

Roofing Filters, Transmitted IMD and Receiver Performance

Rob Sherwood
NCØB

What's important when it comes to
choosing a radio?

Why Did I Start Testing Radios ?

- Purchased a new Drake R-4C in 1975
- Used it during the ARRL 160m CW contest
- **Radio performed miserably, yet Specs Were Good**
- 70s: League expanded testing to include Noise Floor & Dynamic Range, new concepts for the amateur.
- R-4C tested well for Dynamic Range, but flunked CW contest 101.
- Was the wrong thing being tested or did the test not approximate a real amateur environment, especially a CW contest environment?

- **20 kHz Dynamic Range** test showed that in a multi-conversion radio, it was only testing the radio's front end.
- If the first IF was 6 - 20 kHz wide, be it at 5 MHz, 9 MHz or 45 - 70 MHz, the radio would overload in a CW pile up.
- **20 kHz test showed no hint of the problem**
- **Solution:** Place test signals close together so they pass through **1st IF Filter** → **the Next Amplifier** → **Mixer**
- Close-in dynamic range numbers are **ALWAYS** worse than the wide-spaced numbers, for a radio with a single wide roofing filter.

What 2 Numbers are Most Important for a CW Contester?

- **Noise Floor**
- **Close-in 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.

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

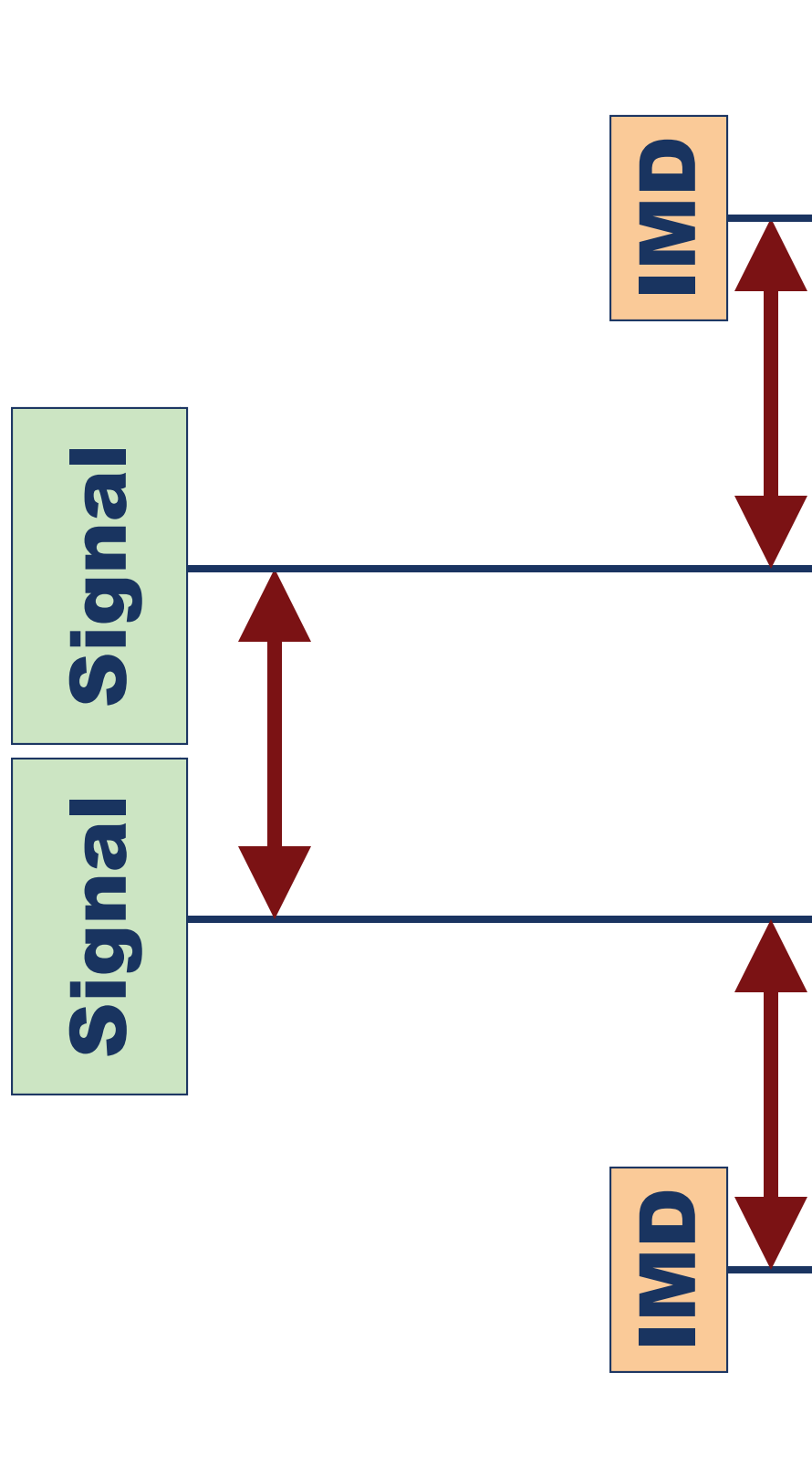
What is Dynamic Range?

What is **Close-in** Dynamic Range vs. **Wide-Spaced** Dynamic Range?

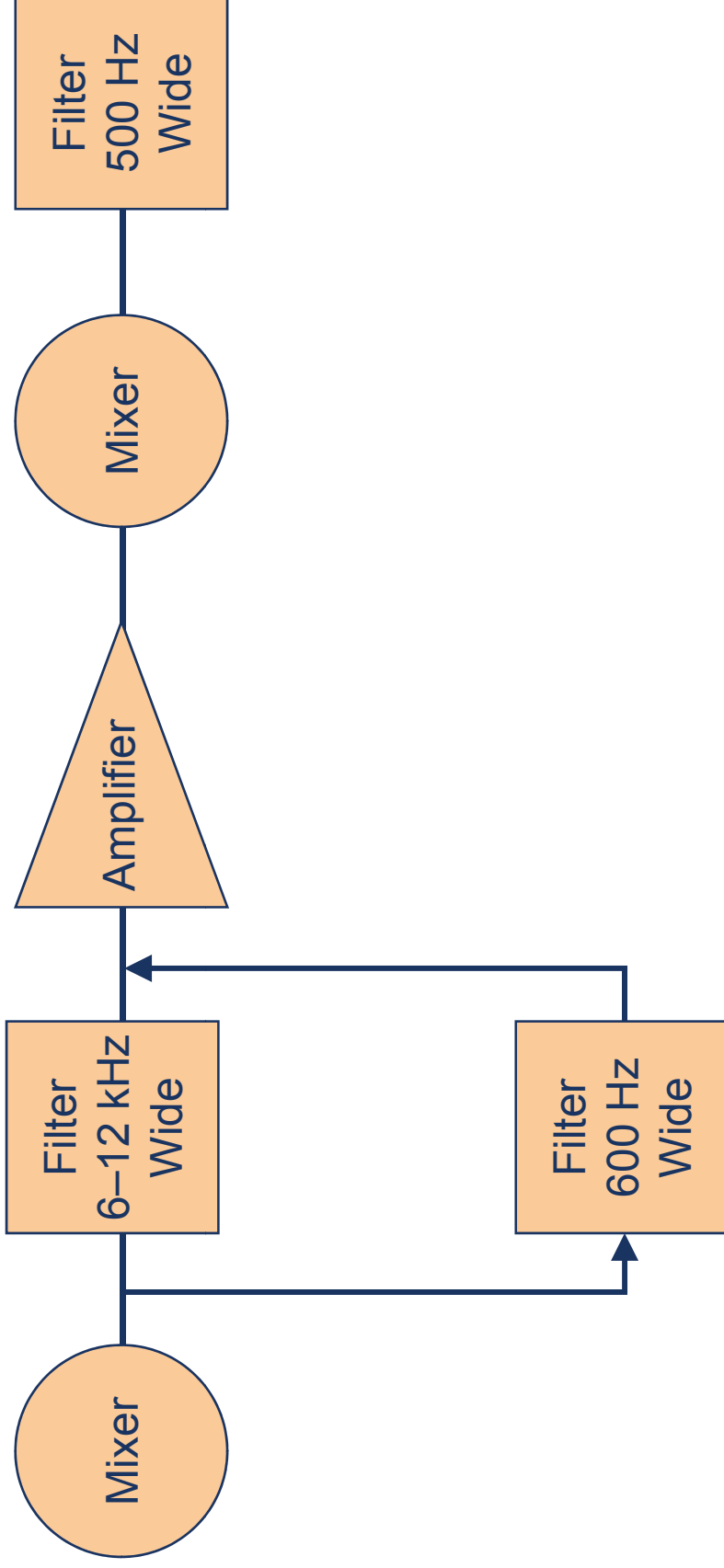
Why is **Close-in Dynamic** so important for CW ops?

Why is it less important for SSB operators?

Third Order IMD



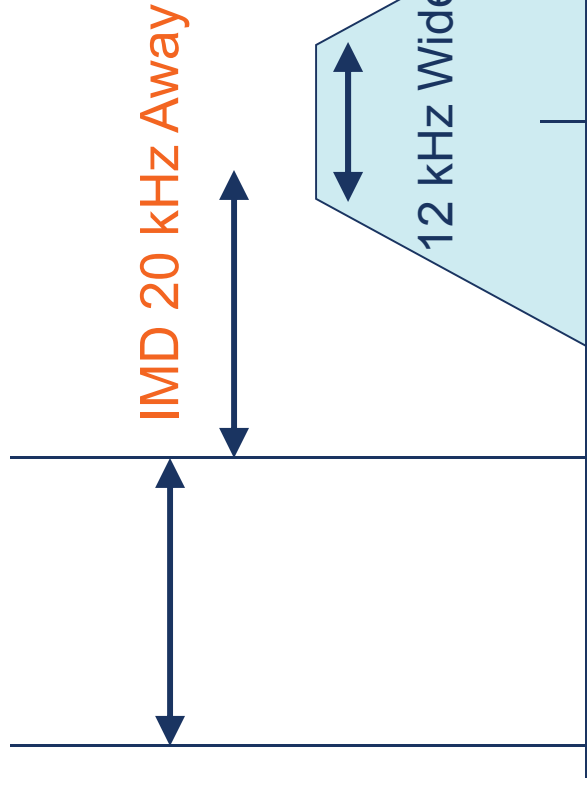
What if we could switch in a narrow Roofing Filter only slightly wider than the final selectivity?



This keeps the undesired strong signals from progressing downstream to the next stages ↵

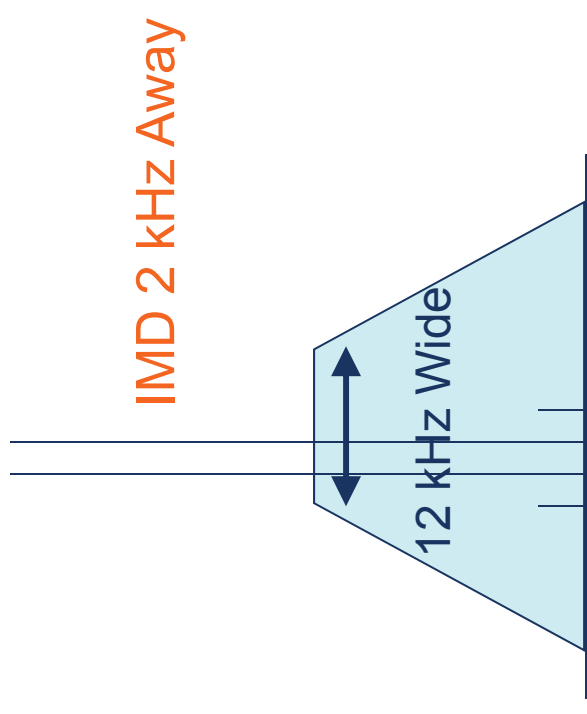
Wide & Close Dynamic Range

20 kHz Spacing



First IF Filter at 70.455 MHz

2 kHz Spacing



First IF Filter at 70.455 MHz

When are 2 Out of Pass Band Signals a Problem?

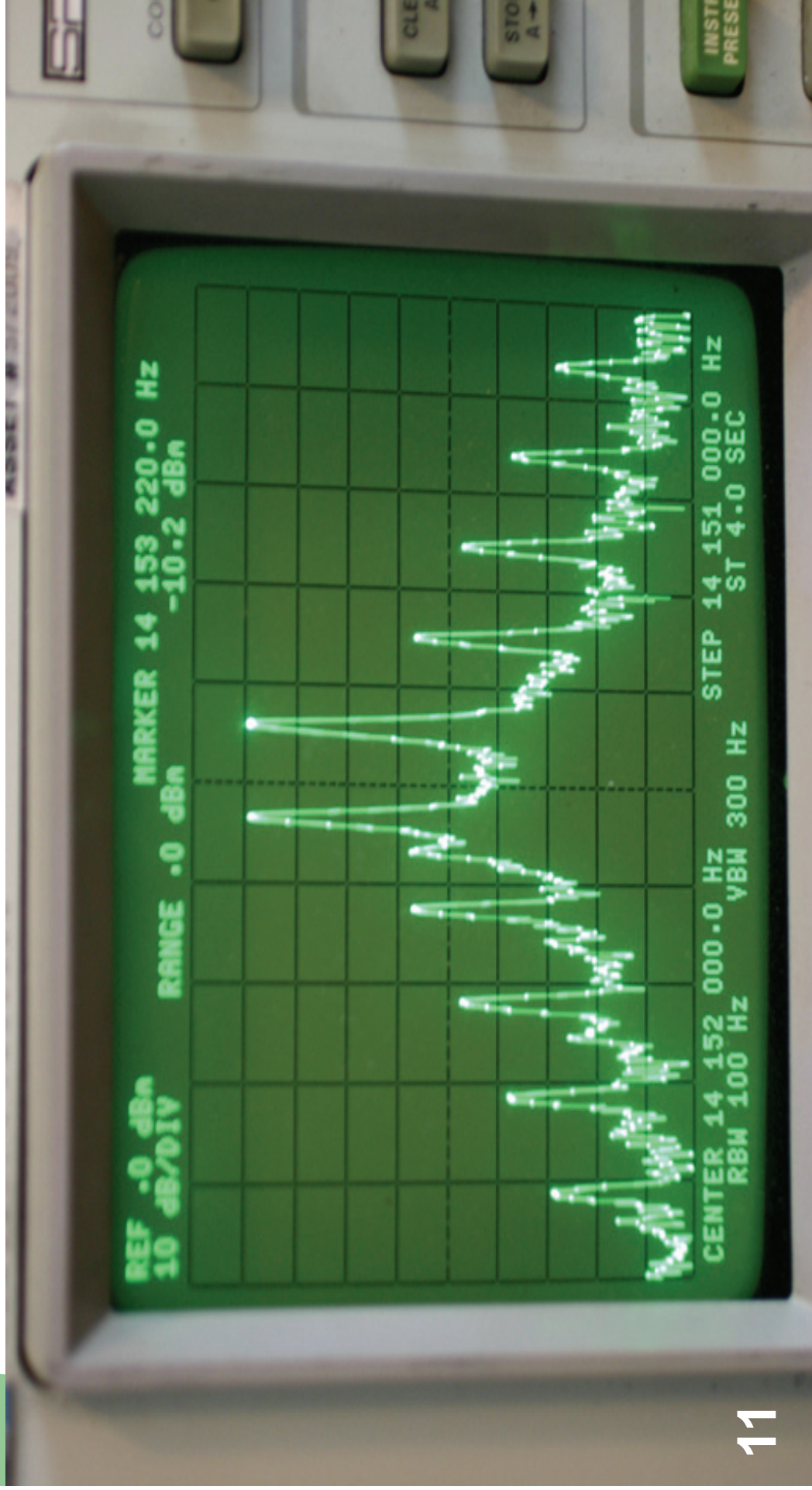
- If you know the close-in dynamic range of a radio, at what signal level will IMD start to be a problem?
- Assume $S_9 = 50 \mu\text{V}$ which is -73 dBm
- Assume a typical radio:

▶ **500 Hz CW filter** ▶ **Noise Floor of -128 dBm** ▶ **Preamp OFF**

Dynamic Range Signal Level Causing IMD = Noise Floor

55 dB	S9
60 dB	S9 + 5 dB
65 dB	S9 + 10 dB
70 dB	S9 + 15 dB
75 dB	S9 + 20 dB
80 dB	S9 + 25 dB
85 dB	S9 + 30 dB
90 dB	S9 + 35 dB
95 dB	S9 + 40 dB
100 dB	S9 + 45 dB

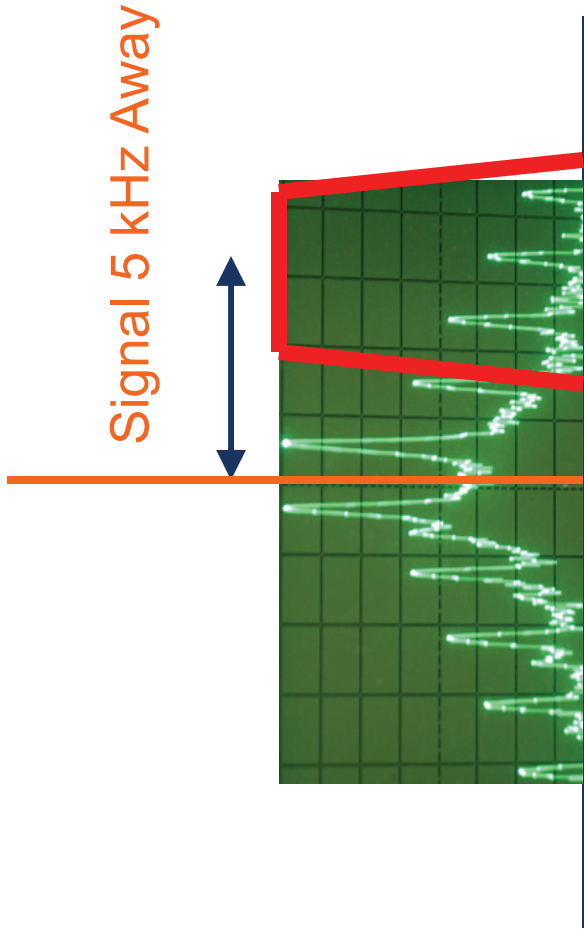
Transmitted IMD Collins 32S-3



Compare the Old vs. New

Order	Collins	Yaesu	Difference
IMD	32S-3	FT-450	in dB
3 rd	-39 dB	-30 dB	9 dB
5 th	-49 dB	-37 dB	12 dB
7 th	-59 dB	-42 dB	17 dB
9 th	-68 dB	-48 dB	20 dB

Close-in Signal and Splatter



IF Filter vs. Adjacent Signal and IMD Splatter

How Many Roofing Filters are Needed?

- It depends on your mode of operation.
- For SSB, a single 15 kHz roofing filter is adequate, such as in the Icom 756 Pro II / Pro III with a close-in dynamic range of 75 dB.
- Other radios, old and new with similar performance: Drake R7/TR7, Collins 75S-3B/C, Icom 781, TS-830/930, FT-1000X, T-T Omni-V
- Would a 3 kHz roofing filter be better? **Yes, a fairly new concept.**
- On CW, a single wide roofing filter is **not** adequate.
- CW signals do not have IMD products, thus strong adjacent signals do not have much energy in the CW passband of your filter.
- (Some key click and phase-noise energy may be heard.)

Conclusions

- Contesters – DXers – Pileup operators need the best receiver possible, especially for CW operation
- The Sherwood 600 Hz CW roofing filter fixed the R-4C in 1976, and the Ten-Tec Orion put that concept in a commercial design in 2003. Now the Elecraft K3 also offers multiple roofing filters of AM, SSB & CW bandwidths.

- 25 years of up conversion radios have generally offered a 20 kHz dynamic range in the 90s but a 2 kHz close-in dynamic range in the 70s. Typical degradation of dynamic range within the up conversion filter bandwidth is 25 dB.
- Now the buzz word is a 3-kHz roofing filter in up-conversion radios, though some are pure hype.
- IC-7800 3-kHz filter is 5+ kHz wide. FT-2000 3-kHz filter is 7 kHz wide, with worse IMD than its 6 kHz filter.



It is not possible to offer CW bandwidth Roofing Filters at VHF (up-conversion) frequencies.

The Orion II and the K3 roofing filters are in the 8 to 9 MHz range, similar to the R-4C at 5 MHz.

The only radios with no roofing filters at all are from Flex, like the 5000A. It basically converts everything to audio and filters it in DSP.

What dynamic range is possible and needed for CW?
80 dB or better @ 2 kHz.

1976 Sherwood / Drake R-4C: 84 dB

2001 Ten-Tec Omni-VI+: 80 dB

2005 Ten-Tec Orion II: 95 dB

2007 Flex 5000A: 96 dB

2007 Ten-Tec Omni-VII: 80 dB

2008 Elecraft K3: 101 dB (with 200 Hz roofing filter)

Other radios for comparison, 2 kHz data:

Kenwood TS-850S: 77 dB

Collins 75S-3B/C: 72 dB

Kenwood TS-870S: 69 dB

Yaesu FT-2000: 63 dB

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



Sherwood Engineering

<http://www.sherwood-engineering.com>

<http://www.NC0B.com>