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 REALISTIC 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 $> f_{\text{max}}$
  – Filters not practically realizable
  – With real filters always get signal distortion
UNIFORM SAMPLING METHODS

• Oversampling
  – Sample at rates $> 2 f_{\text{max}}$
  – Improves SNR
  – Eases requirements on anti-aliasing filter

• Bandpass sampling
  – Sample at 2 or more times signal bandwidth not $2f_{\text{max}}$
  – Good for bandpass signals (no freq. content below $f_1$ or above $f_h$)
  – Stringent restrictions on exact sample frequencies between 2 times BW and $2f_{\text{max}}$
  – Requires much lower sampling frequencies than $2f_{\text{max}}$
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_{\text{max}}) \text{ dB}
    B = \# \text{ of bits}, f_s = \text{sampling freq.}
  – If f_s = 2f_{\text{max}}, \text{SNR} \approx 6B
  – SNR increases as f_s > 2f_{\text{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

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<thead>
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<th>Parallelism</th>
<th>Reuse of Gates/Time Sharing</th>
<th>Flexibility/Reprogrammability</th>
<th>Speed</th>
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<td>ASIC</td>
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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
  – Transmitter: Signal Processing Hardware & DAC’s
    (also Linear Pwr Amp)

• 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