Contest University 2021

Transceiver Performance for the HF Contest & DX Operator

Rob Sherwood
NCØB

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

Sherwood Engineering

Don’t focus just on RX performance

- I started testing receivers in 1976.
- Receiver performance was mediocre.
- Receivers today have vastly improved.
- Transmitters have gotten worse!

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.

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
Pot Grow lights

Why isn’t great RX alone adequate ?

If a wide signal is in RX passband, reception can be degraded or blocked.

A wide signal can be:
SSB splatter
Excessive CW key clicks
Broad transmit composite noise

What has improved in recent years?

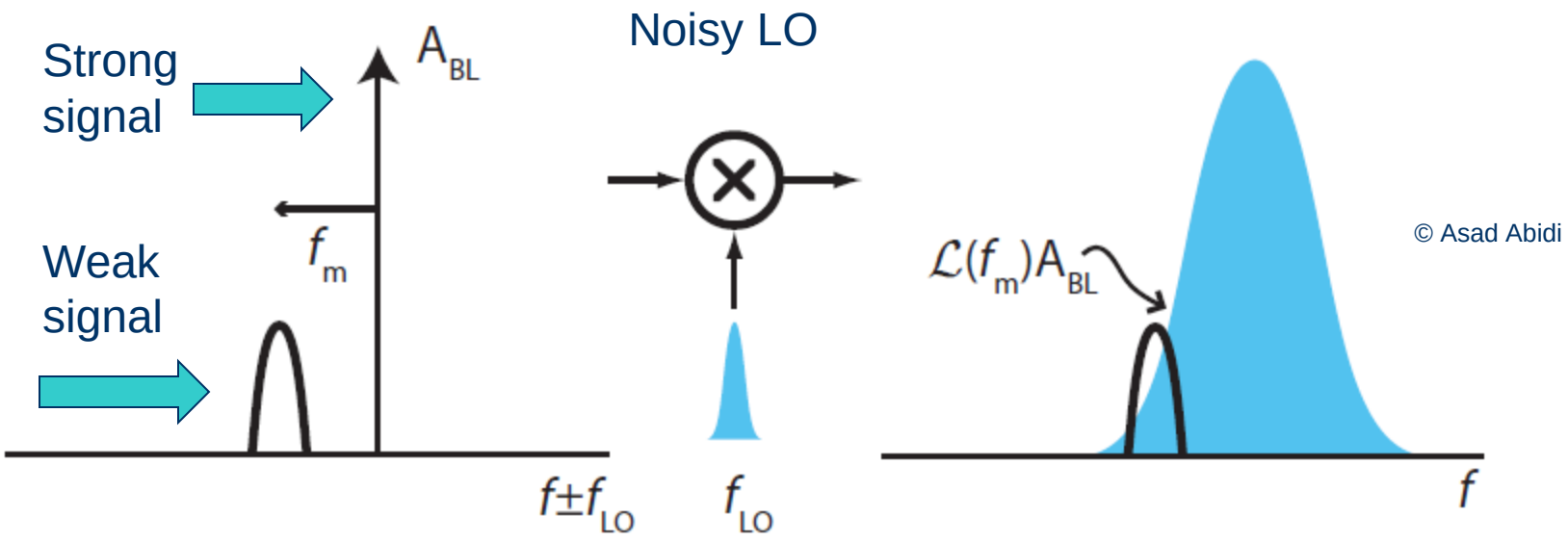
- As Reciprocal Mixing Dynamic Range* has improved, transmit composite noise is better on certain models.
- Examples: K3S, IC-7851, FTdx-101D, FTdx10
- At wider signal offsets include: TS-890S, IC-7610
- This is the first time in years that Yaesu has offered acceptable transmit composite noise !
- * RMDR measures LO or clock phase noise.

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

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

Hopefully the noise improves with offset.

A noisy LO or Clock Oscillator affects TX and RX



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 !

Bob Allison's sidebars held the key information

March 2020 QST review of the Xiegu G90 transceiver has mediocre RMDR.

Bob's sidebar also pointed out:

CW sidebands higher than average (key clicks)
Transmit IMD (splatter) higher than we would like to see
Transmit noise close-in higher than we would like to see.

Bob said We do not recommend using an amp with this transceiver.

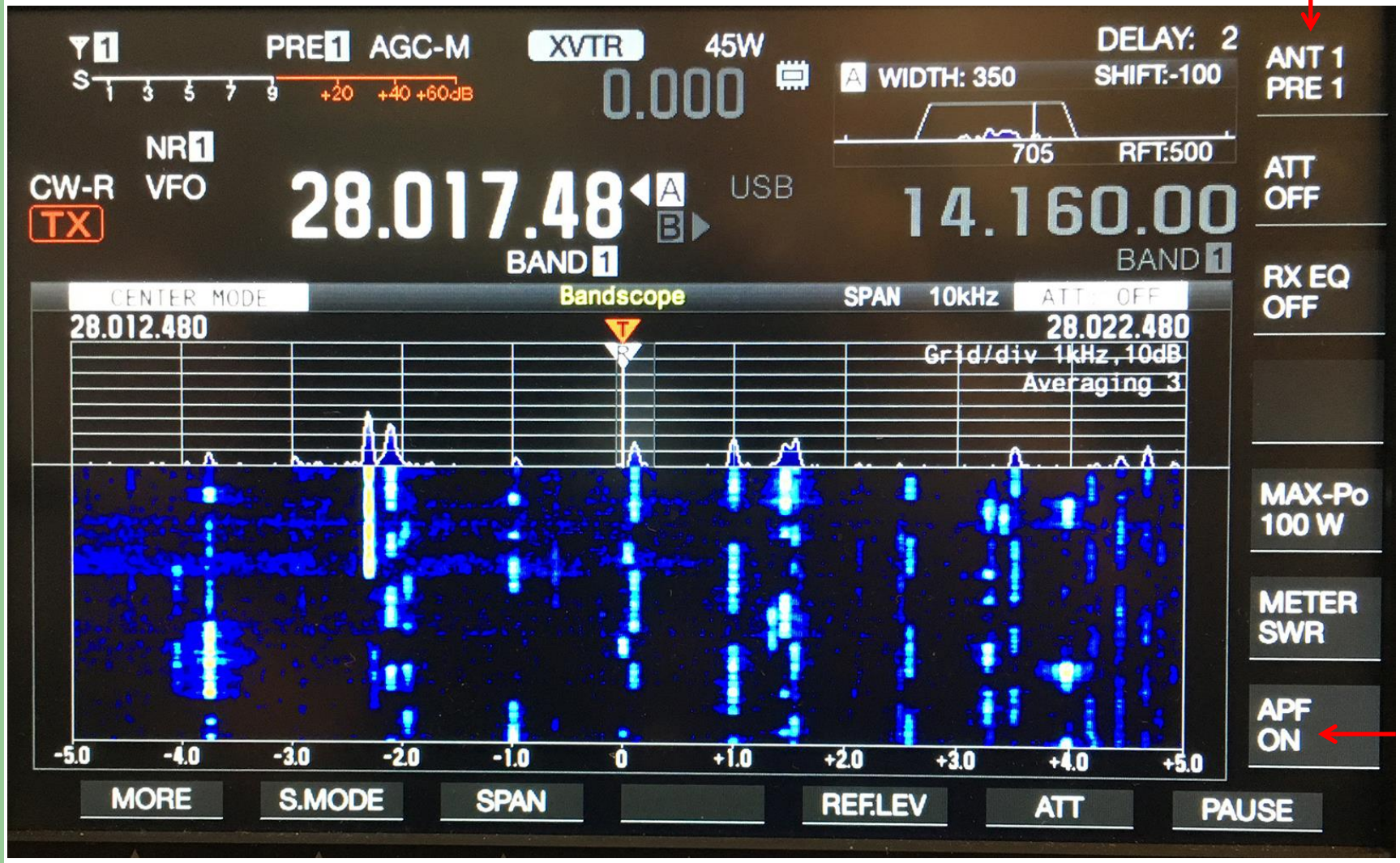
We all need to be good neighbors and not pollute the airwaves with poor quality signals that makes QRM worse.

December 2018

Over 20 stations in 10 kHz TS-890S

ARRL 10m Saturday afternoon

Note preamp



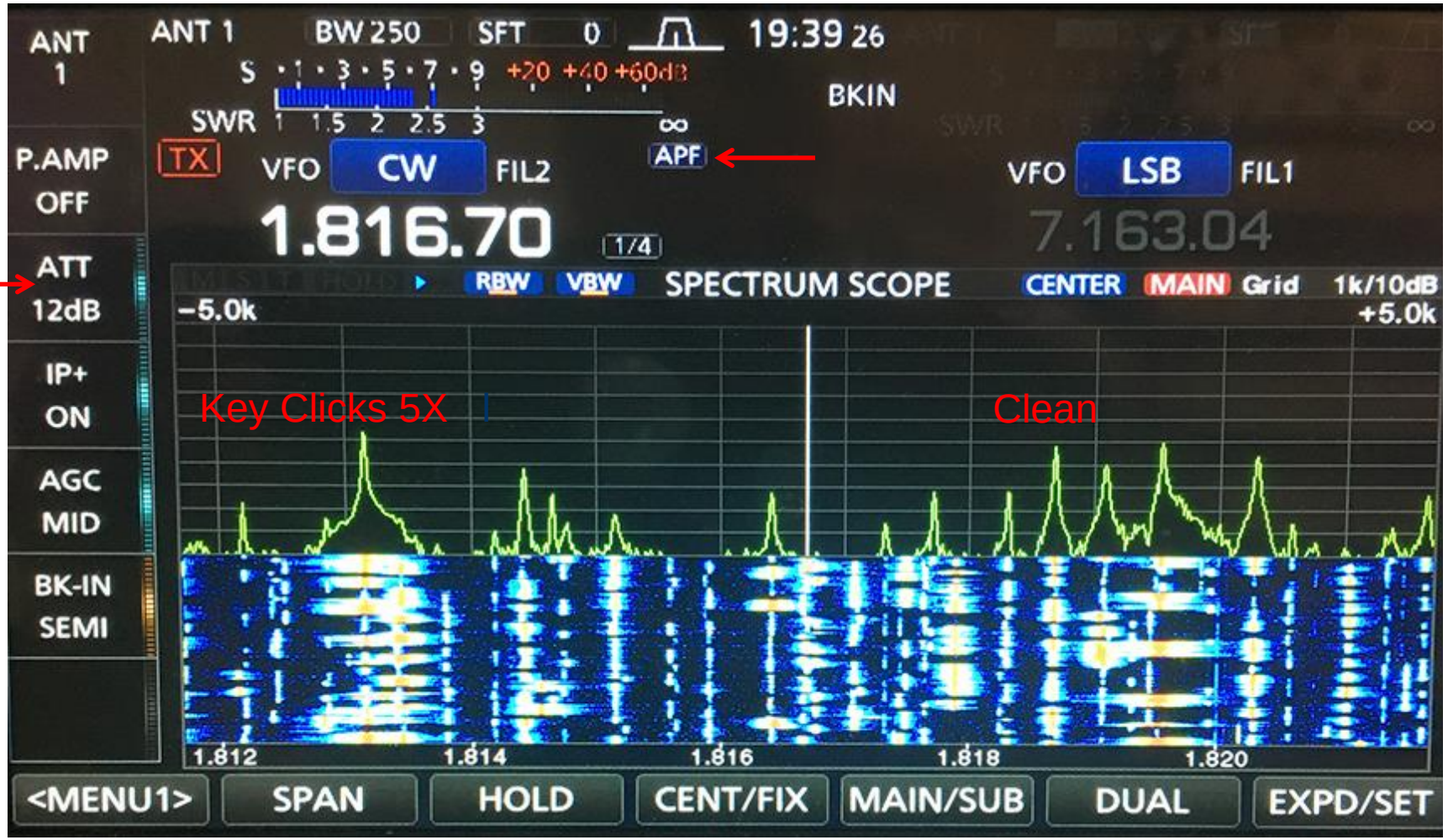
December 2018

Over 30 stations in 10 kHz IC-7610

ARRL 160m CW Friday 7:40 PM

Note

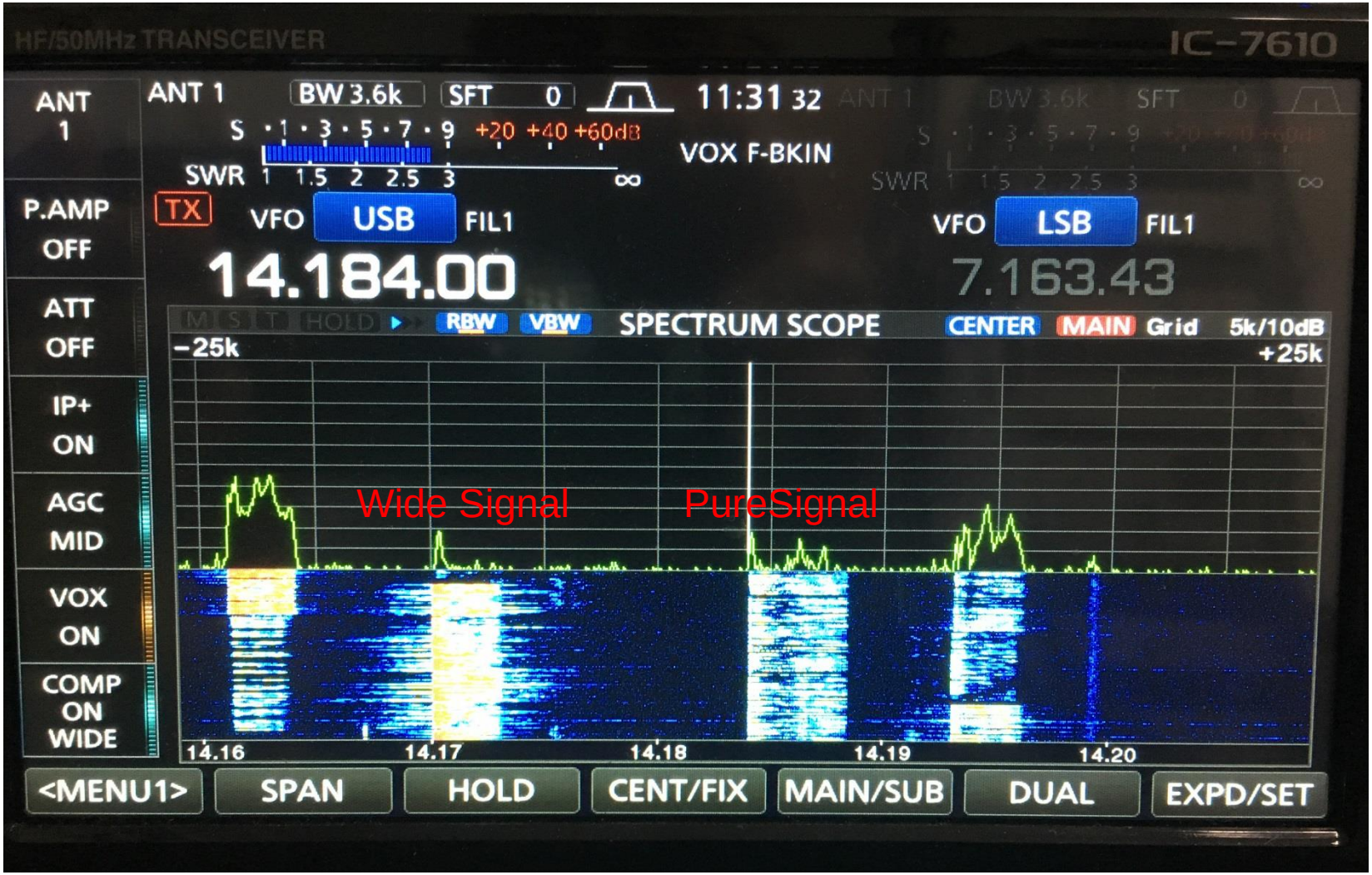
ATT



PureSignal TX BW 4.6 kHz not a good choice!

Pre-distortion example on 20m June 2019

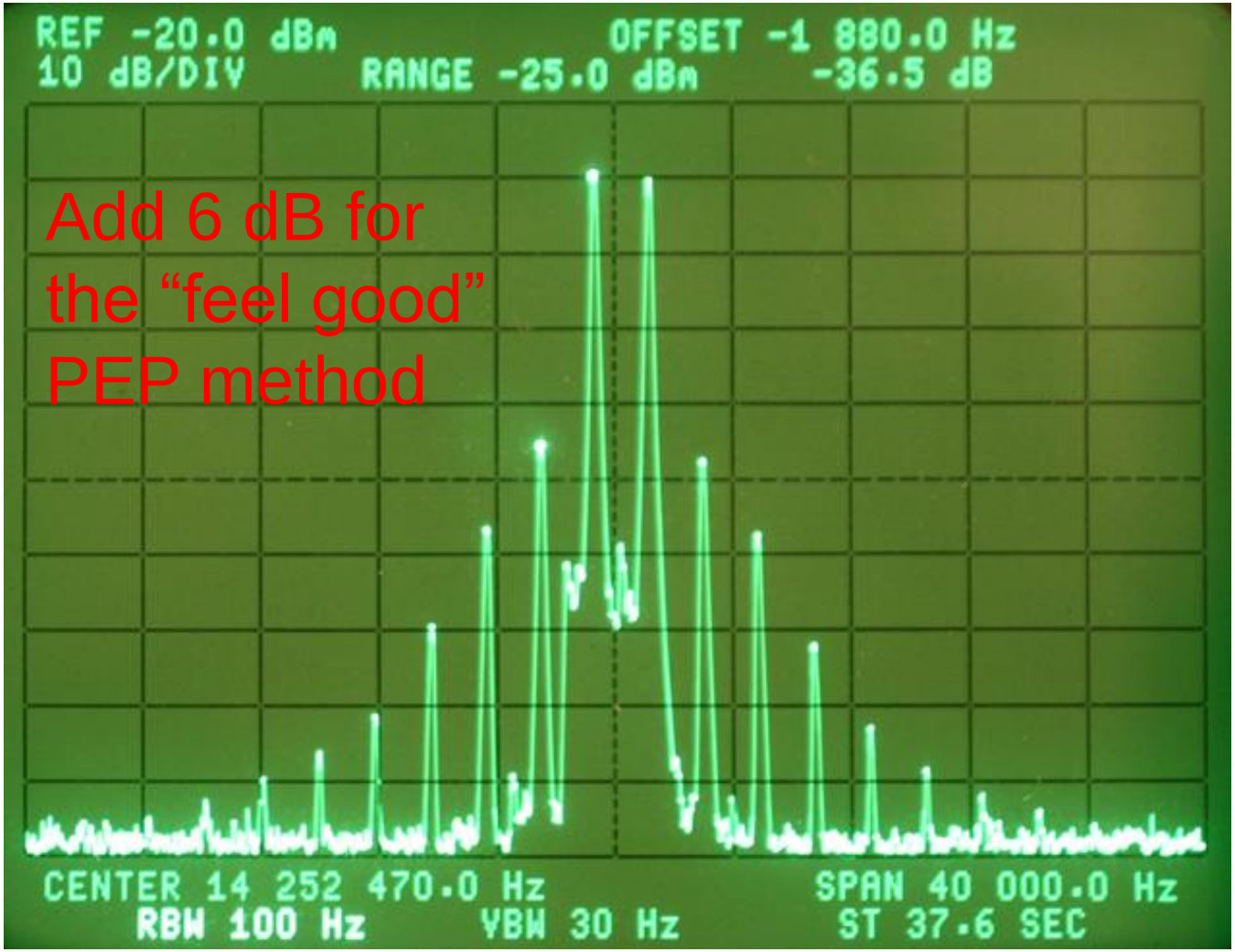
Currently only Apache offers pre-distortion



The cleanest transmitter I have ever owned.

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

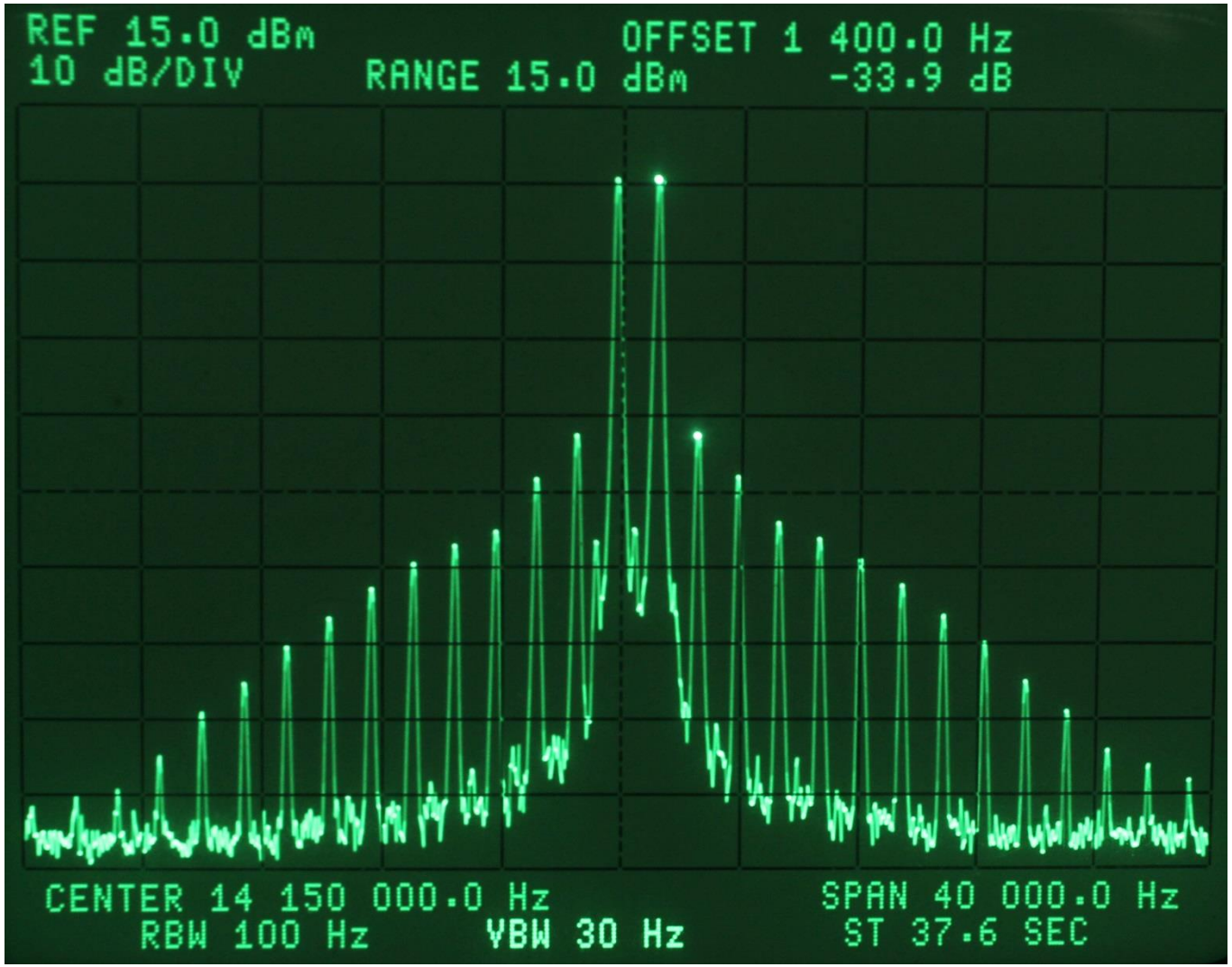
Collins 32S-3 on 20m at 100 watts



My 2nd cleanest

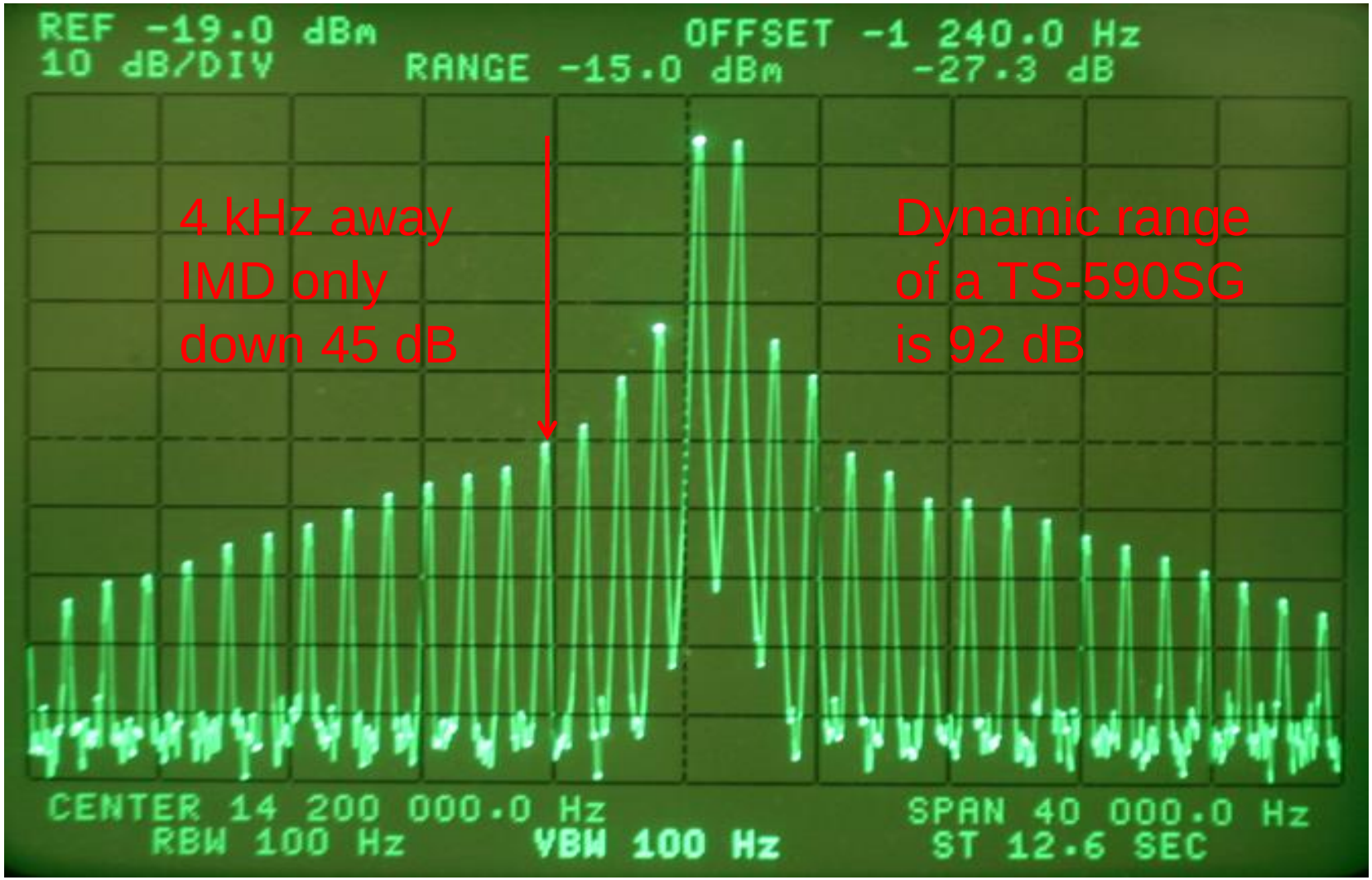
Kenwood TS-990S: -34 dBc 3rd order

A 50 volt PA can be cleaner



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

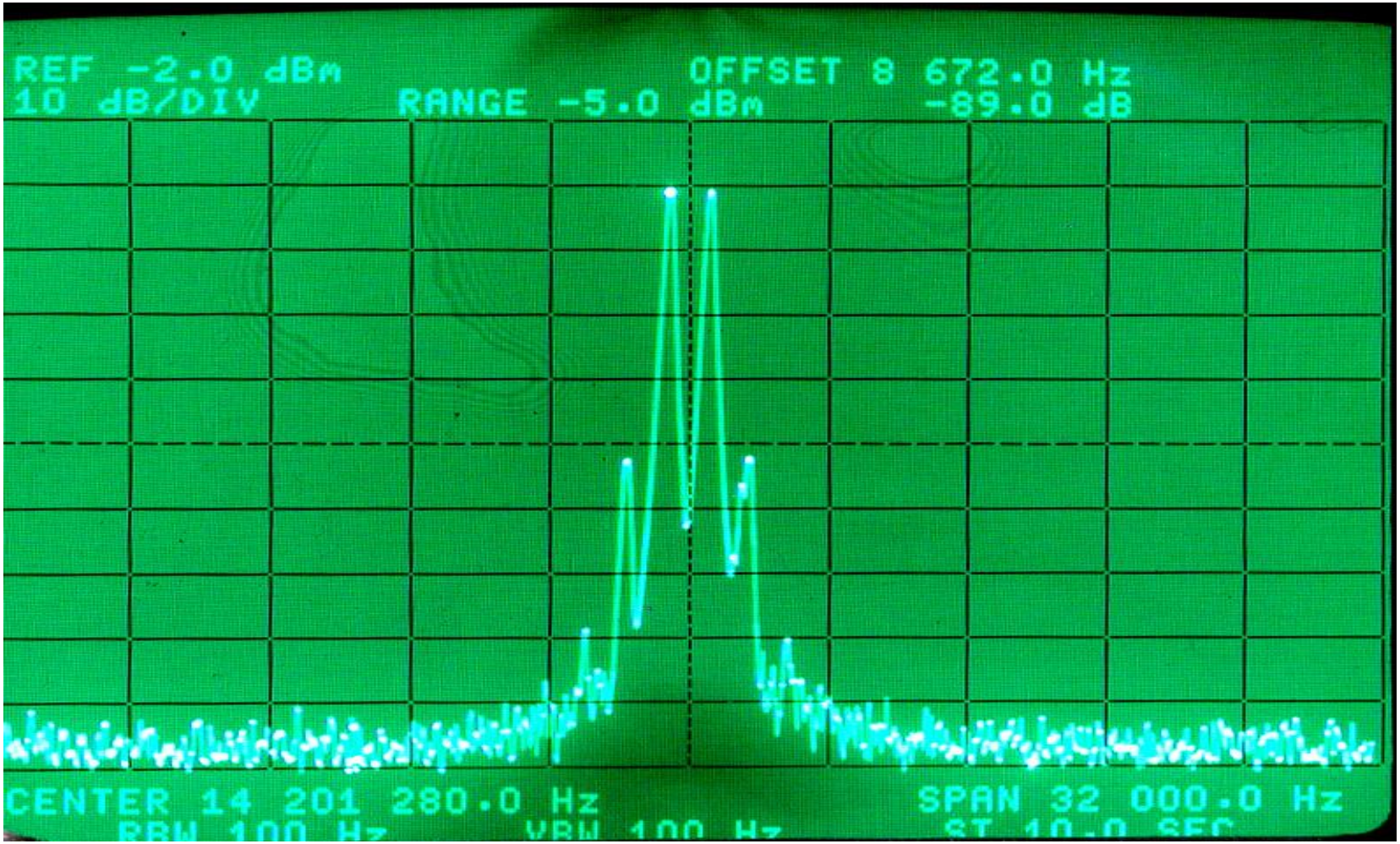
K3 Transceiver on 20 meters @ 100 W



-42 dB 3rd Order, -70 dB 5th Order

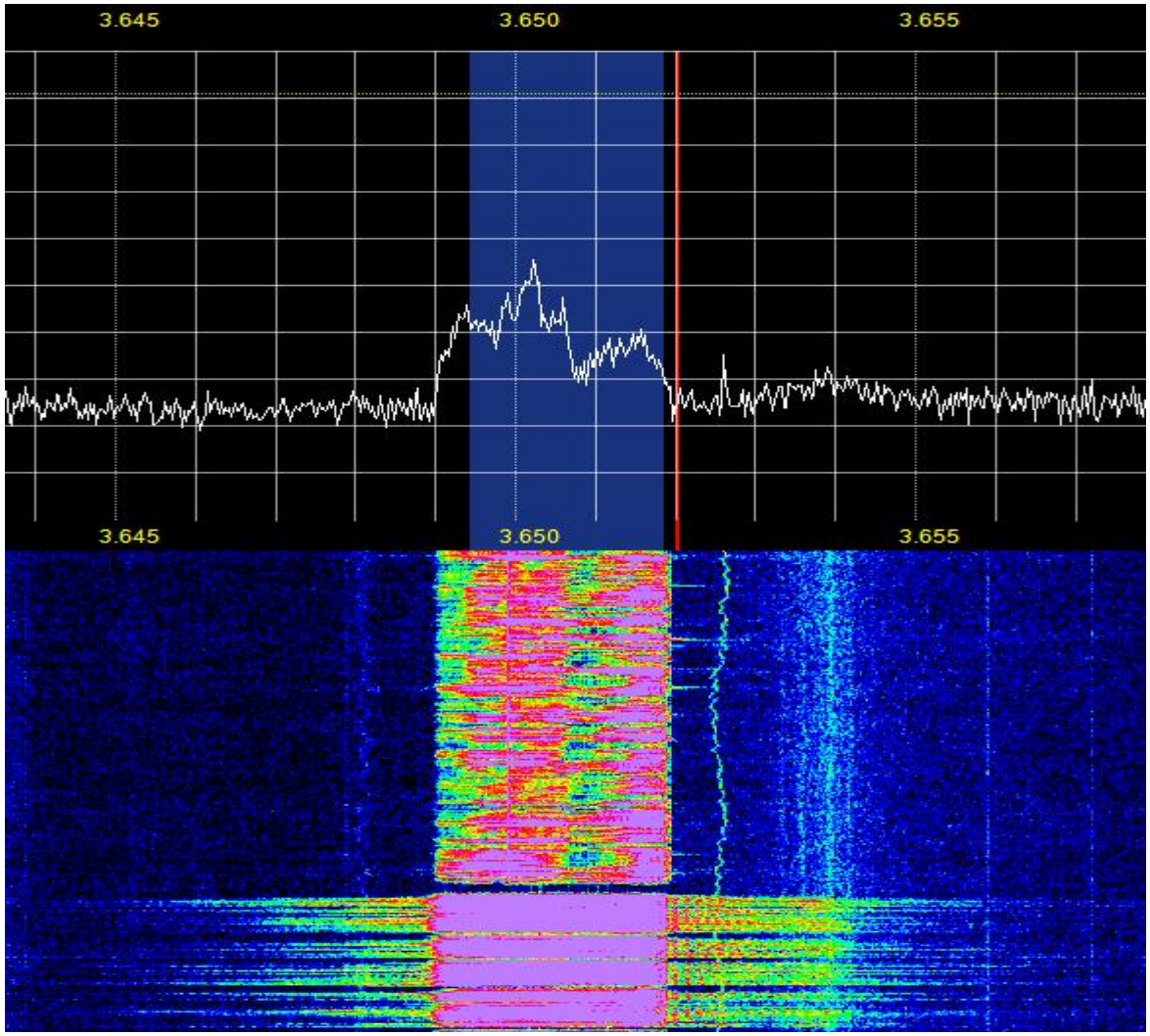
Yaesu FT-1000 Mk V, 20 M, Class A @ 75 W

Provided by Pete, W6XX



Both stations running legal limit amplifiers

Typical SSB Splatter vs. PureSignal Adaptive Pre-distortion



Class A is gone with current rigs

Elecraft & Flex may offer pre-distortion

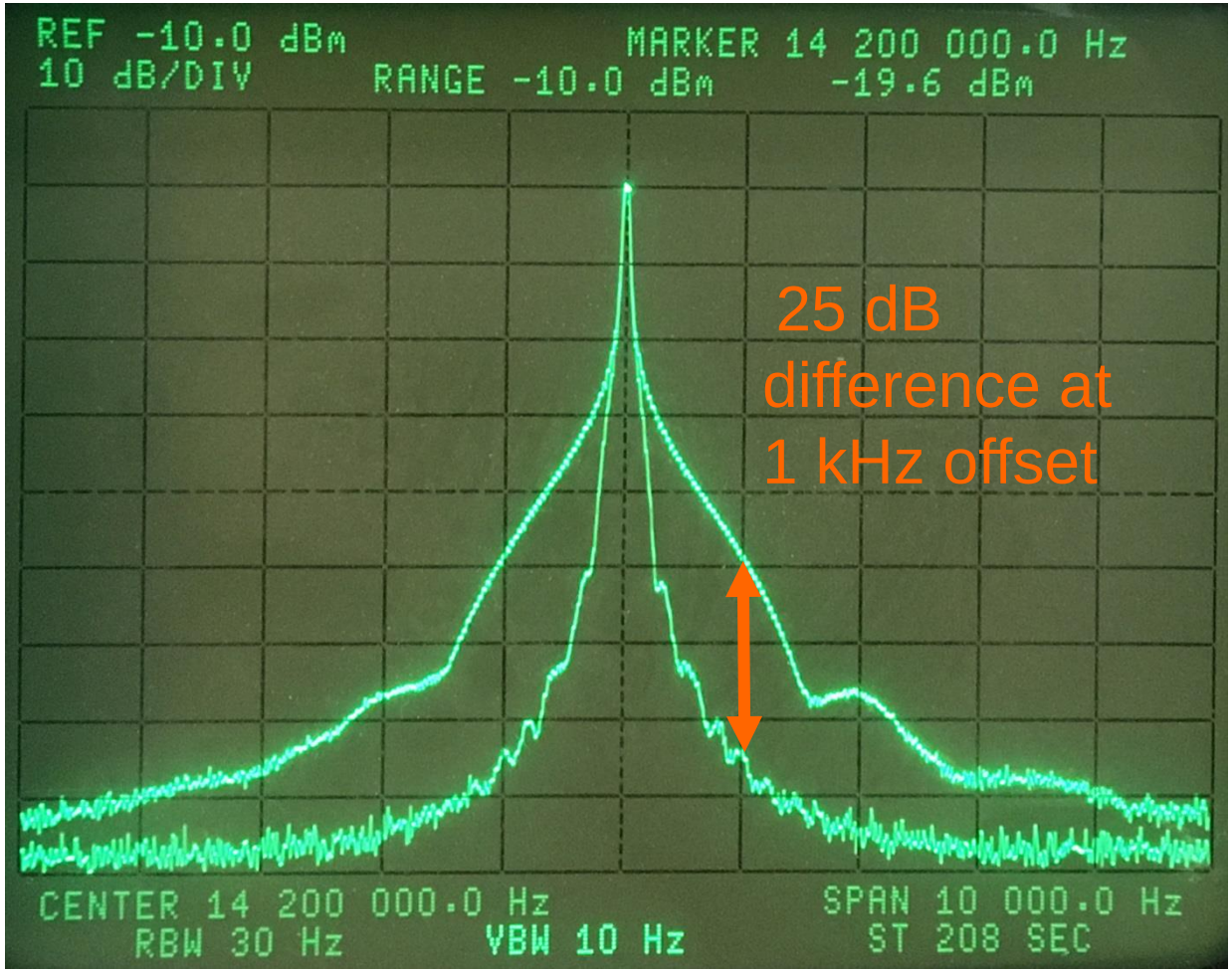
Apache PureSignal is the only option now

Kenwood

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

Spectrum of CW Signal on HP 3585A Analyzer

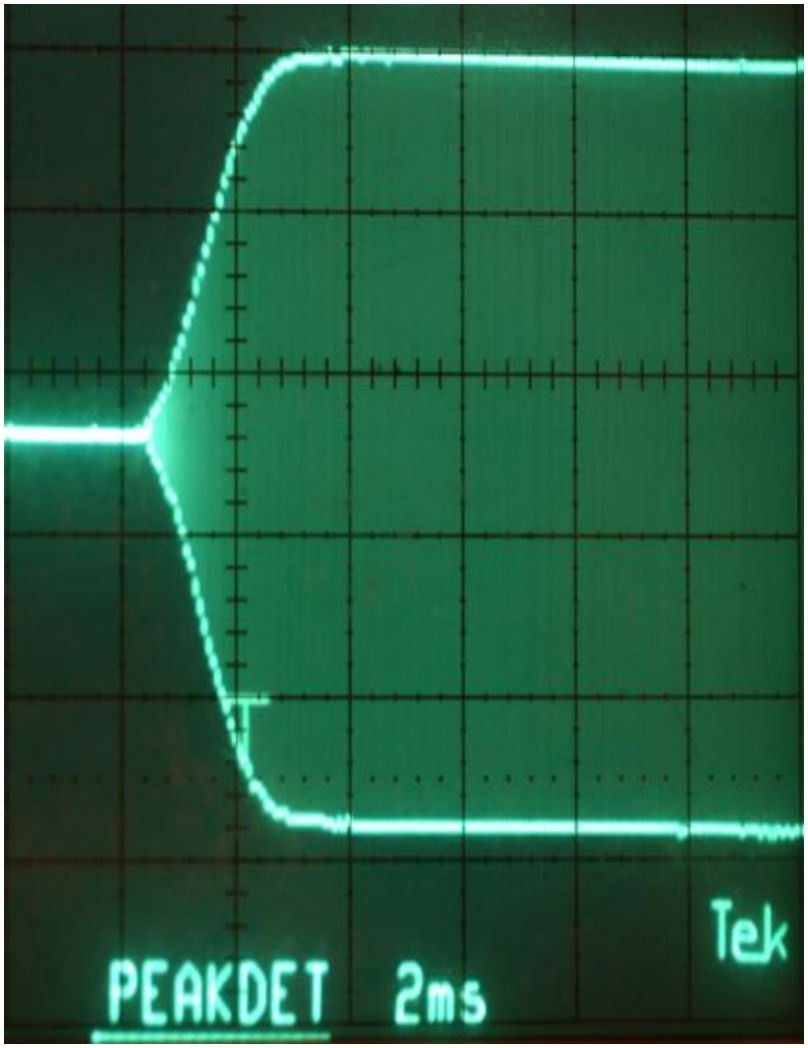
Comparison of 1 msec vs 6 msec rise time

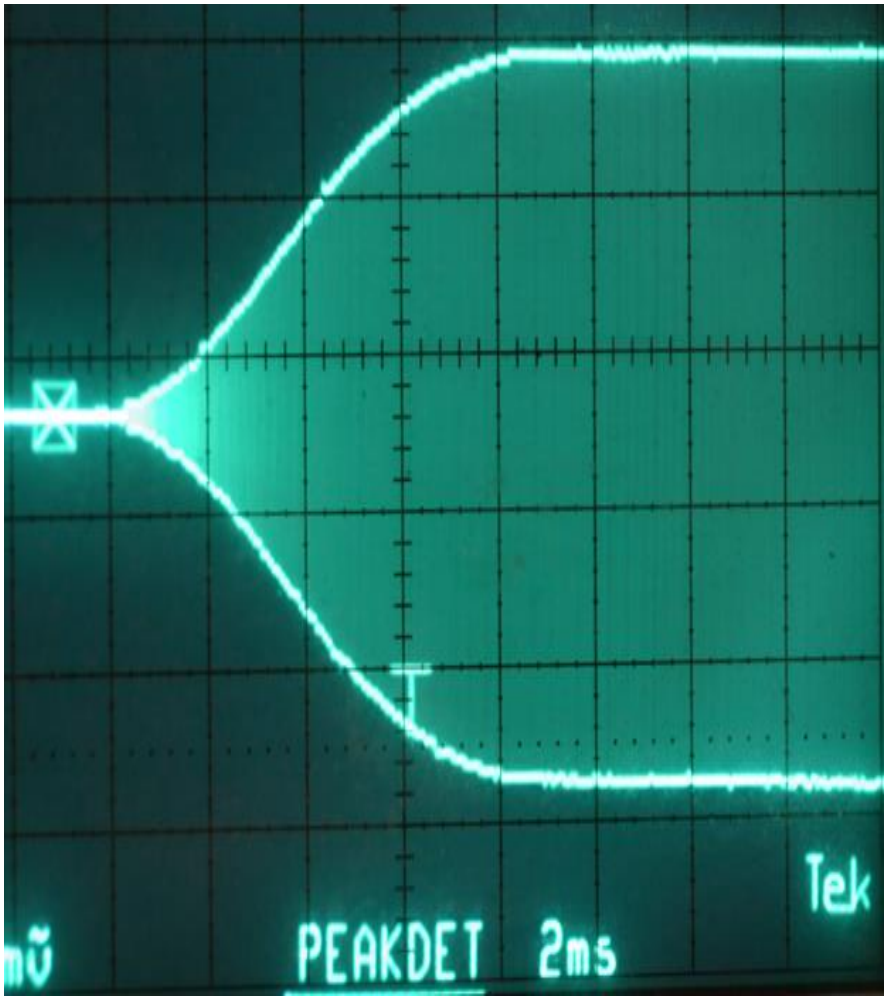


1 or 2 ms should be labeled "Turn Key Clicks ON"

This screen capture is in the time domain

Leading edge of “dit” 3 & 10 msec





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

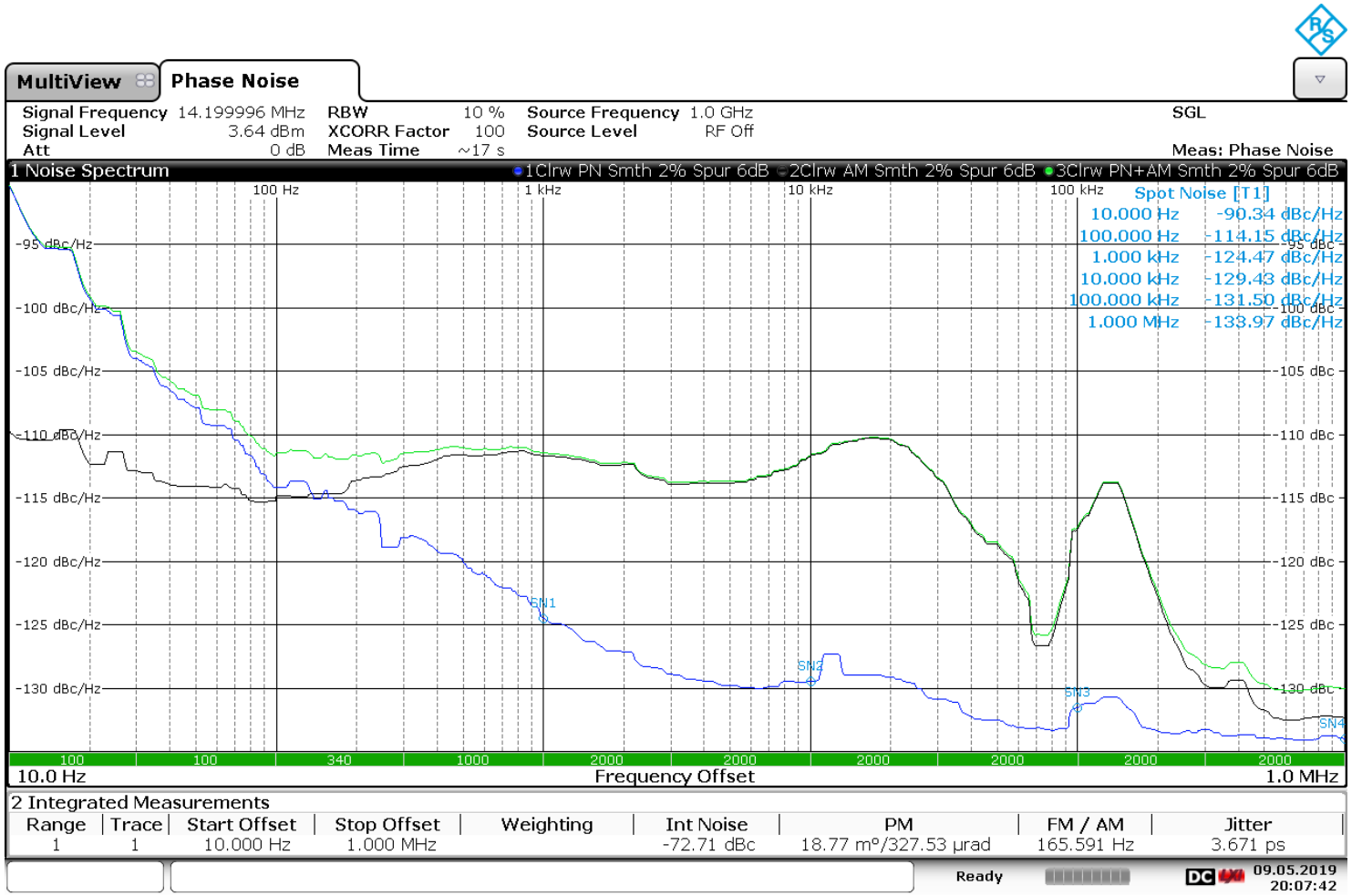
When the transmit noise doesn't fall off at 100 kHz, that rig would be a terrible choice for Field Day.

Same problem with another ham close to your location

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

AM noise + phase noise = composite noise
At 20 kHz AM noise 18 dB worse than phase noise

IC-7300 30 watts AM Noise Dominates



20:07:43 09.05.2019

Next slide transmit composite noise data

In difficult RF environments such as Field Day, a multi-transmitter contest station, or hams in close proximity, broadband transmit composite noise is a major issue.

If there is a ham a mile away, you hope his transceiver isn't near the bottom of the following list.

Note: Data sorted by 10 kHz column (DX & Contest Pileup)

For Field Day, focus on 100 kHz data. (2 or 3 signals same band)

Combined data from NC0B and @S53WW

Transmit Composite Noise
Radio Comparisons

By Rob Sherwood, NC0B
and Robi Vilhar, S53WW

	Radio	Offset Frequency 10 kHz	20 kHz	100 kHz
^^^^^^^^^^ BETTER >	Apache 7000DLE	-145	-147	-151
	Flex 6700	-143	n/a	-148
	K3S	-141	n/a	-143
	FTdx-101D	-137	-138	-141
	@FTdx-101D	-134	-137	-140
	FTdx-101MP	-134	-136	-139
	@K3	-133	-140	-149
	FTdx10	-130	-131	-135
	IC-7851	-129	n/a	-138
	@IC-7610	-129	-133	-141
	IC-7610	-128	-130	-142
	@FT-1000 MP	-123	-129	-133
	@IC-7600	-122	-130	-142
	Flex 6400	-122	-127	-139
	IC-705 ^	-121	-122	-128
	IC-7300	-121	-121	-124
	FTdx-3000	-120	n/a	-121
	TS-890S	-119	-127	-139
	@TS-590SG	-119	-133	-139
	@Flex 6600	-118	-123	-141
	@TS-890S	-117	-127	-138
	@FT-2000	-117	-127	-130
	@Flex 1500 #	-116	-119	-120
	@IC-7300 *	-112	-112	-118
vvvvvvvvvv WORSE	IC-7300 +	-110	-109	-116

¦ Rev. D ¦ April 30, 2021 ¦

NOTES
Data sorted by 10 kHz composite noise column
Results shown in dBc/Hz using
Measurements made on 20 meters
TX power: 100 Watts, (unless indicated)
Robi Vilhar's (S53WW) data was measured using a QS1R SDR Receiver; (data preceded by @)
Rob Sherwood's (NC0B) data was measured using a Perseus SDR Receiver

LEGEND
n/a = data not available
^ Power at 10 watts IC-705
# Power at 5 watts Flex 1500
* Measured at 50 watts for IC-7300
+ Measured at 30 watts for IC-7300
@ [Model] **=** data from Robi Vilhar, S53WW

Note: although we used two different types of receivers, where we measured the same model of transceiver, the data corolation was reasonably good. We are comfortable publishing this combined chart.

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

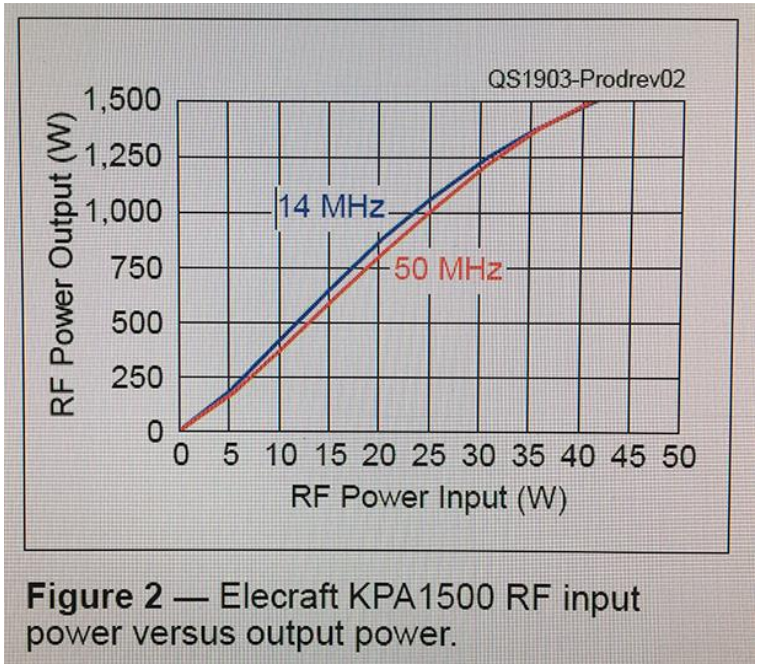


Figure 2 — Elecraft KPA1500 RF input power versus output power.

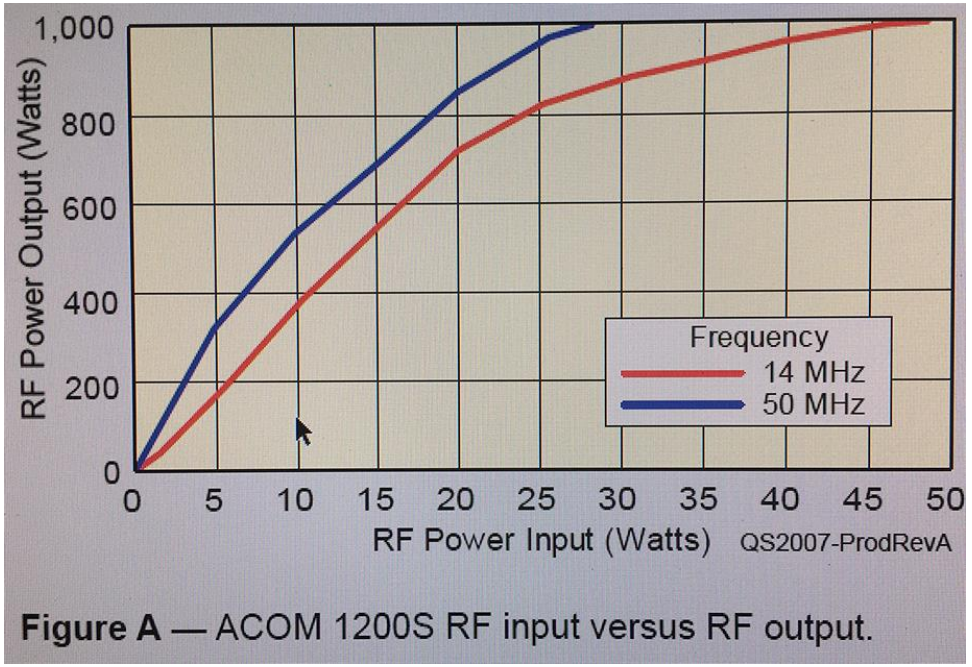


Figure A — ACOM 1200S RF input versus RF output.

Graph QST March 2019

Graph QST July 2020

Clean at half power

Bottom Line Today

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

The challenge for us the consumer

- Unless we demand cleaner transmitters it likely won't happen.
- Competition drove RX dynamic range from the mid 70s 15 to 20 years ago, to today when 100 dB is the middle of the pack.
- OEMs finally learned how to design clean synthesizers.
- The technology is there to improve transmitters if we vote with our pocketbook.

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	(16 dB preamp ON)
Flex 6700 (2017)	99 dB	(Preamp OFF)
Icom 7610	98 dB	(IP+ ON)
Icom 7300	97 dB	(IP+ ON, S/N around 10,000 and up)
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	(No IP+ ADC linearization)

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 15 of the 21

N2IC uses two TS-590 models.

Where will the K4 fit in this table?

- We do know the architecture.
- K4 Performance estimated: DR3 upper 90s, Blocking mid 120s

- A K4 will have one ADC and bandpass filter set.
- Similar to half an IC-7610
- Can be on 2 bands, but with input filtering broadband.

- An Elecraft K4D will be much like an Icom IC-7610.
- Direct sampling, 2 ADC, 2 BP filter sets, 2 independent receivers

- The K4HD (superhet module) has up to 3 roofing filters per RX.
- Has an architecture similar to the Yaesu FTdx-101D.

What new rigs came out in 2020 ?

- Lab data and contest evaluation
- Icom IC-705: 5 -10 watts 160m – 70cm
- Yaesu FTdx10: 100 watts 160m – 6m

Comments on the IC-705

- 160m – 70cm, lab numbers = 7300 IP+ OFF
- IP+ (dither) helps lab numbers.
- Hard to tell on the air whether IP+ makes a difference.
- My be significant 10m near sun spot maximum.
- For HF, operates just like an IC-7300
- Lots of VHF features
- Excellent ergonomics and scope display
- Common user interface for all the Icom direct sampling transceivers: 7300, 7610, 9700 & now the 705
- Great new scrolling feature for these four Icom rigs.

Contests operated with the new Icom

- IC-705 Note: I wasn't running QRP.
- Sweepstakes, 100 Qs just for fun
- ARRL 160m CW, 392 contacts, S&P only, 2 JA Qs, 80 sections, 16+ hours on air
- ARRL 10m CW and SSB, sensitivity fine
- Lack of a headset with VOX an issue

Comments on the FTdx10

- Lab numbers almost at FTdx-101D/MP level
- Ergonomics seem clumsy to me.
- April firmware update fixed a few issues, but created some new problems.
- 3D waterfall useless for an S&P operator
- All 3D waterfall history goes away the instant you transmit in any mode.
- 2D waterfall ok now with firmware update.
- The 101D & MP have this same 3D limitation.

Contest operated with FTdx10

- CQ WW 160m CW
- 212 Qs, S&P, 3 JAs, 45 sections
- 7+ hours on the air, (no Sunday operating)
- Selectivity and APF worked very well.
- Excluding ergonomics and poor band scope & waterfall, the radios is a good performer.
- Jumpy band scope needs averaging.
- Firmware bugs still need work.

http://www.NC0B.com

Sherwood Engineering

Ask for a PDF of this presentation via email.

Email: rob@nc0b.com

Feel free to email questions !