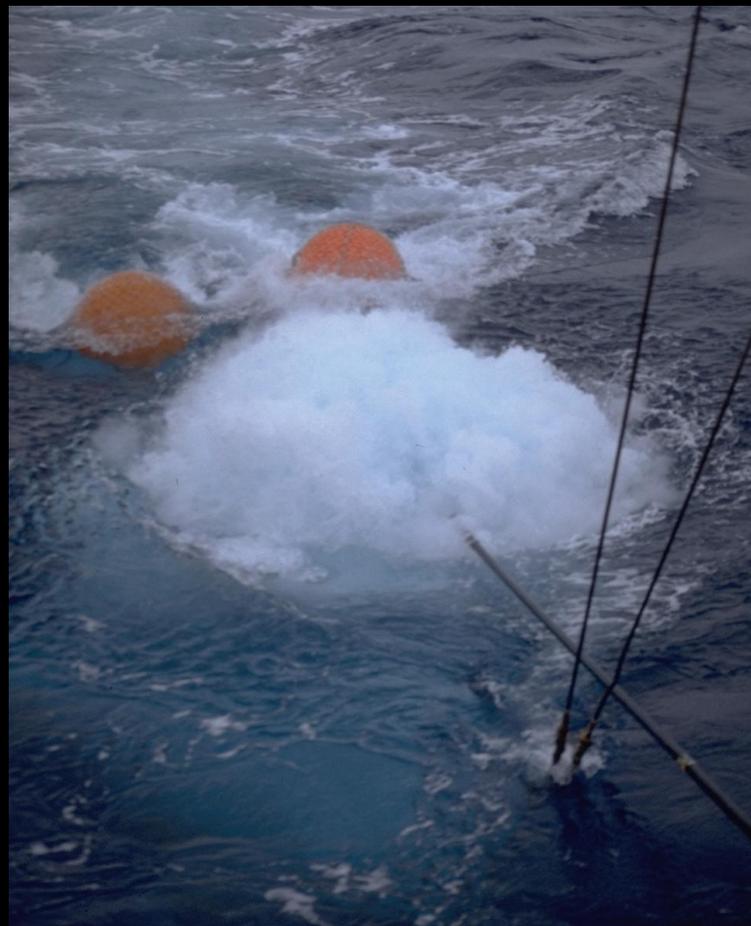


Aquisição sísmica

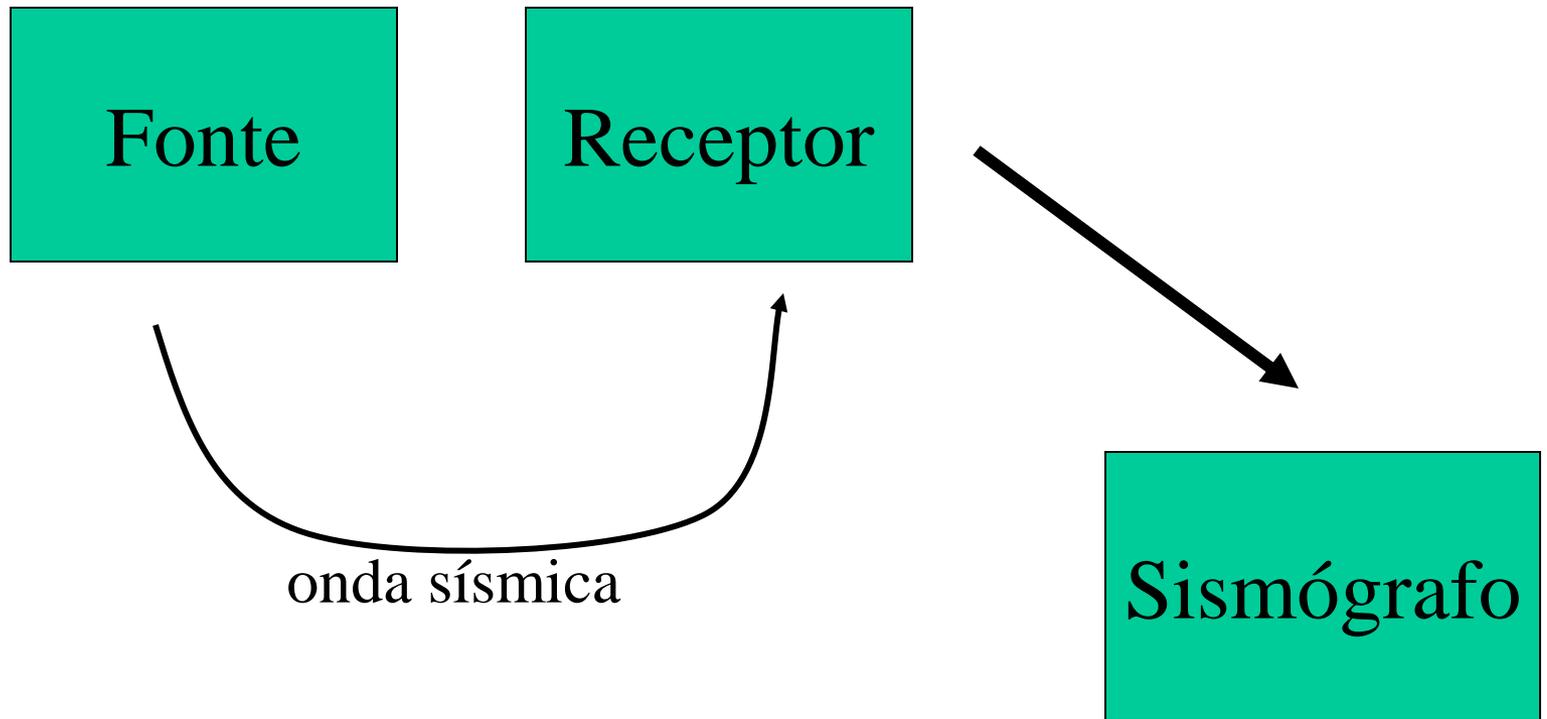


terrestre



marinha

Sistema de aquisição



Fontes sísmicas

As fontes sísmicas podem variar bastante em tamanho e complexidade, mas todas devem ter, idealmente, as seguintes características:

=> “repetibilidade - repeatability”, ou seja, a natureza da energia liberada (quantidade e duração) não pode mudar se a fonte for usada em diferentes locais ou entre sucessivos “disparos”.

=> o instante de liberação e/ou tempo de duração deve ser controlado

Fontes sísmicas

=> energia suficiente para gerar sinal mensurável
com boa razão sinal-ruído - S/R *

=> idealmente, gerar pulso de curta duração, suficiente para
garantir boa resolução (fontes impulsivas) *

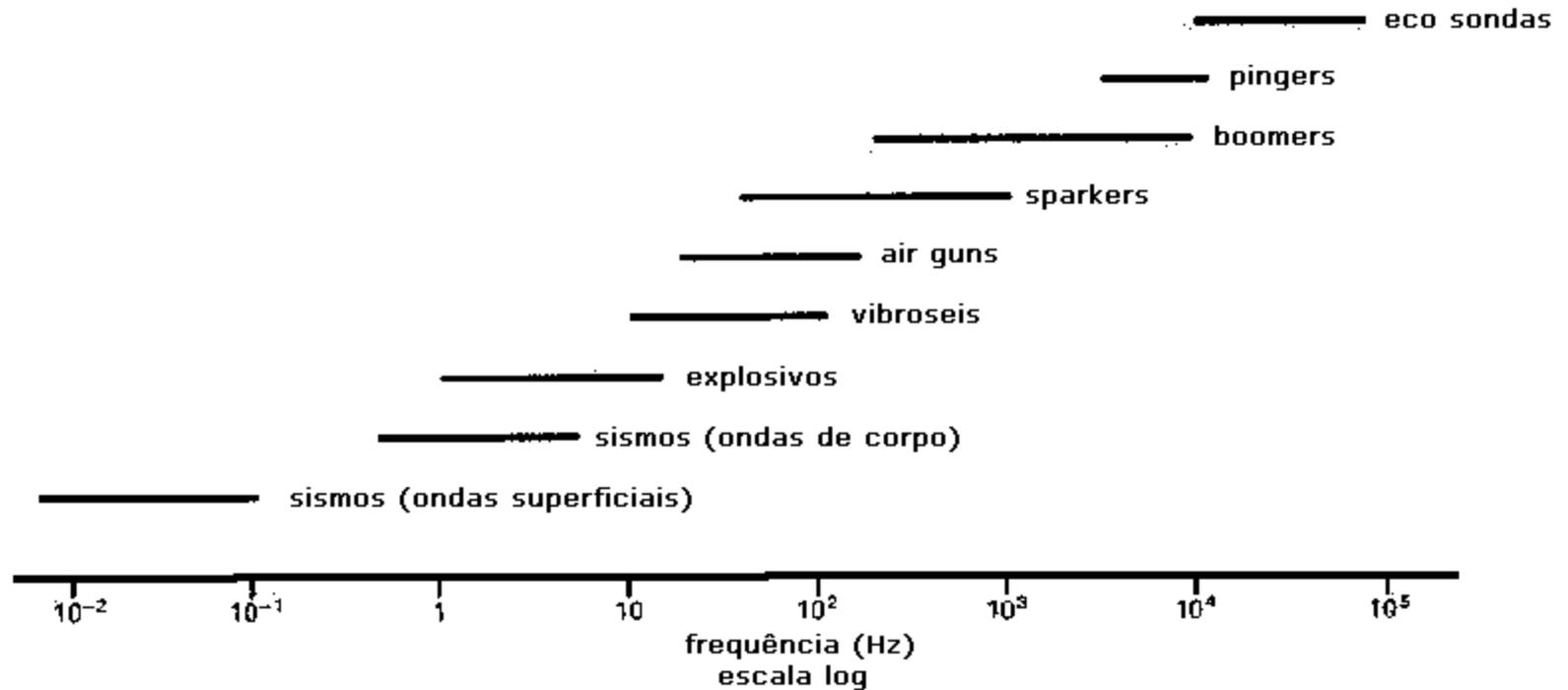
* dependente das condições do meio

Fontes sísmicas

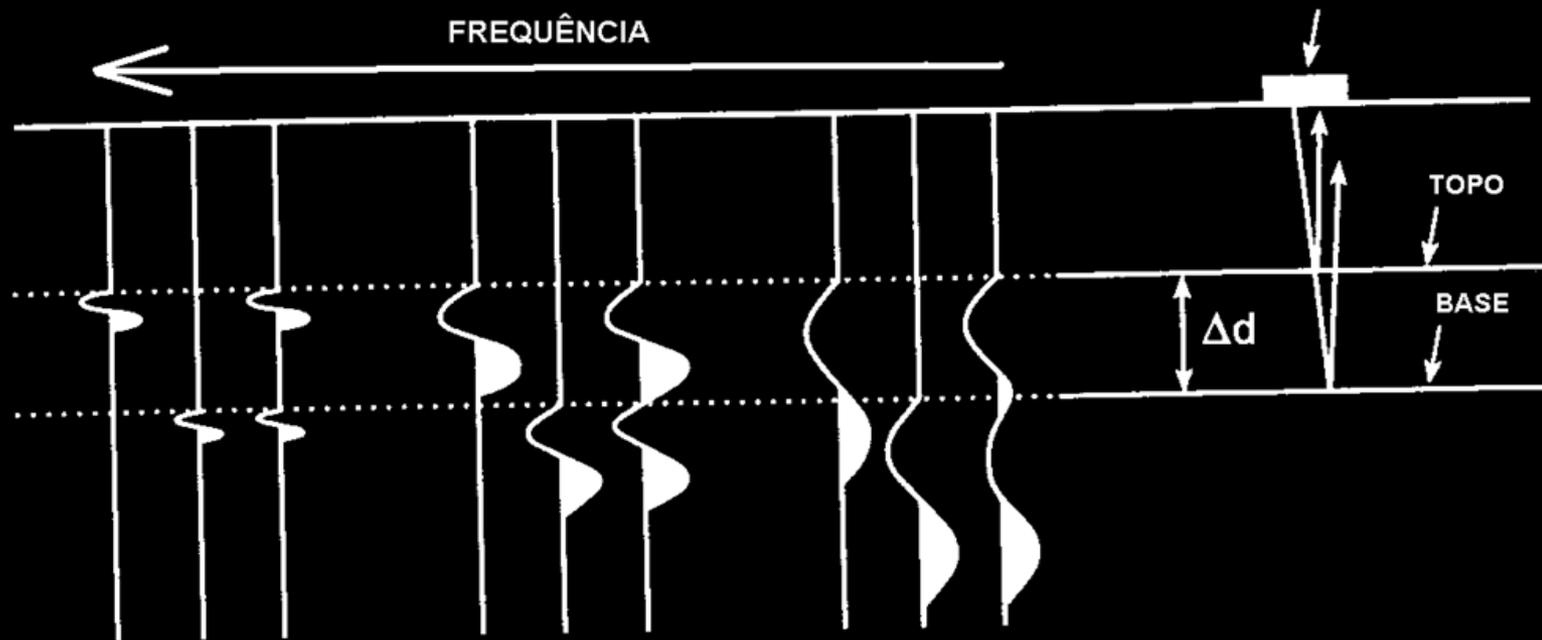
Propriedades importantes:

- energia liberada
- forma da onda (frequência)
- repetibilidade
- custo e praticidade

Espectro sísmico



FREQUÊNCIA DO SINAL x RESOLUÇÃO



Fontes sísmicas

fonte impulsiva x fonte não impulsiva

FONTE DE ALTA POTÊNCIA

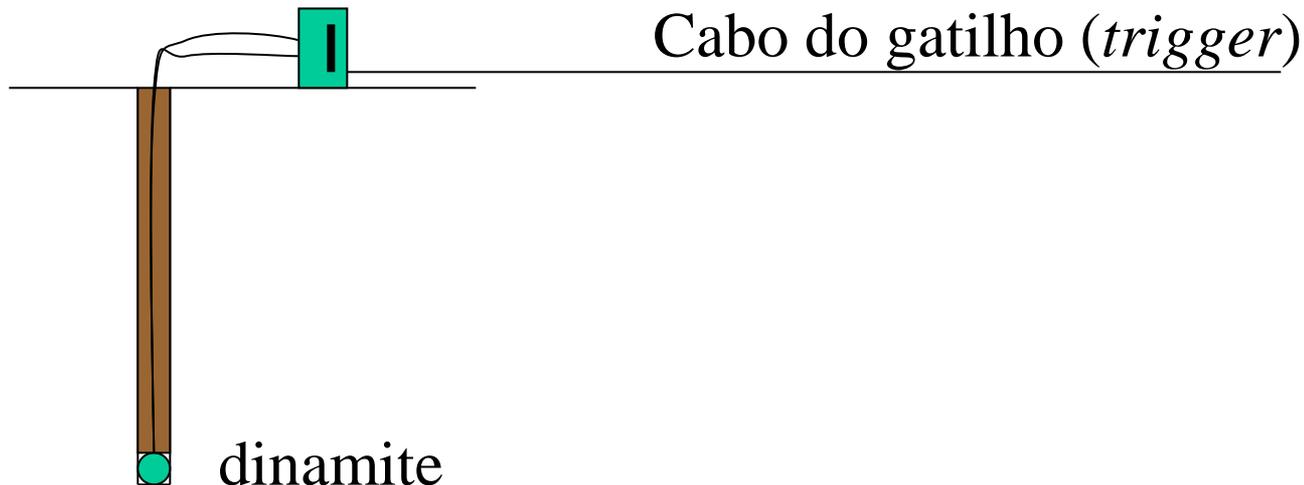


FONTE DE BAIXA POTÊNCIA



Dynamite (fonte impulsiva - explosiva):

- => “repetibilidade” baixa
- => tempo zero de detonação é difícil de se obter
- => baixa energia (espoleta elétrica) a alta energia (grandes cargas)
- => para cada aplicação deve ser programado o volume de explosivo



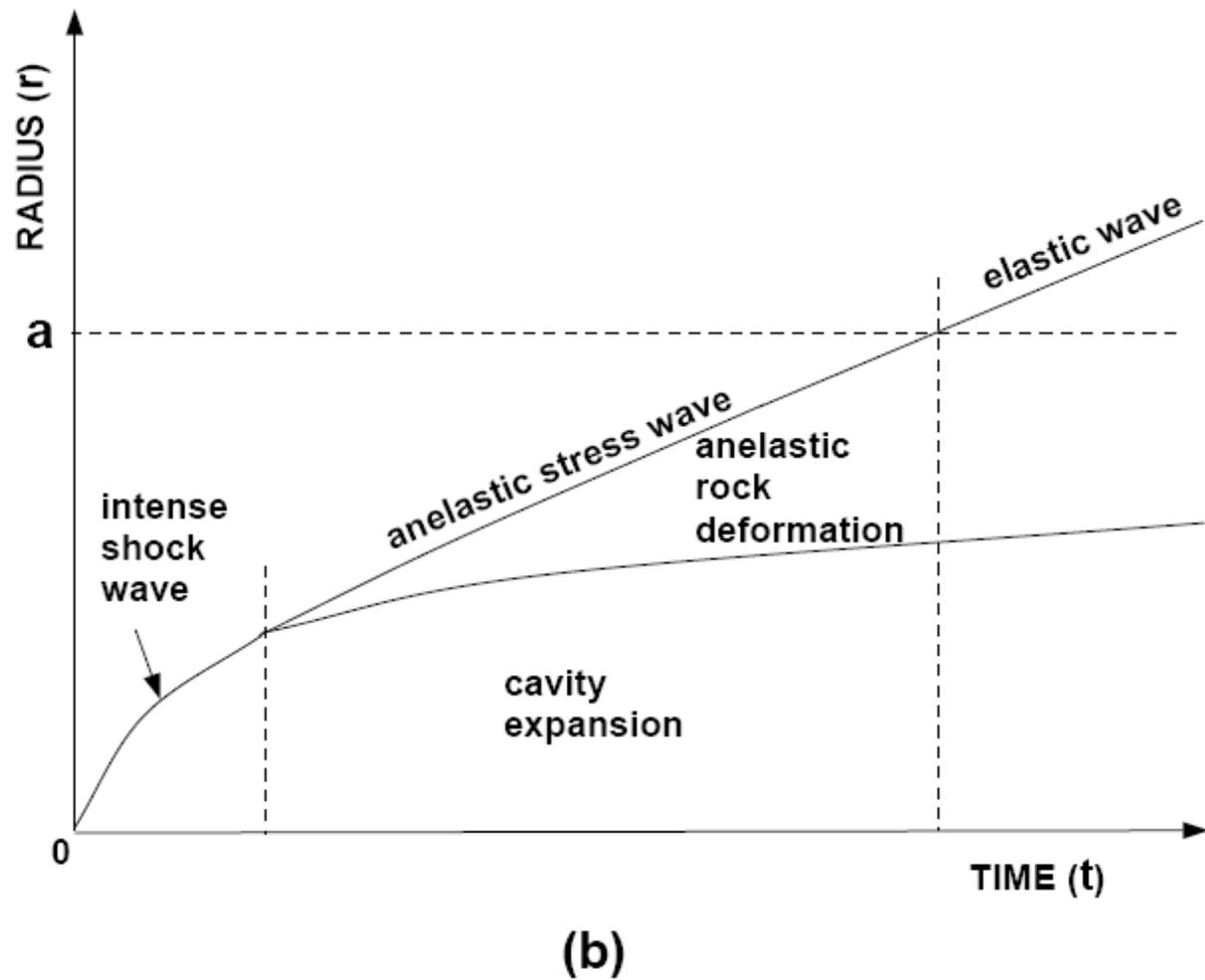


Figure 2.8: The behaviour of dynamite: (a) the characteristic zones in space, and (b) the radius as a function of time with its characteristic zones.

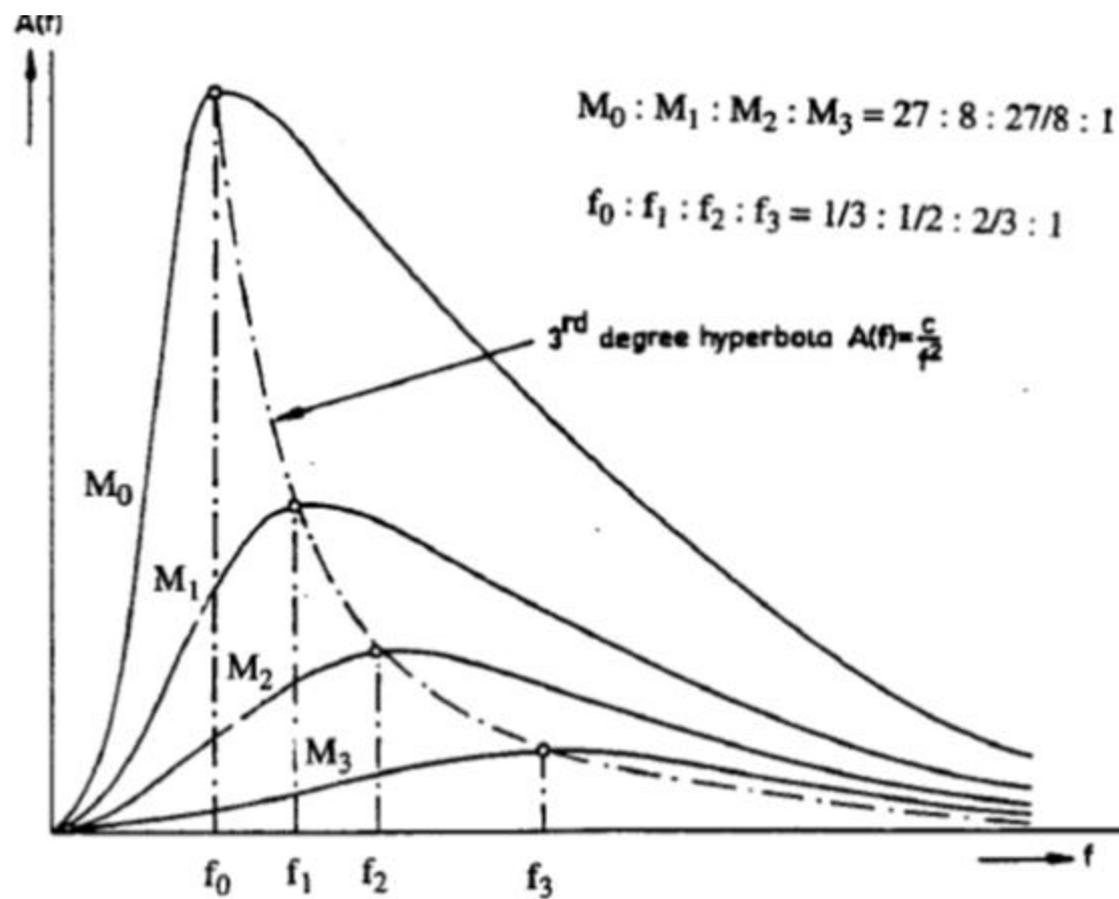
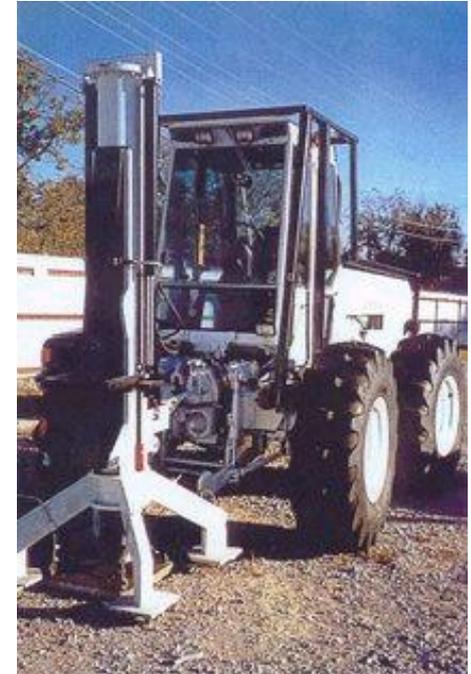


Figure 2.10: Scaling of amplitudes as function of frequency

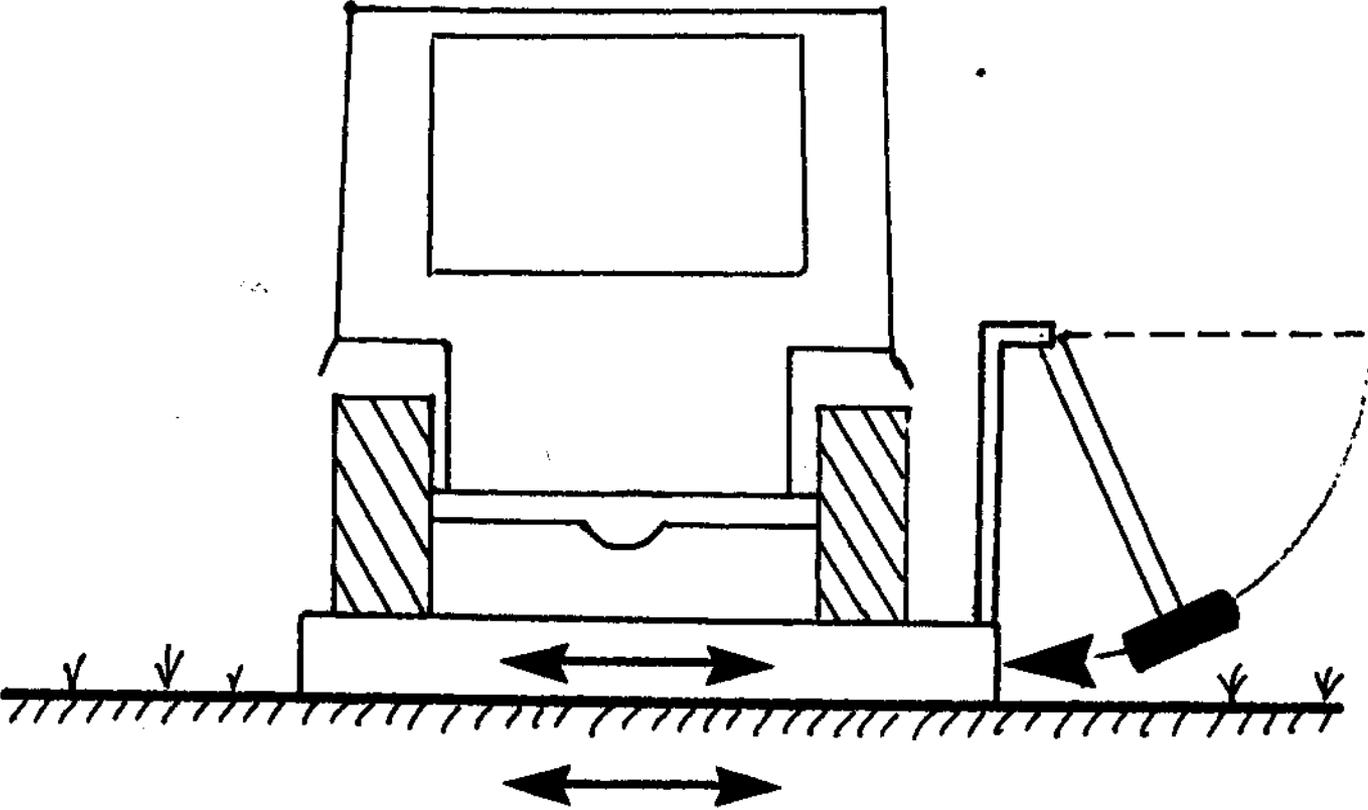


<https://www.youtube.com/watch?v=fdQNJpaM3wk>

Martelo (fonte impulsiva - de impacto) => onda P



Martelo (fonte impulsiva) gerando preferencialmente ondas S







MÉTODO MINI-SOSIE



O método Mini-sosie foi desenvolvido por Barbier *et al.* (1976) e se utiliza de um sinal sísmico de baixa potência e longa duração.

Um sismograma de reflexão, $r_s(t)$, pode ser representado como o pulso aplicado, $s(t)$, convolvido com a função refletividade (resposta ao impulso da terra), $e(t)$, mais o ruído presente, $n(t)$.

$$r_s(t) = s(t) * e(t) + n(t)$$

$s(t)$ é gerado várias vezes ao longo de um período de tempo determinado de acordo com uma seqüência $y(t)$. A forma completa do sinal sísmico gerado, $\psi(t)$, pode, portanto, ser escrita como:

$$\psi(t) = y(t) * s(t)$$

O sismograma assim registrado, $r_c(t)$, chamado de sismograma codificado, pode ser expresso como a convolução deste sinal de longa duração com a resposta impulsiva da terra.

$$r_c(t) = y(t) * s(t) * e(t) + n(t)$$

O sismograma final decodificado $r_D(t)$ resulta da correlação cruzada (\otimes) do sismograma codificado $r_c(t)$ com a sequência de impactos $y(t)$, denominada traço piloto.

$$r_D(t) = y(t) \otimes r_c(t) = y(t) \otimes \{y(t) * s(t) * e(t) + n(t)\}$$

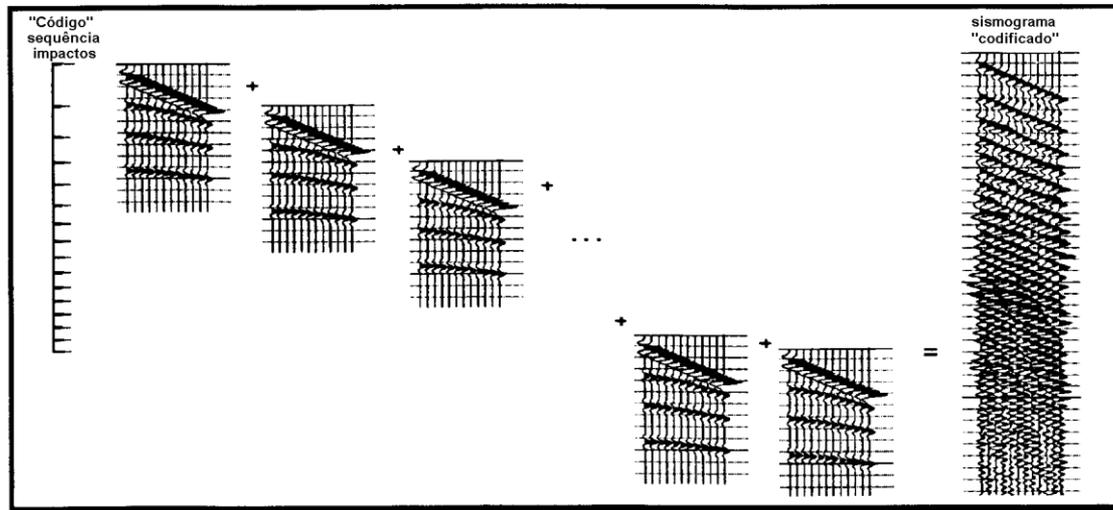
O procedimento acima pode ser reescrito como:

$$r_D(t) = ACF\{y(t)\} * s(t) * e(t) + y(t) * n(t)$$

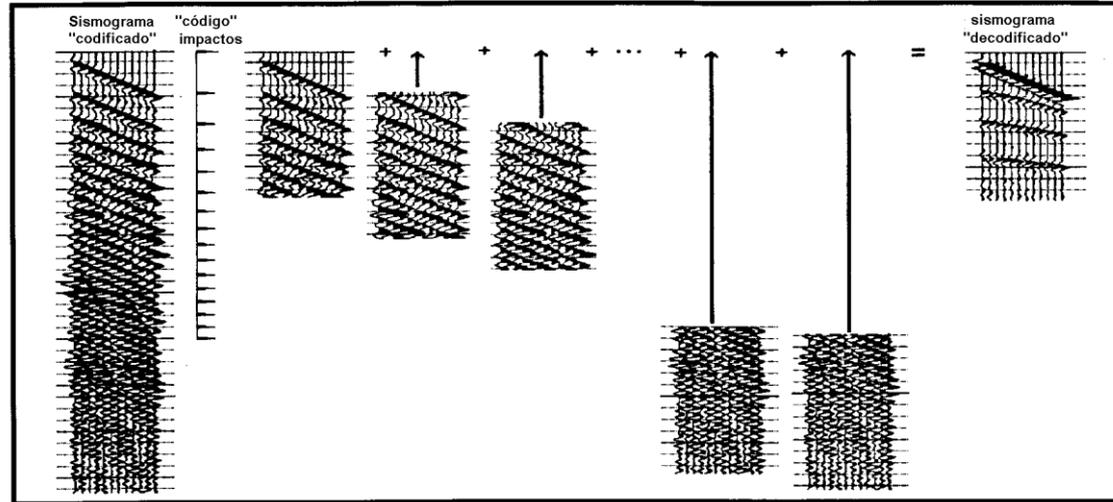
No domínio da frequência, a equação acima pode ser reescrita como:

$$|P_D(j\omega)| = |Y(j\omega)|^2 \times |S(j\omega)| \times |E(j\omega)| + |Y(j\omega)| \times |N(j\omega)|$$

CODIFICAÇÃO



DECODIFICAÇÃO



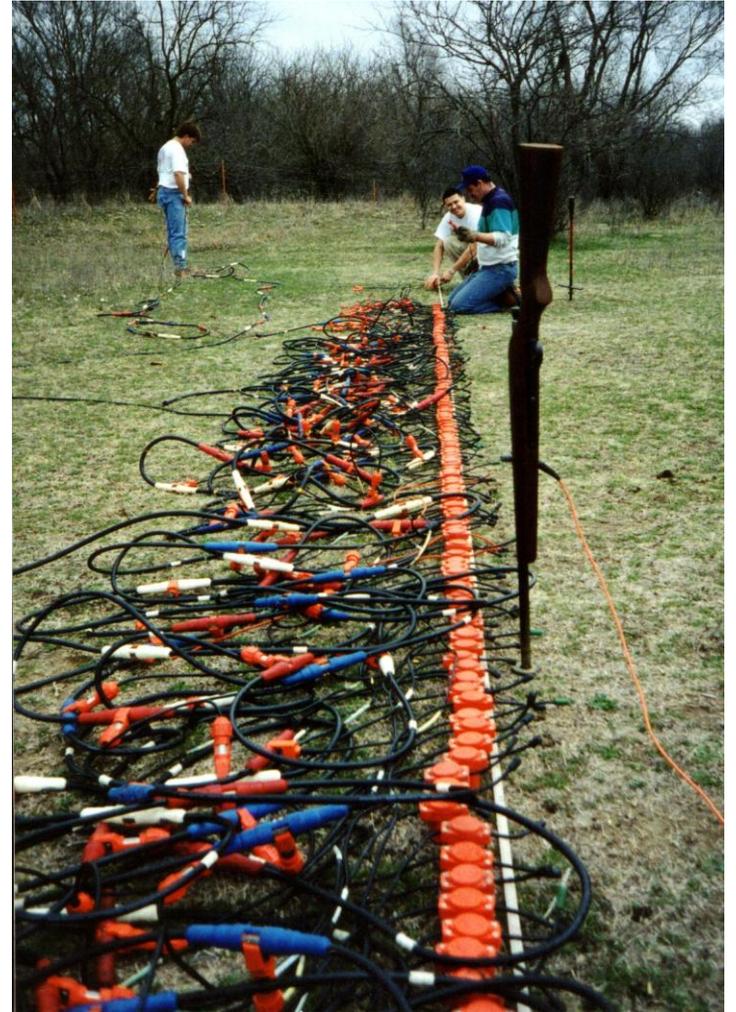
SIST – Swept impact seismic technique (Park, Miller, Steeples, 1996)

Mini-Sosie => ondas S

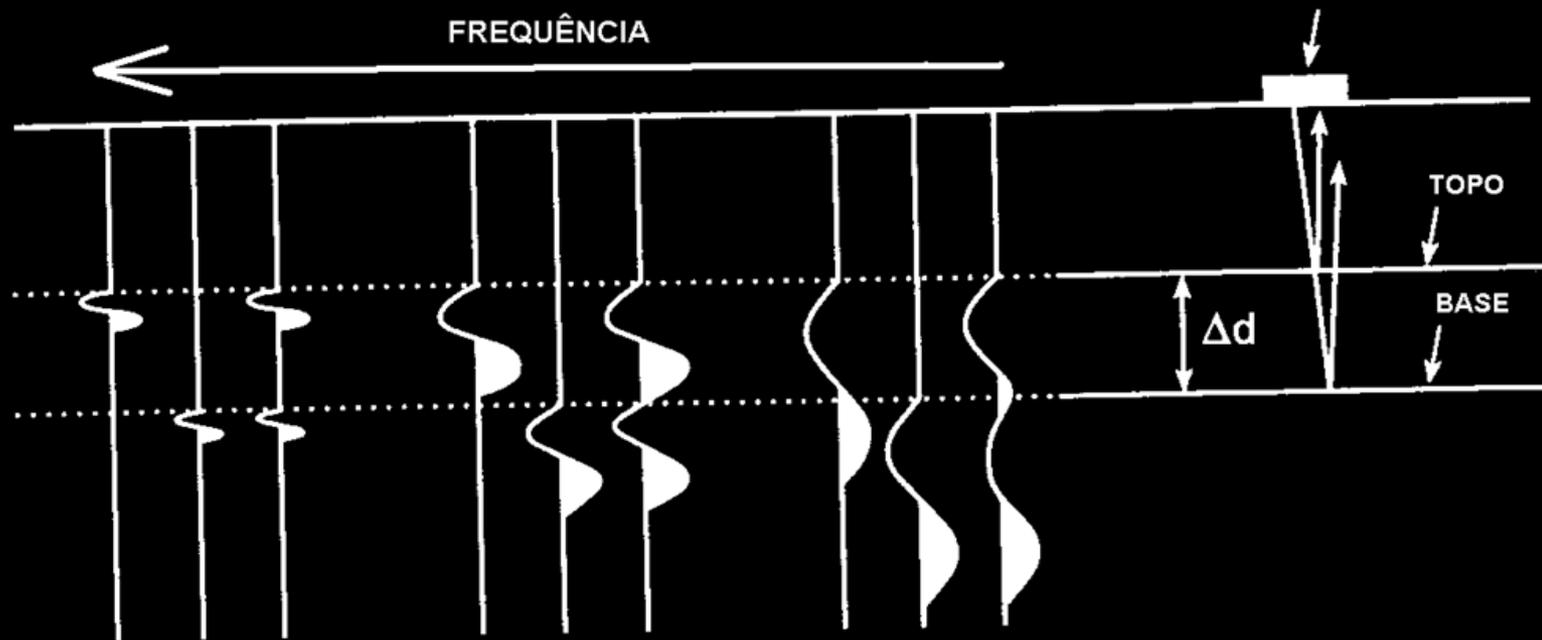


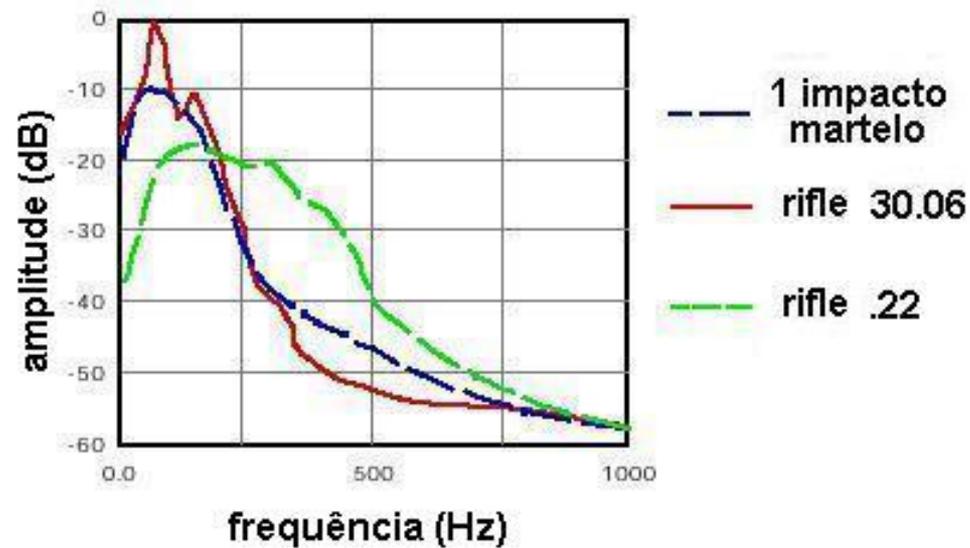
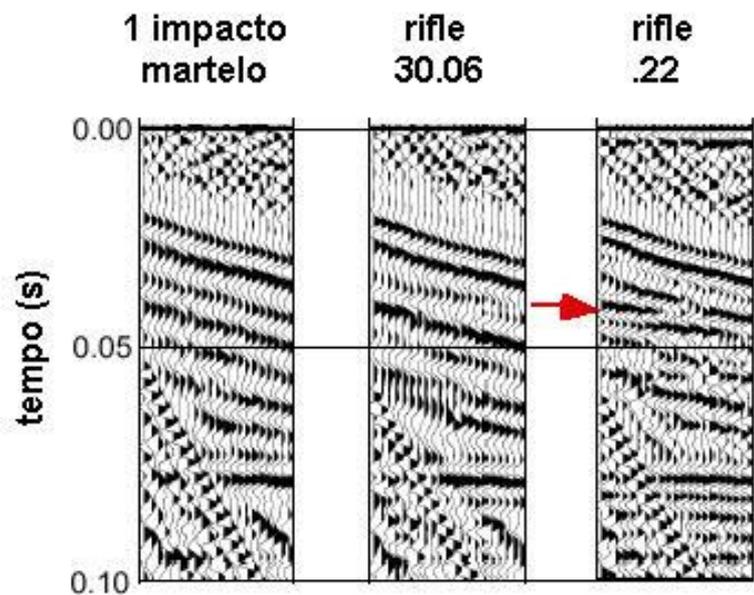
Rifle sísmico (fonte impulsiva explosiva) => onda P





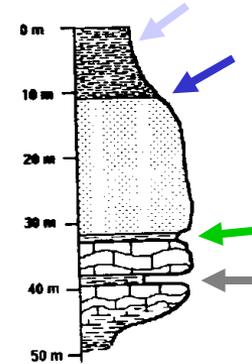
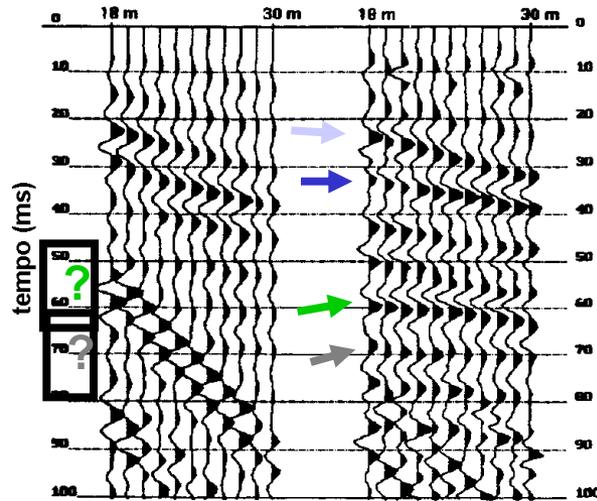
FREQUÊNCIA DO SINAL x RESOLUÇÃO



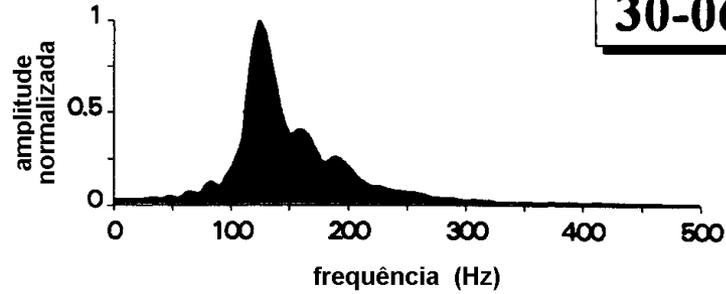


30-06

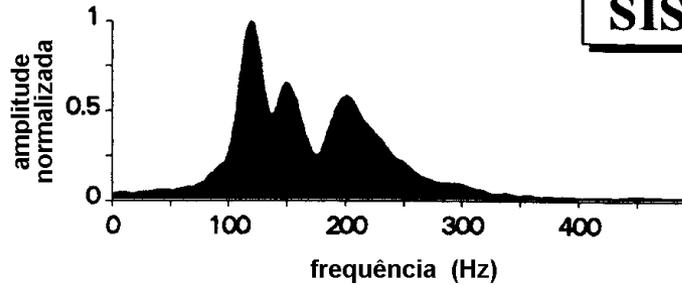
SIST



30-06



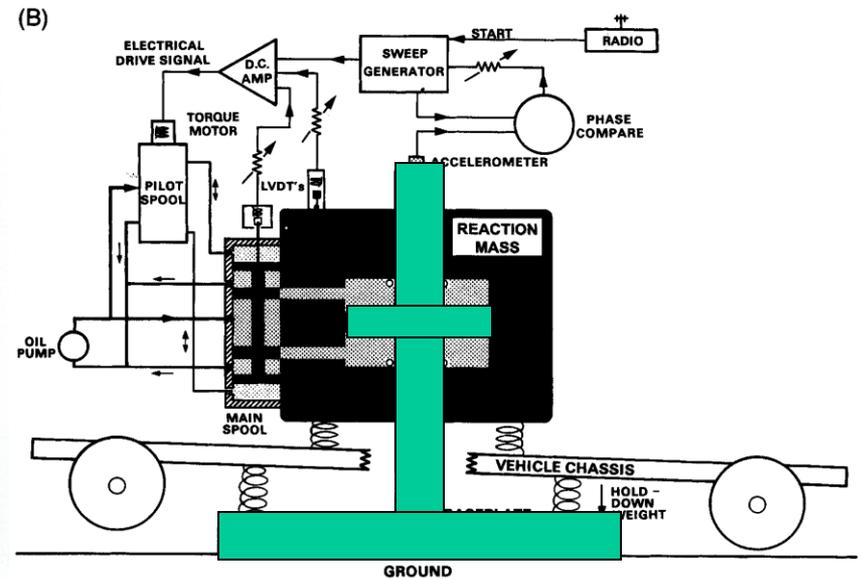
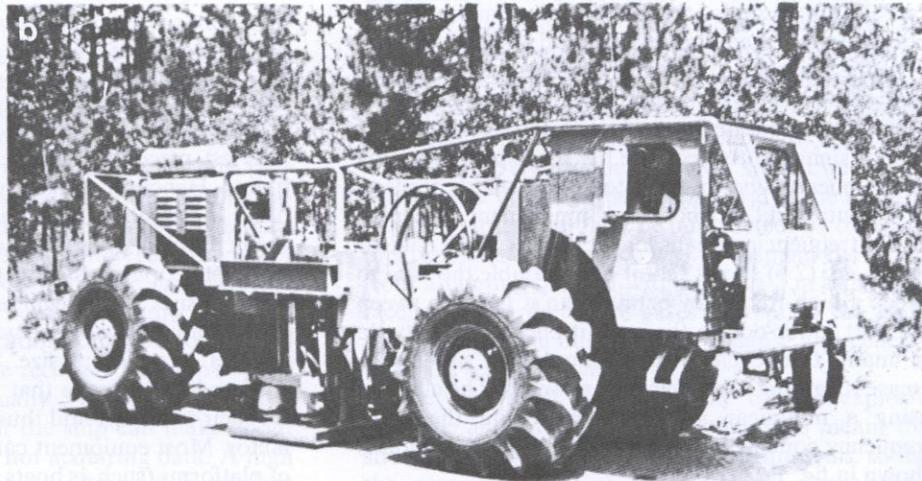
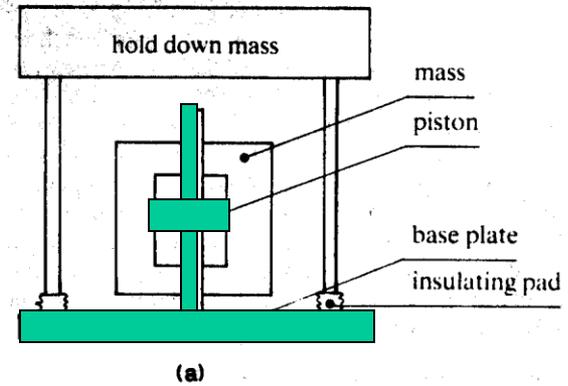
SIST

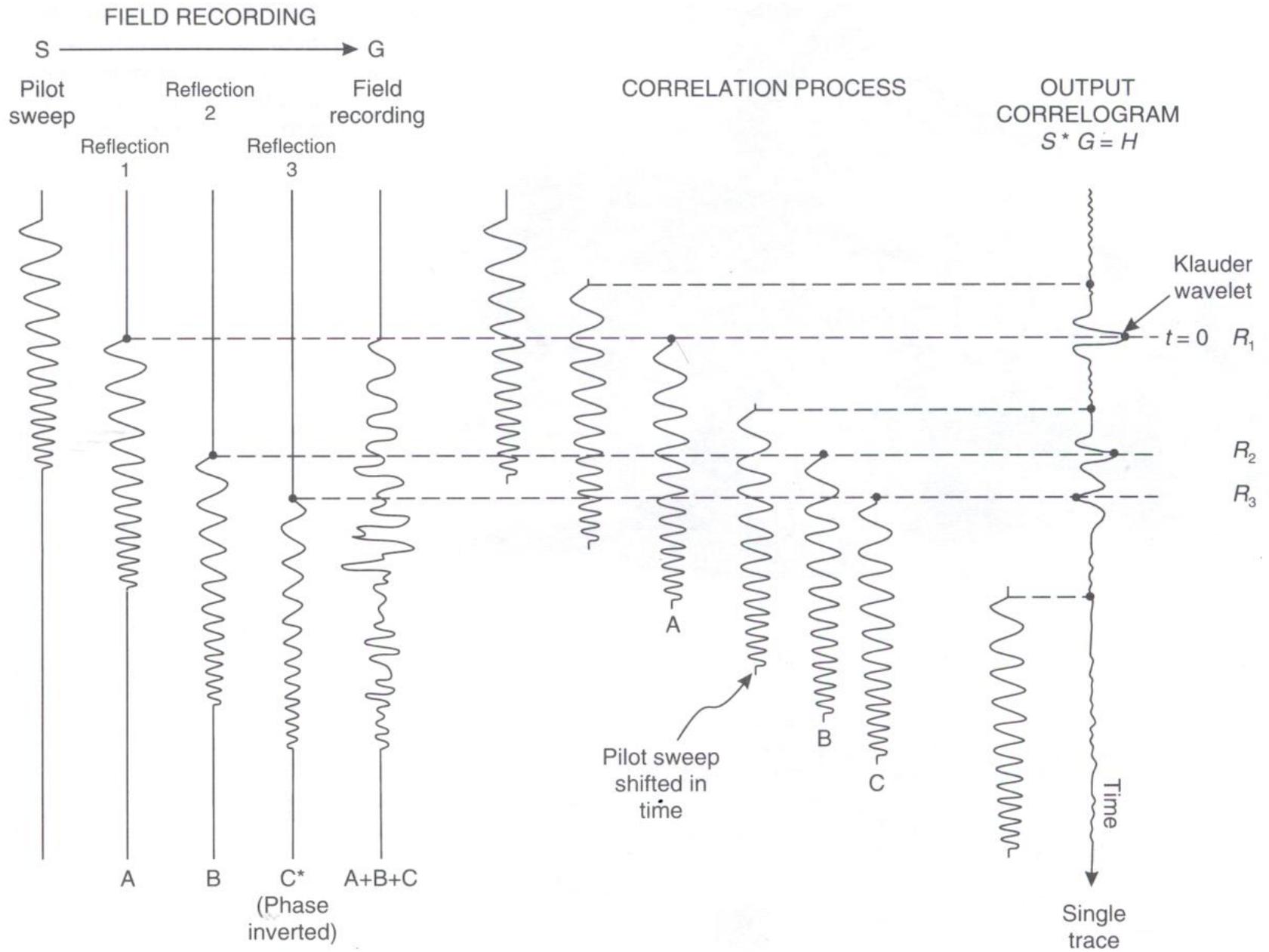


FONTE NÃO IMPULSIVA

VIBROSEIS

Vibroseis (fonte não impulsiva)





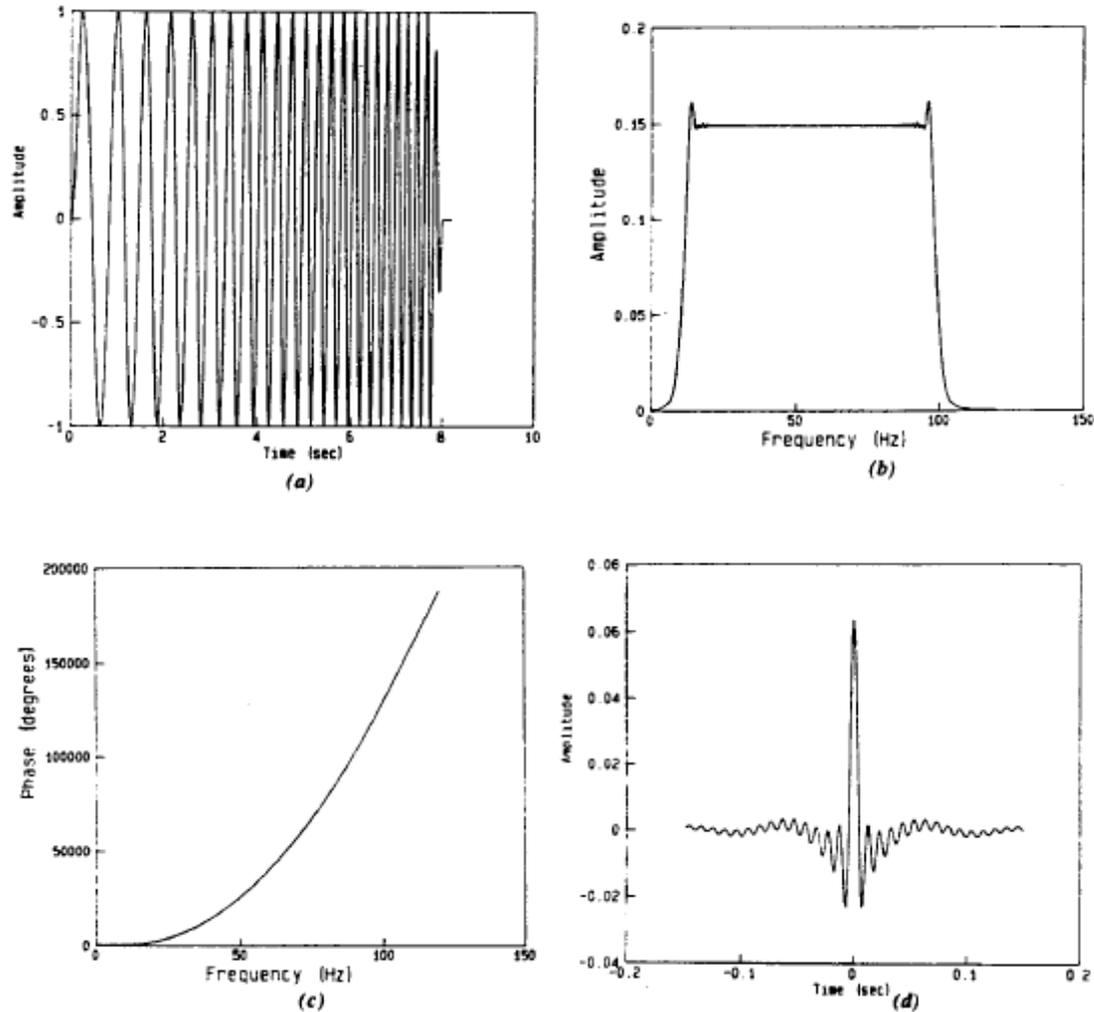


Figure 2.19: An 8 sec, 10-100 Hz up-sweep with taper length of 250 msec. (a) Sweep in time domain; frequency range for this Figure is 1-5 Hz for display purposes, (b) amplitude spectrum of sweep, (c) phase spectrum of the sweep, in degrees, and (d) autocorrelation of sweep.



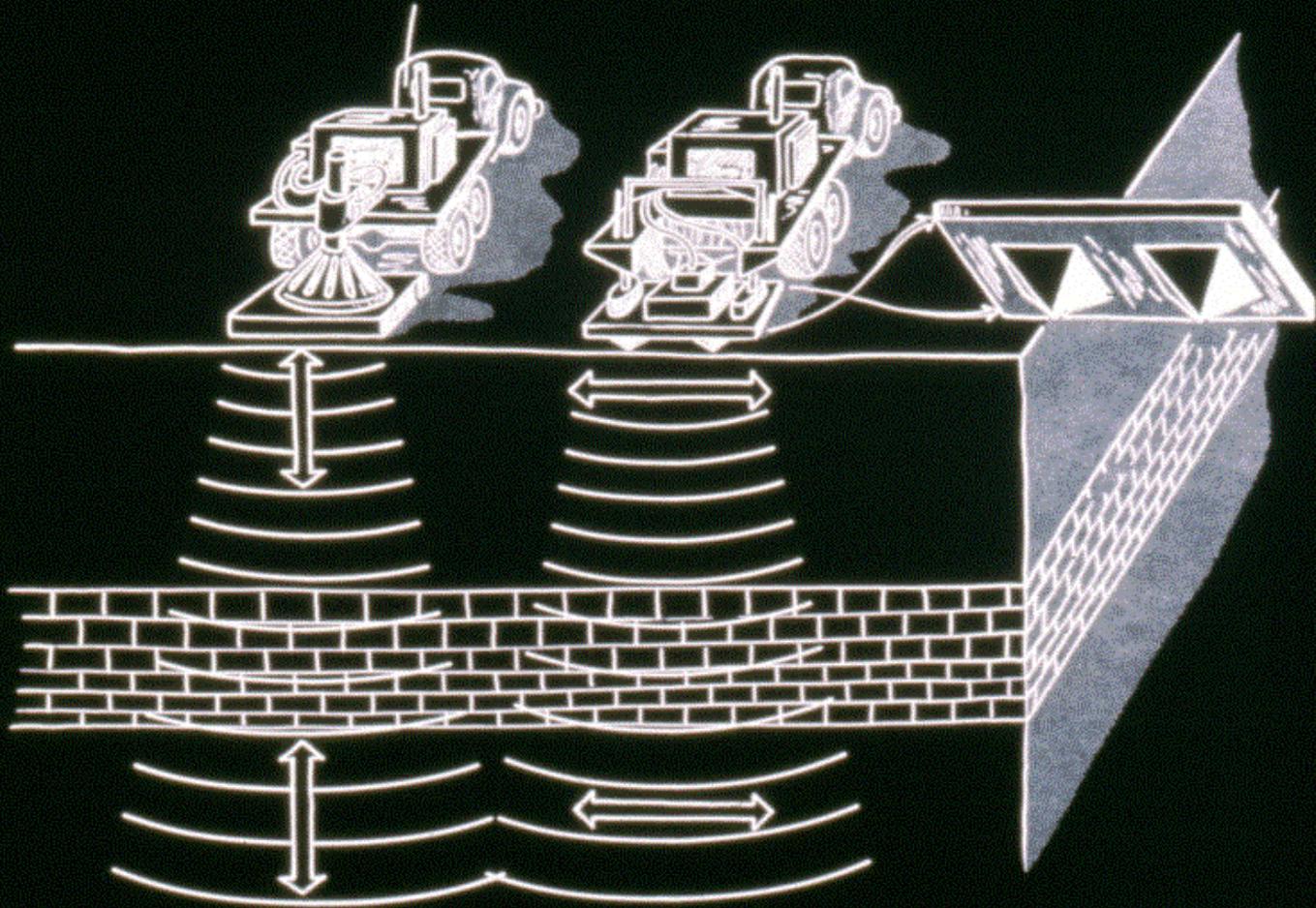
<https://www.youtube.com/watch?v=tQxC8ahSdkg>



“mini vibroseis” (protótipos)

P-Wave

Shear Wave





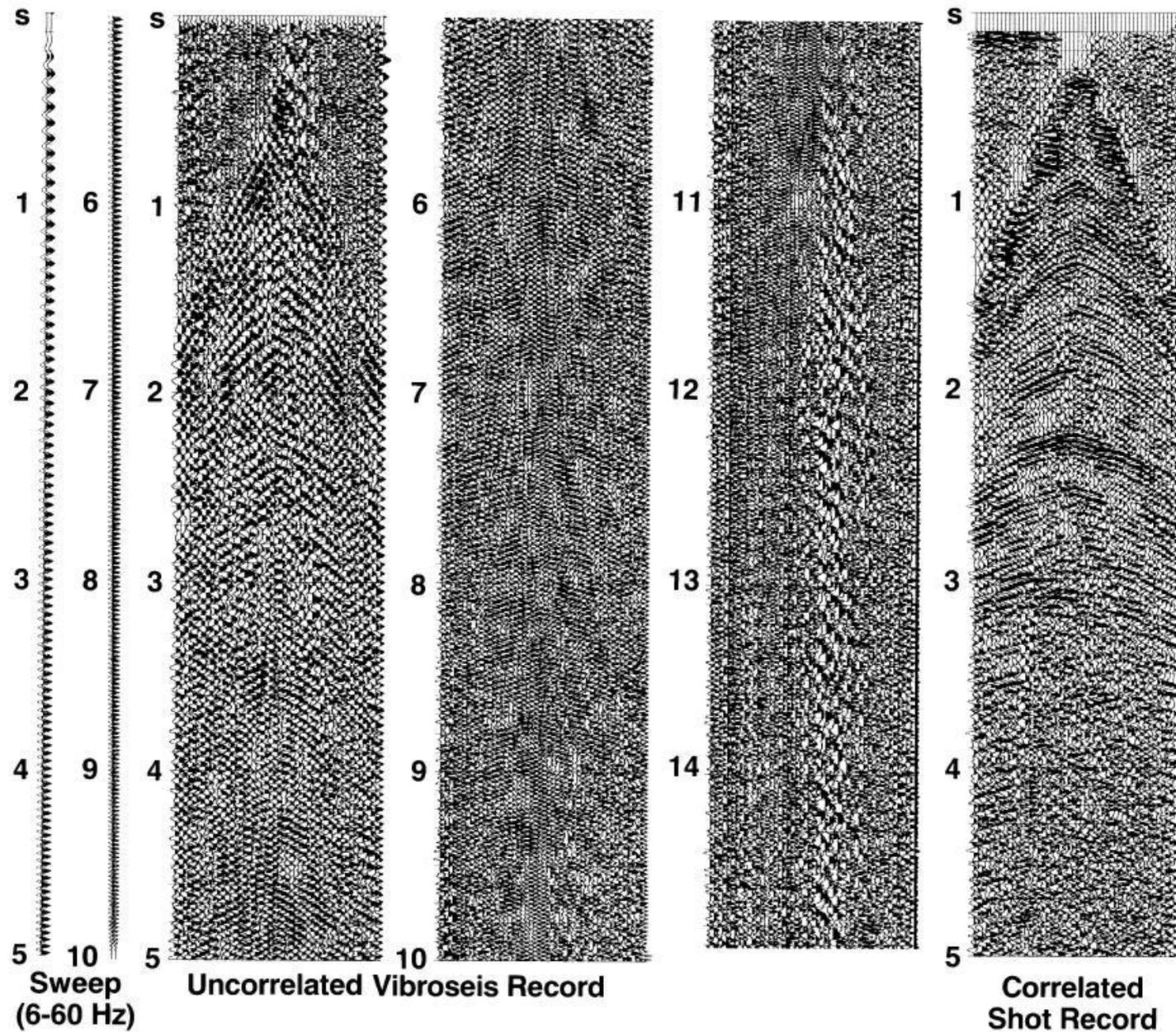


FIG. 1.1-20. Vibroseis correlation: the sweep signal is correlated with the recorded vibroseis record to get correlated field data. A 10-s sweep and 15-s recorded data yield a 5-s correlated record.

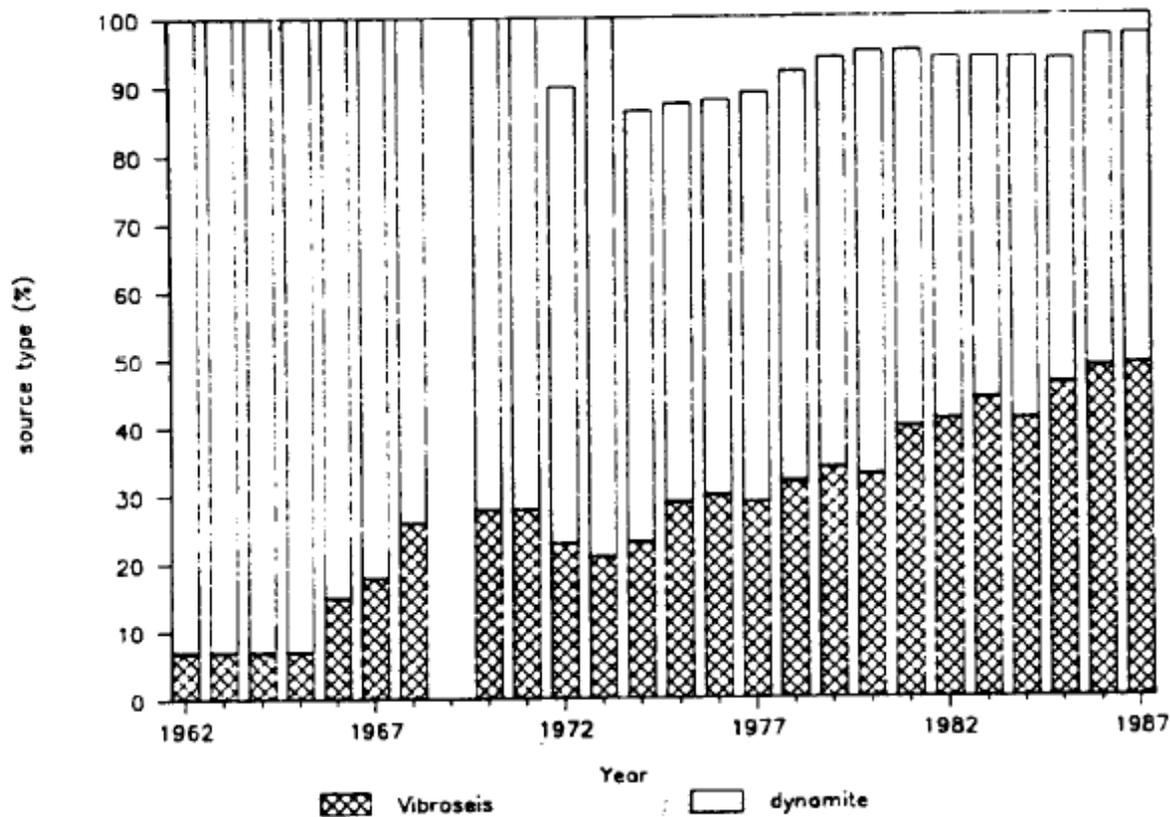


Figure 2.21: The contribution of Vibroseis and dynamite to the total number of crew months spent in land petroleum exploration, in %, for the years 1962-1987.

Table 2.1: *Advantages and disadvantages of Vibroseis and dynamite.*

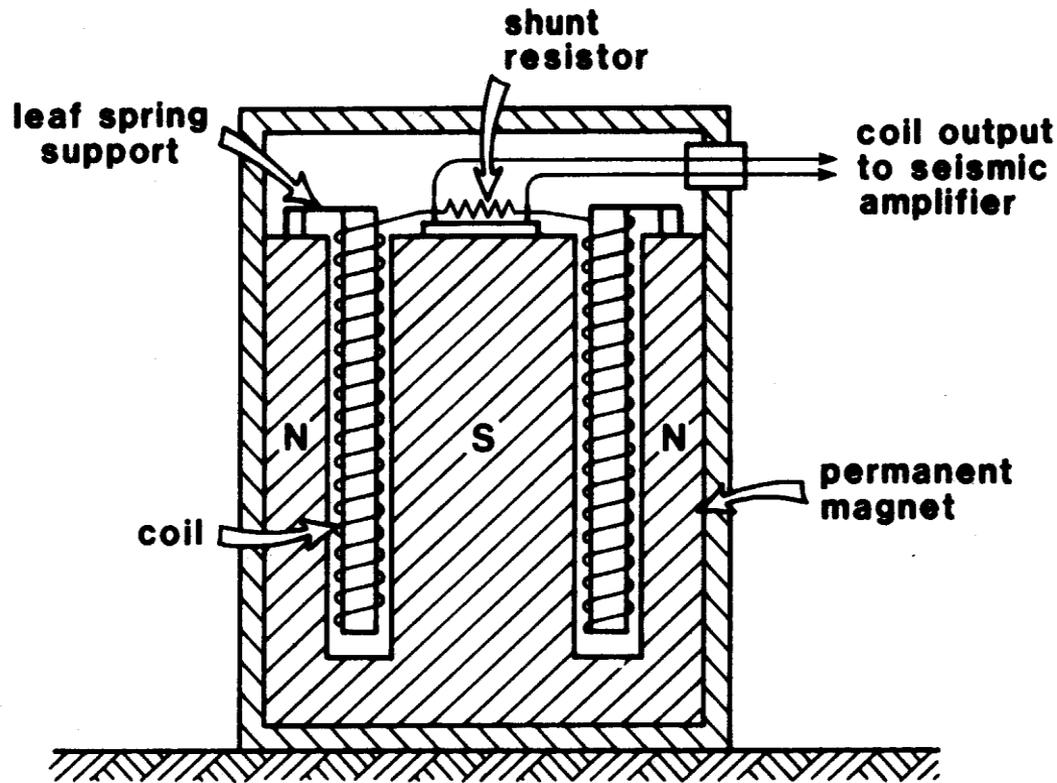
Source type	Advantages	Disadvantages
Vibroseis	<ul style="list-style-type: none"> 1. Much less destructive than dynamite : can operate in urban areas 2. Not labour-intensive: cheap in operation 3. Some control over outgoing signal 	<ul style="list-style-type: none"> 1. Surface noise: many Rayleigh waves 2. Correlation not perfect: correlation noise 3. Can only operate in areas that can support 14 tons 4. One truck does not deliver enough energy: arrays, so directivity
Dynamite	<ul style="list-style-type: none"> 1. Buried source: much less surface waves generated than with Vibroseis 2. Signal close to δ-pulse 	<ul style="list-style-type: none"> 1. Destructive: cannot operate in urban areas 2. Labour intensive for making shot-holes: expensive in operation

- a) explosivos**
- b) queda de peso**
- c) martelo**
- d) rifles**
- e) vibradores**

aspectos (+) => ordenar em ordem decrescente

- 1) >segurança
- 2) energia (> prof.)
- 3) frequência (> res.)
- 4) <custo
- 5) operacionalidade
- 6) legislação (> rigor)

GEOFONES



Geofones

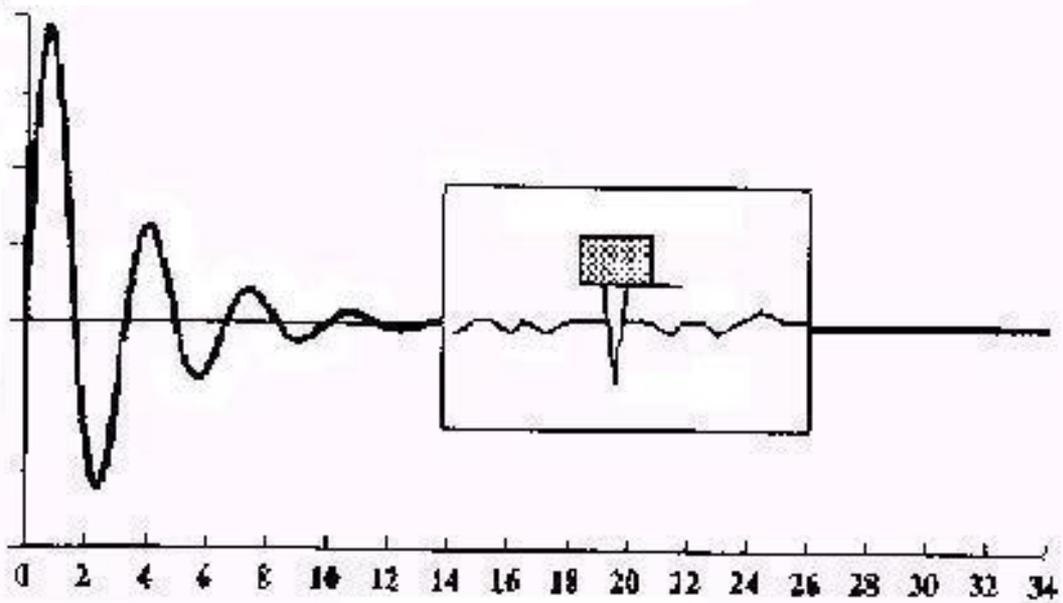
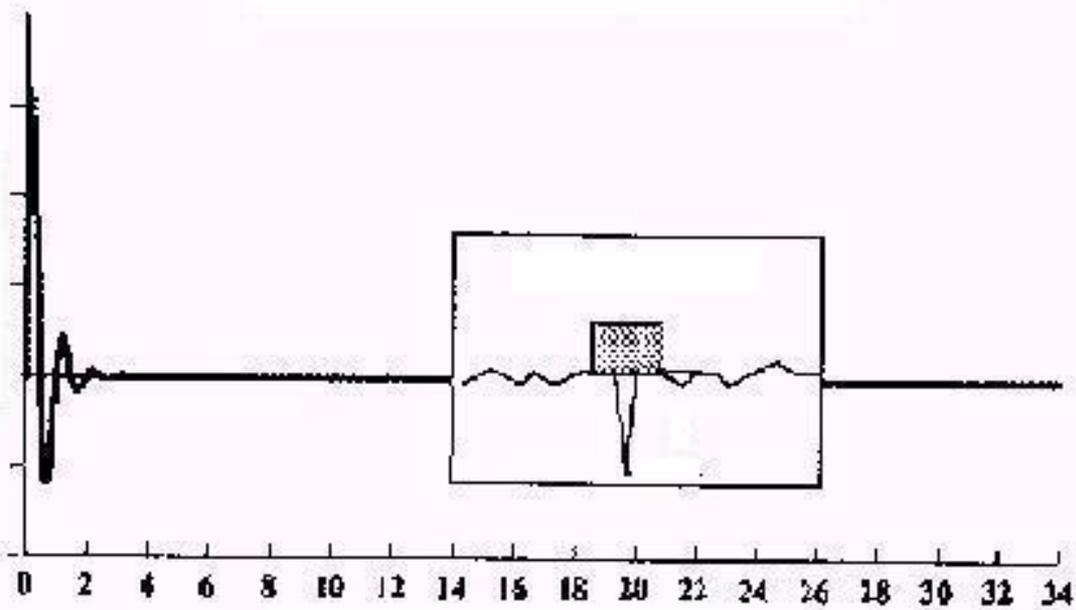
(mais comuns sísmica exploratória)



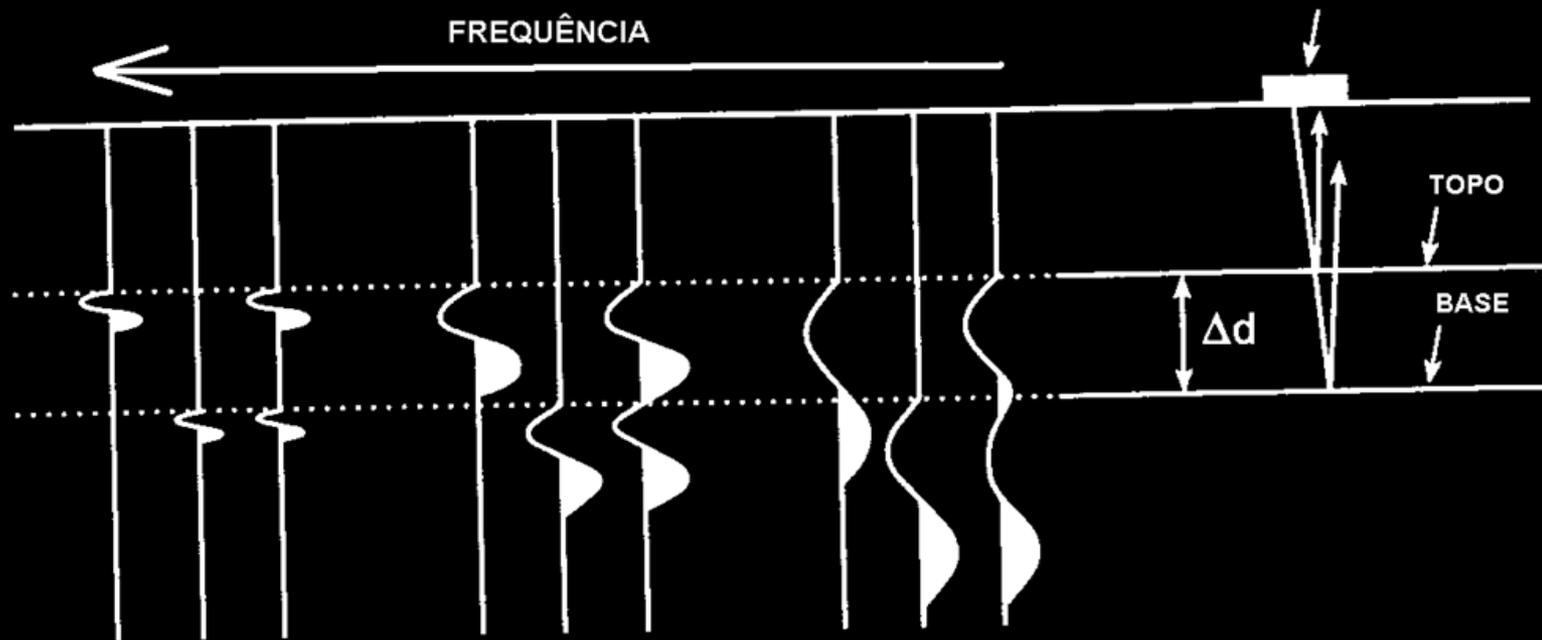
faixa 4 a 100 Hz de frequência natural



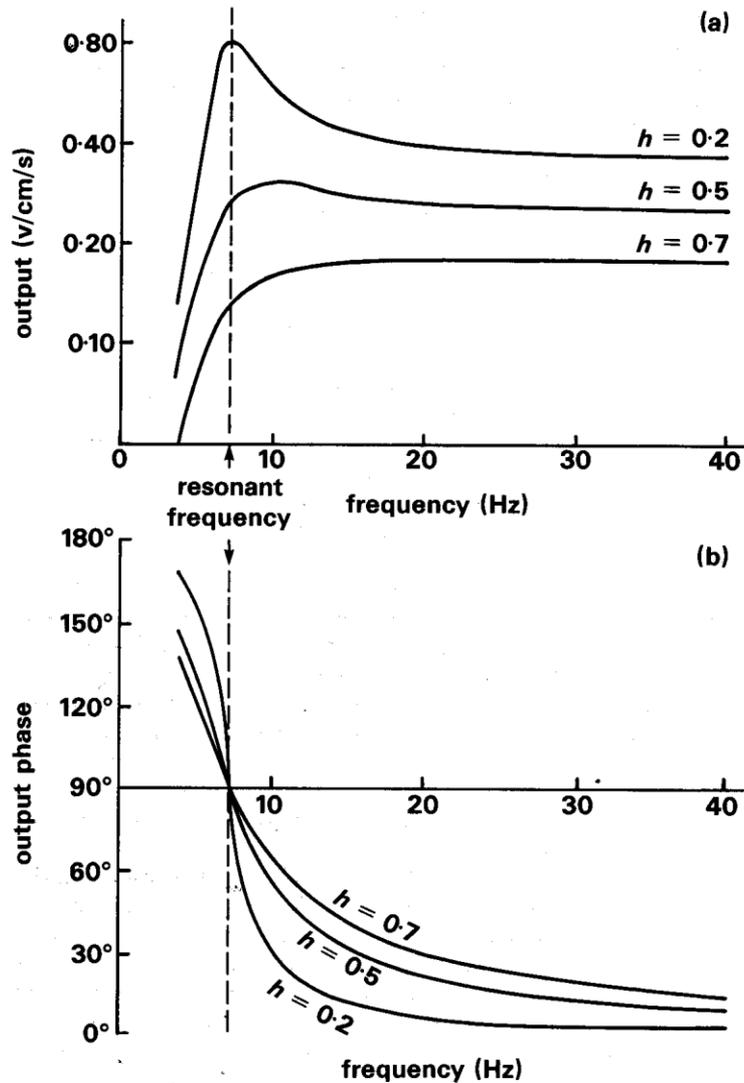
Aspecto crítico => acoplamento



FREQUÊNCIA DO SINAL x RESOLUÇÃO

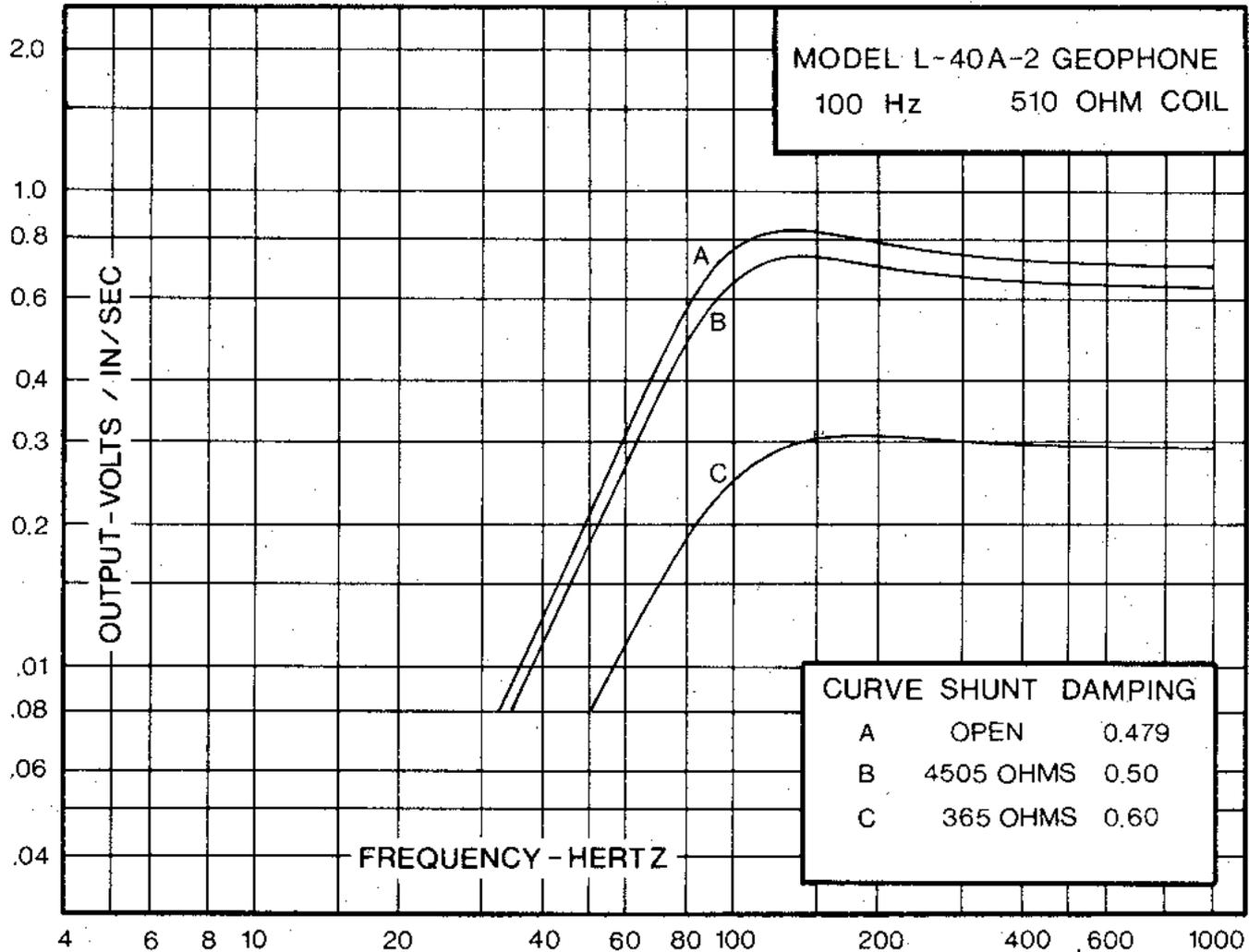


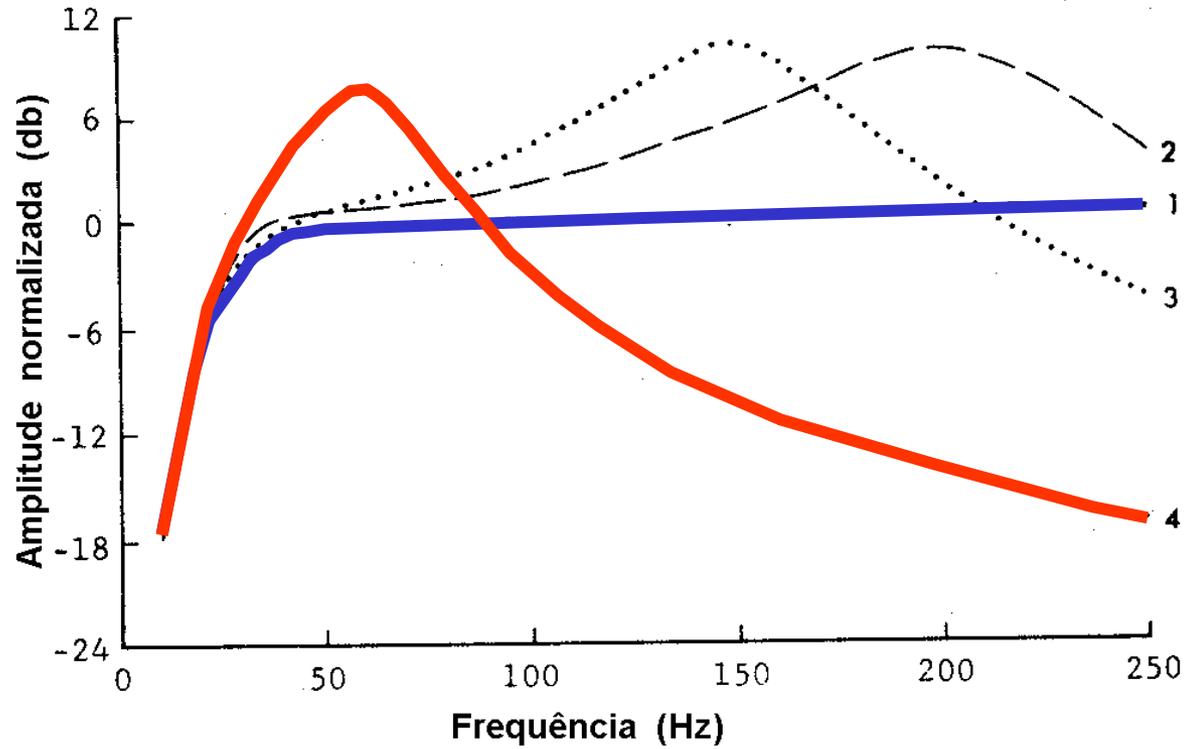
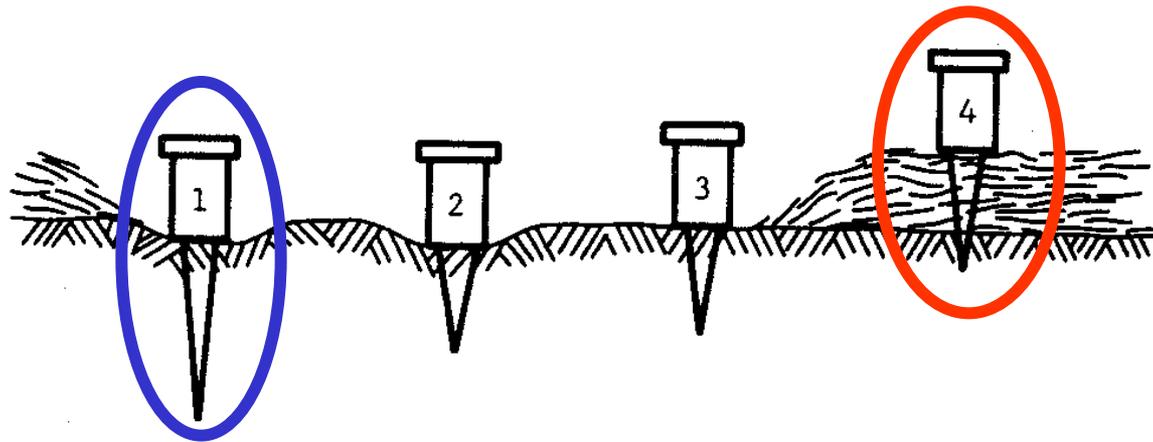
Características de um geofone

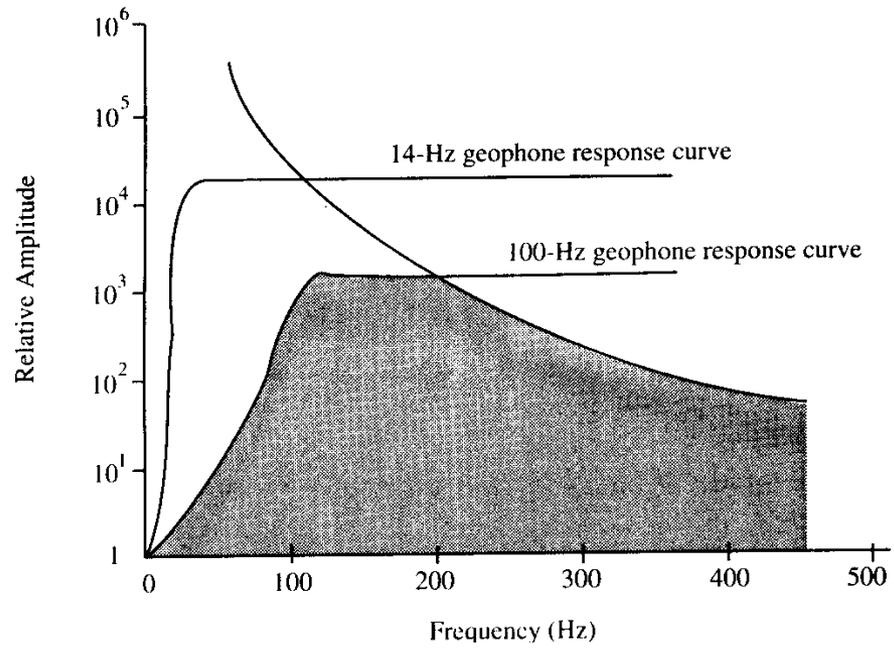
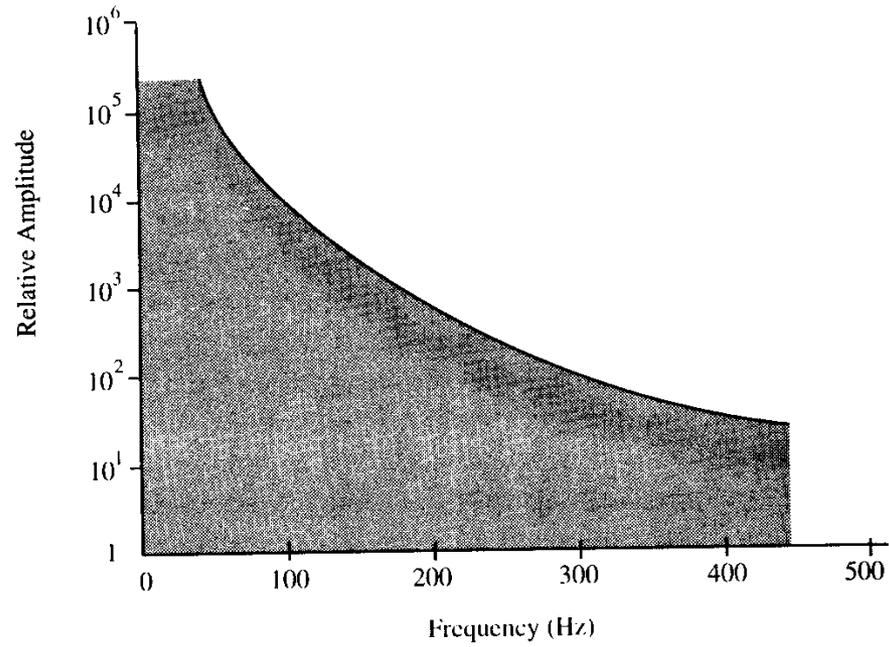


Fator de amortecimento h

Curva de resposta geofone

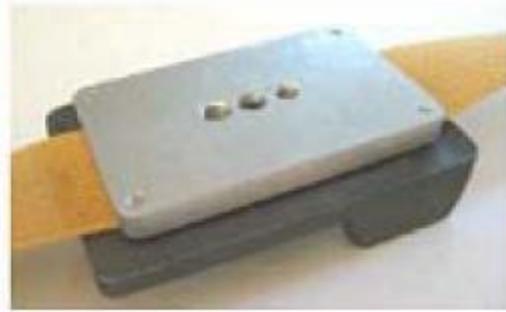








(a)



(b)

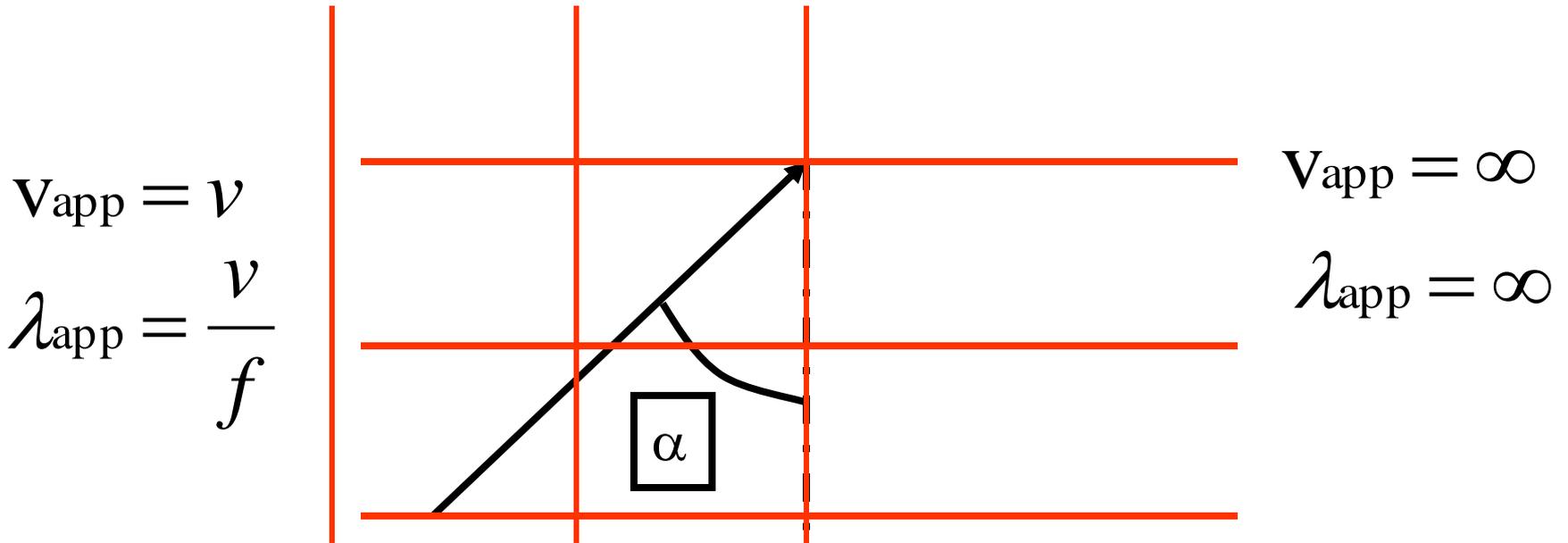


(c)



Arranjo de geofones

(Seismic Unix => group interval)



$$V_{app} = v$$
$$\lambda_{app} = \frac{v}{f}$$

$$V_{app} = \infty$$
$$\lambda_{app} = \infty$$

Velocidade aparente:

$$V_{app} = \frac{v}{\sin \alpha}$$

Comprimento de onda aparente:

$$\lambda_{app} = \frac{V_{app}}{f}$$

Função resposta:

$$R = \frac{\sin(n\beta)}{\sin(\beta)}$$

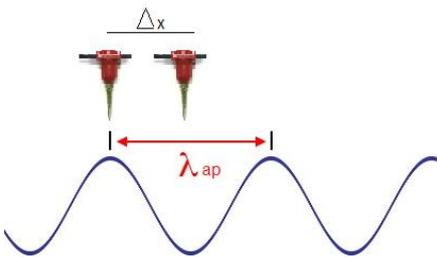
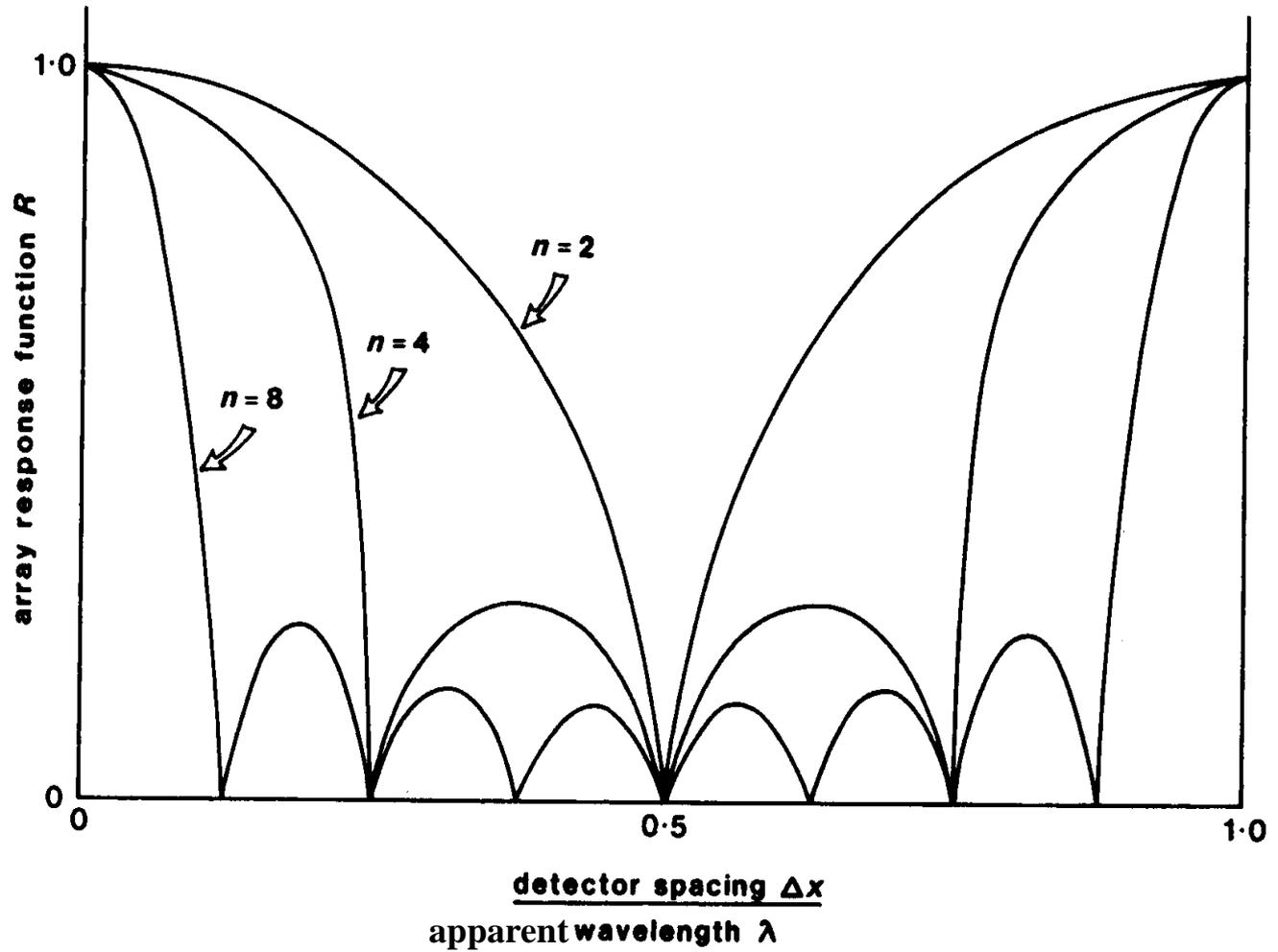
onde:

$$\beta = \frac{\pi\Delta x}{\lambda_{app}}$$

$n \Rightarrow$ número de geofones no grupo

$\Delta x \Rightarrow$ intervalo entre geofones no grupo

Arranjo função resposta

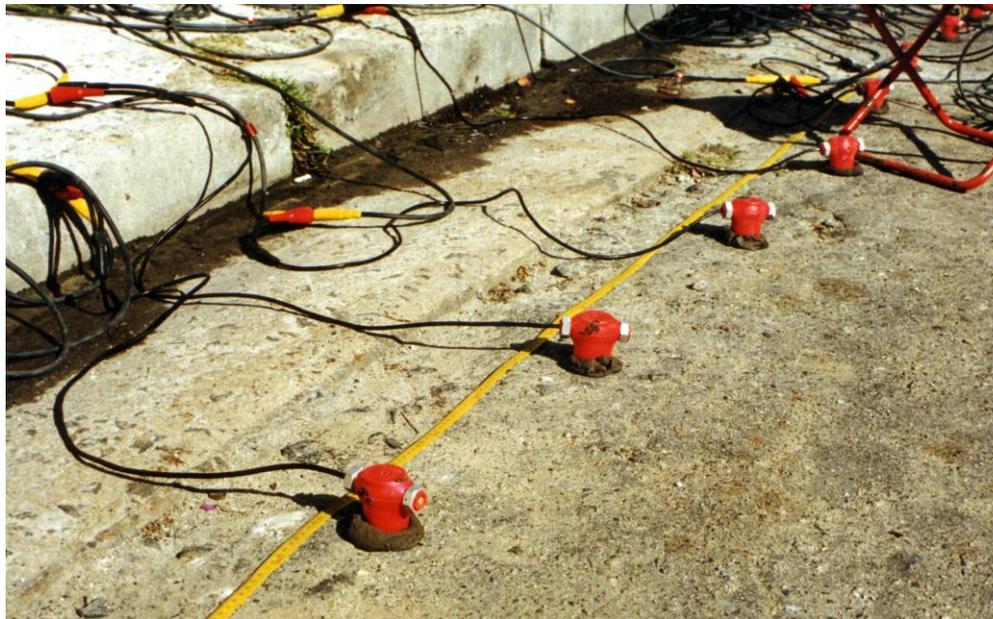


=> peso do geofone

=> área efetiva de contato

=> amplitude do movimento do solo

=> módulos elásticos do solo











Sísmica marinha

Aquisição de dados



PGS J.W. Schoolmeesters

A photograph of a boat on a lake. The boat is on the left side of the frame, with a mast and rigging. In the middle ground, there is a small buoy with a red flag on a pole, labeled as a boomer. In the bottom right corner, there is a label for hydrophones. The background shows a forested shoreline under a cloudy sky.

equipamento de registro

fonte de sinais
(boomer)

hidrofonos

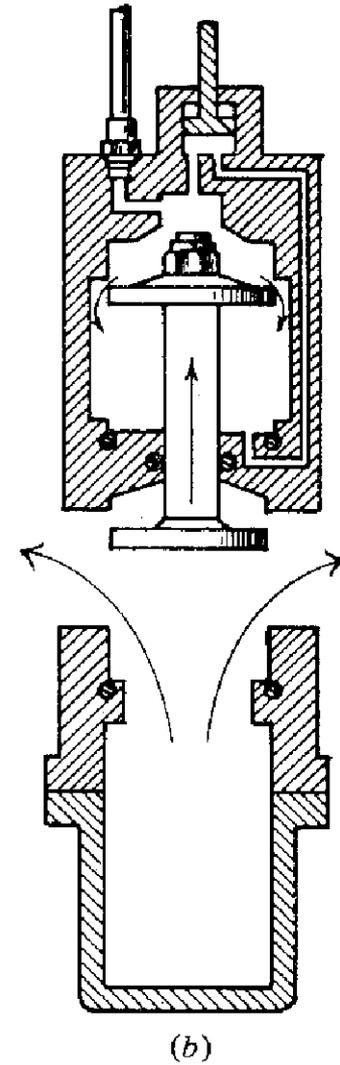
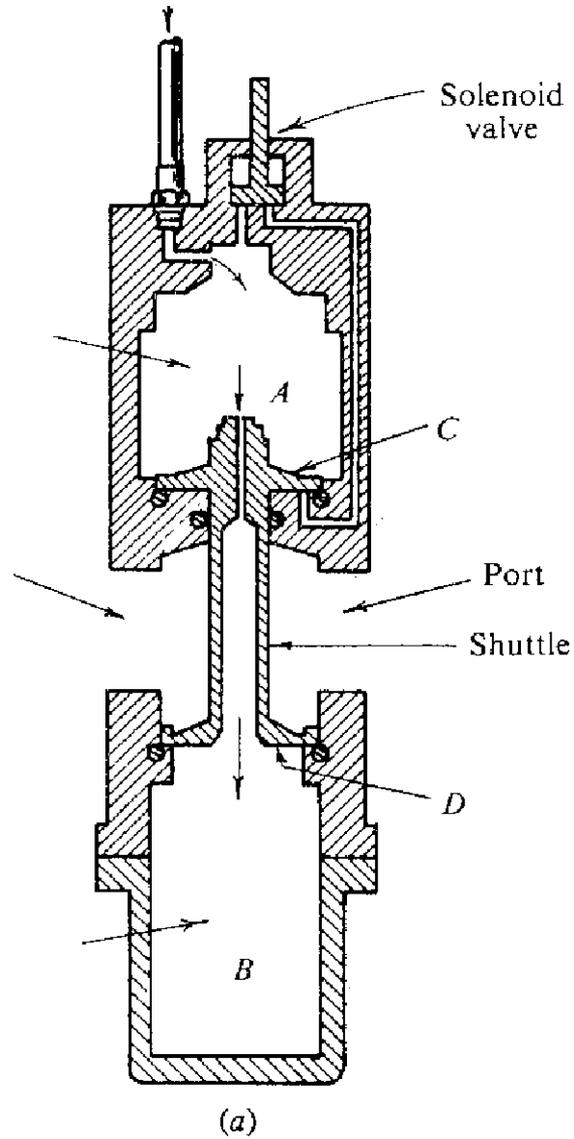
Sala de processamento sísmica marinha profunda



Sísmica rasa em água

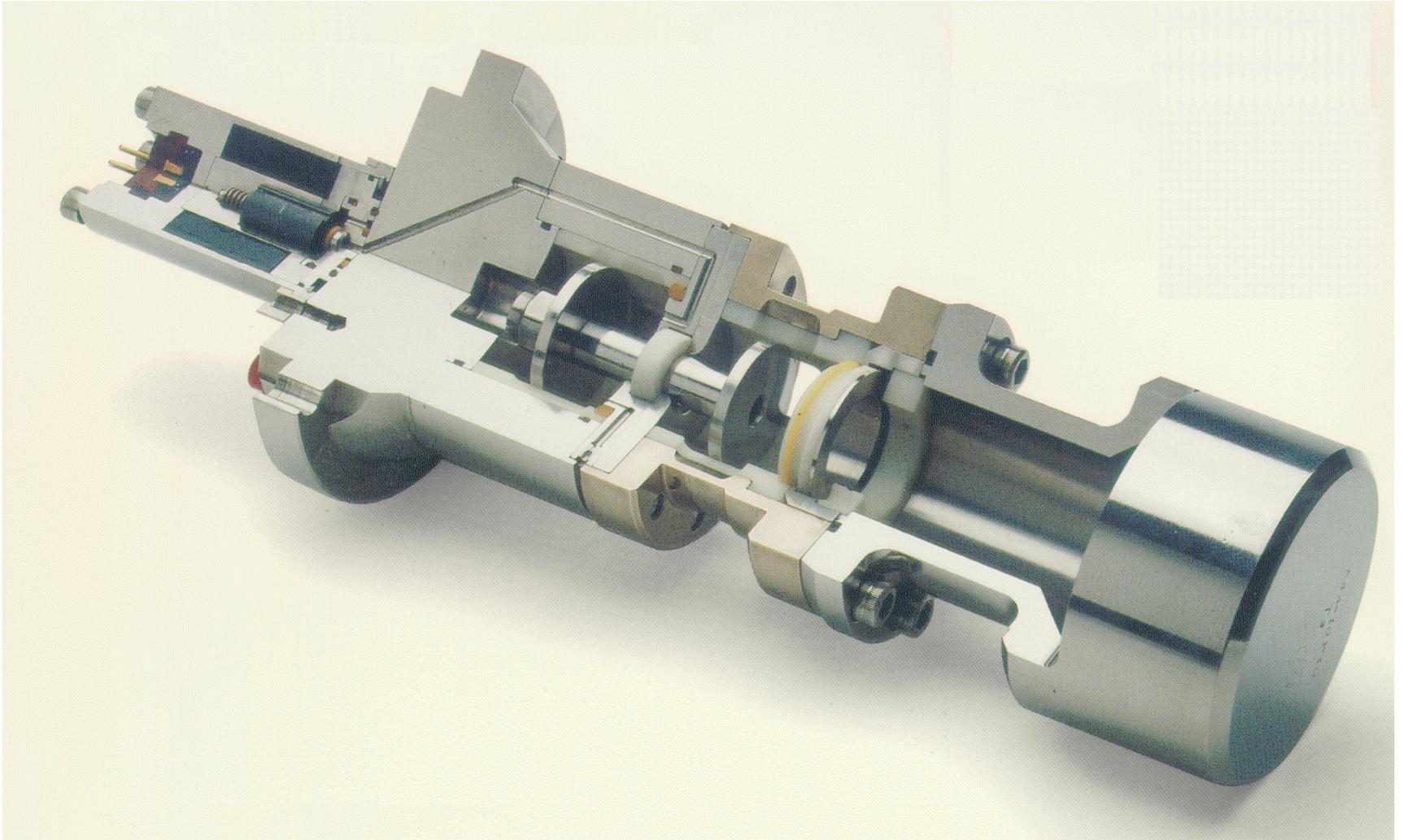


Princípio do Airgun



(Bolt-Systems)

Interior de um airgun



(Bolt-Systems)

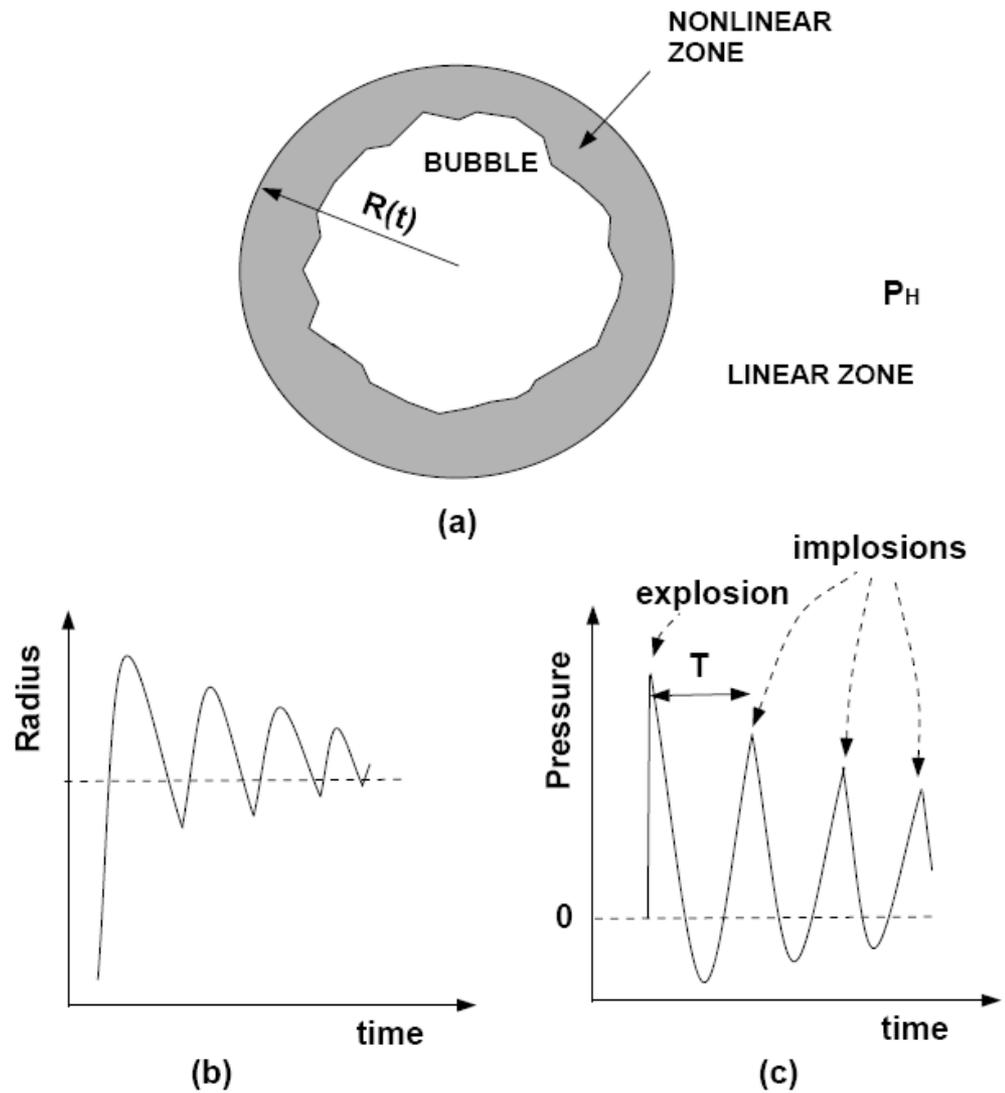
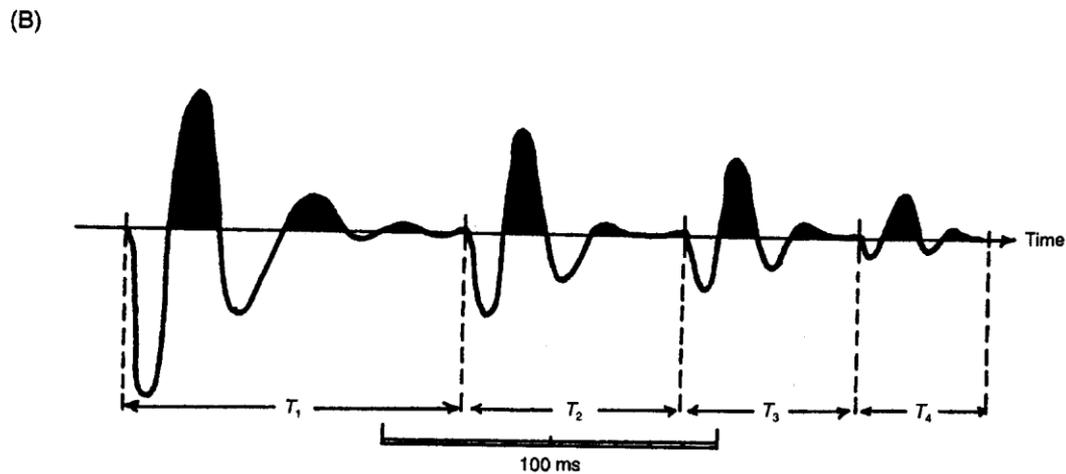
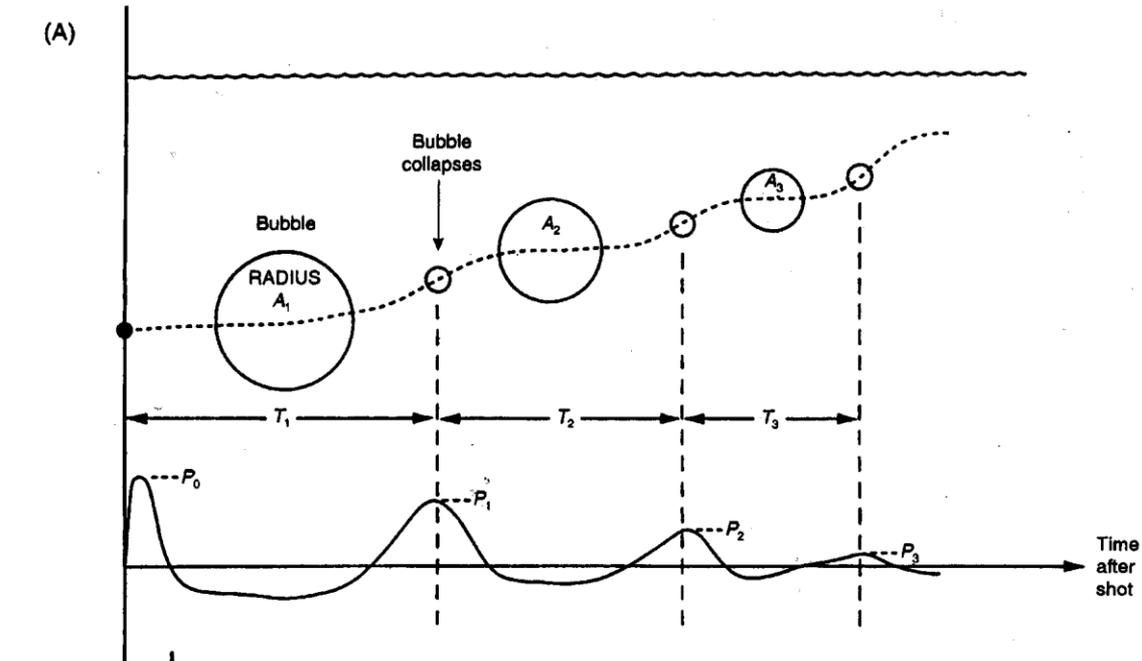
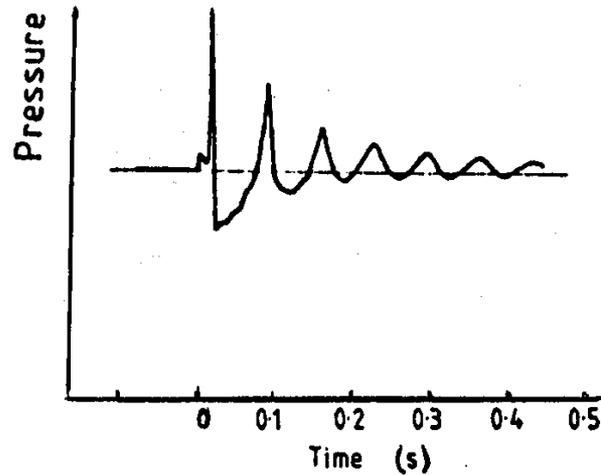


Figure 2.2: (a) Schematic section of the released air bubble; the radius (b) and the pressure (c) as a function of time for the air bubble of an airgun.

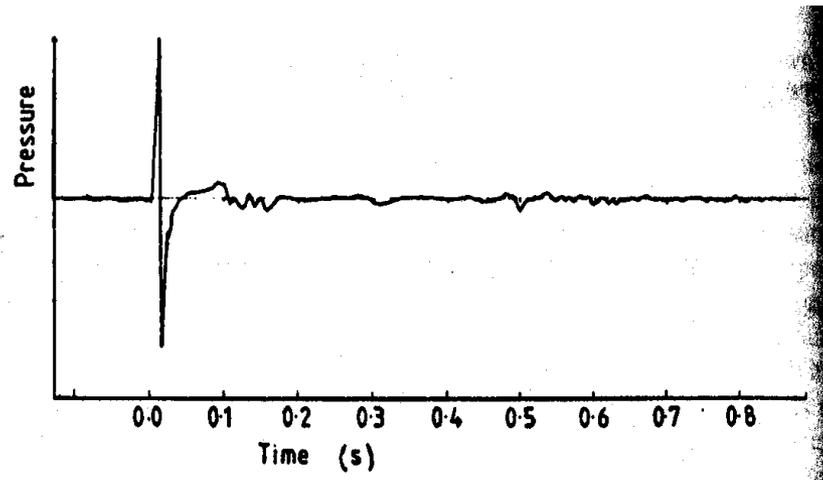
Resposta de um airgun



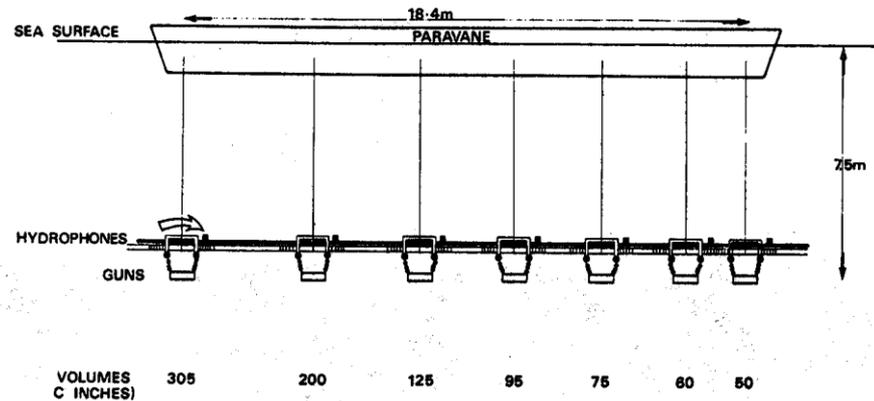
Arranjo de Air guns



um air gun



Arranjo de air guns



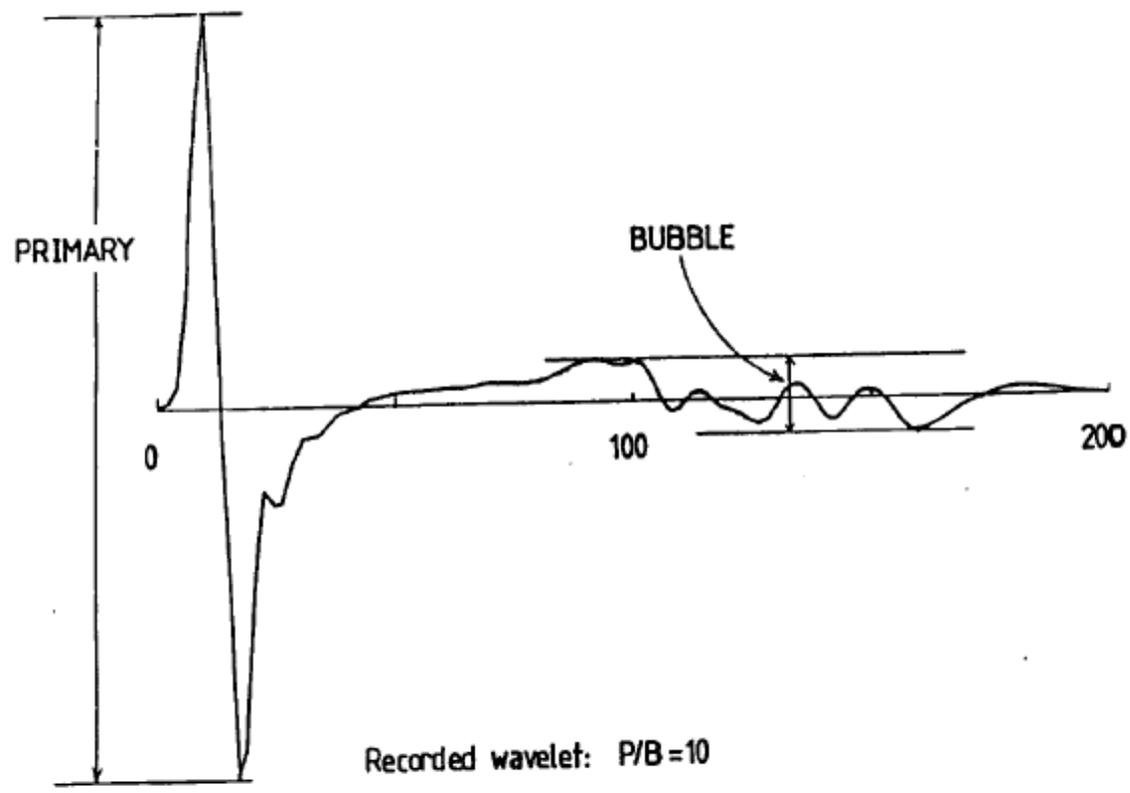


Figure 2.3: Far-field wavelet of tuned air-gun array

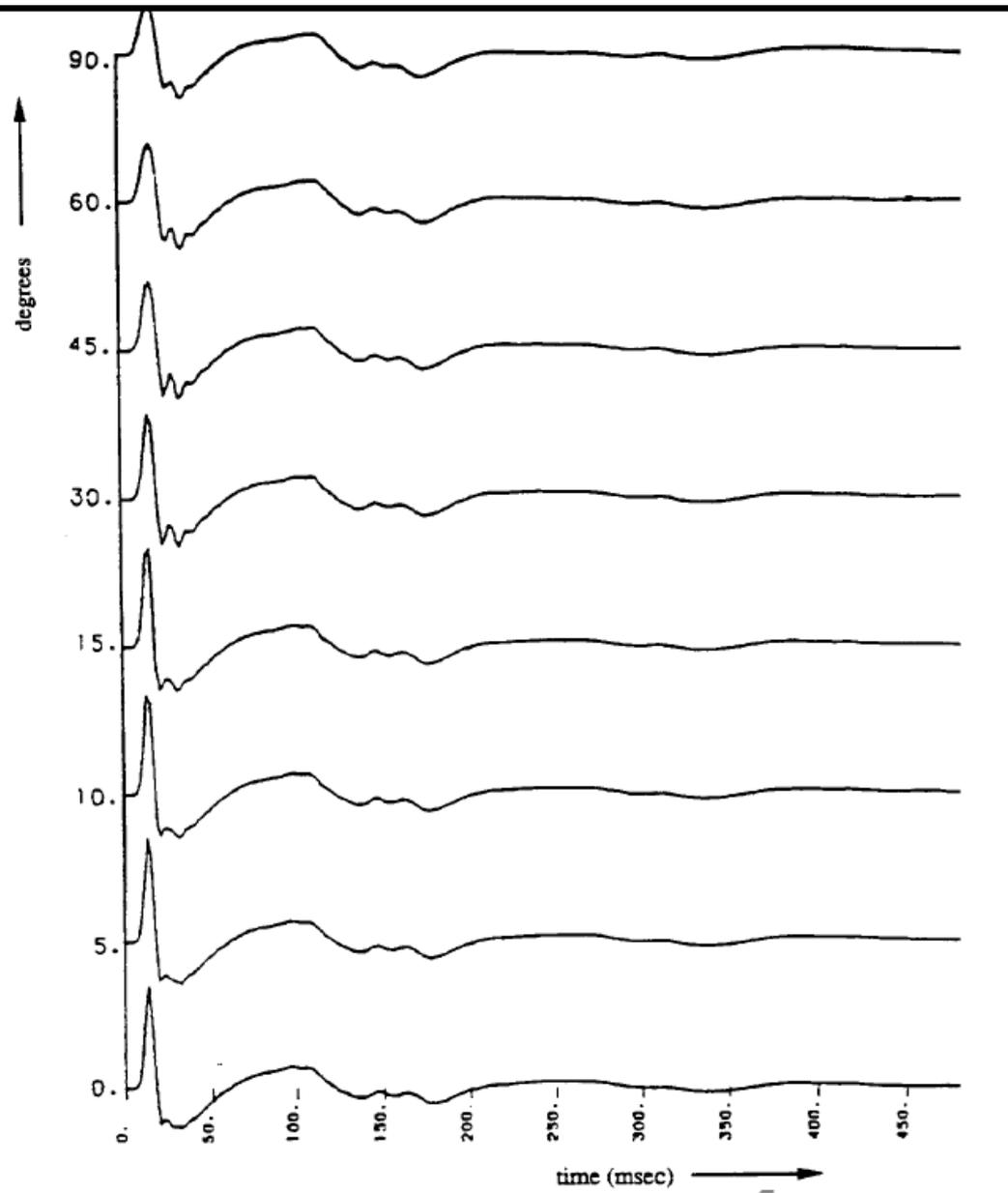
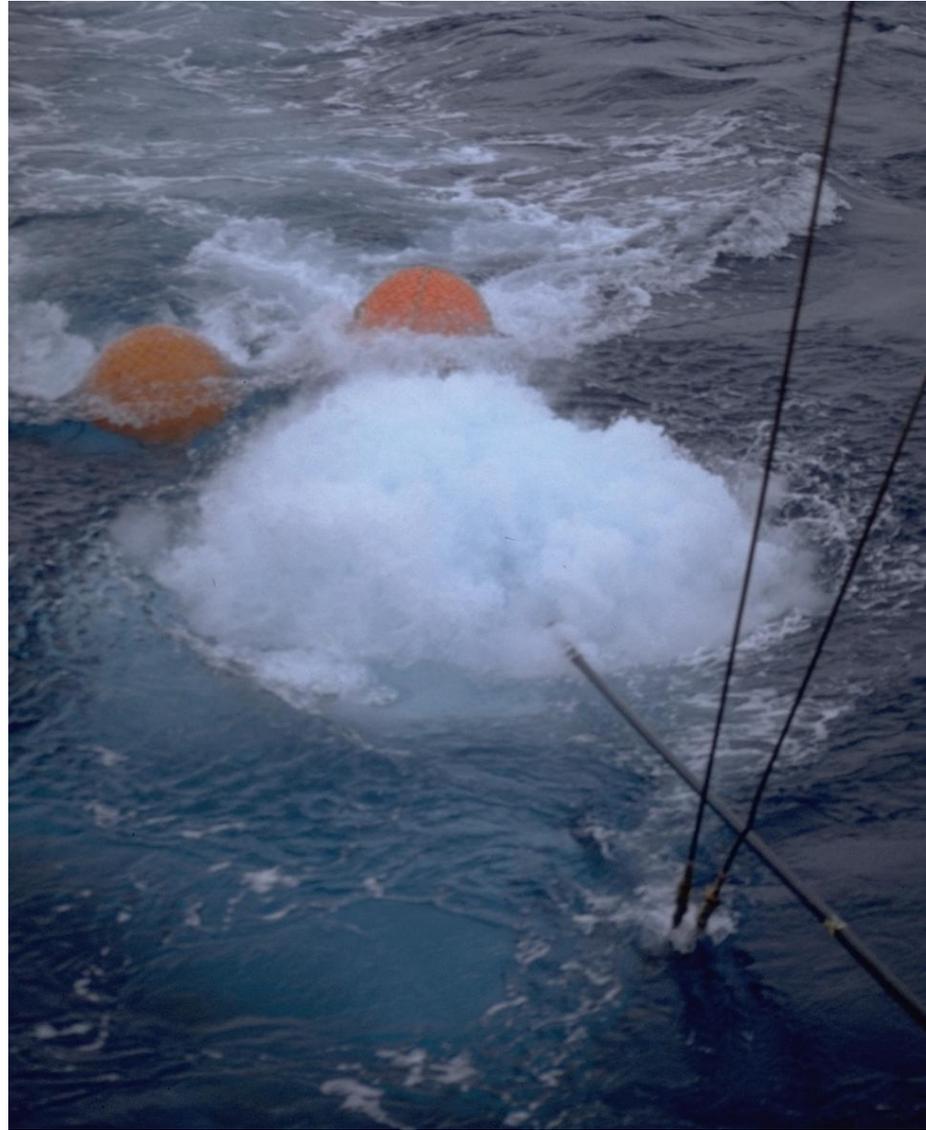


Figure 2.5: The airgun signature at different angles (directivity)





Boomer

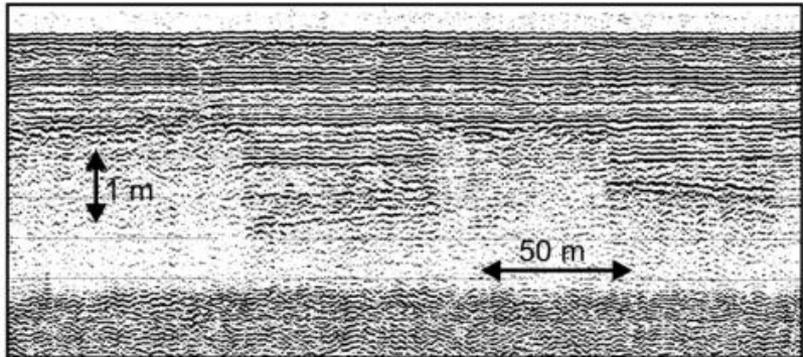


Fig. 4. Seistec boomer profile off the Belgian coast showing different levels of upward gas migration.
(© RCMG Universiteit Gent)

(Huntec-systems)

0.5 – 1.5 kHz 100-200 μ s

SPARKER



Fig. 1 Multi-tip sparker, cable and floaters (© Geo Resources)



Fig. 2 "Squid-like" sparker source (© Applied Acoustics)

CHIRP



Fig. 1 Typical Chirp towfish (© EG&G)



Fig. 2 Small boat with chirp towfish deployed on the side; the fender protects it against vibrations from the hull. © Ole Grøn.

Water gun	20-1500 Hz
------------------	------------

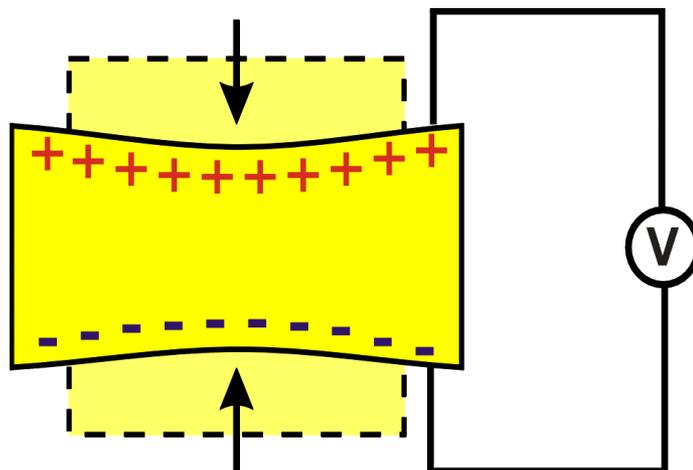
Air Gun	100-1500 Hz
----------------	-------------

Sparker	50-4000 Hz
----------------	------------

Boomer	300-3000 Hz
---------------	-------------

Chirp systems	500 Hz-12 kHz
	2 - 7 kHz
	4 - 24 kHz
	3.5 kHz and 200 kHz

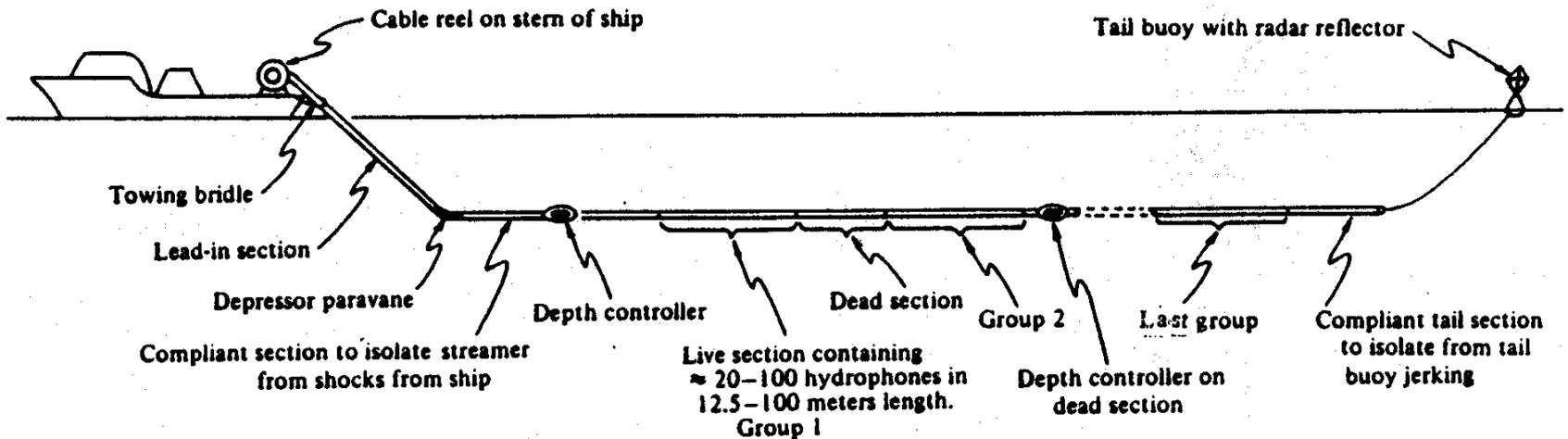
Hidrofone

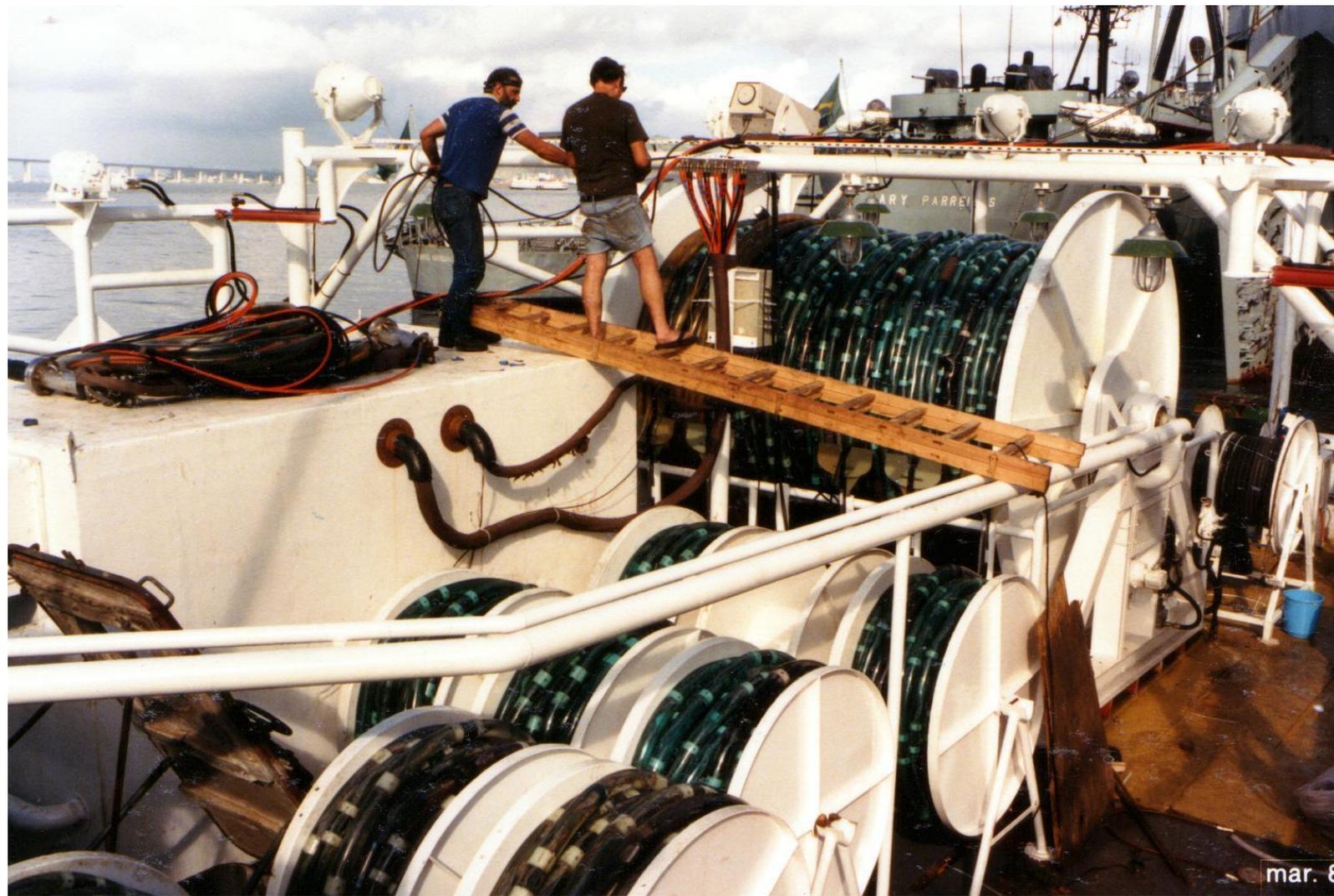


Princípio do efeito piezoelétrico

Voltagem proporcional à variação de pressão

Cabo de hidrofones





mar. 8

SISMÓGRAFO



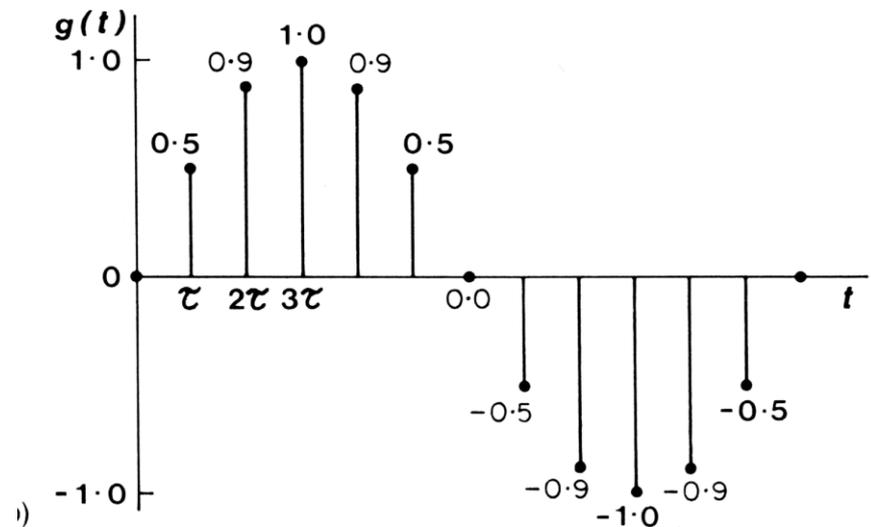
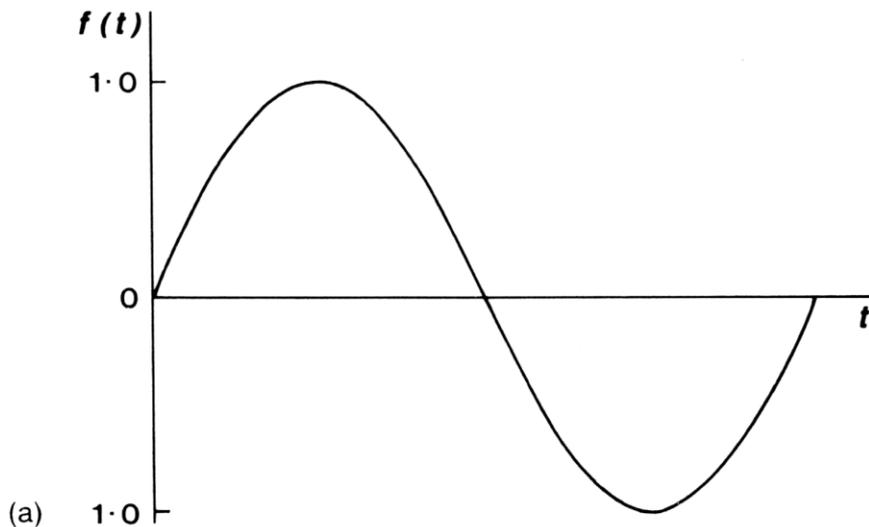
- alcance dinâmico (conversor A/D 24 bit)
- intervalo de amostragem
- tempo de aquisição

amostragem

Registros dos dados a intervalos regulares

intervalo de amostragem Δt

A amostragem deve preservar todas frequências até a frequência de Nyquist: $f_N = 1/(2 \Delta t)$



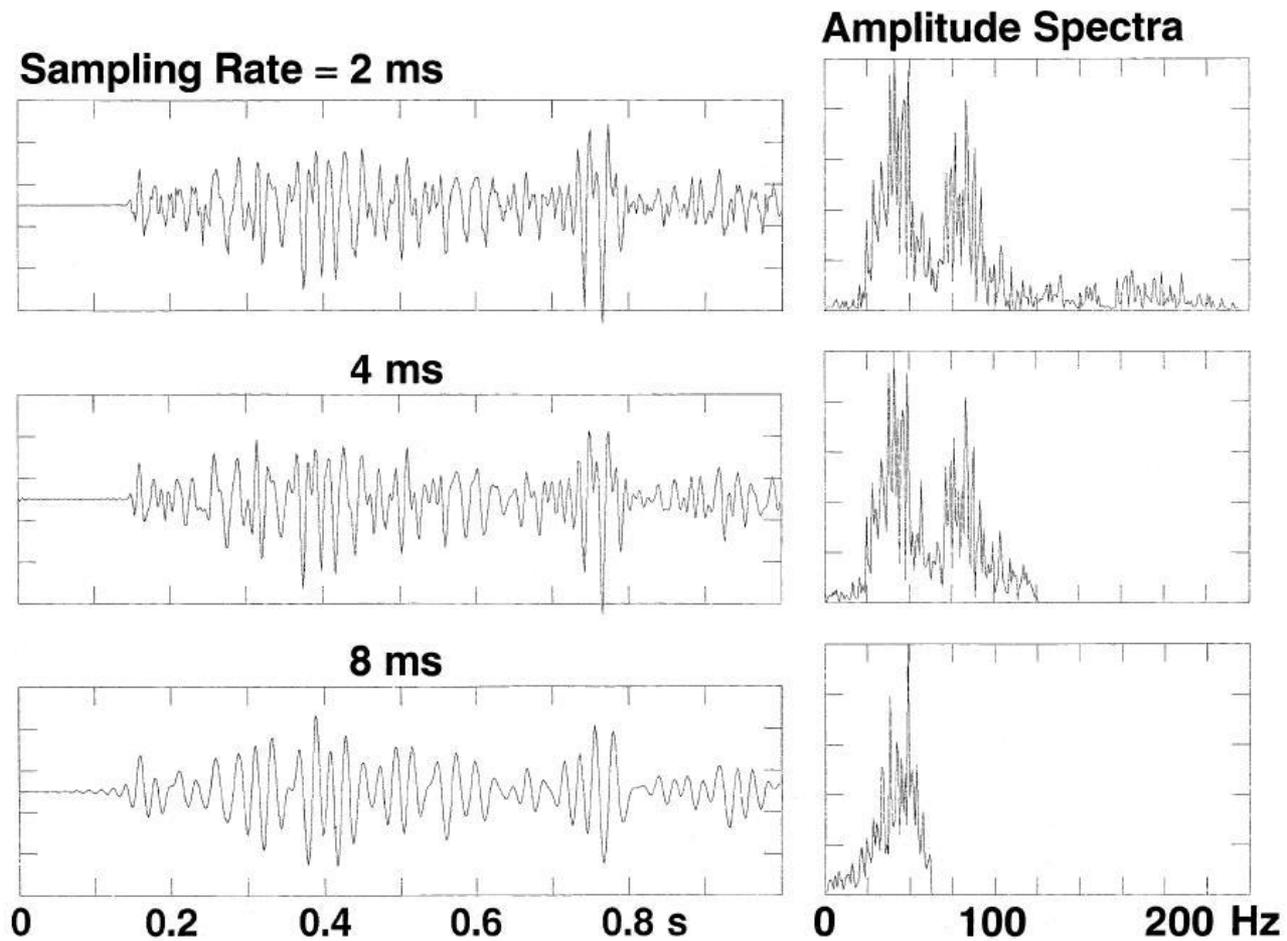


FIG. 1.1-6. A time series sampled at 2 ms has a Nyquist frequency of 250 Hz. Resampling to 4 and 8 ms confines the frequency band to 125 and 62.5 Hz, respectively. Note the loss of high frequencies at larger sampling intervals.

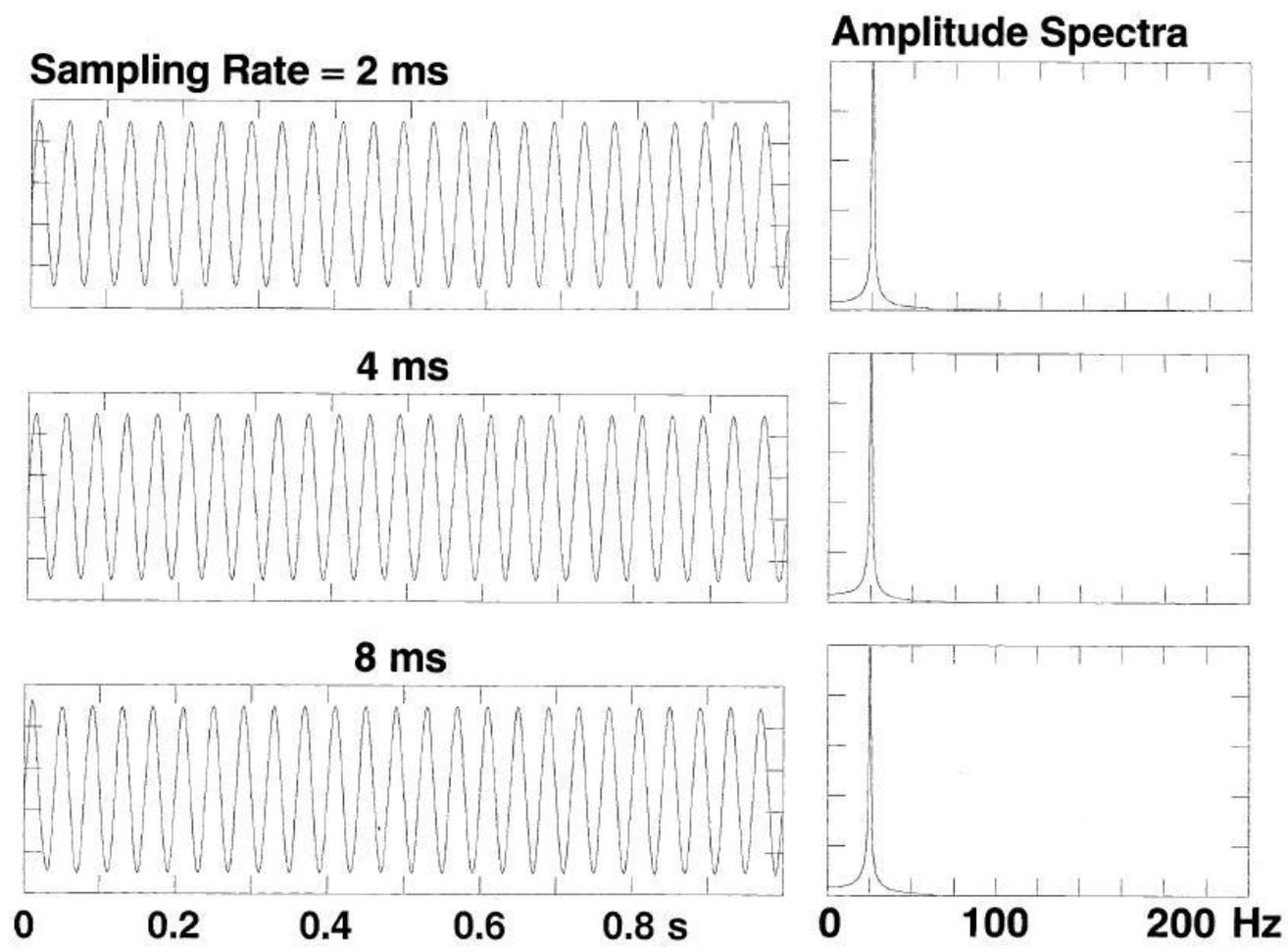


FIG. 1.1-7. A 25-Hz sinusoid sampled at 2 ms remains unchanged when resampled at 4 or 8 ms.

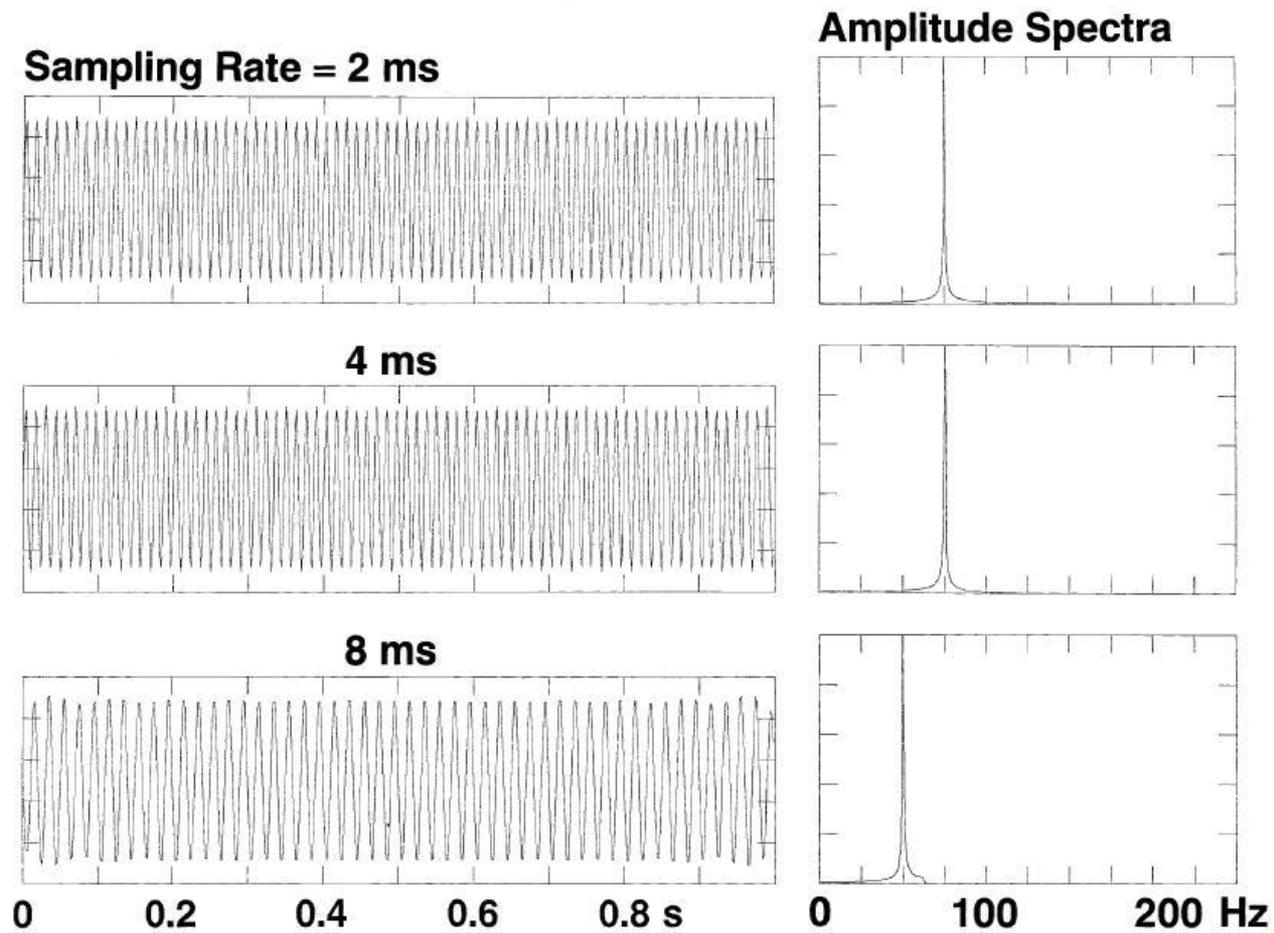


FIG. 1.1-8. A 75-Hz sinusoid sampled at 2 ms remains unchanged when resampled at 4 ms, but appears as a 50-Hz sinusoid when resampled at 8 ms. Hence, the latter is the alias of the original sinusoid.

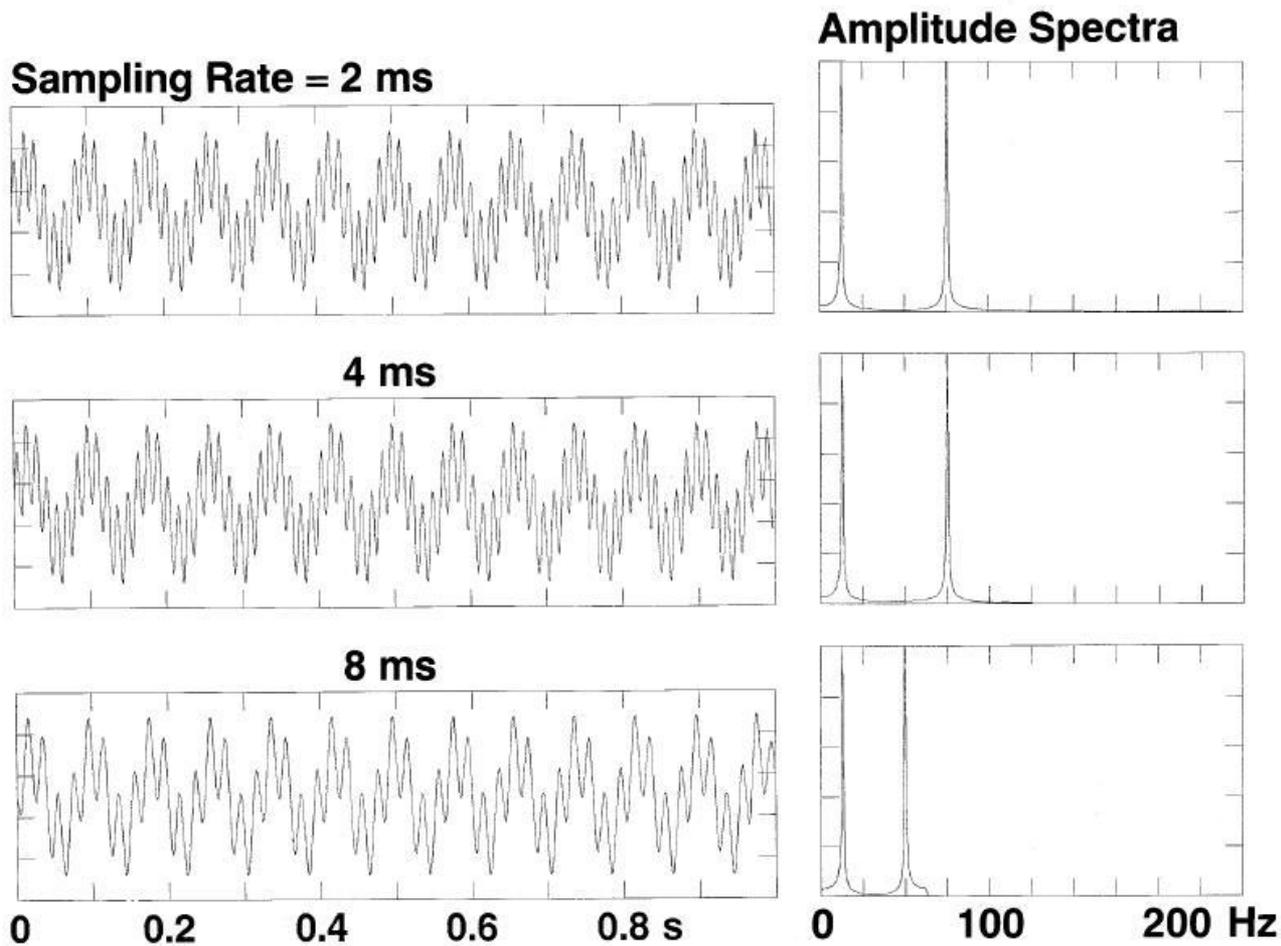
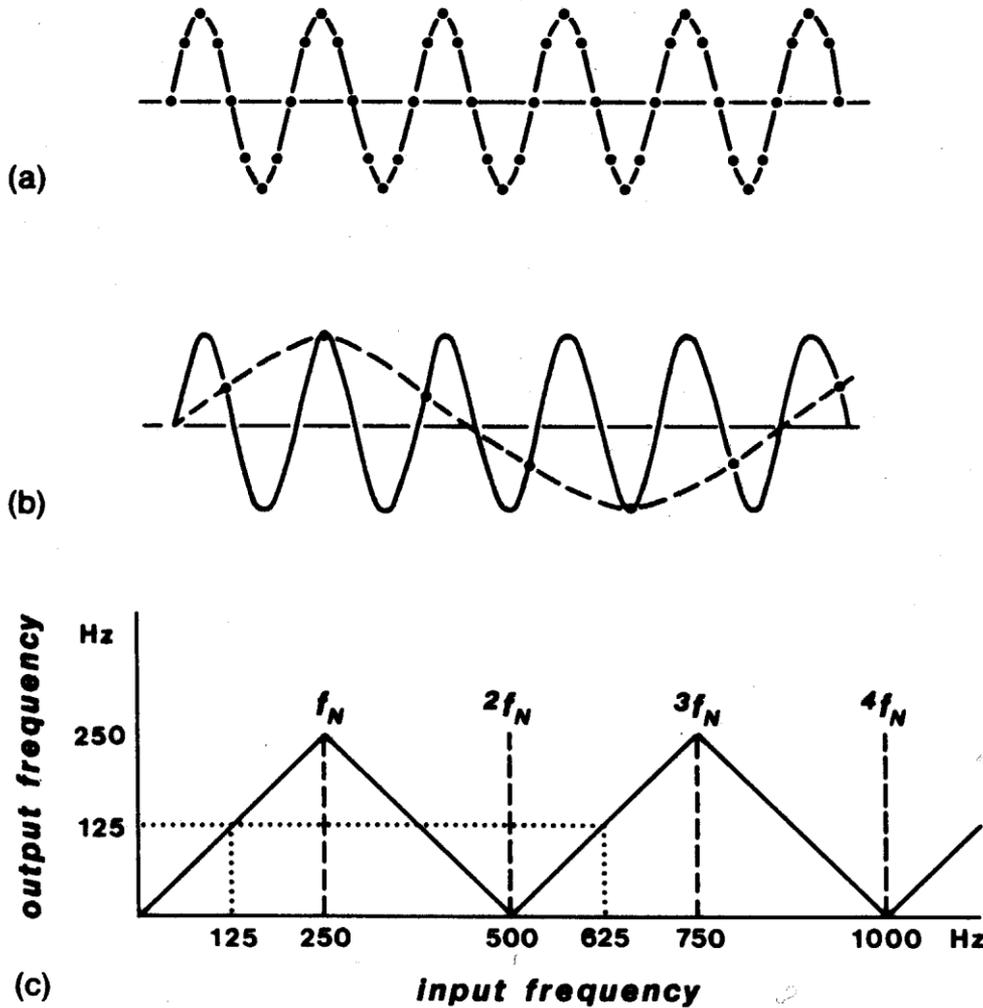


FIG. 1.1-10. A time series synthesized from two sinusoids with 12.5 and 75 Hz at 2-ms sampling rate remains unchanged when resampled at 4 ms. However, at 8 ms, its high-frequency component shifts from 75 to 50 Hz, while its low-frequency component remains the same.

$$f_a = |2mf_n - f_s|$$

m = inteiro tal que $f_a < f_n$

Alias



Intervalos de amostragem usuais:

0.25 - 0.5 ms:

sísmica de “alta resolução”

1 ms - 4 ms

petróleo

4 ms ou maior

sismologia

(Kearey and Brooks, 1991)

QUESTÃO

Máxima frequência do sinal a ser registrado = 100 Hz

Qual o máximo intervalo de amostragem que deve ser empregado?

Suponha que na área exista uma máquina em operação transmitindo ao solo uma vibração de 350 Hz

Considerando o uso do máximo intervalo de amostragem definido anteriormente, o que poderíamos esperar do ruído da máquina no nosso sismograma?

Qual a solução?

FILTRO ANTI-ALIAS

→ ajustado a partir da frequência de amostragem escolhida

Alcance dinâmico

“range” de registro usando diferentes números de bits:

8-bit : 1 mV - 256 mV

24-bit: 1 μ V - 16 V

Alcance dinâmico é expresso em dB

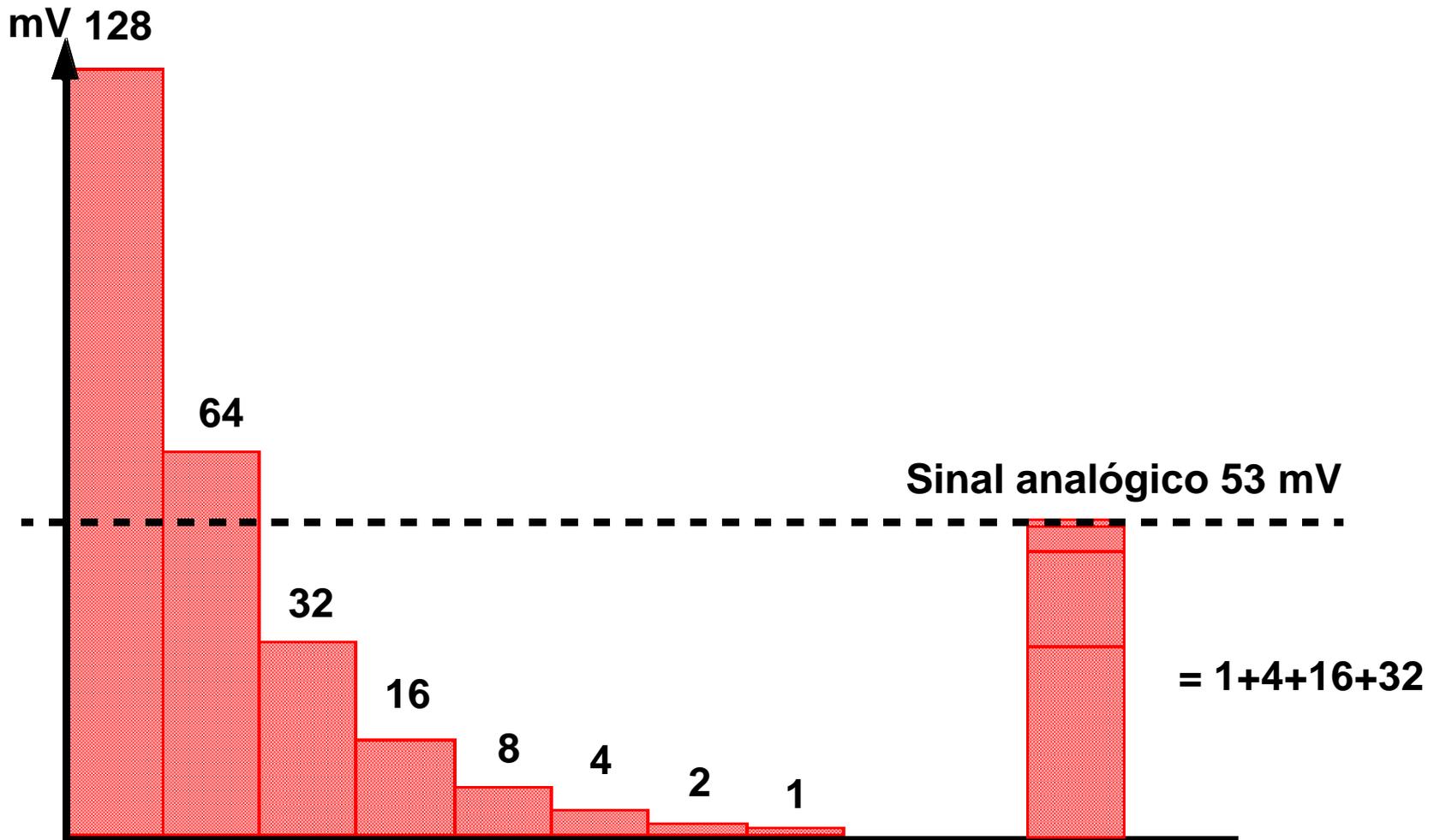
Exemplos:

$$20 \log \left(\frac{A_{\max}}{A_{\min}} \right)$$

$$20 \log \left(\frac{256 \text{mV}}{1 \text{mV}} \right) = 48 \text{dB}$$

$$20 \log \left(\frac{16 \text{V}}{1 \mu\text{V}} \right) = 144 \text{dB}$$

Conversor AD



Armazenamento

Armazenamento depende:

=> Número de canais

=> Número de amostras por canal
(intervalo de amostragem, tempo de aquisição)

=> Número de bytes por valor amostrado

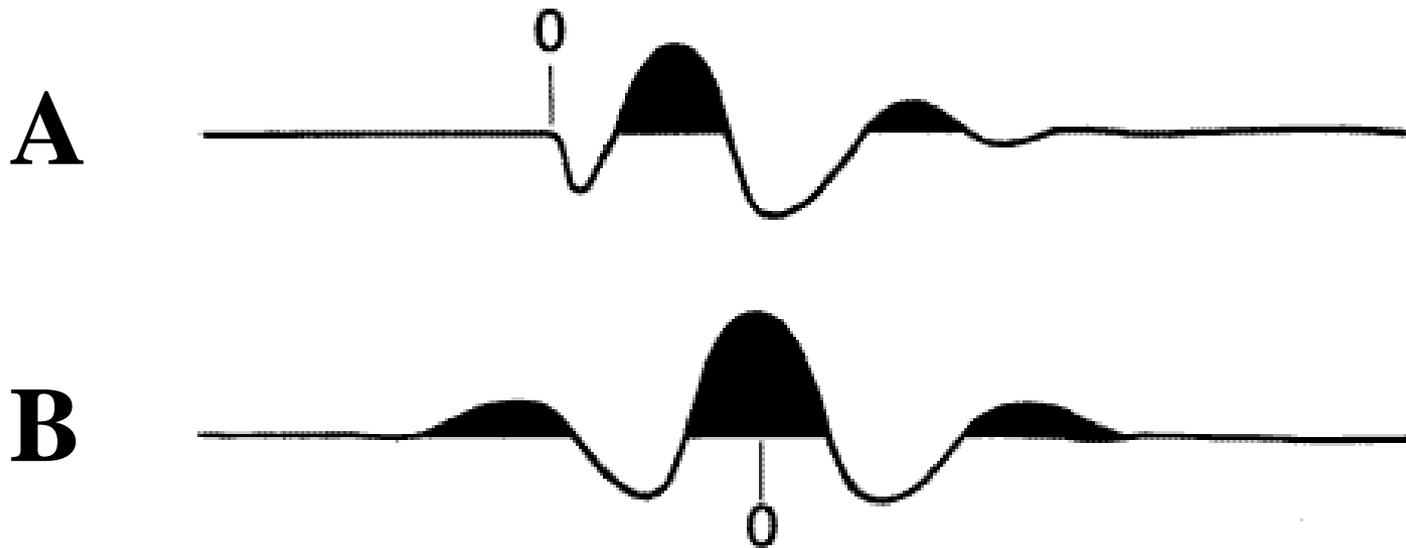
Exercício

Canais:	48
Amostragem:	0,5 ms
Tempo de aquisição	0.3 s
Formato:	4 Bytes por valor

⇒ $(300 / 0,5) \text{ Valores} \times 48 \text{ canais} \times 4 \text{ Bytes} = 115,2 \text{ KBytes}$

```
user@debian03:~/2015/agg5727$ surange < bora2.su
```

```
tracl      1 17280 (1 - 17280)
tracr      1 17280 (1 - 17280)
fldr       1 191 (1 - 191)
tracf      1 96 (1 - 96)
ep         1 180 (1 - 180)
cdp        -1 1482 (-1 - 1482)
trid       1
nvs        1 8 (1 - 7)
offset     -86 192 (2 - 104)
sx         0 192 (0 - 192)
gx         0 190 (190 - 0)
ns         2000
dt         500
```



SEG polarity standard. For a positive reflection, a minimum-phase wavelet (top) begins with a down kick; the center of a positive symmetrical (zero-phase) wavelet (bottom) is a peak. In the North Sea and some other areas the opposite convention is used for zero-phase wavelets.

Fonte explosiva => A ou B ?

Fonte vibroseis => A ou B ?