2020 Edition

Transceiver Performance for the HF - DX Operator

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NCØB

RX performance is now so good,
TX limitations dominate today.

Don’t focus on just a few transceivers

- I started testing receivers in 1976.
- Our HF choices today are amazing.
- We also have several new challenges.
- Let’s look at the issues.

HF Sensitivity specifications are a non-issue

- I keep getting asked to sort my web table by sensitivity.
- SSB Sensitivity rating in microvolts goes back decades.
- R-390A from 1954 is 0.2 microvolts
- Drake R-4C 0.2 microvolts
- K3S with preamp #1 is also 0.2 microvolts.
- Reception limits today are often urban noise (RFI).

What is Sensitivity & Noise Floor?

- Sensitivity for SSB means a 10 dB S+N/N ratio in a 2400 Hz bandwidth (BW). I list it in microvolts for historic reasons. (Legacy data pre 1975)

- Reviews today emphasize noise floor. (500 Hz BW)

- Noise floor in dBm is similar, but it is a 3 dB S+N/N ratio.

- R-390A noise floor: -137 dBm
- R-4C noise floor: -138 dBm
- K3S noise floor: -138 dBm

At HF local noise is often the limit

Urban noise a major issue today.

1969 to 2019 urban noise increased 3 dB per decade.

Sources of noise:
Line noise
Wall warts
Switching power supplies (computers)
Household appliances with microprocessors
Light dimmers
LED light bulbs, some worse than others
VDSL leakage
Grow lights

The other main performance value

Dynamic Range

The search for the “magic” 100 dB radio

Not uncommon today 160 – 6 meters

Note: 85 dB very rare on 2m and up

What is Dynamic Range?

- Dynamic Range - measures the ability to hear weak signals in the presence of nearby strong signals.
- 20 kHz Dynamic Range measurement in an up-conversion radio only tests the radio's front end.
- Except for the Icom IC-7851, most up-conversion radios are a compromise in CW contests and DX pile-ups.
- VHF/UHF radios are decades behind HF in performance.

What Numbers are Most Important in a multi-signal environment ?

- Close-in Dynamic Range (DR3) on CW or RTTY
- Noise floor value need for DR3 calculation.
- Reciprocal Mixing Dynamic Range (RMDR)
- Transmitted broadband composite noise
- Transmit IMD splatter limits RX performance.
- Key clicks limit close-in CW reception.

Defined in QST and *hr magazine* in 1975

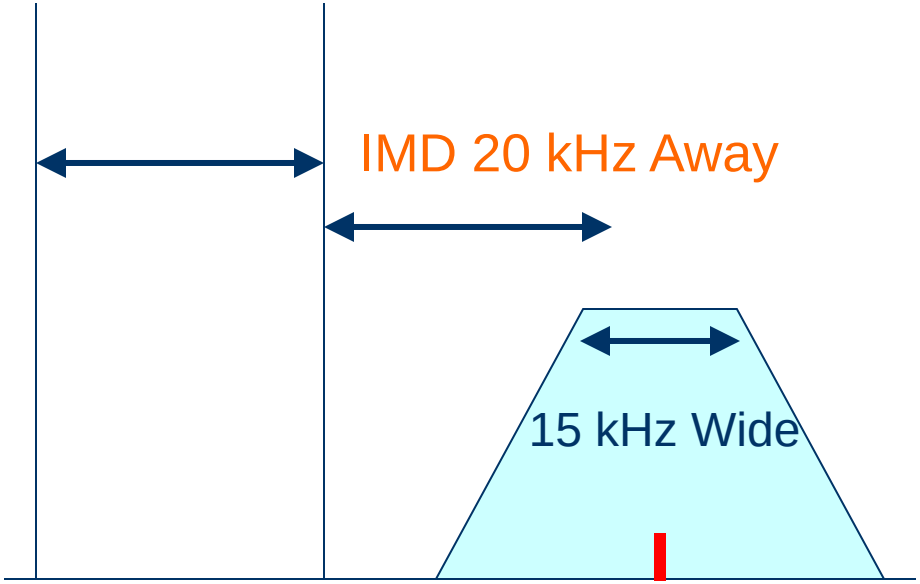
What does dynamic range mean?

- Two equal signals are fed into the receiver.
- Third-order IMD is dominant.
- Level adjusted until distortion = noise floor
- This level vs. the noise floor = dynamic range
- Example:
- Noise floor = -128 dBm, test signals = -28 dBm
- -128 dBm minus -28 dBm = 100 dB
- Dynamic Range (DR3) = 100 dB

Example of an up-conversion radio

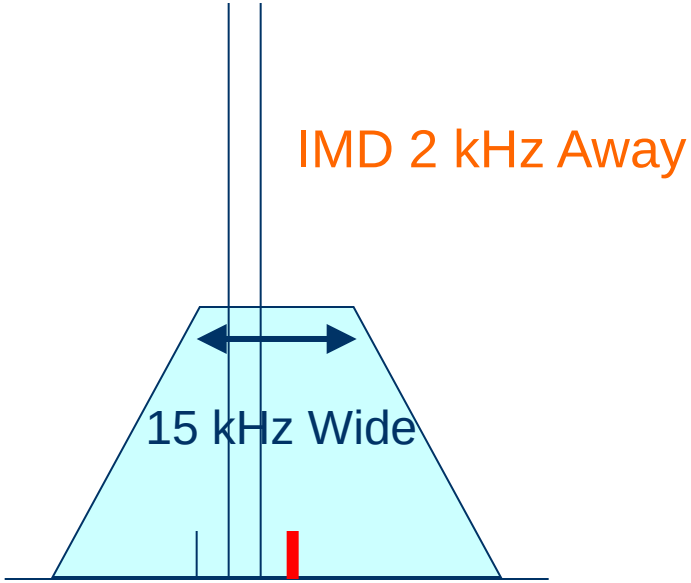
Wide & Close Dynamic Range

20 kHz Spacing



First IF Filter at 70.455 MHz

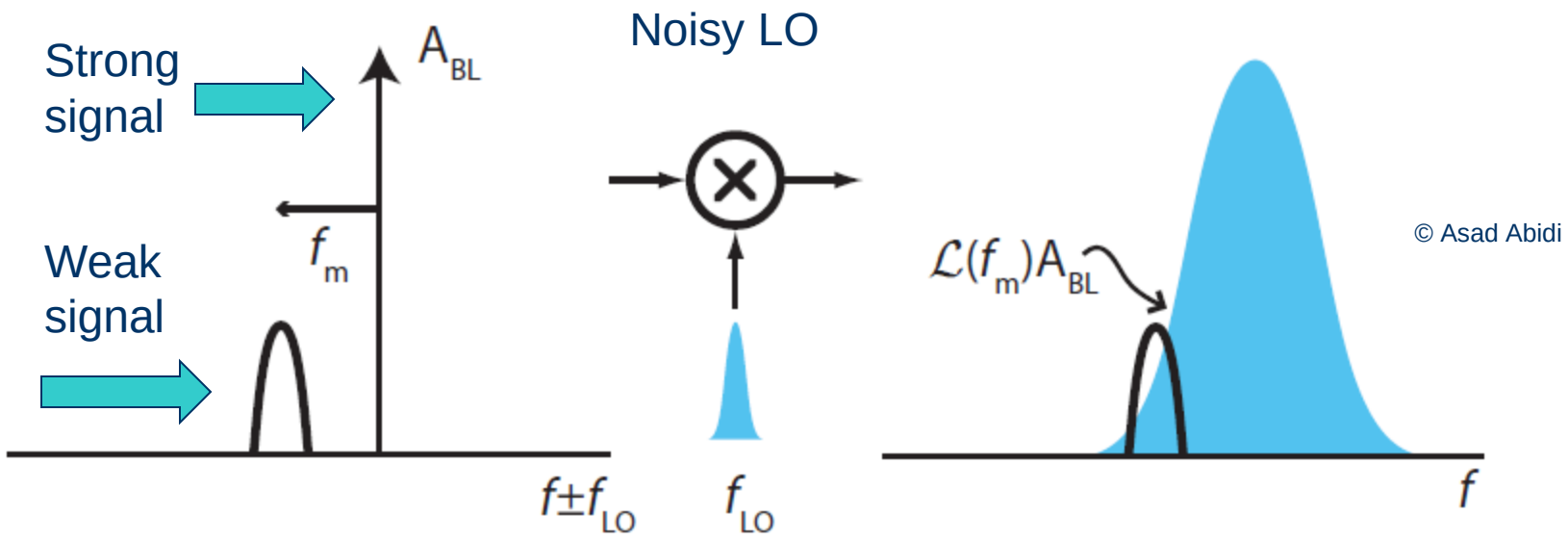
2 kHz Spacing



First IF Filter at 70.455 MHz

Noise spectra my be flat, and not fall off .

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.

The devil is in the details !

A caution about the latest QST Product Reviews

Reciprocal Mixing Dynamic Range (RMDR) has been explained by Bob Allison in QST sidebars in April 2012 and May 2016.

RMDR can dominate over the more obvious dynamic range (DR3) values.

A 2013 FTdx-3000 Product Review quoted DR3 = 100 dB.
At the same time in “fine print” QST quoted RMDR = 82 dB.
The 100 dB value is meaningless since 82 dB dominates.

March 2020 QST review of the Xiegu G90 transceiver has the same issue.
DR3 = 91 dB while RMDR = 84 dB. Ignore the 91 dB value!

Bob’s sidebar also pointed out mediocre CW keying sidebands, SSB IMD splatter performance, and transmit phase noise. Bob said Don’t use an amp!

We all need to be good neighbors and not pollute the airwaves with poor quality signals that makes QRM worse.

RMDR often dominates over DR3

- Only a few “legacy” superheterodyne transceivers, plus “direct-sampling SDR” radios have RMDR > DR3.
- Superhet
- Elecraft K3s, IC-7851, FTdx-101D, TS-890S
- Direct Sampling
- IC-7610, IC-7300 & IC-9700
- Flex 6000 series
- Apache ANAN series

There are two basic types of transceivers today

- Superheterodyne, hybrid or not, and Direct Sampling
- Hybrid = Superhet with direct sampling band scope
- They both work, and each has its strengths and weaknesses.
- Superhet is likely a better choice for Field Day because it has a roofing filter. Blocking 25 dB above ADC overload for direct sampling radios.

Possible concerns for Direct Sampling

- Field Day or a ham 1 mile or blocks away
- Front-end L/C filter is likely a half octave filter, 11 to 15 MHz for the Icom 7300 or 7610.
- A superhet with a crystal roofing filter has an advantage in these difficult RF environments.
- Hopefully another ham isn't this this close.

Some are only CW oriented *

Features desirable today

- QSK, or at least click-free semi-break-in *
- APF to reduce band noise and fatigue *
- Band scope & waterfall to watch the DX pile-up
- Efficient User Interface
- Rock solid connection to logging program
- Tuning knob for computer-controlled direct sampling transceivers

Time for the numbers

- What do performance numbers mean?
- Do you need the absolute best numbers? NO !
- You can optimize the performance of whatever transceiver you own.
- Lots of transceivers can be perfectly adequate.

Performance up through 6 meters

State-of-the-Art in Dynamic Range today

- Close-in dynamic range (DR3) > 95 dB
- Reciprocal Mixing (RMDR) > 110 dB
- Rigs with this kind of performance:
- Icom 7851, 7610, 7300
- Flex 6000 series & Apache ANAN series
- Elecraft K3S
- Kenwood TS-890S & Yaesu FTdx-101D
- All 6 major OEMs are this good.
- Unfortunately above 6m performance drops

Close-in 2-kHz Test @ 500 Hz BW

Dynamic Range of Top 18 HF Transceivers

• Yaesu FTdx-101D	110 dB	
• Elecraft K3S	106 dB	
• Icom 7851	105 dB	
• Kenwood TS-890S	105 dB	
• Hilberling PT-8000A	105 dB	
• Elecraft KX3	104 dB	
• Apache 7000DLE	103 dB	
• Yaesu FTdx-5000D	101 dB	
• Flex 6400	100 dB	
• Flex 6600	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	
• Ten-Tec Orion II	95 dB	
• Ten-Tec Orion I	93 dB	
• Kenwood TS-590SG	92 dB	
• Ten-Tec Eagle	90 dB	

You can effectively work DX and Contests with any of these fine transceivers.

New price range $1000 to $12,000+

Used market price even lower

I have run contests with 12 of the 18
N2IC uses two TS-590 models.

Where will the K4 fit in this table?

- We don’t yet know, since it hasn’t shipped, but we do know the architecture.
- A basic Elecraft K4 will be much like an Icom IC-7610. Direct sampling & 2 receivers
- The K4HD (with the superhet module and four roofing filters) will have an architecture similar to the Yaesu FTdx-101D or MP.

New and used price bargains today

- A new IC-7300 sells for as little as $899.
- A used TS-590S sells for $600 or less.
- I prefer a radio with a built-in band scope but LP-PAN and SDR “dongles” provide viable options.

Pay attention to NET GAIN

- The following 10m and 160m slides emphasizes using common sense on preamp and attenuator settings.
- 40m and below at night, use the attenuator.
- On 15m and above, a preamp is useful if you are in a quiet location.
- Urban noise may make a preamp useless.

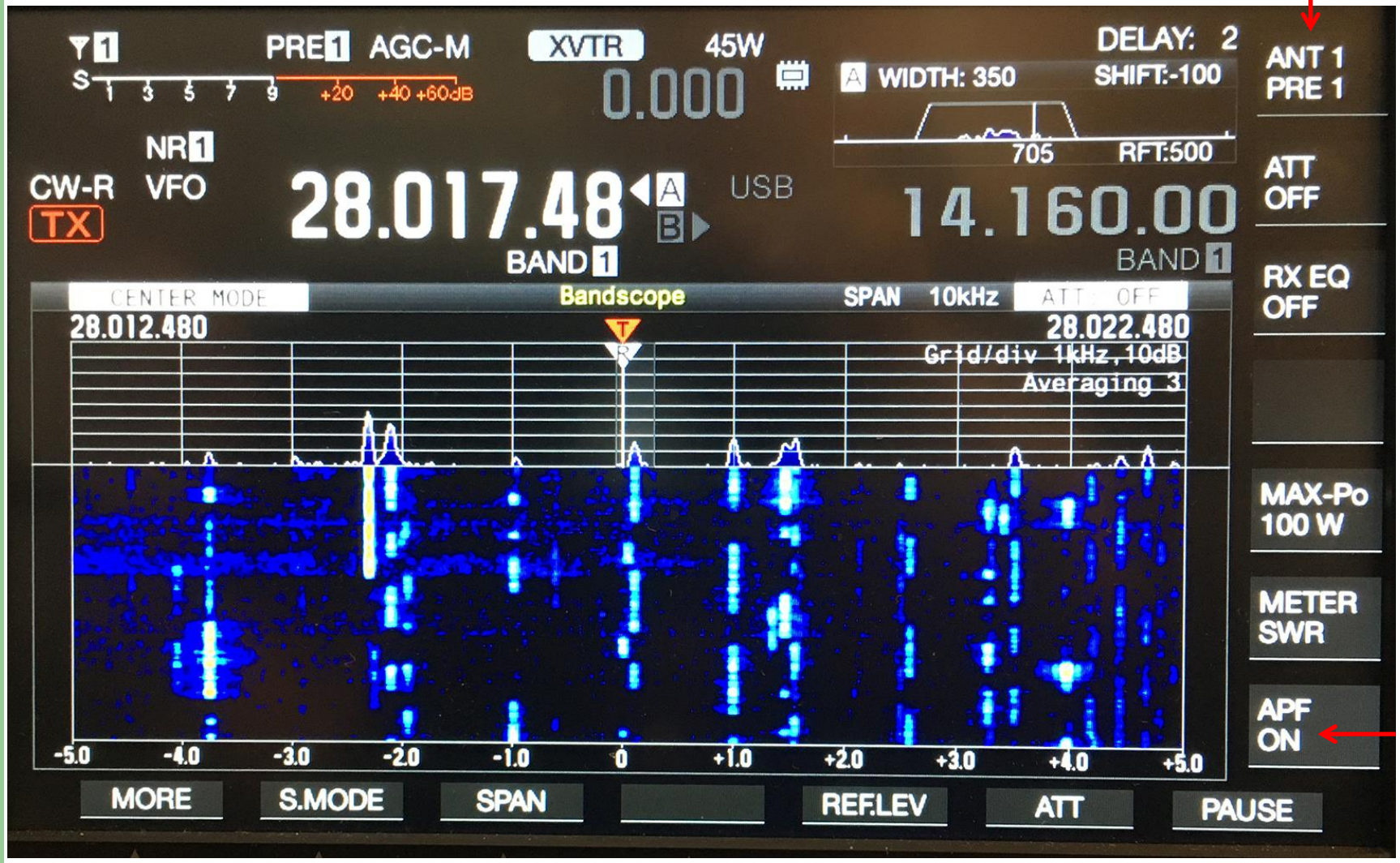
- A preamp at night on 40m is crazy!

December 2018

Over 20 stations in 10 kHz TS-890S

ARRL 10m Saturday afternoon

Note preamp



What can else a band scope show?

- Not only can we observe a DXpedition running split, the scope and waterfall also show other causes for QRM.

- Your receiver filters cannot eliminate in-passband QRM such as Key Clicks, SSB Splatter, or Transmit Composite Noise.

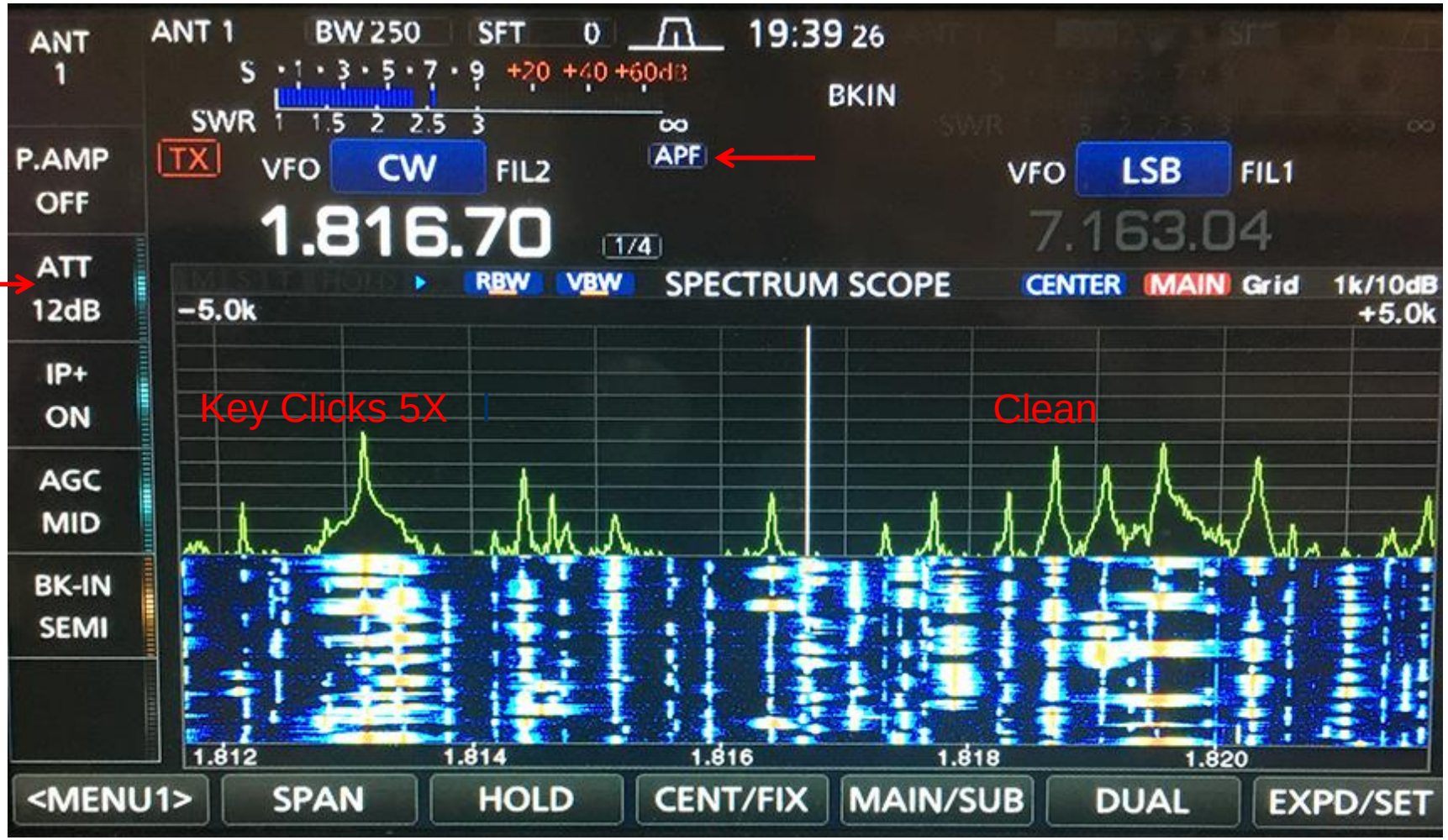
December 2018

Over 30 stations in 10 kHz IC-7610

ARRL 160m CW Friday 7:40 PM

Note

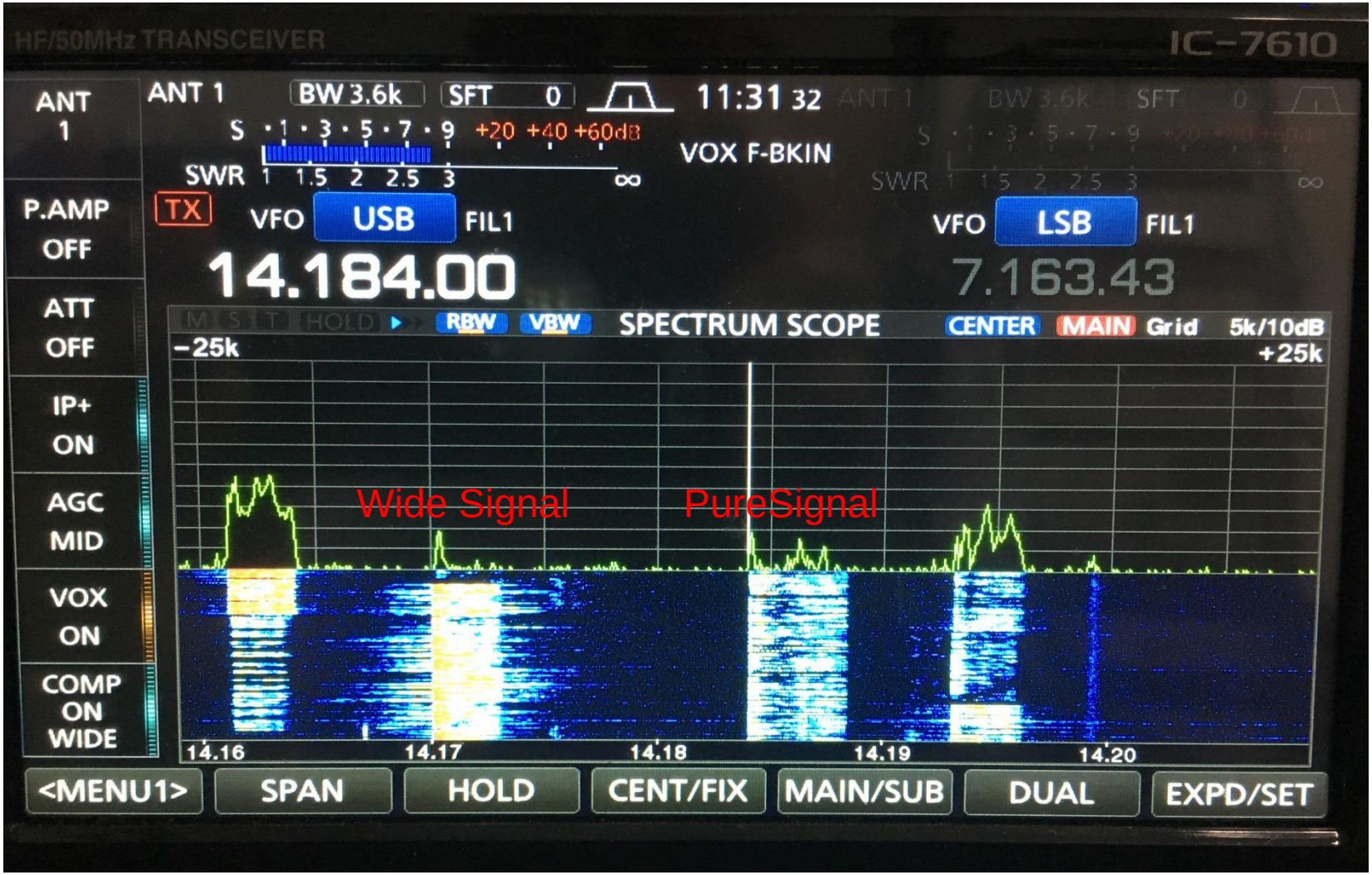
ATT



PureSignal TX BW 4.6 kHz not a good choice!

Pre-distortion example on 20m June 2019

Currently only Apache offers pre-distortion



What happens above 6 meters?

- Since all new transceivers now cover 6 meters, performance at HF is generally maintained through 6 meters.
- 6m RMDR and TX IMD modestly worse

- Sadly as we move to 2m and above, it is a very different story.
- RX and TX performance drops significantly

10 & 6 meter antenna noise gain

6 m antenna = Ariane C5-50 @ 50 feet

10 m antenna = Hy-gain 105CA @ 65 feet

3 dB noise gain: RX noise = band noise

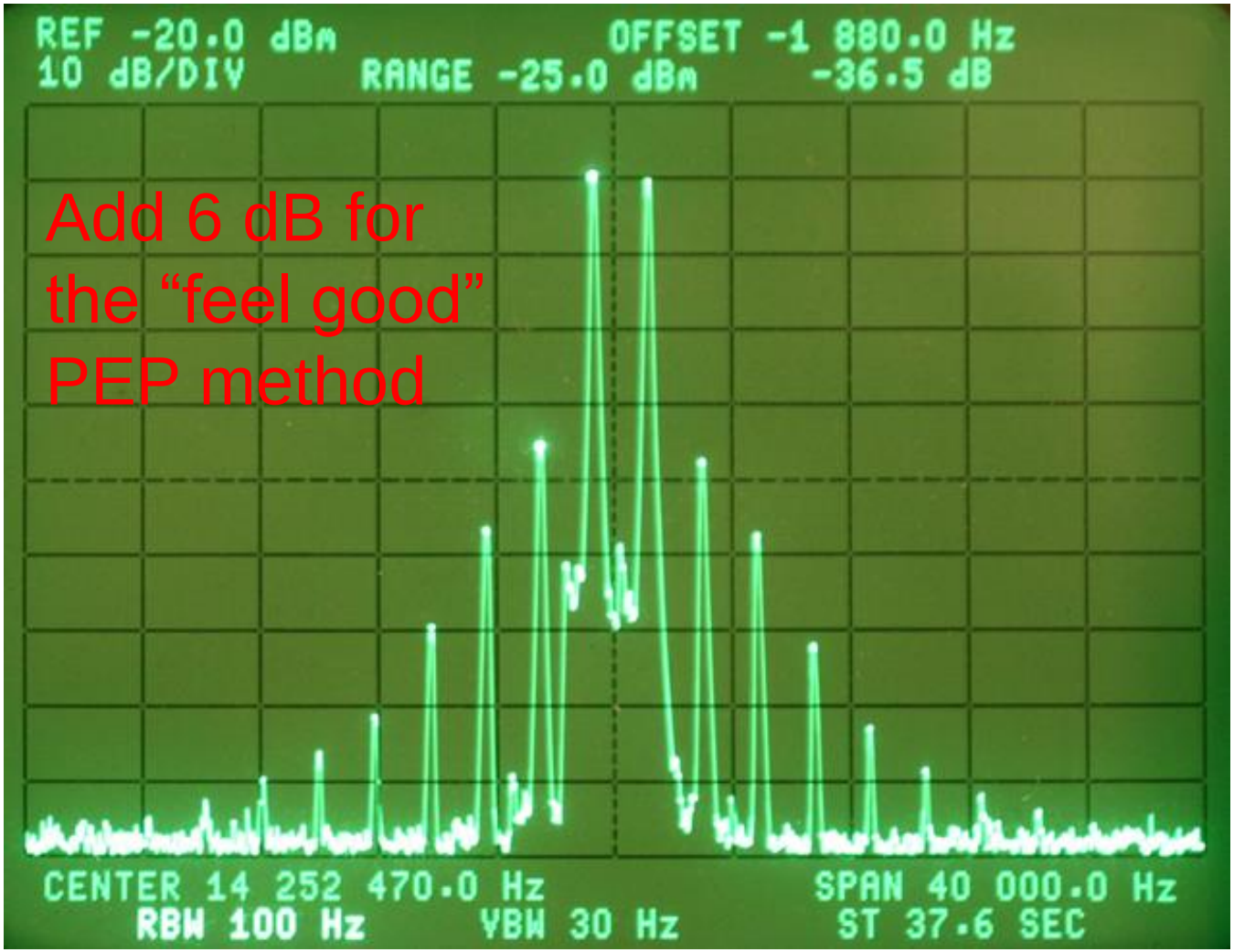
Preamp	10m	6m
None	3 dB	1 dB
Preamp 1	9.5 dB	4.5 dB
Preamp 2	11.0 dB	9.5 dB

Consider hardline over normal coax

The cleanest transmitter I have ever owned.

-36 dBc 3rd Order, -47 dBc 5th Order

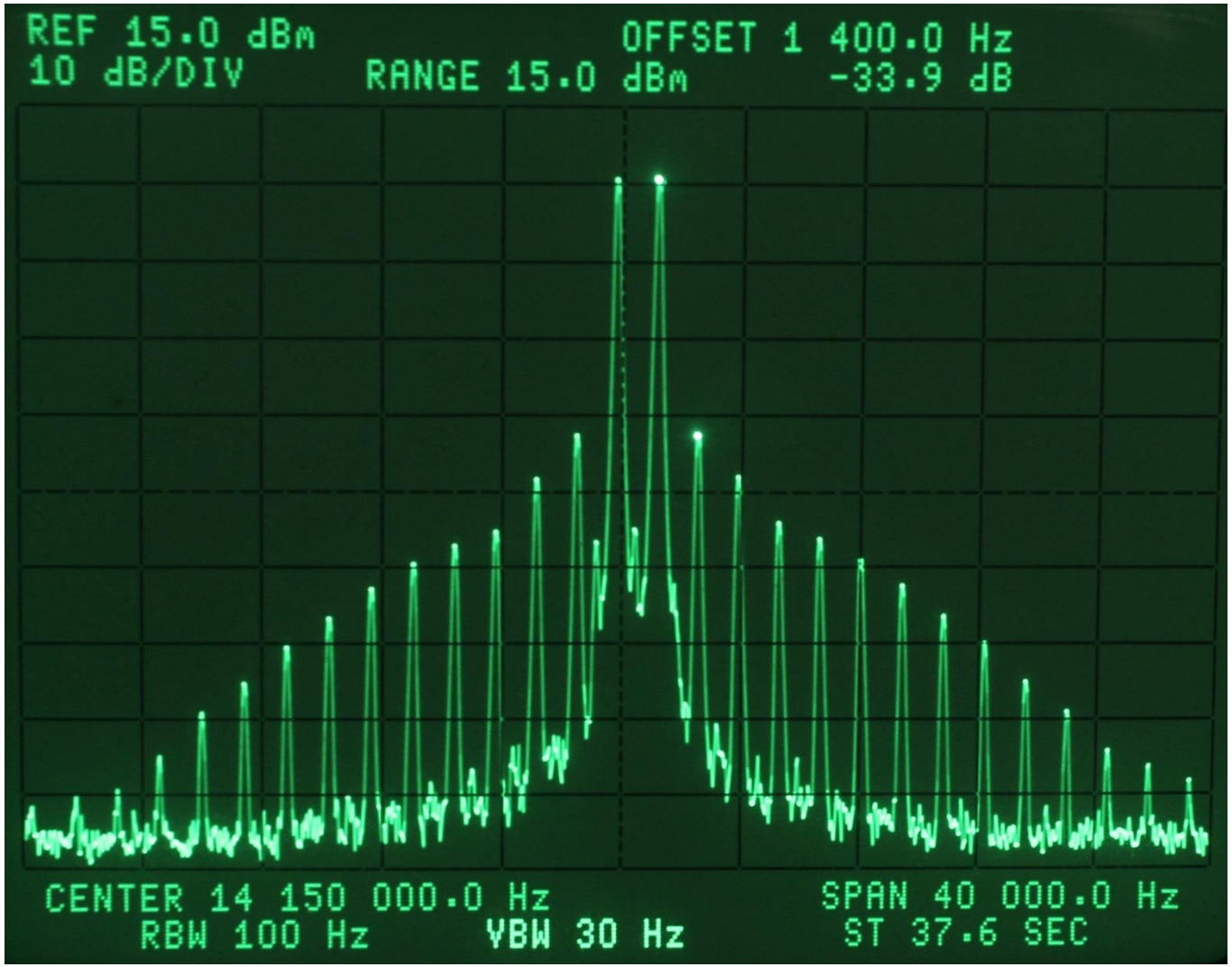
Collins 32S-3 on 20m at 100 watts



My 2nd cleanest

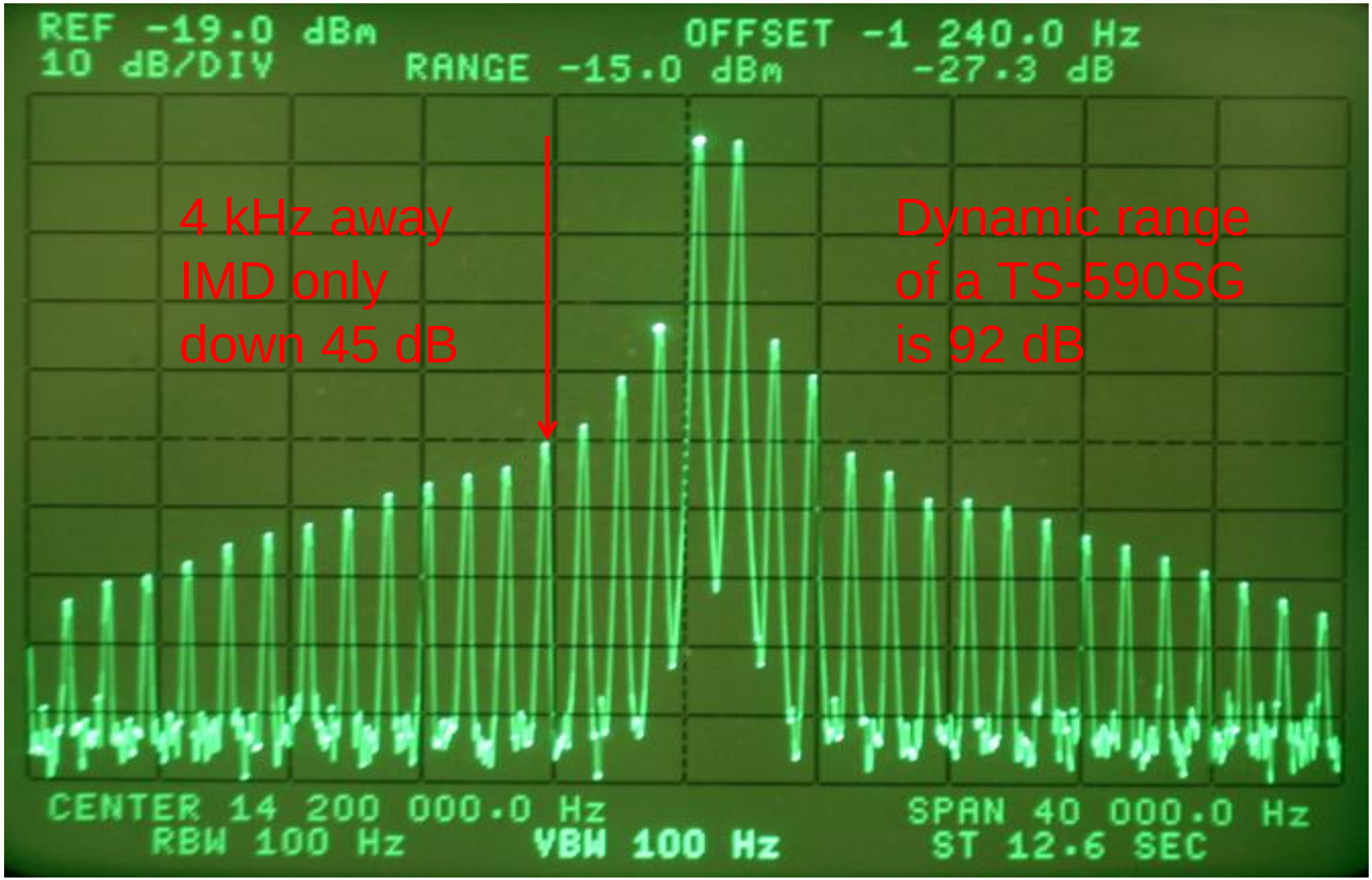
Kenwood TS-990S: -34 dBc 3rd order

A 50 volt PA can be cleaner



-27 dBc 3rd order, -34 dBc 5th order

K3 Transceiver on 20 meters @ 100 W



SSB vs. CW signal bandwidths

SSB splatter can be a significant problem

Are you overdriving your amplifier into saturation?

I use a -40 dB sampler and a Tektronix scope full the time.

How does CW compare?

How close can we work to a strong adjacent CW signal?

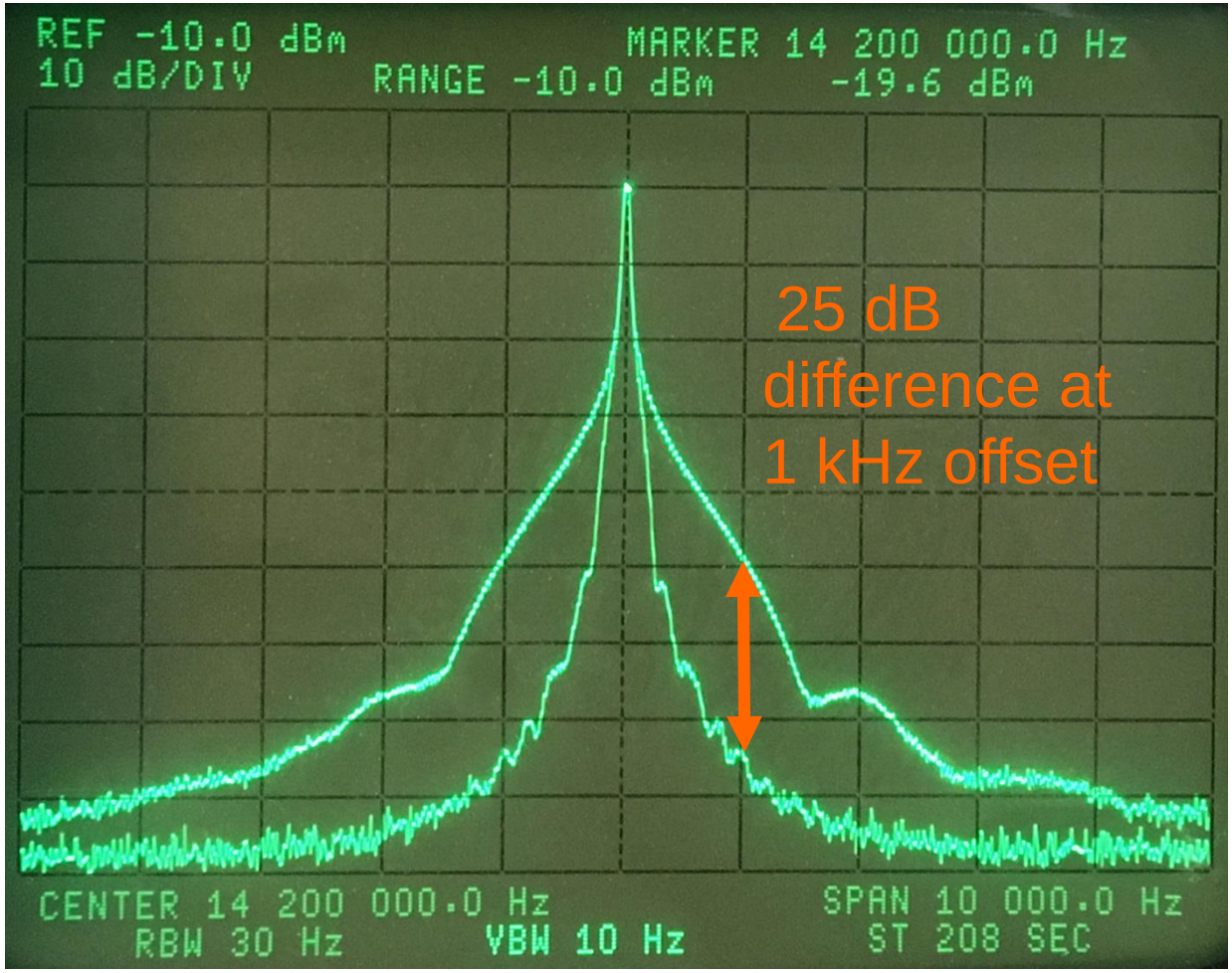
It often comes down to a menu selection.

1 and 2 ms key click special

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

Spectrum of CW Signal on HP 3585A Analyzer

Comparison of 1 msec vs 6 msec rise time



1 or 2 ms should be labeled "Turn Key Clicks ON"

Another source of transmitted interference

Transmit Composite Noise

Elecraft K3S, Icom IC-7610 & Yaesu FTdx-3000 on 20m in dBc/Hz

Offset kHz	K3S	Icom	Yaesu
10 kHz	-141	-128	-120
100 kHz	-143	-142	-121

When the transmit noise doesn't fall off at 100 kHz, that rig would be a terrible choice for Field Day.

Same problem with another ham close to your location

Note: Give Boulder FT-1000MP vs. FTdx-3000 example.

Did you read my article in November 2019 QST ?

"It's Time to Clean Up our Transmitters"

A "tip of the hat" to the League for emphasizing it is time for the OEMs to do better on the transmit side.

Note: In the same issue, the review of the SPE Expert 1.5K-FA
Normal IMD -30 dB PEP
PureSignal* -47 dB PEP, a 17 dB improvement
* Predistortion

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 PEP.

QST review Elecraft KPA1500 amp listed third-order IMD at -30 dB PEP.

Flex PowerGenius XL -30 dB on 20m, -27 dB PEP on 10 & 6 meters.

SPE Expert 1.5K-FA ARRL measured -30 dB PEP on 20 meters.

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

TS-990S has 3rd order IMD down -40 dB PEP !

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

The I/O IMD curve is important !

The I/O Data should be a straight line

Note: Elecraft KPA1500 curve much more linear than Acom 1200S

Figure 2 — Elecraft KPA1500 RF input power versus output power.

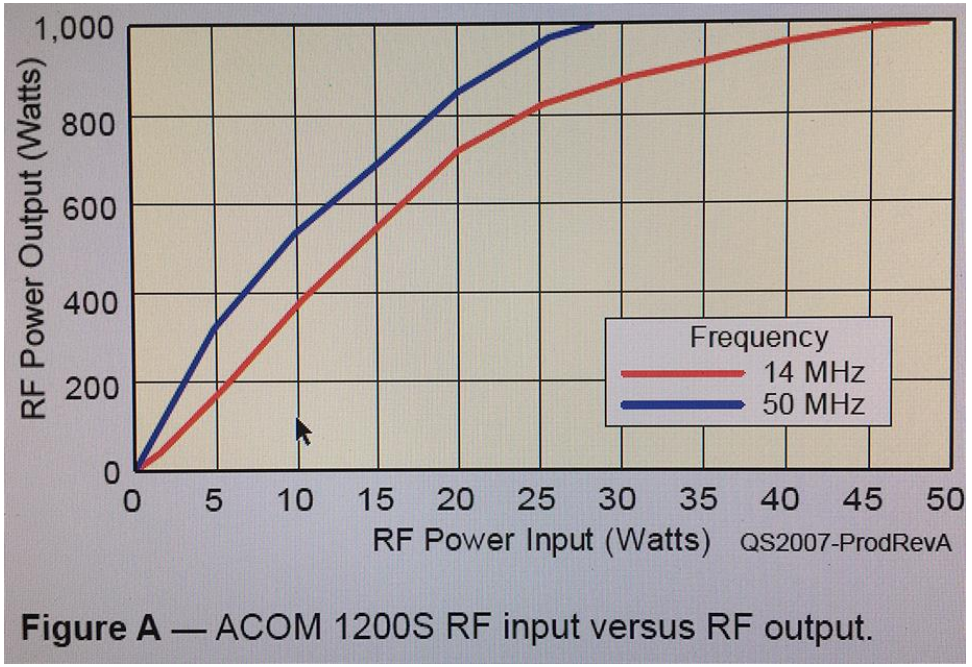


Figure A — ACOM 1200S RF input versus RF output.

Graph QST March 2019

Graph QST July 2020

3rd order IMD better than 5th order is a red flag !

While the Acom 1200S is advertised as a 1000 watt “linear” amplifier, it should be run no higher than 600 watts to be relatively clean.

Model	3rd order	5th order	7th order	9th order	Power
1200S	-34	-33	-47	-64	1 KW
1200S	-33	-41	-54	-62	500 W
SPE	-30	-38	-42	-53	1.5 KW
KPA	-30	-40	-48	-59	1.5 KW
PG XL	-31	-40	-51	-53	1.5 KW

Look at 5th order as a more valid method of comparison.

Bottom Line Today

- Receiver performance from all six major brands is excellent.
- The limit today in a pile-up is likely to be the broadband “noise” of the adjacent QRM.
- SSB Splatter “noise”, CW Key Clicks “noise” or Broadband Composite “noise”.

Sherwood Engineering

Videos from past CTU presentations

CTU 2013 through 2020 (Select desired year)

http://www.contestuniversity.com/videos

Sherwood Shootouts (Contest Comparisons) published by DJ0IP

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

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