SkyRoof: An Integrated Satellite Tracking and SDR Application

Alex Shovkoplyas, VE3NEA

Abstract

SkyRoof is an open-source, 64-bit Windows application designed for amateur radio operators engaged in satellite communications. Combining real-time satellite tracking with SDR-based reception and Doppler-corrected tuning, SkyRoof presents a unified environment where operators can predict passes, identify satellite signals, and directly receive and demodulate transmissions from the satellites. This paper presents an overview of SkyRoof's architecture, key features, operation and applications, and illustrates its utility for both casual satellite listening and advanced communications experiments.

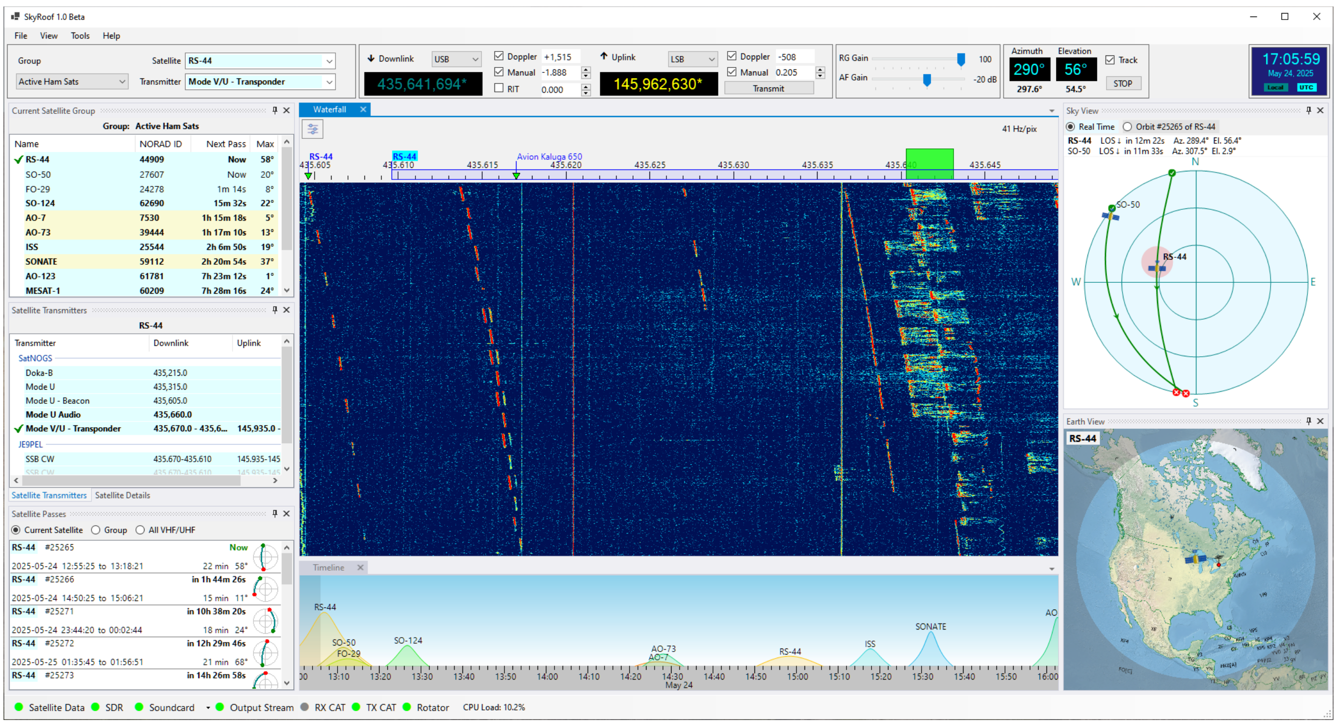

Figure 1. The main window of SkyRoof

Overview

The availability of inexpensive software-defined radios (SDRs) and the increased computational power of modern computers have encouraged the development of integrated applications for amateur satellite work. Traditional station setups often require multiple independent programs for tracking, Doppler correction, audio routing, and demodulation. SkyRoof merges these functions into a single, coherent interface.

Developed as a free and open-source project under GPLv3, SkyRoof runs on Windows 64-bit systems and supports a wide range of SDR front-ends. Its user interface combines a waterfall spectrum display with tracking visualizations, such as Sky View, Earth View, and Timeline, enabling users to interactively follow satellites and their operating frequencies in real time. Automatic control of the transceiver frequencies and antenna rotation simplifies two-way radio communication via the satellites.

System Requirements

SkyRoof requires:

- **Computer**: A 64-bit PC; 3-GHz Quad-core CPU recommended;
- **Video Card**: OpenGL 3.3+ support, 512 MB of texture memory;
- **Monitor**: 1920×1280 resolution minimum; 4K recommended;
- **Internet**: required to download satellite data;
- **SDR**: optional, but highly recommended;
- **Transceiver and antenna rotator**: optional.

The range of supported SDR receivers depends on the installed plugins. SkyRoof is distributed with plugins for Airspy R2, Airspy Mini, Airspy HF, RTL-SDR, SDRplay, PlutoSDR, and HackRF.

SkyRoof can also operate without an SDR or transceiver. While this limits functionality, it allows exploration of pass prediction and visual panels in offline or demonstration scenarios.

Satellite Data

SkyRoof uses information about currently active satellites, their transmitters and orbit elements from SatNOGS, a publicly available, crowd-sourced database. The Satellites and Groups window in SkyRoof allows viewing, searching and filtering satellite data. Users can organize satellites into groups for easier management.

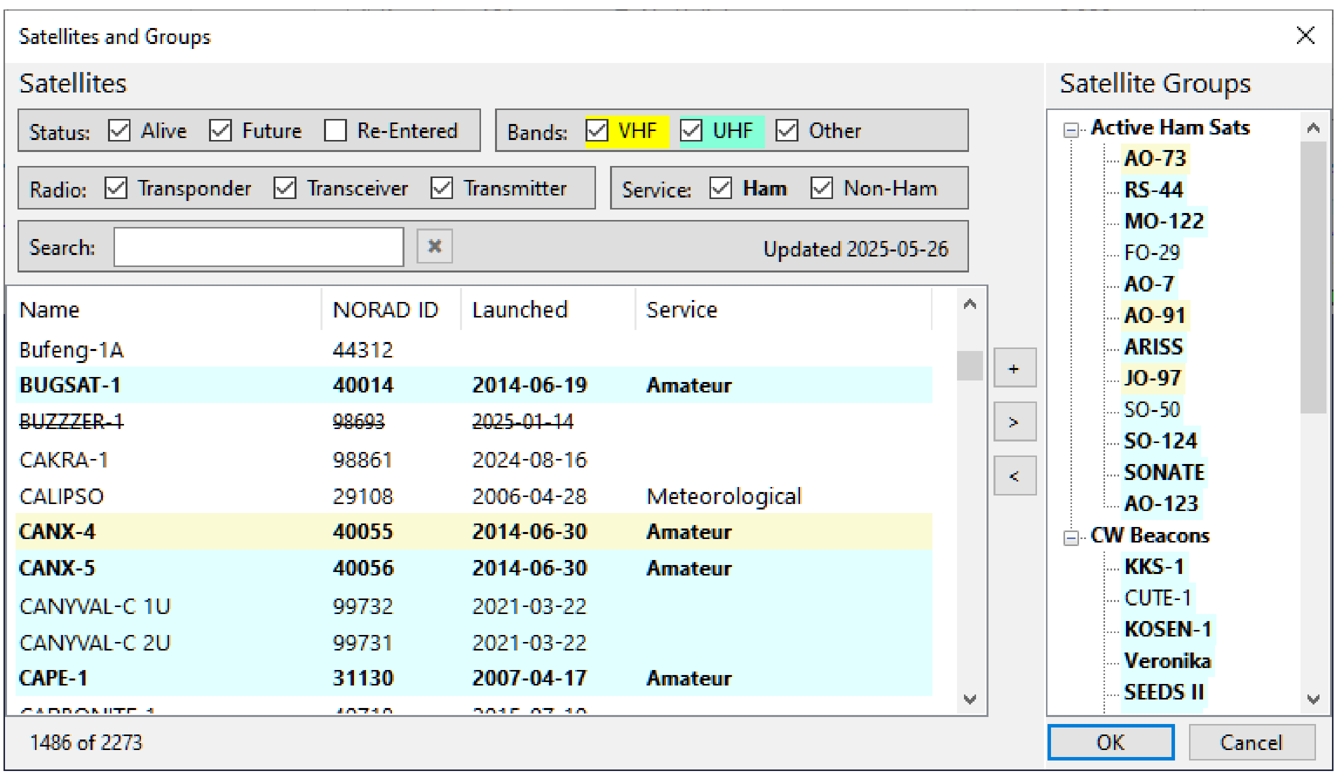

Figure 2. Satellites and Groups window

Satellite pass predictions are computed using the SGP-4 algorithm. Information about the passes is presented in the textual and graphical forms.

The Pass List panel displays the details of the predicted passes and includes mini-charts of satellite paths over the sky, making it easy to assess the suitability of the pass for reception or two-way contacts.

The Sky View panel shows the satellite path, as seen from the observation point, and current direction of the antenna if antenna rotation control is enabled. The azimuth and elevation of the satellite are also displayed in the numerical form.

The Earth View panel shows the Earth, as seen from the satellite. This view uses a high resolution world map, and the user can zoom in using the mouse wheel to view the details. At maximum zoom, the satellite's motion across the Earth becomes visible in real time.

The Timeline panel displays the satellite passes on a chart with time on the horizontal scale and satellite elevation on the vertical scale, as shown in the screenshot below.

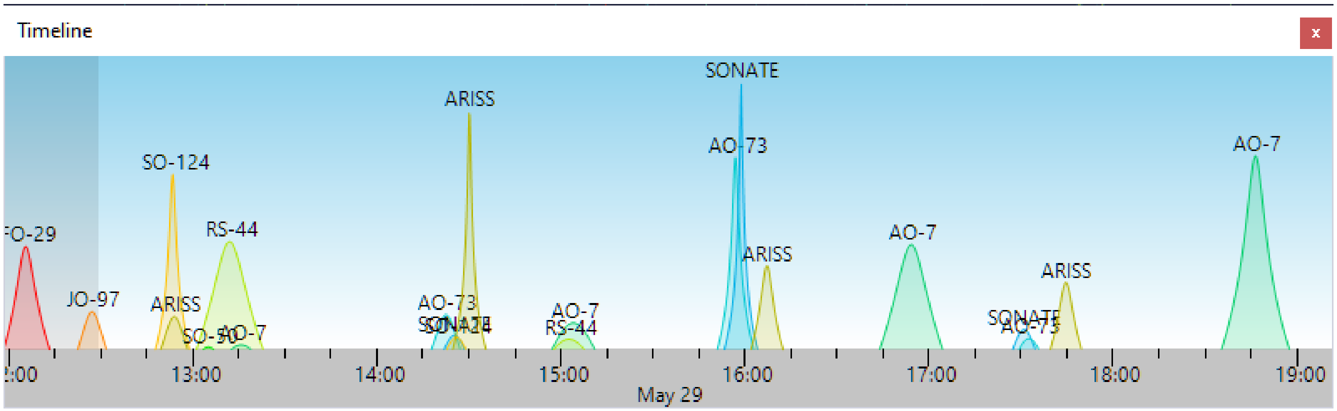

Figure 3. The Timeline panel

SkyRoof also provides optional voice announcements for key events such as satellite acquisition of signal (AOS), loss of signal (LOS), and real-time satellite azimuth and elevation. This feature is particularly valuable for the operators that use hand-held antennas, as it allows them to adjust antenna direction without needing to watch the screen.

Waterfall Display

The waterfall display and its attached band map form the central part of the software where satellite data, pass predictions, Doppler tracking and SDR signal processing work together to allow the user to find and identify the satellite signals. The labels on the band map have mouse-over tool-tips and popup menus that provide additional information and commands.

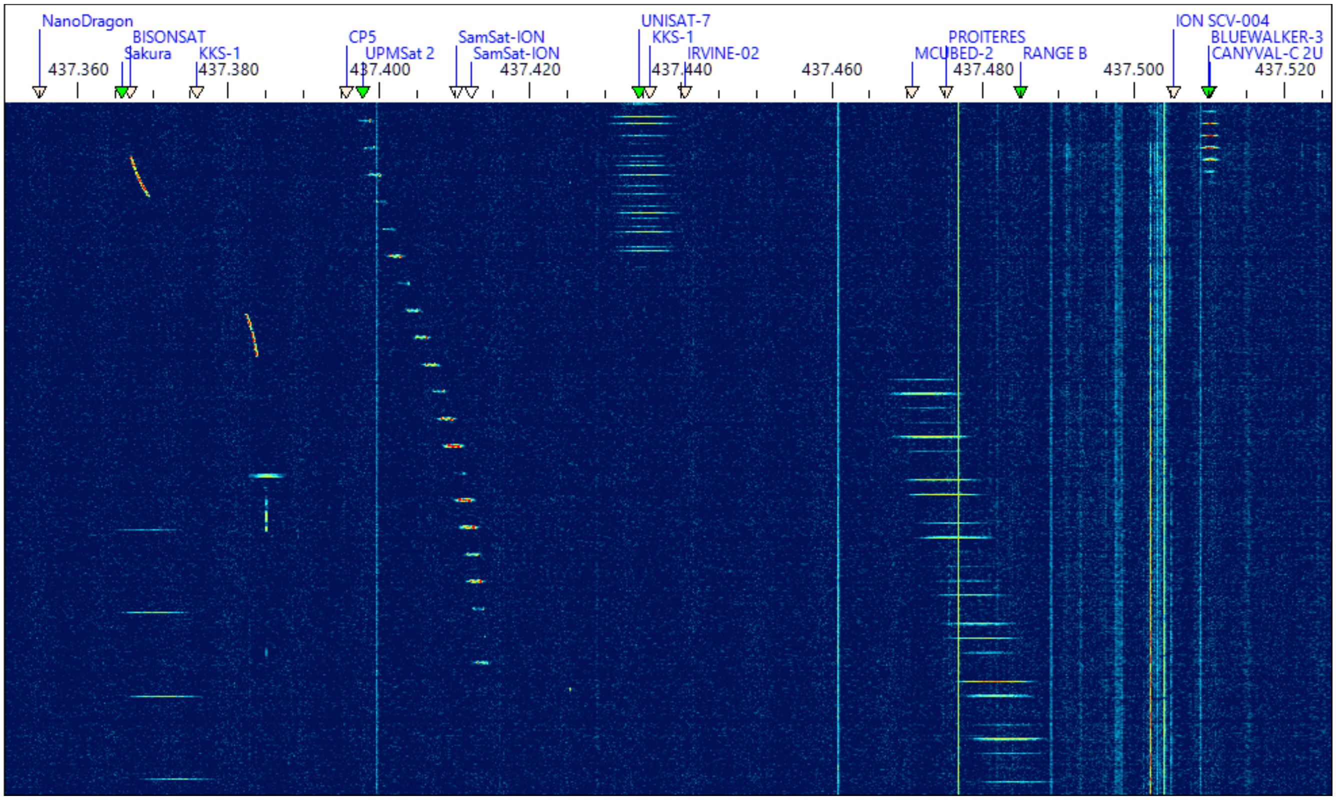

Figure 4. Waterfall display with labelled satellite signals

Finding and tracking satellite signals on the VHF and UHF bands is a difficult task. These signals are weak because the output power of most satellite transmitters is in the milliwatt range. The fact that an omnidirectional antenna needs to be used to receive all in-range satellites at the same time makes this task even more difficult. On top of that, the user needs to see the whole segment of frequencies allocated to the satellites (3 MHz on the 70 cm band) where the satellite signals may appear, and at the same time a very high spectrum resolution is required to examine the structure of the signals, and to tune precisely to the CW, SSB and digital transmissions.

The waterfall display in SkyRoof solves these problems by computing the power spectra oversampled by a factor of about 100. This has three important consequences:

1. The user can zoom in the waterfall display just by spinning the mouse wheel. When zoomed in to the maximum, the signals appear with a **100x** magnification (20 Hz resolution).
2. When zoomed out to the maximum, the waterfall displays the whole 3-MHz segment, and the signal-to-noise ratio of the narrowband signals improves by about **15 dB** due to oversampling.
3. Spectrum oversampling, however, increases the requirements to the CPU and GPU hardware, as can be seen in the system requirements.

Demodulation

A set of mixers, DSP filters, and demodulators of SSB, CW, and FM modes in SkyRoof comprise a software-defined receiver. The user can configure the receiver to either receive terrestrial signals on a fixed frequency or track the Doppler offset of the selected satellite. Additional wideband demodulators are available for the digital modes, including LSB-D, USB-D and FM-D. The audio is sent to a soundcard for listening, and optionally streamed to an external application via a VAC (virtual audio cable) or TCP connection for decoding. The User's Guide includes tutorials explaining how to decode satellite telemetry, weather images and SSTV signals using a number of external decoders.

Two-Way Communication

SkyRoof has a number of functions that assist operators in making two-way radio contacts using the repeaters and transponders carried by the satellites. The operator tunes to the signals of interest visually, by clicking on the signal traces in the waterfall, by using the mouse wheel and various keyboard and mouse commands. Precise alignment of the receive and transmit frequencies is also performed visually. The satellite beacon is used to correct the downlink frequency error (trace 1 in the image below), and their own CW signals are used to correct the uplink frequency (trace 2). These corrections need to be done only once, the software remembers them and uses them during the subsequent satellite passes. Once corrections are applied, the receive and transmit frequencies are automatically synchronized by applying the proper Doppler correction, so the operator can keep a conversation with correspondent without further adjusting the frequencies.

Transceiver CAT control in SkyRoof is performed through the companion SkyCAT software, which provides frequency and mode control for supported models. The current release includes command definition files for the Yaesu FT-817/818, FT-847, and FT-991A; the Icom IC-705, IC-706MKIIG, IC-905, IC-910, and IC-9700; and the Kenwood TS-2000. For transceivers without available command definition files, the Hamlib command-line utility `rigctld.exe` can be used as an alternative interface. Antenna rotator control is handled in a similar way, using `rotctld.exe`, another Hamlib utility that communicates with a wide range of rotator controllers.

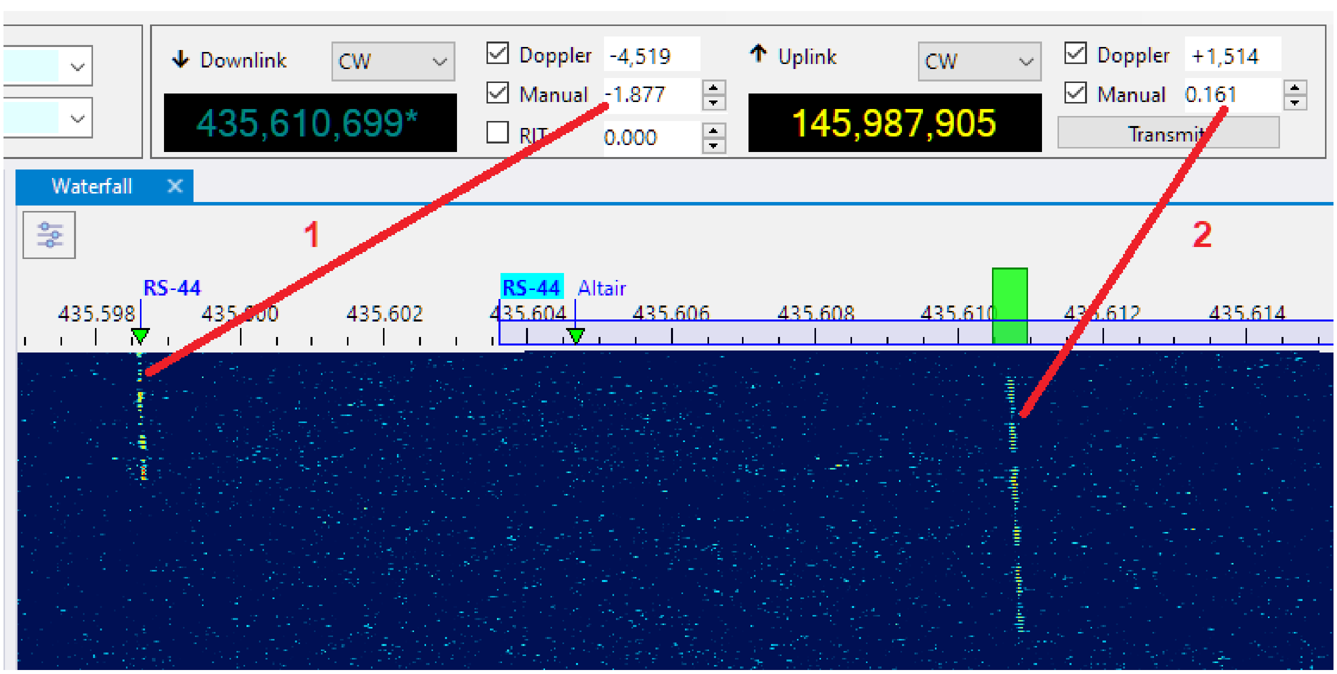

Figure 5. Visual alignment of TX and RX frequencies

Logging

SkyRoof includes a dedicated QSO Entry panel for recording callsigns, frequencies, modes, and other details during satellite contacts in real time. Records are saved in ADIF format compatible with standard logging software. The panel also supports direct integration with external loggers through a plugin interface.

Open Architecture

SkyRoof has an open architecture. Many of its functions may be extended by adding the external files, such as plugins and datasets.

The interface to SDR is plugin-based, support of new radio models is added by creating the plugins for those models.

CAT command definitions for the transceiver as stored in the external files. Support of new transceiver models is added by creating the new command-set files.

The interface to Ham logging software is also plugin based, the authors of the loggers can create plugins that allow SkyRoof to write QSO records directly to the logger database.

Users can also customize the waterfall display appearance by editing the color palettes, which are stored in external text files.

Remote Operation

SDR, transceiver and antenna rotator control are performed via TCP/IP. This allows the operator to use the devices installed on a remote computer and control them over the network. This feature makes SkyRoof suitable for remote station operation and integration with distributed networks of receivers.

Conclusion

SkyRoof is a modern, open-source application that integrates satellite pass prediction, SDR functionality, and station control into a single environment. By unifying these traditionally separate tools, it enables operators to both receive satellite signals and conduct two-way contacts with greater ease and precision. Features such as satellite signal labeling on the waterfall display and visual frequency alignment extend beyond the capabilities of conventional tracking and SDR programs.

Accessible to newcomers yet powerful enough for experienced operators, SkyRoof lowers the barrier to entry for amateur satellite communications while offering advanced features for experimentation and research. Its open architecture and extensibility also encourage community-driven development and customization. By combining prediction, reception, and control in one platform, SkyRoof is therefore a valuable tool for advancing amateur satellite operations, education, and outreach.

References

(1) SkyRoof: https://ve3nea.github.io/SkyRoof/index.html.

(2) SkyCAT: https://ve3nea.github.io/SkyCAT/index.html

(3) SatNOGS DB: https://db.satnogs.org/

(4) HamLib: https://hamlib.github.io/