2017 / 2018 Rig Contest Comparisons
+
3 New Rigs & 2 other Rigs Evaluated

Rob Sherwood

NCØB

What features are a must ?

- **What is important in a Contest Environment?**
- We need Good Dynamic Range to hear weak signals in the presence of near-by strong signals.
- In a DXpedition the pile-up is typically:
- CW signals “Up 2” or SSB signals “Up 5 to 10”
- Contests – DX pile-up, it is the same problem
- You need a better receiver for CW than for SSB.
- **How does published test data relate to reception of weak signals?**

State-of-the-Art in Dynamic Range today

- Close-in dynamic range (DR3) > 100 dB
- Phase noise @ 10 kHz ≤ -145 dBc / Hz
- Reciprocal Mixing (RMDR) > 115 dB

- Rigs with this kind of performance:
- Icom IC-7851, Flex 6000 & Elecraft K3S
- Icom 7300/7610 slightly less DR3
- Apache 7000DLE 100+ DR3, slightly less RMDR
- None are RMDR (phase noise) limited

What is new since last year?

- Icom IC-7610 big brother of IC-7300
- Both are direct sampling & 7610 dual receivers.
- 7610 adds solid-state QSK and APF (audio peak filter), a major feature for CW operators.

- Apache ANAN-7000DLE
- 100 watts instead of 200 watt 8000DLE

- Flex 6600/M & 6400/M (M = built-in Maestro)

Icom IC-7610 Direct Sampling

- Identical Dual ADC Receivers
- CW feature upgrade over IC-7300

- 20 kHz dynamic range: 98 dB IP+
- 2 kHz dynamic range: 98 dB IP+
- 20 kHz RMDR: >122 dB (OVF)
- 2 kHz RMDR: 112 dB

- Noise floor as low as -142 dBm Preamp 2

Icom 7610 vs. 7300 Comparisons

Data with IP+ ON	7610	7300
20 kHz dynamic range:	98 dB	106 dB *
2 kHz dynamic range:	98 dB	97 dB
20 kHz RMDR:	>122 dB	113 dB
2 kHz RMDR:	112 dB	100 dB

- Both noise floor -142 dBm with Preamp 2

* Sample #1 103 dB, sample #2 106 dB

* ADC variation can be more than 10 dB as noted in IC-R8600 on 4 different receivers.

Apache ANAN-7000DLE numbers

- 20 kHz dynamic range: 103 dB
- 2 kHz dynamic range: 103 dB
- 20 kHz RMDR: 114 dB
- 2 kHz RMDR: 109 dB
- Noise floor -131 dBm HF
- Noise floor -140 dBm 6 meters
- (An external preamp may be needed on 10, 12 and possibly 15 meters in a quiet location.)

Apache ANAN new software features

- Open Source code = new features fast
- PureSignal version 2.0
- Support for 7000DLE
- Spectral NB works in contest conditions *
- New NR algorithms
- Lower latency for better QSK
- Midi support for DJ Console and Behringer
- A slew of TX audio tools all in software

* I used the spectral NB during CQWW 160m

* PEN = Product Enhancement Notice

ANAN-7000DLE vs. Flex 6600M*

ANAN data w/ dither ON	7000	6600M
20 kHz dynamic range	103 dB	91 dB
20 kHz DR3 after PEN		99 dB*
2 kHz dynamic range	103 dB	91 dB
2 kHz DR3 after PEN		99 dB*
20 kHz RMDR	114 dB	111 dB
20 kHz RMDR after PEN		121 dB*
2 kHz RMDR	109 dB	105 dB
2 kHz RMDR after PEN		115 dB*
Noise floor HF	-131 dBm	-135 dBm
Noise floor 6m	-140 dBm	-137 dBm

Rigs run at NC0B during this past season

CQ WW SSB October 2017	IC-7300 20m only *
CQ WW SSB October 2017	IC-781 all but 10 & 20
CQ WW SSB October 2017	TS-990S 10m only
ARRL 160m CW Dec 2017	IC-7300 & TS-990S
ARRL 10m December 2017	IC-7610 CW & SSB
W1BB Top Band Dec 2017	IC-7610
CQ WW 160 CW Jan 2018	7000DLE & IC-7610
ARRL DX SSB March 2018	IC-7610 all but 15/10m #

* My most Qs were on 20m, edging out 15m by 1.5%

* 2016 / 2017 IC-7300 only used on 10m and 160m

\# A pair of IC-7300s on 15 and 10 meters

How did the rigs stack up?

- Let’s cover the two new rigs first during CQ WW 160m CW contest in January.
- The 7000DLE was paired against the IC-7610.
- Since the 7610 was used in ARRL 10m and W1BB contests previously, the bulk of the air time was allocated to the Apache.
- 12 hours 7000DLE
- 4.5 hours IC-7610

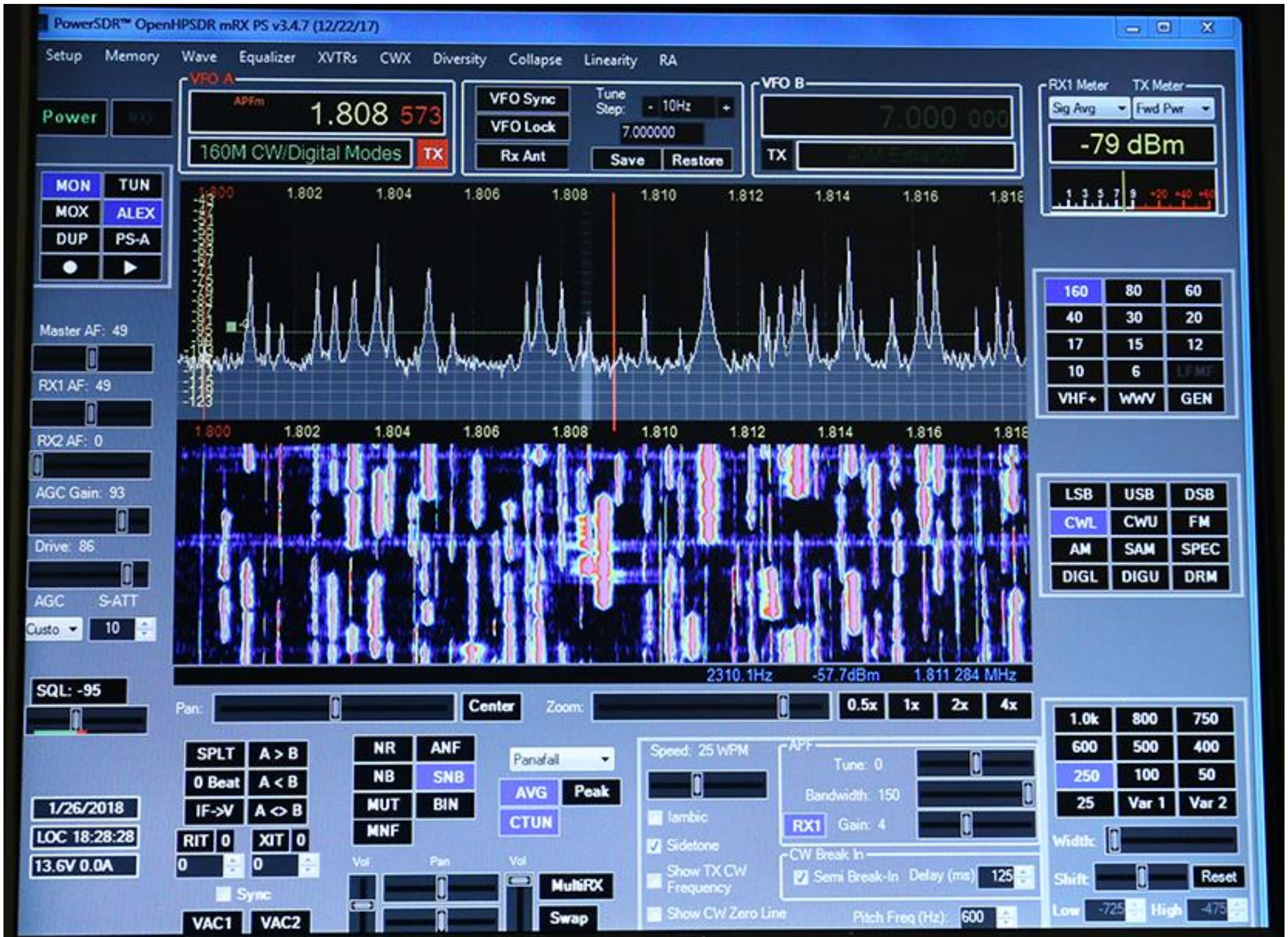
Very different UI but similar results

- The Icom and the Apache couldn’t be more different as to User Interface.
- Performance wise, it was a toss-up as far as copying CW signals “wall to wall” from 1800 to 1860 kHz on Friday, and 1800 to 1880 with even worse QRM on Saturday night.
- Apache setup more complex requiring dual monitors for the UI, plus the logging program.

Apache 7000DLE Operating Position

Icom IC-7610 Operating Position

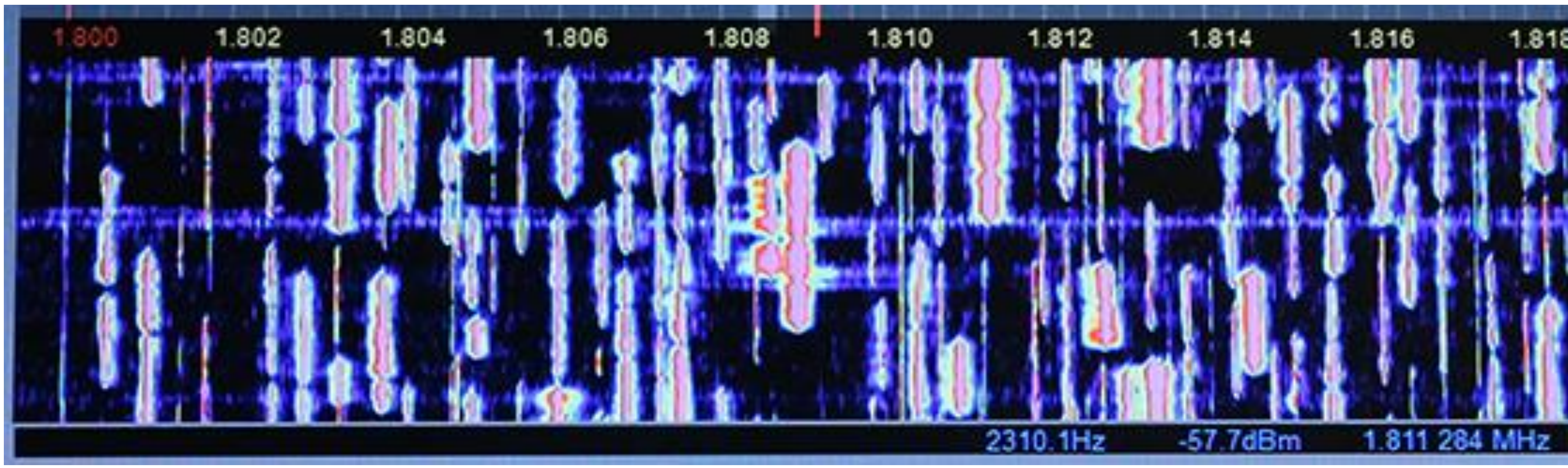
What did the band look like?



I do use waterfall extensively on 630m

Bandscope vs. Waterfall

- The waterfall was almost useless, at least to me, compared to the spectrum scope.



How were the rigs setup?

- **Icom:** BW 250 or 150 Hz, APF 160 Hz 4 dB gain, front-end attenuation 15 dB, NR 3 out of 10, bandscope 5 kHz total span. Tune with main knob.
- **Apache:** BW 250 or 100 Hz, APF 150 Hz 4 dB gain, front-end attenuation 10 dB, NB spectral, bandscope total span of 10 to 15 kHz. Tune with Flex knob.

With 20K IC-7300 sold, compare to TS-990S

- ARRL 160m CW contest I split operation 50/50 between the Icom and the Kenwood.
- Setup both rigs identically as possible
- QSK = Kenwood wins
- Noise Reduction = Icom wins
- Bandscope detail = Icom wins
- Front-End Filtering = Kenwood wins
- Kenwood blocking vs. Icom OVF = 990 wins, not that either was anywhere near overload.

Some are only CW oriented

Contest features desirable today

- QSK, or at least click-free semi-break-in
- APF to reduce band noise and fatigue
- Bandscope / spectrum display for S&P operation and for multipliers
- Efficient User Interface
- Rock solid connection to logging program
- For most, at least some kind of external manual controls for computer-controlled rigs.

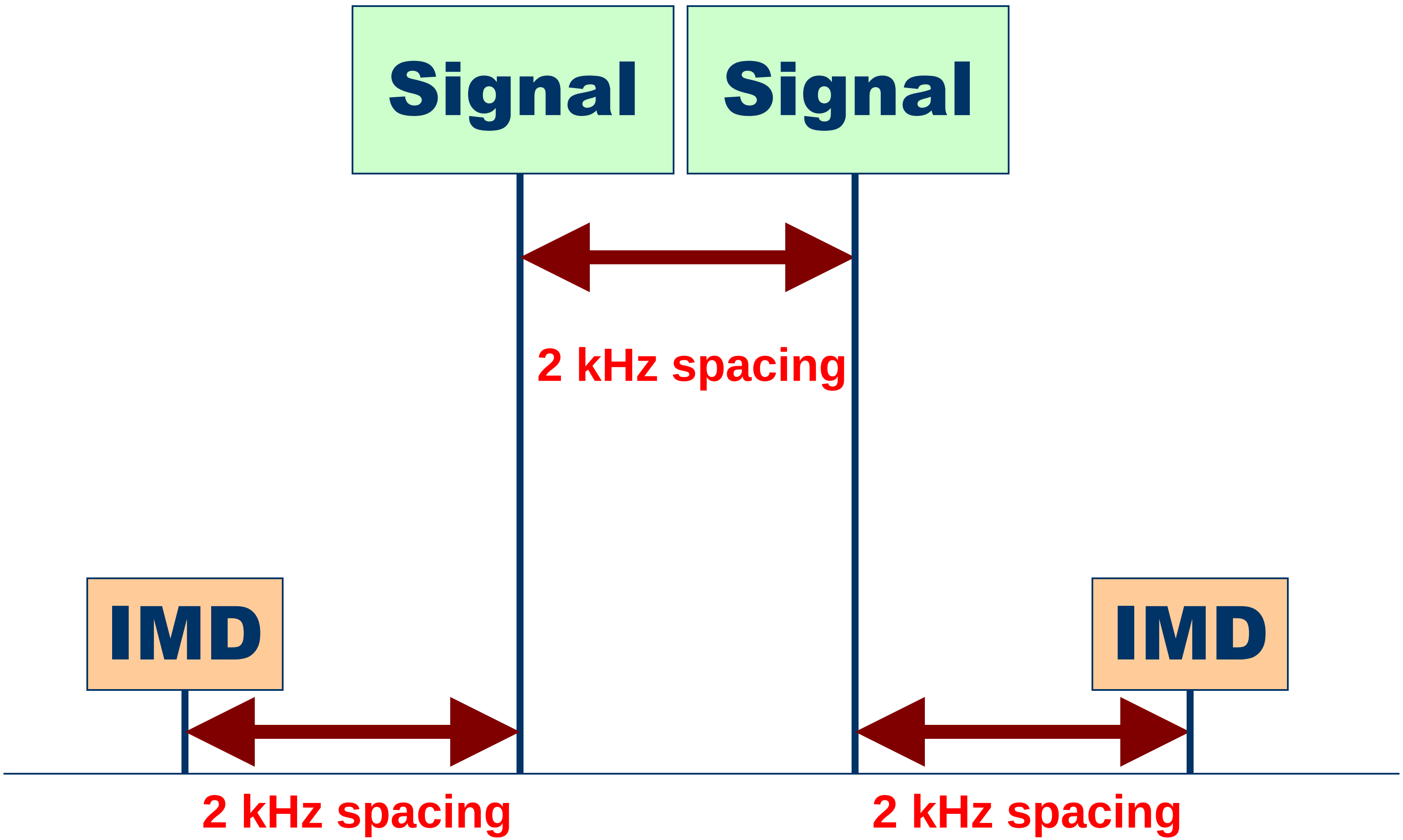
Time for the numbers

- What do these state-of-the-art numbers mean?
- How do we cope with a more typical radio?
- Optimize performance of what we own

What does dynamic range mean?

- Two equal signals are fed into the receiver.
- Third-order IMD is dominant.
- Level increased until distortion = noise floor
- This level vs. the noise floor = dynamic range
- Defined in QST & *hr magazine* 1975
- Noise floor = -128 dBm, test signals = -28 dBm
- -128 dBm minus -28 dBm = 100 dB
- Dynamic Range (DR3) = 100 dB

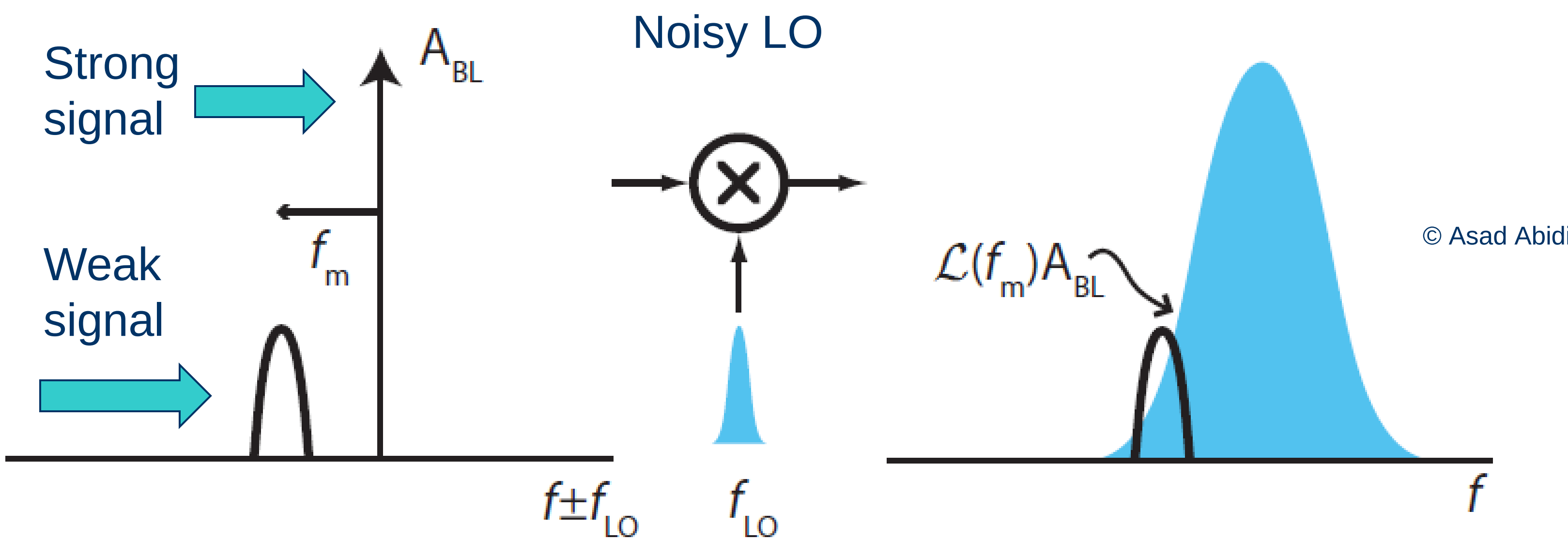
Third Order IMD to Measure Dynamic Range



A note on phase noise / RMDR

- Reciprocal Mixing Dynamic Range (RMDR)
- Only since late in 2013 has the ARRL consistently emphasized the importance of good phase noise performance (RMDR).
- Read Bob Allison's sidebar April 2012 QST & latest update May 2016 QST for details.
- Peter Hart (G3SJX) for RSGB has long published RMDR data.

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.

RMDR often dominates over DR3

- Only a few “legacy” transceivers, plus direct sampling SDR radios have RMDR > DR3.

- Elecraft K3 w/ new synthesizer, K3S or KX3
- Hilberling PT-8000A
- Icom IC-7850, IC-7851, IC-7610 & IC-7300
- Flex 6000 series, old and new
- Apache ANAN series

How do you relate to this data?

- Typical receiver, preamp OFF
- Noise floor = -128 dBm
- “Holy grail” 100 dB DR3 radio (@ 2kHz)
- Can handle signals -28 dBm = S9 +45 dB
- Note: That is above the receiver’s noise floor
- How does that relate to band noise?
- Will get to that in a moment.

Luckily we can live with 85 dB radios

- What performance is usually good enough?
- From the advent of “up-conversion” radios around 1979 (TR-7) until 2003 with the Orion I, all we had were 70 dB DR3 radios at 2 kHz.
- These were barely adequate on SSB and not acceptable on CW in DX pile-ups or contests.
- If we operate our 85 to 90 dB radios properly, they perform well in most environments.
- Most of the time our radios are not stressed to their limits.

Close-in 2-kHz Test @ 500 Hz BW

Dynamic Range of Top 17 Transceivers

Elecraft K3S	106 dB	
Icom 7851	105 dB	
Hilberling	105 dB	
Elecraft KX3	104 dB	
ANAN-7000DLE	103 dB	
FTdx-5000D	101 dB	
Flex 6600 / 6600M	99 dB	(16 dB preamp ON)*
Flex 6700 (2017)	99 dB	(Preamp OFF)
Icom 7610	98 dB	
Icom 7300 #2	97 dB	(IP+ ON, high serial number)
Flex 5000	96 dB	
Elecraft K3	95 dB	(Original Synthesizer)
Orion II	95 dB	
Icom 7300 #1	94 dB	(IP+ ON, low serial number)
Orion I	93 dB	
TS-590SG	92 dB	
Ten-Tec Eagle	90 dB	

- * (Due to 7-pole BPF on contest bands, recommend +16 dB all daytime operation)

Why is higher DR3 needed on CW?

- Transmitted bandwidth of an adjacent strong signal may be the limit, not receiver overload.

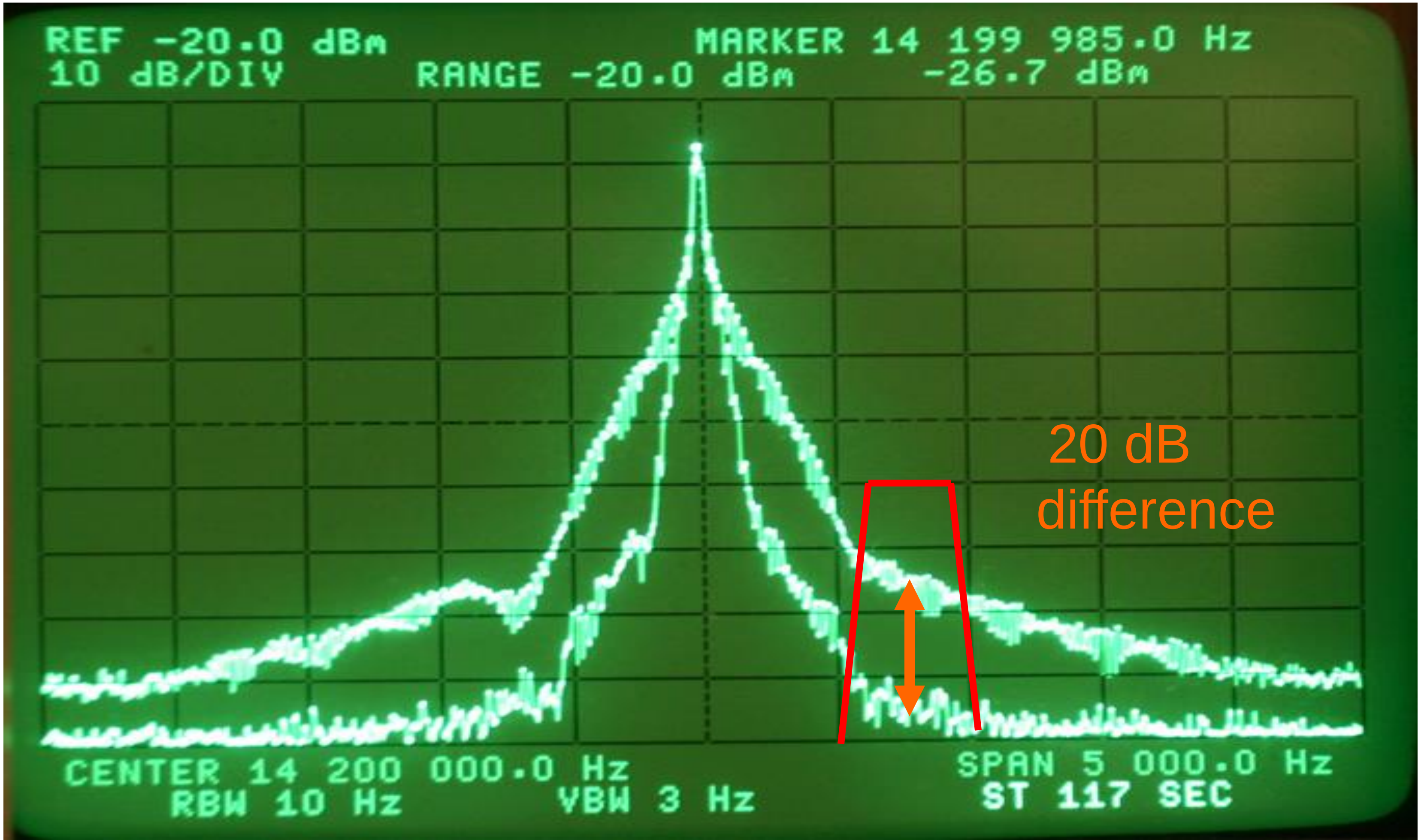
- A CW signal is about 1 kHz wide at -60 dB.
- An SSB signal is about 10 kHz wide at -60 dB.

- A CW pile-up may overload your receiver.
- On SSB, splatter will likely dominate before the receiver dynamic range is exceeded.

Many rigs are much faster than 3 msec

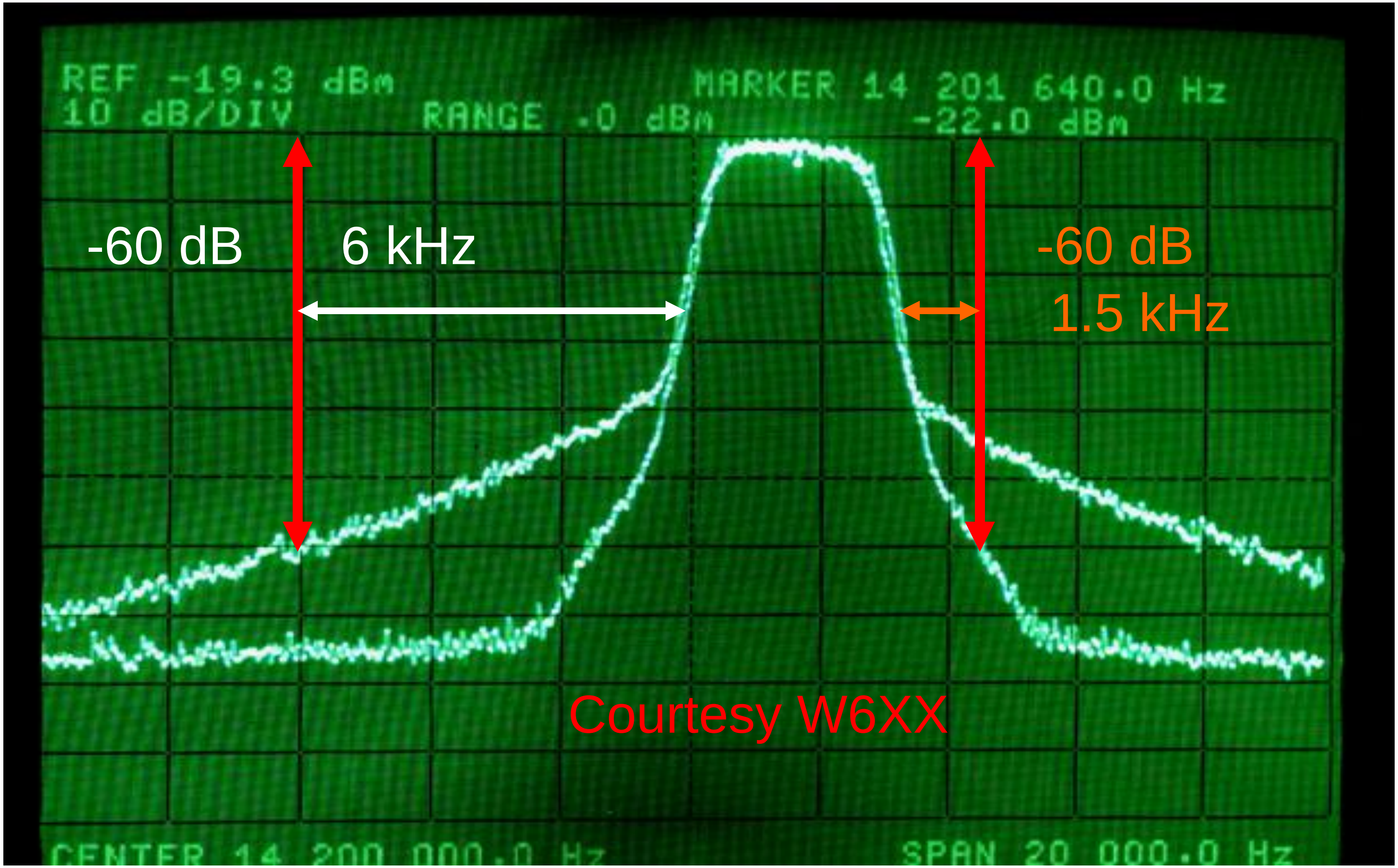
Spectrum of CW Signal on HP 3585A Analyzer

Comparison of 3 msec vs 10 msec rise time



Apache PureSignal much like class A

White Noise Mk V Class A vs. K3 Class B @ 75 Watts

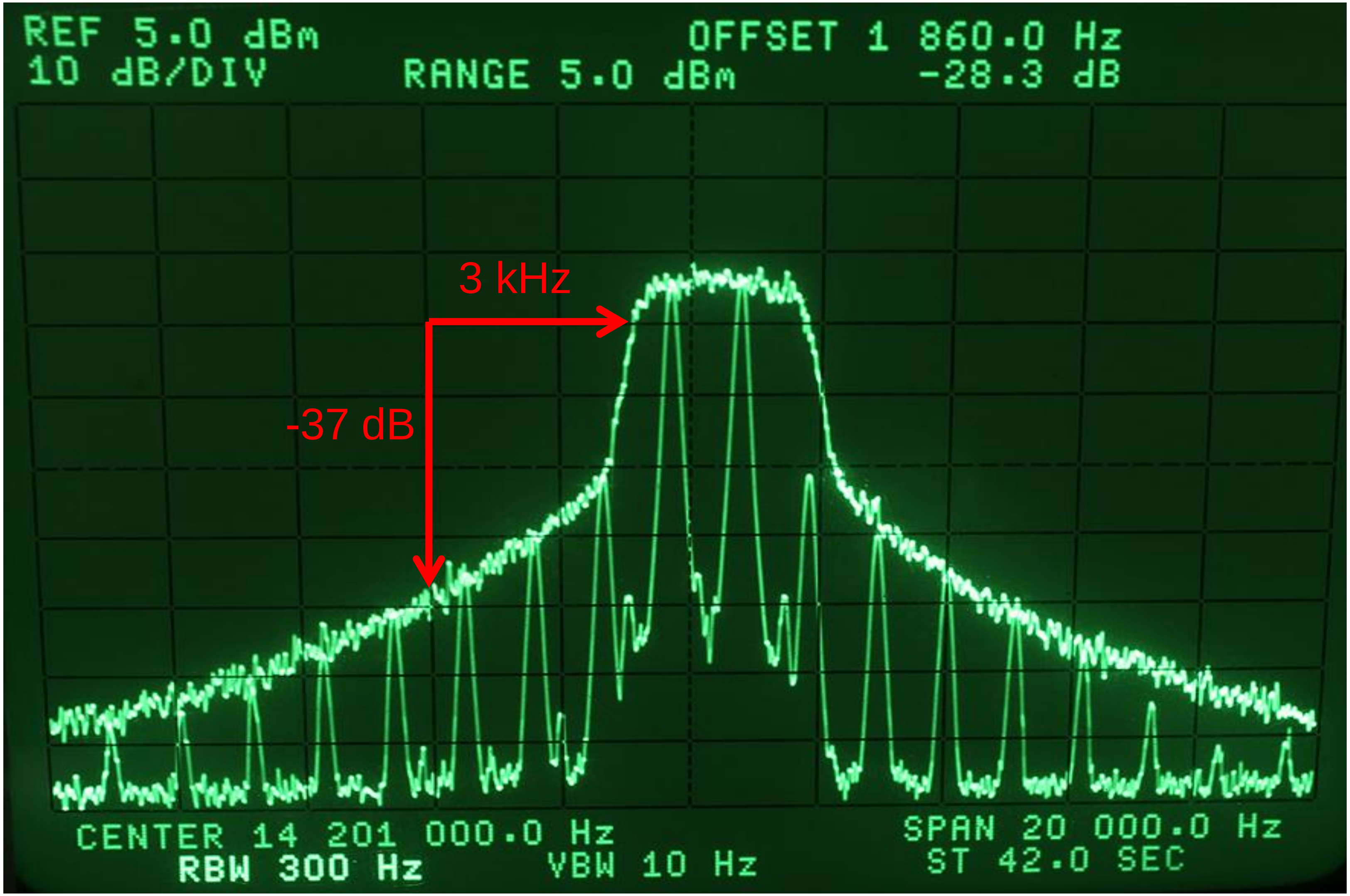


Noise source = GR 1381, 5-kHz -3 dB BW

Icom IC-7410 Class AB, White Noise

How Wide Is Your Signal ?

Comparison 2-Tone vs. Noise Intermodulation Bandwidth



How do we optimize what we have?

- While we might own a 100 dB DR3 radio, many of us have somewhat less performance.
- A TS-990S is around a 90 dB radio @ 2 kHz.
- Consider dynamic range a “window” of performance that can be moved around in absolute level by properly using your attenuator or preamp.

Receiver Noise Floor vs. Band Noise

When is the spec for noise floor significant?

Why does it rarely matter on most bands?

Noise Floor is usually significantly lower than Band Noise.

An ITU graph published in the ARRL Handbook gives us a starting point to relate band noise to noise floor.

This ITU data is in a 500-Hz bandwidth, just like typical noise floor data.

Band Noise vs. Frequency from ARRL Handbook

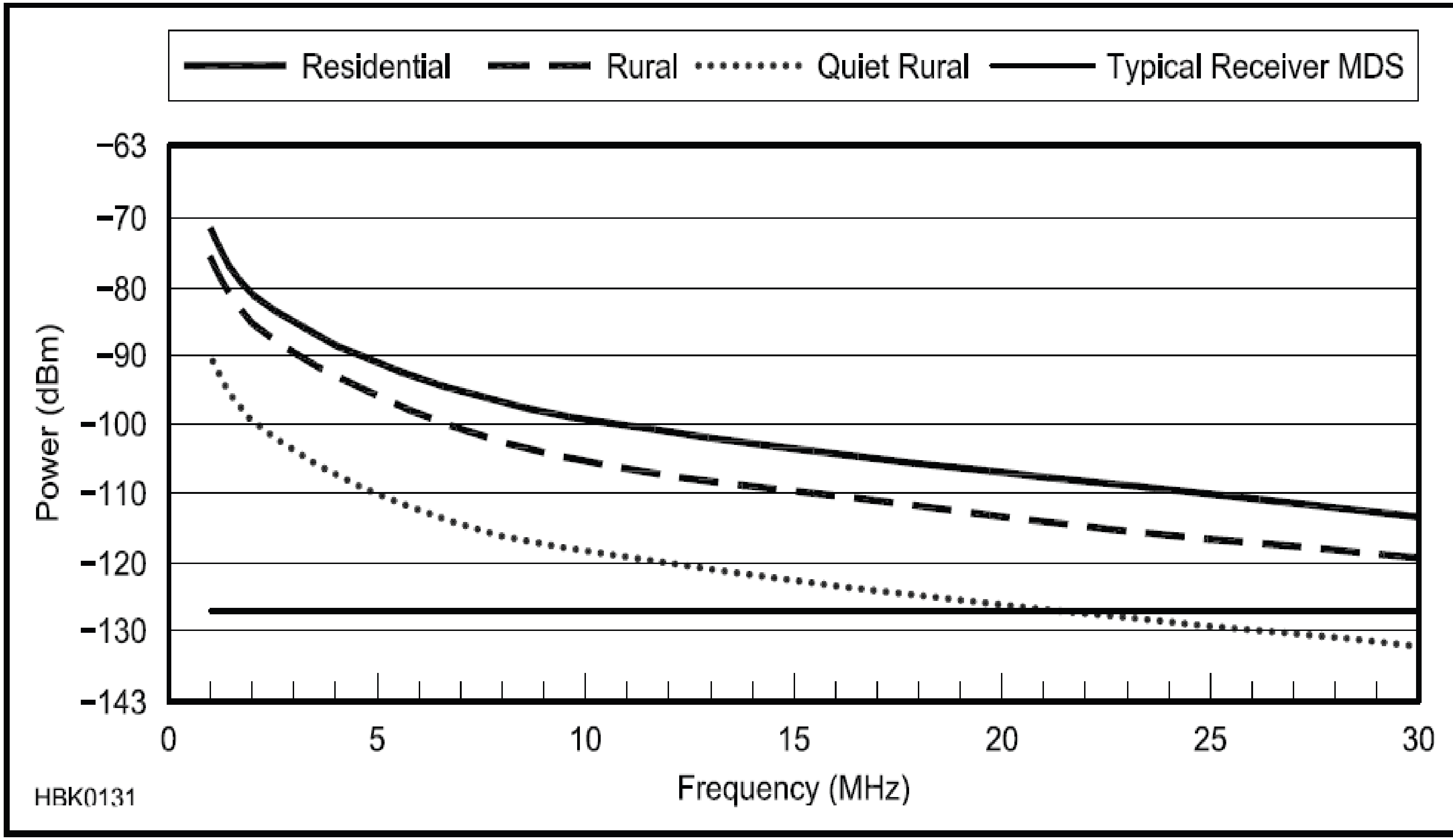


Fig 1 —Typical noise levels versus frequency for various environments. (Man-made noise in a 500-Hz bandwidth, from Rec. ITU-R P.372.7, *Radio Noise*)

Most Radios are designed for 10 meters

Typical rural band noise on 10 meters is -120 dBm

Typical rural band noise on 20 meters is -110 dBm

On 20 meters, band noise is almost 20 dB higher than typical receiver noise with the preamp OFF !

Optimally receiver noise should be 8 to 10 dB lower than band noise to have minimal effect on receiving weak signals.

Even on 10 & 15 meters, a preamp isn't needed all the time in a rural environment.

How does band noise vary by band?

If we take the ITU rural data as a starting point, what is typical?

160 meters:	-87 dBm *
80 meters:	-93 dBm *
40 meters:	-101 dBm *
20 meters:	-109 dBm #
15 meters:	-114 dBm #
10 meters:	-119 dBm #

That's a 30+ dB difference in band noise

* = nighttime   # = daytime

Beam headings October 20, 2013 9 to 11 AM

Measured band noise at NC0B

Band	20 meters	15 meters	10 meters
0 degrees:	-114 dBm	-124 dBm	-129 dBm
30 degrees:	-113 dBm	-124 dBm	-123 dBm
60 degrees:	-110 dBm	-118 dBm	-120 dBm
90 degrees:	-108 dBm	-114 dBm	-120 dBm
120 degrees:	-107 dBm	-113 dBm	-122 dBm
150 degrees:	-107 dBm	-114 dBm	-122 dBm
180 degrees:	-108 dBm	-114 dBm	-121 dBm
225 degrees:	-109 dBm	-120 dBm	-130 dBm
270 degrees:	-109 dBm	-120 dBm	-130 dBm
315 degrees:	-111 dBm	-122 dBm	-130 dBm
ITU rural value:	-109 dBm	-114 dBm	-119 dBm
Antenna	204BA	155CA	105CA
Height	70 feet	70 feet	65 feet

A note about the ITU data

- The ITU data assumes an omni-directional antenna.

- Your Yagi or directional low-band antenna (4-square) can significantly improve on your band noise in some directions.

A quick look at latency across the brands @ 500 Hz BW

Model	Latency (delay antenna to speaker in milliseconds)	
IC-781	5.9 ms	analog
IC-756 Pro III	5.9 ms	IF DSP
IC-7300	7.4 ms	Direct Sampling
IC-7610	12.7 ms	Direct Sampling
IC-7851	16.8 ms	IF DSP
TS-990S	17.6 ms	IF DSP
7000DLE	20.0 ms	Direct Sampling #
Flex 6600M	106 ms	Direct Sampling (default)*
Apache 200D	131.6 ms	Direct Sampling (software 2016)
Flex 6700	162 ms	Direct Sampling (software 2016)

Note: 7 settings have to be optimized to obtain 20ms on CW.

* Latency vs. shape factor adjustable from 58 ms to 170 ms

What does all this imply?

- For most radios: Up-conversion / down-conversion
- On the lower bands at night, attenuation is often appropriate.
- There is no point in band noise reading upscale on your S meter.
- A preamp is generally NOT needed on 20 meters.
- A preamp would ***never*** be needed at night on 40 meters and below, assuming the transmit antenna is used on receive.

Gain management critical with direct sampling radios

- A post on IC-7610 groups.io May 1, 2018
- “People have said that preamp 2 gives best signal to noise ratio. If that’s true, why not always use it?”
- “I’m in an extremely high noise area with compromise antennas and often can’t hear signals others can hear.”

My reply that I posted to the group

- If the S meter is reading upscale on band noise, there is no reason to use a preamp.
- With a superhet, like the K3S, you can often get away with improper usage of a preamp due to its narrow roofing filter. Almost all the signals on the band will be rejected by the roofing filter. Overload is unlikely.
- On the other hand, a direct sampling radio in effect has a roofing filter (BPF) of at least the bandwidth of the whole band. Running preamp gain when there is zero reason to do so just asks for the ADC to be driven into overload (OVF).
- Note: preamp does NOT help his high noise level.

How do we evaluate & optimize a transceiver?

- 160 – 40m receivers are too sensitive at night.
- Make the most of the radio's dynamic range by properly using the attenuator and using the preamp only when necessary on the high bands.
- Published dynamic range can be misleading, depending on how it is measured. This could be a complete presentation on its own.
- Look at RMDR, as this typically dominates.
- (RMDR* = Reciprocal Mixing Dynamic Range)
- [*QST April 2012 for sidebar – Bob Allison]
- It is a numbers game today!
- Evaluation in pile-up conditions is critical.
- A lab setup can never approximate CQ WW !

Sherwood Engineering

Videos from past CTU presentations

CTU 2013 through 2017 (Select desired year)

http://www.contestuniversity.com/videos