New transceiver options since CTU 2015
+
Performance – What's Possible & What's Needed?

Rob Sherwood
NCØB

How to optimize what you currently own

- **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”
- 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) > 105 dB
- Phase noise @ 10 kHz ≤ -145 dBc / Hz
- Reciprocal Mixing (RMDR) > 115 dB

- Rigs with this kind of performance:
- Icom IC-7851, Flex 6700 & Elecraft K3S
- Apache ANAN-200D not far behind

What is new since last year?

- Icom 7851 Flagship up-conversion transceiver
- Icom 7300 Direct-Sampling transceiver
- Elecraft K3S update of the K3
- New software for Apache ANAN-200D

Icom IC-7851 numbers

- Greatly improved synthesizer (phase noise)
- New 1.2 kHz VHF roofing filter

- 20 kHz dynamic range: 110 dB
- 2 kHz dynamic range: 105 dB
- 20 kHz RMDR: 125 dB
- 2 kHz RMDR: 115 dB

- Noise floor as low at -141 dBm Preamp 2

Icom IC-7300 numbers

- First direct-sampling SDR from the big three!
- Tunes with knobs & touch LCD, no computer

- 20 kHz dynamic range: 103 dB (IP+)
- 2 kHz dynamic range: 94 dB (IP+)
- 20 kHz RMDR: 113 dB
- 2 kHz RMDR: 100 dB

- Noise floor as low at -142 dBm Preamp 2

Elecraft K3S numbers

- Greatly improved synthesizer
- Improved receive audio
- New 6-pole roofing filters, low passive IMD
- 20 kHz dynamic range: 107 dB
- 2 kHz dynamic range: 106 dB
- 20 kHz RMDR: 118 dB
- 2 kHz RMDR: 113 dB
- New internal preamp 12 – 6 meters
- Noise floor as low as -145 dBm

Apache ANAN new software features

- Open Source code = new features fast
- Better DSP filter defaults, particularly CW
- Spectral NB works in contest conditions
- New NR algorithms
- Midi support for DJ Console for mechanical knobs or control via a tablet
- For the “techie” new band noise measurement capabilities

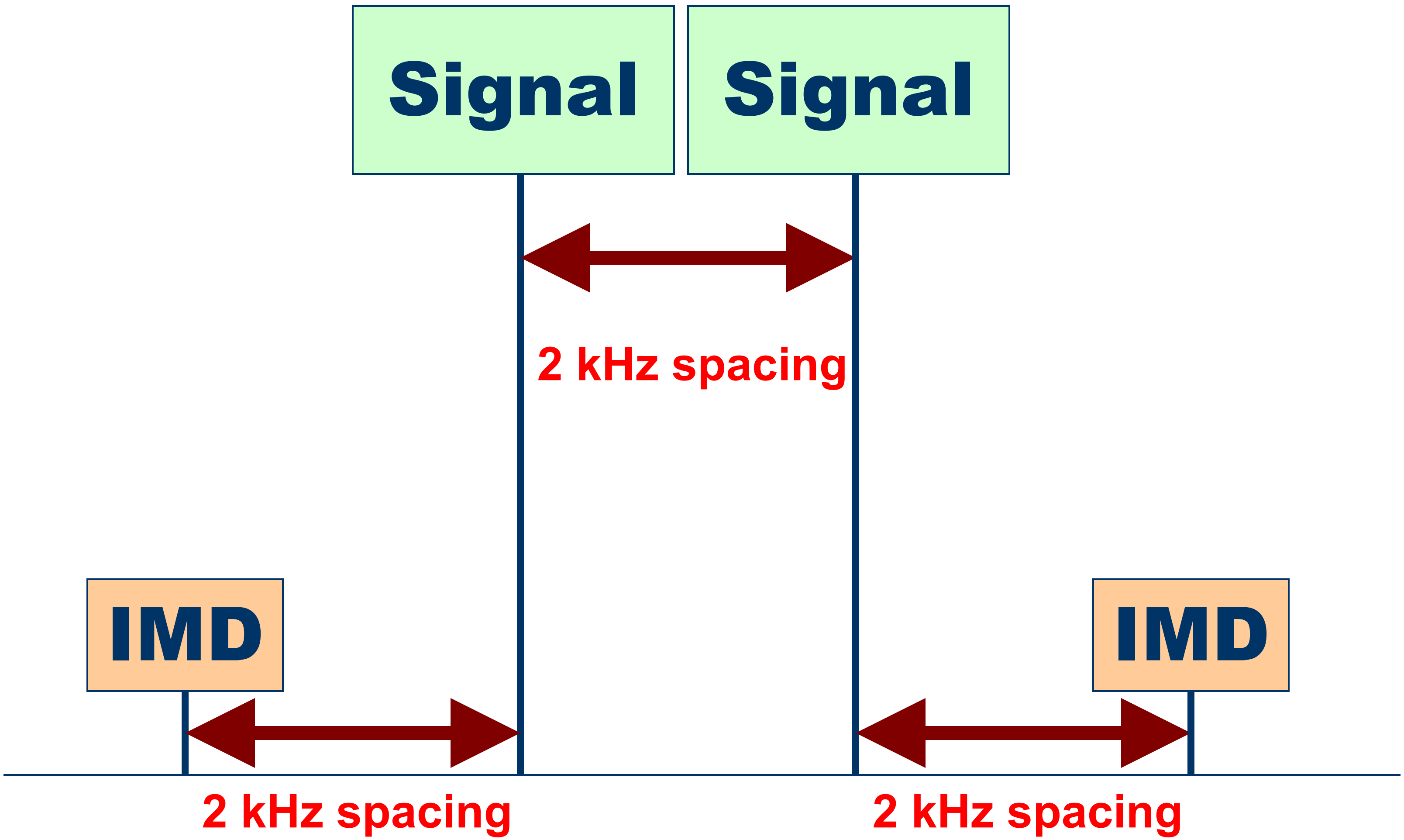
Time for the numbers

- 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 1975
- Noise floor = -128 dBm, test level = -28 dBm
- -128 dBm minus -28 dBm = 100 dB
- Dynamic Range (DR3) = 100 dB

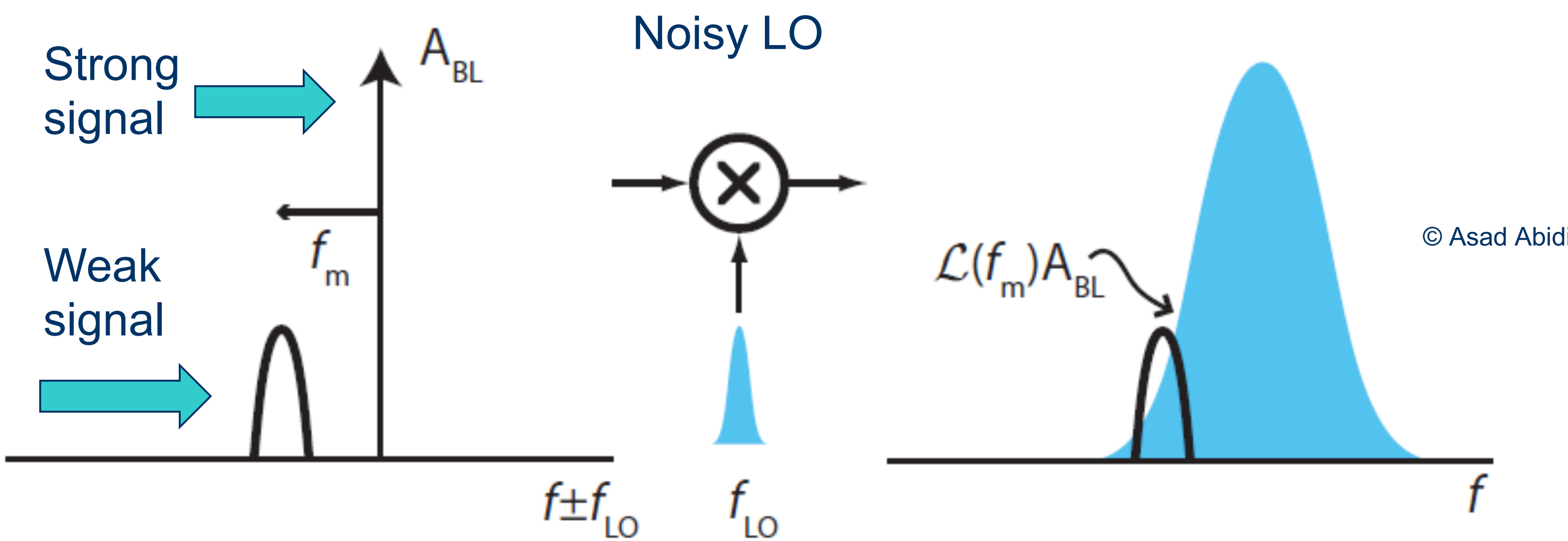
Third Order IMD to Measure Dynamic Range



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-7300
- Flex 6700, 6500 & 6300
- Apache ANAN-200D

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 14 Transceivers

Elecraft K3S	106 dB	
Icom 7851	105 dB	
Flex 6700	99 / 108 dB	(preamp Off/On)
Hilberling	105 dB	
Elecraft KX3	104 dB	
FTdx-5000D	101 dB	
Flex 5000	96 dB	
Elecraft K3	95 dB	(original synthesizer)
Orion II	95 dB	
Icom 7300	94 dB	(IP+)
Orion I	93 dB	
TS-590SG	92 dB	
TT Eagle	90 dB	
Flex 3000	90 dB	

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.

What is the Bandwidth of a CW Signal?

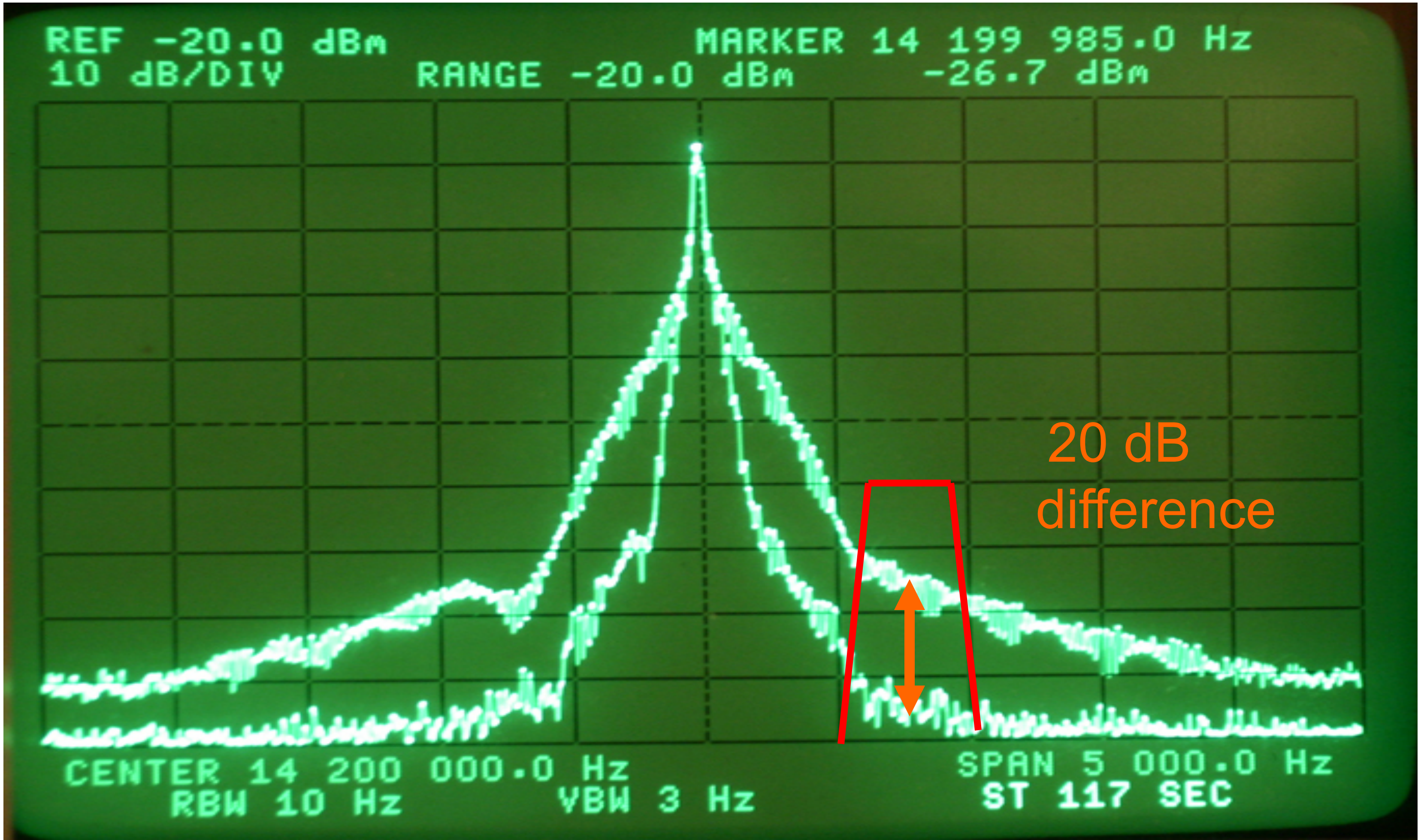
On-channel signal = S9 + 40 dB (-33 dBm)
Receiver = K3, 400 Hz 8-pole roofing + 400 Hz DSP Filter
Transmitter = Omni-VII with adjustable rise time
Undesired signal 700 Hz away, continuous "dits" at 30 wpm

Rise time of Omni-VII	Strength of CW sidebands		
Signal	S9 + 40	-33 dBm	Ref
3 msec	S7	-83 dBm	-50 dB
4 msec	S6	-88 dBm	
5 msec	S6	-88 dBm	
6 msec	S5	-93 dBm	22 dB !
7 msec	S4	-99 dBm	
8 msec	S4	-99 dBm	
9 msec	S4	-99 dBm	
10 msec	S3	-105 dBm	-72 dB

Many rigs are much faster than 3 msec

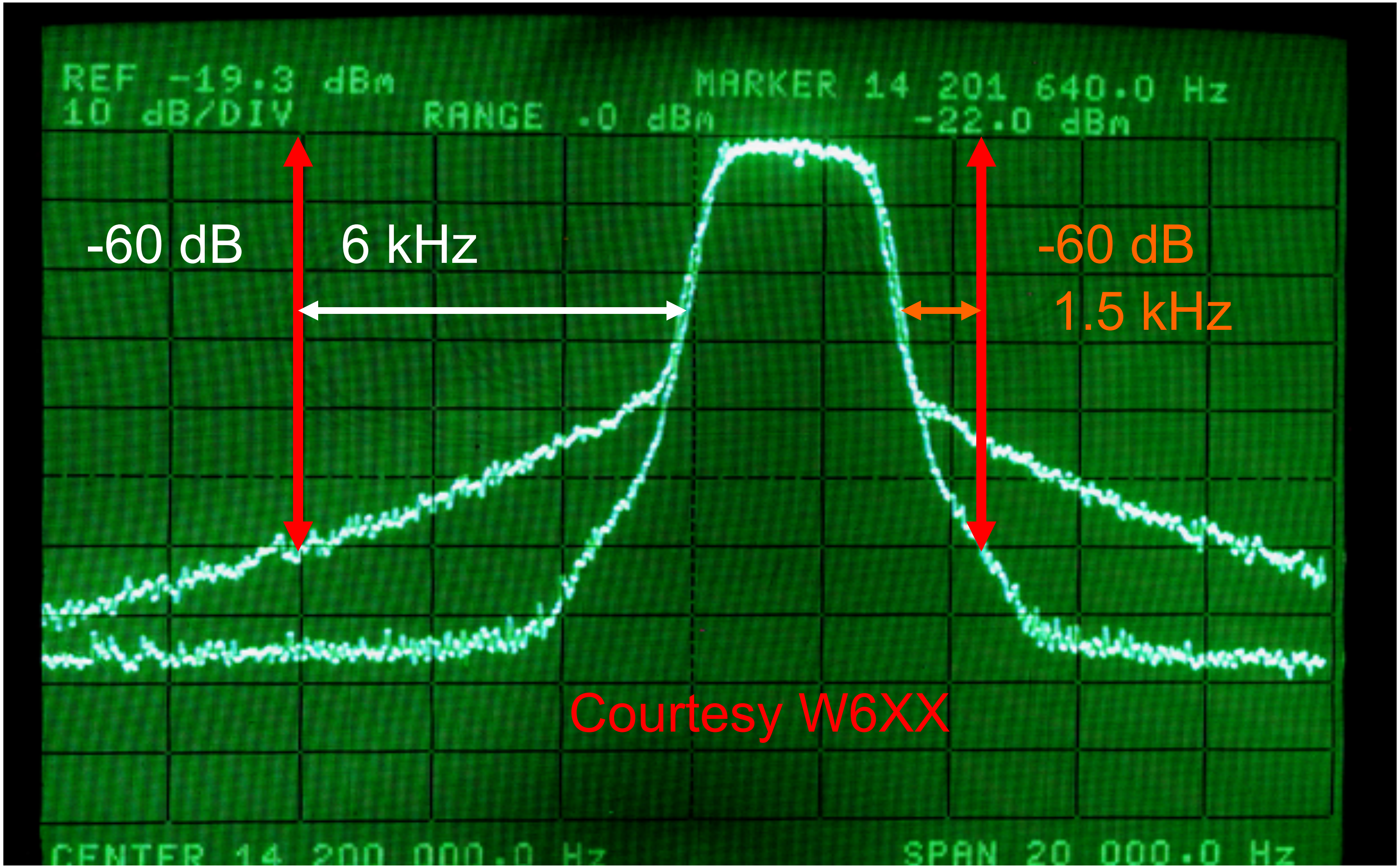
Spectrum of CW Signal on HP 3585A Analyzer

Comparison of 3 msec vs 10 msec rise time



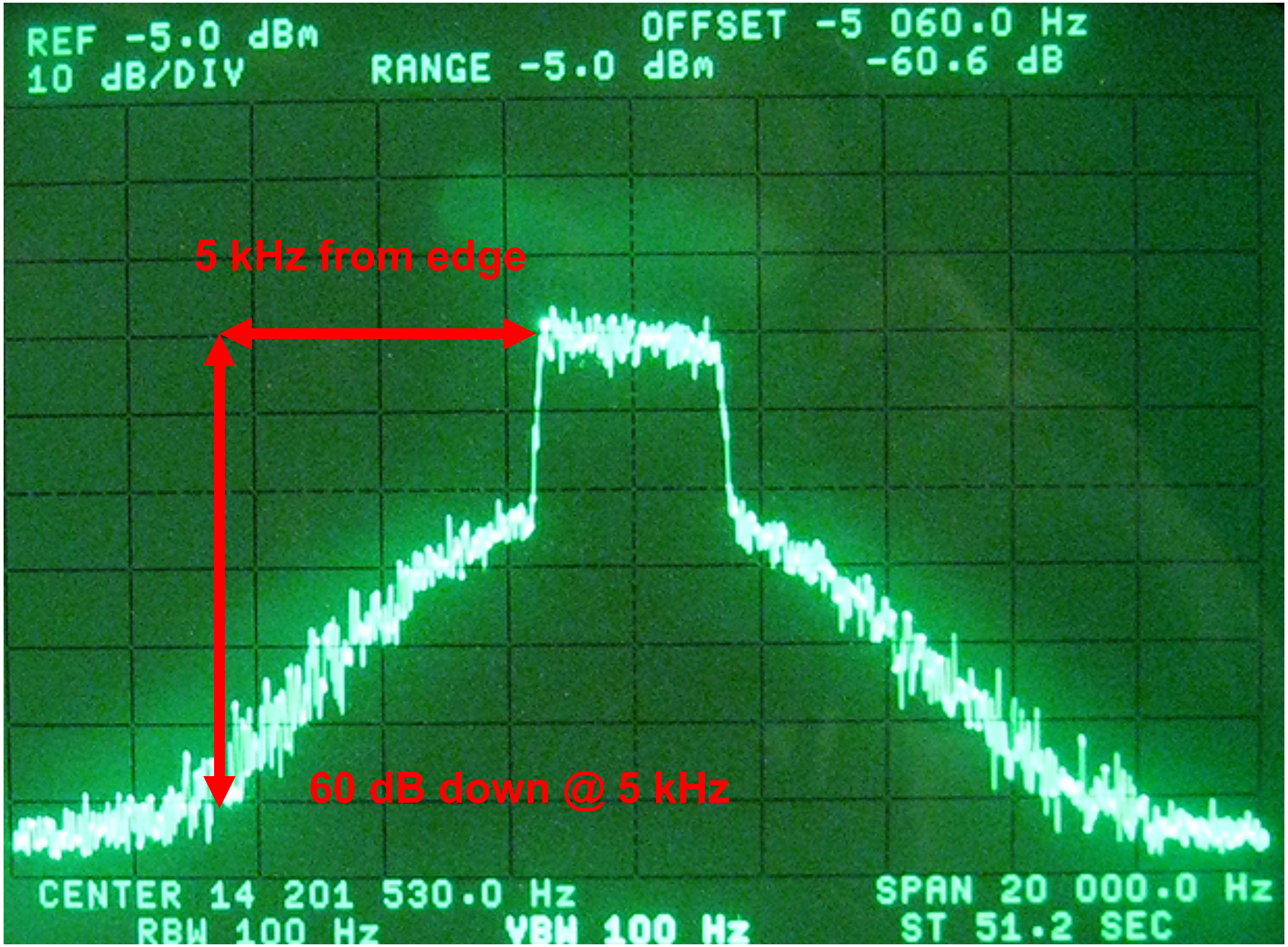
Apache PureSignal much like class A

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



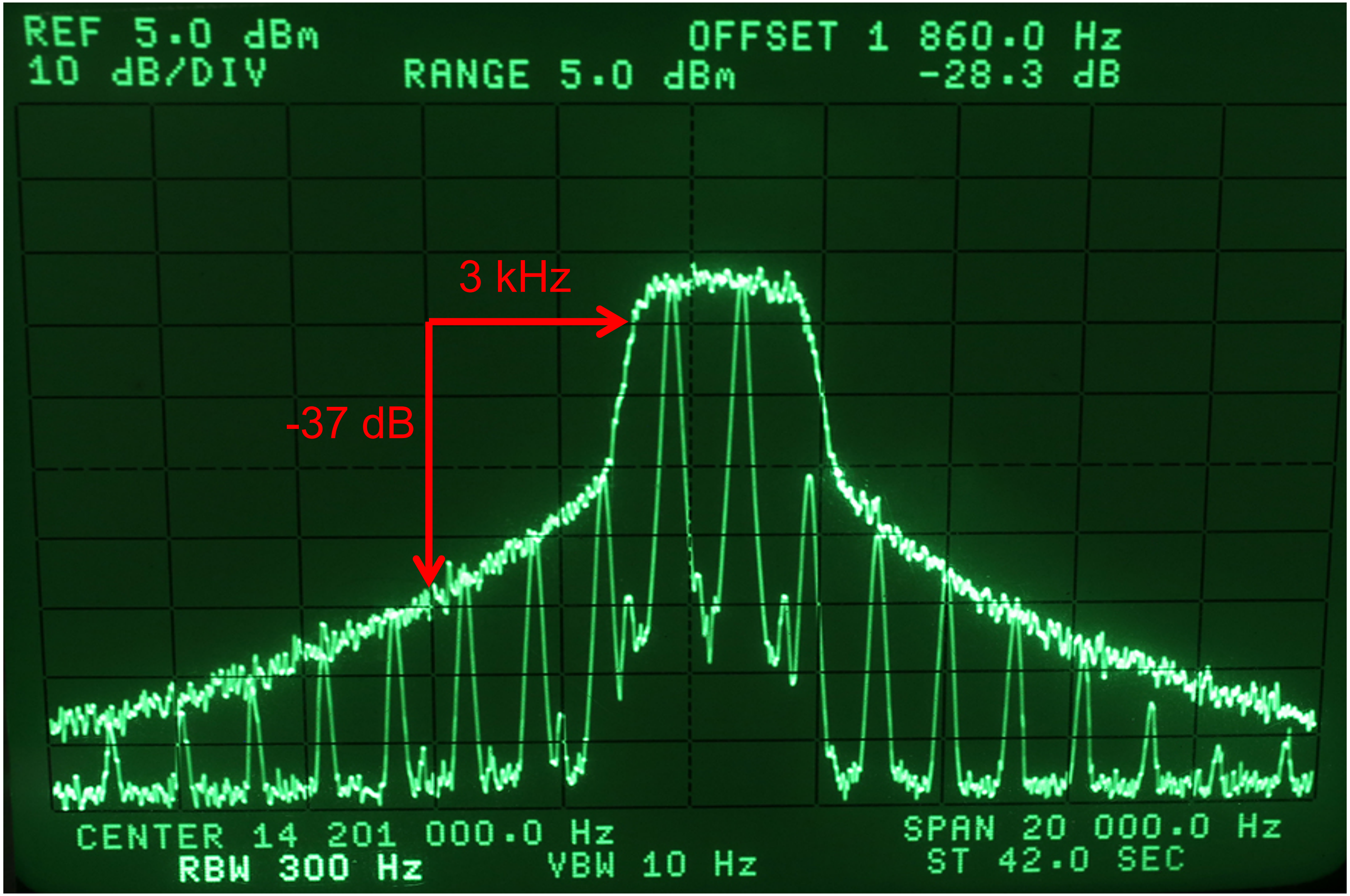
Noise source = GR 1381, 5-kHz -3 dB BW

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.
- My 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

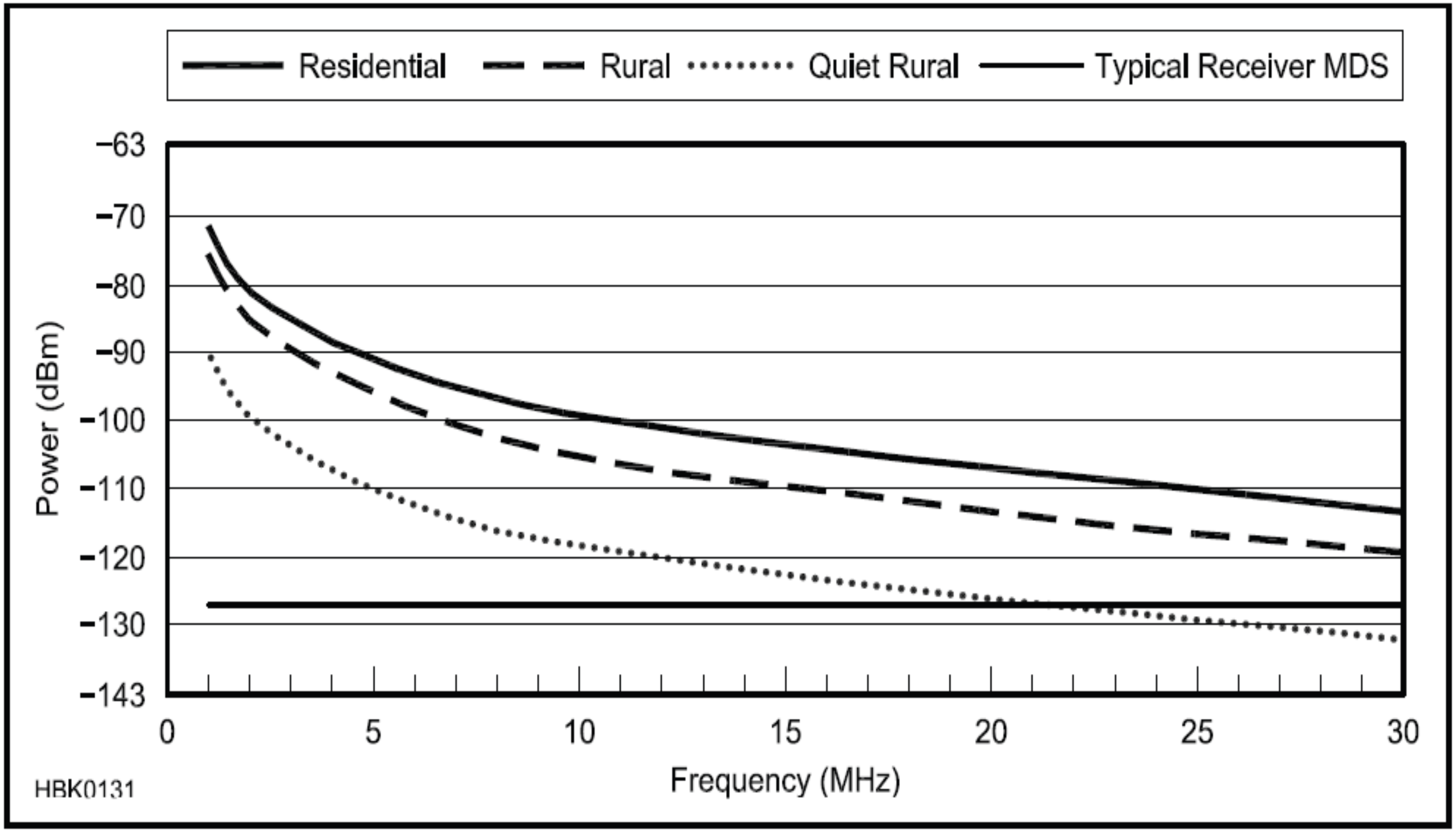


Fig 1 —Typical noise levels versus frequency for various environments. (Man-made noise in a 500-Hz bandwidth, from Rec. ITU-R P.372.7, *Radio Noise*)

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.

A simple test with only an analog meter

- Most hams don’t own a calibrated signal generator.
- How do you evaluate your receiver?
- This also evaluates your antenna !

- Measure the noise gain when you connect your antenna.

- All you need is an analog meter with a dB scale, hooked up to your speaker.

Measure the noise gain

- Disconnect your antenna and set the volume so your dB meter reads -10 dB.
- (Put a dummy load on the rig, though open circuit usually works OK, too.)
- Connect the antenna and see how many dB the noise goes up when tuned to a dead spot on the band.
- Do this with Preamp OFF and ON.
- Also rotate your Yagi 360 degrees.
- Noise can easily change 10 dB with azimuth!

15 & 10 meters noise gain

Rig = Icom IC-756 Pro III

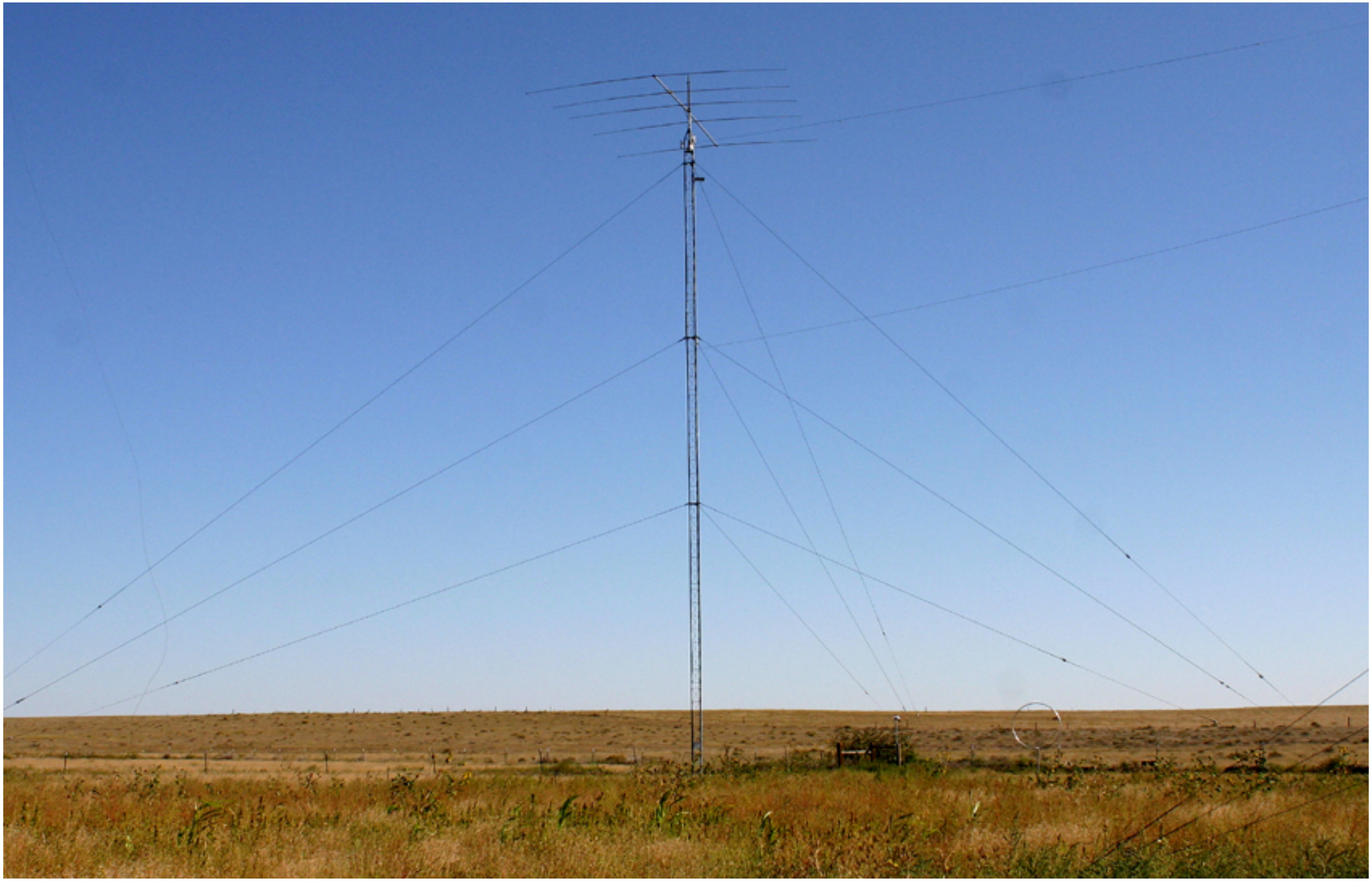
10 meter antenna = Hy-gain 105CA @ 65 feet

15 meter antenna = Hy-gain 155CA @ 70 feet

Preamp	15m	10m
None	4 dB	3 dB*
Preamp 1	11.5 dB	9.5 dB
Preamp 2	13.0 dB	11.0 dB

* @ 3 dB, receiver noise = band noise = not OK

LJ-155CA Yagi in band noise example



LJ-105CA in band noise example

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

Measured band noise at NC0B

160 meters 8:00 AM MST:	-105 dBm	January 2014
160 meters 4:00 PM MST:	-101 dBm	160 meter CQ
160 meters 6:30 PM MST:	-91 dBm	CW Contest
ITU rural nominal value:	-87 dBm	

Beam Heading, October 2013	15 meters	10 meters
0 degrees beam heading:	-124 dBm	-129 dBm
30 degrees:	-124 dBm	-123 dBm
60 degrees:	-118 dBm	-120 dBm
90 degrees:	-114 dBm	-120 dBm
120 degrees:	-113 dBm	-122 dBm
150 degrees:	-114 dBm	-122 dBm
ITU rural nominal value:	-114 dBm	-119 dBm

ITU / ARRL Data is generally correct

- Those numbers = starting point for a rural QTH
- On a give day there can be ± 10 dB differences
- In 2014 ARRL 10 Meter SSB my noise floor was 10 dB lower than the rural ITU value, pointed West between 3 and 5 PM local time while working ZL, VK & JAs.
- (5 element monoband Yagi @ 65 feet)

- Urban QTH with RFI noise, all bets are off
- How's your neighbor's Plasma TV ?

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.

Numbers with Preamp-1 ON

Noise Floor Quite Consistent in Top 12

- Flex 6700 -135 dBm
- Icom 7851 -135 dBm
- Elecraft K3s -138 dBm
- Elecraft KX3 -138 dBm
- FTdx-5000D -135 dBm
- Flex 5000 -135 dBm
- Orion II -133 dBm
- Icom 7300 -141 dBm
- Orion I -135 dBm
- T-T Eagle -132 dBm
- Flex 3000 -139 dBm
- TS-590SG -135 dBm
- Drake R-4C -138 dBm (For comparison)

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 usually 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.

Contests: 2015 / 2016

February CQ SSB Contest 160m

Using a TS-990S during the day attenuator = 6 dB
During nighttime, attenuator = 12 dB, occasionally 18 dB !

Set the AGC threshold about 6 dB above band noise.

January CQ CW Contest 160m
Using Apache ANAN-200D, I set the AGC threshold about 6 dB above band noise. Time of day dependent

(December 2014 ARRL 160 m CW contest set AGC-T)

March 2016 ARRL SSB DX Contest using TS-990S
10m – Preamp & 6 dB pad or occasionally 12 dB pad !

Times of day can break the general rules

- In a rural environment, daytime band noise on 80 and 40 meters can be quite low.
- Noon at my QTH 40 meters -115 dBm
- 8:30 AM my QTH 80 meters -120 dBm
- Flex 6300 has no preamp below 30 meters*
- There are times when you need a -128 dBm noise floor on 40 and 80 meters.

* Flex says this will be corrected, likely 2nd quarter 2016. Cost to retrofit unknown.

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 2015 (select from all presenters)

https://www.youtube.com/playlist?list=PLRSwUN4qr1Lq50amRtsZm-y2nKPHHRz0v

CTU 2013 & 2014 (Select desired year)
http://www.contestuniversity.com/main/page_videos.html

CTU 2011
http://www.pvrc.org/webinar/radioperformance.wmv