OVERVIEW OF SOFTWARE RADIOS

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INTRODUCTION

- Software Radio Definition
- General Benefits of Software Radios
- Key Factors in Software Radios
  - Receiver: ADC's & Signal Processing Hardware
  - Transmitter: Signal Processing Hardware & DAC's (also Linear Pwr Amp)
- Conclusion & Software Radio Presentations at Symposium
  - Opening Session
  - Technologies Session
  - Applications Session

SOFTWARE RADIO DEFINITION

- The term “software radio”
  - Prefer very broad definition
  - Define in terms of receiver & transmitter
- Software Radio Receiver
  - Received signal digitized & processed w/DSP
  - Digitization may occur at RF, IF, or baseband
  - Inherent in definition: flexibility to change processing
  - Possesses some level of programmability to change the way it processes received signal
  - Belongs to general class Digitized Signal Receivers
  - Digitized Signal Receivers: Not necessarily programmable

SOFTWARE RADIO DEFINITION

- Software Radio Transmitter
  - Modulated signal to be transmitted generated w/DSP & converted to analog for transmission
  - Modulated signal generated as digitized signal
  - Conversion to analog may occur at baseband, IF, or RF
  - Inherent in definition: flexibility to change processing
  - Possesses some level of programmability to change the way it processes transmitted signal
  - Belongs to general class Digitized Signal Transmitters
  - Digitized Signal Transmitters: Not necessarily programmable

SOFTWARE RADIOS

- Software Radios do not necessarily imply digital modulation (FSK, PSK, etc.)
  - Modulation may be analog (FM, AM, etc.)
- Don’t confuse modulation type w/Software Radio definition
  - Received signal digitized
  - Modulated signal generated as digitized signal in transmitter

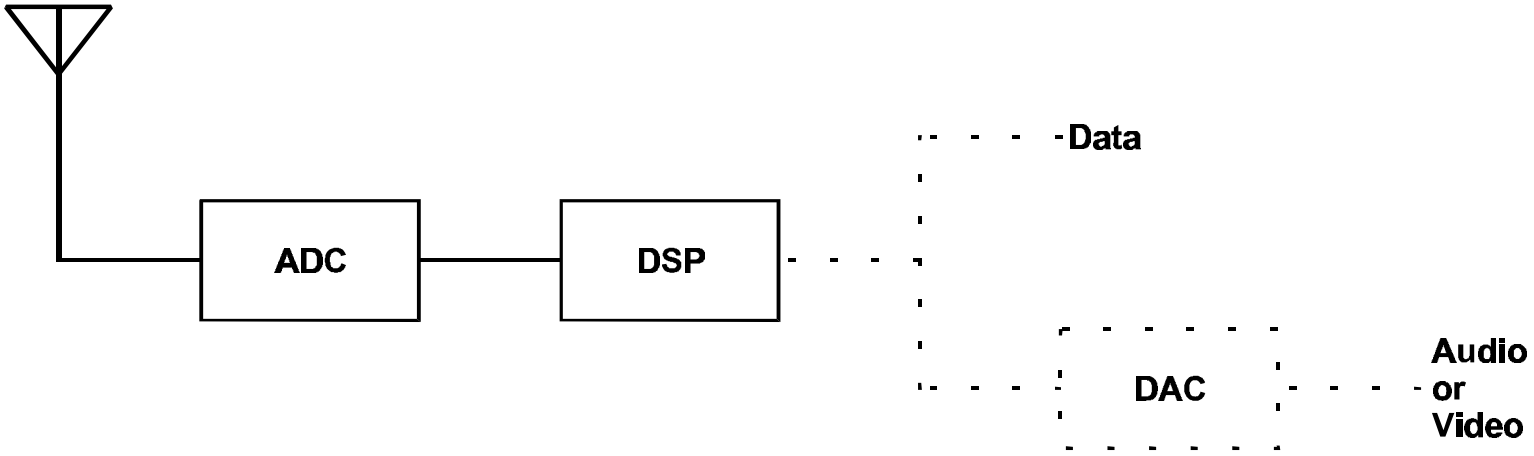
BENEFITS OF SOFTWARE RADIOS

- Many benefits result replacing analog implementations radio functions w/ software or digital hardware
- Radios can be designed for transmission & reception w/ different freq. bands, modulation types, & BW's simply by changing software
- Potential reduction in product development time
- Radio functions can be implemented that cannot be implemented in analog hardware
  - Example: FIR filter, sharp rolloff & linear phase

BENEFITS OF SOFTWARE RADIOS

- Radio functions implemented w/ DSP offer performance closer to ideal
- Repeatability and temp stability substantially better than w/ analog hardware
- Radio functions implemented w/ DSP don't require tuning or tweaking typically required in analog hardware

Ideal Software Radio Receiver

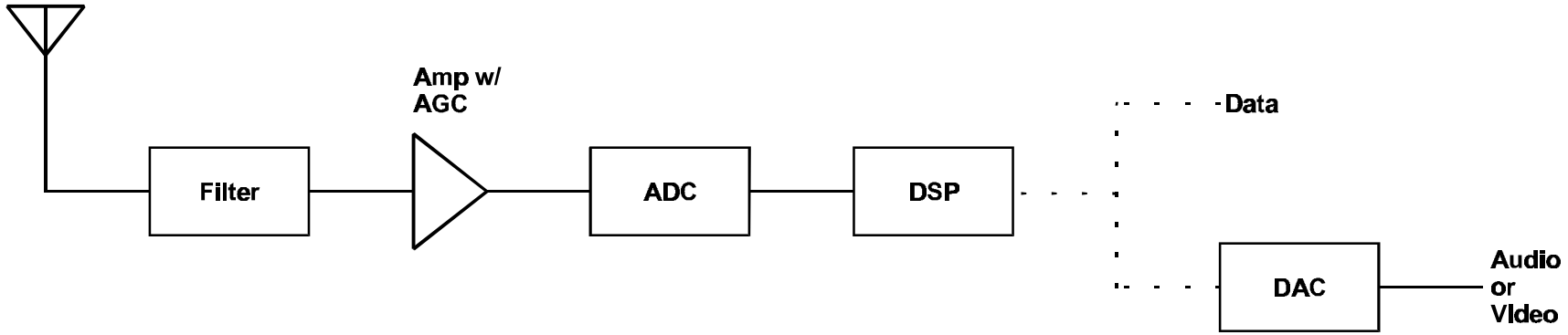


- Digitization at output of antenna
- Illustrates key components: ADC & DSP
- Practical problems w/ideal software receivers
  - Bandlimit ADC input, prevent aliasing
  - ADC's require large signals (FSR ≈ 1V or more)
  - RF signals much smaller

Ideal Software Radio Receiver - Practical Problems

- RF signals
  - Overall amplitude at any time: very small to large
  - Small desired & Large undesired signals simultaneously
- Small RF signals require amplifier before ADC
- Large variation in overall amplitude requires AGC before ADC
  - AGC prevents ADC overload by large signals
  - AGC preserves good sensitivity for small signals
- Small desired w/ large undesired signal requires high SFDR ADC

MORE REALISITC SOFTWARE RADIO RECEIVER



- Practical implementation problems w/ configuration
  - Practical ADC & sig proc hardware constrain architecture
- For given radio service/ freq band
  - ADC sample rate, SFDR, & SNR along w/ speed of sig proc hardware determine where digitization can occur
  - RF, IF, or baseband
- Require closer look at ADC's and DSP hardware
- Overview: discuss briefly; Technology session: more detail

ANALOG TO DIGITAL CONVERSION

- Methods of Sampling
- Important Specifications for Receivers
- Current State-of-the Art in ADC's

SAMPLING METHODS

- Two basic classes
  - Uniform time spacing between samples
  - Non-uniform (not readily available)

- When sampling signal uniformly
  - Spectrum of signal repeated at integer multiples of sampling frequency

UNIFORM SAMPLING METHODS

- 2 times max frequency
  - For perfectly bandlimited signal allows exact reconstruction of input signal
  - Need filter with infinite attenuation at frequencies > f_{max}
  - Filters not practically realizable
  - With real filters always get signal distortion

UNIFORM SAMPLING METHODS

- Oversampling
  - Sample at rates > 2 f_{max}
  - Improves SNR
  - Eases requirements on anti-aliasing filter
- Bandpass sampling
  - Sample at 2 or more times signal bandwidth not 2fmax
  - Good for bandpass signals (no freq. content below f_l or above f_h)
  - Stringent restrictions on exact sample frequencies between 2 times BW and 2fmax
  - Requires much lower sampling frequencies than 2fmax

BANDPASS SAMPLING EXAMPLE

- 1 MHz BW signal @ 900 MHz center freq
  - Need to sample > 2 Msamples/sec not > 1800 Msamples/sec
  - Exact sample rates above 2 Msamples/sec restricted
  - ADC must be able to operate on 900 MHz signal

IMPORTANT ADC SPECS

- Important software radio ADC specs include
  - Sample rate, Max analog input freq, SNR, & SFDR

- Theoretical maximum SNR for sinusoidal input
  - $SNR = 6.02B + 1.76 + 10 \log_{10} (f_s / 2f_{max})$ dB
    B = # of bits, f_s = sampling freq.
  - If $f_s = 2f_{max}$, $SNR \approx 6B$
  - SNR increases as $f_s > 2f_{max}$ (Oversampling)

IMPORTANT ADC SPECS

- SFDR
  - Ratio between signal power & largest spur
  - Input signal - Single tone or multitone (IMD)
  - SFDR important - Detect small signal in presence of large signal
  - Theoretical prediction difficult (must measure)
  - Misconception - SFDR not equal to SNR
  - SFDR can be much > SNR

DIGITAL SIGNAL PROCESSING

- Key considerations:
  - What RCVR/XMTR functions need implemented
  - Type of signal processing hardware to use
- Most radio receiver applications: need real time proc
  - Speed of processing must keep up w/ input data rate
- Estimate required processing speed by:
  - Number & complexity functions to implement
  - Input data rate into processing hardware
- Compare required proc speed to avail proc throughput of proc hardware

DIGITAL SIGNAL PROCESSING RADIO FUNCTIONS

- Radio functions possibly needed
  - Upconversion/Downconversion
  - Filtering
  - Modulation/Demodulation
  - Multiple Access Processing
  - Frequency Spreading/ Despreading
  - Encryption/Decryption
  - Channel & Source Coding/ Decoding

SIGNAL PROCESSING OPTIONS

- Four general classes of signal processing hardware
  1) General purpose microprocessors
  2) Digital signal processors
  3) Field programmable gate arrays (FPGA's)
  4) Application Specific Integrated Circuits (ASIC's)
     – Examples: digital downconverters, upconverters, demodulators

SIGNAL PROCESSING OPTIONS – COMPARISON METHODS

- Methods of comparison of different signal processing options
  1) Parallelism – number of operations performed at same time
  2) Reuse of gates/ time sharing of same hardware to implement radio functions (algorithms)
  3) Flexibility/ Reprogrammability/ Reconfigurability
  4) Speed

COMPARISON OF SIGNAL PROCESSING OPTIONS

	Parallelism	Reuse of Gates/ Time Sharing	Flexibility/ Reprogrammability	Speed
Microprocessor	Low (none)	High	High	Low
DSP Chip	Some	Moderate		
FPGA	High	None		High
ASIC	High	None	Low (None)	High

SIGNAL PROCESSING OPTIONS – CHOICES

- Choice of signal processing devices depends on:
  1) Required processing throughput for radio functions implemented
  2) Required amount reprogrammability/ reconfigurability
  3) Background/ experience design team
  4) Time to market considerations
  5) Power consumption
  6) Cost – related to quantity

CONCLUSION

- Software Radio Definition
  - Receiver & Transmitter
- General Benefits of Software Radios
- Key Factors in Software Radios
  - Receiver: ADC's & Signal Processing Hardware
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- Software Radio Presentations at Symposium
  - Two half-day sessions: Technologies, Applications
  - This Opening Session

SOFTWARE RADIO PRESENTATIONS

- Opening Session
  - MMITS Forum Activities Presentation
- Technologies Session
  - More about software radio architectures
  - RF interface issues
  - ADC's & DAC's
  - Digital Signal Processing: Techniques, DSP chips, FPGA's, & ASIC's

SOFTWARE RADIO PRESENTATIONS

- Applications Session
  - Current implementations of software radios
  - Cellular/ PCS applications
  - Speakeasy military software radio
  - GPS receiver application
  - HF/VHF/UHF applications
  - Wireless network applications