Enclosures in the Acoustical Library

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In the Acoustical Library for Simscape, starting with version 1.2.0, the number and complexity of the components for acoustical enclosures has been increased. In previous versions of the library, only a single `enclosure` component was included. That component was just the acoustical compliance of an ideal lossless air volume in a box with rigid walls. Version 1.2.0 and later include a slightly improved version of the simple enclosure and additional enclosure components that are more useful in modeling transducer assemblies such as moving coil speaker boxes and the front and back volumes of other acoustical transducer systems.

THE SIMPLE ENCLOSURE

The `enclosure` component in the original Acoustical Library for Simscape is a two terminal acoustical component. However, all correct uses of that component require that one of its terminals be connected to the acoustical reference node. (No error would be flagged if this was not done. However, the model would not have been mathematically correct unless that was done.) Starting in version 1.2.0 of the Acoustical Domain Library, this component is changed to that shown in Fig. 1. The original `enclosure` component is deprecated, but remains available in the library so that legacy models will run. It may be removed in a future version.

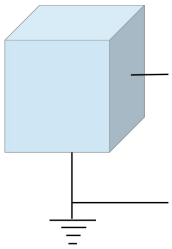

Figure 1. The original enclosure component had two terminals, but one of them was required to be connected to the acoustical reference.

THE SEALED BOX ENCLOSURE

The sealed box enclosure is used in many transducer systems. A condenser microphone, for example, may be considered as a (mostly) sealed enclosure with the microphone diaphragm mounted on one side of the encosure. Other acoustical components needed for a complete microphone model will not be discussed here, but the sealed box is a good start. A more common example is a moving coil loudspeaker mounted in an otherwise closed box. Perhaps the most common speaker design in home entertainment systems is a "bookshelf" speaker component that is a closed box that mounts one or two speakers in a mostly empty box. The

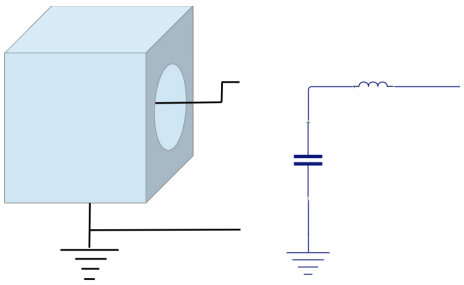

Figure 2. Left: symbol for `encl_w_hole`; Right: Simscape model that is implemented in the .ssc code.

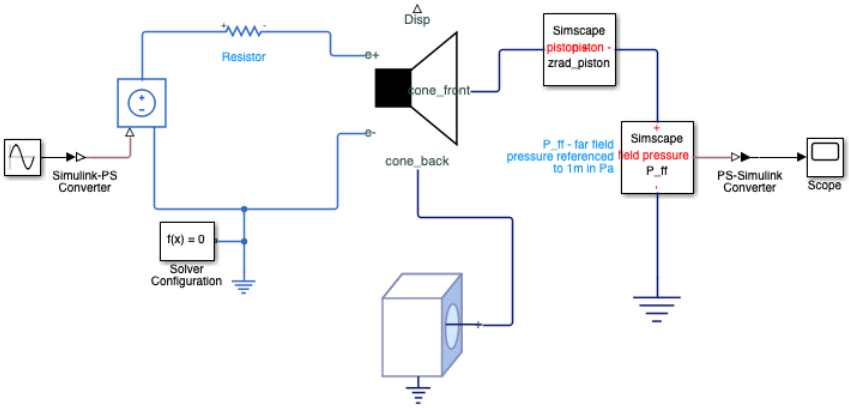

Figure 3. A simple model of a speaker in a sealed box enclosure. The electrical drive signal is from a voltage source with a small output impedance. The acoustical output drives the radiation impedance and is sensed in the far field.

box may contain some wiring connections and perhaps a few small electrical components for a crossover network, but is mostly just empty air space. This assembly was called an "acoustic suspension" speaker by one of its early developers who perfected the design.

One new component in the Acoustical Domain Library is the an sealed box with a round hole intended to mount a speaker. The new component, which is called "Acoustical enclosure with hole for speaker mount," is shown in Fig. 2 with the Simscape acoustical domain circuit that is implemented in the .ssc code. This component includes the lossless acoustic compliance and also an acoustical inertance to models the effect of the mass of the air that moves with the back side speaker cone. The magnitude of this moving mass is the same as the radiation mass for an equal size piston in a rigid baffle, as discussed in Beranek and Mellow[1].

An example of the use of this new component is shown in Fig. 3. The back side of the speaker cone is coupled to the sealed box, while the front side of the cone radiates top the

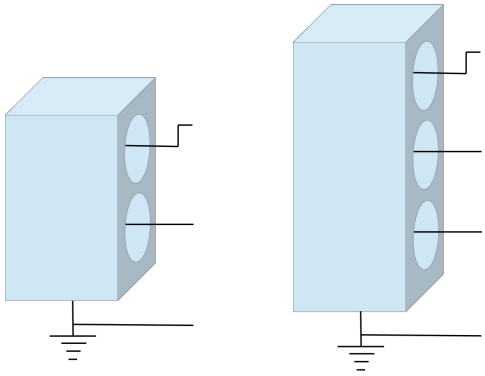

Figure 4. Enclosures with holes for additional speakers, ports or passive radiators are included in the library.

far field. The volume velocity of the speaker passes through the radiation impedance, and is sensed by the far field pressure calculation block. Note that the far field pressure at a range of r_{ff} is calculated as

$$P_{ff} = \frac{j\omega\rho}{4\pi r_{ff}} U_{cone}$$

assuming that the source is small compared to the wavelength.

The library also includes enclosures with two and three holds for various applications. The symbols for these enclosure components are shown in Fig. 4. The hold might be used to mount multiple speakers of the same or different designs, possibly to implement a midrange-tweeter (MT) design, an MTM design, a ported speaker, or a subwoofer with one or two passive radiators.

THE PORTED SPEAKER ENCLOSURE

The ported enclosure extends the low frequency response of the speaker by adding a controlled second resonance at a frequency below that of a of the speaker in a sealed box of an appropriate size. This is done by adding a circular opening (port) in the box and fitting it with a tube of appropriate size. The compliance of the air in the box resonates with the mass of the air in the tube to provide this additional low frequency resonance. The enclosure with two holes is a good starting point for this model. The speaker mounts in one hole, and the port tube mounts in the other. The size of each of the holes is adjusted int eh input dialog for the enclosure.A ported enclosure model made in this way is shown in Fig. 5.

The ported speaker enclosure is a common enough construction that it deserves its own component in the library. A component has been written that includes the tube in the second enclosure opening. That model is shown in Fig. 6

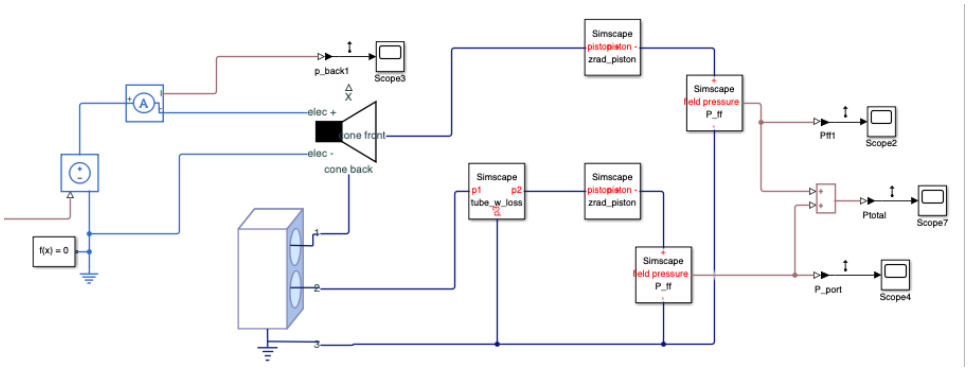

Figure 5. A ported speaker can be made with a speaker, enclosure and tube components from the Acoustical Domain Library.

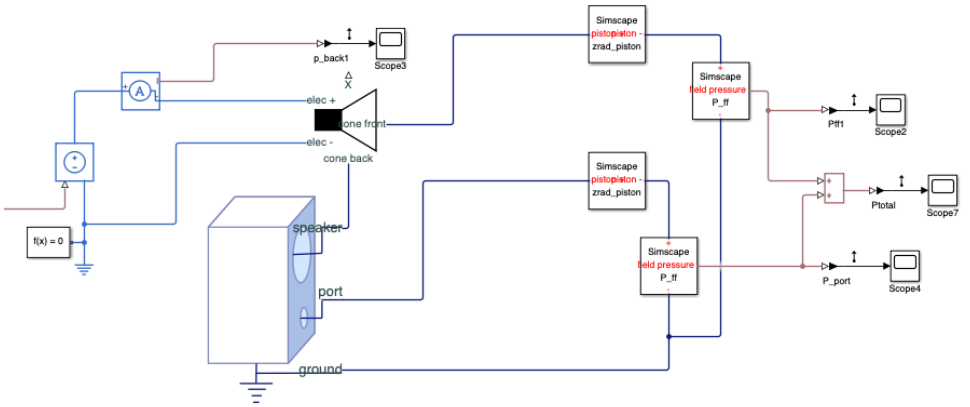

Figure 6. The ported speaker using the enclosure component with the tube included.

[1] Leo Beranek and Tim Mellow, Acoustics: Sound Fields, Transducers and Vibration, 2nd Ed., Academic Press, London, 2019.