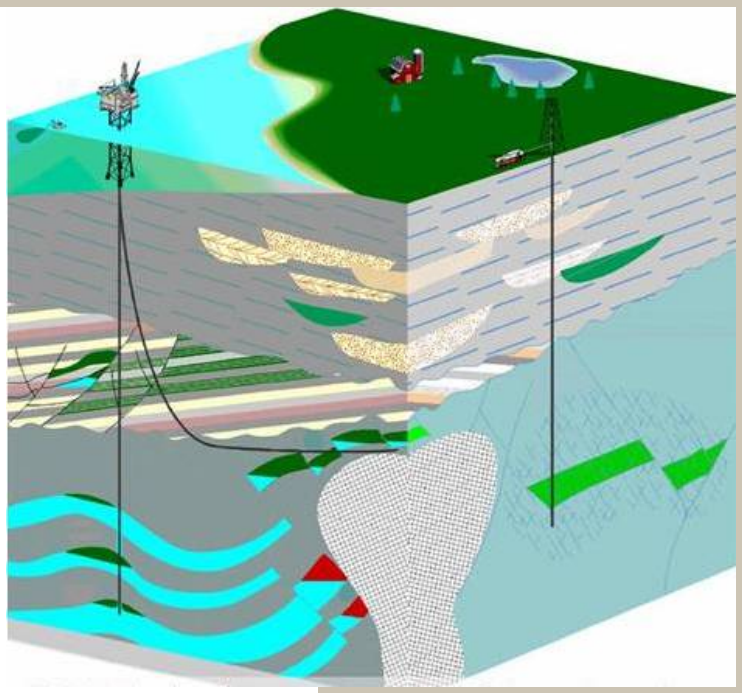
KMS Technologies

Innovating Solutions

KMS Company Overview




KMS

WELCOME

Dear Customer:

KMS Technologies is proud to outline to you the wealth of product and services accumulated of the past 18 years since the company was formed:

Our Mission is:

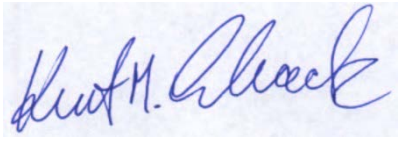
Provide exploration & reservoir monitoring technology to the oil/geothermal industry by focusing on innovative sensors & integrated interpretation for exploration, appraisal & production monitoring of hydrocarbons/geothermal resources.

While most of our emphasis is on technology development, we are delivering EM data acquisition system worldwide and they have been used in well over 20 countries. With our joint venture for sensor development, LEMI, in even many more countries.

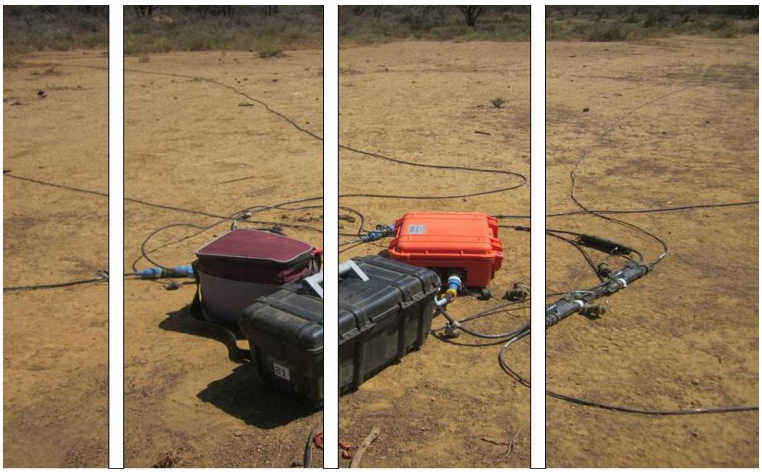
Here we will give you a **Quick Overview** of our company, followed by a summary of our MT family of MT systems and then the **Array Acquisition System**, KMS-820, which is used for magnetotellurics, microseismic, and controlled source electromagnetics. We then show **New Products** followed by some sample **Technology Summaries**.

For more information please go to www.kmstechologies.com or www.lemisensors.com.

Dr. Kurt Strack



President, KMS Technologies



Vision

To make electromagnetics (EM) in general & time domain-controlled source electromagnetics (tCSEM™) as routine tools in hydrocarbon exploration & production fully integrated with seismic. To use the technology for monitoring of water & steam-flooding of hydrocarbon reservoirs and production of geothermal reservoirs. Our products support borehole, land and marine real-time applications. Our services complement our technology offerings.

Quick Overview

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

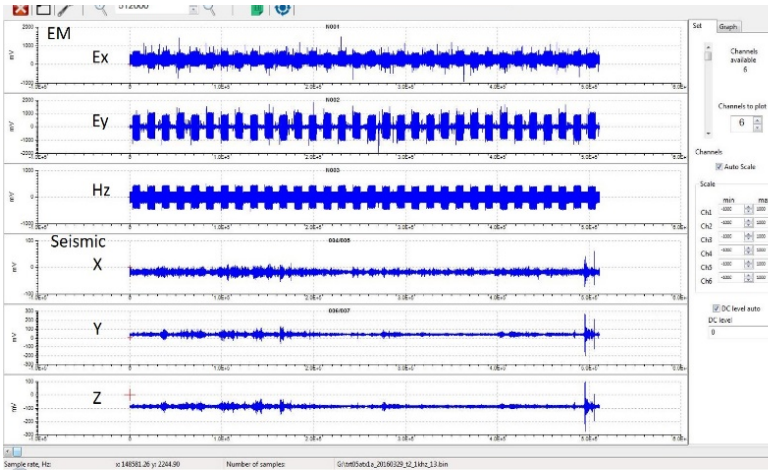
- Land 100 kVA or 150 kVA
- Transition zone
- Marine (custom)

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

Fluxgate & induction coil magnetometers

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)*
- *WI-FI (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*
- *Ruggedized design for field application*
- *Low-cost*

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

Magnetotelluric (MT) systems

KMS Technologies provides variety of Magnetotelluric (MT) systems, these systems are customized, fit for purpose and save cost. Most systems work with NOISE-FREE web access box, which offers real-time data access from anywhere in the world, fast in field results, and remote QA/QC. Please see system features & specifications below.

1. LEMI-424 MT system

- Lowest power consumption - <0.35 W
- Frequency band – DC - 0.5 Hz
- Crustal investigations; Used by US MT array

2. Mini-MT system

- Low power consumption - <5 W
- Frequency band – DC - 180 Hz
- Crustal investigation; MT & CSEM
- MT system in a suitcase < 30 Kg

3. Super broadband MT system

- Low power - <5 W
- One coil for MT & AMT
- Frequency band - 0.00025 - 10,000 Hz
- MT, AMT, CSEM
- Industrial system for operational efficiency

4. Standard MT system

- Low power - <5 W
- Frequency band - 0.0001 - 1,000 Hz
- Crustal investigation, MT, CSEM

5. MT/AMT system

- Low power - <5 W
- MT Frequency band - 0.0001 - 1,000 Hz
- AMT Frequency band – 1 - 70,000 Hz
- Lowest noise operation

6. MT MAX system – 11 channels

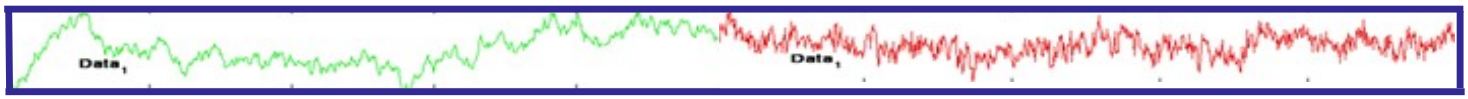
- Low power - <5 W
- MT, AMT, and Fluxgate sensor included

Magnetotelluric (MT) systems advantages

- Customized, fit-for-purpose saves cost
- Smooth, switch-free single time series (no band limited acquisition)
- Easy, windows-driven operation
- Real-time data access from anywhere using **Noise-free web access**
- Fast in field results
- Remote QA/QC and calibration
- On site automated data processing
- Autonomous recording MT/AMT etc via scheduler

Specifications

System	Frequency band	Noise	Components	Comments
LEMI-424	DC - 0.5 Hz	≤ 10 pT/√Hz @1 Hz	LEMI-424 & Fluxgate Various options	Lowest cost, standard for research applications
Min-MT	DC - 180 Hz	≤ 6 pT/√Hz @1 Hz	KMS-820 & Fluxgate	MT system in suitcase. ENTRY LEVEL system
Broadband MT	0.00025 - 10,000 Hz	≤ 0.3 pT/√Hz @1 Hz	KMS-820 & LEMI-152	Cost effective for industrial operational
Standard MT	0.0001 - 1,000 Hz	≤ 0.1 pT/√Hz @1 Hz	KMS-820 & LEMI-120	Lowest noise system
MT/AMT	0.0001 - 1,000 Hz (MT)	≤ 0.1 pT/√Hz @1 Hz	KMS-820, LEMI-118, & LEMI-120	Standard system for many years
	1 - 20,000 Hz (AMT)	≤ 5 pT/√Hz @1 Hz		
MT MAX	DC - 70,000 Hz	≤ 6 pT/√Hz @1 Hz ≤ 0.1 pT/√Hz @1 Hz ≤ 5 pT/√Hz @1 Hz	KMS-820, Fluxgate, LEMI-120 LEMI-118	All in one MT solution



Product overview

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

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.

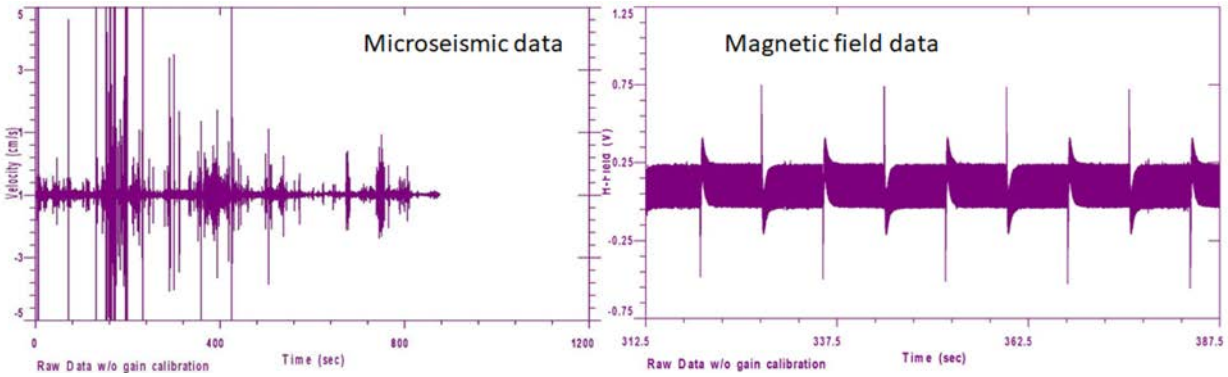
In addition, the KMS-820 can be used to control the KMS-500 marine or the KMS-5100 land transmitter. Multiple communication and data harvesting options exist: USB cable, SD card exchange, long range wireless, Wi-Fi via router (when available), and Wi-Fi point-to-point direct connections. LAN is optional.

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)
- High sampling rate to adapt to various geophysical methods (24-bit to 80 kHz, 32-bit to 4 KHz)

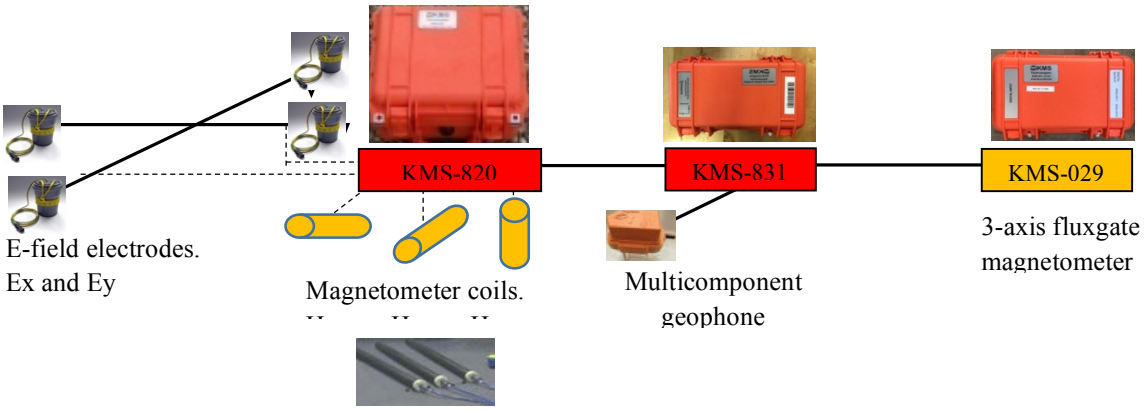


Main components

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.

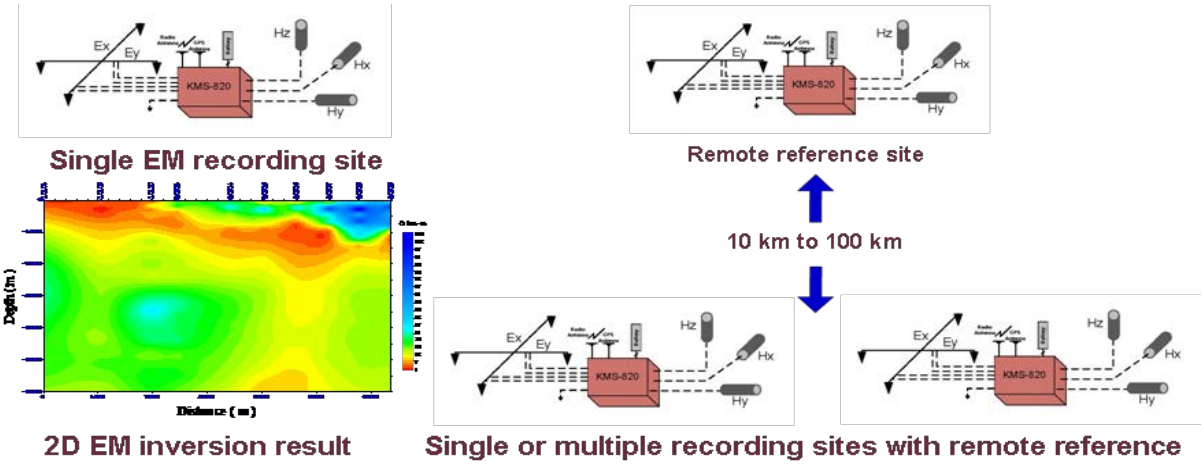


Applications

- Reservoir monitoring
- Oil and gas exploration (land & marine)
- Hydrocarbon reservoir dynamics & CO_2 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.

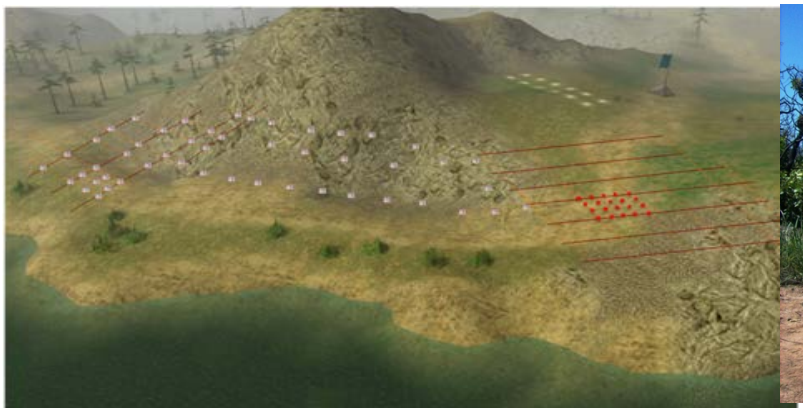
3D EM/seismic array layouts

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.



Controlled source transmitter can be added to this at desired locations.

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

System configuration table

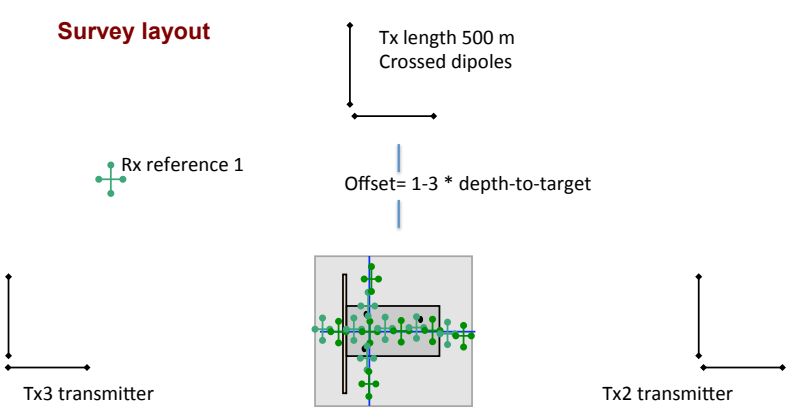
The following table shows the various system configuration options for different surveys and applications. System components can be mixed and matched in a modular fashion. Seismic sensors can be added to each configuration. Each configuration is expandable by adding more KMS-831 sub-acquisition controller.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

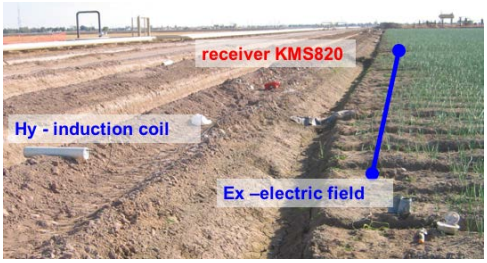
Survey	Receiver	Transmitter	Sensors	Applications / Depth
MT	KMS-820 & KMS-831	N/A	Electrode: LEMI-701 Magnetometer: LEMI-120 LEMI-118 LEMI-152 KMS-029	Onshore / Deep targets & basin study
CSAMT	KMS-820	KMS-500	Electrode: LEMI-701 Magnetometer: LEMI-118 LEMI-152	Onshore, transition zone / Shallow targets
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

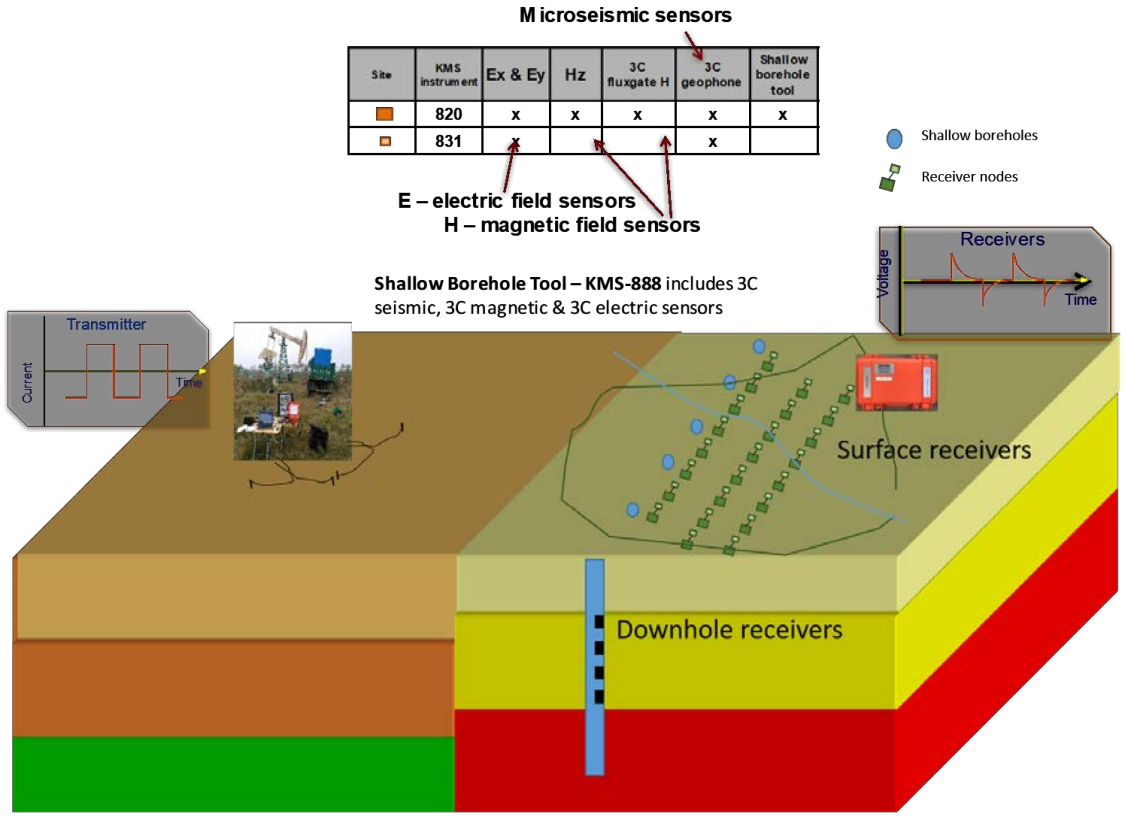
Reservoir monitoring has many different options. Since the reservoir changes are always 3D, careful design is required, and multiple transmitter must be used to understand the 3D effects. We use at least two transmitters. Below are examples of the CSEM transmitters, receivers and a sample layout. (Colombo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

KMS recommends carrying 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 transmitters in this case are not shown. You may add the Shallow Borehole Tool to the receiver sites.



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.

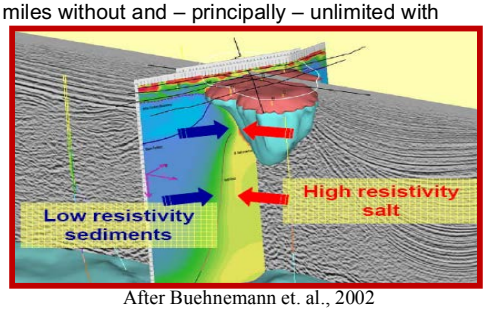
MT is usually used to map conductive zones like geothermal zones or sediment packages. To map resistors like a hydrocarbon reservoir you must use a grounded dipole transmitter (Passalacqua, 1983; Strack et al., 1889), which means you use Controlled Source Electromagnetics.

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

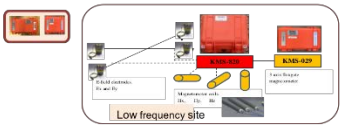
Low cost geothermal array application (AMT – MT)

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.

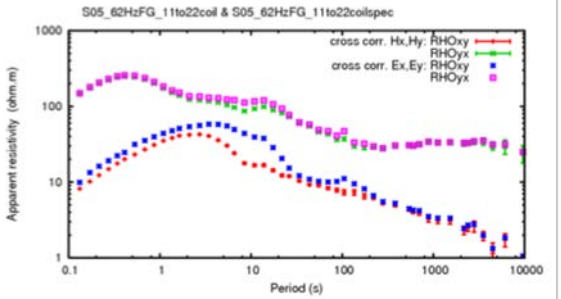
Advantage:

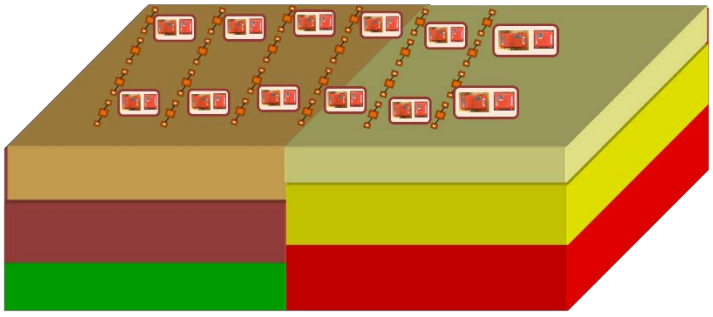
- Lower equipment cost
- Faster acquisition
- Consistent high quality data



AMT roving sites
LF MT – reference for basin depth

Receiver nodes: KMS-820 & 2 KMS-831





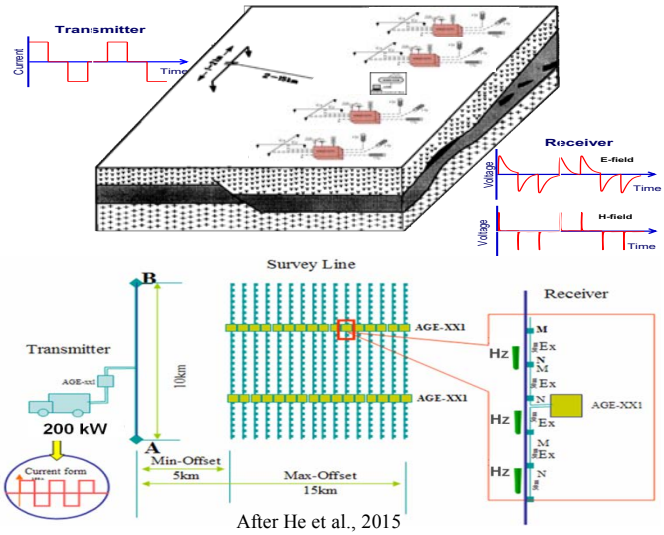
TFEM method

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

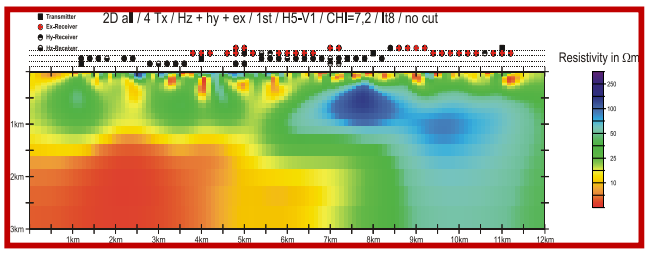
LOTEM method

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)

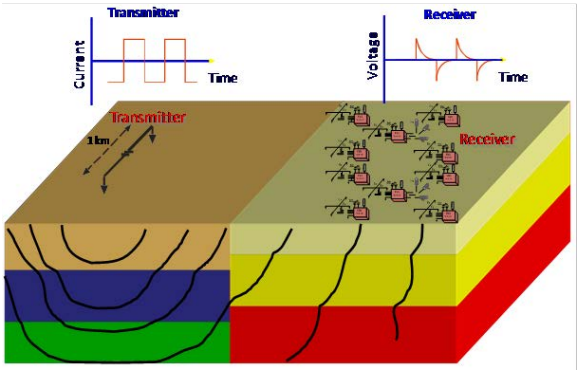
Using the KMS array system scheduling function and synchronization with multiple transmitters, the system can realize focused TEM applications, which allow for better volume focusing.

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).

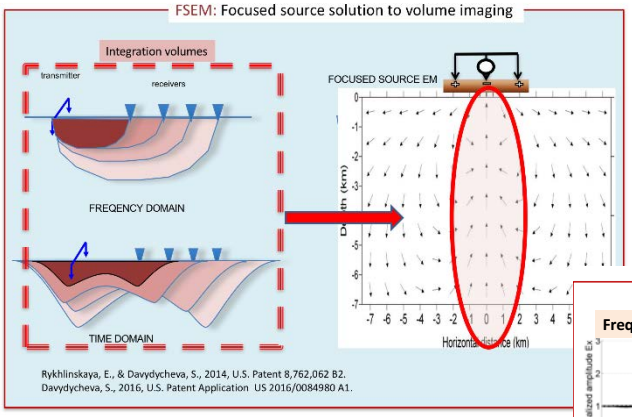


After Martin, 2009



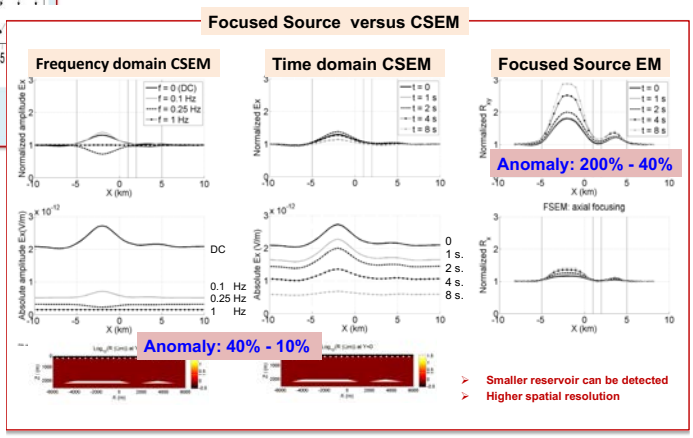
FSEM method

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.



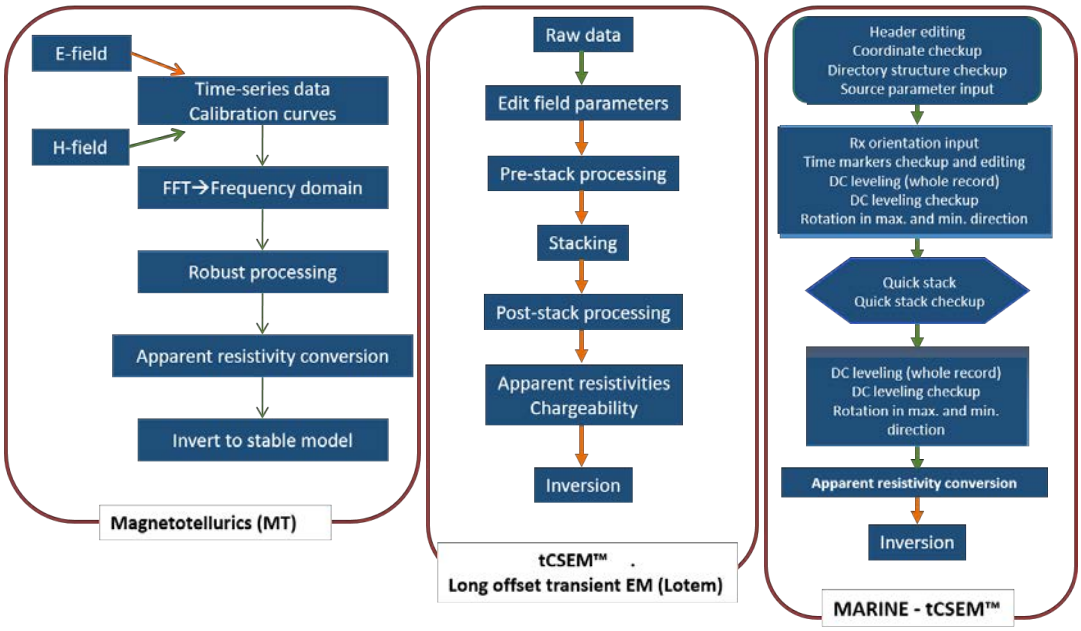
On the left the 2D sensitivity volumes for frequency and time domain are shown as a function of receiver-to-transmitter distance. On the right is the focused source EM current flow illustrating that the information comes from below the receiver.

On the right, we show 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 data acquisition system includes basic acquisition and monitoring software. Different products are governed by different software policies. For magnetotelluric applications the world's leading experts provide KMS and our clients with multiple robust software versions for purchase. For LOTEM and EM reservoir monitoring applications, appropriate processing software is available on a lease-basis only, due to the proprietary nature of the algorithms. All software leads the interpreter to a 3D model of the data. Below are sample flow charts of the magnetotelluric, LOTEM and marine time domain CSEM. (tCSEM™) workflows.



Software products:

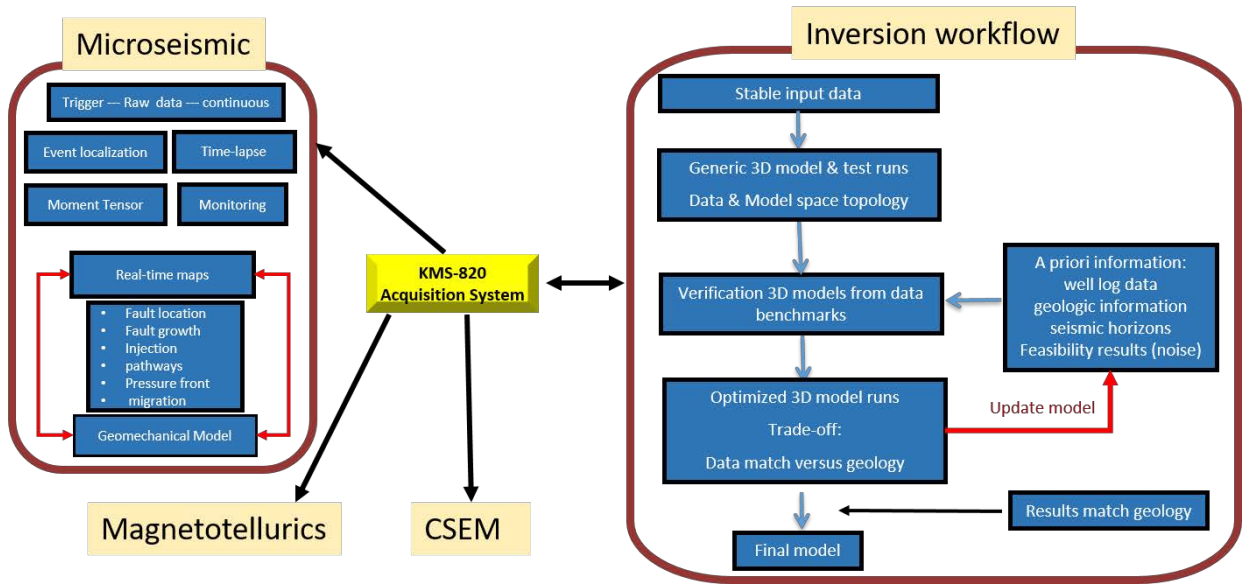
- **Acquisition software: KMS-200-ACQ**
  - Receiver acquisition control & monitor
  - Acquisition scheduler
  - Sensor calibration
- **Transmitter control & monitor software: KMS-200-TX**
  - Transmitter control & monitor
  - Pre-defined & customized transmitter waveform
  - Special transmitter safety feature
- **Basic robust MT processing software: KMS-200-P**
  - Robust MT processing
  - Standard MT processing workflow
- **Fast robust MT processing software: KMS-200-AP**
  - Fast robust processing
  - Adjustable processing parameter
  - Batch processing mode
  - Improved graphic display
- **1D MT inversion software: KMS-200-IX1D**
  - IX1D MT sounding inversion
  - Graphic display of apparent resistivity & impedance phase
- **2D MT inversion software: KMS-200-ZONDMT2D**
  - Zond 2D MT inversion
- **TEM processing software: KMS-200-tCSEM**
  - KMSPro 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 the 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 – FROM ANYWHERE

In addition to SD card swapping and wired connection, acquisition systems have multiple wireless options.

- The KMS-820 array data acquisition system default is 900 MHz long range wireless.
- An additional Wi-Fi chip is available. This connects to any Wi-Fi enabled laptop or Wi-Fi router.
- A full network kit – Web access box - can be added. (LAN and WAN, Bluetooth, HDMI, keyboard and monitor).

KMS Wi-Fi chip feature:

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

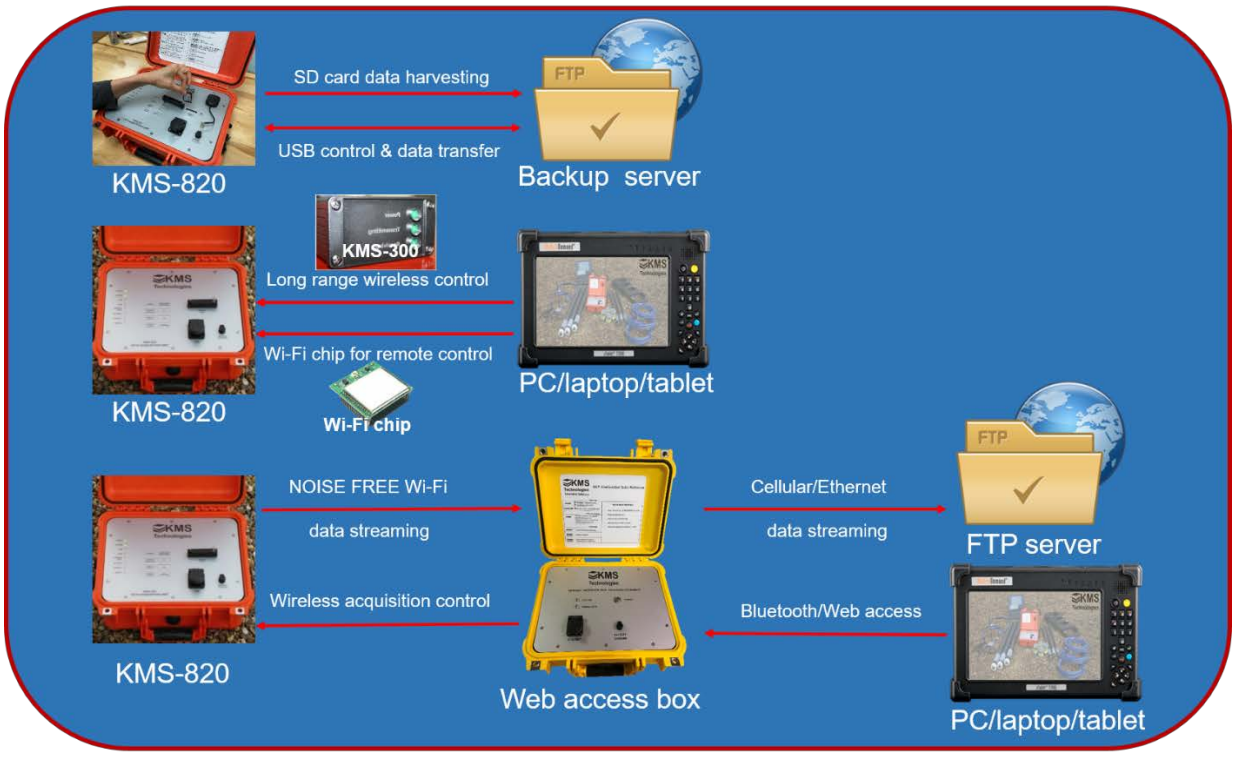
KMS Web access box features:

- Separating data acquisition and network delivery (less acquisition interrupts, FIREWALL, faster).
- Remote acquisition control of KMS-820 & LEMI-424 with field data QC.
- 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 over oversampling, we get 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.

The KMS-820 connectivity can be enhanced by adding a web access box. It allows FULL real time data streaming through wireless or wired connection. For MT applications we use a short Wi-Fi connection to this box that generates little to no noise in the MT sensors.

The KMS-820 acquires the data and writes files that are then accessed by the controller. The controller uses high level operating system and can control addition SD cards and hard disks in observatory mode. To simplify control of KMS-820 configuration and real-time data monitoring, we run a web server providing access to file system and share the control of the system. The KMS-820 will be accessible from anywhere.



LEMI-424 system full set layout (left); LEMI-424 system in transportation case (middle); Transportation case has wheels (right top); All parts in case are well protected (right bottom).

The Long-Period Magnetotelluric Station LEMI-424 is composed of two units - Data Logger (DL) and Analog Magnetometer (AM). DL (at the photo above) is developed for the analog signals received both from AM and from electric lines for telluric field measurements digitizing and storage. In order to realize the design of electric channels major attention was paid to thermal and temporal stability, high input impedance and low drift. High-pass filter-free technology of input stages was used in order to let super-long period signals (up to 100.000 second) to be measured. The lightning protection unit (at the photo, two models shown left and right, below) allows both the protection against nearby lightning discharges and easy connection of electric lines in the field. Specially developed very low noise LEMI-701 electrodes are recommended (at the photo, upper right), but any other electrode types may be used too. (not included in the delivery set)

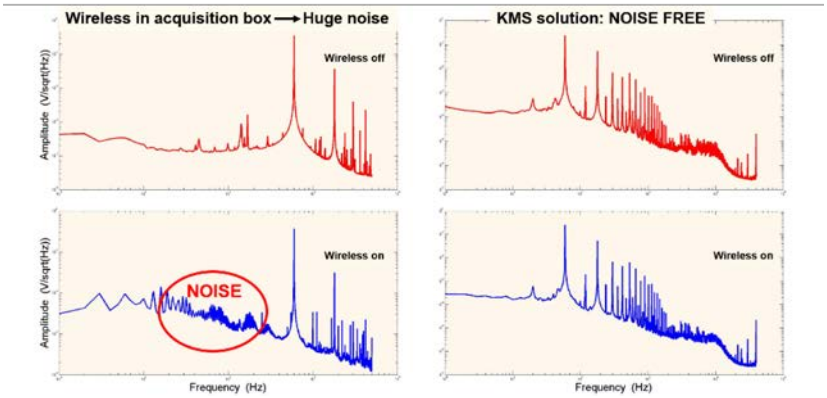
Product features

- High resolution and accuracy
- Very low noise
- 4 electric and 4 magnetic channels
- Very low temporal and thermal drift
- Low power consumption
- 8 GB SD card
- Satellite synchronization
- Graphic display with touch screen
- USB output
- Waterproof plastic case
- Two models of lightning protection units to choose

Product specifications

Frequency band	DC-0.5 Hz
Measured range	±2450 mV
Resolution of electric meter along each component (ADC 32 bit)	2 nV
Sample rate	1 per s
SD card	8 GB
Digital output and control	USB or Via Web access box (optional)
GPS	GPS timing, coordinates and altitude determination (antenna cable length 3m)
Operating temperature range	minus 20 to +60°C
Power supply	(5-20) V
Power consumption	<0.35 W
Weight: Electronic unit Lighting protection unit	 2.0 kg 1.0 kg

Web access box



Web access box performance

Problem & solution

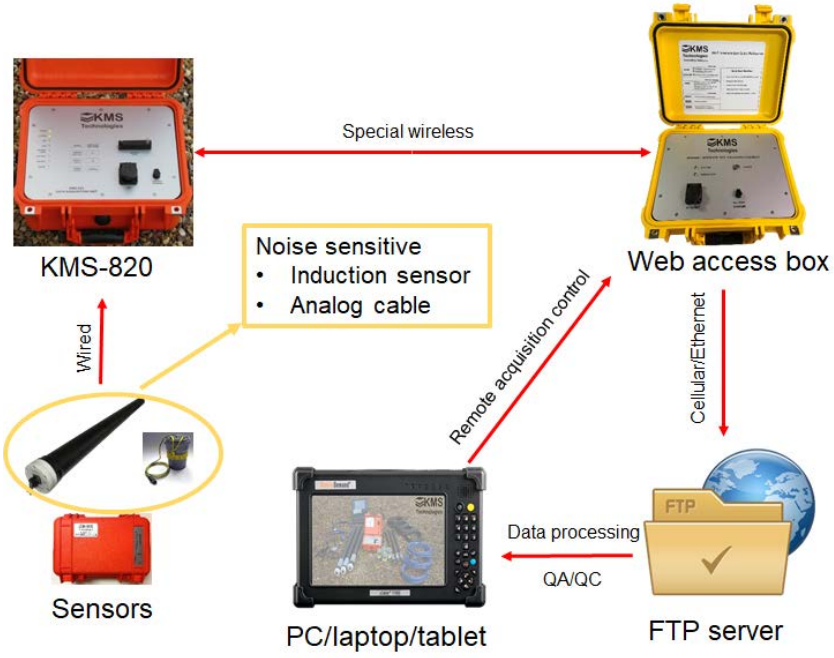
Problem:

- Wi-Fi transmission during EM acquisition generates noise
- Lack of real-time control of acquisition

KMS solution: Web access box

Solution benefits:

- NOISE FREE data transfer during MT acquisition
- Real-time remote acquisition control
- Real-time remote data processing
- Lower operational cost



Wi-Fi interface box configuration diagram

- The broadband design allows you to record the high & low frequency bands in ONE saving setup time, equipment cost, and processing time.
- State of the art preamplifier with low power consumption ensures that the sensor can be used with any acquisition station provided that the distance is less than 30 meters.
- Waterproof and rugged, the LEMI-152 is ready for use right after switching on.
- Calibration windings for auto calibration is provided.
- Extremely low noise and wide frequency range LEMI-152 is the perfect choice for an assortment of geophysical applications (MT, CSEM etc.)

LEMI-152 induction coil

LEMI-152 in shipping container

LEMI-152 in field

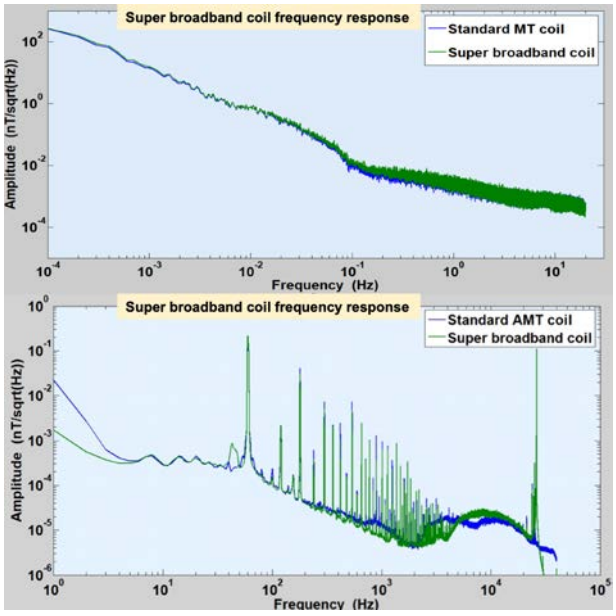
Product applications

LEMI-152 induction coil magnetometers are used for measurements of magnetic field variations in the frequency range from 0.00025 Hz to 10,000 Hz. Their super-wide bandwidth and low noise make them the ideal sensors for magnetotelluric measurements

.

Highlights:

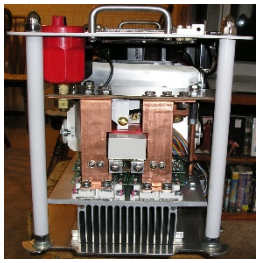
- Lowest noise in class
- Wide range of power supply voltage +/-6 V to +/-15 V
- Low power consumption. More than twice the battery life of other commercial coils. For KMS/LEMI instruments power is supplied from acquisition unit.
- Super-wide bandwidth 0.00025 to 10,000 Hz
- Lightweight < 4 kg



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*

LEMI-026 DRONE fluxgate magnetometer

New Products

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 highlights

- 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

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

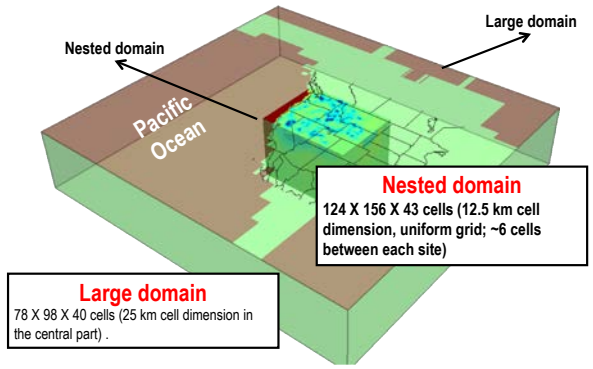
3D modeling & inversion software ModEM

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.



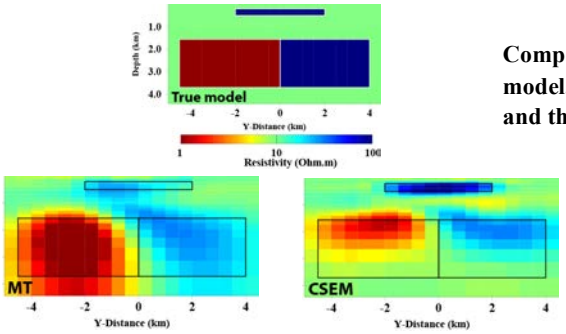
Example of a complex 3D model including detailed model with a large-scale background 3D model.

Data input:

- Apparent resistivity data or spectra in EDI format (other formats are 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.

References

Egbert, G.D., N. Meqbel, and K.M. Strack, 2013, Cabled marine magnetotellurics: Denser data at lower cost and high information content, SEG Technical program Expanded Abstract 2013, 840-844.

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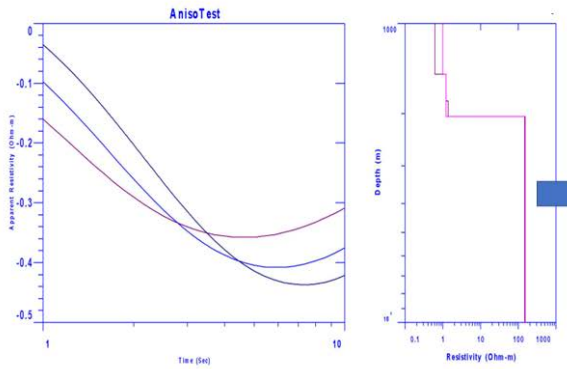
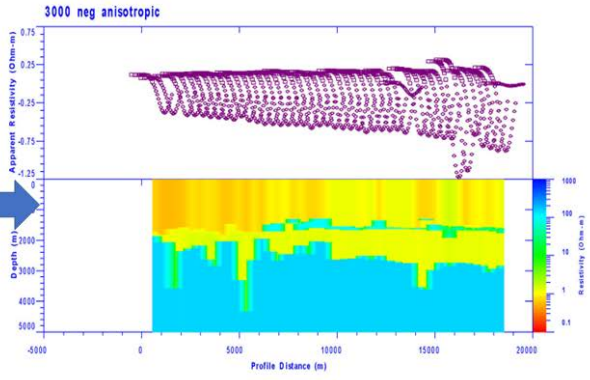
IX1D tCSEM modeling & inversion

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™

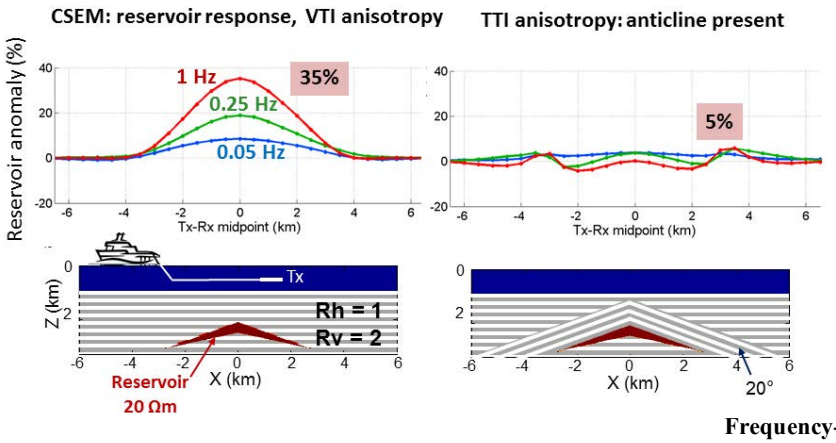
For technology/system design and survey feasibilities, KMS Technologies provides a variety of electromagnetic modeling software, mostly for CSEM (land and marine), surface, surface-to-borehole, and borehole environments. All codes were developed in-house by 3DEM Holding LLC and merged with KMS Technologies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



Data input:

- Adapted project specific
- Treatment of air/earth/ water interfaces with topography & bathymetry

Standard outputs:

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

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.

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).

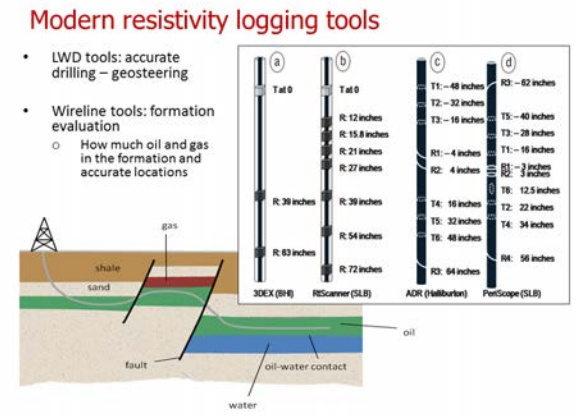
BOREHOLE 1D-2D-3D EM MODELING SOFTWARE

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).

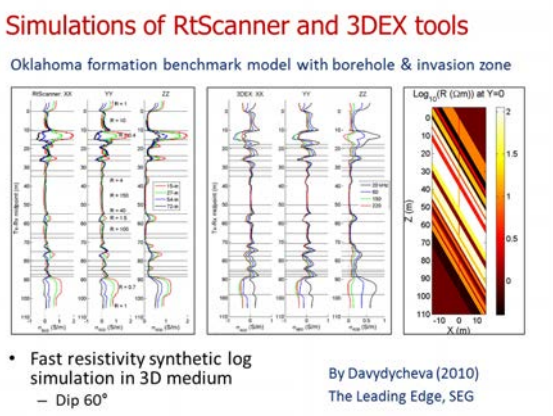
3DEMcyl 3D modeling software in cylindrical coordinates.
General resistivity LWD and induction measurements.
Effect of finite-size coils can be included.

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

* 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.

Patents:

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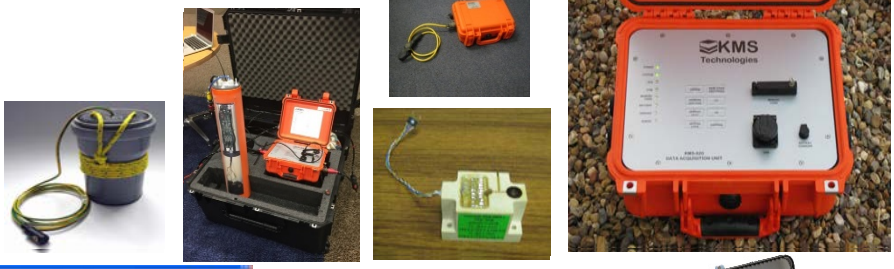
KMS Technologies provides hardware, software and services

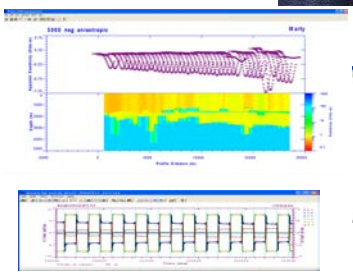
Product overview - hardware

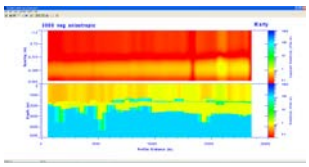
- KMS-820 - Array acquisition unit for MT, CSEM & microseismic
- KMS-831 - Channel expansion module
- KMS-5100 - High power CSEM transmitter (100, 150 kVA)
- KMS-888 - Seismic & EM shallow borehole tool
- EM sensors
  - Induction coils
  - Electrodes
  - Fluxgate magnetometers
  - Borehole tools



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

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

New


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

Product features

- ❖ Low-power design for long recording time
- ❖ Long-range wireless
- ❖ Wi-Fi & add-on web access box
- ❖ Bandwidth: DC - 50 kHz
- ❖ Up to 80 kHz sampling rate (total 480 kHz)
- ❖ 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

New transportation case with web access box (left); Web access box (right)

Benefits:

- NOISE FREE data transfer during MT acquisition
- Real-time remote acquisition control
- Real-time remote data processing
- Lower operational 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
- ✣ Shallow borehole receiver

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

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, IRIS, Laser Interferometer Gravitational-Wave Observatory (**LIGO**))

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