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# RADIAN

## ANY ANGLE TRIAXIAL, BROADBAND, DIGITAL SEISMOMETER FOR BOREHOLE AND SUB-SURFACE INSTALLATIONS



A versatile sub-surface medium-motion instrument available as either a posthole or borehole system for depths up to 2000 m

### KEY FEATURES

> 120 s to 200 Hz response with user-selectable high-pass frequency corner from 10 to 120 seconds
> Operational at any angle with ultra slim 55 mm diameter enclosure and 250 bar/25 MPa connector
> Choose either acceleration or velocity response
> STA/LTA and threshold triggering
> The system can incorporate an additional analogue instrument if desired
> Radian Borehole has hole-lock options for cased holes ranging from 60 mm to 140 mm and can form multi-instrument strings for vertical seismic profiling

### APPLICATIONS

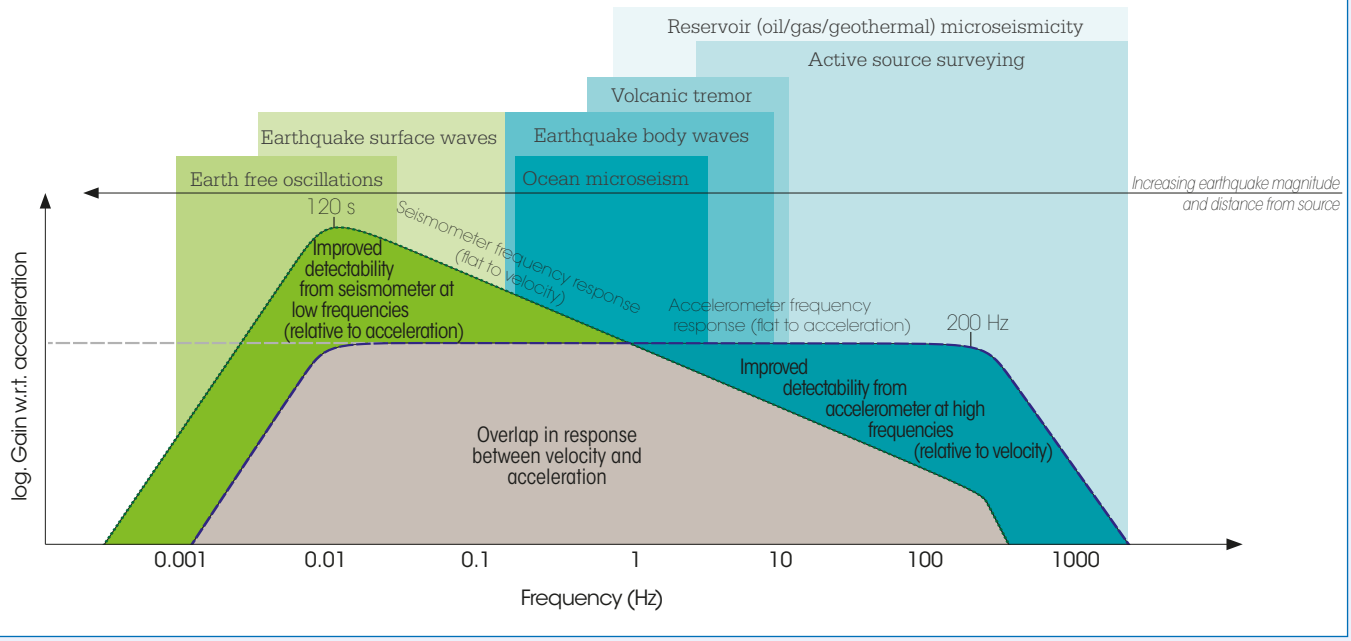
> Microseismic and induced seismicity monitoring
> Volcanic unrest monitoring
> Seismic monitoring in areas of high cultural noise
> Strong motion monitoring caused by local events
> Ice-quake monitoring in glaciers
> Vertical seismic profiling (borehole instrument)
> Traffic light monitoring for energy extraction or storage

# Radian

With an ultra-wide response, an adjustable high-pass frequency corner and, the capability of operating at any angle, Radian offers up opportunities for subsurface deployments that would otherwise prove too challenging or unpredictable.

## Response selection

When ordering, select either a velocity or acceleration instrument response depending on the preferred output.




## Applications

- Microseismic and induced seismicity monitoring
- Volcanic unrest monitoring
- Ice-quake monitoring in glaciers
- Seismic monitoring in areas of high cultural noise
- Strong motion monitoring caused by local events
- To complement dense surface arrays
- Vertical seismic profiling (VSP)
- Traffic light systems for energy extraction or storage

### At just 55 mm diameter, the Radian seismometer is designed for simplified deployments in the subsurface.

Radian is available as either a posthole instrument for deployment in uncased holes, or as a borehole instrument for installation in narrow, (60 mm - 100 mm) or wide (100 mm - 140 mm), cased holes.

Unlike other subsurface seismometers, the Radian can operate at any angle. This opens up opportunities for deployment in unpredictable or challenging environements such as shifting ice shelves or non-vertical boreholes. Additionally, the Radian borehole can be deployed as a single instrument or multiple instruments can be strung together for vertical seismic profiling (VSP).

### Record the full spectrum of seismic events for accurate event cataloguing.

Compared to short-period geophones, Radian's active feedback sensor ensures consistent amplitude and phase response across the bandwidth of the instrument.

Low self-noise and a wide dynamic range allow accurate detection of small seismic events and recording of strong shaking in one instrument.

The ultra-wide frequency response between 120 s and 200 Hz makes the Radian ideal for seismic monitoring at all scales, particularly in areas of high cultural noise. For increased flexibility, the high-pass frequency corner can be remotely configured to suit the deployment environment.

An internal magnetometer and MEMS based accelerometer work together to provide tilt and horizontal orientation. The appropriate correction can be applied to deliver high-quality waveforms with no need for post-processing.

A resilient enclosure constructed from SAE 316 corrosion-resistant stainless steel and a 250 Bar/25 MPa water-proof connector protects the instrument in wet holes.

For installations where back-filling to maximise coupling is not practical, the Radian Borehole with hole-lock mechanisms is recommended.

### Minimus surface interface unit

The Radian system includes the Minimus digitiser as a surface interface unit to deliver sensor configuration as well as data communication, timing and storage capability. Minimus records data on dual-redundant microSD cards and shares the data via Ethernet and Bluetooth connections.

We have two versions of the Minimus surface interface unit, one for deployments up to 100 metres that uses copper cable, and one for deployments over 100 metres that require a fibre optic system. The power requirement is higher with the fibre optic system.

### Confident deployments

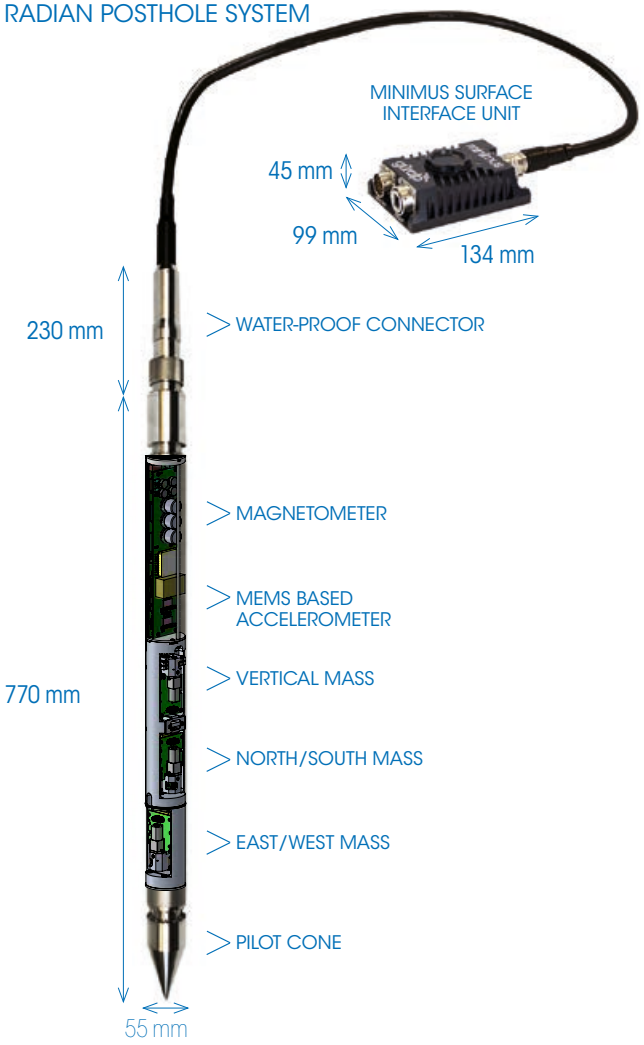
For added confidence during deployments the free GüVü, Bluetooth App, displays waveforms, orientation, temperature and humidity data.

## Key features

- State-of-the-art seismic sensor allows full operation over a full tilt range of ±180° by automatically centring the mass
- Triaxial orthogonal (ZNE) instrument with high cross-axis rejection (> 65 dB)
- 120 s to 200 Hz with user-selectable high-pass frequency corner from 10 s to 120 s
- You can select either velocity or acceleration variants depending on the preferred output (configurable prior to shipping)
- Streaming and storage of instrument response and calibration parameters dramatically simplifies data management (RESP and Dataless SEED formats)
- Slim-line 55 mm diameter enclosure constructed from robust and water-proof, SAE 316 corrosion-resistant stainless steel with a 250 Bar/25 MPa water-proof connector to protect the instrument in wet holes
- Low latency outputs available (approx. 0.04 s data packets)
- Accurate time-base from surface GNSS, Precision Time Protocol (PTP), or internal clock (< 1 ms drift per day unfixed)
- Free GüVü Bluetooth App for checking installation integrity (Android)
- Dual-redundant 16 GB microSD cards (1 fixed, 1 hot-swappable)

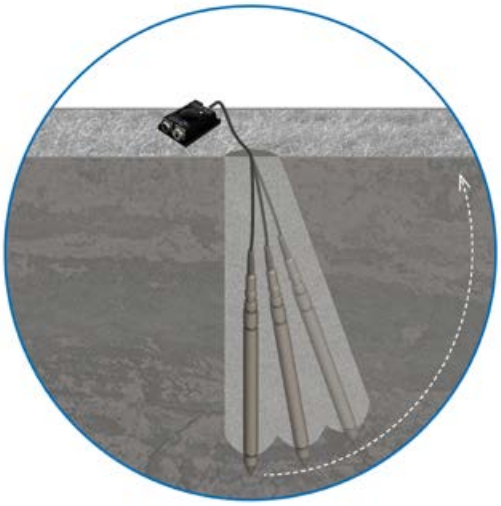
# Radian Posthole system for deployment in uncased holes.

RADIAN POSTHOLE SYSTEM




## EASE OF INSTALLATION

- POSTHOLE OPTIMISES NOISE PERFORMANCE
- NO REQUIREMENT FOR PRECISE VERTICAL OR NORTH-SOUTH ALIGNMENT
- BACK-FILL USING SOIL, SAND OR GLASS BEADS TO MAXIMISE COUPLING



## MAXIMISE YOUR NETWORK

THE MINIMUS CAN ACCOMMODATE AN ADDITIONAL HIGH PERFORMANCE ANALOGUE SENSOR SUCH AS THE FORTIS ACCELEROMETER - IDEAL FOR EARTHQUAKE EARLY WARNING SYSTEMS



## Key features

State-of-the-art seismic sensor allows operation over a full tilt range of ±180° by automatically centring the mass

Triaxial orthogonal (ZNE) instrument with high cross-axis rejection (> 65 dB)

120 s to 200 Hz with user-selectable high-pass frequency corner from 10 s to 120 s

Low latency outputs available (approx. 0.04 s data packets)

Streaming and storage of instrument response and calibration parameters dramatically simplifies data management (RESP and Dataless SEED formats)

Option to accommodate an additional analogue instrument with the Minimus surface interface unit

Depths of up to 100 m suitable for temporary deployments using batteries and solar panels

## Applications

> Microseismic and induced seismicity monitoring

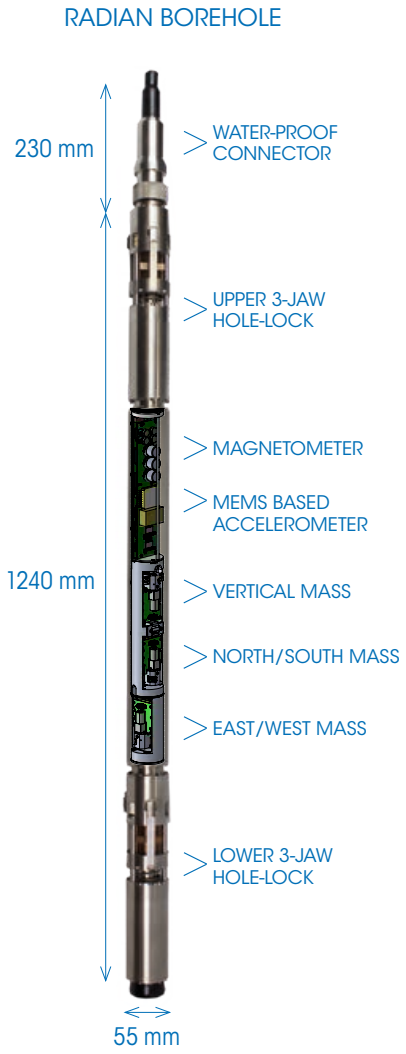
> Volcanic unrest monitoring

> Ice-quake monitoring in glaciers

> Seismic monitoring in areas of high cultural noise

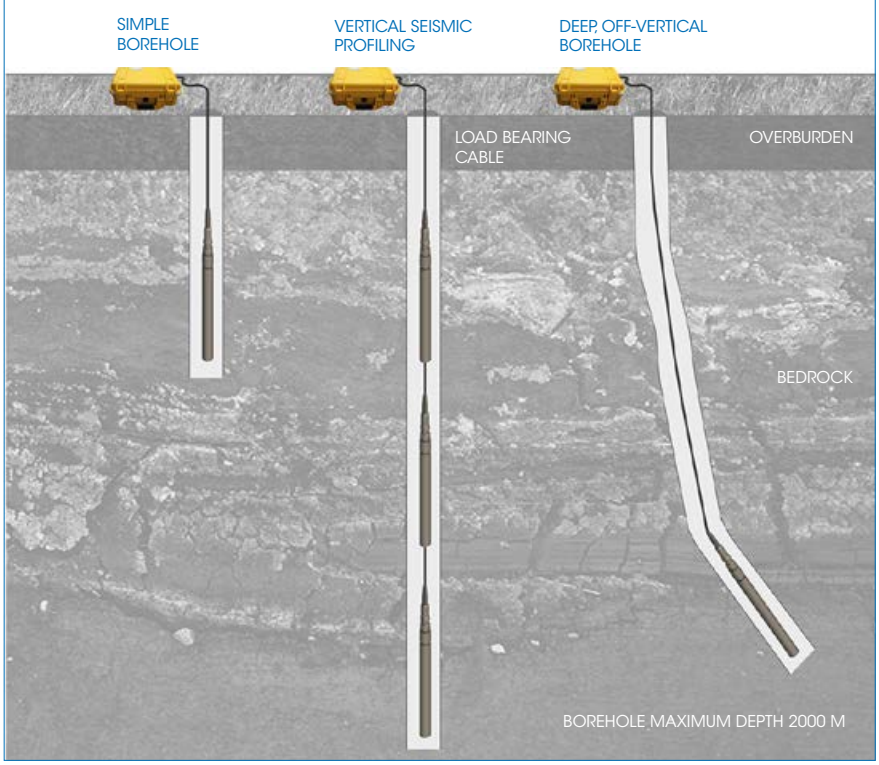
> Strong motion monitoring caused by local events

# Radian Borehole system for deployment in cased vertical or deviated boreholes




**ROBUST VERSATILITY**

- INSTALLATION IN OFF-VERTICAL HOLES
- CAN BE EASILY STRUNG TOGETHER FOR VERTICAL SEISMIC PROFILING (VSP)
- RECOVERY PERFORMED USING SECURE HOLE- LOCK RELEASE MECHANISM
- ROBUST LOAD-BEARING SENSOR CABLE




**MAXIMISE YOUR NETWORK**

THE SURFACE INTERFACE UNIT CAN ACCOMMODATE AN ADDITIONAL HIGH PERFORMANCE ANALOGUE SENSOR SUCH AS THE FORTIS ACCELEROMETER - IDEAL FOR EARTHQUAKE EARLY WARNING SYSTEMS

## Key features

State-of-the-art seismic sensor allows full operation over a full tilt range of ±180° by automatically centring the mass

Triaxial orthogonal (ZNE) instrument with high cross-axis rejection (> 65 dB)

120 s to 200 Hz with user-selectable high-pass frequency corner from 10 s to 120 s

Select either velocity or acceleration output at time of order

Low latency outputs available (approx. 0.04 s data packets)

Industry standard retractable three-jaw motorised hole-locks for either narrow, (60 mm - 100 mm) or wide (100 mm - 140 mm) cased holes

Streaming and storage of instrument response and calibration parameters dramatically simplifies data management (RESP and dataless SEED formats)

## Applications

> Microseismic and induced seismicity monitoring

> To complement dense surface arrays

> Vertical seismic profiling (VSP)

> Seismic monitoring in areas of high cultural noise

> Traffic light systems for energy extraction or storage

# Radian

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# SPECIFICATIONS

| BROADBAND SEISMOMETER SYSTEM | |
|---|---|
| Configuration / Topology | Triaxial orthogonal (ZNE) |
| **PERFORMANCE: BROADBAND SEISMOMETER** | |
| Maximum frequency response bandwidth | 120 s (0.0083 Hz) to 200 Hz with user-selectable options available within this range<br>Velocity or acceleration response (configurable prior to shipping) |
| Full-scale clip level | Velocity response nominal: ±25 mm/s (equivalent to differential output sensitivity of 2000 V/m/s)<br>Acceleration response nominal: ±12.5 mm/s$^2$ (equivalent to differential output sensitivity of 200 V/m/s$^2$) |
| Sensor dynamic range | > 149 dB at 1 Hz |
| Self-noise | Below NLNM (New Low Noise Model) from 17 s (0.06 Hz) to 9 Hz<br>< -155 dB from 120 s to 10 Hz |
| Operational tilt range | ±180° |
| Cross axis rejection | > 65 dB |
| Linearity | > 95 dB |
| Lowest spurious resonance | > 450 Hz |
| Centring | Automatic / can be disabled |
| Transfer function | Measured sensitivity, frequency response and instrument poles and zeros are stored within the instrument and accessible via web interface |
| **ENVIRONMENTAL CHANNELS** | |
| Sensor mass positions | Three independent sensor mass position outputs (integrator) |
| Orientation sensors | MEMS based accelerometer (three component); Magnetometer (three component) |
| Other sensors | Temperature; humidity; pressure; input voltage |
| **INTERNAL DIGITISER** | |
| Digital resolution/output format | 24-bit |
| Dynamic range | > 120 dB |
| Anti-aliasing filter at Nyquist | > 172 dB |
| Sampling rates | 1 to 5000 samples per second, user selectable |
| **ENVIRONMENTAL** | |
| Operating temperatures: | -30 to +60 °C |
| Humidity | 0-100% relative humidity |
| Robustness | IP68 to 2000 m depth |
| **PHYSICAL** | |
| Diameter | 55 mm |
| Radian Borehole diameter options* | Narrow borehole: 60 mm to 100 mm<br>Wide borehole: 100 mm to 140 mm<br><br>*Precise internal diameter of the borehole casing is required prior to order. |
| Radian Posthole case height | 770 mm excluding connector |
| Radian Posthole weight | 7.1 kg excluding connector |
| Radian Borehole case height | 1240 mm excluding connector |
| Radian Borehole weight | 7.5 kg excluding hole-locks and connector |
| Sensor enclosure/materials | SAE 316 corrosion resistant stainless steel<br>Gold plated contacts<br>O-ring seals throughout |
| Connector | 250 Bar / 25 MPa water-proof connector |
| Sensor and load-bearing cable | Kevlar-refinforced, AC-coupled |
| Orientation indicator | North vertical scribe mark on side on outer casing and inside connector |

| DIGITISATION AND STORAGE | |
|---|---|
| Additional sensor inputs | Primary channels:<br>Four at 24 bits. Differential input: 40 V peak-to-peak (± 20 V). Also compatible with single-ended inputs: 20 V peak-to-peak (± 10 V) |
| Secondary channels: | Three analogue channels for sensor mass positions. One internal callibration channel |
| Internal environmental channels: | Humidity<br>Temperature<br>Supply voltage<br>MEMS accelerometer (three component)<br>Magnetometer (three component) |
| Flash memory and storage | Dual redundant 16 GB microSD cards<br>(1 fixed, 1 hot-swappable)<br>Option for 64 GB or 128 GB |
| Data recording formats | miniSEED (metadata stored in Dataless SEED format) |
| Configuration and control | (Ethernet) Güralp Discovery - free download, web browser interface. Free GüVu Bluetooth app (Android) |
| Data streaming protocols (via Ethernet) | GCF (Scream!), GDI-link[1] and SEEDlink[1]<br>([1]metadata sent in RESP, StationXML and dataless SEED file formats) |

| TIMING | |
|---|---|
| Timing protocols | GNSS (GPS or GLONASS, BeiDou optional) or PTP (Precision Time Protocol) timing sources |
| GNSS connector | 14-way Lemo connector (NMEA, PPS and Debug serial) |
| Timing drift without GNSS | Typical drift when unsynchronised <1 ms per day |
| **POWER** | |
| Protection | AC-coupled differential electronics |
| Power input voltage range | 10– 36 V DC |
| Power consumption (at 12 V DC) | Single Radian Posthole: 2.1 W* |
| Power consumption (at 12 V DC) | Single Radian Borehole: 2.3 W* |

**Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement*

| MINIMUS SURFACE INTERFACE UNIT - WITH COPPER CABLE FOR DEPLOYMENTS OF UP TO 100 M DEPTH | |
|---|---|
| Dimensions | 134 mm × 99 mm × 45 mm exc. connectors |
| Weight | 674 g (without connectors) |
| Operating temperature | -20 to +60 °C |
| **MINIMUS SURFACE INTERFACE UNIT - FIBRE OPTIC SYSTEM FOR DEPLOYMENTS OVER 100 M DEPTH** | |
| Dimensions | 422 mm × 323 mm × 175 mm exc. connectors |
| Weight | 7.5 kg |
| Operating temperature | -20 to +60 °C |

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In the interests of continual improvement with respect to design, reliability, function or otherwise, all product specifications and data are subject to change without prior notice.

DAS-RAD-0001 Issue M