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(ALA/INS/87/17)

MANUAL OF ACOUSTICS THEORY AND APPLICATION TO THE BIOSONICS-SYSTEM FOR TARGET STRENGTH MEASUREMENT

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FOREWORD

The activities of the "Java Sea Pelagic Fishery Assessment" Project lead to publish many sorts of documents :

- Administrative documents.
- Mission reports.
- Data compilations.
- Technical and scientific reports.
- Articles in research journals with reading panel.

A serie, called "Scientific and Technical Documents" is published by the Project. The first number issued in July 1991. That collection with restricted distribution includes all the technical and scientific Project's reports, the semestral and annual statistics on catch, effort, biological and economical data, and articles concerning the pelagic fishery in the Java Sea. That basic documentation will serve for the final writing of scientific and technical articles proposed to research journals.

February 1997

ABSTRACT

At the end of 1996, a training course in acoustics was performed. Acoustics, as an important tool in fishery assessment, is destined to be continued by Indonesian scientists, after the closure of the PELFISH Project. This project, sponsored by European Union, Indonesia and France took place, from 1991 to 1995, and twenty acoustic cruises in the Java Sea and the surrounding areas were achieved. To fulfill the aim of the PELFISH Project, besides electronic equipment, this training was therefore indispensable to use it. This paper recalls the basics of acoustics, all about the scientific apparatus and their adjustments, the procedures of data acquisition and their post processing.

PREFACE

It is not worth to justify the use of the acoustics method in the study of pelagic populations. This biomass assessment method by means of acoustic detection is nowadays worldwide used by countries desirous to know their pelagic fish stocks. Even if this method does not show yet the total accuracy of the results we may expect, it is still the only method able to straightway furnish, at any time, an information on stock evaluation and their availability.

To achieve this aim, one needs to cover areas at sea, with a research vessel able to catch fish and equipped with scientific equipment such as : echo-sounder which detects fish, echo-integrator which calculates the amount of fish and computers to process all the data collected during the surveys.

The purpose of this manual is to introduce the Reader to some elementary theory related first to the physical background, second to the properties of fish, and finally to explain roughly the functioning of the equipment whose specific acoustic configuration is composed of:

- A Dual Beam echo-sounder Model 102 BioSonics (working frequency 120 kHz)
- An ESP-Dual Beam processor from BioSonics for Target Strength measurements
- An INES MOVIES system from IFREMER for Echo-Integration

The last part of this work will be devoted to show the processing of the data.

ACKNOWLEDGEMENTS

The present document would not have been without the help of numerous former publications and works. I would like to thank and express my gratitude especially to :

- Mr. Burczynski J. and Marchal E. for their document : Introduction à l'utilisation des systèmes sonar dans l'estimation de la biomasse en poissons. Version française préparée par E. Marchal. FAO, Doc.Tech. Pêches, (191) Rev.1:81.
- BioSonics, Inc. 4027 Leary Way NW. Seattle, WA 98107 USA.
- ORCA / IFREMER for their documents : INES-MOVIES Operating and Technical Manuals.

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ACOUSTICS ELEMENTARY THEORY

MATH RULES AND DEFINITIONS

The purpose of this chapter is to present or to refresh some math basics and the units that will be used in this manual.

1.1 The units

- of distance : the metric system units, such as : meter (m), km (km),... and also the marine units such as : the nautical mile (nmi) with the following relationship :
  1 nautical mile = 1852 m
- of speed : the metric system units, such as : meter/second (m/sec),... and also the marine units such as the knot (no abbreviation) with the following relationship :
  1 knot = 1 nautical mile/hour (= 1852 m/hour)
- of surface : the metric system units such as : square meter (m^2),... and also the marine units such as : square nautical mile (nmi^2)
- of weight : the metric system units such as : kilograms (kg), tons (t),...
- of time : second (s), millisecond (ms),...
- of angle : degree (°), radian (rad), steradian (sr.)

The electrical units are:

- for the voltage : volt (V)
- for the impedance / resistance : ohm (Ω)
- for the intensity : ampere (A)
- for the electric power : watt (W)
- for the frequency : hertz (Hz)

In acoustics, we use common units of physics such as :

- for the sound intensity : watt per square meter (W/m^2)
- for the pressure* : Pascal (Pa), Micropascal (µPa) $1 \mu Pa = 10^{-6}$ Pa

Moreover, all the units, here above, such as voltage, pressure, power and intensity, are expressed in decibel (dB), a specific unit related to the log functions.

- logarithms: because of the dynamics of the values, decimal logarithms are applied (log).
- Symbols used as abbreviations are from the Greek Alphabet, here below:

Alpha	Α	α	Iota	Υ	υ	Rho	Ρ	ρ
Beta	Β	β	Kappa	Κ	κ	Sigma	Σ	σ
Gamma	Γ	γ	Lambda	Λ	λ	Tau	Τ	τ
Delta	Δ	δ	Mu	Μ	μ	Upsilon	Υ	υ
Epsilon	Ε	ε	Nu	Ν	ν	Phi	Φ	ϕ
Zeta	Ζ	ζ	Xi	Ξ	ξ	Chi	Χ	χ
Eta	Η	η	Omicron	Ο	ο	Psi	Ψ	ψ
Theta	Θ	θ	Pi	Π	π	Omega	Ω	ω

---

* We can also meet the Bar (Bar) related to the usual one as : $1 \mu Pa = 10^{-5} \mu Bar$

Question :

What is the equivalence in km/hour of a 10 knots speed (S) ?

Answer :

S =10 knots = 10 nmi/hour = 10 x 1852 m/hour = 18520 m/hour = 18.52 km/h

1.2 Conversions

Some recalling are needed :

1 km = 1000 m = 10^3 m
1 mV = 0.001 V = 10^{-3} V
1 µV = 0.000001 V = 10^{-6} V
1 ms = 0.001 s = 10^{-3} s
1 µs = 0.000001 s = 10^{-6} s

1.3 Definitions

1.3.1 The logarithms

What is a logarithm ? For scaling reasons, mathematicians have created these special functions; there are two kinds of logarithms: the decimal ones (log), and the nepperian (ln) ones. Only the decimal ones will retain our interest.

Here are some specific values of this function :

log of negative number = impossible
log 0 = impossible

log $\mathbf{10^{-3}}$ = - 3
log $\mathbf{10^{-2}}$ = - 2
log **0.5** = - 0.3
log **0.1** = - 1
log **1** = 0

log **2** = 0.3
log **3** = 0.48
log **10** = 1
log $\mathbf{10^{3}}$ = 3
log $\mathbf{10^{n}}$ = n

As you can see, the former numbers (in Bold) are reduced. By this means, we can draw figures and simplify calculations of numbers which have a very large difference. In Acoustics, we commonly apply the formula “10 log (number)”, “20 log (number)” and “40 log (number)”.

Question :

How does a log function look like ?

Answer :

If we draw the function “y = 20 log x”, (it means that both parts of the above equations are simply multiplied by 20 , for example : 20 log 10 = 20 times 1= 20), we obtain the curve on Figure 1 (for the first ten values).

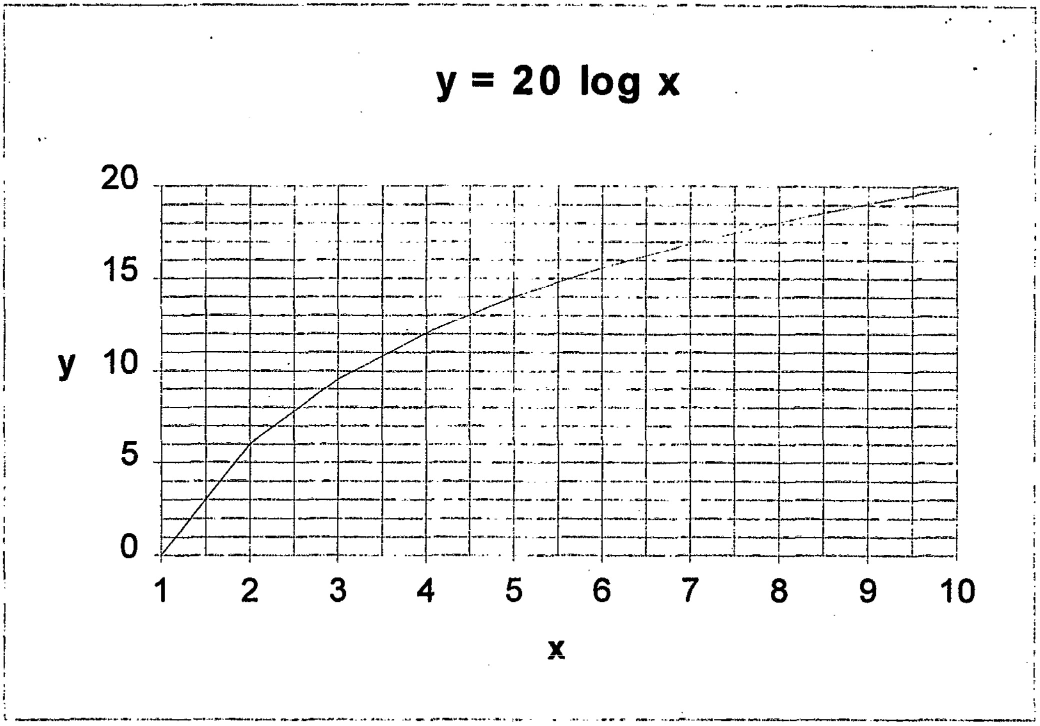


Figure 1 **The "20 log x" curve, for the first ten values.**

Following below, some main rules for calculations with logs :

- log (A x B) = log A + log B
- log (A / B) = log A - log B
- log A^n = n log A
- y = log x => x = 10^y
- z = a log x => x = $10^{z/a}$

1.3.2 The decibels

Decibels are the result of a logarithmic ratio of two values of the same type like : voltage divided by voltage , power divided by power , kg divided by kg ,etc. Following next, the relationships commonly utilized to express basic values in decibels :

Voltage and pressure

Voltage (V)and pressure (p) can be converted to decibel by applying the following relations :

$$V_{dB} = 20 \log (V \text{ measured} / V \text{ reference})$$

$$p_{dB} = 20 \log (p \text{ measured} / p \text{ reference})$$

Question:

How to convert 10 V (volts) in decibels ? .

Answer:

V_{dB} = 20 log (10 volts, "the primary value" / 1 volt, "the reference value")

V_{dB} = 20 log (10 / 1) = 20 log 10 - 20 log 1

$\log 10 = 1$ and $\log 1 = 0$ (see Chapter 1.3.1 - “The logarithms”)

Thus, V_{dB} becomes:

$$V_{dB} = (20 \times 1) - (20 \times 0) = 20 \text{ dB}$$

As we can see, <u>if the reference value is 1</u>, we can shortcut this term and straight use the logarithm of the primary value, times 20, such as:

$$V_{dB} = 20 \log (V)$$

Question :

What is the value in dB (decibel) of the ratio of two numbers whose one is twice the second one ? For example, 220 µPa and 110 µPa, both pressures ?

Answer :

$p_{dB} = 20 \log (220\ \mu\text{Pa} / 110\ \mu\text{Pa}) = 20 \log 2$

$\log 2 = 0.3$ (see Chapter 1.3.1 - “The logarithms”)

$p_{dB} = 20 \times 0.3$

$p_{dB} = 6 \text{ dB}$

Because of the logs, the inverting relations are available : $V = V \text{ reference} \times 10 \text{ Exp } V_{dB} / 20$

and $p = p \text{ reference} \times 10 \text{ Exp } p_{dB} / 20$

for voltage and pressure to be converted, the factor “20 log” must be used

Power and sound Intensity

Power (P)and sound Intensity (I) can be converted to decibel by applying the relations :

$\text{Power}_{dB} = 10 \log (\text{Power measured} / \text{Power reference})$

$\text{Intensity}_{dB} = 10 \log (\text{Intensity measured} / \text{Intensity reference})$

If the reference is 1, then we can write:

$$\text{Power}_{dB} = 10 \log (\text{Power})$$

$$\text{Intensity}_{dB} = 10 \log (\text{Intensity})$$

for Power and Intensity to be converted in dB, the factor “10 log” must be used

2.1 Voltage

A voltage (noted as V) is the difference of potential between two points of a same circuit crossed by the same current (direct current DC or alternative current AC), noted as "I" in ampere: there are two kinds of voltage: Direct Current voltage (V_{DC}) an Alternative Current voltage (V_{AC}) regarding to the current which crosses the circuit.

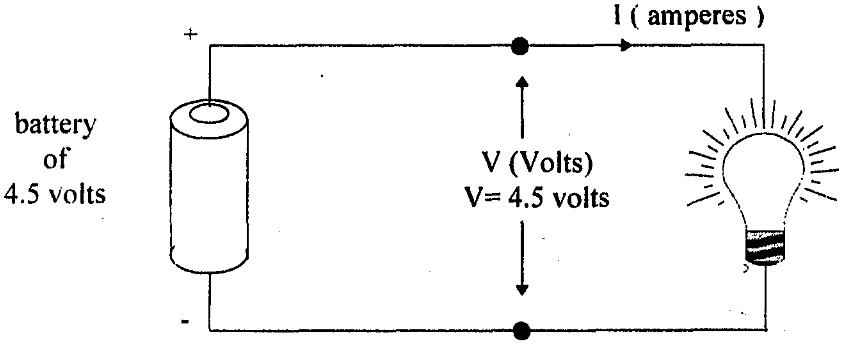


Figure 2 Electrical circuit.

The first relation we can write, is :

$$V_{DC} = R \times I_{DC}$$

where R is the resistance between two points of a circuit, expressed in ohms (Ω), here the resistance of the filament of the lamp.
where I_{DC} is the intensity of the current which crosses this part of the circuit, expressed in amperes (A).

For the alternative current it is nearly the same expression:

$$V_{AC} = Z \times I_{AC}$$

where Z is the impedance in ohms (Ω)
where I_{AC} is the intensity of the current which crosses this part of the circuit, expressed in amperes (A).

For example : 1 V = 1 Ω x 1 A (1 volt = 1 ohm x 1 ampere)

2.2 The power

The power of a part of a circuit is the quantity of energy or heat dissipated in this part in a unit of time; it can be expressed as:

$$P = W / T$$

where P is the power expressed in watts (W)
where W is the energy expressed in Joules (J) [†]
where T is the time in seconds

This energy W can be expressed as follows :

$$W = V \times I \times T$$

Thus, we can combine and link all these expressions which become :

$$P = V \times I$$

thus, $P = R \times I \times I = R \times I^2$
and because, $V = R \times I$ that means $I = V / R$

[†] For information and to get familiar with something known : 1 calorie = 4.18 J

therefore, $P = V \times I = V \times (V / R) = V^2 / R$

For instance : 1 watt = 1 volt^2 /1 ohm

To sum up:

$$\boxed{\begin{array}{l} \mathbf{P = VI} \\ \mathbf{P = W/T} \\ \mathbf{P = RI^2} \\ \mathbf{P = V^2/R} \end{array}}$$

2.3 Alternative current

The characteristics of the alternative current is to change its direction after having reached a maximum level called “amplitude”. It passes back to zero before reaching another maximum, the opposite mathematically speaking, of the first one.

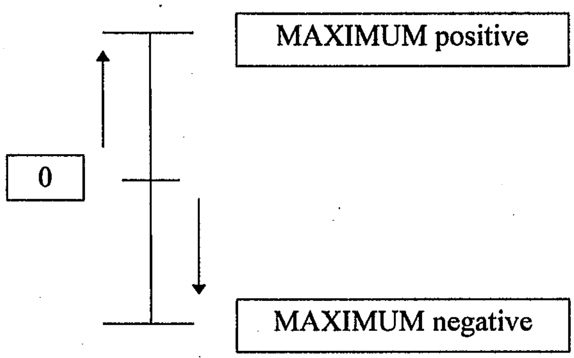


Figure 3 Alternative current.

If we stretch the crosspoint “0”, to the right, the above Figure becomes a sinusoidal function. This stretching can be identified as the “time” variable, reported on the axis X and these variations can be represented as a sinusoidal function related to the time (Fig.4).

All alternative electric signals can be displayed as a sinusoidal function, for example, on the screen of an oscilloscope; the voltage, our prior interest, has different names regarding to the graph (Fig. 4):

-The maximum value is called : Vpeak (the top or the bottom of the curve)

-A specific value, called Vrms (V root mean square) is the equivalent direct voltage which would give the same quantity of energy in the same time; the relation between Vpeak and Vrms is :

$$\boxed{V_{rms} = V_{peak} \times \sqrt{2} / 2 = V_{peak} \times 0.707}$$

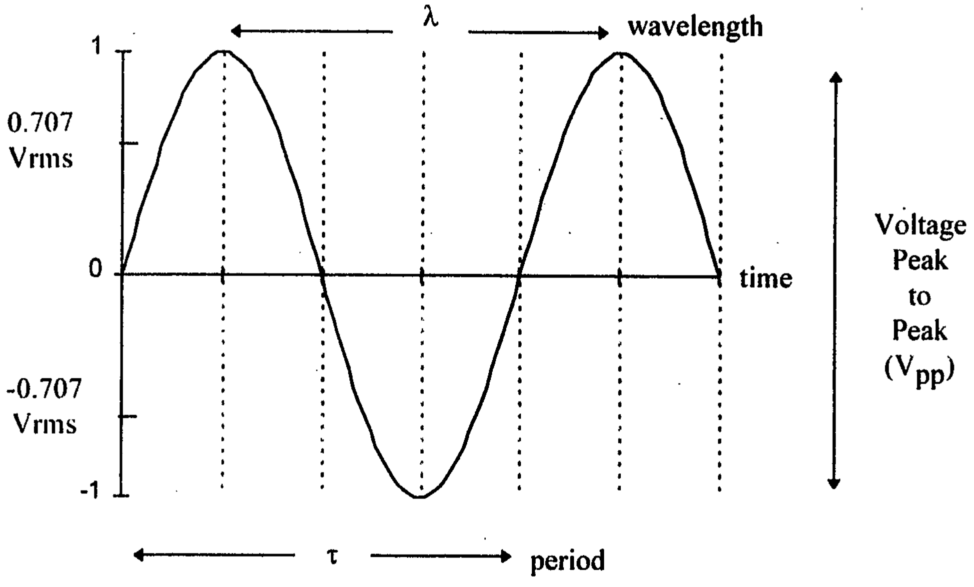


Figure 4 The sinusoidal function.

Multimeters such as voltmeters, indicate this voltage "rms" which is a sort of voltage average, because these apparatus cannot follow the alternances. Only oscilloscopes can display the track of an alternative voltage. Mains, at home, are 220 V_{AC} ; . In fact, this well-known value is a voltage "rms"; that means this value is not the maximum voltage value.

Question :

What is the maximum value of the V_{AC} Mains ?

Answer :

220 V_{AC} give us a maximum voltage of :

220 $V_{rms} = V_{peak} \times 0.707$

Therefore:

$V_{peak} = 220\ V / 0.707 = 311.17\ V$

PHYSICS PRINCIPLES

3.1 The sound waves

The easiest understandable and well - known kind of sound wave is the one created from a vibrating surface, moving backward and forward in a sinusoidal and regular way. Let us see how the sound waves produced by a gong are propagated (Fig.5).

When we hit a gong, this one starts to vibrate and becomes a source of sound waves. The ambient environment, the air in this case, is composed of particles. The closest ones near the gong, are affected by a move and transmit these vibrations to the next particles of the compressible environment. These vibrations provoke a disturbance of the environment, disturbance which is propagated as sound waves: when they reach the ears of someone, they make the tympana and the small bones vibrating. These latter, then, transmit to the brain the signals related to the nature of the sound waves from the gong.

The position of the vibrating surface alternates periodically as a sinusoidal and regular move. As we have seen above, during a vibration cycle, the surface of the gong starts from its resting position also called zero position, to a certain direction, reaches a maximum amplitude, returns to the zero position and then goes to the opposite direction until a new maximum before coming back to the former position. A new cycle of vibration then begins.

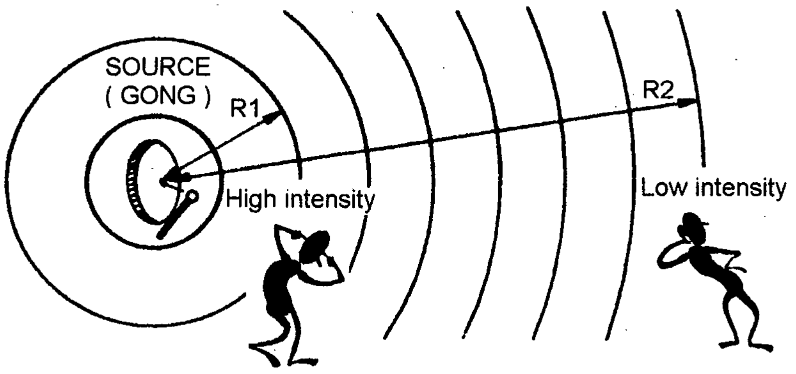


Figure 5 **Sound waves produced by a gong.**

We call frequency of the vibration (f), the number of cycle per time unit, like before in electricity. It is usually measured in : cycles / second or Hertz (Hz).

The vibration makes low and high pressures on the particles close to the vibrating surface and the disturbance spreads off in an omni directional way from the source as spherical pressure waves, also called sound waves. The result is that the pressure at any point of the environment varies periodically in the time and also varies related to the distance from the source.

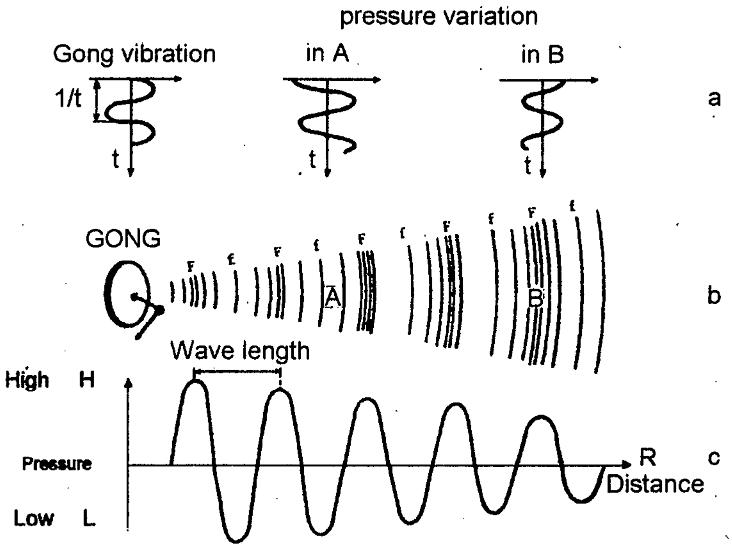


Figure 6 **Formation of the sound waves.**
(a) source vibration and pressure variation at different points of the sound field
(b) sound source and pressure waves in the sound field
(c) amplitude of pressure wave related to the distance at a specific time

The propagation speed of the pressure wave within the environment (that means the move speed of a maximum or a minimum of pressure) is the so called : sound speed or **celerity (c)**; it depends meanly on the environment density, but neither on the frequency, nor the amplitude of the pressure oscillations. In the air the speed of sound is about 330 m/s, in the sea water the speed of sound is about 1500 m/s.

The wavelength (λ, in meters) of a sound wave (the same in electricity) is the distance between 2 successive maxima or 2 successive minima. It is determined by its frequency (f, in cycles/s or Hz) and its speed in the environment (c, in m/s) :

$$\boldsymbol{\lambda = c/f}$$

Question :

What is the wavelength (λ) of a 120 kHz frequency (f) sound wave ?

Answer :

$\lambda = c/f$ thus, $\lambda = 1500/120000 = 0.0125$ m or 1.25 cm

3.2 The sound Intensity

In order to define what the sound Intensity is, we must first link the two following notions :

- The acoustic pressure p (Pa)
- The acoustic power P (W)

<u>The sound intensity related to the acoustic pressure</u>

Any point of the environment within the sound field receives energy from the pressure variations we have seen before. Let us call:

I	this energy named "sound Intensity" or acoustic Intensity
mean p^2	the mean pressure (the total variations of pressure) squared
ρ	the density of the element (here the sea water in kg/m^3)
c	the celerity of the sound (m/sec) in the sea water

As a definition, we will acknowledge the following relationship :

$$\mathbf{I = mean\ p^2 / \rho\ c}$$

<u>The sound intensity related to the acoustic power</u>

The notion of power (P) is more familiar than the notion of pressure (p) and can be used to express the sound intensity.

The sound intensity is defined as the amount of energy per second (power P) passing through a unitary surface perpendicular to the propagation direction:

I = mean Power / surface

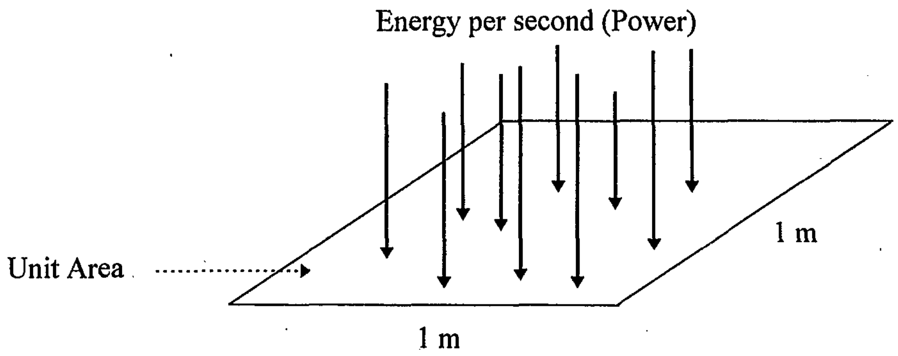


Figure 7 **The sound Intensity.**

$$I = \text{mean } p^2 / \rho \, c$$

$$I = \text{mean } P / S$$

3.3 The propagation

We all know that the closer to the source of sound the louder this sound is received by someone (Fig.5); we can conclude that the sound Intensity decreases with the distance from the source. There are two reasons for that :

- the spread of the sound wave called “the spreading loss”
- the absorption of the sound due to the environment (the sea water) called “the absorption loss”

3.3.1 The spreading loss

Let us suppose that the sound waves are propagated from a single source in an ideal environment that means without any loss. The power transmitted by the source spreads out to all the directions; and therefore spherical sound waves are created around this source (Fig.7).

Because there is no loss in our case, the power P_R, passing through the whole surface of the radiation sphere must be the same whatever the distance R from the source, as we have seen before :

$$I = \text{mean } p^2 / \rho \, c = \text{mean } P / S \qquad\qquad I = P / S$$

We can also write :

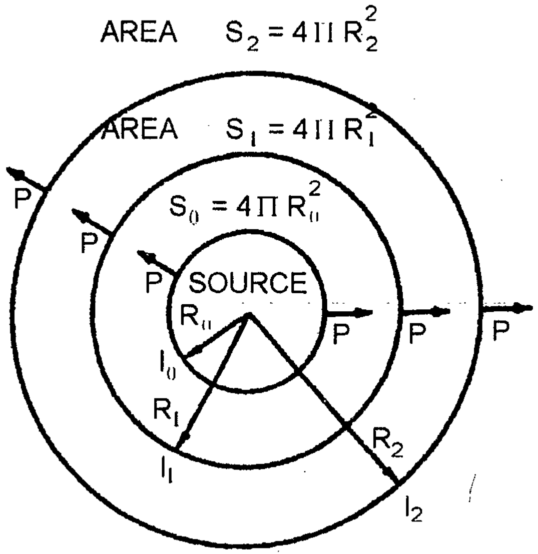
$$P_R = I_R \times S_R$$

where I_R is the sound Intensity at a distance R from the source

and $S_R = 4 \Pi \times R^2$ is the area of the sphere whose beam is R (distance from the source)

The relation between the sound Intensity at distances R_1 and R_2 from the source is:

$$I_1 \times 4 \Pi \times 1^2 = I_2 \times 4 \Pi \times R_2^2$$



$$P_R = I_1 4\Pi R_1^2 = I_2 4\Pi R_2^2 = \ldots = \text{const}$$

P_R = Power radiated

Gambar 8 **Gelombang suara akustik dipancarkan dari sebuah sumber : pancaran ke segala arah.**

Lebih lanjut, mari kita berikan definisi Intensitas suara sebagai Intensitas suara yang diukur pada jarak 1 m dari sumber (R_0) hubungan antara Intensitas sumber dengan Intensitas suara pada jarak R dari sumber adalah :

$$I_0 \text{ x } 4\ \Pi \text{ x } R_0^2 = I_R \text{ x } 4\ \Pi \text{ x } R^2$$

dimana I_0 adalah Intensitas suara yang dipancarkan dari sumber
dan dimana I_R adalah Intensitas suara pada jarak R dari sumber

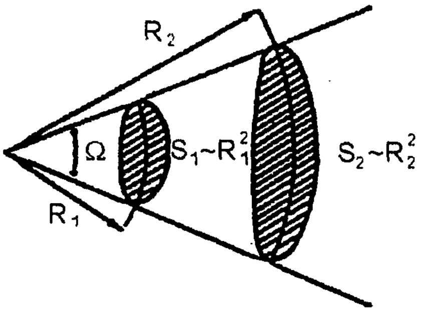
Akhirnya, persamaaan dapat ditulis sebagai berikut :

$$I_R = I_0 / R^2$$

Hal tersebut berarti dalam lingkungan yang ideal, Intensitas suara dari sebuah gelombang suara yang diukur pada jarak "R" dari sumber, berbanding terbalik dengan Intensitas yang dipancarkan sumber.

Jika sebuah sumber yang tepat menghasilkan gelombang suara dengan daya yang konstan di dalam suatu lingkungan yang ideal, Intensitas suara akan menurun dengan pangkat dua dari jarak dan hal ini disebabkan oleh penyebaran geometris dari gelombang suara.

Jika sumber akustik mempunyai satu arah, ini berarti ditransmisikan dalam sudut ruang yang dinamakan Ω, Intensitas suara yang merambat dalam lingkungan ideal, akan menurun dengan bertambahnya jarak. Dia akan mengikuti hukum yang sama karena luas bagian bola yang ada dalam sudut ruang naik secara proporsional dengan pangkat dua dari jarak (Gb.9).



$$P_R \sim I_1 R_1^2 = I_2 R_2^2 = \ldots$$

$$\text{Intensity} = I_2 = \frac{I_1}{R_2^2 / R_1^2} \qquad \text{Pressure} = P_2 = \frac{P_1}{R_2 / R_1}$$

Figure 9 Spherical acoustic waves radiated by a source : directional radiation.

We can take this opportunity to recall some basics about angles:

- we call "degree" (°) the angle which subtends an arc of 1/ 360 of the circumference
- we call "radian" (rad) the angle which subtends an arc with a length (L) equal to the beam (r) of this circle. The general expression is:

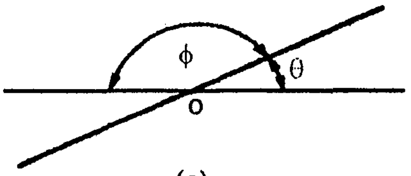
$$\theta = L / r$$

So, the length of the arc can be expressed as:

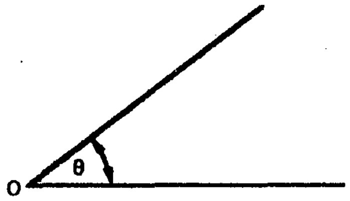
$$L = r\,\theta$$

We can link both degrees and radians as:

$$2\,\Pi / \theta = 360° / \theta$$



(a)



(b)

Solid angle:

The concept of solid angle comes from the measure in radian of an angle, in three dimensions. If we rotate the plan x, y which subtends the angle θ around the axis x, Figure 8 (e), we obtain a 3 - dimension space x, y, z which contains the volumes of Figure 8 (f). During the rotation, the arc sweeps a part of the surface of the sphere and the beam r describes a surface of a cone in the space, called S on Figure 8 (f).

The solid angle called 'Ω', is defined by the relation between S and r. Its unit is expressed in steradian.

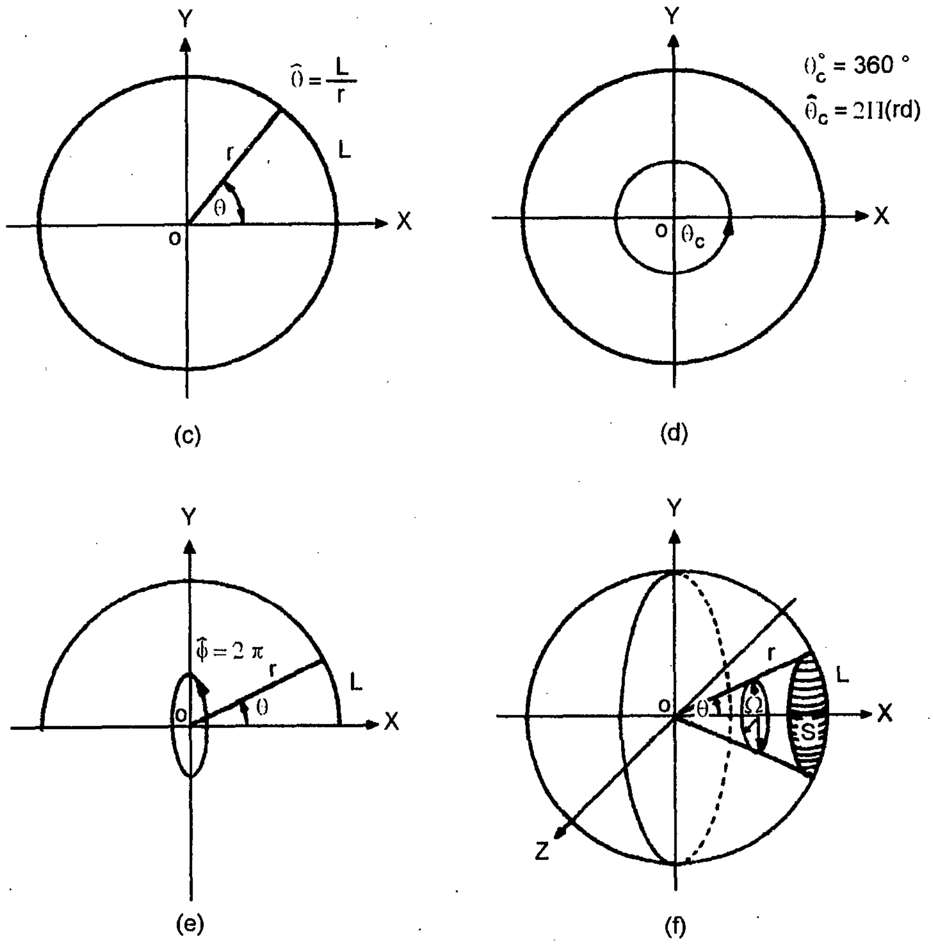


Figure 10 **Plane and solid angles.**
(a) and (b) plane angles
(c) radian
(d) equivalence degree-radian
(e) rotation for 3D space
(f) solid angle

The steradian: (sr)

A steradian is the solid angle which subtends a spherical surface equal to the square of the beam :

$$S = r^2$$

The surface of a sphere is : $S = 4 \Pi r^2$, it leads to the relations:

Ω for a whole sphere : $= 4 \Pi$
Ω for a ½ sphere : $= 2 \Pi$
Ω for other angles : $= 2 \Pi (1 - \cos \theta)$ for $\theta < \Pi / 2$

The spherical surface of a cone at the distance r from the peak corresponding to a solid angle Ω can be expressed as :

$$S = r^2 \times \Omega$$

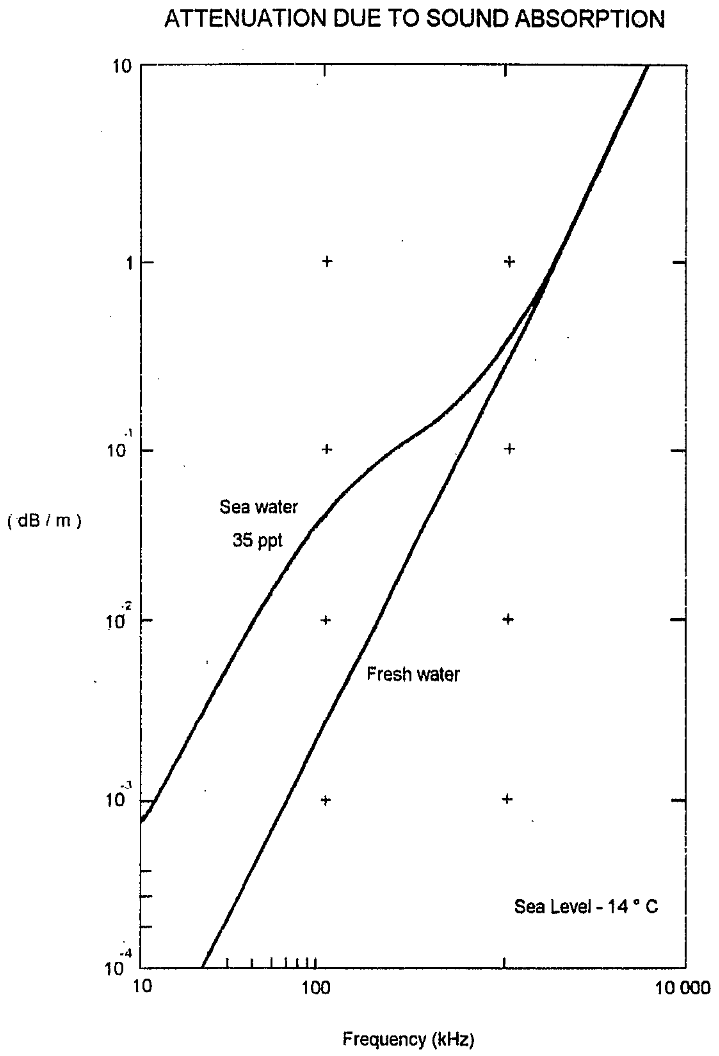


Figure 11 The coefficient Alpha.

Until now, we have followed the sound waves going towards in the sea water, out from a sound source; in our example, the source was a gong. In Acoustics, the device used to produce and to receive sound waves is called a transducer. A transducer is a device which converts electric energy to acoustic energy (like a loudspeaker) and, vice versa, converts acoustic energy to electric energy (like a microphone).

3.3.4 Reflection by a single target

When a sound wave radiated by a transducer and traveling through the water, meets an object whose density is different from the water, for example a fish, a part of the sound power is absorbed by this object and the rest is reflected. (in the air, if you shout out, in front of a mountain wall, your shout will come back to your ears, attenuated by the wall and the geometric spreading of this wall).

Let us see what happens to this sound wave...

First, the intensity transmitted, here called I_t, comes out from the transducer. After a while, at a distance R from the transducer, the wave meets an object called "target". Here, this is a fish. The wave has its intensity reduced during this travel, as we have seen before, due to the distance and due to its spreading. Let us call I_i, this intensity reduced which is incident (perpendicular) to the target.

We can write :

$$I_i = I_t / R^2$$

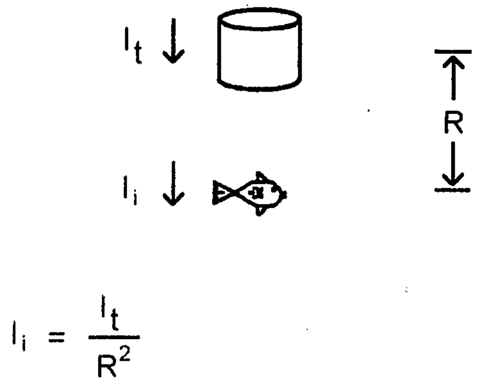


Figure 12 The sound wave starts its travel.

Let us call I_r, the intensity reflected by the fish which becomes a kind of sound source itself, and I_{REC} the intensity received by the transducer. We can write for the same reasons as before (distance and spread losses) :

$$I_{REC} = I_r / R^2$$

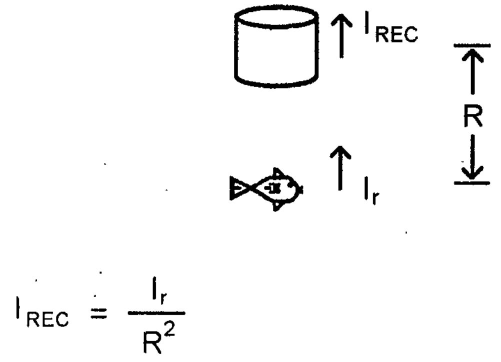


Figure 13 The sound wave is coming back.

Each target (each reflecting object) has its own reflecting properties which can be expressed as the ratio between the incident and the reflected intensities as:

$$\text{target index} = I_i / I_r$$

where I_i is the incident intensity striking the target.
where I_r is the intensity reflected by the target.

This target index can be identified as the equivalent radiating cross section of the target. For better understanding, we have to talk about the concept of ideal target.

Imagine a totally reflecting sphere for example an air bubble; in this case, no sound power is absorbed. This perfect sphere is similar to a sound source when reflecting the sound waves.

From one of the former equations - see Chapter 4.2 - "The sound intensity"- we have seen that the power P_i, received by the sphere, is equal to the incident intensity (I_i) multiplied by the surface (S) which is perpendicular to the direction of the waves, that is to say : $P_i = I_i \times S$

Let us change the name of this surface "S" with "σ" (Sigma) and draw the following figure.

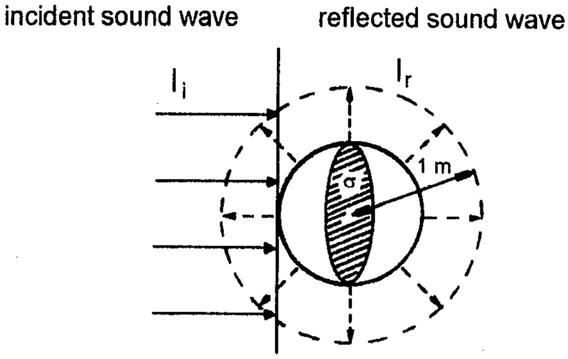


Figure 14 The sphere reflection.

We can write, as already known:

$$P_i = I_i \times \sigma$$

with σ the surface of the section of the sphere

In the chapter 4.3.1 - "Spreading loss", we have seen that the power (P_r) reflected at 1 meter from the center of a sphere whose beam is R_0 = 1 meter, is equal to :

$$P_r = I_r \times 4 \Pi R_0^2$$

Because the reflection is total , $P_i = P_r$, we can link these 2 equations as:

$$I_i \times \sigma = I_r \times 4 \Pi \times 1^2 \qquad (R_0 = 1 \text{ m})$$

So, we can define an equivalent surface of the target as :

$$\sigma = 4 \Pi I_r / I_i$$

We can then write :

$$\sigma / 4 \Pi = I_r / I_i$$

Let us consider a new factor σ_{bs} , such as

$$\sigma_{bs} = \sigma / 4 \Pi$$

We can finally write :

$$\boldsymbol{\sigma_{bs} = I_r / I_i}$$

This new factor "σ_{bs}" is called : **Back Scattering Cross-section.**

We can also deduce from above that expression:

$$I_r = \sigma_{bs} \times I_i$$

Let us go back to the beginning of this chapter. We can introduce, within the former equations, this Back Scattering Cross-section which defines the property of absorption of a target. The last relationship and the 2 former formula met are:

$$I_r = \sigma_{bs} \times I_i \qquad \text{(formula 1)}$$

$$I_i = I_t / R^2 \qquad \text{(formula 2)}$$

$$I_{REC} = I_r / R^2 \qquad \text{(formula 3)}$$

with I_i the incident Intensity
with I_t the transmitted Intensity (straight from the transducer)
with R the distance of the target from the transducer
with I_{REC} the Intensity received by the transducer
with I_r the Intensity reflected by the target
with σ_{bs} the Back Scattering Cross section

After combination, (formula 1) can be then written as :

$$I_r = \sigma_{bs} \times I_t / R^2$$

Then, (formula 3) becomes :

$$I_{REC} = \sigma_{bs} \times I_t / R^2 / R^2$$

Finally, we can conclude:

$$\boxed{I_{REC} = \sigma_{bs} \times I_t / R^4}$$

We have just linked the primary variables which are:

- I_t the intensity which goes out from the transducer when transmits
- I_{REC} the intensity received by the transducer
- σ_{bs} the target properties
- R the distance of the target to this transducer

Expressed in decibels (10 log factor must be used -see Chapter 2.3.2 - "The decibels - Power and Sound Intensity"), the expression becomes:

$$10 \log I_{REC} = 10 \log (\sigma_{bs}) + 10 \log (I_t) - 10 \log (R^4)$$

At last, we can write :

$$\boxed{\mathbf{I_{REC}\ (dB) = 10 \log (I_t) - 40 \log (R) + 10 \log (\sigma_{bs})}}$$

The expression "10 log (σ_{bs})" is called : Target Strength (in dB) and is noted as: **TS**.

This **TS** can be expressed as :

$$\begin{aligned} TS &= 10 \log (\sigma_{bs}) \\ &= 10 \log (\sigma / 4 \Pi) \\ &= 10 \log (I_r / I_i) \end{aligned}$$

To complete the linking equation above, we must not forget the Absorption Loss α **R** (see Chapter 4.3.2 - "The absorption loss") where α , the absorption coefficient also contributes to the decrease of the sound wave Intensity.

This was for 1 way loss. For one way and return, the total absorption loss is : **2 α R**

The final and corrected way equation becomes:

$$\boxed{\mathbf{I_{REC}\ (dB) = 10 \log (I_t) - 40 \log (R) - 2\, \alpha\, R + 10 \log (\sigma_{bs})}}$$

Also written:

$$\boxed{\mathbf{I_{REC}\ (dB) = 10 \log (I_t) - 40 \log (R) - 2\, \alpha\, R + TS}}$$

And, as already studied in the former lesson, the acoustic Power, because proportional to the Intensity ($P_t \sim I_t$, $P_{REC} \sim I_{REC}$), follows the same rules, that is to say :

$$\boxed{\mathbf{P_{REC}\ (dB) = SL - 40 \log (R) - 2\, \alpha\, R + TS}}$$

where P_{REC} is the power received at 1m from the surface of the transducer.

where SL is the power radiated (or transmitted = P_t) by the transducer, at 1m from its surface.

where - 40 log (R) - 2 α R is the total propagation loss for one way and return of the sound.

where TS is the target strength , that means the absorption coefficient of the target (fish). Because targets absorb and spread out a part of the energy which hits them, TS can be considered as a loss. Therefore, TS is always a negative value, for example : - 42 dB.

All this chapter is summed up hereafter, on the next page.

3.3.5 Reflection by a multiple target

If several fishes gathered very closely are insonified simultaneously by a sound wave, each of them becomes a reflecting source of sound and the whole can be identified as a single one whose Intensity is equal to the sum of all the single intensities of each target, such as :

$$I_r \text{ total} = I_{r1} + I_{r2} + I_{r3} + \ldots + I_{rn}$$

with n = number of targets

If the n fish have the same acoustic property, we can write :

$$I_r \text{ total} = n \times I_r$$

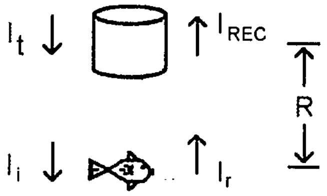
The Back Scattering Cross-section σ, for one single target, is : $\sigma = 4 \Pi I_r / I_i$

For a multi target made of "n" single targets very close together, it will be : $\sigma_{multi} = n \times \sigma$

Finally, we can sum up :

$$I_r \text{ total} \sim n \, \sigma \, I_i$$

2 WAY EQUATION



$$I_i = \frac{I_t}{R^2}$$

$$I_r = I_i \, \sigma_{bs} = \frac{I_t \, \sigma_{bs}}{R^2}$$

$$I_{REC} = \frac{I_r}{R^2} = \frac{I_t \, \sigma_{bs}}{R^4}$$

$$I_{REC}\,(dB) = 10 \log (I_t) - 40 \log (R) + \underbrace{10 \log (\sigma_{bs})}_{\sim \text{ TS } \sim}$$

WITH ABSORPTION

$$\boxed{\begin{gathered} I_{REC}\,(dB) = 10 \log (I_t) - 40 \log (R) - 2 \alpha R + TS \\ P_{REC}\,(dB) = SL - 40 \log (R) - 2 \alpha R + TS \end{gathered}}$$

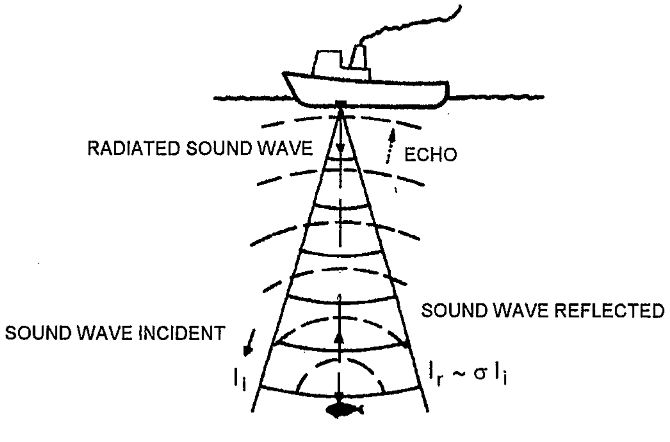


Figure 15 (a) **The single target reflections.**

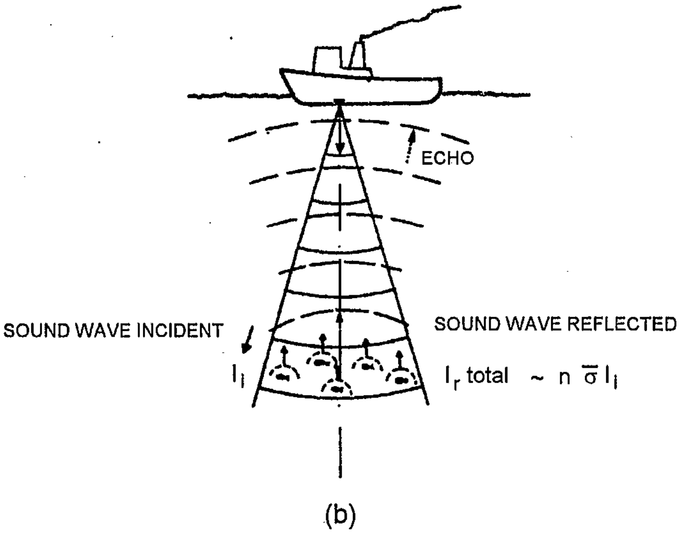


Figure 15 (b) **The multiple target reflections.**

3.3.6 Sound speed or celerity

The celerity of the sound in the sea water is related to the temperature and the salinity; the relationship is:

$$\boxed{c = 1445 + 4.66\, t - 0.055\, t^2 + 1.3\, (s - 35)}$$

where c is the sound celerity in m/s
where t is the temperature in °C
where s is the Salinity in ‰

3.3.7 Reverberation

The sea water is not a pure element; it contains small particles of dust, sand and microorganisms as phytoplankton and zooplankton; also, after a heavy rain, the water at the surface is full of small air bubbles.

These small particles intercept and radiate a part of the acoustic power transmitted. We call "reverberation", this effect of disturbance. This background of noise which can overlay the desired signals, can be eliminated by means of "threshold" we will study later.

After having exposed all the properties and parameters of the sound waves, the propagation laws in the sea water and the reflection of targets, we are going to see now the acoustic equipment used to get these targets and what kind of information it gives.

PRINCIPLES OF INSTRUMENTS FOR ACOUSTICS

GENERAL FUNCTIONING OF AN ECHO-SOUNDER SYSTEM

4.1 General description

An echosounder system can be roughly defined as an apparatus which transmits sounds into the water. These sounds come back as echoes which give information on the objects under the surface. The sound waves radiated by an echo-sounder used to detect fish, are of the same kind as the ones from music instruments, voices,... Nevertheless, the dynamics of reception of the human's ears is short : between 16 and 20,000 Hz. The sounder systems transmit ultrasound waves, that means sounds whose frequency is generally comprised between 20,000 and 500,000 Hz and thus not perceived by human's ears.

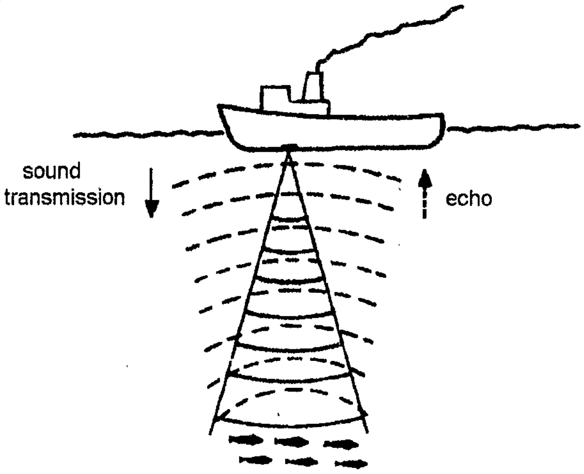


Figure 16 Detection of fish.

The functioning diagram of an echo-sounder used for fish detection is very simple (Fig.17).The sound is transmitted as pulses. After each transmission, the system is switched on "waiting" or "listening" mode, called **reception** during a time long enough, to receive the echoes of the targets met. The pulses are transmitted by an electric transmitter, switched on during a fixed and short time by an electronic signal which firstly allows or not **the transmission**, secondly controls and limits the time duration of the pulse. The electrical oscillations are converted mechanically into pressure oscillations (that means into sound waves) through the vibrating surface of the transducer immersed in the water.

The sounds go on radiating until the transmitter is stopped. A certain time limited pulse is produced traveling through the water far away from the transducer. Any target, for example a fish, on the way of this pulse, sends back an echo to the transducer in "receiving mode" (after the transmission, as we told before). Contrary to the transmission mode, the transducer is going to convert the pressure oscillations received by its vibrating surface, into electrical oscillations. These latter are sent to the receiver which amplifies them and converts them into visible traces on a display system which is usually a chart recorder and/or an oscilloscope.

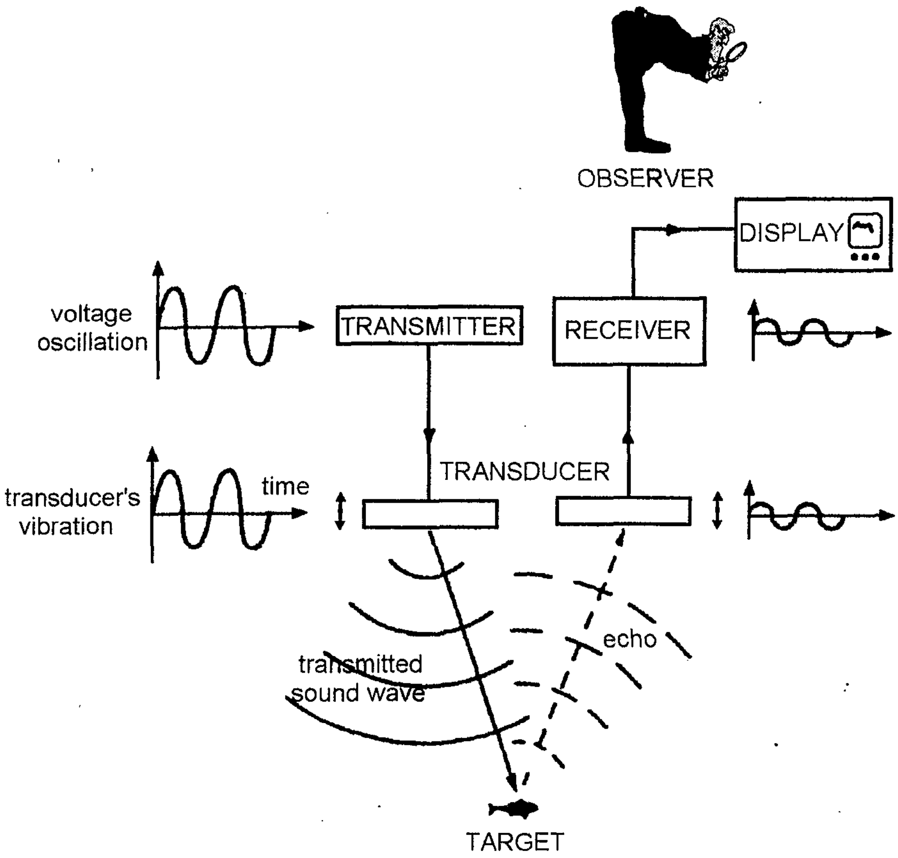


Figure 17 Diagram of an echo-sounder.

Figure 18, which follows, shows the time sequences of an echo-sounder :

- - the transmission mode.
- - the reception mode.
- - its structure.

Specific terms are used to explain how the system works; they are:

- the frequency of the signal (we have already seen this notion before)
- the ping rate is the number of pulses per time unit, for example : 3 pulses / s
- the pulse duration is the time interval while the transducer vibrates, for example : 0.4 ms

Question :

What is the timing of an echo-sounder, working at a ping rate of 1 transmission per second, with a pulse duration of 1 ms ?

Answer :

The echo-sounder will be in transmitting mode during 1 ms and will be in listening mode also called receiving mode, during 999 ms. After that, it will produce another transmitted pulse during one ms, and so on...

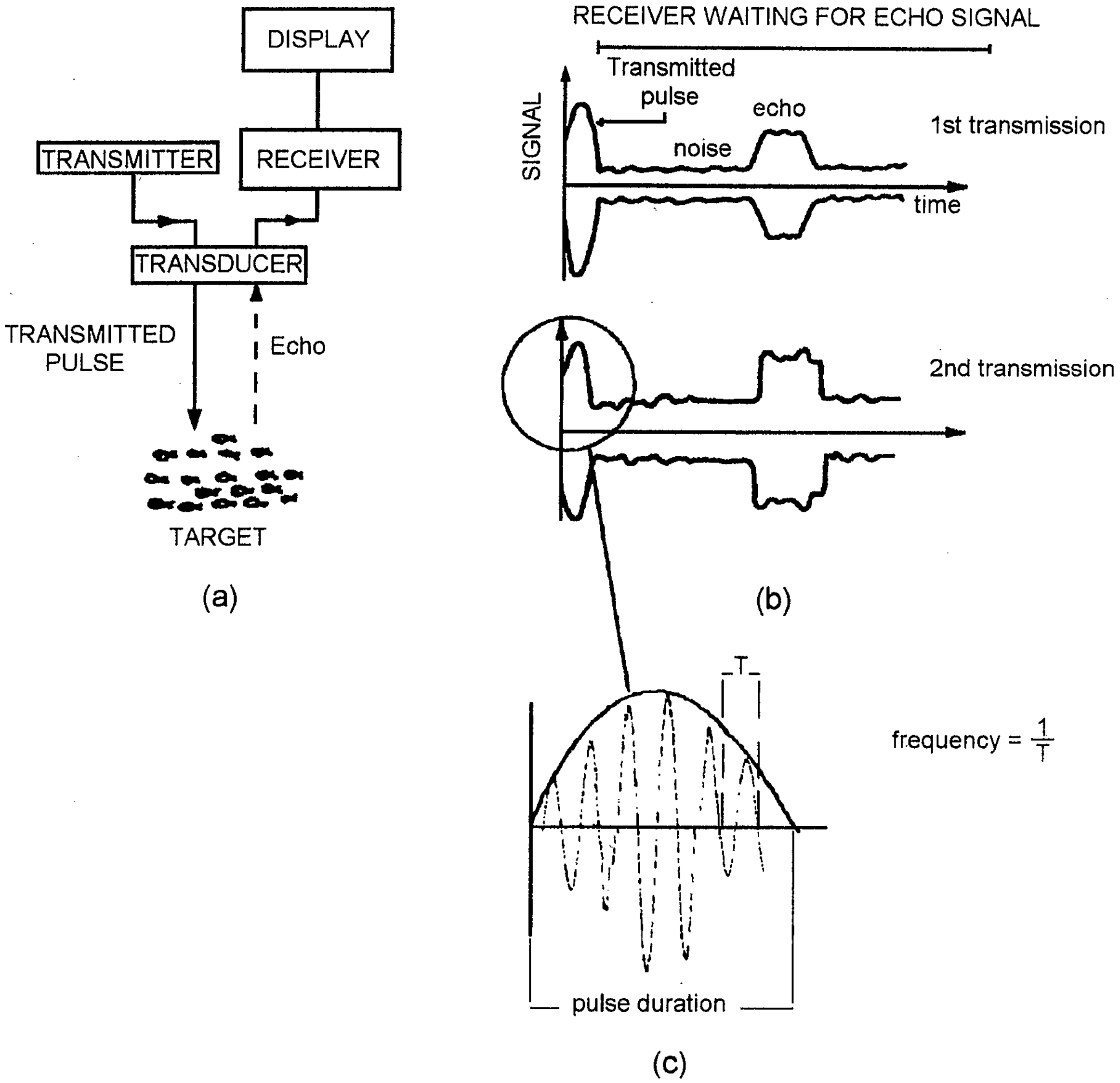


Figure 18 **Time sequences of an echo-sounder.**

(a) structure of a sounder system

(b) form of the transmitted pulse and echo signal on the screen of an oscilloscope

(c) zoom of the pulse

The processing of the echo signals needs to be translated in an easy way in order to give information on these targets. For example, the first information we can get is the presence or the absence of target. If there is a target, a high voltage peak will appear at the transducer output, then at the receiver output. We can see it as a peak on an oscilloscope screen or as a dark spot on the paper of a chart recorder.

Knowing the sound speed in the sea water, we can get an other information, by measuring the time between the transmission and the reception of the echo. It is the distance between this target and the transducer. Let us call "R" this distance (Fig.19). The sound pulse travels from the transducer to the target and comes back, that means "R" is covered twice. We can write that the double distance 2R transducer / target is equal to the speed (or celerity) noted "c" multiplied by the time interval "t" between the transmission and the reception of the echo. Thus : 2R = c t

From the last equation, we can write:

$$\mathbf{R = c\,t / 2}$$

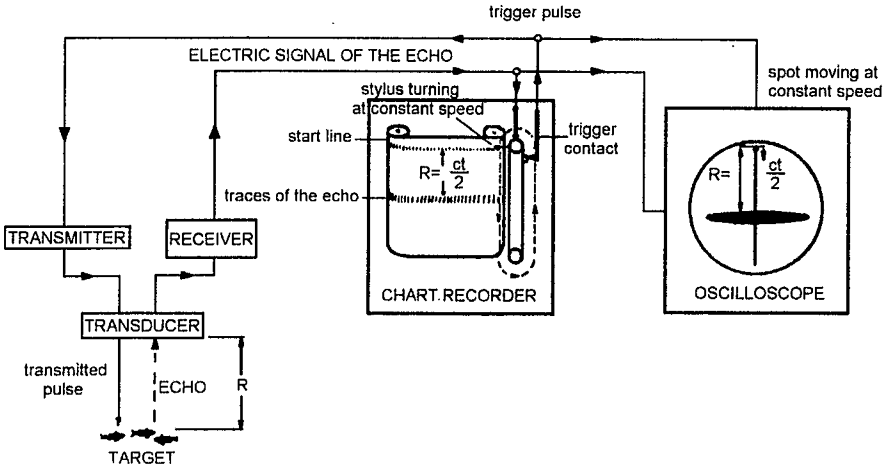


Figure 19 Simplified diagram of the detection, localization and display of fish.

How to visualize these echoes ? The chart recorder has a pen called stylus; this stylus fixed on a belt, turns at a constant speed and the recording paper moves perpendicularly in a regular motion. When the stylus passes the zero line, the trigger contact switches on the transmitter which through the transducer is going to transmit a sound pulse into the water. In the same time, this contact trigs the time base of an oscilloscope, that means the horizontal sweeping of the spot on the screen, from the zero position, usually from the left to the right of the screen. The receiver is then in waiting for echoes; when it appears one, at the output of the transducer, as an electrical pulse of a certain amplitude, it is amplified by the receiver and sent to the display system . Through the stylus of the chart recorder, this echo will be materialized on the recording paper as a dark mark called trace. On the screen of an oscilloscope, we will see an amplitude deviation proportional to the strength of the target. The stylus speed of the chart recorder and the spot speed of the oscilloscope are constant; we can calculate the time interval "t" between the transmission and the reception by measuring the distance between the zero line and the trace on the paper, or between the start position of the spot and the deflection position on the screen of the oscilloscope. Using the equation seen above, we can calculate the distance of the target.

In fact, chart recorders are usually prescaled using depth scale graduations, giving us at once the depth of the target. The display systems such as chart recorders and oscilloscopes give us more information. Imagine two targets of different dimensions but with the same acoustic properties, located at the same depth. The echo of the small target will be weaker than the big one. On the recording paper, a thin trace will be printed and a low deflection will be observed on the screen of the oscilloscope. for the big target, it will be the contrary: on the recording paper, a dark and thick trace will be printed and a high deflection will be observed on the screen.

This kind of information are more qualitative than quantitative. Processing systems more sophisticated are used to measure the quantity of fish detected. They are called echo-integrators and will be studied later.

As we have seen just before, the information about the targets is within an electric signal in a coded way. The main task of a processing system will be to decode this signal to get the desired information for fish stocks and biomass assessment.

We are going to study in more details, each part of the system : the transducer, the receiver, the transmitter, the display system (recorder, oscilloscope).

4.2 The transducer

4.2.1 What is a transducer ?

A major step in the development of sonar systems was the invention of the acoustic transducer and the design of efficient acoustic projectors to generate sound waves. Such equipment uses special quartz crystals or magnetic materials that are able to conduct electric current. These materials change shape when subjected to electric or magnetic fields, converting electrical energy to sound waves. They can produce acoustic beams over a wide range of frequencies. Electrical measurements of currents or voltages that may change millions of times per second, require instruments that can respond to this high frequency. The more rapid the change, the smaller the "sensing" element of the instrument must be to respond to the rapid variations to be measured. In practice this usually requires a component that can sense a high-speed physical phenomenon and translate the measurement into an electric signal.

The signals emanating from transducers may be very weak (thousandths or millionths of a volt). they must be amplified into the range of about 1 to 15 volts before they can be read on an instrument dial, recorded or fed into a computer. Scientific echo-sounders, therefore, usually have a sensor (the transducer) that responds to the characteristics to be measured. This transducer translates the measurement into an electrical signal. An amplifier increases its magnitude to a range where it can be displayed or recorded. Finally, this equipment has an output device that may be visual, graphical and, of course, an "on-line" computer to process the raw data into a useful form.

First, let us have a look at Figure 20, where a 120 kHz transducer is represented. This transducer, also called projector, contains, besides the electric terminals, arrays of quartz elements, within an oil solution. A rubber window is the interface with the sea water. This latter transmits the quartz oscillations and vibrates in the same way.

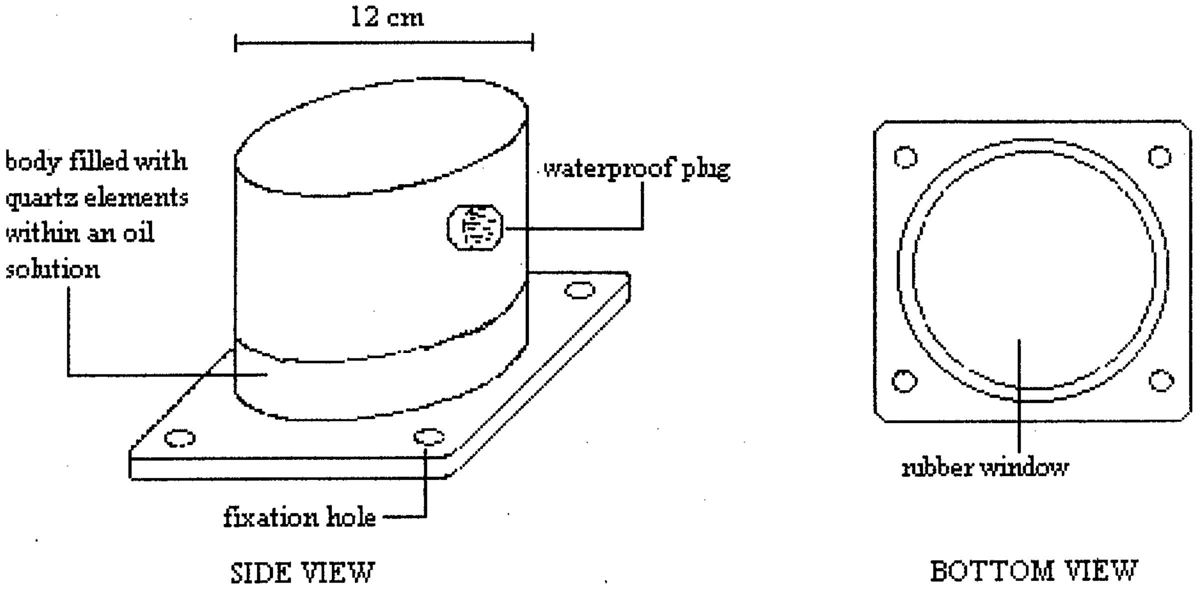


Figure 20 The 120 kHz transducer.

The transducer is placed within this **towed body** which is also called "paravane" or V-Fin (Fig. 21). It can also be fixed on the hull of a ship, but it becomes dependent of the ship's roll and pitch. Besides, to calibrate the equipment and to survey, it is easier to handle this removable transducer than a fixed one whose access is difficult.

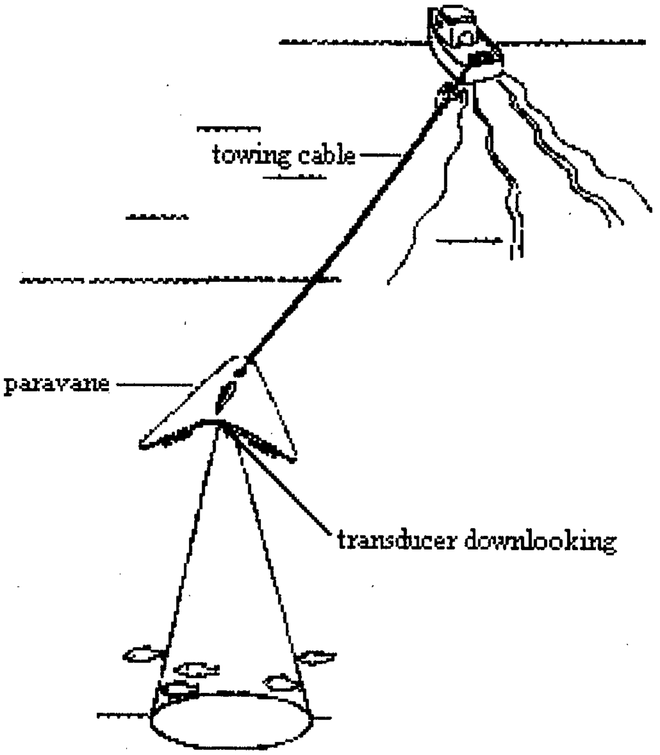


Figure 21 The towed body.

4.2.2 How does it work?

Please, refer to Figure 22 (a) and (b), just hereafter. Figure 22 (a) shows in a simple way, to understand how the transducer operates. In this example, a mechanic point of view allows us to link the notion of a sinusoidal command, here the motion of a crank related to the time, and the move of a piston upwards and downwards, on and on ...This vertical move provokes vibrations which are transmitted into the water.

Actually, a real transducer is not composed of piston and crank. In fact, a transducer is composed of piezo elements, connected to a rubber membrane. An alternative signal is sent to the transducer terminal, and then to the piezoelectric elements. These elements are oscillating components, regarding to the piezoelectricity properties. Piezoelectricity is the generation of pressure in a substance due to electricity and vice versa. It occurs specially in single crystals having polar symmetry. These oscillations will lead the rubber face to vibrate.

We are going to see in details these piezoeletric components.

<u>What is a piezo element ?</u>

All of you had already used piezo devices, for example: electronic lighters, gas lighters, watches... In fact, a piezo element is a quartz (crystal) which has specific properties; we can sum up roughly these properties.

When an electric signal is sent to the terminals of a piezo element, this latter is mechanically distorted (Fig.23 a); it tends to elongate out from its shape; if this signal is alternative, it will reverse this trend , by contracting itself, provoking a vertical move.

In a transducer, there are many of these elements which are linked mechanically with the rubber membrane of this transducer; this membrane, thus, follows these cyclical deformations of the crystals and creates a pressure variation and so, sound waves...That is what happens at each transmission.

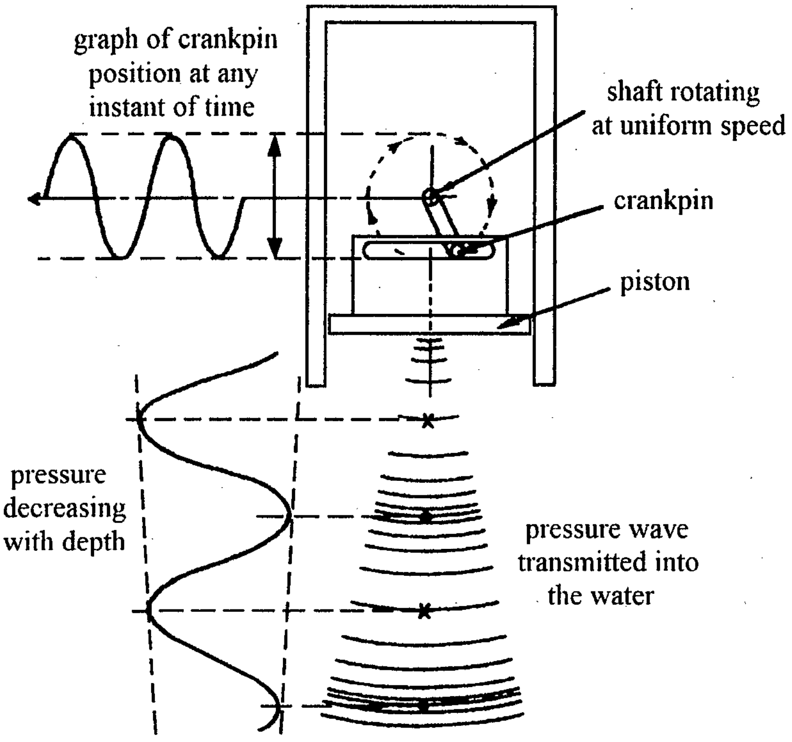


Figure 22 (a) **Principle of a transducer: the mechanic point of view.**

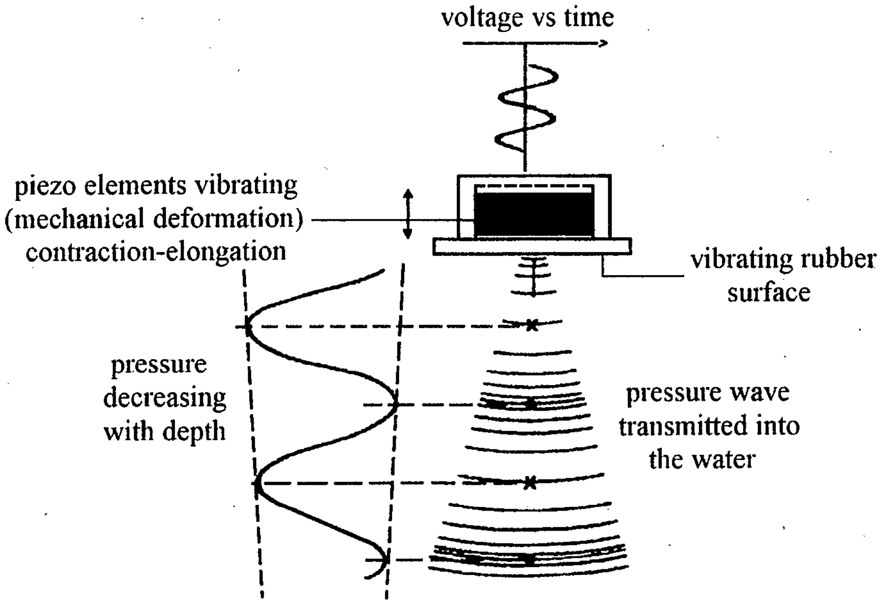


Figure 22 (b) **Principle of a real transducer.**

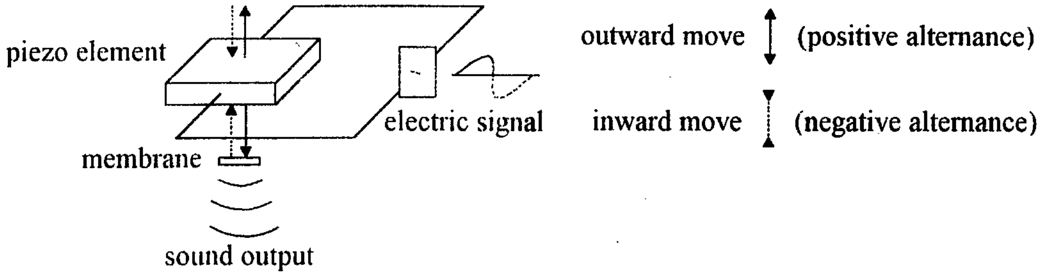


Figure 23 (a) **Deformations of the crystal due to an electric signal.**

On the contrary, these piezo elements, affected by a mechanical constraint, that means a physical distortion, will provide at its terminals an electrical voltage, proportional to the intensity of this constraint (Fig.23 b)

That is what occurs when you use electronic lighters; at the moment you press the button of the lighter, the quartz just below this button is crushed; the result is an electrical arc between two electrodes and this arc ignites the gas coming out.

If the constraint is alternative, the output voltage will be alternative. It is the case in acoustics, when echoes come back, they make the sensitive rubber membrane of the transducer vibrate in a sinusoidal way (sound waves are sinusoidal). The membrane push and pull these elements which, thus, provide a sinusoidal voltage at the output of the transducer. That is what happens during the reception mode.

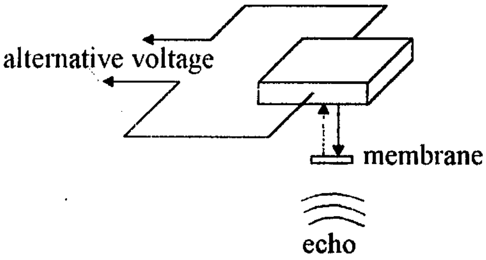


Figure 23 (b) **Generation of an electric signal due to the mechanical deformation of the crystal.**

In these two modes, we always have the relationships between the sound wave and the output voltage parameters, such as:

- the pressure is proportional to the voltage
- as the sound intensity is proportional to the pressure square, it is also proportional to the voltage square:

$$I \approx u^2$$

The transformation of sound wave to output voltage is characterized by what we call the **Sensitivity of a transducer (S_X)**.

4.2.3 The Sensitivity of a transducer

The Sensitivity of a transducer (S_X) as a receiver of acoustic waves, is the degree of response of a transducer to an acoustic signal (the pressure of the sound waves coming back at the reception) or an electric signal. It is expressed in terms of the number of dB with reference to one volt for each micropascal of pressure, such as : dB / Volt / 1µPa.

Question :

How many volts does a transducer with a Sensitivity of -80 dB/1volt/1µPa generate when it is placed in a plane wave of 1µPa of Pressure ?

Answer :

The transducer generates a voltage of :

V = antilog (-80/20) - we divide by 20 because the 20 log expression is used for the Pressure)

V = 10 e-4 volts.   V.= (0.0001V)

Until now, we have just followed the signal traveling in the water (see Chapter 4.3.3 - "Reflection by a single target"). We are just entering now the equipment with its own characteristics which must be incorporated in our equations; the first instrument parameter which has to be added up is **the Sensitivity** of the transducer (S_X).related to the transducer itself.

The last relationship of the traveling sound wave was:

$$P_{rec}\ (dB) = SL - 40 \log (R) - 2\ \alpha\ R + TS$$

where P_{rec} was the power received at 1m from the surface of the transducer
where SL was the power radiated (or transmitted) by the transducer , at 1m from the surface of this transducer.
where 40 log (R) - 2 α R was the total loss for one way and return of the sound
where TS was the Target Strength , the absorption coefficient of the fish.

Passing through the transducer, we can say that the Voltage at its output V (in dB) is related to the acoustic Power P_{rec} (dB) at its surface, as :

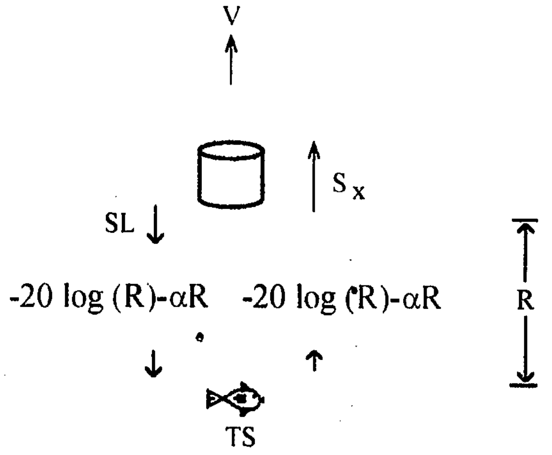
$$V\ (dB) = P_{rec}\ (dB) + S_X$$

So, taking into account the transducer, the next step of the way equation will be :

$$\boxed{\mathbf{V\ (dB) = SL - 40 \log (R) - 2\ \alpha\ R + TS + S_X}}$$

where V (dB) is the voltage at the output of the transducer
where SL is the power transmitted by the transducer
where - 40 log (R) - 2 α R is the total loss for one way and return of the sound
where TS is the target strength of the fish
Where S_X is the Sensitivity of the transducer.

You will find hereafter all the parameters of this last relationship represented schematically.



$$\boxed{V\,(dB) = SL + S_X - 40 \log(R) - 2\,\alpha R + TS}$$

4.2.4 The Directivity of a transducer

A sounder system, used to detect and localize fish, insonifies a well-known volume of water, in a well delimited beam which could be compared with a light beam of a search light; only the targets insonified (that means targets situated within the sound beam) will be detected and recorded.

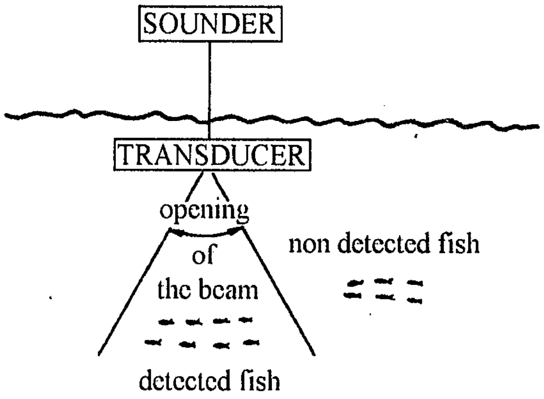


Figure 24 The water volume insonified.

The effect of Directivity can be compared with a search light, as we already said before. As you know, when we use a search light to lighten a screen perpendicular to the beams, we can observe rings of different intensities (Fig. 25). In the center of the beam, appears a small spot very bright which decreases in light intensity as we go to the outer limits. The light will fade when far away from the center.

The same effect can be observed with a planar section of volume insonified in an acoustic beam (Fig.26). Imagine to simplify, that a fish is a perfect and uniform reflector. If we place this fish at the center of the transducer beam at a distance "R", it will reflect a sound intensity maximum I_0 , because the transducer radiates a maximum intensity along the acoustic axis (the radiated intensity is proportional to the vector b_0). If we put the same fish away from the acoustic axis at the same distance, it will reflect a sound wave with an intensity lower in this direction.(the intensity is proportional to vector b_1).

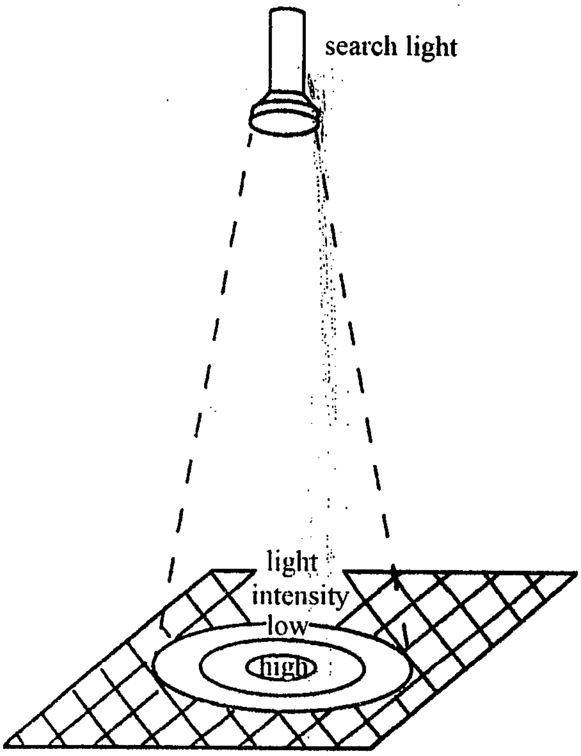


Figure 25 Directivity of a search light beam.

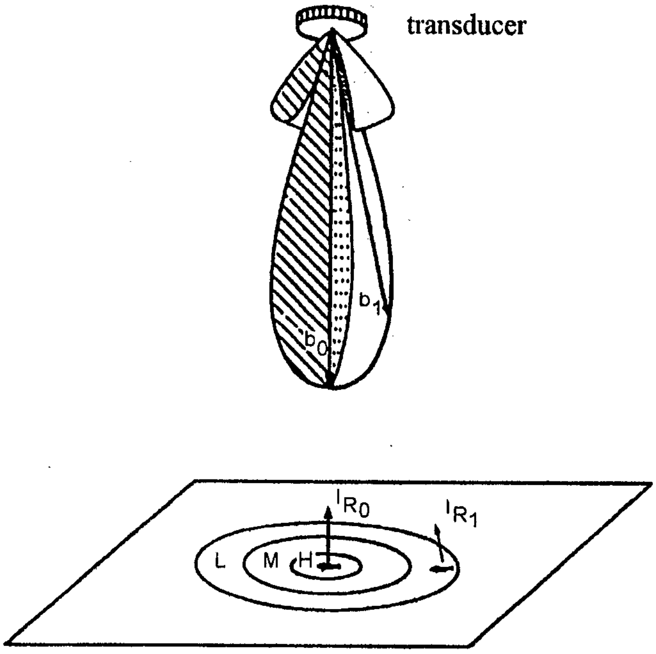


Figure 26 Directivity of a transducer sound beam.

The cause of this phenomenon must be explained. A simple sound source radiates uniformly in all directions; meanwhile, if two sources which are close enough from each other, radiate the same sound, the resultant intensity will not be the same in all directions. In certain directions, the sound waves will be in phase, and the resultant intensity will be stronger, in other directions, the waves will cancel each other (Fig. 27).

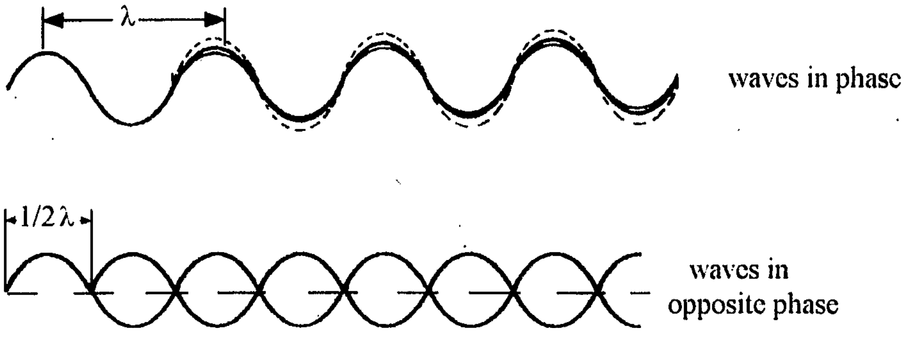


Figure 27 **Representation of sound source interferences.**

This phenomenon, called interference, leads to a regular distribution but non uniform of the sound intensity related to the direction. The zone of interference is called : "**near field**" (Fig. 28).

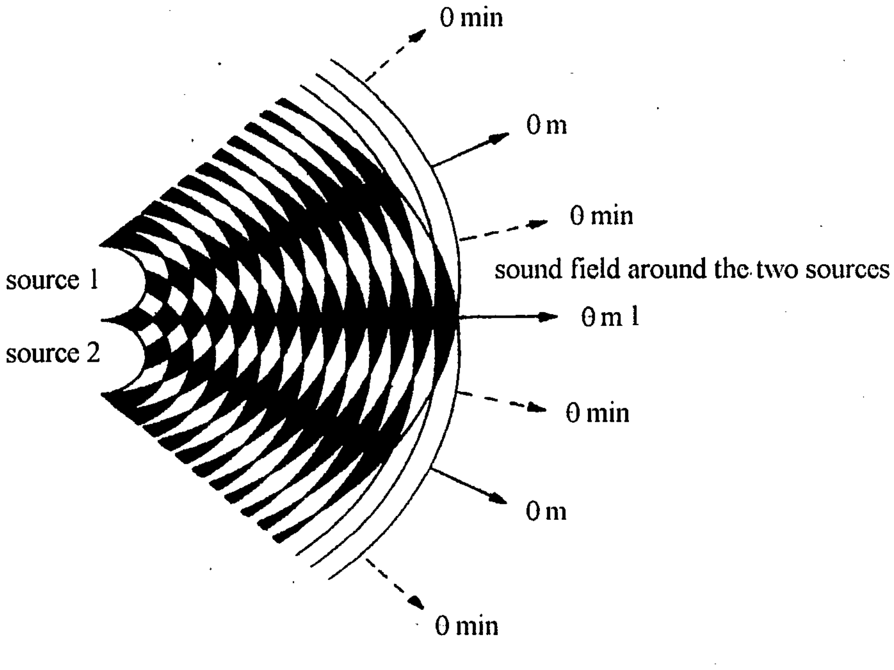


Figure 28 **The near field in black and white.**

The critical distance where the phenomenon ends can be calculated because related to the size of the transducer, the frequency used and the sound speed in the water. Let us call R this distance (in meter); the relations is:

$$R= D^2 f / c$$

where D is the diameter of the transducer, in meters
where f is the frequency used, in Herz
where c is the celerity of sound in the water, in meters per second.

In our case, D = 12 cm ; f = 120 kHz ; c = 1500 m / s .

$$R = [(0.12)^2 \times 120\ 10^3] / 1500$$

$$R = 1.152 \text{ m}$$

Passed this near field, the sound waves are formed and do not suffer interference anymore; this zone is called the "**far field**".

A transducer can be considered as a network of simple sound sources. As we have just seen before, the distribution of the resultant Intensity presents a maximum on the axis of the transducer (a line passing through the center and perpendicular to the surface) and lower values outside. To describe the distribution of the Intensity of a transducer, called "**Directivity**", we use the ratio of the Intensity of a point in the space with polar coordinates (ϕ,θ) and the Intensity on axis $I(0,0) = I_m$. Figure 29 represents in the space the Directivity of a circular transducer.

This ratio of Intensities is a relative value and is noted as :

$$b(\phi,\theta)$$

and can be expressed as :

$$\boxed{b(\phi,\theta) = I(\phi,\theta) / I(0,0)}$$

where ϕ is the angle delimited by the heading line of the transducer and the position in the horizontal plane of the point.
where θ is the angle delimited by the vertical axis named acoustic axis of the transducer and the position in the vertical plane of the point.

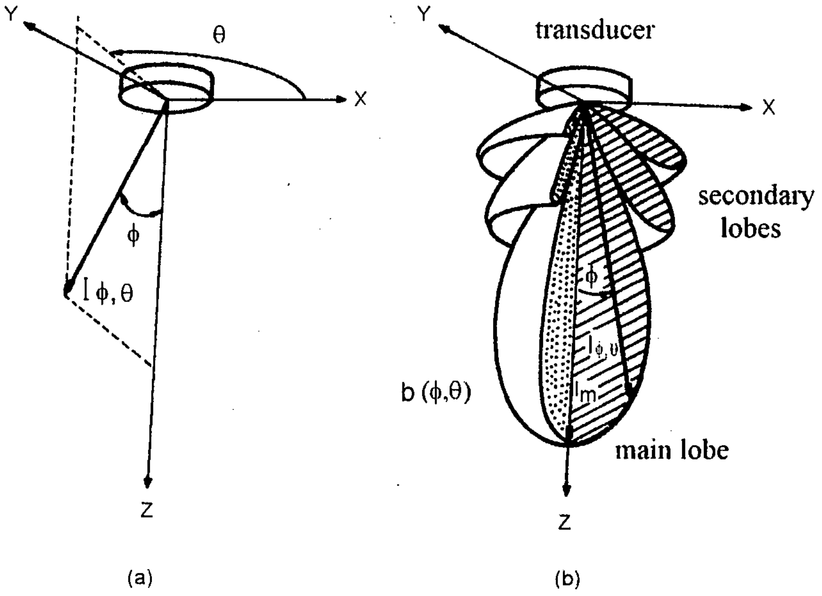


Figure 29 **The Directivity of a circular transducer.**
(a) the coordinate system
(b) the Directivity surface sliced in two parts, at 90°

These two Intensities ($I(0,0)$ and $I(\phi,\theta)$ can be measured at any distance from the transducer, their ratio remains the same.

The functions of Directivity of a transducer are the same for the transmission and the reception. For one way, we can write:

$$b(\phi,\theta) = b$$

In decibels, this expression becomes :

$$10 \log b(\theta) = B$$

Therefore, for the two ways (transmit and receive), the function will be :

2B

That means that the received echo, in order to eliminate the Directivity effect of the 2ways, will have to be corrected by a factor 2B. ϕ and θ are the polar coordinates of the target. In fact, ϕ can be ignored in our case, because our transducer is circular, thus, the response in the horizontal plane is the same anywhere.

2B is called **the Beam Pattern Factor**, for the 2 ways of the sound wave. In the next Figure, you can see a data sheet called "**Directivity pattern**" of a transducer. This diagram is the result of a calibration in laboratory at the manufacturer's. It gives information about the opening angle of the beam and the attenuation of the intensity related to the angle made by any echo at position A, B, C, and the acoustic axis.

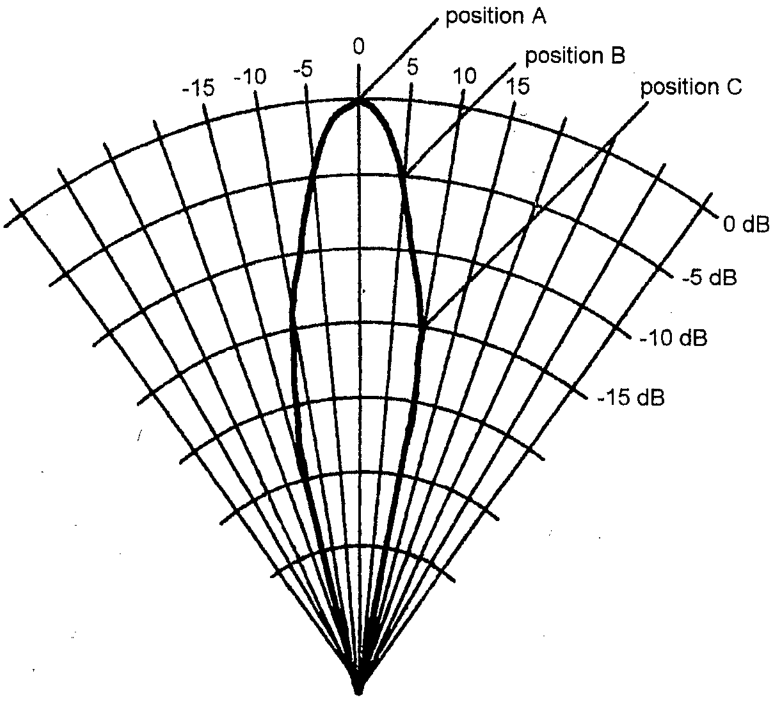


Figure 30 **The Directivity pattern schematics.**

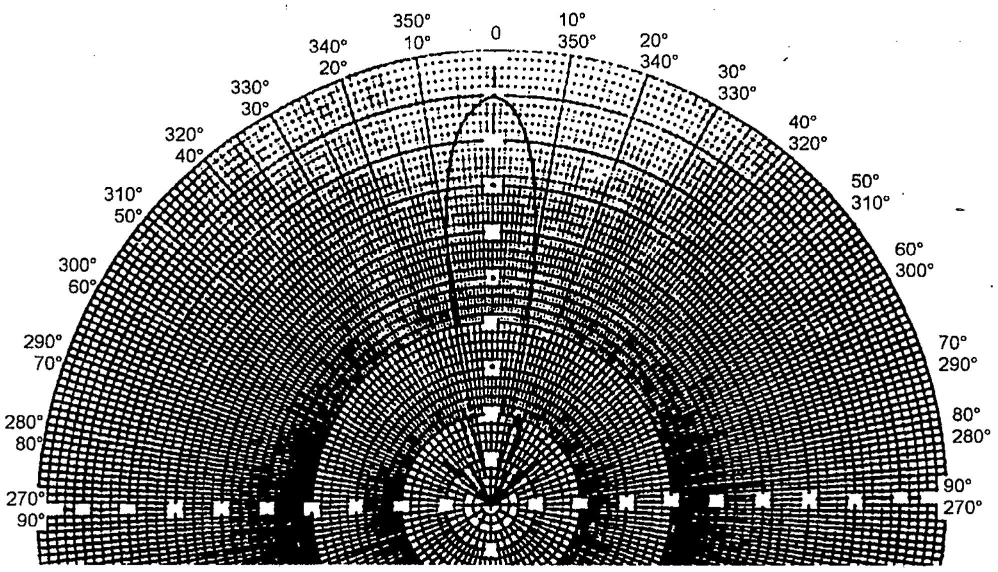


Figure 31 **The directivity pattern data sheet.**

This Directivity must be taken into account, of course in the former 2 way equation (Chapter 4.2.3 - "Sensitivity of a transducer") to complete the relationship. This formula now is:

$$\boxed{V = SL - 40 \log (R) - 2\,\alpha\, R + TS + S_X + 2B\,(\theta)}$$

where V is the voltage at the output of the transducer
where SL is the power transmitted by the transducer
where - 40 log (R) - 2 α R is the total loss for one way and return of the sound
where TS is the target strength of the fish.
where S_X is the receiving sensitivity of the transducer
where **2B (θ) is the Beam Pattern Factor** (the Directivity Factor)

4.3 The receiver

A brief recall on the functioning of the system must be done, step by step.

The electric signal transmitted by the transmitter is first transformed in sound waves by the transducer; these sound waves travel within the sea water until they hit a target, and, reflected by this target, come back taking the inverse way to the transducer; they are transformed again by the transducer in electrical voltages.

These voltages are input into the receiver which has many functions:

- to filter the signal received to reject the noise
- to amplify the weak echo voltages coming straight from the output of the transducer and, in the same time to apply corrections to these voltages in order to eliminate the **absorption loss and the spreading loss,** by means of logarithmic functions.
- to limit the reception by means of a listening gate.
- to convert the original frequency of the transmit/receive pulses into audio frequencies (10 kHz) and/or into direct current voltages (called detected voltages : in this case, exclusively the envelope of the primary signal is used) for further use.

4.3.1 The amplification and the corrections

To give you an order of the voltage dynamics encountered, we can say, that at the reception, the echoes give few µVolts. Amplification is needed in order to enlarge these weak echoes, weakened during the transit of the sound in the sea water. In the same time, corrections are made to compensate the losses due to the sea water environment, such as the **absorption loss** and the **spreading loss,** already studied before.

The receiver amplifier is the most complex electronic unit in the echo-sounder. A diagram illustrating the receiver amplifier principal functions appears at Figure 32. The purpose of this unit is to amplify the signals received from the transducer in a precisely controlled manner and to present them to the following instruments such as the echo-integrator or echo-counter, at a suitable level of amplitude for further processing.

Starting at the input of Figure 32, the transducer output is electrically matched to the input of the receiver in term of impedance and adjustable frequency bandwidth which filters echoes and accepts whose frequencies are around the pure original frequency; for example, a 5 kHz bandwidth for a pure frequency of 120 kHz, will reject all echoes out of the frequency fork from 115 kHz to 125 kHz. This is the first stage which is called preamplifier.

The voltage signal is then amplified; In the BioSonics receiver (Fig.33). The amplification stage is composed of two amplifiers. This amplification stage has a great dynamic range. The total amplification is called the **Static Gain.**

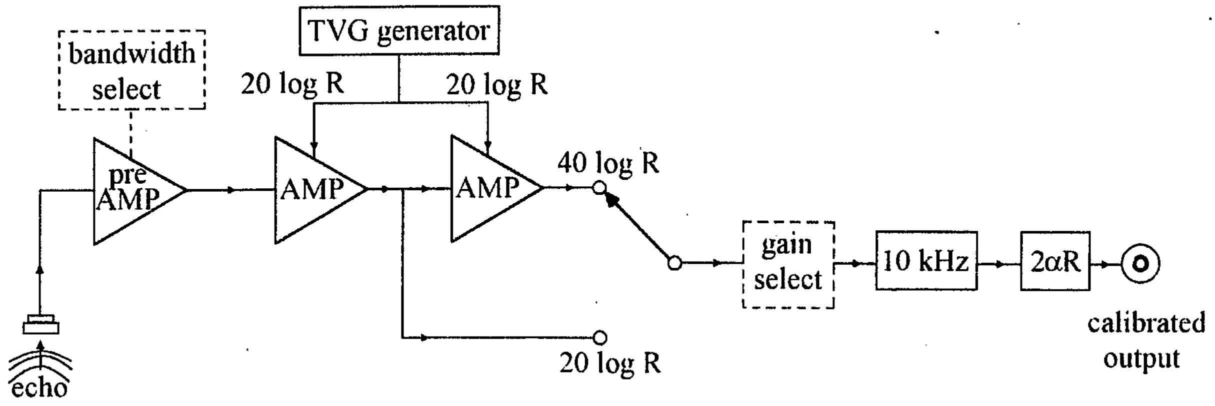


Figure 32 The receiver amplifier principal functions.

This static gain is a gain controlled in logarithmic way by a generator, called "**TVG generator**" (Time Varied Gain), because it supplies the amplification stage with time varied commands. The TVG generator furnishes a controlled voltage signal following the "20 log R" function and acts on both amplifiers. In this way, it compensates the **spreading loss**, totally - "40 log R", or partially - "20 log R", depending on the selection of the operator. The "40 log R" compensation (**spreading loss** totally compensated) will be selected for TS measurements, the "20 log R" compensation (**spreading loss** partially compensated) will be selected for Echo-Integration

As you can see, on Figure 32, the following parts of the receiver are common for both. 20 log R and 40 log R.[*]

The **Static Gain** can be adjusted, around a medium setting referred as "**0 dB**", with a front panel button from: - 18 dB to + 24 dB. A negative setting reduces the amplification, a positive one increases the amplification. For example, if a gain of -6 dB is used, it means that the signal will be only half amplified, and therefore divided by 2, when referred to the **medium** setting (it is the case when the echo voltages are too high). If we use a positive gain of + 6 dB, it means that you multiply by two the amplification referred to the **medium** setting and the receiver output signal is then twice higher.

The frequency of the resulting signal is then converted in lower frequency (10 kHz). The correction of the **absorption loss** (-2 αR) is at that time applied. The signal fully corrected is then output to different devices, such as chart recorder, oscilloscope, and of course to postprocessing devices (echo-integrator, computer). This output is called "**calibrated output**". Modern TVG circuits operate digitally. For each small time increment, there is a corresponding change of gain in the amplifier.

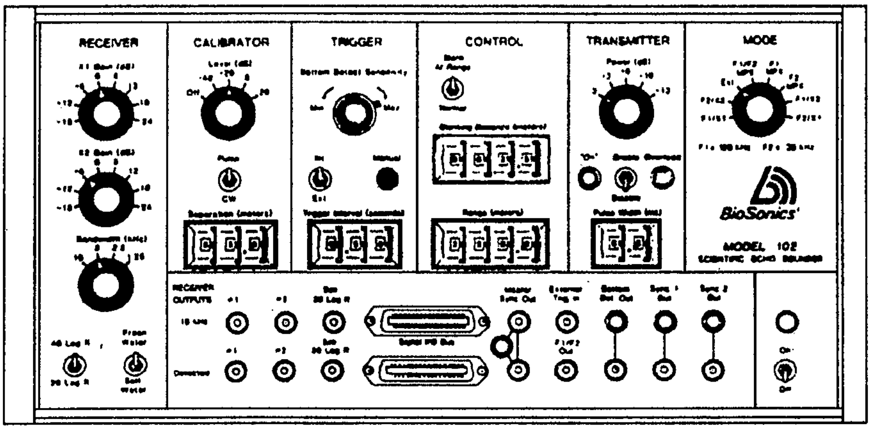


Figure 33 The transceiver BioSonics Model 102.

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[*] When you change the gain setting, you act on both 20 log R and 40 log R outputs.

4.3.2 The 40 log (R) compensation

In an ordinary sounder without sophisticated correction (TVG), the receiver output signal is not corrected and its voltage, U_e here below on Figure 33, is still dependent of the depth "R" and the absorption "exp (2 β R)", and of course of the target strength of the echo "σ".

We can express this output voltage U_e in non logarithmic terms such as :

$$U_e \sim \sqrt{\frac{1}{R^4 \exp(2\beta R)}}\sigma$$

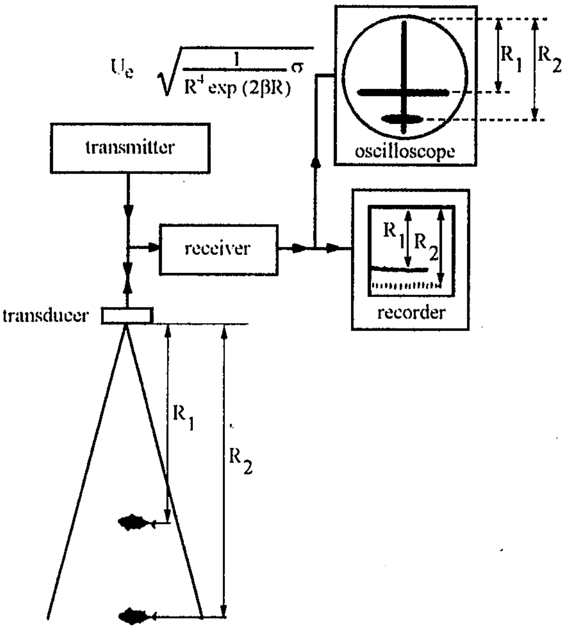


Figure 34 Echo-sounder without TVG.

Let us consider two targets of the same size but at different depth (R_1 and R_2). The return echo voltages are different at the output of the transducer: due to the spreading loss, voltages follow a logarithmic decrease of 40 log R and therefore, the deeper the target stands, the weaker the voltage is. On Figure 34 above, are represented two fishes of the same size and with the same acoustic response; they give different returned voltages at the output of the transducer, due to the difference of depth and thus standing the spreading loss and the absorption loss. On the chart recorder, can be seen a dark trace at the depth R_1, and a light one at the depth R_2, because the voltage coming from a nearer distance R_1 is higher than the one at a further distance R_2. The first one burns the sensitive recording paper (black), the second one less (gray). On the scope, for the same reason, the first voltage provokes a higher deflection of the spot than the second one.

A **scientific echo-sounder** has a sophisticated correction system called TVG, abbreviation which means: **Time Varied Gain.** On Figure 35, our two previous targets of the same size but at different depth (R_1 and R_2), have their returned echo voltages corrected within the receiver; the correction is: $R^4 \exp(2\beta R)$. The receiver output voltage U_e still remains proportional to the target strength σ of the target, but is not dependent any longer of both attenuations due to the sea water (absorption and spreading losses); thus, we can see, displayed on the paper of the chart recorder, two identical traces because the targets have the same acoustic properties (the same σ) , and on the oscilloscope, two identical deflections can be observed on the screen.

What happens within the receiver ? Referred to the previous Figure 32, where are illustrated the receiver amplifier principal functions, both amplifiers are used and the compensation of the **spreading**

loss, is complete (when the channel 40 log R is selected). Figure 36 shows the effect of the Time Varied Gain "40 log R on the amplification.

The **absorption loss** (2 α R) is also compensated and in this way, the **calibrated output voltage** of the receiver with this "40 log (R) + 2 α R" correction, is independent of the depth to the target.

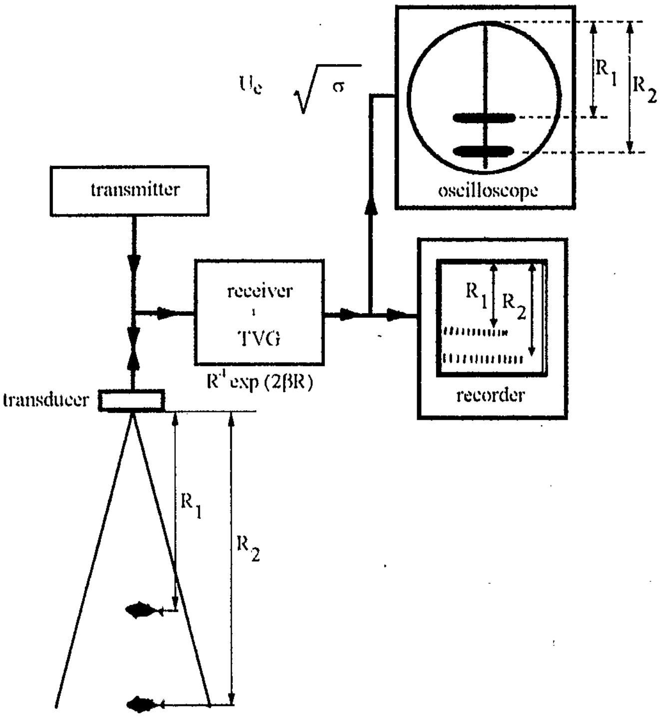


Figure 35 **Scientific echo-sounder with a TVG correction.**

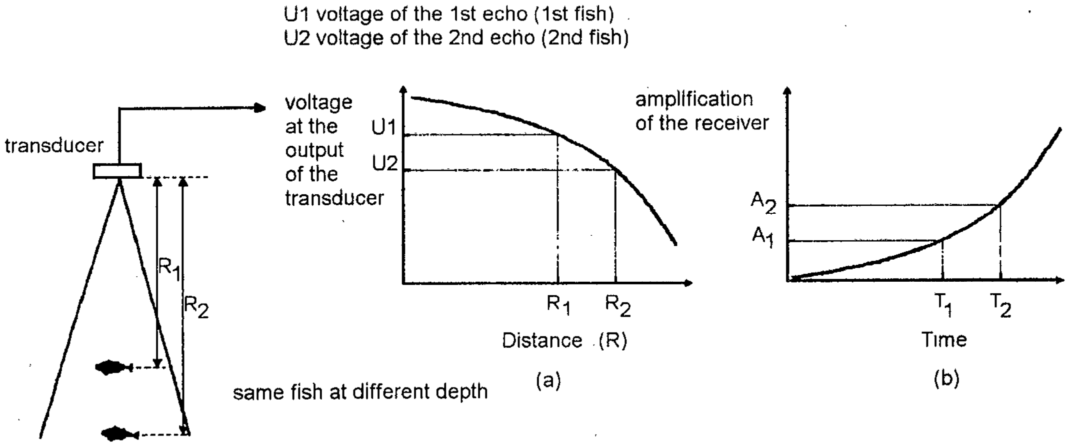


Figure 36 **The effect of the Time Varied Gain "40 log R".**
(a) due to the spreading loss, voltages follow a logarithmic decrease of 40 log R
(b) the amplifier is controlled by the TVG generator and then the total amplification is applied, reestablishing the same level of voltages because the targets are identical and by this means, the logarithmic attenuation due to the distance (depth) is corrected
(U1 x A1 = U2 x A2).

4.3.3 The 20 log (R) compensation

As we have seen before (Fig.32), only the first amplifier output is used. Because the correction concerns only one way loss, the output voltage is still dependent of the depth.

4.3.4 Summary of the amplification and correction

The Summary of the signal amplification and correction is given in Figure 37. This Figure represents the signal path through the receiver and its shape.

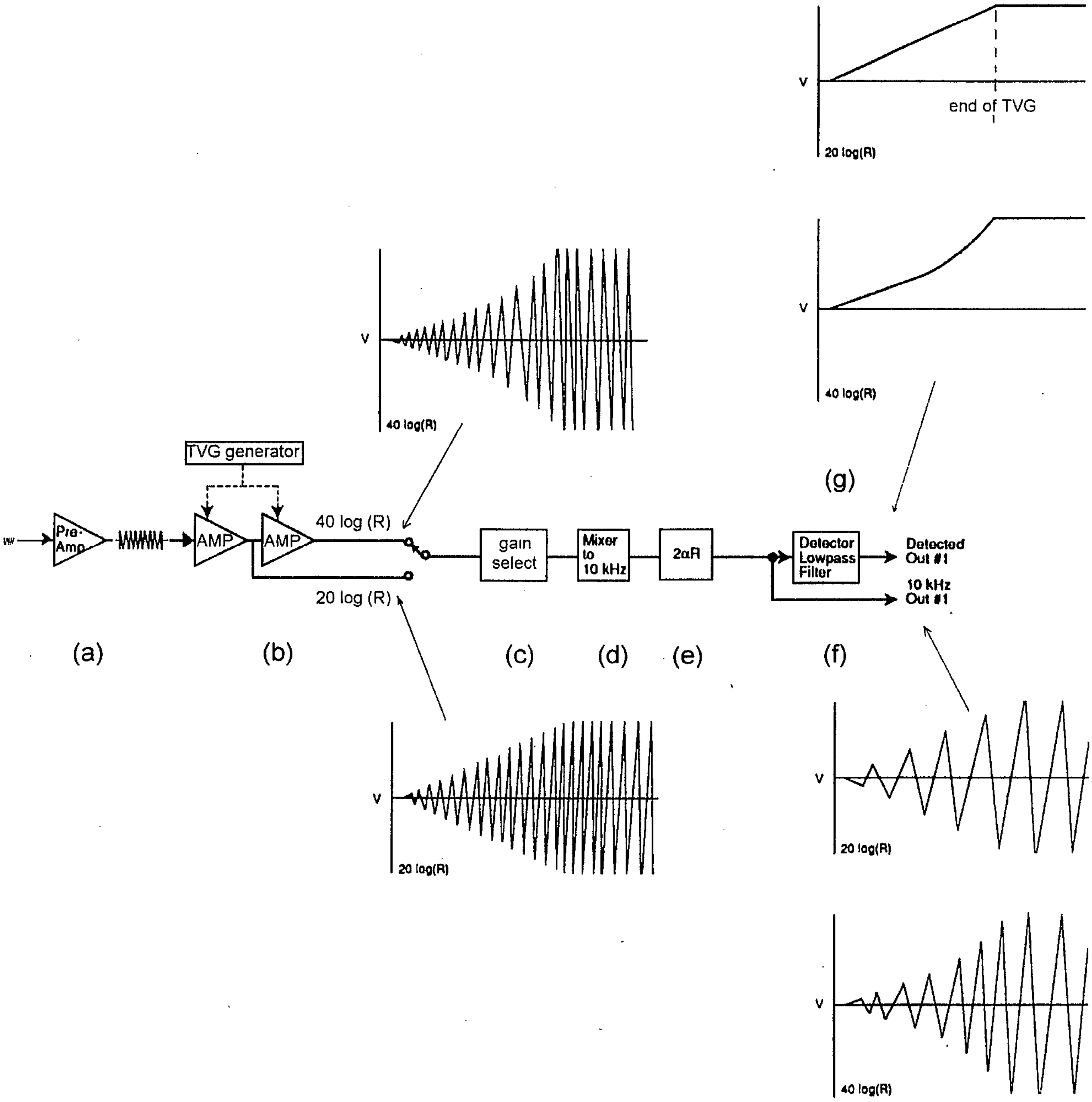


Figure 37 The signal path through the receiver and its shape.

The small signal, coming from the transducer terminals, is first amplified by the preamplifier in (a). Then, the TVG control modulates the following amplification in amplitude: each amplifier receives a "20 log R" modulation, in (b). After the log selection switch, the gain is adjusted (c) and the frequency of the signal is lowered (in our case the original frequency is 120 kHz) via the frequency mixer, in (d); the frequency becomes 10 kHz.

This signal is corrected with a 2 αR amplification (e); it is output for tape recording or some echo-integrators whose input need AC signals, in our case, the interface INES - MOVIES (f); the second output, which comes from this mixer, passes through a detector which creates an envelope of the positive alternances of the signal and rejects all sinusoids (g). This output is the second main output; it is used to postprocess the signal through the BioSonics ESP echo-integrator and TS processor, for the Target Strength. On Figure 38, 2 zooms are represented; the zoom of the frequency change (a) and the zoom of the detection of the signal (b).

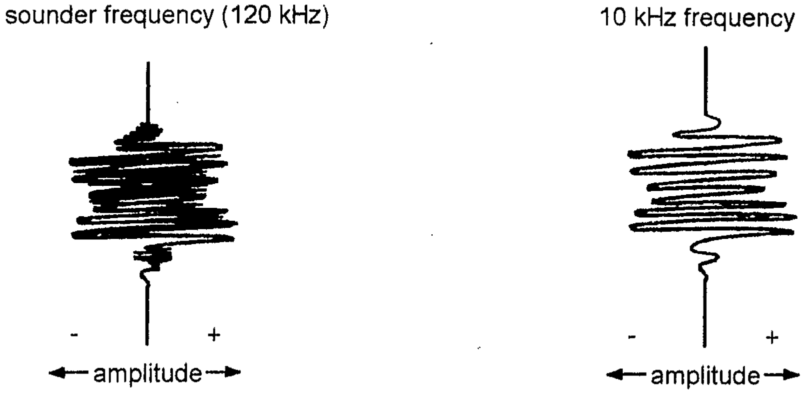


Figure 38 (a) **Zoom of the frequency change.**

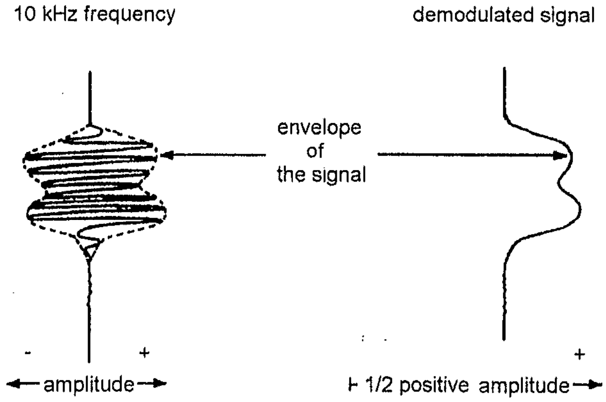


Figure 38 (b) **Zoom of the detection of the signal.**

As we already know, the receiver applies **the absorption loss** and **the spreading loss** corrections to the signals, by means of logarithmic function amplifiers, and also applies static gain to them.

We need to recall once again why there are two kinds of selection:

- **The 40 log R selection** is used for TS measurements and whole losses are corrected, because we generally work on single targets which must be "perfect". As we have seen before, the intensity of the returning echo is proportional to $1 / R^4$.
- **The 20 log R selection** is used for echo-integration, only one way loss is corrected. Why ? Because, in echo-integration, we think in terms of multiple echoes in a same pulse- insonified volume. We can say briefly, that the intensity of the returning echo is proportional to $1/R^2$.

We have reached the end of the receiving chain, we can, therefore, add up to our 2 way equations seen some pages before (chapter 4.2.1 - "The transducer"), the input of the receiver. We can express the voltage at the exit of the echo-sounder, called **V output**, in dB, in both TS and Echo-Integration measurements. We must take into account the Static Gain which is not the same for each case, because we take different parts of the receiving chain (one amplifier for 20 log, two amplifiers for the 40 log R).

We must also take into account the adjustment of these gains selected on the front panel by the operator (see Fig. 32).

For a better understanding, let us call "**Static Gain$_{40}$**", the total static gain for the "40 log R" channel, "**Static Gain$_{20}$**", the total static gain for the "20 log R" channel, and "**G**", the Gain Setting.

If we use "the 40 log R" channel of the receiver (for TS), **V output** can be expressed as:

$$\text{V output (dB)} = \text{SL} - 40\log(\text{R}) - 2\,\alpha\text{R} + \text{TS} + S_x + 2\text{B}(\theta) + \underbrace{\text{Static Gain}_{40} + \text{G} + 40\log(\text{R}) + 2\alpha\,\text{R}}_{\text{Receiver amplification and corrections}}$$

Because, $[-40\log(\text{R}) - 2\,\alpha\text{R} + 40\log(\text{R}) + 2\alpha\,\text{R}] = 0$

After simplification, the equation becomes :

$$\boxed{\textbf{V output (dB)} = \text{SL} + S_x + \text{Static Gain}_{40} + \text{G} + \text{TS} + 2\text{B}(\theta)}$$

where V output (dB) is the value of the voltage in dB, at the output of the receiver
where SL is the Source Level or power transmitted (in dB)
where S_x is the Sensitivity of the transducer (in dB)
where Static Gain $_{40}$ is the total Static Gain for the 40 log R channel
where G is the Gain adjustment of the receiver (in dB)
where TS is the Target Strength of the fish (in dB)
where 2B is the beam pattern factor (in dB)

If we use the 20 log R channel (for Echo-Integration), **V output** can be expressed as:

$$\text{Voutput (dB)} = \text{SL} + S_x - 40\log(\text{R}) - 2\,\alpha\text{R} + \text{TS} + 2\text{B}(\theta) + \underbrace{\text{Static Gain}_{20} + \text{G} + 20\log(\text{R}) + 2\,\alpha\,\text{R}}_{\text{Receiver amplification and corrections}}$$

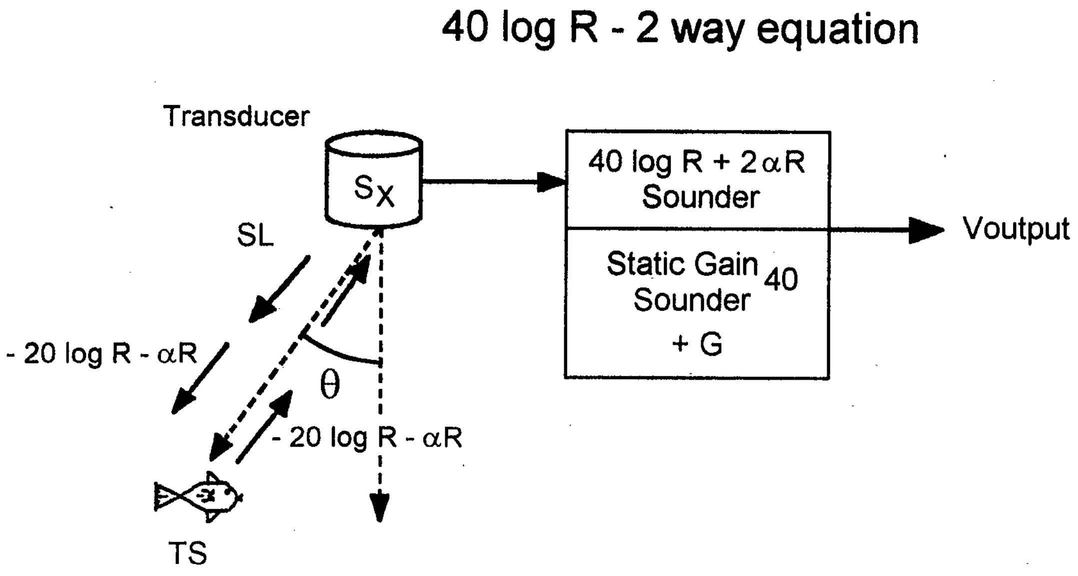
Because, $[-40\log(\text{R}) - 2\,\alpha\text{R} + 20\log(\text{R}) + 2\,\alpha\,\text{R}] = 20\log(\text{R})$

That can be written, after simplification :

$$\boxed{\textbf{V output (dB)} = \text{SL} + S_x + \text{Static Gain}_{20} + \text{G} - 20\log(\text{R}) + \text{TS} + 2\text{B}(\theta)}$$

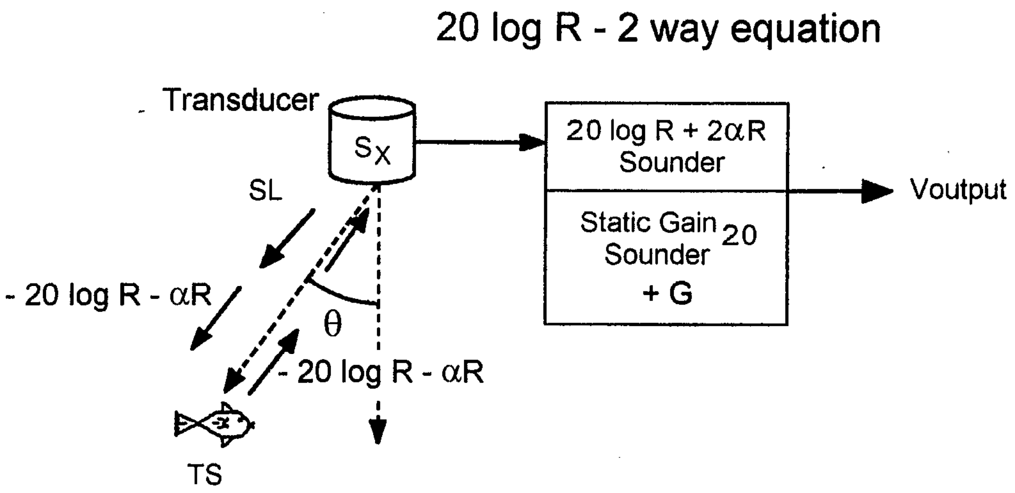
where V output (dB), SL, S_x, G , TS and 2B like before
where Static Gain$_{20}$ is the Static Gain of the receiver (in dB)
where - 20 log (R) is the remaining spreading loss on 1 way, not corrected.

In order to concretize visually these two way equations, one will find hereafter the diagrams of the receiving channel, where are shown all the parameters of the 2 last formula.



V output (dB) = SL + S_X + Static Gain$_{40}$ + G + TS + 2B (θ)

Figure 39 **The 40 log R receiving channel diagram.**



V output (dB) = SL + S_X + Static Gain$_{20}$ + G - 20 log (R) + TS + 2B (θ)

Figure 40 **The 20 log R receiving channel diagram.**

These two equations are still "heavy" and therefore can be lighted. Indeed, if we regroup the Sensitivity of the transducer **S_X** and the **Static Gain**, in a single term called **Receiving Sensitivity channel** and expressed respectively, regarding to the channel in use, as "**RS channel 40**" and "**RS channel 20**", our last equations become:

- for 40 log R -

V output (dB) = SL + RS channel 40 + G + TS + 2B (θ)

where **V output (dB)** is the value of the voltage in dB, at the output of the receiver
where **SL** is the Source Level or power transmitted (in dB)
where **RS channel 40** is the receiving sensitivity of the channel 40 (in dB) (=S_X + **Static Gain$_{40}$**)
where **G** is the Gain adjustment of the receiver (in dB)
where **TS** is the target strength of the fish (in dB)
where **2B** is the beam pattern factor (in dB)

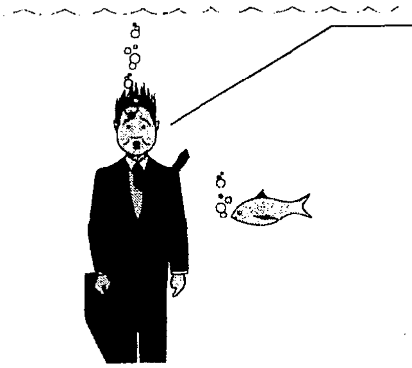
for 20 log R -

V output (dB) = SL + RS channel 20 - 20 log (R) + G + TS + 2B (θ)

where **V output (dB)** is the value of the voltage in dB, at the output of the receiver
where **SL** is the source level or power transmitted (in dB)
where is the receiving sensitivity of the transducer (in dB)
where **RS channel 20** is the receiving sensitivity of the channel 20 (in dB) (= S_X + **Static Gain$_{20}$**)
where **G** is the Gain adjustment of the receiver (in dB)
where **TS** is the target strength of the fish (in dB)
where **2B** is the beam pattern factor (in dB)
where - **20 log (R)** is the remaining spreading loss on 1 way, not corrected

These two parameters: **RS channel 40** and **RS channel 20** which characterize the whole receiving chain as constant terms, are obtained by the manufacturer's calibration in laboratory. They are given as preset values and data sheets of the results are joined with the equipment.

Do not forget: SL, **RS channel 40** and **RS channel 20** are referred to 1 meter.



Example :
An echo-sounder has the following characteristics:
SL = 220 dB / 1m / 1 µPa
RS channel 40 = - 170 dB /1V/ 1m
RS channel 20 = - 150 dB /1V/ 1m
G= - 6 dB

Question :

What is the value of the Target strength of a fish detected at a depth of 10 meters, right on the acoustic axis and giving an echo voltage of 1 volt?

Answer :

For the TS measurements, the "40 log R" function must be used, and the depth can be forgotten because the total propagation loss is corrected and therefore the voltage measured is independent of the depth.

Applying the "40 log R" formula , we can write:

V output (dB) = SL + RS channel 40 + G + TS + 2B (θ)

Because the echo is right upon the acoustic axis, the directivity 2B (θ) = 0

and also, **V output (dB)** = 20 log 1 volt = 0

Thus, if we replace the terms of the equation with their values, it becomes :

0 = 220 + (-170) + (-6) + TS + 0

The TS value of the fish is therefore:

TS = - 44 dB   Be careful with the algebraic signs!

Question :

What is the voltage value at "the 20 log R" output of the echo-sounder, for a fish on-axis whose TS is -40 dB, detected at a depth of 10 meters ?

Answer :

In this case, the 20 log R function is needed. Applying the formula, we can write :

V output (dB) = SL + RS channel 20 - 20 log (R) + G + TS + 2B (θ)

Thus, if we replace the terms of the equation with their values, it becomes :

V output (dB) = 220 + (-150) - 20 log 10 + (-6) + (- 40) + 0

V output (dB) = 4 dB

Voltages are linked with the decibels in such a way: V (dB) = 20 log Voutput

So, V output = antilog (4 / 20)

V output = 1.5848 volts

As we have just seen with these numeric applications, we can, from the two 2 way equations of the sound, and their parameters, extract what we are looking for: the **TS** (in dB)

First rewrite these two final equations:

$$\mathbf{V\ output\ (dB) = SL + RS\ channel\ 40 + G + TS + 2B\ (\theta)}$$

and

$$\mathbf{V\ output\ (dB) = SL + RS\ channel\ 20 - 20\ log\ (\ R\ ) + G + TS + 2B\ (\theta)}$$

What is known on measurement?

- Voutput (dB) is calculated from the voltage Voutput measured with an oscilloscope (on its vertical axis, at the output of the receiver).
- SL, RS channel 40 and RS channel 20 are the values of calibration from the manufacturer's.
- 20 log (R) is calculated from the time measured on the oscilloscope, on the horizontal axis (time base).
- G is set by the operator and verified while checking the equipment (by voltage measurements with a multimeter).

What is unknown ?

- The **TS** we are searching for.
- **2B** (θ) related to the target's position in the acoustic beam.

Before using them, some known parameters need to be verified; they are the ones given by the manufacturer. This verification is called "**the calibration of the echo-sounder**."

4.4 Calibration of SL, RS channel 40, RS channel 20, SL+VR for a single beam

To perform this calibration, we use a standard target, placed below the transducer. It is a copper or a tungsten sphere whose TS is known. This sphere is a perfect target, which will reflect totally the energy. If we adjust the sphere right on the acoustic axis, the beam pattern factor 2B (θ) is equal to 0. In laboratory, this task is facilitated by means of X-Y positioning system (sphere handled with nylon thread). *In situ*, this perfect positioning of the sphere below the transducer is difficult to realize: the operator will have to wait for the maximum echo and consider it as the result of its on-axis position. Let us see now what happens in our equations :

In 40 log R, V output (dB) = SL + RS channel 40 + G + TS + 2B (θ) becomes:

$$\text{V output (dB)} = \text{SL} + \text{RS channel 40} + \text{G} + \text{TS}$$

We can rearrange the equation as:

$$\text{SL+ RS channel 40} = \text{V output (dB)} - \text{G} - \text{TS}$$

with Voutput (dB), G measurable and TS, the well-known acoustic response of the standard sphere.

Thus, SL+ RS channel 40 can be checked.

Question :

Our tungsten calibration sphere of 20 mm diameter, has a TS of -42 dB: the gain used during the calibration is -6 dB. The voltage output obtained is 1V. What is the value of the SL+RS channel 40 ?

Answer :

SL+ RS channel 40 = Voutput (dB) - G - TS
= 0 - (-6) - (-42)
= 48 dB

From our former typical echo-sounder example, it might be: 220 - 170 = 50 dB

This deviation observed, we can eventually correct one of these two parameters, SL or RS channel 40, by adding or subtracting this deviation, to fit with the basic equation. For example: no change for SL =220 and adoption of a new value for RS channel 40 which would become : -172 dB

In 20 log R, when the sphere is well-centered [2B (θ) = 0], we can write :

V output (dB) = SL + RS channel 20 - 20 log (R) + G + TS

We can rearrange the equation as:

SL + RS channel 20 = V output (dB) + 20 log (R) - G - TS

V output (dB), G, 20 log (R) measured, and as before , TS, the standard sphere acoustic response well-known. Thus, SL+ RS channel 20 can be checked.

Question :

Our tungsten calibration sphere of 20 mm diameter, has a TS of -42 dB; it is placed at 10 m from the transducer; the gain used is -6 dB. The voltage output is 1V. What is the value of the SL+RS channel 20 ?

Answer :

SL + RS channel 20 = V output (dB) + 20 log (R) - G - TS
= 0 + 20 - (-6) - (-42)
= 68 dB

From our former typical echo-sounder example, it might be: 220 - 150 = 70 dB

As we did before, we can correct one of these two parameters, SL or RS channel 20, by adding or subtracting this deviation, to fit with the basic equation. For example : no change for SL (= 220 dB) and a new value for RS channel 20 which woul become: -152 dB.

The advantage of this method is to evaluate, in a simple direct measurement, this couple of parameters SL and RS channels which are so difficult to estimate because they need precise experimentation with accurate hydrophone in laboratory, or at sea.

In echo-integration, in order to characterize the echo-sounder performances, biologists use another expression:

SL + VR

with VR = RS channel 20 referred at 1 meter + total gain of the TVG_{20} at its maximum.

It is, in fact, a receiving sensitivity but referred at the maximum of the TVG range, as a global view of the echo-sounder performance.

This relationship can be expressed as :

SL + VR = V output (dB) + 20 log (R) - G - TS - 2B (θ) + total gain of the TVG_{20}

For the calibration, when the sphere is well - centered, 2B (θ)=0, and if the static Gain (G) is 0 dB, we can apply the formula:

$$\textbf{SL} + \textbf{VR} = \text{V output (dB)} + 20 \log (R) - \text{TS} + \text{total gain of the } \text{TVG}_{20}$$

Question :

What is usually the value of SL+VR, for most of scientific echo-sounders ?

Answer :

Usually SL+VR is comprised between 100 dB and 120 dB.(depending of the gain used). In our model* :

SL+VR = V output (dB) + 20 log (R) - TS + total gain of the TVG_{20}
= 0 + 20 -(-42) + 20 log 125
SL+VR = 103.94 dB

After this brain storming, it is time to sum up what you have to recall for the following lessons :

For the TS measurements:

$$\mathbf{V_{out} \text{ (dB)} = SL + RS \text{ channel } 40 + G + TS + 2B\ (\theta)}$$

For Echo-integration:

$$\mathbf{SL + VR = V_{out} \text{ (dB)} + 20 \log (R) - G - TS - 2B\ (\theta) + \text{total gain of the } TVG_{20}}$$

Great care must be taken with the voltages used. While working in the same system, no error occurs. When 2 systems are compared, be sure that the voltages are of the same kind. For example, BioSonics uses the detected voltage V_{peak} for all measures and other systems, like INES, use Voltages RMS ($V_{peak} / \sqrt{2}$). Therefore, equations will have to be adjusted mathematically.

---

* The BioSonics TVG used for our surveys spans from 1.25m to 125m.

4.5 The transmitter

A special circuit, the "Time Base", referred on Figure 41 as block 1, provides the "clock" to the whole system, to trigger the transmission and also the receiving period (and so to control the TVG start). This circuit initiates a "trigger pulse" which switches on the transmitter during a certain and adjustable time, called duration or pulse width, for example, 0.4 msec. The shape of this pulse has a square shape. The transmitter will output via a power amplifier, a transmitting signal of actual frequency (in our case 120 kHz) during this period (Fig.41, block 2) to the transducer (Fig.41, block 3).

At the end of this period, when the square pulse is dropping down, the falling edge triggers the reception mode of the echo-sounder, that means, starts the TVG function, and in the same time, stops the transmission.

After a certain time, the following trigger stops the receiving activity of the echo-sounder and permits a new transmission and so on...This trigger pulse must be adjusted in a defined time interval called "**transmission rate**" or "**pulse rate**" accorded to the depth of the surveyed area. It means this interval must be long enough between to pulses to allow all echoes to return before the next transmission.

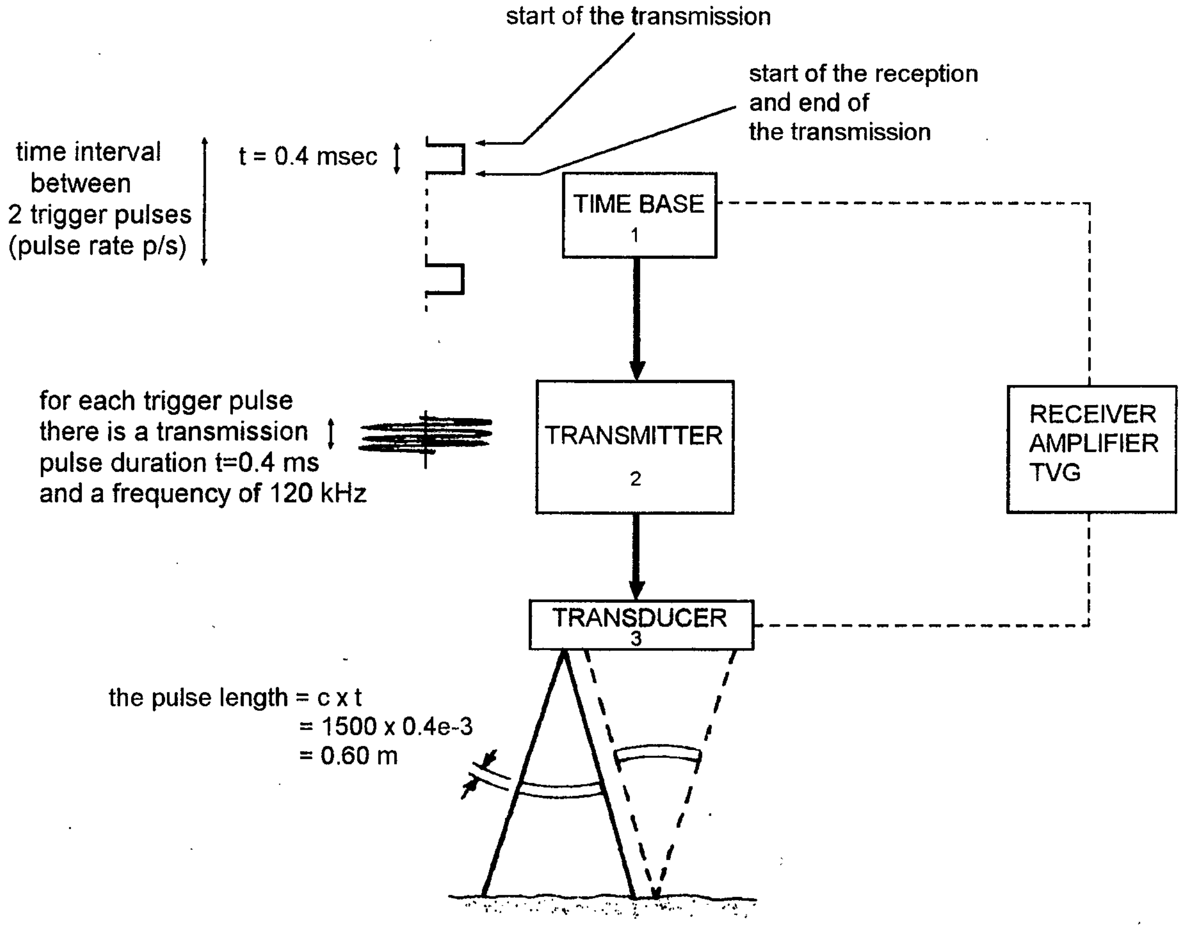


Figure 41 **The transmitter.**
In continuous line : the transmit mode
In dot line : the receiving mode

4.5.1 The Pulse Length

If we use a frequency of 120 kHz, with a pulse duration, which limits in time this signal, we can say that the period (t) of the signal is :

$$t = 1 / f$$
$$= 1/120{,}000$$
$$= 8{,}333\ \mu\text{sec (1 cycle)}$$

If we allow the transmission during 0.4 msec (= 400 µsec) that means that :

400 / 8,.333 = 48 cycles of the sinewave will be transmitted.

We know that the acoustic waves travel at a speed of 1500 m/sec. So, the distance covered in this time of 0.4 msec is :

$$c\,\tau = 1500 \times 0.4\ 10^{-3}$$
$$= 0.6\ \text{m}$$

$c\tau$ is called the Pulse Length. The Pulse Length is the actual physical length of the pulse in the water. This is an important parameter of the echo-sounder because:

- it determines the vertical resolution (depth) between targets (2 fishes), or between a fish and the sea bed. The minimum distance between any objects X and Y, sufficient for their echoes to be discriminated is :

$$\frac{c\tau}{2}$$

  In our case, that means : 2 fishes will have to be separated from each other with a minimum distance of : 0.6 m / 2 = 0.3 m or 30 cm.

  If they are closer, the returned echo will be a composite echo of both targets, and difficult to estimate.

  The shorter is τ , the better the resolution.

- it affects the transmitted energy. The longer the pulse in the water the greater is the chance of detecting targets at long distances because the average power is increased.

4.5.2 The transmitted Power

A power amplifier within the transmitter raises the power output to hundred watts, and the power level must remain exceptionally constant. The output voltage is measured with an oscilloscope and a probe, the transducer connected, by taking the peak- to- peak value, then squaring it and dividing by eight times the transducer impedance (Z). Let us explain this relationship, more in detail; in the Chapter 2.2 - "Power", we have seen that : **$P = V^2/R$.** (or Z). We must precise that the voltage is expressed in RMS values with the following relationship : $V_{rms} = V_{peak} \times \sqrt{2} / 2$.

Thus, we can write :

$P = [V_{peak} \times \sqrt{2} / 2\,]^2 / Z$ with $V_{peak} = V_{\text{peak-to-peak}} / 2$

thus, $P = [V_{\text{peak-to-peak}} \times \sqrt{2} / 4\,]^2 / Z$ then $P = V^2_{\text{peak-to-peak}} / 8Z$

For our echo-sounder, at -3 dB transmission level, the output voltage peak- to- peak is : 560 Vpp. The power transmitted on the transducer with 62 Ω impedance (Z), is :

$$P = (V^2\ \text{peak-to-peak}) / (8Z)$$
$$P = (560^{2)} / (8 \times 62) = 632\ \text{watts}$$

4.6 The display system

The display system is at least, composed of a chart recorder and an oscilloscope. Both use the calibrated output signal and the trigger pulses of the time base we have seen earlier, to display this signal intelligibly.

4.6.1 The chart recorder

There are many kinds of chart recorders. Figure 42 shows one of them, the one we used during the surveys (BioSonics). As you can see, there are settings on the front panel, such as:

- the range which is the selection of the depth range by changing the speed of the recording stylus. The greater the range, the lower is the rotation speed of the stylus, related to the traveling speed of the sound wave in the water.
- the paper speed which moves from right to left; the paper is a roll of 25 m long, and dry.
- You can observe the different inputs such as trigger, signal, bottom signal inputs.

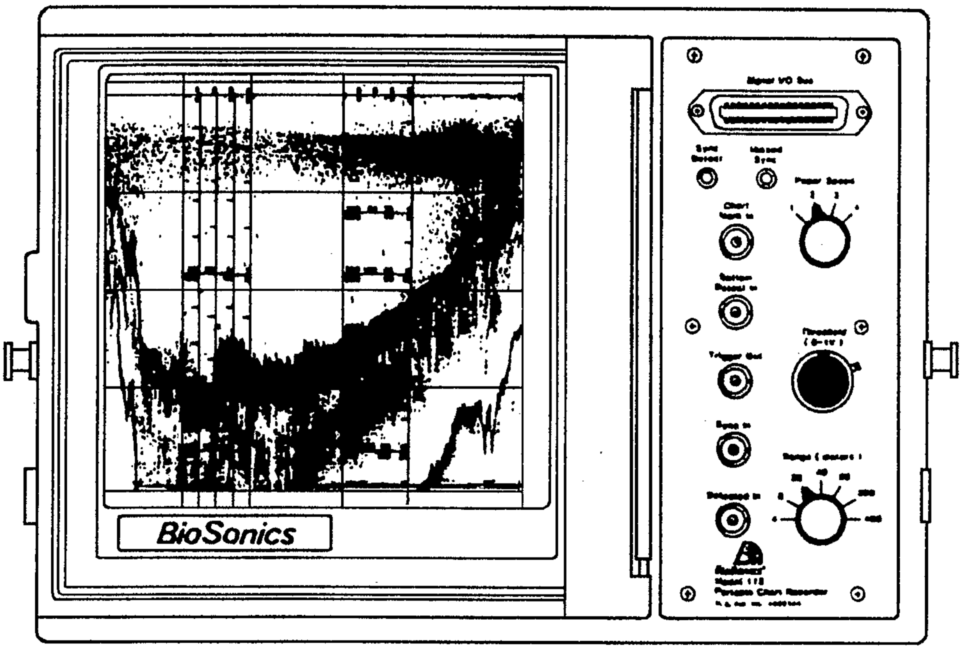


Figure 42 The chart recorder.

We must say that these chart recorders can be used as slaves, that means they only receive all signals coming from the transceiver, trigger and echoes, but also they can be used as masters for triggering the echo-sounder: as the stylus rotates, it moves past the zero mark on the recorder and operates an electric contact which supplies a trigger pulse to the rest of the equipment; in this case the time base circuit within the transceiver is shortcut and this is the chart recorder which starts the transmitting mode and the following receiving mode. The pulse rate, in this case, is dependent of the rotating speed of the stylus and so the depth range selected. This can be a problem on survey where depth often fluctuates, leading to several changes of pulse rate. That the reason why we have decided to use the chart recorder as a simple slave and to use the built-in time base generator of the transceiver, at a pulse rate of 3 pulses per second. Modern chart recorder can stand this kind of remote triggering control and follow as well the transceiver's law.

4.6.2 The oscilloscope

This tool is essential in acoustics. This instrument is based on the ability of a cathode-ray tube to display oscillatory voltages. It does this by deflecting an electron beam, directed at a fluorescent screen, simultaneously in two mutually perpendicular planes. When DC coupled, oscilloscopes can also measure steady voltages. The detailed functioning of an oscilloscope is beyond the topics of this training course

(Fig.43). To sum up the aims of an oscilloscope, the first one is to visualize what happens along the electronic chain of an echo-sounder and the peripheral. The second one will be to undergo precise electric measurements, to control, to calibrate this equipment, in order to make the right settings for our surveys. This apparatus, is in fact a voltmeter which displays is the picture of the signal on the screen. Calibrated scales with great accuracy, give us the value of the measure. The horizontal scale is the time base and the vertical one is the deflection of the input voltage signals. If the input signals are too high, a voltage probe will be needed and the results will be self-corrected for instant reading.

There are two kinds of oscilloscopes: analogic and digital. The digital ones are programmable and have built-in memories which allow the capture of traces: pictures are stored and available to be played back. The display can be frozen for analysis. The performance of such scopes depends on their sampling rate. If the built-in analog-to-digital converter is too low, it may lead to signal distortion or false values. Great care must be taken about their use, and it would be recommended to use a classic scope in parallel, simultaneously to check both displays.

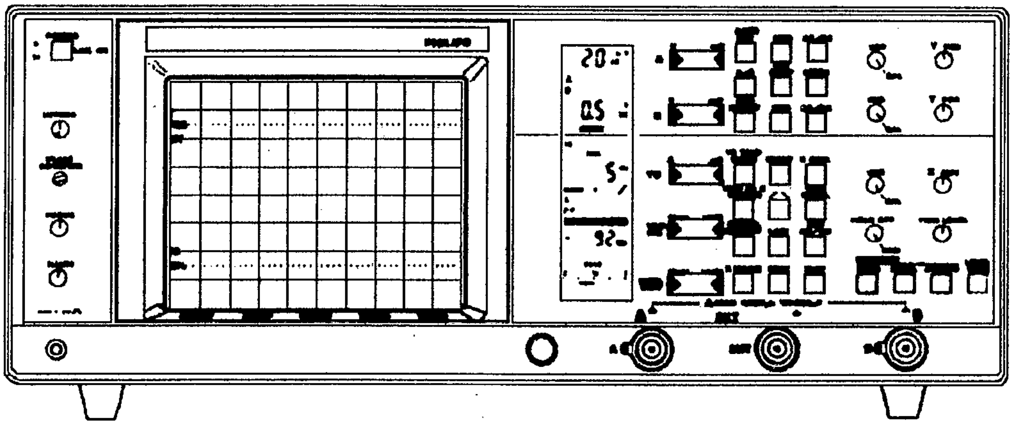


Figure 43 **The oscilloscope.**

4.7 Complementary electronic equipment

4.7.1 The signal generator

This instrument provides the means of electrically calibrating receiving amplifiers for their sensitivities, dynamics, and bandwidth (Fig.44). The signal generator provides constant waves or pulses at the frequency of the echo-sounder (120 kHz), which are input into the circuit to be tested or repaired. Although our acoustics equipment has already an internal built-in signal generator, it would be worth to have one.

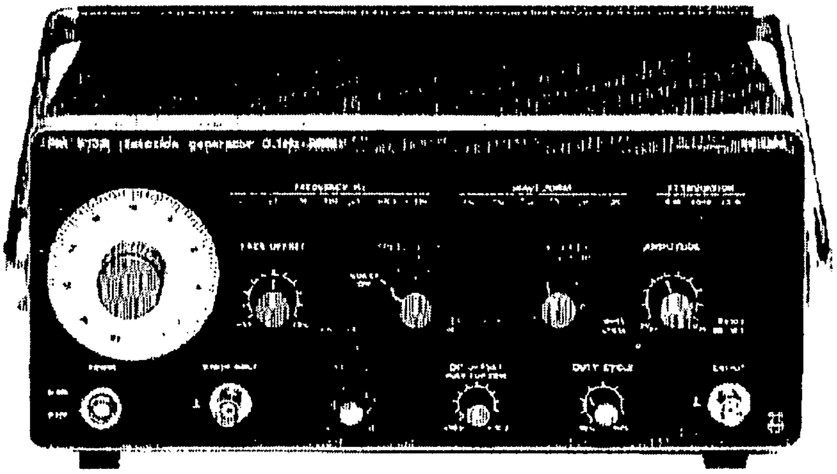


Figure 44 **The signal generator.**

4.7.2 The tape recorder

The Digital Tape Recorder has been used to record electric signals output from the receiver of the echo-sounder. These signals have been played back for postprocessing, at the laboratory (Fig. 45). We used a DAT (**D**igital **A**udio **T**ape) recorder, preferable to any analogic recorder which loses dynamics with the time. The DAT system converts analogic voltage signals into digital (0, 1, 0, 1, ...) before saving them. In this way , when played back, the system reconverts these bytes into analogic values without any amplitude loss occuring when using analogic recorders. The accuracy is perfect and sequences can be replayed and the playback is completely controled such as stop, pause as often as desired. Moreover, besides the classical dual recording channels (left and right stereo system), this apparatus has a third track which allows to record special events, called "flag", such as the beginning and the end of the record, the date, the time, the recording time remaining and special built-in features such as dials, battery test; it can be either connected to the Mains or to car batteries. Its very accurate mechanism is protected by hygrometric sensors which prevents from head failures.

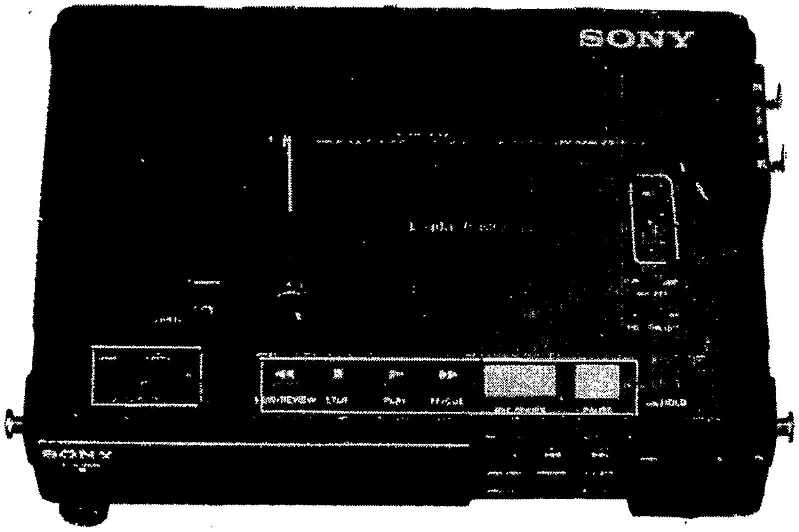


Figure 45 The digital audio tape recorder (DAT).

4.7.3 Multimeters

These apparatus are used to check any electronic system (Fig. 46).

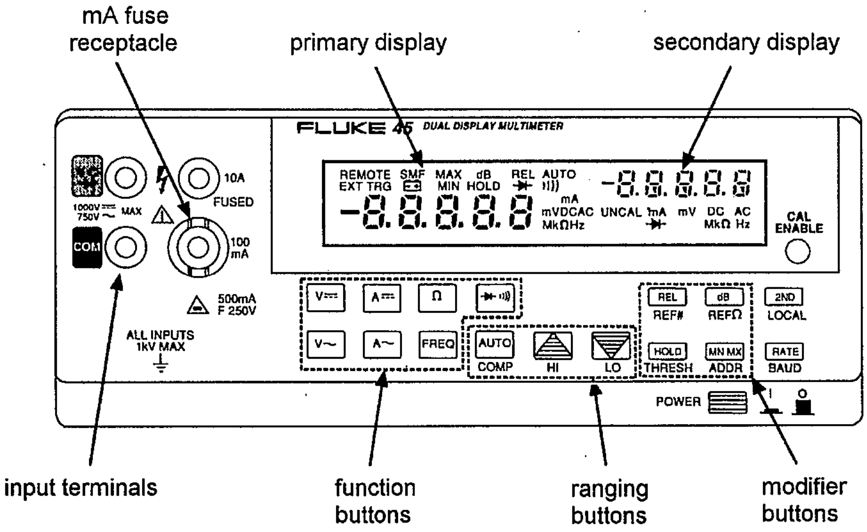


Figure 46 The multimeter.

Nowadays, multimeters are digital, which means that these meters display the measured quantity in decimal form by light emitting diode (LED) digits or liquid crystal display (LCD). Their accuracy are very high for both AC and DC signals.

This equipment has multiple function, that means it is used for voltage measurement (DC and AC), intensity measurement (DC and AC), frequency measurement, resistance measurement, and much more.

4.7.4 The echo-integrator

An echo-integrator receives all signals from the calibrated output of the scientific echo-sounder. These signals require further processing and the facility for the operator to select sections, or intervals in the water column at depths which can be adjusted to make the echo-integrator into a practical tool. Because of this there are many circuits functions, of which only one is strictly an integrator, but it is convenient to place them together and call the resulting system of units, an echo-integrator. The term "integrator" is used in its mathematical sense of measuring the area under a curve of voltage versus time. Time is usually proportional to the distance moved by the survey vessel and the voltage output is proportional to fish density.

The most recent instruments developed for fish stock assessment purposes are based on digital techniques. In our case, the echo-integrator is composed of :

- an interface called **INES**, which is an electronic interface to digitalize the echoes from the sounder, placed between the sounder and a computer. It receives the echoes from the sounder, put them in form before transferring them to the computer (Fig.47).
- A software resident in this computer, called **MOVIES**, which is a module used for the visualization, the Integration, the processing of the data preprocessed by INES. It can be run in real time or in play back after the storage of the survey data on diskettes or hard disk.

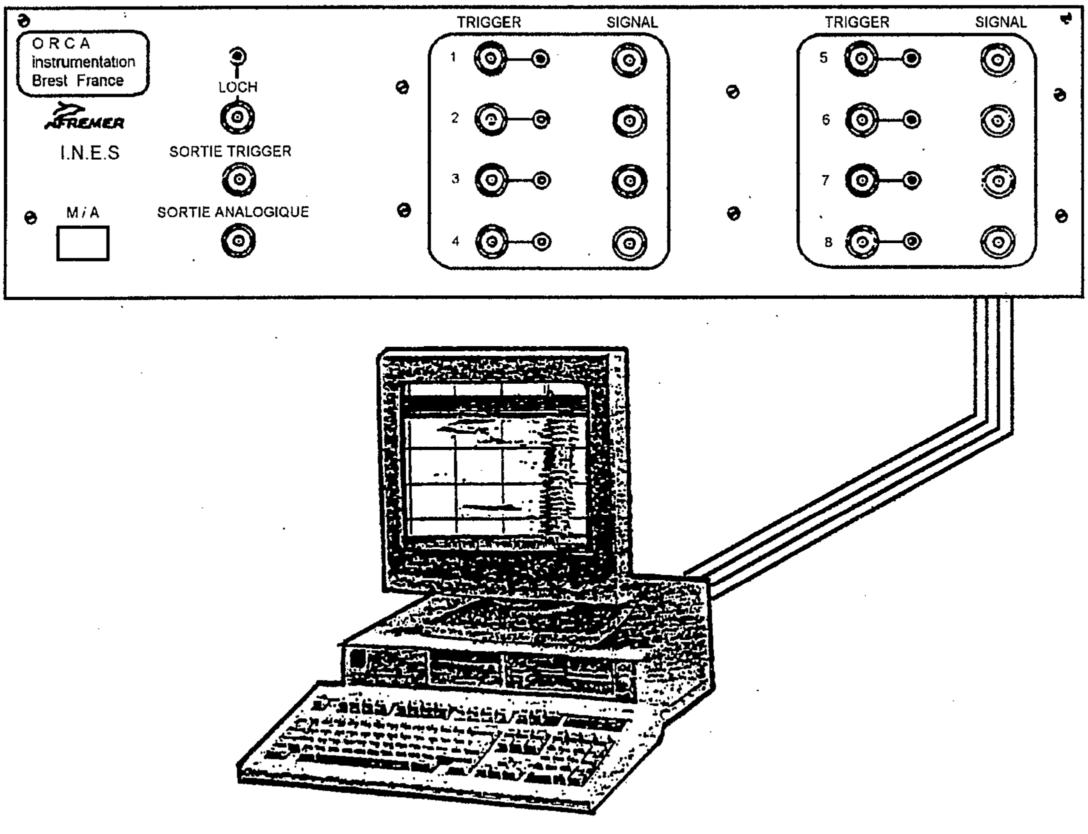


Figure 47 The interface INES and MOVIES (software) display.

A block diagram showing the main functions of the echo-integrator appears in Figure 48 (a) and the associated waveforms in Figure 48 (b). Let us follow the signal through the unit:

Block 1 - The receiver output delivers echo signals already corrected (gain, threshold, TVG, low frequency and dynamics...)

Block 2 - The demodulator

We have already seen formerly what this function is. Although the echo-sounder has already a detected output as we saw before, our interface INES needs the sinewave signal output from the 10 kHz output of the transceiver; the alternative signal of the echo-sounder is detected, that means, this part of the circuit removes the sinewave and just keeps the envelope.

Block 3 - The amplifier

In regard to density of fish and depth, we have to be able to adjust the amplitude of the signals by a precisely known amount.

Block 4 - The threshold

This setting eliminates the small echoes of noise, by varying the zero reference of the DC waveform. We will see later in detail the function of the threshold which must be used with great care.

Block 5 - Depth and interval selection

Although the echo-intgrator accepts signals from the whole water column it is necessary to have means of excluding the transmission and the bottom echo from being integrated and this is the function of block 5 of Figure 48. It is desirable to be able to select specific depth layers within the water column and to vary the extend of the layers and the depth at which they start.

Even though the depth intervals have been selected, the signals are still not ready for integrating.

Block 6 - Analog -to -Digital converter

The signal, until now, is still analogic. It is then changed by means of an analog-to-digital converter, into bits (binary digits) before output to the computer (see block 6 of Figure 48).

Block 7 - Voltage squarer

Within the computer, the software MOVIES takes in charges these bits for processing. Seen as block 7 in Figure 48, the data bits go through a first step which is the "voltage squaring" of the values. Even if these voltages have been transformed into computer words, they still remain voltages, just coded in software language. This achievement is one of the most critical functions in the integration system. It is necessary because the signal voltages V are still proportional to acoustic pressure p.

Density of fish is proportional to acoustic intensity which is proportional to p^2 (see Chapter 3.2 - "the sound intensity").

Using the relationships and the analogies discussed in this Chapter 3.2, we can recall here:

$$V \text{ is analogous to } p \text{ and } p \propto W \quad \text{thus } V^2 \propto W$$

$$W \text{ is analogous to } I \qquad \text{so } V^2 \propto I$$

We can say that by squaring the "voltages" (or the bits representing them), they become proportional to intensity.

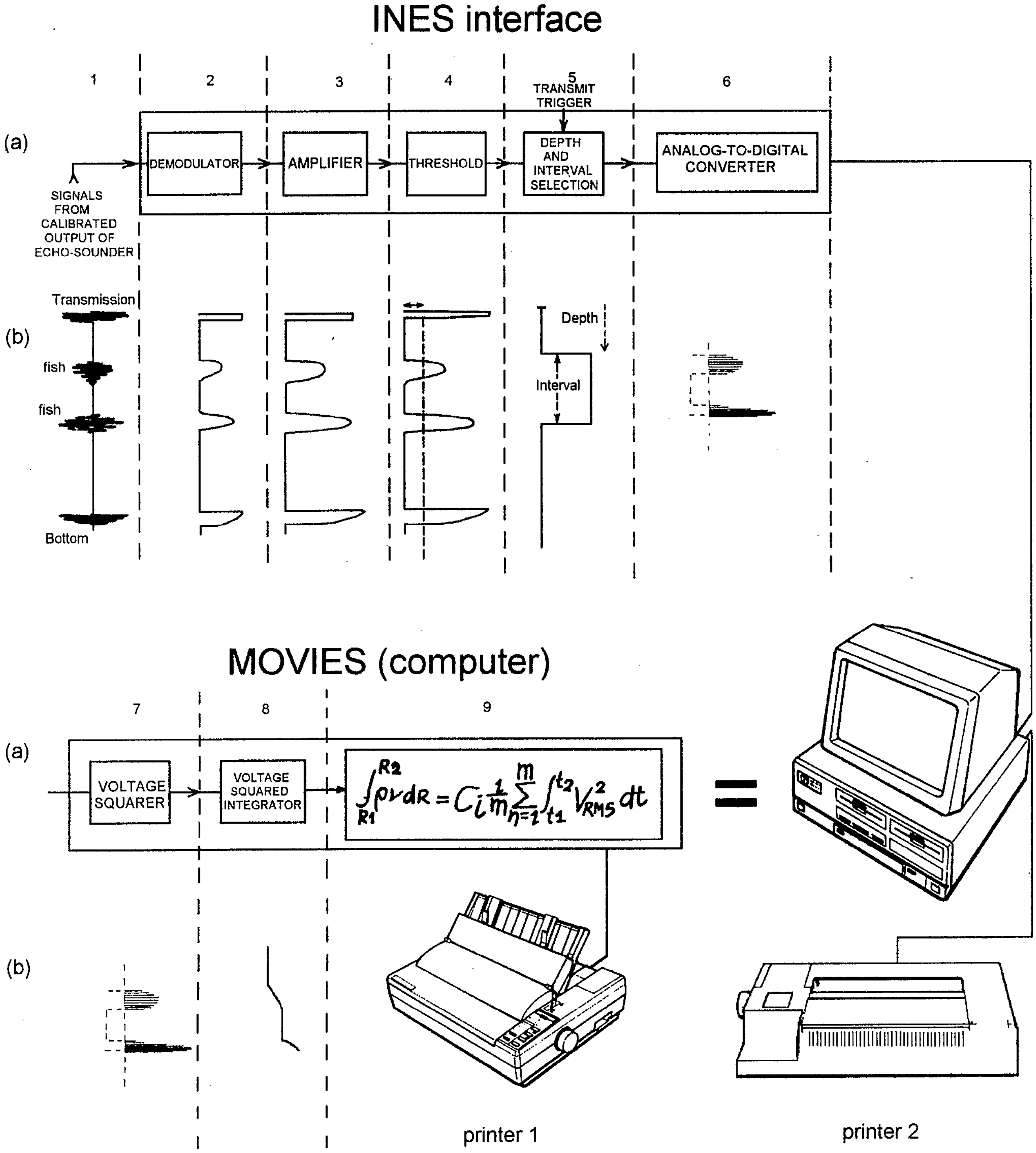


Figure 48 **The echo-integrator system.**
(a) main functions
(b) the associated waveforms

Block 8 - Voltage squared integrator

When the echo signal voltages, coded in bits, have been squared, they are input into Block 8 of Figure 48. It is there that the energy, represented by the area under the squared voltage curve, is input into its final form which is a DC voltage whose amplitude at any given time is proportional to the acoustic intensity of the signal. We can see in the waveform of Block 8, the integrator voltage increasing as the first echo rises to its maximum then falls again. When this echo finishes, the DC is maintained at the level it has reached until the next signal occurs; the level then rises again when the second signal occurs. This DC deflection is displayed on the screen of the computer and is printed on the paper of a colour printer used as a paper recorder (printer 2).

The result is then postprocessed via mathematical formula, in Block 9, including all the acoustic and electronic characteristics of the echo-sounder, the electronic characteristics of the interface INES, the acoustic mean value of the targets (the fish) measured by means of the Target Strength processor installed in a second computer, and then output to a printer (printer 1). This printer prints the estimated weight of the fish stock, after each distance unit pre-selected, usually after one mile, per layer and for the whole water volume insonified during the distance unit.

We can precise that the screen of the computer is used as a chart recorder displaying in real time (or in playback) the echo signals (Fig.49) and the DC curve of integration while the colour printer (printer 2) prints the same display (Fig.50).

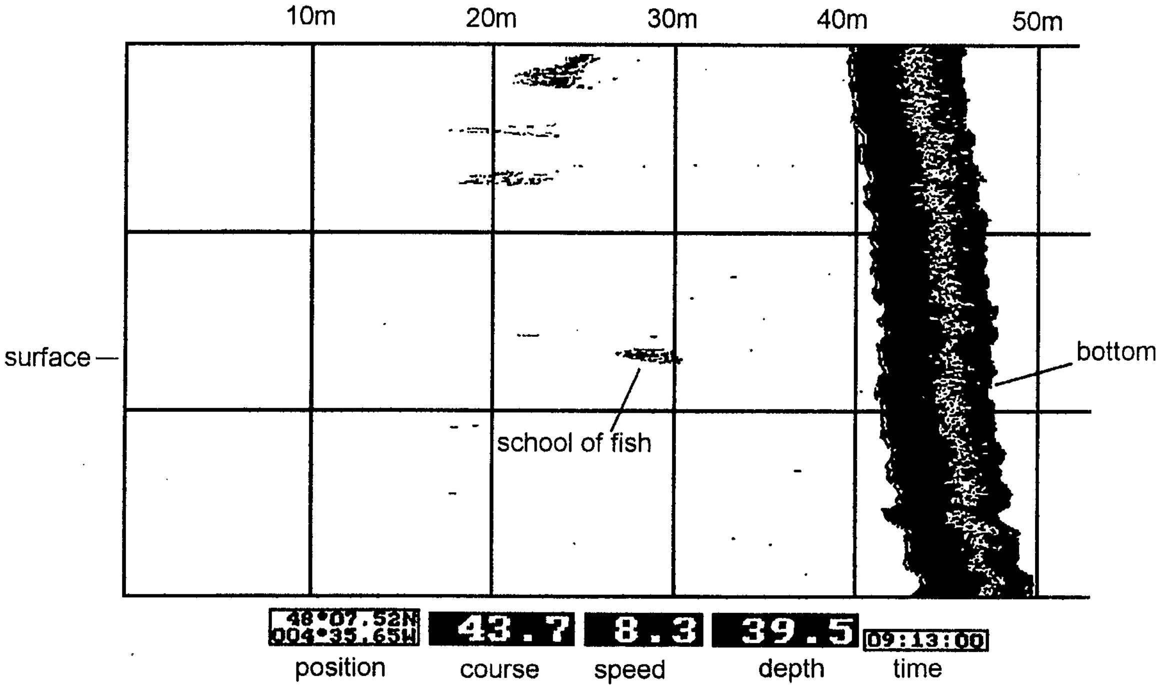


Figure 49 The screen display.

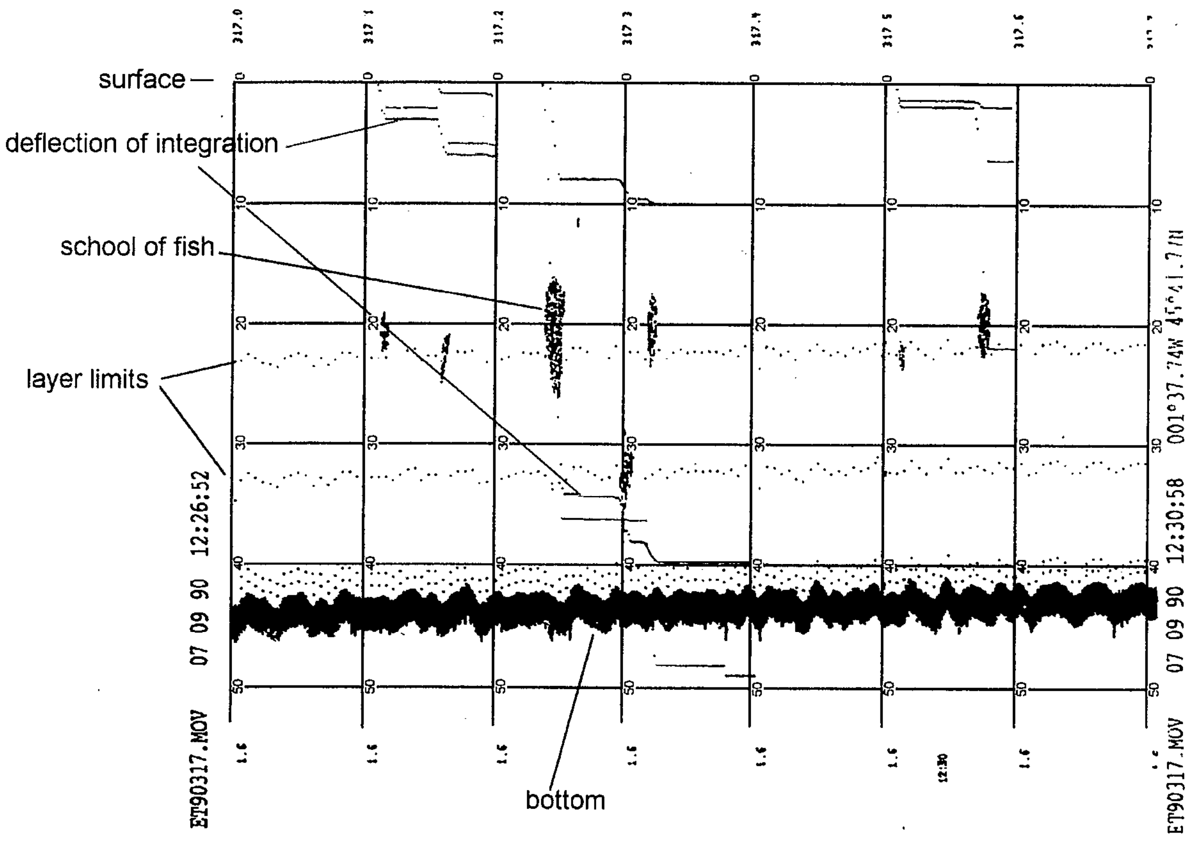


Figure 50 Echogram printing.

4.7.5 The Echo Signal Processing System (BioSonics)

The basic Echo Signal Processor (ESP) product consists of a signal processing board housed in a personal computer. To perform a particular signal processing function with the ESP, the user simply runs the appropriate BioSonics program. These functions include :

- the Model 221 Echo-integrator for estimating fish densities.
- the Model 281 Dual-Beam Processor for estimating fish target strengths.

These two functions cannot be run in the same time. In order to keep the integration running all the time, we have decided to use the system INES-MOVIES for the Echo-integration with one computer, and to use the BioSonics Dual-Beam Processor for estimating target strength assorted with a second computer.

Consequently, the ESP system was completely reserved for the Target Strength evaluation. Target Strength which is the acoustic response of a fish, is used in the final echo-integration equation to obtain the total quantity of fish in an area.

Coming from the echo-sounder the detected signal, via a flat cable called "Biobus", is sent to a small box called "ESP conditioning Pod" (Fig.51). Within this box, the signal is digitized before being sent to the interface ESP installed in a second computer; this interface contains a built-in processor.

The ESP Dual-Beam Processor is a programmable signal processor that identifies and measures single and multiple target echoes in the output of a dual-beam hydroacoustic system. Dual-beam techniques are used to estimate fish target strengths, which are related to fish size. Signal inputs are the narrow and wide beam detected output from a dual beam echo-sounder. Data are processed and displayed in real time, while digital measurements from each echo are saved to disk so that the experiment can be reconstructed or re-run using different processing parameters. We will see in detail all about the Dual-Beam technique during the course on Target Strength.

4.7.6 The Tape Recorder Interface

Signals can be recorded on a high quality digital recorder, we have already met this apparatus. They can be played back in the laboratory on-shore. The recording system consists of a model 171 recorder Interface and the DAT seen before. This interface allows the user to adjust the levels of the records, and of course by means of built-in amplifiers, to restore the signal at its right level. Many functions are carried out in this clever interface, such as the bottom detection and the multiplexing of signals recorded (Fig.52).

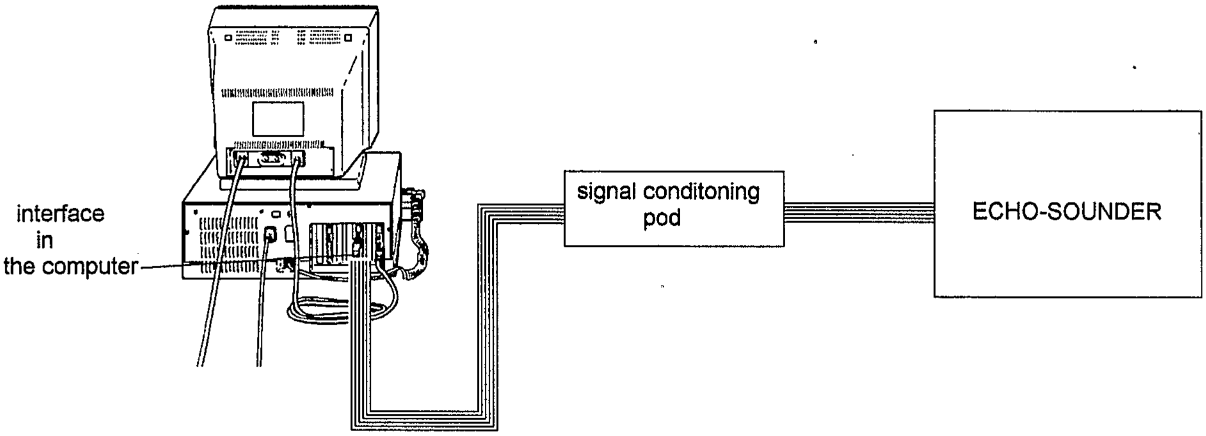


Figure 51 The Echo Signal Processing and the Dual-Beam BioSonics system.

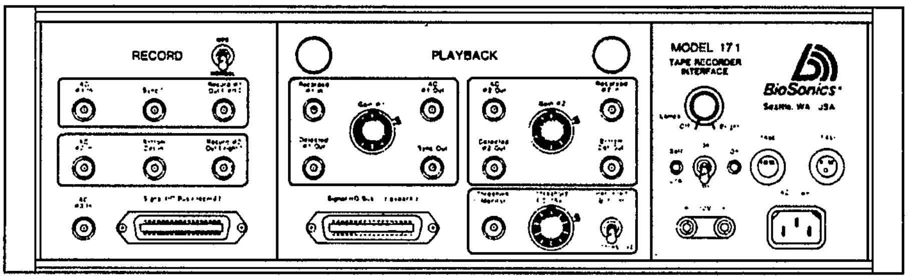


Figure 52 The tape recorder interface.

We just have finished the presentation of the whole equipment; will be found following, the final diagram of the equipment as used during the survey of echo-integration and Target Strength measurements (Fig.53).

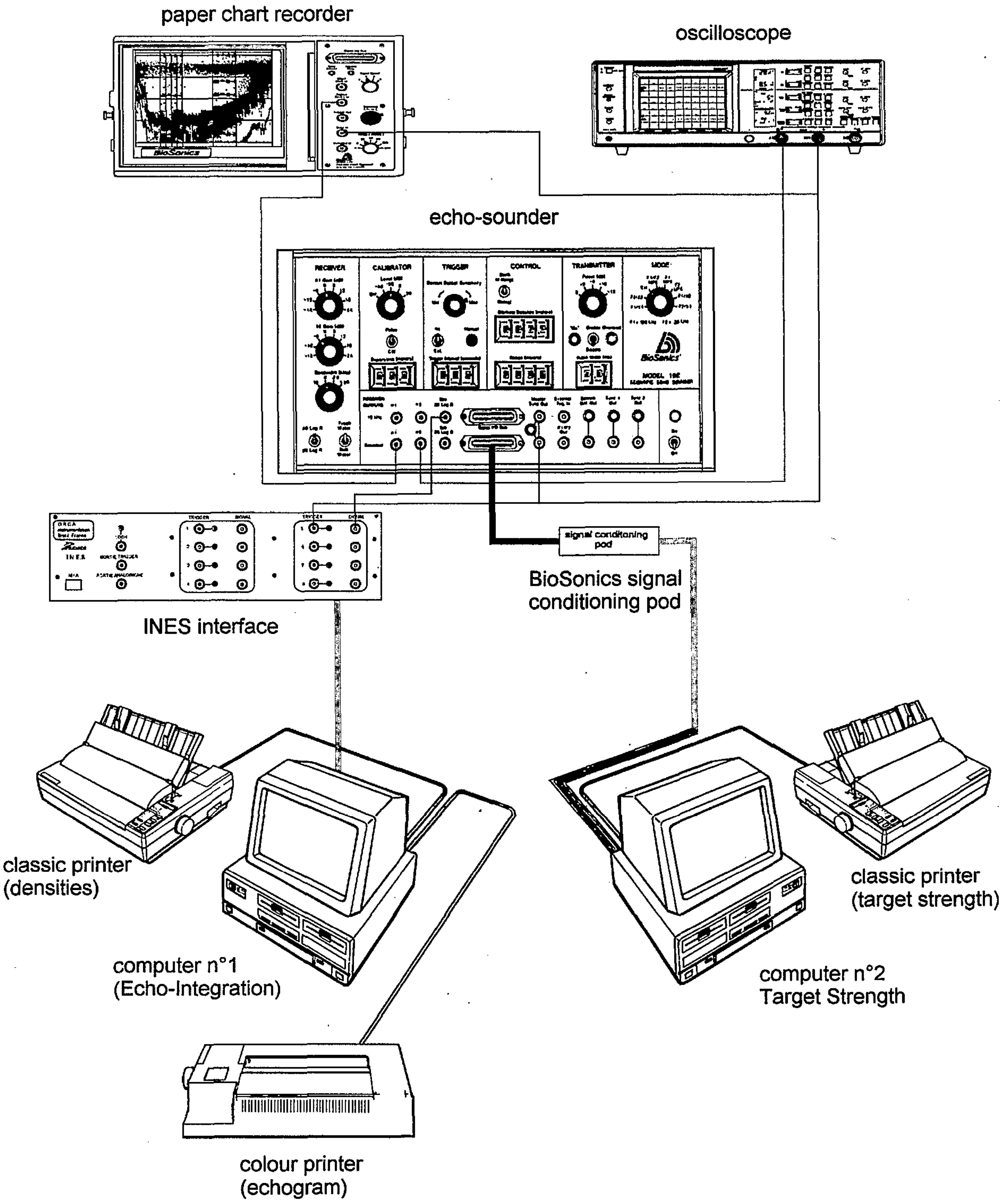


Figure 53 The data acquisition system.

TARGET STRENGTH

INTRODUCTION

When an acoustic wave strikes a fish, a proportion of energy is reflected (the echo). For acoustic surveys we need to determine the amount of the so-called "Target Strength", because this value is one of the terms of the final equation to calculate the total weight of fish in a prospected area. We can briefly demonstrate its need, showing the final relationship.

The final relationship is:

$$Wb = 10^{0.1(10\log M - 10\log G - 10\log Cin - \mathbf{TS}^{*})} \int (A\ dA)$$

where Wb is the weight of the biomass, and TS is the Target Strength value* of the fish. The other factors are parts of Echo-Integration.

We are going to examine specific aspects of fish characteristics which affect the echoes so that the various factors can be assessed. These relate to the fish size, morphology, physiology , orientation and location in the acoustic beam. The frequency of the sound pulse has also an effect on TS because related to fish size. Various methods of making TS measurements will be described and values of some species will be given.

ACOUSTIC PROPERTIES OF FISH AND DEFINITION

Target Strength (TS) is defined as 10 times the logarithm of the reflected Intensity (I_r) at one meter from the fish, divided by the Intensity which strikes the fish (I_i). Thus:

$$TS = 10 \log I_r / I_i$$

The term Target Strength originates from the Navy; the simplest object to consider as an acoustic target is the sphere because it radiates its echo equally in all directions. We have already studied it in chapter 3.3.3-"reflection by a single target". We have seen in this chapter that the amount of sound energy reflected depends on the acoustic cross-section σ of the sphere. This can be written as:

$$TS = 10 \log \sigma / 4 \Pi$$

where we can see in this relationship, a constant term which is : 4Π

We can rewrite this relationship and simplify it by pausing as a definition:

$$\sigma_{bs} = \sigma / 4 \Pi$$

σ_{bs} is called : **Back Scattering Cross-section.**

Thus, the former equation can be expressed as:

$$\boxed{\mathbf{TS = 10 \log \sigma_{bs}}}$$

---

* In fact, this is the Mean Back Scattering Cross-section σ_{av}. This misnomer is intentional to simplify the understanding and will be explained further.

The Back Scattering Cross-section σ_{bs} of a fish is a measure of the effectiveness of a target as an acoustic reflector. When discussing fish densities estimated from integrated echo intensities, it is more useful to refer to Back Scattering Cross-section, since the linearity is related to the integrator value.

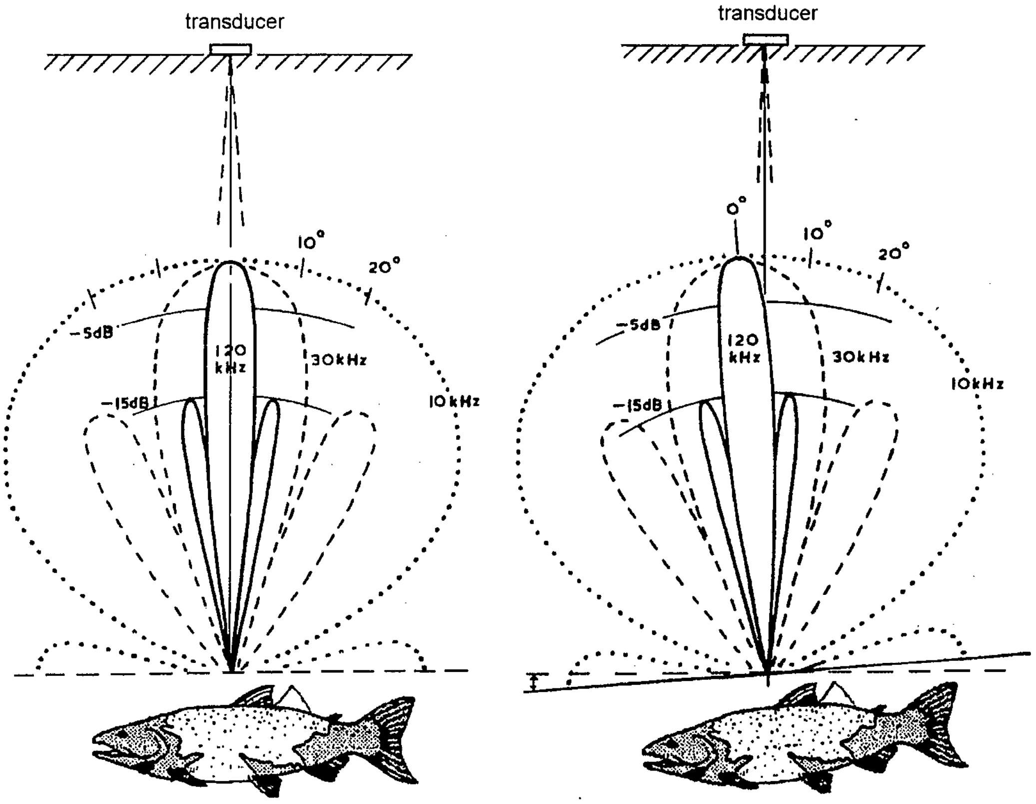
What about fish ? Fish are neither spherical, nor rigid, so they do not radiate uniformly. Fish are composed mainly of flesh and bones and their acoustic impedance are very close to that of the water, so the amount of reflected energy from these substances, is small. The most important part of the acoustic energy reflected comes from their swimbladder. Swimbladders are gas filled organs which are used by fish to adjust their buoyancy when migrating up or down in the water column. They can tolerate sudden pressure increases of up to 400 %, but decreases of only 50 %, thus they can dive more easily than ascend. The state of the swimbladder at any given time depends on the extend of the last significant vertical movement and the rate at which it took place. This indicates that the swimbladder may cause changes of TS with time. The species which don't have swimbladders, like tunas, reflect less energy.

THE FISH PARAMETERS

5.1 The orientation of the fish - The tilt angle

When working with common echo sounder frequencies, the orientation of the fish relative to the horizontal plane (the tilt angle) is the greatest potential source of variations in Target Strength.

Figure 54 (a) and (b) shows a typical Directivity pattern of a fish, at 120 kHz, in dark, at 30 kHz, in dot at 10 kHz in point marks.



(a) (b)

Figure 54 Response of a fish at different frequencies.
(a) when horizontal (max)
(b) when tilting (attenuation)

As you can see, the acoustic response of a fish follows a Directivity function identical to a transducer. The Intensity of sound reflected by a fish, depends on the striking angle of the sound wave related to the horizontal. This Directivity generally depends on the fish anatomy, its length and its swimbladder dimensions related to the frequency of the sound wave. In practice, the maximum response of a fish is not always perpendicular to the long axis of this fish, but very close. This maximum value is obtained when the sound wave strikes the fish on its back or below it.

You also can see, on the figure 54 (b), that few degrees of tilt are very significant when the frequency is 120 kHz. At 30 kHz, and 10 kHz, the lobe is wider, the response curve either, thus, for the same given tilt angle, the rate of change will be lesser as the fish tilts up or down from its normal swimming state.

5.2 Fish size, frequency and the Target Strength

Target Strength is complex and far from being understood. This lack of knowledge, particularly on tropical species, could be a perfect subject for your future research.

There is a relationship between size of fish and TS but it varies widely with species. Certain species appear to have similar TS / length characteristics within limits, but we must be careful to use this relationship. Many works have been performed on several species, covering wide range of frequencies. These measurements have been carried out on northern species but never on tropical fish. Besides, regression line equations, mixing the two parameters-length and frequency- from different authors, always differ and sometimes are in opposite with the others.

We can retain for our own purpose, the formula of Love which is as follows:

$$\boxed{\mathbf{TS = 19.1 \log L - 0.9 \log (f) - 62.03}}$$

where L is the length of the fish (in meter)
f is the frequency of the sound wave (in kHz)
TS in dB

Compared to fish orientation, fish size has less impact on the Back Scattering Cross-section. Generally, it is proportional to the square of the fish length, thus we can write:

$$\sigma \sim \mathbf{L}^2$$

Most of the species caught by fisheries have a weight proportional to the third power of length, that is to say :

$$\mathbf{W} \sim \mathbf{L}^3$$

So, finally, the Back Scattering Cross-section of a fish is proportional to the two-third power of weight, that is to say:

$$\sigma \sim \mathbf{W}^{2/3}$$

Meanwhile, this relationship can vary from one species to another, until the following relationship:

$$\sigma \sim \mathbf{W}$$

We can conclude that:

the TS of a fish increases with its length.
the TS of a fish decreases with the frequency.
the TS of a fish is is proportional to its weight

Obviously, it remains difficult to compare TS of same species measured at different frequencies. Moreover, reported Target Strength measurements show between- species, variation of the same order as many of the within-species variations at a fixed frequency.

There are also, strong doubts that fish is able to keep constant swimbladder volume. Particularly fish making extended vertical migrations are likely to have decreasing swimbladder volume with depth. In addition, fat content, stomach content and gonad size are observed to influence the volume and the shape of the swimbladder.

In order to assess all these various factors, it would be necessary to have frequent measurements of Back Scattering Cross-section *in situ*, during the surveys, at day and night or on live fish in a cage. We will see how to achieve these measurements, later.

5.3 Fish school Target Strength

Acoustic surveys of fish are mostly based on the assumption that total echo Intensity from schools is equal to the arithmetic sum of echo contributions from individual fish, which is justified if the echoes are not correlated. They must be enough far from each other, at a distance more than **ct/2** and not at the same depth to avoid in both case overlapping : "c" is the celerity of the sound in the sea water in meters/second, "t" is the transmitted pulse in seconds.

Question :

What is the minimum distance required between two echoes to be discriminated when the celerity is 1500m/s for a transmitted pulse of 0.4 ms ?

Answer :

The discrimination will occur if the echoes are separated from each other at a distance more than : (1500 x 0.4 10^{-3}) / 2 = 0.30 m or 30 cm.

In a uniform population therefore, doubling the number of fish should double the echo power. In fact, it is more complex than this hypothesis: multiple scattering occur when the incident Intensity intercepted by one target is re-radiated in all directions and a portion is in turn intercepted by a second target, also re-radiated in all directions, some towards the transducer. And so on for a third target: another effect in fish schools is the acoustic shadowing of fish low down in a school by those above them.

Figures 55 (a), (b), and (c) show the effect of close positions. In (a), the two targets are separated from each other, at a distance higher than "ct/2". As the sound pulse has a length of "ct", its front will reach the bottom of the layer "t/2" time units, after reached the top. The reflected wave of this part of the pulse, going back to the transducer will reach the top of the layer "t/2" later, exactly at the time when the rear front is also reflected by the top of the layer. At this moment the sound wave leaves the top of the layer and goes back to the transducer, bringing with it, the reflections of all targets met in the volume of water of width "ct/2". That means that, at any time, the Intensity of the echo arriving to the transducer, represents all the targets contained in a layer whose width is "ct/2".

In our example, Figure 55 (a) the targets are discriminated and are not correlated. They are acceptable echoes which can be analyzed.

In figure 55 (b), the targets are at the same depth, and stand together within the discrimination layer. The composite echo resulting of the interactions of these two targets, is obviously biased and in any case, cannot be considered as a good value. The echo-sounder is blind and receives this combination of multiple targets because both of them, coming back to the transducer in the same time will be mixed: it will be impossible to say how they mix each other; in phase or in opposite phase or in an intermediate way ?

In Figure 55 (c), the targets are in one hand too close; so we have an overlapping like just before, but also , in the other hand, they suffer of interactions; the fish on the left, reflects a part of the energy towards the fish in the center; the result is a composite echo, as unacceptable as the former case. We can see also, what happens to the lowest fish; it is masked and hidden by its neighbour just above it; the energy which strikes it, has been in part absorbed and reflected by this fish above; the resultant Intensity is therefore decreased and the return echo is weaker than it would be if not screened.

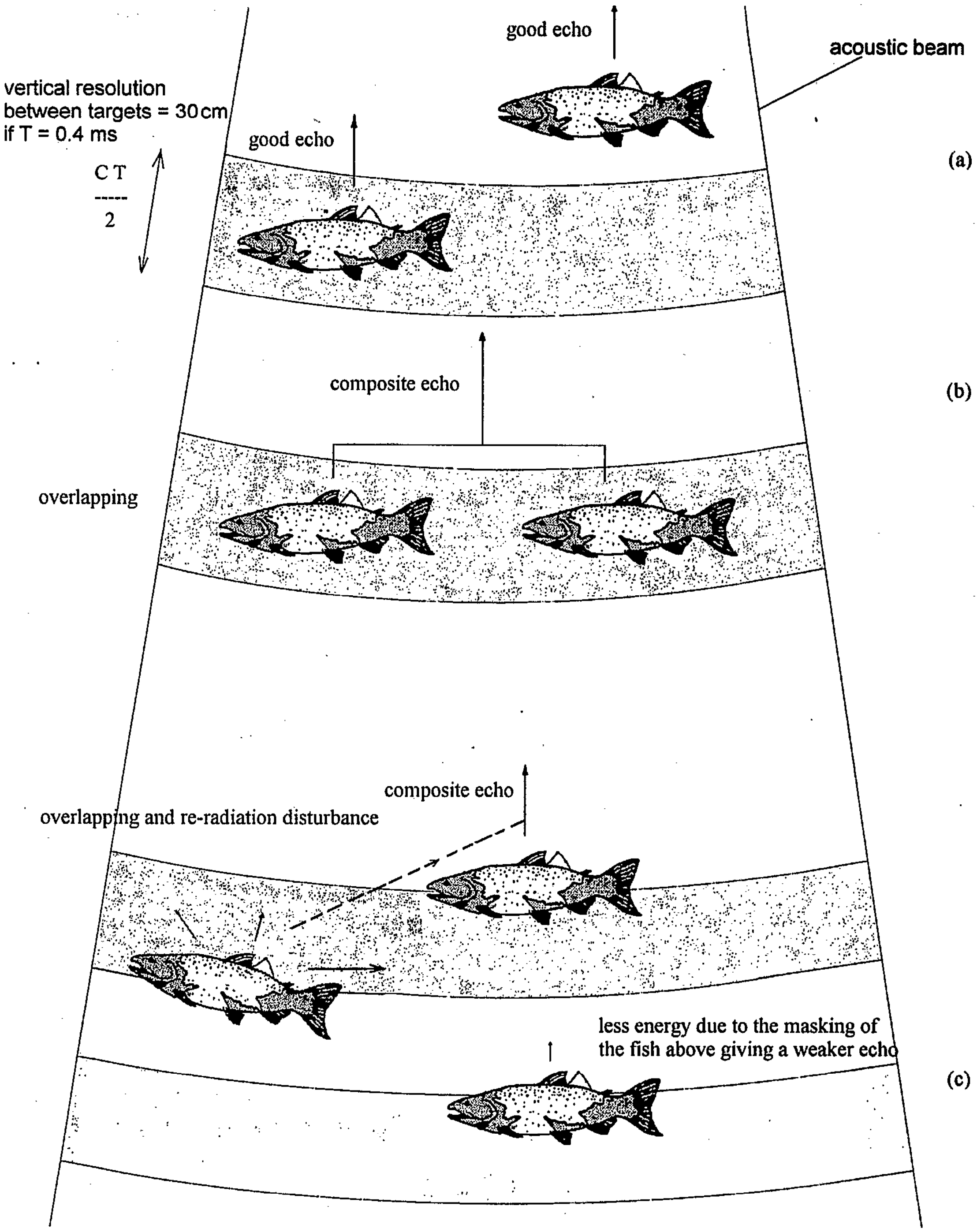


Figure 55 School of fish with different biases in TS measurements.
(a) good echoes
(b) overlapping
(c) attenuation by masking

5.4 Position of the fish in the acoustic beam

This is a flashback to what we already learnt some time ago. You are invited to look back at the Chapter 4.2.1 - "The transducer", where it is explained that the Intensity within an acoustic beam was not uniform, because:

1°)- the Intensity decreases with the depth : **absorption loss and spreading loss**
2°)- the Intensity decreases with **the Directivity** which is the distribution of the Intensity within the acoustic beam.

The Intensity is maximum on the acoustic axis and the more a target is away from this axis to the outer limits, the weaker Intensity is. This phenomena is called the "Directivity effect."

We must recall what we have seen before. Let us look back at Figure 26 of the Chapter 4.2.1 - "The transducer". Suppose that the 2 small fishes are of the same size, with the same acoustic properties; one is right upon the axis, the second one is far away; they are at the same depth; the returning echoes from these two targets are not the same. First, the energies striking the fishes, are not the same. Second, the reflected intensities also have their own directions; the first fish reflects the Intensity normally to the transducer, the second one forms an angle with the transducer direction.

That's why we concluded some time ago this chapter by saying :

"The functions of Directivity of a transducer are the same for the transmission and the reception." For one way we can write:

$$b = b (\phi, \theta)$$

where b is the beam pattern factor
(ϕ, θ) are the polar ordinates of the target : ϕ, in the vertical plan, is the angle between the axis and the target direction; θ, in the horizontal plan, is the angle between a theoretical front reference and the projection of the target direction.

For the two ways (transmit and receive) the function will be :

$$b^2 = b^2 (\phi, \theta)$$

5.5 Summary of the constraints

5.5.1 The fish size, morphology, physiology

These three characteristics are **natural** parameters related to the species. Many experiments have already been carried out in order to correlate each species and length. Today, fishery laboratories work on electronic devices for the identification of the fish by signal analyzing called "acoustic signature" and the use of multifrequency sounders. It is not yet performant, that is why measurements must be conducted to complete our knowledge, specially in tropical area .where multiple species live mixed together.

5.5.2 The orientation of the fish

The best way to evaluate the orientation of a fish within an acoustic beam is to study the records of the echoes on the echograms. To better understand what a picture on the echogram represents, let us see now what happens when a fish crosses the acoustic beam and what kind of traces are recorded.

On Figure 56, you can see fish entering into the acoustic beam in different ways. On the right side, the fish C crosses the left limit of the acoustic beam; this crosspoint, referred on the Drawing as n°1 is at a distance R1 from the transducer. Still going through, the fish at the point n°2 is right upon the vertical axis of the acoustic beam. This point is at a distance of R2 from the transducer. Geometrically speaking, R2 is shorter than R1 in the triangle made with the cross point n°1, the point n°2 and the transducer. Then, the fish goes out of the beam, crossing the right limit at point n°3 which is at a distance R3 from the transducer.

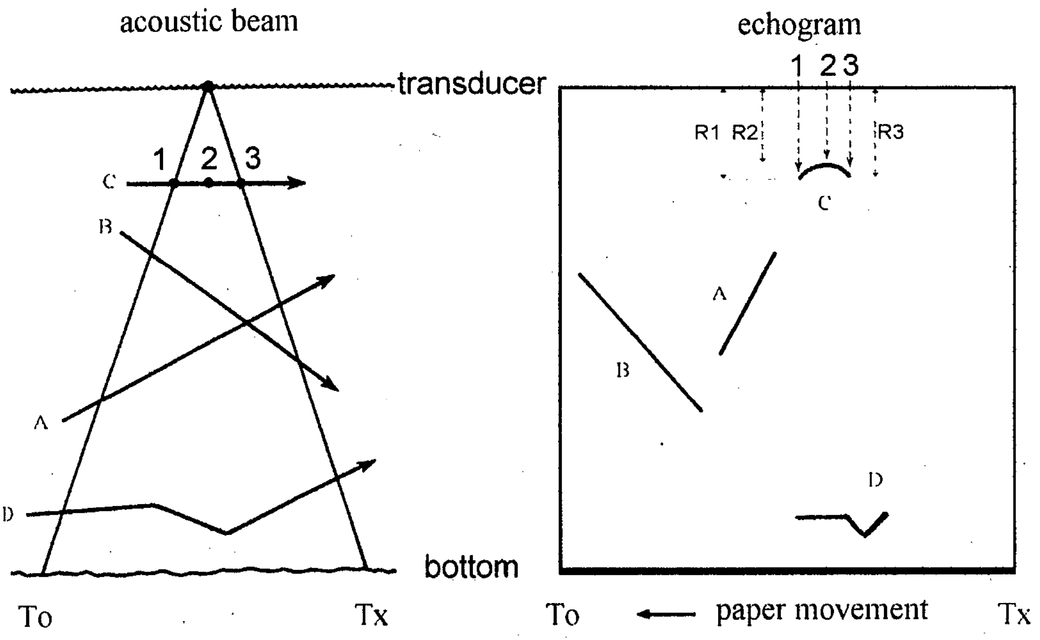


Figure 56 Fish crossing and recorded traces types.

Due to the difference of the distances R1, R2 and R3, the traces show different depth giving, in this case, a convex curve. You can extrapolate yourself to the other fish in the same way.

It is easy to get information on the orientation of the fish when the ship is stopped. Let us see Figure 57. We are in a fixed- location situation, the ship anchored. The transducer does not move and collects echo data on fish as they pass through the ensonified volume of water.

Figure 57 shows the result of the fish tracking, it is the term used for this kind of study. As the fish passes through the acoustic beam, data are collected, ping after ping; let us draw all the vectors related to the echoes recorded on the echogram. We can find out the orientation and thus the tilt angle deducted from the course the fish has followed.

Because of the paper speed, we cannot evaluate straight from the picture, the tilt angle; we must go through trigonometry relationship to determine this angle. The echogram gives us the two extreme depths R1 and R2, corresponding to the entrance and the exit of the fish within the acoustic beam. We can calculate the lengths L1 and L2 by trigonometry such as:

$$L1 = tg\, \varepsilon \times R1$$
$$L2 = tg\, \varepsilon \times R2$$

the actual tilt angle will be such as:

$$tg \text{ tilt angle } (\chi) = R1 - R2 / L1 + L2$$

thus :

$$tg\, \chi = R1 - R2 / tg\, \varepsilon\, (R1 + R2)$$

ε is the half angle of the beam width (for one of our transducers : $\varepsilon = 7°/2 = 3.5°$)

On survey, continuing transects do not allow us to stop and thus, on running, the evaluation of the tilt angle becomes hazardous and complex because of the ship's motion.

Indeed, in mobile surveys, TS tracking cannot provide the direction of the fish movement and therefore the tilting must be evaluated with great care, because of the ordinate system motion, here the transducer's (the ship is moving, the fish is moving).

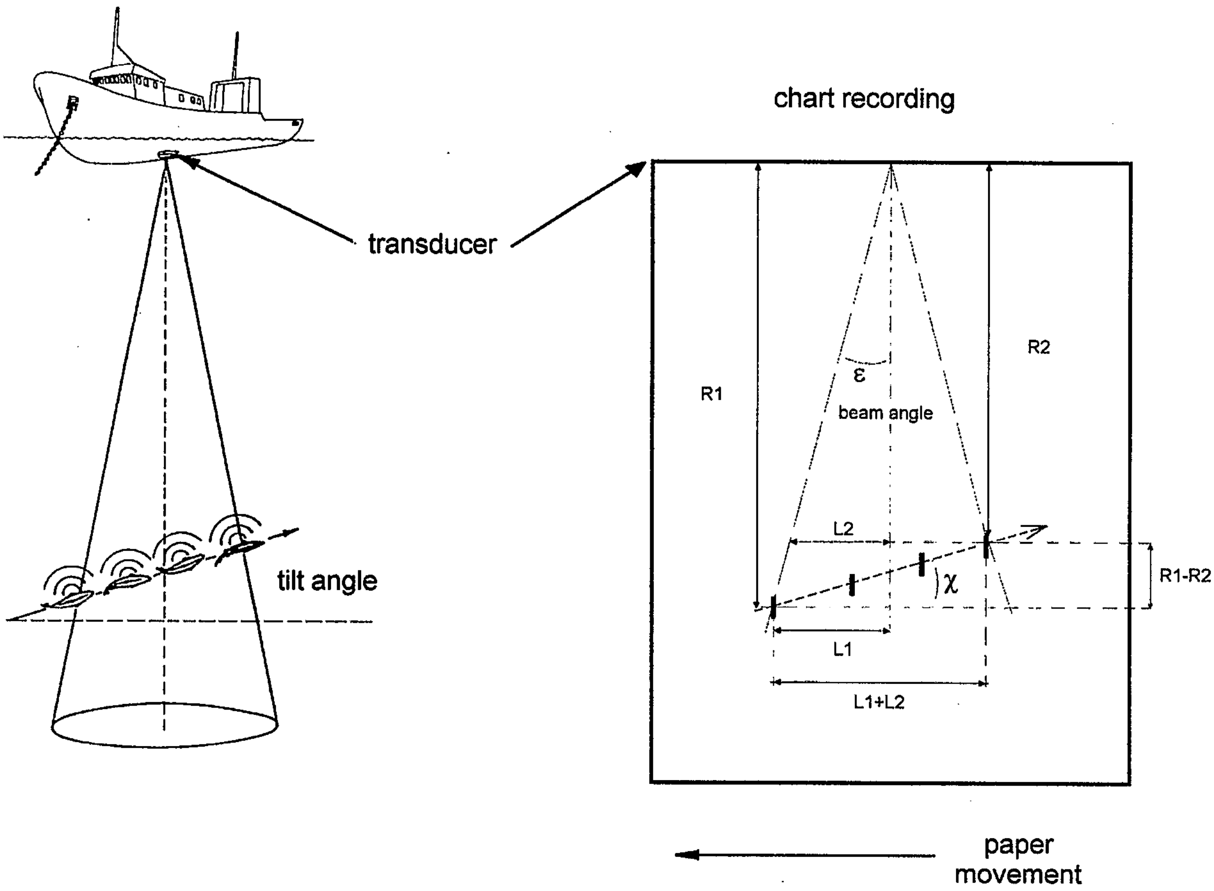


Figure 57 Fish tracking.

Nevertheless, based on the fact that the fish and the ship do not move so fast between 2 or 3 consecutive pings (transmission-reception), we may use (with great care) a special BioSonics software called ESP-ECHO. This software displays echograms of recorded echoes; it allows us to zoom each of the targets for deeper analyzes such as:

- the TS
- the depth
- the electric levels
- all the data related to each echo.

With great precautions it may provide the tilt angle. For that, we must consider the speed of the ship as the main parameter in order to evaluate the distance run between 2 pings and then calculate the tilting angle delimited by the vectors "speed and depth."

In fact this software has been created to be used for fixed-location tracking to study the fish migration in rivers. For example : their behaviour in front of dams or else.

5.5.3 Fish in schools

The attenuation of energy within a school of fish is still on study and by means of experiments such as assessment and catches for comparison, it would be possible to improve our knowledge on these physical phenomenon. Software already exist to study schools of fish : their size, their identification, their energy, like Movies B, an IFREMER product, but still needs valuable data to calibrate the system. This is of a great interest for echo-integration, but TS measurements are also concerned.

5.5.4 Position of the fish in the acoustic beam

The absorption loss and the spreading loss problems have already been solved by means of electronic devices within the echo-sounder such as : the TVG function amplifier which corrects the spreading loss by means of **40 log R** function amplifier which corrects also the absorption by the input of the function : **2 α R**.

The Directivity, as mathematical variable, can be also defined and corrected. I remember you that the Directivity is the transducer's receiving response as a function of angle; it is because of the Directivity problem that sounder technology has been improved recently. The two last upgraded advice are:

- the Dual-Beam system
- the Split-Beam system.

Both of them allow us to localize the echoes within the acoustic beam and to correct their values like if they were situated on the acoustic axis which is always the reference of the performances of the sounders.

In this training course, we will study only the Dual-Beam system : its theory, the equipment and its practice.

THE ESP DUAL-BEAM SYSTEM

6.1 Functioning

As you can guess from its name, the Dual-Beam system uses two acoustic beams: a narrow beam and a wide beam, within one single transducer (Fig.58). The acoustic axes of these two beams are aligned.

The echo-sounder operates by transmitting pulses on the narrow beam transducer elements.

The echo-sounder receives echoes on both the narrow beam and wide beam elements, like shown on Figure 58.

Our transducer has a narrow beam of 7° width and a wide beam of 18° width. These 2 listening parts of the transducer, transforming the acoustic energy into electric signal (see Chapter 4.2.1 - "The transducer") give 2 electric signals V_n and V_W . V_n is the denomination for the voltage outcoming from the narrow beam, V_W is the denomination for the voltage outcoming from the wide beam.

These electric signals are then input into two respective receiving channels, called channel 1 and channel 2; these channels are identical (but differences of gain can occur) and both apply 40 log R +2 αR functions to these signals which are sent to the Dual-Beam processor installed within a personnal microcomputer (PC board).

Some pages before, we studied the path of a signal through 1 receiver (see Chapter 4.2.2 - "The receiver - Fig.23"). It is the same principle, but for 2 channels, instead of 1.

Figure 59 shows the diagram of the Dual-Beam system, with a new complement : the appearance of a Satellite Navigator system which provides the ship's position and her speed : any kind of GPS (Global Positioning System) can fit provided that its data ooutput is in NMEA format.

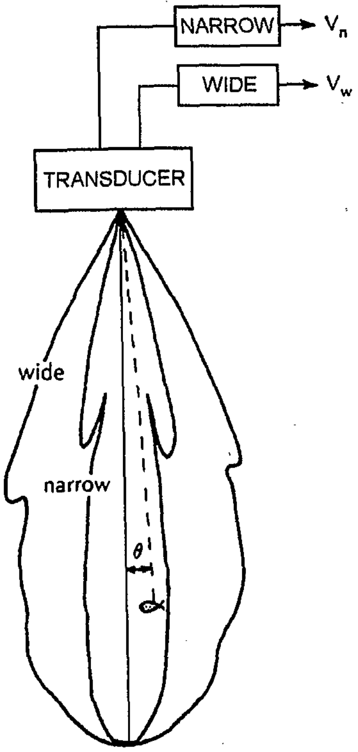


Figure 58 **The Dual Beam system.**

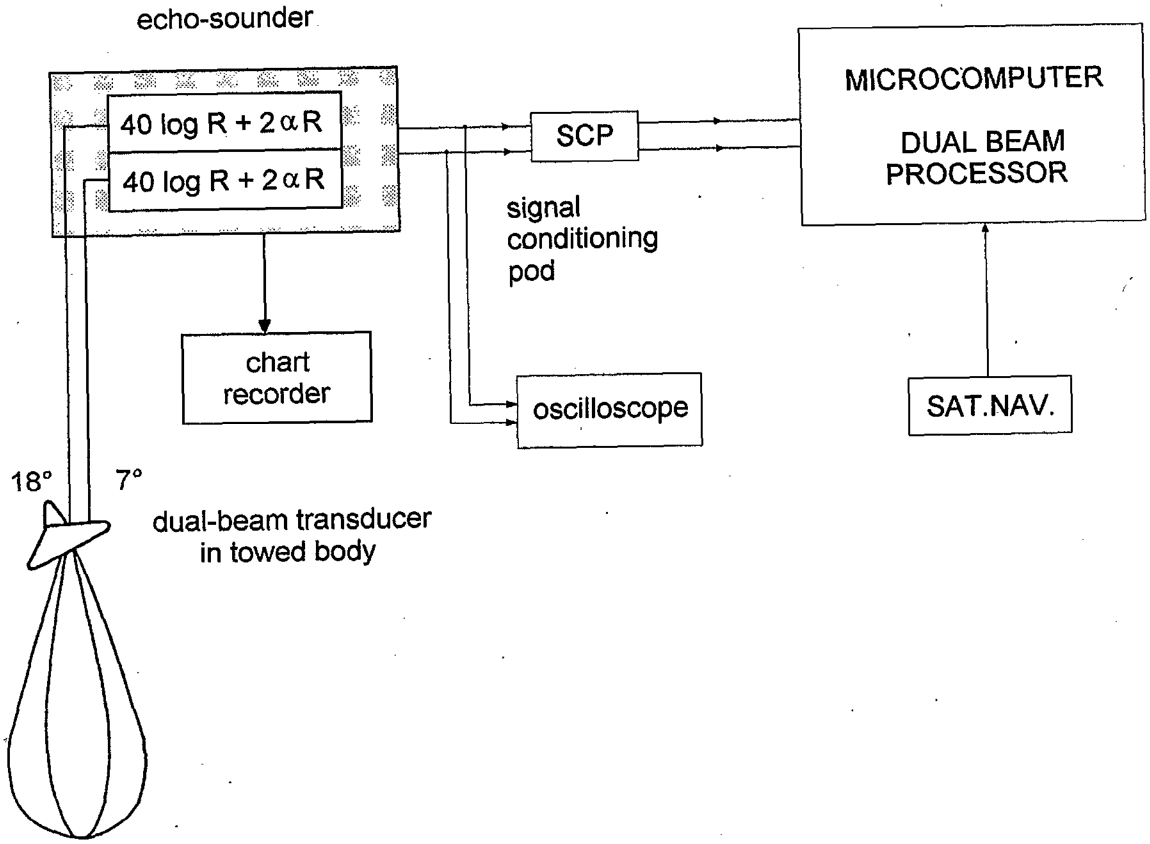


Figure 59 **The BioSonics Dual Beam System.**

6.2 The Dual-Beam method

Since the narrow and wide beams have different characteristics, it is possible to measure the off-axis angle of the returning echoes .

You can see on Figure 60, the Beam Patterns of a typical Dual Beam transducer. The narrow beam is a classical beam with its Directivity pattern called "Beam Pattern" which is the diagram of the function of the transducer's receiving response as a function of angle. The wide beam has almost a circular Directivity pattern. If we zoom the edge of these patterns, we can see that in the zone common for both, the attenuation for the wide beam is equal to zero dB (Fig.61).

For the simplicity of comprehension, assume that **the wide beam has an effective Beam Pattern factor equal to 1, over the main lobe of the narrow beam.** What does that mean ? By engineering device, this particular part of the wide beam is transformed in such a way that the acoustic intensities of a given target are the same wherever it stands in this part which overlaps the narrow beam. That means the attenuation of the echo is equal to 0 dB for the wide beam. On axis or off-axis, the responses would be the same, in this part. This wide beam becomes a reference.

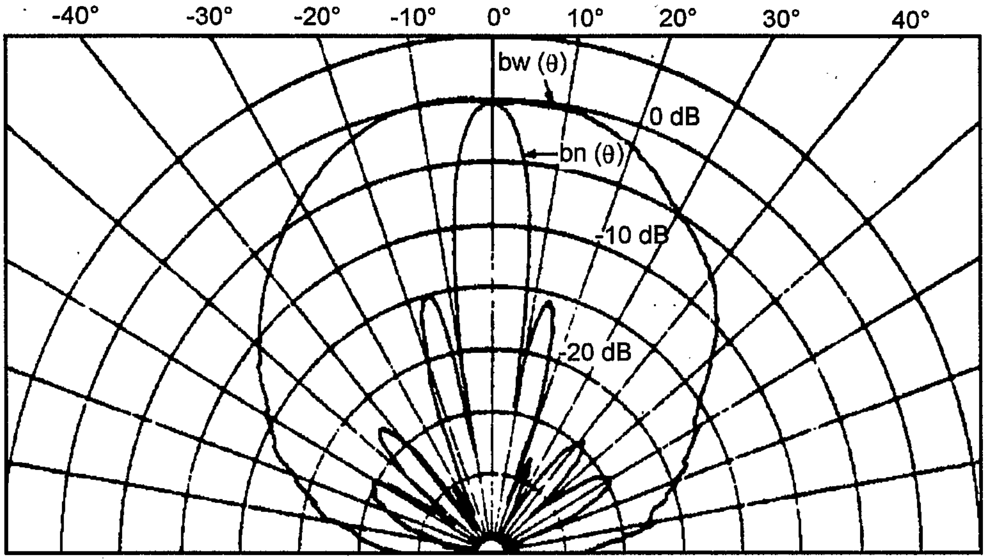


Figure 60 Beam Pattern of a typical Dual Beam transducer.

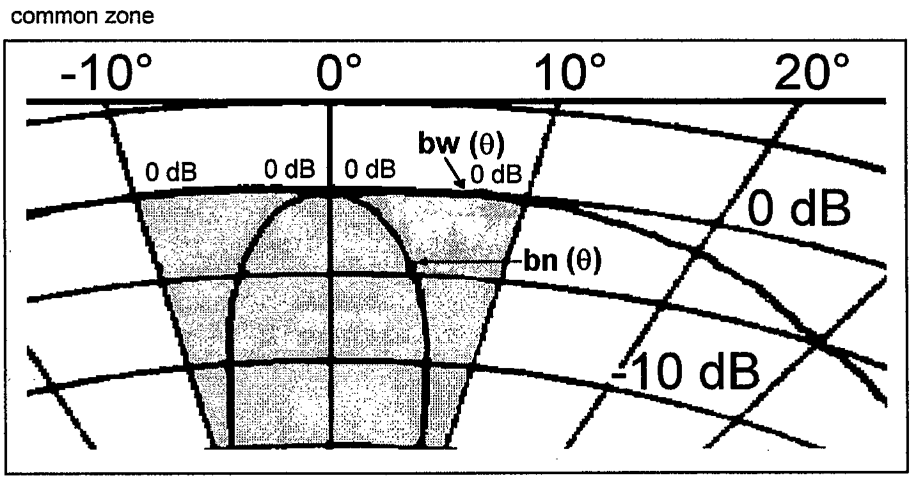


Figure 61 Zoom of the common zone of the 2 beams.

On Figure 62, are shown the output voltages V_n and V_W, respectively from the narrow beam elements and the wide beam elements, voltages due to a fish crossing the acoustic cone of a Dual-Beam system.

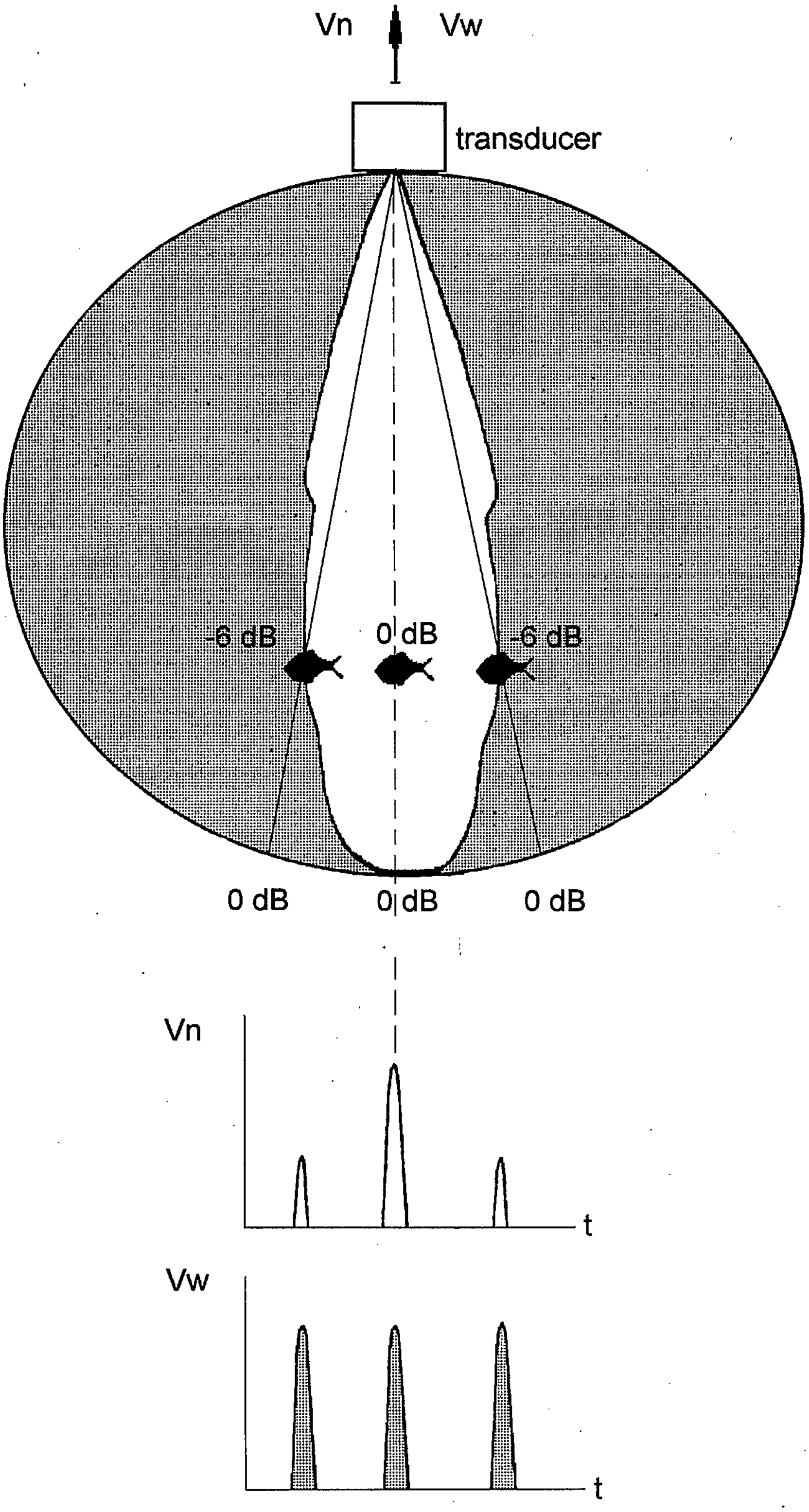


Figure 62 Voltages at the output of the Dual-Beam transducer.

If we draw a line from the center of the transducer to the fish, this line will cross the beam pattern giving us the attenuation of the echo due to its off-axis position (here -6 dB). When the fish is right on the acoustic axis, the response is maximum and thus the Voltage V_n is also maximum (Attenuation : 0 dB). The same lines as before cross also the wide beam pattern. The voltage V_W is constant wherever it happens. The response is not attenuated because the Beam Pattern factor is 0 dB in this part of the wide beam which overlaps the narrow beam.

So, we can write, for the wide beam, the Beam Pattern factor is:

$$\mathbf{b_W (\theta,\phi) = 1}$$

We have concluded the Chapter 4.3 - "The receiver - the 40 log R 2 way equation" with the relationship :

$$\boxed{V_{out}\,(dB) = SL + RS\ channel\ 40 + G + TS + 2B\,(\theta)}$$

We can express each of the voltages (V_n and V_W) going out from both channels, in dB. The voltage V_n , for the narrow beam channel, can be written as :

$$V_n\ out\ (dB) = SL + RS_n\ channel\ 40 + G + TS + 2\ B_n\ (\theta)$$

For the second equation related to the wide beam, we must recall first that the echo-sounder transmits on the narrow beam and receives on the wide beam. That means that the target is hit with a Directivity related to the narrow beam B_n (θ) (one way) and the return echo undergoes the Directivity law of the wide beam B_W (θ) (return).

So we can write this second equation in dB, for the wide beam channel, in this way :

$$V_W\ out\ (dB) = SL + RS_W\ channel\ 40 + G + TS + B_n\ (\theta) + B_W\ (\theta)$$

where B_n (θ) and B_W (θ) are the Beam Pattern factors respectively of the narrow and the wide beam of the transducer. We must recall, once again, that this is the ratio of the transmitted or received Intensity (I) of the acoustic beam at the angular coordinates (θ, ϕ) to the transmitted or received Intensity on the acoustic axis of the transducer; such as : $b\ (\theta, \phi\ ) = I\ (\theta, \phi\ ) / I\ (\ 0,0\ )$

.The concept of the wide beam is such that $\mathbf{B_W (\theta) = 0}$

If we subtract these two former voltage equations, including the last consideration , we can write :

$$V_n\ out\ (dB) - V_W\ out\ (dB) = [SL + RS_n\ channel\ 40 + G + TS + 2\ B_n\ (\theta)] - [SL + RS_W\ channel\ 40 + G + TS + B_n\ (\theta)]$$

After simplification, it becomes :

$$V_n\ out\ (dB) - V_W\ out\ (dB) = RS_n\ channel\ 40 - RS_W\ channel\ 40 + B_n\ (\theta)$$

Thus, we can extract the Beam Pattern factor of the target B_n (θ) such as:

$$B_n\ (\theta) = V_n\ out\ (dB) - V_W\ out\ (dB) - [RS_n\ channel\ 40 - RS_W\ channel\ 40]$$

Here appears the difference of the 2 receiving sensitivities, between the two channels 1 and 2 (due to electronic characteristics of each channel).

In order to facilitate the writing of the next formula, it has been decided that :

- Channel 1 (ch1) is dedicated to the narrow beam and channnel 2 (ch2) to the wide beam.
- B_n (θ) will be expressed such as : B

We can finally write the relationship :

$$B = V\ output\ ch1\ (dB) - V\ output\ ch2\ (dB) + (RSch2_{\ 40} - RSch1_{\ 40})$$

We can remark the input of the gain correction (sensitivity) in the formula ($RSch2_{40}$ - $RSch1_{40}$). This correction is necessary because we compare both channels, and of course both must be ajusted. In this way, we can obtain the value of the beam pattern factor B, because all the terms of the equation are known ($RSch2_{40}$, $RSch1_{40}$) or measured : V output ch1 (dB) and V output ch2 (dB).

Question :

What would the Beam Pattern formula be if the echo-sounder has two receiving channels perfectly identical (the same receiving sensitivities) ? In this case, what would the Beam Pattern be, when the target is right on the acoustic axis ?

Answer :

In this case, the correction of channel gain is null, thus :

$$(RSch2_{40} - RSch1_{40}) = 0$$

And the formula becomes:

B = V output ch1 (dB) - V output ch2 (dB)

If the target is on axis, that means that the two voltages output from the narrow beam and the wide beam are identical, thus :

V output ch1 (dB) = V output ch2 (dB)

and therefore :

B = 0

In fact, the Dual Beam system is not quite designed so that $\mathbf{b_W}$ **(θ,ϕ)** = 1. The wide beam is not ideal and its overlay on the main lobe of the narrow beam is not equal to 1. In order to obtain this value, a correction factor must be used. This correction factor is called : **the Wide Beam Drop-off**. It describes the decrease in the wide beam Directivity over the usable angular range of the narrow beam (the common zone coloured in gray, Fig.61). This parameter is usually supplied by the manufacturer of the transducer.

On Figure 63, the transducer Beam Patterns of the narrow and wide beams are shown; the nominal beamwidths are measured in degrees at the point where the acoustic power is 3 dB less than the on-axis acoustic power. The nominal bandwidth is the approximate width of the acoustic beam as stated by the manufacturer. In practice, variations among transducers of similar design requires that the actual beamwidth be measured for each transducer. You can see, at the -3 dB point which is at the crossing of the two thick lines that the 1/2 angle for the narrow beam is 3.5° and for the wide beam 9°. Therefore, the beamwidths of the narrow and the wide beams are respectively : 7° and 18°.

The Figure 64 shows the effect of the so-called **Wide Beam Drop-off** which corrects the decrease of the curve of the wide beam pattern factor in a way that it becomes a reference with 0 dB of attenuation in the common part of both beams (see the small vectors drawn). This common part is the comparison area to obtain the off-axis angle of the target. In our system, the transducer has a wide beam drop-off equal to: 1.10949 (close to 1). This factor must be input in the latter Directivity formula and thus we can write:

B = Wide Beam Drop-off x [(V output ch1 (dB) - V output ch2 (dB)+ ($RSch2_{40}$ - $RSch1_{40}$)]

In order to match with our former equations, where 2B (θ) is used, we can finally write:

2B = 2 x Wide Beam Drop-off x [(V output ch1 $_{40}$ - V output ch2 $_{40}$ + ($RSch2_{40}$ - $RSch1_{40}$)]

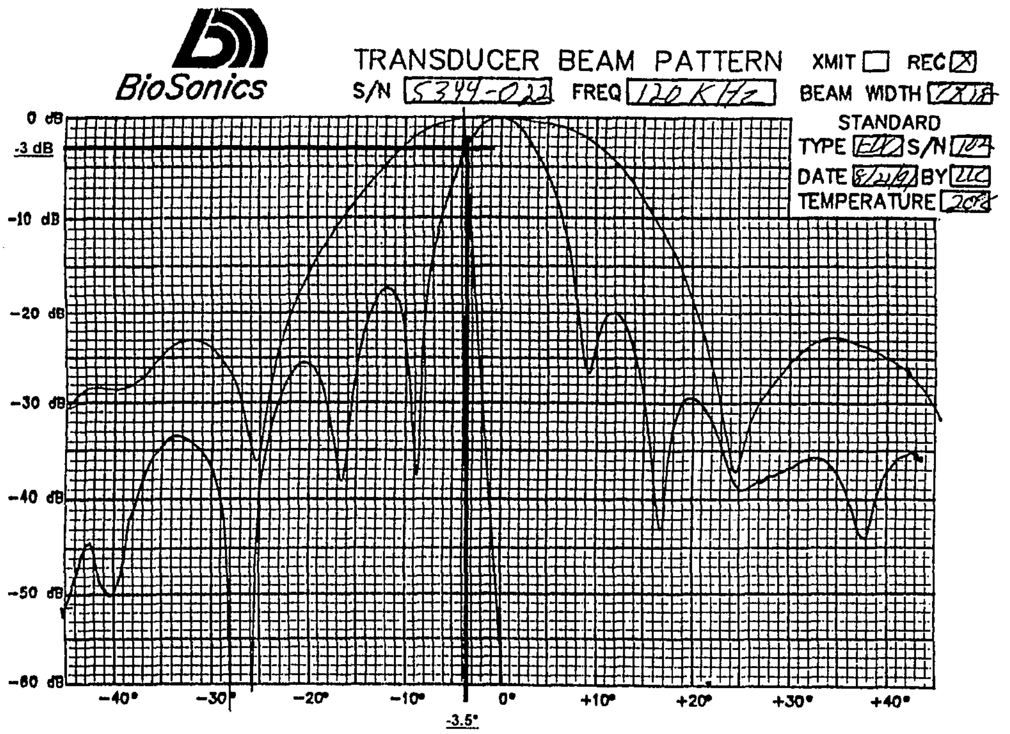
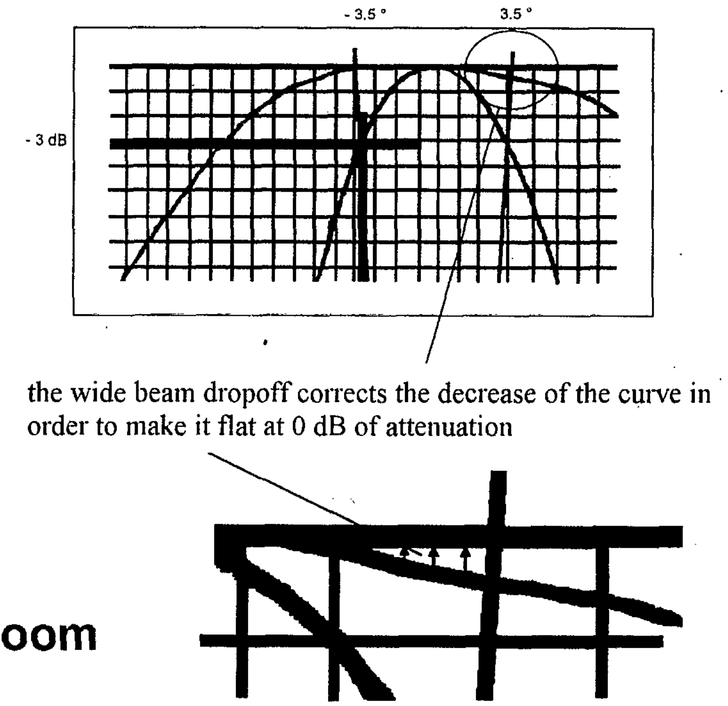


Figure 63 Patterns of the narrow and the wide beams.



the wide beam dropoff corrects the decrease of the curve in order to make it flat at 0 dB of attenuation

Figure 64 The wide beam drop-off.

6.3 The Target Strength determination

The latest 2 way equation applied with the 40 log R function (Chapter 4.2.2 - "The receiver"), was:

$$\boxed{\mathbf{V\ output_{(dB)} = SL + RS\ channel\ 40 + G + TS + 2B\ (\theta)}}$$

We must precise again, because we are working with 2 channels, that this is the narrow beam channel, in our case the channel 1, which is used with this formula. The wide beam channel input intervenes just for the **2B (θ)** evaluation.

We can re-arrange this equation in order to express what is looked for, and also to input what we have just seen, as follows:

$$\boxed{\mathbf{TS = V\ output\ ch1_{40} - SL - RS\ ch1_{40} - G - 2B\ (\theta)}}$$

with **2B** (θ) = 2 x Wide Beam Drop-off x [(V output ch1 $_{40}$ - V output ch2 $_{40}$ + (RSch2 $_{40}$ - RSch1 $_{40}$)]

where **TS** is the Target Strength in dB of the fish (or the calibration sphere)

where **V output ch1** $_{40}$ is the detected voltage at the output of the channel 1, expressed in dB such as :

V output ch1 $_{40}$ = 20 log V detected at the output of the channel 1 (in volts)

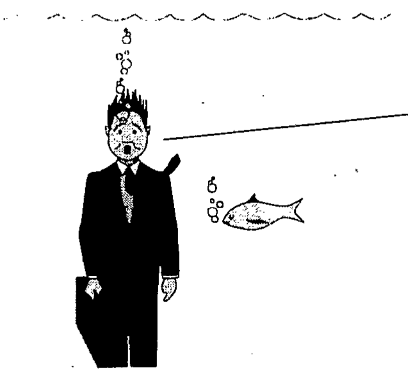
where **SL** is the Source Level of the echo-sounder system (in dB)

where **RS ch1** $_{40}$ is the Receiving Sensitivity of the narrow channel, referred as channel number 1 (in dB)

where **G** is the receiver gain (in dB)

where **2B** (θ) is the beam pattern factor for the 2 ways (transmit and receive)

It is time to quit for a while these general terms and to use some concrete numbers, related to our system in order to have an idea of the values we can get.



Our echo-sounder has the following characteristics:

SL = 222.54 dB / 1m / 1 μPa

RS channel 1 $_{40}$ = - 173.13 dB /1V/ 1m

RS channel 2 $_{40}$ = - 172.17 dB /1V/ 1m

G= - 6 dB

The Wide Beam Drop-off is : 1.10949

Question :

The receiver has the following voltages, at its two outputs :

channel 1	Vnarrow peak:	1.20117 V
channel 2	Vwide peak :	1.36474 V

What is the TS of this target ?

Answer :

Converted in logarithms these voltages become:

V output ch1 $_{40}$ = 20 log 1.20117 = 1.59208 dB

V output ch2 $_{40}$ = 20 log 1.36474 = 2.70101 dB

We can calculate the TS of this target by using the formula:

$TS = V\ output\ ch1_{40} - SL - RS\ ch1_{40} - G - 2B(\theta)$

$TS = 1.59208\ dB - 222.\ 54\ dB - (-\ 173.13\ dB\ ) - (-\ 6\ dB\ ) - 2B(\theta)$

with :

$2B(\theta) = 2 \times Wide\ Beam\ Drop\text{-}off \times [(Voutput\ ch1_{40} - Voutput\ ch2_{40} + (RSch2_{40} - RSch1_{40}\ )]$

$= 2 \times 1.10949 \times [1.59208 - 2.70101 + (-\ 172.17) - (-\ 173.13\ )]$

$= -\ 0.33047\ dB$

Therefore, $TS = -\ 41.15\ dB$

All these tasks are assumed by the computer, but it is better to understand how it computes the data in order to verify the algorithms of the software.

Until now, we have reasoned in terms of simple targets, hit once, but in fact, one target can be insonified twice, three times, and this is also true on multiple targets.

The postprocessing software ESPTS gives us, in this case, mean TS values and mean TS Back Scattering Cross-sections. You must be very careful about any confusion often made between both, and the mistake induced.

Let us recall the nuance of meaning between both, and first the basic relationship linking them :

$$TS = 10 \log \sigma_{bs}$$

This is true for 1 strike (or 1 hit) only.

When we talk about mean TS values (TS_{av}), for "n" measurements, we must understand this, as:

$TS_{av} = (TS_1 + TS_2 + \ldots TS_n) / n$

$= [(10 \log \sigma 1_{bs} + 10 \log \sigma 2_{bs} + \ldots + 10 \log \sigma n_{bs})] / n$

From the logarithm rules, the factorization of the terms of that equation implies :

$TS_{av} = 10 \log (\sigma 1_{bs} \times \sigma 2_{bs} \times \ldots \times \sigma n_{bs}) / n$ equation 1

When we talk about mean Back Scattering Cross section values (σ_{av}), for "n" measurements, we must understand this, as:

$\sigma_{av} = 10 \log \sigma_{bs(av)}$

$\sigma_{av} = 10 \log [(\sigma 1_{bs} + \sigma 2_{bs} + \ldots + \sigma n_{bs}) / n]$ equation 2

As we can see, these 2 equations are not the same and thus we can summarize this demonstration as follows "

The mean of logs ≠ the log of means

$\mathbf{TS_{av} \neq 10 \log \sigma_{bs(av)}}$

thus, $\mathbf{TS_{av} \neq \sigma_{av}}$

This relationship is generally true, except for the calibration sphere, because the sphere has a constant Cross-section and responds therefore with the same value. So, all the σ_{sphere} and TS_{sphere} are the same; thus we can write, for "n" measurements:

$TS_{sphere\ av} = (n \times 10 \log \sigma_{sphere\ bs}) / n$

$\boxed{TS_{\text{sphere av}} = 10 \log \sigma_{\text{sphere bs}}}$

$\sigma_{\text{sphere av}} = 10 \log [(\sigma_{\text{sphere bs}} + \sigma_{\text{sphere bs}} + ... + \sigma_{\text{sphere bs}}) / n]$

We can also write : $\sigma_{\text{sphere bs}} + \sigma_{\text{sphere bs}} + ... + \sigma_{\text{sphere}\ bs}$ (n times) = n x $\sigma_{\text{sphere bs}}$

So, the mean Back Scattering Cross-section becomes :

$\sigma_{\text{sphere av}} = 10 \log [n \times \sigma_{\text{sphere bs}} /n]$

$\boxed{\sigma_{\text{sphere av}} = 10 \log \sigma_{\text{sphere bs}}}$

In this case, and <u>only in this case when the target shows the same Back Scattering Cross-section at each strike</u>, we can write: $TS_{av} = 10 \log \sigma_{bs\ (av\ )}$. It is <u>always true for the sphere</u>, and <u>never for fish</u> even if single, because it never shows the same reflecting surface (Back Scattering Cross-section), due to its changing position and moves in the water.

This confusion may appear at the output and/or printing of the results after ESPTS processing. This software outputs the following data:

```
AVERAGE BACK SCATTERING CROSS SECTION : .1536 E-04  in dB  = - 48.14
AVERAGE TARGET STRENGTH in dB                              = - 50.96
```

.1536 E-04 is the mean equivalent reflecting area in m^2 of the target, $\sigma_{bs\ (av)}$

- 48.14 dB is the mean Back Scattering Cross-section σ_{av} , in decibels :$\sigma_{av} = 10 \log \sigma_{bs\ (av)}$

- 50.96 dB is the mean Target Strength TS_{av}, expressed in decibels.

6.4 Calibration

In this chapter, we will see respectively:

- the system calibration at sea, with a standard sphere.
- the system calibration at sea, or in laboratory with a standard hydrophone.
- the TS determination by measurements on fish in cage.

6.4.1 system calibration at sea, with a standard sphere

In order to verify quickly at sea, before survey, the perfect functioning of the whole electronics, we usually use a standard sphere as the acoustic reference. The standard sphere specially made with precision, can be composed of copper, steel or tungsten-carbide. This sphere has a well-known acoustic response, which is the reference for the calibration. In our case, the carbide sphere of 33 mm diameter has a Target Strength of - 41 dB. You can see on Figure 65 (a), the installation of the sphere, at sea. This TS of - 41 dB must be obtained after processed the ESP Dual-beam program which contains the echo-sounder parameters. If not, we must check the equipment to find out where the problem is. On Figure 65 (b), the characteristics of the sphere are shown.

6.4.2 The system calibration at sea, or in laboratory with a standard hydrophone

This calibration is generally performed in laboratory, but can be also performed at sea meanly, for the Source Level and the Receiving Sensitivity measurement, if you dispose of course, of a standard hydrophone which must be very accurate and also calibrated regularly. Although we haven't any hydrophone at our disposal, the explanation of this experiment will clear up lack of understanding which could still remain.

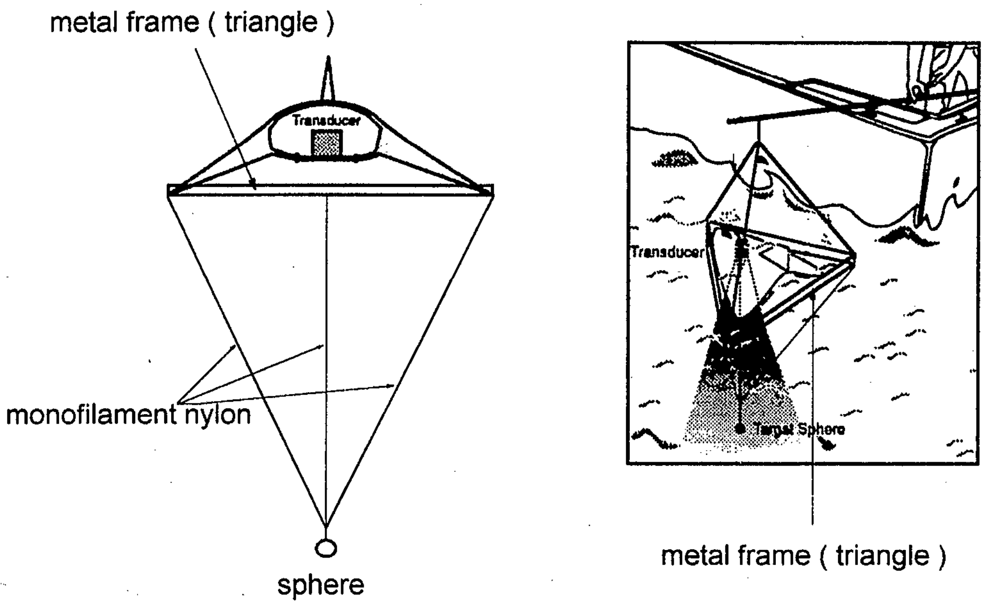


Figure 65 (a) **Installation of the standard sphere.**

Physical Specifications		**Application**	
Approximate diameter	33 mm	Sonar frequency	120 kHz

Target Strength Data

Sound speed in water in (m/s)	Sphere Target Strength (dB)	
	fresh water (density 1000 kg/m³)	in sea water (density 1027 kg/m³)
1410	-41.5	-41.5
1420	-41.3	-41.3
1430	-41.1	-41.1
1440	-41.0	-41.0
1450	-40.8	-40.8
1460	-40.7	-40.7
1470	-40.6	-40.6
1480	-40.6	-40.6
1490	-40.6	-40.6
1500	-40.6	-40.6
1510	-40.7	-40.7
1520	-40.9	-40.9
1530	-41.0	-41.0

Figure 65 (b) **Characteristics of the standard sphere.**

The Source Level measurement

The Source Level measurement is shown on Figure 66; the acoustic power transmitted by the echo-sounder is measured. The echo-sounder transmits and the hydrophone is in listening mode; the hydrophone receives the big acoustic pressure and reacts like a transducer, (its membrane vibrates) and gives an electric signal measured on a voltmeter or an oscilloscope. Then, we apply the equations written on the sheet of this figure.

It is a "one way" measurement, from the transmitter of the echo-sounder, via the transducer, to the listening hydrophone.

CALIBRATION NOTES Source Level

NOTE: Both transducers must be aligned for on axis response to set B = 0.

EQ2 $SL = Vso - Ss + TL - \overset{0}{\cancel{B}}$

Where: SL = Source level in dBuPa @ 1 meter
Vso = Output voltage from standard in dBv (RMS)
Ss = Receiving sensitivity of standard in dBv/uPa
TL = Transmission loss in dB
(20 log(Rs) + aRs for one way loss)
B = One way beam pattern factor in dB
(0 dB for on–axis alignment)
Rs = Separation between transducers (meters)

EQ3 $SL = Vx + Tx$

Where: Vx = Transmit voltage in dBv (RMS)
Tx = Transmit sensitivity of transducer
(dB re uPa/Vrms @ 1 meter)

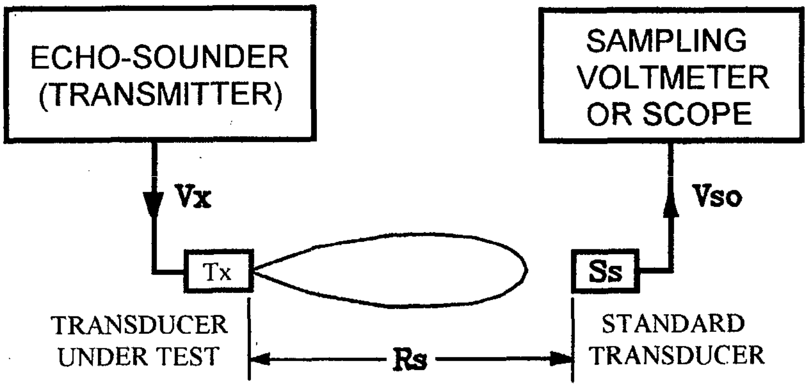


Figure 66 Source Level measurement.

The Receiving Sensitivity measurement

The Receiving Sensitivity measurement is the inverse of the former experiment. The echo-sounder is in listening mode (receiving mode) and the hydrophone transmits. We measure the voltage at the output of the receiver and apply the equations written on the sheet of Figure 67.

It is, also, a "one way" measurement, from the hydrophone to the receiver of the echo-sounder. (via the transducer).

To complete these calibrations, we can also determine the Directivity Pattern of the transducer, which gives the diagrams of Directivity we have already seen; the way to proceed to obtain these curves is shown on Figure 68.

CALIBRATION NOTES Receiving Sensitivity

NOTE: Both transducers must be aligned for on axis response to set B = 0.

EQ4 $Gx = Vdet - \overset{0}{\cancel{B}} + TL - Ts - Vs$

Where: Gx = Receiving system sensitivity in dBv/uPa (at range Rcal)
Vdet = Receiver detected output voltage in dBv
B = One way beam pattern in dB (0 dB for on–axis alignment)
TL = Transmission loss in dB (20 log(Rc) + aRc for one way loss)
Ts = Transmitting sensitivity of standard transducer dB||uPa/v @ 1 meter
Vs = Voltage into standard transducer in dBv (RMS)
Rs = Separation between transducers (meters)

EQ5 $G1 = Gx - Gtvg - RG$

Where: G1 = Gain of receiving system @ 1 meter and RG = 0 dB
Gtvg = TVG gain at range Rcal (20 log(Rcal) + 2aRcal) or (40 log(Rcal) + 2aRcal) as applicable
RG = Receiver gain switch setting

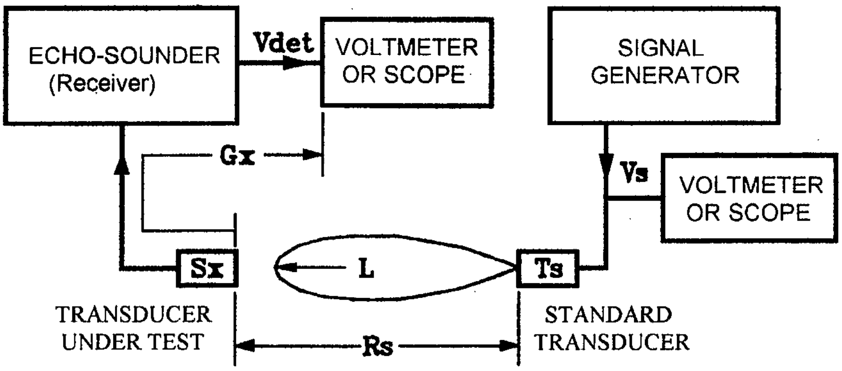


Figure 67´ Receiving Sensitivity measurement.

Generally performed in a test tank, this experiment needs mechanic devices to rotate the transducer under test. By these means, we can draw on an XY recorder, the beam pattern of the transducer at the transmission and also at the reception, in the same way as before, that is to say: the echo-sounder transmits and rotates, the hydrophone which is fixed, is listening. The recorder records the evolution of the transmitted signal received at the terminals of the hydrophone during the whole rotation of the transmitting transducer; for the reception, it is the inverse: the hydrophone transmits as the transducer rotates and the echo-sounder is listening; in this case, the XY recorder is connected to the output of the receiver and draws the received voltage evolution.

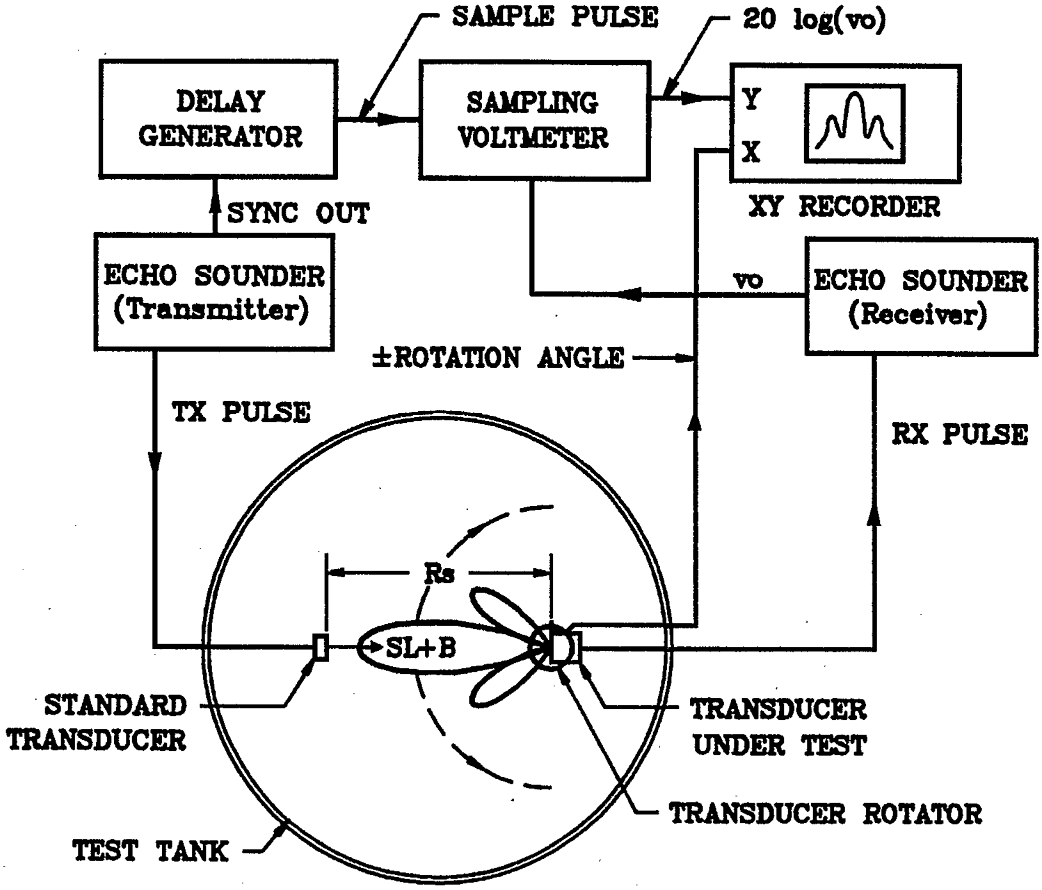


Figure 68 Beam Pattern measurement.

Although these experiments might be done in laboratory, it is possible to perform them at sea. Figure 69 is an example of device which can be used. An aluminium frame is used to hold the transducer and the hydrophone, for the SL, the Receiving Sensitivity and the Beam Pattern of the transducer measurements. The distance, between the transducer to test and the hydrophone must be greater than the ratio D^2 f / c because of the **near field** of the transducer, which is a forbidden zone due to interferences of the signal in formation while transmitting.

$$\boxed{R > D^2 f / c}$$

R the minimum distance available for measurement in meters (from the transducer's face).
with D the diameter of the transducer
f, the frequency of the echo-sounder
c, the celerity of the sound in the sea water

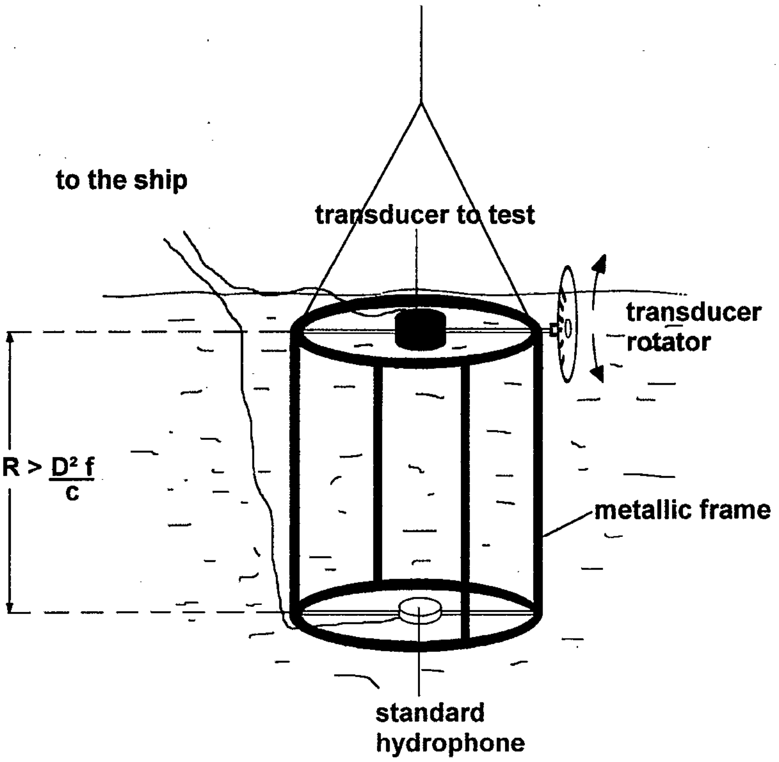


Figure 69 SL, Receiving Sensitivity and Directivity measurements at sea.

Question :

What is the minimum distance from our transducer available, regarding to these characteristics: D = 12 cm ; f = 120 kHz ; c = 1500 m/s ?

Answer :

$R > D^2 f / c$

$R > [(0.12)^2 \ 120.\ 10^3] / 1500$

$R > 1.152$ m

6.4.3 The TS determination by measurements on live fish in cage

With the calibration of acoustic equipment, reflection index TS and/or σ measuring of live fish constitutes the first stage in the evaluation of abundance. This operation should allow the adjustment of the threshold on the echo voltages which are to be taken into account; it should also allow the calculation of a conversion constant of integrated voltages during prospection of biomass measuring.

You can see on Figure 70, the model of live fish calibration cage used for the TS/σ measurements.

In order to keep the fish in the acoustic beam, the latter is introduced into a conical cage specially built in order not to be disturbed by the reflecting contribution of the lateral surface. The transducer in the cage is an integral part of it. In this way, the transmitting signal is not attenuated by the net, the cage is sufficiently spacious to permit the movement of the fish and to record the echo without interference.

The fish are introduced into the cage in sets of 1, 2, 4 or 6. The cage is then submerged. Reverberation measurements are taken both night and day. These experiments need to be repetitive and take a long time for observation.

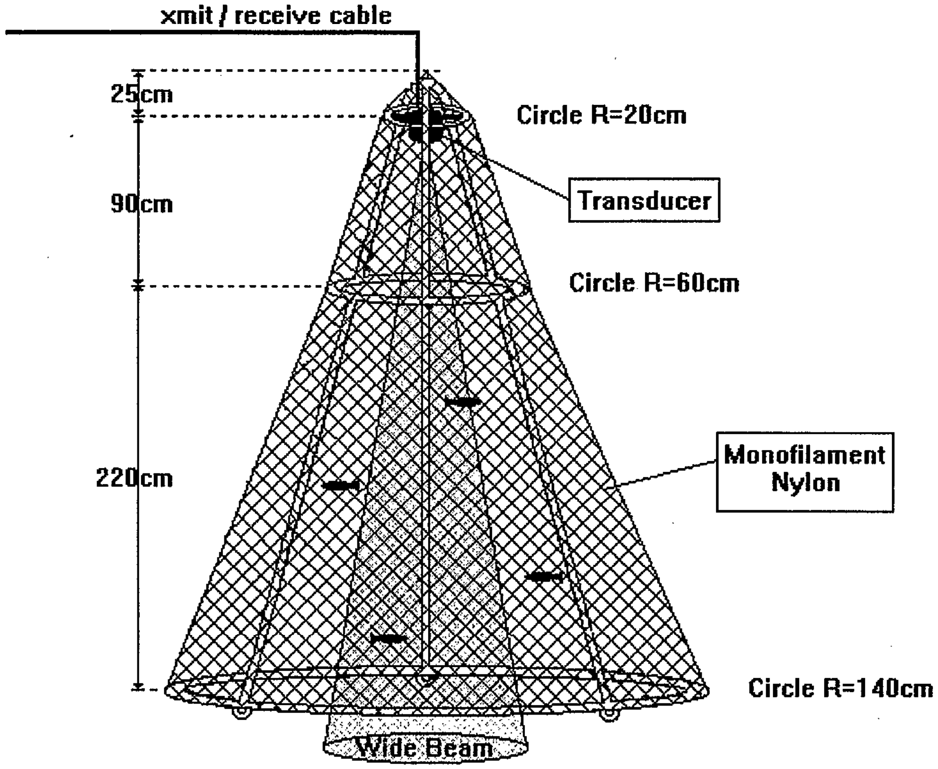


Figure 70 The live fish cage.

The first requirement is to keep the fish in good condition and to be careful when handling it. Special tanks with sea water recycling have been used by means of water pumps. Handling has been performed through handling nets. After each experiment, the fish have been measured in order to obtain the relationships size - weight and TS/σ.

A period of acoutumance of the fish must be respected before getting averaged results available. These results must be considered with great care due to the eventual bias input by the stress of the "prisoner(s)".

Here below, some results from our experiments, the sounder characteristics and the settings used:

- Transmitter Source Level : 222.54 dB /µPa/m
- Narrow beam Receiving Sensitivity : -173.13 dB/V/µPa
- Wide beam Receiving Sensitivity : - 172.17 dB/V/µPa
- Pulse Duration : 0.4 ms
- Ping Rate : 3/second
- Threshold : 100 mV
- TVG : 40 Log R + 2 aR a = 34.7 dB/km R = 125 m
- Dual-Beam transducer : 7° narrow and 18° wide circular beams.

The average values observed were:

- *Decapterus. russelli* : σ_{av} = - 47.7 dB (Lf = 16 cm)
- *Selar. crumenophtalmus* : σ_{av} = - 44.9 dB (Lf = 16 cm)
- *Rastrelliger. kanagurta* : σ_{av} = - 50 dB (Lf = 11 cm) [1]

---

[1] This value concerns a small number of values.

THE ESP DB PROCESSOR

INTRODUCTION

Dual-Beam techniques are used to estimate fish Target Strengths, which are related to fish size. A Dual-Beam data acquisition system requires a Dual-Beam sounder and a Dual-Beam transducer. The system transmits on the narrow beam of the transducer and receives on both the narrow and the wide beams. If a target such as a fish enters the sound beam, it will echo the signal back on both the narrow and the wide beams. By measuring the difference in voltage between the narrow and the wide beam echoes and performing data processing techniques, the Target Strength can be determined. The comparison of both beams allow the user to situate the target exactly within the sound beam and thus, allow to correct precisely the attenuation due to the off-àxis position of the fish.

THE EQUIPMENT

The BioSonics' Echo Signal Processor consists of a signal processing board housed in computer. To perform a particular signal processing function, the user simply runs the appropriate program, written in Microsoft Windows. Even though completed ESP functions include the Model 221 Echo Integrator for estimating fish densities, only the Model 281 Dual-Beam Processor for estimating fish Target Strength will retain our interest.

7.1 The Hardware

First of all, the echo-sounder outputs are interfaced with the ESP main board via the Signal Conditioning Pod (SCP) which is outside the computer. This small box contains BNC outputs so that certain signals can be independently monitored. Within it, the analogic voltages are suited to match with the ESP board hosted by the PC (Fig.71). Although the computer controls the ESP main board, this board carries out the major signal processing functions. Via Analog/Digital converters, the sampled voltages are digitized at a clock rate of 25 kHz, which is equivalent to 33.3 samples / meter at a speed of sound of 1500 m/s. So every 3.33 cm depth, we get one information (Fig.72). The analog/digital converter operates at 12-bits resolution in 2.44 mV steps until 10 volts.

7.2 The Software

The programs are resident in Windows ™ software. This interactive management permits multiple functions to be used simultaneously. Entries of echo signal processing parameters are very convenient and rapid. The display of graphics on the screen facilitates the controls and the adjustments of the data collection. For example, with the display of a digital oscilloscope, one can monitor the input of the echo-sounder and set the right threshold or change the gain of the receiver,...Data analysis can be performed in real-time, through updated histograms shown on the computer screen; data are output to disk files in format easily accessible to post-processing software.

The following chapters will describe the operation of the data acquisition software called :

Esp_db.exe

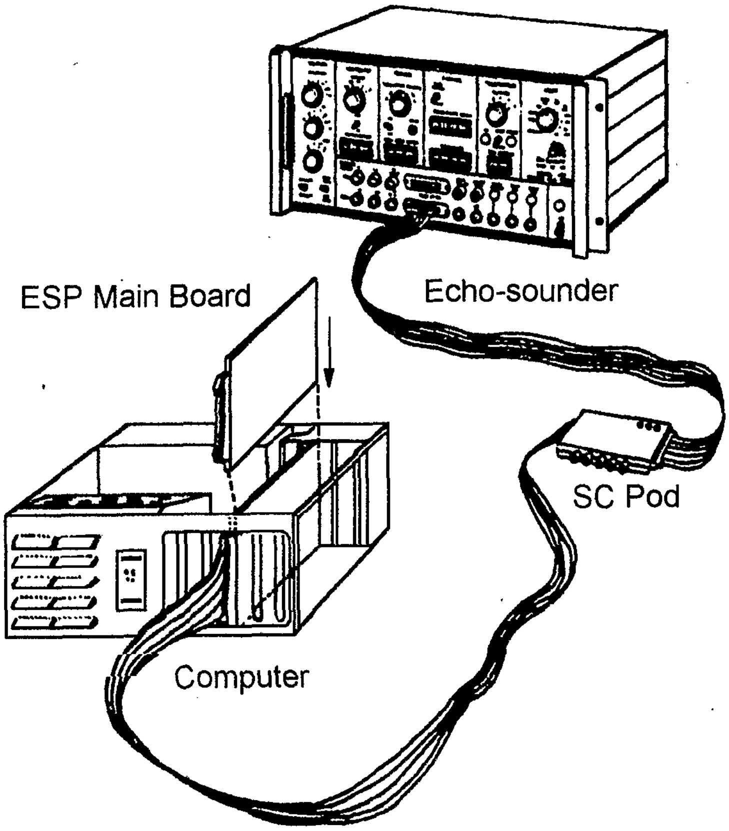


Figure 71 **The ESP hardware system view.**

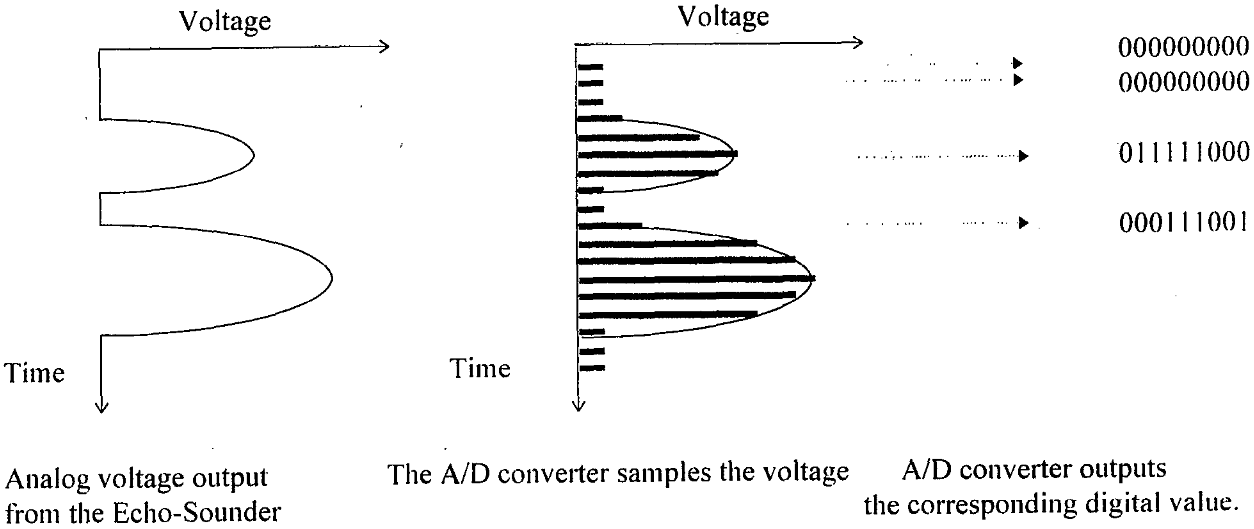
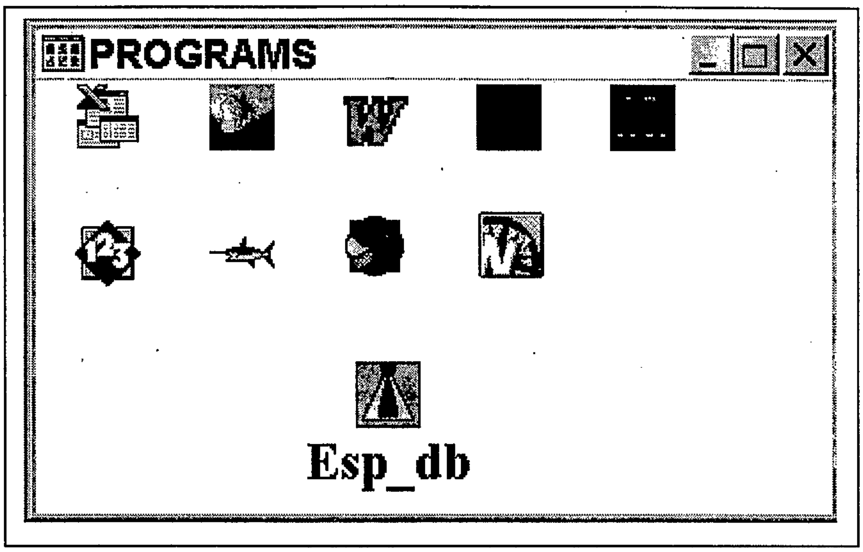


Figure 72 **Digitalization of the analog signal for computerizing.**

THE MODEL 281 DUAL BEAM PROCESSOR : THE ESP_DB.EXE PROGRAM

After accessed to the Program Manager of Windows ™, double-click on the icon ESP_DB.EXE.



A Default main display will appear. Along the top of the page are the main ESP_DB menu headings; the menus are listed left to right in the order that one normally access them.(Fig.74)

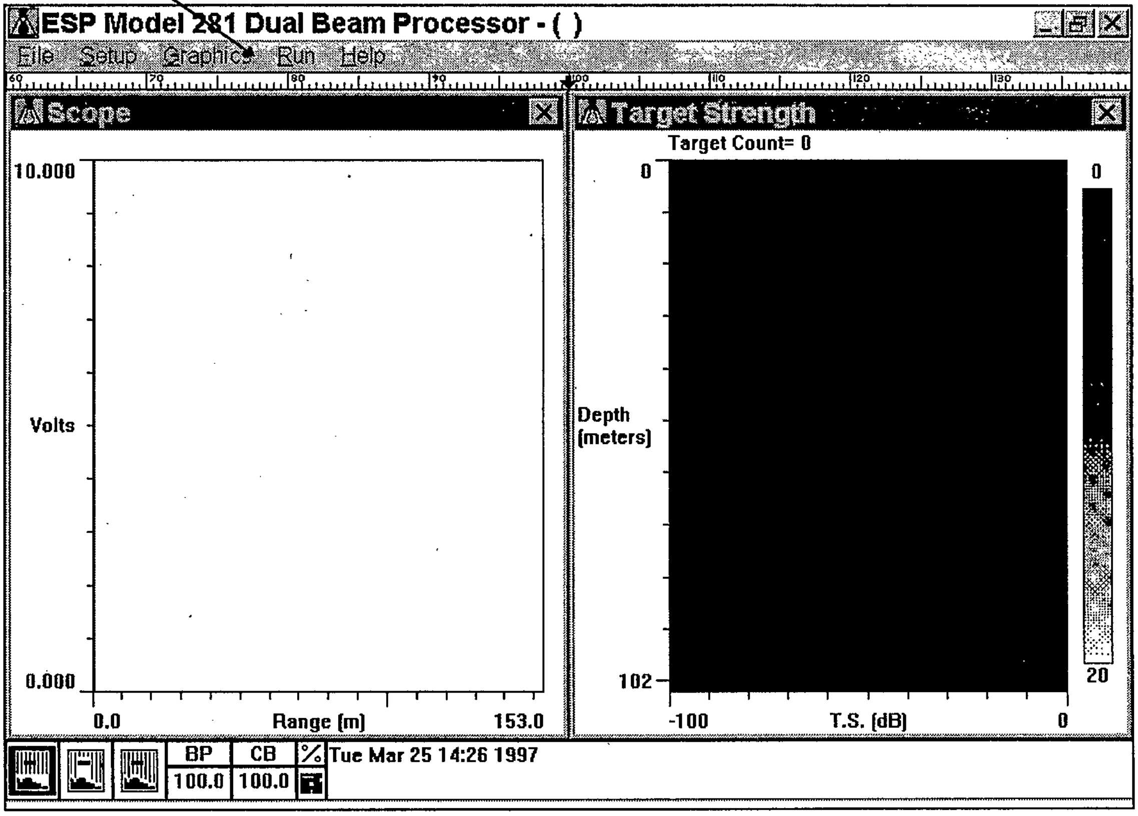
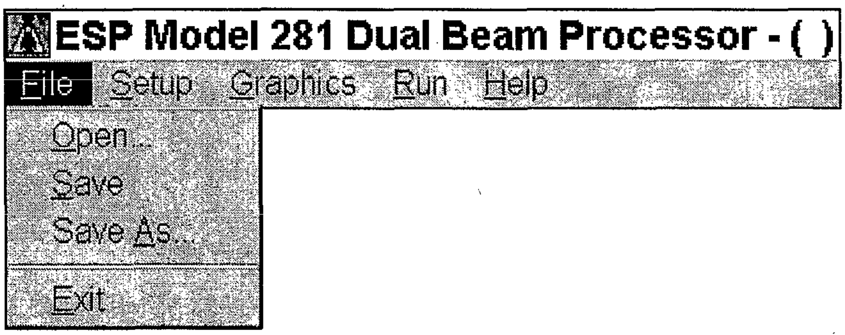


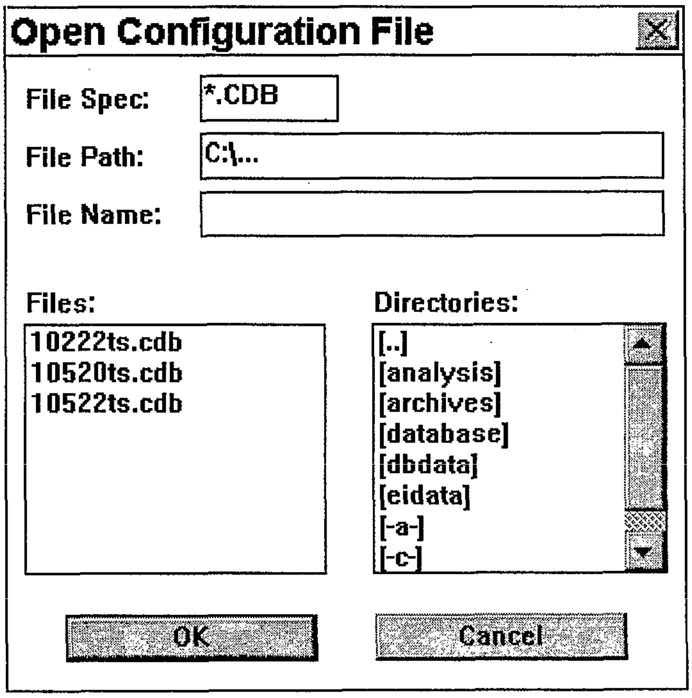
Figure 73 The ESP main display (default).

Figure 74 **The ESP menus.**

8.1 The File Menu

The purpose of the File menu is to allow you to create or quickly recall a configuration file containing preset values for the calibration and processing parameters. This is done by selecting the Open menu item, and select the file called : 10222TS.CDB which is the updated configuration file well matched for our equipment. We will see in details, this configuration file and its parameters which can be accessed within the Setup menu described further..





File Spec: *.CDB

File Path: C:\...

File Name:

Files:

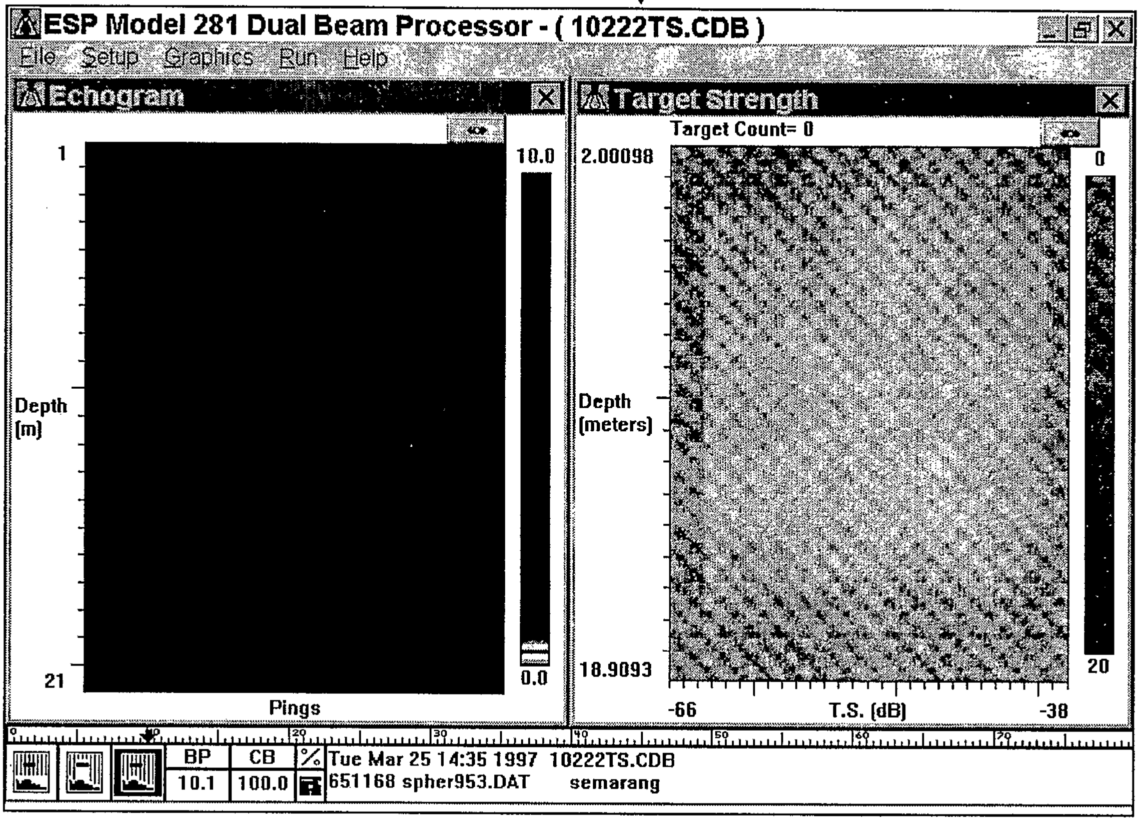
10222ts.cdb
10520ts.cdb
10522ts.cdb

Directories:

[..]
[analysis]
[archives]
[database]
[dbdata]
[eidata]
[-a-]
[-c-]

After having selected the configuration file (for us 10222ts.cdb), a new page is displayed with the configuration file name in use with the same menu headings, and with a new view (colours,...) depending of this config. File.

Here, the configuration file name, just recalled.

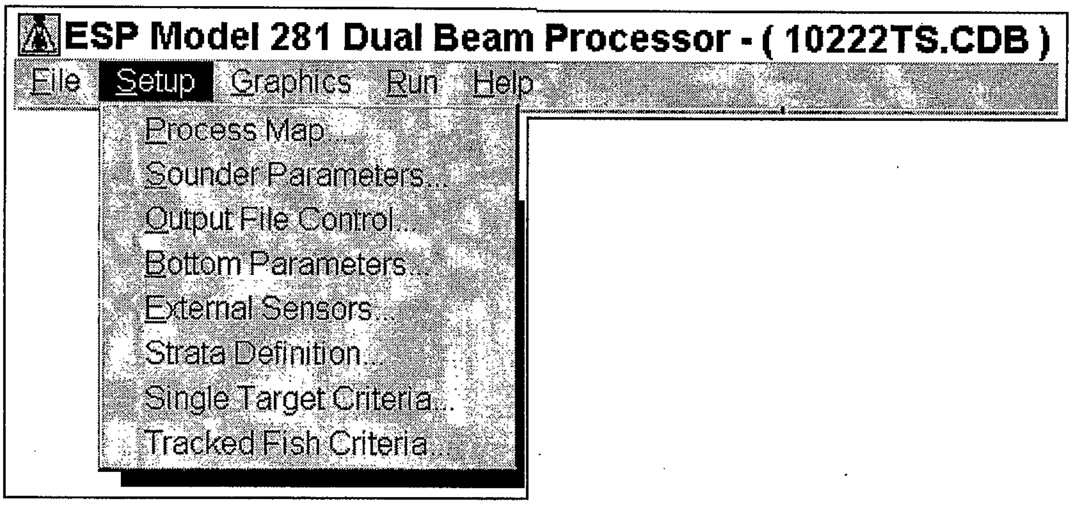


BP	CB	%	Tue Mar 25 14:35 1997 10222TS.CDB
10.1	100.0		651168 spher953.DAT semarang

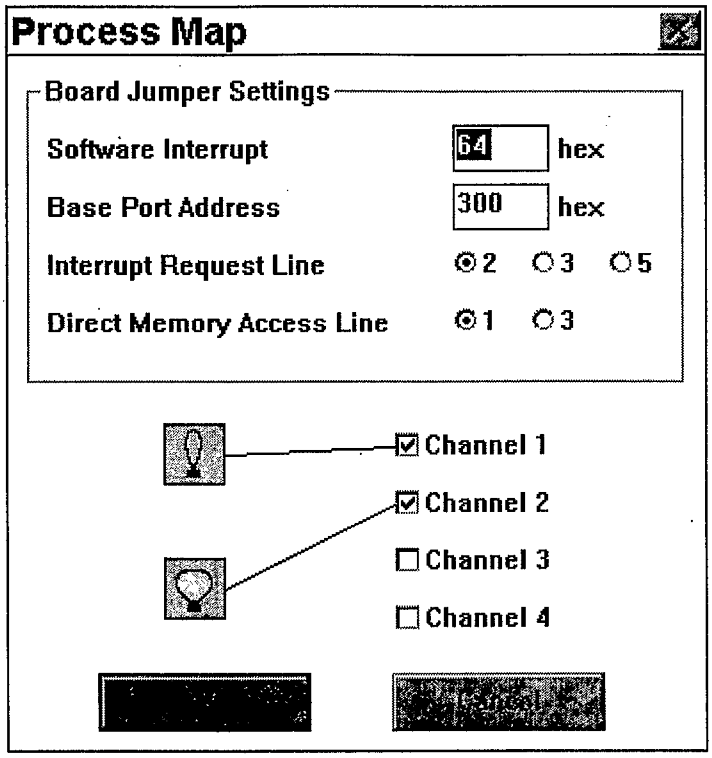
We can straight go to the next menu called Setup.

8.2 Setup

This menu contains all parameters used to process dual-beam data. The parameters entered in the Setup menu items may be saved using the former menu "File" and the Save As command within.



8.2.1 The Process map



Software Interrupt 64 hex

Base Port Address 300 hex

Interrupt Request Line ● 2 ○ 3 ○ 5

Direct Memory Access Line ● 1 ○ 3

☑ Channel 1

☑ Channel 2

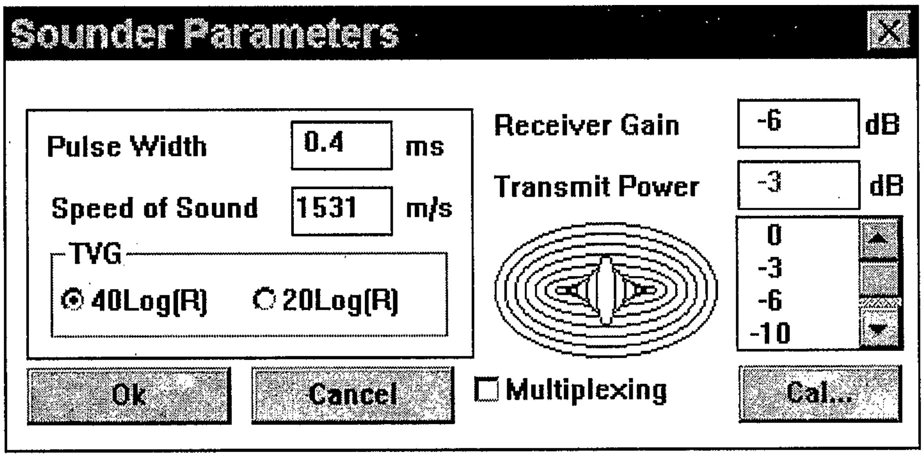
☐ Channel 3

☐ Channel 4

This item concerns the internal configuration of the ESP main board within the computer. Addresses and jumpers are preset and usually the user does not have to make any change. That is better, anyway, to check how the narrow and the wide beams are declared in the appropriate panel. It might be as shown on the picture.

8.2.2 The sounder parameters

This item allows you to enter sounding constants, such as the speed of sound and the echo-sounder settings such as pulse width, TVG, receiver gain and transmit power. The calibration command button calls up another dialog box which allows you to enter your transducer calibration data.



Pulse Width 0.4 ms

Speed of Sound 1531 m/s

TVG ● 40Log(R) ○ 20Log(R)

Receiver Gain -6 dB

Transmit Power -3 dB

☐ Multiplexing

- **Pulse width -** enter (or confirm) this value; it must be the same as the transmitted pulse width set on the echo-sounder. This value must beer thiese two values. Valid range is from 0.1 milliseconds to 10 milliseconds (ms). Our own setting was 0.4 ms and is still recommended.

- **Speed of sound** - enter (or confirm) the speed of sound in meters/second. Speed of sound as already studied in Chapter 3.3.6 - "Sound Speed or Celerity", varies with temperature and salinity according to the following formula :

$$\boxed{c = 1445 + 4.66\,t - 0.055\,t^2 + 1.3\,(s - 35)}$$

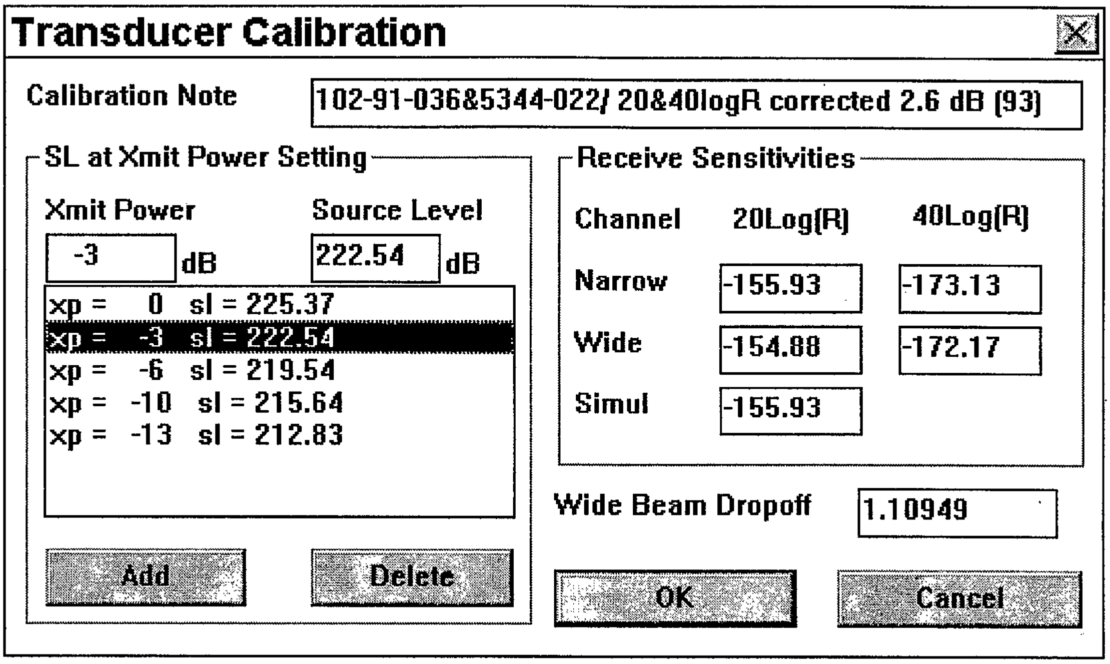
where c is the Sound Celerity in m/s
where t is the Temperature in °C
where s is the Salinity in ‰

We used the value of 1541 m/s displayed on the picture, based on average of temperature and salinity in the Java Sea. This parameter is important because it affects the number of samples per echo.

- **TVG** - The echo-sounder applies a Time-Varied-Gain to the signal to amplify echoes in order to correct the attenuation, the spreading loss and the absorption loss (see Chapter 3.3 - "The propagation"). For TS measurement, the 40 Log (R) function must be selected (when clicked, the selection shows a black dot in the center of the bullet as shown on the picture).
- **Receiver Gain** - Use this box to enter the Receiver gain of the echo-sounder during data collection. Almost all the time, we set the gain at -6 dB, regarding to detection amplitude of fish schools.
- **Transmit power** - Once again you must fit this value with the setting of the echo-sounder. The -3 dB value has been recommended by the manufacturer in order to avoid the transducer saturation (at 0 dB) and therefore its deformation.
- **Multiplexing** - Is only selected when you collect data from two transducers which have different beams, operating frequencies, receiving sensitivities. In multiplexing the echo-sounder alternately sends and receives signals from both transducers. It is out of our concern because we use only one transducer. This case should not have to be clicked !

When the **Cal... command button is clicked**, a dialog box appears, the "**transducer calibration**" menu. This box is of primary importance and might be checked any time before data collecting. This menu is for entering (or checking) the results of calibration of the acoustic system. We can find within :

- **The calibration note** which is a text box for recording information about the calibration date, the serial number of the echo-sounder, the reference of the transducer,...
- **The SL at Xmit Power Setting** - is the value of the Source Level of the system (see chapter 3.3.4 - "Reflection by a single target- The two way equation"). You can see on the picture, the pre-selected value of 222.54 dB which is the actual Source Level (SL) from laboratory calibration, when -3 dB power setting is used (our own setting).
- **The Receive Sensitivities** - This box is for entering (or checking) the Receiving Sensitivities of the narrow beam and wide beam channels of our Dual-Beam transducer : **RS ch1 $_{40}$**, **RS ch2 $_{40}$** (see Chapter 6.3 - "The Target Strength determination"). You can see a third one called "**Simul**" which is the third output of the echo-sounder. This output is actually a part of the first channel (narrow beam), the first stage of the amplifier which assumes the 20 log R correction (see chapter 4.2.2-"The receiver- Figure 32/The receiver amplifier principal function"). Thus, this third calibrated output always presents a 20 log R corrected signal and is used for echo-integration. This is from this output called channel 3, that the signal is sent to the Echo-integration interface, INES, before input into the second computer. That is the reason why the RSch3 (always 20 log R) is the same as the RSch1 (20 log R).



Transducer Calibration

Calibration Note: 102-91-036&5344-022/ 20&40logR corrected 2.6 dB (93)

SL at Xmit Power Setting

Xmit Power: -3 dB

Source Level: 222.54 dB

xp = 0 sl = 225.37
xp = -3 sl = 222.54
xp = -6 sl = 219.54
xp = -10 sl = 215.64
xp = -13 sl = 212.83

Receive Sensitivities

Channel	20Log(R)	40Log(R)
Narrow	-155.93	-173.13
Wide	-154.88	-172.17
Simul	-155.93	

Wide Beam Dropoff: 1.10949

During TS measurements channel 1 and channel 2 are used with the 40 log R function, and thus these both values must be carefully adjusted, regarding to calibration (standard sphere). For our concern, we use the following settings :

⇒ Narrow beam channel (channel 1) : $RSch1_{40} = - 173.13$ dB

⇒ Wide beam channel (channel 2) : $RSch2_{40} = - 172.17$ dB

⇒ Simultaneous channel (1/2 part of channel 1 always 20 log R output) = -155.93 dB

- **Wide Beam Drop-off** - The Wide Beam Drop-off is the correction factor applied on the two beams, related to their Directivity characteristics. It describes the decrease in the wide beam Directivity over the usable angular range of the narrow beam. This parameter is supplied by the manufacturer of the transducer. As shown on the picture above, it is equal to : 1.10949

All these parameters, above, are familiar to us as terms of the final TS equation (see chapter 6.3 - "The Target Strength determination") where TS is expressed as follows :

$$\mathbf{TS = V\ output\ ch1_{40} - SL - RS\ ch1_{40} - G - 2B\ (\theta)}$$

with

$$\mathbf{2B = 2 \times Wide\ Beam\ Drop\text{-}off \times [(V\ output\ ch1_{40} - V\ output\ ch2_{40} + (RSch2_{40} - RSch1_{40})]}$$

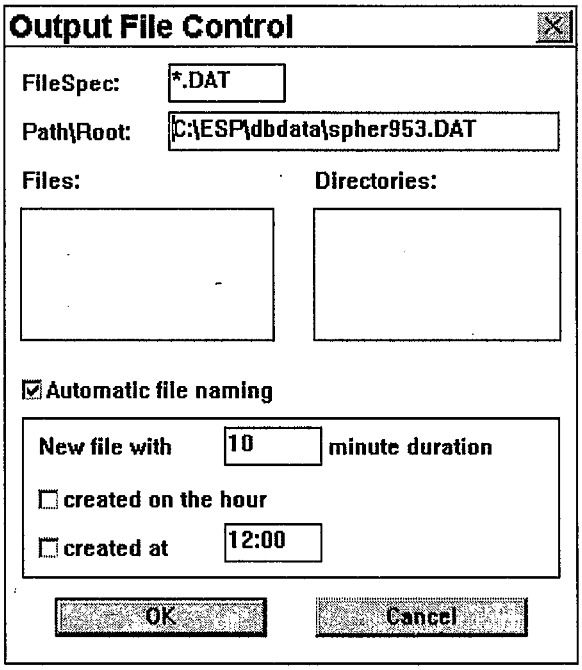
After filled the transducer calibration box and clicked OK, one must, for the second time click OK to end the Setup/Sounder parameters.

8.2.3 The Output File Control

This item provides the ESP with information for naming Output Data Files, as well as for controlling start and end times of these files. The five components of the Output File Control are :

- The File Specification which is the file extension needed to complete the name of the file saved.
- The Path/Root is the specification of the drive, directory, subdirectory to which you want your Data File written and the name of this Data File.

- The File List box, just below, allows to see all files listed on the selected drive, directory and subdirectory, in order to avoid duplicate naming of files and to keep track of the files already named and saved.
- The Directory box displays the drives, directories and subdirectories of your system. The current drive (here **c:**), the current directory (here ESP) and the current subdirectory (here **dbdata**) are shown and the file name (here **spher953.DAT**) as well.
- The Automatic File Naming, if selected, will create new subfiles systematically using the information in the group box below.



Output File Control

FileSpec: *.DAT

Path\Root: C:\ESP\dbdata\spher953.DAT

Files:

Directories:

☑ Automatic file naming

New file with 10 minute duration

☐ created on the hour

☐ created at 12:00

We must clarify the contents of a Data File. A Data File comprises subfiles named **runs**. Each run can be delimited in time, as shown on the picture above (10 minutes). That means that, every 10 minutes, a subfile is open and/or closed. For example, we began TS measurements at 17:00 and ended at 18:00, thus the measurements lasted one hour. We have collected the data under the file name **spher953.DAT**; with our time setting of **10 minutes** per run, we can say that within the **"motherfile" spher953.DAT**, there are **6 runs**, called RUN #1, RUN#2, RUN#3,...

The term New file which can be read on the menu picture is not really appropriate. The term "run" might have been more accurate.

The two other options are less important and personally never used, preferring the time duration limitation instead of fixed hours.

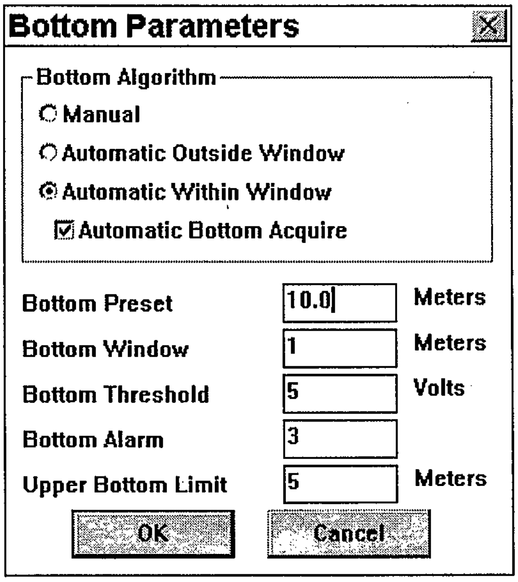
8.2.4 The Bottom Parameters

It is very important to exclude the bottom echo from fish signal processing. The processing starts from the surface and stops when the bottom is met. The bottom is the limit of the data collection.

- The Bottom Algorithm- which allows the bottom to be tracked in one of three modes : Manual, Automatic Outside Window or Automatic Within Window.
  - * In Manual tracking, the operator watches the digital oscilloscope displayed on the screen and manually excludes the bottom from data collection, by moving a marked line with the mouse of the computer. This marked line is the effective stop of the data collection. Beyond this line, the data will not be taken into account. That is why one must be as

close as possible of the bottom to have the maximum of the targets. One must be very careful when using this mode; if the marked line is beyond the bottom echo, this latter will be considered as echoes. Even if the TS process has safety filters to reject false or multiple targets, it is recommended to avoid this incursion. For Echo-Integration, it is a disaster.

- When ESP tracks the bottom using the Automatic Outside Window algorithm, it automatically searches and tracks the bottom using only a threshold (a voltage value). This threshold must be higher than fish target voltages, so that the processor will not mistakenly identify fish as bottom echoes. This mode is recommended to be used on TS measurements where schools or multiple targets have to be rejected. When a school is met, the level of the echoes returned is higher than the preset threshold. The system considers this school as the bottom echo and stops the data collection. This school passed away, the mode will automatically search the bottom (it must be higher than the threshold) and track it again. In any situation and for safety reasons, the data collection stands by if no bottom echo is returned or if the bottom echo is lower than the threshold. In this case, we can call the Manual tracking algorithm back to pursue the data collection or decrease the bottom threshold until it fits with the automatic tracking but also with fish target voltages. When the bottom is back, the collection goes on. In echo-integration, where schools have to be taken into account, this mode represents too many risks to lose information due to the preceeding reasons. The following mode is recommended, in this case and/or for TS measurements as well.
- **The Automatic Within Window algorithm** is the safest mode because ESP automatically tracks the bottom and assumes a second control by expecting the bottom to occur within a pre-specified depth window. This confirmation is very useful mainly for Echo-Integration to avoid the school echo level to stop the data collection but also for TS meassurements if echoes in the surrounding borders of the school or within it have to be studied. If Automatic Bottom Acquire is selected as it is shown on the next picture, the ESP will automatically find the bottom whenever it becomes lost, by simply switches to the Automatic Outside Window algorithm until the bottom is found. Then the Automatic Within Window will again become active. This research is activated when the bottom alarm sounds. Here also, the data collection stands by if no bottom echo is returned or if the bottom return echo is lower than the bottom threshold. In this case, we can call the Manual tracking algorithm back to pursue the data collection or lower the bottom threshold until it fits with the automatic tracking but also with fish target voltages



Bottom Parameters

Bottom Algorithm

○ Manual

○ Automatic Outside Window

● Automatic Within Window

☑ Automatic Bottom Acquire

Bottom Preset 10.0 Meters

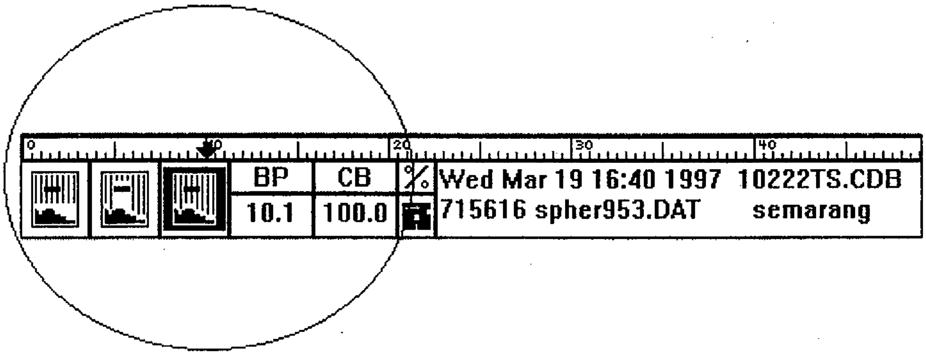
Bottom Window 1 Meters

Bottom Threshold 5 Volts

Bottom Alarm 3

Upper Bottom Limit 5 Meters

- The Bottom Preset- is useful to find the bottom rapidly, when expected at a specific depth. The Automatic Within Window will recognize more easily the bottom echo and then the data collection will start faster.
- The Bottom Window- is the size of the <u>Automatic Within Window</u> but also the size of the other algorithm windows. Once the bottom has been located the processor will expect each subsequent ping to find a bottom signal at approximately the same depth as the previous ping. For example, if the bottom is found at 30 meters from the transducer and our bottom window is 4 meters, the processor will look for the bottom between 28 and 32 meters on the next ping. If the bottom changes rapidly, exceeding the bottom boundaries, the Automatic Within Window will not find it. The processing is at once stopped and the data of the sequence are not taken into acount until the Automatic Bottom Acquire function meets the bottom again after an immediate research. That is why this mode is recommended because of the safety and also its self-control. We always used the 2 settings shown here above. We had to use the manual mode once when we worked on the ridge of the continental shelf where the bottom drops from one hundred to thousands meters rapidly.
- The Bottom Threshold - is the minimum voltage value expected from the bottom return echo. <u>This Threshold must be higher than fish target voltages</u> so that the processor will not mistakenly identify fish as bottom echoes.
- The Bottom Alarm- is an alert which warns the operator when the processor loses tracks of the bottom. The number you enter or already entered, in the text box indicates how many successive bottom echoes can be lost before the alarm sounds. There are many reasons when losing tracks of the bottom. The research window is too small for a rapidly changing bottom depth, the bottom threshold is too high, or too low, or the pitch and roll of the ship causes rapid change in distance to the bottom, the paravane which contains the transducer is upside down,...
- The Upper Bottom Limit - is the minimum distance in meters from the transducer that the bottom echo can be processed. The purpose of this limit is to prevent the processor from mistaking the surface noise included the transmitted pulse for a bottom return.
- Additional Bottom Tracking tools - The three bottom tracking modes are represented at the lower left of the general display and can be solicited by clicking the icons for a rapid intervention instead of opening the main menu. The far left icon is the Manual tracking mode, the second is the Automatic Outside Window mode, and the third from the left is the Automatic Within Window mode. The text box whose title is BP is the bottom preset value which can be changed if needed rapidly for the same practical reason. By clicking the title we have access at the text box BT bottom threshold, and by re-clicking twice this case we access at the bottom research window width. Finally at the extreme right, we have a text box referred as CB (Current Bottom) which is the display of the present bottom.



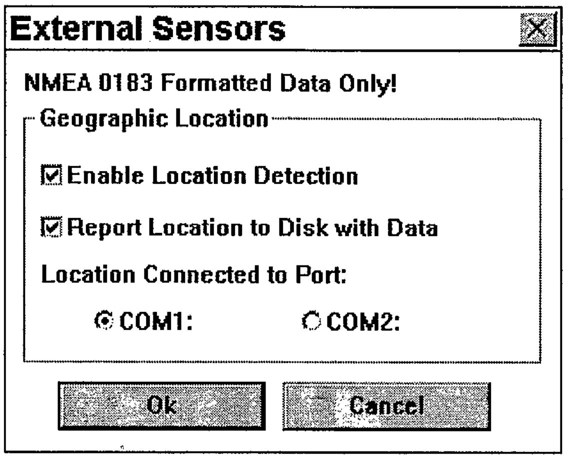
BP	CB
10.1	100.0

Wed Mar 19 16:40 1997 10222TS.CDB

715616 spher953.DAT semarang

8.2.5 External Sensors

The External Sensors menu is used if any external device is connected, such as a Satnav or a GPS (Group Positioning System). During our surveys, a GPS (Raytheon) was permanently used in order to provide the ship's position all along the transects. The same kind of selection is offered by clicking the related options as shown below.



NMEA 0183 Formatted Data Only!

Geographic Location

☑ Enable Location Detection

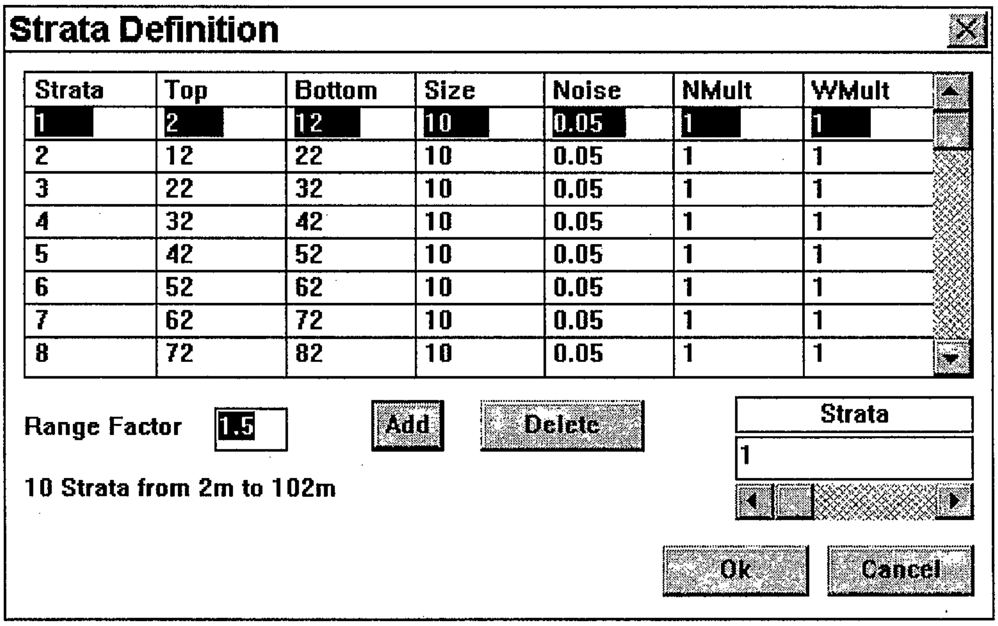
☑ Report Location to Disk with Data

Location Connected to Port:

● COM1: ○ COM2:

8.2.6 Strata Definition

The ESP allows to process echo signal in depth strata. The user can specify in this menu item, the number and size of strata in which echo signals will be processed. In the same time, for each stratum you can enter a separate noise threshold (in volts) and also Nmult and Wmult which are range-dependent multipliers for the narrow and wide channels. If multiplexing has been selected at the early beginning of the program launch in the Sounder Parameters menu item (see before), there will be two strata tables, one for each of the transducers in use. These transducer are referred as X1 and X2. In our case, we never worked in multiplexing mode, and the configuration was :



Strata	Top	Bottom	Size	Noise	NMult	WMult
1	2	12	10	0.05	1	1
2	12	22	10	0.05	1	1
3	22	32	10	0.05	1	1
4	32	42	10	0.05	1	1
5	42	52	10	0.05	1	1
6	52	62	10	0.05	1	1
7	62	72	10	0.05	1	1
8	72	82	10	0.05	1	1

Range Factor 1.5

10 Strata from 2m to 102m

Strata 1

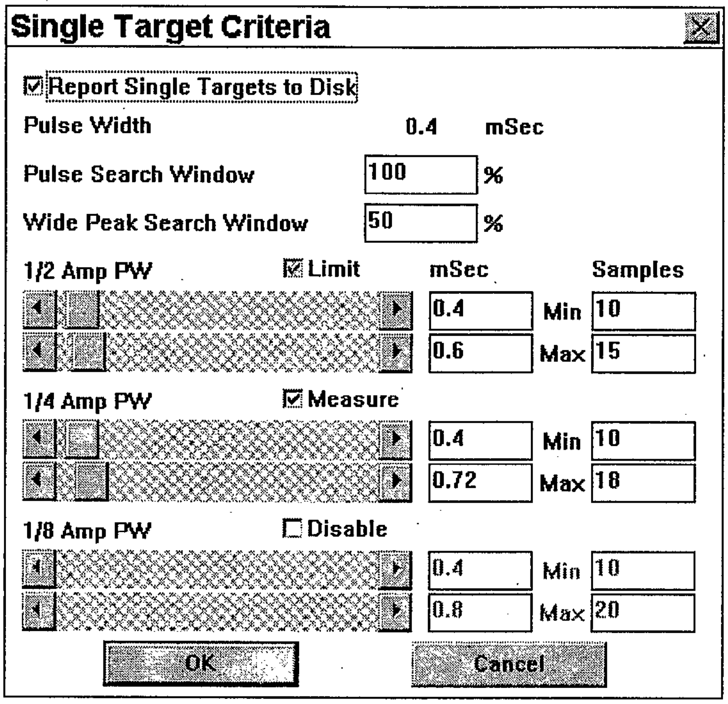
- Strata : the number in this column represent the stratum numbers. They are incremented with greater distance from the transducer. Up to 100 strata can be specified. It is not worth to have too many strata, which leads to heavy postprocessing, but also it is recommended to match the strata repartition with the layers preset for echo-integration. The thickness of these latter was 10 meters and because the maximum depth in the Java Sea is less that 100 m, we have decided to limit the number of strata at 10. Nevertheless, when working on the ridge of the continental shelf, we added up complementary strata up to the dropping bottom. We must, anyway, keep in mind that our TVGs functions are preset to work between 1.25 m until 125 m depth : that means, all echoes deeper than this lower limit will not be corrected anymore !

- Top and Bottom : these two columns represent the start and end of each stratum, from the top to the bottom. All ranges are referenced from the transducer. The top of the first stratum is the actual start range for analyzing. As you make changes in either column 2, 3 or 4, the ESP calculates and adjust the changes in the other columns which are affected by these changes.
- Size : the thickness of each stratum can be 0.1 meters to 1000 meters. However, the total size cannot exceed 1000 meters. We adopted 10 meters for the reasons explained above. When one stratum size is changed, all values in the Top and Bottom columns are changed accordingly. We can see in the lower left part of the picture, the summary of all the layers or strata, including the upper limit of the first layer and the lower limit of the last stratum.
- Noise : is the voltage threshold for each of the strata. Signals whose levels would be lower that the indicated value (for example, here, 0.05 volts or 50 mV) would be rejected and not processed. To adjust the threshold level, we must refer to the oscilloscope (digital or analogic) to determine precisely the appropriate seal to accept the echoes.
- Nmult and Wmult : these values are correction factors to adjust the TVG functions of both channels (narrow and wide beam channels), if needed. Our equipment never failed, that is why we always adopted the value of 1 for both and this, for the whole TVG range as shown on the picture.
- Range factor : is used just for the display of the echogram or the oscilloscope on the Windows™ screen. It is a multiplier of the total strata range. In our example, shown on the picture, the range factor is 1.5 and our depth maximum range is 102 meters depth; the display of the echogram will show a picture from 0 until 153 m.

8.2.7 Single Target Criteria

Echoes which exceed the noise threshold (see Strata Definition just before) are subsequently classified as single or multiple targets. Multiple targets must be rejected for Target Strength measurements. To be classified as a single target an echo must satisfy minimum and maximum pulse width criteria. In this way each reception is analyzed and each echo filtered before being accepted for computerizing. The ESP analyses pulse width of each echo at the half (-6 dB), at the quarter (-12 dB), at the eighth of its signal peak

- Report Single Targets to disk : select this box if you want all processed single targets written to disk It is obvious that we always select this function for post-processing purpose. This option exists to avoid, if useless, the tremendous amount of disk place taken by lot of echoes.
- Pulse Width : is shown, here, the value of the pulse width you entered at the beginning, in the Sounder Parameters criteria menu (see paragraph : Setup/ Sounder Parameters).
- Pulse search Window : this parameter applies to both the narrow and the wide beams. It indicates to the processor how far on either side of the peak to search for the -6 dB, -12 dB, -18 dB points of the echo signal. The size of the pulse Search Window is specified as a percentage of the pulse width. For example, if the pulse width is 0.4 ms and the pulse search window is set at 100%, the processor will search 0.4 ms on either side of both the narrow beam peak and the wide beam peak. If one returned echo on one beam or both beams is wider than the search limits, this echo will be rejected by the processor.


Single Target Criteria

☑ Report Single Targets to Disk

Pulse Width 0.4 mSec

Pulse Search Window 100 %

Wide Peak Search Window 50 %

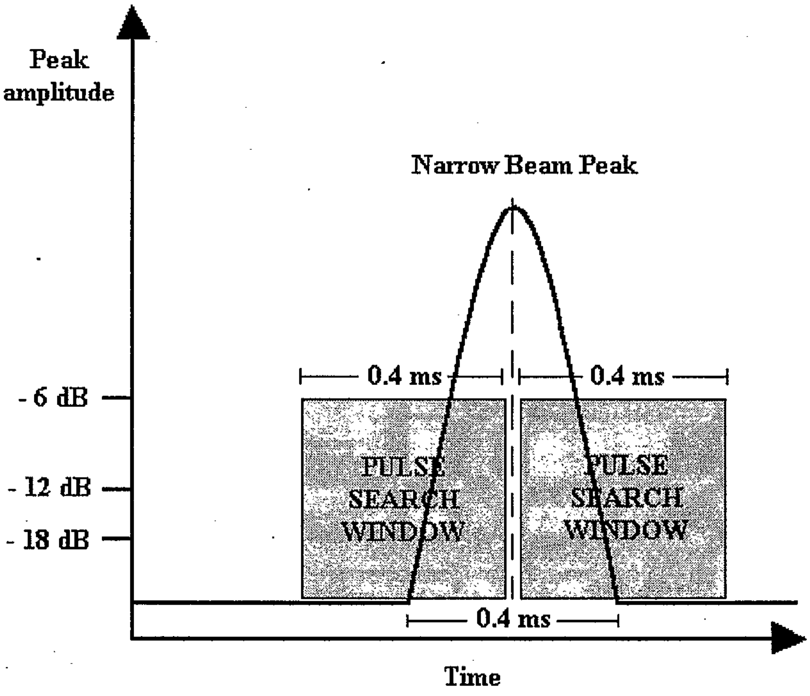
1/2 Amp PW ☑ Limit

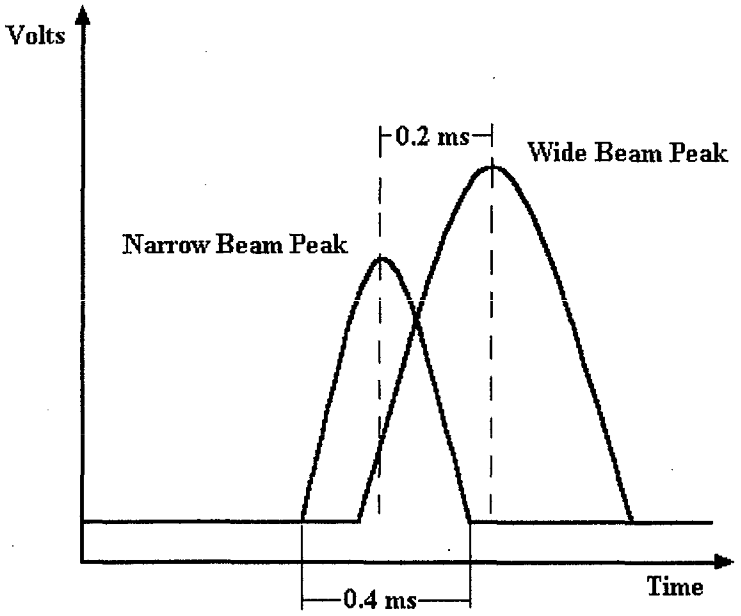
	mSec		Samples
1/2 Amp PW	0.4	Min	10
	0.6	Max	15
1/4 Amp PW	0.4	Min	10
	0.72	Max	18
1/8 Amp PW	0.4	Min	10
	0.8	Max	20

1/4 Amp PW ☑ Measure

1/8 Amp PW ☐ Disable

- Wide Peak Search Window : This second criteria indicates how far on either side of the narrow peak echo, the processor is to search for the wide peak echo of the same ping. As before, this criteria is expressed in percentage of the pulse width. For example, if the pulse width is 0.4 ms, and the wide peak search is set at 50 %, the processor will search 0.2 ms on either side of the narrow peak for the wide peak echo. If the echo returned on the wide beam is out of this limit, it will not be accepted for further comparison.





- Pulse Width Measurement Criteria : (1/2, 1/4, 1/8 amplitude pulse width). You may select, for each amplitude level the limits of the pulse width by time in milliseconds or by number of samples within each pulse (see chapter 7.2 - "The software-Figure 72"). There is a check box for each of the three levels. If you click on this box, three options are proposed :

⇒ Limit
⇒ measure
⇒ disable

If you select "limit", the ESP will apply the pulse width limits on both beams at the amplitude level (1/2, 1/4, 1/8). If you select "measure", the processor will measure all echoes without limitation criteria. If you select "disable", these measurements at the referenced echo levels will not be made. We always used the settings shown on the picture, that is to say :

⇒ For the 1/2 amplitude : limit
⇒ For the 1/4 amplitude : measure (in order to confirm the former measure)
⇒ For the 1/8 amplitude : disable (less interesting)

The processor, itself, gives us default values related to the pulse width used by the echo-sounder. Usually this help, very useful, matches with the settings of the sounder parameters. The important thing is to enter, at the early beginning, at the Setup menu Sounder parameters, the right value of the pulse width actually used.

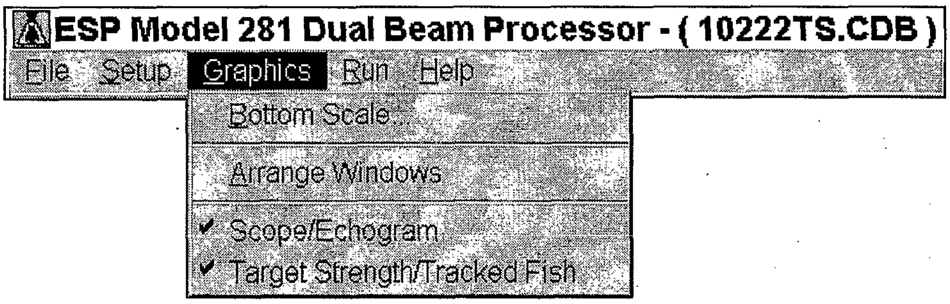
8.2.8 Tracked Fish Criteria

This function is generally used for fixed-location fish tracking (see chapter 5.5.2 - "The orientation of the fish"). In fixed-location studies, the basic function is the echo-counting. Thus, results expressed in terms of numbers of fish is needed rather than TS averages. This function requires input of many criteria, acting as filters which are algorithms such as : tilting of the target, convexity of the target, inflection of the fish, limit of range, search window,... On non-stop survey, the tracking is jeopardized because of the ship's motion and, actually fish tracking cannot provide the direction of the fish movement and therefore its tilting, because of the ordinate system motion (the transducer).

Moreover, this item uses a lot of disk place to store data (in fact twice an ordinary file). That is the reason why we rarely used this item which was disabled. (enable fish tracking remaining blank).

We have just finished with the Setup family and can jump to the next column on the right named : **Graphics.**

8.3 Graphics



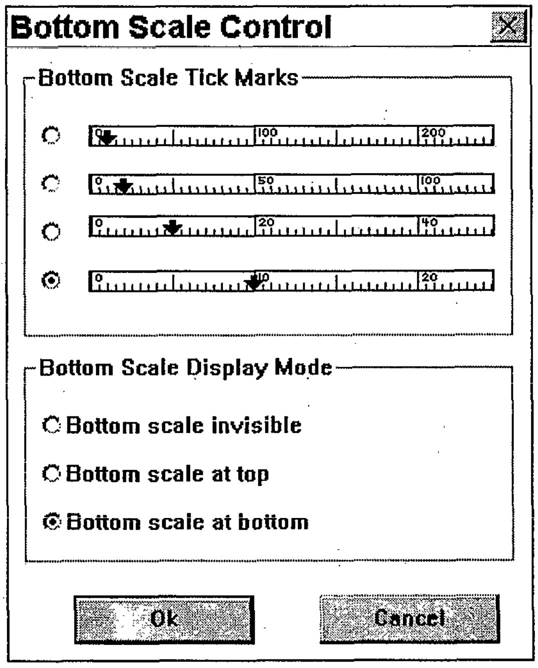
This Graphics menu allows you to control the display of graphics on the screen. There are five types of real-time displays :

- An oscilloscope (scope) display : similar to a real oscilloscope screen
- An echogram display : similar to chart recording
- A frequency plot of the Target Strength vs Depth
- A frequency plot of Tracked Fish vs Depth
- Bottom Scale and bottom tracking ruler.

8.3.1 Bottom Scale

It is the ruler stretching horizontally across the screen. It can be used as a visual aid to preset a bottom or to control the bottom tracking in manual mode. By using the mouse, you can move the cursor of the ruler until the value you want. It also shows the bottom preset you select before with the former menu.

We usually use the settings shown on the following picture in order to come back at the preset position of the bottom window and adjust quickly as close as possible the last lost bottom position. By this means, we help the automatic search process and gain some time. The scale at the bottom of the Windows display is better than the top already filled with the menu bars.



Bottom Scale Control

Bottom Scale Tick Marks

○ 0 … 100 … 200
○ 0 … 50 … 100
○ 0 … 20 … 40
● 0 … 10 … 20

Bottom Scale Display Mode

○ Bottom scale invisible
○ Bottom scale at top
● Bottom scale at bottom

8.3.2 Arrange Windows

Clicked to rearrange quickly the display of the different windows on the screen in the best fit.

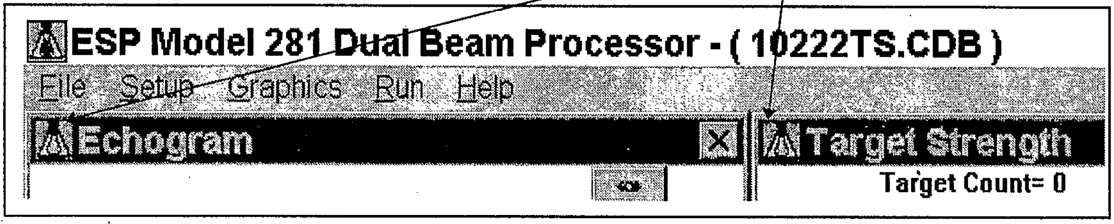
8.3.3 Scope / Echogram

This item must be clicked in order to display the scope or the echogram. If not clicked you will get an empty space for other display you wish.

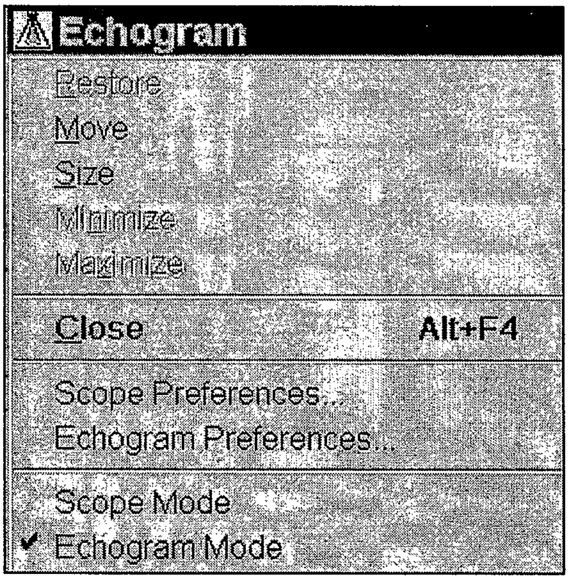
8.3.4 Target Strength / Tracked Fish

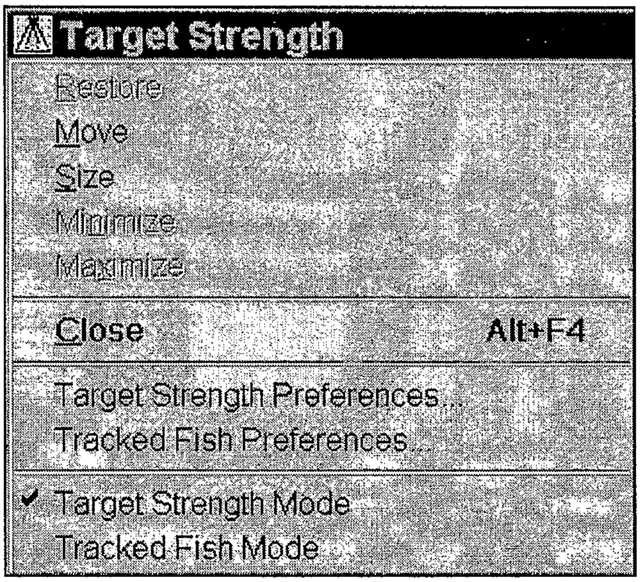
The same function as before, to display the frequency plot of the Target Strength vs Depth or the frequency plot of Tracked Fish vs Depth.

If these two graphic displays are selected, it is usually the default case and also the usual case, a Windows screen appears like in the former Figure 73. The choices between the scope / echogram display, the Target Strength / Tracked Fish plot are made from the small boxes located just close to either plot names.



When you click on this small boxes, you have access at special menus where colour preferences, modes and other settings can be changed. The submenus are shown below :

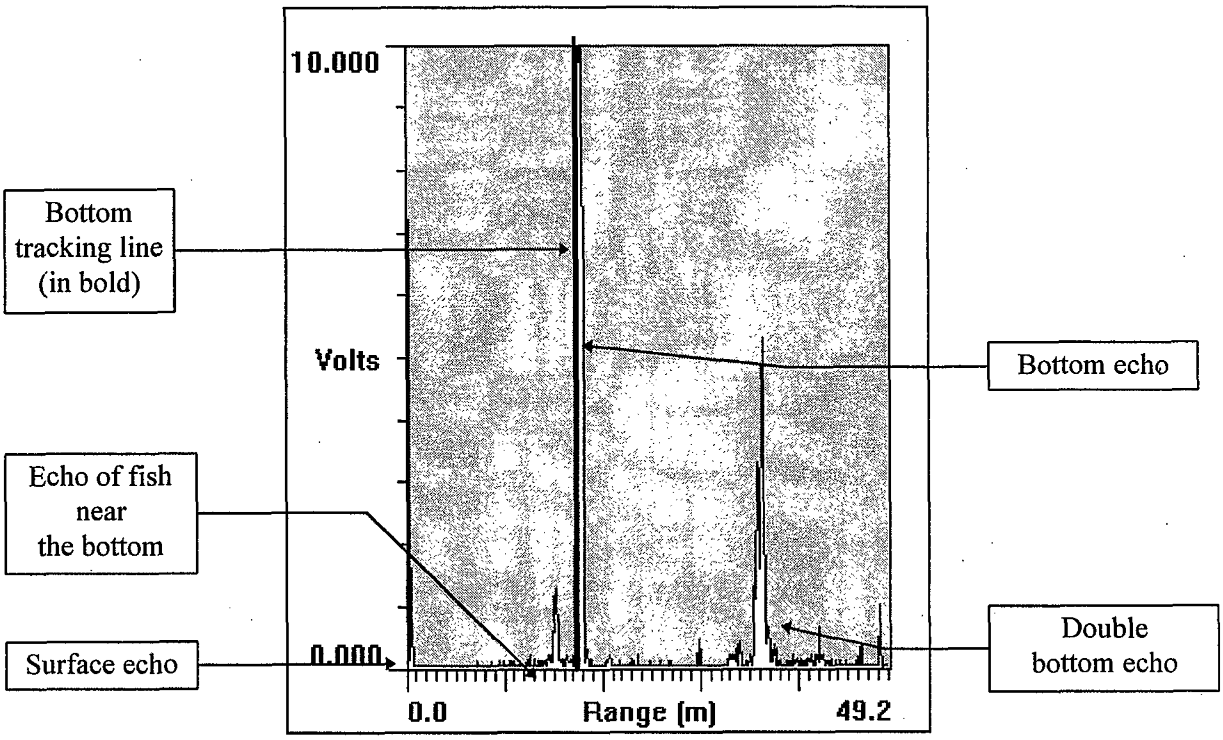




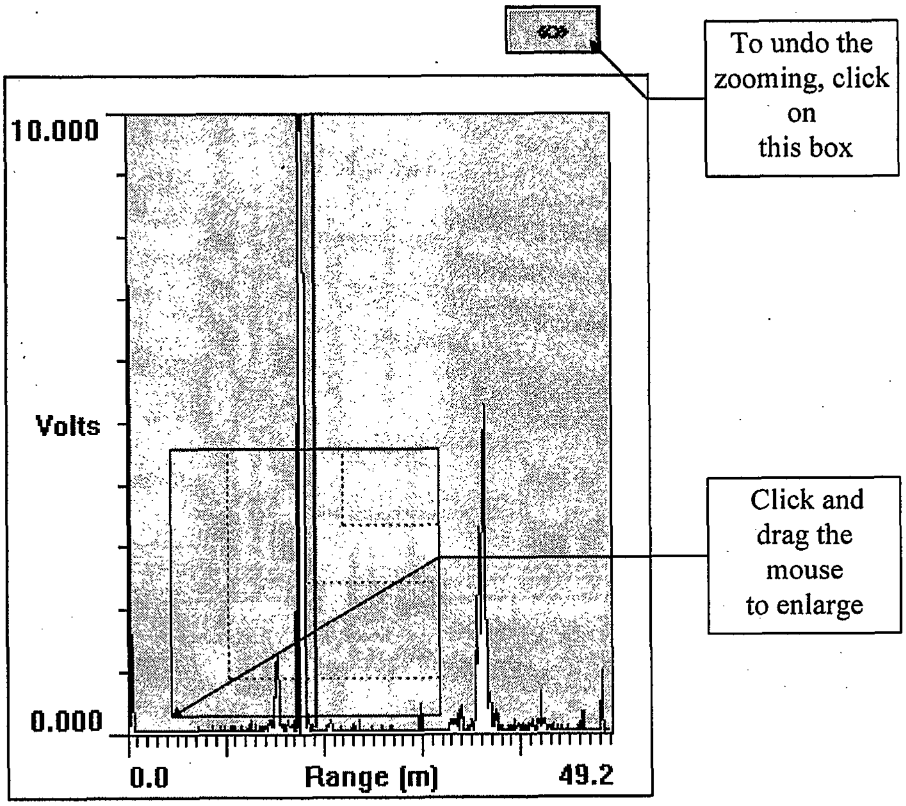
* **The Scope Mode**

The Scope allows you to monitor the narrow beam echo signals, as well as the position of the bottom location signal. It appears as a vertical line extending from bottom to the top of the display.

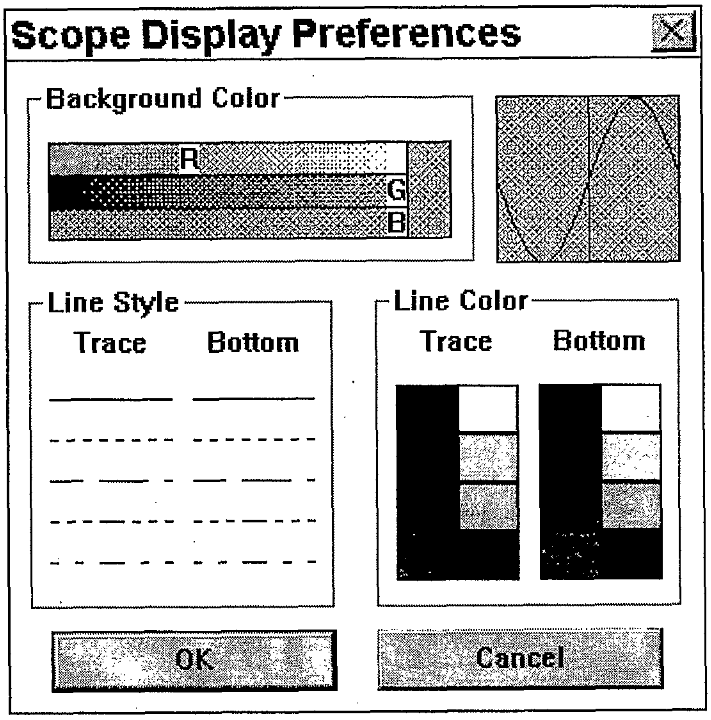
The scope is triggered by the sounder's synchro pulse. The maximum voltage scale (vertical axis) is 10 volts. The maximum x-axis is the lower limit of the last strata you entered in the Setup/Strata Definition menu.



To enlarge (zoom) the graphic, click on the graph and hold down to delimit the interesting area, then release the mouse.



- **The Scope Preferences**


Scope Display Preferences

Background Color

Line Style

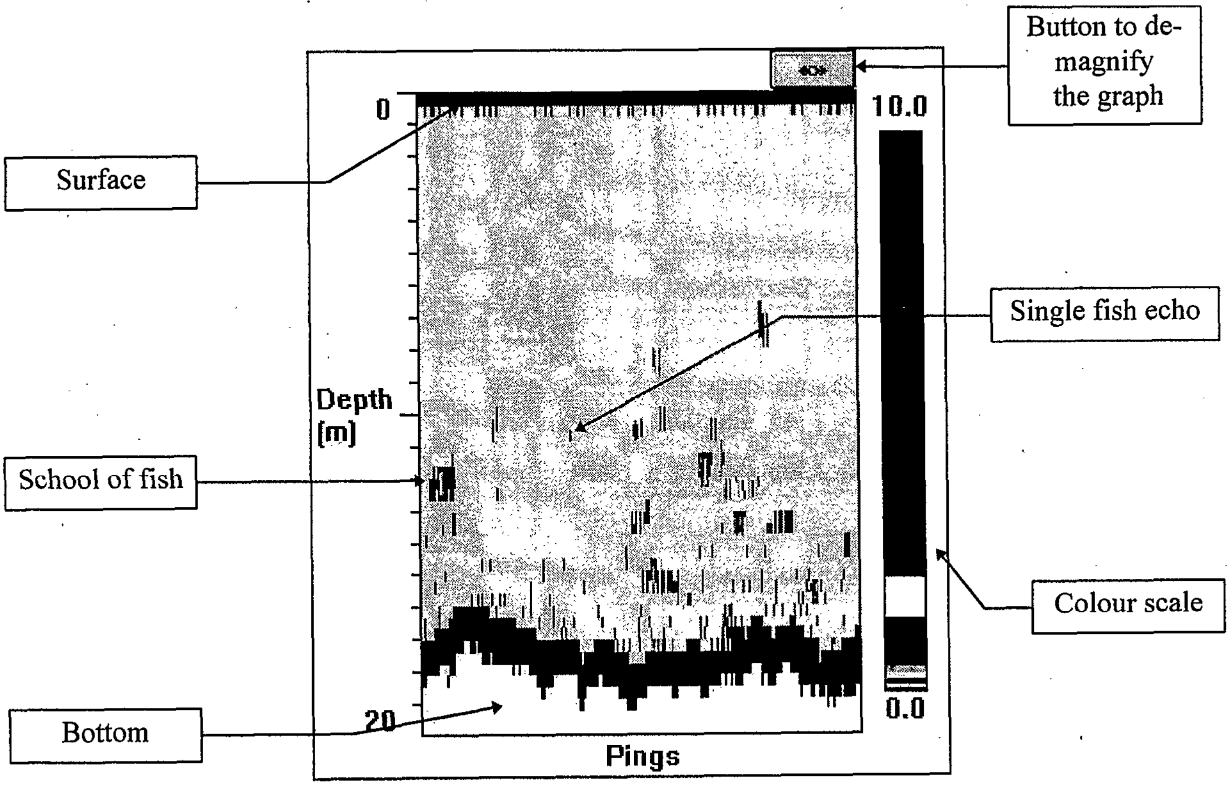
Trace | Bottom

Line Color

Trace | Bottom

This dialog box allows us to specify colours and line styles displayed on the scope which represents the incoming signal and the bottom tracking signal.

- **The Echogram Mode**

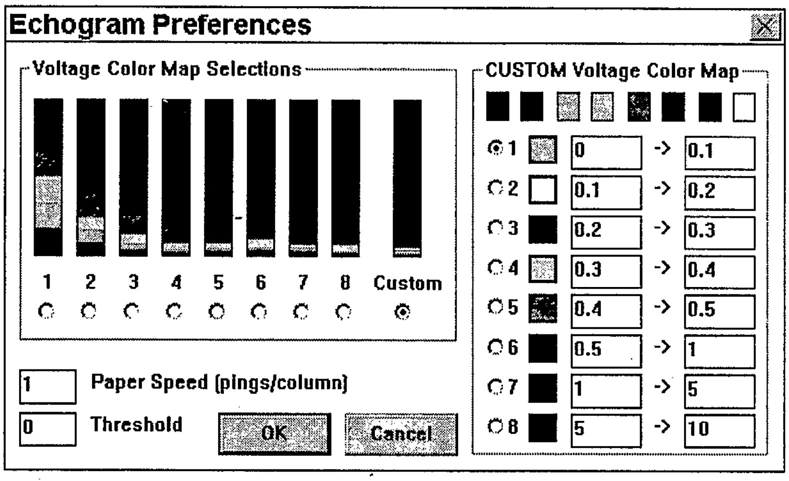


This is a colour chart recording identical at the classical one used in parallel. The transducer line is at the top of the screen; the vertical line represents the depth in meters At first, the maximum depth range entered in the Setup/strata menu is displayed; enlarging is available in the same way as for the scope, by clicking and dragging the mouse across the graph. The echoes are represented as coloured spots at their corresponding range from the transducer. The colour of the marks indicate a voltage range defined in the Echogram Preferences explained just after. The whole display advances across the screen triggered by the successive pings of the echo-sounder (the sounder's synchro pulse), which is similar to a paper advance.

* The Echogram Preferences

This dialog box is used to define the colour range, the threshold of the display, and also the rate of the "paper advance".

- The Voltage Colour Map Selections offer eight preset choices of colour codes. The ninth one is at custom disposal : its setup is made by filling the box on the right (**Custom Voltage Colour Map**), by choosing the colour and the voltage range (minimum and maximum value corresponding to the colour).



Echogram Preferences

Voltage Color Map Selections

1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ Custom ●

CUSTOM Voltage Color Map

● 1 0 -> 0.1
○ 2 0.1 -> 0.2
○ 3 0.2 -> 0.3
○ 4 0.3 -> 0.4
○ 5 0.4 -> 0.5
○ 6 0.5 -> 1
○ 7 1 -> 5
○ 8 5 -> 10

1 Paper Speed (pings/column)

0 Threshold

OK Cancel

- The Paper Speed (pings/column) is used to adjust the horizontal scrolling of the display. The speed is based on pings per column. The fastest is 1, the slowest is 100.
- The Threshold (in volts) only affects the display and doesn't intervene in the ESP processing of the echoes. Weak incoming signals (below this value) will not be displayed and meanwhile they could be processed regarding to their levels and the effective processing threshold entered in the Setup/ Strata definition.

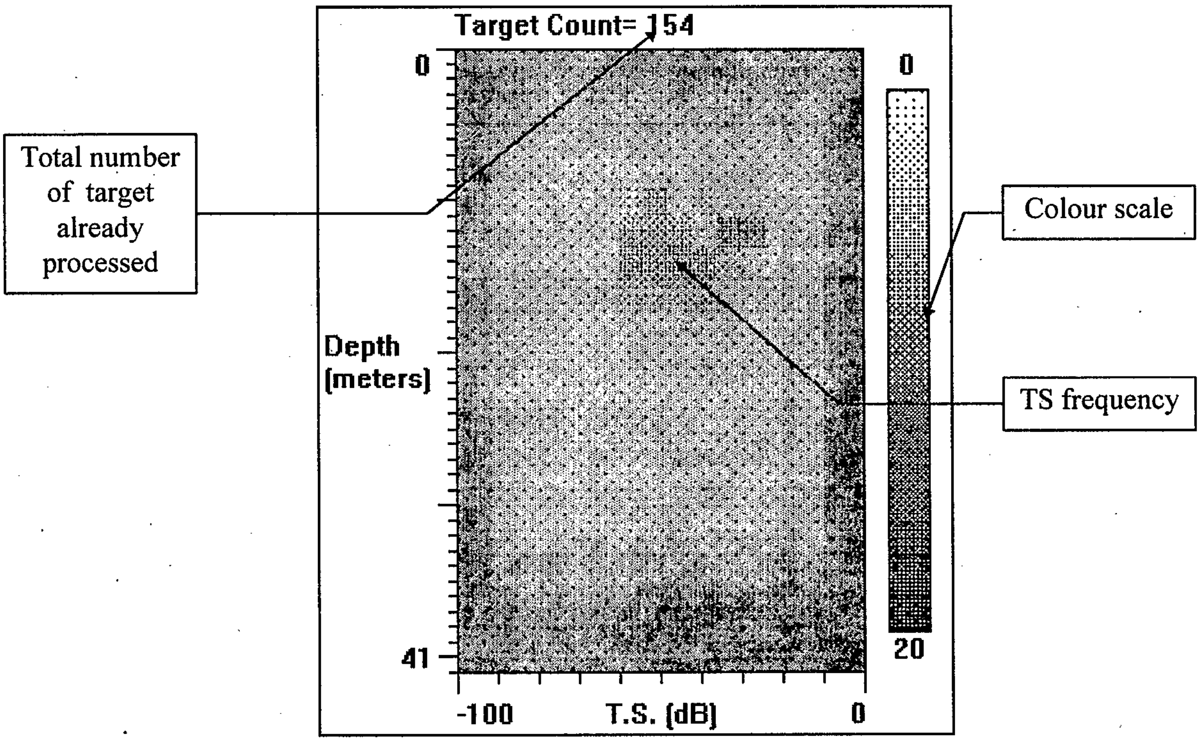
* Target Strength Mode

The Target Strength mode shows Target Strengths in decibels on the x-axis and their corresponding ranges (depth) on the y-axis. Frequency is expressed by the colour shown on the plot. The more the primary colour is dark, the more the number of echoes of the related TS is high. The default value for the TS range axis is -100 dB to 0 dB and, of course, can be enlarged in the same manner as before by clicking and dragging. The default value for the depth (y-axis) is the total range issued from the Setup/Strata definition menu, as usual.

The target count displayed at the top of the plot can be used to limit, in quantity and time, the TS measurement. In order to have accurate TS averages, it is recommended to collect a minimum target count of 10 000. It is not worth to go any longer, for two reasons : firstly, it takes a significant memory place (10 000 targets is equivalent to 400 kbytes, that means a 3.5" diskette can store 3 TS files);

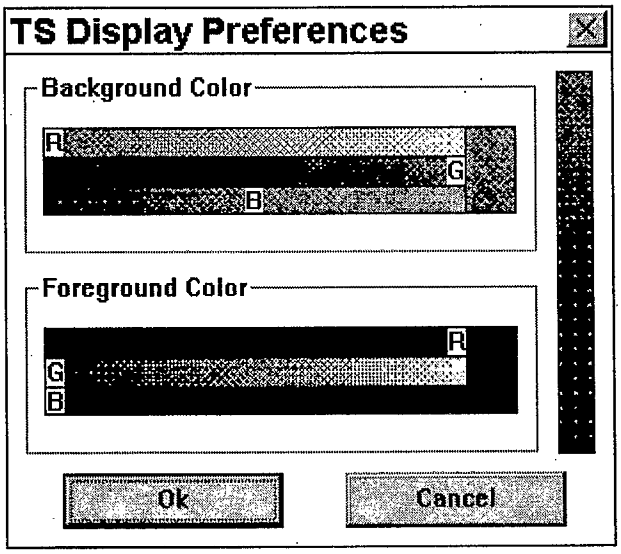
secondly, if the targets are scarce, it takes a long time, and during this time, the ship is still going on; consequences : the average will not be the actual spontaneous representation of targets well localized, and thus, it would be difficult to sort species and place if the distance is too long.

At the end of each *run* (time subdivision of the motherfile, preset in Setup/Output File Control), the counter is reset; therefore, it is necessary to add up all the target count from the beginning in order to decide when to end.



* **Target Strength Preferences**

Like before, this dialog box allows you to specify the colour of the background and the colour scale of the TS (foreground colour); the colour shown at the bottom of the vertical bar represents the highest frequency of observations on the Target Strength plot.



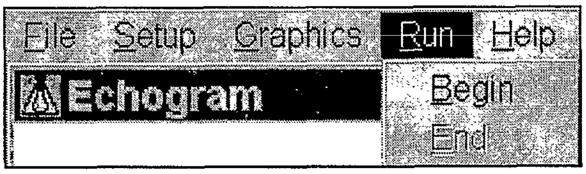
- **Tracked Fish Mode**

This mode is similar to the TS mode and is mainly used on fixed location studies. The plot is the same and the frequency shows the number of fish whose characteristics have been defined in the Setup/Tracked fish criteria.

- **Tracked Fish Preferences**

This dialog box is similar to the TS's.

8.4 Run



8.4.1 Begin

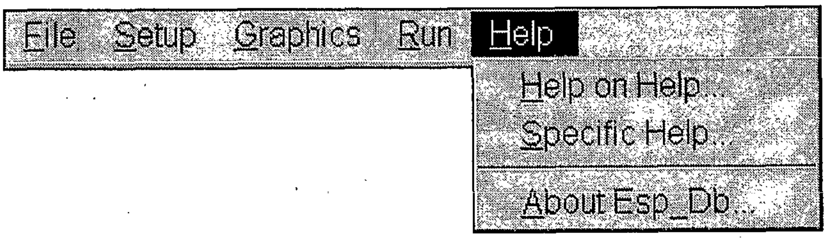
When all the settings have been entered or checked, click on **Begin** to start the TS measurements. To avoid any mistake, the most important part of the parameters seen before cannot be changed while running. In this case, the texts are grayed. The safety of the data collection obliges the user to end first the run being going on. When stopped (**End**), all the menu items are available for change; in this case, the texts are black.

8.4.2 End

By clicking the End item, you stop the process and close the subfile called "run". If you start again by clicking the Begin item, the next run will be incremented as a continuity of the same "motherfile" (in our example, the motherfile is SPHER953.DAT). To close a (mother) file, you must in any case, first end by clicking the End item and then change the name of the file by calling the Setup / **Output File Control** menu item before starting a new data collection.

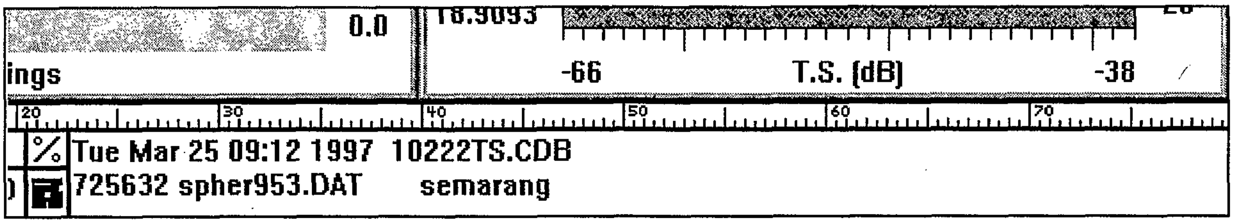
Warning : each time you run ESP_DB, check first your output file name in the Output File Control !

8.5 Help



The classical Windows™ Help on the Esp_db software. Referred by chapter or in alphabetical order. To conclude, the version and the copyright of BioSonics Incorporation.

To conclude this topic, we have to explain the items remaining. These items are displayed permanently at the bottom of the screen, as shown below :



```
Tue Mar 25 09:12 1997  10222TS.CDB
725632 spher953.DAT      semarang
```

On the left of this picture, are two boxes : one with the symbol %, the second one with a diskette representation. The first one (%), is the only available ; when double-clicked, it allows us to write comments or to call information from the file managing. These commands are :

%a	which allows us to display the actual Date and Time (without seconds)
%d	only the Date is displayed
%h	only the Time is displayed
%j	is the Julian Date
%k	Free disk place in kilobytes
%m	Free memory in kilobytes
%o	Output file name
%p	Ping number
%t	Temperature sensor (we had no sensor)
%x	Latitude
%y	longitude
%la	Long form of Time and Date
%lc	Long form of Configuration file name
%lh	Long form of Time of the day
%lo	Long form of Output file name

We can entry more than one % command to add up the information; for example, if we want to display the Date and Time (short form), the File Name and the Free Disk Place, we will enter, after double-clicked on the box :

%a %o %k

To validate the selection, we have to double-click again and the comment are displayed immediately.

We are allowed at any moment of the measurement to write comment by double-clicking the same box and positioning the cursor after the % serie, straight write any text. In the same manner to validate all, a double-click , always on the % box is needed.

In our example (see picture above), **%a %c %k %o SEMARANG** (in full letters) have been entered. We also can see the free disk place remaining (725632, in bytes) and the name of the File (spher953.dat).

This chapter is closing the THE ESP_ DB PROCESSOR topics; following, the **ESPTS** software which is the postprocessing program of the acoustic data collected with the ESP_DB facilities.

ESPTS

INTRODUCTION

The ESPTS program calculates the Target Strength (TS) from the rough data files collected by the ESP Model 281 Dual-Beam processor.

This program can process up to 25 files at a time, separately or regrouped, but uses the same calibration and processing parameters during the same process (because they are input at the very beginning of the program execution). It is often the case because we usually have and keep the same sounder's settings during surveys. Therefore, one must be very careful and check first if ever one of the files has different sounder characteristics and/or processing parameters during the data collection. If so, this file will have to be processed separately from the others.

The outputs are:

- Average Back Scattering Cross-section (Sigma, σ)
- Average TS
- Standard deviation
- Total number of recorded targets
- Number of targets used for statistics (echoes effectively recognized after filtering of the user's parameters).

In option, we also have:

- The table of the Target Strength distribution vs Depth
- The number of targets with a Beam Pattern > 0 dB (doubtful echoes suffering of overlapping or noise,etc.)
- Density estimation (Echo-Integration)
- One ASCII file containing all the pings with their characteristics (voltages, pulse duration, depth,etc.). Its is a big file usually used for zooming each ping, but it is also a big consumer of listing paper when printed
- One file for 3D plotting, TS vs Depth
- One transfer file for the ESPCRNCH program (CRUNCH program which mixes TS and Echo-Integration files to calculate a biomass).

The ESPTS needs 2 basic programs, usually resident in the same directory (or subdirectory) as the executive in order to gain access time and to be linked without any path. They are:

- **The Calibration File** which contains the calibration data of the transducer and the sounder (Source Level SL, and Receiving sensitivities of the channels RS ch1, RS ch2, for 40 log R and 20 log R,etc.). These data are from the manufacturer's data sheets but must be updated regarding your own calibration with the standard sphere or by means of hydrophone.
- **The Processing Parameter File** which contains the parameter settings of the echo-sounder while TS measuring.

Usually, the **Calibration File** does not need any modification if the results of the sphere calibration are satisfying.

The **Processing Parameter File** related to the settings of the operator during the measurement has to be modified in order to match with the controls effectively in use while measuring. For example, the Power, the Receiver Gain, the Threshold used,etc. For a more selective processing, one may need to fix new parameters such as new Threshold, new Target Pulse Duration Criteria,etc.

INSTRUCTION FOR USE

This program is installed within the ESP Directory and in the subdirectory ANALYSIS

(C:\ESP\ANALYSIS)

Here below is shown the content of this subdirectory (from XTREE software) :

```
Path: C:\ESP\ANALYSIS                          9-04-96 11:51:13 am
+------------------------------------------------------------------------+
_ 102-22  .CAL     ADDENDUM.DOC       ORDER .DOC
_ 102-22  .PAR     APPNOTE .TXT       PKSFX .PGM
_ 102-22B .PAR     B .                PKUNZIP .EXE
_ 102-22C .CAL     CAL .              PKZIP .EXE
_ 102-22C .PAR     CHKLIST .MS        PKZIPFIX .EXE
_ 102-22CG.PAR     COCO .CAL          PRNT .BAT
_ 102-22D .PAR     CPROC .            PROC .
_ 102-22E .PAR     DEDICATE .DOC      README .DOC
_ 102-22G .PAR     ESPCRNCH .EXE      SPLITTER .EXE
_ 102-22L .PAR     ESPTS .EXE         TVG1-95 .OUT
_ 102-22P .PAR     ESPTSNEW .EXE      TVG1-95 .UUT
_ 102-22S .CAL     ESPTSOUT .TXT      WHATSNEW .110
_ 102-22S .PAR     GCOPY .EXE         WHEREIS .EXE
_ 102-22X .PAR     GDEL .EXE          ZIP2EXE .DOC
_ 105-020A .PAR    LICENSE .DOC       ZIP2EXE .EXE
_ 105-20A .CAL     MAKESFX .COM       ZIPPER .EXE
_ 105-22 .CAL      MANUAL .DOC
_ 105-22 .PAR      NEW_END .EXE
_ 10522TS .CAL     OMBUDSMN .ASP
```

To run the ESPTS program, we must be in the Root Directory "C:\" in MSDOS mode. We then access to the subdirectory (ANALYSIS) via the mother directory ESP as :

```
C:\ cd ESP              <enter>
C:\ESP\ cd ANALYSIS     <enter>
```

After the prompt C:\ESP\ANALYSIS, you have to type <ESPTS> (or <ESPTSNEW>, if it is a new version) and the program will start.

Immediately, this header is displayed :

```
************** TS Version 2.31 **************
        Dual Beam Data Reduction Program
   For ESP V1.x, V2.x, V3.x, and DBM data files
*************************************************
(c) Copyright BioSonics Inc., 1 March, 1995 for BioSonics Consulting Division and Friends Serial
Number
  This program uses ESP output files and will process up to 25 data files. The processing parameters
will be the same for all input.
```

At the first question : < ***route printer output to disk file ?*** > You must answer :

- YES (**Y**) - if you want to save, on the Hard Disk or diskette, the file (s) which is (are)) about to be processed in an editable format (Excel or else)
- NO (**N**) - if you only want a printing output or only a display output on the screen. This display will be limited by its dimensions and will show only the lowest lines of the postprocessing which are the most important.

If you answer YES, a file will be created similar to the display scroll and will be named systematically (default name): **ESPTSOUT.TXT**. Do not forget to rename it before any new processing because it will be overwritten due to this default routine. The best way to proceed is to give at this new file a name very close to the rough data file name from where they have extracted. For example, we have processed a rough data file named "TRY123. DAT". The output file , per default, is "ESPTSOUT.TXT". We may rename this new saved file as : "TRY123.TXT".

Just after this choice, it will be asked to enter the name of the rough ESP Data File to be processed with the following prompt :

Enter Drive, Path, and Name of the ESP Data File **[C:\DBDATA\ name of the file.DAT]** ***or press*** **<Enter>** ***to end input list.***

FILE NAME =

Just after entered the rough data file name, a second prompt line asks for a new file such as before:

FILE NAME =

Enter the new name if necessary; you are allowed to enter until 25 files. If not, just press ENTER and the following step will appear:

< Enter file name for X1 calibration parameters: (return for none)>

It is precisely here that must be entered the Calibration File we have presented before (102-22.CAL). **102** is the number of the echo-sounder , **22** the number of the transducer **.CAL** because related to the BioSonics calibration. Enter 102-22.CAL without any optional path because already stored in the same subdirectory ESPTS\ANALYSIS.

If you press **return** instead of entering your file name, you will have to fill again the entire menu, which is fastidious; that is the reason why recalling a pre-stored file is so useful !

At once, a listing is displayed with 13 main lines. Following here, for a better understanding, these lines are left blank. In fact, they are completed with all the calibration values from BioSonics, corrected and related to our own measurements. We will see the complete listing further. The most important values are: the **Source Level** of the transmission and the **Receiving Sensitivities** of the channels.

(1) CALIBRATION DATE (MO/DA/YR)
(2) ECHOSOUNDER SERIAL NUMBER
(3) SYSTEM OPERATING FREQUENCY
(4) TVG STARTUP RANGE IN METERS
(5) ABSORPTION COEFFICIENT AT CALIBRATION (dB/km)
(6) RECEIVER RANGE AT CALIBRATION
(7) RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 1, 40logR:
    RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 1, 20logR:
    RECEIVING SENSITIVITY AT CAL RANGE SIMULTANEOUS 20logR:
    RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 2, 40logR:
    RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 2, 20logR:

(8) SOURCE LEVEL FOR EACH TRANSMIT POWER SETTING:
For 105 Sounders, Enter <0> for settings other than ZERO
If Value was not measured, enter estimate as a negative value.
AT 0 TRANSMIT POWER
AT -3 TRANSMIT POWER
AT -6 TRANSMIT POWER
AT -10 TRANSMIT POWER
AT -13 TRANSMIT POWER
(9) TRANSDUCER SERIAL NUMBER:
(10) CABLE LENGTH AT CALIBRATION (METERS):
(11) TRANSDUCER IS SIDE BY SIDE CIRCULAR " DUAL BEAM"
NOMINAL BEAMWIDTHS WHERE APPLICABLE:
NARROW BEAMWIDTH, OR LONG AXIS OF NARROW ELLIPSE:
SHORT AXIS OF NARROW BEAM ELLIPSE:
WIDE BEAMWIDTH, OR LONG AXIS OF WIDE ELLIPSE:
SHORT AXIS OF WIDE BEAM ELLIPSE:
(12) WIDE BEAM DROPOFF IN dB:
"A" COEFFICIENT FOR POWER EQUATION:
"B" COEFFICIENT FOR POWER EQUATION:
(13) AV. SQUARED NARROW BEAM PATTERN FACTOR:
AV. SQUARED COMPOSITE BEAM PATTERN FACTOR:

Explanations:

line (1) CALIBRATION DATE (MO/DA/YR) - Any comment (number/letter can be entered included slash marks)

line (2) ECHOSOUNDER SERIAL NUMBER - Any comment (number/letter can be entered included slash marks)

line (3) SYSTEM OPERATING FREQUENCY- This is the acoustic frequency of the Echo-sounder and of course the transducer. In our case the frequency is: 120 kHz

line (4) TVG STARTUP RANGE IN METERS - Our Echo-sounder has a built-in TVG circuit which is preset at 1.25 meters to 125 meters. So, the startup is : 1.25

line (5) ABSORPTION COEFFICIENT AT CALIBRATION (dB/km) - The factory calibration has been performed in tank filled with fresh water. Thus, the Absorption coefficient is 0.00

line (6) RECEIVER RANGE AT CALIBRATION - Because all the calibration results are referred at 1 meter, the receiver range is 1.00

line (7) RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 1, 40logR: - This is the Receiving Sensitivity for the narrow beam in 40 log R (- 173.13 dB).

RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 1, 20logR: - This is the Receiving Sensitivity for the narrow beam in 20 log R (- 155.93 dB)

RECEIVING SENSITIVITY AT CAL RANGE SIMULTANEOUS 20logR: -This is the Receiving Sensitivity of the third output, in fact a part of the first channel (the 20 log R part) and this output is always a 20 log R function for Echo-Integration purpose. (-155.93 dB)

RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 2, 40logR: - This is the Receiving Sensitivity for the wide beam in 40 log R (- 172.17 dB).

RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 2, 20logR: - This is the Receiving Sensitivity for the wide beam in 20 log R (- 154.96 dB)

line (8) SOURCE LEVEL FOR EACH TRANSMIT POWER SETTING:- These are the different values of Source Level related to the setting used.

AT 0 TRANSMIT POWER : 225.37 dB
AT -3 TRANSMIT POWER : 222.54 dB
AT -6 TRANSMIT POWER : 219.54 dB
AT -10 TRANSMIT POWER : 215.64 dB
AT -13 TRANSMIT POWER : 212.83 dB

⚠

It has been recommended by BioSonics **not to use the 0 TRANSMIT POWER** which is the highest level of transmission in order **to avoid saturation** and/or quick distortion of the transducer.

At the end of this 8th line you can intervene and correct any former value within this page before turning it, by simply enter the number of the parameter you want to change at the prompt :

< enter number parameter to change >

Press ENTER if no change is required.

A new page is displayed and starts with the line (9). This pagination is voluntary to separate the "Echo-sounder"part and the "Transducer" part which just begins :

line (9) TRANSDUCER SERIAL NUMBER: - Any comment (number/letter can be entered included slash marks)

line (10) CABLE LENGTH AT CALIBRATION (METERS): - This is to indicate if any cable conductivity loss must be involved in the different results. For 10 meters length, in fact, the attenuation due to the length is negligible.

line (11) TRANSDUCER IS SIDE BY SIDE CIRCULAR "DUAL BEAM"- One must declare what kind of transducer is used; in our case a Dual Beam is used.

NOMINAL BEAMWIDTHS WHERE APPLICABLE

NARROW BEAMWIDTH, OR LONG AXIS OF NARROW ELLIPSE: - This is the opening angle of the narrow beam, measured at the - 6 dB point of the Directivity pattern (see Chapter 4.2.4 - "The Directivity of a transducer"). Our narrow beam angle is 7 degrees.

SHORT AXIS OF NARROW BEAM ELLIPSE:- Our transducer is not elliptic; thus, this value would be 0.000

WIDE BEAMWIDTH, OR LONG AXIS OF WIDE ELLIPSE: - This is the opening of the wide beam. Our transducer has a wide beam opening of 18 degrees.

SHORT AXIS OF WIDE BEAM ELLIPSE: - Our transducer is not elliptic; thus, this value would be 0.000.

line (12) WIDE BEAM DROPOFF IN dB: - Here is the multiplier to correct the decrease of the wide beam Directivity across the main lobe of the narrow beam, also called the WIDE BEAM DROPOFF (see Chapter 6.2 - "The Dual-Beam method"). Our Wide Beam Drop-off is : 1.109 dB

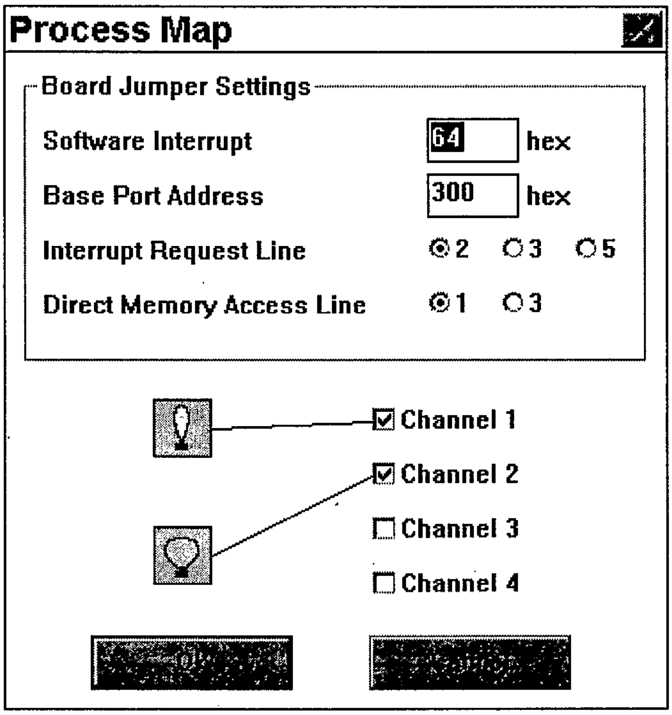
"A" COEFFICIENT FOR POWER EQUATION:
"B" COEFFICIENT FOR POWER EQUATION:

- These are regression parameters from a power function relating beam pattern and beam angle; they usually never change and if so, a special calibration must be made. It is recommended not to change

MINIMUM -12dB PULSE WIDTH IN msec
MAXIMUM -12dB PULSE WIDTH IN msec
MINIMUM -18dB PULSE WIDTH IN msec
MAXIMUM -18dB PULSE WIDTH IN msec
(10) RECEIVER GAIN USED TO COLLECT DATA
(11) TRANSMIT POWER USED TO COLLECT DATA
(12) MAXIMUM HALF-ANGLE FOR PROCESSING TARGETS
(13) HISTOGRAM CENTERED ABOUT WHAT TS VALUE
(14) BEAM PATTERN FACTOR > ZERO THRESHOLD IN dB

Explanations:

line (1) NARROW BEAM CHANNEL NUMBER - is required the reference number of the narrow channel, usually 1; it must match with the Setup / Process Map, entered while starting the ESP_DB program, as shown below (see Chapter 8.2 -"SETUP").



Process Map

Board Jumper Settings

Software Interrupt 64 hex

Base Port Address 300 hex

Interrupt Request Line ● 2 ○ 3 ○ 5

Direct Memory Access Line ● 1 ○ 3

☑ Channel 1

☑ Channel 2

☐ Channel 3

☐ Channel 4

line (2) NARROW BEAM CORRECTION MULTIPLIER: - Arbitrary value given as the correction factor of the narrow beam gain; here : 1 ; that means that we take this narrow beam as the channel of reference for any voltage correction. The correction is made by multiplying the values by the correction factor; for this channel, because the factor is 1, the voltage values are fully accepted without any change.

line (3) WIDE BEAM CORRECTION MULTIPLIER : - The correction multiplier for the wide beam is AUTOMATICALLY computed from the Calibration File, just studied before. The narrow and wide beam sensitivities for 40 log R, entered in line (7) of the Calibration File are converted from decibels to volts (V_n and V_W). As we have seen just before, the narrow beam correction multiplier is set to 1. The wide beam correction multiplier is computed as V_n/V_W. In our case, we have the following calibration results:

RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 1, 40logR: - 173.13 dB. ($RSch1_{40}$)
RECEIVING SENSITIVITY AT CAL RANGE CHANNEL 2, 40logR: - 172.17 dB. ($RSch2_{40}$)

Thus, $RSch1_{40}$ converted from decibels to volts (V_n) becomes: V_n = Antilog (- 173.13/20)

And, $RSch2_{40}$ converted from decibels to volts (V_w) becomes: V_w = Antilog (-172.17/20)

Then, V_n/V_w = Antilog [{- 173.13 - (-172.17)} / 20]

= Antilog (-096 / 20)

= 0.8953647655496

line (4) NARROW BEAM THRESHOLD IN mV (BEFORE CORRECTION): - This threshold value is acting as an accepted echo level limitation for the postprocessing. Of course the former THRESHOLD of the ESP_DB program, while collecting the TS data, has already been applied and the rough data recorded and postprocessed now by the ESPTS program are the accepted echo voltages issued from this first limitation.

Nevertheless, this new postprocessing threshold allows us to set up a new selection still based on the peak value limitation as before. This new threshold will be effective at the condition that the value entered is higher than the ESP_DB THRESHOLD entered in the SETUP / STRATA Definition of the ESP_DB processor- see Chapter 8.2.6.

For example : my ESP_DB THRESHOLD was 100 mV. I enter the value of 50 mV in the ESPTS as the NARROW BEAM THRESHOLD IN mV. This latter will not take into account this value; it will process the rough data already sealed during their collection without any complementary limitation. At the inverse, if I enter a value of 150 mV, the ESPTS will process the former rough data with an uprising of limitation equal to 50 mVso that the total threshold applied to the rough and processed data be effectively 150 mV

line (5) WIDE BEAM THRESHOLD IN mV (BEFORE CORRECTION): - Same as before. Because this threshold is applied before the voltages be multiplied by the correction factor, we must take into account the fact that the 2 channels are not identical and then the threshold must balance this difference. To set this threshold in order to match with the following correction, one must apply the inverse of this correction multiplier to the value of this threshold: the wide beam correction multiplier is 0.895 (see before), thus the wide beam threshold will be, if the narrow beam threshold has been set at 100 mV:

100 mV / 0.895 = 111.7 mV

line (6) MINIMUM DEPTH TO PROCESS IN METERS : - Is the starting depth value for postprocessing; usually preset at 1.25 meters which is the beginning of the TVG and also the minimum distance from the transducer which must be avoided cause of the "near field" (see Chapter 4.2.4 - "Directivity of the transducer").

line (7) MAXIMUM DEPTH TO PROCESS IN METERS : - Is the lowest limit for the postprocessing; usually matched with the SETUP / STRATA Definition menu of the ESP_DB program, between 100 meters and 125 meters.

line (8) BOTTOM THRESHOLD IN mV (BEFORE CORRECTION): - This threshold is entered in order to eliminate bottom echoes that may have been inadvertently recorded along with valid echoes; usually this threshold is the same as the setting in the ESP_DB program (see Chapter 8.2.4 - "Bottom Parameters").

line (9) MINIMUM -6 dB PULSE WIDTH IN msec : - Here are the target criteria, coming over the ones already preset and used while running the ESP_DB program. We never used these criteria because the former ones (while running ESP_DB) are enough for TS evaluations. The default values are : 9.999 and .000. The ESPTS program understands that these criteria are not requested.

MAXIMUM -6 dB PULSE WIDTH IN msec
MINIMUM -12dB PULSE WIDTH IN msec

MAXIMUM -12dB PULSE WIDTH IN msec
MINIMUM -18dB PULSE WIDTH IN msec
MAXIMUM -18dB PULSE WIDTH IN msec

line (10) RECEIVER GAIN USED TO COLLECT DATA: - The fixed gain setting on the echo-sounder must be entered; we generally used the -6 dB gain on survey.

line (11) TRANSMIT POWER USED TO COLLECT DATA:- Enter the value of the transmitter setting while collecting the TS data.

line (12) MAXIMUM HALF-ANGLE FOR PROCESSING TARGETS: - The purpose of this parameter is to eliminate targets that are detected at the edges of the acoustic beam. It is recommended to limit the processing at the half of the nominal beam width value of the narrow beam. Our transducer has a total narrow beam opening of 7 degrees, thus the half-angle will be 3.5 degrees.

line (13) HISTOGRAM CENTERED ABOUT WHAT TS VALUE : - This parameters sets the mid-range of the vertical axis for the Target Strength vs Depth histogram we can obtain with the options which will be seen after this Chapter. Usually -45 dB, a medium value often encountered.

line (14) BEAM PATTERN FACTOR > ZERO THRESHOLD IN dB : - Echoes with Beam Pattern factor greater than this value will not be accepted for analysis. Normally this threshold is zero or positive. If you do not want to use this criterion, enter 20. It would be recommended not to use this criterion or very carefully. Personally, we never used it, too much selective and very reckless.

At the end of this 14th line, you can intervene and correct any value within this menu, by simply enter the number of the parameter you want to change at the prompt :

< enter number parameter to change >

Press ENTER if no change is required.

As before, the values stored at the present time, are peculiar to our echo-sounder and our surveys; for any sounder or settings else, these values will have to be matched and entered one by one related to the settings used. Then this new Processing Parameters File will be saved as a .PAR file in order to be recalled later.

After pressed ENTER, the following options are proposed:

< TS outputs can be grouped by the following: >

1) by ESP runs
2) by data files
3) all data in all files

Please enter the number of selection :

- **by ESP runs** - We have already seen that a data file was composed of subfiles called "runs"; these subfiles are limited in time or by any "begin" and "end" actions while the ESP_DB processor is running. If you choose this option, ESPTS will present a summary for each run.
- **by data files** - Each data file specified at the early beginning of the ESPTS at the prompts < Enter Drive, Path, and Name of the ESP Data File [C:\DBDATA\ name of the file.DAT] or press <Enter> to end input list. FILE NAME = > will be individually and wholly postprocessed (no run details).
- **all data in all files** - all the data files input at the prompts above will be processed at a time. The result will therefore be an average of all the TS files mixed together.

For our own convenience, we generally use the option 2.

The option number entered, a new proposal is displayed as:

< Would you like TS statistics in up to 20 specified (non overlapping) depth strata ? >

Up to you to decide the process mode. If you say YES (Y), the ESPTS program will ask you the upper and lower boundaries of each stratum you desire to study. If you do not need up to 20 strata, you can stop the list by simply input a negative value (meters) or zero when the lower boundary is asked. Be careful not to overlap the strata ! If you need juxtaposed strata, the upper limit of the stratum Y (for example) must be the same as the lower limit of the stratum X (for example).

In any case (Yes or No), the ESPTS program sums up the result of the whole water column.

After answer the question, nine **output options** are proposed; they are :

1) PRINT ESP SET-UP PARAMETERS
2) PRINT THIS PROGRAM'S CAL AND PROC FILES
3) PRINT RAW DATA FOR EACH PING
4) PRINT TARGET STRENGTH vs DEPTH TABLE
5) PRINT DISTRIBUTION OF BEAM PATTERN FACTORS GREATER THAN ZERO
6) CALCULATE AND PRINT TARGET DENSITY ESTIMATES
7) WRITE TO FILE EACH ACCEPTED ECHOES WITH TS AND BP
8) WRITE A FILE SUITABLE FOR 3-D PLOTTING
9) WRITE A FILE FOR THE ESPCRNCH PROGRAM

ENTER OPTIONS DESIRED FOR ADDITIONAL OUTPUT : (RETURN FOR NONE)

Explanations:

line (1) - Allows you to print (on the printer) the **collect parameters** of the rough data or to store them in the final file ESPTSOUT.TXT seen before, regarding to what you selected at the early beginning while prompts < **route printer output to disk file ?** > .

line (2) - Allows you to print the CALIBRATION (.CAL) and the PROCESSING PARAMETERS (.PAR) or to store them in the ESPTSOUT.TXT file (regarding to what you selected at the early beginning while prompts < **route printer output to disk file ?** >) .

line (3) - Allows you to print the data related to each echo or to store them in the ESPTSOUT.TXT file (regarding to what you selected at the early beginning while prompts < **route printer output to disk file ?** >) such as: bottom depth, target depth, ping number, voltages (narrow beam and wide beam) per ping, pulse duration (narrow beam and wide beam) per ping. That represents a very long listing output on the printer ! This option can be used only when few echoes are used for the processing. For example, this option can be used for TS measurements on live fish in cage in order to analyze each ping, one by one, or to check the algorithm of the ESPTS program.

line (4) - Allows you to print the table TS / Depth or to store it in the ESPTSOUT.TXT file (regarding to what you selected at the early beginning while prompts < **route printer output to disk file ?** >) . Always used, in any case, to visualize the spatial repartition of the echoes in the water column.

line (5) - Allows you to print the Beam Pattern Factors > 0 dB histogram or to store it in the ESPTSOUT.TXT file (regarding to what you selected at the early beginning while prompts < **route printer output to disk file ?** >) . Allows you to evaluate the number of hazardous echoes which have received a strong Directivity correction.

line (6) - Allows you to print the echo density estimate (number of fish used, equivalent beam, estimated density per cubic meter, volume estimated per cubic meter). This option is never used in TS measurements. (possibly in Echo-Integration if the BioSonics ESP_EI system is used).

line (7) - Allows you to create an ASCII file, composed of the same items as in line (3), plus the TS of each echo and its off-axis angle; consequently, it needs a lot of memory space and/or a long printer listing output. Nevertheless, this file is very interesting for sharper analysis and for the checking of the ESPTS processing. It was, in the former version, the single option to create an output disk file because there were no option **<route printer output to disk file>**. If you chose this option, the file will be saved under a different name you will be invited to precise at he prompts:

< Enter individual echo output data file name >

Like before, it would be recommended to give a file name close to the rough data file with a special extension other than the one used for the former (ESPTSOUT) .TXT.

line (8) - Allows you to create a TS file for 3D plotting (Winsurf, Surfer, Excel ...) The ordinates are :

- The TS values
- The Depth
- The number of echoes per TS interval

This file will be saved under a new name you will have to enter at the prompts:

< Enter 3D plotting output file >

line (9) Allows you to create a special file to be used with the mixing BioSonics program called "ESPCRNCH"; ESPCRNCH is a program written in FORTRAN language devoted to analysis in Echo-Integration. The file that ESPTS creates , contains the sum of sigmas (Back Scattering Cross-section), the sum of squared sigmas and the number of sigmas per stratum of 1 meter interval...

At the prompt :

< Enter options desired for additional output >

Enter the numbers (the most commonly used) without any space:

1245 <Enter>

And then, the process starts !...

The display begins to scroll and we can follow each step of the processing. At the end, due to size limitation of the screen, only the last lines are shown and the program exits, giving back the hand to the user for starting again or to quit the program.

THE RESULTS

You will find here below an example of TS file output after postprocessing the rough data through ESPTS. These results are issued from the additional option numbers 1245 and the reroute of the printer output to a disk file (at the early beginning of the execution of the program). This disk file is a .TXT file which can be imported into Winword, Excel, ...

Of course, if no file is desired but only the display on the screen, the user will run the ESPTS program without rerouting the printer output to disk file and also without filling the last part of the menu when prompts : < Enter options desired for additional output >

By simply pressing ENTER, no option will be chosen and the program will start and scroll at each step of the processing and finally will display the last lines of this process : the main results. At the end. the program stops and gives the commands back; at this moment, <u>if no option has been chosen</u>, this postprocessed output file will be lost.

```
              ************** TS Version 2.31 **************
                     Dual Beam Data Reduction Program
                  For ESP V1.x, V2.x, V3.x, and DBM  data files
              **********************************************

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Serial Number 5205-V2.31-95-000

Reading file a:\41B4.DAT
 Analyzing Run #    1
 (1) CALIBRATION DATE (MO/DA/YR)                                    12/16/93
 (2) ECHOSOUNDER SERIAL NUMBER                                      102 -91-036
 (3) SYSTEM OPERATING FREQUENCY                                     120.00
 (4) TVG STARTUP RANGE IN METERS                                    1.25
 (5) ABSORPTION COEFFICIENT AT CALIBRATION (dB/km)                  .0000
 (6) RECEIVER RANGE AT CALIBRATION                                  1.00
 (7) RECEIVING SENSITIVITY AT CAL RANGE  CHANNEL 1, 40logR:         -173.13
     RECEIVING SENSITIVITY AT CAL RANGE  CHANNEL 1, 20logR:         -155.93
     RECEIVING SENSITIVITY AT CAL RANGE  SIMULTANEOUS 20logR:       -155.93
     RECEIVING SENSITIVITY AT CAL RANGE  CHANNEL 2, 40logR:         -172.17
     RECEIVING SENSITIVITY AT CAL RANGE  CHANNEL 2, 20logR:         -154.96
 (8) SOURCE LEVEL FOR EACH TRANSMIT POWER SETTING:
    For 105 Sounders, Enter <0> for settings other than ZERO
    If Value was not measured, enter estimate as a negative value
          AT   0 TRANSMIT POWER              225.37
          AT  -3 TRANSMIT POWER              222.54
          AT  -6 TRANSMIT POWER              219.54
          AT -10 TRANSMIT POWER              215.64
          AT -13 TRANSMIT POWER              212.83

 ( 9) TRANSDUCER SERIAL NUMBER:                                     5344-022
 (10) CABLE LENGTH AT CALIBRATION (METERS):                         10.00
 (11) TRANSDUCER IS CONCENTRIC CIRCULAR DUAL BEAM
      NOMINAL BEAMWIDTHS WHERE APPLICABLE
      NARROW BEAMWIDTH, OR LONG AXIS OF NARROW ELLIPSE:             7.00
      SHORT AXIS OF NARROW BEAM ELLIPSE:                            .00
      WIDE BEAMWIDTH, OR LONG AXIS OF WIDE ELLIPSE:                 18.00
      SHORT AXIS OF WIDE BEAM ELLIPSE:                              .00
 (12) WIDE BEAM DROPOFF IN dB:                                      1.109
    "A" COEFFICIENT FOR POWER EQUATION:                             .234
    "B" COEFFICIENT FOR POWER EQUATION:                             .629
 (13) AV. SQUARED NARROW BEAM PATTERN FACTOR:                       .1353E-02
      AV. SQUARED COMPOSITE BEAM PATTERN FACTOR:                    .2387E-02
```

```
THE PROCESSING PARAMETER FILE CONTAINS THE FOLLOWING PARAMETERS

  (1)  NARROW BEAM CHANNEL NUMBER                                    1
  (2)  NARROW BEAM CORRECTION MULTIPLIER                             1.000
  (3)  WIDE BEAM CORRECTION MULTIPLIER                               .895
  (4)  NARROW BEAM THRESHOLD IN mV (BEFORE CORRECTION)               100.0
  (5)  WIDE BEAM THRESHOLD IN mV (BEFORE CORRECTION)                 111.7
  (6)  MINIMUM DEPTH TO PROCESS IN METERS                            2.0
  (7)  MAXIMUM DEPTH TO PROCESS IN METERS                            102.0
  (8)  BOTTOM THRESHOLD IN mV (BEFORE CORRECTION)                    3000.0
  (9)  MINIMUM -6 dB PULSE WIDTH IN msec                             .000
       MAXIMUM -6 dB PULSE WIDTH IN msec                             9.999
       MINIMUM -12dB PULSE WIDTH IN msec                             .000
       MAXIMUM -12dB PULSE WIDTH IN msec                             9.999
       MINIMUM -18dB PULSE WIDTH IN msec                             .000
       MAXIMUM -18dB PULSE WIDTH IN msec                             9.999
  (10) RECEIVER GAIN USED TO COLLECT DATA                            -6.0
  (11) TRANSMIT POWER USED TO COLLECT DATA                           -3
  (12) MAXIMUM HALF-ANGLE FOR PROCESSING TARGETS                      3.5
  (13) HISTOGRAM CENTERED ABOUT WHAT TS VALUE:                       -45.00
  (14) BEAM PATTERN FACTOR > ZERO THRESHOLD IN dB                    20


  FILE NUMBER  1 =                                                   a:\41B4.DAT
  DATA GROUP REPORT FOR TRANSDUCER 1
  TOTAL NUMBER OF PINGS =                                            1669
  ANALYSIS START RANGE, m =                                          1.20
  PULSE WIDTH, mSec =                                                .4000
  SOUND VELOCITY IN WATER, m/sec =                                   1531.0
  MIN - 6dB PULSE WIDTH, msec =                                      .4000
  MAX - 6dB PULSE WIDTH, msec =                                      .6000
  MAXIMUM ANALYSIS DEPTH, m =                                        101
  "LIMIT DATA COLLECTION" IS ON

 DATA FOR FREQUENCY 120.
----------------------------------------------------------------------------

 SUMMARY OF DATA FROM DEPTH   2.0 TO 102.0

                          DEPTH INTERVALS

   FROM   2.00   12.00   22.00   32.00   42.00   52.00   62.00   72.00   82.00   92.00
     TO  12.00   22.00   32.00   42.00   52.00   62.00   72.00   82.00   92.00  102.00
  TS                                                                                     SUM
---------------------------------------------------------------------------------------------
  -74 |      0       0       0       0       0       0       0       0       0       0     0
  -72 |      0       0       0       0       0       0       0       0       0       0     0
  -70 |      0       0       0       0       0       0       0       0       0       0     0
  -68 |      0       0       0       0       0       0       0       0       0       0     0
  -66 |      0       0       0       0       0       0       0       0       0       0     0
  -64 |      6      15       4       1       0       0       0       0       0       0    26
  -62 |    165     345     117      15       0       0       0       0       0       0   642
  -60 |    174     580     366      66       0       0       0       0       0       0  1186
```

```
 -58 |   138   712   560   166     0     0     0     0     0     0  1576
 -56 |    81   610   736   340     2     0     0     0     0     0  1769
 -54 |    30   344   651   564     0     0     0     0     0     0  1589
 -52 |     2   120   429   668     3     0     0     0     0     0  1222
 -50 |     1    14   170   669     3     0     0     0     0     0   857
 -48 |     0     2    17   421     3     0     0     0     0     0   443
 -46 |     0     0     6   199     0     0     0     0     0     0   205
 -44 |     0     0     0    48     0     0     0     0     0     0    48
 -42 |     0     0     0     9     0     0     0     0     0     0     9
 -40 |     0     0     0     1     0     0     0     0     0     0     1
 -38 |     0     0     0     1     0     0     0     0     0     0     1
 -36 |     0     0     0     1     0     0     0     0     0     0     1
 -34 |     0     0     0     0     0     0     0     0     0     0     0
 -32 |     0     0     0     0     0     0     0     0     0     0     0
 -30 |     0     0     0     0     0     0     0     0     0     0     0
 -28 |     0     0     0     0     0     0     0     0     0     0     0
 -26 |     0     0     0     0     0     0     0     0     0     0     0
 -24 |     0     0     0     0     0     0     0     0     0     0     0
 -22 |     0     0     0     0     0     0     0     0     0     0     0
 -20 |     0     0     0     0     0     0     0     0     0     0     0
 -18 |     0     0     0     0     0     0     0     0     0     0     0
 -16 |     0     0     0     0     0     0     0     0     0     0     0
------------------------------------------------------------------------------
 SUM    597  2742  3056  3169    11     0     0     0     0     0  9575

HISTOGRAM OF BEAM PATTERN FACTORS > 0 dB

B=  0 dB  TO B=  1 dB    NUMBER OF ECHOES =         1139
B=  1 dB  TO B=  2 dB    NUMBER OF ECHOES =          405
B=  2 dB  TO B=  3 dB    NUMBER OF ECHOES =           90
B=  3 dB  TO B=  4 dB    NUMBER OF ECHOES =           27
B=  4 dB  TO B=  5 dB    NUMBER OF ECHOES =            5
B=  5 dB  TO B=  6 dB    NUMBER OF ECHOES =            0
B=  6 dB  TO B=  7 dB    NUMBER OF ECHOES =            0
B=  7 dB  TO B=  8 dB    NUMBER OF ECHOES =            0
B=  8 dB  TO B=  9 dB    NUMBER OF ECHOES =            0
B=  9 dB  TO B= 10 dB    NUMBER OF ECHOES =            0
B= 10 dB  TO B= 11 dB    NUMBER OF ECHOES =            0
B= 11 dB  TO B= 12 dB    NUMBER OF ECHOES =            0
B= 12 dB  TO B= 13 dB    NUMBER OF ECHOES =            0
B= 13 dB  TO B= 14 dB    NUMBER OF ECHOES =            0
B= 14 dB  TO B= 15 dB    NUMBER OF ECHOES =            0
B= 15 dB  TO B= 16 dB    NUMBER OF ECHOES =            0
B= 16 dB  TO B= 17 dB    NUMBER OF ECHOES =            0
B= 17 dB  TO B= 18 dB    NUMBER OF ECHOES =            0
B= 18 dB  TO B= 19 dB    NUMBER OF ECHOES =            0
B= 19 dB  TO B= 20 dB    NUMBER OF ECHOES =            0

TOTAL NUMBER OF RECORDED ECHOES =              10106

NUMBER OF ECHOES USED FOR STATISTICS =         9575

AVERAGE BACKSCATTERING CROSS SECTION =     .4798E-05   IN dB =  -53.19
```

BACKSCATTERING CROSS SECTION STD DEV = 6393E-05

AVERAGE TARGET STRENGTH IN dB = -55.21

TARGET STRENGTH STD DEV IN dB = 4.04

ECHOES WITH BEAM PATTERN FACTORS > 0 dB = 1666

Note that the average Target Strength TS_{av} is not equal to the average Back Scattering Cross-section σ_{av} in dB. (see Chapter 6.3 - "Target Strength determination"). Which "average value" , TS_{av} or σ_{av} to use depends on the underlying physical principles of application.

The scaling factor for estimating densities by Echo-Integration is directly proportional to the average Back Scattering Cross-section. Thus, σ_{av} should be used.

TS_{av} is the correct choice for analysis based on TS vs Fish Length relationships, at least for those developed by relating individually measured Target Strengths and fish lengths (Love 1971, 1977)

CONCLUSION

Acoustics applied to fish biomass estimation needs the Back Scattering Cross-section (σ_{av}) of species to be determined to convert the acoustic data collected by the Echo-sounder into weighted values. Until now, the great majority of Back Scattering Cross-section measurements also called Reverberation Index (σ_{av}) has concerned the species of the North Atlantic stocks. Experiments on tropical species are necessary for the Echo-Integration methodology.

These Reverberation Index measurements can be achieved in different ways :

- Echo-integration can be made on known quantities of fish introduced into a cage. This relatively simple method is not without risk ; imprecision about the space really occupied by the fish, handling important quantities, incidence on measurements of minimal occupation space acting by means of behaviour (Foote, 1980a), death, possible multiple reverberations or shadow effect, besides reverberation on the surfaces of the cage of which the importance was only approximated (variable in time).
- The development of new equipment such as Dual-Beam or Split-Beam and the computerization of signal data processing allow the use of a semi-automatic system of measurement and software.

Whatever the way used, the fact is that the operator should always perform measurements with calibrated equipment. The acoustic characteristics can be known exactly. In the case of Dual-Beam sounder, one part of these controls (Source Level and Receiving Sensitivity) is facilitated by a tungsten ball as the standard target. Equipment calibration is the first stage in the evaluation of abundance.

Reverberation Index measuring of live fish constitutes the second stage. This operation should allow the adjustment of the threshold on the echo voltages that are to be taken into account. It should also allow the calculation of a conversion constant of integrated voltages during prospecting of biomass measuring. The choice of a Reverberation Index value should then be defined according to the predicated use (Foote, 1987). In our case, we tried to define an Index destined for weight evaluations on "classical" prospecting.

To reduce a possible effect of being confined in a cage or isolated behaviour, it is recommended to increase the observations made up of a large number of measurements. The procedure aims to obtain an average index value corresponding to the most frequent position of the fish. Our observations show that optimal response values are found to be far away from the "mode" of the histogram or the average of the measures. It indicates that the strongest echoes are not on average representing the usual position of the fish.

Except peculiar situations, measurements *in situ* without simultaneous visual control cannot guarantee a value corresponding to a particular size-known species of fish. Catch sampling, although very useful for data calibration, are not enough to attribute the measurements to a given species. At last, knowledge of the geographical habitat and behaviour are indispensable to sharpen the results.

REFERENCES AND RECOMMENDED READING

BioSonics Inc.,1989. Hydroacoustic Assessment Techniques - Short course notebook.

BioSonics Inc.,1989. Echo Signal Processor Training Course.

BioSonics Inc.,1991. Target Strength Post Processing Program : ESPTS - Operator's Manual.

Burczynski J., 1982. Introduction à l'utilisation des systèmes sonar dans l'estimation de la biomasse en poissons. Version française préparée par E. Marchal. FAO, Doc.Tech. Pêches, (191) Rev.1:81.

Johannesson K.A. and Mitson R.B., 1983. Fisheries acoustics. A practical manual for aquatic biomass estimation. Fao fish. Tech. Pap., (240) : 249 p.

Orca / Ifremer, 1991. INES-MOVIES Manuel Utilisateur.

Orca / Ifremer, 1991. INES-MOVIES Dossier Technique.