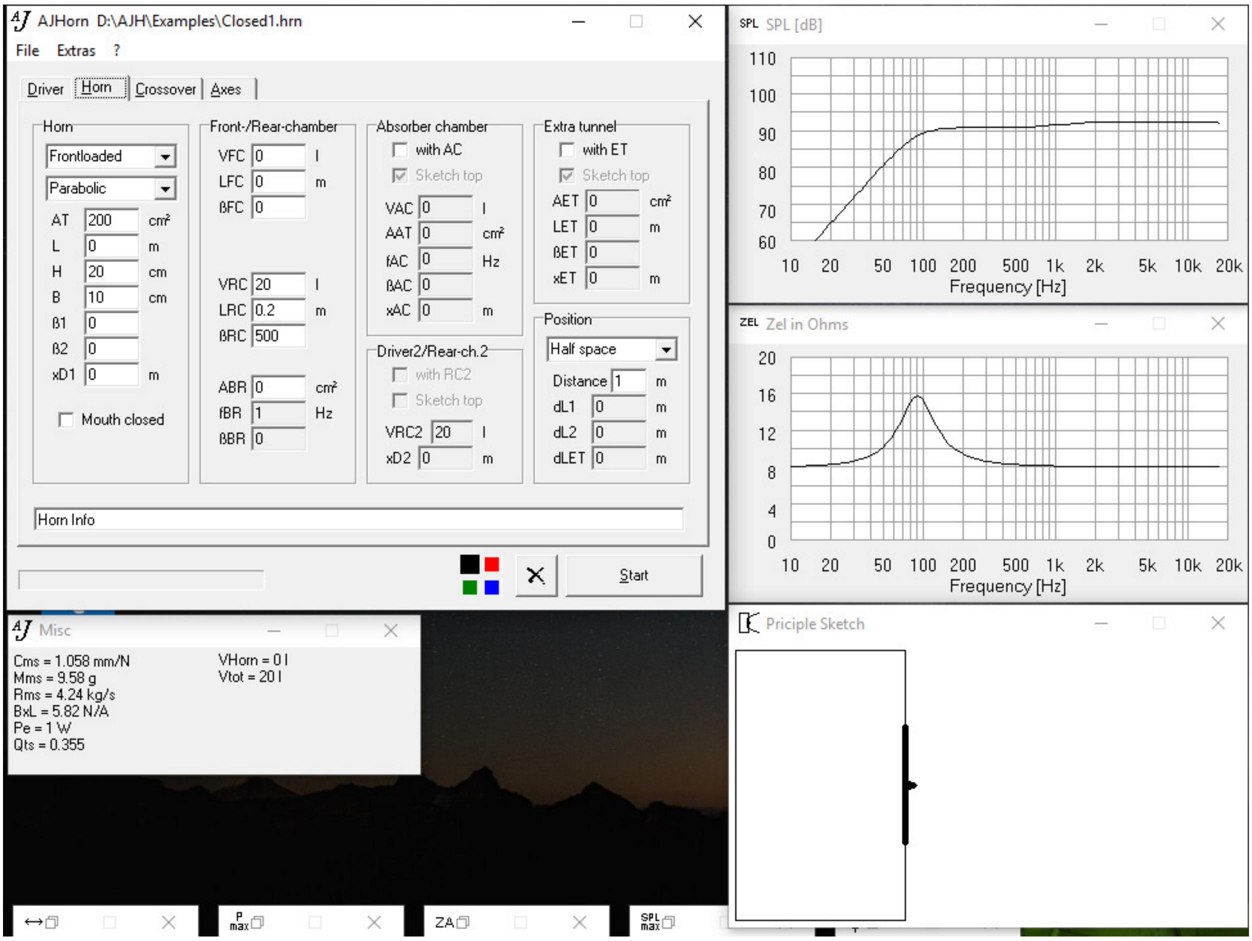
AJHorn 7


AJHorn D:\AJH\Examples\Closed1.hrn
File Extras ?
Driver Horn Crossover Axes
Horn
Frontloaded
Parabolic
Front-/Rear-chamber
Absorber chamber
Extra tunnel
Position
Half space
Driver2/Rear-ch.2
Mouth closed
Horn Info
Start
SPL [dB]
Frequency [Hz]
Zel in Ohms
Priciple Sketch
Misc
Cms = 1.058 mm/N
Mms = 9.58 g
Rms = 4.24 kg/s
BxL = 5.82 N/A
Pe = 1 W
Qts = 0.355
VHorn = 0 l
Vtot = 20 l

Contents

1 Introduction

1.1 License agreement

AJHorn is a software for specialized users with relatively small number of copies but high expenditure for development. The program only could and can be developed when numbers of licences can be sold. As we want to protect against infringement, every delivered version has its' **unique serial number**. This can be found if you click in the main menu on "?" and then on "Info". The last number after the version number (for example 6.0.**127**) is the personal serial number of each licence. Due to this clear assignment, a complete solution is guaranteed in case of missuse. Generally it is not allowed to pass on an AJHorn licence, because AJHorn is licenced to the buyer at the date of purchase. The buyer has the responsibility to keep AJHorn secure.

1.2 Functionalities

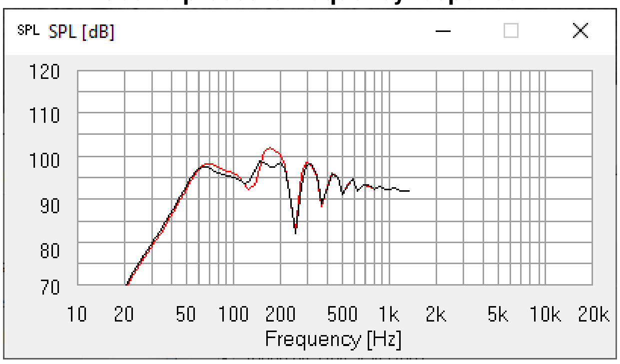
AJHorn is an unique scientific software for horn loudspeakers, transmission lines and special cases of this type, in which a quick and easy input of the parameters is paramount.
The types that can be simulated are for example:

- **Closed box**
- **Frontloaded Horn**
- **Bandpass enclosure**
- **Bassreflex Box**
- **Rearloaded Horn**
- **Transmissionline**
- **MLTL**
- **TQWT**
- **Tapped Horn**
- **Dipole speaker** and much more

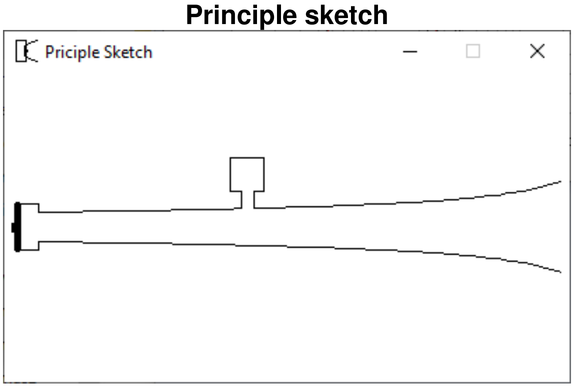
Seven contoures eligible, e.g. conical, exponential or Traktrix ("Spherical Horn")

The various output-parameters of the simulations are:

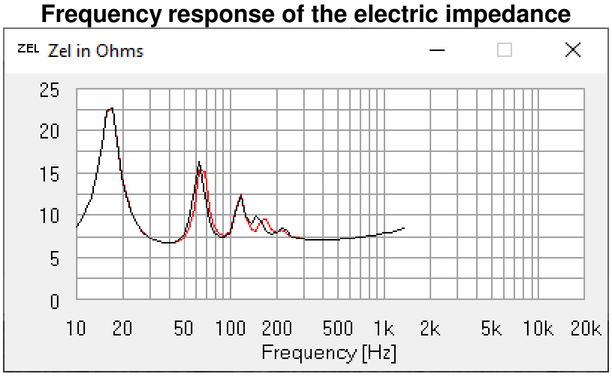
Sound pressure frequency response



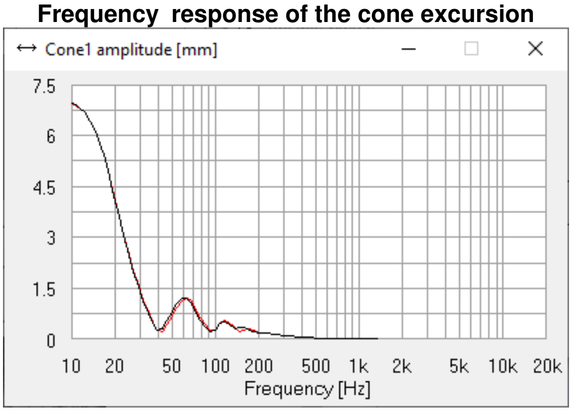
Principle sketch



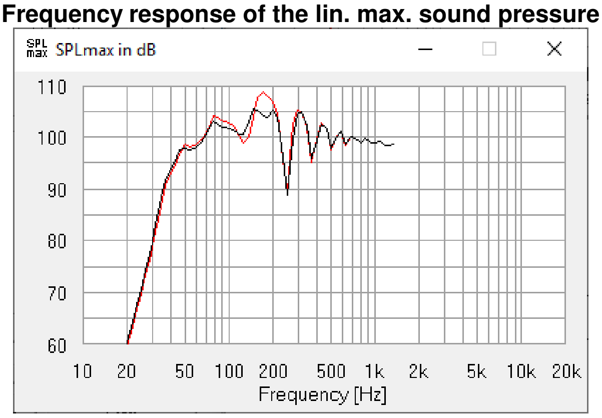
Frequency response of the electric impedance



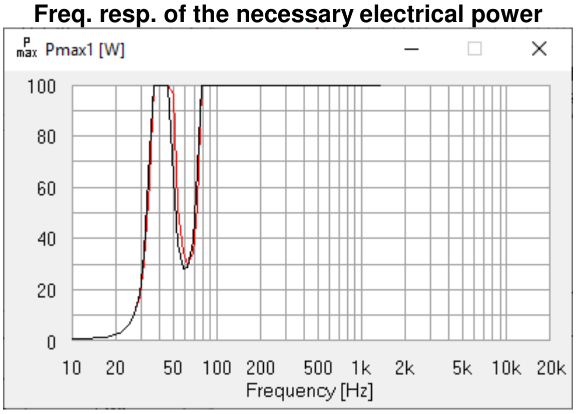
Frequency response of the cone excursion



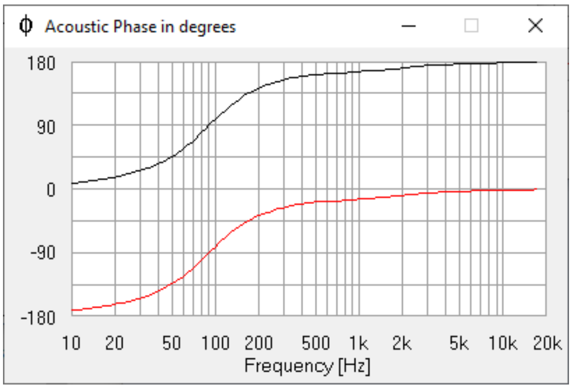
Frequency response of the lin. max. sound pressure



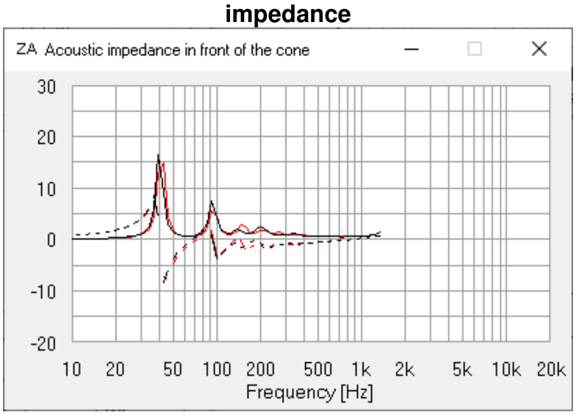
Freq. resp. of the necessary electrical power



Frequency response of the acoustical phase



Frequency response of the unified acoustic radiation impedance



- **All Frequency responses also numerical (ASCII-file)**
- **Area, height and radius of the opening function (ASCII-file)**

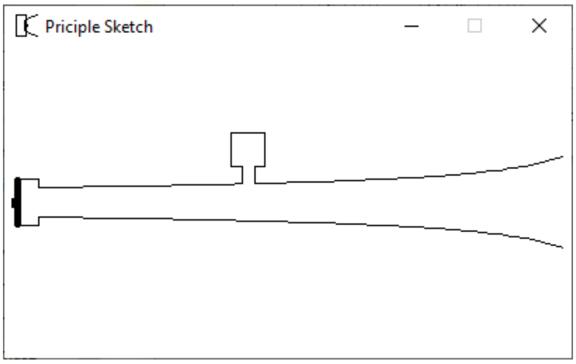
The predictions of the model has been confirmed through accurate testing. The program places no special demands on the relevance of the operating system and runs from Windows[R] XP.

1.3 AJHorn 7 innovations

The changes for AJHorn 7 are technical an graphical. It was tried to build more functionalities user requested and for optimization of existing constructions. The new features are unique and bring the user nearer to the optimum. Projects that were saved with earlier versions can be opend and modified with AJHorn7.

Principle Sketch

Elimination of the static input schematic diagram and replacement by a project-related, automatically generated and proportional schematic diagram in a separate output window.

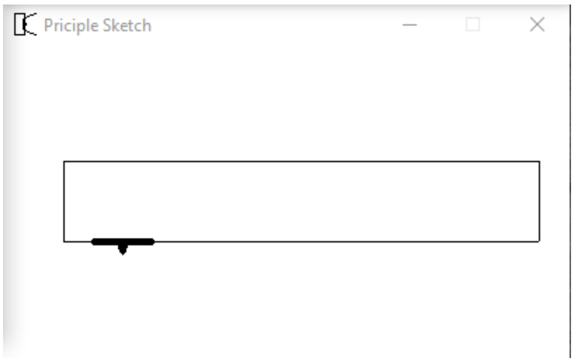


Individually positionable absorber chamber

The position of the absorber chamber is no longer coupled to the driver position and may be located anywhere along the horn.

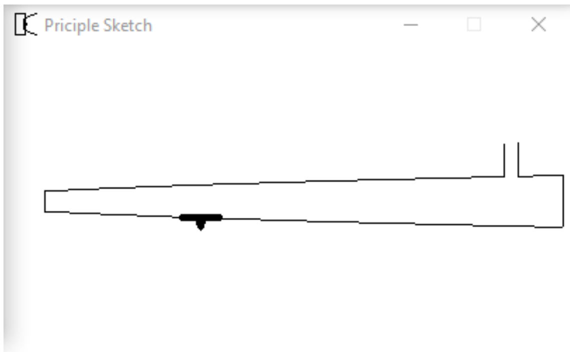
Mouth open/closed

e.g. for the simulation of cavity resonances (standing waves) in closed or bassreflex enclosures.



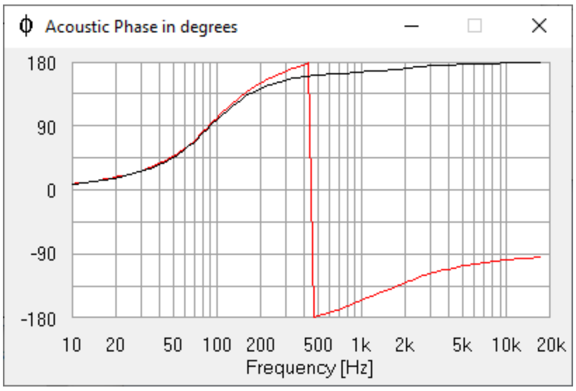
Individually positionable extra tunnel

e.g. for the simulation of MLTL (Mass-Loaded-TML), TQWT (Tapered Quarter Wave Tube) and slim bassreflex-enclosures.



Acousic Phase (Phi_a)

Now also the phase difference between electrical input signal and sound pressure is simulated.



Improved simulation model

By further improving the simulation model, inaccurate simulations of certain chassis / dimension parameter constellations could be eliminated.

Option "change color" for the next simulation

Selectable in the main menu under "Extras" -> "Options"

HTML-Export

This replaces the print preview of earlier versions. Hereby the simulation results can be saved as an HTML file and thus viewed with any (Internet) browser. The possible paper printout then takes place via the print function of the browser.

2 Setup and first steps

2.1 Setup

AJHorn places no special demands on the relevance of the operating system and runs from Windows[R] XP. Above Windows 10, the screen display scale should be set to 100%.
For the installation, the file SETUP.EXE must be executed in administrator mode (right click + “Execute as…”). Follow the instructions on the screen. AJHorn is then installed on your computer.
With 64-bit-Windows-versions AJHorn is executed in the 32-bit compatibility-mode. AJHorn uses global variables. If the security settings of the system are configured very strong, the program itself must be executed in administrator mode, too.

2.2 Starting AJHorn

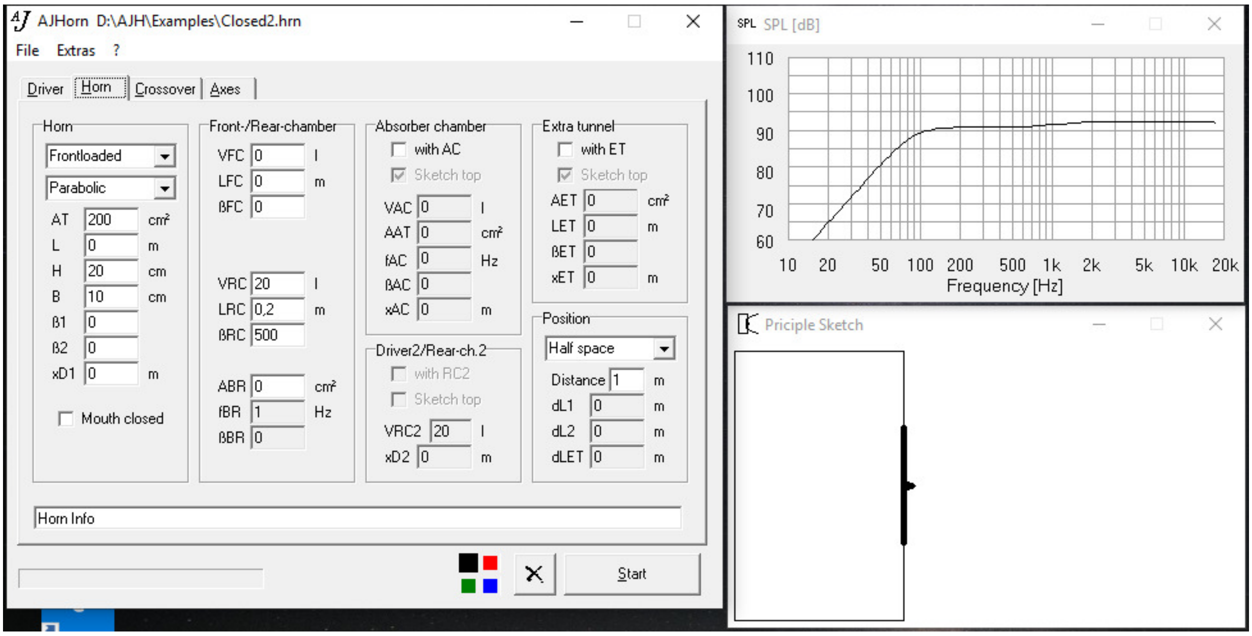
To start AJHorn, use the Start / Programs / AJHorn taskbar. The input and a part of the output windows appear.

3 Simulation of the various enclosure types

Through its modular construction, AJHorn offers the simulation of different enclosure types with the same calculation algorithm. This is interesting, as the theory for the horn calculation is not confined to a single enclosure type. It is the perfect solution of the acoustic conditions. The borderline cases -- transmissionline, bass-reflex, band-pass and closed box types -- are included automatically. Farther, the border between the individual types is fluid.
If a bass-reflex enclosure will be described as a Helmholtz resonator or as a rearloaded conical horn with a relatively big frontchamber whose throat area is equal to the mouth area – that's a purely matter of definition. In practice, both types are identical and the following examples will show this clearly.
The corresponding AJHorn projects (hrn-files) can be found in the AJHorn installation directory (e.g. c:\Program_Files\AJHorn\Examples).
Only a few projects shown are optimizations. The remaining should only explain the input of the parameters.

3.1 Simple Closed Box

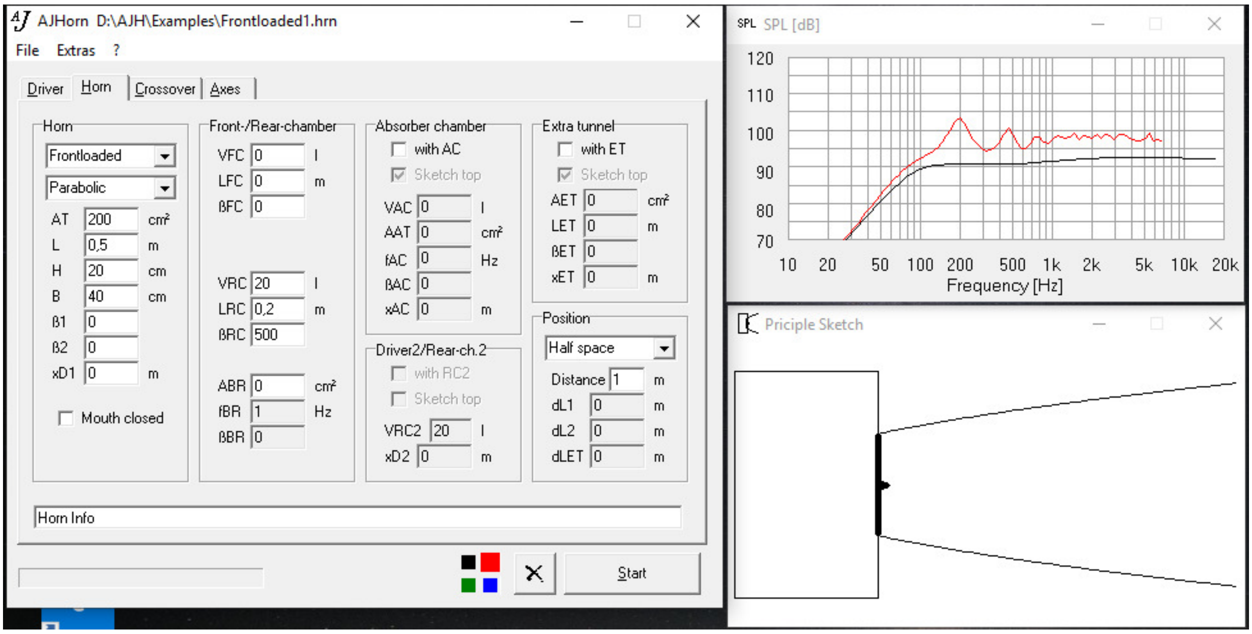
The closed box is the simplest solution to operate a low frequency loudspeaker. It prevents, because of the closed rearchamber, sound output from the front and back of the cone from cancelling each other (acoustic short-circuit).
At startup, AJHorn loads standard values into the file NEW.HRN. This filename is reserved for AJHorn. Click on “Start” in the menu and AJHorn starts to calculate. After the calculation you can see the following graphic.



NEW.HRN is a loudspeaker with a closed box and a Q-factor QTC of 0.71 (Butterworth). This you can see on the smooth fall of the sound pressure to lower frequencies. AJHorn calculated the other responses, which you can see if you activate the minimized windows.
The closed box is thus a frontloaded horn, where the frontchamber volume (VFC) and the hornlength (l) is 0. The throat area (AT) and also the mouth area (H*B) is like the cone area (SD) of the driver (see also 4.2). The length of the closed rear chamber (LRC) has no influence on the simulation result with sufficient damping (βRK).

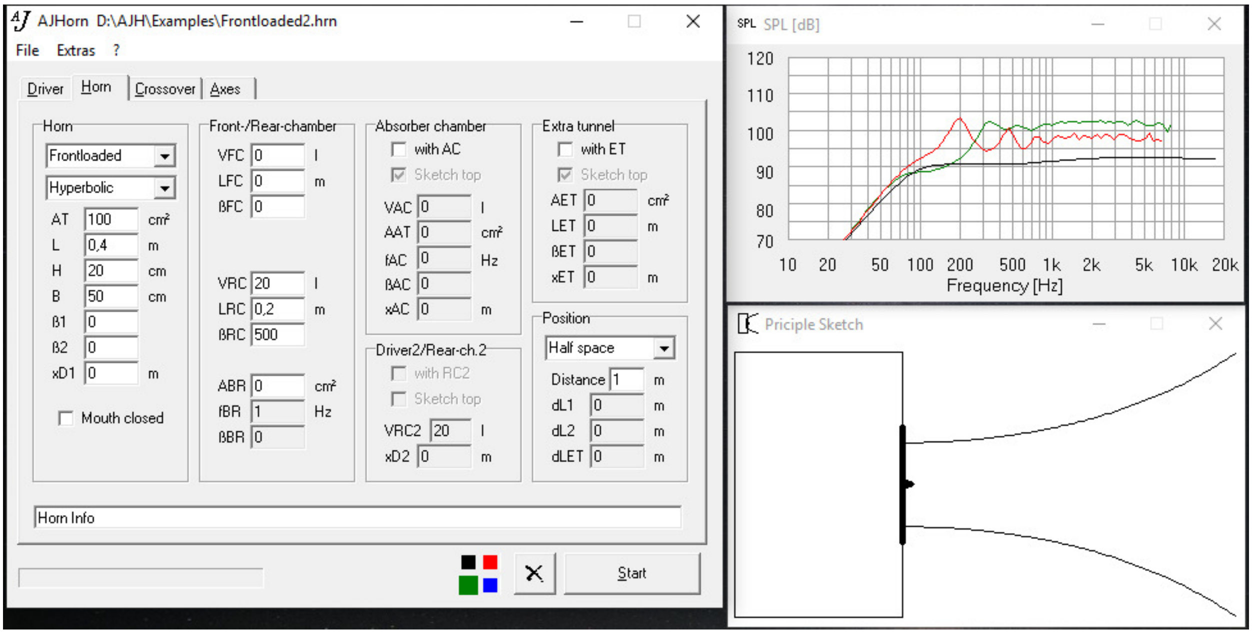
3.2 Frontloaded Horn

Next, a parabolic horn will be simulated in which the throat area is like the cone area and the mouth area corresponds to the fourfold throat area (H*B = 800 cm²). The length of the horn is 0.5 m. The color of the output graph ist changed to red. The input data for AJHorn and the simulation results after the click on “Start” are shown in the following depiction.



Concerning the first version, there is an increase in efficency at the middle frequencies of about 5 dB, but this is accompanied by a more uneven frequency response.

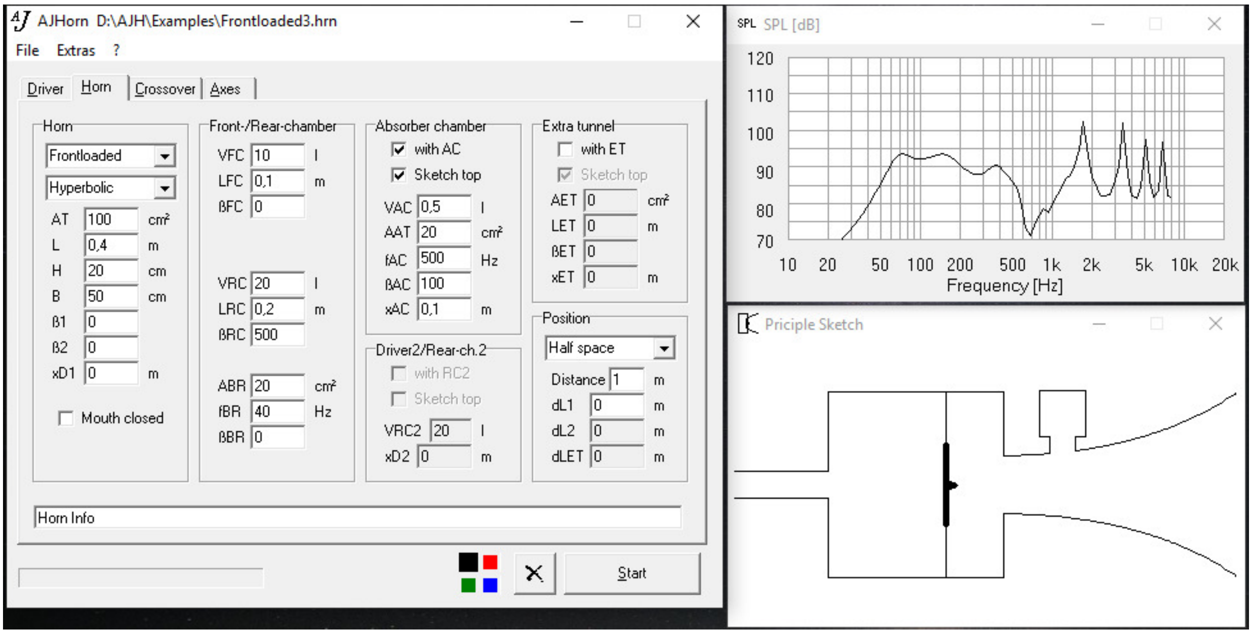
Through the clever choice of the input parameters you can get a smooth frequency response for a pleasant sounding loudspeaker. The result of such optimization is shown in the following figure.



This horn loudspeaker can be used from 300 Hz. It has a much better frequency response and a higher efficency than the non-optimised version.

In front of the cone is a front-chamber (volume VFC, yet 0). Details on the other input parameters can be found in chapter 4.2.

The following schematic figure describes the usage of the bassreflex rear chamber (BR), front chamber (FC) and absorber chamber (AC).

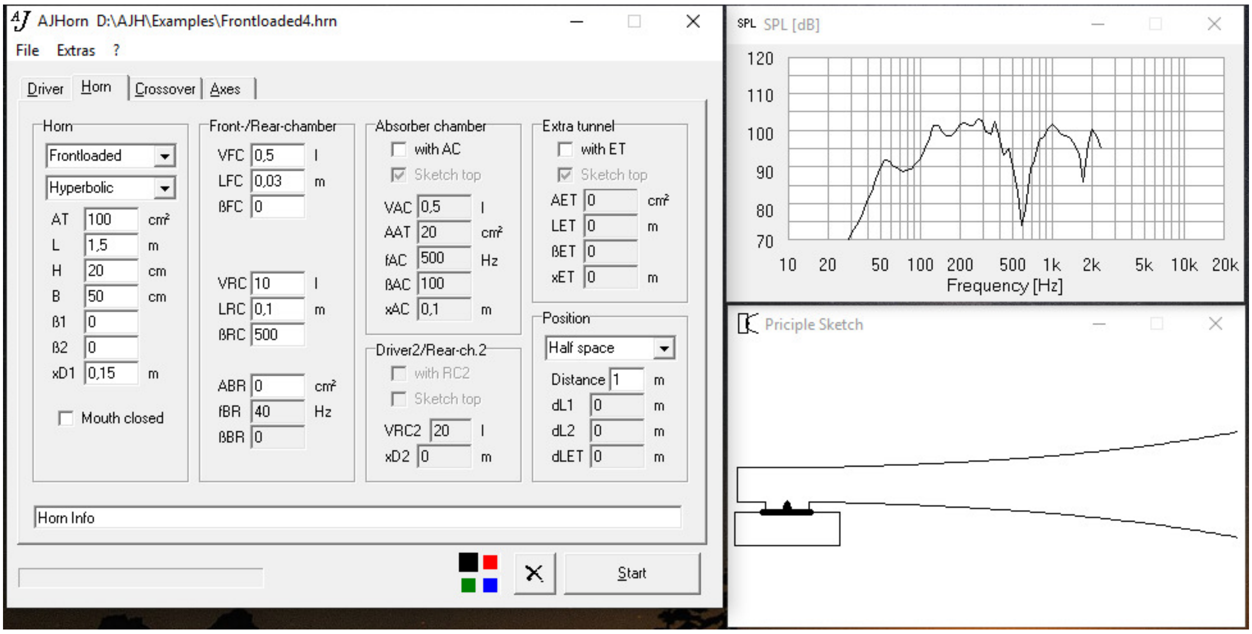


From version 7, the absorber chamber no longer needs to be at the driver position.

Any distance differences between the horn mouth and the bass reflex output relative to the listening position are described using the difference length dL1 (see chapter 4.2).

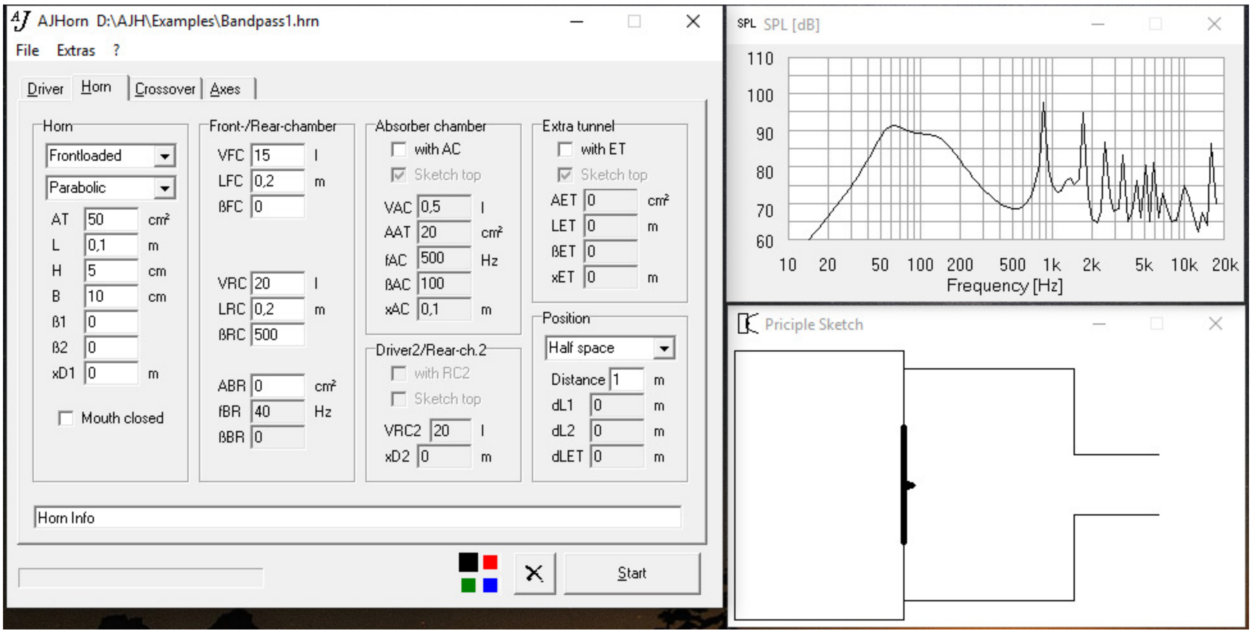
After the principle of the following horn, many frontloaded bass horns on the market function. Here the front chamber is kept as small as possible to reduce the total volume (front chamber volume = cone content of the membrane cone). This leads to asymmetries in the front chamber area, which AJHorn simulates correctly by simply entering the variable xD1 (position driver1).

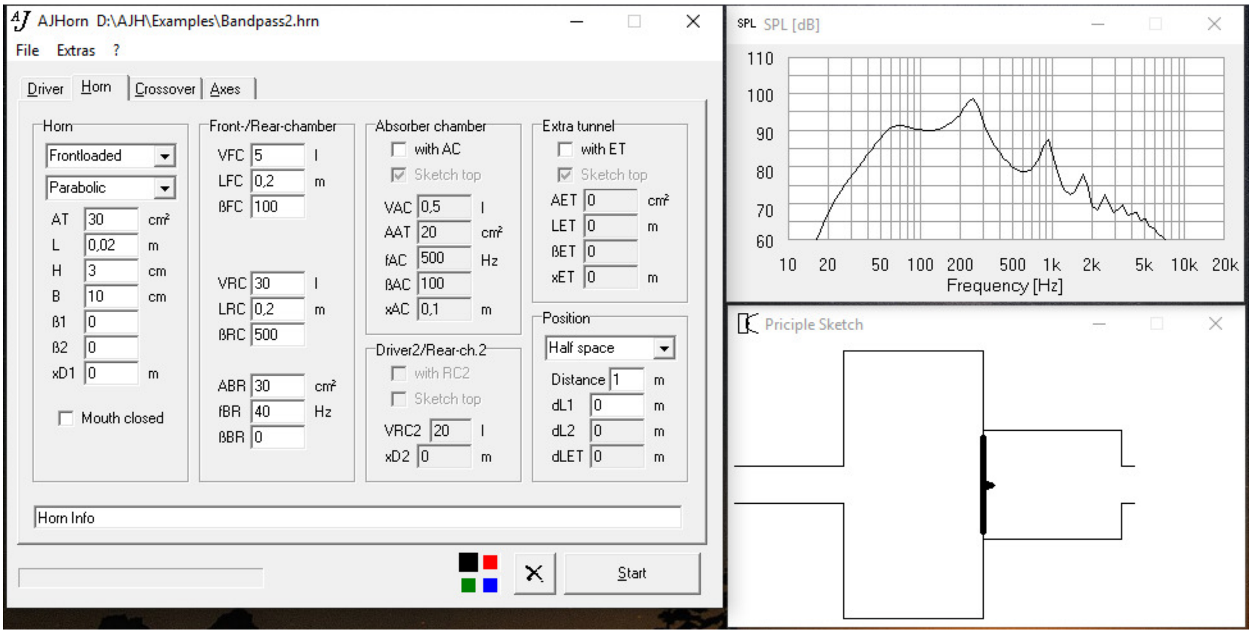
Watch out! The throat area (AT) is the area at the beginning of the horn and not at the driver position!



3.3 Bandpass enclosure

A bandpass enclosure consists of a closed or ventilated rear chamber with the volume VRC and a front chamber (FC) followed by a reflex tunnel of length L.
It is a special case of the **frontloaded** type. The following figures show the input parameters and the simulated schematic diagram of a classic bandpass and a bandpass with ventilated rear chamber.



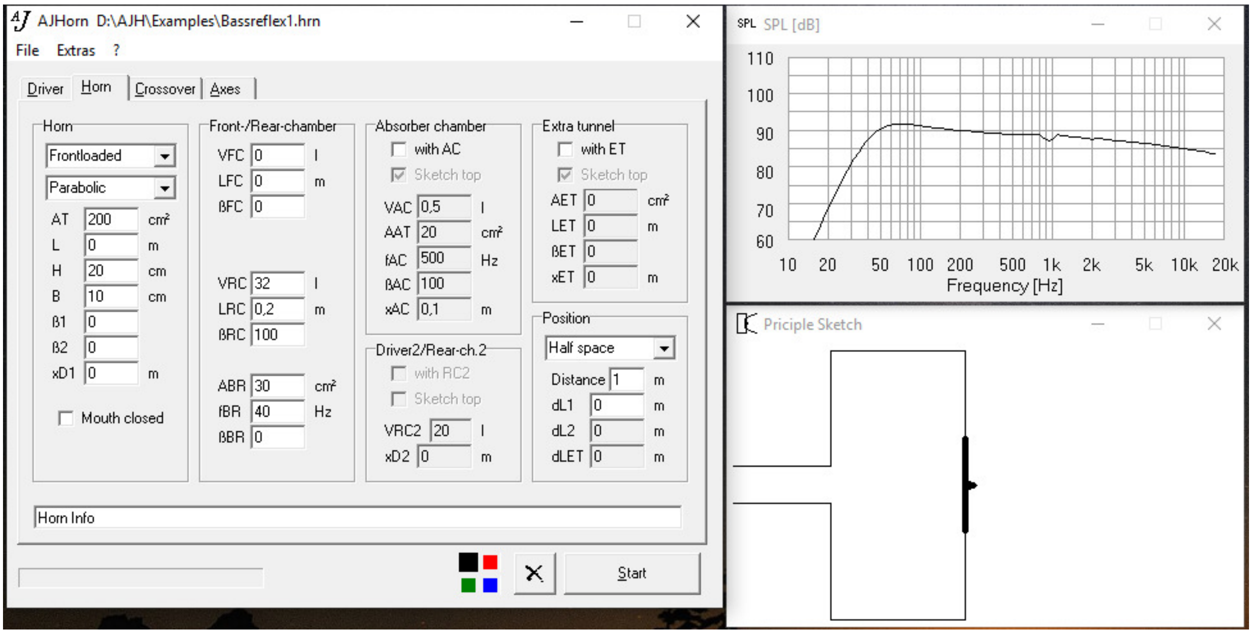


The throat area (AT), mouth height (H), mouth width (B), rear chamber length (LRC) and front chamber length (LFC) are defined as in the previous housing types.
Here, too, the tunnel adjoining the pre-chamber can have a constant cross-section can extend over the length or also taper. A wide variety of housing types such as bandpass transmission line or bandpass horn opens up such a simulation.
The two chambers of the ventilated bandpass should have different tuning frequencies, otherwise there is an acoustic short circuit (mutual extinction of the sound components). By using the extended impedance theory, AJHorn simulates the resonance frequencies of both tunnels.

3.4 Bassreflex enclosure

This very widespread type of speaker housing is often referred to as a ported or vented box. There are many theories of acoustic simulation about this type. Partly in tabular form but also in the form of calculation programs. AJHorn goes one step further and calculates the sound pressure frequency response with the influence of the membrane's impedance, transit time from membrane to the tunnel, and resonant frequencies of the housing and tunnel. Due to AJHorn's diverse simulation modules, bass reflex enclosures can be simulated in a number of ways, depending on the user's particular interest in the simulation.

Frontloaded type mit bassreflex rear chamber



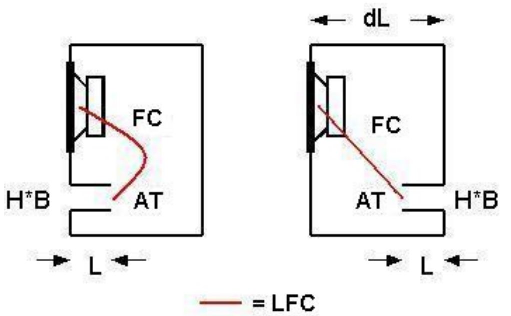
This procedure is recommended if the tuning frequency of the bass reflex enclosure (fBR) is already known. The length of the bass reflex tunnel is displayed as "LBR" in the "Misc" window after the simulation. The difference length (dL1) is described in more detail in chapter 4.2.

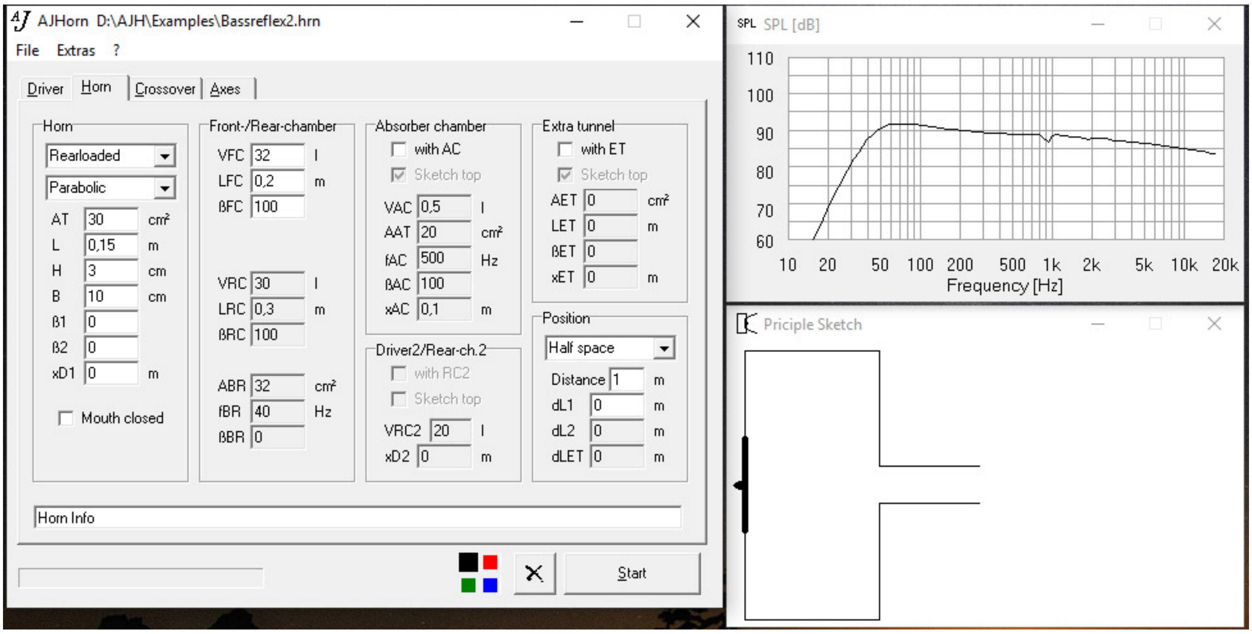
In the case of **reflex tubes with a round cross section**, the surface is chosen so that the cross section corresponds to the surface. The shape plays a minor role. The area is calculated according to the known formula

$$A[cm^2] = \frac{\pi \cdot d^2}{4} \qquad d = \text{tube inner diameter in cm.}$$

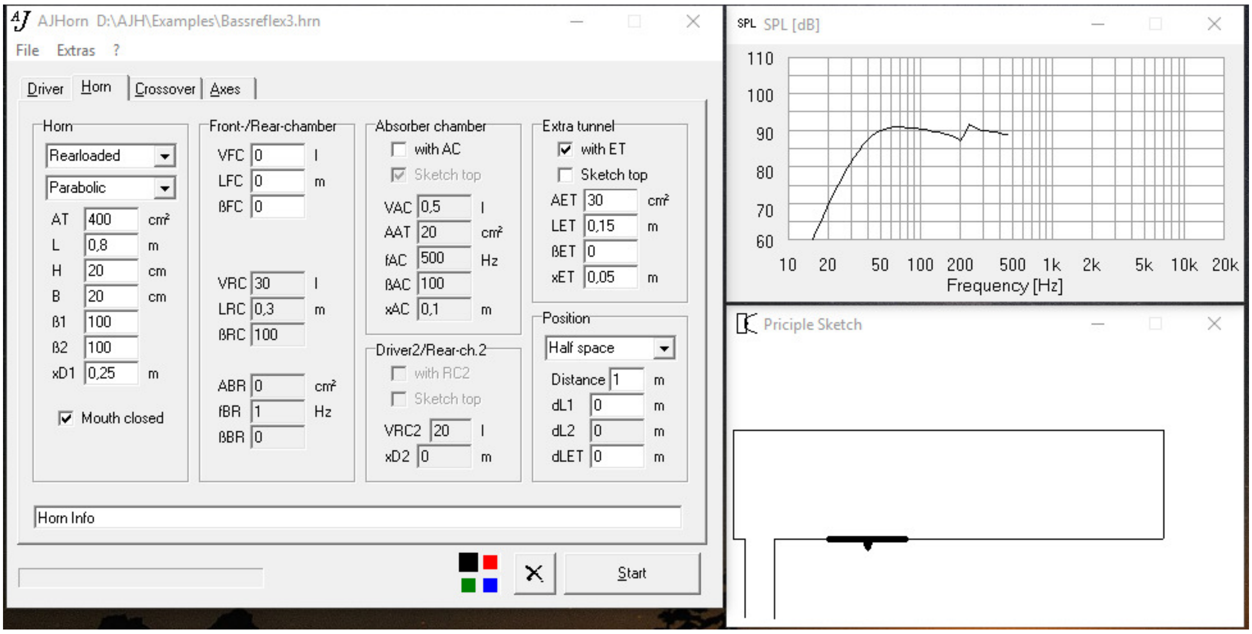
Rearloaded type with front chamber as housing and horn as bass reflex tunnel

This procedure is recommended if the length of the bass reflex tunnel (horn length L) is already known. The input data here are the area at the beginning of the channel (AT), the length of the reflex port (L), the mouth area (H * B), the front chamber volume (VFC) and a possible difference length (dL1).
The length of the front chamber (LFC) is the acoustic path between the driver membrane and the beginning of the port. Damping material in the front chamber as well as the influence of absorption material in the tunnel or channel losses are also taken into account via the coefficients βFC, β1 and β2.
The difference length (dL1) is described in more detail in chapter 4.2. Of course, the reflex port can also expand or taper. Thus, an infinite number of housing types are possible, which one can not give an exact assignment, but the simulation result is correct.





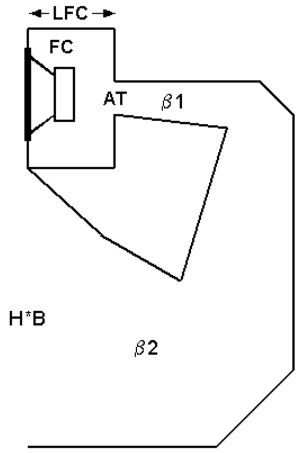
Rearloaded type with horn as housing and extra tunnel as bass reflex tunnel

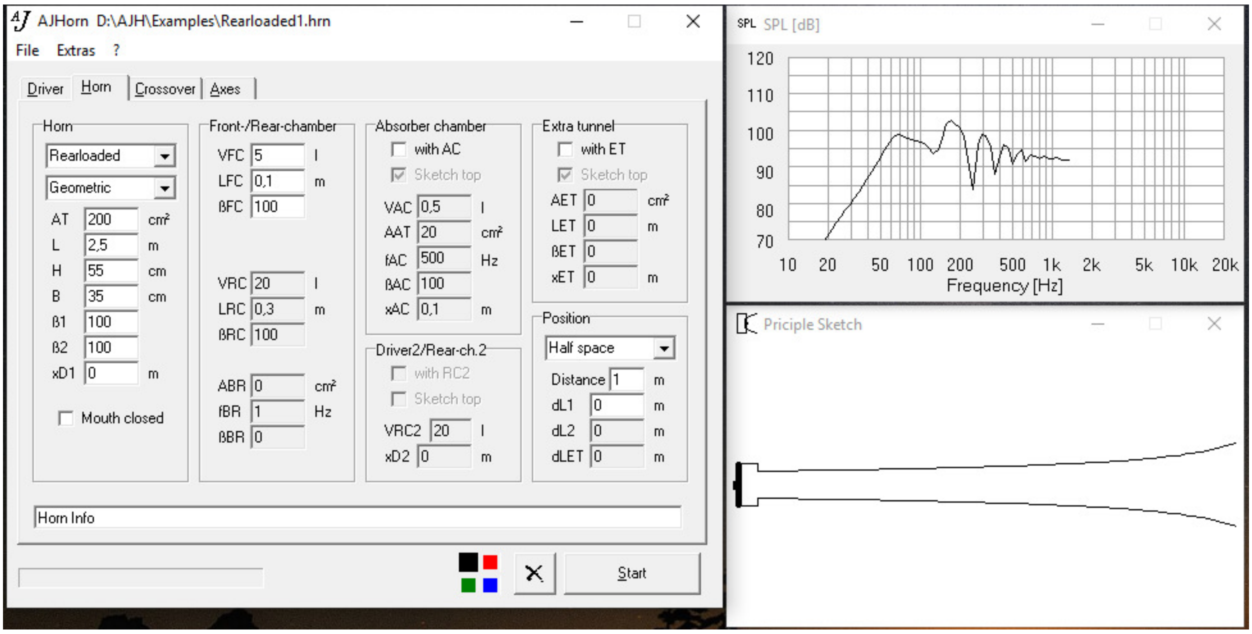


With this input model, interactions between driver, housing and bass reflex tunnel can be examined even more precisely and the positions can be optimized. It should be noted, however, that the interactions (interferences) are simulated only in the horizontal direction of the schematic diagram. Also, no standing waves of the tunnel are taken into account with this model.

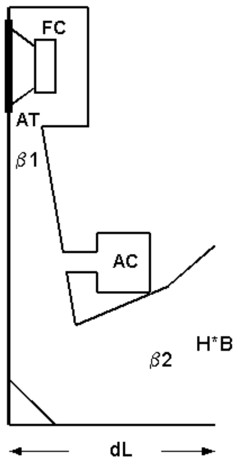
3.5 Rearloaded Horn

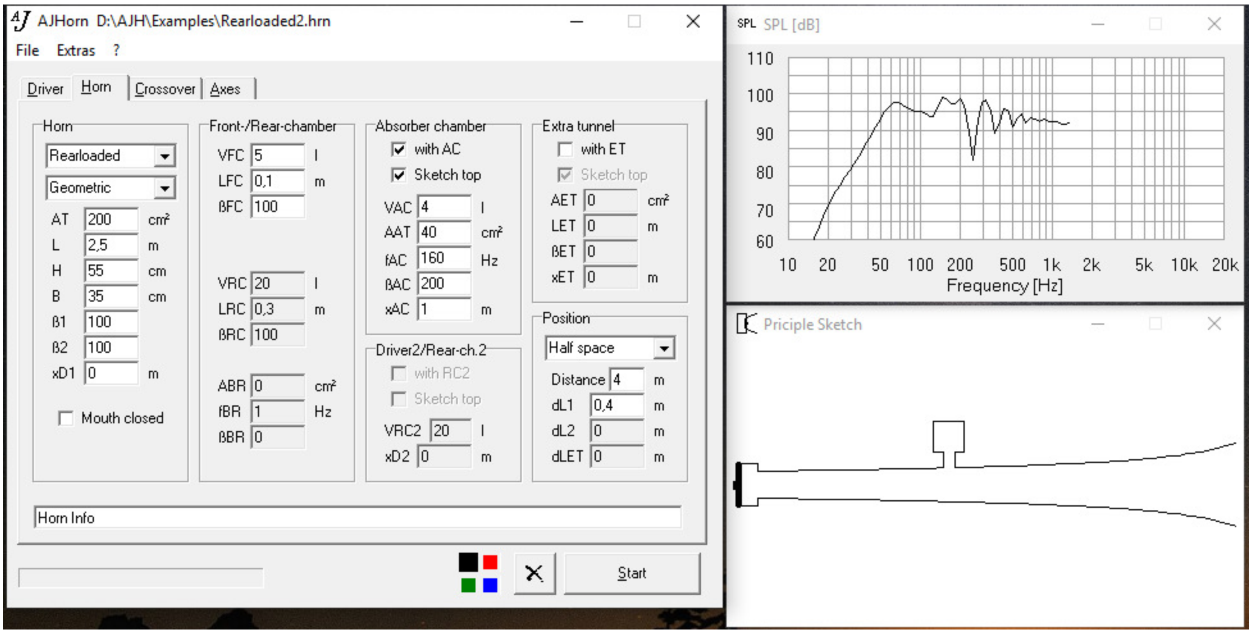
The rearloaded horn (also called backloaded horn) differs from the frontloaded horn in that the back chamber is omitted. Driver 1 emits directly over the membrane and indirectly via the horn. Example entries with associated schematic diagram show the following figures.



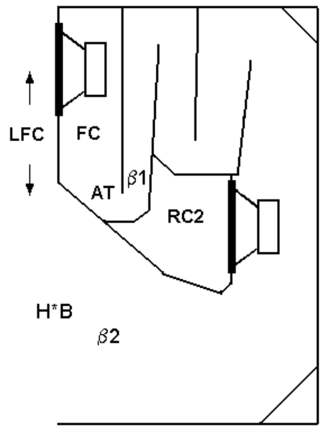


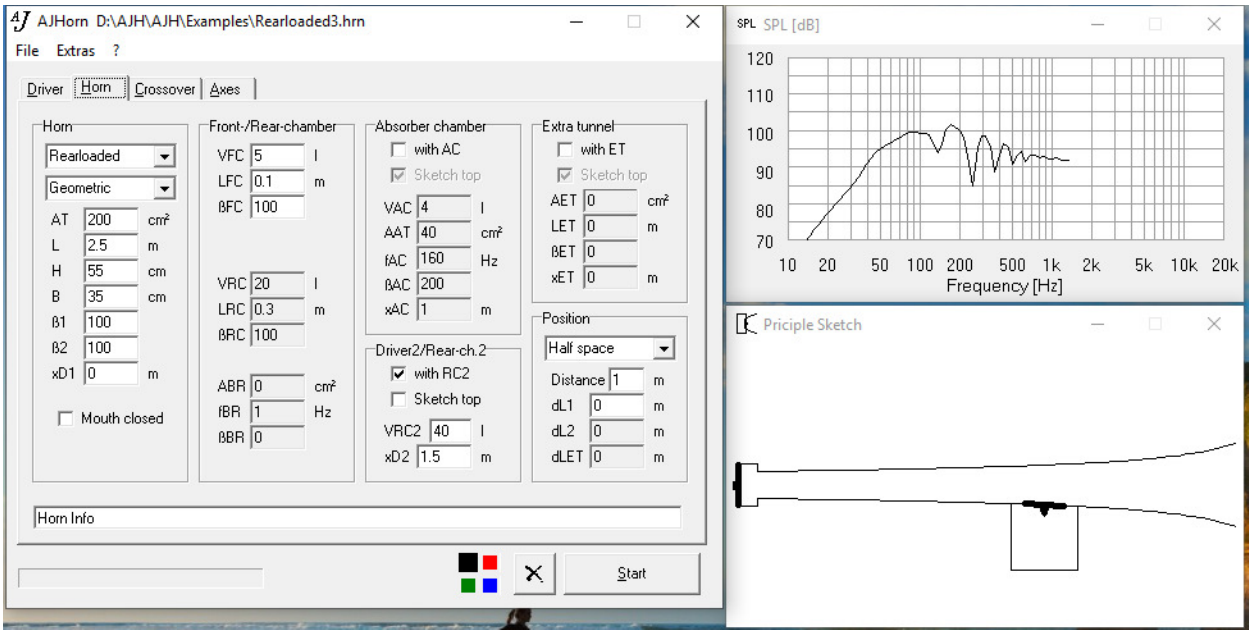
The horn itself has the mouth height (H), the width of the mouth (B), the horn length (L), the difference length (dL), the throat area (AT). For a detailed description of the input parameters refer to chapter 4.2.





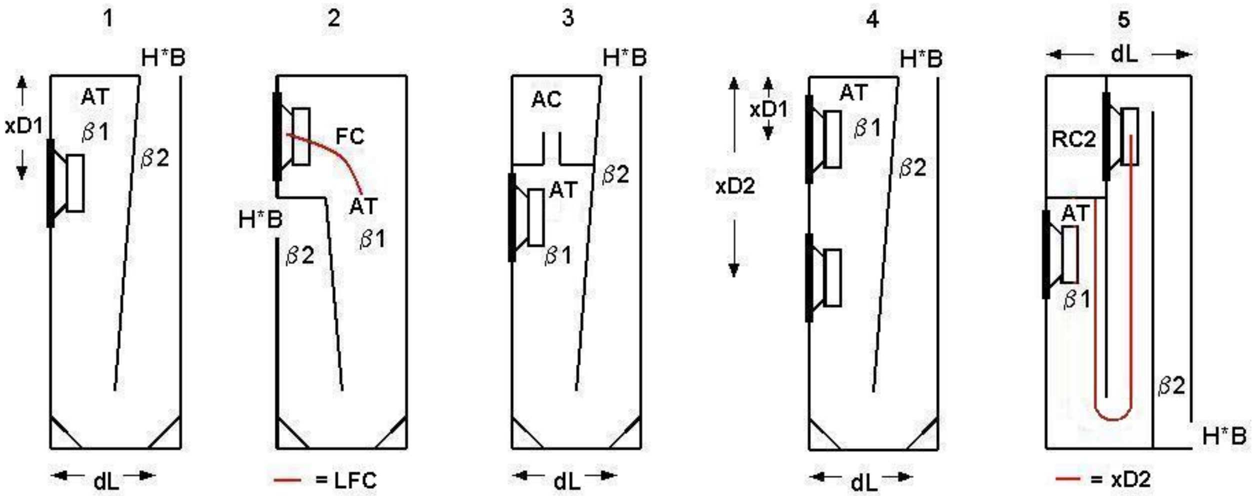
The third horn has an internal driver (driver 2), through the closed back chamber, the deep bass output can be increased. Under certain circumstances, this simulation option can be used to improve older constructions (classic rearloaded horns) in the deep bass area if there is still unused volume. Whether and how such a design works then can be simulated and optimized with AJHorn.



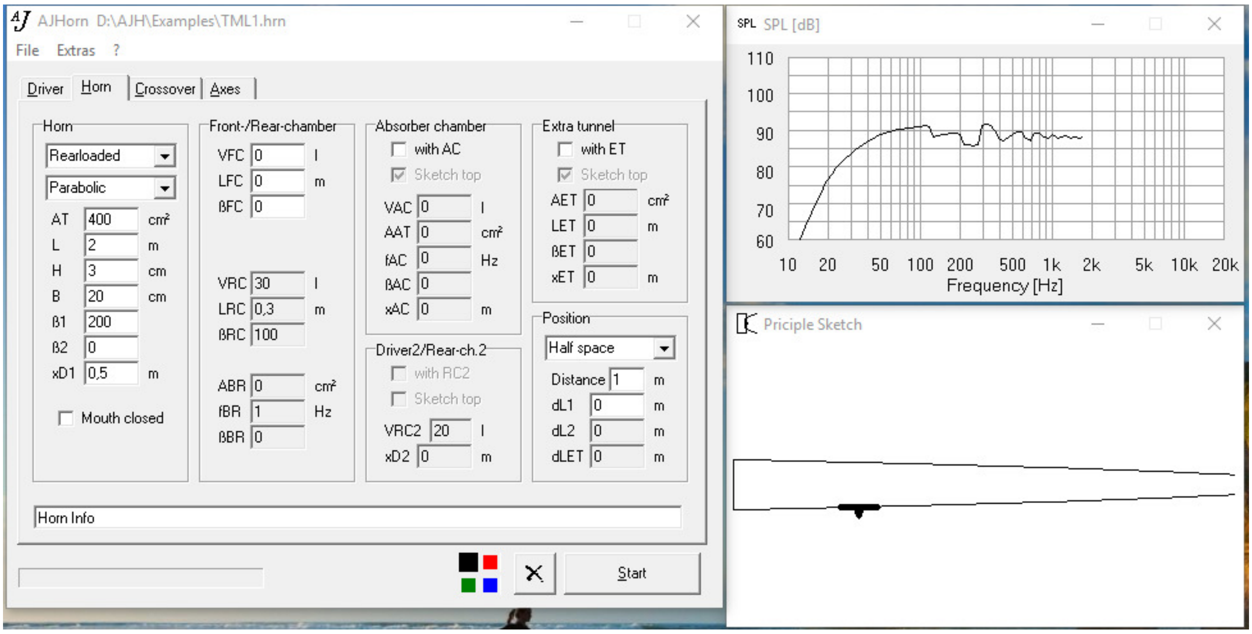


3.6 Transmissionline

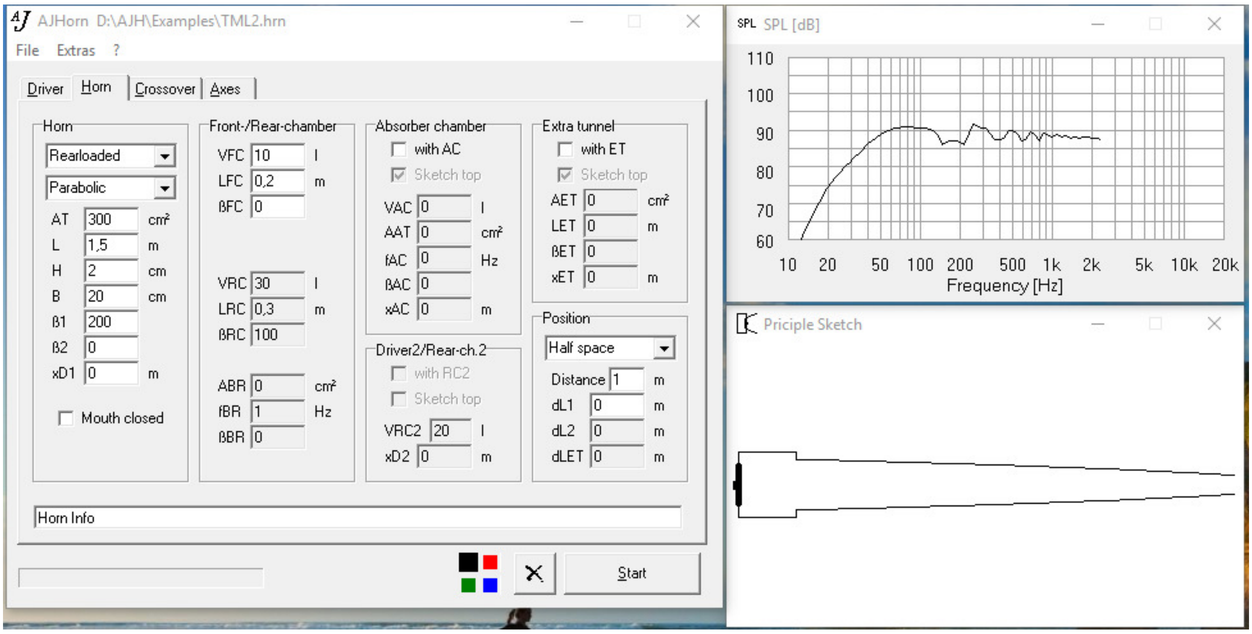
A Transmissionline (TML) is a type of housing similar to the Rearloaded Horn, but in which the horn does not expand, but rejuvenates or retains the same cross section. It may have a front chamber or not. The following projects show different possibilities of realization of a Transmissionline.



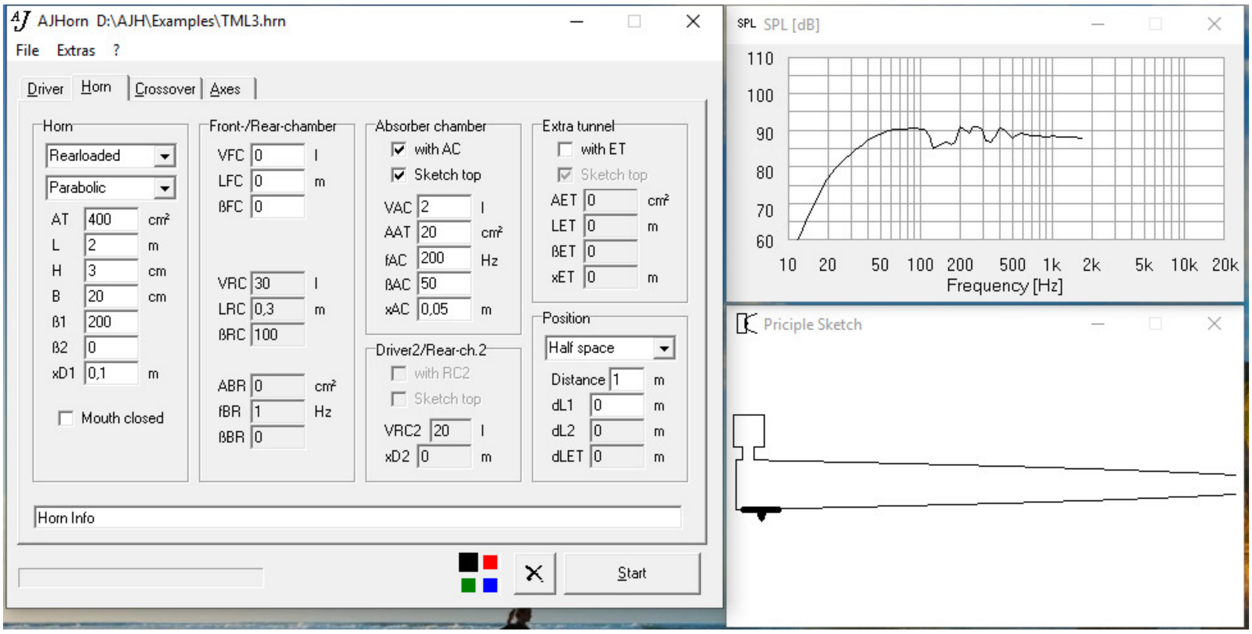
Classic Transmissionline (1)



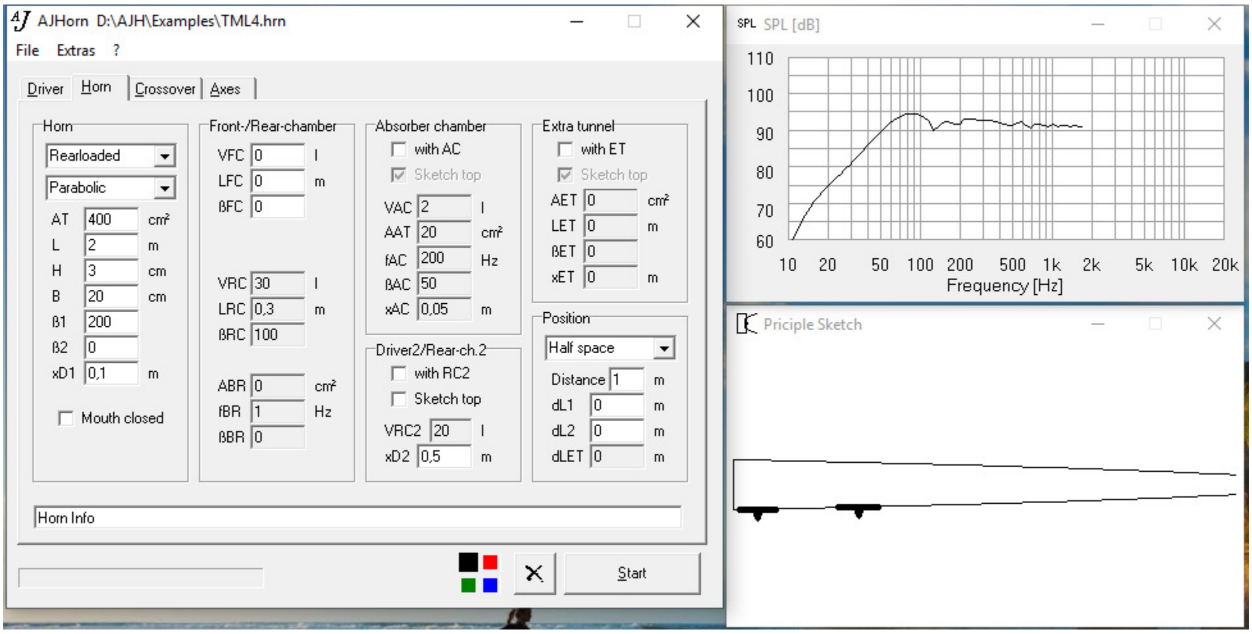
Classic Transmissionline with front chamber (2)



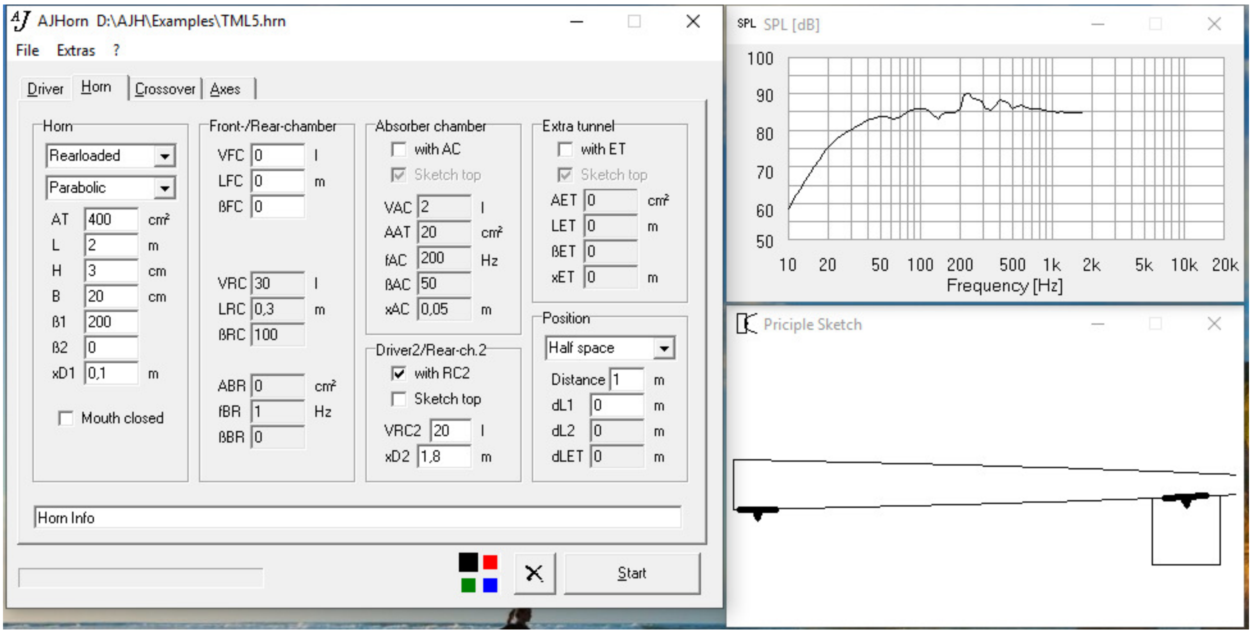
Transmissionline with absorber chamber (3)



Transmissionline with two drivers (4)



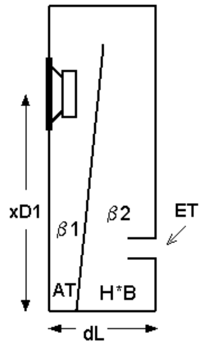
Classic Transmissionline with additional interior driver (5)

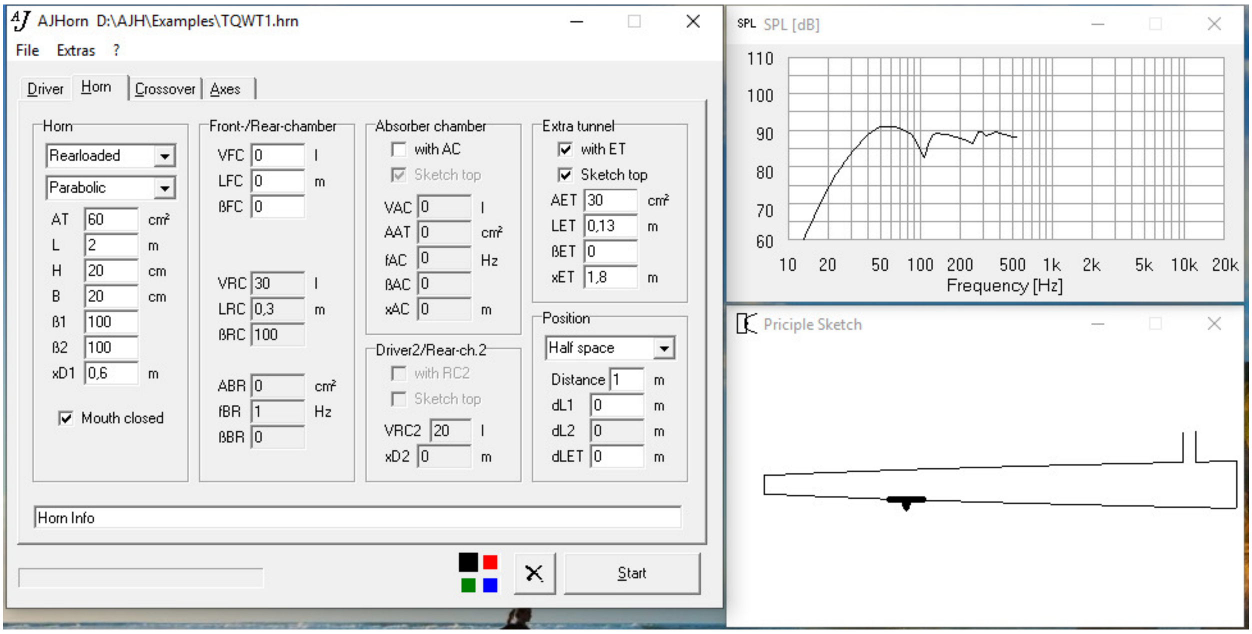


Details about the input parameters are described in chapter 4.2.

3.7 TQWT and MLTL

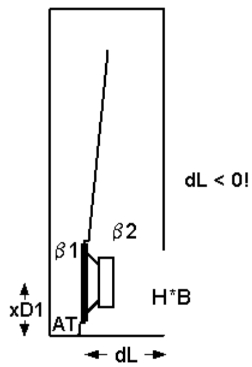
A TQWT (Tapered Quarter Wave Tube) has a very similar internal structure to a rearloaded horn. The mouth area, however, is much smaller or equipped with a channel that has a significantly smaller area than the horn mouth. With AJHorn 7 such a housing can now be simulated, because as an additional object the extra tunnel has been added and the horn mouth can be closed. A MLTL (Mass Loaded Transmission Line) is constructed very similar with the difference that the contour is similar to a transmission line and reduces its area towards the exit.

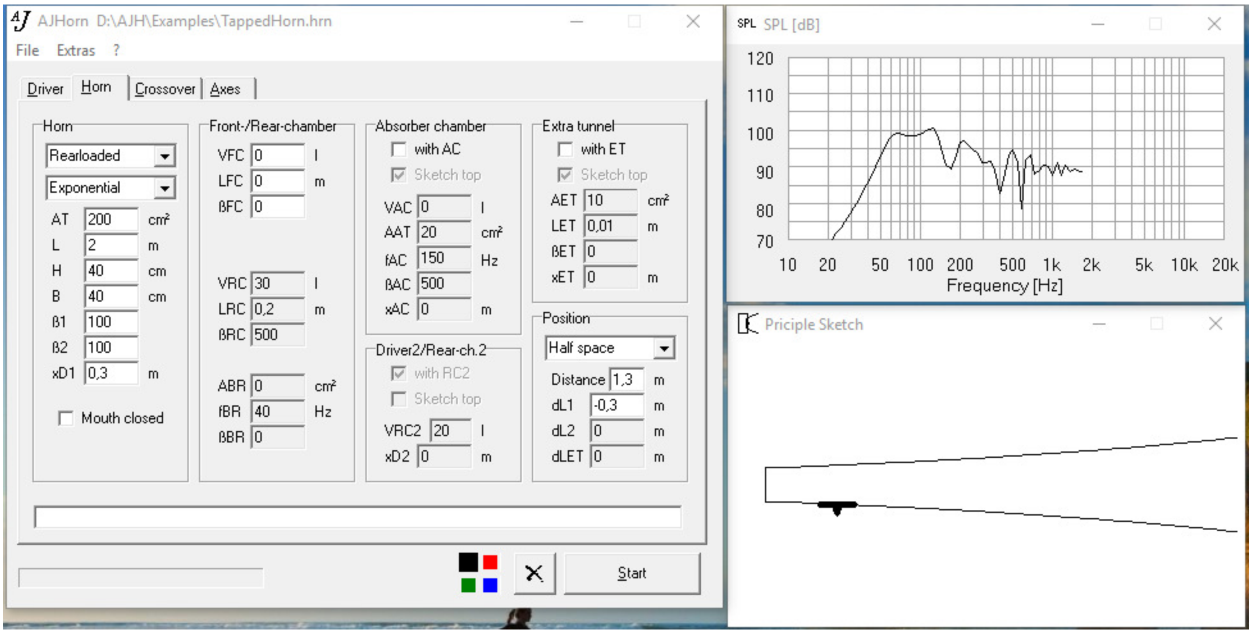




3.8 Tapped Horn

A Tapped Horn is similar to a Rearloaded Horn, with the difference that the driver can not radiate free, but is placed in the area of the horn mouth. This driver offset can be described with the input parameter dL1 (negative!). With dL1 values of a few centimeters, dL only affects the midrange, for which such a construction is in any case not usefull under any circumstances. Too high sound pressure simulations often have to do with the wrong dL input and distance. It's best to make a drawing and read the lengths from it.

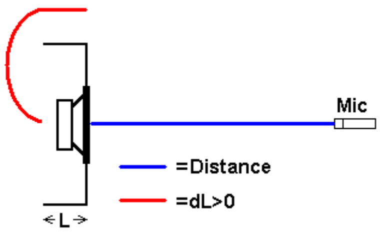


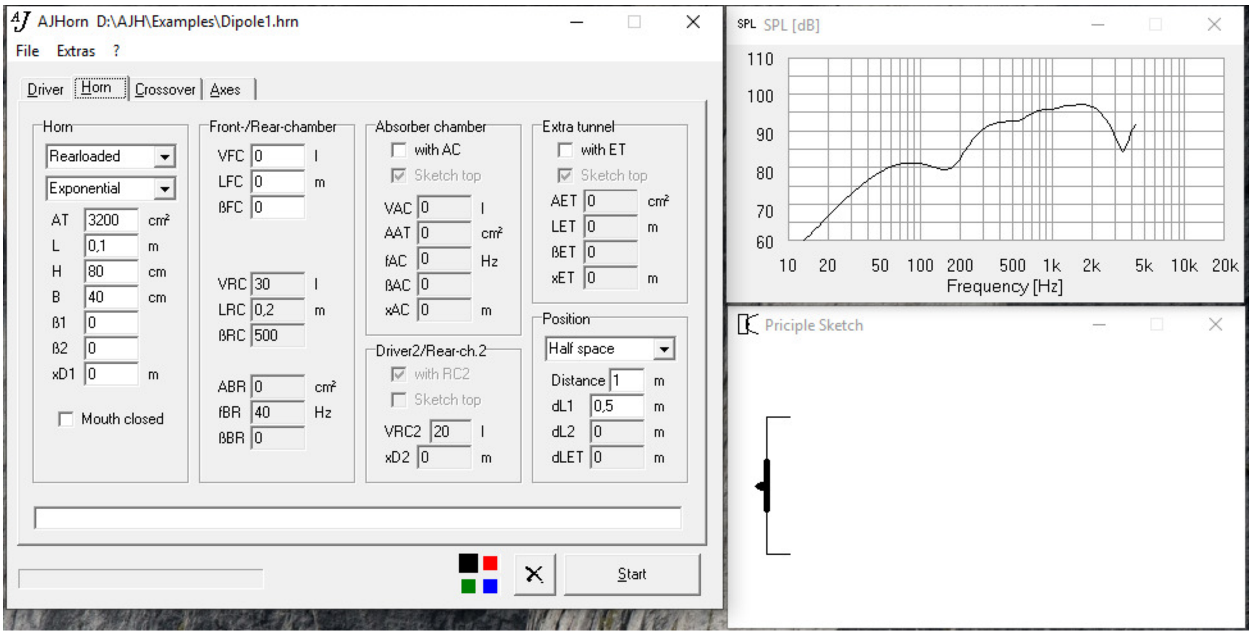


3.9 Dipole

Classic Dipole

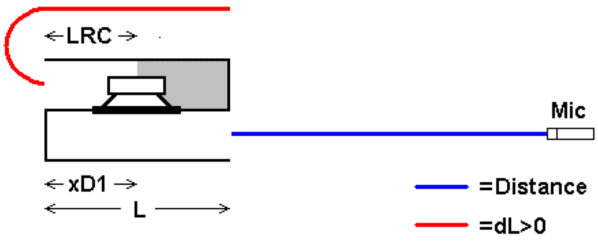
Classic dipoles operate over the transit time difference between the sound from the front and the back of the membrane. This difference is taken into account by entering dL (difference length). The horn type is "Rearloaded". The horn length "L" can also be 0.

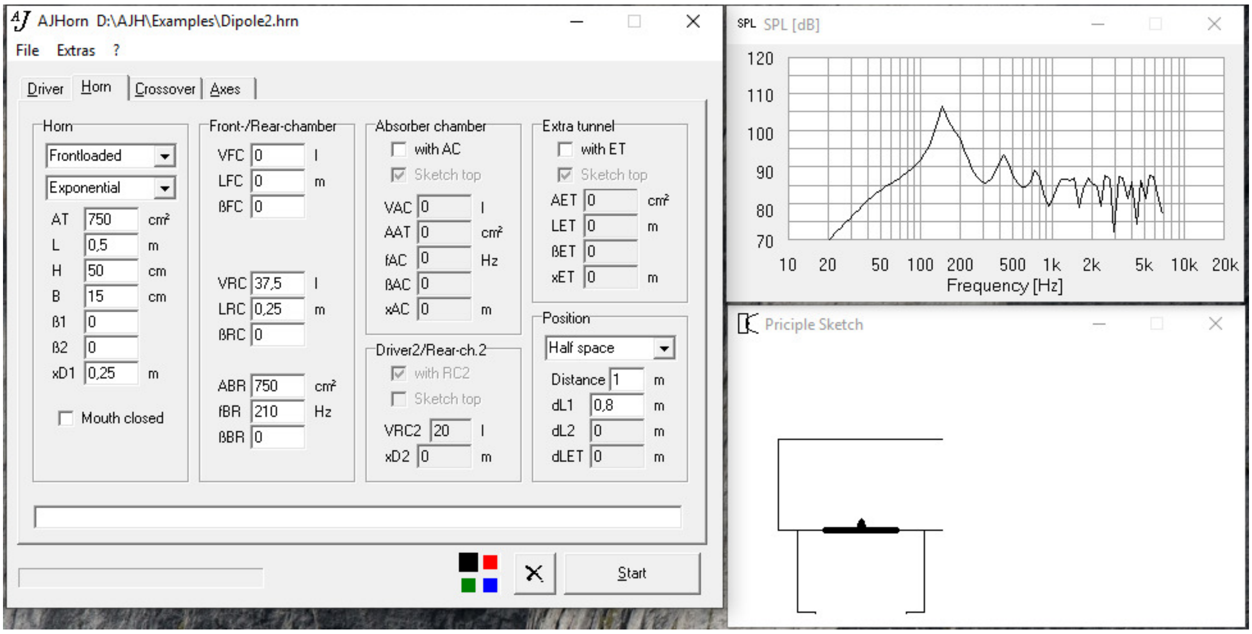




Dipole Subwoofer

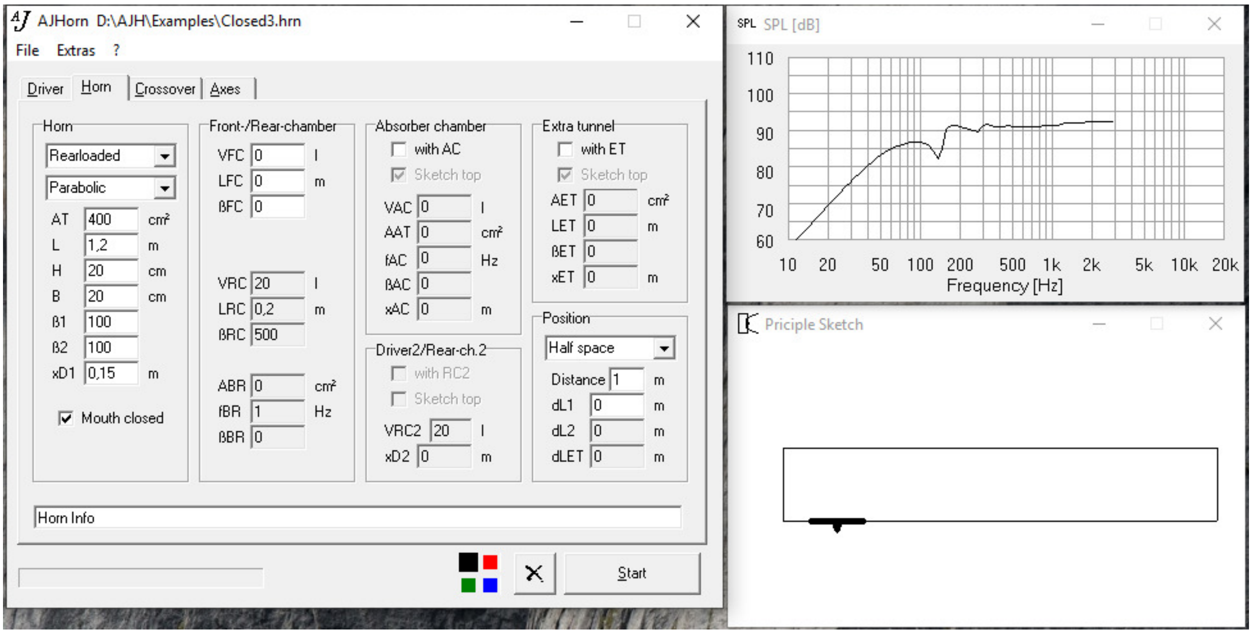
These dipole types have a certain horn length in front of and behind the membrane. So this is the frontloaded type. Behind the membrane AJHorn offers only the possibility to simulate a back chamber together with a bass reflex channel. As a result, only the light gray piece of the housing is not completely correctly simulated. But this only affects the midrange. The area of the bass reflex tunnel (ABR) corresponds to the mouth area of the rear chamber (drawing top left). The bass reflex frequency fBR is then adjusted until the tunnel length is close to 0 cm (LBR in the window "Misc"). Important is also the correct input of dL and the distance. The difference length dL can also be negative ("Horn mouth" is at the back). Too high sound pressure simulations often have to do with the wrong dL input and distance. It's best to make a drawing and read the lengths from it.



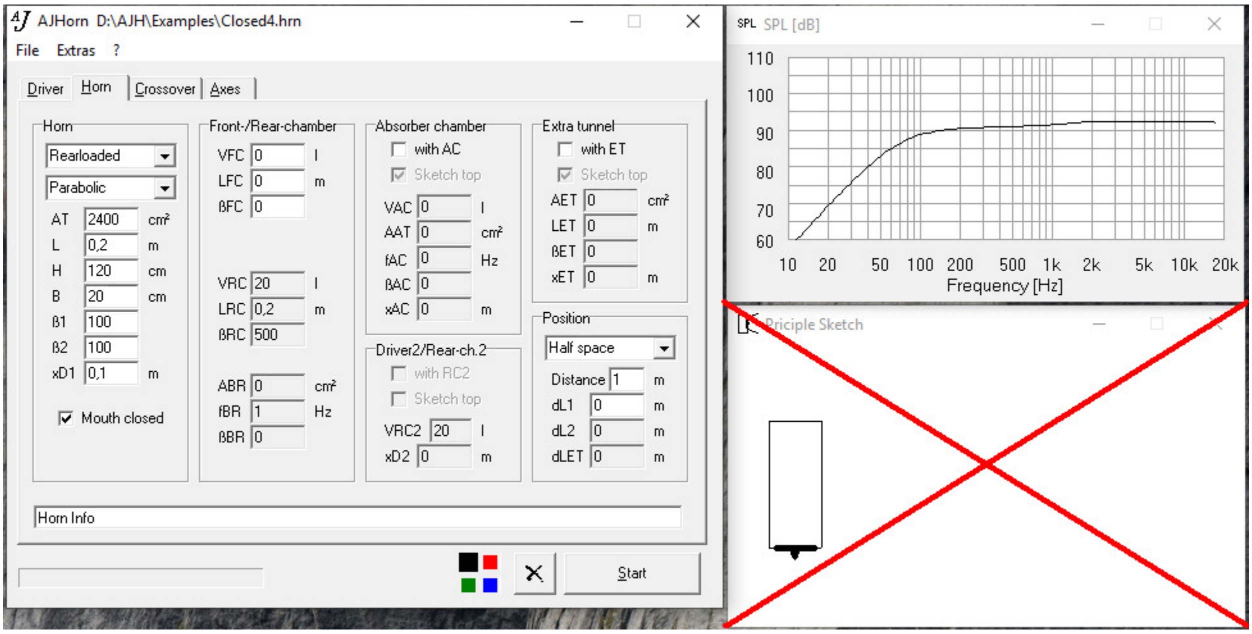


3.10 Cavity resonances and interferences

Due to the possibility from AJHorn Version 7 to close the horn mouth, it is possible to simulate enclosure resonances (standing waves, interferences). These affect especially when the enclosure has a too economical damping.



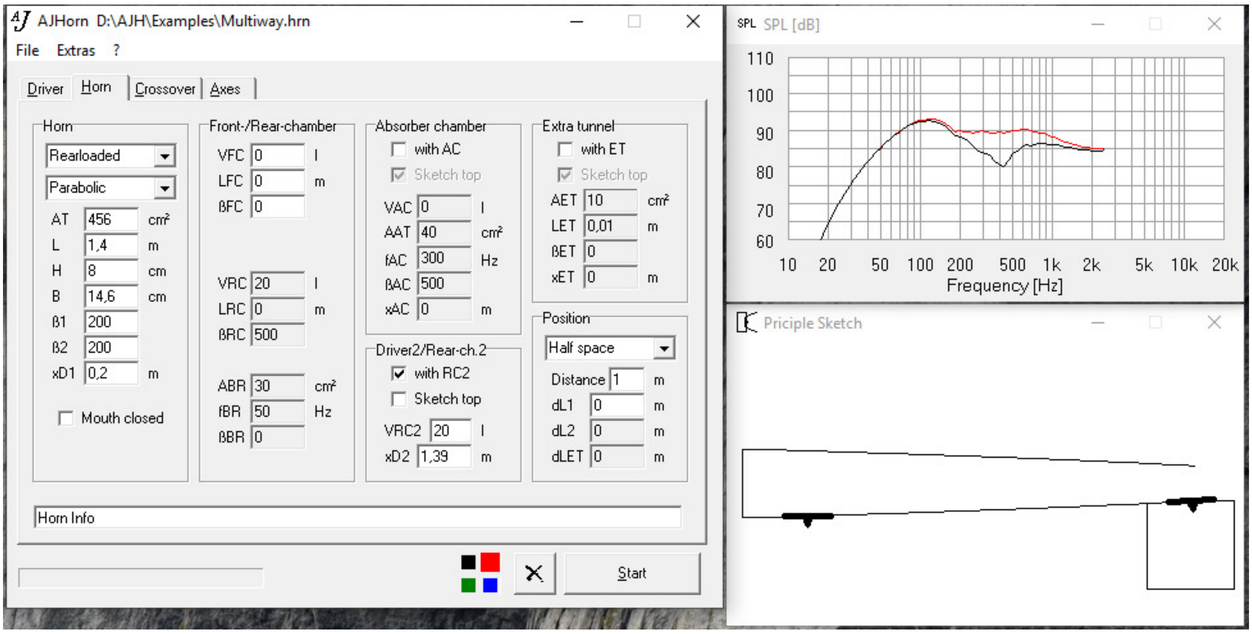
It should be noted, however, that the interactions (interferences) are simulated only in the horizontal direction of the priciple scetch. The following entry leads to a wrong simulation for the same enclosure.



3.11 Multiway-systems

By adding driver 2, systems with two bass chambers and different separation frequencies or multiway systems can also be simulated. The automatic priciple scetch sometimes reaches its limits, but the simulations are correct.
Often, the tuning of the passive crossover between bass and midrange drivers causes problems. The reason for this are phase problems, since the resonance frequencies of the individual drivers are often in the separation range. AJHorn should not be the last option to optimize a crossover. This still happens today and in the future only through precise measurements and listening tests. However, the program can provide optimization assistance.

The following figure shows the input data and the corresponding simulation result for the separation of two drivers at approx. 400 Hz. Driver 2 (midrange) gets its own closed chamber and is set very close to the horn output (xD2 = 1.39 m). This means that it radiates without the influence of the horn.
The black curve shows the simulation with driver 2 turned over (i.e. as in the picture below), the red curve with driver 2 not reversed. Since driver 2 should not be installed with the magnet to the outside, the red simulation result also accurs, when the polarity of driver 2is reversed and installed with the magnet inside.



3.12 Mid- and high frequency horns

The simulation of mid- and high frequency horns or horn-driver combinations is possible in principle with AJHorn. But you have to pay attention to some points. The horn starts already inside the driver. To get accurate dimensions, the driver may need to be disassembled. This may damage the driver. The warranty is naturally extinguished by this as well. Another problem is the assembly, since many diaphragms must be manually centered during installation despite a centering aid. From the found dimensions it is then attempted to determine the Thiele-Small parameters by AJHorn simulations and comparison of the sound pressure and impedance frequency response of a known horn-driver combination. Helpful here is the output window "Misc" by AJHorn.

3.13 Outlook

Using the input data, you were able to see what to pay attention to when entering the parameters of the different enclosure types. To modify and preserve the data, the project should first be saved under a different name (for example, in Documents \ AJHorn \ [filename]).

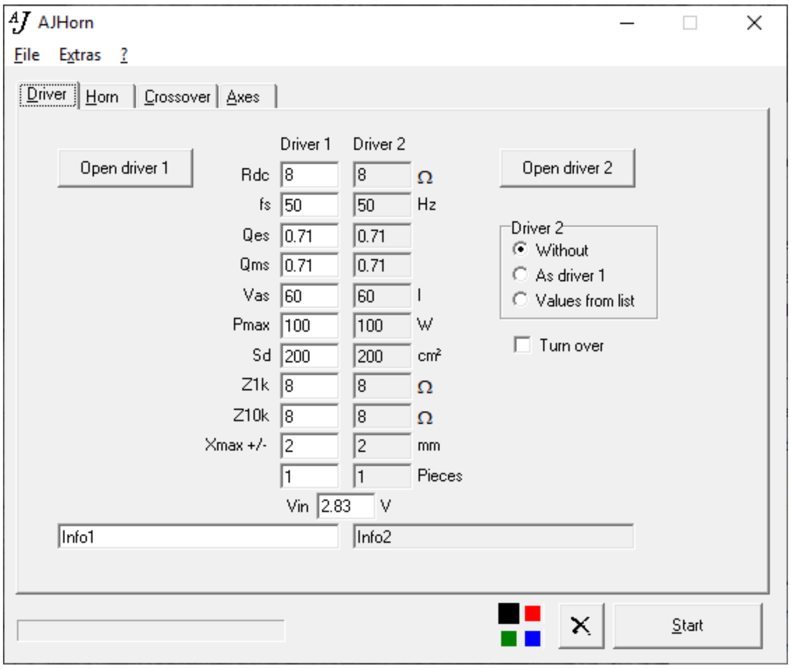
The method presented in this section can now be used to optimize any Horn or Transmissionline loudspeakers and their relatives on the computer. Only when the simulation on the computer convinced, the speaker is also built.

4 Data input

After presenting different types of enclosures that can be simulated with AJHorn, we now turn to data entry in detail. An attempt was made to make data entry as easy as possible so as not to lose track.

4.1 Driver

Loudspeaker chassis are described by today's standard **Thiele Small Parameters (TSP)**. They provide information about the characteristics of the loudspeaker at its resonance frequency. The frequency response of a horn depends, as with the simpler housing types also, to a large extent on the used speaker (driver) and its TSP. That is why it is important to know these parameters. They are either published in various journals, mentioned in data sheets of the manufacturers or are available as a database. You can also contact the manufacturers or distributors directly. It should also be mentioned that the TSP can be determined relatively easily with today's standard computer measuring systems. To determine the parameters without a computer measuring system, there are useful suggestions in acoustic books.



Button “Open driver“

Here you can select an AJHorn file (.hrn) from which only the driver should be loaded. The remaining data of the current project remain untouched. For compatibility with older versions, opening driver 2 from the desired hrn file selects the values of **driver 1** and assigns **driver 2** of the current project.

Rdc (DC Resistance)

This value, expressed in electrical ohms, indicates the resistance of the voice coil when a DC current is flowing through it.

fs (Resonance Frequency)

This value in Hz (Hertz) denotes the natural frequency of the mechanical pendulum of membrane mass, air mass and suspension compliance.

Qes (Elektrische Güte)

This dimensionless value describes the influence of the electrical damping.

Qms (Mechanische Güte)

This dimensionless value describes the influence of the mechanical damping.

Vas (equivalent volume)

This value in l (Liters) indicates the volume that would be needed to achieve the same spring stiffness of the diaphragm suspension as achieved by the surround and spider of the driver.

Pmax (Electrical Power Capacity)

This value in watts indicates the manufacturer's specification of the electrical power capacity. It is needed for the calculation of the linear electric power and for the maximum sound pressure.

Sd (Cone Area)

This value in square cm denotes the effective vibrating area of the loudspeaker diaphragm (membrane).

Z1k and Z10k (Impedance at 1 kHz and 10 kHz)

The voice coil inductance of a loudspeaker is not constant over frequency, but generally decreases toward higher frequencies. Likewise, the voice coil inductance has an imaginary part that typically increases with increasing frequency. This phenomenon is accounted for by inputting the electrical impedance in ohms at two frequencies (1 kHz and 10 kHz). From the impedance of a loudspeaker you can read these two values very well.
Attention! If these values are not available, the DC resistance (Rdc) should be entered for both values. However, it should be considered that the simulation for medium and high frequencies can then no longer be correct and the influence on the passive crossover, especially at higher crossover frequencies, is no longer correct.

Xmax (Linear Excursion)

This value, expressed in +/- mm, indicates the maximum deflection of the voice coil until it leaves the homogeneous area of the magnetic field. Obove this value, the force on the voice coil decreases and it comes to non-linearities (harmonics, harmonic distortion). However, the maximum **nonlinear** deflection of the membrane can be much higher. If this value is not mentioned in the data sheet of the loudspeaker, it can be calculated according to the following formula:

$$X_{\max} = \frac{H_{VC} - H_{AG}}{2}$$

H_{VC} is the winding height of the voice coil and H_{AG} is the height of the air gap (upper pole plate).

Number of drivers

This value indicates the number of paralleled drivers. It should be noted that **all** of these drivers work **together on one** horn with mouth height (H), horn width (B), rear chamber (VRC), and so on.

Ue (Input Voltage)

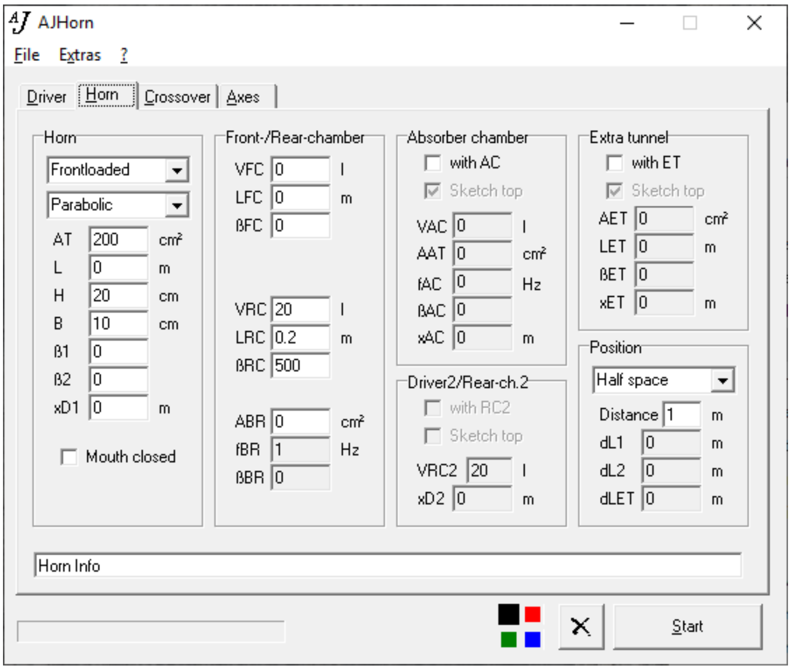
In this menu item you can enter the electrical input voltage in volts (V). If the simulation is to be carried out at one watt, then for 4 Ohm drivers 2 V and for 8 Ohm drivers 2,83 V must be entered here.

Info

Here you can enter comments on the driver (for example its type designation).

4.2 Horn

In this menu section, the dimensions and volumes of the horn, the horn type and the opening function of the horn are indicated. To illustrate the input parameters, the graphics in Section 3 are also helpful.



Horn

The **Frontloaded** type has a closed or ventilated chamber (rear chamber) behind the cone. With the **Rearloaded** type, this chamber is completely omitted.
The naming of the horn opening functions (contour) is based on historical specifications. As a result, the contour is regarded as the radius of a circular horn. People without in-depth knowledge of function theory can skip this section and look at the different contours in AJHorn's principle sketch.

Parabolic A parabolic horn is a horn whose radius expands with the square root function. The area is therefore proportional to the length.

Conic A conical horn is a horn whose radius expands linearly with length. So the area is square with the length.

Exponential The radius of an exponential horn expands with the exponential function (e-function). The peculiarity of the function means that the area expands exponentially as well.

Hyperbolic The radius of a purely hyperbolic horn expands with the cosine hyperbolic function (cosh). The area thus goes with the square of cosh.

Octal hyperbolic The radius of an octal hyperbolic horn goes with the eighth power of the cosh function, that is, the surface with the 16th power of cosh.

Geometric The area of a geometric horn is defined as the sum of the infinite seriesA (x) = const. * (1 + x + x ^ 2 + x ^ 3 + x ^ 4 + ...). In the initial domain, it is very similar to the exponential horn but with increasing length it rises faster and faster.

Tractrix The radius of the Tractrixhorn ("spherical wave horn") follows the Tractrix function ("drag curve"). This contour is said to have advantages in wave propagation in the horn. AJHorn can simulate this horn acoustically as well as mechanically and represent area, radius and height as a function of the length (explicit representation). This is worth mentioning because mathematically there exists only an implicit representation (length depending on the radius) of the tractrix function.

Depending on the speaker used and the individual horn parameters, the different types can produce different frequency responses. Some are more linear than others, some offer a lower cut off frequency, some have the highest efficiency and / or the lowest diaphragm amplitude. The user is thus able to create a loudspeaker according to his wishes by selecting the contour.

The throat area **AT** is the area at the beginning of the horn (i.e. at length 0). **Attention!** The throat area is not necessarily the area at the driver position! The length of the horn **L** is the distance between the throat and the mouth.
H and **B** are the height and width of the horn at its exit (horn mouth). Note that the program uses the one-dimensional solution of the horn equation. For the horn function, only the **surface** depending on the length is needed. Only the **mouth area** and not the ratio of mouth height to mouth width are necessary. By entering mouth height and mouth width, only program operation is facilitated. So you can also simulate **circular** horns after a conversion.
The coefficients **β1** and **β2** describe the influence of damping material. It is assumed that the attenuation is linear from the throat (β1) to the mouth (β2) of the horn. Useful values are between 0 (no damping, smooth walls) and 1000 (full padding with damping material). The driver position **xD1** is the mean distance between driver 1 and the beginning of the horn (throat). By setting the check mark the **mouth** can be **closed**.

Front- and rear chamber

The front chamber is located between driver membrane and horn start (when xD1 = 0) or horn coupling. As input data AJHorn needs the volume **VFC**, the length **LFC** and the damping **βFC**. It is simulated with the AJHorn impedance theory (i.e. as a horn of constant cross section).
The rear chamber is only available with frontloaded horns and is located between driver diaphragm and bass reflex tube or closed rear wall. As input data AJHorn needs the volume **VRC**, the length **LRC** and the damping **βRC**. It is also simulated with the AJHorn impedance theory (i.e. as a horn of constant cross-section).
By entering the area of the bass reflex tunnel **ABR** > 0 cm² and the bass reflex frequency **fBR**, a bass reflex channel is added to the simulation. The value **βBR** again describes the damping. The associated tunnel length is calculated by AJHorn and output in the window "Misc" as **LBR** (length of the bass reflex tunnel).
Except for the rear chamber, it is recommended to set **β** to 0 at the beginning of the calculations, and then observe the influence of the damping by changing the values.

Absorber chamber

By activating the checkmark, entering the volume of the absorber chamber **VAC** > 0 l and the area of the absorber tunnel **AAT** > 0 cm², an absorber chamber is added. Starting from AJHorn 7 the absorber chamber is located at an arbitrary position **xAC** along the horn course. Further input variables are the absorber chamber frequency **fAC** and the damping coefficient of the absorber chamber **βAC**. The absorber chamber should be damped in most cases (βAC > 0), otherwise resonances occur, which will be simulated correctly by AJHorn. The length of the absorber tunnel (**LAT**) is calculated by AJHorn and displayed in the window "Misc".

Driver 2 / rear chamber 2

Optionally, a second driver can be added as well. This is defined in the "Driver" tab. It is located at position **xD2**. By activating the checkmark and entering the volume **VRC2** > 0 l, a rear chamber can be added as well.

Extra tunnel

By activating the checkmark and entering the area of the extra tunnel **AET** > 0 cm², the extra tunnel is added. The extra tunnel is located at an arbitrary position **xET** along the horn course. Further input variables for the extra tunnel are the length **LET** and the damping coefficient **βET**.

Position

The spatial position influences the efficiency and the frequency response linearity in the lower, middle and upper frequency range. The following anechoic installation conditions are accepted and can be selected:

Free This setup variant can be found in a reflection-free measuring room ("unechoic room"). All measurements in section 7 were taken in this way. The free installation is generally always present when the horn opening is not much smaller than the dimensions of the baffle and the speaker can radiate otherwise free on all sides (also down). A correctly performed absolute measurement impressively confirms the accuracy of AJHorn.

Floor In this variant, the speaker of the free installation variant is standing on the floor. So he also has a baffle, which is not much larger than the horn opening.

Half Space This setup variant was based on the calculations of Thiele and Small. The results refer to the mounting of the speaker or horn in an infinite baffle.

Floor + Wall This installation variant refers to the radiation of the speaker in the quarter space.

Corner This setup variant refers to the radiation of the speaker in the eighth space.

Entering **Distance**, **dL1**, **dL2** and **dLET** has different meanings for Front and Rearloaded types. The difference lengths play a role in the phase-correct summation between the individual sound pressures.

For **Frontloaded** types applies:

$$Distance = \overline{Ear, Horn\,mouth}$$

$$dL1 = \overline{Ear, Bassreflex\,tunnel\,exit} - \overline{Ear, Horn\,mouth}$$

$$dL2 = \overline{Ear, Driver2} - \overline{Ear, Horn\,mouth}$$

$$dLET = \overline{Ear, Extra\,tunnel\,exit} - \overline{Ear, Horn\,mouth}$$

The difference length is thus positive when the horn mouth is closer to the listening location (ear or microphone).

For **Rearloaded** types applies:

$$Distance = \overline{Ear, Driver1}$$

$$dL1 = \overline{Ear, Horn\,mouth} - \overline{Ear, Driver1}$$

$$dL2 = \overline{Ear, Driver2} - \overline{Ear, Driver1}$$

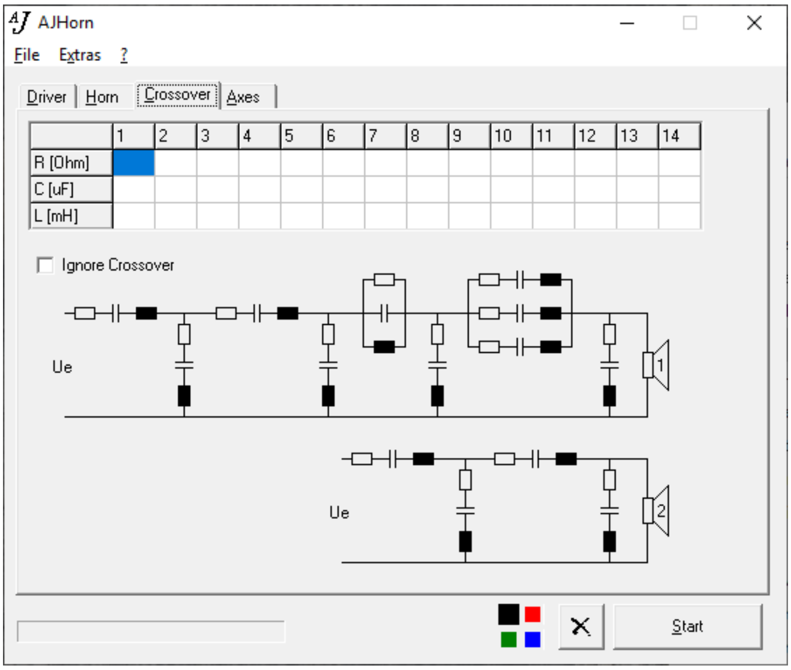
$$dLET = \overline{Ear, Extra\,tunnel\,exit} - \overline{Ear, Driver1}$$

The difference length is thus positive when driver1 is closer to the listening location (ear or microphone).

4.3 Crossover

In this menu section a passive crossover can be added. The resistances Ri are given in ohms (Ω), the inductances Li (coils) in mH and the capacitances Ci (capacitors) in µF. The following figure shows the structure of the passive crossover.

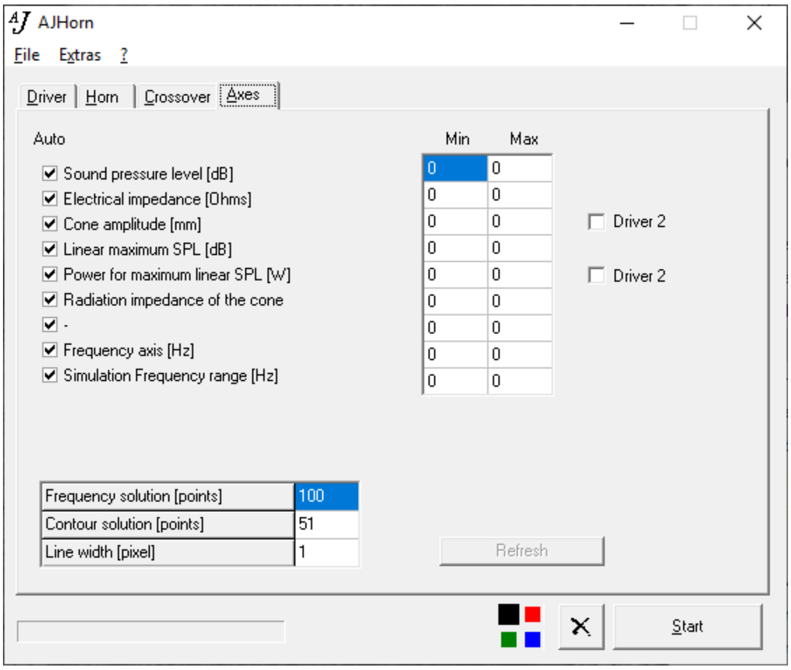
By clicking at one crossover symbol in the schematic below, the cursor is placed on the corresponding field in the input table above. There, the value of the component is then entered. If an input field is left blank, the component will not be taken into account in the calculation (series components are bridged).



4.4 Axes

As mentioned earlier, AJHorn can simulate different characteristics of a (horn) loudspeaker. Use this menu item to specify an automatic or manual axis scaling of the output frequency responses.

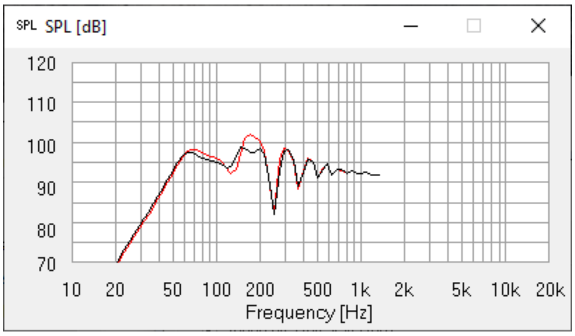
A check mark in the "Auto" column means that AJHorn automatically scales the axis. If a tick is removed, the minimum and maximum values of the axis must be specified. In the line "Simulation frequency", the smallest and largest simulated frequency can be entered. In between, the points are distributed logarithmically. The variable "contour resolution" specifies the number of contour steps for the contour text file. This value is limited to 10000 for safety reasons. With the "Update" button, the graphs are redrawn, but no new calculation is performed.



5 Simulation results

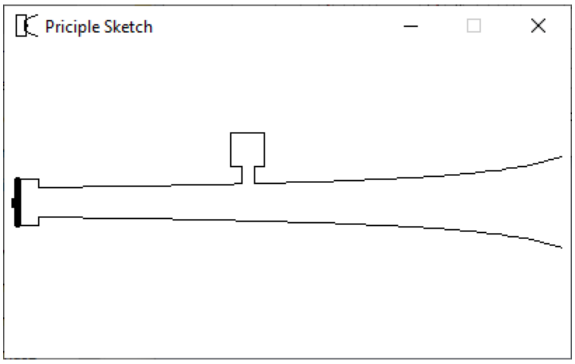
5.1 SPL (Sound pressure level in dB)

This well-known value defines the simulated pressure frequency response of the loudspeaker at a distance of r meters on axis. It belongs to the standard measurement of each loudspeaker and it allows many conclusions as to the sound characteristic of the loudspeaker, because the ear works as pressure sensor as well. It should be as smooth as possible. Narrow peaks in the frequency response of more than ca. 3 dB are absolutely audible and are to be avoided.



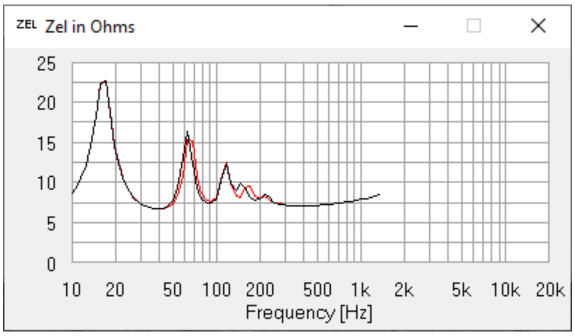
5.2 Principle sketch

Now it is finally possible with AJHorn 7 to see exactly this as a schematic diagram of what you have previously entered as numerical values. Not only the contour but the entire project dimensions are displayed in an automatically generated, proportional graphic. For a more detailed specification of the contour values and a later practical realization, you can also list the numerical values in the main menu under "Extras" -> "Contour list". The current length, the area, the height and the radius are displayed in the individual columns.



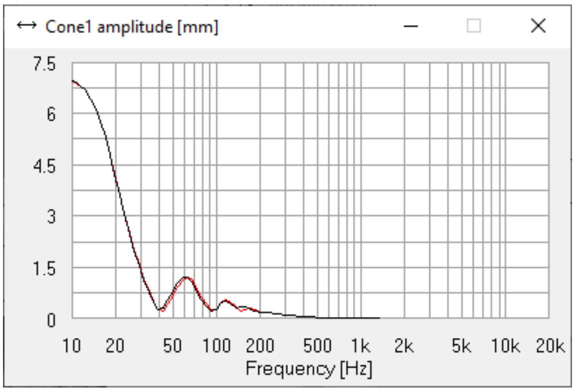
5.3 Electrical impedance in Ω

This frequency response also belongs to the standard measurement and assessment of loudspeakers.



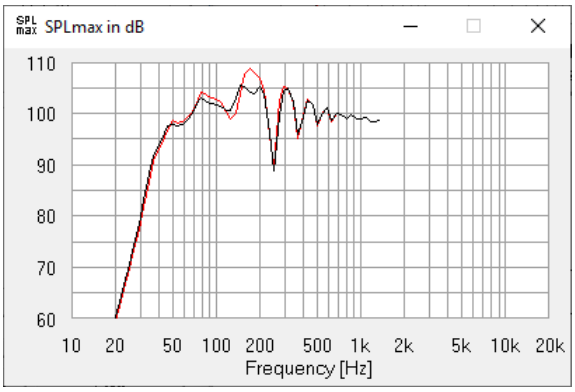
5.4 Cone amplitude in mm

This value shows the frequency response of the effective excursion with a definite input voltage. The peak-peak value is the effective value multiplied by 2.83.
With a horn, the cone amplitude will be reduced in a decisive measure and at the same time the sound pressure will be increased. This is the reason for the nearly incredible sound pressures which can radiate from a correctly constructed horn and for the legendary reputation of this type of loudspeakers.



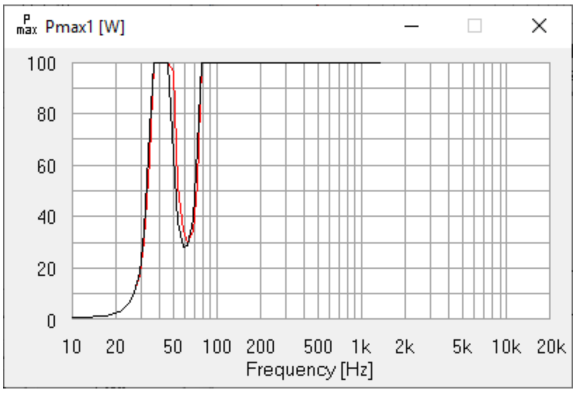
5.5 SPLmax (maximum linear sound pressure in dB)

This frequency response defines the maximum sound pressure which the loudspeaker could produce. It is limited by the effective value of Xmax and the electrical power handling.



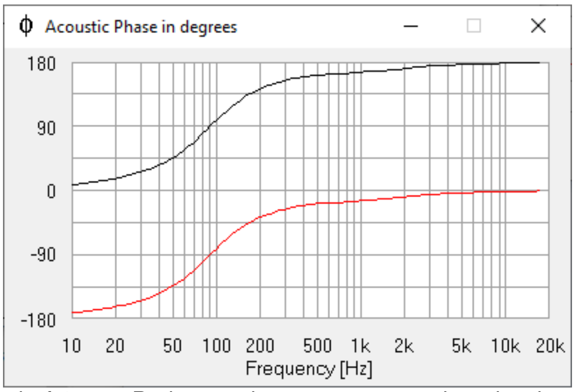
5.6 Pmax (necessary electrical power in watts for SPLmax)

This frequency response shows the required power for the maximum linear sound pressure.



5.7 Acoustic phase

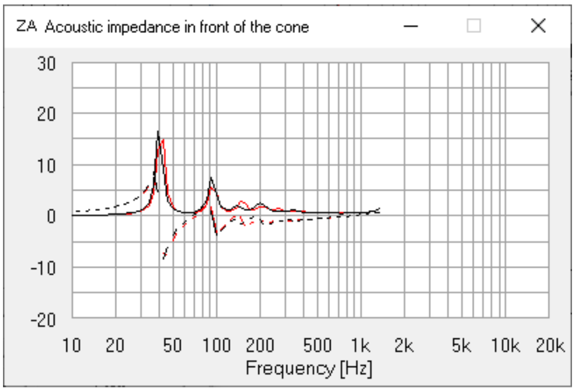
New in AJHorn 7 is the output of the acoustic phase. This is needed to determine if two different projects can be operated together in a certain frequency range. This is important e.g. in the takeover of multiway speakers but also for the parallel connection of different subwoofer constructions too. If the phase difference between the two projects is almost 0 °, the individual sound pressure is added together and at the same individual levels a sound pressure increase of 6 dB is achieved. By contrast, if the phase difference between the two projects is approximately 180 °, with same individual level, both parts cancel out completely.



The figure shows e.g. a phase difference between black and red of 180 °. Both sound pressures cancel each other out. In the listening room only the diffused sound can be heard. Incidentally, the red curve was simply generated with an input voltage of -2.83 V (ie reverse polarity of the driver).

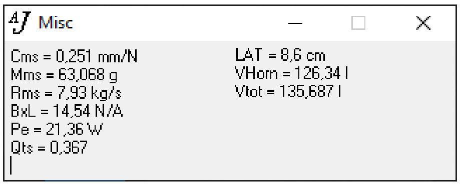
5.8 Acoustic impedance in front of the cone

When the front chamber is zero, this value is identical with the radiation impedance of the horn throat. This value, which is normally hard to find with measurements, is a value for the radiated acoustic power. The impedance is normalized by rho*c. Fundamental literature of acoustics and theoretical publications will refer to this quantity. Because of the completeness of AJHorn, this value will be displayed for comparison to values found in literature. The real part is displayed solid, and the imaginary part is displayed dashed.



5.9 Misc

Here the other driver data calculated by AJHorn as well as further dimensions are listed. These are e.g. the length of the absorber and bass reflex tunnel LAT and LBR.



6 Limitations of simulation accuracy

AJHorn is a precise, scientific program with which Horn Loudspeakers and Transmissionlines and their special cases can be simulated. For a better calculation, some approximations are assumed. Therefore we can't give a guarantee for the simulation results. It's in our interest, too, to tell you the limits of simulation accuracy, because we want, that you can calculate your project as exact as possible.

6.1 The chassis itself

The cone of a loudspeaker chassis oscillates like a piston up to a certain frequency. That means the cone oscillates at all points with the same amplitude. If a cone doesn't oscillate like a piston (e.g. for higher frequencies), it will not have a uniform pressure response. It is obvious that this will influence the frequency response of the Horn.

6.2 The front chamber, rear chamber and bassreflex tunnel

These elements are described as a cylindrical tube of length l with the AJHorn impedance theory, ie as a horn. In contrast to earlier versions, runtime differences and cavity resonances of the chambers can be well described. Even for non-cylindrical chambers, this model is applicable and surprisingly accurate. However, due to the detailed dimensions, pre-chamber resonances in the sound pressure frequency response can occur, but only at relatively high frequencies. These phenomena are described below metrologically. If horns are also to be used at their upper end of transmission, the front chamber must be kept as small as possible. The exact geometry of the pre-chamber also plays a role (phase correction). The rear chamber is damped in the vast majority of cases and thus does not pose a major problem.

6.3 Absorber chamber, absorber tunnel und extra tunnel

Absorber chamber, absorber tunnel and extra tunnel are described by AJHorn by a relatively simple context[1]. This theory is correct only if the dimensions are smaller than the wavelength of the frequency to be radiated. If the absorber chamber is operated at wavelengths in the range or above the dimensions, it must be damped by suitable materials. The frequency above which damping is strongly recommended is

$$f_0[Hz] \approx \frac{17000}{x[cm]}.$$

The variable x is the largest dimension of the chamber, ie the maximum of length, width and height.

Standing waves occur in the tunnel of the absorber chamber and in the extra tunnel, which can negatively influence the sound. The standing wave with the lowest frequency is

$$f_0[Hz] \approx \frac{15000}{L[cm]}.$$

Since the volume VAK is a few liters and the lengths LAT and LET are a few centimeters, this property is unlikely to be disturbing.

6.4 Horn contour

AJHorn uses the solution of the one-dimensional Horn equation. So plane, propagating waves are assumed. For slowly opening contours this is very well fulfilled. But if the slope of the opening function is too large, the wave is no longer flat (no, also not a spherical wave). For most bass and midrange horns, you probably will not have any problems. The simulations are very accurate for these types. Problems can occur with high frequency horns with very large mouth area. The result of the simulation is then still good, but not as gorgeous as a bass horn.

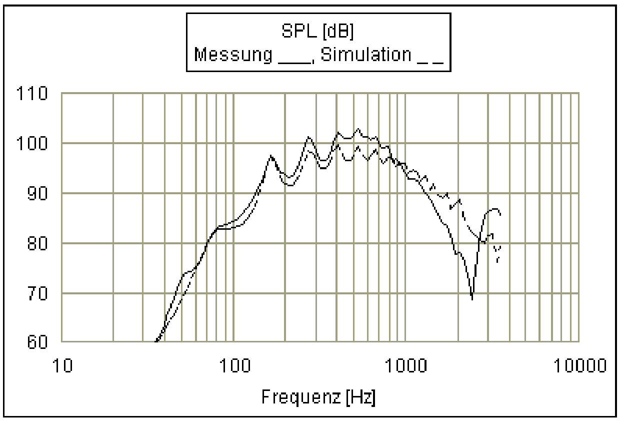
[1] Acoustic compliance, acoustic mass

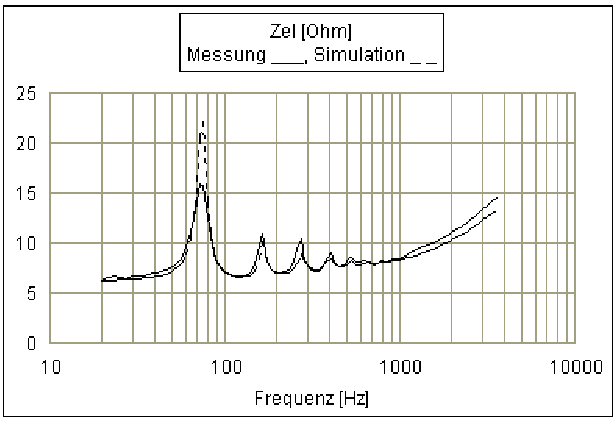
7 Comparison with measurements

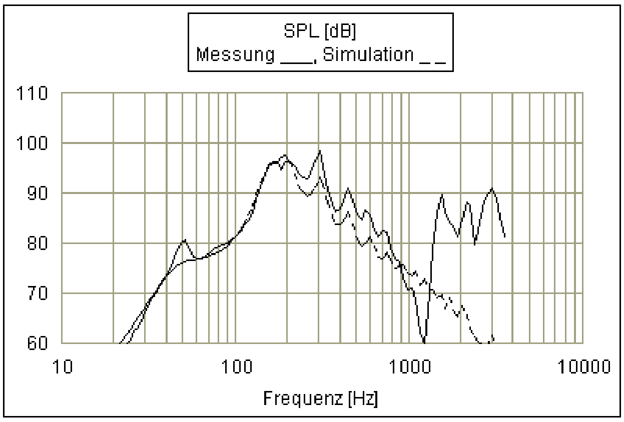
What use is a simulation programm when nobody knows whether the calculated responses are describing the practical measurement? The sense behind a simulation programm is to save time from building costly prototypes and to see what happens when one parameter is changed relative to any others. The prerequisite for this is confidence in the simulation. We have tried to prove this with the folowing examples.
The measurement equipment was a full-automated computer-controlled meassuring-system with high resolution sine-steps. All measurements where made in an anechoic room with a low frequency limit of 70 Hz. The meassurements and simulations are described in the following paragraphs.

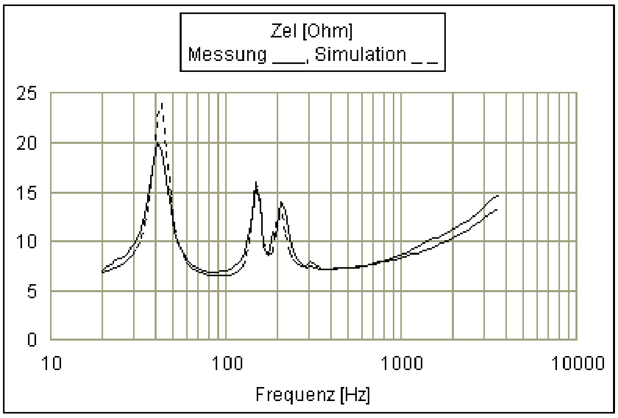
7.1 Variable test horn

The variable test-horn is a frontloaded midrange horn which is not constructed to have a linear frequency response, but with characteristic resonance peaks, to compare the simulation with the measurement. It is built of several parts to change the length, throat area and the mouth area. The shape-function is the e-function. The various simulations with AJHorn and the related meassurements show the following figures.



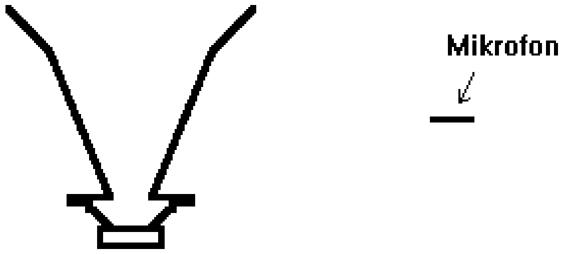




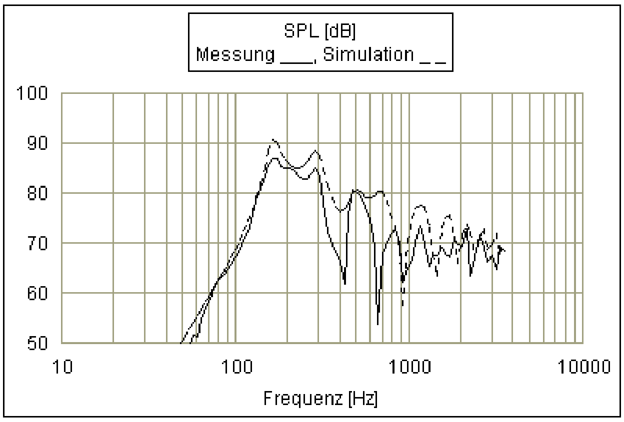


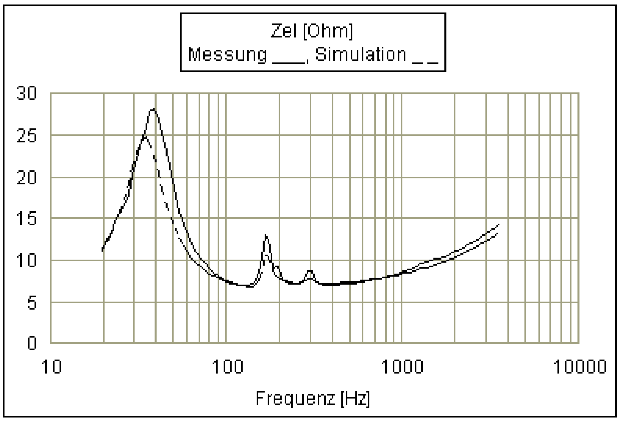
7.2 Little rearloaded horn

The little rearloaded horn is built from the variable testhorn by removing the rear chamber. It is also not constructed to achieve a linear response. It only should compare the simulations with the measurement. The length difference from zero is achieved by positioning the microphone as in the fillowing figure.



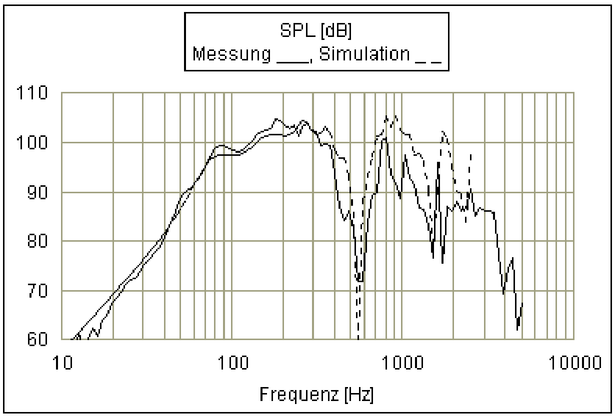
This is only correct for low frequencies because the sound from mouth and cone is then radiated in circular fashion.

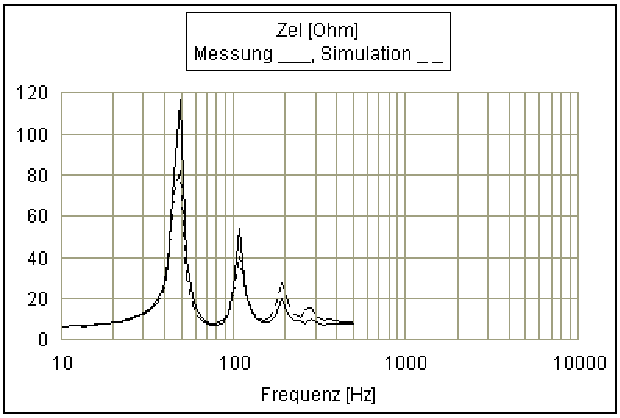


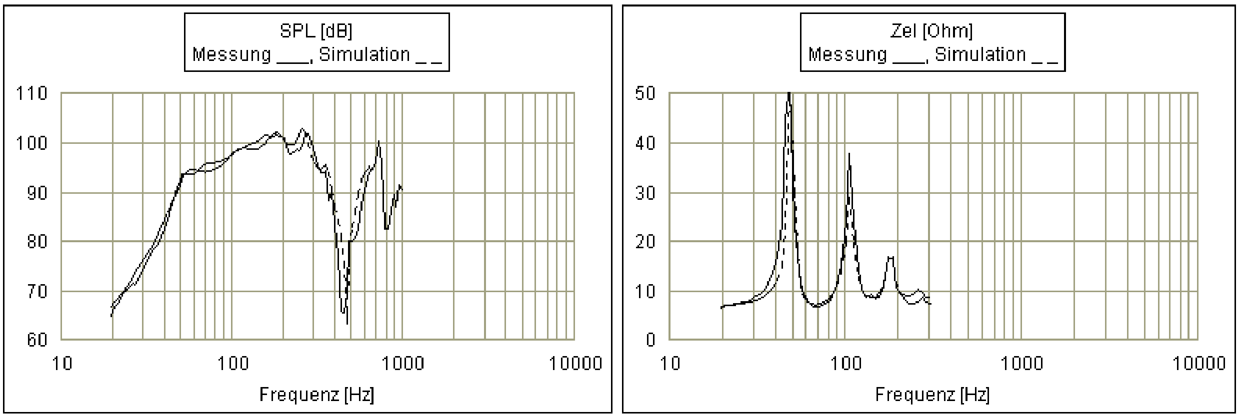


7.3 Folded frontloaded low frequency horns

These are folded low frequency horns with PA-Drivers. The efficiency in free field is very high in comparison to the volume of approx. 200 Liters (>98 dB, >80 Hz, 1 W). In halfspace (Thiele-Small) the efficiency is increased by 6 dB. The results of the simulations with AJHorn and the measurement results show the following figures.







The input value “driver position” (xD1) 0.15 and 0.2 meters result in minima of SPL which are simulated correctly. The measurement shows good agreement with the simulation, especially in the low frequency range.

Further comparisons with reference projects are constantly published on our homepage www.aj-systems.de.

8 Synopsis

We hope to have given you an overview of the capacity and user-friendly nature of AJHorn. With a little practice you will be successful in finding the best geometry for your projects. The costly making of prototypes will be reduced to a minimum, and you can immediately observe the changes to frequency response that your design decisions make. So, it is hoped, AJHorn will save you a lot of time and trouble.
We wish you every success with your projects.

AJ

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9 Appendix

9.1 History of the horn loudspeaker

Horns were used at the beginning of sound reinforcement to increase the efficiency of mechanical and electrodynamic drivers. A good example of this increase in efficiency is the gramophone, which converted the vibrations of the stylus from the record groove into audible vibrations of the air. Later, drivers were inserted in place of the stylus which were in turn fed by electrical signals. The sound quality of such horns was generally quite poor by today's standards. Eventually, primarily because of the development of more powerful amplifiers, direct radiator systems took the place of horn loudspeakers in most areas of sound reproduction and especially in the home.
Today, horns are used for many different reasons. In the case of public address systems, the demands for loudness and precise directivity have increased to the point that, in high quality systems at least, horns must be used. Other applications of horns are the standard installations in discotheques and commercial theaters. Finally, horns are built for home useage in High-End and Ultra-Fi systems. For PA systems at low frequencies, horns make possible efficient reproduction with high maximum sound pressure and acceptable cabinet size. For High-End or HiFi-use the linear sound pressure frequency response is a priority.

All of these horn types can be simulated and optimised by AJHorn.

9.2 To the theory

If you aren't knowledgeable about the theory of electrical-mechanical-acoustical systems, you can skip this section. It is not required for the operation with the program.
The complete theory of horn loudspeakers is too complex to describe here in this manual. Moreover AJHorn does use partly modified attachments, but regardless, the classic theory will be explained roughly. After the theory of one-dimensional acoustic wave guides, the pressure and velocity response versus horn length can be described with the fundamental horn equation (Webster, 1919)

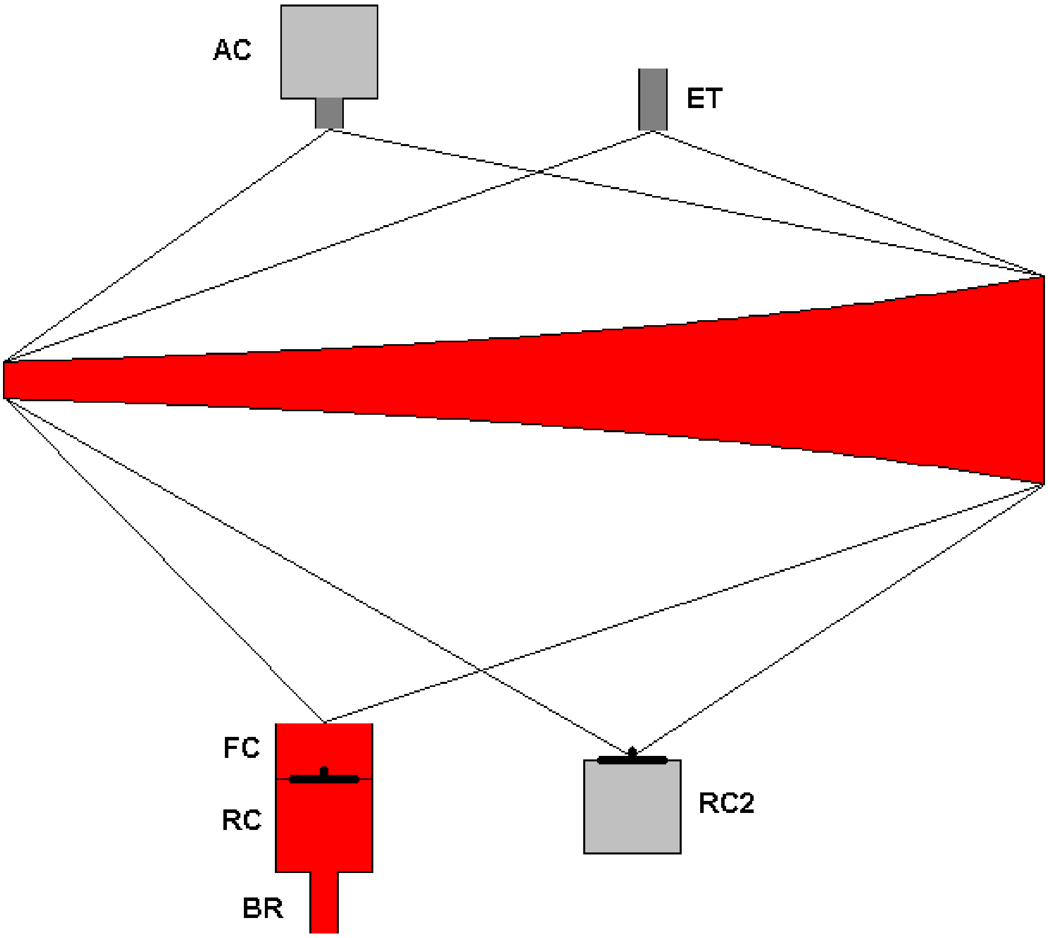
$$\frac{\partial^2 p}{\partial x^2} + \frac{1}{A}\frac{\partial A}{\partial x}\frac{\partial p}{\partial x} + k^2 p = 0$$

This differential equation of the 2nd order has solutions which are dependent on its' boundaries. Through the use of boundaries for the hornthroat and hornmouth, the specific radiation impedance of the hornthroat can be determined as a function of the specific radiation impedance of the hornmouth. In case of a cylindrical tube, the radiation impedance devided by ρ*c (ρ= densitiy of the air, c= speed of the sound) results in a relatively wavey curve with some resonance peaks. This function can be seen very clearly with AJHorn. Because the radiation impedance has its mark immediately in the radiated acoustic power, the resulting sound pressure frequency response of a cylindrical tube must also be very wavey. This is not in accordance with lifelike sound reproduction.
If the unified radiation impedance of a continuously enlarged cone is calculated, it will be established that with increasing moutharea, a linearisation of the impedance occurs. This phenomenon is well-known as “impedance transformation”.
With the clever choice of the opening function (horncontour), the loudspeaker perameters, and front- and rear-chamber volume, a linear sound pressure frequency response can be obtained. This is the primary requirement for lifelike music reproduction.

During the attempts at finding the optimal horn for use, when you change the values you will find that nearly all parameters affect each other. So it's possible for example, that the front chamber volume could affect the low cut-off frequency or the linearity of the sound pressure. Also the throat area can have an effect on the linearity or the efficiency in the middle frequency range. Also it's possible with certain parameters, that a conical horn can have a lower cut-off frequency when compared to a hyperbolic horn.
The program will accurately record the influence of a passive crossover. At this point an investment in a high quality simulation program like AJHorn is recommended because the complex impedance has an important influence on the crossover.

As you can see from these examples, it is not very useful to calculate the low or high cut-off frequency of a horn with the help of simple formulas and a pocket calculator. This is quiet possible and with very good results for a closed or a bass-reflex enclosure, but the only way to calculate the frequency response of a horn (and also of a Transmissionline) with high precision is through a computer simulation program like AJHorn.

9.3 AJHorn 7 simulation model



This graphic shows the modular structure of the AJHorn 7 simulation model. The additional modules can be anchored anywhere in the horn course. Color coded are the acoustic models that are behind the individual modules. Light gray stands for "Acoustic Compliance", dark gray for "Acoustic Mass" and red for the AJHorn "horn formula". As already mentioned, the horn formula is used not only for the actual horn, but also for the front chamber, the rear chamber and the bass reflex tube.