



Repurposing radiosondes for amateur radio high-altitude balloon tracking

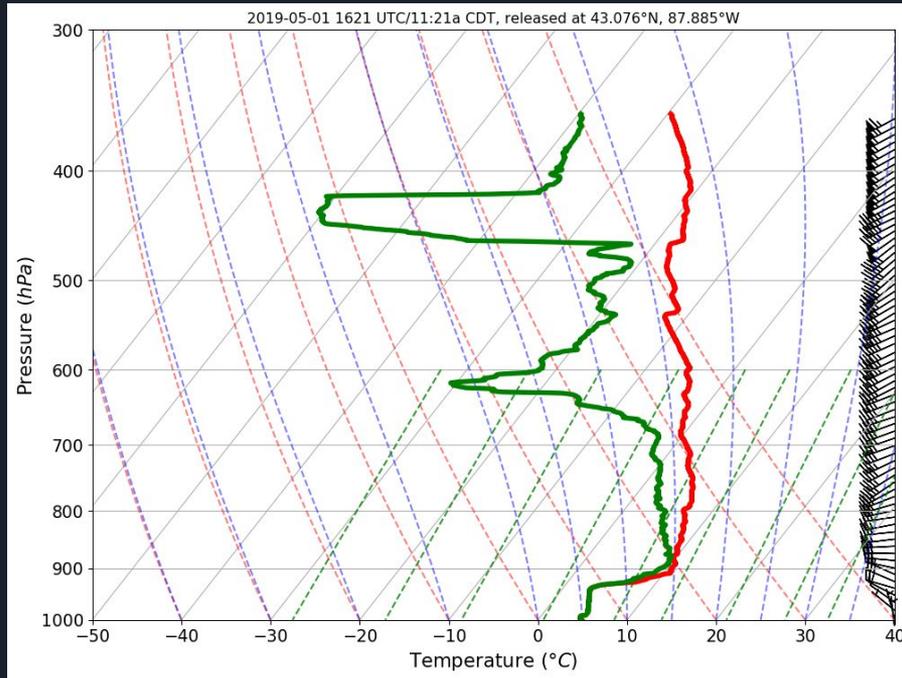
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What are radiosondes anyway? (1)

- A tiny computer + sensors + a radio transmitter
- Flown as the payload of a weather balloon
- Gather and transmit data for weather forecasts
- Used by meteorological institutions
 - Ilmatieteen laitos (FMI) in Finland
- Launched up to 4 times per day from a site
- Usually fly for about 2 hours and land in random places

What are radiosondes anyway? (2)



Data gathered by a radiosonde often represented as a Skew-T plot (dew point, temperature and wind by atmospheric pressure)

What are radiosondes anyway? (3)



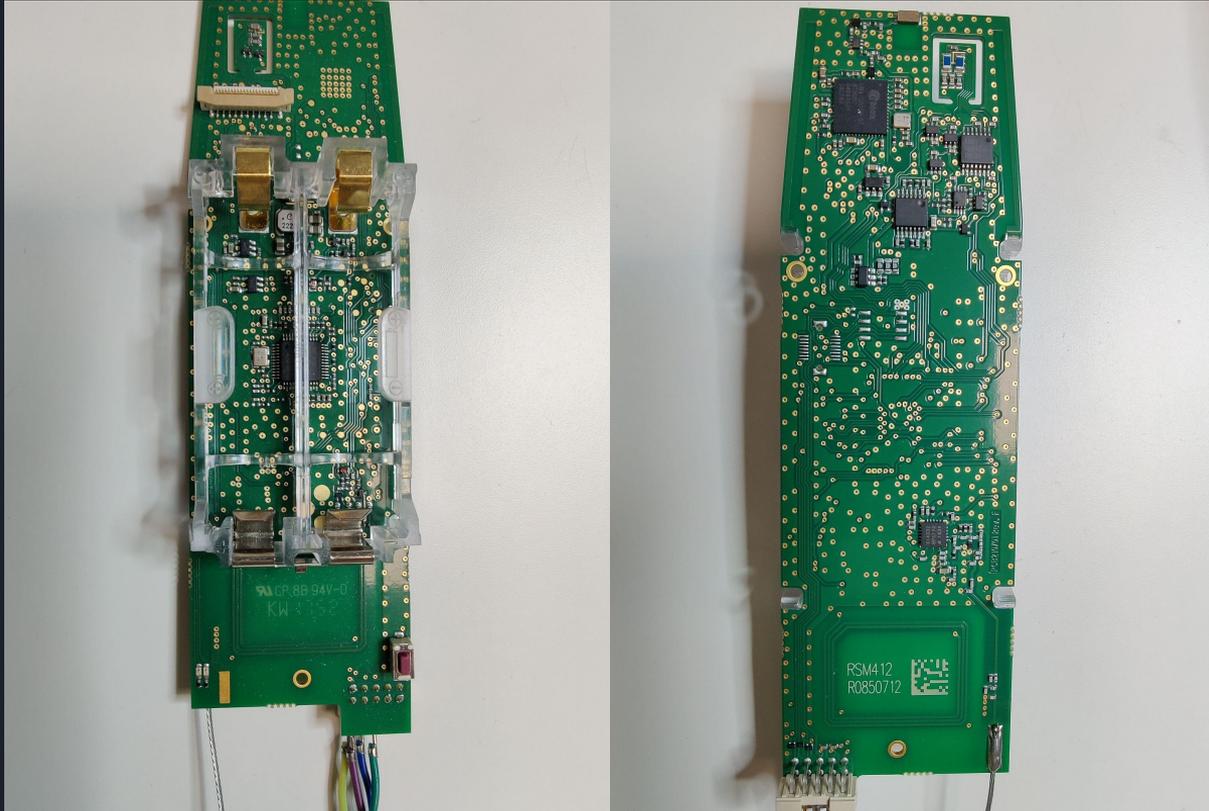
Most common ones in Europe are RS41 radiosondes manufactured by Vaisala (also a Finnish company)



Why are RS41 radiosondes interesting? (1)

- Vaisala RS41 hardware has been reverse-engineered
- Mostly Commercial Off-the-Shelf components
 - CPU: 32-bit STM32F100C8 microcontroller
 - 24 MHz, 64 kB flash
 - GPS: UBlox UBX-6010
 - TX: SiLabs Si4032 (SPI bus), max power ~60 mW
 - External I²C bus and UART serial port
 - Powered by 2 AA batteries
- The STM32 μ C can be reprogrammed
- Sounds a lot like an **STM32 development board, doesn't it?**

Why are RS41 radiosondes interesting? (2)





Why are RS41 radiosondes interesting? (3)

- **Can transmit on 70cm amateur radio band**
- **No hardware modifications needed for amateur radio use**
- Can transmit CW, APRS (AFSK), RTTY + other FSK modulations
- Works as an automatic beacon with GPS positioning
- Open-source amateur radio firmware code available
 - RS41HUP - the original firmware:
<https://github.com/darksidelemm/RS41HUP>
 - RS41ng - more advanced firmware by me:
<https://github.com/mikaelnousiainen/RS41ng>



Why are RS41 radiosondes interesting? (4)

- Horus 4FSK, a new modulation developed by Project Horus folks in Australia
 - “7 dB improved demodulation compared to RTTY”
 - **Significantly better than APRS** for tracking
 - Both RS41HUP + RS41ng firmwares support Horus 4FSK
 - Open-source RX software Horus Telemetry GUI:
<https://github.com/projecthorus/horus-gui>
 - RX chain: any SSB receiver -> audio -> Horus GUI

Why are RS41 radiosondes interesting? (5)

Computer
ITHMM Logger
Home
ITHMM Plotter
Network

Gqrx v2.14.6-33-g2172ef1 - rtl=0
File Tools View Help
432.499.200
4FSK S4032
-20
-40
-60
-80
-100
-120
432.45 432.46 432.47 432.48 432.49 432.50 432.51 432.52

Horus Telemetry GUI - v0.2.3
Audio Device: pulse
Sample Rate (Hz): 48000
Input Level (dBFS): -inf LOW
Mode: Horus Binary v1/v2
Baudrate: 100
Enable Mask Estim.:
Tone Spacing (Hz): 270
Manual Estim. Limits:
Stop
Save Settings

Enable Habitat Upload:
Callsign: OH3AA
Lat/Lon: 60.9507 24.4837
Antenna: Mobile whip
Radio: NooElec RTL-SDR
Upload Position

Spectra
Power (dBFS)
Frequency (kHz)
F1 F2 F3 F4

SNR
SNR (dB)
Time (s)

10.2

Latest Packet (Raw): 0101C501080205157473427037C2416C0E3080B92C5017300000000000C95B
Latest Packet (Decoded): \$\$OH3VHH-4FSK-V2,453,11:02:05,60.86336,24.27707,3692,35,11,1,2.86*A3C8

Callsign	Time	Latitude	Longitude	Altitude	Bearing	Elevation	Range (km)
OH3VHH-4FSK-V2	11:02:05	60.85891	24.27658	3787	227.7	14.0	15.6

13:02:55 [INFO] Habitat - Uploaded sentence: \$\$OH3VHH-4FSK-V2,457,11:02:42,60.85985,24.27665,3766,34,11,1,2.84*2E1A
13:02:58 [INFO] Habitat - Uploaded sentence: \$\$OH3VHH-4FSK-V2,458,11:02:52,60.85954,24.27659,3773,28,11,1,2.86*388E
13:03:03 [INFO] Habitat - Uploaded sentence: \$\$OH3VHH-4FSK-V2,459,11:02:56,60.85921,24.27659,3780,34,11,1,2.84*9241
13:03:07 [INFO] Habitat - Uploaded sentence: \$\$OH3VHH-4FSK-V2,460,11:03:00,60.85891,24.27658,3787,34,11,1,2.84*8059

Audio
Gain: -6.3 dB
Mute UDP Rec Play ...
DSP



RS41ng firmware transmitting CW, APRS, 4FSK

See [this video on Twitter about RS41 transmitting multiple modes.](#)

OK, how can I get one (or two)?



Go for a walk in a forest and you'll find one! (not)



Tracking radiosondes (1): SondeHub

The screenshot displays the SondeHub interface. At the top, a search bar contains 'Sonde Serial' and '60.9873 24.4591'. The main map shows a green path of a radiosonde starting from a launch site near Tampere and moving towards Helsinki. Two pop-up windows provide details for specific stations: 'OH3AA_AUTO_RX' (Radio: radiosonde_auto_rx-1.5.10, Antenna: 403 MHz J pole antenna, Last Contact: 2022-05-26T09:07:32.258Z) and 'U1730680 Not Recovered' (ID: 60.4245, 24.6358, Time: 2022-05-25 19:46:23, Reported by: Chihojan, Notes: High up in tree [via Radiosondy.info], Flight Path: U1730680). On the left, a sidebar lists various radiosonde IDs (e.g., RS41-SG T0840727, RS41-SGP T0950723) and their status. A 'Telemetry Graph' is visible at the bottom of the sidebar. The top right corner shows a 'Welcome' message and a 'User Guide' link. The bottom right corner includes a scale bar (20 km) and a 'websocket | 0 msg/s' indicator.

<https://sondehub.org/> - Displays launch sites too!

Tracking radiosondes (2): radiosonde_auto_rx

Tracking hardware:

- 70cm band antenna
- SDR dongle, RTL-SDR
- PC or Raspberry Pi running radiosonde_auto_rx

Radiosonde Support Matrix

Manufacturer	Model	Position	Temperature	Humidity	Pressure	XDATA
Vaisala	RS92-SGP/NGP	✓	✓	✓	✓	✓
Vaisala	RS41-SG/SGP/SGM	✓	✓	✓	✓ (for -SGP)	✓
Graw	DFM06/09/17	✓	✓	✗	✗	✗
Meteomodem	M10	✓	✓	✓	Not Sent	✗
Meteomodem	M20	✓	✓	✓	✓ (For some models)	✗
Internet Systems	iMet-1	✓	✓	✓	Not Sent	✓
Internet Systems	iMet-4	✓	✓	✓	Not Sent	✓
Internet Systems	iMet-54	✓	✓	✓	Not Sent	✗
Lockheed Martin	LMS6-400/1680	✓	✗	✗	✗	Not Sent
Meisei	iMS-100	✓	✗	✗	✗	Not Sent
Meteo-Radiy	MRZ-H1 (400 MHz)	✓	✓	✓	✗	Not Sent

https://github.com/projecthorus/radiosonde_auto_rx

Tracking radiosondes (3): radiosonde_auto_rx

☰ Radiosonde Auto-RX 1.5.10

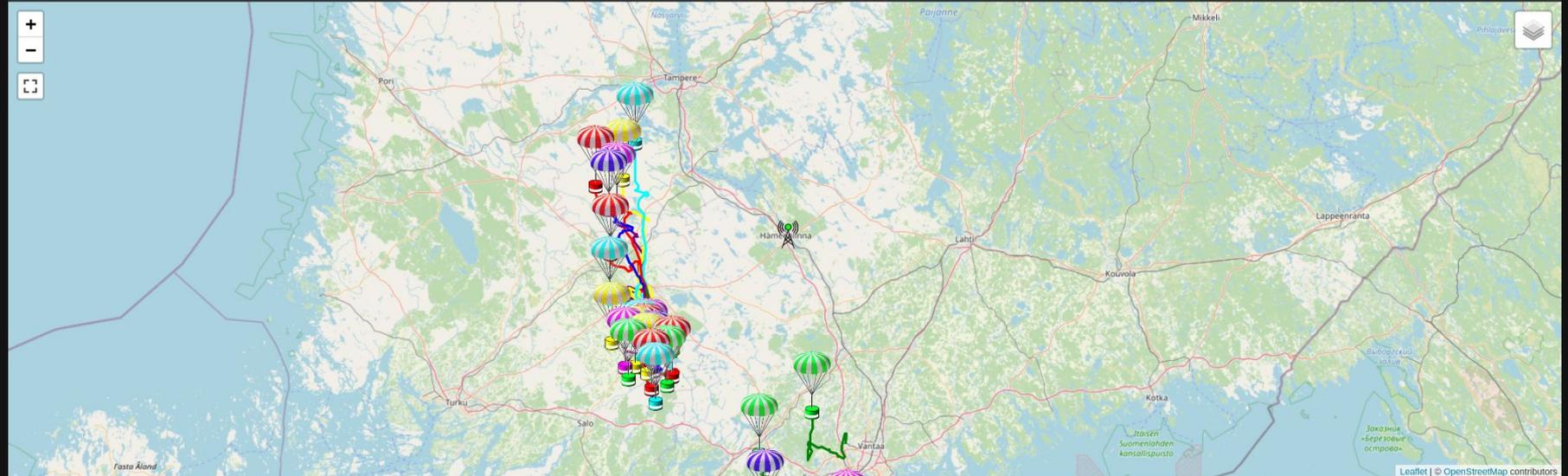
Station: OH3AA_AUTO_RX / OH3AA-1

Current Task: SDR #00001111: Scanning

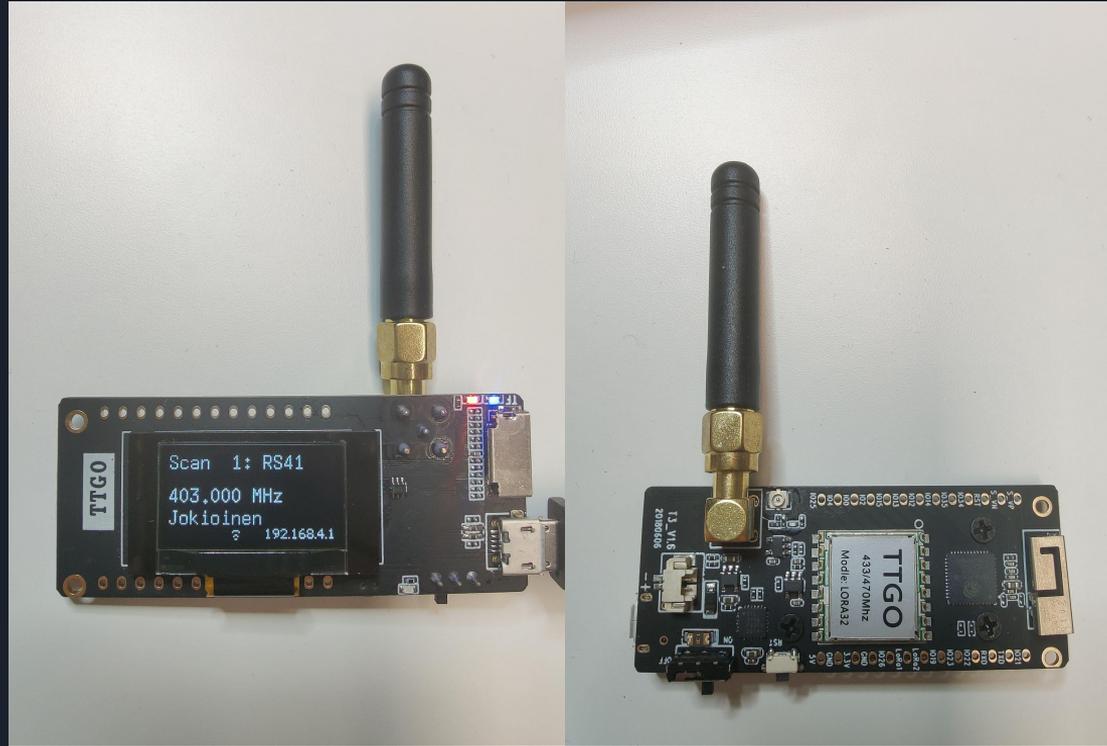


SDR	Age	Type	Freq (MHz)	ID	Time	Frame	Latitude	Longitude	Alt (m)	Vel (kph)	Asc (m/s)	Temp (°C)	RH (%)	Az (°)	El (°)	Range (km)	SNR (dB)	Other
old	RS41-SG	403.000 MHz	T0840727	2022-05-26T13:18:41.001Z	8052	61.07492	23.28644	540.4	7.1	-15.3	8.7	78.2	282.6	0.0	66.0	10.3	BT 08:15:47 2.7 V	
old	RS41-S...	403.400 MHz	U1810720	2022-05-26T10:51:12.000Z	8188	60.27914	24.29256	606.7	17.0	-14.9	8.9	71.1	188.0	0.0	75.4	9.9	BT 08:08:00 2.6 V	
old	RS41-SG	403.000 MHz	T0850668	2022-05-26T07:23:41.001Z	8360	61.14928	23.19539	635.1	8.9	-16.3	7.2	100	288.2	0.0	72.8	8.9	BT 08:16:56 2.7 V	
old	RS41-SG	403.000 MHz	T0820036	2022-05-26T01:23:49.001Z	8359	61.28737	23.46397	907.7	19.4	-7.8	7.1	91.8	304.8	0.3	66.4	8.9	BT 07:57:53 2.7 V	
old	RS41-SG	403.000 MHz	T0820033	2022-05-25T19:30:37.000Z	8797	61.16939	23.37767	448.5	20.0	-11.3	12.4	76.6	292.7	-0.0	64.3	7.7	BT 08:03:04 2.7 V	
old	RS41-SG	403.000 MHz	T0820033	2022-05-25T19:30:37.000Z	8651	60.52907	23.70603	207.6	27.0	0.5	0.3	40.0	200.6	0.1	69.0	0.4	BT 08:05:01 2.7 V	

First Prev 1 2 3 4 5 Next Last



Tracking radiosondes (4): rdz_ttgo_sonde



https://github.com/dl9rdz/rdz_ttgo_sonde

Chasing a landing balloon (1): SondeHub

The screenshot displays the SondeHub web interface. At the top, there is a search bar with 'RS_*:chase' and a status bar showing '61.0088' and '24.4812'. The main map area shows a geographical region with a yellow balloon icon labeled 'RS_R1930435' and a green line indicating its path. The left sidebar contains a list of radiosonde IDs and their status, along with detailed data for the selected balloon: altitude (3,075 m), coordinates (61.03651, 24.44238), and temperature (-16.7°C). The right sidebar features a 'Welcome' message, a 'Radiosondes?' section with a link to Linux.conf.au, a 'Want to setup a receive station?' section with a GitHub link, a 'Habhub' section with IRC and Balloon tracking guide links, and a 'Contribute' section with a GitHub link and IRC information. The bottom of the interface includes a 'Telemetry Graph' button and a footer with 'OpenStreetMaps.org' and '500 m' scale.

Chasing a landing balloon (2): Mobile RX with radiosonde_auto_rx + chasemapper

The screenshot displays the Chasemapper software interface. On the left is a settings panel, and on the right is a map showing a car (blue) and a balloon (purple) with their respective tracks and prediction circles. A data table at the top right shows current tracking information, and another table at the bottom right shows call sign and location data.

Settings Panel:

- Settings
- Data Source: Default
- Map
- Auto-Follow: Payload, Chase Car, None (selected)
- Show Car Track:
- Predictor: Current Model: 2019101000z
- Download Model:
- Enable Predictions:
- Show 'Abort' Predictions:
- Burst Altitude: 30000
- Descent Rate: 5.0
- Update Rate: 15
- Other:

Data Table (Top Right):

Alt (m)	Speed (kph)	Asc Rate (m/s)	Azimuth	Elevation	Range
1918m (21418)	6 kph	-13.8 m/s	186°	26°	4.2km

Data Age: Payload: 0.5s, Car GPS: 0.5s, Predictions: 10.5s

Map: Shows a car (blue) and a balloon (purple) with their tracks and prediction circles. The map includes geographical features like lakes (Kernaalanjärvi, Joutjärvi) and roads (2873, 130, 13836).

Call Sign and Location Data (Bottom Right):

Callsign	Time (Z)	Latitude	Longitude	Alt (m)	V_rate (m/s)
Payload	07:00:00	60.85340	24.56176	1918.0 (21418)	-13.8

Time: 02:19

Scale: 500 m

Footer: Leaflet | © OpenStreetMap contributors

Chasing a landing balloon (3): chase car :)



Chasing a landing balloon (4): Recovery

1. Get latitude/longitude coordinates from SondeHub or your own station/tracker
2. Enter the coordinates to a navigation/map application in your mobile phone
3. Drive as close as you can get
4. Go for a hike :)

**It's like geocaching with a prize:
free STM32 dev boards falling from
the sky!**



Where do the radiosondes land? (1)



An easy one!

Where do the radiosondes land? (2)



Up in the tree, couldn't get that one!

Where do the radiosondes land? (3)



This is fun: Just waiting to be picked up!

Where do the radiosondes land? (4)



And yet another one, right between a road and a railway track!

Where do the radiosondes end up? (1)

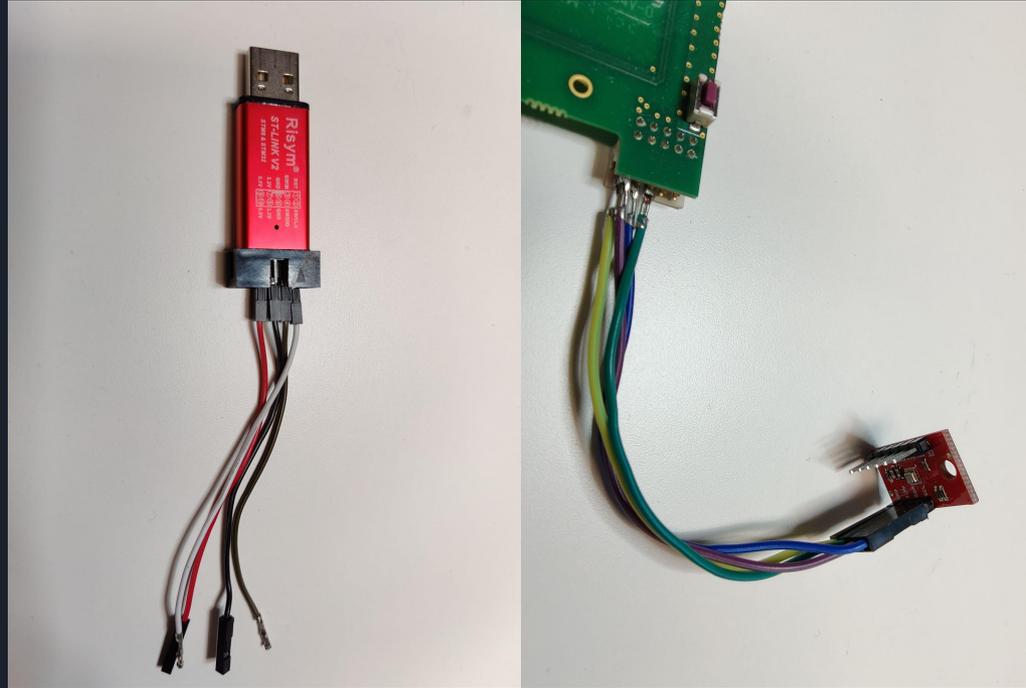


Where do the radiosondes end up? (2)



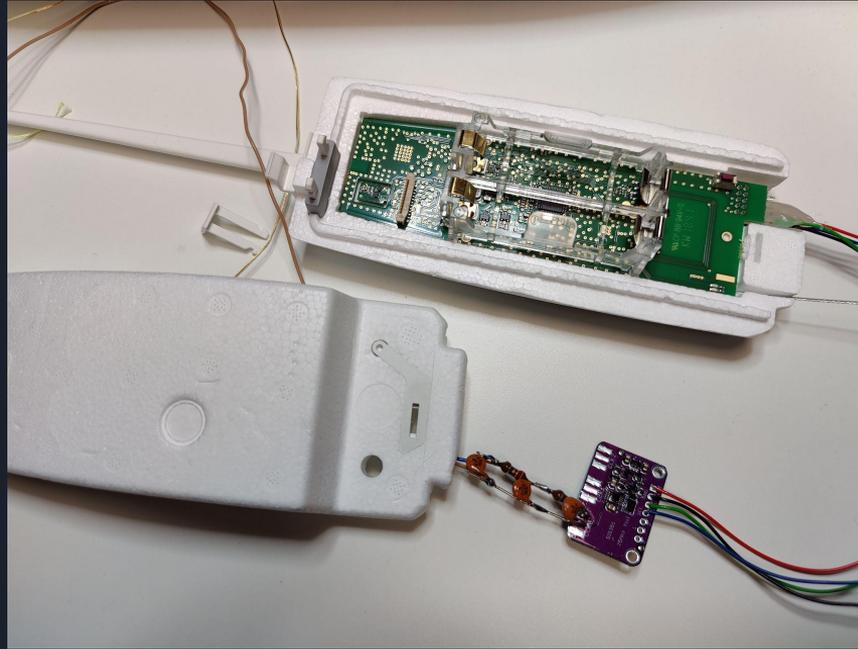
- Vaisala RS41 sondes run on 2 Energizer Ultimate Lithium (Li-Ion) batteries.
- Most of them have plenty of capacity left because of the auto-power-off feature of the sonde!
- Have extended temperature range, from -40 C to 60 C degrees.

Flashing new firmware



Flashing: An ST-LINK USB dongle connected to sonde pin header
Support for sensors: The sonde pin header provides I²C bus

Further experiments with RS41ng firmware



An Si5351 clock generator controlled by the sonde (via I²C bus) can transmit many digital modes on HF: Horus 4FSK, FT8, WSPR, ...

Flying a reprogrammed RS41 sonde (1)



A “feature-rich” flight with live DVB-S video TX by club OH3AA using call sign OH3VHH.
The sonde was a backup APRS tracker on 70cm. (July 2021)

Flying a reprogrammed RS41 sonde (2)



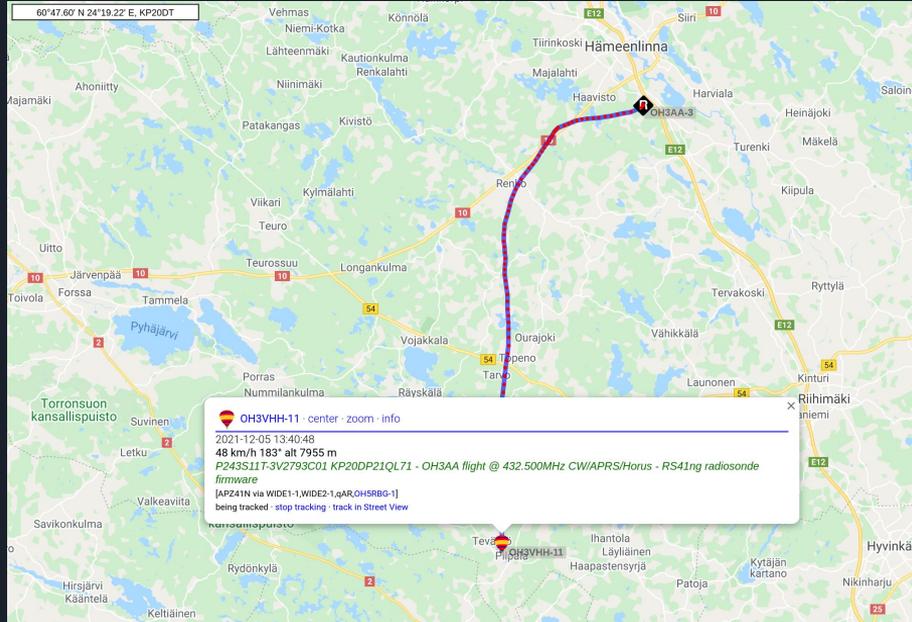
First tests using the Horus 4FSK at club OH3AA.
(August 2021)

Flying a reprogrammed RS41 sonde (3)



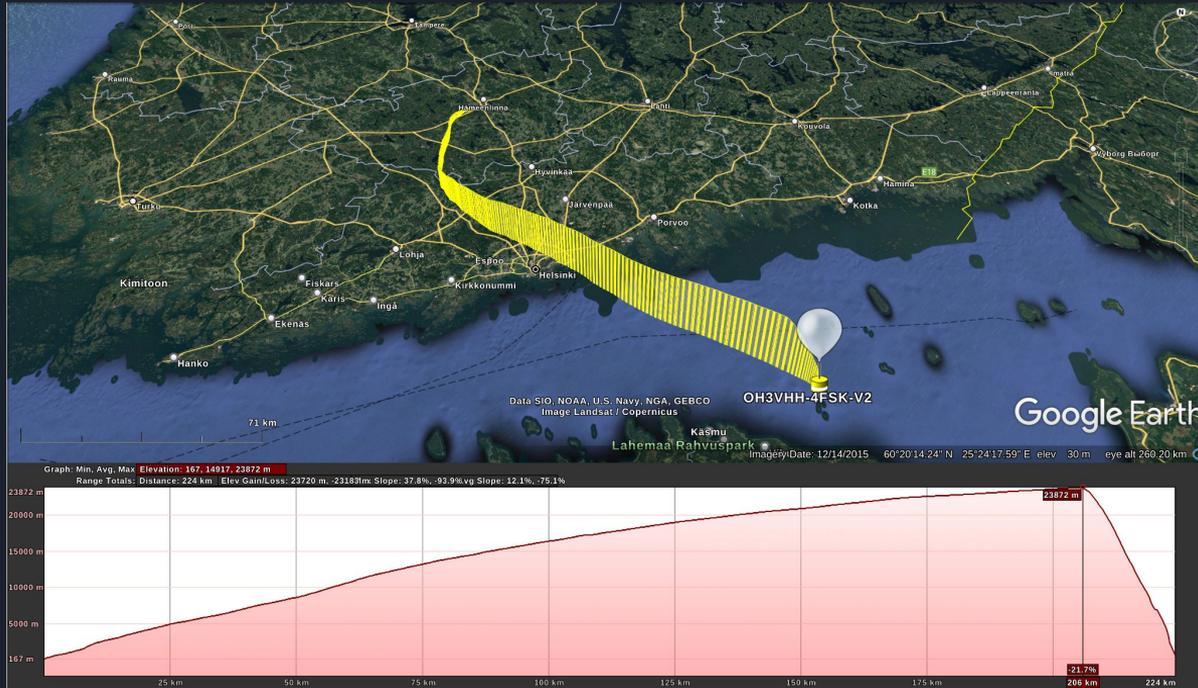
First tests using the Horus 4FSK at club OH3AA.
(August 2021)

Flying a reprogrammed RS41 sonde (4)



Tracking a flight via APRS (December 2021).
The sonde cycles through modes: CW, APRS and Horus 4FSK.

Flying a reprogrammed RS41 sonde (5)



Flight path visualized in Google Earth (December 2021).
Excellent performance for Horus 4FSK reception in low altitudes.



What is needed for a flight?

- Flight permit (free, given by Traficom in Finland)
- Automatic amateur radio station permit (free, Traficom)
- Wind forecasts (e.g. <http://predict.habhub.org/>)
- Helium or hydrogen gas (and possible permits)
- Latex balloons
- Read more about our flights at my blog:
<https://Oxfeed.tech/>



Useful sites about HAB flights / Other applications for radiosondes

- Project Horus: <http://www.projecthorus.org/>
- Dave Akerman: <http://www.daveakerman.com/>
- Overlook Horizons (check out their YouTube channel):
<https://www.overlookhorizon.com/>

Other applications:

- Mobile APRS tracker
- Beacon for fox hunt (radio direction finding)
- Wireless weather station (APRS weather reports!)
- More...?



Thank you!

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