Why Does a Guitar Need a Body to Make Sound?

Ra Inta, Texas Tech University

Making guitars…

Lulot guitars


EXIT


We Sell Soft Serve
Soft Serve
Cottee's
DELICIOUS

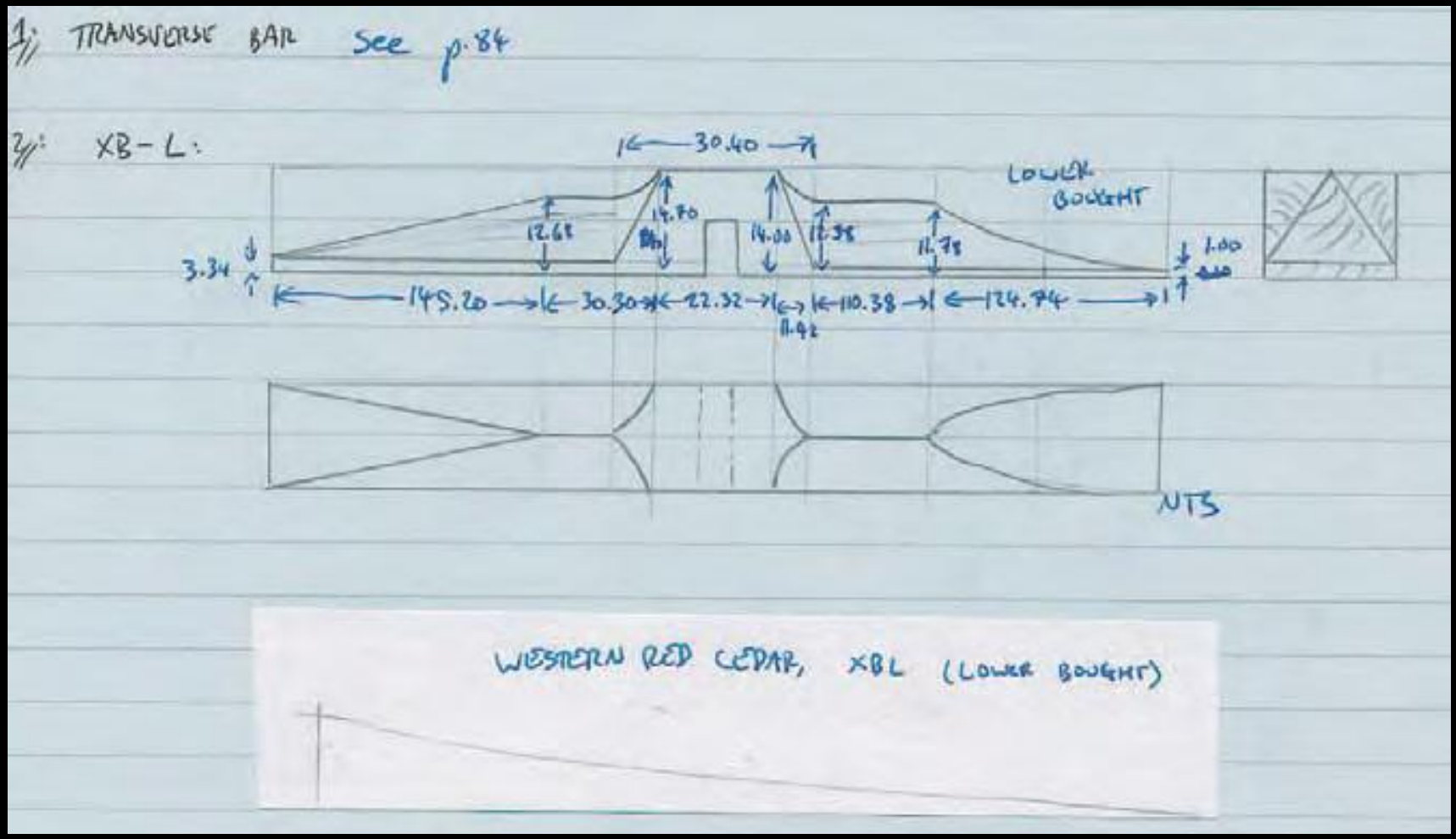
The Experimental Instruments

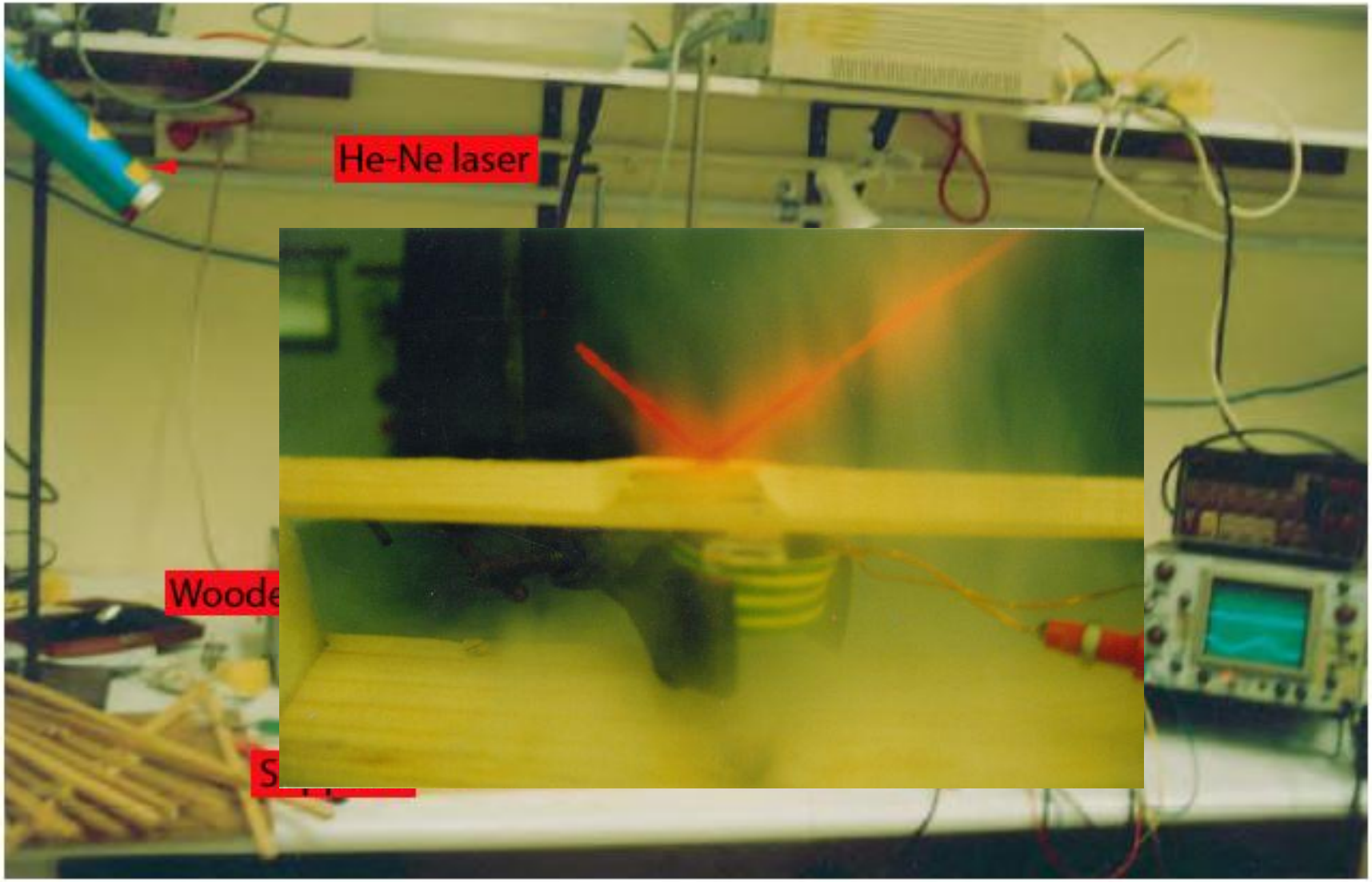
Engelmann Spruce

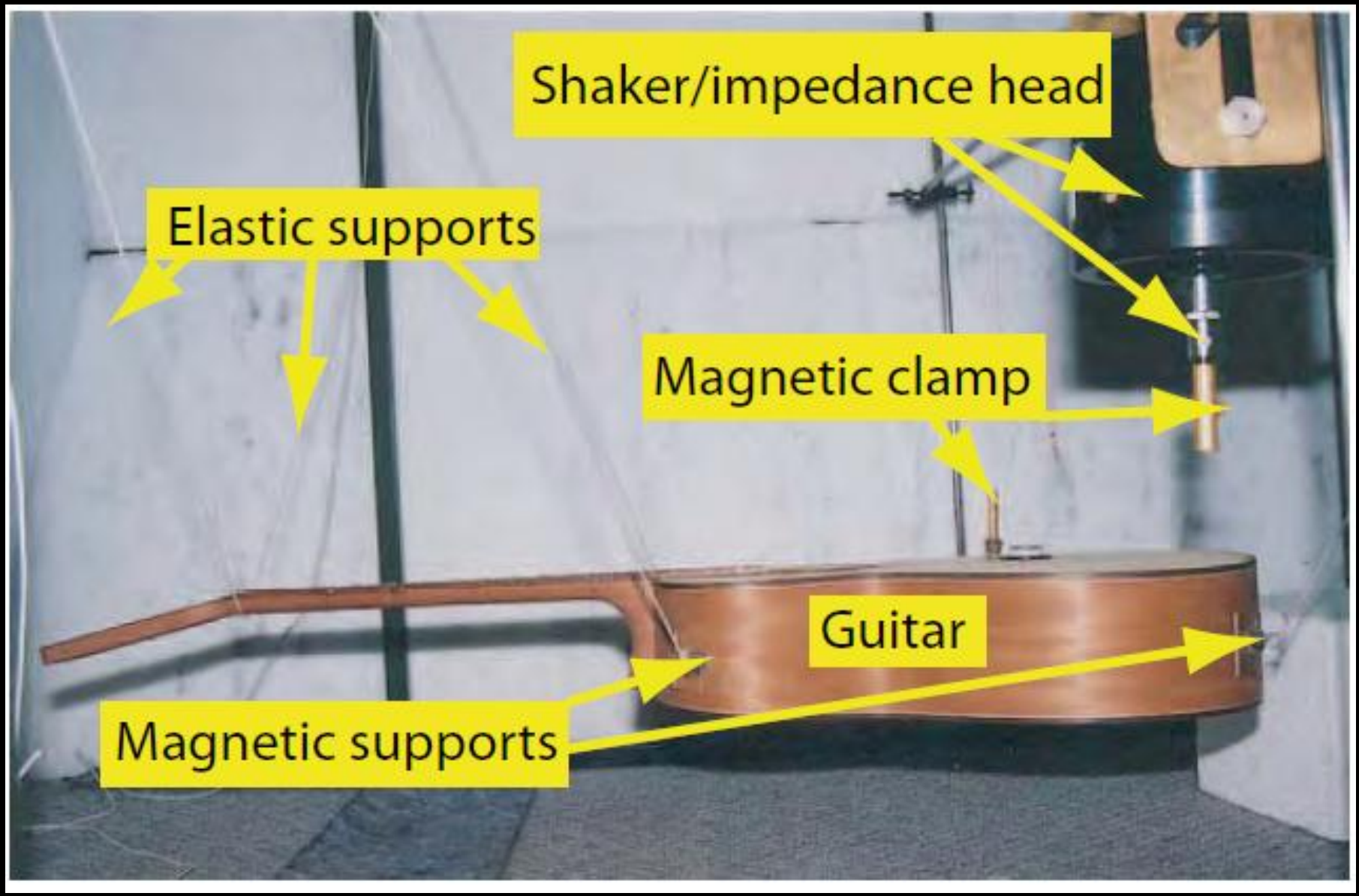
Sitka Spruce

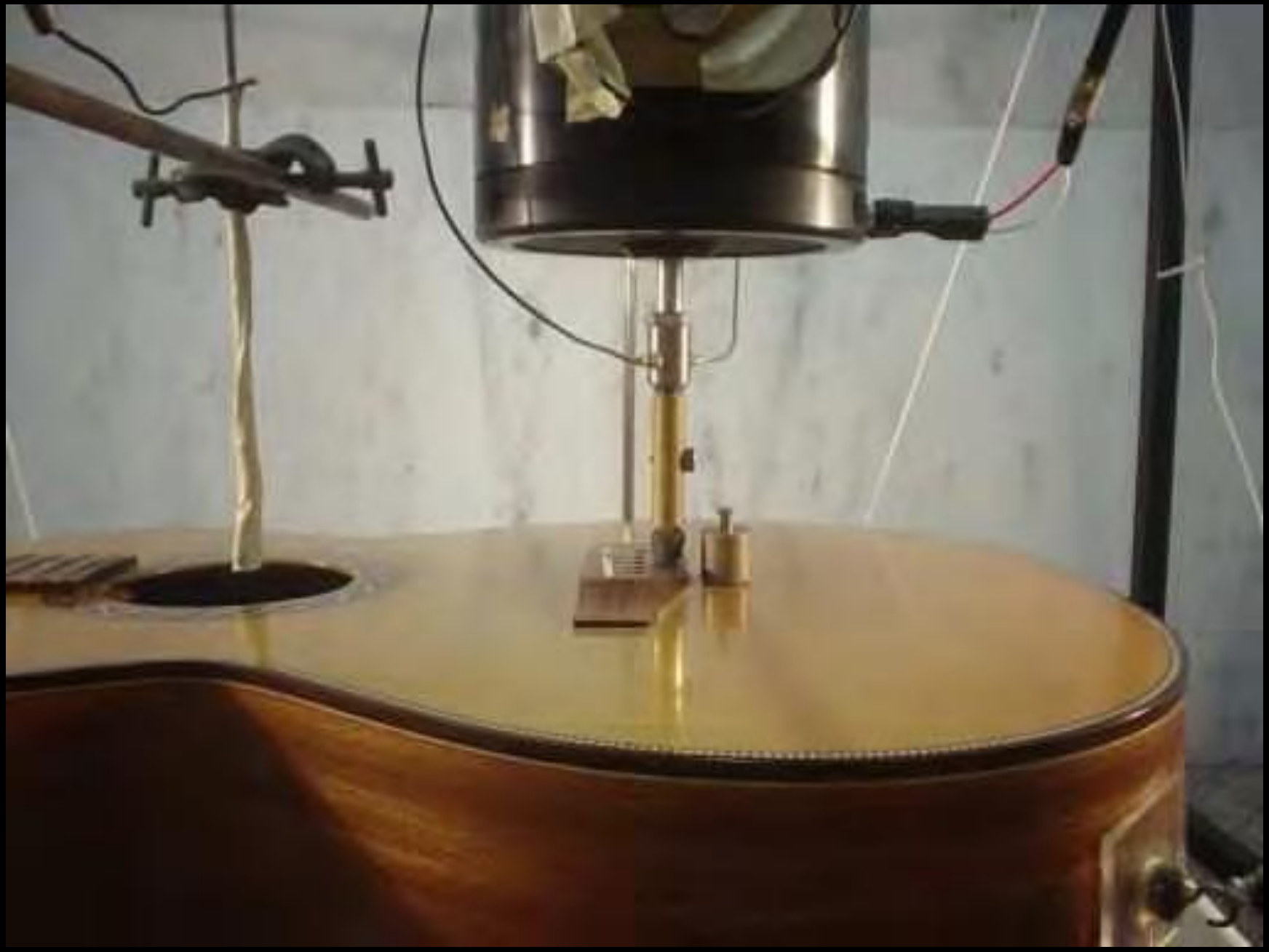
Western Red Cedar

… and measuring guitars

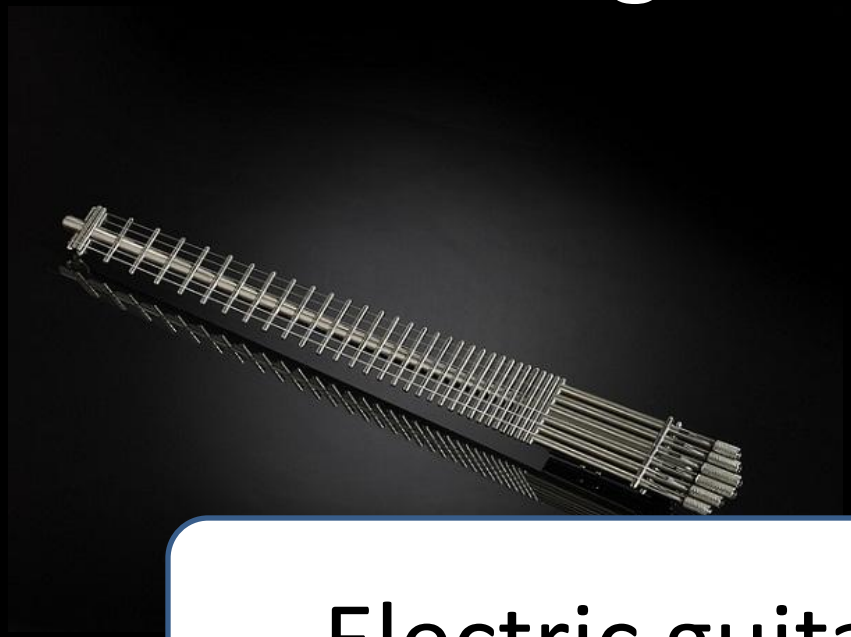


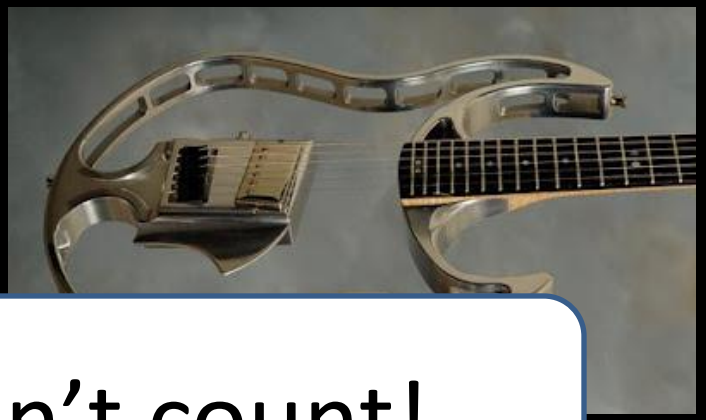

He-Ne laser
Woode
S


Shaker/impedance head
Elastic supports
Magnetic clamp
Guitar
Magnetic supports



“I’ve seen guitars without bodies”



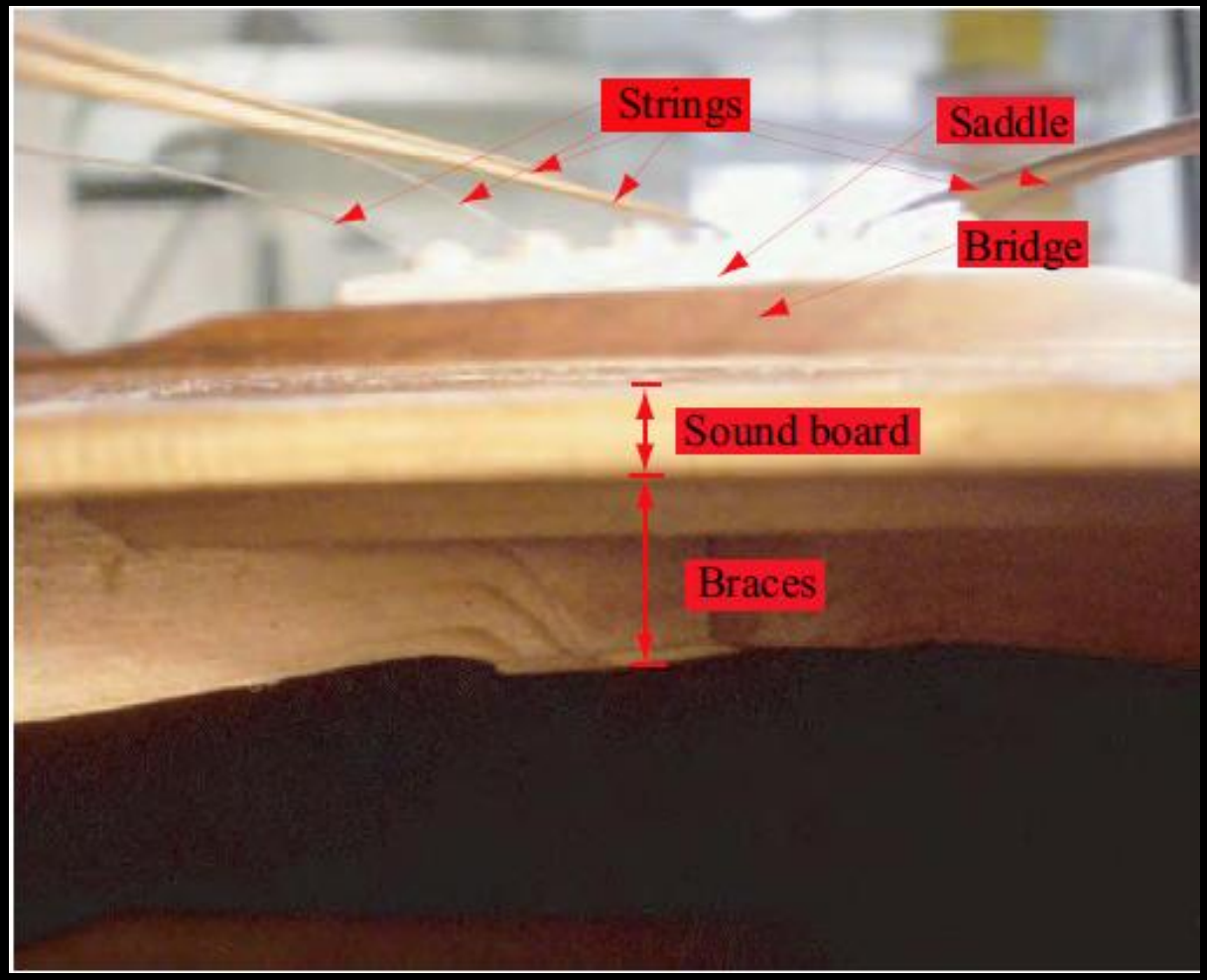


Electric guitars don’t count!

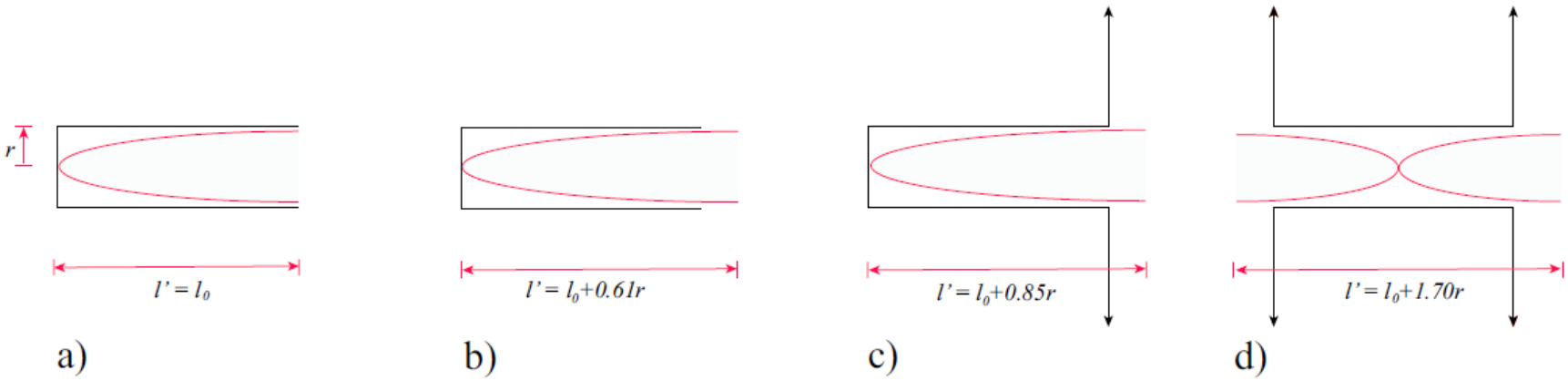
The Helmholtz resonator

$$f_H = \frac{c}{2\pi}\sqrt{\frac{S}{Vl}}$$

Where is the ‘throat’ of the resonator?



It’s the end ‘correction’!



$$\ell' = \left(\frac{8}{3\pi}\right) R \sim 0.85R$$

Here: R=48.0 mm

So: l’ ~ 41 mm (each side)

Helmholtz resonance of this guitar

Volume: 16.60 litres = 1.66×10^{-2} m^3

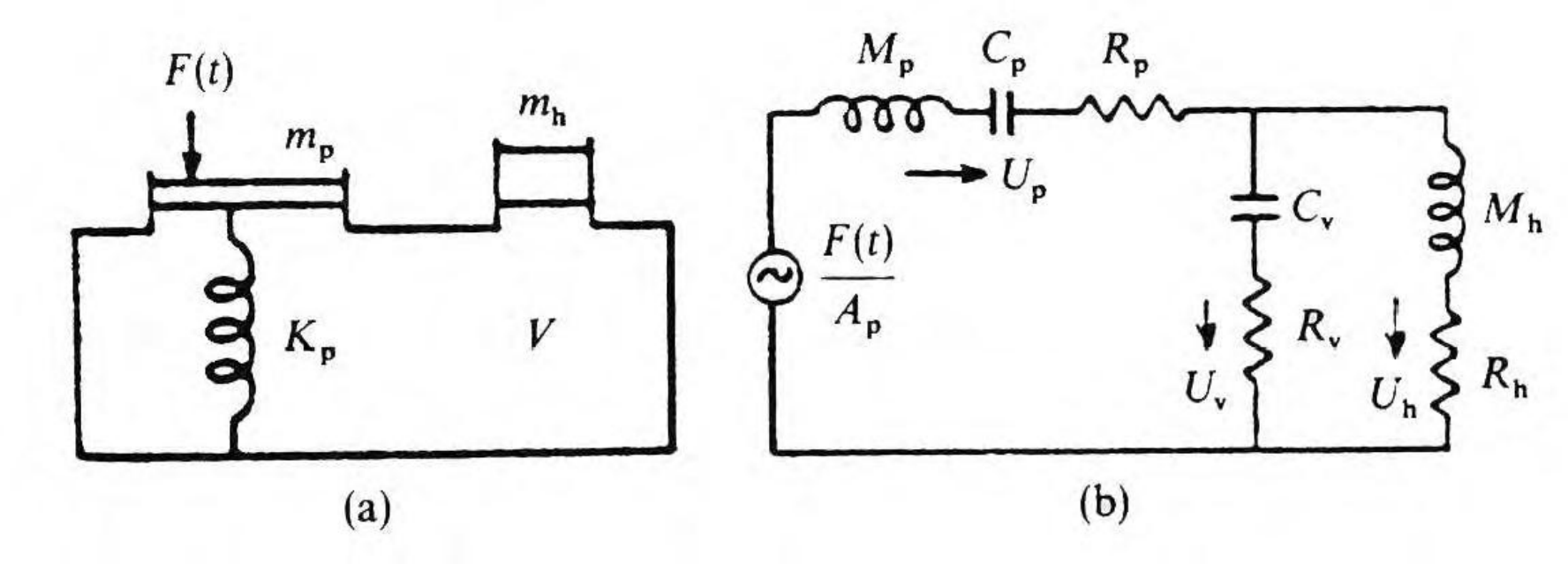
Radius of soundhole: 48.0 mm

Calculated f_H: 122.1 Hz

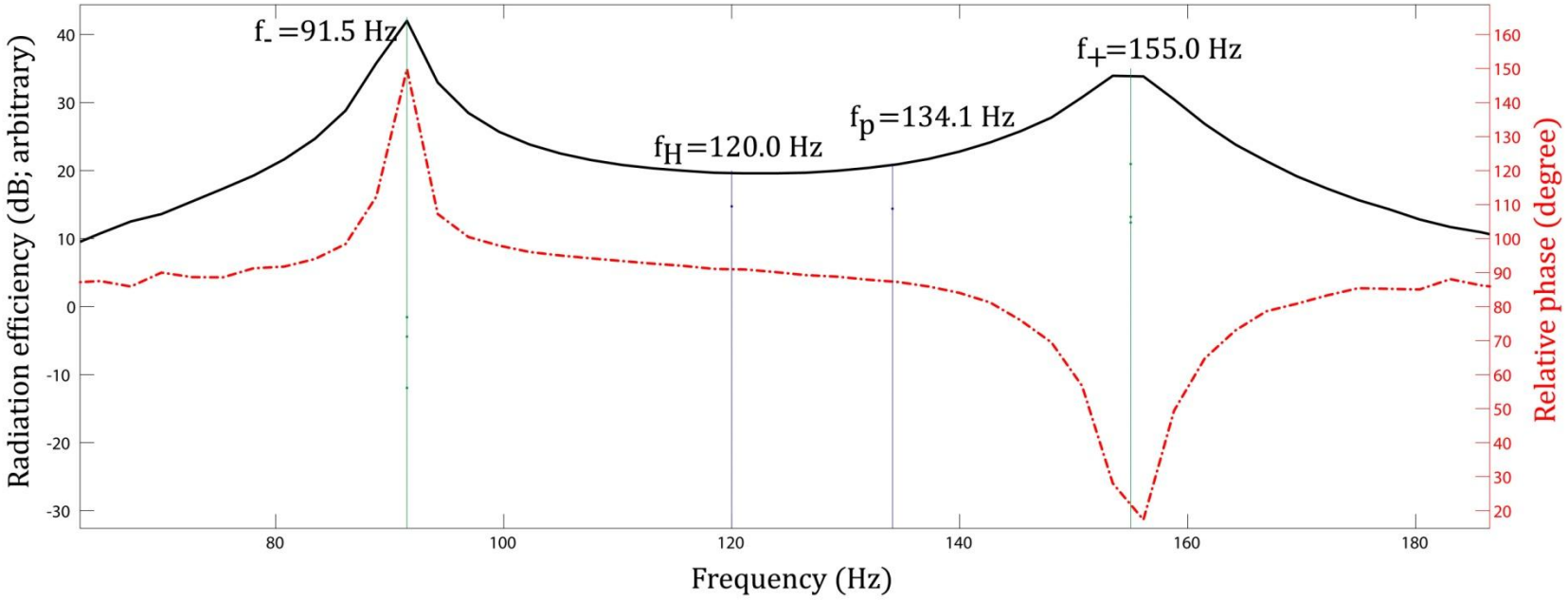
Measured f_H: 120.0 Hz

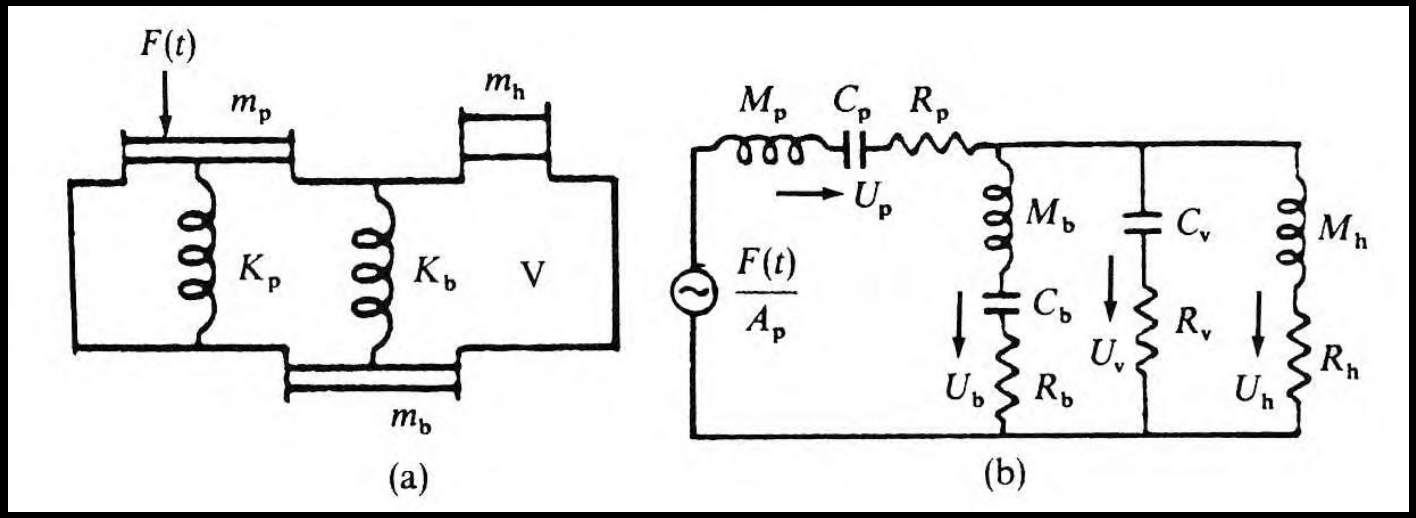
Coupled oscillators

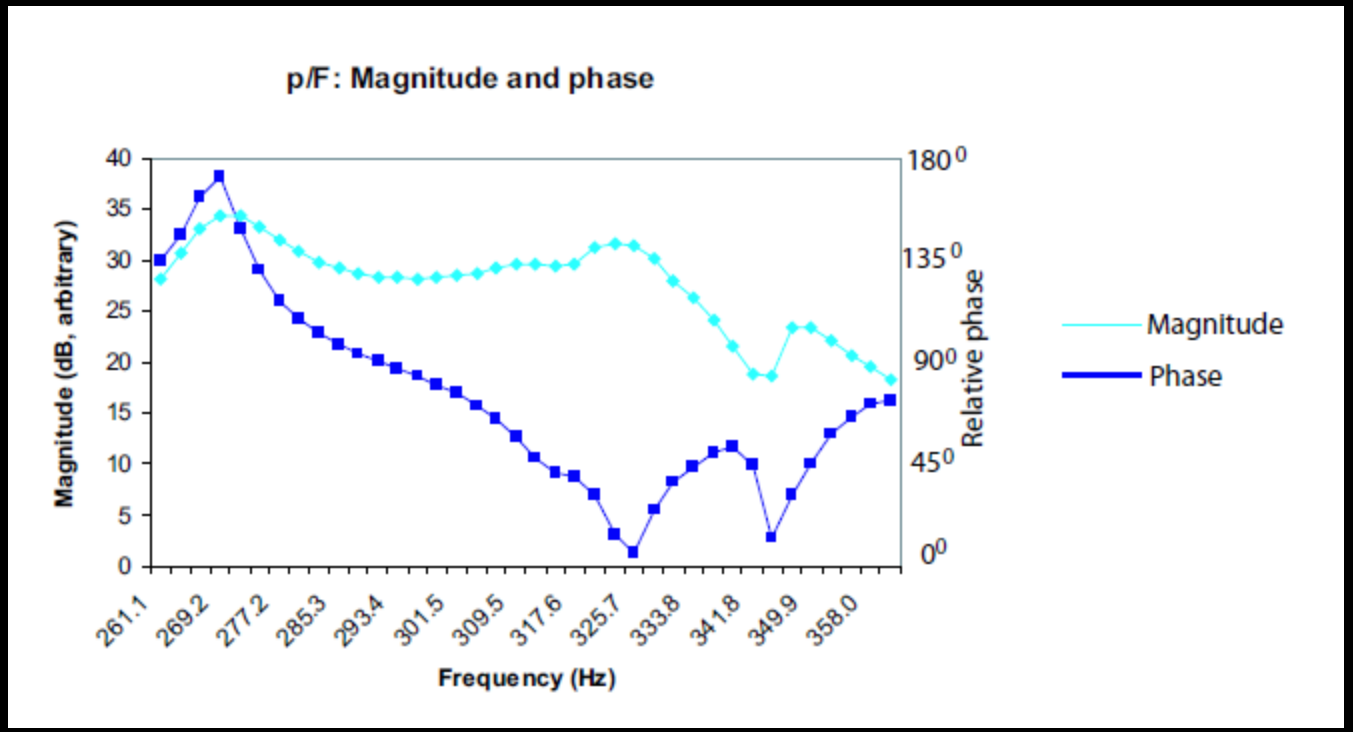
A circuit diagram of the guitar!



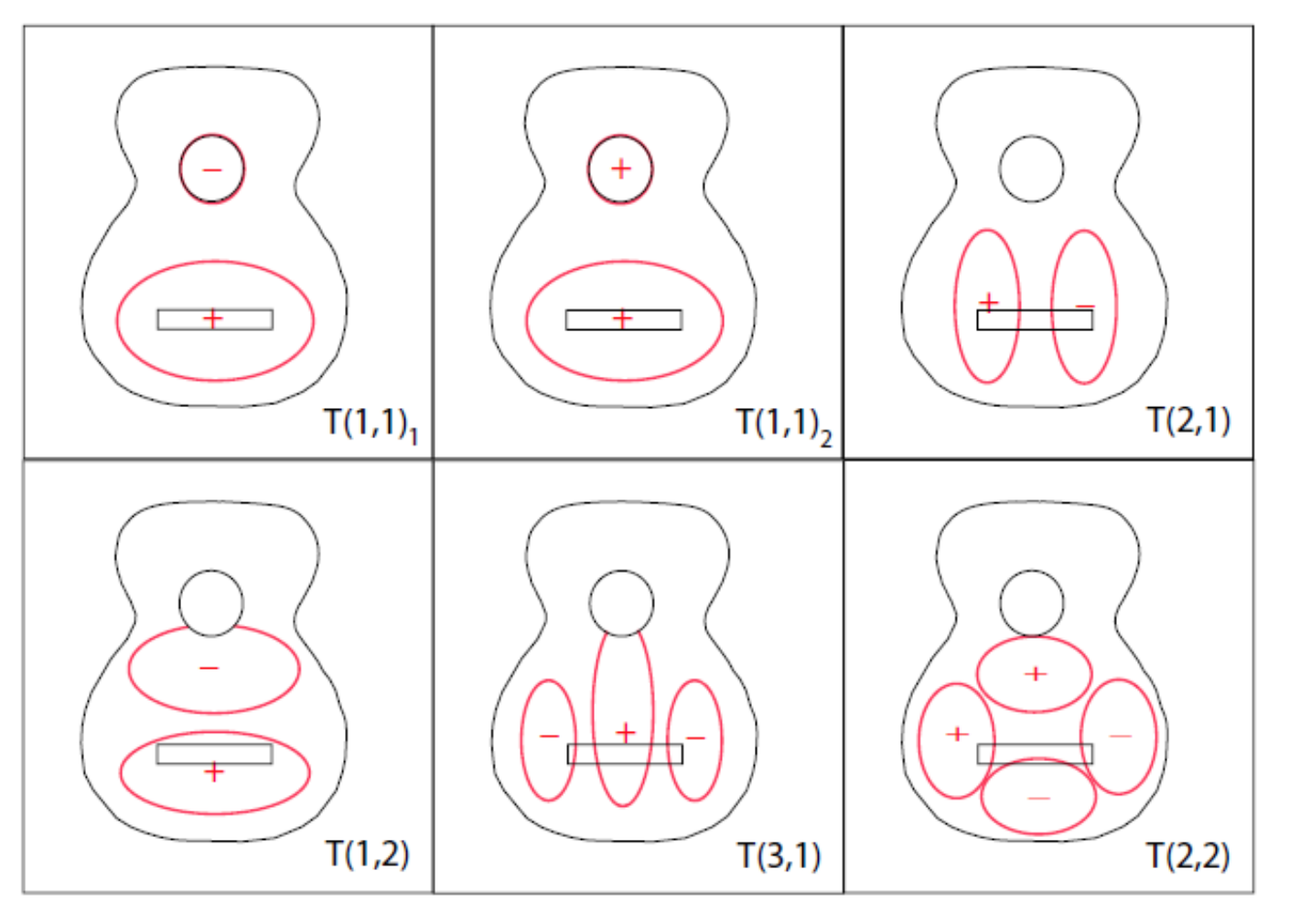
Coupled resonators split frequencies




F(t)
m_p
m_h
K_p
K_b
V
m_b
(a)
M_p
C_p
R_p
U_p
F(t)/A_p
M_b
C_b
U_b
R_b
C_v
R_v
U_v
M_h
R_h
U_h
(b)


p/F: Magnitude and phase
Magnitude (dB, arbitrary)
Relative phase
Frequency (Hz)
40
35
30
25
20
15
10
5
0
180⁰
135⁰
90⁰
45⁰
0⁰
261.1
269.2
277.2
285.3
293.4
301.5
309.5
317.6
325.7
333.8
341.8
349.9
358.0
Magnitude
Phase

Vibrations of the sound-board (top)



ES: 68 Hz
SS: 73 Hz
WRC: 69 Hz

ES: 136 Hz
SS: 137 Hz
WRC: 127 Hz

ES: 150 Hz
SS: 152 Hz
WRC: ---- Hz

ES: 150 Hz
SS: 152 Hz
WRC: 131 Hz

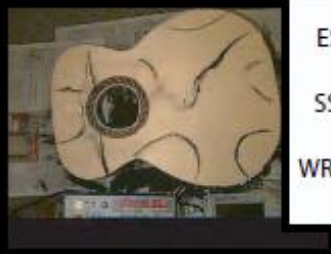
ES: 180 Hz
SS: 185 Hz
WRC: 166 Hz

ES: 241 Hz
SS: 239 Hz
WRC: 232 Hz

ES: 357 Hz
SS: --- Hz
WRC: 335 Hz

ES: 428 Hz
SS: --- Hz
WRC: 400 Hz

ES: 476 Hz
SS: --- Hz
WRC: 69 Hz



ES: 519 Hz
SS: 549 Hz
WRC: 546 Hz

ES: 587 Hz
SS: 591 Hz
WRC: --- Hz

ES: 610 Hz
SS: 590 Hz
WRC: --- Hz

ES: 647 Hz
SS: 676 Hz
WRC: 624 Hz

ES: 681 Hz
SS: ---- Hz
WRC: --- Hz

ES: 138 Hz

SS: 130 Hz

WRC: 135 Hz

ES: 161 Hz

SS: 159 Hz

WRC: --- Hz

ES: 314 Hz

SS: --- Hz

WRC: 316 Hz

ES: 344 Hz

SS: 353 Hz

WRC: 357 Hz

ES: 405 Hz

SS: 400 Hz

WRC: --- Hz

ES: 454 Hz

SS: 447 Hz

WRC: 432 Hz

ES: 559 Hz

SS: 553 Hz

WRC: 535 Hz

ES: 599 Hz

SS: --- Hz

WRC: 593 Hz

ES: 671 Hz

SS: 668 Hz

WRC: 654 Hz

ES: --- Hz

SS: 736 Hz

WRC: 725 Hz

ES: 887 Hz

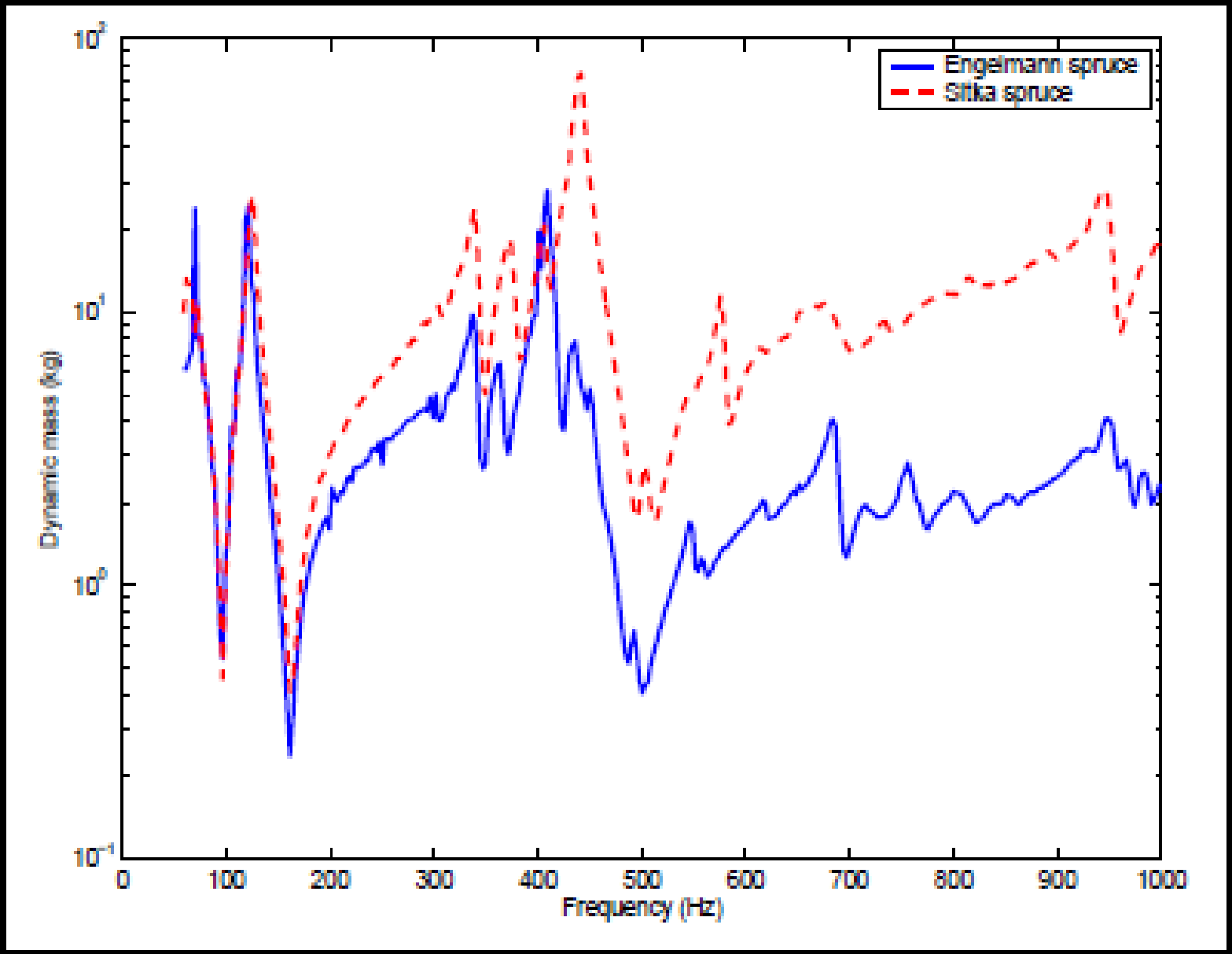
SS: 841 Hz

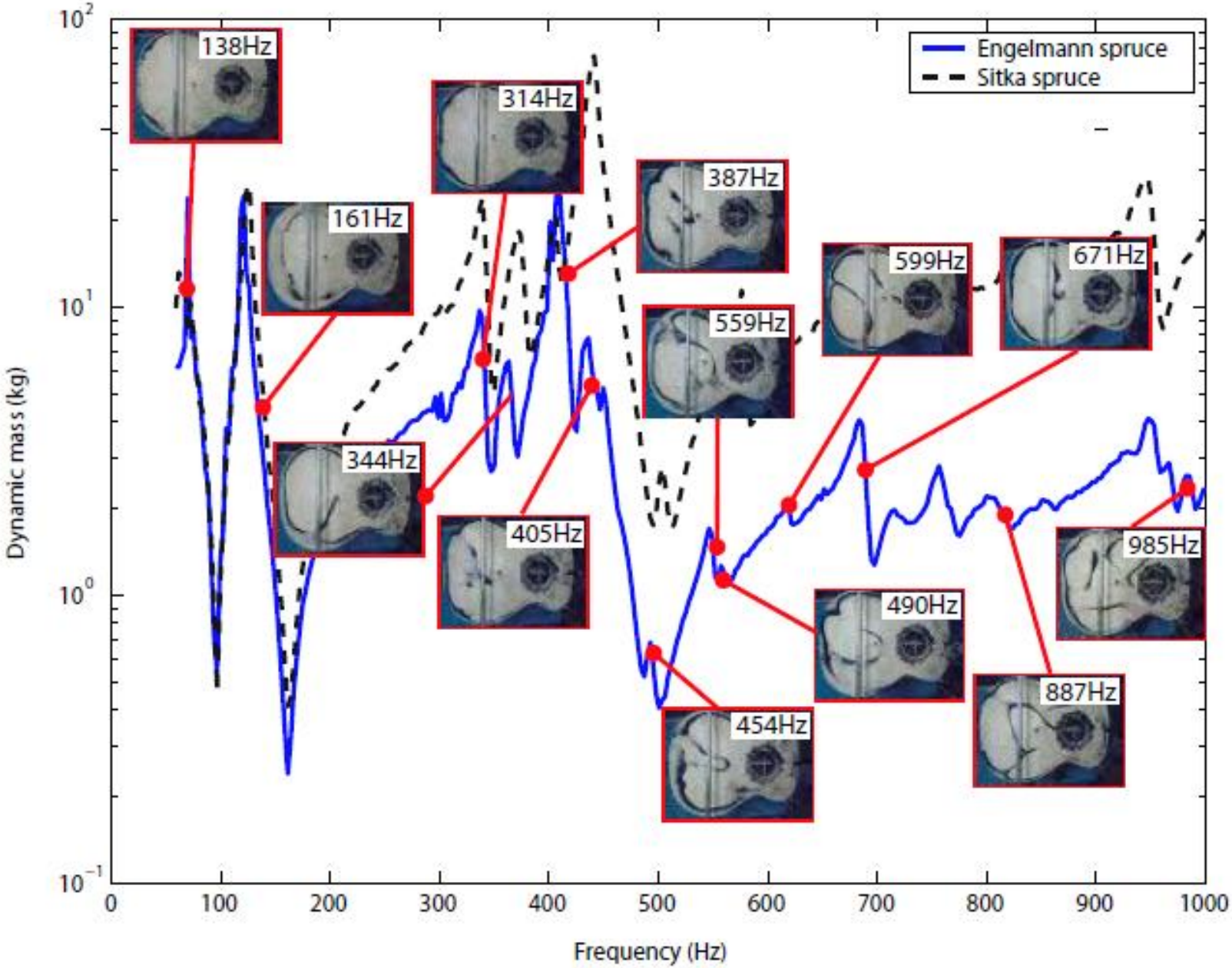
WRC: --- Hz

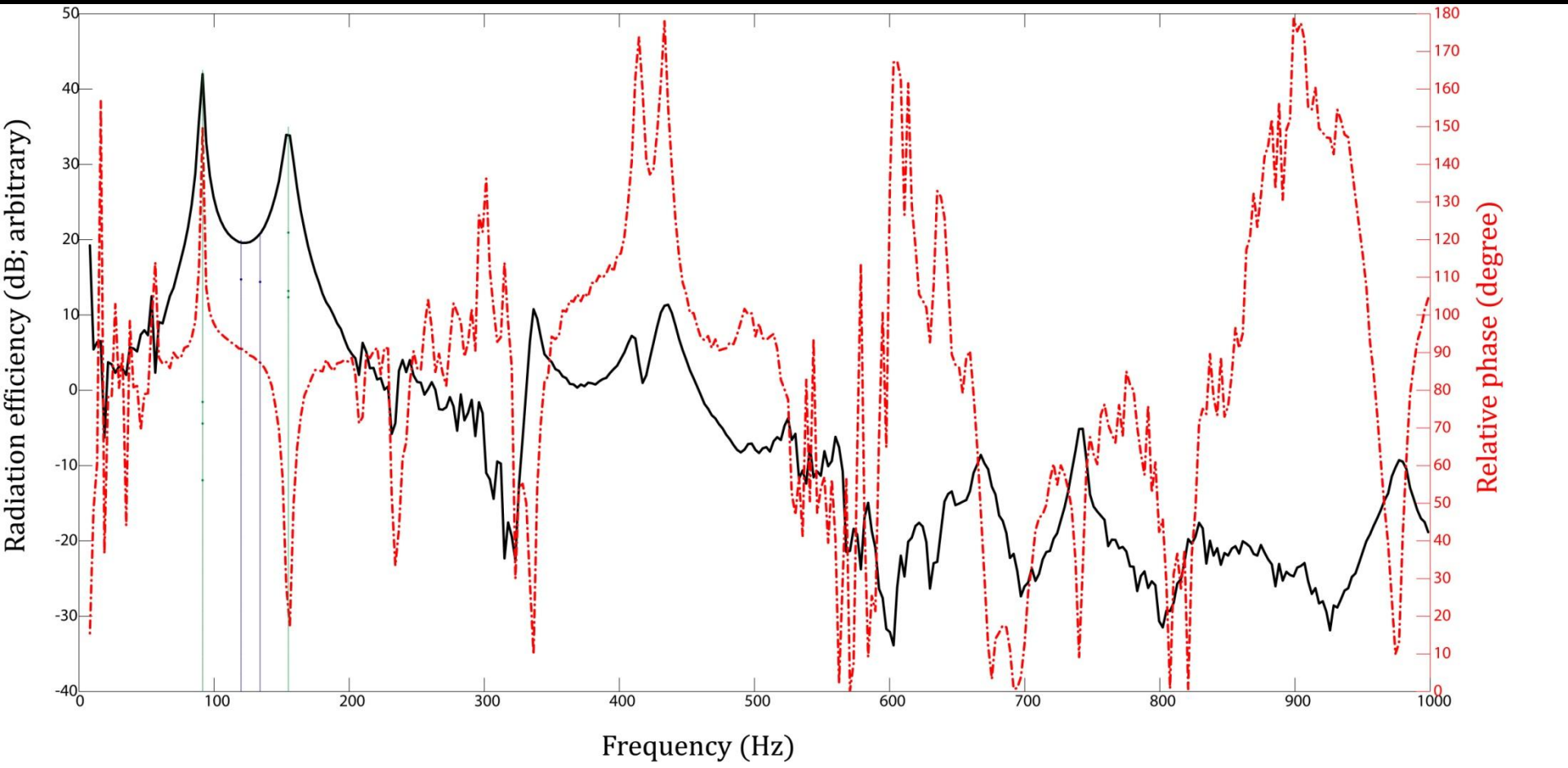
ES: 985 Hz

SS: 914 Hz

WRC: 901 Hz


Engelmann spruce
Sitka spruce
Dynamic mass (kg)
Frequency (Hz)
10^{2}
10^{1}
10^{0}
10^{-1}
0
100
200
300
400
500
600
700
800
900
1000


Engelmann spruce
Sitka spruce
138Hz
161Hz
314Hz
344Hz
387Hz
405Hz
454Hz
559Hz
599Hz
671Hz
490Hz
887Hz
985Hz
Dynamic mass (kg)
Frequency (Hz)
10^2
10^1
10^0
10^{-1}
0
100
200
300
400
500
600
700
800
900
1000


Radiation efficiency (dB; arbitrary)
Relative phase (degree)
Frequency (Hz)
50
40
30
20
10
0
-10
-20
-30
-40
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000

Thanks for listening!