Adaptive Spectrum Utilization with Software Defined Radios

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The MITRE Corporation

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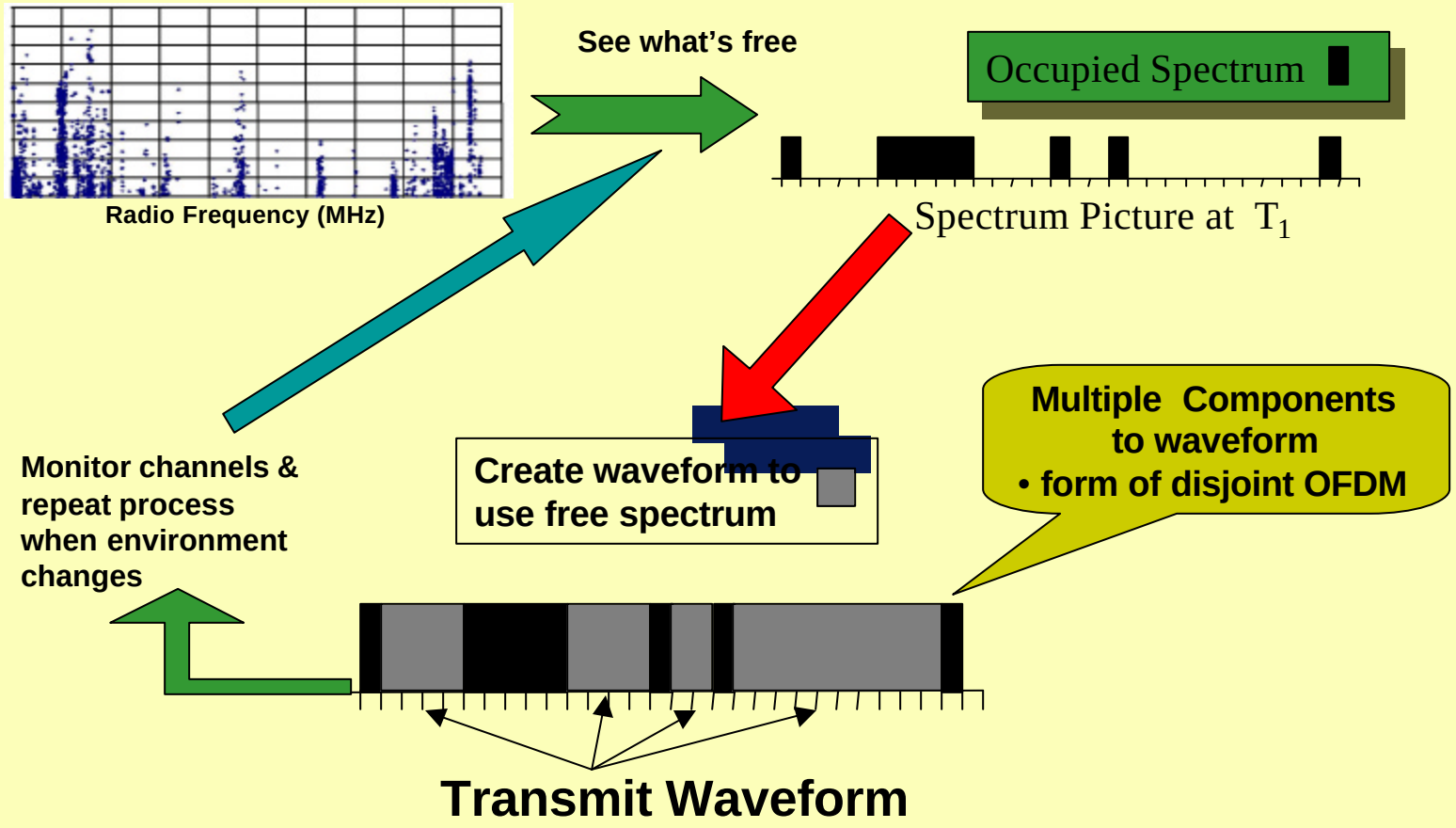
Agenda

- Project Overview
  - What is it?
  - Key components and technology used
- What Capabilities and Resources were developed
  - Spectrum and Research community
- Technology Transfer to Real World Applications
- Ongoing Research & Development Opportunities

Approach: Adaptive System Operation

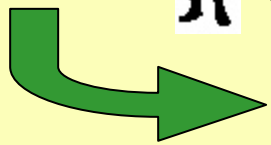
Not all spectrum used 100% of time

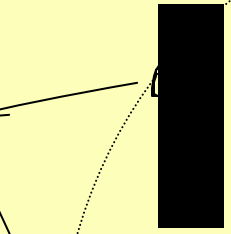


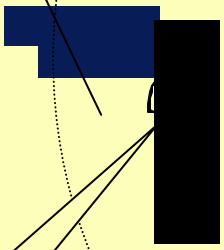
Waveform compatible with existing spectrum channelization plans and scalable to support wide range of user data rates using non-contiguous spectrum

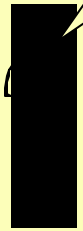
Implementation Considerations

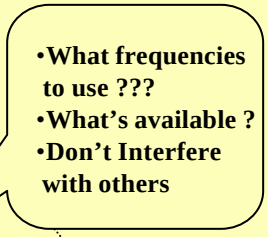
Adaptive Radio

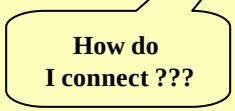


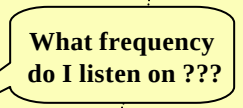












Connectivity !!

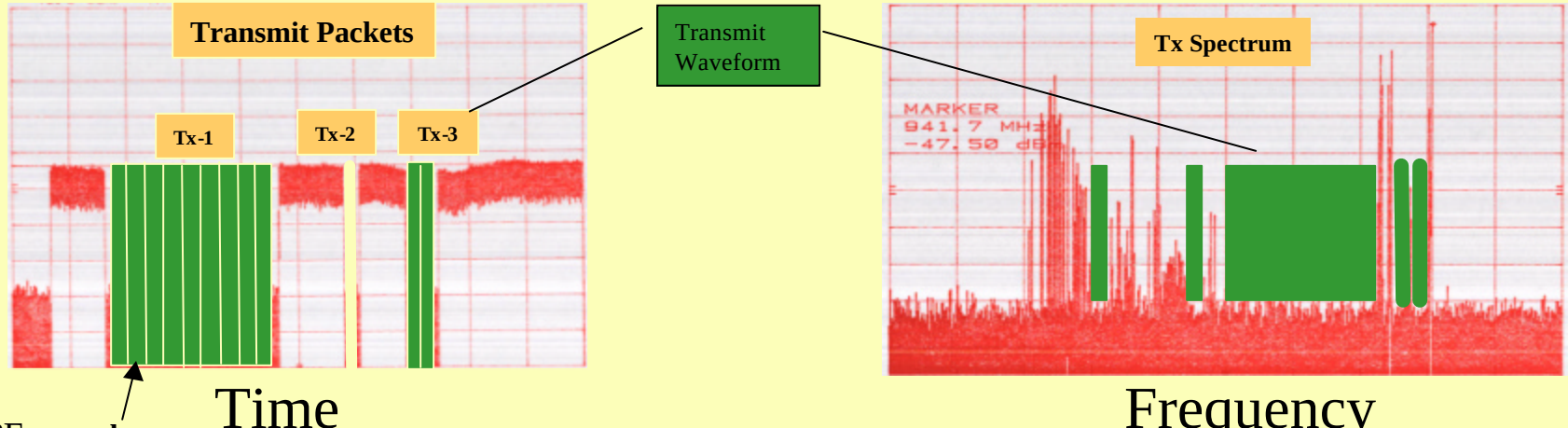
Coordination & Control

Implementation Needs

- *Not interfere with primary users*
- *Close the RF links*
- *Coordinate frequency in network - no dedicated control channels*
- *Connect all network users*
- *Must share spectrum pictures among users* *(Hidden Tx & Rx Solutions)*

What's Different

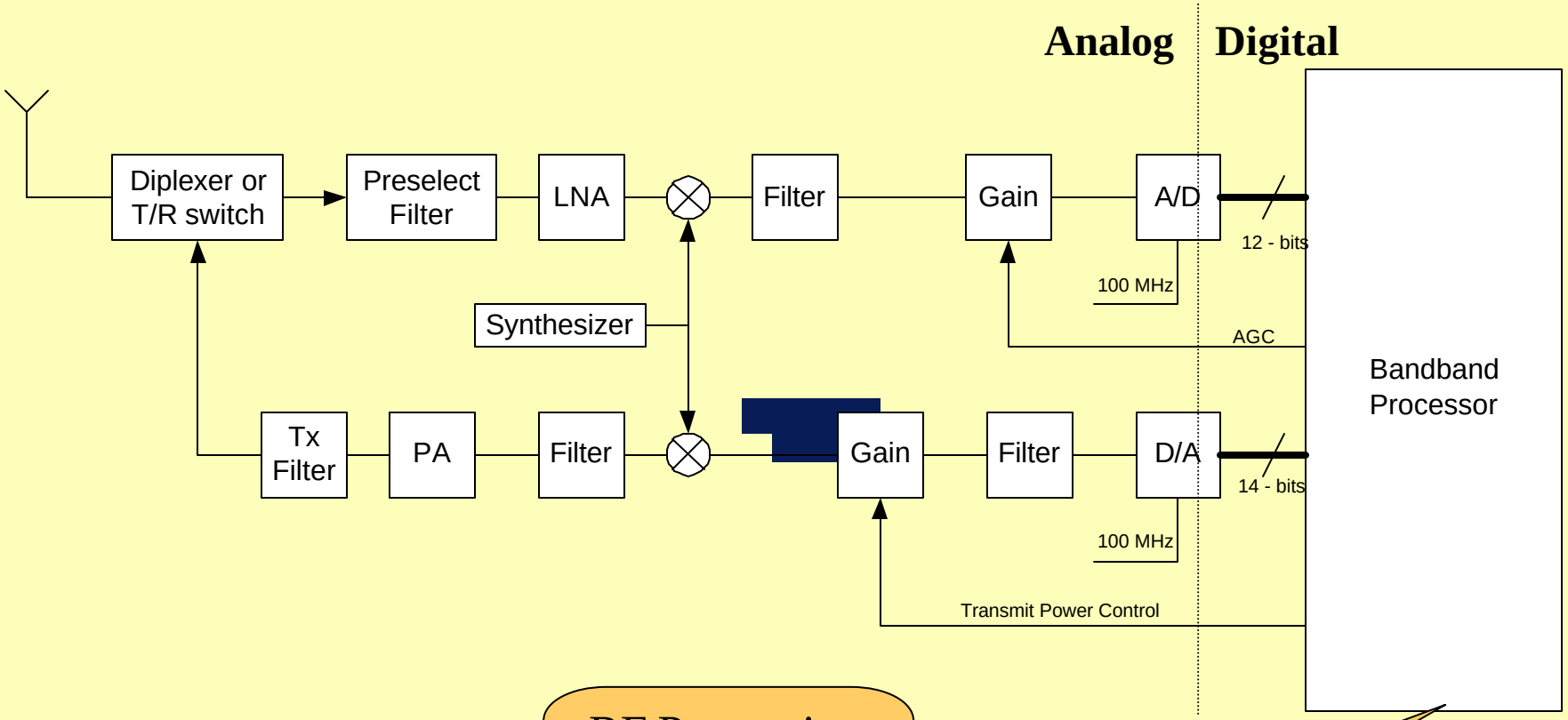
- Many sharing applications use compatible waveforms to simultaneously share spectrum
  - Overlays such as spread spectrum
  - Avoidance by proper frequency selection
  - simultaneous operation limits performance of all systems
- Adaptive Spectrum concept shares spectrum in both time and frequency
  - minimize interference to primary users
  - allow higher transmit energy using transmit burst operation avoiding other primary users.

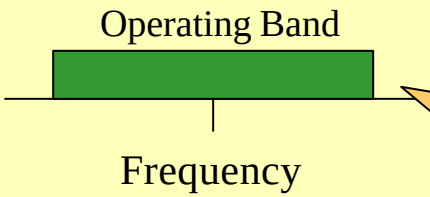


Potential Advantages

- Technology provides opportunity for secondary sharing of frequency channels with both cooperative and uncooperative users
- Use of smart protocols internal to radio minimizes the need for spectrum assignment pre-planning
  - Reduced spectrum related mission preplanning
  - Increased abilities to rapidly adapt to changing missions
- Technology and protocol implementations are hierarchical in structure
  - Totally automatic with no dedicated control channels
  - Dedicated control channel infrastructures for more positive regulation
    - for range use can employ additional scheduling
  - Distributed control architectures to accommodate unique mission needs

Adaptive Spectrum Communication System
RF Processing

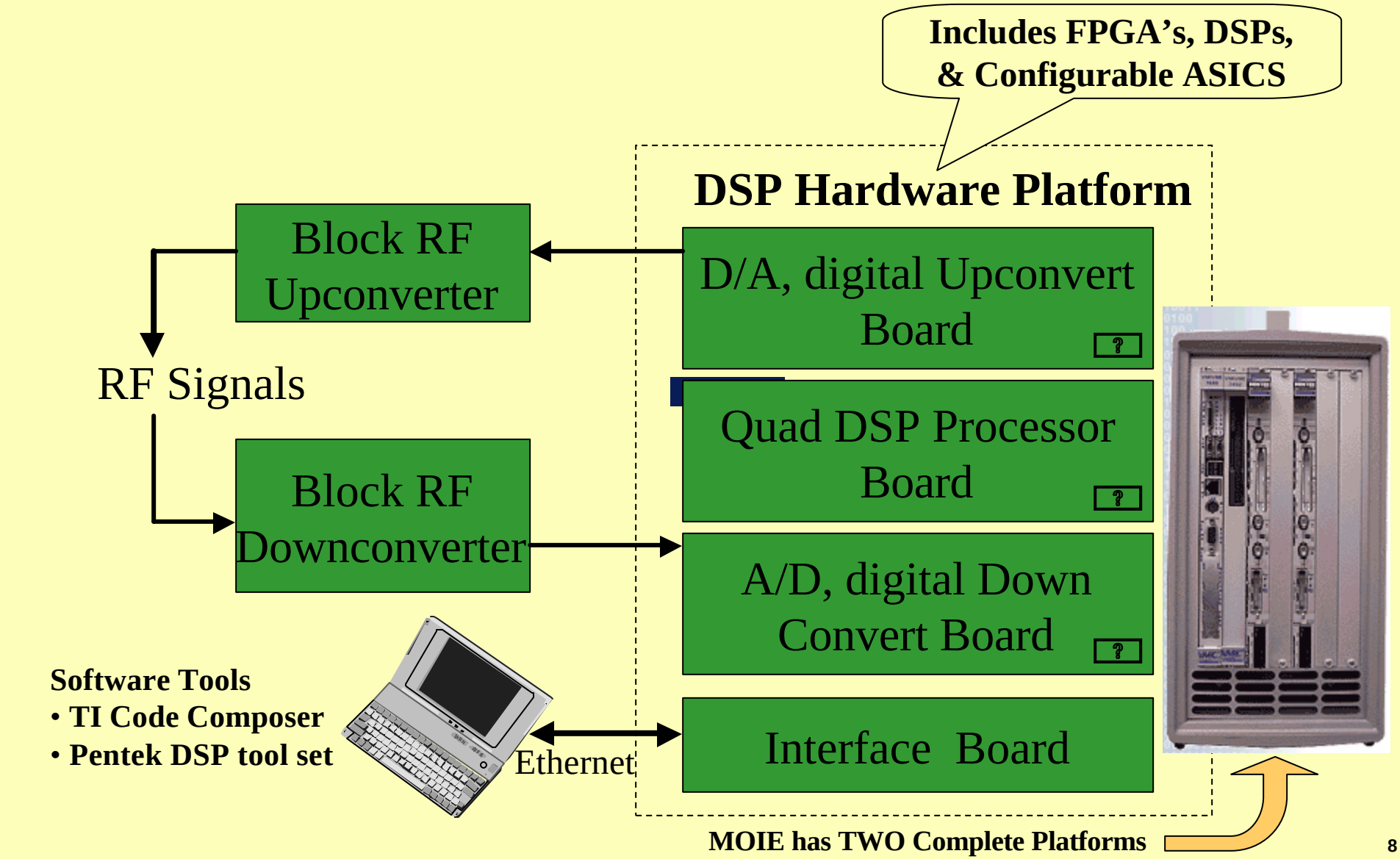




RF Processing Determines Frequency Band

Processes Sub-channels

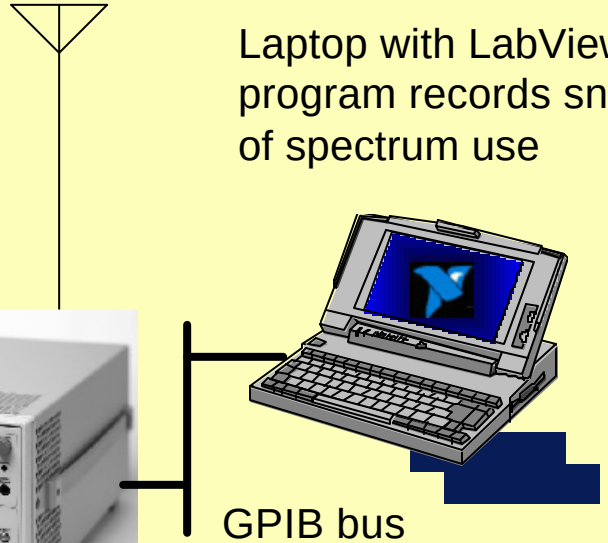
Adaptive Spectrum MOIE Development Environment



Adaptive Spectrum Use Measurements

Reston Building
West Whip Antenna

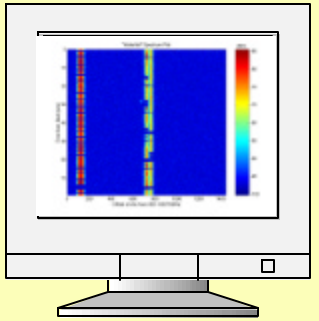
HP 8591E
Spectrum Analyzer



GPIB bus

Laptop with LabView
program records snapshots
of spectrum use

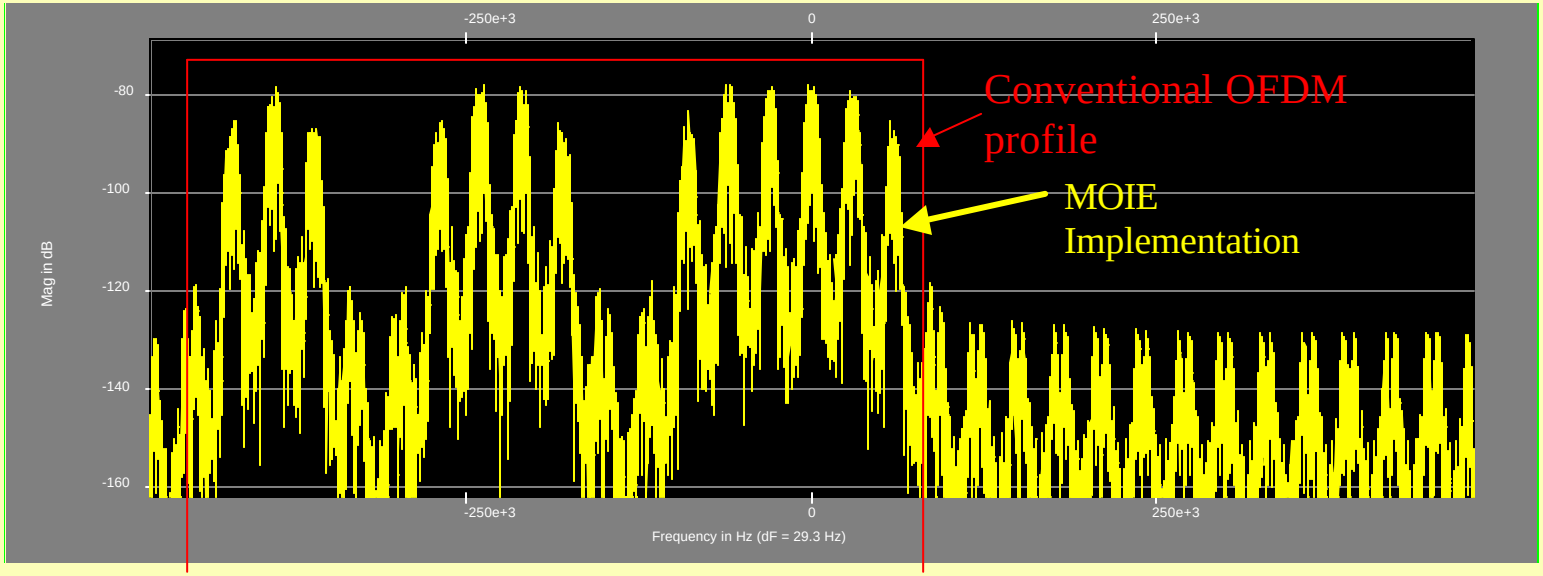
Workstation with
MATLAB analyzes
spectrum use



- Need high time resolution, long term data to determine adaptive system performance potentials ~ 1 sec with spectrum analyzer
- Must develop occupancy statistics to optimally design adaptive system performance requirements

Adaptive Waveform Generation

- Variation on Orthogonal Frequency Division Multiplex
  - Note: Standard OFDM gives gives contiguous set of subcarriers
  - MOIE NEEDS ARBITRARY SETS OF NON_CONTIGOUS Transmit Carriers
- NEW Signal Processing Implementation Approaches
  - Extensive wave shaping for out-of-band rejection and non-contiguous carrier implementation



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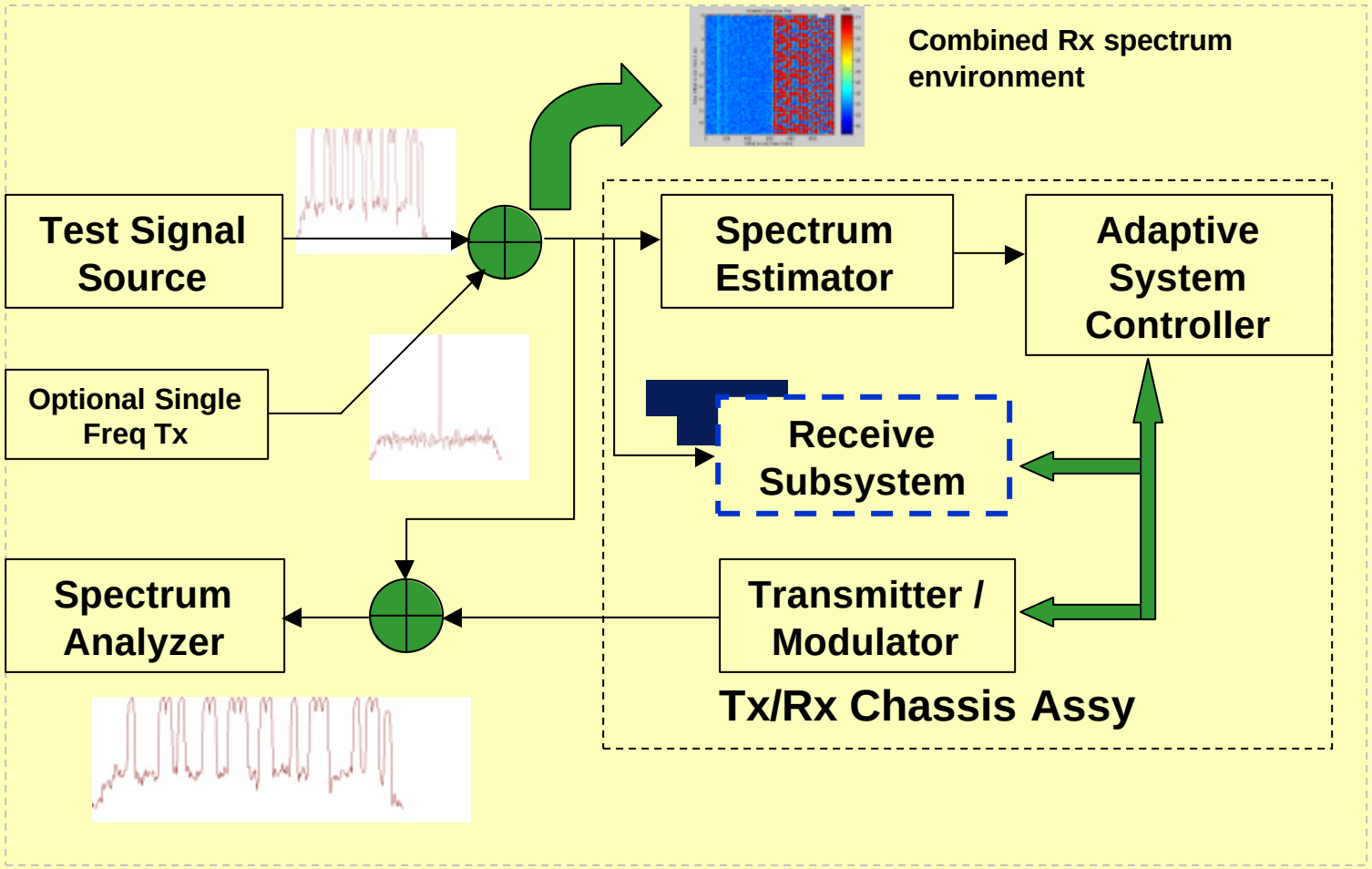
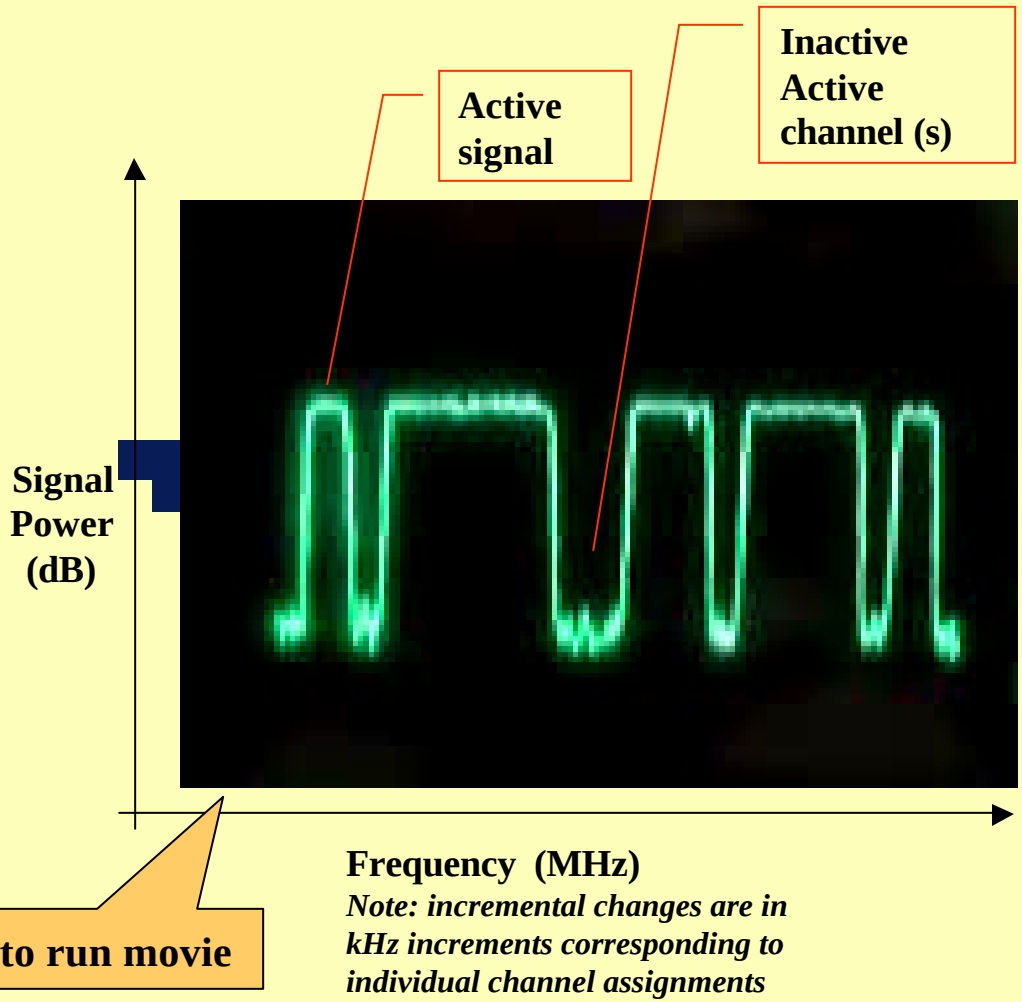
Adaptive Waveform Demonstration



---------- Rx Subsystem in final implementation

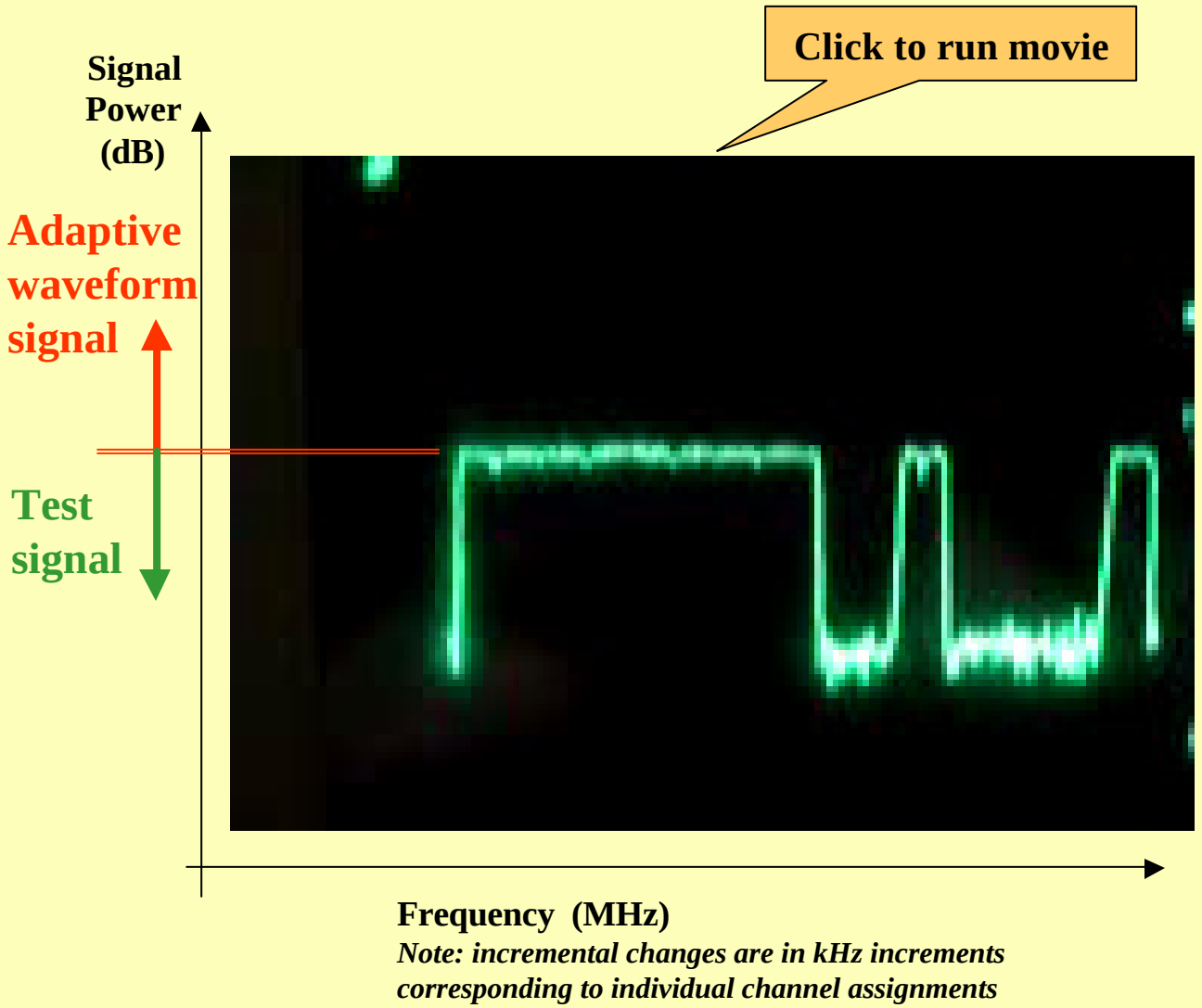
Test Signal Source

- Test Source represents assigned user's signal activity within a frequency band
- Signal bandwidths are multiples of the spectrum channel band plan
- Duration and specific channel combinations are selected on a pseudo random basis



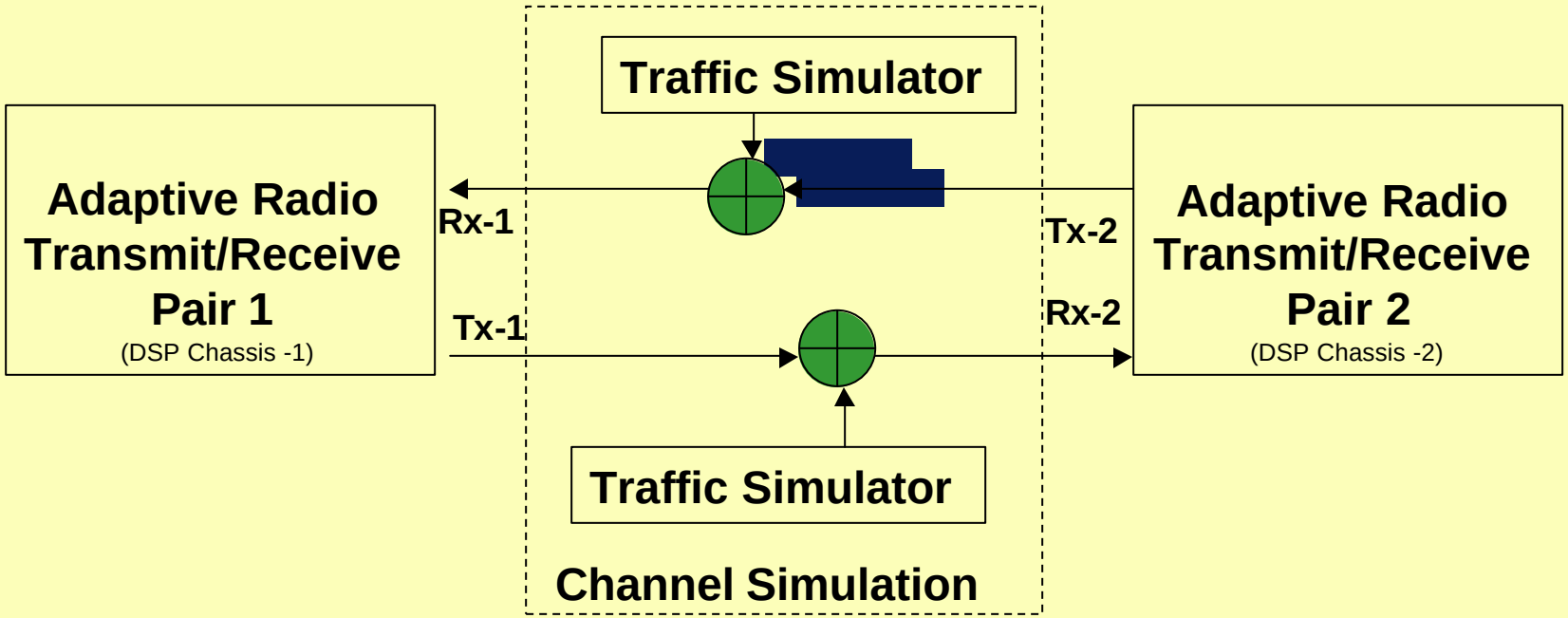
Adaptive Waveform with Test Signal

- Adaptive waveform and test signal superimposed
- *Lower power signal is test signal*
- *Higher power signal is adaptive waveform transmission*
- Adaptation rate is reduced for viewing on spectrum analyzer

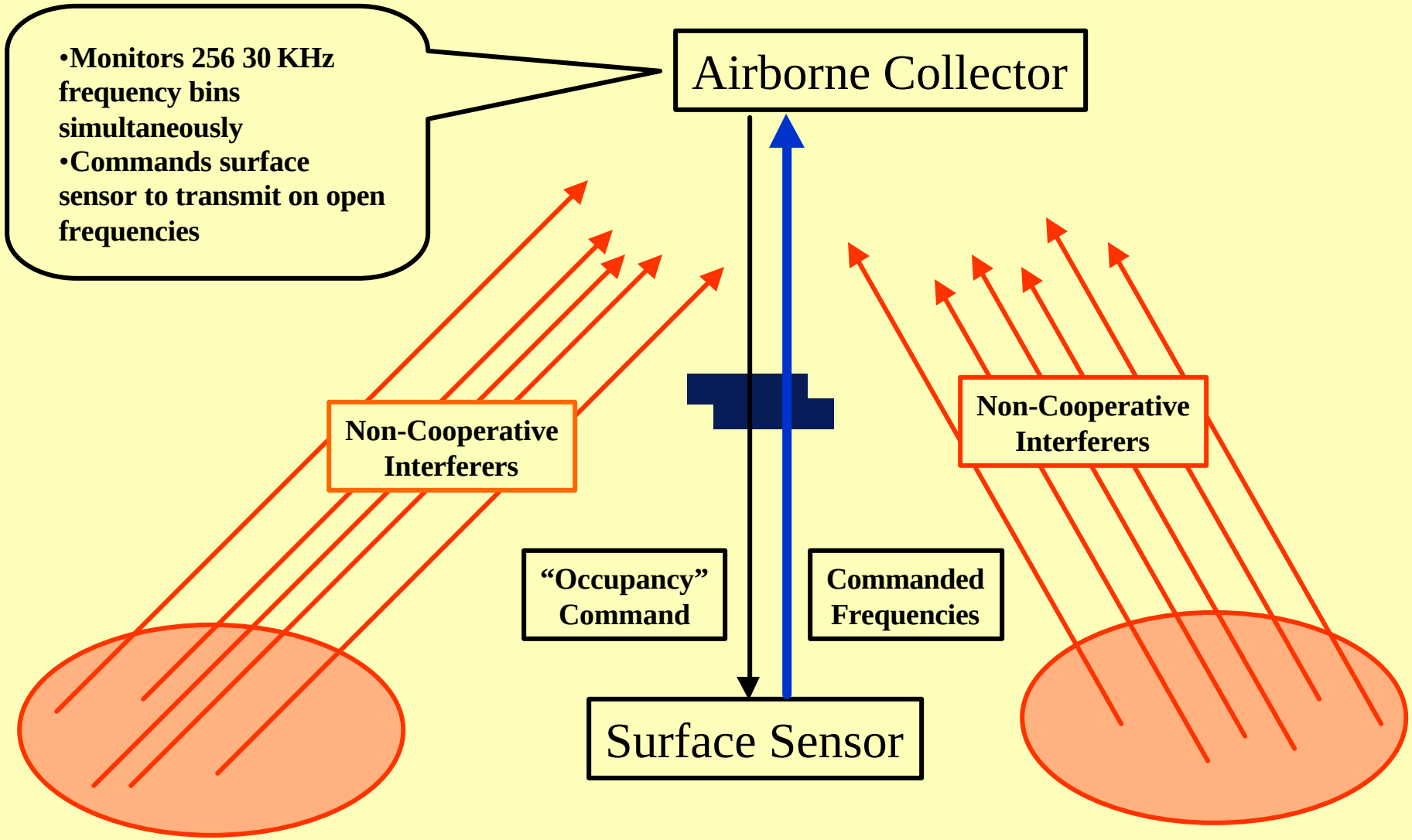


System Demonstration Goal

- **Complete End-to-End System Demonstration**
  - **Two independent radio sets**
  - **Channel and traffic simulator**



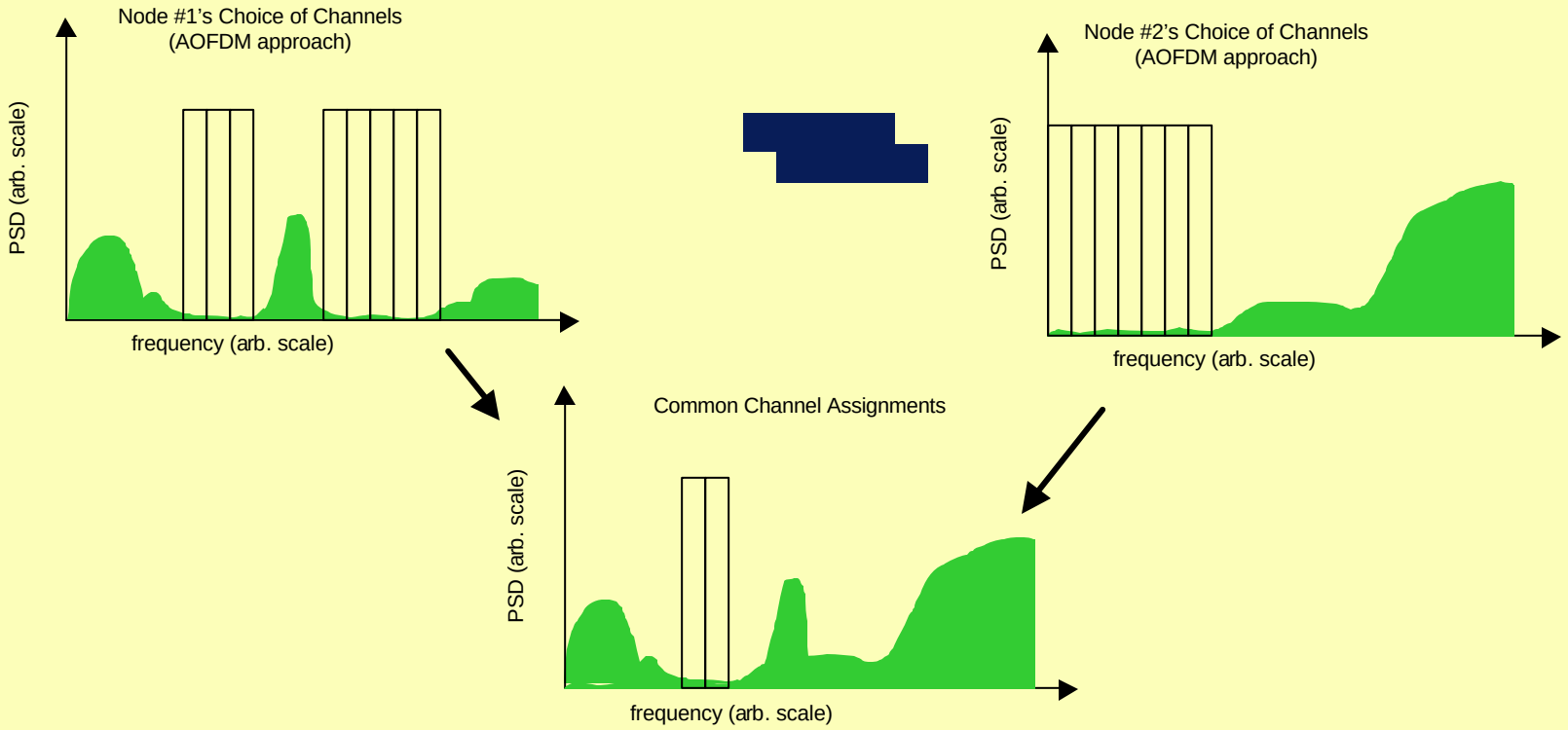
Generic Application Scenario Example



BACKUPS

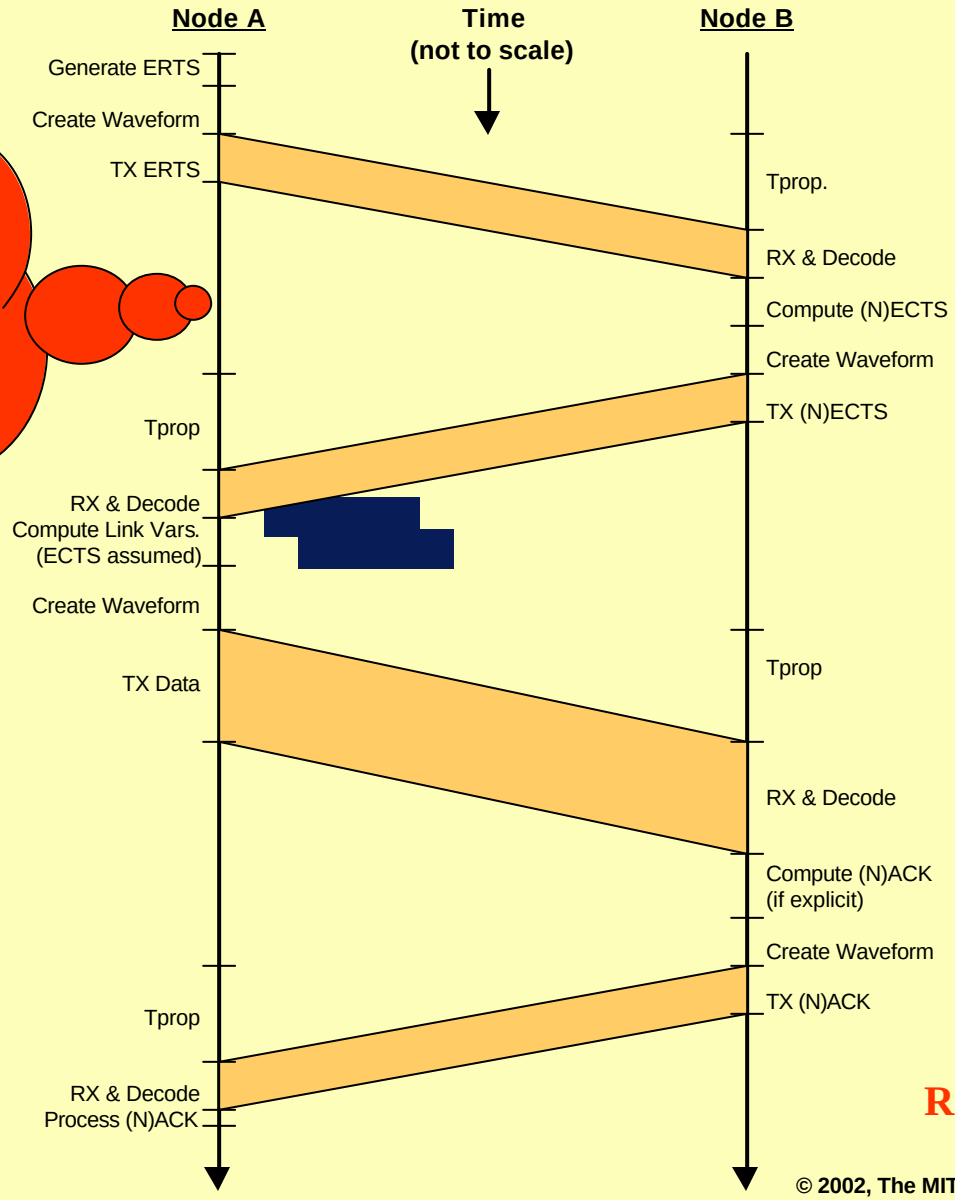
Link Negotiation & Establishment
(Point-to-Point Case Illustrated Here)

- **Since each node makes an independent, local measurement of the radio spectrum some coordination is required before communication can occur:**
  - **spectrum pictures shared between users**
  - **optimum picture sharing dependent on environment**



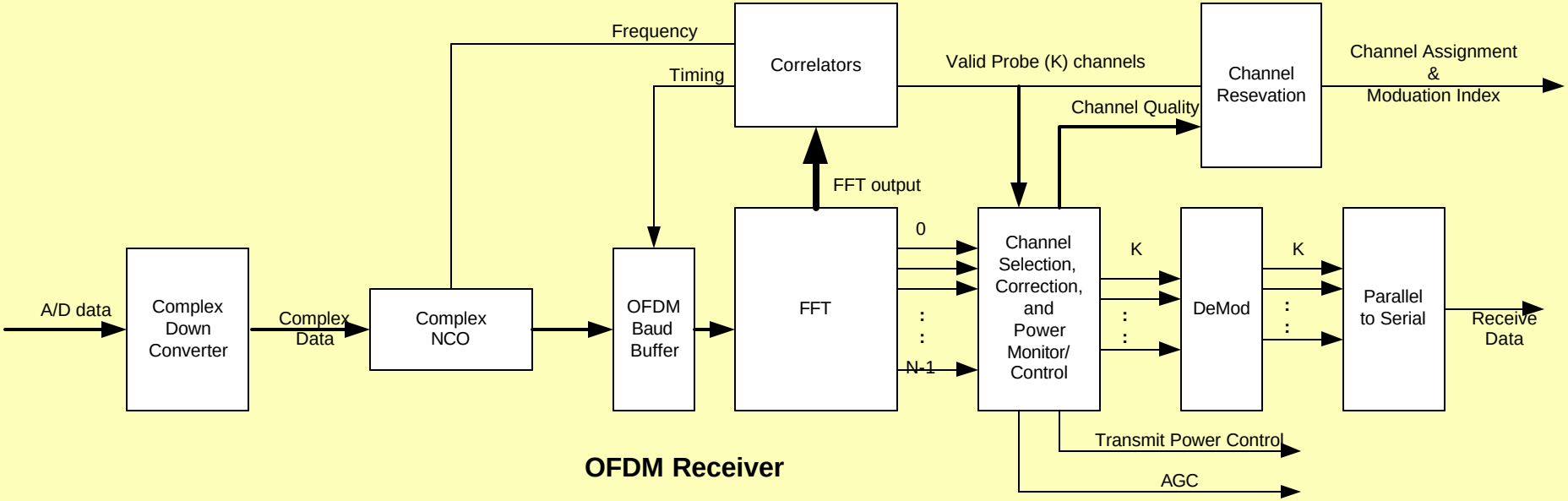
Summary of Link Negotiation via an Extended RTS/CTS Process

Bounds on Adaptation Rates !
- Environment
- Implementation

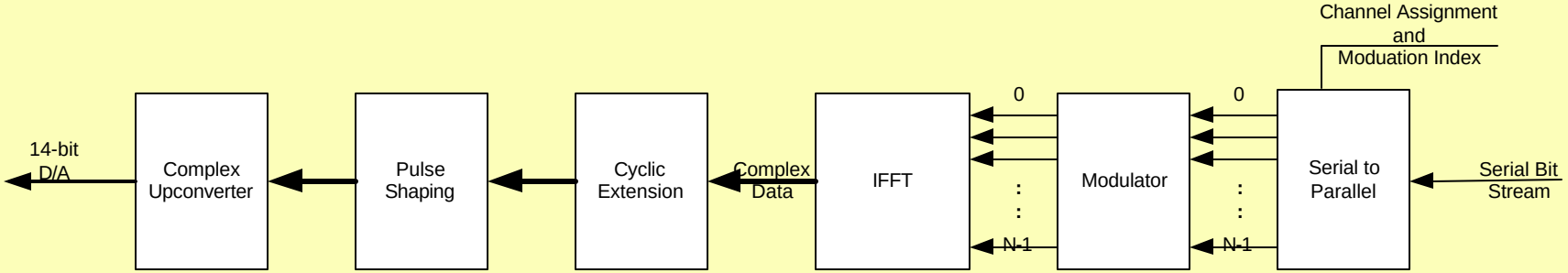


Return

Adaptive Spectrum Communication System Baseband Processing



OFDM Receiver



OFDM Transmitter

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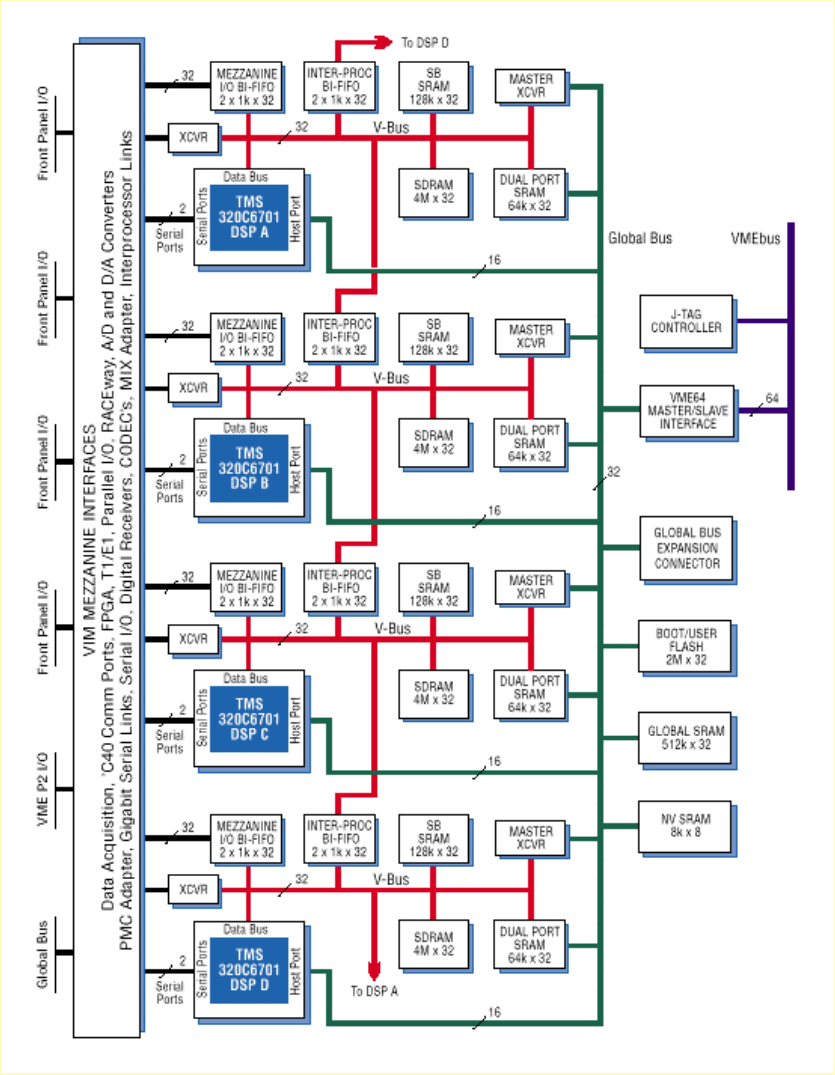
Pentek Quad Processor Board



- Four TMS320C6701 floating-point DSP's
  - operating at 167 MHz
  - 4 GFLOPS performance
  - SDRAM
  - serial full-duplex ports
  - zero-wait sync burst & dual port SRAM
  - flash memory
  - Data transfer rates up to 400 MB/sec

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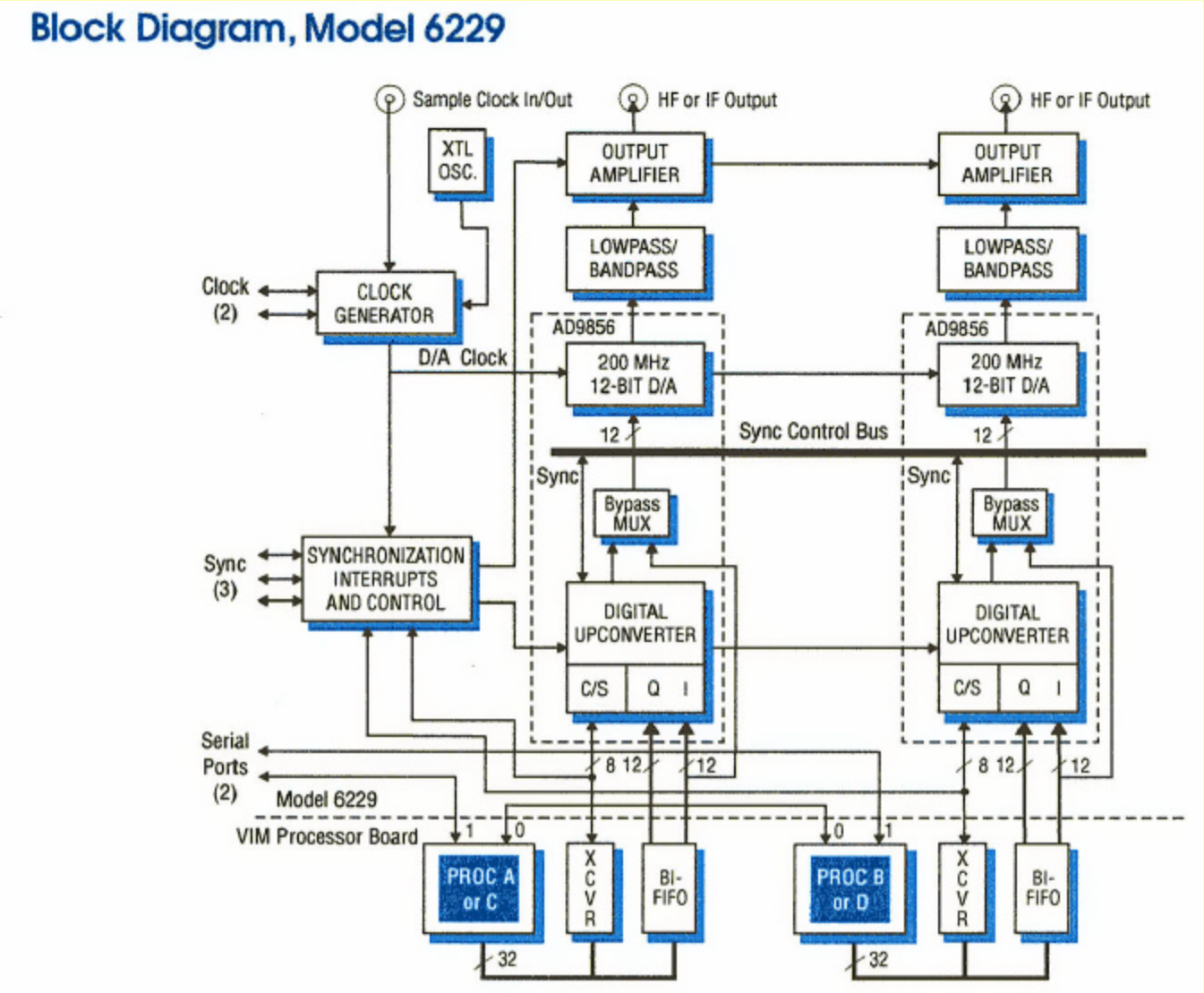
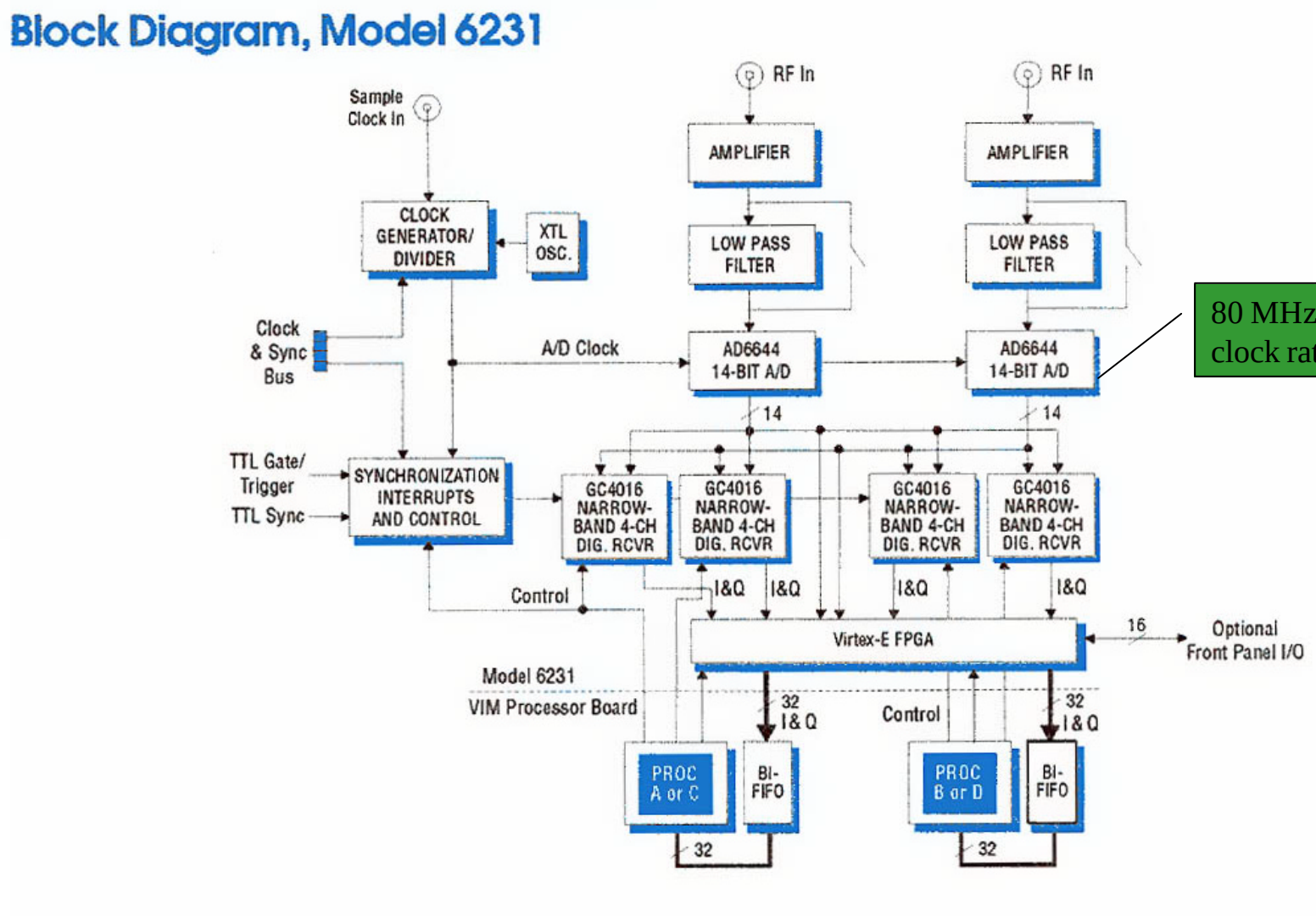
Pentek Upconverter Board



Pentek Downconverter Board



Additional Enhancements

- Transition work to government program activities
- Enhance control infrastructure
- Add directional antennas
- Enhance connectivity by network relay
- Model operational scenarios