

January 2021

# Transceiver Performance for the HF DX & Contest Operator

**Rob Sherwood**  
**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
- I list it in microvolts for historic reasons. (Data pre 1975)
- Noise floor **3 dB** S+N/N in a 500 Hz bandwidth
- Noise floor in dBm is also similar for these radios.
- **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

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

## 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.**
- Unlikely there will be new up-conversion designs.

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

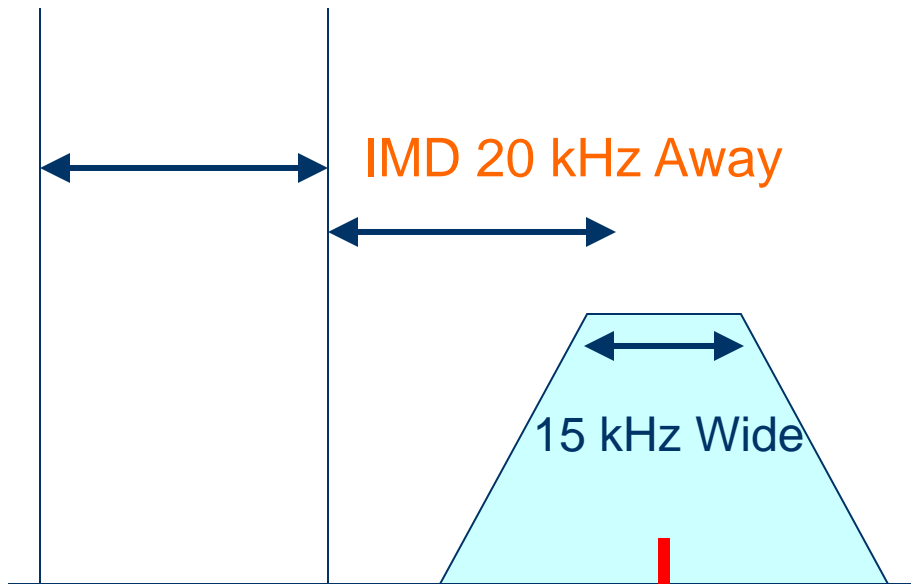
- Close-in Dynamic Range (DR3) on CW or RTTY
- Noise floor value need for DR3 calculation.
- Reciprocal Mixing Dynamic Range (RMDR)
- Transmitted broadband composite noise
- Transmit IMD splatter limits RX performance.
- Key clicks limit close-in CW reception.

# 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

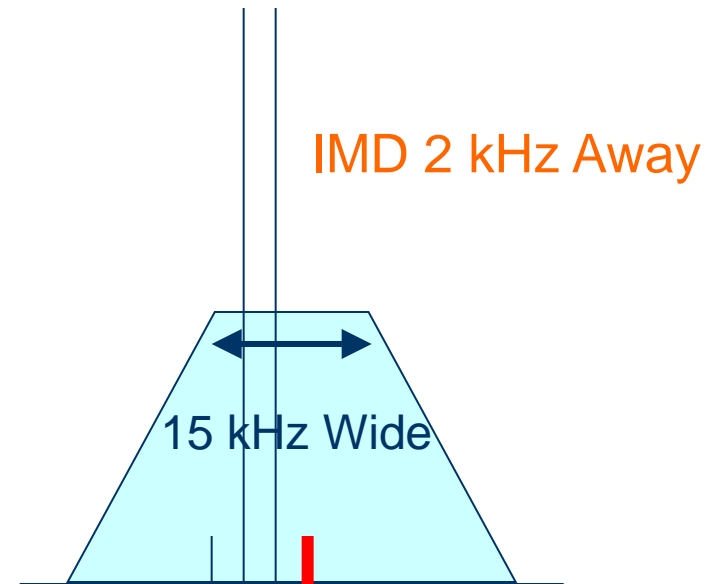
# Wide & Close Dynamic Range

## 20 kHz Spacing



First IF Filter at 70.455 MHz

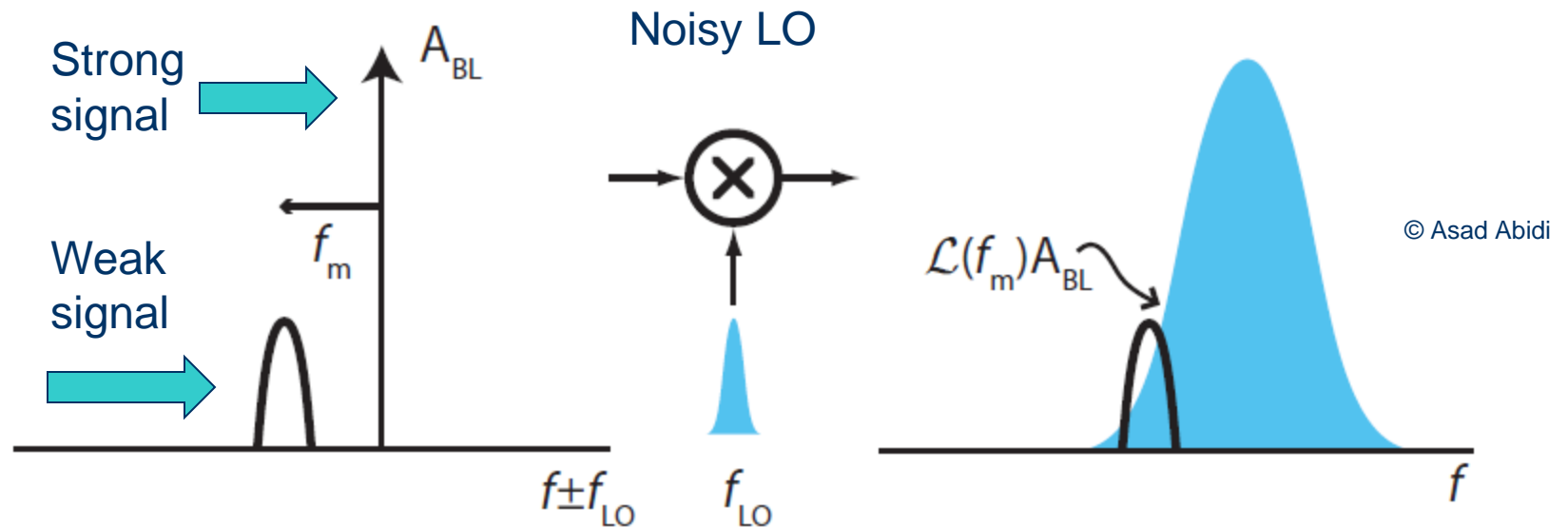
## 2 kHz Spacing



First IF Filter at 70.455 MHz

Noise spectra may 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.

## Blocking definition

“Fine print” issues for the Xiegu G90 QST March 2020

Blocking for a superhet means the onset of gain compression

1 microvolt test signal audio drops 3 dB

Often reciprocal mixing dynamic range (RMDR) dominates.

Blocking 20m @ 5 kHz: **121 dB**

RMDR 20m @ 5 kHz: **84 dB** or 37 dB worse than blocking value !

Blocking was measured with a few Hz FFT filter bandwidth.

As with the G90 DR3 value, the blocking number is meaningless.

# 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
- Flex 6000 series
- Apache ANAN series

- Questions at this time?

## 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. \*
- \* Overload around S9+60 dB, if no Digi-Select
- A superhet with a crystal roofing filter has an advantage in these difficult RF environments.

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 21 HF Transceivers

- Yaesu FTdx-101D 110 dB
- Yaesu FTdx10 107 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
- Flex 6700 (2017) 99 dB
- Icom 7610 98 dB
- Icom 7300 97 dB
- 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
- Flex 6300 89 dB
- Icom 705 88 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

(16 dB preamp ON)

(Preamp OFF)

(IP+ ON, high serial number)

I have run contests with 14 of the 21

N2IC uses two TS-590 models.

## Where will the K4 fit in this table?

- Performance? We do know the architecture.
- A K4 will have one ADC and BP filter set.
- An Elecraft K4D will be much like an Icom IC-7610. Direct sampling & 2 receivers
- The K4HD (with the superhet module, 1 CW & 1 SSB roofing filter per RX) has an architecture similar to the Yaesu FTdx-101D.

# Price of K4 vs. 5 other OEMs today

K4 w/ tuner:	\$4500 ^
K4D w/ tuner:	\$5400 *
K4HD w/ tuner:	Not announced *
Apache Labs 7000DLE:	\$2800 *
Flex 6400 w/ tuner:	\$2300 ^
Flex 6600:	\$4000 *
Icom IC-7610:	\$3000 *
Kenwood TS-890S:	\$3400 +
Yaesu FTdx-101D:	\$3050 #
Yaesu FTdx10	\$1700 +

Note: All transceivers have standard or optional tuner installed.

^ Single ADC, single set of L/C bandpass filters

\* Dual ADC, dual set of L/C bandpass filters

+ Hybrid superhet with one receiver

# Hybrid superhet with dual receivers

# Pay attention to NET GAIN

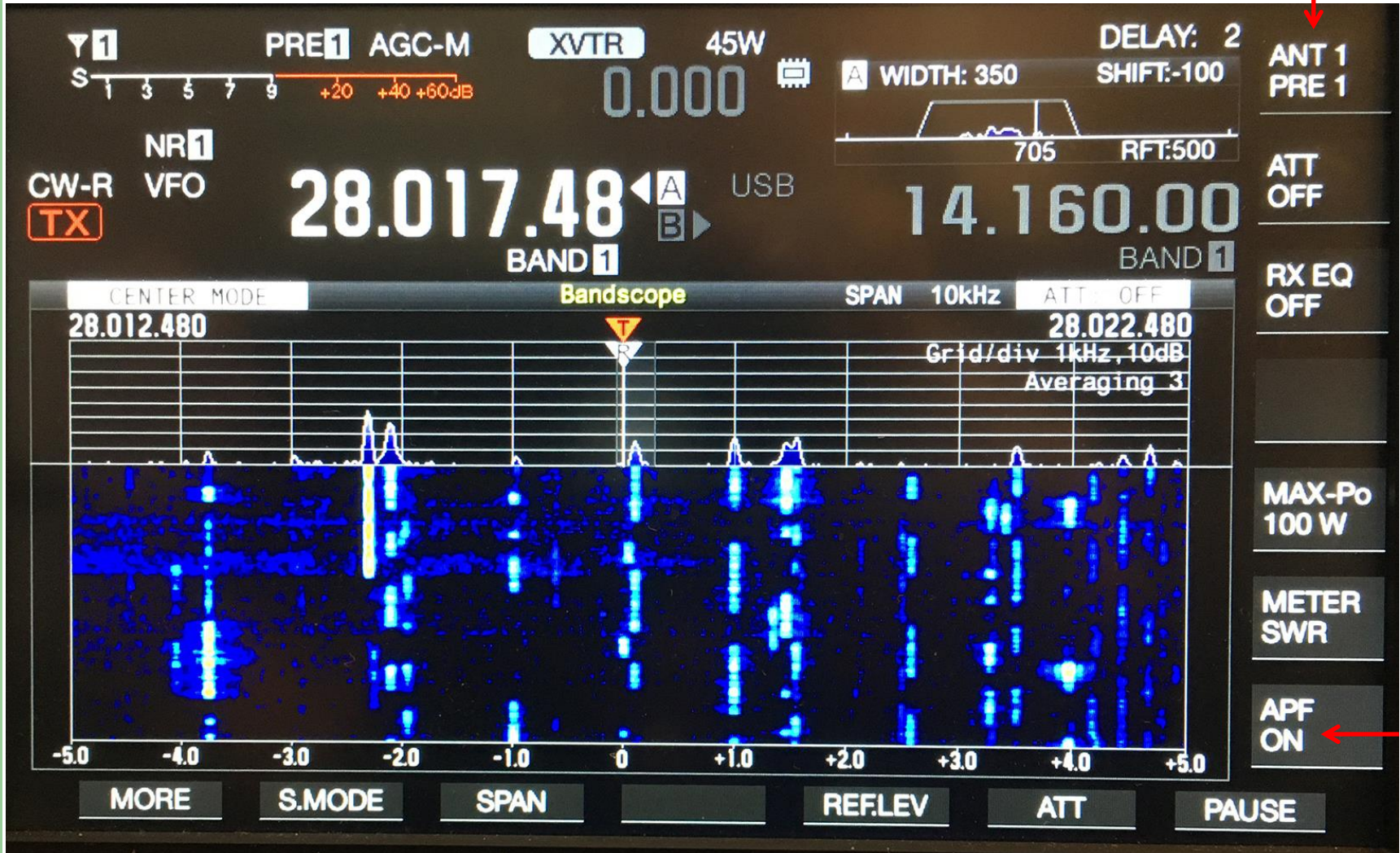
- The following 10m and 160m slides emphasizes using common sense on preamp and attenuator settings.
- 40m and below at night, use the attenuator.
- On 15m and above, a preamp is useful if you are in a quiet location.
- Urban noise may make a preamp useless.
- **A preamp at night on 40m is crazy!**

December 2018

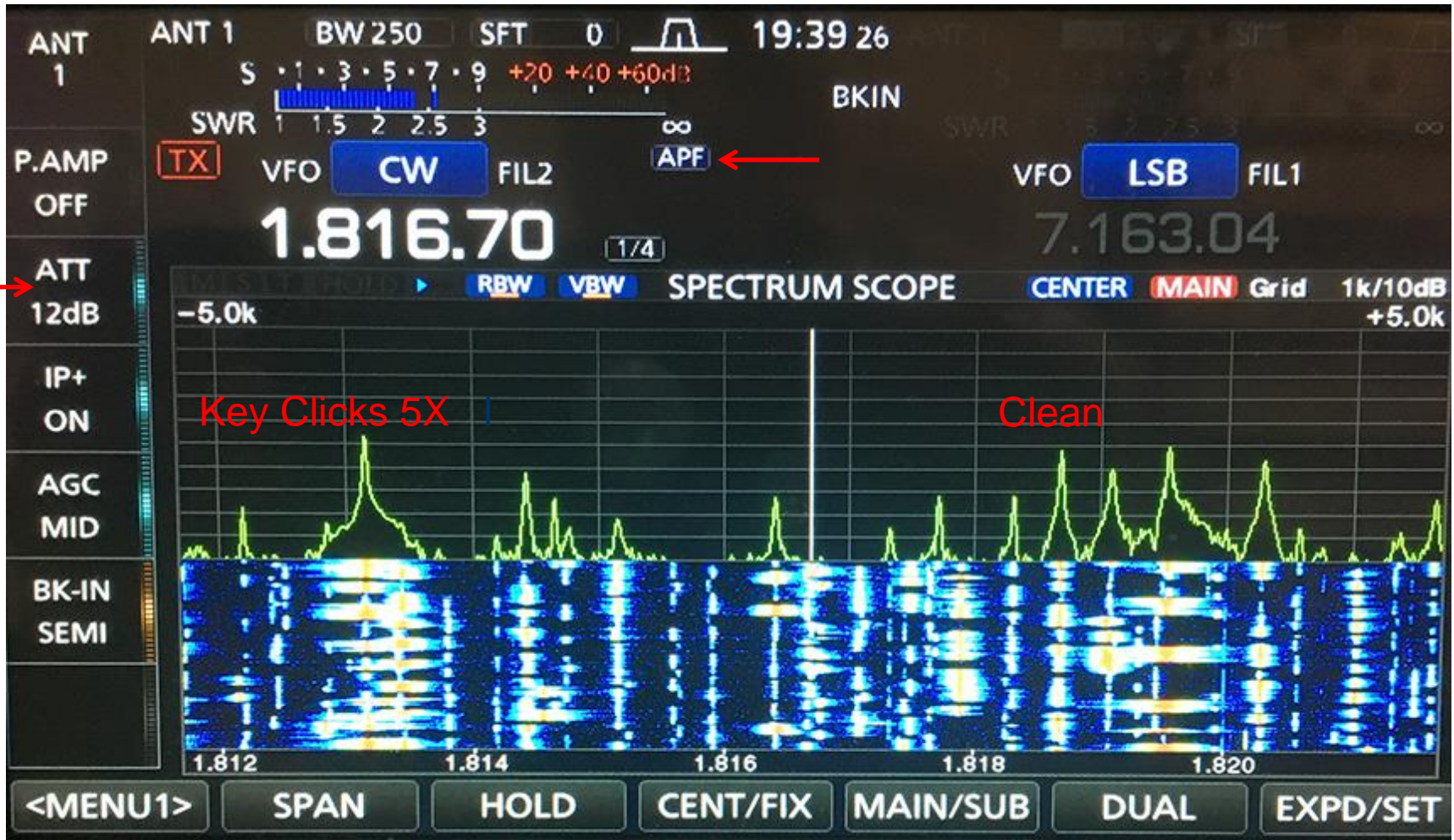
Over 20 stations in 10 kHz TS-890S

# ARRL 10m Saturday afternoon

Note preamp



# ARRL 160m CW Friday 7:40 PM



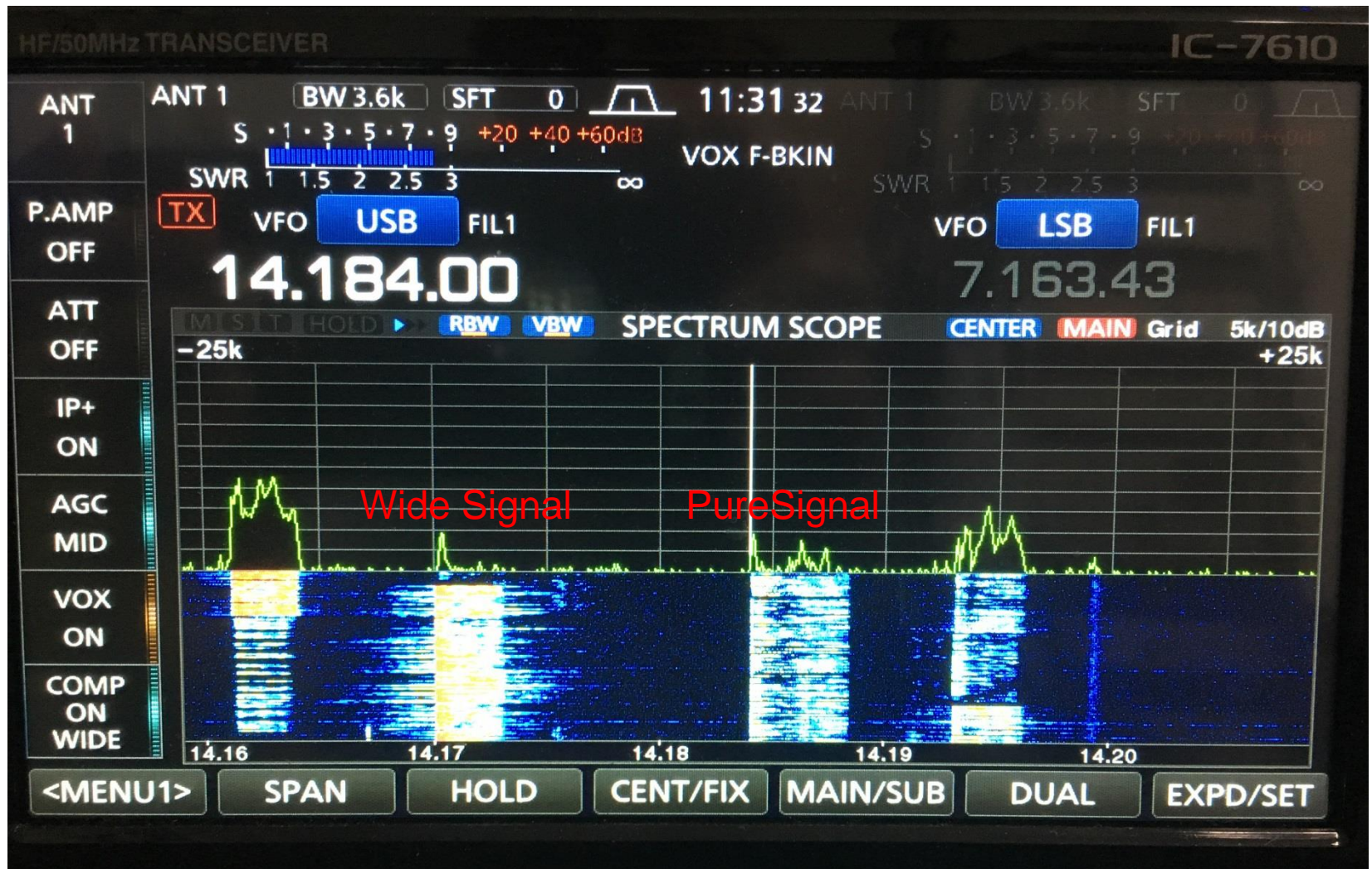
Note  
ATT



PureSignal TX BW 4.6 kHz not a good choice!

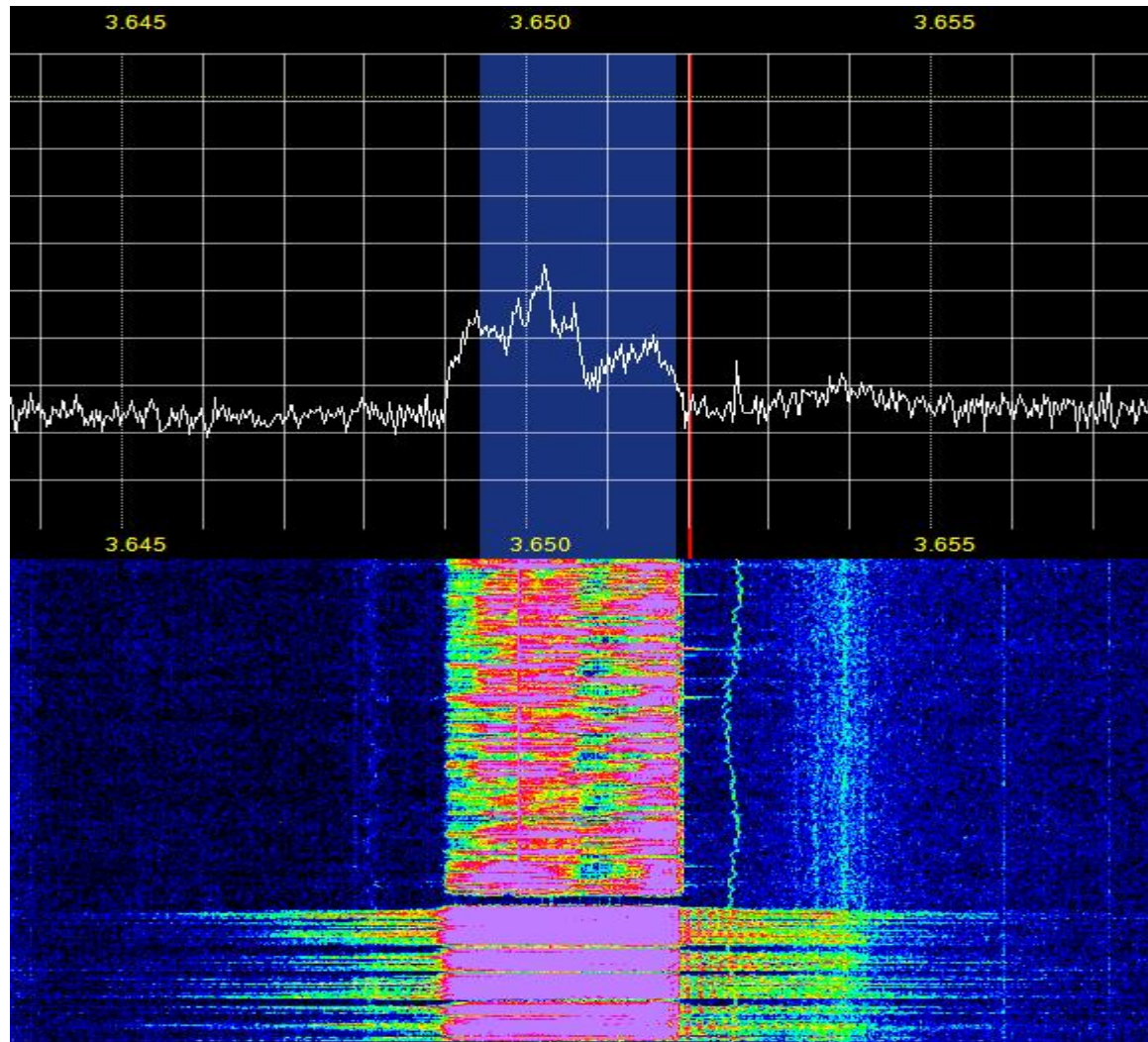
Pre-distortion example on 20m June 2019

# Currently only Apache offers pre-distortion



Both stations running legal limit amplifiers

## Typical SSB Splatter vs. PureSignal Adaptive Pre-distortion



# 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



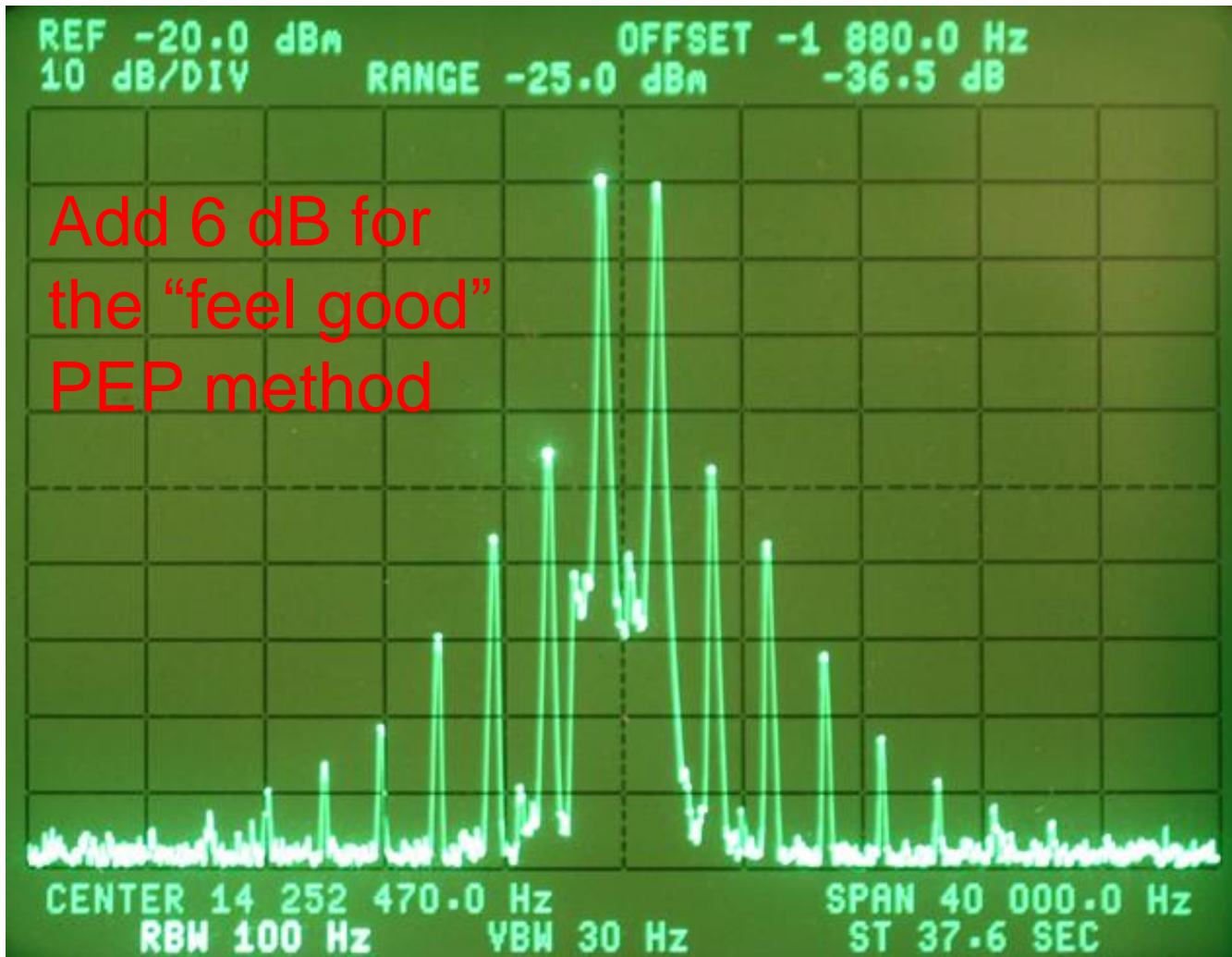
Questions at this time?

The cleanest transmitter  
I have ever owned.

-36 dBc 3<sup>rd</sup> Order, -47 dBc 5<sup>th</sup> Order

## Collins 32S-3 on 20m at 100 watts

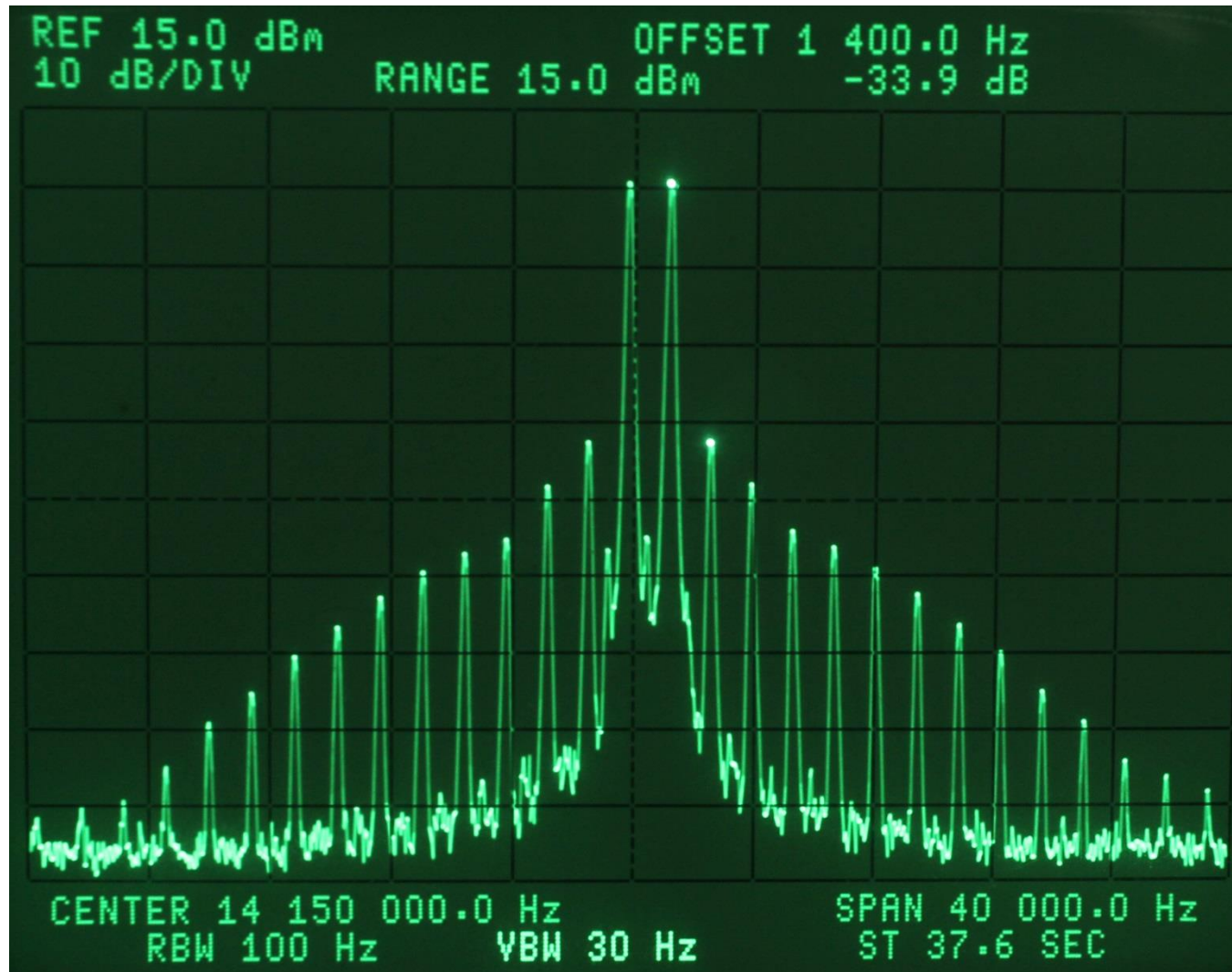
Add 6 dB for  
the “feel good”  
PEP method



My 2<sup>nd</sup> cleanest

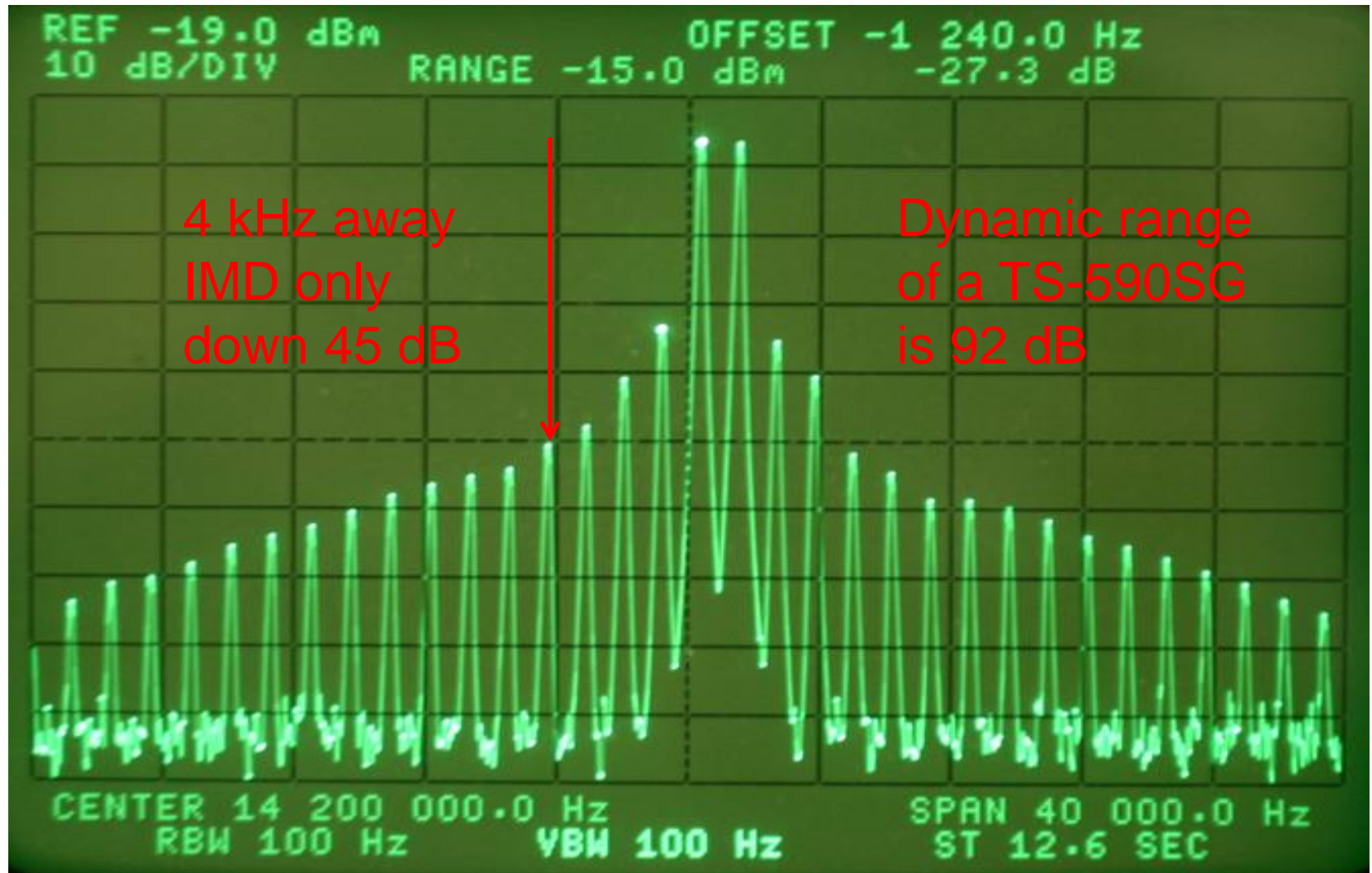
Kenwood TS-990S: -34 dBc 3<sup>rd</sup> order

# A 50 volt PA can be cleaner



-27 dBc 3<sup>rd</sup> order, -34 dBc 5<sup>th</sup> 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?

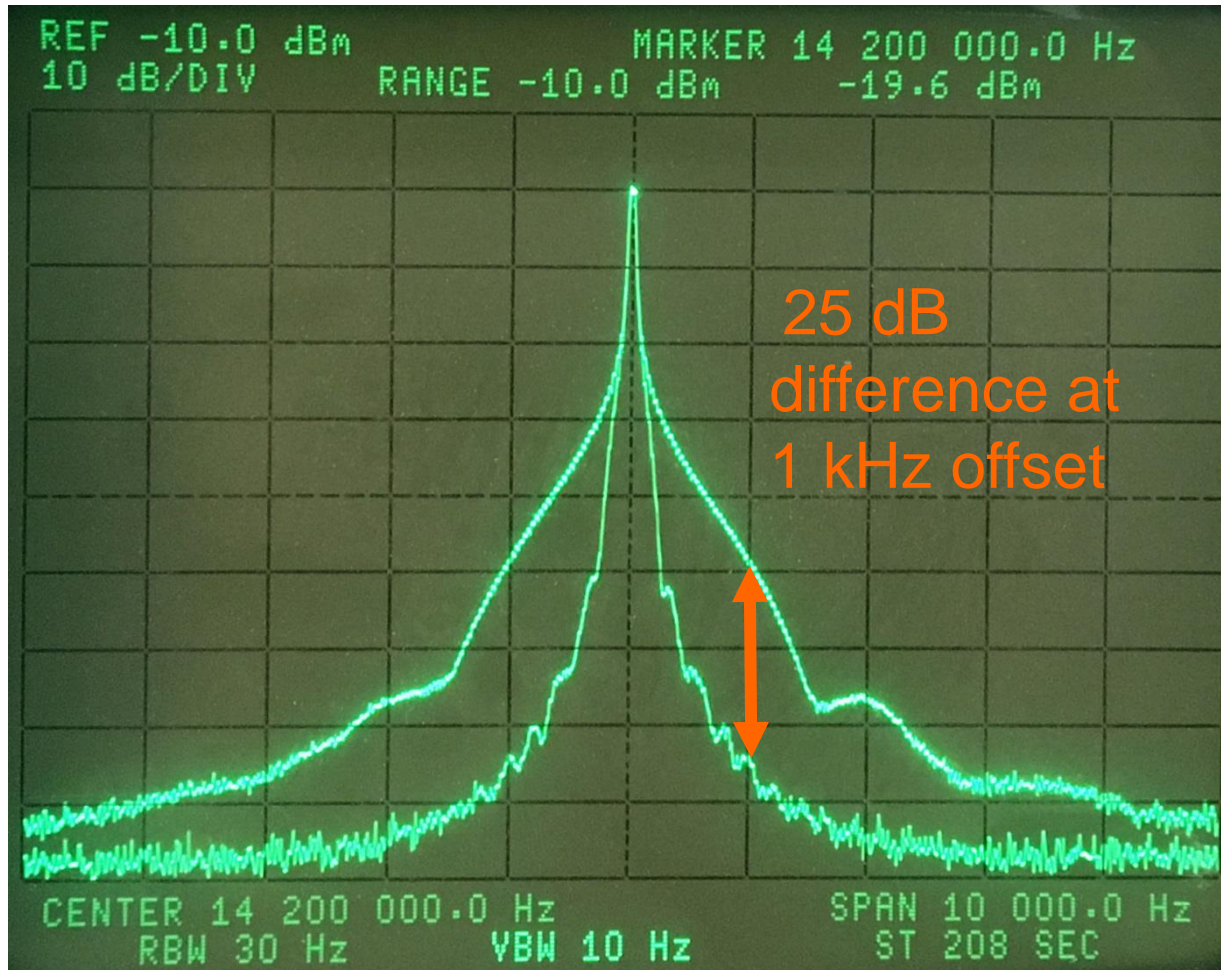
It often comes down to a menu selection.

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 3<sup>rd</sup> 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.

Graph QST March 2019

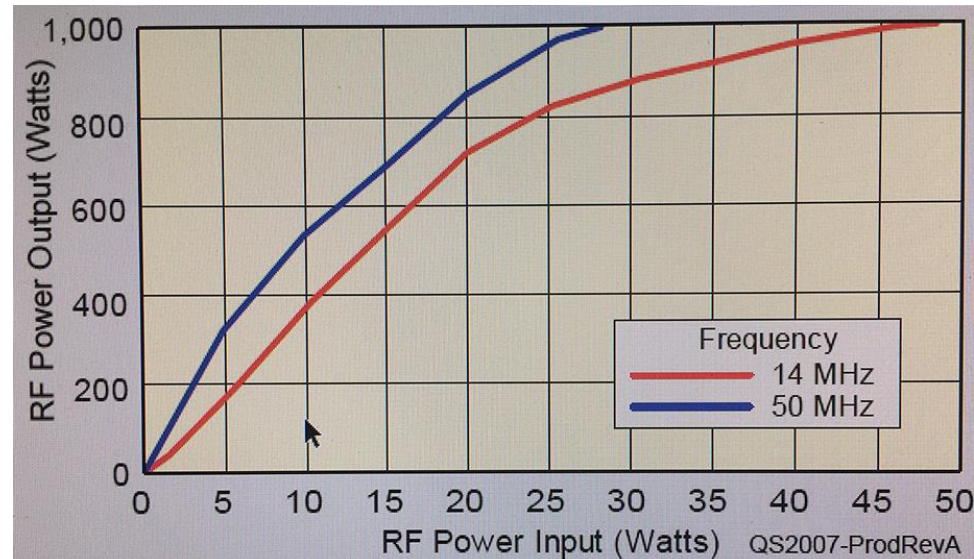


Figure A — ACOM 1200S RF input versus RF output.

Graph QST July 2020

## 3<sup>rd</sup> order IMD better than 5<sup>th</sup> 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	3 <sup>rd</sup> order	5 <sup>th</sup> order	7 <sup>th</sup> order	9 <sup>th</sup> 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 5<sup>th</sup> 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”
- Broadband Composite “noise”.

<http://www.NC0B.com>



# 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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