radio architecture

SRI layer:

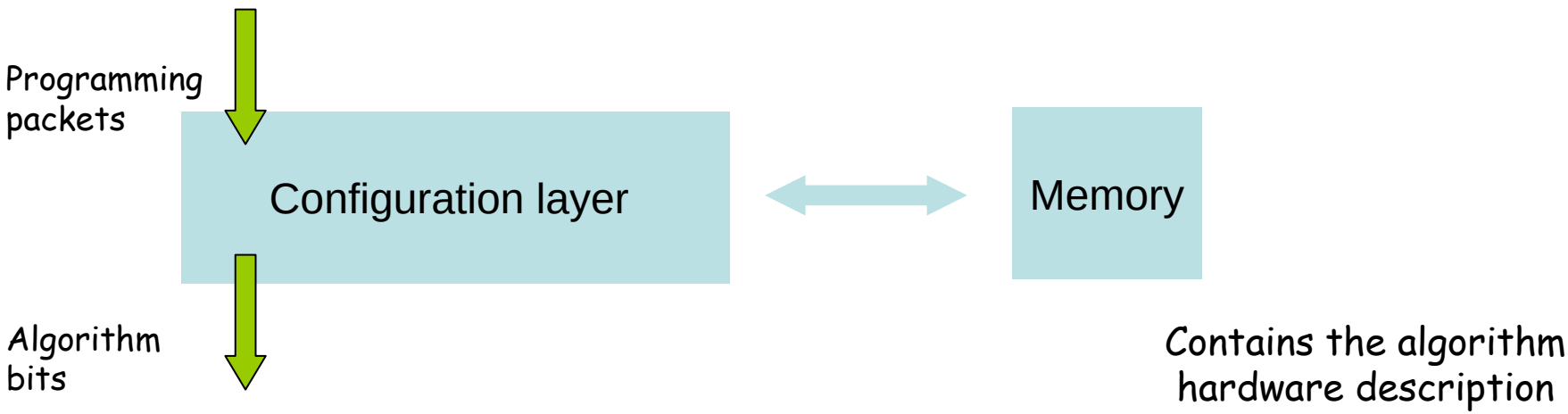
- Coordinates, prioritizes, packetizes the various sources of information
- Configures the processing layer



The layered radio architecture

Configuration layer:

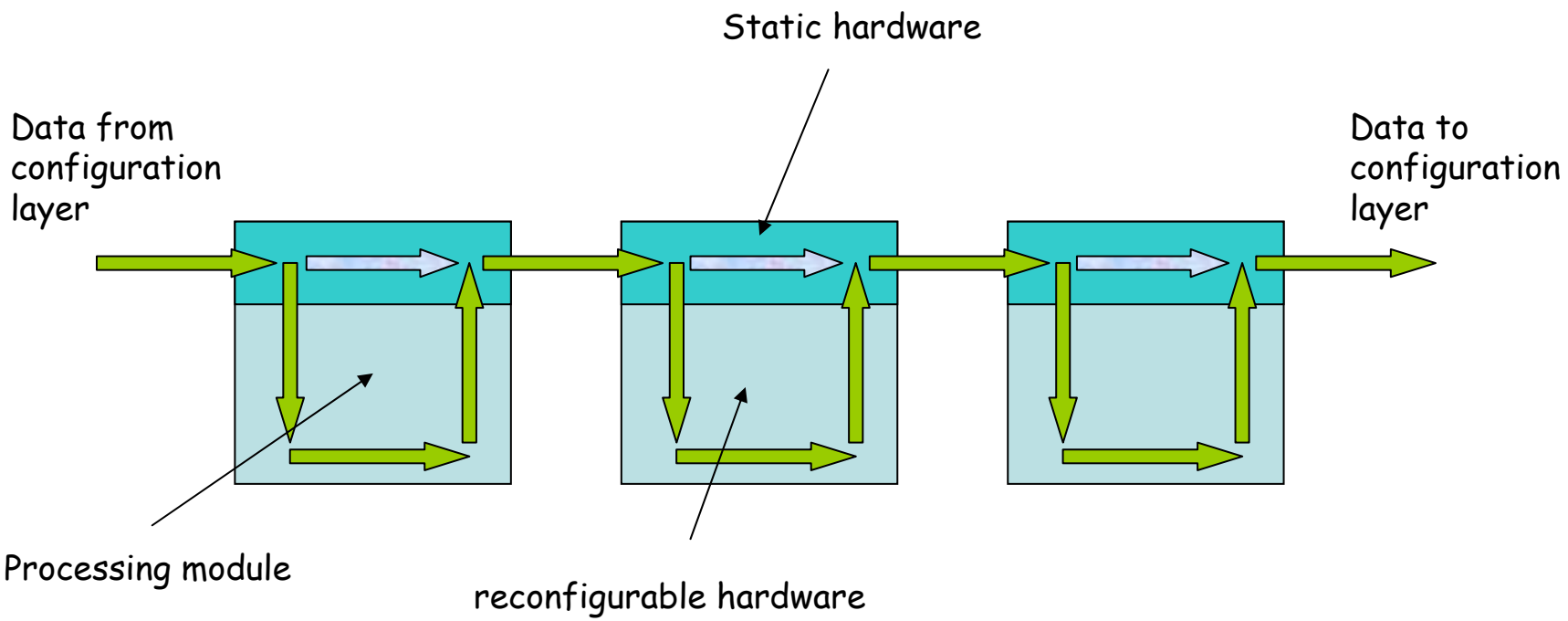
- Programs the processing layer



The layered radio architecture

Processing layer:

- Implements radio functionality



Software radio projects

SPEAKeasy (US Military, Motorola)

JTRS (US Military)

Wireless Information Transfer System (Motorola)

SDR-3000 (Spectrum Signal Processing)

SpectrumWare (MIT)

Chariot (Virginia Tech)

Some important papers

J. Mitola, “Software Radios: Survey, Critical Evaluation and Future Directions”, IEEE National Telesystems Conference, pp. 13.15 – 13.23, 1992

J. Mitola, “The software radio architecture”, IEEE Communications Magazine, Vol. 33, pp. 26-37, May 1995

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Walter H. W. Tuttlebee et al. “Software Defined Radio: Facets of a Developing Technology”, IEEE Personal Communications Magazine, Vol. 6, No. 2, pp. 38-44, April 1999

Joseph Mitola III, “Software Radio Architecture: A Mathematical Perspective”, IEEE Journal on Selected Areas of Communications, Vol 17, No. 4, pp. 514-538, April 1999

Software Radio Technologies – Selected Readings, Edited by Joseph Mitola III and Zoran Zvonar

Some interesting papers

Anne Wiesler, Friedrich K. Jondral, “A Software Radio for Second- and Third-Generation Mobile Systems”, IEEE Trans. on Vehicular Technology, Vol. 51, No. 4, pp. 738 – 748, July 2002

Jay R. Moorman, “Implementation of a 3G W-CDMA Software Radio”, ICC’2003, Vol. 4, pp. 2494 – 2499, May 2003

Glossner J. et al, “A software-defined communications baseband design”, IEEE Communications Magazine, Vol. 41, Issue 1, pp. 120-128, Jan. 2003

Kontouris A.A. et al. “A software radio approach for the transceiver transition from 2G to 2.5G to 3G”, Sixth International Symposium on Signal Processing and its applications, Vol. 2, pp. 485-488, Aug. 2001.

Kontouris A.A. et al. “A reconfigurable radio case study: a software based multi-standard transceiver for UMTS, GSM, EDGE and Bluetooth”, Conference on Vehicular Technology, Vol. 2, pp. 1196-1200, Oct. 2001.

Bucci G. et al. “Smart Antenna BTS based on software radio technique for GSM/DCS system”, Conference on Vehicular Technology, Vol. 2, pp. 1225-1229, May 2000.

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