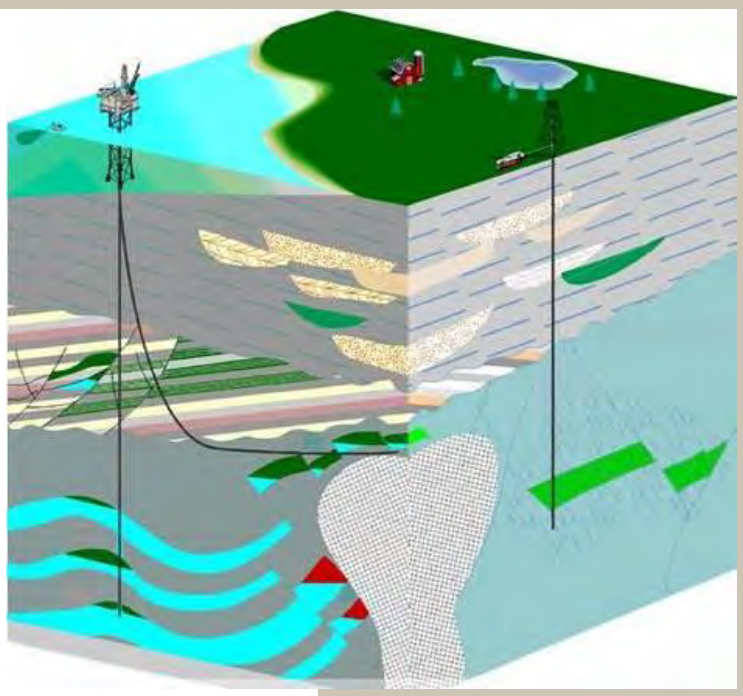
KMS Technologies

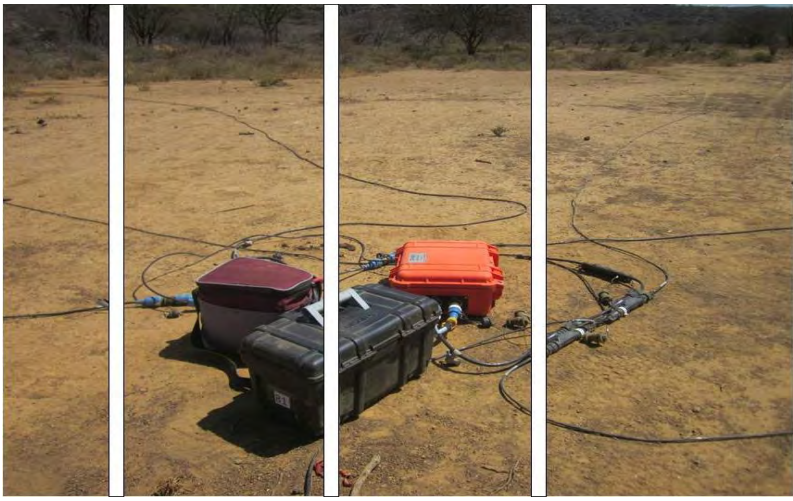
Innovating Solutions

KMS Company Overview



KMS Technologies – KJT Enterprises Inc.


KMS



Vision

To make electromagnetics (EM) in general & time domain controlled source electromagnetics (tCSEM™) in particular a routine tool in hydrocarbon exploration & production fully integrated with seismic. To carry the technology to monitoring of water & steam-flooding of hydrocarbon reservoirs and production monitoring of geothermal reservoirs. This is achieved via installation of permanent arrays. Our products support borehole, land and marine real-time applications. Our services complement our technology offerings.

All about EM

KMS Technologies focuses on advanced electromagnetic methods for the oil/geothermal industry to increase the discovery & recovery factors or carry out production monitoring. We support our technology via high-quality services, state-of-the-art R&D projects, and several unique hardware & software products.

Products

Microseismic / Electromagnetic monitoring system

- Wireless acquisition systems
- Magnetotellurics & CSEM: DC to 40 kHz, 24 & 32 bit; true array functionality (wireless)
- Surface-to-borehole EM
- Custom marine systems
- Mud logging (porosity & permeability) with NMR

Transmitters

- Land 100 kVA or 150 kVA
- Transition zone
- Marine (custom)

Sensors

- Magnetometers (DC to 200 kHz)
- Electrodes
- Drone fluxgate magnetometers

Services

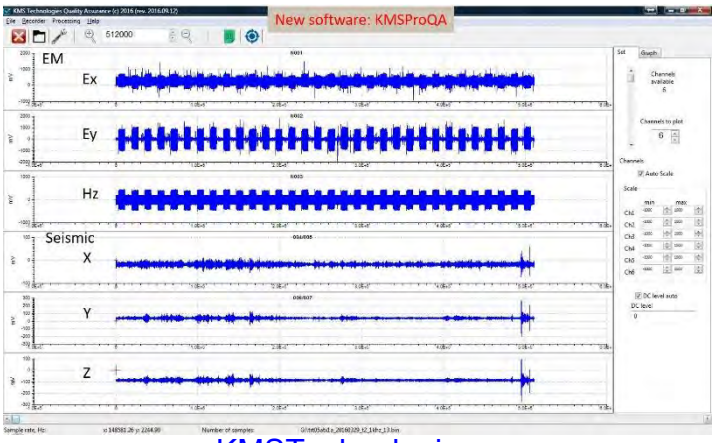
- ***Heavy oil, CO2 & water flood monitoring***
  - *3D feasibility*
  - *Pilot demonstration*
  - *Technology transfer*
- ***3D modeling***
  - *MT Interpretation*
  - *Feasibility studies*
  - *CSEM interpretation*
  - *Frac monitoring*
- ***EM demonstration & training surveys***
  - *Training in EM*
  - *Survey design*
  - *Advisory*

Wide-band Magnetotelluric (MT) system

The next generation wide band system comprises a portable KMS-820 data acquisition unit:

KMS-820 features (land-marine-borehole)

- *Low-power design to increase battery life*
- *Long range capability (up to 5 miles line-of-sight or unlimited distance in mesh network mode)*
- *WIFI (server or point-to-point)*
- *Bandwidth: DC-40 kHz*
- *Up to 80 kHz sampling rate*
- *Six 24-bit GPS synchronized channels & unlimited 32 bit channels*
- *Low noise channels*
- *Customizable digital interface for digital sensors & other devices*
- *Portable & lightweight*



www.KMSTechnologies.com

Fluxgate & induction coil magnetometers

The Laboratory of ElectroMagnetic Innovations (LEMI) was founded 2008 as a joint venture between KMS Technologies & the Lviv Centre of Institute for Space Research (LCISR) to focus on the development & production of high quality electromagnetic (EM) sensors. LEMI is located in Lviv, Ukraine.

www.LEMIsensors.com

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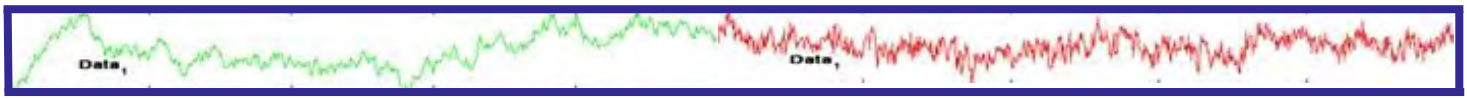
Microseismic & Electromagnetic Array data acquisition system



Main components

Land

KMS-820 data acquisition unit
KMS-831 32-bit interface module
LEMI-701 non-polarizable, lead-free electrodes
LEMI-120 induction coil sensor (0.0001 – 1,000 Hz)
LEMI-118 induction coil sensor (1 – 70,000 Hz)
LEMI-152 Super- broadband induction coil sensor (0.00025 – 10,000 Hz)
KMS-029 fluxgate magnetic sensor 32-bit, (DC – 180 Hz)
Multicomponent geophones

Borehole

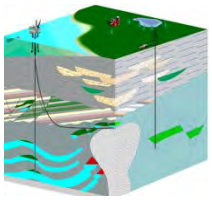
KMS-888 Shallow borehole data acquisition unit & sensors

Marine

KMS-870 broad-band seismic/EM marine deep-water node

Optional

KMS-5100 land transmitter (100/150 kVA)
KMS-500 transition zone transmitter



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Product overview

The KMS array data acquisition system is developed for EM (ElectroMagnetic) and microseismic applications to obtain subsurface resistivity and velocity structure for oil and gas and geothermal exploration. It also can be used in general purpose acquisition and long term monitoring services.

The system comes with various options to facilitate microseismic and ElectroMagnetic reservoir monitoring. It also synchronizes and integrates with our borehole acquisition system and our marine MT acquisition node (KMS-870).

The core of the system is the KMS-820 Data Acquisition Unit which has six 24-bit low noise, low drift analogue channels and, through the digital port, and the KMS-831, unlimited channel expansion. Typically, the digital port is used to record 32-bit fluxgate magnetic fields, at the same time as acquiring coil data. The 24-bit architecture goes to 100 kHz sampling, and the 32-bit architecture to 4,000 Hz. All channels are sampled simultaneously and synchronized with GPS.

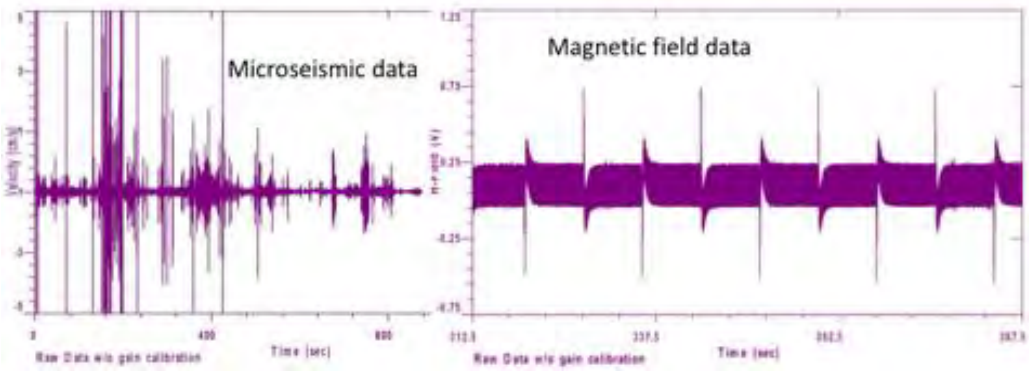
In addition, the KMS-820 can be used to control the KMS-500 marine or the KMS-5100 land transmitter. Multiple communication and data harvesting options exist: USB cable, SD card exchange, long range wireless, Wi-Fi via router (when available), and Wi-Fi point-to-point direct connections. LAN is optional.

All EM methods can also be run on a seismic crew.

A variety of survey configurations, from single recording station to 3D acquisition arrays are possible.

System highlights:

- Acquire microseismic data independently or simultaneously with EM
- Combined CSEM & natural source EM (magnetotellurics – MT) acquisition in one receiver deployment
- Same layout can acquire different methods by adding optional transmitters or geophones
- Combined MT/AMT measurements to give high resolution mapping and great depth
- MT: Fully synchronized SIMULTANEOUS acquisition for ultra-low frequencies (KMS-029: DC-180 Hz), standard MT band (LEMI-120: 0.0001 – 1,000 Hz), AMT band (LEMI-118: 1 – 50,000 Hz)
- Lightweight, portable, rugged, low power consumption
- Wireless network (long range), GPS synchronized, wide bandwidth & dynamic range
- 24-bit or 32-bit digital resolution, DC to 50 kHz signal bandwidth
- Low cost with large channel count (unlimited)
- Efficient field operations with or without cables
- Each KMS-820 can be expanded to unlimited channels with multiple KMS-831 (32-bit)

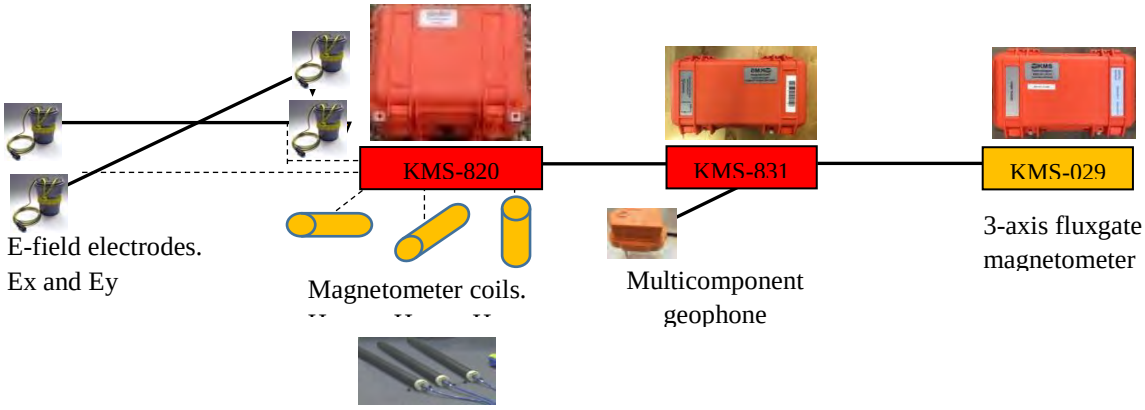


Main components

1. KMS-820 digital acquisition system	2. KMS-831 sub-acquisition controller
3. KMS-029 (fluxgate magnetometer)	4. LEMI-120 (low frequency magnetometer)
5. LEMI-118 (low frequency magnetometer)	6. LEMI-701 electrode
7. S-20 (air coil magnetic sensor)	8. Multicomponent geophone
9. Misc. interconnect cables	10. Accessories (KMS-300, USB cable)
11. Laptop computer 11A KMS-410 Lithium Ion batteries	12. KMS-5100 transmitter (not to scale)

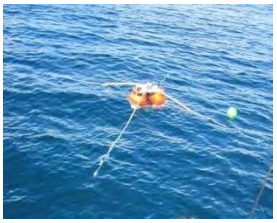
Single receiver station layout (example only)

The KMS array data acquisition system allows great flexibility in acquisition design adjusting with survey requirements, including that all receiver stations may not be identical. The acquisition scheduler allows the system to be used for different acquisitions and even methods in one drop. The figure below shows a sample layout only, purely to illustrate how a receiver station might be configured.



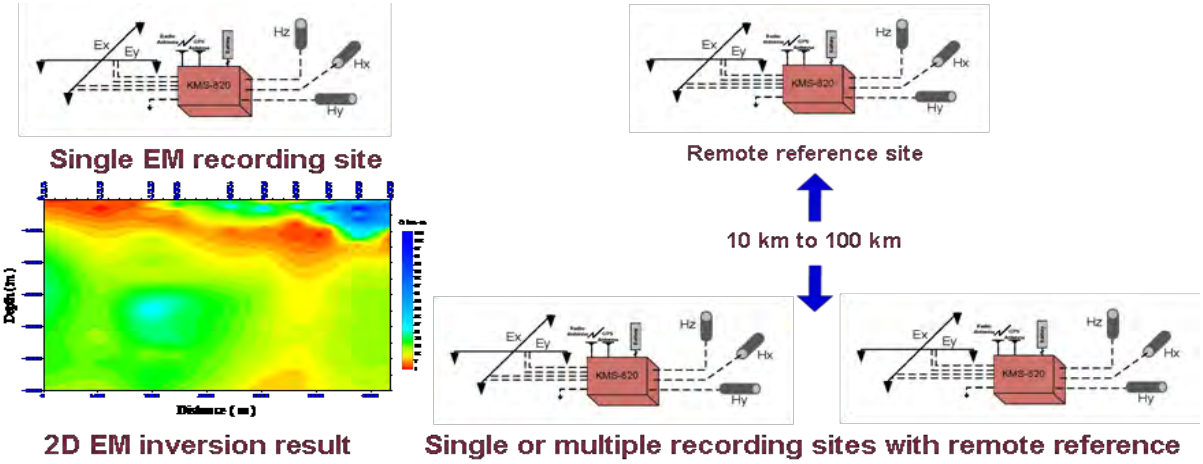
Applications

- Reservoir monitoring
- Oil and gas exploration (land & marine)
- Hydrocarbon reservoir dynamics & CO2 storage monitoring
- Porosity mapping within carbonate reservoirs
- Geothermal exploration & induced seismicity monitoring
- Engineering & environmental studies
- Earthquake prediction research
- Deep crustal research
- Metals and mineral exploration
- Integration to reservoir via borehole (KMS-borehole system)



EM methods & microseismic

For magnetotellurics (MT) one often uses single site or remote reference recording as shown below.



- MT, AMT: Magnetotellurics and Audio MT are used for basin reconnaissance and structure studies including near surface applications, mostly oil &gas and geothermal applications.
- CSAMT: Controlled Source Audio MT uses a transmitter to get better Signal-to-Noise (S/N) ratios for detailed structure investigations of the upper 2 km.
- TFEM, IP: Time-Frequency Domain Electromagnetics and Induced Polarization combine time and frequency domain electromagnetics for hydrocarbon and mineral exploration. (He et al., 2015)
- LOTEM: Long Offset Transient Electromagnetics is applied to detailed structural investigations of the upper 5 km for hydrocarbon and geothermal Exploration & Production. Focused TEM is also possible. (Strack and Pandey, 2007)
- All EM methods can be combined with simultaneous microseismic acquisition, The KMS-870 includes broadband microseismic and marine MT acquisition in one unit.

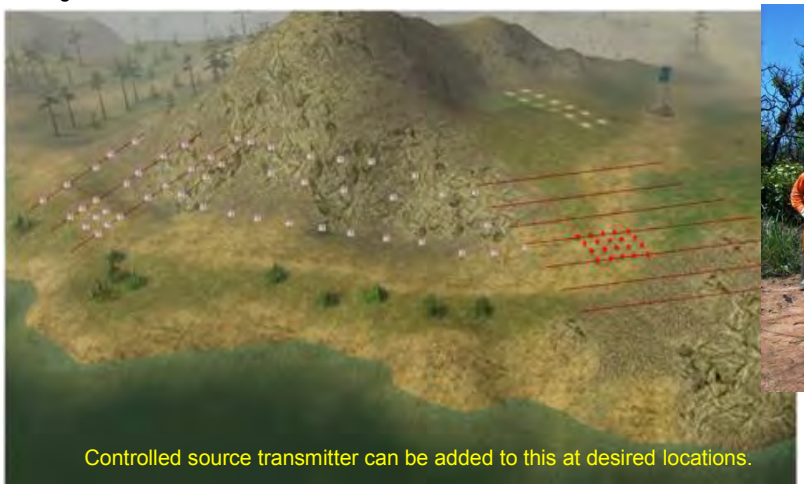
3D EM/seismic array layouts

KMS acquisition systems can be used for large scope 3D EM surveys with densely spaced electric sensors and sparsely installed magnetometers. The system's wireless network feature makes field operations very efficient when conducting massive 3D EM surveys. Depending upon distance between sites, KMS-820 or KMS-831 with digital interconnect (≈100 m) can be used. KMS-831 is about 5 times less expensive than the KMS-820 and connects to a KMS-820.

The figure below shows a layout where on the right you have 3D acquisition using bins where only one site in the bin has all the magnetic sensors. The rest has only electric fields. The center shows mountainous operation for complex terrain which has portable sites and can even be helicopter assisted. On the left are 2D lines where each site has the full sensor component set.

When running MT on a seismic crew, you usually run the MT site ahead or after the seismic line to avoid operations related noise on the MT data.

With CSEM you have multiple options between moving receiver and/or transmitter. Since the CSEM operations are busy you might want to run it after the seismic line.



KMS team as part of a seismic crew in Brazil acquiring MT data.

System configuration table

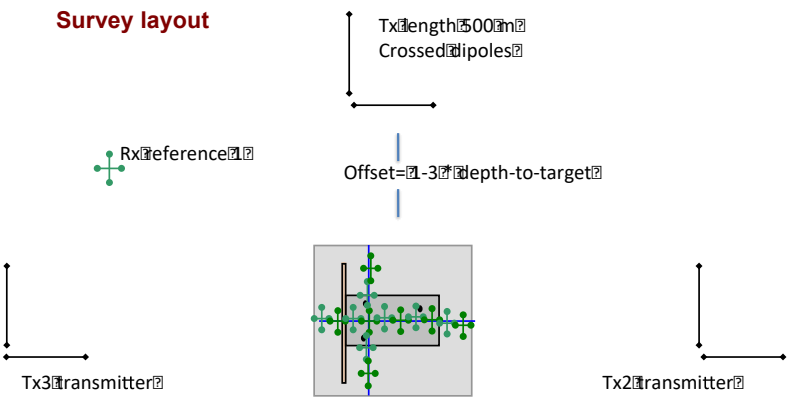
The following table shows the various system configuration options for different surveys and applications. System components can be mixed and matched in a modular fashion. Seismic sensors can be added to each configuration. Each configuration is expandable by adding more KMS-831 sub-acquisition controller. **NEW 2016**: shallow borehole seismic/EM receiver KMS-888 and LEMI-152 Super-Broadband induction coil.

Survey	Receiver	Transmitter	Sensors	Applications / Depth
MT	KMS-820 & KMS-831	N/A	Electrode: LEMI-701 Magnetometer: LEMI-120 LEMI-118 LEMI-152 KMS-029	Onshore / Deep targets & basin study
CSAMT	KMS-820	KMS-500	Electrode: LEMI-701 Magnetometer: LEMI-118 LEMI-152	Onshore, transition zone / Shallow targets
TFEM	KMS-820 & KMS-831	KMS-500 KMS-5100	Electrode: LEMI-701 Magnetometer: LEMI-140 LEMI-120 LEMI-118 LEMI-152 KMS-029	Onshore, transition zone /Shallow to mid-depth targets
LOTEM	KMS-820 & KMS-831	KMS-500 KMS-5100	Electrode: LEMI-701 Magnetometer: LEMI-140 S20-air coil	Onshore, transition zone / Shallow to mid-depth targets Sub-basalt, sub-salt
TFEM, IP	KMS-820 & KMS-831	KMS-500 KMS-5100	Electrode: LEMI-701 Magnetometer: LEMI-140 LEMI-120 LEMI-118 LEMI-152	Onshore, transition zone / Shallow to mid-depth targets
CSEM	KMS-820 & KMS-831	KMS-500 KMS-5100	Electrode: LEMI-701 Magnetometer: LEMI-120 LEMI-118 LEMI-152	Onshore, transition zone / Shallow to mid-depth targets
MMT & CSEM	KMS-870	on request	Seismic & EM included	Deep water ocean bottom imaging
Reservoir monitoring	KMS-820 & KMS-831	KMS-5100 100 or 150 KVA	Seismic: 3C or borehole 3C Electrode: LEMI-701 Magnetometer: LEMI-120 LEMI-118 LEMI-152 KMS-029 S20-air coil Shallow Borehole Tool KMS-888	Water-flood monitoring Porosity mapping in carbonates Monitor induced seismicity CO_2 monitoring Depletion monitoring

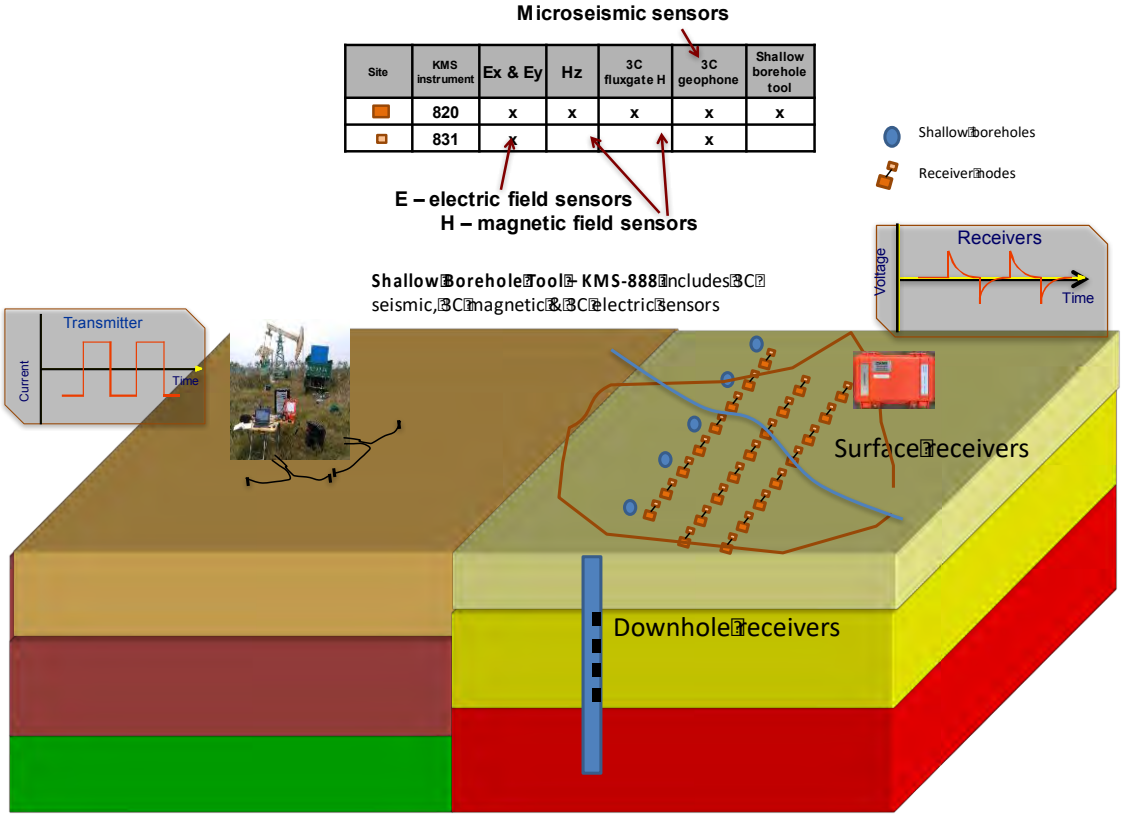
Reservoir monitoring layout

Reservoir monitoring has many different options. Since the reservoir changes are always 3D, careful design is required and multiple transmitter must be used to understand the 3D effects. We use at least two transmitters. Below are examples of the CSEM transmitters, receivers and a sample layout. (Colombo et al., 2010; Hu et al., 2008; Strack, 2010).

KMS recommends to carry out a 3D modeling feasibility including an on-site noise test as FIRST STEP. Below on the right is a typical noise test sensors layout in the field.



Survey layouts are usually designed as per specific objectives. The example figure shows a layout for **water-flood monitoring**. The



MT applications

Magnetotellurics (MT) and Audio MT (AMT) target different depths of investigation in hydrocarbon and geothermal exploration. For hydrocarbon exploration, high resistivity lithology such as salt, basalt, and over thrusting often mask underlying sediments. They are difficult to image with seismic data due to high velocities and diffuse scattering. But they can be easily imaged by MT or Lotem methods because of their associated large resistivity contrasts.

MT utilizes natural variations in the Earth's magnetic field as a source. Natural MT signals come from a variety of induced currents caused by thunderstorms and the ionosphere. The frequency ranges of MT data spans from 0.0001 Hz to 1,000 Hz and for AMT from 10 Hz to 20 kHz.

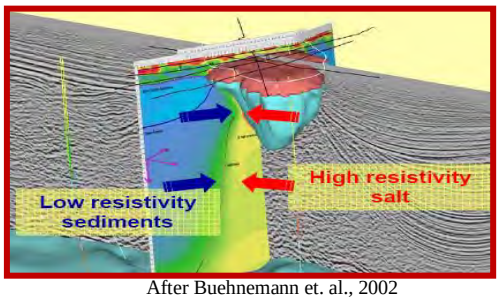
MT is usually used to map conductive zones like geothermal zones or sediment packages. To map resistors like a hydrocarbon reservoir you must use a grounded dipole transmitter (Passalacqua, 1983; Strack et al., 1889), which means you use Controlled Source Electromagnetics.

2D or 3D MT survey configurations

For large site count 2D and 3D MT or AMT surveys, the array configuration is more cost effective. The central control unit of the array can control several thousand recording units wirelessly. Standard distances are 5 miles without and – principally – unlimited with wireless relays.

Commercial benefits:

- Low cost for 2D or 3D MT and AMT surveys
- High speed sampling rate allow acquiring MT & AMT data with the same unit
- Fast and easy operation and deployment of multiple recording units
- Customized wireless system for remote system monitoring
- Designed for dense acquisition spacing for data redundancy & high resolution data recording



After Buehnemann et. al., 2002

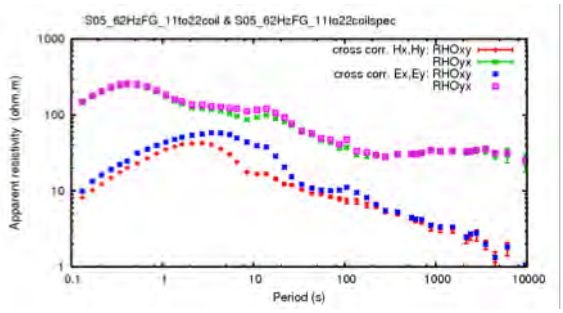
Low cost geothermal array application (AMT – MT)

For geothermal application, one often requires the high frequencies and only limited low frequencies. For this we developed a combination of array with sub-acquisition nodes and combined it with a low frequency fluxgate receiver (KMS-820 MT-Mini package). We are adopting here the concept of 3D bin based MT acquisition which uses limited magnetic field but dense electric field data. With the new broadband sensor LEMI-152, we have sufficient overlap with the fluxgate based site.

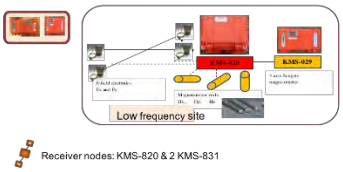
The AMT system includes an AMT or broadband coil. It records only for a few hours. The MT-Mini record for at least 6 hours or a full day. Magnetic fields from the fluxgate sensor and coil are matched (left figure below). In this case coil and fluxgate have been matched and shown the difference between the perpendicular components.

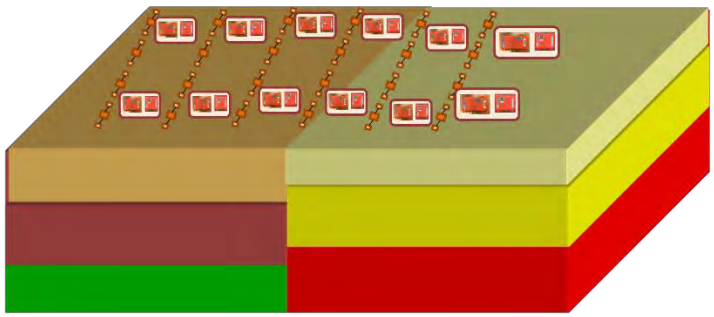
Advantage:

- Lower equipment cost
- Faster acquisition
- Consistent high quality data



AMT roving sites
LF MT – reference for basin depth





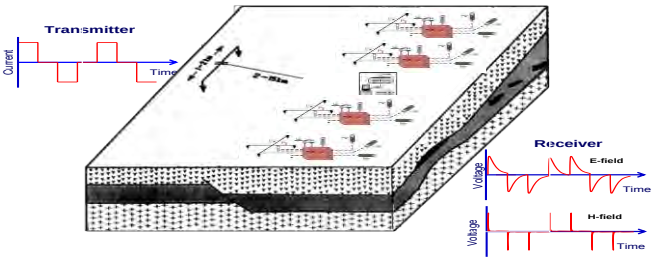
TFEM method

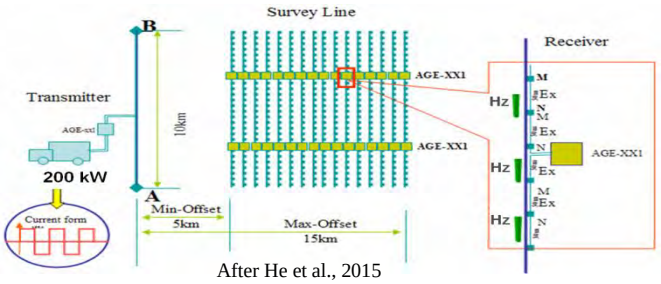
Time-Frequency ElectroMagnetics (TFEM) applies the Transient ElectroMagnetic (TEM) and Spectral Induced Polarization (SIP) techniques. It records broad-band frequency and time domain following a scheduled process.

An anomaly with the combination of high resistivity and high Induced Polarization (IP) can indicate an oil or gas reservoir. The high-power transmitter signal can penetrate the overlying formations to detect this oil and gas anomaly directly.

The layout comprises of a transmitter synchronized with the receivers. A frequency optimized high power square-wave current is injected into the ground by an electric dipole, allowing Ex (horizontal electric field) and Hz (vertical magnetic field) to be recorded.

The KMS array system includes scheduler and synchronization with transmitter to be able to follow any pre-defined transmission and acquisition sequence.





After He et al., 2015

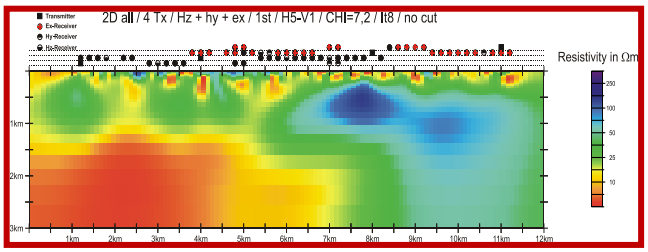
LOTEM method

The Long Offset Transient ElectroMagnetics (LOTEM) method is a Transient ElectroMagnetic (TEM) method in which a primary field is generated by a grounded current dipole. The signal transmitted by the dipole consists of a series of alternating step functions that create a collapsing field which in turn induces electric and magnetic fields in the conducting subsurface. Subsurface properties and features at great depth can be deduced by recording these fields at greater and greater distances from the transmitter during the off times. (Strack, 1992 & 1999)

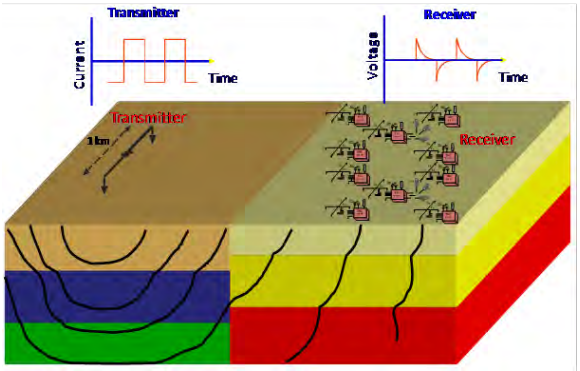
Using the KMS array system scheduling function and synchronization with multiple transmitters, the system can realize focused TEM applications, which allow for better volume focusing.

The LOTEM method can be applied to any of the following targets:

- Sub-basalt and sub-salt mapping (Strack and Pandey, 2007).
- Mapping of thin resistive layers, like hydrocarbons (electric fields).
- Determining conductive structures, like geothermal anomalies (magnetic fields, MT combined).
- Focused source EM (Davydycheva and Rykhlinski, 2009).

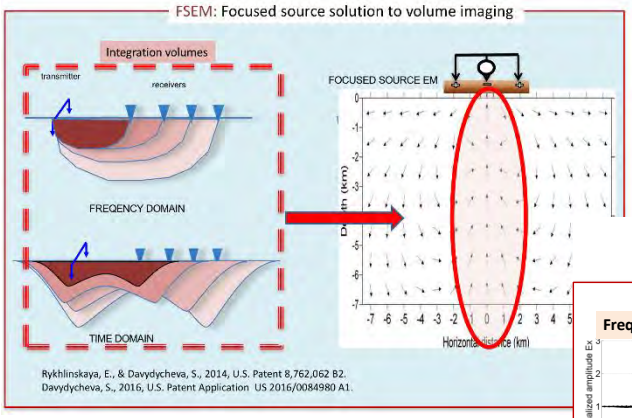


After Martin, 2009



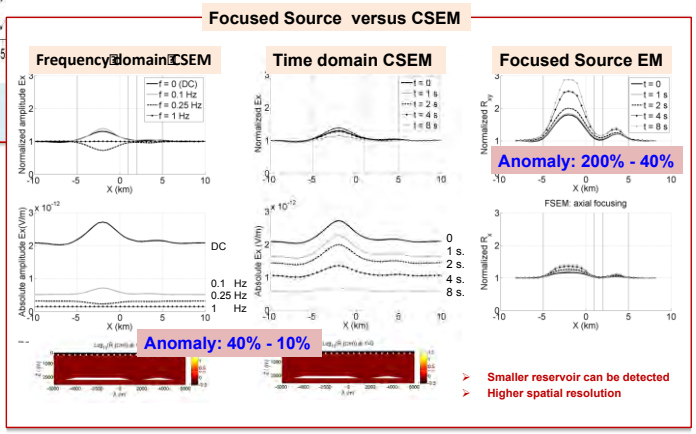
FSEM method

The differential Focused Source EM method FSEM (Rykhlinskaya and Davydycheva, 2014; Davydycheva, 2016) obtains an equivalent vertical electric field measurement. The vertical electric field Ez is more sensitive to deep and shallow resistors than the horizontal electric field, since such structures significantly affect the vertical current flow. It is possible to measure Ez in shallow vertical boreholes with the KMS-888 Shallow Borehole Tool. If borehole Ez measurements are unavailable, the FSEM method can help; it allows accurate determination of small vertical leakage of the electric current.



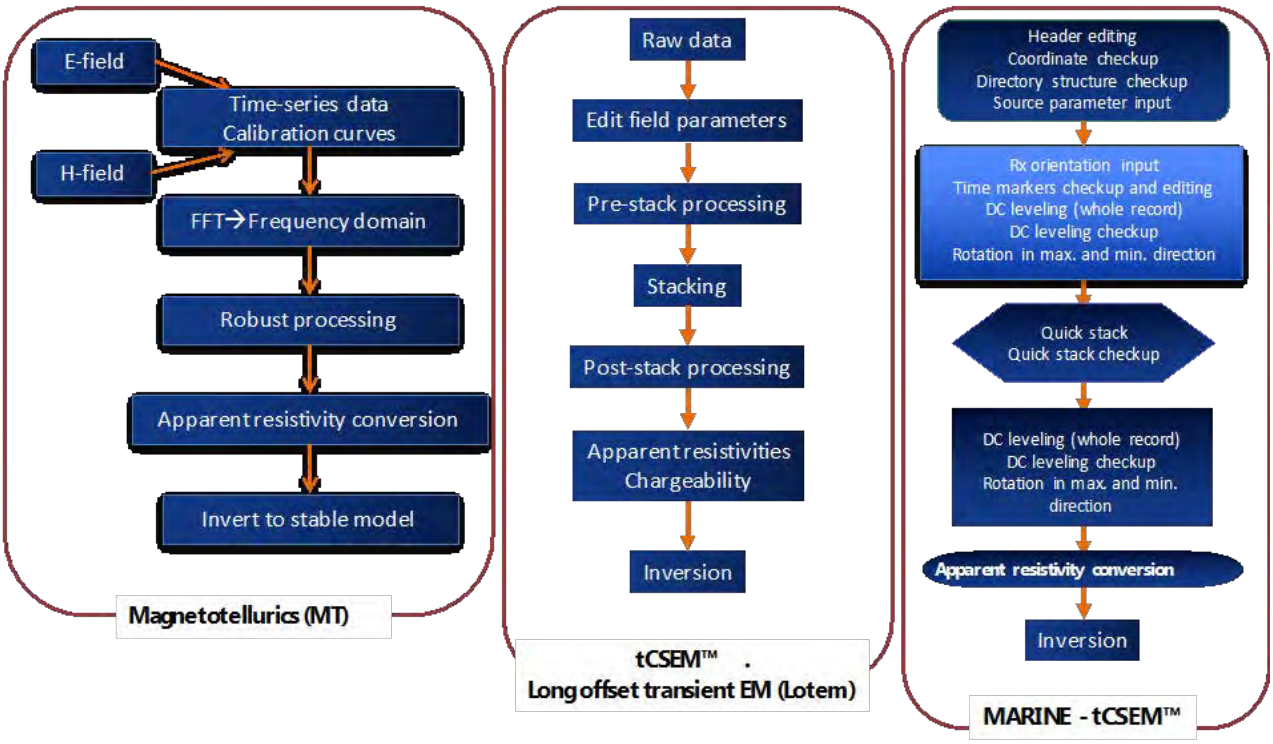
On the left the 2D sensitivity volumes for frequency and time domain are shown as a function of receiver-to-transmitter distance. On the right is the focused source EM current flow depicting that the information comes from below the receiver.

On the right, we have 3D modeling results simulating the response of an oil reservoir at 2 km depth. Frequency and time domain show anomalies between 10-40% while the FSEM anomaly is 40 – 200 %.



Acquisition (QA/QC) & processing software

The KMS-820 array system come with basic acquisition and monitoring software. Different products have different software policies. For magnetotellurics we work with the world's most experienced consultants and provide multiple software version for affixed price with the purchase. For Lotem and EM reservoir monitoring, we only lease the software due to the proprietary nature of the algorithms. All software is available in commercial versions and leads to 3D models of the data. Below is a flow chart of the software for magnetotellurics, Lotem and marine time domain CSEM. (tCSEM™)



Software deliverables:

- Magnetotelluric: Robust processing – EDI files, 1-D inversion – sections; Options: 2-D & 3-D inversion software and custom modeling services.
- Lotem: Robust CSEM processing (time or frequency); Microseismic & EM data separation – SEGY files; Apparent resistivities – ASCII files, time lapse section; 3-D modelling software and custom modeling services. LEASE only
- TFEM: Robust CSEM processing (time or frequency); Apparent resistivities – ASCII files, time lapse section; 3-D modelling software and custom modeling services. BETA RELEASE only

Software license options:

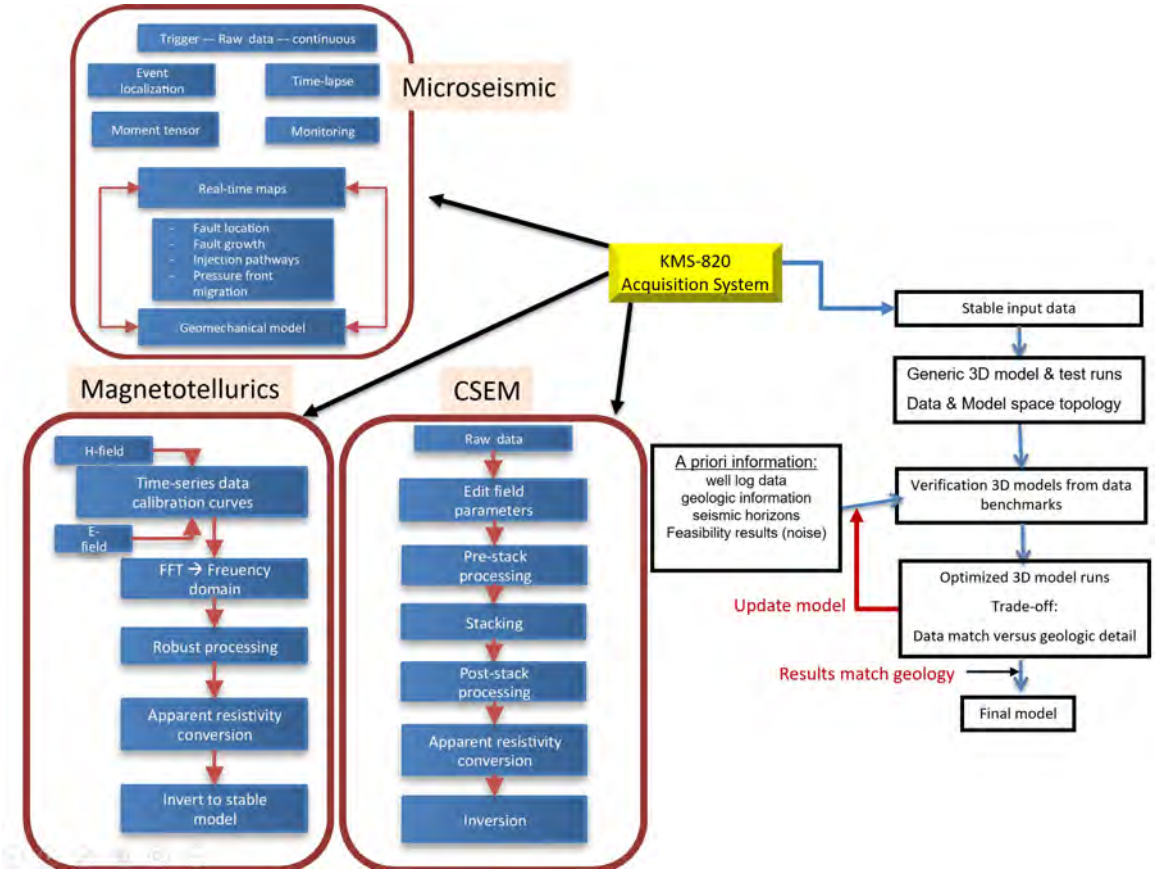
- KMS-200-A: Acquisition software only
- KMS-200-AP: Acquisition software plus MT processing (Egbert Robust and KMSPro MT)
- KMS-200-IX1D: Acquisition software plus IX1D inversion
- KMS-200-TX: Transmitter control software only
- KMS-200-TXP: Transmitter control software plus tCSEM processing (lease only)

Integration with Microseismics

The KMS-820 array data acquisition system has - from the ground up - been conceptualized as a next-generation, integrated data gathering unit. Today, this data integration has reached into the multi-physics domain. By combining the data acquisition of seismic and electromagnetic signals in a single unit we can take advantage of the strong synergy and complimentary nature of electromagnetic and microseismic data and enrich their interpretation.

Integrated acquisition of electromagnetic (EM) and microseismic data provides a unique tool to help reduce risk and improve productivity in reservoir monitoring. For example, in enhanced geothermal systems (EGS) microseismic monitoring allows for the imaging and visualization of active fracture networks within developing and producing EGS, while the EM response will differentiate the heated fluid flow regimes. This outlines active and potential future commercial EGS areas.

For optimized and safe field operation this means that any combination of electromagnetic measurements (MT, CSEM, TEM, etc.) and microseismic data (surface- or borehole-based) can be performed simultaneously and cost effectively. A single acquisition field unit ensures complimentary, time-synched data for enriched data processing and interpretation workflow options.



Networking feature

In addition to SD card swapping and wired connection, the KMS-820 has multiple wireless options.

1. The KMS-820 array data acquisition system default is 900 MHz long range wireless; the laptop transceiver is quoted separately.
2. An additional Wi-Fi chip is available; this allows the unit to be controlled from any Wi-Fi enabled laptop computer or router with Wi-Fi.
3. A full network kit - KMS Wi-Fi interface box - can be added, which includes: LAN and WAN, Bluetooth, HDMI, keyboard and monitor channels.

KMS Wi-Fi chip feature:

- Standard Wi-Fi; any Wi-Fi device can connect (laptop, tablet, phone).
- Ad hoc protocol (peer to-peer).
- Server mode (KMS-820 to server).
- Operating temperature up to + 85 C.
- Multiple units operation available.
- Complement KMS-820 native long range wireless.

KMS Wi-Fi interface box features:

- Separating data acquisition of KMS-820 from networking data delivery (less acquisition interrupts, FIREWALL, faster delivery).
- Unlimited expansion of data storage (via multiple USB ports).
- Custom processing power for specific on site processing.
- Full implementation of the TCP/IP stack, support to most of the low-level communication protocol (UART, I2C, SPI, etc.).
- Ability to provide 100 Mbps throughput.
- Optional support to external display unit (HDMI).

Since we always recommend large oversampling, we suggest to acquire large data volumes. Networking makes sense with a small number of units, because copying the data in the field takes time. If you sample many channels at 1 kHz or larger, field operations are most efficient using SD card swapping. The KMS SD card can be hot swapped at 40 KHz sampling rate.

3D modeling & inversion software

For technology/system design and survey feasibilities, KMS Technologies provides a variety of unique electromagnetic modeling & inversion software. The full suite of 3D modeling and inversion software covers the following applications:

- **Magnetotellurics**: modeling and inversion suite **ModEM** developed in alliance with ModEM Geophysics Inc. and Oregon State University (Egbert). This software is used by over 80 users around the globe and can be run on the KMS cluster, either by the user or by KMS staff.
- **Transient EM** marine/land modeling & inversion software **IX1D** to interpret time-domain data.
- **Transient and frequency-domain CSEM and borehole applications:** we offer 3D forward modeling licenses and services using a full 3D anisotropic modeling family: **MAXANIS**; parallel versions can also be run on the KMS cluster.

See KMS Technologies website for the latest at http://kmstechnologies.com/3D_modeling_services.html

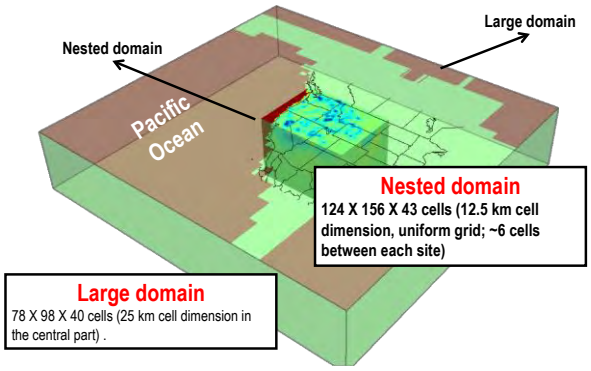
3D modeling & inversion software ModEM

KMS Technologies in alliance with ModEM Geophysics Inc. is providing electromagnetic modeling code for magnetotelluric and CSEM (land and marine) applications. The code is under license from OSU (Oregon State University) to ModEM Geophysics Inc., Prof. Egbert's (principal author).

ModEM 3D modeling is used by over 80 users around the globe. It has been working on the KMS cluster since 2015.

ModEM is a modular system of parallel computer code for inversion of electromagnetic (EM) geophysical data, developed over the past decade at Oregon State University. The code is structured as a flexible system, adaptable to a range of EM geophysical data types, supporting a range of inverse problem solution strategies, and regularization models. ModEM has primarily been applied to 2D and 3D magnetotelluric (MT) applications, with some initial tests on frequency domain controlled source EM (CSEM) problems, and on joint inversion of multiple EM method datasets. A version of the code – custom-made for 3D MT problems – has been released to the academic community, and there are now over 80 registered academic users worldwide.

Ancillary tools are available to support an efficient inversion set up, and post-processing visualization.



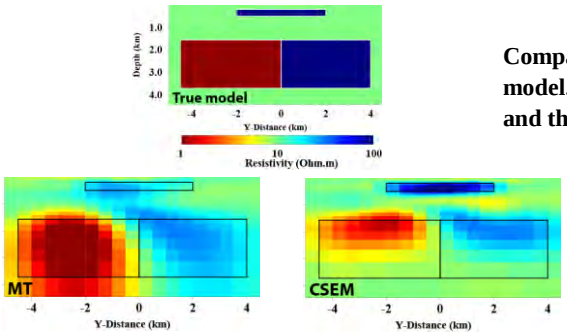
Example of a complex 3D model including detailed model with a large-scale background 3D model.

Data input:

- Apparent resistivity data or spectra in EDI format (other format available)
- Geological constraints
- Static shift values for each site (optional)
- Topography or bathymetry

Standard outputs:

- 3D model with visualizer
- Models and inversion results
- Data match & risk estimates



Comparison between inversion of a 3D MT and CSEM model. The CSEM defines the top boundary of the body and the MT the size of the structure.

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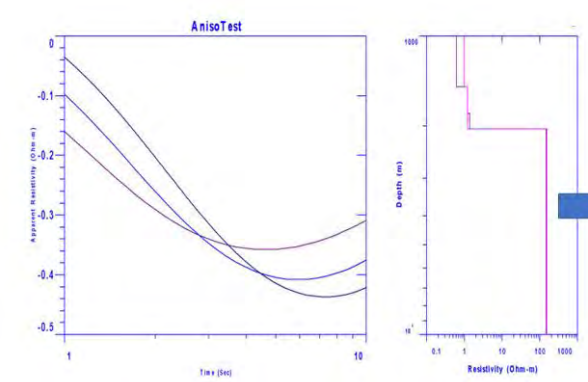
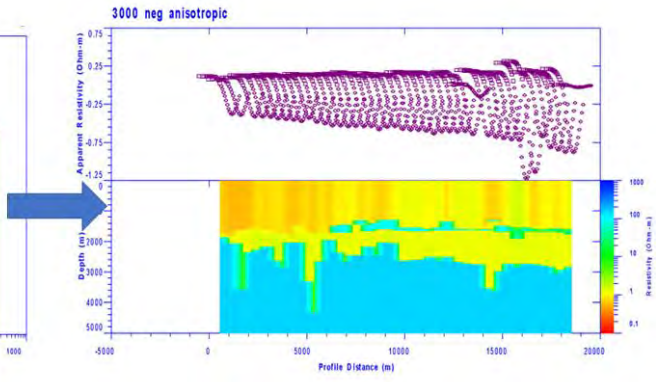
IX1D tCSEM modeling & inversion

IX1D-tCSEM™ is a marine/land electromagnetic (EM) interpretation software that performs 1D DC resistivity, induced polarization (IP), magnetotelluric (MT), transient EM and electromagnetic sounding and inversion.

- Data and models can be imported from and exported to ASCII files.
- Well log data can be imported, and number of layers can be reduced.
- Graphics are exported in DFX, CGM, or WMF formats.
- Multiple soundings can be displayed in a single database file.
- Allows fixing resistivity and/or depth for inversion calculations.
- Ridge regression or Occam's inversion can be calculated.
- Bostick and Niblett inversions can be calculated from MT data.
- All time apparent resistivity can be used for Lotem data.
- Layered model, smooth model, equivalence analysis, or all three of these can be displayed in a sounding window.
- TEM/MT/AMT joint inversion capability for marine/land MT, CSEM and tCSEM™.
- Supports anisotropy models for MT and CSEM applications.



Model Suite window showing 3 curves for varying offsets with the same anisotropic model.



Display of inline E data with apparent resistivity displayed as curves on a Zaborovsky plot and smooth model displayed as colored section.

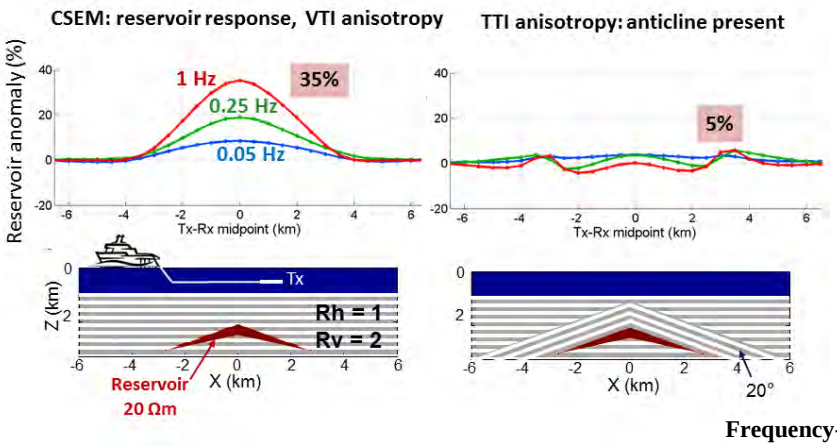
3D modeling family MAXANIS™

For technology/system design and survey feasibilities, KMS Technologies provides a variety of electromagnetic modeling software, mostly for CSEM (land and marine), surface, surface-to-borehole, and borehole environments. All codes were developed in-house by 3DEM Holding LLC and merged with KMS Technologies in 2016.

The 3D modeling software family MAXANIS™ is used by several industry users including Baker Hughes, Shell, Weatherford, EMGS & Schlumberger. Fast and reliable, MAXANIS™ handles hydrocarbon reservoirs with arbitrary anisotropic resistive media and complex structural interfaces. This provides a crucial contribution to the success of EM technology in addressing the needs of the exploration & production industry.

MAXANIS™ core technology is based on proprietary 3D EM finite-difference (FD) modeling software that has been rigorously tested, validated and benchmarked. The software can be applied for most 3D electromagnetic problems whether located in borehole, land, or marine environments. It incorporates complex terrains, seafloor bathymetry, subsurface geology, arbitrary 3D anisotropic resistive media and much more. This best-in-class software is proven to be more robust at much faster execution times than comparable products.

Fast parallel versions of the MAXANIS™ family software are available to run on the KMS cluster (self-use or as service); licenses available, including technical support & training.



Frequency-domain CSEM application with synthetic 3D reservoir and arbitrary TTI (tilted transverse isotropic) versus VTI (vertical TI) anisotropy.
Reservoir anomaly affected by the anticline.

Data input:

- Adapted project specific
- Treatment of air/Earth/water interfaces w/ topography & bathymetry

Standard outputs:

- 3D model with visualizer
- Models & curves as per customer requirements

MARINE & LAND 3D EM MODELING SOFTWARE

MAXANIS™	General 3D FD EM modeling software, arbitrary 3D anisotropy.
Applications:	CSEM in **frequency-** and **time-domain**.
	Surface-to-borehole EM: **effect of steel casing** can be included.
	FSEM (Focused-Source EM) in frequency- and time-domain MT.
	Ground-Penetrating Radar (GPR).

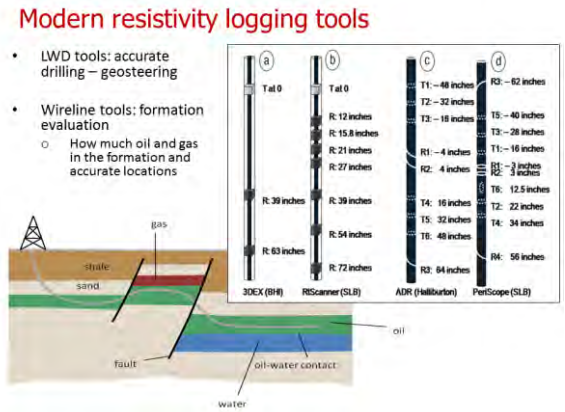
BOREHOLE 1D-2D-3D EM MODELING SOFTWARE

MAXANIS™ General 3D FD modeling software, arbitrary 3D anisotropy.
Applications: Resistivity LWD and induction measurements.
General time-domain measurements.
Galvanic tools (DC).
Cross-well & Surface-to-borehole measurements (restricted).

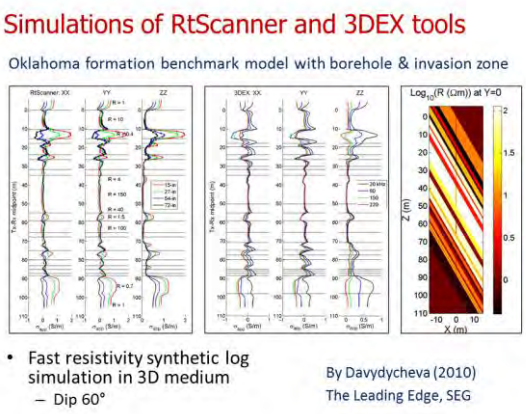
3DEMcyl 3D modeling software in cylindrical coordinates.
General resistivity LWD and induction measurements.
Effect of finite-size coils can be included.

2DEMcyl 2D modeling software in cylindrical coordinates.
General resistivity LWD and induction measurements.
Effect of finite-size coils can be included.

MAXAN1D Fast 1D modeling of resistivity LWD and induction logging.
Arbitrary biaxial anisotropy (fractured formation).



New-generation triaxial induction (a, b) and resistivity LWD tool models (c, d).



Triaxial induction tool response simulation

Benchmarks*

- **Time-domain land/marine EM survey**: see Davydycheva et al. (2006), Davydycheva and Rykhlinski (2009; 2011), Davydycheva et al. (2015).
- **Frequency domain Controlled-Source EM and Magnetotelluric surveys**: see Davydycheva and Rykhlinski (2009; 2011), Frenkel and Davydycheva (2009), Zaslavsky et al. (2011), Frenkel and Davydycheva (2012), Davydycheva and Frenkel (2013).
- **Ground-penetrating radars and near-surface EM application for detection of clandestine tunnels**: see Frenkel and Davydycheva (2010).
- **Conventional induction well-logging**: see Anderson et al. (1999).
- **Triaxial induction logging**: see Davydycheva et al. (2003), Rosthal et al. (2003); Barber et al. (2004); Abubakar et al. (2006), Wang et al. (2006), Wang et al. (2008), Davydycheva et al. (2009), Davydycheva (2010a; 2010b), Davydycheva (2011a; 2011b), Davydycheva et al. (2014).
- **Full 3D inversion of triaxial induction logging data**: see Abubakar et al. (2006), Wang et al. (2008), Davydycheva and Kaminsky (2016).
- **Resistivity logging-while-drilling**: see Anderson et al. (1997), Davydycheva (2010a; 2010b), Pour et al (2011), Davydycheva (2011a; 2011b)
- **Cross-well and surface-to-borehole EM**: see Zaslavsky et al. (2011), Strack et al. (2016), Davydycheva et al. (2017).
- MAXANIS and 3DEMcyl have been used by Baker Hughes, Schlumberger and Weatherford for logging tool design.

* Full references & papers can be found in the bottom of http://www.kmstechnologies.com/KMS_flyer_archive.html#Publication

Application history - references

Since 2010, the KMS-820 array data acquisition system has been used in: Argentina, Azerbaijan, China, Germany, Kenya, India, Indonesia, Israel, Italy, Saudi Arabia, Slovakia, Thailand, and Ukraine, USA (CA, CO, HI, NV, and TX).

Applications include magnetotelluric, audio-magnetotelluric, Lotem, microseismic (intrusion monitoring), bottom hole-to-surface communication, and marine CSEM.

Please check our website for an updated list of publications: http://www.kmstechnologies.com/KMS_flyer_archive.html

The system and methods are covered by various patents – see our website for the latest list. KMS provides their clients a license to the respective patents.

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- Strack, K.M., Thomsen, L. A., and Rueter, H., 2007, Method for acquiring transient electromagnetic survey data, **US 07203599.**
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- Rykhlinskaya, E., and Davydycheva, S., 2014**,** Method for marine geoelectrical exploration with electrical current focusing**, U.S. Patent 8,762,062 B2**.
- Davydycheva, S., 2016, Method and apparatus for detecting and mapping subsurface anomalies**, U.S. Patent Application US2016/0084980 A1.**
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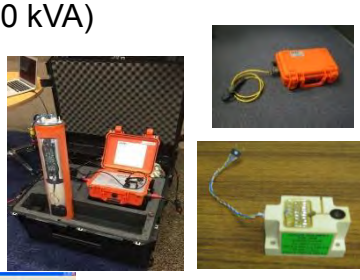
KMS Technologies
Innovating Solutions

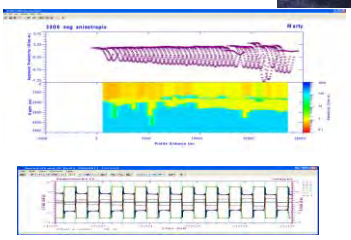
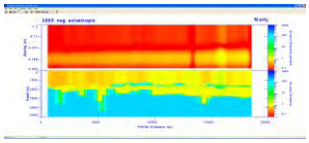
>15 years of advanced Electromagnetic (EM) methods for the Oil & Gas and Geothermal industries

KMS Technologies provides hardware, software and services

Product overview - hardware

- KMS-820 - Array acquisition unit for MT, CSEM & microseismic
- KMS-831 - Channel expansion module
- KMS-5100 - High power CSEM transmitter (100, 150 kVA)
- KMS-888 - Seismic & EM shallow borehole tool
- EM sensors
  - Induction coils
  - Electrodes
  - Fluxgate magnetometers
  - Borehole tools


Product overview - software

- 3D modeling
- Survey design & acquisition QC
- Data processing

Product applications

- Land and Marine Controlled Source EM (CSEM)
- Land and Marine Magnetotellurics (MT)
- EM & microseismic reservoir monitoring
- Geothermal

Services

- Feasibility studies
- Custom R&D projects
- Boutique acquisition services
- Product development & manufacture
  - Hardware
  - Software

Offices in Germany, Thailand & Ukraine

Fluxgate magnetometers:


LEMI-011


LEMI-017


LEMI-018


LEMI-019


LEMI-020


LEMI-024


LEMI-025

LEMI-029


LEMI-035

Induction coils:


LEMI-118


LEMI-120


LEMI-121


LEMI-123


LEMI-142


LEMI-030

LEMI-152

Electrodes:


LEMI-701

Applications:

- Land & marine CSEM
- Marine magnetotellurics
- Land magnetotellurics
- Permanent sensors
- Airborne sensors

Fluxgate magnetometers:

LEMI-011
Low power 3-components fluxgate magnetometer. Frequency (DC-20 Hz)

LEMI-017
Autonomous Meteomagnetic station with 7 channels. Frequency (DC-0.3 Hz)

LEMI-018
Vector magnetometer for the precise measurements of Earth magnetic field with several sensor options.

LEMI-019
Ultra-low power fluxgate featuring two analog outputs: filtered (0.002-5 Hz) & unfiltered (DC-15 Hz)

LEMI-020
Smallest volume compensated fluxgate sensor, with low non-orthogonality, low noise, high resolution. Frequency (DC-100 Hz).

LEMI-024
Low power 3-components & highly sensitive analog fluxgate magnetometer. Frequency (0.003-10 Hz)

LEMI-025
Fluxgate magnetometer for super stable measurements of 3-component Earth magnetic field with new 1-second INTERMAGNET. The only commercially available product in this class. Frequency (DC-3.5 Hz)

LEMI-029 32-bit digital
Low noise fluxgate magnetometer with exceptional low-frequency stability. Frequency (DC-180 Hz)

LEMI-035
High resolution and precision low noise magnetometer with both digital and analog outputs. Frequency (DC-20 Hz)

Induction coils:

LEMI-118
High frequency induction coil (1-70 kHz)

LEMI-120
Broadband induction coil (0.0001- 1 kHz) with the lowest noise in class.

LEMI-121
Low power, very low noise & compact. Frequency (0.0001-500 Hz), marine EM

LEMI-123
Low noise, low power & compact. Frequency (1 Hz -1 kHz), high frequency marine EM

LEMI-030
Three magnetometers with communication unit, intended for study of magnetic field fluctuations. Frequency (0.001 – 30 Hz)

LEMI-142
High sensitive magnetometer with low noise Frequency (1 – 500 kHz)

LEMI-145
Extremely low noise, low power & lightweight. Frequency (0.004-10,000 Hz)

LEMI-152 New
Super broad band coil. Frequency (0.00025-10,000 Hz)

Electrodes:

LEMI-701
Ultra-low noise non-polarizable electrodes (Cu-$CuSO_4$), matched pairs

KMS Technologies – KJT Enterprises Inc.
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Email: info@KMSTechnologies.com

Offices in Germany, Thailand & Ukraine

Array acquisition unit for MT & microseismic
KMS 820

Product features

- Low-power design for long recording time
- Long-range wireless
- Wi-Fi
- Bandwidth : DC - 50 kHz
- Up to 80 kHz sampling rate
- Six 24-bit GPS synchronized channels
- With 32-bit remote acquisition controller
- Unlimited digital channels expansion
- Low noise & low drift input amplifiers
- Portable & lightweight
- Ruggedized design for field application
- Acquisition & monitoring software included
- Processing software for MT & CSEM
- Low cost

Product applications

Land ElectroMagnetics (EM)

- Acquisition: Magnetotellurics (MT), Lotem, CSAMT, Induced Polarization
- EM transmitter controller
- System response recording (time domain)
- EM survey in array configuration

Marine EM

- Transition zone transmitter & monitor
- Source controller & environmental monitor (current & one field component)
- Marine EM version

Land seismic

- Special high bandwidth applications
- Passive microseismic monitoring for regional & local seismic activities
- Seismic security surveillance

General lab measurement

- General acquisition system
- Electrode long term stability
- Custom versions available

KMS Technologies – KJT Enterprises Inc.
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Houston, Texas 77079
Tel.: USA +1.713.532.8144 Fax+1.832.204.8418
Email: info@KMSTechnologies.com

Offices in Germany, Thailand & Ukraine

Product features

- Maximum output: 100, 150 or 200 kVA
- GPS synchronized timing control
- Long-range wireless for remote control & monitoring
- Linear ramp better than 5 µs turn off characteristic
- Bi-polar reversing ramp time < 20 µs
- Suitable for time domain EM (TDEM or LOTEM), induced polarization (IP), TFEM, FSEM etc
- Target depth of 600 m or deeper
- Ideal for deep EM geophysical applications 2-4 km
- Grounded dipole or loop source
- Integrated in KMS array system via KMS-820-T
- Controller has 6 analog & (unlimited) digital channels
- Ruggedized design for field operations
- Data is saved to SD card (16-32 GB)

150 kVA

100 kVA

Product specifications

Current waveform	*Reversing polarity square (100% duty cycle) or bipolar with off-time (firmware selectable from 0.001 Hz to 1000 Hz). Other waveform can be generated by controller*
Transmitter type	*Dipole source or loop source*
Maximum output current	*Limited to 125 A unipolar, 250 A bi-polar (**100 kVA** version) Limited to 175 A unipolar, 350 A bi-polar (**150 kVA** version) Limited at 240 A unipolar, 480 A bipolar (**200 kVA** version)*
Maximum output voltage	*1000 V*
Input voltage	*480 - 600 VAC at 50/60 Hz*
Frequency range	*0.001 - 1 kHz*
Current recording sampling rate	*< 80 kHz, same as receiver acquisition sampling-rate*
Maximum power output	*100/150/200 kVA at 25° C*

Output measurement	*24 bit KMS-820 with KMS-831 up to 32-bit*
Dimensions	*KMS-5100-100: 0.7 m x 0.9 m x 1.01 m (W x H x D) (14U)*
Operating environment	*-20° C to 50° C -35° C to 50° C (storage)*
Weight	*KMS-5100: 30 kg (switchbox only), for 150 kVA = 90 kg and 200 kVA = 120 kg.*
Duty cycle	*100%, 50 %, 33%, 25%, variable*
User interface	*Long range wireless, 802.11, USB, cable or USB*
Standard packaging	*Unit in field container shipped in ruggedized large transport container*

KMS Technologies – KJT Enterprises Inc.
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Offices in Germany, Thailand & Ukraine

LEMI-026 DRONE fluxgate magnetometer

Product description

Fluxgate magnetometer (FG) LEMI-026 was developed for the super sensitive magnetic field measurements for the use in drones or other moving applications. The autonomous fluxgate magnetometer precisely measures the three components of the Earth's magnetic field both in motion and as a reference base. It includes a low power data logger.

It may be used for autonomous measurements with moving carriers (e.g., drones) or included as part of a sea/land station. Featuring two-component tilt-meters and GPS antenna, the sensor allows for precise measurement timing, magnetometer coordinates, altitude and attitude during movement. These data are stored in an SD memory card.

Product description

- Operation in movement
- High resolution and precision
- Low noise
- Low temperature drift
- Two tilt measurement channels
- Temperature measurement channel
- Low power consumption
- Shockproof housing

LEMI-026 system with and without housing cover

Product specifications

Magnetic field range	± 70000 nT
Frequency range	DC...100 Hz
Sampling	250 Hz
Noise level at 1 Hz	<0.1 nT/SQRT(Hz)
ADC	32 bits
Tilt-meter range	±30°
Tilt-meter resolution	0.01°
Operating temperature range	-20... + 60°C
Power supply voltage	5 + 0.25 V
Maximal power consumption	< 1.2 W
Recording time with 1900 mAh internal battery	5 h

GPS Receiver	
Timing accuracy	<100 ns
Maximal data rate	10 Hz
Auxiliary digital interface	USB
SD card flash memory	8 GB
Weight (with internal battery):	1.25 kg
Dimensions	96 x 96 x 270 mm

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Past clients

Summary Client List:

Aramco – Saudi Arabia, Anadarko – Texas, Apache—Texas, Baker Hughes (US & Europe), British Geological Survey - UK, BP – Texas, CGG – Mexico, Chevron – California, CNPC – China, ConocoPhillips- Texas, EMGS- Norway, EMI – California, GDC – Kenya, Geokinetics, Geoelec –Mexico, ENI – Italy, Geosystems – Italy, ION, Mannvit – Iceland, ORMAT – Nevada, PDO – Oman, PTTEP—Thailand, OMV – Austria, Petroalliance – Russia, Oyo-Geospace – Texas, Philips – Oklahoma, Proingo, Argentina, RXT – Norway, RWE-DEA – Germany, Schlumberger Technology Corporation - Texas, Shell – Texas, Sinopec-China, Welldynamics – Texas, WINS ASA—Norway, Wintershall (Germany & Libya)

Hardware sales in > 20 countries

Research organizations in: Australia, China, Germany, India, Indonesia, Malaysia, Mexico, Thailand, Ukraine, USA (TX, CA, CO, LA, OK, MA, NH, NM, NV, Laser Interferometer Gravitational-Wave Observatory (**LIGO**))

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