POLITECNICO MILANO 1863	051483 Musical Acoustics Module 2: Characterization of musical instruments	Homework H5

Synthesis of the guitar sound

Goal

combine the frequency response function of the guitar body with the transfer function from the excitation point to the bridge, to synthesise the vibrational field measured on the body of the guitar.

First component: transfer function from the plucking point to the bridge

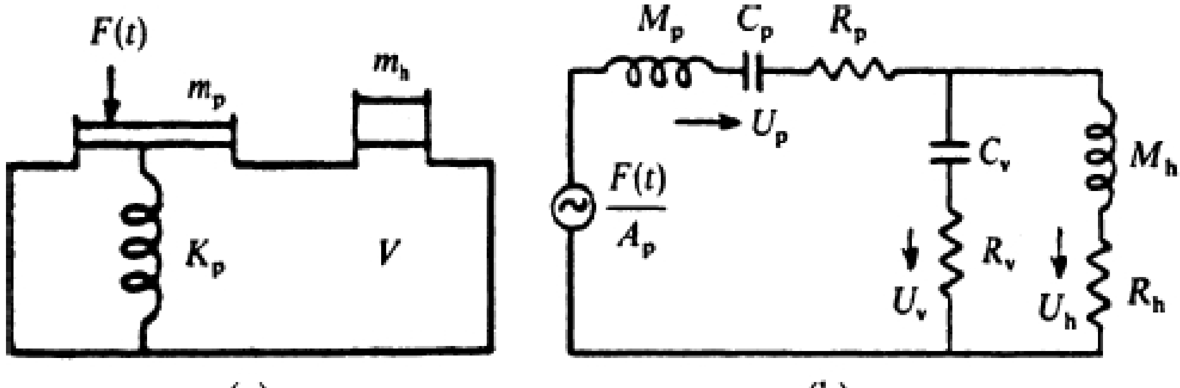
The transfer function between the displacement X(jω) at the excitation point and the force F(jω) exerted by the strings at the bridge is given by $H_{E,B}(j\omega)=F(j\omega)/X(j\omega)$ and can be modelled as

$$H_{E,B}(s) = \frac{F(s)}{X(s)} = 1/2[1 + H_{E_2,R_1}(s)]\frac{H_{E_1,R_1}(s)}{1 - H_{loop}(s)} Z(s)\frac{1}{s}[1 - R_b(s)]$$

where H_{loop} is the transfer function of the string, $H_{E1\,R1}$ is the transfer function from the excitation point to the bridge, $H_{E2\,R1}$ is the transfer function from the excitation point to the bridge passing through the nut, Z is the bridge impedance and finally the filter R_b relates the ingoing and outgoing waves along the string, and therefore can be modeled in a first approximation as a phase inversion filter.

Second component: bridge impedance

The bridge impedance is modeled through the two-mass system shown below (a) mechanical domain, (b) electric domain, which presents two resonances and an antiresonance in the middle.



(a) (b)

For a Martin D28 guitar it can be found that the parameters are:

- Top plate: stiffness $k_p=1.41\text{x}10^5$N/m, effective mass $m_p=0.128\text{x}0.385$kg (the real mass of the plate is 0.128 kg but it is here reduced by a factor 0.385 as the modal mass must be considered), top plate area $A_p=0.0375 \text{ x } 0.385$ m^2 , top plate resistance $r_p=32$ Nm/kg/s
- Soundhole: air piston mass m_h = 0.000804 kg, air piston area A_h = 0.00785 m^2, air piston resistance R_H = 30 N/m
- Air Cavity: volume V = 0.0172 m^3, air volume resistance = 0 (approximation).

Question 1

Derive the bridge impedance Z using the two-mass model given above and plot it in the frequency domain from 0 to 500 Hz.

Question 2

Derive the filter $H_{E,B}(j\omega)$ using Z/(max(abs(Z)) obtained at Question 1 and plot it in the range 0-500 Hz.

Question 3

Compute the time domain response of the system to a plucking at time t_0=0s happening at one fifth of the length of the string and with a maximum displacement of 3mm

Important information

Deadline: send the report by December 15th.
Difficulty coefficient: 3.0