GE Oil & Gas
Oilfield Technology

robust, reliable instrumentation

imagination at work

GE's Measurement While Drilling (MWD) systems and Logging While Drilling (LWD) plug-and-play options provide reliable and accurate instrumentation for optimum well placement in a wide range of drilling environments.

World leaders in drilling measurement instrumentation

GE Oil & Gas designs, develops and engineers state-of-the-art MWD and LWD sensors and systems for customers to run well site operations for oil and gas corporations. Our research and development is continuous to ensure we always provide reliable technology, delivered on a global scale through exceptional customer service, specialist sales and local customer support.

Excellence you can rely on

Escalating costs of drilling operations and increasing well profile complexity are leading to more demand for formation evaluation measurements during the drilling process. Such measurements can be acquired while drilling to optimize the placement of the wellbore and provide valuable information about the reservoir.

Our LWD systems are designed to fit seamlessly into GE MWD platforms and provide a range of features to address numerous drilling applications. Our resistivity systems can be used to complement gamma ray measurements for simple bed boundary identification and determination of hydrocarbon/water contacts. Real-time analysis of resistivity measurements whilst drilling allows the geologist to geosteer the well to optimum well placement within the targeted reservoir zone.

The MWD business is highly capital intensive. The fewer assets needed to perform the job and the more active service days achieved, the better the return on investment. Efficient equipment utilization is directly related to tool reliability.

GE's MWD systems incorporate the latest micro-circuit design and electronic packaging to withstand the severity of the most demanding conditions. The technical sophistication of these systems results in simple to use, uncomplicated designs offering significant improvements in operational efficiency. A wide range of transmission options are available that offer solutions for traditional horizontal and directional drilling, managed pressure drilling, coal bed methane exploitation and high efficiency vertical drilling.

Improving industry standards

Focused on improving industry performance and safety standards, GE is the recognized leader for high accuracy sensors that operate in the most extreme environments with a safe and efficient record.

MWD Systems

Data Acquisition – Surface Systems

GE MWD and LWD systems transmit directional measurements and logging data for real-time display. In addition data are stored at higher resolution in the tool memory for retrieval at surface and merged with depth data to provide final logs. A comprehensive set of surface equipment is supplied with each system.

Transmission Systems – Positive Pulse, Negative Pulse and Electromagnetic

GE offers a range of MWD transmission systems to address a wide range of drilling applications. Transmission systems include positive or negative mud pulse and electromagnetic systems for unconventional drilling applications.

Components

Tensor
Solenoid-driven pulser (Page 6)

Geolink
Mud pulse transmitter (Page 8)

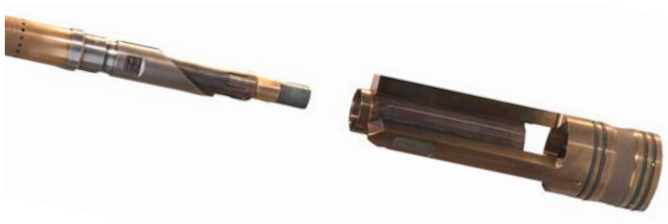
E-link
Electromagnetic transmission system (Page 9)

WellTracer II and Pilot MWD Systems

The WellTracer II and Pilot MWD systems offer an entry-level option for customers wishing to use proven GE technology. WellTracer II systems are specifically designed for vertical well monitoring with minimal operator presence. The Pilot MWD system provides full MWD capability with optional gamma upgrade for drill collar sizes ranging from 3 ½ in. (89 mm) to 9 ½ in. (241 mm) O.D.

• Retrievable/Reseatable	Wireline-retrievable MWD probe reduces lost-in-hole risk and eliminates tripping to replace equipment.
• Motor-Driven Pulser	Pulser exerts up to 100 lb force for improved LCM tolerance.
• Power Efficient	Up to 400 hours battery life with Pilot MWD system, enabling prolonged runs and reducing battery consumption.

Components



Motor-Driven Pulser
The motor-driven pulser is a bottom-mounted, positive mud pulse, retrievable/reseatable, high LCM tolerance device.

Directional Module (DM)
A simplified design of the full-feature DM is used to provide vertical well survey data for the WellTracer II system.

Technical Overview

Pilot Motor-Driven Pulser
A high-efficiency lead-screw motor assembly produces the positive pressure pulses that send information measured downhole to the surface in real time. The pulser design is based on Bernoulli's Principle; the main poppet moves down into the main orifice when the pilot valve is activated. The mud flow is restricted, which generates an increase in circulating pressure. NOTE: Pilot and WellTracer II systems require different pulser versions.

Directional Module (DM)
The Pilot DM uses Q-Flex inclinometers and tri-axial flux-gate magnetometers to provide wellbore inclination, azimuth and toolface orientation measurements. The transmission sequences are completely configurable by the operator at the rig site for pulse width, data resolution, order of parameters within a sequence and number of updates per sequence. A simplified version suitable for vertical wells is available with the WellTracer II system.

WellTracer II and Pilot MWD Systems

The surface systems are compact for efficient rig up and provide a user-friendly interface for operators. The rig floor display (RFD) is based on a rugged computer integrated with GE proprietary hardware and software. The RFD is installed in a compact, toughened enclosure with a touch-screen interface. Two-way wireless communication may be added to provide remote monitoring and additional logging functionality with gamma module.

• Compact with Few Components	Designed for rapid system rig up, the small RFD footprint allows versatile installation on the rig floor.
• Easy to Operate	Simple user interface results in reduced operator training costs. The WellTracer II system does not require an operator except for job set-up and occasional rig visits for battery changes.

Components

Rotary Connector
The GE rotary connector simplifies field tool make-up and reduces risk of damaging connectors.

Surface System
The compact RFD is the central processor for the surface system.

Technical Overview

Battery Module
The lithium thionyl chloride battery pack provides power to operate the pulser, directional sensors and control electronics. For longer operations, two modules can be connected in parallel and power will switch to the second module when the first is fully depleted. Battery life of up to 600 hours for WellTracer II with one battery module.

GE Rotary Connector
The GE Rotary Connector simplifies field tool make-up and reduces risk of damaging connectors. Connection integrity significantly improves mean time between failures (MTBF).

Surface System
Flexible tool programming options allow the operator to select the optimum telemetry sequence and rate for the application. The wireless option permits communication between RFD and a remote laptop (for survey QC or gamma logging) and between RFD and MWD tool for tool programming and testing on deck. In addition to the main components shown above, the surface system includes a complete set of test equipment required to test and fully configure the system. Compatible with numerous depth tracking systems.

Tensor MWD System

The well-established and reliable Tensor MWD system is acknowledged as the industry standard in retrievable MWD systems. Comprised of a downhole probe-based tool with a bottom-mounted pulser, modular tool components and associated surface systems, the Tensor directional system provides real-time azimuth, inclination and tool face data via positive mud pulse telemetry. Plug-and-play options are available to provide gamma and resistivity for LWD applications.

• Retrievable/Reseatable	Wireline-retrievable MWD probe reduces lost-in-hole risk and eliminates tripping to replace equipment.
• High Temperature Rating	Recognized as the system of choice for hot-hole applications, MWD and LWD tools are rated to 175°C (347°F) operating temperature.
• Configurable	Additional modules for gamma or Centerfire propagation resistivity can be easily added as required.

Components

Solenoid-Driven Pulser
The pulser provides the positive pressure pulses to transmit measured data from downhole to surface.

Tensor Directional Module (DM)
The DM makes measurements of the earth's gravitational and magnetic fields to calculate the inclination and azimuth of the wellbore and orientation of drilling tools.

Centralizers
Centralizers are used to minimize vibration within the tool and to centralize the sensors within the drill collar for accurate measurements.

Technical Overview

Solenoid-Driven Pulser
The bottom-mounted solenoid-driven Tensor pulser and MWD probe are wireline retrievable. The pulser is seated in a muleshoe assembly just above the motor. The pulser main poppet moves down into the main orifice when the pilot valve is activated. The mud flow is restricted, resulting in a positive pressure pulse. This design uses Bernoulli's Principle of fluid dynamics to supplement battery power with energy from the fluid flow to increase battery life. The Dual Smart Coil solenoid design maximizes pull force.

The Pilot motor-driven pulser can also be used within the Tensor MWD system if requested.

Tensor Directional Module (DM)
The Tensor DM uses tri-axial flux gate magnetometers and Q-Flex inclinometers to provide measurements of wellbore azimuth, inclination, toolface and tool temperature. The primary DM calibration is performed in our state-of-the-art Total Field Calibration lab, and can be recalibrated in our service centers using the latest techniques in a Helmholtz Coil, ensuring sensor accuracy at all orientations and over the entire operating temperature range.

Centralizers
For the standard retrievable configuration, collapsible bow spring centralizers are used as they allow the tool to be retrieved through the upper BHA. In extremely harsh drilling areas the tool can be fitted with rubber fin stabilizers for more robust vibration protection; however, in this configuration, the tool is not retrievable without tripping.

Tensor MWD System

The Tensor surface system hub is located in a safe area and is an extremely reliable, efficient receiver and decoding system. Color LCD rig floor display, surface sensors and peripherals are all connected to the hub. A comprehensive software interface ensures both surface and downhole systems can be easily programmed for various tool combinations and telemetry parameters.

• User-Friendly Software	Robust decoding and simple tool programming interface results in quick and effective operator training.
• Downlink Telemetry Change	Operator can change data rates and telemetry parameters without tripping.
• Flexible Telemetry	Operator selectable real-time data resolution and data sequences for optimizing telemetry to application.

Components

Surface System
Surface system comprises a Safe Area Interface (SAI), Rig Floor Display (RFD), surface sensors, logging computers and peripherals. The system can be easily upgraded to support Tensor LWD services.

Technical Overview

Surface System
The RFD provides a driller's graphical display. The SAI hub processes and decodes the mud pulse signal and houses the required barriers for an intrinsically safe system. The output signal from the SAI is further processed into displays and logs on a laptop computer.

The proprietary MWD software provides operating and testing programs for MWD and LWD tools, allowing configuration of the RFD.

Geolink MWD System

The Geolink MWD system is ideal for customers who require a collar-mounted system. The system is recognized within the industry for its reliability, accuracy and quality. It is available with either mud pulse or electromagnetic (EM) transmitter options; vibration monitoring is provided in all configurations. A wide range of optional modules (gamma, resistivity and pressure during drilling (PDD) enables expansion into markets requiring increased service levels.

• Integral Vibration Measurements	Real-time lateral and axial vibration data can be used to mitigate BHA damage and optimize drilling efficiency.
• Reliability	Stable, reliable and proven technology with a fixed mounting maximizes operational efficiency and reduces operating costs for harsh environments.
• Accuracy	Industry-leading directional sensor accuracy for precise well placement.

Components

Mud Pulse Transmitter
The transmitters produce negative pulses in the drilling fluid, which are decoded at the surface by the computer system.

Survey Electronics Assembly (SEA2)
High-accuracy measurements of wellbore inclination and azimuth are taken, stored in memory and transmitted in real time to the surface.

Technical Overview

Standard and Ultraslim Transmitters
The transmitters contain a solenoid-operated poppet valve which, when opened for a period of 0.5 s, creates a pressure drop that is detectable by the surface system. The time between the pulses represents the data measured by the downhole sensors. The telemetry sequence is decoded by the surface computer system.

Survey Electronics Assembly (SEA2)
Tri-axial flux-gate magnetometers and Q-Flex Inclinometers make the measurements for wellbore inclination and azimuth with industry-leading accuracy. Additional measurements include toolface, temperature and vibration monitoring. Survey quality control parameters are also transmitted in real time.

Geolink MWD System

The Geolink surface system uses proprietary Geolink software running on a Windows operating system. Additional sensors allow either mud pulse or EM transmission to be detected; each system is compatible with the optional plug-and-play depth tracking kit for formation logging operations.

• Efficient Telemetry	Rotation detection to maximize data update rates, vibration data only transmitted when above safe range. Downlink capability to select optimum transmission sequence.
• Expandable	Additional modules for LWD and pressure measurements can be added as required.
• EM Capable	Provides reliable, high-data-rate signal detection independent of circulation or drilling fluid properties.

Components

EM Surface System
Standard Geolink surface system can be easily be upgraded with an EM signal detection kit.

E-Link Transmission System
Comprising a gap sub, internal gap assembly, mounting kit and E-Link transmitter, the E-Link system can be used instead of the negative pulse transmitter for Underbalanced or Managed Pressure Drilling.

Technical Overview

E-Link Receiver
Ground electrodes are required to receive the EM signal from the E-Link tool. Either single or differential electrode systems (DES) can be used depending on signal strength. The system includes a YAGI directional aerial and signal amplifier for DES detection mode. The surface interface box for the E-link system provides signal reception, filtering, processing functions and data output to the laptop computer for decoding. A range of test equipment is supplied to enable efficient rig up of the surface signal detection system.

E-Link Gap Sub and Transmitter
The gap sub incorporates an insulated tool joint to provide the electrical insulation between the upper and lower bottomhole assembly that is required by the propagation wave data transmission. The E-Link transmitter sends electromagnetic pulses comprising a carrier frequency modulated to one of four transmission frequencies, which are operator selectable for different drilling depths and formation properties.

Tensor LWD System

The Tensor MWD system can be expanded to fulfill specific LWD project requirements by adding the Scinturion Gamma Module and the Centerfire* resistivity tool. The LWD system is specified to 175°C (347°F), uses a standard solenoid-driven pulser with the gamma module and a special solenoid-driven pulser with a wet connect fitting to connect to the Centerfire tool.

Four tool configurations are possible with the Tensor LWD system:

1. **Directional-Gamma** with the gamma tool placed above the pulser and using two battery modules.
2. **Directional-Gamma-Resistivity** with the gamma tool placed below the resistivity and using three battery modules.
3. **Resistivity-Gamma, memory only**, with the tool powered by a battery module below the gamma module.
4. **Resistivity, memory only**, with the tool powered by a battery module below the resistivity sonde.

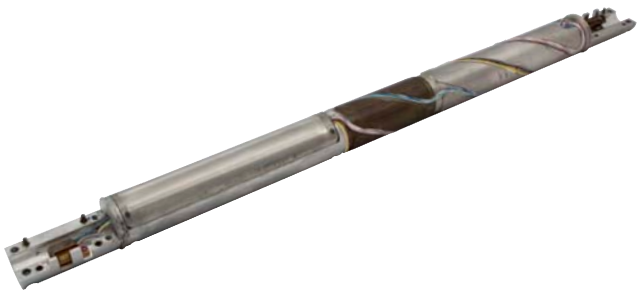
Scinturion Gamma Module

The Scinturion gamma module can be added to a directional bottomhole assembly to provide a directional-gamma (DG) service. The same gamma module can be placed directly below the 4¾ in. and 6¾ in. Centerfire resistivity systems to provide a comprehensive LWD assembly. The 8¼ in. Centerfire system has the gamma module integrated into the body of the sub.

Scinturion Key Features

- High reliability from the gamma module using innovative shock and vibration protection techniques and minimizing number of components.
- Increased gamma sensitivity by using a titanium housing.
- Gamma measurements closer to the drill bit when run below the Centerfire tool.

Components



Scinturion Gamma Module
Connects directly into the directional tool and is powered from the same battery modules. Can be positioned directly below the Centerfire tool for LWD applications.

Scinturion Gamma Crystal
Unique mechanical suspension ensures reliable performance under harsh conditions while maximizing crystal volume.

Technical Overview

Scinturion Gamma Module
The gamma module uses an industry-leading scintillation counter to measure natural formation radioactivity. A patented shock-absorption method reduces the amount of drilling vibration transmitted to the detector and ensures integrity of recorded data.

Tensor LWD System

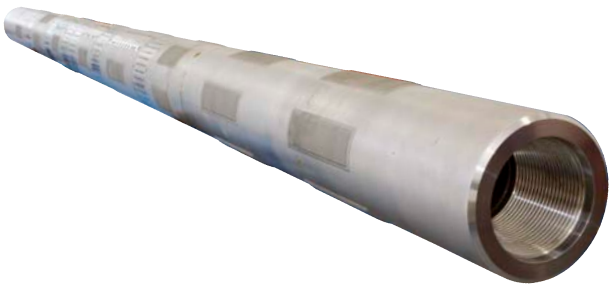
Centerfire Resistivity System

The Centerfire resistivity system uses an industry standard transmitter-receiver design to provide multiple depth of investigation (DOI) borehole compensated resistivities. The fully retrievable probe-based directional MWD module is situated above the resistivity tool and can be removed from the tool string with the logging data downloaded at the surface even if the rest of the bottomhole assembly becomes stuck.

Centerfire Key Features

- Eight borehole compensated resistivity measurements.
- Temperature rated up to 175°C (347°F).
- Retrievable probe-based directional module.

Components



Centerfire Resistivity System
Connects to the directional or directional-gamma tool via a wet connect on the bottom of the solenoid-driven pulser.

Centerfire Wet Connect
The wet connect assembly enables connection of the MWD pulser system to the resistivity collar and allows the probe to be retrieved if required.

Technical Overview

Centerfire Resistivity System
The Centerfire tool uses a standard, symmetrical, four-transmitter and two-receiver antenna configuration to make borehole-compensated measurements of formation resistivities at eight depths of investigation. The tool has 19 and 41 in. transmitter-receiver spacing and uses both 400 kHz and 2 MHz frequencies. The data are transmitted to the surface in real time and recorded in downhole memory at a higher data density. The Centerfire tool may be run in memory-only mode by powering it from a battery module connected below the resistivity sonde.

Geolink LWD System

The Geolink MWD system features a wide range of components that can be added to provide a comprehensive suite of measurements. Along with gamma, pressure and vibration modules, a choice of single or multiple depth of investigation resistivity tools are available to provide LWD services.

Modular Gamma Ray Assembly (MGRA)

The MGRA uses wireline-standard measurement technology in a patented rugged assembly to provide an accurate API gamma log while drilling to allow real-time identification of basic sand-shale sequences and formation tops.

The MGRA is capable of transmitting real-time formation gamma ray information and stores high resolution data downhole that can be downloaded from memory when the tool is brought back to surface.

MGRA Key Features

- Calibrated to the API standard—directly comparable to wireline logs
- Rugged patented design is extremely reliable
- Geolink Navigator Plus software with user-friendly surface interface and log plotting capabilities

Pressure During Drilling (PDD)

The PDD tool measures both drillpipe and annulus pressure, transmits the data in real time via the SEA and transmission system, and stores the information at a higher data density in memory to be downloaded at the surface. The data are presented as either equivalent circulating density (ECD) or pressure allowing for real-time decisions to maintain safety and efficiency levels.

PDD Key Features

- Easy add-on to directional or directional-gamma tool strings
- Self-powered
- Rated to 15,000 psi/1,034 bar (20,000 psi/1,380 bar on request)

Components

Modular Gamma Ray Assembly (MGRA)
Rugged scintillation counter, state-of-the-art electronics and compact assembly for reliable determination of formation boundaries and estimation of formation composition.

Pressure During Drilling (PDD)
Drillpipe and annulus pressure measurements make the PDD tool ideal for managed pressure drilling.

Technical Overview

Modular Gamma Ray Assembly (MGRA)
The MGRA measures natural formation gamma ray emissions by means of a NaI crystal scintillation counter and photo-multiplier tube, transmits the data to surface and stores in memory at a higher data density for surface download. The tool is calibrated to API standards using a secondary calibration technique (the primary calibration having been performed at the University of Houston test pit) and the log is presented in Apparent API units (AAPI).

Pressure During Drilling (PDD)
The PDD tool uses two piezo-resistive sensors to accurately measure wellbore pressures, is self-powered from lithium thionyl chloride batteries and may be added to any other Geolink tool string configuration or run in standalone, memory-only mode.

Geolink LWD System

TRIM Induction Resistivity Tool

TRIM provides wireline-comparable induction resistivity measurements from its unique side-mounted coil arrangement. The physical layout of the tool ensures protection for electronics and coils and enables quick and easy service turnaround.

TRIM Key Features

- 20 kHz frequency, comparable to wireline induction tools
- Unique physical layout protects sensitive components and ensures ease of maintenance
- Depth of investigation (DOI) equivalent to deep-reading wireline induction measurement

Compact Propagation Resistivity (CPR)

The CPR tool uses propagation wave techniques to provide phase and attenuation resistivity measurements from three sensor spacings and two frequencies. The tool uses a unique transmitter-receiver configuration to keep tool length shorter than conventional propagation wave tools—with borehole compensation achieved using the properties of EM reciprocity.

CPR Key Features

- Up to 12 depths of investigation
- Compensated or uncompensated data available depending on client requirements
- Short tool length for ease of handling and maintenance

Components

TRIM Induction Resistivity Tool

Unique design ensures a robust and compact tool for the provision of wireline-comparable induction resistivity measurements.

Compact Propagation Resistivity (CPR)

Innovative tool design provides industry-standard propagation wave resistivity measurements at multiple DOI from a shorter instrument length.

Technical Overview

TRIM Induction Resistivity Tool

TRIM uses the principle of electromagnetic induction to measure formation resistivities. The use of a 20 kHz frequency makes the measurement directly comparable to deep wireline induction tool measurements and less likely to require borehole corrections (drilling fluid and borehole size dependant). One (1) deep measurement is made.

Compact Propagation Resistivity (CPR)

The CPR tool uses the principles of electromagnetic propagation to make measurements of formation resistivities at three transmitter-receiver spacings (18, 27 and 36 in.) using two frequencies (400 kHz and 2 MHz). Uncompensated phase difference and attenuation resistivities are calculated giving a total of 12 possible DOI measurements. Borehole compensation is achieved using the principle of electromagnetic reciprocity, depth aligning dual receiver and dual transmitter measurements and taking an average. By using only two transmitters and three receivers, tool length is kept shorter than competitor tools, while also offering borehole compensated measurements.

Systems Feature Comparison

	WellTracer II	Pilot	Tensor	Geolink
Positive Pulse	■	■	■	
Negative Pulse				■
Electromagnetic (EM) Transmission				■
Motor Driven Pulser	■	■	1	
Retrievable	■	■	■	2
Directional Sensor Full Range	3	■	■	■
Vibration Monitoring				■
Temperature Sensor	■	■	■	■
175°C (347°F) Temperature Rated			■	
Gamma Option		■	■	■
Pressure During Drilling Option				■
Propagation Resistivity Option			■	■
Induction Resistivity Option				■

1 Optional for Tensor directional and directional-gamma systems

2 Only EM is retrievable

3 Limited toolface and inclination range

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