

# Transceiver Performance for the HF Contest & DX Operator

**Rob Sherwood**  
**NCØB**

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

## Why did I start testing radios?

### Testing which started in 1976 was a fluke

- K8RRH and I owned Drake R-4Cs, which had good reviews, but had poor performance in CW contests.
- Testing did not approximate the real world.
- Added 2kHz dynamic range test besides 20 kHz.
- It took the ARRL decades to include 2 kHz testing.
- Radios with a wide first IF were the problem.
- Up-conversion radios were particularly bad.
- 20 kHz dynamic range (DR3) 90+ dB, but 2 kHz 70 dB.
- 70 dB not acceptable for CW contesting / DXpeditions.

# How did I obtain sample radios?

- In the 1980s the local ham store took trade-ins.
- I could borrow and test radios over a weekend.
- In the last 10+ years hams loan me a radio.
- Some I own, and occasionally I buy a radio just for testing, and then sell it. IC-705 & FTdx10
- For the last 14 years I also operate rigs at my contest station for “hands on” evaluations.

# Antenna Farm on Colorado Plains



# 1 of 3 Operating positions at Ault



Often I'll compare two different rigs in a given contest.

# Examples of contesting with 2 radios

- IC-781 & FTdx-5000D Poor scope 5000D
  - IC-7300 & TS-990S Amazingly similar
  - TS-590S & Ten-Tec Eagle 590 easier to use
  - Flex 6300 + Maestro & IC-7300 Icom cleaner QSK
  - KX3 & IC-756 Pro III Icom AGC issues
  - Apache 200D & IC-7610 200D filters poor \*
- \* Note: NR0V walked me through changing the poor default DSP filter settings. CW shape factors went from 4:1 to 1.8:1.

## A new requirement in last 5 years

- With so many competing products, testing a random sample has become very important.
- I won't test a "cherry-picked tweaked" radio.
- Kenwood lets me go to HRO and select a random box off the shelf.
- For brands that don't sell through dealers, I have to depend on borrowing a rig from a ham.

# Don't just focus on RX performance

- The Ten-Tec Orion I started a new trend.
- Up-conversion could not compete.
- Elecraft K3 greatly continued this trend.
- Receivers today have vastly improved.
- Hybrid superhet & direct sampling dominate today's OEM RX offerings.
- **Transmitters have gotten worse!**
- Examples to follow



## Dynamic Range vs. test signal spacing

- Wide roofing filter, big difference **25 dB**
- Narrow roofing filter (K3, 890S, 101D) very little difference. DR3 **105 to 110 dB**
- Direct sampling (Apache, K4, Flex, Icom) no roofing filters, no difference 20 kHz vs 2 kHz
- Direct sampling **100 dB +/- 3 dB**
- Big signals, line of sight, S9+70 to 85 dB  
superhet with roofing filter: **blocking advantage**
- This assumes the other transmitter is clean!
- (K3s 150 dB example)

# 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

2020 10m ARRL CW contest examples !

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

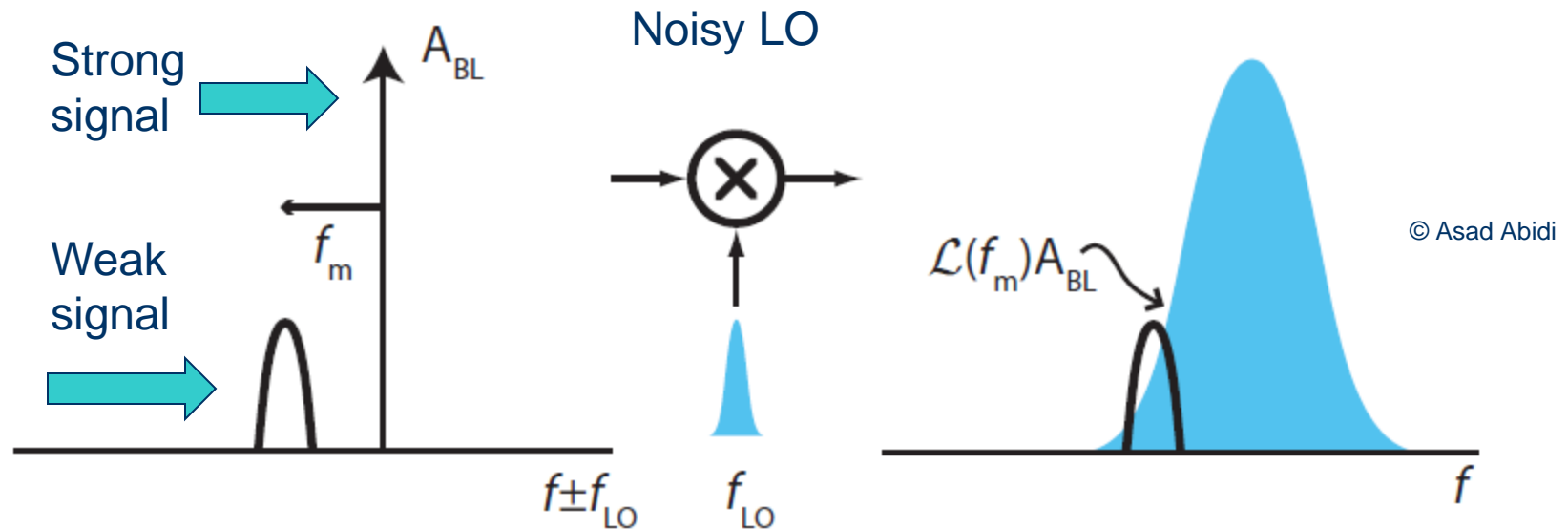
- Close-in Dynamic Range (DR3) on CW or RTTY
- Noise floor is needed to calculate DR3.
- Reciprocal Mixing Dynamic Range (RMDR)
- Transmitted broadband composite noise
- SSB transmit IMD splatter limits RX performance.
- Key clicks limit close-in CW reception.

## What has improved in recent years?

- Reciprocal Mixing Dynamic Range\* has improved thus -
- Transmit composite noise is better on certain models.
- Superhet: K3S, IC-7851, FTdx-101D/MP, FTdx10
- At wider signal offsets include: TS-890S, IC-7610
- Direct sampling: Apache, Flex, Elecraft K4
- This is the first time in years that Yaesu has offered acceptable transmit composite noise !
- \* RMDR measures LO or clock phase noise.

Hopefully the noise improves with offset.

## A noisy LO or Clock Oscillator affects TX and RX



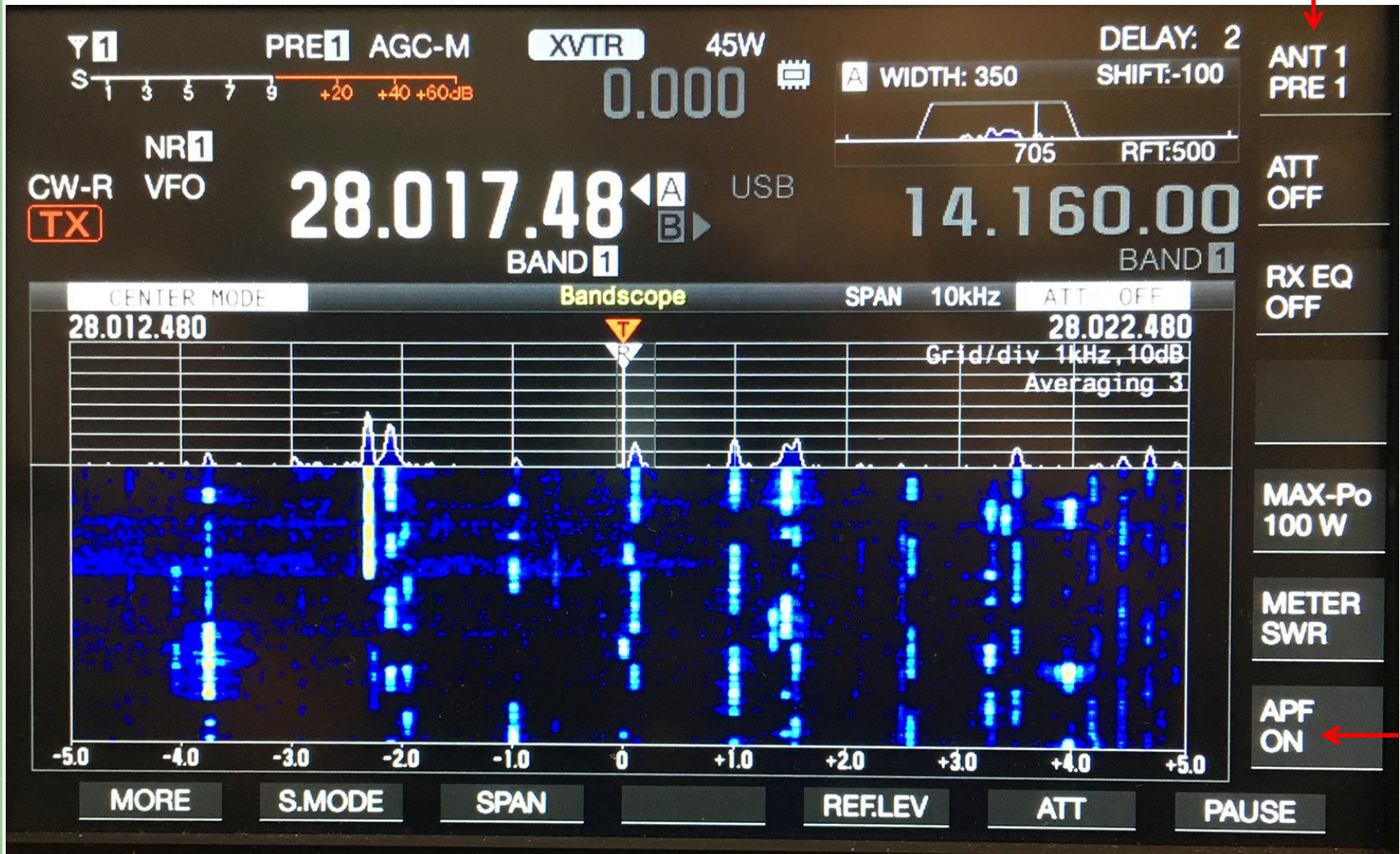
Noisy local oscillator (LO) transfers its noise to the strong out-of-passband signal and on top of the weak signal we are trying to copy.

December 2018

Over 20 stations in 10 kHz TS-890S

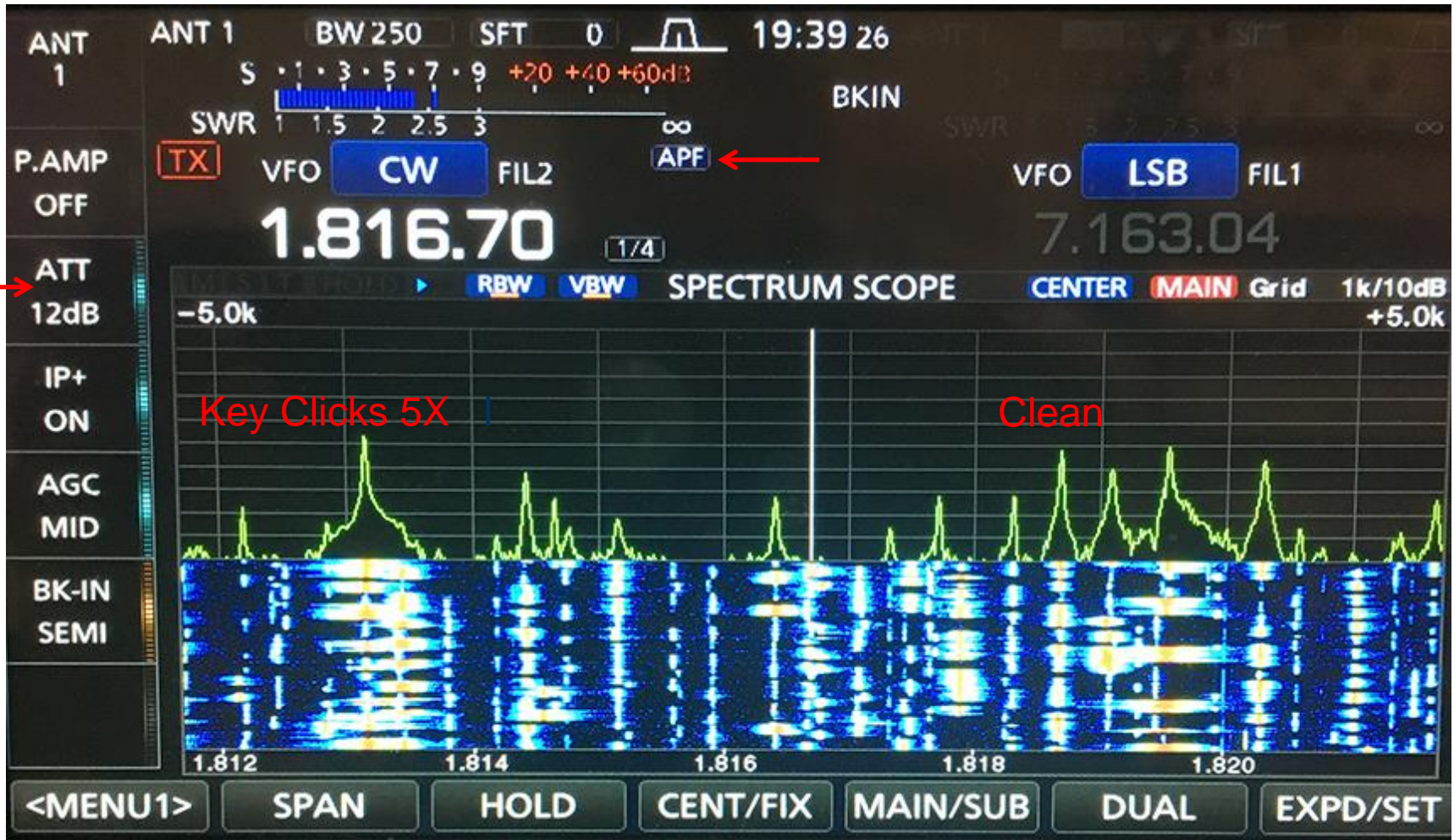
# ARRL 10m Saturday afternoon

Note preamp \*



\* Antenna noise gain vs. preamp setting

# ARRL 160m CW Friday 7:40 PM



Note  
ATT

IC-7300 & TS-990S 18 dB attenuation + Flex & Apache threshold adjustment



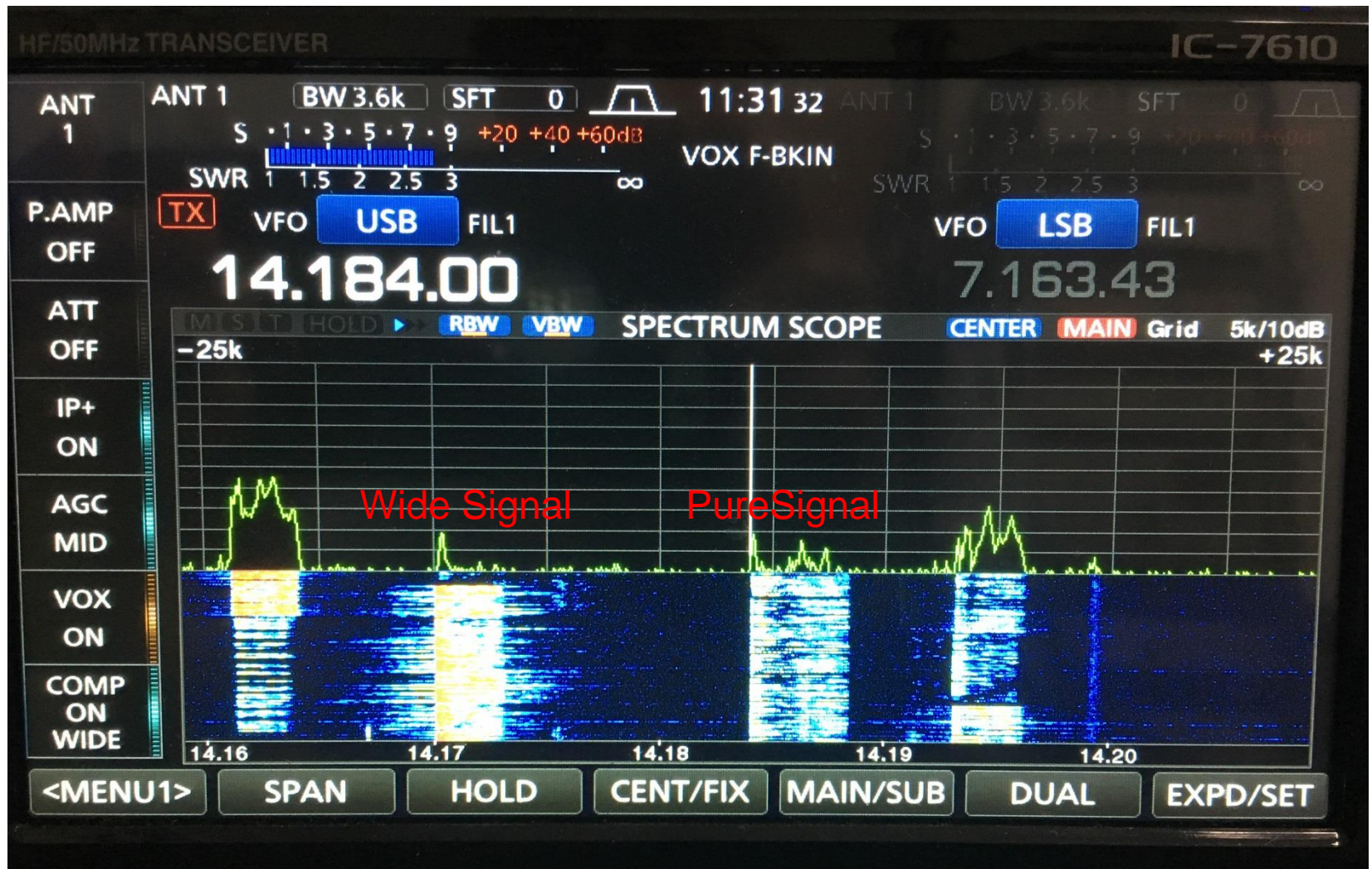
# New feature from Apache Labs

- Open Source software
- Automatically set maximum AGC gain a certain amount above band noise.
- (Sets AGC Threshold)
- **Note:** Band noise isn't constant:
- Varies by time of day
- Directional antenna – Yagi, 4 Square, etc.
- Don't yet know the UI implementation.

PureSignal TX BW 4.6 kHz not a good choice!

Pre-distortion example on 20m June 2019

# Currently only Apache offers pre-distortion



## Quick break for short Q&A

Next we will next look at today's disappointing transmitters.

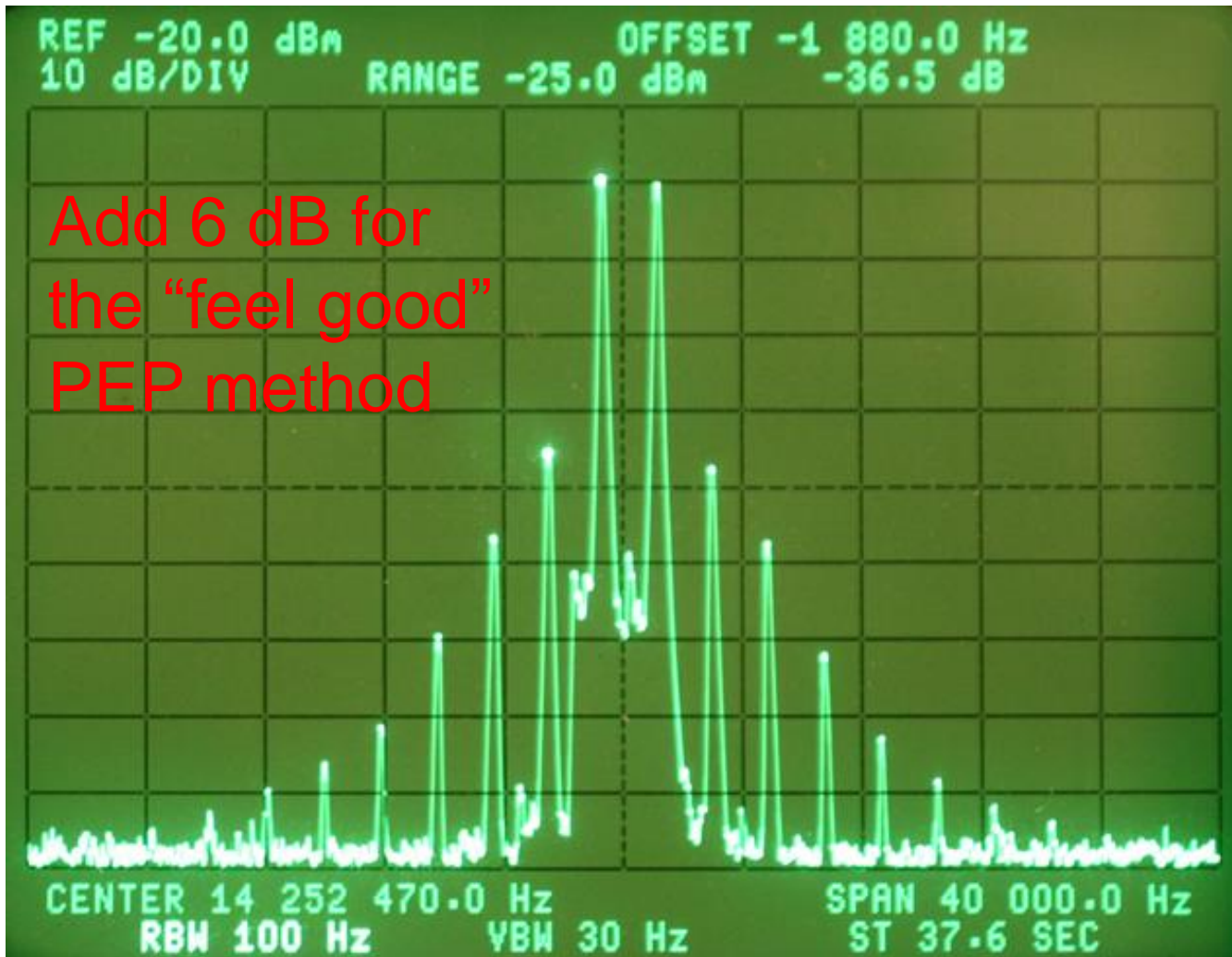
Why hasn't transmit performance improved in parallel with receivers?

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

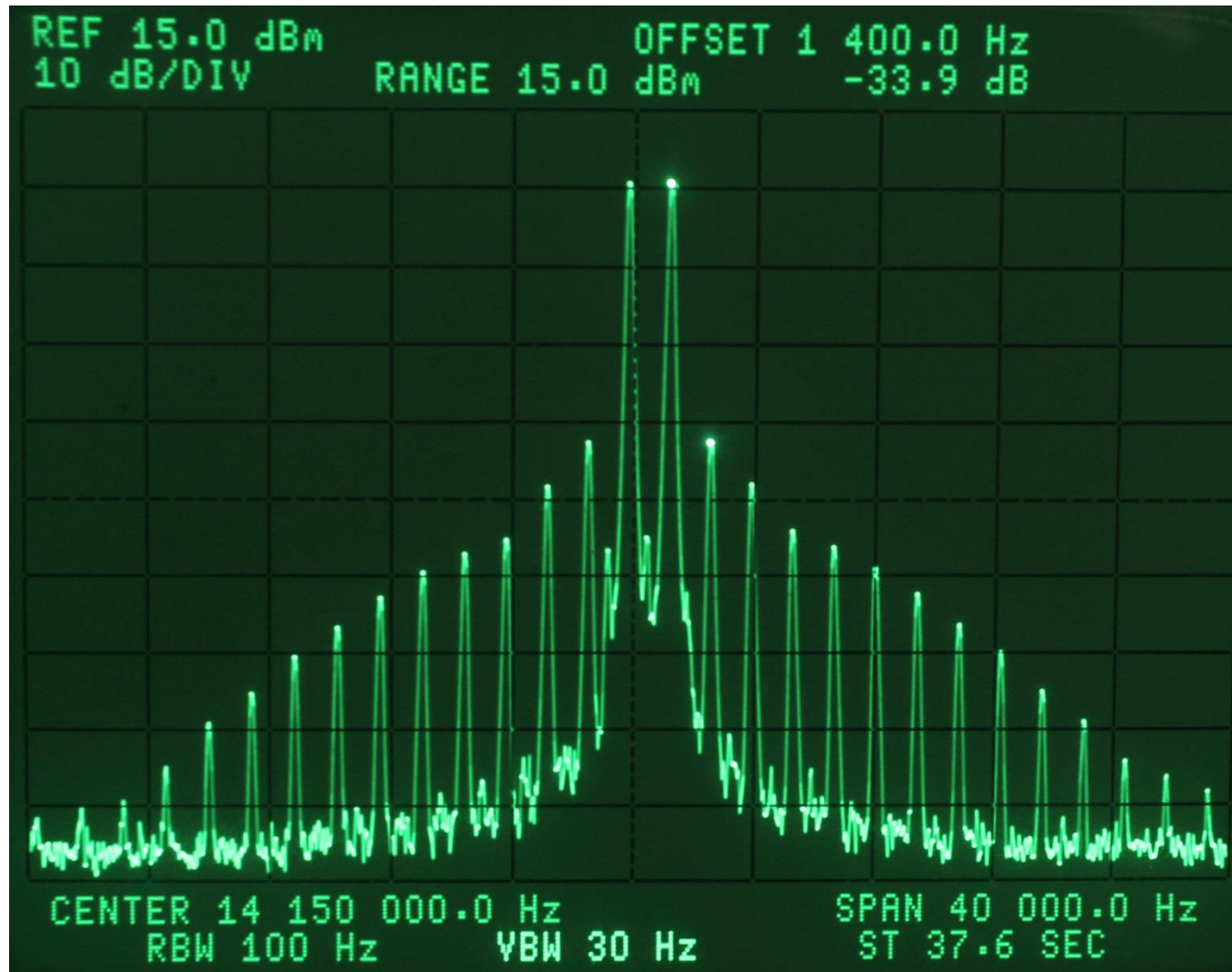
Add 6 dB for  
the “feel good”  
PEP method



My 2<sup>nd</sup> cleanest

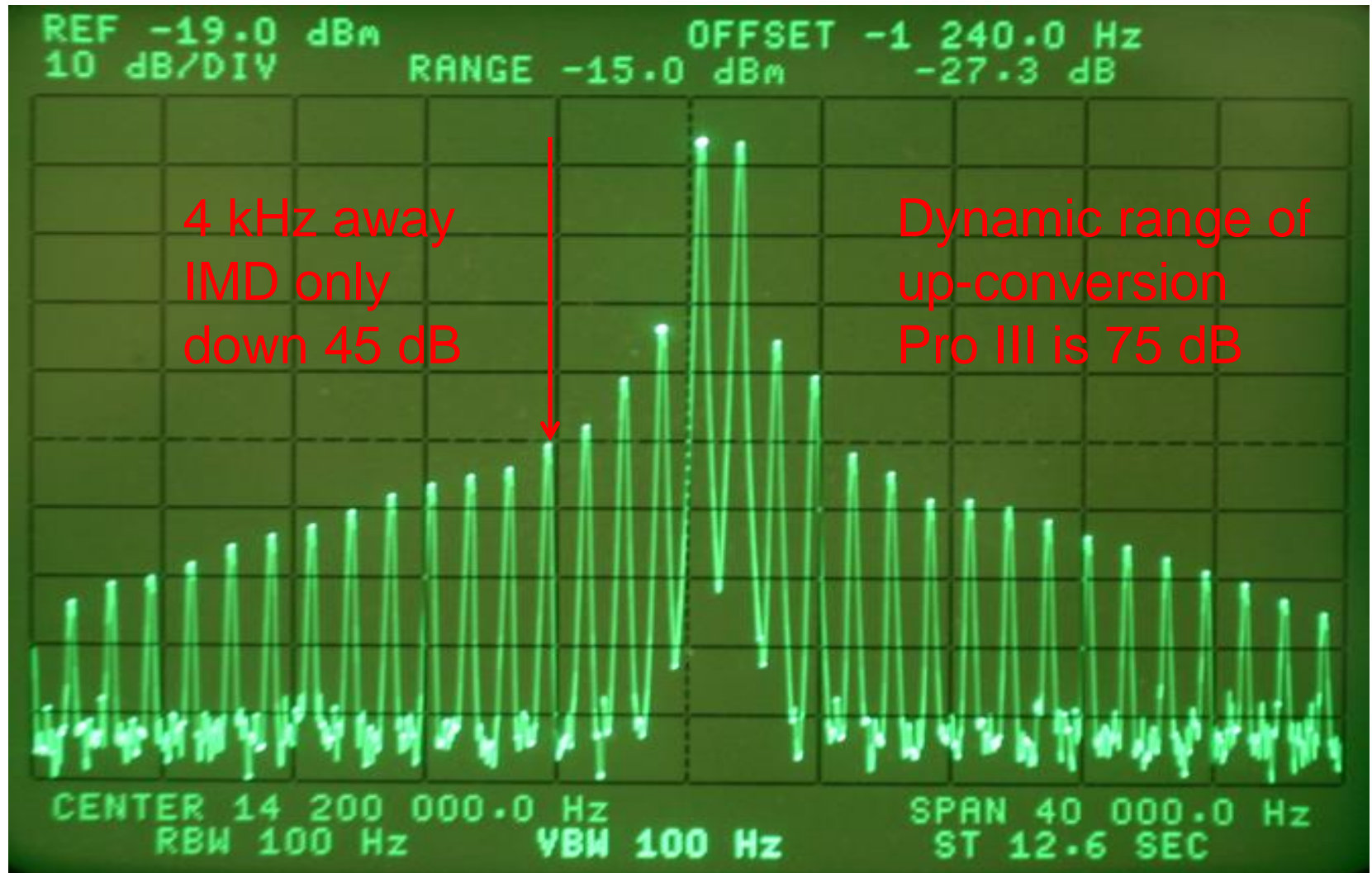
Kenwood TS-990S: -34 dBc 3<sup>rd</sup> order

# A 50 volt PA can be cleaner



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

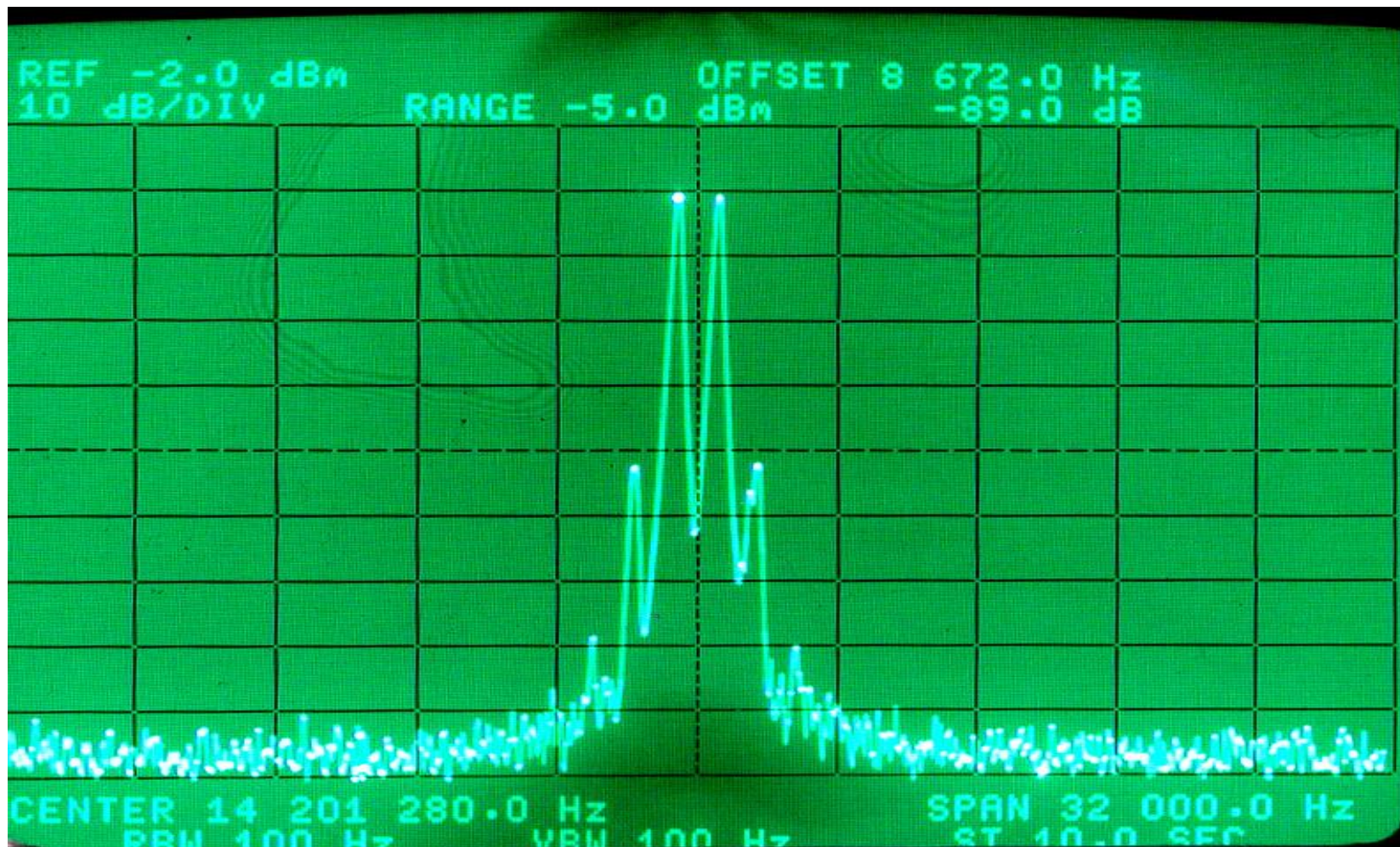
## K3 Transceiver on 20 meters @ 100 W



-42 dB 3<sup>rd</sup> Order, -70 dB 5<sup>th</sup> Order

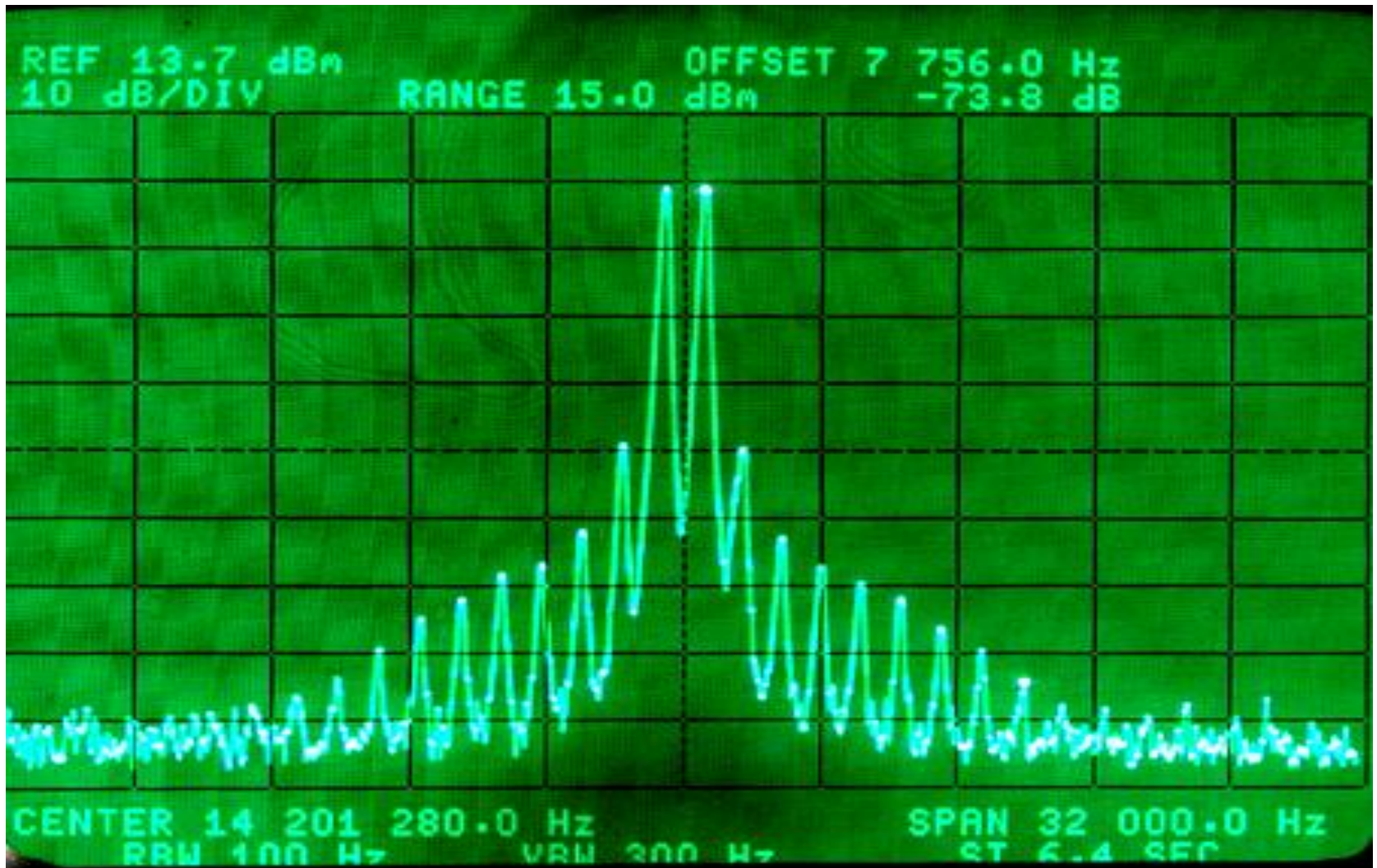
# Yaesu FT-1000 Mk V, 20 M, Class A @ 75 W

Provided by Pete, W6XX



-40 dB 3<sup>rd</sup> Order, -52 dB 5<sup>th</sup> Order

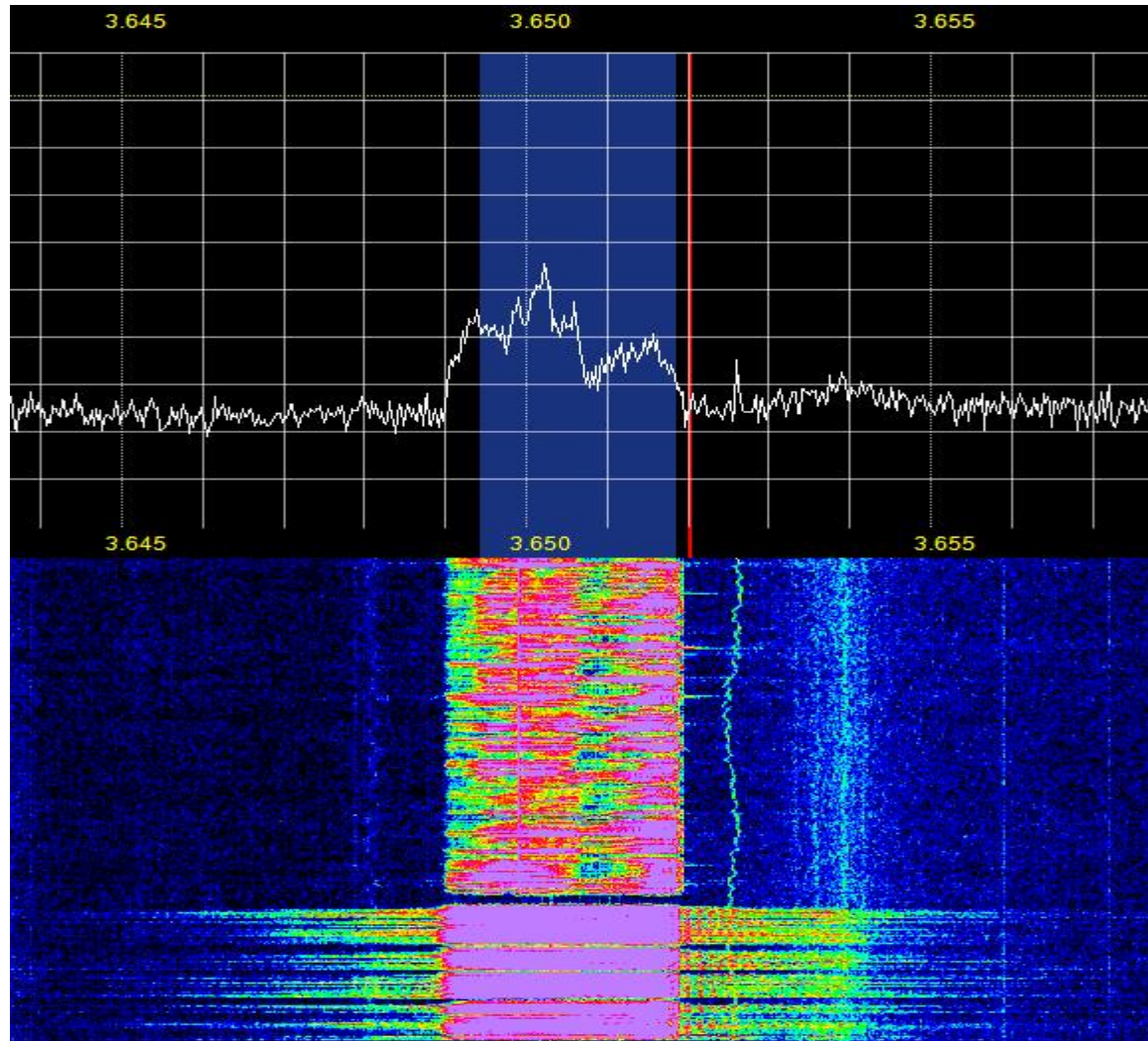
# Mk V Class A + 8877, 20 meters @ 1.5 kW





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

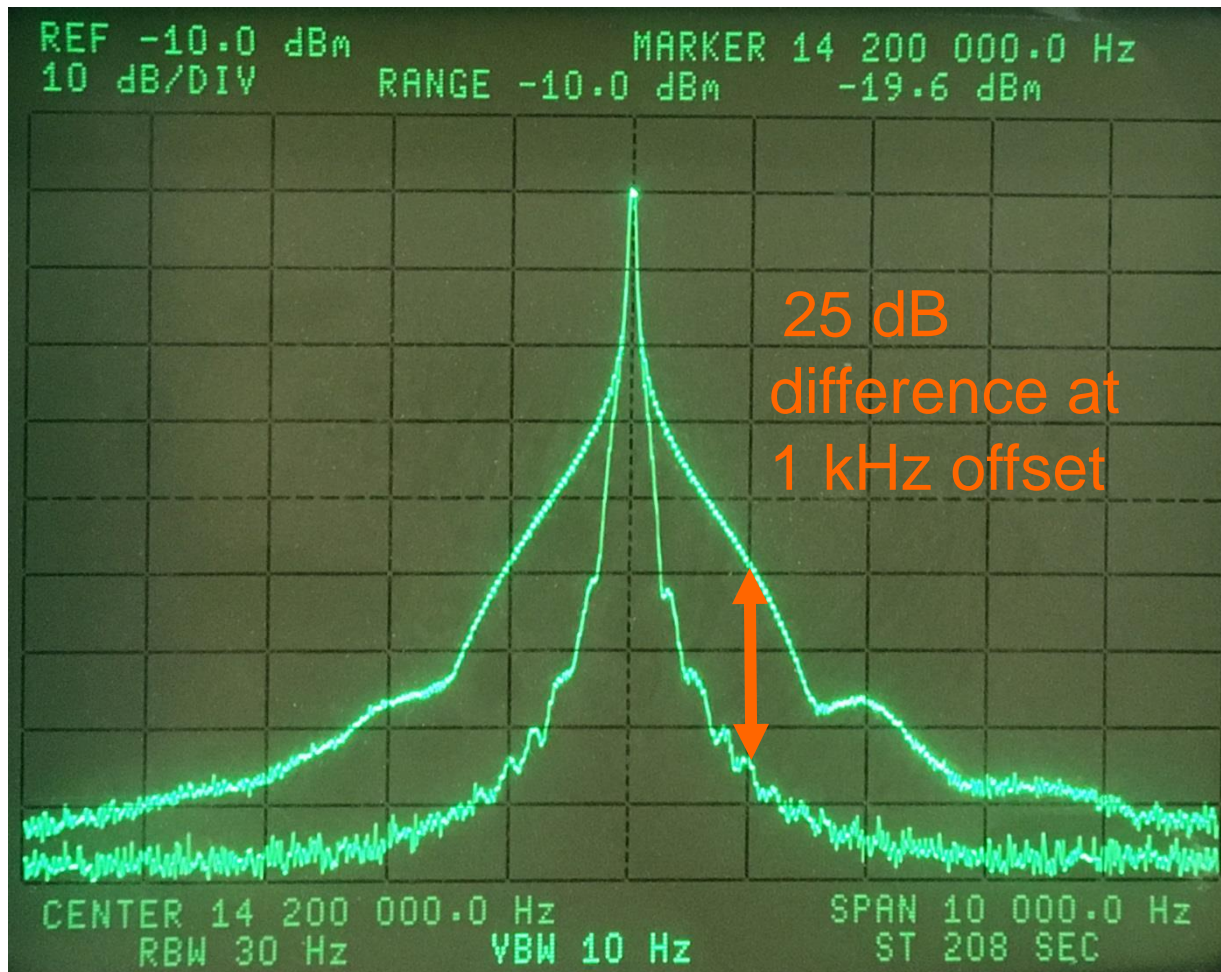
Kenwood

1 and 2 ms key click special

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

## Spectrum of CW Signal on HP 3585A Analyzer

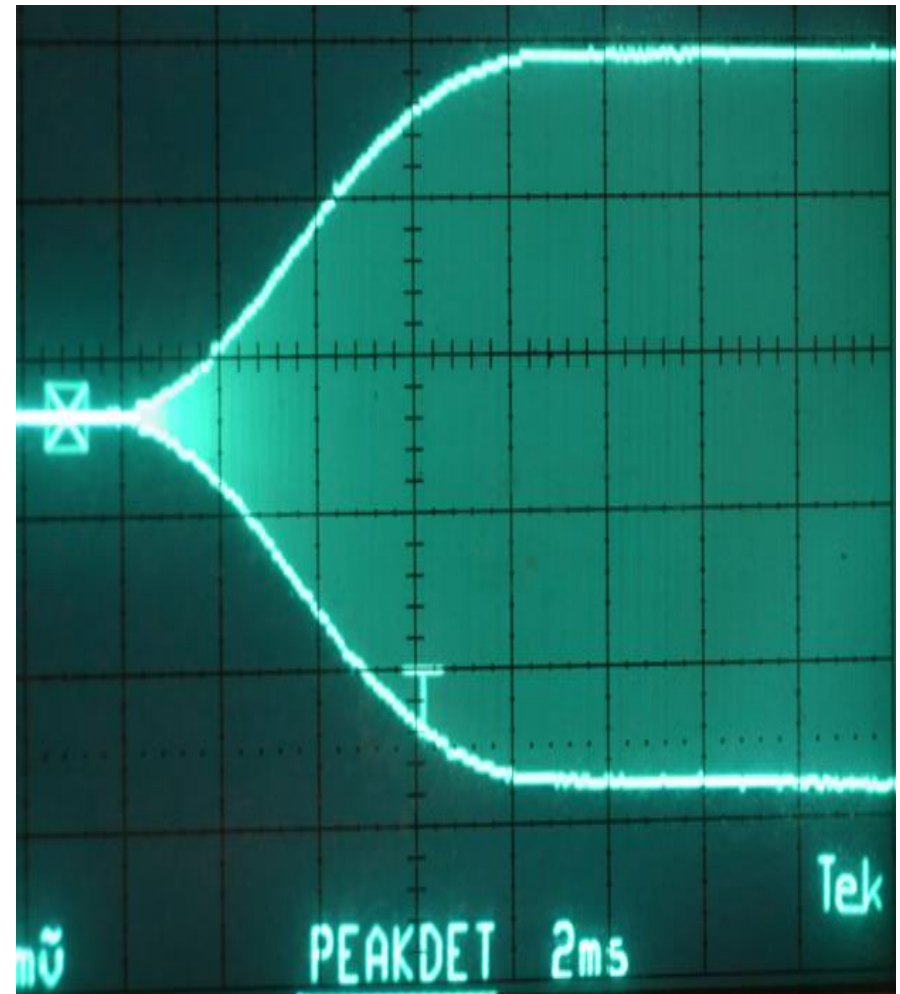
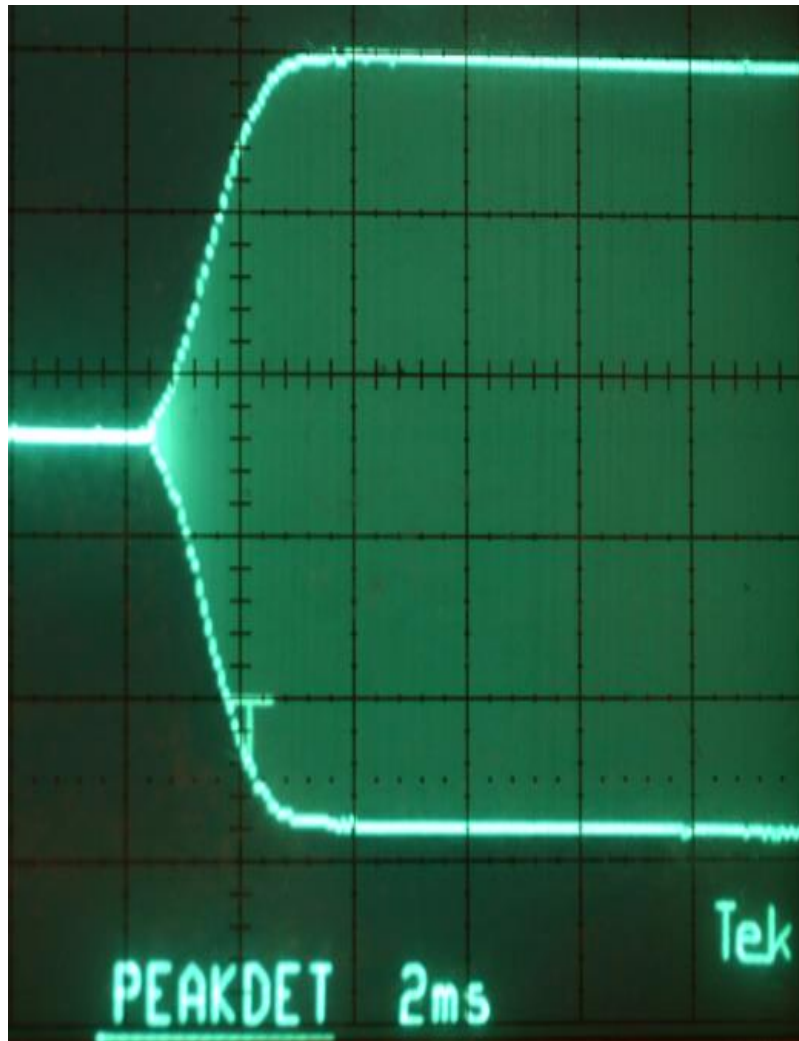
Comparison of 1 msec vs 6 msec rise time



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

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.

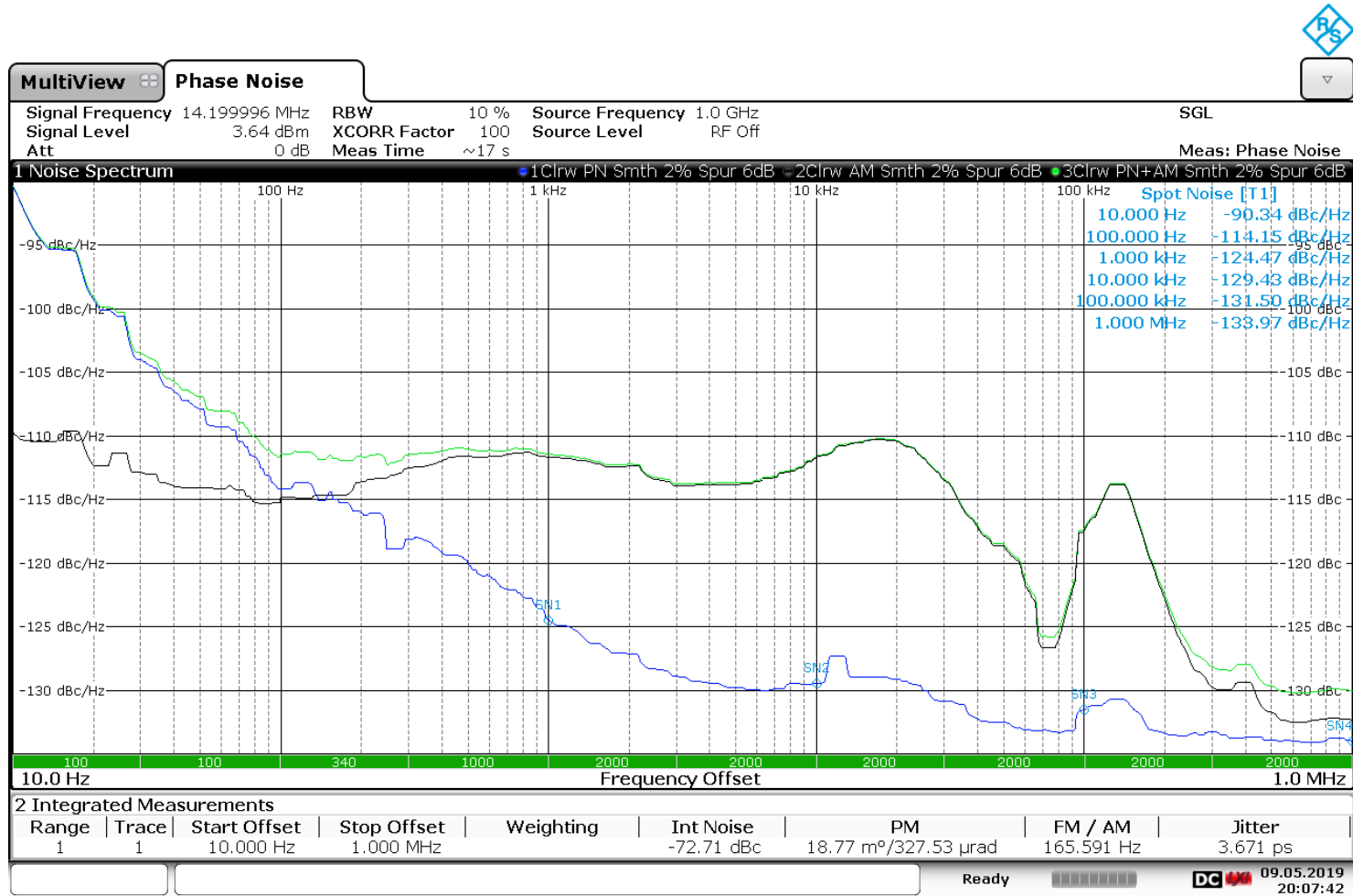
Same problem with another ham close to your location

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

\* Data measured by Ken, **N0QO**, on site.

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

# IC-7300 30 watts AM Noise Dominates



## Next slide transmit composite noise data

In difficult RF environments such as Field Day, a multi-transmitter contest station, or hams in close proximity such as line-of-sight, 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, N0QO and @S53WW

## Transmit Composite Noise Radio Comparisons

**By Rob Sherwood, NC0B  
and Robi Vilhar, S53WW**

\* Data also from N0QO

	Radio	Offset Frequency		
		10 kHz	20 kHz	100 kHz
^	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
^^	IC-7300 +	-110	-109	-116

^^^^ BETTER  
 ---  
 ^^^^ WORSE

### 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 correlation 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 \*

QST 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.

\* Data taken by N0QO

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

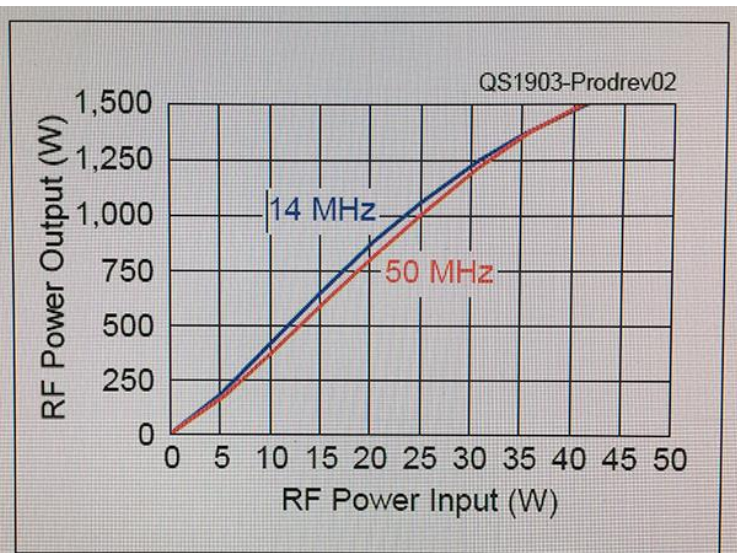


Figure 2 — Elecraft KPA1500 RF input power versus output power.

Graph QST March 2019

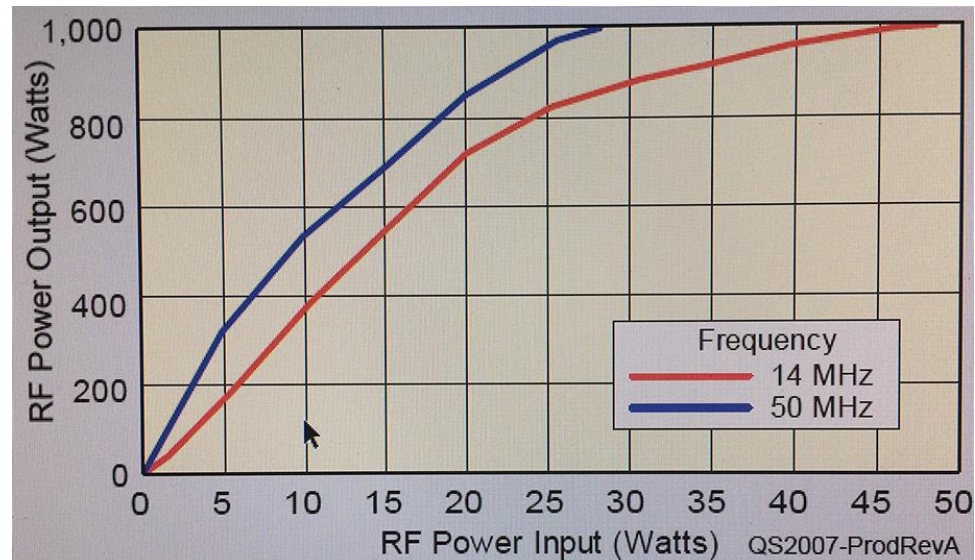


Figure A — ACOM 1200S RF input versus RF output.

Graph QST July 2020

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.

K4HD cost completely unknown

## Finally data in 2021 on the new K4 !

- K4 Performance DR3 101 dB, ADC over-range 128 dB
- Similar to half an IC-7610
- Can be on 2 bands at once, but with input filtering broadband.
  
- An Elecraft K4D is similar to an Icom IC-7610.
- 2 independent receivers
- Independent L/C front-end filters
  
- Future K4HD superhet module can have **up to 3 roofing filters** for each receiver, (total of 6). Only available as an upgrade to K4D.
  
- Three weeks of testing at NC0B and N0QO resulted in finding many firmware bugs: AGC, CW timing, RX audio distortion, etc.
- Elecraft will be updating FW over time to address these issues.

# New rigs in 2020 / 2021

- Lab data and contest evaluation
- Icom IC-705: 5 -10 watts 160m – 70cm
- Yaesu FTdx10: 100 watts 160m – 6m
- Unfortunately no contest data on K4/K4D yet
- In very difficult RF environments the K3S may perform better due to roofing filters.
- A mouse will be helpful to navigate the UI.

# 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 !

Only \$1600 today at HRO !

## Comments on the FTdx10

- Lab numbers almost at FTdx-101D/MP level
- Ergonomics seem clumsy to me.
- May 14<sup>th</sup> firmware update is the latest version.
- Key clicks are no longer a problem.
- 3D waterfall useless for an S&P operator
- All 3D waterfall history goes away the instant you transmit in any mode.
- **2D waterfall now ok 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.
- A mouse is helpful due to small buttons.

Don't select a new radio on one number !

## Important factors to consider

- Operator fatigue is made worse by poor receive audio and poor AGC performance.
- Bad ergonomics slows you down in a contest.
- Is speech processor adequate?
- NB and NR very important for urban QTHs.
- Is firmware regularly updated?
- Is warranty service done well and quickly?
- Is the radio supported with parts and service after it is out of production?
- Bottom Line: Do you enjoy using your radio?

# Your turn for Q&A

- I always look forward to feed back from you.
- Contact info on next slide
  
- Full disclosure
- Brands I have owned in the last 60 years:
  - National, Johnson, Drake, Collins, Kenwood & Icom
- Present base station rigs in my shacks:
  - Direct sampling IC-7300, 7610, 9700 & R8600



# Sherwood Engineering

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Feel free to email questions !