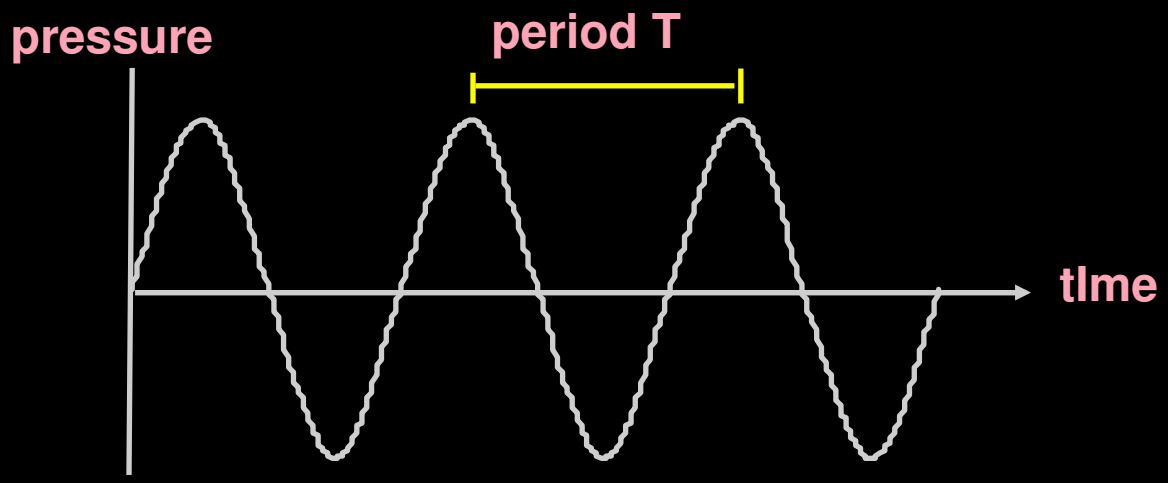
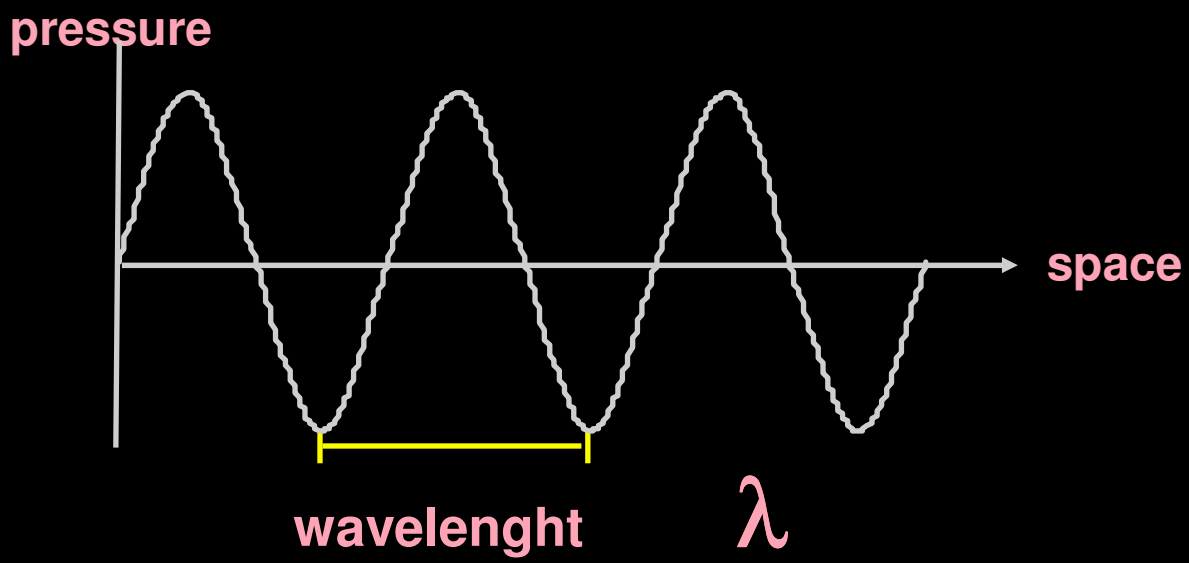
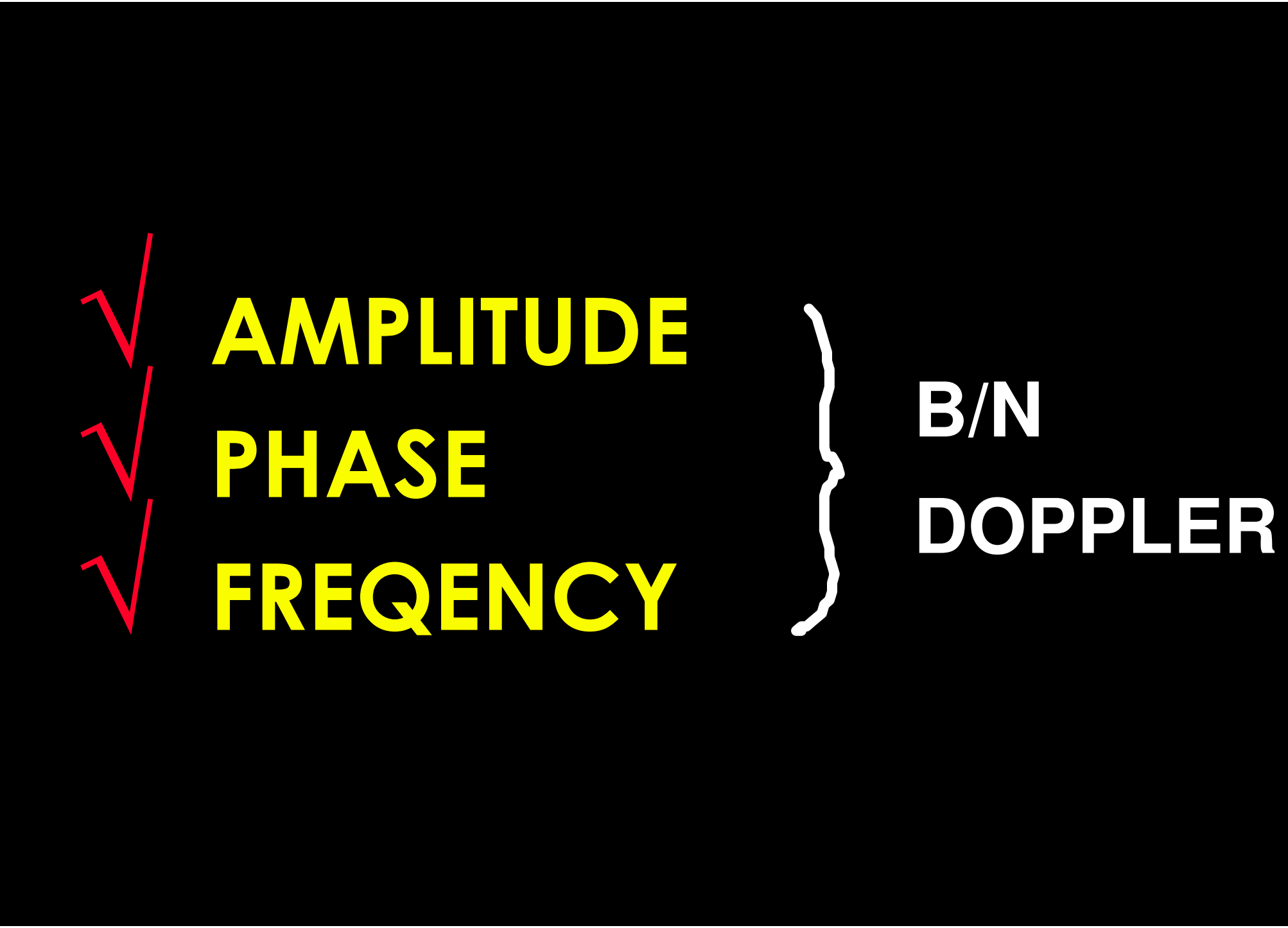


$$f = \frac{1}{T} \qquad \lambda \cdot f = c$$



graphic

- A MODE
- REAL TIME (B-MODE)
  - 2D
  - 3D
- M - MODE
- GATED MODE
- DOPPLER MODE :
  - CW
  - PW
  - COLOR (2D - 3D)
  - ENERGY / POWER (2D - 3D)
  - DTI (2D - 3D)


√ AMPLITUDE
√ PHASE
√ FREQENCY
B/N
DOPPLER

TRANSDUCER = Device converting an energy type in another

ELECTRICAL ENERGY → MECHANICAL ENERGY

EMITTER

MECHANICAL ENERGY → ELECTRICAL ENERGY

RECEIVER

INTERACTION US - TISSUE

- REFLECTION → IMAGING
- REFRACTION
- DIFFUSION
- ATTENUATION

→ ABSORPTION OR DIFFUSION OF ENERGY

CLINICAL USE OF US
frequency 1-20 MHz in tissue

Frequency (MHz)	Period (μ s)	Wavelength (mm)
1	1	1,54
2	0,5	0,77
3,5	0,29	0,44
5	0,2	0,31
10	0,1	0,15
20	0,05	0,08

$C \propto 1/\sqrt{\rho}$

$C \propto 1/\sqrt{\text{compressibility}}$

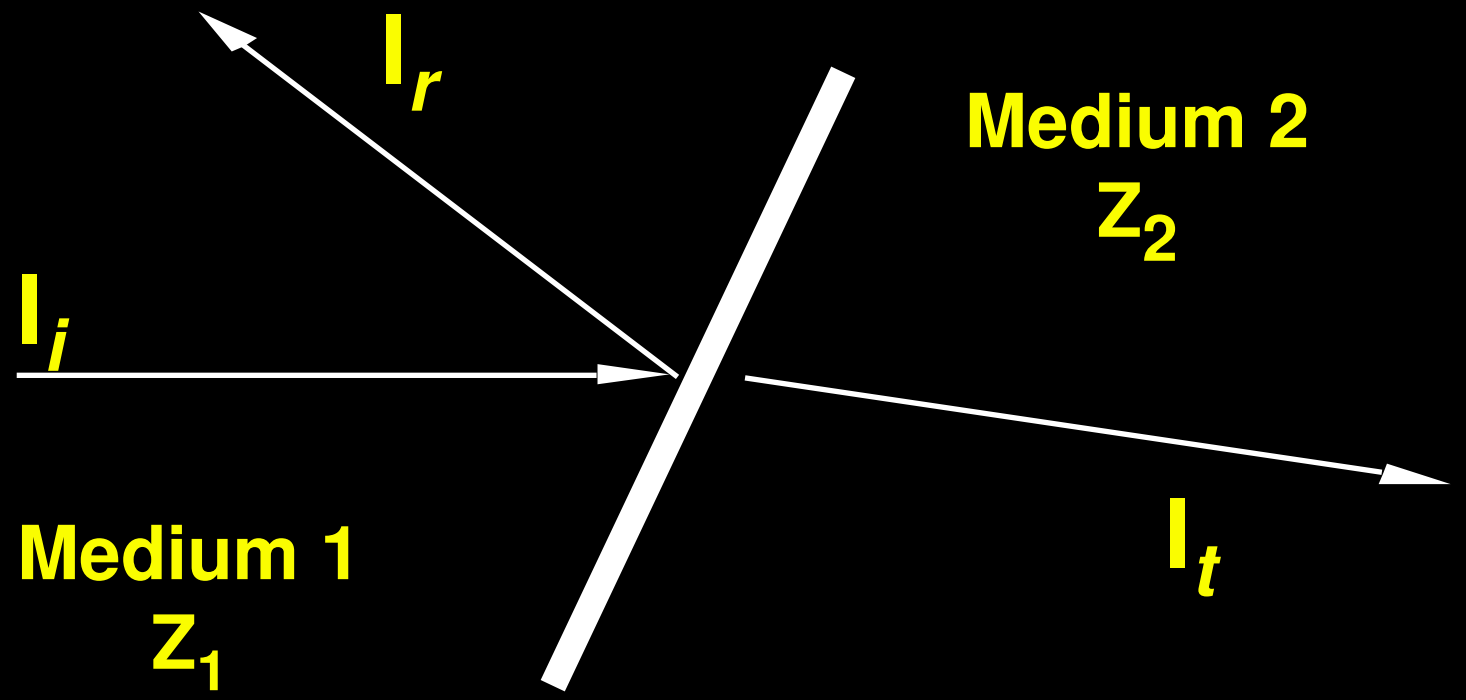
$C = C(f)$ dispersion (< 1 %)

$C = C$ (Temp.) (< 1 %)

MATERIAL	DENSITY Kg / m^3	US SPEED m / s	Z $Kg / m^2 \cdot s \cdot 10^{-6}$
AIR	1,2	330	0,0004
WATER (20 ℃)	1000	1480	1,48
MERCURY	13600	1450	20
TISSUE (AVG)	1060	1540	1,63
LIVER	1060	1550	1,64
MUSCLE	1080	1580	1,70
FAT	952	1459	1,38
BONE	1912	4080	7,8
PZT	7650	3791	29

ACOUSTIC IMPEDANCE

$$Z = \rho \cdot c$$



$$I_r = I_i \cdot \alpha \qquad I_t = I_i - I_r = (1-\alpha)\, I_r$$

$$\alpha = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2$$

show

MATERIAL	DENSITY Kg / m^3	US SPEED m / s	Z $Kg / m^2 \cdot s \cdot 10^{-6}$
AIR	1,2	330	0,0004
WATER (20 ℃)	1000	1480	1,48
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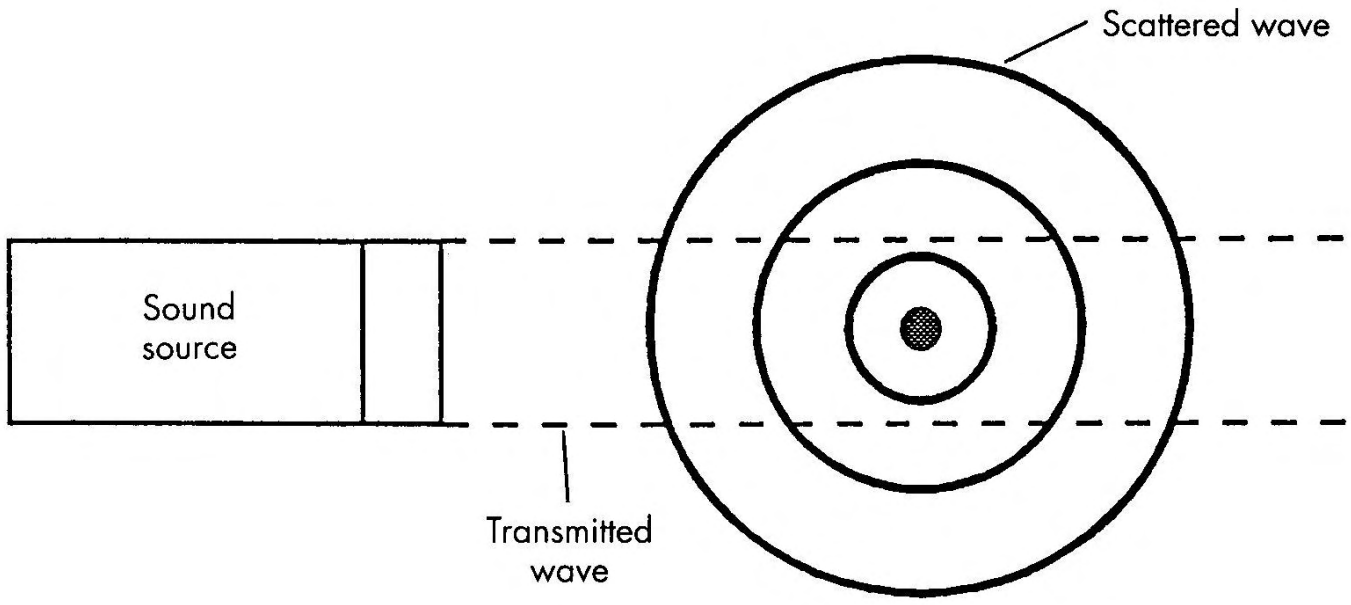


Nonspecular reflection. The scattered wave is emitted in all directions, shown here in two dimensions only.

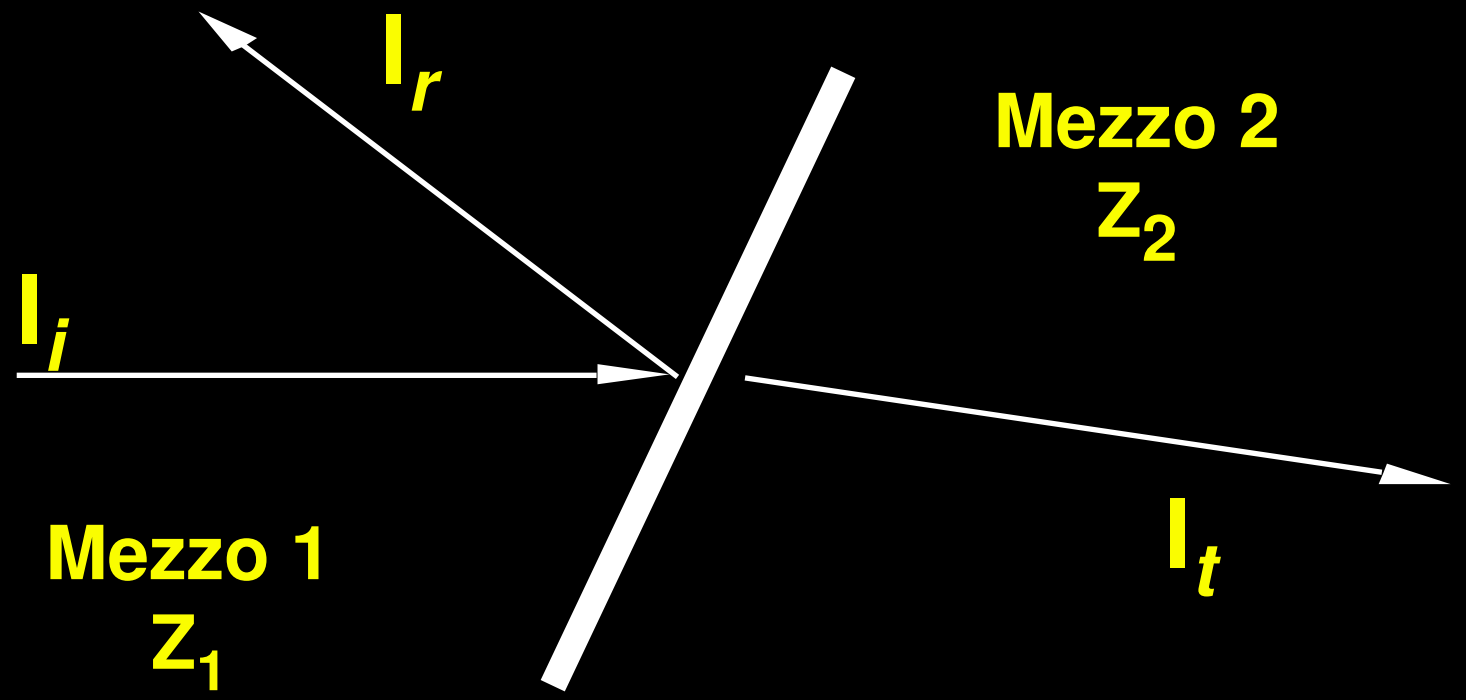
Diffusion

ABSORPTION

$$I = I_0 e^{-\alpha x}$$

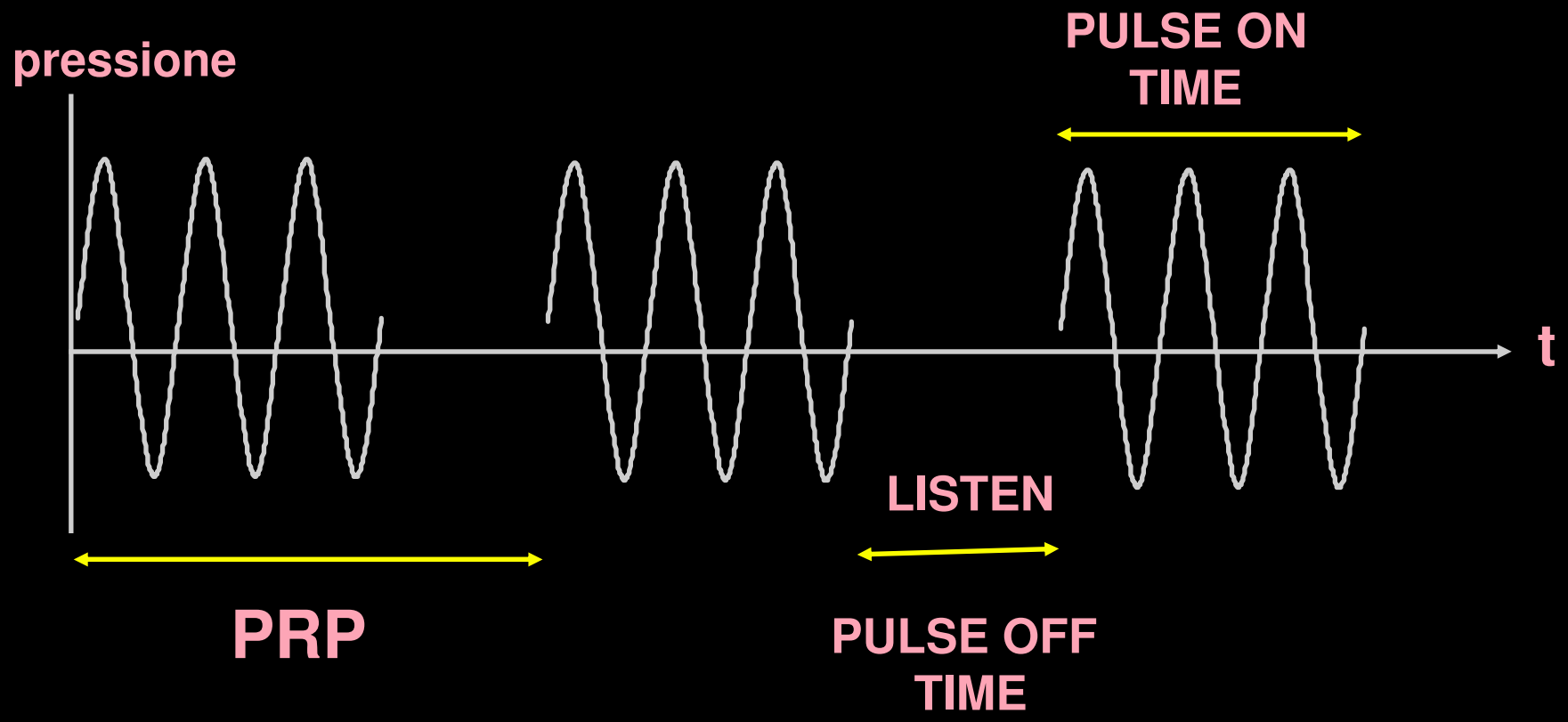
MATERIAL	FREQUENCY			
	1 MHz	2 MHz	5 MHz	10 MHz
AIW	0,25	0,06	0,01	-
WATER	1360	340	54	14
BLOOD	17	8,5	3	2
BONE	0,2	0,1	0,04	-
BRAIN	3,5	2	1	-
FAT	5	2,5	1	0,5
LIVER	3	1,5	0,5	-
MUSCLE	1,5	0,75	0,3	0,15
TISSUE (AVG)	4,3	2,1	0,86	0,43

HVL in cm



$$I_r = I_i \cdot \alpha \qquad I_t = I_i - I_r = (1-\alpha)\, I_r$$

$$\alpha = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2$$



ON / OFF << 1%

$$PRF = \frac{1}{PRP} = \frac{c}{2d}$$

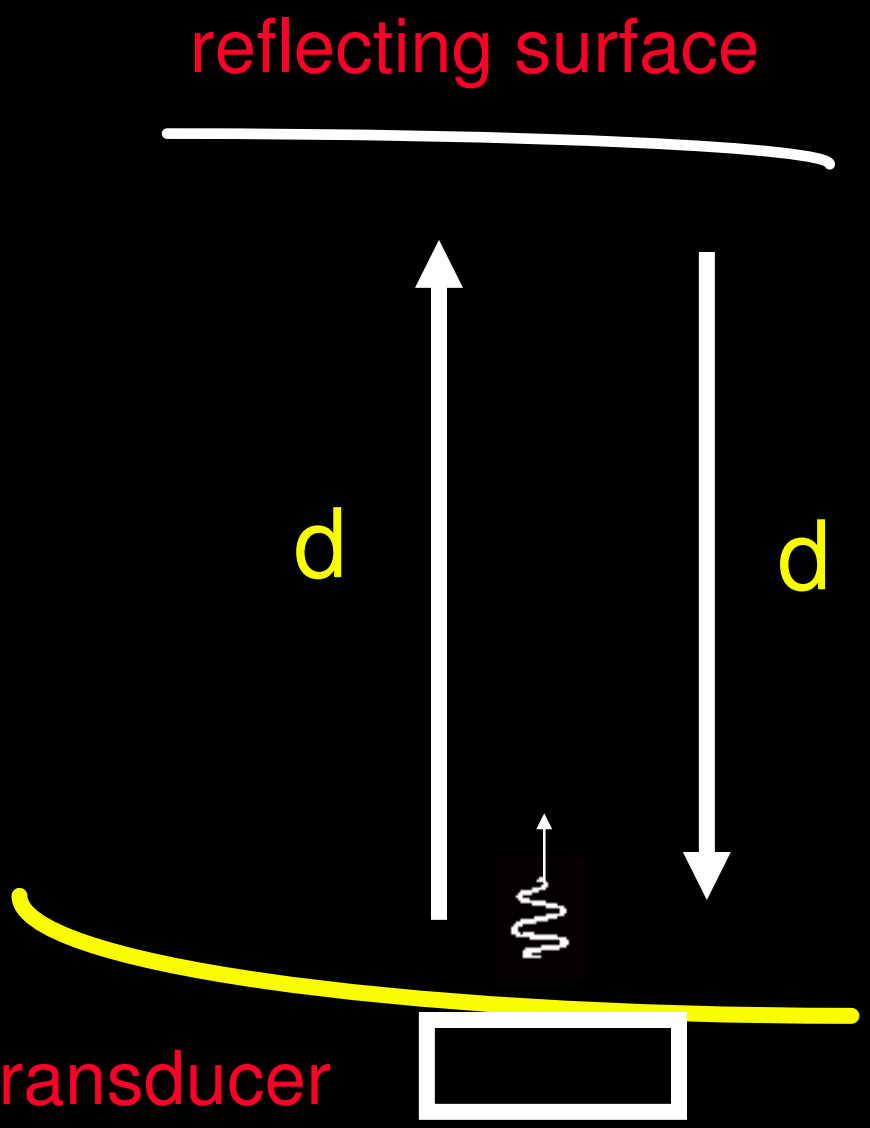
show

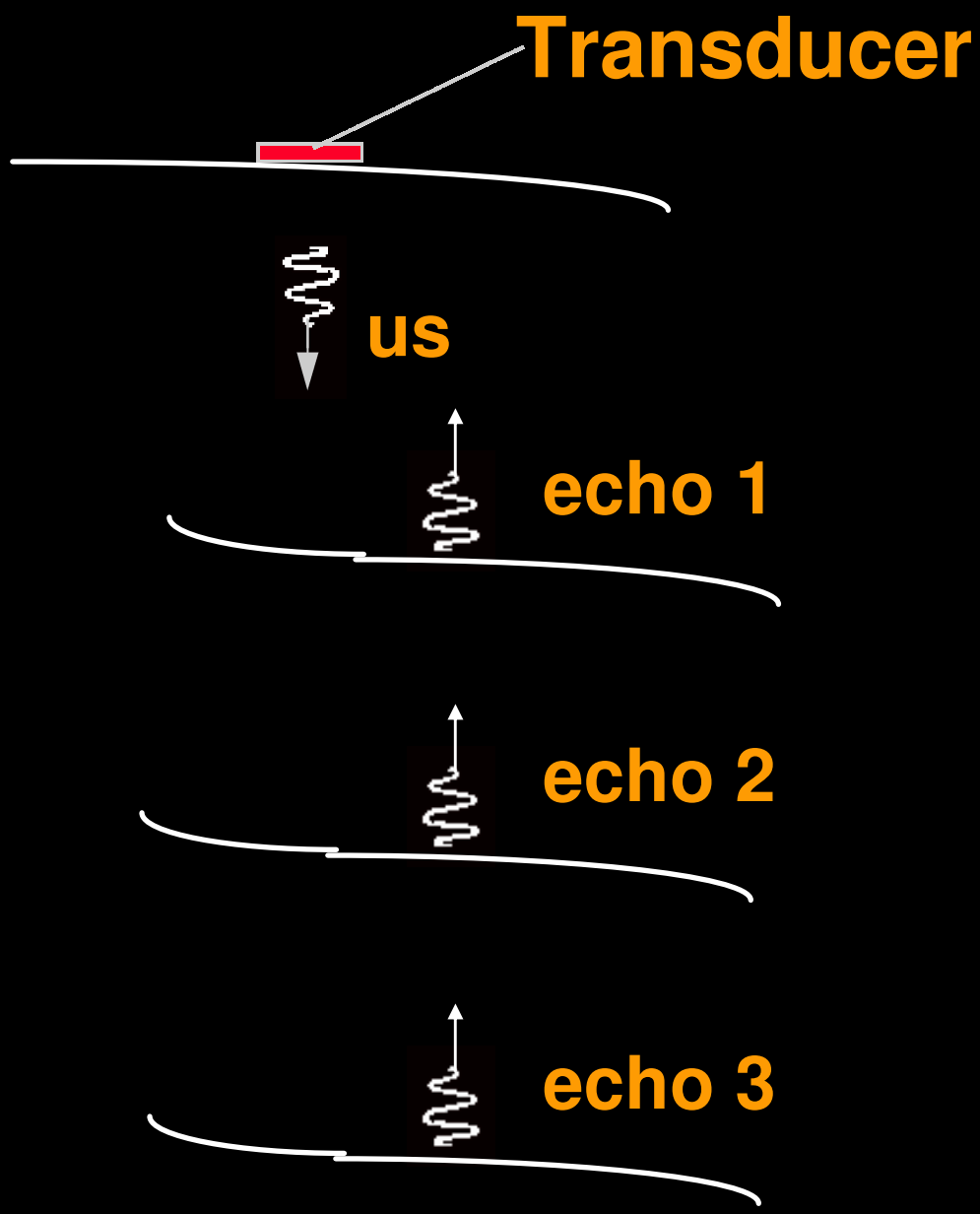
time=space / speed

$t = 2d / c$

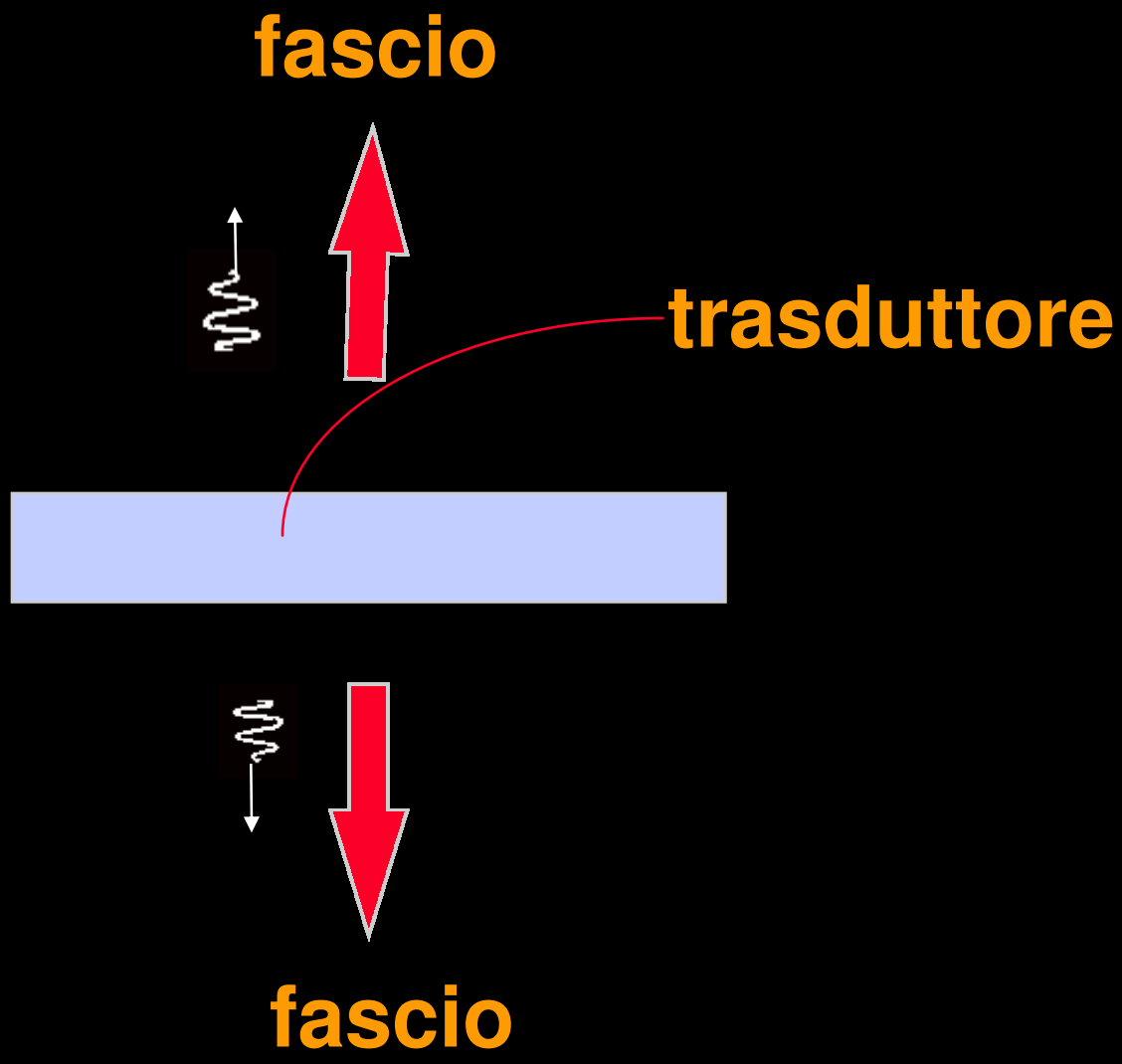
PRP min = $2d / c$

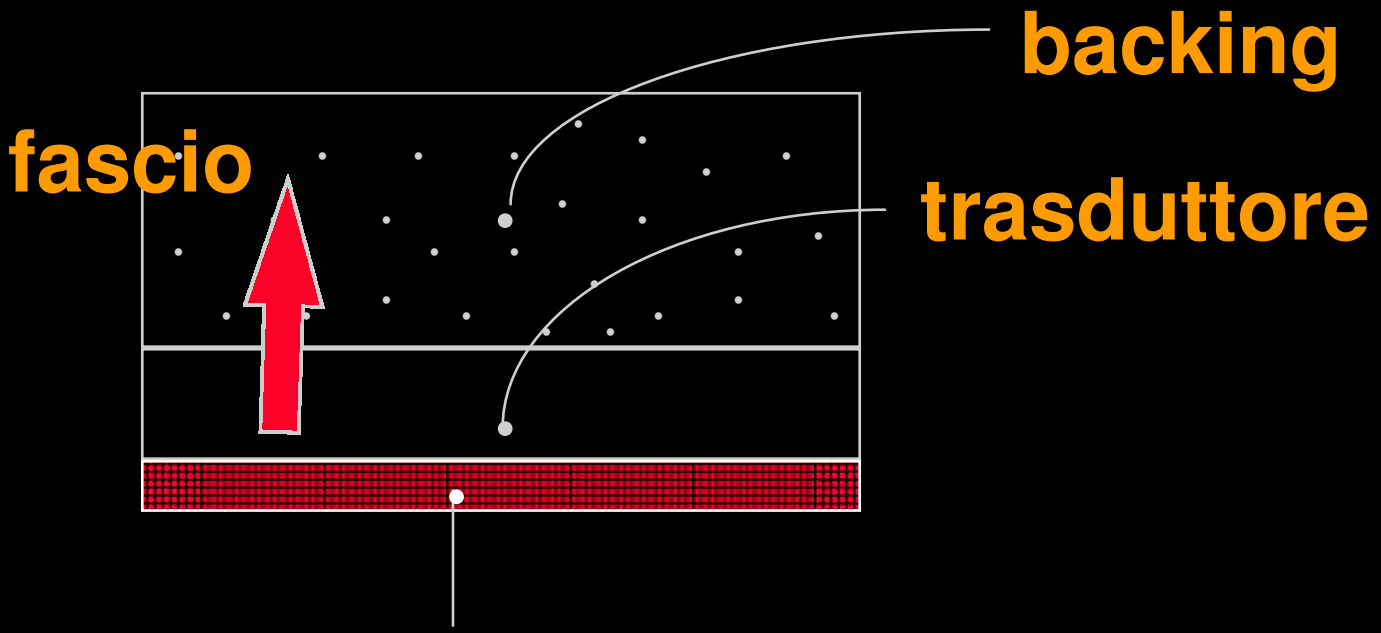
PRF max = $c / 2d$




Transducer
us
echo 1
echo 2
echo 3

show

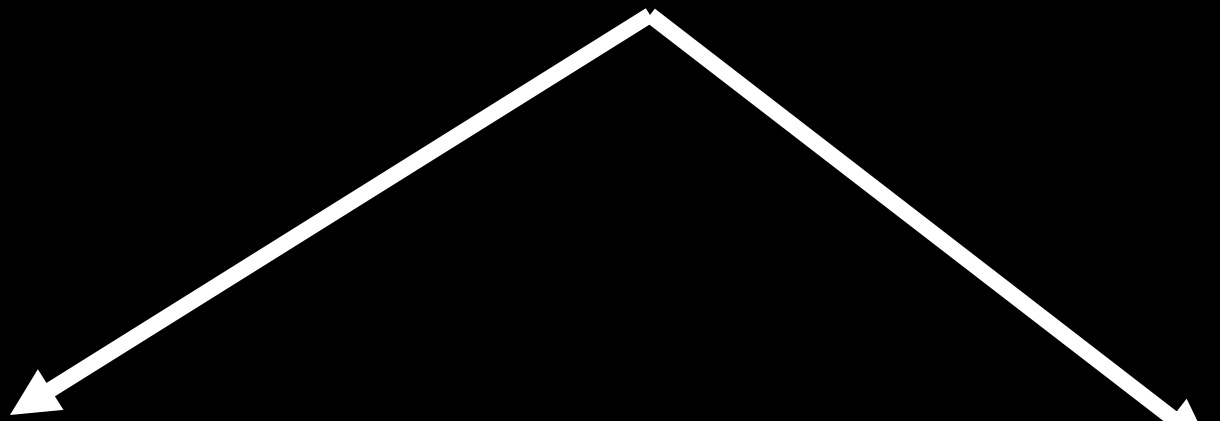

fascio
trasduttore
fascio



fascio

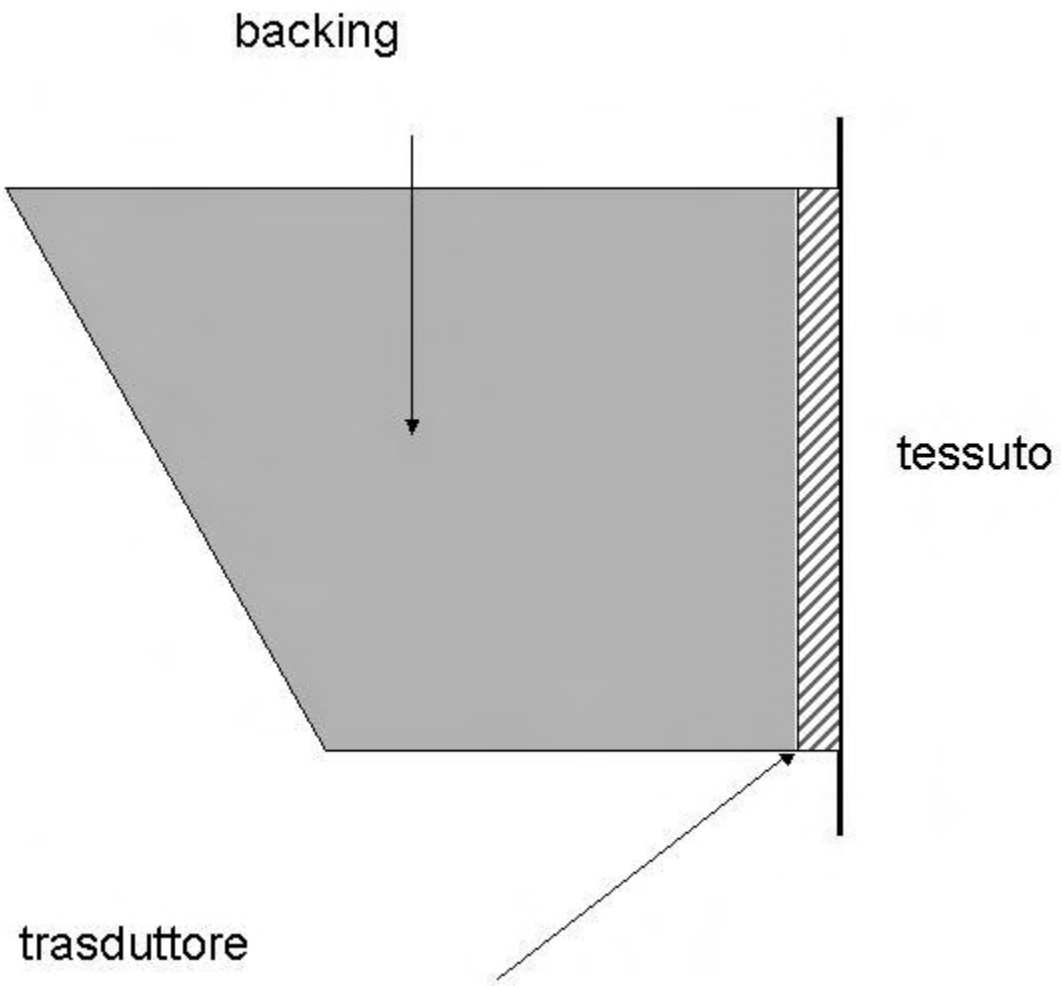
Stesso trasduttore per emettere US e ricevere gli echi

Damping

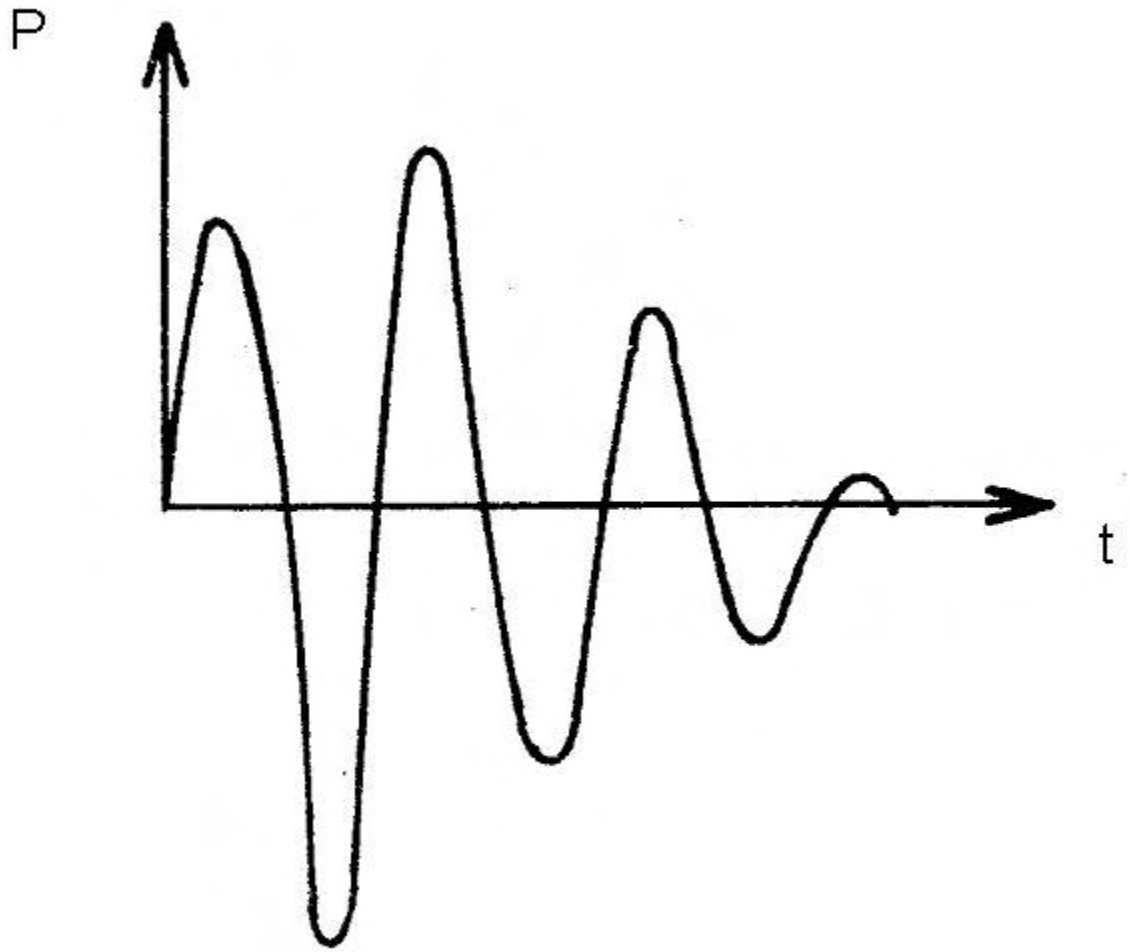


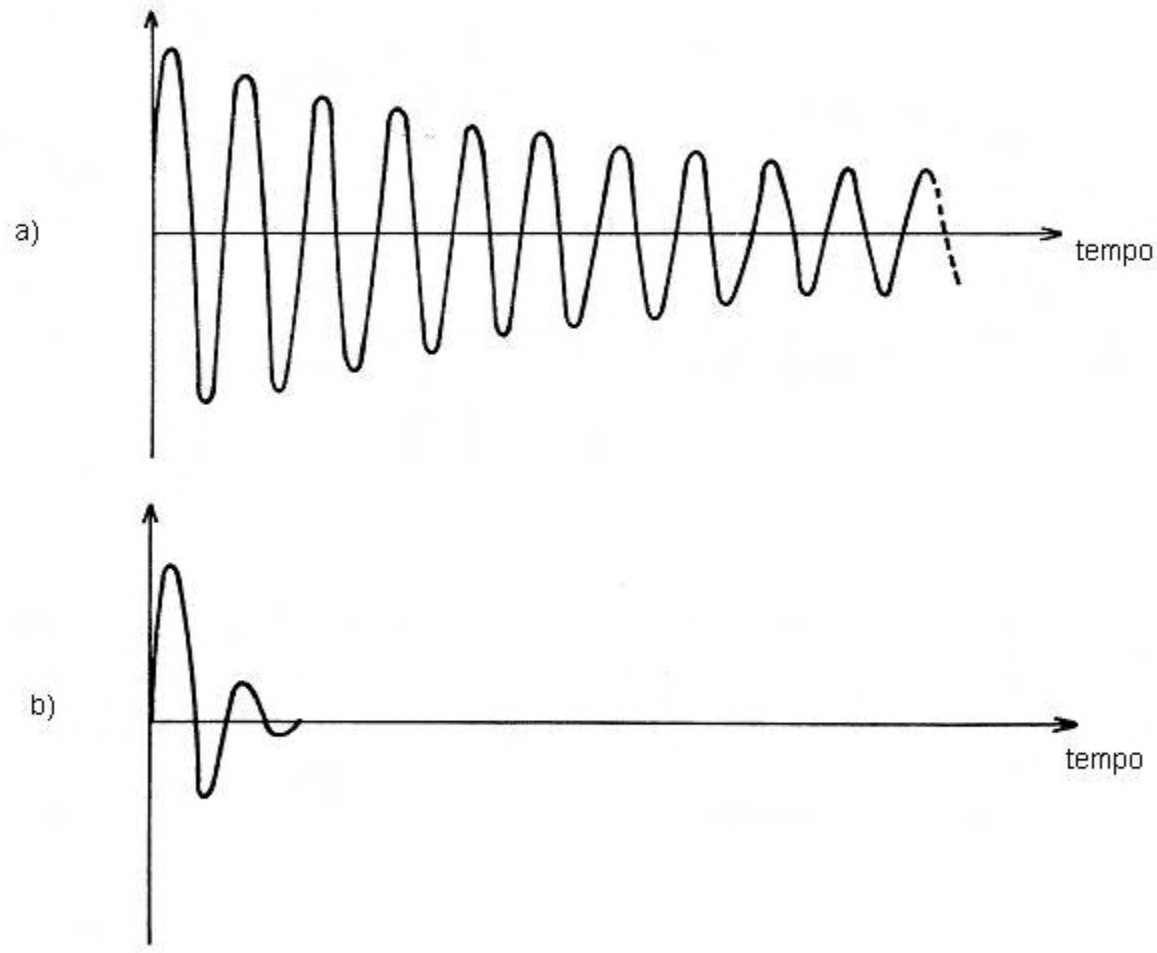
dynamic

by backing


backing
tessuto
trasduttore

Dynamic damping


P
t


a)
tempo
b)
tempo

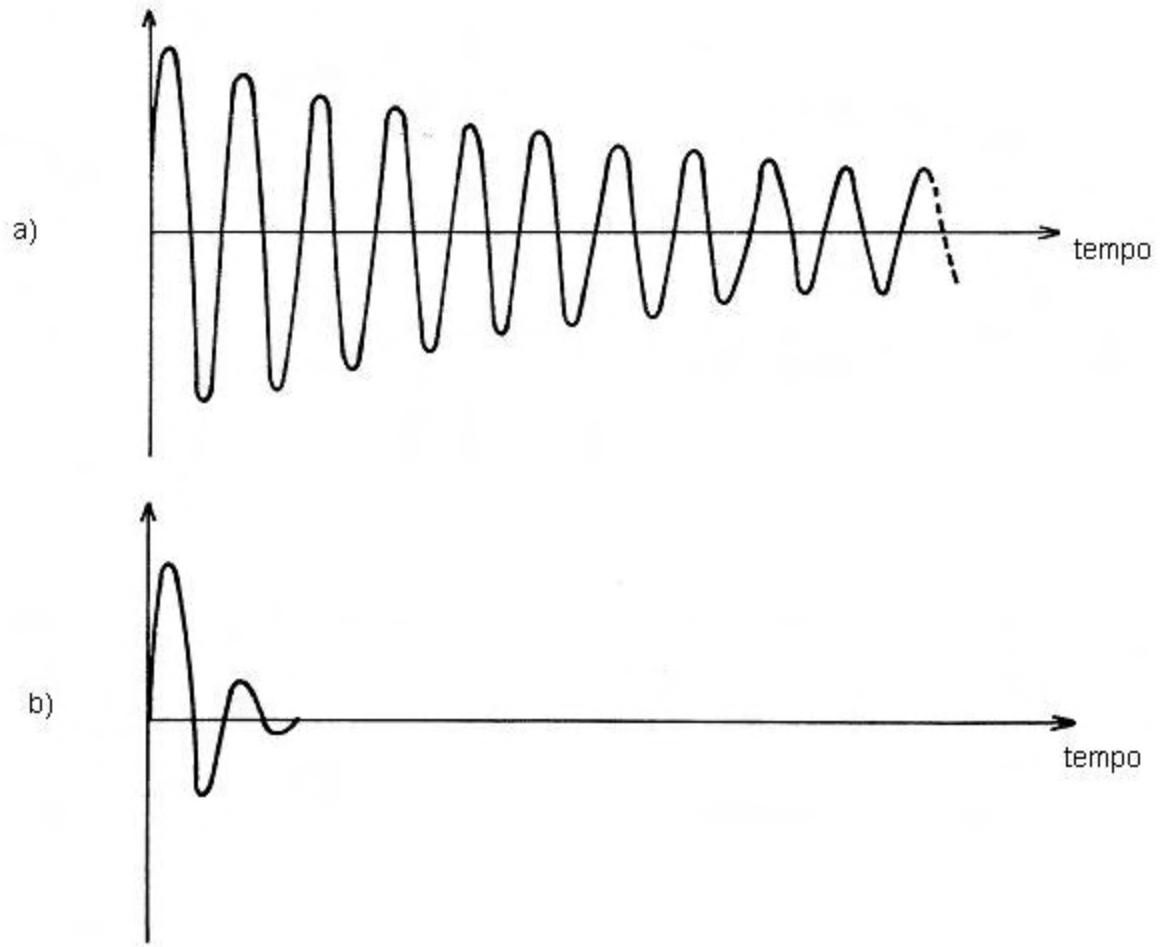
Q=mechanical coefficient

$$Q = \frac{\text{Energy stored per cycle}}{\text{Energy lost per cycle}}$$

$$Q = \frac{\text{Center frequency}}{\text{bandwidth}}$$

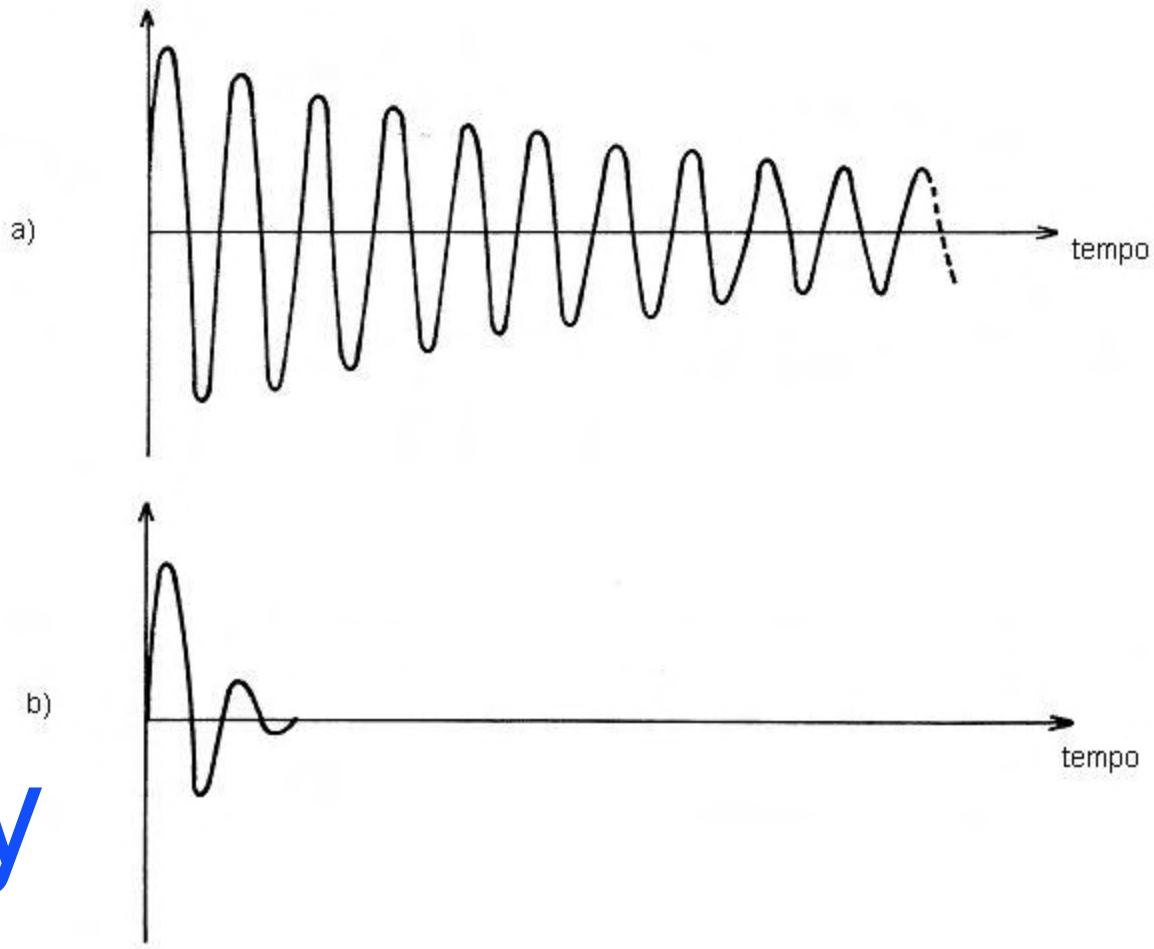
High Q

Low Q

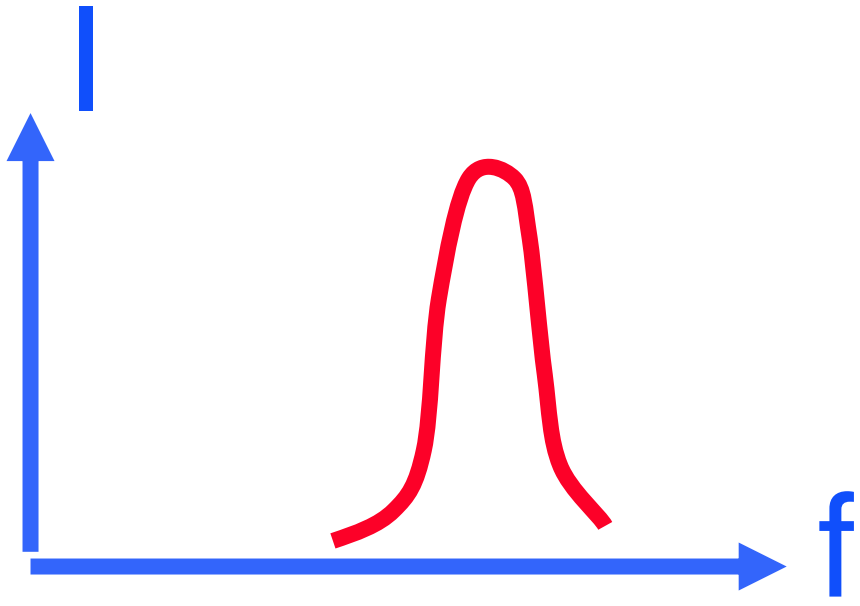


Narrow fequency band

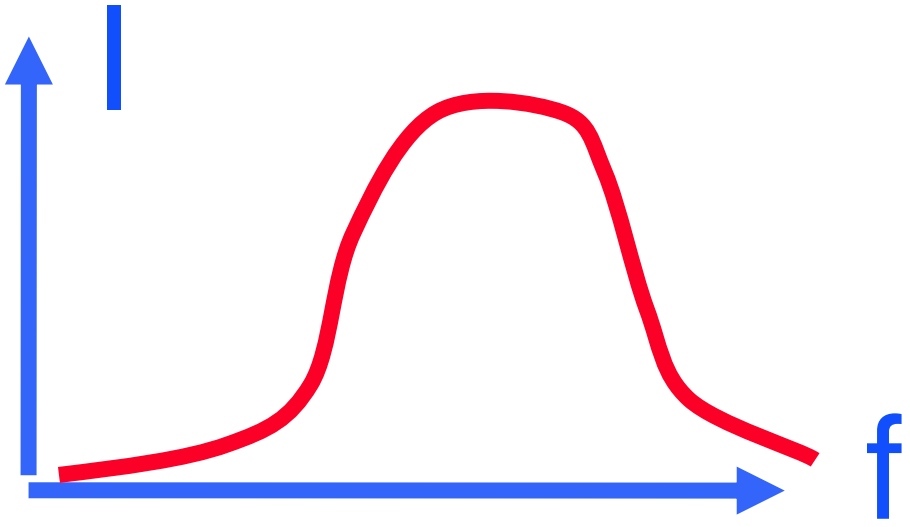
Wide frequency band

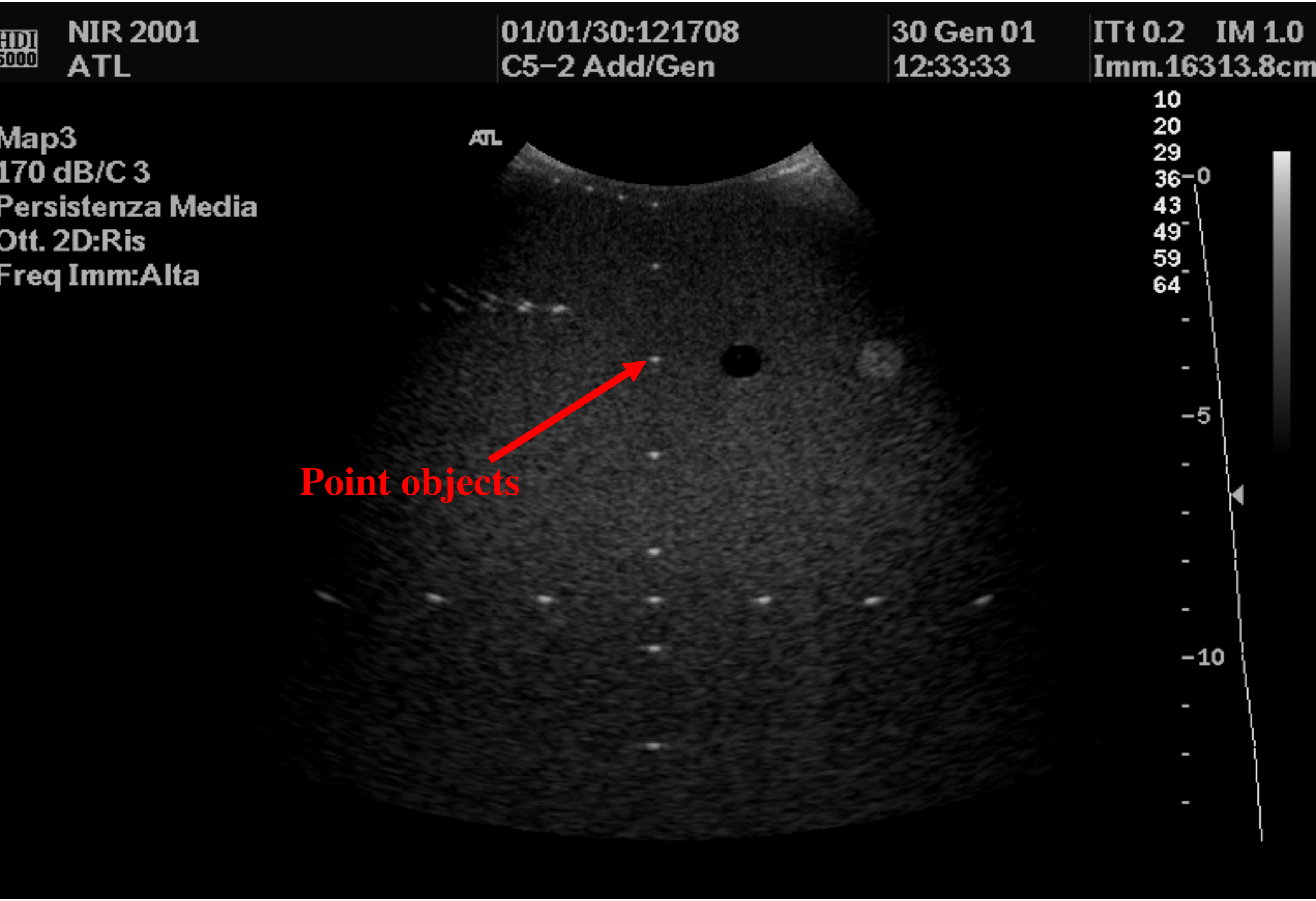


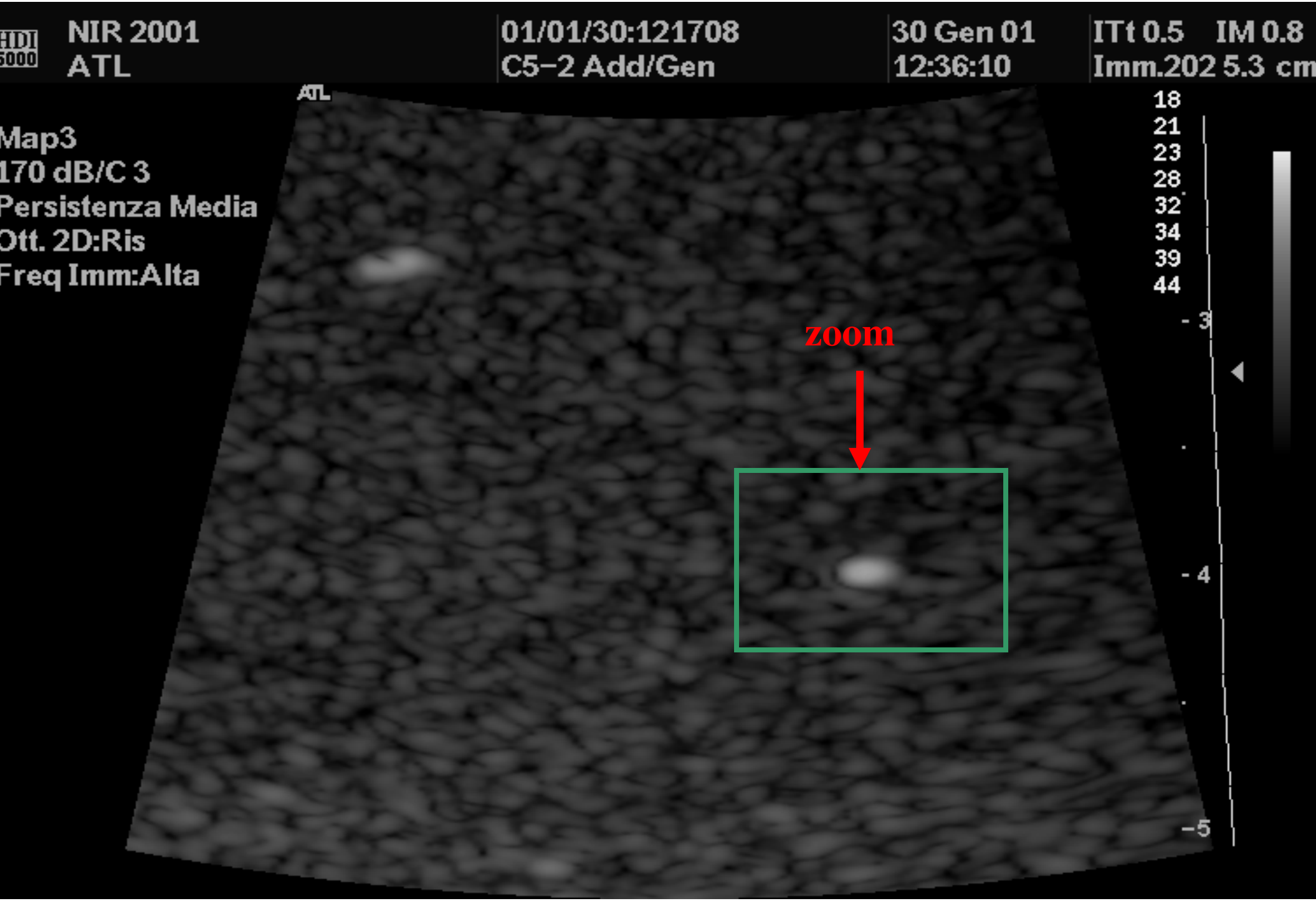
Narrow fequency band

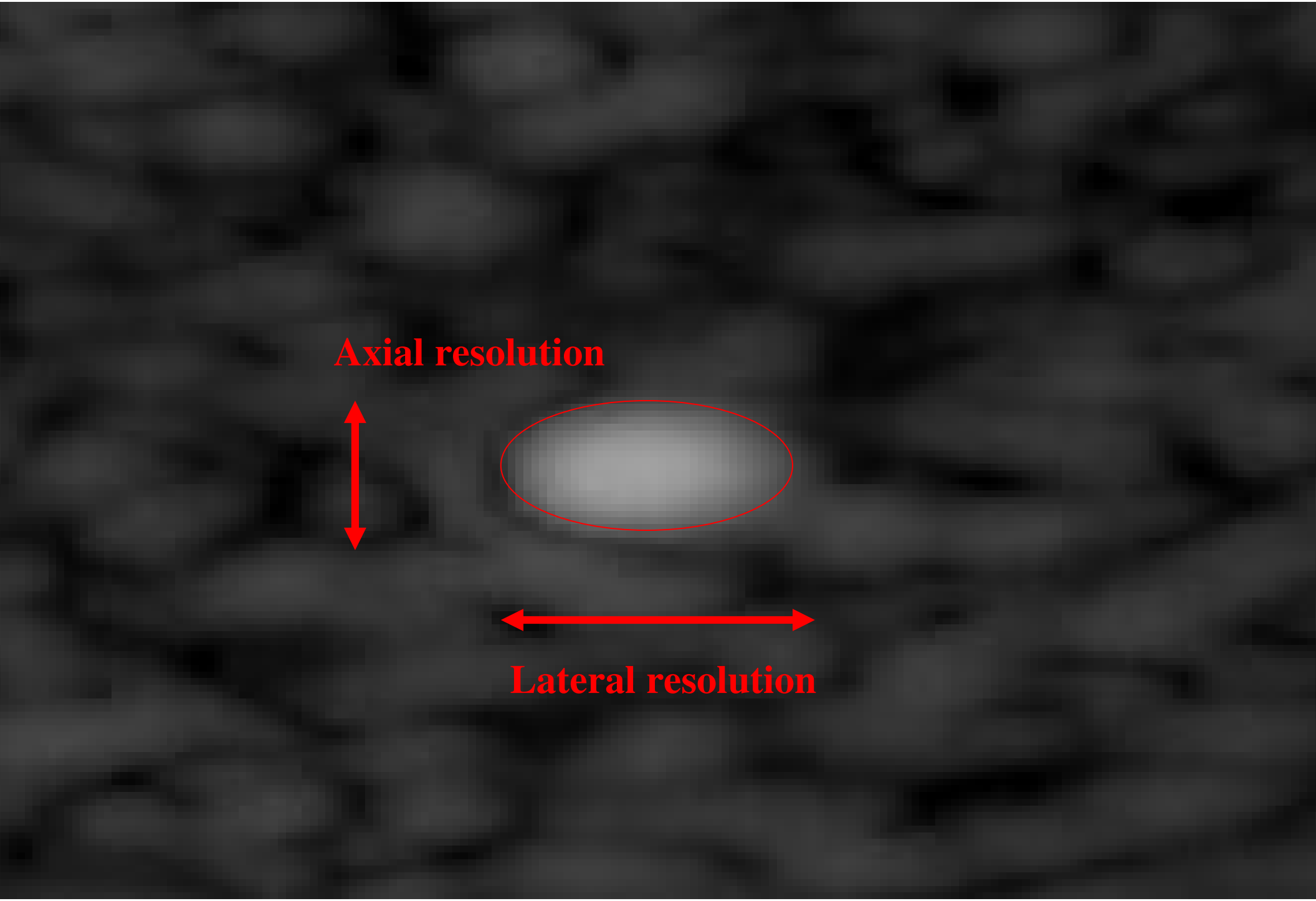


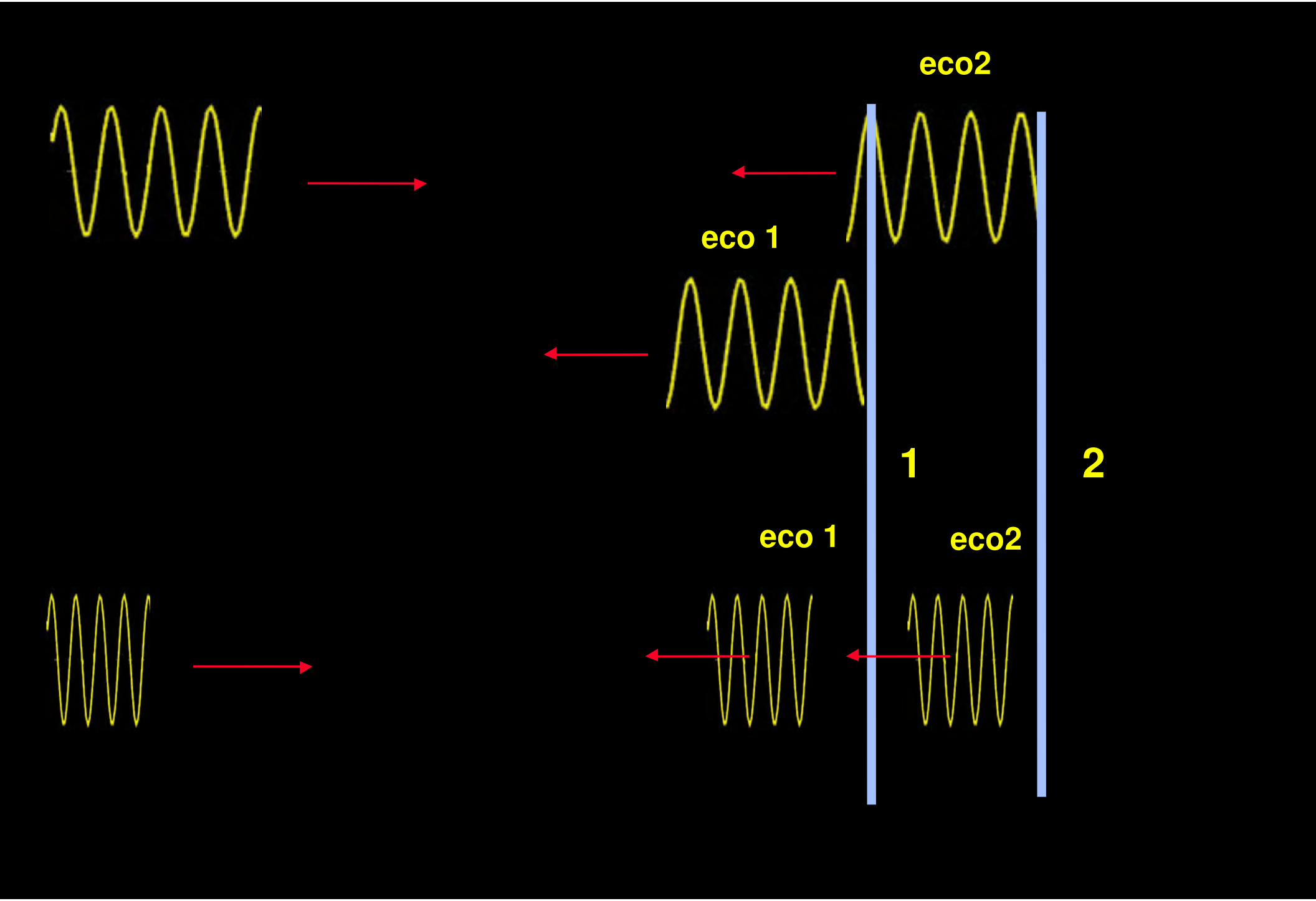
Wide frequency band




HDI 5000
NIR 2001
ATL
01/01/30:121708
C5-2 Add/Gen
30 Gen 01
12:33:33
ITt 0.2 IM 1.0
Imm.16313.8cm
Map3
170 dB/C 3
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
ATL
10
20
29
36
43
49
59
64
0
-5
-10
Point objects

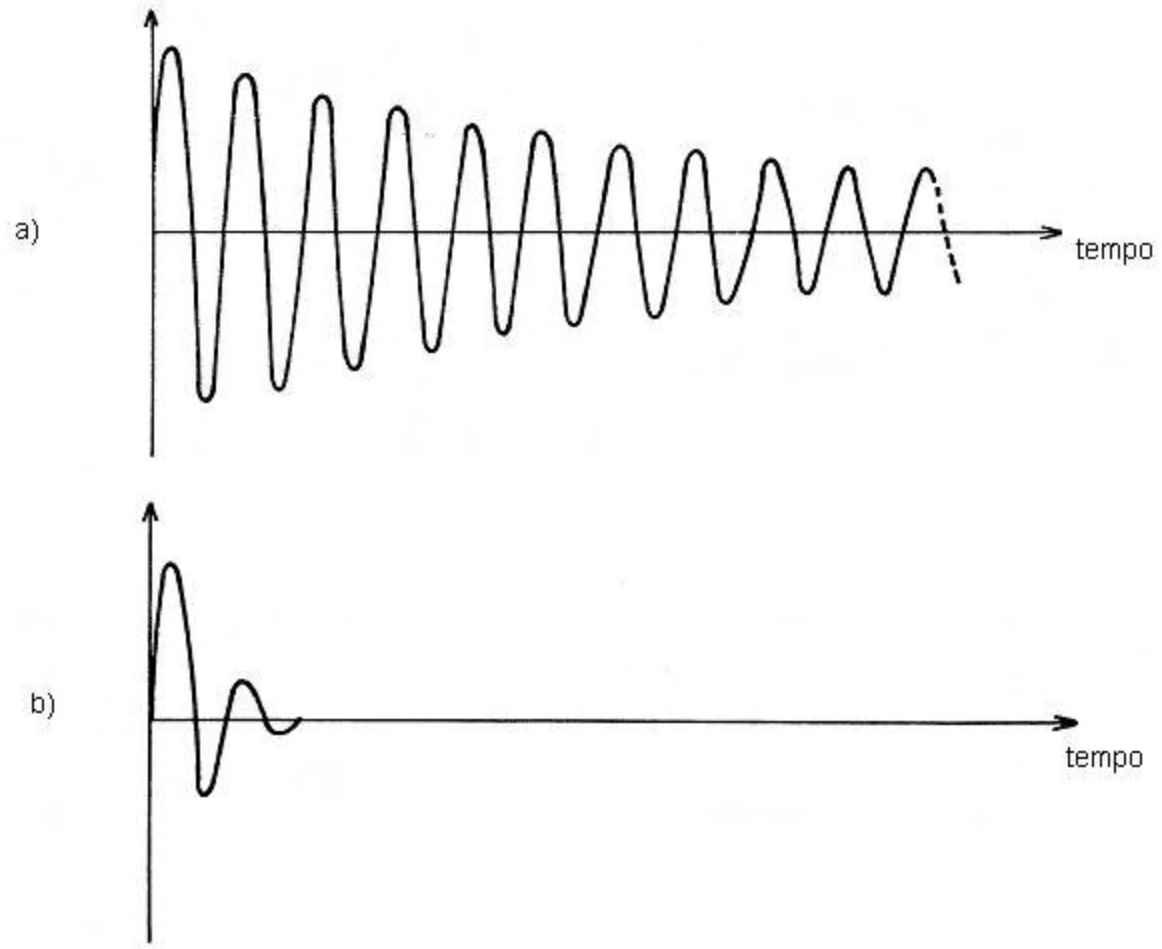

HDI 5000
NIR 2001
ATL
01/01/30:121708
C5-2 Add/Gen
30 Gen 01
12:36:10
ITt 0.5 IM 0.8
Imm.202 5.3 cm
ATL
Map3
170 dB/C 3
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
zoom
18
21
23
28
32
34
39
44
3
4
5

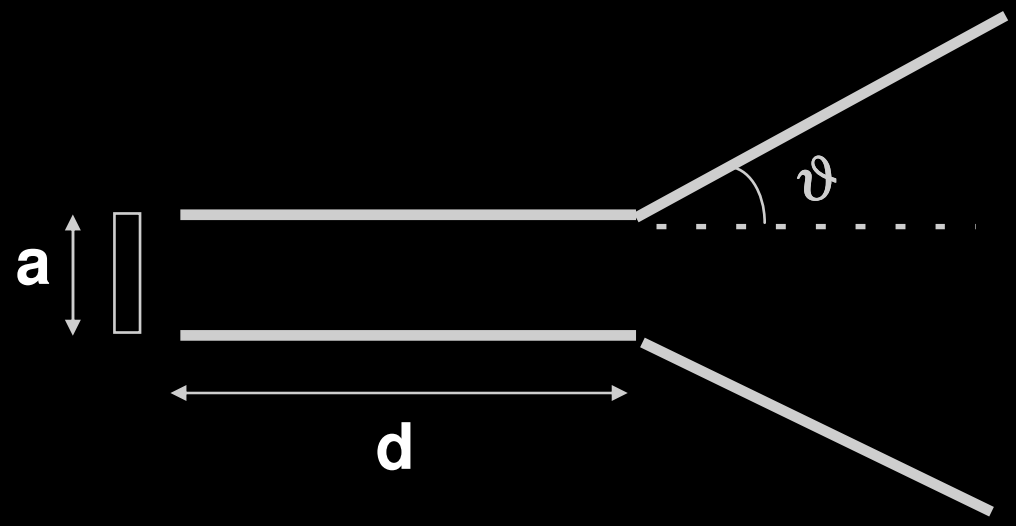

Axial resolution
Lateral resolution


eco2
eco 1
1
2
eco 1
eco2

Poor
Axial SR

Good
Axial SR



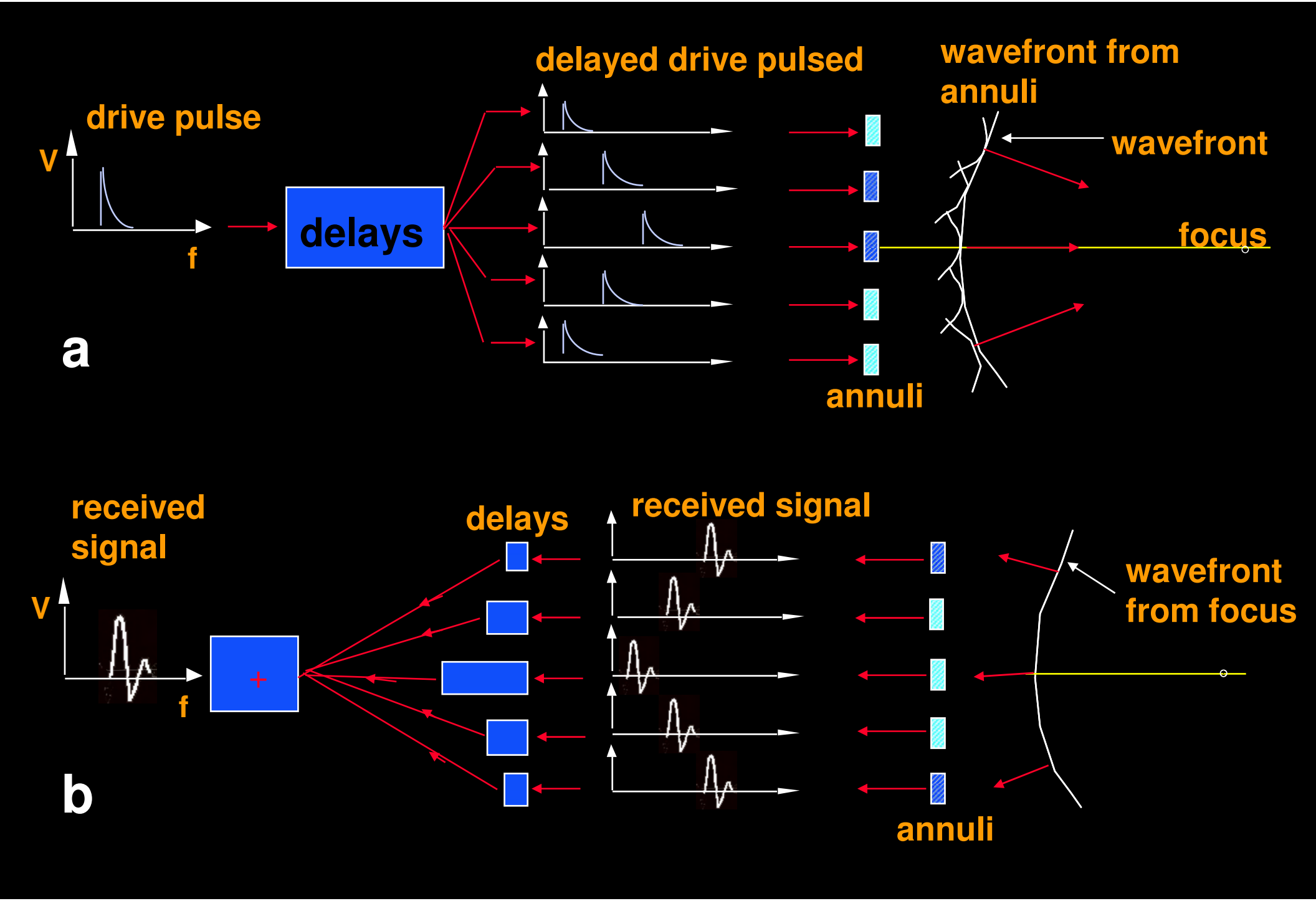


Campo vicino

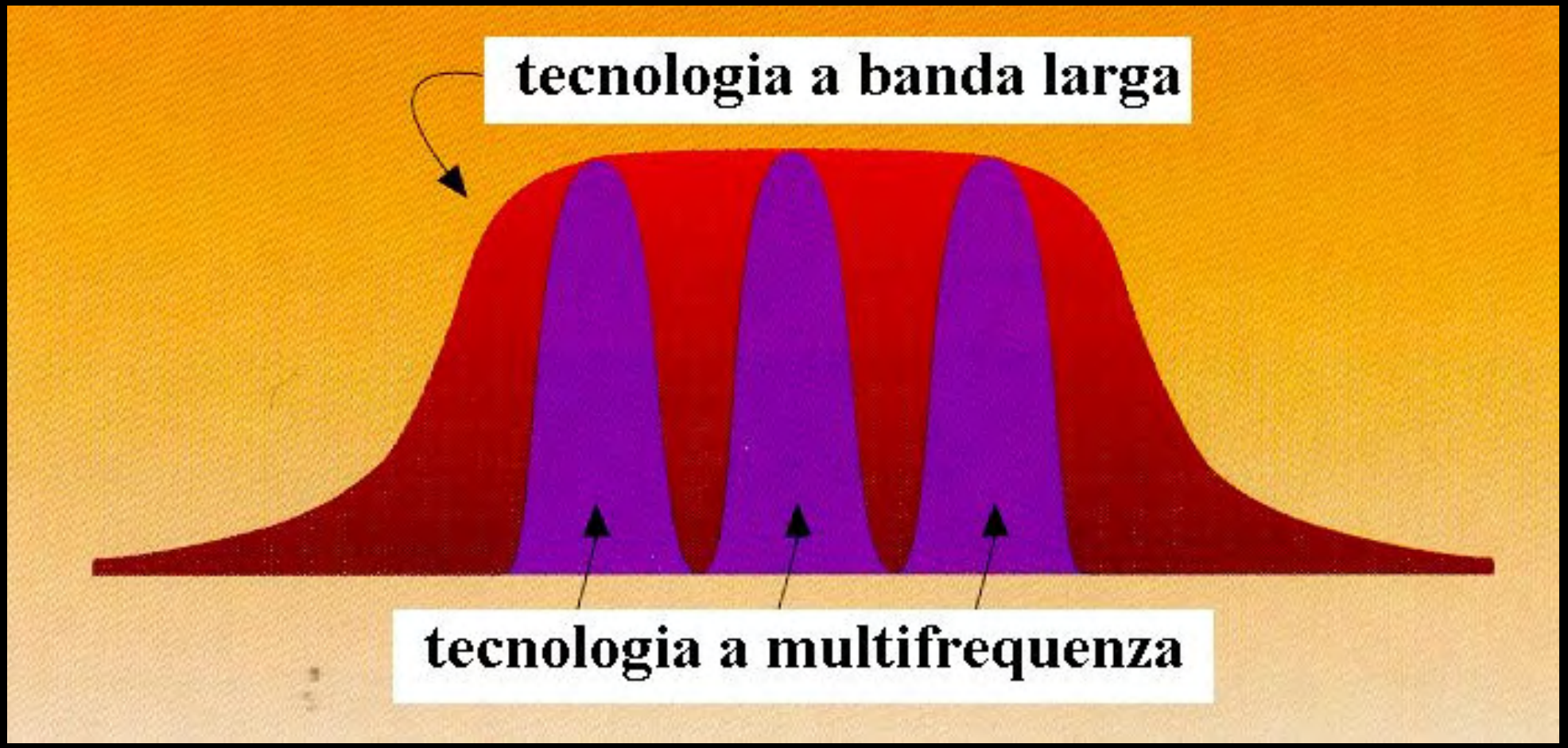
Campo lontano

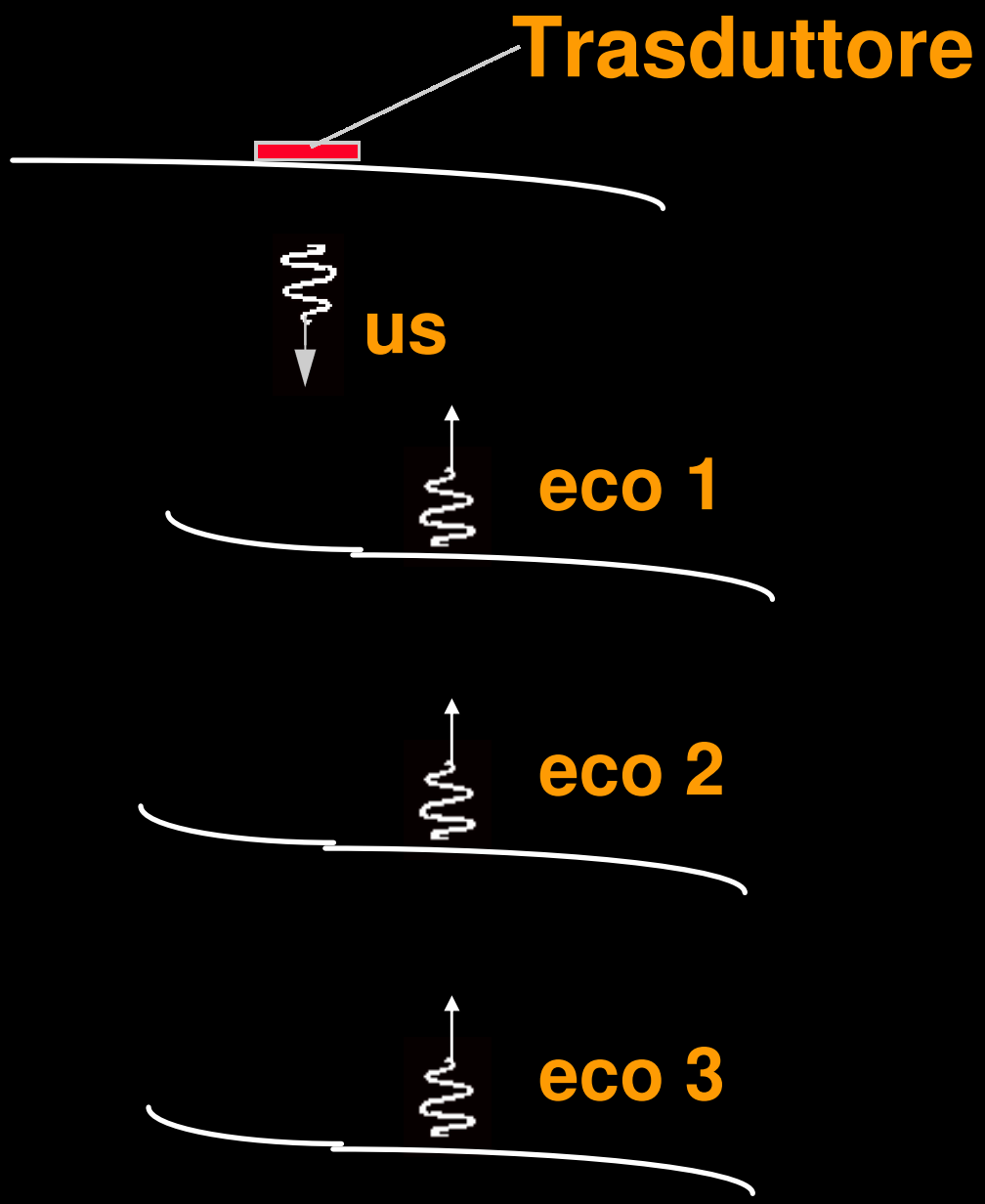
$$d = \frac{a^2}{4\lambda}$$

$$\sin\vartheta = \frac{0{,}6\lambda}{\frac{1}{2}a}$$


drive pulse
V
f
delays
delayed drive pulsed
annuli
wavefront from annuli
wavefront
focus
a
received signal
V
f
delays
received signal
annuli
wavefront from focus
b

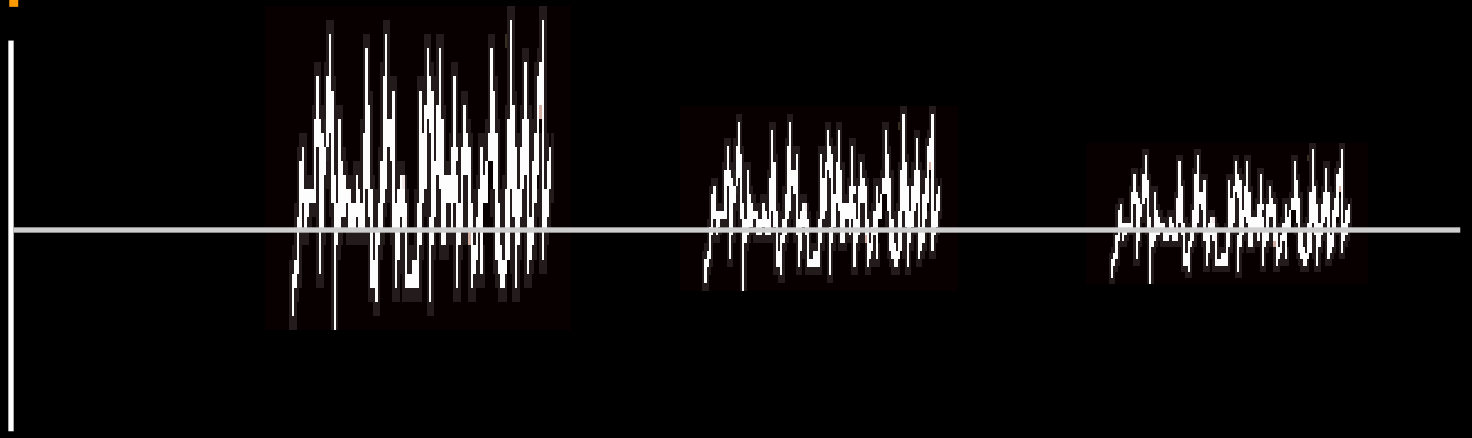
show


tecnologia a banda larga
tecnologia a multifrequenza


Trasduttore
us
eco 1
eco 2
eco 3

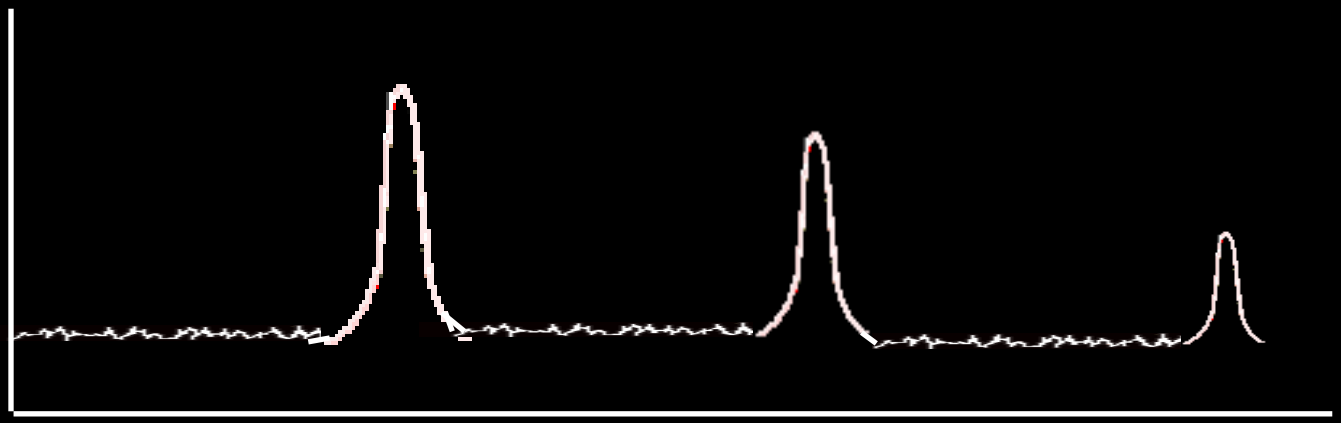
show

pressione

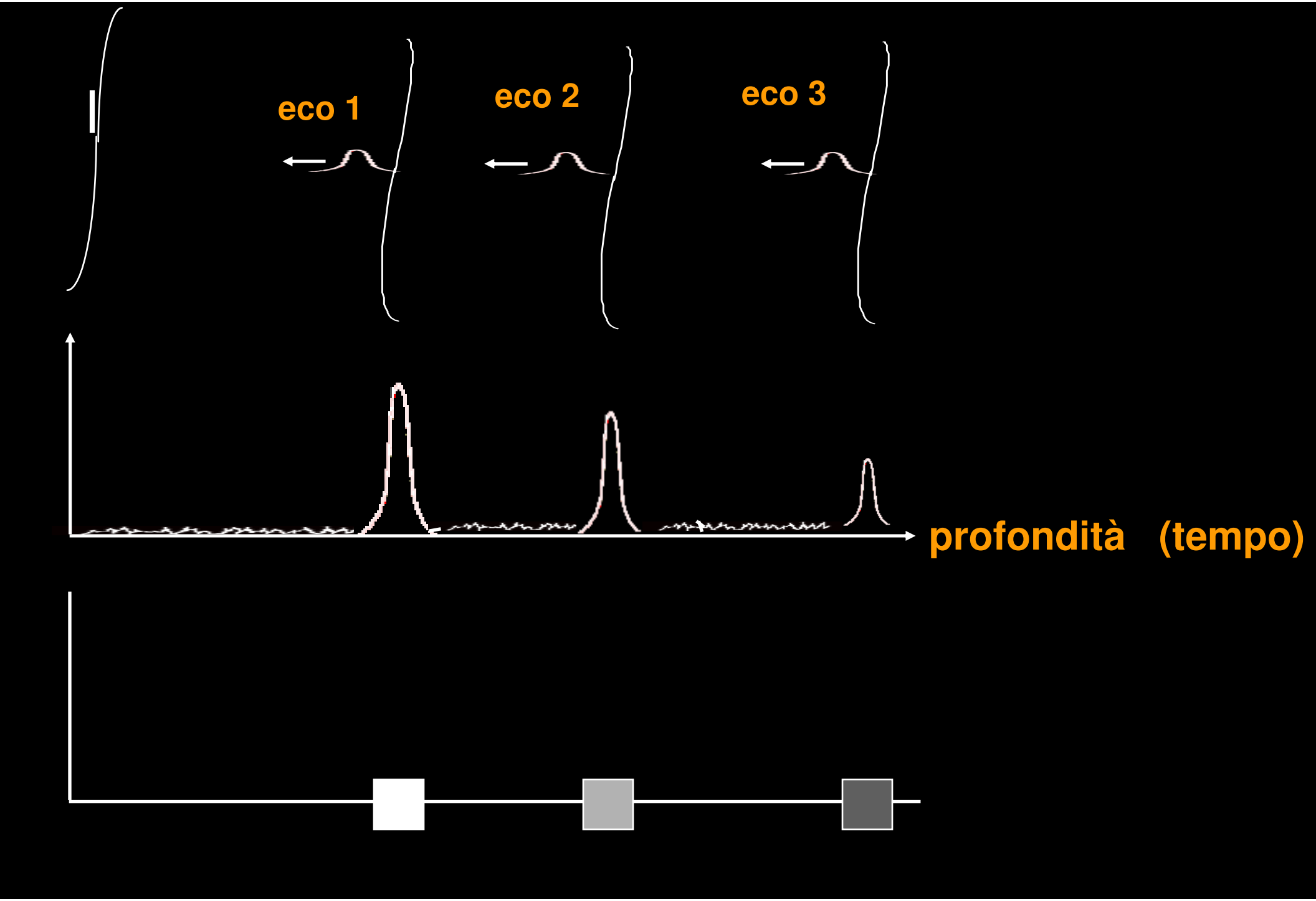


tempo

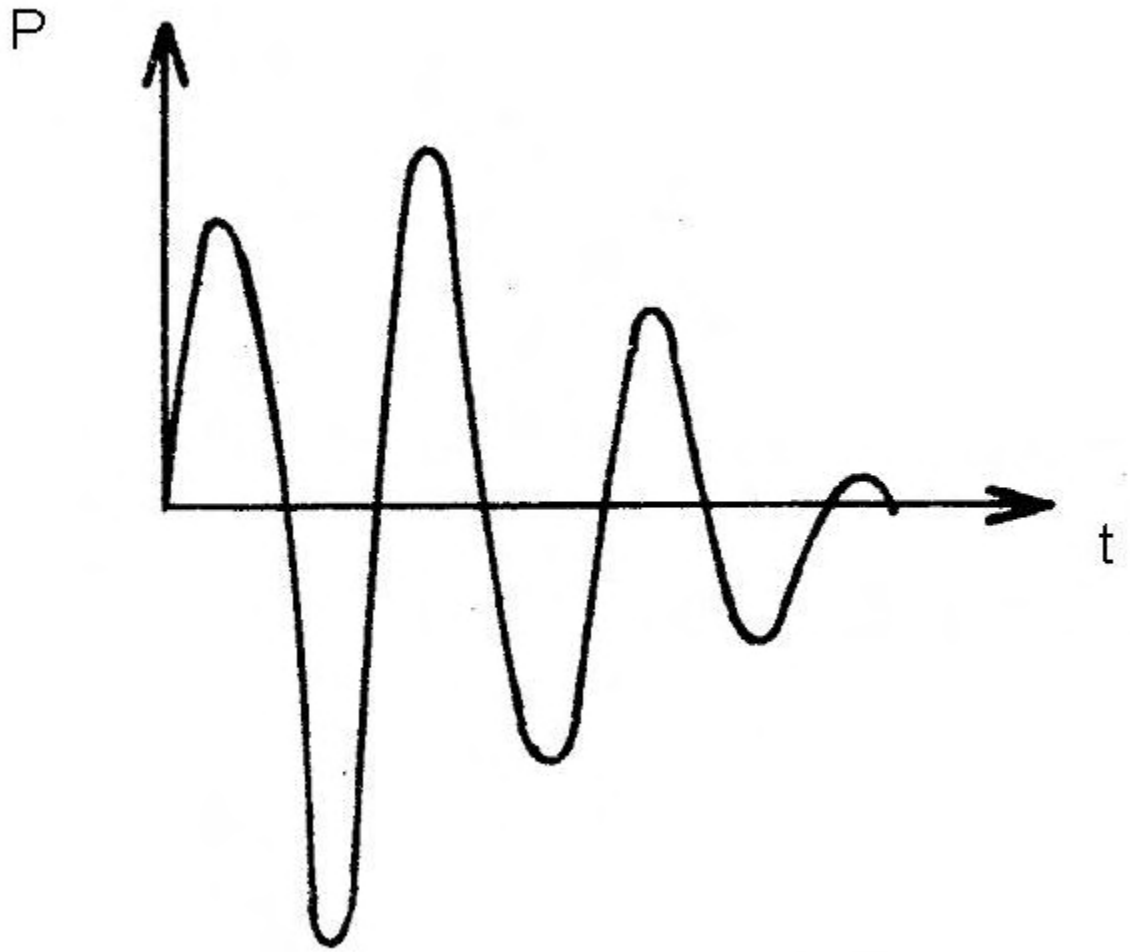
intensità dell'eco

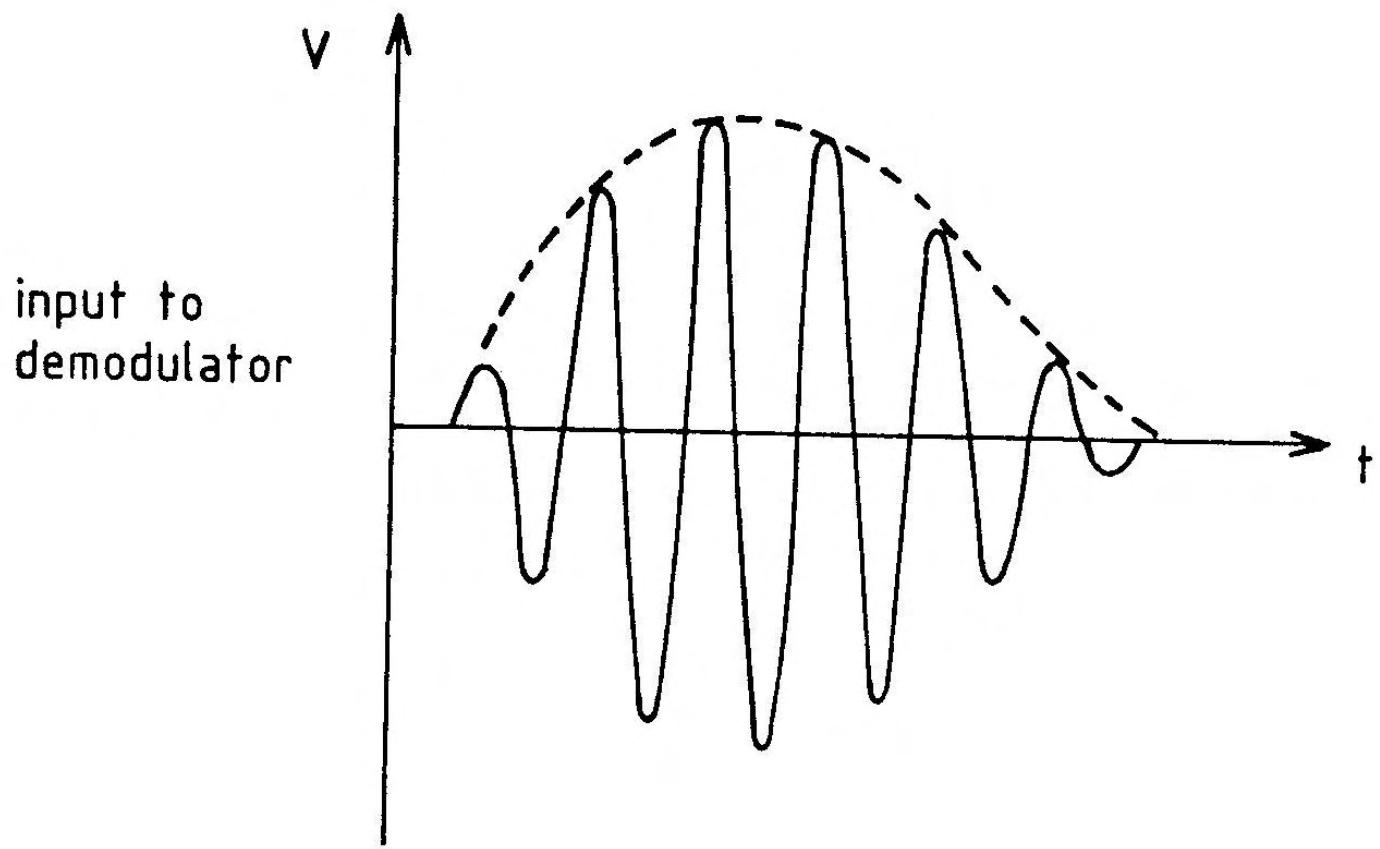


tempo ⇒ profondità


eco 1
eco 2
eco 3
profondità (tempo)

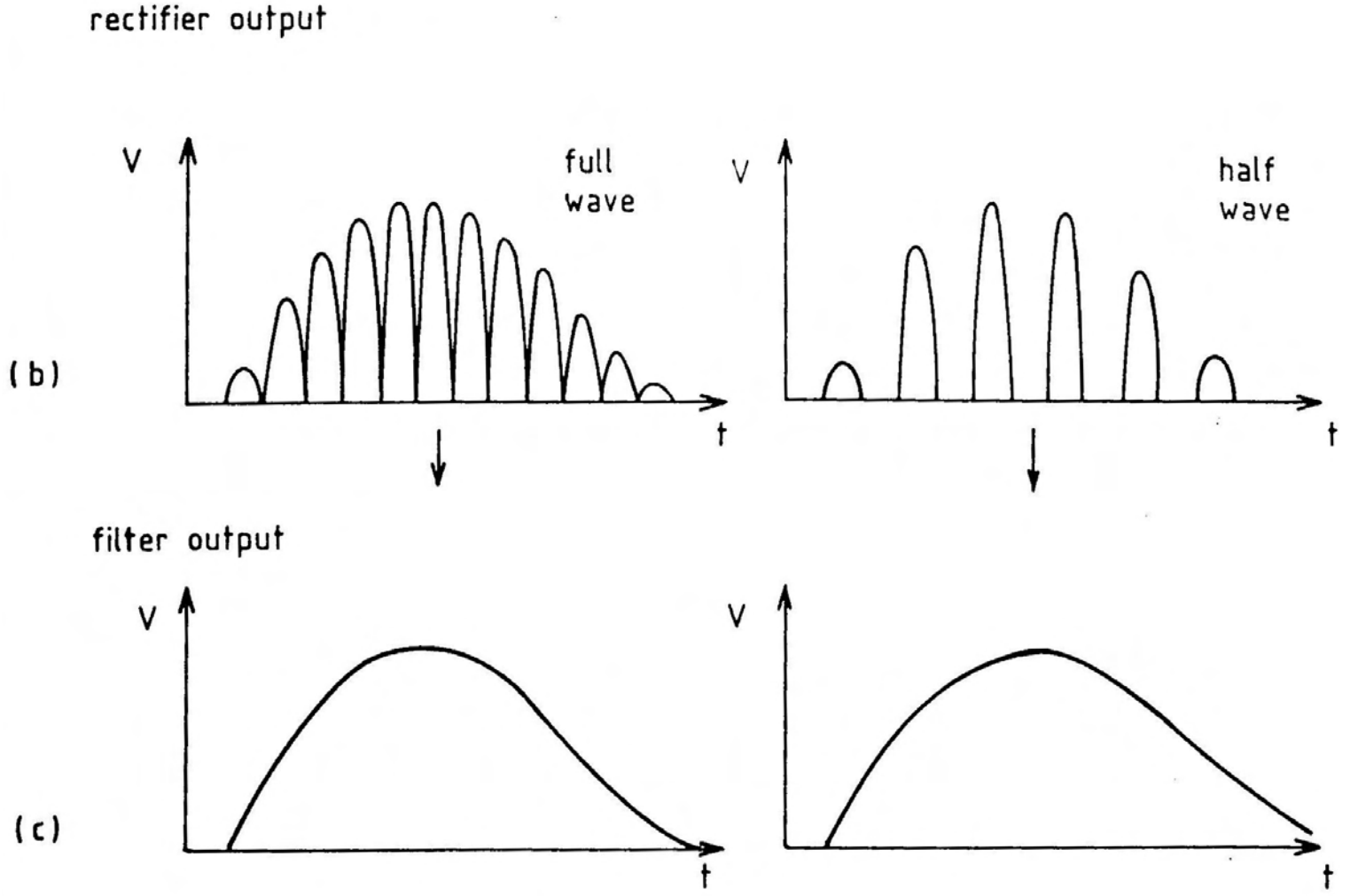
show


P
t

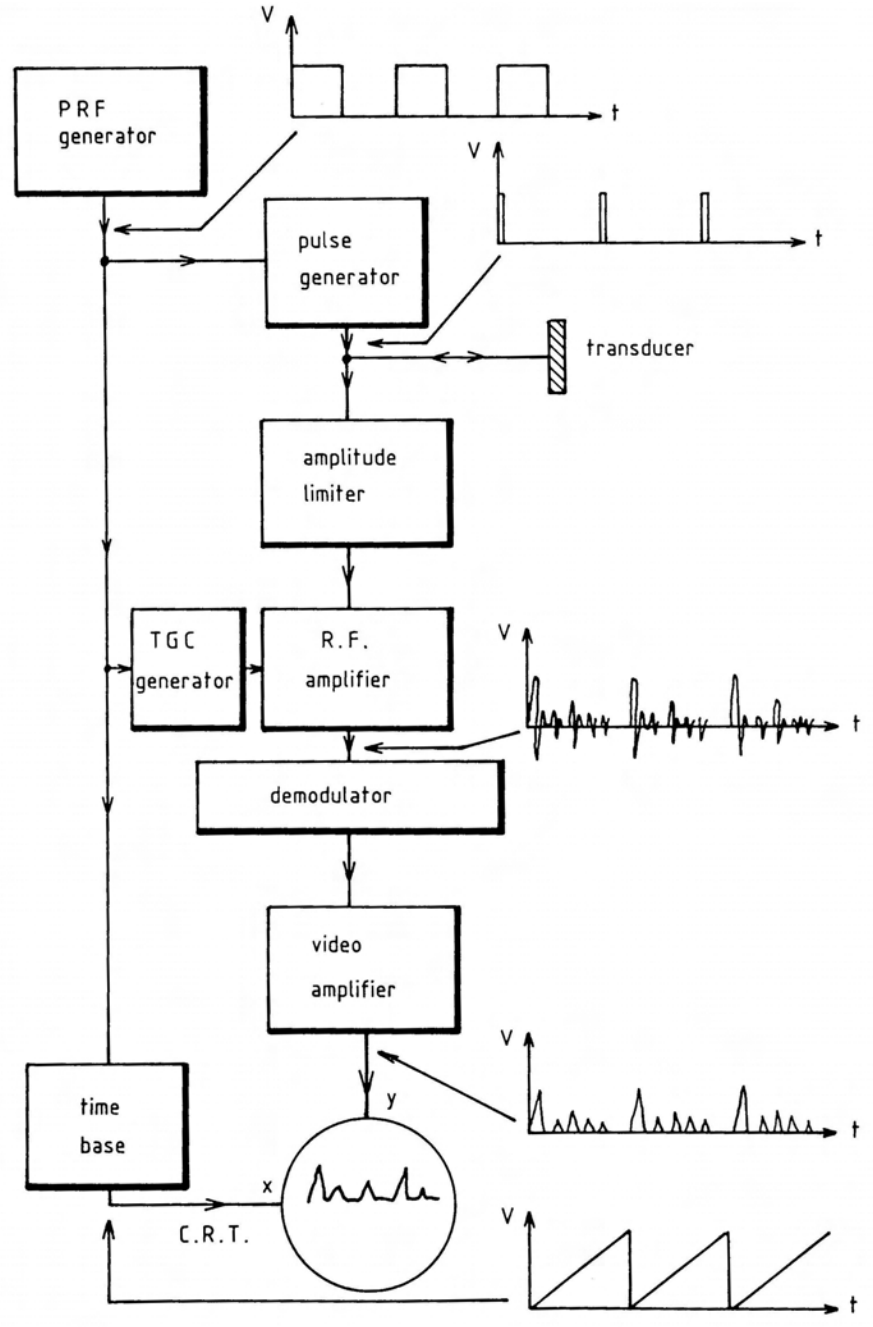


(a)

rectifier output



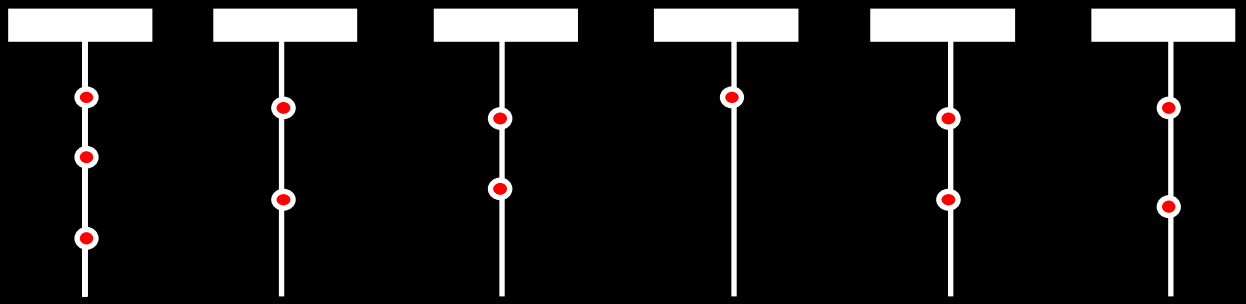
Full-wave and half-wave demodulation.

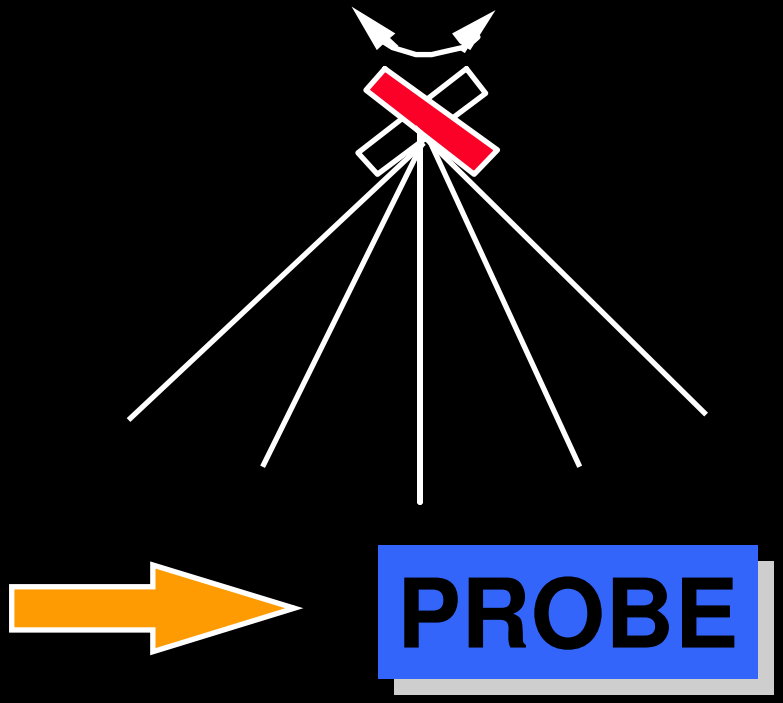


4 A-scan instrument block diagram.

Some transducers → 1 line

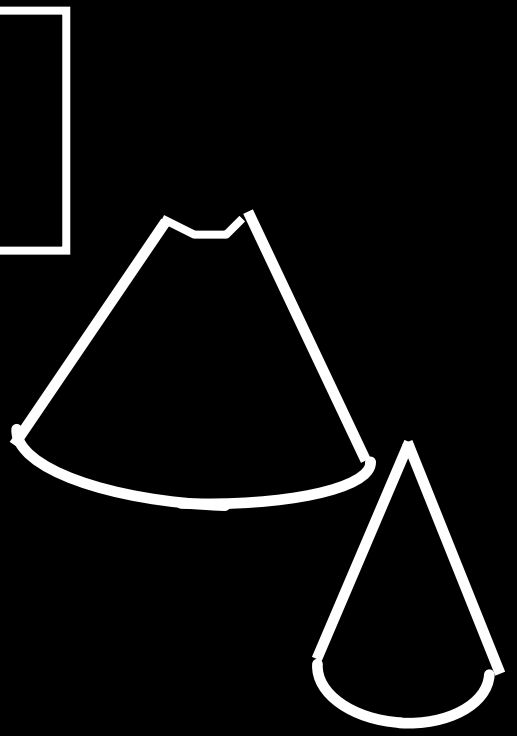
How to obtain several lines ?





PROBES

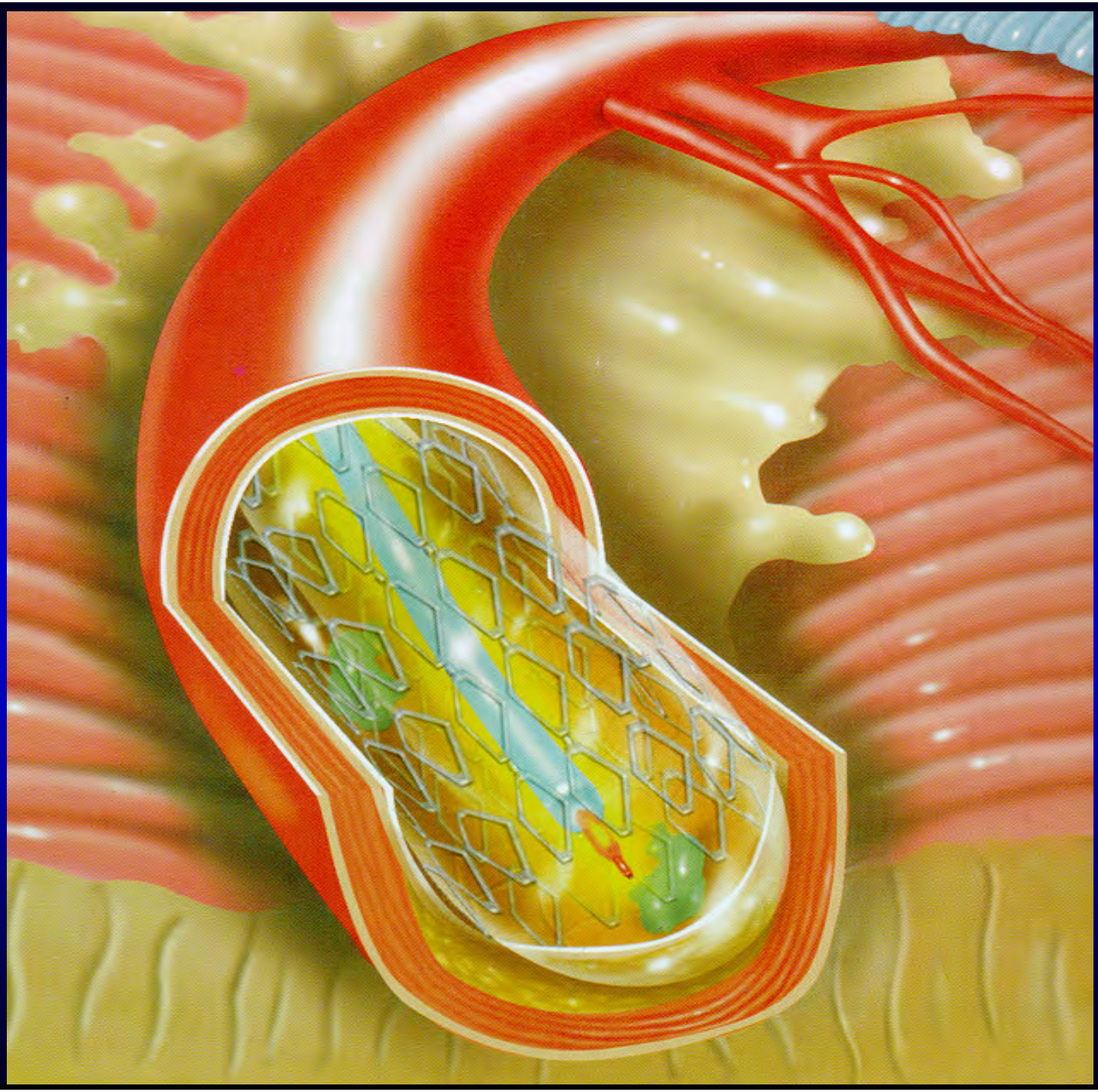
- linear
- convex
- sector
- special (EE, EL, 3D..)



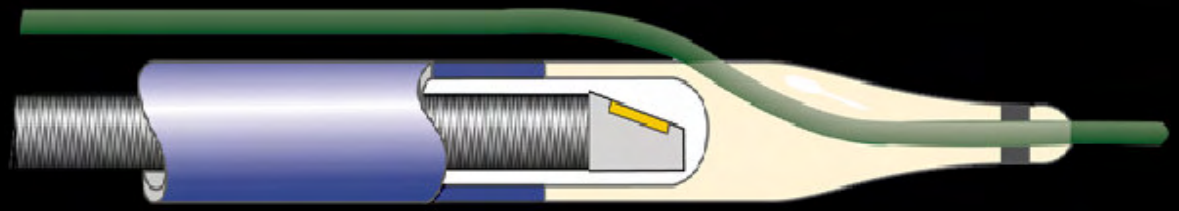
lineare

convex

sector



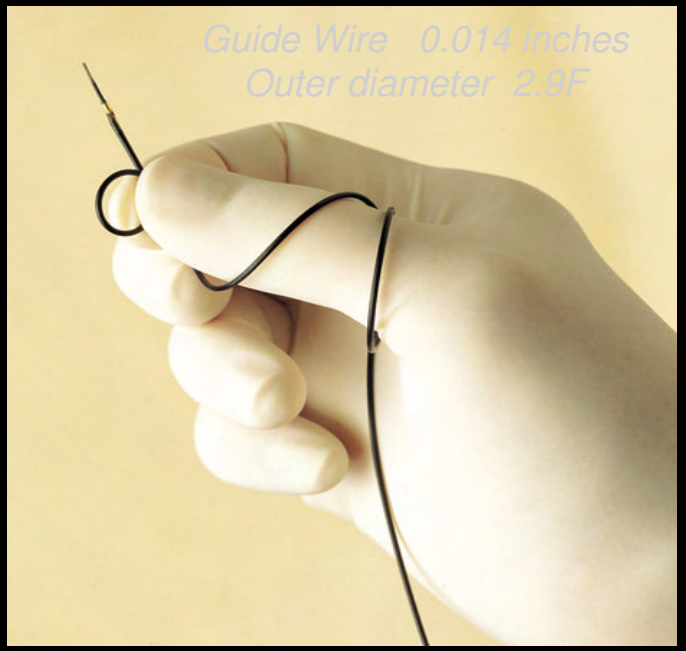
Mechanical Transducer



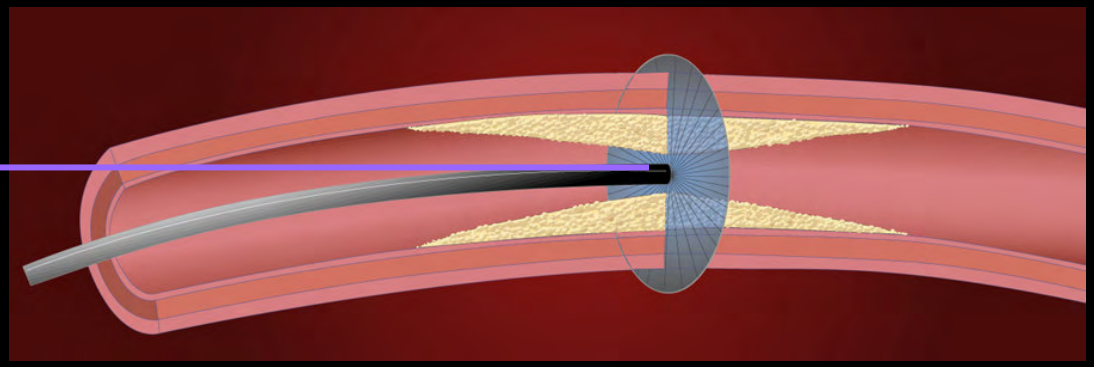
- Stiff rotating drive shaft
- External guidewire
- Mechanical design makes tracking difficult and limited
- Catheter vibration causes risk of arterial spasm

Solid-State Transducer

Visions® Five-64 F/X Intravascular Ultrasound Catheter

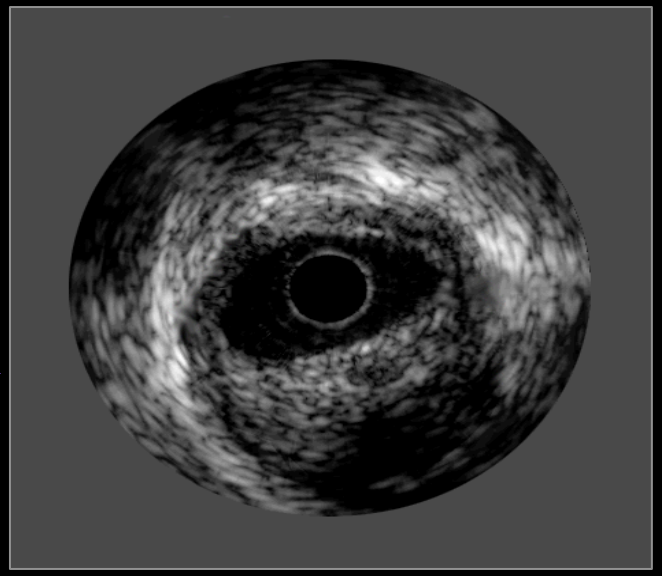


- No moving parts
- No rotating drive shaft
- central guidewire lumen
- Coaxial design enhances trackability and pushability

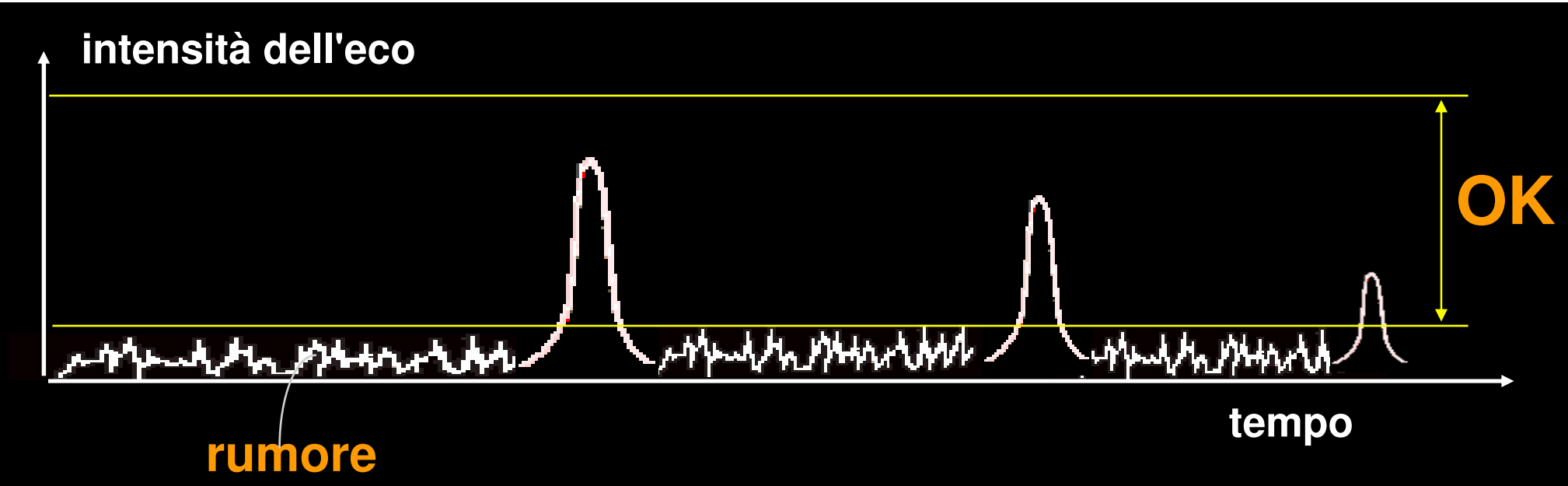


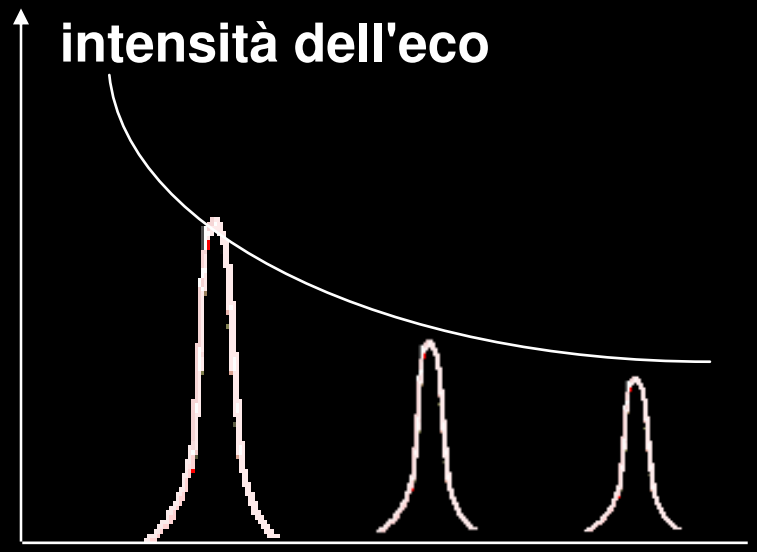
High frequency sound waves echo off vessel walls and are sent back to system

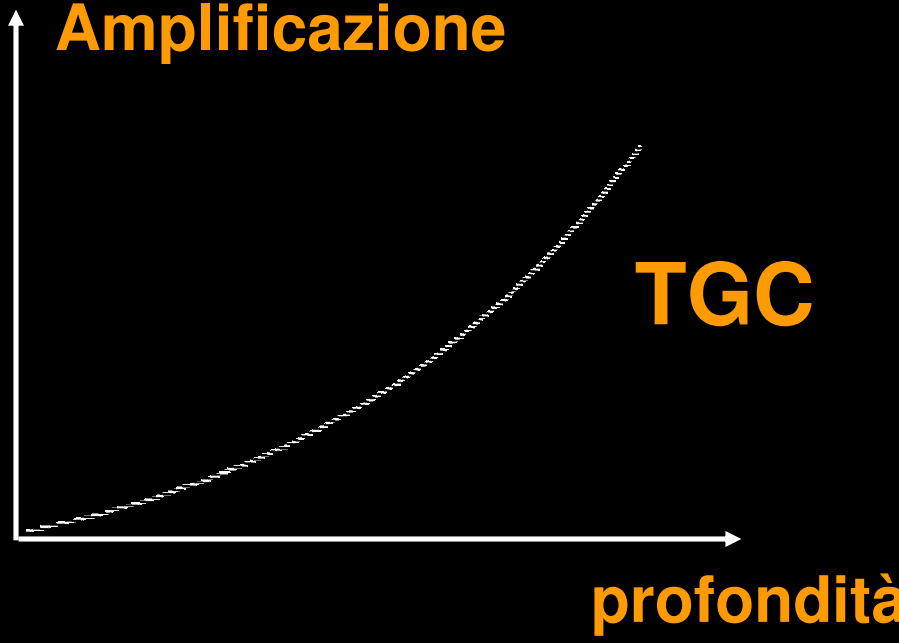
System electronics process the signal

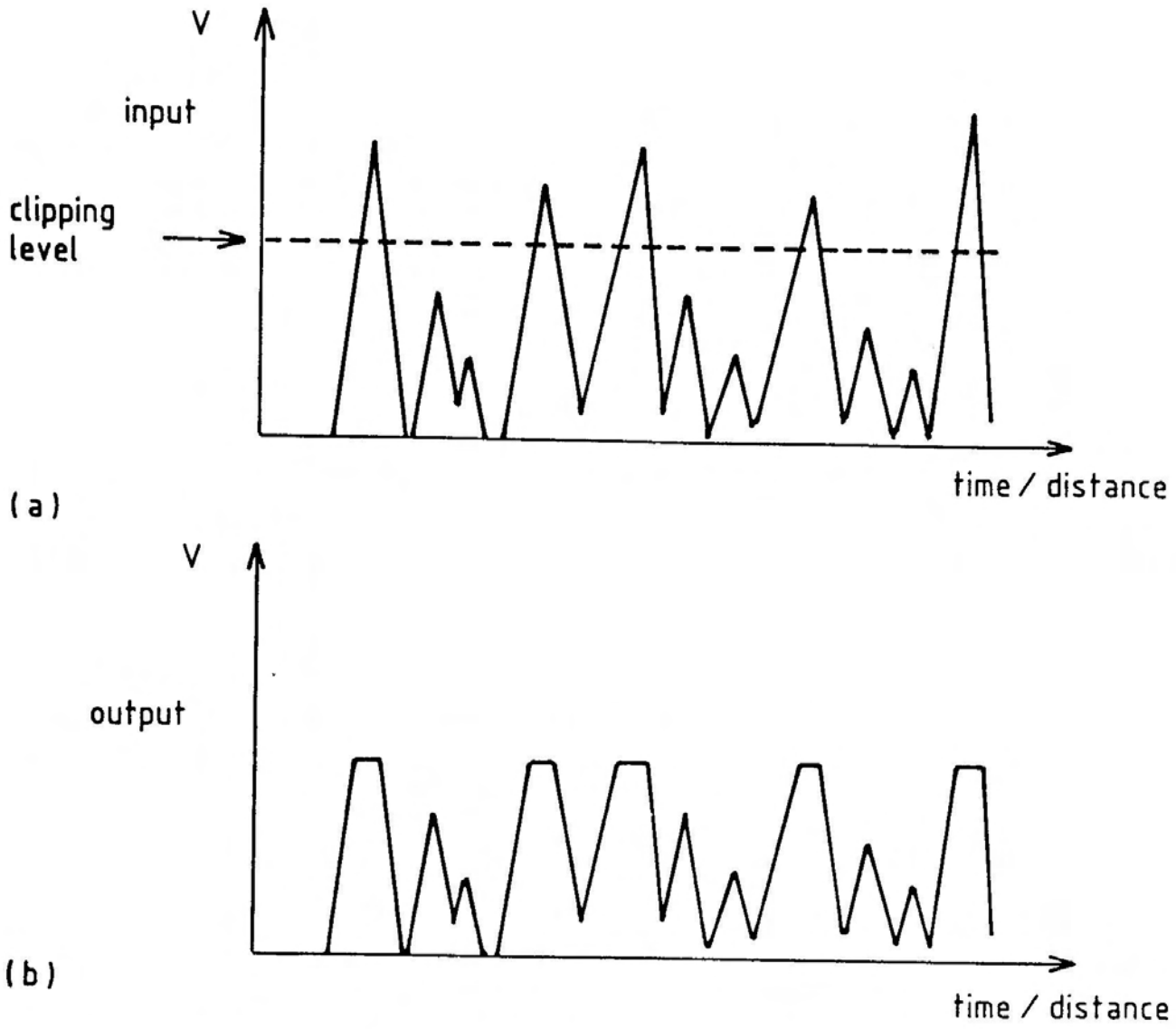


vector

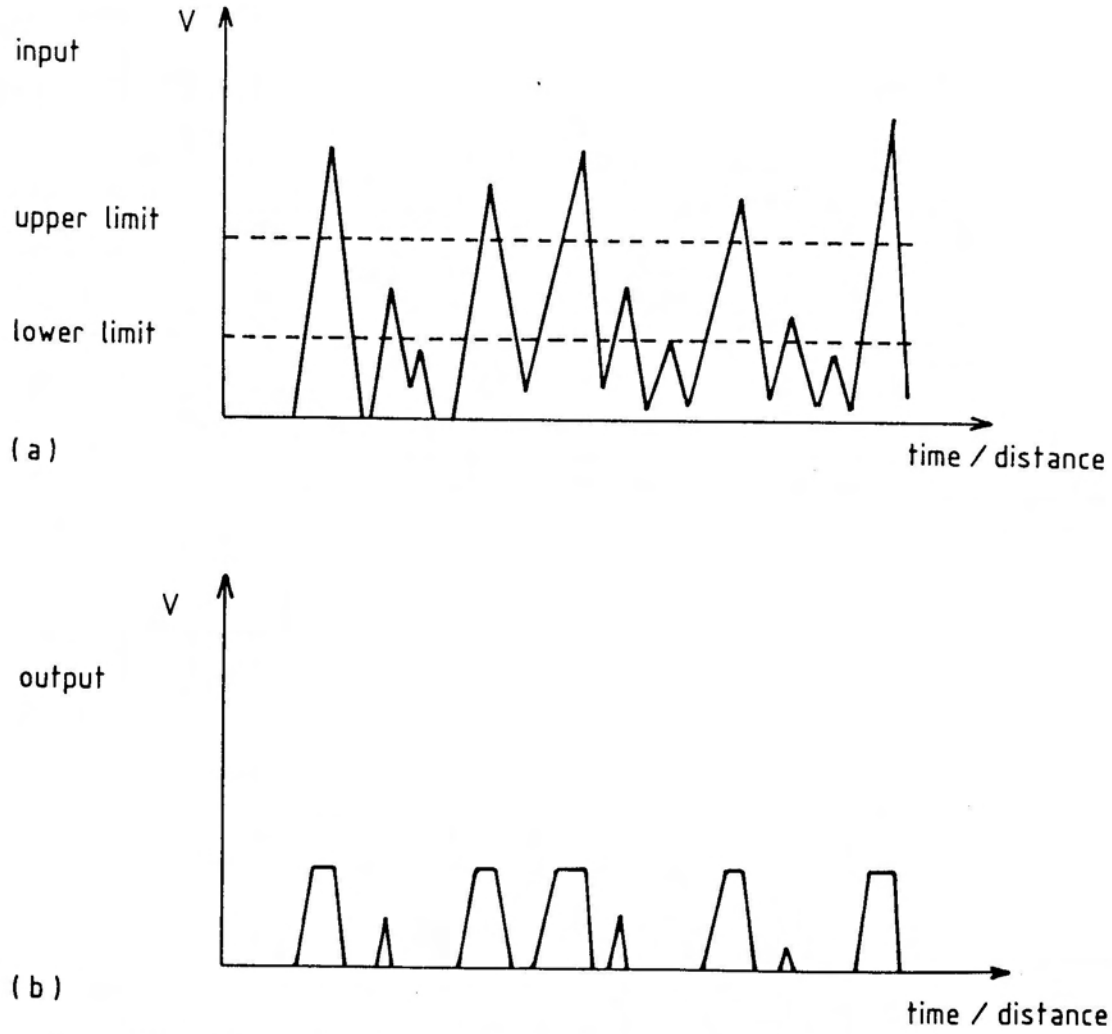

intensità dell'eco
OK
tempo
rumore


intensità dell'eco

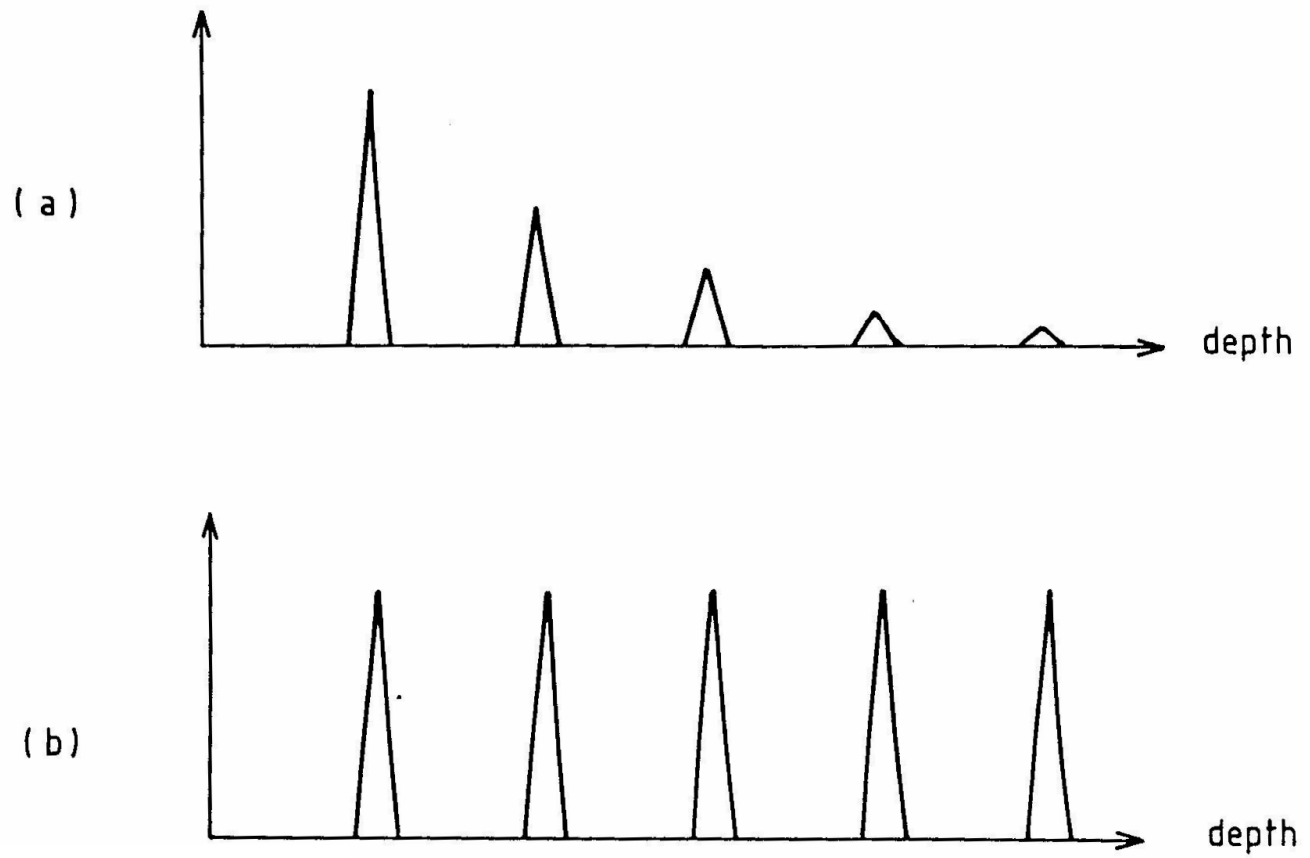

Amplificazione
TGC
profondità



Clipping. Signal before (a) and after (b) clipping.



Windowing (dynamic range control). Signal before (a) and after (b) windowing.



A-scan display with TGC off (a) and on (b).

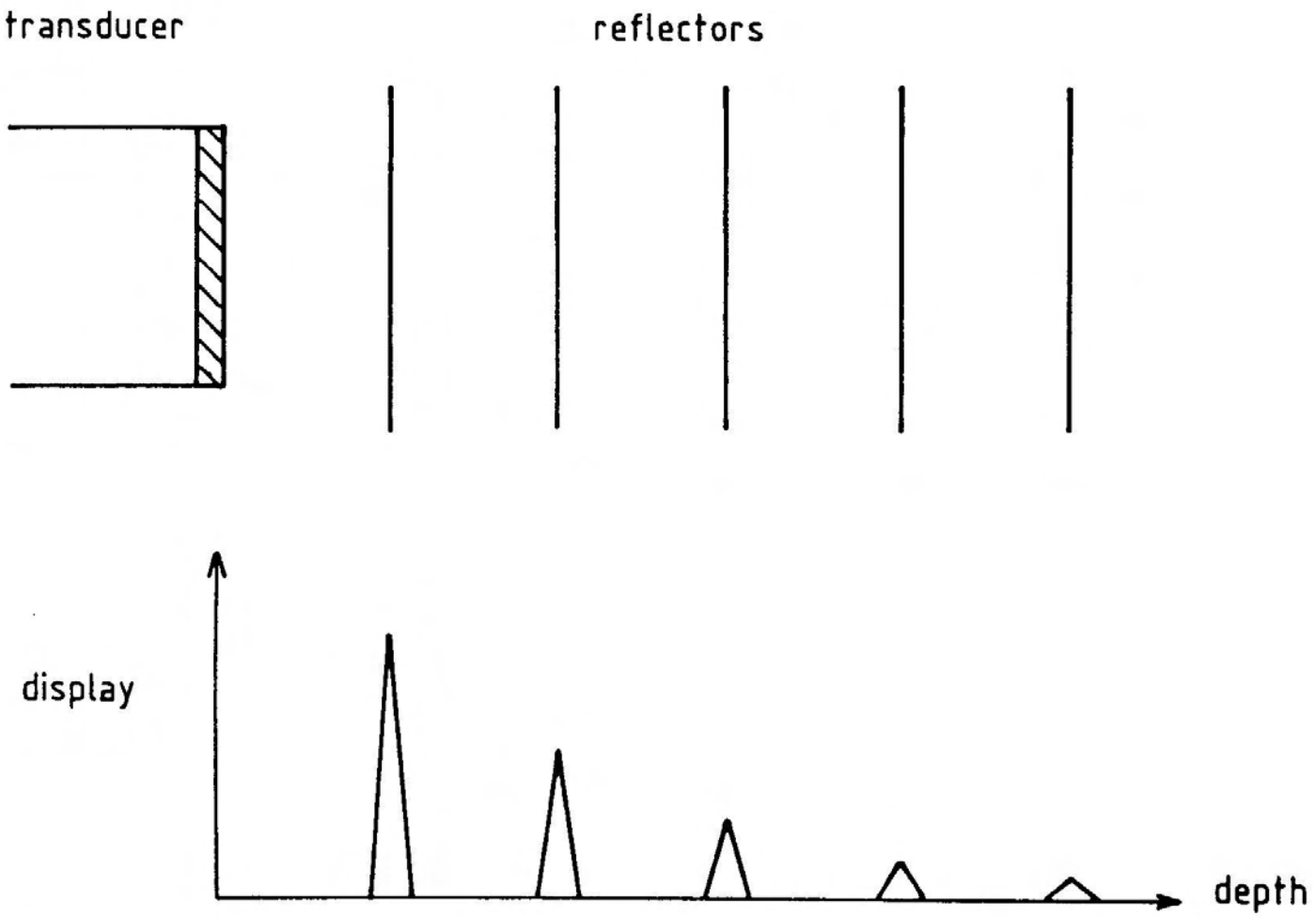
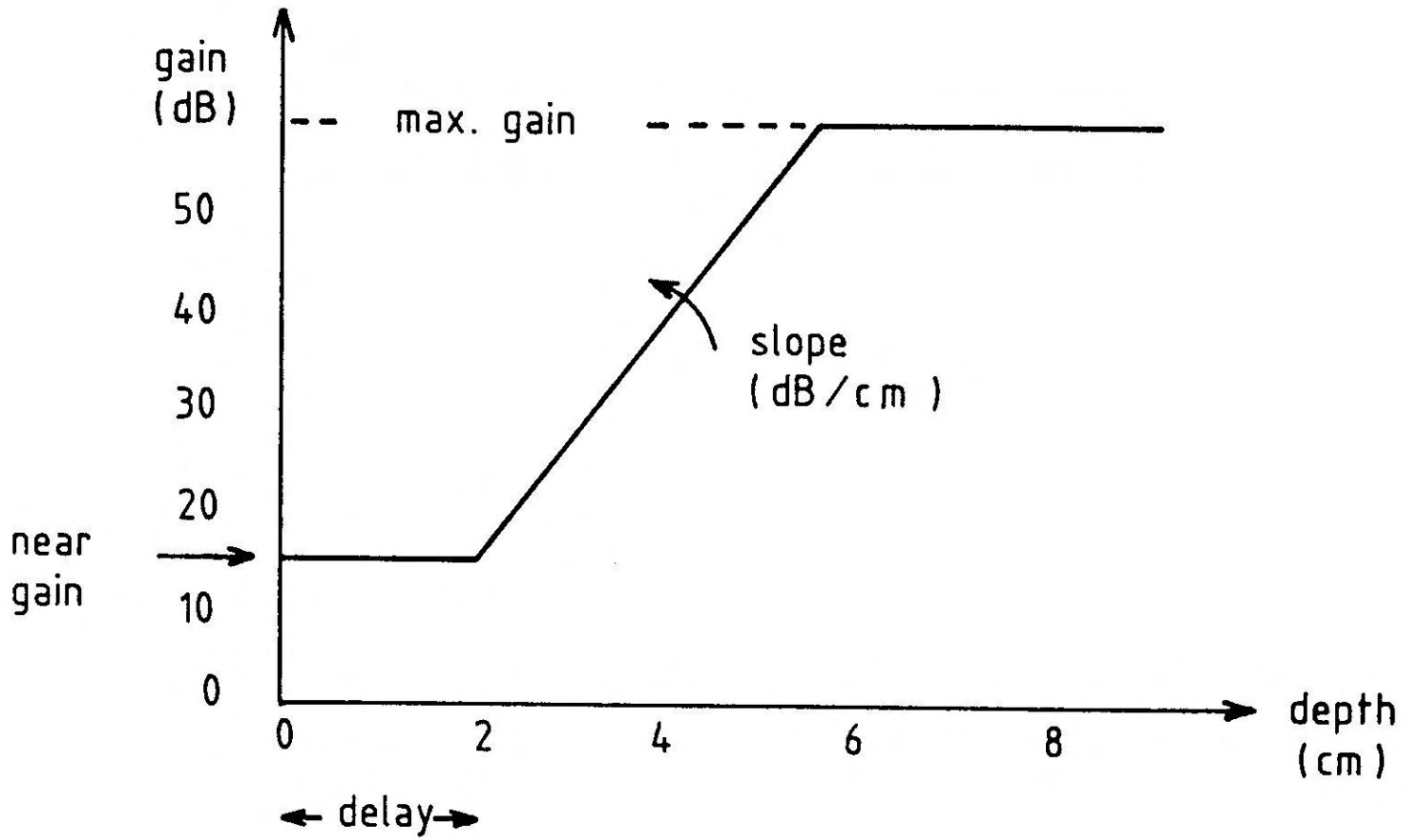
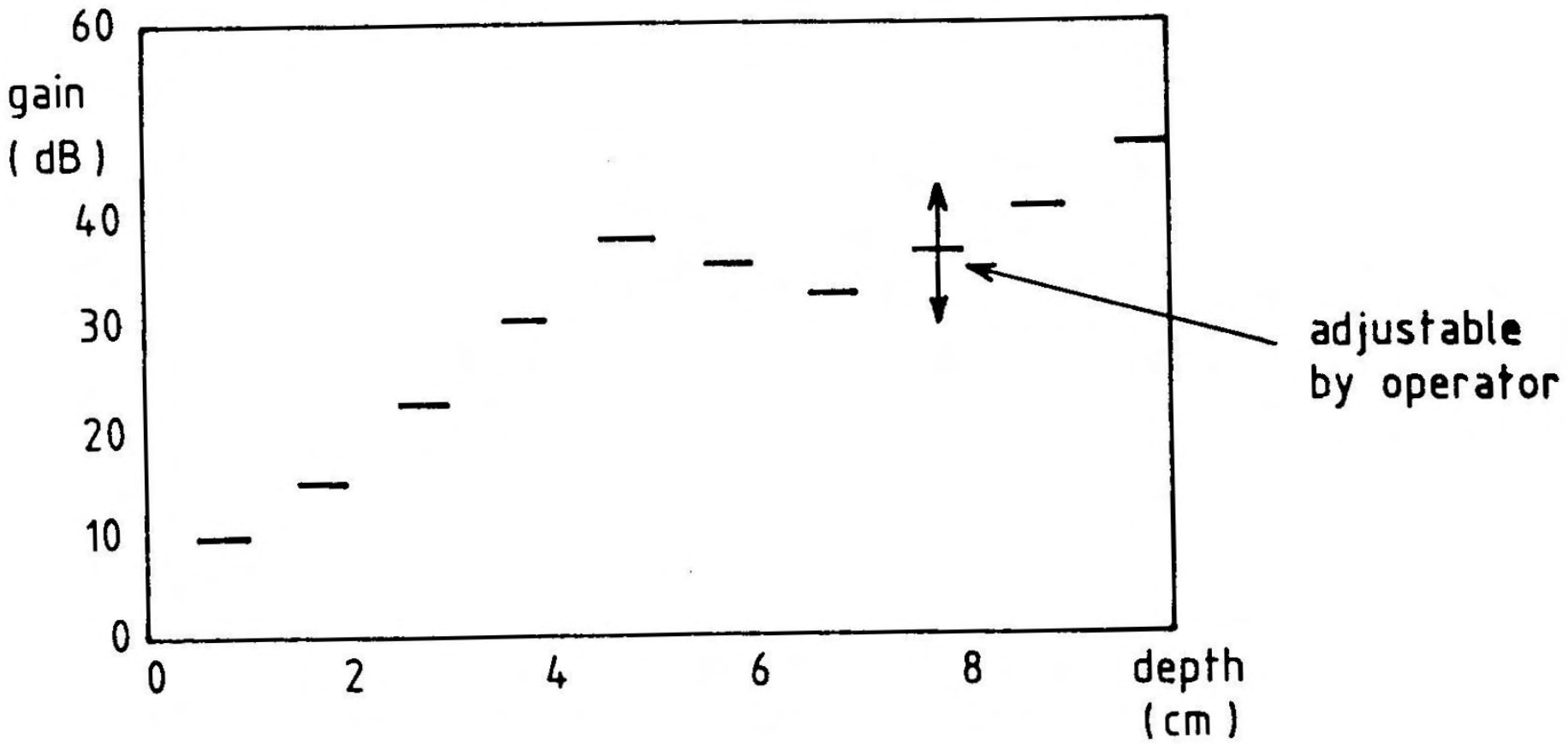


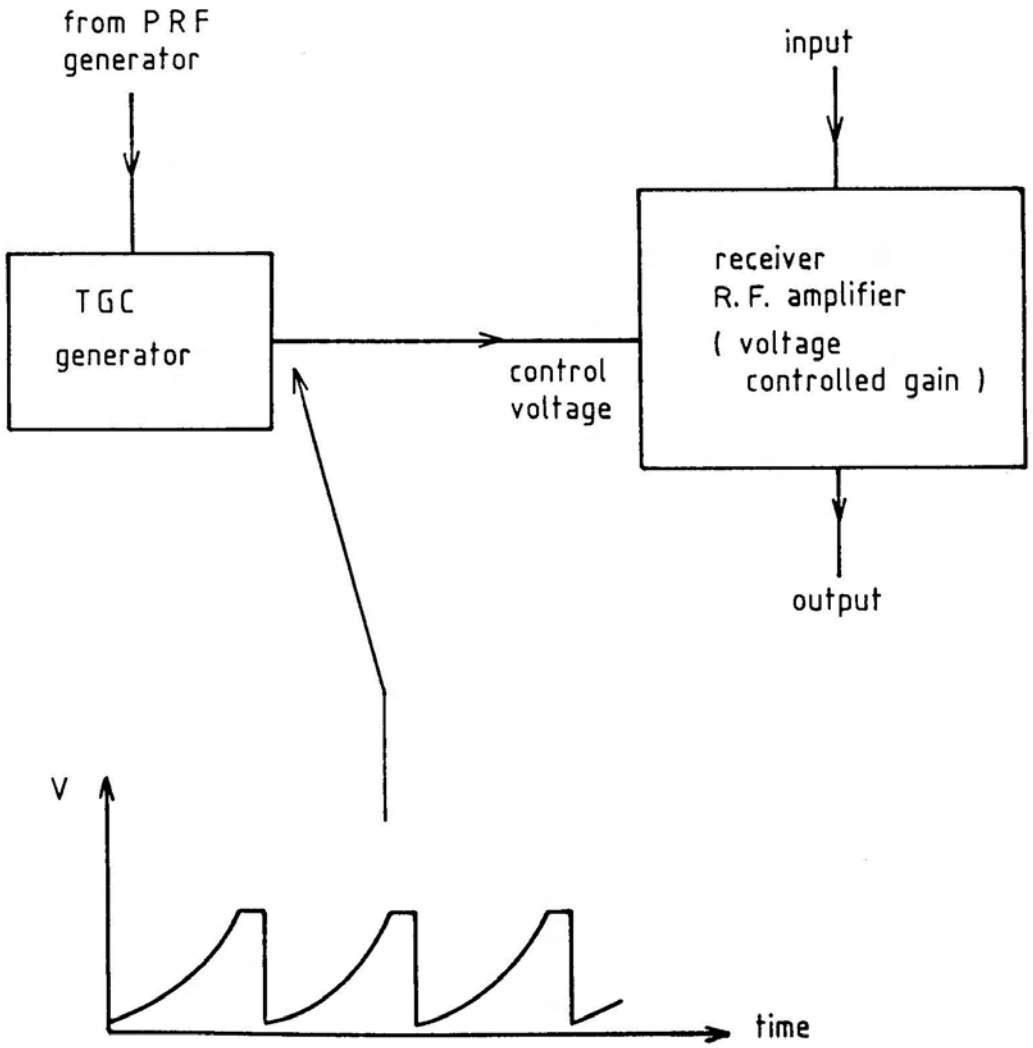
Figure 5.7 Demodulated echo pulses from similar reflectors in an attenuating medium.


gain
(dB)
max. gain
50
40
30
20
near
gain
10
0
slope
(dB/cm)
0
2
4
6
8
depth
(cm)
delay

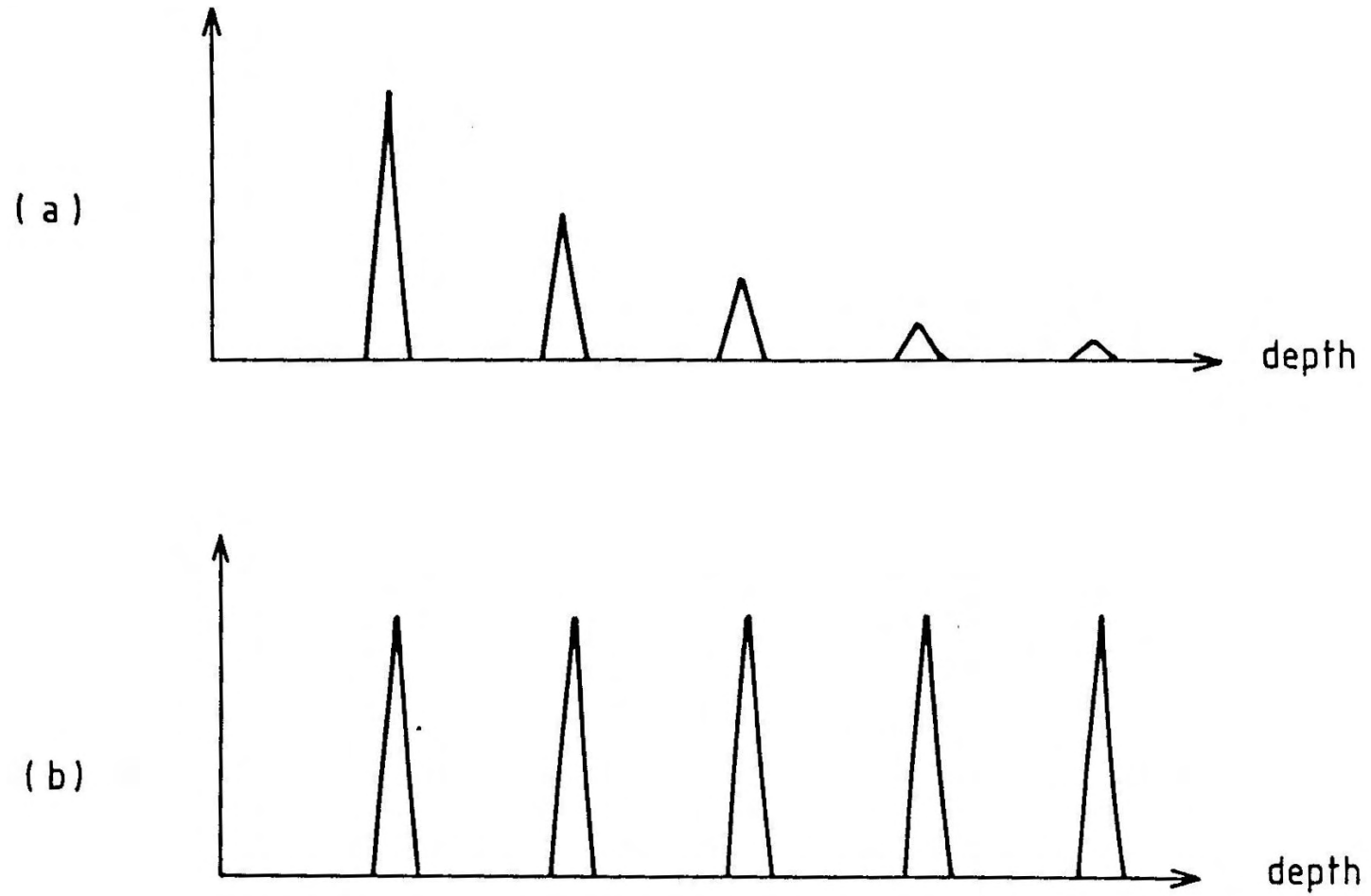
(a)



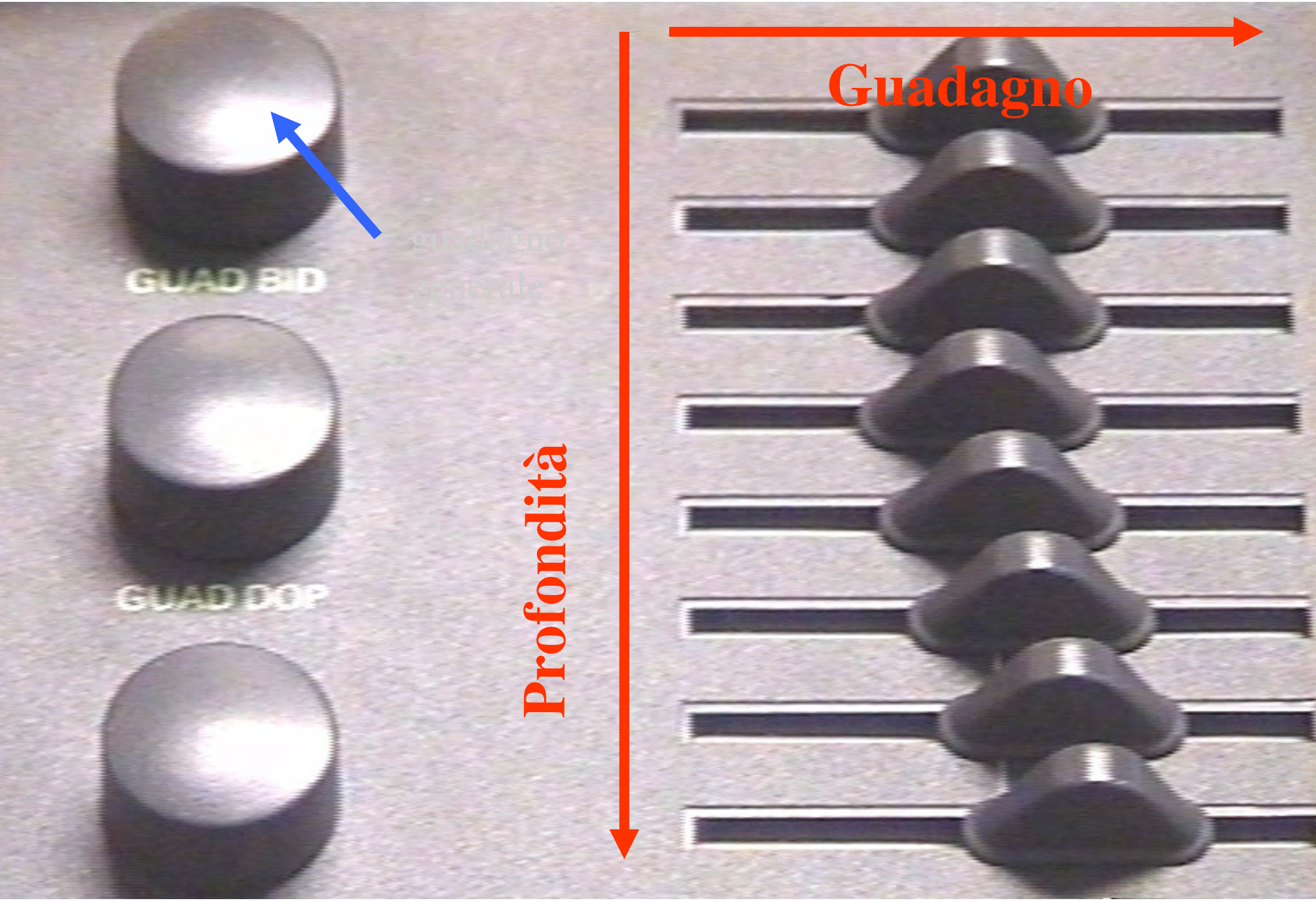
(b)

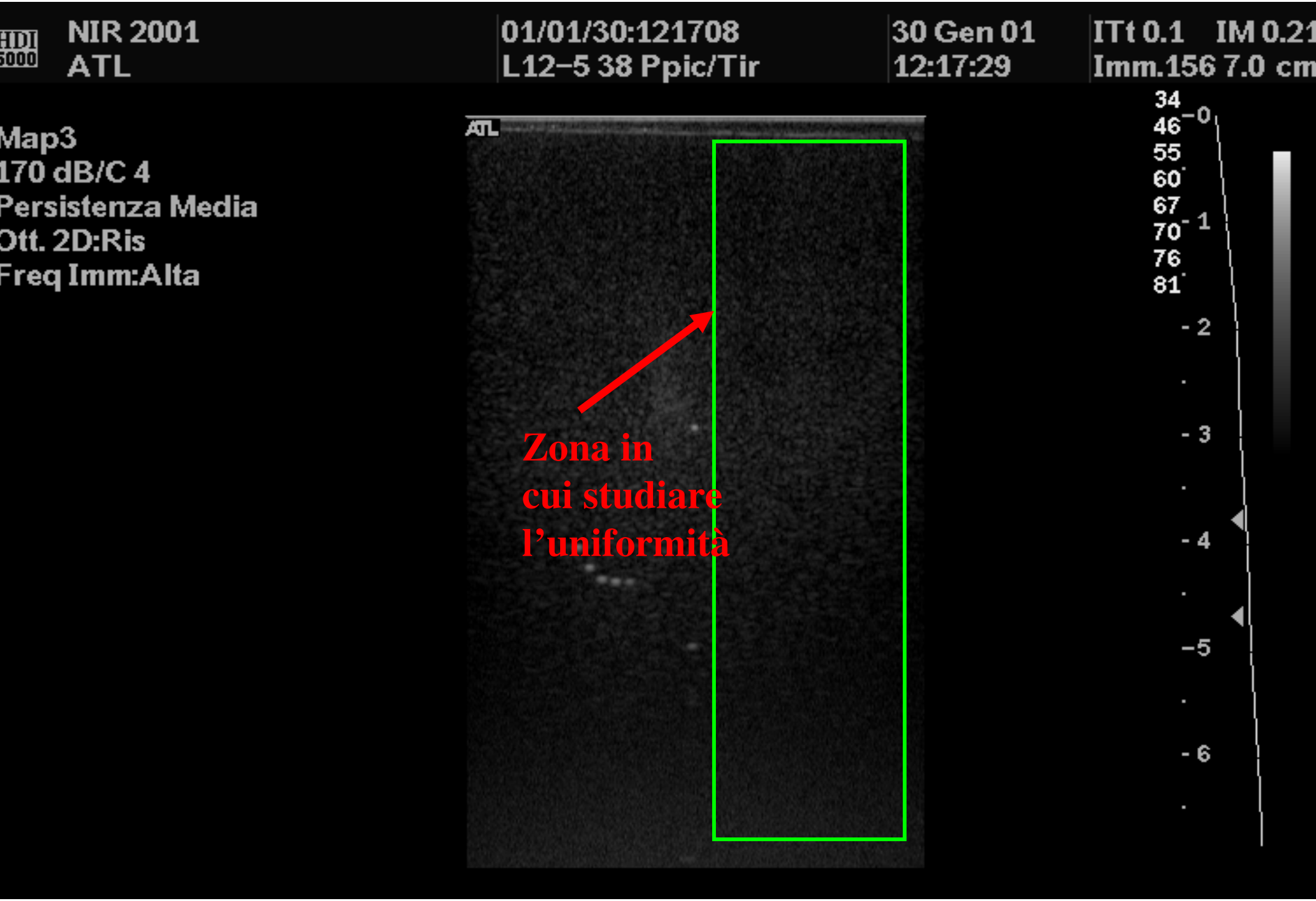


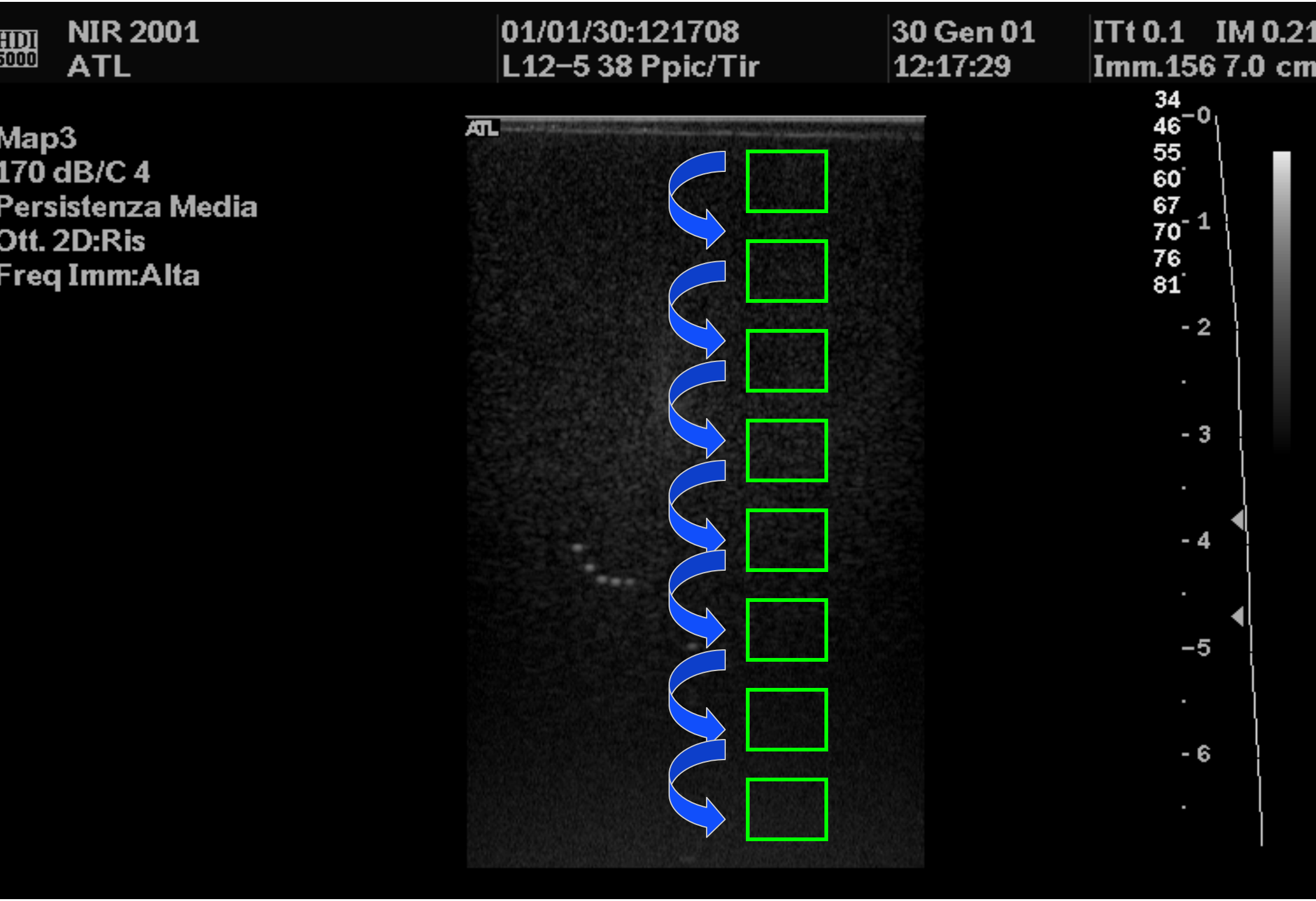
TGC block diagram and control voltage waveform.

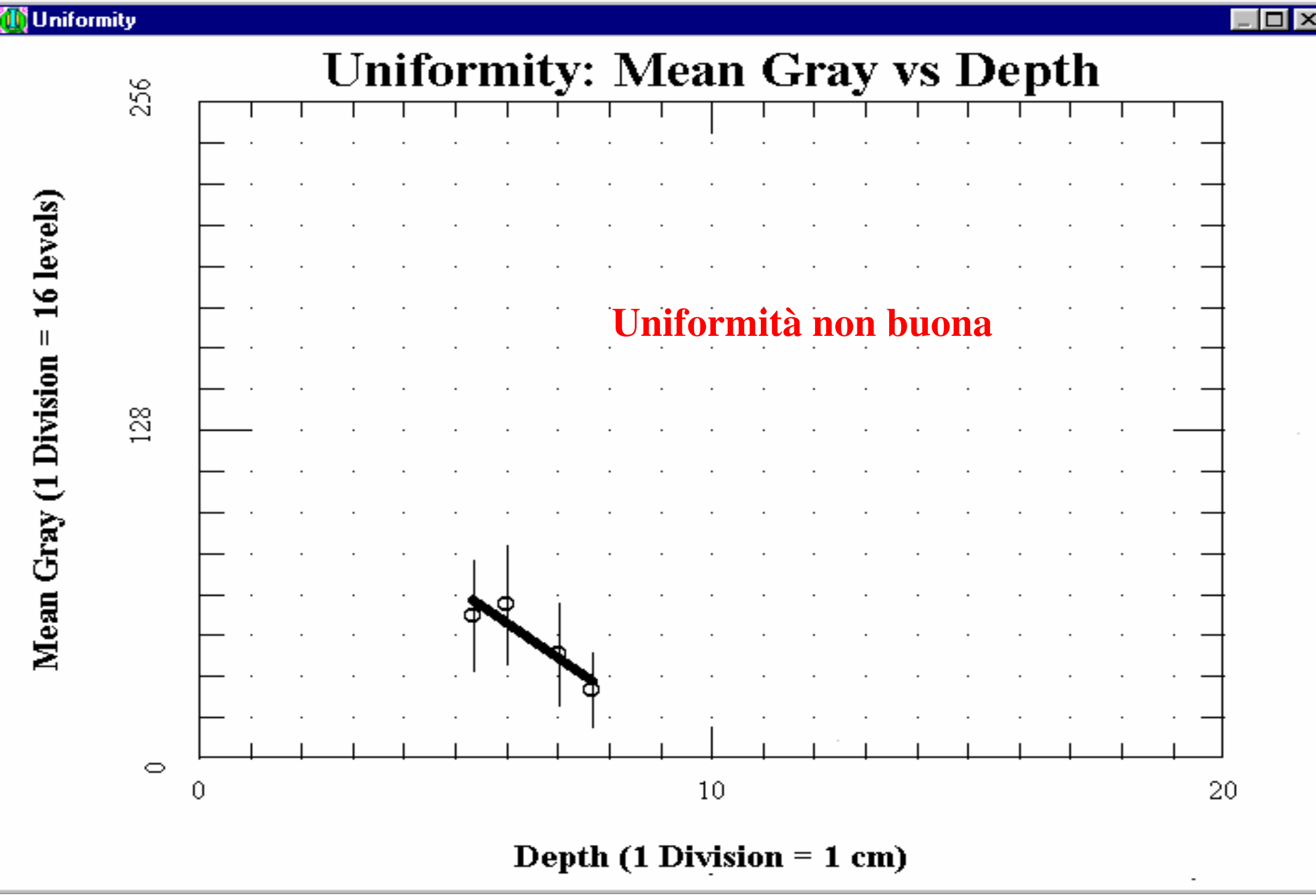


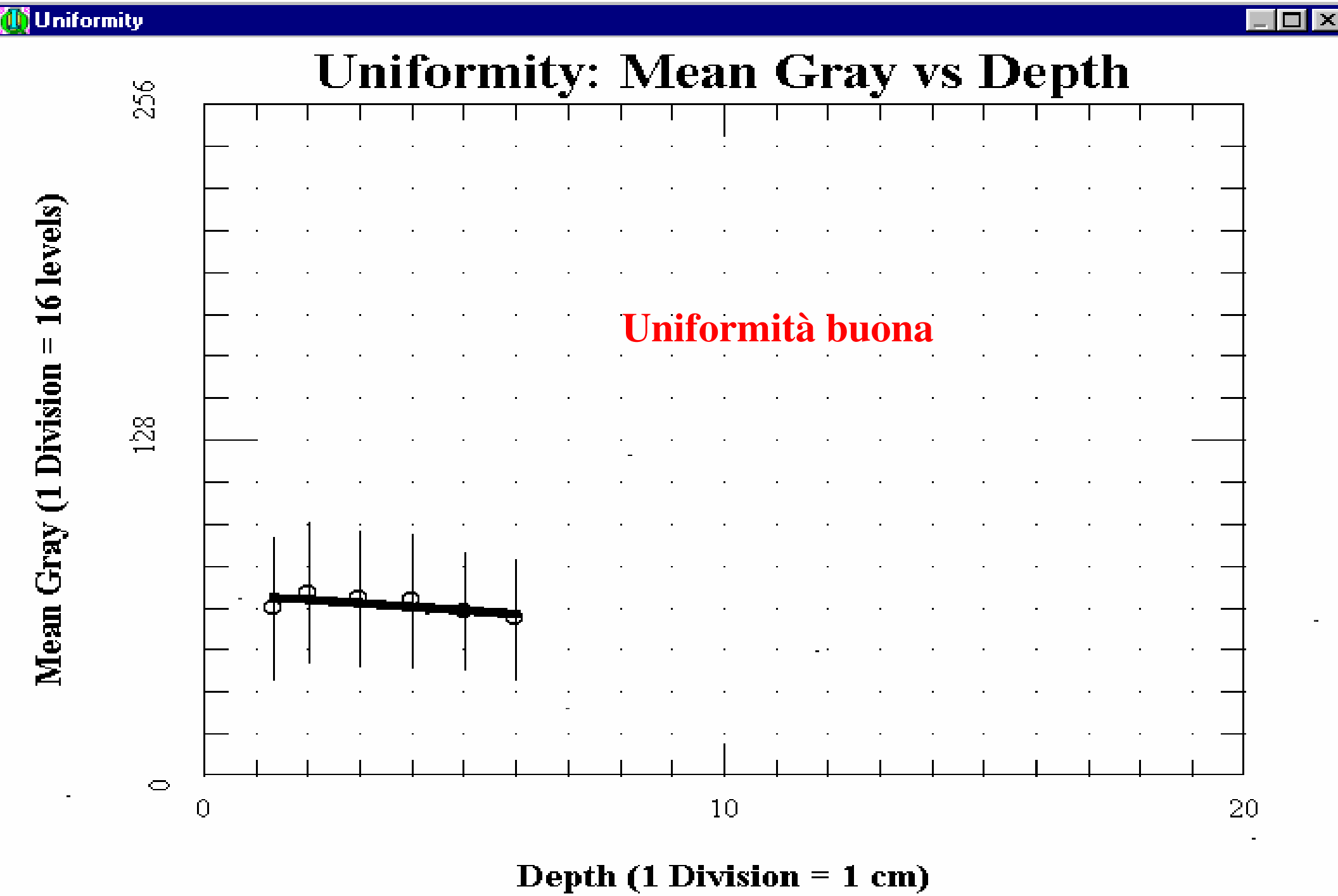
A-scan display with TGC off (a) and on (b).

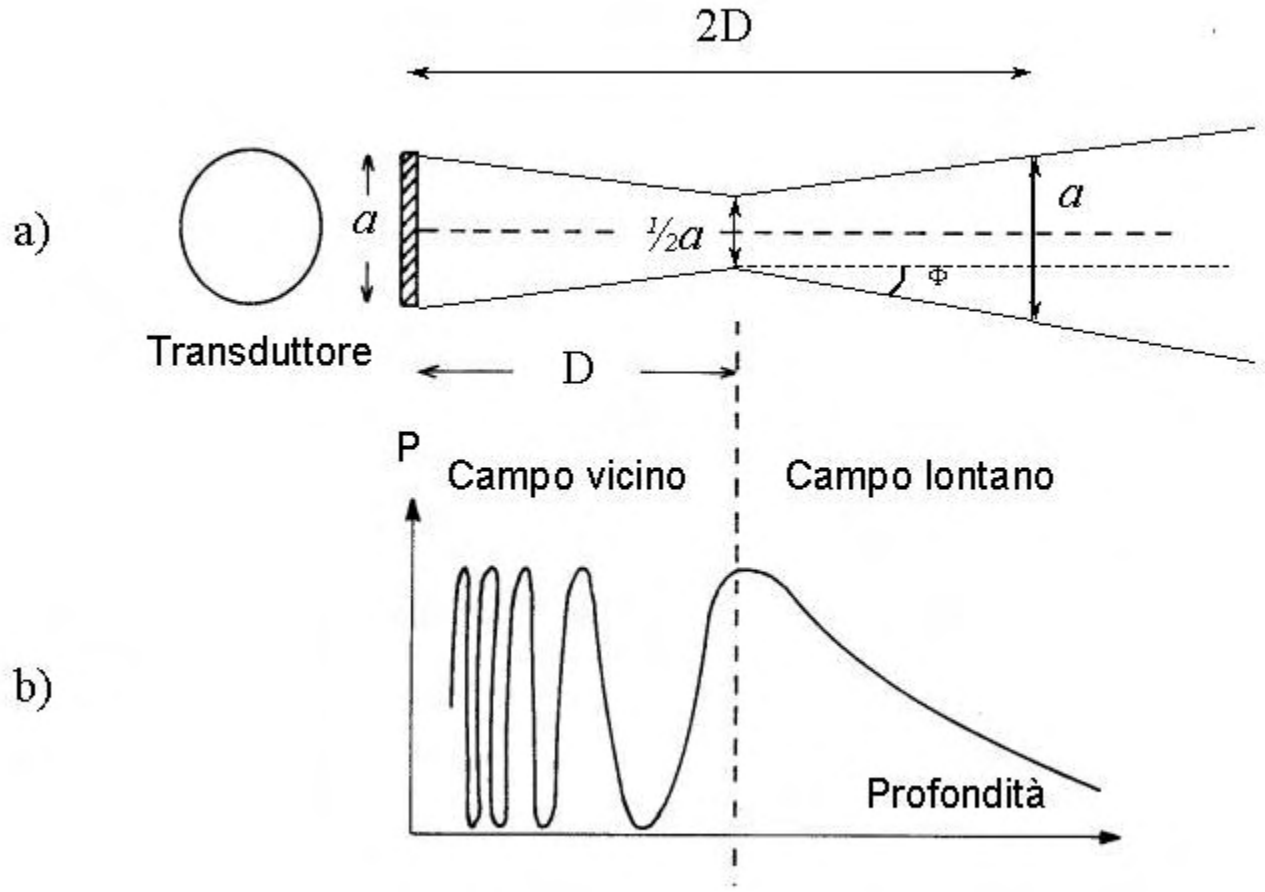

GUAD BID
GUAD DOP
guadagno generale
Guadagno
Profondità

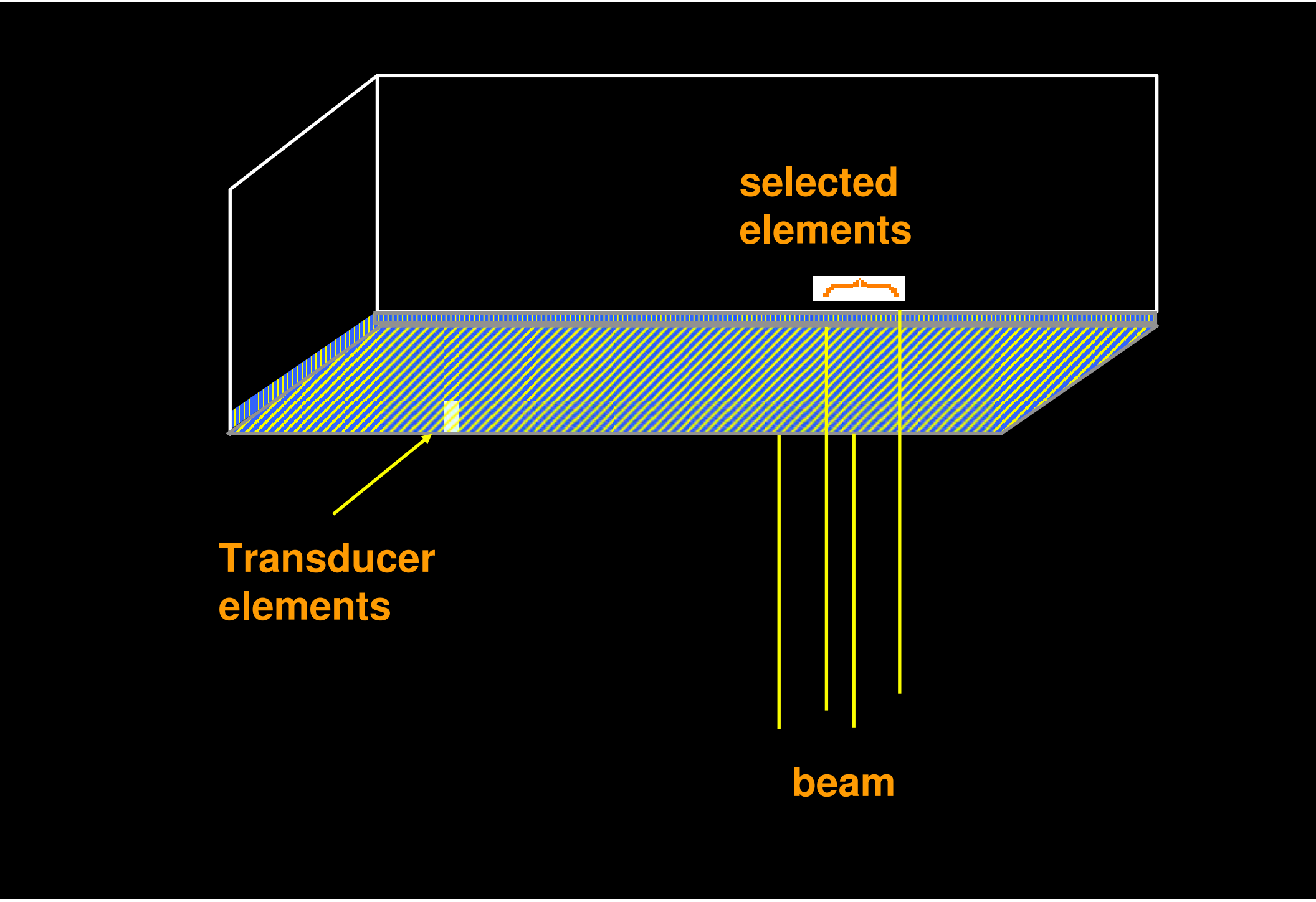

NIR 2001
ATL
01/01/30:121708
L12-5 38 Ppic/Tir
30 Gen 01
12:17:29
ITt 0.1 IM 0.21
Imm.156 7.0 cm
Map3
170 dB/C 4
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
ATL
Zona in
cui studiare
l'uniformità
34
46
55
60
67
70
76
81
0
1
2
3
4
5
6

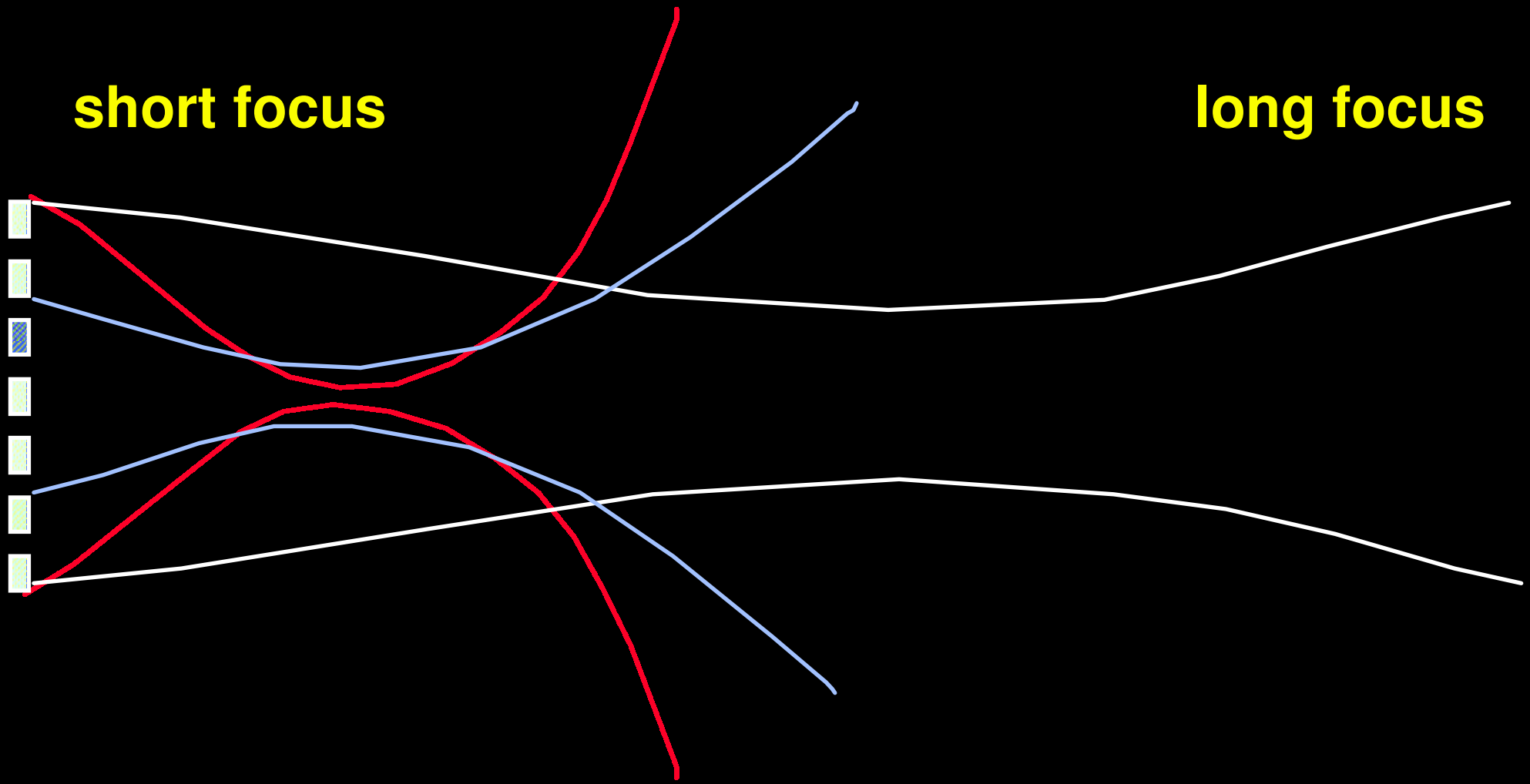

HDI 5000
NIR 2001
ATL
01/01/30:121708
L12-5 38 Ppic/Tir
30 Gen 01
12:17:29
ITt 0.1 IM 0.21
Imm.156 7.0 cm
Map3
170 dB/C 4
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
ATL
34
46
55
60
67
70
76
81
0
1
2
3
4
5
6


Uniformity
Uniformity: Mean Gray vs Depth
Uniformità non buona
Mean Gray (1 Division = 16 levels)
256
128
0
0
10
20
Depth (1 Division = 1 cm)

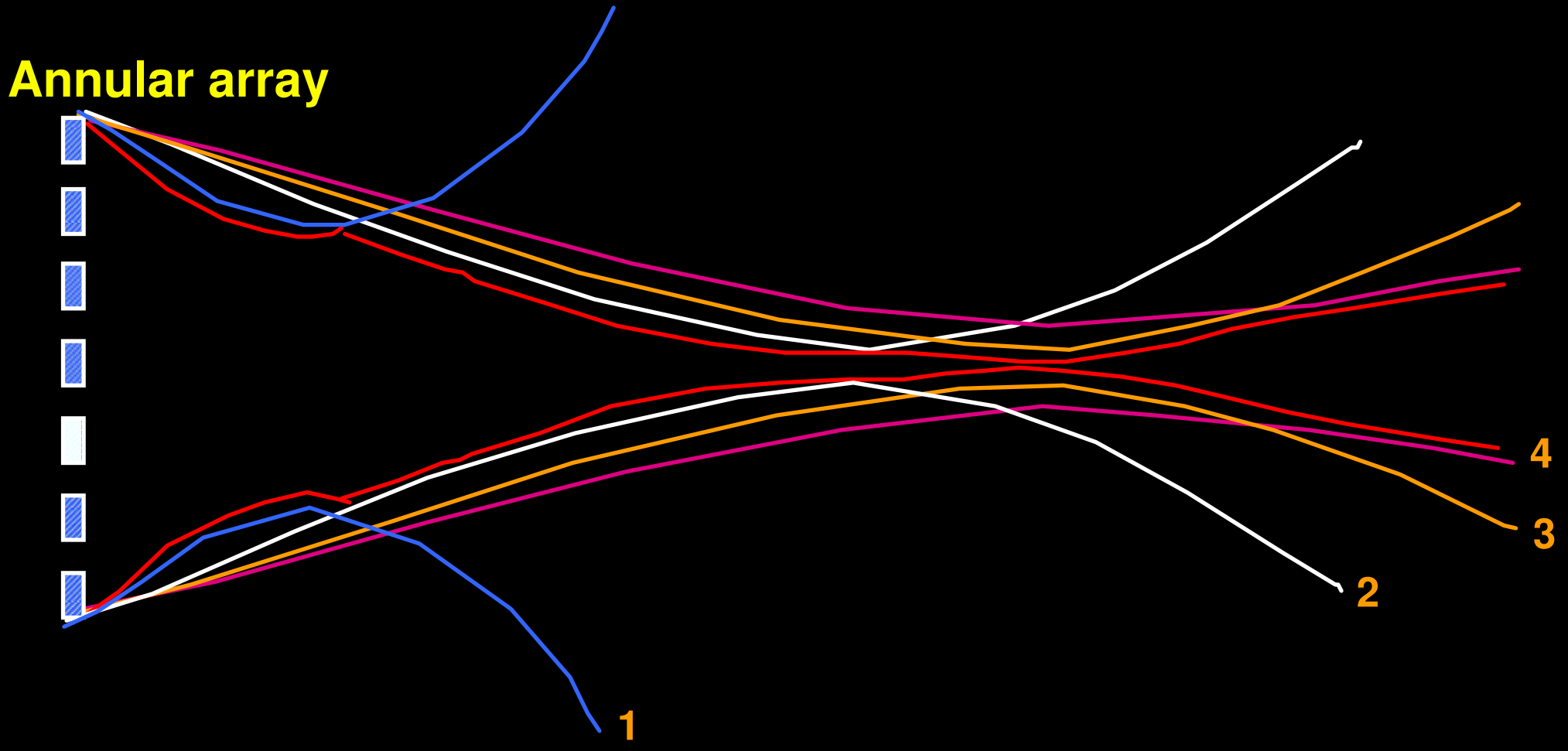

Uniformity
Uniformity: Mean Gray vs Depth
Uniformità buona
Mean Gray (1 Division = 16 levels)
256
128
0
0
10
20
Depth (1 Division = 1 cm)


a)
2D
a
½a
a
Φ
Transduttore
D
P
Campo vicino
Campo lontano
b)
Profondità

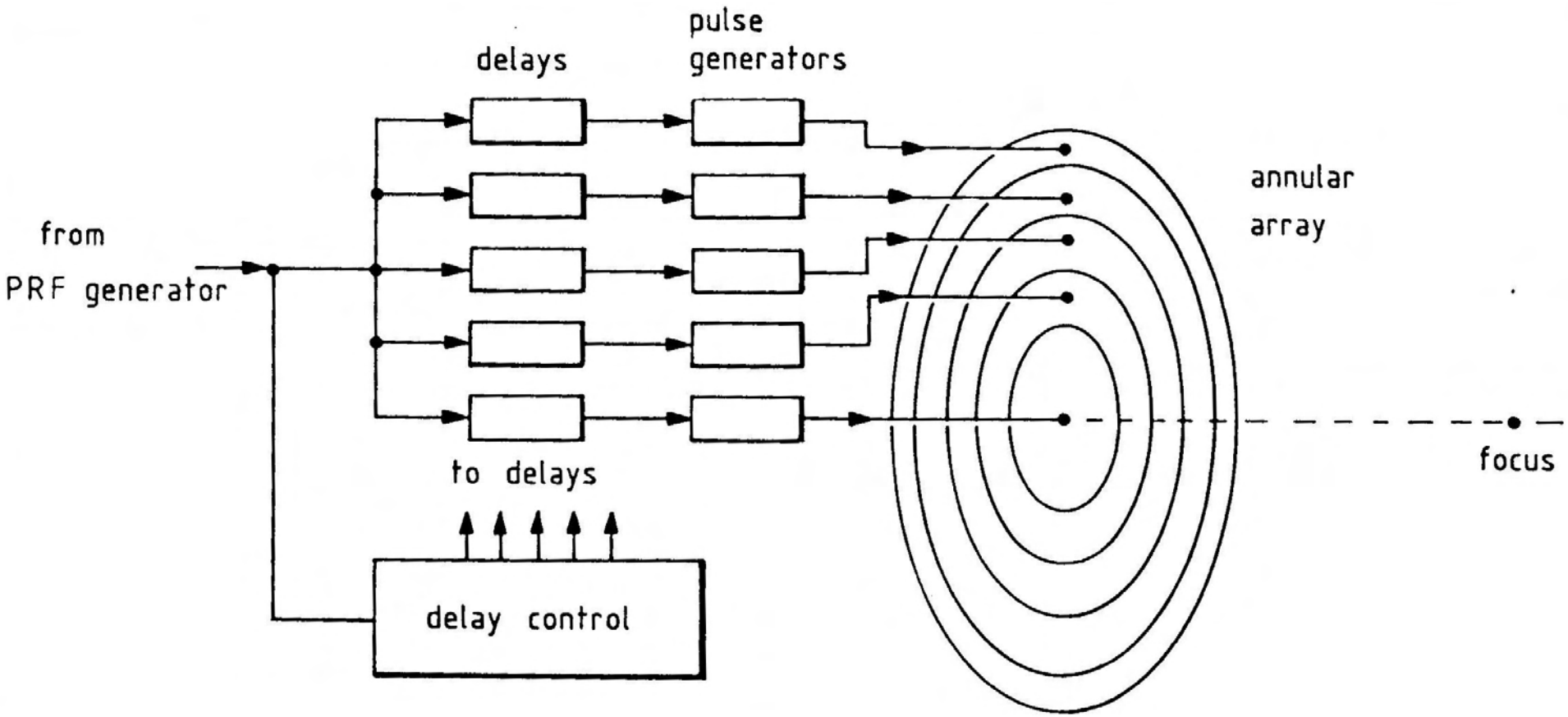

selected
elements
Transducer
elements
beam


short focus
long focus

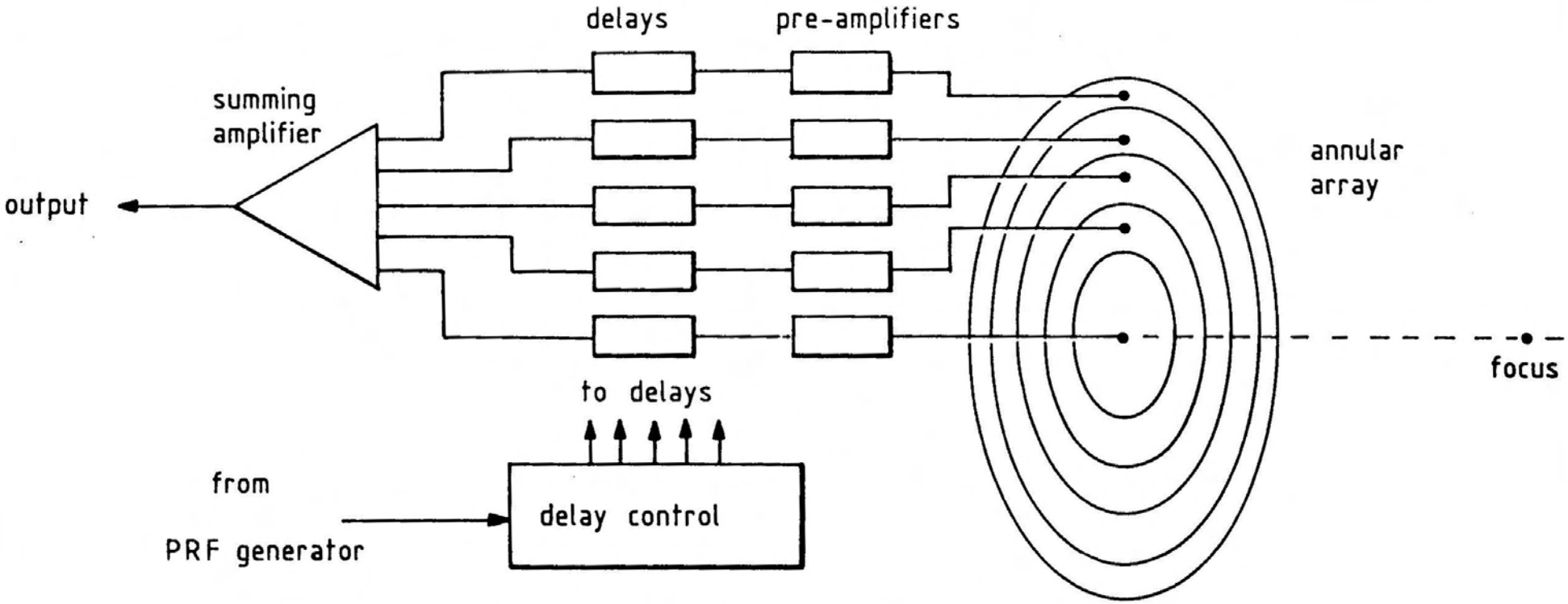
FOCALIZZAZIONE ELETTRONICA



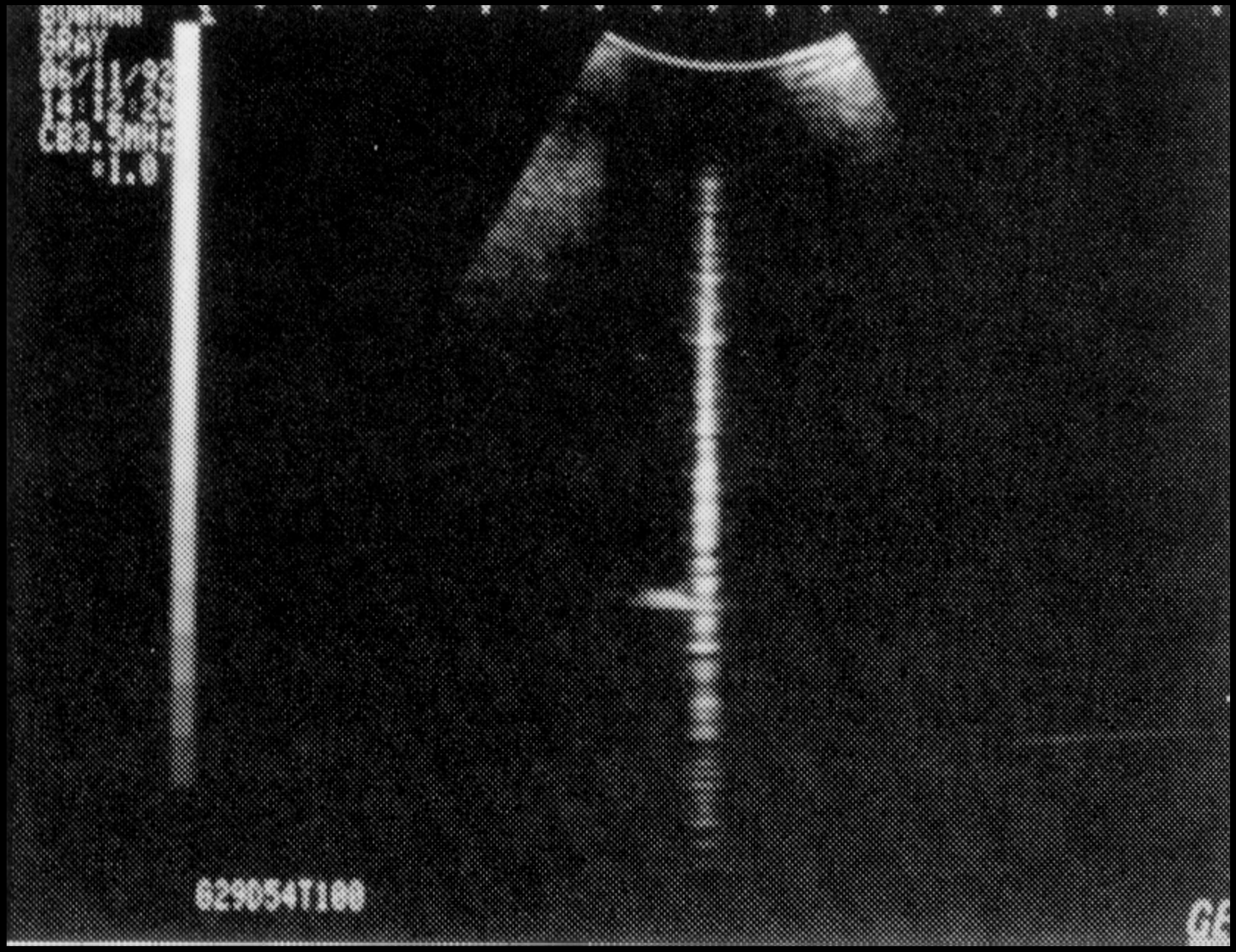
Multiple zone focussing



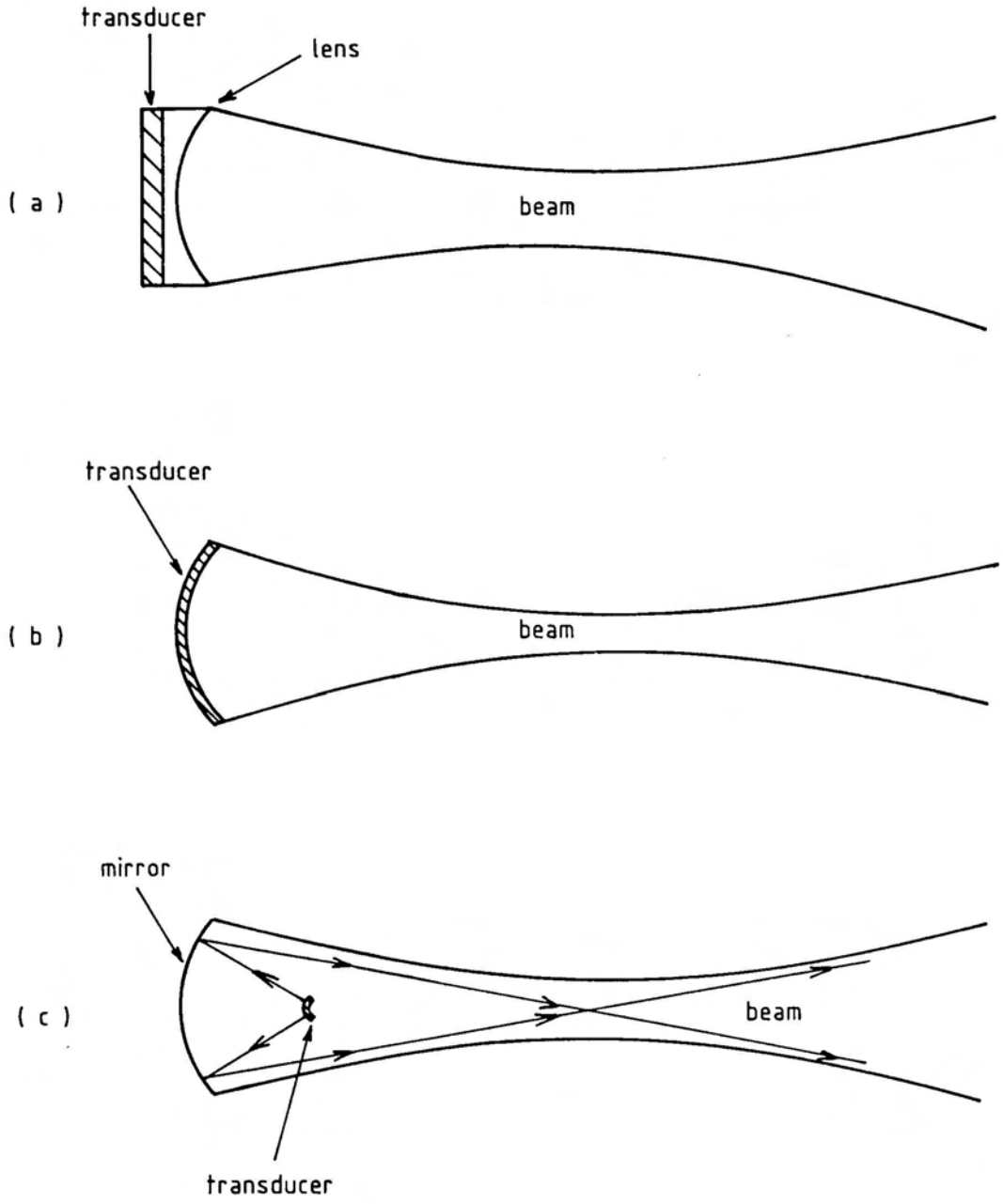
Electronic focussing in transmission—block diagram.



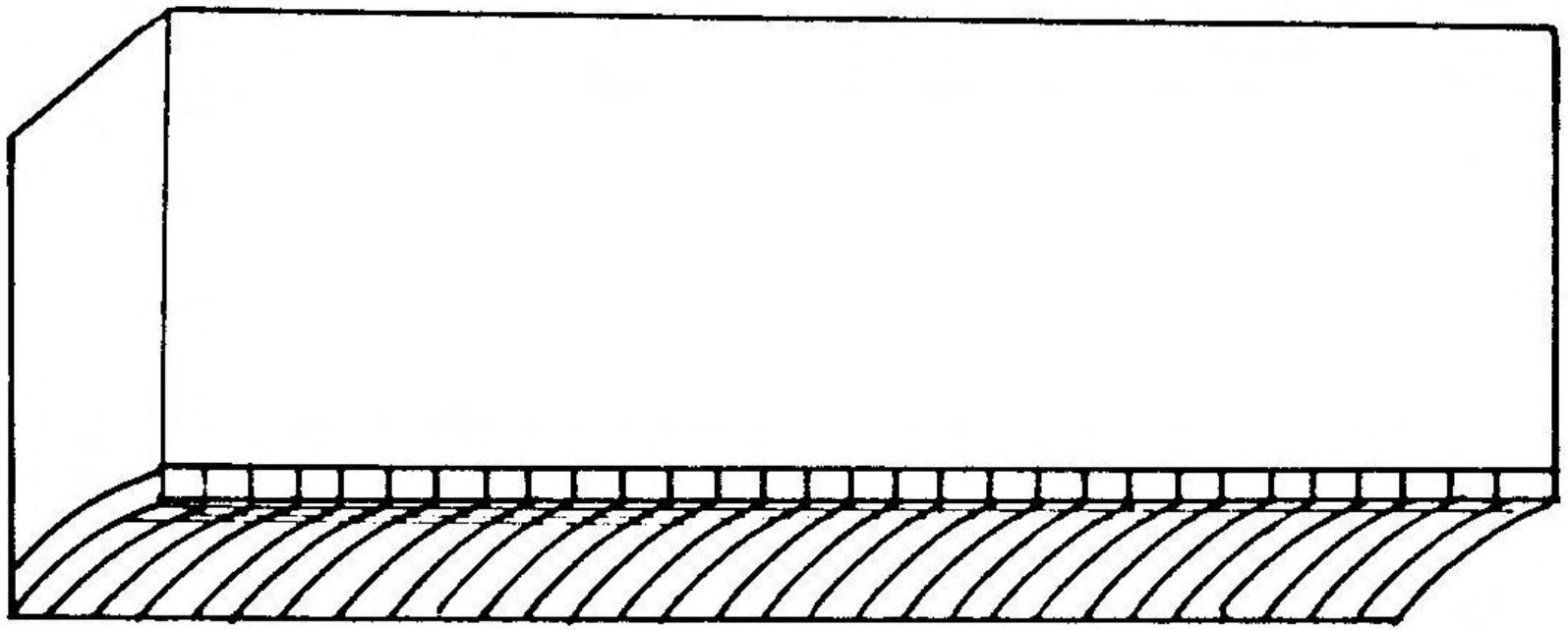
Electronic focussing in reception—block diagram.


11.0
62905471M0

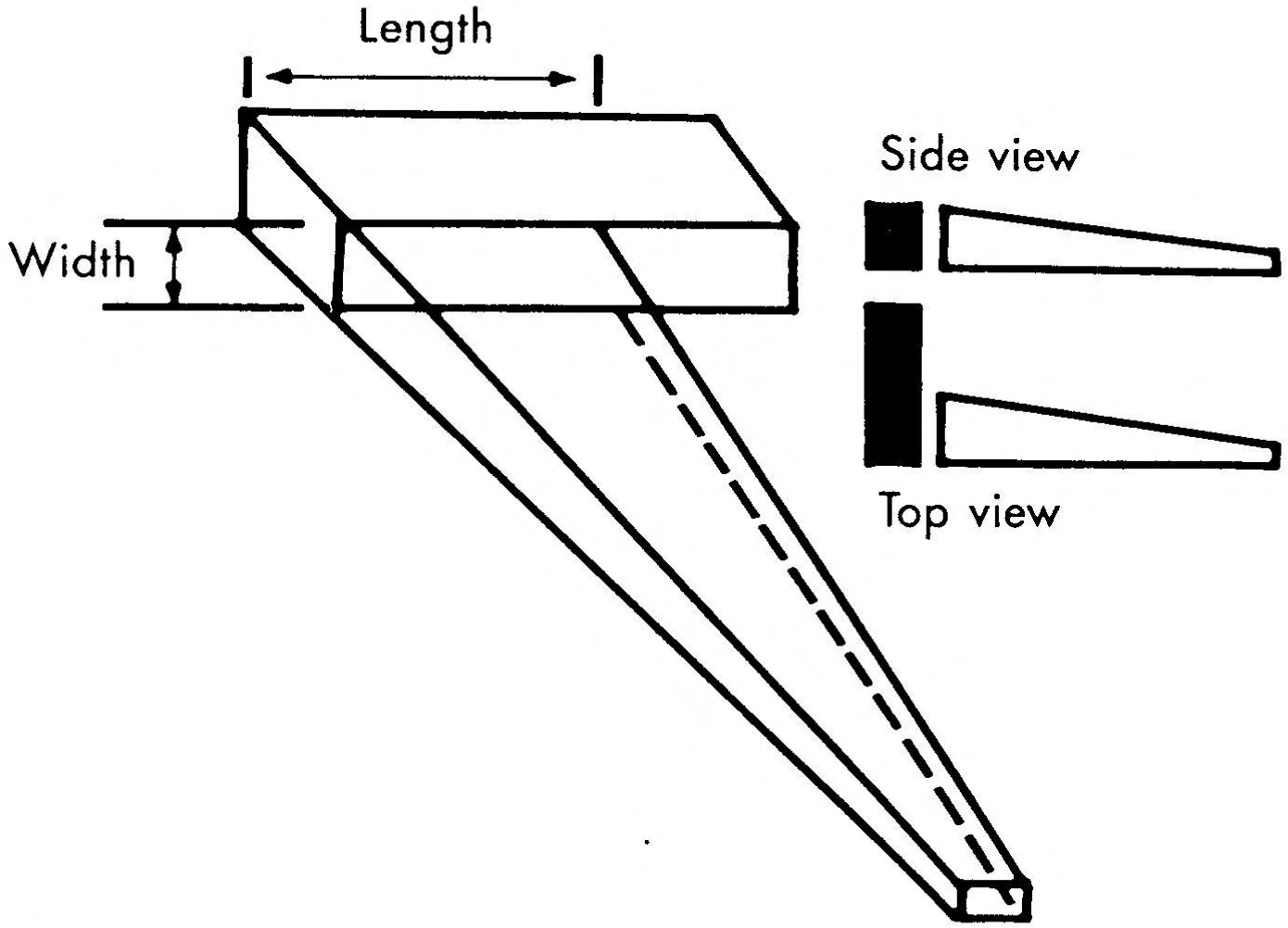
BEAM SHAPES AND TRANSDUCERS



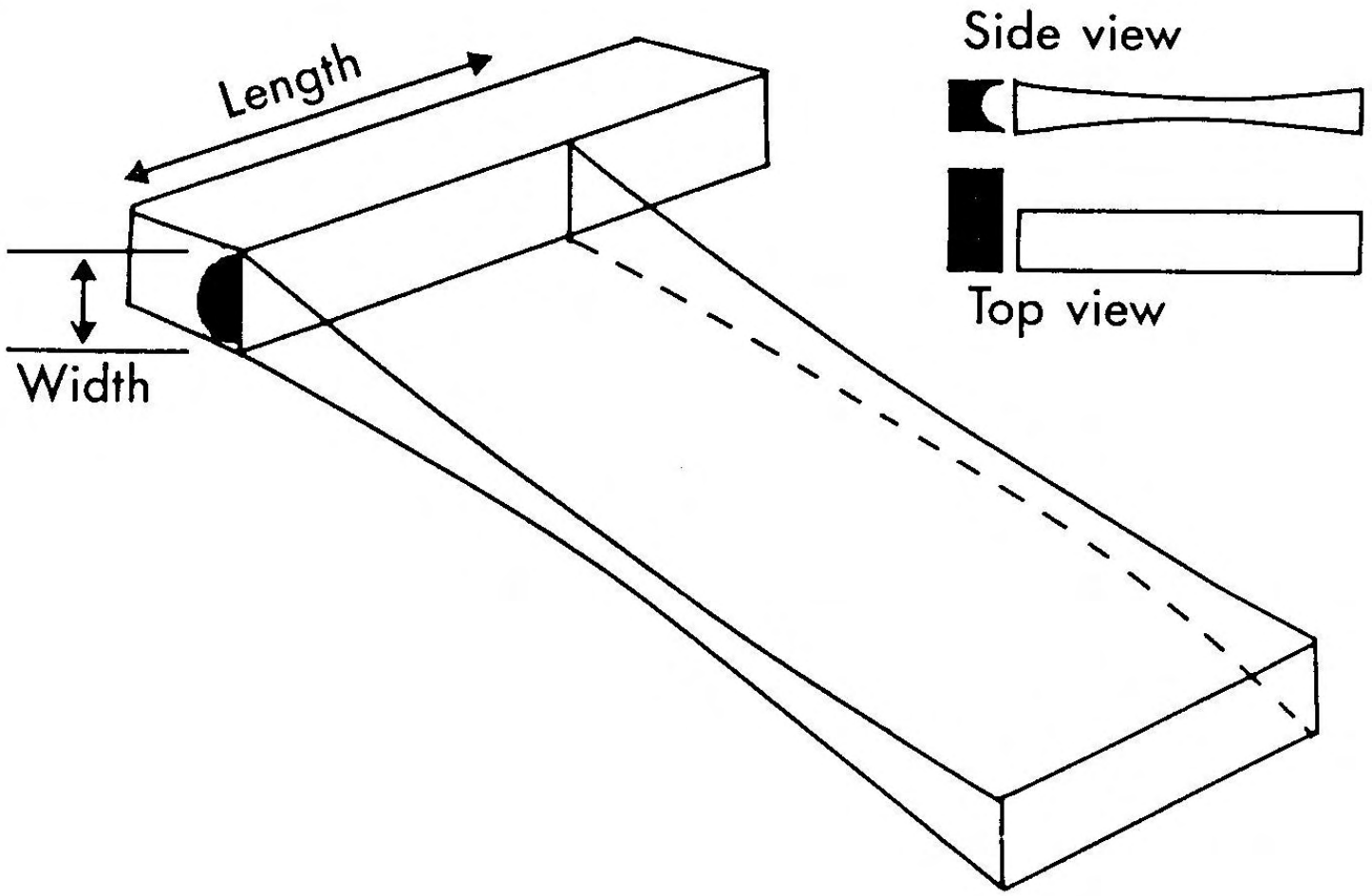
Focussing by (a) lens, (b) transducer shaping and (c) concave mirror.



(a)



Resultant beam pattern from both mechanical width focusing and electronic length focusing.



Mechanical focusing of an array in the width direction using an acoustic lens or curved crystal elements.

FRAME RATE (FR)

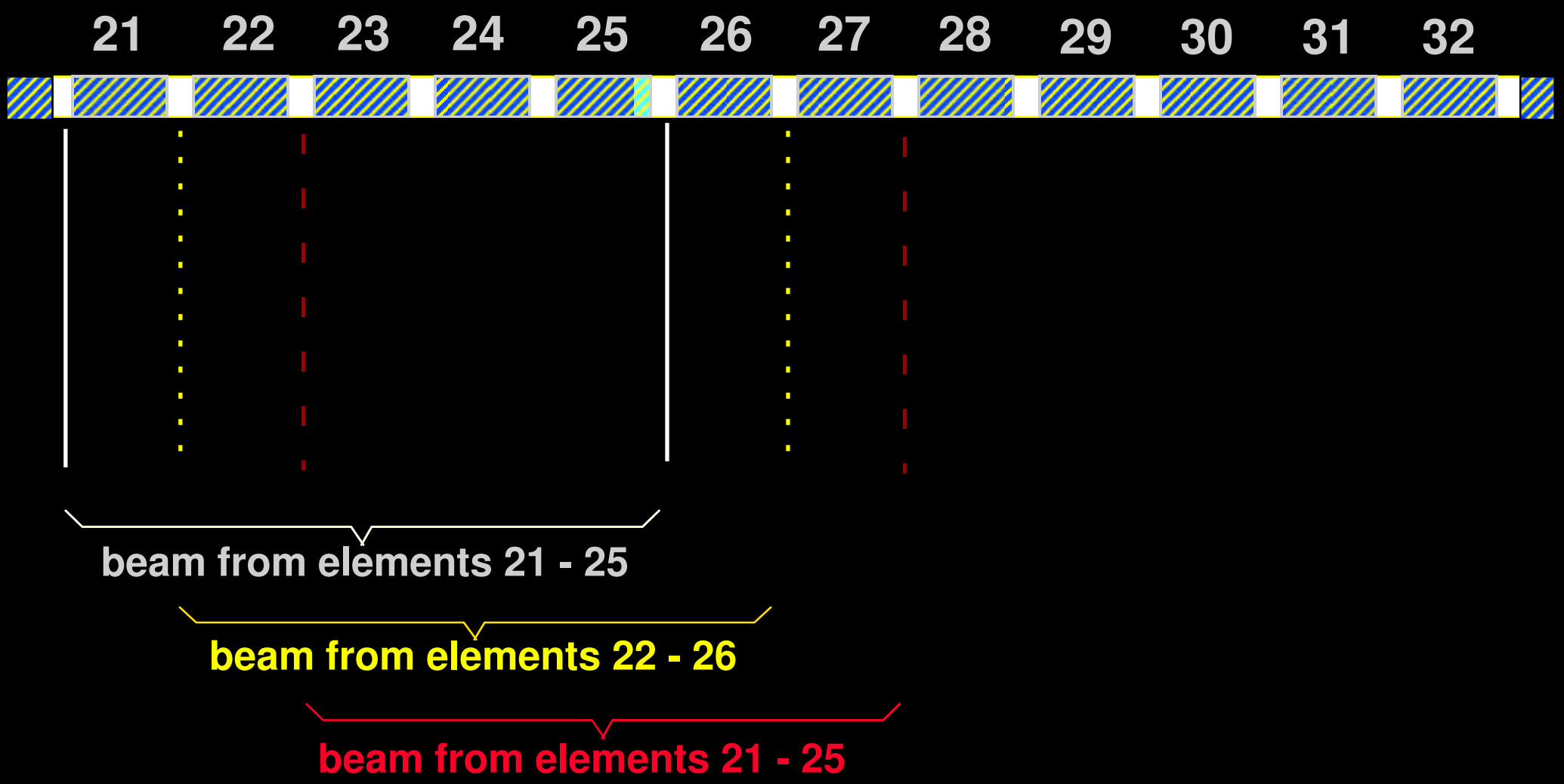
$$FR = \frac{PRF}{\text{numero di linee} \times \text{numero di fuochi}}$$

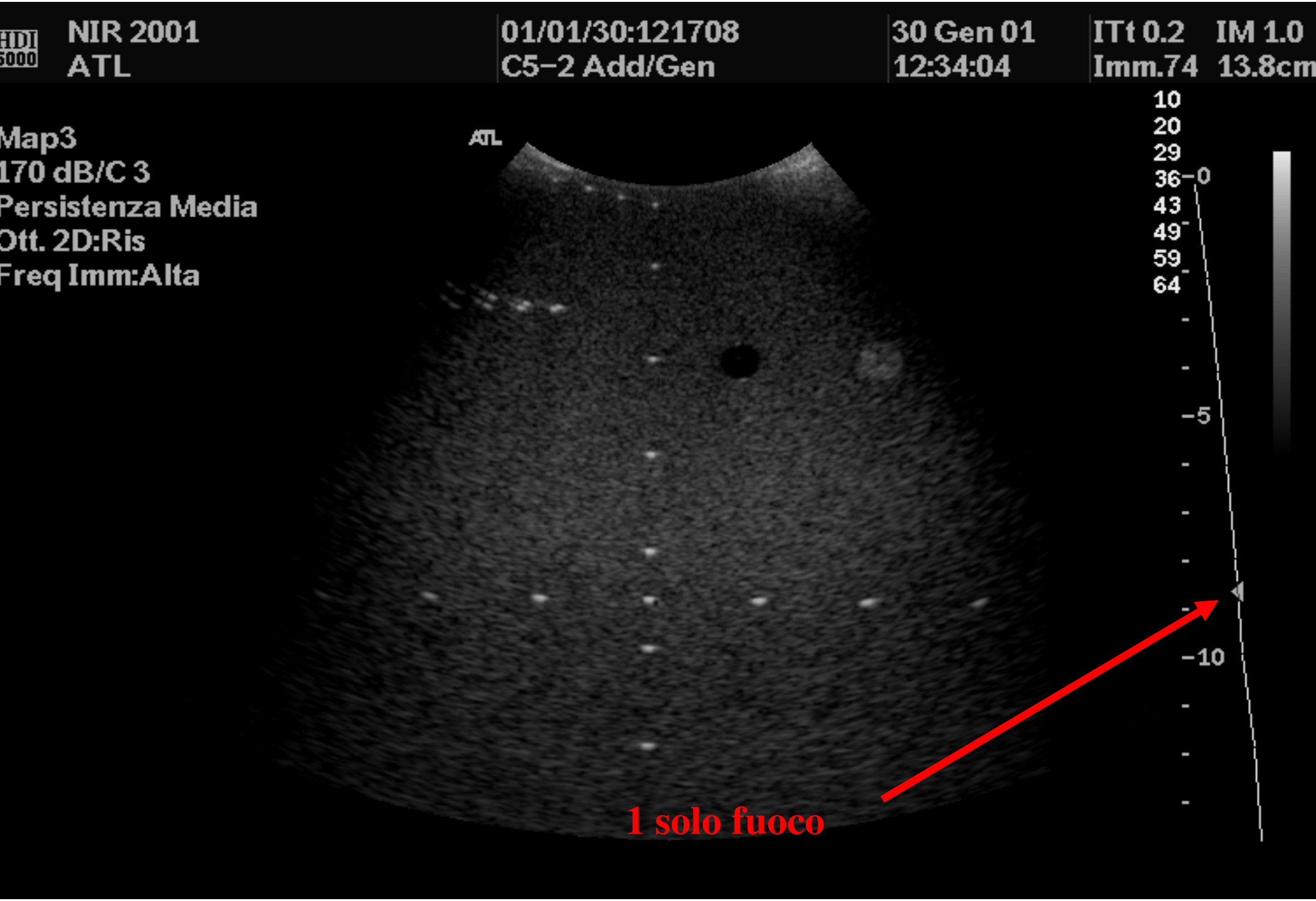
PRF ↑ → FR ↑ → PROFONDITA' ↓

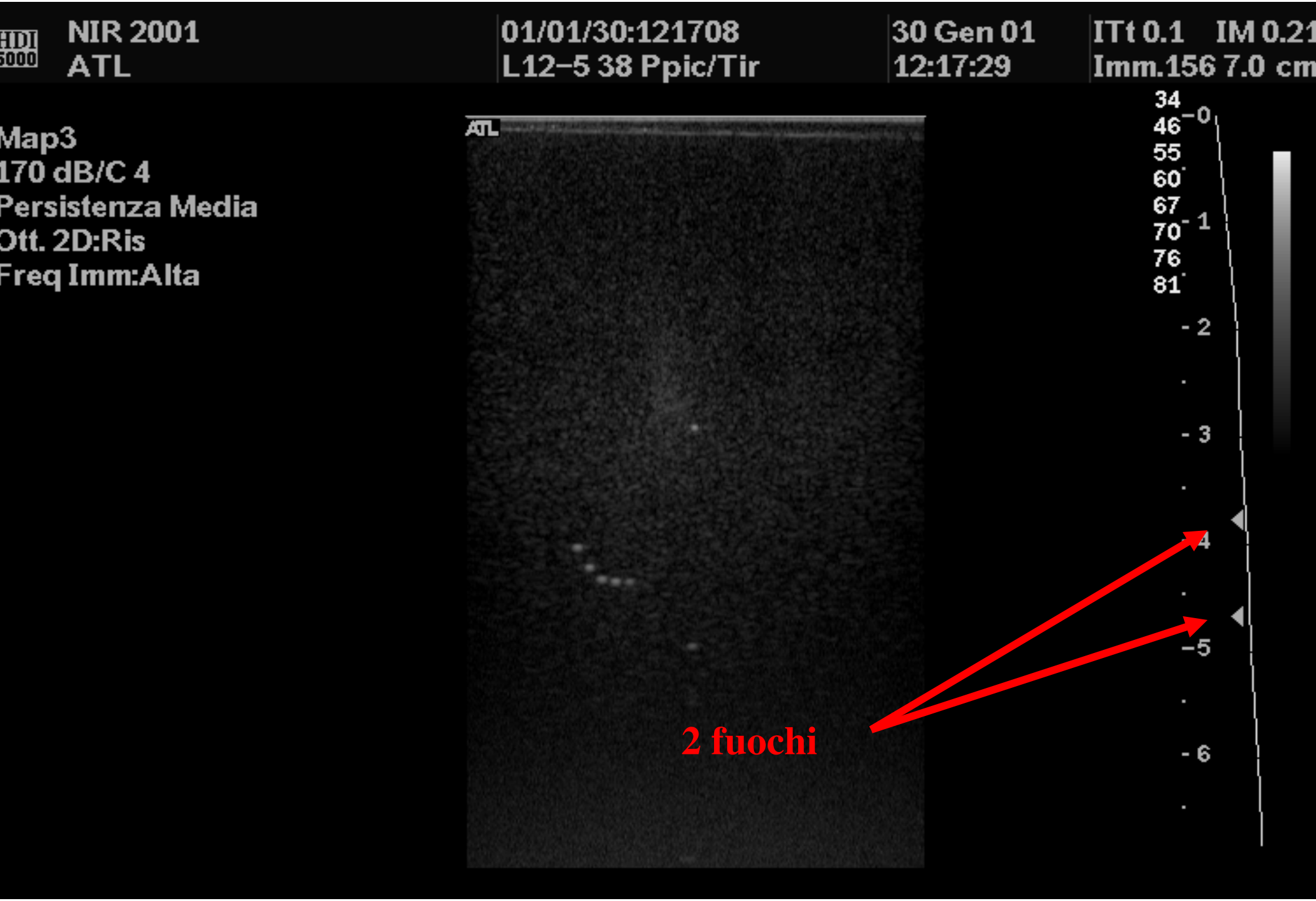
n. linee ↑ → FR ↓ → RISOLUZIONE ↑

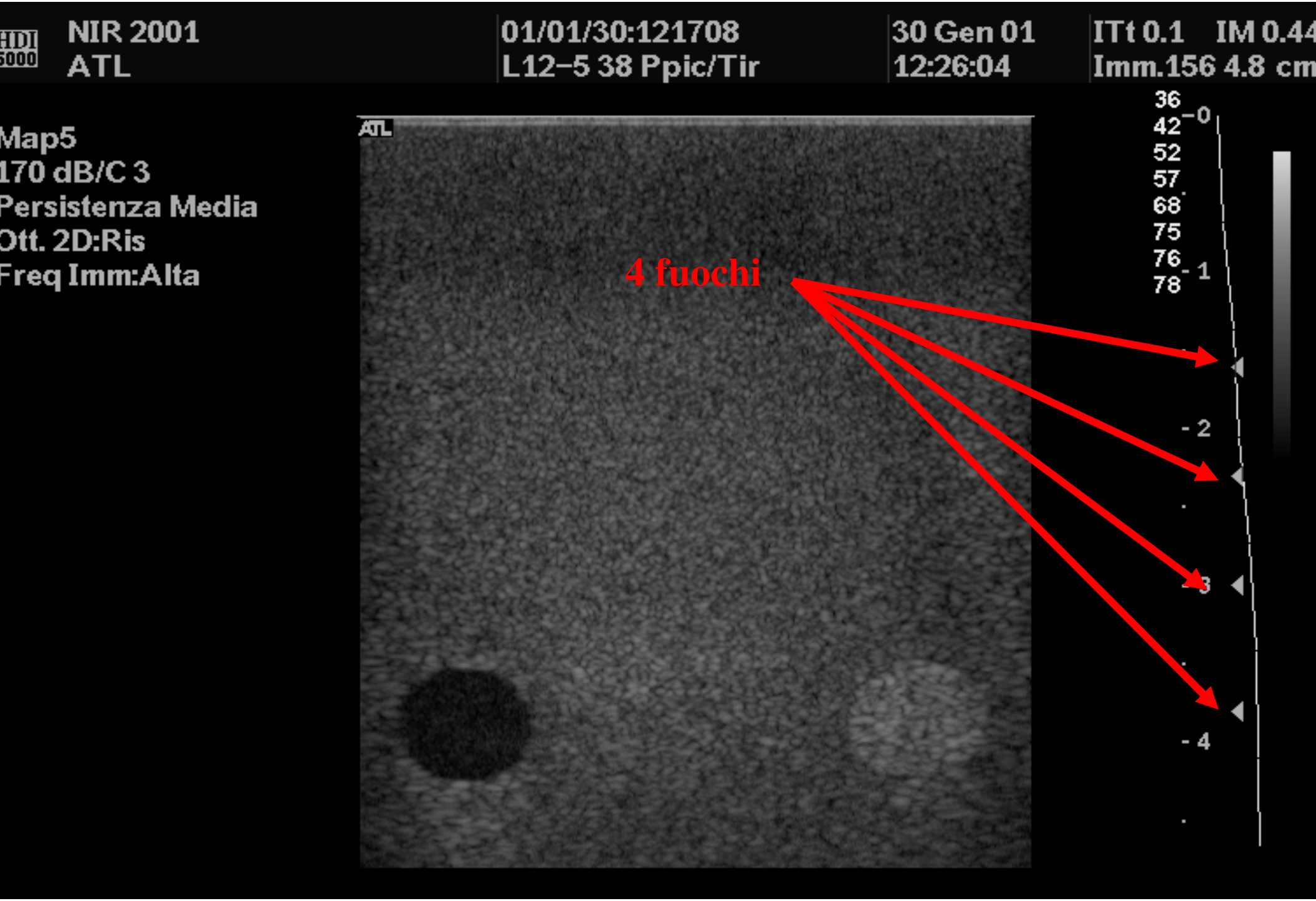
n. fuochi ↑ → FR ↓ → RISOLUZIONE ↑

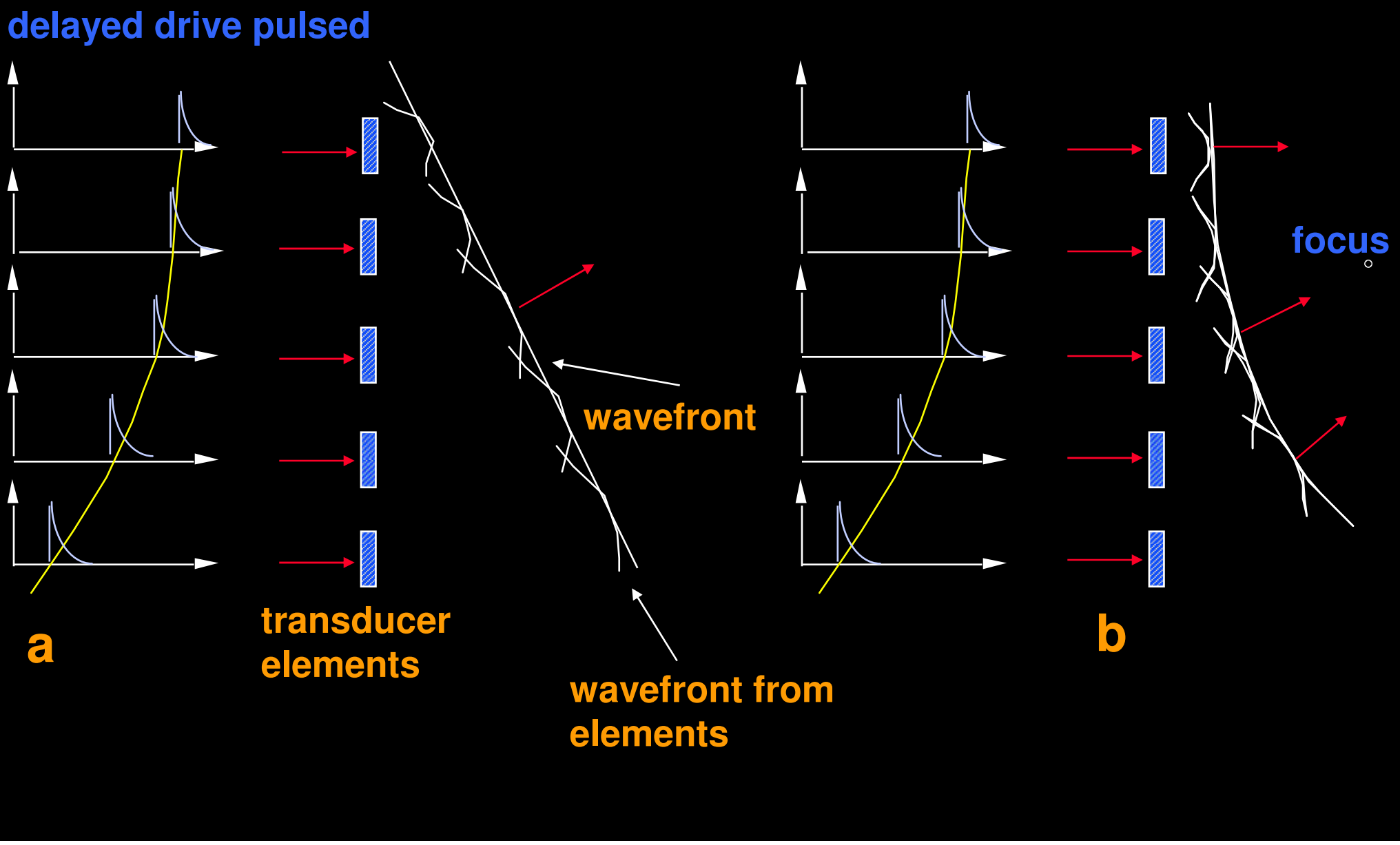
REAL - TIME SCANNER



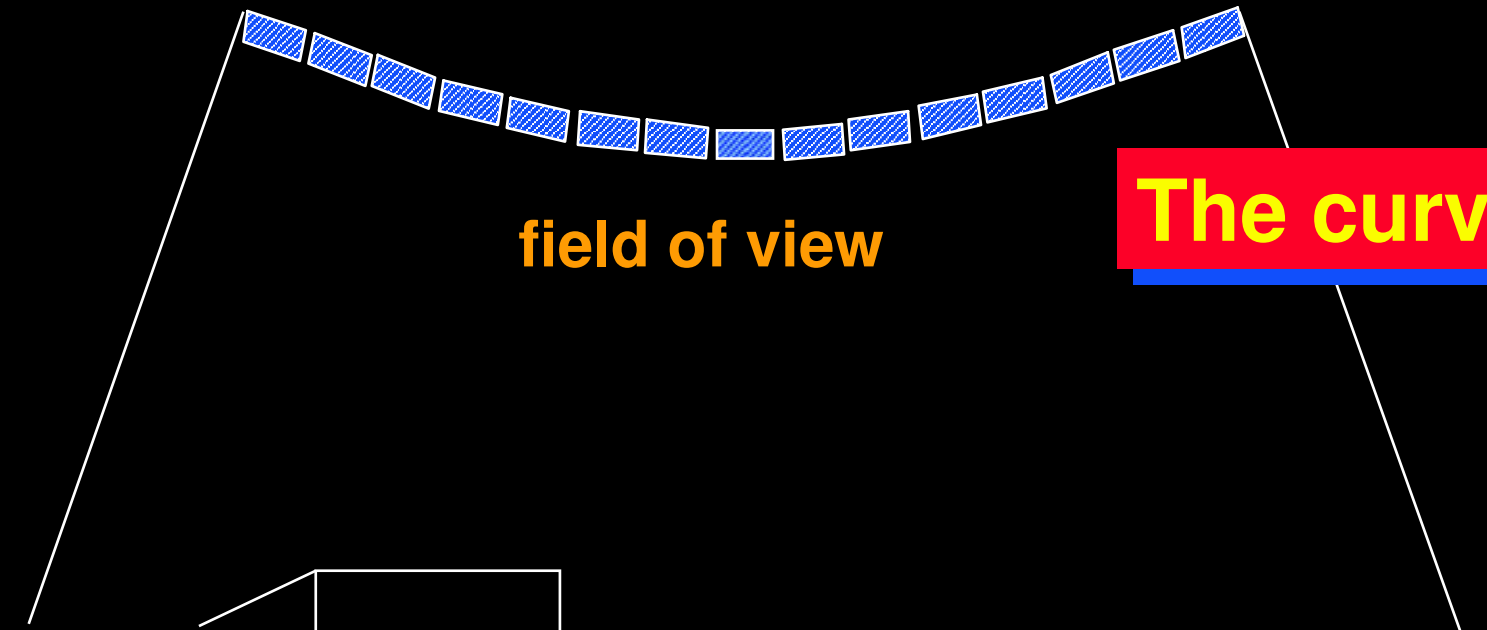

HDI 5000
NIR 2001
ATL
01/01/30:121708
C5-2 Add/Gen
30 Gen 01
12:34:04
ITt 0.2
Imm.74
IM 1.0
13.8cm
Map3
170 dB/C 3
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
ATL
10
20
29
36
43
49
59
64
0
-5
-10
1 solo fuoco


HDI 5000
NIR 2001
ATL
01/01/30:121708
L12-5 38 Ppic/Tir
30 Gen 01
12:17:29
ITt 0.1 IM 0.21
Imm.156 7.0 cm
Map3
170 dB/C 4
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
ATL
34
46
55
60
67
70
76
81
0
1
2
3
4
5
6
2 fuochi

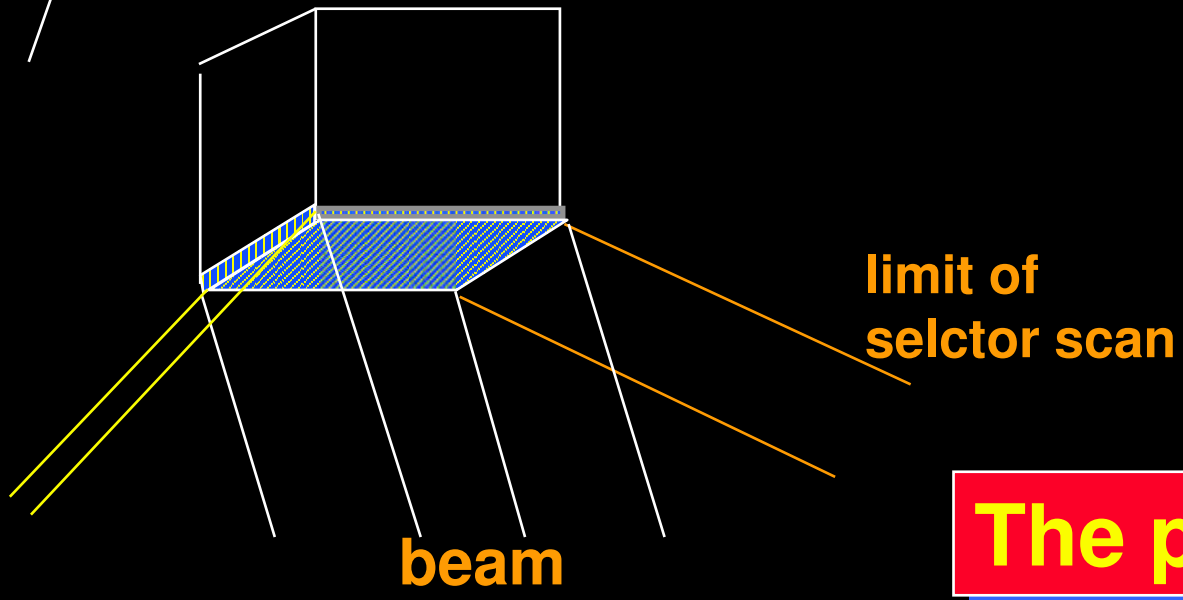

HDI 5000
NIR 2001
ATL
01/01/30:121708
L12-5 38 Ppic/Tir
30 Gen 01
12:26:04
ITt 0.1 IM 0.44
Imm.156 4.8 cm
Map5
170 dB/C 3
Persistenza Media
Ott. 2D:Ris
Freq Imm:Alta
ATL
4 fuochi
36
42
52
57
68
75
76
78
0
1
2
3
4


delayed drive pulsed
wavefront
transducer elements
wavefront from elements
focus
a
b

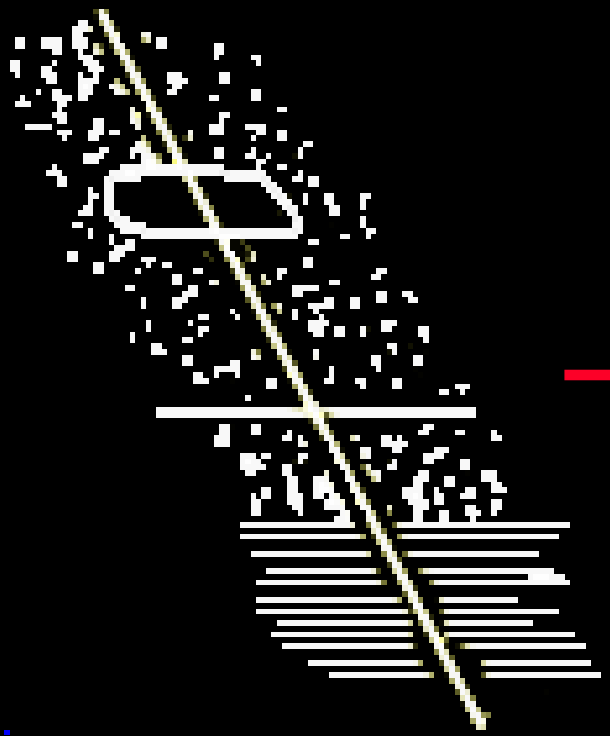
show



The curvilinear array



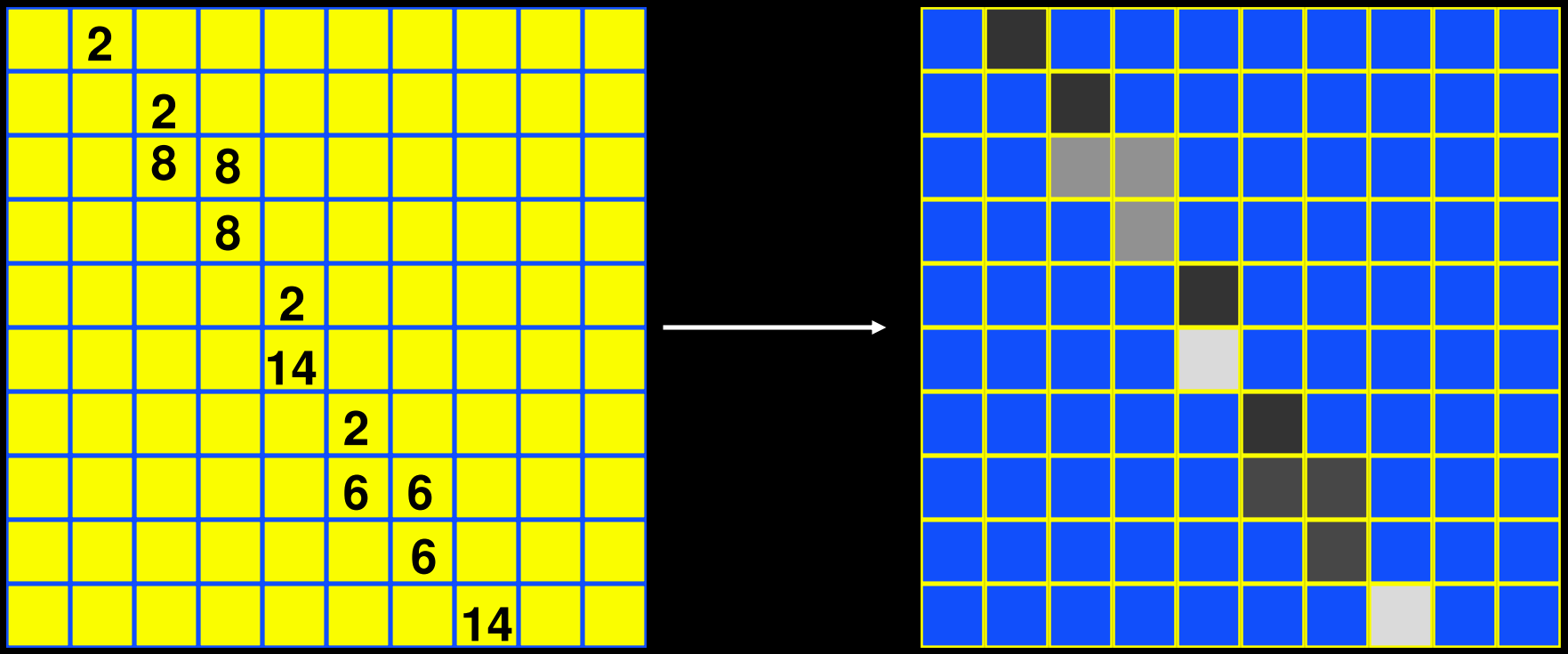
The phased array probe



C

	2								
		2							
		8	8						
			8						
				2					
				14					
					2				
					6	6			
						6			
							14		

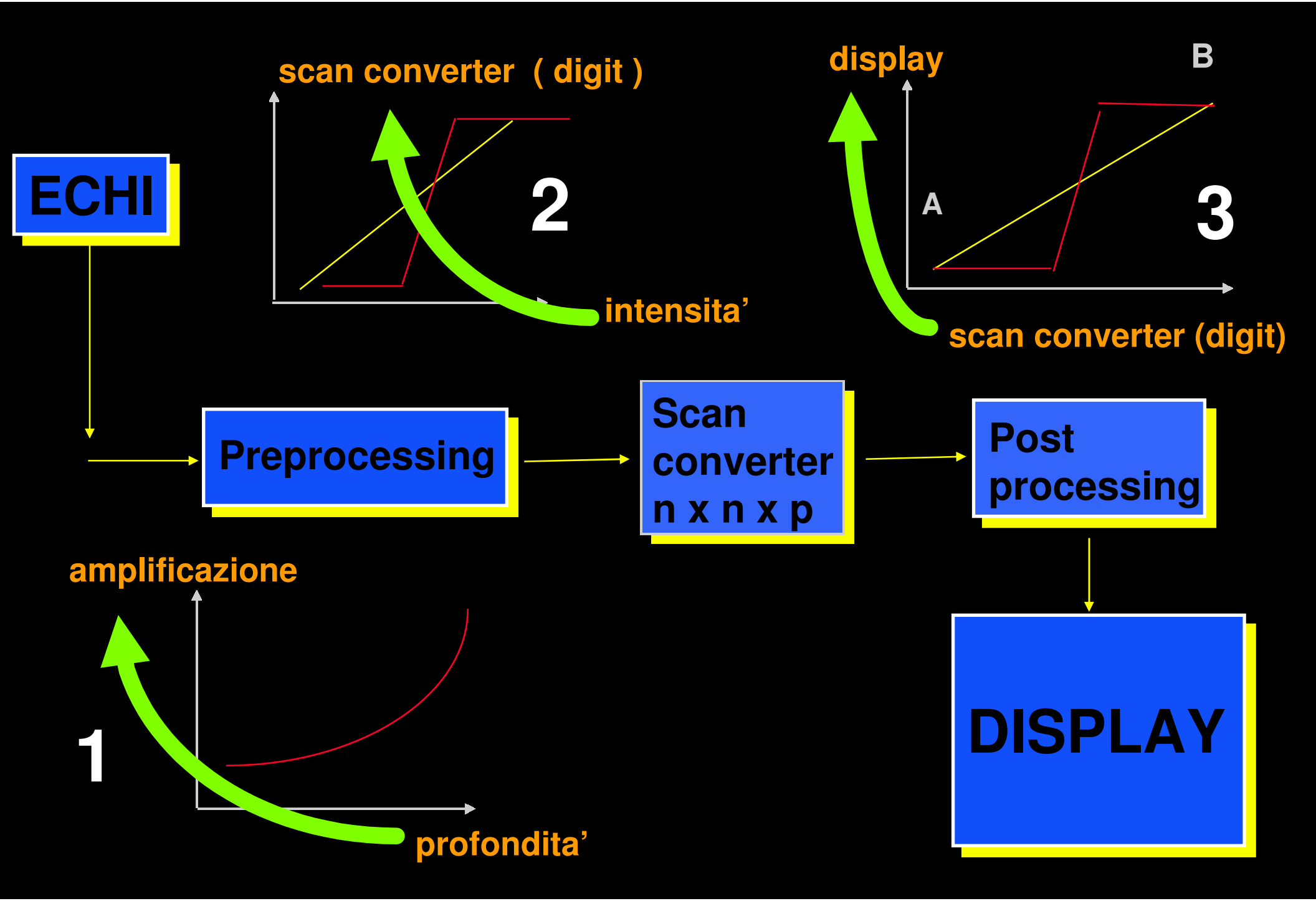
DIAGNOSTIC ULTRASOUND



A

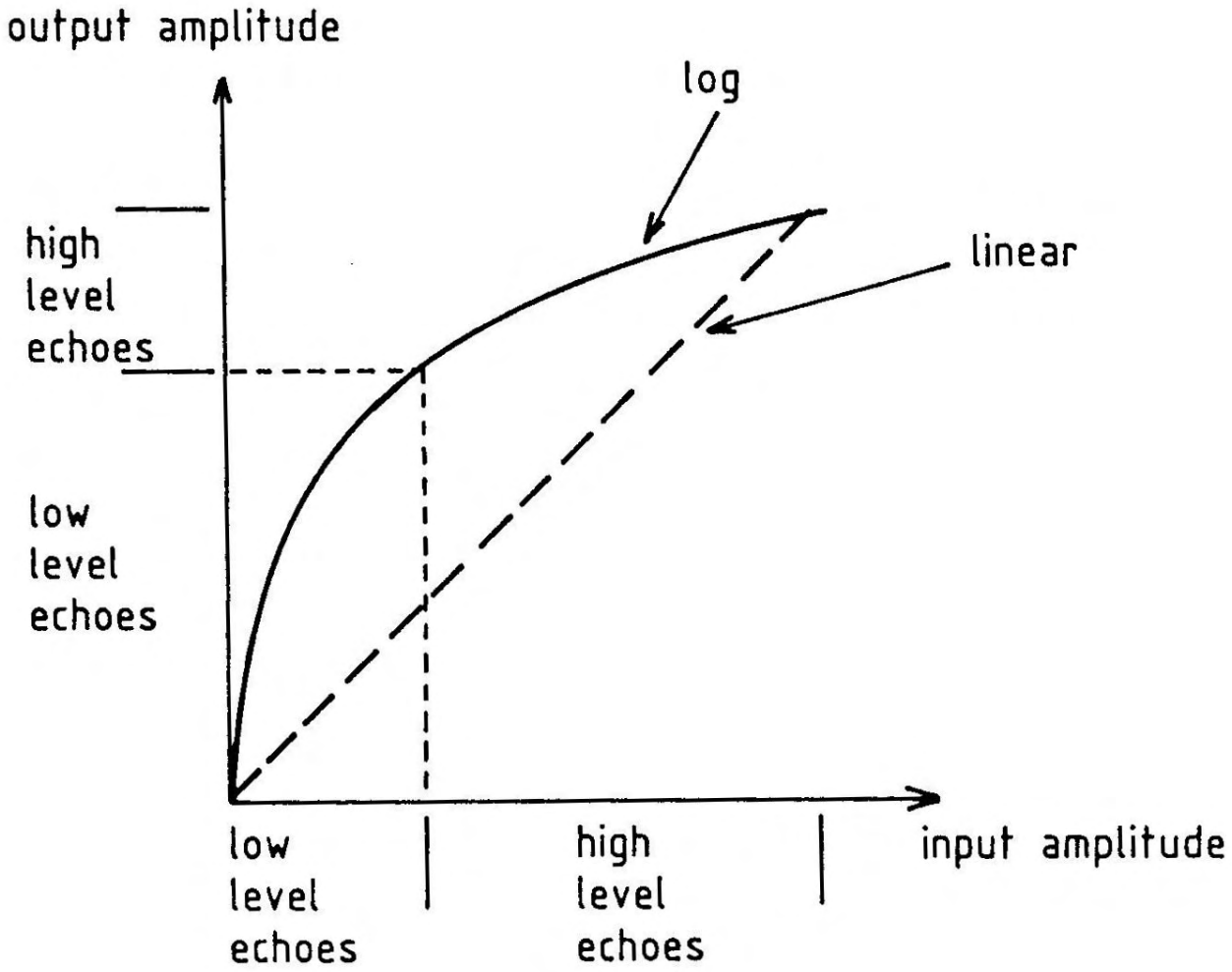
B

show

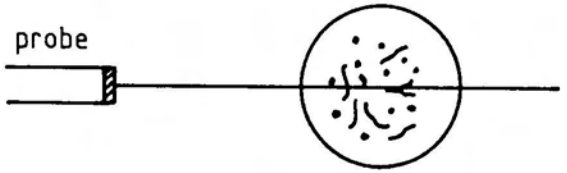

scan converter (digit)
2
intensita'
display
B
A
3
scan converter (digit)
ECHI
Preprocessing
Scan converter n x n x p
Post processing
amplificazione
1
profondita'
DISPLAY

Echo amplitudes.

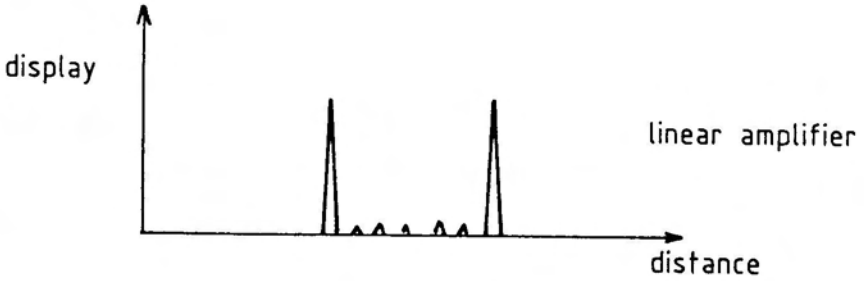
Reflecting/Scattering structure	Relative echo amplitude (dB)
Soft tissue–gas	0
Soft tissue–bone	−20
Fat–muscle	−40
Liver	−65
Brain	−100


output amplitude
log
linear
high
level
echoes
low
level
echoes
low
level
echoes
high
level
echoes
input amplitude

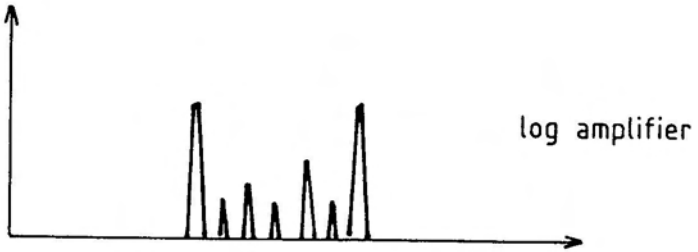
(a)



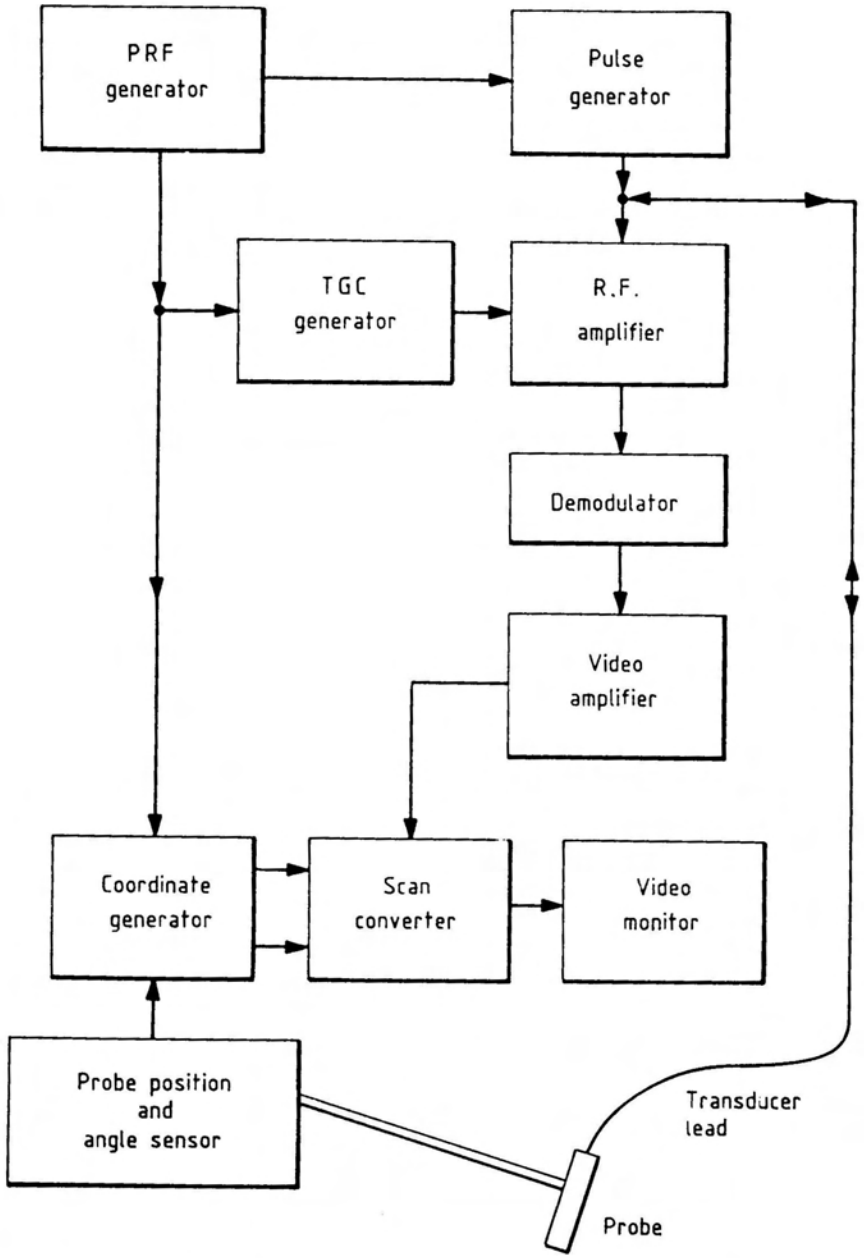
(b)



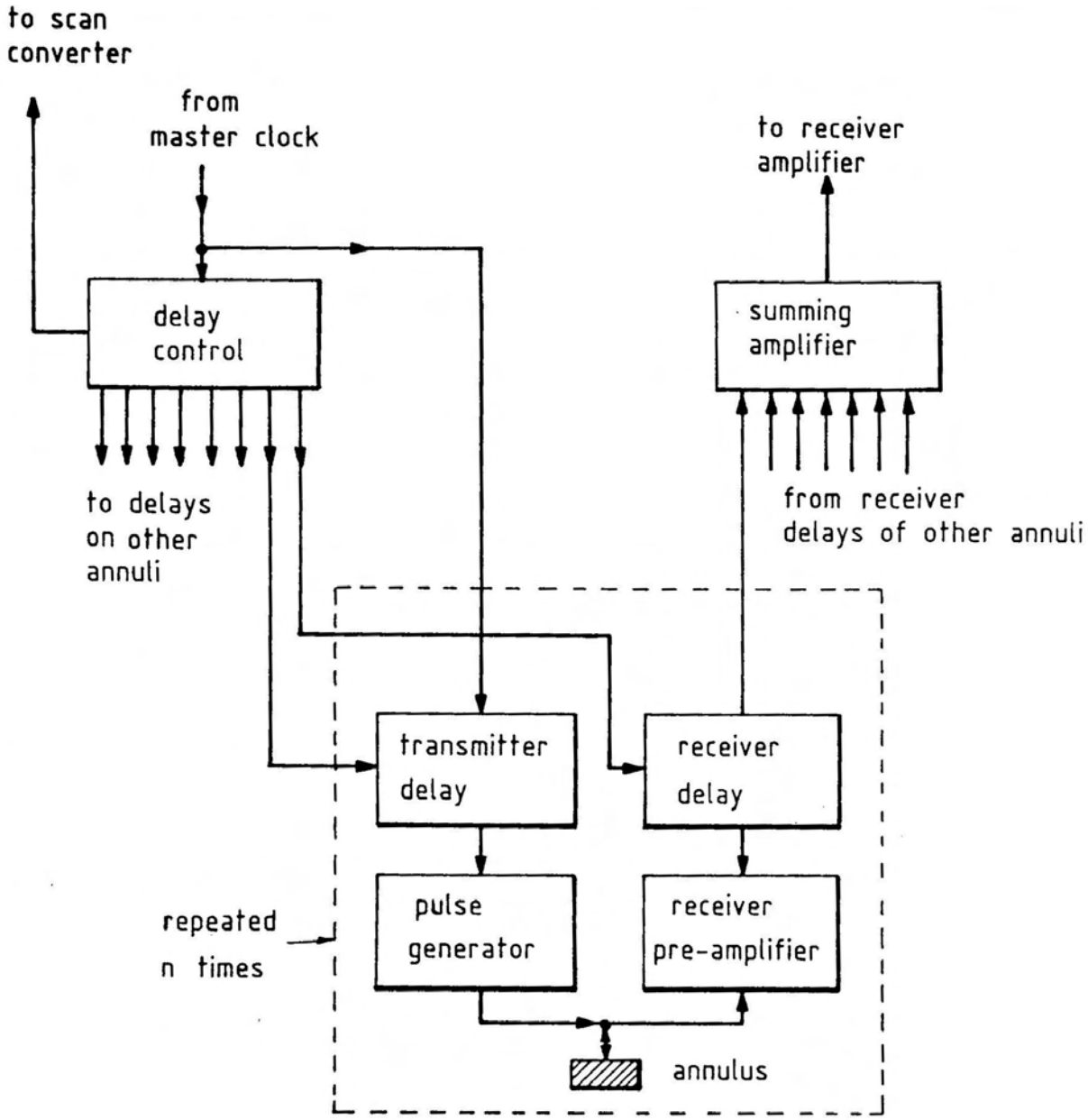
(c)



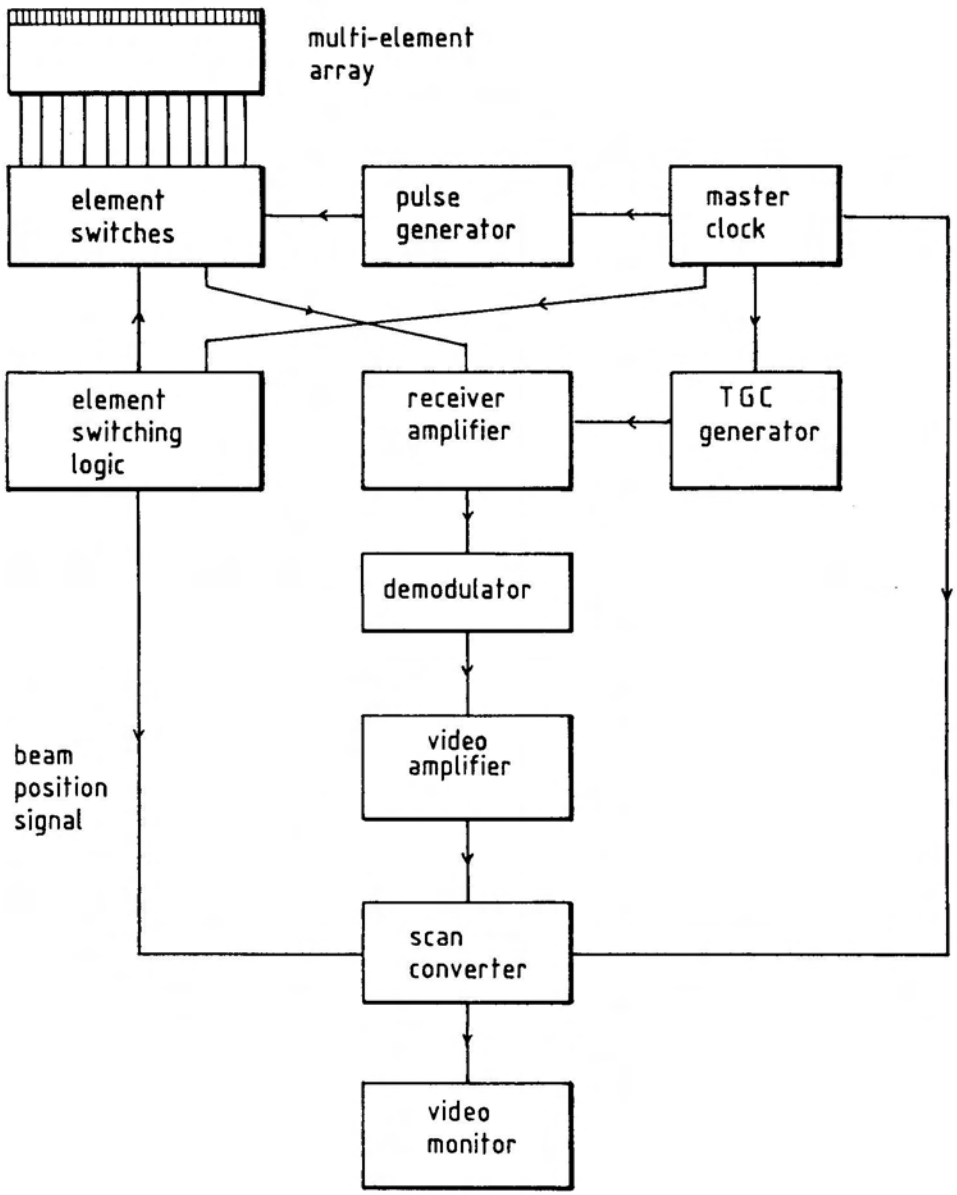
(d)



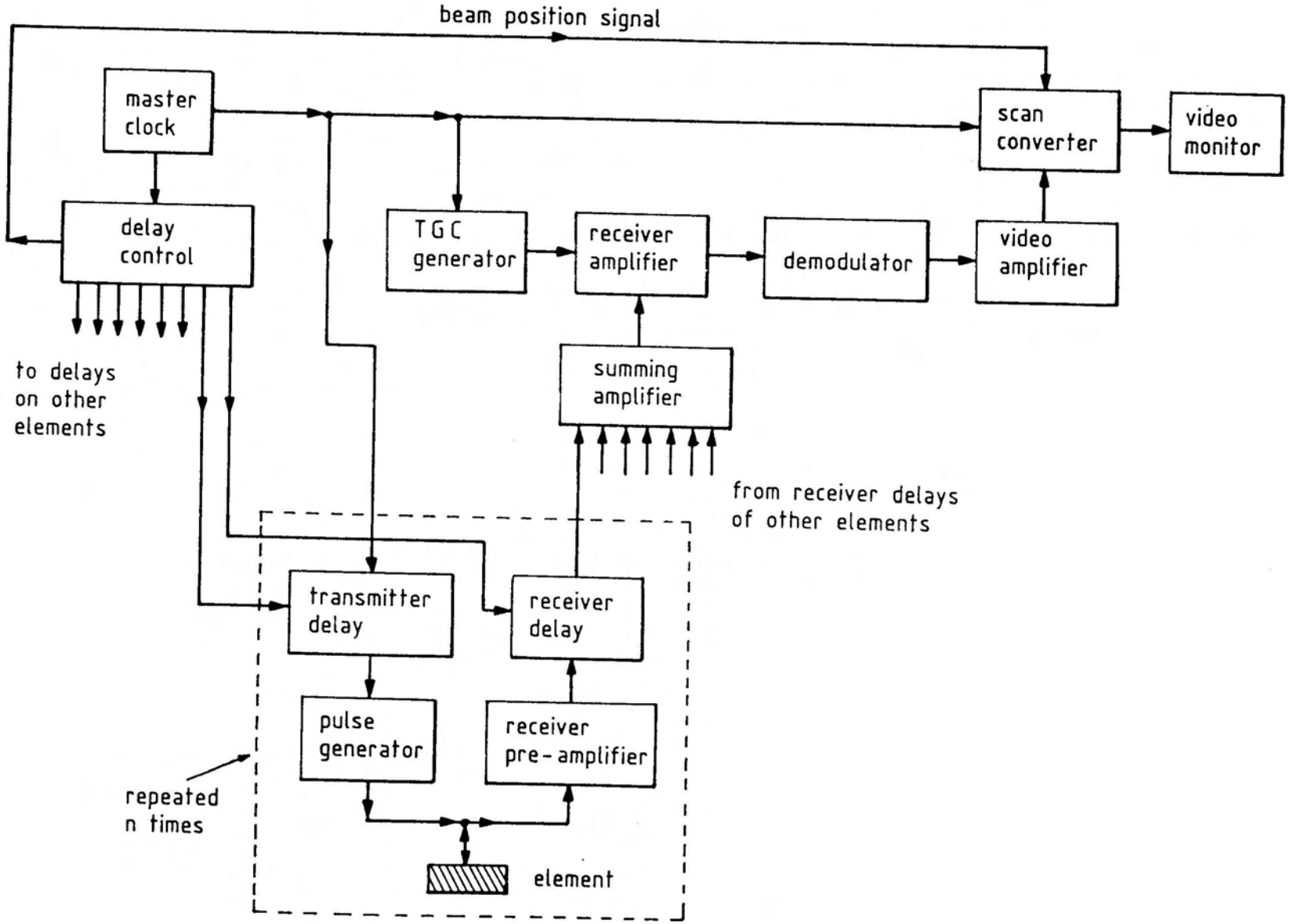
Block diagram of B-scanner with scan converter.



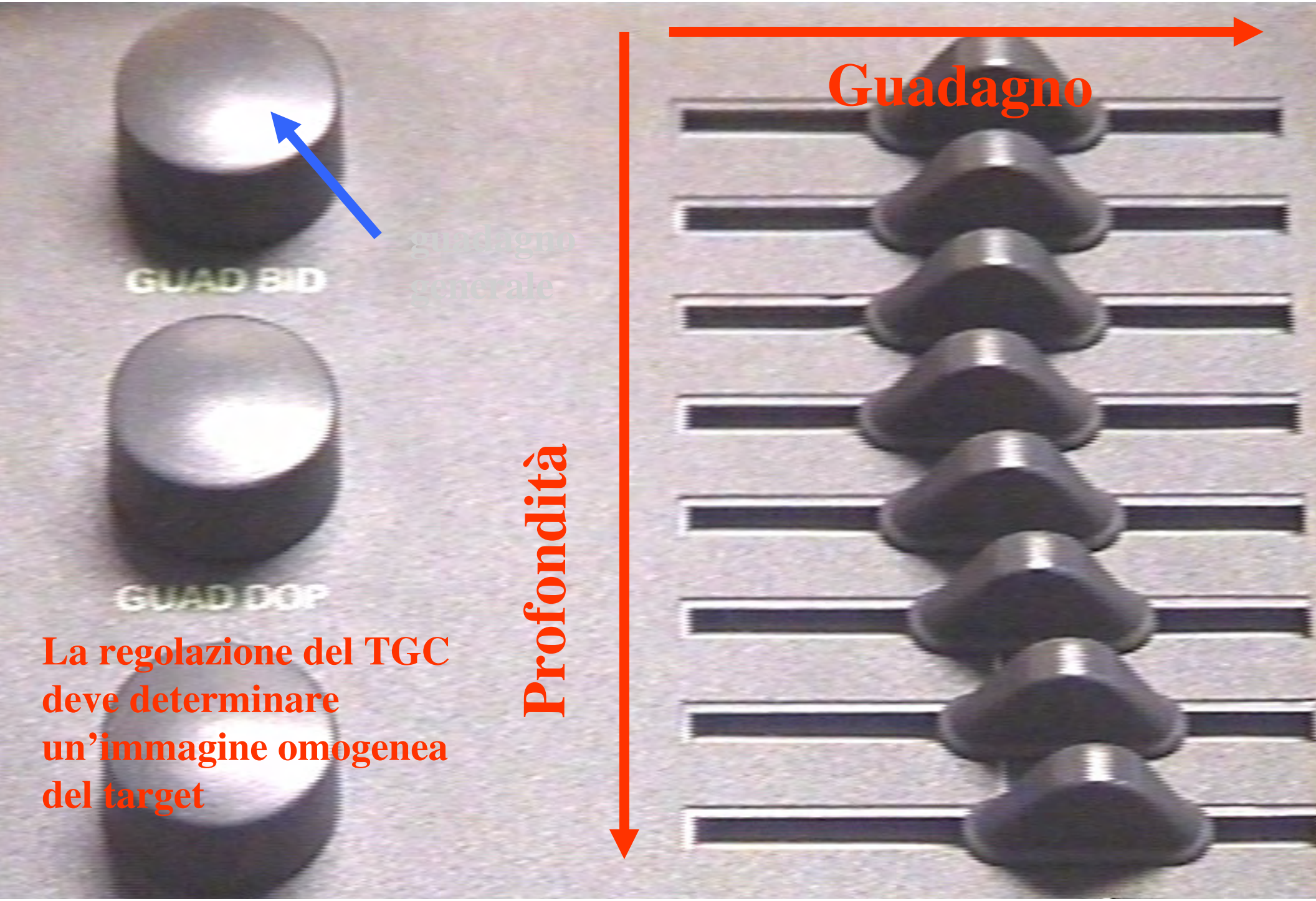
Additions to the circuit of a mechanical scanner to allow electronic focussing in transmission and reception.



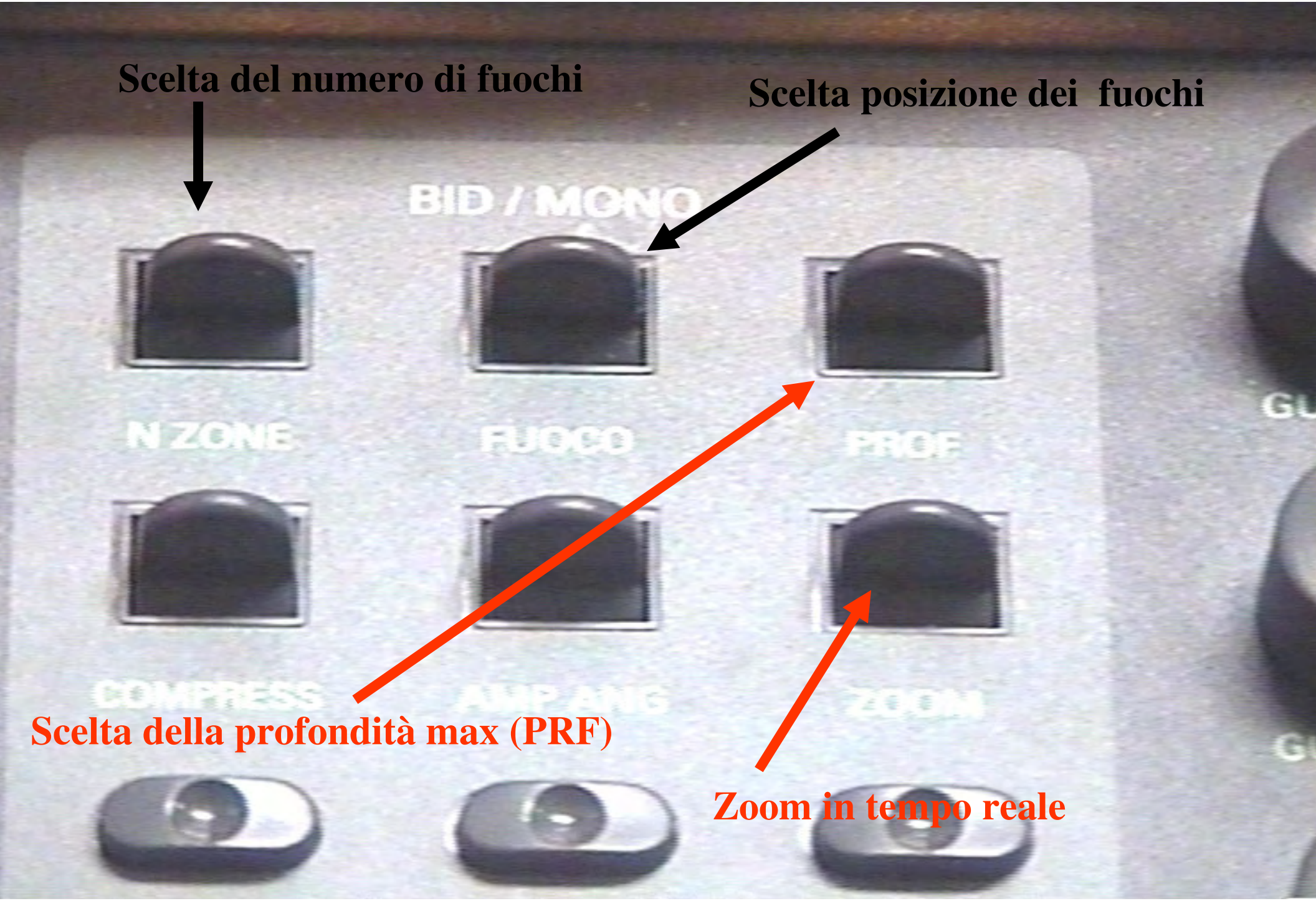
Linear array scanner block diagram.

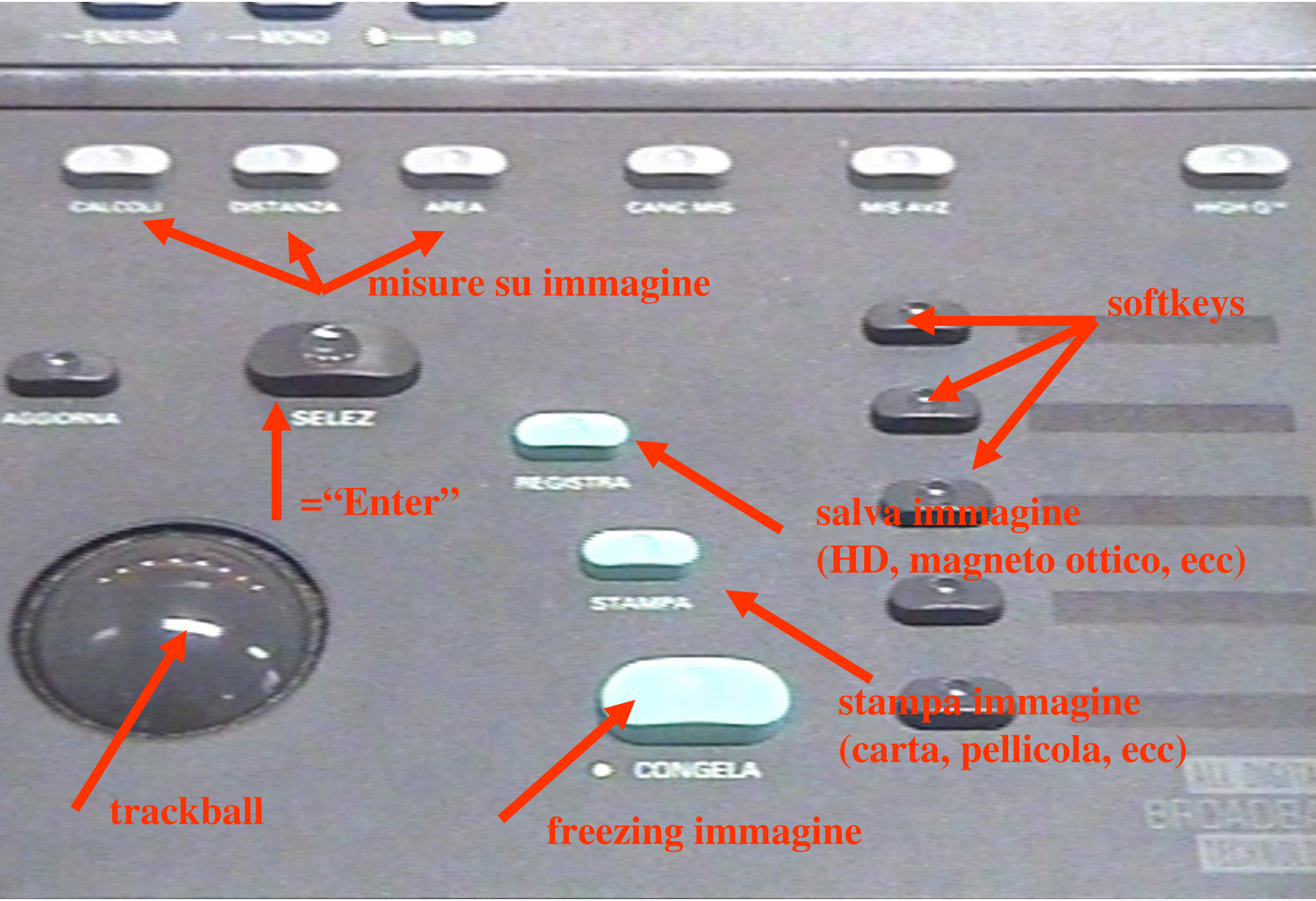


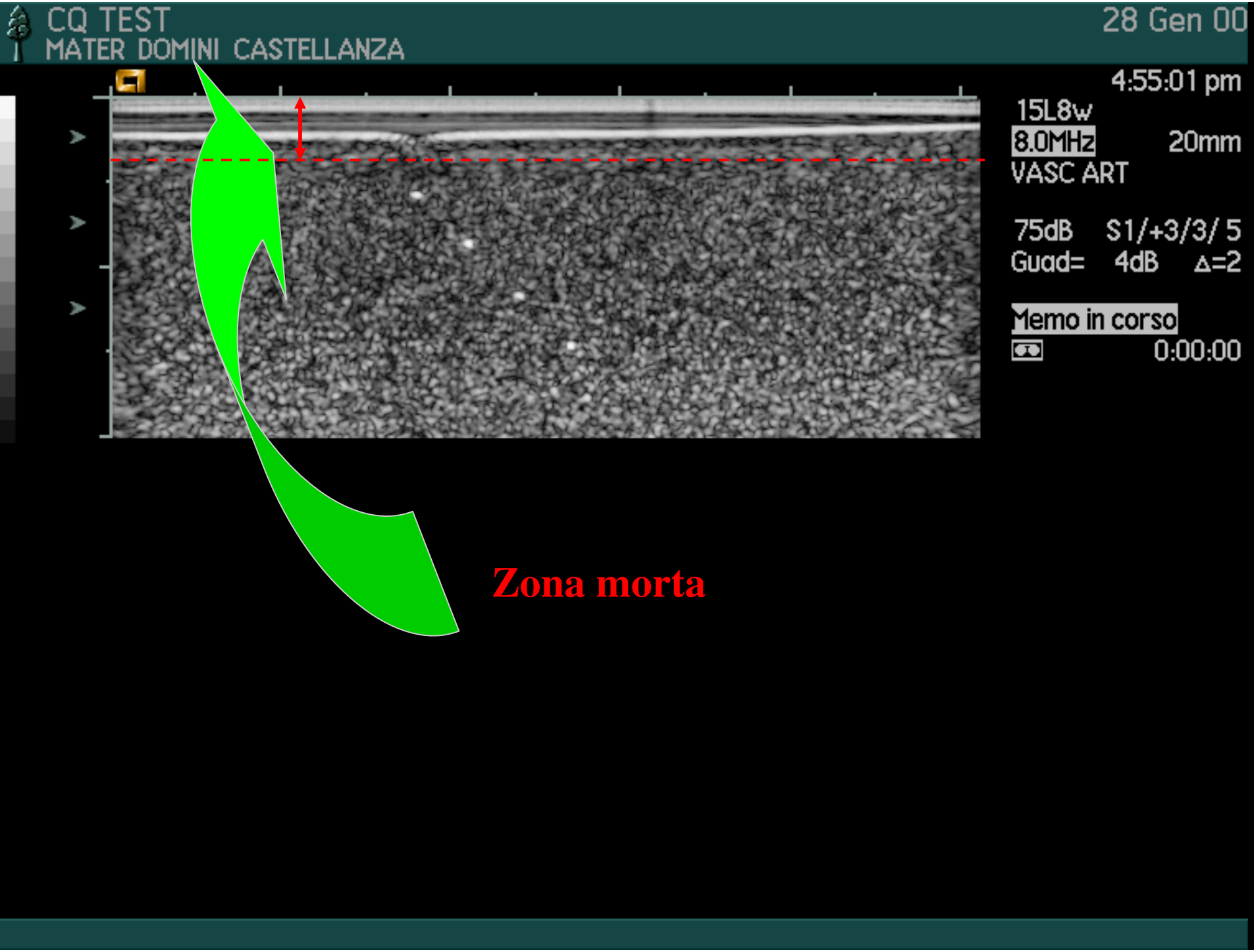
Phased array scanner block diagram.

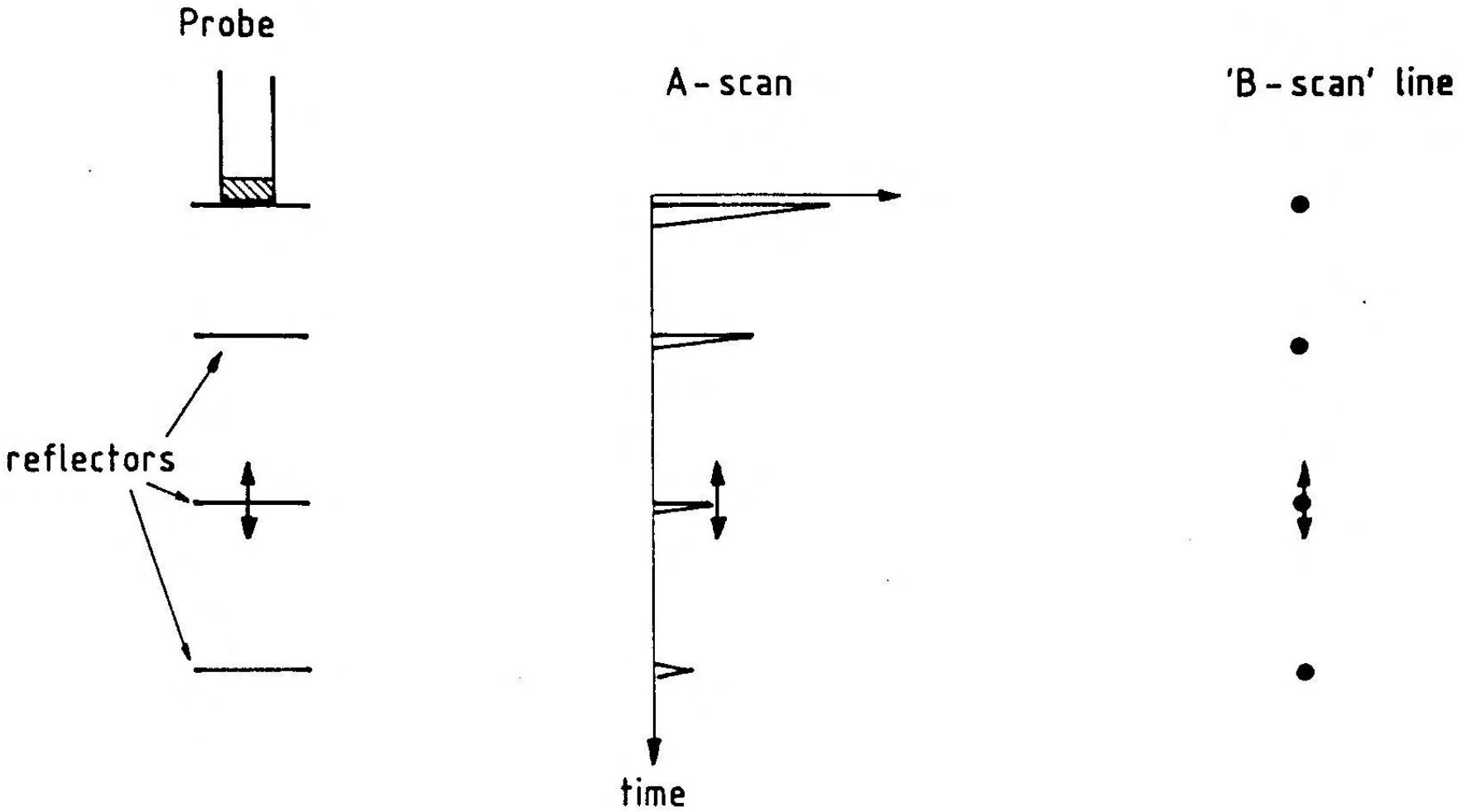


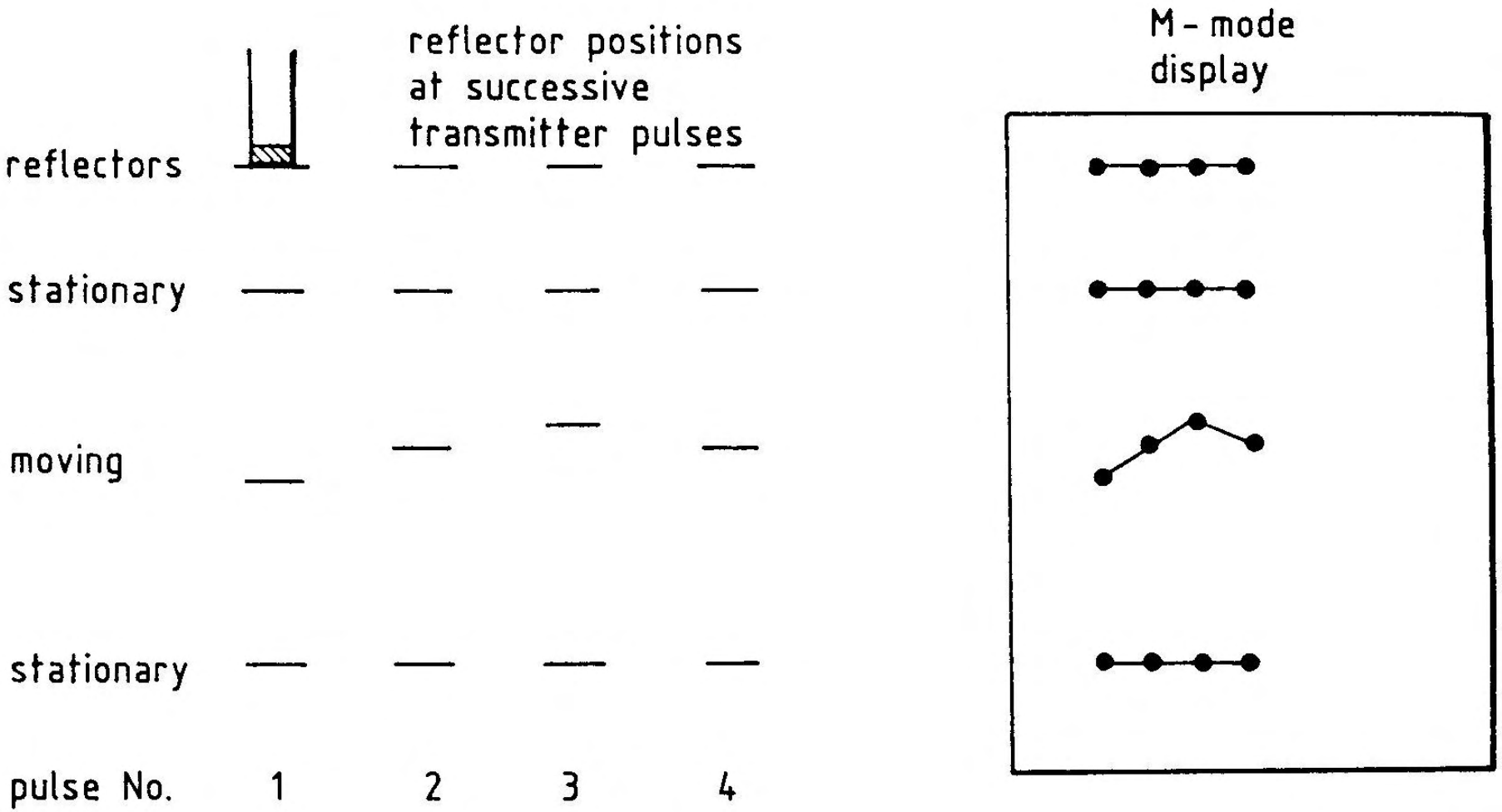
La regolazione del TGC deve determinare un'immagine omogenea del target

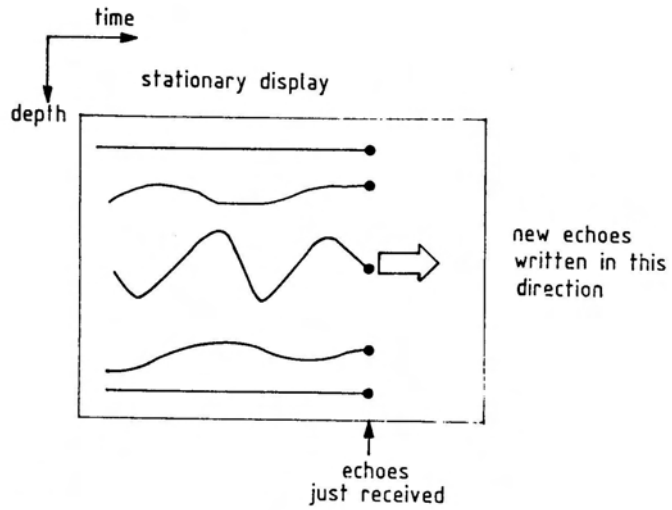

Scelta del numero di fuochi
Scelta posizione dei fuochi
BID / MONO
N ZONE
FUOCO
PROF
COMPRESS
AMP ANG
ZOOM
Scelta della profondità max (PRF)
Zoom in tempo reale


misure su immagine
softkeys
SELEZ
="Enter"
salva immagine
(HD, magneto ottico, ecc)
STAMPA
stampa immagine
(carta, pellicola, ecc)
CONGELA
trackball
freezing immagine

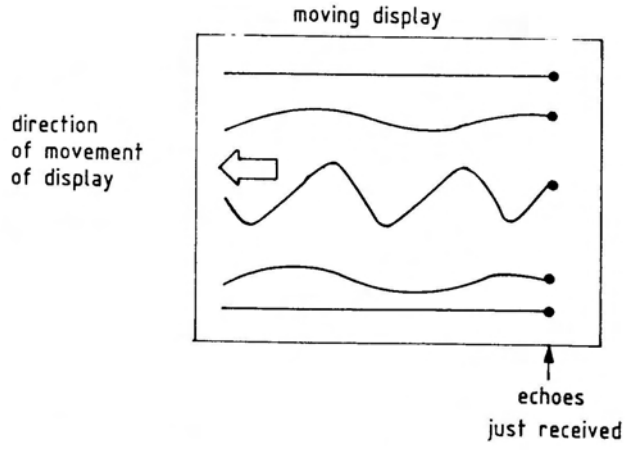

CQ TEST
MATER DOMINI CASTELLANZA
28 Gen 00
4:55:01 pm
15L8w
8.0MHz
20mm
VASC ART
75dB
S1/+3/3/ 5
Guad=
4dB
Δ=2
Memo in corso
0:00:00
Zona morta


Probe
A - scan
'B - scan' line
reflectors
time


reflector positions
at successive
transmitter pulses
reflectors
stationary
moving
stationary
pulse No.
1
2
3
4
M - mode
display

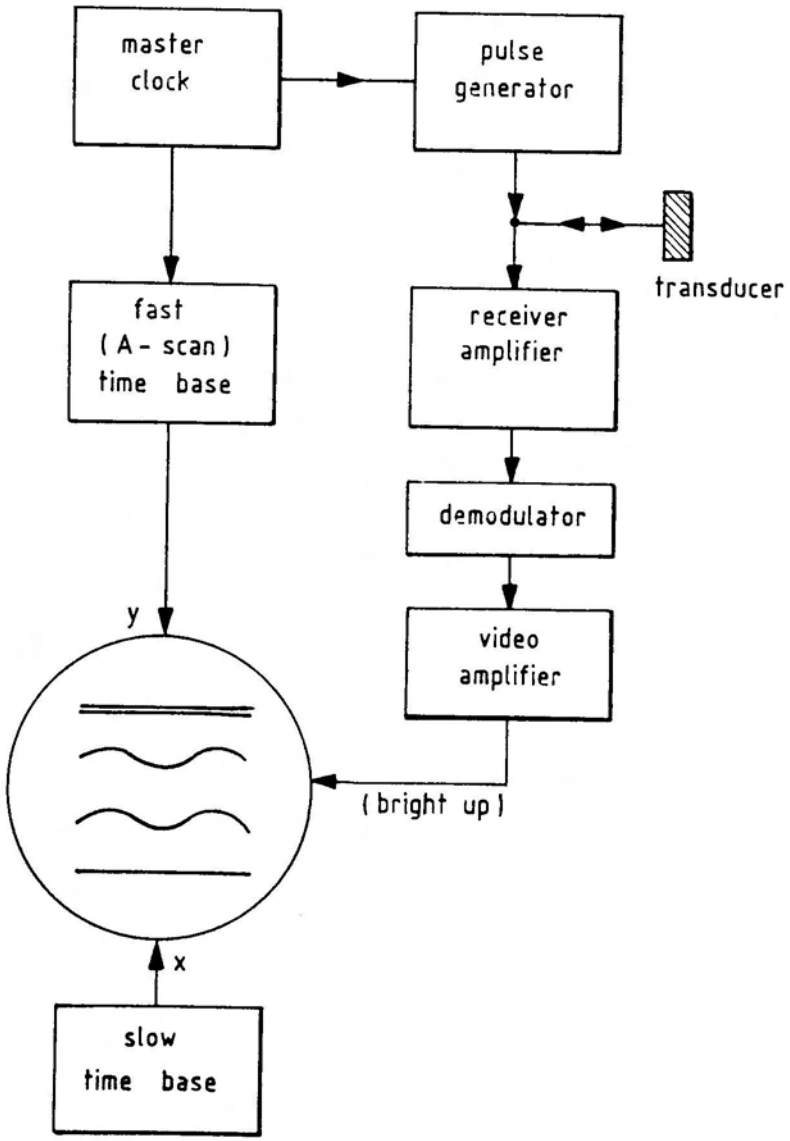


(a)

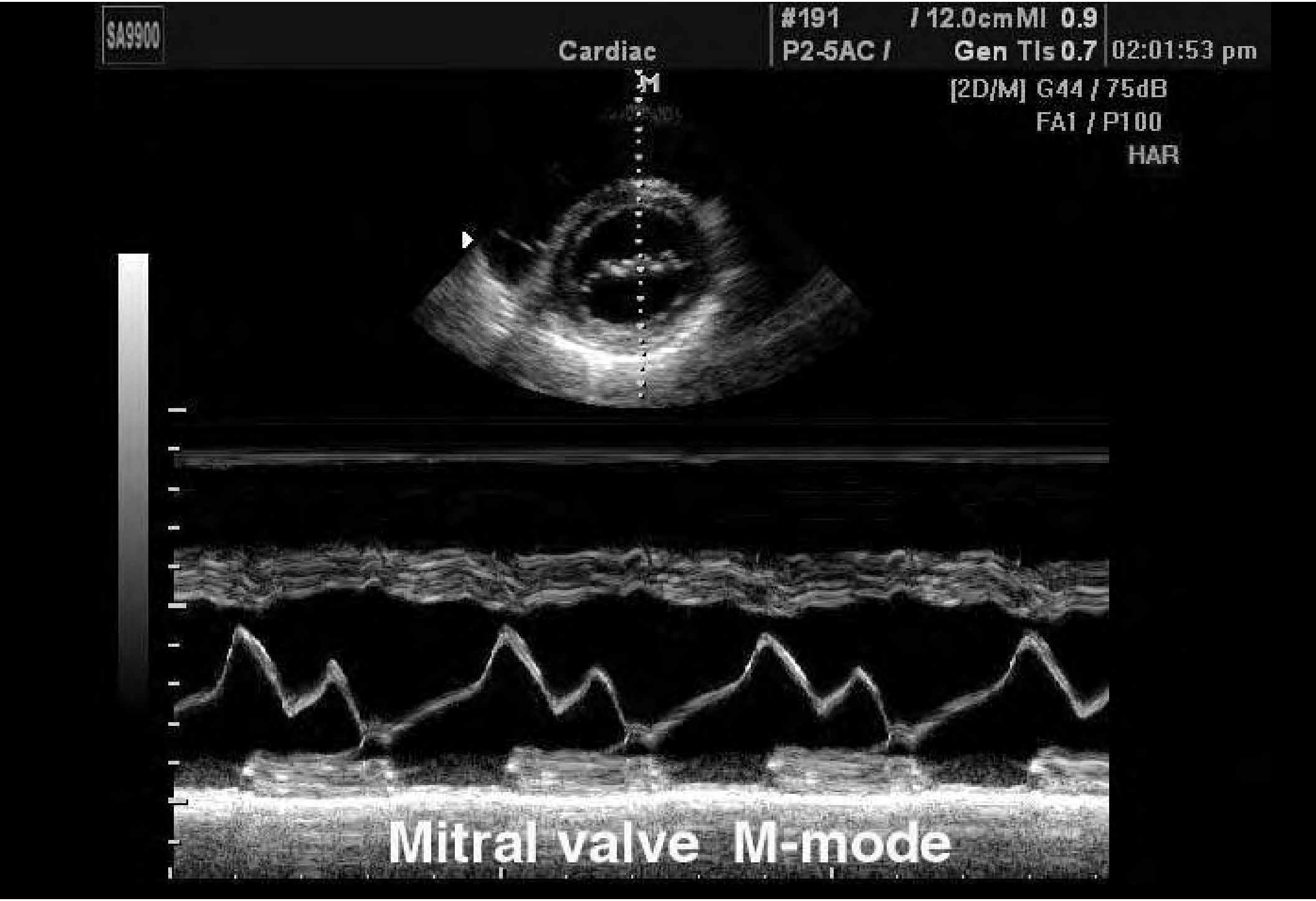


(b)

Display during sweep mode (a) and scroll mode (b).



M-mode scanner block diagram.


SA3900
Cardiac
#191
/ 12.0cm MI 0.9
P2-5AC /
Gen TIs 0.7
02:01:53 pm
M
[2D/M] G44 / 75dB
FA1 / P100
HAR
Mitral valve M-mode