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DESIGN AND IMPLEMENTATION OF A SOFTWARE-DEFINED SPECTRUM ANALYZER BASED ON PLUTO-SDR

Wireless signals are essential to daily life—phones, Wi-Fi, Bluetooth, IoT devices, factory sensors, and RF trackers share the same air [1], so interference can slow data or cause dropouts; licensed bands are tightly managed [2], while unlicensed bands (e.g., 2.4 and 5.6 GHz) require low power, short bursts, and Listen Before Talk (LBT) [3]. Because the RF environment changes in milliseconds and classic swept-tuned analyzers view only one narrow slice, we use Real-Time Spectrum Analyzers (RTSA/RSA) that continuously watch the spectrum, catch very short events, trigger on set conditions, and record data for repeatable time-and-frequency checks of interference, out-of-band emissions, spurious tones, and timing issues [1]. For this purpose, different analyzer architectures exist [1].

A Swept Spectrum Analyzer (SA), or superheterodyne spectrum analyzer, downconverts the input and sweeps a narrow resolution bandwidth (RBW) filter across the chosen span, measuring one small slice at a time—providing strong dynamic range and accurate results for steady, continuous signals, but potentially missing rapid changes that occur between slices [1].

A Vector Signal Analyzer (VSA) downconverts to IF/baseband, digitizes the signal, and uses digital downconversion, filtering, and an FFT to produce spectrum/time views and modulation metrics (e.g., EVM, channel power); it excels for known, repeatable waveforms yet is blind between captures, so rare or very short events can be missed and it is not designed for continuous, gap-free watching of the spectrum [1].

A Real-Time Spectrum Analyzer (RTSA/RSA) continuously watches a chosen slice of the radio band, sampling fast enough to satisfy Nyquist criteria so it can catch very short events—brief bursts, hops, or unwanted tones—with "real-time" retaining its simulation meaning of processing events as fast as the real system [1].

Software-Defined Radio (SDR) can be programmed to act as a Real-Time Spectrum Analyzer (RSA), providing a flexible, affordable solution that adapts to project needs: the viewing range and detection rules live in software, data can be recorded for replay/sharing, and the instrument can plug into tools or tests without buying new RSA hardware each time [4]. We use PlutoSDR and a program based on the ADALM-Pluto Spectrum Analyzer (Python + pyadi-iio) under the MIT license [4].

In broad terms, the baseline program performs a simple step-by-step sweep with live updates and basic smoothing: it is convenient and feature-complete (markers, thresholds, peak hold), but on wide spans frequent tuner hops and per-point rendering make it slow and liable to miss very short bursts between steps. By contrast, the developed “fast spectrum analyzer” program is optimized for wide spans and stable results: it runs higher sample rates to minimize LO changes, derives FFT size from a chosen RBW for predictable resolution, applies VBW after detection on linear power, limits plotted points, and renders once per sweep; in practice this yields much faster sweeps and more consistent levels across the band—for example, about 400 ms for 100 MHz–5.8 GHz—while preserving peak-hold visibility of short events [4].

So, an SDR used as a real-time spectrum analyzer can watch one band continuously, trigger on quick events, and save IQ data for later study—supporting faster interference hunting, clearer compliance checks, and an open toolchain we can improve. We compared two PlutoSDR programs: a simple sweep that shows each point but gets slow on wide spans and may miss narrow or short signals, and a second design that reduces tuner steps, sets FFT size from the chosen RBW, applies VBW after detection, and draws once per sweep; this second design gives faster scans, a cleaner display, and more stable levels across the band, with performance limited by the chosen RBW/VBW, memory needs for long captures, and SDR computational resources.

References

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