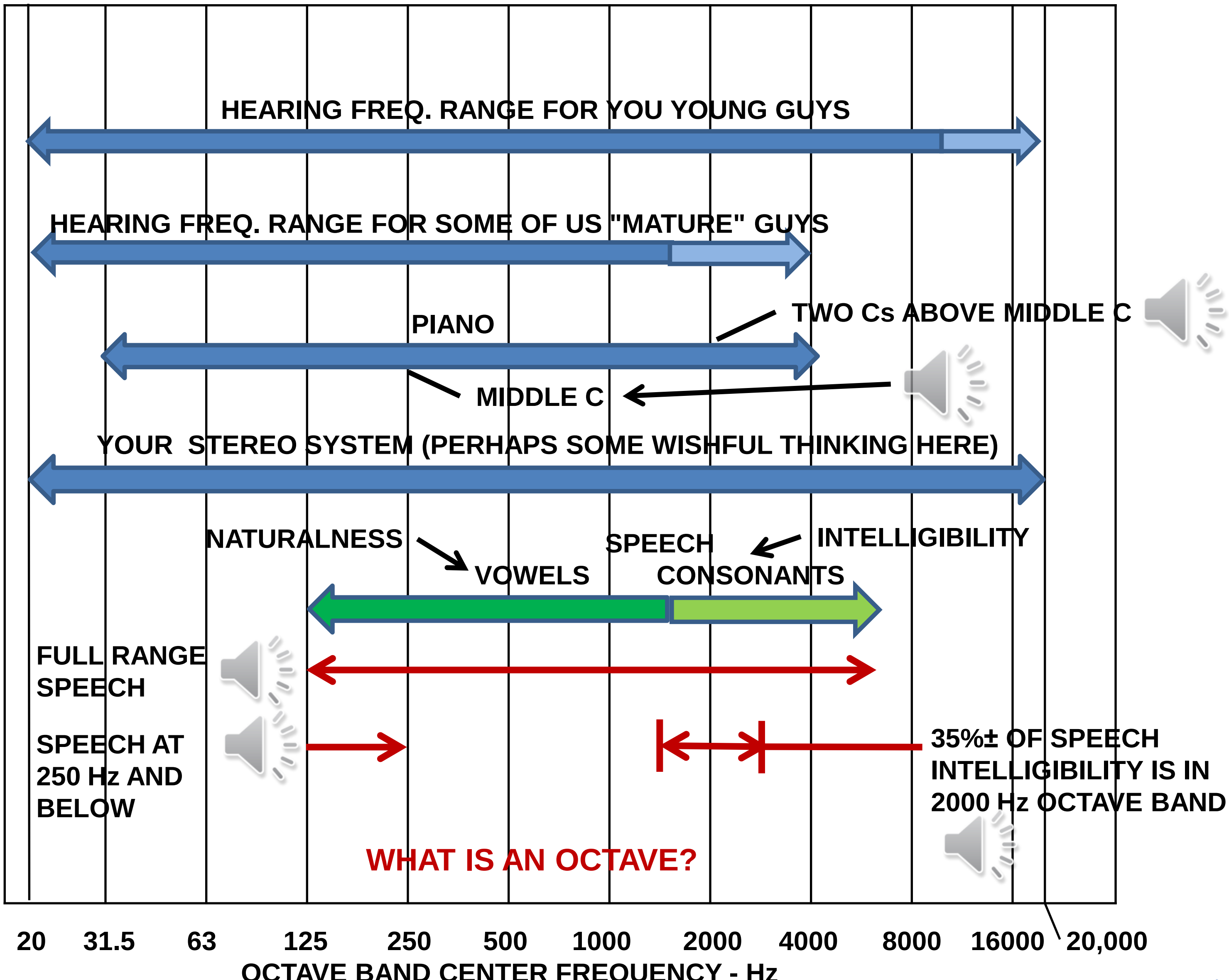
LET'S TAKE A LOOK AT SOME FREQUENCY STUFF AND ITS RELATION TO SPEECH INTELLIGIBILITY



What is an octave?

- http://www.phy.mtu.edu/~suits/notefreqs.html

- What is the relationship between A’s?
- How about C’s?

Main Entry: **oc·tave**

Pronunciation: 'äk-tiv, -t&v, -"tAv

Function: *noun*

Etymology: Middle English, from Medieval Latin *octava,* from Latin, feminine of *octavus* eighth, from *octo* eight -- more at EIGHT

Date: 14th century

1 : an 8-day period of observances beginning with a festival day

2 a : a stanza of eight lines **:** OTTAVA RIMA **b :** the first eight lines of an Italian sonnet

3 a : a musical interval embracing eight diatonic degrees **b :** a tone or note at this interval **c :** the harmonic combination of two tones an octave apart **d :** the whole series of notes, tones, or digitals comprised within this interval and forming the unit of the modern scale **e :** an organ stop giving tones an octave above those corresponding to the digitals

4 : the interval between two frequencies (as in an electromagnetic spectrum) having a ratio of 2 to 1

5 : a group of eight

KU

LET'S BACK UP A BIT…

WHAT IS SOUND?

One definition is…

**Wave motion consisting of very small changes in air pressure which cause our eardrums (tympanic membrane)
to "wiggle" (vibrate)**

What two parameters must be identified to describe any sound?

Frequency (Pitch)

Amplitude (Intensity…Pressure)

How do we describe frequency?

Repetition rate in

Cycles per second

Hertz (Hz)

How can we describe the frequency content of a sound?

By determining the sound pressure level within an octave frequency band or subdivisions of an octave band such as one-third octave band, one-sixth octave band, etc.

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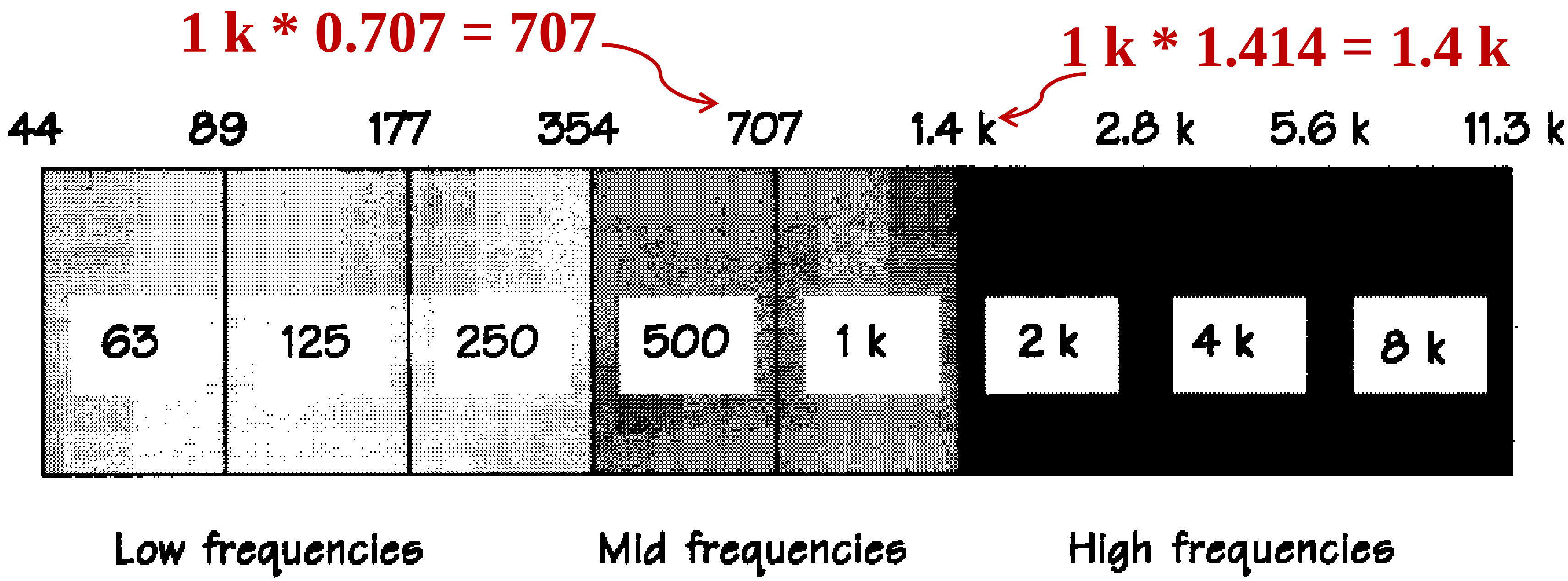


From Metha Johnson Rockafort text

The center frequencies of octave frequency bands have been standardized and are accepted the world over.

The upper and lower frequency limits can be determined as follows:

Upper limit = (center freq)* $\sqrt{2}$ = (center freq) * 1.414

Lower limit = (center freq)/ $\sqrt{2}$ = (center freq) * 0.707

THUS FAR WE HAVE TALKED ABOUT OCTAVE FREQUENCY BANDS. BUT, FOR HIGHER RESOLUTION IN DESCRIBING THE SPECTRUM OF A SOUND, WE OFTEN USE ONE-THIRD OCTAVE BANDS…

CENTER FREQ.- Hz	CENTER FREQ.- Hz
50	1000
63	1250
80	1600
100	2000
125	2500
160	3150
200	4000
250	5000
315	6300
400	8000
500	10000
630	12500
800	16000

THE OCTAVE FREQ BAND CENTERED AT 250 Hz CONTAINS THE ONE-THIRD OCTAVE BANDS CENTERED AT 200, 250, AND 315 Hz

STANDARD OCTAVE BAND CENTER FREQUENCIES ARE SHOWN IN RED

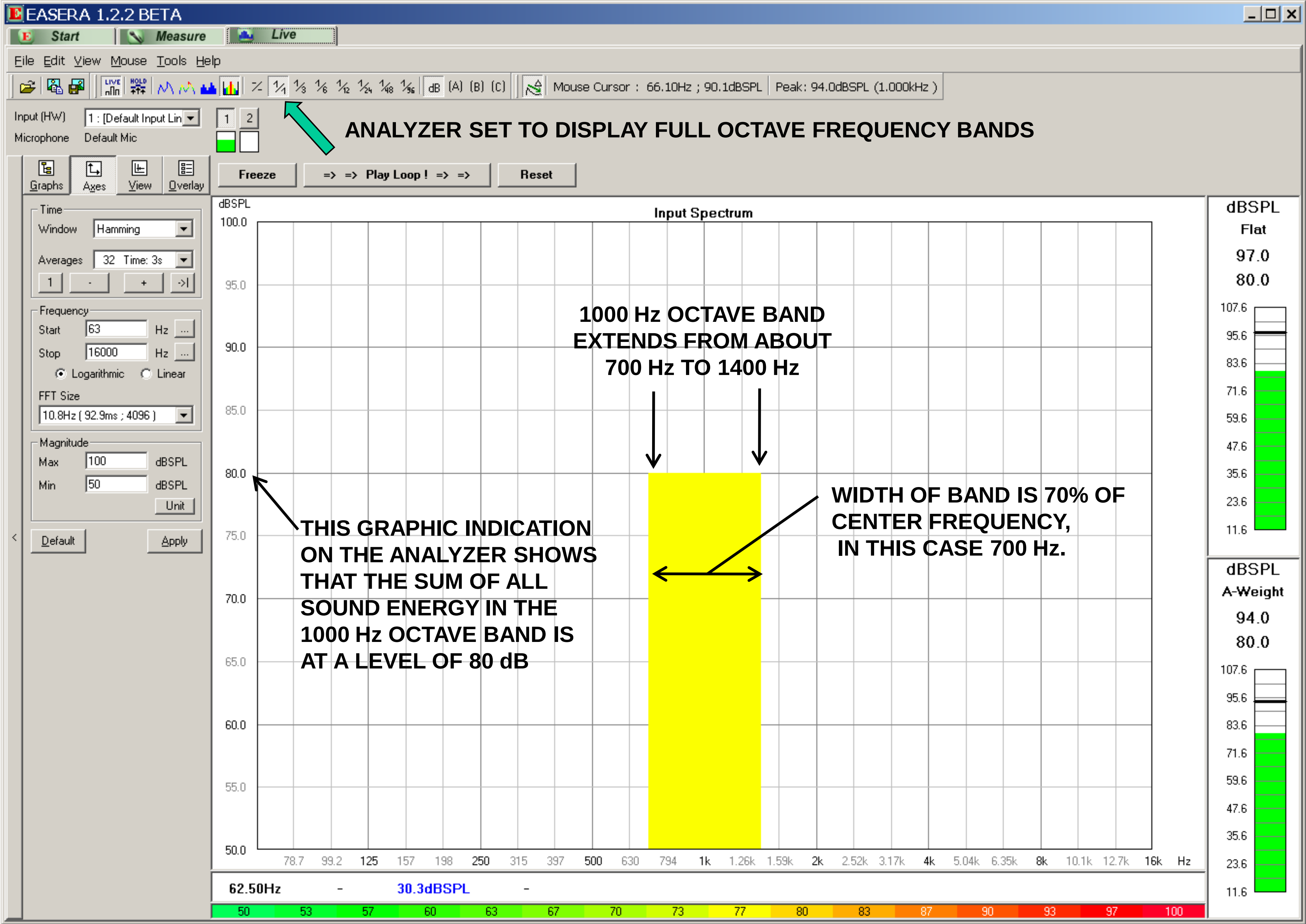
One-third octave bands are said to be 23 percent bands. The band width is approximately 23 percent of the center frequency.

For octave bands the center frequency is multiplied by 2 to obtain the center frequency of the next higher band.

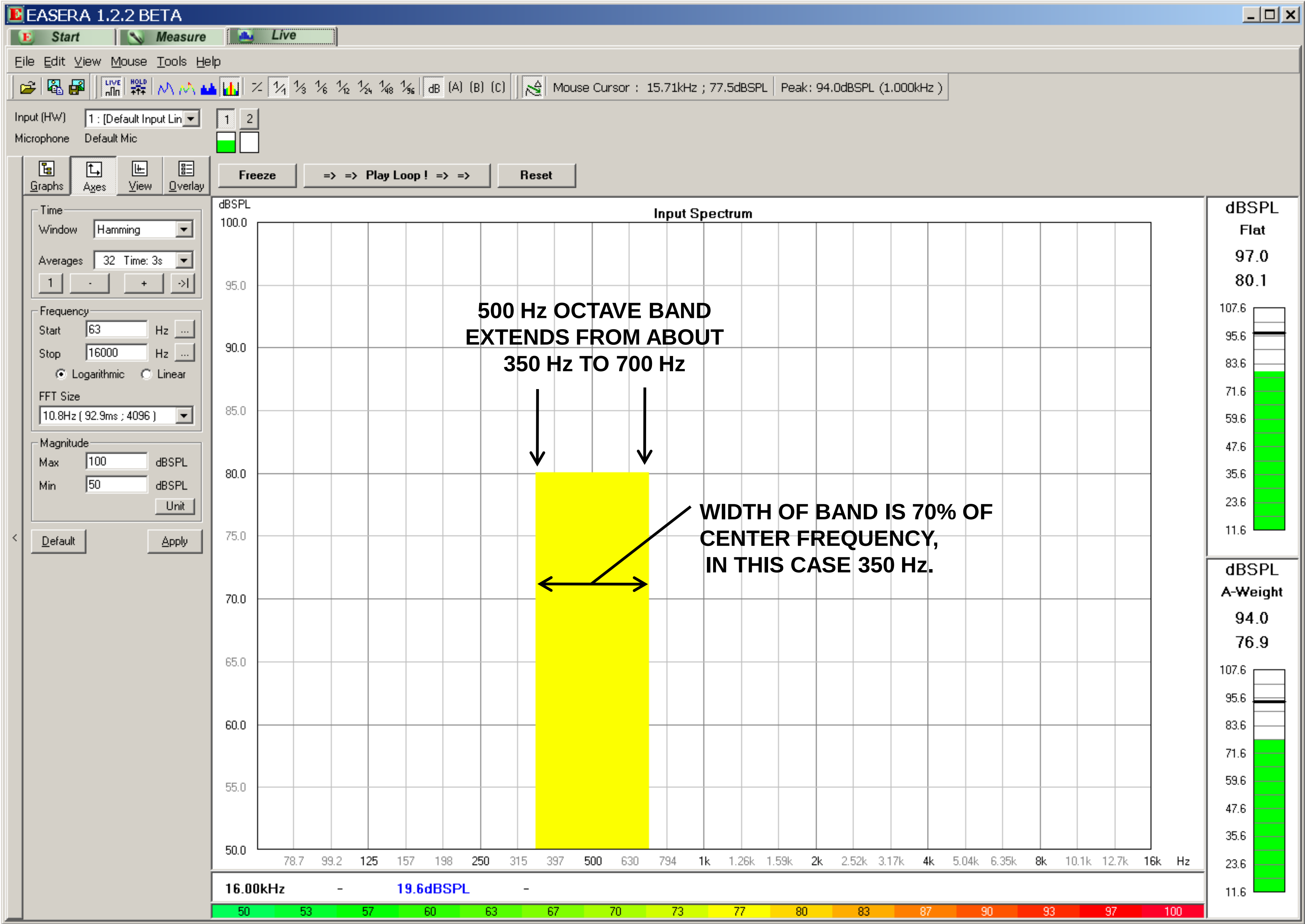
For one-third octave bands the center frequency of a 1/3 octave band is multiplied by $2^{1/3}$ (1.26) to obtain the center frequency of the next higher band.

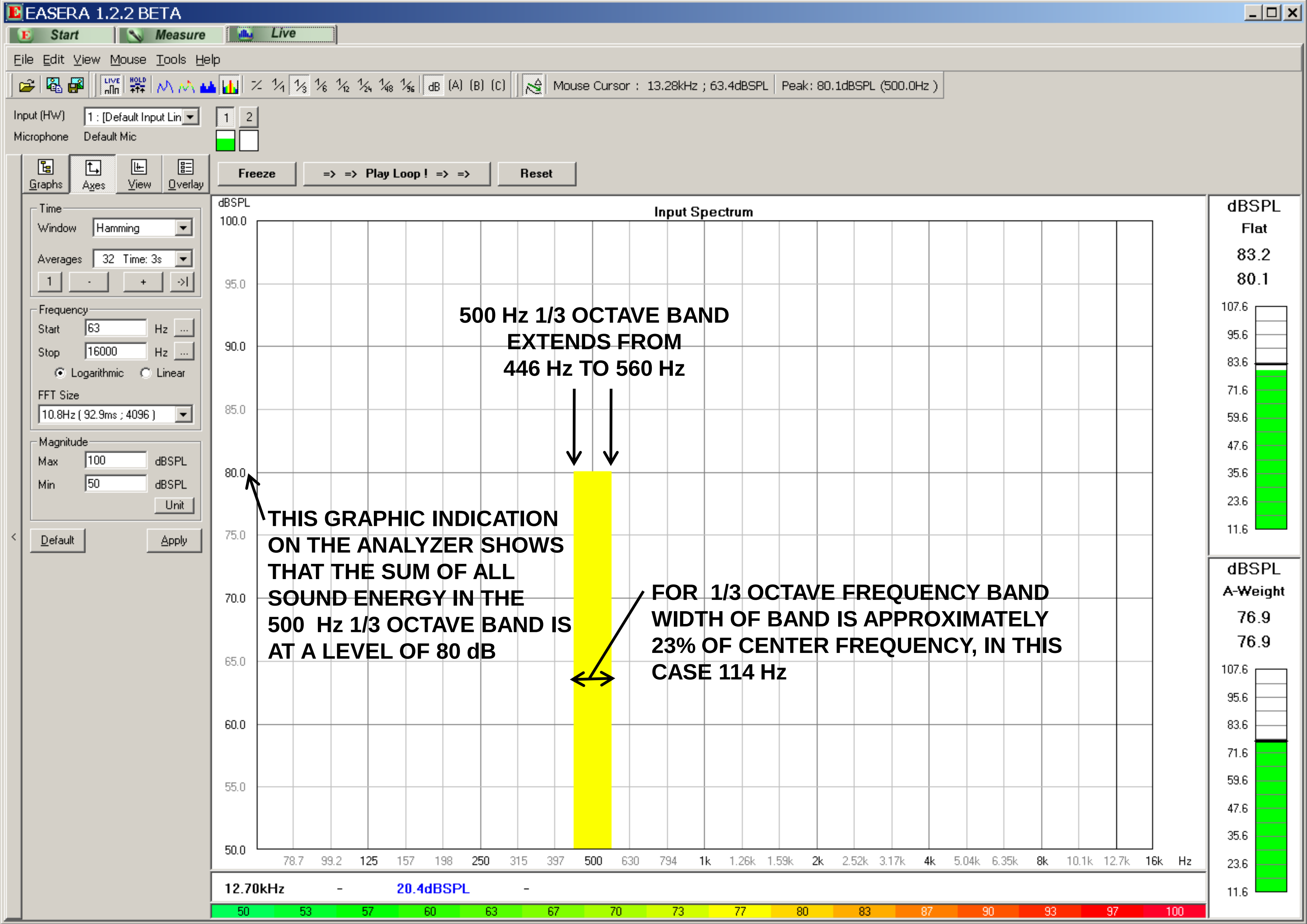
Let’s see how we can observe the frequency characteristics of a particular sound

WE'LL LOOK AT MEASUREMENTS FROM THE COMPUTER PROGRAMS
EASERA and systune



EASERA 1.2.2 BETA
Start
Measure
Live
File Edit View Mouse Tools Help
Mouse Cursor : 66.10Hz ; 90.1dBSPL
Peak: 94.0dBSPL (1.000kHz)
Input (HW)
1 : [Default Input Lin
Microphone
Default Mic
ANALYZER SET TO DISPLAY FULL OCTAVE FREQUENCY BANDS
Freeze
=> => Play Loop ! => =>
Reset
Graphs
Axes
View
Overlay
Time
Window
Hamming
Averages
32 Time: 3s
Frequency
Start
63
Hz
Stop
16000
Hz
Logarithmic
Linear
FFT Size
10.8Hz (92.9ms ; 4096)
Magnitude
Max
100
dBSPL
Min
50
dBSPL
Unit
Default
Apply
dBSPL
Input Spectrum
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
78.7 99.2 125 157 198 250 315 397 500 630 794 1k 1.26k 1.59k 2k 2.52k 3.17k 4k 5.04k 6.35k 8k 10.1k 12.7k 16k Hz
1000 Hz OCTAVE BAND EXTENDS FROM ABOUT 700 Hz TO 1400 Hz
THIS GRAPHIC INDICATION ON THE ANALYZER SHOWS THAT THE SUM OF ALL SOUND ENERGY IN THE 1000 Hz OCTAVE BAND IS AT A LEVEL OF 80 dB
WIDTH OF BAND IS 70% OF CENTER FREQUENCY, IN THIS CASE 700 Hz.
62.50Hz
30.3dBSPL
50 53 57 60 63 67 70 73 77 80 83 87 90 93 97 100
dBSPL
Flat
97.0
80.0
dBSPL
A-Weight
94.0
80.0
107.6
95.6
83.6
71.6
59.6
47.6
35.6
23.6
11.6

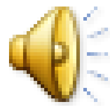

EASERA 1.2.2 BETA
Start
Measure
Live
File Edit View Mouse Tools Help
Mouse Cursor : 15.71kHz ; 77.5dBSPL
Peak: 94.0dBSPL (1.000kHz)
Input (HW)
1 : [Default Input Lin
Microphone
Default Mic
Graphs
Axes
View
Overlay
Freeze
=> => Play Loop ! => =>
Reset
Time
Window
Hamming
Averages
32 Time: 3s
Frequency
Start
63
Hz
Stop
16000
Hz
Logarithmic
Linear
FFT Size
10.8Hz (92.9ms ; 4096)
Magnitude
Max
100
dBSPL
Min
50
dBSPL
Unit
Default
Apply
Input Spectrum
dBSPL
500 Hz OCTAVE BAND
EXTENDS FROM ABOUT
350 Hz TO 700 Hz
WIDTH OF BAND IS 70% OF
CENTER FREQUENCY,
IN THIS CASE 350 Hz.
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
78.7 99.2 125 157 198 250 315 397 500 630 794 1k 1.26k 1.59k 2k 2.52k 3.17k 4k 5.04k 6.35k 8k 10.1k 12.7k 16k Hz
16.00kHz - 19.6dBSPL -
50 53 57 60 63 67 70 73 77 80 83 87 90 93 97 100
dBSPL
Flat
97.0
80.1
107.6
95.6
83.6
71.6
59.6
47.6
35.6
23.6
11.6
dBSPL
A-Weight
94.0
76.9
107.6
95.6
83.6
71.6
59.6
47.6
35.6
23.6
11.6


EASERA 1.2.2 BETA
Start
Measure
Live
File Edit View Mouse Tools Help
Mouse Cursor : 13.28kHz ; 63.4dBSPL
Peak: 80.1dBSPL (500.0Hz)
Input (HW)
1 : [Default Input Lin
Microphone
Default Mic
Freeze
=> => Play Loop ! => =>
Reset
Graphs
Axes
View
Overlay
Time
Window
Hamming
Averages
32 Time: 3s
Frequency
Start
63
Hz
Stop
16000
Hz
Logarithmic
Linear
FFT Size
10.8Hz (92.9ms ; 4096)
Magnitude
Max
100
dBSPL
Min
50
dBSPL
Unit
Default
Apply
Input Spectrum
dBSPL
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
78.7
99.2
125
157
198
250
315
397
500
630
794
1k
1.26k
1.59k
2k
2.52k
3.17k
4k
5.04k
6.35k
8k
10.1k
12.7k
16k
Hz
500 Hz 1/3 OCTAVE BAND
EXTENDS FROM
446 Hz TO 560 Hz
THIS GRAPHIC INDICATION
ON THE ANALYZER SHOWS
THAT THE SUM OF ALL
SOUND ENERGY IN THE
500 Hz 1/3 OCTAVE BAND IS
AT A LEVEL OF 80 dB
FOR 1/3 OCTAVE FREQUENCY BAND
WIDTH OF BAND IS APPROXIMATELY
23% OF CENTER FREQUENCY, IN THIS
CASE 114 Hz
12.70kHz
20.4dBSPL
50
53
57
60
63
67
70
73
77
80
83
87
90
93
97
100
dBSPL
Flat
83.2
80.1
dBSPL
A-Weight
76.9
76.9
107.6
95.6
83.6
71.6
59.6
47.6
35.6
23.6
11.6

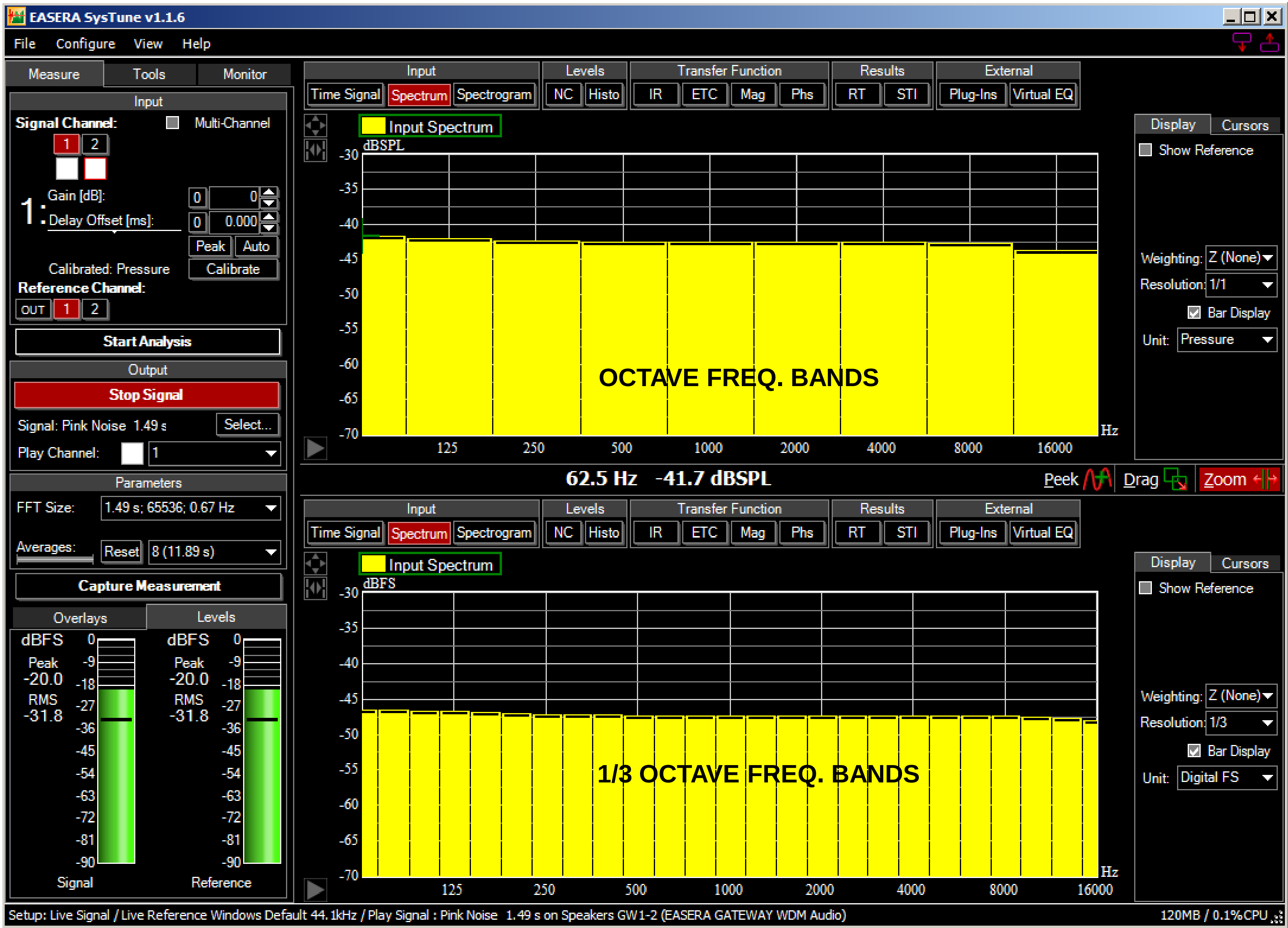
Noise is often used as a test signal or for other uses.

What are the frequency characteristics of pink noise and white noise?

LISTEN TO PINK NOISE



PINK NOISE – EQUAL ENERGY IN EVERY "CONSTANT PERCENTAGE" BANDWIDTH…OCTAVE BAND, 1/3 OCTAVE BAND, ETC… APPEARS "FLAT" (OR NEARLY "FLAT") WITH FREQUENCY



LISTEN TO WHITE NOISE

WHITE NOISE – EQUAL ENERGY IN EVERY CYCLE…WHEN ANALYZED IN OCTAVE FREQUENCY BANDS THE LEVEL INCREASES WITH EACH HIGHER FREQUENCY OCTAVE BAND BY 3 dB. WHEN ANALYZED IN 1/3 OCTAVE FREQUENCY BANDS THE LEVEL INCREASES WITH EACH HIGHER 1/3 OCTAVE BAND BY 1 dB.

ANALYSIS BY EASERA SYSTUNE


Discovery of Sound in the Sea
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Marine Mammals - Toothed Whales
Common Dolphin (Delphinus spp.)
Picture:
Two common dolphins. Photo courtesy of NOAA Fisheries.
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Amazon River Dolphin
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Baiji
Marine Mammals - Toothed Whales
Marine Mammals - Toothed Whales

Frequency Attenuation

- Which travel further – high frequencies or low frequencies?

Dolphins

- Use lower sounds in captivity
- Use higher frequency in the wild

Why?

Whit Au discovered in 1974

Whit's answer

- First of all, absorption losses increase with frequency. So the higher the frequency the more the absorption losses will be for a given range.
- Secondly, the center frequency of the output signals tend to increase with amplitude. In other words, the higher the output the higher the frequency content will be.
- In small tanks, dolphins tend to use much lower amplitude bisonar signals than in large tanks or net-enclosure in open bays. The temporal resolution will be dependent of the bandwidth of the signal - higher bandwidth better resolution. The bandwidth tend to be wider for high frequency signals. So, in many situations, its hard to generalize since the biosonar signals dolphin use depends on the specific situation. Their system seems to be very flexible so dolphins tend to adapt to the situation.

Voices

- Recognizability
  - Humans, velvet monkeys, baboons, elephants
- Imitation in Speech
- Human voice evolution
- Phonetics

Noise

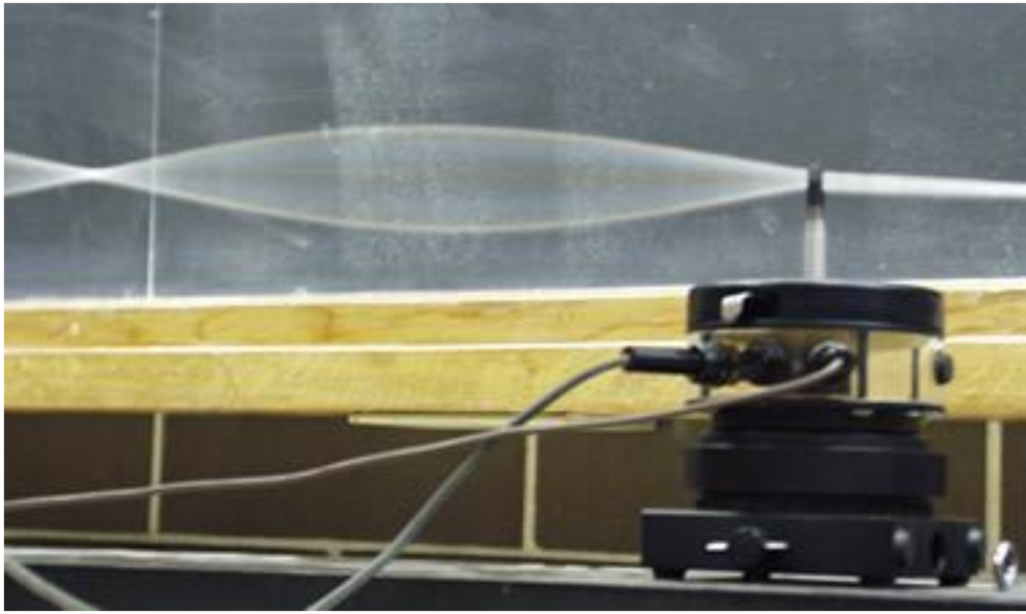
- Factories
- City streets
- Ocean effects on animals

What is the Fundamental?

Wave on a string lab

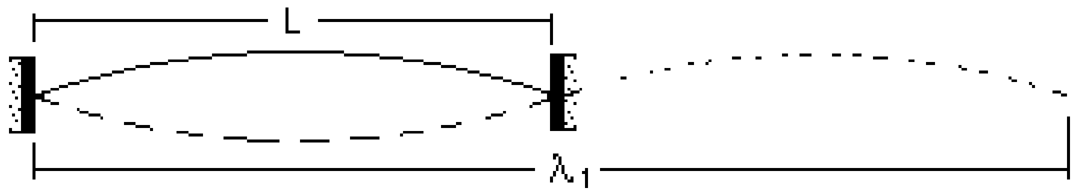
What are the least number of loops possible?

Why?

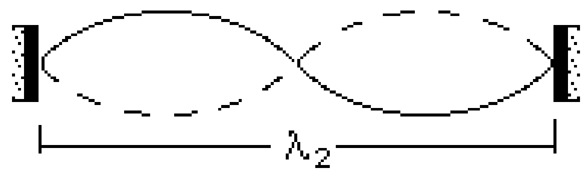


$$f = v/\lambda$$

Fundamental or 1st harmonic $\lambda_1 = 2L$

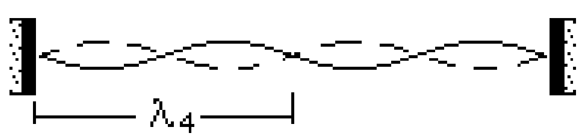


2nd harmonic $\lambda_2 = L$



3rd harmonic $\lambda_3 = 2/3L$

4th harmonic $\lambda_4 = 1/2L$

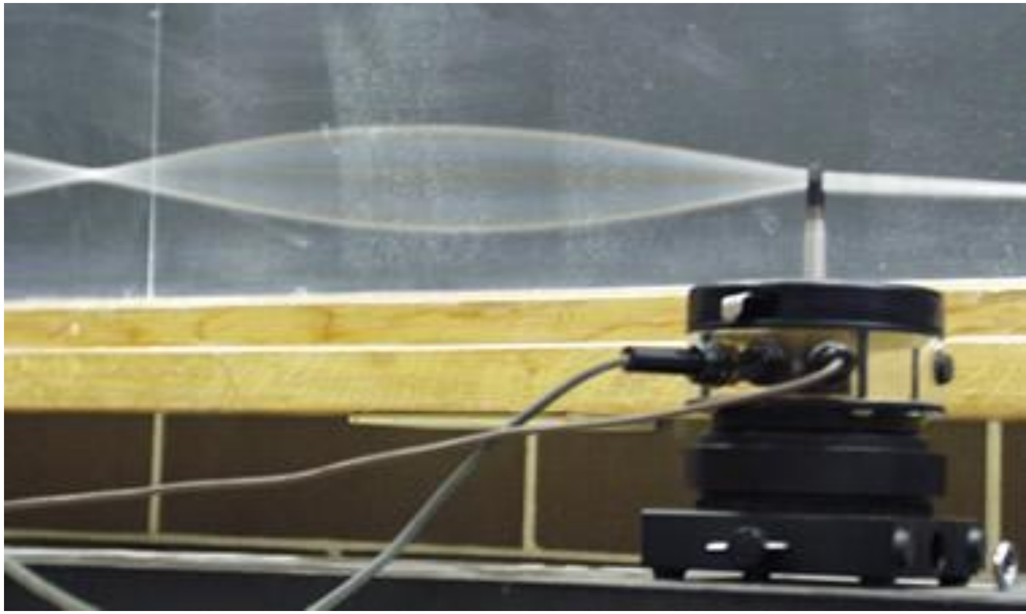


Nth harmonic $\lambda_n = 2L/n$ so $f = nv/(2L)$

What is the <u>Fundamental</u>?

Wave on a string lab

Why can't you have a harmonic with $\lambda = 4L$?

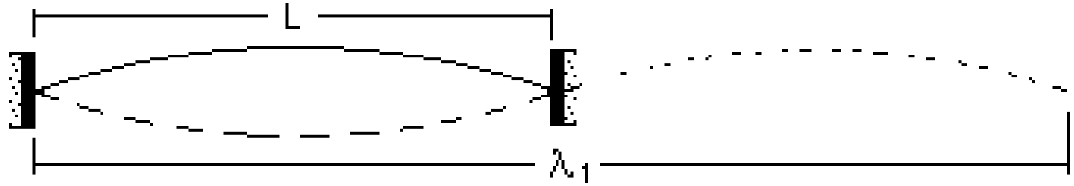


The ***Fundamental*** frequency is determined by the physical characteristics of the medium.

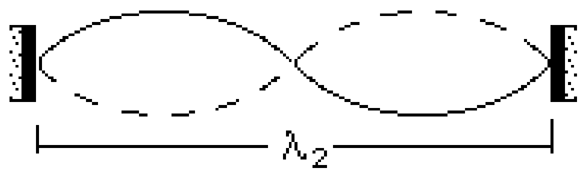
It is the longest wavelength that can resonate.

$f = v/\lambda$

Fundamental or 1st harmonic $\lambda_1 = 2L$



2nd harmonic $\lambda_2 = L$



3rd harmonic $\lambda_3 = 2/3L$

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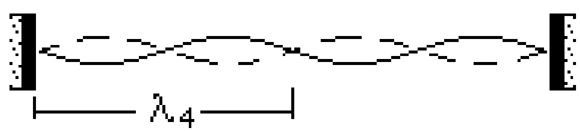
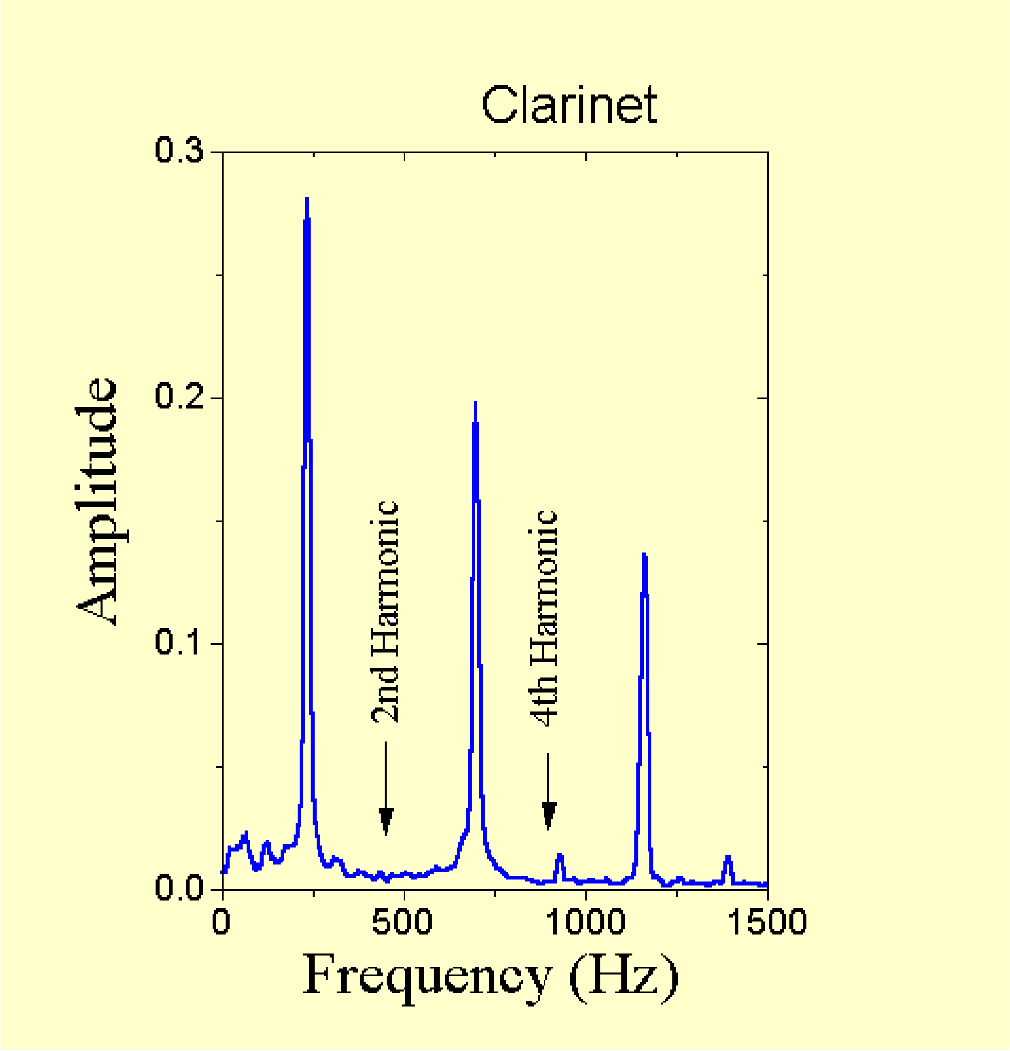


Nth harmonic $\lambda_n = 2L/n$ so $f = nv/(2L)$

Clarinet


Clarinet
0.3
0.2
0.1
0.0
Amplitude
2nd Harmonic
4th Harmonic
0
500
1000
1500
Frequency (Hz)

Piano

- Frequency spectrum