

# Sound Card Oscilloscopes and Digital Modes

K3EUI

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# Hardware for Digital Modes

Interface - between computer and radio by two audio cables or by a single usb cable

Sound Card INPUT - from speaker/headphone  
or DATA jack (constant vol)

Sound Card OUTPUT - to MIC or Data jack

PTT - usb/serial or VOX (SignalLink)

GND - common ground cable

**Goals:** set proper RX and TX levels  
optical isolation of audio lines  
avoid RF feedback

Tigertronics Signalink (usb) both RX and TX audio connects to DATA jack or MIC jack cost about \$100



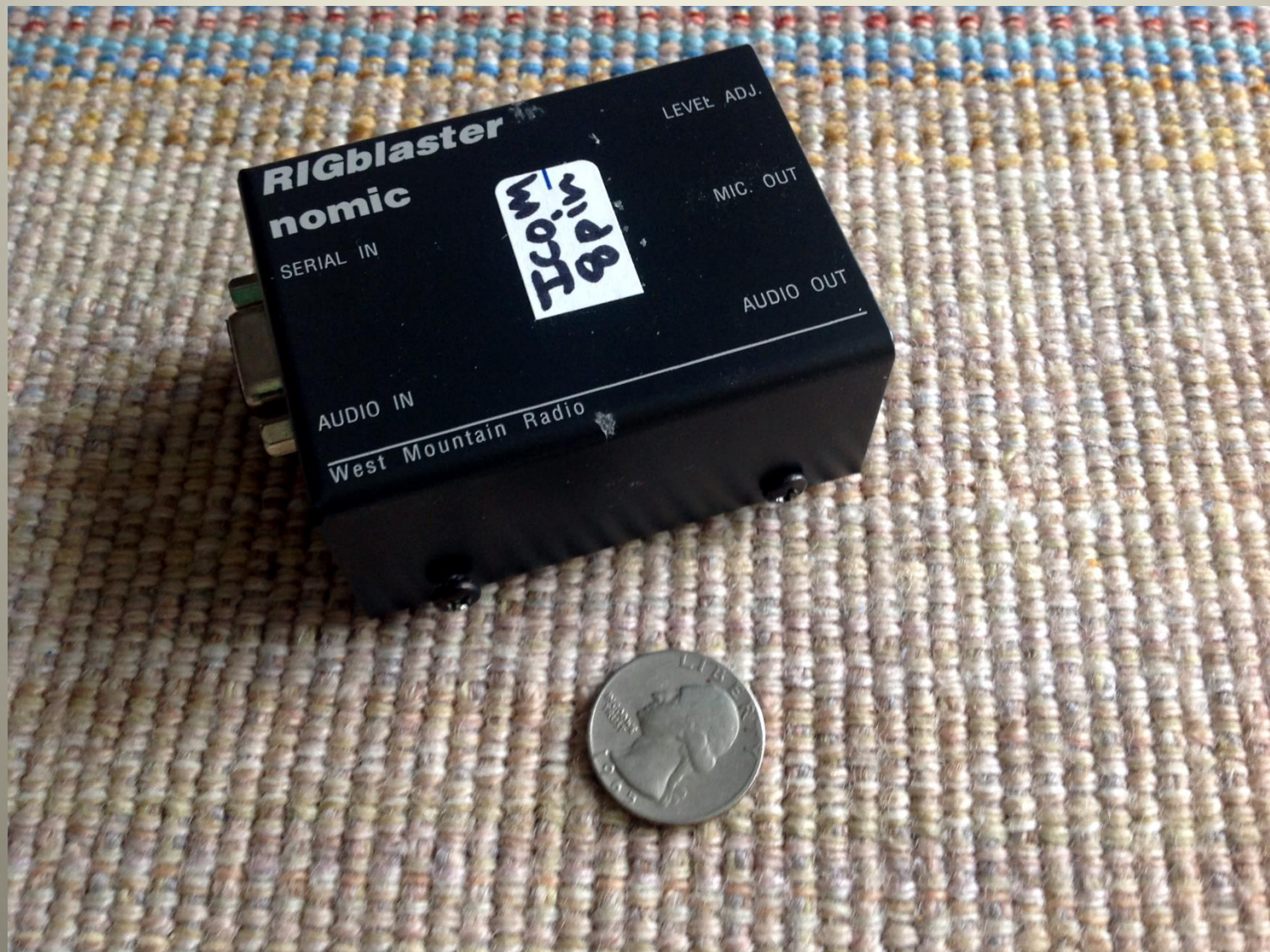
Rigblaster: uses sound chips in computer  
allows for L/R/both audio for TX  
Designed to plug into a MIC jack  
VOX or PTT circuit via a COM port  
cost about \$50 used market



**Rigblaster "Advantage"**  
usb port with built-in low-noise sound chips  
cost about \$150



Simple Rigblaster "nomic"  
only handles sound card TX audio (no mic connection)  
cost well under \$100



External USB Sound Blaster usb hardware  
very high quality, low-noise sound chips (\$100)



Simple 2-cond shielded cable with TX and RX audio  
via 1:1 isolation transformers





What is the "best" interface?

# Oscilloscopes

How do hams use these in the radio shack?

(stand up if you have a "scope" in your shack)

Physical Oscilloscopes vs. Sound Card Oscilloscopes

analog with CRT beam vs. Digital and LCD display

useful frequency range (Radio frequencies vs. audio freq)

cost comparison

Tektronics scope 50 MHz about \$500

Rigol scope 50 MHz about \$350

Sound Card (audio) Oscilloscope - most are FREE

**What is a  
"sound card oscilloscope" ?**

An oscilloscope is just a  
fast graphic voltmeter  
allowing you to "see"  
the shapes of AC voltages over time

You can use an oscilloscope to

measure period or frequency

measure peak voltages

measure rise/fall times

check for clipping

check for harmonics

Most modern oscilloscopes can do  
"math" functions  
like a FFT calculation  
to plot a frequency spectrum

"Fast Fourier Transform"  
breaks up a complex wave into its sine-  
wave components

## Sound Card Oscilloscopes

use the PC's built in soundcard for the audio analog/digital (A/D) conversion

How can we use Sound Card Oscilloscope apps with our radios?

Examine shapes of RX and TX signals

Examine audio bandpass

Look for 60 Hz hum

Examine the envelopes of digi signals



# Oscilloscope apps for Windows machines

Christian Zeitnitz: Sound Card Scope

## Soundcard Scope 1.46

This Software is NO Freeware !

Usage of the program incl. documentation is granted free of charge for private and public educational usage.

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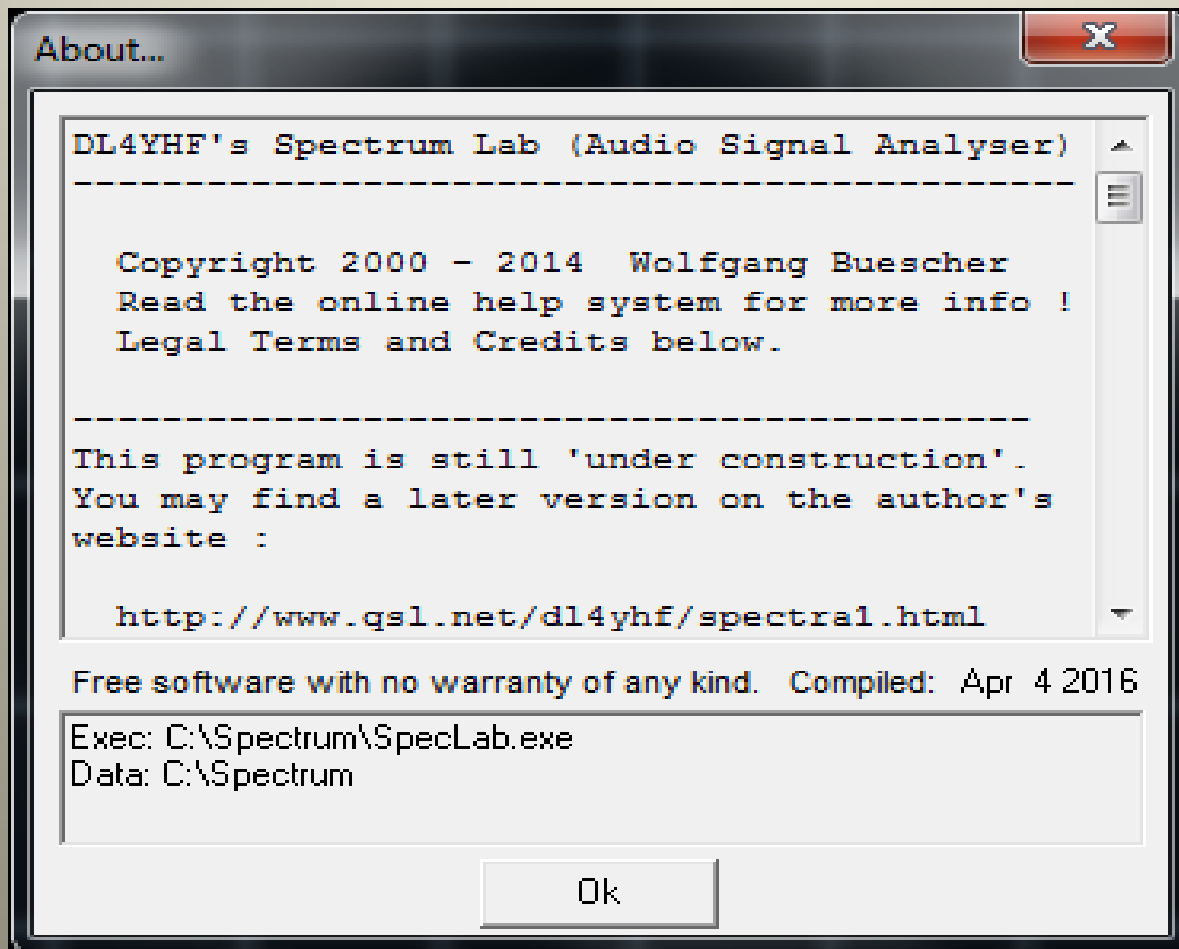
Christian@Zeitnitz.de

[http://www.zeitnitz.de/Christian/scope\\_en](http://www.zeitnitz.de/Christian/scope_en)

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OK

# DL4YHF Spectrum Lab



# Spectrum Labs

## Sound Card Oscilloscope

More powerful FFT analysis

Finer resolution in Hz bins

Larger Screen Size

Many more options for averaging

Needs a faster processor

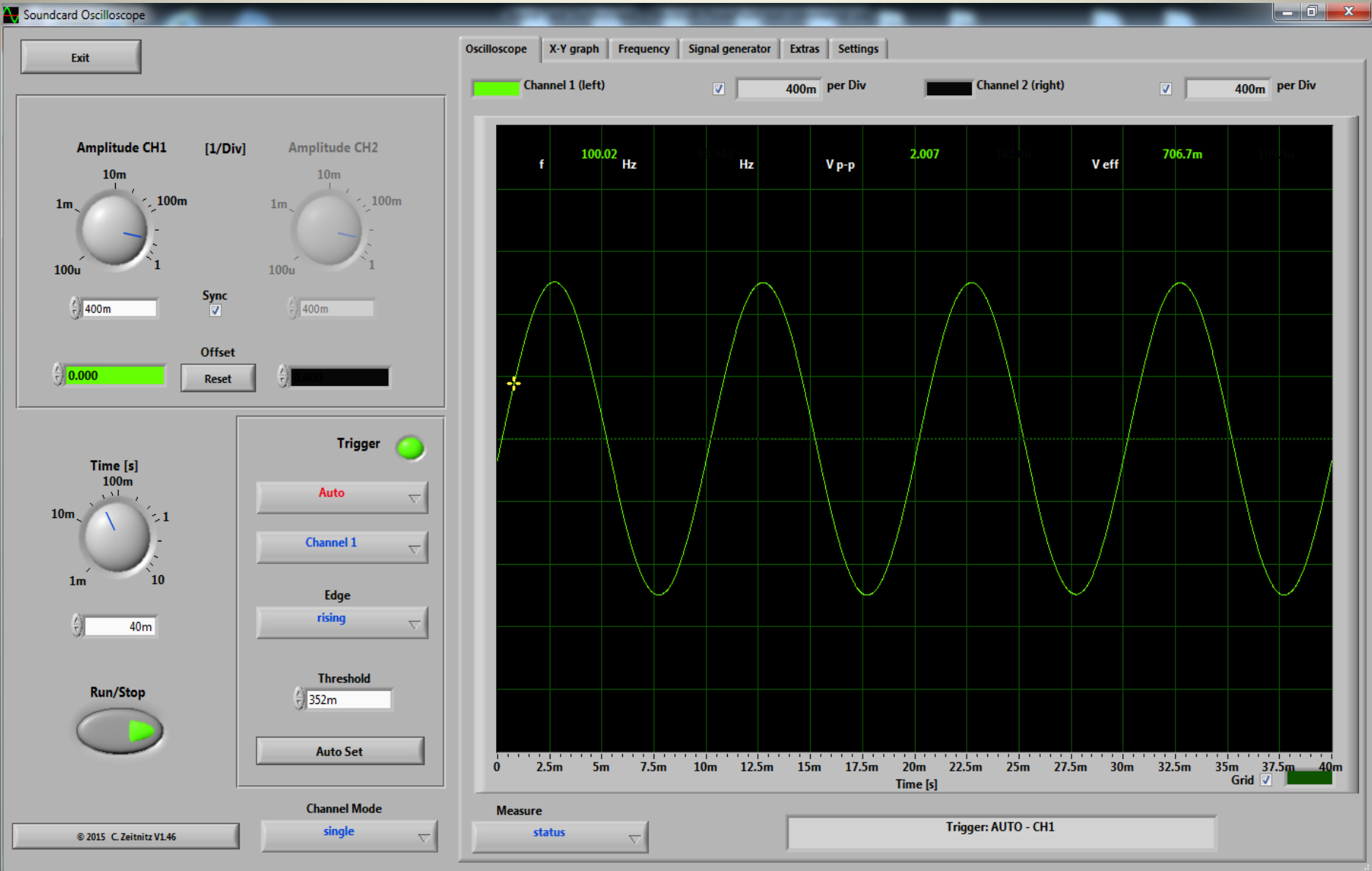
# Zeitnitz's Settings: choose sound card input and output, Y and X scale values, type of triggering, channel (L/R)

The screenshot displays the 'Settings' tab of the 'Soundcard Oscilloscope' application. The interface is organized into several functional panels:

- Amplitude CH1 & CH2:** Two knobs for adjusting channel amplitudes, with scales from 100u to 10m. A 'Sync' checkbox is checked, and a 'Reset' button is present.
- Time [s]:** A knob for time scale (10m to 1) and a text input field set to 40m.
- Run/Stop:** A large button with a green play icon.
- Trigger:** A green indicator light, a dropdown menu set to 'Auto', another set to 'Channel 1', an 'Edge' dropdown set to 'rising', a 'Threshold' input field set to 6m, and an 'Auto Set' button.
- Channel Mode:** A dropdown menu set to 'single'.
- Windows Sound Parameters:** Includes 'Open Audio Mixer' (Output and Input buttons), 'Audio Devices' (Output: 'Speakers (Realtek High Definition Audio)', Input: 'Line In (Realtek High Definition Audio)'), 'auto enable' (checked), and 'Volume [%]' (50.0). It also shows 'Data Format' (44100 Samples/s) and 'Bits/sample' (16).
- Scope Parameters:** Features 'On-screen values update period' (500 ms), 'Averaging time for f measurement' (300 ms), and 'Calibration of amplitude' (1.0000 V/Div). A 'Change Language' button is also present.
- Save and Restore Settings:** Contains four checkboxes: 'Save current settings', 'Read settings from file', 'Restore last settings', and 'Restore default settings'.
- Default file:** A text field containing the path 'C:\Users\bfeierman\AppData\Roaming\scoop\scope.xml' with a folder selection icon.

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Oscilloscope Screen:  $Y = \text{amplitude}$      $X = \text{time}$   
100 Hz sine wave: 2 volts peak/peak: 10 ms period



# Viewing the frequency distribution (FFT) of a 100 Hz sine wave, looking for harmonics

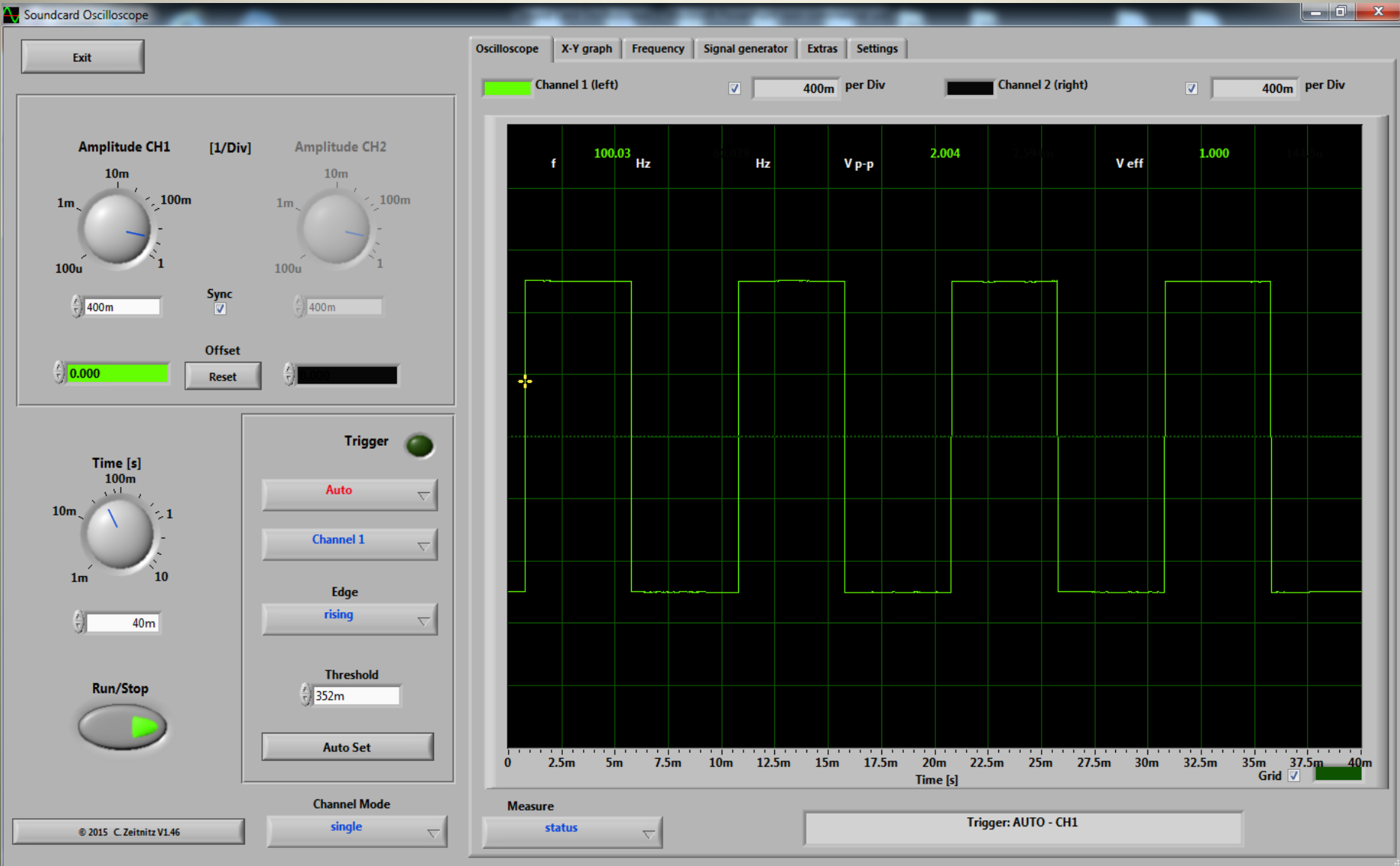
The screenshot displays the Soundcard Oscilloscope software interface. The main window is titled "Soundcard Oscilloscope" and contains several tabs: "Oscilloscope", "X-Y graph", "Frequency", "Signal generator", "Extras", and "Settings". The "Frequency" tab is active, showing a Fast Fourier Transform (FFT) plot of a signal. The plot has a vertical axis labeled "dB" ranging from 0 to -100 and a horizontal axis labeled "Frequency [Hz]" ranging from 0 to 4000. A prominent peak is visible at 100.04 Hz, with several smaller peaks representing harmonics. The interface includes various control panels:

- Amplitude CH1 and CH2:** Two rotary knobs for amplitude, both set to 10m. Below them are input fields for "400m" and "400m".
- Time [s]:** A rotary knob set to 10m, with an input field for "120m".
- Trigger:** A green indicator light is on. The trigger mode is set to "Off", the source to "Channel 1", the edge to "rising", and the threshold to "360m".
- Filter in separate window:** Two filter sections for CH 1 and CH 2. Both have a "Cut off frequency" of 1000 Hz and a "High cut off frequency" of 20000 Hz. The filter mode is set to "Off".
- Main Frequency and THD:** The "Main frequency" is displayed as 100.04 Hz. The "Frequency at cursor position" is 8.3318 Hz. The "Total harmonic distortion" is 0.11%.
- Channel Mode:** Set to "single".

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# Oscilloscope Screen: 100 Hz "square wave"

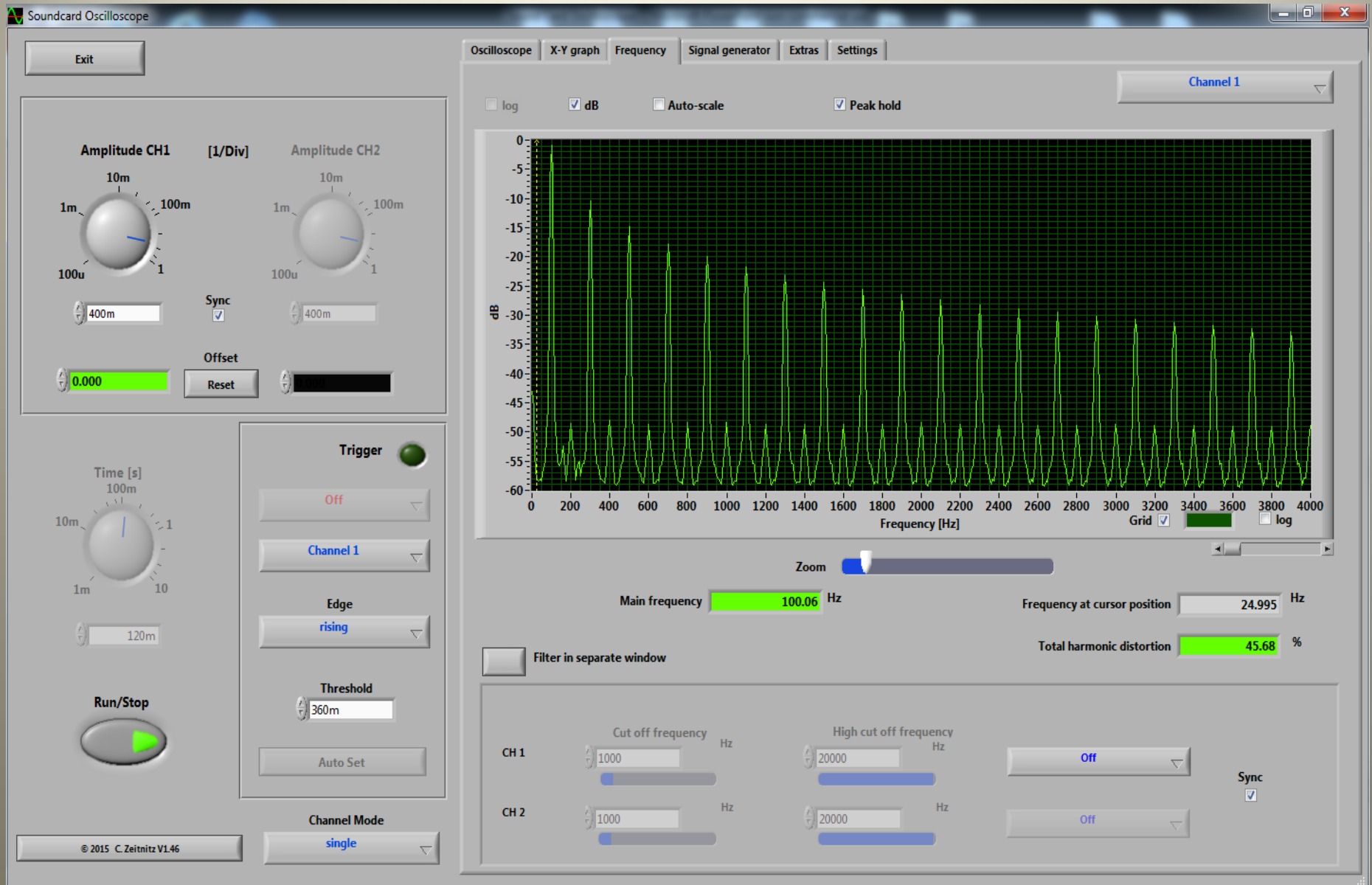
A square wave has many "odd" harmonics



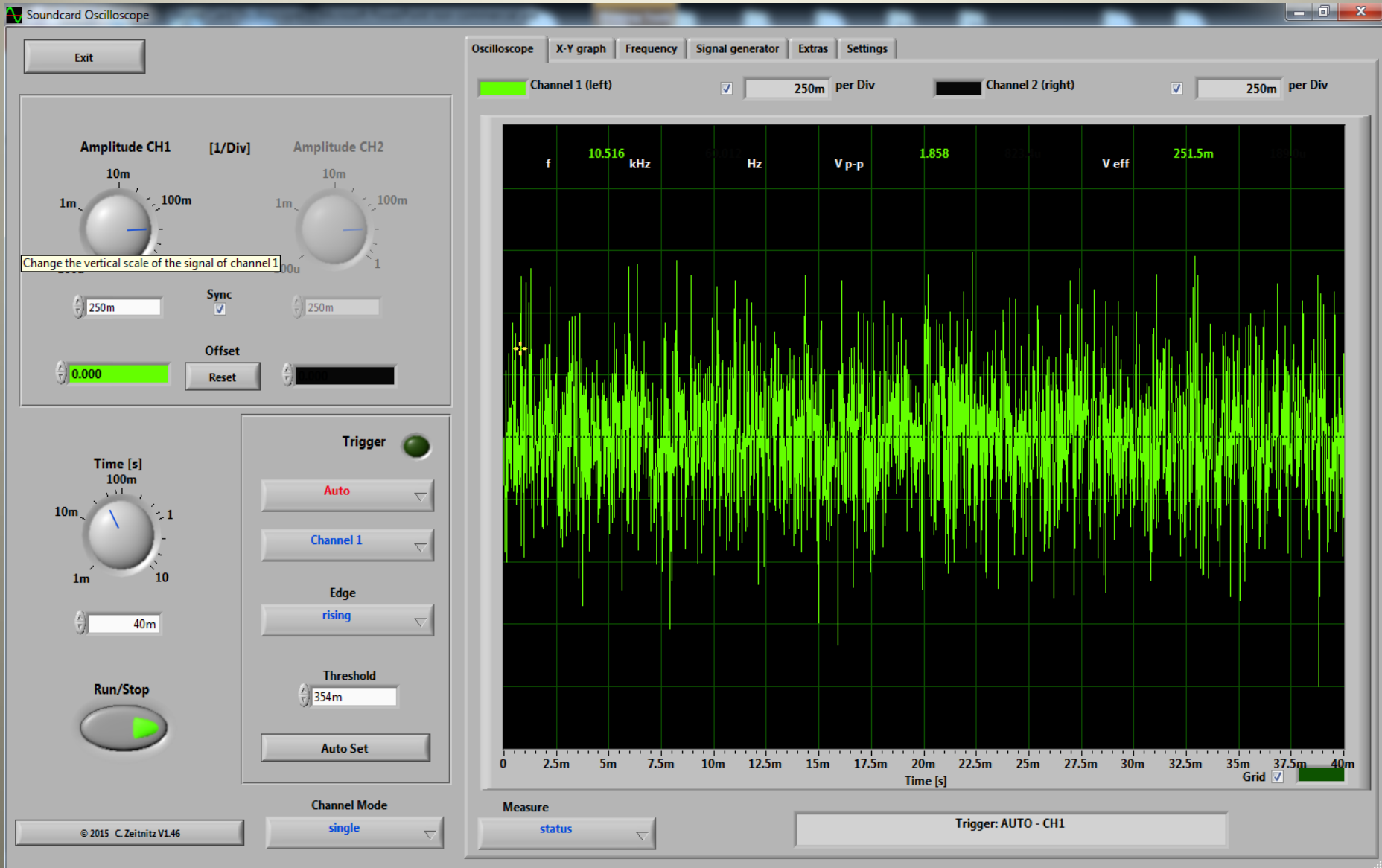


# Frequency Distribution of 100 Hz square wave

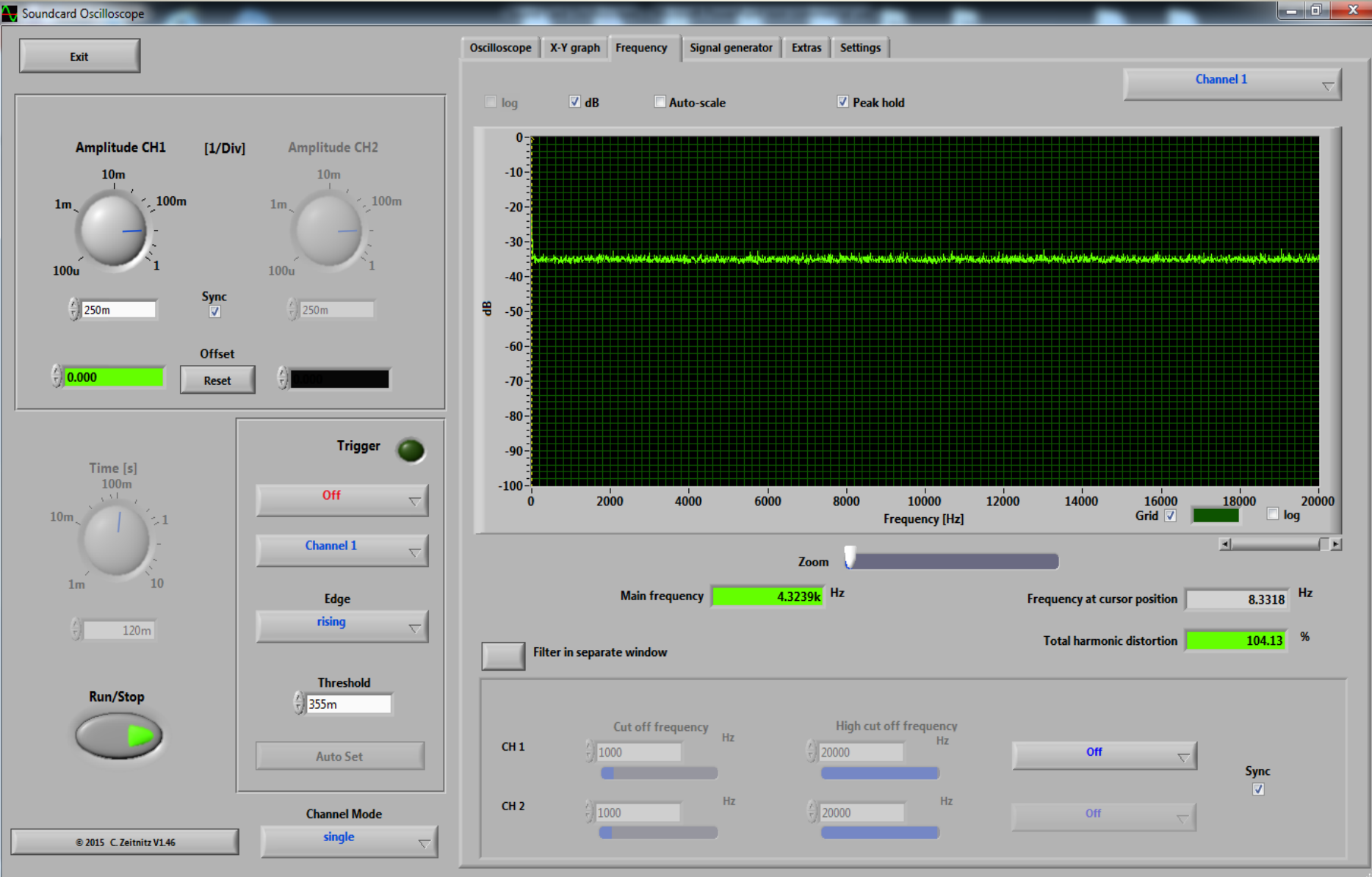
note all "odd" order harmonics (100, 300, 500, 700 Hz)



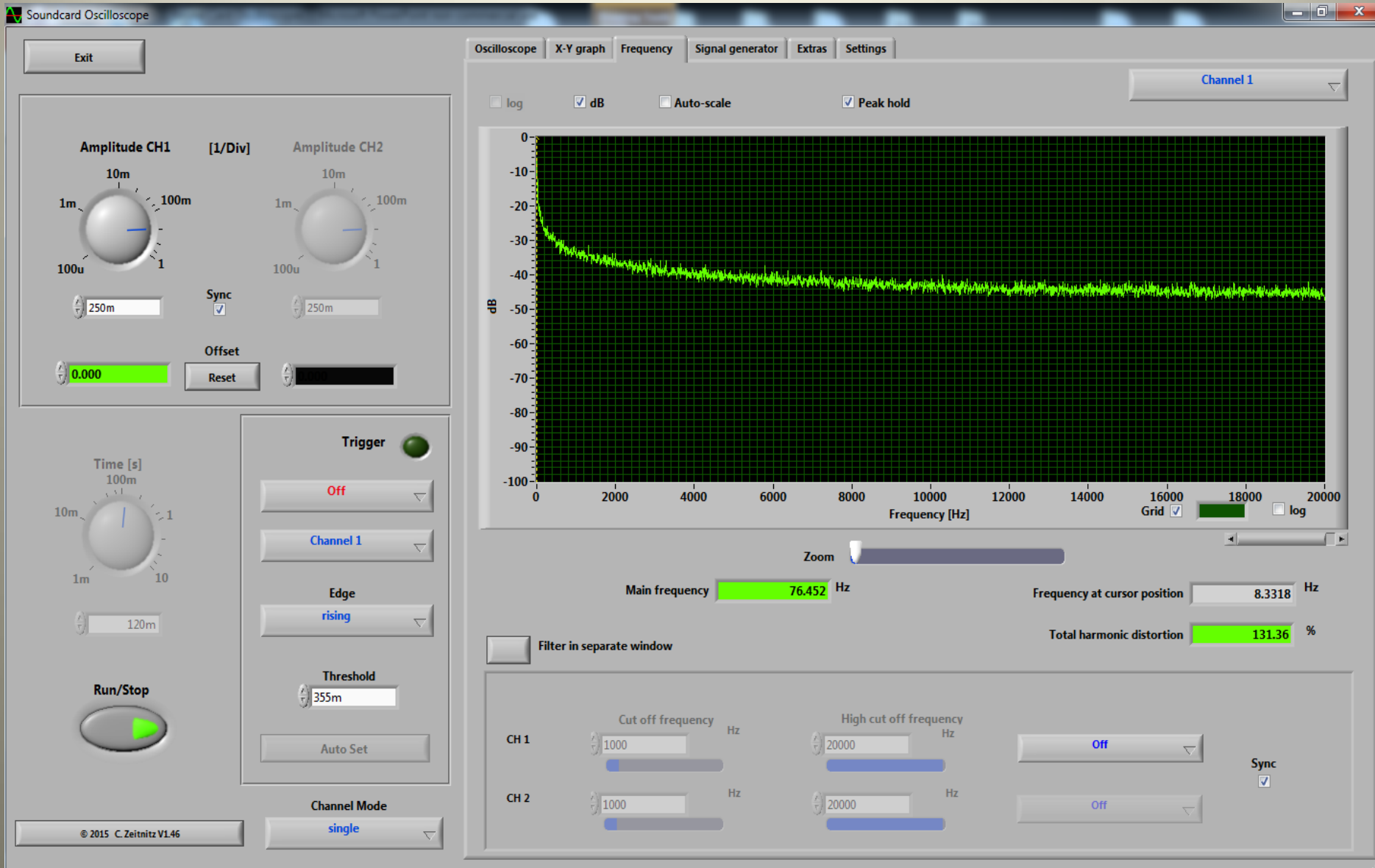
# Oscilloscope View: "White Noise" has no periodicity, no noticeable pitch



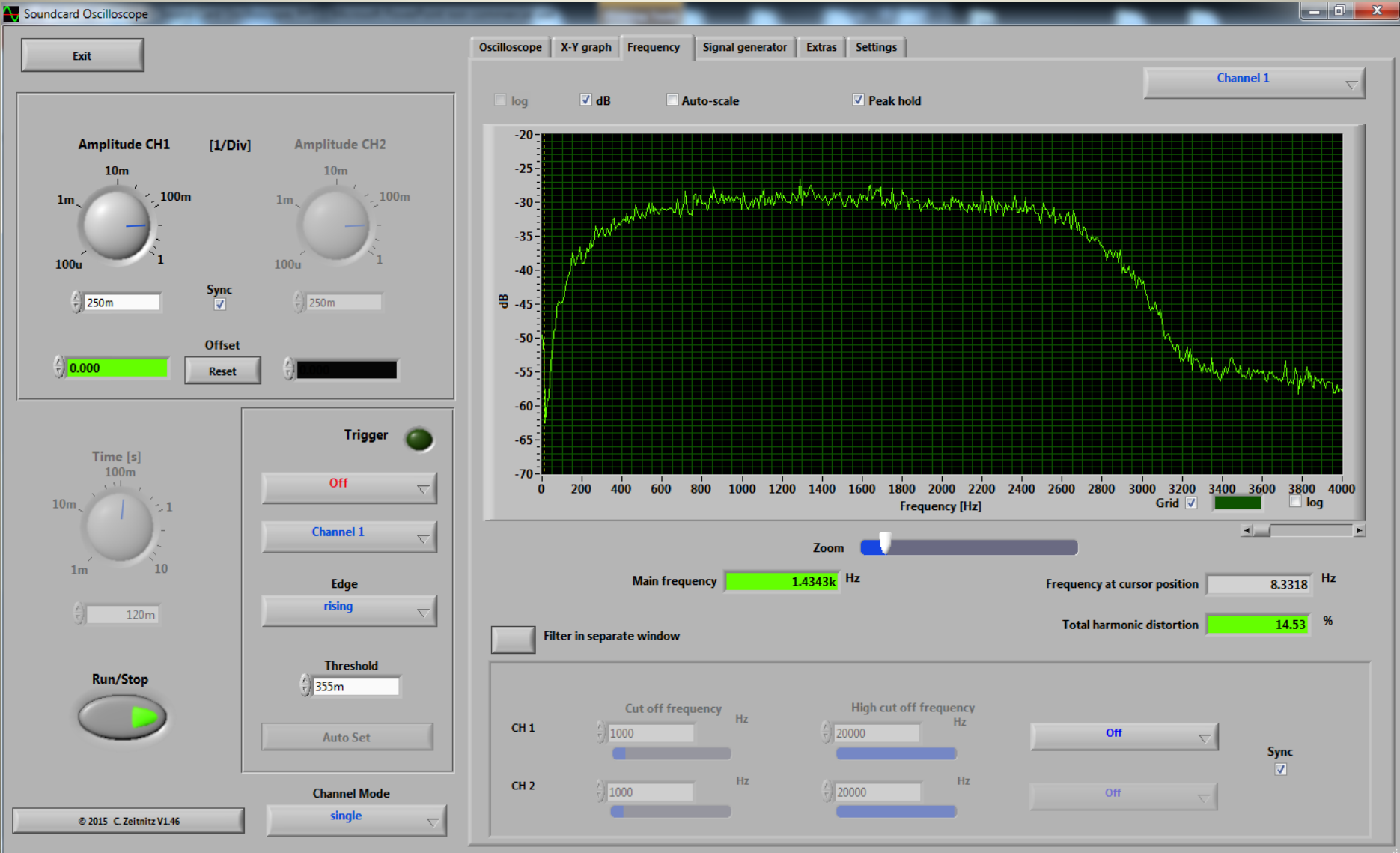
# Frequency Distribution of White Noise 0 - 20 kHz (equal energy everywhere)



# Frequency Distribution: Pink Noise 0 to 20 kHz

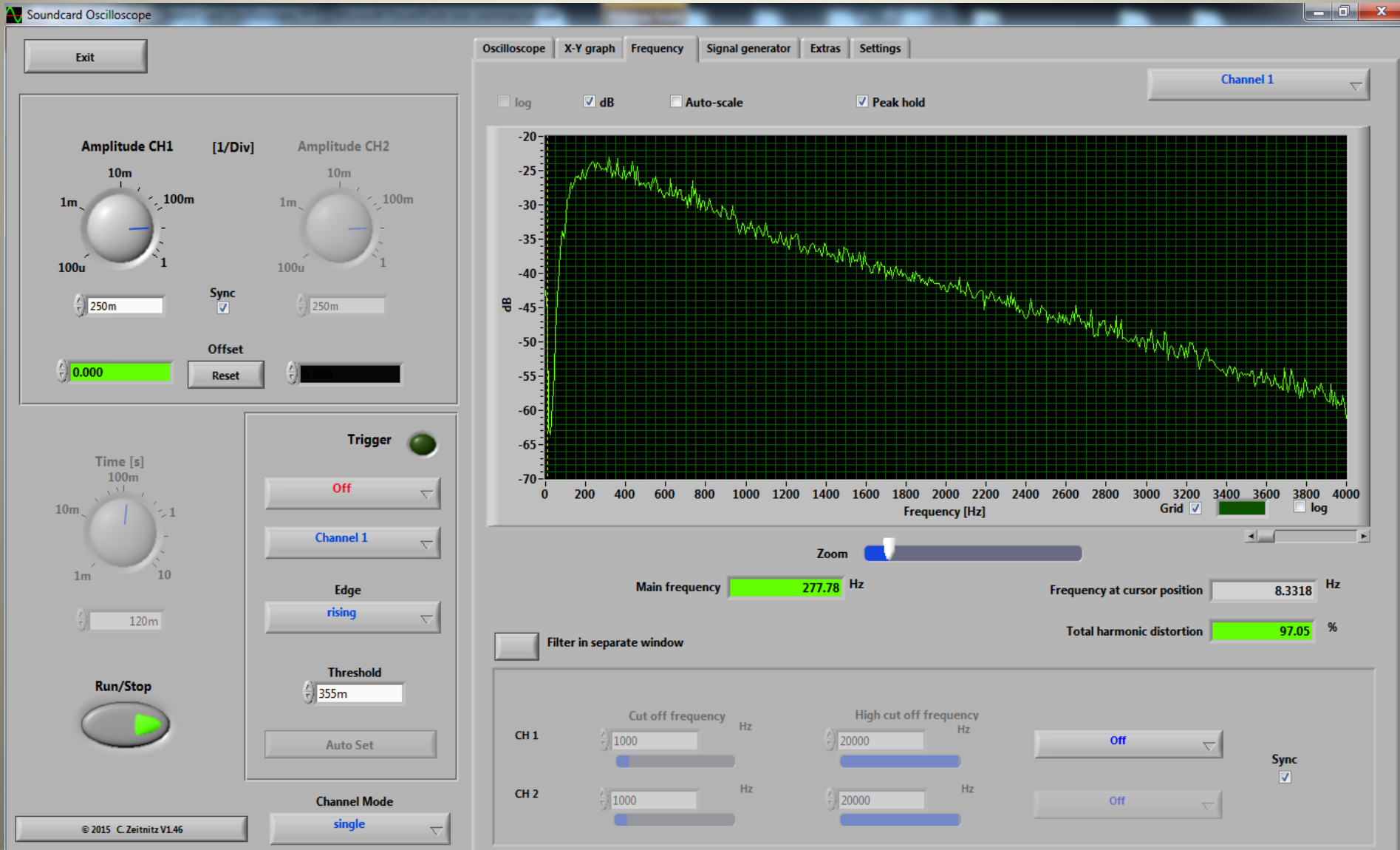


# Bandpass of a typical SSB radio: Yaesu FT 1000 (1990) in USB mode (400 - 2600 Hz bandpass)



# Bandpass of a typical FM radio 0 - 4000 Hz

## Why the gradual decline of intensity with frequency?



**What is the bandwidth of an RF carrier  
with no modulation?**

**(often called a “dead” carrier)**

**Modulation: adding information to a carrier**

**3 ways to modulate a carrier**

- 1) amplitude changes (AM)**
- 2) frequency or angle changes (FM)**
- 3) phase changes (PM)**



What **MODE** is

**on/off**

**amplitude-shift-keying?**

# CW of course

In CW a "carrier" (EM wave) is keyed on/off producing in a receiver equipped with a bfo the sounds we call "dit and dah" → Morse Code

So CW is a digital mode in the sense that a machine can interpret the ON/OFF sounds as 0's and 1's

Spaces (no sound) = 0's      tone on = 1

000 between letters, 0000000 between words

1 dah = 3 dits (3:1 typical ratio)

letter	binary equivalent
Dit e	= 10
Dah t	= 1110
Letter i	= 1010
Letter m	= 11101110
Letter o	= 111011101110

Why is CW still such a popular mode of operation especially for DX?

# Advantages of CW

A good CW operator can copy CW when the signal to noise ratio (S/N) is only 0 dB

The human ear/brain can detect and filter out the pitch you want in a qrm situation (pile up)

CW receive filters can be very narrow bandwidth (100 Hz) and hence, improve the S/N and eliminate unwanted signals

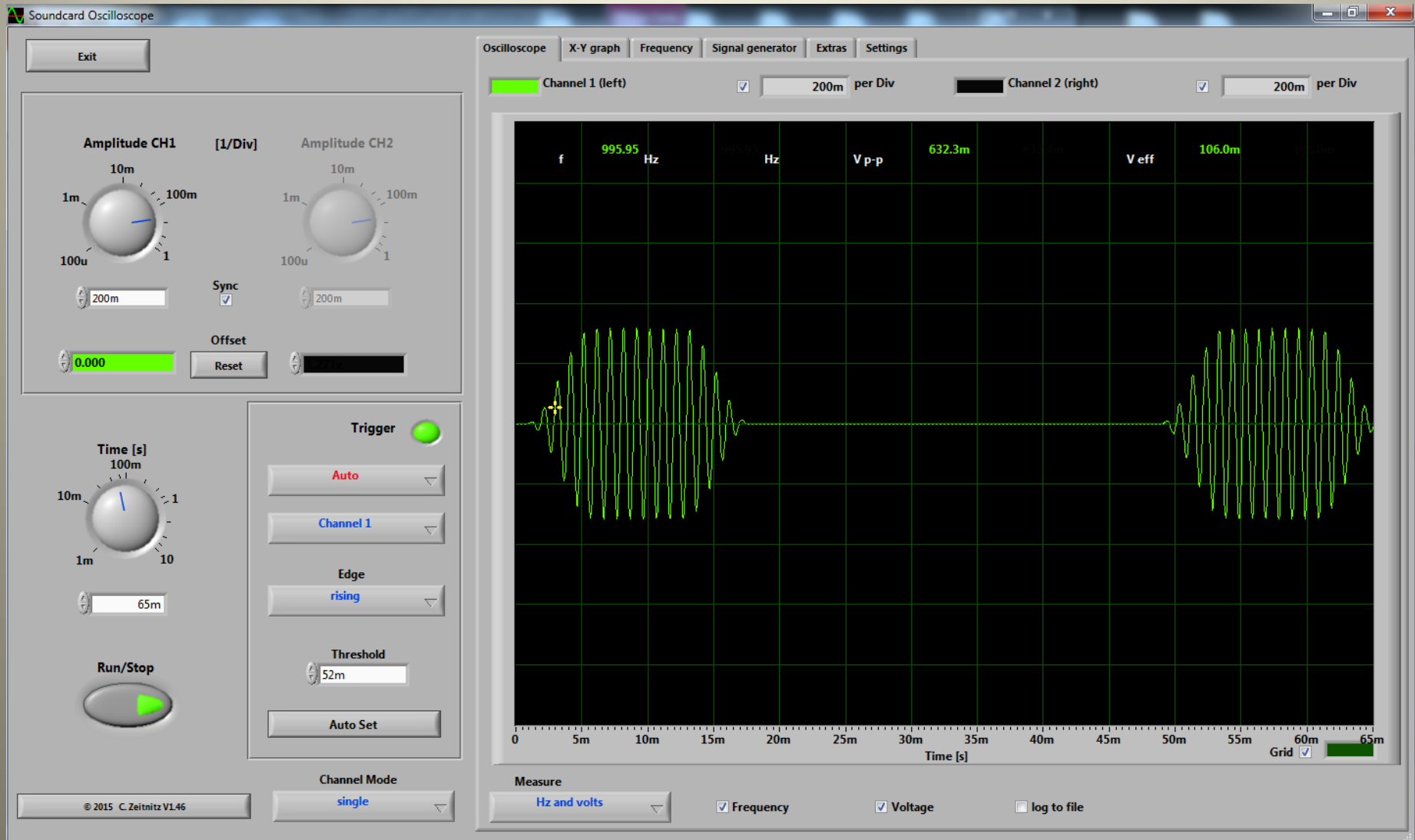
\*\*\* do not use noise "blankers" or noise "clippers" \*\*\*

What is the minimum "bandwidth" of a CW signal operating at 30 wpm

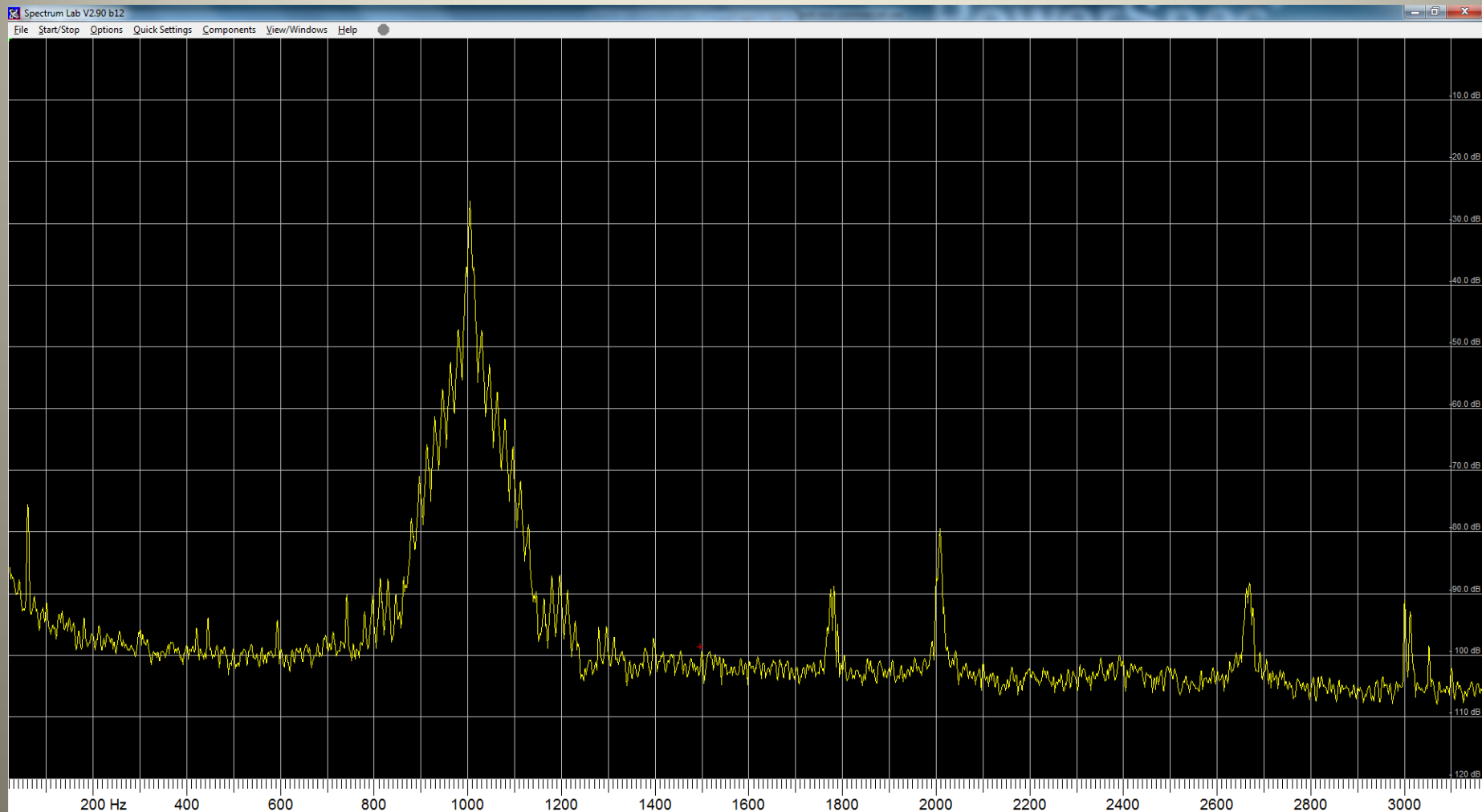
What factors determine the "bandwidth" of a CW signal?

How might an oscilloscope help you transmit a cleaner CW signal ?

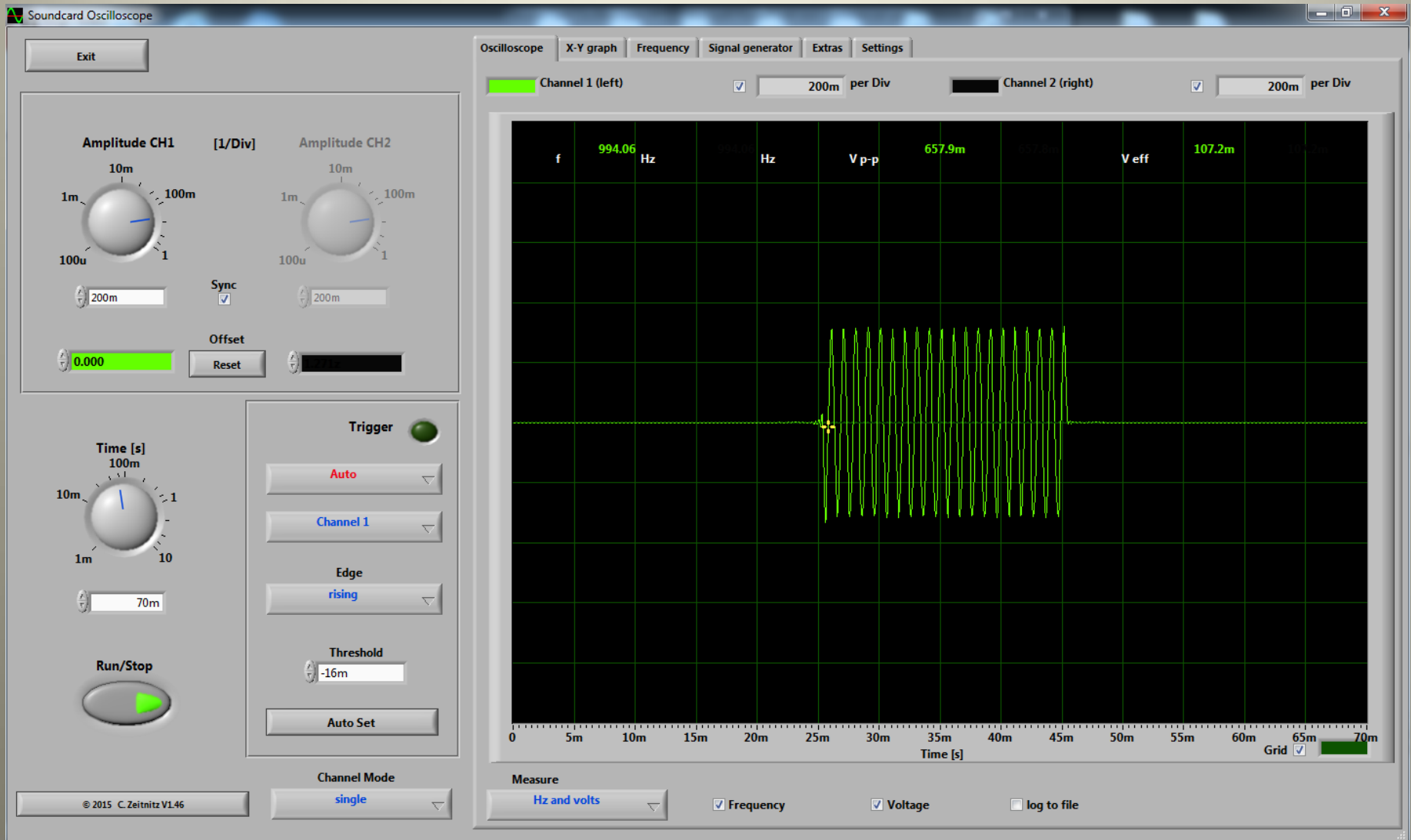
CW: dits (e) at 30 wpm  
note the 4 millisecond "rise/fall times"



Spectrum of a "clean" CW TX at 20 wpm  
center 1000 Hz 6 ms rise/decay times  
bandwidth 200 Hz @ -50 dB

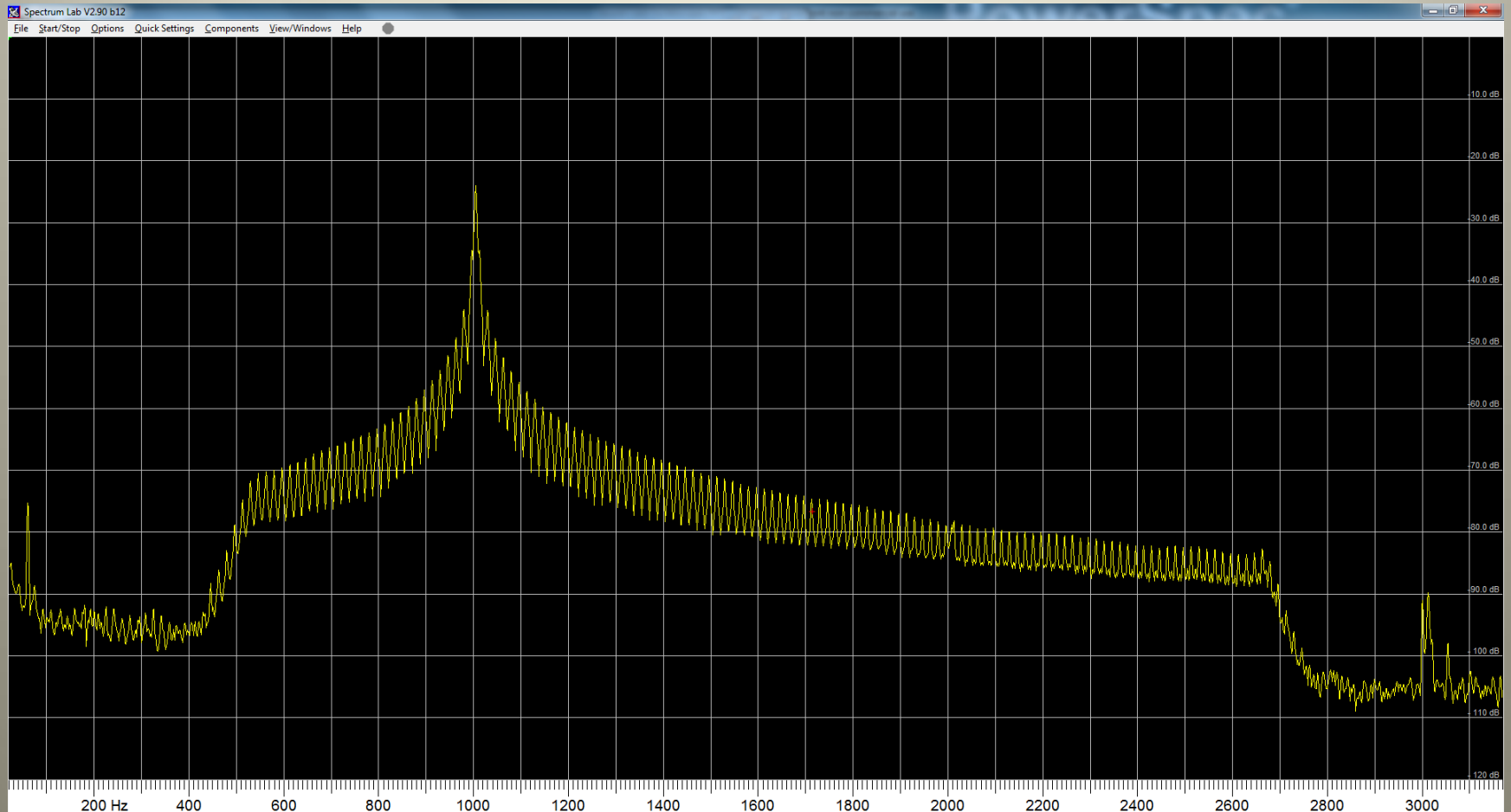


# Turning the RF on/off too quickly produces harmonics called "key clicks"

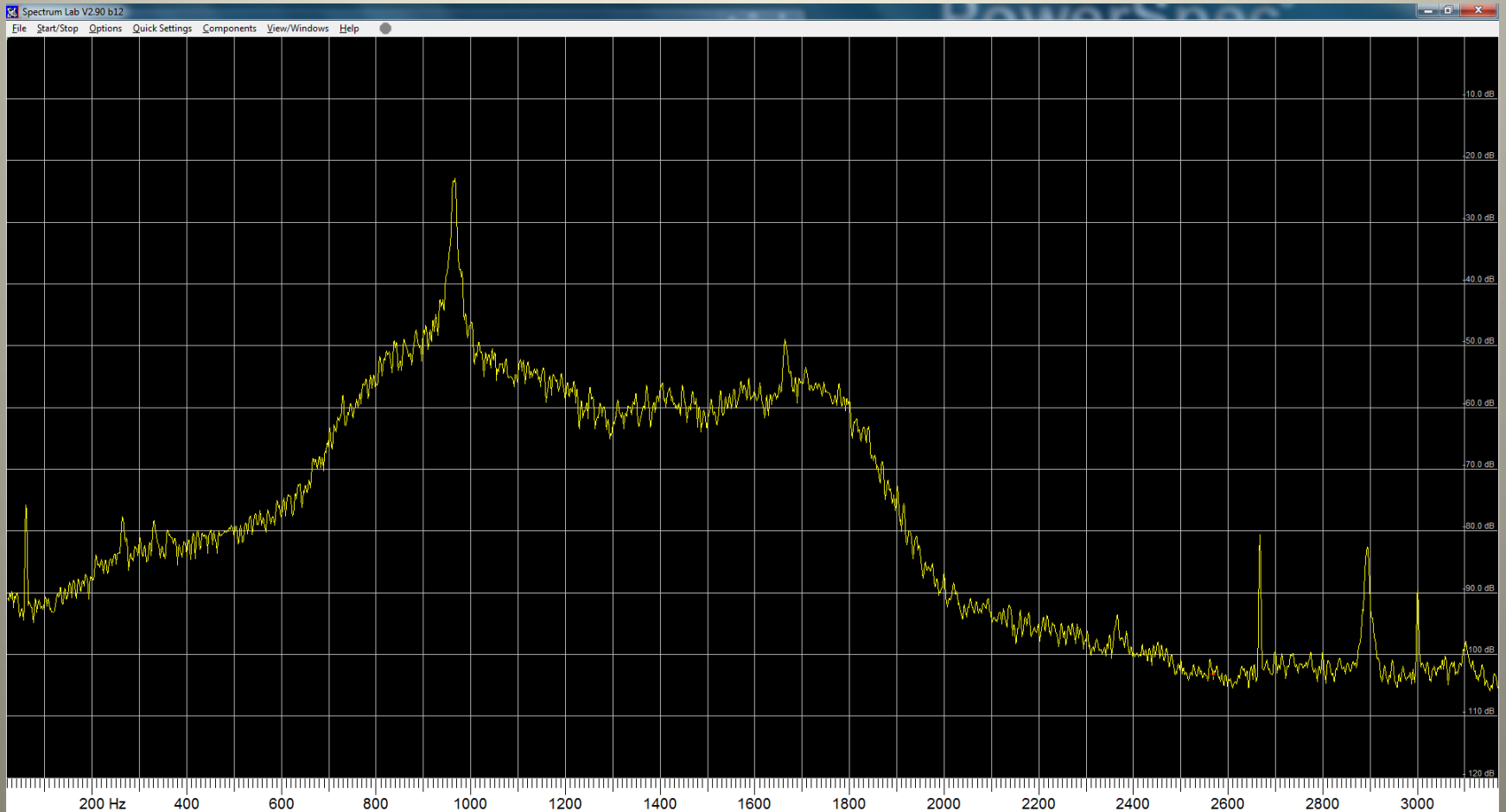




Spectrum of CW TX 20 wpm with "hard keying"  
1 ms rise/decay times - increased bandwidth  
many sidebands - "key clicks"



"clean" CW received on 40 meters from K4DAL (Va)  
He was sending @20 wpm with a keyer and TenTec Jupiter  
my RX IF bandwidth set for about 1 kHz



# RTTY: radio teletype

Rather than ON/OFF keying, like CW, why not just switch the carrier between two different radio frequencies (mark/space) to send the 0's and 1's

Pros: no time for "noise"

easy, fast, reliable, good for contests

FM rather than AM modulation

constant amplitude signals (linear amp not needed)

Cons: hard on finals ==> continuous duty cycle

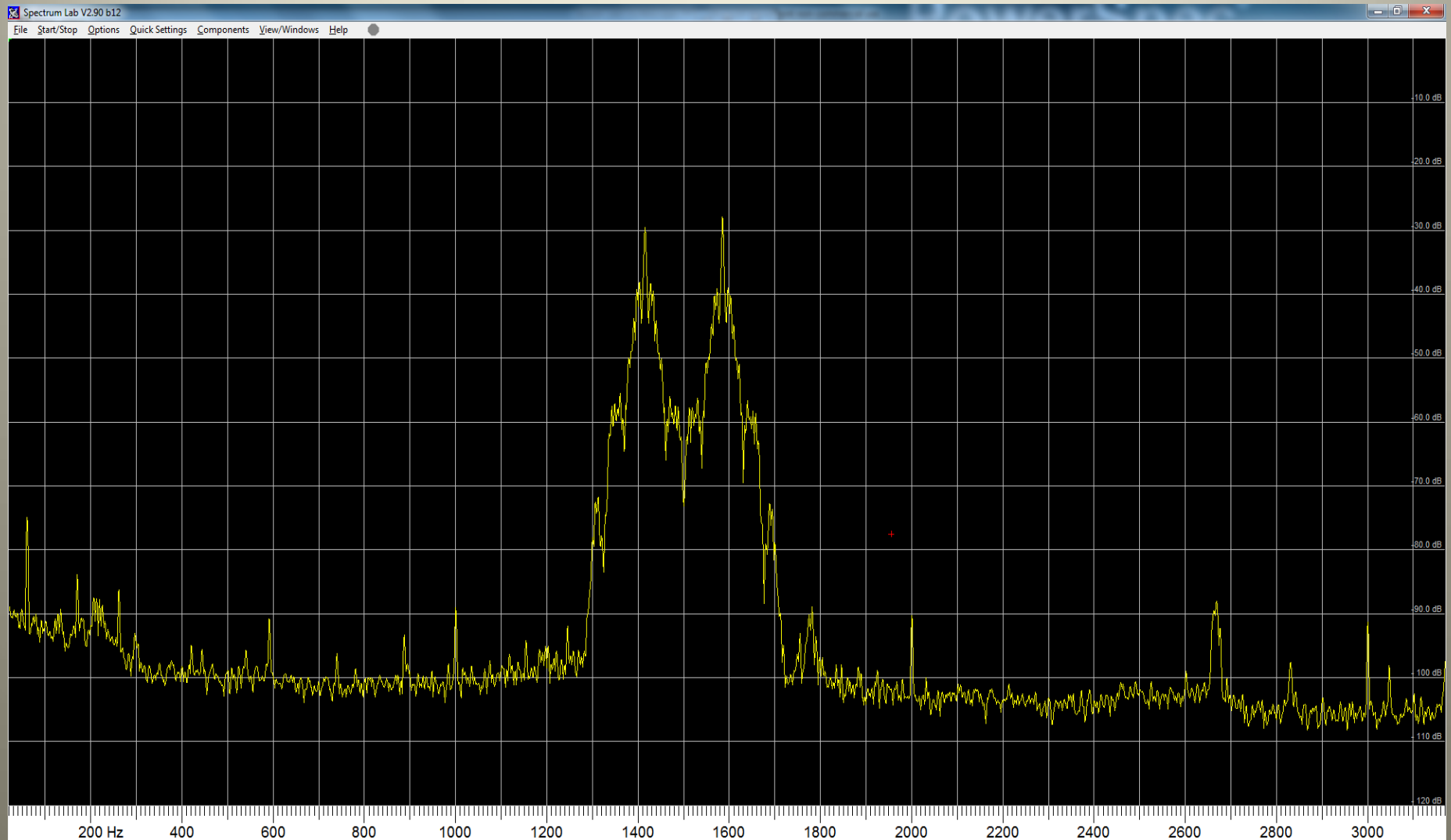
takes more bandwidth than CW

Common RTTY: 45 baud (22 millisecond per symbol)

170 Hz shift, 60 wpm, 350 Hz bandwidth

# Conventional two-tone RTTY

45 baud, 60 wpm, 400 Hz wide @ -60 dB



# Problems with RTTY 45 on HF

Fading and phase delays due to changing ionospheric refraction (not reflection) of the EM wave

Poor on "long path" contacts around the world when you get "echo-like" signals

5 bit Baudot code ==> same time to send any character and no lower case, only UPPER CASE and numbers

No FEC or any kind of error detection

# Data Rate vs. Symbol Rate

What if instead of binary modulation  
on/off CW (0/1)  
or mark/space RTTY (0/1)

You use 4, 8, 16, or 32 different audio tones in  
each "symbol"?

Then each "symbol" could carry more information,  
but needs more bandwidth, hence we have

MFSK, Olivia, Domino, THOR modes

# Multi Frequency Modes

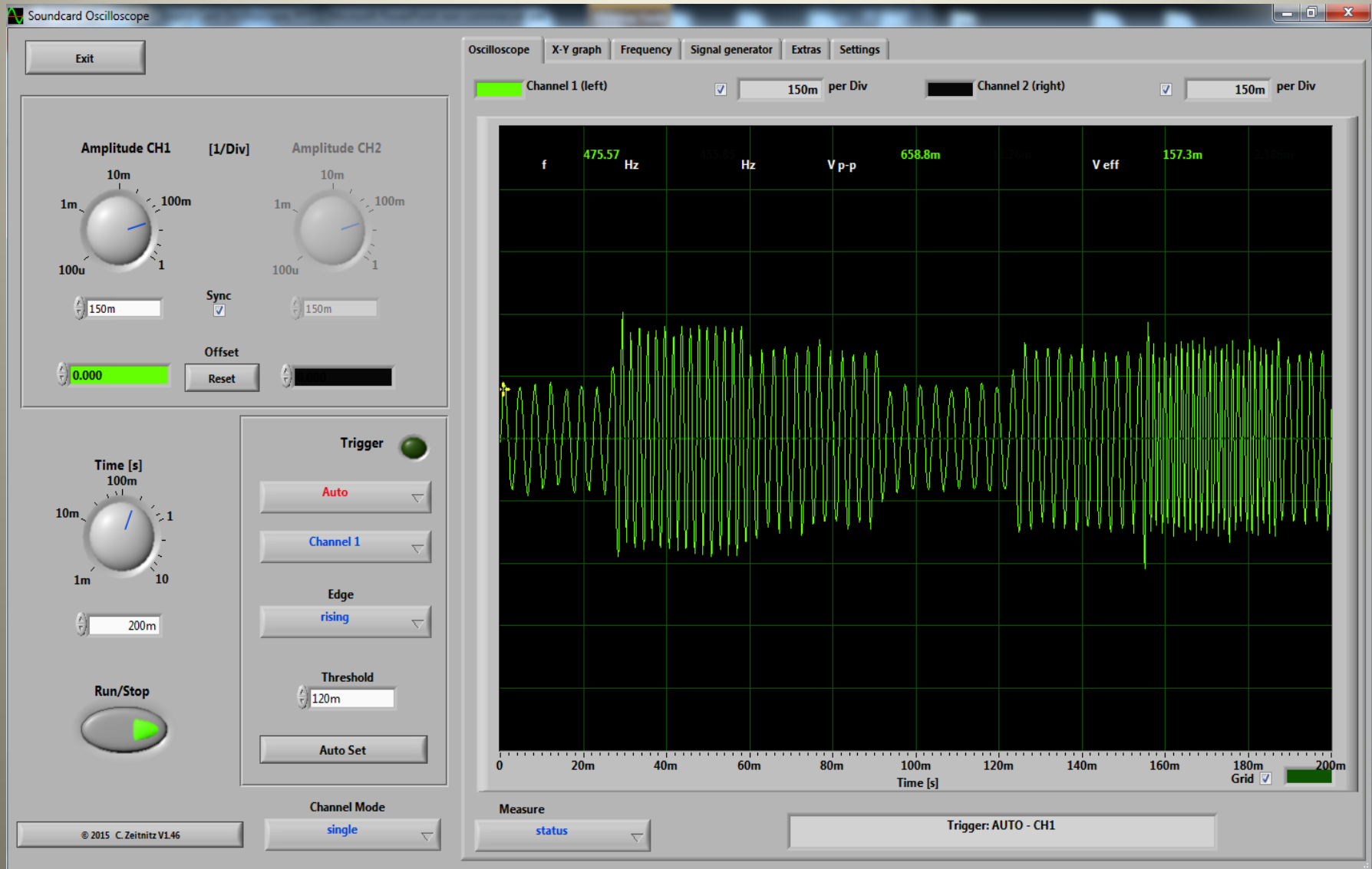
Each tone (sent one at a time) represents more data

MFSK 8/16/32/64/128 (3bit,4bit,5bit,6bit,7bit)

In F1B modes (FM) the amplitude shifts are ignored and we find noise (qrn) is mostly amplitude shifts

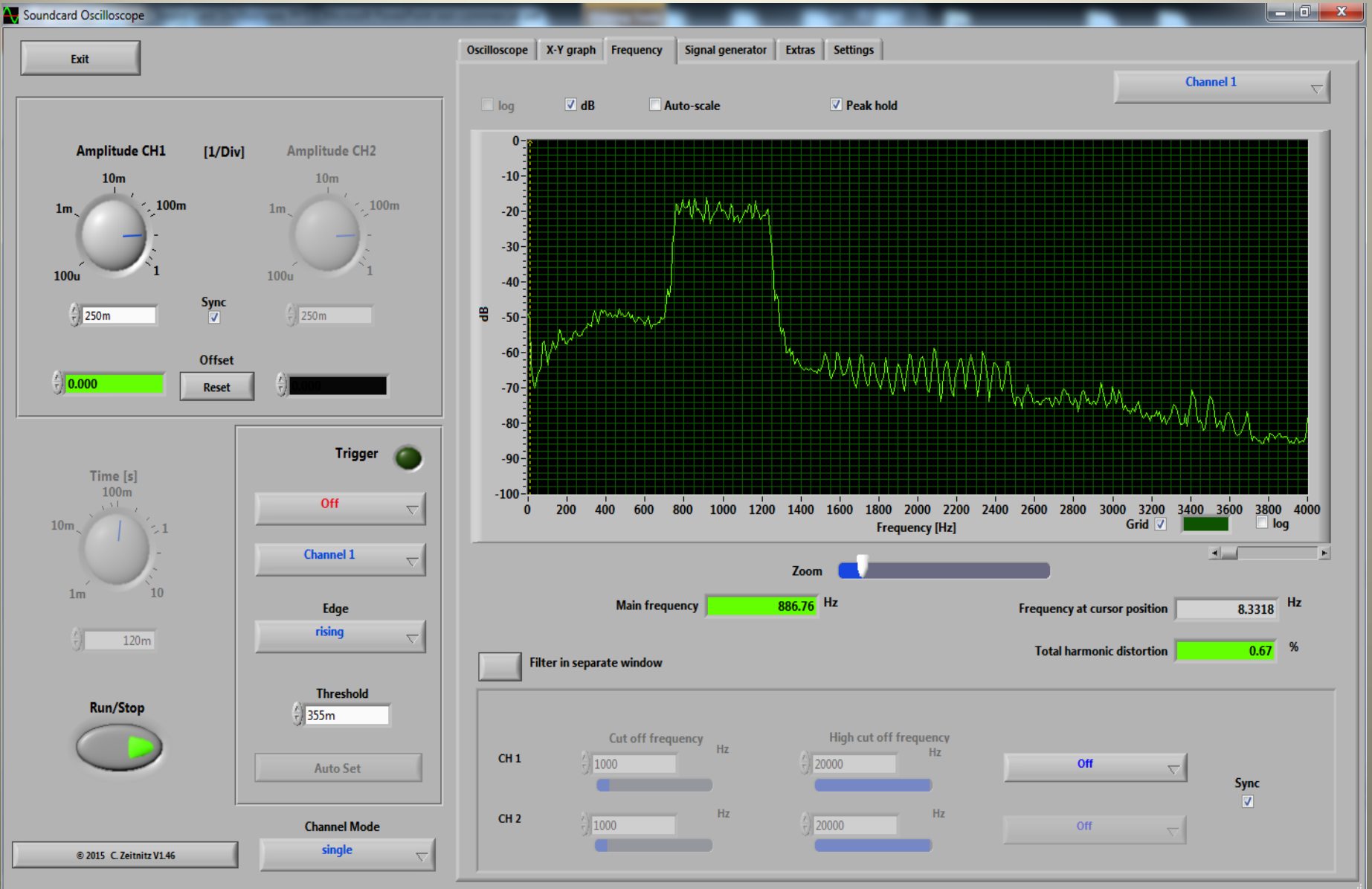
MFSK is a very sensitive mode on HF bands like 80/40/20 meters, works well with low power and simple antennas

# MFSK Oscilloscope View: energy vs. time nearly constant amplitude with frequency changes





# MFSK32 Spectrum View: 500 Hz wide



# Problems with MFSK

The sound card/processor must be able to distinguish one tone from its adjacent tone in the presence of HF "noise" and "phase distortion" in the ionosphere.

Hence, there is a minimum spacing between tones.

Switching tones too quickly (high baud) causes errors due to phase and time distortions produced by ionosphere

Popular HF MFSK modes

MFSK 8 (32 tones, 36 wpm, 316 Hz bandwidth)

MFSK 16 (16 tones, 58 wpm, 316 Hz bandwidth)

MFSK 32 (16 tones, 120 wpm, 630 Hz bandwidth)

# Olivia

(named after the author's daughter)

Designed for copy under marginal S/N (-10 dB)

Has FEC (forward error correction)

Upper and Lower case

Resistant to qrn, qrm, qsb, frequency drift

Sounds like a calliope at a carnival

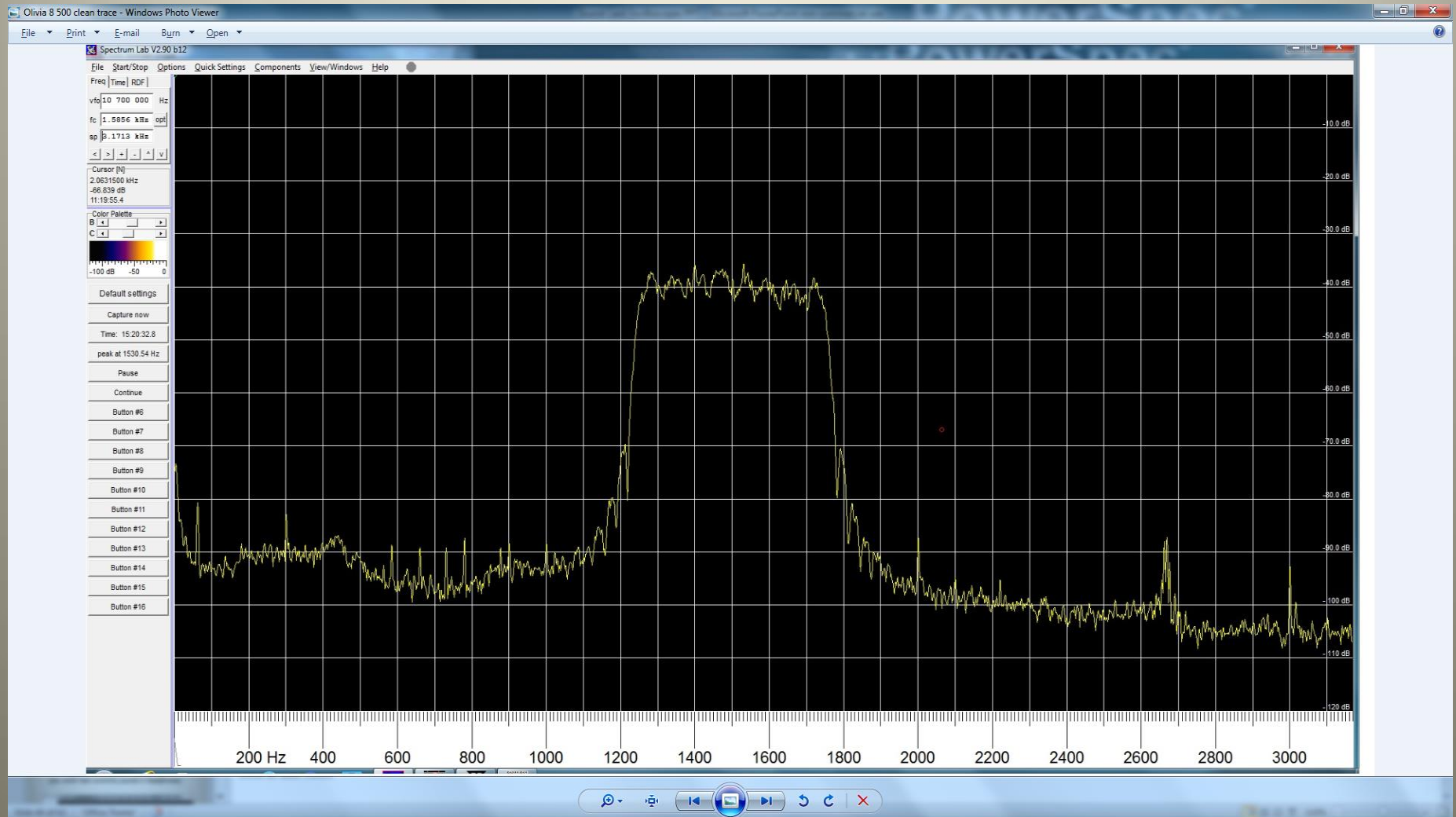
## Speed, Tones and Bandwidth vary

Olivia 4/8/16/32/64/128 number of tones (one at a time)

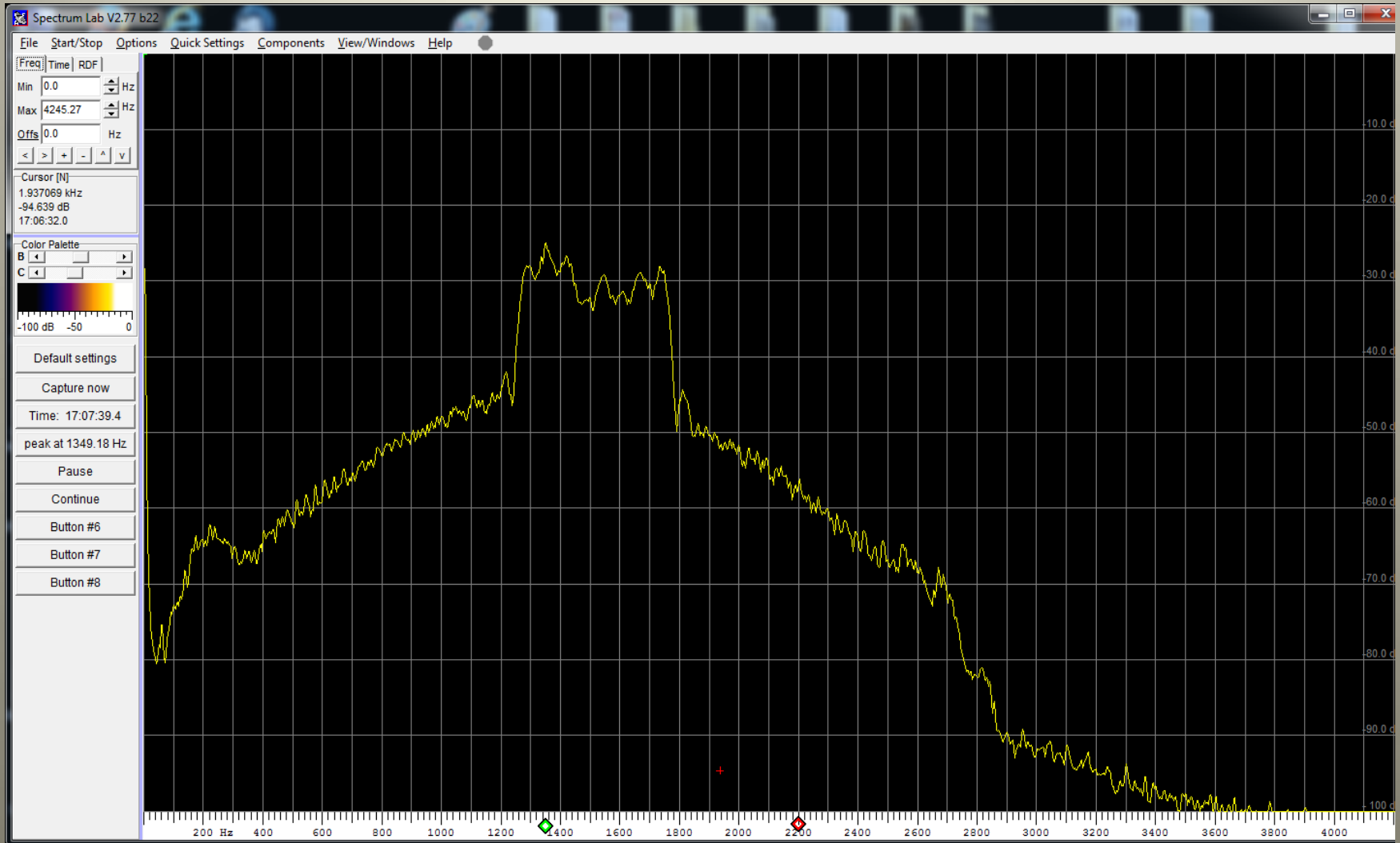
Olivia 125/250/500/1000/2000 Hz bandwidth

Olivia modes are 31 baud, 63 baud, or 125 baud

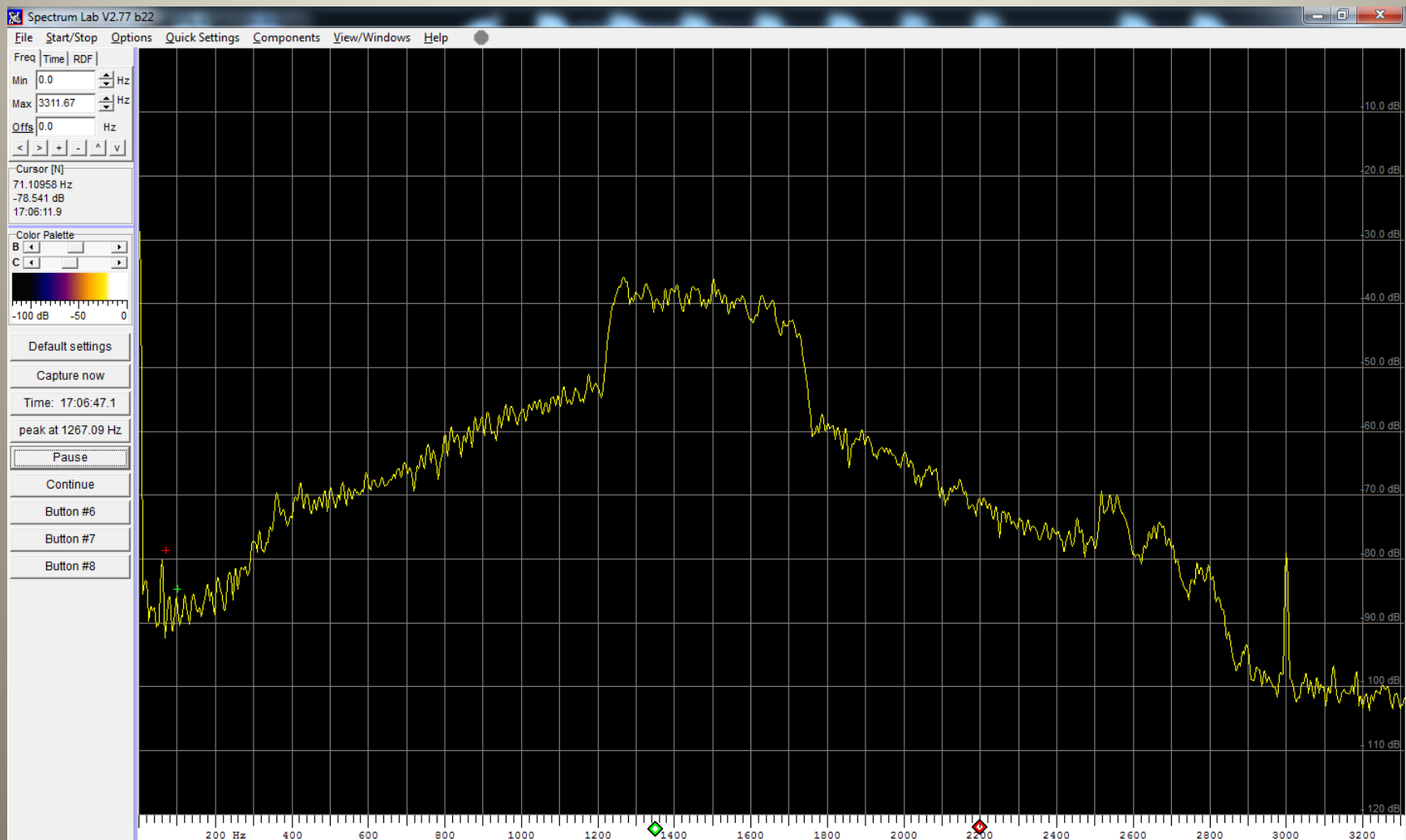
**Olivia 8/500 Spectrum:**  
8 tones, 500 Hz bandwidth, 63 baud, 30 wpm  
signal is 50 dB above baseline noise  
This is what a "clean" Olivia 8/500 signal should look like



# Olivia 8/500 TX signal "over-driven" into ALC action bandwidth 1700 Hz @ -30 dB causes "splatter"



# Distorted Olivia 8/500 signal received on 40 meters PA-NBEMS net (you could hear scratchy sounds in headphones)



# THOR

Uses a type of modulation called "incremental frequency shift"

18 tones are sent one at a time at constant amplitude (F1B) but the **CHANGE IN PITCH** from one tone to the next tone is what determines the symbol, not the actual pitch of the tone (MFSK, Olivia)

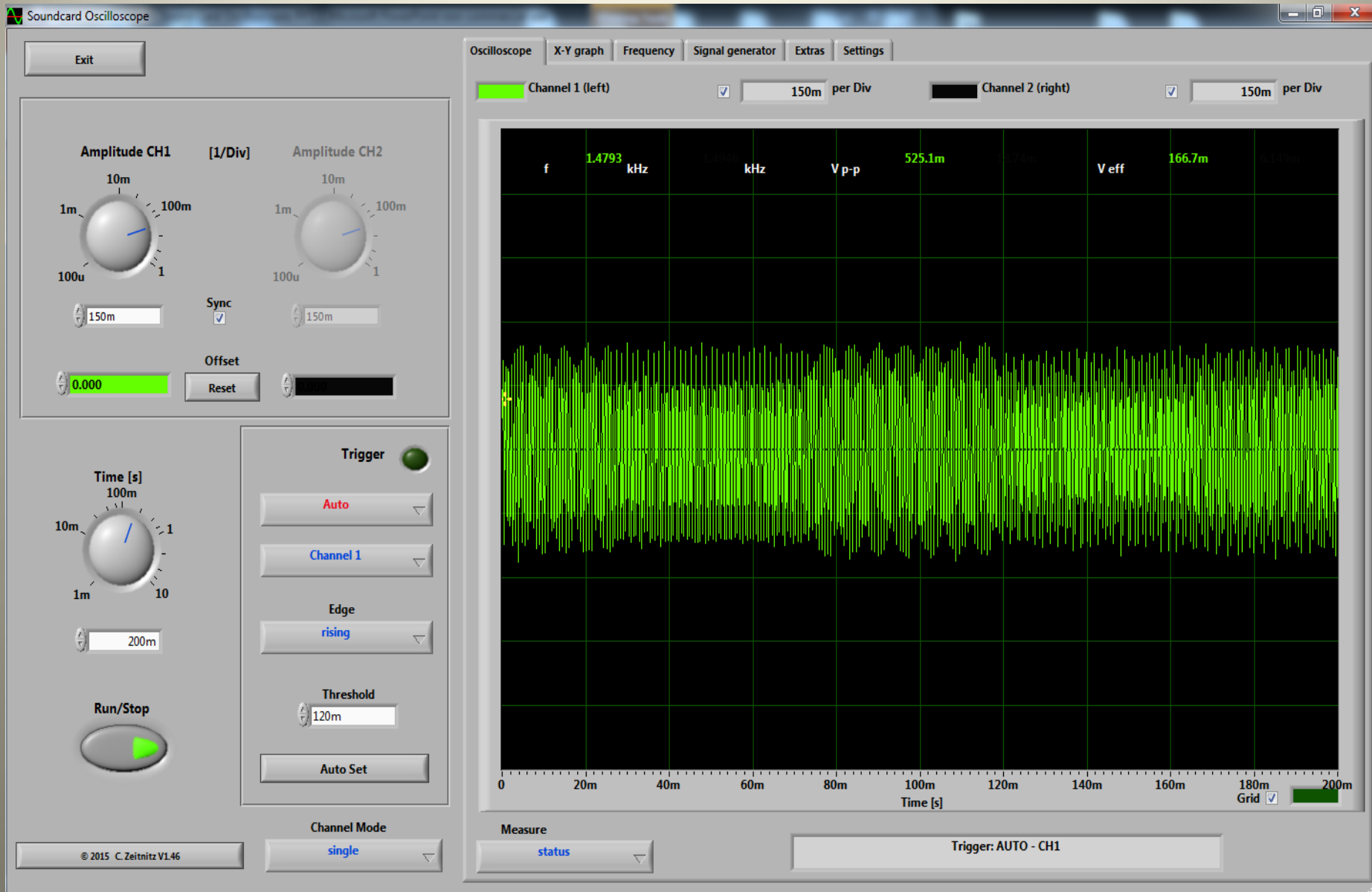
THOR is very tolerant of drift in your radio's vfo or drift in your sound card's oscillator (+/- 100 Hz is ok)

MODES: Thor 4,5,8,11,22,50,100 baud  
Speed from 14 to 350 wpm

Secondary Channel: call, grid, etc.

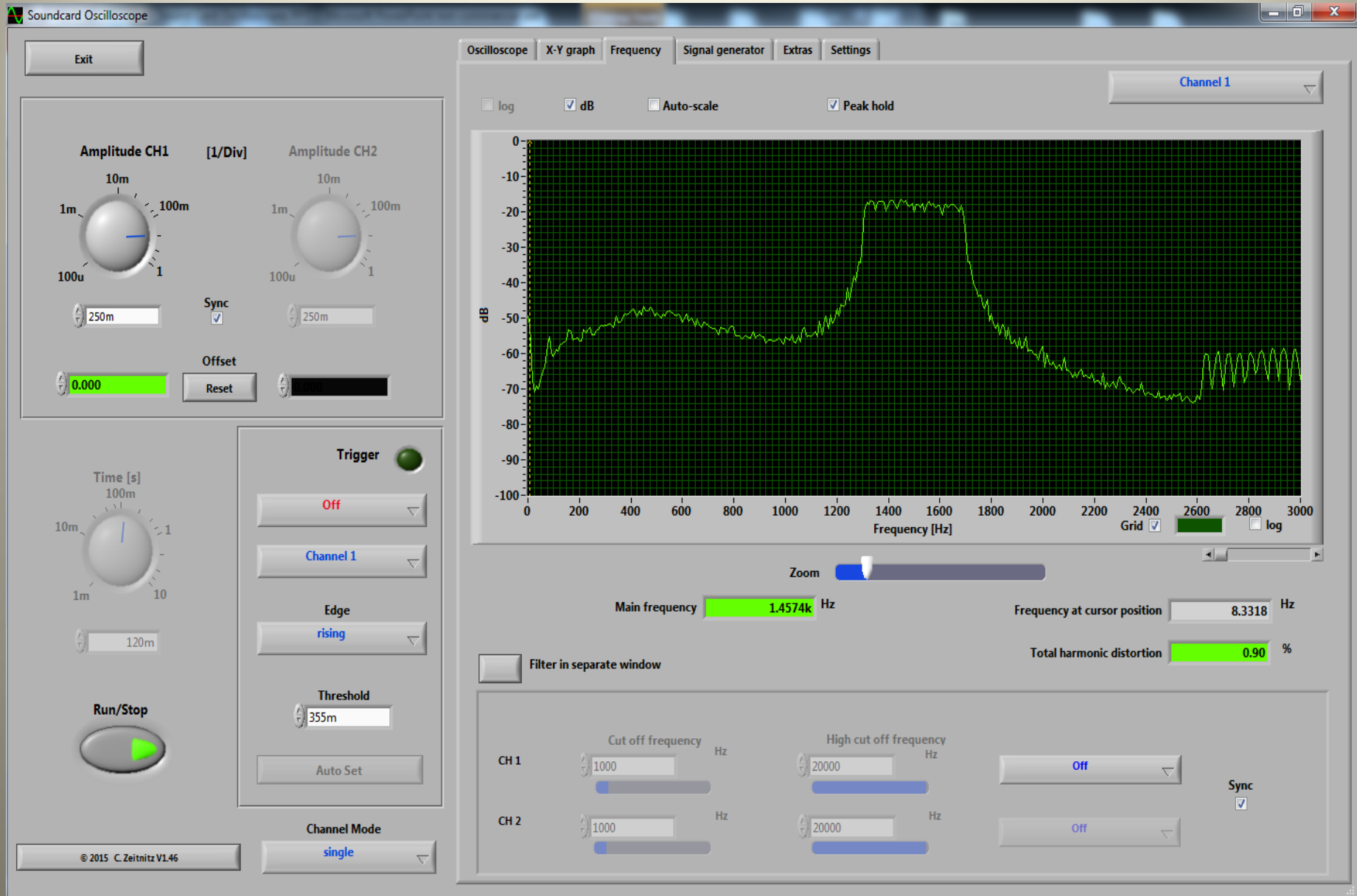
# THOR 22 Oscilloscope View

nearly constant amplitude, 22 baud, 78 wpm, 524 Hz wide



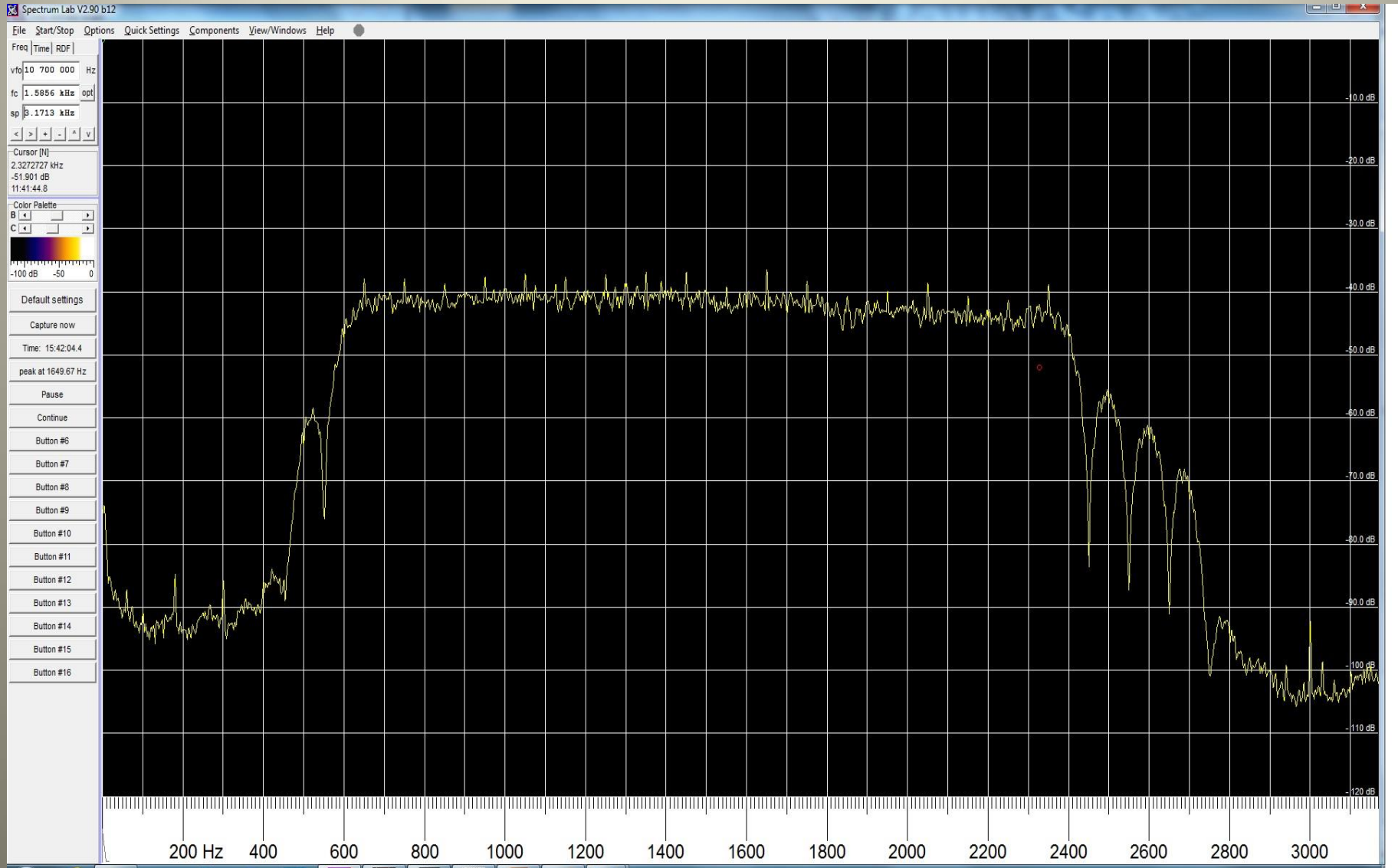


# THOR 22: Spectrum View



# THOR 100

97 baud, 352 wpm, 1800 Hz bandwidth



# BPSK modes

Advantages of Phase-Shift Keying (PSK)

over amplitude keying? (CW)

over frequency keying? (RTTY, MFSK, Olivia, Thor)

**BPSK31** about 60 Hz bandwidth, 50 wpm, no FEC

Pros: upper / lower case

superbrowser capability: translate multiple signals

efficient use of limited RF spectrum

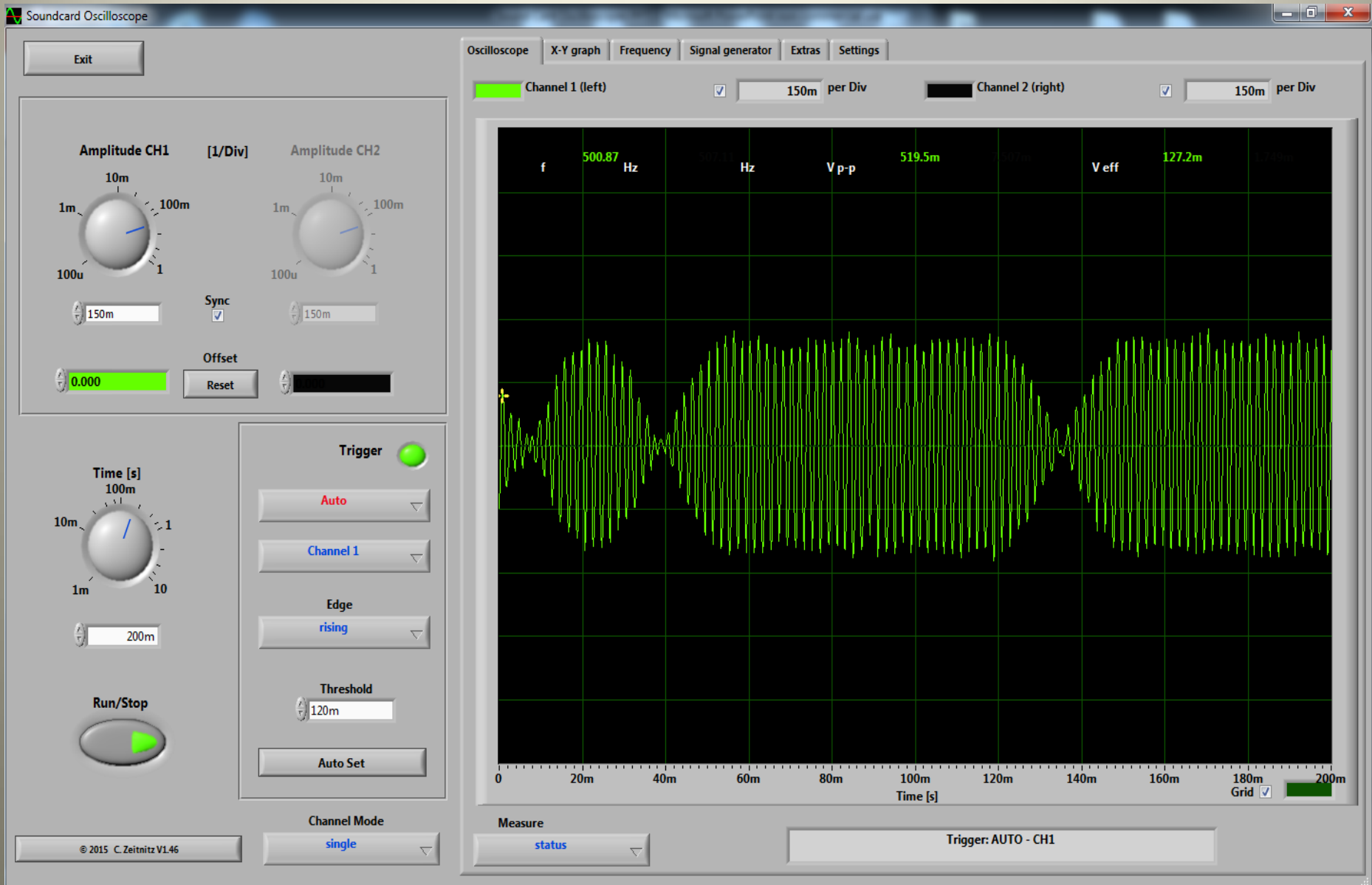
no need for high power

Cons: needs a linear amplifier

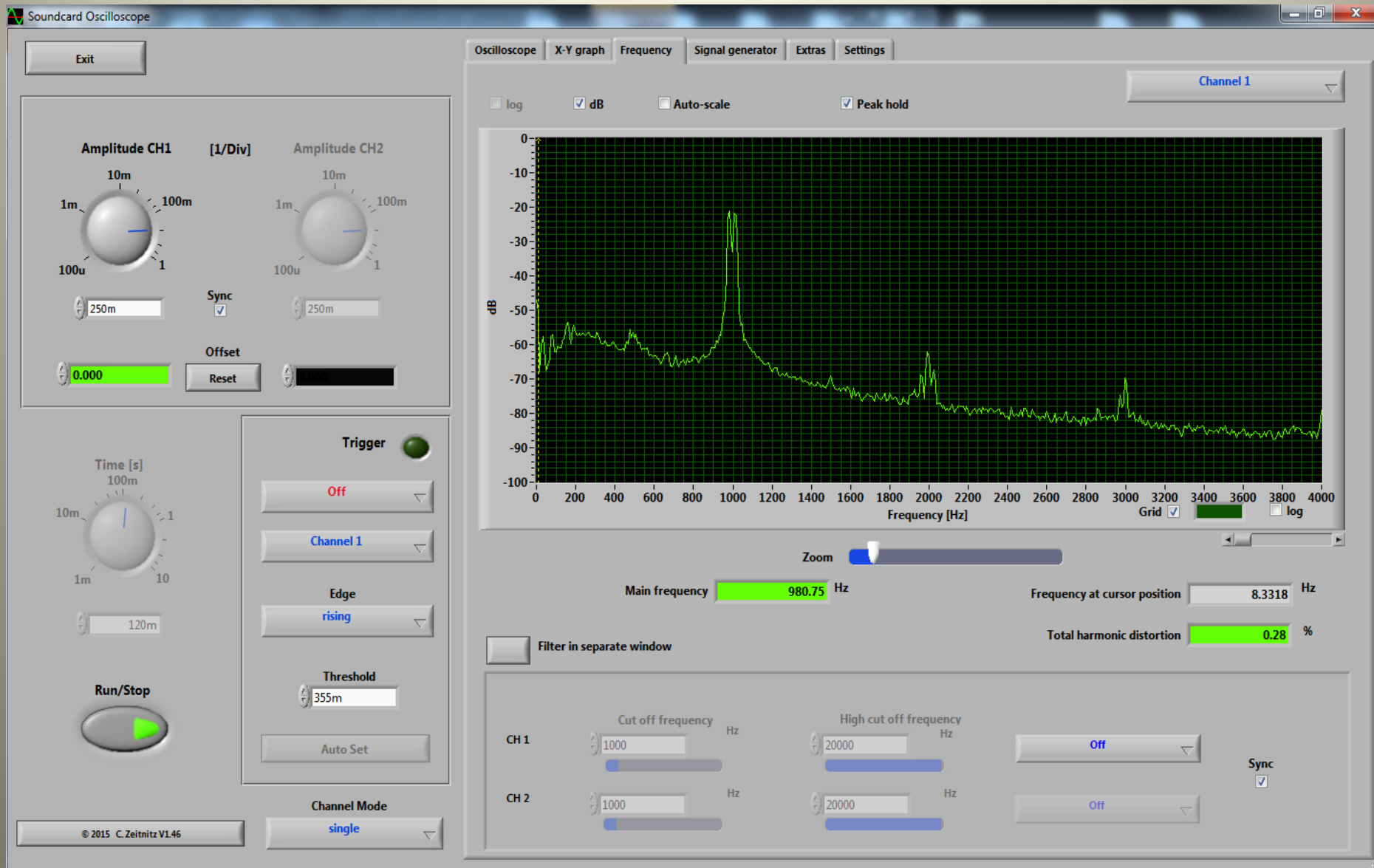
no FEC (no error detection/correction)

# PSK31 Oscilloscope view: 32 ms per "symbol"

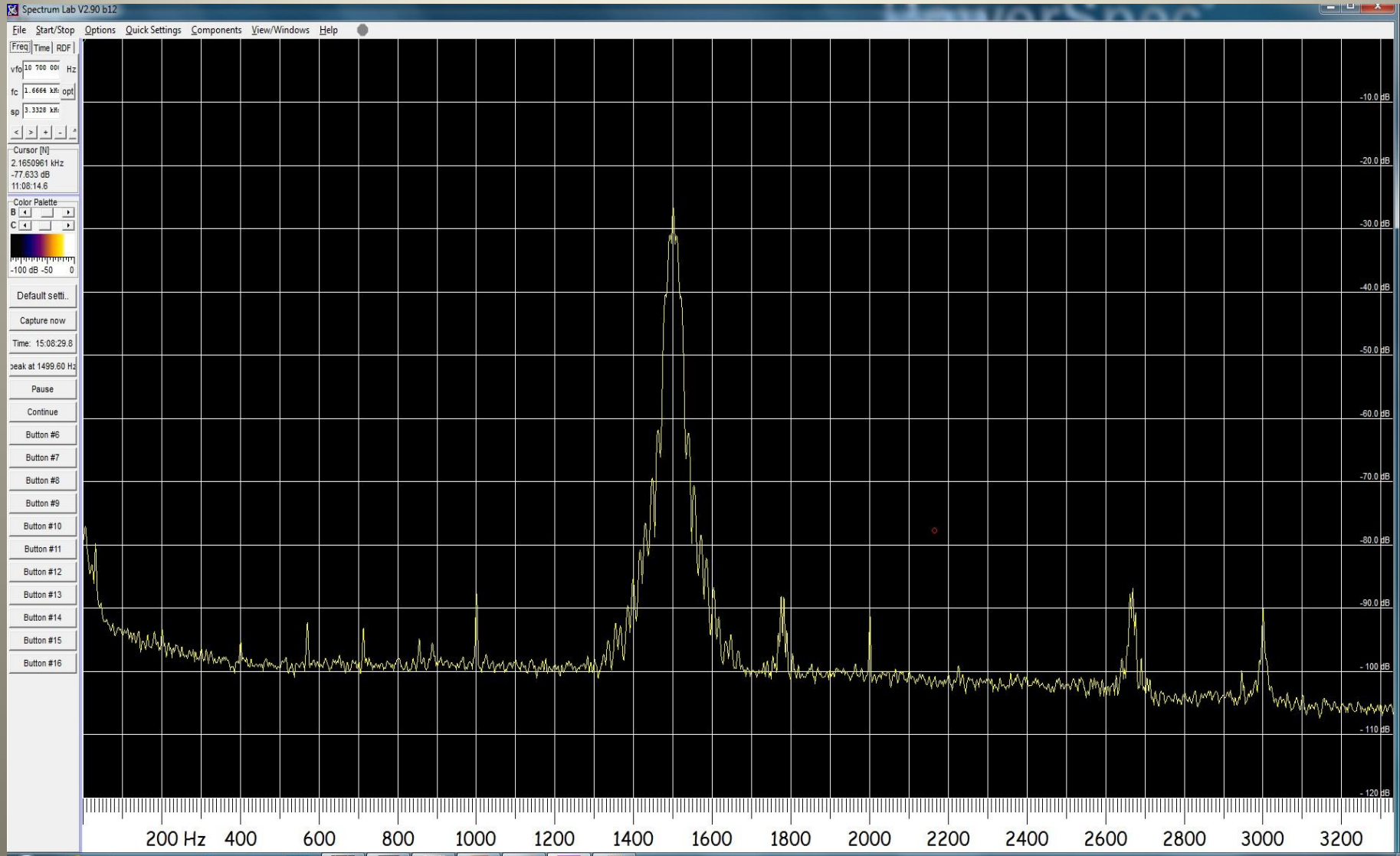
0 = phase shift    1=no phase shift



# BPSK31 Spectrum View: bandwidth <math>< 100\text{ Hz}</math> note slight 2<sup>nd</sup> and 3<sup>rd</sup> harmonic (down >math>> 30\text{ dB}</math>)

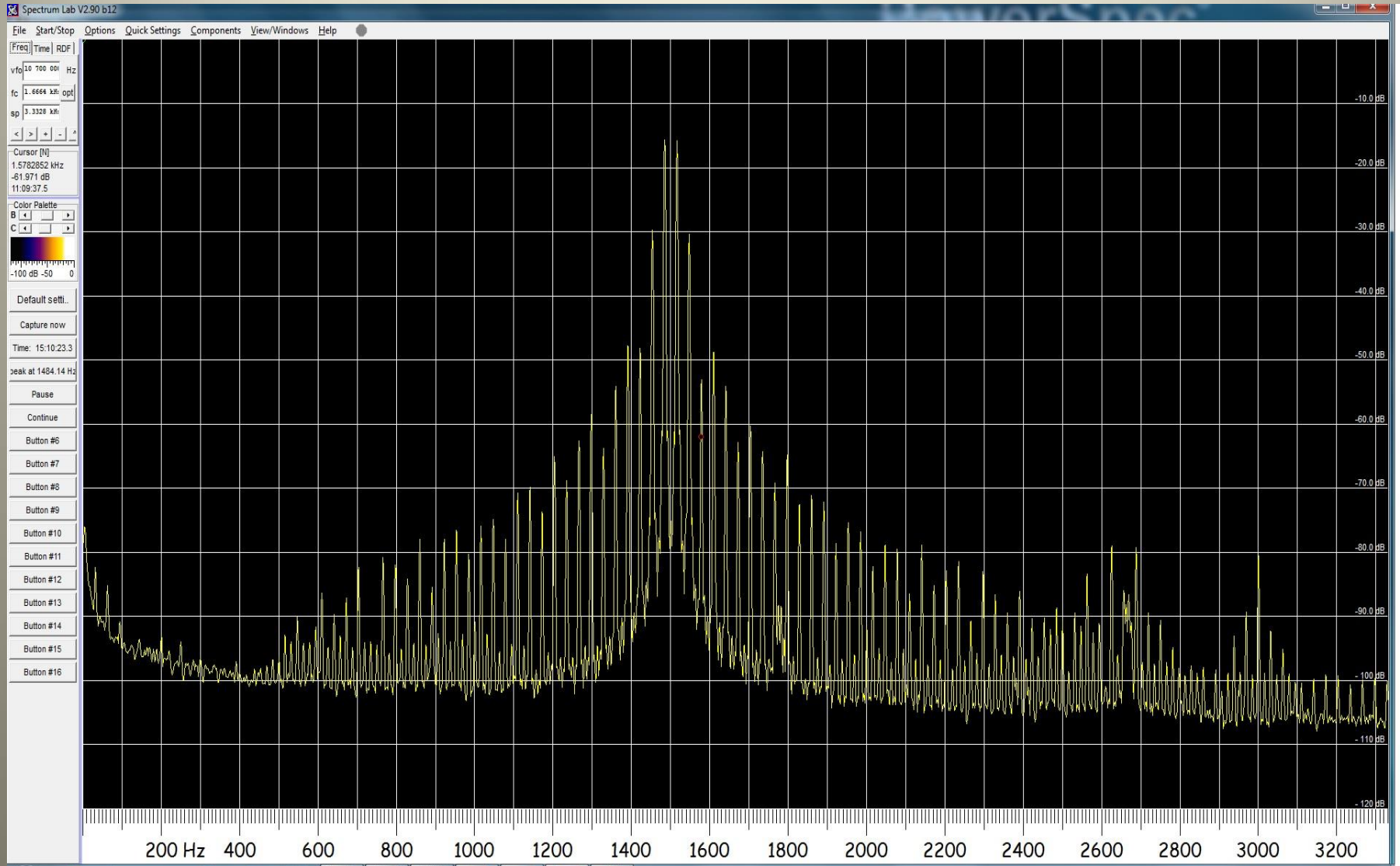


"clean" BPSK31 TX with no ALC  
TX bandwidth 150 Hz @ -50 dB

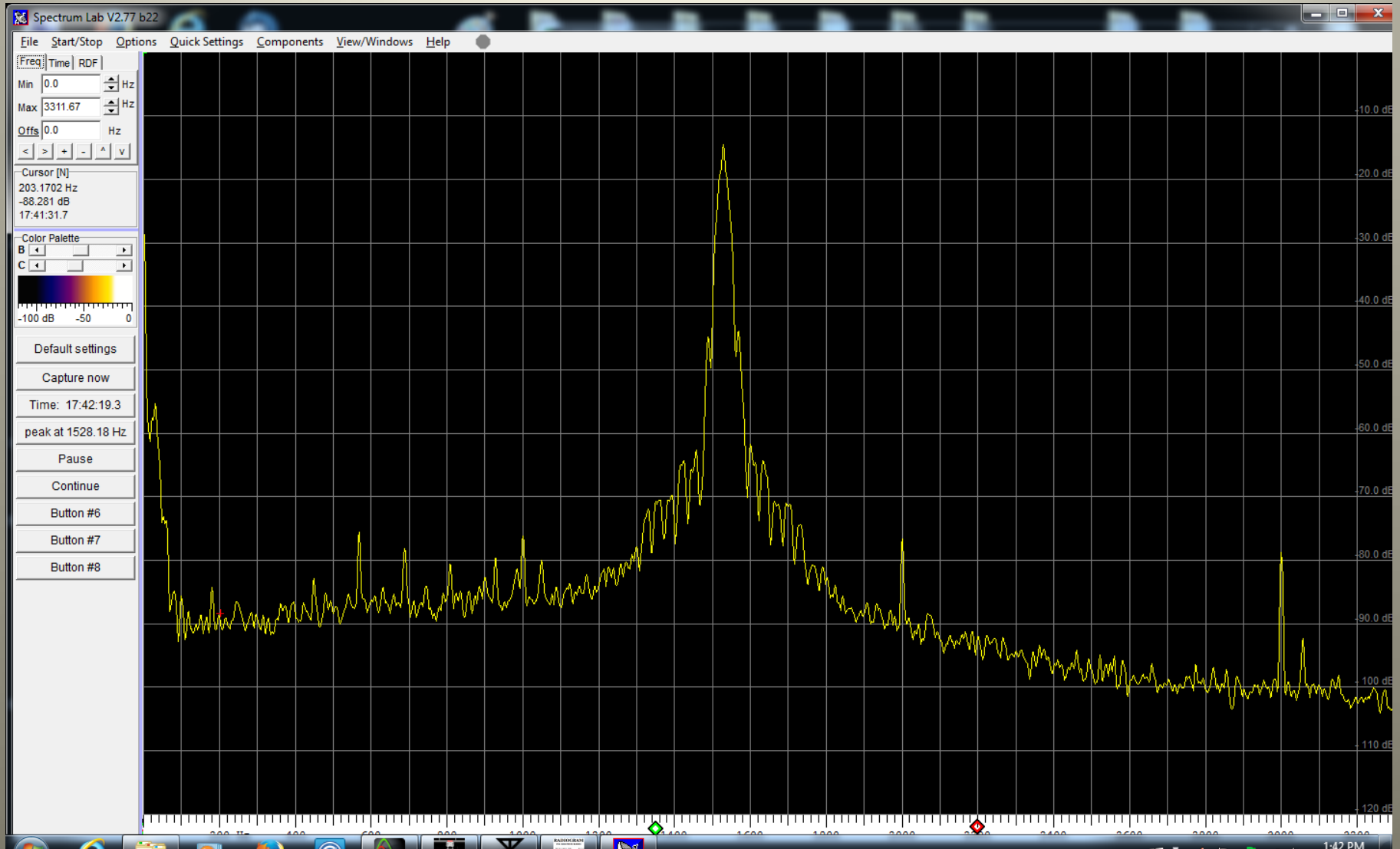


# Wide BPSK31 - TX driven into excessive ALC

TX bandwidth 600 Hz @ -50 dB

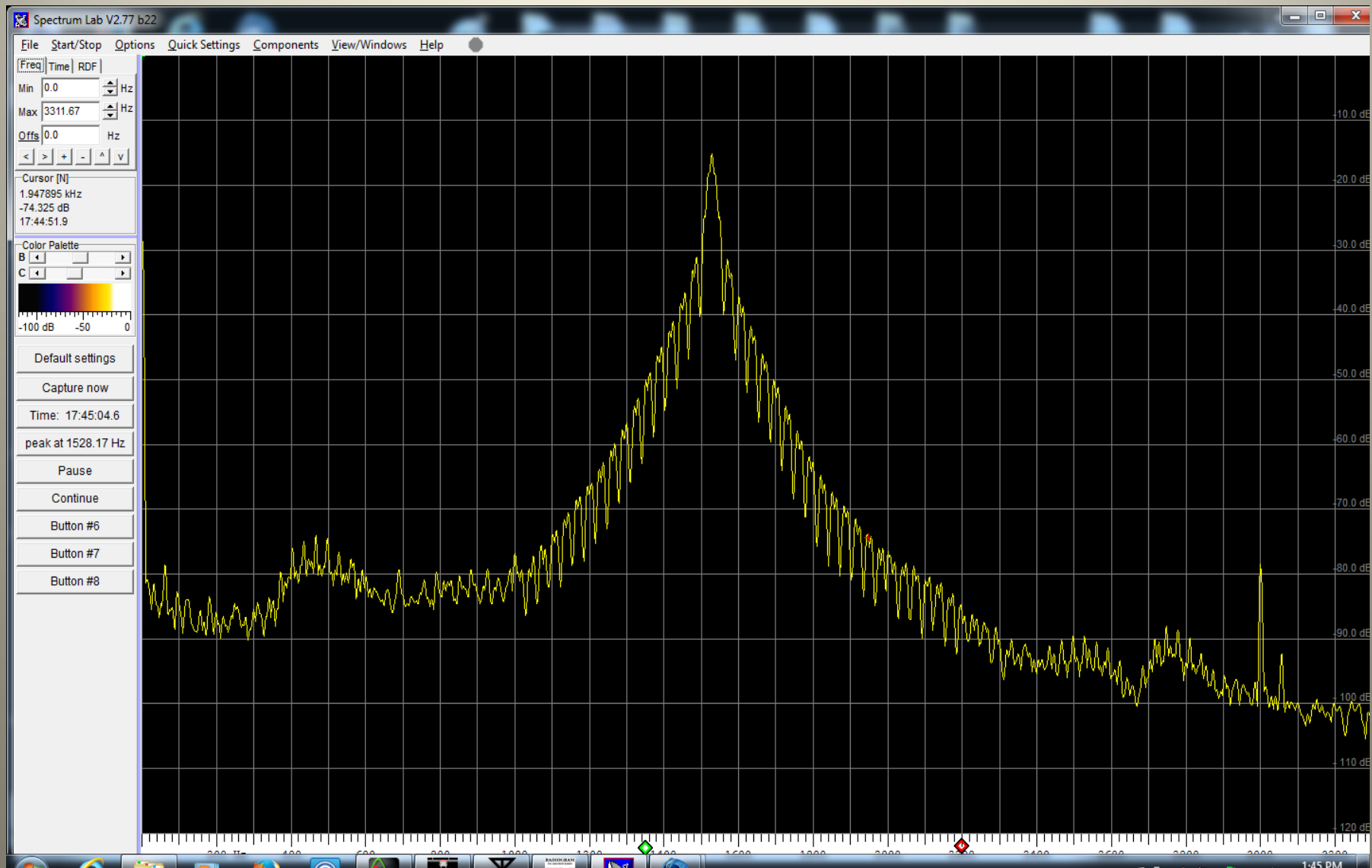


# Example of a CLEAN BPSK31 signal received on 20 meters





# Example of a distorted BPSK31 signal received on 20 meters



# 8PSK modes

Remember: BPSK is a two-state system (shift/no shift)

8 PSK modes employ shifts of

0, 45, 90, 135, 180, 225, 270, 315 degrees

Each "symbol" contains more information: 8 "states" (3 bit)

8PSK1200F is almost 4000 words per minute

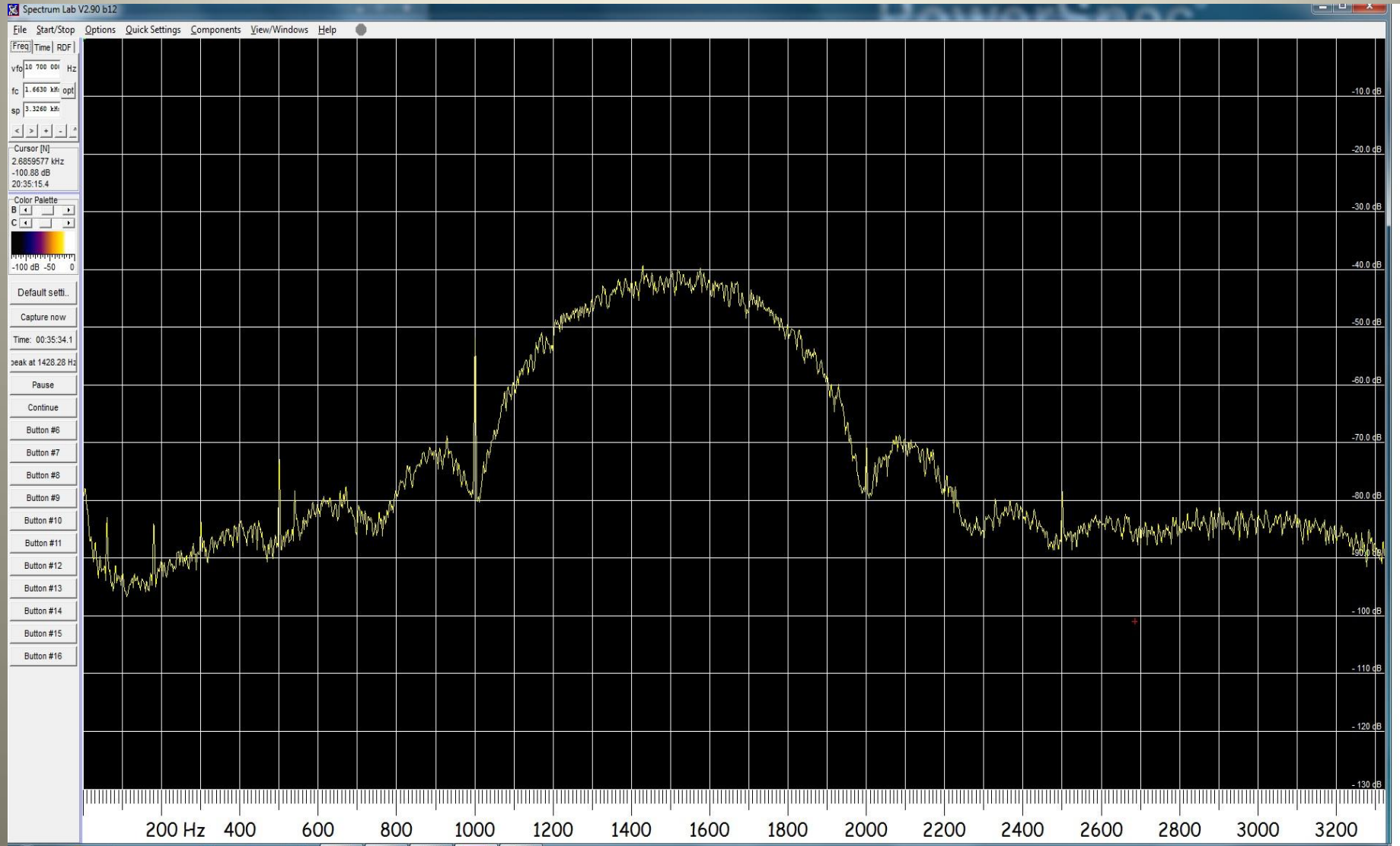
Ideal on VHF/UHF FM to send long FLAMP files

Ideal for ARES/RACES traffic

Con: takes more bandwidth

# 8PSK500F Spectrum View

note sidebands and "pilot tone" at 1000 Hz



# Safety in Numbers?

BPSK31 is one carrier modulated at 31.25 baud → 50 wpm

Why not send multiple simultaneous carriers each modulated with a psk information?

## MT63 is born

64 carriers, each carrying an independent PSK signal

Choice of 5, 10, 20 baud (500, 1000, 1500 Hz wide)

Speeds of 50, 100, 200 wpm

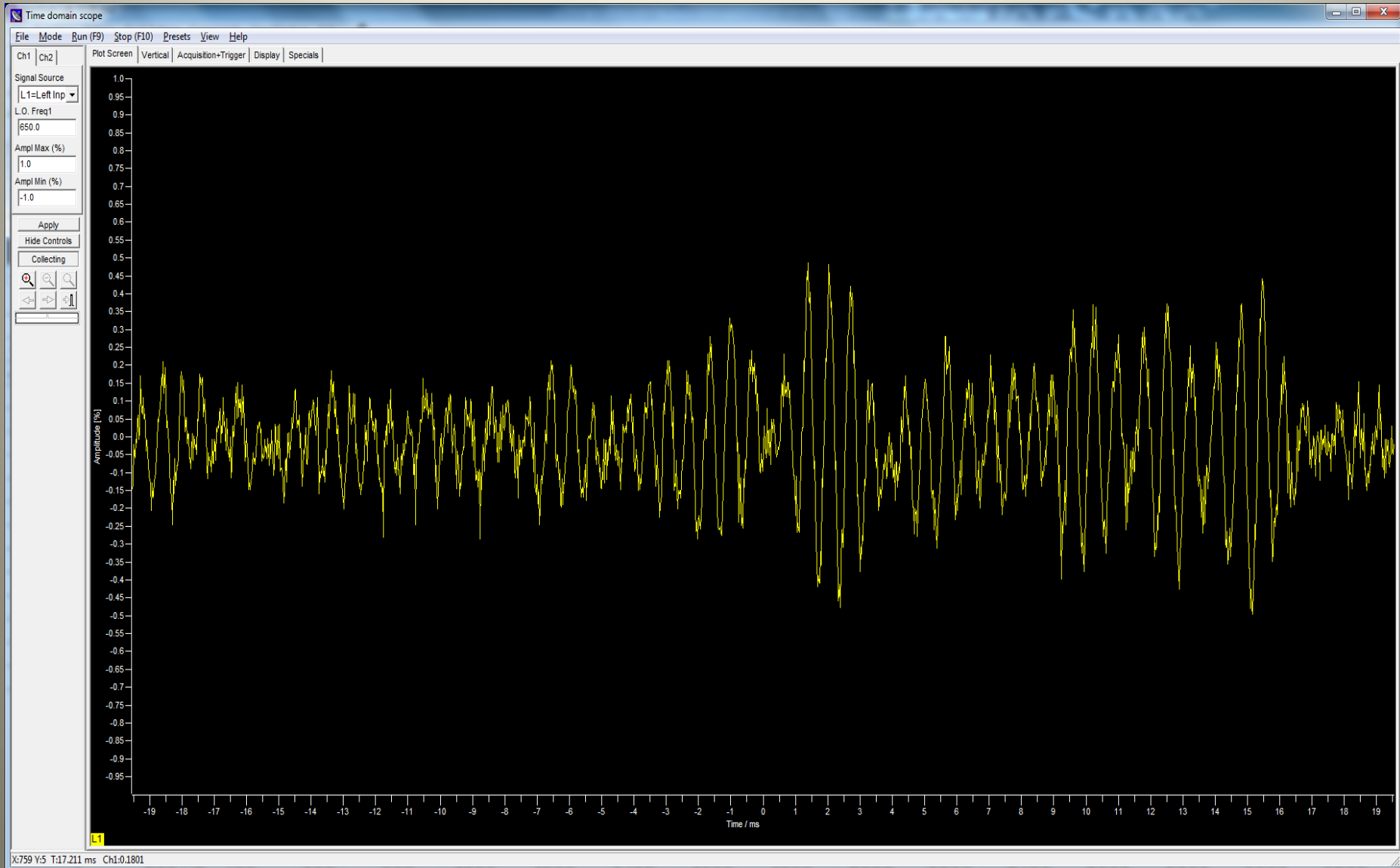
Pros: Highly immune to noise

Works wonders on an FM repeater for ARES/RACES drills

Works on FM radios with "acoustic coupling"

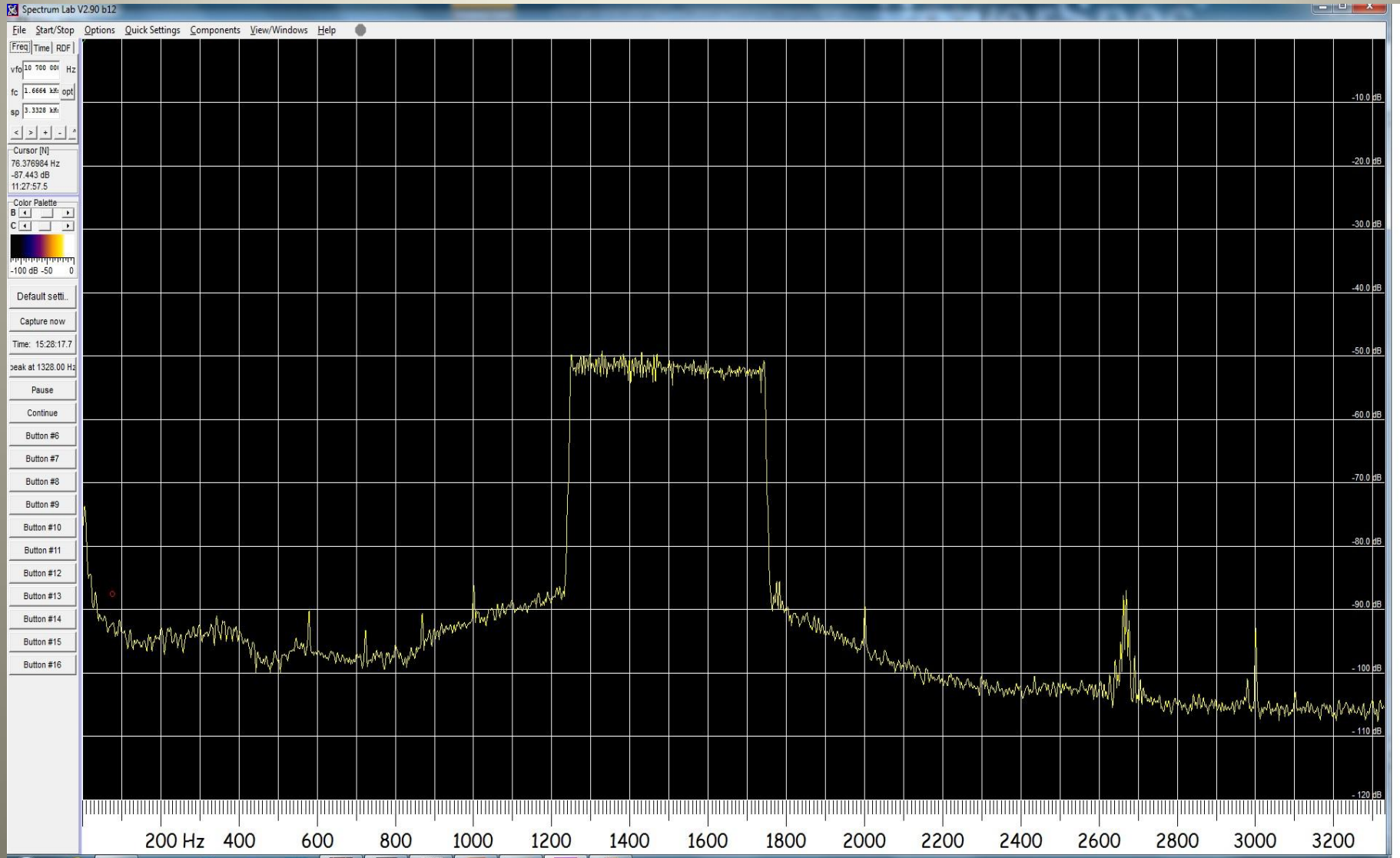
# MT63 - 500 in Oscilloscope View

note the high peak to average rates



# MT63 - 500 Spectrum

## 64 carriers, 5 baud, 50 wpm



# Speed vs. Sensitivity

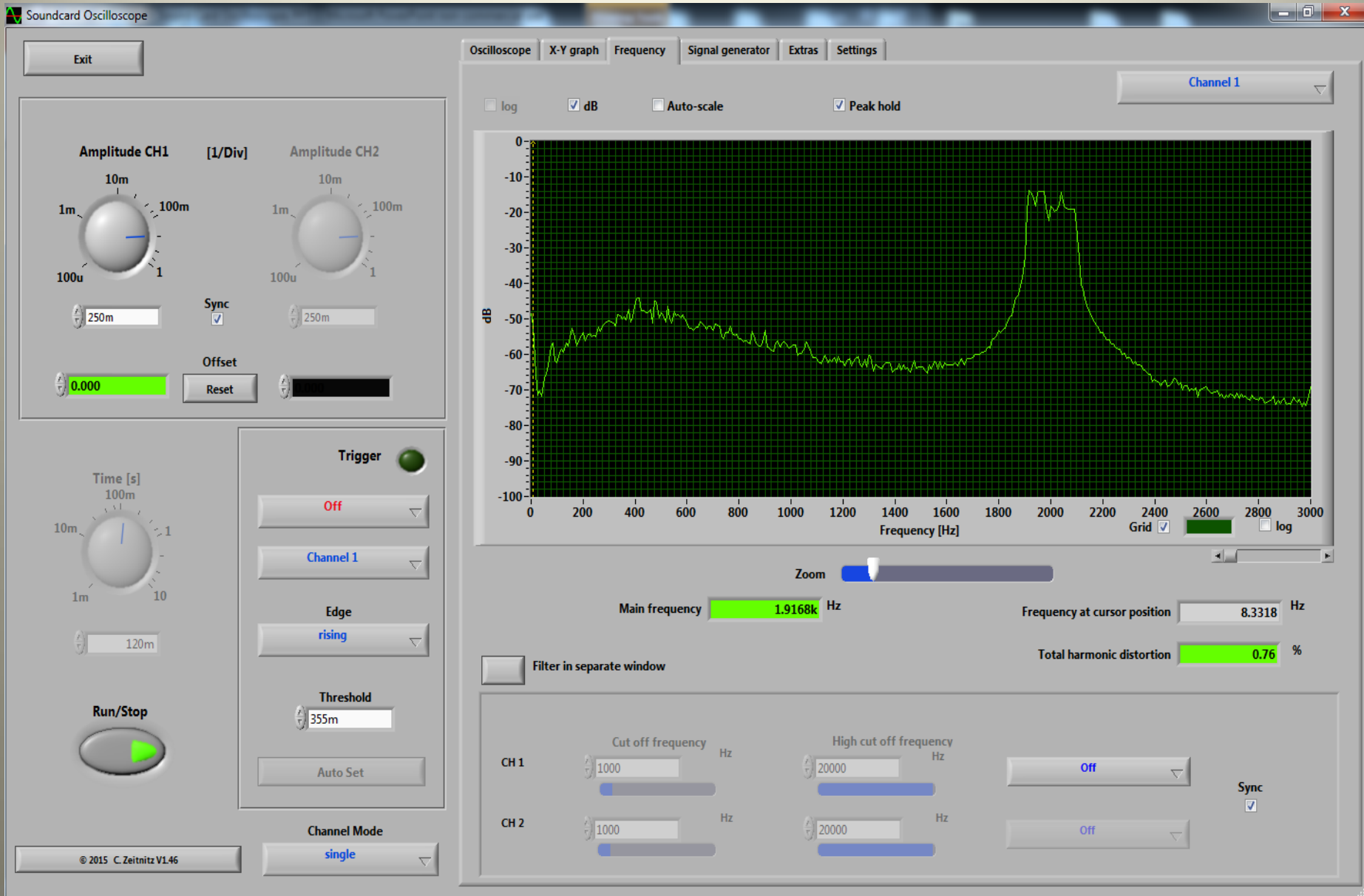
Highest sensitivity modes take more time to detect the signal from the "noise"

**JT modes: JT65, JT9**

Use special coding for the message but can work at S/N ratios of -24 dB but at only 3 wpm  
(you can work the world with 1 watt and a dipole)

# JT 65 Spectrum View

3 wpm but can be copied at -24 dB S/N





# Other uses for C.Zeitnitz's Sound Card Scope Two Channel Signal Generator (sine, triangle, square waves, white noise)

The screenshot displays the 'Soundcard Oscilloscope' software interface, specifically the 'Signal generator' tab. The interface is divided into several sections:

- Amplitude CH1 and CH2:** Two knobs for adjusting amplitude, ranging from 100u to 10m. Both are set to 250m. A 'Sync' checkbox is checked, and an 'Offset' bar is set to 0.000.
- Time [s]:** A knob for time scale, ranging from 1m to 100m, set to 40m.
- Trigger:** A green indicator light is on. The trigger source is set to 'Auto', the edge to 'rising', and the threshold to 355m. An 'Auto Set' button is present.
- Channel Mode:** A dropdown menu is set to 'single'.
- Signal Generator Section:** A checkbox 'Signalgenerator in separate window' is checked. Two channels are shown, both with 'On' indicators and 'Sine' waveforms selected. Duty cycle is set to 50% for both.
- Amplitude and Frequency:** Two knobs for amplitude (0 to 1) and frequency (10 to 10k Hz). Channel 1 amplitude is 1.000 and frequency is 100 Hz. Channel 2 amplitude is 0.400 and frequency is 500 Hz.
- Sweep:** Two checkboxes for 'Sweep' are present, both unchecked.
- f end and Time:** Two sets of controls for frequency end and time. Channel 1: f end 500 Hz, Time 60 s. Channel 2: f end 400 Hz, Time 5 s.
- Send to Scope:** Radio buttons for 'CH1' and 'CH2' are present. A 'dt' control is set to 0.000 ms.
- Phase:** A knob for phase is set to 0 deg.

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# Audio Recorder / Playback

The screenshot displays the 'Soundcard Oscilloscope' software interface. The main window is titled 'Soundcard Oscilloscope' and contains several tabs: 'Oscilloscope', 'X-Y graph', 'Frequency', 'Signal generator', 'Extras', and 'Settings'. The 'Audio Recorder' panel is active, showing recording controls and settings.

**Amplitude CH1 [1/Div]**

- Knob: 10m, 1m, 100m, 100u, 1
- Slider: 250m

**Amplitude CH2**

- Knob: 10m, 1m, 100m, 100u, 1
- Slider: 250m

**Time [s]**

- Knob: 10m, 100m, 1m, 10
- Slider: 40m

**Trigger**

- Trigger Mode: Auto
- Channel: Channel 1
- Edge: rising
- Threshold: 355m
- Auto Set

**Channel Mode**

- Mode: single

**Audio Recorder**

- Recorder in separate window:
- Buttons: Rec (red dot), Pause (two vertical bars), Stop (square)
- Open file with Pause or Rec. (text box)
- Write to file on: Trigger (auto) (dropdown)
- Time Window:  Auto, pre-Trigger: 0.0008 sec, length: 0.04 sec
- Filename: C:\Users\bfeierman\AppData\Roaming\scope\scope.wav

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# Useful References

Oscilloscopes for Radio Amateurs, Paul Danzer N1ii (ARRL)

Sound Card Oscilloscopes QST Feb 2016

ARRL Handbook

HF Digital Handbook, 4<sup>th</sup> edition, Steve Ford, WB8IMY (ARRL)

Get on the Air with HF Digital, Steve Ford, WB8IMY (ARRL)

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