Problem 5

Sea-shell

Problem

When you put a sea-shell to your ear you can hear 'the sea'. Study the nature and the characteristics of the sound.

The basics of the explanation

- The sound we hear in the shell originates from outside of the shell (white noise)
- Without external sounds the shell is dumb
- The characteristic sound in the shell is produced by:

  Resonance of the air column in the shell

  Sound energy concentration
- Some frequencies are much louder than others due to resonance
- The other frequencies are also amplified by the sound energy concentration

Contents

Experimental approach

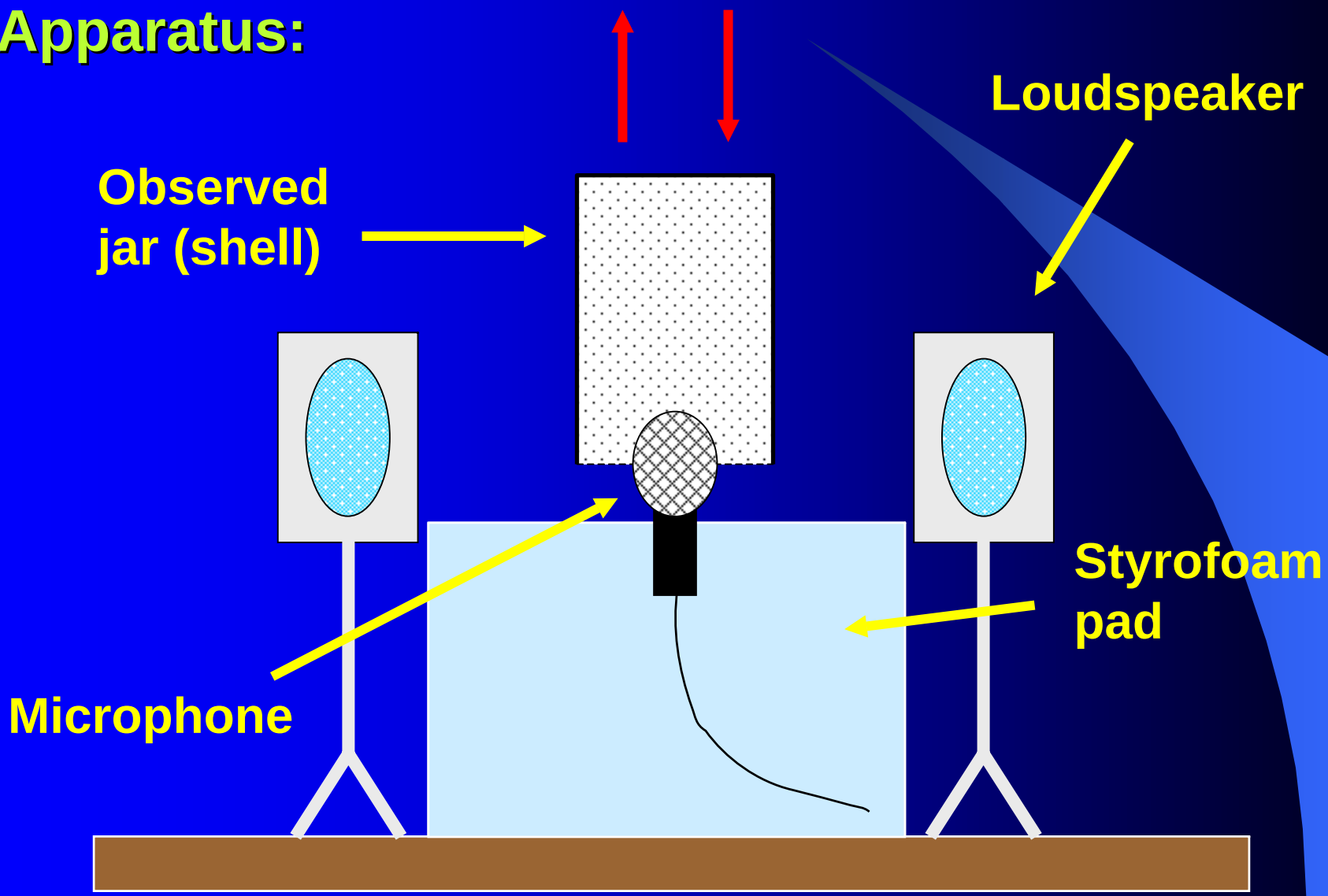
- Apparatus
- Observations
- Defining the relevant parameters

Theoretical explanation

- Sound energy concetration
- Resonance

Experiment

Apparatus:



Real look

How does it work?

- Sound generator generates white noise (contains all frequencies from 20Hz – 20000Hz)
- Loudspeakers plays it with constant intesity for every jar
- Noise enters the jar and hiss occurs
- Microphone records the hiss and sends it to the computer
- Computer analyses the input signal and writes the spectrogram

We used many jars with different shape and size

The shell used in experiments

Three modes of observations:

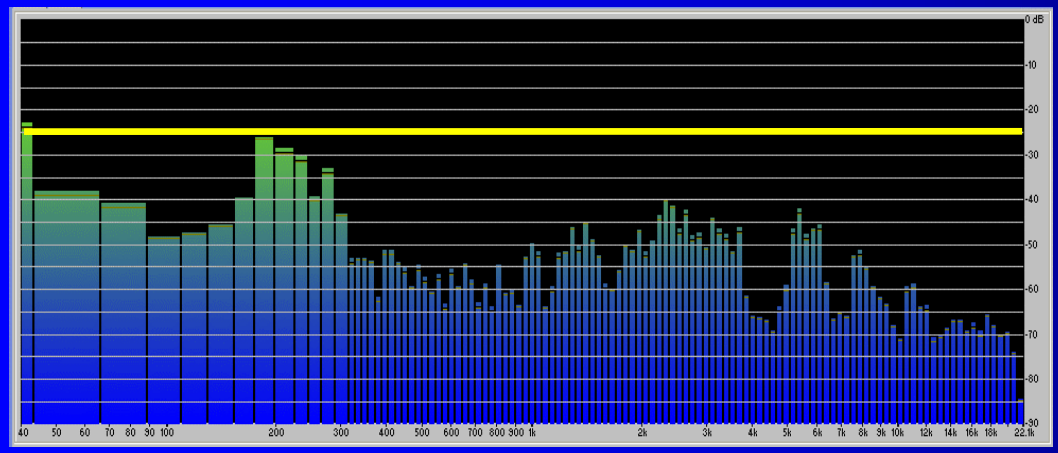
1. Jars are loaded with 10N load
2. Jars are standing freely above the microphone
3. The distance between the jar and the microphone was varyed from 0 – 20 cm

Observations with and without load

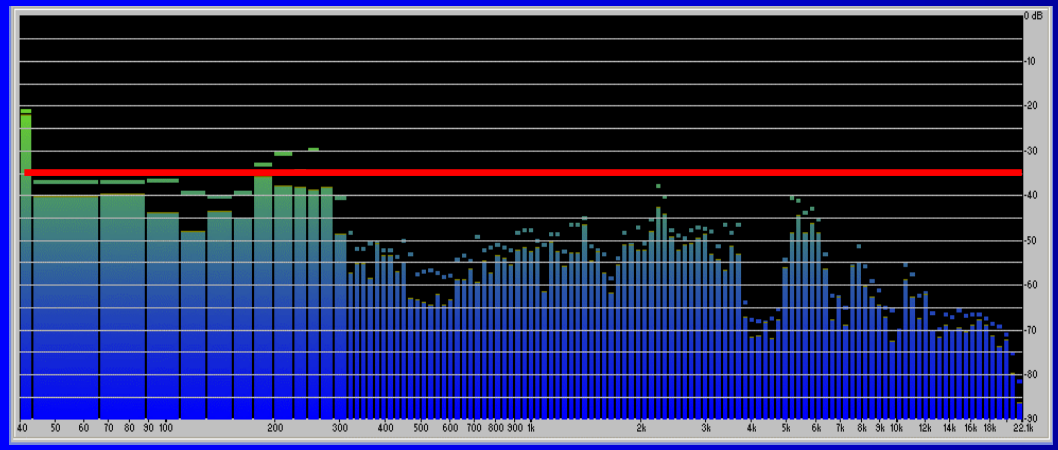
Goal: to prove that the gap between the pad and the jar affects the hiss

Apparatus

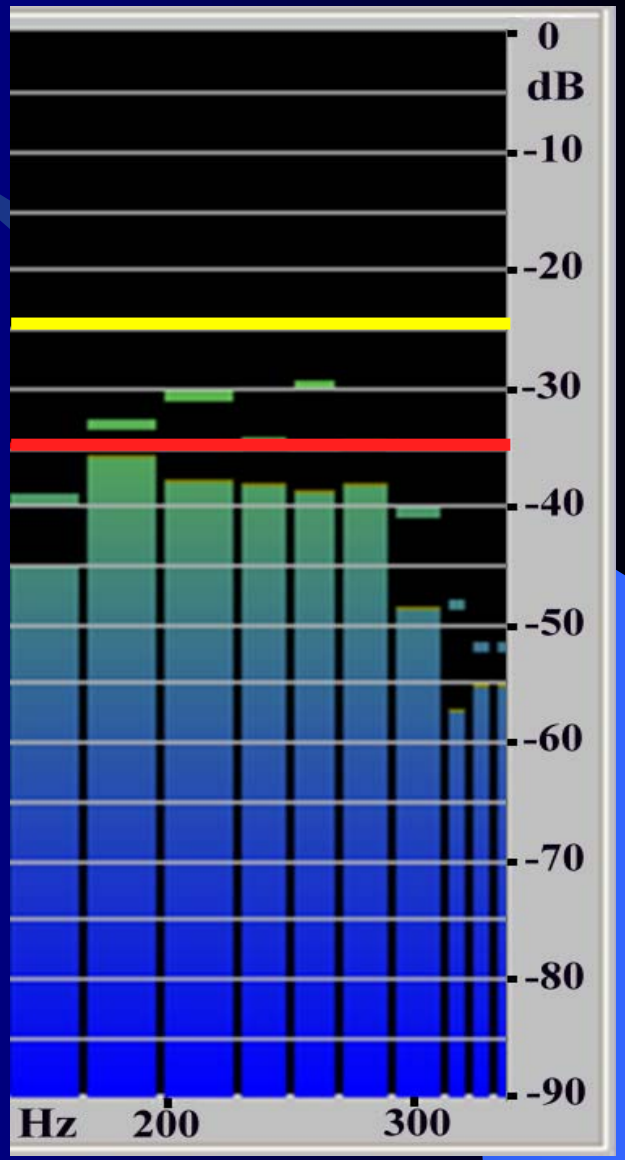
Difference of intensity measured with and without the load is 10 dB



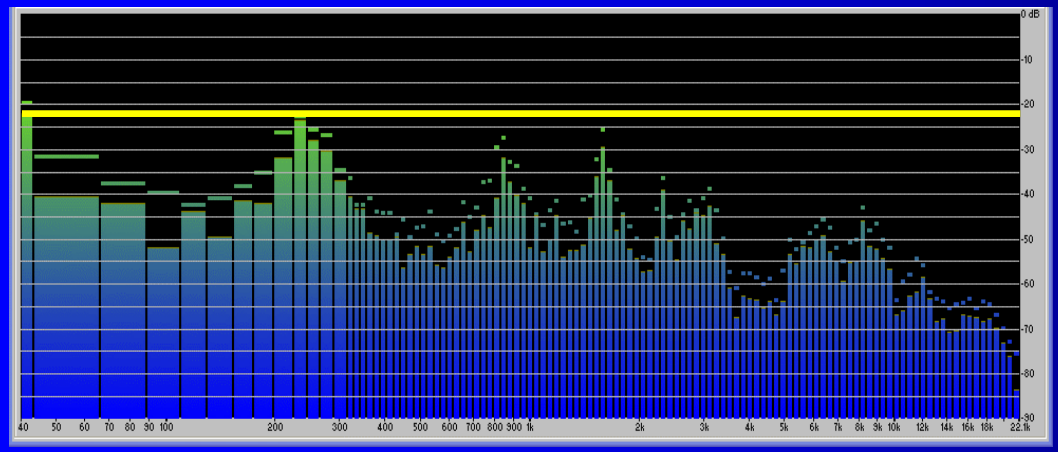
Jar without the load



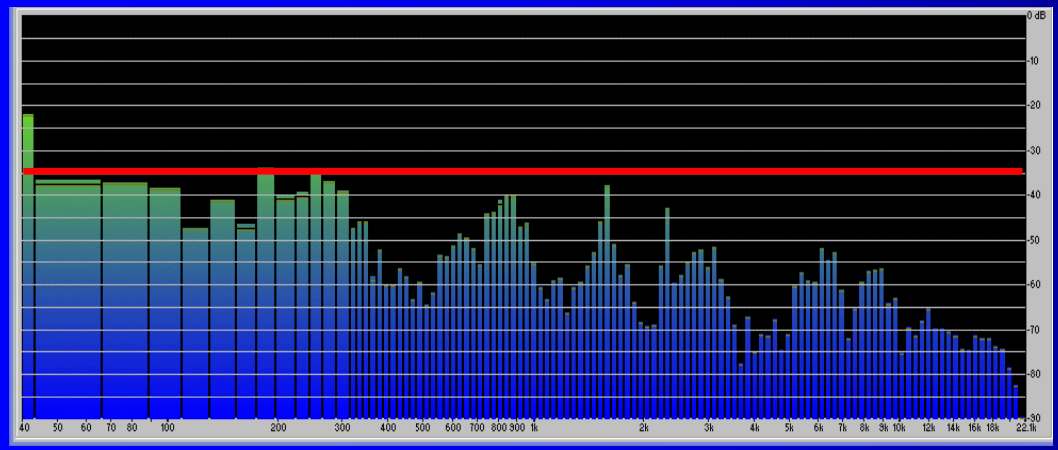
Jar with the load



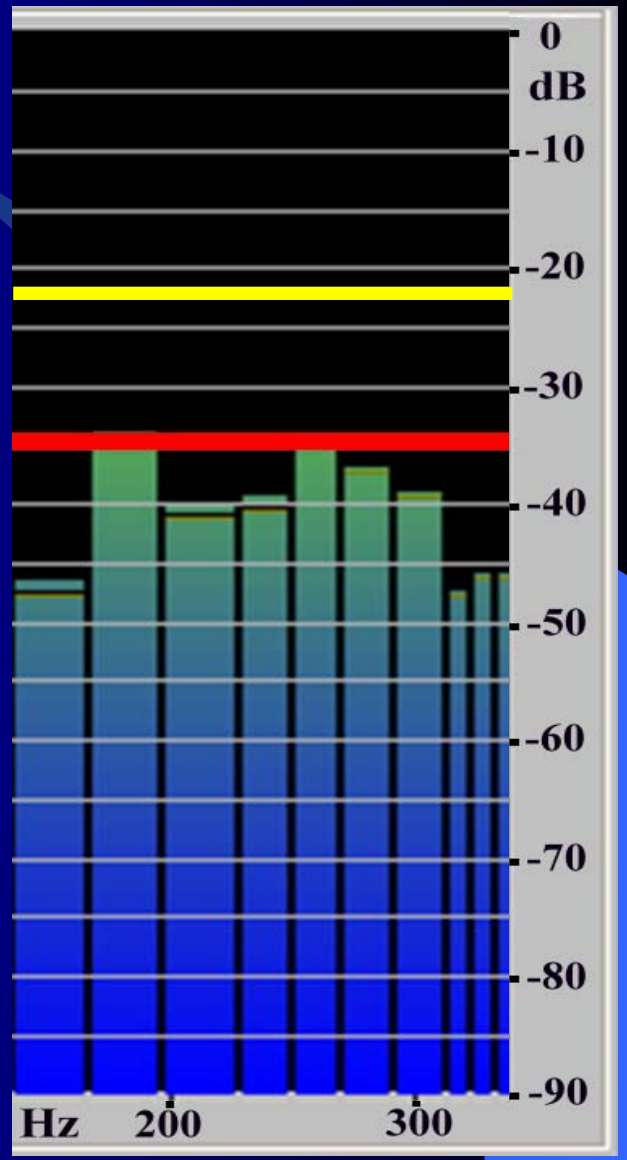
Difference of intensity for another jar is about 12 dB



Jar without the load

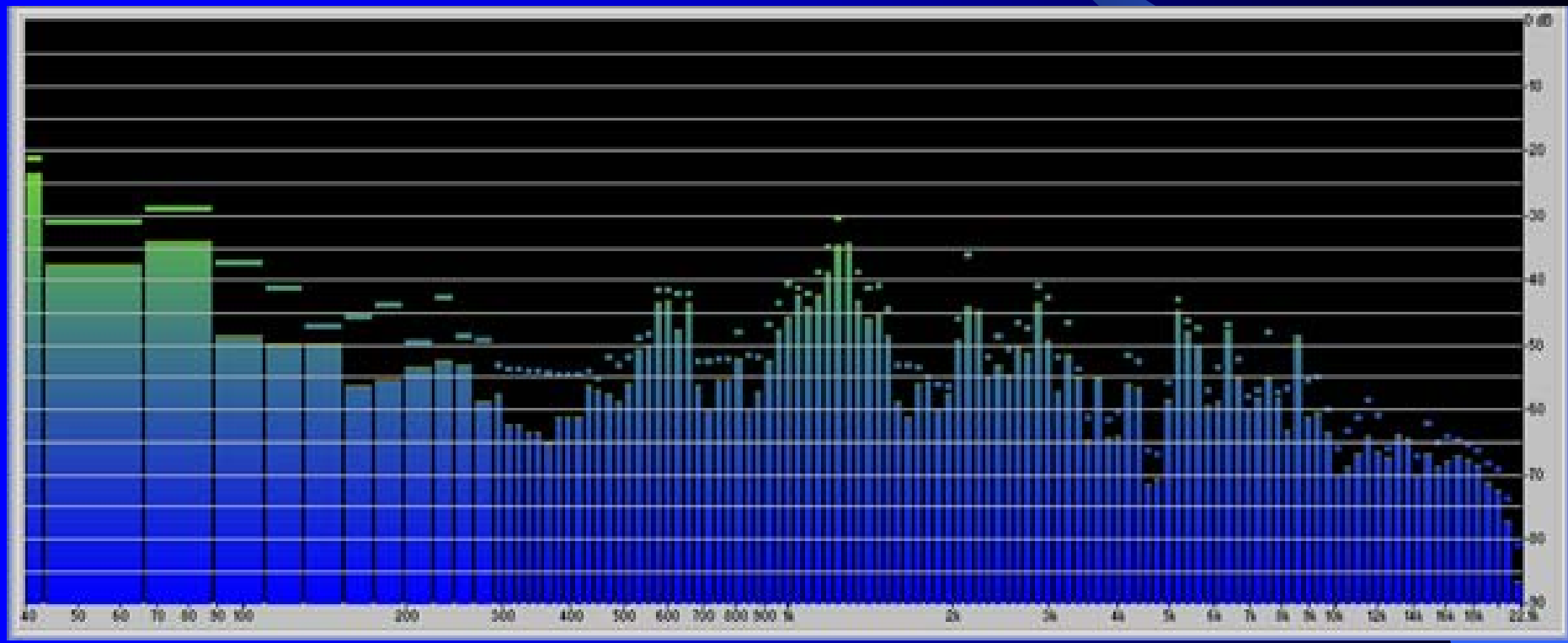


Jar with the load

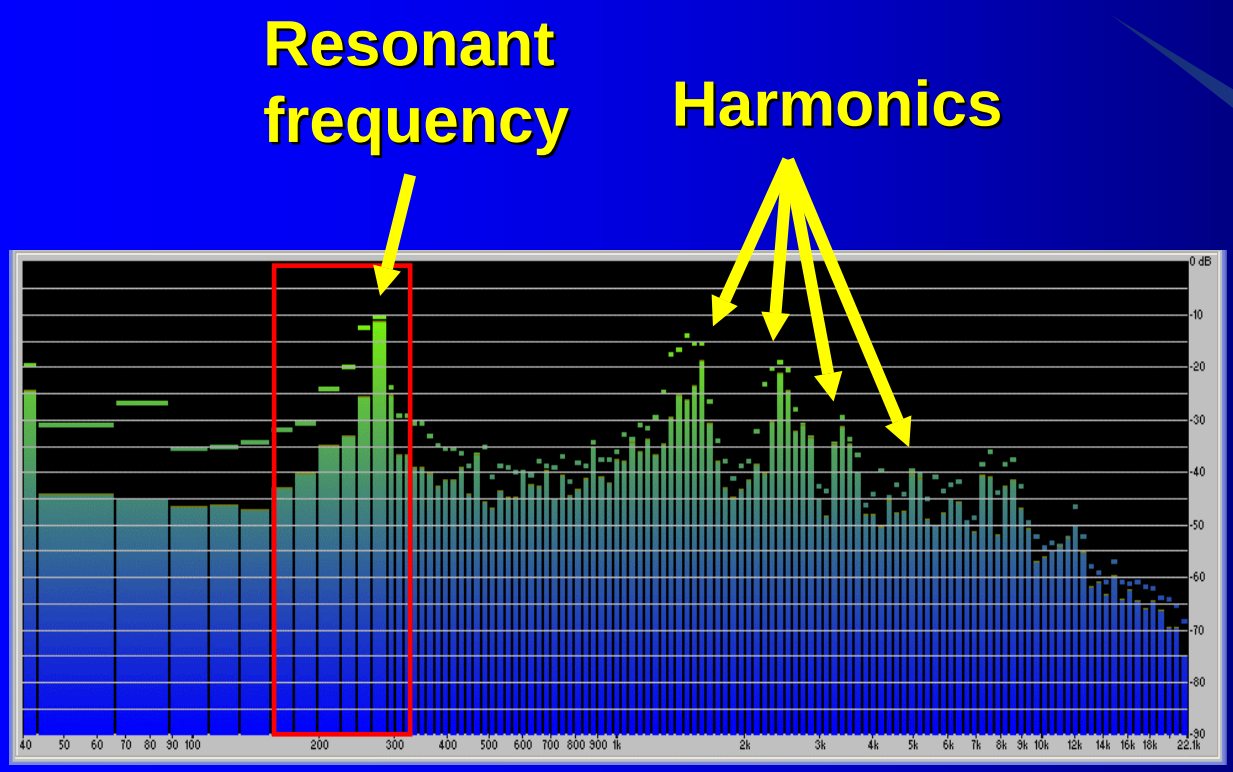


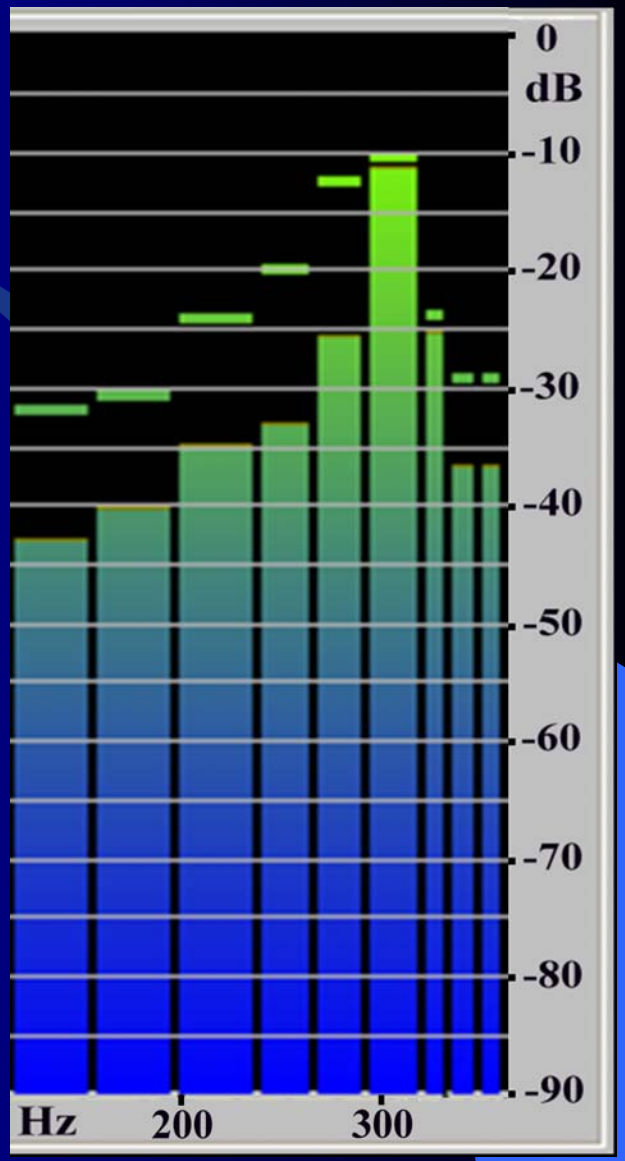
Observations with variation of distance

Goals: to find the frequencies which are amplified



Resonance:


Resonant frequency
Harmonics
0 dB
-10
-20
-30
-40
-50
-60
-70
-80
-90
40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1k 2k 3k 4k 5k 6k 7k 8k 9k 10k 12k 14k 16k 18k 22.1k


0
dB
-10
-20
-30
-40
-50
-60
-70
-80
-90
Hz
200
300

Parameters considered as relevant:

1. Characteristics of the used jar (shell)

Volume
Length
Shape

} They define which frequencies will be amplified

2. Characteristics of external sound

Frequencies

Intensity

Hiss is produced only in presence of external sound!

In absolute silence the hiss doesn't exist!

Theoretical explanation

Energy concentration

- Sound spreads in all directions
- Its energy is distributed on big surface
- The shell concentrates the energy on a little surface and thus intensity increases:

$$I = \frac{P}{S}$$

I – intensity

P – power

S - area

Resonance

- Simplification: shell is replaced by tube
- For the resonant frequency of the closed tube we have:

$$f = \frac{c}{4L}$$

f – resonant frequency

c – the speed of sound

L – length of the tube

- The tube has its overtones:

$$f_n = (2n-1)f_0$$

F_n – frequency of the n–th overtone

F_0 – basic frequency

n - integer

- For amplitude of resonant frequency we have:

$$A = \frac{A_0}{\sqrt{\left(\omega^2 - \omega_0^2\right)^2 + \left(\frac{b\omega}{\rho}\right)^2}}$$

A_0 – source amplitude

ω – input circular frequency

ω_0 – resonant circular frequency

b – damping coeficient

P – air density

- In ideal case damping becomes zero
- If $\omega \approx \omega_0$ resonance occurs and amplitude increases

Conclusion

- The hiss occurs only with presence of external sound
- Characteristics of the hiss depend on:
    1. Shell parameters
    2. Input sound characteristics
- The hiss is caused by:
    1. Sound energy concentration
    2. Resonance
- Real sound of the sea is not always possible due to eventual high frequency loss in input sound