Introduction and advances in Software Defined Radios

NEWS / MidAtlantic VHF Conference

October 13, 2012

Phil Theis K3TUF

FlexRadio Systems
Software Defined Radios

Tune In Excitement!™

Who is this K5GJ guy???

FlexRadio Systems
Software Defined Radios

DEFINITIONS: Software Defined vs. Controlled

- Controlled
  - PC Control of Fixed Capabilities (frequency, band, etc)
- Defined
  - All Modulation, Demodulation, filtering, and processing; as well as Control Capabilities Software Defined, Thus Upgradeable

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Software Defined Radios

Is this radio an SDR?

- Modulation: FM Only
- Change Controls? No
- Change Functions? Yes
- User programmable? Yes
- Software controlled? Yes

FlexRadio Systems
Software Defined Radios

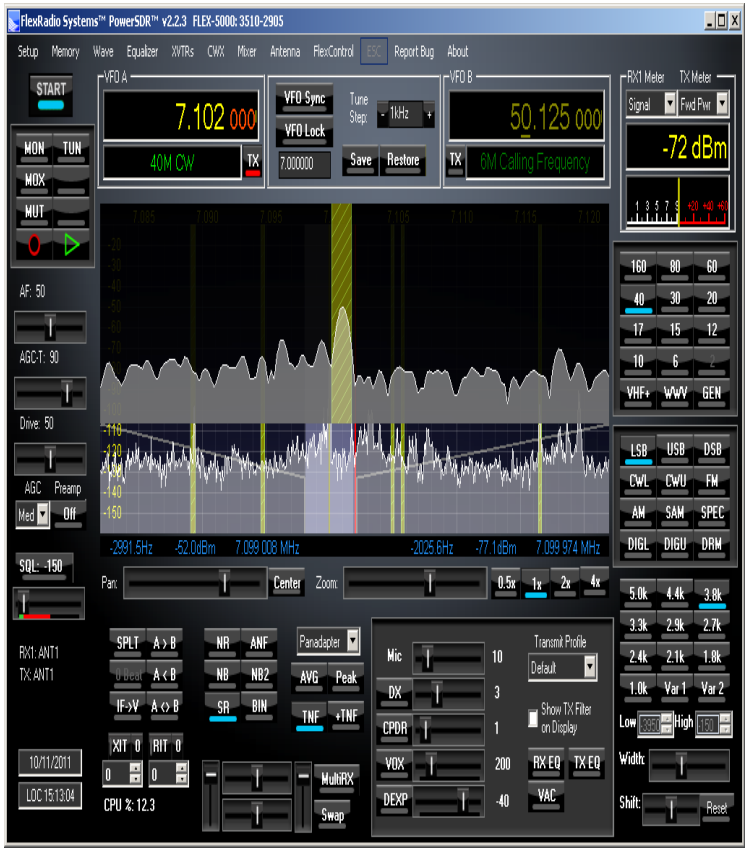
Is this radio an SDR?

- Modulation: Fixed set
- Change Controls? No
- Change Features? Theoretically…
- User programmable? No
- Software controlled? Yes

FlexRadio Systems
Software Defined Radios

Is this radio an SDR?

- Modulation: expandable
- Change Controls? Yes
- Change Features? Yes
- User programmable? Yes
- Software controlled? Yes



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What is *Software Defined*?

- Modulation using software, changeable YES
- Digital Signal Processing in software YES
- Control Surface Reconfigurable YES
- Can add new feature with new control YES
- Radio controlled by software YES

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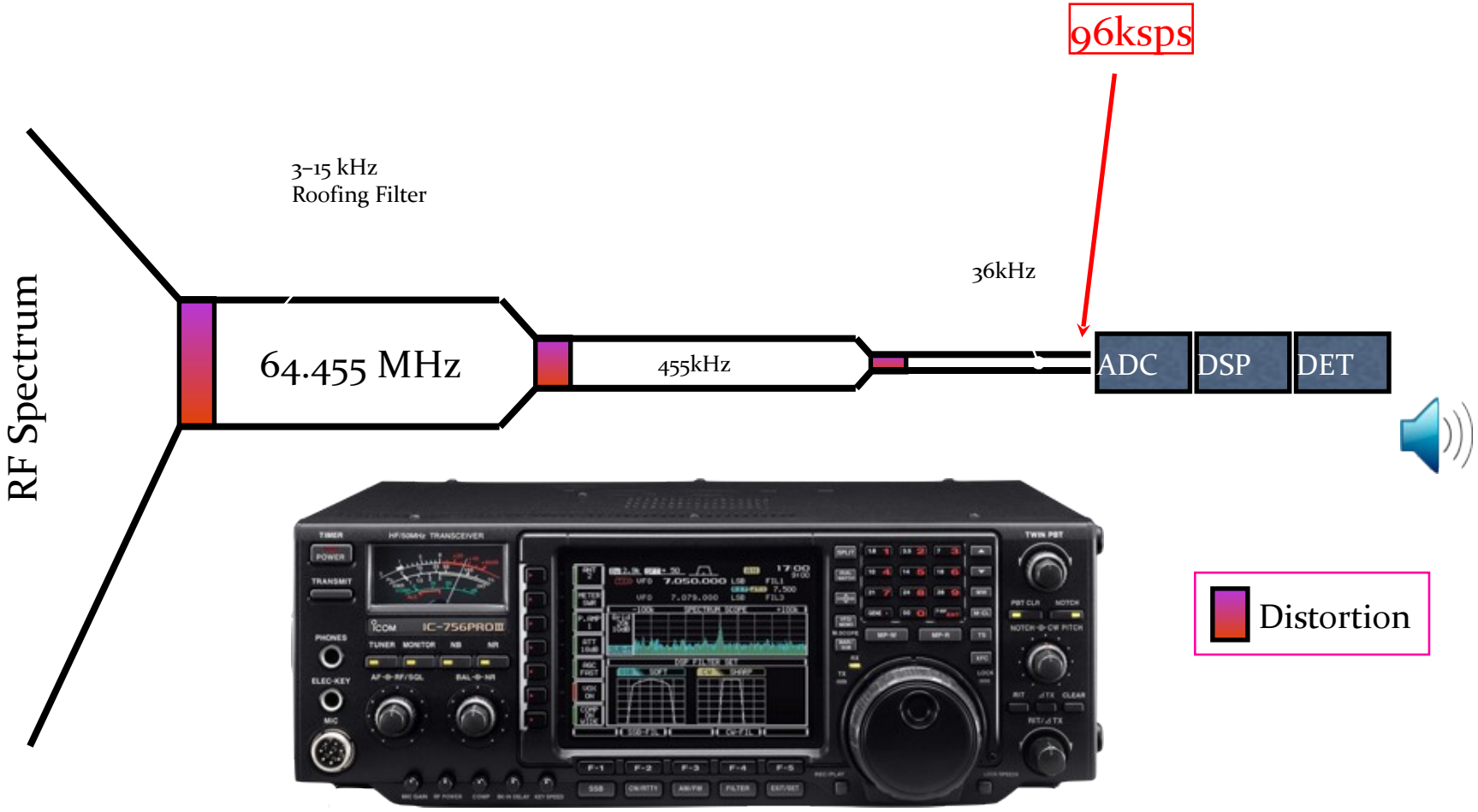
Radio RF/IF Architectures

- Multi-conversion a.k.a. superheterodyne
  - Your car radio, your TV, any older scanner you have
  - Most every Kenwood, Icom, Ten-Tec, Elecraft and Yaesu on the market today
- Direct Conversion
  - FLEX-5000, FLEX-3000, FLEX1500, Elecraft KX3
- Direct Sampling a.k.a wideband
  - FLEX-6000, HPSDR

Multi-Conversion



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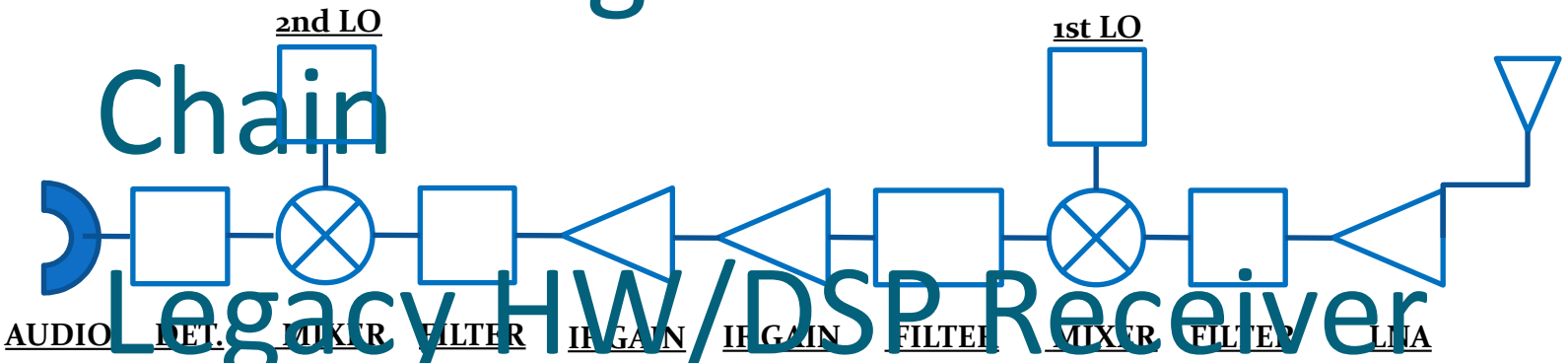
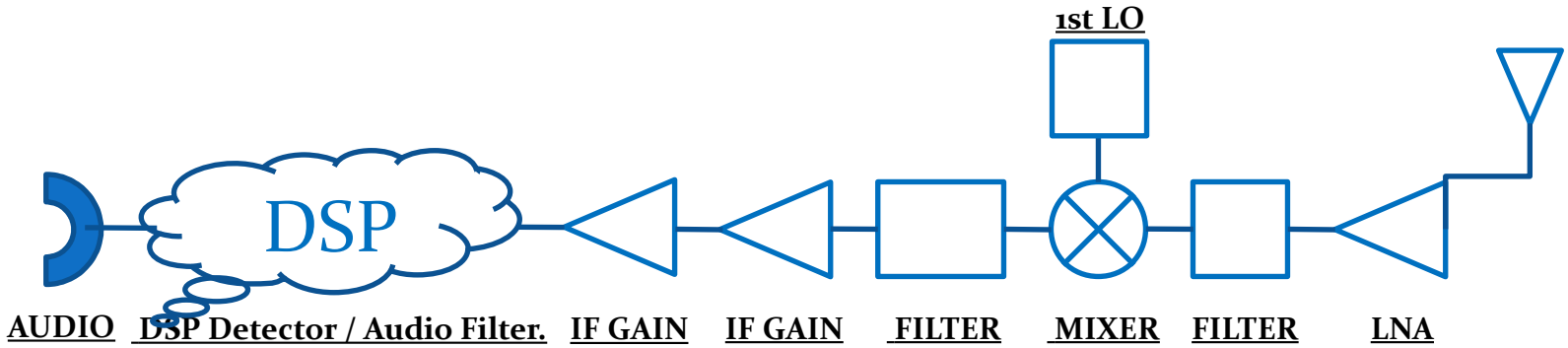
Multi-Stage HW Receiver Chain



Legacy HW/DSP Receiver Chain



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Multi-Conversion
The good and bad

- \+ Adjacent band signal rejection: operate in harsh signal conditions
- \+ Common, well-accepted design: works well
- – Only signals in the final IF can be tuned
- – Distortion introduced in each stage of filtering and mixing
- – Limited view of spectrum
- – For best filtering, requires expensive crystal filters (multiple)

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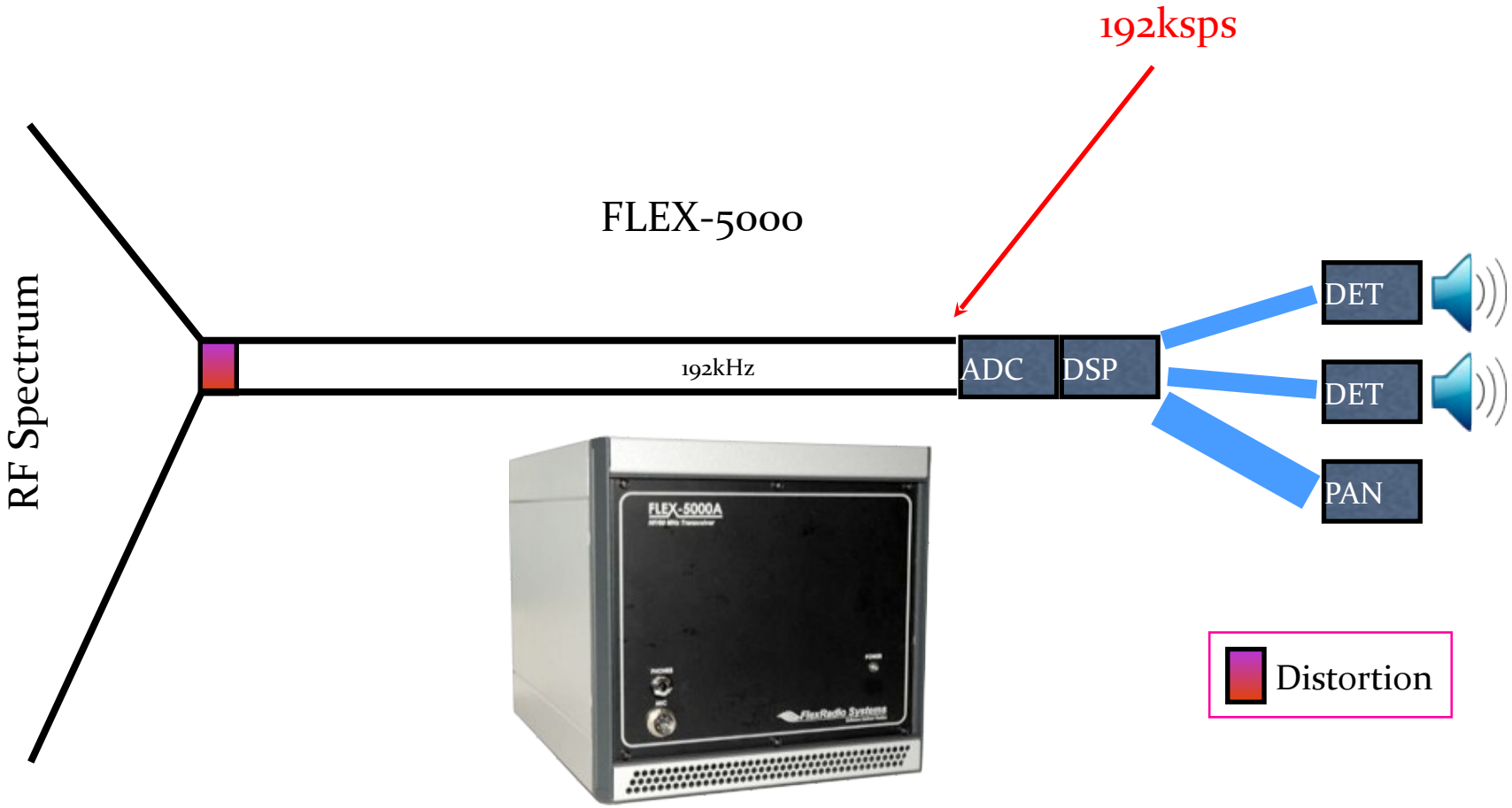
Direct Conversion



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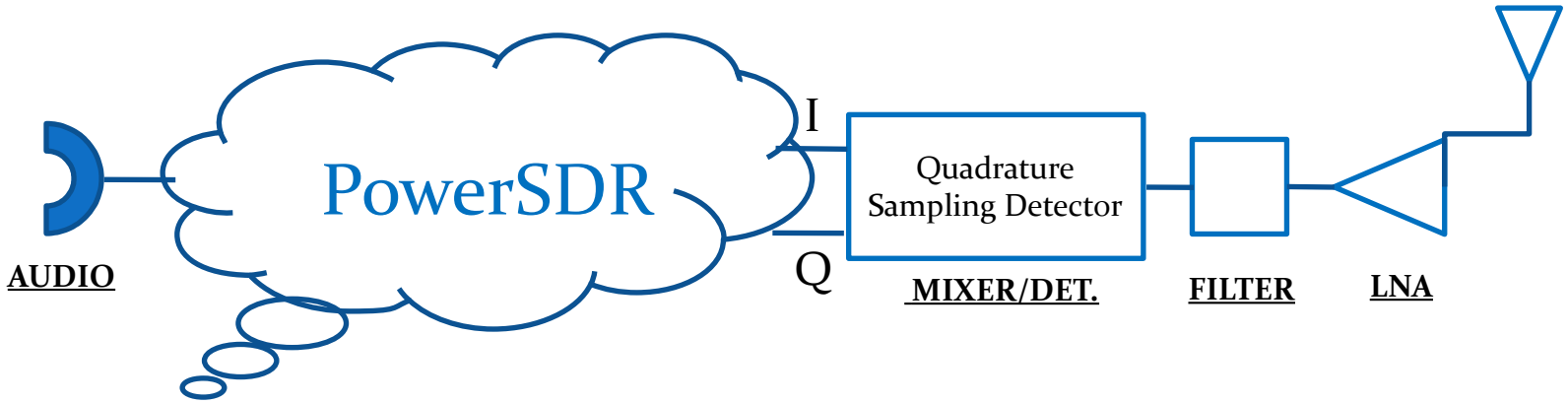
"QSD" Direct Conversion Chain



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Direct Conversion
The good and not-so-good

- \+ Distortion minimized with only one mixer: clear signal –– sounds better, less fatigue (less in-band distortion)
- \+ Can show 192kHz to our customers: wide panadapter view
- \+ Low power, high dynamic range: interference mitigation
- – Image rejection difficult (balanced IQ mixer, WBIR)
- – Better, but still limited view of spectrum

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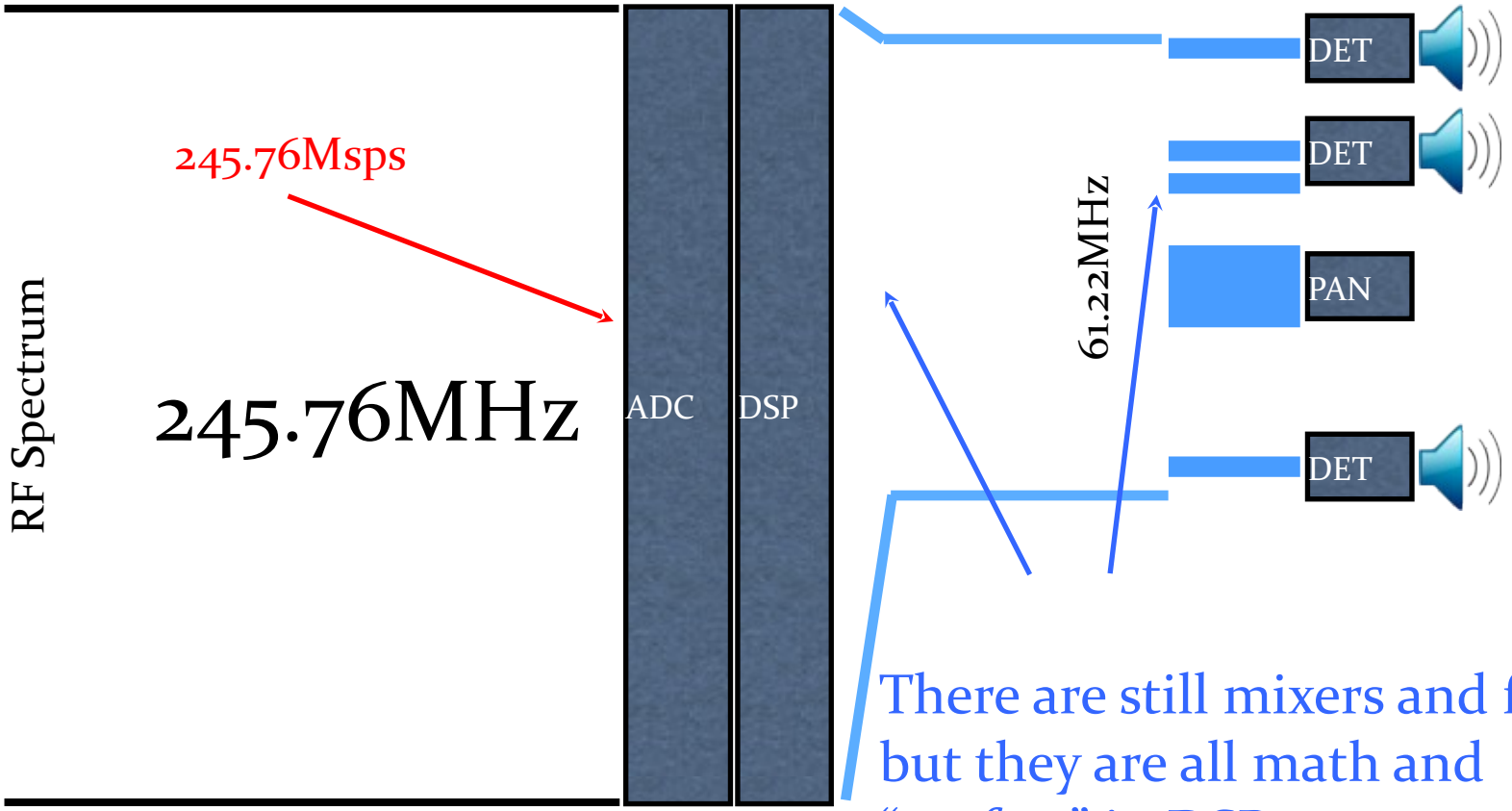
Direct Sampling

It's all good! FLEX-6000



There are still mixers and filters, but they are all math and "perfect" in DSP

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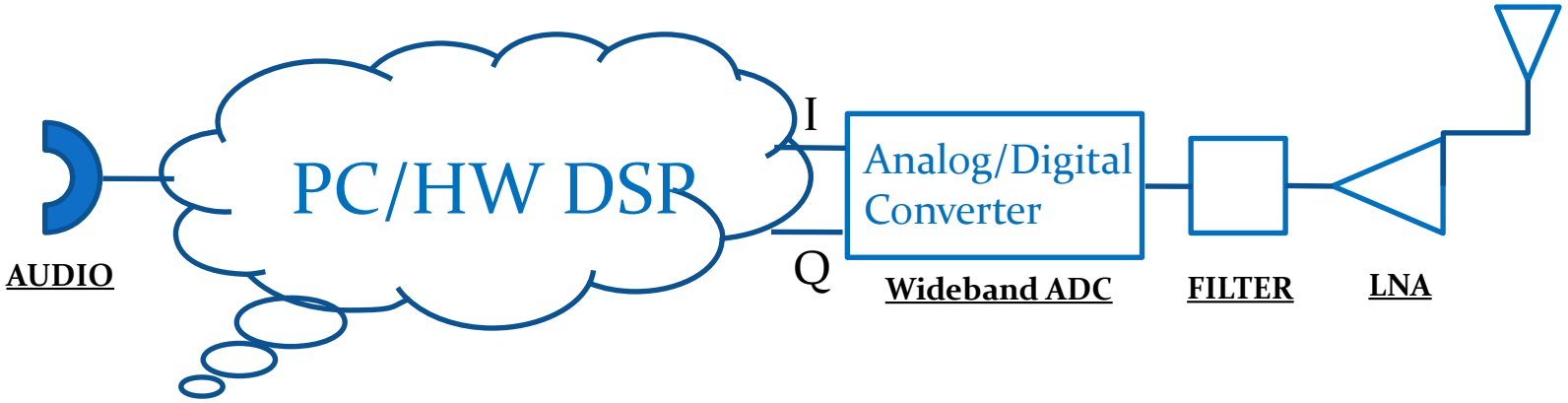
Direct Sampling Converter Chain



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Direct Sampling Benefits

- \+ Distortion minimized (ADC @ antenna): best signal clarity
- \+ n-Receivers, n-Panadapters and varying widths see more bands, more receivers
- \+ Extremely high dynamic range: operate in worst conditions
- \+ Extreme flexibility through reprogrammability (*ultimate* SDR): future benefits
- – Technically challenging to design

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What about that great SDR Filter Performance?

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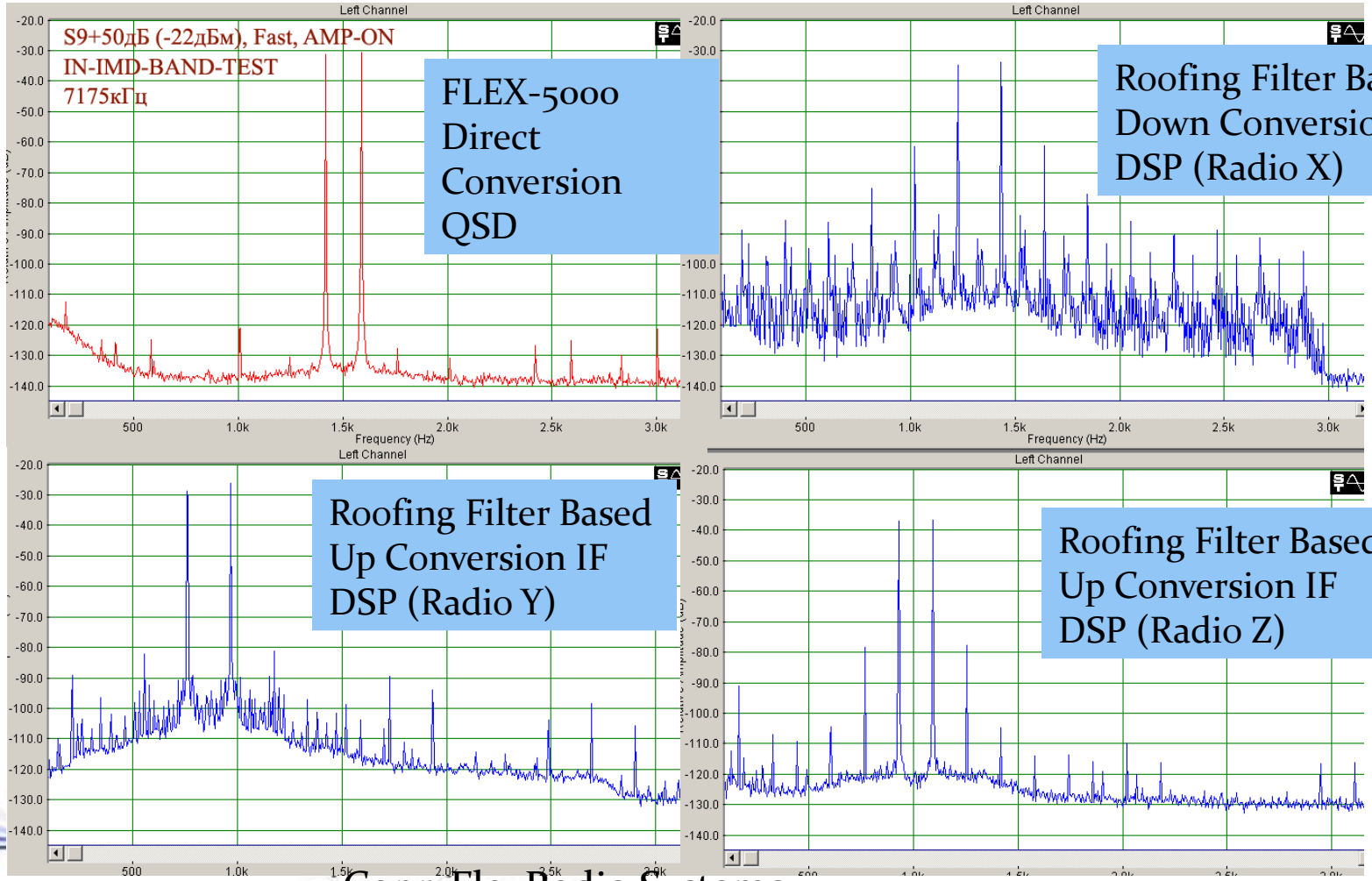
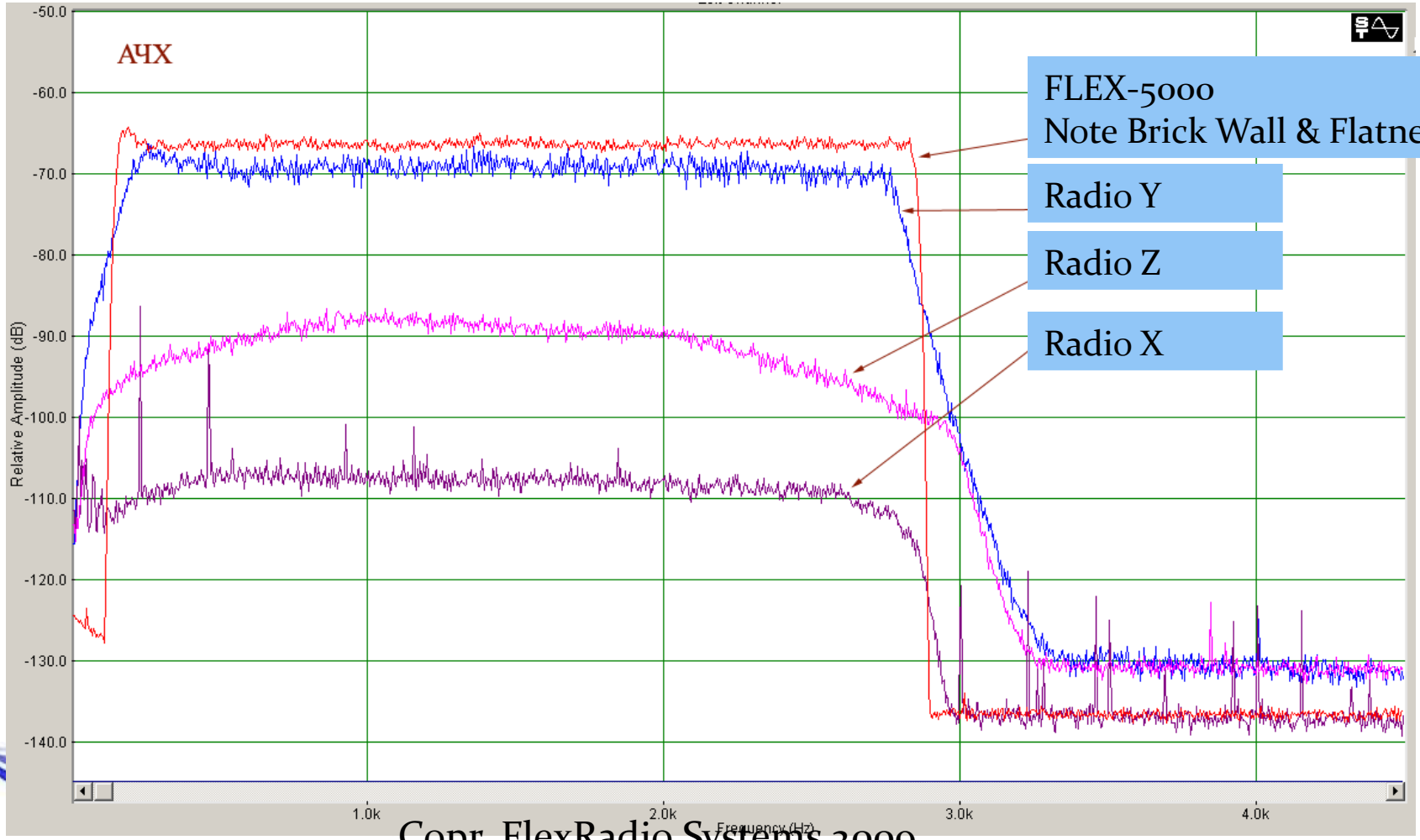
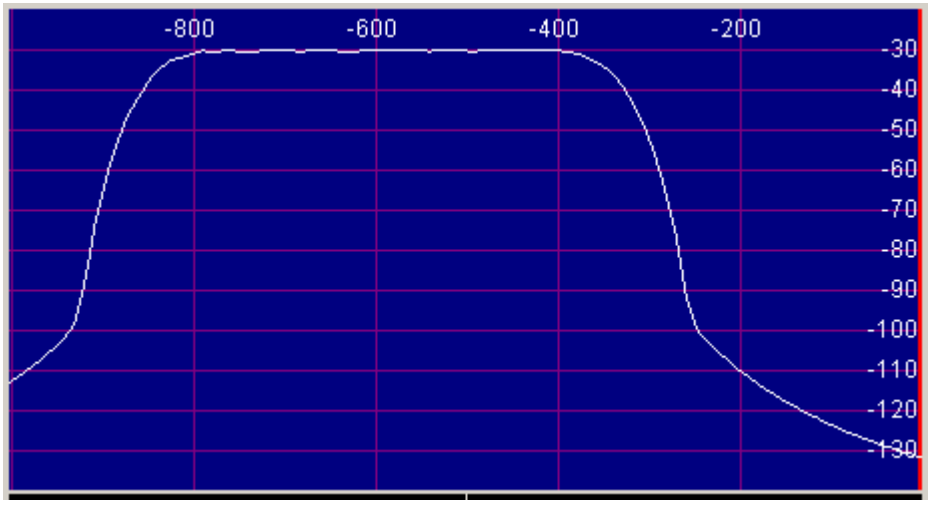
In-Band IMD Comparisons



Filter Shape Factor



500 Hz Brick Wall Filter



6dB Bandwidth 487 Hz, 60dB Bandwidth 660 Hz, Shape Factor ~1.35

4096 Bin FFT and 2048 Tap Filter

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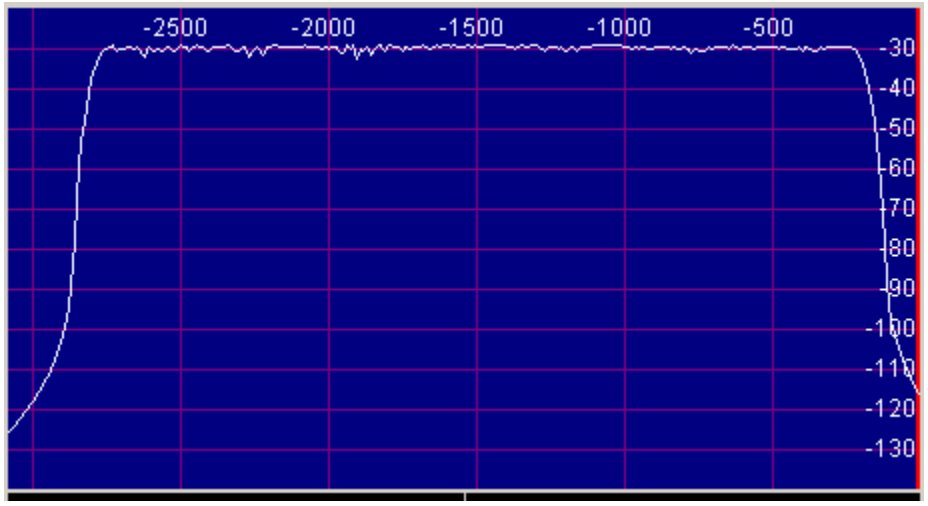
2.8KHz SSB Filter Spectrum



6dB Bandwidth 2587 Hz, 60dB Bandwidth 2756
Shape Factor ~1.06, 2048 Tap Filter

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A Little History…

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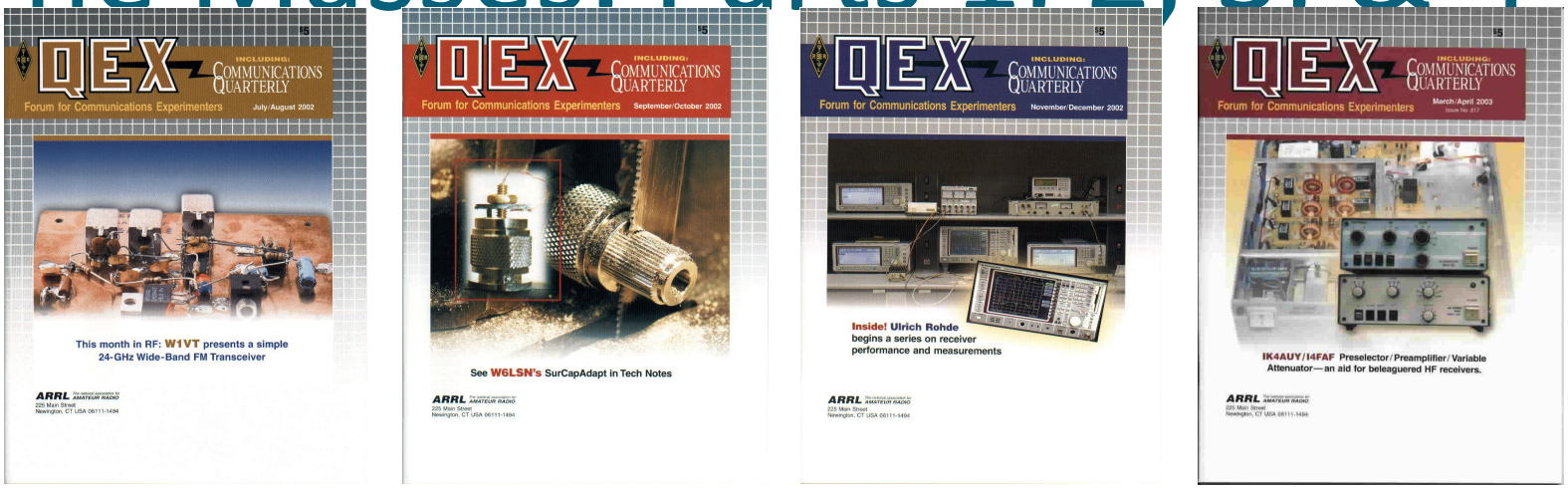
A Software Defined Radio For The Masses: Parts 1, 2, 3, & 4



By Gerald Youngblood, K5SDR (formerly AC5OG)

Reprints may be found at www.flex-radio.com

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SDR-1000 Evolution

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SoftRock RXTX Ensemble

Photo Credit: www.wb5rvz.com

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FLEX-5000A

- 160-6m
- 192 kHz Panadapter
- 99dB IMD DR3
- All Mode
- 100W transmitter
- Optional 2nd RX
- Optional ATU
- 0 dBm Transverter IF
- 10 MHz Ref. Input
- Firewire 1394 I/F
- 9" W x 11" D x 10" H

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FLEX-3000

- 160-6m
- 96 kHz Panadapter
- 93dB IMD DR3
- All Mode
- 100W continuous duty transmitter PA output
- Built-in Ant. Tuner
- Firewire 1394 Intf.
- Only 7 Pounds
- 12” W x 12” D x 2” H

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FLEX-1500

- 160-6m
- 48 kHz Panadapter
- 86dB IMD DR3
- All Mode
- 5W PEP & CW
- 0 dBm Transverter IF
- 10 MHz Ref. Input
- USB Interface
- Only 1.2 Pounds
- 4" W x 6" D x 2" H

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Genesis 59

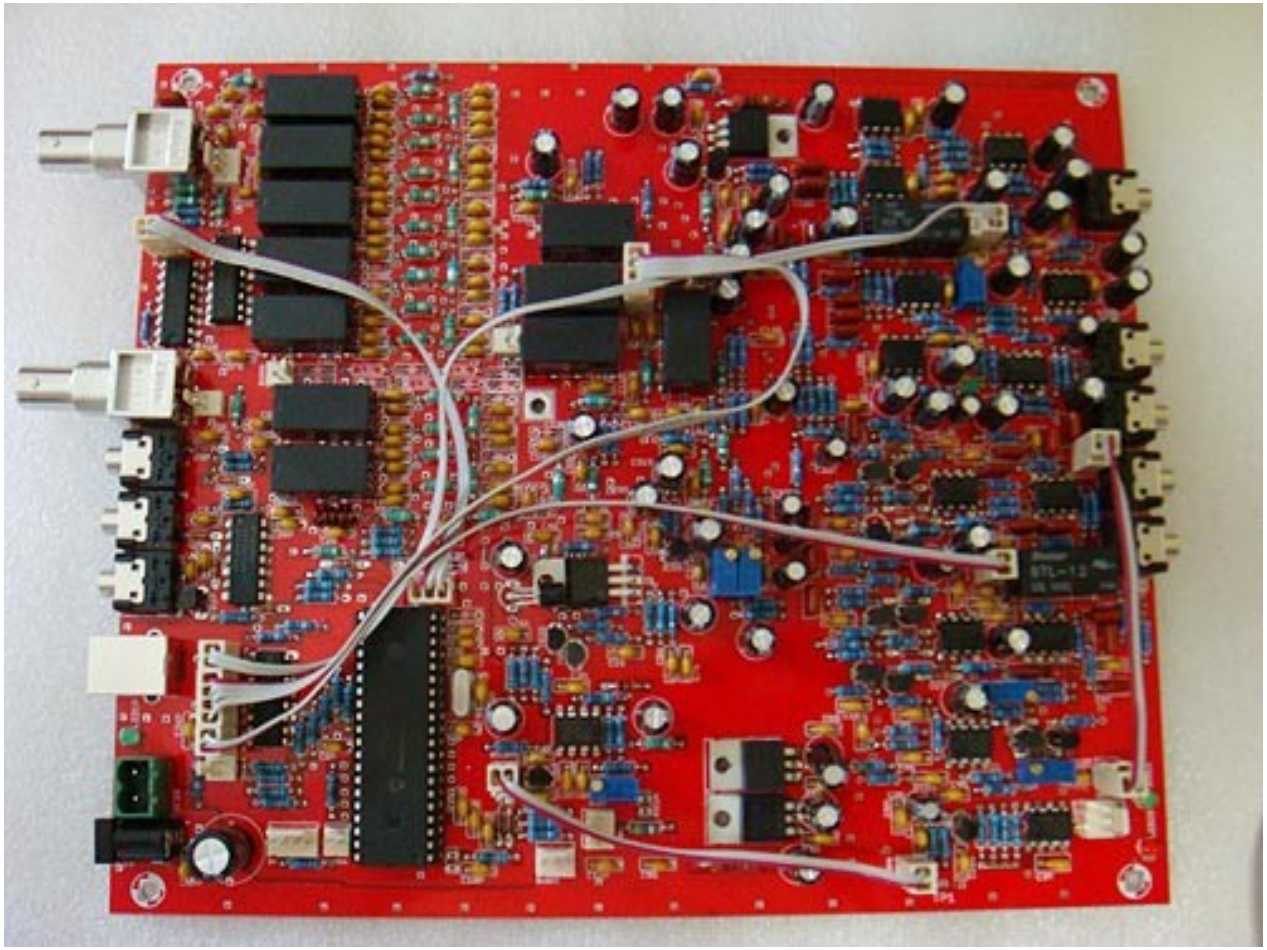

Photo Credit: Genesisradio.com.au

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CDRX-3200 32 Channel Synchronous Receiver

- 32 Fully Independent Receivers
- Patent Pending Technology
- Synchronous to GPS System
- 200 kHz Channels
- 100 kHz – 100 MHz Tuning
- IMD DR3: >105 dB @ 100 Hz
- Phase Noise: < -150 dBc/Hz
- GigE Streaming I/Q Data
- 7U Chassis, 100W Total

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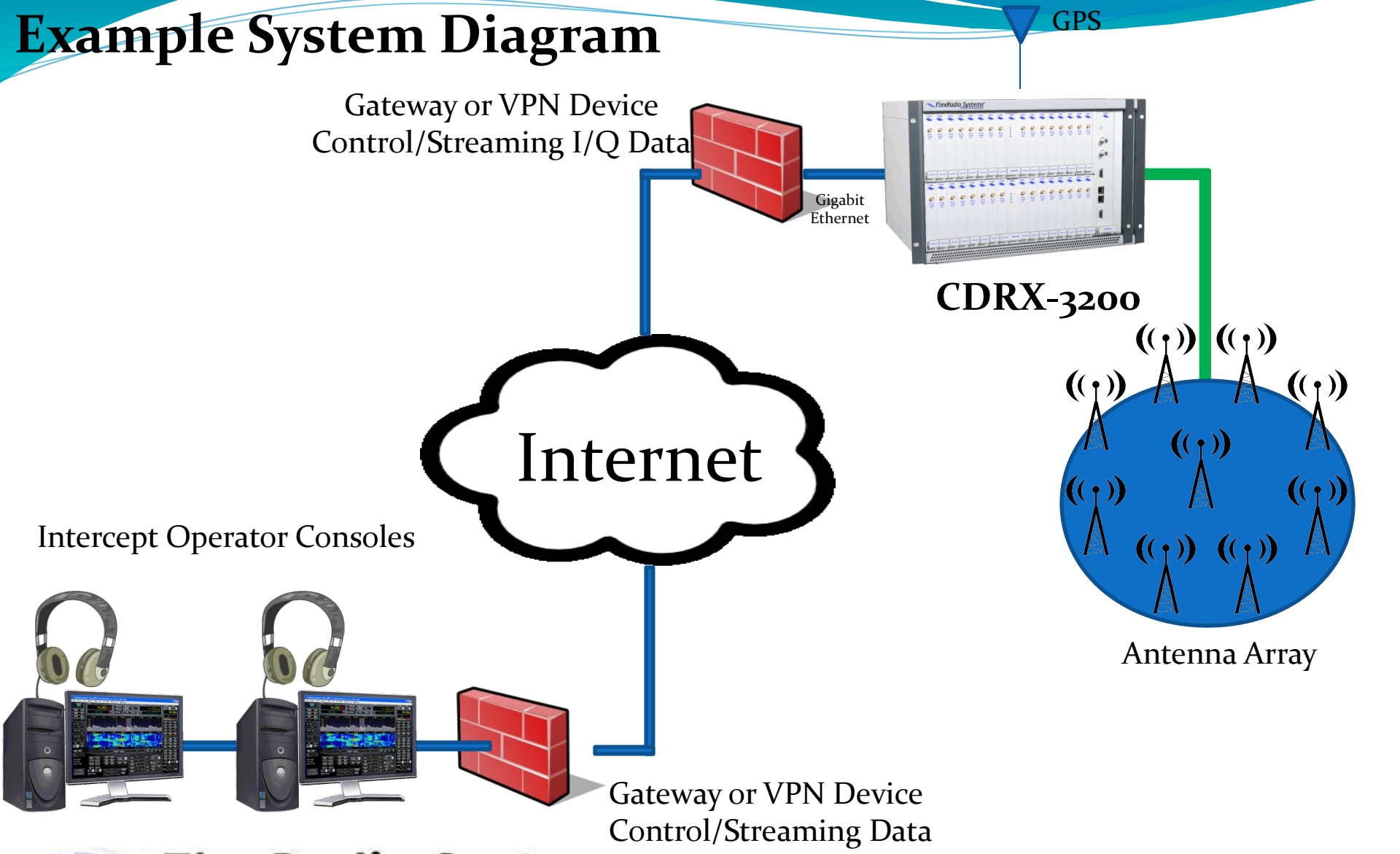
CDRX-3200 Intercept Operator Example System Diagram



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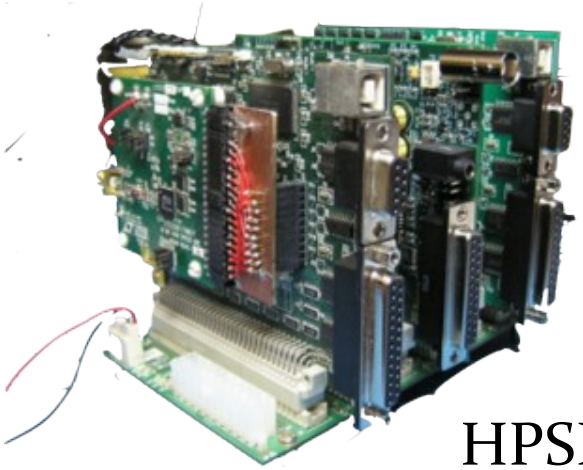
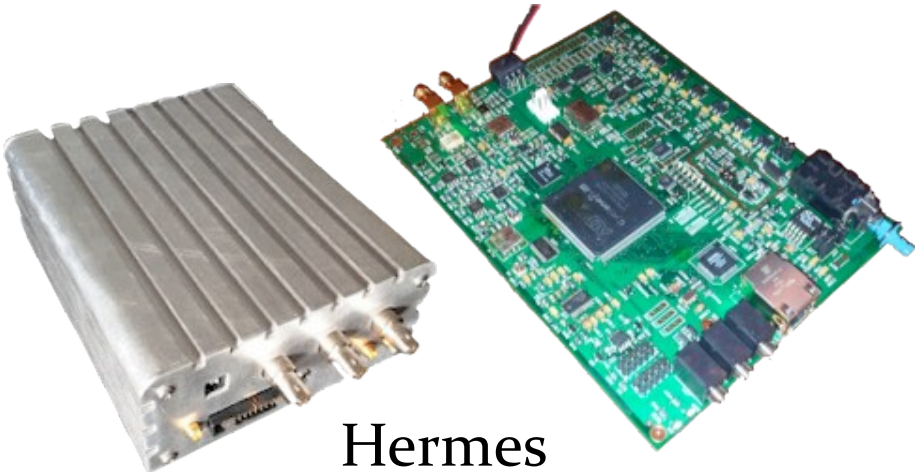
Direct Sampling Radios



HPSDR



Hermes

Perseus

GEN1

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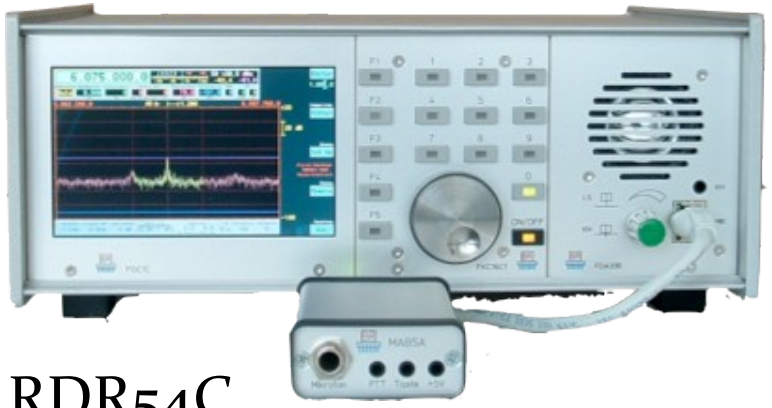
Direct Sampling Radios

RDR50B



RDR54C

Rueter Elektronik, Germany

GEN2

RF DSP CTRL

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Direct Sampling Radios

FLEX-6000

GEN3

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Introducing - FLEX-6000™ *Signature Series*

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FLEX-6000 Family Highlights

- Up to 8 full performance Slice receivers in one radio!
- >100dB 2-tone 3rdOrder Dynamic range
- IP3 > +40dB
- Unimaginable Digital Signal Processing Power
- Designed for Networked Operations
- New SmartSDR™ Technology and User Client Interface

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FLEX-6500 HF/6M Transceiver

- Up to 4 full performance Slice receivers in one radio!
- >100dB 2-tone 3rdOrder Dynamic range
- IP3 > +40dB
- 10KHz to 72MHz reception
- 100W PA with built in Antenna Tuner
- Ethernet Interface

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FLEX-6700 HF/6M Transceiver

- Up to 8 full performance Slice receivers in one radio!
- Dual Spectral Capture Units
  - Optimal Signal combining
  - Beam Steering, Null Forming, Diversity
- >100dB 2-tone 3rdOrder Dynamic range
- IP3 > +40dB
- 10KHz to 72MHz + 135 to 165MHz reception
- Low Power 144MHz output (+10dBm nom.)
- 100W PA with built in Antenna Tuner
- Ethernet Interface

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FLEX-6700R HF/6M/VHF Receiver

- Up to 8 full performance Slice receivers in one radio!
- Dual Spectral Capture Units
  - Optimal Signal combining
  - Beam Steering, Null Forming, Diversity
- >100dB 2-tone 3rdOrder Dynamic range
- IP3 > +40dB
- 10KHz to 72MHz + 135 to 165MHz reception
- Built in AC Power Supply
- Ethernet Interface

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FLEX-6000 Availability

- Early Pre-orders for the “Limited Edition” units will begin shipment Q4 2012
- General Availability Q1 2013

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Lineage of FLEX-6000

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Signal Processing

CRAY-1

- 1976
- $5,000,000
- 0.08 GFLOPS
- $62M / GFLOP

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Signal Processing

CRAY X1

- 2002
- $2.5M
- 205 GFLOPS
- $12,000 / GFLOP

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Amateur Radios

How Much Signal Processing Power is There?

BRAND A
Texas Instruments TMS320VC33

0.120 GFLOPS

BRAND B
Texas Instruments TMS320C6713

1.350 GFLOPS

0.450 GMAC

BRAND C
Texas Instruments TMS320C6713 x3 + TMS320C6711

4.950 GFLOPS

1.350 GMAC

BRAND B
Texas Instruments TMS320C6727B x2

4.2 GFLOPS

1.40 GMAC

FLEX-6500
Texas Instruments TMS320C6A8167 + XC6VLX75T

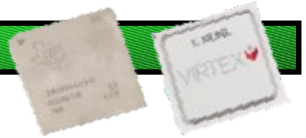
78 GFLOPS

191 GMAC

FLEX-6700
Texas Instruments TMS320C6A8167 + XC6VLX130T

121 GFLOPS

317 GMAC



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Signal Processing

FLEX-6700

- 2012
- $6,999
- 121 GFLOPS
- $57.84 / GFLOP

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Signal Processing: Why?

- Many panadapters at once
- Many receivers at once
- Demodulation / Decoding in the radio
- Many bands, One antenna
- Advanced DSP Functions, all in the radio

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FPGA:

Field Programmable Gate Array

- Massive DSP Power
- Can't build a Direct Sampling Receiver without one!
- >90% of the FLEX-6000 Power

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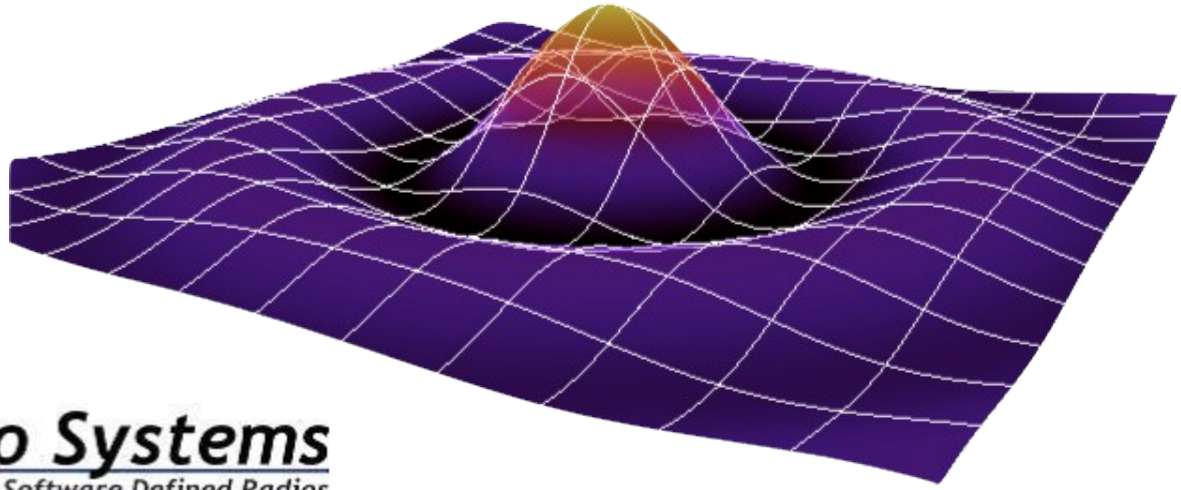
DSP 101

- GOAL #1: convert signals captured with an A-to-D Converter (ADC) to an audible signal
- GOAL #2: convert signals captured with the ADC to a visual representation of the panadapter
- TOOLS: Digital Filters, Fast Fourier Transform (FFT)



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DSP 101: Sampling

.
.
.
312
578
965
2230
4084
2130
875
632
298
.
.
.

245 Msps

For FLEX-6000, 245 *million* numbers per second

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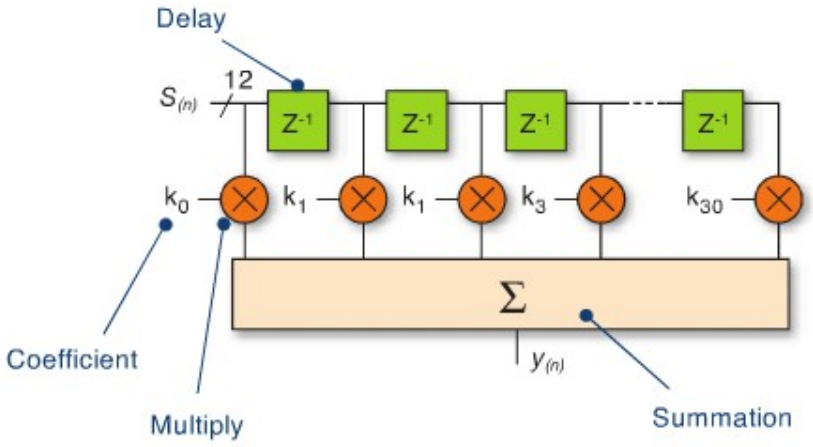
DSP 101: Filtering

Filtering, a key component of DSP, is used to separate signals from each other and clarify those signals



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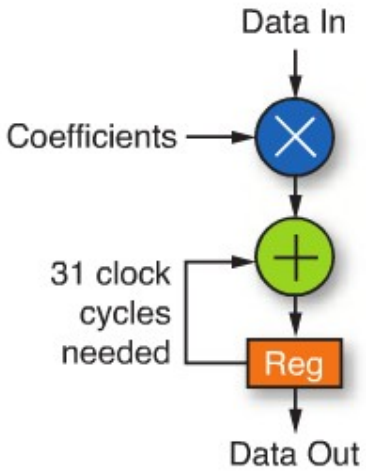
DSP 101: Filtering on a DSP




```
// Capture the sample
sample = input();

// Store in a buffer
buf[n] = sample;

//multiply by coefficients and accumulate
y = 0;
for (i = 0; i<N; i++)
{
      y += k[i] * S[(n + 1) % N];
}
n = (n+1) %N;

// Output filtered result
output(y);
```

A 1.0GHz DSP with a 31-tap filter can handle about 8.1Msps

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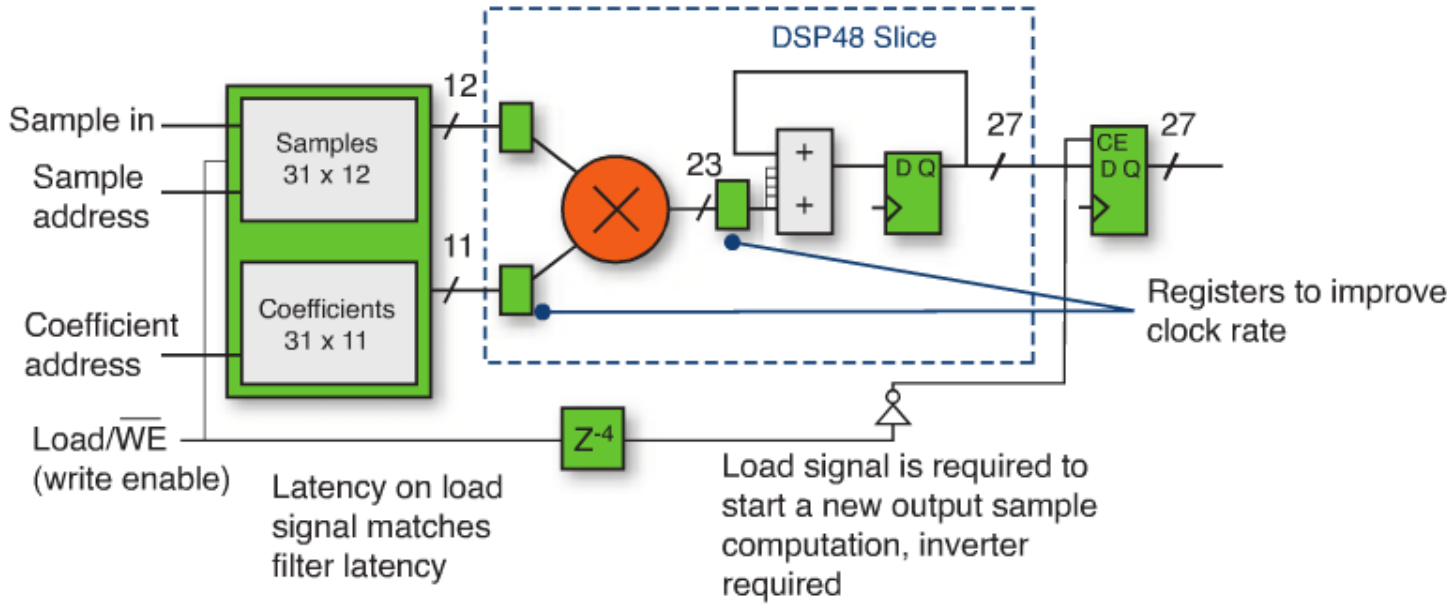
DSP 101: Filtering on an FPGA



A 600MHz FPGA with a 31-tap filter can handle about 19.3Msps

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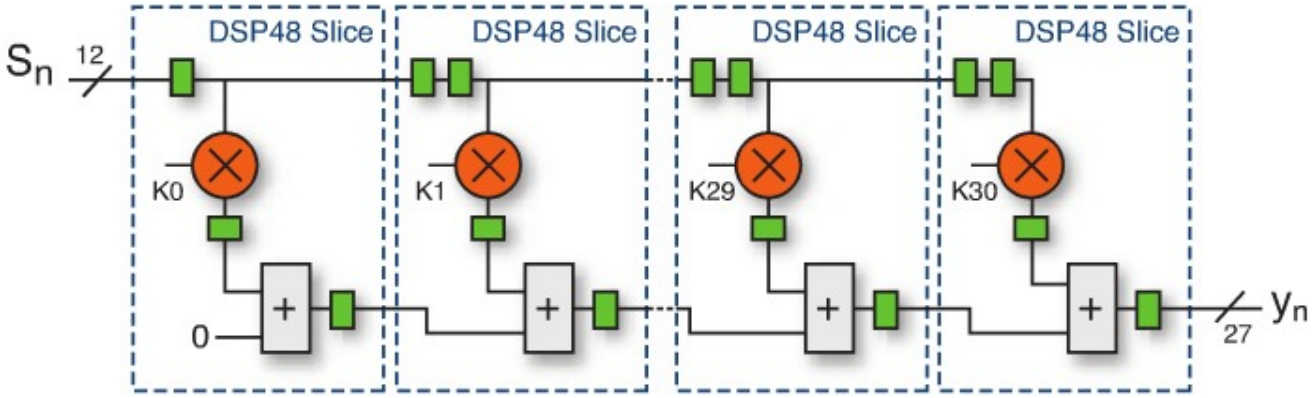
DSP 101: Filtering on an FPGA

Now, we use multiple "slices," one per tap



Now a 600MHz FPGA with a 31-tap filter can handle 600Msps

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All this horsepower is useful to accomplish the ULTIMATE goal:

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SIMPLICITY!

Simplicity is the Ultimate Sophistication

— Leonardo da Vinci

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C-130

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C-130

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Boeing 787

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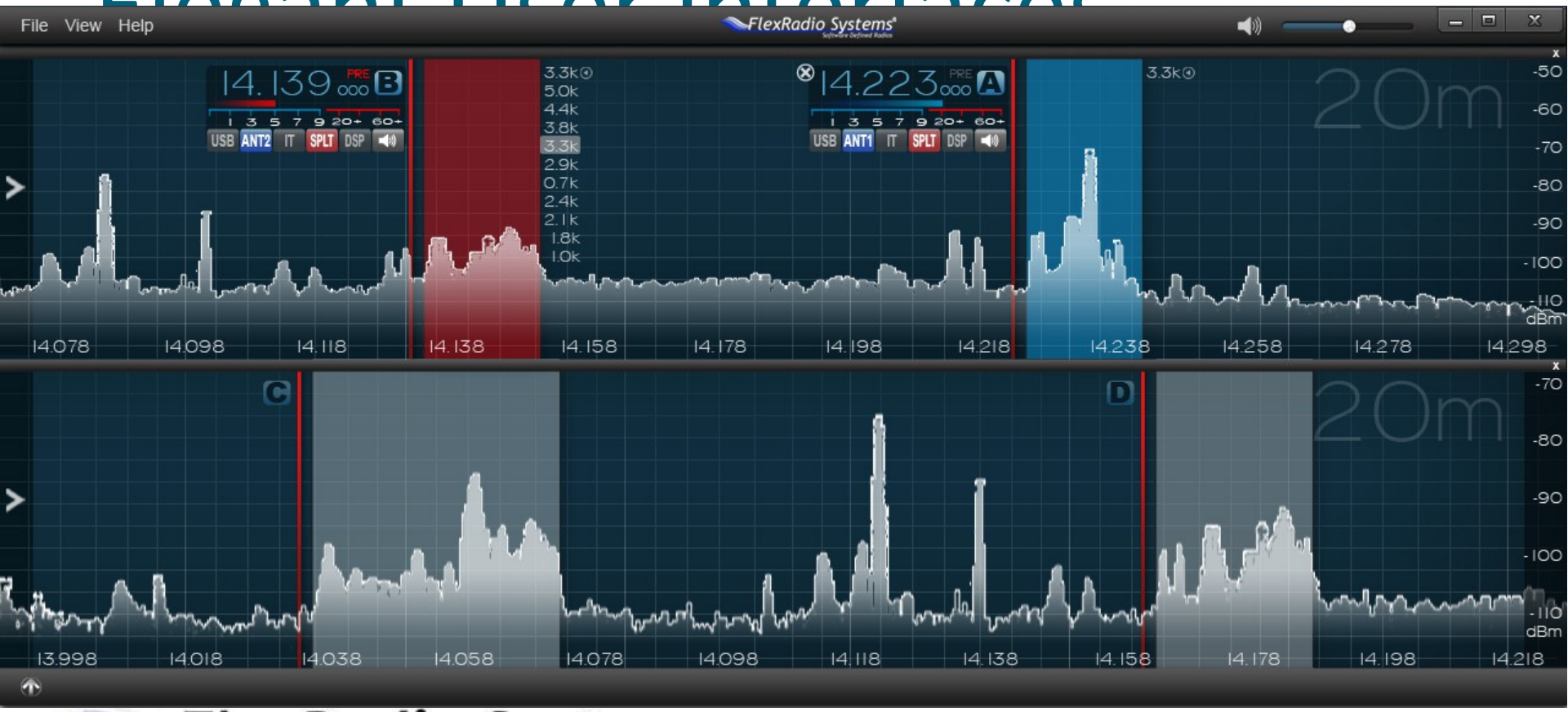
SmartSDR™

Elegant User Interfaces



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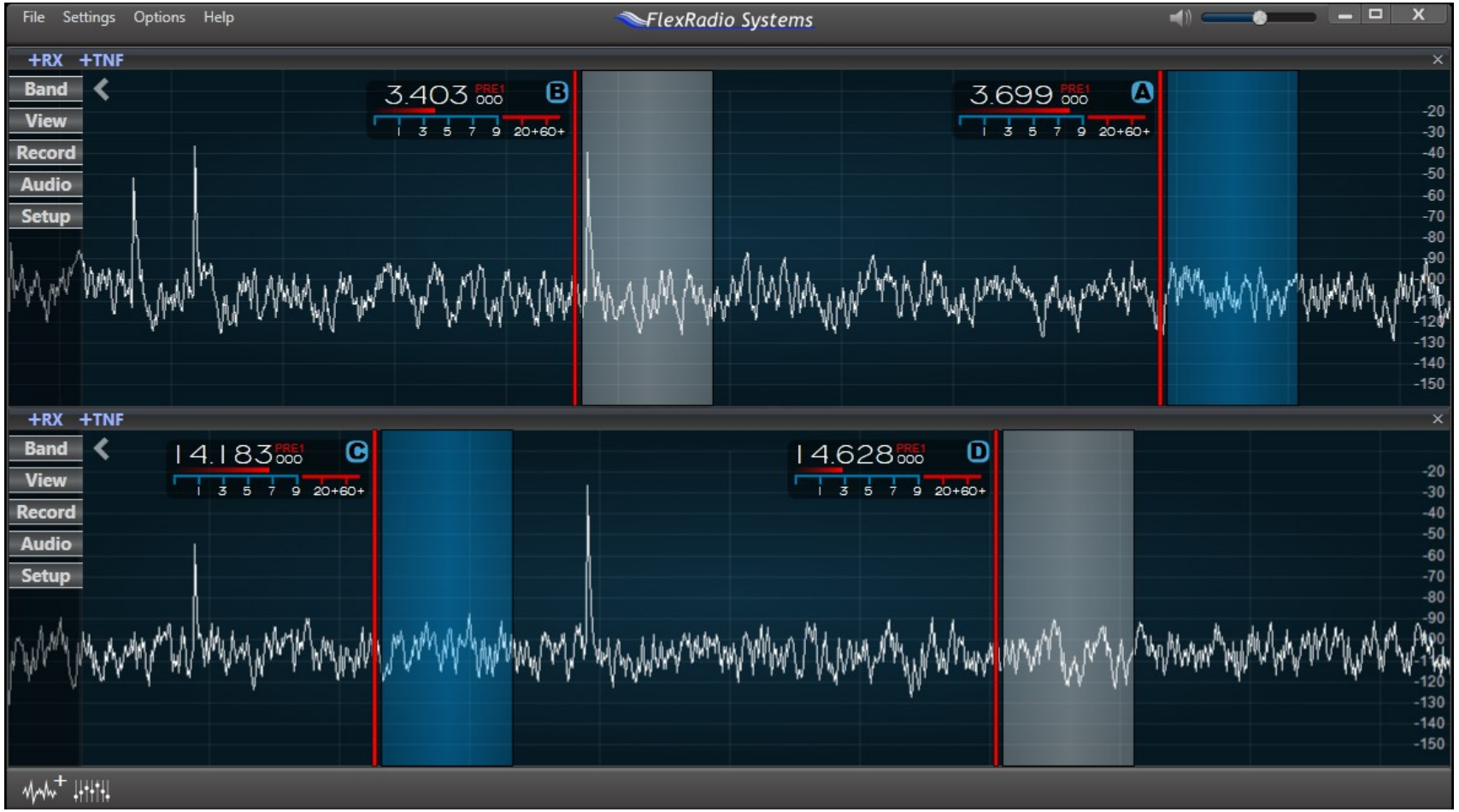
2 Panadapters and 4 RX Slices



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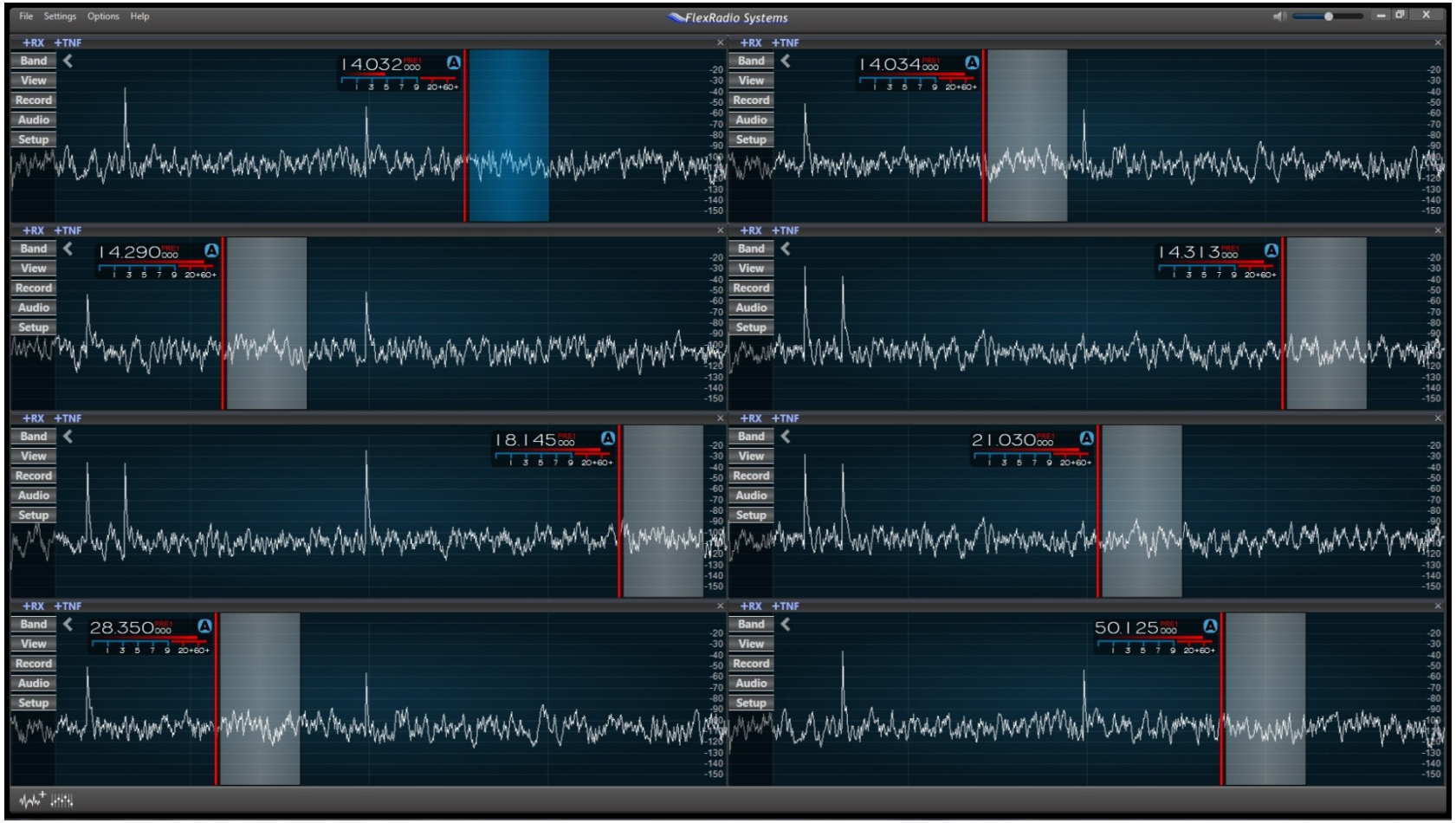
How About 8 Panadapters?!



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Possibilities —

What could you do with:

- Four, six, or eight receivers or panadapters
- The ability to directly decode and display digital modes
- Ethernet connectivity to talk to the world
- The ability to combine receivers in disparate locations
- The ability to transmit locally and listen to yourself remotely
- Access to remote databases on the Internet
- A radio appliance that can be connected via Ethernet to any computer

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RF Tracking Notch Filter™

New control

New display

New DSP
(inside)

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Software Upgradability

DSP software
- Receivers
- Panadapters
- Digital modes
- ...dream

- Control Software
- remote capabilities
- radio server

FLEX-6000

GUI Interfaces
- Amateur AppSpec
- Amateur Fun
- Public Safety
- Military
- SIGINT

- Applications
- Research
- Education
- SIGINT
- Ionosonde
- New Amateur

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Is PowerSDR still being enhanced?

YES!!!

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PowerSDR Today – V2.x

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PowerSDR Development

- PowerSDR v2.3.5 in production
  - Tracking Notch Filters
  - New Profile management
- V2.4 in final Beta Testing
  - New Firewire Driver
  - New Installer
  - Lower Latency in DSP Chain
- V2.5 already in development
  - Stay tuned…..

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QUESTIONS?

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