# re-discover radio



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# SDR Advances and the Future of SDR

April 18, 2015

Phil Theis, K3TUF

Engineering, PennSun Solar

# SDR Advances

## Agenda

- What is an SDR?
- New Technologies in SDR
  - Direct Sampling
  - SmartSDR Architecture
  - Networking
  - CESSB
  - Wide and Narrow simultaneously

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# Is this radio an SDR?

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




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# Is this radio an SDR?

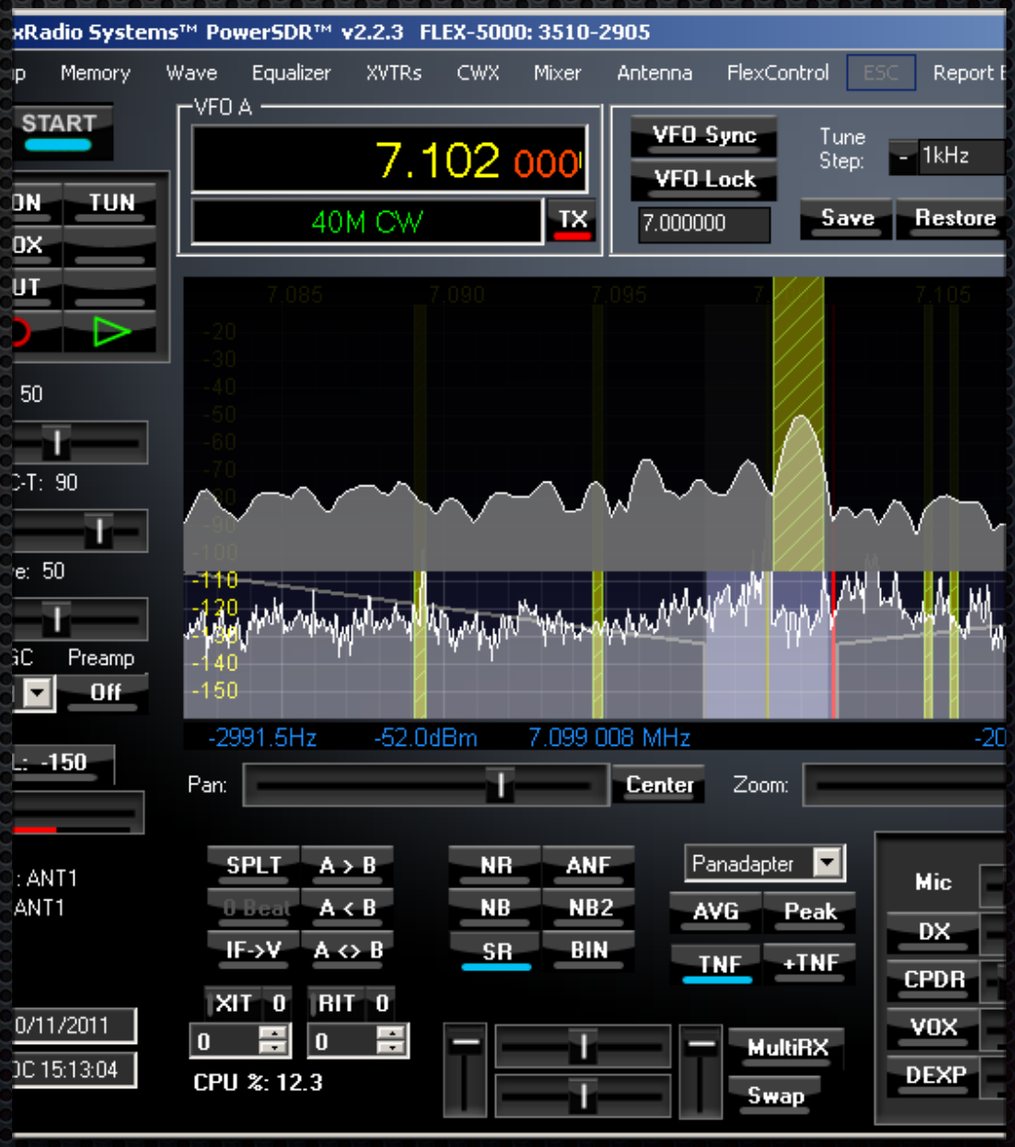
- Modulation: Fixed set
- Change Controls? No
- Change Features? Theoretically...
- User programmable? No
- Software controlled? Yes




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# 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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# Yes, yes, but: BENEFIT?

- What has SDR done for you lately?
- New mode?
- New feature?
- New controls?
- New capabilities?
- If not, who cares if it's called SDR?




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# RF Tracking Notch Filter™




**New control**

**New display**

**New DSP (inside)**

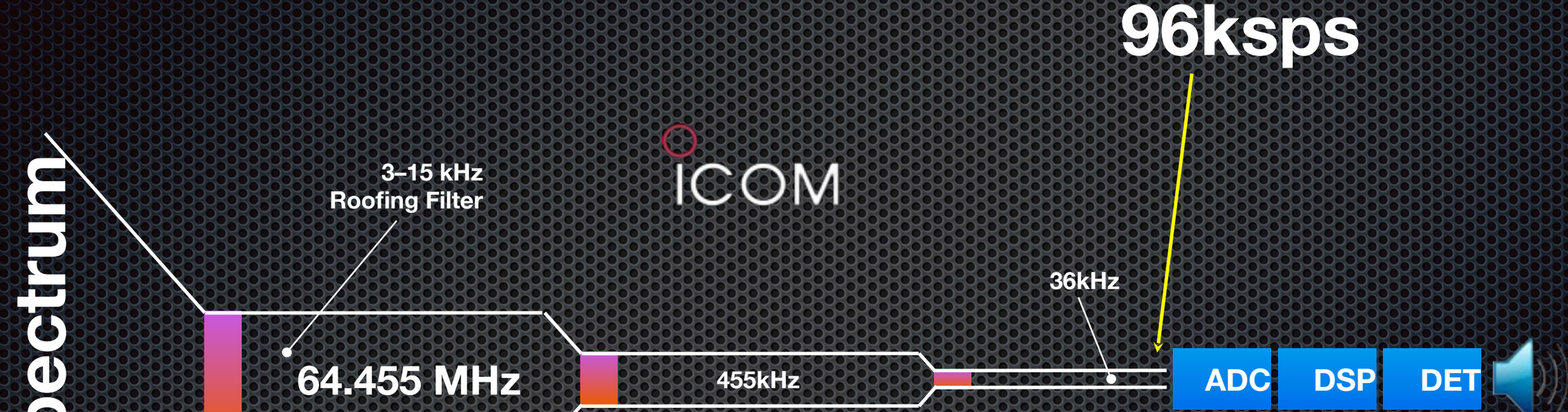



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# Radio RF/IF Architectures

- 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






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

Distortion

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# Direct Conversion



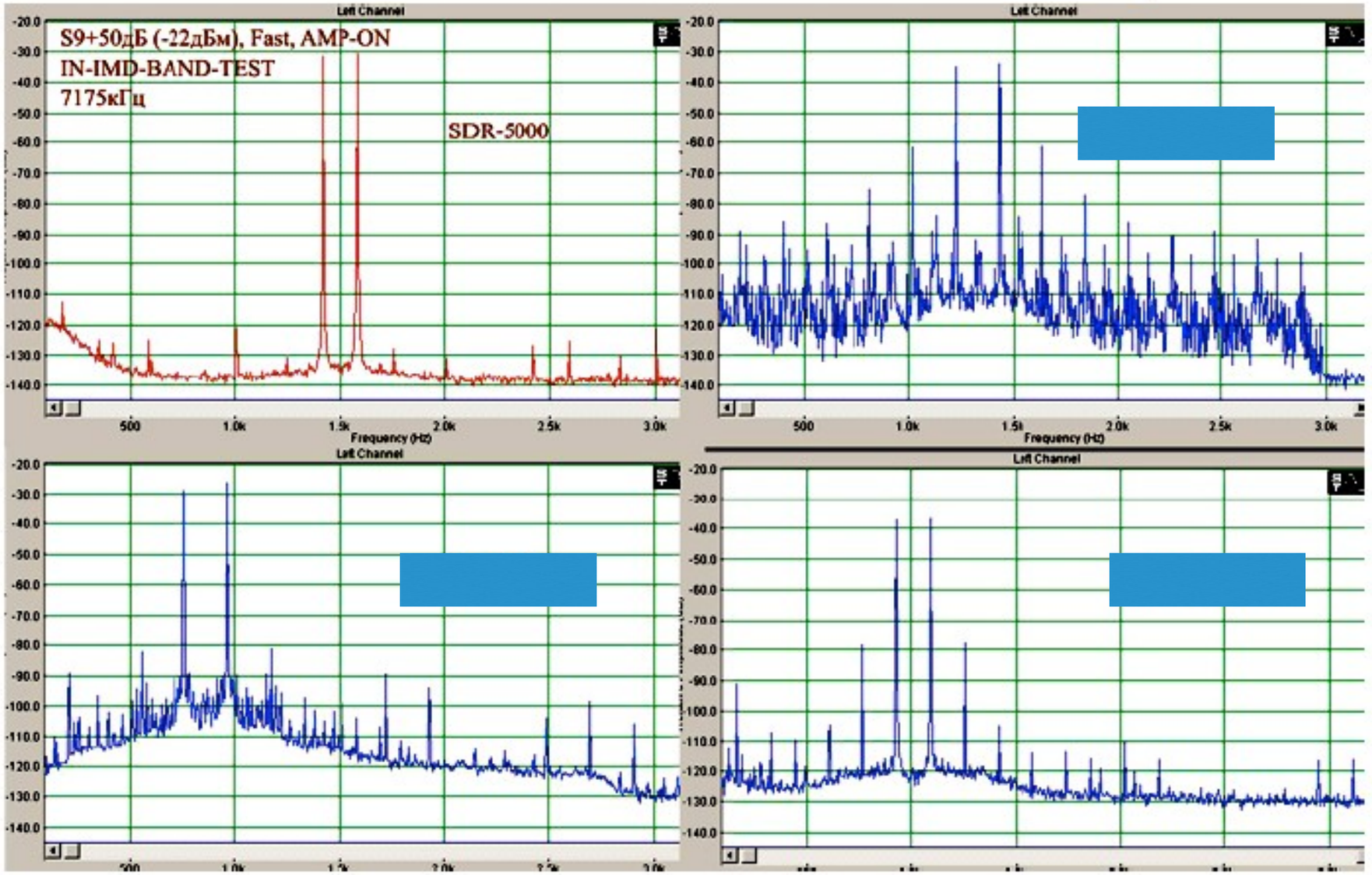




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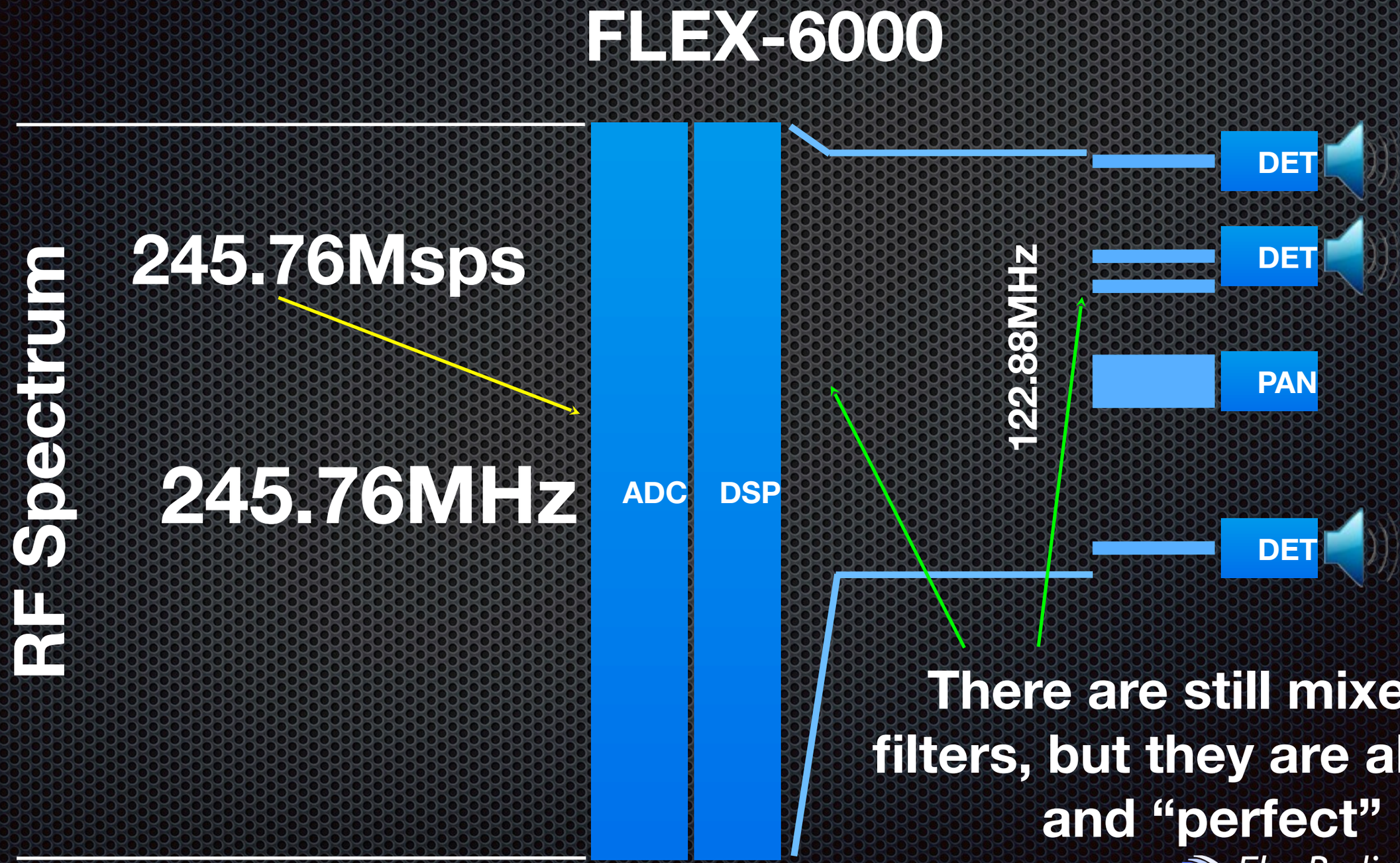
# Sherwood Engineering

## Data from UR5LAM on 4 Transceivers




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# Direct Sampling




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

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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

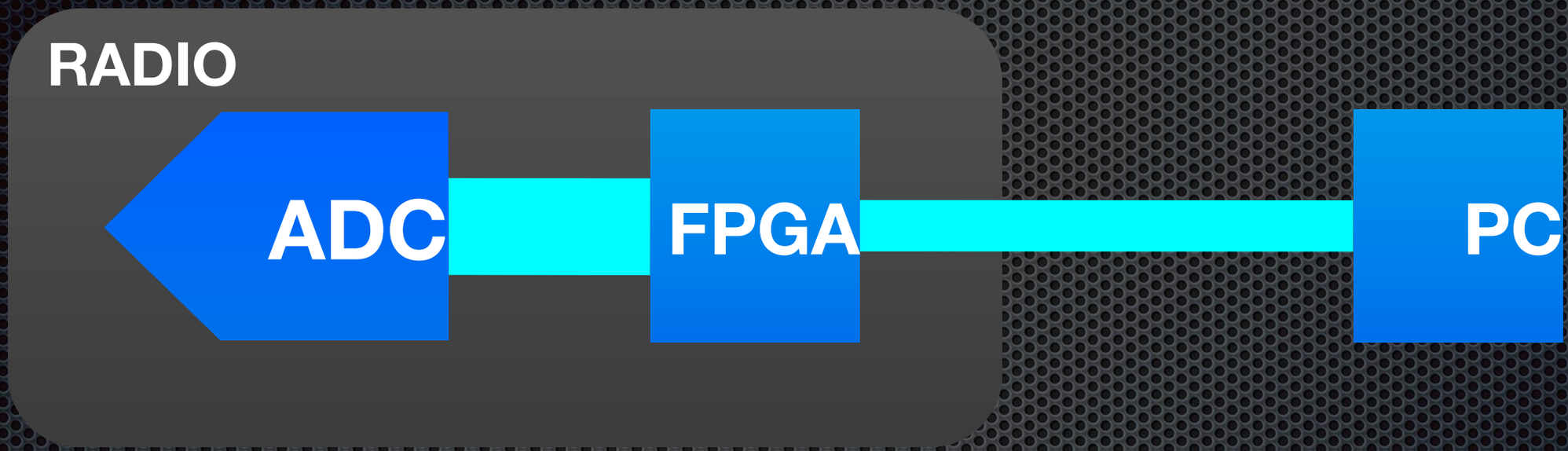
– Technically challenging to design

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We are called to be
the architects of the future,
not it's victims

—R. Buckminster
Fuller

# Design Options: #1: ADC and a hose




- Radio is ADC ⟹ FPGA ⟹ Ethernet
- Leverage PowerSDR; minimal SW investment

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# ADC and a hose: CDRX-3200



- CDRX-3200, [illegible]
- 32 Synchronous, Coherent ADCs + FPGA
- 440Mbps bandwidth
- Our customers have trouble absorbing the bandwidth

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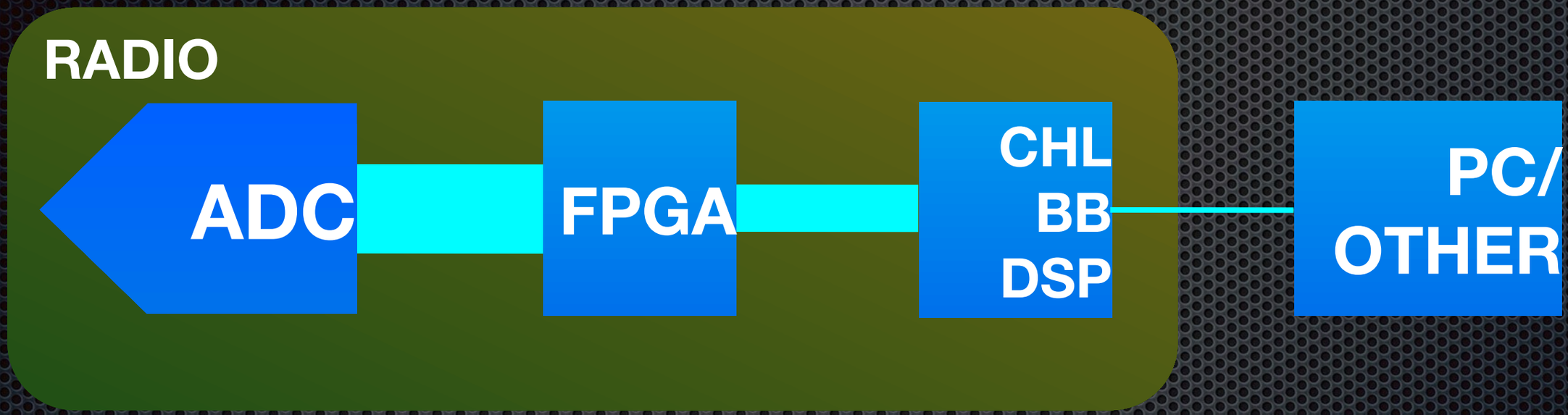
# ADC and a hose: LBRX-24



- LBRX-24, circa 2010
- 24 Microwave ADCs + 2 FPGAs
- 40Gbps bandwidth, yes Gigabit, 4x10Gb SFP+
- Our customers' PCs have memory in the 100s of GB

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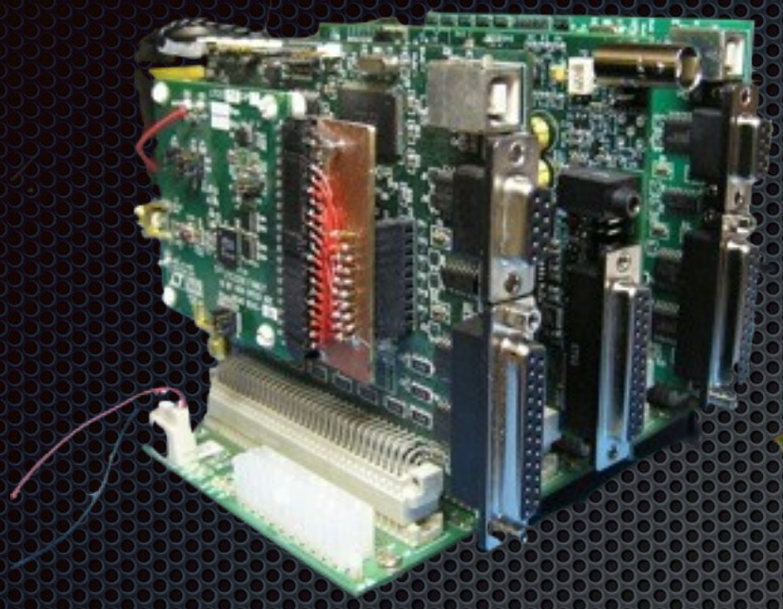
# Design Options:
# #2: ADC + FPGA + DSP/uP




- Radio reduces bandwidth to minimum before Ethernet
  - Oh gosh: start over with SW: big investment!

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# Direct Sampling Radios



HPSDR



Hermes




ANAN-100D

HPSDR

RF DSP — DSP CTRL

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# Direct Sampling Radios




## FLEX-6000

**RF DSP** — **CTRL**

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# Integrating the Baseband Processor

## Key Benefits

- Consistent performance independent of PC
- Minimized network bandwidth (think remote)
- Minimization of “system” problems
- Self-contained, rapid startup platform
- Spectrum displays (panadapter) independent of available network bandwidth
- Network optimized

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# Spectrum Display BW



1MHz
<500kbps



10MHz
770Mbps

1500:1
Bandwidth
Difference

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# Long Ago, People Danced @ Concerts, Now They Video / Click / Share / Tweet…

**1990s**



**2010s**





Source: Left image – 123RF.com. Right image – amadarose.co.uk.

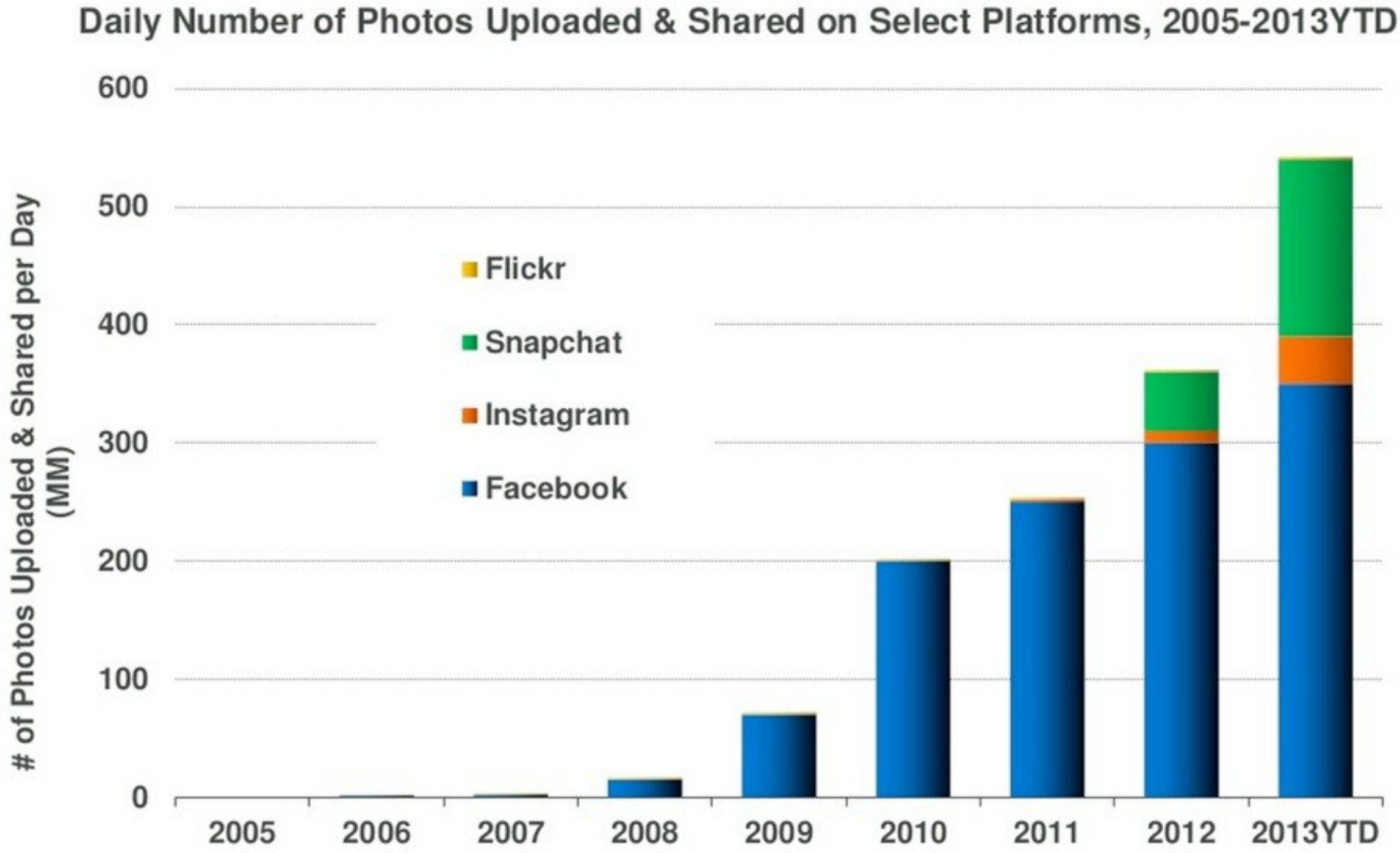
# Media + Data Uploading + Sharing from Mobiles = Ramping Fast & Still Early Stage

| First | Now | Next | Next |
|---|---|---|---|
|  |  |  |  |
| PHOTOS | VIDEO | SOUND | DATA |
| **Explosive Growth, But Still Early Stage** | **Ramping Very Fast** | **Emerging** | **Emerging** |

KPCB

Source: Far right Illustration – Eric Prommelt.

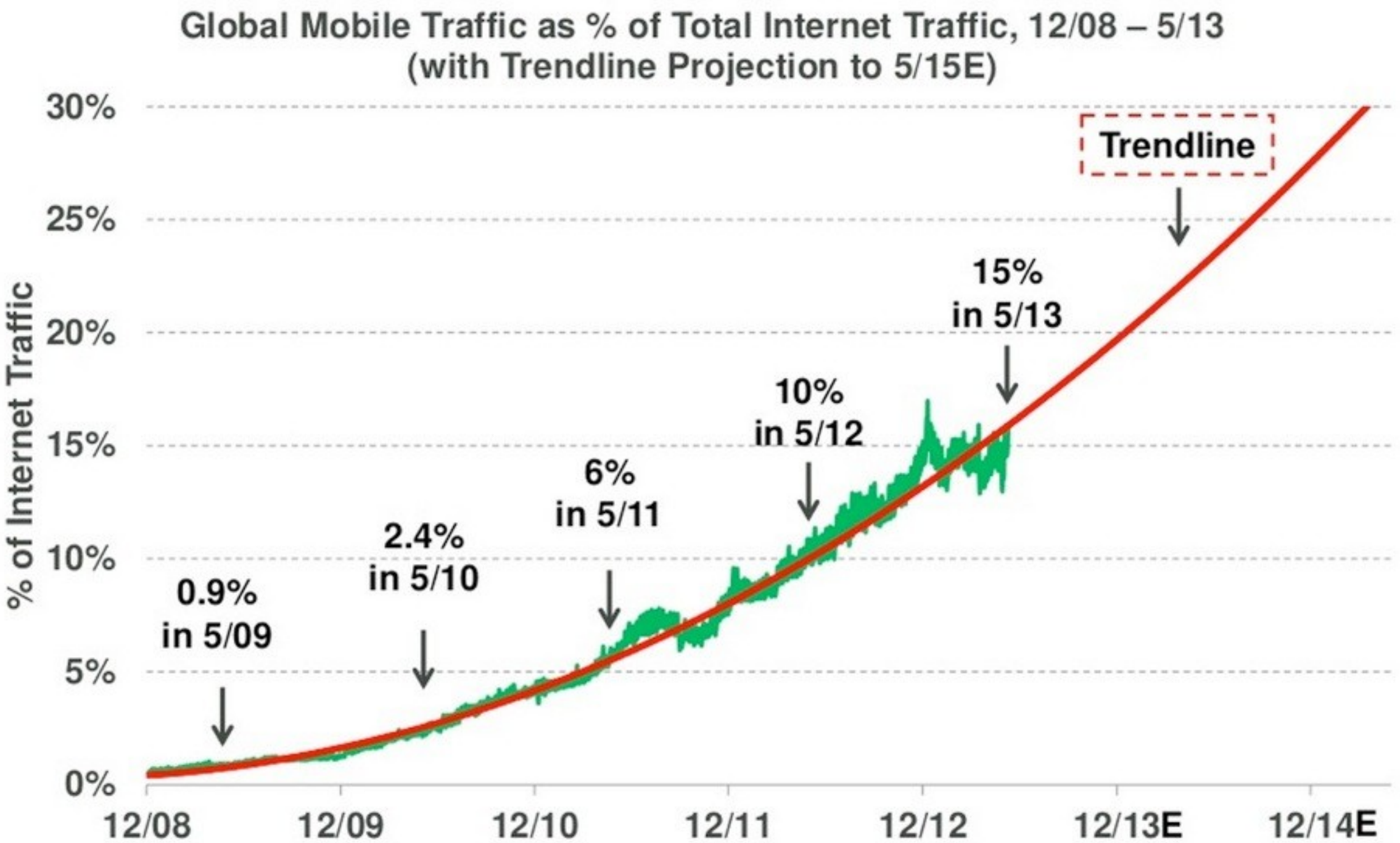
# **Photos** = 500MM+ Uploaded & Shared Per Day, Growth Accelerating, on Trend to Rise 2x Y/Y…




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Source: KPCB estimates based on publicly disclosed company data.

# Mobile Traffic as % of Global Internet Traffic =
## Growing 1.5x per Year & Likely to Maintain Trajectory or Accelerate

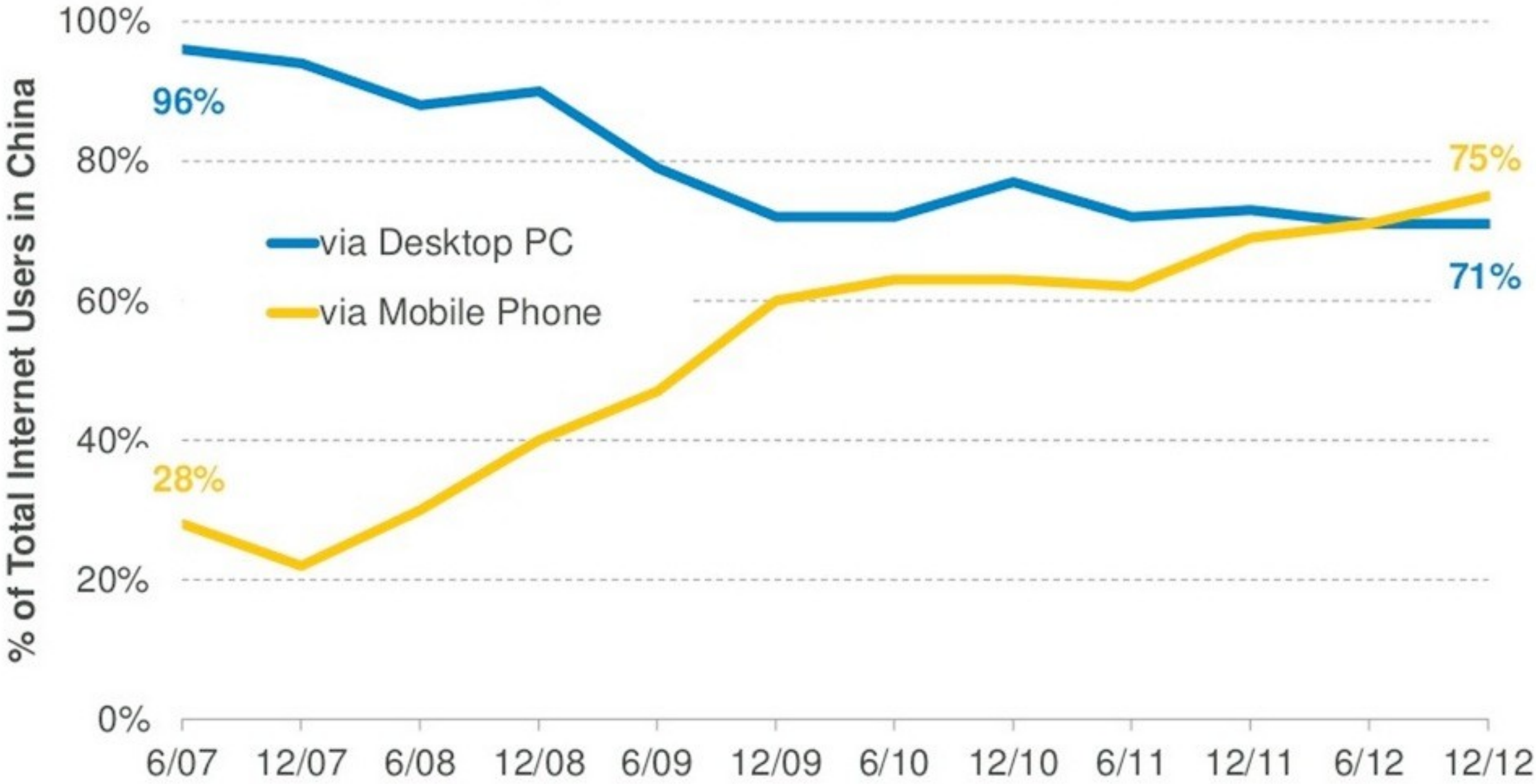



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Source: StatCounter Global Stats, 5/13. Note that PC-based Internet data bolstered by streaming.

# China –
## Mobile Internet Access Surpassed PC, Q2:12

**% of Chinese Internet Users Accessing the Web via Desktop PCs vs. via Mobile Phones, 6/07 – 12/12**




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Source: CNNIC, 1/13.

# A Car or a Computer on Four Wheels?








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# Networking

EVERYTHING is moving to the network.

You can TAKE YOUR FUN WITH YOU

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# What is a contact?

- You’re at your QTH and you work Christmas Island




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# What is a contact?

- You're trade emails with the operator of T32C on Christmas Island.  His email says "You are 599 here!"




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# What is a contact?

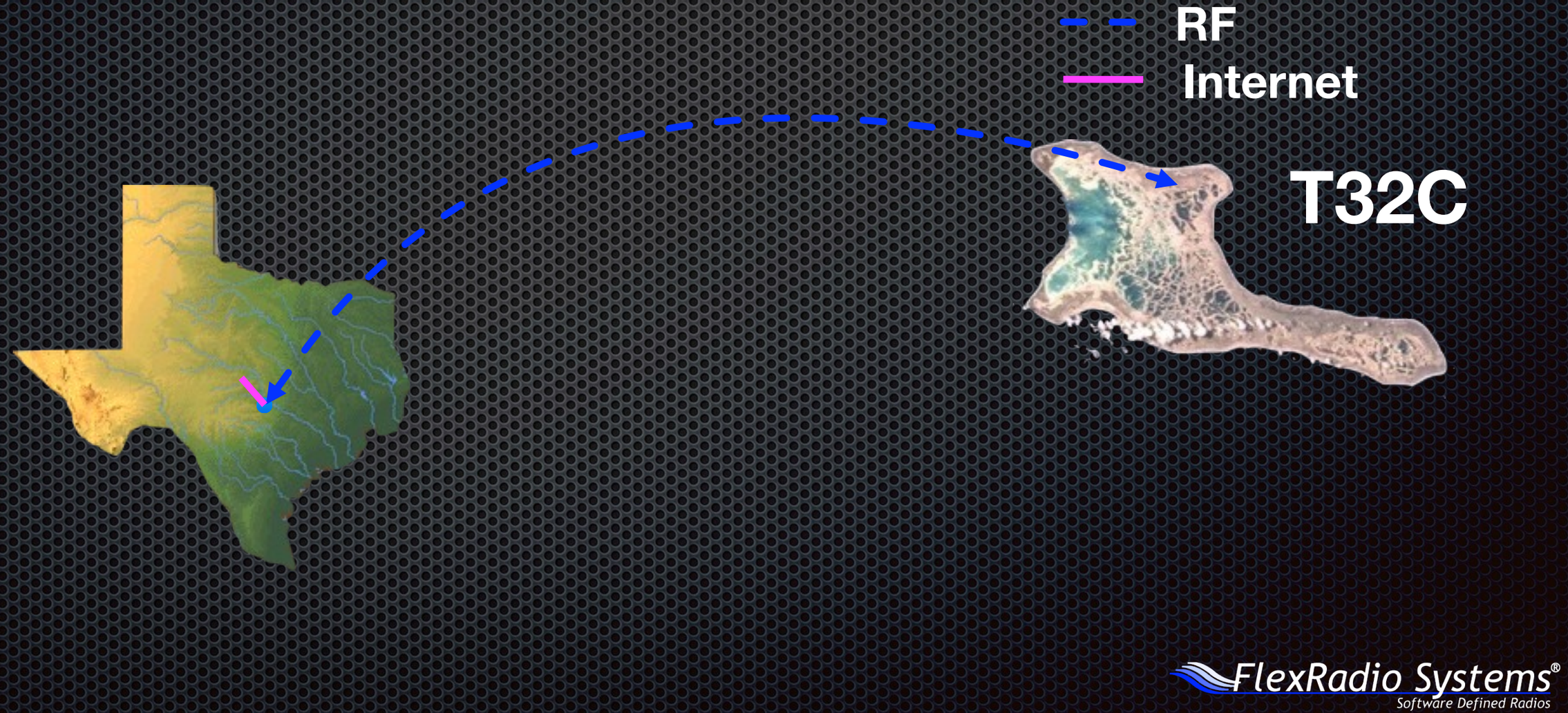
- You talk to Christmas Island using your local 2m repeater and EchoLink




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# What is a contact?

- You're at the store and you remote control your home station to work Christmas Island




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# Does your radio need THIS?



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# Does your radio run HERE?



# T/F: Rare DX is convenient

## Where's your operating position?





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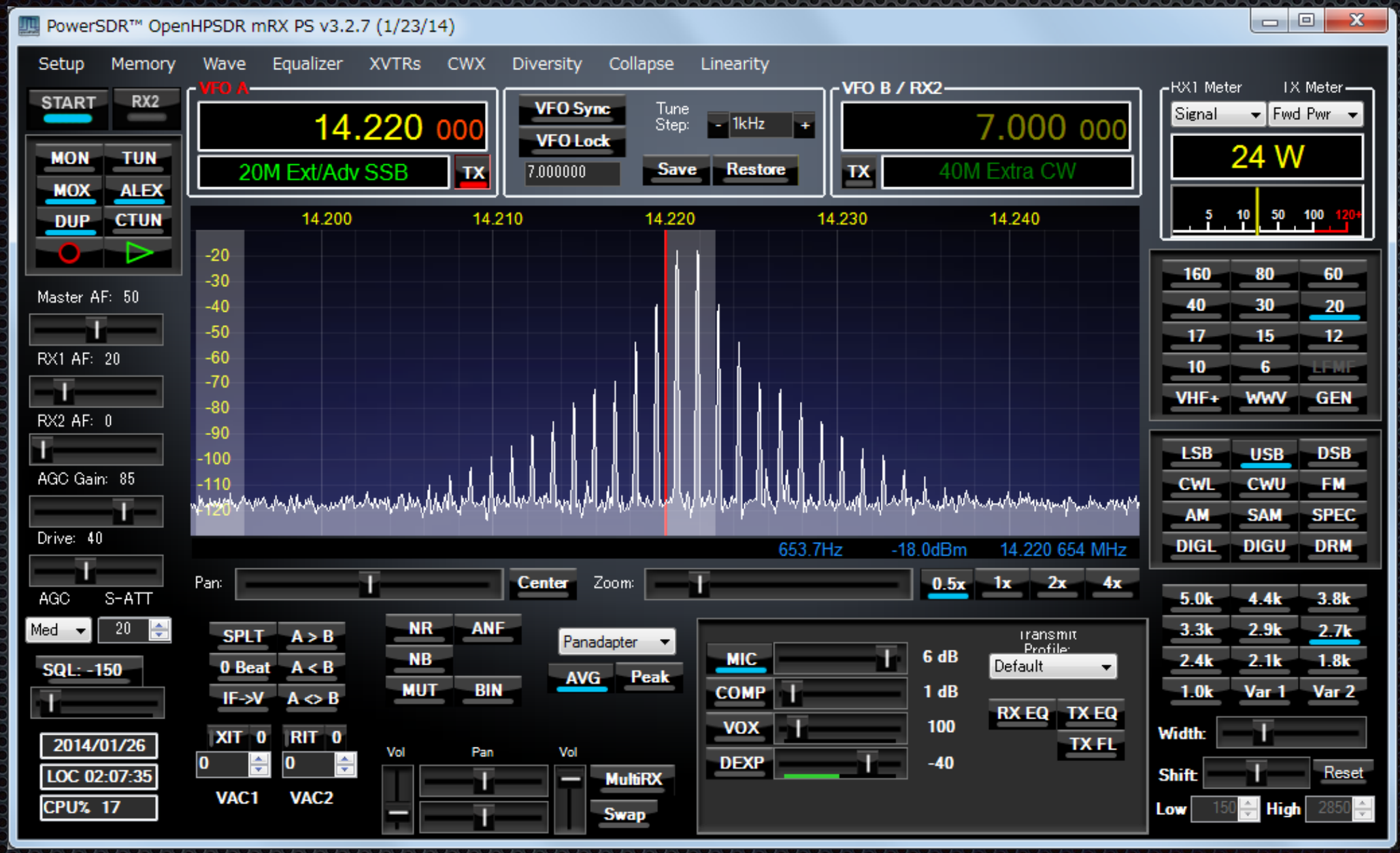
# Adaptive Predistortion

- Power Amplifiers: Nonlinearities
  - Designs have improved
- What if we knew in advance of the PA?
  - Could we correct?
- HPSDR: Pure Signal

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# Predistortion

## Before




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# Predistortion

## After




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# Phase Noise

- Affects both RX and TX interference capabilities
- Oscillator phase noise getting better every year
- Direct Sampling radios demanding
- Take a look at the all FLEX-6000 Thunderbird FD

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# Low Phase Noise

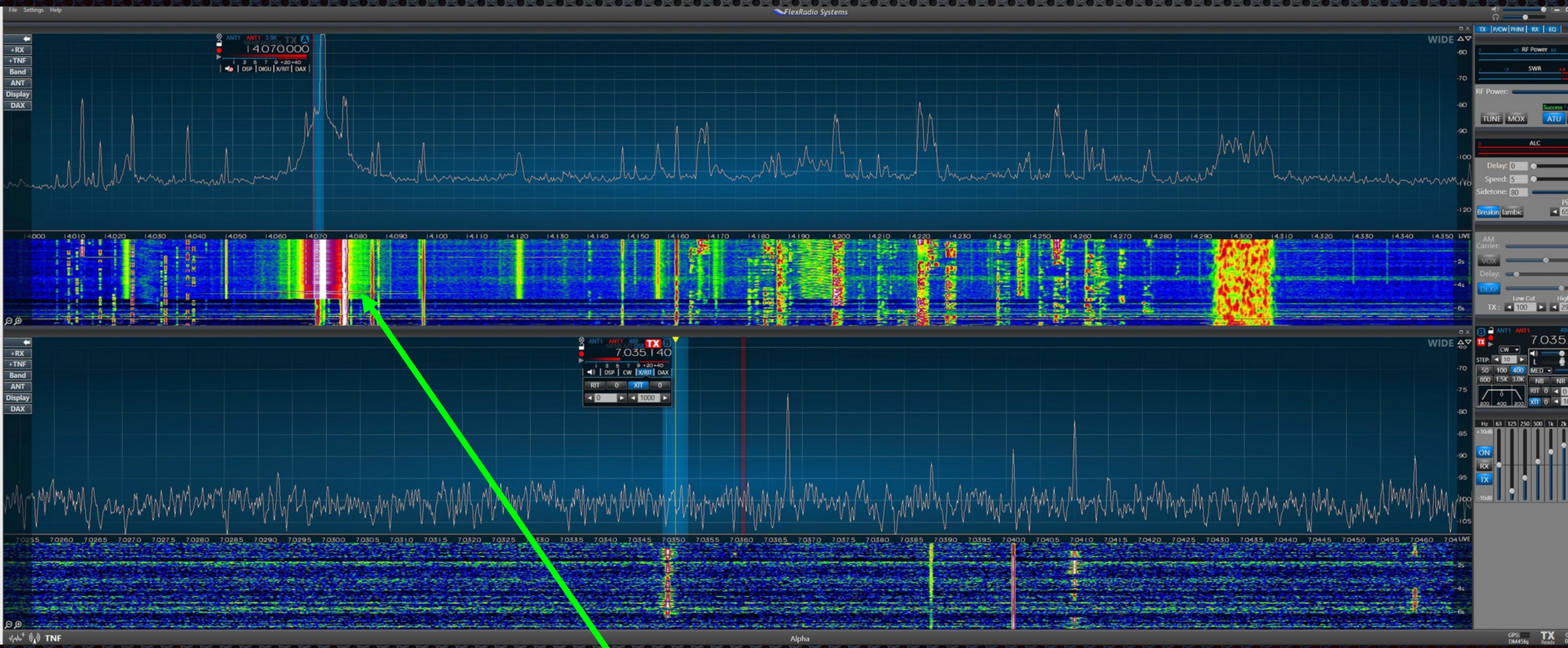
## Field Day




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# Low Phase Noise

## Field Day




## 100W PSK31

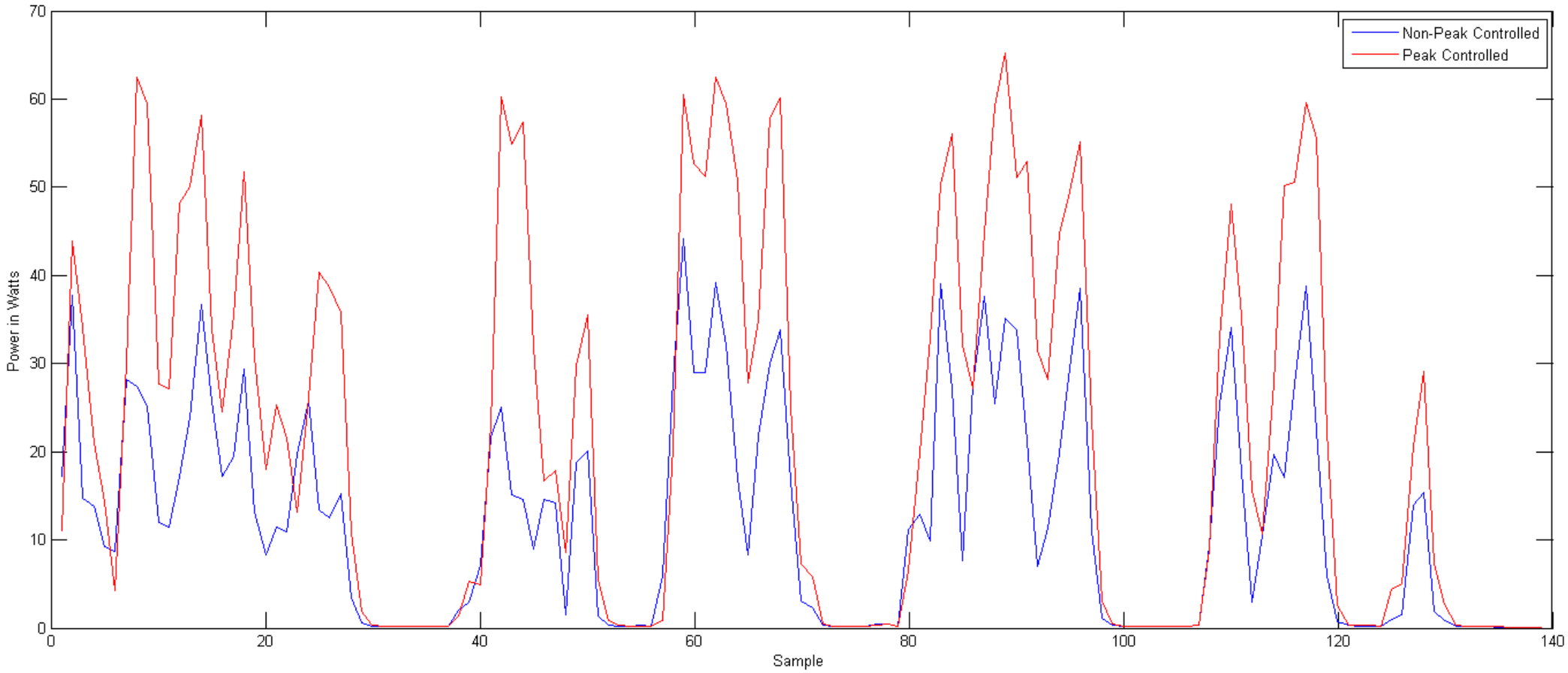
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# Speech Processor (CESSB)

- David Hershberger, W9GR, approached us at Dayton 2013
- Algorithm implemented in SmartSDR + on-air testing
  - Excellent speech and a ~2.5dB power improvement
- Results and algorithm to be published in QEX later this year




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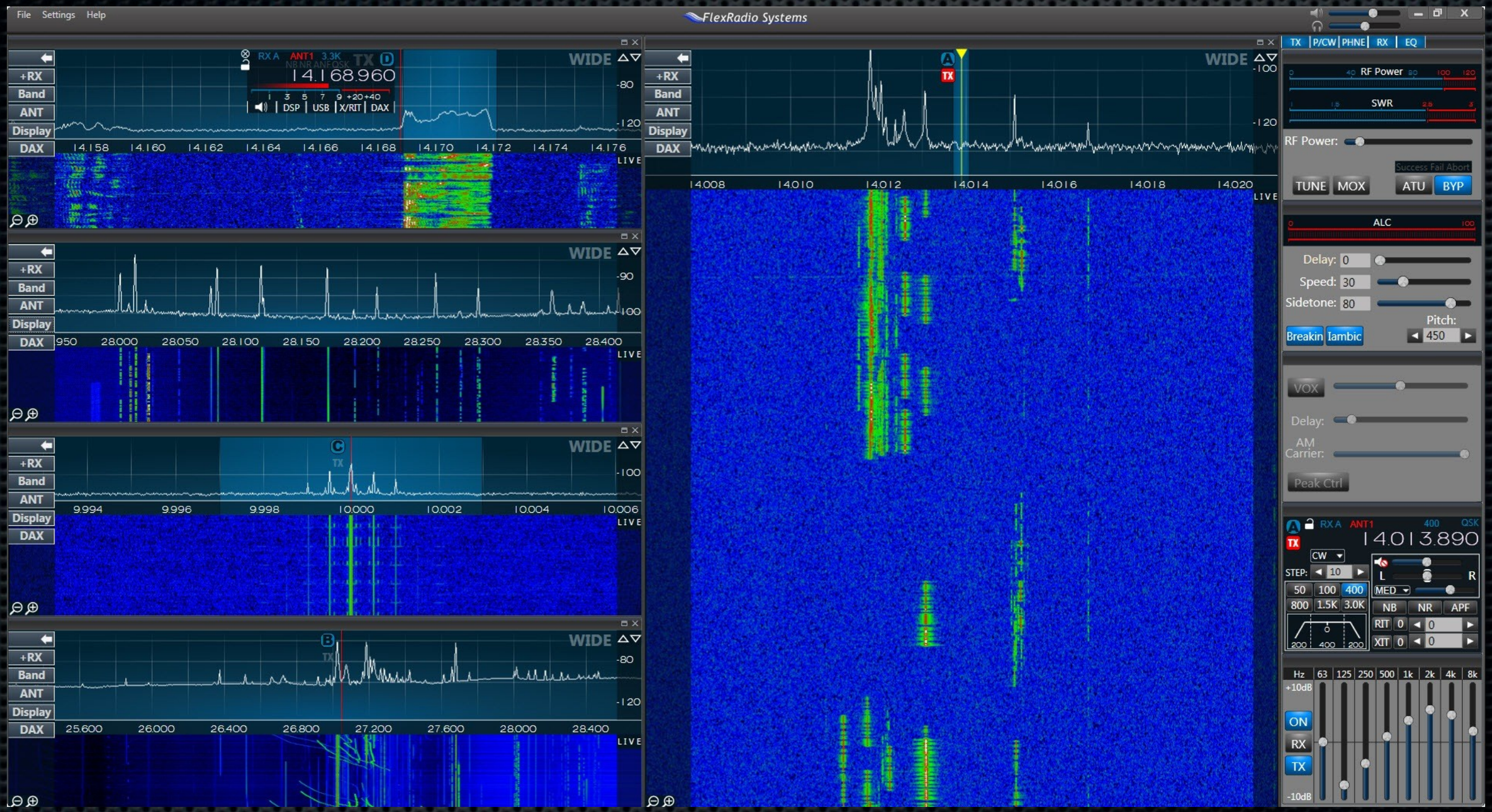

Non-Peak Controlled
Peak Controlled
Power in Watts
Sample
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140

# Many data streams at once

- FLEX-6700
- 8 narrow-band 24kHz receivers
- 8 panadapters
- 4 wide-band (192kHz) I/Q streams for skimming

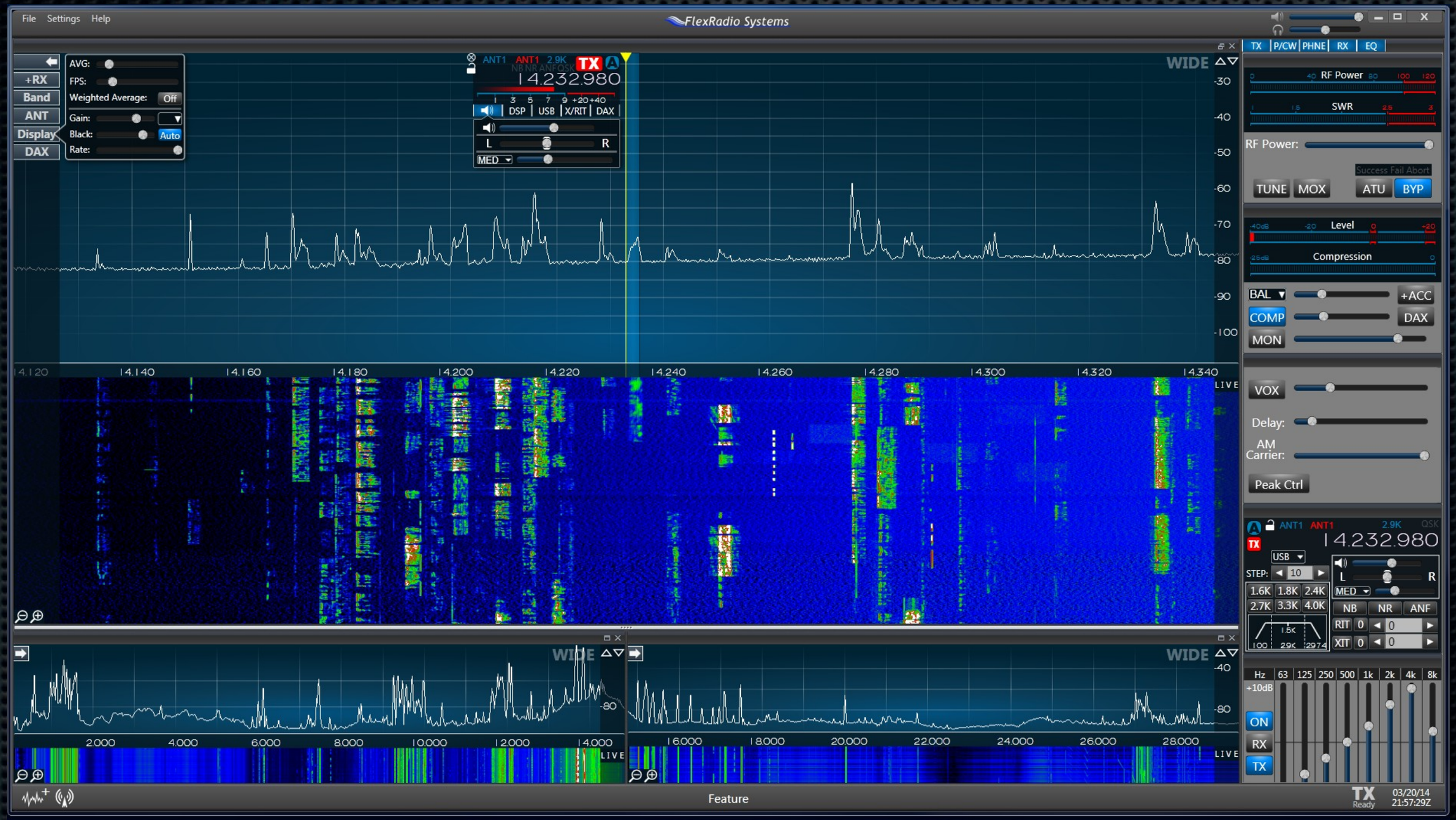
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# Multi-mode Waterfall



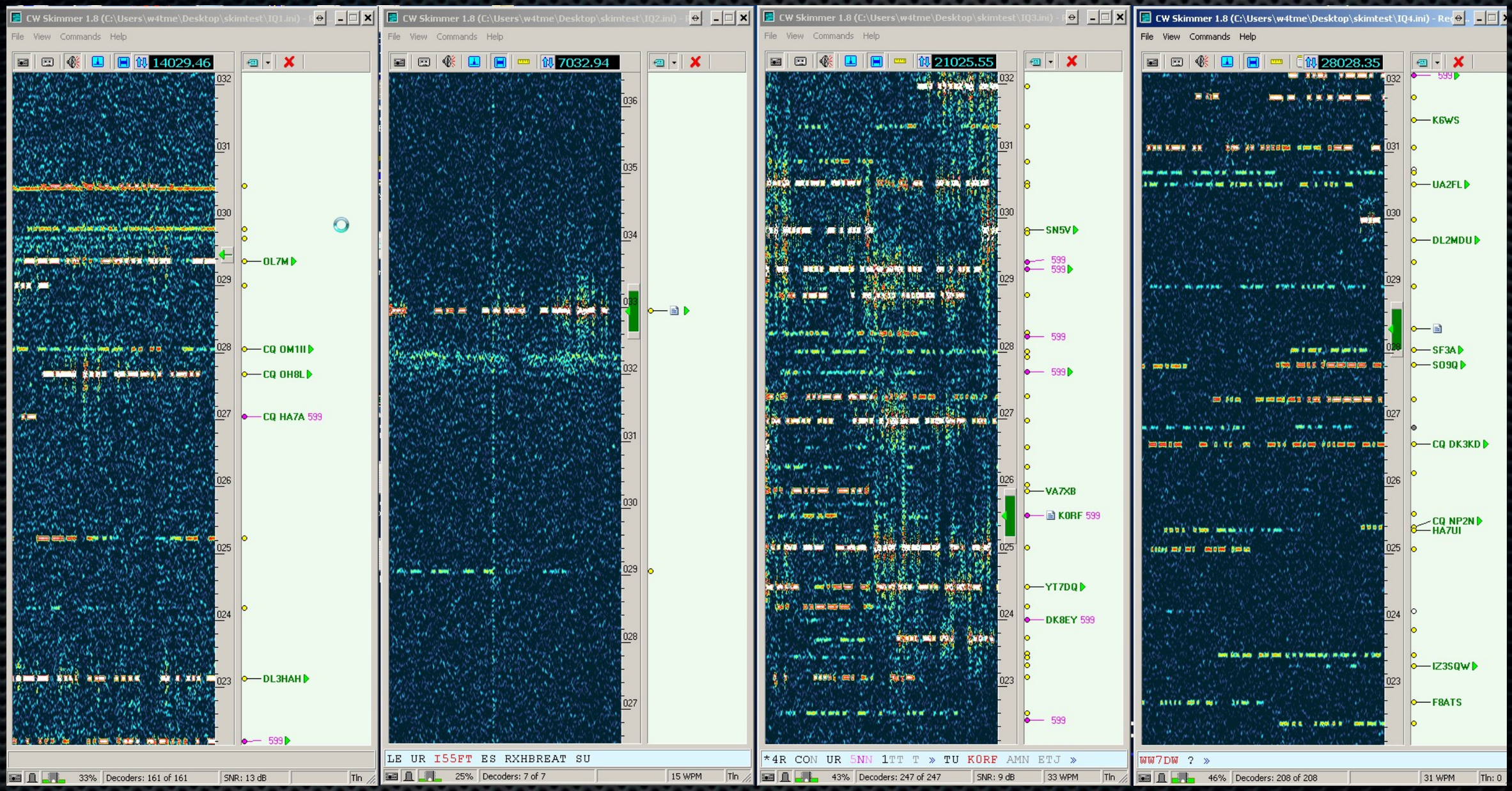

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# Waterfall plus Bandscope



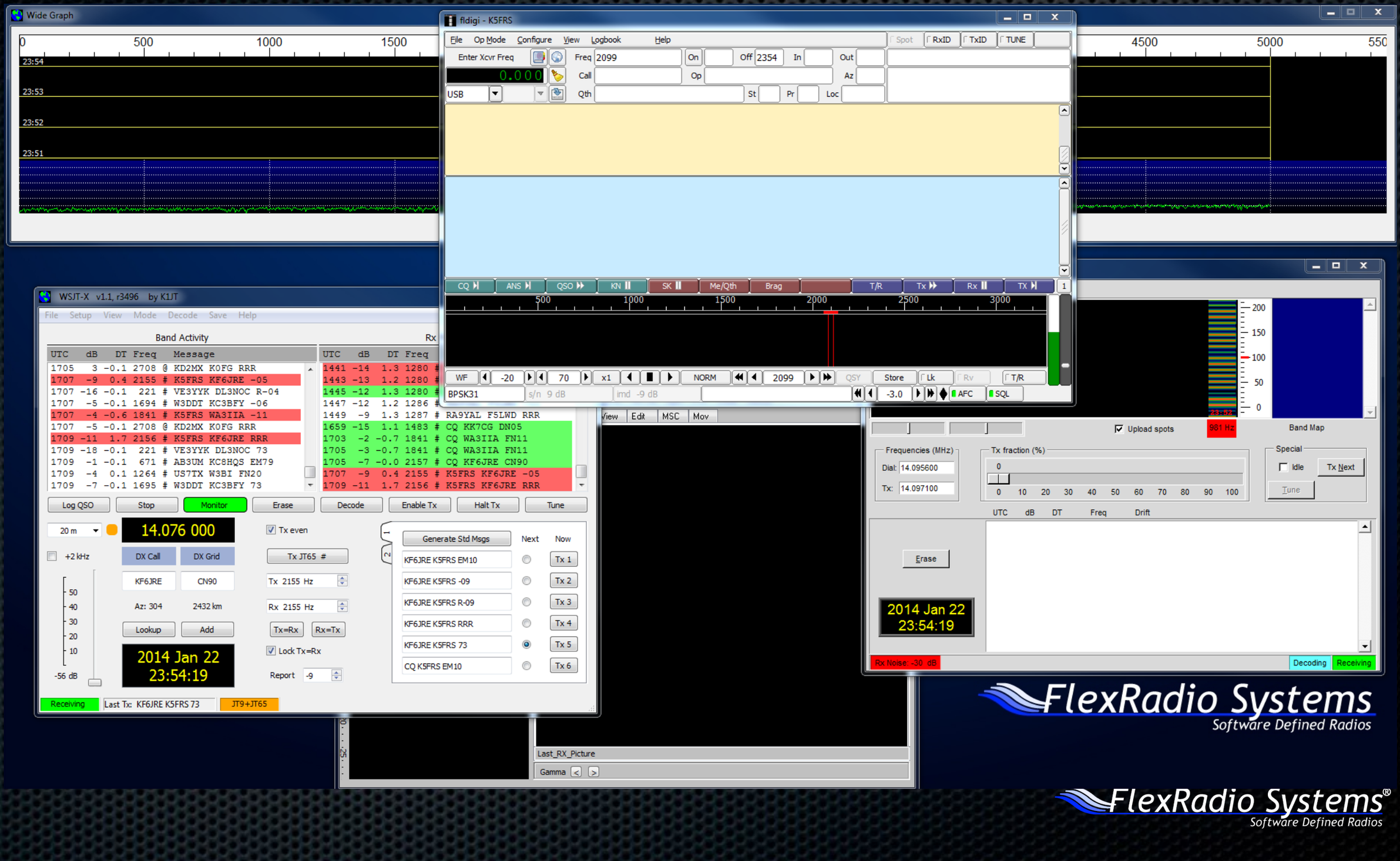

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# CW Skimmer x4




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# Digital Modes




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FLEX 6000
with SmartSDR™
Never before in amateur radio has the advanced operator been given the ability to be on so many bands at the same time. Check into your favorite
while watching for a far away

CW Skimmer 1.71 - Registered to
File View Commands Help

DAX Control Panel v1.0.3.189
Audio Streams
1 TX Slice - RX Gain: TX Gain: Rate: 0 kbps
2 TX Slice B RX Gain: TX Gain: Rate: 1573 kbps
3 TX Slice - RX Gain: TX Gain: Rate: 0 kbps
4 TX Slice - RX Gain: TX Gain: Rate: 0 kbps
5 TX Slice - RX Gain: TX Gain: Rate: 0 kbps
6 TX Slice D RX Gain: TX Gain: Rate: 1582 kbps
7 TX Slice - RX Gain: TX Gain: Rate: 0 kbps
8 TX Slice - RX Gain: TX Gain: Rate: 0 kbps
IQ Streams
1 14.034420 Sample Rate: 96000 Rate: 6336 kb
2 - Sample Rate: 48000 Rate: 0 kb
3 - Sample Rate: 48000 Rate: 0 kb
4 - Sample Rate: 48000 Rate: 0 kb

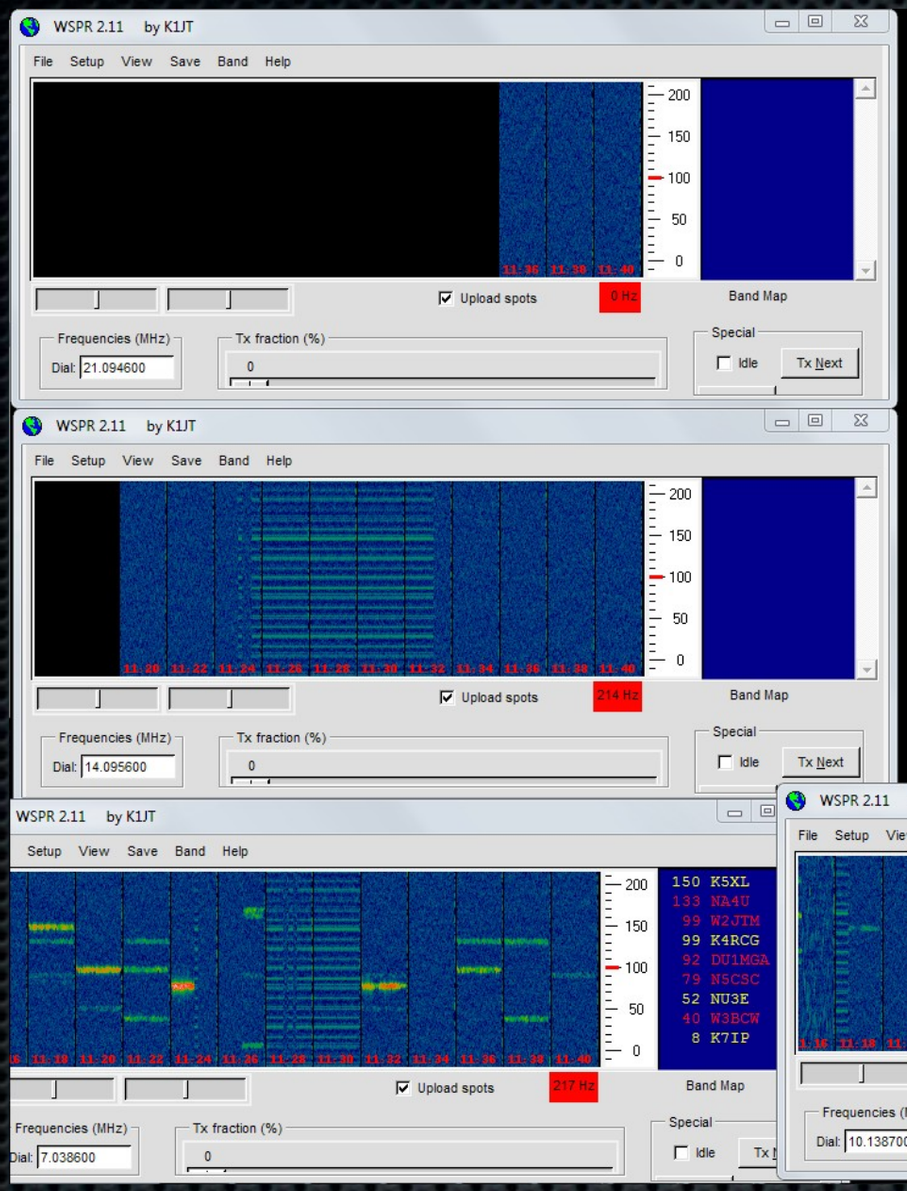
SmartSDR v1.0.4

Digital Master 780 - [SuperSweeper]
File Edit View QSO Browser Logbook SSTV SuperSweeper World Map Tools Window Help
QSO SuperSweeper Radio Soundcard Waterfall Rig Control Logbook Rotator Program Options
06:53:03
Full Screen
BPSK-31 SuperSweeper
BPSK-31 Restart Redraw History QSO Alarms Options
80m 40m 30m 20m 15m 10m 6m Faves
History
KG4TTQ
cfm, gl= gdxp 73! J3LtDE RAaM7CM OM7tta mtki" pt 3on ya ana rANK
2EØHEF
F Tnx for aall YouOR is 589 589 with QSnSB iMy na Janis Ganis QT
G4MUL
NNA 1 VERTAL 5V 2 DELTA 84M SOFTWE: MIXW 2.1-tREG OP 1958/1976 D
Active: 6/20 Hold: 20 secs Rewind: 10 secs Decoder: 0% Overload 06:53
Ready CPU: 1% Audio: 9% Overload HRD Logbook: Not Connected RSID OVR CAP NUM SCRL

fldigi - K5FRS
File Op Mode Configure
Enter Xcvr Freq
0.000
USB
CQ ANS QSO KN SK Me/Qth Brag T/R Tx Rx TX
WF -20 70 x1 NORM 817 QSY Store Lk Rv T/R
BPSK31 s/n 2 dB imd -31 dB AFC SQL

6:53 AM
1/25/2014

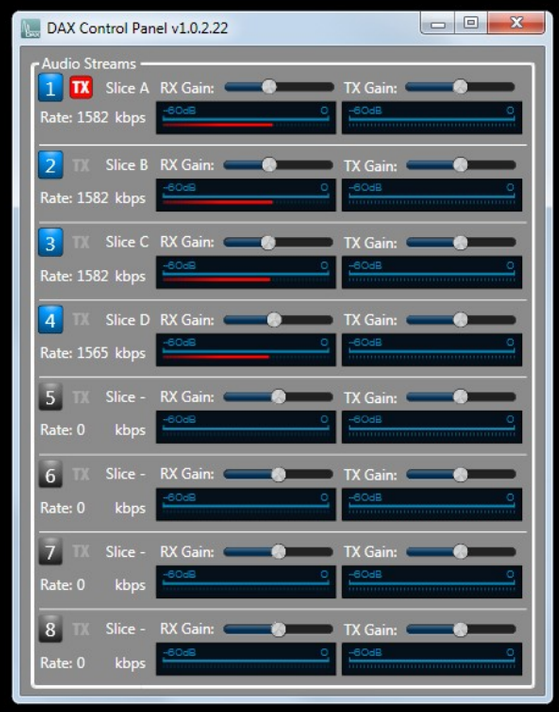
# WSPR times 4!

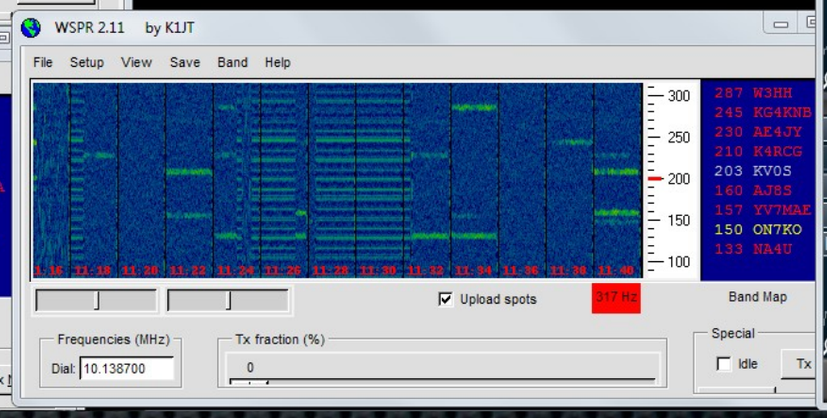


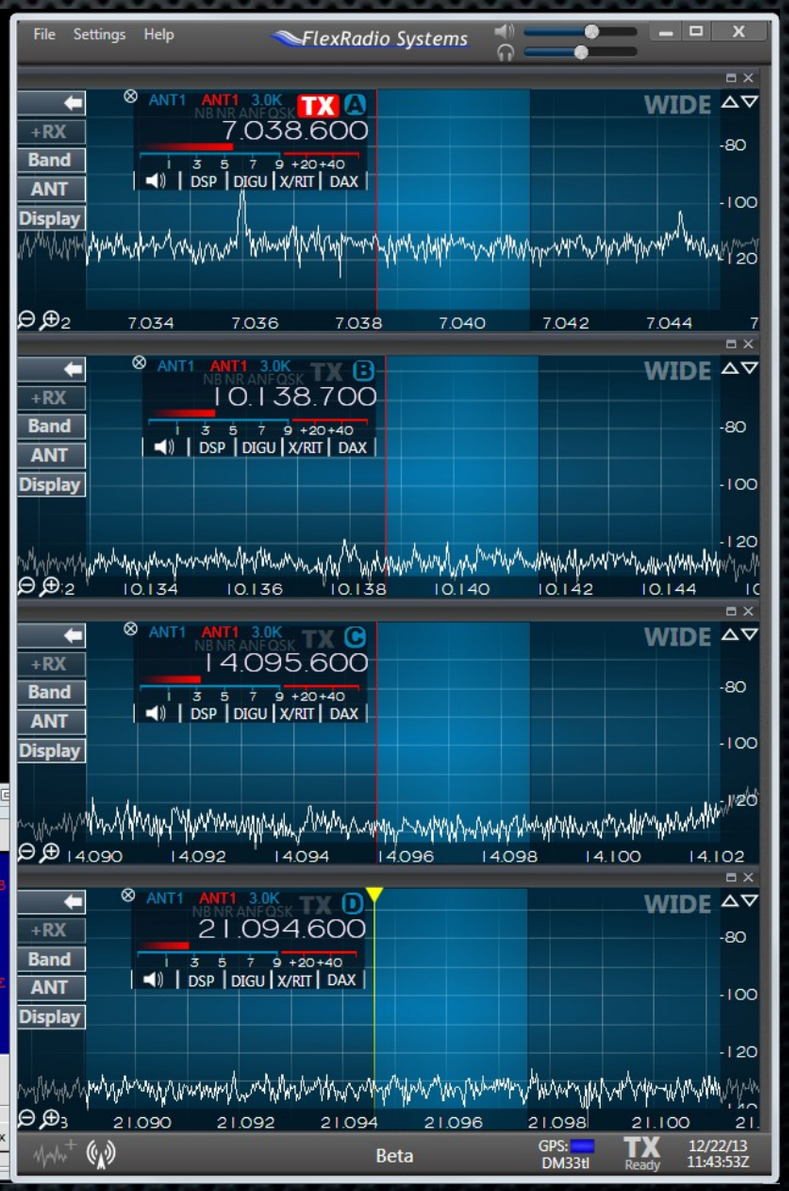






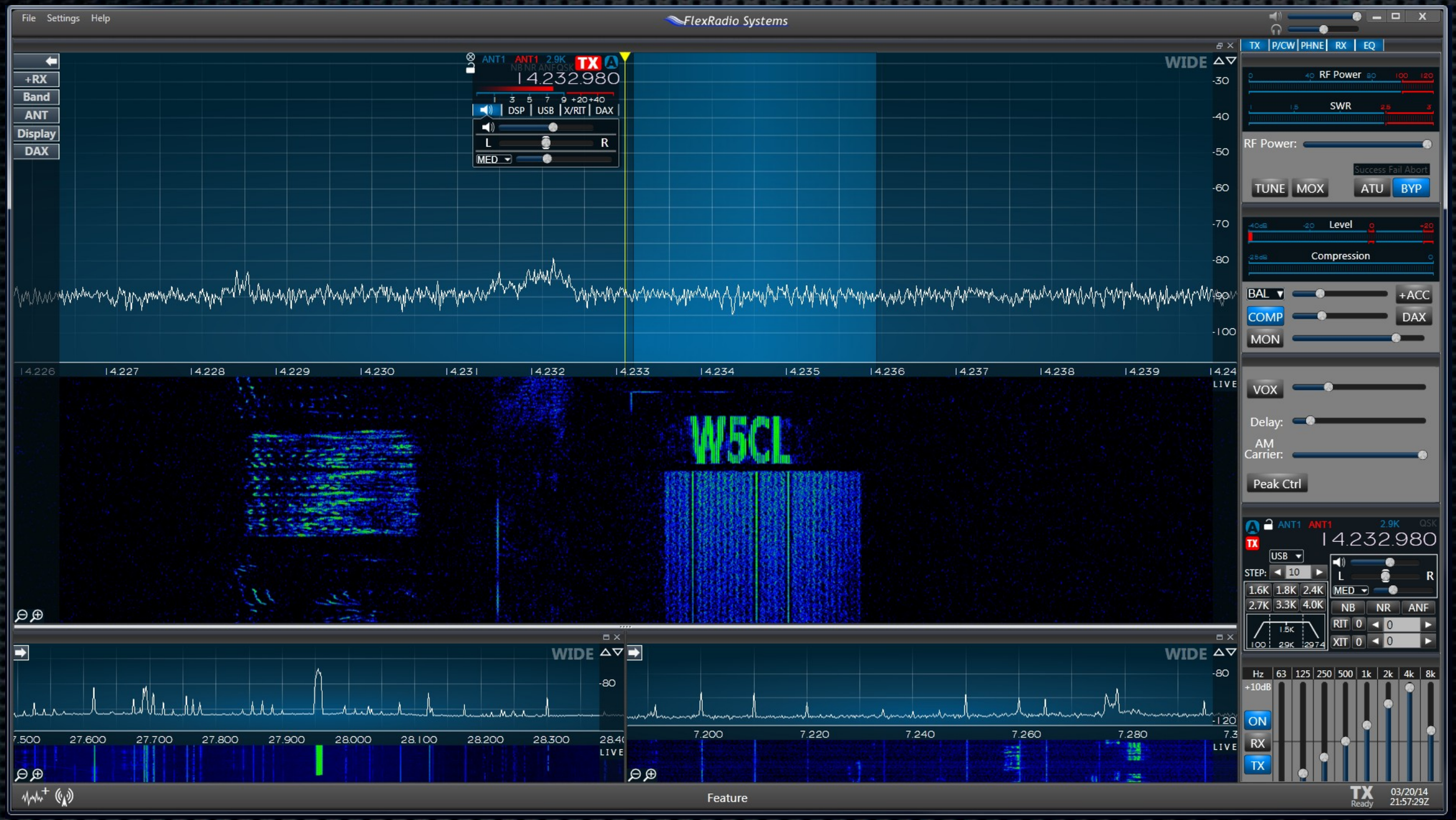



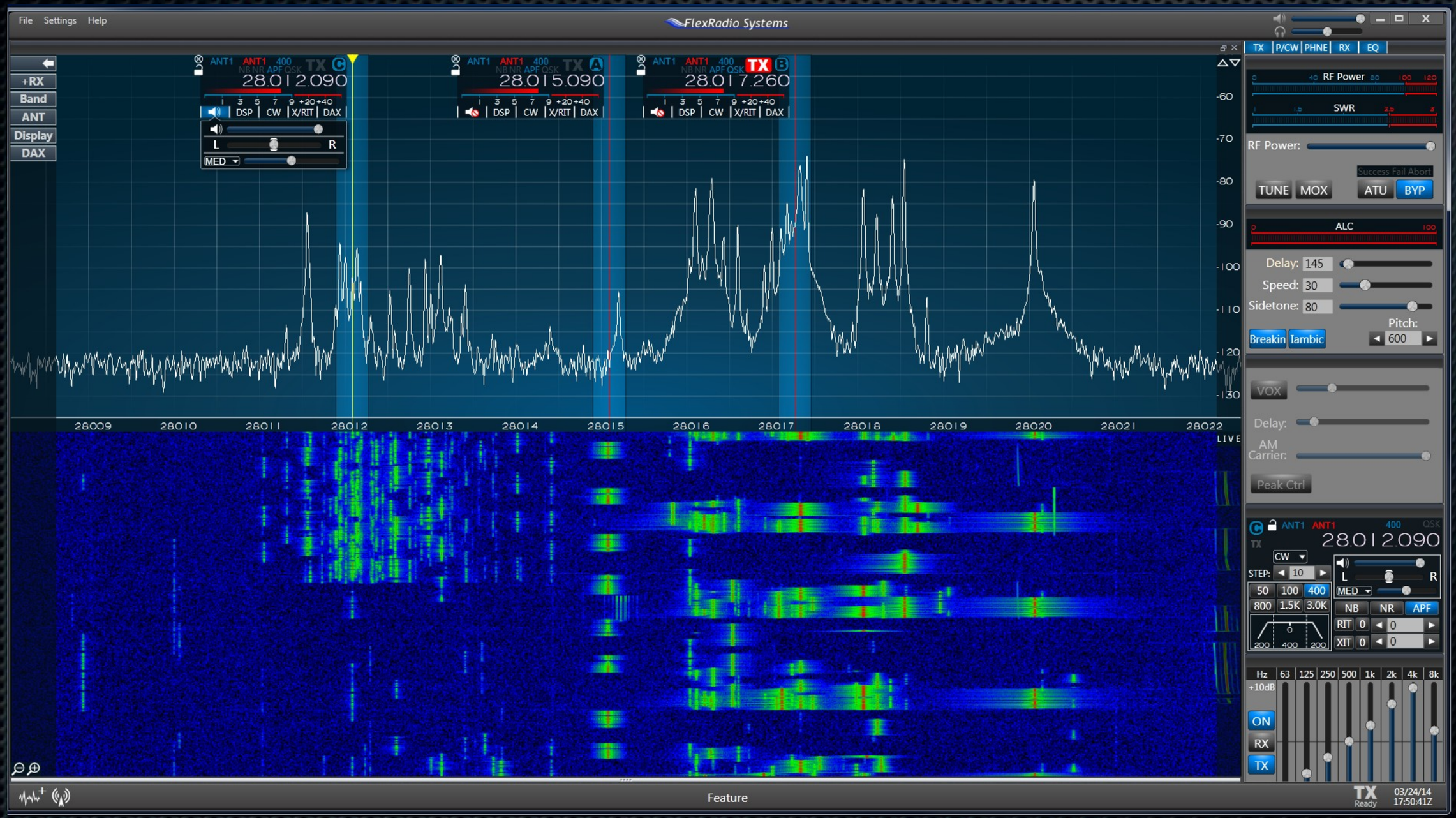

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# EasyPAL




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# TX6G: A Picture is worth 1,000 words




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# The Future:

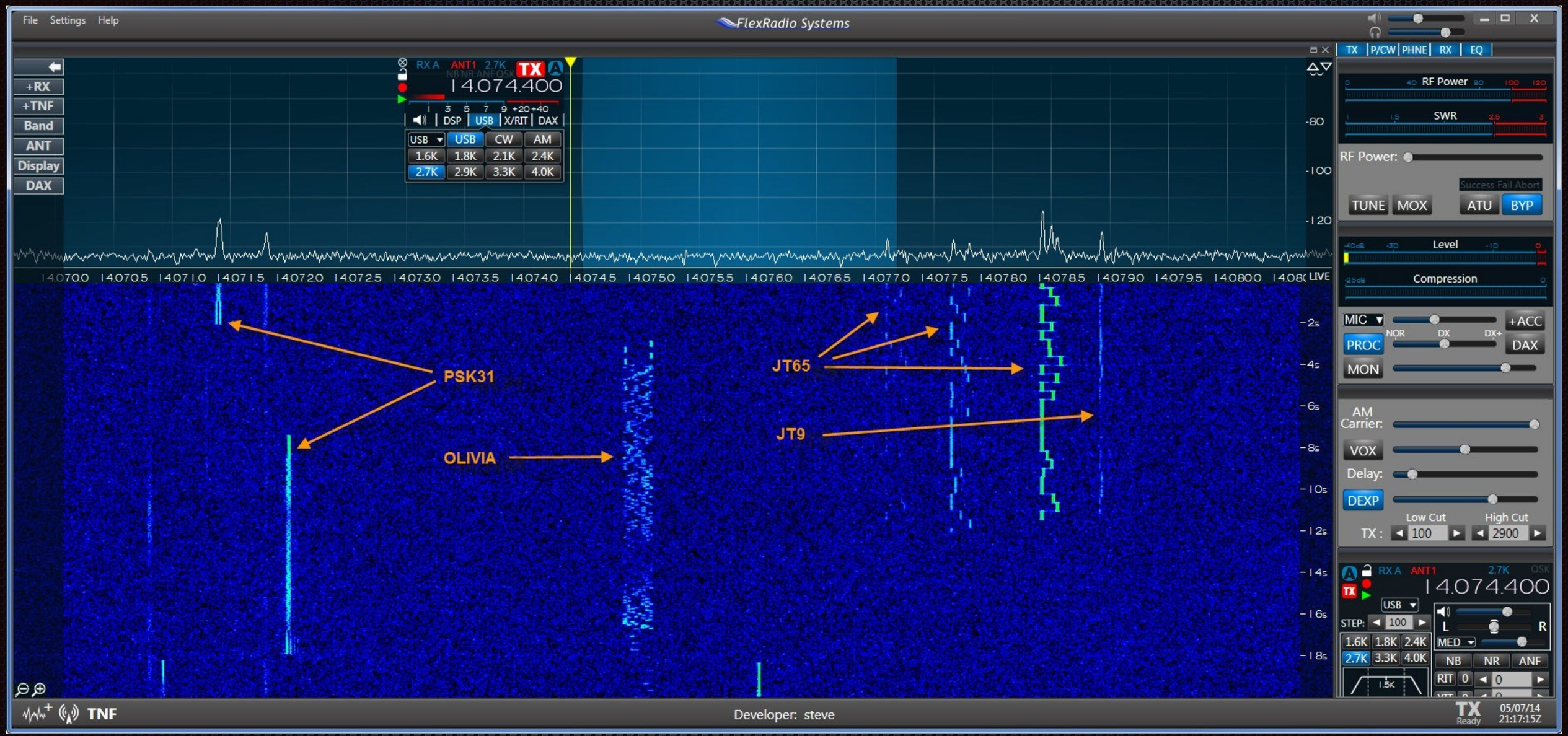
## Decoding

- Today: CW, PSK, RTTY
- Tomorrow: Everything Digital and voice
- Digital is fully integrated .... no cables

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# The Future:

## Decoding



# The Future:

Remote

- Today: Mostly hacked together and inconvenient
- Tomorrow: Easy remote, tablets everywhere



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# The Future:

Integration

- Today: On premise integration driven by contesters
- Tomorrow: Integration driven by plethora of remote solutions and the need to drive other hardware







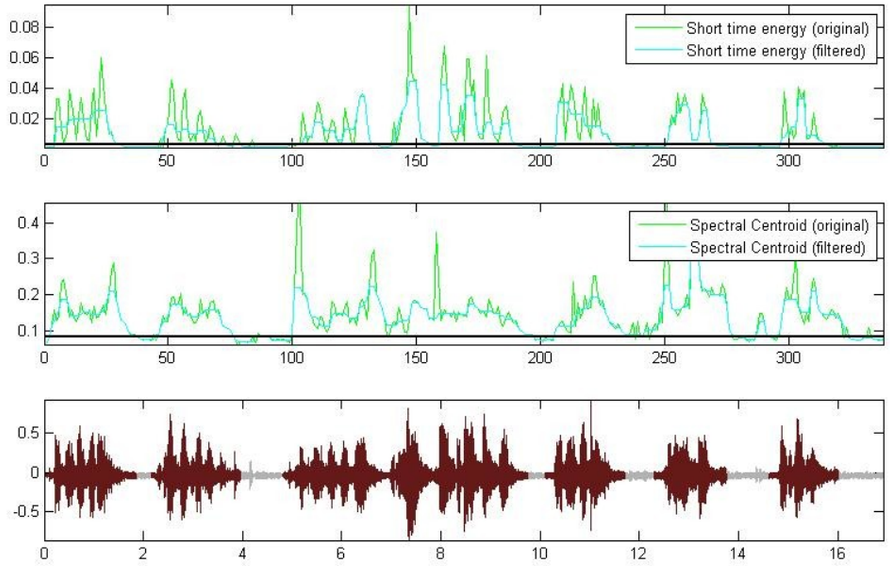


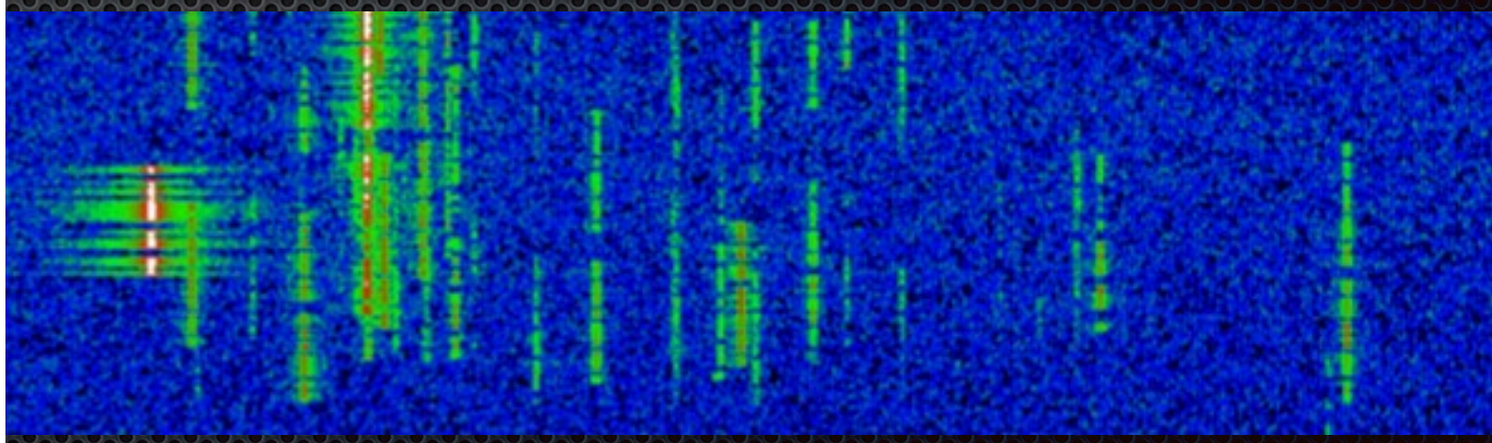
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# The Future:

## Signal Classification

- Today: Virtually none
- Tomorrow: Radios will find and classify signals (determine mode)



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# The Future:

## Steering and MIMO

- Today: Phased receive arrays, few TX arrays
- Tomorrow: Every antenna will have an SCU and for operators with multiple antennas, instant arbitrary, rotation will be possible

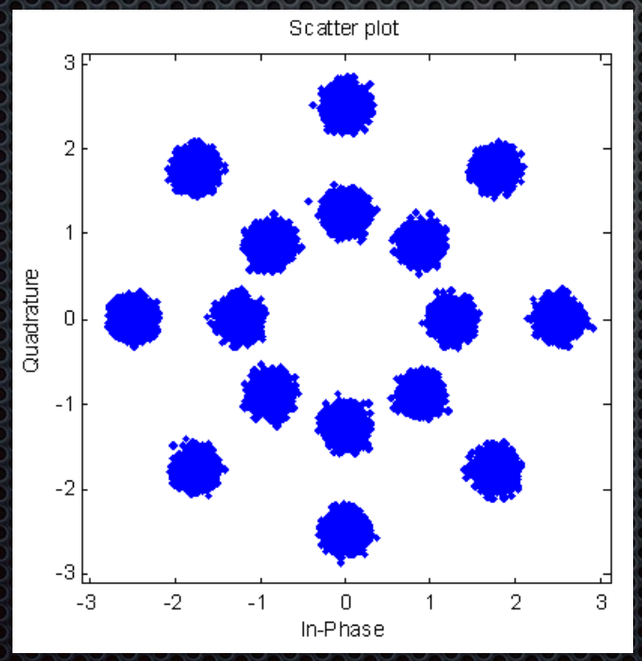


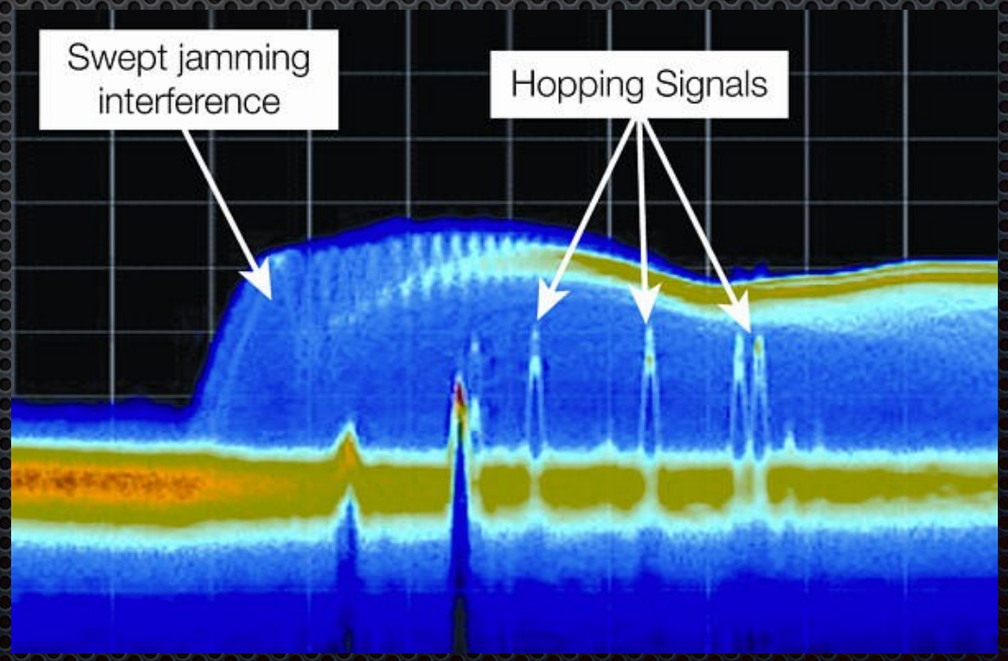
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# The Future:

## Visualization

- Today: Panadapters, Waterfalls and the occasional scope
- Tomorrow: New displays that show perspectives of data not previously seen.  Operational advantage will drive innovation




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# The Future:

## Noise Reduction

- Today: Advanced NB, NR techniques in many radios
- Tomorrow: Dedicated noise receivers will be used to eliminate noise more effectively, optimal combining across multiple antennas will emerge

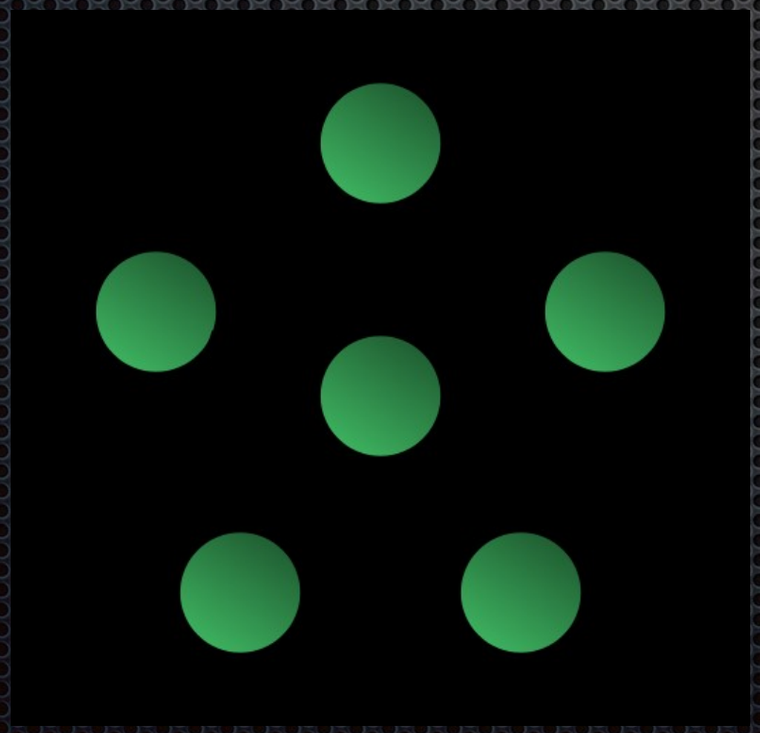


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# The Future:

## Networking

- Today: Occasional Remote-to-base operation
- Tomorrow: Remote assets will be combined inside of a single program to enhance operational capabilities. Remotes may be used in combining, DFing or other applications



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# re-discover radio



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