Assignment

Homework HW3

Master program in Music and Acoustic Engineering

Musical Acoustics

course code: 051483

Academic year 2023/2024

POLITECNICO
MILANO 1863

November 20, 2023

Problem

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(j) at the excitation point and the force F(j) exerted by the strings at the bridge is given by $H_{E,B}(\omega) = \frac{F(\omega}{X(\omega)}$ and can be modelled as

F bridge (conseguenza del plucking) /
X displacement della corda nel punto d'eccitazione

$$H_{E,B}(\omega) = 1/2\left[1 + H_{E_2R_1}(\omega)\right] \frac{H_{E_1R_1}(\omega)}{1 - H_{\text{loop}}(\omega)} \frac{Z(\omega)}{\omega} \left[1 - R_b(\omega)\right],$$

where $H_{\text{loop}}(\omega)$ is the trasnfer function of the string, $H_{E_1R_1}(\omega)$ is the transfer function from the excitation point to the bridge, $H_{E_2R_1}(\omega)$ is the transfer function from the excitation point to the bridge passing through the nut, $Z(\omega)$ is the bridge impedance and finally the filter $R_b(\omega)$ 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 in Fig.1 (a) mechanical domain, (b) electric domain, which presents two resonances and an antiresonance in the middle.

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

- Top plate: stiffness $k_p = 1.41 \times 10^5 N/m$, effective mass $m_p = 0.128 \times 0.385 kg$ (i.e. 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 $A_p = 0.0375x0.385m^2$, top plate resistance $r_p = 32Nm/kg/s$.
- Soundhole: air piston mass $m_h = 0.000804kg$, air piston area $A_h = 0.00785m^2$, air piston resistance $RH = 30N/m$.
- Air Cavity: volume $V = 0.0172m^3$, air volume resistance = 0 (approximation).

Question 1

Derive the bridge impedance $Z(\omega)$ using the two-mass model given above and plot it in the frequency range from 0 to 500 Hz.

Question 2

Derive the filter $H_{E,B}(\omega)$ 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

Provide the solution by Oct. 21, 2023, using the WeBeep assignment tool.

- **The report must fit in 6 pages of the Latex template available at https://www.overleaf.com/read/rnkchgybrrsm;**
- **Answer concisely;**
- **Describe – concisely - the procedure used to obtain the results: if an error is present, I cannot identify the reason – numerical or conceptual - if the**

procedure is not described: in grading I will be forced to use the worst-case option.

- **All students who participated to the same group must upload the report;**
- **In the PDF file and in the filename, specify the name, surname and ID of all the students participating to the HW, if more than one student worked on it.**

BRIDGE IMPEDANCE

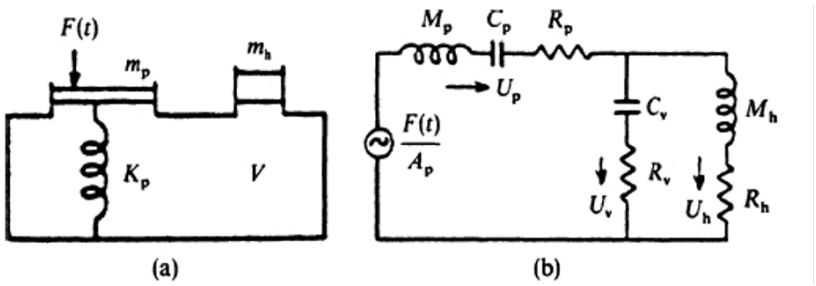

Figure 1: Mechanical and electric analog of a guitar