Loudspeaker impedance

Many of you will have wondered what speakers should you choose for a particular amplifier or vice versa, given the amplifier, what speakers should you buy. In the following lines, we will try to give an answer to this question. To begin with, a decent power amplifier should be able to drive the majority of commercially available speakers, except perhaps for what we call "difficult loads". To explain what constitutes a difficult load we should clarify the concept of impedance. The *impedance* is a generalization of resistance, i.e. voltage divided by current. The impedance of a speaker is not constant but depends on the frequency. The impedance magnitude determines how hard the speaker loads the amplifier, i.e. how much current the amplifier will have to provide for a given voltage at its output.

The impedance of the drivers, the crossover network and the cabinet determine the impedance of loudspeaker. In the figure below we have drawn the impedance magnitude for a woofer with a nominal diameter of 8'' and a tweeter with a 28 mm dome. Both are specified by their manufacturer as 8 ohm drivers, but it is clear that the actual impedance differs from this value. Starting with the woofer, there is a peak at around 30 Hz which corresponds to the driver mechanical resonance. This will be modified if the driver is installed on a cabin. From there on the Impedance decreases to about 7 ohm to increase again at high frequencies. This increase is due to the self-inductance of the voice coil. The tweeter Impedance shows a similar behavior. The resonance around 800 Hz is less pronounced and its self-inductance much lower.

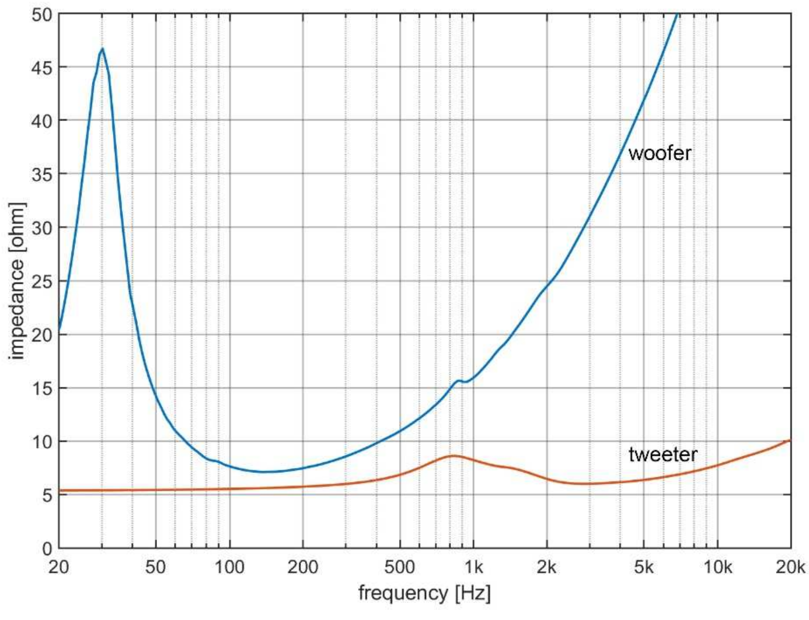

Figure 1. The impedance magnitude of an 8'' woofer and a tweeter with 28 mm dome

Let's review now the impedance of a typical commercial two-way loudspeaker specified by its manufacturer as an 8 ohm load. According to IEC-268-5 the minima of the loudspeaker impedance shall not be less than 80 percent of its nominal value. For an 8 ohm speaker the impedance should not drop below $0.8 \cdot 8 = 6.4$ ohm at any frequency. In the figure below the blue continuous line is the magnitude of the impedance and the red dashed line the phase. For this particular loudspeaker the magnitude has a minimum value of 6 ohm so it can marginally be characterized as an 8 ohm speaker. There are some pronounced peaks on this graph we need to explain. The two peaks on the left are due to the bass reflex loading. Their magnitude depends on the amount of sound absorbing material inside the cabinet. The peak just above 1 kHz is due to the interaction of the woofer self-inductance with the tweeter high-pass filter capacitor. Let's examine the phase now. For an ideal resistor the phase would be zero degrees regardless of frequency. This means that at any frequency the current is in phase with the voltage. Positive phase indicates inductive behavior (voltage leads) whereas negative phase capacitive behavior (current leads). The phase of this loudspeaker varies between -36 deg and +45 deg.

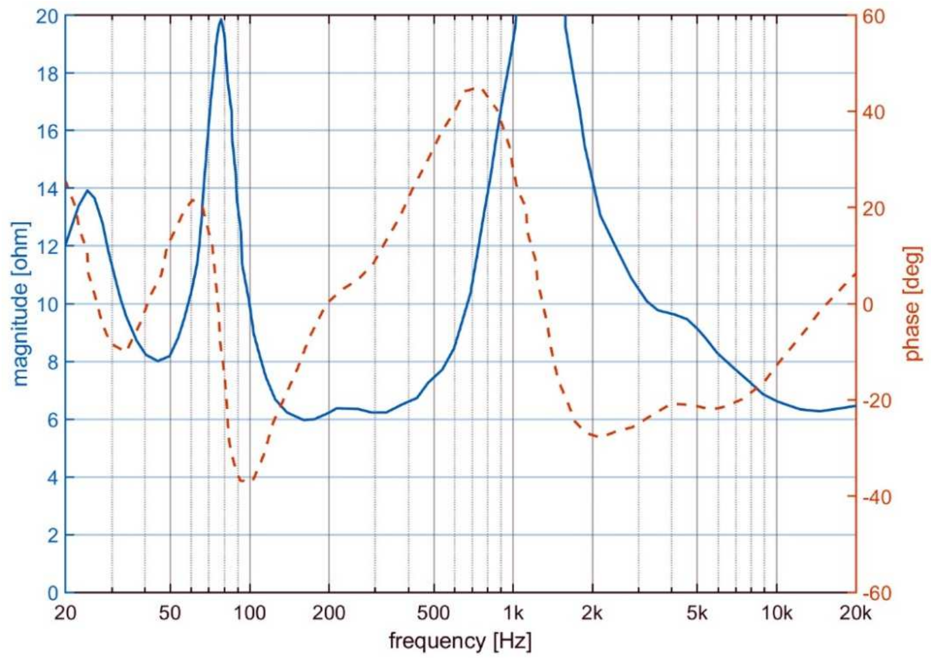

Figure 2. The impedance of a 2-way loudspeaker

Is this loudspeaker a difficult load? To answer the question we need to have an idea of how the frequencies in recorded music are distributed. Below is the average spectrum of popular music recordings. Other genres of music, such as classical or jazz, show a similar picture with minor differences. There is a peak around 100 Hz and plenty of energy between 50 Hz and 2 kHz. There is not much energy above 5 kHz. Returning to figure 2, we see that the region where the speaker shows a minimum in the impedance curve coincides with the region where music has a lot of energy. Values between 6 and 8 ohms may not be considered low, but the phase variation in this region is almost ±40 deg. Ideally, we would like the phase to change no more than ±20 degrees. We may conclude that this is a moderately difficult load.

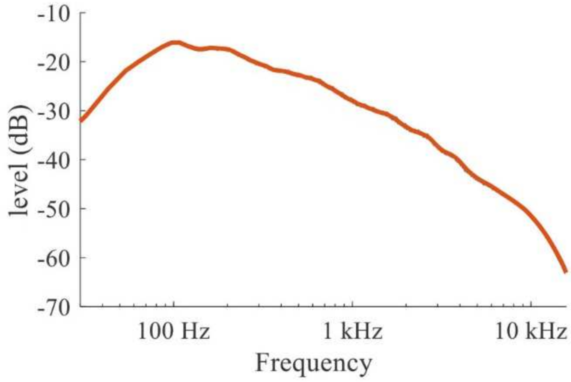

Figure 3. The average spectrum of popular music recordings

Are electrostatic speakers difficult to drive? It depends. Below is a graph of the impedance of the Quad ESL-989, magnitude and phase. The peak around 90 Hz is the lowest resonance of the membrane. As we can see the impedance magnitude reaches a minimum value of 3.6 ohm at 10 kHz, therefore this speaker qualifies as a 4 ohm nominal load. Between 100 Hz and 10 kHz the phase is slightly capacitive, another way to determine that this is an electrostatic speaker. Is this speaker a difficult load? In the region where music has a lot of energy, i.e. between 50 and 2000 Hz the impedance magnitude remains above 7 ohm and the phase is low and almost constant. This speaker is an easier load than the previous one we have examined.

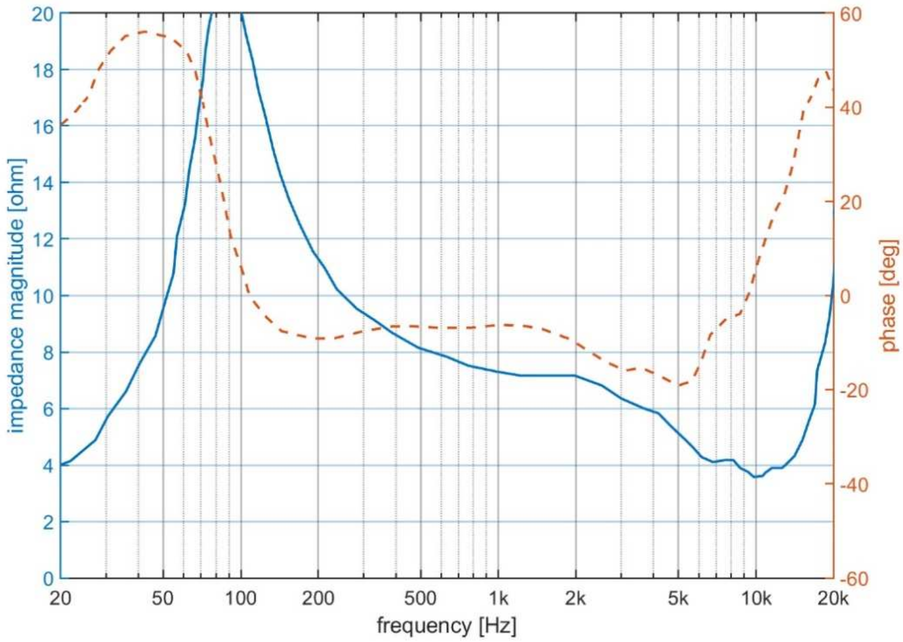

Figure 4. The impedance of Quad ESL-989

In conclusion, the nominal impedance of a speaker does not necessarily determine whether it is a demanding load for a power amplifier. For a speaker to be considered a difficult load it should have a low impedance in the range between 50 Hz and 2 kHz and at the same time a phase that varies widely.

For Echo Diastasis

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