Observatory Report for 2023–2024

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Széchenyi István Geophysical Observatory

Geomagnetic Observations

The geomagnetic observations in the Széchenyi István Geophysical Observatory (IAGA code: NCK) have been perturbed in the years 2023–2024 as the construction works of the Zero Magnetic Field Lab (ZBL) were going on at that time. These works included the installation of a 2-layer, 3-meter side length μ-metal chamber, which weighs more than 6 tons and the construction of a 10 m characteristic size triaxial Merritt coil system which serves the purpose of compensating the geomagnetic field. The central point of ZBL is located not more than 60 meters from the absolute measurement pillar. This year the interaction of the compensation magnetic field and the chamber's shielding transients are analysed and tuned to be as stable as possible. This tuning process goes along with a systematic setting of the compensation magnetic field in a wide range of 0–110%.

The effect of the varying compensation field and the presence of the μ-metal chamber on the absolute measurements are significant at the distance of the pillar of the absolute measurements. For this reason, a new absolute measurement pillar location is proposed to be set. The new location is much farther from the ZBL, and the perturbation effect of the preliminary location is being investigated.

We intend to continue providing definitive data to INTERMAGNET utilising the baseline determined from the absolute measurements taken at the new location to be installed.

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Geoelectric Observations

The basis of the geoelectric observation in the Széchenyi István Geophysical Observatory is a high-resolution and very sensitive digital voltmeter equipped with a 32 bit analogue/digital converter, programmed for automatic switching between measurement ranges to prevent saturation and preserve the high-resolution measurement ability. It operates two independent measurement channels corresponding to the North–South and the East–West oriented electrode pairs. The raw sampling of the hardware is 40 Hz and the data is low-pass filtered to have a 10 Hz effective sampling rate of the geoelectric field. Each of the four electrodes has been replaced with a new 1 m^2 lead-plate electrode of 1 cm width. The distance between the corresponding electrodes has been reduced to 250 m as the sensitivity of the modern instruments no longer necessitates a large span. The test phase of the instrument is in progress.

Digisonde Observations

The Digisonde (DPS 4D ionosonde) at the Széchenyi István Geophysical Observatory has operated in normal mode for most of the time of 2024.

The normal 15-minute schedule contains the following programs:

- Vertical Ionograms [1–13/14 MHz].
- Vertical and oblique sounding synchronised with Athens (AT138) [1–18 MHz].
- Skymaps for the F layer [the appropriate frequency is determined from the last recorded ionogram] and for the E layer [∼2.1 MHz] during the daytime.
- D2D (Digisonde-to-Digisonde) measurements synchronised with Pruhonice (PQ052) and Dourbes (DB049). Sopron is the receiver station.
- Maintenance programs (Built-in Test BIT, Auto gain control AG, Channel equalising CCEQ).

A quiet radio mode (TAV) also has been set on 2024-02-21, in this mode the Digisonde is able to listen to the radio universe above foF2 (it starts from 10 MHz according to the settings) up to the maximum 30 MHz limit.

The 15-minute schedule in the normal operational mode is the following:

Number	**Program**	**Start**
1	Vertical ionogram [1–13 MHz]	0:00
2	D2D PQ 052, Passive	2:35
3	Skymap [F region]	3:55
4	D2D DB049, Passive	4:36

5	Vertical, oblique sounding with AT138	5:00
6	Radio listening mode (TAV)	7:00
7	D2D PQ 052, Passive	7:35
8	BIT	8:20
9	CCEQ	8:22
10	AG	8:34
11	D2D DB049, Passive	9:36
12	Vertical ionogram [1–14 MHz]	10:00
13	Skymap [E region]	11:45
14	D2D PQ 052, Passive	12:35
15	Radio listening mode (TAV)	14:30
16	D2D DB049, Passive	14:36

High-cadence campaigns (1 ionogram/min) have been performed during the year to study the Medium Scale Travelling Ionospheric Disturbances generated by the terminator and/or by intense tropospheric events (Cyclone Boris). The dates of the 1-min campaigns are the following: 2024-03-20; 2024-06-20; 2024-09-08-2024-09-10; 2024-09-12; 2024-09-13.

It is important to note that the strength of the received signal was lower especially in the lower frequency band (< 5 MHz) in the first part of the year because of a hardware issue that was solved on 18 July 2024. Therefore, the Digisonde provided the standard good-quality ionograms after 19 July 2024.

Sopron Digisonde data is available at: http://iono.nck.ggki.hu/. Furthermore Sopron station provides data to GIRO (Global Ionosphere Radio Observatory, https://giro.uml.edu/), to the European Mirror site of GIRO (Prague), to DIAS (DIgital upper Atmosphere Server) and TechTIDE (https://techtide.eu/) servers at Athens and the eSWua portal of INGV (electronic space weather upper atmosphere, Istituto Nazionale di Geofisica e Vulcanologia, Rome).

Atmospheric Electricity

Atmospheric electricity measurements were continuous in the years 2023–2024.

VLF Observations

The VLF measurements were operated continuously at Nagycenk in 2023–2024 and supplied data for AWDANet (inferring plasmaspheric electron density from whistler data) and AARDDVARK (for monitoring ionospheric D-region perturbations) networks.

Meteorological Observations

Meteorological measurements were continuous in the years 2023–2024, meteorological records have been regularly submitted to the central database of HungaroMet, the National Meteorological Service in Hungary.

Tihany Geophysical Observatory

Tihany Geomagnetic Observatory (IAGA code: THY) was established in 1954. For almost 70 years, THY belonged to the Eötvös Loránd Geophysical Institute and its legal successors. In 1991, THY was one of the founding members of INTERMAGNET. In 2023, THY was taken over by the Institute of Earth Physics and Space Science (EPSS).

In addition to its original task, the observatory has always hosted other geophysical measurements, such as observation of paleomagnetic, geothermic, seismologic, and different space phenomena.

Geomagnetic Observations

In 2023, data were recorded by three parallelly run vector magnetometers (two fluxgate and one DIDD). Following the INTERMAGNET standard, we calculate and record minute mean values by applying a standardised Gaussian filter to the instruments 1-second samples (5 seconds for the DIDD), using our data collection system. Since 2019, a new LEMI-035 magnetometer with suspended sensors, which has a high tolerance against external electromagnetic noise, has been operated as the primary system. It was installed in the pavilion (#4 in Fig. 2). To meet the anticipated new INTERMAGNET standards, we implemented an OBSDAQ system with an A/D converter of 24-bit resolution and 128 Hz sampling rate in the primary system.

For recording the total field, alongside the continuously operating GSM-19 Overhauser magnetometer (which operates in the attic of the absolute house), we operated at least one additional scalar magnetometer running in parallel. The DIDD systems data can serve as a backup for three-component recording, as this instrument performs measurements every 5 seconds needed for determining inclination and declination. Each measurement sequence also includes the total field value, which can thus be used to generate the observatorys XYZ minute averages. The instrument measures the geomagnetic components in the eastern room of the variation house (#3 in Fig. 2). The data collection task is handled by a version of MAGLIN software adapted for DIDD systems. Naturally, we record and archive all measurements, including 1- and 5-second samples.

Since 2020 the DTU FGE device has been operated in the western room of the variation house (#3 in Fig. 2). The data-collecting system of this device is a MAGOR DAQ system. The DAQ fulfils the new INTERMAGNET standards as well.

The absolute measurements were performed in the absolute house (#2 in Fig. 2) on the absolute pillar (pillar 1). In 1991, pillar 1 was rebuilt. In this year the azimuth value of the reference mark was determined. For absolute measurements, our instrument set consists of Zeiss 010A (primary) and Zeiss 20A (DIM) theodolites transformed into non-magnetic by MinGeo Ltd., and equipped with DMI (Danish) magnetometers. Using the Zeiss instruments, we conducted measurements at least weekly, following the null-point method. The difference between the total field values measured on the absolute pillar and the site of the GSM-19 instrument was regularly observed. The pillar difference (total field measurement site absolute pillar) was −1.6 nT in 2023. Annual mean values are for the year 2023: Decl.: 5°10.3; Incl.: 63°42.5; H: 21584 nT; X: 21496 nT; Y: 1946 nT; Z: 43688 nT; F: 48729 nT.

The absolute measurements were performed, and the definitive yearly dataset was processed by András Attila Csontos.

Most of our data collection systems are based on the MAGLIN software, and remote access is provided when needed. In addition to INTERMAGNET minute averages, we also perform continuous one-second sampling with the LEMI magnetometer.

The observatory provided a quasi absolute quasi-real-time minute mean record of geomagnetic components for the INTERMAGNET GIN server in Edinburgh. Since 2023 the quasi absolute quasi-real-time one-second sampled record has also been transmitted. The preliminary geomagnetic records for 2023, as well as definitive data for years 1991–2022, are available at the INTERMAGNET website (https://intermagnet.org/).

EMMA Observations

The European quasi-Meridional Magnetometer Array (EMMA) was established in 2012 in the frame of the EU FP7 PLASMON project. The network was taken over in 2023 by EPSS and is now coordinated by this institute. EMMA consists of 27 variometer stations equipped with fluxgate vector magnetometers from northern Finland to the middle of Italy, covering low middle and high geomagnetic latitudes (L = 1.56). Currently, EPSS operates three of these stations. Besides the Tihany station, one magnetometer is operated in Vyhne (Slovakia) in cooperation with the Hurbanovo Geophysical Observatory of the Slovak Academy of Sciences, and one in Lonjsko Polje Geomagnetic Observatory (IAGA code: LON) in collaboration with the University of Zagreb. EMMA stations were operational in 2023 and 2024. The availability of the observations varied station by station. Detailed information on the availability, as well as quick look line plots and dynamic power spectra are available at the EMMA website: http://geofizika.canet.hu/plasmon/.

VLF Observations

The VLF measurements had been operated continuously at Tihany in 2023–2024 and supplied data for AWDANet (inferring plasmaspheric electron density from whistler data), AARDDVARK (for monitoring ionospheric D-region perturbations) and WWLLN (for global lightning locations) networks.

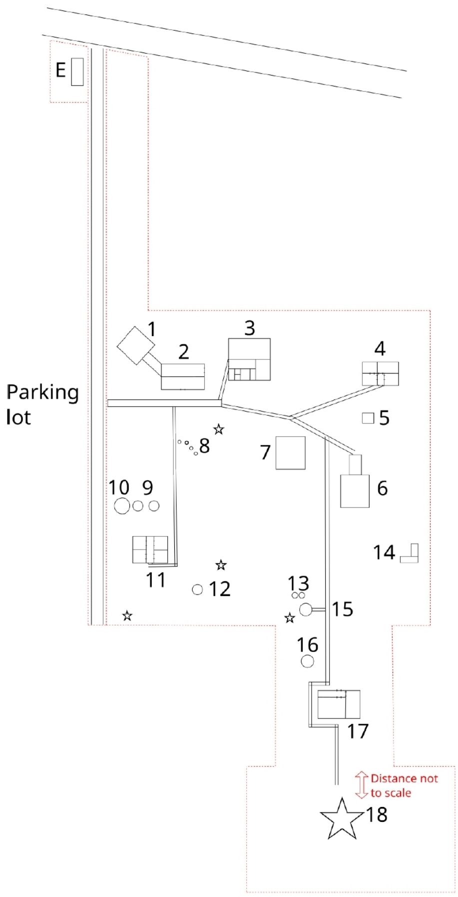

Fig. 1. Schematic of the buildings, measurements operate at the SZIGO. E Entrance; 1 Zero Magnetic Field Laboratory with corridor; 2 Telluric measurements; 3 Main building with staff hostel and electronic laboratory; 4 Computer centre (data loggers, server of local network, satellite transmitter); 5 Proton magnetometer (DI/DD); 6 Building of geomagnetic variometer station; 7 Building for geomagnetic absolute measurements with 4 pillars installed; 8 Meteorological measurement instruments (Campbell meteorological station central stand, Visibility meter, LIDAR for measuring cloud base); 9 Twin Atmospheric electric potential gradient sensors (radioactive); 10 Atmospheric electric potential gradient sensors (field mill); 11 Atmospheric electricity house (data logging of the Schumann resonance data (ELF-band electric and magnetic field records), atmospheric electric potential gradient, LINET lightning detection network station, atmospheric UV detection); 12 Electric ball antenna of the Schumann resonance recording system; 13 InSAR corner reflectors; 14 Magnetic induction coils of the Schumann resonance recording system; 15 Place of the old meteorological station; 16 VLF antenna; 17 Digisonde station; 18 Digisonde transmitter antenna. The smaller star symbols represent the receiver antennas of the Digisonde.

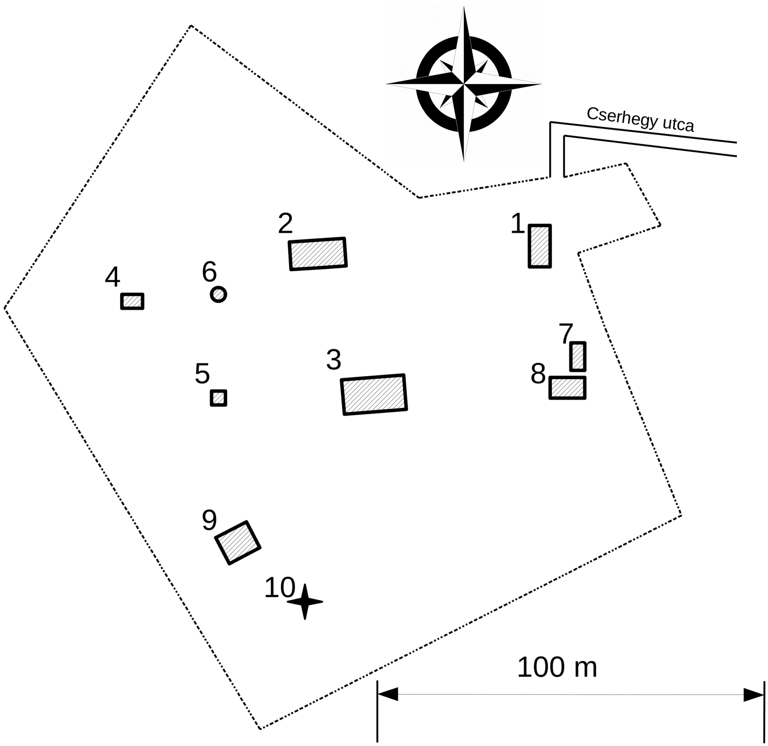

Fig. 2. Schematic of the buildings, measurements operate at the THY. 1 Clock house; 2 Absolute house (absolute pillars [1 and 2] and total field measurement); 3 Variation house (pillars are in the eastern and in the western room); 4 Pavilion (two pillars); 5 New measurement hut; 6 Temperature hut; 7 Test building; 8 Laboratory; 9 Green house; 10 VLF antenna.

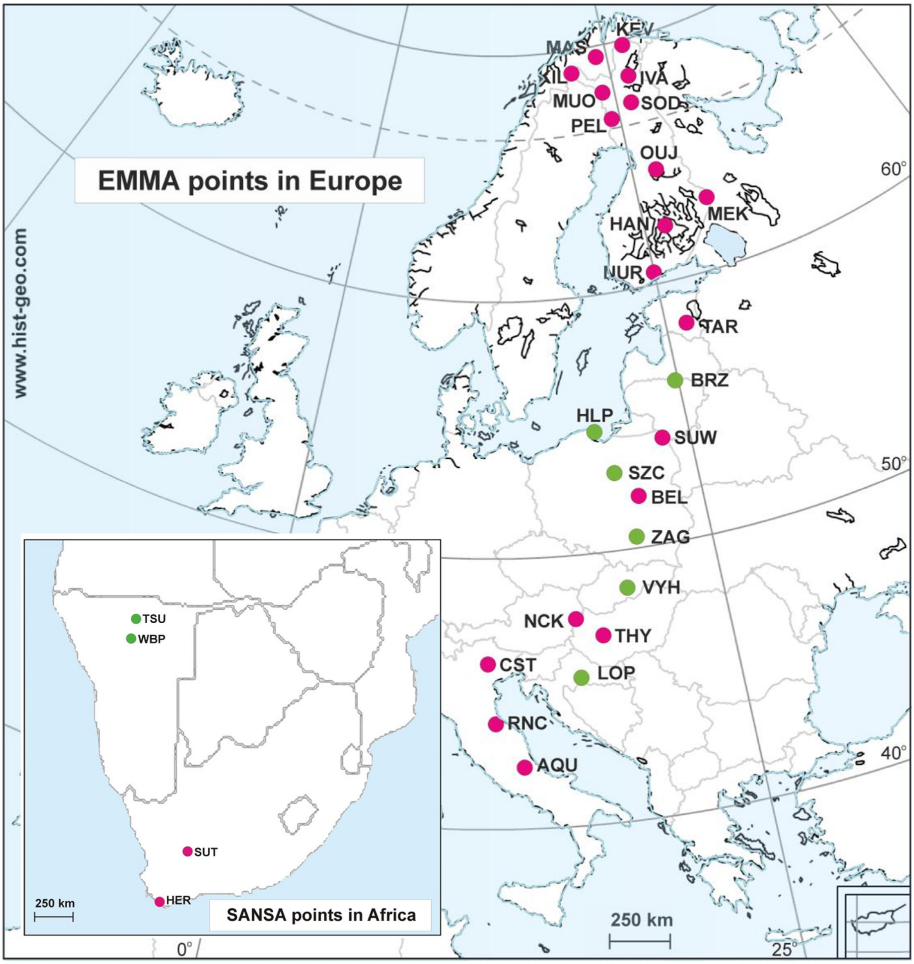

Fig. 3. EMMA stations (Jorgensen et al, 2017).

Table I. Observations at Széchenyi István Geophysical Observatory.
∗: Referenced to the geometrical center of the two electrode pairs positioned in N–S and E–W directions buried in a depth of 2 m nearby the observatory.

Geomagnetic Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
variation recording / primary	DTU FGE	DTU, Lyngby, Denmark	2020	2020	DC–0.2 Hz	20 Hz	1 s	variation house, pier 1	EPSS	Orientation: XYZ
back-up	LEMI-025	LEMI LLC., Lviv, Ukraine	2010	2010	DC–5 Hz	10 Hz	1 s	variation house, pier 1	EPSS	Orientation: XYZ
absolute measurement	Zeiss-10A + DTU DIM	Zeiss-DTU-MinGeo Ltd.	2018	2019		twice a week (Mon and Thu)	twice a week (Mon and Thu)	absolute variation house, pier 2	EPSS	
absolute measurement	GSM-19	Gem Systems, Markham, Canada	2016	2016		1 s	1 s	absolute variation house, pier 2	EPSS	
MIRA	in-house	in-house	2000	2000	n/a	once every two years	once every two years	absolute variation house, pier 2	EPSS	Azimuth: 298°33.92’
Geoelectric Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
variation recording			2022	2022	DC–10 Hz	40 Hz	10 Hz	∗	EPSS	Orientation: x – North, y – East

Ionosonde Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
Ionosonde	DPS-4D	Lowell Digital International		2018	1–30 MHz	5 min	5 min	SZIGO, ionosonde house + antenna system	EPSS	
Atmospheric Electricity Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
Schumann resonance (SR) electric	SR electric monitoring system	in-house		1993	5–35 Hz	500 Hz	0.002 s	SZIGO	EPSS	
SR magnetic	SR magnetic measuring system	in-house		1996	3–40 Hz	500 hz	0.002 s	SZIGO	EPSS	
Atmospheric electricity, potential gradient (PG)	Radioactive collector-tpye PG measuring instrument #1	in-house		1961	DC	11 Hz	11 Hz	SZIGO	EPSS	

PG	Radioactive collector-tpye PG measuring instrument #2	in-house		1998				SZIGO	EPSS	
PG	EFM-100	Boltek, Port Colborne, Canada		2013	DC	2 Hz	2 Hz	SZIGO	EPSS	
VLF Wave Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
AWDANet										
VLF receiver	VLF receiver	ELTE, BL Electronics Ltd.	2003	2002	100 Hz–20 kHz	40 kHz	variable	Nagycenk	ELTE	
AARDDVARK										
VLF receiver	VLF receiver	ELTE, BL Electronics Ltd.	2007	2007	100 Hz–40 kHz	96 kHz	0.05 s	Nagycenk	ELTE	
Meteorological Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
Temperature	Campbell HMP35D, BME280	Campbell Scientific		1997, 2020		5 s	variable, 1.5, 10 min, lately 1 min	SZIGO	EPSS	

Relative humidity (RH)	Campbell HMP35D	Campbell Scientific		2020		6 s	variable, 1.5, 10 min, lately 1 min	SZIGO	EPSS	
Wind (direction and speed)	Campbell 05103-LC	Campbell Scientific		1997		5 s	variable, 1.5, 10 min, lately 1 min	SZIGO	EPSS	
Air pressure	Campbell CS106	Campbell Scientific		2022		5 s	variable, 1.5, 10 min, lately 1 min	SZIGO	EPSS	
Air pressure	BME280	Bosch Sensortec		2020		6 s	variable, 1.5, 10 min, lately 1 min	SZIGO	EPSS	
Precipitation	Campbell ARG100	Campbell Scientific		1997		5 s	variable, 1.5, 10 min, lately 1 min	SZIGO	EPSS	

Table II. Observations at the Tihany Geophysical Observatory.

Geomagnetic Observations	type	manufacturer	year of production	year of installation	frequency band	sampling rate	data rate	observation site	owner of data	other
variation recording / primary	LEMI-035	LEMI LLC., Lviv, Ukraine	2017	2018	DC–5 Hz	128 Hz	1 s	new variation pavilion, pier 1	EPSS	Orientation: XYZ
back-up	DTU FGE (upgraded)	DTU, Lyngby, Denmark	1999 (sensor)	2019	DC–5 Hz	128 Hz	1 s	variation house, eastern room	EPSS	Orientation: XYZ
back-up	DIDD (upgraded)	Gem Systems, AMrkham, Canada; MinGEO LTd., Budapest, Hungary	1999 (sensor)	2019	DC–0.2 Hz	1 Hz	0.2 Hz	variation house, western room	EPSS	Orientation: IDF
absolute measurements	Zeiss-10A + DTU DIM	Zeiss–DTU–MinGeo Ltd.	2004	2005		weekly	weekly	absolute house, pier 1	EPSS	
absolute measurements	Zeiss 020A + DTU DIM	Zeiss–DTU–MinGEo Ltd.	2006	2006		occasionally		absolute house, pier 1	EPSS	
absolute measurement	GSM-19	Gem Systems, Markham, Canada	1991	1991		5 s	5 s	absolute house, attic	EPSS	

MIRA	the southern tower of the Tihany Benedictine Abbey					occasionally		absolute house, pier 1	EPSS	Azimuth: 3°59'10"
Geomagnetic Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
EMMA										
variometer	LEMI-035 fluxgate	LEMI LLC., Lviv, Ukraine	2010	2011	DC–5 Hz	128 Hz	1 s	Lonjsko Polije (HR)	EPSS	Orientation: DHZ
variometer	LEMI-035 fluxgate	LEMI LLC., Lviv, Ukraine	2010	2011	DC–5 Hz	128 Hz	1 s	Tihany	EPSS	Orientation: DHZ
variometer	Narod STE fluxgate	Narod Geophysics Ltd., Vancouver, Canada	2006	2012	DC–5 Hz	128 Hz	1 s	Vyhne (SK)	EPSS	Orientation: DHZ
VLF Wave Observations	**type**	**manufacturer**	**year of production**	**year of installation**	**frequency band**	**sampling rate**	**data rate**	**observation site**	**owner of data**	**other**
AWDANet										
VLF receiver	VLF receiver	ELTE, BL Electronics Ltd.	2002	2002	100 Hz–20 kHz	40 kHz	variable	Tihany	ELTE	
WWLLN										
VLF receiver	VLF receiver	ELTE, BL Electronics Ltd.	2005	2005	100 Hz–48 kHz	96 kHz	variable	Tihany	ELTE/ wwlln.net	

AARD-DVARK										
VLF receiver	VLF receiver	ELTE, BL Electronics Ltd.	2007	2007	100 Hz–48 kHz	96 kHz	0.05 s	Tihany	ELTE	