Transceiver Performance 10 Years of Change

Rob Sherwood
NCØB

Great Strides + Many Problems Ignored

- **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.
- Lots of choices today in the top performers.
- **Many secondary issues still not addressed.**

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.
- Lab measurements Icom 756 Pro III

- Receiver sensitivity, no preamp, 2.4 kHz = 0.35 µV
- Receiver sensitivity, w/ preamp, 2.4 kHz = 0.14 µV

- Receiver noise floor, no preamp, 500 Hz = -132 dBm
- Receiver noise floor, w/ preamp, 500 Hz = -140 dBm

A simple test with only an 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.

- Or do some simple math: 20LogV2/V1

Measure the noise gain

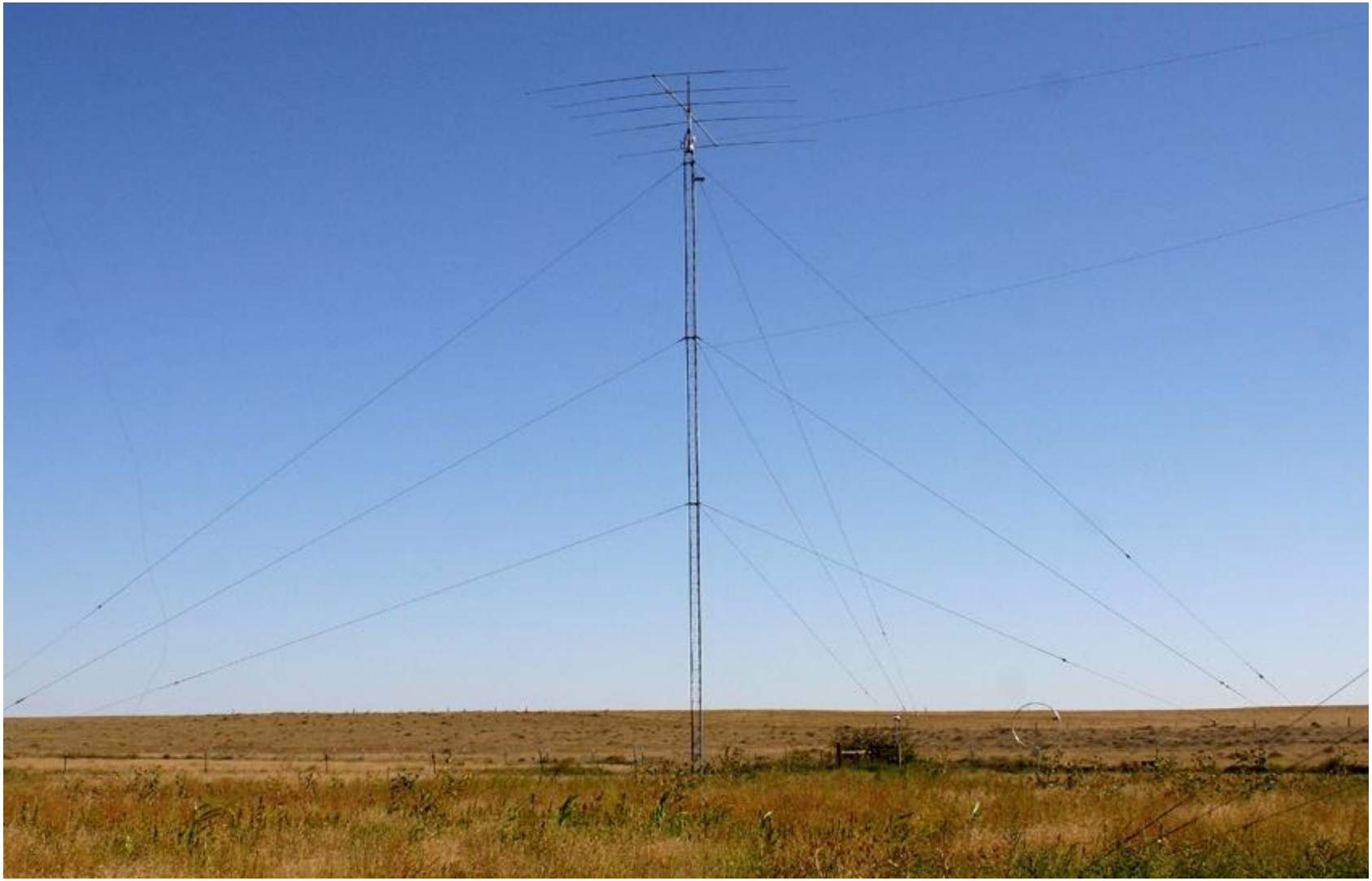
- Disconnect your antenna and set the volume so your dB meter reads -10 dB.
- (Put a dummy load on the rig, but it will likely make no difference.)
- Connect the antenna and see how many dB the noise goes up when tuned to a dead spot on the band.
- Do this with Preamp OFF and ON
- Also rotate your yagi 360 degrees
- Noise can easily change 10 dB !

NC0B 15 meter tower and yagi

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.

Similar 5 element yagi at 65 feet on 10 meters, 500 feet of half-inch hard line.

LJ-155CA yagi at my quiet rural QTH



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	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 worse for the close-in towers, unless I turn off electronic devices.
- TVs (CRT or plasma), UPS (battery backup) on computers, broadband router (makes birdies), wall warts with switching power supplies for iPhone, & hand touch lamp !
- (That lamp got lost in the last move.)

Tower Distance vs. local RFI (noise)

Numbers with Preamp-1 ON

Noise Floor Quite Consistent Top Xcvrs

• Elecraft KX3	-138 dBm	
• Yaesu FTdx-5000D	-135 dBm	
• Elecraft K3	-138 dBm	
• Flex 5000	-135 dBm	
• T-T Orion II	-133 dBm	
• T-T Orion I	-135 dBm	
• T-T Argonaut VI	-135 dBm	
• T-T Eagle	-132 dBm	
• Kenwood TS-590S	-137 dBm	
• Drake R-4C	-138 dBm	(compare)
• Collins 75A-4	-141 dBm	(Too low)

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

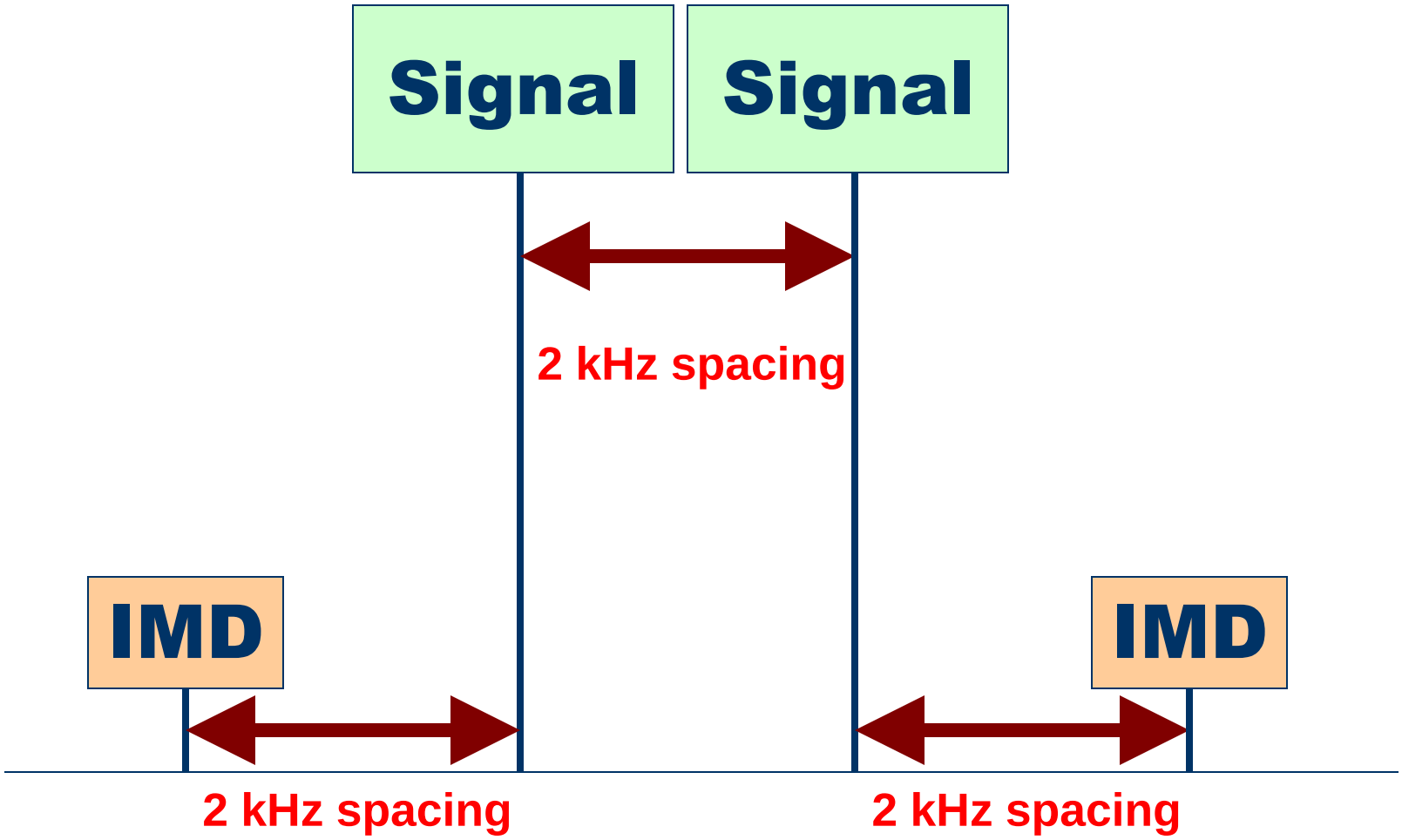
What is Close-in Dynamic Range vs

Wide-Spaced Dynamic Range?

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

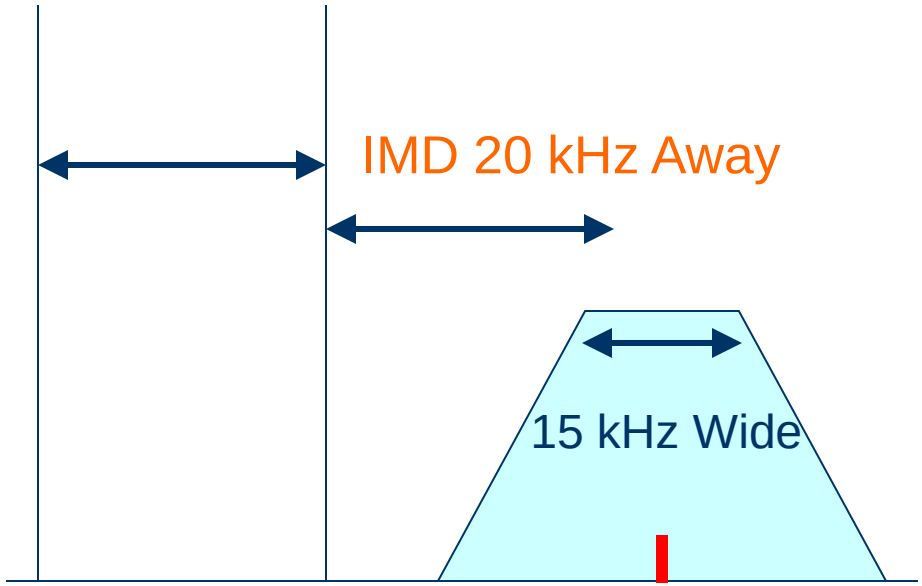
Why is it less important for SSB operators?

Third Order IMD to Measure Dynamic Range



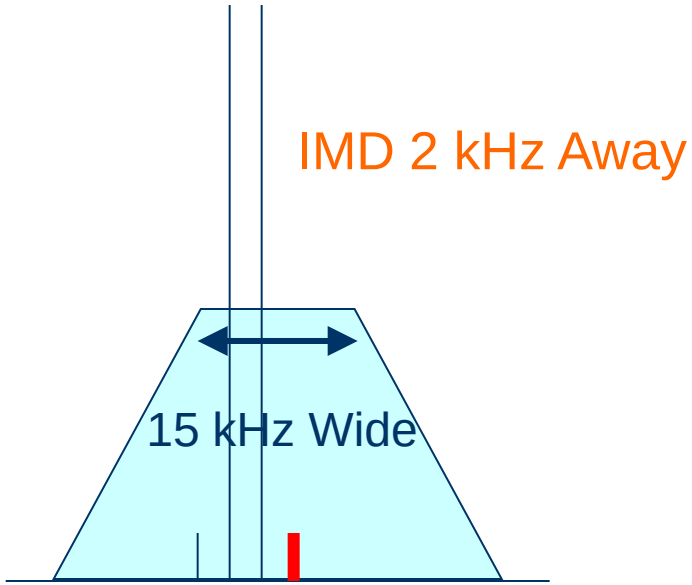
Wide & Close Dynamic Range

20 kHz Spacing



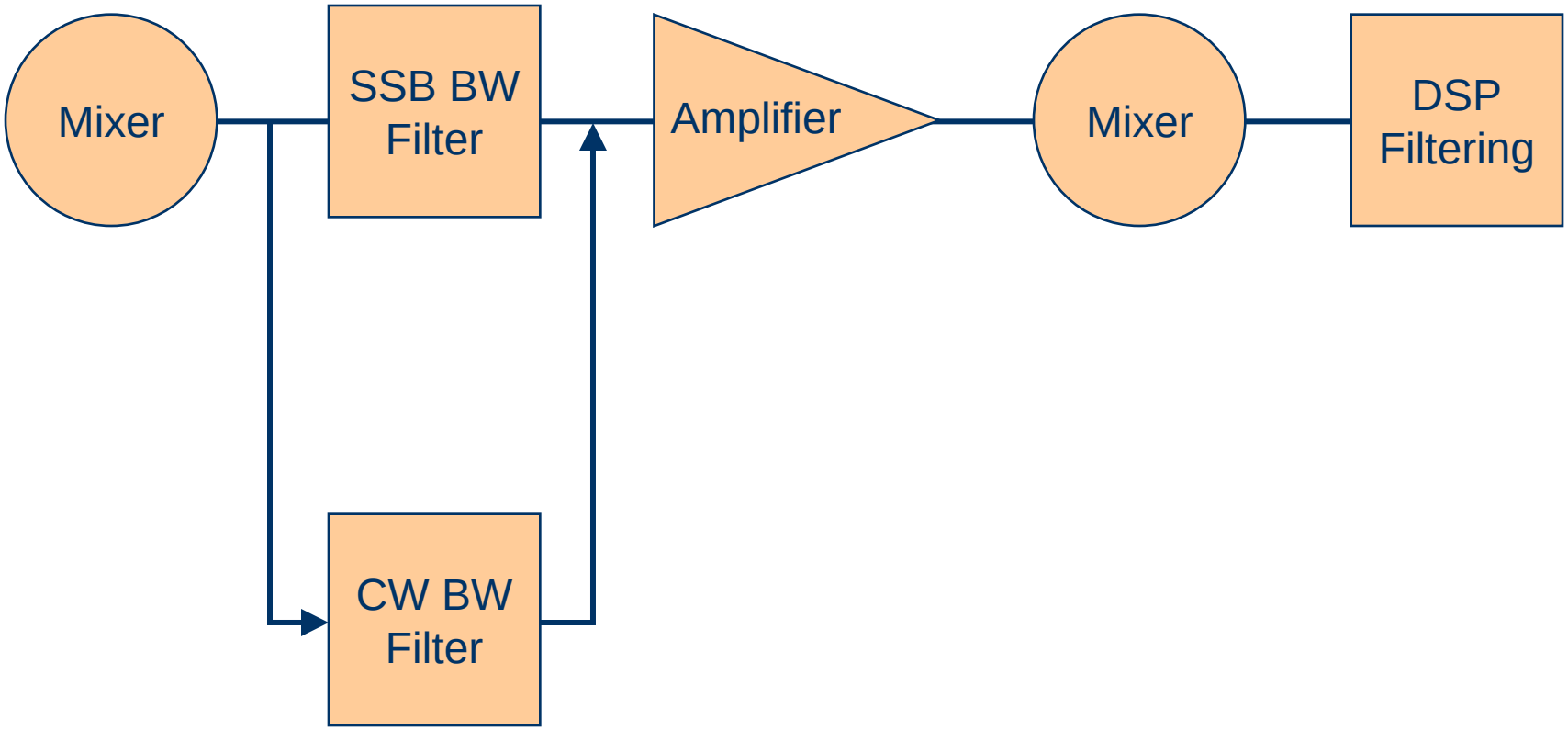
First IF Filter at 70.455 MHz

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 the last 10 years?

- Ten-Tec started the change in 2003 with the Orion, going back to “down-conversion” (a first IF between 5 and 11 MHz, not VHF).
- Elecraft, Yaesu and Kenwood followed suit
- TS-590S big seller at a great price point.
- The T-T Eagle receiver can be added as the Orion sub receiver
- TS-990S shipped Spring 2013
- Many choices from $1650 to $8000+

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 & Argonaut (90 dB)
95 dB	S9 + 40 dB	Orion II & Flex 5000A (95 dB)
100 dB	S9 + 45 dB	FTdx-5000, KX3

Close-in 2-kHz Test @ 500 Hz BW

Dynamic Range of Top 10 Transceivers

- Hilberling 105 dB
- Elecraft KX3 104 dB
- FTdx-5000D 101 dB
- Flex 5000 96 dB
- Elecraft K3 95 dB
- Orion II 95 dB
- Orion I 93 dB
- Argonaut VI 92 dB
- TT Eagle 90 dB
- TS-590S 88 dB (down conversion)

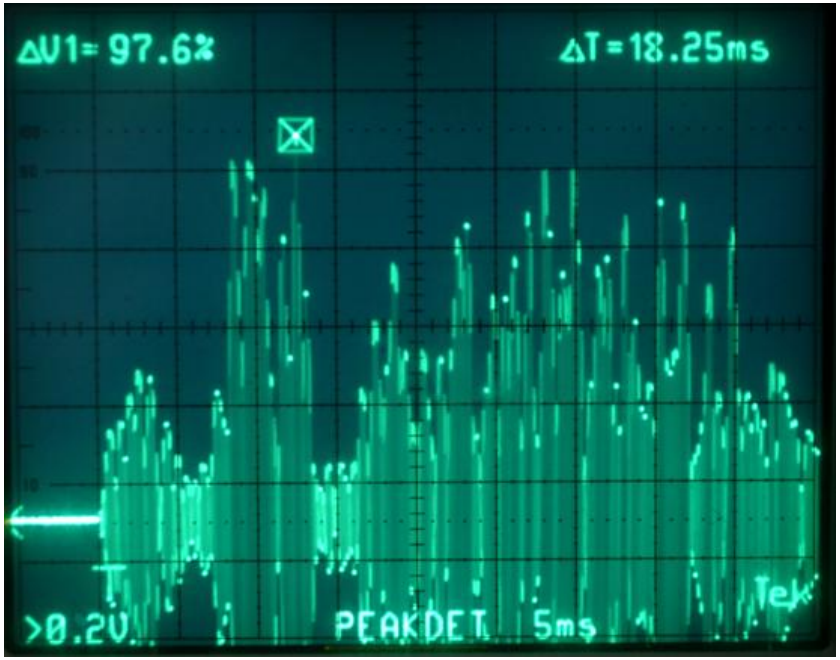
Let’s now look at the transmitters

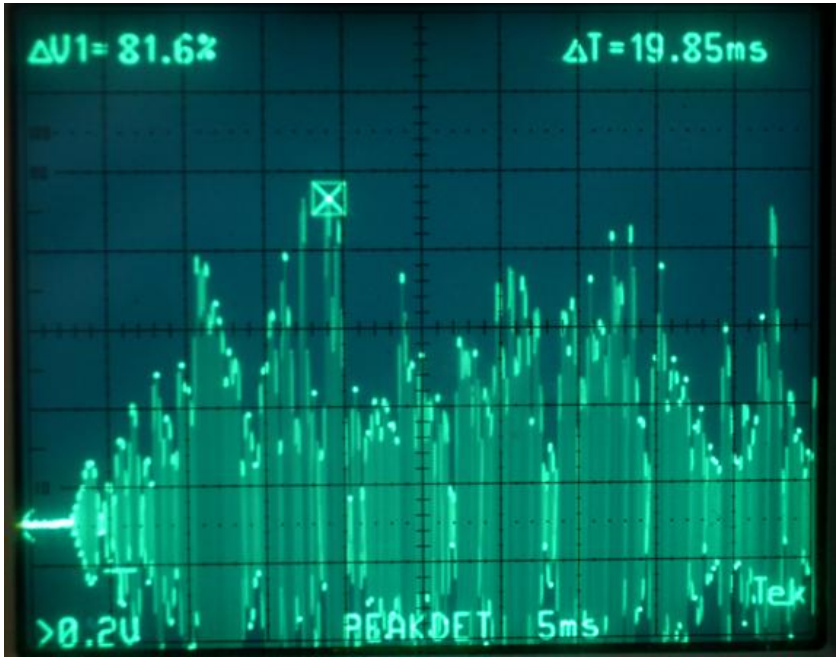
- ALC overshoot is a common problem
- How clean is your signal?
- Ten-Tec doesn’t use ALC any more !
- I am now testing transmitters with white noise feeding the microphone, in addition to a two-tone test.
- The effect of IMD products bandwidth are more obvious with noise than two tones.
- Think of it as a 1000 tone test, more approximating real voice.

ALC Transmit Overshoot Problems

- ALC time constants often too fast or too slow.
- Too fast = increases distortion / IMD
- Too slow = Overshoot could damage linears that only need 40 to 60 watts of drive.
- Unfortunately many rigs today exhibit ALC issues.
- ALC overshoot often worse at reduced power

TS-590S with firmware 1.06





- Rig set to 50 watts
- 100% = 100 watts
- Peaks at 97.6% voltage
- Peak = 95 watts

Rig set to 25 watts
100% = 100 watts
Peaks at 81.6% voltage
Peak = 67 watts

IC-7410 data from PA3EKE

Set for 20 watt carrier

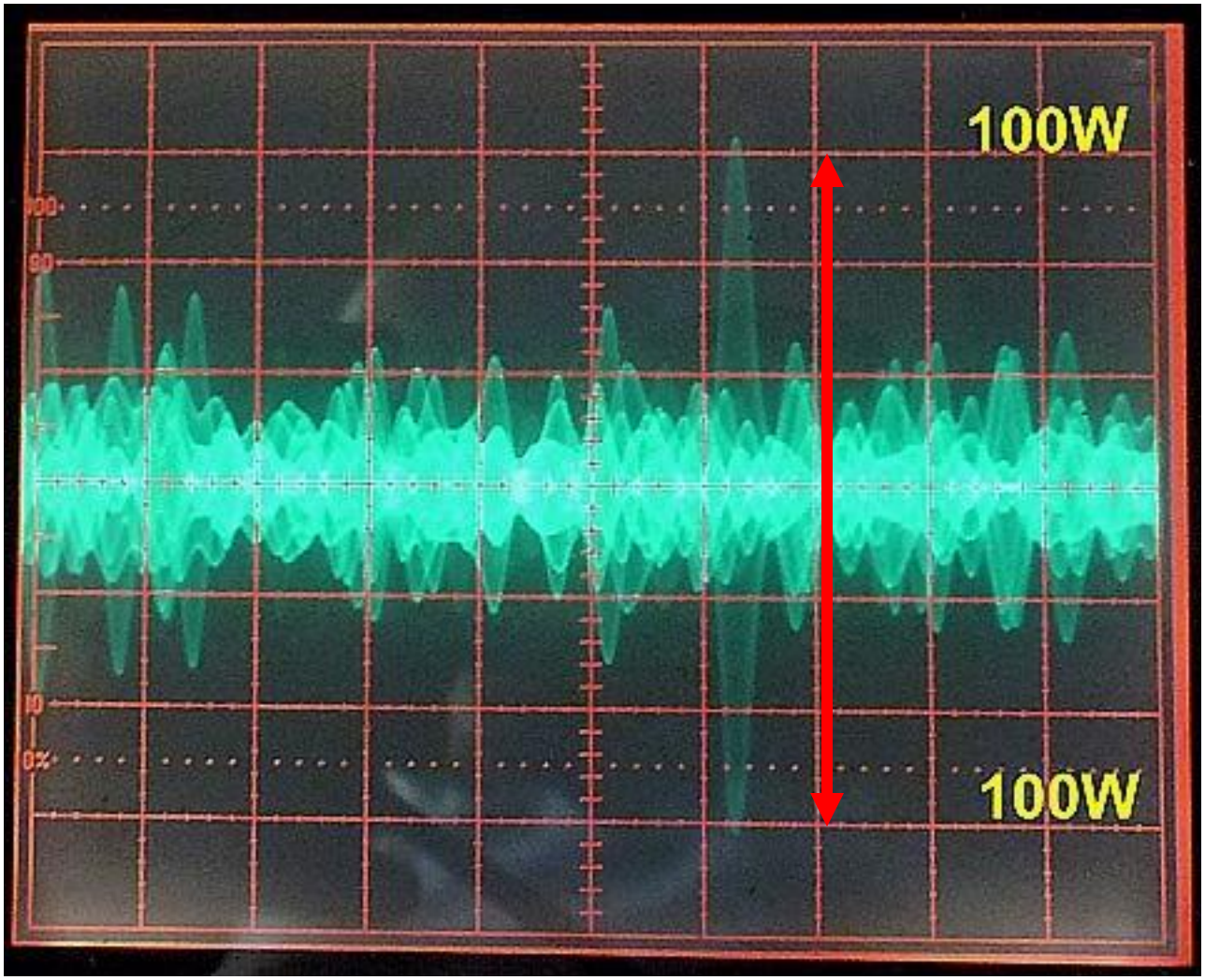
Overshoot 80+ watts
on voice peaks

For comparison: IC-7410

- 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

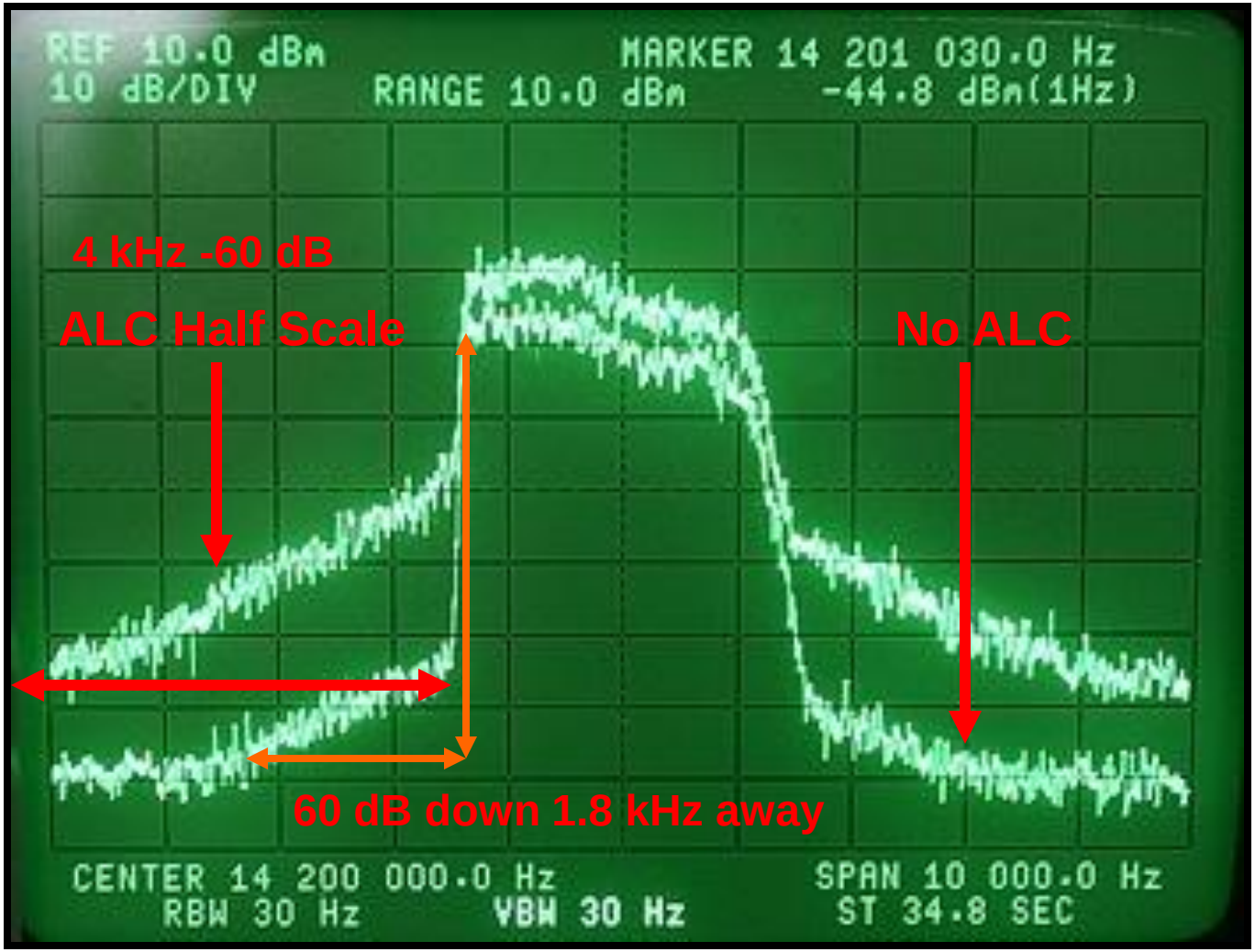


6 Div = 100 W PEP. Rig at half power, but spikes to 100 watts every 2 or 3 sec.

Different ALC philosophy at Yaesu

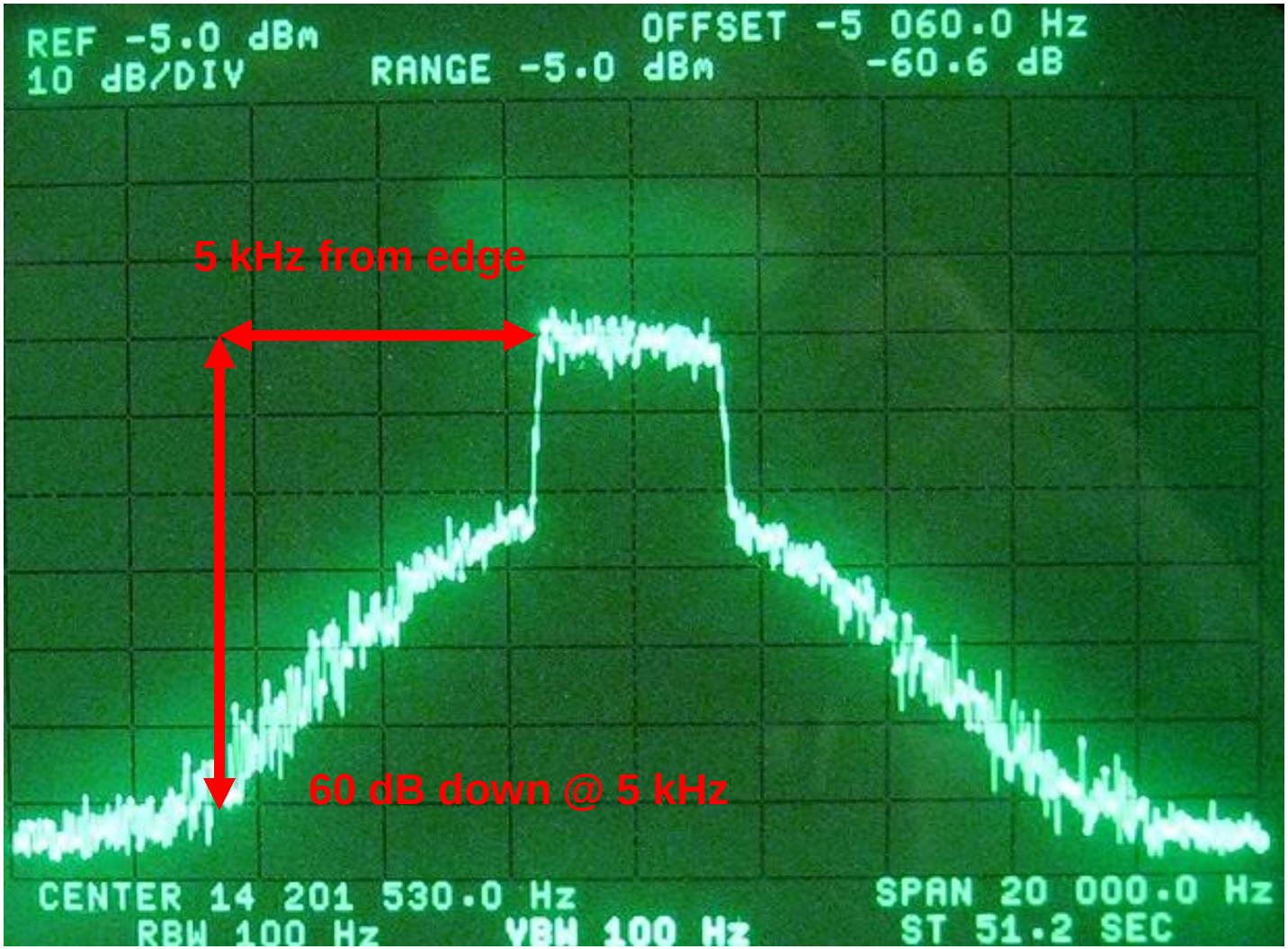
- Decades ago Collins stated that an ALC circuit should have a SLOW decay time constant. ALC should just be a slow leveling circuit. Speech processing should be done way before the PA and the ALC.
- Yaesu: “If the ALC responds to a short pulse, the overall power level will be too low, and become a major concern of users.”
- Unfortunately this design negates much of the advantage of their very clean rigs that offer class A operation.

FTdx-5000D Class A – Two Levels ALC



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

Icom IC-7410 Class AB, White Noise



CW Signals – How wide are they?

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

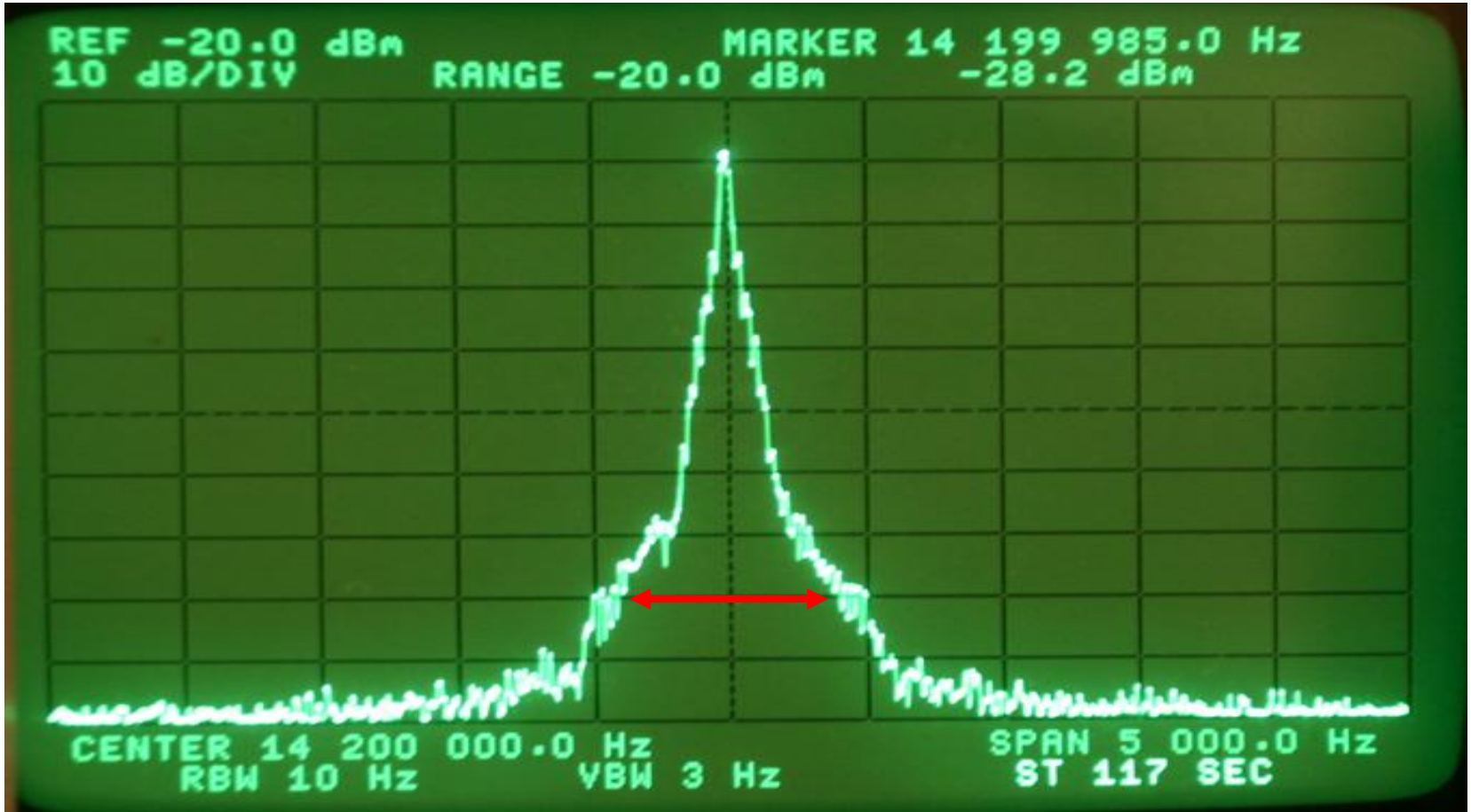
How does CW compare?

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

Ten-Tec Omni-VII with adjustable rise time

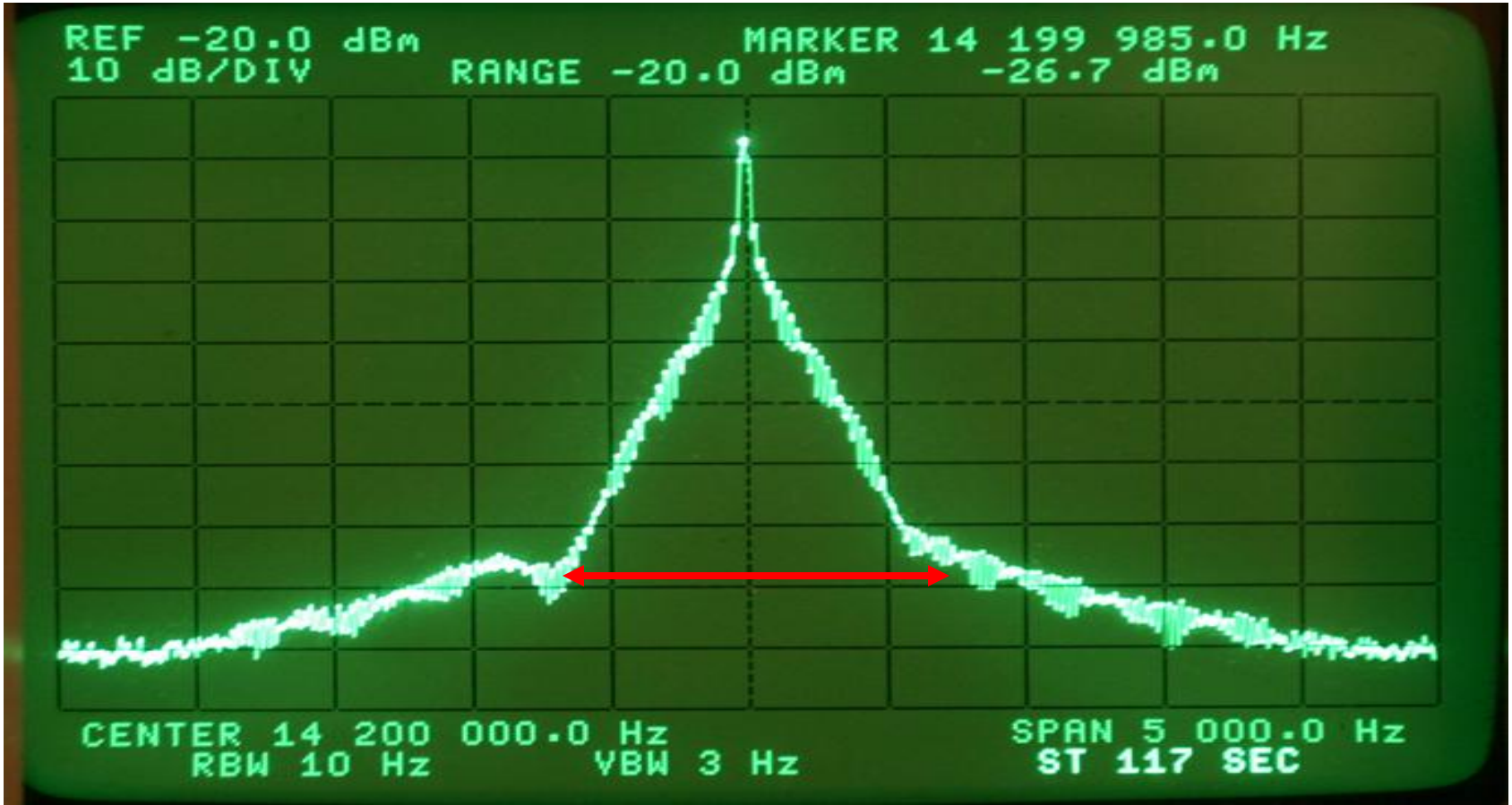
Spectrum of CW Signal on HP 3585A Analyzer

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



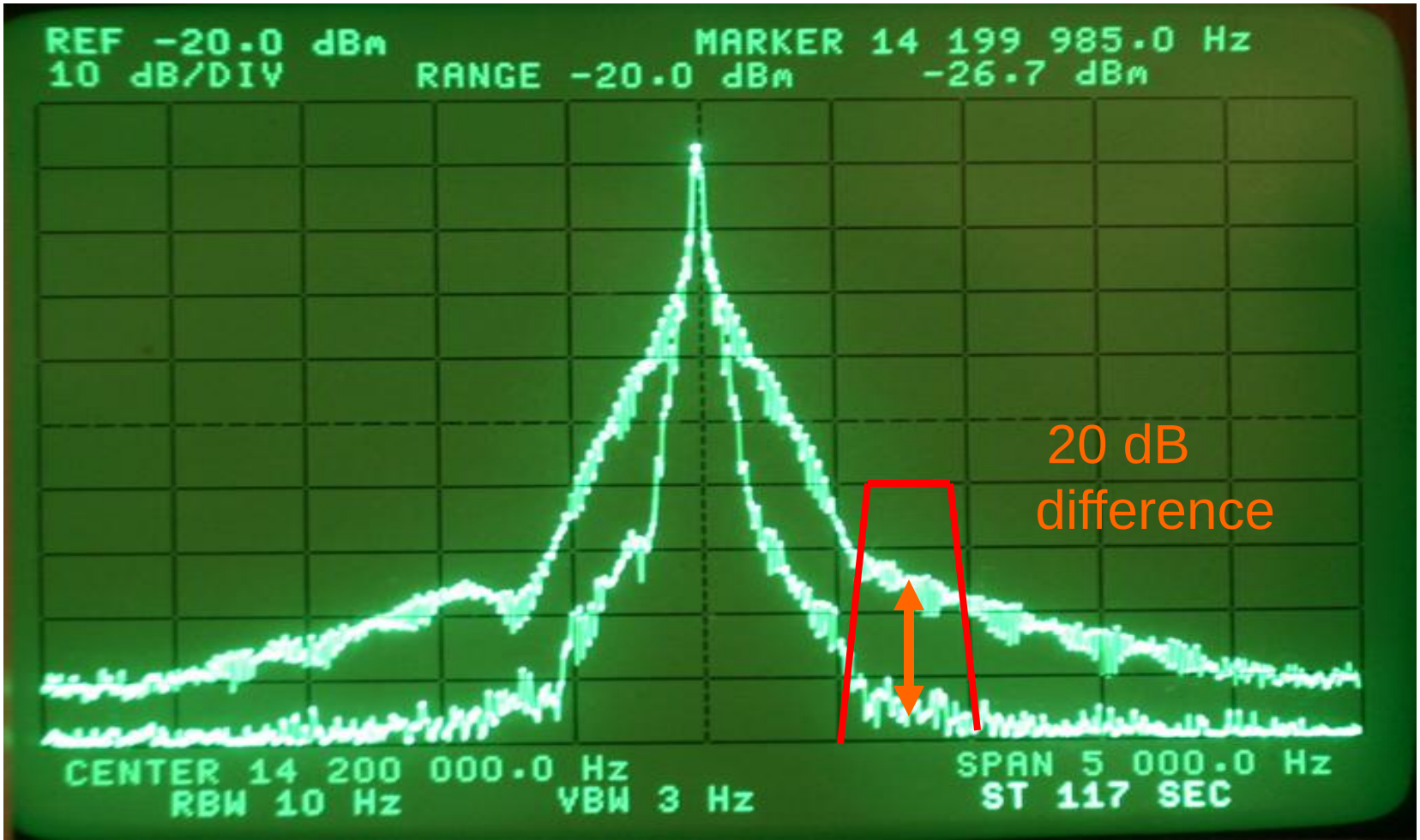
Spectrum of CW Signal on HP 3585A Analyzer

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

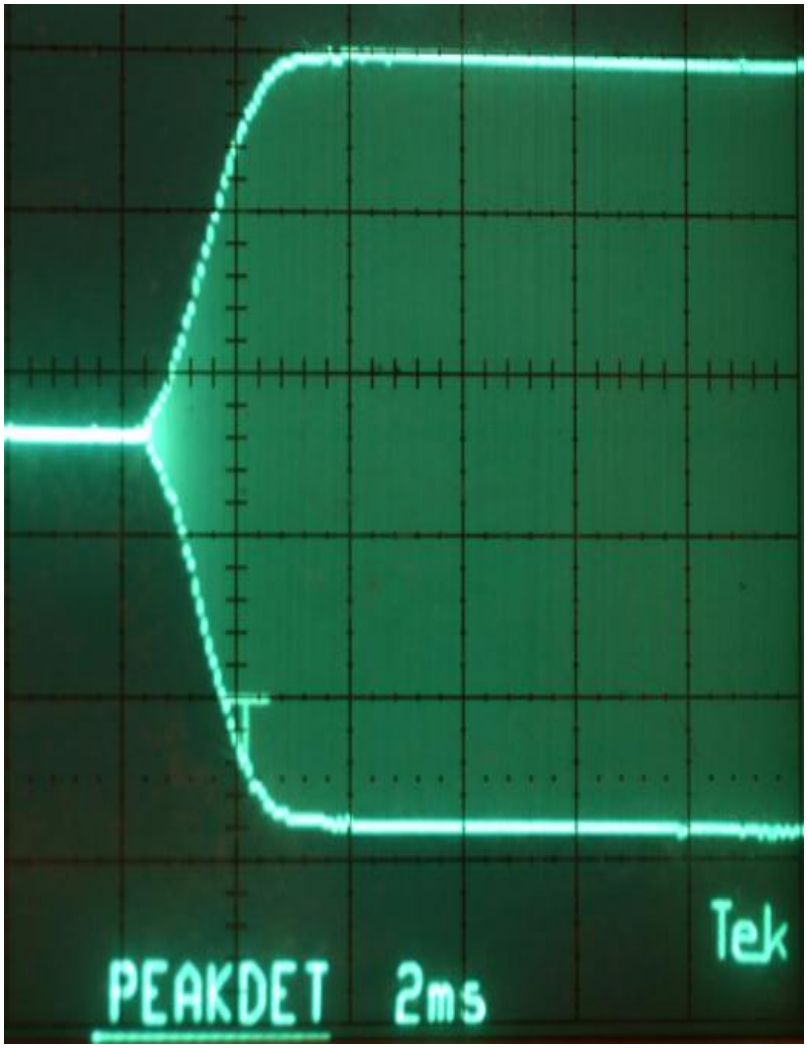


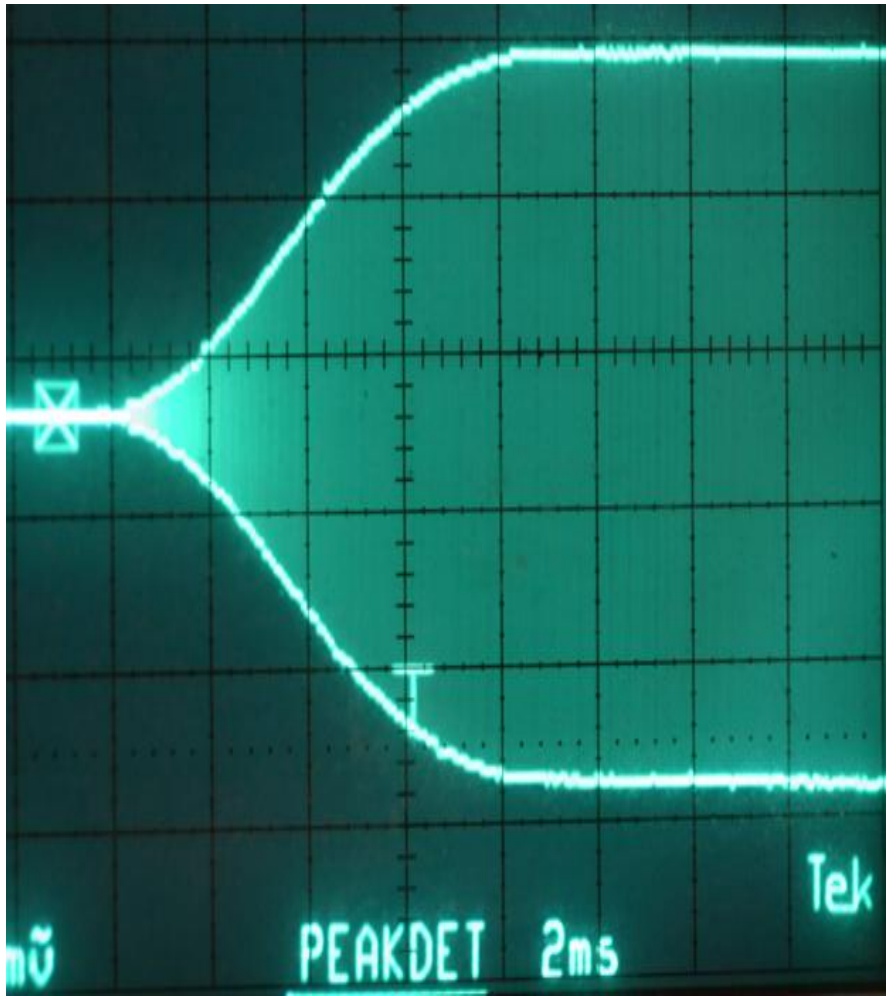
Spectrum of CW Signal on HP 3585A Analyzer

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 to 75 dB, or more.

On CW you want DR3 = 80 to 85 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.

Hilberling does it for $18,000 !

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

What dynamic range can we choose from 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**
2013 Argonaut VI	**92 dB**
2013 PT-8000A	**105 dB**

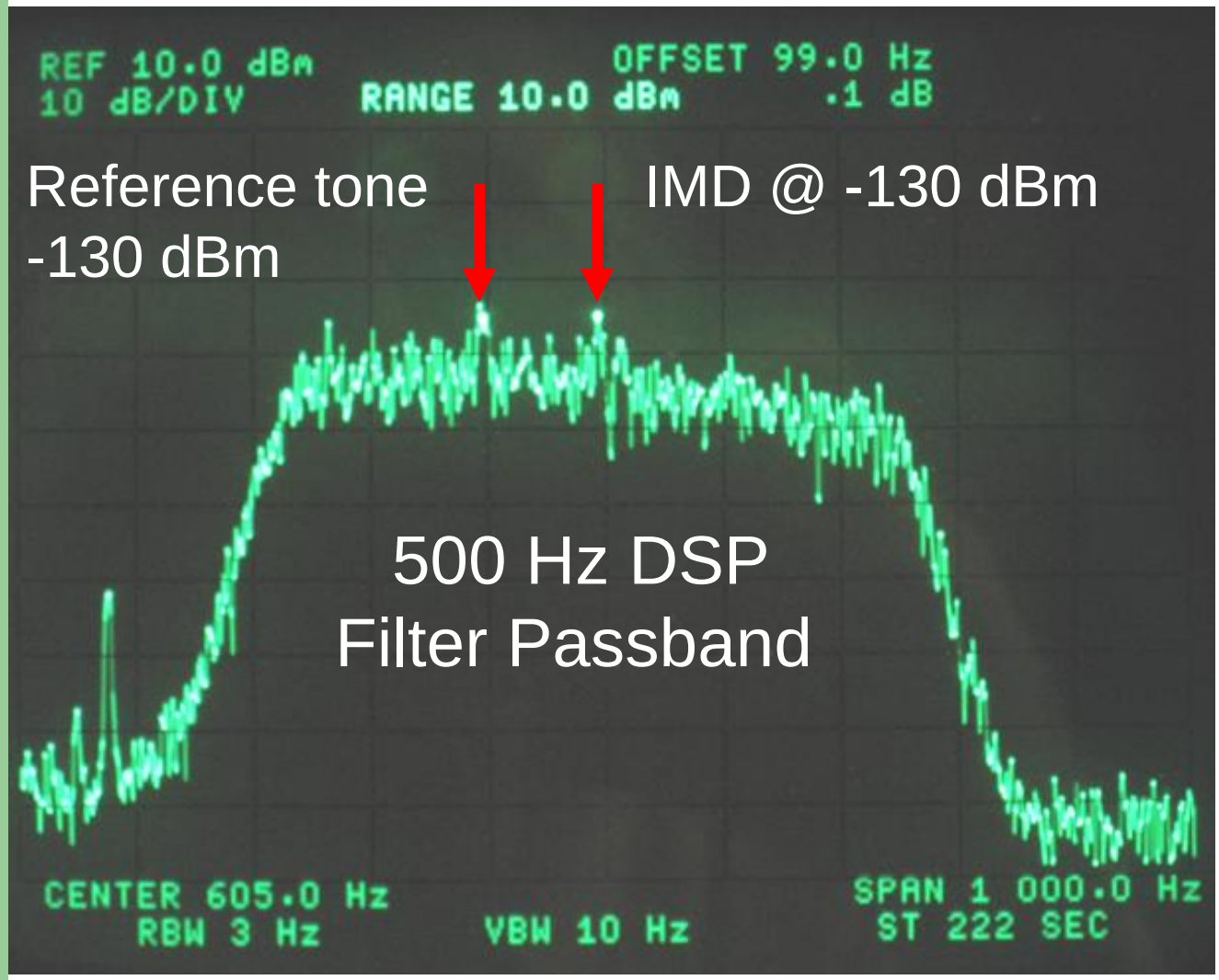
Other radios for comparison, 2 kHz dynamic range data

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**	
Icom IC-7100	**69 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 !**

ARRL Dynamic Range Numbers

- Many modern transceivers are phase noise limited, particularly close-in at 2 kHz. The League wanted to be able subtract out the phase noise when measuring IMD, and came up with a new method in 2007 using a spectrum analyzer with a 3-Hz filter.
- Useful to the design engineer only.
- Now they use an FFT analyzer and a 1-Hz filter with 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!

ARRL 2007 – 2011 DR3 Method

- 2006 and earlier, IMD or noise increased 3 dB. This was published as the dynamic range, either IMD or noise limited.
- With the 2007 - 2011 method, the IMD product was usually buried in phase noise.
- 3-Hz or 1-Hz filter used for the third-order dynamic range measurement resulted in values greater than in 2006 and before.
- Non synthesized rigs (S-Line / C-Line) would not have any reciprocal-mixing issues.

IC-7410 Dynamic Range Data

Example

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 1 Hz filter)

The ARRL / Sherwood Compromise

- In September 2011 the League agreed to add emphasis to their reciprocal-mixing data. The first Product review with the testing change was April 2012.
- The League's reciprocal-mixing (RM) values should equal their pre-2007 noise-limited data, and my published noise-limited or IMD limited data.
- IC-7410 RM limited dynamic range = 78 dB
- Sherwood noise-limited DR3 = 78 dB
- The April 2012 IC-9100 review used the new reporting, and has a nice sidebar on page 55 explaining the changes.

Bob clearly explains importance RMDR

Note how reciprocal mixing relates to the two-tone third order DR figures, especially at 5 and 2 kHz spacing. A single, strong adjacent signal 5 or 2 kHz from the desired signal with resulting reciprocal mixing has a greater impact on your ability to hear a desired weak signal than do two strong signals 5 and 10 kHz away (5 kHz spacing) or 2 and 4 kHz away (2 kHz spacing) with a resulting intermodulation distortion (IMD) product that covers up the desired signal. In many cases, reciprocal mixing dynamic range is the primary limiting factor of a receiver's performance.

-Bob Allison, WB1GCM, ARRL Laboratory Engineer

Is ARRL 1-Hz filter method useful ?

- FTdx-3000 QST Review April 2013
- Third-Order Dynamic Range with 1 Hz testing method = 100 dB @ 2 kHz
- RMDR 82 dB @ 2 kHz
- The 100 dB number meaningless on the air.

AGC Impulse Noise Anomaly

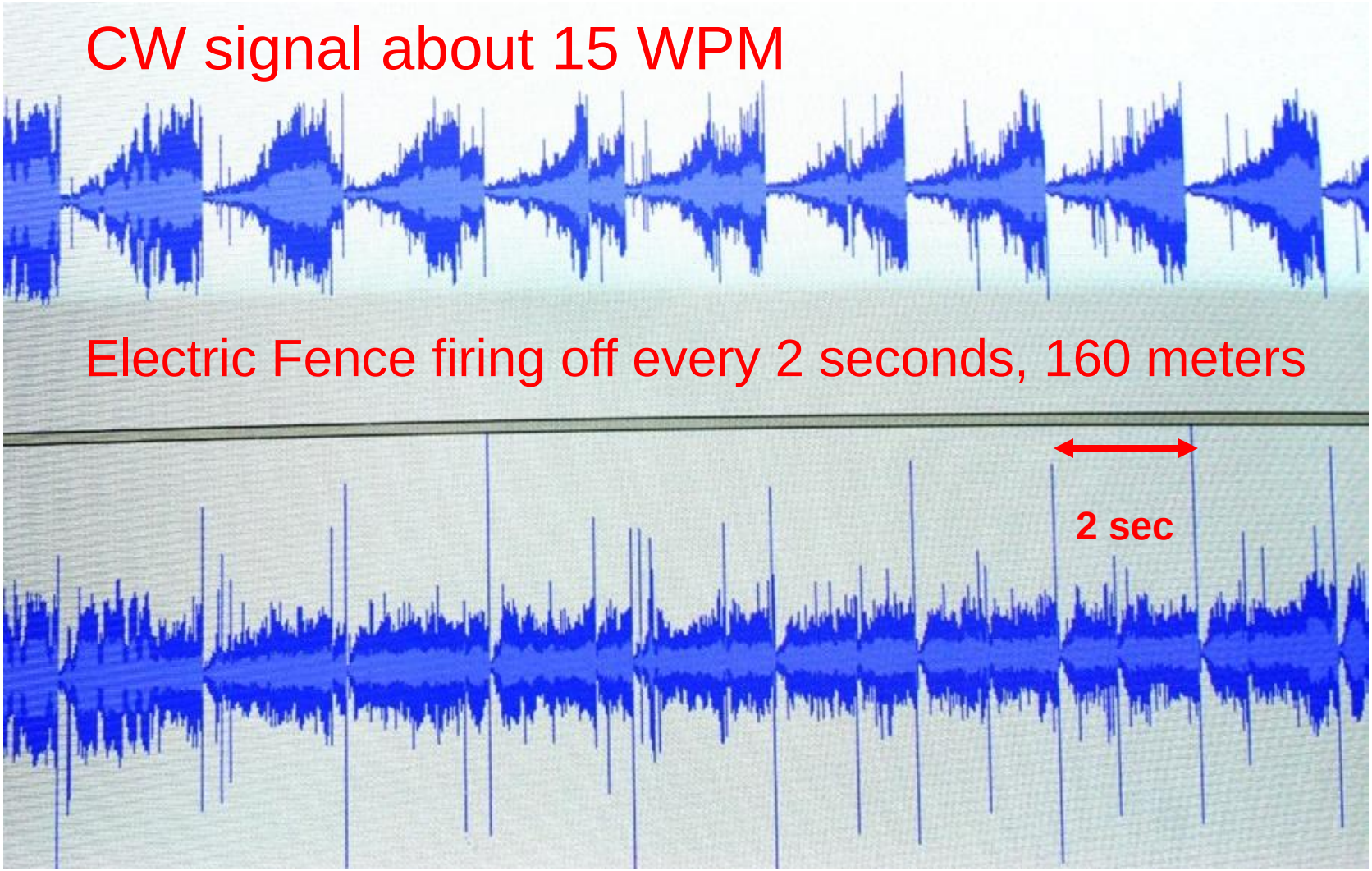
Most new radios since 2003 exaggerate impulse noise.

The exceptions: Elecraft K3, Flex 5000 & now Ten-Tec

Programmed DSP to ignore a tick, click or pop.

Elecraft calls it the Sherwood Test.

Omni-7 on Top - Pro III on Bottom



Listen to 30 second audio clip

- Audio Icom 756 Pro III
- 160 meters, 4 PM, Dec 13, 2008
- Electric fence & CW signals
- KV4FZ calling DX station
- Note volume level relatively constant

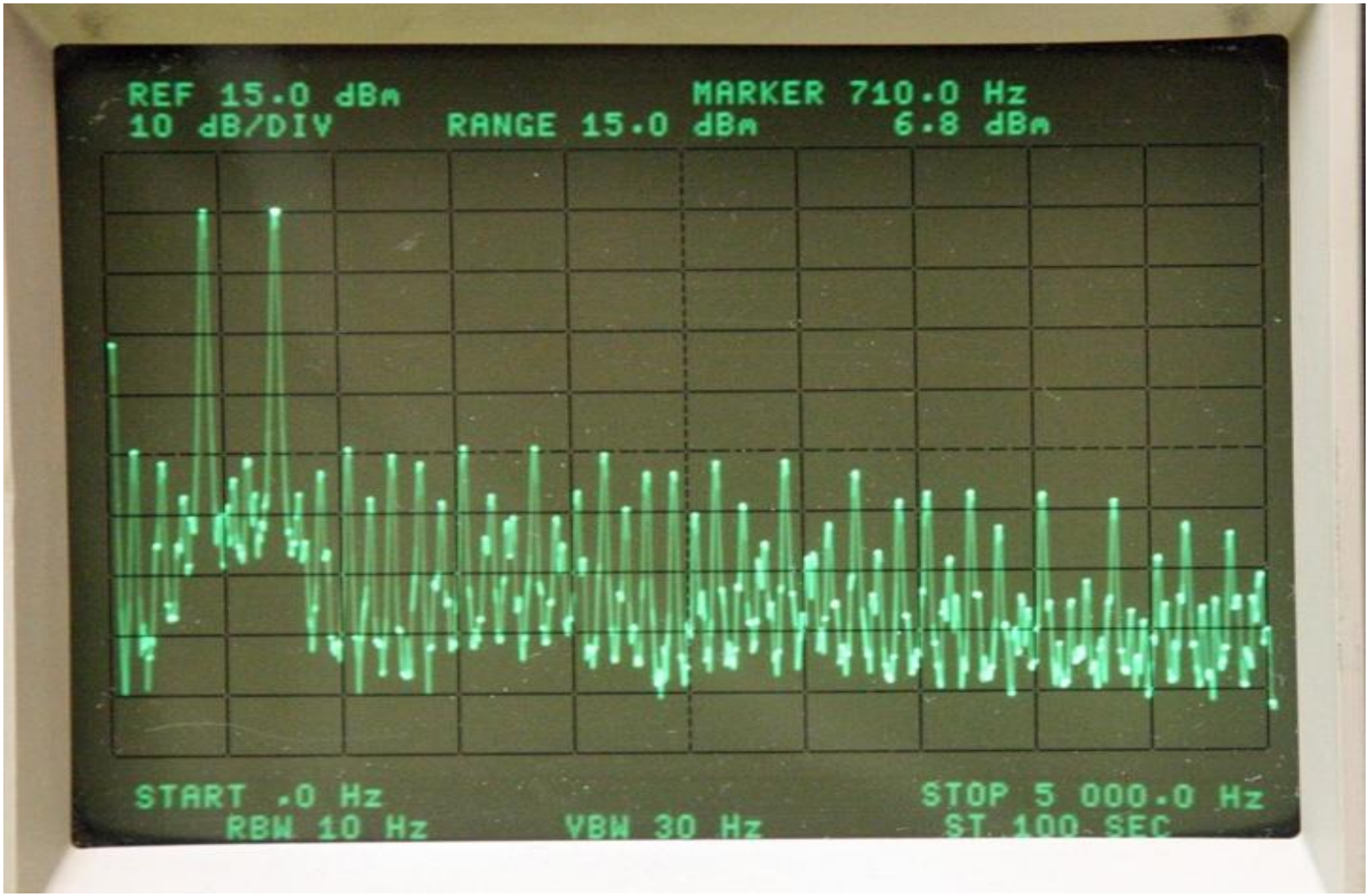
Audio clip with DSP AGC problem

- Audio Ten-Tec Omni-VII
- 160 meters, 4 PM, Dec 13, 2008
- Electric Fence & CW signals
- Exact same signals as with Pro III
- Note AGC being hammered by impulses
- No problem Elecraft, Flex and now Ten-Tec
- Other rigs with the same AGC problem:
- IC-7800, IC-7700, IC-7600 & IC-7000
- FTdx-9000, FTdx-5000, FT-950, TS-990S

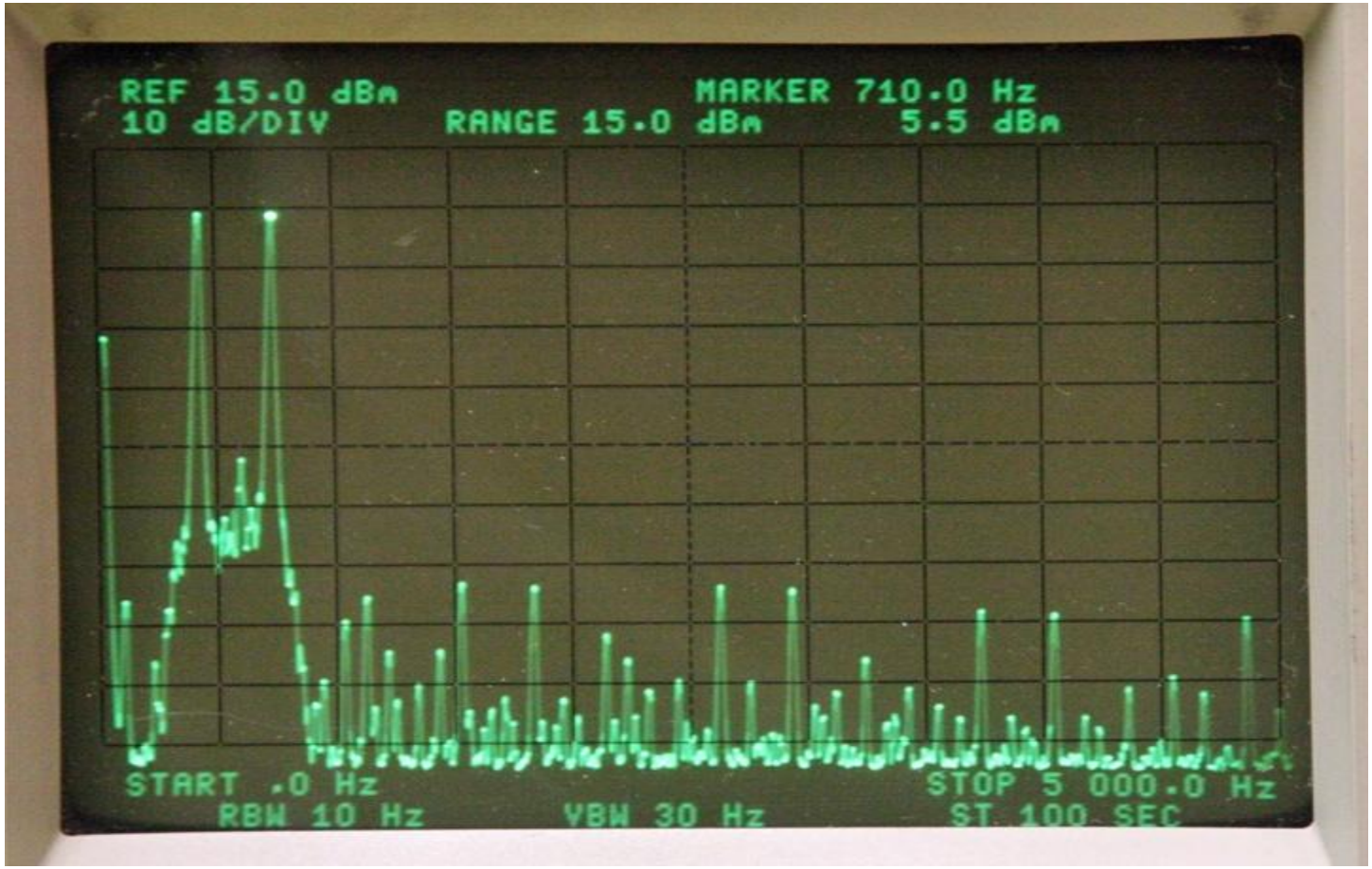
Contest Fatigue from audio artifacts

- In the “good old days”, a pair of 6V6s in push pull were common. Audio was smooth and pleasant.
- Often today receive audio is an after thought.
- The rig manufacturers need to be concerned about the noise and distortion beyond the 300 to 3000 Hz bandwidth. Our ears hear much more than 2700 Hz of bandwidth.

Screen shot from Elecraft Lab Fall 2008

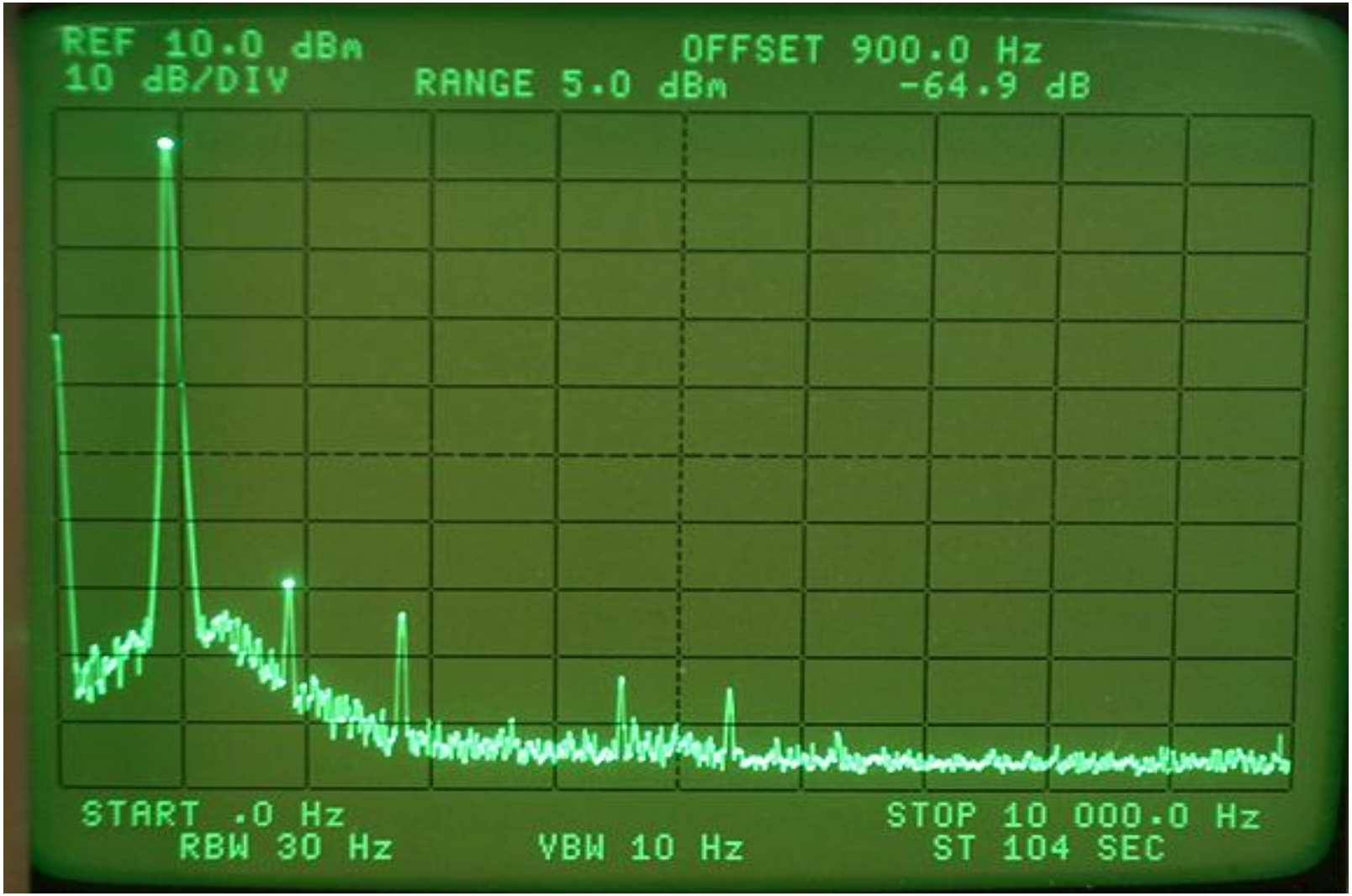


K3 After New Choke Installed



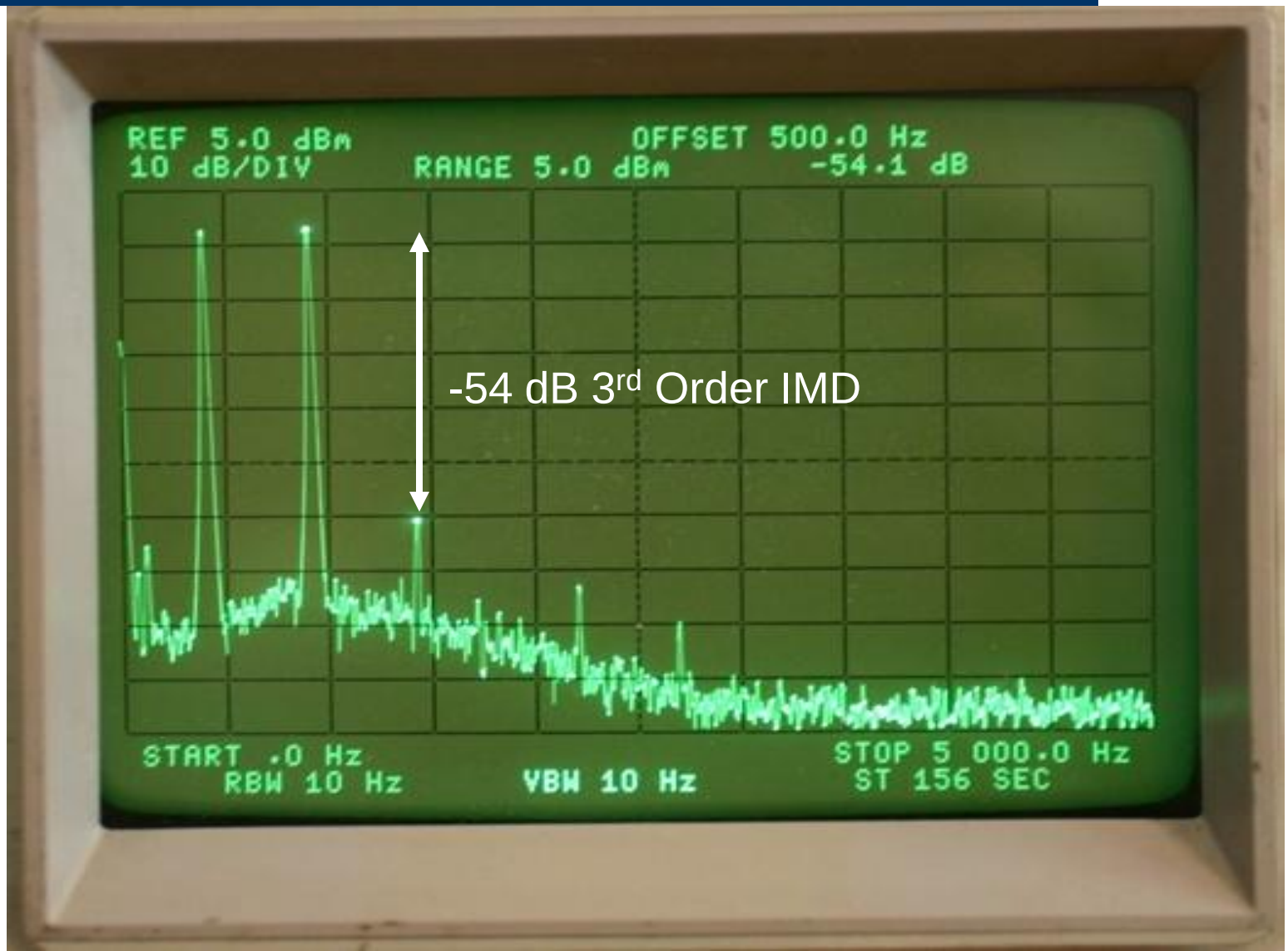
0.1 % distortion

Icom 756 Pro III Harmonic Distortion



< 0.3 % distortion

Icom 756 Pro III in-band IMD Distortion



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.

Areas needing improvement:

Transmit ALC, Transmit IMD & Receive AGC

In general, how a transceiver performs dynamically with real signals, not just in the lab with a signal generator.

Sherwood Engineering

http://www.sherwood-engineering.com

http://www.NC0B.com