Madison DX 2021

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 had the same issue.
- 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 radios.
- 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
- IC-7300 & TS-990S
- TS-590S & Ten-Tec Eagle
- Flex 6300 + Maestro & IC-7300 Icom cleaner QSK
- KX3 & IC-756 Pro III
 Icom AGC issues
- Apache 200D & IC-7610

200D filters poor *

Poor scope 5000D

Amazingly similar

590 easier to use

* Note: NR0V walked me through fixing DSP filter issues.

A new requirement in last 5 years

- As technology changed, guaranteeing a random sample became very important.
- I won't test a "cherry picked tweaked" radio.
- All transceivers run on software / firmware.
- 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.

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 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.
- 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.

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-ofpassband signal and on top of the weak signal we are trying to copy.



December 2018

Over 30 stations in 10 kHz IC-7610

ARRL 160m CW Friday 7:40 PM



IC-7300 & TS-890S 18 dB attenuation example

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

We will next look at the disappointing transmitters.

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

The cleanest transmitter I have ever owned.

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

Collins 32S-3 on 20m at 100 watts



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

A 50 volt PA can be cleaner

My 2nd cleanest



-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 predistortion

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.*

* Data measured by Ken, N0QO, on site.

Courtesy PA5Y

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 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, NCOB	
and Robi Vilhar, S53WW	

*	Data	also	from	N0QO
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ΝΟΤΕΣ

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 (NCOB) 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.

		Offset Frequency		
	Radio	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
R	@K3	-133	-140	-149
ΤE	FTdx10	-130	-131	-135
ΕT	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
R S	IC-7300	-121	-121	-124
0/	FTdx-3000	-120	n/a	-121
× >	TS-890S	-119	-127	-139
×	@TS-590SG	-119	-133	-139
V	@Flex 6600	-118	-123	-141
v	@TS-890S	-117	-127	-138
v	@FT-2000	-117	-127	-130
v	@Flex 1500 #	-116	-119	-120
V V	@IC-7300 *	-112	-112	-118
V	IC-7300 +	-110	-109	-116

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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 3rd 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



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

(No IP+ ADC linearization)

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) (IP+ ON, S/N around 10,000 and up) I have run contests with 15 of the 21 N2IC uses two TS-590 models.

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

Comments on the FTdx10

- Lab numbers almost at FTdx-101D/MP level
- Ergonomics seem clumsy to me.
- May 14th firmware update is the latest version.
- 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 past:
- Drake, Collins, Kenwood & Icom
- Present base station rigs in my shacks:
- IC-7300, 7610, 9700 & R8600

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