INFLUENCE OF THE PERFOMANCE PARAMETERS IN TRANSMISSION LINE LOUDSPEAKER SYSTEM

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Basilio Pueo, José Escolano, and Miguel Romá

Department of Physics, System Engineering and Signal Theory,
University of Alicante
E-03080 Alicante, Spain
e-mail: basilio@disc.ua.es, jescolano@disc.ua.es, mroma@disc.ua.es

ABSTRACT

Various different Transmission Line (TL) prototypes were fabricated to characterise the influence of the main performance parameters of a TL. In this paper it has been demostrated that low frequency response and electric input impedance changes due to several parameters are presents line length, cross sectional areas and stuffing density are the main perfomance parameters. Not also these known parameters perfomance but also some other unexplored ones are tested on several TL prototypes. Finally, a set of non affecting parameters are presented.

INTRODUCTION

Acoustic Labyrinth loudspeaker enclosure has been studied since 1936 by Olney [1]. In a classic model, the sound wave from the back of the woofer is channelled down a long pathway filled with an absorbent material. The total response is achieved by adding front and back radiation. Theorically, this extends the low frequency response up to one-third octave below the fundamental resonance of the driver.

Unlike classical enclosures, Transmission Lines cannot be analyzed by using Thiele-Small parameters [2]. Since a valid model is not developed, a first approach is to know the influence of some parameters and how they operate on the system response. Objective information is seldom provided and it is confined mostly to a few designs frequency response measurement.

A deep study of electroacoustic device must consider two sides: the electric input impedance, in terms of electric coupling, and the pressure response. Length and shape of the pipe, stuffing density and cross sectional area are the main parameters to change the response. An optimum Transmission Line enclosure for a given loudspeaker is not the purpose of this paper. On the contrary, the influence of the known parameters are reconsidered in a more general view. This means to consider other tested parameters that has not been performed before.

PROTOTYPE DESCRIPTION

An acoustic Transmission Line is a low frequency radiation system comprising a loudspeaker in a damped pipe. Its length is the quarter wavelength of alignment frequency, and generally, this is the loudspeaker resonance frequency. As vented boxes [3], the total response is adding the two responses. Notwithstanding, the Transmission Line has an open-back so the acoustic load increases at the backside of the cone, this produces a extension of the low frequency response. Although the Transmission Line has never been completely and successfully modelled, the mobility analogue circuit of a figure 1 is a good starting point:

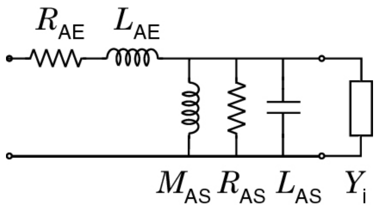

Figure 1. *Transmission Line acoustic mobility analogy circuit.*

It is straightforward to solve this circuit for the electric input impedance:

$$Z_{ee} = R_{AE} + j\omega L_{AE} + \frac{(Bl)^2}{S_D^2\left(\frac{1}{j\omega L_{AD}} + j\omega C_{AD} + \frac{1}{R_{AD}} + Y_i\right)}$$

The influence of the enclosure in the electric input impedance is shown in the previous equation.

On the other hand, this circuit can be seen as a electric current divisor in mobility analogy, so the electric current is sound pressure. The radiation impedance of the diaphragm is then:

$$R_{atd} = R_{AS} + \frac{(Bl)^2}{S_D^2(R_{AE} + j\omega L_{AE})}$$

$$p_{speaker} = \frac{e_g S_D Z_{ar_{speaker}}}{Bl\left(Z_i + R_{atd} + j\omega M_{AS} + \frac{1}{j\omega C_{AS}}\right)}$$

Without damping material, a first approach to solve for Zi is the impedance seen by an open-ended tube [4]:

$$Z_i = j\frac{\rho_o c}{S_o}\tan(kl)$$

This expression shows the influence of the length and section on the input impedance.

Firstly, to test the influence of the cited parameters, a Transmission Line prototype with five rectangular section modules was built. The complete module is tuned with loudspeaker resonance frequency. Each added module provides different harmoniously alignment frequencies. Furthermore each module can modify its cross sectional area to obtain three different sections. Finally, the prototype will be damped with a hollow polyester fibre, having an initial density of 1.16 g/cm³.

A prior laboratory test to accuretly measure the driver Thiele-Small parameters brings a 32.7 Hz resonance frequency and a 22 cm² cone. Each length is then tuned to 32.7, 41.2, 51.9, 65.4 and 82.4 Hz, and section ratios S_o/S_D are 2.2, 3 and 5 (see in figure 2). Five stuffing densities are used: 0, 1.5, 3, 5 and 8 Kg/cm³. These parameters are individually varied and their effects are studied both in electric input and front and mouth pressure level.

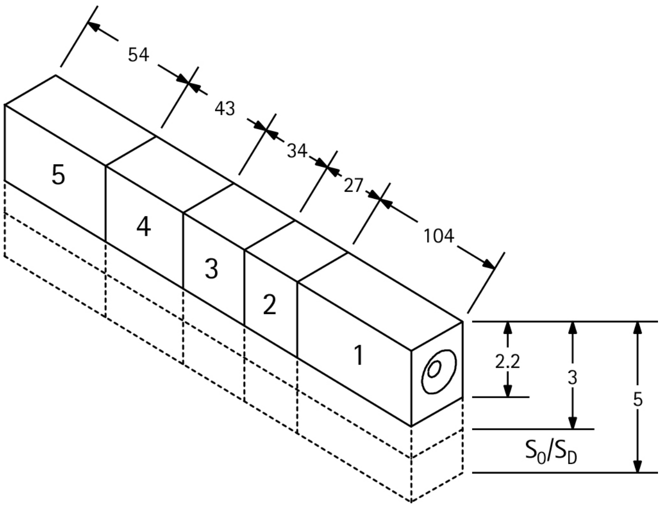

Figure 2. *Transmission line prototype.*

TEST PROCEDURE

For the response and impedance measurements, the modular pipe was set horizontally on a solid table about 0.5 m above the floor. Two G.R.A.S. 1/2" free field condenser microphones with preamplifier were connected to a System One Dual Domain Audio Precision analyzer.
Frequency response measurements were made by using MLS (Maximum Length Sequence) technique so reflection effects were avoided [5]. Cone and mouth measurements were made simultaneously, and then repeated ten times to obtain averaged values. A time window comprising two “half-windows” is used in this technique. When the impulse response, it is to say direct arrival signal before reflections, is isolated and transformed into the frequency domain, the impulse amplitude at both the beginning and ending is not exactly the same. Introduced sharp edges in impulsive response by splicing unequal amplitudes will produce ripples. Windowing the time domain data by attenuating the amplitude at the beginning (5 % time span multiplied by sample period) and at the end (30 %) of the section reduce this rippling. A limited band analysis (20-1000 Hz) with a 2 Hz resolution is achieved by a operating the Sweep control.

Electric input impedance was measured through an Audio Precision application [6]. It uses a known accurate resistor of 600 Ω to make the classic voltage divisor method and to obtain the impedance module and phase.

SYSTEM BEHAVIOUR

Line length or alignment frequency

This parameter determines the position of resonance frequencies. For that reason, in order to optimize the system response, the pipe length is a quarter wavelength of the loudspeaker resonance frequency. Various harmonic lengths are presented to know the Transmission Line behaviour:

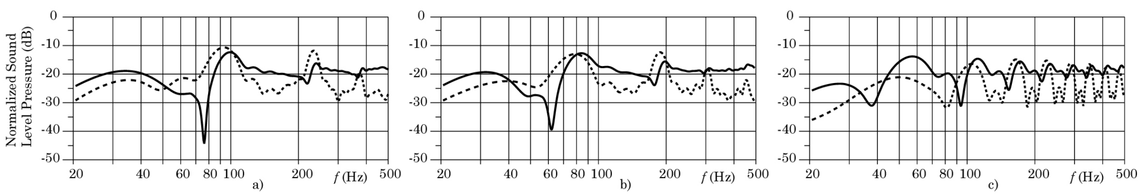

Figure 3. *Sound pressure level in loudspeaker (continuous) and in mouth (dashed) for a) 1’04, b) 1’31 and c) 2’62 m length (Cross sectional ratio of 2’2 and no stuffing density).*

Figure 3 shows the trend of resonance frequencies to displace at low frequencies as the line length decreases together with the relative distance between them. The module impedance (see in figure 4) has the same behaviour. Furthermore, the loudspeaker peak impedance module decreases when the length grows up to become an infinite plane piston.

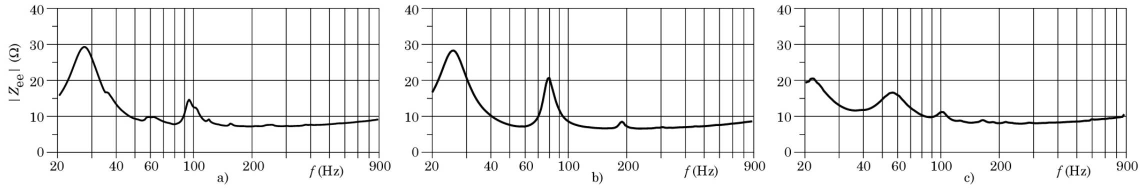

Figure 4. *Electric input impedance module for a) 1'04, b) 1'31 and c) 2'62 m length. Cross sectional relationship 2'2 with no stuffing density.*

Stuffing package density

Probably, the stuffing is the most important parameter because it shapes the pressure and impedance curve. In figure 5, various sound pressure levels and impedance curves are presented.

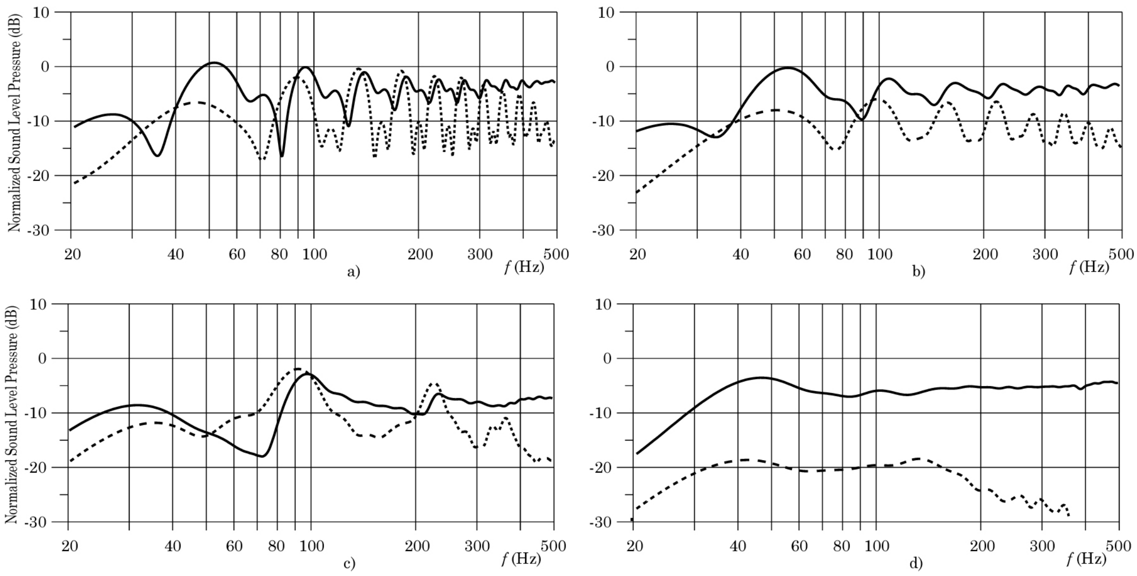

Figure 5. *Sound pressure level in loudspeaker (continuous) and in mouth (discontinuous) to a) 0 Kg/cm³, b) 1'5 Kg/cm³ c) 3 Kg/cm³ and d) 8 Kg/cm³ stuffing package density (Cross sectional relationship 2'2 and length 1'04 m).*

Loudspeaker first pressure peak decreases in frequency and level as the damping material is augment; the rest of the curve peaks, only decreases in level. Rear pressure peaks maintains its frequency but not its level, and high frequency are attenuated. A high quantity of damping material becomes this enclosure in a closed box.

As seen in figure 6, the trend is same in electric input impedance behaviour. The first peak decreases in frequency and module whereas the rest of resonance peaks only do in module.

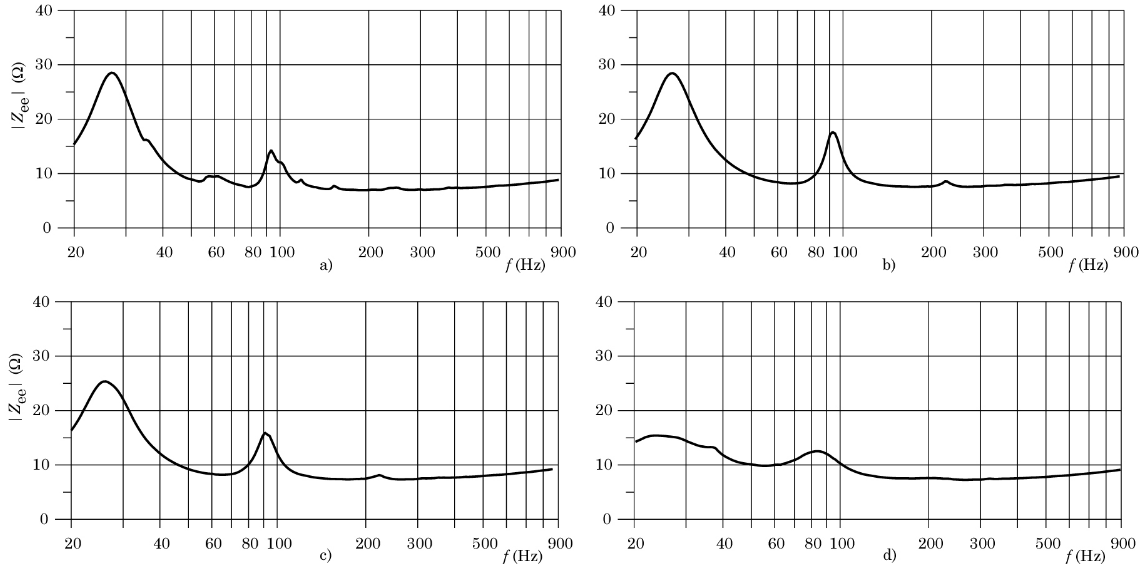

Figure 6. Electric Input impedance module to a) 0 Kg/cm³, b) 1'5 Kg/cm³ c) 5 Kg/cm³ and d) 8 Kg/cm³ stuffing package density (Cross sectional relationship 2'2 and length 1'04 m).

The key point is that the damping material is used to muffle the resonance frequencies of the enclosure, and high frequency are attenuated. As it has been shown empirically, an excesive damping material will decrease the rear pressure. Assuming that global response is obtained by adding the two outputs, high damping densities will cause the output to less than a simple closed box.

Cross Section Area Ratio

Cross section area ratio between diaphragm and enclosure (S_o/S_D) is essential in the Transmission Line response. This parameter controls the relative distance between resonance peaks both in pressure level and in module impedance. As S_o/S_D increases, the distance between resonance frequencies decreases. On the contrary, when the relation grows, loudspeaker resonance frequency module does too, whereas the rest of peaks grows down. If S_D tend to infinity, this system will be a piston in a infinite baffle.

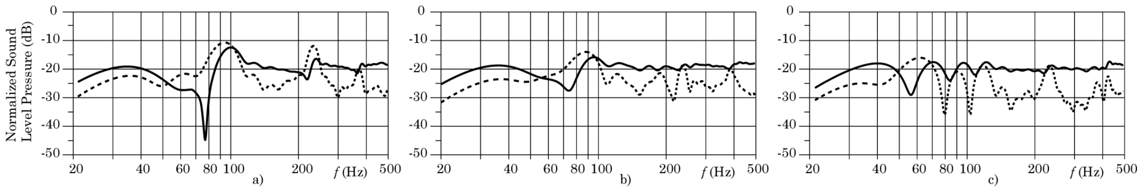

Figure 7. Sound level pressure in loudspeaker (continuous) and in mouth (discontinuous) to 2'2, 3 and 5 cross sectional relationship (0 Kg/cm³ stuffing package density and length 1'04 m).

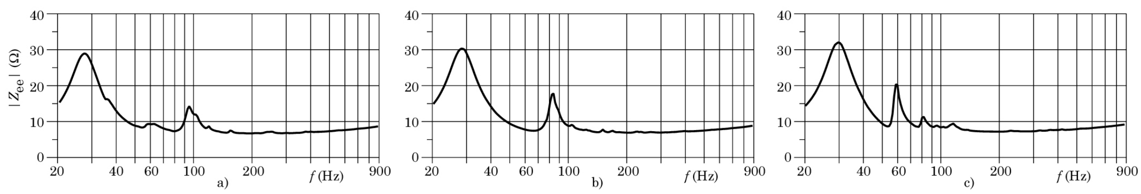

Figure 8. Electric Input impedance module to 2'2, 3 and 5 cross sectional relationship (0 Kg/cm³ stuffing package density and length 1'04 m).

CONCLUSION

Acoustic Transmission Lines are a sort of low frequency sound radiation system, where sound pressure and electric input impedance can be modelled by a known set of parameters. Adding the front and back output pressure, a global sound pressure level with increased response is achieved by this system. With no valid model, the system can be alignmented as certain parameters are varied.
The control of the sound level response and electric input impedance is the ability to allocate the resonance frequencies and their magnitudes, and in this way a relative plane response and cut-off frequency can be achieved.
On the other hand, the geometry of the section does not affect any measurement. Most papers present a Transmission Line with circular section and this particular design has been consolidate as the only one. Providing generality of the discussion, the measurements carried out in this experiment fullfil our expectations, independently of any geometry considered. In this way, a circular section pipe was measured (108 Hz loudspeaker resonance frequency, S_o/S_D =1, length 1.41 m and 0 kg/cm³ stuffing package density), and the pressure and electric impedance response are presented in figure 9. The shape of these curves is that for the rest presented in the body of the paper.

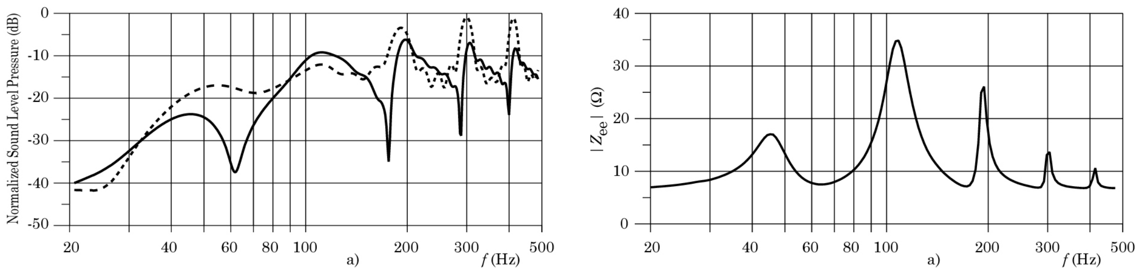

Figure 9. a) Sound pressure level and b) electric Input impedance .

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