

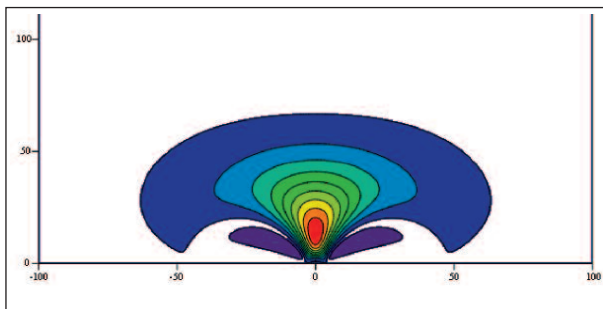


MFR™ Multi-Frequency Resistivity High-Temperature LWD Sensor

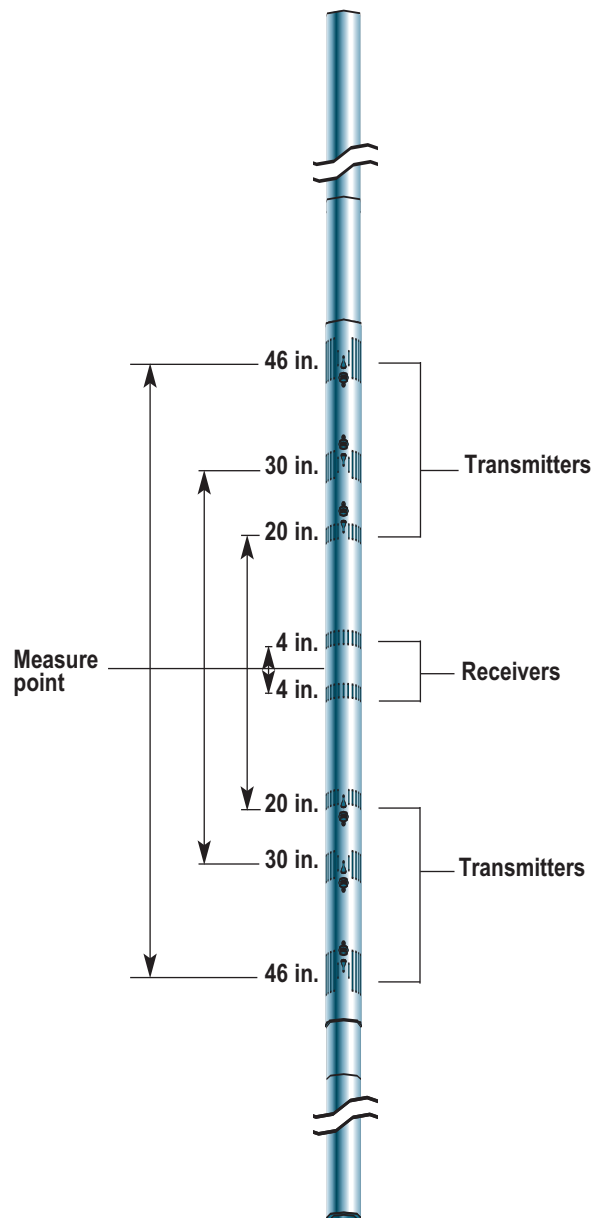
The *MFR* HT sensor is designed to operate at borehole pressures up to 30,000 psi (207 MPa) and flow rates from 400 to 1800 gal/min, depending on tool size. The *MFR* HT sensor operates in all mud types at 2 MHz and 400 kHz with transmitter-receiver spacings of 20, 30 and 46 in.

Applications

- May be run in any mud system.
- Deeper reading 400 kHz measurements are unaffected by eccentricity and hole rugosity, providing stable measurements in highly conductive formations drilled with oil-based mud.
- Deep-reading resistivity measurements and log inversion capabilities enhance geosteering applications and horizontal log interpretation.



A compensated antenna design minimizes borehole effects, increases accuracy and provides a symmetrical log response.





MFR™ Multi-Frequency Resistivity High-Temperature LWD Sensor

Features, Advantages and Benefits

- Fully-compensated antenna arrays integrated into the drill collar for increased reliability.
- Rated up to 30,000 psi (207 MPa) operating pressure, depending on tool size.
- Designed for high flow—4 3/4 in. (400 gal/min) to 9 1/2 in. (1800 gal/min).
- Fully digital electronics measure phase and attenuation at each transmitter-receiver pair, resulting in highly accurate measurements.
- Three transmitter-receiver spacings measure 12 fully compensated phase and attenuation measurements at unique radial distances from the borehole.
- Diameter of investigation of 197 in. at 20 ohm-m is the industry's deepest reading LWD resistivity measurement.
- Three independent transmitter-receiver antenna spacings and two operating frequencies provide accurate measurements over a wide range of drilling conditions.
- Each compensated measurement has a unique depth of investigation. Any three can be combined to compute invasion diameter, flushed resistivity zone (R_{xo}) and true resistivity (R_t) over a wide range of borehole conditions and resistivity contrasts.
- Symmetrical antenna design minimizes borehole effects and cancels impedance changes in antennas caused by pressure and temperature variations while drilling.



MFR™ Multi-Frequency Resistivity High-Temperature LWD Sensor Specifications

Mechanical Specifications					
Nominal Sensor OD	4 3/4 in.	6 3/4 in.	8 in.	8 1/4 in.	9 1/2 in.
Maximum OD	5 1/4 in.	7 3/8 in.	8 5/8 in.	8 7/8 in.	10 1/8 in.
Length (HEL system)	20.8 ft	20.8 ft	20.8 ft	20.8 ft	20.8 ft
Weight	1225 lb	2425 lb	3500 lb	4500 lb	6200 lb
Top connection	3 1/2 IF box	4 1/2 IF box	6 5/8 Reg box	5 1/2 IF box	7 5/8 Reg box
Bottom connection	3 1/2 IF pin	4 1/2 IF pin	6 5/8 Reg pin	5 1/2 IF pin	7 5/8 Reg pin
Make-up torque	9,900– 10,900 ft-lb	28,000– 32,000 ft-lb	52,000– 56,000 ft-lb	53,000– 56,000 ft-lb	75,000– 78,000 ft-lb
Maximum torque	16,700 ft-lb	48,200 ft-lb	77,250 ft-lb	80,100 ft-lb	112,000 ft-lb
Maximum tension	750,000 lb	1,800,000 lb	2,850,000 lb	1,450,000 lb	1,870,000 lb
Bending strength ratio	2:10	2:53	2:70	2:47	3:10
Maximum dogleg severity, rotating	20°/100 ft	11°/100 ft	10°/100 ft	9°/100 ft	8°/100 ft
Maximum dogleg severity, sliding	36°/100 ft	19°/100 ft	16°/100 ft	15°/100 ft	14°/100 ft
Equivalent bending stiffness (OD x ID)	4.75 in. x 2.29 in.	6.75 in. x 3.06 in.	8.0 in. x 4.20 in.	8.25 in. x 5.28 in.	9.5 in. x 6.08 in.
Maximum operating temperature	356°F (180°C)	356°F (180°C)	356°F (180°C)	356°F (180°C)	356°F (180°C)
Maximum operating pressure	30,000 psi (207 MPa)	30,000 psi (207 MPa)	30,000 psi (207 MPa)	25,000 psi (172 MPa)	25,000 psi (172 MPa)
Maximum flow rate	400 gal/min	800 gal/min	800 gal/min	1800 gal/min	1800 gal/min
Maximum sand content	2%	2%	2%	2%	2%



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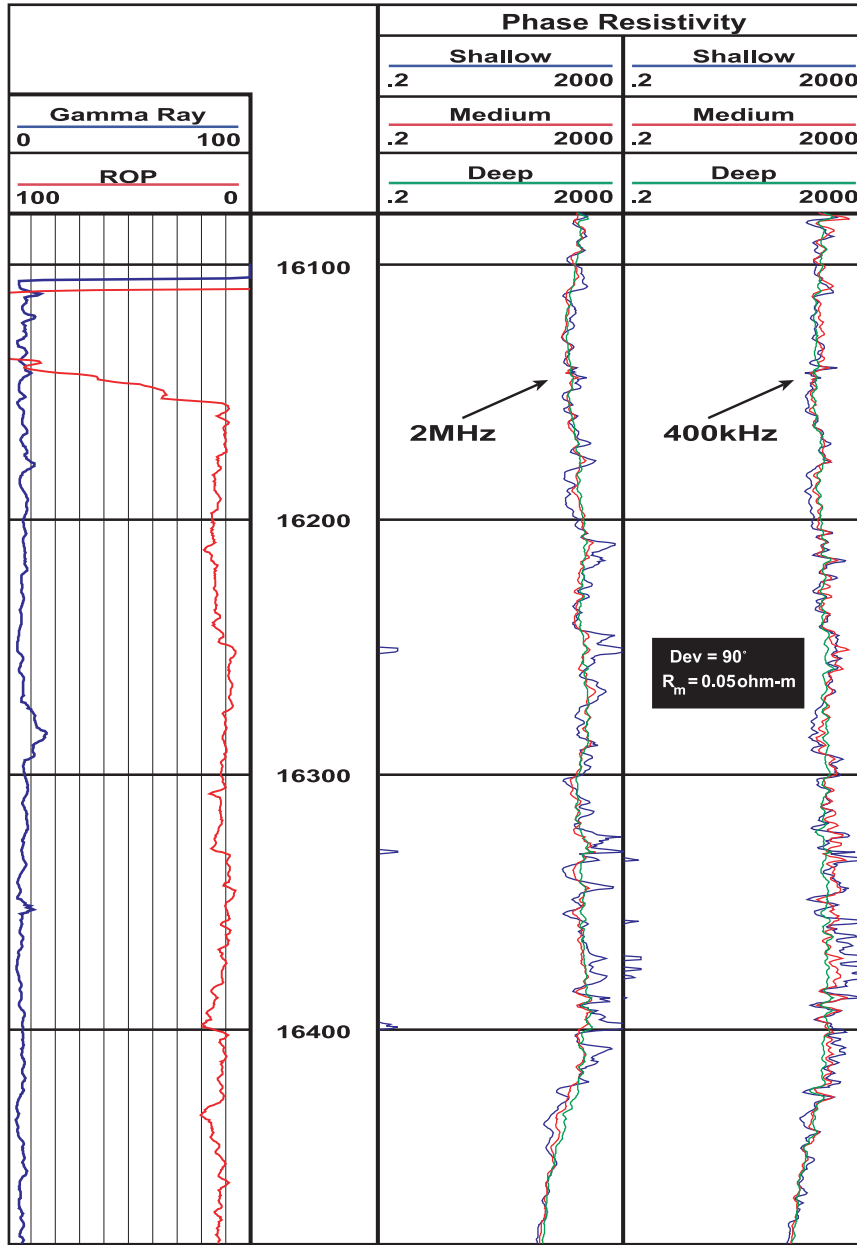
Diameter of Investigation						
Phase Measurement						
Frequency Spacing	2 MHz 20 in.	2 MHz 30 in.	2 MHz 46 in.	400 kHz. 20 in.	400 kHz 30 in.	400 kHz 46 in.
Resistivity, ohm-m						
0.2	19.1 in.	23.1 in.	28.2 in.	26.0 in.	31.7 in.	39.4 in.
2	28.2 in.	36.0 in.	44.9 in.	39.4 in.	49.7 in.	62.9 in.
20	43.1 in.	55.5 in.	71.3 in.	53.0 in.	71.4 in.	95.8 in.
200	56.4 in.	77.5 in.	106.2 in.	61.8 in.	87.8 in.	126.1 in.
2000	64.3 in.	91.3 in.	133.2 in.	65.1 in.	95.1 in.	141.9 in.
Attenuation Measurement						
Frequency Spacing	2 MHz 20 in.	2 MHz 30 in.	2 MHz 46 in.	400 kHz 20 in.	400 kHz 30 in.	400 kHz 46 in.
Resistivity, ohm-m						
0.2	28.2 in.	34.7 in.	42.3 in.	41.0 in.	49.7 in.	61.1 in.
2	46.7 in.	57.7 in.	71.2 in.	72.8 in.	85.8 in.	104.4 in.
20	88.5 in.	102.9 in.	123.5 in.	153.2 in.	170.8 in.	196.6 in.
200	200.3 in.	219.2 in.	247.1 in.	390.0 in.	412.8 in.	445.4 in.

Performance Specifications		
Nominal Sensor OD(in.)	4 3/4, 6 3/4, 8, 8 1/4, 9 1/2	
Measure point from bottom of sensor	10.4 ft	
	Phase	Attenuation
Measurement range	0.1–3000 ohm-m	0.1–200 ohm-m
Accuracy (all spacings)	±.25 mmhos	±.5 mmhos

Vertical Resolution—50% Response			
100-ohm-m bed	20-in. spacing	30-in. spacing	46-in. spacing
2-MHz phase	22 in.	28 in.	36 in.
2-MHz attenuation	56 in.	66 in.	79 in.
400-kHz phase	25 in.	35 in.	48 in.
400-kHz attenuation	87 in.	96 in.	111 in.
1-ohm-m bed	20-in. spacing	30-in. spacing	46-in. spacing
2-MHz phase	6 in.	6 in.	6 in.
2-MHz attenuation	16 in.	17 in.	17 in.
400-kHz phase	12 in.	12 in.	12 in.
400-kHz attenuation	25 in.	29 in.	33 in.



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Limestone—horizontal well with salt-saturated mud