Choosing the Best System Architecture for Tradeoffs in your SDR Design

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Outline

For every receiver and transmitter specification, there are many possible implementations:

List and Understand the Specifications

What are the Implications of the Specifications on the Design Implementation?

List and Discuss Important Design Tradeoffs

What to Do when Cost is Primary and Performance is Secondary

Outline continued

What to Do when Power Consumption is Primary. What might be sacrificed?

High Performance and High Reliability Systems

- Cell base stations
- Military communications
- Space communications

Outline continued

This presentation will be interactive and the attendees will be asked to participate.

The majority of block diagrams will be drawn on the screen during the lecture. This will be done using a tablet and pen and work like a white board in a classroom.

Carefully Read and Understand the Technical Specifications

- Frequency Band(s)
- Types of Signals and their bandwidths
- Number of Signals to be Simultaneously Received or Transmitted
- What is the Dynamic Range Requirement
- Distortion Requirements (both Rx and Tx)
- How much Rejection of Images
- How much Rejection of out-of-band signals
- Noise Floor
- Frequency Stability

Design Tradeoffs
-- an interactive discussion

- Performance
- Reliability
- Environmental specs
- Power consumption
- Heat dissipation methods allowed
- Cost
  - Availability of all components
  - Labor required for tuning or alignment
- Size and weight
- Ease of modifying and upgrades

What are the Implications of the Specifications on the Design Implementation?

- Start by drawing a conventional analog block diagram that you think would satisfy the specification requirements without considering the design tradeoffs.

- Look at your design tradeoffs on this product

- Now think about changes you must make as a result of the additional tradeoffs

Modify your Block Diagram to Include the Design Tradeoffs

What can you do if:

- cost is more important than performance,
- power consumption is the primary concern
- size or shape is the primary
- weight is the primary
- reliability is primary
- performance over a wide temperature range
- adaptations to future standards is primary

Audience Participation: other design tradeoffs suggested:

Design Tradeoffs

What to Do When Cost is Primary and Performance is Secondary

Use inexpensive components. Rules out:

- most custom RF filters
- circuits that requires alignment
- expensive high performance FPGAs
- PCBs with high performance teflon or ceramic materials
- high density BGA packaged devices that require many layers for layout
- precision machined cavities

Design Tradeoffs

What to Do when Power Consumption is Primary

- Consider low voltage parts
- Use high efficiency circuits
- Reduce the number of stages
- Do most of the signal processing at baseband or a low frequency IF

Interactive participation

Design Tradeoffs

What to Do when Power Consumption is Primary

Interactive participation

Design Tradeoffs

when Power Consumption is Primary

Downside: what might be sacrificed?

Low voltage = small voltage swing

- **Limits the dynamic range and increases distortion**
- **reduces SNR**
- **increased susceptibility to noise both on board and from outside**

Interactive participation

Design Tradeoffs:

1. How are the IF frequencies chosen?
   - Bandwidth specification
   - Image, Alias, and IMD reduction
   - Out-of-band strong signal rejection
   - Component cost & availability
   - Speed of the A/D converters

Design Tradeoffs:

2. Mixer choices

- Conventional double balanced mixers
- Subharmonic double balanced mixers
- Monolithic active mixers, single ended
- Monolithic active mixers, quadrature
- All-digital mixers
  - Switching mixers
  - Mixers in the digital time domain

Design Tradeoffs:

3. How are the A/D converters chosen?

- Required bandwidth
- Dynamic Range   ENOB
- Cost & availability
- Power consumption

Design Tradeoffs

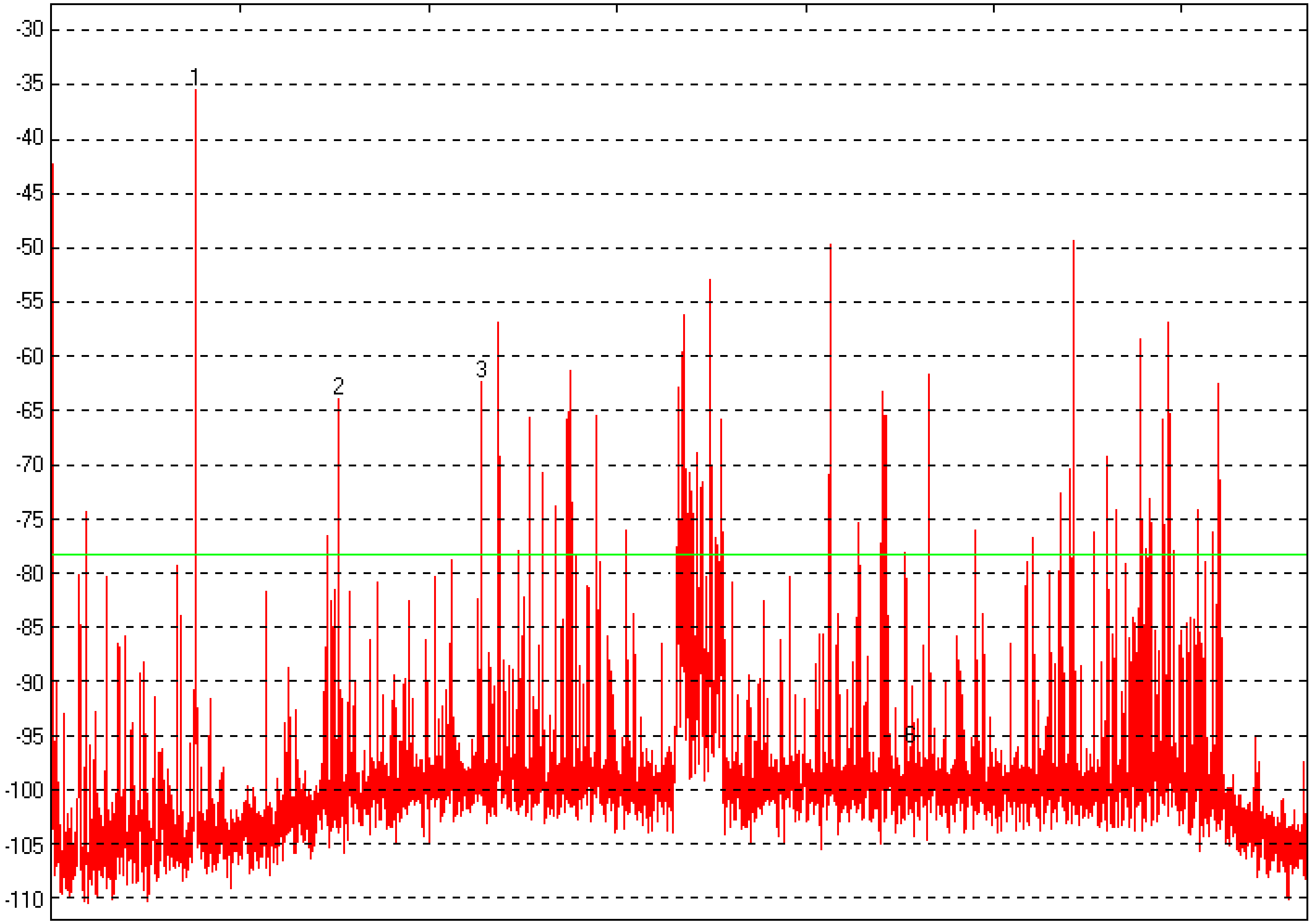
High Performance and High Reliability systems include:

Cell base-stations

Military communications

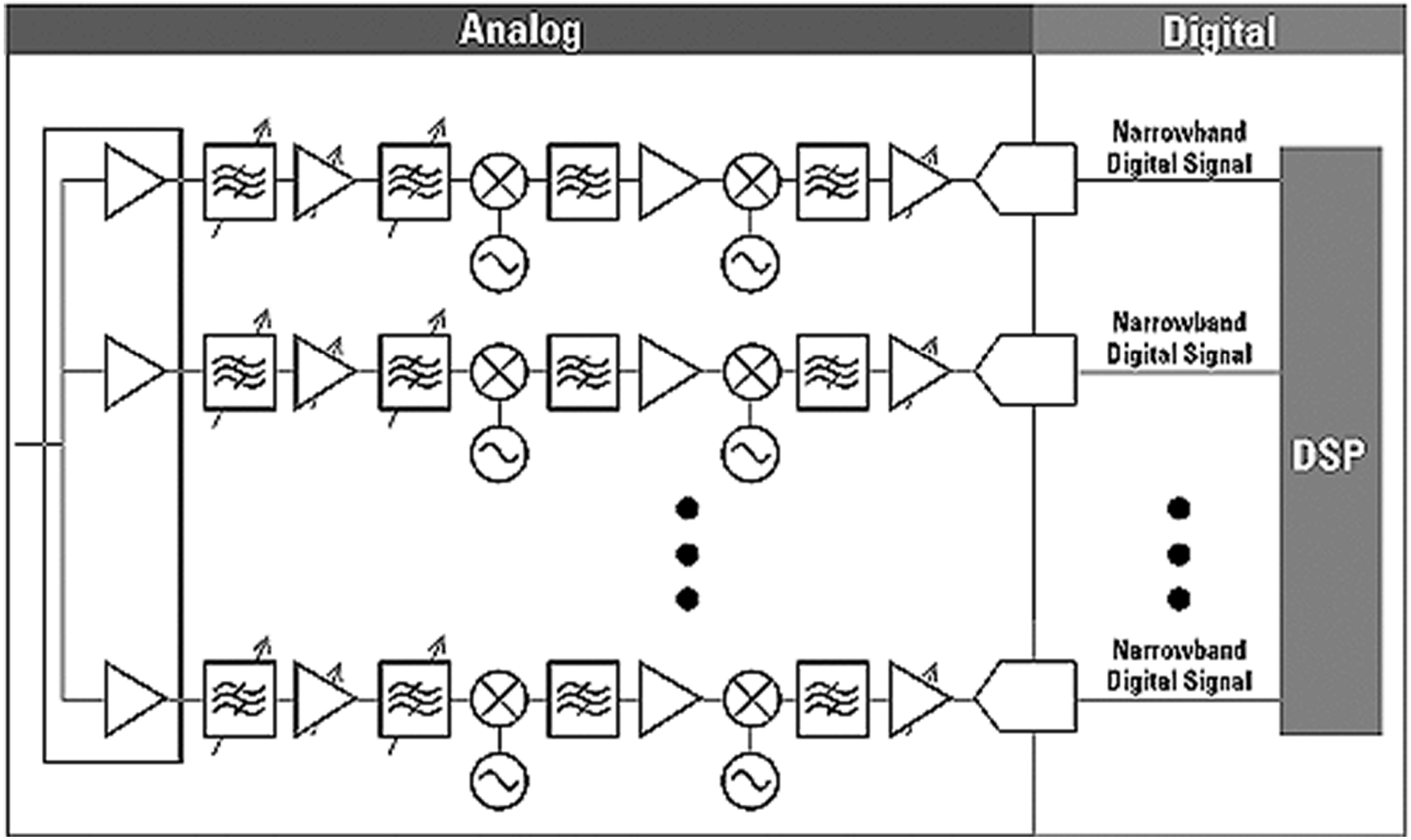
Space communications

Actual Cell Site Spectrum Survey



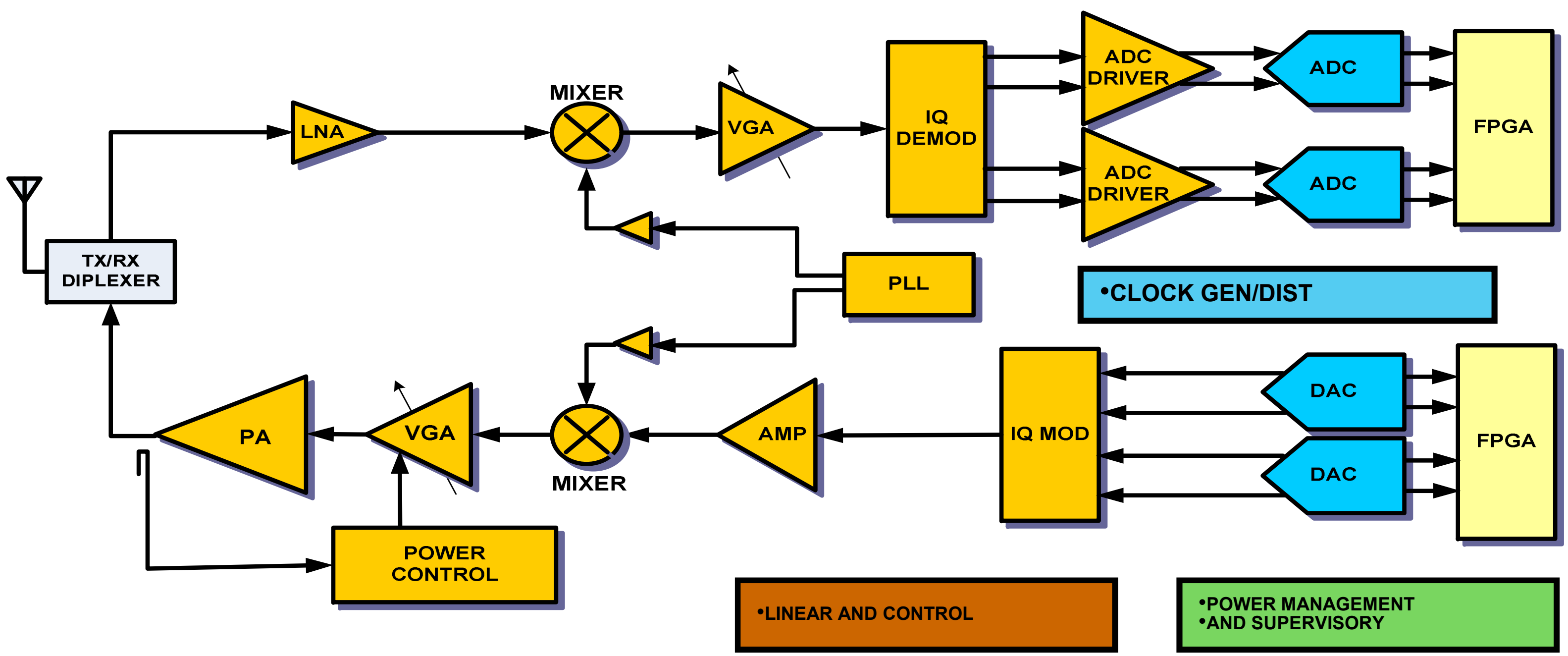
Courtesy of Analog Devices

Cell Base-station Design Traditional Approach



Courtesy of NSC

Cell Base-station Design Possible SDR Implementation



Courtesy of ADI

Looking at the previous slide

What is the IQ Demod part?

Why are there two A/D converters?

Advantages of this circuit:

- Low cost
- Wide bandwidth
- Good image rejection

Disadvantages of this circuit:

- Moderately high noise figure
- Requires diff inputs + stable DC
- Temperature compensation needed
- Image rejection varies with frequency

Looking at the previous slide

What is the IQ Mod part?

Why are there two D/A converters?

Advantages of this circuit:

- Low cost
- Wide bandwidth
- Good image rejection

Disadvantages of this circuit:

- Moderately high noise figure
- Requires diff inputs + stable DC
- Temperature compensation needed
- Image rejection varies with frequency

Cell Base-station Design
New SDR Approach

Do as much mixing and signal processing as possible within the FPGA

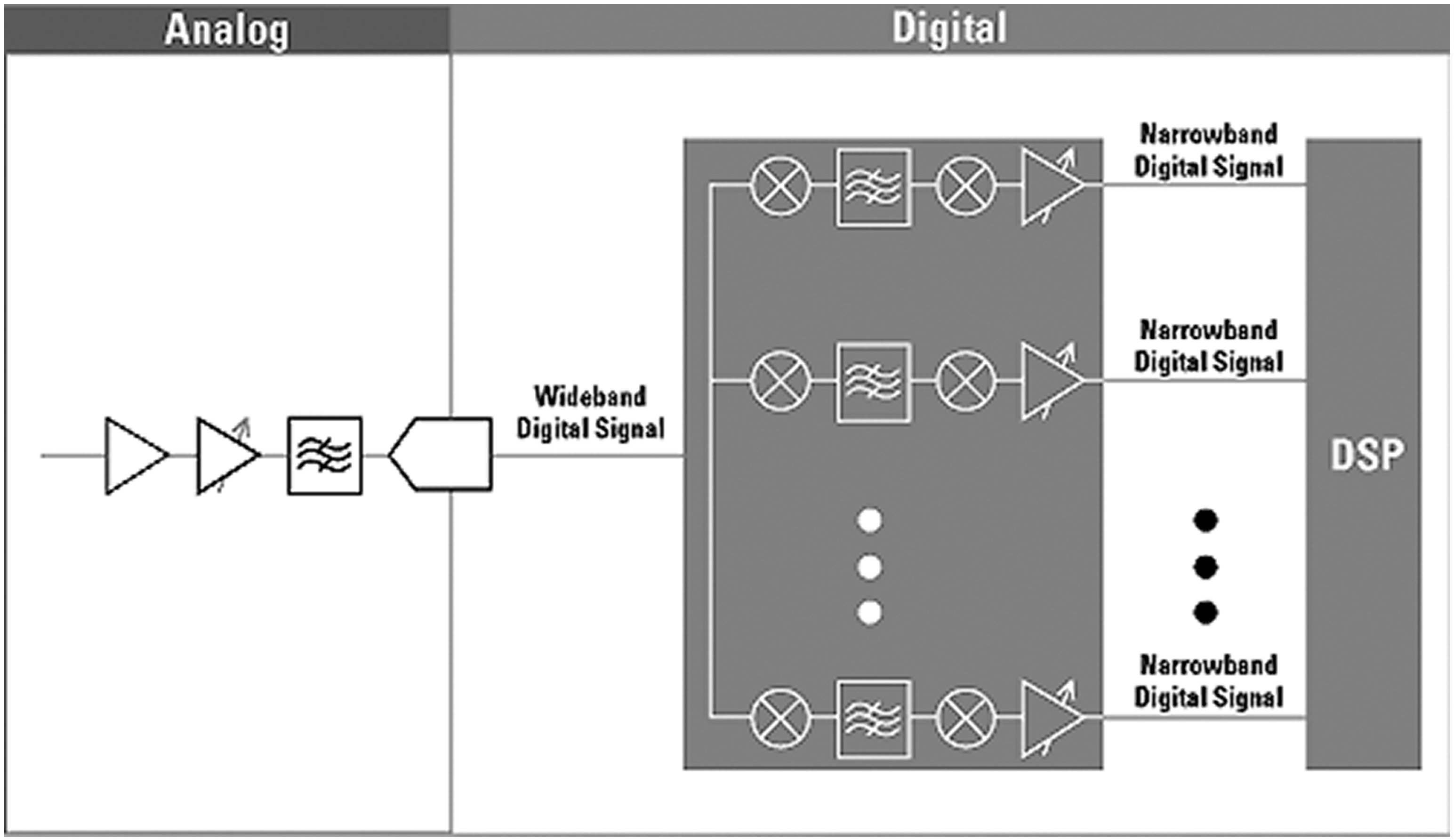
Quadrature is excellent, making near perfect image rejection

Lock UHF, microwave oscillators to an external reference

Complete stability over temperature range

Transmit PA can have digital pre-distortion

Cell Base-station Design
New SDR Approach



Courtesy of NSC

Cell Base-station Design
New SDR Approach

Notice that only one A/D converter is needed when the mixer is implemented in the FPGA

How does this work?

Notice that the only one RF chain with one A/D converter can now demodulate many independent channels simultaneously

Just use a larger FPGA

Military Communications

The dynamic range requirement depends on the frequency band

High reliability and wide temperature range

Power dissipation methods may be limited
- Often airtight and no fans

Usually requires approved parts

Interactive participation

Space Communications

S-Band near earth:
2.025 – 2.1GHz paired with 2.2GHz – 2.3GHz
3MHz PN coded

X-Band:
7.15GHz paired with 8.4GHz
100MHz wide for near earth
50MHz wide for deep space

Ka-Band:
32GHz paired with 34GHz
100MHz wide

Space Communications

These bands are generally devoid of interference and strong signals

The modulation is constant envelope

Therefore only needs low dynamic range

Working backwards in the chain:

- Pick the A/D converters first
- Use either passive or active mixers that meet the reliability requirements
- Space = low power

Interactive discussion of S-Band Receiver Design

- Front End
- 1^{st} IF
- 2^{nd} IF
- 3^{rd} IF
- A/D

Interactive participation

block diagrams

Space Communications

Concentrate on

- Low phase noise oscillators
- Temperature and vibration stability
- Radiation hardness for space

Interactive participation

Design Tradeoffs

Within the limitations of cost, power consumption, and reliability put as much of the signal processing chain within a FPGA as you can.

Design Tradeoffs

Advantages of putting the mixer, LO, filters, and demodulators in a FPGA

- Dynamic range and also phase noise are limited only by the number of cells used in the FPGA
- Everything implemented in the FPGA cannot drift with temperature or aging
- Improvements or changing standards can be quickly loaded

What can you do in the software?

The outputs from the FPGA are usually further processed by software running under an operating system.

- Operator control of parameters
- Display of the signals
- Narrowband filtering
- Noise reduction
- Demodulation

Remote Processing

You may want to remotely control a receiver or station

The signal processing functions may be split between the station site and the control site

Ethernet or a radio link may connect the two sites

Radio Demonstration

Show the overall result when some of the processing is done in the FPGA and some is done in software running on a computer

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