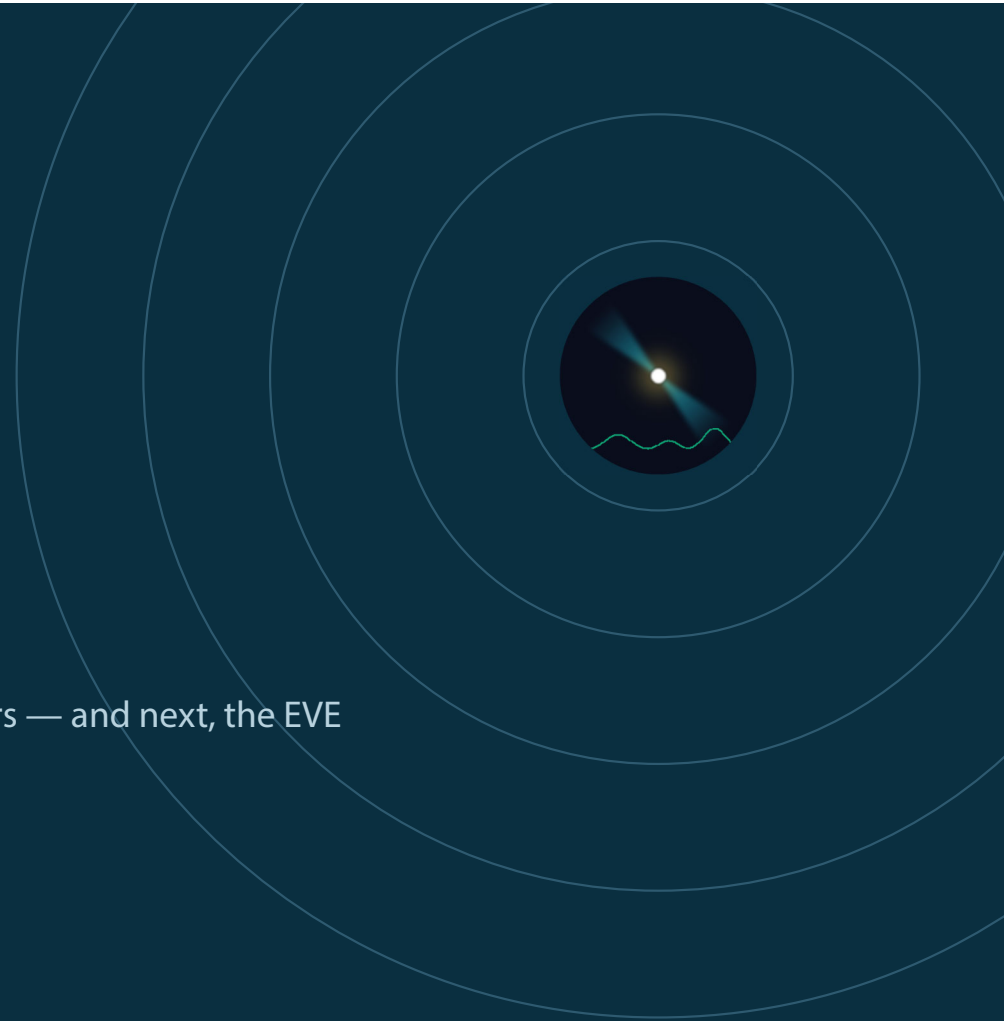


DSES SCIENCE MEETING • SEPTEMBER 28, 2026

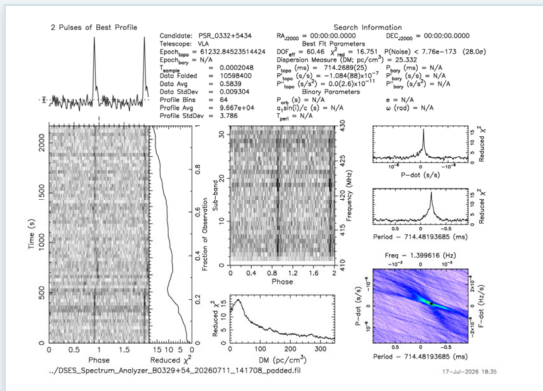
Lowering the Barrier to Radio Astronomy

From the SARA pulsar talk to Workbench 1.6.0, built with its users — and next, the EVE
modem for the October 24 Venus bounce

Richard M. Hambly (K0GD) • Deep Space Exploration Society

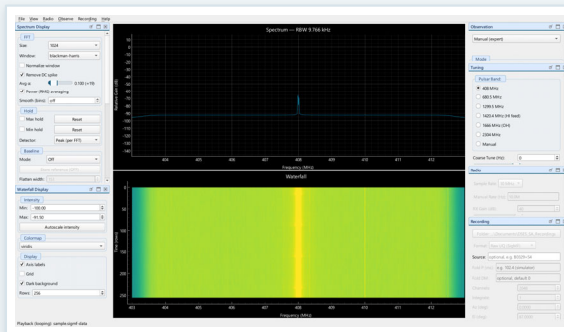


Three parts, one thread: the people who use it



1 Lowering the barrier

The SARA East talk, August 4: first pulsars with software the Society wrote



2 Built with its users

Twelve releases in 54 days — Workbench 1.2 to 1.6.0, shaped by Rick, Ray, and Rich



3 Next: EVE-26

A DSES-built modem and a new 23 cm chain for the October 24 Venus bounce

Pulsar observing had become an experts-only craft

For years, the Society's results rested on two members — **Dr. Richard Russel (AC0UB)** and **Dan Layne (AD0CY)** — and the professional toolchain they mastered:

PRESTO v5 + TEMPO1 + TEMPO2

built from source; hand-edited
observatory and clock files

RIPTIDE

a second, independent pulsar-search
code (fast-folding)

GNU Radio

custom filterbank flowgraphs driving the
B210

SIGPROC

filterbank-format utilities

blimpy / watutil

Breakthrough Listen RFI and saturation
checks

PINT

high-precision pulsar timing in Python

ATNF pulsar catalog

ephemeris data (.par) for every fold

Murmur + Best Profile Analyzer

IONAA planning/analysis tools — run
under Wine

Stellarium + experience

above all, knowing how the pieces fit
together

100s

of pages of DSES training
material for this stack

2

members who could run an
observation end to end

PSRCHIVE — the professional community's archiving & timing suite, in common use — beyond even our experts' stack

*First-rate results — but a learning curve
that kept everyone else watching.*

The new stack — much simpler

The same observation today takes two pieces:

ACQUISITION — ON SITE

DSES Radio Astronomy Workbench

plan, observe, verify, record, review —
one application on one laptop (Windows /
macOS / Linux)



ANALYSIS — ANY MACHINE

PRESTO v6.0.0 + TEMPO2

the professional analysis suite, installed by
one DSES build script — v6 barycenters
in-process, so classic TEMPO is no longer
needed

2

pieces in the whole chain —
acquisition and analysis

1

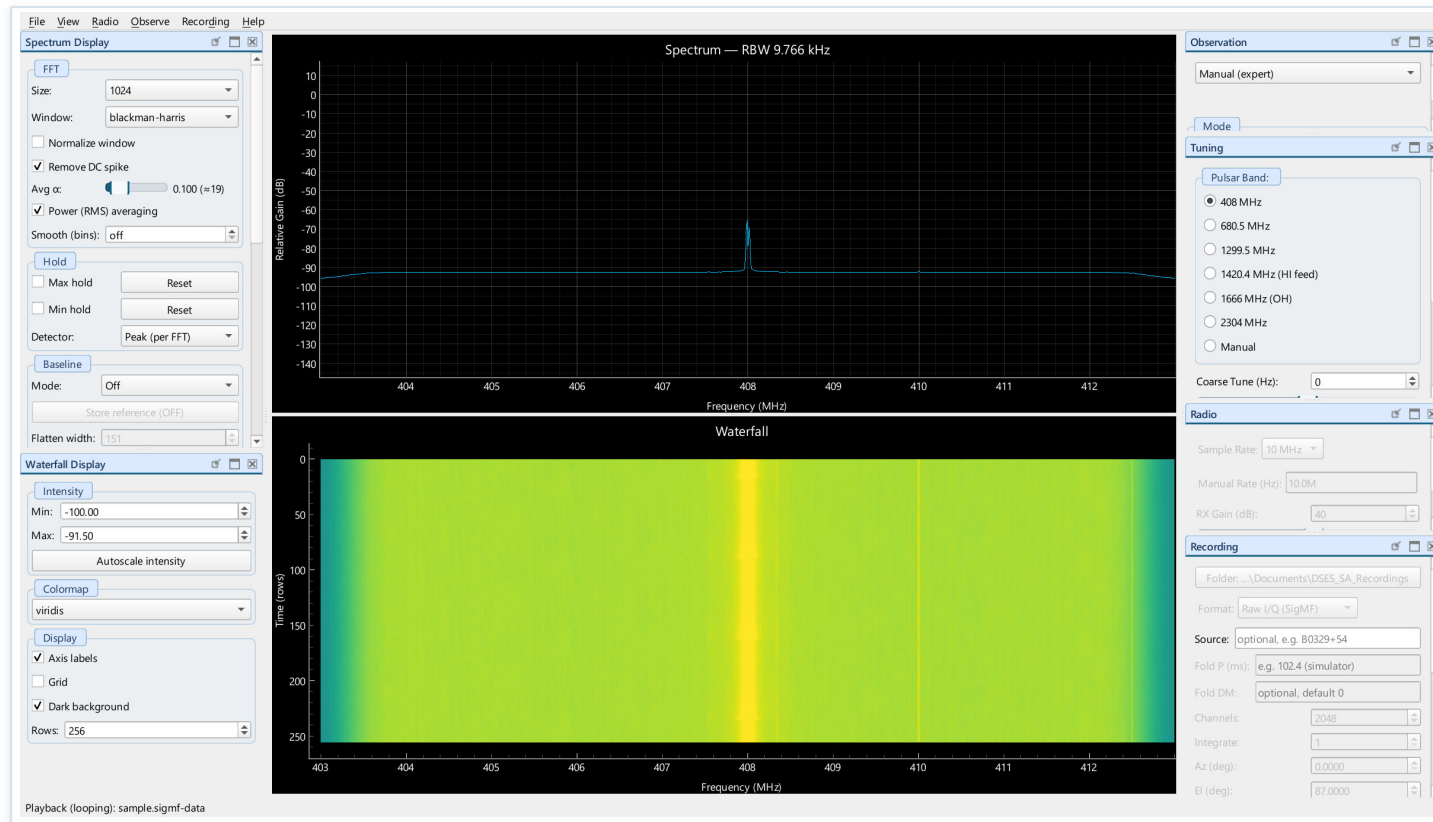
build script installs the
analysis stack, per platform

That's the whole list — no Wine, no custom flowgraphs, no hand-edited configuration files

*Same professional-quality results
— on a far gentler learning curve.*

DSES Radio Astronomy Workbench 1.6.0

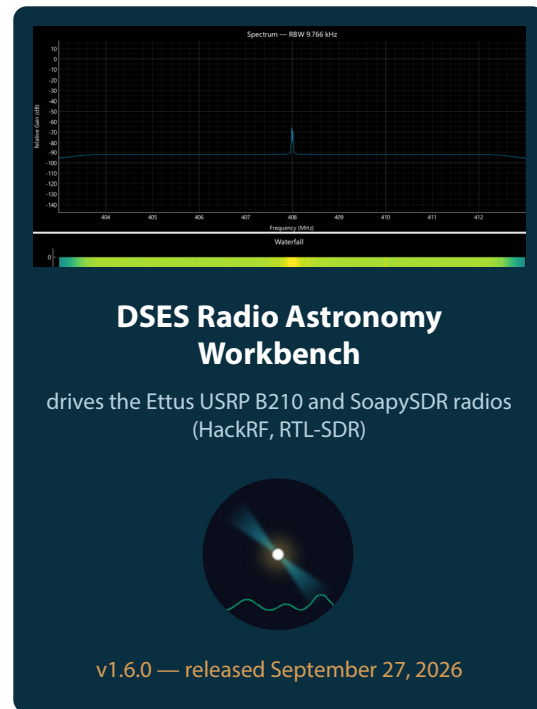
Redesigned in 1.2.0: menus and six dockable panels — here replaying a 408 MHz B210 capture



One instrument instead of a toolchain

The DSES Radio Astronomy Workbench — the Spectrum Analyzer, renamed in 1.4.0. Written within the Society; born as an RFI-survey tool for the Haswell site, now a radio-astronomy observing system.

- 1 **Plan** — pulsars in view for any date and time, minimum recording time, best band
- 2 **Observe** — one-click presets for pulsars and hydrogen, radio-aware; spectrum, waterfall, Sweep
- 3 **Verify** — B210 Self Test — a built-in pulsar simulator, graded by PRESTO
- 4 **Record** — SIGPROC .fil, SigMF, ezRA drift scans; gap padding; daily files; “Start at”
- 5 **Analyze** — automatic PRESTO fold with a plain verdict; Drift-Scan Review
- 6 **Update** — in-app updater; free download under GPL, public GitHub mirror



Windows • macOS • Linux
(incl. Raspberry Pi 5 field box)

Put non-experts in front of the dish

The question: can members who are not pulsar-processing experts plan an observation, capture pulsar data, and process it into professional-quality reports?



Ray Uberecken

AA0L



Anne Haney

W0ZDW



Richard Hambly

K0GD

60-ft dish

DSES site, Haswell, Colorado

Ettus USRP B210

software-defined radio receiver

Spectrum Analyzer

one laptop — planning, RF checks, recording

Two pulsars recorded live to filterbank

20 MHz

bandwidth, centered on 420 MHz

256

frequency channels

204.8 μ s

time resolution

32-bit

samples — SIGPROC .fil

Target	Start (MDT)	Duration	Data volume	Why this target
B0329+54	14:17	36.6 min	11.0 GB	Brightest northern pulsar — the standard reference source
B0950+08	15:12	22.2 min	6.7 GB	Bright, low-dispersion; transiting at $\sim 59^\circ$ altitude during the session

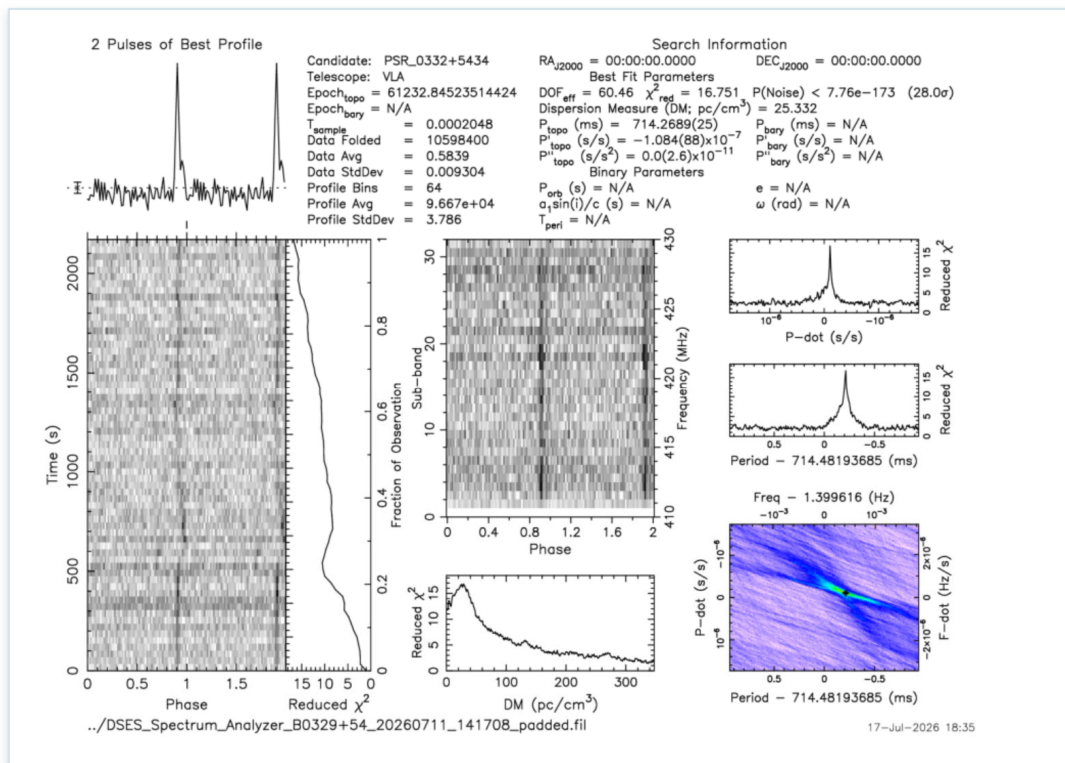
Targets were chosen live — the software computed current altitude/azimuth for the catalog pulsars from the Haswell site. Most southern sources never rise there, which made the transiting B0950+08 the natural second pick.

B0329+54 — a textbook detection

28.0 σ

probability the signal is noise: $< 8 \times 10^{-173}$

- Textbook single-peaked profile at the catalog period of 714.5 ms, coherent across the full 36.6 minutes
- Detection peaks at dispersion measure ≈ 25 — catalog value 26.8 — and falls off toward zero
- In the field it stood at $\sim 20 \sigma$; RFI cleanup and one timebase repair recovered the rest — that story is the next slide



Gap-bridged, RFI-cleaned ephemeris fold — the full 36.6-minute integration (2026-07-17 re-analysis)

One review comment was worth 5.6σ

1

The comment

Dan Layne (AD0CY), reviewing the trip report: the fold shows a phase drift it shouldn't have

2

The forensics

A rigid no-search ephemeris fold: smooth 1.2-rotation drift plus one $+0.22$ -rotation step — parts in 10^4 , five orders beyond any physics. Our clock, not the sky

3

The culprit

USB sample drops during recording silently shorten the .fil's sample-count clock — the app showed overflows live but didn't count or log them

4

The repair

0.558 s of noise padded at the step: $22.4 \sigma \rightarrow 28.0 \sigma$, single textbook profile, DM back at 25.3 — diagnosis confirmed by repair

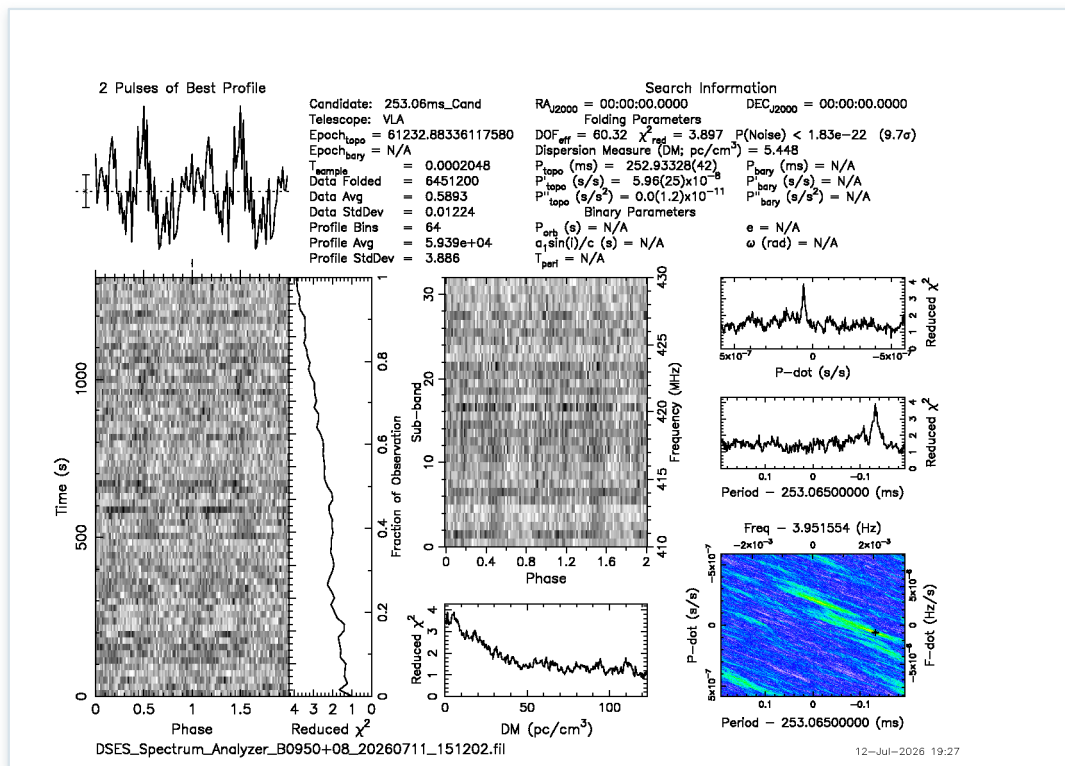
Return on criticism. Shipped in v1.1.8 (August 3): dropped samples are measured from radio timestamps and zero-padded live — every recording keeps an honest clock.

B0950+08 — a strong candidate, honestly framed

$\sim 9 \sigma$

after cleanup, the best fit lands on the catalog values

- Clear peak at the pulsar's 253 ms period when folded at the known ephemeris ($\sim 9.7 \sigma$ as recorded)
- With RFI masked and the timebase repaired, the search converges on $P = 253.05$ ms and $DM \approx 2.9$ — the catalog values — exactly how a real detection behaves
- But it is noise-limited: at 20 MHz bandwidth DM 2.97 is indistinguishable from zero, and $\sim 9 \sigma$ leaves no room for decisive sub-tests — a strong candidate, not yet a publishable detection
- The remaining gains are observational: a 90-minute track ($\approx 20 \sigma$), several sessions to catch scintillation maxima, wider bandwidth



Fold at the known 253 ms period — 22.2-minute observation

Real — and independently reproducible

Dispersion: the celestial fingerprint

- Interstellar plasma delays lower frequencies — a sweep imposed by light-years of travel
- Detection strength peaks at the catalog dispersion measure and falls toward zero
- Terrestrial interference shows no dispersion at all
- **One curve separates a genuine pulsar from RFI**

Two platforms, two toolchains, one answer

- macOS — PRESTO v5.0.2, re-run on v6.0.0
- Windows — PRESTO v6.0.0 under WSL (a new DSES capability)
- Identical fold commands, independently built stacks

B0329+54 probability-of-noise

4.49×10^{-90} Windows **4.5×10^{-90}** macOS

Every fold now produces a standardized PDF diagnostic stored beside the recording — validation minutes after capture, on whichever machine is at hand.

The case of the headless Raspberry Pi

1

Symptoms

Dropdown menus dead, Help menu blank, window opens tiny in a corner — on the field box, mid-session

2

Diagnosis

Remote SSH into the site over Tailscale — while the trip continued

3

Root cause

No monitor attached: the graphics system reports a 0×0-pixel screen, collapsing every popup and confusing window placement

4

Fix — in v1.1.6

Launcher synthesizes a virtual monitor when none is connected; the app refuses to reposition windows against an empty screen

Not an application bug. A display-configuration condition that had silently affected every prior software version — found because real hardware was running at a real site.

Field wish-list → v1.1.6 in two days

Spectrum Analyzer v1.1.6 — cut and published July 12, one day after the observing session:

Sweep mode

Stepped wide-spectrum scan for RFI surveys beyond the radio's instantaneous bandwidth — retunes across a range (e.g. 100–1000 MHz) and stitches one wide trace, with cross-pass max-hold.

Recording, finished

Source name stamped into the filename and the .fil header — with RA/Dec derived from the pulsar designation. Red REC indicator, elapsed time, timed auto-stop. July 11's files had to be renamed and patched by hand; never again.

Headless fixes

The virtual-monitor launcher and empty-screen safeguards from the previous slide, plus updated documentation and operating guide.

Epilogue: one day after release, the field box caught a packaging defect desktop testing had missed — Windows line endings in the Unix launcher script. Rebuilt and republished within hours, with two independent build-pipeline safeguards added. Real installations in the field earn their keep.

v1.1.7 six days later — the display was hiding signals

1

The report

Ray (AAOL): on the same hardware, other SDR software shows weak signals ours doesn't

2

The root cause

The display FFT examined only the newest FFT-length of samples each screen tick — about 0.3% of the stream at 20 MS/s. The other 99.7% never reached the screen

3

The fix

Welch-average every sample between screen updates; true per-block peak/min hold detectors; an adaptive CPU budget so slower machines shed coverage gracefully

4

The result

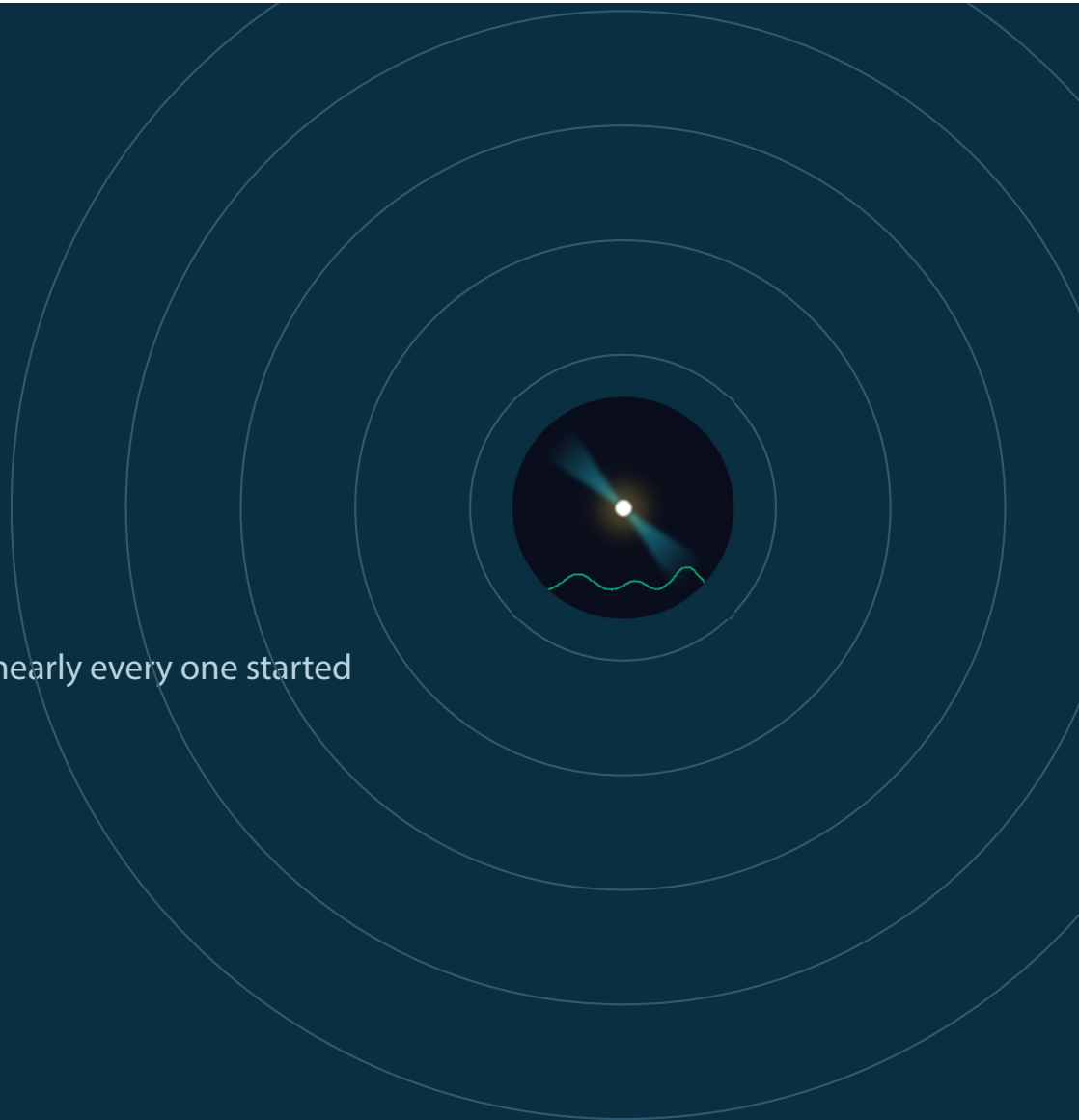
A razor-flat noise floor with sub-dB scatter — weak signals stand clear. Verified live on the B210; released July 18

Recordings were never affected — the filterbank path always processed every sample; this was display-only. Two field reports, two releases, seven days.

PART 2 • SINCE SARA

Built with its users

Twelve releases in 54 days — Workbench 1.2 to 1.6.0 — nearly every one started as a field report from Rick, Ray, or Rich.



Twelve releases in 54 days

The pivot: after 1.3.0 (August 6), new features paused to wait for users. The releases that followed were written by the field.

1.2.0	Aug 5	Menus and six dockable panels; pulsar visibility planner	RICK	RAY	
1.3.0	Aug 6	B210 Self Test: a built-in pulsar simulator	RICK		
1.3.1	Aug 14	A new file every UTC midnight for multi-day scans	RICK		
1.3.2	Aug 19	LO offset moves the DC spike off the hydrogen line	RICK		
1.3.3	Aug 24	Two tuning bugs, found from the sky, fixed	RICK		
1.3.4	Sep 7	Planner: minimum recording time, 2° mask	RICK	RAY	
1.4.0	Sep 8	Renamed: DSES Radio Astronomy Workbench	RICK		
1.5.0	Sep 11	Planner: any date and time, preprocessed sky math	RICK		
1.5.1	Sep 13	Hydrogen preset on the line; out-of-band warning		RAY	
1.5.2	Sep 13	That warning made impossible to miss	RICK		
1.5.3	Sep 13	Radio-aware preset: “the Ray configuration”		RAY	
1.6.0	Sep 27	Drift-Scan Review; scheduled “Start at”; 4-decimal az/el	RICH	RAY	RICK
Whose report started it: RICK 10 releases RAY 5 releases RICH 1 release <i>some releases answer several users</i>					

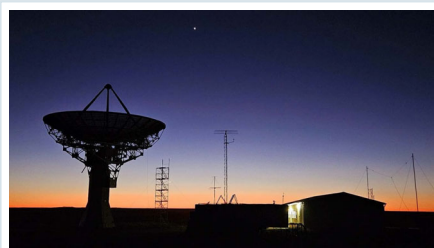
Three users, three stations



Richard Hambly

KOGD

DSES 60-ft dish, Haswell — an unattended Raspberry Pi 5 + B210



RESULT

HI every sidereal day, zero gaps; Cyg A on 17 of 17 days; beam 0.70°, SEFD $\approx$ 4,100 Jy

SHAPED

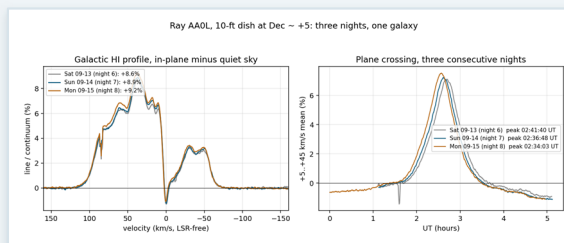
1.3.1 daily files · 1.3.2 LO offset · 1.3.3 tuning fixes ·
1.5.0 planner · 1.6.0 Review and 4-decimal az/el



Ray Uberecken

AAOL

10-ft home dish, steered by hand — HackRF



RESULT

Nine nights, every file clean; first HI Sep 11; +9.2% at +38 km/s; transit 16 s from prediction

SHAPED

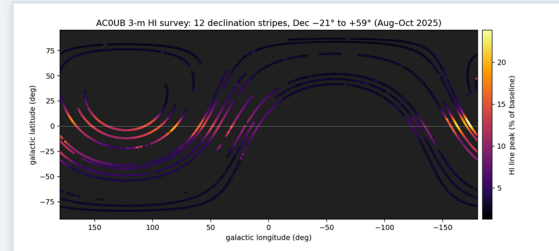
1.5.1 hydrogen preset fix · 1.5.3 “the Ray configuration” · 1.6.0 “Start at” — cut because “Ray needs it today”



Dr. Richard Russel

ACOU

3-m home dish, Colorado Springs — ezRA and ezCol



RESULT

2025 survey (ezCol): the galactic plane at all 11 declinations; 60 crossings; rotation curve to 7 kpc

SHAPED

1.6.0 Drift-Scan Review: its scope, and a loader that reads his ezCol files

Haswell drift scans drove four releases

1

Multi-day scans

Aug 14, at the dish: a multi-day HI scan needs one file per day → 1.3.1 rolls a new file at UTC midnight

2

A spike in the line

16,205 spectra later: the receiver's DC spike sat 1.3 km/s from the HI line → 1.3.2 LO offset

3

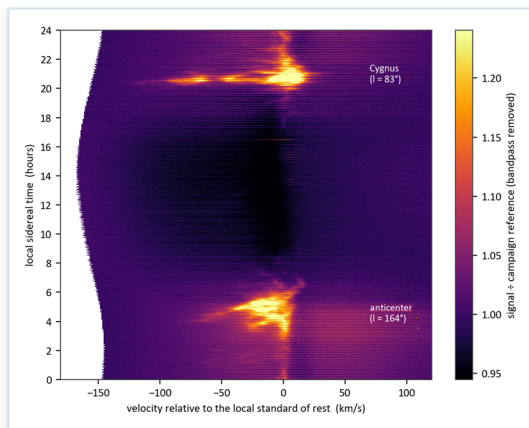
Found from the sky

Segment-2 headers read 1.5 MHz low: two stacked tuning bugs → 1.3.3

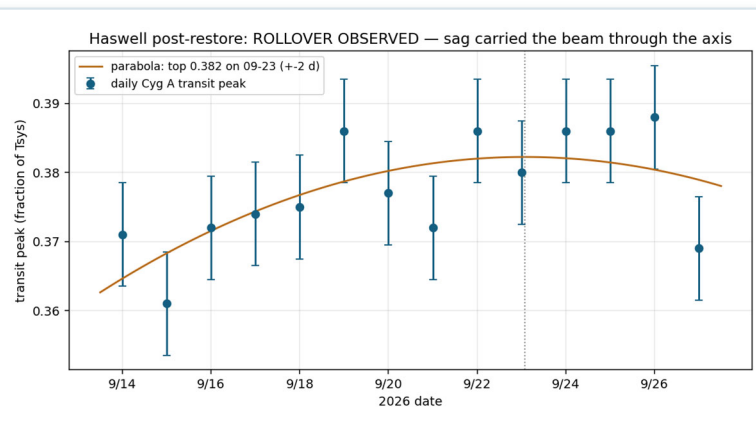
4

A calibrated dish

Segment 4: 9,791 spectra, zero gaps.
Cyg A daily: beam 0.70° , pointing term 0.152° , SEFD $\approx 4,100$ Jy



HI, 7 days folded on sidereal time (Aug 24–31)



Cyg A peak after the Sep 13 restore — vertex Sep 23 ± 2 d, preliminary

26,000

spectra in August, zero gaps

± 2 s

Cyg A transit timing, 17 days

One question, three releases in 3.5 hours

1

The report

Sep 12: night 5 had no hydrogen, and Ray asked why the “1422 MHz (HI)” button wasn’t on the line

2

The cause

It tuned the feed's nominal 1422.000 MHz — 0.8 MHz above the gas — and the Help said otherwise

3

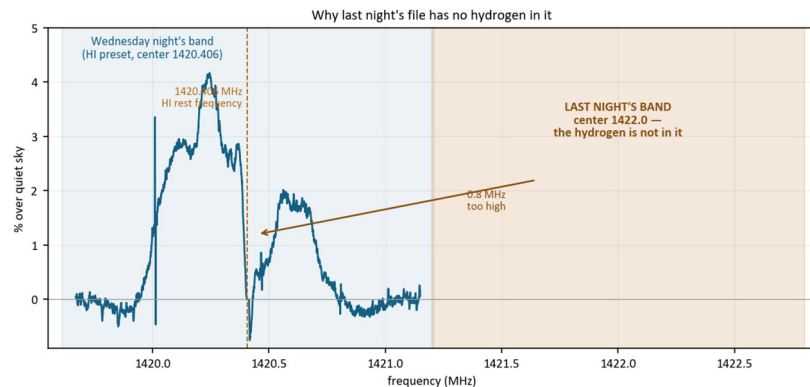
The fix

Sep 13: 1.5.1 retunes to 1420.406; 1.5.2 warns at record start; 1.5.3 makes Ray's own setup the preset

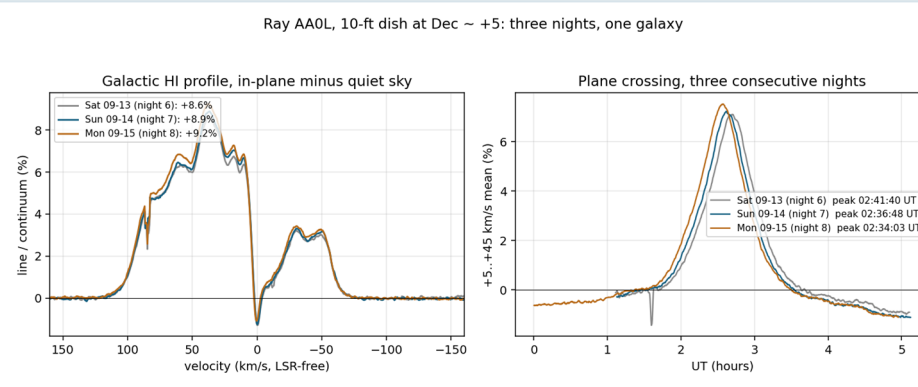
4

The result

Nights 6–8: +8.6, +8.8, +9.2% at +37 to +38 km/s; night 8's transit 16 s from prediction

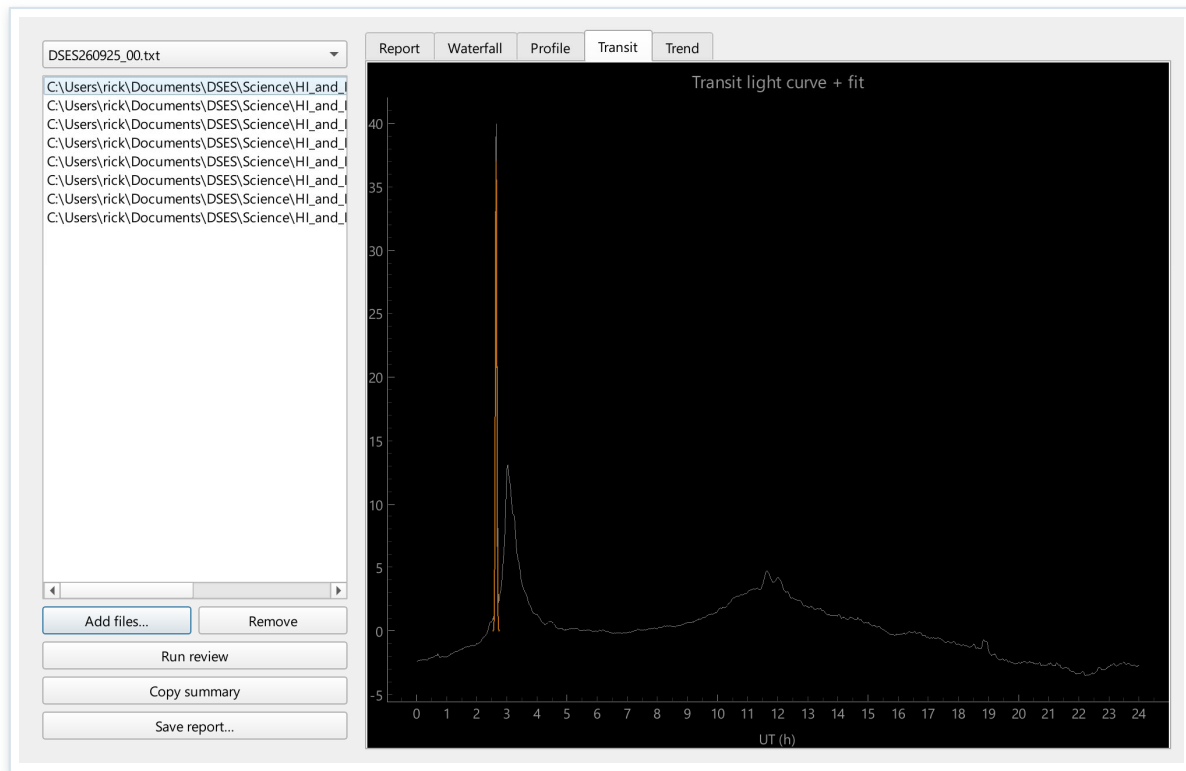


The diagnosis sent to Ray: night 5's band (right) missed the line (left)



Nights 6–8: the same galaxy, three nights running

Hand analysis became a tool: Drift-Scan Review



Workbench 1.6.0, Observe → Drift-Scan Review, on eight Haswell days (Sep 19–26): Cyg A transit at 35–37% of T_{sys} , zero gaps

THE NEED

Ray's nightly files, Rich's twelve-stripe survey, and every Haswell post-restore check needed the same hand-written analysis.

RICH'S PART

His ezRA plots (Sep 19) set the scope: a morning-after quicklook below ezRA, not a copy of it. His 2025 ezCol files taught the loader their format.

WHAT IT CHECKS

Header and pointing sanity, gaps and spurs, flattened HI waterfall and profile, transit fit with the half-integration correction, and the day-by-day trend.

Rich's survey was recorded with ezCol in 2025 — the Workbench reads it; it did not record it.

The SARA road-ahead list, eight weeks later

SHIPPED · 1.2.0

Pulsar visibility planner

any date and time, minimum recording time, best band

SHIPPED · 1.1.8

One-click post-processing

recording stops → PRESTO fold → PDF with a plain verdict

SHIPPED · 1.1.8

Quick-look during recording

a draft fold on a snapshot of the growing file

SHIPPED · 1.1.8

Timebase integrity

gaps measured, zero-padded, logged — Haswell segment 4: zero gaps

SHIPPED · 1.1.8

Self-contained fold PDFs

commands, numbers, and verdict inside every chart

SHIPPED · 1.1.8

ezRA drift-scan format

now the collector at Haswell and at Ray's station

QUEUED

Audio demodulators for RFI ID

click a signal and listen

WAITING ON API

System-1 steering integration

pick a pulsar, the dish points

6 of 8

shipped — all within two days of the talk

NEXT IN THE QUEUE

- Live Dec readout (Ray, night 9)
- Steady display statistics while recording (Ray)
- Mid-integration timestamps
- An Observer's Guide

Not yet: the x86-64 site computer, and the 90-minute B0950+08 re-observation.

PART 3 • THE FOLLOW-UP PROJECT

EVE-26: Earth–Venus–Earth

A DSES-built modem and a new 23 cm signal chain — to decode our own echo from Venus at inferior conjunction, October 24, 2026.



Send a message to Venus; decode our own echo

272 s

round trip at 40.8 million km (0.273 AU)

1299.5 MHz

23 cm — the frequency Dwingeloo, Stockert and Effelsberg use

1200 W

SSPA into the 60-ft dish, 46 dBi — transmit and receive

KOPRT KOPRT

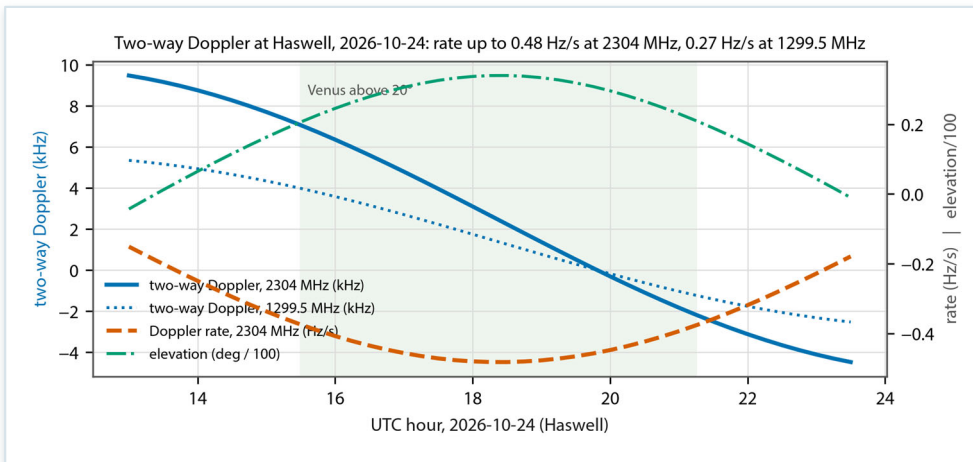
11 symbols of 4096-FSK, BCH + CRC — 30 minutes per message

−4.2 dB-Hz

C/N0 per pass (−5.4 with dynamic albedo): combine 2–3 passes

6°

from the Sun; Venus above 20° elevation
15:30–21:15 UTC

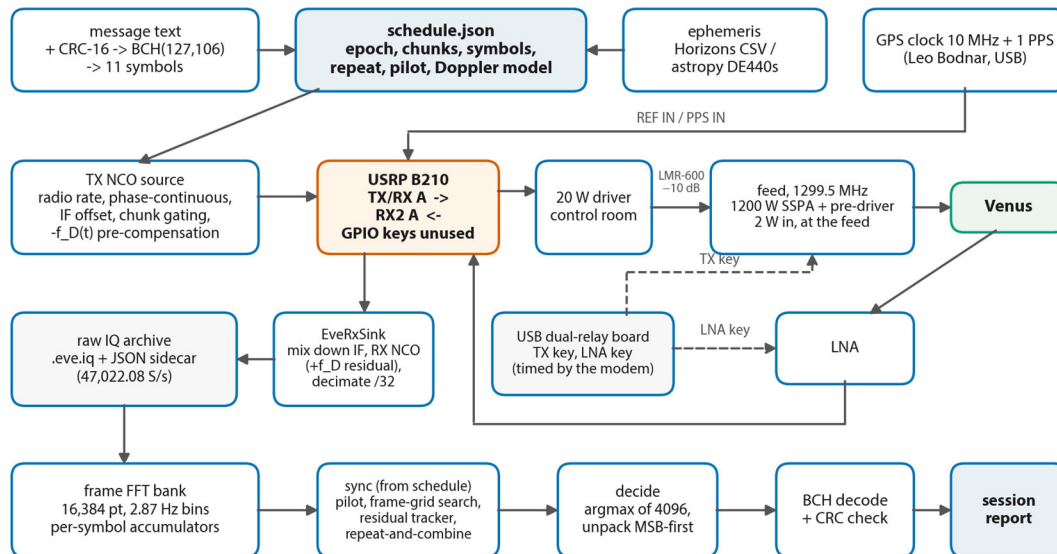


Two-way Doppler and Venus elevation at Haswell, October 24 (Design & ICD, Fig. 1)

Success = the station decodes its own echo — BCH decode and CRC match — confirmed offline from the archived IQ.

Waveform: the Open Research Institute's open "Spiral #2" design (Pete Wyckoff, KA3WCA) — implemented bit-exact by the DSES modem, which adds the receiver.

One program from schedule to decoded message



One B210, one schedule, one Doppler model shared by transmit and receive. The schedule file is the contract with any partner station. The sequencer is the modem: it times the TX and LNA key lines through the USB dual-relay board. The B210 GPIO pins carry the same keys in parallel, for a station with an external sequencer at the feed as ORI has, but DSES does not use them.

After the EVE Modem Design & ICD Figure 3, corrected September 28: 20 W driver in the control room, ~10 dB of LMR-600, SSPA with pre-driver at the feed; keys from the USB relay board

BUILT

Sep 10–23: v1.0.0 on Sep 13, v1.0.8 on Sep 23 — about 9,800 lines of Python, GPL-3.0; Windows, macOS, Linux

COMPATIBLE

ORI's open Spiral #2 air interface, verified bit-exact against ORI's reference generator

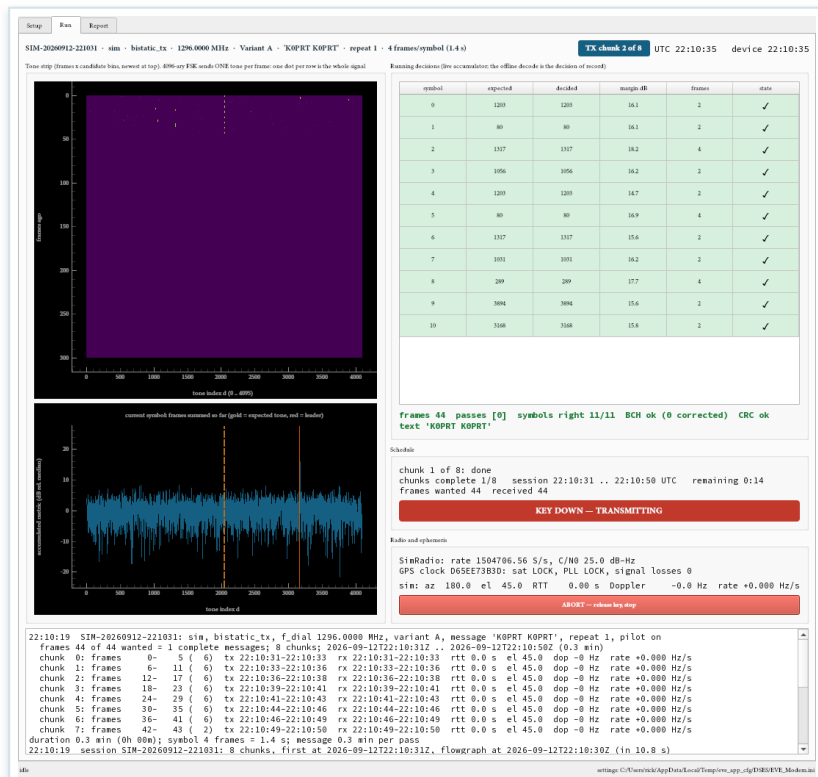
ADDS

Live phase-continuous synthesis (no 3.6 GB file), Doppler pre-compensation, sync, keying, a repeat-and-combine receiver, offline decode, a PDF report

SHARED WITH THE WORKBENCH

The B210 layer (`dses_radio.py`), LO-offset tuning, the updater, gpstime releases, GitHub (`dses-science/eve-modem`)

Proven on the bench, stage by stage



Run tab, simulated session: 11 of 11 symbols right, BCH ok, CRC ok — "KOPRT KOPRT"

0 Reference vectors: bit-exact against ORI's generator

PASSED

1 Modulator: streaming synthesizer matches ORI's file

PASSED

2 Receiver in simulation: reproduces ORI's error-rate table

PASSED

3 Doppler ramp, gaps, 4-pass combining decode; CAMRAS echoes still to run

IN PART

4 B210 loopback on the GPS clock: 24–26 dB margin; TX –0.03 Hz at 1296.025 MHz

PASSED

5 EME at very low power: end-to-end decode near 0 dB-Hz

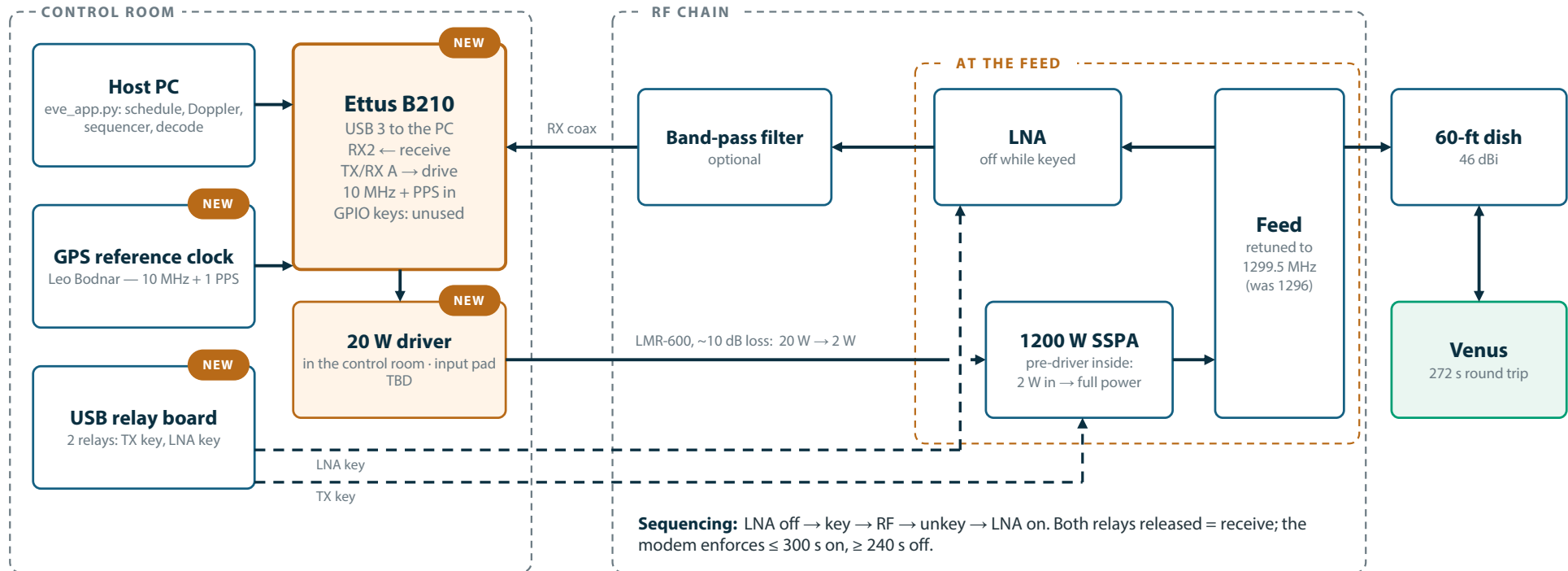
NEXT

6 Venus — sessions from mid-October

OCTOBER

53 automated tests. September 23: the sequencer keyed a USB relay board through 8 of 8 chunks.

One B210 now drives the whole 23 cm chain



Gone: the transverter (1296–1298 MHz only) and the rig — the B210 synthesizes 1299.5 MHz itself and streams the 4096-FSK message live.

What changed since EVE-25, and why

	EVE-25 • MARCH 2025	EVE-26 • OCTOBER 2026	WHY
Exciter	Elecraft K4 into the transverter, a CW carrier; backup rig an IC-705	The B210 synthesizes 1299.5 MHz and streams the 4096-FSK message	The transverter covers only 1296–1298 MHz; live synthesis allows chunks and Doppler
Frequency	1296 MHz	1299.5 MHz, feed retuned	The frequency Dwingeloo, Stockert and Effelsberg use
Drive	Transverter output	A 20 W driver in the control room; ~10 dB of LMR-600 to the feed; 2 W into the SSPA's pre-driver	The SSPA's pre-driver needs 2 W; the coax run to the feed costs about 10 dB; the B210 gives only 10 mW
Reference	Rubidium on loan (2025); site HP 5065A	GPS clock, 10 MHz + 1 PPS, programmed by the modem	The HP 5065A and the site NTP server failed in September 2026
Sequencing	None in the station	The modem is the sequencer, keying through a USB dual-relay board (B210 GPIO unused)	None existed; amplifier duty limits must be enforced
Receiver	Separate LNA and switch into the transverter and rig	The same B210 receives: one schedule, one Doppler model	Single radio, shared timing, offline-first decode

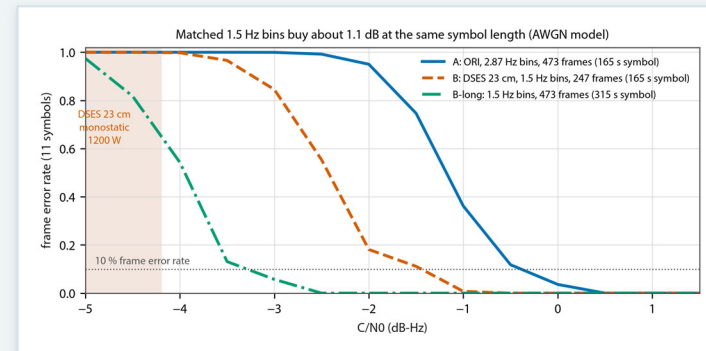
Band: the March 2026 plan was 13 cm; those amplifier modules roll off below about 2350 MHz, so 2026 runs on the EVE-25 23 cm package and 13 cm moves to 2028.

Four weeks to conjunction

- Sep 10–11** Design & ICD Rev A and Rev B to the team; first B210 loopback decoded
- Sep 12** GPS clock adopted; bench stage 4 passed
- Sep 13–14** v1.0.0; tested on Windows, macOS, Linux; 1.0.5 to the EVE team
- Sep 22–23** Public GitHub mirror; sequencer + relay boards; signal generator (1.0.8)
- Next** RF package with the signal generator: driver, SSPA, filter, feed
- Then** EME (Moon) end-to-end test at very low power
- Oct 24** Conjunction day: 5 passes, 38 chunks, 15:30–20:53 UTC

OPEN RISKS

- The link needs 2–3 combined passes: +4.5 / +3.3 dB after five, before fading, pointing, and solar noise (Venus is 6° from the Sun)
- The SSPA's delivered power at 1299.5 MHz, 0.5 MHz inside its top band edge — at 500 W the link does not close
- Thermal limits untested: the test needs a 2 kW, 7/16 DIN load
- B210 side-A port isolation only ~5 dB: receive on B:RX2
- EME test date not yet set



One pass lands in the shaded band, left of every curve — hence combining passes (Design & ICD, Fig. 2)

All of it is open, on DSES's GitHub

github.com/dses-science

Deep Space Exploration Society — organization opened September 24, 2026 · GPL-3.0

2

repositories

394

commits

18

release tags



dses-science/dses-workbench

DSES Radio Astronomy Workbench — v1.6.0, September 27

- Source: Python, GNU Radio + UHD; B210 and SoapySDR radios
- Installation guide and release workflow (PDF)
- ROADMAP.md — the shared upgrade queue, item by item
- The July 2026 Haswell pulsar trip report
- Releases and the in-app updater: gpstime.com/sw_distribution/dses-workbench

294 commits · 6 release tags



dses-science/eve-modem

Earth-Venus-Earth modem — v1.0.8, September 23

- Source: the modem, station control, sequencer, tests, link-budget code
- Design Description & ICD, Rev C — PDF and Markdown
- Operator's Guide — also the program's Help
- Release workflow; hardware notes
- Releases and the updater: gpstime.com/sw_distribution/eve-modem

100 commits · 12 release tags

The master repositories live on the Society's NAS; GitHub is a read-only mirror refreshed after every push. dses.science links both, with the reports and results.

WHAT WE HAVE SHOWN

- 1 **Non-experts detected B0329+54 at 28 σ with software the Society wrote, controls, and can teach.**
- 2 **Users now steer it: twelve releases in 54 days, nearly all started by field reports — Rick at Haswell, Ray at home, Rich's survey.**
- 3 **The same foundation now carries the EVE modem: built, bench-proven, and aimed at Venus on October 24.**

Standing on the work of Dr. Richard Russel (AC0UB) and Dan Layne (AD0CY), whose review made the headline number stronger.

Field team and users: Ray Uberecken (AA0L), Anne Haney (W0ZDW), Richard Hambly (K0GD). EVE-26 hardware: Alex Nersesian (K6VHF), Roger Oakey (W3MIX); dish control: Glenn Davis (W0OFZ). EVE waveform: ORI's open Spiral #2 design (Pete Wyckoff, KA3WCA).

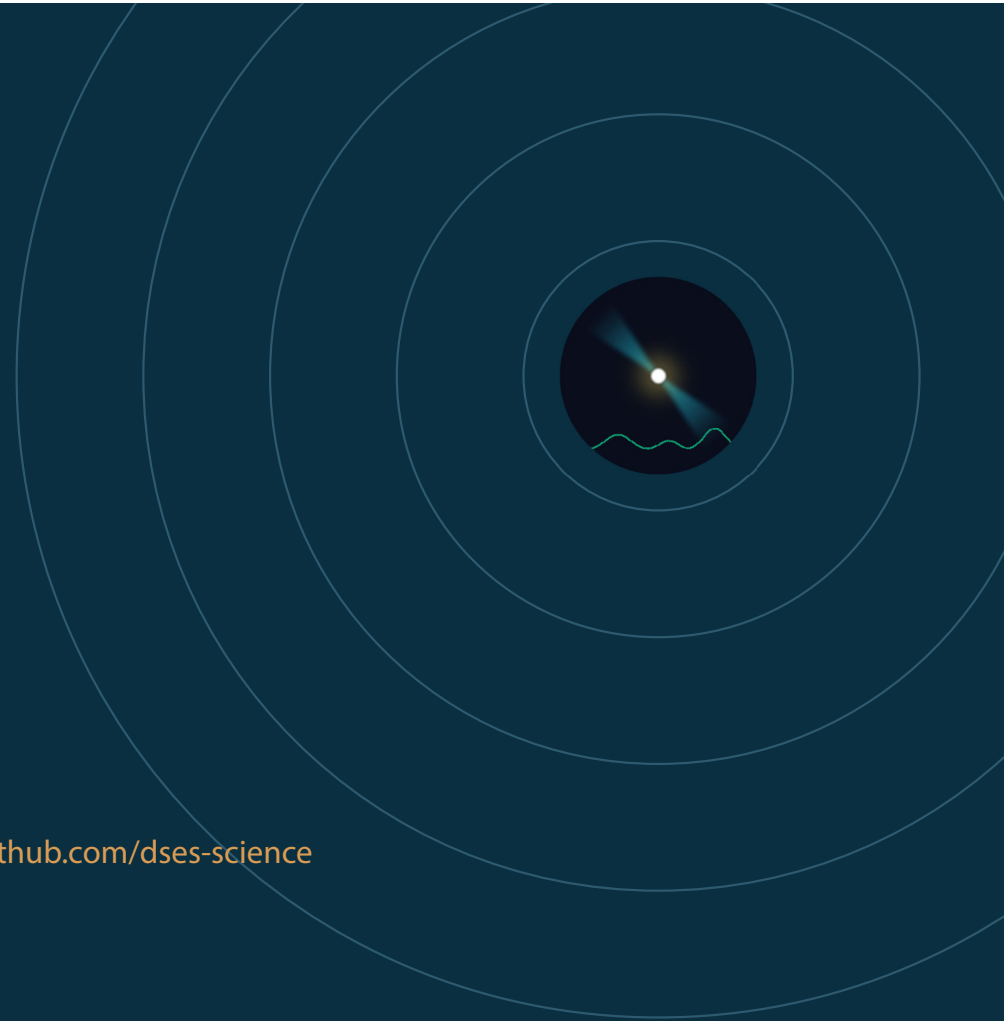
Development, field diagnosis, and data processing accelerated by AI-assisted engineering (Claude Code).

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DISCUSSION

Questions



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