* Modern Radio's SDR-101

Howard White PhD, P.Eng. KY6LA

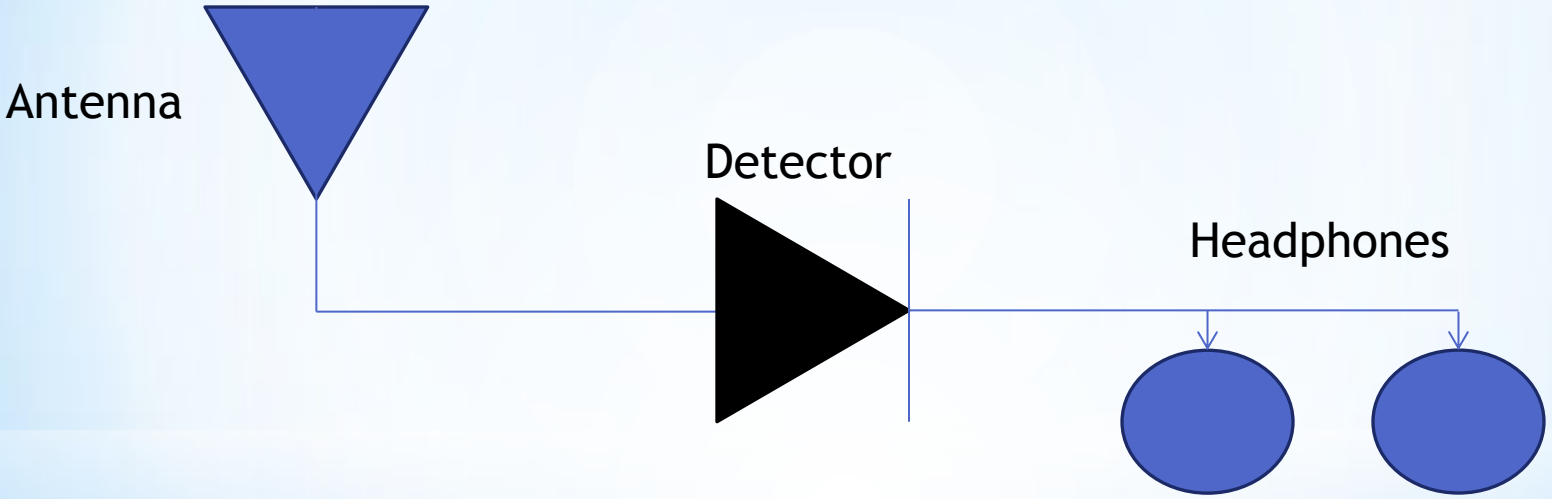
Official Flex Radio Systems Elmer (Unpaid)

*Topics

- *History of Ham Radios
- *6 Radio Architectures
- *What is an SDR?
- *How SDR's Work
- *How SDR's Benefits YOU?
- *Remote Operations Demo

*This is an SDR Without Knobs

* 1901 Antenna + Detector - Marconi



* 1901-Architecture #1

* Hear the entire spectrum (Like Modern Radios)
* But Only One Signal to hear (Unlike Now)

1894 Coherer

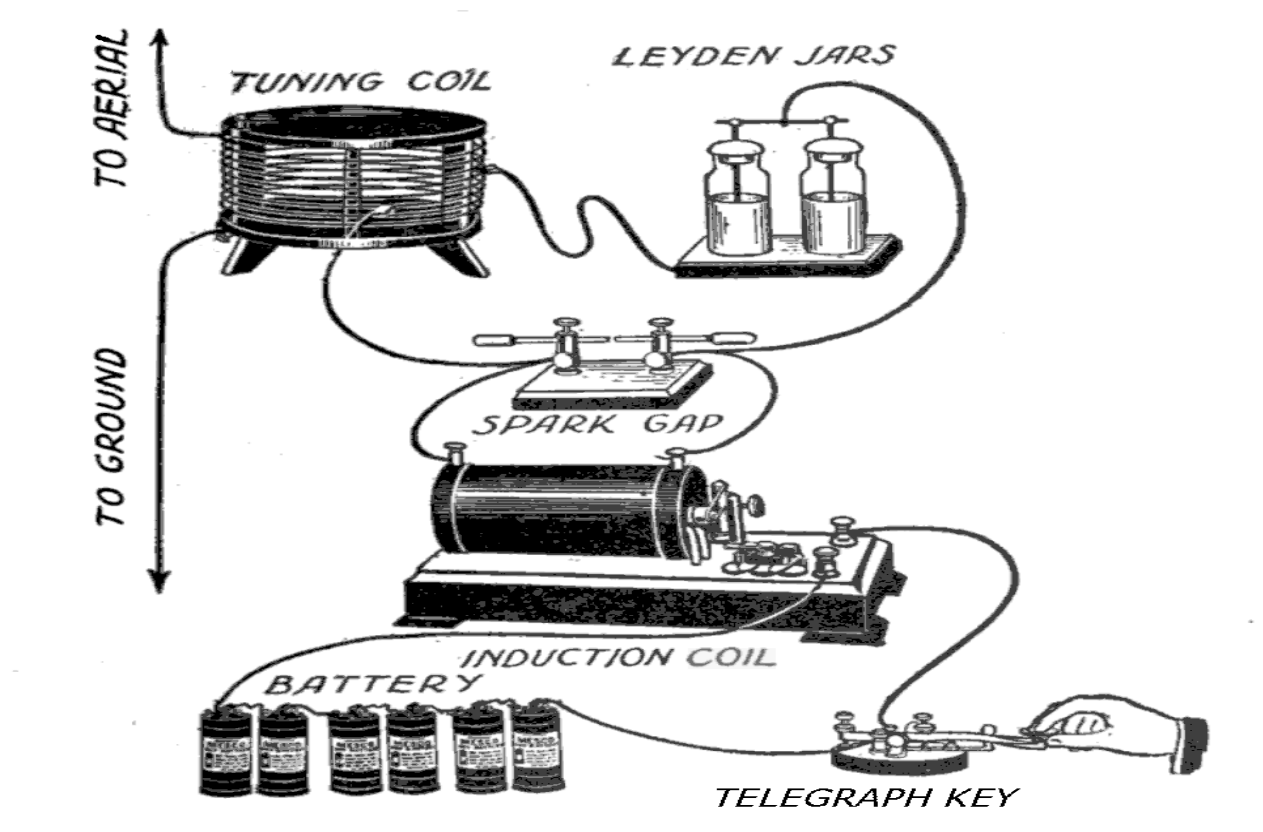
1902 Magnetic Detector

First Radio With a Knob

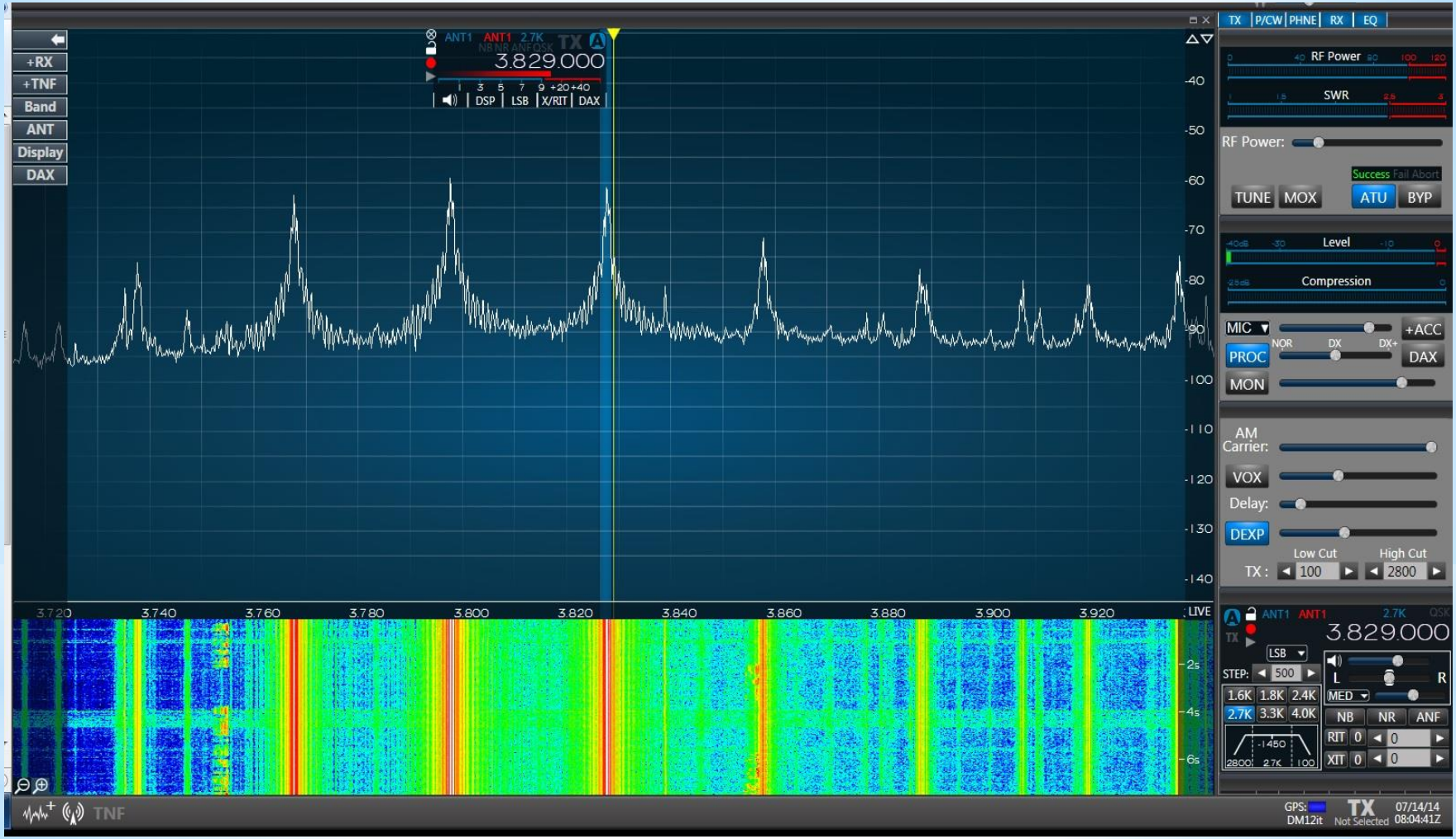
1906 Cat Whisker

* 1901-Architecture #1

* Spark Gap Transmitter



* Transmitters

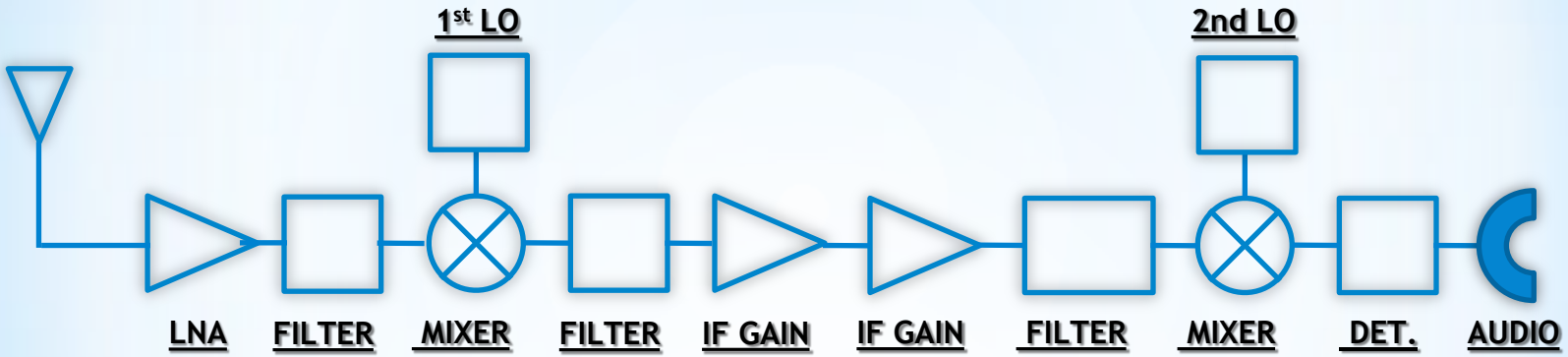


*Spark Gap Noise

1901 - Simple Detector

- The Good
  - Great Signal To Noise Ratio (Better than Superhet)
  - Heard The Entire Spectrum
- The Bad
  - Poor Selectivity
  - Unable To Separate Stations
  - Heard All The Images

Multi-Stage HW Receiver Chain - 1928



*Circa 1928 – Architecture #2 Superhetrodyne

*1928 -Legacy

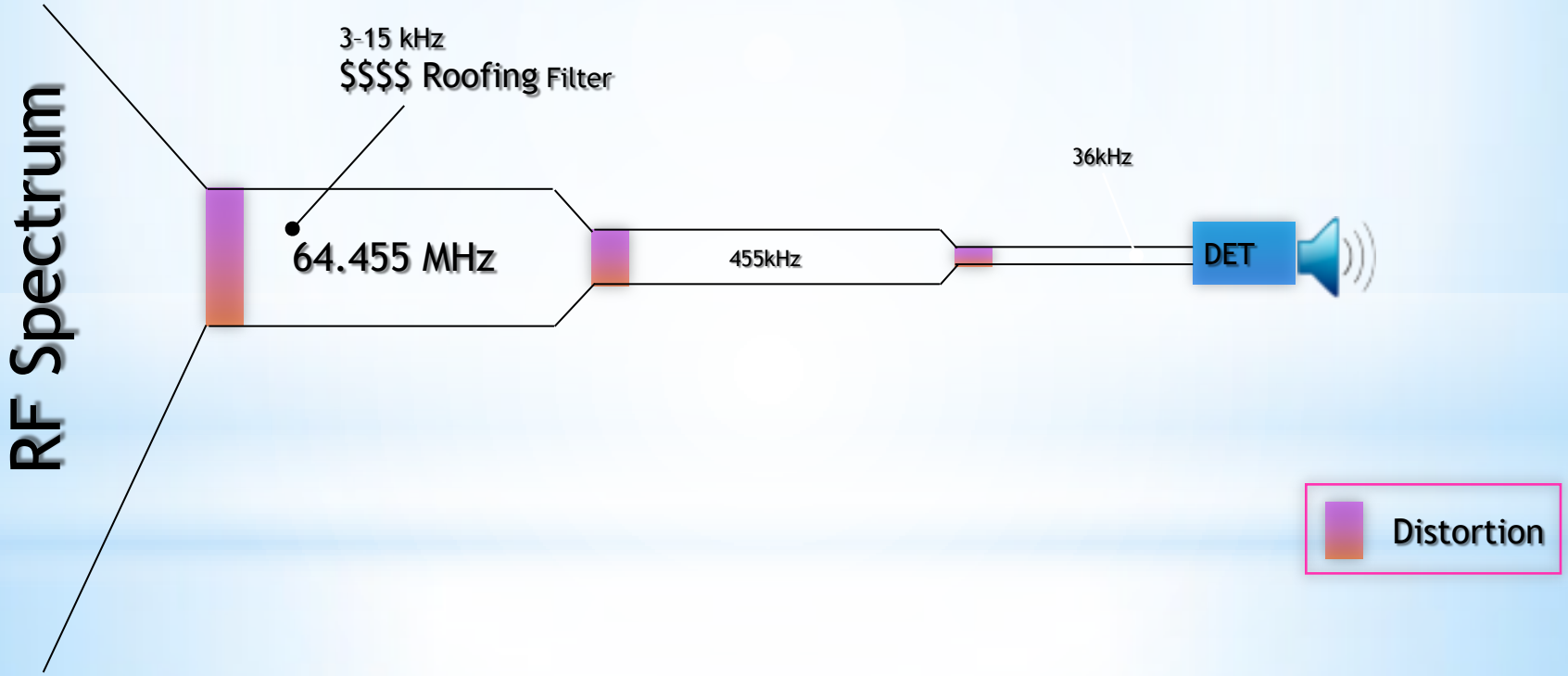
* Multi-conversion a.k.a. Superhetrodyne

* Legacy Technology

  * Your OLD car radio, your OLD TV,
  * Any older scanner you have
  * Most every Hilberling, Kenwood, Icom, Ten-Tec, Elecraft and Yaesu on the market today

Multi-Conversion

All Analog Domain



1928-1957 Era

* WW2 - USA Using CW + AM
* USA Ham Radio Lead The World With Major Manufacturers Such As
  * **Collins,**
  * **Hallicrafters,**
  * **Heathkit,**
  * **Swan,**
  * **Drake,**
  * **Gonset**

* Major Shock to US Technological Pride

* 1957 - Sputnik

*1968 Disaster Struck Ham Radio

*PROVING

*There Is Nothing That A Government Can't Make

Worse!

1968 Reaction To Sputnik

* FCC Decided USA Needed More Technically Competent Hams
* Introduced Incentive Licensing
* FCC Decided USA Needed To Be Ready To fight WW2 Again
* So CW Speeds were Increased
* **Of Course, The Opposite Happened**

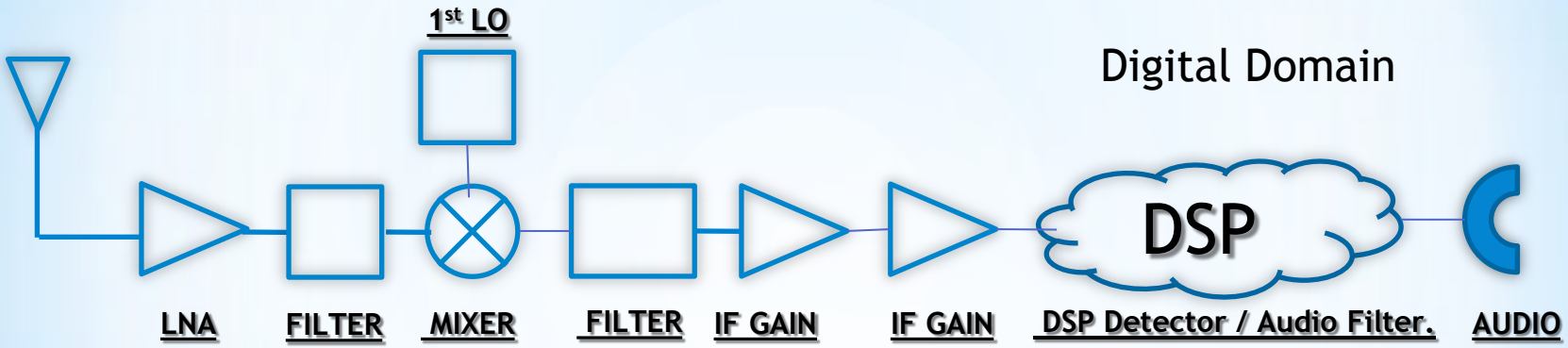
* Numbers Of Hams Plunged
* Bright Young Engineers No Longer Became Hams
* USA Ham Radio Innovation Stagnated
* All USA Ham Manufacturers Failed And/or Went Out Of The Ham Radio Business

* Unintended Consequences

Circa-1973 Japan

* Japan Learned The Lesson Of WW2
* Breaking CW Codes Cost Them The War
* Dropped CW As An Impediment For Ham Licenses
* Numbers Soared - Over 1,000,000 New Japanese Hams
* Bright Young Japanese Engineers Became Hams
* Icom Yaesu And Kenwood Became the Dominant Ham Manufacturers Worldwide
* No New Technology But Improved On The 1928 Superheterodyne at Much Better Prices

Legacy HW/DSP Receiver Chain - 1980



* US Digital Signal Processing Chips
* Convert to Digital Domain To Become Detectors And Improve Audio And Noise Characteristics
* Japanese Radios Continued To Dominate

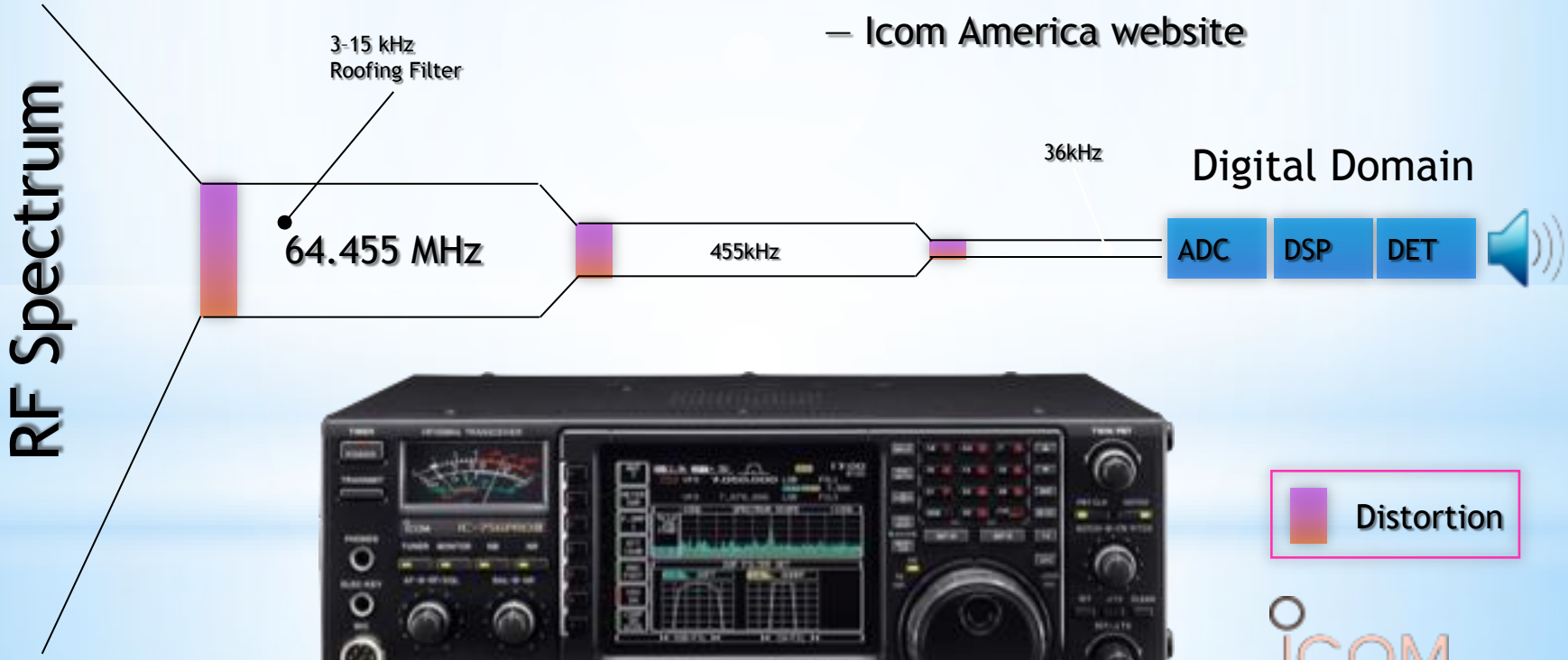
* 1980 - Architecture #3

Multi-Conversion

On the IC-7600:

"When compared to a typical triple-conversion system, the double conversion system is more difficult to implement but it dramatically reduces signal distortion and provides a high-fidelity RF signal to the DSP processor."

— Icom America website



* Legacy Radios add:
  * Distortion to the received signals (Harder to Hear)
  * 5 to 15 dBm of Crud to the received signals (Harder to hear)
  * Or 1 -2 S Units of Noise+Distortion to the received signals
  * Worse Audio Signal to Noise Ratios Compared to Architecture #1

* Architecture #3 Legacy Receivers

+ Adjacent band signal rejection: operate in harsh signal conditions
+ Common, well-accepted old design: works well

- Distortion introduced in each stage of filtering and mixing
- Noise (CRUD) amplified at each stage
- Only signals in the final IF can be tuned
- Limited view of spectrum
- For best filtering, requires expensive crystal filters (multiple)

*Architecture #3 Multi-Conversion The good and bad

*1999 Reprieve

- *CW Speed Reduced To 5wpm
- *CW Eliminated For Techs
- *American Ham Radio Numbers Started To Increase
- *Bright Young USA Engineers Started To Become Hams
- *New USA Ham Radio Manufacturers Started To Re-appear

*Legacy Limits

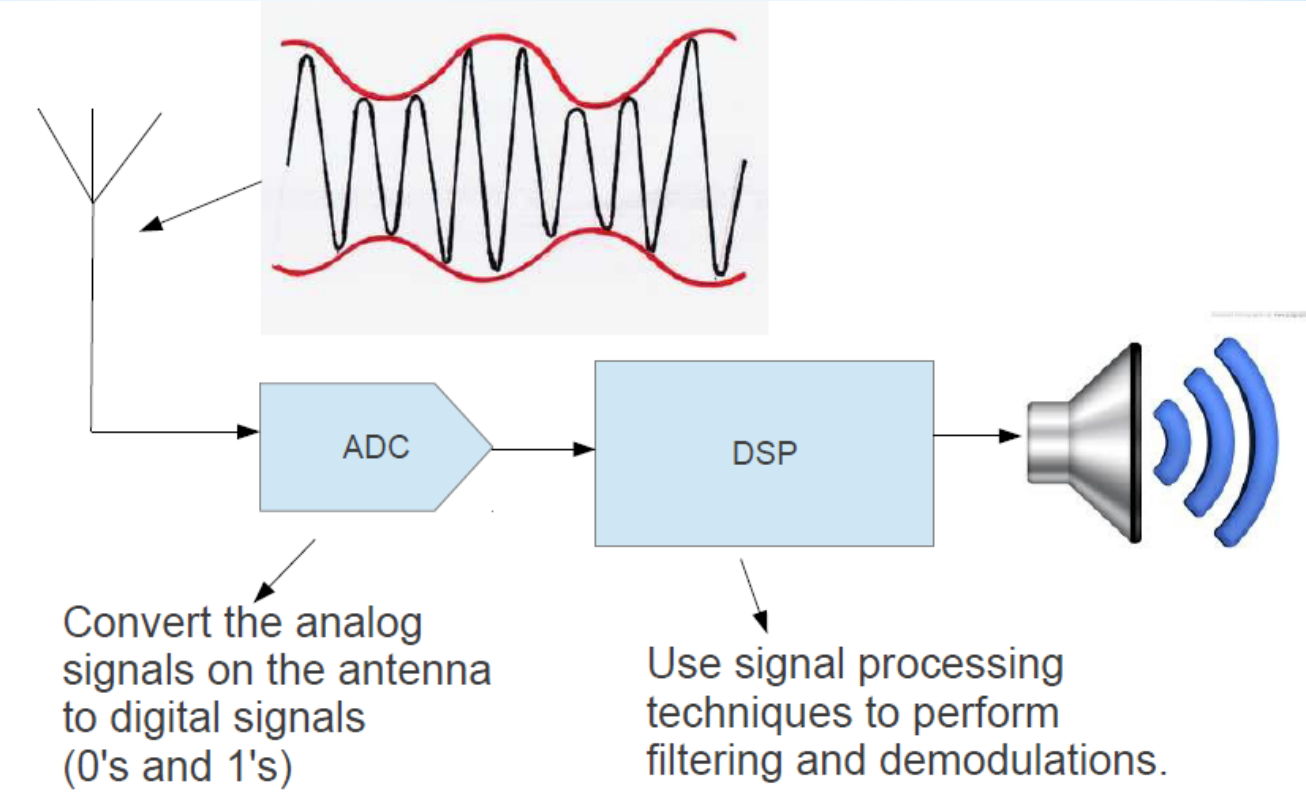
* Legacy Analog Technology had reached its practical limits
* Expensive Filters to Improve Selectivity
* Expensive Technology to Improve Dynamic Range
* Each Stage increased internal noise
* Each Stage increased internal distortion
* Harder to Hear More Due to Internal Noise and Distortion
* Miniscule Visual Displays
* Lots of $$$$$ for a minor improvement

A Lot Of Money For A Little Bit Better Hilberling PT-8000A

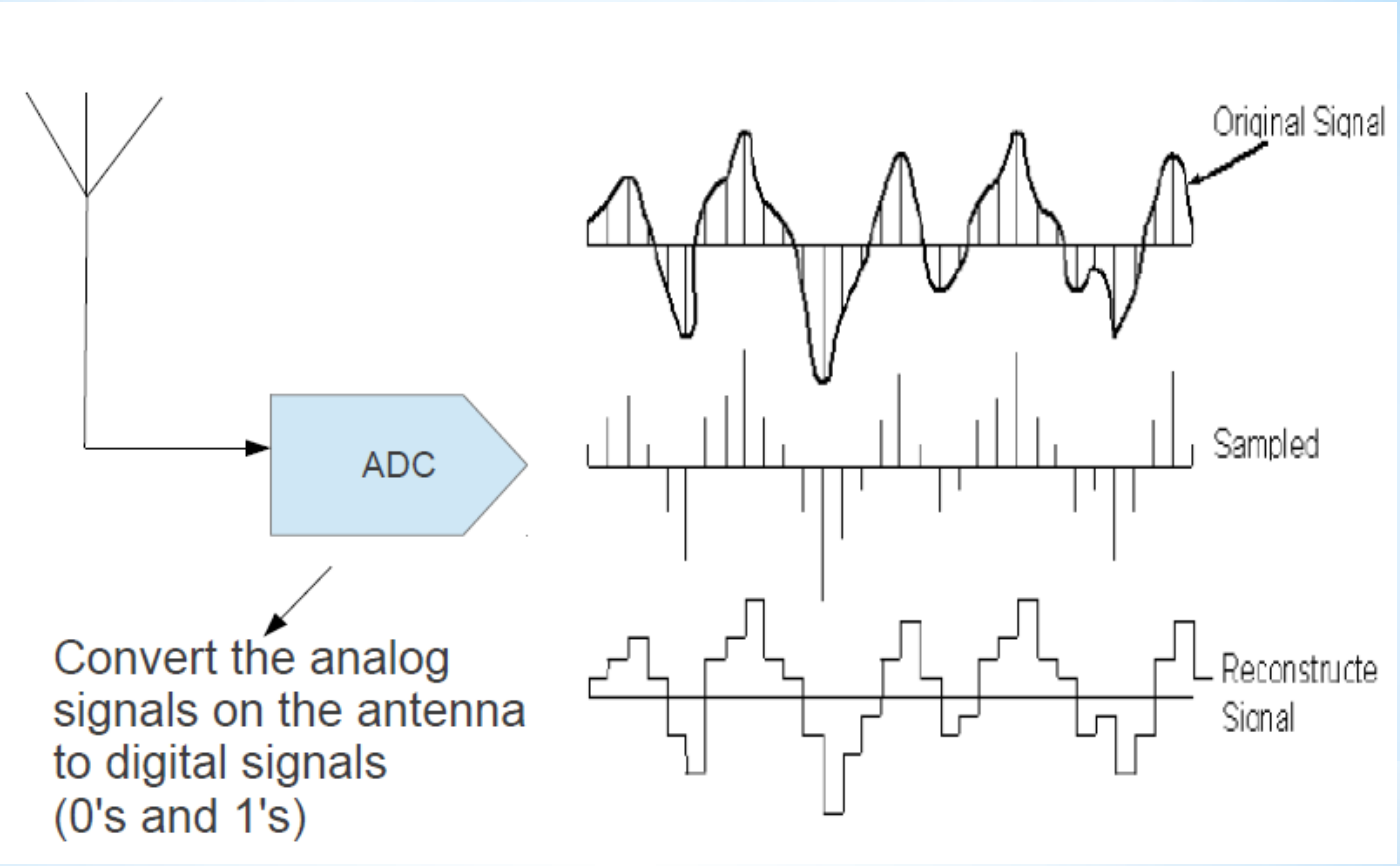
No Panafall Display

*$18,000 Ultimate Legacy Radio

*SDR to the Rescue

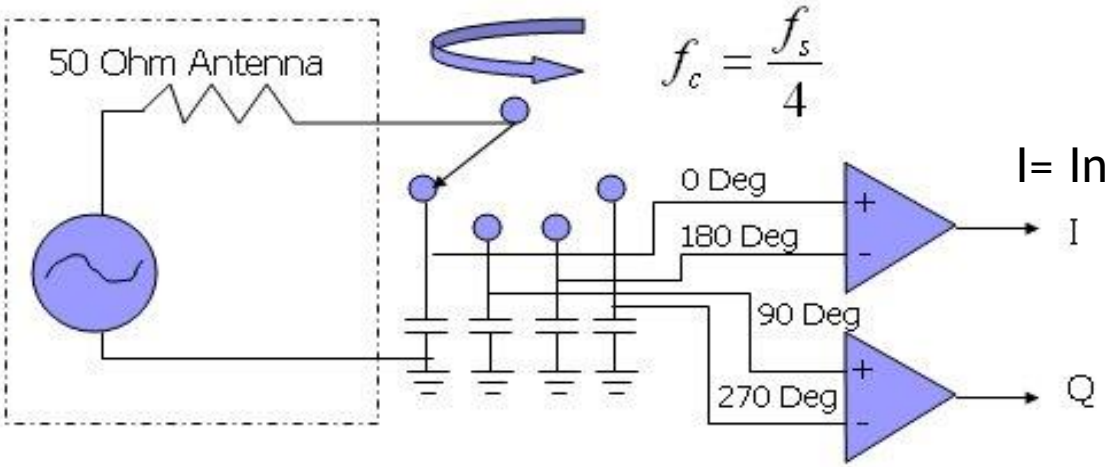


*How SDR's Work



*How SDR's Work

Quadrature Sampling Detector



$$f_c = \frac{f_s}{4}$$

I= In Phase

Q= Quadrature

$$BW = \frac{1}{\pi n R_{ant} C_s}$$

*Quadrature Sampling Detector

*MATH

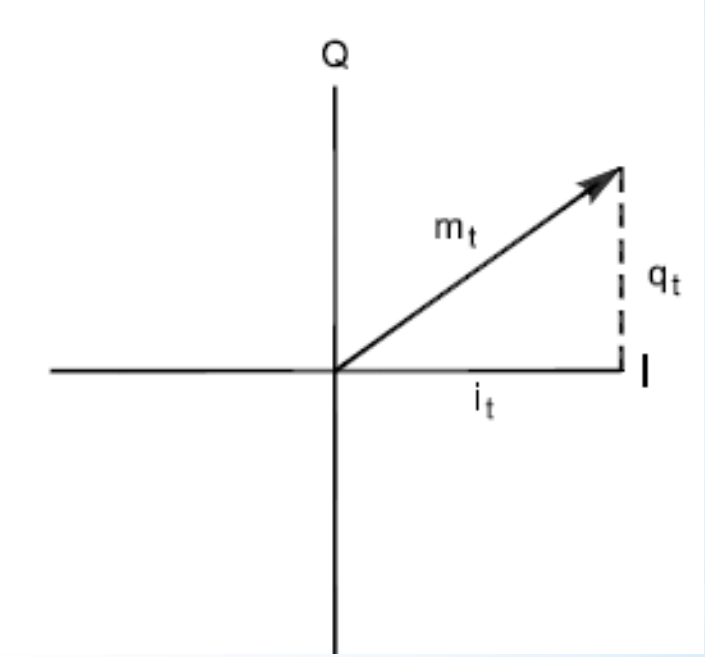
*---- ON THE EXAM

$$m_t = \sqrt{I_t^2 + Q_t^2}$$

Magnitude

$$\phi_t = \tan^{-1}\left(\frac{Q_t}{I_t}\right)$$

Phase



*How SDR's Work

*Dirty Little Secret

Don’t tell N6KI

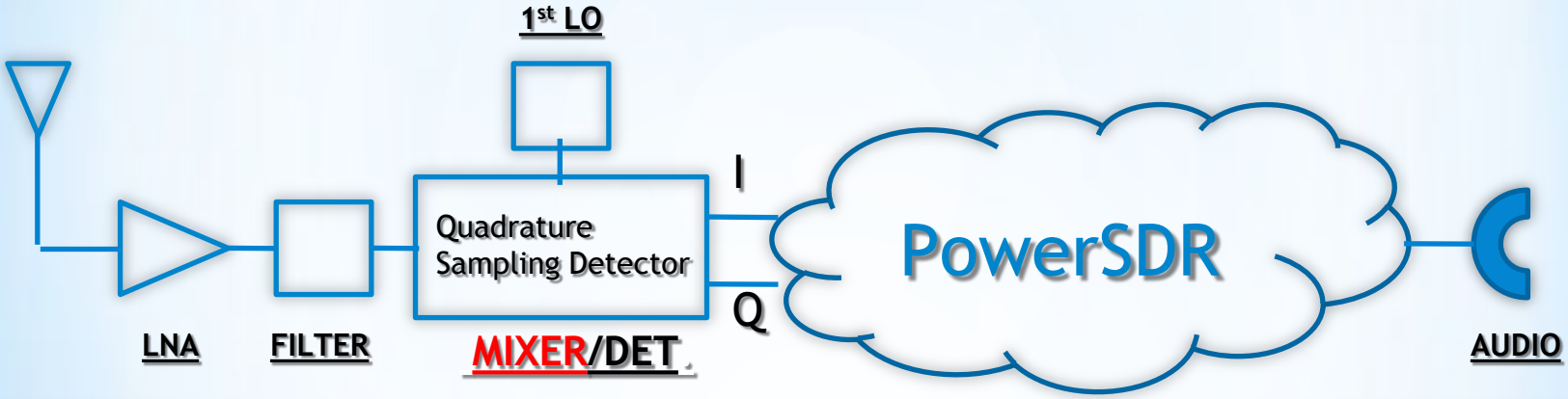
*All Future Radios will be SDR’s

* **1st Generation SDR**
* ADC Too Expensive to Direct Sample RF
* Convert To Digital Baseband - Fast ADC
* Direct Conversion SDR
* Invented in USA
* US Military – Prime Mover
* Cell Phones SDR
* Ham Radio - Software Defined Radio

* 2000 – Architecture #4 Direct Conversion SDR

MODERN RADIO - 2000 TECHNOLOGY - 1st Generation SDR

One Stage



*"QSD" Direct Conversion Chain

* FLEX-5000

FLEX-3000

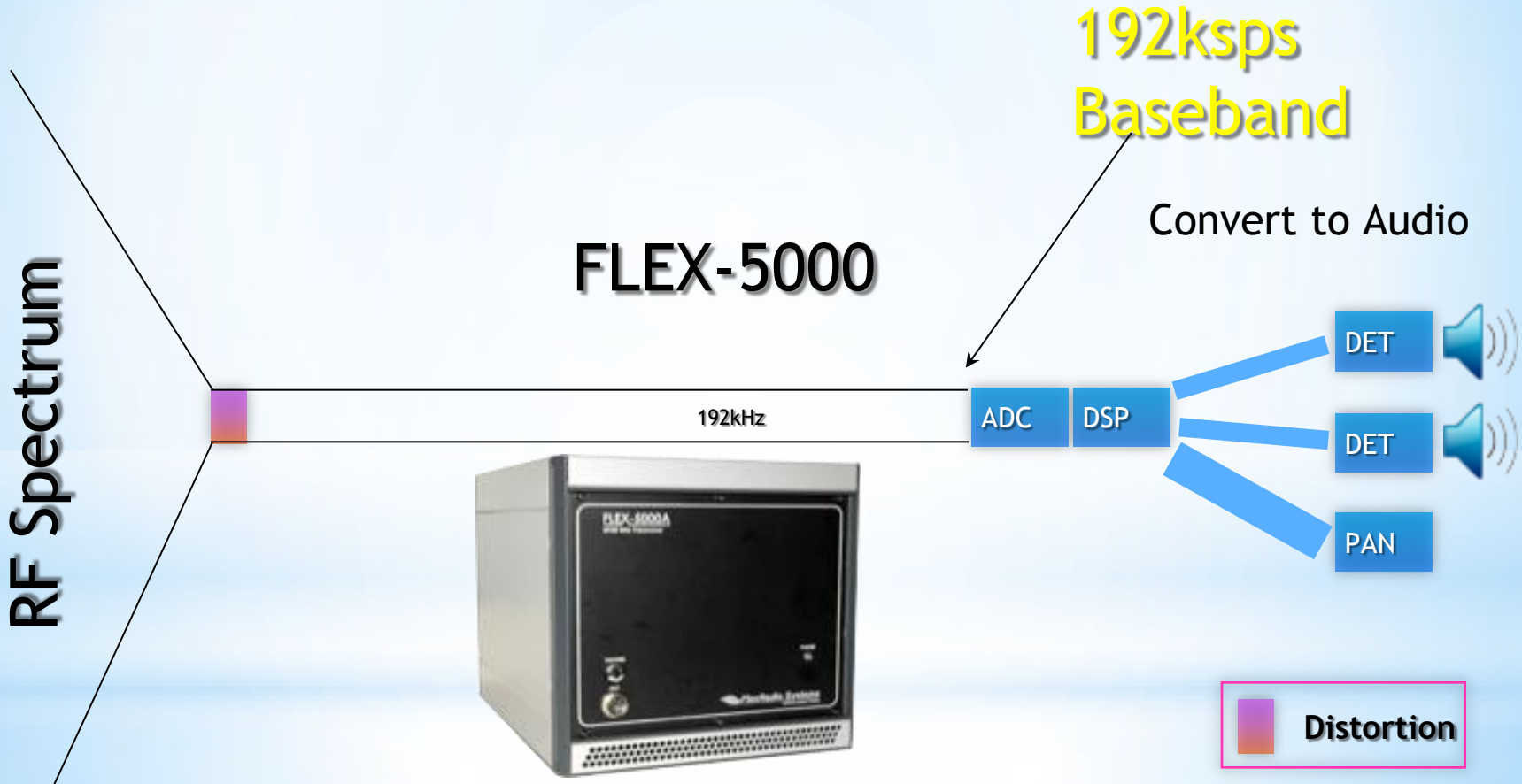
* Elecraft KX3

Elad FDM-DUO

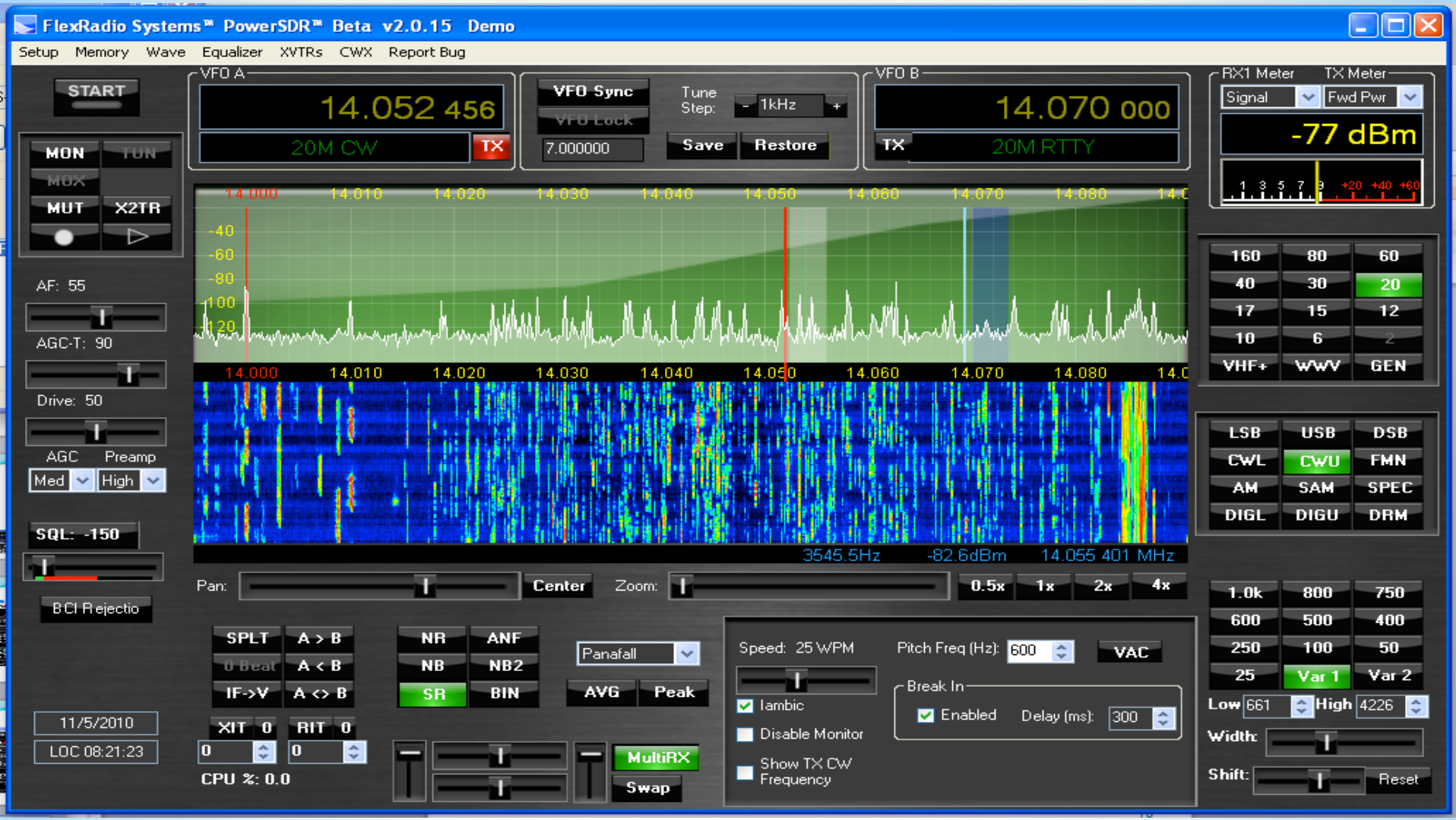
* **Some SDR's still have Knobs**

* 1ST Generation SDR

* Direct Conversion SDR



* 1ST Generation SDR



*1st Generation Direct Conversion

3/4/2015

+ Distortion minimized with only one mixer:
clear signal -- sounds better, less fatigue (less in-band distortion)

- Noise amplified by only 1 stage

+ Can show 192kHz of realtime spectrum:
wide panadapter view

+ Low power, high dynamic range:
interference mitigation

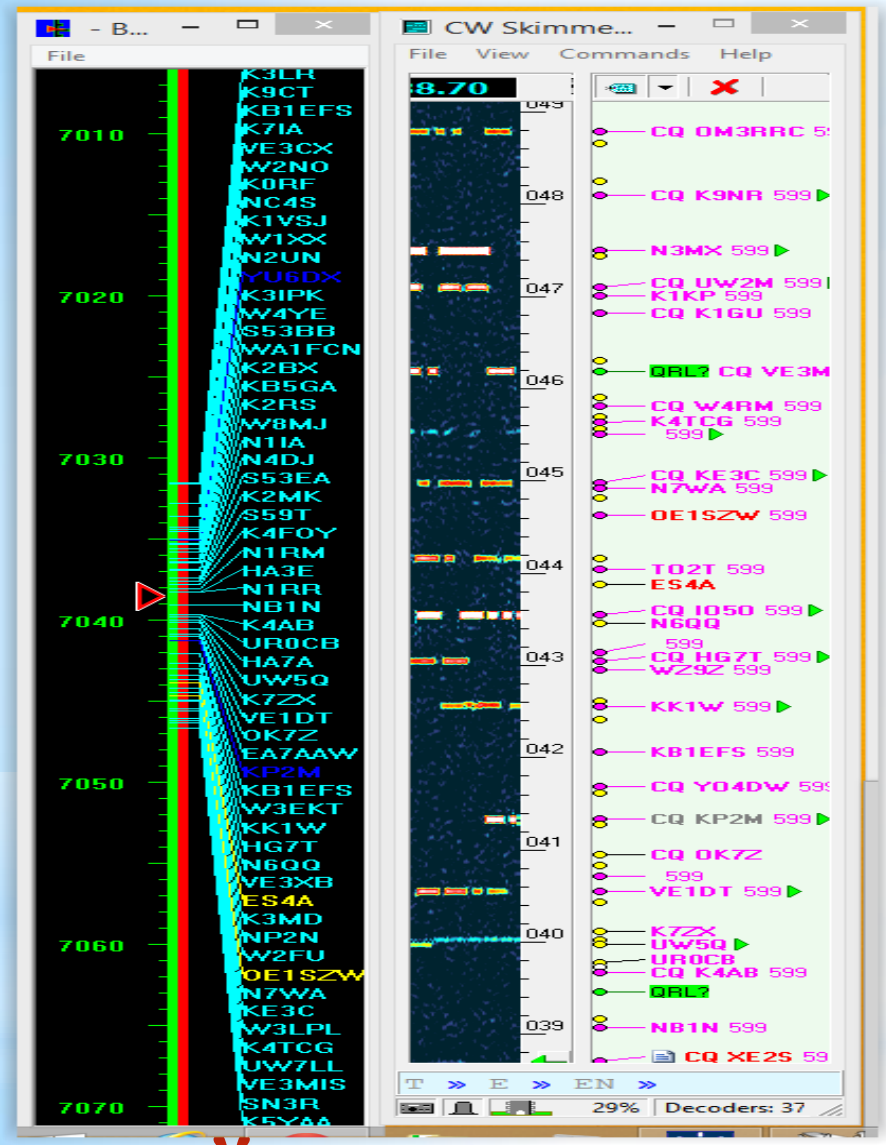
- Image rejection difficult (balanced IQ mixer, WBIR)
- Better, but still limited view of spectrum (192Khz)

*Direct Conversion The good and not-so-good

*1ST Generation SDR

2007 Freedom Reigns

- CW Eliminated
- USA Ham Radio Numbers Soars
- Bright Young Engineers Became Hams
- USA Now The Home Of The Top Ham Manufacturers
  - Elecraft
  - Ten Tech
  - Flex Radio



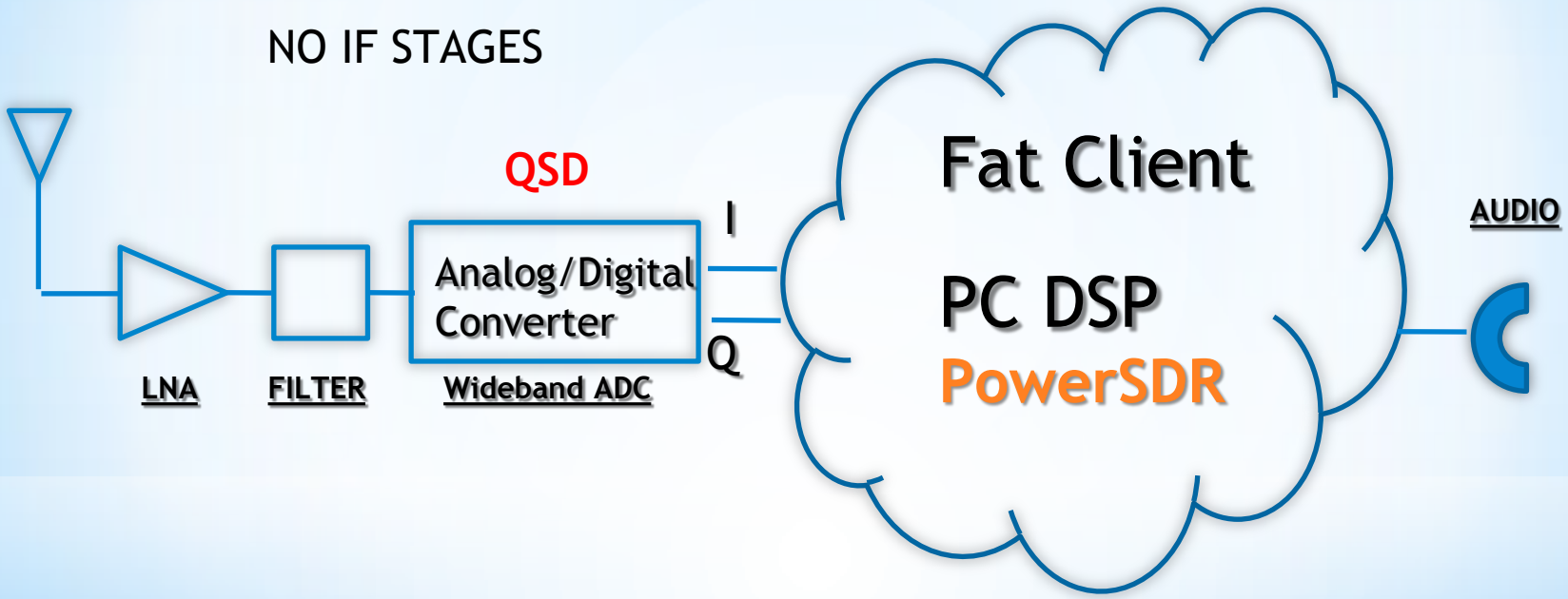
*CW More Popular Now Than When It Was FORCED Upon Us.

*Unintended Consequences

* 2nd Generation SDR
* ADC got faster and cheaper
* Direct Sampling at RF
* Processing was complicated
* External DSP Processing
* Fat Client – HPSDR
* VERY FAST PC for DSP

* 2009 Architecture #5
Fat Client Direct Sampling SDR

MODERN RADIO - 2009+ TECHNOLOGY - 2nd Generation SDR
Wide Band - EXTERNAL Processing



*Direct Sampling Converter Chain 2009 Architecture #5

+ **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 - IP3 +50db +125db Dynamic Range or better**

+ **Extreme flexibility through reprogrammability (*ultimate* SDR): future benefits**

- **Very Fast PC to Process Data**

- **Huge Bandwidth between Radio and PC**

2nd Generation SDR
Wide Band - EXTERNAL Processing

Direct Sampling Benefits

2nd Generation SDR - Wide Band – EXTERNAL Processing

*HPSDR

ANAN-100D

*2009 Architecture #5
Fat Client Direct Sampling SDR

Yes Dennis, N6KI

*Modern Radio's 2nd Generation SDR can have Knobs

By 2012 FPGA Prices Cost Effective For Internal Processing

Brand A
Texas Instruments TMS320VC33

0.120 GFLOPS

Brand B
Texas Instruments TMS320C6713 x3 + TMS320C6711

4.95 GFLOPS
1.35 GMAC

Brand C
Texas Instruments TMS320C6727B x2

4.2 GFLOPS
1.40 GMAC

FLEX-6500
Texas Instruments TMS320C6A8167 + XC6VLX75T

78 GFLOPS
191 GMAC

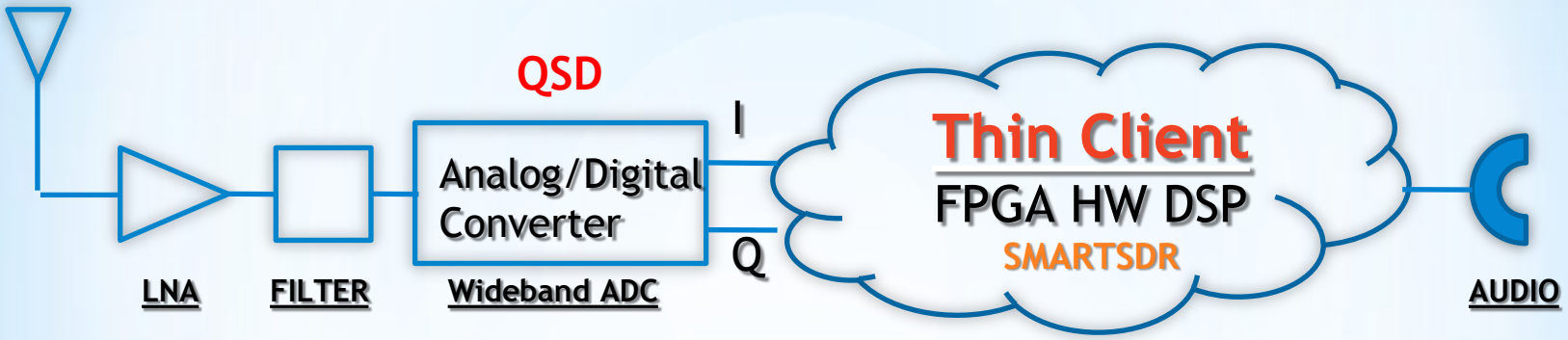
FLEX-6700 / FLEX-6700R
Texas Instruments TMS320C6A8167 + XC6VLX130T

121 GFLOPS
317 GMAC

Transceiver DSP Performance Comparison

*Compute Power for Internal Processing

Wide Band - INTERNAL Processing



*Direct Sampling Converter Chain

*2012 Architecture #6
Thin Client Direct Sampling SDR

+ 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 - IP3 +50db +125db Dynamic Range or better

+ Extreme flexibility through reprogrammability (*ultimate* SDR): future benefits

+ Regular PC to Display Video Only

+ Acceptable Bandwidth between PC and Radio.

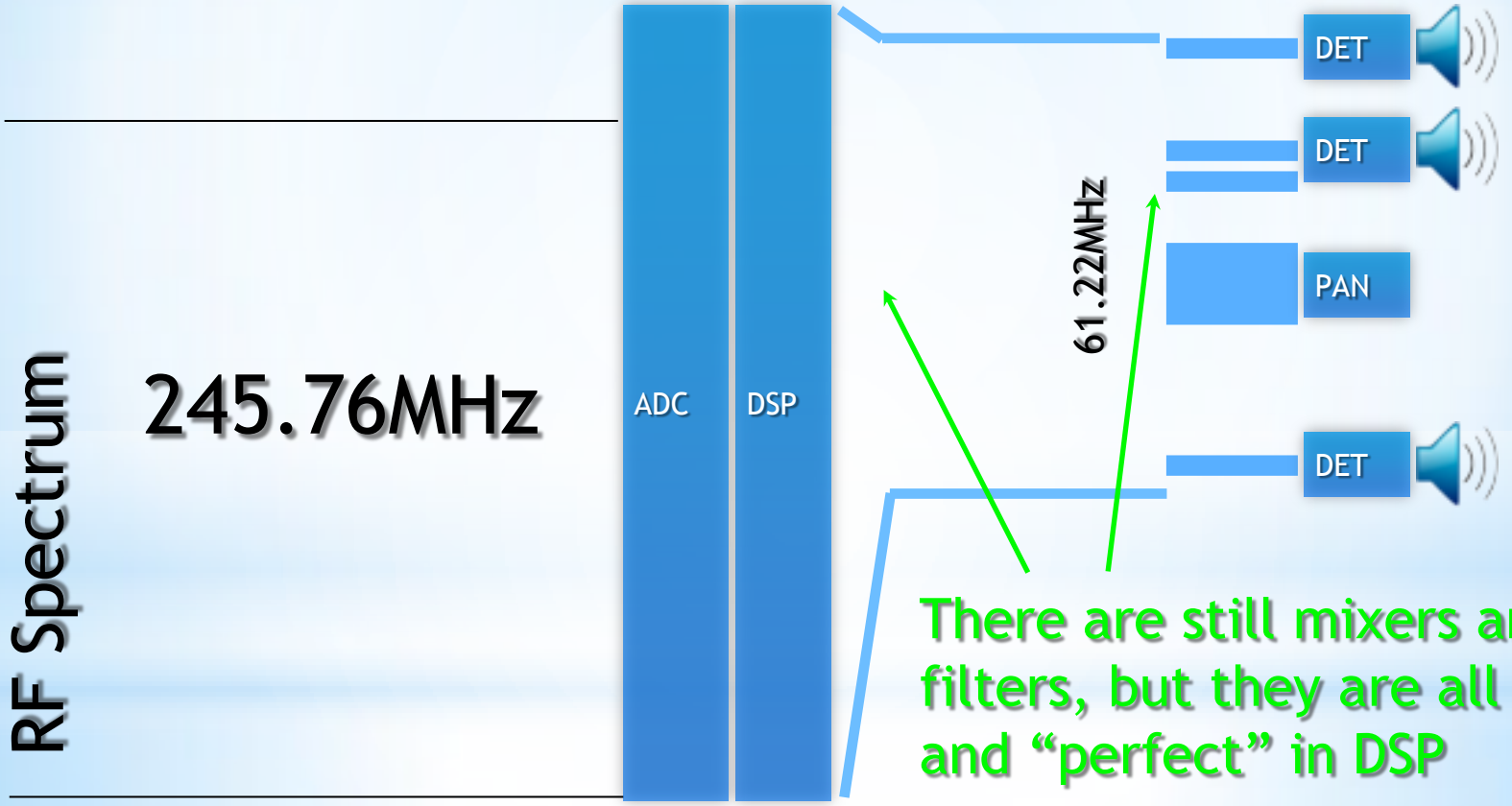
- Technically challenging to design and write software

3rd Generation SDR
Wide Band - INTERNAL Processing

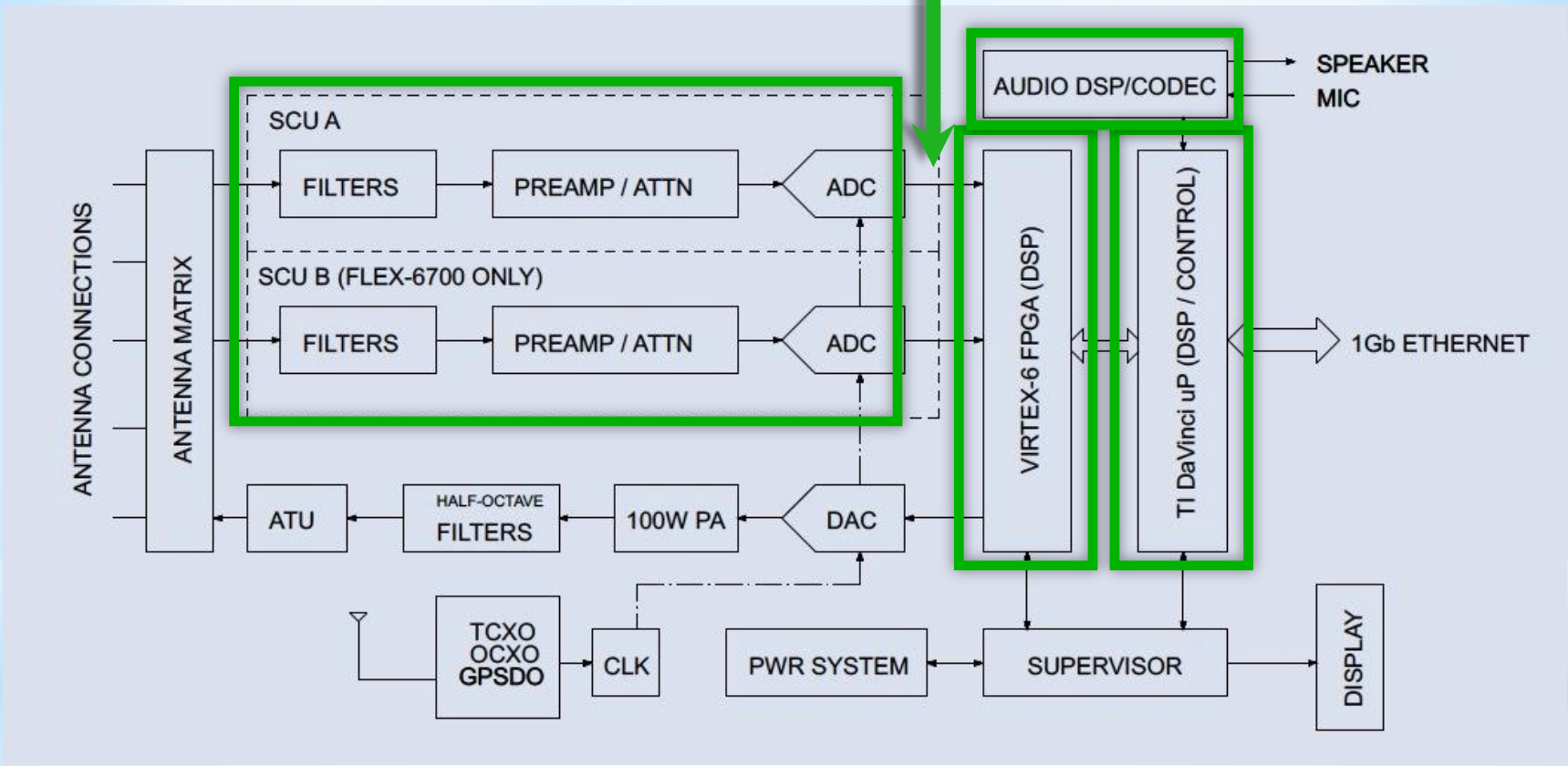
Direct Sampling Benefits

Direct Sampling

FLEX-6000



7.9Gbps + 1Gbps



* 3rd Generation SDR Architecture

© KY6LA

FLEX-6000 Series

ANAN-200

*3rd Generation Direct Sampled Thin Client SDR

Sherwood Engineering Inc.

1268 South Ogden Street Denver, Colorado 80210 USA

email Phone: 303-722-2257 FAX: 303-744-8876

9 a.m. - 5 p.m. MST Monday - Friday

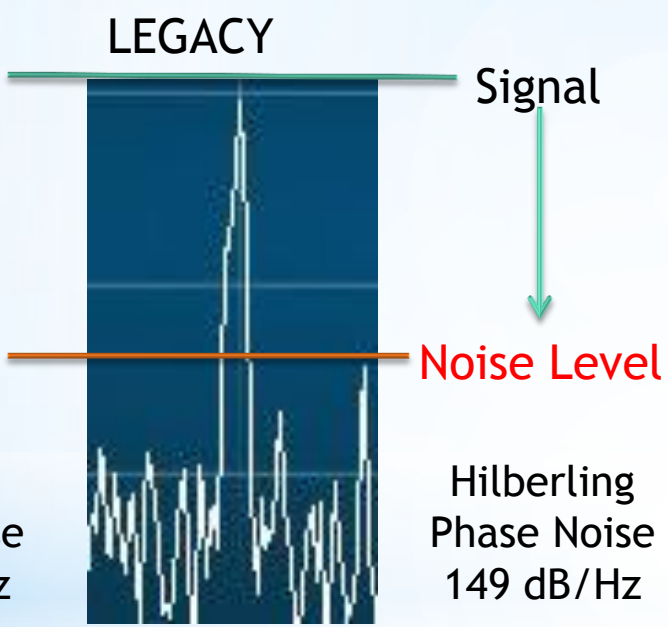
Receiver Test Data

Sorted by Third-Order Dynamic Range Narrow Spaced - or- ARRL RMDR (Reciprocal Mixing Dynamic Range) if Phase Noise Limited

Updated 9 December 2014 with Kenwood TS-590SG

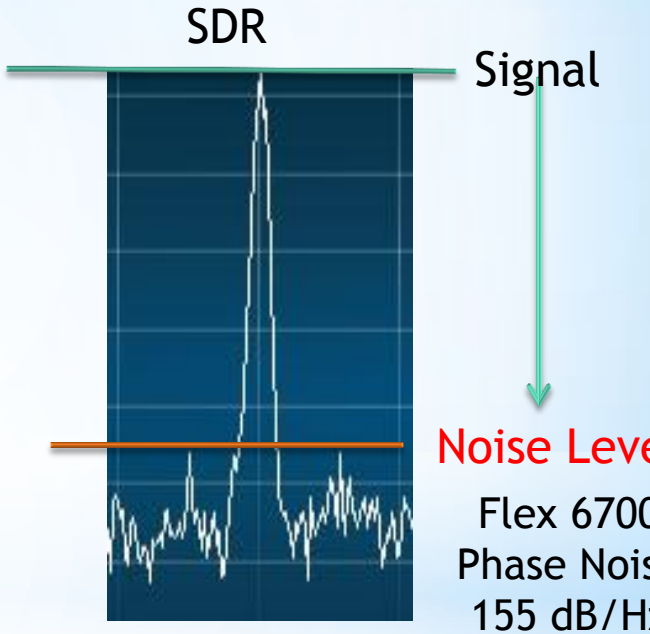
Device Under Test	Noise Floor (dBm)	AGC Thrshld (uV)	dB	100kHz Blocking (dB)	Sensitivity (uV)	LO Noise (dBc/Hz)	Spacing kHz	Front End Selectivity	Filter Ultimate (dB)	Dynamic Range Wide Spaced (dB)	kHz	Dynamic Range Narrow Spaced (dB)	kHz
Added 9/29/14 FlexRadio Systems 6700 Hardware Updated	-118 -135[b2]	3.0 1.0[b2]	Var	A/D Limit	2.0 0.25[b2]	145 155	10 50	B Band Pass	115	99	20&2	108[y]	20&2
Added 10/02/12 Hilberling PT-8000A Hardware Rev 2.00	-128 -141[b]	5.4 1.0[b]	3	142	0.45 0.11[b]	144 149	10 50	A Trk Presel	100	105	20	105[w]	2
Added 08/10/12 Elecraft KX3	-123 -138[b2]	12 1.3[b2]	3	138	0.9 0.09[b2]	144	10	B Band Pass	110	105	20	104[t] 96[u] 65[v]	2
Added 12/01/10 Yaesu FTdx-5000D	-123 -135[b] -141[b1]	4.6 1.2[b] 0.33[b1]	3	127[s]	1.1 0.27[b] 0.13[b1]	135	10	B Band Pass	90[f]	104	20	101[f]	2
Added 2/15/08 Elecraft K3	-130 -138[b]	2.1 0.6[b]	3	140[s]	0.33 0.19[b]	138	10	B Band Pass	105	104	20	101[pf] 96[qf] 95[r]	2
Updated 7/2/09 Perseus	-123 -125[b]	0.15 0.1[b]	3	125	0.8 0.6[b]	147	10	B Band Pass	109[f]	99	20	99	2
Added 2/15/08 FlexRadio Systems FLEX-5000A	-123 -135[b]	2.0 0.5[b]	3	123[s]	1.3 0.3[b]	123	10	B Band Pass	98	96	20	96	2

*1. Best Received Signal to Noise Ratio- SDR Hears Best



IC-7800
Phase Noise
130 dB/Hz

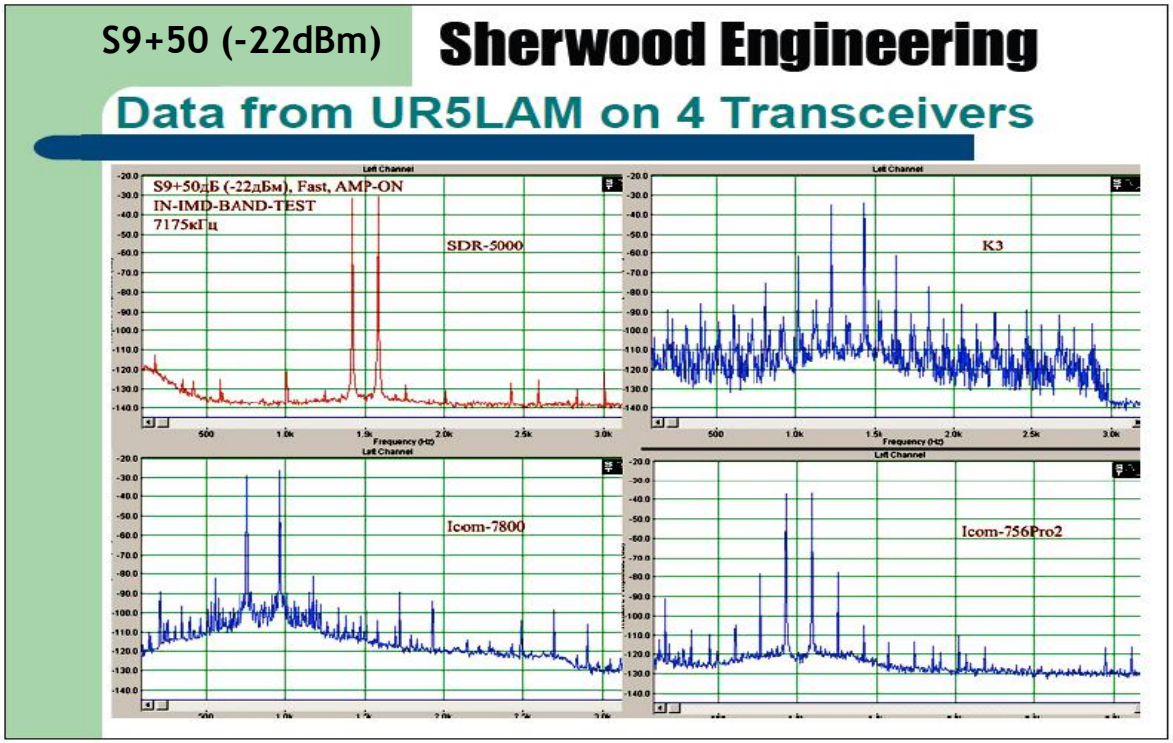
Hilberling
Phase Noise
149 dB/Hz

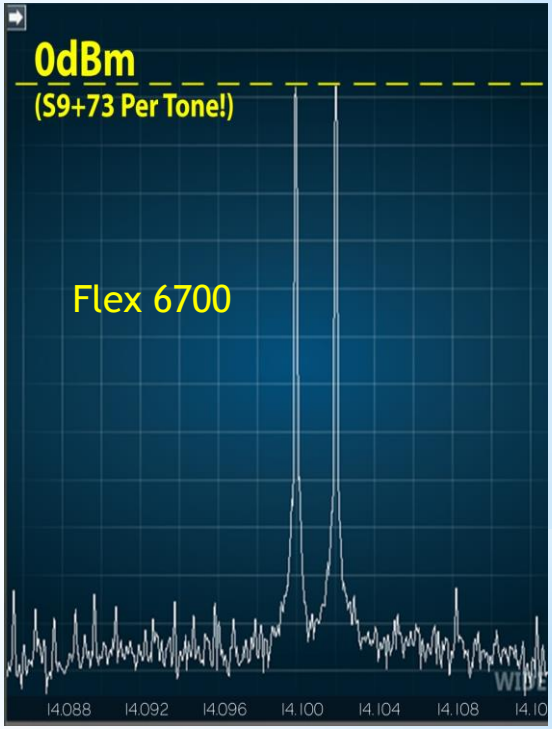


Flex 6700
Phase Noise
155 dB/Hz

*SDR Benefits for you

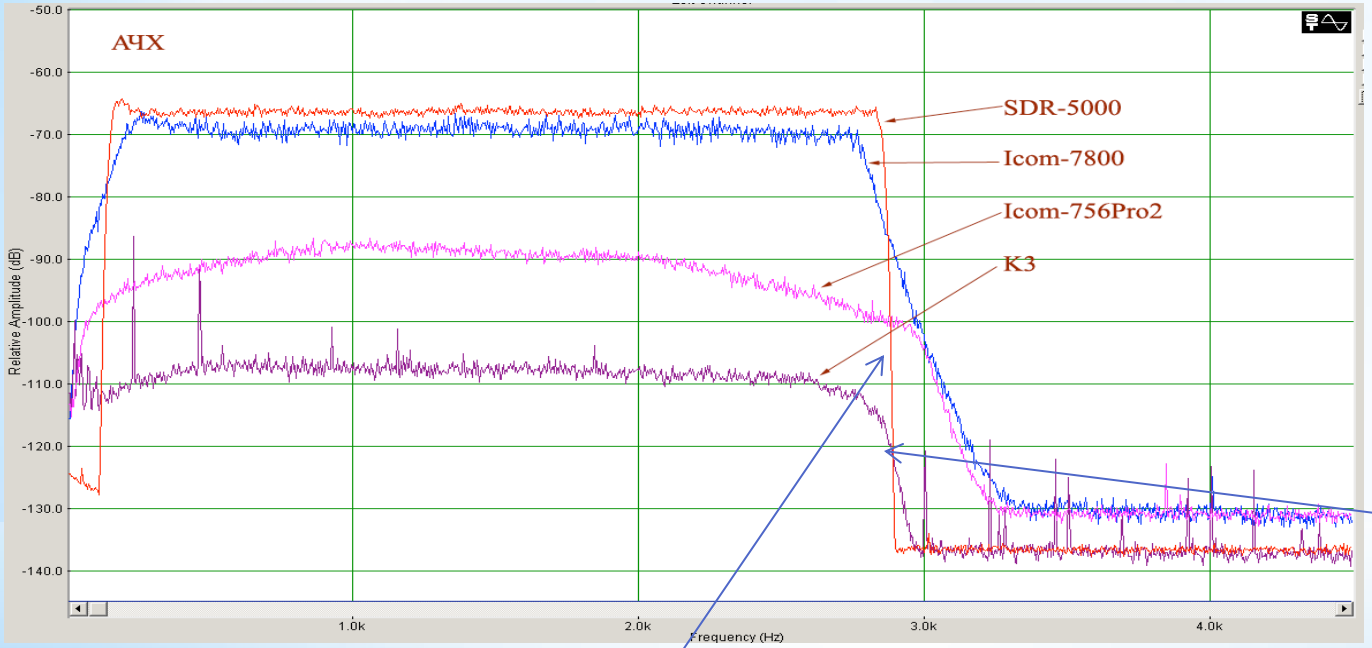
*2. Least Distortion – SDR Hears Best





*SDR Benefits for you

*3. Best Filter Selectivity – Brick Wall Filters



Ultimate Filter	
Flex 6700	115 dB
KX3	110db
K3	105dB
Hilberling	100dB
IC-7800	100dB

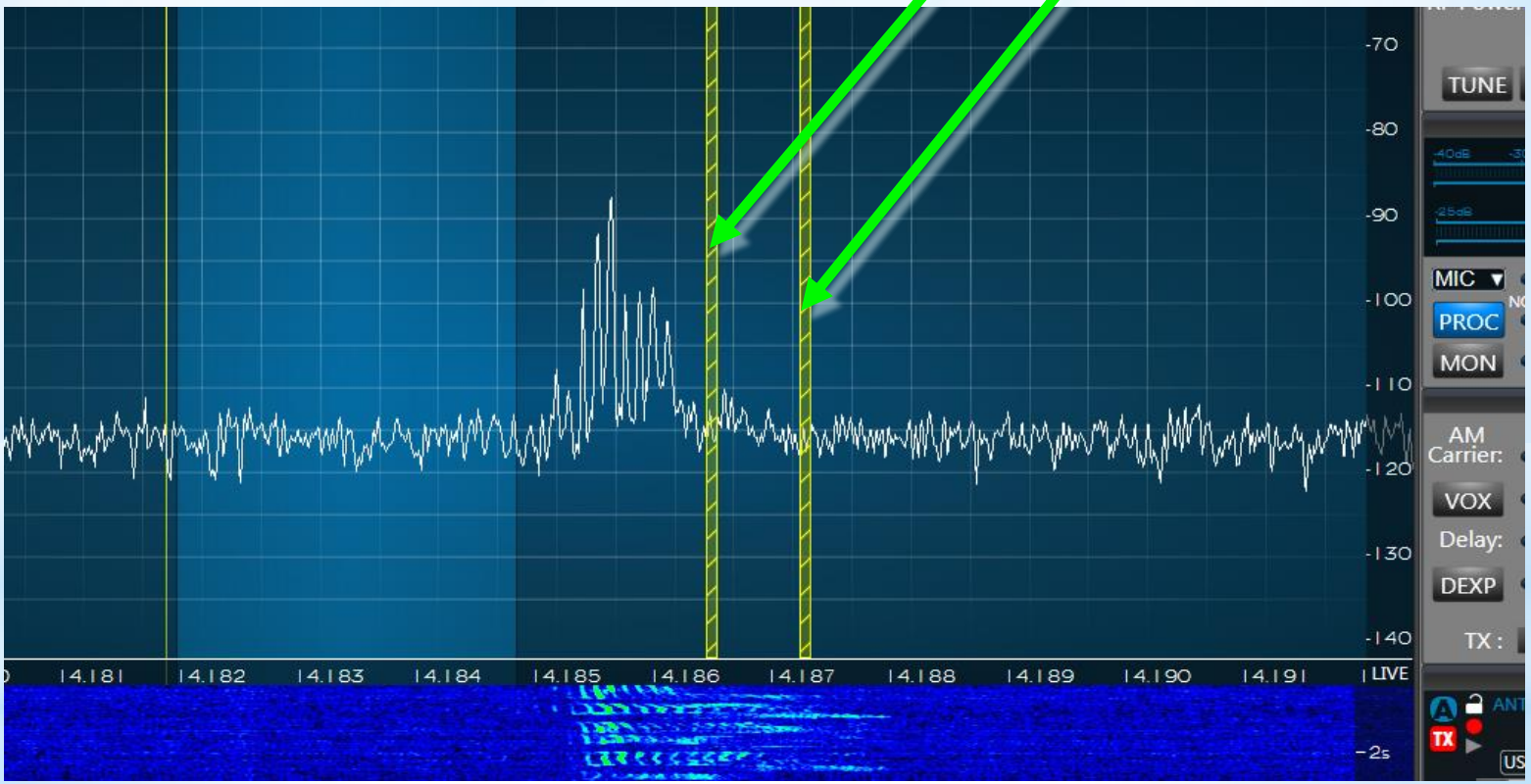
1.05 Shape Factor

Don't do the math for signals you don't want to hear

*SDR Benefits for you

*4. Infinite Number Tracking Notch Filters

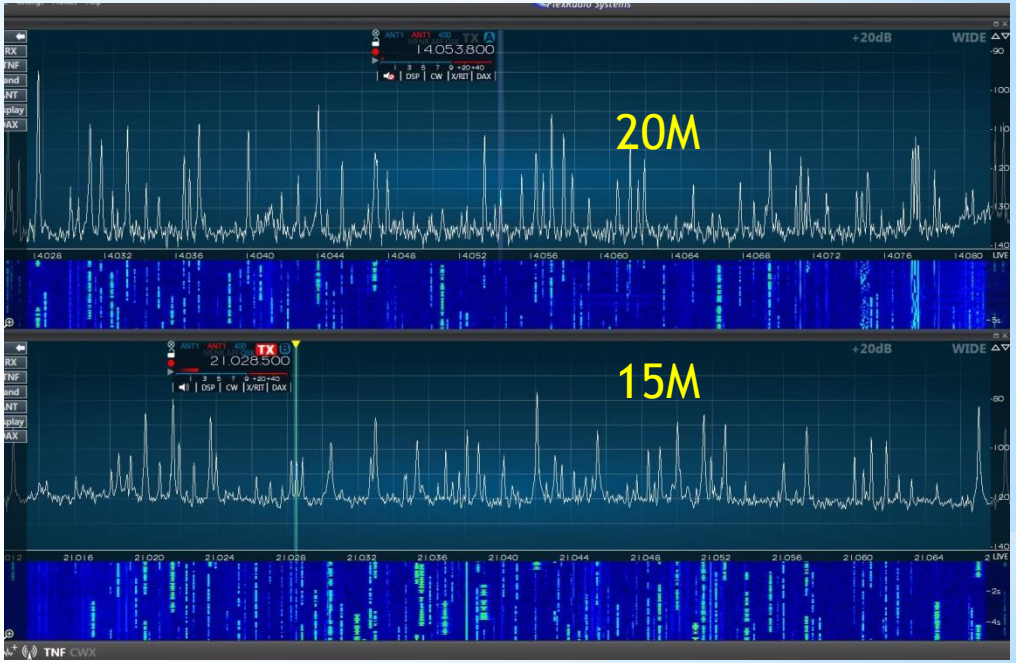
As you tune, the TNF follows *RF, not IF/Audio*



*SDR Benefits for you

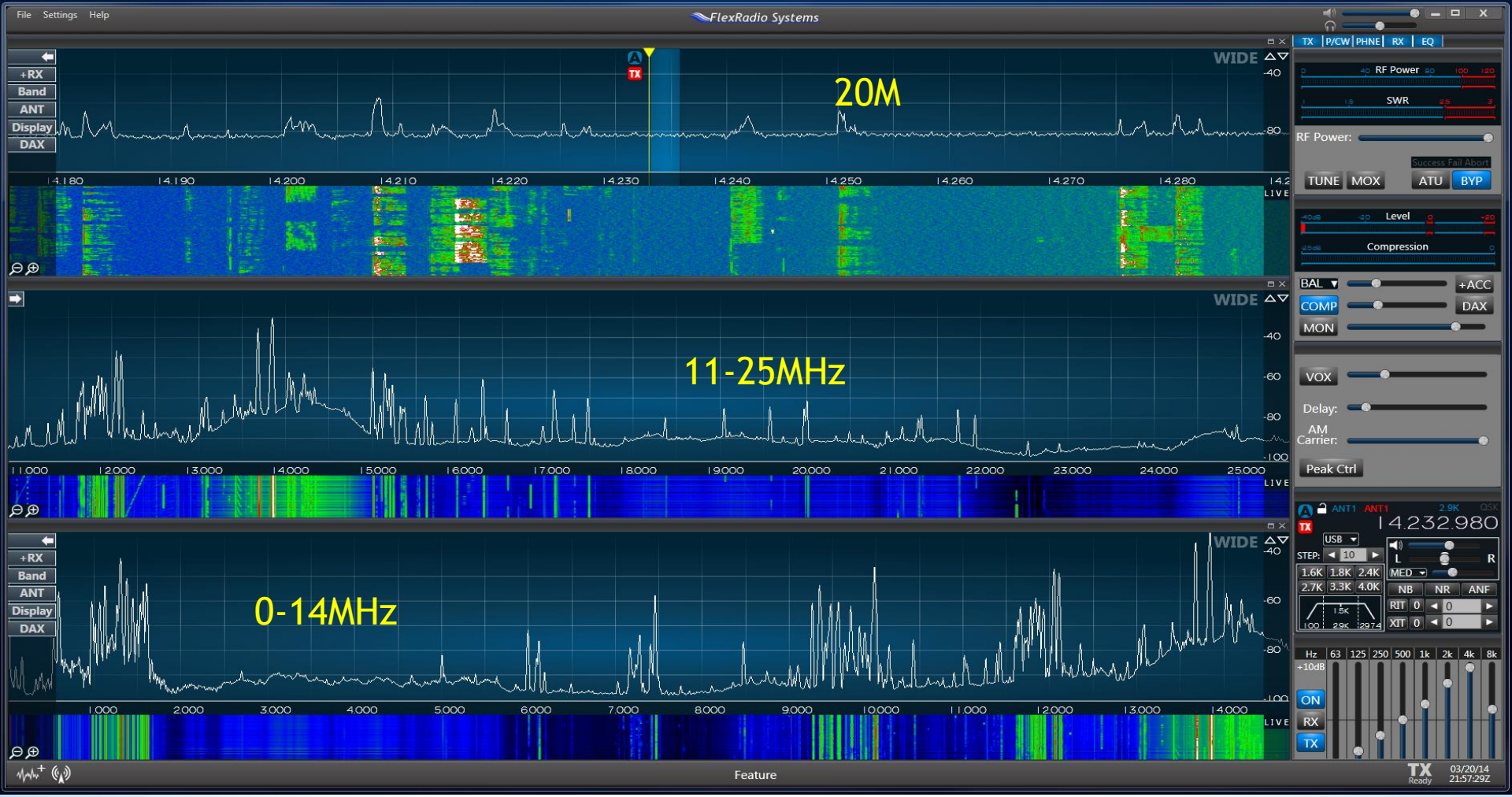
*5. Sees Every Signal – No More BLIND RADIOS

Blind Legacy Radio



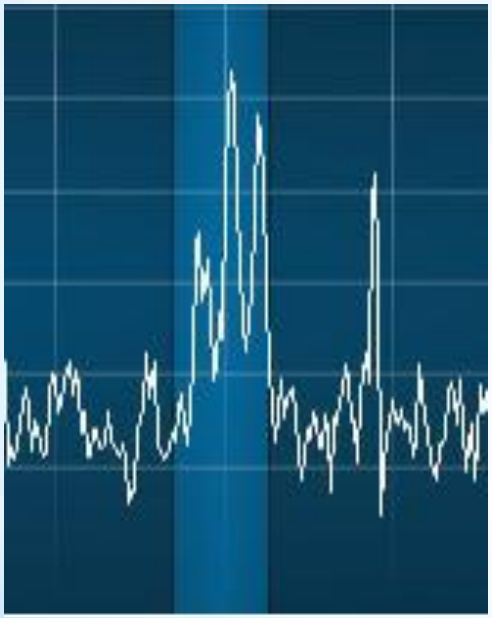
SDR Sees Entire Band

*SDR Benefits for you



*20M as well as 0 MHz-25MHz

*6. Best Dynamic Range - Block Adjacent Signals



Flex 6700	108dB
Hilberling	105dB
KX-3	104dB
K-3	101dB
FTdx-5000D	101dB
IC-7800	80dB

*SDR Benefits for you

*7. Digital - No Costly External Interfaces or Cables

Legacy Radio Arrangement

Analog to Digital to Analog Converter
Like a SignalLink

Cables

SDR Radio Arrangement

Every in Digital Domain
Inside computer

*SDR Benefits for you

*8. Best Digital Decoding

Legacy Radio Arrangement

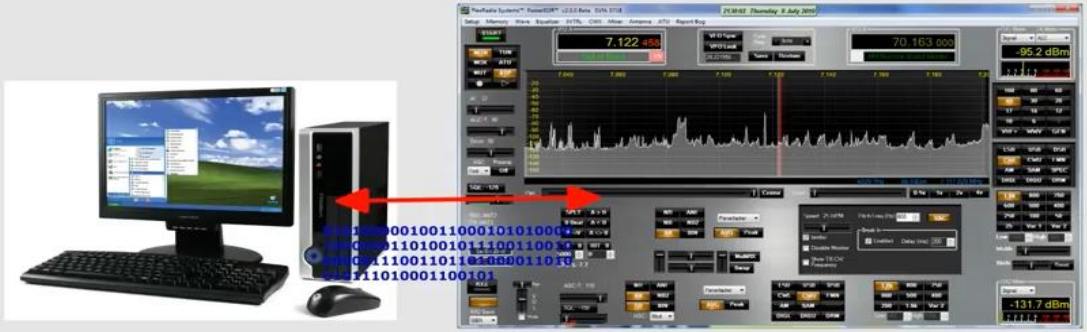
Flex 6700 decodes -27db S/N
No Legacy decodes below -20 dB S/N

WA3IHV JT65 Real World Example

Legacy Icom 7700 -19dB S/N
Modern Flex 6700 -26dB S/N

Modern – 7dB Gain Advantage

SDR Radio Arrangement



*SDR Benefits for you

*9. Easiest Remote Operations

DAYTON 2012

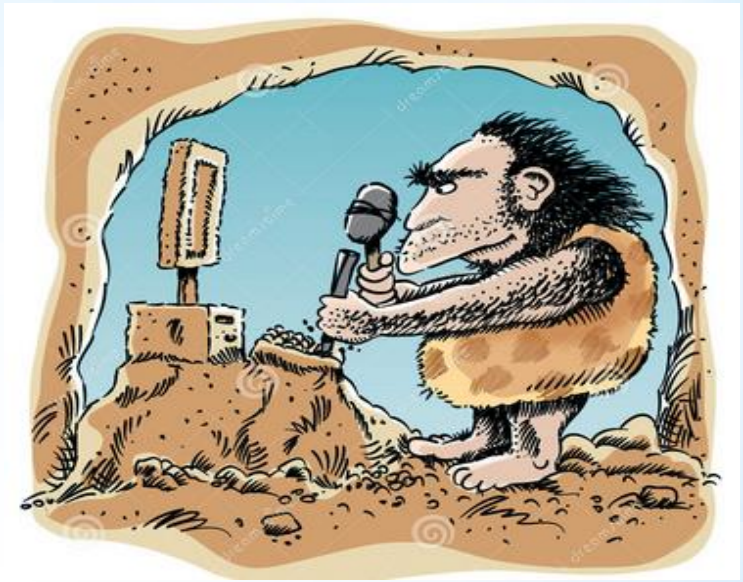
Friedrichshafen 2014

iPad Remote via Flex 6700 through KY6LA in La Jolla, CA
from 22 Different Countries
Maybe today too

*SDR Benefits for you

*10. SDR Software Continually Improves

Legacy Radios Fixed in Stone
Rarely improve with age



SDR – New Features/Modes added all the time
Like a new radio every few months

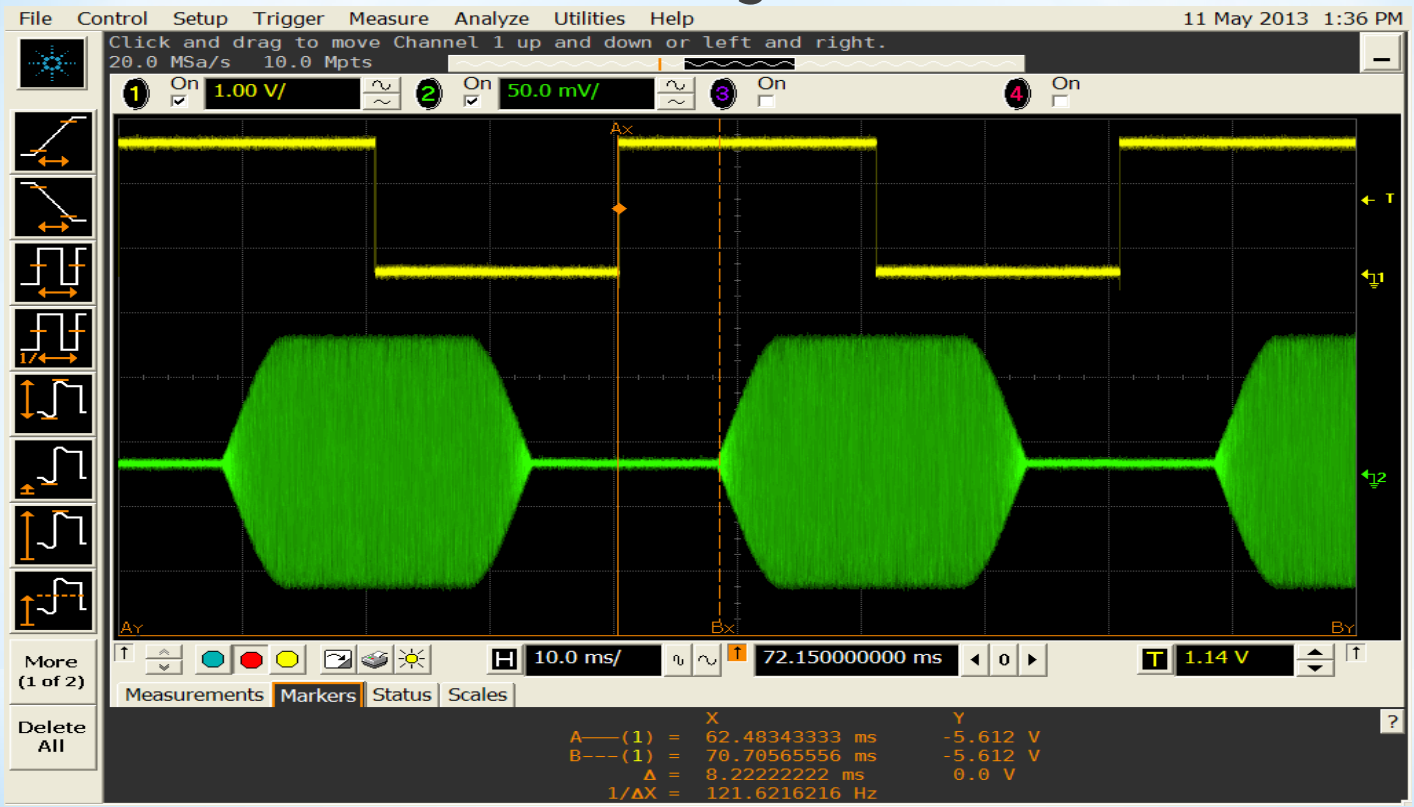
*SDR Benefits for you

*11. Open Applications Programming Interfaces

Lots Of Hams Writing New Software To Make SDR's Better
On Windows, MAC, Linux, iOS and Android

*SDR Benefits for you

*12. Cleanest Transmit Signals

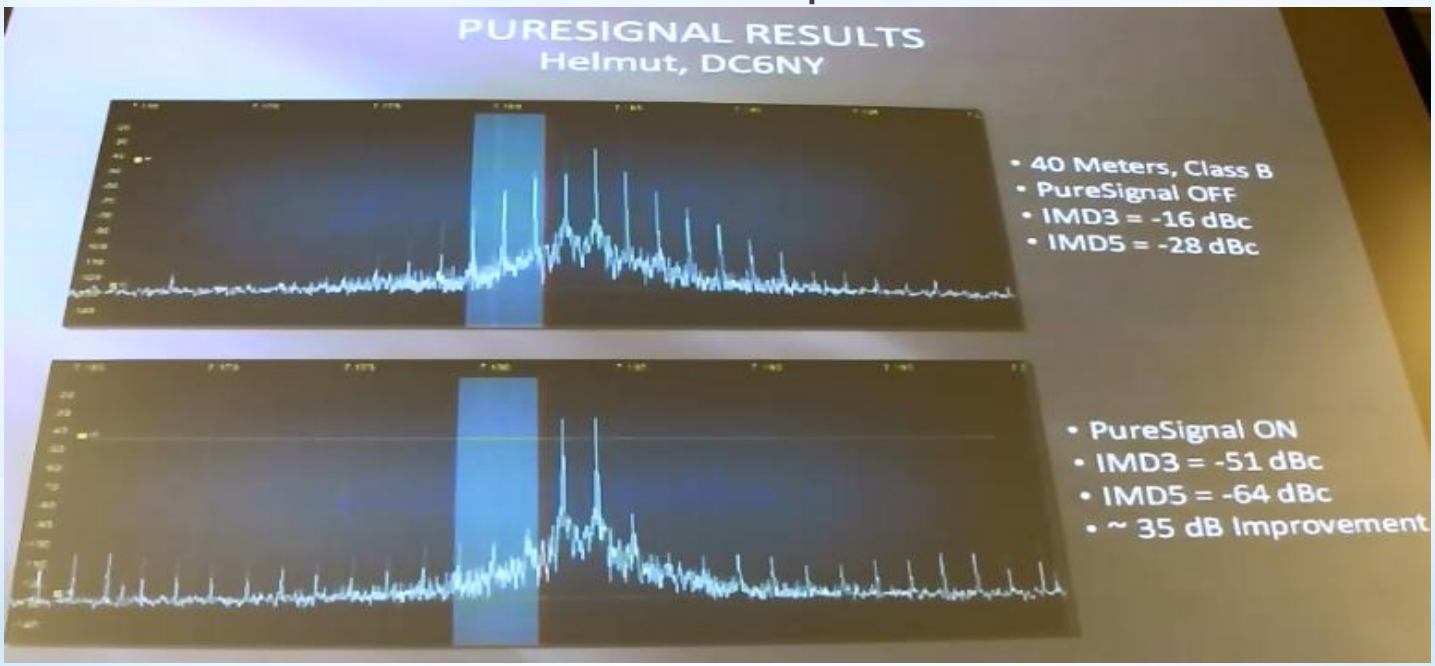


Modern Radios - Perfect CW Signal Shaping

Modern Radios - Lowest Transmit Audio Distortion

*SDR Benefits for you

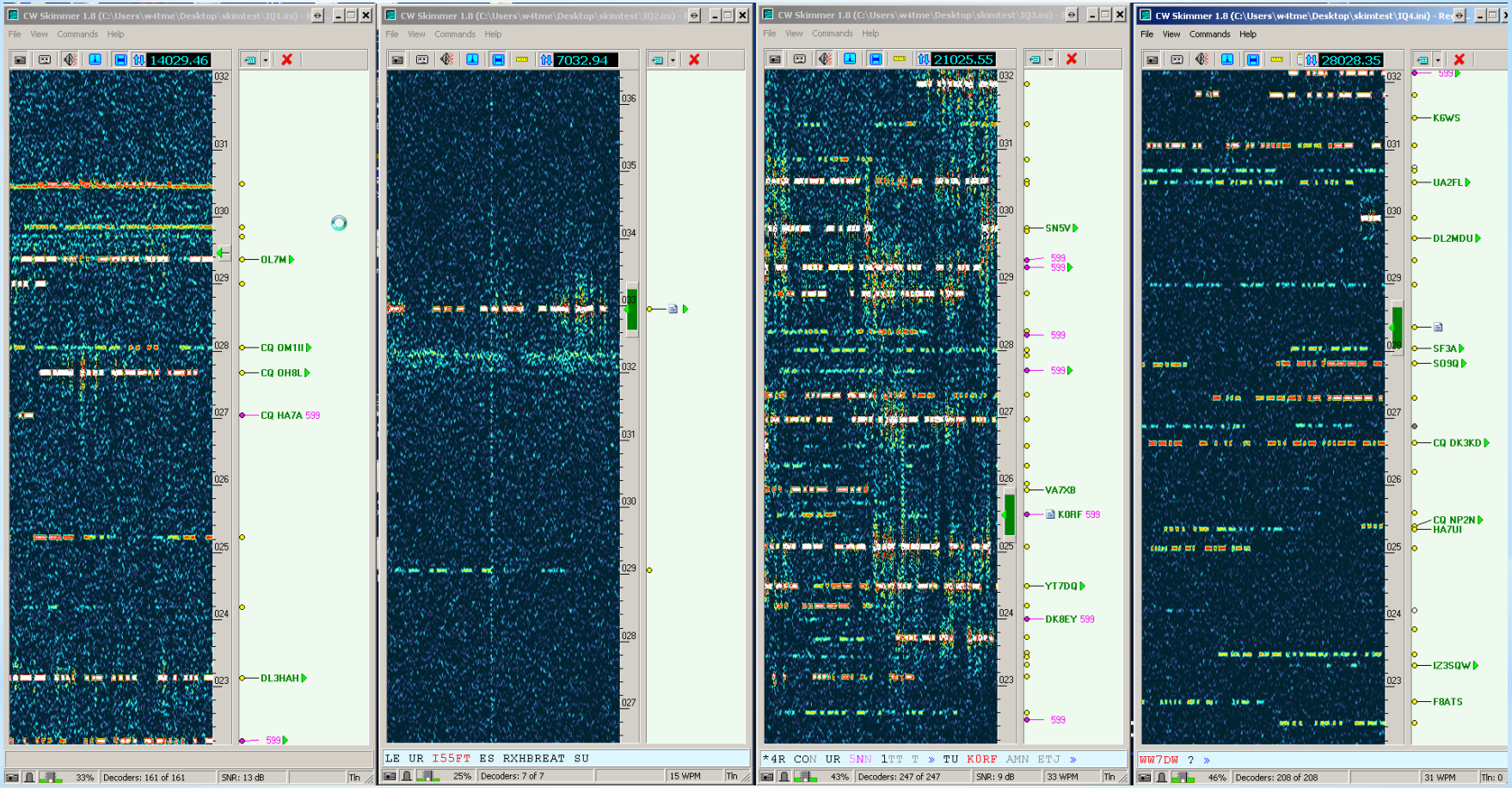
* 12. Cleanest Transmit Signals
  * Even 35dB Cleaner with Adaptive Pre-Distortion



Source Dr Warren Pratt NR0V
Friedrichshafen, June 2014

* SDR Benefits for you

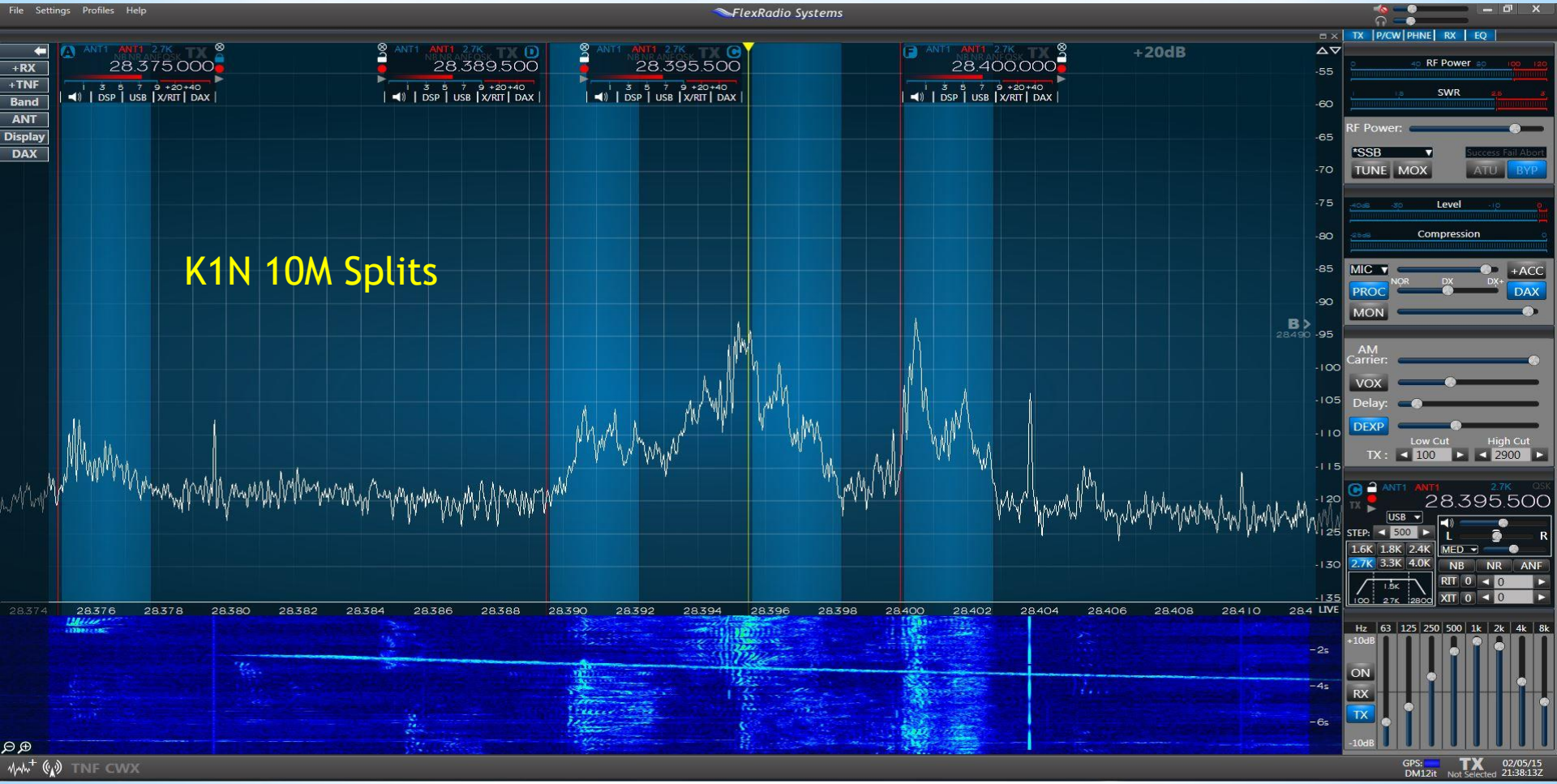
*13. 4 CWSkimmers – Each Decoding 192KHz



20M 40M 15M 10M

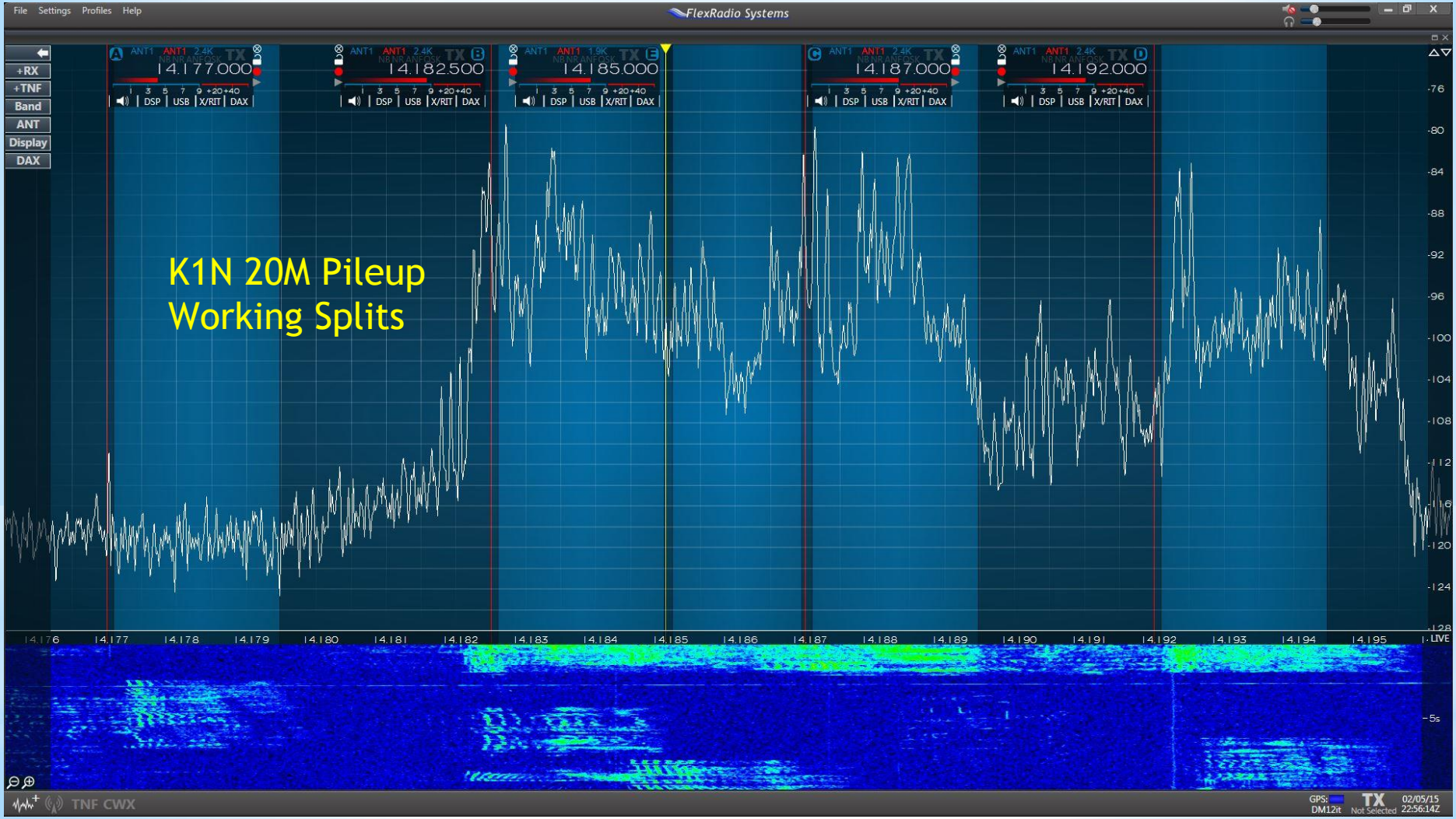
*SDR Benefits for you

*14. 4 Receivers at the Same Time



*SDR Benefits for you

*15. 8 Receivers at the Same Time



*SDR Benefits for you

*16. SDR - Easy to Use Human Interface

- *Late 20th Century - C130 – Complex Buttons, Dials and Knobs

*SDR Benefits for you

* 16. SDR Easy to Use Human Interface
  * Late 20th Century Legacy Radio – FTdx5000
  * Blind Radio –Complex Buttons, Dials, Knobs

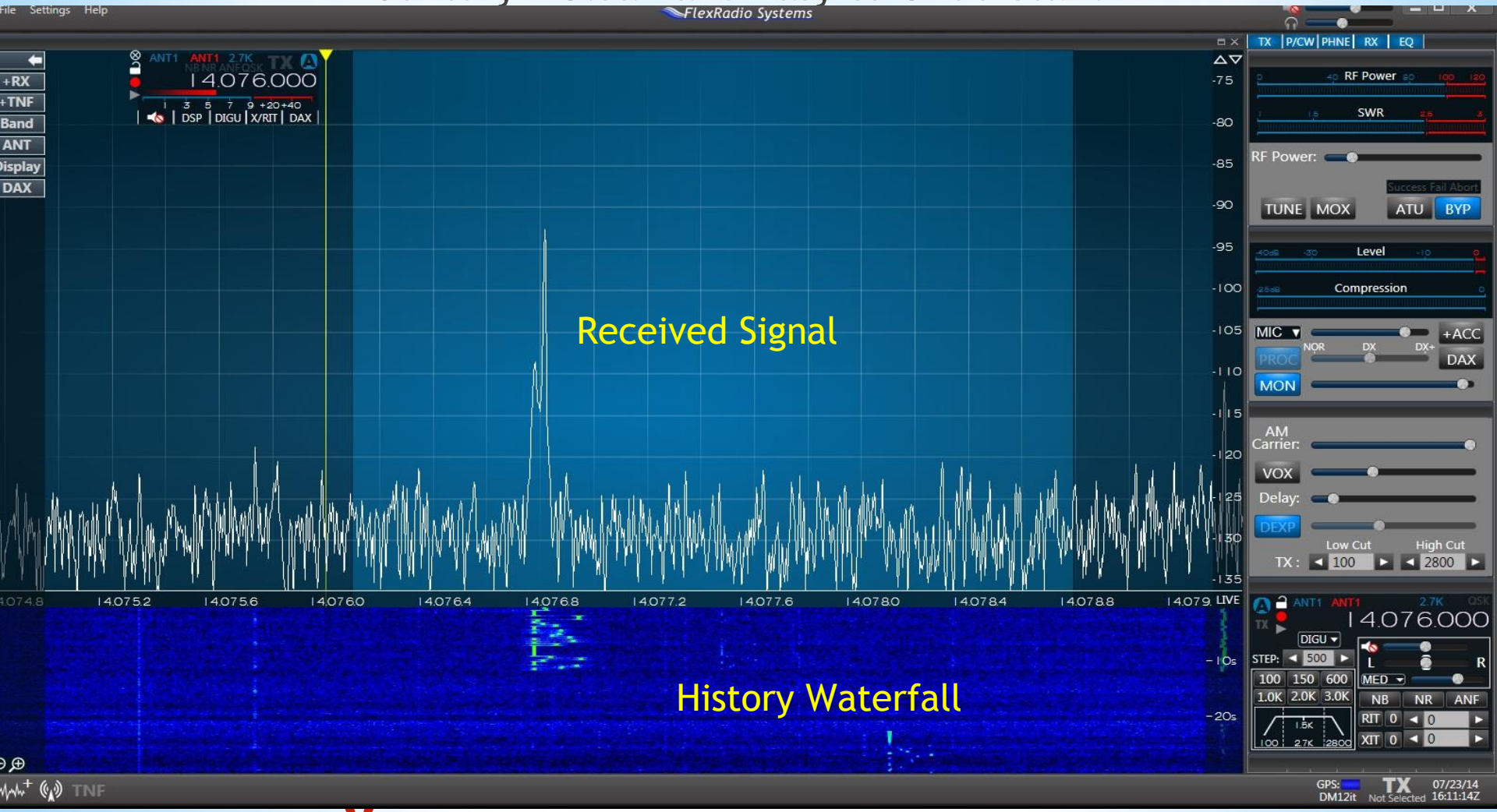
* SDR Benefits for you

* 16. Easy to Use Human Interface
  * 21st Century - Modern 787 Cockpit

* SDR Benefits for you

*16. SDR Easy to Use Human Interface

*21st Century – Clean and Easy to Understand



*SDR Benefits for you

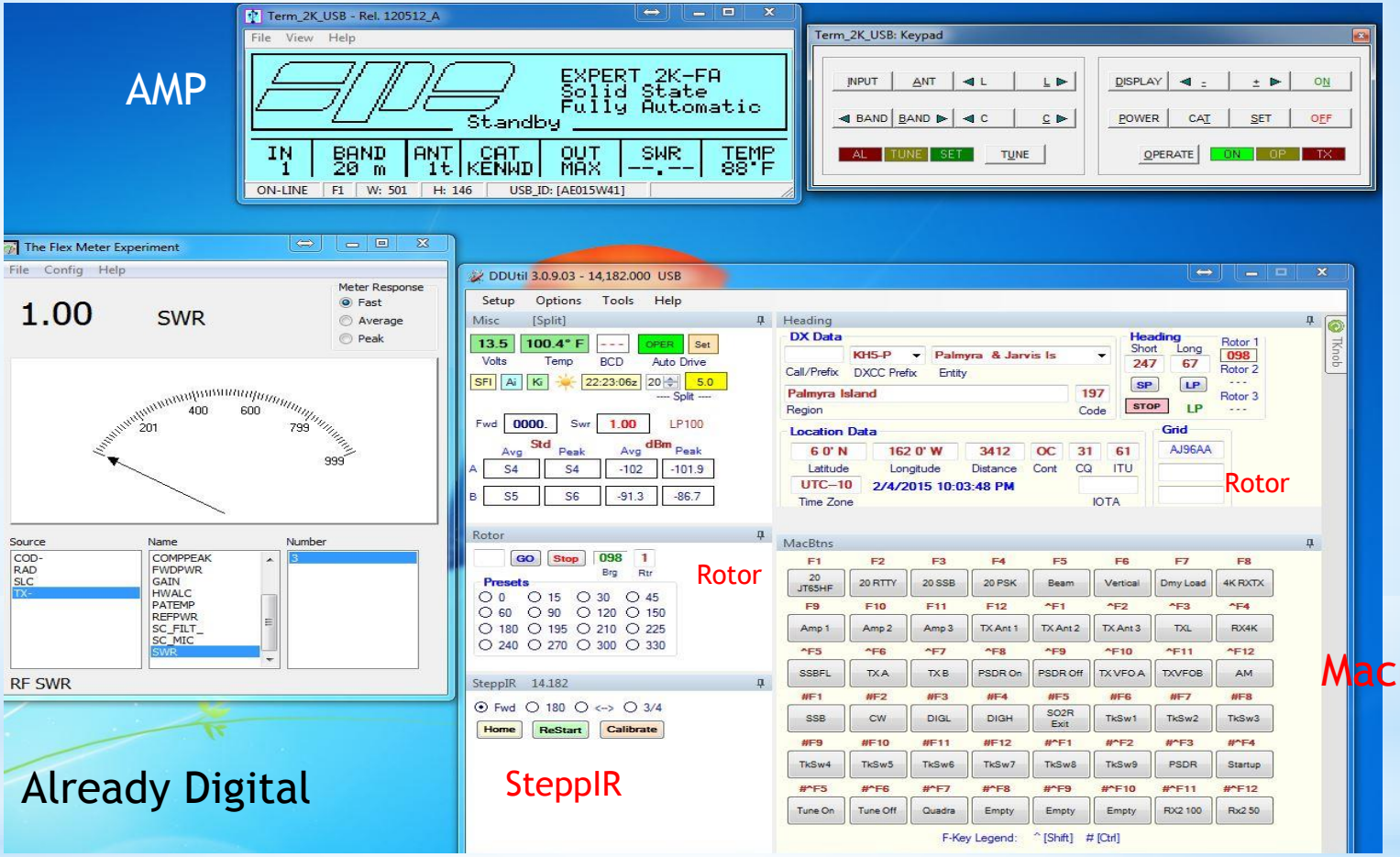
*16. SDR Easy to Use Human Interface

* Legacy – Hours of reading manual
* Legacy – Hours to Setup Correctly
* Legacy - Easy to screw up by pushing wrong button or twisting the wrong knob

* SDR - Easiest Learning Curve for Newbies
* SDR - Operational with visual interface in a Few Minutes
  - Without Reading The Manual

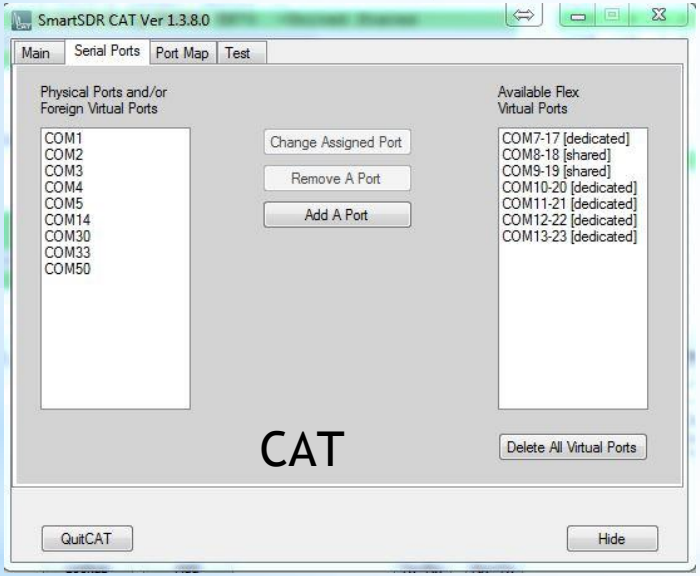
*SDR Benefits for you

*17. Easy Auto Control of Amps, Rotors, Meters, etc

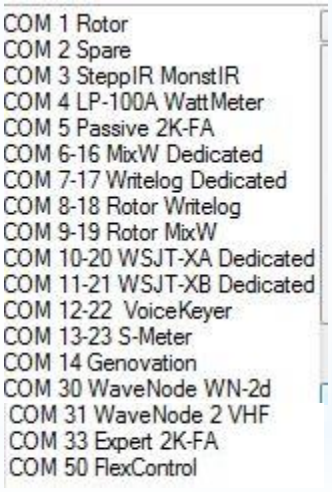


*SDR Benefits for you

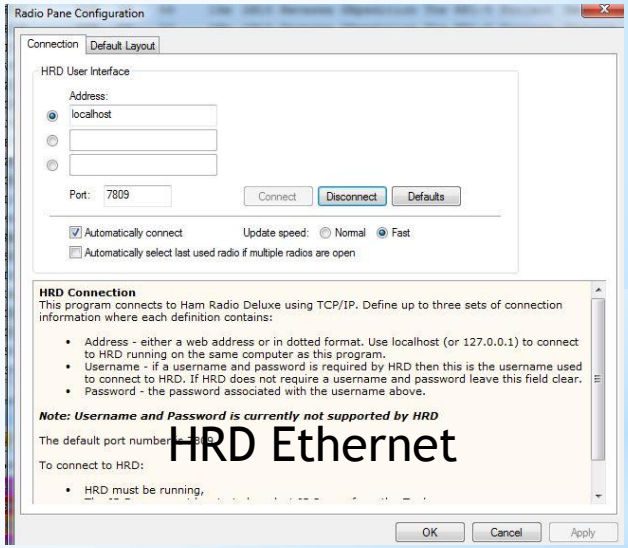
* 18. Easy CAT Interface to Logging and Digital Software
  * CAT = Computer Aided Transceiver
  * Virtual Serial Port Pairs (New Concept)
  * CAT – already digital inside the computer
  * CAT (max 115kb/s) and SDR Ethernet (1Gb/S) connections
  * Ethernet – 9,000,000 x faster connection than CAT



CAT



CAT

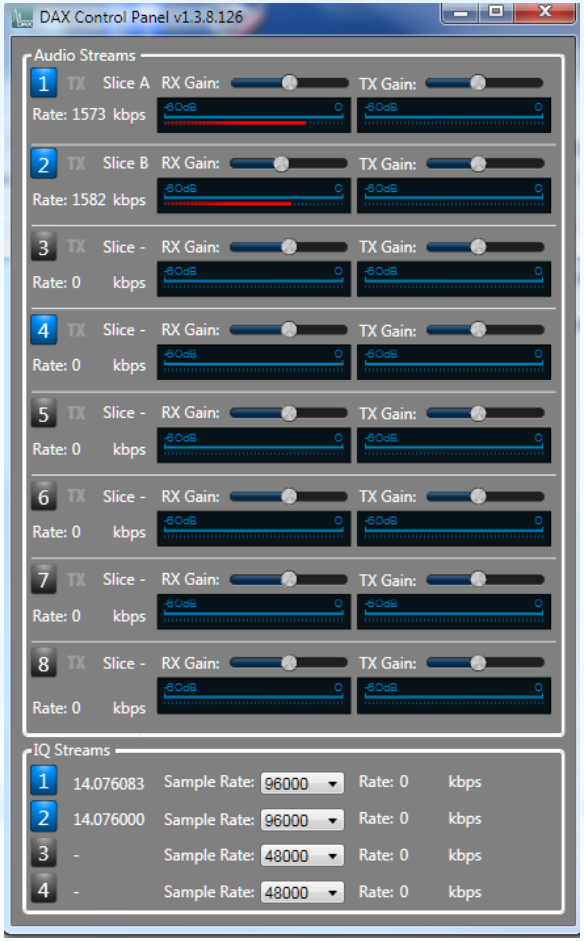


HRD Ethernet

* SDR Benefits for you

*19. Easy Audio Connections WITHOUT Cables/Interfaces

* Connect to All Digital (PSK, RTTY, WSJT) Programs inside computer
* 8 Virtual Audio Cables – Digital Audio Xchange



Up to 8 Sound Channels

Up to 4 - 192KHz Channels

*SDR Benefits for you

SDR Benefits for you

* 20. HAVING FUN!!!!!
  * SDR - CAN DO MORE THINGS THAN ANY OTHER RADIO
  * SDR - BUILT IN LAB GRADE TEST EQUIPMENT
  * SDR - ALWAYS SOMETHING NEW TO TRY
  * MOST FUN OF ANY RADIO I HAVE EVER OWNED

* LEGACY RADIOS
* 1. 1901 - Simple Detector
* 2. 1928 - Multi-conversion a.k.a. Superhetrodyne– Legacy
* 3. 1980 - Superhetrodyne with DSP
  * Your car radio, your TV, any older scanner you have
  * Most every Hilberling,Kenwood, Icom, Ten-Tec, Elecraft and Yaesu on the market today

* MODERN RADIOS
* 4. 2000- 1St Generation SDR – Direct Conversion
  FLEX-5000, FLEX-3000, FLEX1500, Elecraft KX3, Elad FDM-Duo
* 5. 2009 2nd Generation SDR – Direct Sampling External Processing
  HPSDR, ANAN-100, SUNSDR-2
* 6. 2012 3rd Generation SDR - Direct Sampling INTERNAL Processing
  FLEX-6000, ANAN-200D

*Summary of Architectures

* Unless You Trying To Start A Collection Of Antique Radios

* It Is A Total Waste Of $$ To Buy A Legacy Radio In The 21st Century

* My Opinion

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