An Overview of SDR and Enabling Technologies

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Introduction

- What is an SDR?
- Advantages of SDR
- Why so much interest in SDR?
- Design of SDR's
- Key enabling technologies for SDR
- SDR Forum

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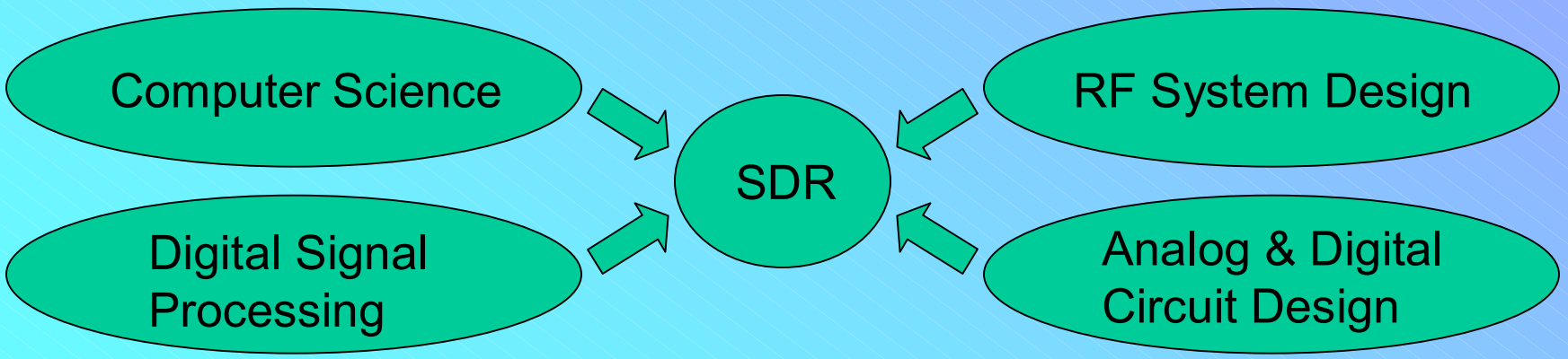
Definition of SDR

- Differing opinions on definition
  - Many different ways to design SDR
  - SDR design represents merging of different fields:



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Definition of SDR

- Definition adopted in American Nat'l Standard Telecom Glossary 2000
- SDR consists of RCVR and/or XMTR where:
  - Received signal digitized
  - Processed with software programmable DSP techniques
  - Digitization may occur at RF, IF, or baseband

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Definition of SDR

- Modulated signal to be transmitted generated as digital signal using software programmable DSP techniques
- Digital signal converted to analog for transmission
- Conversion to analog may occur at RF, IF, or baseband

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SDR Programmability

- Key factor in SDR's:
- Programmability allows easy changes of radio's fundamental characteristics
  - Operating frequencies, bandwidths, modulation types
  - Multiple access schemes, source & channel coding/decoding
  - Frequency spreading/despreading, encryption/decryption
- Traditional radios - hardware changes

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SDR Programmability

- Different ways to provide programmability
  - Over-the-air download
  - Internet download
  - From software on a PC using standard external port (PC serial port)
  - Keypad on radio
  - Remove & reprogram PROM
  - Proprietary internal or external port

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Advantages of SDR

- Programmability
- Advantages result replacing analog implementations radio functions w/ software or digital hardware
- Radio functions can be implemented not possible in analog hardware
  - Example: FIR filter, sharp rolloff & linear phase

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Advantages of SDR

- Radio functions implemented w/ DSP offer performance closer to ideal
- Repeatability and temp stability much better
- Radio functions implemented w/ DSP don't require tuning or tweaking

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Interest in SDR

- Military, Public Safety/Law Enforcement, & Commercial Sectors great interest in SDR
- SDR potential aid for interoperability problems
  - Military: Many different types of legacy radios and new radios
    - Within same service
    - Between services
    - Between allies
  - Need to communicate between these different radios

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Interest in SDR

- Large Joint Services SDR program
  - JTRS (Joint Tactical Radio System)
  - Requirements state JTRS should be compatible with over 30 different air interfaces!

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Interest in SDR

- Public Safety/Law Enforcement
  - Equipment operates over 10 distinct frequency bands 30 – 869 MHz
  - New 700 MHz band being proposed
  - Equipment uses different air interfaces/protocols
    - Proj 25, analog FM, proprietary trunked, etc.
  - Need to communicate between these different radios

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Interest in SDR

- Commercial Sector
  - Many different existing air interfaces
    - AMPS, TDMA, GSM, CDMA, etc.
  - New air interfaces being developed (3G)
  - Different frequency bands for different services & different world regions
    - Cellular, PCS, 3G
  - Need to have equipment that can be used universally

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The SDR Solution

- Replace many radios with 1 SDR
  - Just change software to change radio type
  - Minimizes cost of procurement, spare parts, & logistics
  - Can reduce size & weight of required radio equipment
    - Aircraft may need only 1 radio not 6 or 7
  - Eventually achieve cost savings by economy of scale

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SDR Designs

- Primary differences in SDR designs
  - DSP platform used
    - ASIC's, DSP chips, FPGA's, general purpose processors, or combination of these
    - Platform affects software that needs to be developed
  - Where digitization in RCVR & conversion to analog in XMTR occurs (RF, IF, or baseband)

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SDR Designs

- Digitization in RCVR & conversion to analog in XMTR
  - Ideal goal: occurs at RF
    - Many radio applications: current ADC's & DAC's do not have high enough speed with required performance
    - OK for some radios with low SFDR requirements
  - Typically occurs at IF in current designs
  - Occurs at baseband in some designs
    - Some new RCVR designs downconvert directly from RF to baseband
    - Some new XMTR designs upconvert directly from baseband to RF

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Key SDR Enabling Technologies

- High sampling rate, high performance data converters (ADC's & DAC's)
- Wideband Tunable Analog RF Transceiver Front-Ends
- Digital signal processing hardware
- Flash Memory
- Wideband Linear RF Power Amplifiers

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Data Converters

- For given radio RCVR application
  - ADC sample rate, max analog input frequency & performance determine whether digitization can occur at RF, IF, or baseband
- For given radio XMTR application
  - DAC update rate & performance determine whether conversion to analog can occur at baseband, IF, or RF
- SFDR & SNR (or SINAD): useful performance measures

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Data Converters

- SFDR
  - Ratio signal power & power largest spur within given BW
  - Input signal: single tone or multitone
  - SFDR important
    - RCVR: detect small signal in presence of large signal
    - XMTR: ensure out-of-band spurs below spectral mask before transmission

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Data Converters

- Be careful with SFDR specs
  - Must know details of test
    - Type of input, frequencies & amplitude of input
    - Sample rate
    - BW of measurement
- Example ADC's
  - High SFDR, moderate sample rate
    - 14-bit, 80 Msample/sec, ~90 dB SFDR
  - Moderate SFDR, high sample rate
    - 8-bit, 1.5 Gsample/sec, ~50 dB SFDR

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Wideband Tunable Analog RF Transceiver Front-Ends

- Important since data converters currently can't be used at RF for many applications
- Convert received RF to IF or baseband for digitization
- Convert baseband or IF signal (at output of DAC) to RF for transmission

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Wideband Tunable Analog RF Transceiver Front-Ends

- Example: DARPA Miniature Radio Codec
  - Direct conversion RF to baseband
  - Operates from 20-2500 MHz
  - 10 MHz BW
  - 1 Watt transmitter output power

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Digital Signal Processing Hardware

- Programmable digital downconverter & upconverter ASIC's
- Larger, faster FPGA's
  - FPGA's reconfigurable digital hardware
  - Up to 10 million gates, > 400 MHz internal clock
  - FPGA's were used just for digital logic
  - Now gate count & speed permit FPGA use in digital signal processing

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Digital Signal Processing Hardware

- New, high-speed DSP chips
  - 16-bit fixed point, 6 GOPS
  - 32-bit floating point, up to 1.5 GFLOPS
- DSP chip vs. FPGA
  - FPGA: architecture tailored to the algorithm to be implemented
  - DSP chip: algorithm must be tailored to the architecture

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Digital Signal Processing Hardware

- General purpose processors
  - Very flexible
  - Probably easiest to program (can use high level languages)
  - Speed has increased dramatically

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SDR Enabling Technologies

- Flash memory
  - Erasable, reprogrammable ROM
  - Enables download of new radio configuration
- Wideband linear power amplifiers
  - Class A amplifiers: linear but consume too much power
  - Alternative: use linearization techniques on more power efficient, nonlinear amplifiers
    - Example: Feed forward & feedback techniques

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Challenges in SDR

- SDR's currently available for cellular/ PCS base stations & fixed military applications
- Big challenge: developing practical handheld devices
  - Need to reduce power consumption, size, weight, and cost of SDR
- Mobile (Vehicular) applications: more doable
  - Constraints of power consumption, size, weight less critical

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SDR Forum

- Non-profit org dedicated to promotion
  - Development, deployment, & use of open architecture for advanced wireless systems
- Established in 1996
- Membership:
  - More than 100 organizations worldwide
  - Commercial, government, & academic sectors

SDR Forum

- Comprised of 3 core committees
  - Markets, Technical, Regulatory
- Markets committee key outputs:
  - Predictions of SDR market size & business revenue
  - Identification of primary market characteristics & drivers (commercial, military, civil government sectors)

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SDR Forum

- Technical Committee
  - Developing open architecture specs of SDR hardware & software structures
  - Separate working groups for handheld, base station, & mobile SDR's
- Regulatory Committee
  - Addresses international regulatory issues for SDR's
- For more info: www.sdrforum.org

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Conclusion

- Gave broad definition of SDR
- Advantages of SDR
  - Programmability
  - Benefits of digital vs. analog implementation
- Interest in SDR's
  - Potential to aid interoperability problem
  - Replace many radios with one SDR

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Conclusion

- Design of SDR's driven by enabling technologies – In particular
  - Data converters
  - Digital signal processing hardware
- SDR Forum

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