



UNIVERSITÀ
DEGLI STUDI
DI TRIESTE

Seismic MICROZONATION

Instrumentation

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Ricevimenti

Tutti i giorni su appuntamento (previa richiesta via mail)

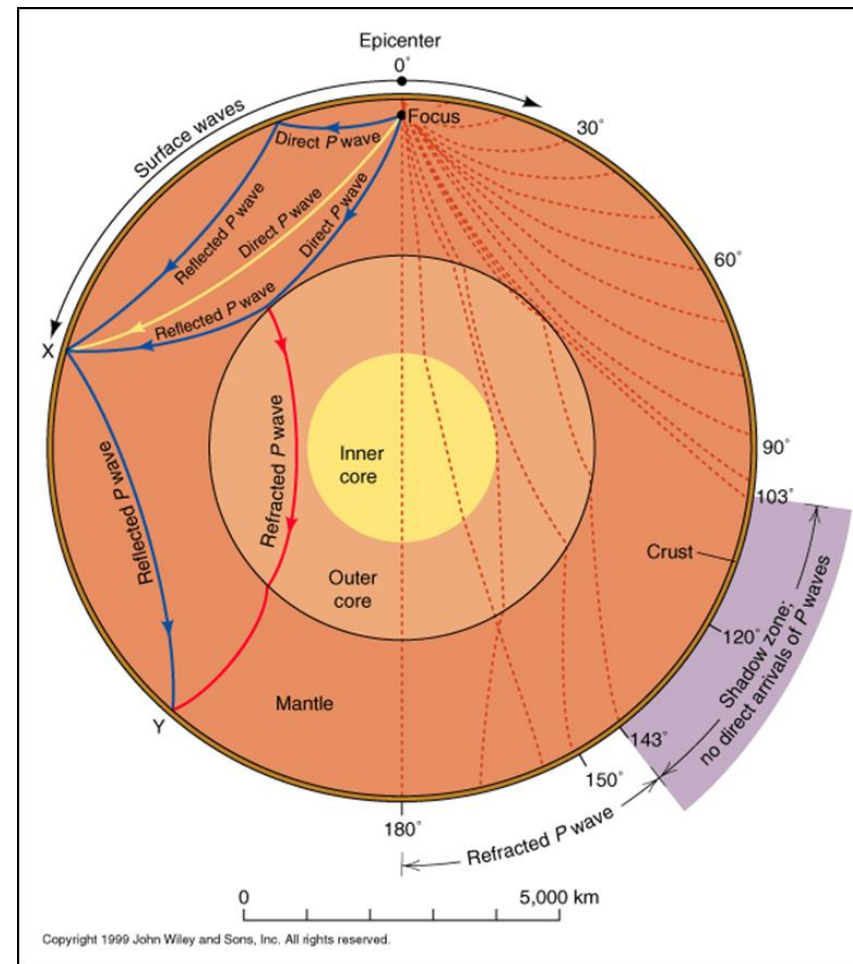
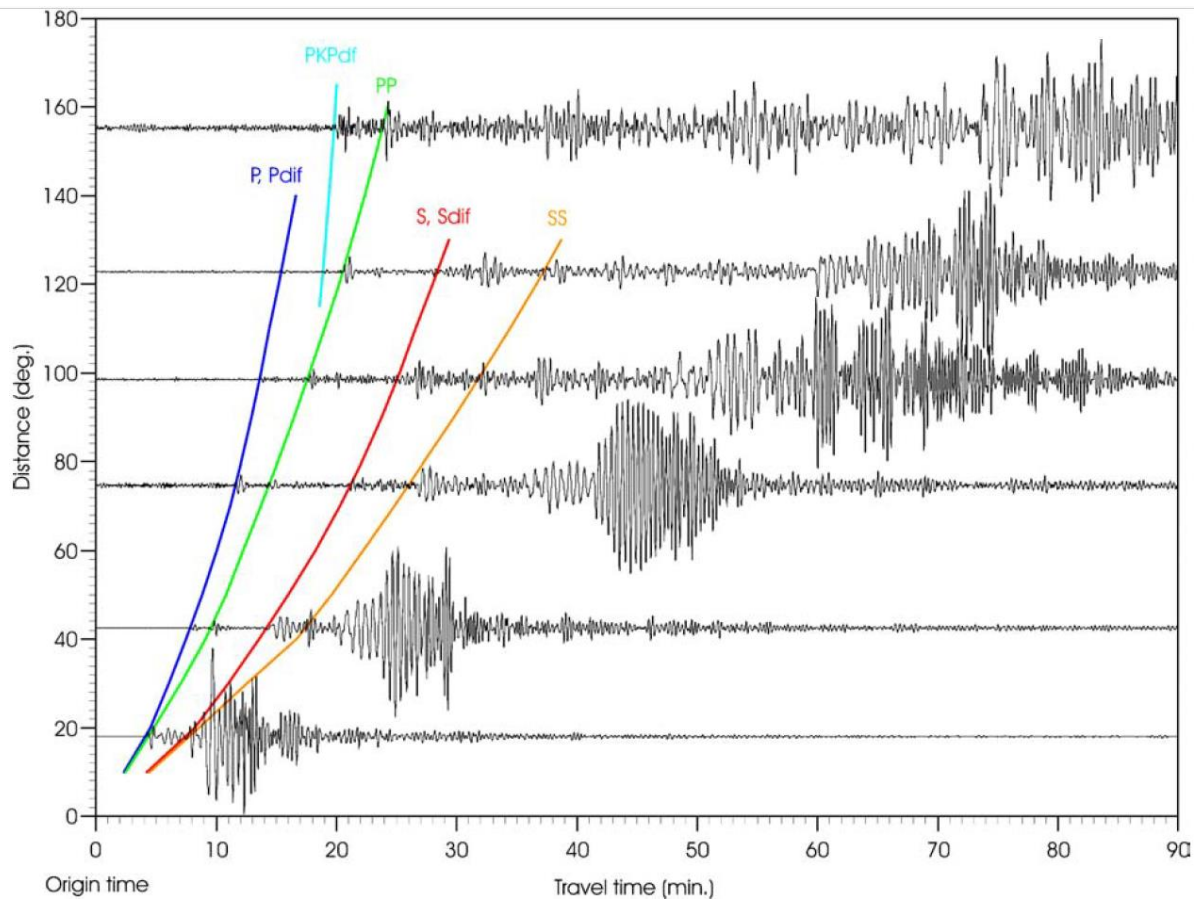
- Il corso viene suddiviso in diverse unità didattiche.
- Il corso, altamente multidisciplinare, viene suddiviso in diverse unità didattiche.
- In particolare:
 - Normativa vigente (docente: Prof. V. Pazzi)
 - Parametri e linee guida (docente: Prof. V. Pazzi)
 - Introduzione alle onde sismiche e modalità per ottenere gli spettri di risposta (docente: Prof. F. Romanelli)
 - **Strumentazione (docente: Prof. G. Costa)**
 - **Tecnica H/V: acquisizione ed analisi dei dati; potenzialità e limiti (docente: Prof. G. Costa)**
 - MASW: principi e modalità operative (docente: Prof. E. Forte)
 - Faglie attive e capaci (docente: Prof. E. Forte)
 - Informatizzazione e cartografia tematica (docente: Prof. L. Zini)
 - Liquefazione (docente: Prof. L. Zini)
 - Frane sismoindotte (docente: Prof. V. Pazzi)
 - Pericolosità sismica di riferimento. Abachi e modellazione (docente: Prof. F. Romanelli)
 - Analisi di casi studio (docenti: Prof. L. Zini & Prof. V. Pazzi)

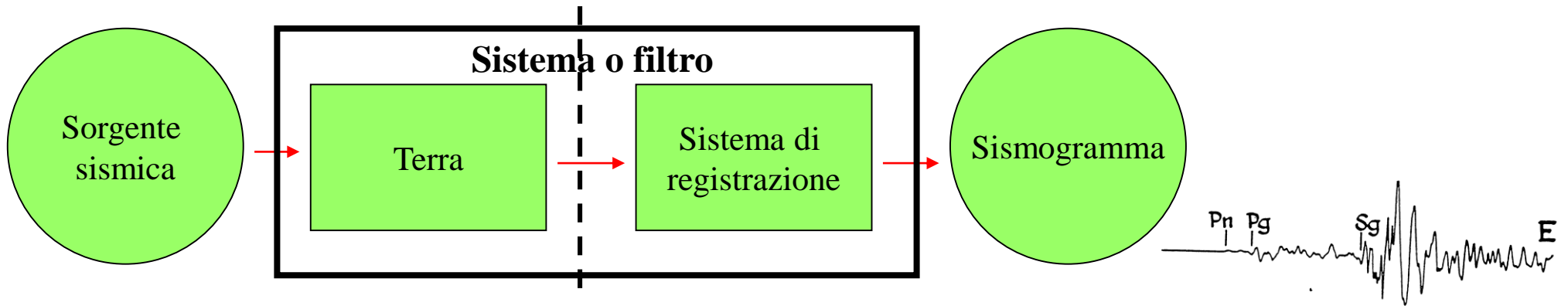
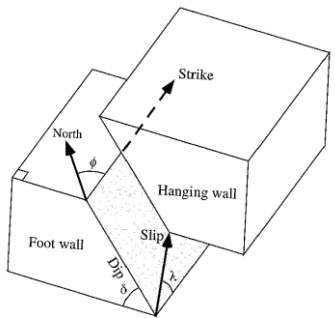
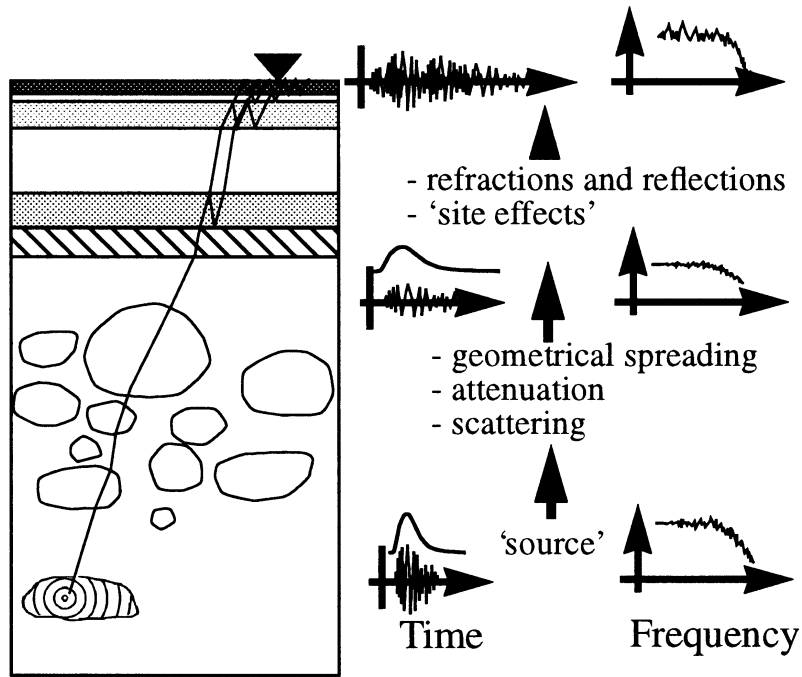
Materiale didattico

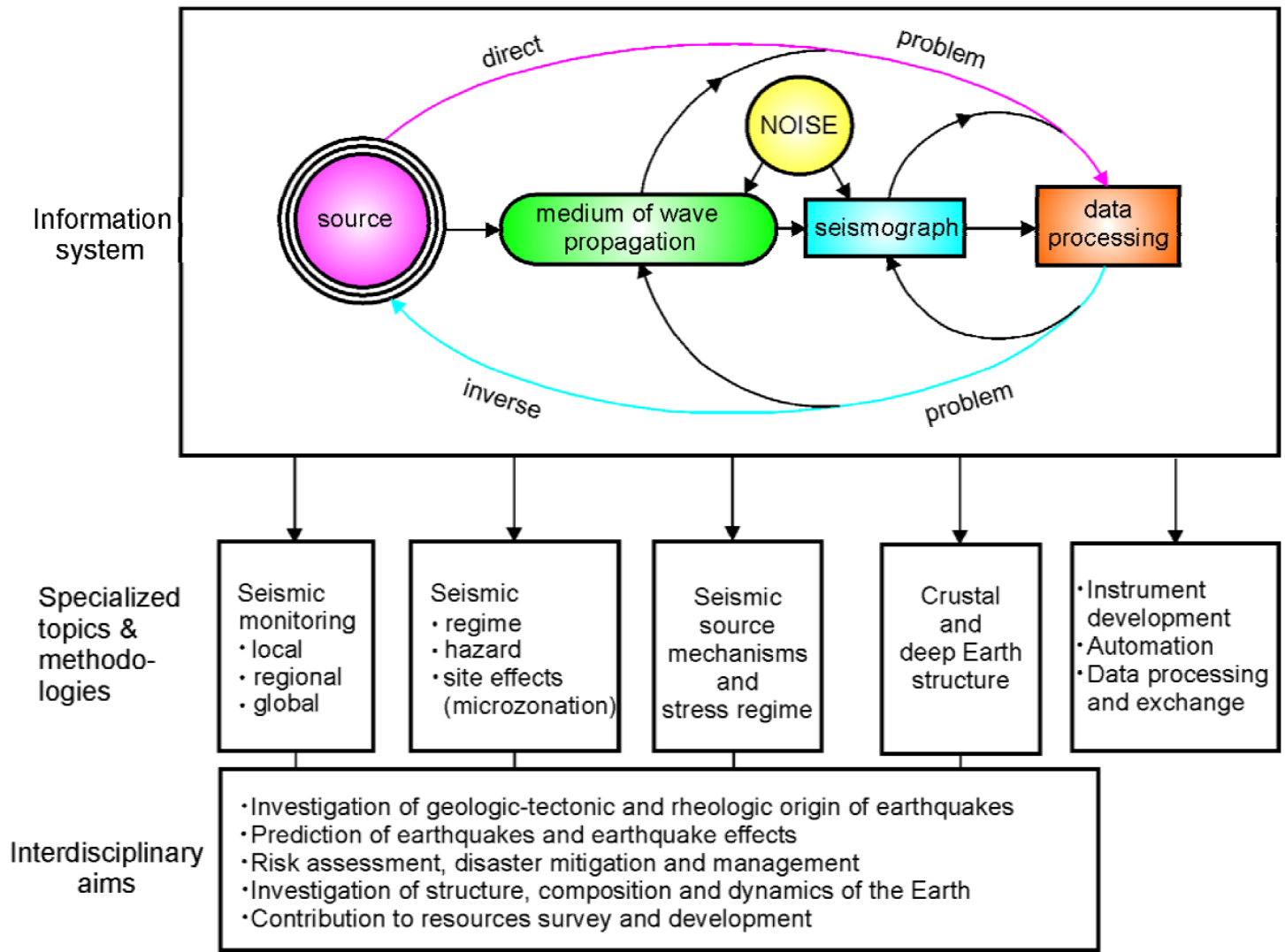
- New manual of seismological observatory practice - P Bormann - 2002
- [New Manual of Seismological Observatory Practice – NMSOP](#)

- Seismic Analysis Code Users Manual
- <https://ds.iris.edu/files/sac-manual/>

- Geopsy project (manual)
- <https://www.geopsy.org/documentation/geopsy/>



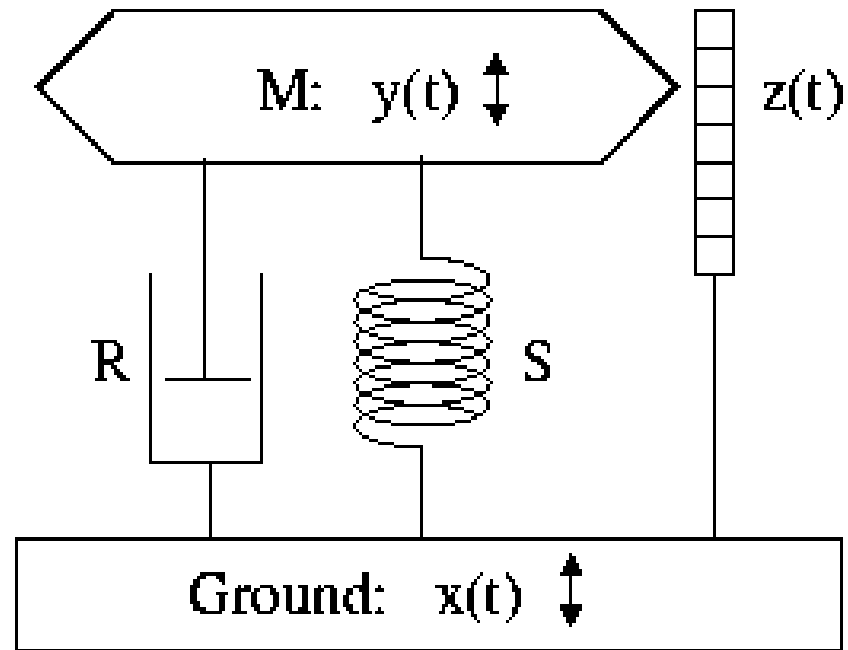


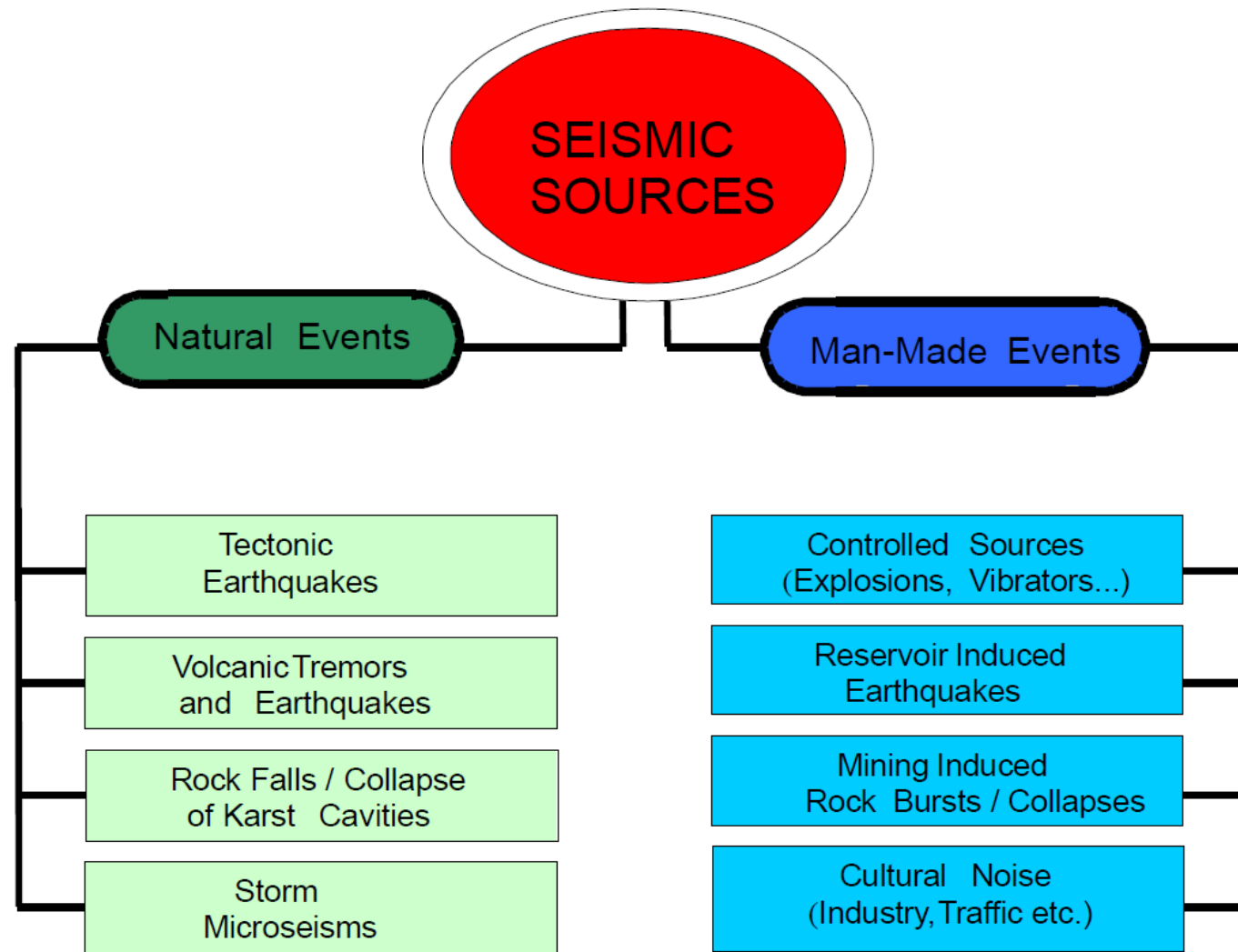


A seismometer is said to be any instrument that measures the time dependence of ground displacement.

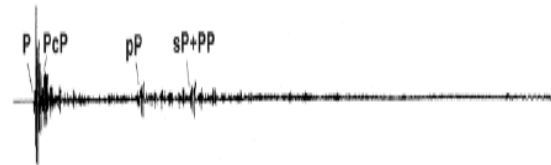
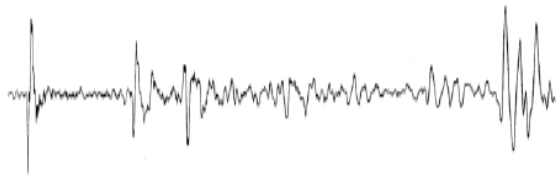
A seismograph basically consists of one or more seismometers, a clock or receiver of the time signal, and an acquirer.

Sismografo





Classificazione schematica di vari tipi di eventi che generano onde sismiche.



$f(t)$



$h(t)$



$g(t) = h(t) * f(t)$

time
domain

he signal radiated from a seismic source, be it an explosion or a fault, is usually a more or less complicated displacement step function or velocity pulse of finite duration from milliseconds to a few minutes at most.

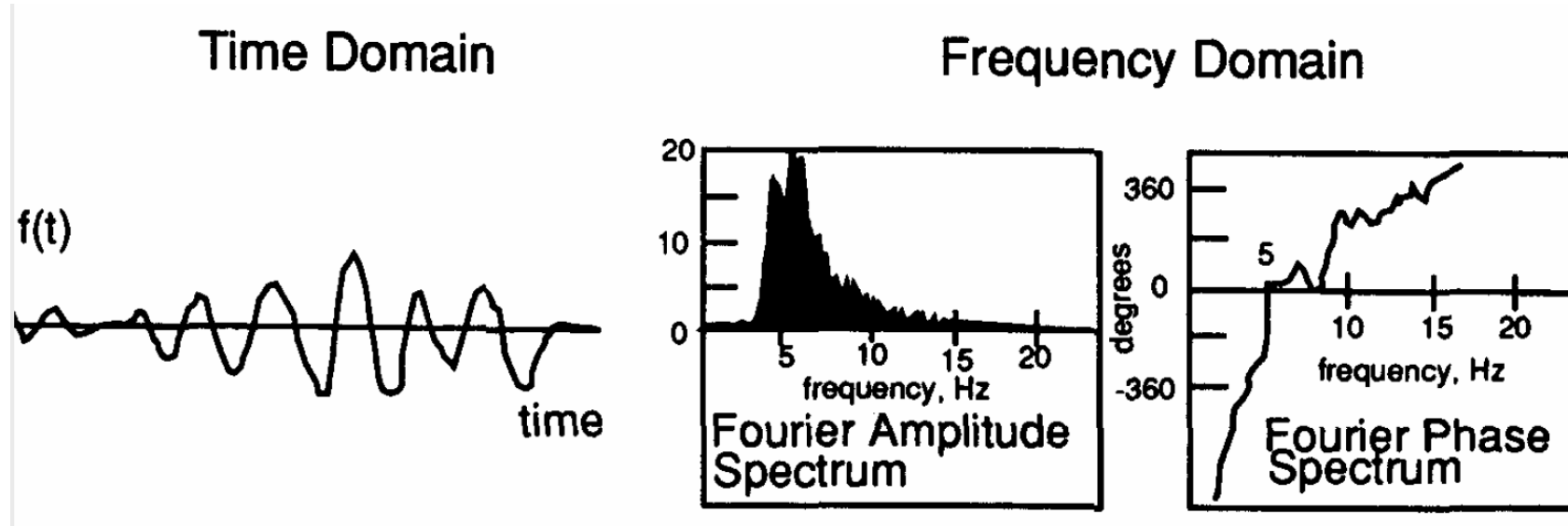
According to the Fourier theorem any arbitrary transient function $f(t)$ in the time domain can be represented by an equivalent function $F(\omega)$ in the frequency domain, i.e., the Fourier transform of $f(t)$. The following relationships apply:

$$f(t) = (2\pi)^{-1} \int_{-\infty}^{\infty} F(\omega) \exp(i\omega t) d\omega$$

$$F(\omega) = \int_{-\infty}^{\infty} f(t) \exp(-i\omega t) dt = |F(\omega)| \exp(i\phi(\omega))$$

$|F(\omega)|=A(\omega)$ is the spectral amplitude with units m/Hz, $\omega=2\pi f$ is the angular frequency (with f - frequency with units Hz) and $\phi(\omega)$ the phase spectrum with units deg, rad or 2π rad. The integral is equivalent to a sum. Thus, Fourier's theorem states that an arbitrary finite time series, even an impulsive one, can be expressed as a sum of monochromatic periodic functions, viz.

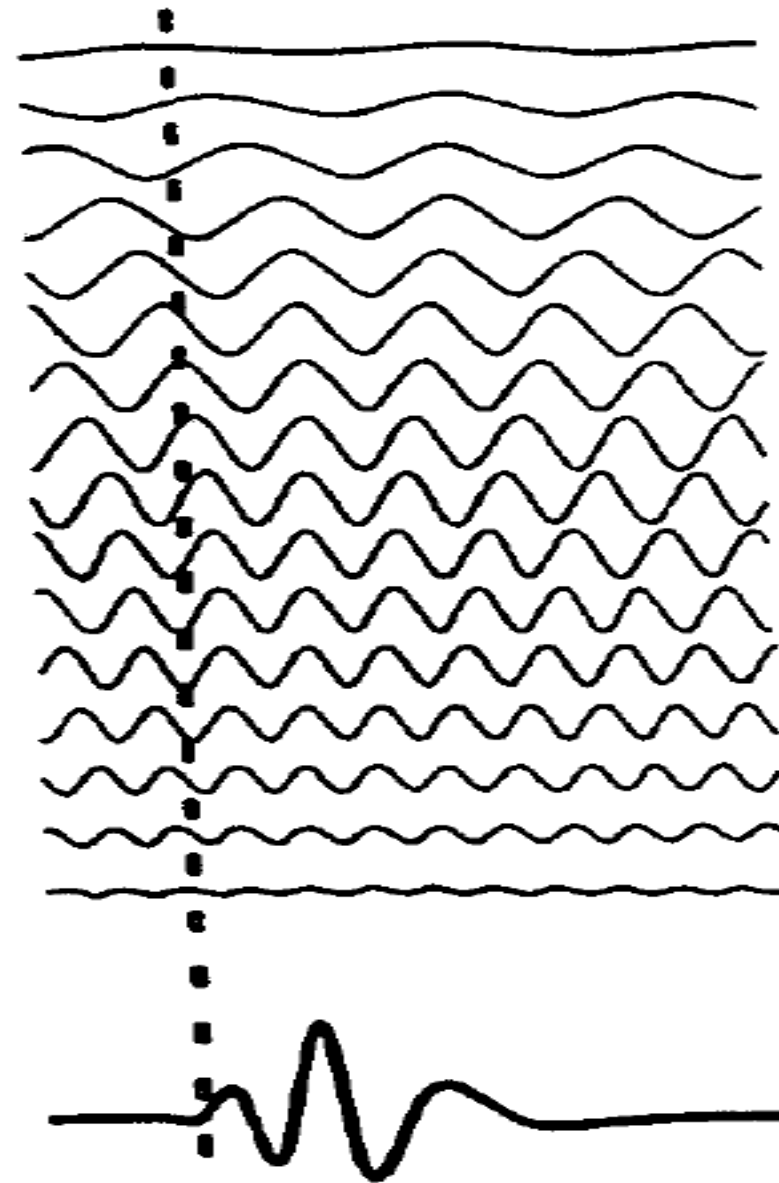
$$f(t) = 2\pi^{-1} \sum |F(\omega)| \exp(i[\omega t + \phi(\omega)]) \Delta\omega.$$

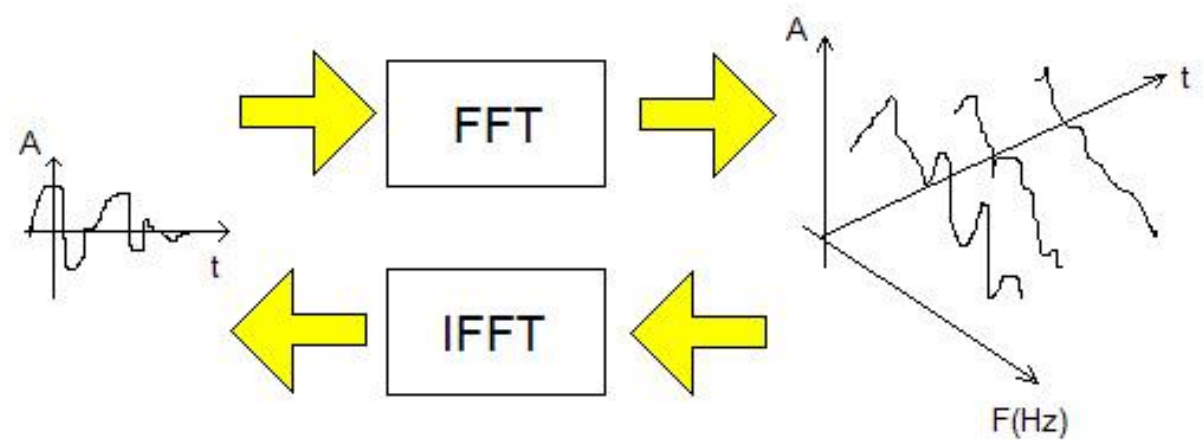
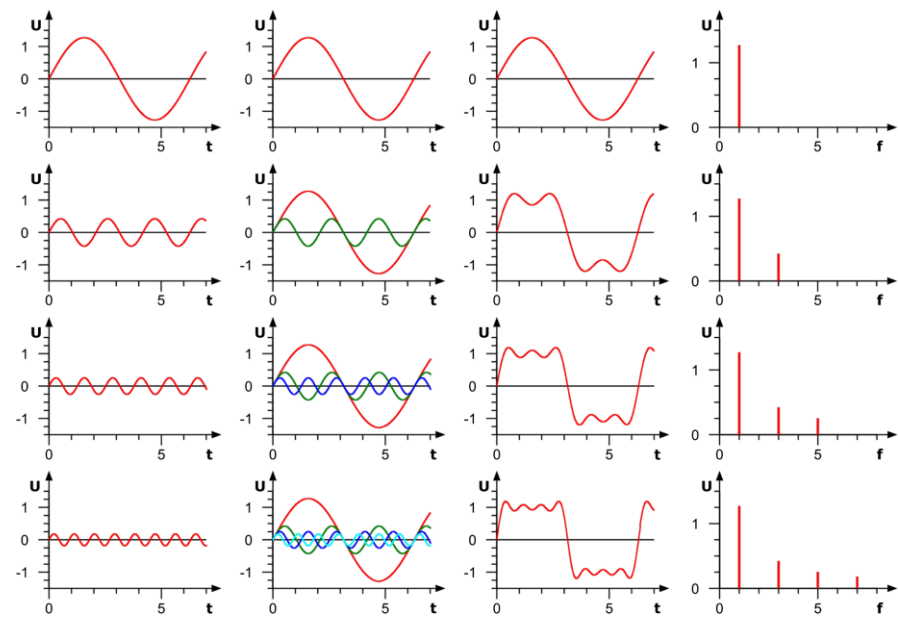
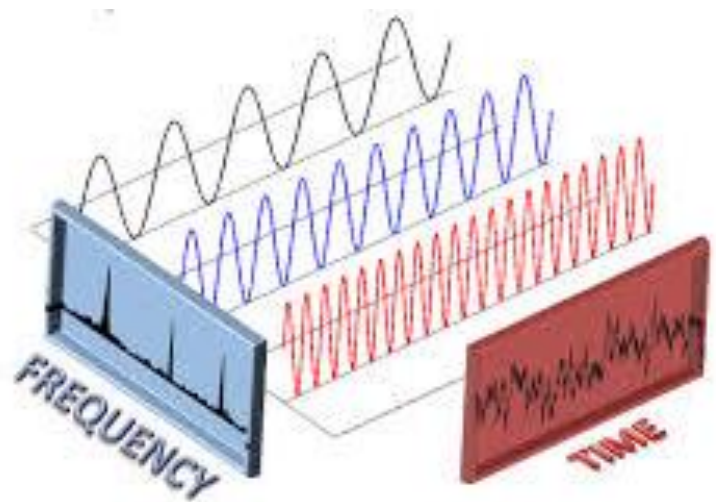


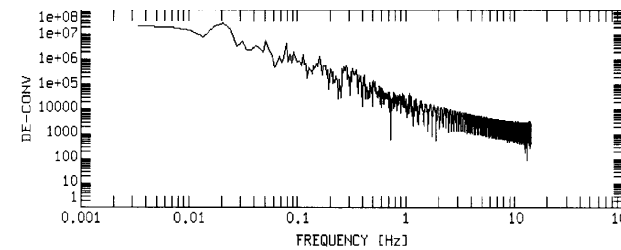
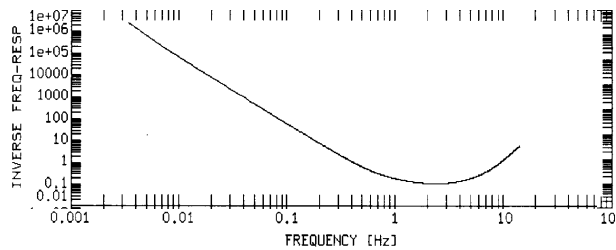
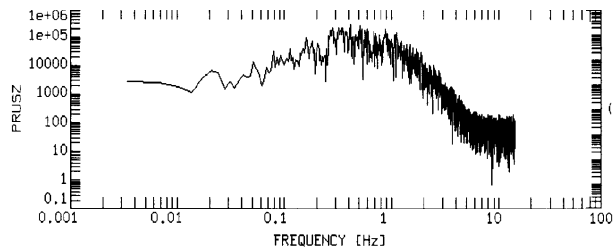
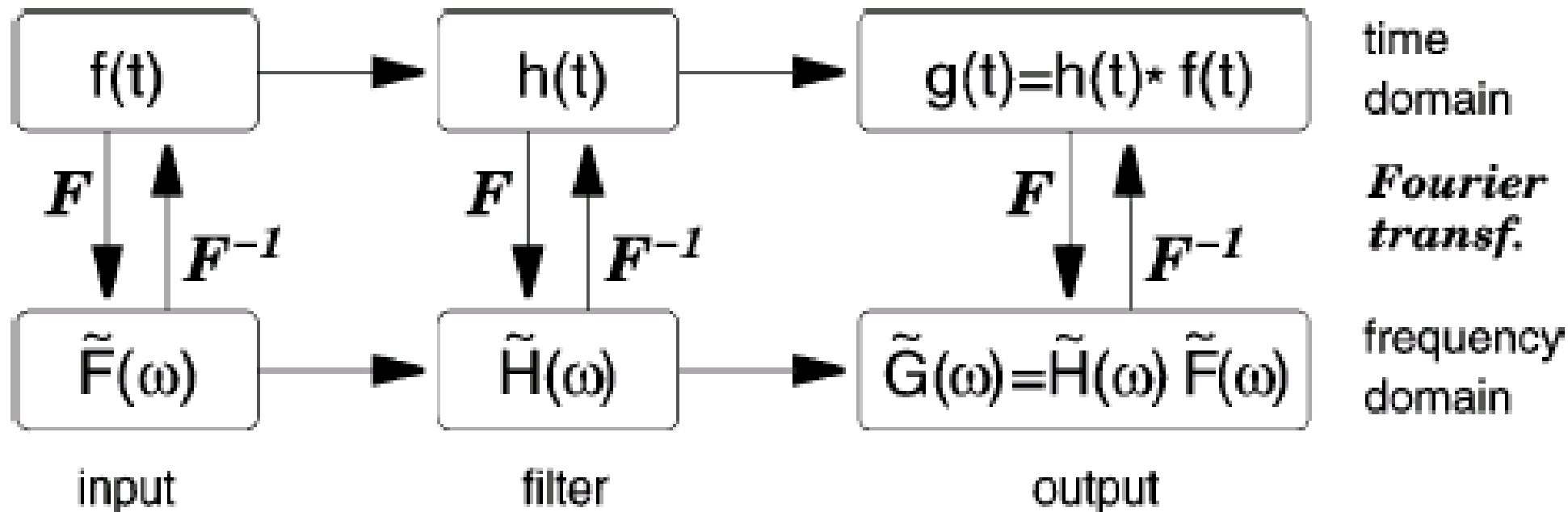
A signal recorded as a function of time (left) can be represented equivalently in the frequency domain by its Fourier spectrum. The amplitude (center) and phase spectrum (right) are both required to obtain the complete time series.

The transient $f(t)$ is formed infinite harmonic terms. The amplitudes of each harmonic term vary, being described by the amplitude spectrum. The shift of the the phase of each harmonic term is given by the phase spectrum.

$$f(t) = \frac{1}{2\pi} \sum |F(\omega)| \exp(i[\omega t + \phi(\omega)]) \Delta\omega$$



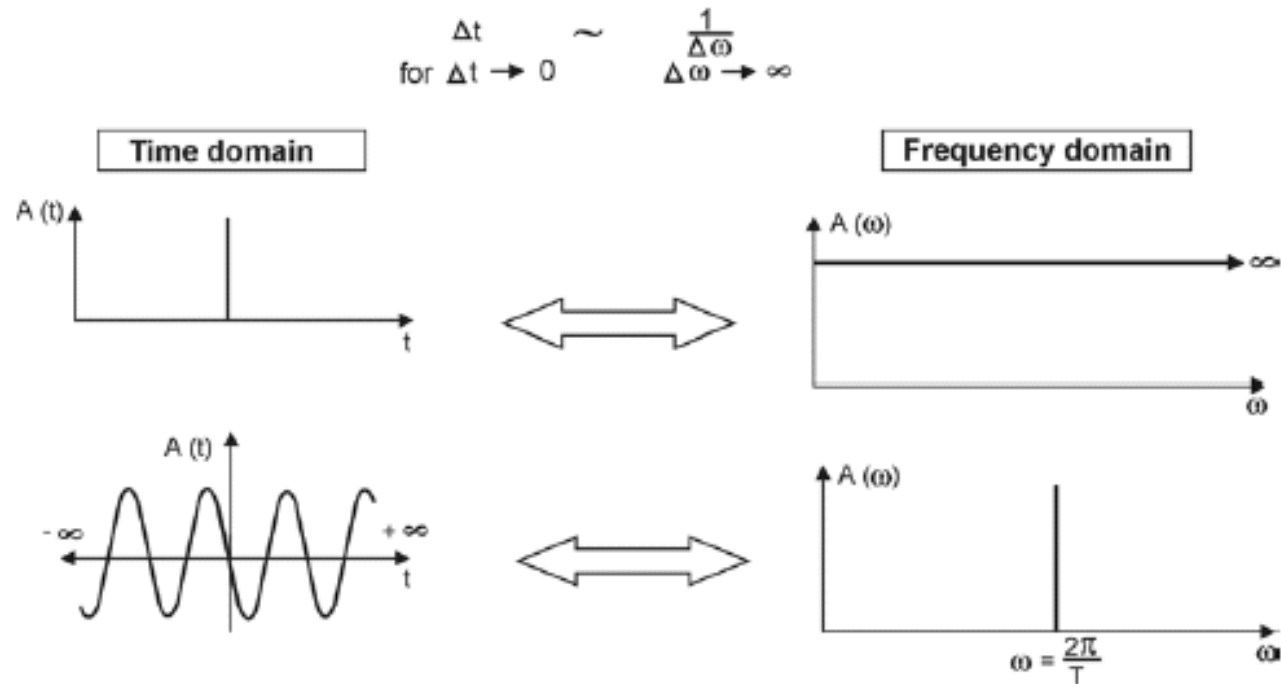




Percorsi di elaborazione del segnale nei domini di tempo e frequenza. L'asterisco tra $f(t)$ e $g(t)$ indica una convoluzione.

The impulsive response

The function $\delta(t)$ (Dirac delta) is an infinitely short, infinitely high positive function centered at time 0. Both its Laplace and Fourier transforms have the constant value 1. Its amplitude spectrum contains all frequencies.



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So the

$$G(s) = H(s) \cdot F(s)$$

becomes

$$G(s) = H(s)$$

Consequently, $H(s)$ is the Laplace transform of the impulsive response $G(s)$



The convolution theorem

Any signal can be understood as consisting of a sequence of pulses. This is evident in the case of sampled signals, but it can be generalized to continuous signals by representing the signal as a continuous sequence of Dirac pulses. We can construct the response of a linear system to an arbitrary input signal as a sum of appropriately delayed and scaled impulse responses.

This process is called convolution:

$$g(t) = \int_0^{\infty} h(t') f(t - t') dt' = \int_0^{\infty} h(t - t') f(t') dt'$$

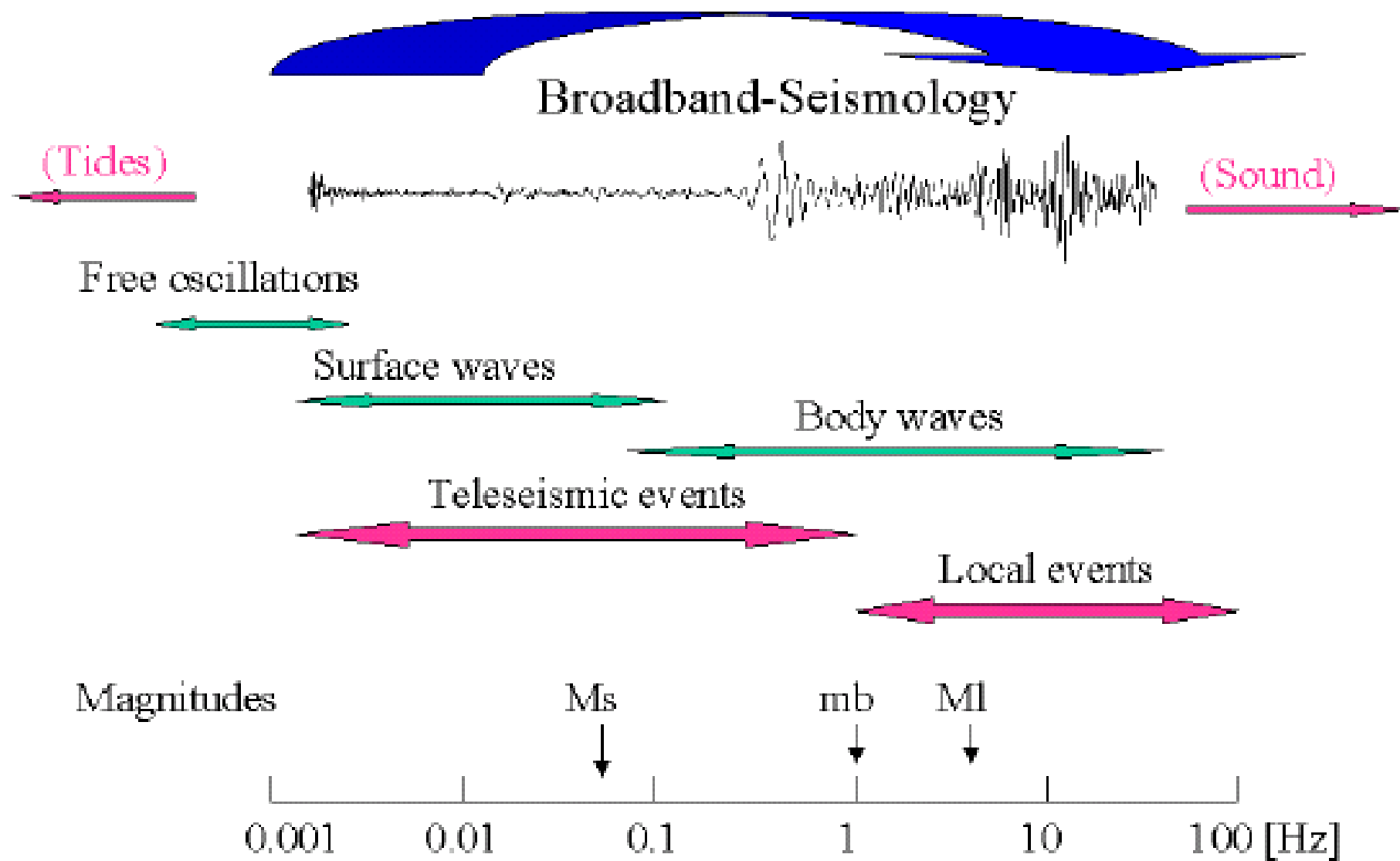
The convolution theorem

$$g(t) = \int_0^{\infty} h(t') f(t - t') dt' = \int_0^{\infty} h(t - t') f(t') dt'$$

$$f(t) = \delta(t),$$

$$g(t) = \int h(t') \delta(t - t') dt' = h(t)$$

$h(t)$ is the impulsive response to the system

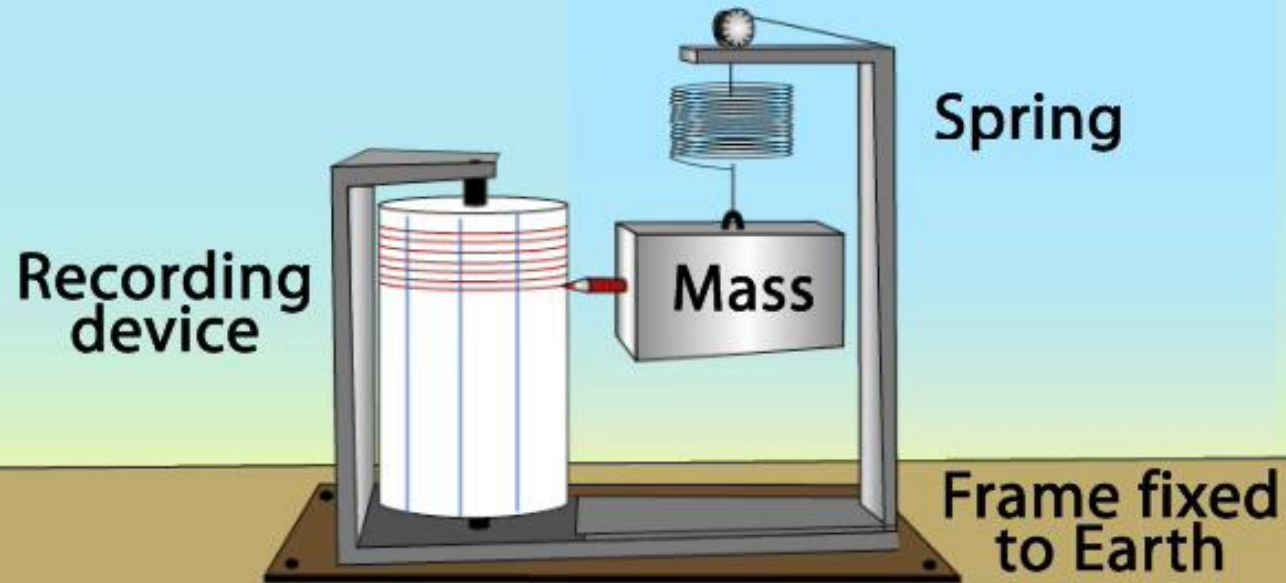


FUNDAMENTAL SEISMOMETRY PROBLEM

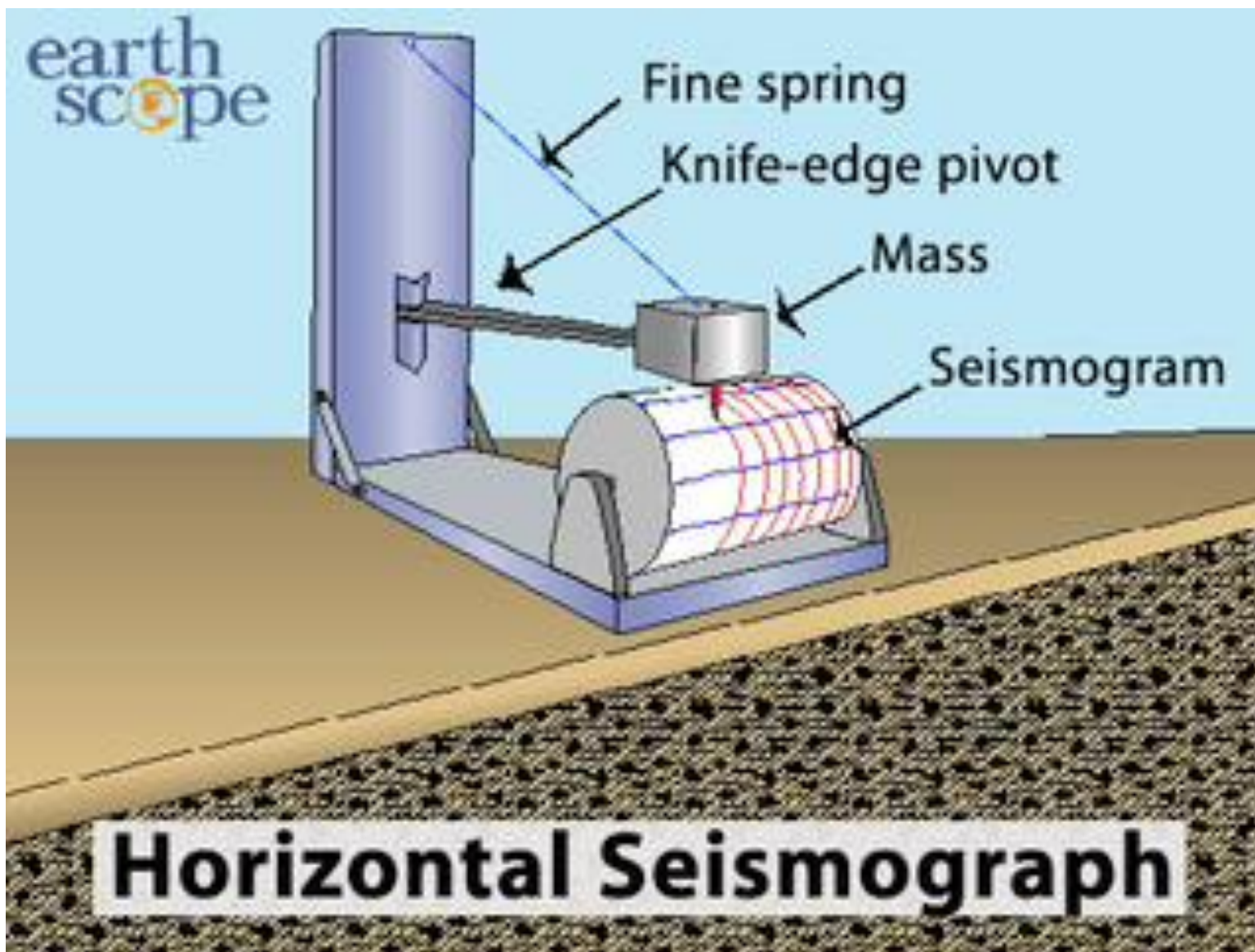
Move from the 6 equations representing the relative motion of the seismograph with respect to the ground (3 for translational and 3 for rotational components) to the corresponding functions describing ground motion so that the characteristics (parameters) of seismic motion can be determined:

PERIOD, AMPLITUDE, PHASE, DAMPING

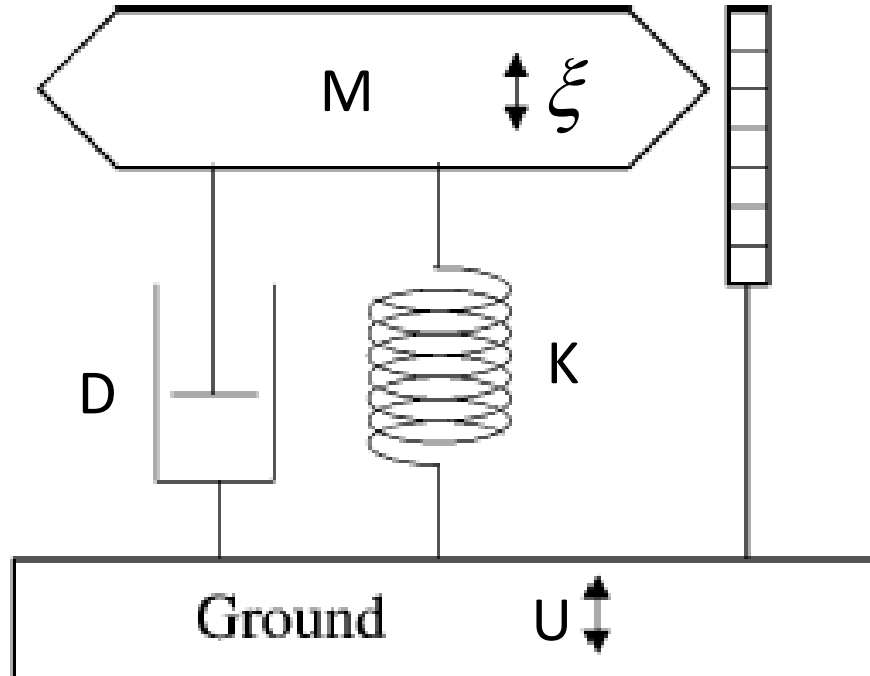
For each Wave System.



Vertical Seismograph with generalized P- and S-wave behavior



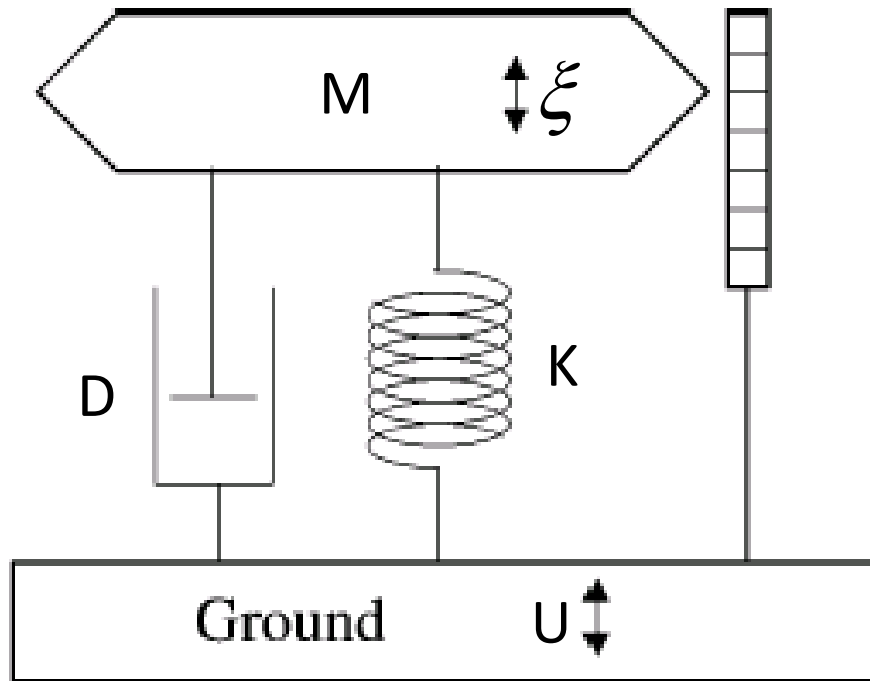
MECHANIC PENDULUM



The seismograph pendulum consists of a mass M hanging from a spring with a constant K and a damper with constant D in parallel.

The spring force is proportional to the displacement, the damper force instead to speed.
If ξ is the mass displacement, the equation of motion will be:

$$M(\ddot{\xi} + \ddot{u}) + D\dot{\xi} + K\xi$$



$$M(\ddot{\xi} + \ddot{u}) + D\dot{\xi} + K\xi$$

Dividing for **M** and introducing the quantity

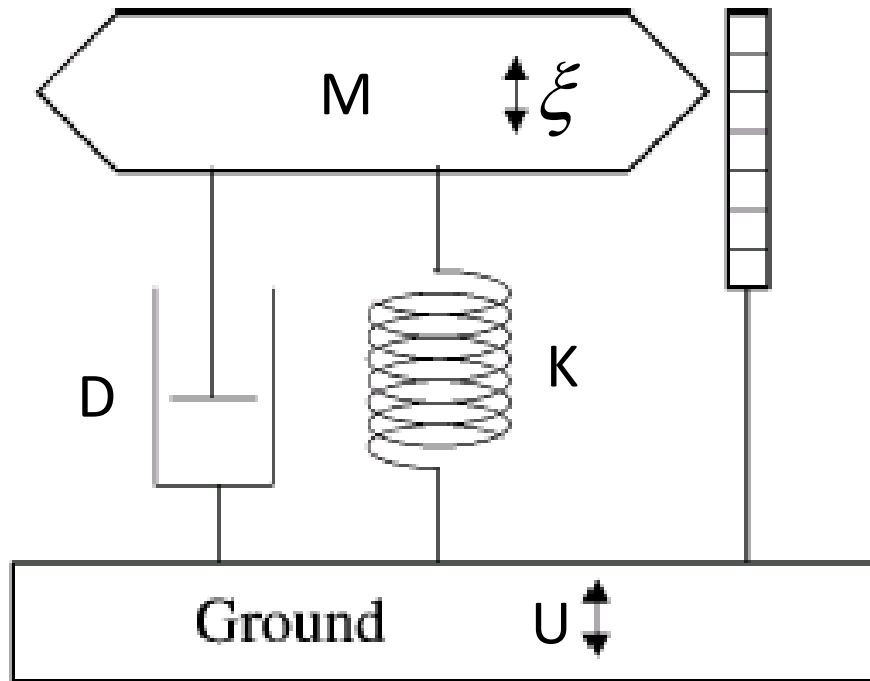
$$\varepsilon = -\frac{D}{2M}$$

$$\omega_0^2 = \frac{K}{M}$$

We have:

$$\ddot{\xi} + 2\varepsilon\dot{\xi} + \omega_0^2\xi = -\ddot{u}$$

From this equation we can find the ground motion ξ and its time derivative.



$$\ddot{\xi} + 2\varepsilon\dot{\xi} + \omega_0^2\xi = -\ddot{u}$$

The instrument response to the motion at a some frequency can be determined using the time dependence of the displacement due to a wave:

$$u \approx e^{-i\omega t}$$

Assuming the same time dependence for ξ and remembering that $\frac{d}{dt}(e^{-i\omega t}) = -i\omega e^{-i\omega t}$
 We obtain the motion equation:

$$\begin{aligned} (-i\omega)^2 \xi + 2\varepsilon(-i\omega)\xi + \omega_0^2 \xi &= (-i\omega)^2 u \\ -\omega^2 \xi - 2i\varepsilon\omega\xi + \omega_0^2 \xi &= \omega^2 u \end{aligned}$$

$$\xi = \frac{-\omega^2}{\omega^2 + 2i\varepsilon\omega - \omega_0^2} u$$

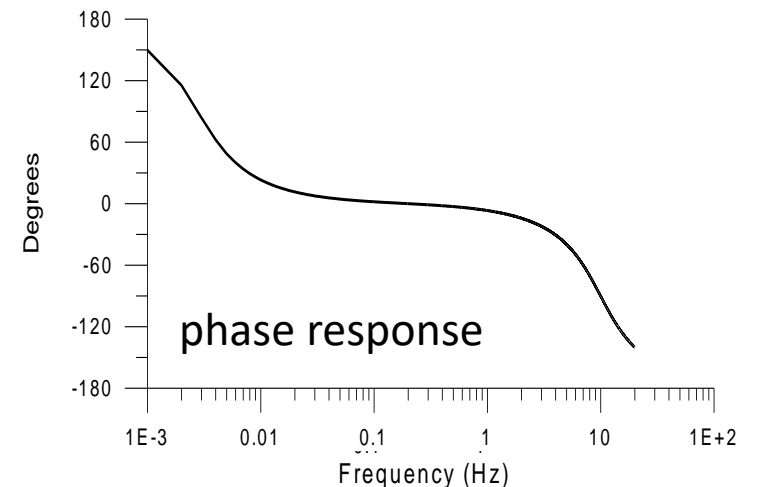
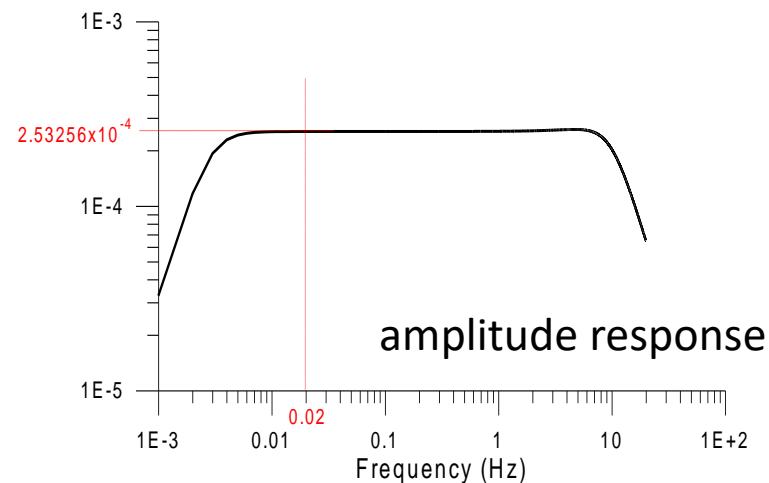
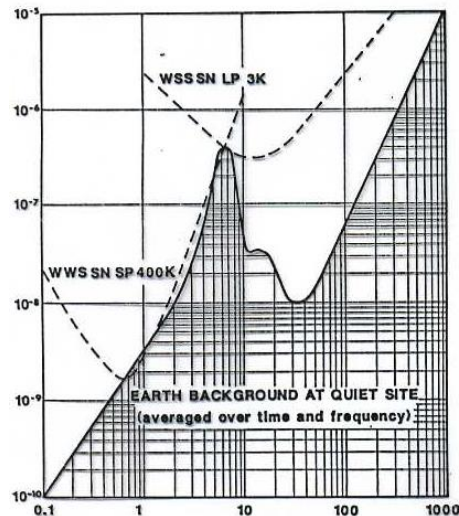
The ratio:

$$x(\omega) = \frac{-\omega^2}{\omega^2 + 2i\varepsilon\omega - \omega_0^2}$$

Is named frequency response that is the transfer function of the instrument. It is a complex number, so it can be divided in an amplitude response $|x(\omega)|$ and in a phase response $\phi(\omega)$

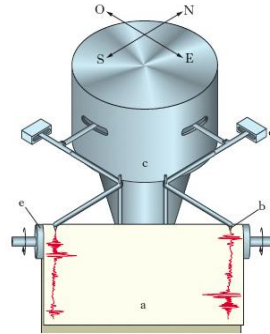
$$x(\omega) = |x(\omega)| \exp i\phi(\omega)$$

The amplitude response curve of an instrument shows which frequencies are amplified and good recorded and says in which frequency band the instrument are not sensible.

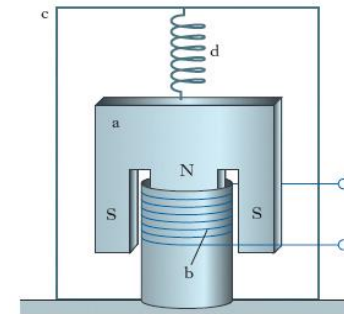


TRASDUTTORI

MECCANICI

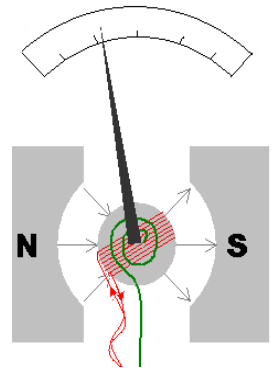


GEOFONI

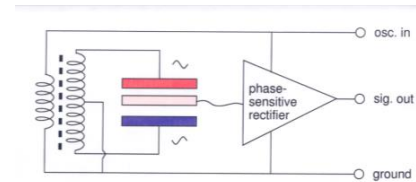


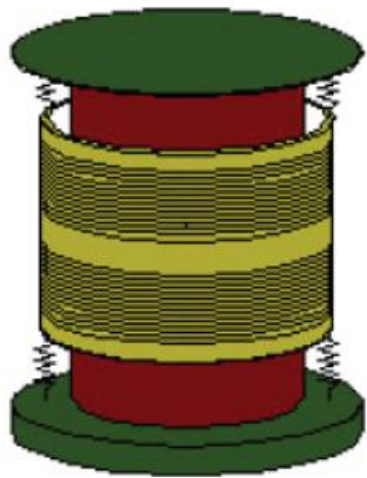
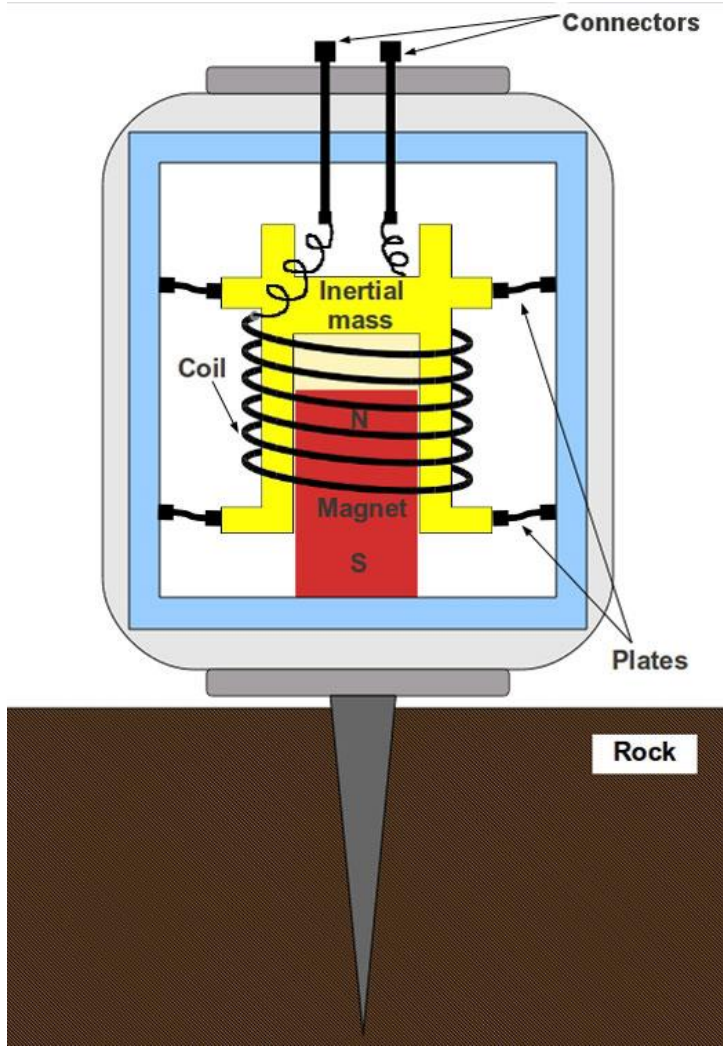
ELETTROMAGNETICI

A GALVANOMETRO



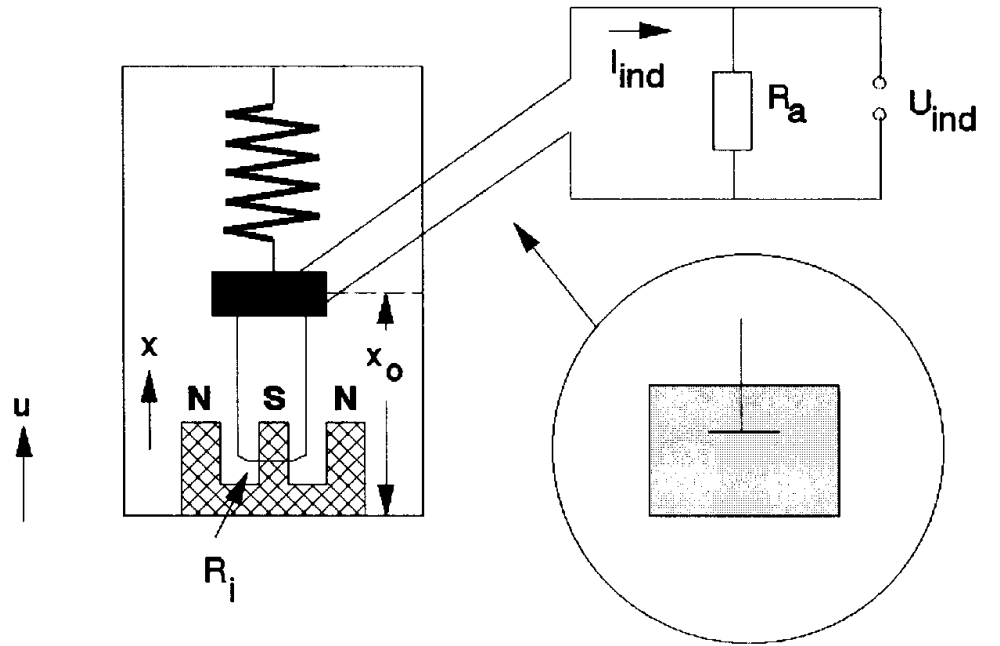
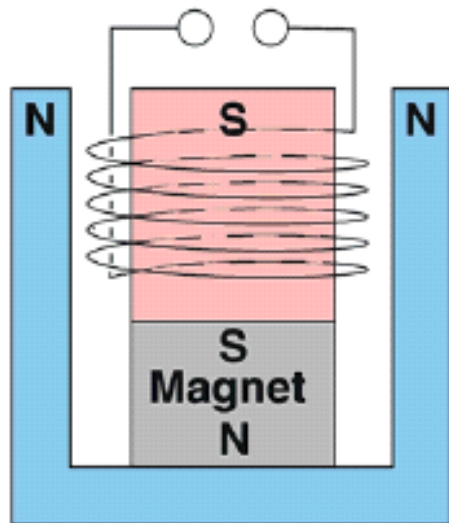
ELETTRONICI A BANDA LARGA



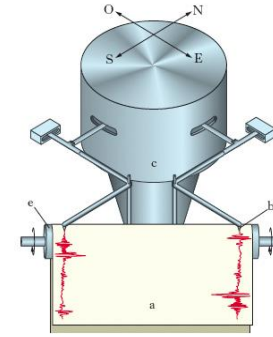
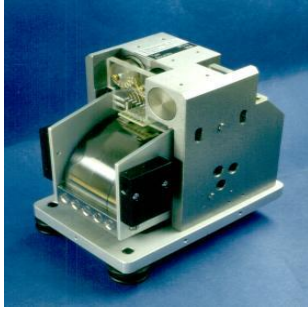
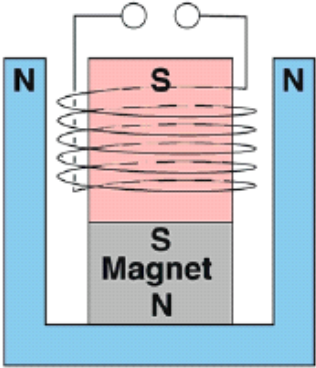


$y(t)$, coil displacement

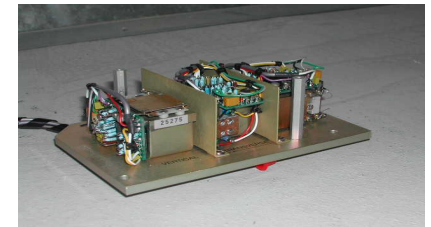
$x(t)$, base displacement



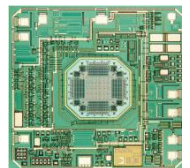
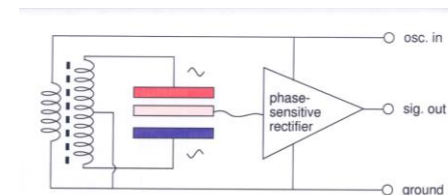
SYSMOMETER: output proportional to displacement

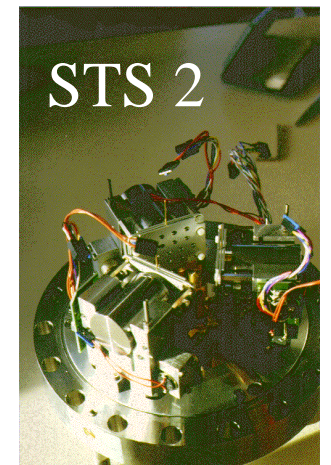


VELOCIMETER: output proportional to velocity



ACCELEROMETER: output proportional to acceleration





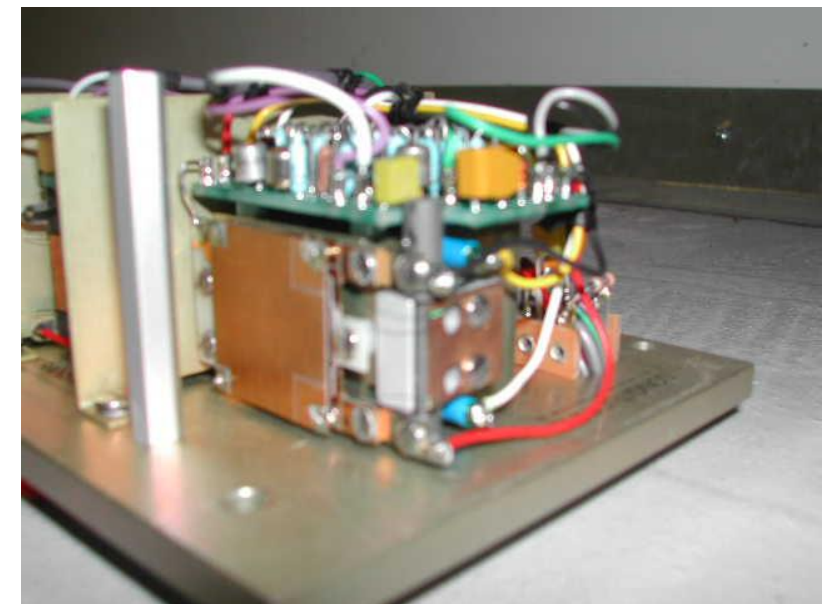


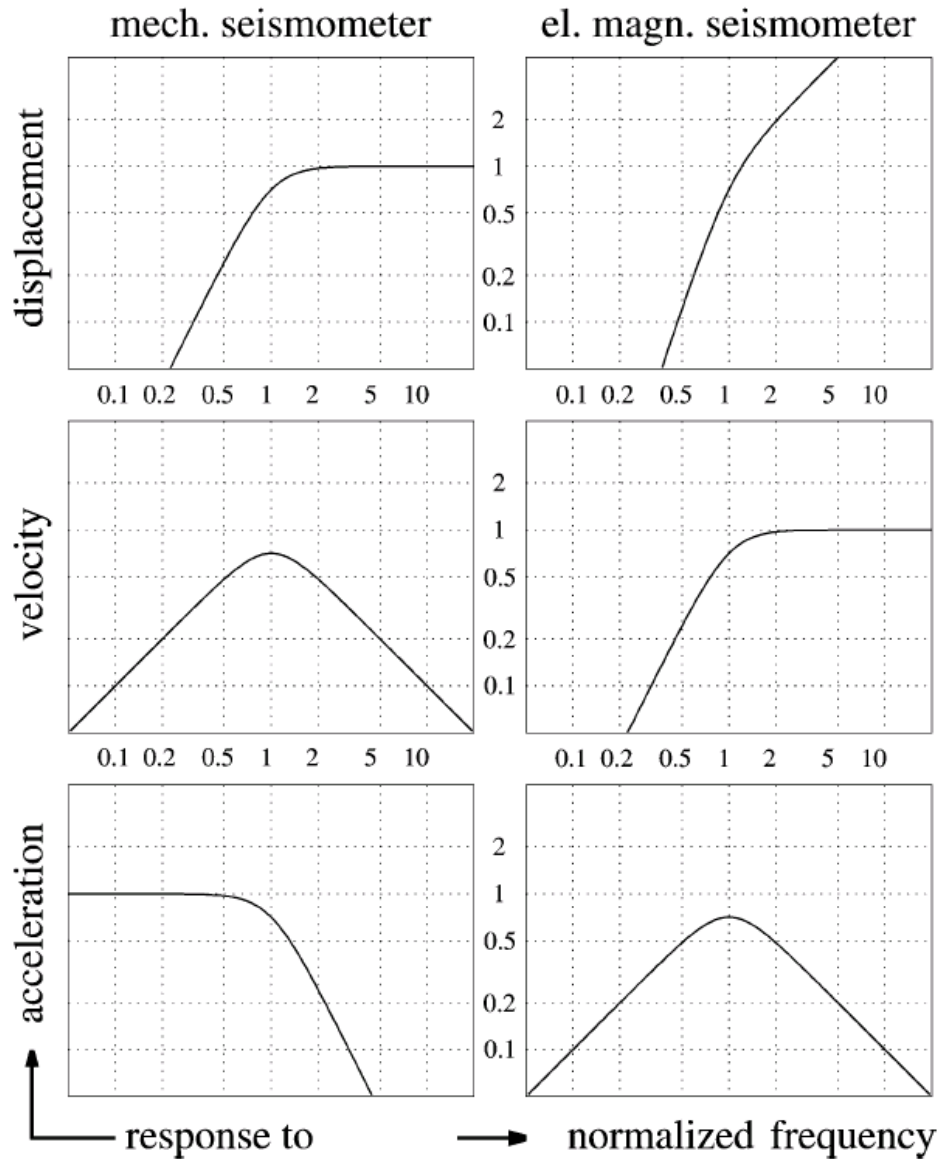


Accelerometro Guralp CMG 5T



Accelerometro Kinometrics FBA23

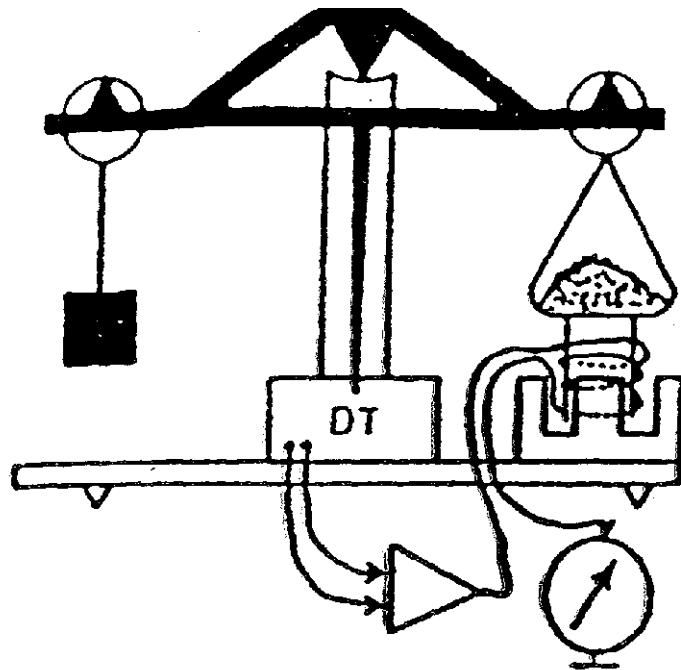




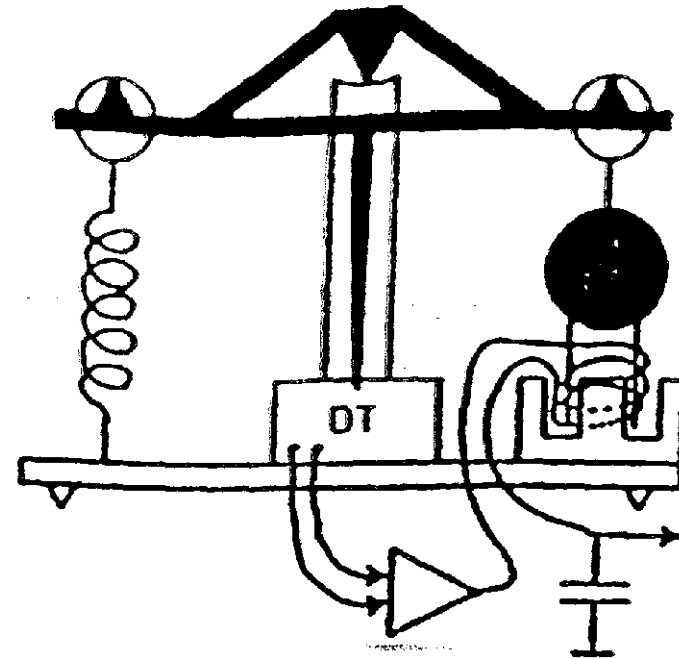
Curve di risposta di un sismometro meccanico (pendolo e molla, a sinistra) ed sismometro elettrodinamico (geofono, a destra) rispetto ai diversi tipi di segnali di ingresso (spostamento, velocità e accelerazione, rispettivamente). La frequenza normalizzata è il segnale frequenza divisa per l'autofrequenza (frequenza d'angolo) del sismometro.

Seismometers and “Force balance” accelerometer

The inertial force is compensated (or balanced) with a force electrically generated so as to move the mass the less possible. A small movement is still necessary otherwise the inertial force can not be observed.

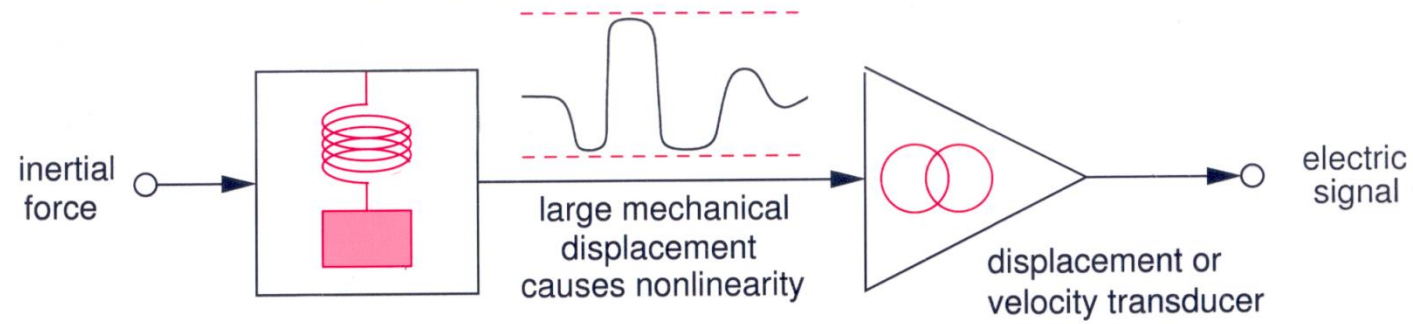


Balance with replacement of automatic weight

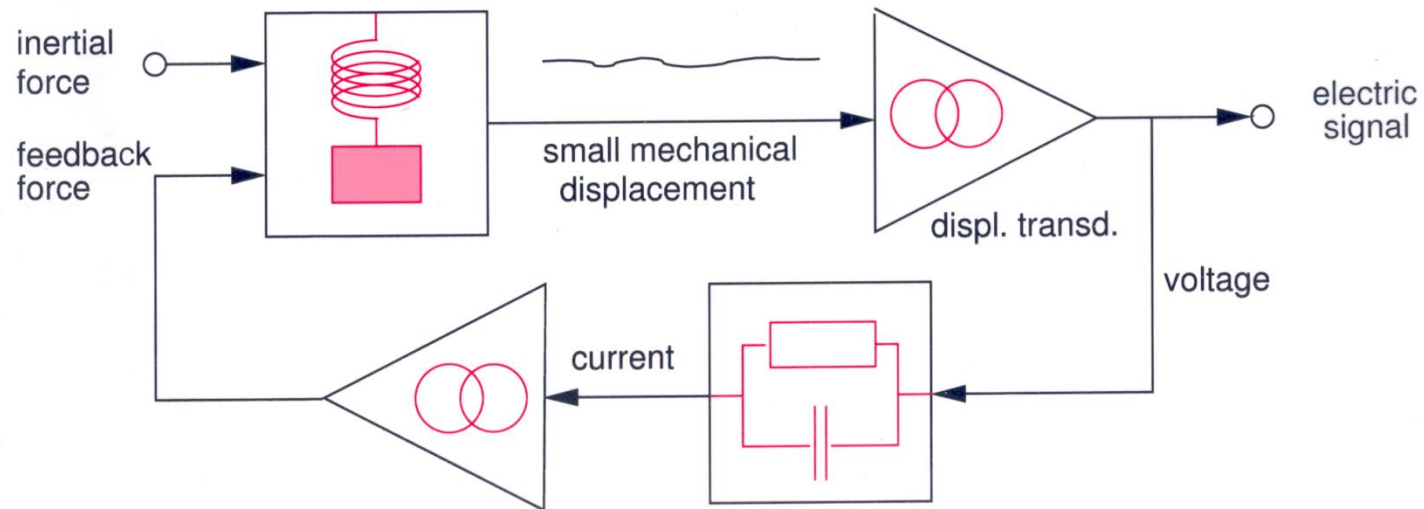


Feedback Seismometer

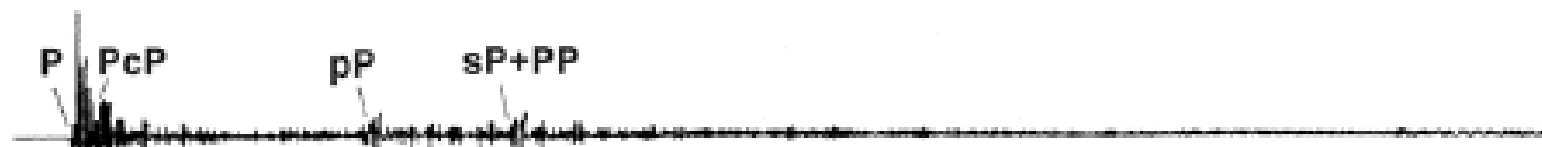
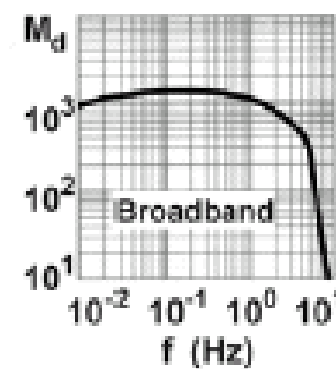
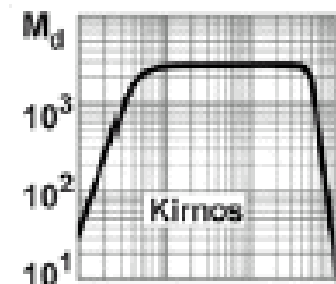
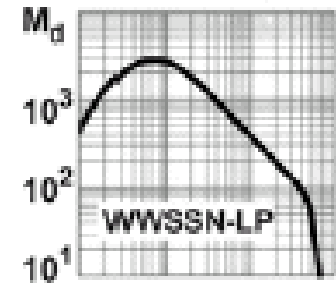
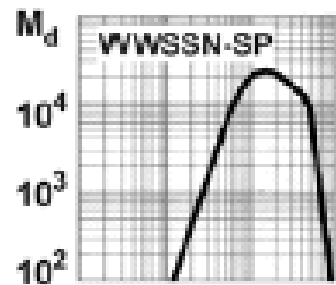
Seismometer without feedback

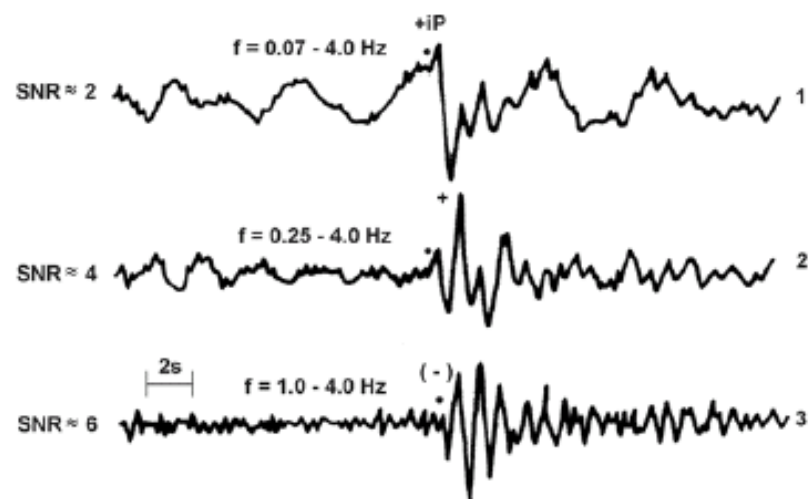
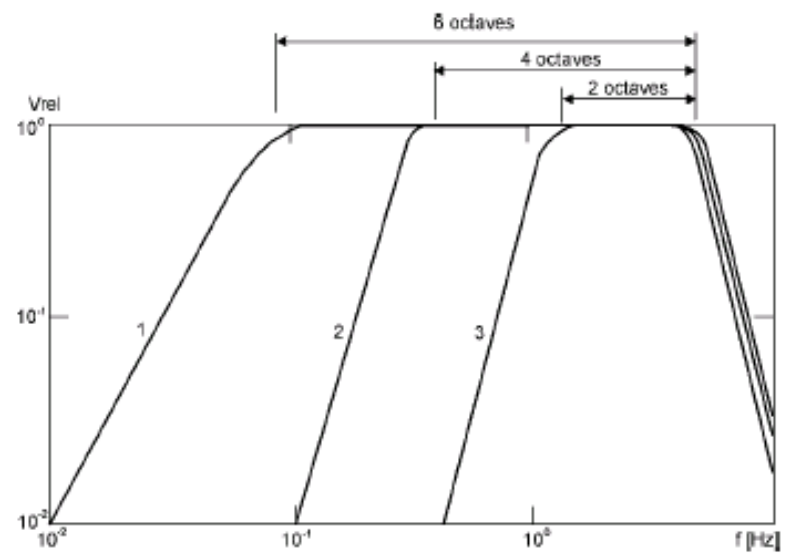


Force-Balance Seismometer

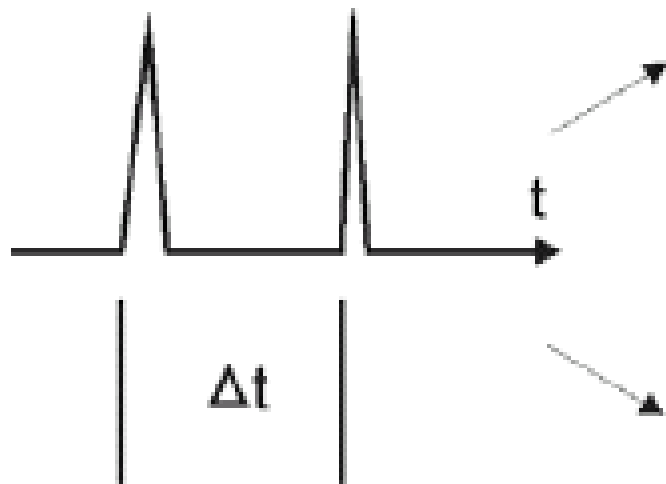


ideally, the mechanical sensor "doesn't know" how large the seismic signal is

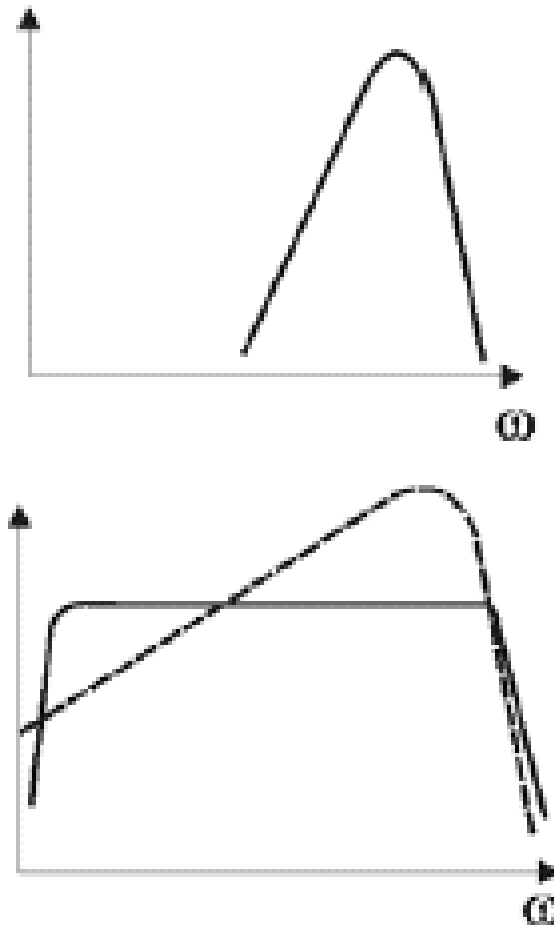




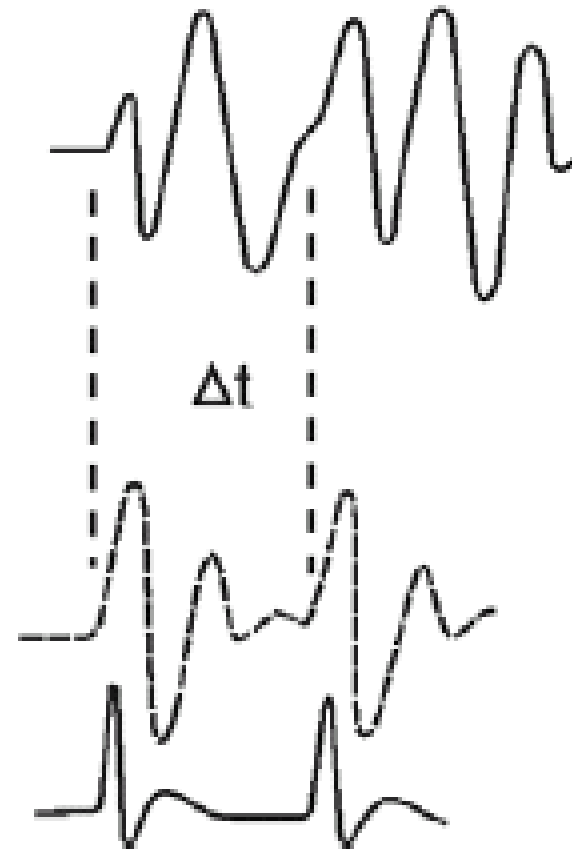
Input time series

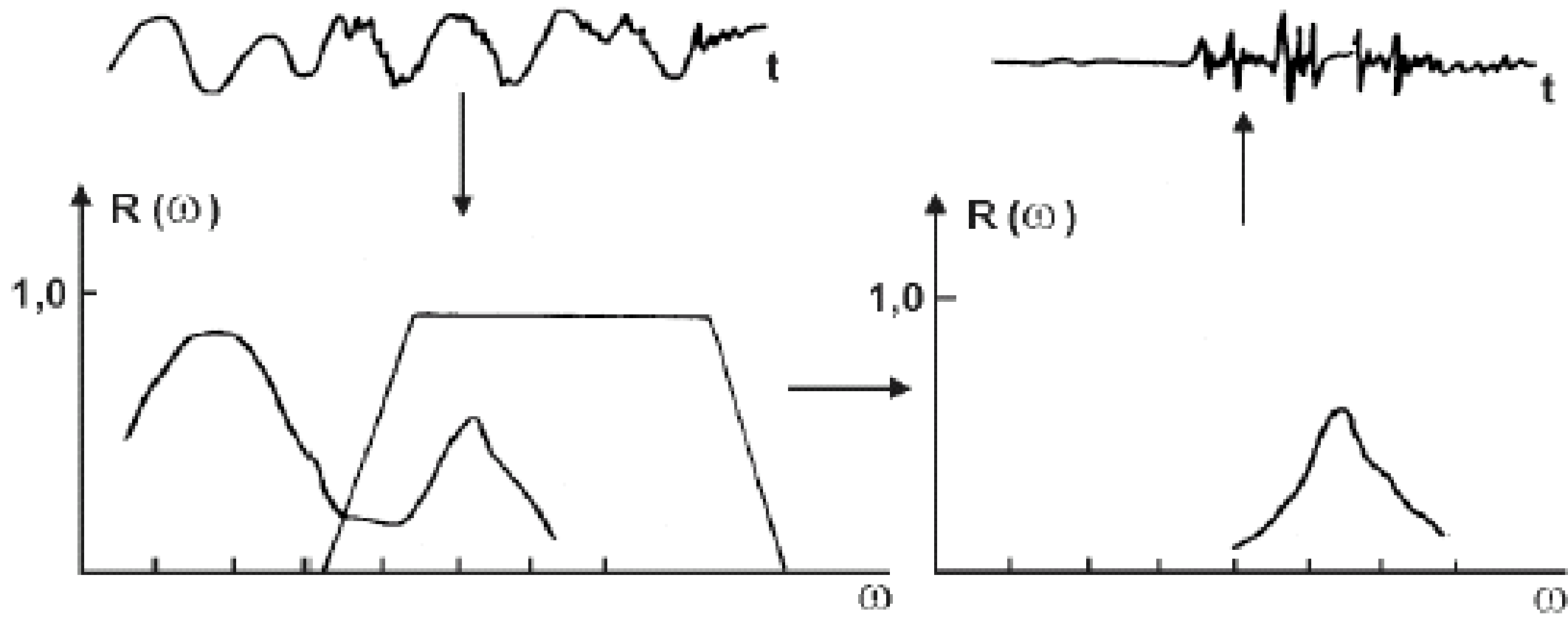


Seismometer
amplitude response



Output time series





La funzione razionale

$$H(s) = \frac{c_2 s^2 + c_1 s + c_0}{d_2 s^2 + d_1 s + d_0}$$

È la funzione di trasferimento del sistema descritto dall'equazione differenziale. Essa contiene le stesse informazioni sul sistema dell'equazione differenziale stessa.

$$c_2 \ddot{f}(t) + c_1 \dot{f}(t) + c_0 f(t) = d_2 \ddot{g}(t) + d_1 \dot{g}(t) + d_0 g(t)$$

In generale, la funzione di trasferimento $H(s)$ di un sistema LTI è la funzione complessa per la quale

$$G(s) = H(s) \cdot F(s)$$

con $F(s)$ e $G(s)$ che rappresentano le trasformazioni di Laplace dei segnali di ingresso e uscita.

Se $P(s)$ è un polinomio di s e $P(\alpha) = 0$, allora $s = \alpha$ è chiamata una radice, od uno zero, del polinomio.

Un polinomio di grado n ha n zero complessi e può essere fattorizzato come:

$$P(s) = p \cdot \prod (s - s_i).$$

Gli zeri di un polinomio, con il fattore p , determinano completamente il polinomio. Poiché le nostre funzioni di trasferimento $H(s)$ sono il rapporto di due polinomi, possono essere specificati dai loro zeri (gli zeri del numeratore $G(s)$), loro poli (gli zeri del denominatore $F(s)$) e un fattore di guadagno (o equivalentemente il guadagno totale a una data frequenza). L'intero sistema, purché rimanga nel suo campo operativo lineare e non produce rumore, può, quindi, essere descritto da un piccolo numero di parametri discreti.

$$H(s) = \frac{c_2 s^2 + c_1 s + c_0}{d_2 s^2 + d_1 s + d_0}$$

$$H(s) = A \frac{\prod_{n=1}^N (s - z_n)}{\prod_{m=1}^M (s - p_m)}$$

POLES: 4 (rad/sec)

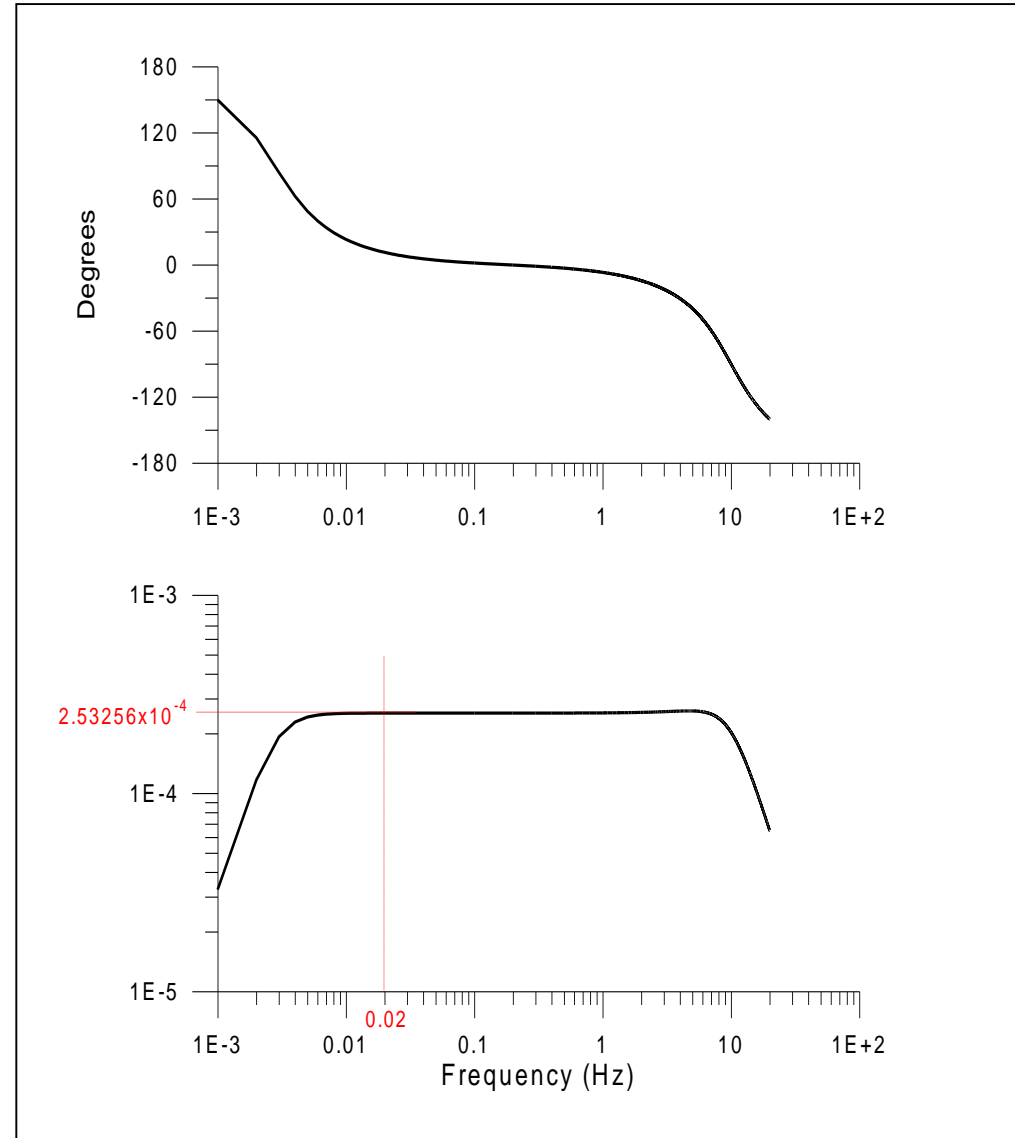
-0.123400d-01	0.123400d-01
-0.123400d-01	-0.123400d-01
-0.391800d+02	0.491200d+02
-0.391800d+02	-0.491200d+02

ZEROS: 2

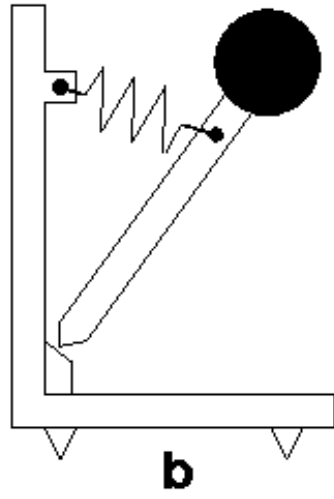
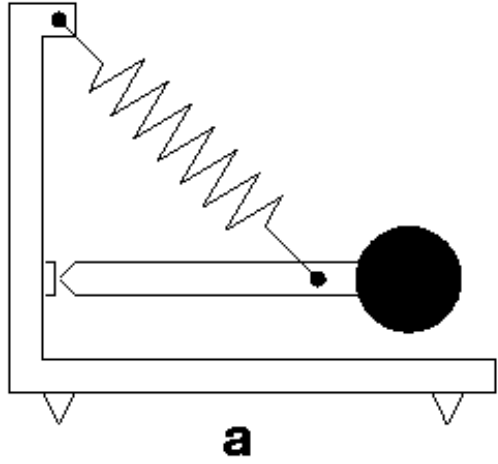
0.000000d+00	0.000000d+00
0.000000d+00	0.000000d+00

NORMALIZATION FREQUENCY: 0.02 Hz

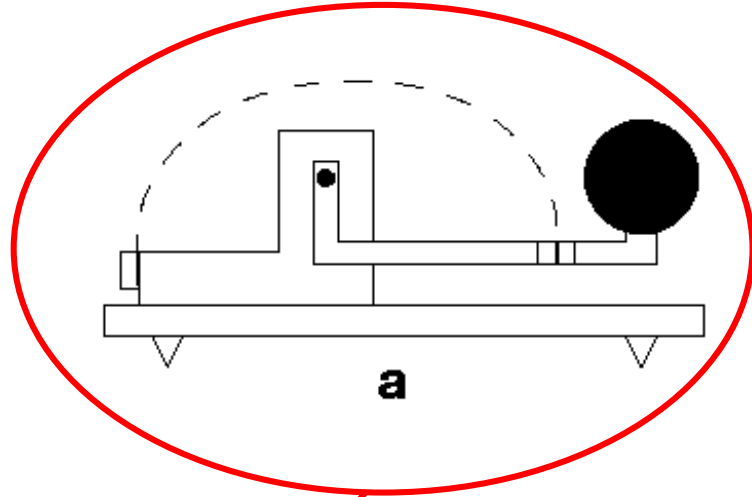
NORMALIZATION FACTOR: 3948.573



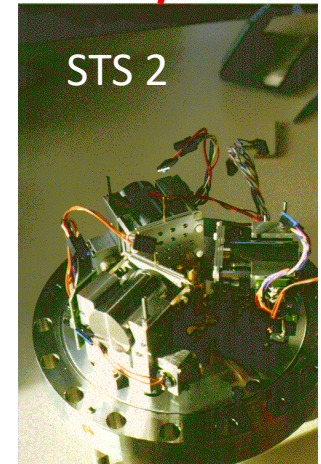
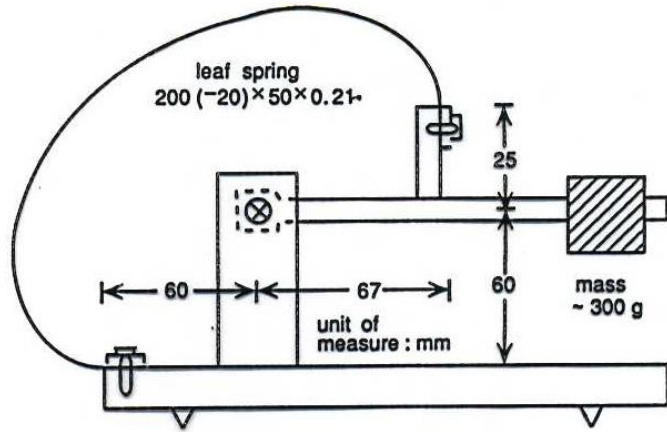
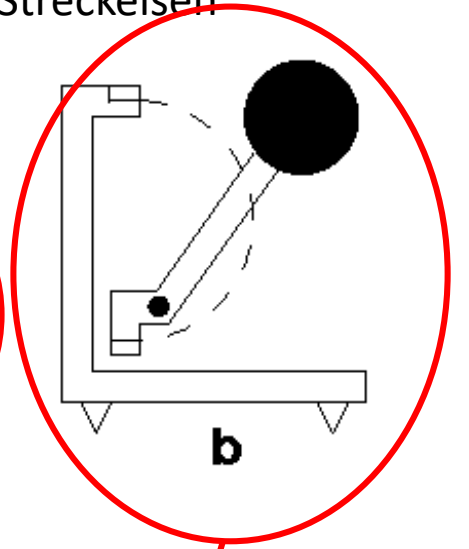
Suspension of La Coste

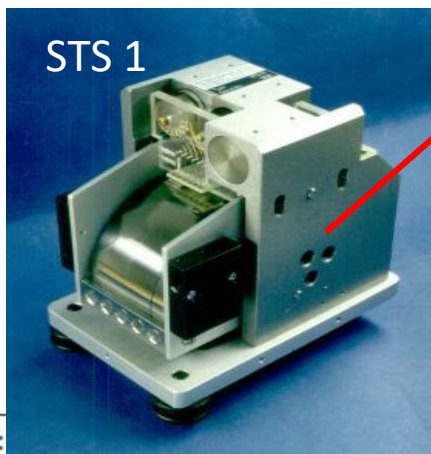
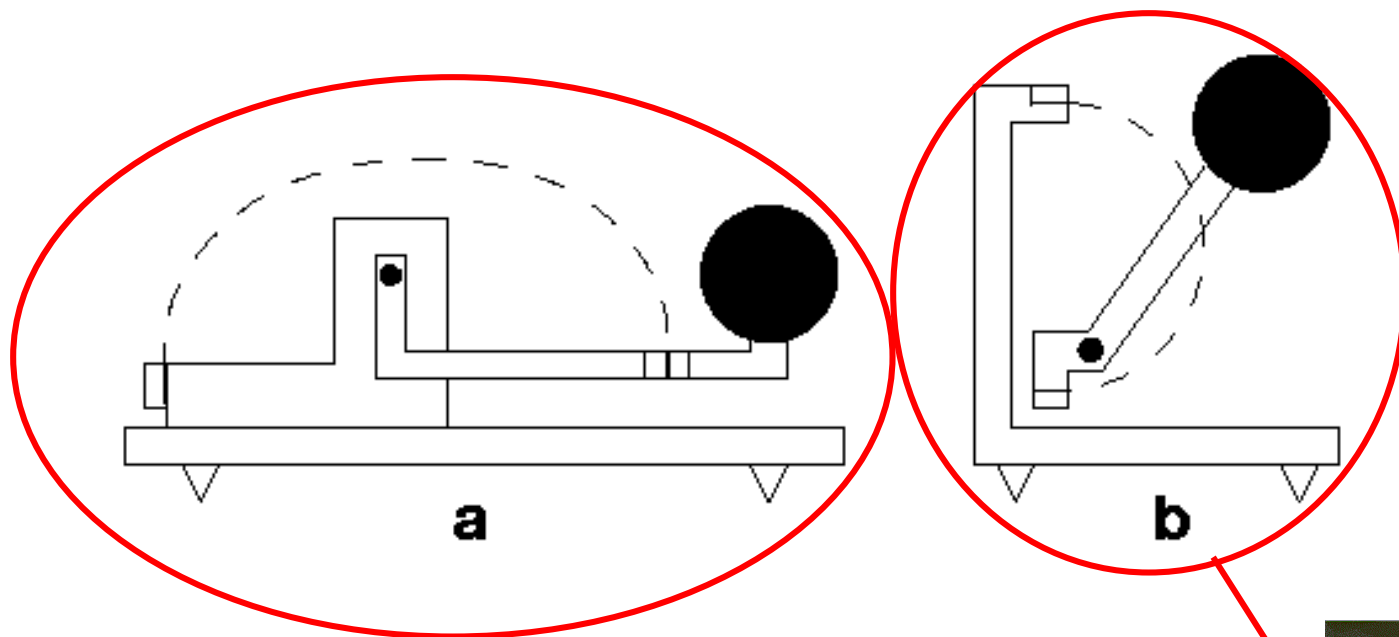


a Wielandt

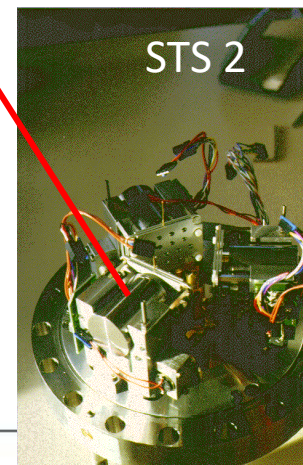


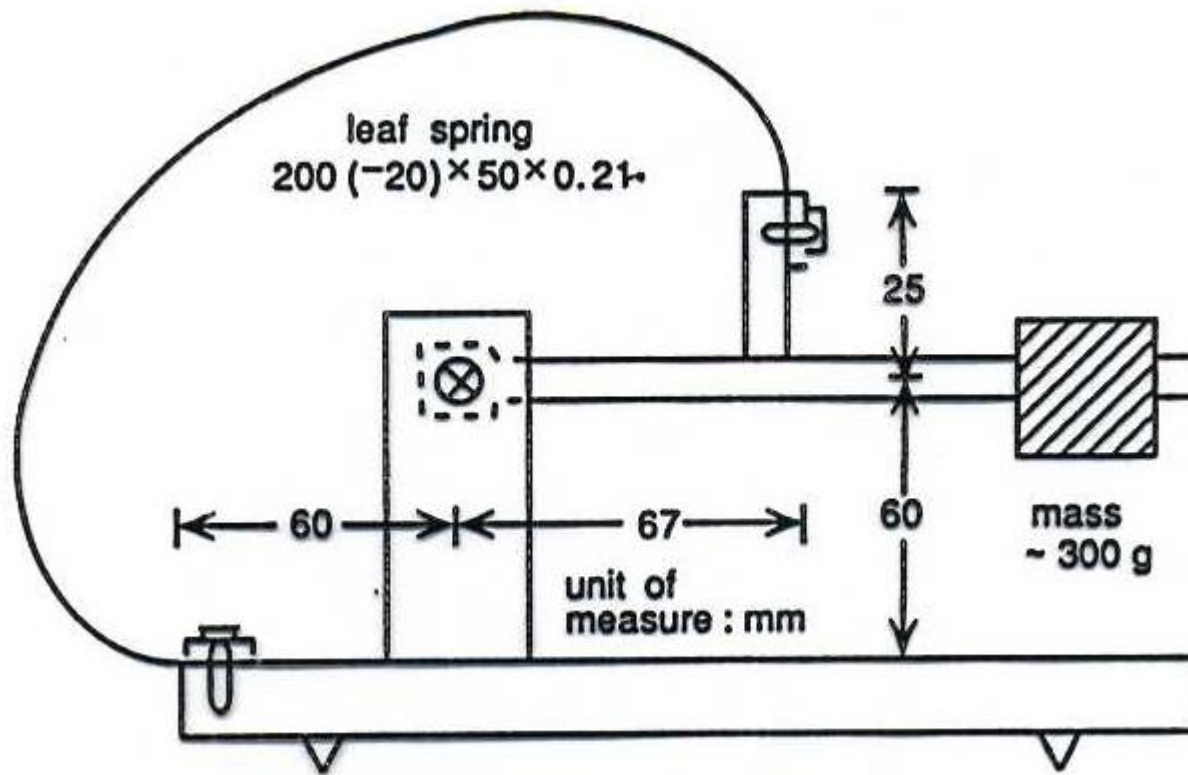
b Streckeisen



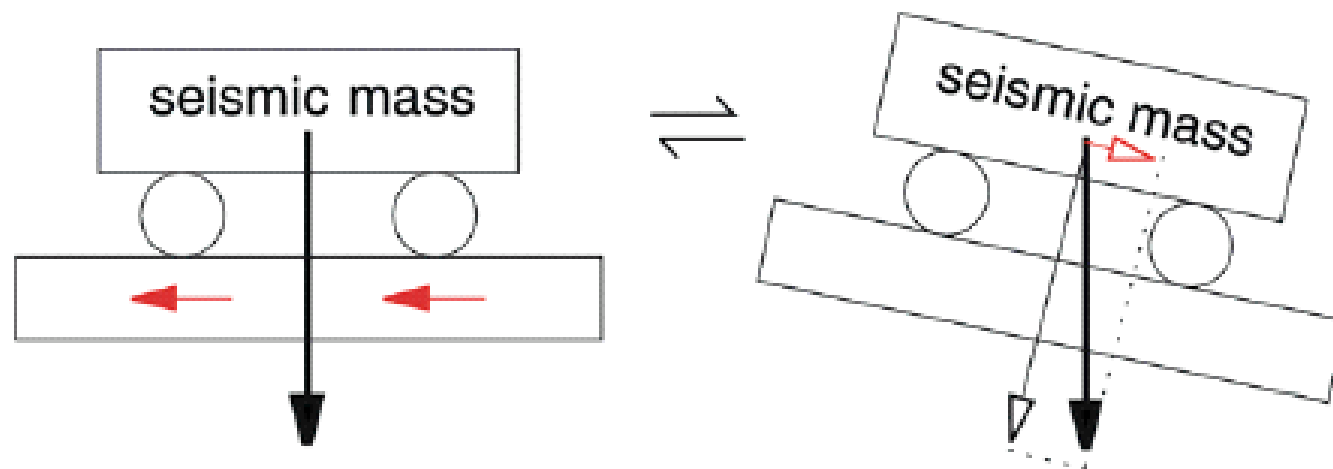


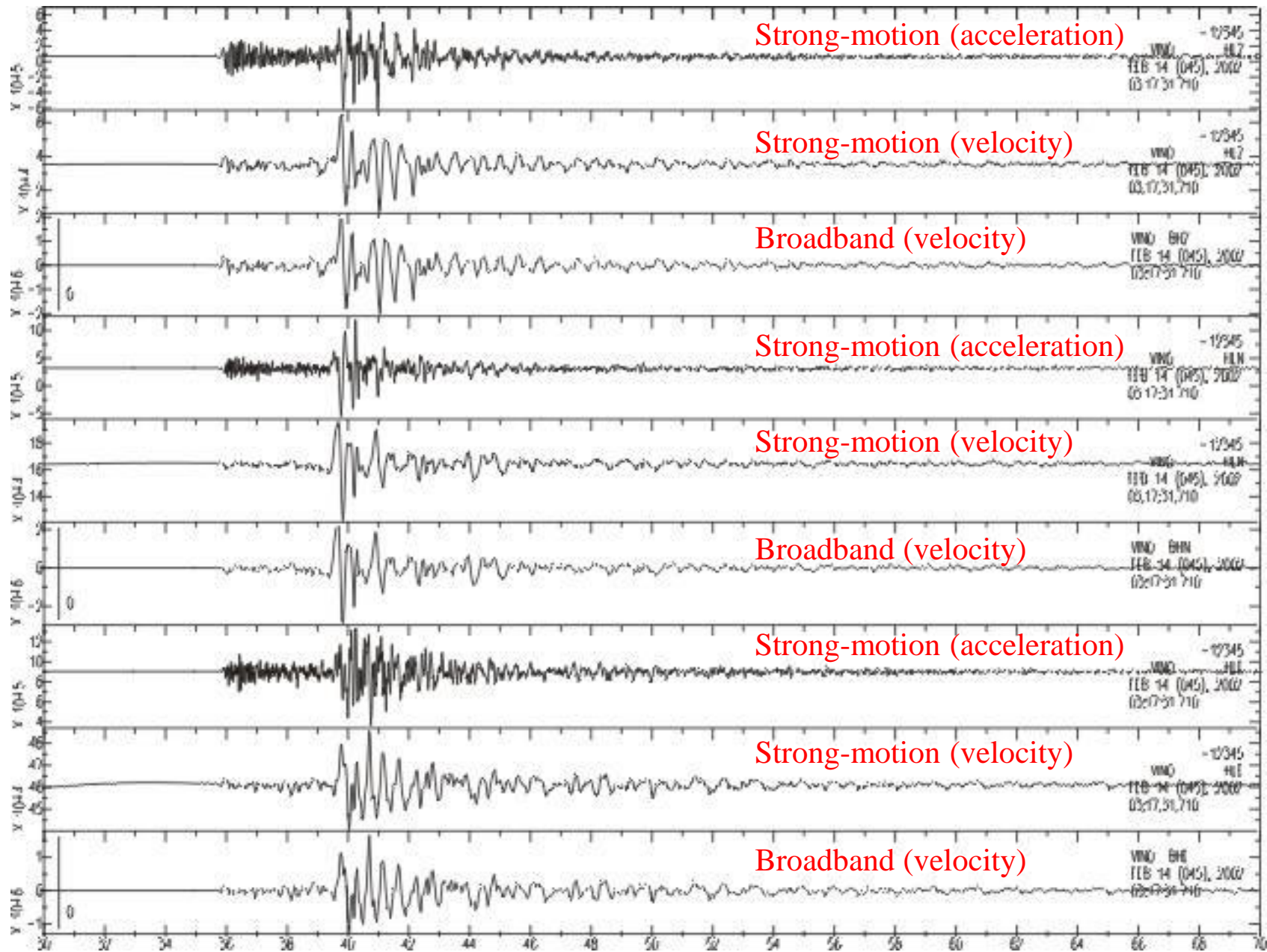
- a) a Wielandt
- b) b Streckeisen

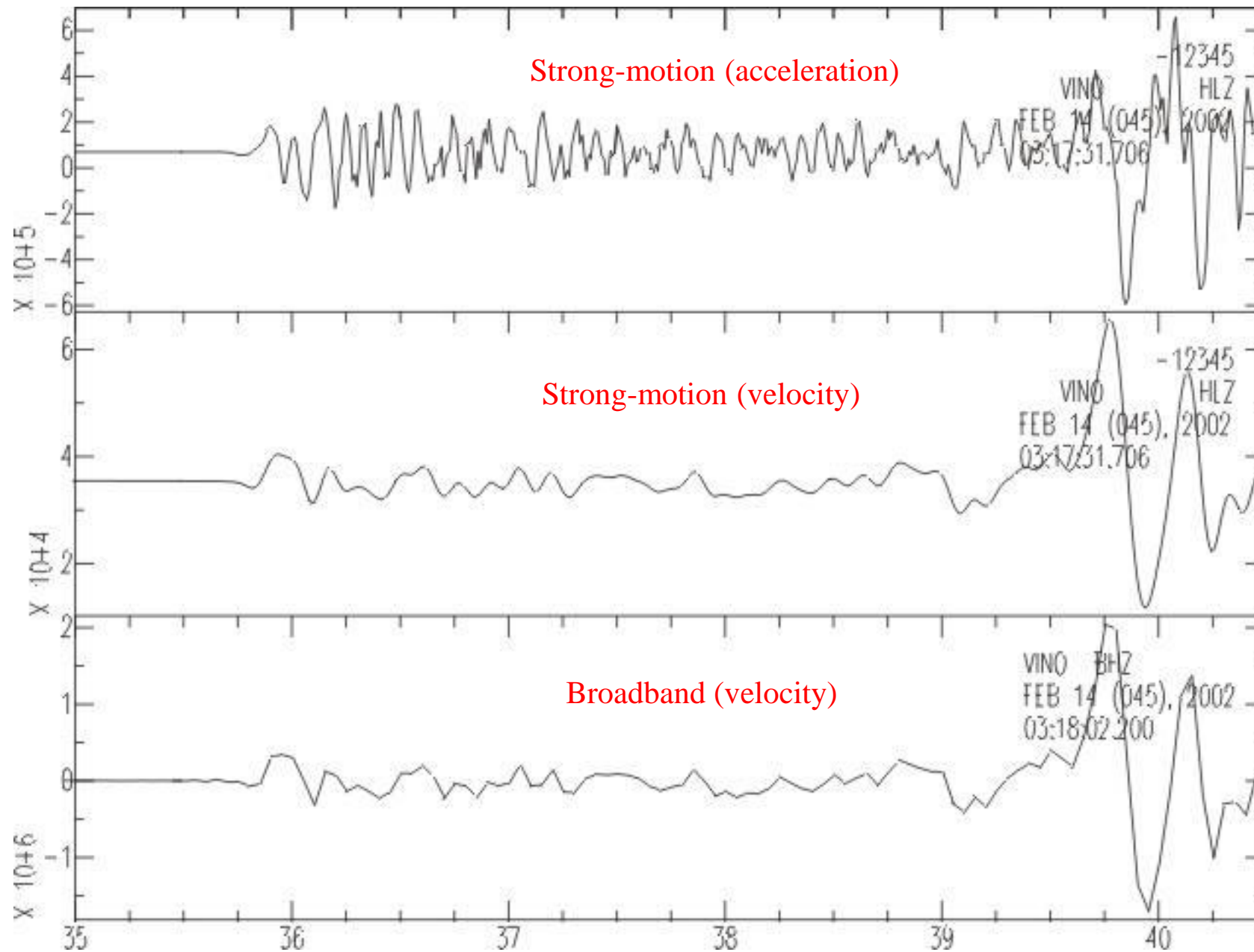




Un'accelerazione sismica del terreno ha lo stesso effetto sulla massa sismica di una forza esterna. La più grande tra tali forze è la gravità. È normalmente annullato dalla sospensione, ma quando il sismometro è inclinato, la proiezione del vettore gravità sull'asse della sensibilità cambia, producendo una forza che nella maggior parte dei casi non è distinguibile da un segnale sismico. L'inclinazione indesiderata alle frequenze sismiche può essere causato da carichi in superficie variabili come auto, persone o pressione atmosferica. I disturbi risultanti sono un effetto di secondo ordine nei sismometri verticali ben installati ma per il resto sono un effetto del primo ordine. Questo spiega perché le tracce sismiche orizzontali a lungo periodo sono sempre più rumorose di quelle verticali. Un tilt breve e impulsivo equivale a uno step della velocità del suolo e pertanto causerà un transiente di lungo periodo in un sismometro orizzontale a banda larga. Per segnali periodici, lo spostamento orizzontale apparente associato a una data inclinazione aumenta con il quadrato del periodo







STAZIONE SISMOLOGICA

Sensori



Sensore larga banda,
3 componenti

Sensore accelerometrico,
3 componenti

Sistema acquisizione

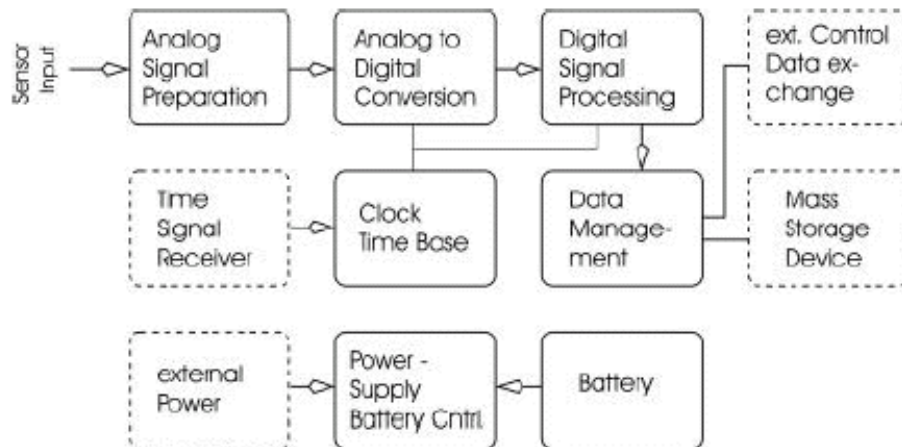


Acquisitore 6 canali a 24 bits

Antenna GPS per la
sincronizzazione del tempo
tramite satelliti

Unità disco per la
memorizzazione dei dati
presso la stazione

Switch per la connessione
alla rete informatica per la
trasmissione dei dati

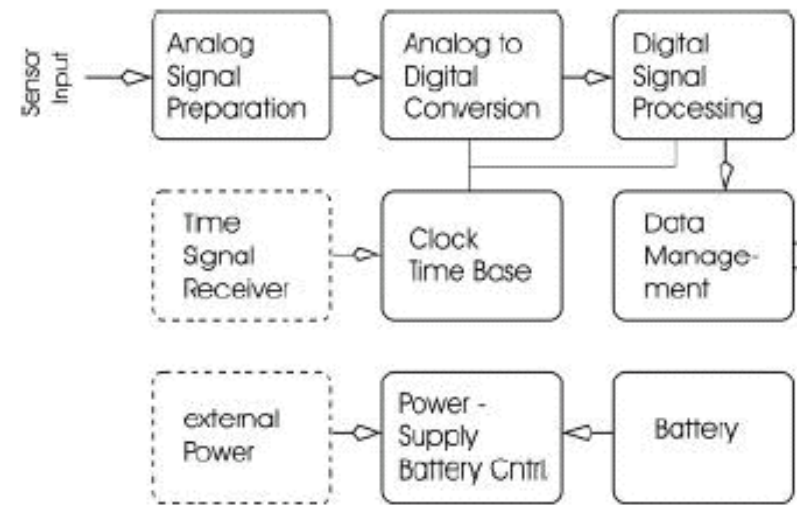
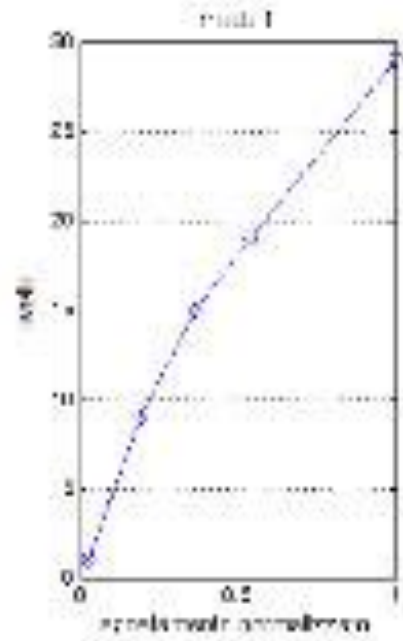
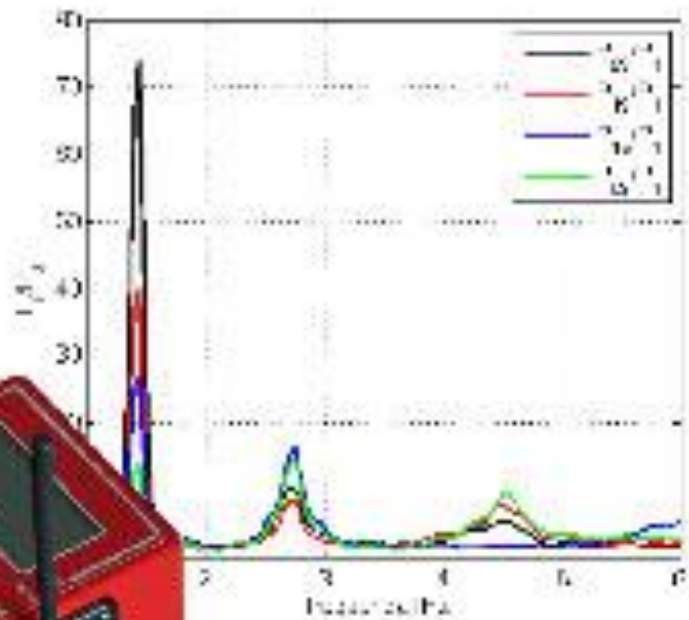


Alimentazione



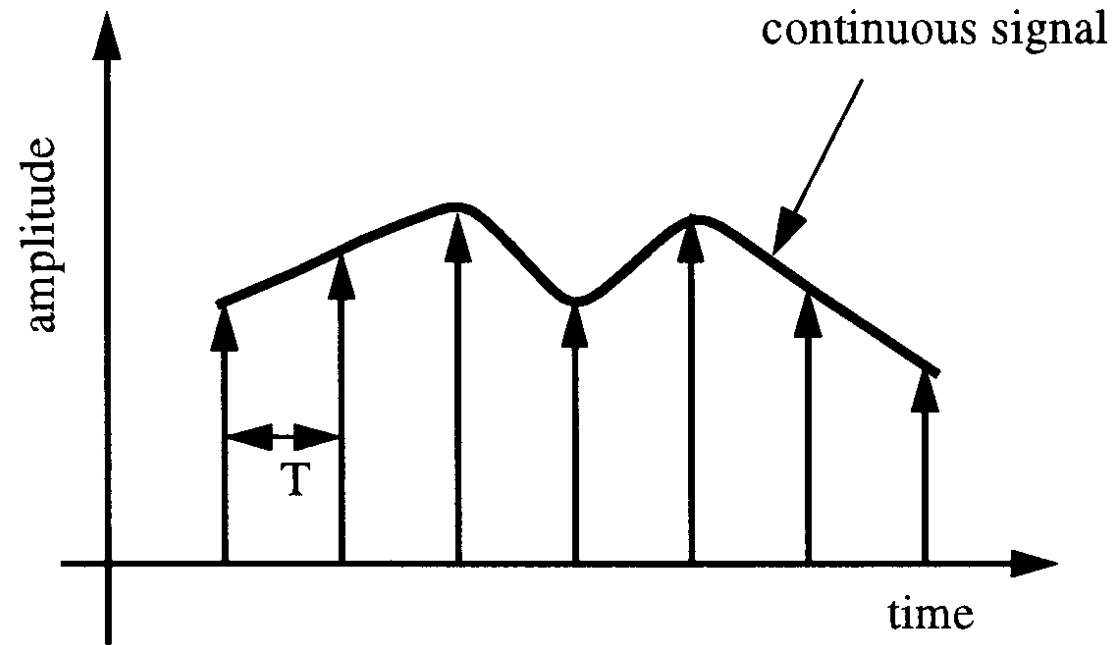
Alimentatore

Batteria tampone



Il principio del processo di discretizzazione.

Un segnale continuo viene campionato in tempi discreti indicati dalle posizioni delle frecce verticali. Le ampiezze delle anse corrispondono alle ampiezze del segnale al tempo del campionamento.



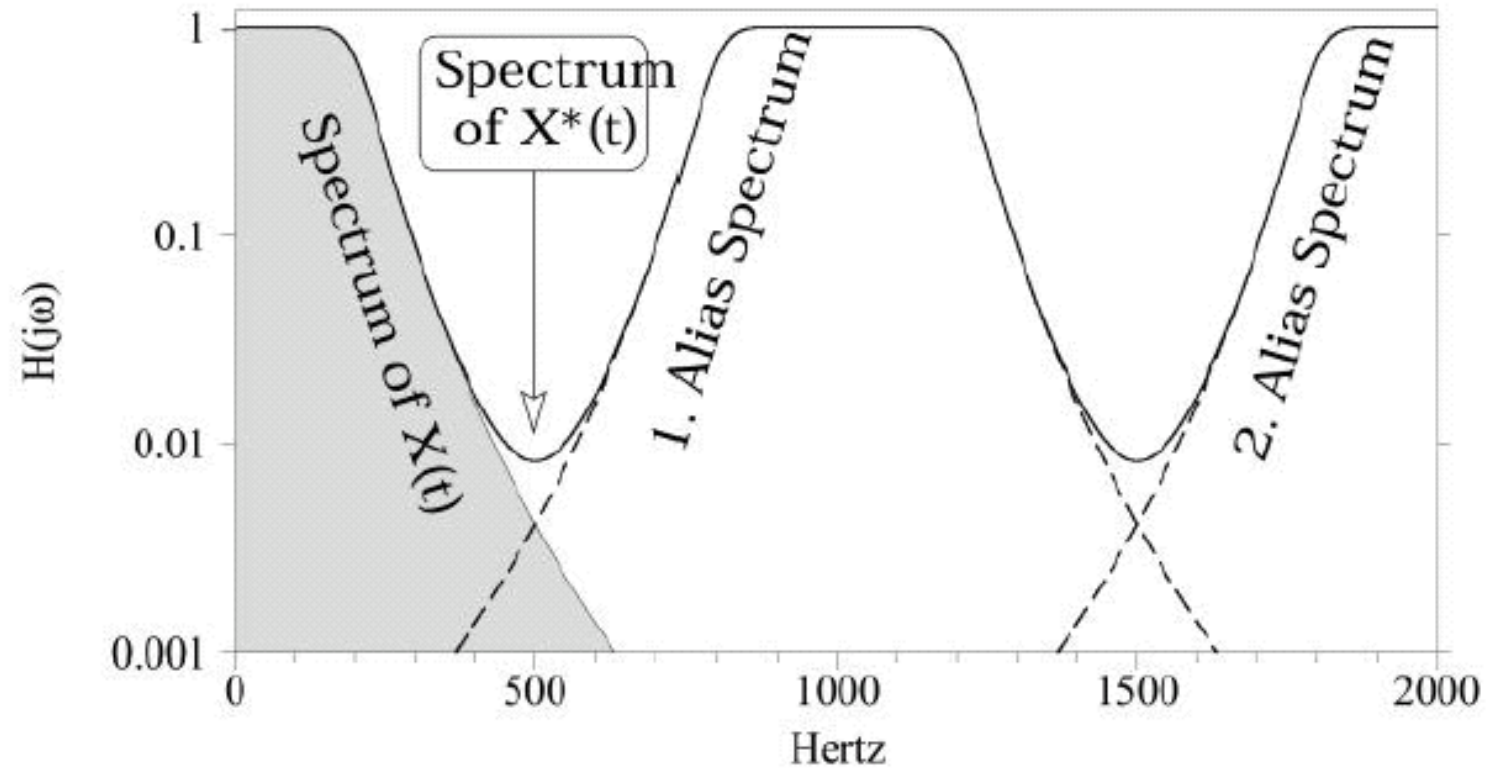
Processo di discretizzazione (campionamento). Le frecce verticali indicano le posizioni e i valori dei campioni. T indica l'intervallo di campionamento

Teorema del campionamento

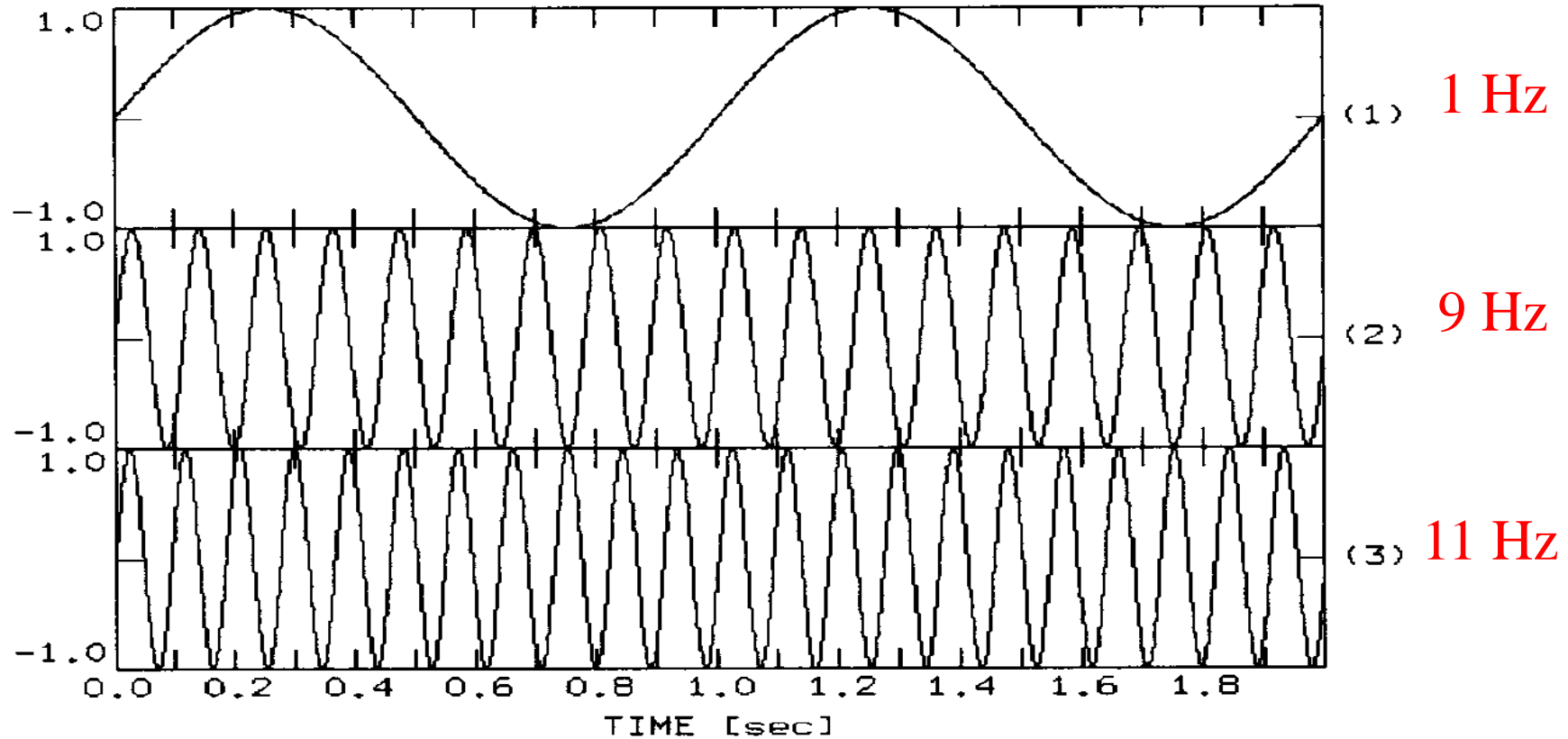
Perchè un segnale continuo venga rappresentato univocamente dai campioni presi ad una frequenza di campionamento di f_{dig} , non deve contenere energia alla e sopra la frequenza $f_{dig}/2$. Questa frequenza viene chiamata **frequenza di Nyquist**.

Componenti del segnale con energia al di sopra di questa frequenza verranno mappate dal processo di campionamento, nella banda di frequenza tra 0 e la frequenza di Nyquist (frequenze di alias). Questo effetto viene chiamato **alias**.

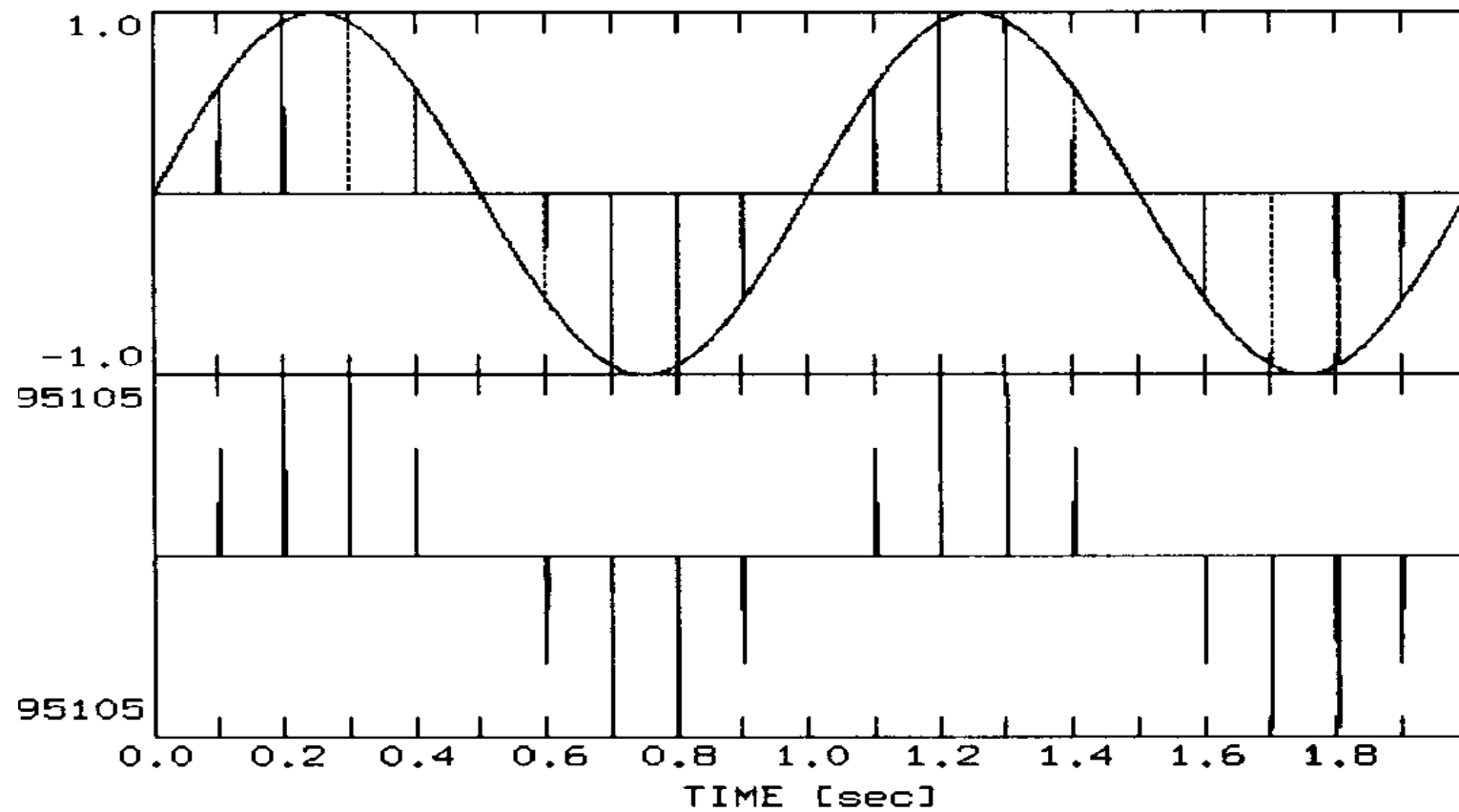
La conseguenza dell'aliasing è che tutti i segnali con frequenze al di sopra della frequenza di Nyquist $f_N = f_s / 2$ si riflette nello spettro di $X(t)$. Ecco perché dobbiamo assicurare, applicando un filtro antialias passa-basso per le serie temporali analogiche di ingresso, che le sue ampiezze ad alta frequenza vengano drasticamente ridotte e, quindi, non rispecchi molta energia negli spettri alias.



Segnali utilizzati per la simulazione del processo di discretizzazione.

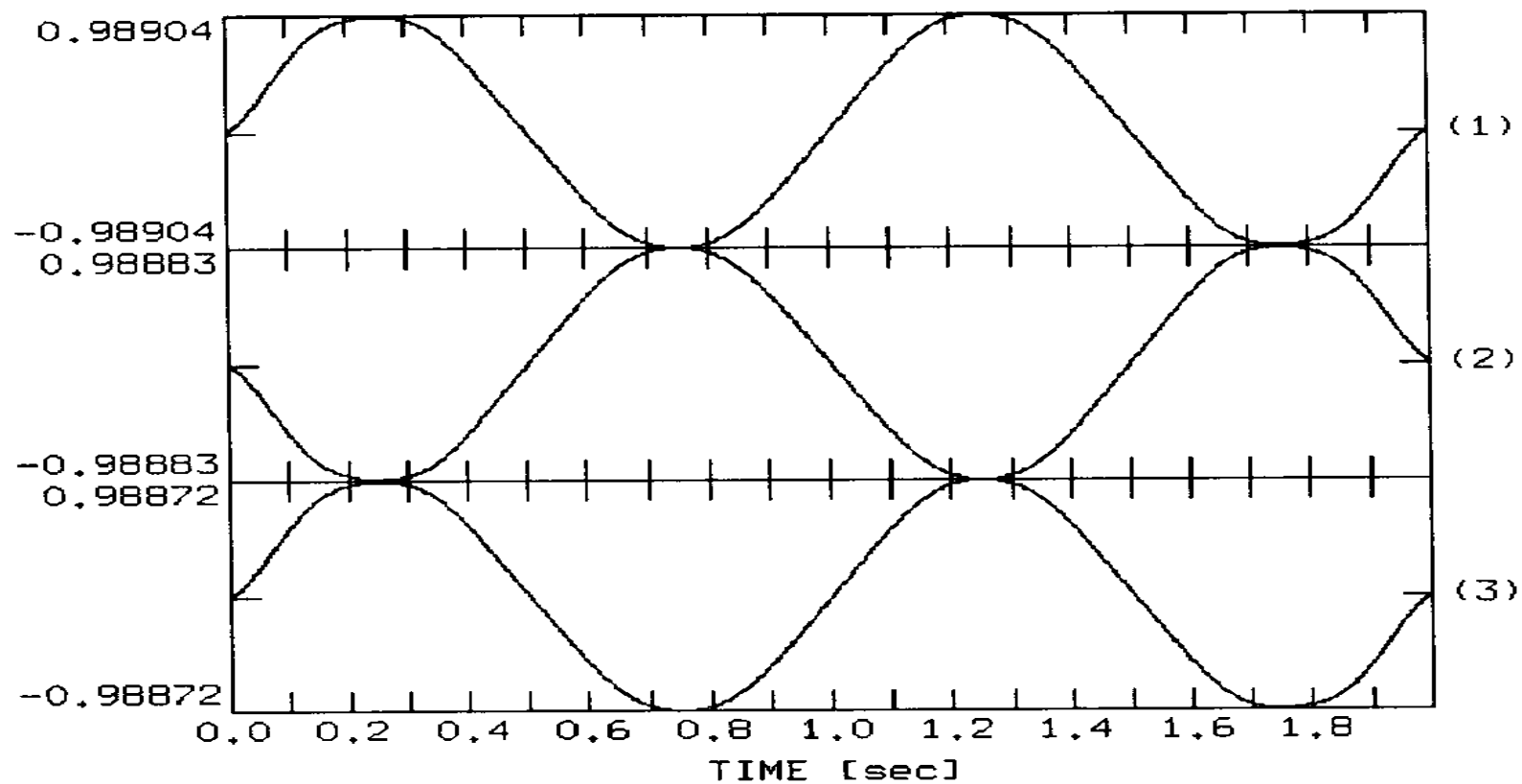


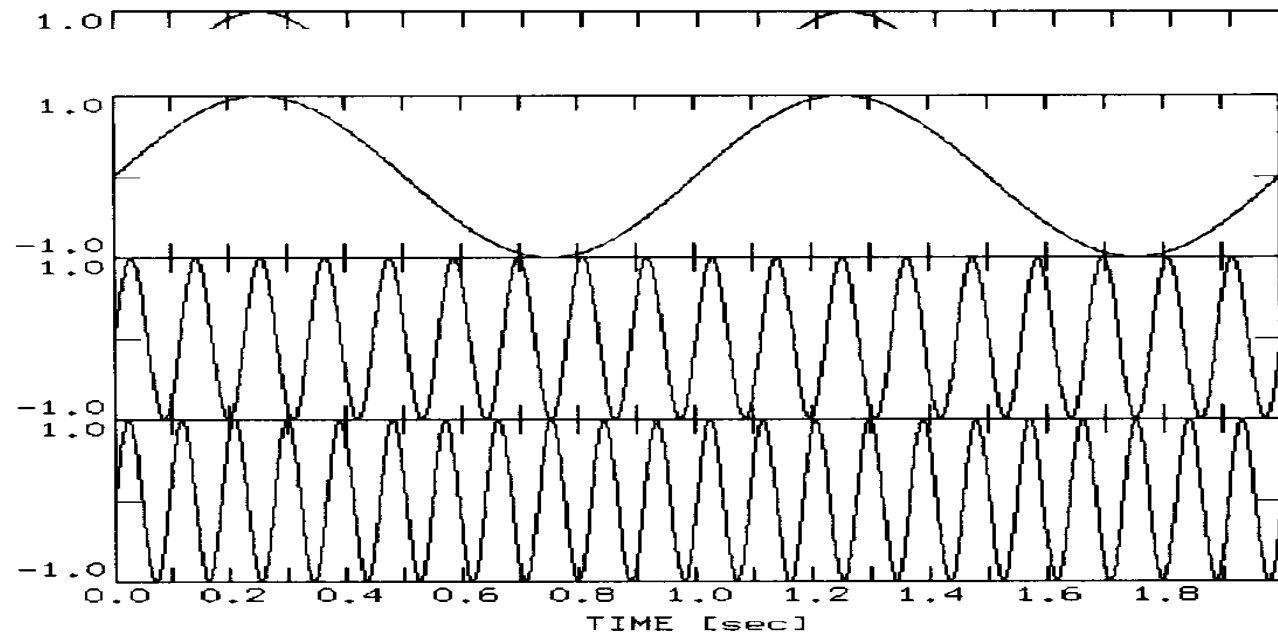
Discretizzazione del segnale usando una frequenza di 10 Hz. Le barre verticali mostrano le posizioni e i valori della funzione ai tempi campionati.



10 Hz

Ricostruzione dei segnali usando una frequenza di 10 Hz.

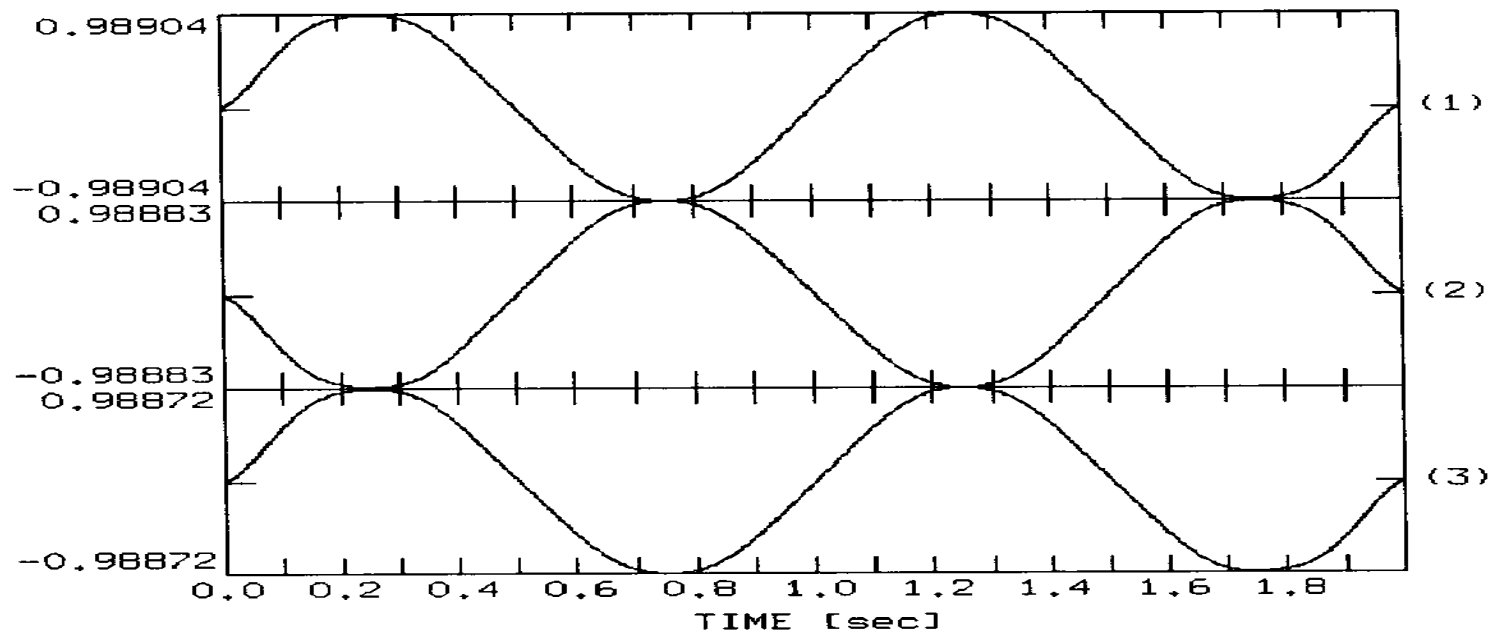




(1) 1 Hz

(2) 9 Hz

(3) 11 Hz

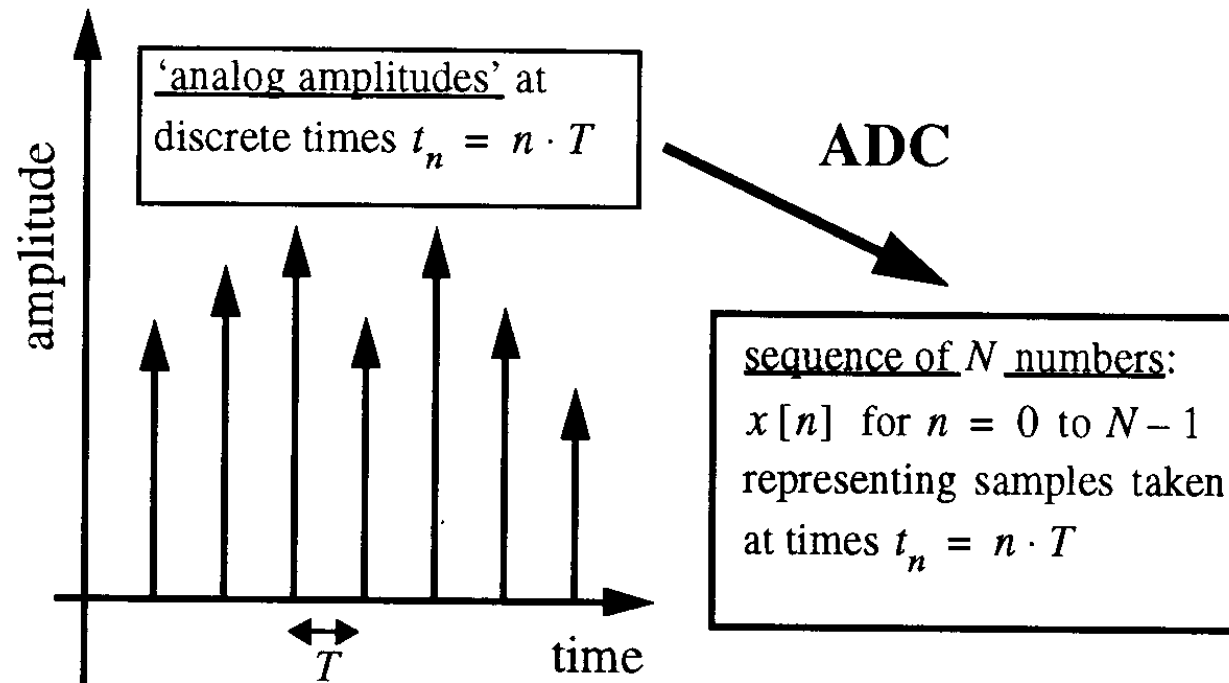


(1)

(2)

(3)

Schema del processo di conversione da analogico a digitale (ADC). Le frecce verticali indicano le posizioni e i valori dei campioni. Attraverso l'ADC i valori di ampiezza vengono convertiti in una sequenza di numeri che rappresentano i campioni prelevati ai tempi $T_n = n \cdot T$



decimal system

$$x_{(10)} = \sum_i d_i^{(10)} \cdot 10^i$$

e.g. $512_{(10)} = 2 \cdot 10^0 + 1 \cdot 10^1 + 5 \cdot 10^2$

least significant digit most significant digit

conventional notation:
digits are written from
most significant to least
significant:
512

binary system

$$x_{(2)} = \sum_i d_i^{(2)} \cdot 2^i$$

e.g.

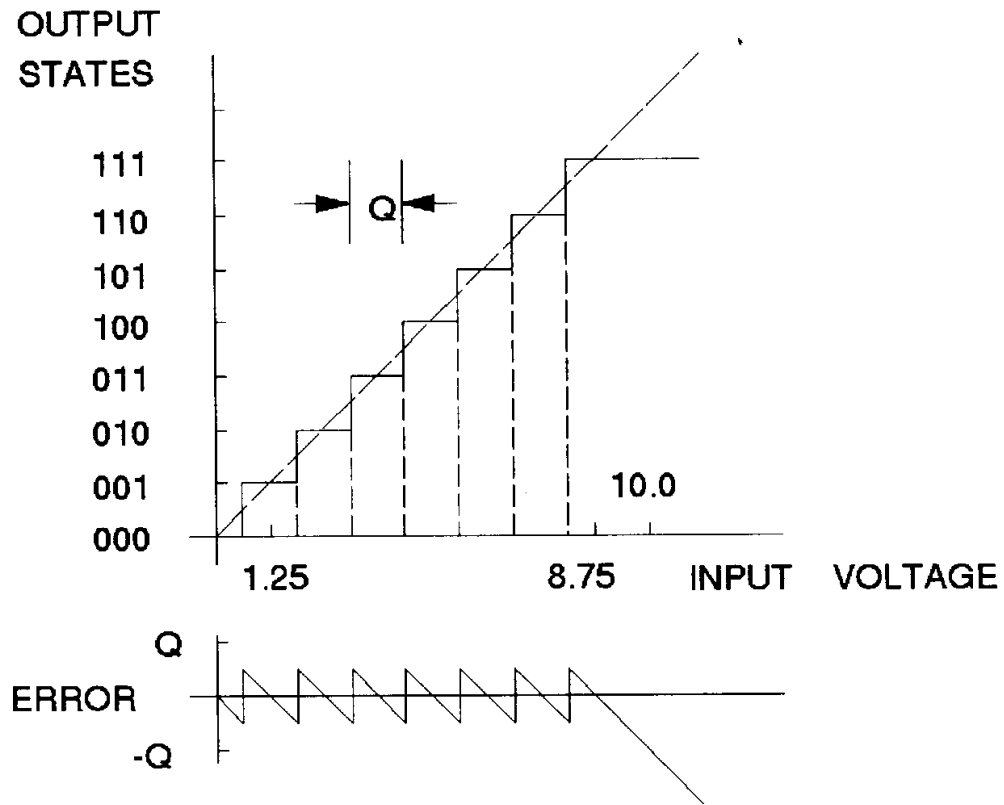
$13_{(10)} = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3$

least significant bit value most significant bit value

conventional notation:
bit values are written
from most significant
(MSB) to least signifi-
cant (LSB):
1101

Fig. 6.3 Number representation in the decimal and binary number codes.

3 bit ADC per una tensione di ingresso a fondo scala di 10 V.

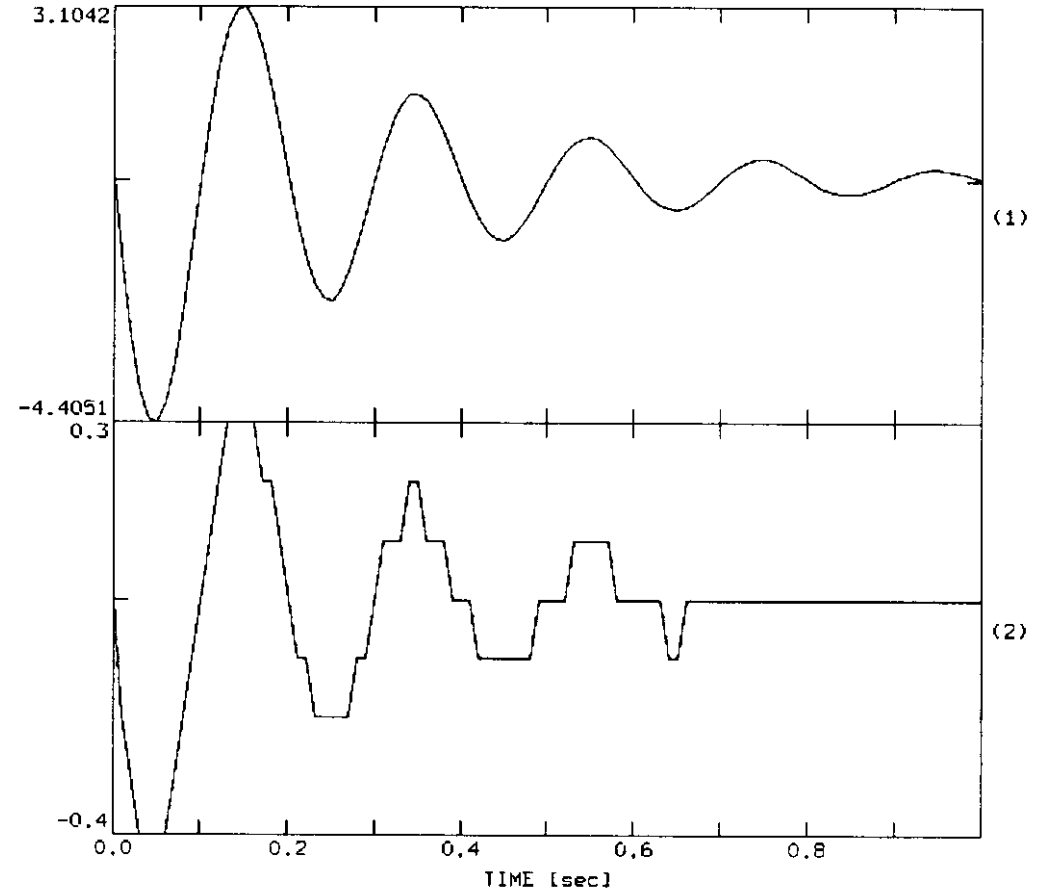
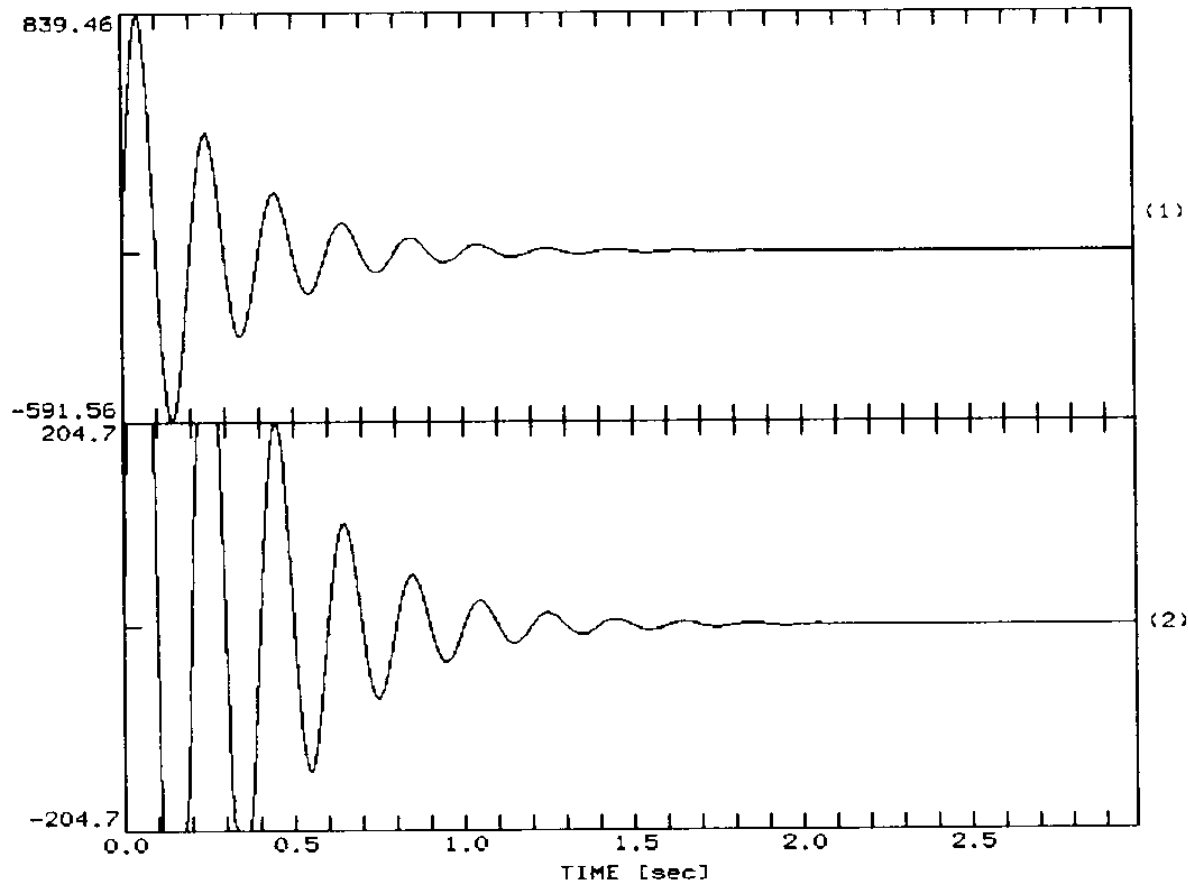


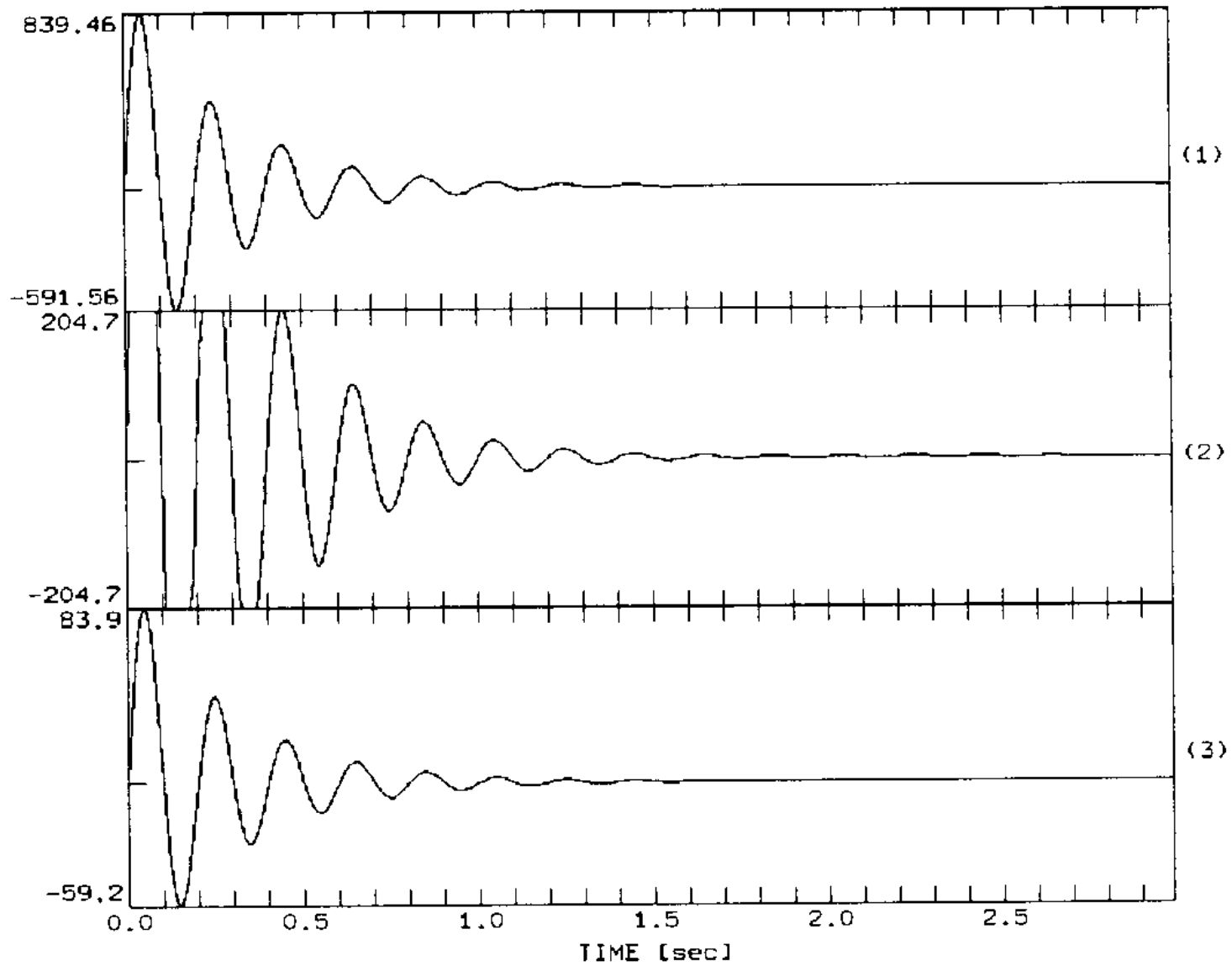
$$Q = \text{LSB value} = \frac{FULL_{SCALE VOLTAGE}}{2^n}$$

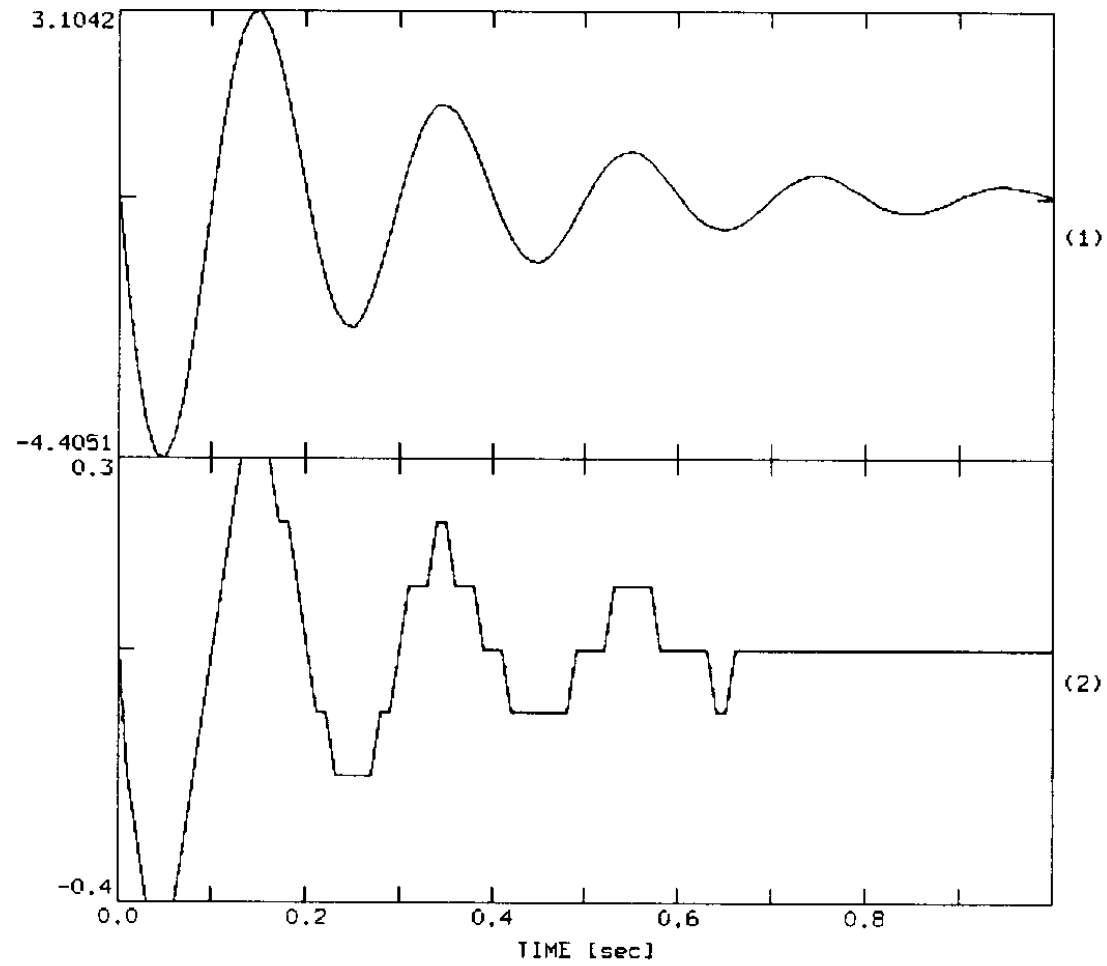
Mappatura della tensione di input nello stato di uscita per un ADC a 3 bit. In basso il segnale di errore. Q corrisponde al valore del quanto o least significant bit (LSB).

12 bit LSB = 0.1

Saturazione: $0.1 \cdot (2^{12} - 1) = 0.1 \cdot 2047 = 204.7$



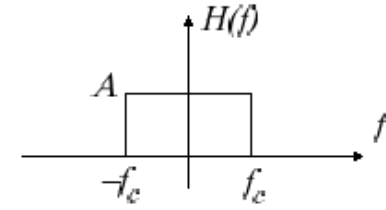




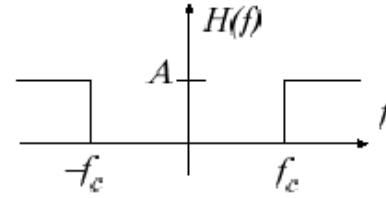
Filtri ideali

Sono di quattro tipi:

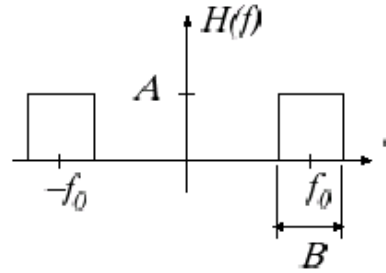
Passa basso
($f_c =$ frequenza di taglio)



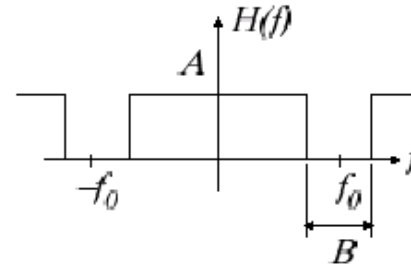
Passa alto
($f_c =$ frequenza di taglio)



Passa banda
 $f_0 =$ frequenza di riferimento
(usualm. centrale)
 $B =$ banda passante



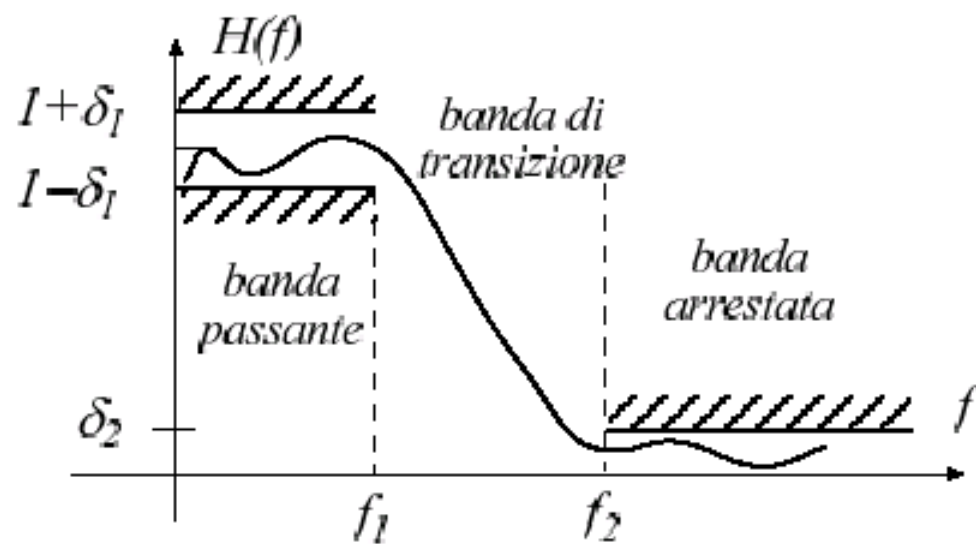
Arresta banda



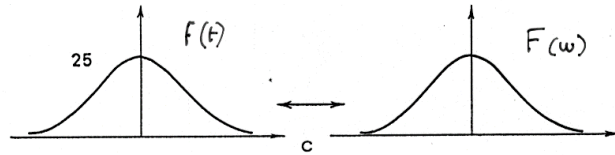
Filtri reali

La loro risposta in frequenza viene specificata mediante maschera:

Esempio (passa basso)



FILTRO GAUSSIANO



$$H(\omega) = \exp\left(-\alpha\left(\frac{\omega-\omega_i}{\omega_i}\right)^2\right)$$

$$\alpha_{\text{opt}}(\omega_i) = \frac{\omega_i}{2} \left| \frac{d\tau_{\text{gr}}(\omega)}{d\omega} \right|_{\omega=\omega_i}$$

Filtro di Butterworth

$$|H_n(f)| = \frac{1}{\sqrt{1 + \left(\frac{f}{f_c}\right)^{2n}}}$$

Oppure:

$$|H_n(\omega)|^2 = \frac{1}{1 + \omega^{2n}}$$

Con: $\omega = \frac{2\pi f}{2\pi f_c}$

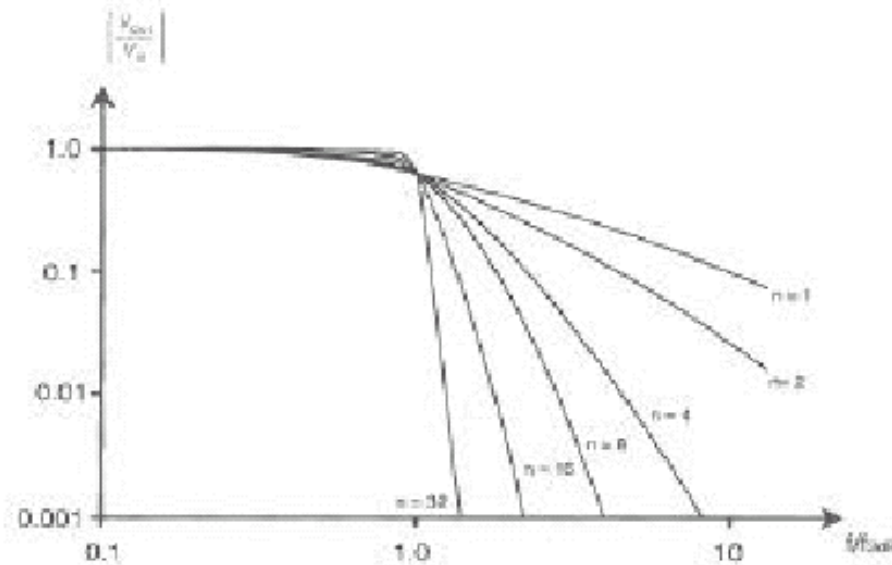
Frequenza normalizzata

FILTRI DI BUTTERWORTH

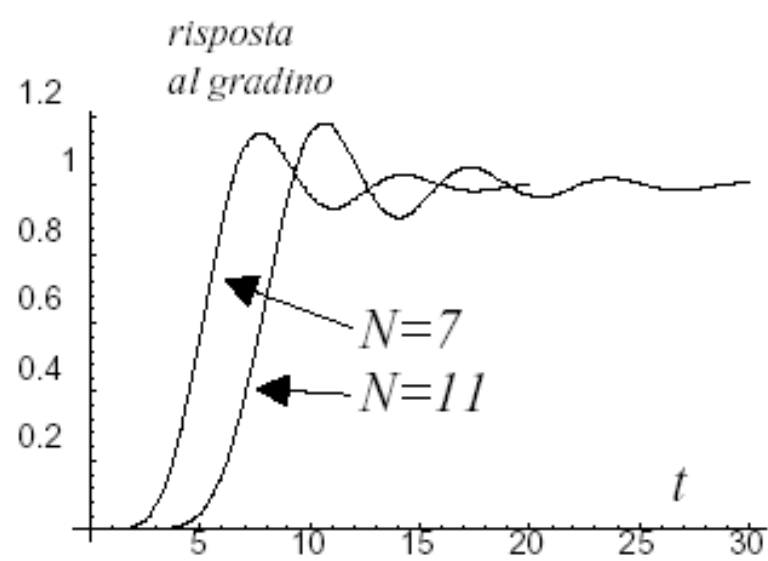
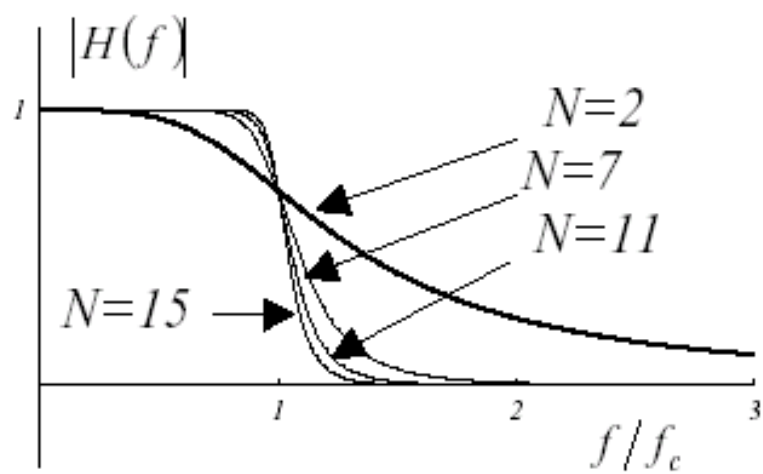
Si tratta di filtri “massimamente piatti” nella banda passante, con risposta in frequenza:

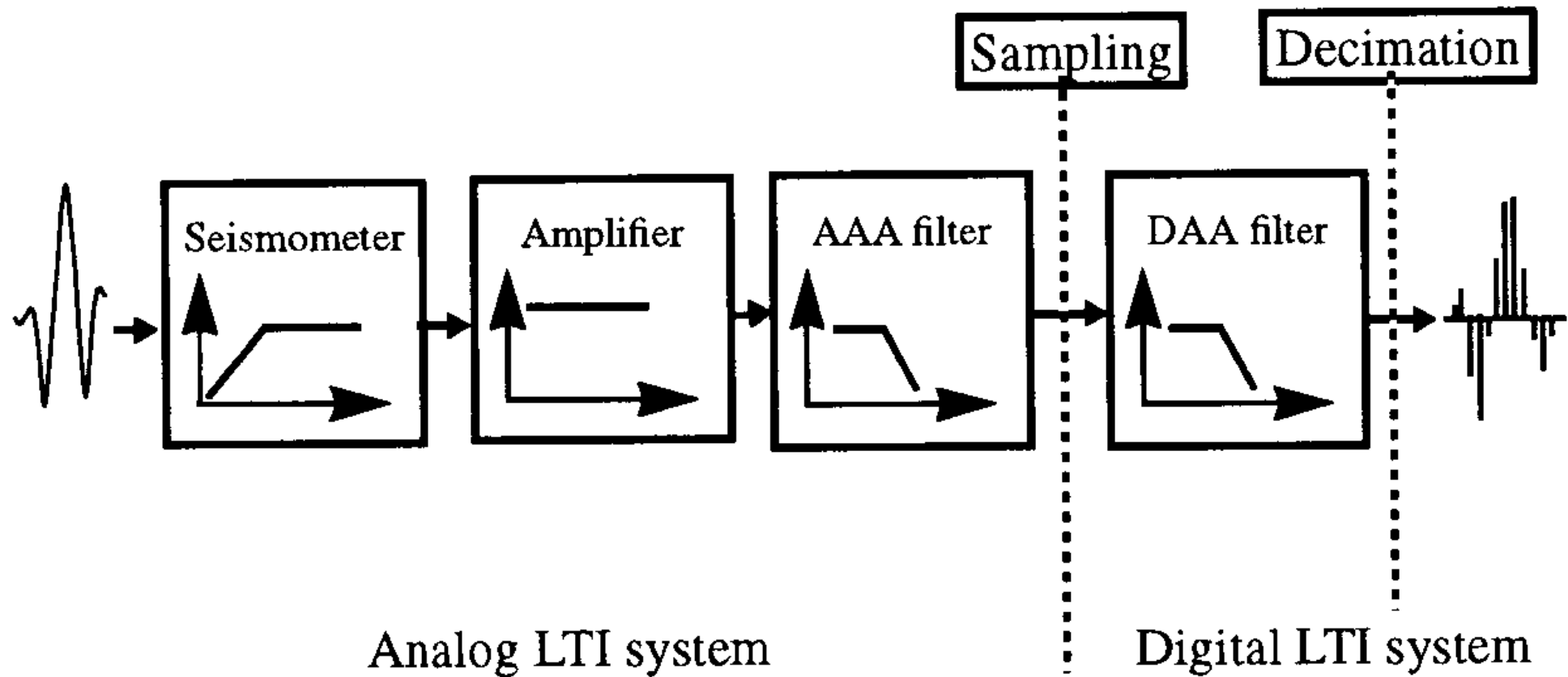
$$\left| \frac{V_{out}}{V_{in}} \right| = \frac{1}{\sqrt{1 + \left(\frac{f}{f_{3db}} \right)^{2n}}}$$

dove n è l'ordine del filtro.

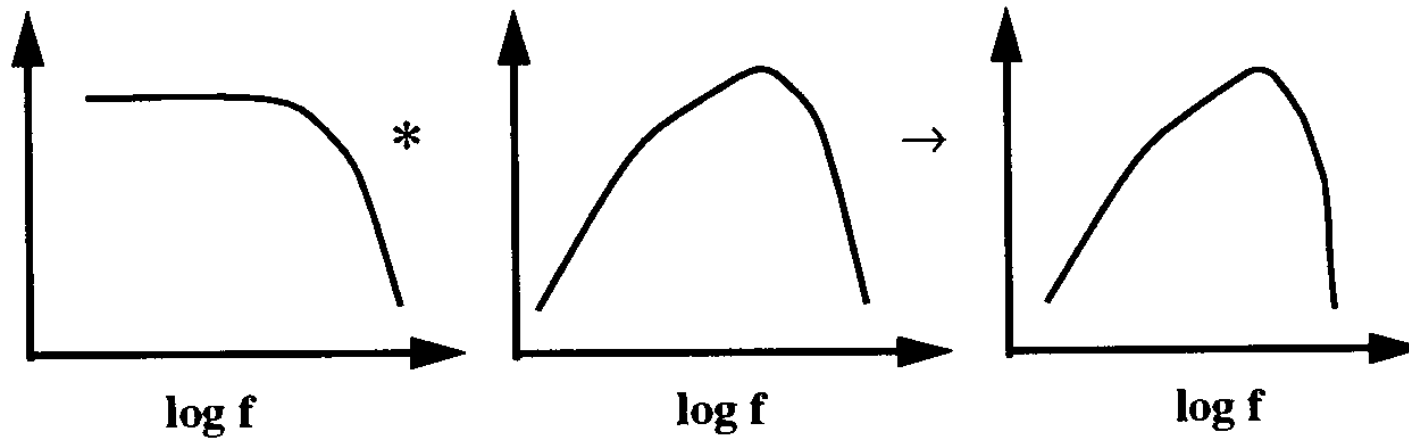


I filtri di Butterworth hanno le limitazioni di non essere a fase lineare e di richiedere un ordine elevato per garantire una regione di transizione sufficientemente ripida.



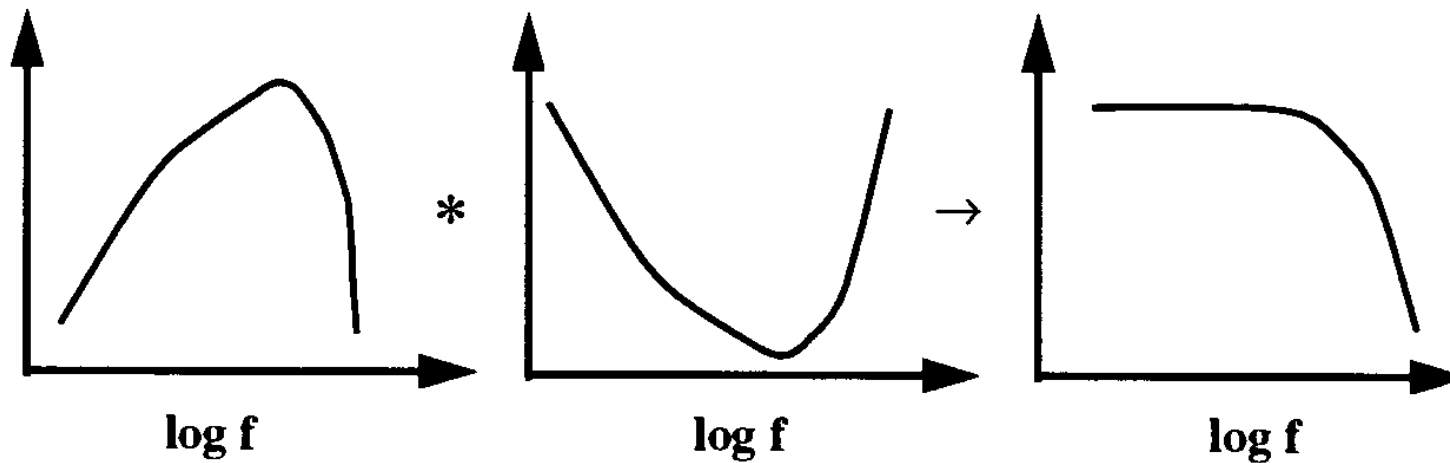


source spectrum * recording system → recorded spectrum



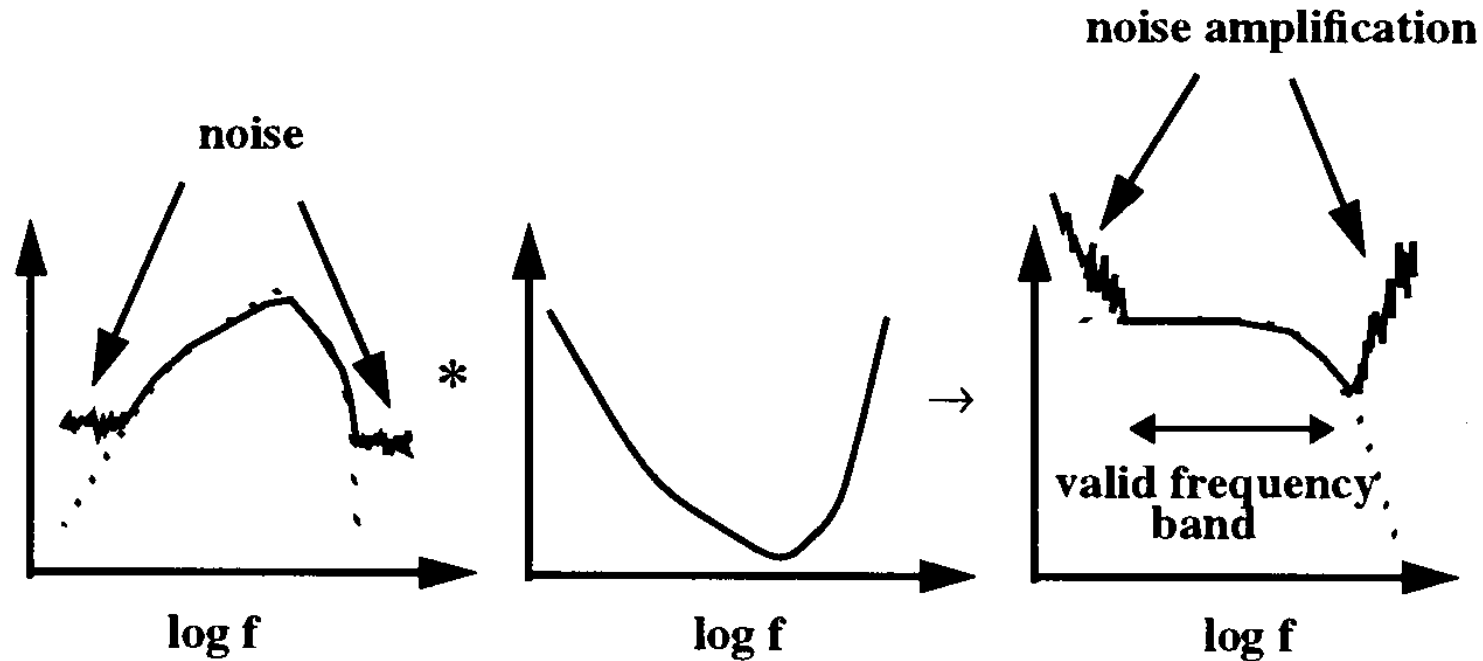
Registrazione dello spettro di spostamento di una sorgente di terremoto idealizzata.

recorded spectrum * inverse filter → source spectrum



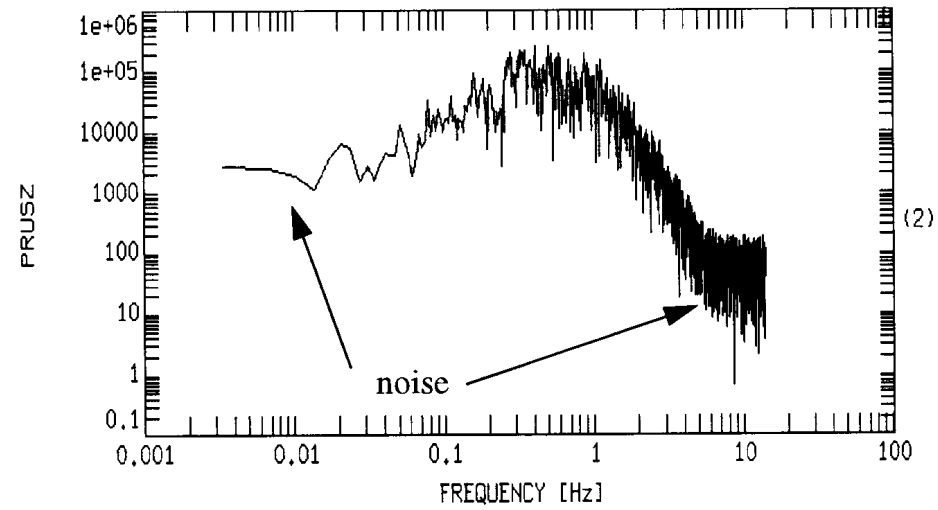
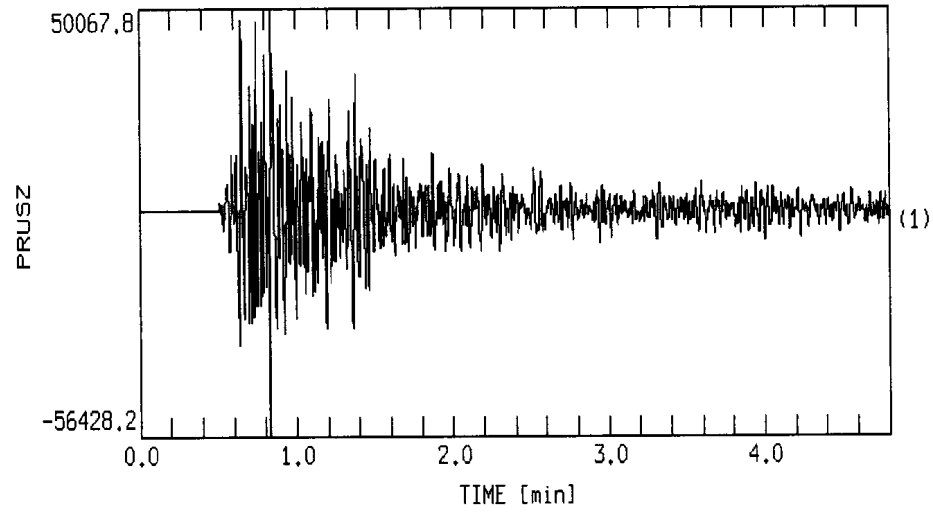
Ripristino dello spettro sorgente mediante filtro inverso nel caso privo di rumore

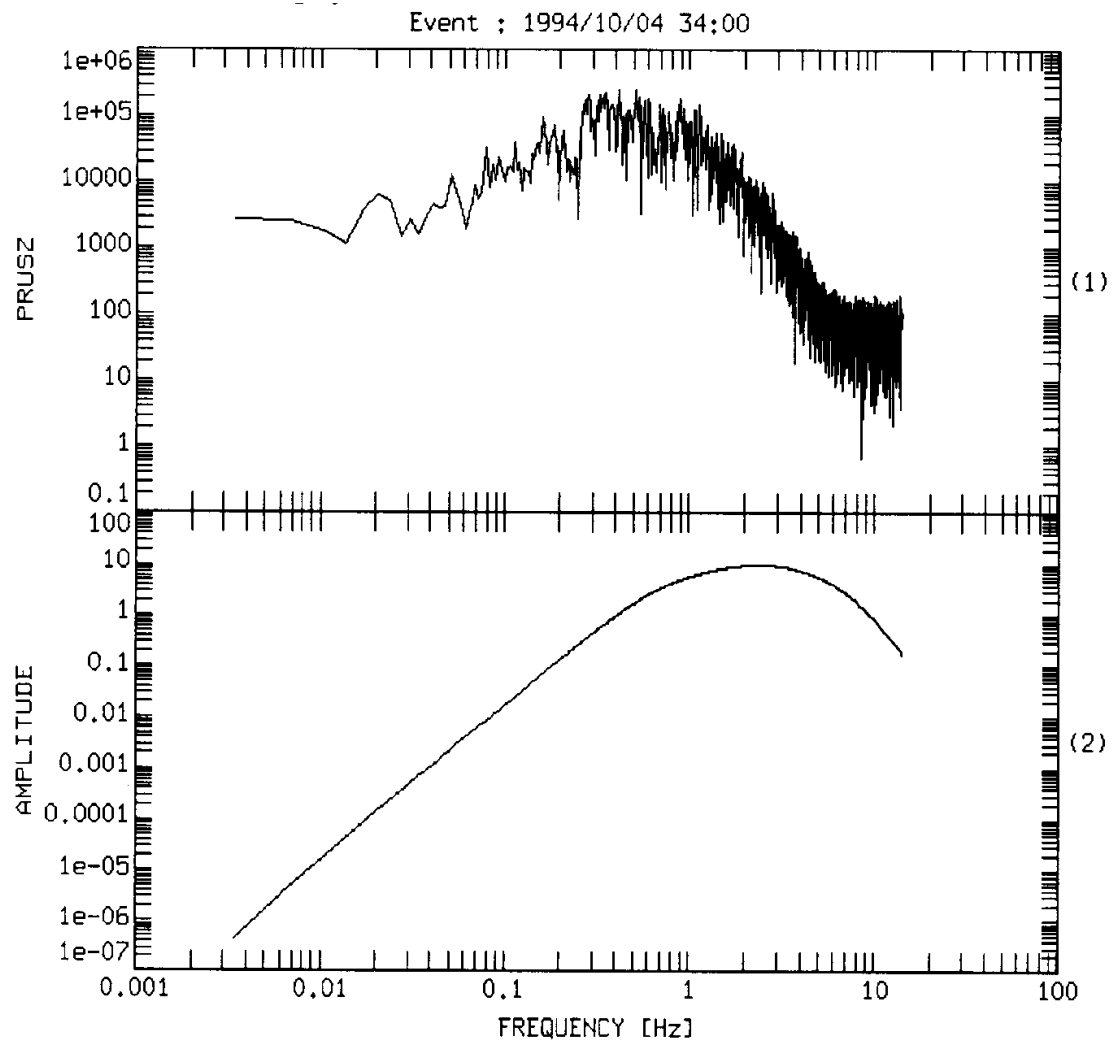
'noisy' spectrum * inverse filter → 'noisy' source spectrum



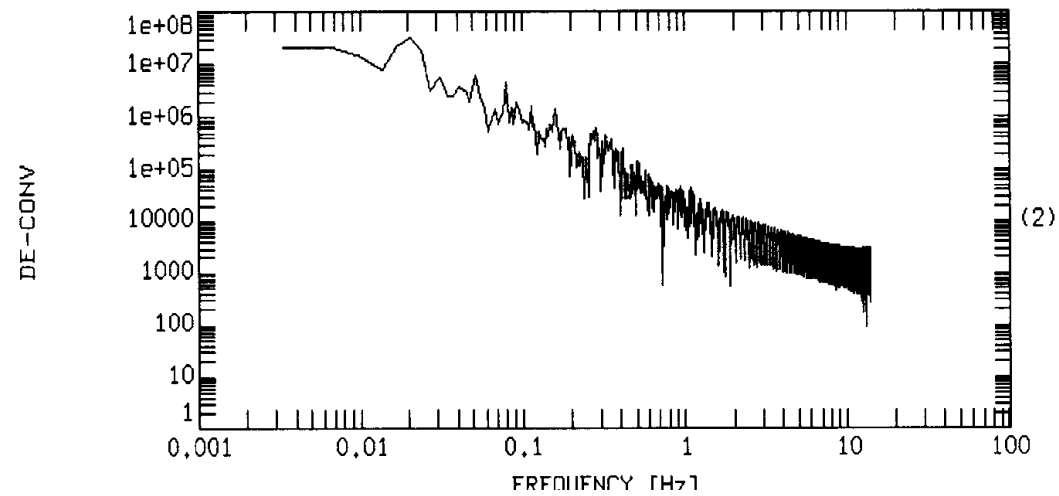
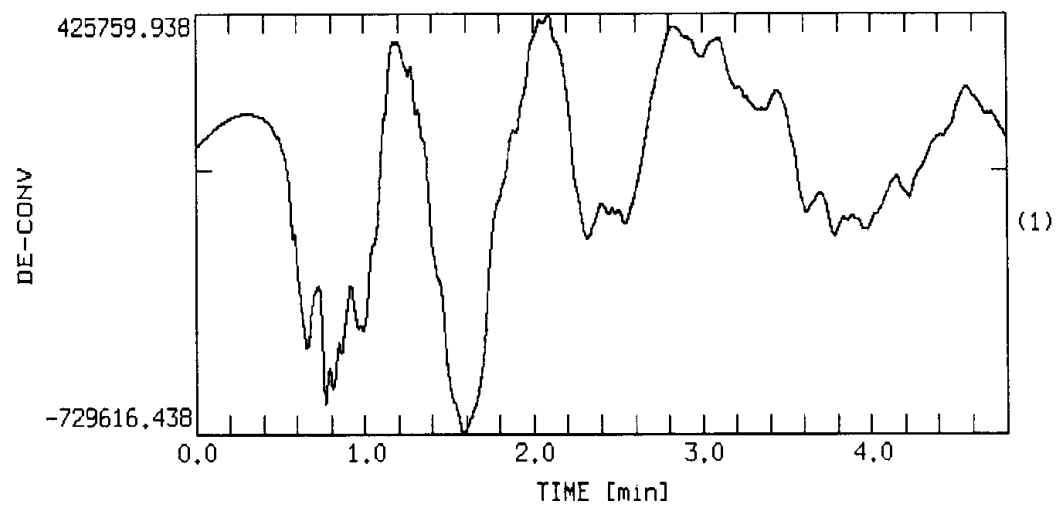
Amplificazione del rumore mediante filtro inverso. La linea continua nel pannello di sinistra mostra il segnale più il rumore mentre il segnale privo di rumore è mostrato dalla linea tratteggiata.

Event : 1994/10/04 34:00





Event : 1994/10/04 34:00



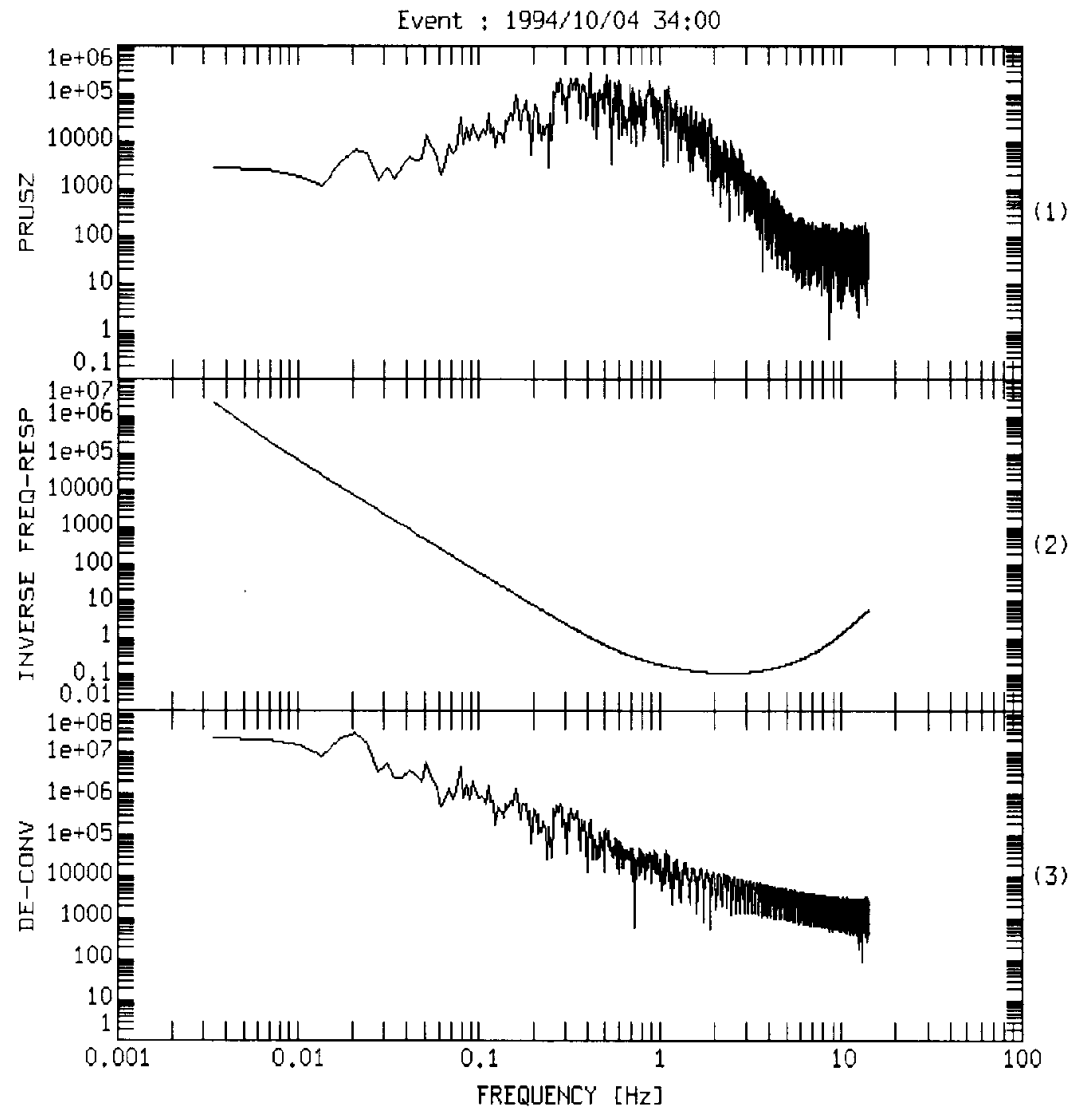
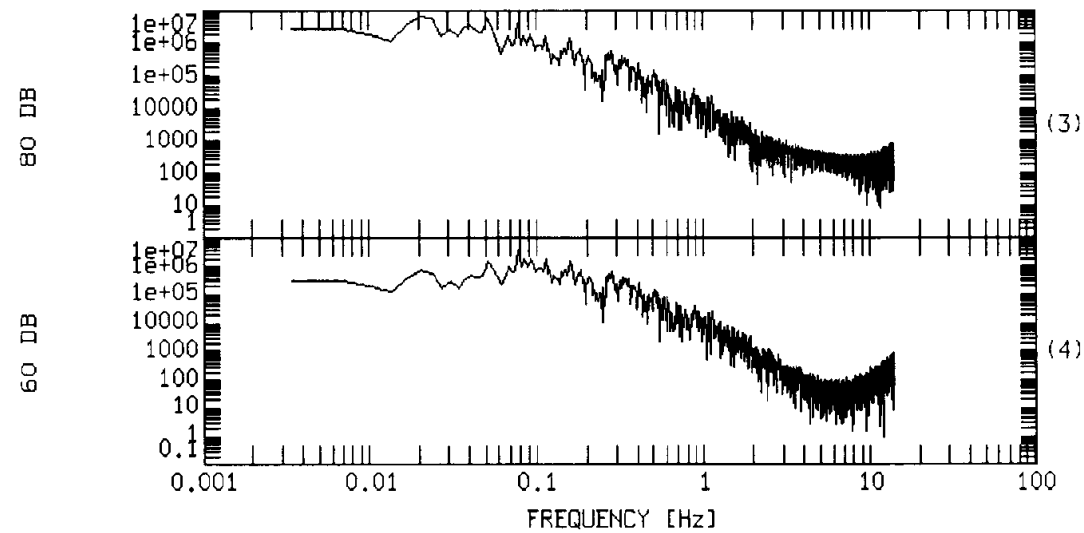
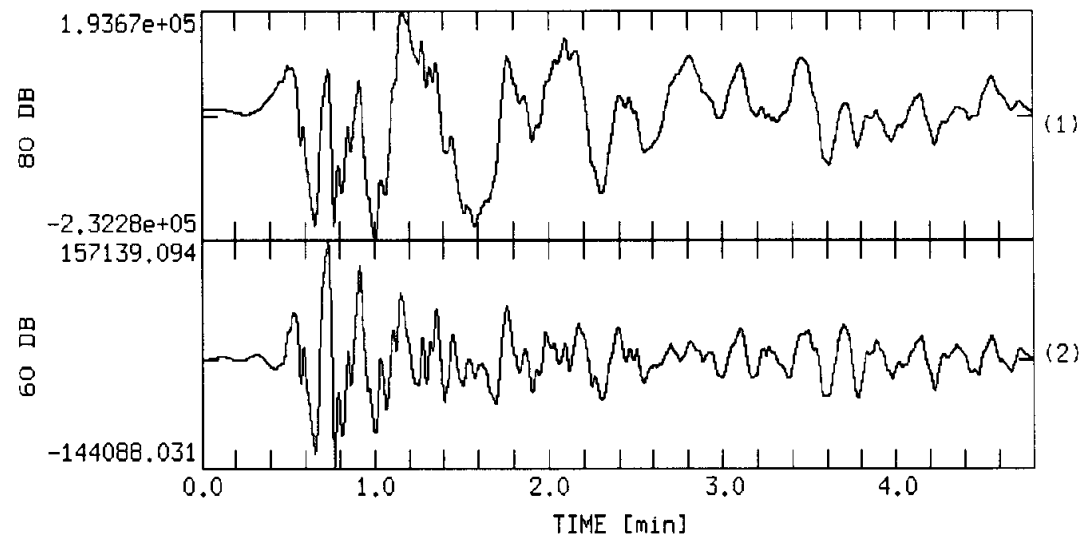
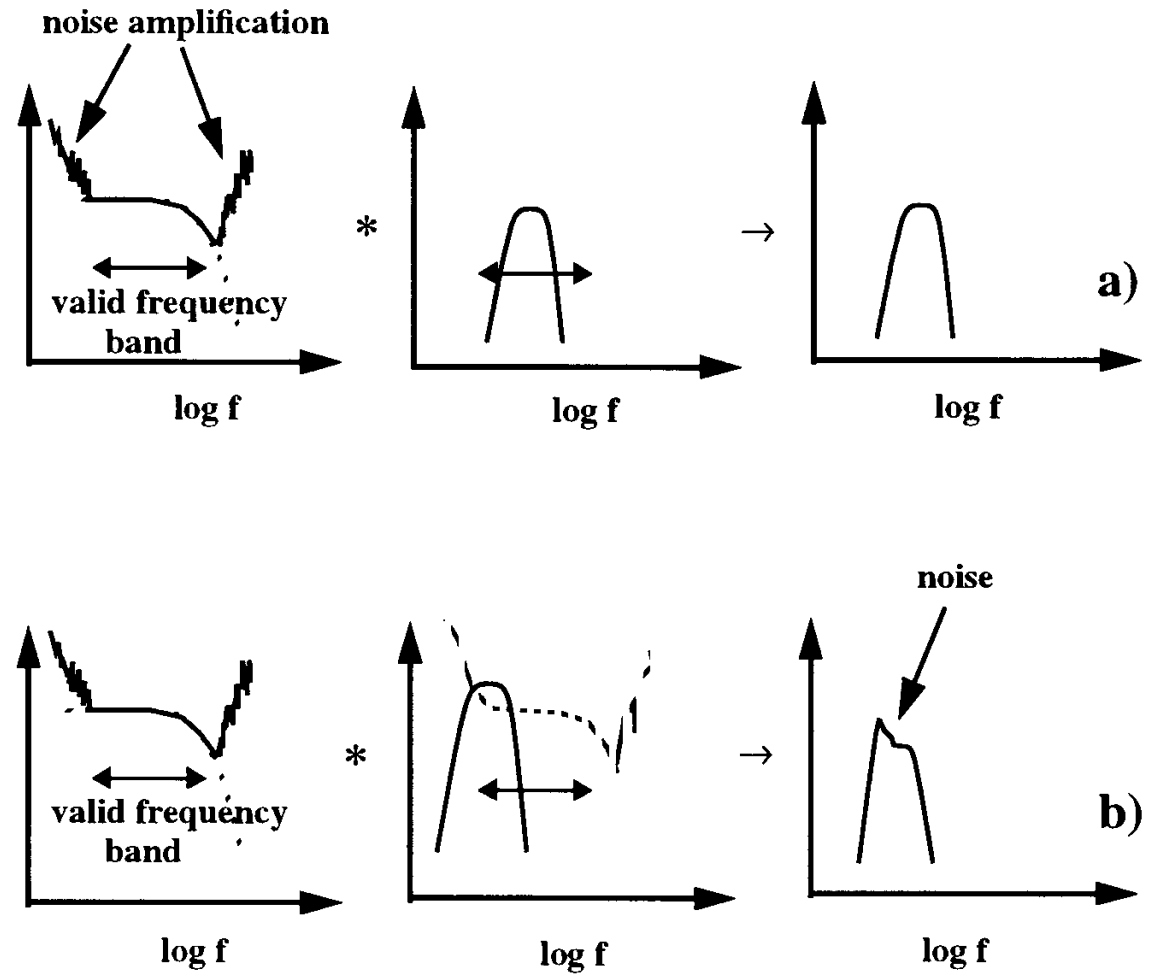


Fig. 0.0 Deconvolution illustrated in the frequency domain. From top to bottom: the amplified spectrum of

Event : 1994/10/04 34:00





Mappatura del rumore di deconvoluzione nel sistema simulato. a) La banda passante dello strumento simulato rientra pienamente nella banda di frequenza valida. b) La banda passante dello strumento simulato va parte al di fuori della banda di frequenza valida. Da qui il rumore di deconvoluzione viene mappato nel sistema simulato.

CMG-40T CALIBRATION SHEET

POLES AND ZEROS TABLE

WORKS ORDER No: 2712

SENSOR SERIAL No: T4H33

WORKS ORDER: 2712 DATE: 22-Feb-2005
 SERIAL No: T4H33 TESTED BY: P. Stott

Velocity response output, Vertical Sensor:

<u>POLES (HZ)</u>	<u>ZEROS HZ</u>
$-23.56 \times 10^{-3} \pm j 23.56 \times 10^{-3}$	0
-180.0	0
-160	
-80	

Normalizing factor at 1 Hz: A = 2304000

Sensor Sensitivity: See Calibration Sheet.

Velocity response output, Horizontal Sensors:

<u>POLES (HZ)</u>	<u>ZEROS (HZ)</u>
$-23.56 \times 10^{-3} \pm j 23.56 \times 10^{-3}$	0
-180.0	0
-160	
-80	

Normalizing factor at 1 Hz: A = 2304000

Sensor Sensitivity: See Calibration Sheet.

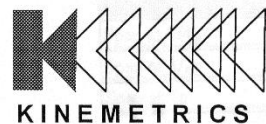
NOTE: The above poles and zeros apply to the vertical and the horizontal sensors and are in units of Hz. To convert to Radian/sec multiply each pole or zero with 2π . The normalizing factor should also be recalculated.

	Velocity Output V/m/s (Differential)	Mass Position Output (Acceleration output) V/m/s ²	Feedback Coil Constant Amp/m/s ²
VERTICAL	2 x 399.6	19.6	0.004176
NORTH/SOUTH	2 x 400.4	20.8	0.004421
EAST/WEST	2 x 403.1	21.0	0.004466

Power Consumption: 62.8mA @ +12V input
 Calibration Resistor: 51000

NOTE: A factor of 2 x must be used when the sensor outputs are used differentially (also known as push-pull or balanced output). Under no conditions should the negative outputs be connected to the signal ground. A separate signal ground pin is provided.





EpiSensor
FBA ES-DECK
Calibration Data

Unit Serial Number	E 2877	
Oscillator Board Serial Number	4800268	
Current	+12V	-12V
	/mA	/mA
	13	10.2
Sensor Output Voltage Level	2.5V	10V
	X	
Standard or Low Noise Output	Standard	Low Noise
	X	
Output Type	Single Ended	Differential
	X	
Sensitivity	1.25 V/g	
Final Setup Check by	AK	
Test Date	06/12/2001	

	Serial Number	Range Set
X Axis Module	6055	2G
Y Axis Module	6029	2G
Z Axis Module	6083	2G

This data sheet reflects the configuration of the EpiSensor set in the factory. If you wish to change this refer to the Operating Manual included with your EpiSensor ES-DH. The data for the individual modules is included on the following pages.

ES-T Calibration Sheet Version 1.0

Kinometrics Inc.
 222 Vista Avenue
 Pasadena
 California 91107
 USA

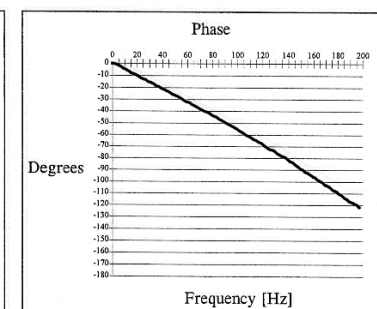
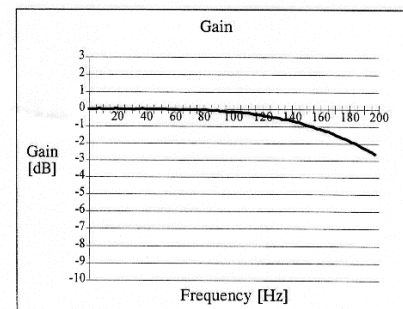
(626) 795 2220
 www.kinometrics.com

EpiSensor Module Data Sheet

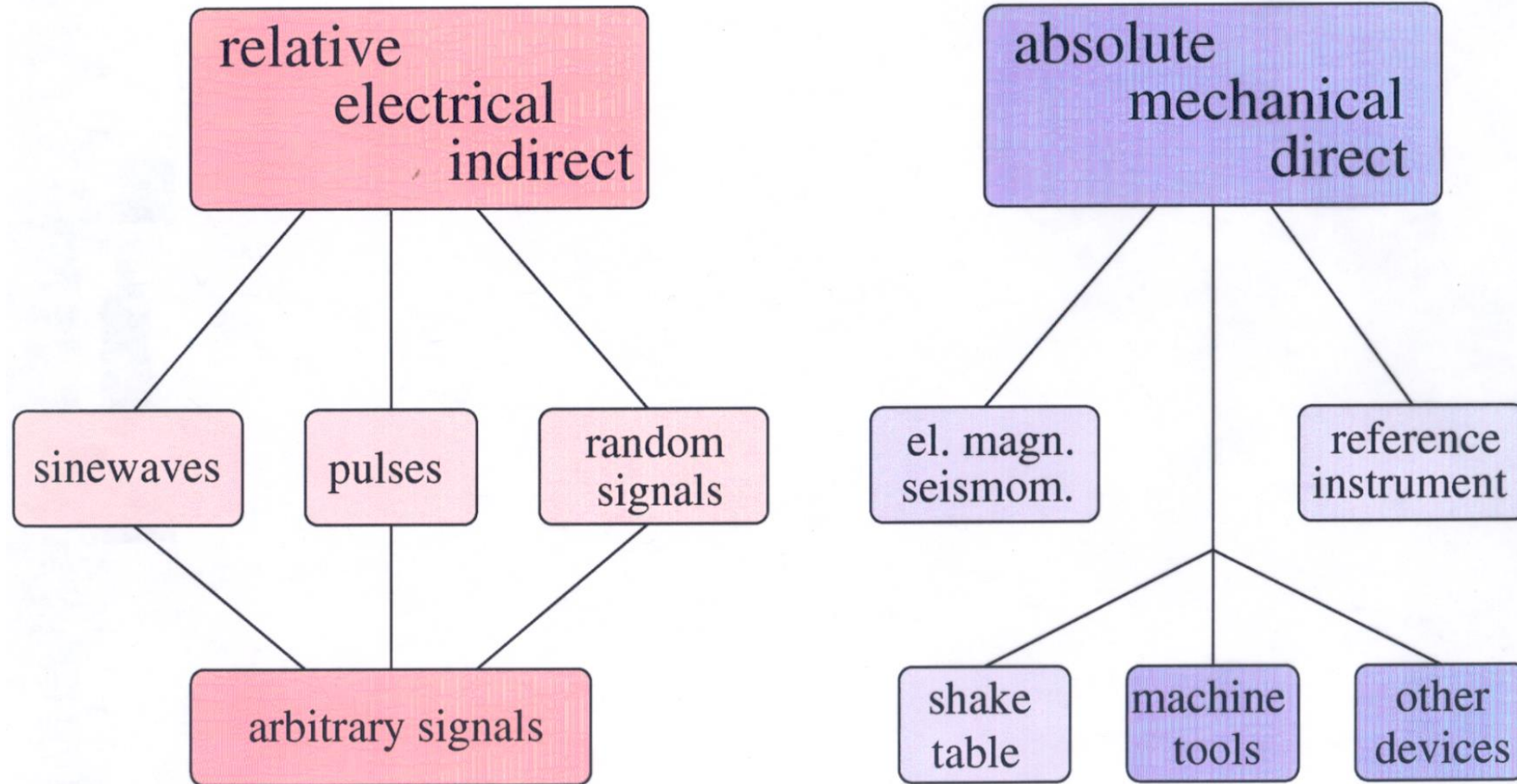
Serial Number 6055

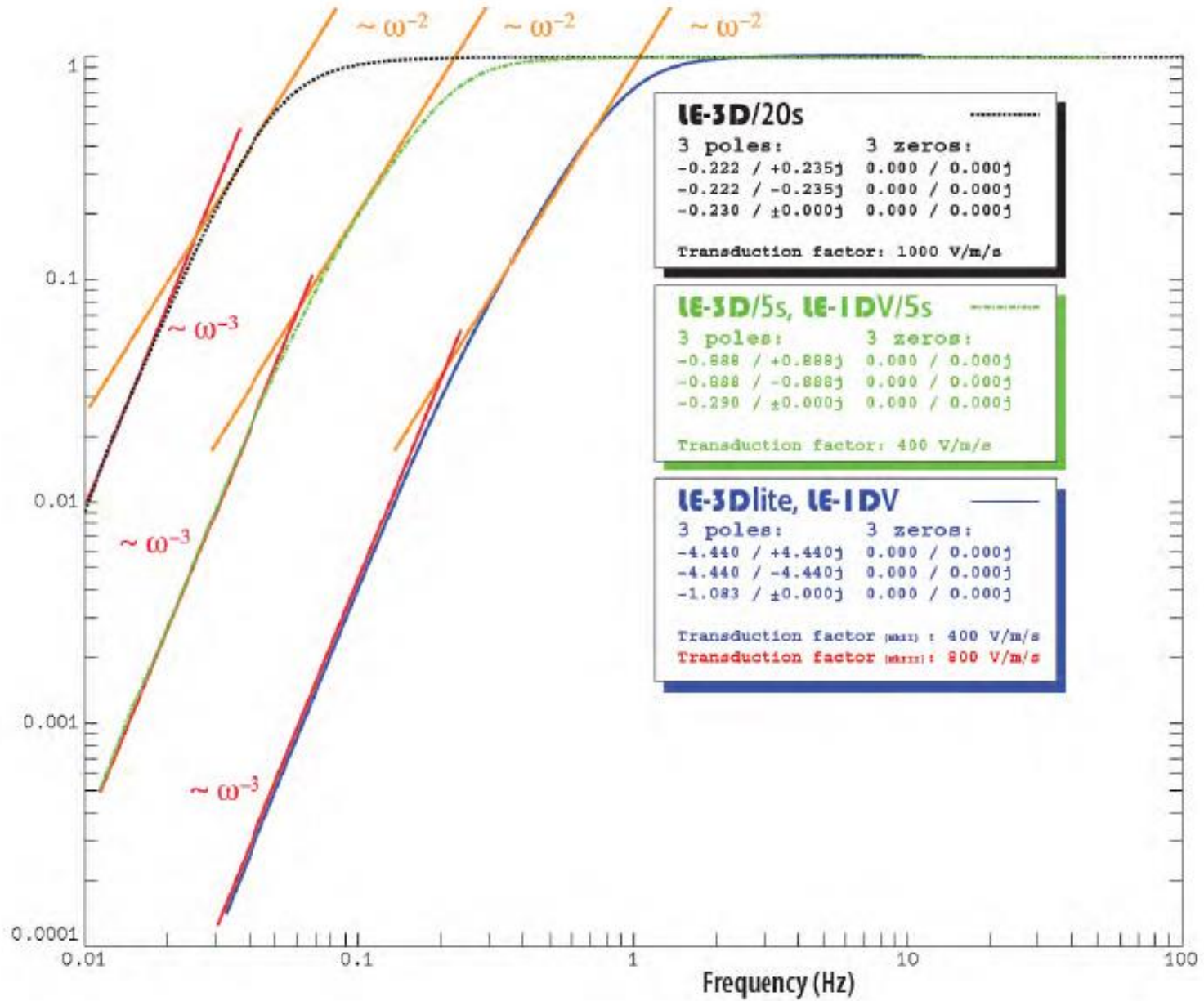
Date: 05/10/2001

Parameter	Value	Units
Span at 1/4g	10.0014	Volts/g
Span at 1/2g	5.0035	Volts/g
Span at 1g	2.5003	Volts/g
Span at 2g	1.2512	Volts/g
Span at 4g	0.6261	Volts/g
Bandwidth (-3dB) @ 1g	212	Hz
Gain Variation at 100Hz @ 1g	-0.14	dB
Phase at 100Hz @ 1g	-56.6	Degrees
Non-Linearity @ 1g	261	ug/g^2
Mechanical Alignment Error	0.1011	Degrees
Cal-Coil Sensitivity	0.0554	g/Volt
Poles and Zeros	See Manual	rad/sec



Systematics of Seismometer calibration

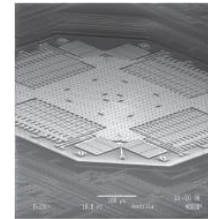
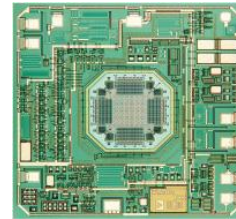
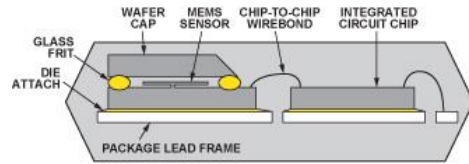
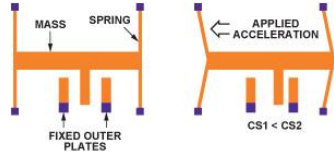
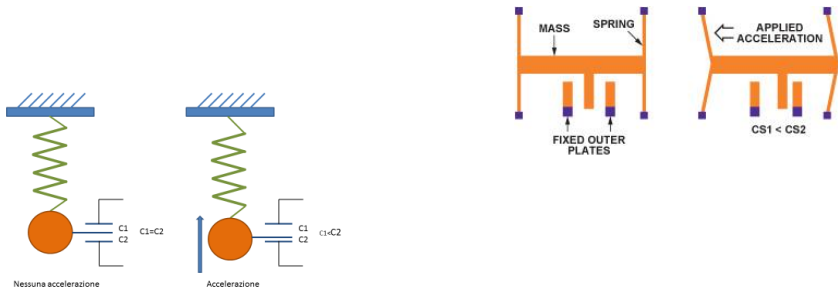






	LE-1DV	LE-3Dlite	LE-1DV/5s	LE-3D/5s	LE-3D/20s
Sensitivity	400 V/m/s (800 V/m/s for MkIII models when used with a differential input)				1000 V/m/s
Natural frequency	1 Hz		0.2 Hz		0.05 Hz
Upper corner frequency	~100 Hz		~50 Hz		
Full scale output voltage	± 7 V (suitable for differential operation) differential for MkIII models when used with a differential input (resulting in max 28Vpp)				± 6.5 V (suitable for differential operation)
Damping	0.707 critical				
Dimensions	85 mm diameter, 55 mm height	97 mm diameter, 68 mm height	97 mm diameter, 140 mm height	195 mm diameter, 165 mm height	
Weight (not including transport box)	0.9 kg	1.8 kg	2.5 kg	6 kg	
Temperature range	-15 ... +65 °C				
Supply current @ 12 V DC <small>(quiescent current with only background seismic noise present; at full scale, supply current may be up to 2 times that value)</small>	3 mA 2.2 mA for MkIII	8 mA 6 mA for MkIII	3 mA	8 mA	50 mA
Warm-up time	30 seconds				2 minutes

Accelerometri MEMS





MODELLO STAZIONE	ACCELEROMETRO 3D PER BREVI E LUNGI PERIODI
PRODUTTORE	MOHO SCIENCE AND TECHNOLOGY
SENSORE	3 ACCELEROMETRI ED UN CANALE ANALOGICO DI SUPPLEMENTO PER LA TEMPERATURA
SISTEMA DI RACCOLTA DATI	MEMORIA INTERNA MIN 50 GIORNI
RANGE DINAMICO	
OFFSET	
TASSO DI CAMPIONAMENTO	16 KHZ SU TUTTI I CANALI / 128,256,512 IN OUTPUT
FREQUENZA DI BANDA	
POLI E ZERI	
SENSITIVITA'	
TIPO CONNESSIONE	ETHERNET CAT 5, WIRELESS OPZIONALE
NUMERO CANALI	4
RISOLUZIONE	ACCELEROMETRI +-0.15mG (+-2G) / 0.45mG (+-6G)

