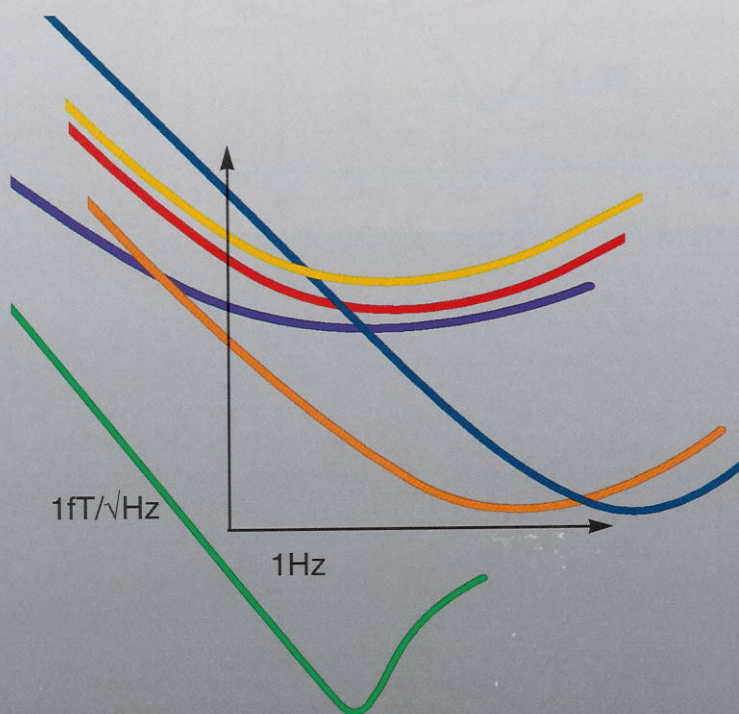


# EMI

ELECTROMAGNETIC INSTRUMENTS, INC.

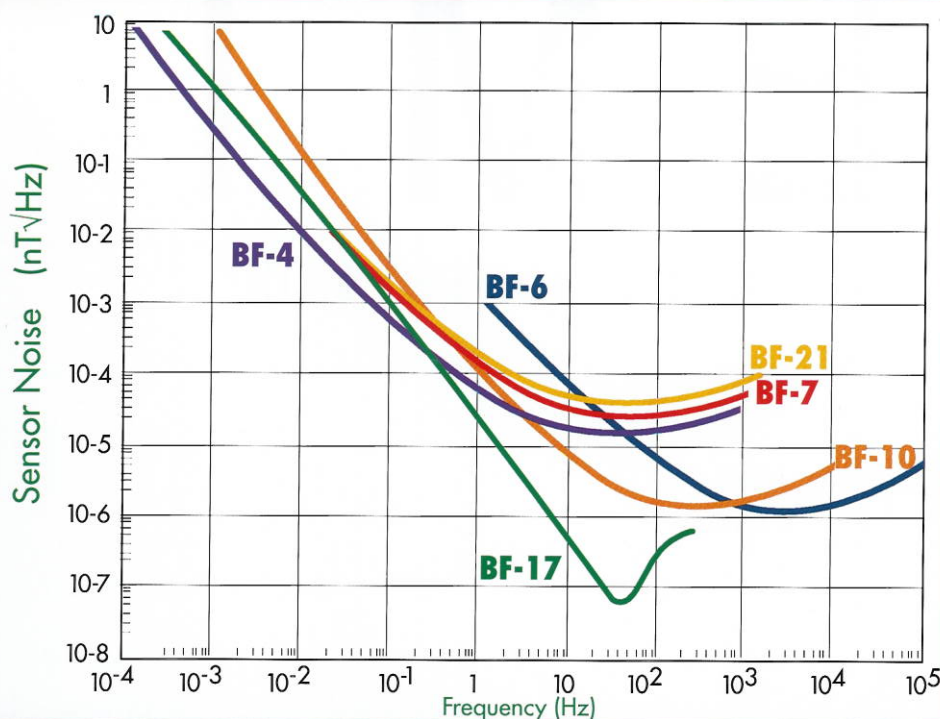


# SENSORS

BF SERIES INDUCTION MAGNETOMETERS



# INTRODUCTION



EMI manufactures a wide range of induction coils primarily addressing the needs of the geophysical exploration community for controlled-source soundings, audio-magnetotellurics, broad band electromagnetic exploration and magnetotellurics.

EMI's BF sensors have been modified to be used as marine sensors, deep borehole sensors and as high sensitivity, gimbal mounted airborne sensors. EMI specializes in custom design for these sensors. Non standard packaging options range from high temperature (260°C), high pressure 6000 psi oil-filled pressure compensated sensors, to composite graphite epoxy cased sensors.

The standard BF line of sensors are magnetic feedback induction sensors. They are constructed using a high magnetic permeability, mumetal core with proprietary windings. The coil windings are shielded and then epoxy potted inside a tube, typically made of strong NEMA G fiberGlass. Each sensor includes a matched low noise preamplifier, which is normally mounted at one end of the coil tube using waterproof "O" ring assembly. The sensor design is optimized to maximize noise performance for a given length/weight specification.

EMI currently manufactures 6 standard sensor designs and 5 borehole versions are in production. Noise of standard sensors is shown in the graph above.

available in the market, the output of EMI's induction coils is proportional to the induction field **B** threading the coil rather than to its time derivative. This reduces the dynamic range requirements of the recording system and allows for smaller sensor calibration corrections. The magnetic field feedback technique is also responsible for the excellent long term and thermal stability of the sensors.

For data collection in the band from 0.0003 Hz to 500 Hz the BF-4 sensor is ideal. It is lightweight (7.9 Kg), uses low power (225mW), and has lower internal noise than other sensors commercially available. The BF-6 sensor operates from 10 Hz to more than 100 KHz. This sensor is preferred for high frequency data acquisition. It is smaller and lighter (1.7 Kg) than the BF-4 and easier to install in the field. To take full advantage of the signal processing capabilities of the EMI-magnetotelluric system over its wide frequency range (0.0001- 25,000 Hz), both sensors are required.

The BF-10 sensor offers a compromise in performance between the BF-4 and BF-6. It is suitable for frequencies between 0.1 Hz and 10 kHz and is an ideal sensor for Audiofrequency (AMT) and Controlled Source (CSAMT) magnetotelluric applications. EMI also manufactures the BF-7 and BF-21 sensors which have the same frequency range as the BF-4 but are shorter in length making them more useful for deployment as vertical sensors, since a much shallower hole needs to be prepared. The BF-5 is a lightweight version of the BF-10 with lower performance.

## POWER SUPPLY FOR MAGNETIC FIELD SENSORS (BFPS)

A single power supply module is used for three magnetic sensors. Since power is supplied through the same cable (CAB-3) that carries the signal, no separate cabling is necessary. The power is supplied to the coils by simply connecting the cable; there is no switch. A set of fully charged batteries is sufficient for more than 72 hours of continuous operation. EMI also supplies a battery charging module (BFPS-CH) for easy recharging of the BFPS power supply.

## MAGNETIC FIELD MEASUREMENTS

As opposed to many other magnetic field sensors

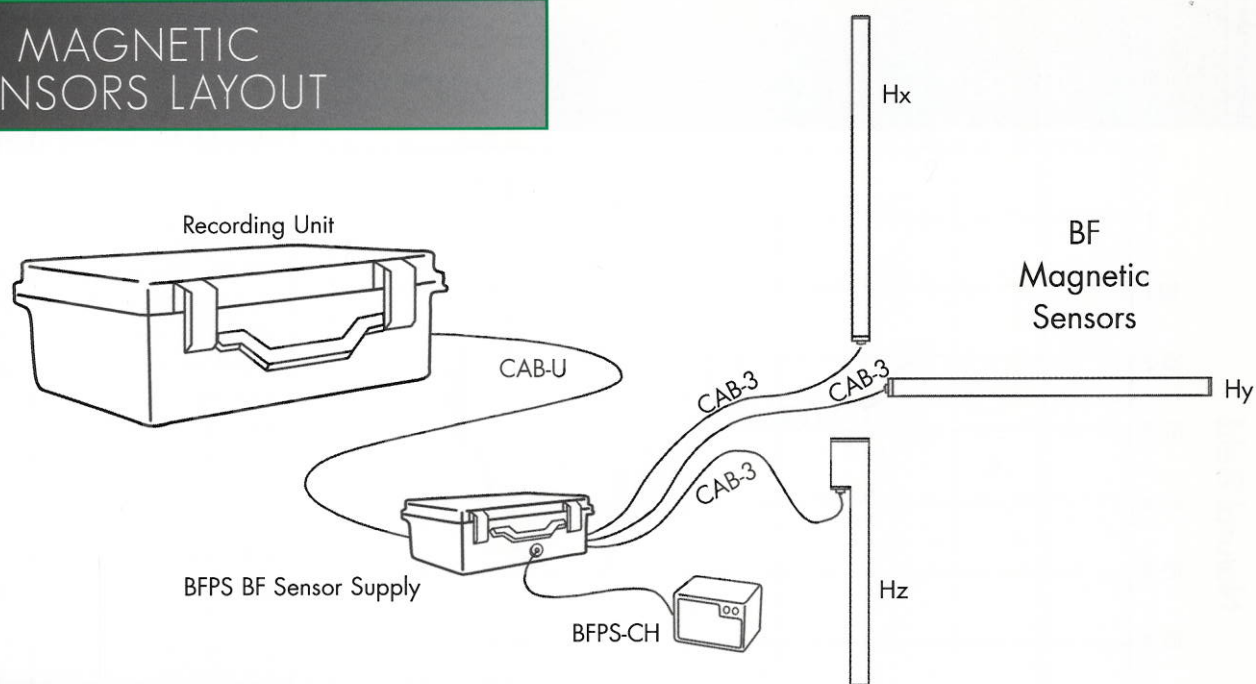


EMI, Electromagnetic Instruments, Inc., 1301 S. 46th St., UCRFS Bldg. 300, Richmond, CA 94804, U.S.A.  
Phone: 510-232-7997, Fax: 510-232-7998





## BF MAGNETIC SENSORS LAYOUT



## BF MAGNETIC SENSORS

PART #	RECOMMENDED FREQUENCY RANGE	LENGTH	WEIGHT
BF-4	.0001Hz - 1000Hz	142 cm (56 in.)	7.9 Kg (17.4 lbs)
BF-6	1Hz - 100kHz	73 cm (29 in.)	1.7 Kg (3.7 lbs)
BF-7	.0001Hz - 1000Hz	104 cm (41 in.)	7 Kg (15 lbs)
BF-10	.1Hz - 10kHz	142 cm (56 in.)	7.9 Kg (17.4 lbs)
BF-21	.0001Hz - 300Hz	63 cm (25 in.)	23 Kg (51 lbs)

## STANDARD ACCESSORIES

PART #	DESCRIPTION
CAB-U	Heavy duty urethane cable, 100 m length with 14 pin female connector
CAB-3	Heavy duty urethane cable, 10 m length with 8 pin female connector
BFPS	Power supply for BF magnetic sensors with three 8 pin male input connectors and one 14 pin male output connector
BFPS-CH	Battery charger for BFPS, 110V input

## OPTIONAL ACCESSORIES

PART #	DESCRIPTION
CAB-U PVC	PVC cable, 100 m length with 14 pin female connector
BFPS - BNC	Power supply for BF magnetic sensors with three 8 pin male input connectors and three BNC output connectors

\* EMI can customize for other configurations of cable length and connectors.

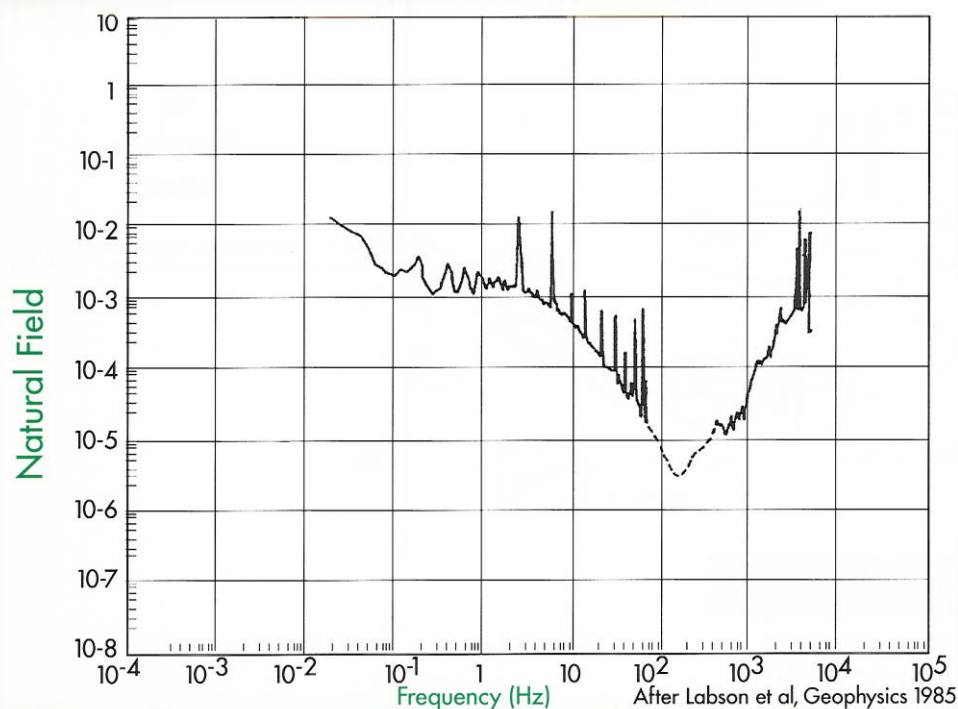
\* Specifications subject to change without notice.







## TYPICAL NATURAL MAGNETIC FIELD SPECTRUM



Natural field magnetic signals are normally buried under high background noise levels and are thus difficult to detect without very low-noise and wide dynamic range magnetic field signal detectors. The graph above shows a typical magnetic field power density spectrum in the audio frequency band. Below 0.2 Hz, signal energy results from ionospheric currents caused by solar emissions and is roughly continuous in nature, increasing in strength as the frequency is lowered. Natural signals above 1 Hz are due to electrical storm activity and are characterized by predominance of impulses with a very low background energy level. Total energy above 1 Hz varies widely depending on geographic separation between the measurement site and the nearest electrical storms. Electrical power distribution systems provide very high energy levels (relative to the other sources) at 50 Hz or 60 Hz and the higher harmonics of these frequencies. In most cases the source of this energy is too near the measurement site and is too complex in source geometry to be used for geophysical exploration methods. Thus, the cultural energy is normally treated as noise and these frequencies and their harmonics are avoided.

## INSTALLATION

Before burial, record the serial number of each sensor, its orientation, and the connections made to a field conditioner in a sketch as an aid in later processing. Each sensor has its own calibration file that is located using the serial number. It is also recommended to verify that the sensor is operating correctly to move a magnetic object such as a shovel or knife or keys near each

sensor to verify coil and cable integrity.

Bury the sensors 10-50 cm below the surface of the earth. In very windy areas, the coils should be buried deeper. To minimize wind-induced motion noise, the earth should be packed carefully around the coil and further compacted by walking on it. Make sure the surface is as smooth as possible without large lumps or cables sticking up. These lumps will transmit wind noise to the magnetometer. A rope or strap may be attached to the coil near the cable end as an aid when retrieving the magnetometers after data acquisition.

Observation of the magnetometer signals, using an acquisition system with a sampling frequency of 20 Hz, will generally identify any problems with the site setup. In this band, the background magnetic fields are generally small so that any contaminating signals may be easily identified. A good practice is to set up two parallel sensors and then visual comparisons of the observed signals will verify sensor operation.

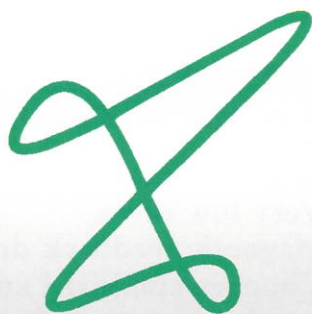
## COMMON FIELD SITES FOR MAGNETOMETERS

The magnetometers are extremely sensitive devices and are easily contaminated by a variety of sources. It is therefore very important to choose a site location with minimal noise sources and to make a good installation. In general, the site location should be isolated. All efforts must be made to avoid seismically transmitted motion energy, magnetic noise, and electrical noise. This means avoiding motion induced by nearby ocean waves, magnetic noise such as that generated by metal fence posts, or electrical noise such as that made by electric machinery. Below is a short list of site attributes which would effect an installation adversely:

- Electric fences, buried cables, power lines, electrical machines, irrigation pumps.
- Foot traffic which might carry coils or shovels (or anything metal).
- Oceans or streams.
- Road traffic (require 100+ meters clearance).
- Trains (require 500+ meters clearance), \*note that DC trains and subway signals can be seen at least 50 km.
- Sites near large tree roots.
- Metal fence posts or towers, which move slightly in the wind.
- Pipelines with cathodic protection.



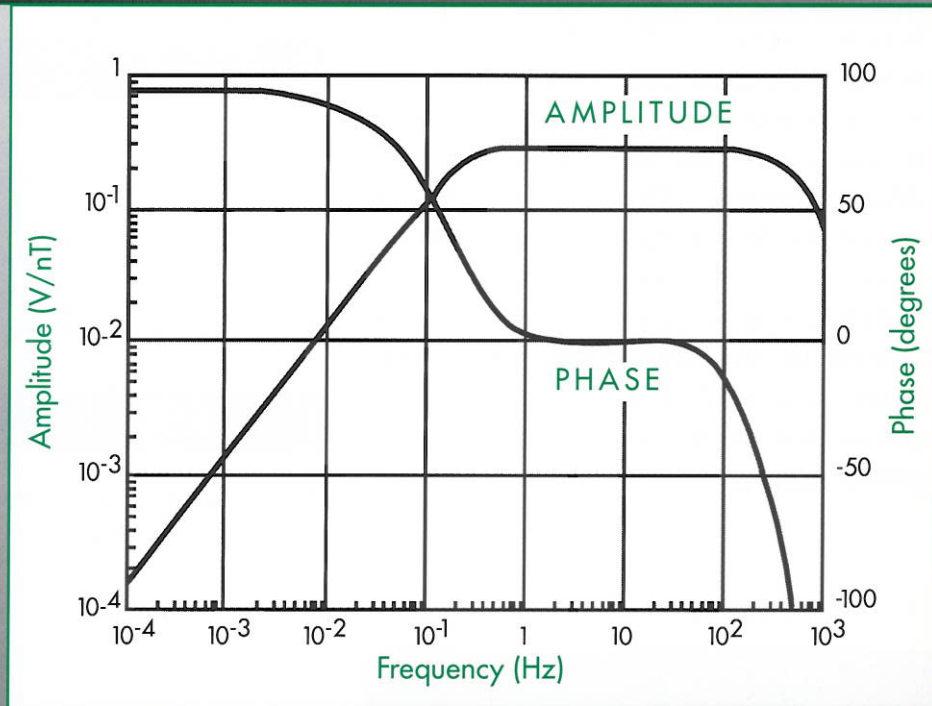




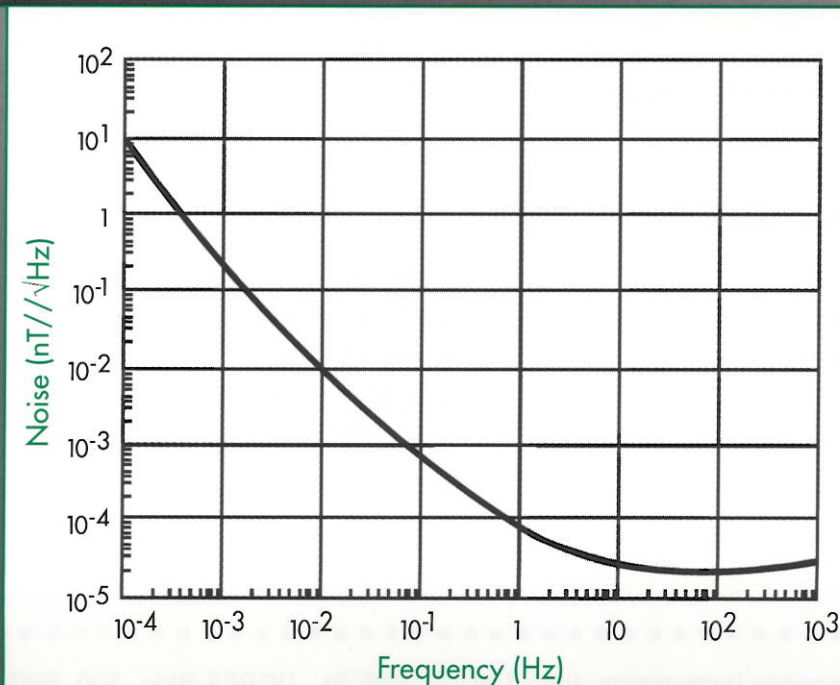
# BF-4

MAGNETIC FIELD INDUCTION SENSOR

FREQUENCY RANGE: 0.0001 to 1000 Hz



NOISE PERFORMANCE



# BF-4

## FEATURES

- High sensitivity
- Very low noise
- Magnetic feedback design
- Chopper stabilized amplifier for best low frequency performance
- Ruggedized and waterproof
- Light weight and compact design
- Low power consumption (290 mW)
- Stable phase response

## APPLICATIONS

- Geophysical surveys: MT, AMT, CSAMT, MMR, MIP, CSEM
- Marine surveys
- Atmospheric studies
- Earthquake studies
- High accuracy magnetic field studies

## OPTIONS

- Marine connector for underwater applications

The BF-4 sensor design utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and +/- 1 degree in phase between sensors. For the frequencies below the flat response region the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is sealed in epoxy inside a rugged impact resistant Nema G-10 fiberglass tube. A matched low noise preamplifier is connected to the coil inside the waterproof case and is powered from the connector using a nearby +/- 12V power supply.

## TECHNICAL SPECIFICATIONS

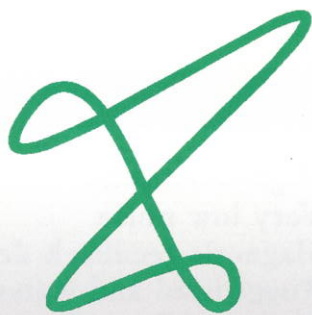
### PERFORMANCE

Frequency range:	0.0001 to 1000 Hz
3 dB frequency corners:	0.2 Hz, 500 Hz
Sensitivity (flat region):	0.3 V/nT (standard)
Power consumption:	12 mA at +/- 12V

### MECHANICAL

Case style:	Nema G-10 Straight Tube
Length:	142 cm (56 in.)
Diameter:	6 cm (2.4 in.)
Weight:	7.9 Kg (17.4 lbs)
Connector:	8 pin Waterproof Tajimi

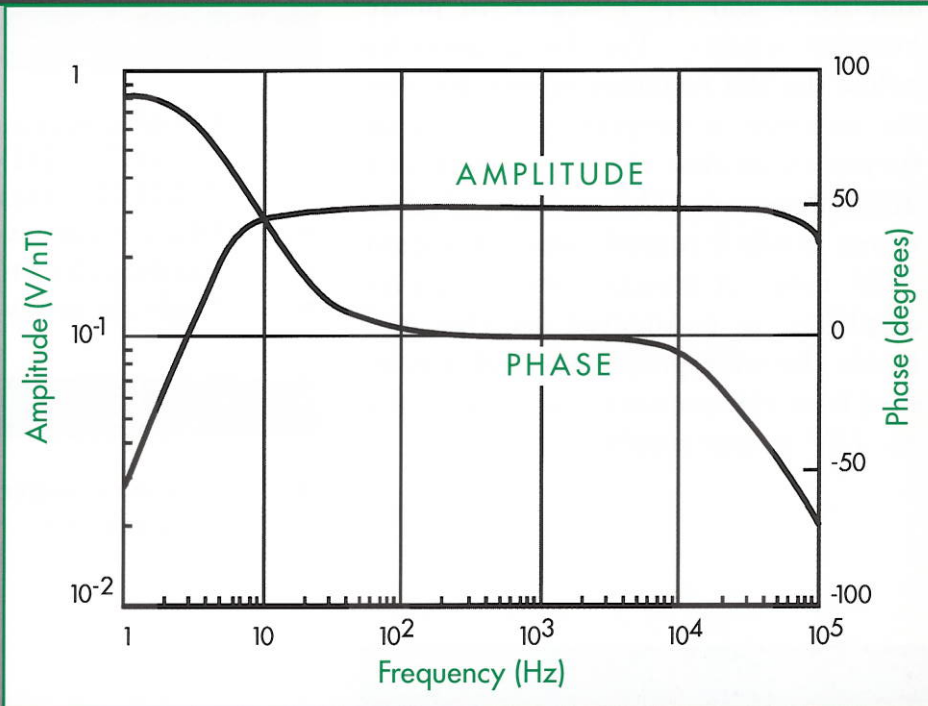




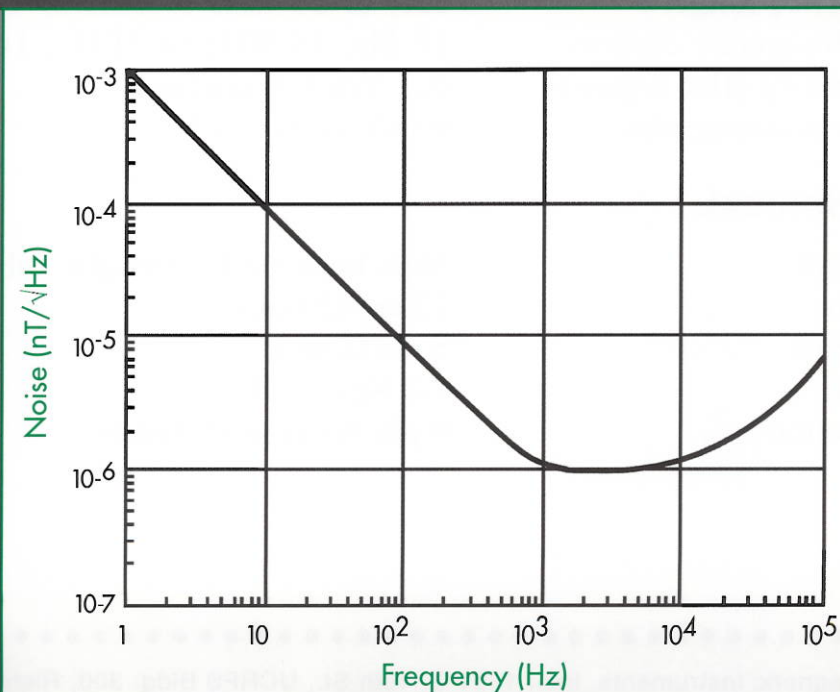
# BF-6

MAGNETIC FIELD INDUCTION SENSOR

FREQUENCY RANGE: 1Hz to 25 kHz or 1Hz to 100 kHz



NOISE PERFORMANCE



# BF-6

## FEATURES

- High sensitivity
- Very low noise
- Magnetic feedback design
- Ruggedized and waterproof
- Light weight and compact design
- Low power consumption (210 mW)
- Stable phase response

## APPLICATIONS

- Geophysical surveys: MT, AMT, CSAMT, MMR, MIP, CSEM, TSHMT, Statagem™
- Marine surveys
- Earthquake studies
- High accuracy magnetic field studies

## OPTIONS

- Marine connector for underwater applications

The BF-6 sensor design utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1$  degree in phase between sensors. For the frequencies below the flat response region the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is sealed in epoxy inside a rugged impact resistant ABS tube. A matched low noise pre-amplifier is connected to the coil inside the waterproof case and is powered from the connector using a nearby  $\pm 12V$  power supply.

## TECHNICAL SPECIFICATIONS

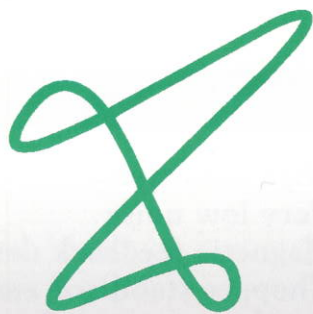
### PERFORMANCE

Frequency range:	1Hz to 25 kHz or 1Hz to 100 kHz
3 dB frequency corners:	10 Hz, 25 KHz or 10Hz, 100kHz
Sensitivity (flat region):	0.3 V/nT (standard)
Power consumption:	9 mA at $\pm 12V$

### MECHANICAL

Case style:	High Impact ABS Straight Tube
Length:	73 cm (29 in.)
Diameter:	5 cm (2 in.)
Weight:	1.7 Kg (3.7 lbs)
Connector:	8 pin Waterproof Tajimi

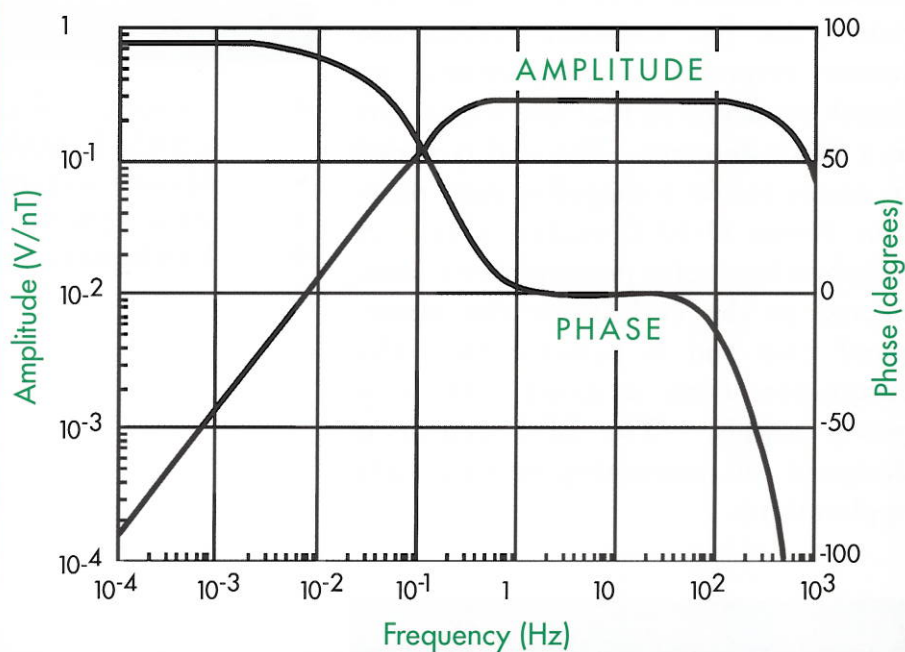




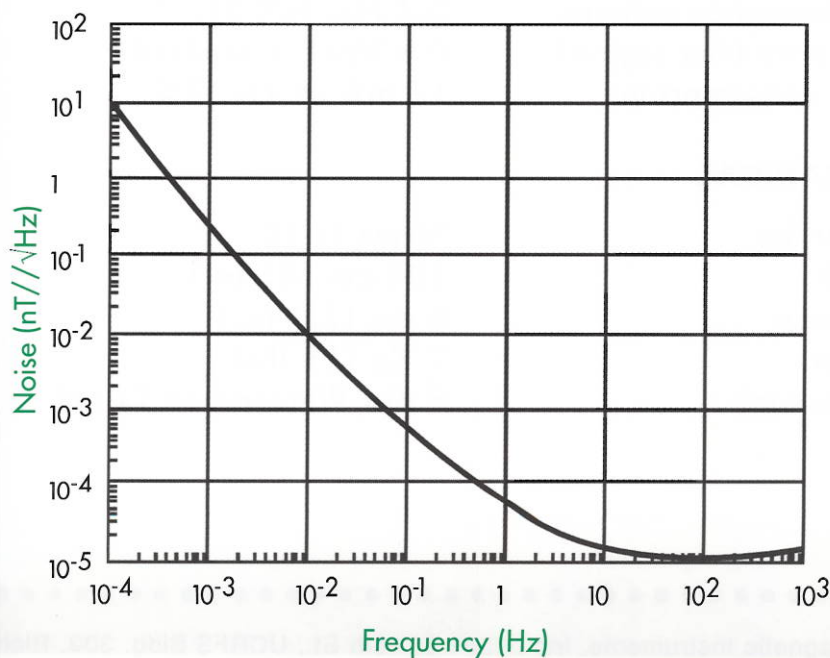
# BF-7

MAGNETIC FIELD INDUCTION SENSOR

FREQUENCY RANGE: 0.0001 to 1000 Hz



NOISE PERFORMANCE





# BF-7

## FEATURES

The BF-7 sensor design utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1$  degree in phase between sensors. For the frequencies below the flat response region the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is sealed in epoxy inside a rugged impact resistant Nema G-10 fiberglass tube. A matched low noise preamplifier is connected to the coil inside the waterproof case and is powered from the connector using a nearby  $\pm 12V$  power supply. The BF-7 sensor is designed for monitoring vertical field applications.

- High sensitivity
- Very low noise
- Magnetic feedback design
- Chopper stabilized amplifier for best low frequency performance
- Ruggedized and waterproof
- Light weight and compact design
- Low power consumption (210 mW)
- Stable phase response

## APPLICATIONS

- Geophysical surveys: MT, AMT, CSAMT, MMR, MIP, CSEM
- Marine surveys
- Atmospheric studies
- Earthquake studies

## TECHNICAL SPECIFICATIONS

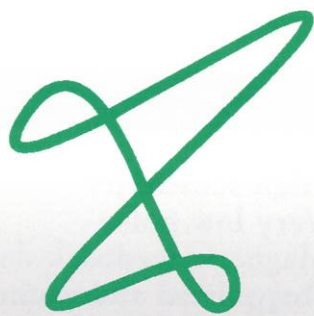
### PERFORMANCE

Frequency range:	0.0001 to 1000 Hz
3 dB frequency corners:	0.2 Hz, 500 Hz
Sensitivity (flat region):	0.3 V/nT (standard)
Power consumption:	12 mA at $\pm 12V$

### MECHANICAL

Case style:	Nema G-10
Length:	104 cm (41 in.)
Diameter:	6 cm (2.4 in.)
Weight:	7 Kg (15 lbs)
Connector:	8 pin Waterproof Tajimi

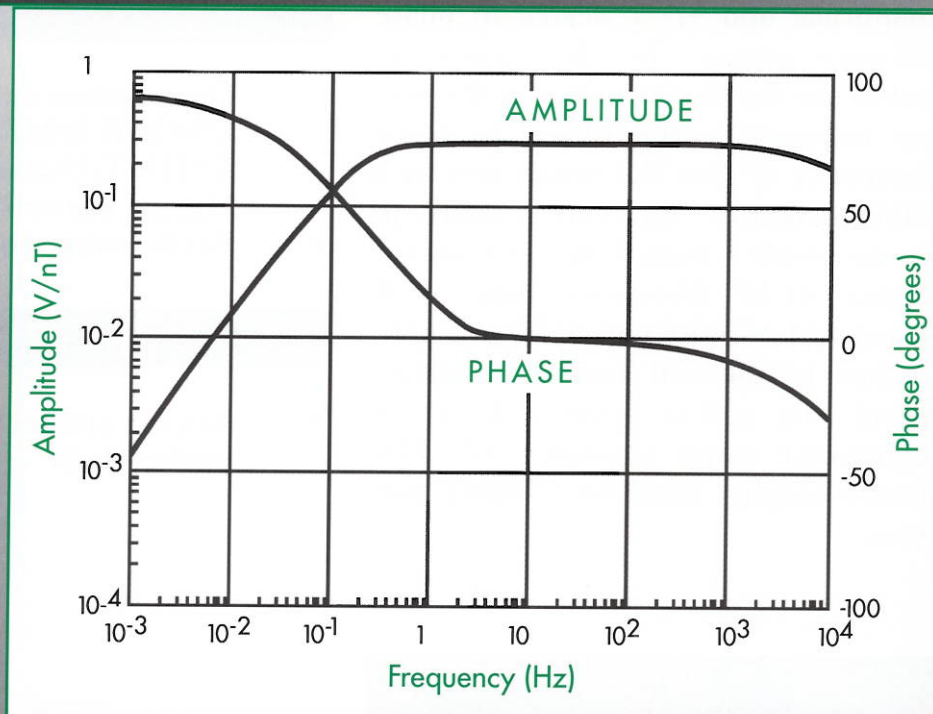




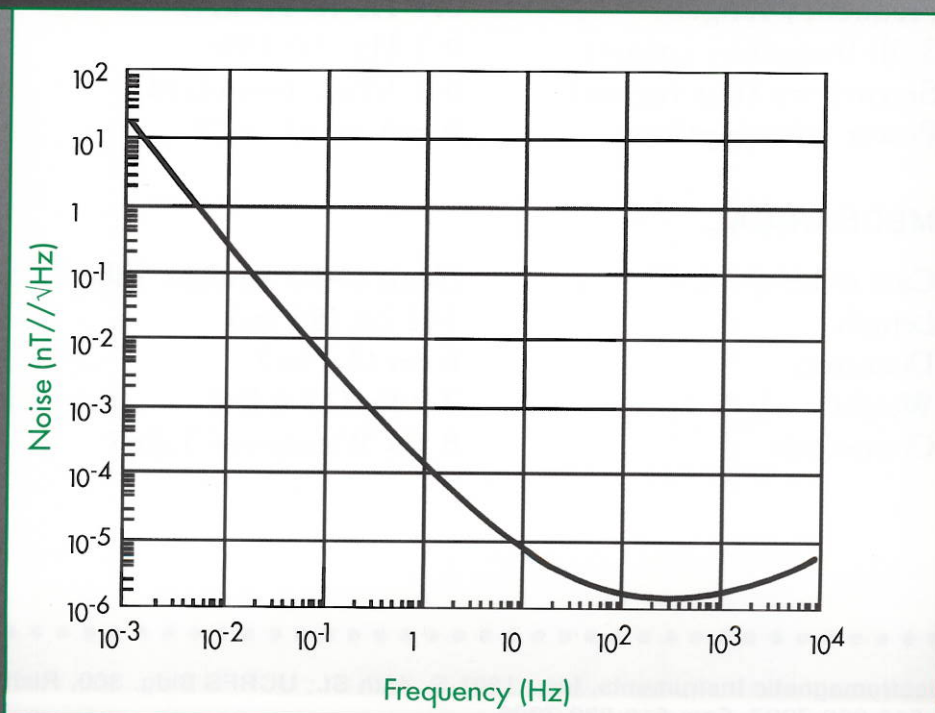
# BF-10

MAGNETIC FIELD INDUCTION SENSOR

FREQUENCY RANGE: 0.1 Hz to 10 kHz



NOISE PERFORMANCE





# BF-10

## FEATURES

- High sensitivity
- Very low noise
- Magnetic feedback design
- Ruggedized and waterproof
- Light weight and compact design
- Low power consumption (210 mW)
- Stable phase response

## APPLICATIONS

- Geophysical surveys: MT, AMT, CSAMT, MMR, MIP, CSEM, TSHMT, Statagem™
- Marine surveys
- Earthquake studies

## OPTIONS

- Marine connector for underwater applications

The BF-10 sensor design utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1$  degree in phase between sensors. For the frequencies below the flat response region the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is sealed in epoxy inside a rugged impact resistant Nema G-10 fiberglass tube. A matched low noise preamplifier is connected to the coil inside the waterproof case and is powered from the connector using a nearby  $\pm 12V$  power supply. Ideal for CSAMT surveys.

## TECHNICAL SPECIFICATIONS

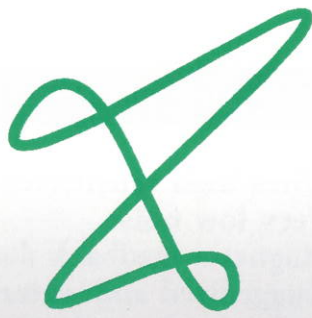
### PERFORMANCE

Frequency range:	0.1 Hz to 10 kHz
3 dB frequency corners:	0.2 Hz, 10 kHz
Sensitivity (flat region):	0.3 V/nT (standard)
Power consumption:	9 mA at $\pm 12V$

### MECHANICAL

Case style:	Nema G-10 Straight Tube
Length:	142 cm (56 in.)
Diameter:	6 cm (2.4 in.)
Weight:	7.9 Kg (17.4 lbs)
Connector:	8 pin Waterproof Tajimi

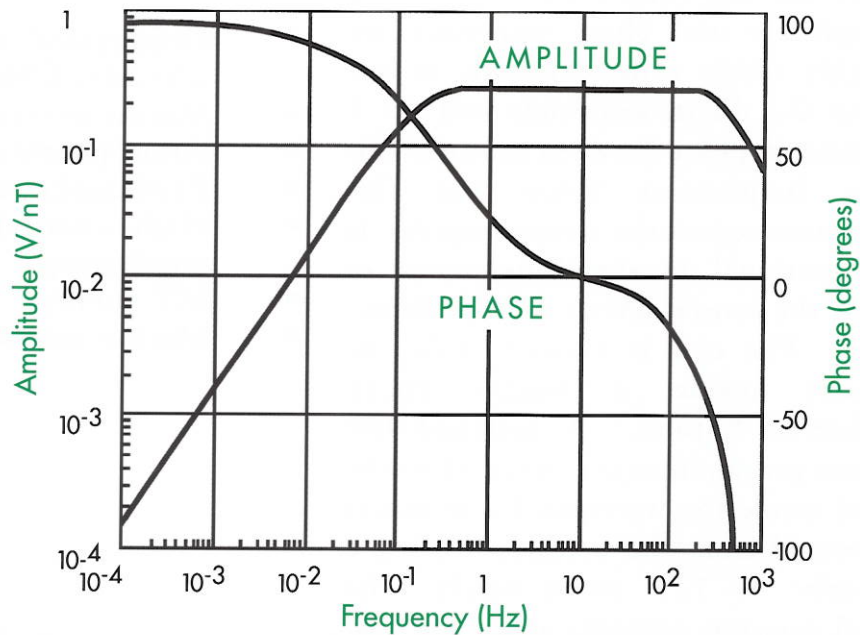




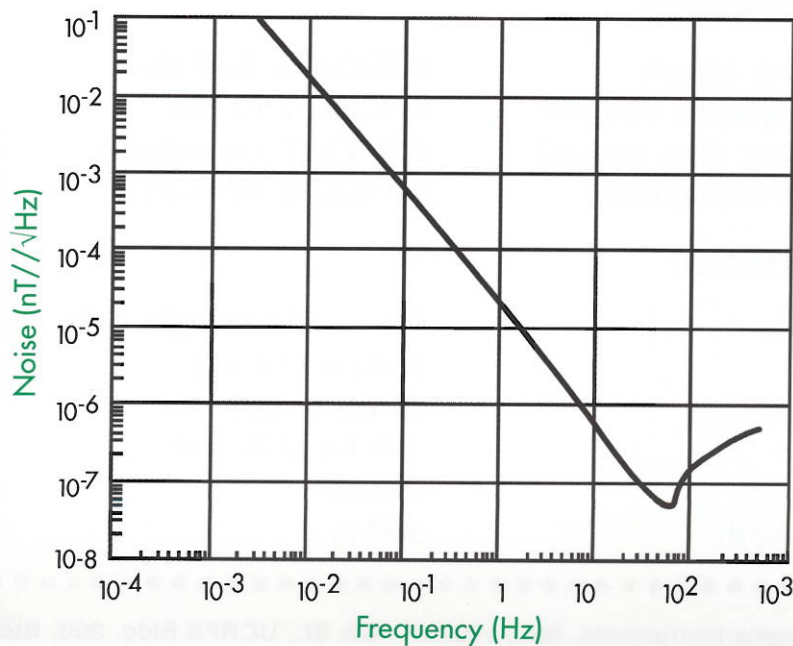
# BF-17

ULTRA HIGH SENSITIVITY MAGNETIC FIELD SENSOR

FREQUENCY RANGE: 0.0001 to 500 Hz



NOISE PERFORMANCE





## FEATURES

- Ultra high sensitivity
- Very low noise
- Magnetic feedback design
- Ruggedized and waterproof
- Light weight and compact design
- Low power consumption (1440 mW)
- Stable phase response

## APPLICATIONS

- Geophysical surveys: MT, AMT, CSAMT, CSEM
- Marine surveys
- Atmospheric studies
- Earthquake studies
- High sensitivity magnetic field monitoring
- MT surveys
- Marine magnetic field monitoring

The BF-17 sensor is an ultra high sensitivity device primarily designed for marine applications where the magnetic fields are reduced by the conductive sea water. The sensor utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensor responds as a B field detector over the flat band region. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1$  degree in phase between sensors. For the frequencies below the flat response region the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is vacuum sealed in epoxy inside a rugged epoxy Fibercast™ tube. A matched low noise preamplifier is connected to the coil inside the waterproof case and is powered from the connector using a nearby  $\pm 12V$  power supply. The coil housing contains space for custom signal conditioning electronics.

## TECHNICAL SPECIFICATIONS

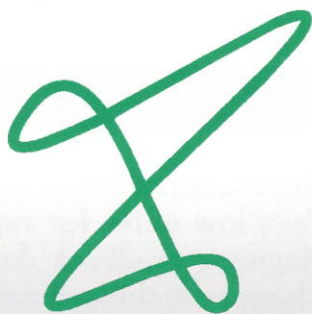
### PERFORMANCE

Frequency range:	0.0001 to 500 Hz
3 dB frequency corners:	0.2 Hz, 250 Hz
Sensitivity (flat region):	0.3 V/nT (standard)
Power consumption:	60 mA at $\pm 12V$

### MECHANICAL

Case style:	Fibercast™ Straight Tube
Length:	254 cm (54 in.)
Diameter:	20 cm (8 in.)
Weight:	100 Kg (220 lbs)
Connector:	Custom
Water Depth:	300 m

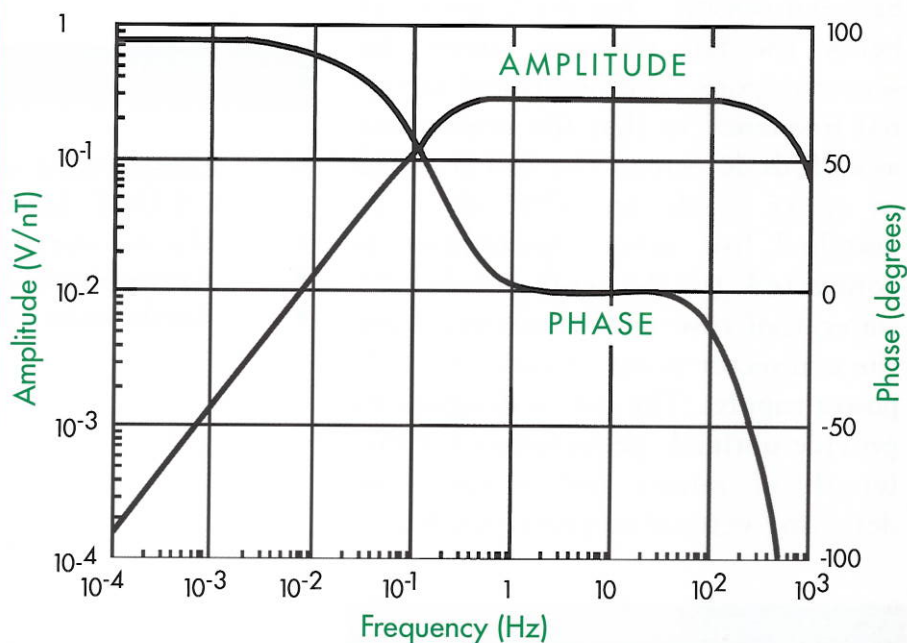




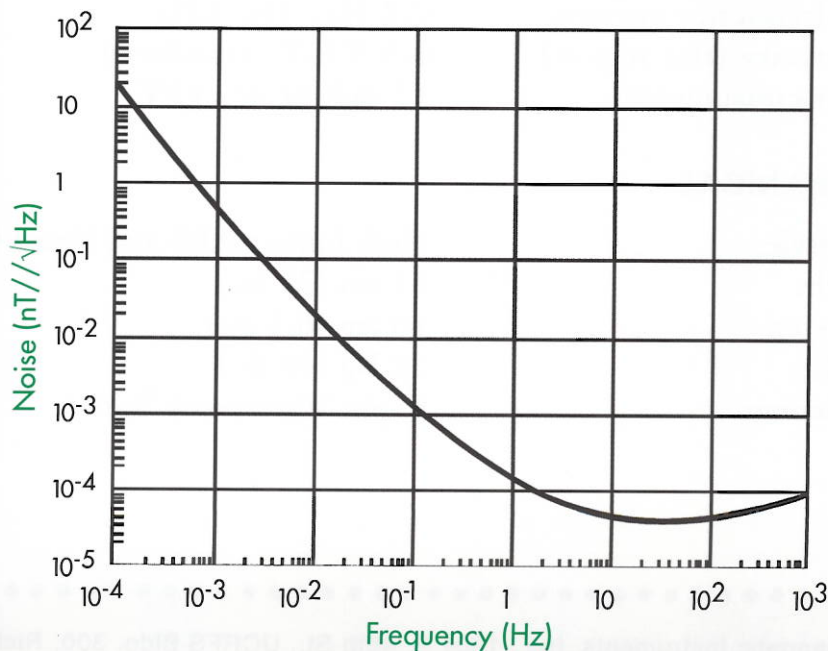
# BF-21

MAGNETIC FIELD INDUCTION SENSOR

FREQUENCY RANGE: 0.0001 to 300 Hz



NOISE PERFORMANCE





# BF-21

## FEATURES

- High sensitivity
- Very low noise for replacing loops
- Magnetic feedback design
- Chopper stabilized amplifier for best low frequency performance
- Ruggedized and waterproof
- Compact size for vertical measurements
- Low power consumption (290 mW)
- Stable phase response

## APPLICATIONS

- Geophysical surveys: MT, AMT, CSAMT, MMR, MIP, CSEM
- Marine surveys
- Atmospheric studies
- Earthquake studies

The BF-21 sensor design utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1$  degree in phase between sensors. For the frequencies below the flat response region the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is sealed in epoxy inside an ABS tube. A matched low noise preamplifier is connected to the coil inside the waterproof case and is powered from the connector using a nearby  $\pm 12V$  power supply. The coil is designed to provide optimal performance for this length of sensor and is ideal for detecting vertical magnetic fields.

## TECHNICAL SPECIFICATIONS

### PERFORMANCE

Frequency range:	0.0001 to 300 Hz
3 dB frequency corners:	0.2 Hz, 350 kHz
Sensitivity (flat region):	0.3 V/nT (standard)
Power consumption:	12 mA at $\pm 12V$

### MECHANICAL

Case style:	High Impact ABS and Nema G-10 Tube
Length:	63 cm (25 in.)
Diameter:	16 cm (6.2 in.)
Weight:	22 Kg (48 lbs)
Connector:	8 pin Waterproof Tajimi




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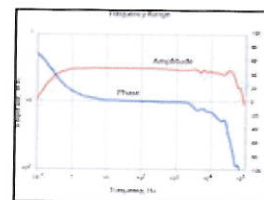
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## BF-10 Magnetic Field Induction Sensor

The BF-10 sensor utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1^\circ$  in phase between sensors. For the frequencies below the flat response region, the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is potted with epoxy and housed inside a Black Amalgon tube. A matched low-noise preamplifier is connected to the coil in a waterproof case and powered by an external  $\pm 12$ -V power supply.


[Click to view](#)

Frequency and noise performance.

### Performance

- ▶ Frequency range: 0.0001 Hz to 700 Hz
- ▶ 3-dB frequency corners: 0.3 Hz, 500 kHz
- ▶ Sensitivity (flat region): 0.3 V/nT (standard)
- ▶ Power consumption: 9 mA at  $\pm 12$  V

### Physical Specifications

- ▶ Housing: Black Amalgon straight tube
- ▶ Length: 142 cm [56 in]
- ▶ Diameter: 6 cm [2.4 in]
- ▶ Weight: 7.9 kg [17.4 lbm]
- ▶ Connector: 8-pin Tajimi

### Applications

- ▶ Magnetotellurics
- ▶ Audiomagnetotellurics
- ▶ Controlled-source electromagnetics
- ▶ Magnetometric resistivity
- ▶ Time-domain electromagnetics

### Features

- ▶ High sensitivity
- ▶ Very low noise
- ▶ Magnetic feedback design
- ▶ Rugged and waterproof
- ▶ Lightweight and compact
- ▶ Low power consumption
- ▶ Stable phase response

[Request more information](#) about BF-10 Magnetic Field Induction Sensor and other Schlumberger innovations.






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## BF-10 Magnetic Field Induction Sensor

The BF-10 sensor utilizes a magnetic feedback design to provide a stable flat response over several decades of frequency. The sensors respond as a B field detector over the flat band regions. Both the amplitude and phase responses are highly stable with variations of less than 0.1 dB in amplitude and  $\pm 1^\circ$  in phase between sensors. For the frequencies below the flat response region, the sensor response is proportional to signal frequency so that the sensor acts as a dB/dt detector. The coil is potted with epoxy and housed inside a Black Amalgon tube. A matched low-noise preamplifier is connected to the coil in a waterproof case and powered by an external  $\pm 12$ -V power supply.

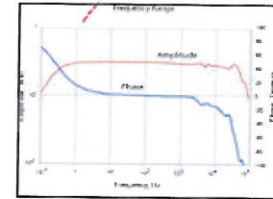
### Performance

- ▶ Frequency range: 0.1 Hz to 700 Hz
- ▶ 3-dB frequency corners: 0.3 Hz, 500 Hz
- ▶ Sensitivity (flat region): 0.3 V/nT (standard)
- ▶ Power consumption: 9 mA at  $\pm 12$  V

### Physical Specifications

- ▶ Housing: Black Amalgon straight tube
- ▶ Length: 142 cm [56 in]
- ▶ Diameter: 6 cm [2.4 in]
- ▶ Weight: 7.9 kg [17.4 lbm]
- ▶ Connector: 8-pin Tajimi

[Request more information](#) about BF-10 Magnetic Field Induction Sensor and other Schlumberger innovations.



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Frequency and noise performance.

### Applications

- ▶ Magnetotellurics
- ▶ Audiomagnetotellurics
- ▶ Controlled-source electromagnetics
- ▶ Magnetometric resistivity
- ▶ Time-domain electromagnetics

### Features

- ▶ High sensitivity
- ▶ Very low noise
- ▶ Magnetic feedback design
- ▶ Rugged and waterproof
- ▶ Lightweight and compact
- ▶ Low power consumption
- ▶ Stable phase response



