



**Tektronix**

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# RF Record & Playback

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APPLICATION ENGINEER





# Introduction

# Recording RF Signals

## WHAT DO WE USE TO RECORD THE RF ?



- Where do we start ?
- Swept spectrum analyzer
- Real-time spectrum analyzer
- Oscilloscope
- Mixed domain oscilloscope
- Software defined radio



- Important Questions
- What are we measuring or recording ?
- How much BW do we need to record ?
- How long do we need to record ?
- How much data will be produced ?
- Do we need to playback a “real” signal ?

# Basic Spectrum Analyzer Interface

## COMMON CONTROLS FOR MOST SPECTRUM ANALYZERS



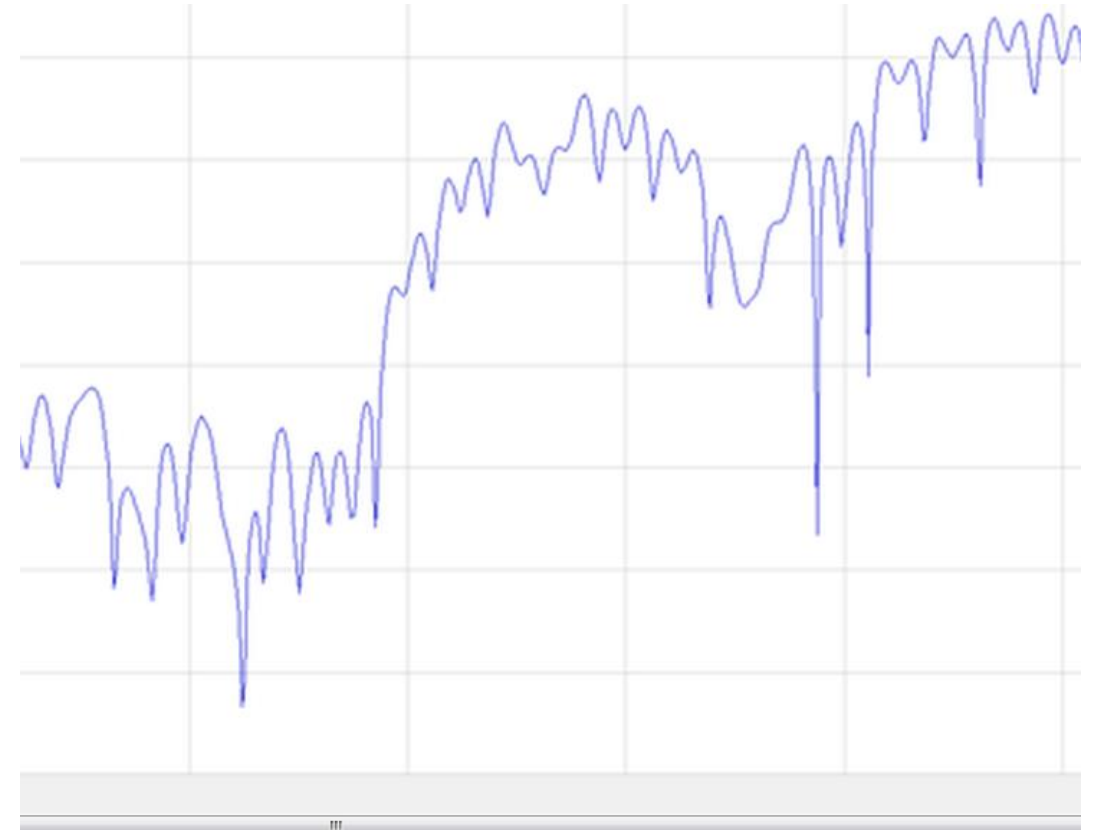


# Trace Data

## THE SIMPLEST FORM OF SPECTRUM INFORMATION

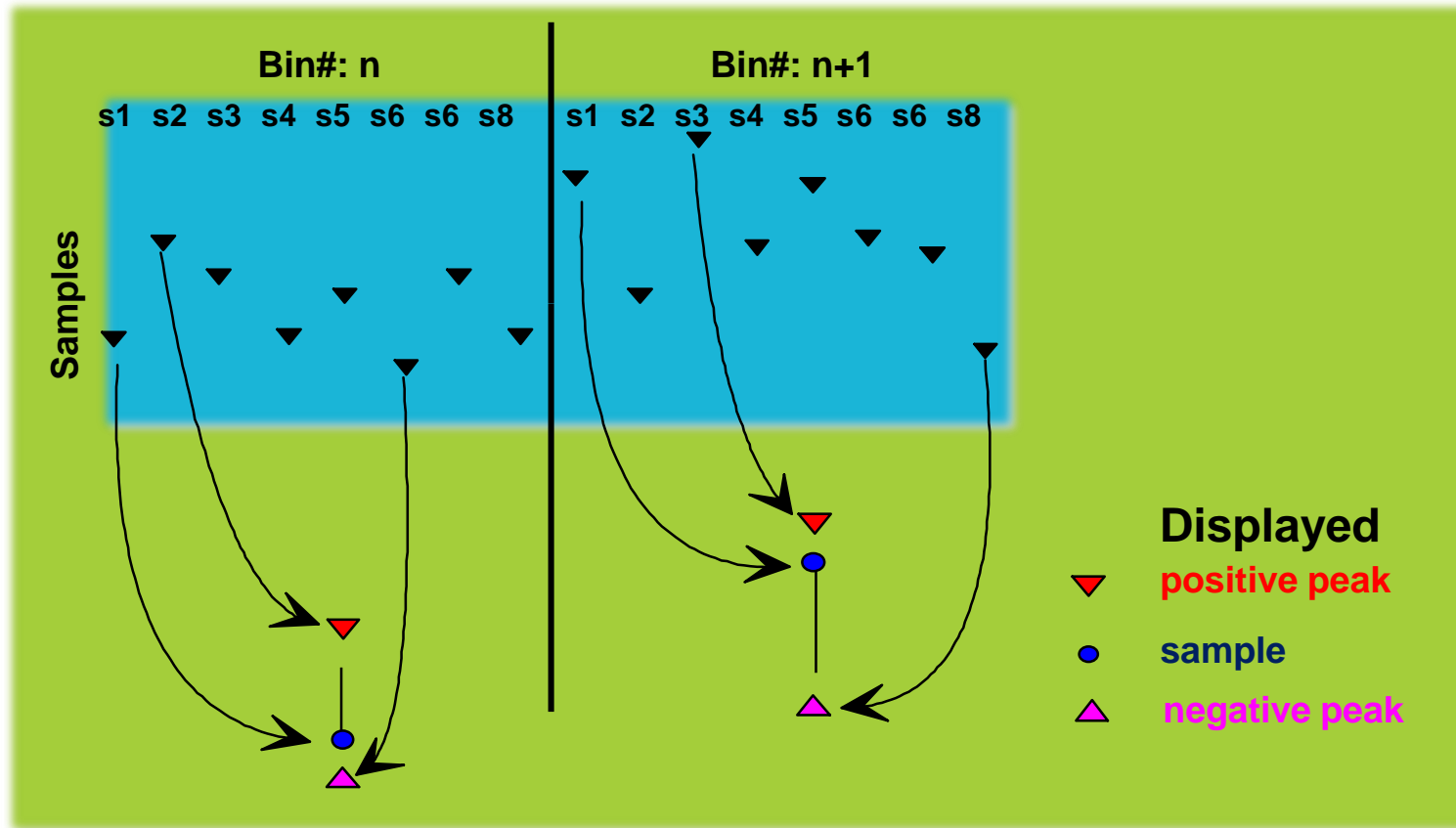


- Classic spectrum information
- Basic frequency vs amplitude info
- Data is arranged in “bins”
  - X (Freq) & Y (Power)
- Amplitude info based on detector type & trace mode
  - Peak, Average(RMS)
  - Max/Min Hold, Average



# Trace Detector Types

HOW DO WE MEASURE AMPLITUDE ?

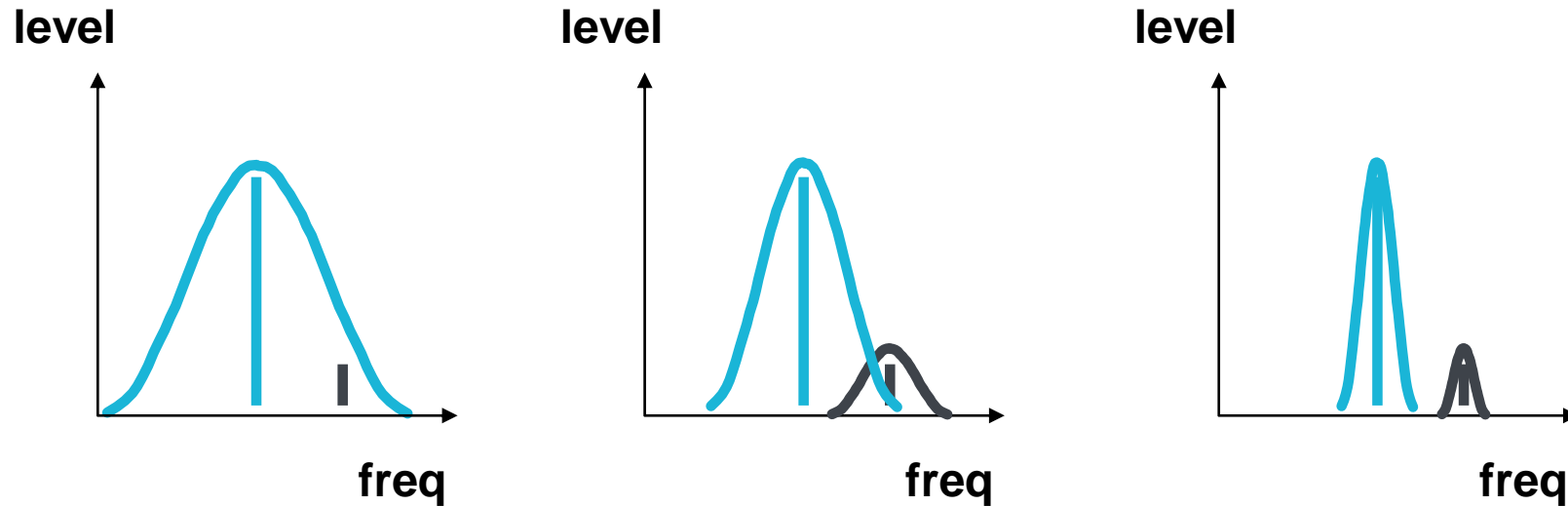


## Detector Types;

- Auto
- Positive Peak
- Negative Peak
- Sample
- RMS

# Resolution Bandwidth Filter

SPEED VS MINIMUM DISCERNABLE SIGNAL

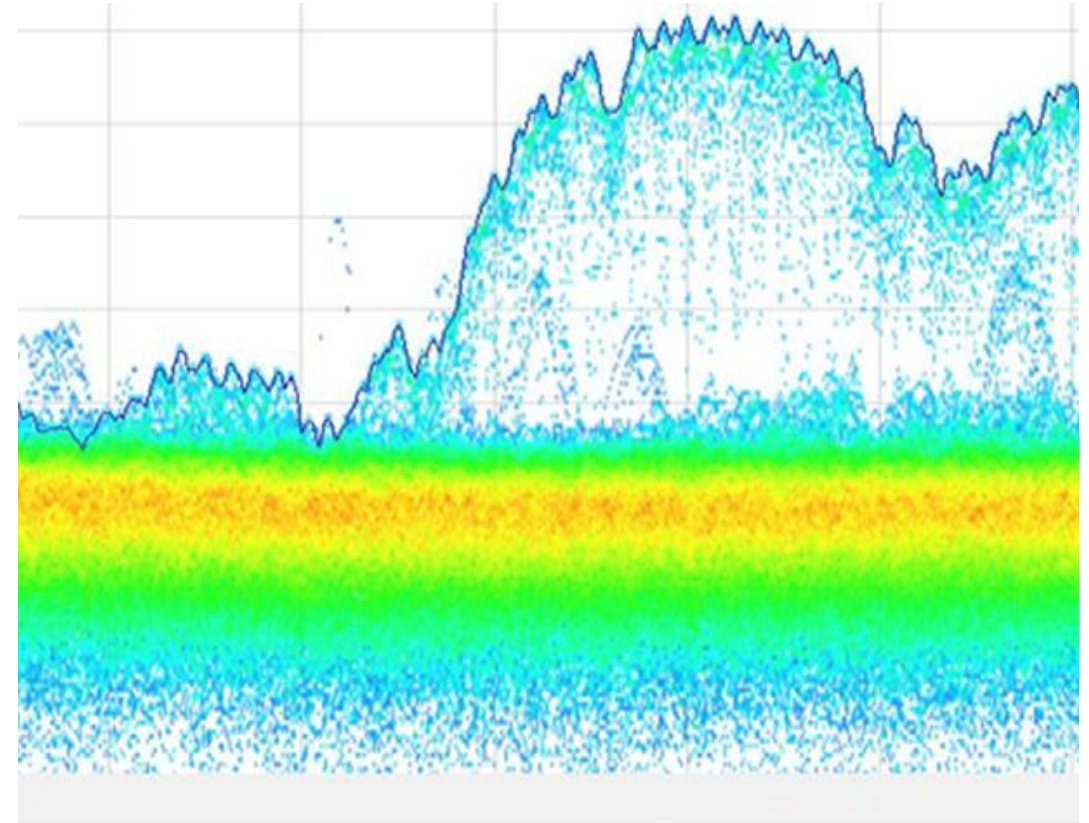


# Real Time Spectrum Data

## IMPROVING THE PROBABILITY OF INTERCEPT



- Frequency vs amplitude vs occupancy
- Data is also arranged in “bins”
  - X (Freq), Y(Power) & Z(Occupancy)
- Amplitude info based on detector type & trace mode
  - Peak, Average(RMS)
  - Max/Min Hold, Average
- Big challenge with volume of spectrum information





# Real Time Spectrum Processing



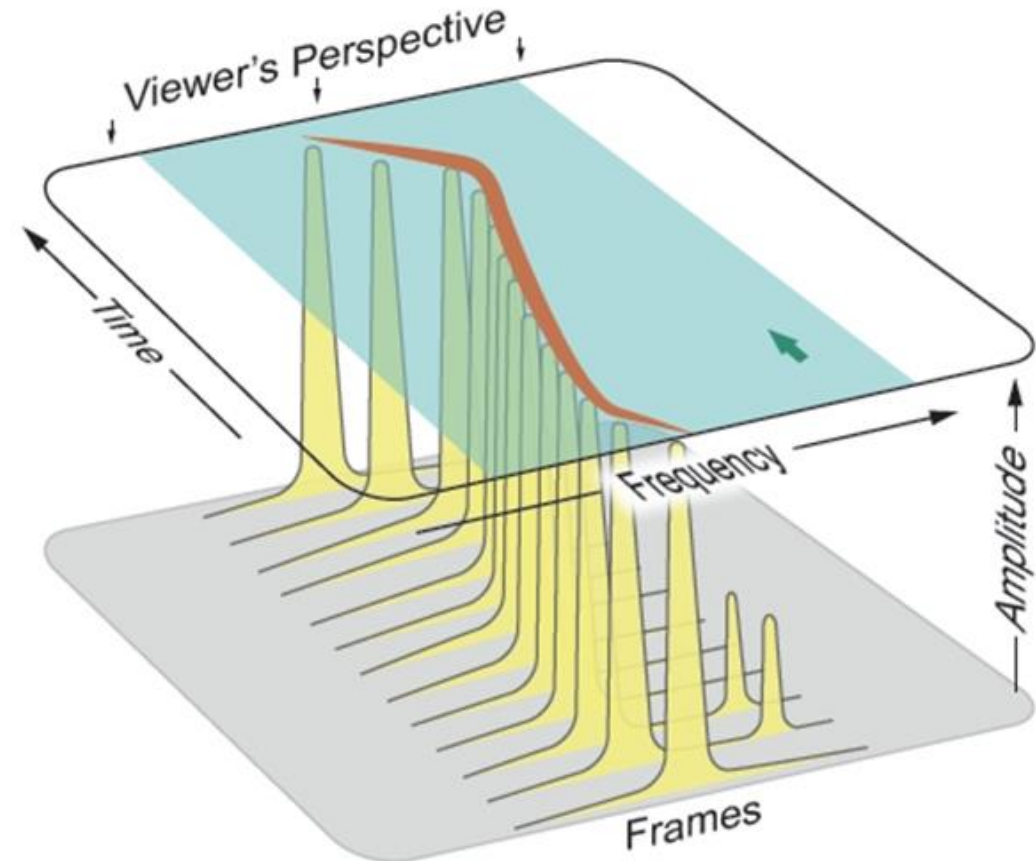
- Volume of spectrum data based on
  - Bandwidth of spectrum being sampled
  - Speed of spectrum processing engine
  - 10's of thousand to millions of spectrums per second

# Spectrogram Or “Waterfall” Displays

DISPLAYS FREQUENCY VS. AMPLITUDE VS. TIME



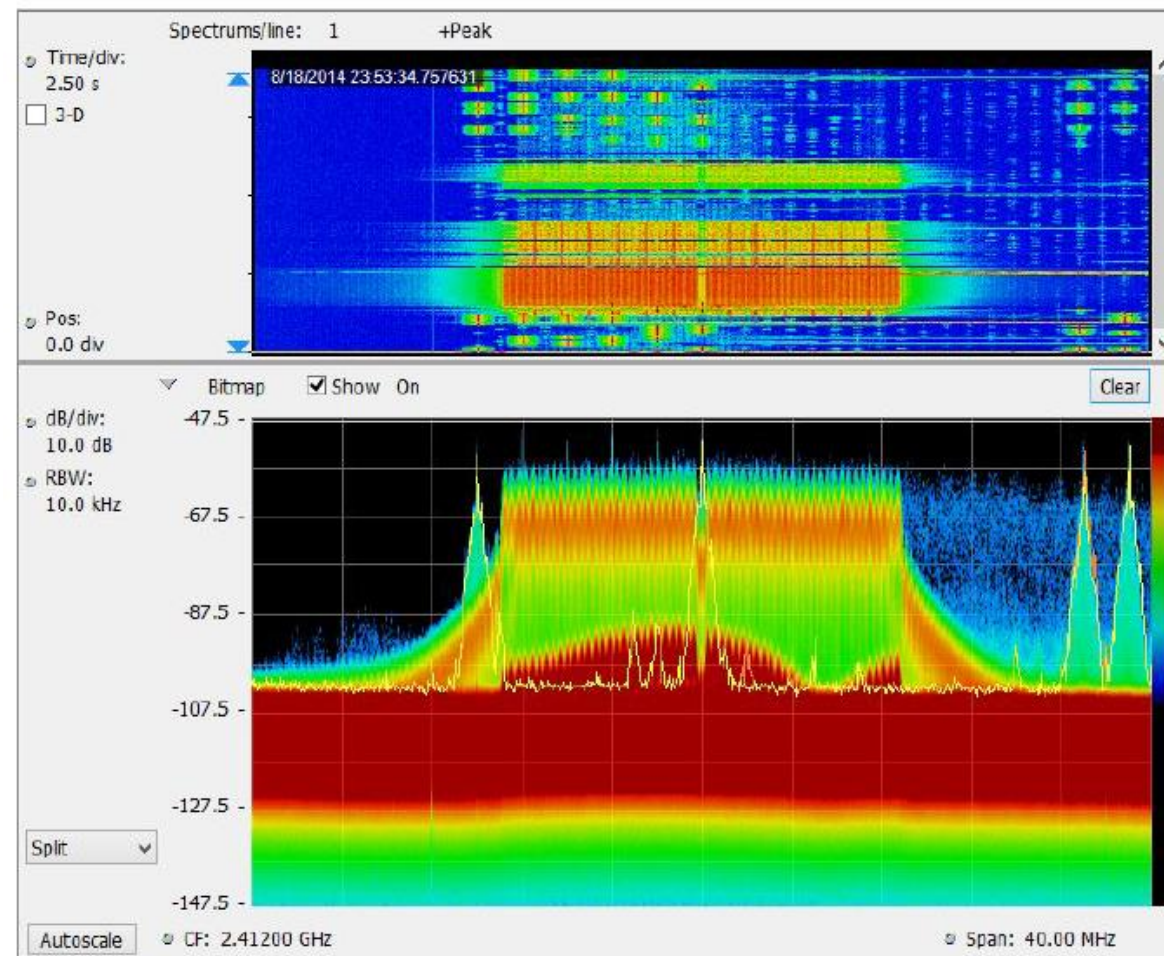
- Rasterized spectrum data with 3D perspective
  - X (Freq), Y(Time) & Z(Amplitude)
- Same impact of RBW and RF detector
- Data can be collected for very long time (days)
- May Not Be Contiguous Data !
  - Spectrum and/or time



# Real Time Spectrogram

## COMPRESSING SPECTRUM DATA

- Spectrum traces compressed large numbers of spectrums over time (up to hours) so
- DPX spectrogram (top image) shows long-term history of a DPX trace
- No special SW required for playback

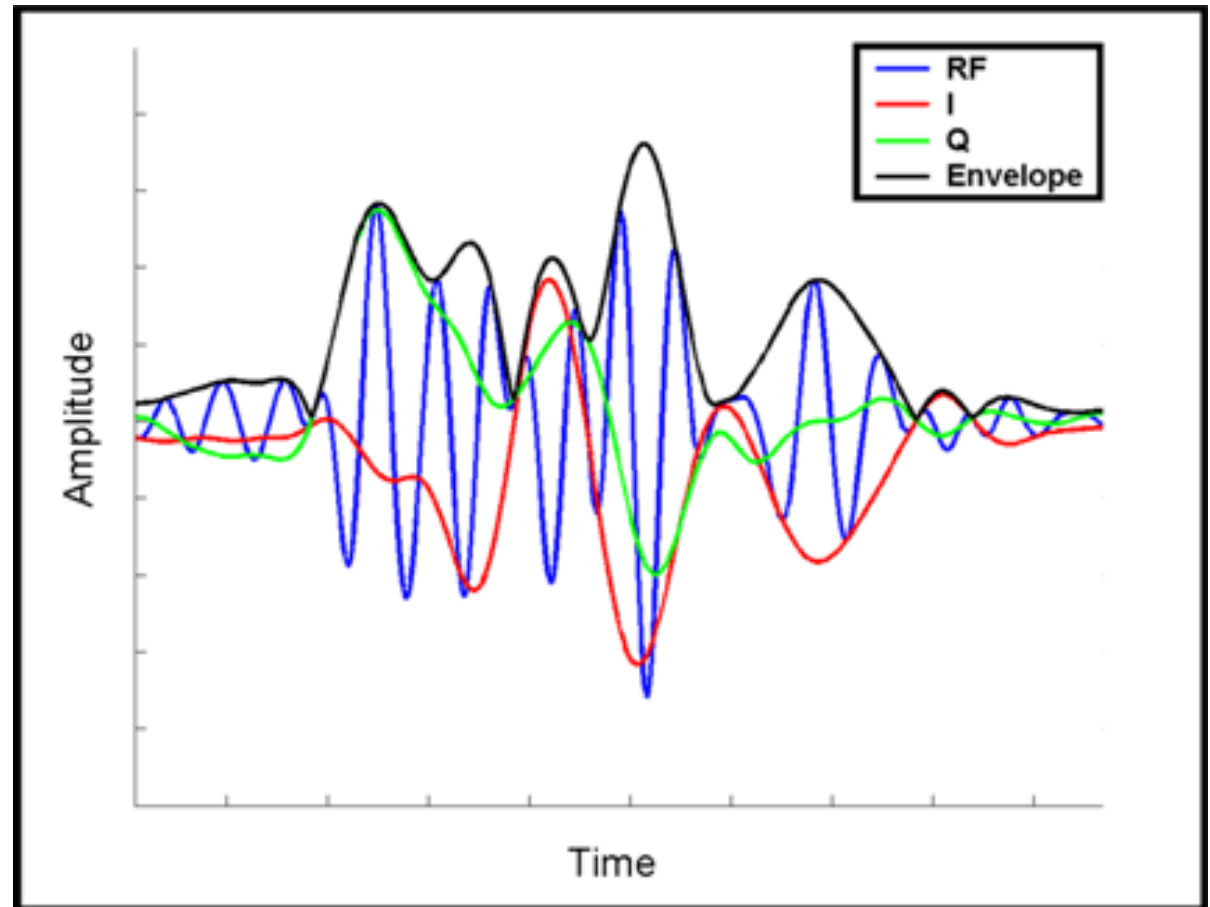


# IQ Data

## RECORDING THE OUTPUT OF A RF DIGITIZER



- In-phase & quadrature information
- Combination of HW/SW to preserve amplitude & phase information
- Determine RF from FFT processing
- IQ info contains all of the information for signal analysis
- IQ streams ?

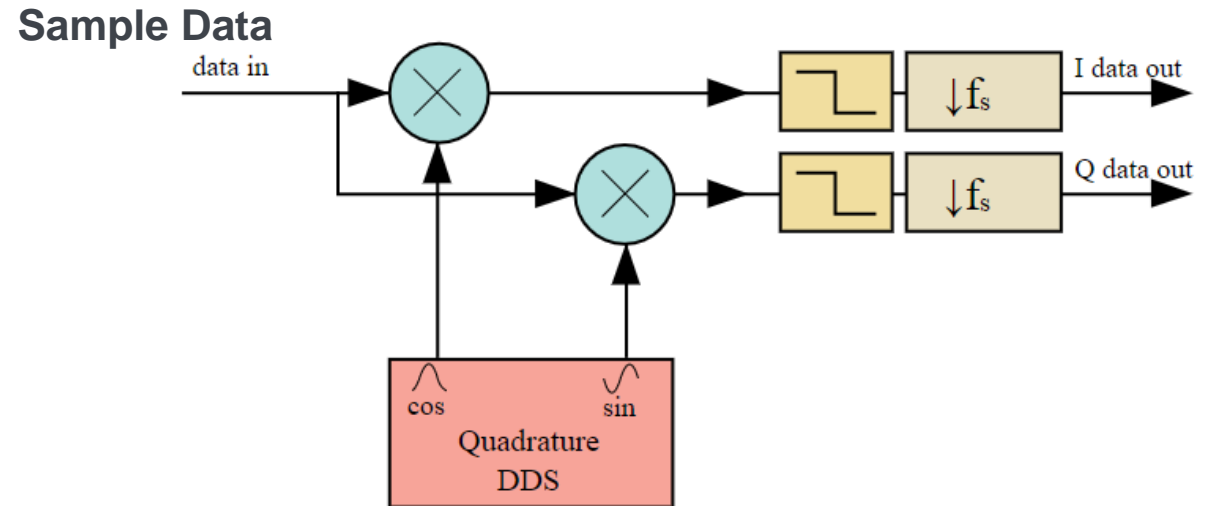
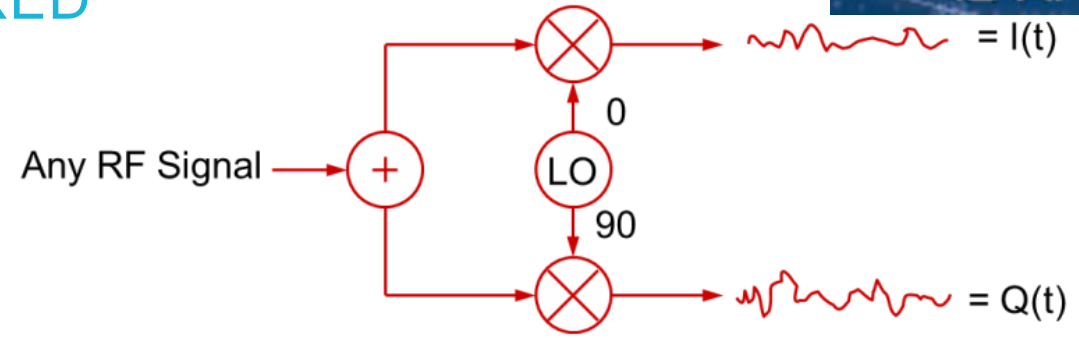




# IQ Data

## MUCH MORE STORAGE SPACE REQUIRED

- More sample rate = more data
- More bits = more data
- Longer time = more data
- How much dynamic range ?
- Streaming ?
- Blocks ?
- RF Corrections ?

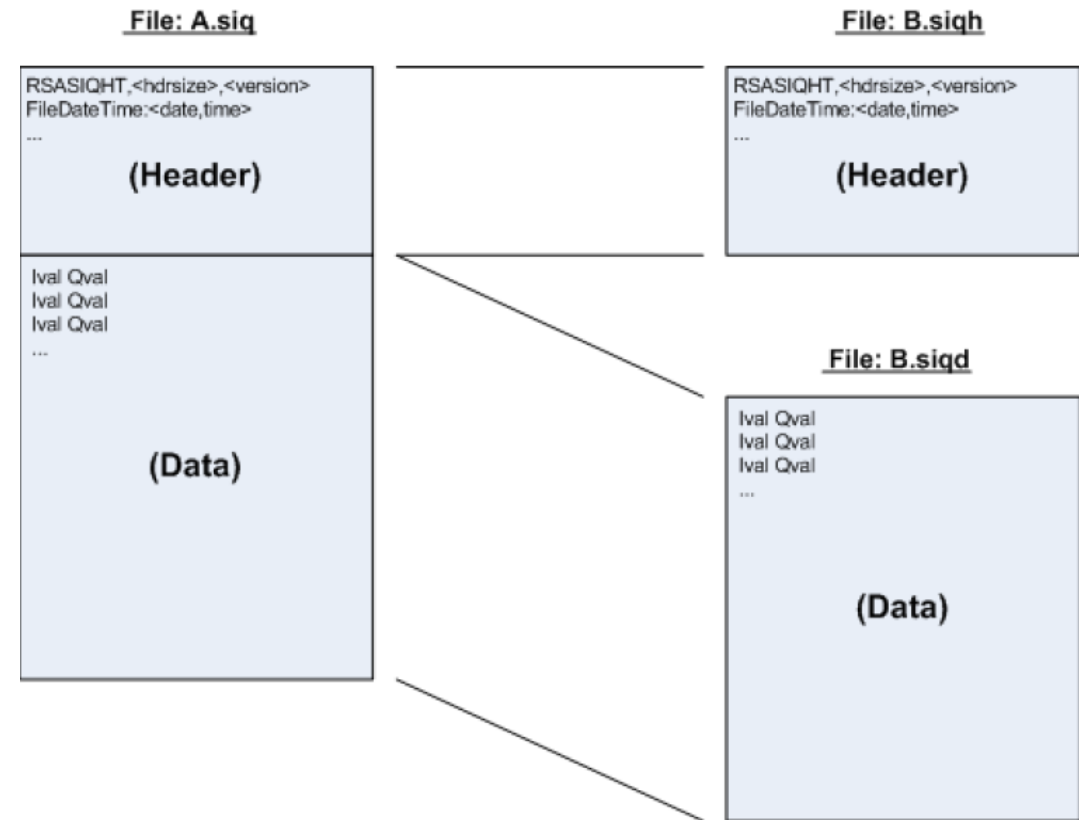




# How Do We Store IQ Data?

## ANATOMY OF AN IQ FILE

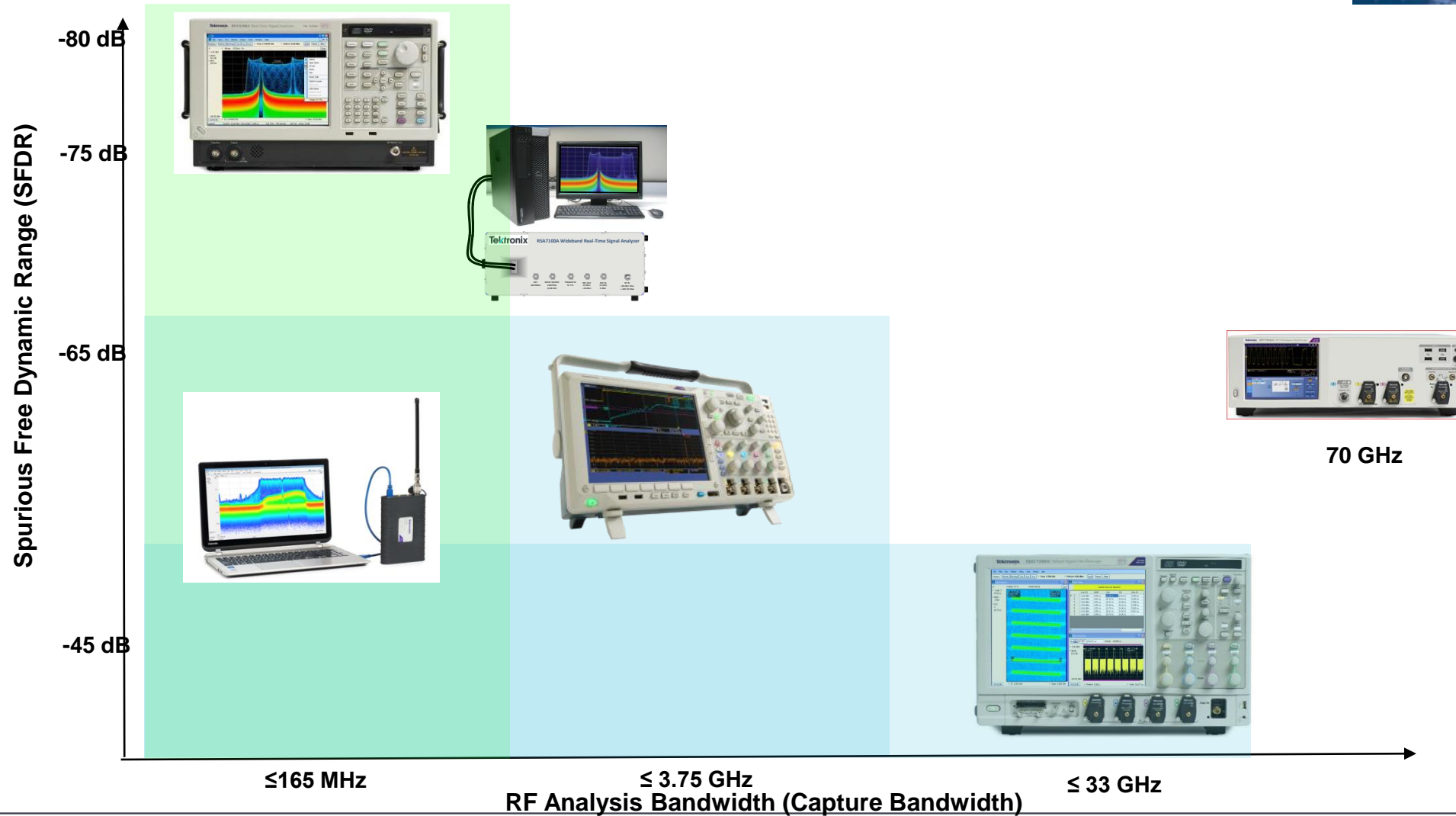
- Need to preserve complete details
- Header Info
  - Time, Date, Sample Rate
  - Calibration factors
  - Time information
- Body
  - I Value
  - Q Value



# Spectrum Analyzer Architecture

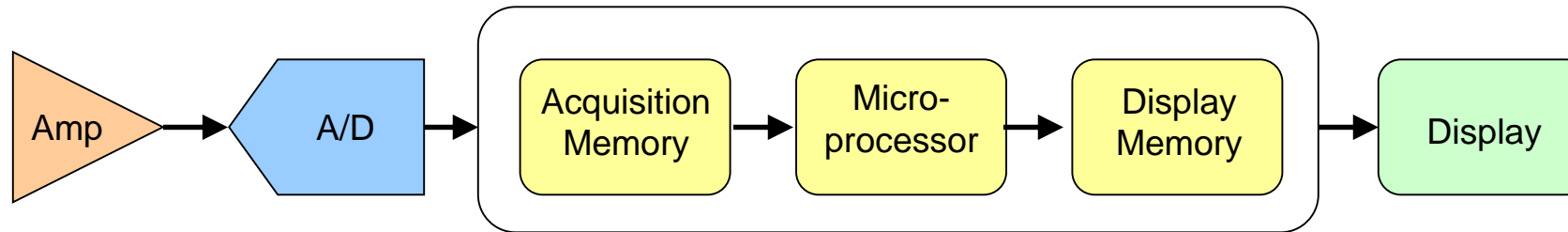
The screens may look similar but the engines are different

# Capture BW vs Fidelity



# RF With An Oscilloscope

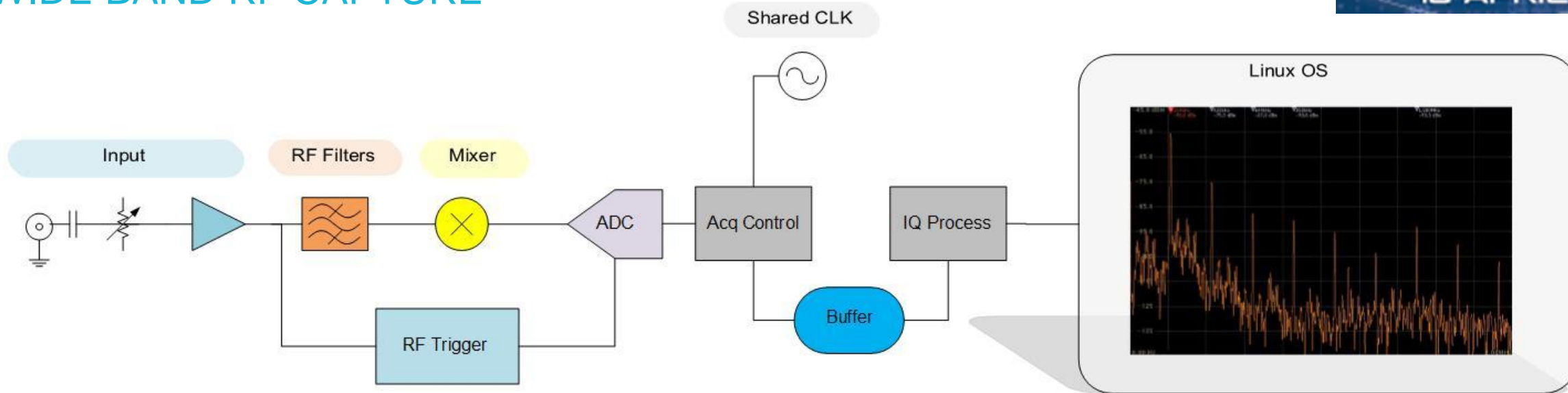
## WIDE BAND CAPTURE



- Very wide band capture available
- Multi-channel capture available
- Limited dynamic range
- Limited memory
- Limited FFT
- Advanced probing available
- Limited sensitivity
- Limited RF controls
- Amplitude flatness
- Phase linearity

# Mixed Domain Analyzer

## WIDE BAND RF CAPTURE



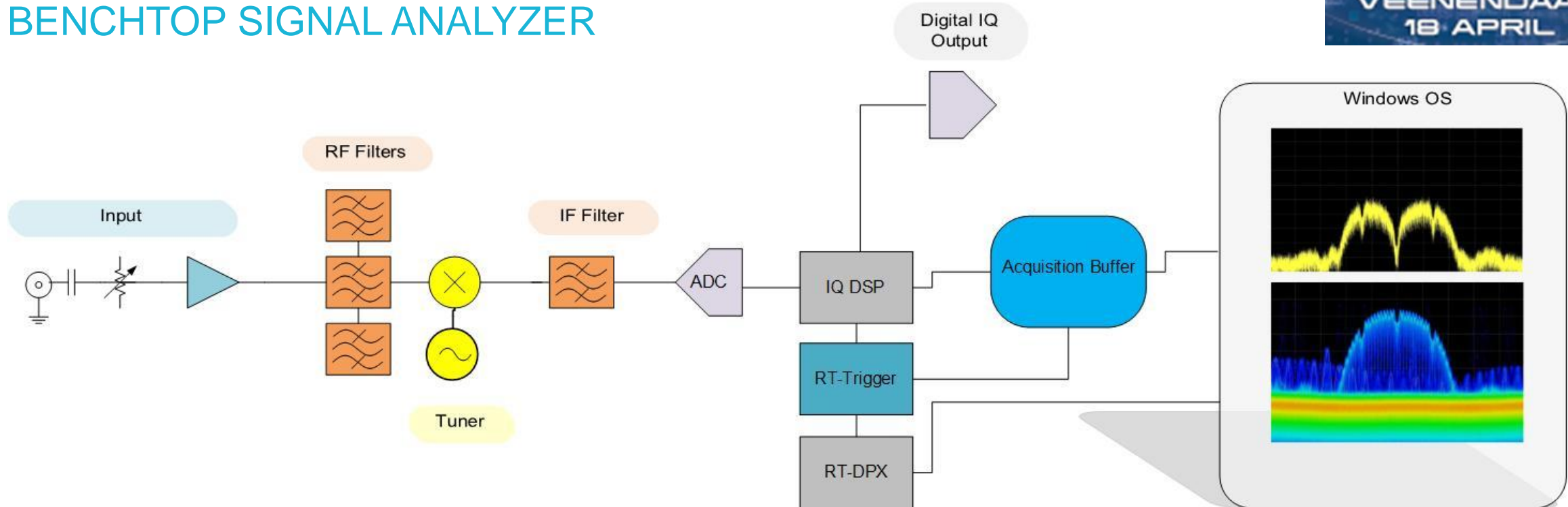
- Low Cost HW
- Wide BW (up to 3.75 GHz)
- High DR (unlike scope)
- Limited memory
- Vector calibrated (unlike scope)

- Storage Options
  - Trace data
  - Spectrogram
  - Block IQ Data



# Real Time Spectrum Analyzer

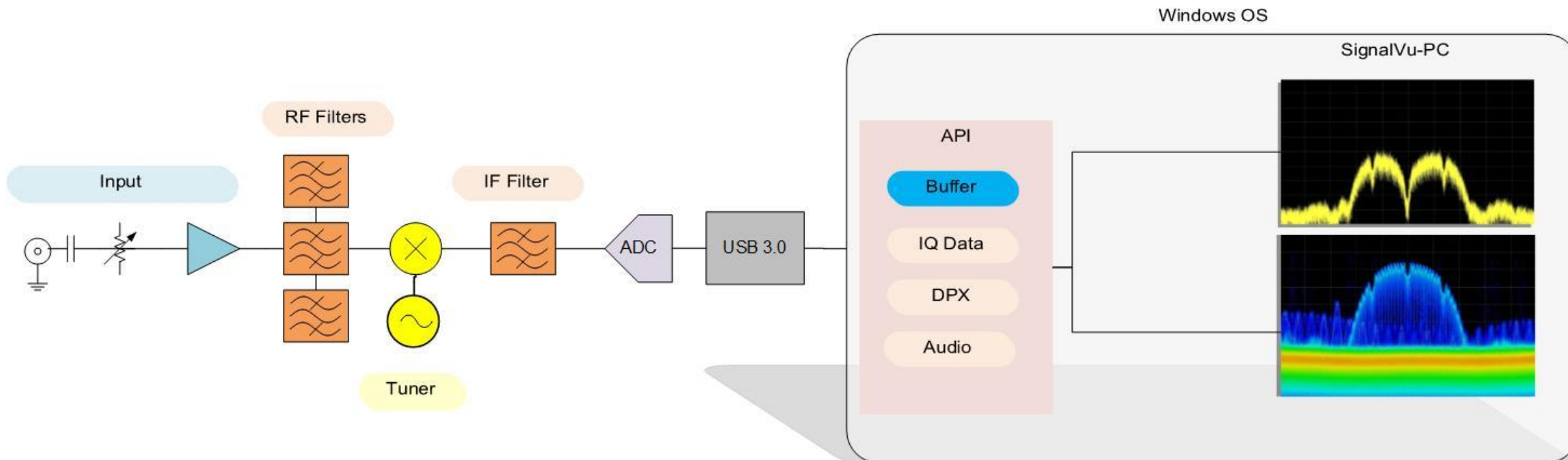
## BENCHTOP SIGNAL ANALYZER



- Wide capture bandwidth
- Advanced triggering
- High dynamic range
- Stream & measure
- Storage Options
  - Trace data
  - Spectrogram
  - Block IQ Data
  - Digital IQ

# Real Time USB Spectrum Analyzer

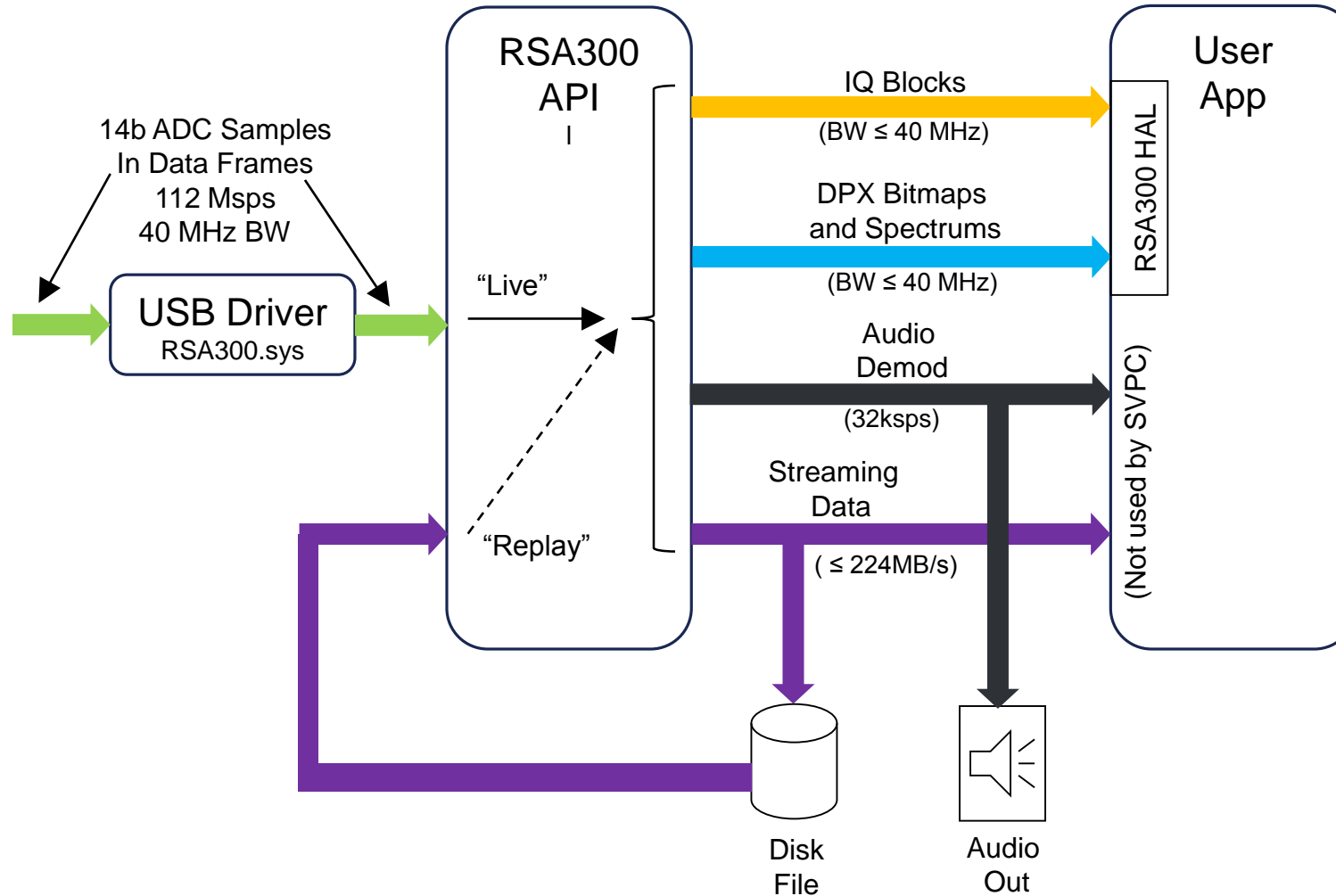
## LOW COST RF RECORDING



- Low Cost
- Portable
- Good Demod/RT BW (40MHz)
- Software Defined Feature Set
- GPS Time Stamps
- 14 bit samples (112 MHz)
- Storage Options
  - Trace data
  - Spectrogram
  - Block IQ Data
  - Stream IQ

# Low Cost RF Recording

## SW SOLUTION



# Example Recording Times

REDUCED BANDWIDTH EXTENDS RECORDING TIME



IQ BW	RECORDING TIME		
	250 GB HD	500 GB HD	1 TB HD
40 MHz	18.6 min.	37.2 min.	1.2 hr.
20 MHz	37 min.	74 min.	2.5 hr.
10 MHz	1.2 hr.	2.5 hr.	4.9 hr.
5 MHz	2.5 hr.	4.9 hr.	9.9 hr.

# Record and Playback

There are two ways to record:

- 1) Block IQ and DPX (TIQ) data
- 2) Streaming ADC (R3F) data



# Block IQ Data



- All recent acquisitions are kept in memory
- The user can chose to store some or all of the acquisitions to files
- Both IQ data and DPX data can be stored for later recall

# Recording Block IQ Data



- IQ Blocks and DPX data are stored by SignalVu-PC in memory (2 sec max record length)
- Both types of data can be stored to disk
  - Options > Save and Export
- Choose which records to include in saved data
  - Current acquisition
  - Current frame
  - Selected frames (Define Replay > Select data records)
  - All in history

# Recording Block IQ Data

CHOOSE “ACQUISITION SAVE OPTIONS” FROM FILE MENU



Select data to save

The screenshot shows the Tek SignalVu-PC software interface. At the top, there is a menu bar with 'File', 'View', 'Markers', 'Setup', 'Presets', 'Tools', 'Connect', 'Window', and 'Help'. Below the menu bar is a toolbar with various icons. The main window is divided into two panes: 'Spectrum' on the left and 'DPX Spectrum' on the right. Both panes show a plot of signal data. The 'Spectrum' pane shows a line plot of signal amplitude over time, with a label 'Data from warm-up period'. The 'DPX Spectrum' pane shows a color-coded plot of signal amplitude over time, also with a label 'Data from warm-up period'. Below the plots is an 'Options' panel with tabs for 'Presets', 'Analysis Time', 'Save and Export', 'Security', and 'Prefs'. The 'Save and Export' tab is active, showing 'All files' and 'Acquisition data files' sections. In the 'Acquisition data files' section, the 'Data types to include:' dropdown menu is open, and 'IQ records' is selected. Other options include 'DPX spectra' and 'Both'. A 'Save TIQ file now' button is also visible. At the bottom of the interface, there is a 'Replay' section with a dropdown menu set to 'Acq Data' and several playback controls. The status bar at the very bottom shows 'Stopped', 'Warm-up period', 'Real Time', 'Free Run', 'Ref: Int', 'Atten: 15 dB', 'Preamp: Off', and 'TG: Off'. A red arrow points from the text 'Select data to save' to the 'IQ records' option in the dropdown menu.

# Replaying Block IQ Data

VIEW REPLAY STRIP, THEN SELECT DEFINE REPLAY BUTTON



Select data to replay

The screenshot shows the Tek SignalVu-PC software interface. At the top, there is a menu bar (File, View, Markers, Setup, Presets, Tools, Connect, Window, Help) and a toolbar with various icons. Below the menu bar, there are two main display areas: 'Spectrum' and 'DPX Spectrum'. Both displays show a signal spectrum with a frequency range from 80.00 MHz to 120.00 MHz. The 'Spectrum' display shows a single trace with a peak level of 0.0 dB/div. The 'DPX Spectrum' display shows a multi-trace spectrum with a peak level of 10.0 dB/div. Below the displays, there is a 'Define Replay' dialog box with several tabs: 'Select data records', 'Select DPX Spectra', 'Acquisition Info', and 'Replay Speed'. The 'Select data records' tab is active, showing a list of acquisitions. A red arrow points from the text 'Select data to replay' to the 'Select All' button in the 'Select data records' tab. The 'Define Replay' dialog box also includes a 'Replay' section with playback controls and a 'DPX Spectrum' section with parameters like Frequency (100.00 MHz), Ref Lev (0.00 dBm), Span (40.00 MHz), and Res BW (100 kHz). At the bottom of the interface, there is a status bar showing 'Stopped' and 'Warm-up period'.

# Streaming ADC data: USB SAs



- Data is always recorded at 40 MHz bandwidth (224 MB/s)
- Raw ADC samples are recorded at the native sampling rate of the spectrum analyzer
  - 14-bit ADC samples
  - 112 MHz sampling rate
- Recorded data is handed to SignalVu-PC for playback as if it were live data



# Recording Streaming R3F Files

INCLUDED IN BASE SIGNALVU-PC



- Requires a fast storage device, > 300 MB/s sustained write speed
- Files are recorded in .R3F format
  - Records 16-bit ADC samples at the 112 MHz IF of the instrument.
  - Not an IQ file
  - Files include trigger stamps, basic settings information, time, and calibration information
- Records at ~13 GB/minute rate

The screenshot shows the 'Record' tab of the SignalVu-PC software. It features several controls for recording:

- Record to disk:** A dropdown menu set to 'Record now' with a 'Start' button below it.
- Location:** A text field containing 'C:\SignalVu-PC Files' and a browse button ('...').
- Base file name:** A text field containing 'SAVED'.
- Max saved files per run:** A numeric input field set to '10'.
- Data structure:** A dropdown menu set to 'Formatted'.
- File Length:** A checkbox checked, followed by a numeric input '1' and a unit dropdown set to 'msec'.

Three callout boxes provide additional information:

- A box on the left points to the 'Record now' dropdown, stating: "Recordings can start from a trigger, or manually".
- A box on the right points to the 'Location' field, stating: "Specify location and number of files to record".
- A box at the bottom right points to the 'Base file name' field, stating: "Base file name auto-increments when multiple recording are made".

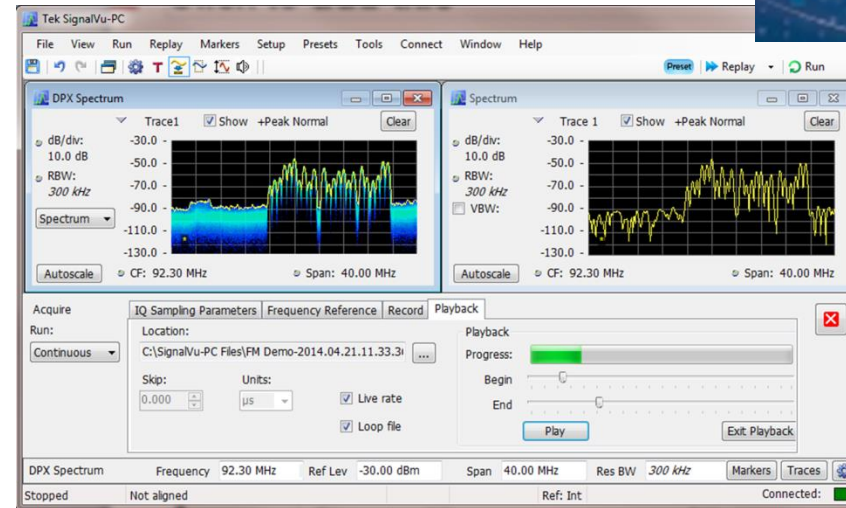
# Playback Controls



The screenshot shows the Tek SignalVu-PC software interface. At the top, there is a menu bar (File, View, Run, Replay, Markers, Setup, Presets, Tools, Connect, Window, Help) and a toolbar with icons for file operations and playback. Below the menu bar are two spectrum display windows: 'DPX Spectrum' and 'Spectrum'. Both displays show a signal spectrum with a yellow trace and a blue background. The 'DPX Spectrum' window has settings: dB/div: -30.0, 10.0 dB; RBW: 300 kHz; Span: 40.0 MHz; CF: 92.30 MHz. The 'Spectrum' window has settings: dB/div: -30.0, 10.0 dB; RBW: 300 kHz; Span: 40.00 MHz. Below the spectrum displays are the 'Acquire' and 'Playback' sections. The 'Acquire' section has a 'Run' dropdown set to 'Continuous'. The 'Playback' section has a 'Progress' bar, 'Begin' and 'End' sliders, and 'Play' and 'Exit Playback' buttons. Three callout boxes highlight specific features: 'Live-rate control sets playback rate to 1:1 vs record rate' points to the 'Live rate' checkbox; 'User-adjusted Begin/End point' points to the 'Begin' and 'End' sliders; 'Skip control for fast review of results' points to the 'Skip' field set to '0.000' with units of 'µs'. At the bottom, there is a status bar with fields for 'DPX Spectrum', 'Frequency 92.30 MHz', 'Ref Lev -30.00 dBm', 'Span 40.00 MHz', 'Res BW 300 kHz', 'Markers', 'Traces', 'Stopped', 'Not aligned', 'Ref: Int', and 'Connected: [green indicator]'.

# Playback controls

- File opening: From control panel for Playback, or File: Recall menu
- Play: Establishes connection to R3F file, applies all Playback settings (Begin/end, loop, skip)
  - Stop/Play is required for changes in setup of playback to take effect
  - Play disconnects any RSA306 present, and connect to the selected file
- Exit Playback: Breaks connection from file to SignalVu-PC. You exit Playback in order to re-connect to an instrument.





# Recording from the RSA300/500/600 API

How to record directly from the API using demo applications with variable data rates

# IQcapture.exe

THIS PROVIDES FUNCTIONALITY NOT IN SIGNALVU-PC



- Streaming IQ has flatness corrections applied to time series data
- Output bandwidth and data rate are adjustable:

IQ BW	IQ Sample Rate	IQ Output Data rate	
		32b fixed or float	16b fixed
40 MHz	56 M Sa/sec	448 MB/sec	224 MB/sec
20 MHz	28 M Sa/sec	224 MB/sec	112 MB/sec
10 MHz	14 M Sa/sec	112 MB/sec	56 MB/sec
5 MHz	7 M Sa/sec	56 MB/sec	28 MB/sec



# Recording Time vs Bandwidth

REDUCED BANDWIDTH EXTENDS RECORDING TIME



IQ BW	Recording time		
	250 GB	500 GB	1 TB
40 MHz	18.6 min.	37.2 min.	1.2 hr.
20 MHz	37 min.	74 min.	2.5 hr.
10 MHz	1.2 hr.	2.5 hr.	4.9 hr.
5 MHz	2.5 hr.	4.9 hr.	9.9 hr.

# IQcapture.exe recording

THE FOLLOWING COMMAND CAPTURES TIQ DATA TO DISK FOR

10 SECONDS

- 40 MHz capture (224 MB/s):
- `iqcapture dev=0 rl=-20 cf=100e6 bw=40e6 msec=10000 dest=2 dtyp=3 fn=c:\data\IQdat fnsfx=-1`
  - `rl=-20` reference level = -20 dBm
  - `cf=100e6` center frequency = 100 MHz
  - `bw=40e6` bandwidth = 40 MHz
  - `msec=10000` record length = 10 sec
  - `dest=2` destination = File-TIQ
  - `dtyp=3` data type = int16
  - `fn=c:\data\IQdat` filename = IQdat
  - `fnsfx=-1` filename suffix = date & time

# Analyzing Large Files

Real time playback is time consuming....

# Importing Files into SignalVu-PC

TYPES OF STREAMING DATA FILES THAT SIGNALVU-PC

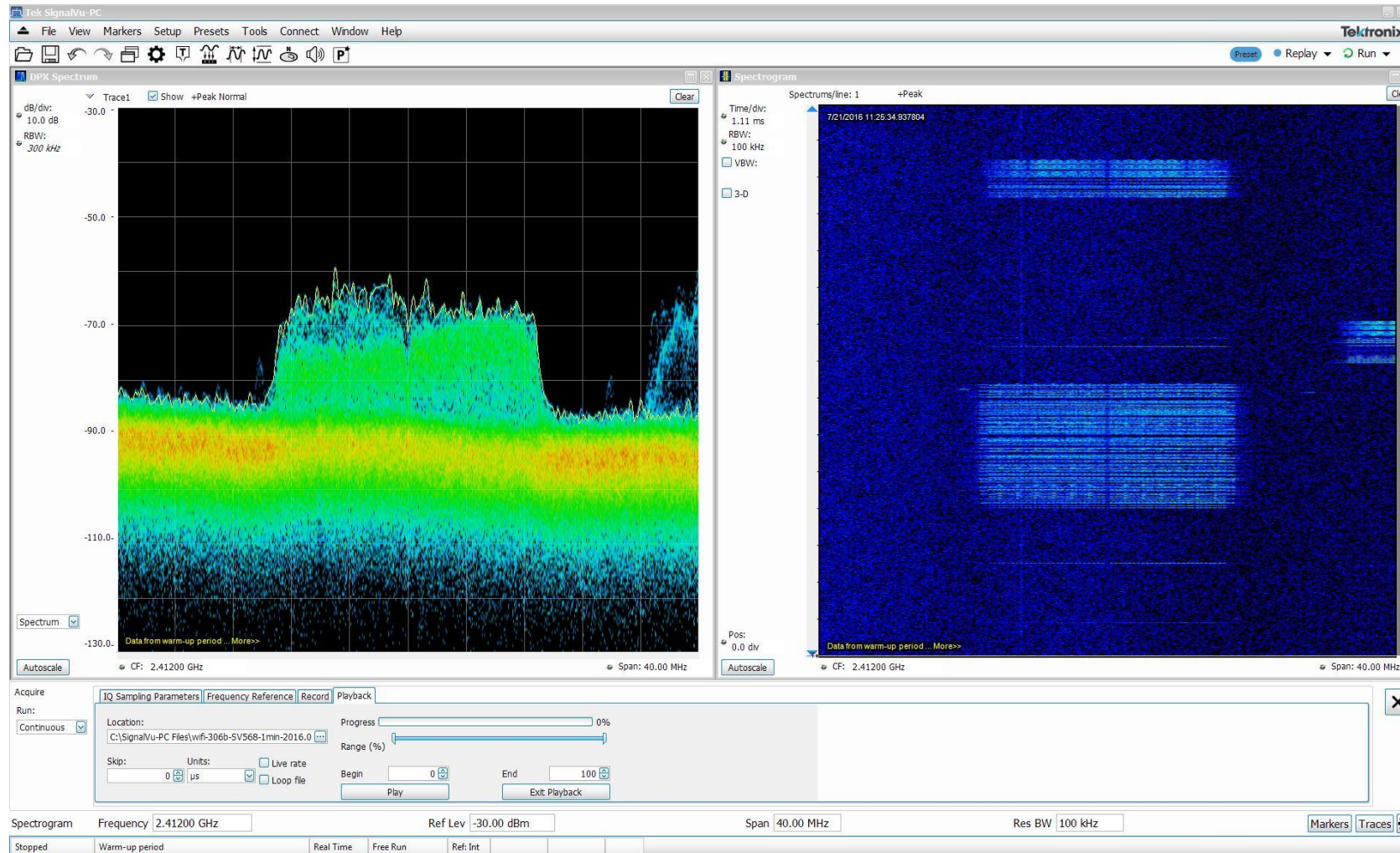
CAN OPEN AND PLAY BACK

- ADC sample data (R3F)
- Acquisition data with setup (TIQ)
- Acquisition data with setup (MAT)
- Acquisition data with settings (IQT)
- Scope waveform IQ (ISF)



# SignalVu-PC Playback

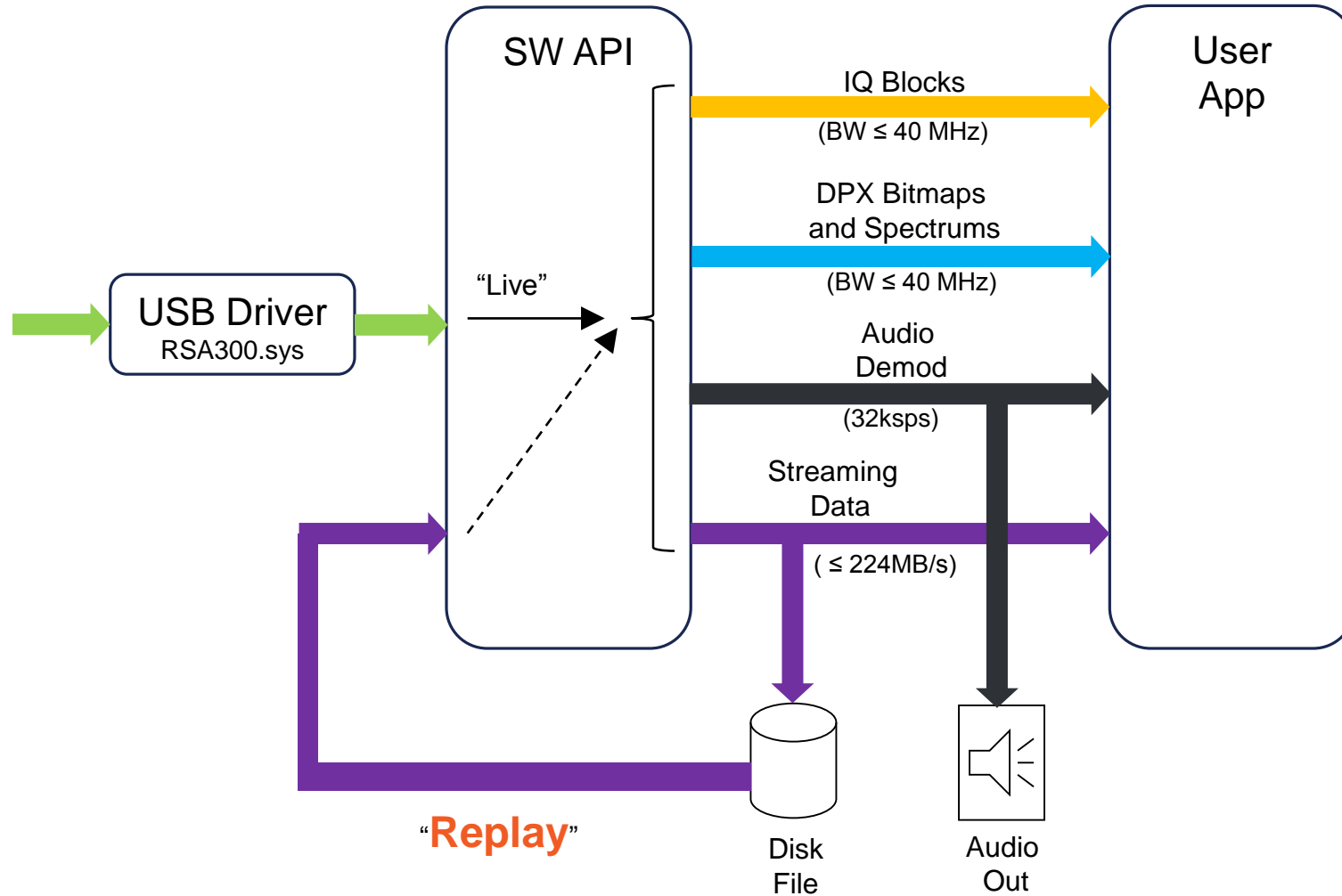
SHOWN ARE WI-FI SPECTROGRAM, DPX DISPLAY





# Large File Analysis

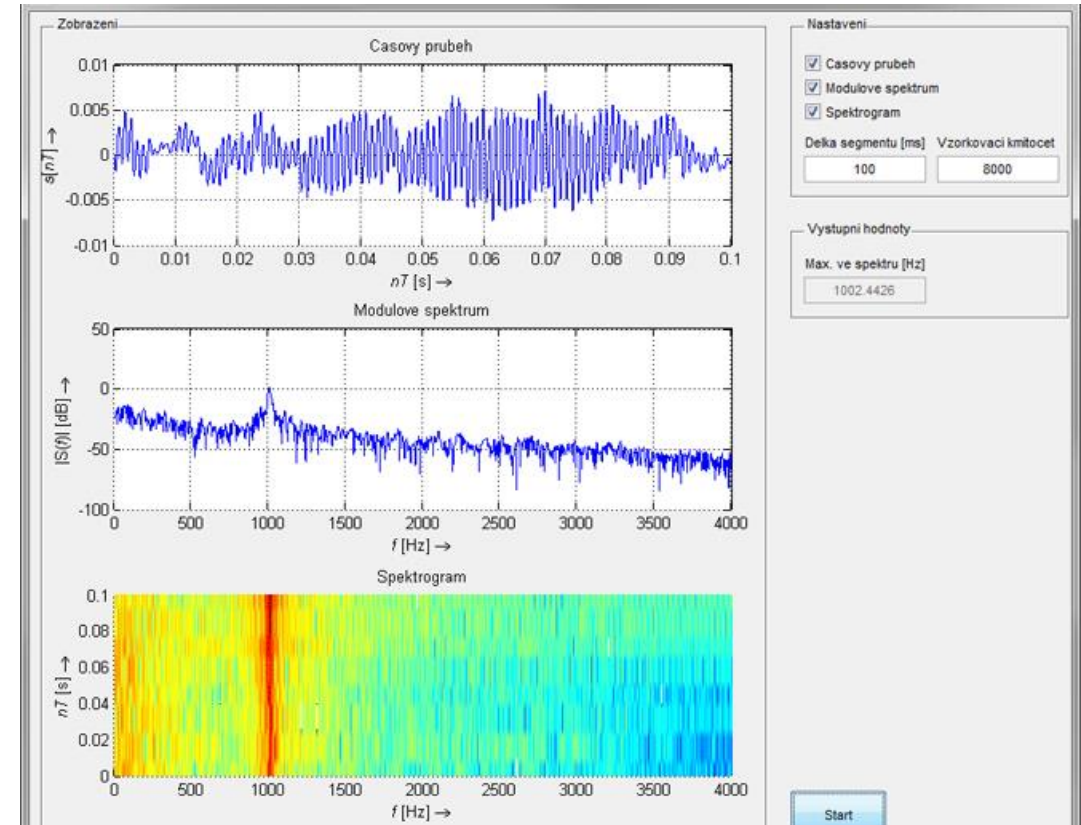
## SW REPLAY SOLUTION



# Large File Analysis

## MATLAB ANALYSIS OF EXTRACTED FILES

- Flexible environment with rich set of tools for signal analysis
- Common data conduit for multiple vendors
- Supports multiple file structures
- Caution: Varying levels of support for large files



# Importing Files into DataVu

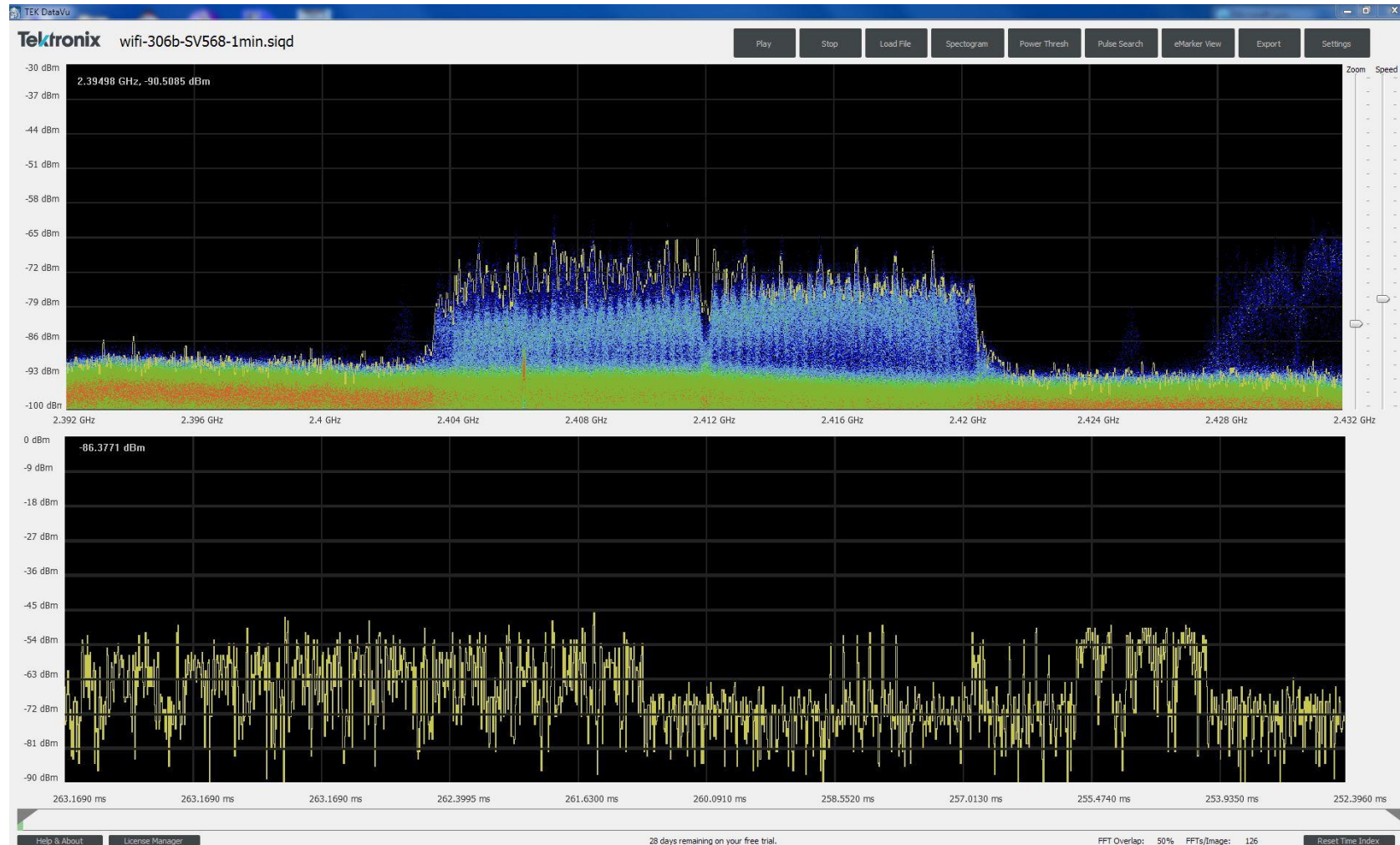
TYPES OF STREAMING DATA FILES THAT DATAVU CAN OPEN  
AND PLAY BACK

- IQ data in simple format (SIQD)
- IQ data in XCOM format (XDAT)



# DataVu Playback

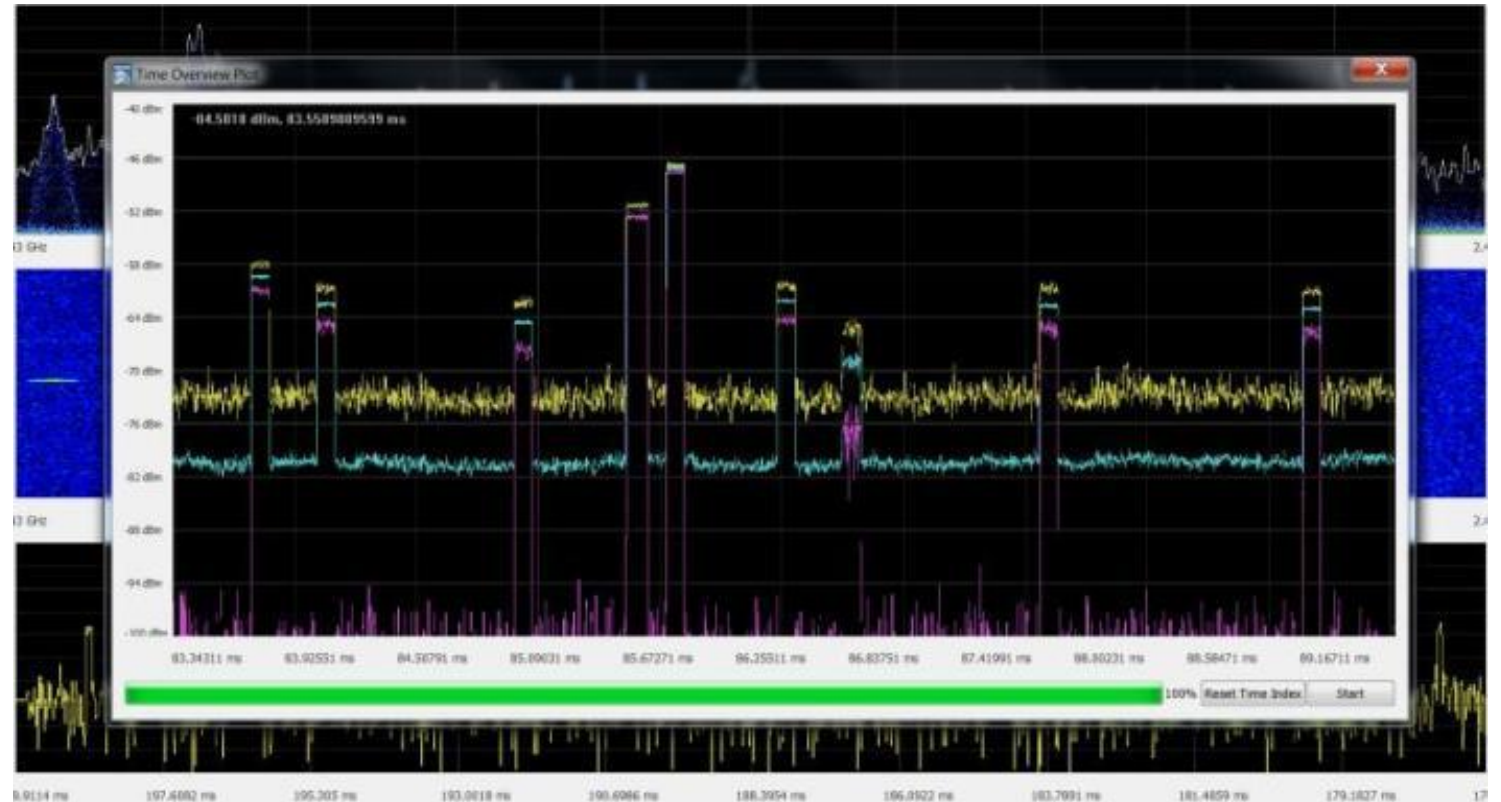
## SPECTRUM, POWER VS. TIME



# Large File Analysis

TIME OVERVIEW TO SEE THE WHOLE FILE AT ONCE

- Fast way to find signals in recordings
- Mark events in time
- Export portions of recording for further analysis

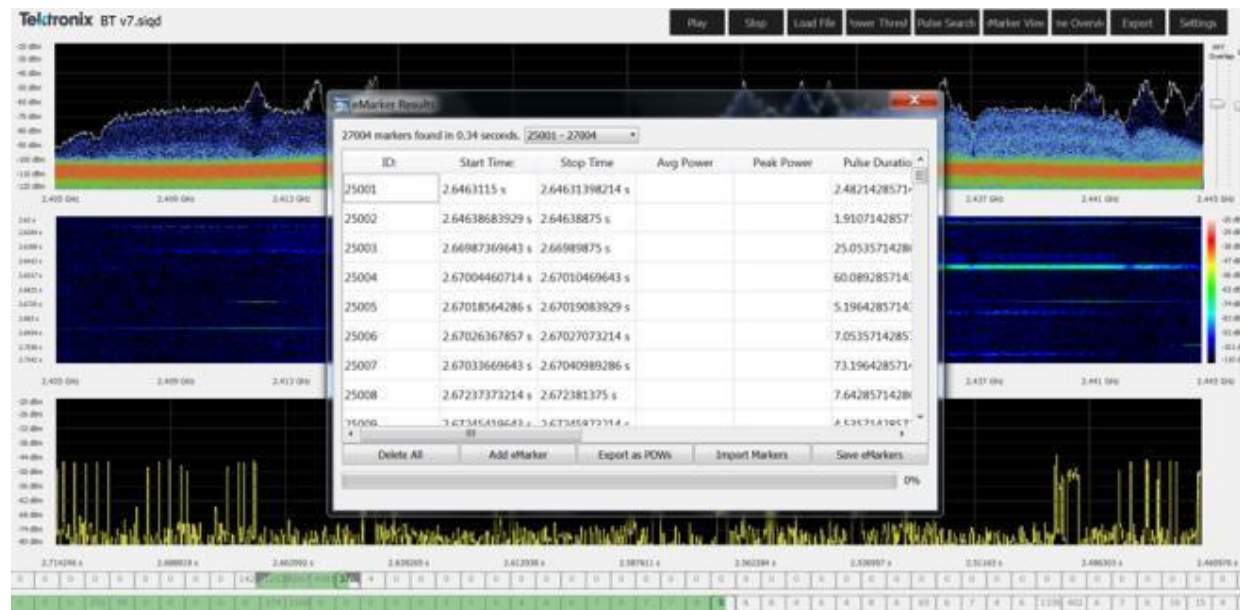
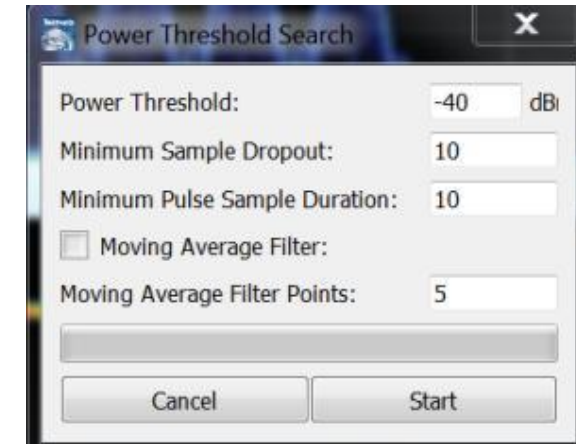




# Large File Analysis

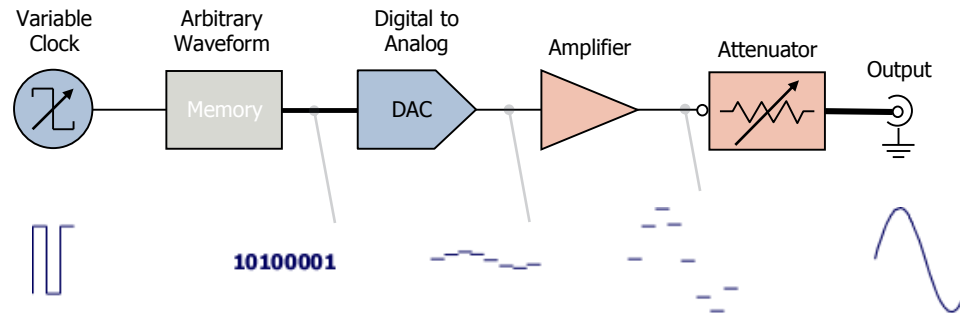
## THRESHOLD SEARCH AND TIME OVERVIEW

- Detect signals with amplitude search
- Mark and extract time records



# Playback RF Data

## ARBITRARY WAVEFORM SOURCES



- IQ blocks can be loaded into ARB memory
- Very wide IF bandwidths can be replayed for long
- Easily generate analog IQ or RF signals



Questions ?