# 2018 / 2019 Rig Contest Comparisons
# +
# Hybrid Architecture Explained

Rob Sherwood
NCØB

Lots of good RX but transmitters lagging

- **What is important in a Contest Environment?**
- We need Good Dynamic Range to hear weak signals in the presence of near-by strong signals.
- In a DXpedition the pile-up is typically:
- CW signals “Up 2” or SSB signals “Up 5 to 10”
- Contests – DX pile-up, it is the same problem
- You need a better receiver for CW than for SSB.
- **What is the weak link today? Transmitters!**

# State-of-the-Art in Dynamic Range today

- Close-in dynamic range (DR3) > 100 dB
- Reciprocal Mixing (RMDR) > 115 dB

- Rigs with DR3 96 dB or greater:
- Icom IC-7851, Flex 6000 &  Elecraft K3S
- Icom 7300/7610
- TS-890S & FTdx-101D top RMDR performers
- Apache 7000DLE
- None are RMDR (phase noise) limited

# What is new since last year?

- Kenwood TS-890S
- Hybrid architecture
- Best RMDR I have ever measured
- Single receiver, unlike TS-990S
- Shipped in time for October CQWW SSB

- Yaesu FTdx-101D shipped in late April 2019
- Hybrid architecture
- Dual receivers
- Arrives at Sherwood lab May 9, 2019.

# Kenwood TS-890S

- The weak point of the TS-990S was phase noise in the LO (local oscillator).
- Likely only a problem in high RF environments
- This limitation is 100% corrected in the new TS-890S.
- To get accurate RMDR measurements I had to purchase several Wenzel low-noise crystal oscillators.
- However measuring dynamic range (DR3) was not an issue with HP 8642A synthesizers.

# TS-990S vs. TS-890S Comparisons

| RIG | TS-990S | TS-890S |
|---|---|---|
| • 20 kHz dynamic range: | 111 dB | 106 dB |
| • 2 kHz dynamic range: | 87 dB* | 105 dB |
| • 20 kHz RMDR: | 116 dB | 131 dB^ |
| • 2 kHz RMDR: | 89 dB | 127 dB^ |

* (phase noise [RMDR] limited)

^ (measured on 40 meters, Wenzel oscillator)

FTdx-101D provided by Randy W2KRY

# Yaesu FTdx-101D vs. TS-890S

| RIG | FTdx-101D | TS-890S |
|---|---|---|
| • 20 kHz dynamic range: | 110 dB | 106 dB |
| • 2 kHz dynamic range: | 110 dB | 105 dB |
| • 20 kHz RMDR: | 129 dB | 131 dB |
| • 2 kHz RMDR: | 125 dB | 127 dB |

Hybrid Down-conversion Superhet with Direct Sampling Bandscope & Waterfall
RMDR measurements made on 7.0 MHz with Wenzel crystal oscillator.

# Rigs run at NC0B during this past season

- CQ WW SSB October 2018 TS-890S 15 & 20m*
- CQ WW SSB October 2018 IC-7610 40 & 80m
- ARRL 160m CW Dec 2018 TS-890S & IC-7610
- ARRL 10m December 2018 TS-890S & IC-7610
- W1BB Top Band Dec 2018 TS-890S & IC-7610
- CQ WW 160 CW Jan 2019 IC-7610

* 20 meters was the “money band”, but with good Qs on 15 meters. I missed any 10m openings. (IC-7300)

# How did the rigs stack up?

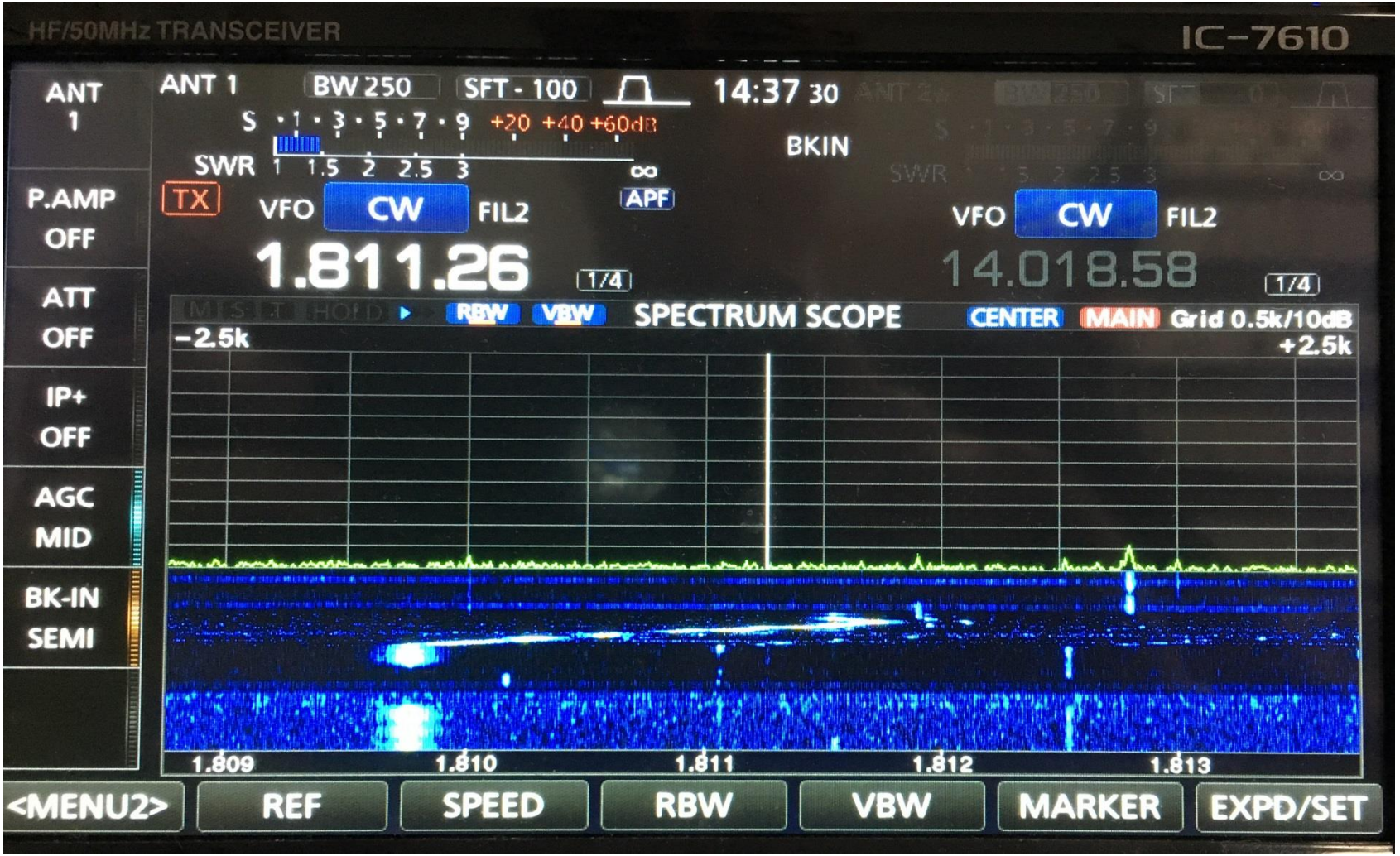
- While CQWW SSB is important, adjacent-channel splatter dominates over rig differences.
- ARRL 160m & 10m CW were good tests.
- DSP & APF selectivity excellent on both.
- I spent much more time on the new TS-890S.
- Ran both with semi-break-in at 26 wpm.
- NR & NB the Icom wins
- Waterfall the Kenwood wins hands down, at least the way I operate S&P CW.

# For me the Kenwood waterfall makes the radio

- If you are “running”, I doubt the scope/waterfall make much difference.
- For the S&P operator, CW or SSB, Kenwood “thought out-of-the-box” from my perspective.
- The following show the differences in the waterfall as you tune the radio to the next station to work.

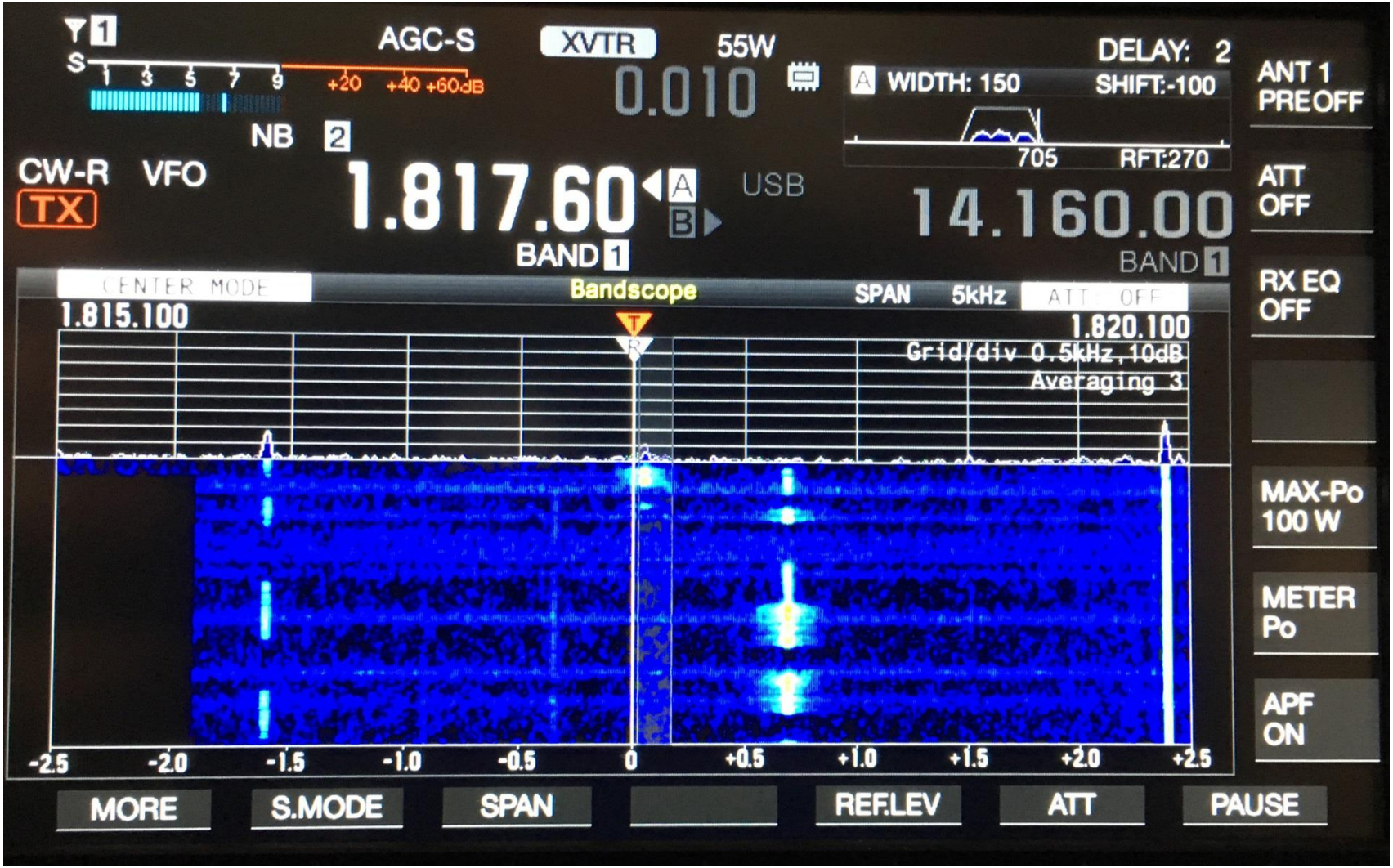
My workaround: use band scope with averaging OFF

# Icom waterfall slewing issue while tuning



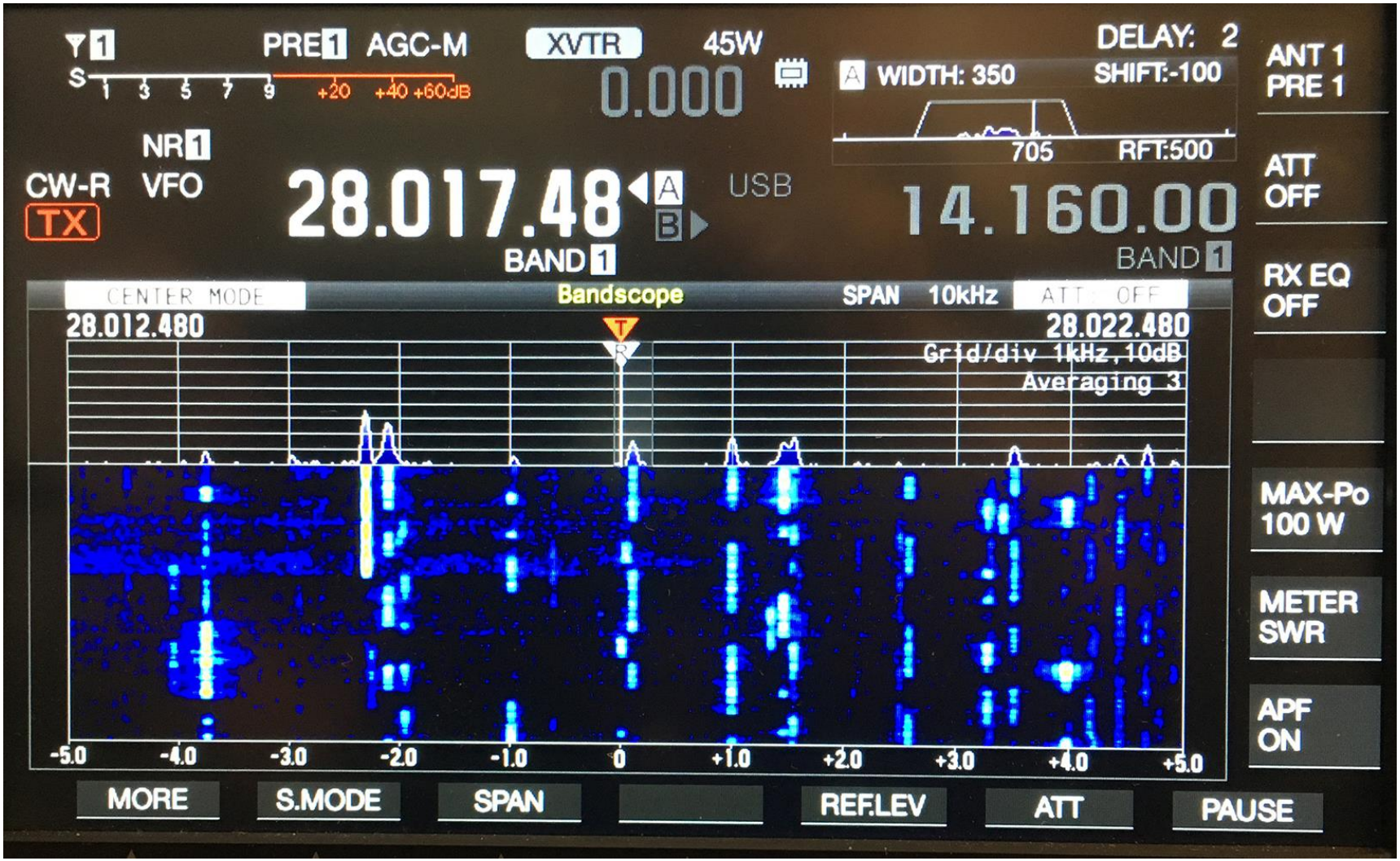
Whole waterfall shifts, but leaves a blank space

# Kenwood waterfall while tuning



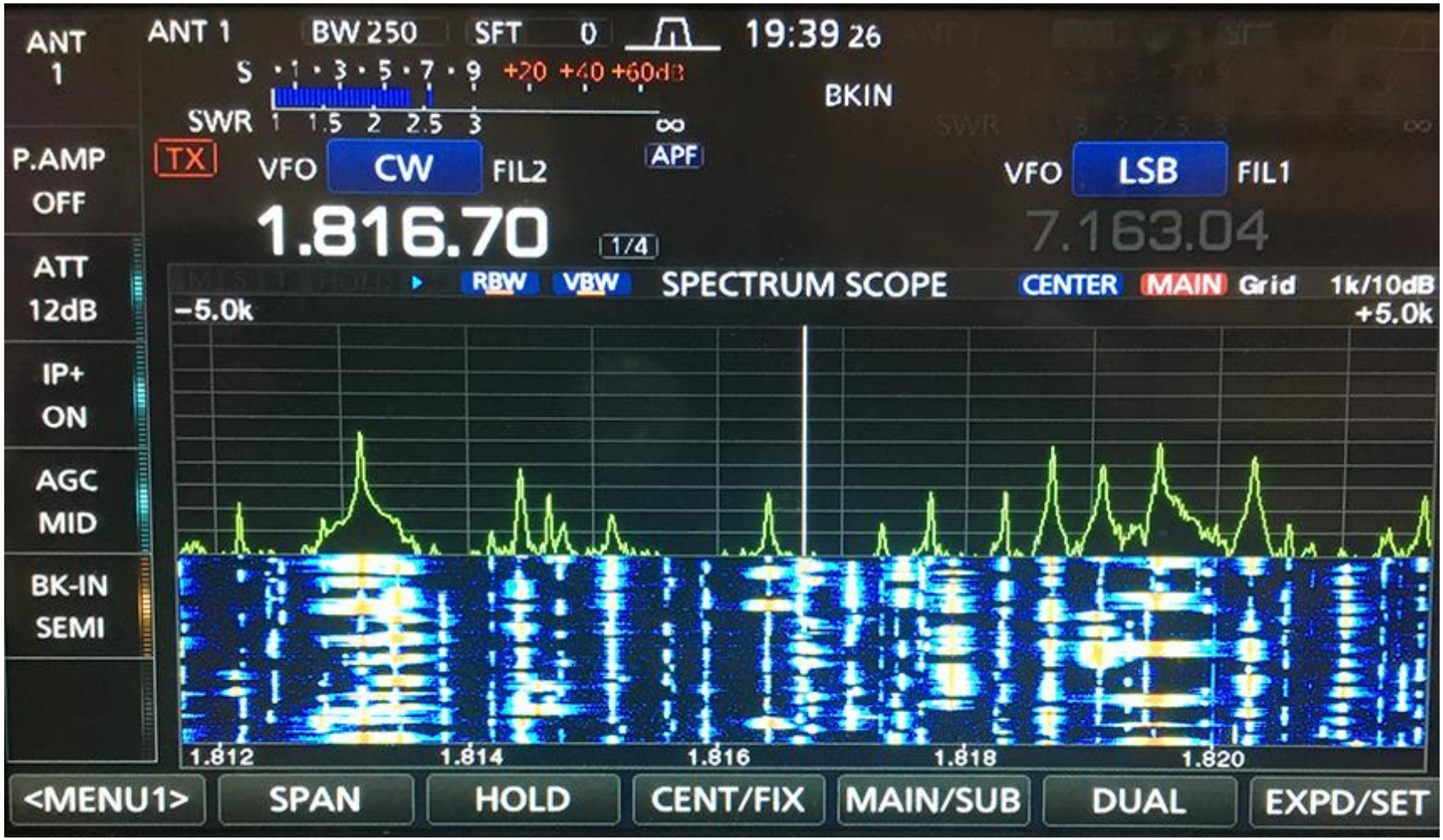
Over 20 stations in 10 kHz (ARRL)

# The 10m band Saturday afternoon



Over 30 stations in 10 kHz IC-7610

# CQWW 160m CW Friday 7:40 PM



# The year of the hybrid legacy & DS SDR radios

- Examples Legacy: K3S & Ftdx-5000, down conversion
- Examples Direct Sampling: Apache, Flex & Icom
- Dayton 2018 displayed a combination of the two.
- Main RF/IF chain: mixer, roofing filter, mixer, DSP
- Display: Direct Sampling after the first mixer but before the roofing filter
- Best of both world?  In some cases.
- Pure direct sampling SDR (DS SDR) requires the operator to manage net receiver gain more carefully.
- With a down-conversion radio with a roofing filter you can be careless!

# Why is direct sampling gain important?

- Field Day, a ham 1 mile away, or a multi-multi contest station is a tough RF environment for a direct sampling radio.
- In effect the roofing filter bandwidth is the entire band.
- A tracking preselector helps only a little.
- More helpful on 160m, almost none on 10m
- Keep the preamp OFF, and use input attenuation or RF gain to control overload.

# When is Attenuation a Win – Win Scenario?

- Note: If band noise is reading upscale on your S meter, then add attenuation.
- You lose NOTHING in terms of sensitivity!
- I set AGC threshold about 6 dB or so above band noise for least “contest fatigue” and lowest chance of overload on ANY radio.
- Attenuation at night on 40, 80 and 160m is a given, assuming you are listening on your transmit antenna. 12 dB 40/80, 18 dB 160m

Some are only CW oriented

# Contest features desirable today

- QSK, or at least click-free semi-break-in
- APF to reduce band noise and fatigue
- Bandscope & waterfall spectrum display for S&P operation and for multipliers
- Efficient User Interface
- Rock solid connection to logging program
- For most, at least some kind of external manual controls for computer-controlled rigs.
- DJ Console, as an example for Apache

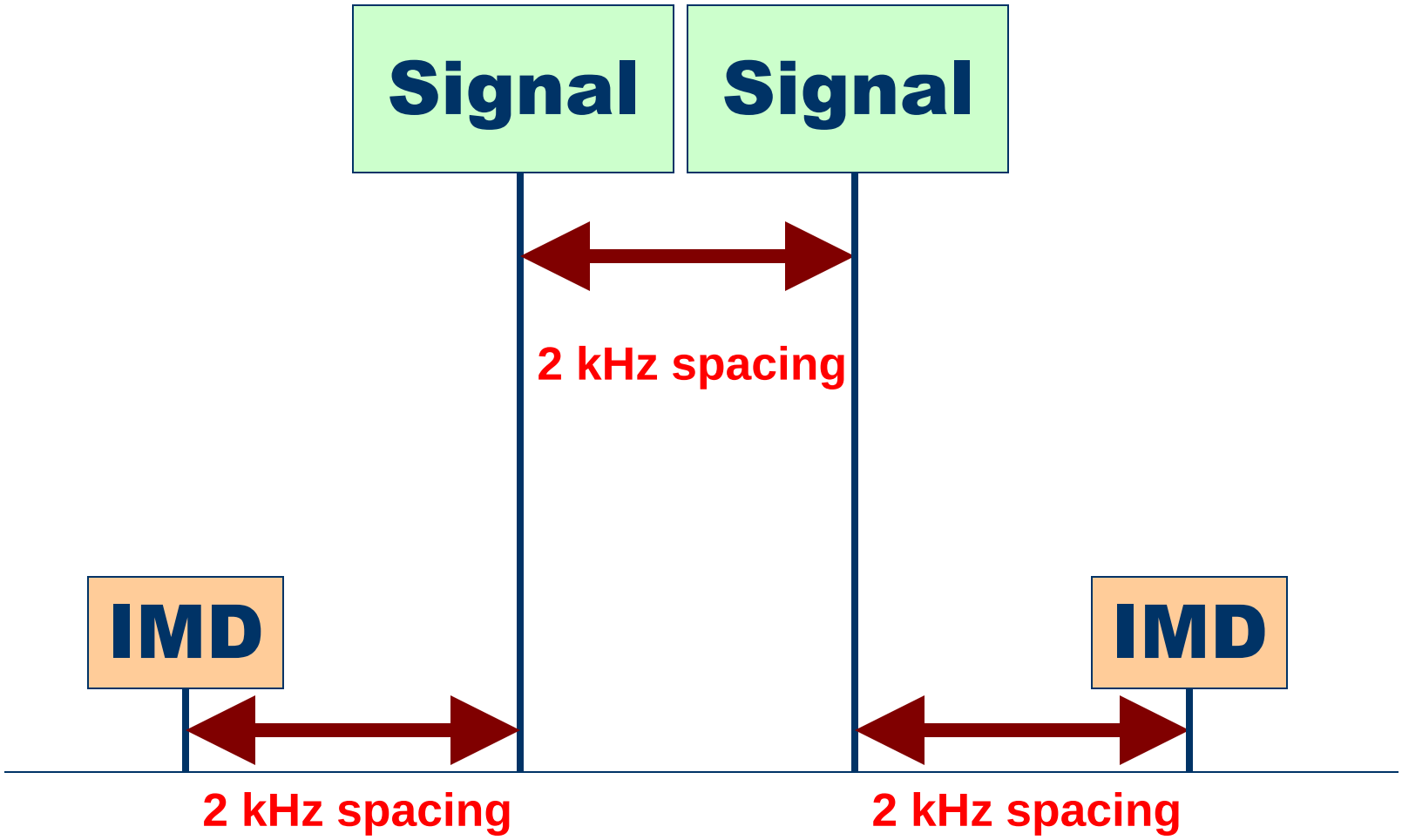
# Time for the numbers

- What do these state-of-the-art numbers mean?
- How do we cope with a more typical radio?
- We can optimize the performance of an 85 dB radio we own, and it can be perfectly adequate.

# What does dynamic range mean?

- Two equal signals are fed into the receiver.
- Third-order IMD is dominant.
- Level increased until distortion = noise floor
- This level vs. the noise floor = dynamic range
- Defined in QST *& hr magazine* 1975
- Noise floor = -128 dBm, test signals = -28 dBm
- -128 dBm minus -28 dBm = 100 dB
- Dynamic Range (DR3) = 100 dB

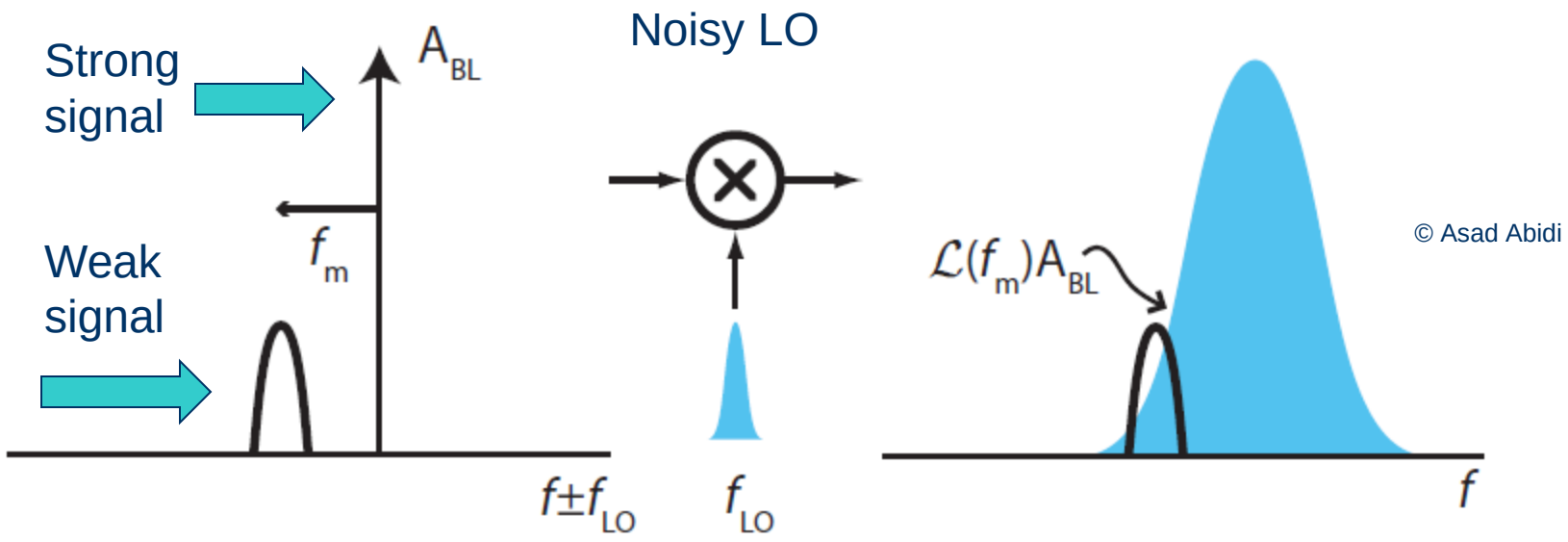
# Third Order IMD to Measure Dynamic Range



# A note on phase noise / RMDR

- Reciprocal Mixing Dynamic Range (RMDR)
- Since late in 2013 the ARRL has consistently emphasized the importance of good phase noise performance (RMDR).
- Read Bob Allison's sidebar April 2012 QST & latest update May 2016 QST for details.

# Reciprocal mixing puts LO noise on top of weak signal






Noisy local oscillator (LO) transfers its noise to the strong out-of-passband signal and on top of the weak signal we are trying to copy.

# RMDR often dominates over DR3

- Only a few “legacy” transceivers, plus direct sampling SDR radios have RMDR > DR3.

- Kenwood TS-890S & Yaesu FTdx-101D
- Elecraft K3S or K3 w/ new synthesizer
- Hilberling PT-8000A
- Icom IC-7850, IC-7851, IC-7610 & IC-7300
- Flex 6000 series, old and new
- Apache ANAN series

# Luckily we can live with 85 dB radios

- What performance is usually good enough?
- From the advent of “up-conversion” radios around 1979 (TR-7) until 2003 with the Orion I, all we had were 70 dB DR3 radios at 2 kHz.
- These were barely adequate on SSB and not acceptable on CW in DX pile-ups or contests.
- If we operate our 85 to 90 dB radios properly, they perform well in most environments.
- Most of the time our radios are not stressed to their limits.

Close-in 2-kHz Test @ 500 Hz BW

# Dynamic Range of Top 18 Transceivers

| | | |
|---|---|---|
| Yaesu FTdx-101D | 110 dB | |
| Elecraft K3S | 106 dB | |
| Icom 7851 | 105 dB | |
| Kenwood TS-890S | 105 dB | |
| Hilberling | 105 dB | |
| Elecraft KX3 | 104 dB | |
| ANAN-7000DLE | 103 dB | |
| Yaesu FTdx-5000D | 101 dB | |
| Flex 6600 / 6600M | 99 dB | (16 dB preamp ON) |
| Flex 6700 (2017) | 99 dB | (Preamp OFF) |
| Icom 7610 | 98 dB | |
| Icom 7300 | 97 dB | (IP+ ON, high serial number) |
| Flex 5000 | 96 dB | |
| Elecraft K3 | 95 dB | (Original Synthesizer) |
| Orion II | 95 dB | |
| Orion I | 93 dB | |
| TS-590SG | 92 dB | |
| Ten-Tec Eagle | 90 dB | |

# Why is higher DR3 needed on CW?

- Transmitted bandwidth of an adjacent strong signal may be the limit, not receiver overload.

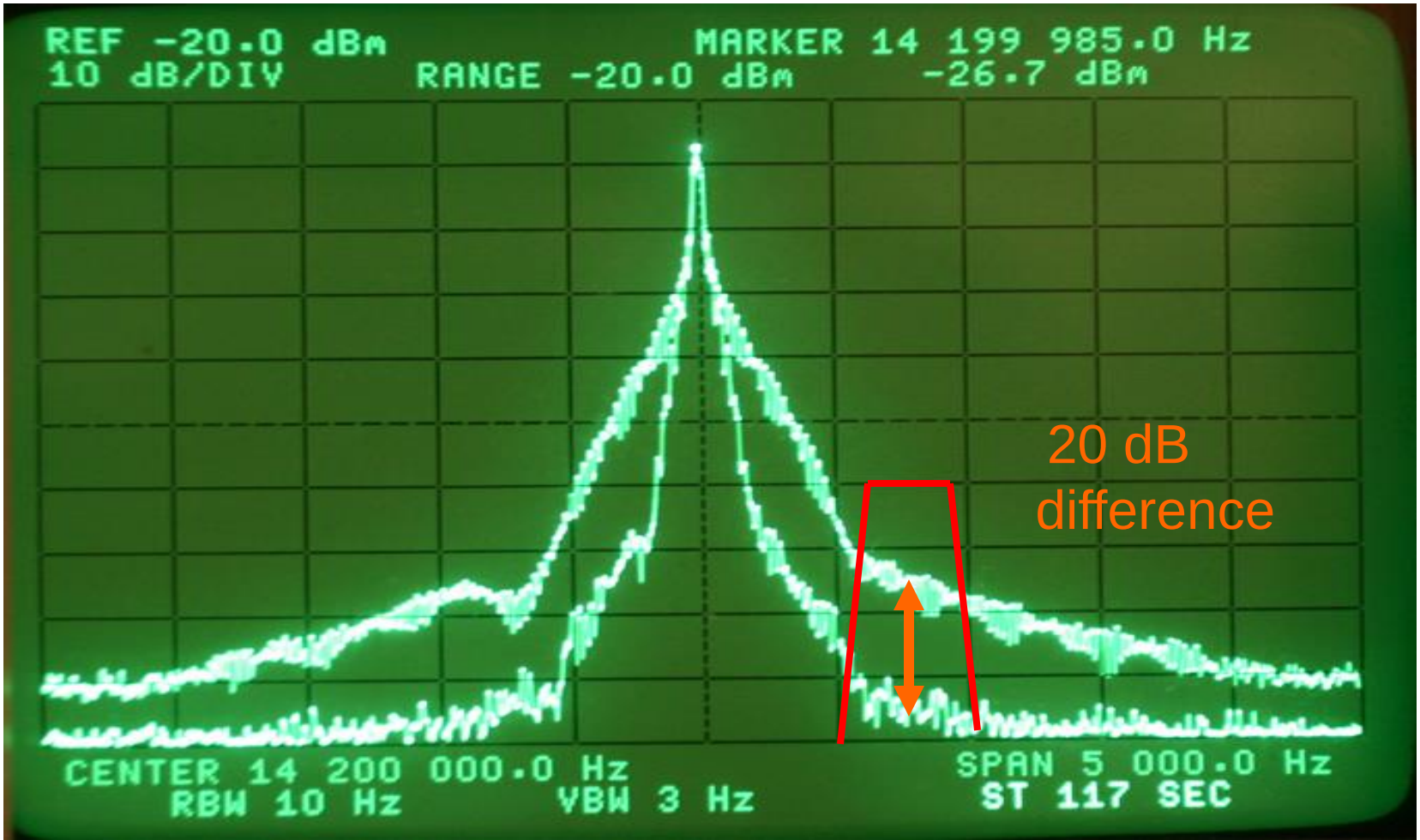
- A CW signal is about 1 kHz wide at -60 dB.
- An SSB signal is about 10 kHz wide at -60 dB.

- A CW pile-up may overload your receiver.
- On SSB, splatter will likely dominate before the receiver dynamic range is exceeded.

You can select 1 msec on many rigs !!!!

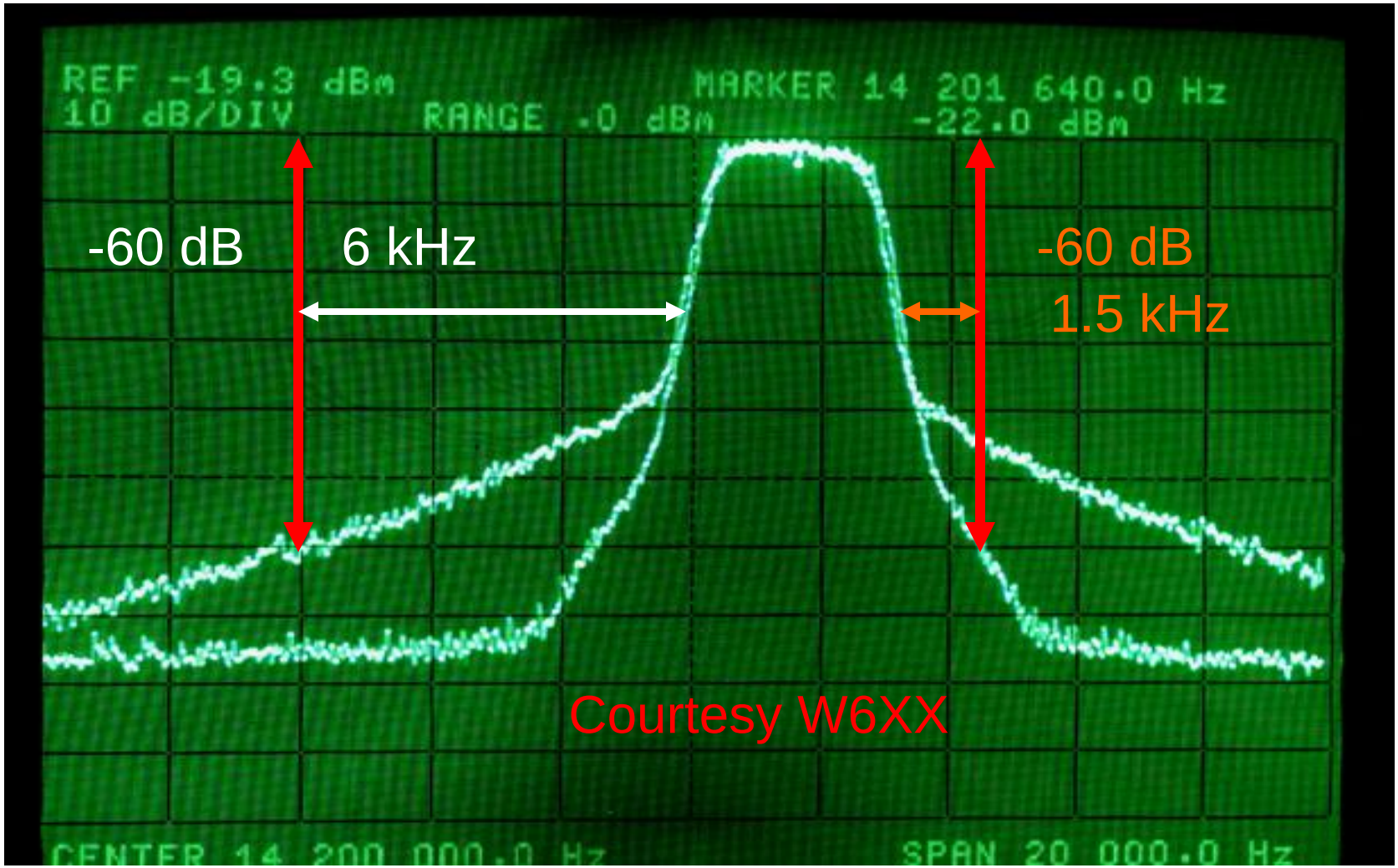
# Spectrum of CW Signal on HP 3585A Analyzer

Comparison of 3 msec vs 10 msec rise time



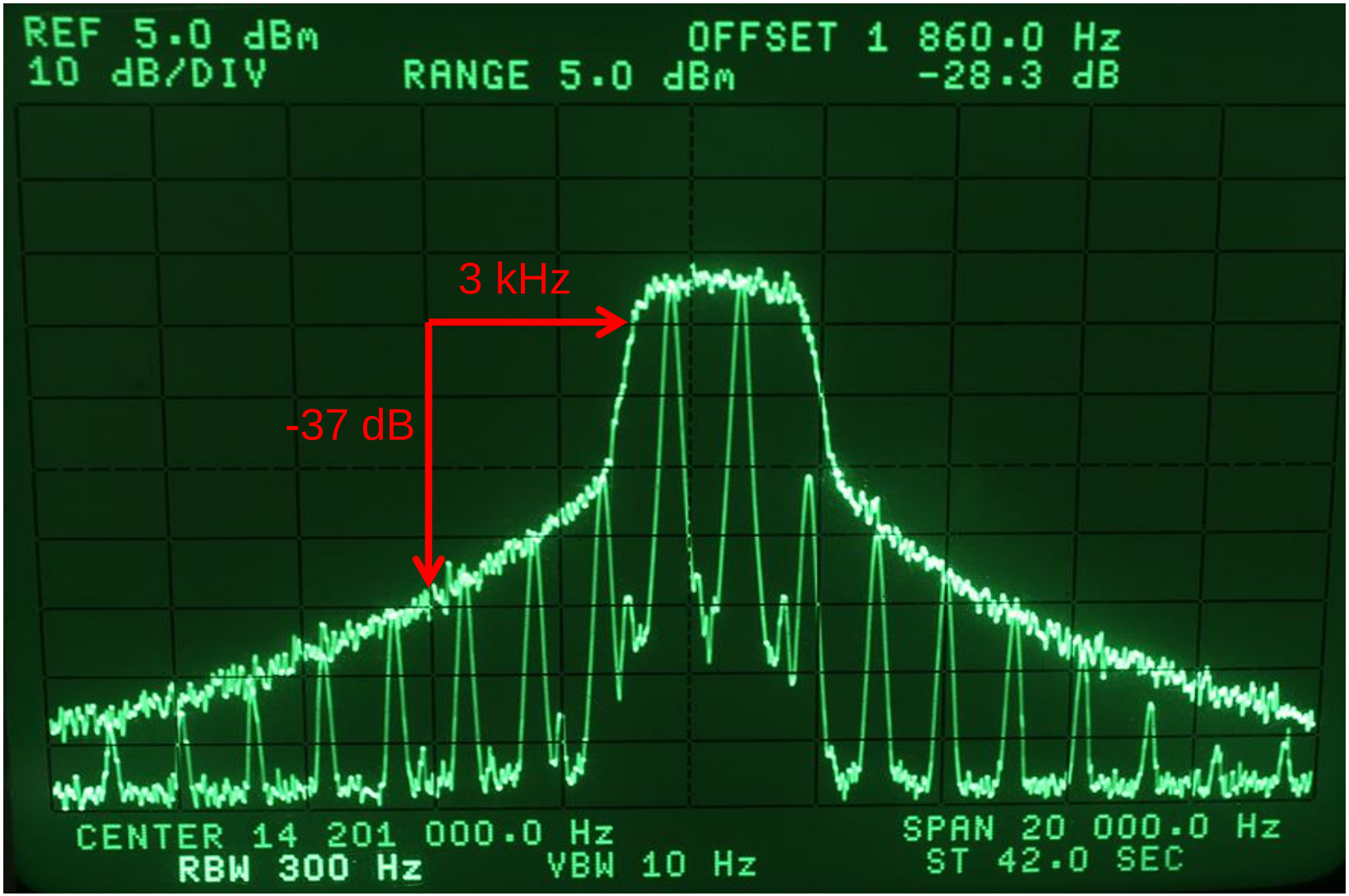
Apache PureSignal similar to class A

# White Noise Mk V Class A vs. K3 Class B @ 75 Watts



# How Wide Is Your Signal ?

## Comparison 2-Tone vs. Noise Intermodulation Bandwidth



# How do we optimize what we have?

- While we might own a 100 dB DR3 radio, many of us have somewhat less performance.

- A TS-590SG is a 92 dB radio @ 2 kHz.
- N2IC wins contests with two TS-590 radios.
- Consider dynamic range a “window” of performance that can be moved around in absolute level by properly using your attenuator or preamp.

# What is often the limit today?

- Receivers have drastically improved in the past 10 years.
- Transmitter cleanliness: No Improvement !*
- Transmitted splatter, transmitted broadband noise, and CW key clicks are now usually the limit today.
- During January CQWW 160m CW, one station had key clicks at least 1.6 kHz wide running an FTdx-5000MP.

* Apache PureSignal the exception on SSB

# Transmitted noise

- We have 3rd order IMD splatter “noise”
- Rigs where you can “turn on” key clicks!
  (Rise time can be set to 1 millisecond!)
- I recommend no faster than 6 milliseconds.
- Rarely mentioned “transmitted noise”
- I believe only Icom even mentions transmitted noise in their ad copy.
- We need to be a good neighbor.

Noise hopefully falls off with spacing

# Broadband noise comparisons 100 watts

| Rig | 10 kHz dBc/Hz | 100 kHz dBc/Hz |
|---|---|---|
| K3S | -141 | -143 |
| IC-7851 | -129 | -138 |
| IC-7610 | -128 | -142 |
| Flex 6400 | -122 | -139 |
| IC-7300 | -121* | -124 * |
| FTdx-3K | -120* | -121 * |
| TS-890S | -119 | -139 |

- * Note: Noise hardly falls off at all. Likely a problem on Field Day with two stations on the same band.

Low drive amps are an issue

# Noise gets worse at 30 watts output

| Rig | 10 kHz dBc/Hz | 100 kHz dBc/Hz |
|---|---|---|
| K3S | -132 | -140 |
| IC-7851 | -123 | -133 |
| IC-7610 | -122 | -127 |
| Flex 6400 | -120 | -137 |
| FTdx-3K | -117 | -117 |
| TS-890S | -115 | -135 |
| IC-7300 | -110 | -116 |

Do you have a multiplier station besides your run station?

Broadband noise matters.

There is a trade-off. The rig may be cleaner from an IMD splatter standpoint at 30 to 50 watts, but the composite noise is worse.

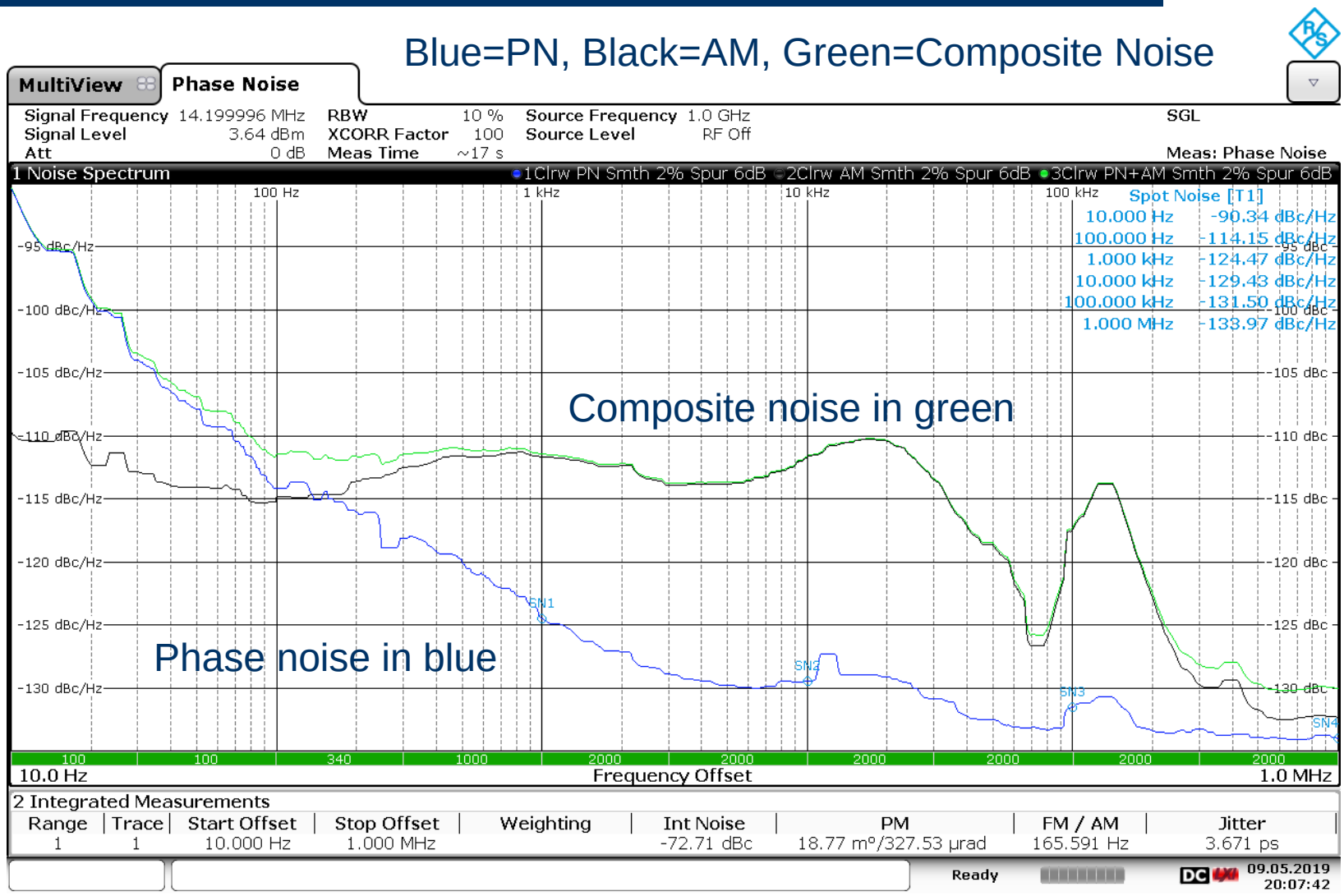
# ARRL noise measurements are incomplete

- How transmit noise is measured is important.
- Two types of noise exist: Phase and Amplitude
- ARRL only measures Phase Noise.
- “On the air” Composite Noise is what matters.
- Composite noise measures both types !
- Some rigs have minimal AM noise.
- Other rigs have lots of AM noise.
- The following slide is of the IC-7300 where AM noise dominates past 200 Hz offset.

Data courtesy Conrad PA5Y

# Transmit noise IC-7300 on 20 meters

Blue=PN, Black=AM, Green=Composite Noise

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# Solid-state Linear Amps not so Linear

The ARRL published a compendium of tube-type linear amplifier odd-order distortion performance copyright 1997.

All the amps had third-order IMD down between 40 and 50 dB below PEP.

A recent review in QST of a popular solid-state amp listed third-order IMD down only 30 dB, with no comment on this value.

Another new amp measured only 27 dB on 10 and 6 meters !

30 dB is 6 to 10 dB worse than the cleaner transceivers in use today.

The cleanest transmitter I have ever owned was the Collins 32S-3.

Transmitters have gotten worse, and now solid-state amps are worse.

We have wonderful receiver performance today, not so much our transmitted signal. This problem adds to QRM.

# What is the bottom line?

- On the lower bands at night, use of your receiver attenuator is usually appropriate.
- There is no point in band noise reading upscale on your S meter.
- A preamp is generally NOT needed on 20 meters.
- A preamp would ***never*** be needed at night on 40 meters and below, assuming the transmit antenna is used on receive.

# My caution about preamp usage !

- With a superhet, like a K3S, TS-890S & FTdx-101D, you can often get away with improper usage of a preamp due to the narrow roofing filters. Most signals on the band will be rejected by the roofing filter. Overload is less likely.
- A direct sampling radio in effect has a roofing filter (BPF) of at least the bandwidth of the whole band.
- During WRTC direct sampling & superhets were fine.
- Running a preamp when there is zero reason to do so just asks for the ADC to be driven into overload.

  (OVF display for an Icom 7610/7300)

# How do we evaluate & optimize a transceiver?

- 160 – 40m receivers are too sensitive at night.
- Make the most of the radio's dynamic range by properly using the attenuator, and using the preamp only when necessary on the high bands.
- Published dynamic range can be misleading, depending on how it is measured.  This could be a complete presentation on its own.
- It is a numbers game today!
- Get feedback from successful contesters.
- What works for them?

http://www.NC0B.com

# Sherwood Engineering

Videos from past CTU presentations

CTU 2013 through 2018  (Select desired year)

http://www.contestuniversity.com/videos

Sherwood Shootouts (Contest Comparisons) published by DJ0IP

http://www.dj0ip.de/sherwood-forest/sherwood-s-shootouts/