re-discover radio

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Software Defined Radios

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SDRs and Stuff

TAPR DCC: October 10, 2015

Stephen Hicks, N5AC
VP Engineering, FlexRadio Systems

SDRs and Stuff

Agenda

- Phase noise considerations
- The ADC Overload Myth
- Noise Reduction Techniques
- Wideband Noise Blanking
- Digital Voice Modes
- SO2R / Full Duplex
- Maestro
- GLASS

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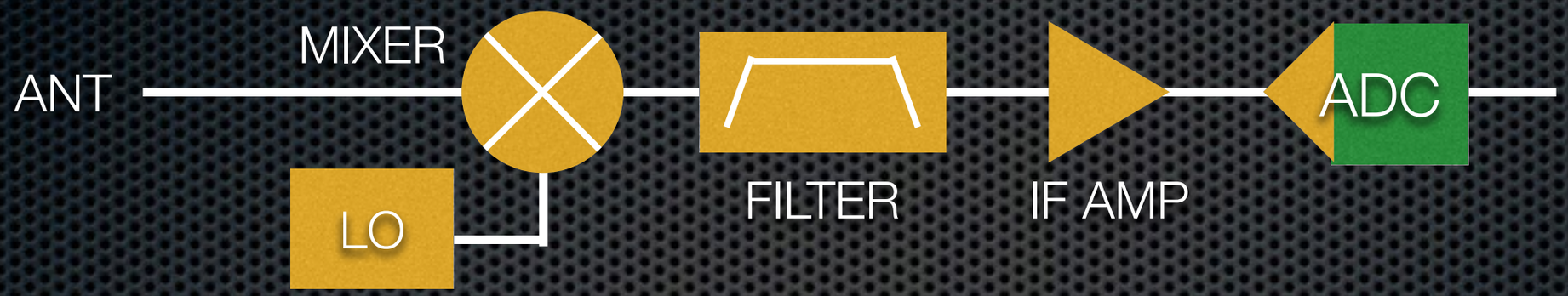
Phase Noise Considerations

Phase noise imparted at MIX



- Synthesizer in Superheterodyne
  - Divided down via DDS — but phase noise worse where you need it most (10m+)
  - First Mixer is at LOWER frequency: better phase noise
  - But, phase noise imparted later (2 or 3 oscillators)
  - Reciprocal Mixing generally exacerbated in subsequent stages … plus spurs

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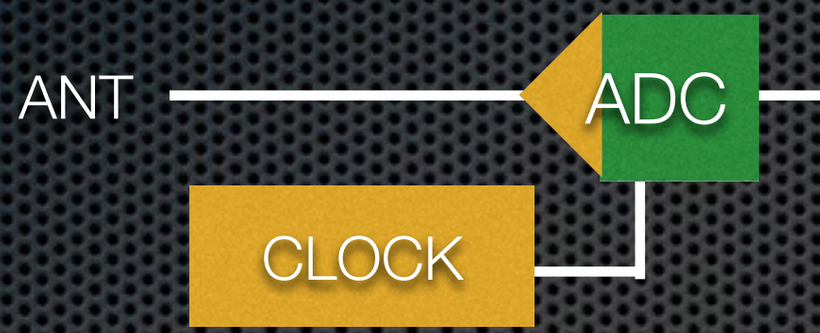
Phase Noise Considerations

Phase noise imparted at SAMPLING



- Sampling clock in Direct Sampling receiver
  - Phase noise imparted at sampling
  - Requirement more stringent because of higher freq
  - Phase noise imparted only ONCE
  - So … oscillator in direct sampling MORE important

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How important is Good Phase Noise?

- What are you trying to do?
- Single op, rural, modest antennas — not so important
- Single op, strong neighbors - MAYBE IMPORTANT
- Multi op, run and mult on same band — IMPORTANT
- Field day — IMPORTANT

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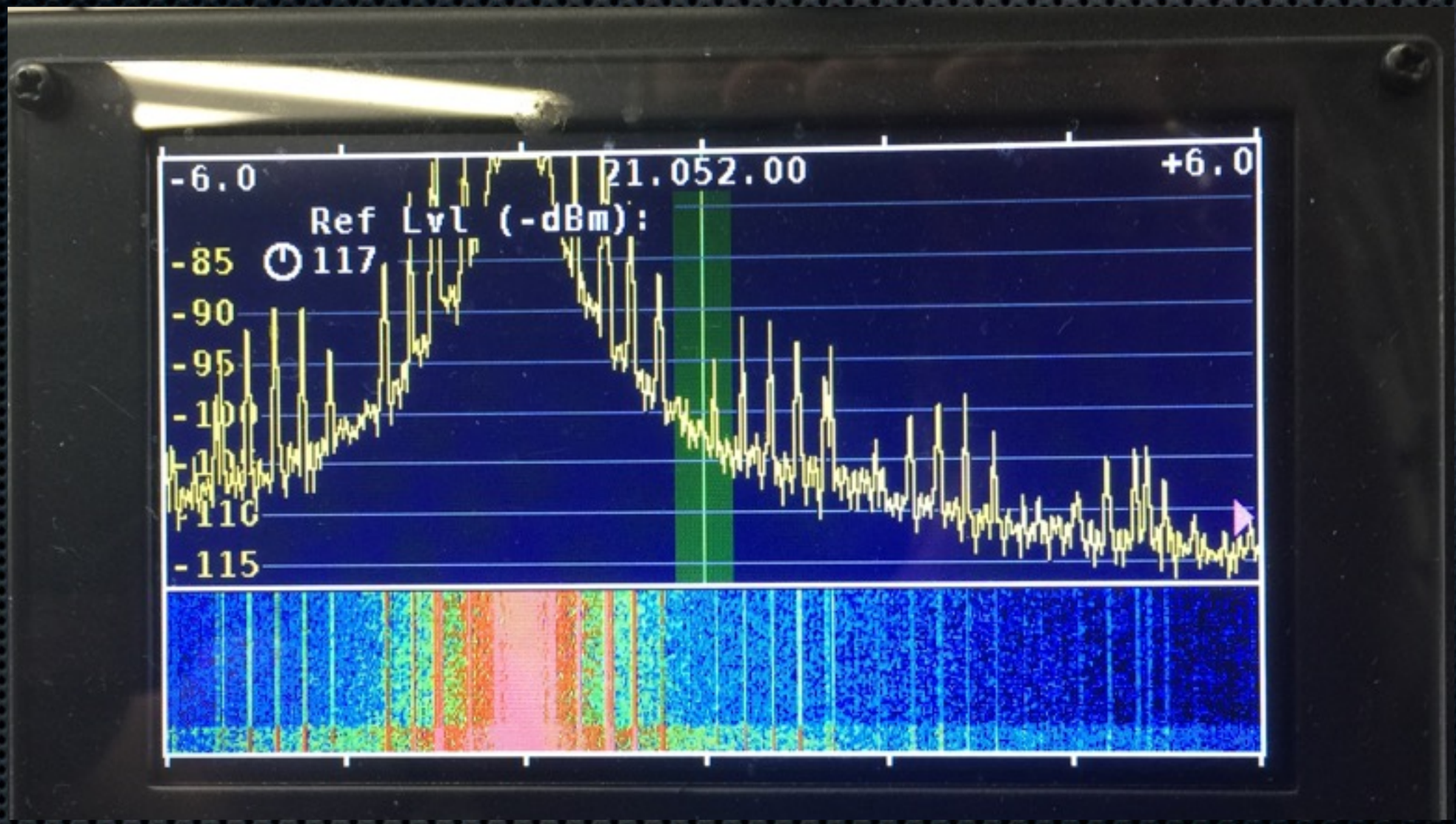
What does bad PN look like?



35dB Noise Floor Rise @2kHz

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What's possible?

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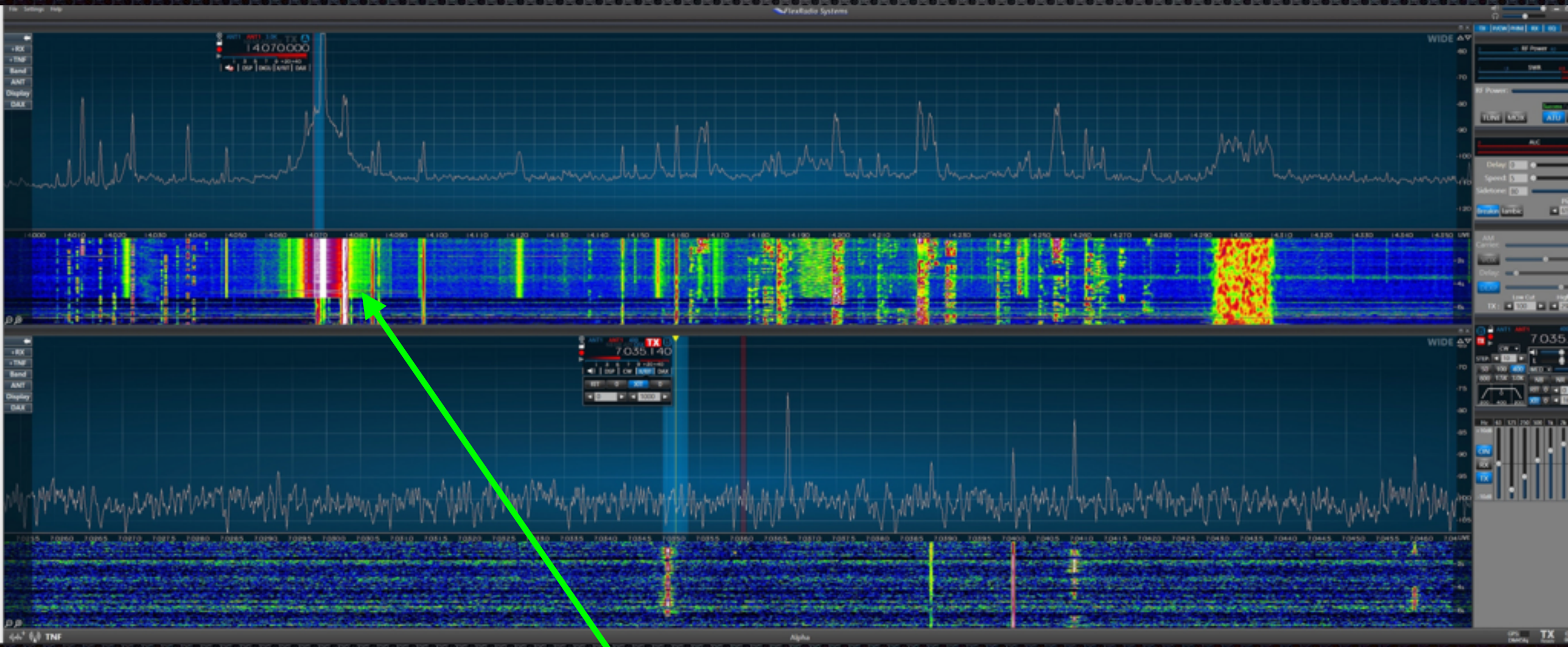
Low Phase Noise

Field Day



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From Adam's Talk Yesterday

- If IMD DR3 OR BDR > RMDR, your radio is *RMDR limited*
- This means the IMD DR3 and/or BDR number are *meaningless*
- Yesterday's performance number was IMD DR3
- Now that that's better, RMDR is important

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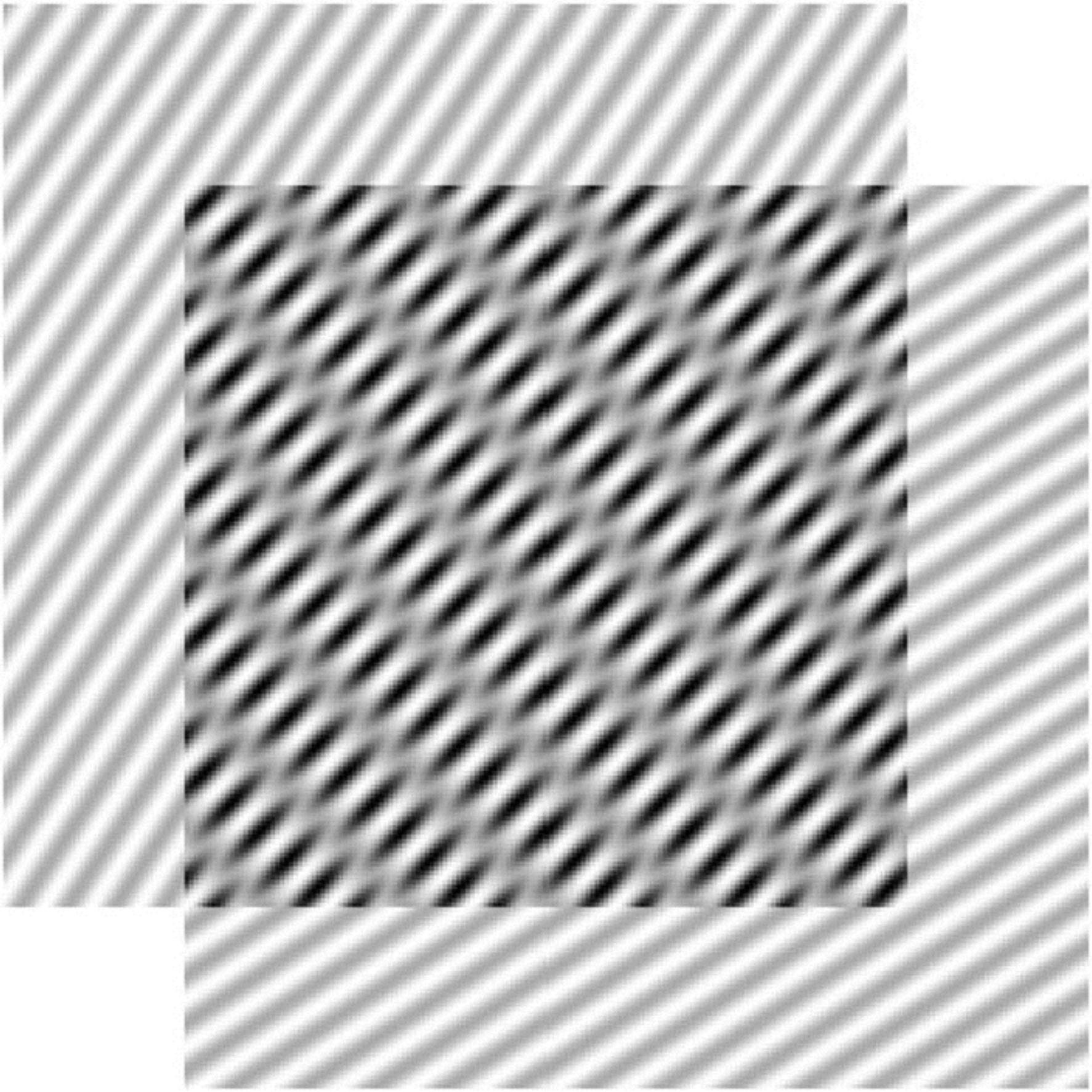

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ADC Overload Myth

- Background:
  - Superheterodyne systems have narrow IFs
    - Filtering is done in these IFs to reduce signals
    - Direct Sampling receivers can be exposed to everything
    - … they “MUST” overload from seeing everything!

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ADC Overload Myth

*"The evangelists for direct sampling SDRs can do all the hand waving they want - the facts are that multiple signals will add to a level that causes clipping in the ADC. It only takes a half dozen or so S9+40 dB signals when the DS SDR has maximum preamplification enabled for best weak signal reception or it only takes *one* neighbor a half mile away with a 1.5KW signal anywhere on the same band to reduce the direct sampling SDR to a mass of clicks and pops."*

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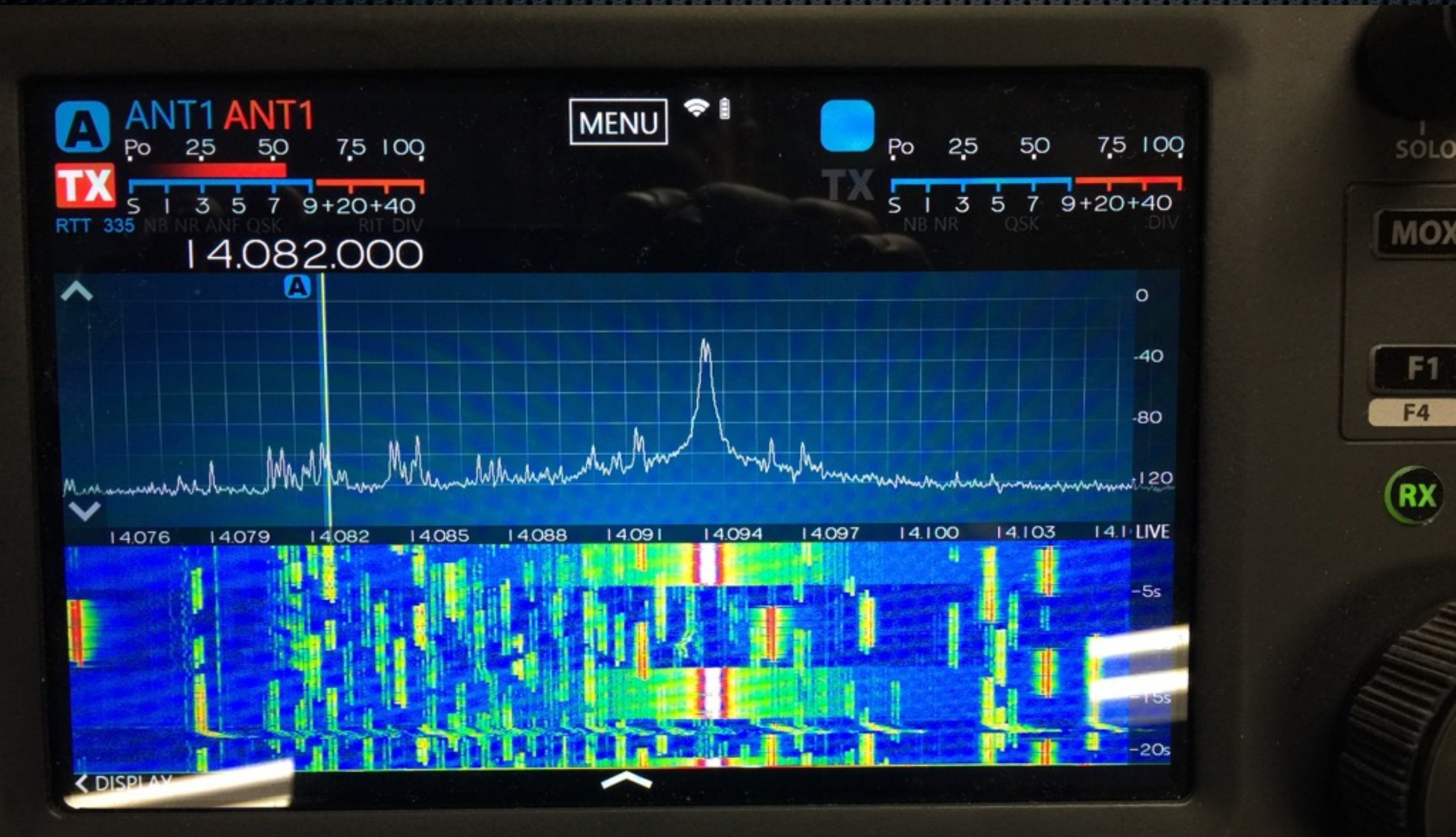
1.5kW Transmitter on 6700



Review of sampled signals

- You have two signals, A & B
- Each are on 20m
- Each measured at 0dBm on my power meter
- I combine them and take a power meter reading
- What is the result?
- +3dBm, but produces a PEP 6dB higher

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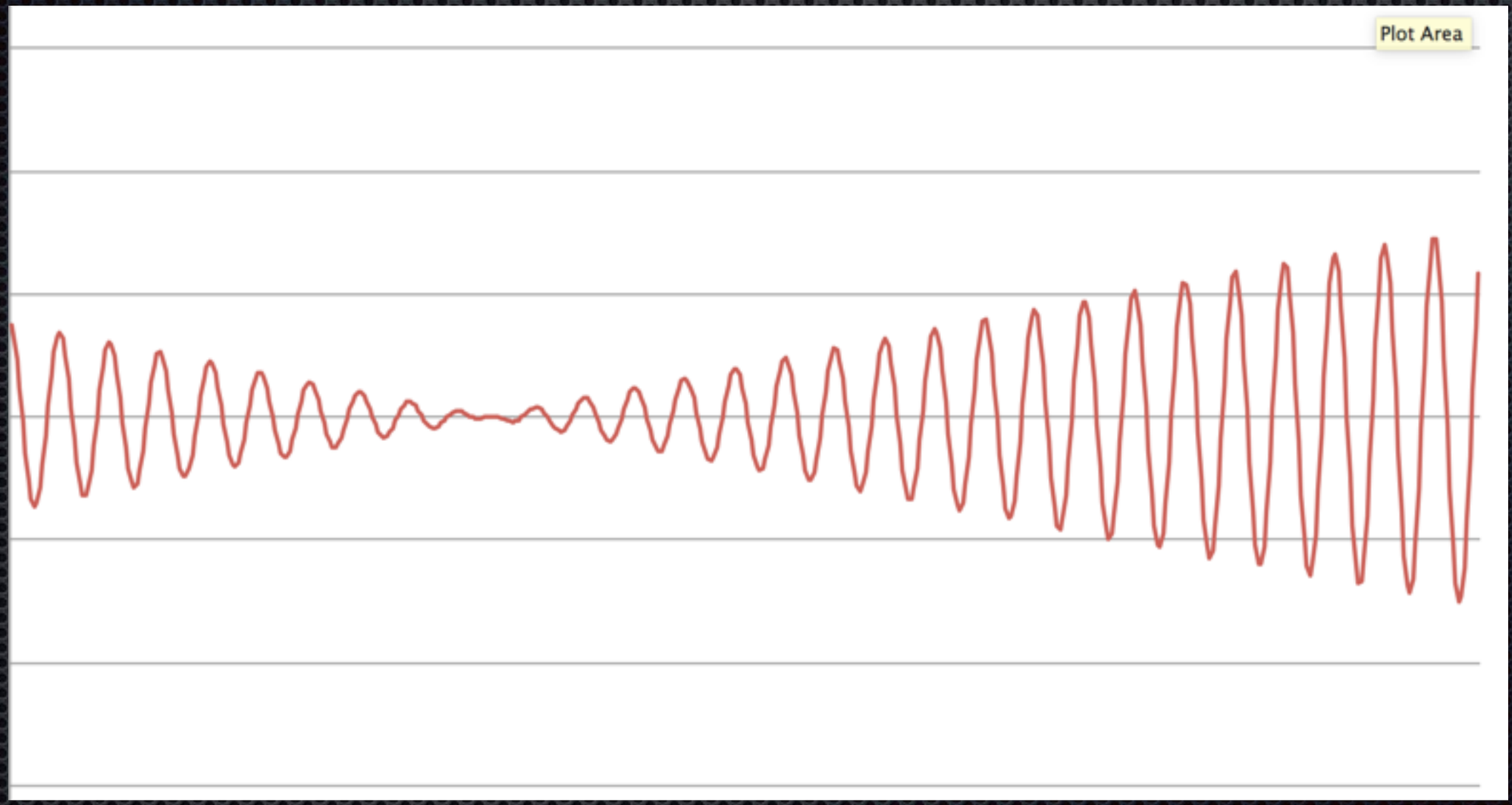
What does my ADC see?



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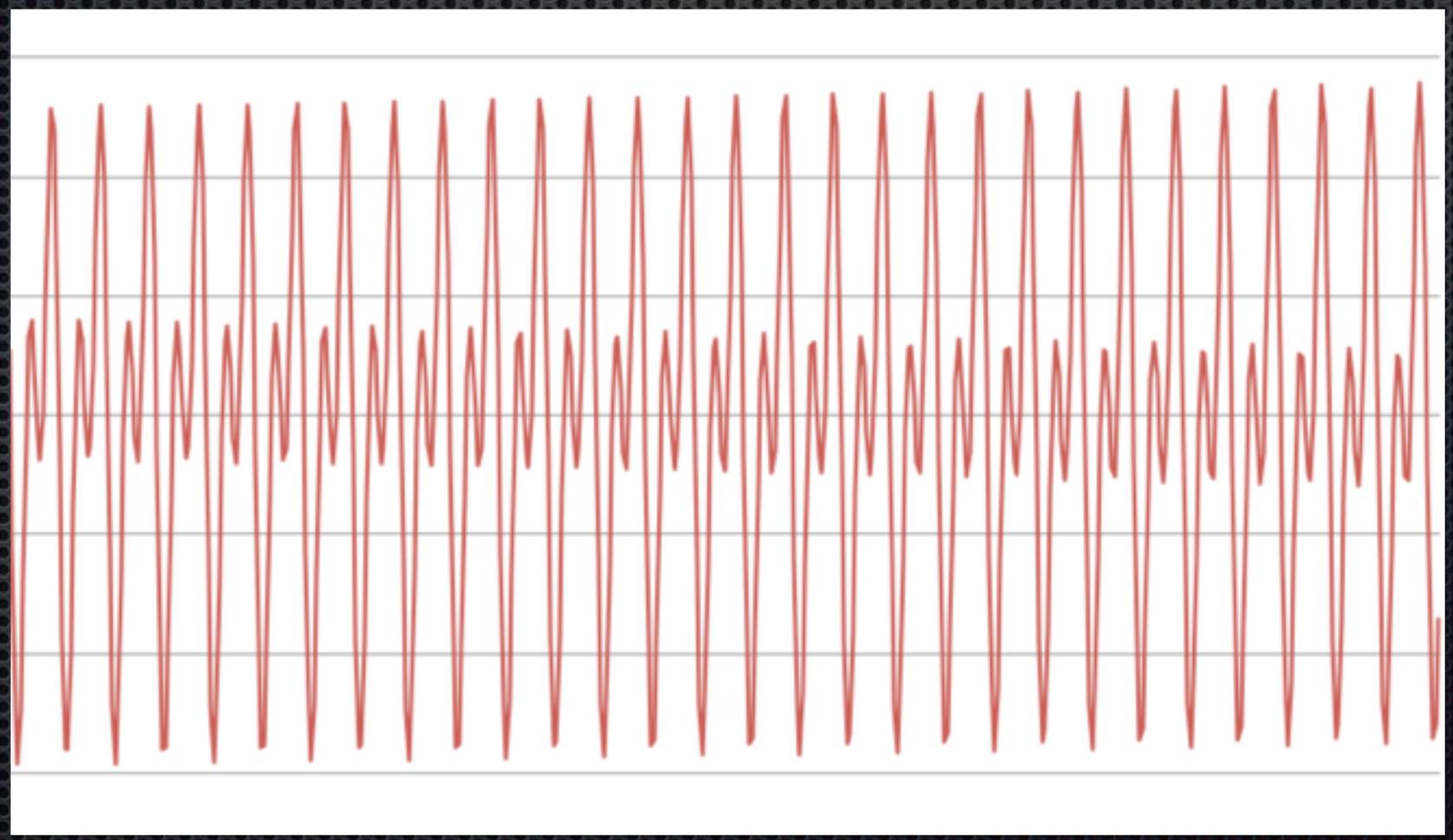
ADC Overload con’t

- What if one signal is on 20m and one is on 10m?



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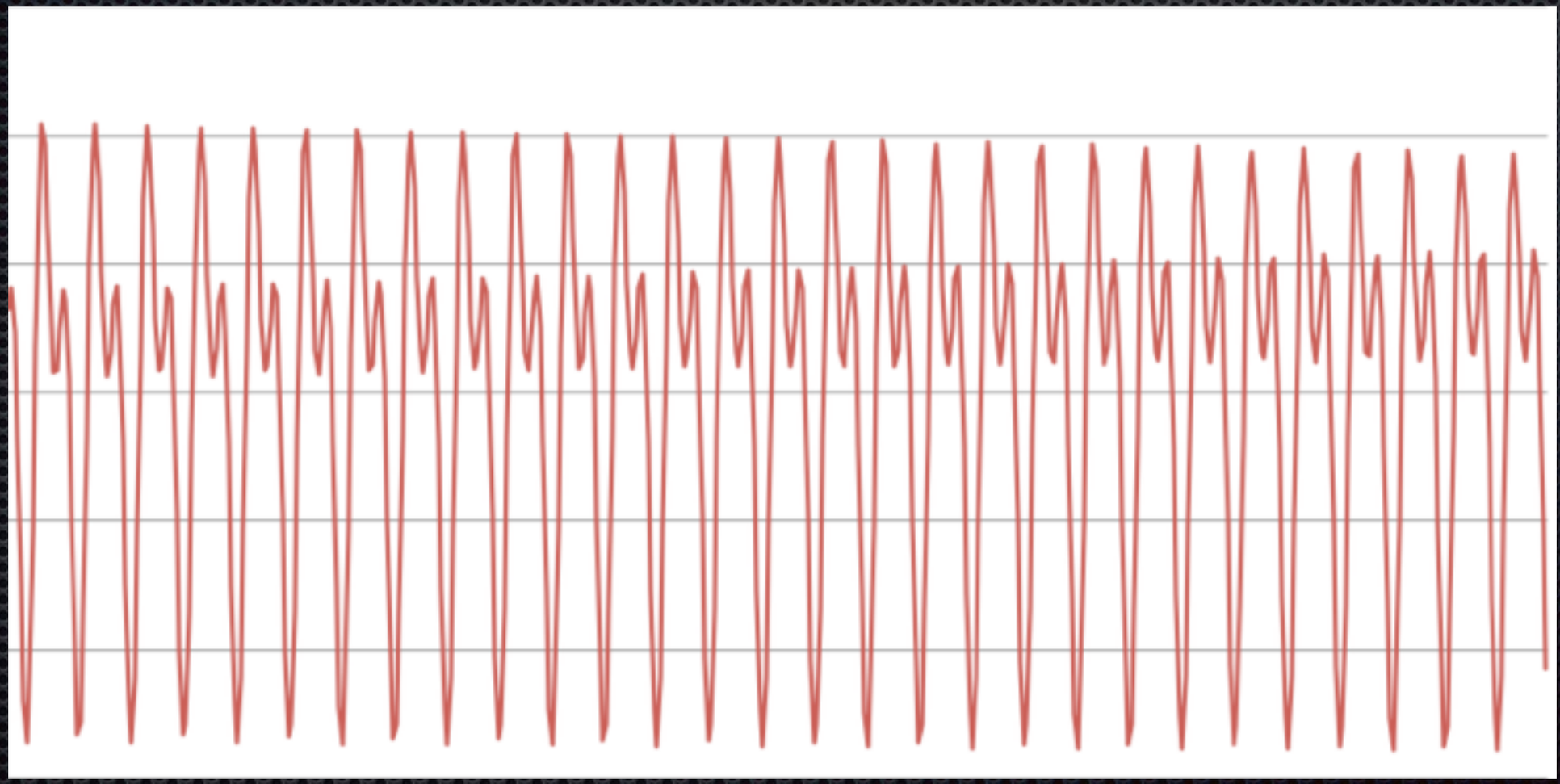
ADC Overload con’t

- What if one signal is weaker: -20dBm & -22dBm



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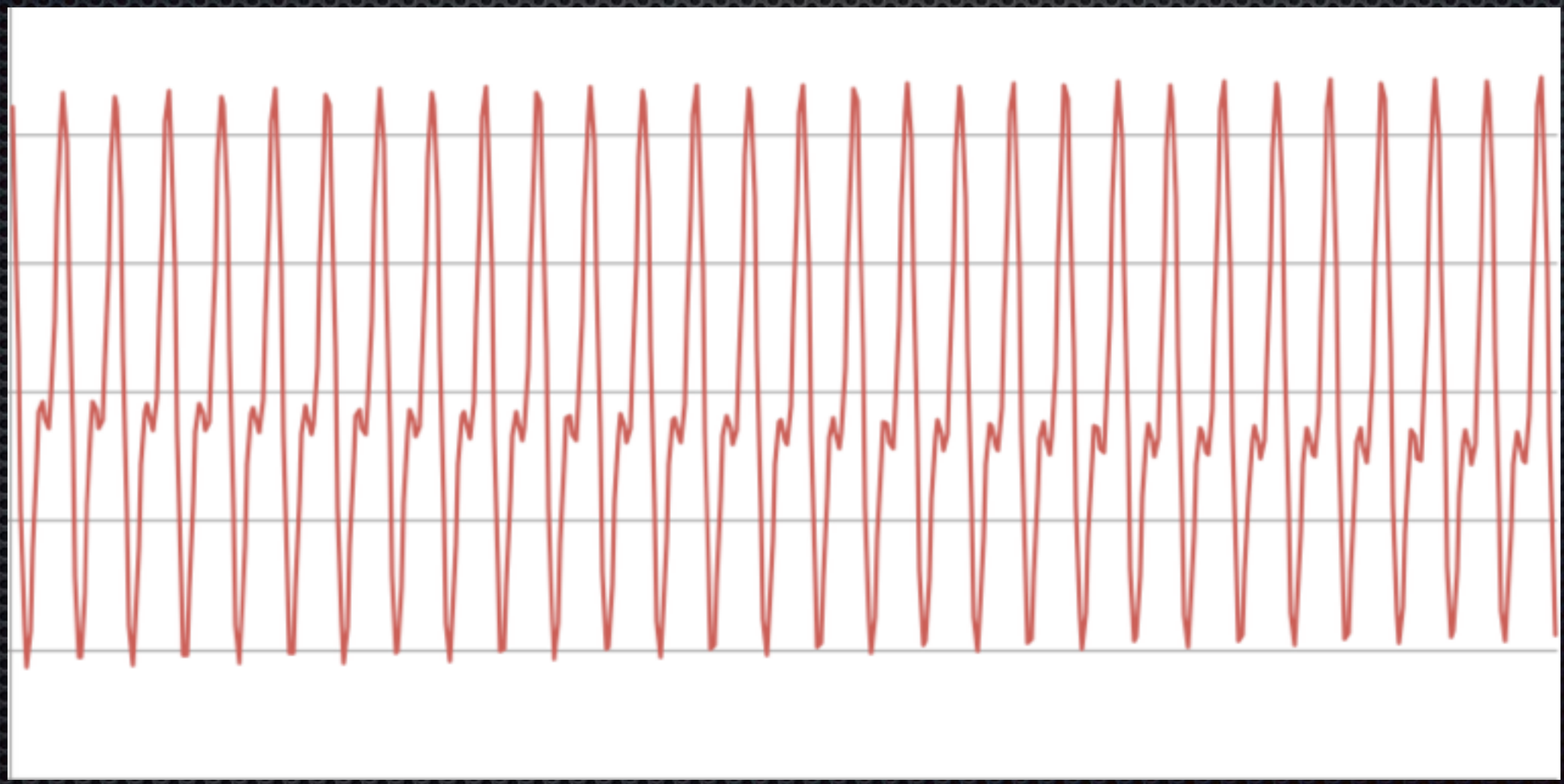
ADC Overload con’t

- What if one signal is weaker: -20dBm & -24dBm



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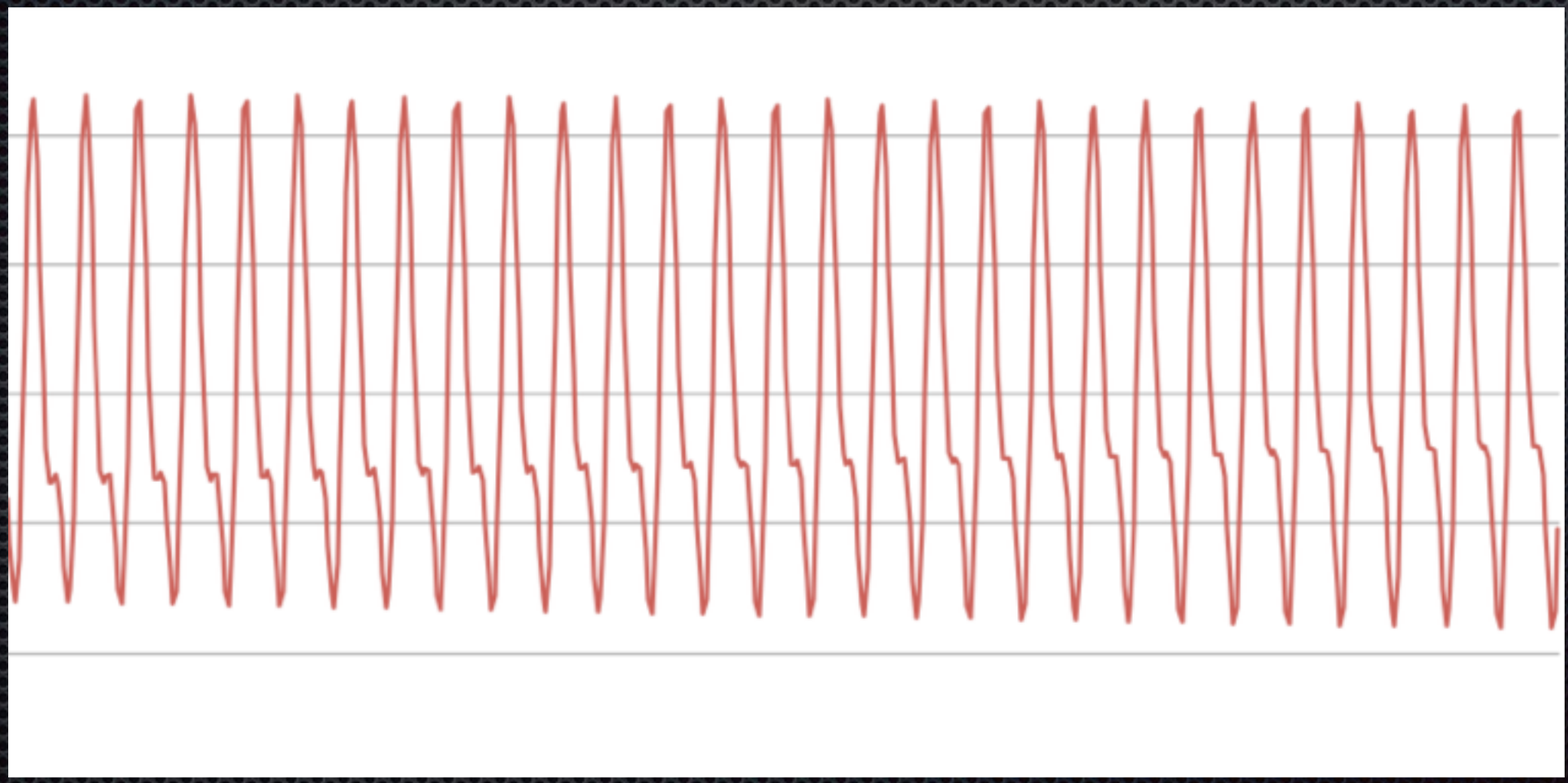
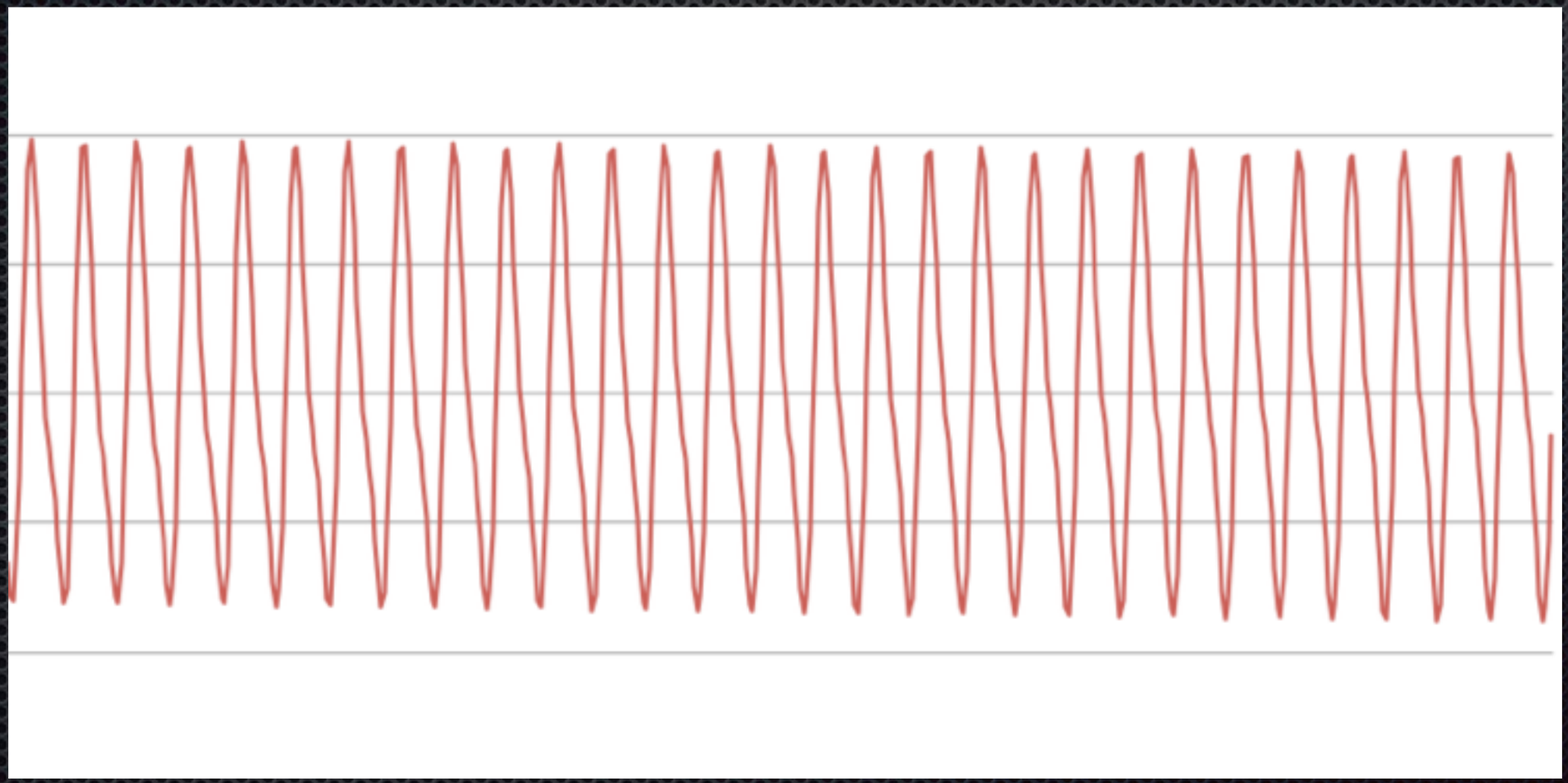
ADC Overload con’t

- What if one signal is weaker: -20dBm & -26dBm



ADC Overload con’t

- What if one signal is weaker: -20dBm & -30dBm



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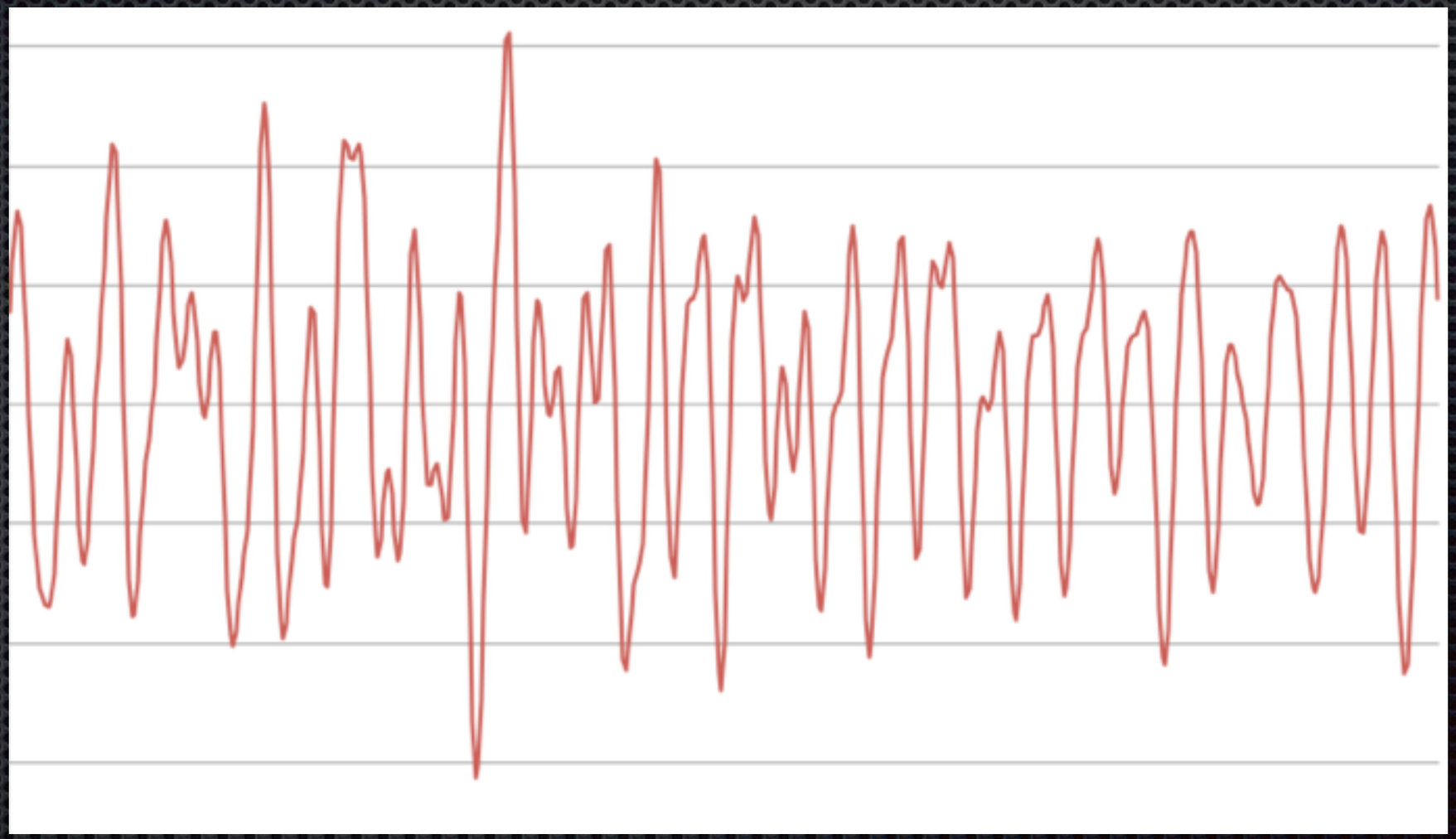
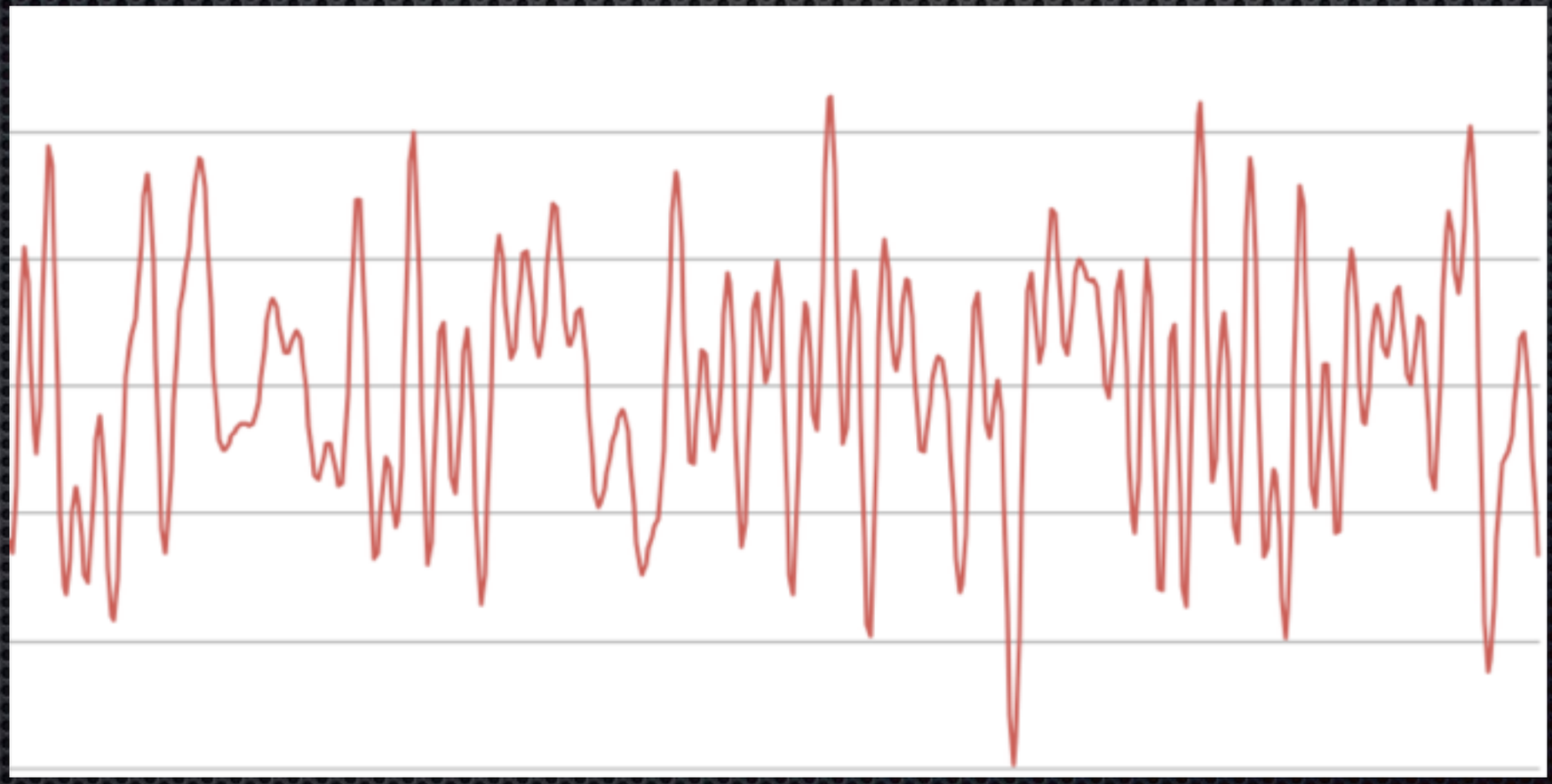
ADC Overload con’t

- one at -23dBm (S9+50), 11 at -33dBm (S9+40)



ADC Overload con’t

- one at -23dBm (S9+50), **99** at -33dBm (S9+40)



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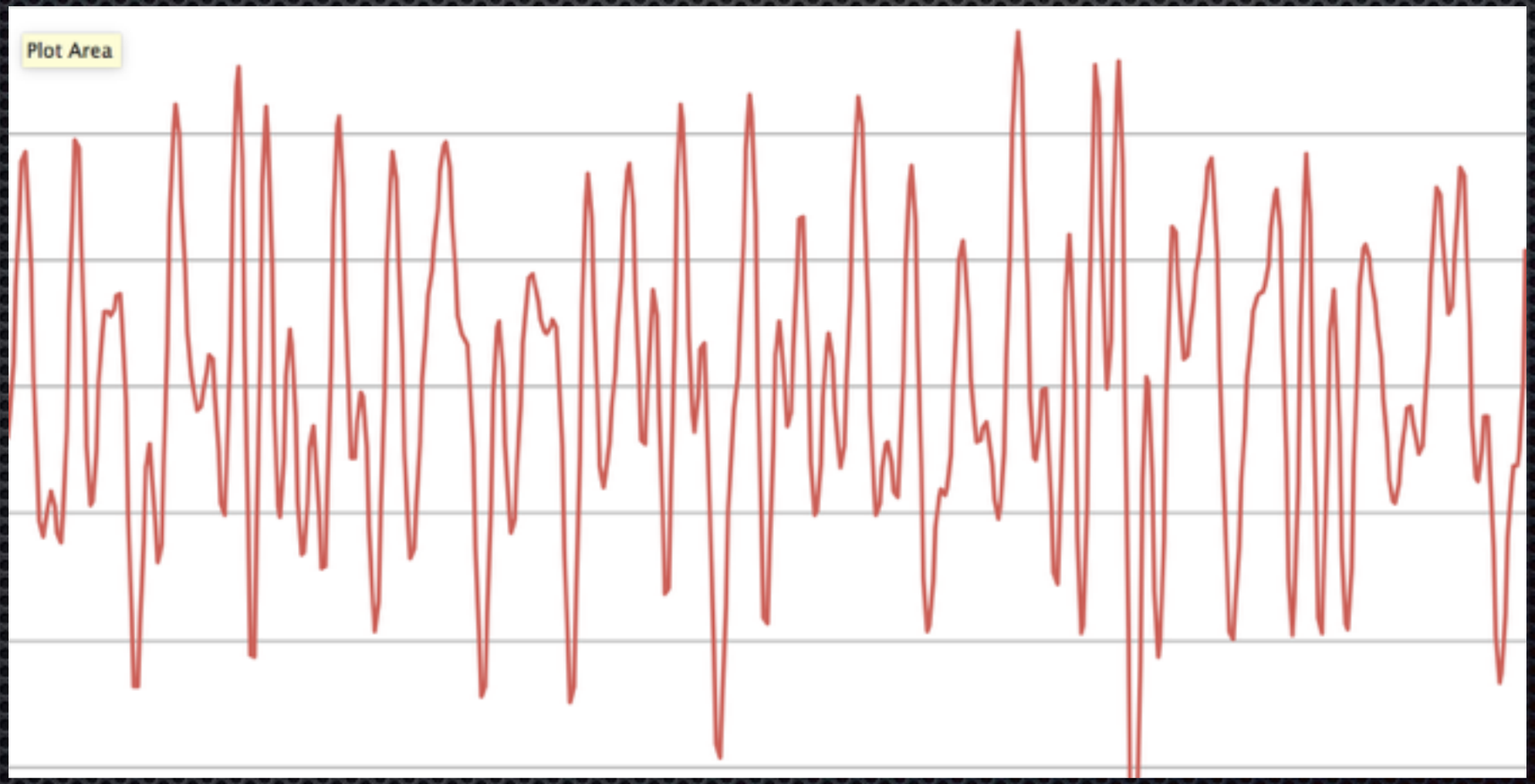
ADC Overload con’t

- one at **100** at -33dBm (S9+40)



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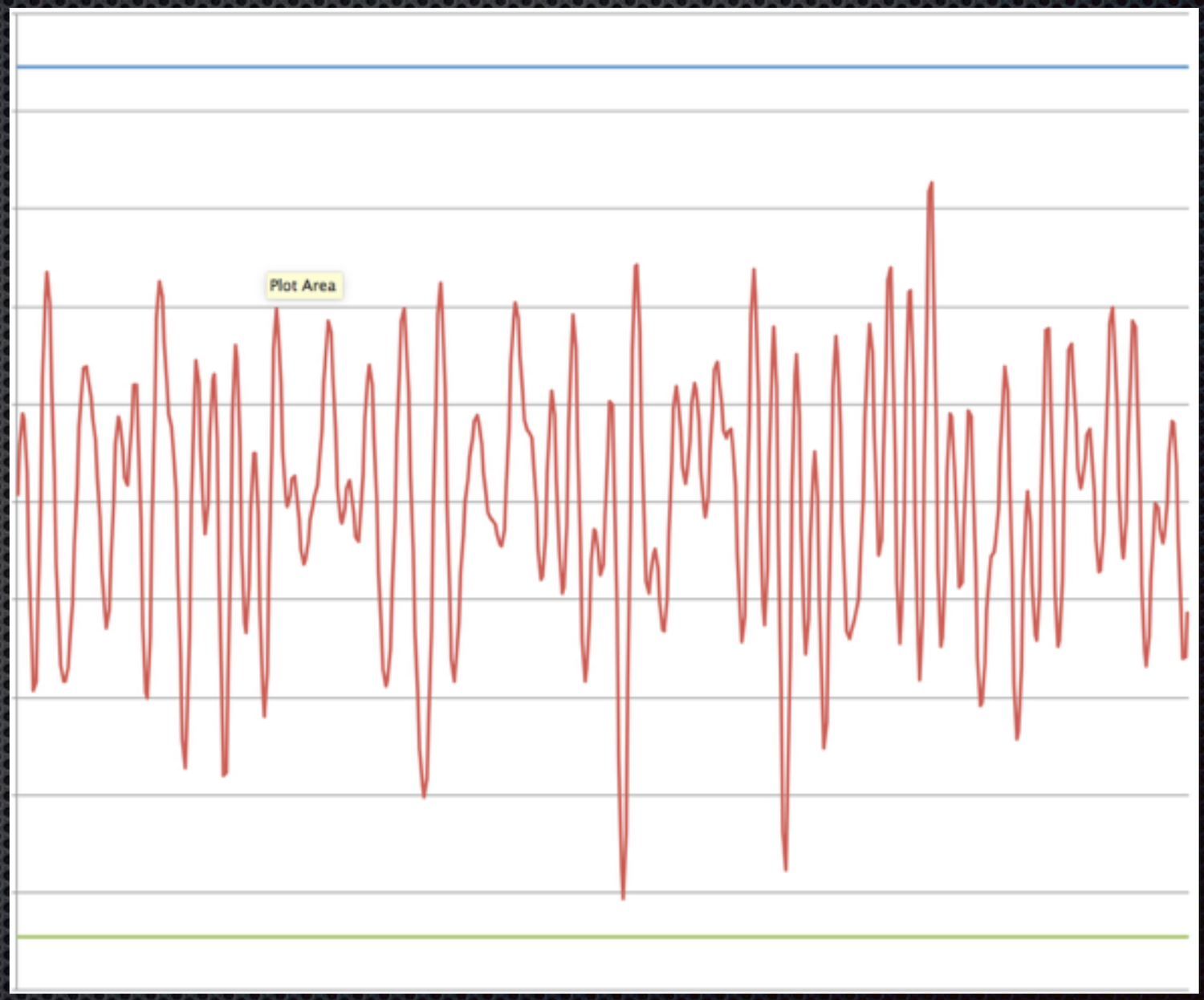
ADC Overload con't

- **100** at -33dBm (S9+40) showing full scale, preamp on



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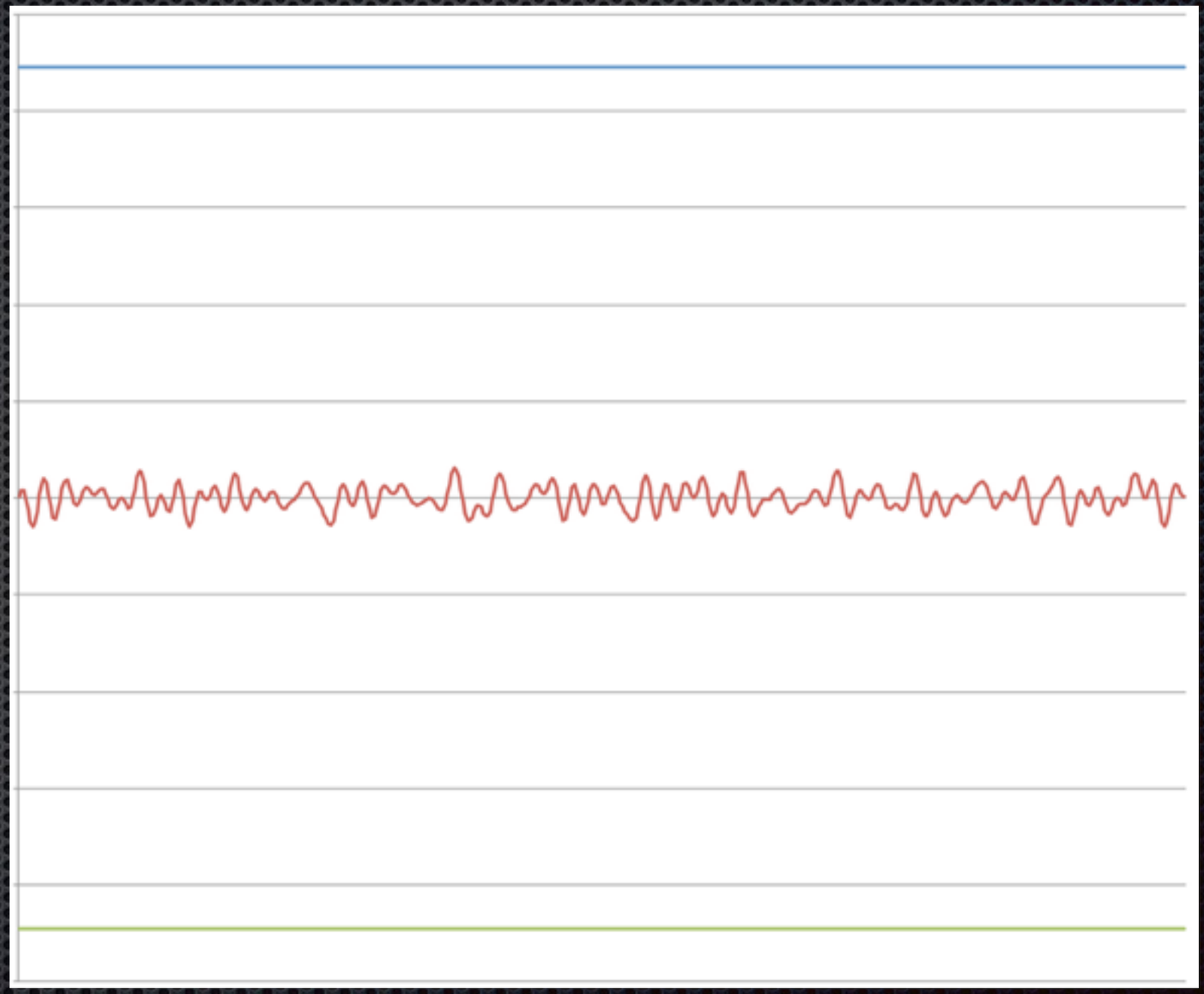
ADC Overload con't

- **100** at -33dBm (S9+40) showing full scale, preamp off



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WHAT is going on?

- Signals may ADD or SUBTRACT at any instant
- The more signals there are, the more the result looks like Gaussian noise
- An overload, when it occurs, is brief and inconsequential
- Random phase, frequency and power do not add up to one huge number …
- ADC overload from a large number of signals is a myth

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ADC Overload Myth

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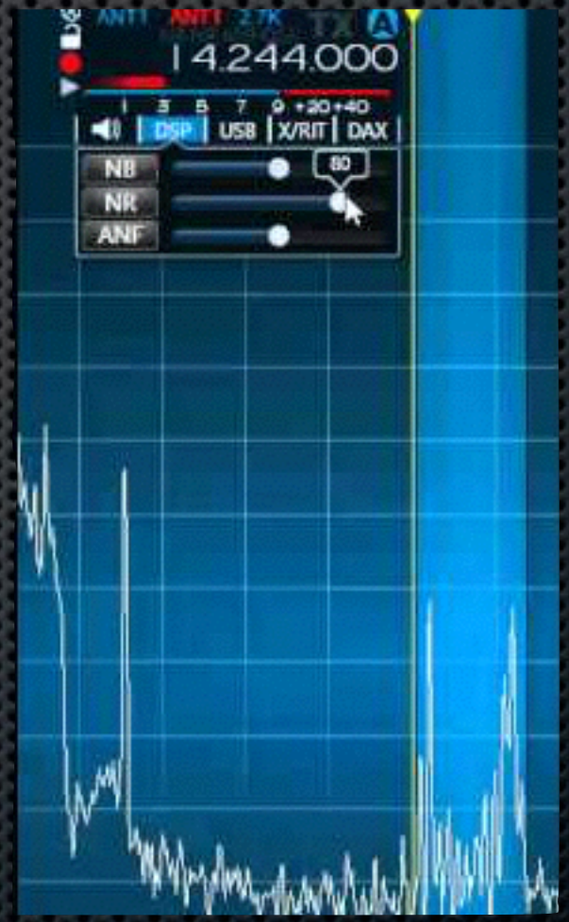
Autocorrelation

- Informal Definition:
  - The similarity between observations as a function of the time lag between them

Noise Mitigation Systems

- Noise Reduction
- Noise Blanker
- Automatic Notch Filter
- Notch Filter
- Audio Peaking Filter



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Noise Reduction (NR)

- Automatic filter
- Coefficients dynamically adjusted
  - deemphasize all non-autocorrelated signals
  - Applications:
    - Best: reduce random noise in presence of CW
    - Good: reduce random noise in presence of voice

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Automatic Notch Filter (ANF)

- Automatic filter
- Coefficients dynamically adjusted
- deemphasize all autocorrelated signals
- Applications:
  - Best: remove carrier in SSB signal
  - OK: remove carrier in CW band

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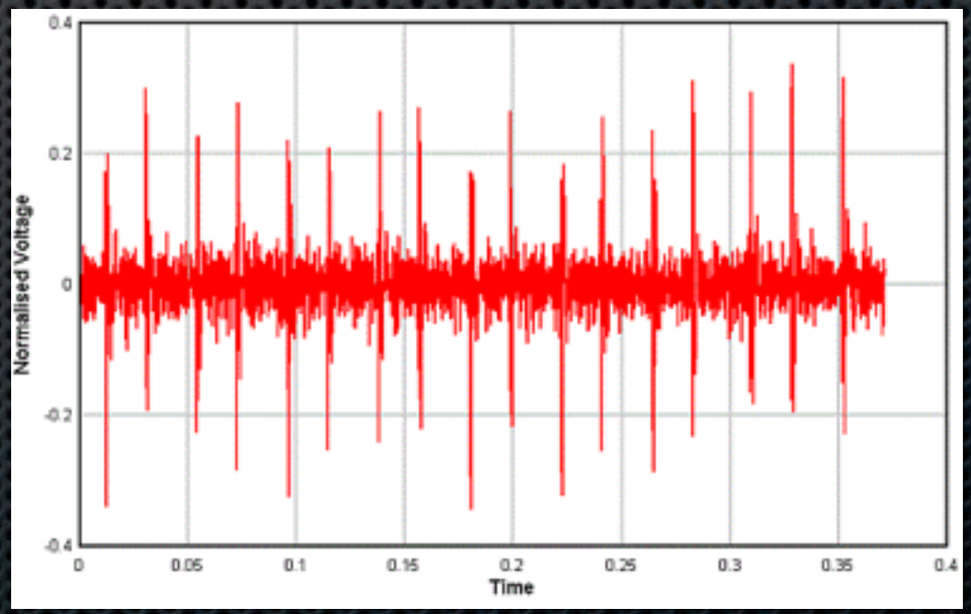
Noise Blanker (NB)

- Detect an impulse signal in time-domain
- Remove any noise samples (typical = set to zero)
- Rely on receiver to self-heal

- But …
  - What does an impulse look like in a 36kHz IF??



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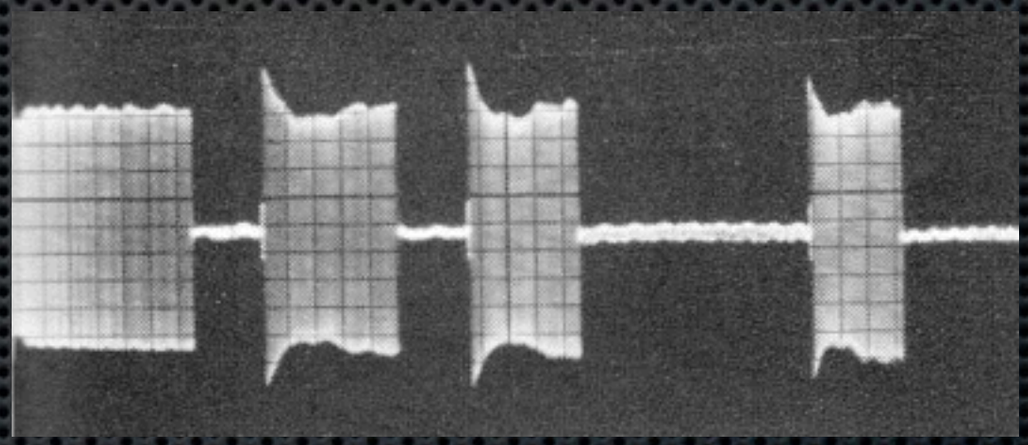
Noise Blanker discussion

- The minimum rise time possible is $\frac{2}{f_s}$
- … so for a 36kHz IF this is 55us
- So narrow band noise blankers false on strong signals



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Noise Blanker Discussion

- What to do?
- Use a “noise receiver” away from strong signals
- Observe a wider bandwidth, decreasing minimum rise time

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SmartSDR WNB

- Digests samples at 24.576Msps (440Mbps)
- Adapts to changing conditions
  - Noise levels, effects of filtering, signal levels
- Has a control to set the aggressiveness of the algorithm
- Technically, not a blanker
- Works on a panadapter and any included slice receivers

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SmartSDR WNB Demo

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SmartSDR WNB

- In the video, we are refactoring something like 1,500 samples each blanking period
- This was power line noise
  - frequency = 60/120Hz
- Samples refactored per second = 180,000 !
- Samples used per second = 24,396,000 … oh

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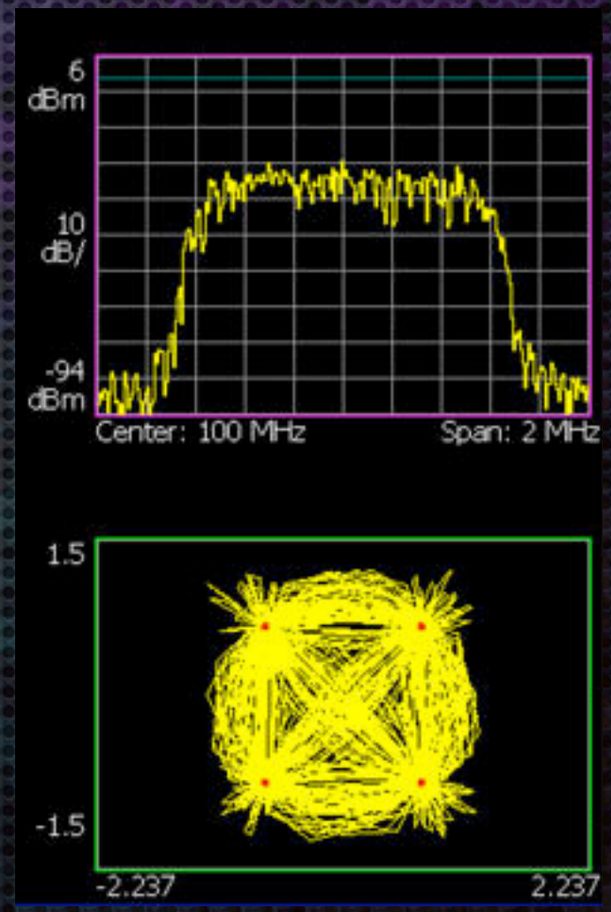
Waveform API

Examples: CODEC2, D-STAR, System Fusion, PSK31, RTTY, CODEC2, WSJT, etc.

- Open Source Wrapper
- Enable development of waveforms on PC
- Could remain on PC or moved inside radio
- Inside radio runs as a separate process alleviating open source issues



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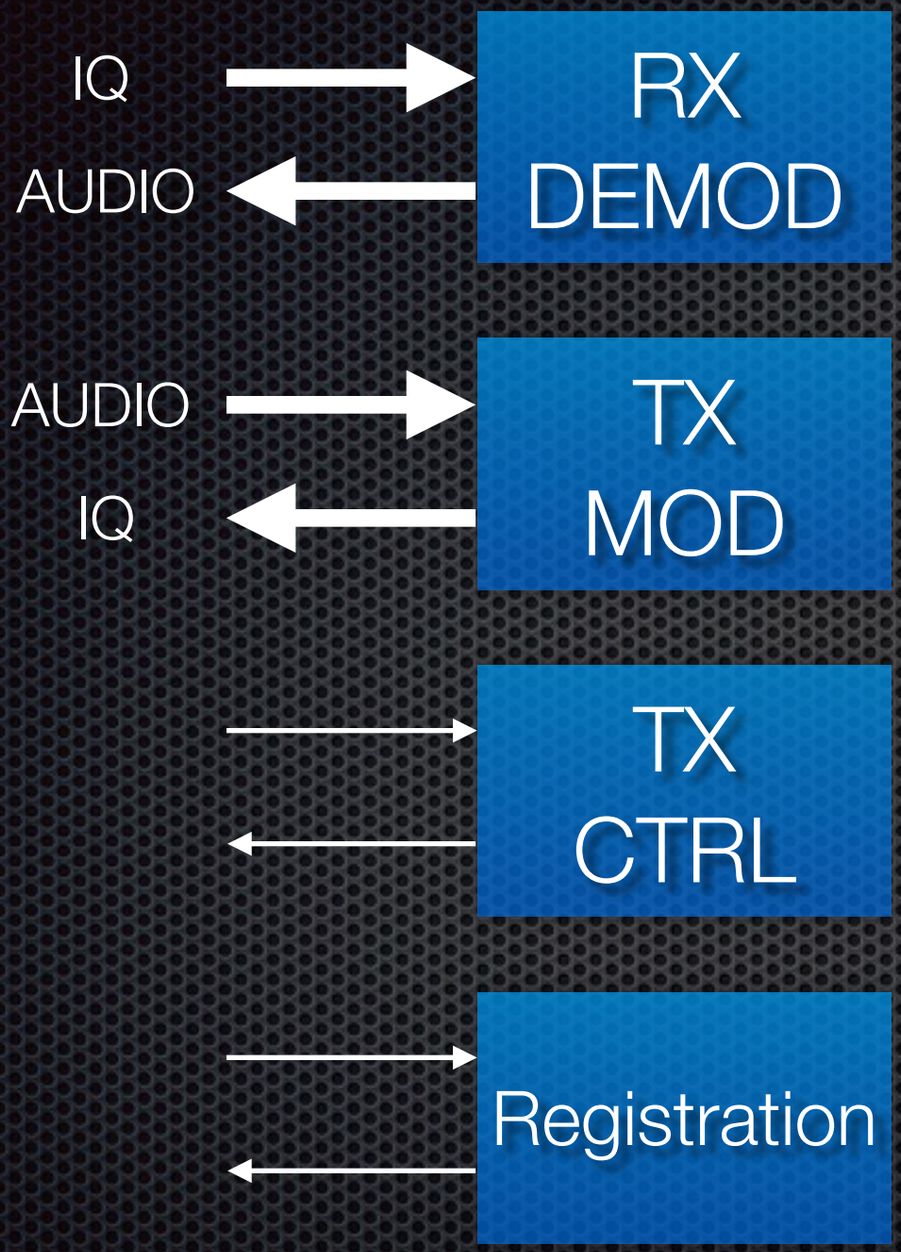
Voice Mode (voice ↔ IQ)



24ksps IQ in, audio out (RX stream)

audio in, 24ksps IQ out (TX stream)

Transmit Control

Mode and services registration

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SmartSDR

Introducing D-STAR Capability

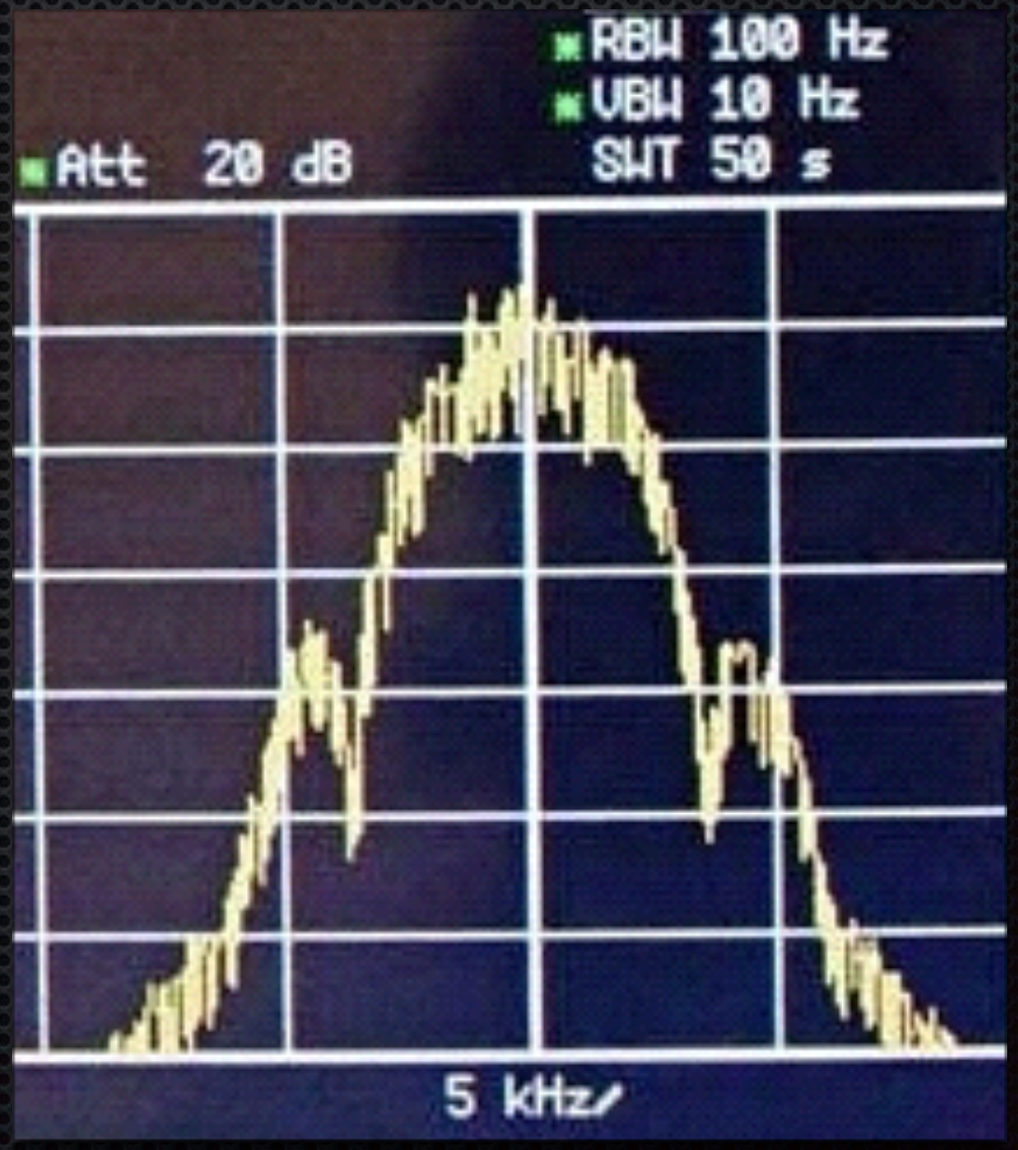
- For all FLEX-6000s
- Both HF and VHF (6700)
- via ThumbDV device
- Open Source
- Expandable
- With FLEX-6000 transverter access, can be used on ANY band

D-STAR

SmartSDR

Digital Voice Interoperability Platform

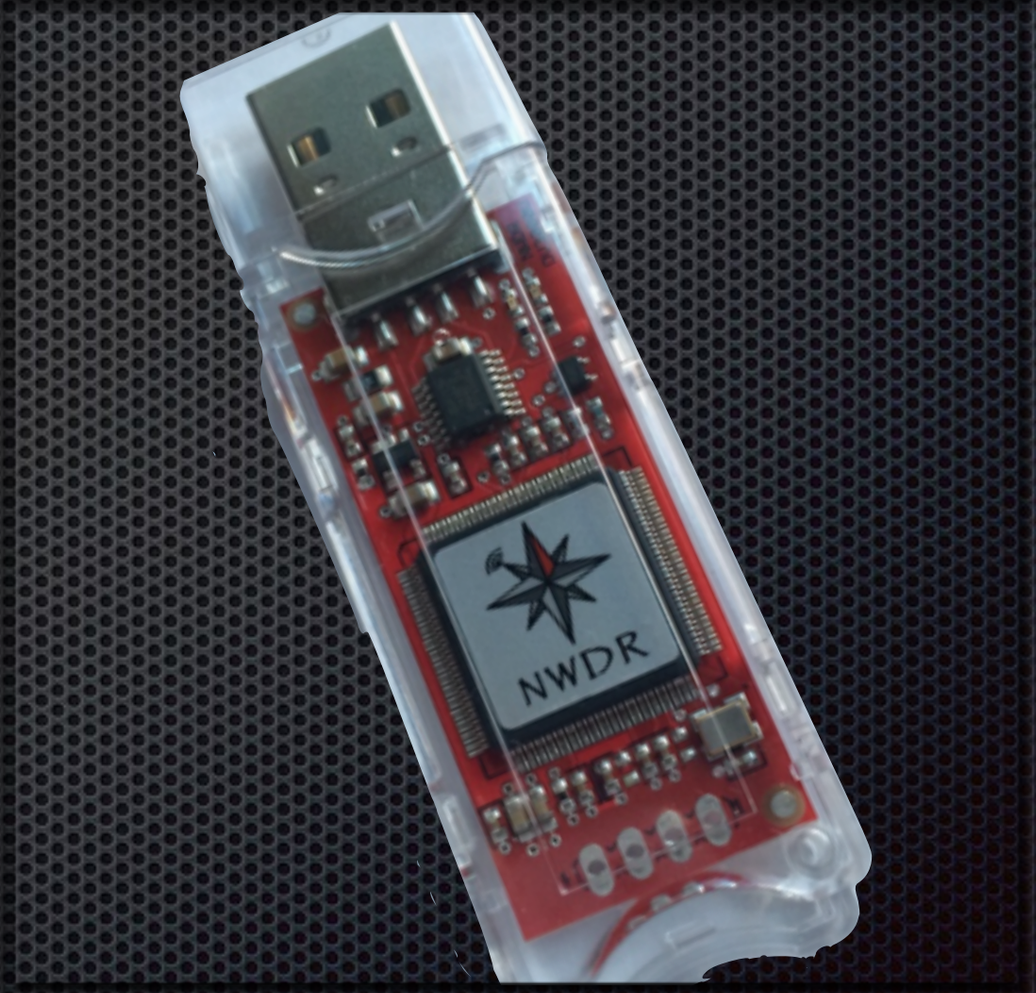
- Waveform API enabler
- CODEC2/FreeDV
- D-STAR
- …more to come!



SmartSDR v1.5

September 2015

- Wideband Impulse Noise Blanker
- RTTY mode
- D-STAR Mode
- Full Duplex (RX/TX simultaneously)
- 1-Radio SO2R (FLEX-6700)
- DX/Contesting additions



Single Radio SO2R

September, FLEX-6700

- Today, SO2R requires two radios (doubles cost)
- Connection devices (more cost)


403A
MONTENEGRO

Single Radio SO2R

September, FLEX-6700

- With SmartSDR v1.5, ONE radio (lower cost)
- No connection devices (lower cost, simplicity)

Single Radio SO2R

Current Priorities

- DXing and Contesting (4Q15)
- Maestro (4Q15)
- v2.0 (Full Internet Remote, 1H16)

“SO2R Box”

Early 2016

- Provides 1-Radio SO2R capability to all FLEX Signature Series Transceivers
- Contest filters
- Antenna switching for SO2R

“SO2R Box”

Early 2016

- Cuts the cost of SO2R contesting in HALF
- Eliminate all the complexities
- Simplifies operations and station construction
- Simplifies station reconfiguration

Maestro

The interviews…

- Continued to hear that knobs/buttons are important
- Often, existing products maligned for complexity
- Station reconfiguration time frustrating
- Integration in SO2R, M/1, M/2, M/M stations a problem
- The dream of simple remote operation…

Maestro

Control surface and more...

Maestro

Control surface and more

- Essentially a remotable SmartSDR with knobs & buttons
- Can be used in place of a computer to run any FLEX-6000
- Optimized to have just frequently used controls
- Let's take a closer look ....

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Maestro

Display

- WXGA (1280x800) 8” IPS Cap Touch
- Can show one or two panafalls
- Up to two slices
- Cap touch, pinch to zoom, buttons and pop-up menus
- Built on SmartSDR API

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Maestro

Controls

Slice A

Slice B
or
RIT/XIT

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Maestro

Capabilities

- Integrated CW keyer
- Mic, headphones, line in/out
- ~6 hours of battery life or plug-in (12V nom.)
- WiFi (802.11 a/b/g/n) and wired Ethernet (1GbE)
- VESA mount for Public Safety comms, mobile use, etc

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Maestro

What's next?

- Control of a computer and large display (fairly easy)
- Multiple Maestros on a single radio
- WAN use (away from the shack)
- Who knows …

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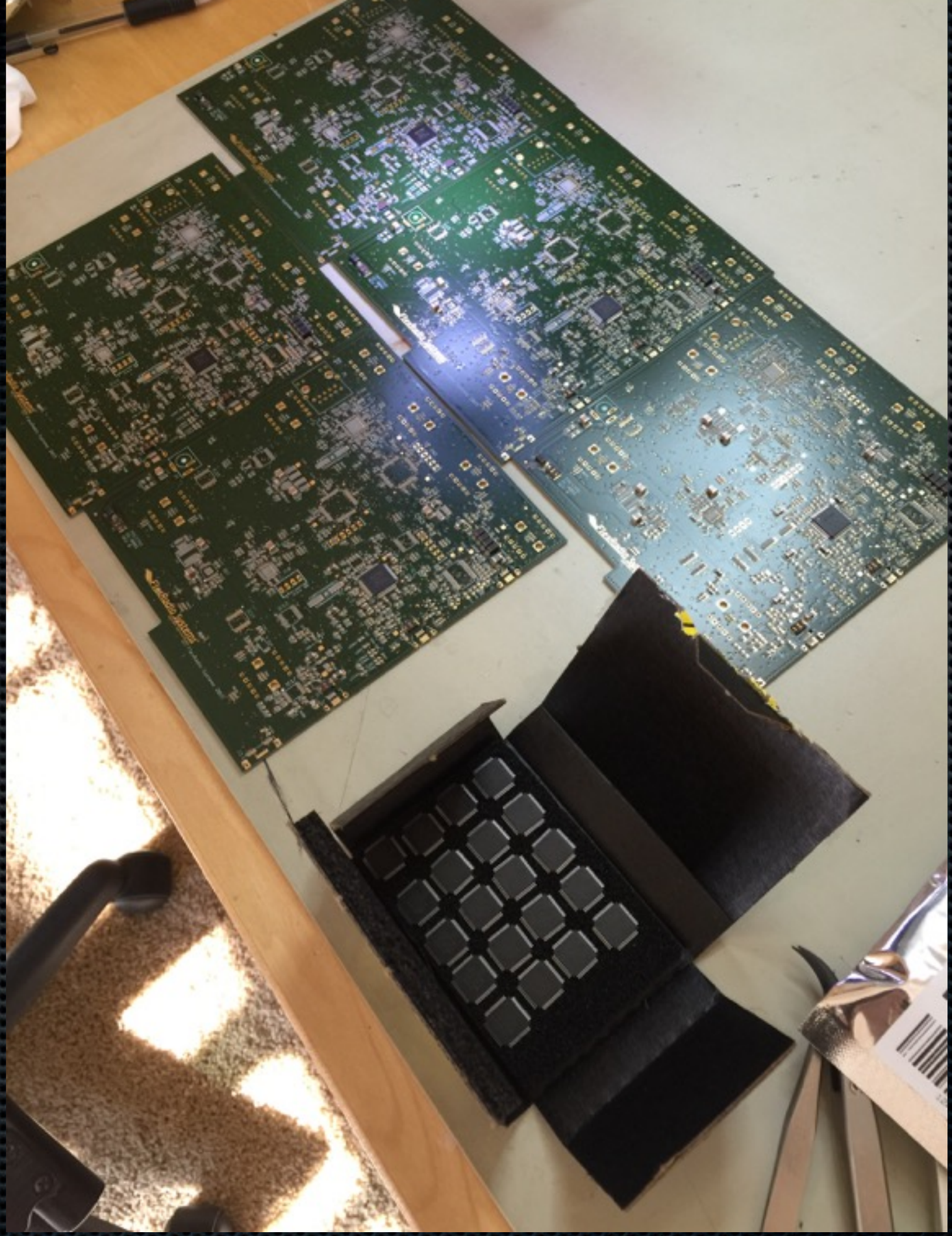

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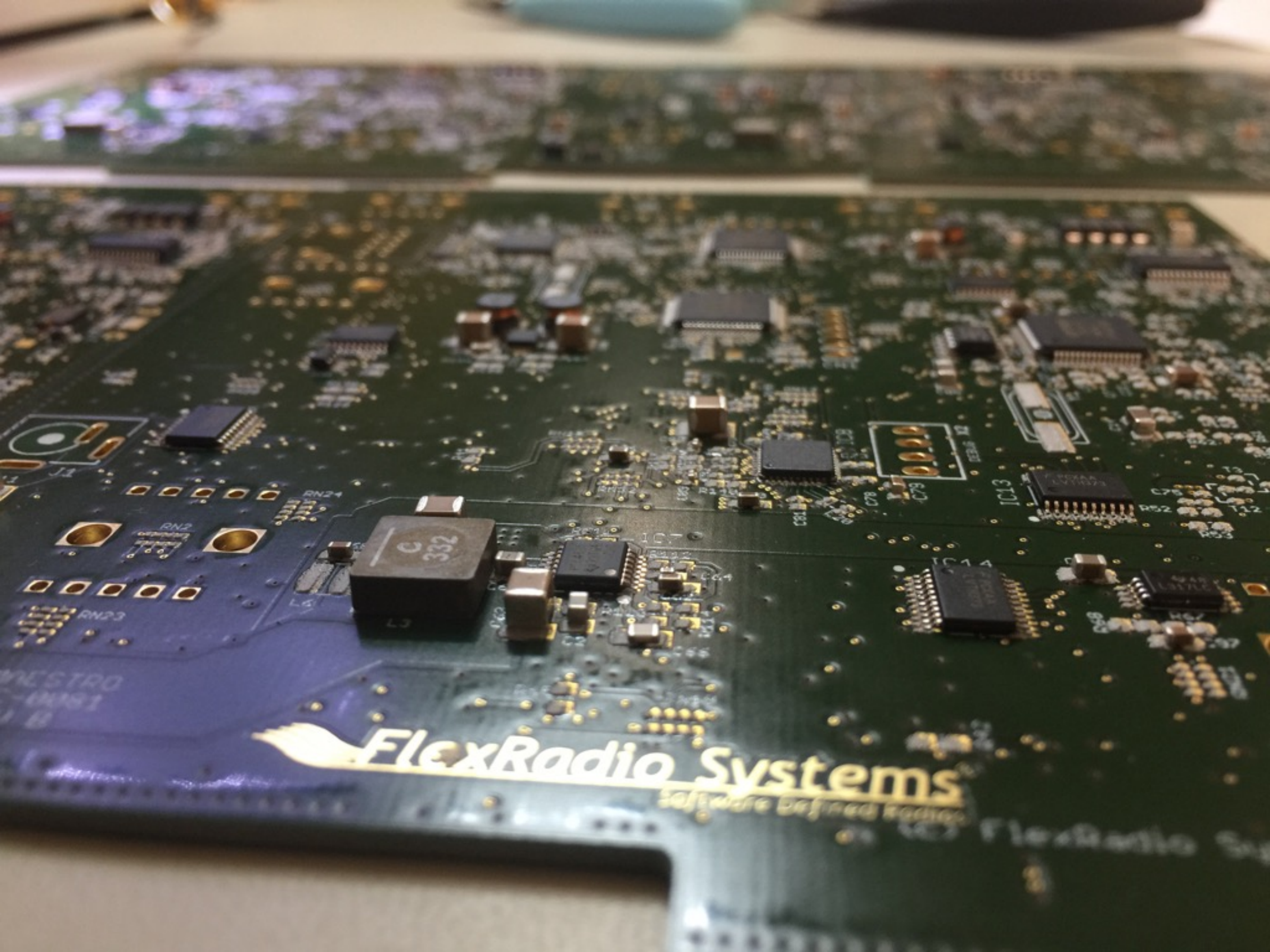
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Maestro

By the numbers

	Controller	Audio
Layers	6	6
Vias	2,494	543
SMD Pads	1,582	547
ICs	22	11

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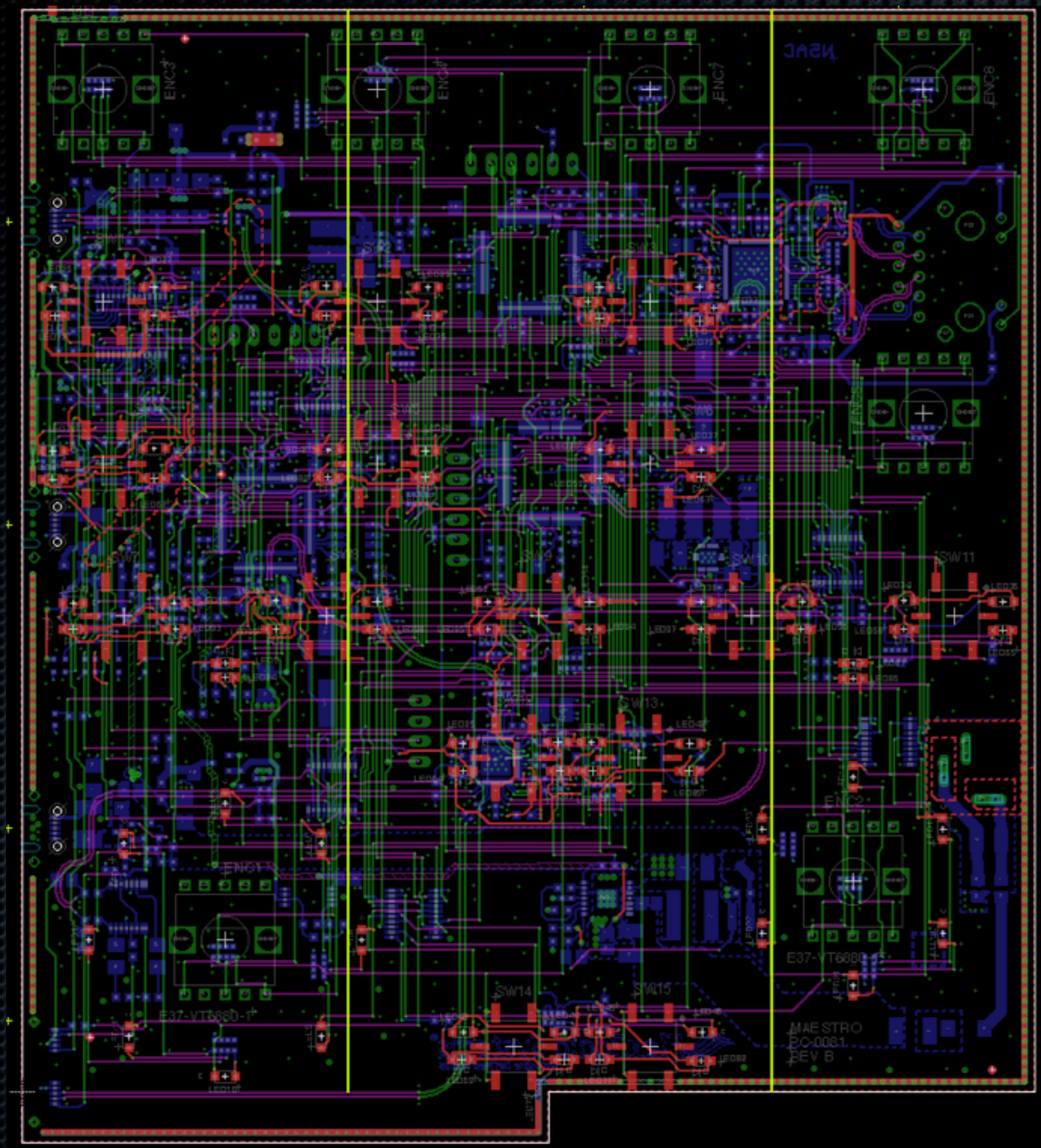
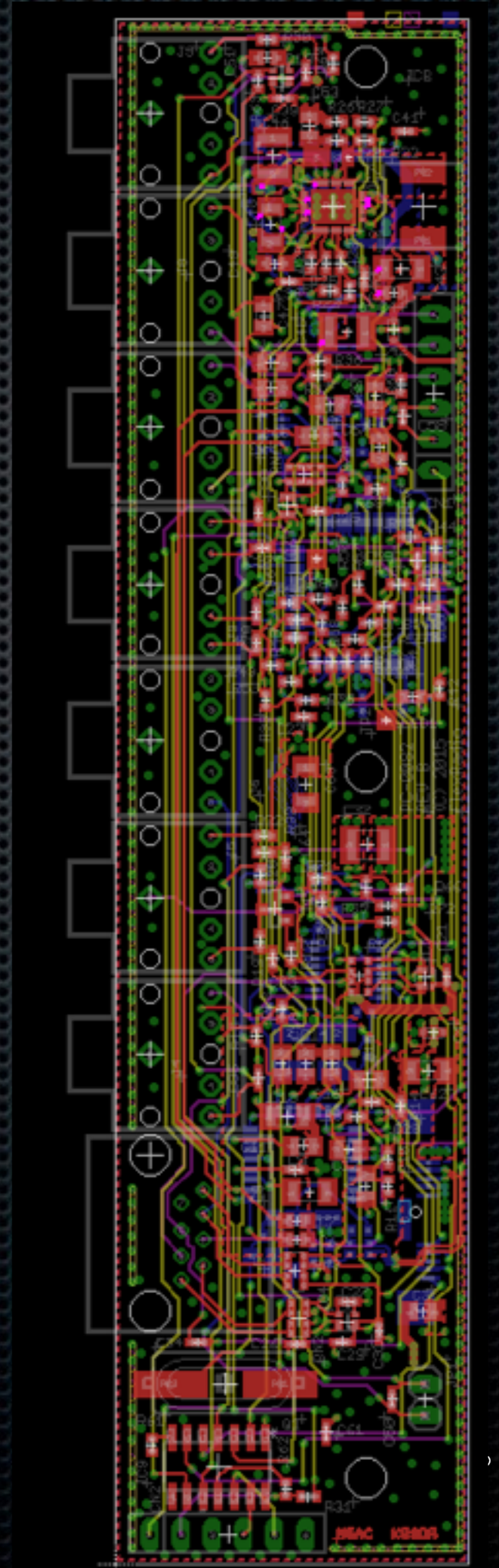

ENC5
ENC6
ENC7
ENC8
SW12
SW11
SW13
ENC2
ENC1
E37-VT6880-1
SW14
SW15
E37-VT6880
MAESTRO
PC-0001
REV B



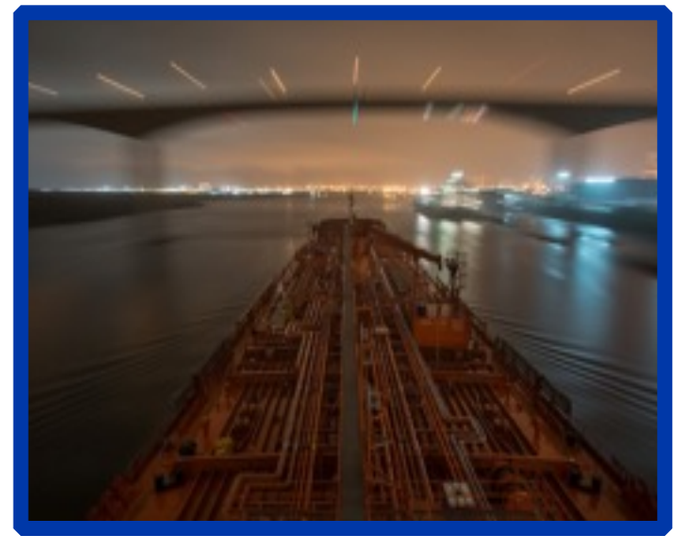
Global AIS on Space Station

May 2015

GLASS Project Overview

GLASS Project

- GLASS Project
  - Global AIS on Space Station (GLASS) is a collaborative applied research and development project to assess the practical value of AIS data collected on the International Space Station (ISS) for maritime operations and worldwide MDA



- Majority funded by CASIS, an organization selected by NASA to maximize use of the ISS U.S. National Laboratory
  - Two-year initiative beginning September 2014
  - CASIS contribution of more than $500,000
  - All participants making significant in-kind contributions

Rationale

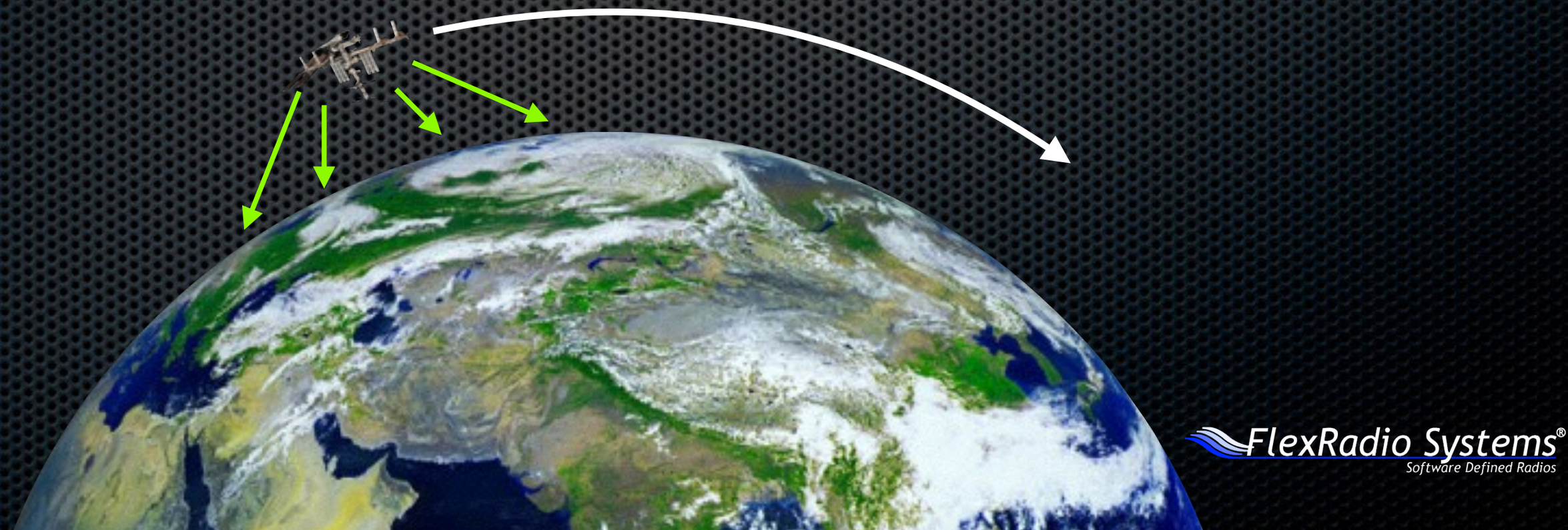
- Nearly all commercial ships are tracked using Automatic Identification System (AIS)
- AIS receivers are typically limited to line-of-site signal reception
- GLASS to acquire world-wide, real-time AIS data from ISS
- ISS ideally suited to maximize reception of AIS signals and offers opportunities for upgrades and maintenance by on-board crew
- Better information will enhance commercial business, improve national security, protect the environment, and provide economic and societal benefits

Team & Roles

- **JAMSS America, Inc**. – principal investigator and project integrator
- **University of Hawaii** – co-investigator, maritime researcher and GLASS operational evaluator
- **Greater Houston Port Bureau** – co-investigator, maritime consultant and GLASS operational evaluator
- **Mare Liberum Consulting, L.P**. – co-investigator, data systems and AIS signal processing/analysis
- **Flexitech, LLC** – consultant, aerospace radio communications technologies
- **VPI Engineering, FlexRadio Systems & Flexitech, LLC** – developers, GLASS space segment system

Why FlexRadio?

- Two channels with up to four doppler regions = 8CH
- Access to samples from receivers (Waveform API)
- Ethernet output to get samples to ground station



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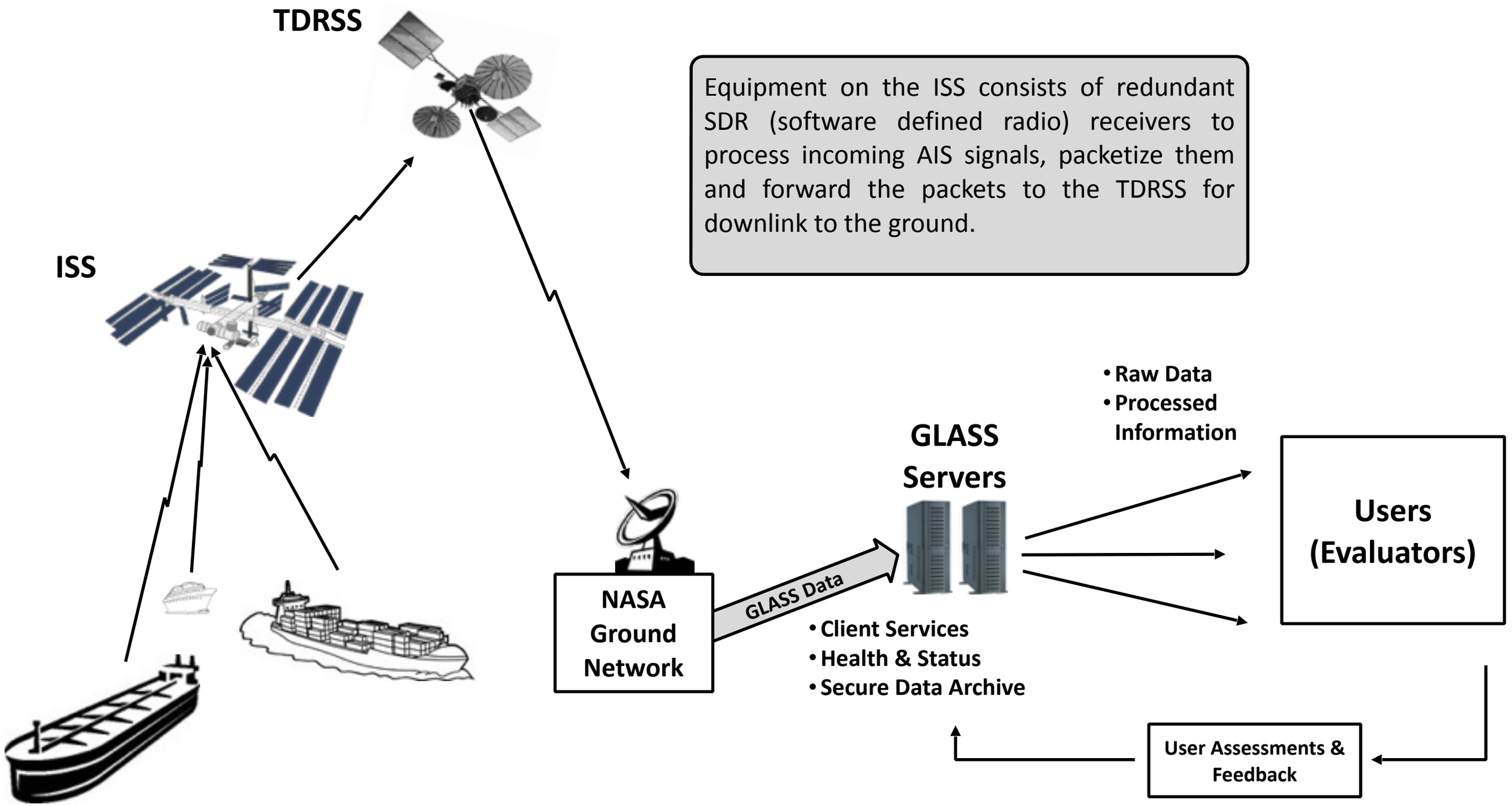
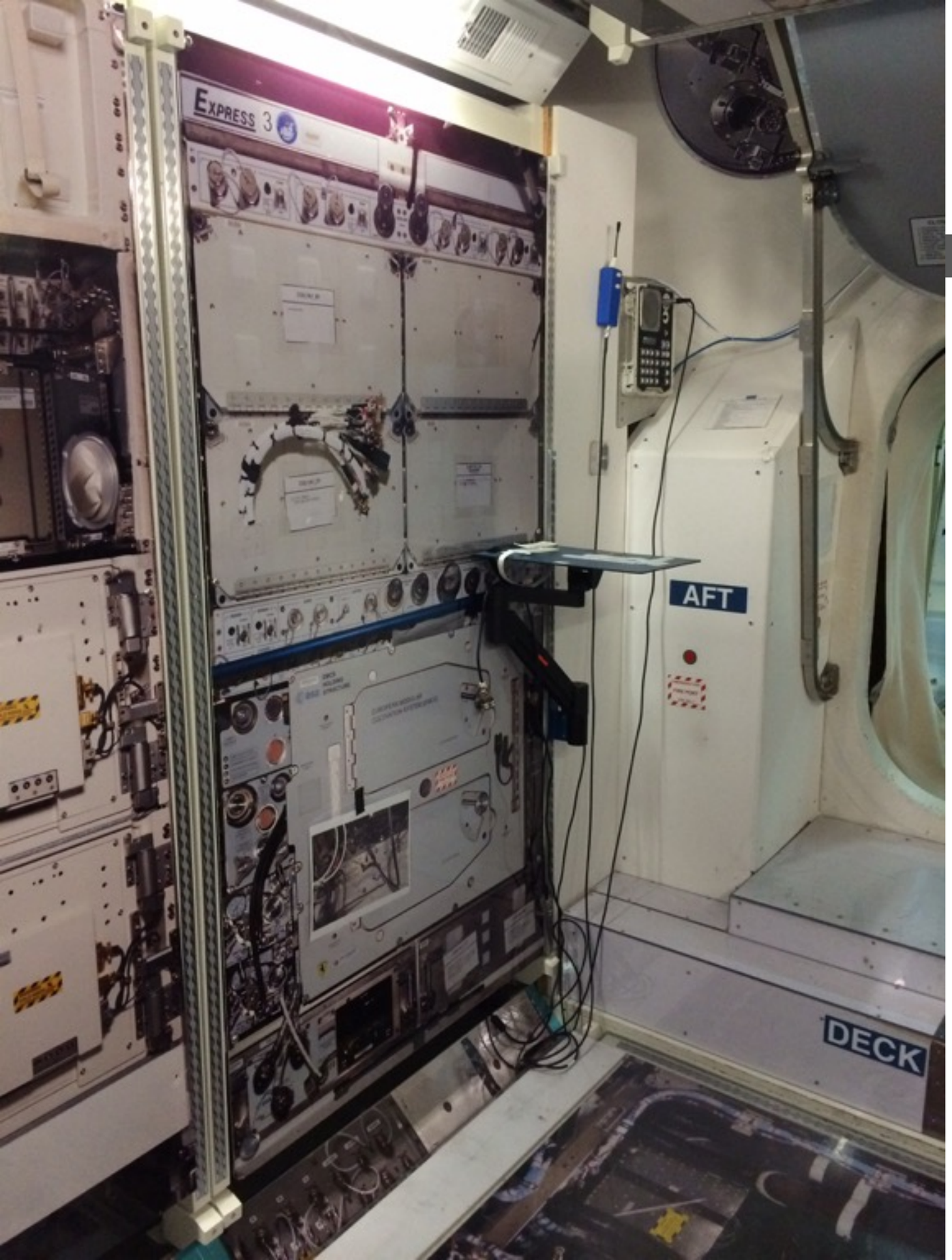
Project Overview

Equipment on the ISS consists of redundant SDR (software defined radio) receivers to process incoming AIS signals, packetize them and forward the packets to the TDRSS for downlink to the ground.

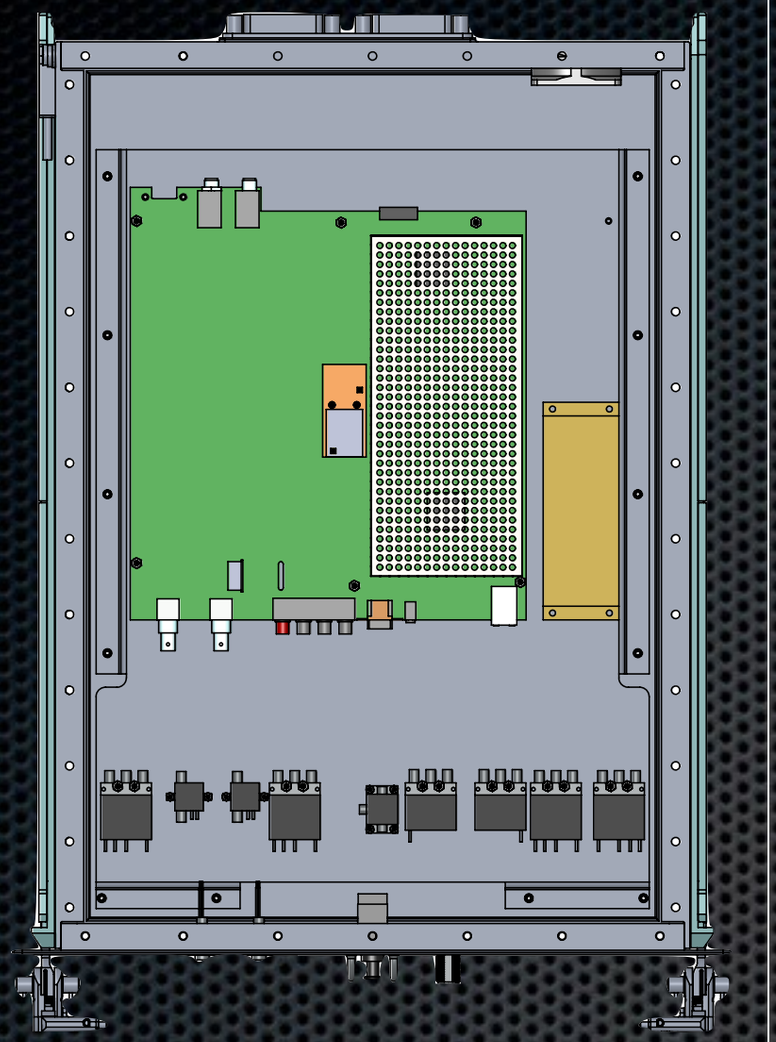


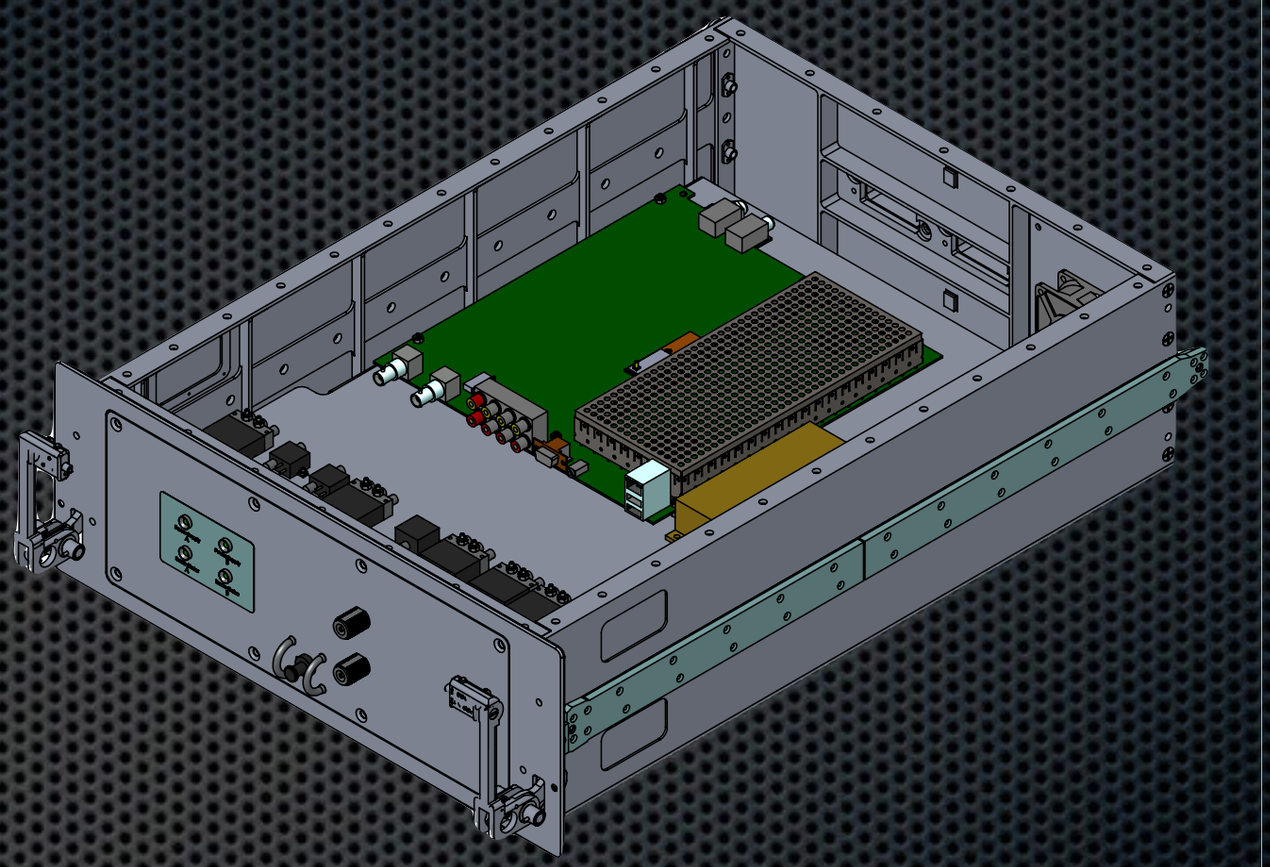
ISS – International Space Station
TDRSS – Tracking and Data Relay Satellite System

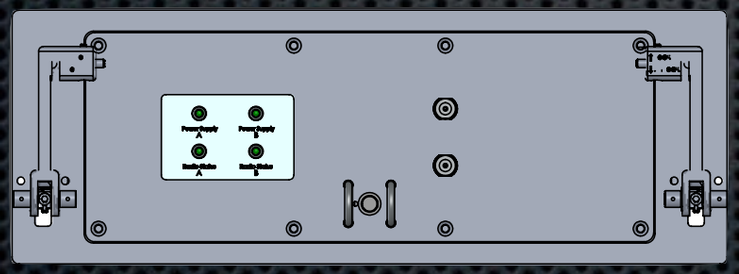


GLOBAL AIS
ON SPACE STATION

Express Racks







GLASS
Express Rack Drawer

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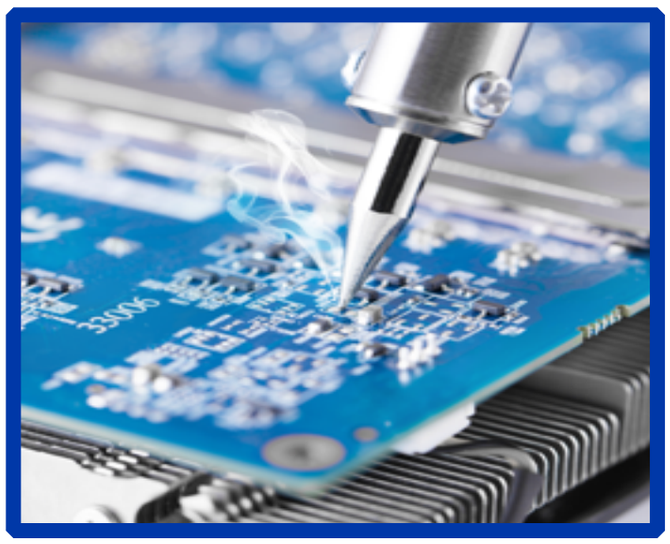
Software Defined Radios

Schedule

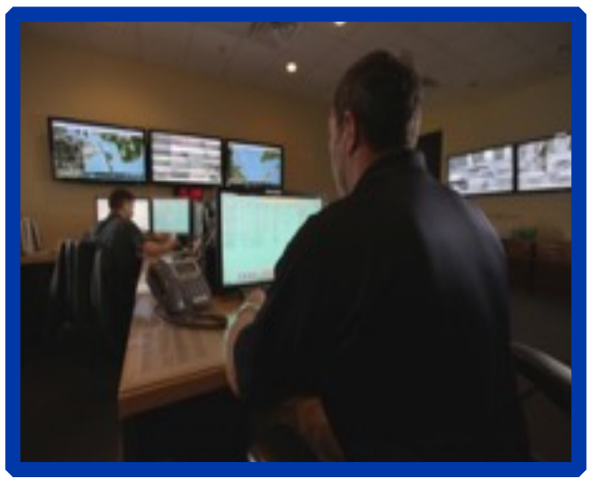


- Grant awarded (September 2014)
- Hardware/software development (initiated October 2014)
- Equipment launched to ISS and readied for operation (late 2015)
- System operation and data collection (12-month duration)
- Final assessment and report
- Project completion (late 2016)
- Commercial business initiation (2017)

Anticipated Value

GLOBAL AIS ON SPACE STATION

“Better information will enhance commercial business, improve national security, protect the environment, and provide economic and societal benefits.”



- Enhanced global competitiveness
- Adaptation to supply chain disruptions
- Improved protection of U.S. Exclusive Economic Zones
- Decreased environmental impacts
- Increased environmental protection
- Decreased illegal activities
- Expedited emergency response
- Enhanced education and training
- Data mining for societal benefit

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Questions?

re-discover radio

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