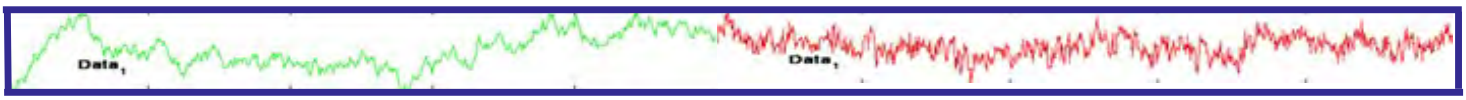
KMS Technologies
Innovating Solutions

Microseismic & Electromagnetic Array data acquisition system



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)
KMS-029 fluxgate magnetic sensor 32-bit, (DC – 180 Hz)
Multicomponent geophones

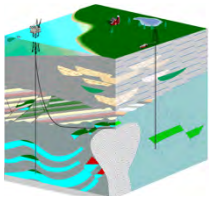
Marine

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

Optional

KMS-5100 land transmitter
KMS-500 transition zone transmitter

3D software license & interpretation services



The KMS Array data acquisition system is developed for EM (ElectroMagnetic) and micro-seismic applications to obtain subsurface resistivity and velocity structure for oil and gas 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).

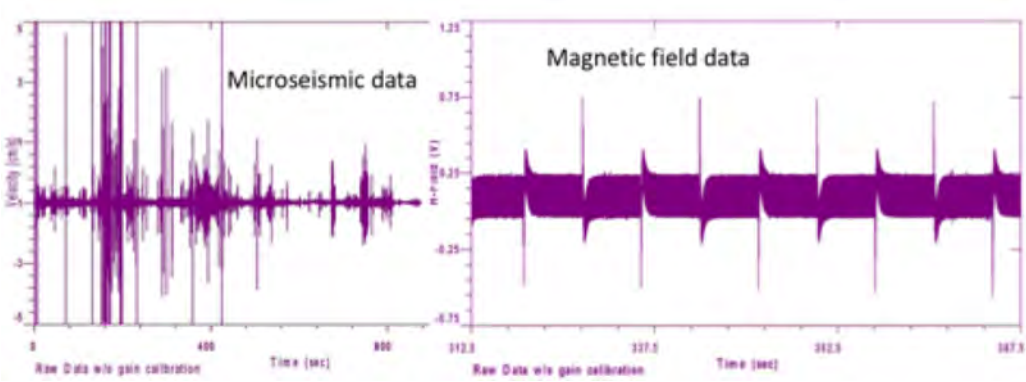
The core of the system is the KMS-820 Data Acquisition Unit which has six 24-bit low noise, low drift analoge channels and, through the digital port, and using the KMS-831, unlimited channel expansion. Typically, the digital port is used to record 32- bit fluxgate magnetic fields, at the same time as acquiring coils. 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 WIFI point-to-point direct connections. LAN is optional.

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 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 – 1000 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 up to 80 kHz, 32-bit up to 4 KHz)



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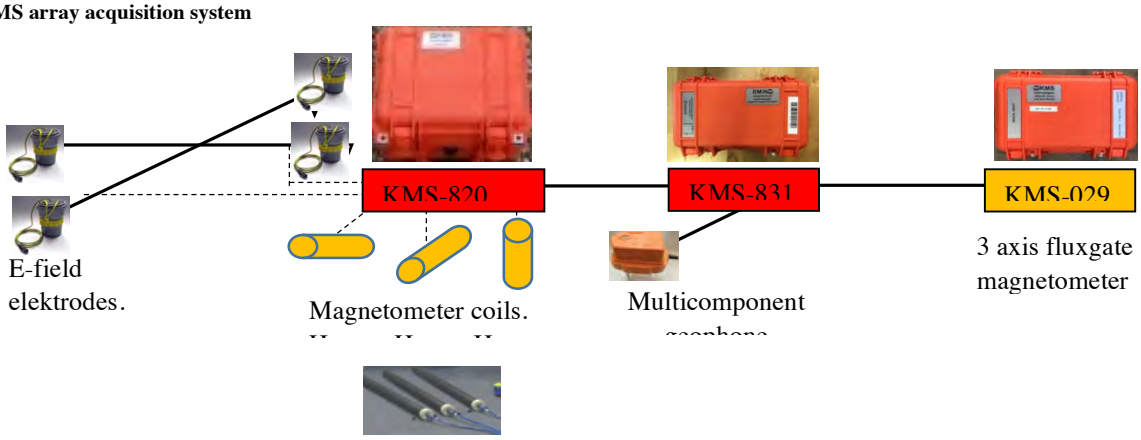
Main components

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 method sin one drop. The figure below shows a sample layout only, purely to illustrate how a receiver station might be configured.

KMS array acquisition system

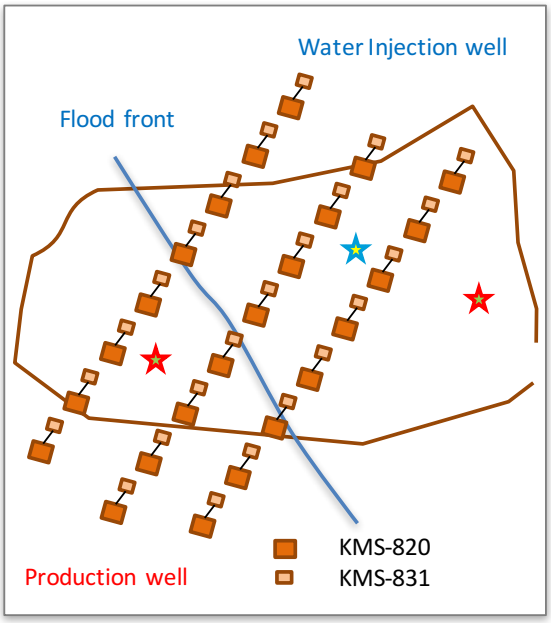


Applications

- Reservoir monitoring
- Oil and gas exploration (land & marine)
- Hydrocarbon reservoir dynamics & CO2 storage monitoring
- 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)

Survey receiver station layout (example only)

Survey layouts are usually design as per specific objectives. The example figure shows a layout for **water-flood monitoring**. The transmitters in this case are not shown.



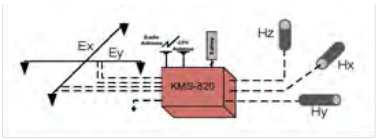
Microseismic sensors

Site	KMS instrument	Ex & Ey	Hz	3C fluxgate H	3C geophone
■	820	x	x	x	x
□	831	x			x

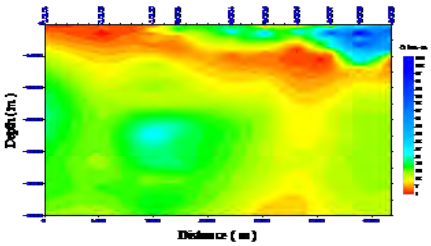
E – electric field sensors
H – magnetic field sensors

EM methods & microseismics

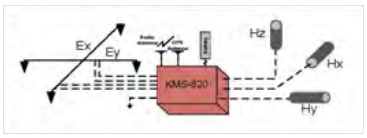
For magnetotellurics (MT) one often uses single site or remote reference recording as shown below.



Single EM recording site

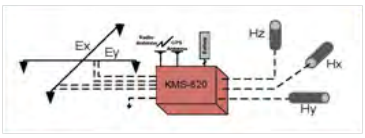


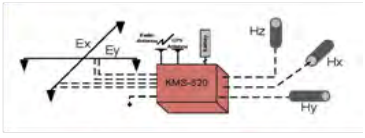
2D EM inversion result



Remote reference site

10 km to 100 km





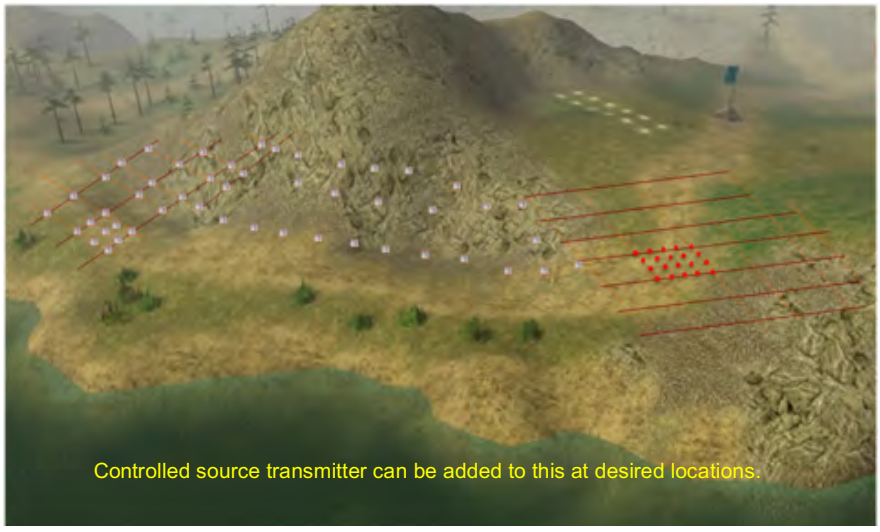
Single or multiple recording sites with remote reference

- 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 eta 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 survey 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 survey. 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 site and can even be helicopter assisted. On the left are 2D lines where each site has the full sensor component set.



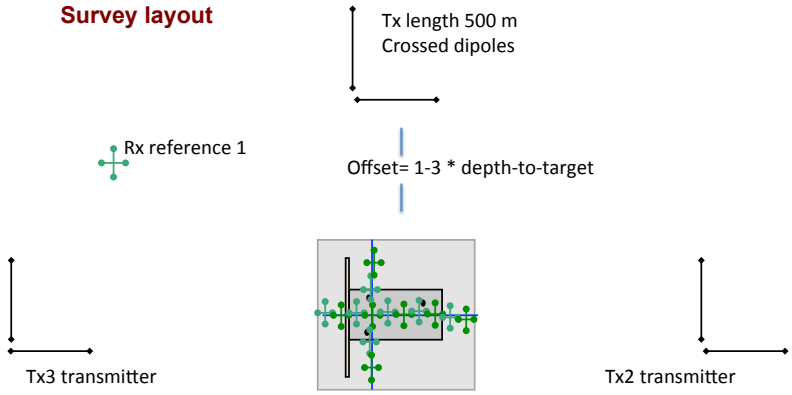
System configuration table

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

Survey	Receiver	Transmitter	Sensors	Applications / Depth
MT	*KMS-820 & KMS-831*	*N/A*	*Electrode: LEMI-701 Magnetometer: LEMI-120 LEMI-118 KMS-029*	*Onshore / Deep targets & basin study*
CSAMT	*KMS-820*	*KMS-500*	*Electrode: LEMI-701 Magnetometer: LEMI-118*	*Onshore, transition zone /Shallow targets*
TFEM	*KMS-820 & KMS-831*	*KMS-500 KMS-5100*	*Electrode: LEMI-701 Magnetometer: LEMI-140 LEMI-120 LEMI-118 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 KMS-air coi*	*Onshore, transition zone /Shallow to mid-depth targets*
TFEM, IP	*KMS-820 & KMS-831*	*KMS-500 KMS-5100*	*Electrode: LEMI-701 Magnetometer: LEMI-140 LEMI-120 LEMI-118*	*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*	*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 KMS-029 S-20*	*Water-flood monitoring Monitor induced seismicity CO_2 monitoring Depletion monitoring*

Reservoir monitoring layout

Reservoir monitoring has many different option. 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)



MT applications

Magnetotellurics (MT) and Audio MT (AMT) target different depth of investigation in hydrocarbon and geothermal exploration. For hydrocarbon exploration, high resistivity lithology such as salt, basalt, and overthrusting 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 method 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 1000 Hz and for AMT from 10 Hz to 20 kHz.

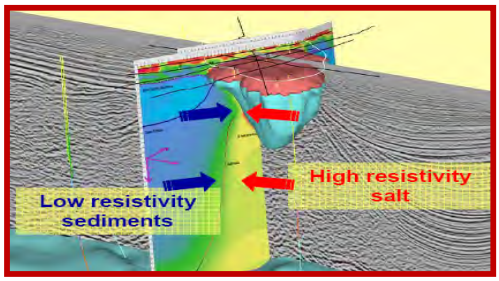
MT is usually used to map conductive zones like geothermal zones or sediment packages. To map resistors like hydrocarbon reservoir you must use a grounded dipole transmitter (Passalacqua, 1983; Strack et al., 1889).

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 is capable of controlling 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

TFEM method

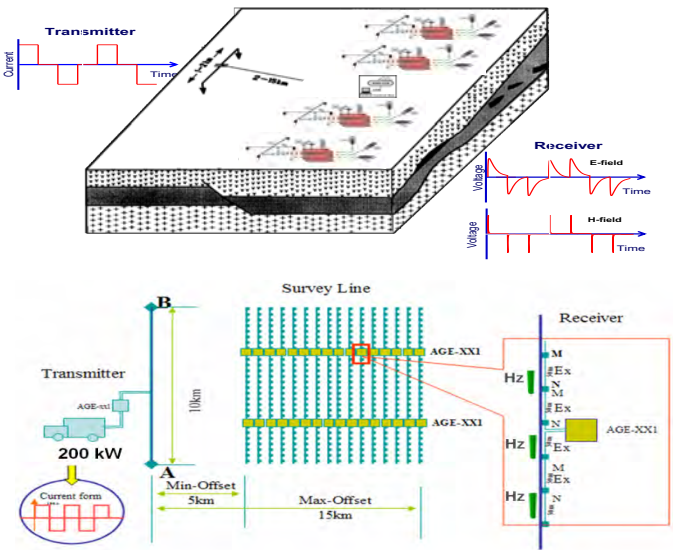
Time-Frequency ElectroMagnetics (TFEM) applies the Transient ElectroMagnetic (TEM) and Spectral Induced Polarization (SIP) techniques. It records broad-band frequency and time domain following a scheduled process.

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

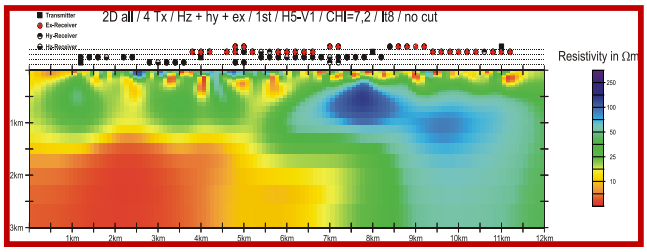
The Long Offset Transient ElectroMagnetics (LOTEM) method is a Transient ElectroMagnetic (TEM) method in which a primary field is generated by a grounded current dipole. The signal transmitted by the dipole consists of a series of alternating step functions that create a collapsing field that in turn 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)

KMS array acquisition system

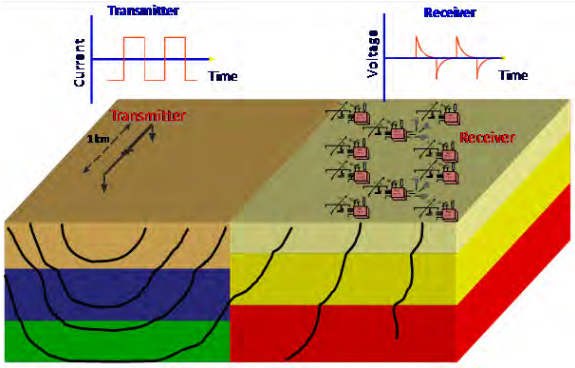
Using the KMS array system scheduling function and synchronization with multiple transmitters, the system can realize focused TEM applications, which give better volume focusing.

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



Application history - references

Since 2010, the system has ben used in: Argentina, Azerbajan, China, Germany, Kenya, India, Indonesia, Israel, Italy, Saudi Arabia, Slovakia, Thailand, Ukraine, USA (CA, CO, HI, NV, TX).

Applications include magnetotellurics, Audio-magnetotellurics, Lotem, microseismics (intrusion monitoring), bottom hole to surface communication, marine CSEM.

Patents: the system and methods are covered by various patents – see our website for the latest list

- Strack, K. -M., 2003, Integrated borehole system for reservoir detection and monitoring, **US 06541975 & US 06670813.**
- Strack, K. -M., 2004, Surface and borehole integrated electromagnetic apparatus to determine reservoir fluid properties, **US 06739165.**
- Strack, K.M., Thomsen, L. A., and Rueter, H., 2007, Method for acquiring transient electromagnetic survey data, **US 07203599.**
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