Transceiver Performance What's new in 2011?

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NCØB

Lots of options for your dollars.

- **What is important in a contest or DX pile-up environment?**
- Good Dynamic Range to hear weak signals in the presence of near-by strong signals.
- You need a better receiver for CW than for SSB.
- Be a good neighbor: i.e. Have a clean signal.
- **Transmitters continue to be a mixed bag.**

What Parameter is Most Important for a CW Contester?

- Close-in Dynamic Range (DR3)
- (We have to know the noise floor to calculate Dynamic Range)

What is Noise Floor?

Sensitivity is a familiar number, normally applies to SSB.

Sensitivity = 10 dB Signal + Noise / Noise (10 dB S+N/N)

Noise Floor = 3 dB Signal + Noise / Noise (3 dB S+N/N)

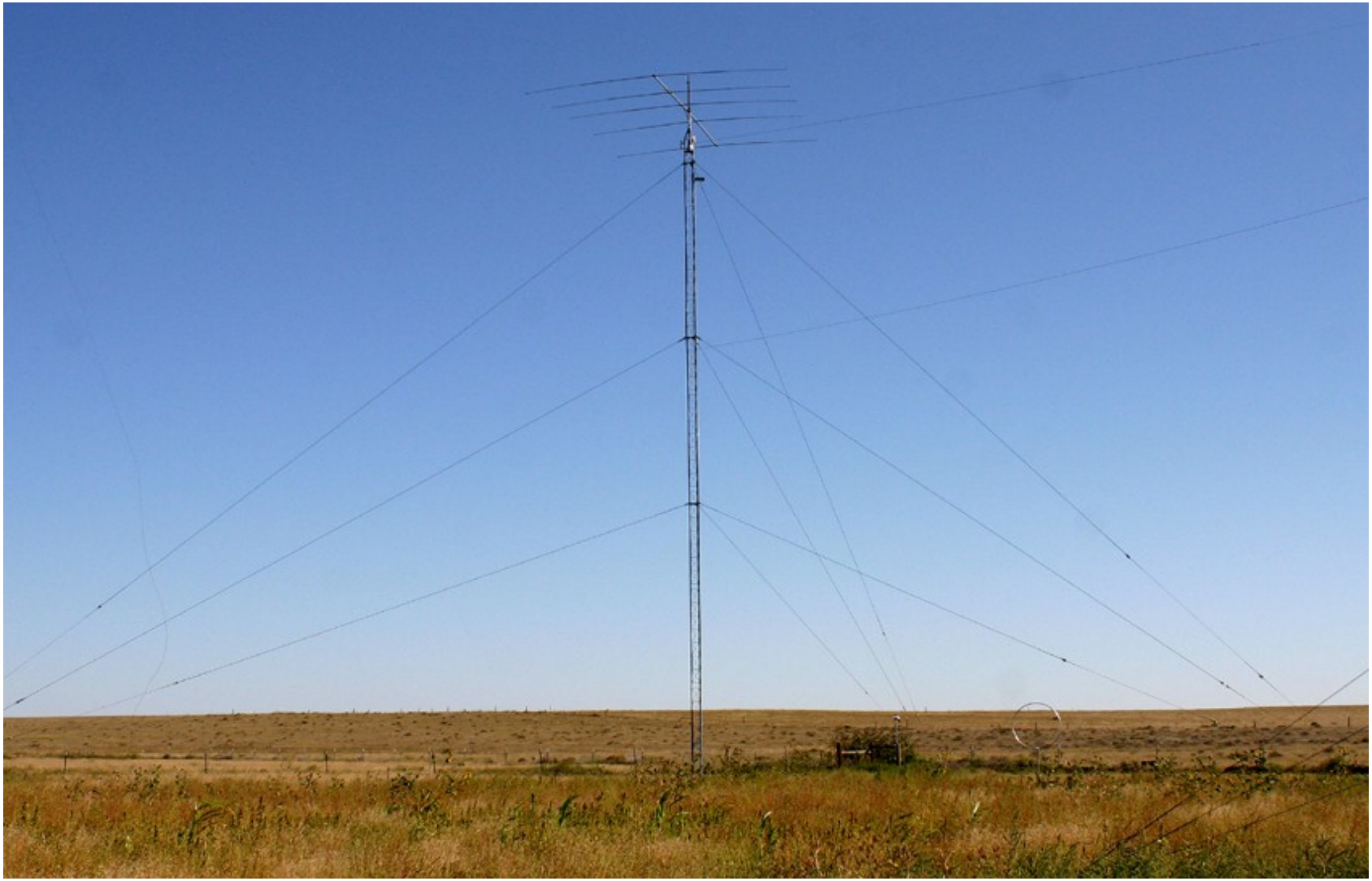
Noise floor can be measured at any filter bandwidth, CW or SSB, for example, and is bandwidth dependent.

League normally only publishes noise floor for a CW bandwidth, typically 500 Hz CW filter.

Noise Floor – Rarely an Issue on HF

- On 20 meters and below, atmospheric, galactic and man-made noise predominates.
- On 15 meters, in a quiet rural location, the receiver is still rarely the limit. Example:
- NC0B, 5 element yagi at 70 feet, 270 feet of 7/8th inch hardline, antenna pointed in the quietest direction (30 degrees) at 4 PM on 2/28/2010.
- Receiver sensitivity, no preamp, 2.4 kHz = 0.5 uV
- Receiver sensitivity, w/ preamp, 2.4 kHz = 0.2 uV
- Receiver noise floor, w/ preamp, 500 Hz = -135 dBm

LJ-155CA yagi in the previous example



A simple test with only a analog meter

- Most hams don’t own a calibrated signal generator.
- How do you evaluate your receiver?
- 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, but it will likely make no difference.)
- 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

What did I measure on 15 meters ?

- Rig = Icom IC-781
- With preamp OFF, noise gain = 3.1 dB
- With preamp ON, noise gain = 8.3 dB
- (This was in the quietest direction – i.e. No Skip !)
- With the preamp ON, now rotate your yagi 360 degrees and note the difference in noise.
- In the direction there is skip, the noise will be higher.
- Can easily be a 10 dB difference in band noise vs. direction.

15 & 10 meters not that different

Rig = IC-756 Pro III

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

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

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

More Variables – Plan ahead if you can

- At my QTH there are two towers near the house and four 200 to 350 feet away. My noise level on 20 – 10 meters is vastly worse for the close-in towers, unless I turn off electronic devices.
- TVs (CRT or plasma), UPS & family-room computer, broadband router (makes birdies), wireless Internet dish, wall warts with switching power supplies, hand touch lamp !

Tower Distance vs. local RFI (noise)

Numbers with Preamp-1 ON

Noise Floor Quite Consistent in Top 10

- FTdx-5000D -135 dBm
- Elecraft K3 -138 dBm
- Perseus -125 dBm (No preamp)
- Flex 5000 -135 dBm
- Orion II -133 dBm
- Orion I -135 dBm
- T-T Eagle -132 dBm
- Flex 3000 -139 dBm
- TS-590S -137 dBm
- Icom R9500 -130 dBm
- Drake R-4C -138 dBm (For comparison)

What is Dynamic Range?

The range in dB of very strong signals to very weak signals that the receiver can handle At The Same Time

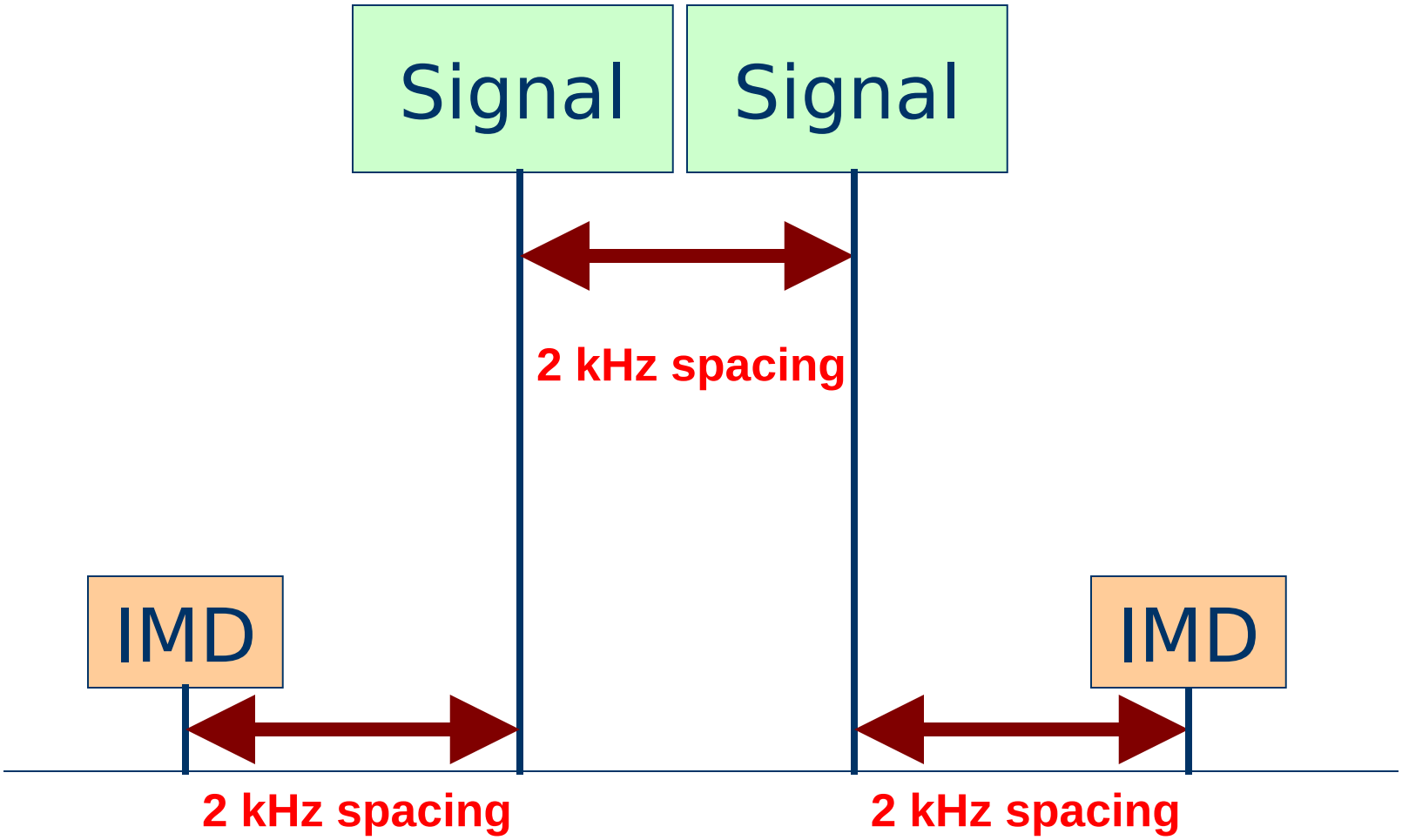
What is Close-in Dynamic Range vs

Wide-Spaced Dynamic Range?

Why is Close-in Dynamic so important for CW ops?

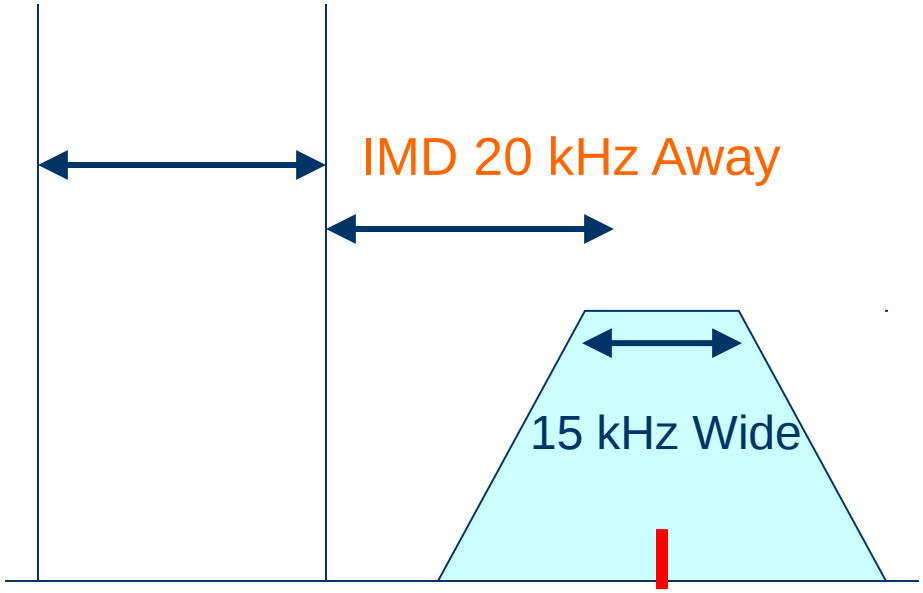
Why is it less important for SSB operators?

Third Order IMD to Measure Dynamic Range



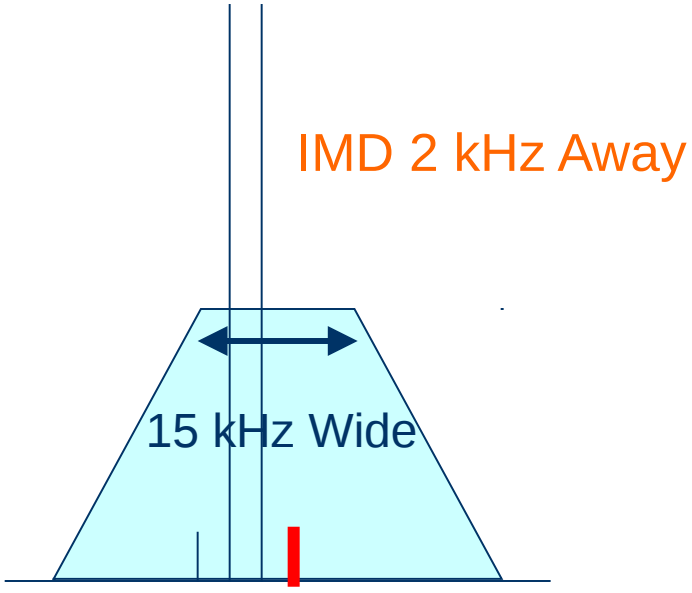
Wide & Close Dynamic Range

20 kHz Spacing



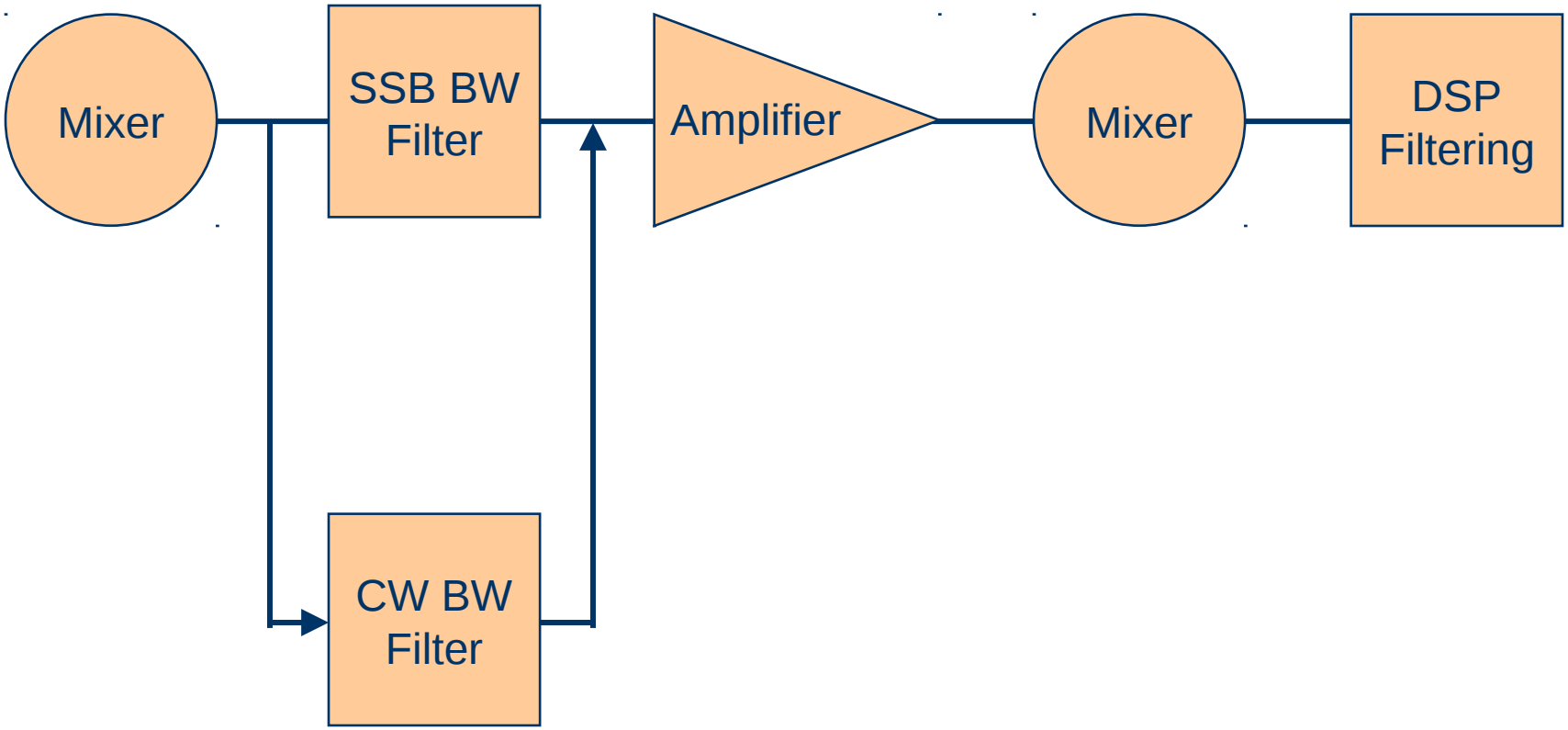
First IF Filter at 70.455 MHz

2 kHz Spacing



First IF Filter at 70.455 MHz

Highest performance with a bandwidth appropriate filter right up front after the first mixer.



This keeps the undesired strong signals from progressing down stream to the next stages.

What has changed in last 8 years?

- Ten-Tec started the change in 2003 with the Orion, the first radio to drop “up-conversion” and go back to a low first IF.
- Elecraft followed, and now Yaesu and Kenwood in 2010.
- Only Icom has of yet not offered a “down-conversion” radio
- If the TS-590S is a big seller, will Kenwood follow on with a larger and more expensive model? At Dayton they said YES.

When are 2 Out of Pass Band Signals a Problem?

- If you know the close-in dynamic range of a radio, at what signal level will IMD start to be a problem?
- S Meter standard is S9 = 50 μV, which is –73 dBm
- Assume a typical radio:
  - 500 Hz CW filter
  - Noise Floor of -128 dBm
  - Preamp OFF

Dynamic Range	Signal Level Causing IMD = Noise Floor	
55 dB	S9	FT-757 (56 dB)
60 dB	S9 + 5 dB	FT-2000 (61 dB)
65 dB	S9 + 10 dB	IC-7000 (63 dB)
70 dB **Typical Up-conversion**	S9 + 15 dB	1000 MP / Mk V Field (68 / 69 dB)
75 dB	S9 + 20 dB	756 Pro II / III (75 dB)
80 dB	S9 + 25 dB	Omni-VII / IC-7800 (80 dB)
85 dB	S9 + 30 dB	TS-590S (88 dB)
90 dB	S9 + 35 dB	Eagle & Flex 3K (90 dB)
95 dB	S9 + 40 dB	Orion II & Flex 5000A (95 dB)
100 dB	S9 + 45 dB	FTdx-5000, K3 (200 Hz roofing)

Close-in 2-kHz Test @ 500 Hz BW

Dynamic Range of Top 8 Transceivers

- FTdx-5000D 101 dB
- Flex 5000 96 dB (Flex users raise hand)
- Elecraft K3 95 dB (with 500 Hz filter)
- Orion II 95 dB
- Orion I 93 dB
- TT Eagle 90 dB
- Flex 3000 90 dB
- TS-590S 88 dB (Low Freq 1st IF mode)
- TS-590S 76 dB (30, 17, 12, 10 & 6 M)

How did the new rigs perform on CW?

- I used the FTdx-5000, TS-590S and Eagle in the 160 m. ARRL, Stew Perry & CQ contests.
- Switched between the Kenwood and the Ten-Tec during the CQ contest.
- Overload was never an issue.
- All could crank down the DSP filter to 100 Hz or narrower.
- Ran most of the contest at 200 Hz BW
- Definitely needed 50 to 100 Hz BW

Narrow DSP Filters Come Through

- In all three contests working CE1/K7CA required the narrowest bandwidths to copy through the pile-up, since he was not working split.
- Thank goodness the DXpeditions work split, so you can hear when the DX comes back to you.
- You can imagine what it is like at the DX location: total pandemonium for days!

The DR3 “window” is not fixed

The dynamic range of a radio is the same with an attenuator ON or OFF.

If on a noisy band, attenuate the noise and all signals to make better use of the dynamic range, and reduce the chance of overload.

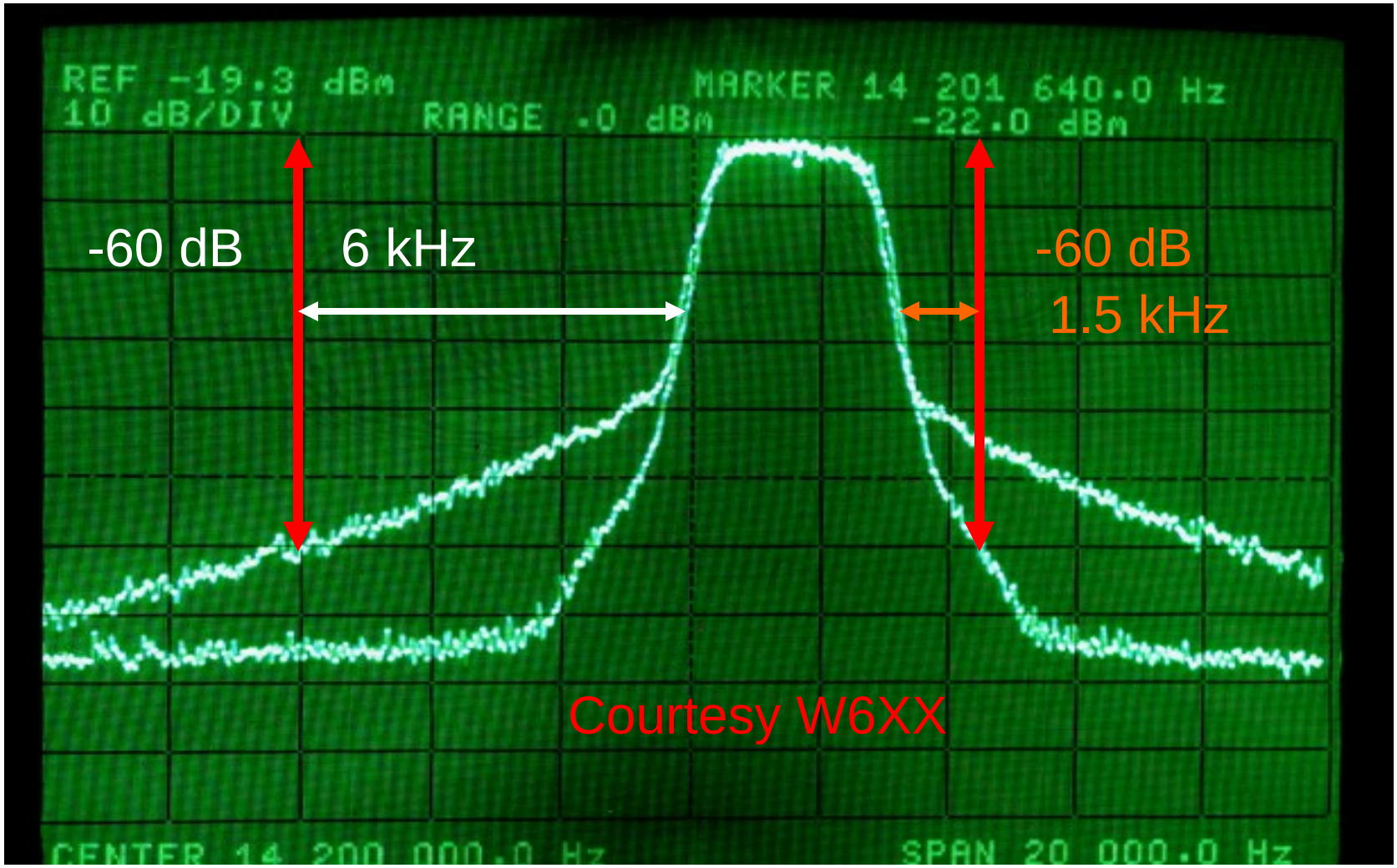
If band noise goes from S6 to S2 by turning on the attenuator, you have lost nothing, yet your radio is being stressed much less.

There is no reason to have band noise reading up scale on the S meter.

Let’s now look at the transmitters

- I am now testing transmitters with white noise feeding the microphone, in addition to a two-tone test.
- The effect of IMD products (splatter) are more obvious with noise.
- Think of it as a 1000 tone test, more approximating real voice.

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



What shipped since Dayton 2010?

- Yaesu FTdx-5000D
- Kenwood TS-590S
- Ten-Tec Eagle
- Icom IC-7410
- Icom IC-9100

A Quick Note on ALC Overshoot

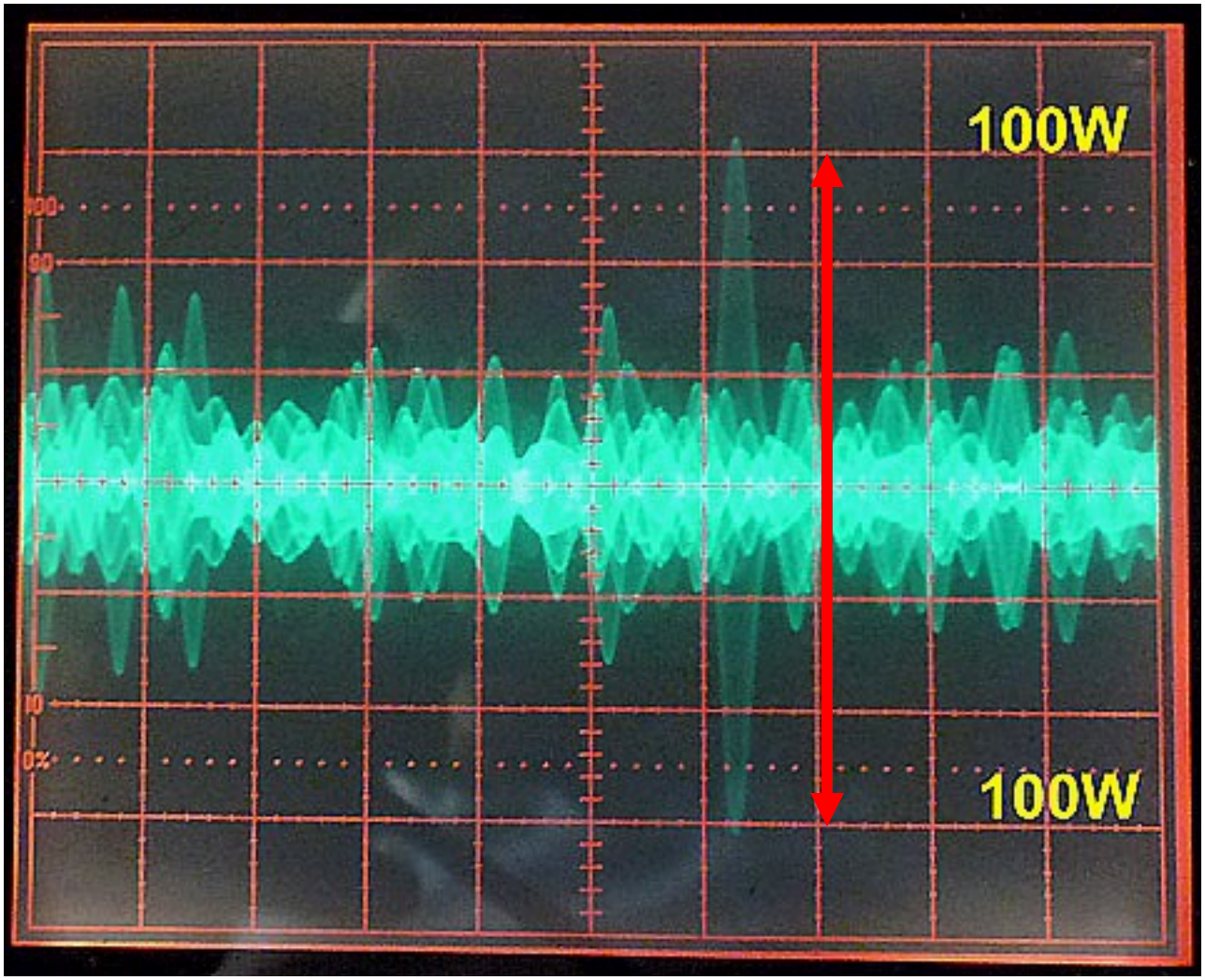
- Four of these rigs have ALC issues
- The 5000D clips off 100% of the peaks
- TS-590S had a 20% overshoot with FW 1.00
- (This improved with version 1.02 @ 13%)
- The Icoms have 3 dB overshoot @ 50 watts
- Have measured as much as 6 dB at 25 watts
- http://www.youtube.com/watch?v=T2DpdO8RJxA
- Google search = IC-7410 ALC overshoot

Testing with White Noise on Transmit

- Two tests with white noise instead of two tones.
- See the total bandwidth better
- Many linear amps need only 50 to 60 watts
- ALC overshoot often worse at reduced power
- Look at what happens to ALC spikes with the IC-7410 and IC-9100 with white noise and 50% ALC reading on the meter.

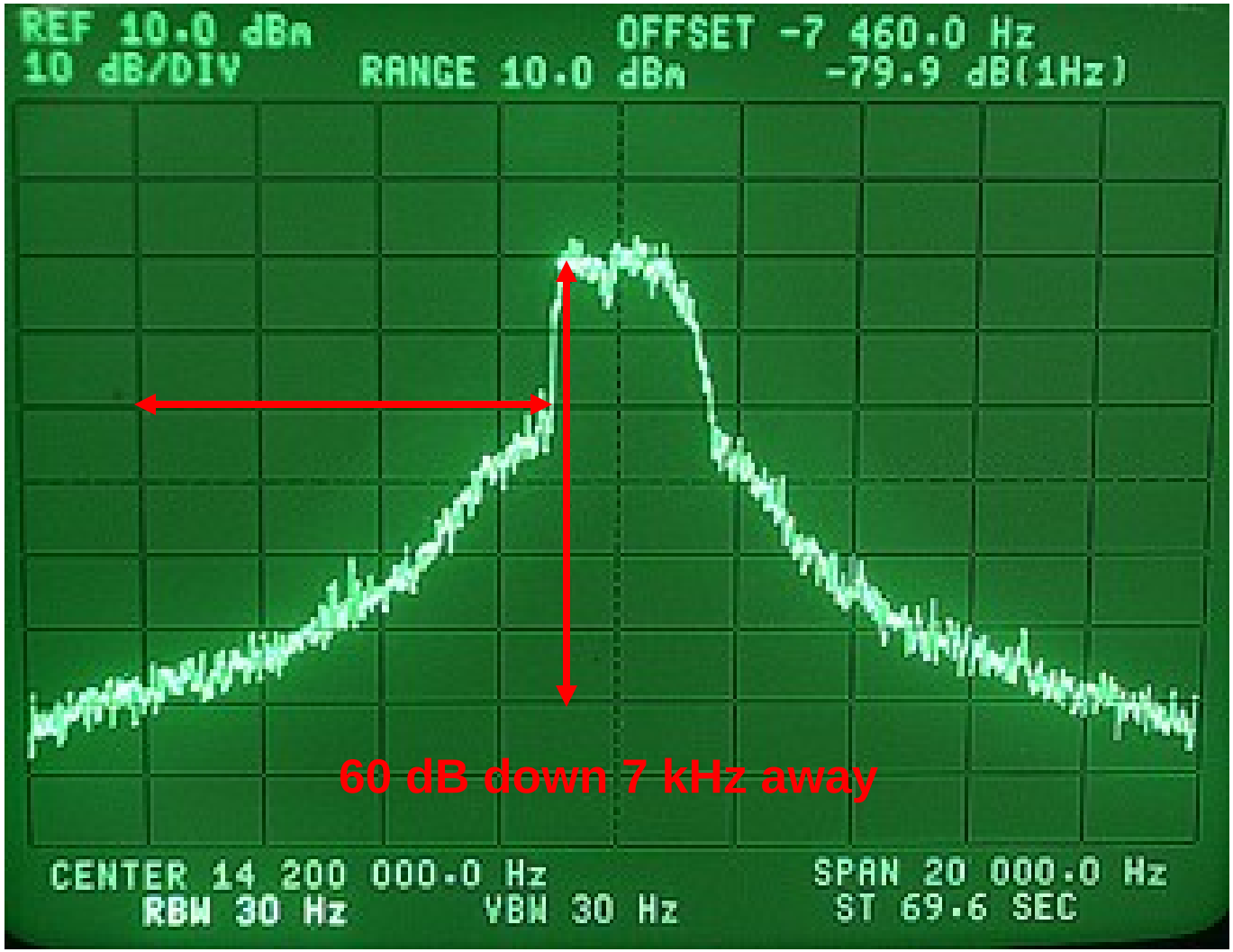
Courtesy Adam Farson – VA7OJ

Set to 50 Watts Key Down - White Noise



6 Div = 100 W PEP. Rig at half power, but spikes to 100 watts every 2 or 3 sec.

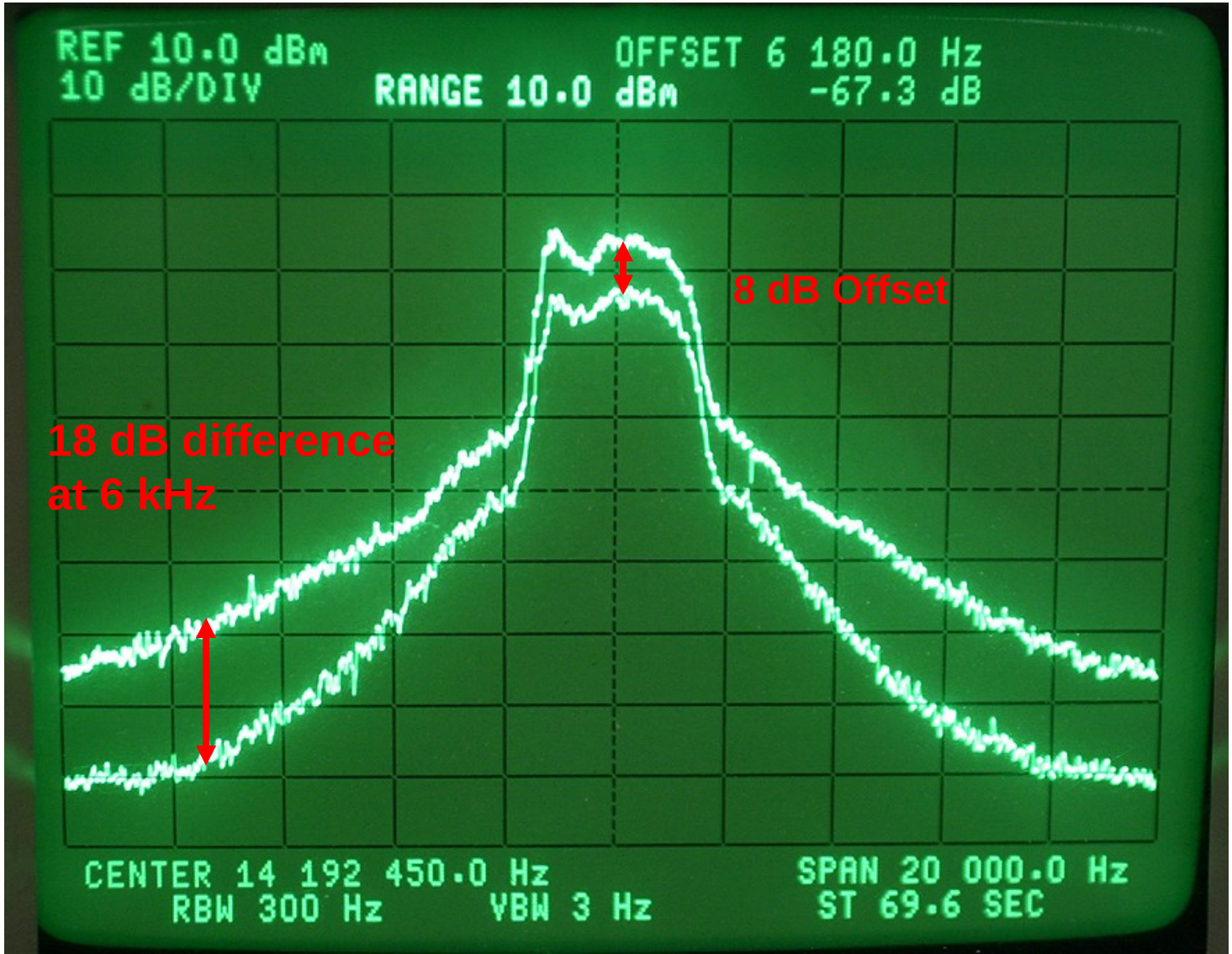
Ten-Tec Eagle Class B White Noise



Kenwood 590S Class B White Noise

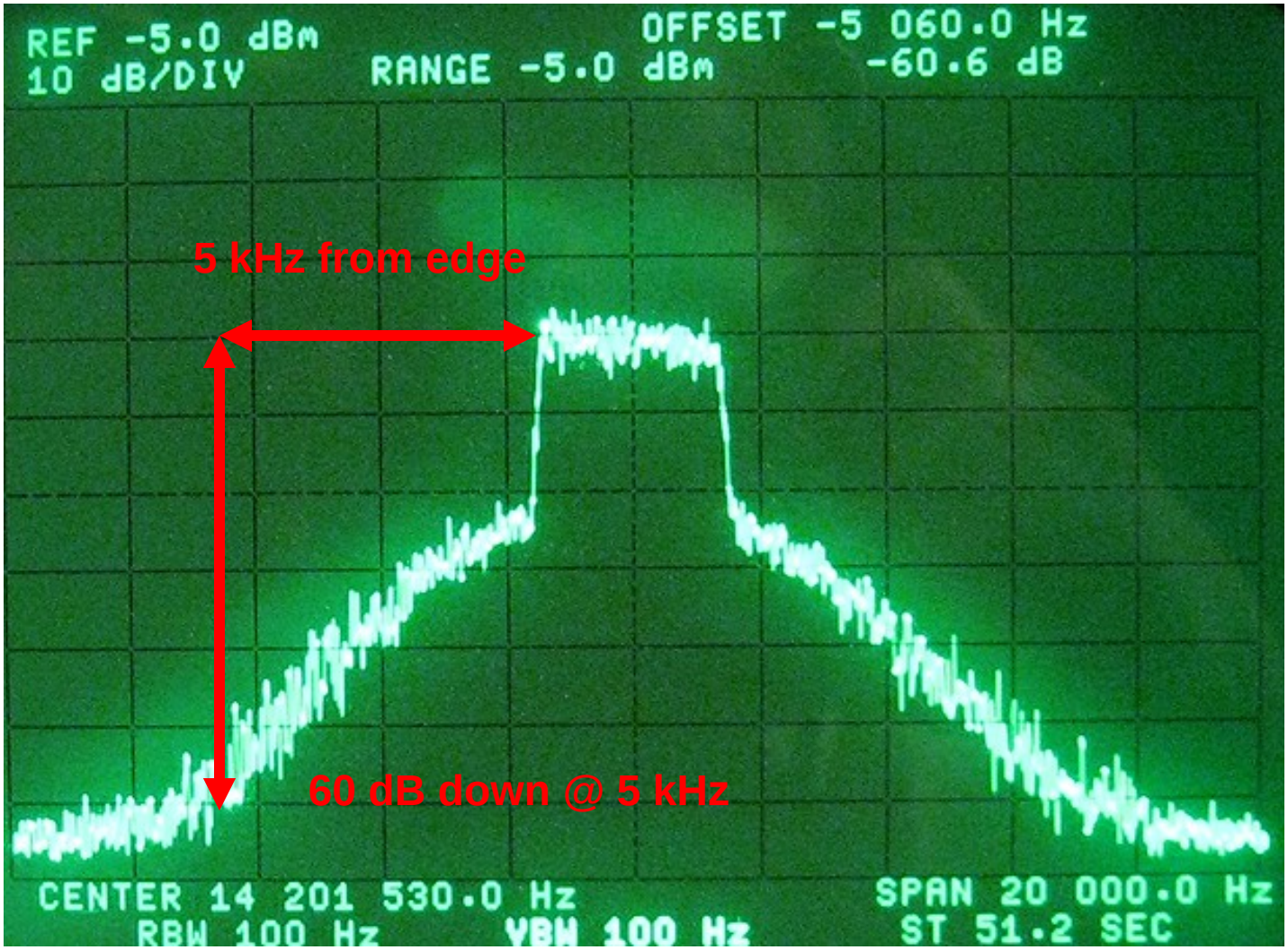
7600 about 10 dB worse than the Pro III

IC-7600 on top, 756 Pro III on bottom

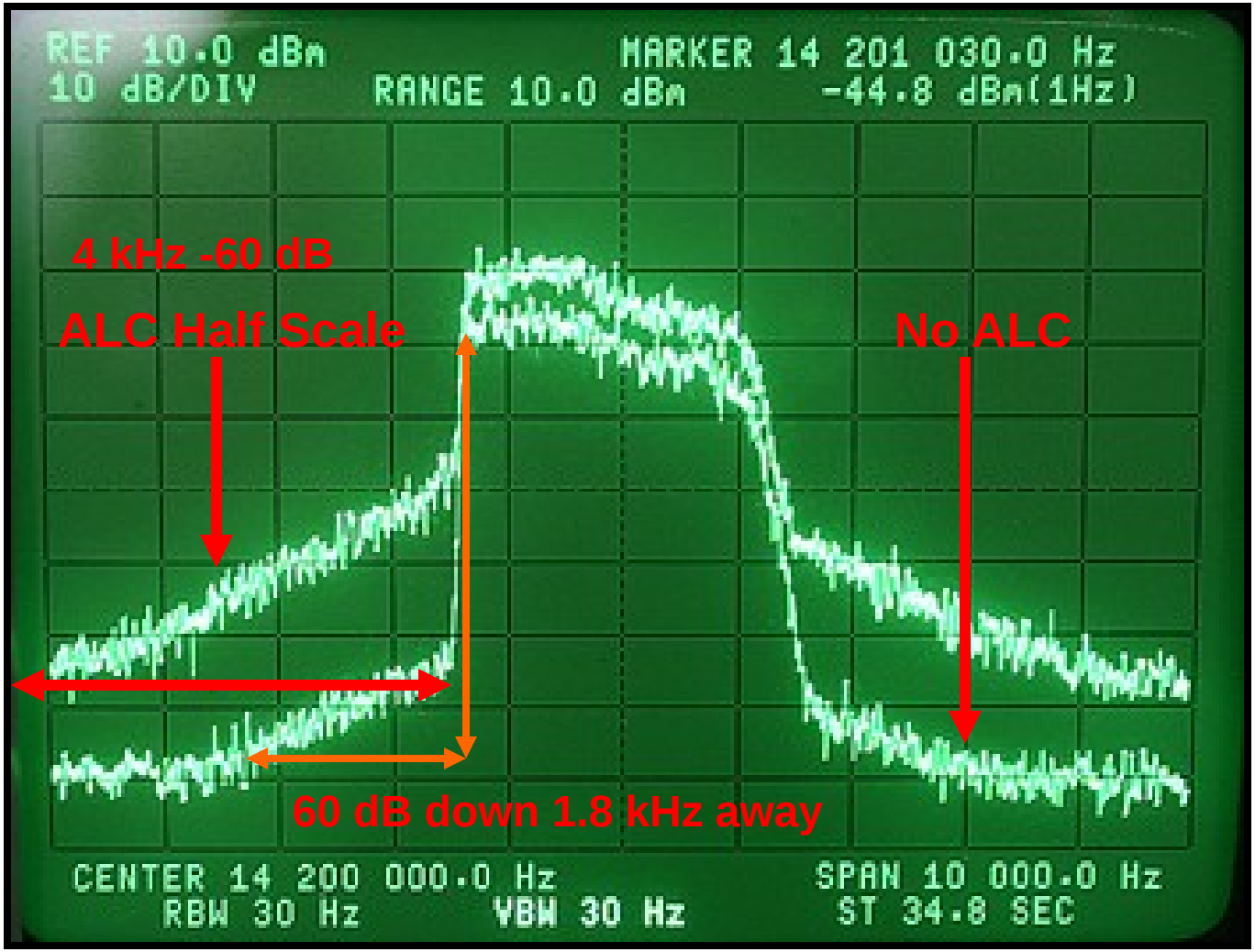


Noise source = GR 1381, 5-kHz -3 dB BW

Icom IC-7410 Class B, White Noise



FTdx-5000D Class A – Two Levels ALC



What's wrong with the FTdx-5000D?

- Decades ago Collins clearly stated that an ALC circuit should have a SLOW time constant (decay). ALC should just be a slow leveling circuit. Speech processing should be done way before the PA and the ALC.
- This issue can be fixed, either in hardware or in firmware, but I don't know which it is.

Ham breaks into my 20 meter QSO

- When some breaks in to comment on your signal, what is your first thought?
- “I must be splattering”
- With the 5000D in Class A, and NO ALC, the ham broke in to say I had the cleanest signal he had ever seen on the air with his K3 and his P3 bandscope.

What Could Contests Be Like?

- What would CQ WW or ARRL DX be like if everyone had a signal this clean?
- Yet some hams don’t want a clean signal.
- They want “elbow room”.
- This goes back to Contest Ethics !

Back to CW signals

We have seen how width of an SSB signal & its IMD products affects how close you can operate to another station.

How does CW compare?

How close can we work to a strong adjacent CW signal?

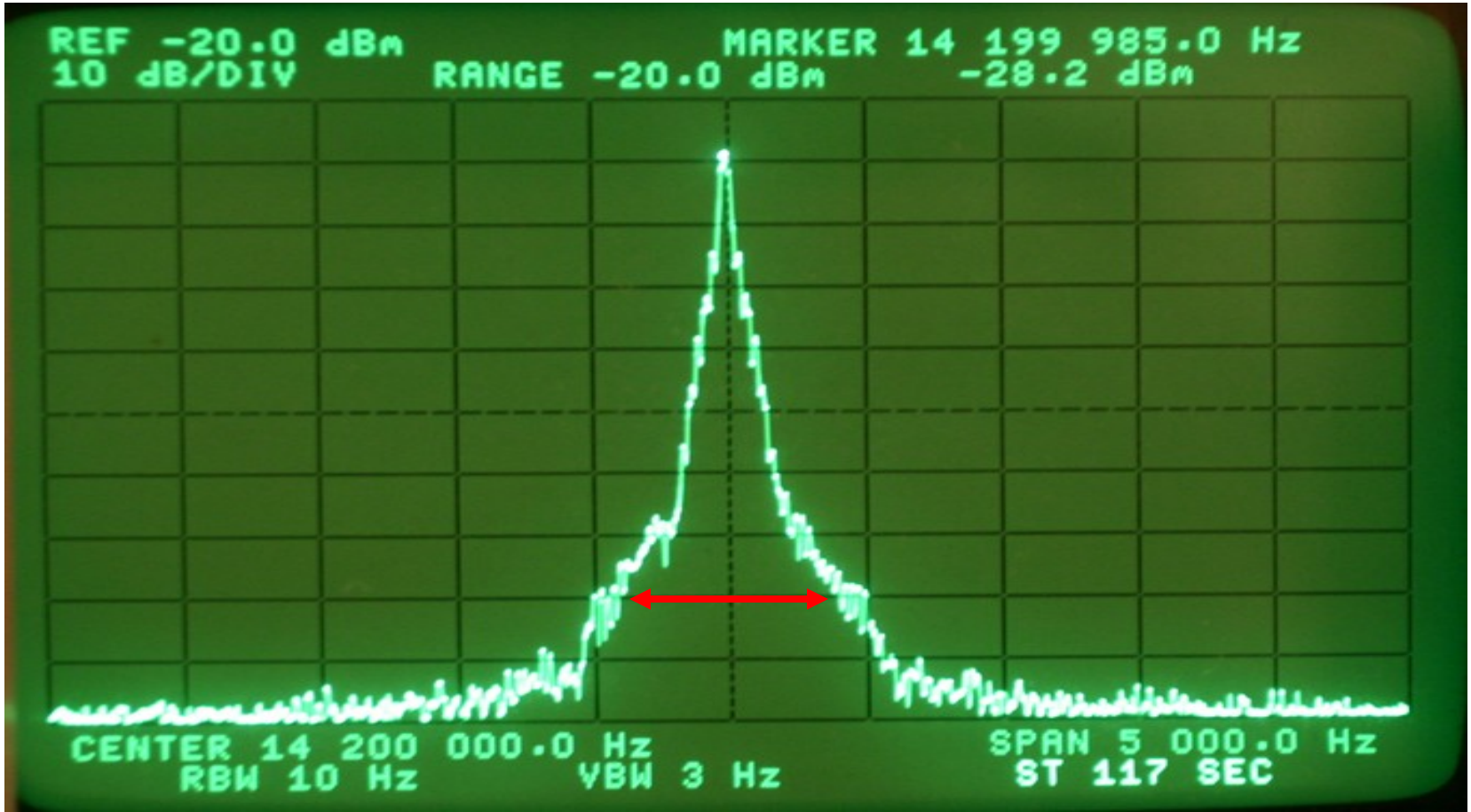
What is the Bandwidth of CW Signal?

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

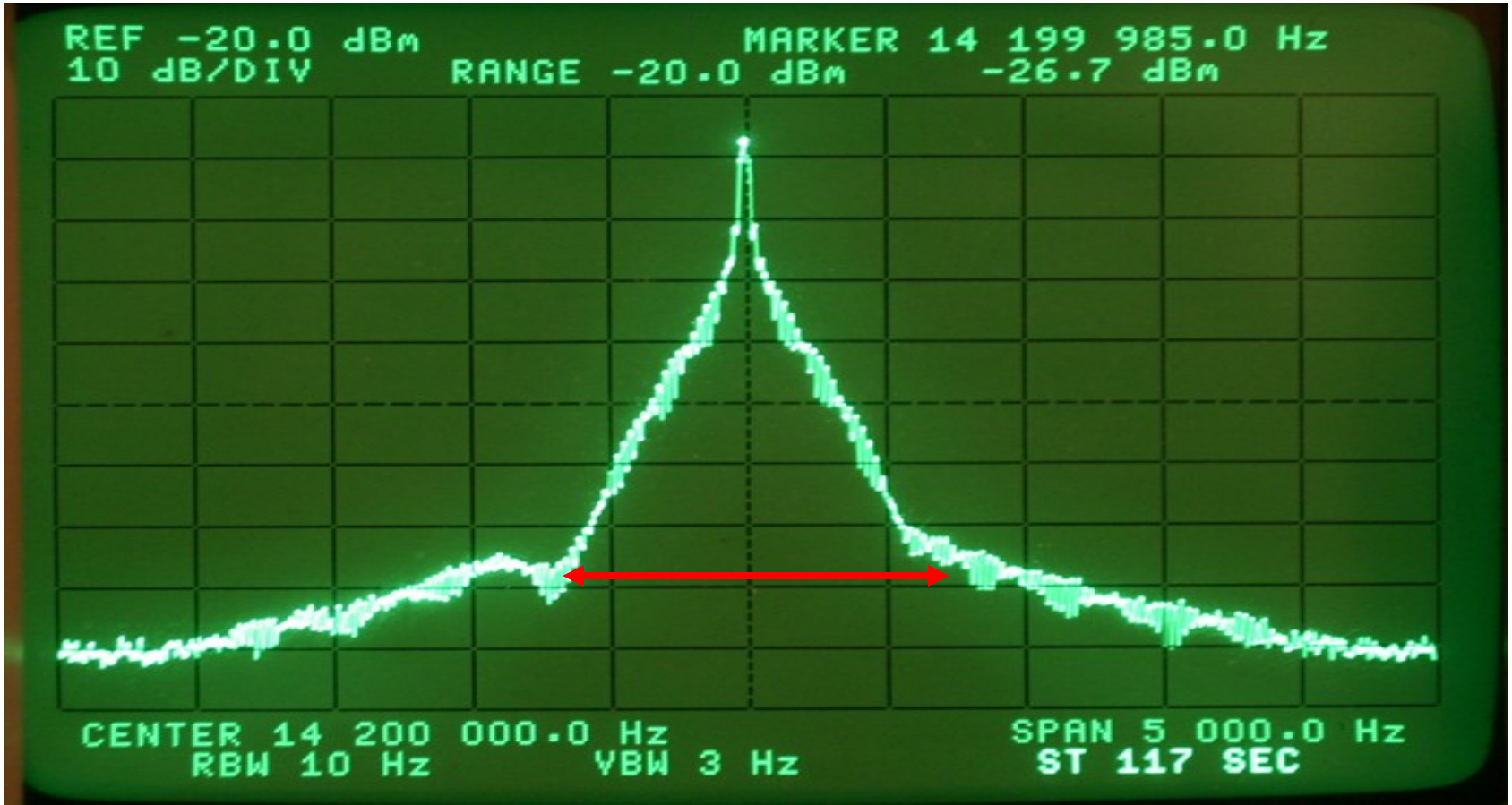
Spectrum of CW Signal on HP 3585A Analyzer

Rise Time 10 msec, “dits” at 30 WPM,
Bandwidth -70 dB = +/- 450 Hz = 900 Hz



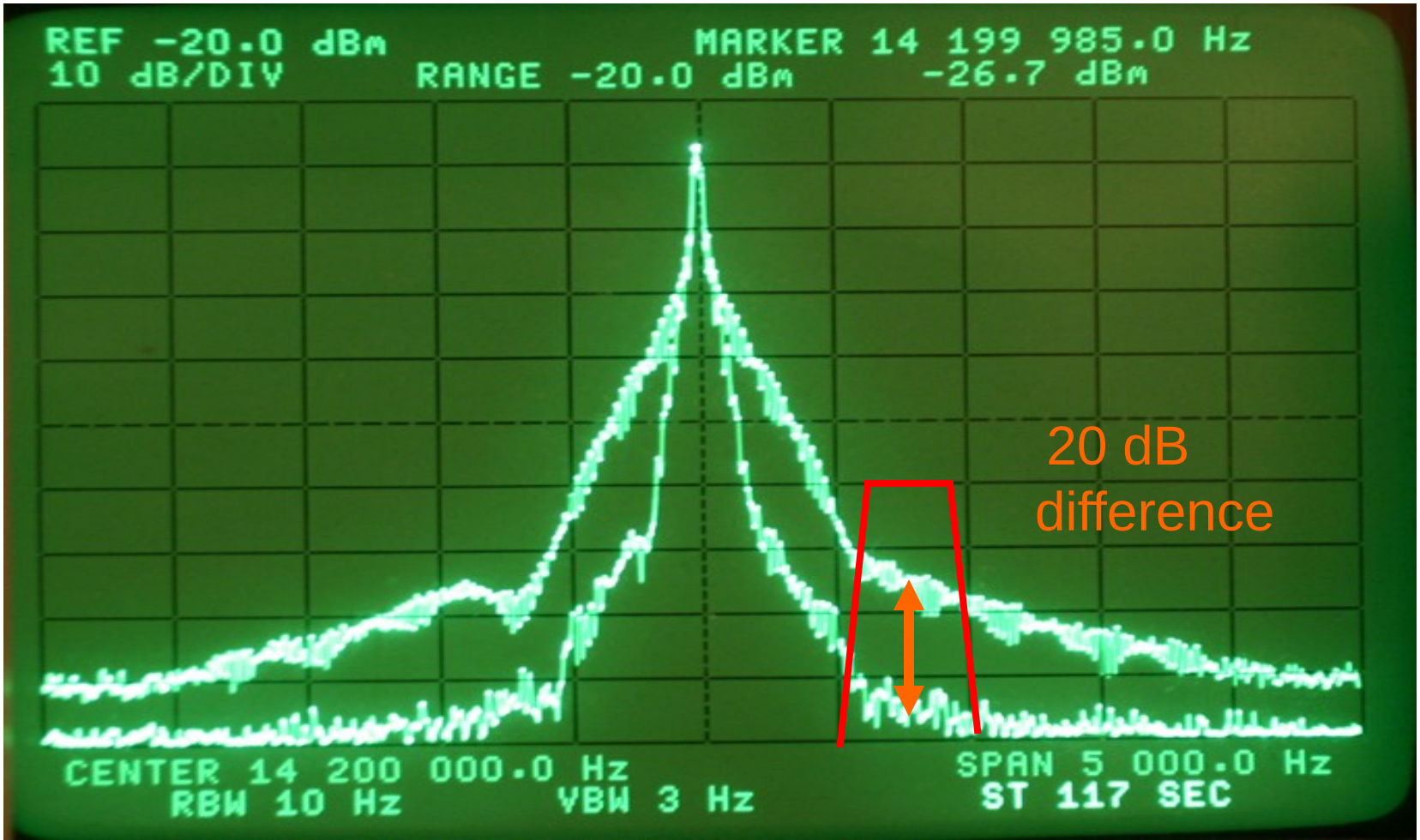
Spectrum of CW Signal on HP 3585A Analyzer

Rise Time 3 msec, “dits” at 30 WPM,
Bandwidth -70 dB = +/- 750 Hz = 1500 Hz

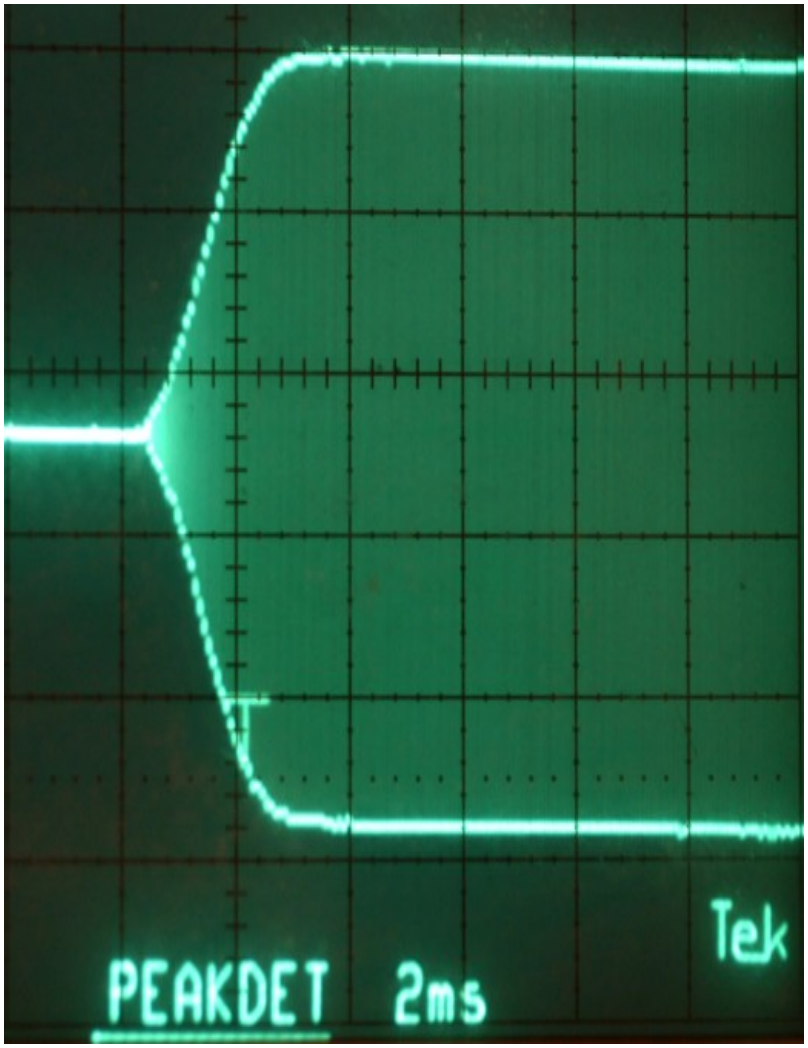


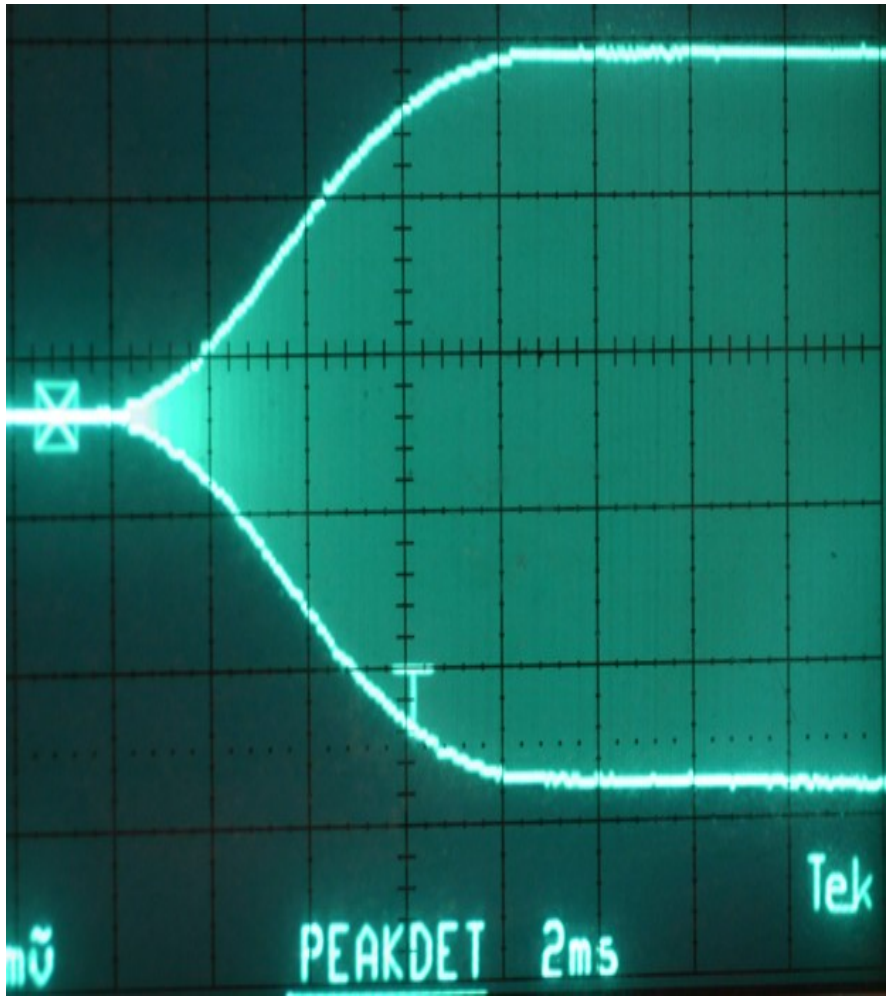
Spectrum of CW Signal on HP 3585A Analyzer

Comparison of 3 msec vs 10 msec rise time



Leading edge of “dit” 3 & 10 msec





Just the Facts

On SSB you want DR3 = 70 dB, or more.

On CW you want DR3 = 80 dB, or more.

This is most economically accomplished with low IF (5 to 9 MHz) selectable crystal roofing filters.

It is much more difficult to deliver 80 dB or higher DR3 with the more common Up-Conversion design.

Transmitted bandwidth of the interfering signal is often the limit, not the receiver.

What dynamic range is possible and needed for CW?

80 dB or better @ 2 kHz with a 500 Hz bandwidth.

2001 Ten-Tec Omni-VI+:	**80 dB**
2003 Icom IC-7800:	**80 dB**
2003 Ten-Tec Orion I:	**93 dB**
2005 Ten-Tec Orion II:	**95 dB**
2007 Flex 5000A:	**96 dB**
2007 Ten-Tec Omni-VII:	**80 dB**
2008 Elecraft K3:	**95 dB**
2010 Kenwood TS-590S:	**88 dB**
2010 Ten-Tec Eagle:	**90 dB**
2010 FTdx-5000:	**101 dB**

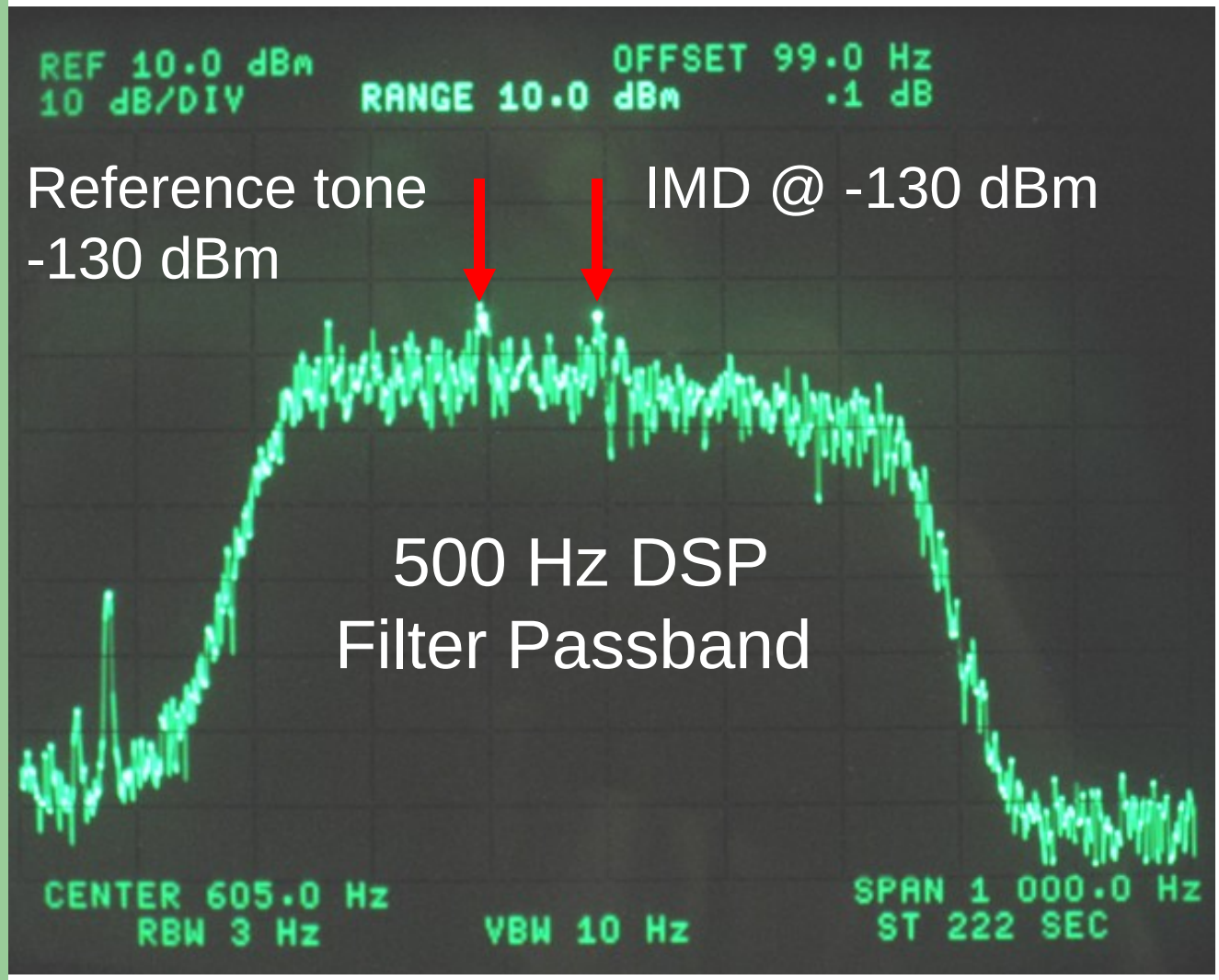
Other radios for comparison, 2 kHz dynamic range data

Elecraft K2:	**80 dB**	
Collins R-390A:	**79 dB**	
Kenwood TS-850S:	**77 dB**	
Icom Pro II / Pro III	**75 dB**	
Collins 75S-3B/C:	**72 dB**	
Kenwood TS-870S:	**69 dB**	
Yaesu FT-2000:	**63 dB**	**This is shockingly bad**
Icom IC-7000:	**63 dB**	
Yaesu FT-One:	**63 dB**	
Yaesu FT-101E:	**59 dB**	
Drake R-4C Stock:	**58 dB**	
Yaesu FT-757:	**56 dB**	
Yaesu VR-5000:	**49 dB**	**Worst radio I have ever tested !**

Strange ARRL Dynamic Range Numbers

- Many modern transceivers are phase noise limited, particularly close-in at 2 kHz. The League wanted be able to measure the IMD buried in the phase noise, and came up with a new method a few years ago using a spectrum analyzer with a 3-Hz filter. (HP 3585A) It can also be done with a 10-Hz filter and averaging of the signal over time. (HP 8568B)
- One may also use an FFT analyzer with long-term averaging to suppress the noise, and make the measurement more quickly.

IC-7600 with 3-Hz Spectrum Analyzer



Phase noise limited dynamic range is 78 dB at 2 kHz.

Measured with a 3-Hz filter on the analyzer, the dynamic range is 87 dB at 2 kHz!

What the New ARRL DR3 Method Means

- Old method, IMD or noise increased 3 dB.
- IMD tone at noise floor = 
- This was DR3, either IMD or noise limited.
- With the new method, noise increased 10 dB, and by ear you hear nothing but noise.
- How is this the same? 
- Unless you work a contest using a 3-Hz CW filter, the new League dynamic range measurements are significantly greater than on-air usage, if the radio is phase noise limited.

IC-7800 ARRL Old vs. New Method

- 4/18/2006 IC-7800 test data, old method
- 2 kHz, Phase Noise Limited @ 80 dB
- 1 kHz, Phase Noise Limited @ 67 dB

- 2/6/2007 IC-7800 test data, new method
- 2 kHz, dynamic range = 86 dB
- No measurement reported at 1 kHz.

IC-7410 Dynamic Range Data

Spacing	Value
100 kHz	107 dB some noise
20 kHz	102 dB noise limited
5 kHz	90 dB noise limited
2 kHz	78 dB noise limited
2 kHz ARRL*	89 dB noise ignored

- * (Using spectrum analyzer and narrow BW)

Signal is buried in phase noise

- Ken, N0QO & I measured the 7410 3 ways
- In 500 Hz CW bandwidth, only noise
- In 3 Hz bandwidth, you can “see” the signals
- In 10 Hz BW with long term averaging to reduce the noise, you can “see” the signals
- In no case could the actual signals be heard coming from the speaker

Flex 3000 Old Method vs. 3 Hz Filter

- Flex 3000 with Old Method: DR3 = 90 and is completely phase noise limited.
- Flex 3000 with 3 Hz Spectrum Analyzer method measures a dynamic range between 95 and 99 dB, depending on the spacing.
- The Orion II and the K3 perform better, but now you cannot tell that by the QST numbers.

Phase noise should not be ignored !

- The problem is the League is now measuring dynamic range in such a way to eliminate phase noise from the equation. Phase noise (reciprocal mixing in a QST review) up till now got but a single line of data.

- An Elecraft K3 at 99 dB is not the same as a Flex 3000 at 99 dB, yet you would never know that from a QST review.

The League and Sherwood Compromise

- In September 2011 the League agreed to add emphasis to their reciprocal-mixing data. Hopefully this will appear in QST by year end.
- The League's reciprocal-mixing (RM) values should equal their pre-2007 noise-limited data, and my published noise-limited data.
- IC-7410 RM limited dynamic range = 78 dB
- Sherwood noise-limited DR3 = 78 dB

Question: How good is good enough?

High Dynamic Range Receiver (DR3).

Minimum 70 dB for SSB & 80 dB for CW

If the “real” DR3 > 90 dB, your receiver is fine.

Differences of a few dB are NOT significant.

Sensitivity 15 meters and below, preamp ON: 0.2 uV

Noise floor 15 meters and below, preamp ON: -135 dBm

Receiver testing needs to approximate the real world.

Sherwood Engineering

http://www.sherwood-engineering.com

http://www.NC0B.com