Photo Story

Dipol and Cardioid Loudspeaker

One of the present themes of loudspeaker technology today is the Dipol-subwoofer. But not all descriptions found in literature are correct. This research will on the one hand show the acoustic properties of Dipol and Cardioid speakers and on the other hand offer a construction version. The from science derived Dipol-Cardioid Subwoofer has in comparison to the well known Dipol oder Cardioid Loudspeakers a better efficiency, more even frequency response and much simpler construction.

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Index

1.Microphone

For acoustic measurements microphones are needed. First of all the microphones used here are presented.

Microphones for measurement technology can in general be put into two groups: The pressure transducers with spherical characteristic and velocity transducers with figure of eight characteristics.

Spherical characteristic

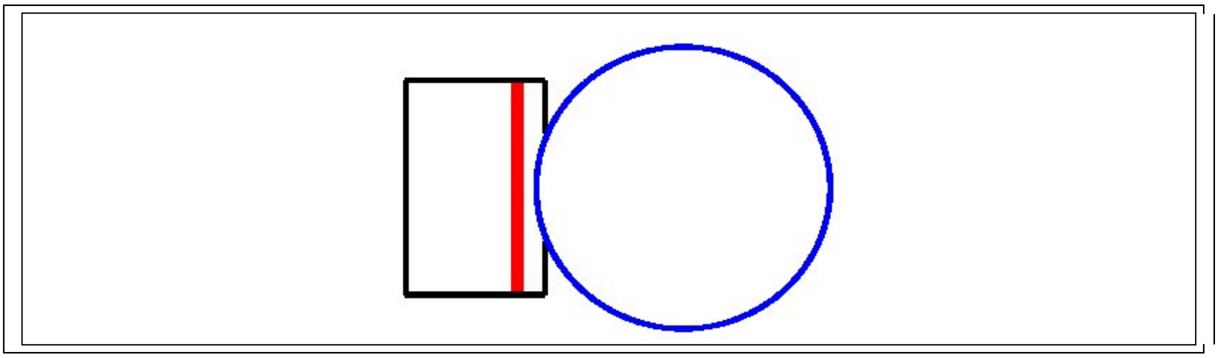


Fig. 1.1

With the spherical characteristic behind the (red) membrane there is a closed enclosure (Fig 1.1). Due to this the microphone reacts to pressure changes. Because of the back pressure of the air enclosed in the microphone body the membrane can not follow the velocity movement of the air molecules. Microphones with spherical characteristic are not directional dependant as to their sencitivity, so that the recording area (blue) is circular.
These microphones are mainly used in measurement technology, as they have the most even frequency response.
The human ear is also a pressure transducer and because of the ear canal has a directional dependency.

Figure of eight characteristics

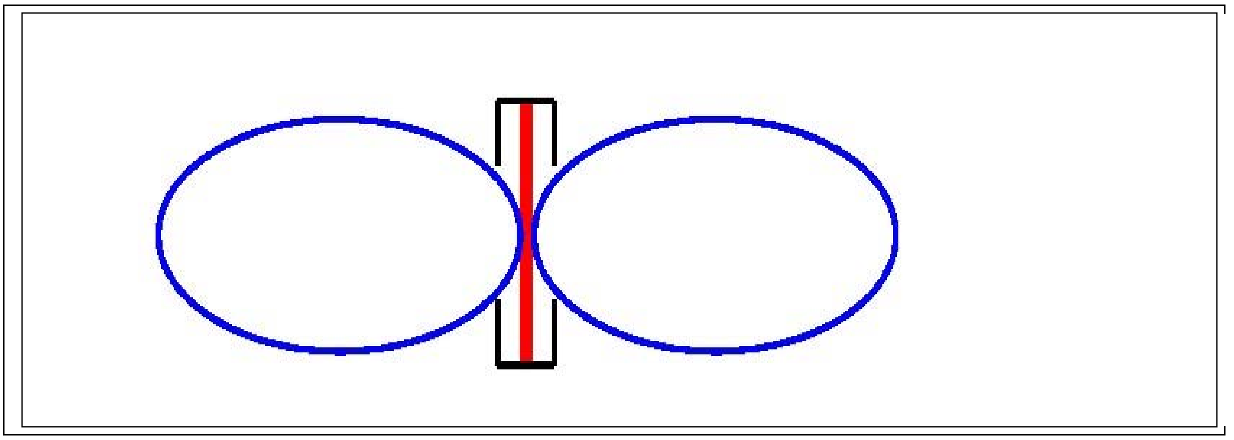


Fig. 1.2

Microphones with figure of eight characteristics have a front and backside openly suspended membrane (red) (Fig. 1.2). Due to that they can record velocities. Velocities describe the directional speed of the air molecules. Velocities are direction dependant. The direction is measured with the figure of eight characteristic microphone. Fig. 1.2 shows the recording area which has the shape of an eight (blue).
The microphone for the velocity measurement is also known as pressure gradient microphone.

The microphone for pressure and velocity.

To describe the Dipol or Cardioid Subwoofer both pressure and velocity have to be measured. So for this you need a microphone with both pressure and velocity transducers.

Fig. 1.3

The pressure transducer is the M1 of the ATB PC and the velocity transducer is our own production. To test the velocity transducer, pressure and velocity in a bass reflex canal are measured.

Fig. 1.4

Fig. 1.5

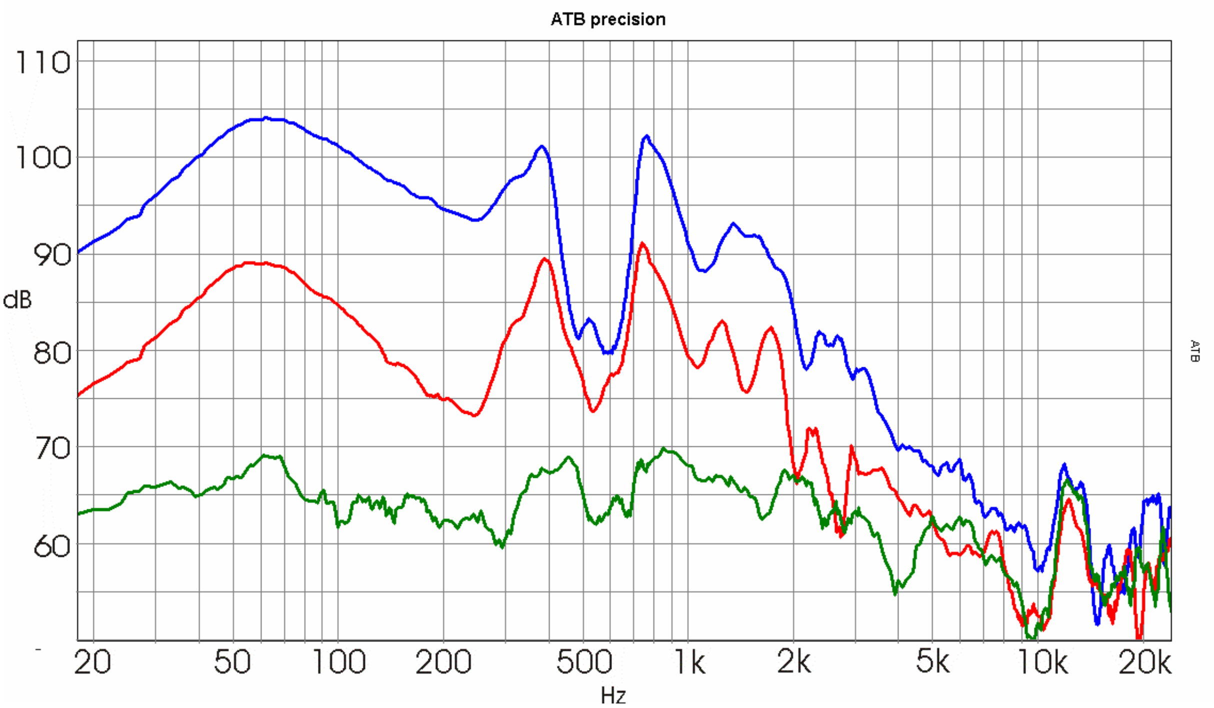


Fig. 1.6

Figure 1.4 shows the setup of the microphone in front of the bassreflex port. Figure 1.6 shows that the frequency response of the pressure transducer (blue) and velocity transducer (red) are comparable. In figure 1.5 the velocity transducer is placed 90° to the velocity direction. This is also shown in fig. 1.6. The green curve shows the velocity as just a hint. Both measurements show the correct function of the velocity transducer.

2.Sound propagation

The sound propagation is dependant on the frequency of the sound wave. Here we differ between low, middle and high tones.

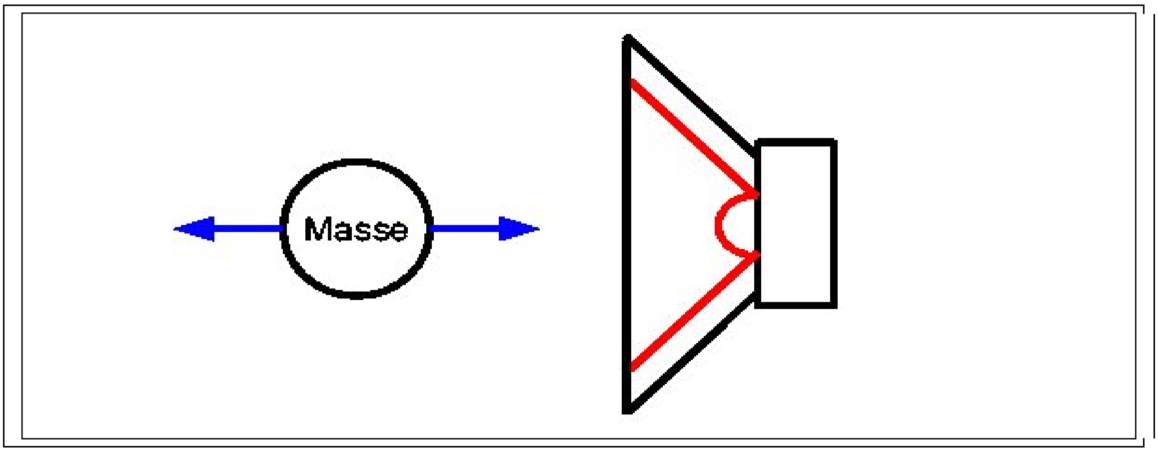


Fig. 2.1

Sound propagates through the movement of air molecules. Every molecule has a certain mass (fig.2.1). When sound is to propagate through the movement of these molecules, this mass has to be accelerated. To accelerate this mass you need a force. The force is delivered by the loudspeaker. The speaker transfers energy to the air molecules. The propagation of the sound wave succeeds over the transfer of this energy to the neighbouring molecule by impact.
The function of sound propagation is divided into three frequency ranges:

1. Low frequency range from 20Hz to 300Hz
2. Mid frequency range from 300Hz to 3KHz
3. High frequency range from 3KHz to 20KHz

2.1 Sound propagation in the low frequency range

In the low frequency range with its slow oscillation the molecules are excited with only a low energy. This is not much larger than the natural energy in non excited state. So the energy can be transferred also by indirect impact and with great direction change. As to be shown, the velocity of the molecule is very small.

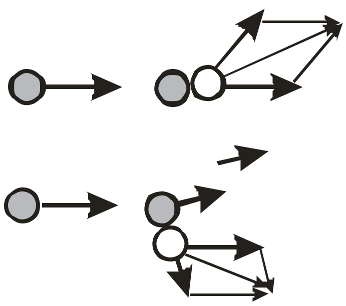


Fig. 2.1

When an accelerated molecule hits another that is not directly in its flight path, figure 2.1, it can not transfer the whole of its energy to the molecule and carries on with a part of its energy

in a different direction. When it hits another molecule it again can not transfer its energy optimally.
In the low frequency range with its slow oscillation the molecules are only excited with a low energy. This is not much greater than the energy in natural state. As such the energy can be transferred by non direct collision and with great change of direction. Also by the propagation in space the velocity of the molecule is very small and hard to measure.

The propagation is described by the sound radiation resistance. The sound radiation resistance is a function of the membrane surface and frequency. By constant membrane surface it gets larger towards higher frequencies. The sound pressure frequency response appears accordingly. At low frequencies it has a low value. The sound pressure is created with many air molecules with low velocity. A higher sound pressure is achieved with a larger membrane surface.
Towards the higher frequencies the sound radiation resistance and frequency response rises. At higher frequencies a smaller membrane surface is needed for the same sound pressure level. The sound propagation succeeds over lesser molecules, but with a higher velocity.

One construction for a transducer, by which the air molecules have a higher velocity, is the bandpass subwoofer. With such a loudspeaker the properties of velocities at low frequency range can be well demonstrated.

Fig. 2.2

Figure 2.2 shows a bandpass loudspeaker for music.

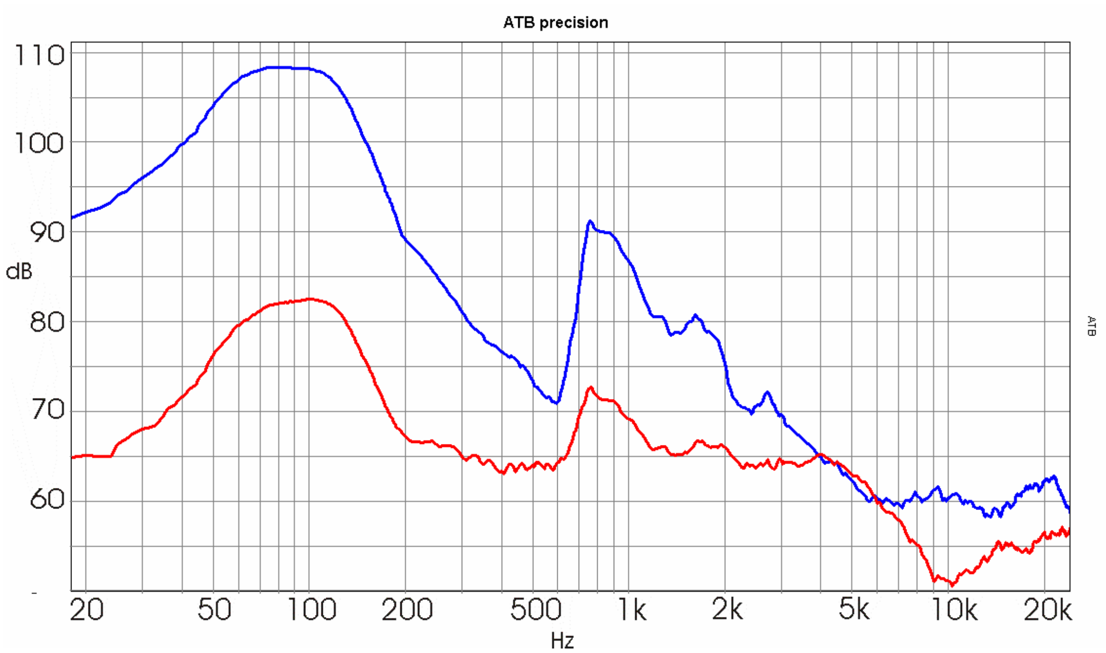


Fig. 2.3

Figure 2.3 shows the sound pressure response (blue) and velocity (red) at nearfield. By the bandpass subwoofer the velocity has a high level.

The next diagrams show the dependency of sound pressure and velocity.

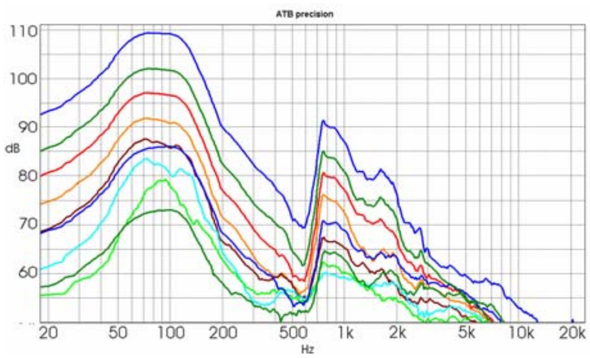


Fig. 2.4

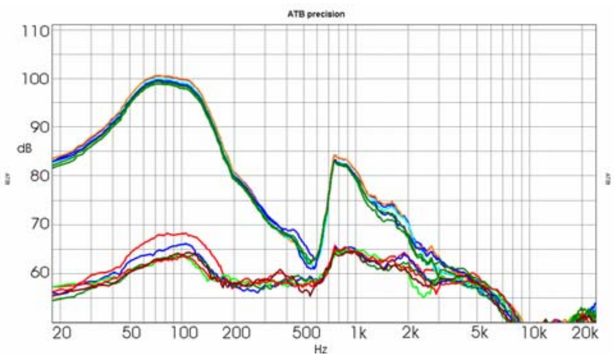


Fig. 2.5

Figure 2.4 shows the pressure and velocity level in dependency to distance.
Blue = 0, Green = 6.3cm, Red = 12.5cm, Orange = 25cm, Brown = 50cm,
Lightblue = 1m, Lightgreen =2m (Room influence).
Where as the sound pressure curves show at double distance -6dB, the level of the velocity decreases with -12dB.

Figure 2.5 shows the sound level of the sound pressure and velocity at a distance of 15cm measured at different angles. The velocity shows a directional dependency. The maximum level shows the measurement at 0° (red). At 15° (blue) it is already weaker. The sound pressure level stays constant.

2.2 Soundpropagation in the mid frequency range

In the mid frequency range there is a crossover area of the sound propagation of the low frequency range to the high frequency range. The directional dependency is less distinctive here and depends on the speaker construction. To create sound, cone speakers are used for the low frequency range and dome or horn loudspeakers for the high frequencies.

2.3 Sound propagation in the high frequency range

In the high frequency range the air molecules have a high energy and correspondingly high velocity. The energy can only be transferred by direct impact. By a slanted impact the energy loss is too large. This results in a near to straight line propagation of the sound wave.

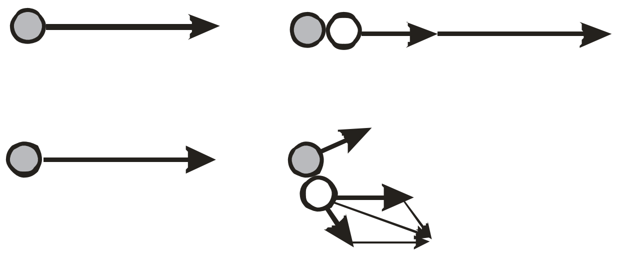


Fig. 2.6

The figure 2.6 shows the sound propagation through direct impact in the high frequency range.
Directional sound propagation can also be explained through the velocity.

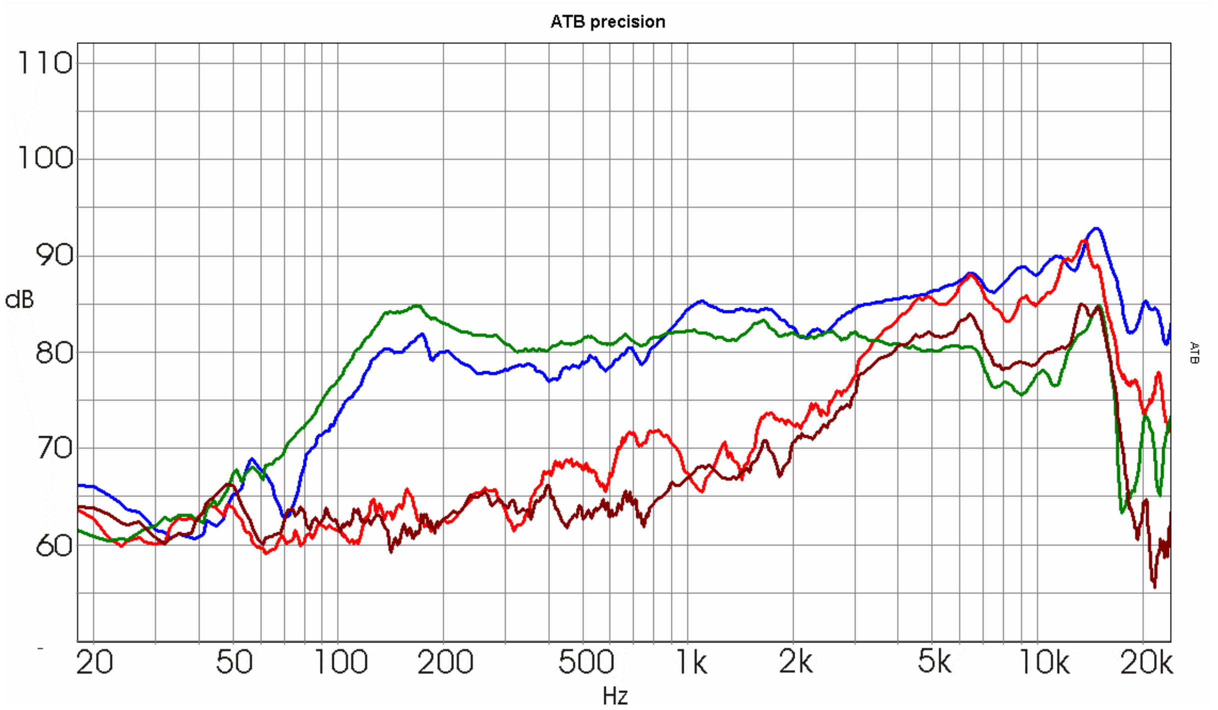


Fig. 2.7

Figure 2.7 shows the sound pressure (blue) and velocity frequency response (red) of a fullrange loudspeaker chassis. Above 3KHz the curves adapt to each other. This means that in this frequency range sound pressure and velocity emerge together. The same measurement was made at an angle of 45°. The sound pressure (green) and velocity (brown) frequency response show the directional dependency of the speaker. It is clearly to be seen that the directional dependency starts there where the velocity reaches the same level as the sound pressure. This also shows that the velocity has a directional propagation.

Another property of sound is that there is a phase difference of 90° between sound pressure and velocity.

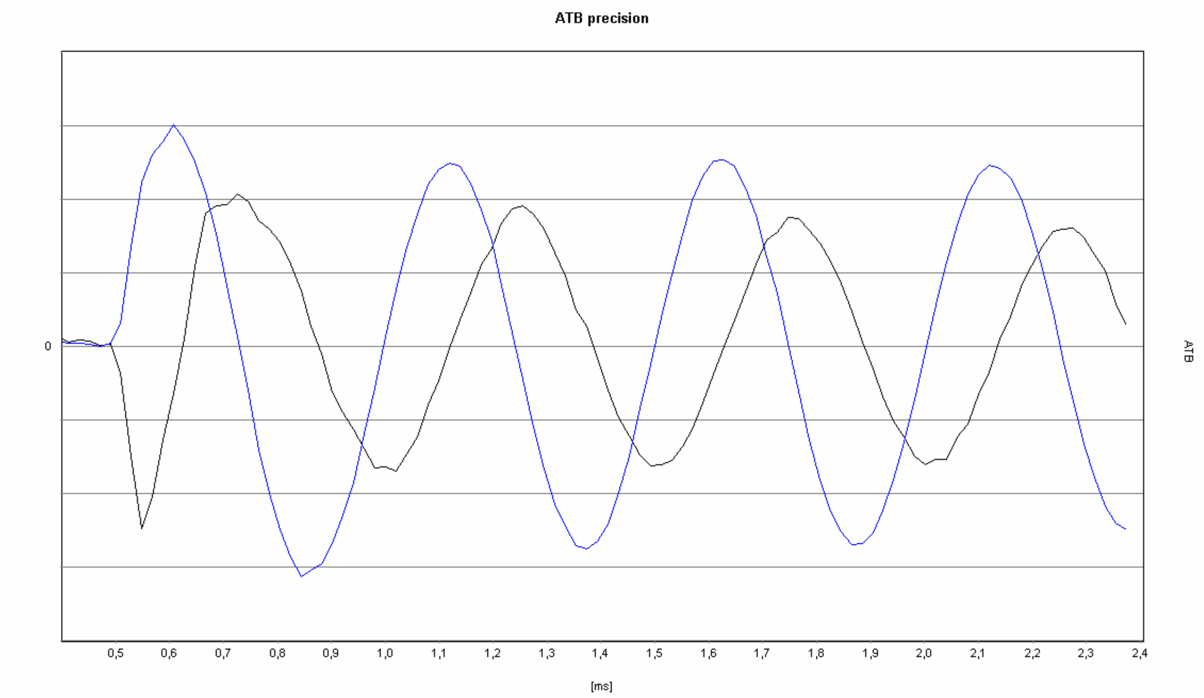


Fig. 2.8

Figure 2.8 shows the oscillogram of a 2-channel measurement. The measurement signal is a sinewave of 2KHz. The blue curve is the sound pressure and the black curve is the velocity. As the velocity does not have the same level as the pressure, its amplitude is shown amplified. It can clearly be seen, that when the pressure passes through zero the velocity is at maximum and when the pressure is at maximum the velocity passes zero.

In the high frequency range the sound radiation resistance is high. Due to that the sound pressure can be created from a small membrane. A tweeter as such needs only a small membrane, but has to transfer the high velocity to the molecules. It can only do this with a small dynamic mass, consisting of a light weight coil and membrane. Because of the lightweight coil the electrical power handling capacity is limited. Horn loudspeakers have a higher power level, because the horn raises the sound radiation resistance.

3.The open baffle step

3.1 The acoustic shortcircuit

In the HiFi area a dipol is a common construction. This is a baffle step that is open at the back. The loudspeakers have no enclosure cabinet. As such speakers have advantages very much at low frequencies, this frequency range will also be looked into.
From examples the function of dipols in the low frequency range is to be explained. The baffle step for our example has the dimensions 44 x 44cm. As speaker we use a professional 12`` woofer.


Fig. 3.1


Fig. 3.2


Fig. 3.3

The figures 3.1 and 3.2 show a loudspeaker mounted in an open cabinet. The small cabinet reproduces the baffle step. As the side walls are small in comparison to the wavelength, they can be disregarded. Fig. 3.3 shows the microphone setup for the nearfield measurement.

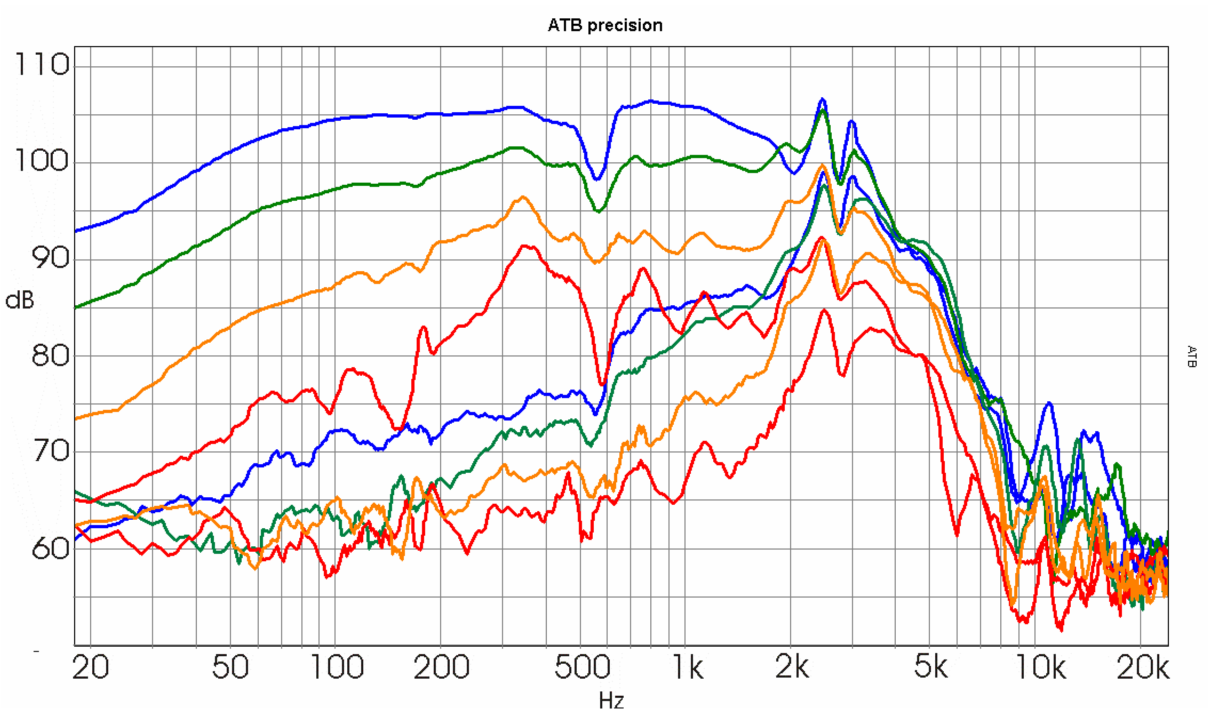


Fig. 3.4

Figure 3.4 shows on the upper curves the soundpressure levels and in same colour the lower curves the velocity at different distances. Blue = 0.10m, green = 0.20m, orange = 0.40m and red = 1m.
Clear to see is that the sound pressure level declines with the distance. In nearfield the -6dB point is at 38Hz and on the measurement with greater distance, red=1m, at 240Hz. The velocity is in nearfield for frequencies < 200Hz still measureable, at a distance of 0.20m no more.

Fig. 3.5

Fig. 3.6

To find out why, at a distance >0.20m no velocity is measureable, in accordance with figure 3.5 and 3.6 the sound pressure level and velocity on the rim of the baffle step is measured.

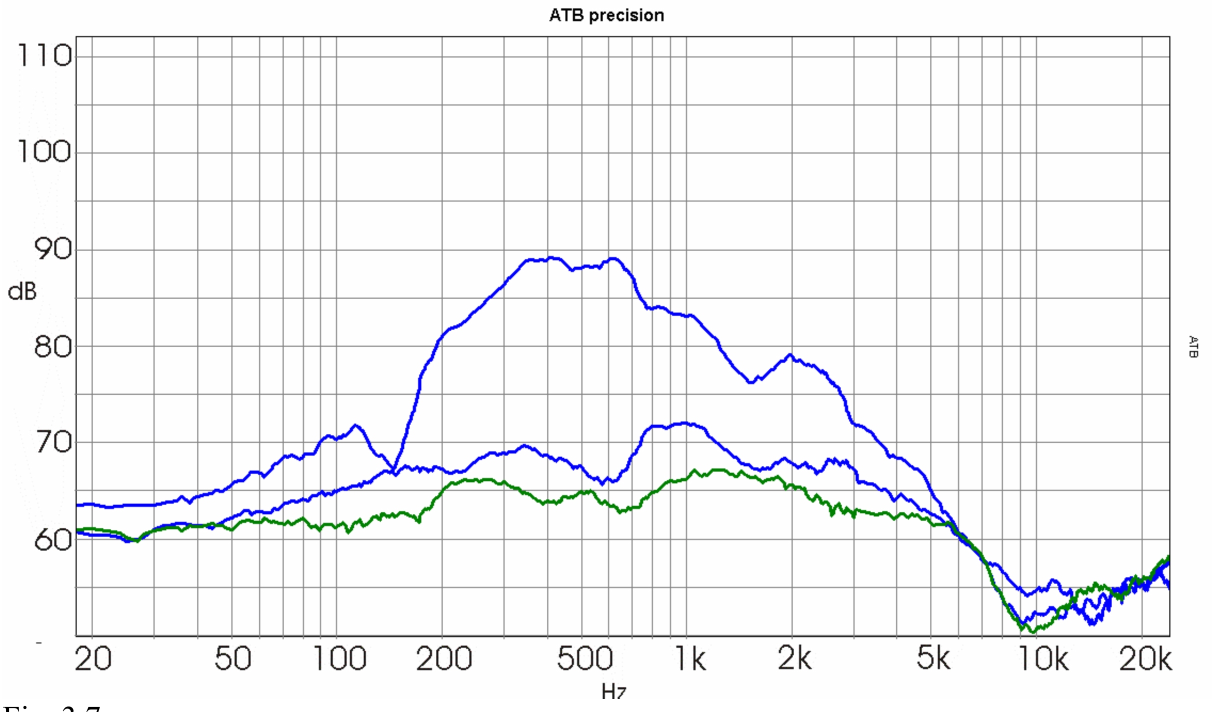


Fig. 3.7

Figure 3.7 shows on the upper curve the sound pressure and on the lower curve the velocity. For frequencies <200Hz the sound pressure has nearly disappeared. The velocity is still there. This indicates air motionflow from the front to the rear of the loudspeaker. To find out the direction of the velocity the velocity microphone is placed perpendicular to the baffle step as shown in figure 3.6. The measurement is shown in figure 3.7 as green curve. In the region of < 200Hz only a low level is measured. This also shows that air molecules move from the front to the rearside of the loudspeaker and this is known as acoustic short circuit.

3.2 The nearfield measurement and the acoustic short circuit

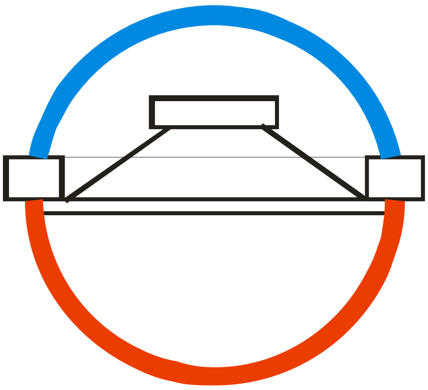


Fig. 3.8

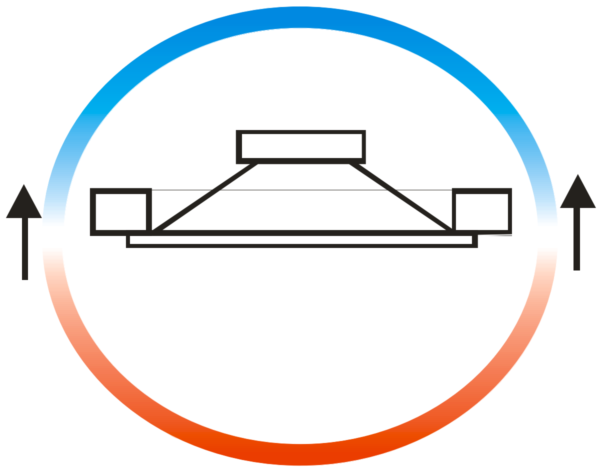


Fig. 3.9

Figure 3.8 shows the nearfield. In the low frequency range looked into, the soundwave propagates spherically. In front of the bafflestep as pressure (red) and behind the bafflestep as under-pressure (blue). As long as the microphone distance is not greater than half the baffle step width, measurements are in nearfield. This is shown by the sound pressure curves in figure 3.4. the blue = 0.10m distance and green = 0.20m distance run parallel. The green curve shows due to the double distance a 6bB lower sound pressure. Figure 3.9 shows the acoustic short circuit. With a microphone distance >0.20m the acoustic short circuit is measured. The sound pressure created in front of the baffle step meets in the region of the baffle step rim the rear under-pressure. During pressure adaption a fast movement of the molecules results, the velocity. This is measured with the measurement setup in figure 3.5. Figure 3.7 shows the frequency response of the pressure and velocity, blue curves measured on the rim of the baffle step. The sound pressure for frequencies < 150Hz is very low and the velocity relatively high. The green curve shows the velocity in the direction of the baffle step using the measurement setup shown in figure 3.6.
The measurements with a microphone distance > than half the baffle step width show the real sound pressure level for the listener.

The acoustic behaviour of bafflesteps is described in Photo Story OK^2.

http://kirchner-elektronik.de/~kirchner/Photo-Story-OK_eng.pdf Photo-Story-OK_eng.pdf

There also the waveguide and baffle step are explained.

3.3 Dipol loudspeaker construction with two woofers.

Fig. 3.10

Fig. 3.11

Fig. 3.12

The figures 3.10, 3.11 and 3.12 show setups of dipol loudspeakers. The setup in figure 3.10 is most common. With figure 3.11 it is to be shown which effect neighbouring floor surfaces have. Figure 3.12 shows the V-shape setup. This is further explained in the following article.

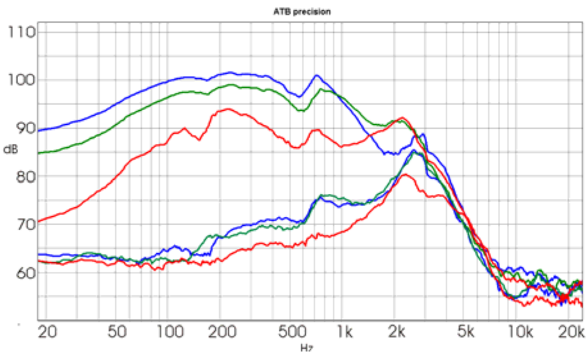


Fig. 3.13 Double bass above one another

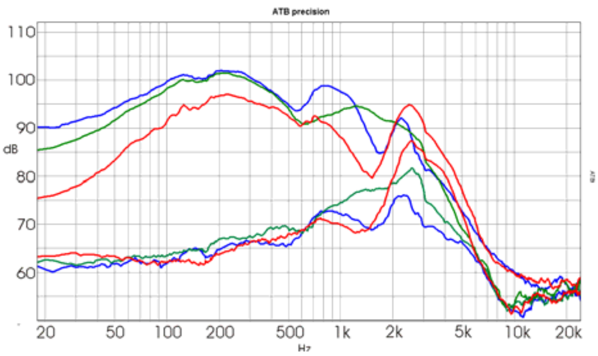


Fig. 3.14 Double bass next to each other

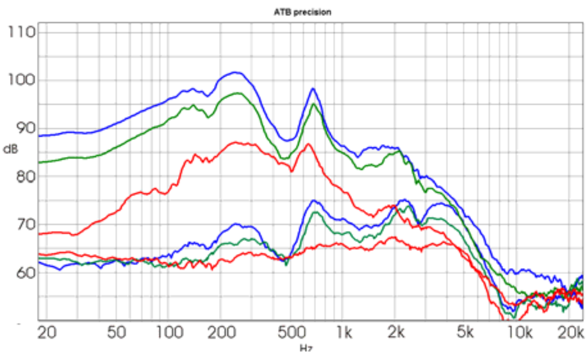


Fig. 3.15 Double bass V-setup

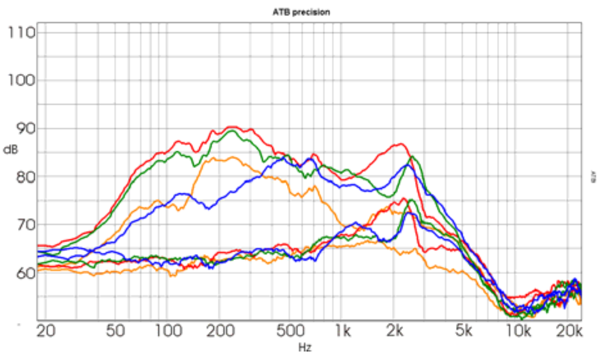


Fig. 3.16 Room measurement at listening position

The figures 3.13, 3.14 and 3.15 show frequency responses with a microphone distance of blue = 10cm and green =20, and red = 1m.

Figure 3.16 shows the sound pressure and velocity frequency responses in the room measured at listening position.

Blue = single speaker, green = Doublebass vertical, red = doublebass horizontal, orange = doublebass in V-setup.

Whereas the vertical and horizontal show a slight low frequency reproduction, the single Bass and V-setup with simple baffle step without enclosure are not suitable.
The measurements show, that next to the vertical double bass the V-setup can firstly be considered as a velocity transducer. This setup has next to the single speaker the weakest low frequency range.

Fig. 3.7

Fig. 3.8

Figure 3.7 shows the setup with microphone in direction of the velocity.
Figure 3.8 shows the setup with microphone perpendicular to velocity direction.

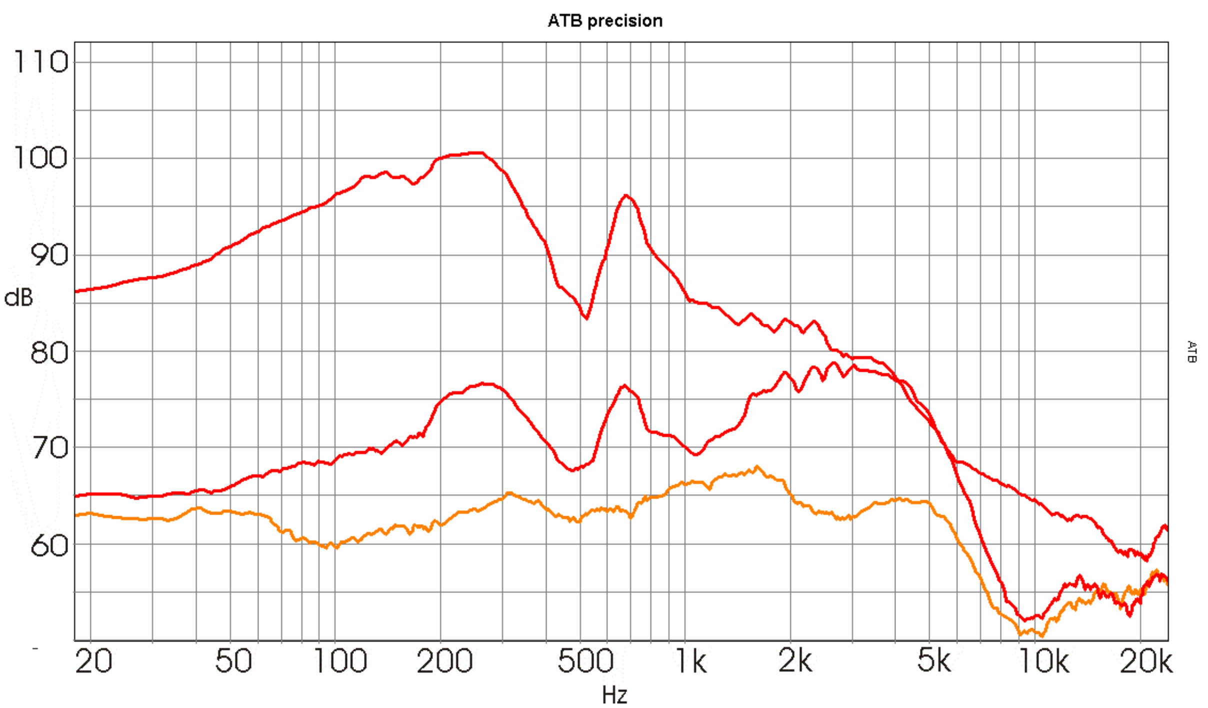


Fig. 3.9

Figure 3.9 shows in the upper curve the sound pressure. The lower red curve shows the velocity at the rim of the baffle step. The large velocity also explains, why the setup has no bass at the listening position. There is a very great pressure compensation. The orange curve shows the velocity measured perpendicular to propagation direction.

The velocity of the double bass in V-setup

The double bass in V-setup shows at the nearfield measurement a high velocity. This setup can realise the velocity transducer described in litrature. First of all the dependancy of the velocity to opening surface is looked into.

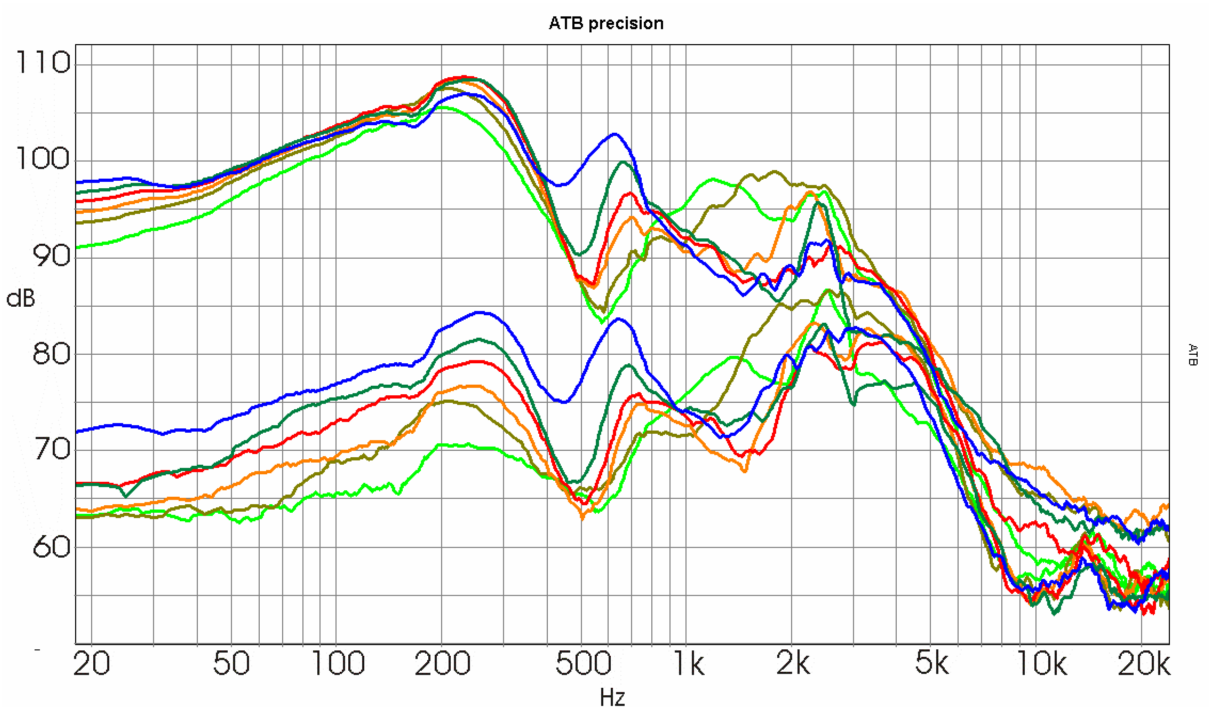


Fig. 3.10

Figure 3.10 shows the sound pressure of the double bass in V-setup, measured in nearfield. The upper curves are pressure and the lower curves velocity. Following opening surfaces are measured:

Blue = 220cm^2, green = 440cm^2, red = 660cm^2, orange = 880cm^2, brown = 13200cm^2, light green = 1980cm^2

Whereas the pressure changes only slightly, the velocity increases with smaller gap width. At a gap width of 5cm the curves have a different characteristic. Here the relationship of membrane surface to opening surface is critical. For further development the opening surface of 440cm^2 corresponding to a gap with of 10cm was chosen. The membrane surface of the speaker is 1080cm^2.

In the Photo-Story Loudspeaker development

http://kirchner-elektronik.de/~kirchner/photostory2.pdf

the velocity of the sound waves in space, speaker cabinets or listening rooms, are described.

3.4 The Thiele-Small Parameter of double bass in V-setup

The electrical properties of the double bass in V-setup depending on the opening surface are looked into by impedance measurements.

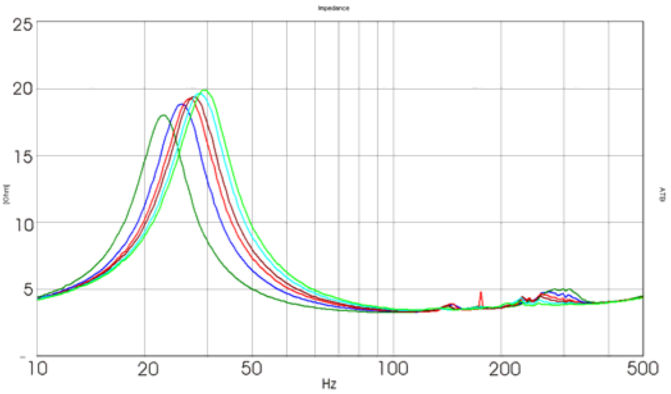


Fig. 3.11

For the opening surfaces following resonance frequencies were found:

Blue = 220cm^2 23Hz, green = 440cm^2 25Hz, red = 660cm^2 27Hz, orange = 880cm^2 28Hz, brown = 13200cm^2 29Hz, lightgreen = 1980cm^2 30Hz

As further measurement the Thiele-Small-Parameter are determined. This is important to find out the tuning of the V-setup.
The woofer has following parameter:

RDC: 5,41 Ohm	SD: 540,00 cm²	fs: 30,56 Hz
Qm: 1,94	Qe: 0,36	Qt: 0,30
Mms: 61,75 g	Rms: 6,64 kg/s	Cms: 0,44 mm/N
VAS: 179,90 l	B*L: 12,81 Tm	
No: 1,37 %	SPL: 93,38 db 1W/1m ,SPL: 95,08 db 2.83V/m	

In the V-setup following parameters are measured:

RDC: 2,71 Ohm	SD: 1080,00 cm²	fs: 24,18 Hz
Qm: 2,88	Qe: 0,51	Qt: 0,43
Mms: 193,04 g	Rms: 11,07 kg/s	Cms: 0,22 mm/N
VAS: 367,66 l	B*L: 12,06 Tm	
No: 0,98 %	SPL: 91,92 db 1W/1m, SPL: 96,56 db 2.83V/m	

The V-setup has a lower resonance frequency which can be explained by the effective increase of the moved mass. The mass increase is due to the air load. The measurement is controlled by comparing the BxL factor. They are nearly identical in both measurements. This means the measurements are correct.

4.The controlled acoustic short circuit

4.1 The Cardioid Loudspeaker

Cardioid subwoofers are used for public adress. They have a sound radiation with cardioid (heart shape) characteristic. The low frequency range is radiated forward and reduced side ways. Towards the back the sound is suppressed. This is achieved through a backward radiating speaker. The rear speaker is controlled by its own amplifier and DSP, by which the acoustic phase is turned 180° to that of the front speaker. In comparison to the figure of eight characteristic of a dipol the sidewards radiated sound is nearly unreduced. To that the advantages of the cardioid loudspeaker are rather small. Going to such lengths is not suitable for the reproduction in studios or home.

4.2 The Dipol with sound directivity

The described dipol setups show a very high low frequency sound pressure level in the nearfield area. At greater distances the sound pressure becomes constantly lower. The sound pressure loss is at around 15dB – 20dB. The loss of power has to be replaced by stronger amplifiers and speakers with very high power handling. Here the problem is the power handling ability of the speaker. The maximum sound pressure level is less restricted through the electrical power level than the linear hub of the speaker. This can be reached at 1/5 of the electrical power level. So that dipol speakers with backward open baffle step just about reach living room loudness.
With the V-setup described above for the subwoofer the air molecules also have an amplified velocity. These have though the bad power ratio of dipol systems.
By using sound directive measures the short circuit is to be reduced.
First of all the known constructions were replicated. This showed no satisfying results.

The question was if it is possible to achieve the advantageous sound radiation of a dipol loudspeaker with a better power ratio. By such a loudspeaker the acoustical short circuit has to be inhibited to an amount.
The usual speaker calculation software could not help with this challenge.

5.The Dipol-Cardioid Loudspeaker

5.1 Construction

Fig. 5.1

Fig. 5.2

At the end of the development there is a demo subwoofer construction. It is only for showing the sound pattern. Figure 5.1 shows the front and figure 5.2 the rear of the subwoofer.
First the acoustical shortcircuit was to be inhibited through different experimental sound directivity measures. That did not work.
To avoid the accoustical shortcircuit a theoretical approach had to be found. The answer can only succeed over the velocity. The sound velocity has been measured by us when constructing loudspeakers since years. The velocity gives important hints for understanding sound propagation. We have used this knowledge developing the dipole loudspeaker.

The optimal subwoofer radiates the low frequency range forward, where as sideways and backward no low tones are radiated. This is to be achieved through the addition of two sound sources. The first sound source is the forward radiated sound and the second the backward radiated sound. The construction of the cabinet is made as such that the forward radiated low frequencies have a greater sound level than the backward radiated sound. For the backward sound source it is of advantage, when the higher frequencies have a higher level than that of the forward sound source. Through this division the low frequencies are withheld for the front radiated sound. Through the higher sound level of the high frequencies of the rear sound source, this frequency range is reduced in front of the speaker. A lowpass function is created.
In accordance with these considerations a large enclosure is chosen for the forward radiated sound and a small enclosure for the backward radiated sound. The different air masses oscillate when excited by the speaker differently. In the larger enclosure the air oscillate at a lower frequency as the air in the smaller enclosure.

5.2 Frequency response

On the sides the forward and backward radiated sound waves encounter each other. As the soundwaves have a phase difference of 180^0, they deplete each other. Through this the sound radiation has a figure of eight characteristic. This corresponds with the velocity microphone described above.

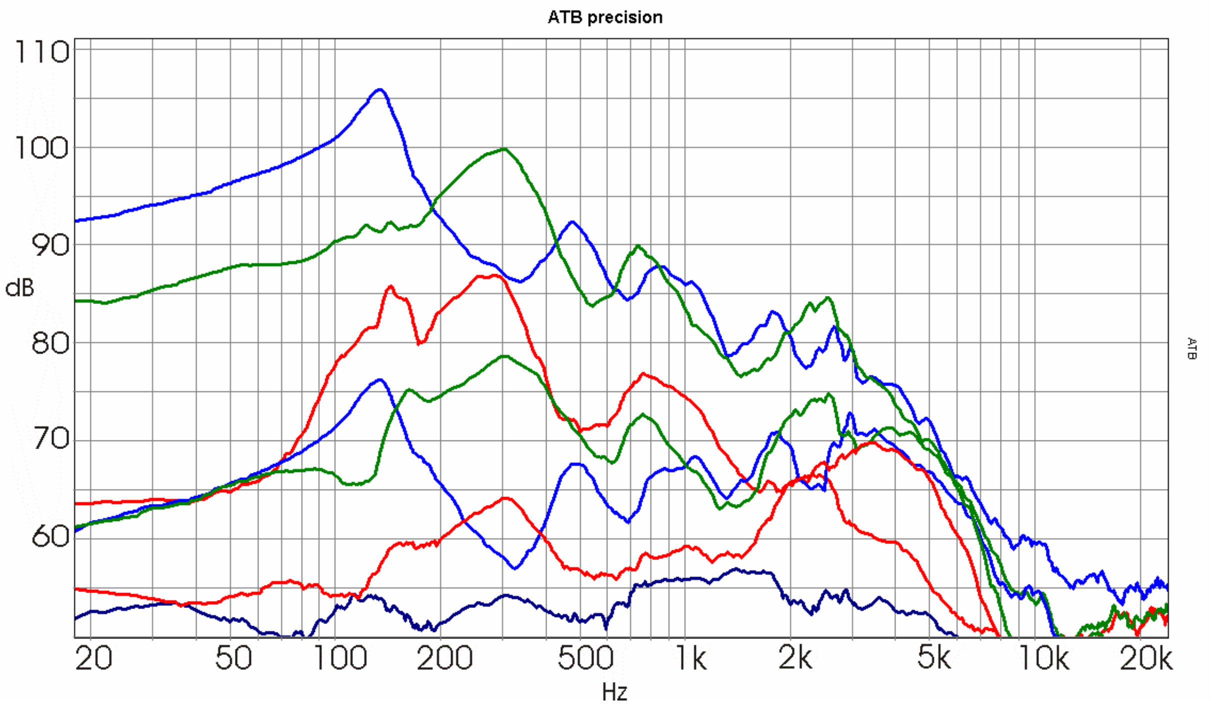


Fig. 5.3

Figure 5.3 shows the nearfield measurements of the demo Dipol-Cardiod subwoofer. The light blue curves show the sound pressure level and velocity on the forward opening. Both curves have the largest amount at the desicive transmission range < 100Hz. The red curves show the sound pressure and velocity on the side of the cabinet. For the range < 100Hz the sound pressure is low level. This means that sideways only little sound is radiated and that the construction is successful. To the weak sound pressure level, also the weak level of the velocity fits. There is only a compensation for the sound wave frequencies > 100Hz as planed. The green curve shows the sound pressure level and velocity for the backward openings. Shown is the sound pressure of one of the backward openings. With the second opening the sound pressure level is 3dB higher than shown in the curve. Because of the lower sound pressure level the Cardioid characteristic is created.
Sound pressure and velocity have the highest level for the frequency range > 100Hz. Through this the forward radiated sound pressure is not weakened in the transmission range. The dark blue curve is a reference curve for the velocity with low amplitude.

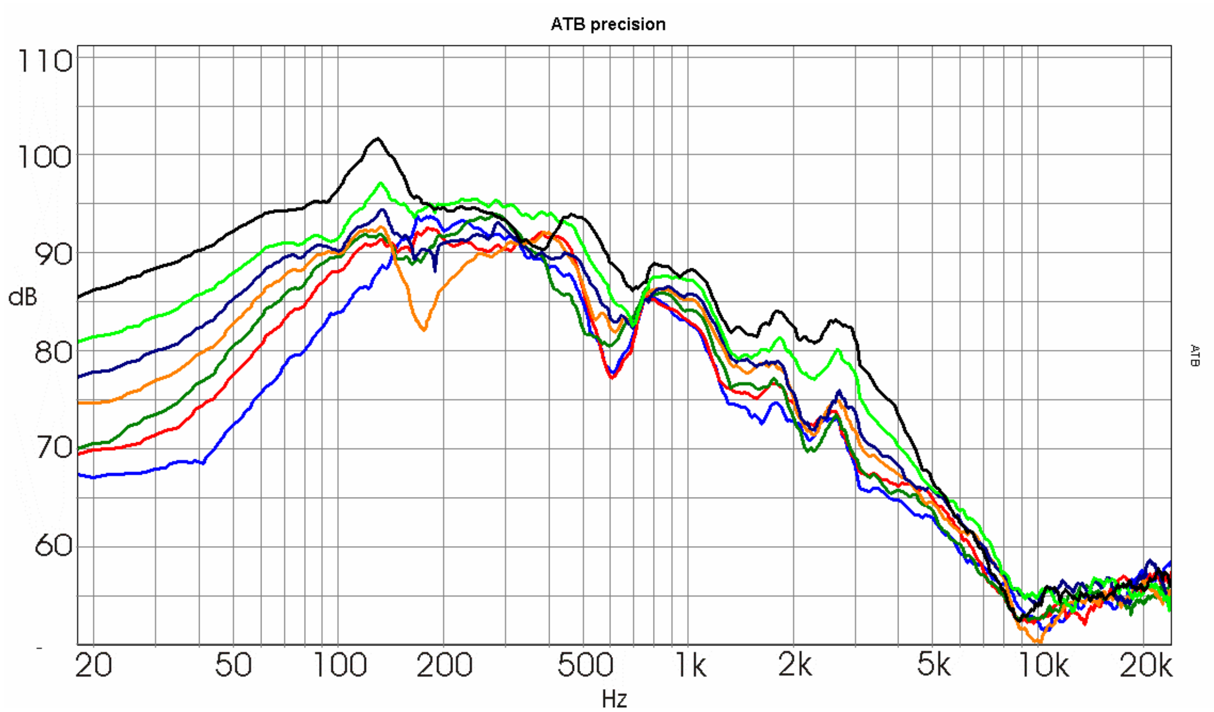


Fig. 5.4

The figure 5.1 shows a further property of the Dipol-Cardioid subwoofer. The sound pressure level is measured with a ground surface microphone. The curves show different distances to walls.
Blue = 0.25m, red = 0.5m, green = 0.75m, orange = 1m, dark blue = 1.25m, light green = 1.5m, black = 1.75m.
The blue curve with a distance of 0.25m shows the weakest low frequency reproduction. At a distance of 1m the orange curve shows a depletion at 180Hz, that is already outside the transmission range.
The black curve already shows the nearfield measurement.
Very remarkable is the high sound pressure level. A 40watt amplifier is already sufficient for a loud musical reproduction.

5.3 Thiele-Small Parameter

RDC: 2,71 Ohm
SD: 1080,00 cm²
Qm: 3,10
Qe: 0,58
Qt: 0,49
fs: 21,80 Hz

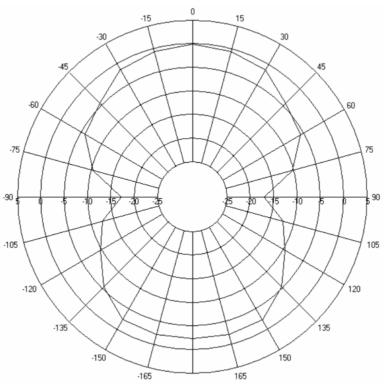
Remarkable is the low resonance frequency. It is around the lowest audible frequency and does not influence the sound impression. The best impulse behaviour has a speaker with a Q-factor of 0.5. With a Q-factor of 0.49 the Dipol-Cardioid loudspeaker has an optimal impulse reproduction. A Q-factor of 0.5 leads, by closed or bassreflex loudspeakers, to a decline of the low frequency range. This can be compensated with electronics by amplifying the lower frequencies.

5.4 Polarplots

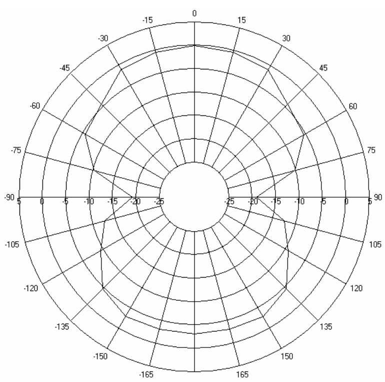
Fig. 5.5

Fig. 5.6

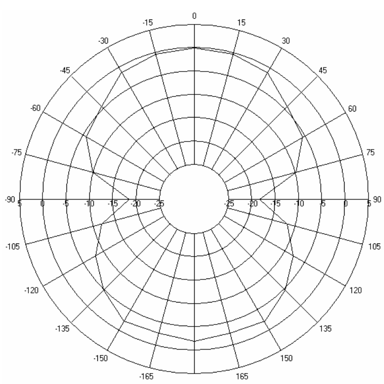
Figures 5.5 and 5.6 show the setup of the freefield measurement.



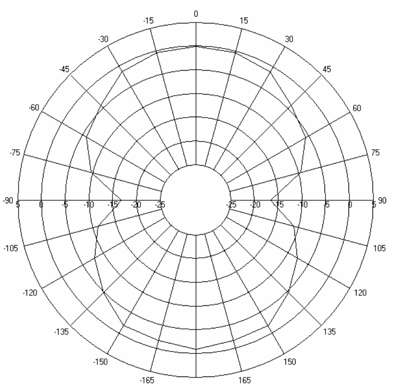
31,5Hz



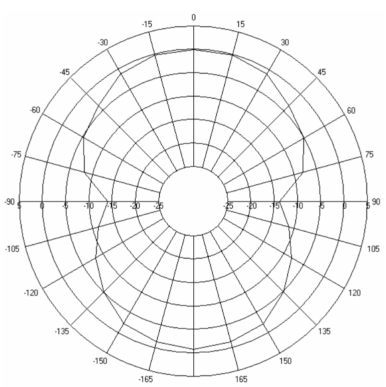
40Hz



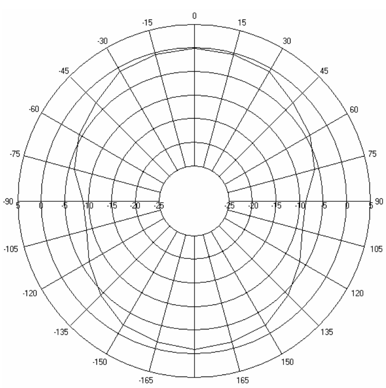
50Hz



63Hz



80Hz



100Hz

Fig. 5.6

Figure 5.6 shows the polarplots of the demo Dipol-Cradioid subwoofer. At 31.5Hz, 40Hz, and 50Hz the sidewards sound pressure is -18dB reduced. The sound pressure at the back is -3dB lower than the forward radiated sound. At 63Hz and 80Hz the sidewards sound pressure is -15dB reduced. At 100Hz the sidewards sound pressure with -10dB is not reduced to the same extent. At frequencies > 100Hz the sidewards sound pressure increases. This frequency range has no longer the dipol characteristic.

5.5 Setup in rooms

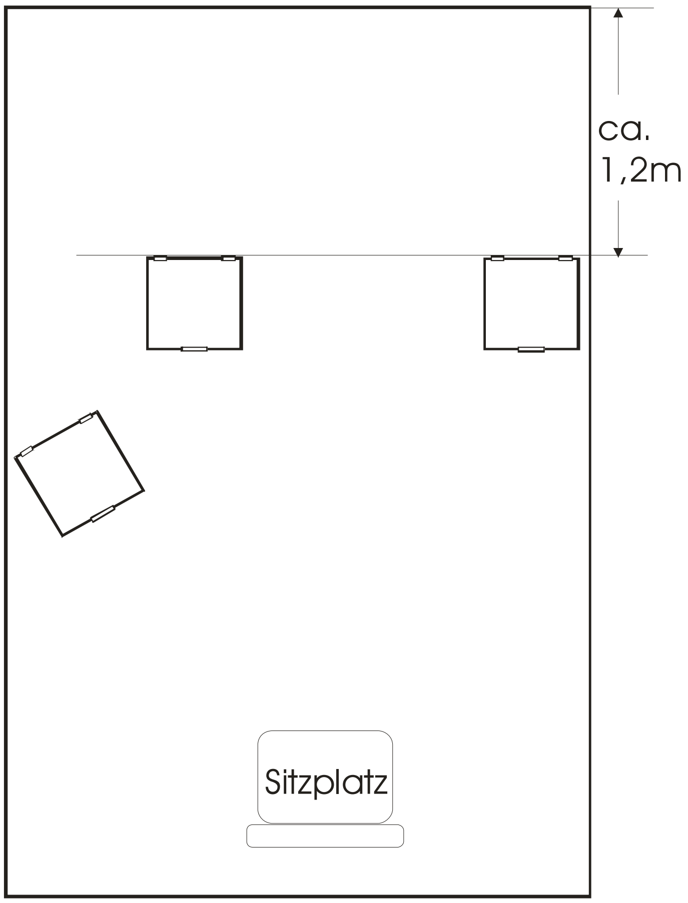


Fig. 5.7

Figure 5.7 shows the setup for the Dipol-Cardioid loudspeaker in rooms. The loudspeaker should always be placed with the front towards the listener. Also a minimum distance of 1.2m to the back wall should be maintained.
The distance to the back wall of the listening room restricts the application of the Dipol-Cardioid loudspeaker. This setup is not possible in every livingroom.
The setup of subwoofers is always critical. The bassreflex subwoofer described in the Photo Story shows a large depletion in the frequency response when placed near a wall and is not suited for a near to wall setup.

The low frequency reproduction is much dependant on the listening room. A natural reproduction demands an exact positioning of the loudspeaker. If this is not possible because of the rooms circumstances, an equaliser can be used. The setup of the speaker and adjustment of the equaliser demand acoustic measurement technology. Doing this not only the frequency response but, very important for subwoofers, also the acoustic phase has to be measured.
A price free measurement program for the low frequency range can be downloaded at following link:

http://www.kirchner-elektronik.de/~kirchner/ATB_PC_DEMO.zip ATB_PC_DEMO.zip

As measurement microphone for the low frequency range most PC-multimedia have a microphone with sufficient accuracy.

5.6 The advantages of the Dipol-Cardioid Subwoofer

1. In the livingroom with HiFi equipment
Not all room resonances, modes, are stimulated. Especially the modes along the setup line of the speaker are not stimulated. These are mainly at the setup on the short sides at higher frequencies, that in particular falsify the sound impression.
The Dipol-Cradioid has the best impulse behaviour. It is very fast and as such the ideal compliment for planar speakers, electrostatics or magnetostatics.
2.In halls, public address.
Halls have the same conditions as livingrooms, but at slightly lower frequencies. For live music the great advantage is that the speakers usually placed on the side of the stage produce low, low frequency sound sideways. This avoids the most feared acoustic feedback effects in the low frequency range.
3. At open air events with disco or live music.
At open air events the Dipol-Cradioid characteristic reduces the overall loudness to public ratio. This means that the loudness for the neighbourhood is reduced. Also by live music the acoustic feedback effect in the low frequency range is avoided.

6. Comparing Measurements

6.1 Frequency responses

As reference loudspeaker a 15`` bass with low resonance frequency is chosen. This bass is used in the most elaborate studio monitors and the best High-End loudspeakers. We drive it in an optimally tuned 110 l cabinet.

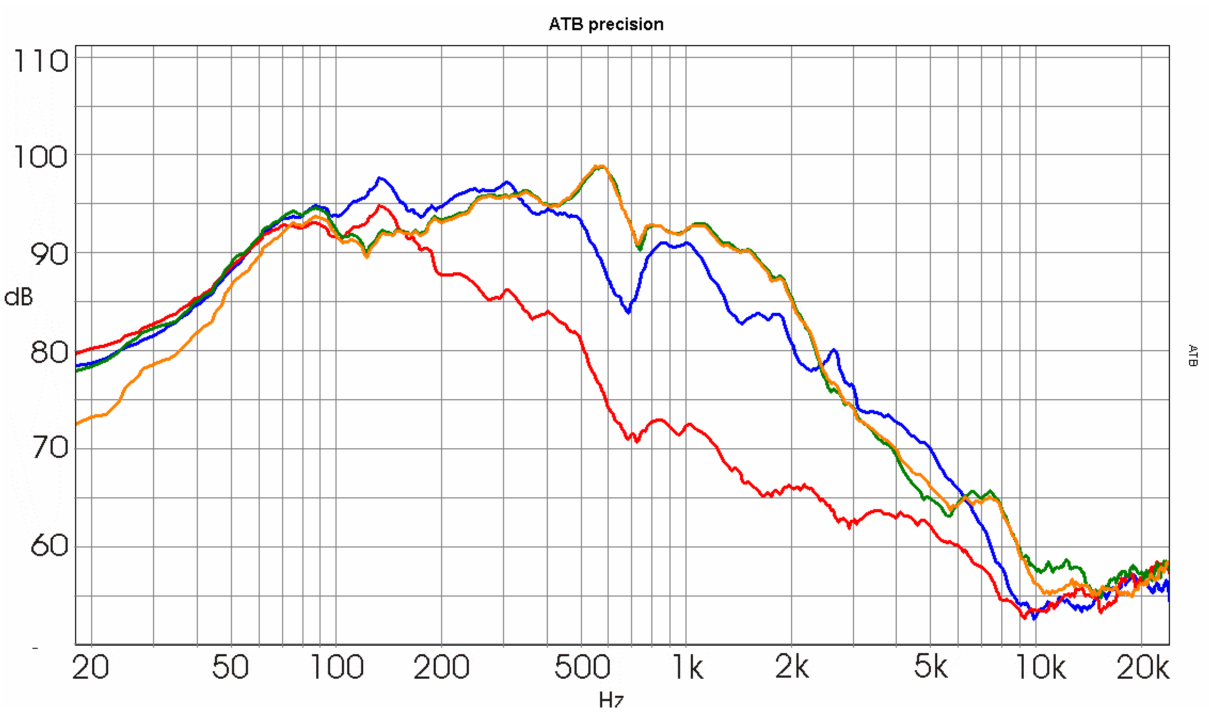


Fig. 6.1

Figure 6.1 shows the frequency response of the reference speaker and Dipol-Cardioid measured under livingroom conditions. Green is the reference loudspeaker in the bassreflex cabinet and orange in closed cabinet. Blue is the Dipol-Cardiod without crossover and red with passive crossover 12dB and absorption circuit. The bassreflex and Dipol-Cardiod loudspeakers have an identical low frequency range and the same sound pressure level. The power ratio of the Dipol-Cardioid loudspeaker is 3dB smaller as the reference loudspeaker has an impedance of 8Ω and the Dipol-Cardiod 4Ω.

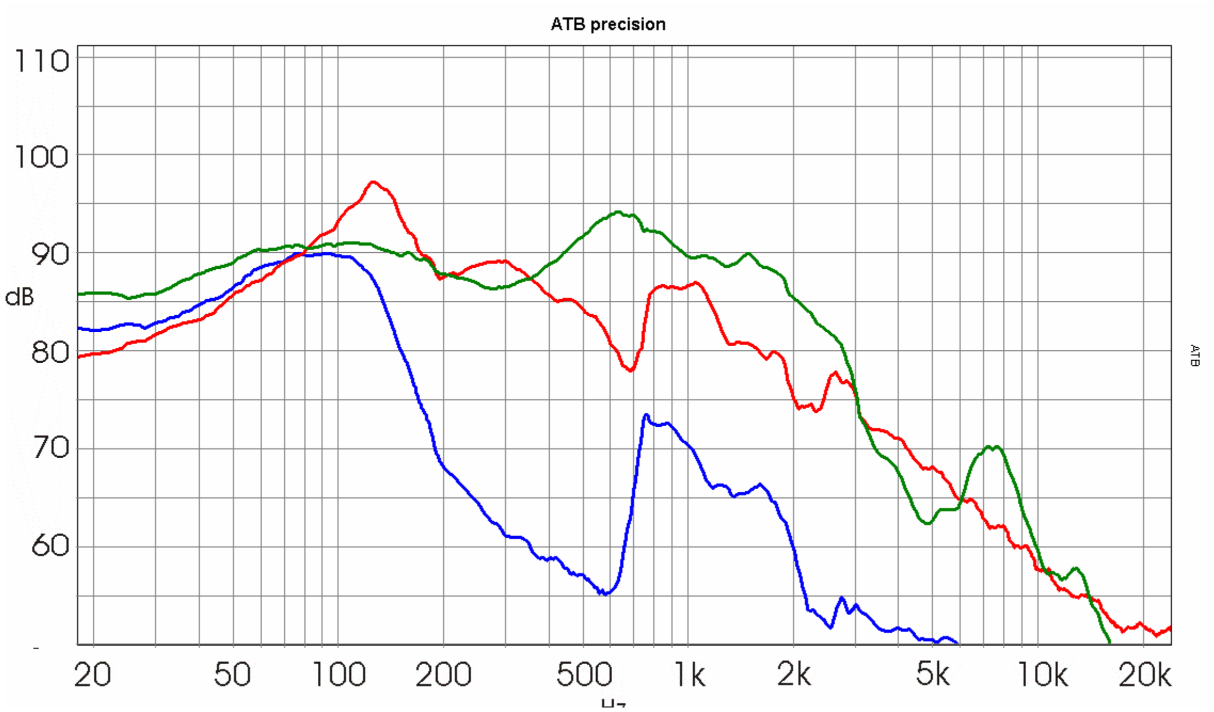


Fig. 6.2

Figure 6.2 shows the freefield frequency response of the subwoofer with a 2m microphone distance. Red = Dipol-Cardiod, green = bassreflex, blue = bandpass.

6.2 Acoustic Phase

Next to the sound pressure frequency response the acoustic phase is the decisive unit to judge loudspeaker systems.

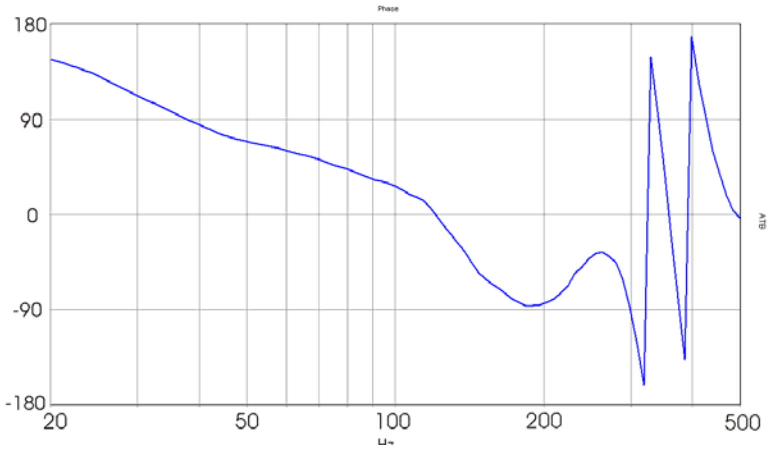


Fig. 6.3 Dipol-Cardioid

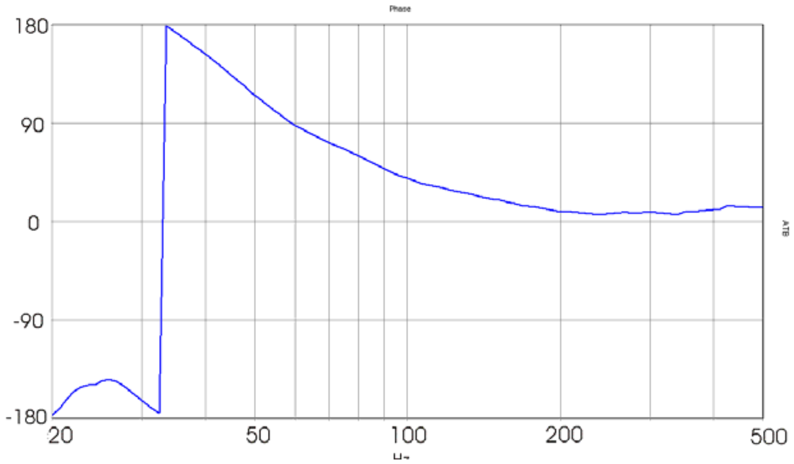


Fig. 6.4 Bassreflex

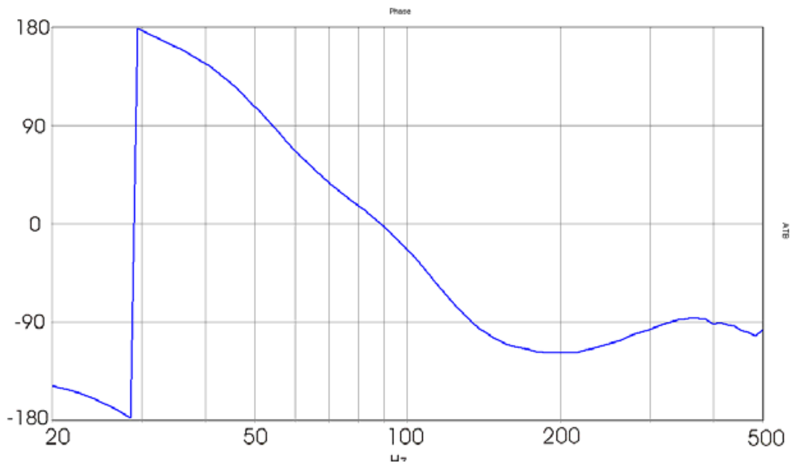


Fig. 6.6 Bandpass

By the display of the acoustic phase the range from -180^0 to 180^0 is shown. At greater phase shift the curve reaches the boundary of the diagram. To show the further run of phase the

display makes a jump to the opposite boundary. This way a greater range as the 360^0 of the display can be achieved.
The phase jump in figure 6.5 at 32Hz happens because, the curve has reached the -180^0 boundary and can not be further displayed. As the phase curve runs underneath the display, it is further displayed by making the jump to 180^0. When measuring the phase of woofers in closed cabinets or bassreflex boxes the phase shift is near to 0^0. Such loudspeakers have a decrease in frequency response towards lower frequencies of about 12dB/Octave. This lowpass function has a phase of $+ 180^0$. This is good to see in the measurement of the bass loudspeaker.

The acoustic phase of the Dipol-Cardioid, figure 6.3 shows in the frequency range from 20Hz to 100Hz with 90^0 the least turn of phase. Which means that the loudspeaker is suitable for a correctly-timed loudspeaker combination. At the frequency range > 120Hz strong phase jumps appear because of the sound from the rear opening. This area is outside the transmission range and can be neglected.

The bassreflex loudspeaker, figure 6.4 has a turn of phase of 180^0 . With a phase shift this order it is not suited for a correctly-timed loudspeaker combination.

In figure 6.6 the bandpass loudspeaker is shown. Its acoustic phase shift near to 360^0 is a problem for any loudspeaker combination.
The bandpass function is acoustically created, which is usually described as an advantage. But the phase measurement shows, that it is not of matter for the transmission function if it was created acoustically, electrically, passive or active or even digital. The dependency of amplitude and phase always follows the mathematical function. Also the digital FIR functions are no exception. They are just a different kind of filter, by which instead of the phase the impulse is a function of the amplitude.

6.3 Transient Oscillation

To measure the transient oscillation behaviour a sine burst with the frequency 60Hz was used.

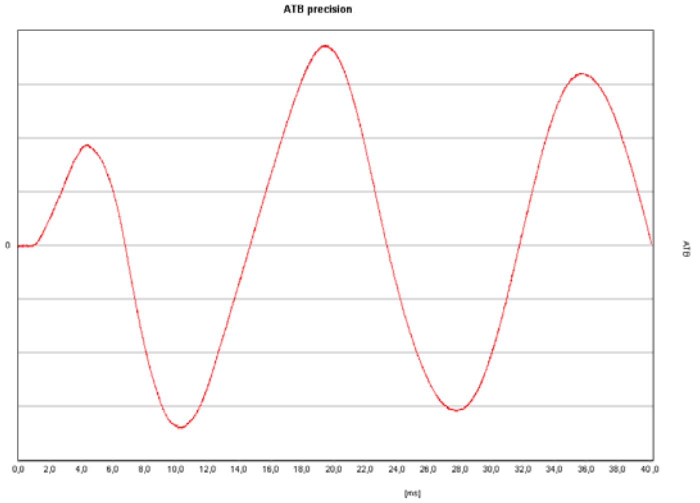


Fig. 6.7 Dipol-Cardioid

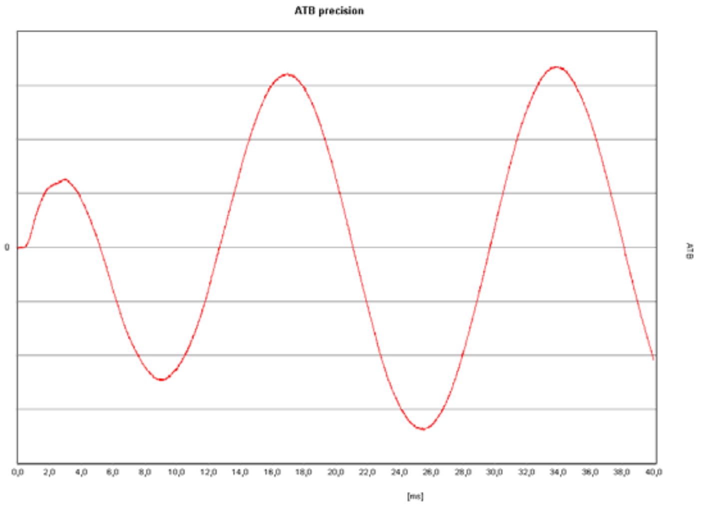


Fig. 6.8 Bassreflex

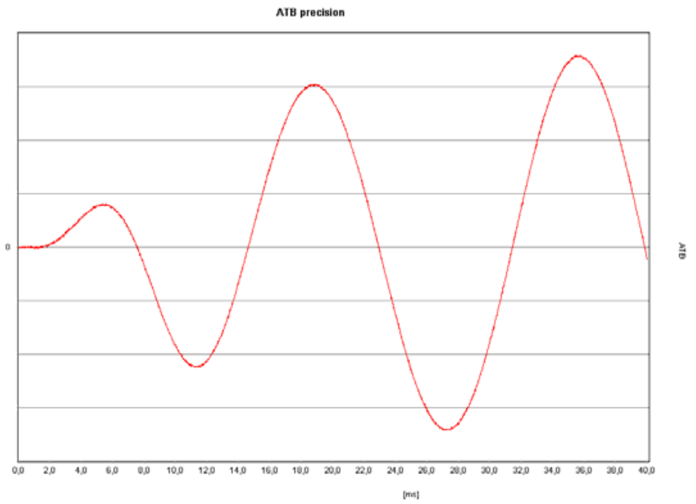


Fig. 6.9 Bandpass

A Dipol-Cardiod subwoofer, figure 6.7, distinguishes it self by a exceptionally good impulse behaviour. With a display of greater time length it showed that the overswing is created by the resonance frequency of 22Hz. This frequency is below the hearing range.
The bassreflex loudspeaker, figure 6.8, takes a half wave longer to reach the signal amplitude. Figure 6.9 shows the bandpass. The bandpass function of the subwoofer causes a slow transient oscillation.

6.4 Step response

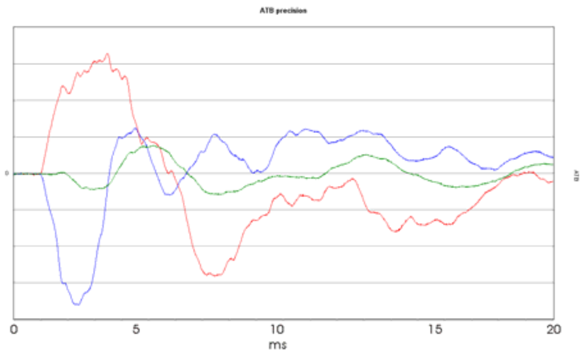


Fig. 6.10

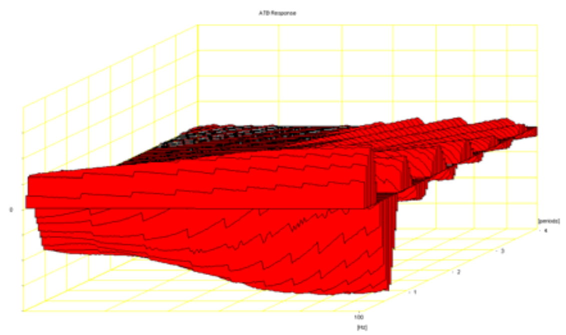


Fig. 6.11

Figure 6.10 shows the step response of the Dipol-Cardiod in nearfield. The red curve shows the sound pressure of the front port with the lowfrequency part. The green curve shows the sound pressure of rear port. This shows in comparison with the front port double frequency. The blue curve shows the low sound pressure level measured at the side.
Figure 6.10 shows the time behaviour separately. The jump function shows the amplitude over time. The frequencies withheld in the signal are only poorly readable. These are carried out in the 3D measurement with the Dynamic Measurement programme. The front port in nearfield is measured. Figure 6.11 shows 3 mountains. The front shows the positive signal of the front port. The middle one shows the negative signal of the rear port and the overswing of the front signal. As both signals exactly overlay in time, there is an exact impulse behaviour. The rear mountain shows the overswing of the rear port.

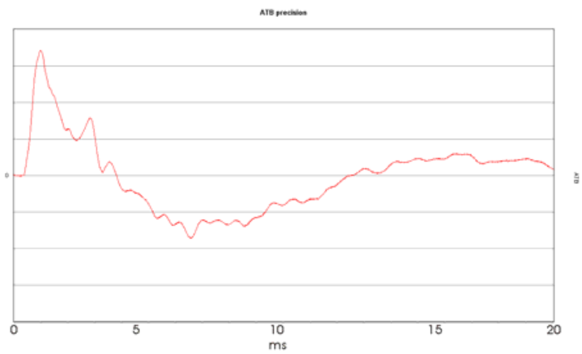


Fig. 6.12

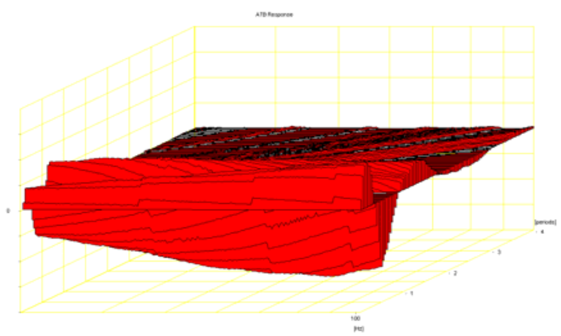


Fig. 6.13

Fig. 6.12 shows the jump response of the bassreflex loudspeaker.
Fig. 6.13 the Dynamic Measurement plot. The 3rd mountain is the signal of the bassreflex loudspeaker vent.

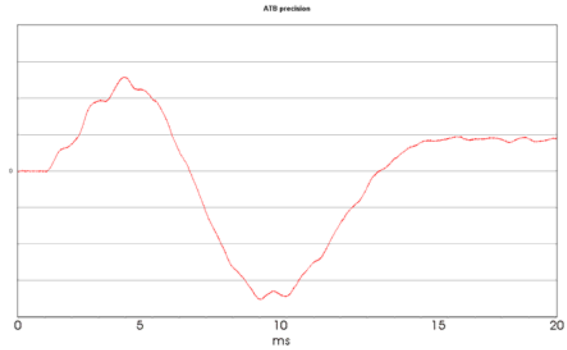


Fig. 6.14

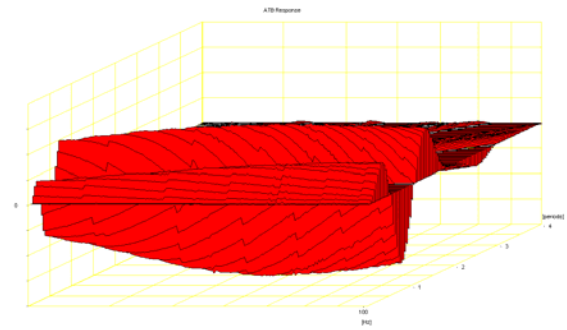


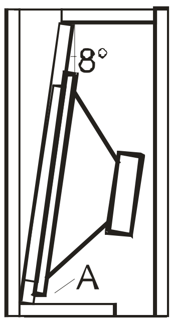
Fig. 6.15

Figure 6.14 shows the jump response of the bandpass loudspeaker. Through the bandpass function, that suppresses higher frequencies, a slow rise of the signal results. The waviness shows the frequency range at 750Hz.

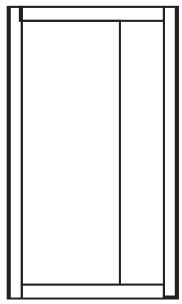
Figure 6.15 shows the Dynamic Measurement plot. The first mountain is low. This shows a bad transient oscillation behaviour. The actual signal consists of the negative overswing and 3rd mountain, which is very pronounced.

7.Affix

7.1 Cabinet drawing for the Diopol-Cardioid



Crosscut



Front