Transceiver Performance for the 6m - UHF operator

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VHF / UHF vs. HF Rig Performance

What is Dynamic Range?

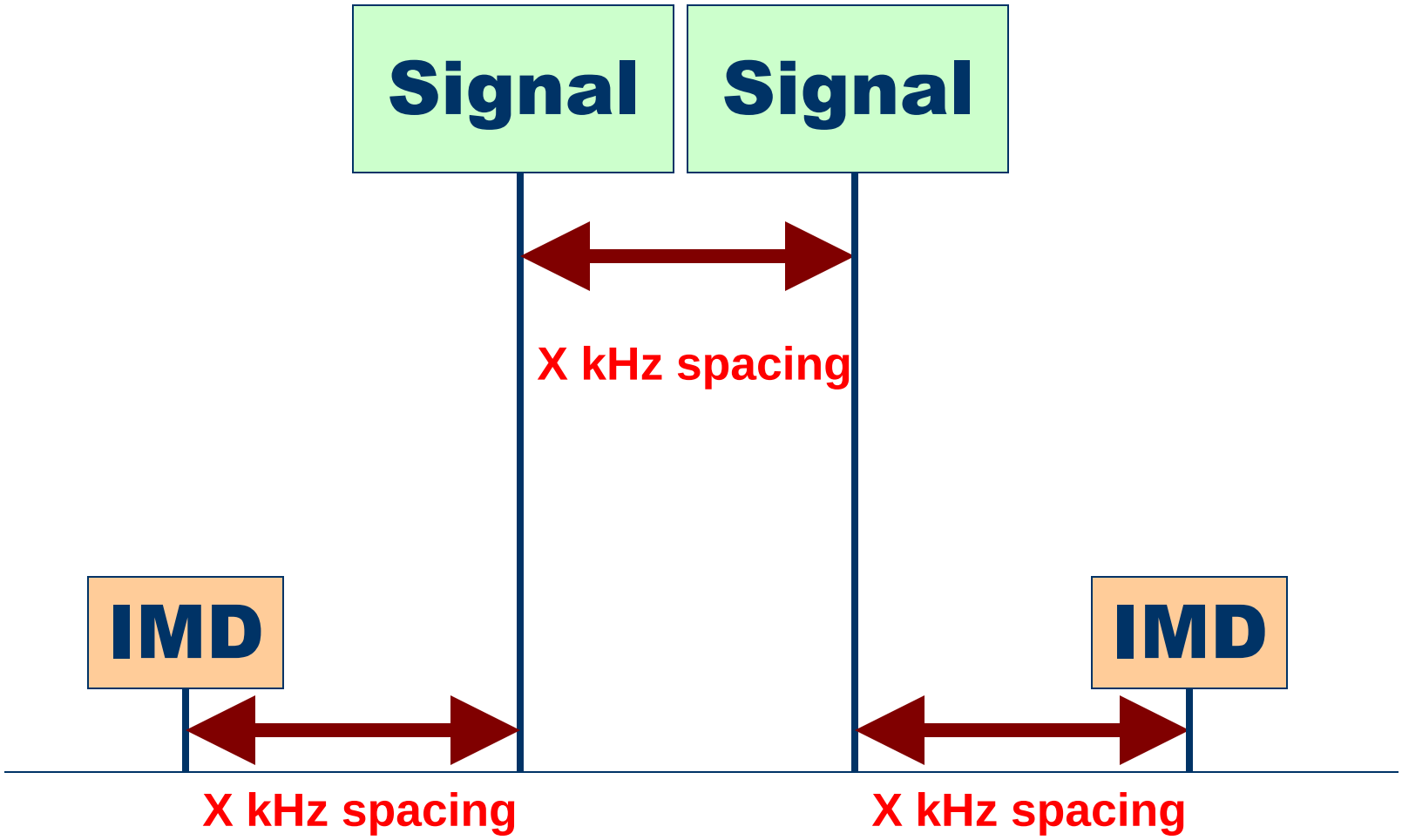
- Dynamic Range - measures the ability to hear weak signals in the presence of nearby strong signals.
- A 20 kHz Dynamic Range measurement in a multi-conversion radio only tests the radio's front end.
- Now that 6 meters is common on all new transceivers, we have a mixture of up and down-conversion products.
- Except for the Icom IC-7851, most up-conversion radios are a compromise in CW contests and DX pile-ups.
- VHF/UHF radios are decades behind HF in performance.
- **On 2 meters and up, performance is still mediocre. (Flex 6700 an exception on 2m, but needs a PA)**

What Numbers are Most Important in a multi-signal environment ?

- Close-in Dynamic Range (DR3)
- Noise floor
- Reciprocal Mixing Dynamic Range (RMDR)
- Transmitted broadband noise (phase noise)
- Noise floor much more important on 6m and above than at HF frequencies

No need to search for the third-order product

Third Order IMD mathematically defined



What is Third-Order Dynamic Range?

The range in dB of very strong signals to very weak signals that the receiver can handle At The Same Time without creating additional spurious in the receiver.

What is Close-in Dynamic Range vs.

Wide-Spaced Dynamic Range?

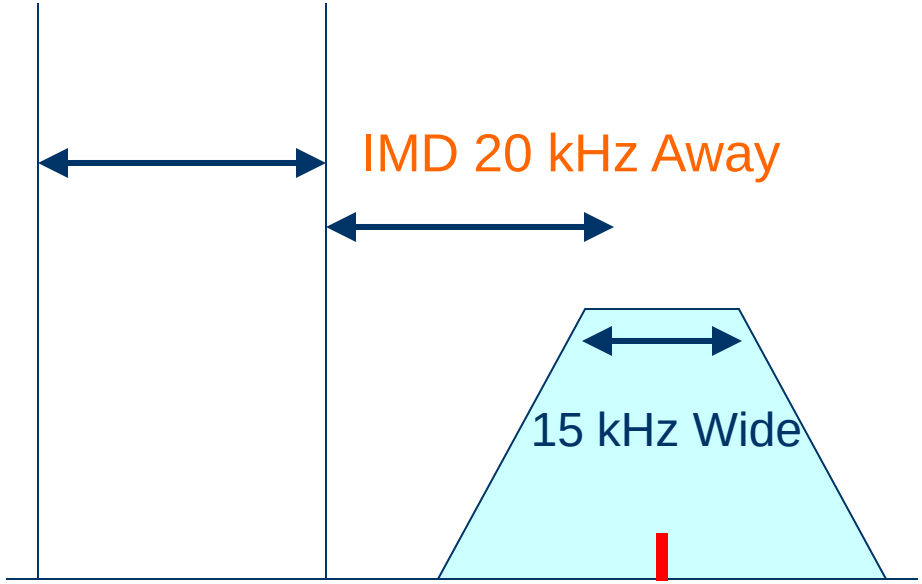
Why is Close-in Dynamic more important for CW ops?

Transmitted splatter may be more important for SSB operators.

Example of an up-conversion radio

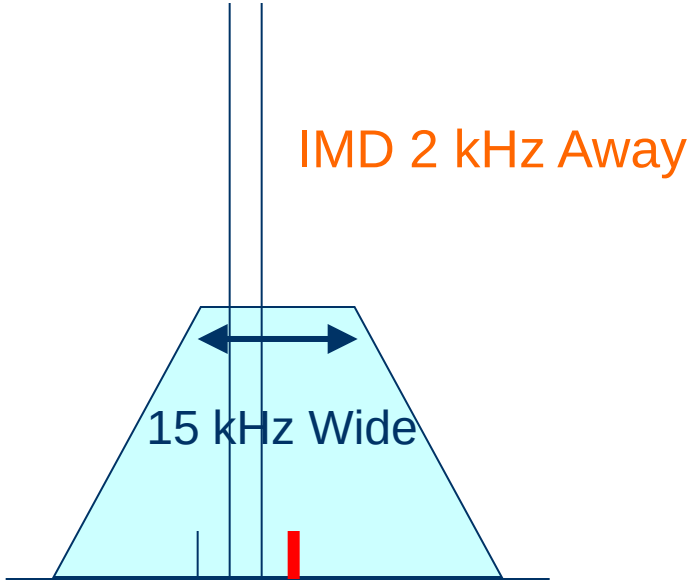
Wide & Close Dynamic Range

20 kHz Spacing



First IF Filter at 70.455 MHz

2 kHz Spacing



First IF Filter at 70.455 MHz

What are roofing filter limits for legacy radios?

Fractional bandwidth of the filter is a big issue.

It is easy to make a narrow IF filter at 9 MHz, but not at 60 to 70 MHz

Most VHF / UHF radios have a single high-frequency first-IF filter.

Same problem for many HF radios that cover 6 meters.

The wider the roofing filter, the more likely overload.

Examples:

TS-590S/SG on 6 meters on CW where desense or intermod can occur.

Same problem with IC-756 Pro, Pro II or Pro III

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 figure is not filter bandwidth dependent.

15, 10 & 6 meter antenna noise gain

Rig = Icom IC-756 Pro III

6 meter antenna = Ariane C5-50 @ 50 feet

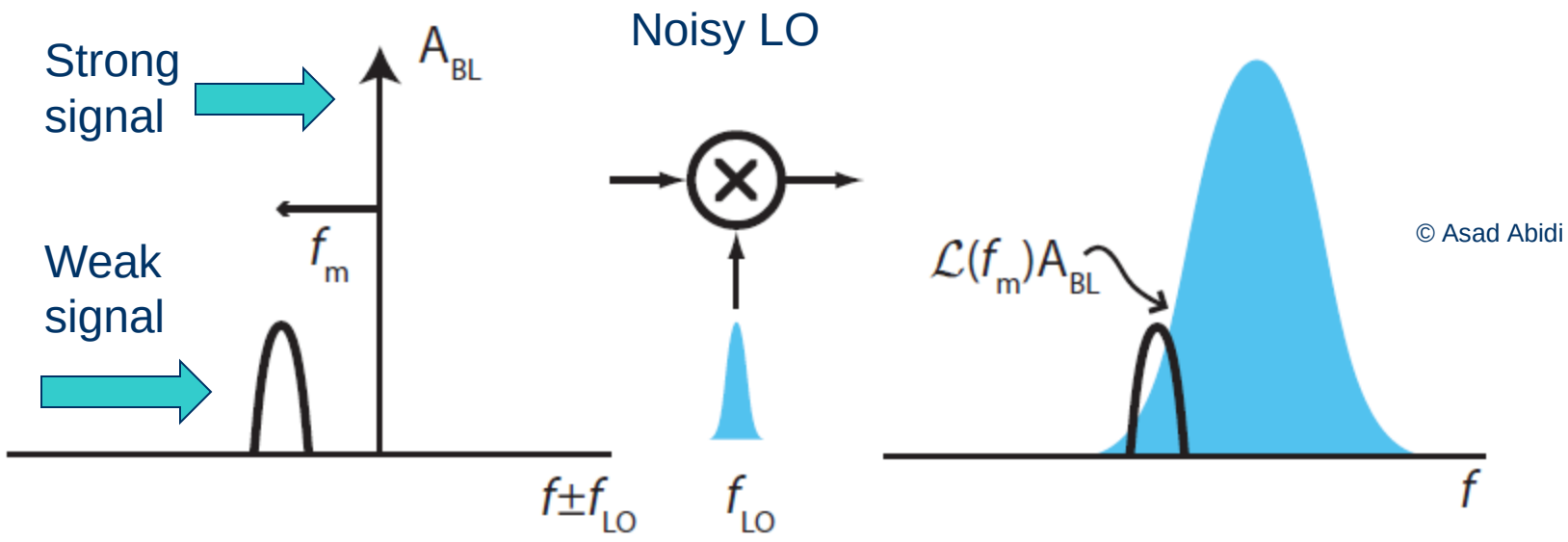
10 meter antenna = Hy-gain 105CA @ 65 feet

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

Preamp	15m	10m	6m
None	4 dB	3 dB*	1 dB
Preamp 1	11.5 dB	9.5 dB	4.5 dB
Preamp 2	13.0 dB	11.0 dB	9.5 dB

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

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” superheterodyne transceivers, plus “direct-sampling SDR”* radios have RMDR > DR3.

- Elecraft K3 w/ new synthesizer, K3S or KX3
- Hilberling PT-8000A
- Icom IC-7851 & IC-7300*
- Flex 6700*, 6500* & 6300*
- Apache ANAN-200D* & 8000DLE*

Performance up through 6 meters

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 6700 & 6500
- Elecraft K3S & K3 with new $200 synth
- Apache ANAN 8000DLE
- Unfortunately above 6m performance drops

All cover 6 meters

Close-in 2-kHz Test @ 500 Hz BW

Dynamic Range of Top 13 Transceivers on Sherwood website

• Elecraft K3S	106 dB	
• Icom 7851	105 dB	
• Hilberling	105 dB	
• Elecraft KX3	104 dB	(Opposite sideband limited)
• FTdx-5000D	101 dB	
• Flex 6700	99 dB	(preamp OFF)
• Apache 200D	99 dB	(New clock update)
• Flex 5000	96 dB	
• Elecraft K3	95 dB	(original synthesizer)
• Icom 7300	94 dB	(81 dB with IP+ OFF)*
• TS-590SG	92 dB	
• TT Eagle	90 dB	
• Flex 6300	89 dB	

* Do not recommend using IP+ on 20 – 6 meters due to noise floor degradation

What happens above 6 meters?

- Since all new transceivers now cover 6 meters, performance at HF is maintained through 6 meters.
- Sadly as we move to 2m and above, it is a very different story.
- Dynamic range and RMDR plummets, plus transmit intermodulation (splatter) easily degrades 10 dB or more.

IC-9100 DR3 & RMDR 144 & 432 MHz

Example 2 Meters 70 cm

Spacing	DR3	RMDR	DR3	RMDR
20 kHz	91	91	85	82
10 kHz		86		76
5 kHz		75		63
2 kHz		64		55

(From RSGB – Peter Hart Values in dB)

Phase noise (RMDR) clearly dominates close-in performance

HF vs. VHF/UHF Transceiver Performance

Icom IC-9100 test data example:

20 kHz numbers at VHF/UHF are similar to many HF transceivers today.

At 2 kHz, on 2m and above, the RMDR performance would be near the bottom of my chart of over 100 transceivers.

Compare IC-275H (1987) & IC-9100 (2012)

IC-275H (2 meters)

DR3 20 & 2 kHz		RMDR 20 & 2 kHz	
85 dB	63 dB	98 dB	74 dB

IC-9100 (2 meters)

DR3 20 & 2 kHz		RMDR 20 & 2 kHz	
92 dB*	69 dB*	92 dB	65 dB

*Measured 500 Hz. All others in 2400-Hz BW

275H data NC0B

9100 data VA7OJ

Dynamic Range numbers vs. band

Yaesu & Kenwood Receiver Data - QST

Freq MHz	FT-847 DR3 in dB	FT-897 DR3 in dB
50 MHz	89 dB @ 20 kHz	89 dB @ 20 kHz, 68 dB @ 5 kHz
144 MHz	88 dB @ 20 kHz	85 dB @ 20 kHz, 64 dB @ 5 kHz
432 MHz	85 dB @ 20 kHz	82 dB @ 20 kHz, 63 dB @ 5 kHz

Note: FT-897 DR3 is 20 dB worse at 5 kHz vs. 20 kHz.

Freq MHz	TS-2000 DR3 in dB
50 MHz	94 dB @ 20 kHz, 69 dB @ 5 kHz
144 MHz	89 dB @ 20 kHz, 65 dB @ 5 kHz
432 MHz	86 dB @ 20 kHz, 69 dB @ 5 kHz

Note a similar drop-off at 5 kHz for the Kenwood.

50 MHz – 1296 MHz Reception Limits

Do you operate mostly SSB? Show of hands

While transmit IMD isn't particularly clean on HF, it is even worse on VHF / UHF.

On HF, most SSB third-order products with 13.8 volt PAs are around 35 dB below PEP. (-29 dBc)

On 2 meters and 70 cm, IMD at -26 dB is common.

ARRL data, IC-275A, IC-910H & IC-9100 -26 dB +/- 1 dB are the published numbers on 2 meters.

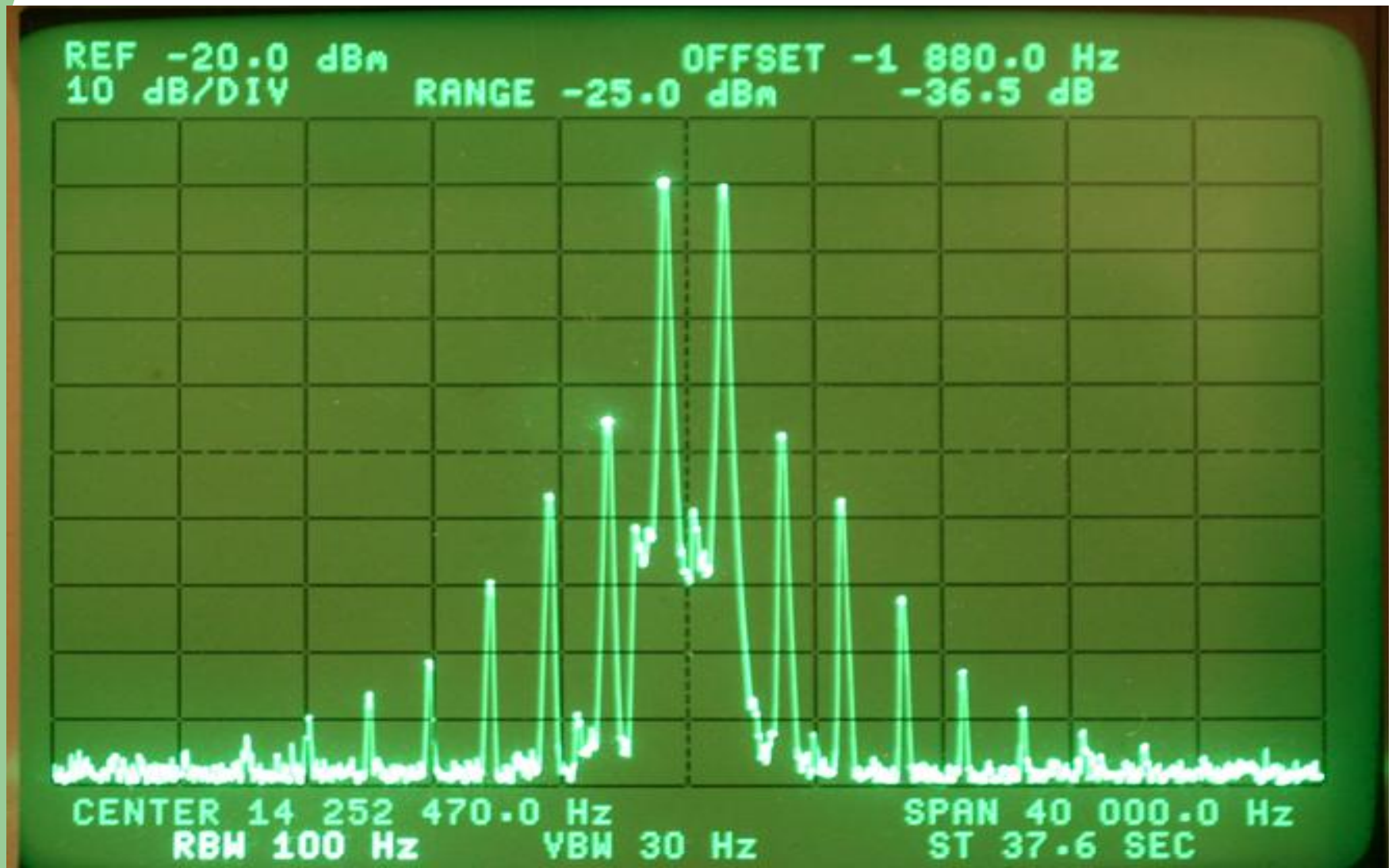
26 dB below PEP = -20 dBc referenced to one of two equal test tones.

Cleanest transmitter I ever owned !

Third order down -36 dBc

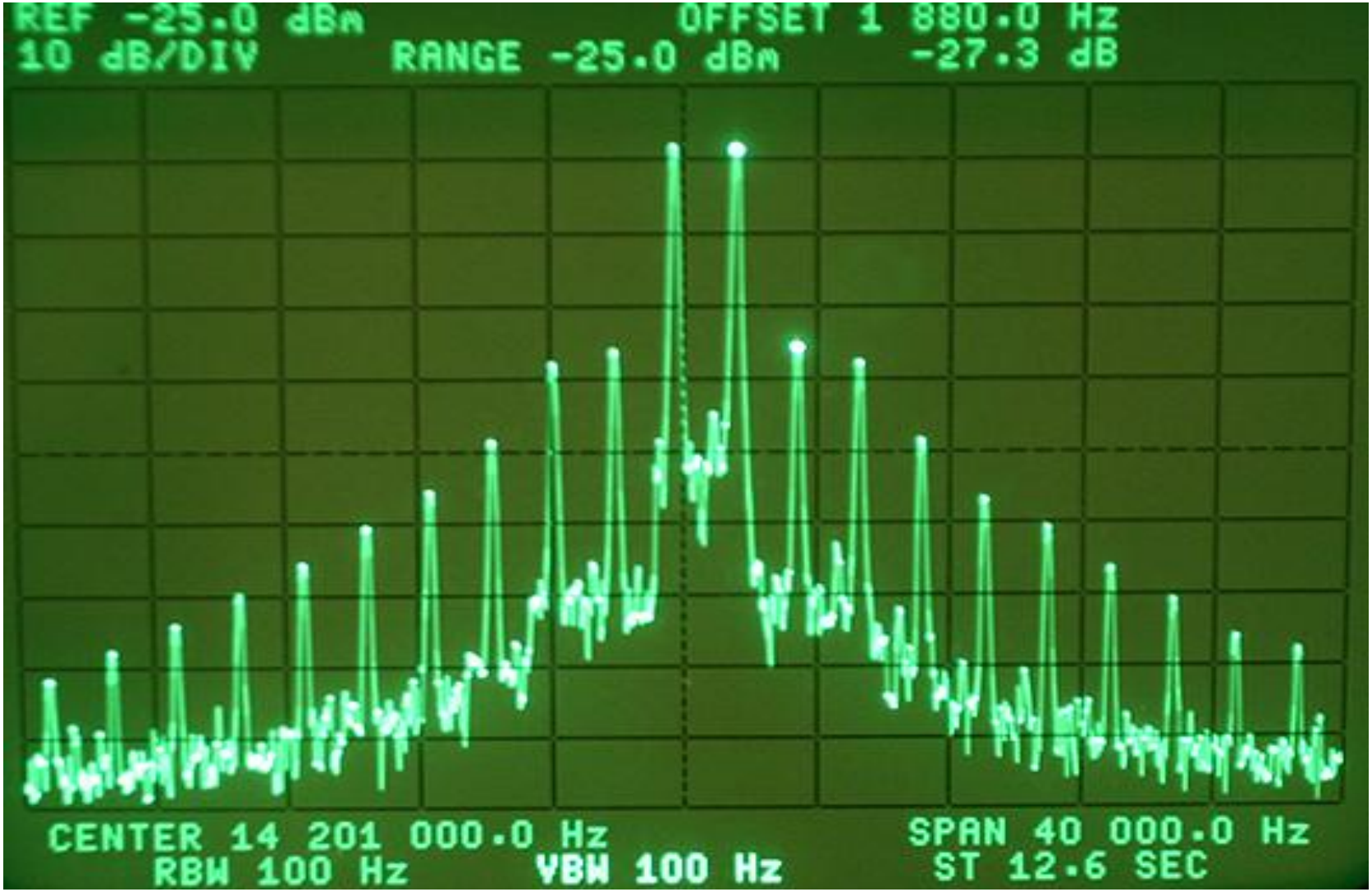
7th order down -60 dBc

Transmitted IMD Collins 32S-3



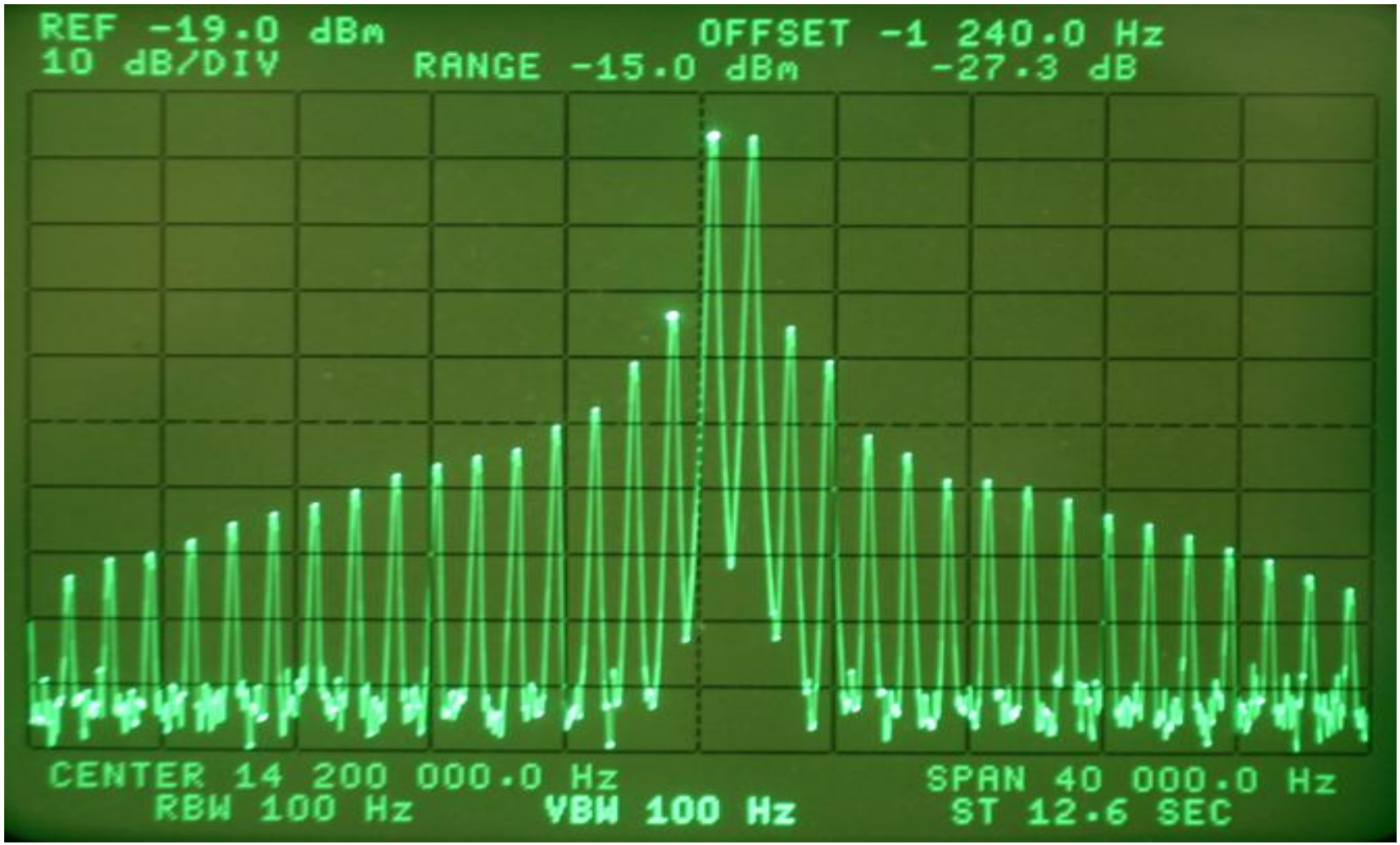
-27 dBc 3rd order, 40 dBc 7th order

Icom 756 Pro III on 20 meters @ 70 W



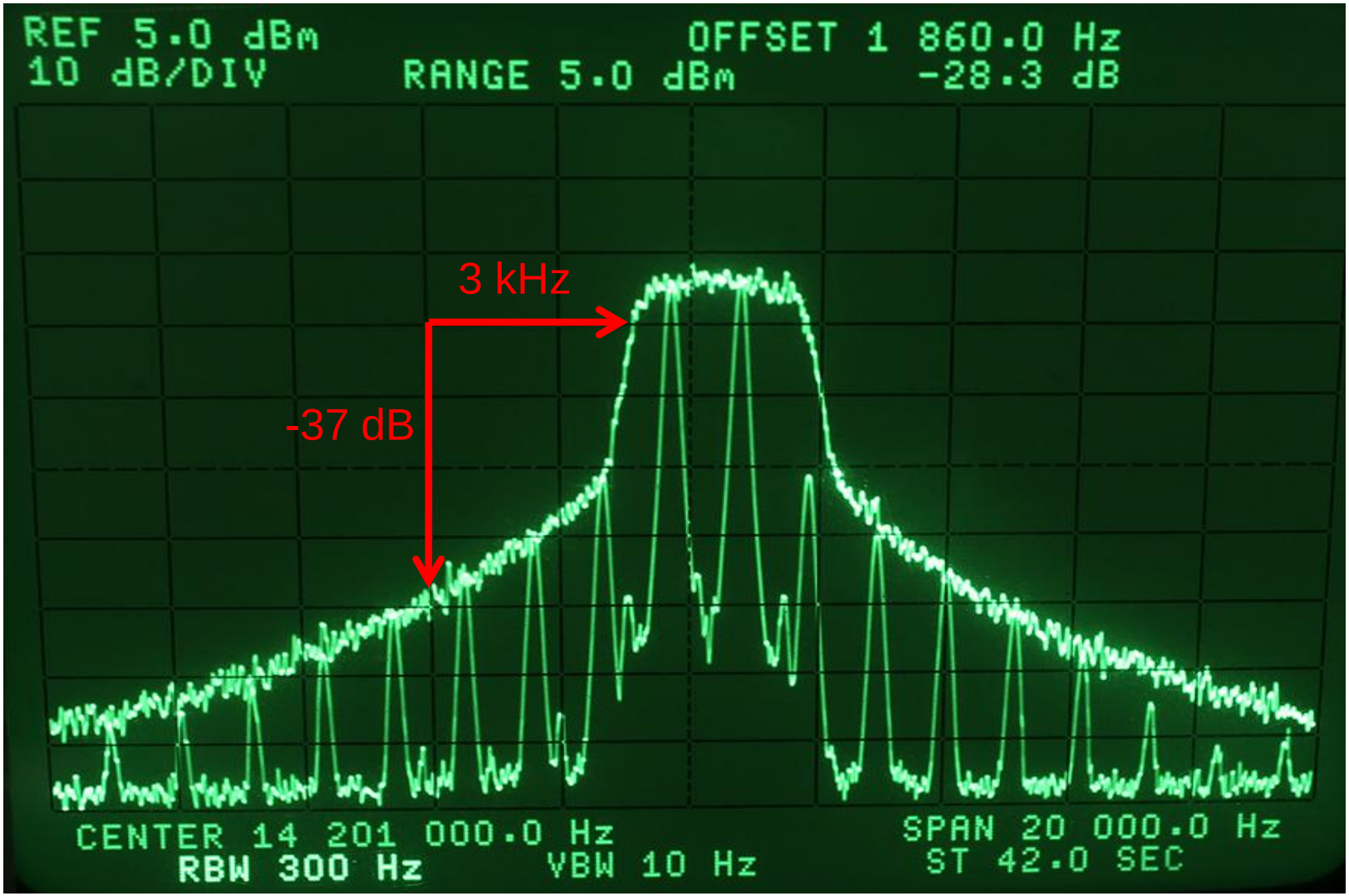
Third order IMD down only -27 dBc

Elecraft K3 on 20 meters



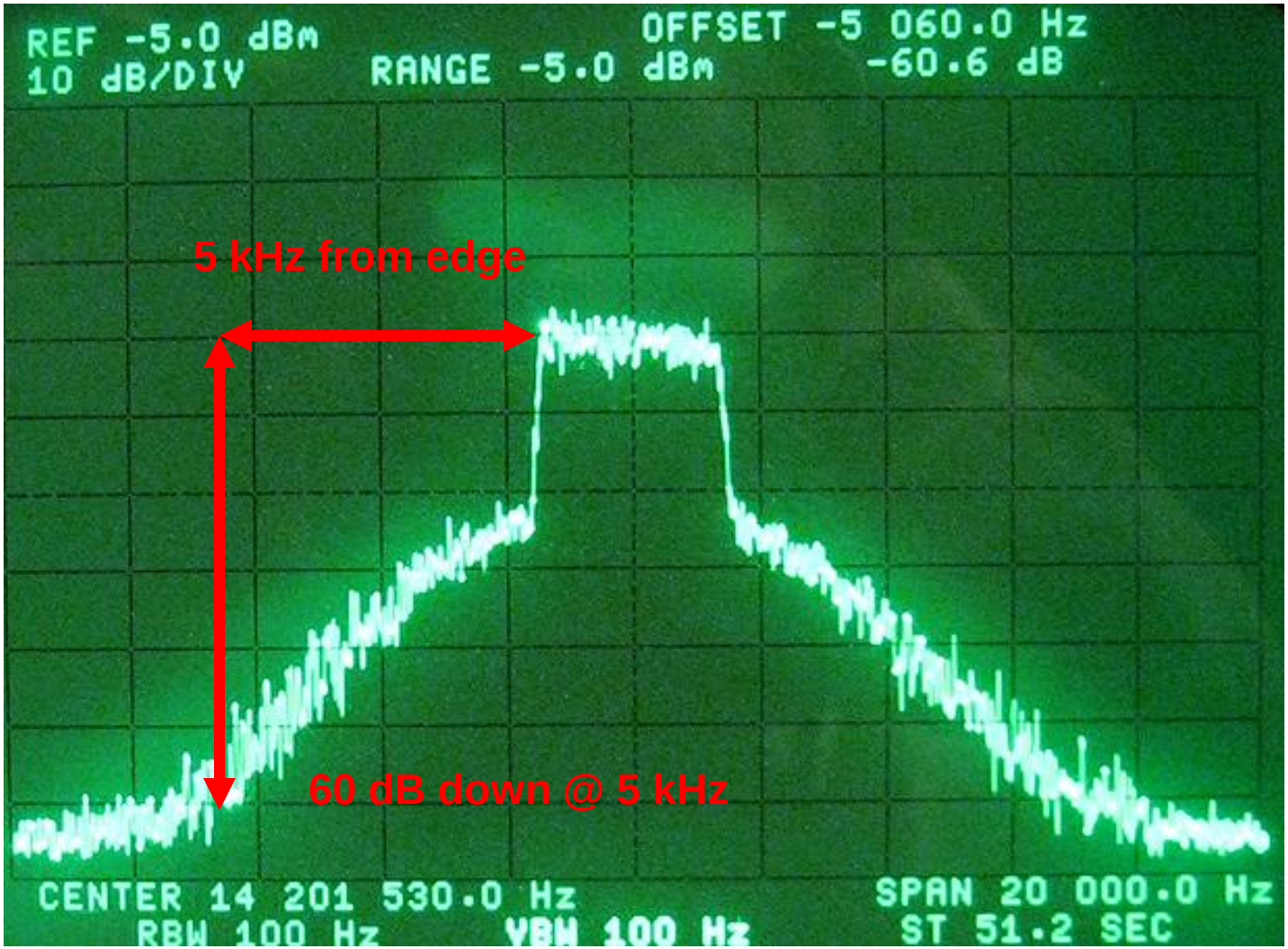
How Wide Is Your Signal ?

Comparison 2-Tone vs. Noise Intermodulation Bandwidth



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

Icom IC-7410 Class AB, White Noise



Yaesu and Kenwood Transmit Data

Third-order IMD measured dBc (Add 6 dB for PEP method)

Freq MHz	FT-847	FT-897	TS-2000
50 MHz	-33 dBc	-21 dBc	-14 dBc
144 MHz	-24 dBc	-18 dBc	-16 dBc
432 MHz	-22 dBc	-26 dBc*	-23 dBc*

Third-order numbers in the teens are unacceptable.

You really want to be at least -27 dBc (typical HF #s)

* Lower power on 432 MHz than 144 MHz

1 dB Compression Point is Critical

Watch your linear amplifier specs CW vs. SSB

Beko HLV series solid-state linear amps, 6m, 2m & 70cm
(Beko is just an example since I have tested the 2m version.)

The amps imply the power rating on SSB is near 1 KW, but the specified 1 dB compression point is also about 1 KW.

In the case of the tested HLV-1000 2m amp, the third-order IMD is excellent at 400 watts PEP, acceptable at 500 watts PEP, but seriously degrades at 600 watts PEP. Unusable at 1 KW PEP.

•Specs from Beko website

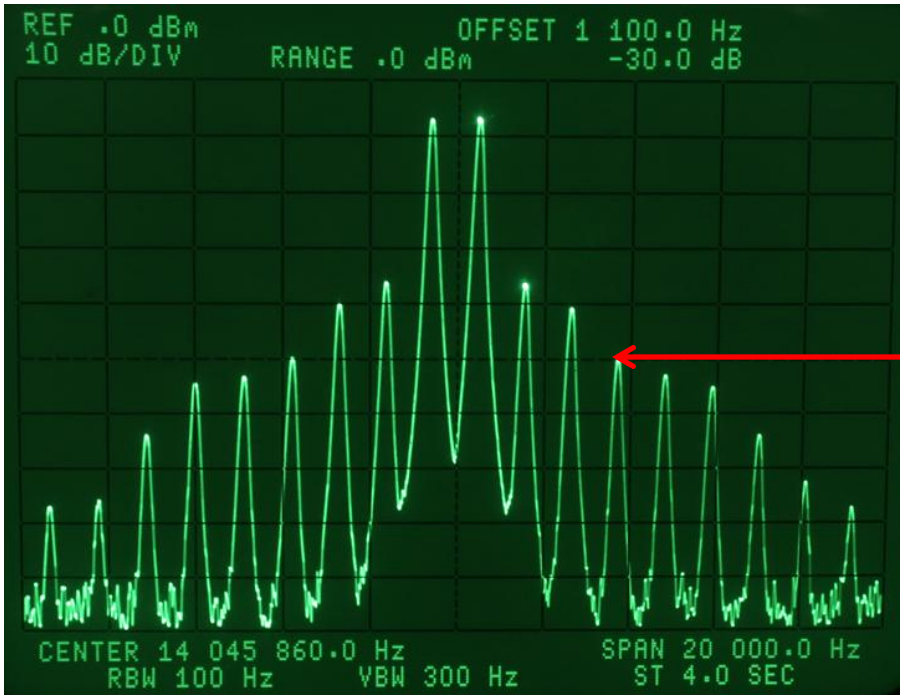
•1,000 watts RF Output SSB/CW/Digital Modes/FM (** 1100 watts typical**)

* Output Transistors: NXP BLF188XR

* 1 dB Compression Point > 1050 W

What dominates on 6-meter SSB? Splatter or DR3?
Measured 3rd order IMD -30 dBc (-36 dB PEP method)

Close-in Signal and Splatter



Splatter dominates unless the PA is class A.

Weaker Signal 5kHz Away

-43 dB, 7th Order dBc

(-49 dB PEP method)

Typical up-conversion radio DR3 = 70 dB

With many receiver DR3 or RMDR values over 90 dB, splatter is almost always stronger than the receiver limit.

Will other transceiver OEMs offer pre-distortion?

Is there hope for cleaner SSB signals?

Pre-distortion is likely the only solution for a significant improvement.

At present only Warren Pratt's PureSignal pre-distortion software is in production for the Apache ANAN series transceivers.

A high-power linear amplifier can also be included in the pre-distortion loop.

2017 PureSignal with a legal-limit PA has 3rd order as good as -70 dBc !

At least three amplifier OEMs are including a -60 dB sampler to feed a correction signal back to the exciter.

Amps with a built-in sampler output:

Elecraft KPA1500
Flex PowerGenius XL
Hilberling HPA-8000B

PURESIGNAL RESULTS

Mike, N1JEZ

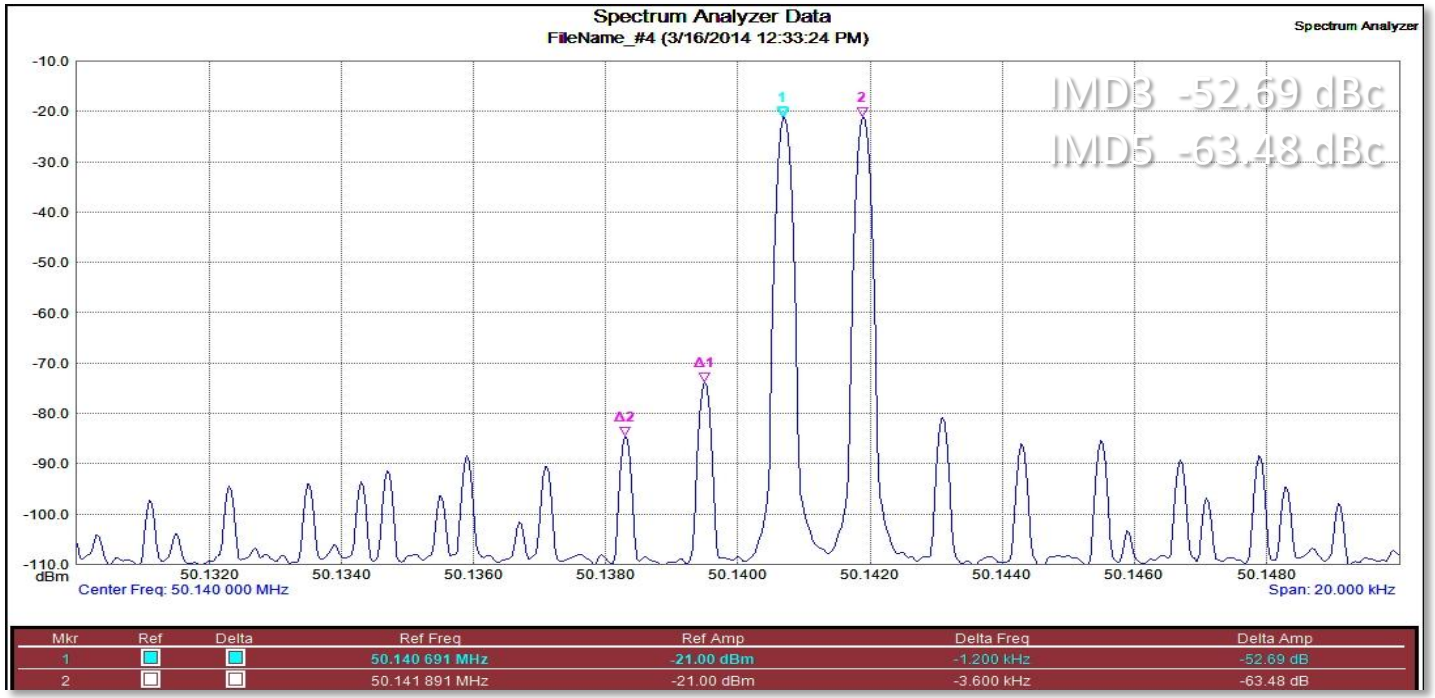
Pre-Distortion results with RF sampler at output of Acom linear amp

ANAN-100

ACOM-1006

3rd order -52 dBc

5th order -63 dBc



Compare to a MK V in class A and an 8877 amp at -40 dBc

CW signal bandwidths

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

How does CW compare?

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

At least on 6m, performance is often as good as HF.

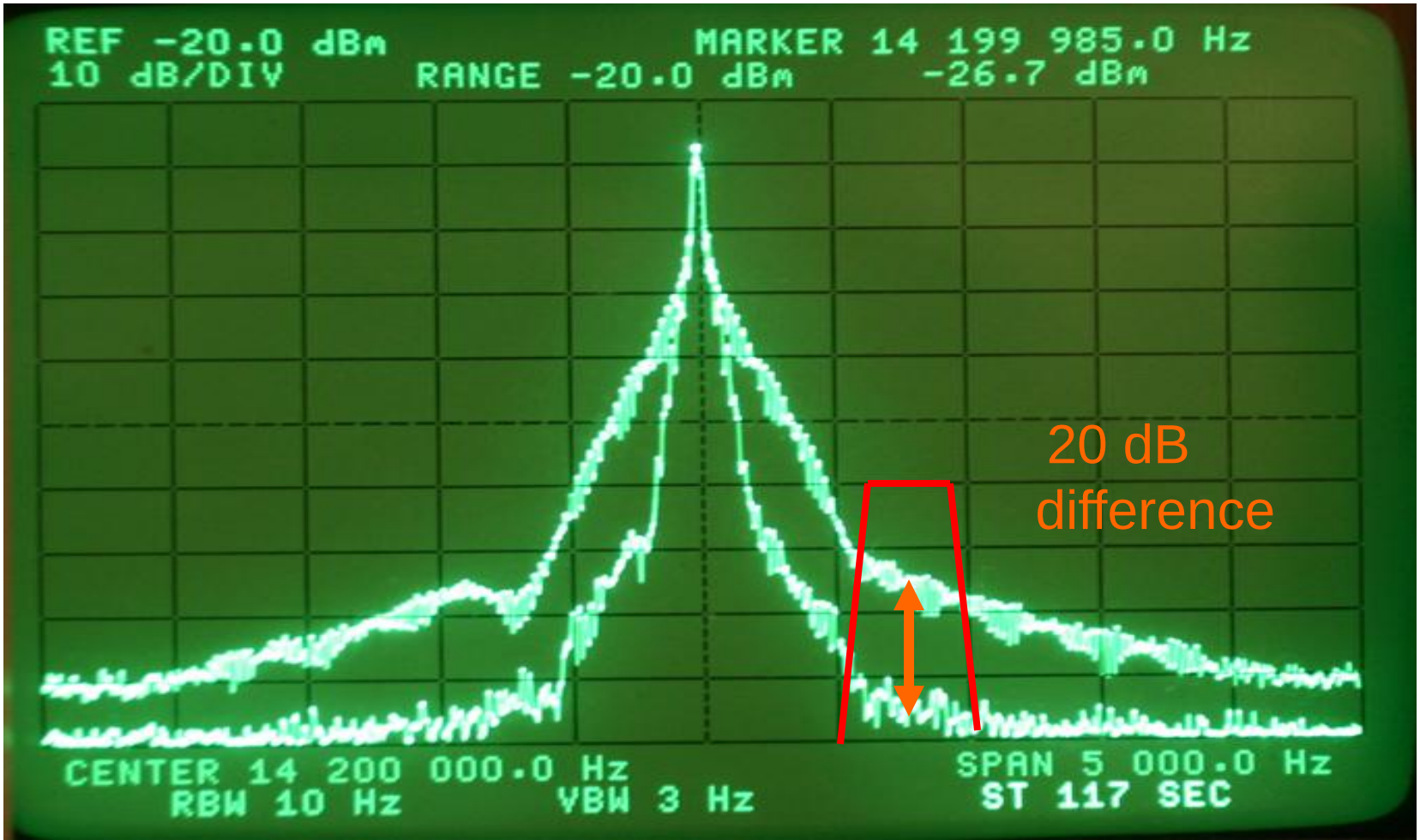
What is the Bandwidth of CW Signal?

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

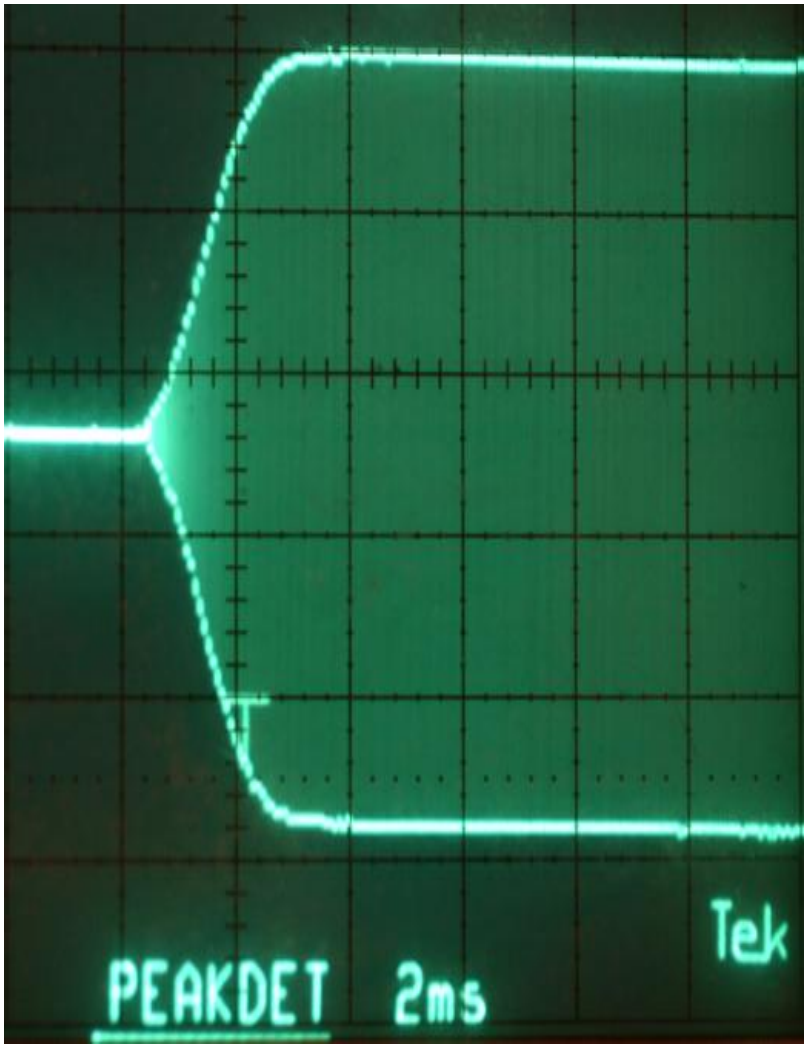
Rise time of Omni-VII	Strength of CW sidebands		
Signal	S9 + 40	-33 dBm	Ref
3 msec	S7	-83 dBm	-50 dB
4 msec	S6	-88 dBm	
5 msec	S6	-88 dBm	
6 msec	S5	-93 dBm	22 dB !
7 msec	S4	-99 dBm	
8 msec	S4	-99 dBm	
9 msec	S4	-99 dBm	
10 msec	S3	-105 dBm	-72 dB

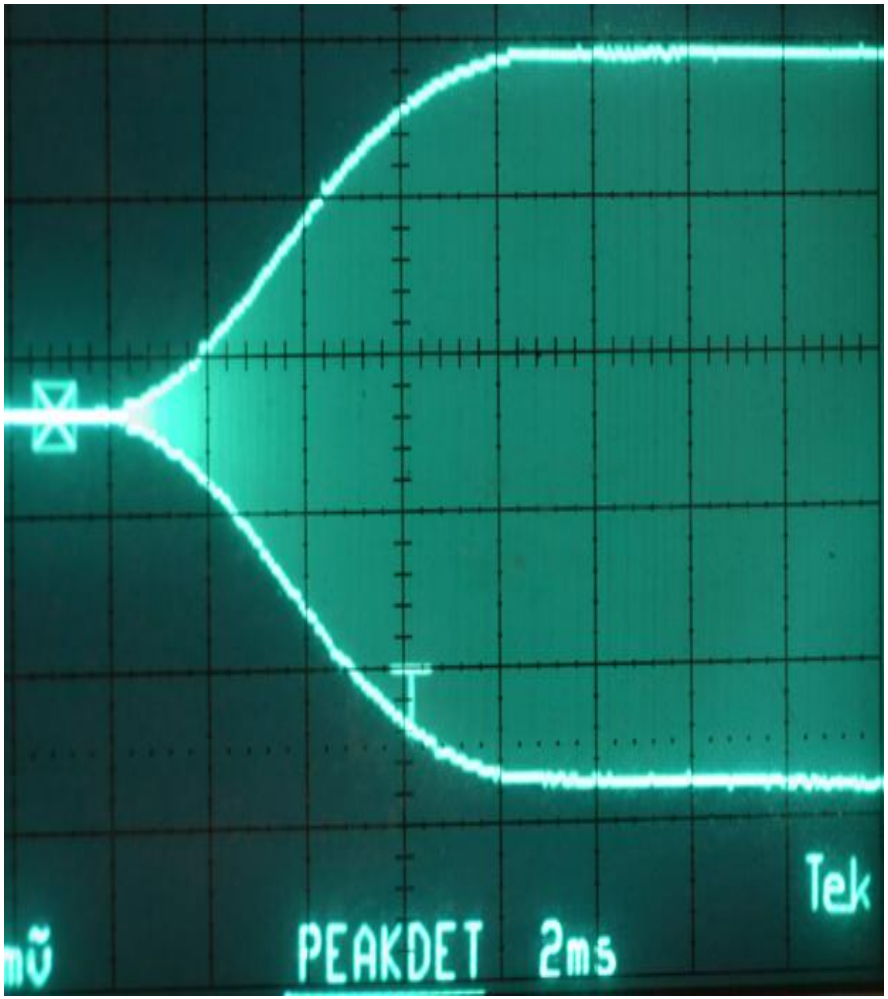
Spectrum of CW Signal on HP 3585A Analyzer

Comparison of 3 msec vs 10 msec rise time



Leading edge of “dit” 3 & 10 msec





Conclusions

- Very little data is published on transceivers above 6m.
- 20-kHz & maybe 5 kHz DR3 and Xmit IMD in reviews
- Transmitted splatter at 5- to 10-kHz likely dominates over receiver limitations on SSB, and even more so above 6 meters.
- On CW, down-conversion 6m radio reception limit is often limited at 1 kHz by adjacent-signal key clicks.
- Out-of-the-box OEM 2 meter & 70cm transceivers are 10 to 20 years behind 160 – 6m performance levels.

- 25 years of up-conversion radios have generally offered a 20 kHz dynamic range of more than 85 dB but a 2 kHz close-in dynamic range only in the 70s.

- On 2 meters and up this is still typical.

- Show of hands: How many of you are using transverters for better performance above 6m?

- Direct sampling SDR radios are now enhancing performance up through 6 meters.

- DS SDR generally offers significantly better RMDR.

Is there hope of better VHF/UHF performance in the future?

With little improvement from the IC-275H, to IC-910H to IC-9100, will any OEM take seriously both receive and transmit VHF/UHF performance?

What might be possible with a hybrid superhet / direct sampling SDR?

The R8600 is already shipping in an IC-7300 size package.
This receiver covers 10 kHz to 3 GHz.
(Direct-Sampling SDR up to 30 MHz, superhet to DS above 30 MHz)

Currently I can find no published test data on the R8600 that could imply potential receiver performance of a transceiver.

We definitely need better third-order dynamic range and RMDR (reciprocal mixing dynamic range) on 2m, 70cm and 23cm.

Transmit IMD on SSB is still pathetic on VHF / UHF.

So far no one is taking about pre-distortion above 6 meters.

Sherwood Engineering

http://www.sherwood-engineering.com

http://www.NC0B.com