Signal Cleanliness is Godliness

K6XX & K9YC

Northern California Contest Club
11 November 2013

Signal Cleanliness is Godliness

And definitely good manners.

Disclaimer

- Although K6XX is an engineer employed by Elecraft, his opinions and analysis are his own, and not necessarily those of his employer. Most of the technical principles presented here are his, and based on his extensive work on power amps. The Rigol measurements are his.

- I am retired, and have never worked for Elecraft. I made the P3 measurements, choosing what signals to present. KW6S, also an engineer, provided the 7600 to measure, carefully setting it with my direction to illustrate the principles Bob was presenting. I chose to measure it because I knew from on-air experience that it could be a very dirty rig.

Terms

- **Phase Noise**
- **Key Klix**
- **Splatter**
- **Linearity**
  - **IMD (Intermodulation Distortion)**
  - **Mostly heard off-freq, but can be heard in the audio if it's really bad**
- **Harmonics**

Interference: Complimentary (phase noise) vs. Bad Neighbor

- **Phase noise hurts both of us**
- **Rotten signal (Klix, splatter, excessive "fidelity") hurts *me*, but not you**

Until you annoy me enough to hunt you down and kill you.

Phase Noise Hurts TX and RX

- **On receive, your own rig's phase noise makes other strong signals sound broad when they are not**
  - Others will tell you you're broad
  - You respond, "you're broad too – we're just too close"

Key Clicks

- **CW is really square wave AM of a carrier**
- **Transition (on/off) is the modulation**
- **Modulation creates sidebands**
- **Clicks excite IM distortion, make signal wider**

Key Clicks—Two Manifestations

- **Poor Radio Design**

- **Operator Error**

Key Clicks—Poor Design

- **Generally due to rise time and overshoots**
- **Fast rise/fall times => strong sidebands**
- **Slow rise/fall times => minimal sidebands**

Key Clicks—Poor Design

- **Design issues**
  - **ALC system (slow attack=overshoot)**
  - **Rise Time Adjustable in a few rigs (bad)**
  - **Analog radios need circuitry**
  - **DSP-based radios may shape via firmware**
  - **Optimum for power density vs bandwidth: "Sigmoidal" rise time – used by Elecraft**

Key Clicks—Operator Error

Operator-Induced Key Clicks

- **Maladjusted Rise Time**
  - **menu, carrier control**
- **Poor amplifier tuning**
  - **Poor amplifier linearity (Class C)**
  - **More gain at lower input power means the waveform is modified by amplifier**
  - **Impedance mismatch to antenna**
  - **Alpha 87: Autotune or AutoRETUNE?**

Splatter, Sidebands

- **Caused by distortion**
  - **Overdrive**
  - **Intermodulation**
  - **On CW, copies of your signal either side of the main signal**

Transmitter IMD

Intermodulation Distortion

- When is a "Linear" not?

    - When 2x the input does not produce double the output

    - When 2 clean tones on the input produces multiple tones on the output (Two-Tone Test)
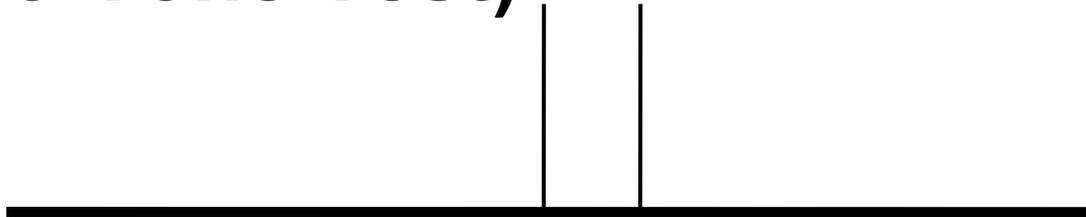
Driver (Transceiver) Problems

- **Klix, Splatter**
- **Leading Edge Spike**
- **Phase Noise**
- **Non-linear (dirty) output**
- **Generally wide, rotten signals. Even if new, expensive, and "approved"**

Improving your Transceiver

- IMD Products are strongly determined by Output

- Comparisons are made at full output

- Most "12V" transceivers generate IMD products about -28 to -32dBc at 100W

- Dropping power by a dB improves IMD by SEVERAL dB

- Easy way to clean up your signal: Run 40-50W

Improving Your Transceiver

– IMD improves when PEP is lower

– IMD generally improves when Supply Voltage is higher

  • 13.8V noticeably better than 12.0V

– IMD is best with a 50 Ohm load

  • Use a tuner, even with an SWR of 1.5:1 or 2:1

  • Amplifier input network a good match?

Improving Your Transceiver

Harmonics

- -43dBc is NOT ENOUGH (FCC, CE limit)
- Use BPF to improve rejection
- Use monoband antennas
- Most HF rig harmonics are down about 55 dBc
  - Harmonics of a 60dB/S9 sig are still over S9…

Problem Equipment

- **K2—Phase Noise**
  - **No cure – don't run high power**
- **FT1000MP—Klix –**
  - **Well known mods can fix**
- **Icoms—leading edge spike**
  - *Bucket Technique*
- **Alpha 77-EBS, Ameritron AL-series EBS option**
  - *Fix or disable*

Keying Overshoot

Causes Key Klix. Is hard on Amplifiers
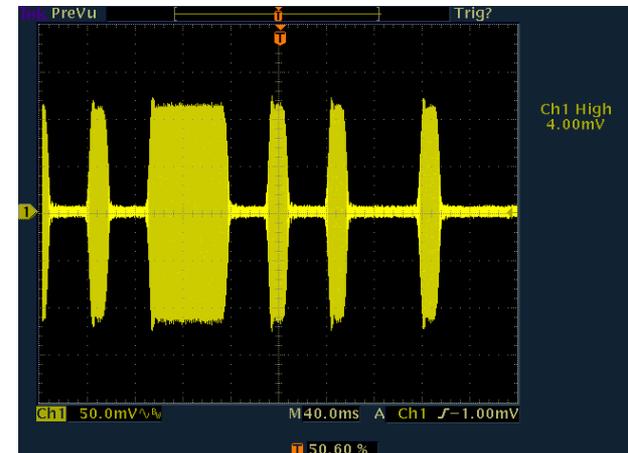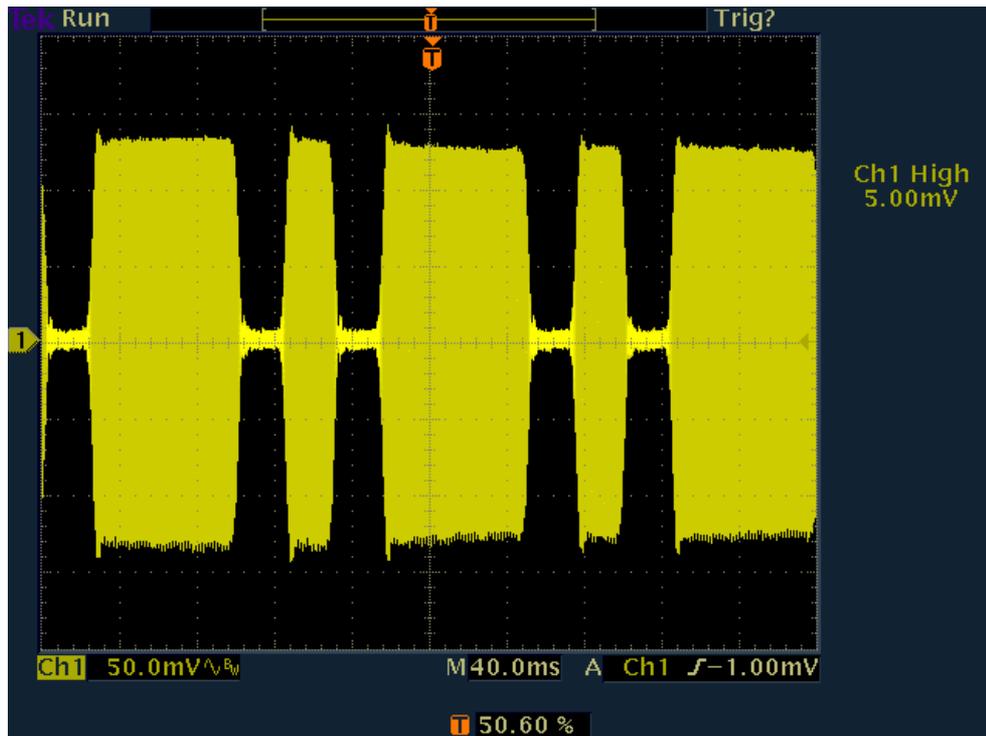
CW Width—Bench Data

Popular 1990s Radio

(AFTER Modification)

Modern Design
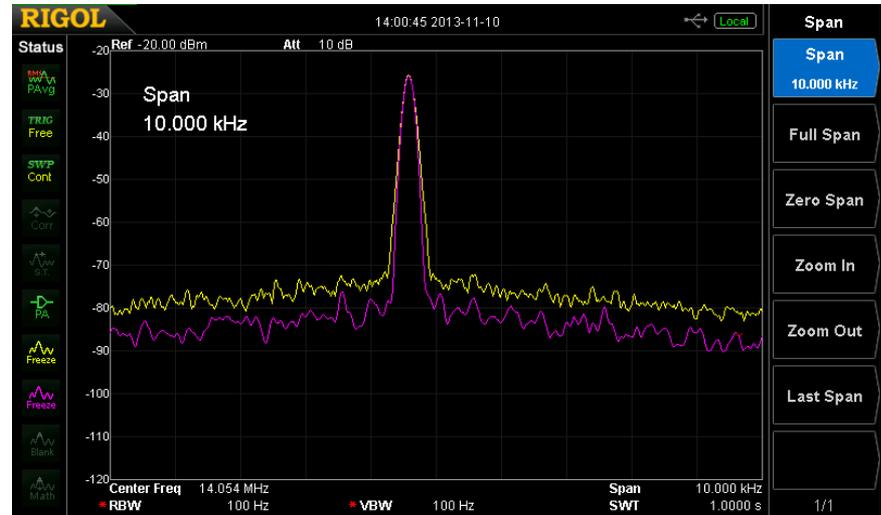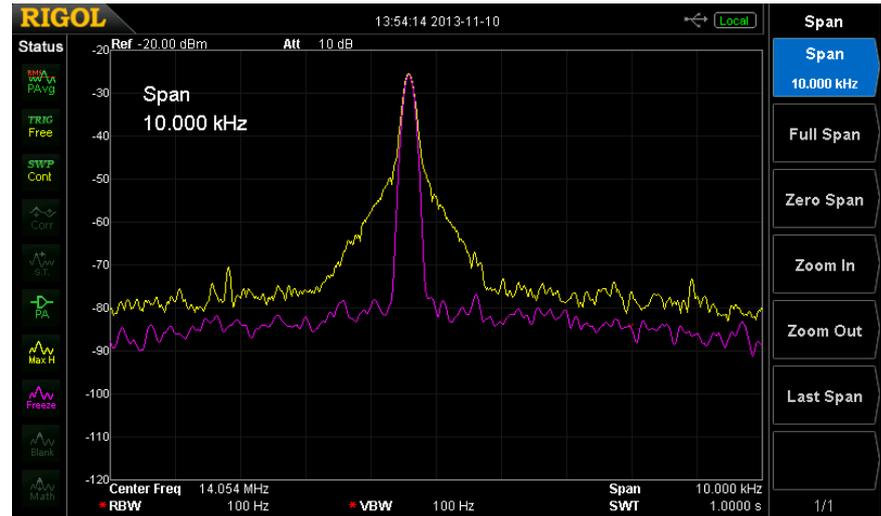
FT-1000MP Clicks, Phase Noise
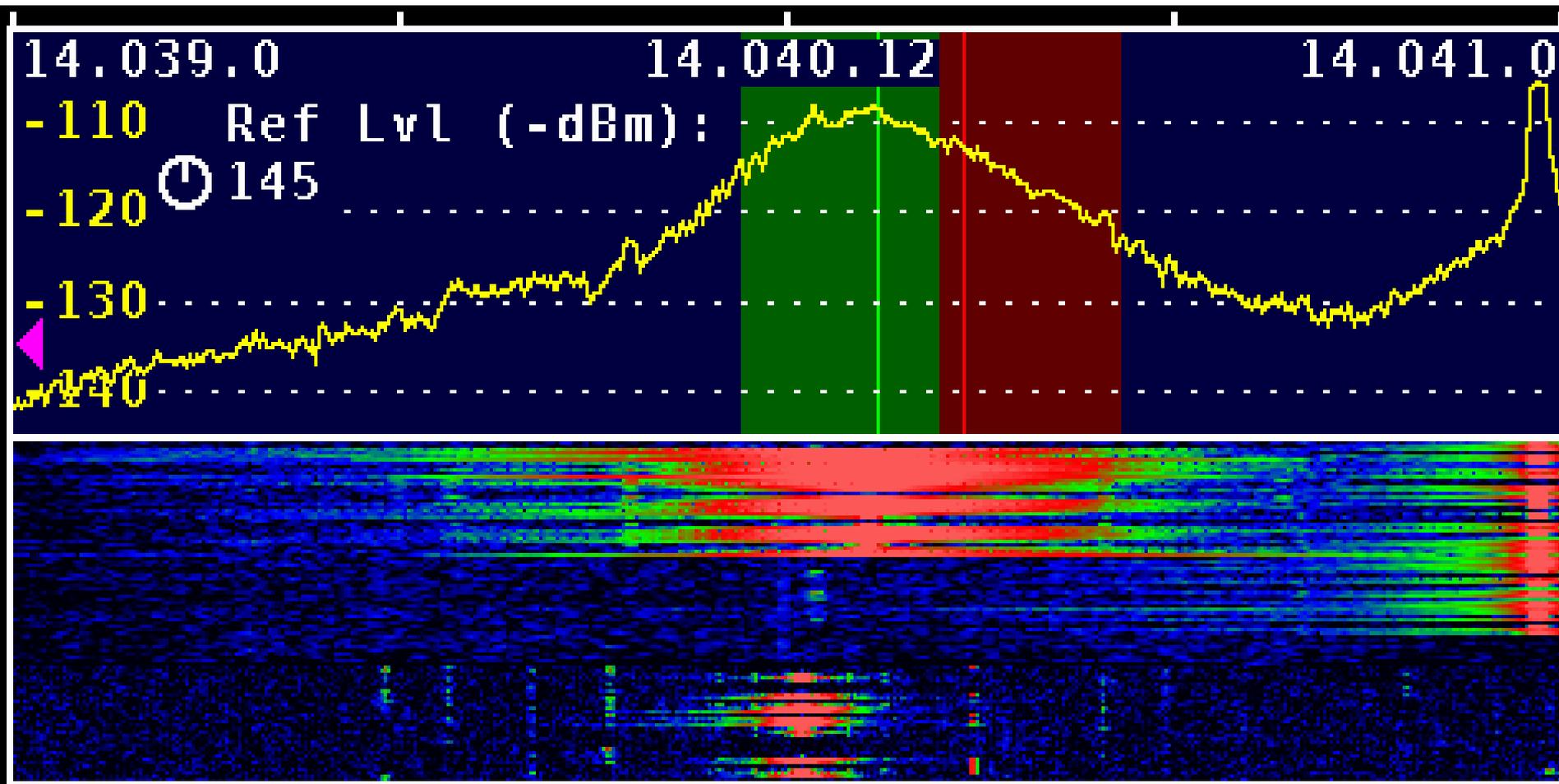
ICOM 7600 50W 4 msec Keying (Default)
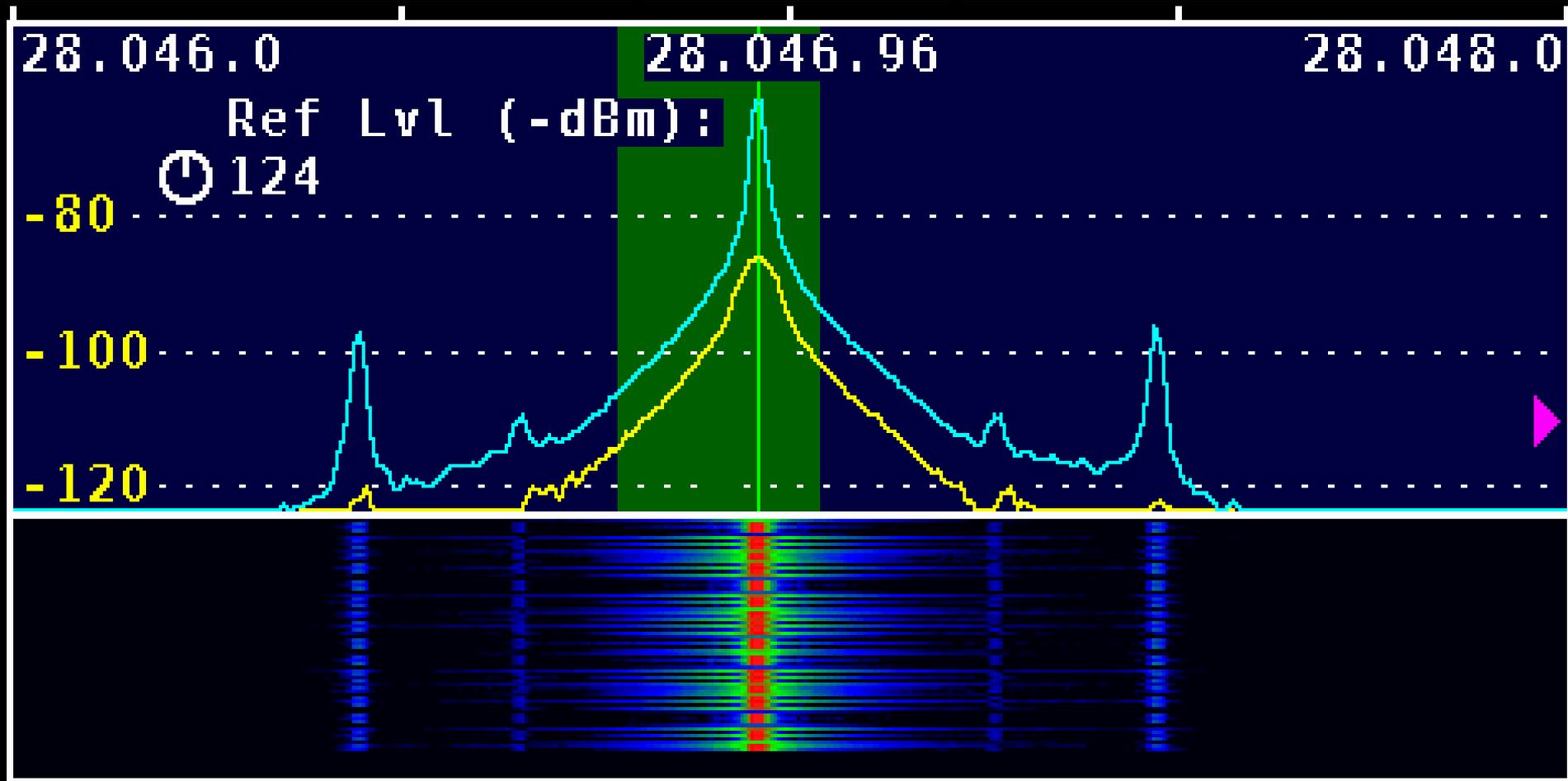
ICOM 7600 6 msec 50W

28.046.0   28.046.96   28.048.0

MKR A:
28.046.44

-80

-100

-120

Peak   Span 2   Span 10   FixTrack
Span 20   Span 50   Span 100   Span 200

ICOM 7600 8 msec 50W

28.046.0   28.046.96   28.048.0

-80

-100

-120
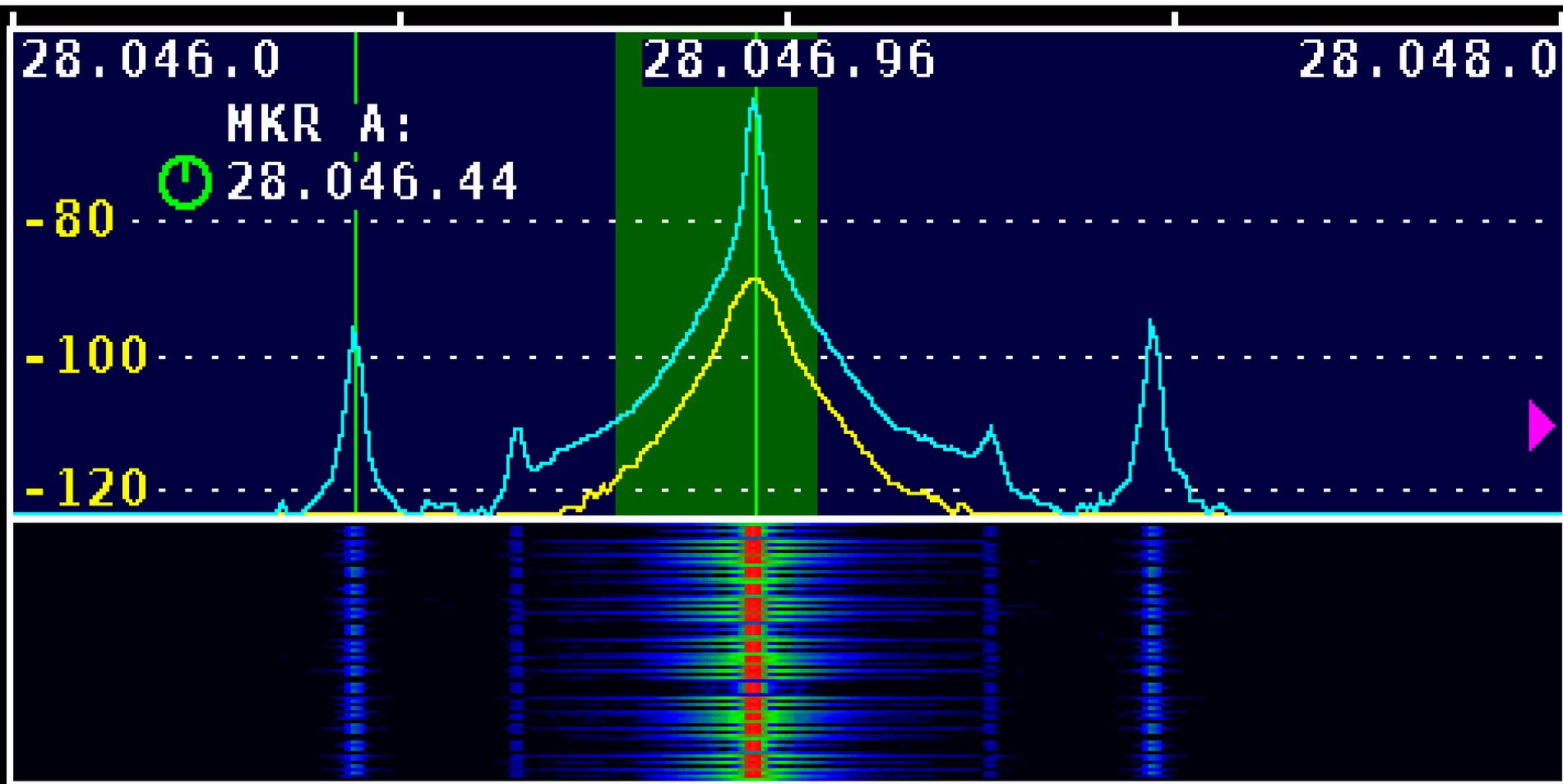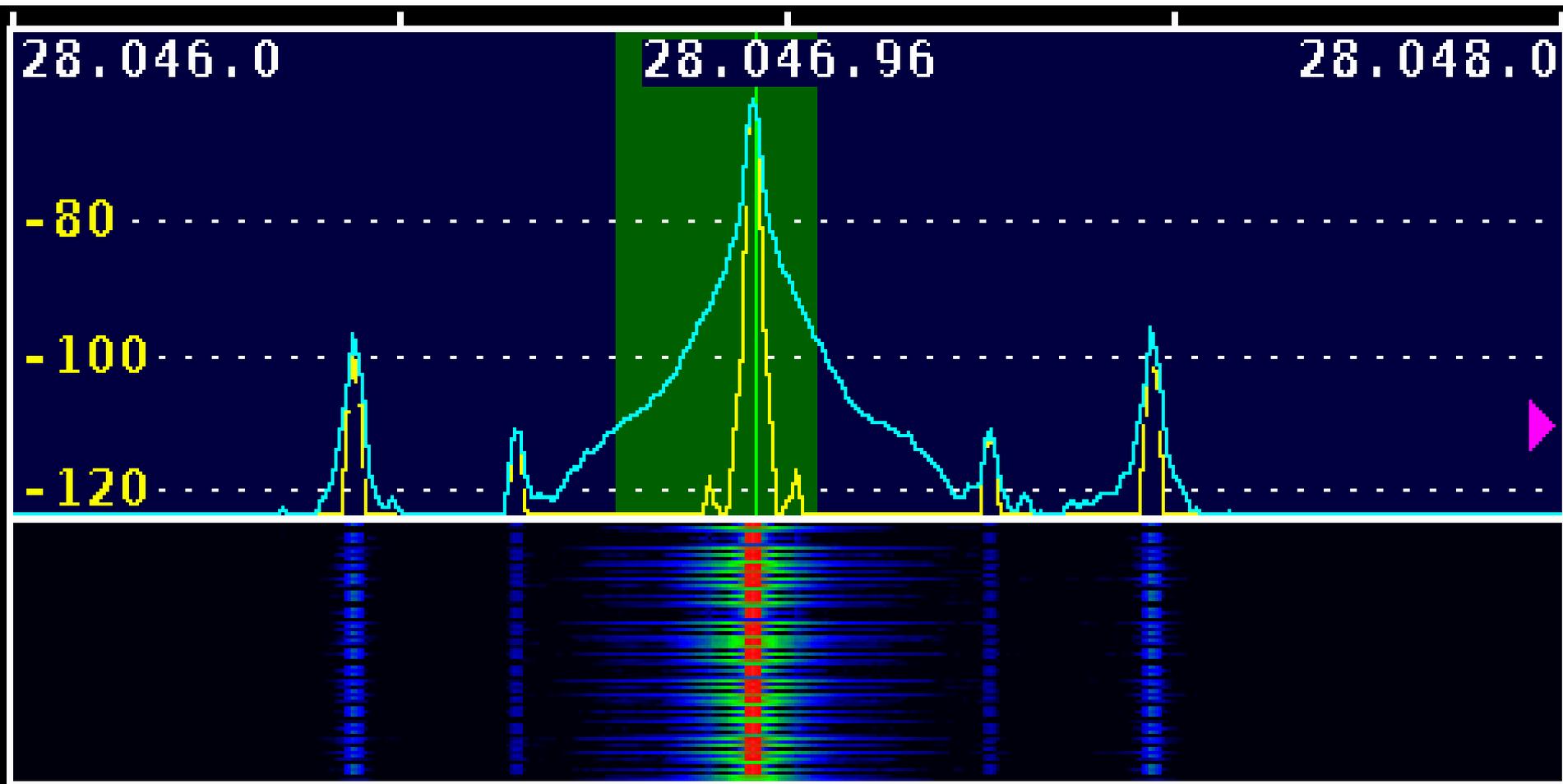
Peak   Span 2   Span 10   FixTrack
Span 20   Span 50   Span 100   Span 200

ICOM 7600 10 msec 50W
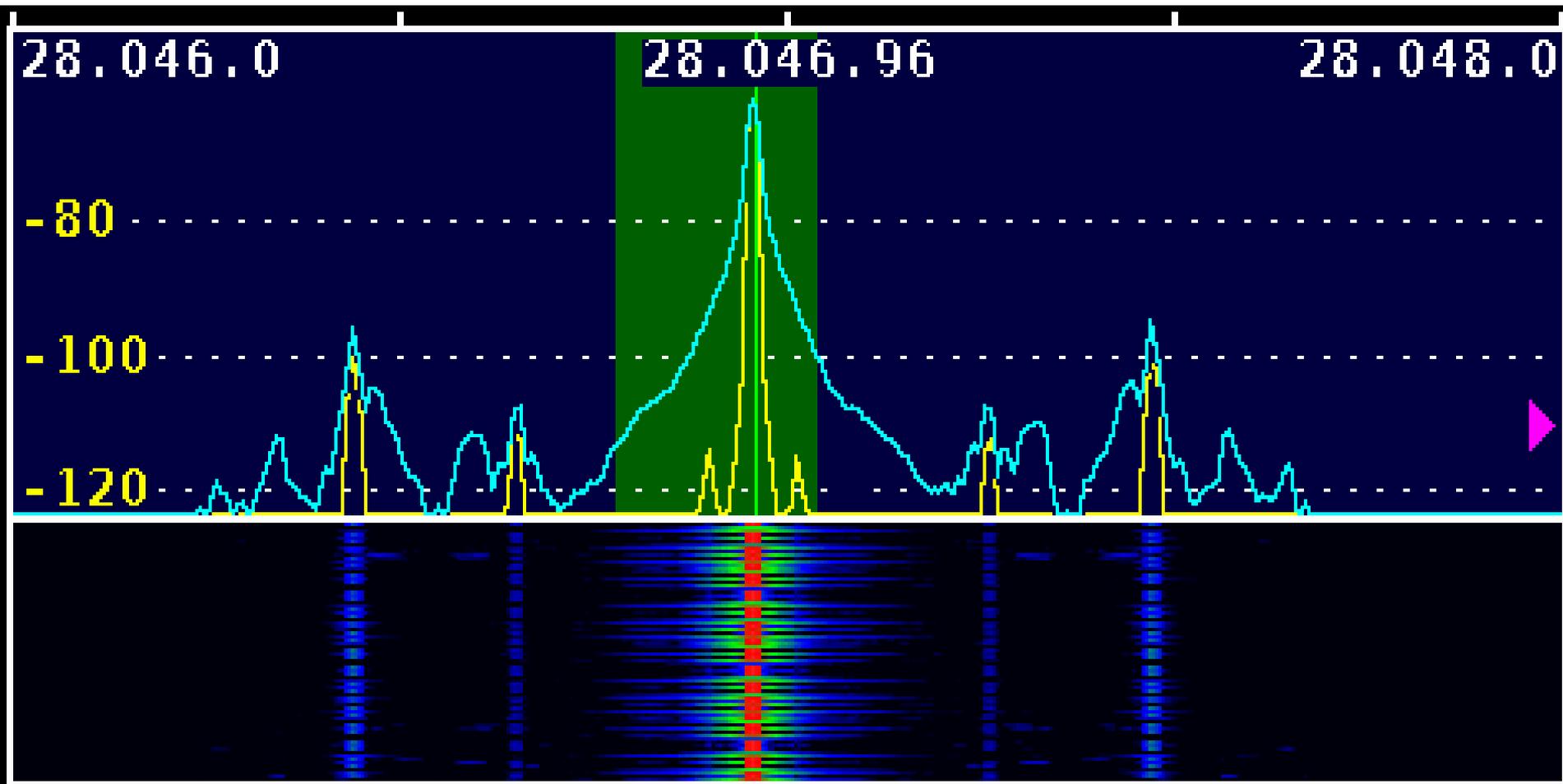
ICOM 7600 2 msec 50W

28.046.0   28.046.96   28.048.0

−80

−100

−120
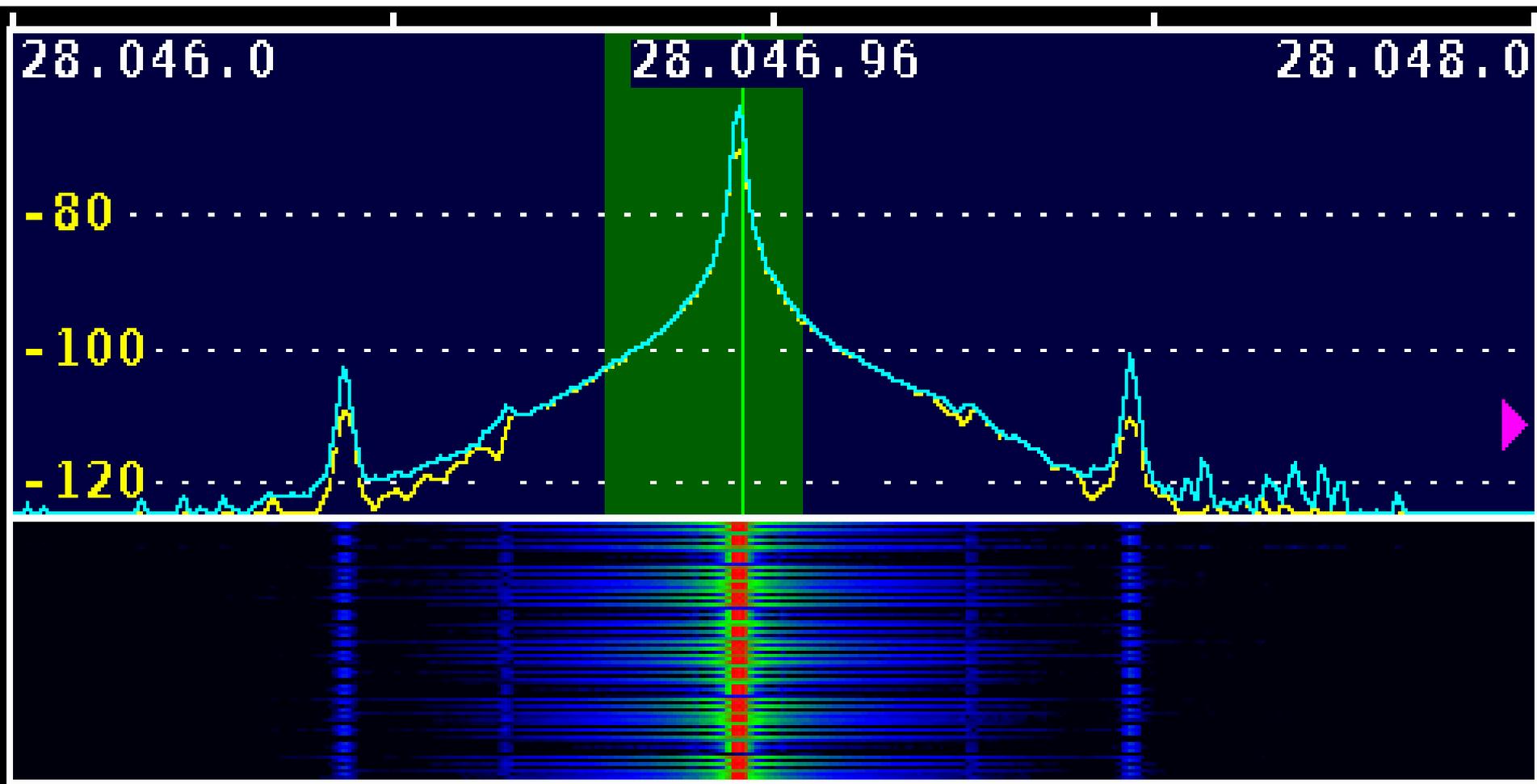
Peak   Span 2   Span 10   FixTrack
Span 20   Span 50   Span 100   Span 200

ICOM 7600 2 msec 100W

ICOM 7600 8 msec 50W

28.046.0	28.046.96	28.048.0

-80

-100

-120
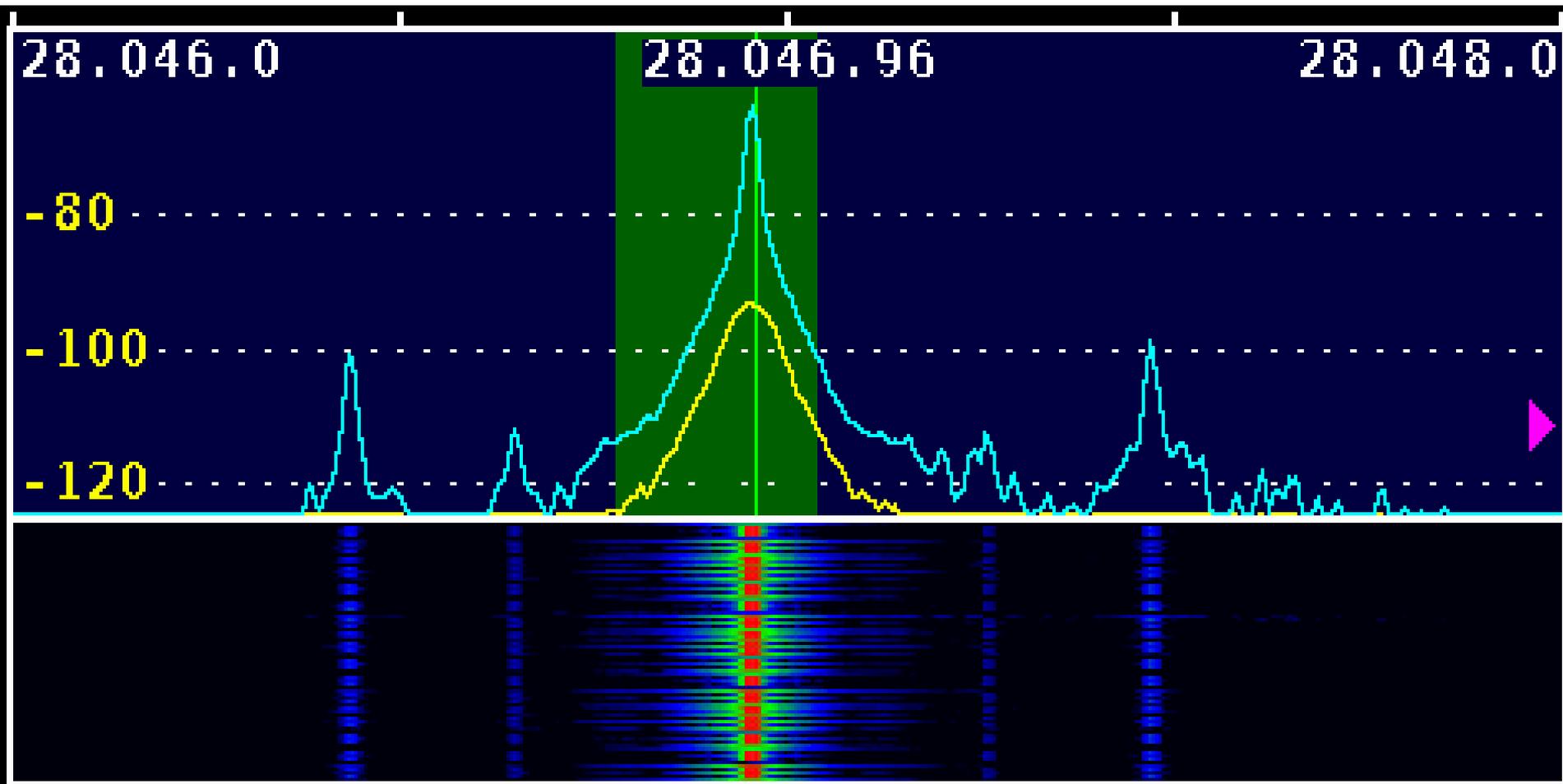
Peak	Span 2	Span 10	FixTrack
Span 20	Span 50	Span 100	Span 200

K6XX at K9YC IARU (3 miles)
72 dB Full Scale, 2 kHz Span

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72 dB Full Scale, 2 kHz Span

21.033.49

-1.0   +1.0

-50
-60
-70
-80
-90
-100

-20 dBc

80 Hz Wide

-50 dBc

-49 dBc
+/- 310 Hz

-60 dBc
+/- 350 Hz
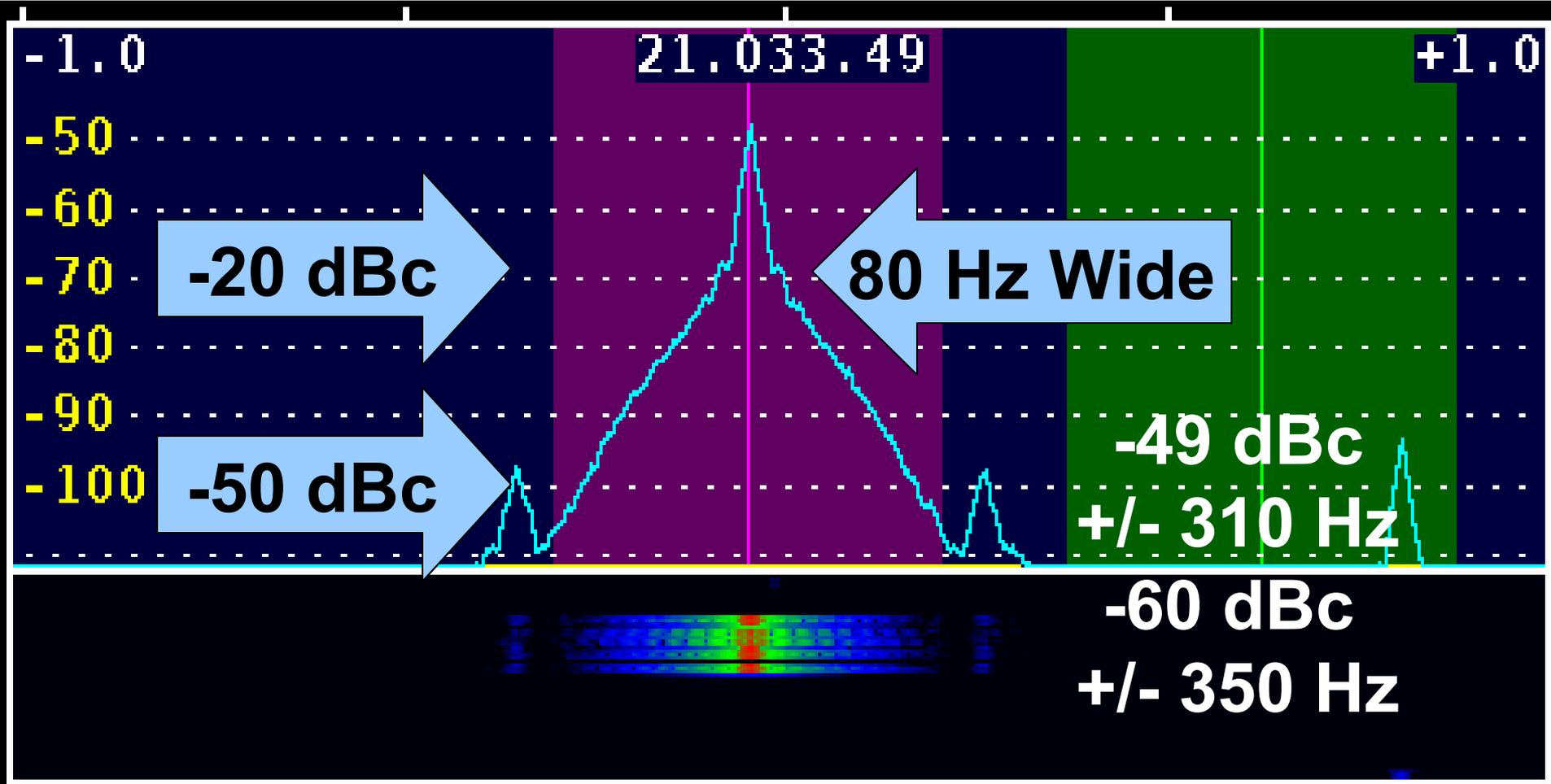
Peak   Span 2   Lvl Mode   FixTrack
Span 10   Span 100   Span 50   Span 200

Two Strong Dirty Signals
42 dB Full Scale, 8 kHz Span

Two Strong Dirty Signals (8 & 16 miles)
42 dB Full Scale, 8 kHz Span

K6XX at K9YC IARU (3 miles)
72 dB Full Scale, 2kHz Span

-1.0   21.033.49   +1.0

-50
-60
-70
-80
-90
-100

-28 dBc
170 Hz Wide
-50 dBc
-49 dBc
+/- 310 Hz
-60 dBc
+/- 350 Hz

Peak   Span 2   Lvl Mode   FixTrack
Span 10   Span 100   Span 50   Span 200

Strong Dirty Signal (8 miles)
42 dB Scale, 10 kHz Span
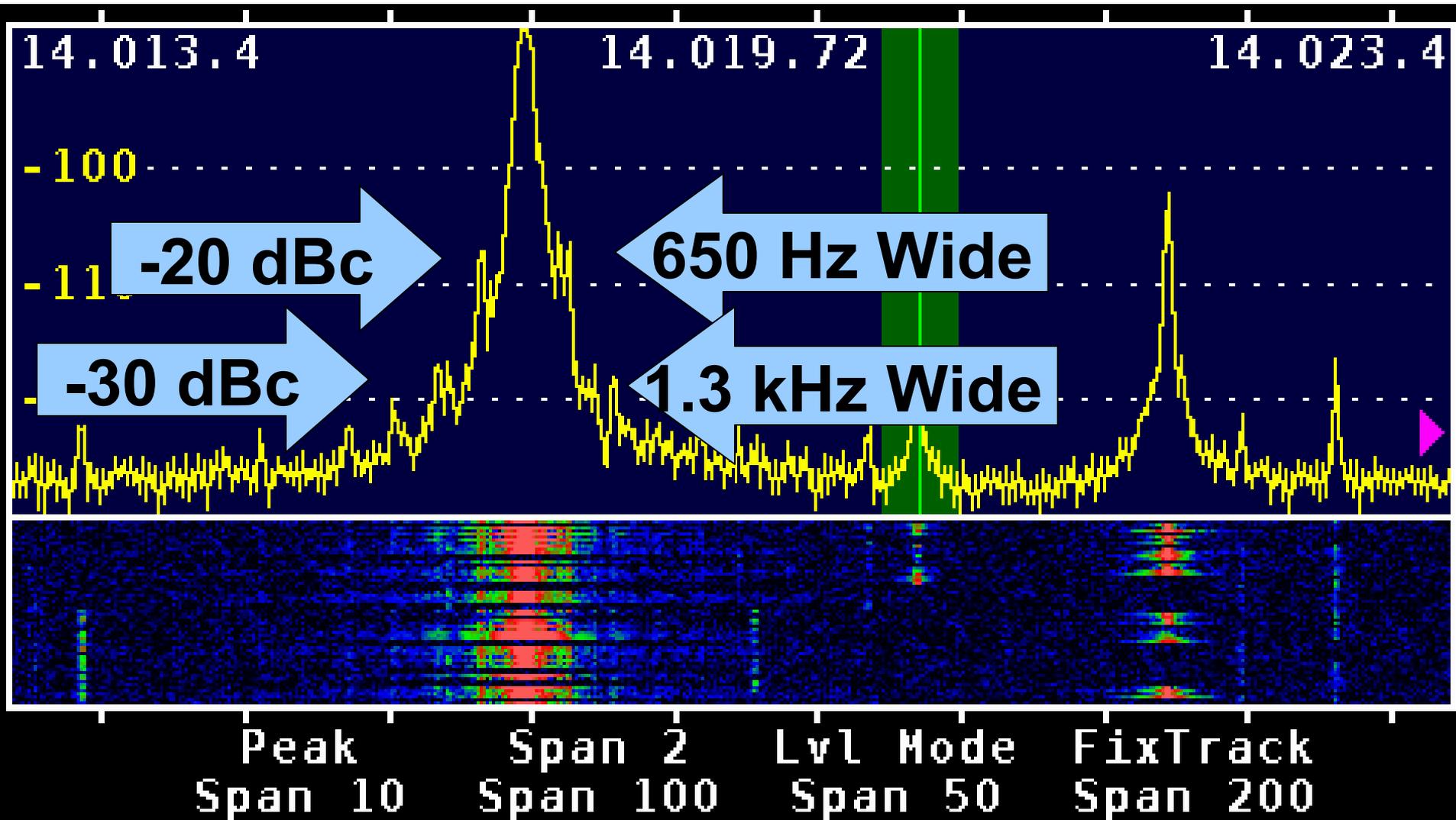
14.013.4   14.019.72   14.023.4

-100

-110

-20 dBc

-30 dBc

650 Hz Wide

1.3 kHz Wide

Peak   Span 2   Lvl Mode   FixTrack
Span 10   Span 100   Span 50   Span 200

Transmitter IMD

Intermodulation Distortion

- **When is a "Linear" not?**
    - **When 2x the input does not produce double the output**
    - **When 2 clean tones on the input produces multiple tones on the output (Two-Tone Test)**

Transcriter IMD
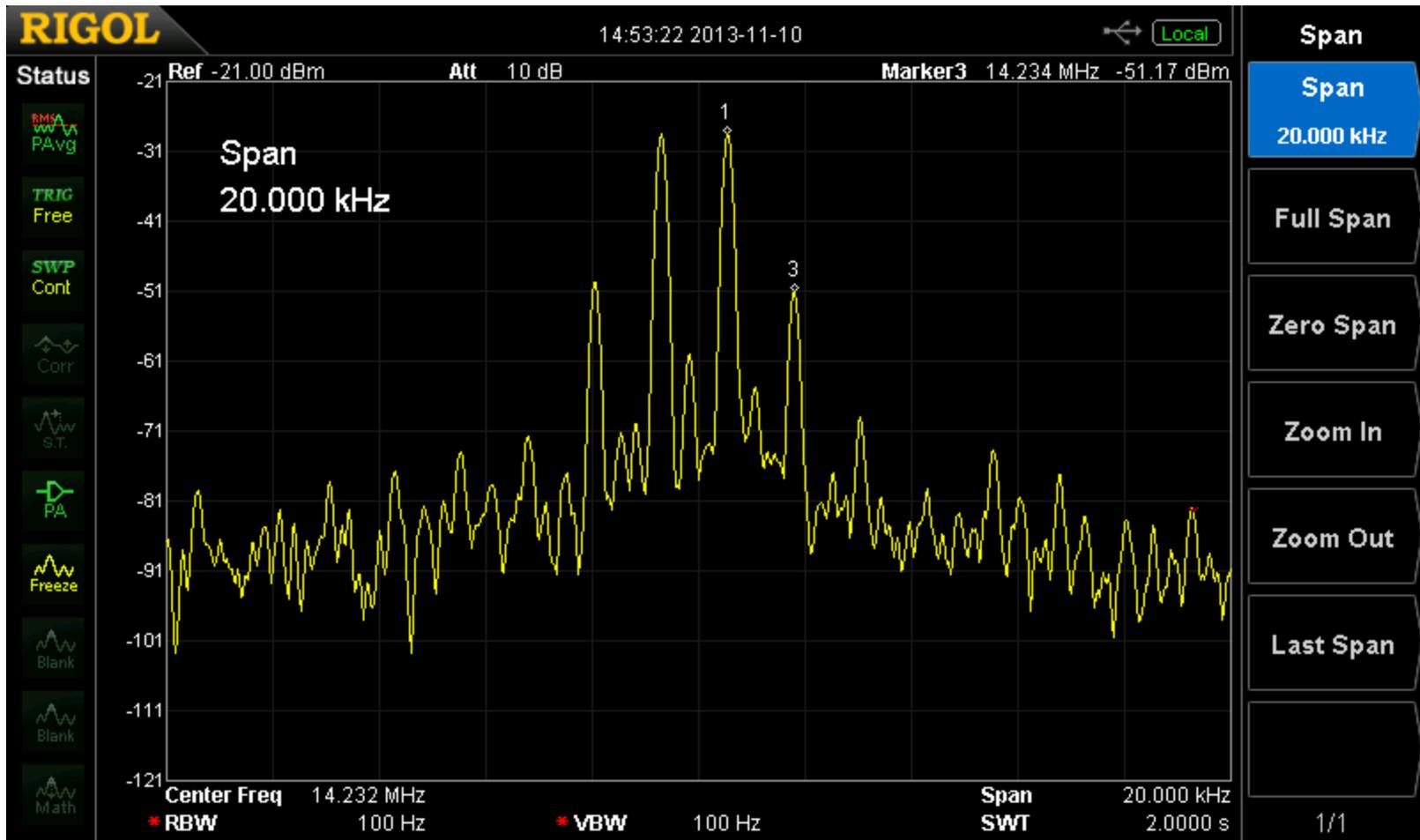
Transmitter IMD—Half Power
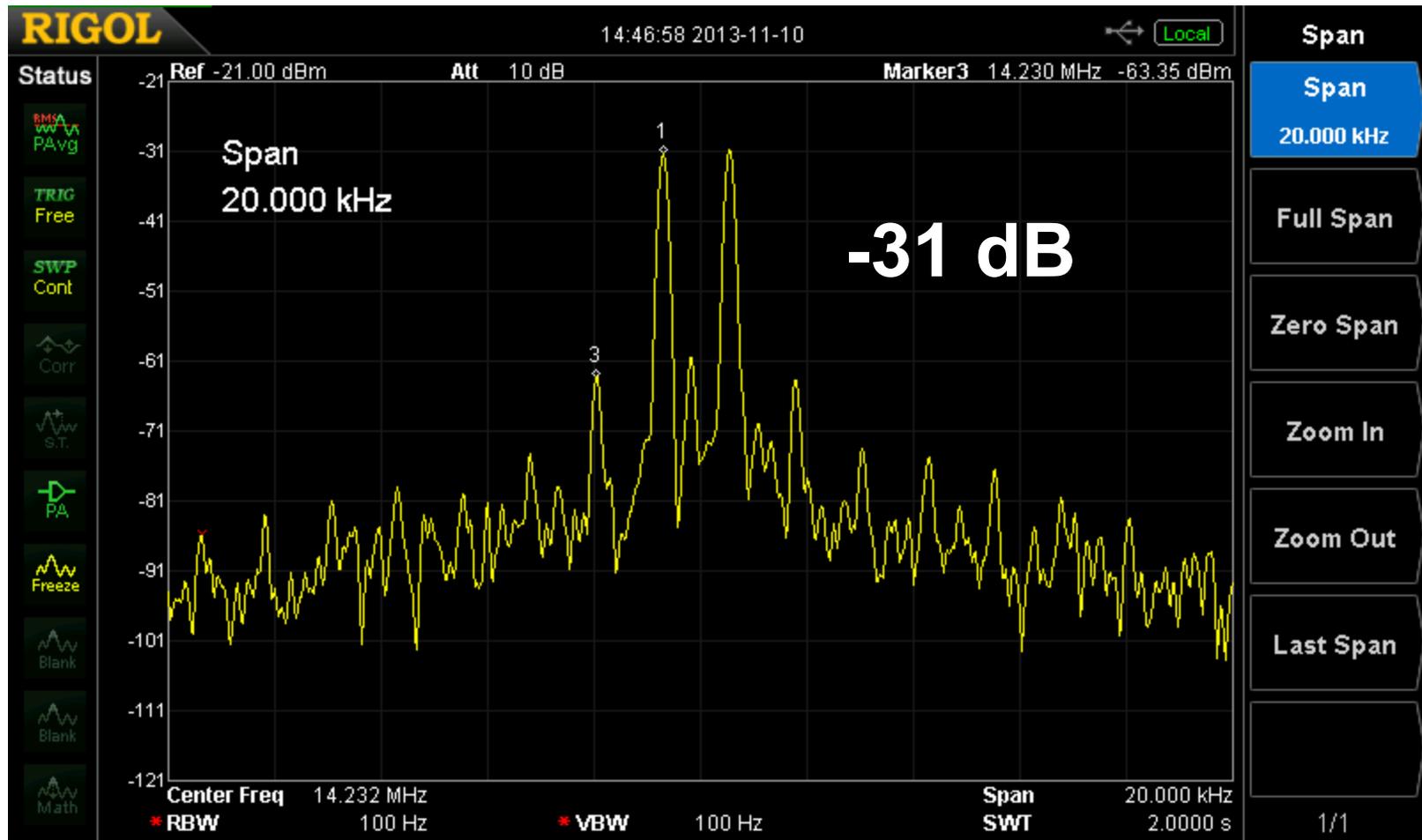
Transmitter IMD
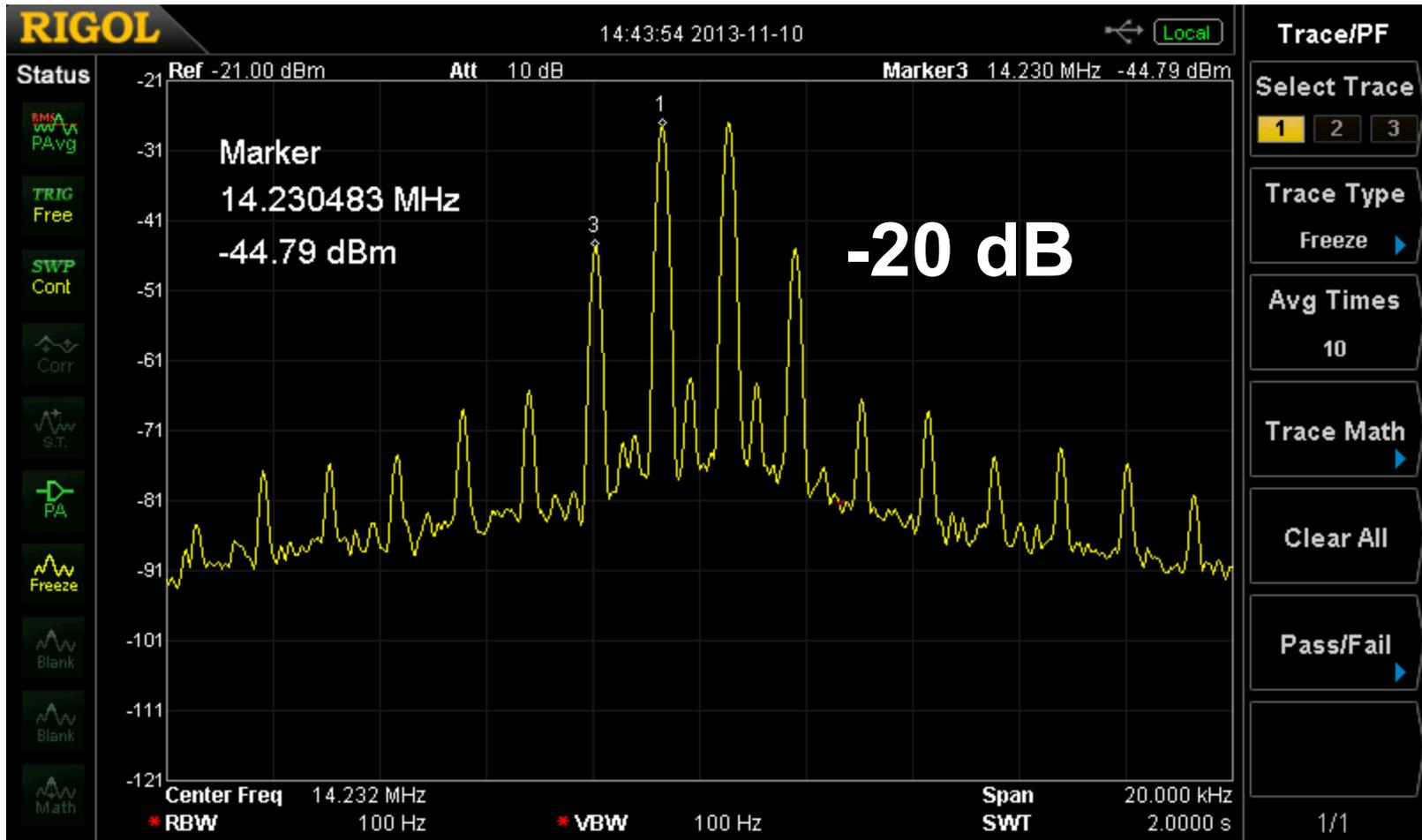
Transmitter IMD—Slight Overdrive
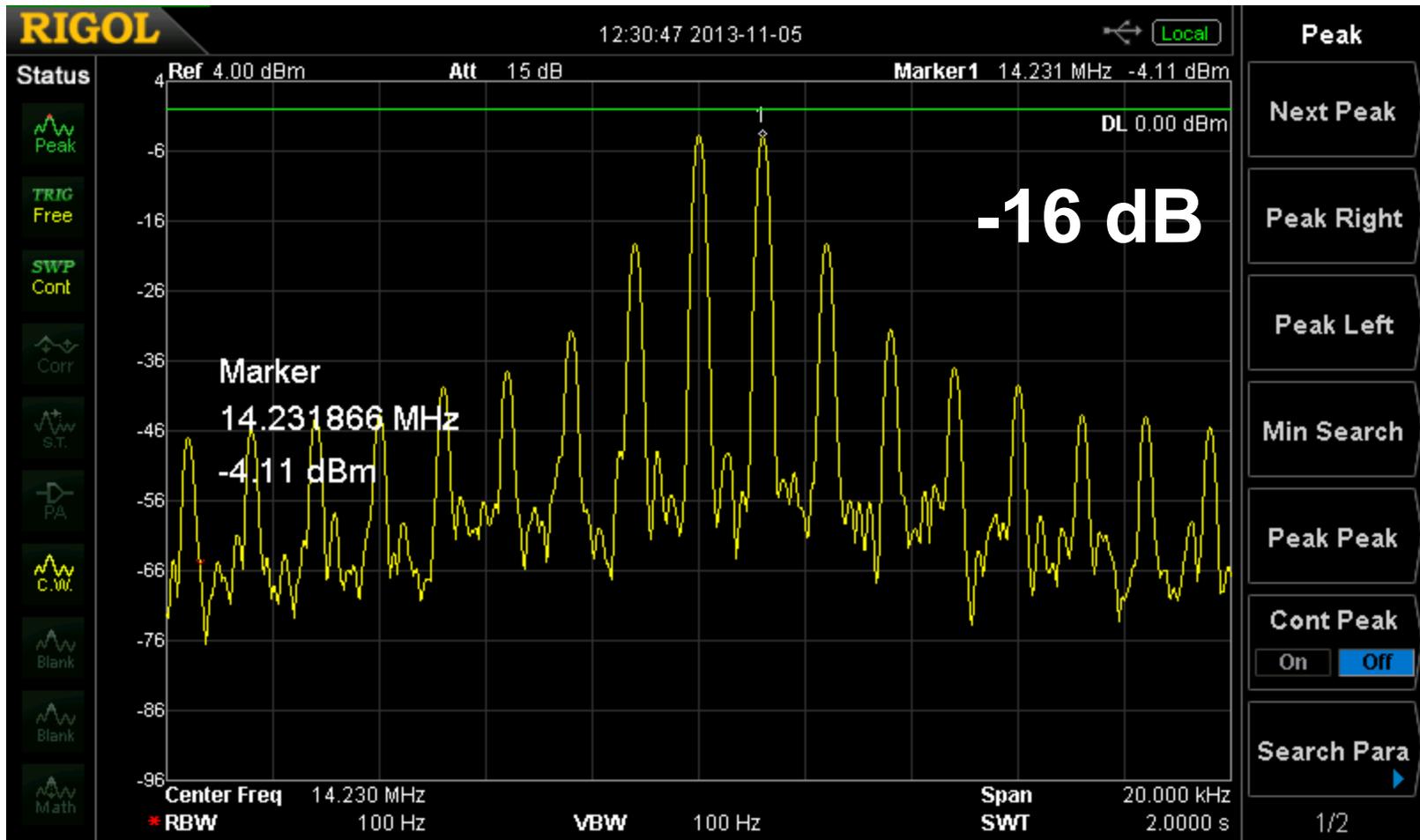
Transmitter IMD—Class A
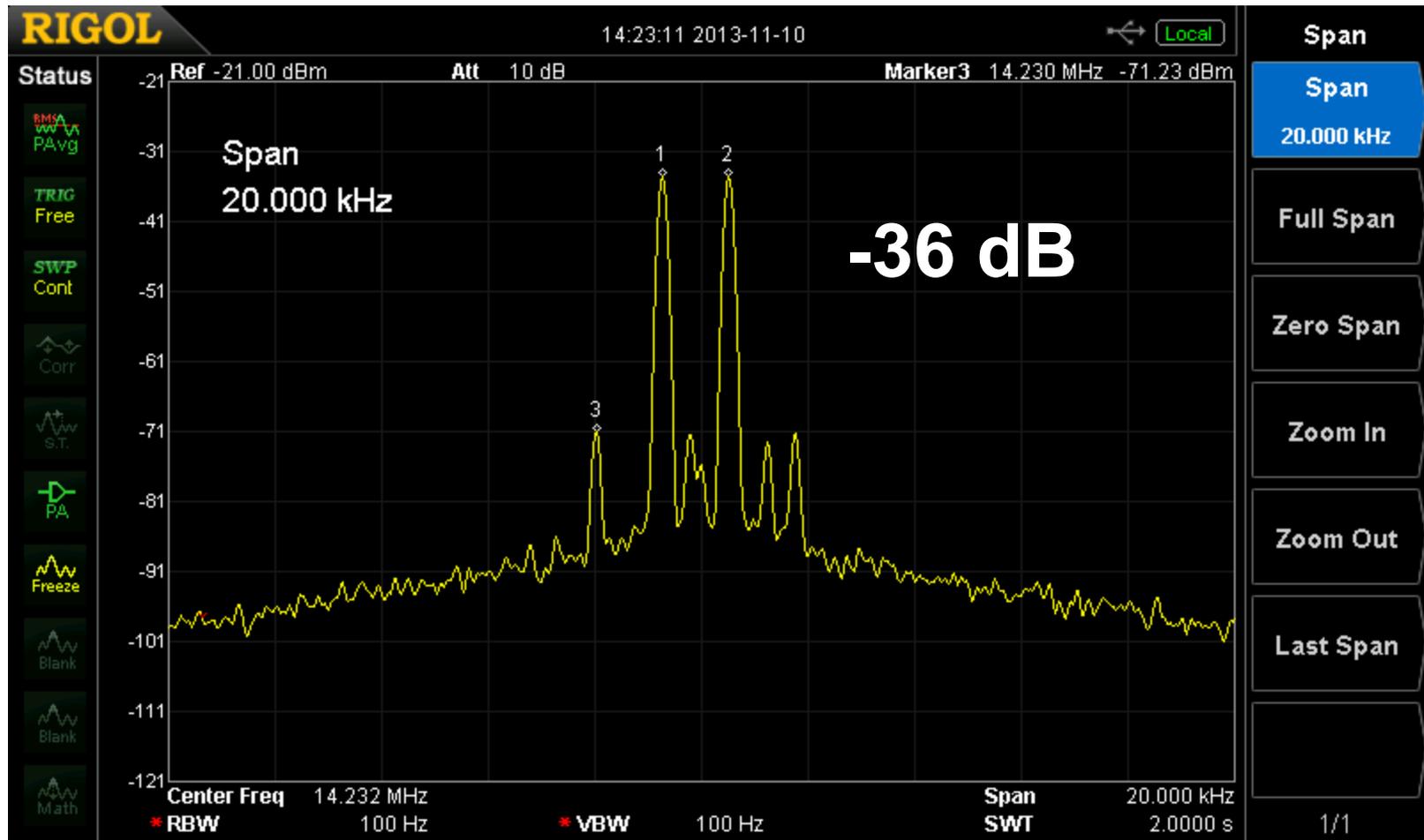
Transmitter IMD—Supply Voltage
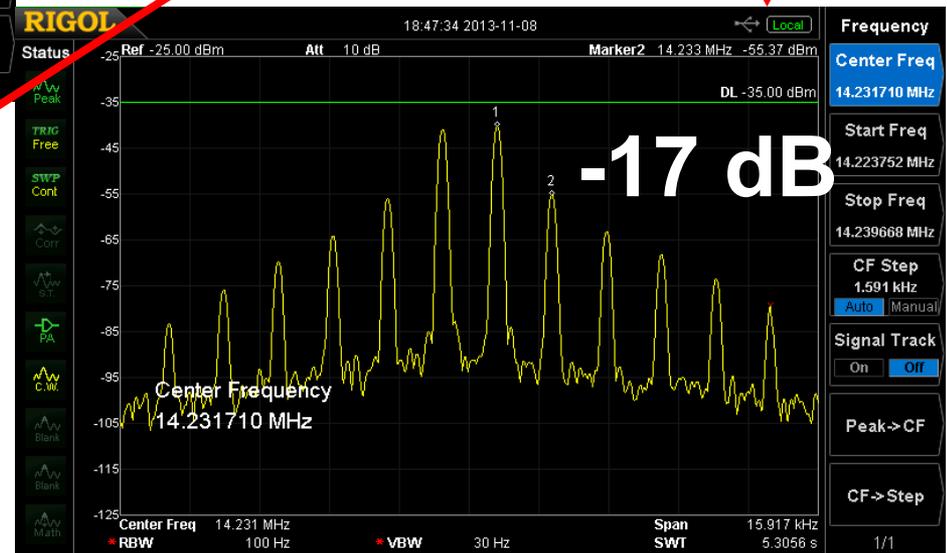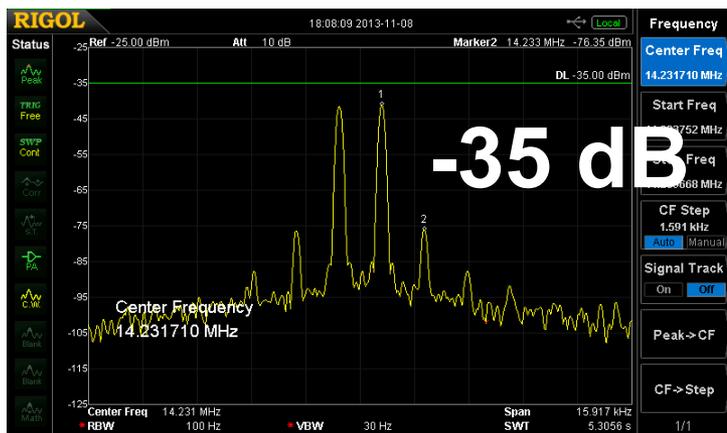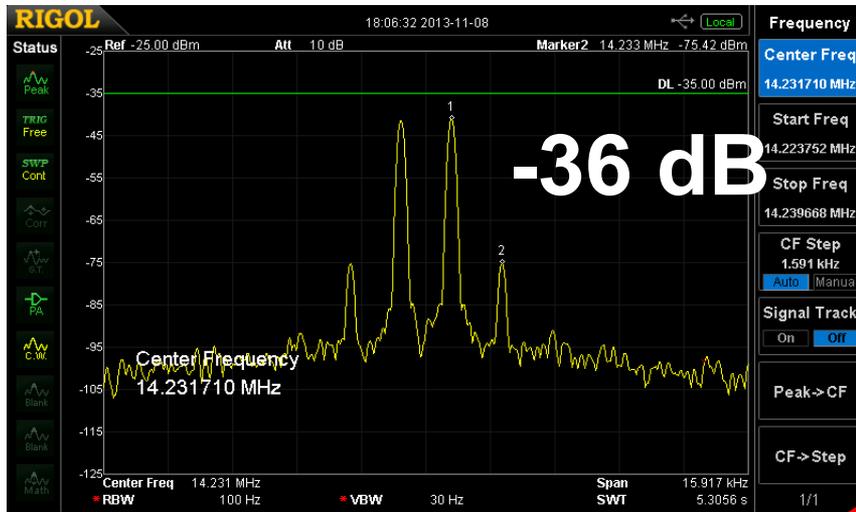
ICOM 7600 2-Tone IMD 50W
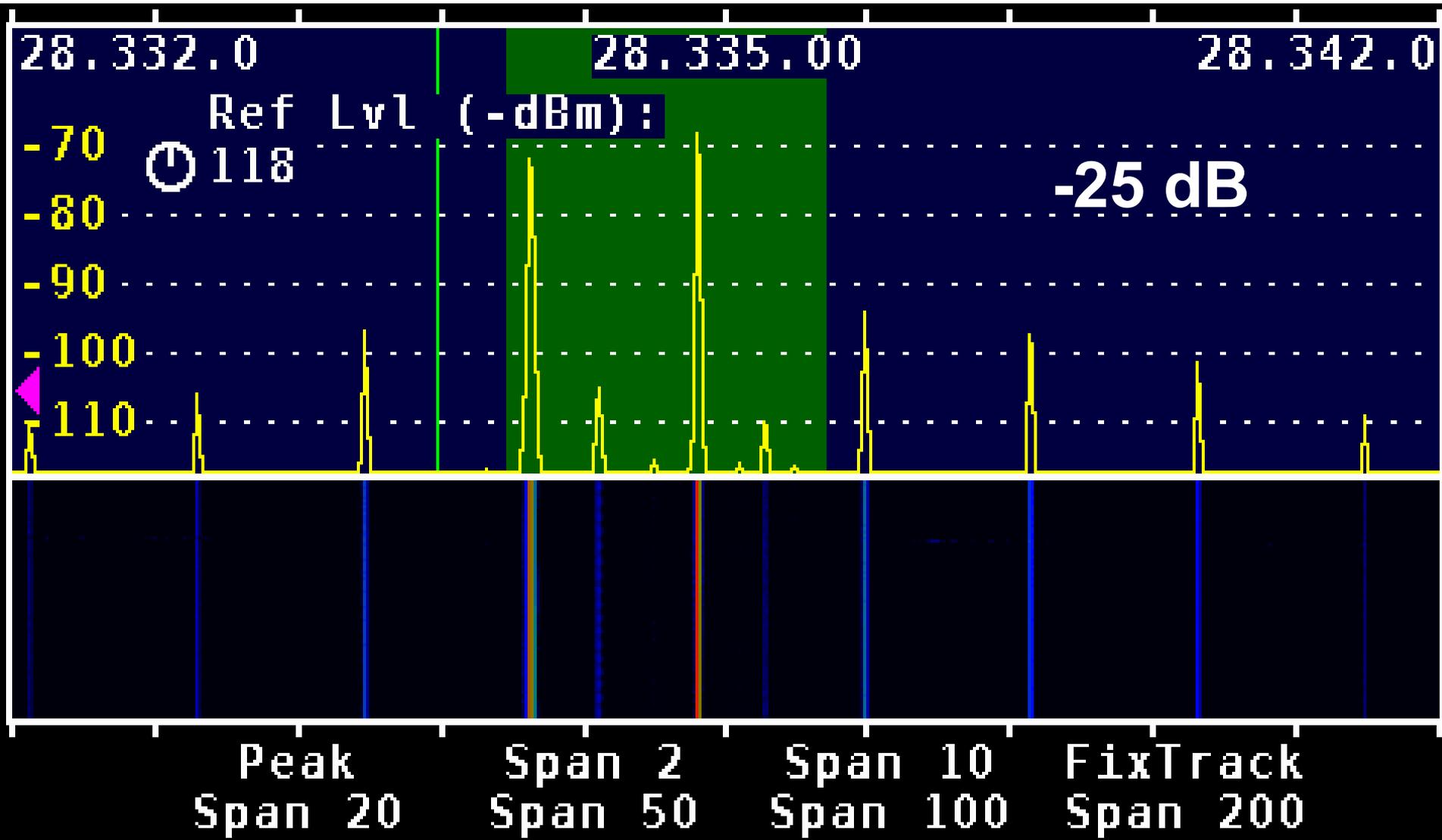
Icom 7600 2-Tone IMD 100W
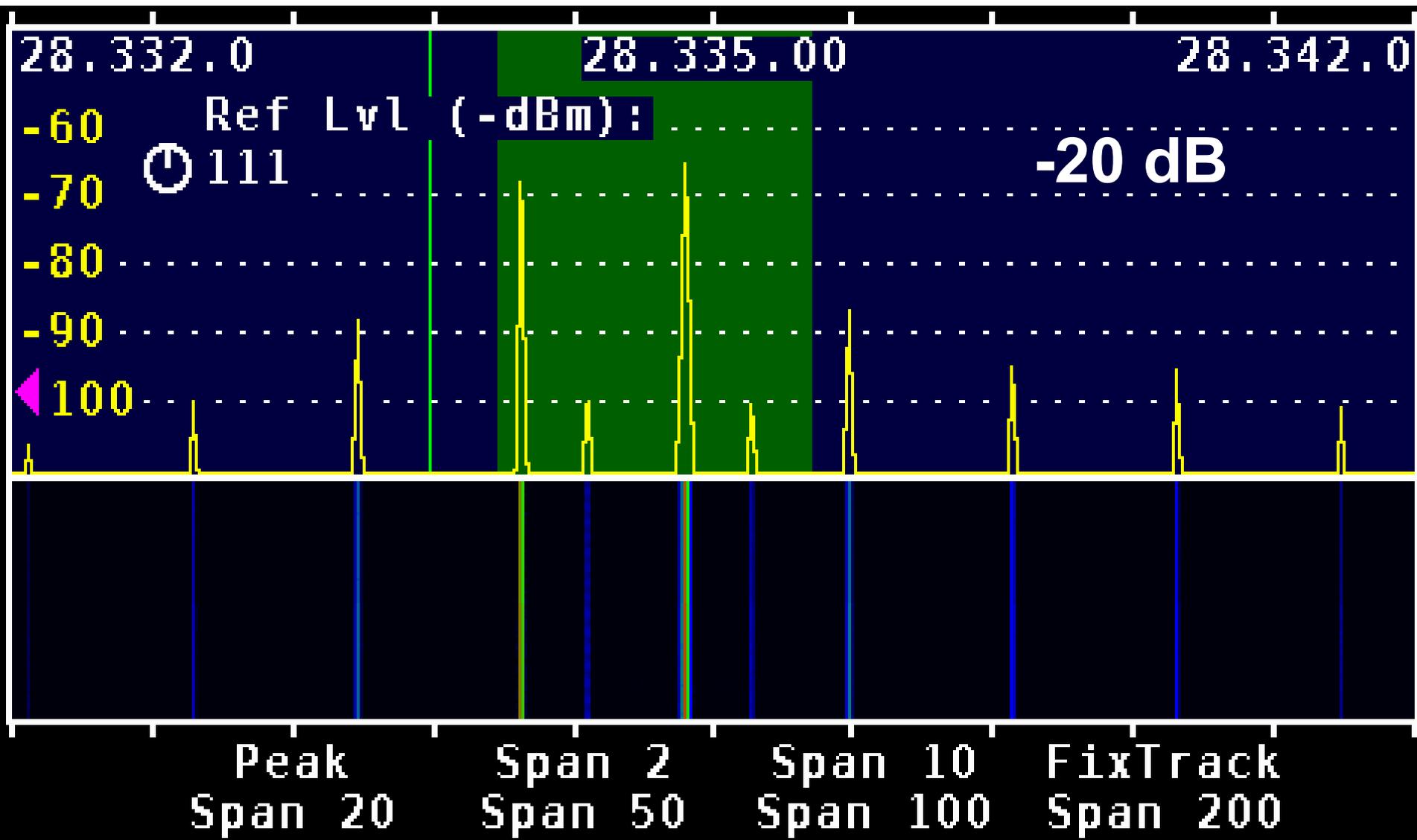
7600 50W "Wide" No Compression (Default) (Trash in LSB)

28.332.0   28.834.09   28.342.0

Ref Lvl (-dBm):

-90

⏱142

-100

-110

-120

-130

Peak   Span 2   Span 10   FixTrack
Span 20   Span 50   Span 100   Span 200
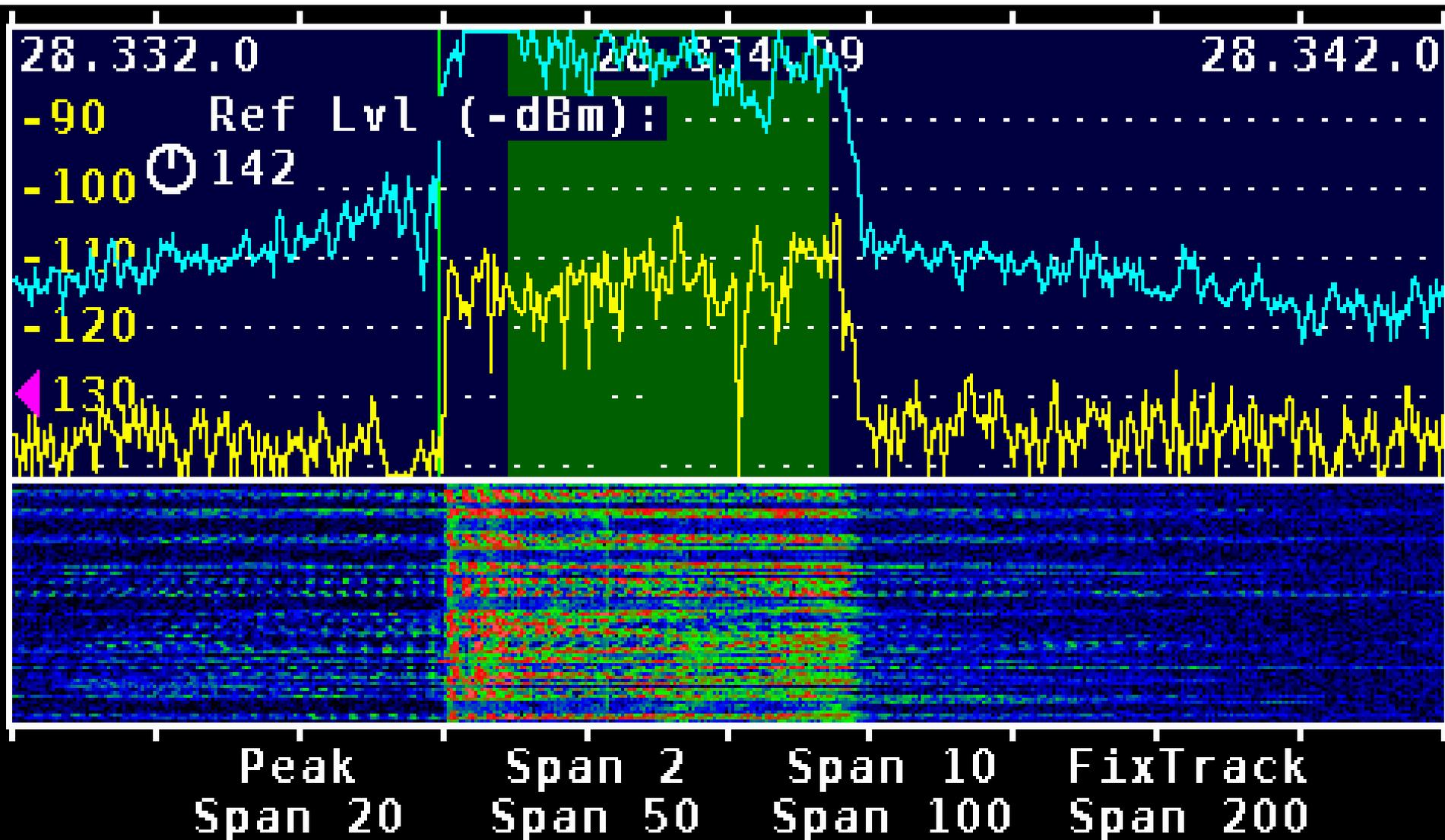
7600 50W "Narrow" w/Compression
Less Wide, still trash in LSB
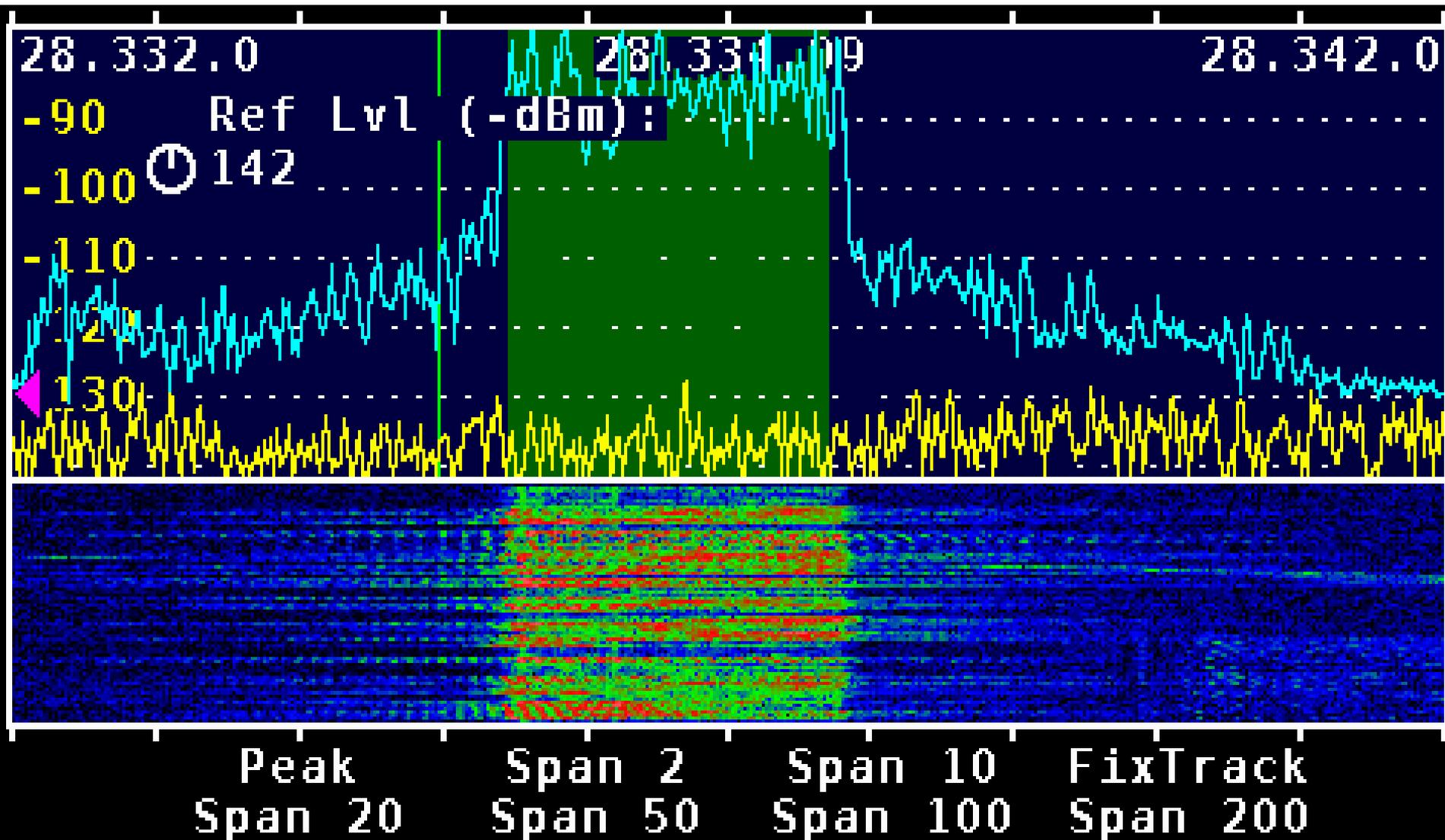
7600 50W "Narrow" w/Compression
20 kHz Wide Display

28.327.0   28.335.04   28.347.0

Ref Lvl (-dBm):

9 kHz Wide -40dB

-90
139
-100
-110
-120

Peak   Span 2   Span 10   FixTrack
Span 20   Span 50   Span 100 Span 200
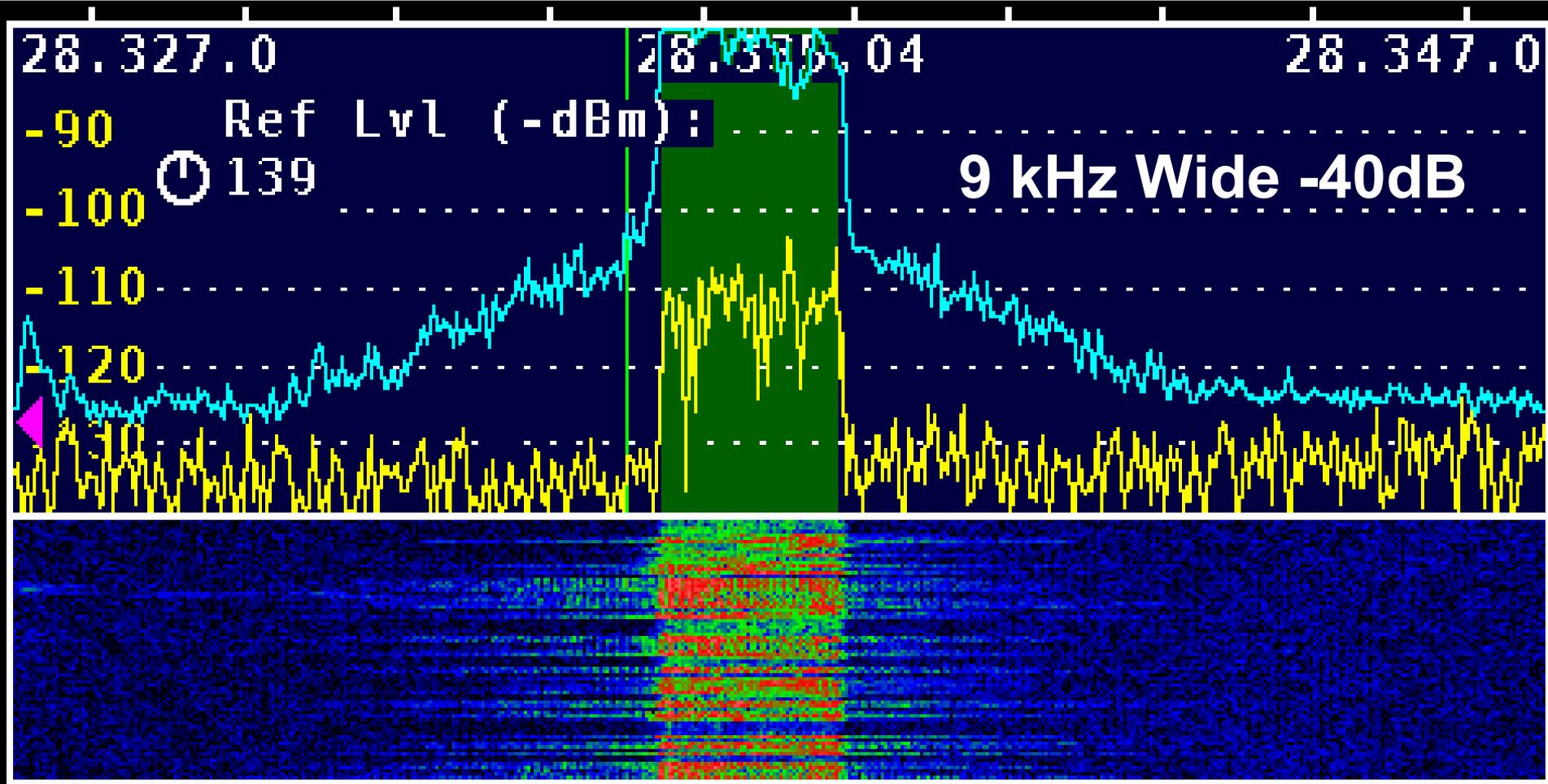
Power Amp Problems

- **Linearity**
  - **Insufficient Bias**
  - **Mistuning**
- **Power Supply Hum**
- **EBS Problems (paper crunch)**
- **ALC**
- *Garbage In = Garbage Out*

Amplifier Linearity

- **Production Solid State Amps are NOT as clean as 40-year old Tube technology**
  - **SS: Mid 30-dBc IMD reading**
  - **8877: High 30s to mid 40-dBc**
- **Solid state amps have same issue as SS Xcvr**
  - **Sensitive to P_{OUT}**
  - **Sensitive to Load Impedance (Fixed Tune)**

Fixes

- **Tune Your Amp!**
  - **General Amp tuning**
  - **Alpha 87A (tune it right)**
  - **Use tuner with Solid State Amp**
- **Repair Your Amp!**
  - **Hum (PS Capacitors)**
  - **Linearity (Bias, AL-series mode switch)**
  - **EBS (time constant)**

Fixes

- **ALC: Don't use it**
    - **Gross Overdrive Protection only**
- **Set amp power using output power control of transceiver**
- **Drive your amp with a decent exciter**

Amplifier is Clean Enough

Output
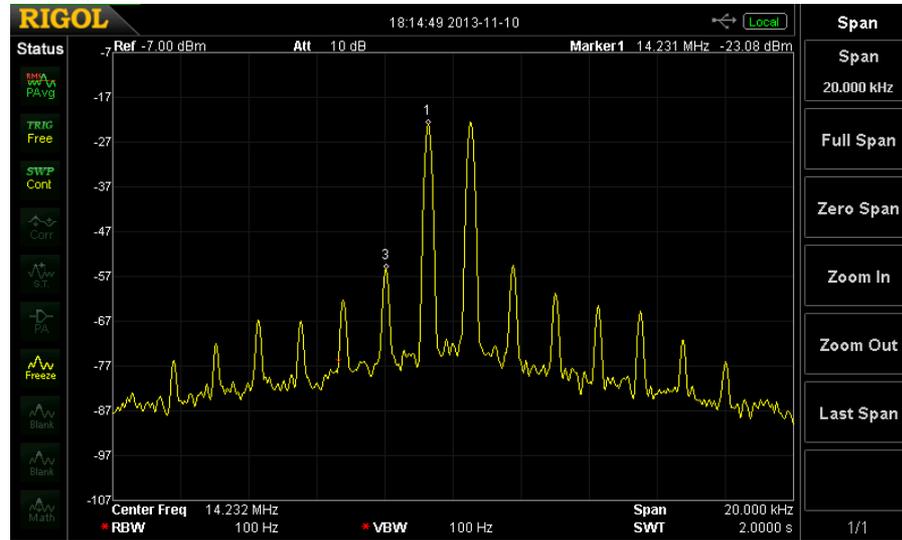
Only 3 dB more distortion

Input
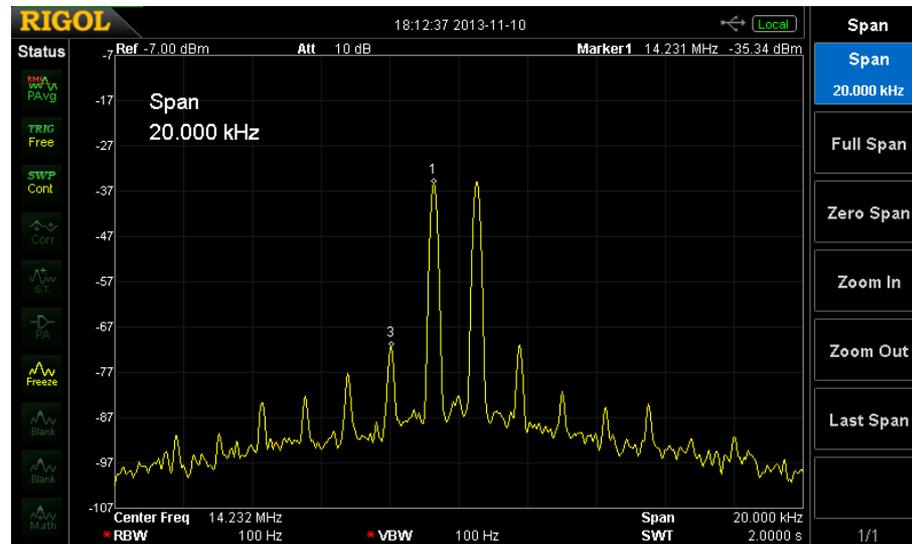
Amp is Adding Distortion

Output
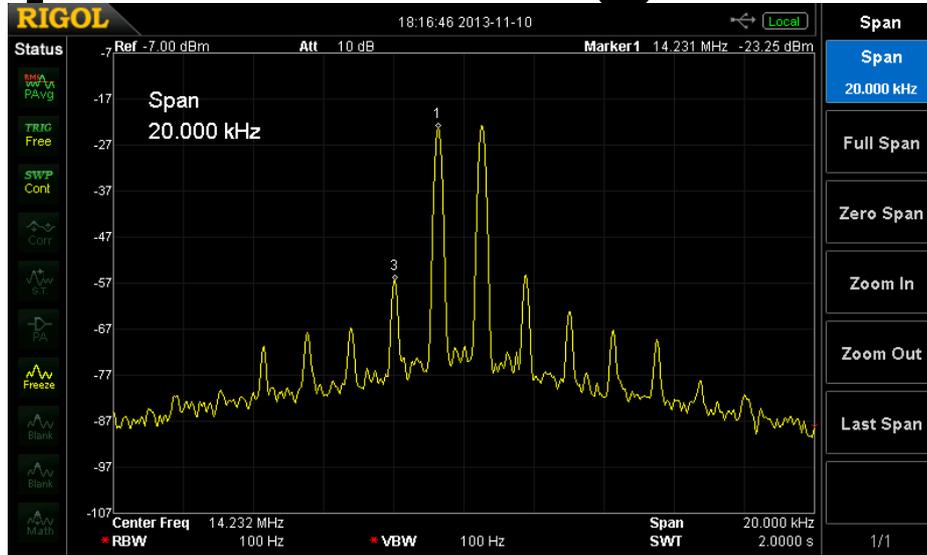
Note added sidebands

Input
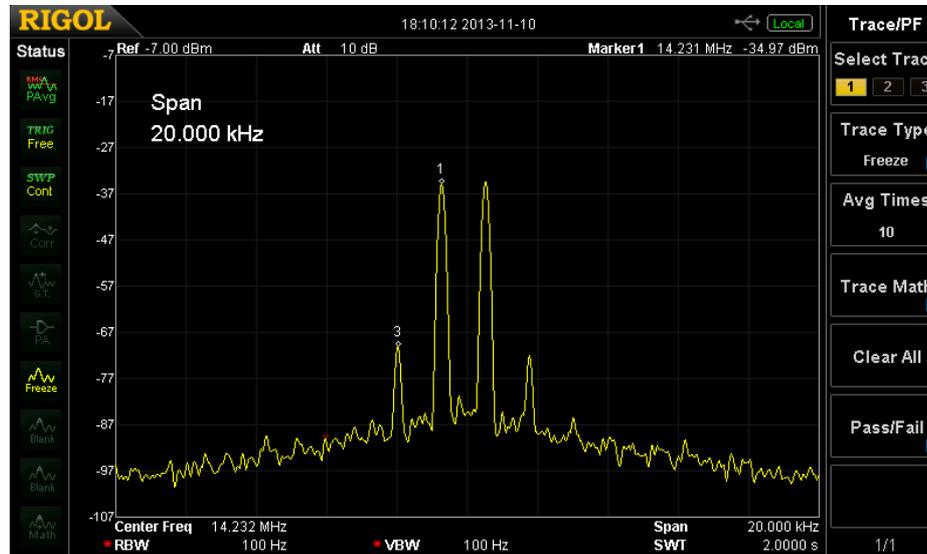
Only first difference frequencies

ICOM 7600 8 msec Driving AL1500
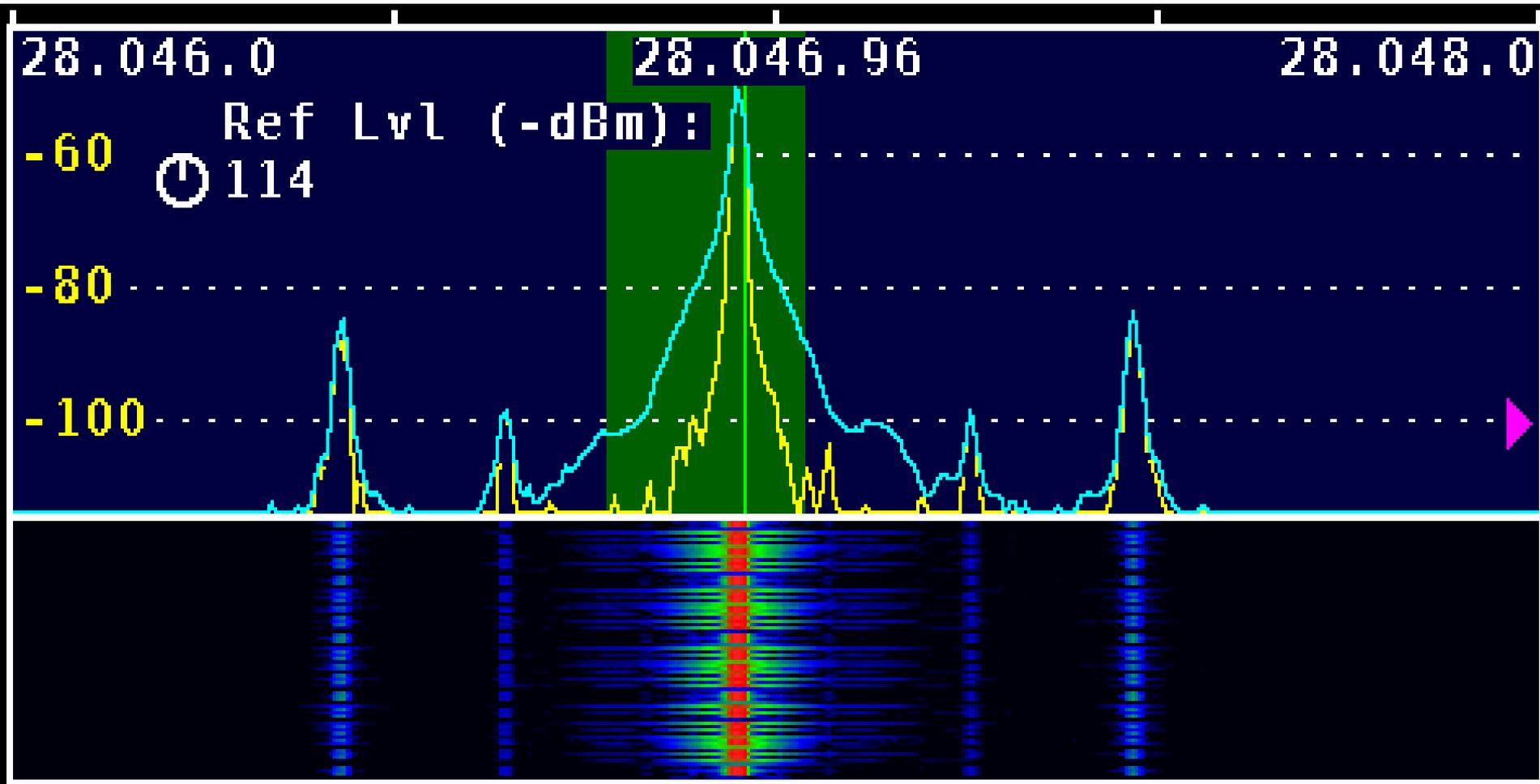
ICOM 7600 8msec Overdriving AL1500
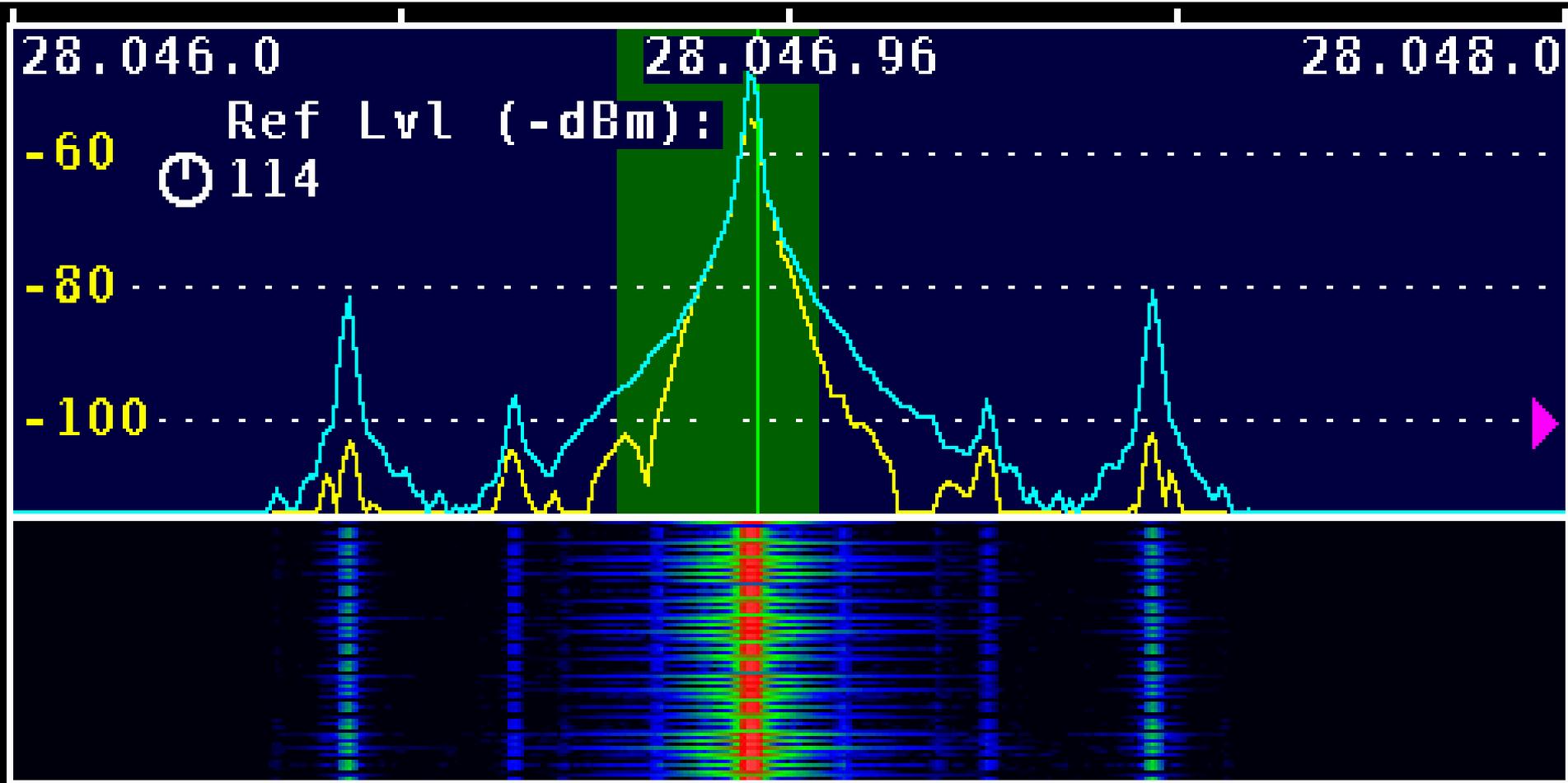
Transmitter Testing—Equipment

Test Equipment

Clean Operating

- **Adjust your transceiver properly**
  - **Mic Gain/Compression**
  - **Drive/Carrier Level**
  - **Menu settings**
  - **Most aggressive settings may not be best**
- **Tune Your Amplifier**
  - **Then RE-Tune it**
- **Results are Measureable**

The Audio Side of It

Audio Distortion = Splatter

- **Distorted audio hurts everyone**
  - **Fills bands with trash**
  - **Makes you hard to copy**
- **Mic gain turned up too high**
- **Compression turned up too high**
- **Computer output distorted**

Computer Playback Problems

- Computer playback turned up to high at rig
- Computer overdrives mic input of rig
  - Computer ~ 1V peak ("Line" level)
  - Mics ~ 0.05 – 0.1 V peak
- Feed computer to a "Line" input
  - Called "Patch" on some rigs

Computer Playback Problems

- **Add simple voltage divider between computer and rig (4.7K series, 1K shunt)**
- **Audio can be distorted by computer itself**
  - **Output turned up too high**
  - **6 dB lower output => 10 dB less distortion (splatter)**
  - **Recording can be distorted**

Computer Recording Problems

- Plug good headphones into your computer and listen carefully to your recording

- Reduce mic gain when recording until it sounds clean

- Don't crowd your mic

Don't Crowd Your Mic

- **Minimizes breath pops**
- **Minimizes low end boost**
- **Drink coffee, eat munchies**
- **Close enough to minimize room noise**

Computer Recording Problems

- Plug good headphones into your computer and listen carefully to your recording

- Reduce mic gain when recording until it sounds clean

Getting Clean Punchy Audio

- **Record your messages carefully**
- **Avoid distortion through entire signal chain**
- **Roll off lows below 400 Hz**
  - **Room/fan noise, breath pops**
  - **Wasted RF power**
  - **Lows make voices muddy**

Getting Clean Punchy Audio

- **Use compression, but adjust carefully**
  - **> 10 dB starts getting crunchy**
- **Get someone to listen to you as you adjust compression and EQ**
  - **He should listen wide (3 kHz)**
  - **No lows in your voice**
  - **No distortion**
  - **Listen both sides to hear splatter**

Suggestions for Specific Rigs

- **K3 – set TXEQ for max cut of 3 lowest bands, some cut of fourth (listen), flat for the rest**
  - **Start with 10 dB compression on peaks, exceed that only with a critical listener looking for splatter**
- **FT1000 family – only one menu option is acceptable, can be carefully tweaked with a good listener to sound good**
- **ICOM 7600 – sell it to a PVRC member**

Why Bother With Audio?

- **Doing it well is as good as adding a power amp!**
  - **10-13 dB from careful compression**
  - **2-3 dB from rolling off low end**
  - **You're louder and easier to copy**
  - **Carefully avoid distortion**
  - **Doing it badly can make you unreadable**
- **WebEx tutorial on NCCC website about recording audio messages and rig setup**