# The development of the loudspeaker

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**Abstract**

The following outlines the technical development of the Loudspeaker system. At first, only headphones were used, which were developed from telephone receivers. At that time there was also the acoustic Gramophone, which used a horn to "amplify" the signal that was sampled from the shellac record. More strictly speaking, the horn did not amplify the sound. Instead, it transmitted the sound from the sound-box of the Gramophone acoustically to the sound field. In order to gain higher sound output from headphones, it became obvious to couple the headphones to Gramophone horns. This was the start of the development of horn speakers in the 1920's. The sound quality of these horn loudspeakers left much to be desired. Horns were relatively loud but with poor quality sound [1]. This was due primarily to the drive system with a steel diaphragm in the earphone cup. Improvements were needed regarding volume, but so were also balanced frequency response and "purity of tone"[2]. Remedies for these deficiencies were attempted with magnetic systems. The fact that many such magnetic systems were created shows that the deficiencies were not completely eliminated. These loudspeakers differ technically depending on the movement of their magnetic armature[3]. In magnetic systems the excitation coil is fixed and an iron armature moves and drives the diaphragm. However, one can also fix the entire magnetic system and let the excitation coil (voice-coil) move to drive the diaphragm. To this end, there were several attempts at a solution, and the moving voice-coil prevailed. Most speakers today use voice-coils.

In the early days of the dynamic loudspeaker there were no strong magnets available yet. Therefore a field coil was used to create a constant strong magnetic field. These were fed by rectified AC current, which produced noticeable hum. The hum was initially minimized with a bucking coil that was driven by ripple voltage with opposing phase, or with a short-circuit ring over the field coil , which ring reduced variations in the induced magnetic field, while increasing the coil ripple current due to the drop in inductance. In this case, the field coil with reduced inductance from the shorting ring could no longer be used as a filter choke for the anode current. Both concepts could not be applied simultaneously. The compensation of ripple voltage was later implemented in a bridge arrangement with a tap in the output transformer primary. This allowed the speaker to be more easily constructed.

With the advent of strong permanent magnets, the permanent magnet loudspeaker became the norm. The reproduction range of most speakers is limited by unwanted partial vibrations. Special construction techniques help extend the frequency range. The straight-sided cone horn loudspeaker led to the development of the exponential horn loudspeaker, which became used as a high frequency speaker (Tweeter) or as a public address speaker (train station speaker). Special types of loudspeakers include electrostatic, piezoelectric and ionic types.

[1] A well known musician felt it reminded him of "bronchial catarrh".

[2] Early speakers tended to have resonant peaks and non-linear distortion.

[3] The "Freischwinger" with it's free moving armature, is only one of these types, but became very common as it was built into the "Volksempfänger - People's radio".

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# 1 From Telephone receivers to headphones

The earliest realization of an electrodynamic acoustic transducer came from telephone receivers which were called "lond-distance receivers" . Figure 1.1 shows the realization by Alexander Graham Bell. [*1]

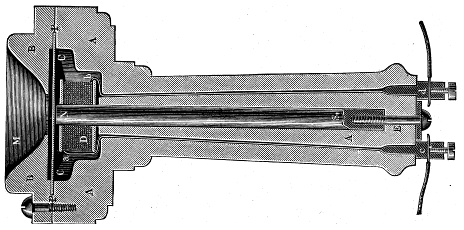

Figure 1.1: Bell receiver in cross-section

The Bell receiver only had a bar magnet. An obvious improvement was to replace it with the horse-shoe magnet as shown in Figure 1.2. The Horse-shoe magnet increase the magnetic field strength and, consequently, the loudness.

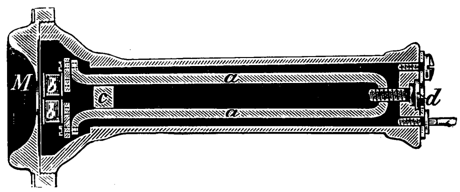


Figure 1.2: Telephone receiver with horse-shoe magnet shown in cross-section

An improvement over the Bell system was the separation of the microphone (telephone transmitter) and telephone receiver into separate units.[*2]. The long-distance Bell receiver no longer needed a handle. Thus was the form now suitable for the headphone[*3] as shown in the example in Figure 1.3.

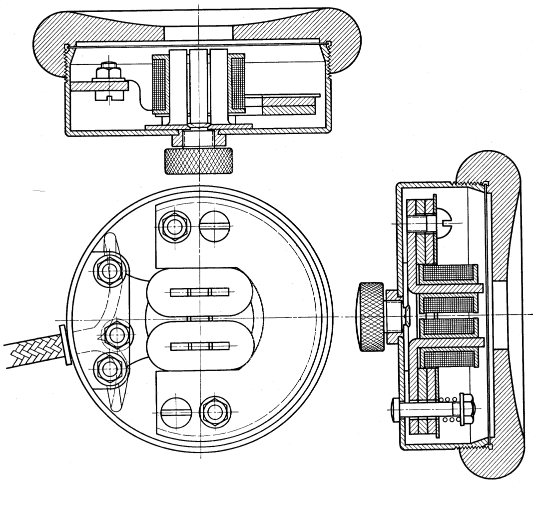

Figure 1.3: Headphone construction with adjustment for diaphragm distance.

[*1] In Bell's telephone, the receiver was also used as microphone, which gave half-duplex operation.

[*2] An operating method was used for the microphone where carbon was compressed and relaxed by a diaphragm, and it's resistance varied at the rhythm of the sound waves. The telephone circuit needed a battery, but this gave the advantage of full-duplex operation.

[*3] Historically, radio literature mentions "double headphones" when 2 earpieces are present.

When transducers are applied directly to the ear, the least possible power is needed. A few $\mu W$ is enough*4. Reception with a detector can be done with headphones, but one is tied down by the earphone wires and is not free to move about. This is also awkward and uncomfortable when several people want to hear something simultaneously. This led to the desire for a loudspeaker quite early on.

# 2 From headphones to the Horn speaker

Sounds that are heard directly by the ear from the earphone are hardly perceptible when the earphone is moved some distance away from the ear. The power level is very low and secondly only higher frequencies are audible. A horn can be coupled to the transducer of an earphone as a "necessary" solution. Such were the actual first attempts at a loud-speaking telephone, figure 2.1.

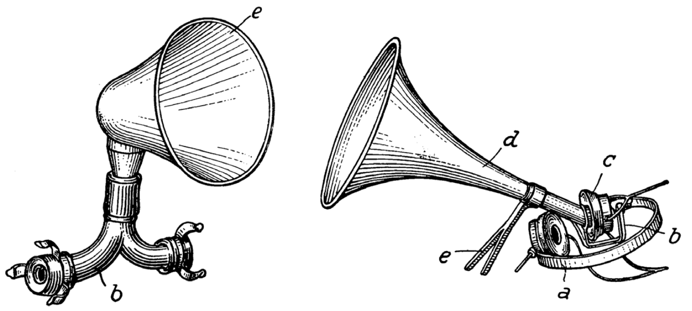


Figure 2.1: Coupling of earphones to horns: Left – for double headphones, right – improvised coupling to single transducer

The horn was later mounted on a foot and thus came to be the typical Horn-loudspeaker. See figure 2.2.

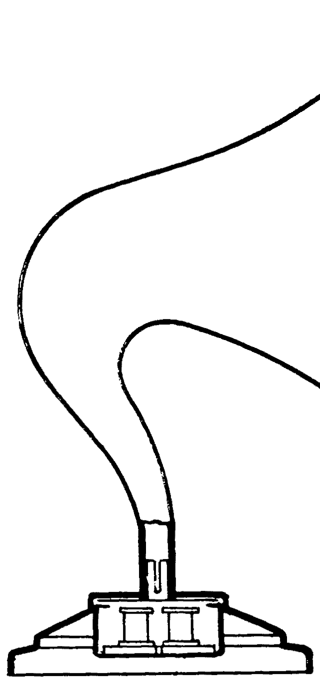

Figure 2.2: Typical horn-loudspeaker form.

A somewhat larger transducer is built in the bottom of the horn-loudspeaker which is more powerful than an earpiece.

*4Anyone who has tried wearing earbuds should know that power levels in the mW range can lead to hearing loss. "Your neighbor can hear the buzzing hiss from your earbuds!" (Munich subway)

However, one cannot make this transducer arbitrarily large because higher tones would not be properly reproduced with a larger diaphragm.
For these reasons there were modified drive systems for horn-loudspeakers, as shown in the examples in figure 2.3.

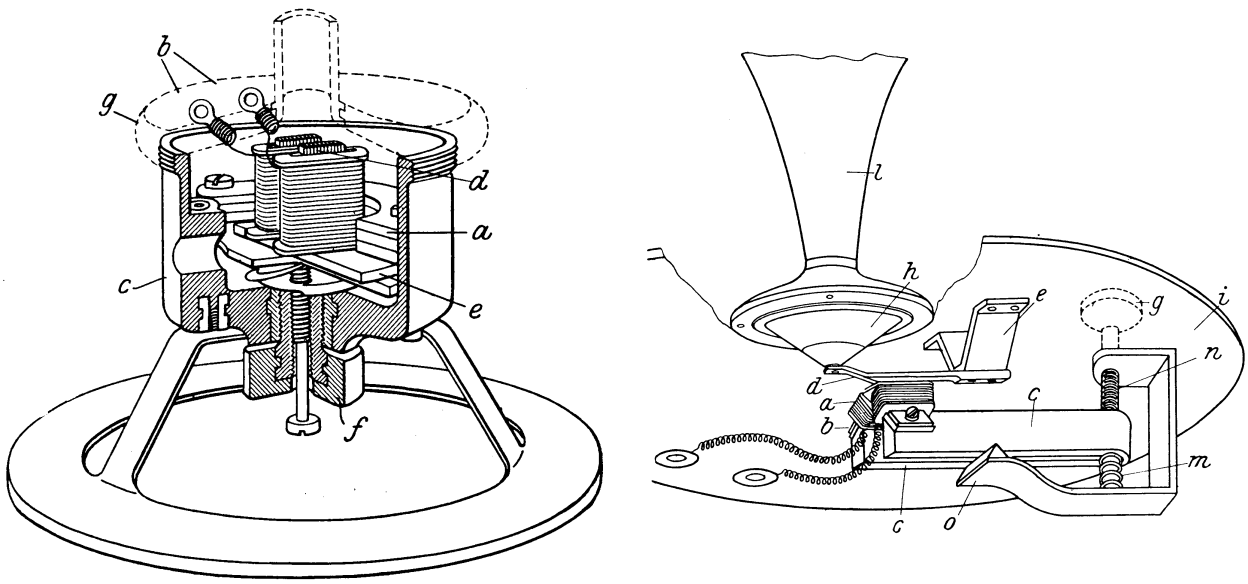


Figure 2.3: Examples of drive systems for horn-loudspeakers

The coils of these drive systems have high resistance and are made with many turns of very thin wire. One can place these coils directly in the anode circuit of the output tube without a coupling transformer. The then typical loudspeaker tube (i. e. RE144, RE134, RES164 [in Europe]; 10, 12A, 71A, [in the USA]) had an anode current around 10 - 20mA [†1]. The anode current leads to a magnetization bias that tightens or bends the diaphragm[†2]. The distance between the the magnet and the diaphragm can be adjusted to get enough loudness. Therefore horn-loudspeakers usually have adjustments. Figure 2.3 shows the adjustment left of the screw in the bottom center to the right of the the screw labeled with g. Horn-loudspeakers can develop considerable volume, but have a limited frequency response, which is typical of the "horn sound". See figure 2.4 curve b).

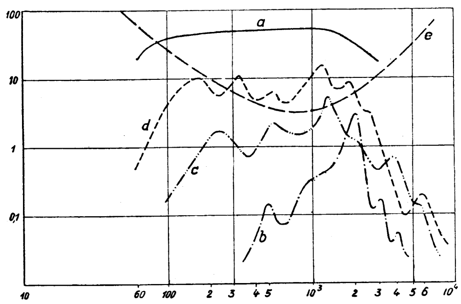


Figure 2.4: Typical loudspeaker frequency ranges: a) "ideal" b) ordinary horn c) Exponential horn d)dynamic loudspeaker in a baffle e)Ideal measured ear sensitivity.

[†1]With stronger output tubes, like the AL4 with 36mA of anode current, the speaker winding heat dissipation, as measured with $P = I^2 \cdot R$, increased 9-fold. This lead to the melting of the shellack winding insulation and, via a short-circuit, to the charring of the coil.

[†2]When connecting the speaker it is important to have the correct direction of current flow. If connected in reverse, the permanent magnet field is weakened in the drive system. When the current direction is correct, it is also possible for the diaphragm to stick to the magnet. The adjustment screw is then used to free the diaphragm with a noticeable "clack" sound.

# 3 Alternative Transducers

Looking for more ways to convert electrical oscillations into acoustic signals, different physical principles were tried; some of which seem strange today.

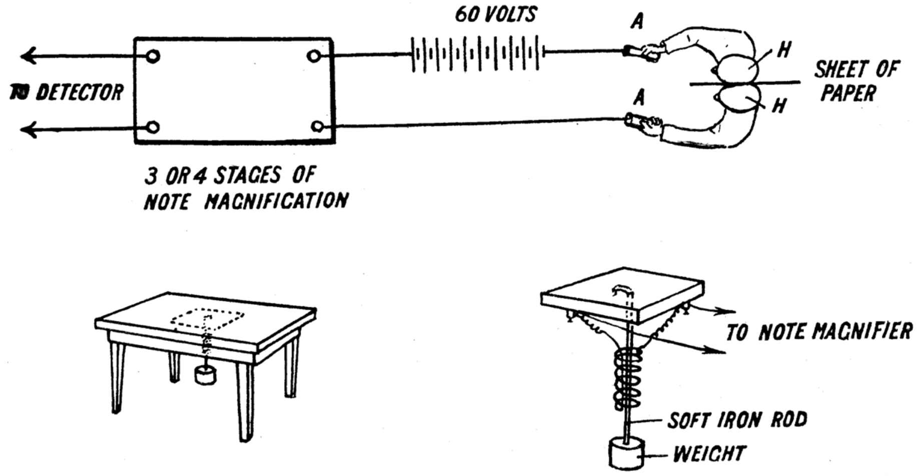


Figure 3.1: Unusual transducer forms

The first type in figure 3.1 shows an old method that is not without risk and is not recommended for imitation.
A table top with help from a solenoid eventually showed operation in one direction.
A very different principle used Johnsen-Rahbek's loudspeakers. This speaker uses the electrostatic attraction between a cylinder of agate and a metal strip. See figure 3.2.

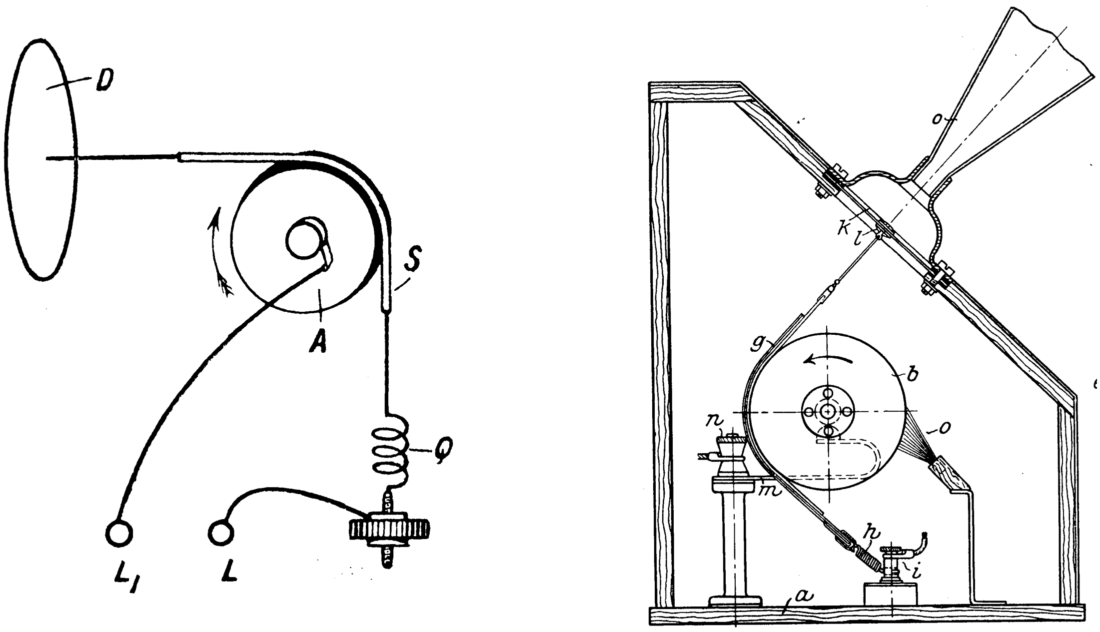


Figure 3.2: Principle and construction of a Johnson-Rahbek loudspeaker

A practical realization of a Johnsen-Rahbek loudspeaker is shown in figure 3.3. A musical instrument was used as a sounding board to radiate the sound. It was thought that musical instruments were particularly appropriate to play back music.
The Johnson-Rahbek speaker draws it's sound reproductive power (gain) from the mechanical rotation of the cylindrical roller. Therefore, a larger volume can be achieved. A modification of the principle is shown in figure 3.4 where a cork drags

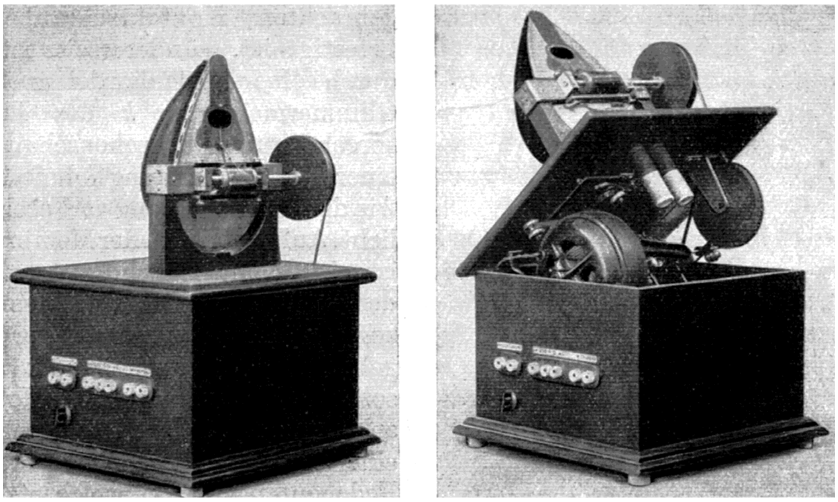

Figure 3.3: Example of a Johnson-Rahbek loudspeaker

on an agate slice.

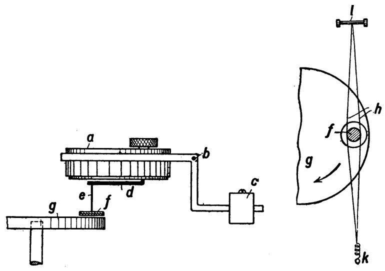

Figure 3.4: Motor-Loudspeaker

This principle was also realized with flowing air current as seen in figure 3.5

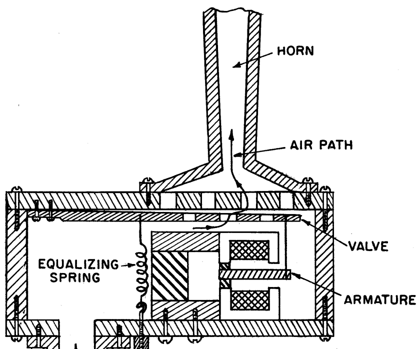


Figure 3.5: Pneumatic loudspeaker

This air pressure loudspeaker principle recalls the control of organ pipes. How would have this sounded?

# 4 Drive systems for loudspeakers

## 4.1 Magnetic systems

Electromagnetic drive systems are now considered. These convert signals in electrical current form to signals into corresponding movements and thus into acoustic signals. This is done with the aid of magnetic effects which are produced by coils in a constant magnetic field. Two typical magnetic loudspeaker systems are shown in Figure 4.1.

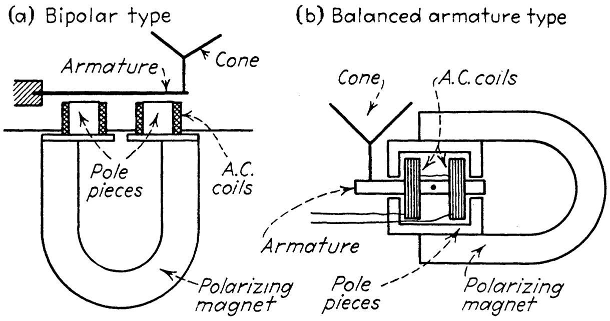


Figure 4.1: Drive systems for magnetic loudspeakers; left: steel reed anchored on a single end; right: unsprung balanced system.

Reed systems include singled ended and double ended configurations where the reeds are clamped on one end or both ends as shown in figure 4.2.

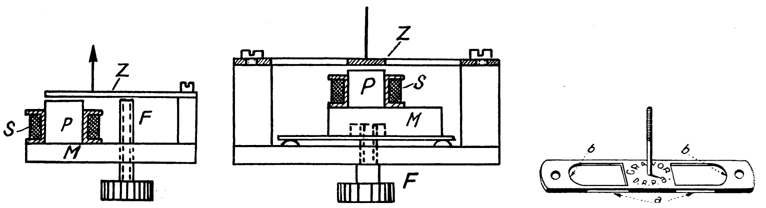


Figure 4.2: Reed system for magnetic loudspeakers; left:anchored on a single end; middle: anchored on two ends; right: steel reed detail $a$ is damping material.

The four-pole system is shown in detail in figure 4.3.

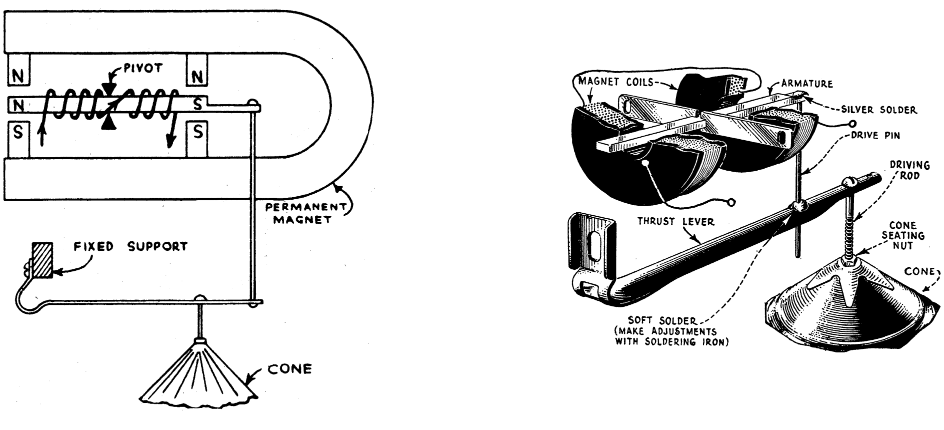


Figure 4.3: Four-pole system principle and perspective detail; The lever tilt is adjustable.

## 4.2 The AEG System

AEG developed for it's Gealion loudspeaker a magnetic drive system with low frequency compensation. This is achieved in that the pivot point of the reed is moved to keep the magnetic force approximately proportional to the applied current, whereby the usual magnetic system non-linearity is reduced, figure 4.4.

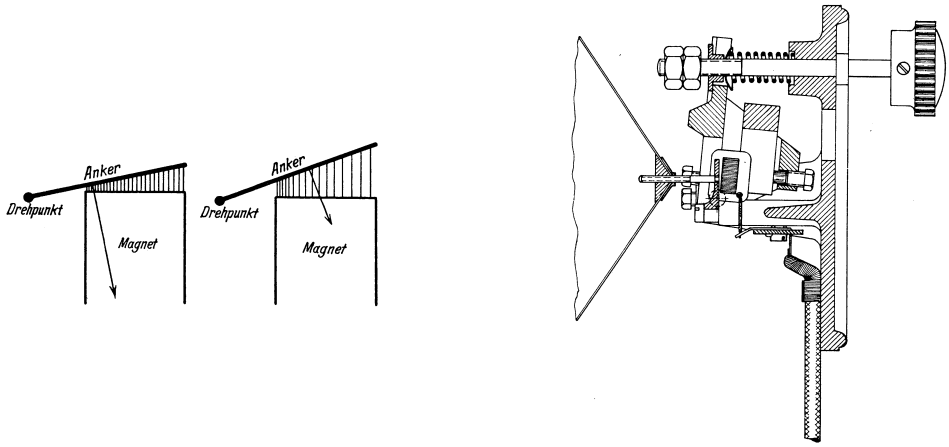


Figure 4.4: Principle and cross-section of the AEG Gealion loudspeaker with low frequency compensation

## 4.3 The Inductor-Dynamic system

At a glance, it is easy to confuse the Inductor-dynamic system with the aforementioned four-pole system.
The essential difference is that the armature is not rotatable, but is horizontally reciprocated as shown in figure 4.5:

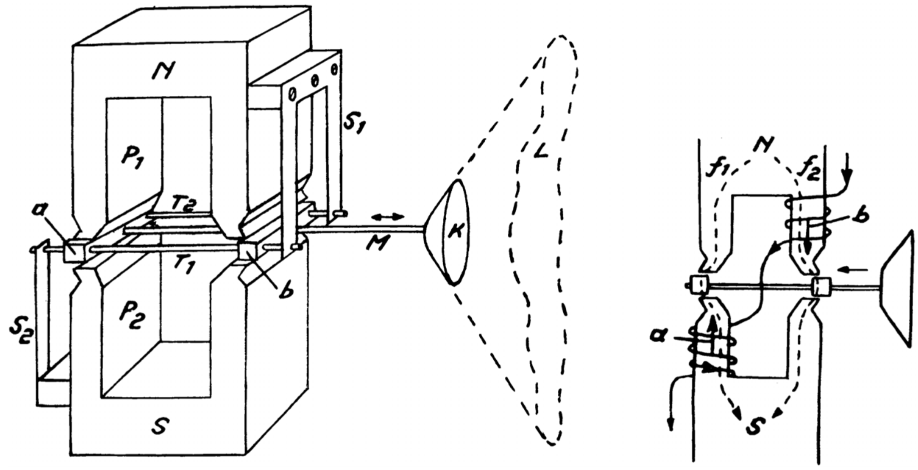


Figure 4.5: The inductor-dynamic system.

The horizontal movement of the armature ensures that, at even large deflections, the pole pieces will not be hit or make noises. This is contrast with the four-pole system, where these noises are possible.

## 4.4 The Cantilever system (Freischwinger)

The cantilever system assures that the armature and the magnet do not abut at high amplitudes. The armature has to be arranged in front of the air gap of the magnet as shown in figure 4.6.
One can, in principle, think of the cantilever system as a simplified version of the four-pole system as shown in figure 4.7.

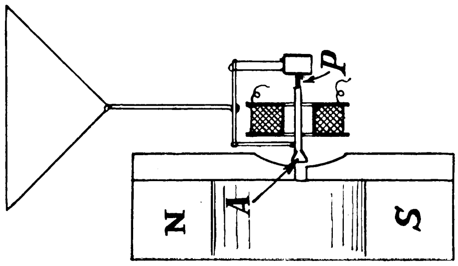


Figure 4.6: Principle of the Cantilever system.

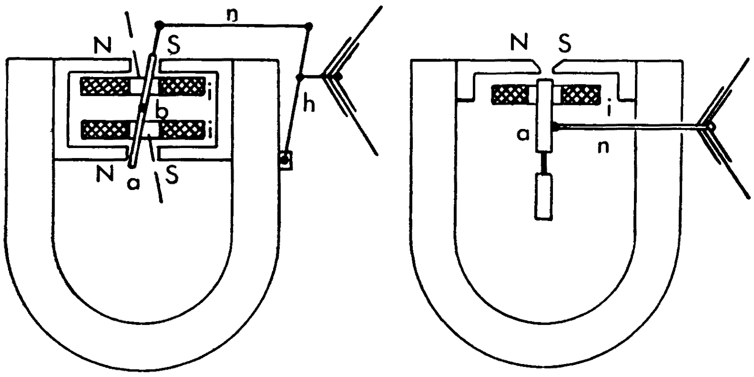


Figure 4.7: Cantilever system as a simplified four-pole system.

The armature may have large swings without hitting the magnet, but the deflection is still not linear with respect to the applied signal current. Consequently, non-linear distortion occurs. Cantilever systems are cheaper to produce than all other systems, so they are quite common. They are easily found in many "people's-radios" (Volksempfänger) and in the DKE (Deutscher Kleinempfänger - small German receiver). Figure 4.8 shows two cantilever systems.

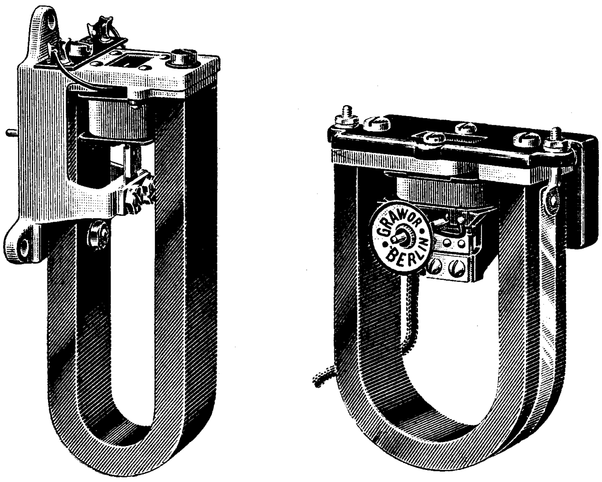


Figure 4.8: Cantilever system of the VE301 (left) and a power-cantilever (right).

## 4.5 The Electrodynamic moving-coil system

While the coil is fixed and the armature moves in an electromagnetic system, the coil moves in an electrodynamic system. In order to reproduce higher frequencies, the moving parts must have little mass, or be lightweight. This means that the coil must have few turns of relatively thin wire[§1]. A cross-section of one of the earliest electrodynamic systems (Magnavox) is shown in figure 4.9. The magnetic DC field is produced by an electromagnet which is denoted in the figure by $c$.

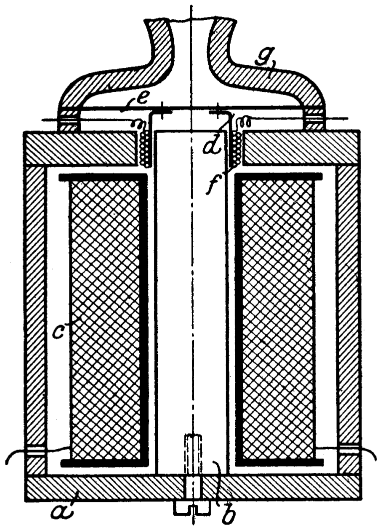


Figure 4.9: Cross-section of the Magnavox electrodynamic system.

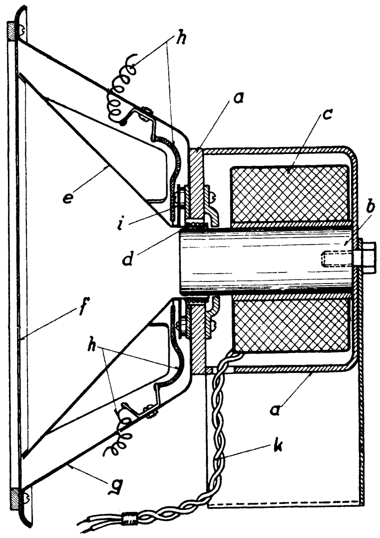


Figure 4.10: Cross-section of an electrodynamic loudspeaker.

Except for diaphragm $e$, which is very small and drives a horn, this system had all the features that were found in later electrodynamic systems as shown in figure 4.10.

## 4.6 Permanent-magnet dynamic loudspeakers

When adequately strong magnets became available, most speakers became permanent-magnet dynamic types as shown in figure 4.11.

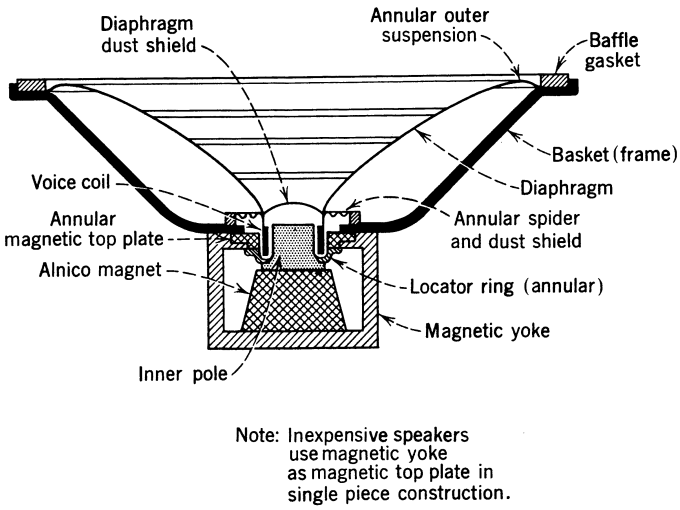


Figure 4.11: Cross-section through a modern permanent-magnet dynamic loudspeaker.

[§1] Since these are low impedance coils, output transformers are required to match the impedance to the high output resistance of tubes.

## 4.7 Ribbon and Leaf loudspeakers

Ribbon and leaf loudspeakers systems hail from the 1930's. There is no moving armature nor moving-coil in these systems, but a moving conductor in the form of a ribbon as shown in figure 4.12.

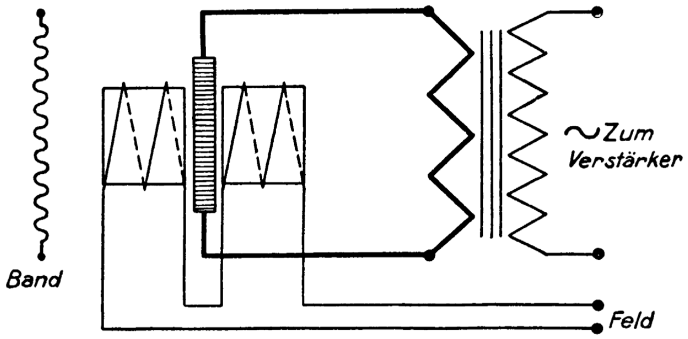


Figure 4.12: Principle of the Ribbon loudspeaker

The ribbon is made of very thin corrugated aluminum foil. The leaf loudspeaker has a large surface for sound radiation, under which is an electrical meandering conductor B and which plunges into a corresponding magnet gap as shown in figure 4.13.

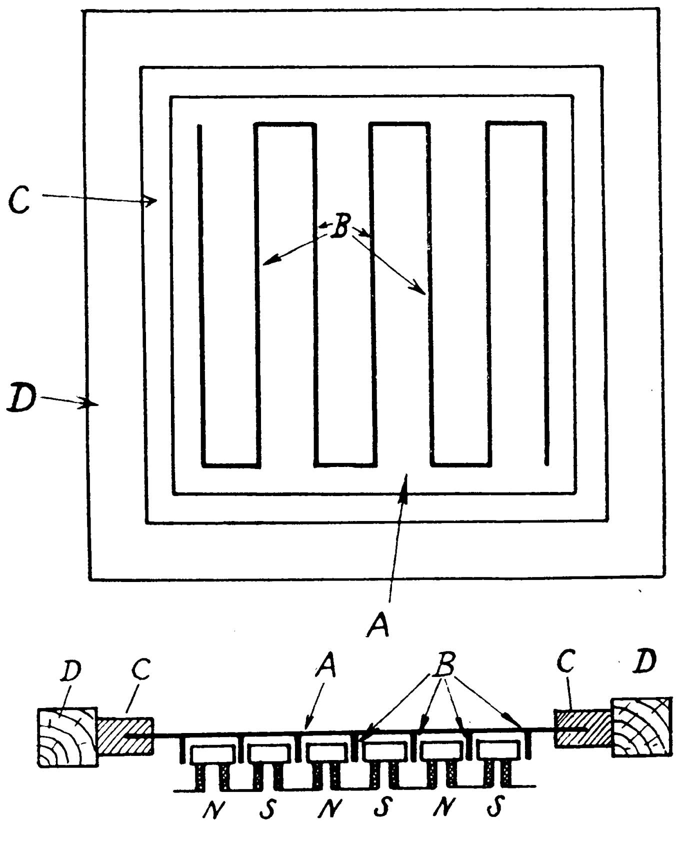


Figure 4.13: Principle of the leaf loudspeaker

Neither form prevailed against the dynamic moving coil loud-speaker.

# 5 Diaphragm loudspeakers

In principle, all loudspeakers have a diaphragm. But in contrast with horn speakers, diaphragm speakers can radiate sound directly from the diaphragm unaided. This loudspeaker technique, i.e. in fig 4.11, is the most widespread today.

## 5.1 The electrodynamic Loudspeaker

Electrodynamic speakers were standard in pre-war radios (and also in radios shortly after the war). See Figure 5.1. The magnetic DC field was created by current flow in field coil.

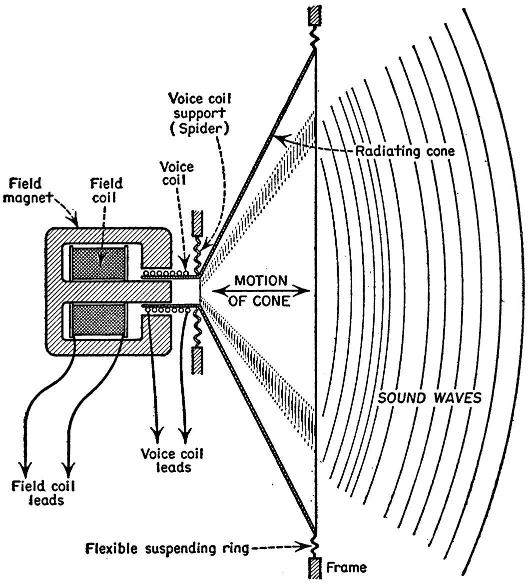


Figure 5.1: Cross-sectional view through an electrodynamic loudspeaker

The exploded view in figure 5.2 allows for close exploration of the various components of the electrodynamic loudspeaker¶[1].

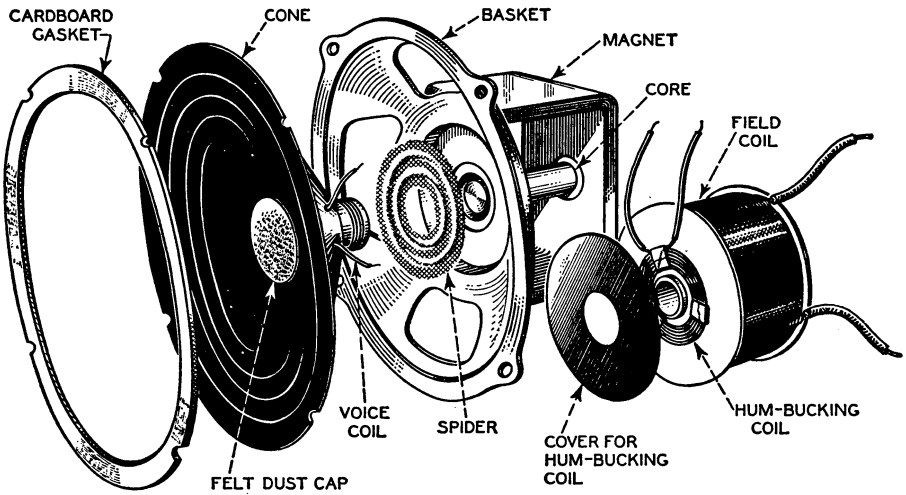


Figure 5.2: Exploded view of an electrodynamic loudspeaker

¶[1]In comparison to the cross-sectional view of figure 5.1 there is an additional coil: The "Hum-Bucking Coil". This coil reduces hum by canceling the ripple of the field coil current.

### 5.1.1 Field coil power supply

There two possibilities to supply power to the field coil of the electrodynamic loudspeaker, as shown in Figure 5.3.

**A:** Series connection to pass the anode current of the radio.

**B:** Parallel connection.

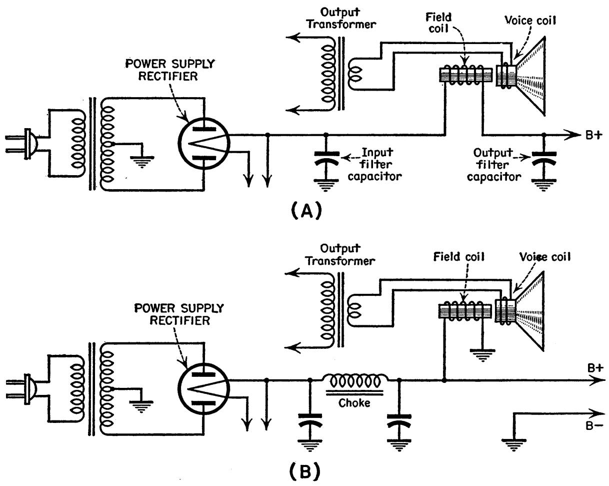


Figure 5.3: Field excitation of an electrodynamic loudspeaker: (A) Series-connection, (B) Parallel-connection.

The parallel connection became widespread in the early 1930's, as there were radios that came with built-in speaker and some used an external speaker. In this transitional period there were speakers available with an attached power supply. In the following example, the field coil has low resistance. The rectification of the field current is carried out with a selenium bridge rectifier. See Figure 5.4 ¶2

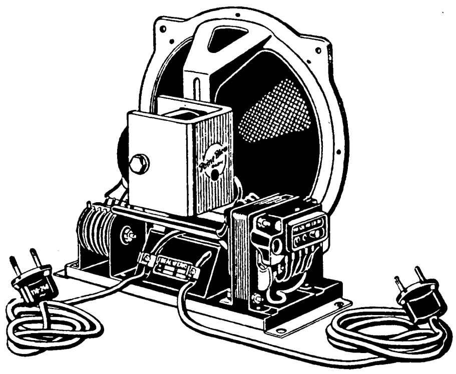

Figure 5.4: Electrodynamic loudspeaker with power supply for field excitation.

The anode voltage for the radio was generated with help from a rectifier tube on the secondary of the power supply transformer in full-wave push-pull configuration. The ripple was filtered by capacitors (at most a few $\mu$F) and the chocking effect of the speaker field excitation coil (A) or by an extra choke coil (B). The ripple was, however, never completely eliminated.

### 5.1.2 "Hum Bucking" and "Shading Ring"

There are two possibilities to reduce hum that is caused by the ripple current of the field coil.

¶2 Loudspeakers had high resistance field coils far more often, for which tube rectification was employed with tubes such as the RGN1503 or RGN1064 resp. the '80.

1. Compensation of hum with an opposing current of equal magnitude: “Hum Bucking”
2. Attaching a short-circuit ring over the field coil: “Shading Ring”

The compensation method is shown in figure 5.5 and the short-circuit ring method is shown in figure 5.6.

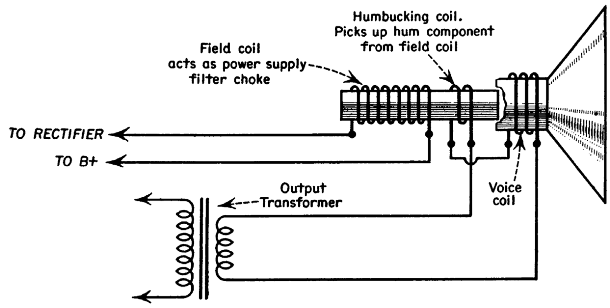


Figure 5.5: Electrodynamic loudspeaker with Hum-bucking.

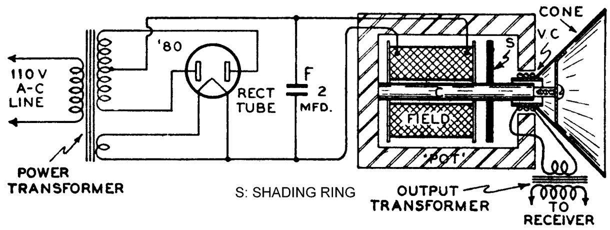


Figure 5.6: Electrodynamic loudspeaker with short-circuit field shading ring.

Both methods shown here only reduce the effects of field coil ripple current. The hum is not completely eliminated, as it is also caused by ripple in the anode voltage and it’s effect of the amplifier stages. A compensation method for the remaining hum consists in supplying the anode current through a tap in the primary of the output transformer. This results in a bridge circuit that helps minimize hum.[6] These methods were also applied in receivers with permanent-magnet loudspeakers.
When repairing radios with electrodynamic loudspeakers it is very important to reconnect all transformer and field coil wires in the original configuration. If, for example, the field wiring is connected in reverse, the original hum-bucking is lost and excessive hum develops in the speakers in a way that can’t be corrected by increasing the values of the electrolytic capacitors.

## 5.2 The Permanent-Magnet Dynamic Loudspeaker

With the availability of strong magnets, loudspeakers became permanent-magnet dynamic types, figure 5.7.

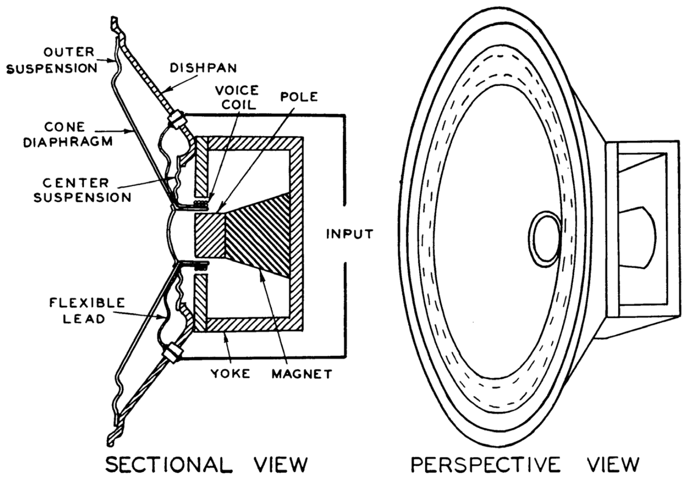


Figure 5.7: Permanent-magnet dynamic loudspeaker in cross-sectional and perspective views.

The exploded view of a permanent-magnet dynamic loudspeaker shown in Figure 5.8 shows how much simpler it is, as compared to the electrodynamic loudspeaker shown in Figure 5.2.

## 5.3 Holding the diaphragm in place

The air gap, where the voice-coil moves freely, must be as narrow as possible to obtain a strong magnetic field strength in the gap itself. It is, therefore necessary, that the diaphragm be perfectly centered and guided at the air-gap. The “Spider” serves

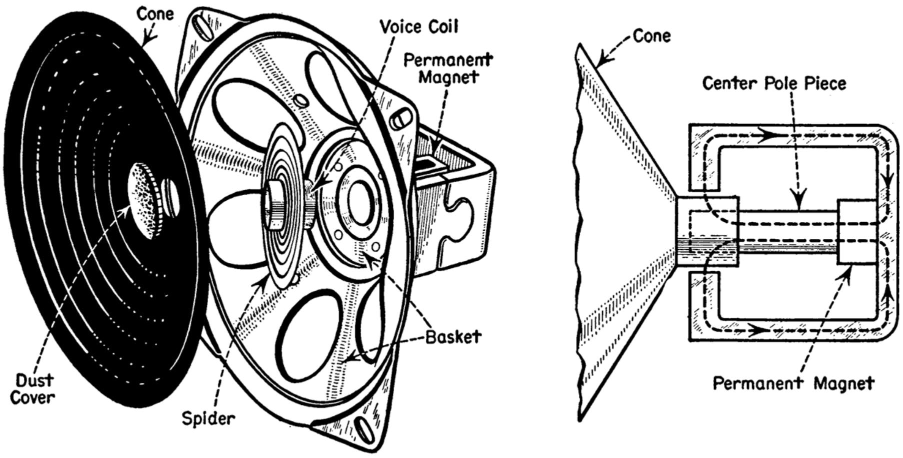


Figure 5.8: Exploded view of a permanent-magnet dynamic loudspeaker.

this purpose as shown in figure 5.9.

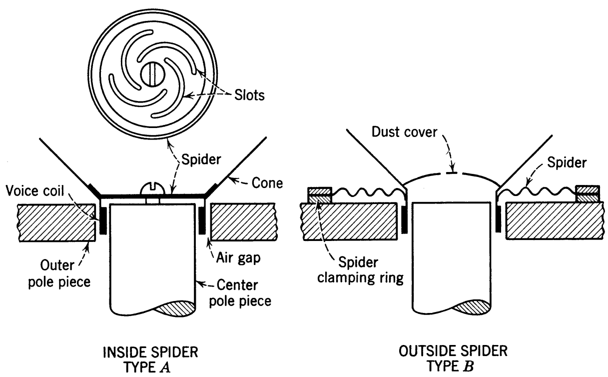


Figure 5.9: Inner centering spider of a dynamic loudspeaker; $A$ internally mounted $B$ externally mounted.

Method $A$, with internal centering, is the oldest. It has the disadvantage, that the air gap is not protected against dust or iron filings. By contrast, the modern externally mounted spider serves also as dust barrier. See figure 5.2. Alternatively, figure 5.10 shows older forms of spider that were made of thin Pertinax. This includes externally mounted spiders, but which don't offer a dust barrier.

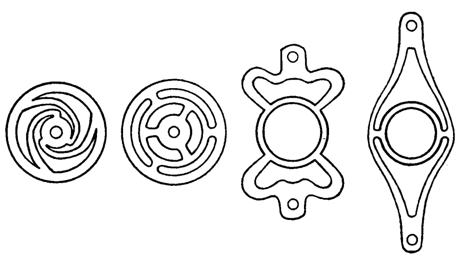

Figure 5.10: Older types of spiders for dynamic loudspeakers; on the right, two for internal mounting; on the left, two for external mounting.

The spiders have to be made, regardless of type, such that they offer very little opposing force to the movement of the diaphragm in the direction of the intended deflection. This requirement also applies to the outer attachment of the diaphragm to the loudspeaker basket. See figure 5.11.

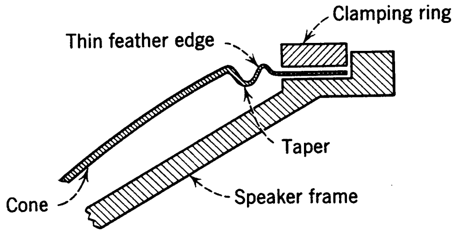


Figure 5.11: Outer attachment of the diaphragm; the bead runs softly so that the restoring force is minimized.

An ideal loudspeaker has a mass-less, yet very stiff, diaphragm, which is held very softly at the center and periphery. Such an ideal loudspeaker would reproduce the deepest as well as the highest frequencies with equal efficiency. It would also be an ideally damped system without any kind of periodic ringing. Practical loudspeakers have, however, a diaphragm and voice-coil with finite mass and also restoring forces via the spider and bead at the outer edge of the diaphragm. Physically, this is a damped spring-mass system that is capable of oscillations.[¶3]

## 5.4 Buckling and resonance of the diaphragm.

Real diaphragms have a distributed mass which causes both buckling as well as oscillations. Either of these is undesirable because they lead to frequency-dependent resonant peaks and directional radiation.
The buckling problem was recognized early. Consequently, the **NAWI** (nicht abwickelbar – not unwindable) diaphragm was developed, at least for woofers, at the end of the 1930's. See figure 5.12.

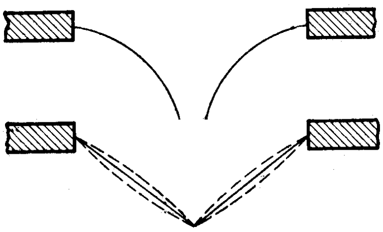

Figure 5.12: The NAWI diaphragm (above) as apposed to the cone shaped diaphragm, which can easily buckle (below).

Diaphragms can develop complicated standing-wave patterns. See figure 5.13.

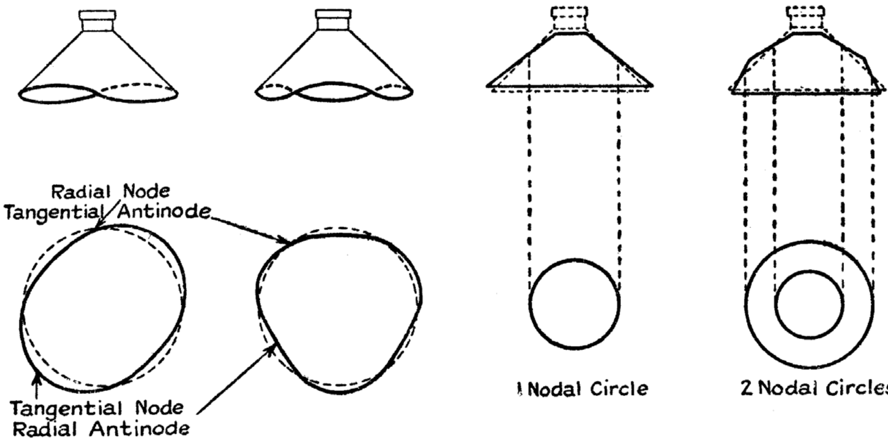


Figure 5.13: Examples of standing-waves which can develop in the diaphragm at high frequencies.

[¶3]The loudspeaker designer ensures that these resonant peaks are at the lowest frequency possible, when they are measured with a sweep of frequencies from a generator.

The standing-wave patterns are one reason, among others, why loudspeakers operate over limited frequency ranges.¶4 The higher the number of standing-wave patterns a loudspeaker develops, the more erratic it's frequency response. See Figure 5.14 and figure 2.4 (page 3)..

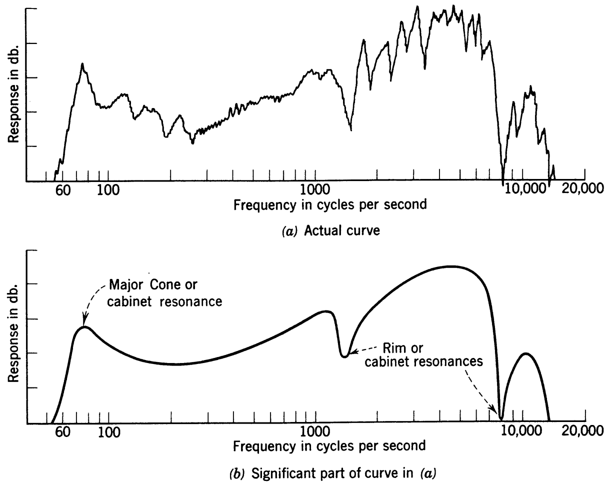


Figure 5.14: Example of the frequency response of a built-in speaker.

### 5.4.1 Directionality

The higher the frequency, the more concentrated the diaphragm movement becomes around the center, while the outer regions move in opposite phase (standing waves). If you measure the sound level over a half circle around the speaker, you see a clear directionality pattern. See Figure 5.15. This also means that the frequency response also depends on the direction of the sound radiation. See figure 5.16.

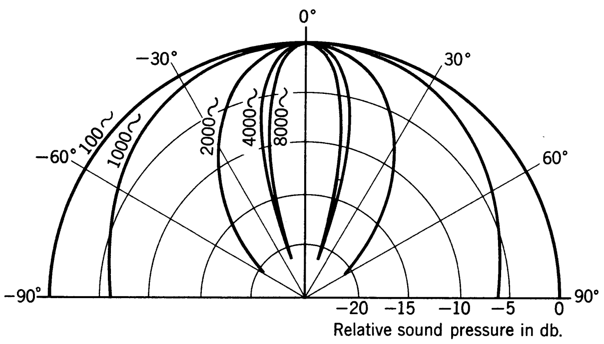


Figure 5.15: Example of the directivity of a loudspeaker as a function of frequency.

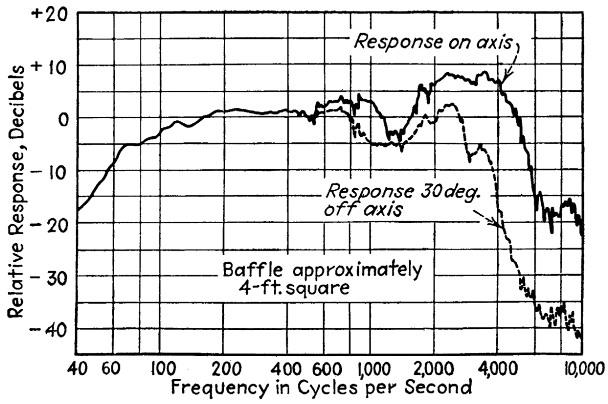


Figure 5.16: Angular dependence of the frequency response of a speaker in a baffle.

### 5.4.2 Full-range loudspeakers

The sound reproduction characteristics of the loudspeaker can be improved through the shape of the diaphragm. Figure 5.17 shows typical diaphragm forms.

¶4Therefore, loudspeakers have several built-in drivers: Woofers, tweeters, and midrange, if necessary.

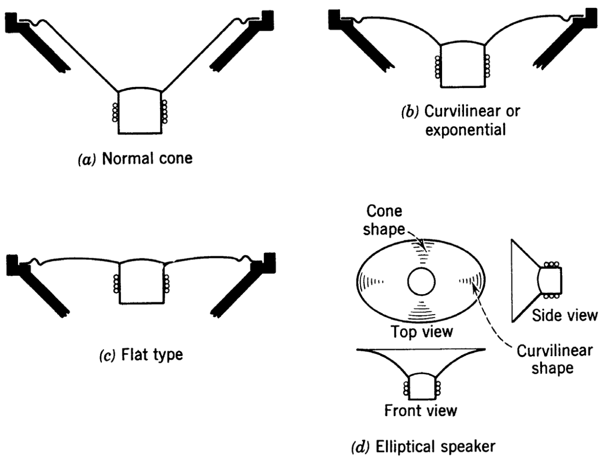


Figure 5.17: Typical diaphragm forms.

The shapes shown in (b) and (c) are especially advantageous for the frequency response.¶5 However, the shape shown in (a) has the highest maximum deliverable power. Alternative shapes use a partitioned diaphragm. See Figure 5.18.

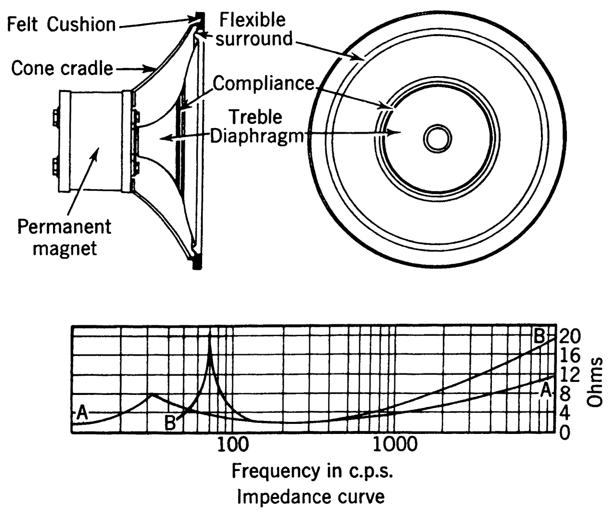


Figure 5.18: Wideband loudspeaker with subdivided diaphragm; impedance of the voice-coil (A) in comparison to a conventional loudspeaker (B).

Figure 5.18 shows the voice-coil impedance as a function of frequency. The acoustic resonance at low frequencies corresponds to an increase in impedance at the voice-coil. An impedance rise toward the higher frequencies is also typical. Because there is a reaction between the voice-coil impedance and the frequency response of the speaker, it is, in principle, preferable that the impedance rises less steeply at higher frequencies.

## 5.5 Loudspeaker combinations

Another possibility to widen the frequency range (for higher frequencies), is the combination of a woofer with a tweeter. There are several possible combinations:

- Mounting a tweeter in front of the woofer, figure 5.19
- Low frequency diaphragm with a high frequency whizzer cone, figure 5.20

¶5 A 35cm wide speaker with diaphragm shape (b) can have an effective working frequency range from 40Hz to 10kHz. Form (c) has an even higher frequency limit.

- Low frequency diaphragm with a high frequency dome, figure 5.21
- Coaxial system, figure 5.23

Coaxial systems have the advantage that the sound comes from the same position, regardless of whether the sound has high or low frequency tones. Coaxial combinations are not very common, which is probably a result of their higher cost. Woofers, mid-range speakers and tweeters are usually found separated from each other in speaker baffles.

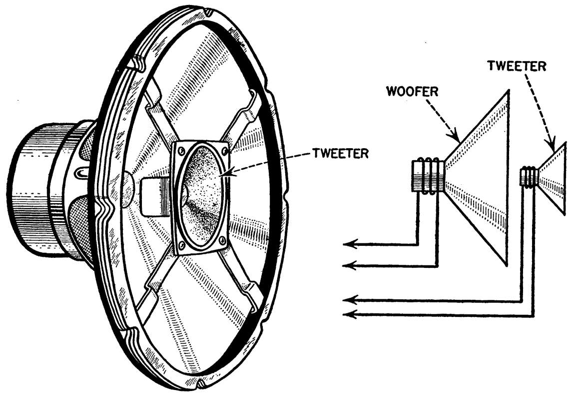


Figure 5.19: Combination of woofer with coaxial tweeter. The speakers are connected with a cross-over network.

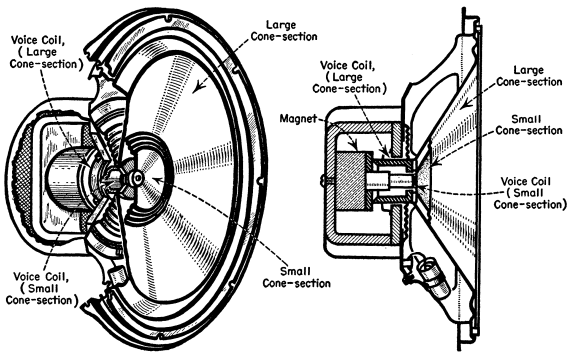


Figure 5.20: Woofer with built-in high frequency tweeter sharing different portions of the diaphragm. The two voice-coils are connected with a cross-over network.

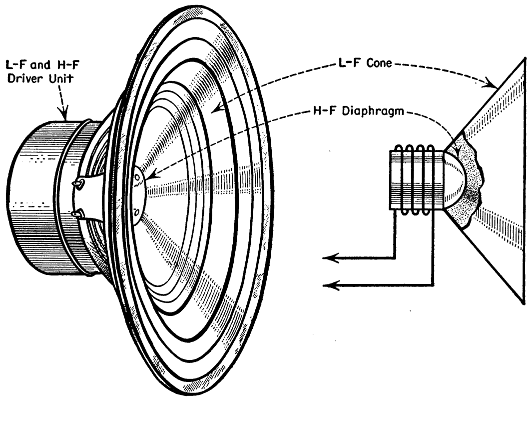


Figure 5.21: Woofer with high frequency dome.

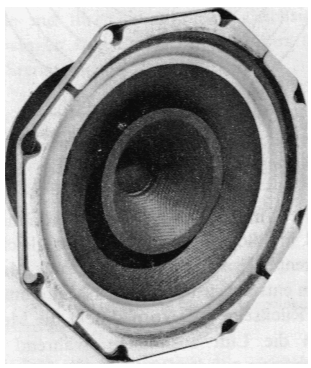

Figure 5.22: Woofer with high frequency whizzer cone.

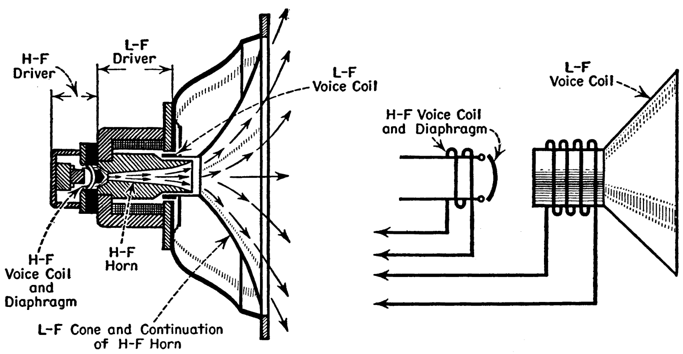


Figure 5.23: Coaxial speaker. The two voice-coils are connected with a cross-over network.

Except for speakers with high frequency domes in Figure 5.21 or whizzer cones in Figure 5.22, which only have a single voice-coil, the combination speakers need an intervening cross-over network, figure 5.24.

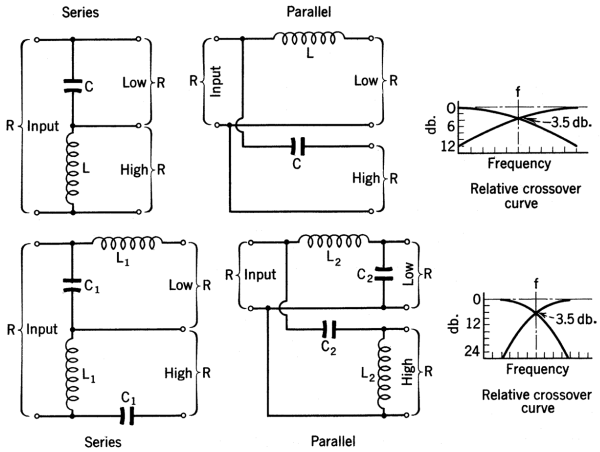


Figure 5.24: Single and two-pole and cross-over networks; series and parallel-connections.

## 5.6 Special diaphragm shapes

In addition to the generally conventional circular diaphragm, the oval diaphragm is also used, sometimes for space-saving reasons. Figure 5.25.
In the 1930's there was also the "Folded Loudspeaker" which had a magnetic drive system. Figure 5.26.

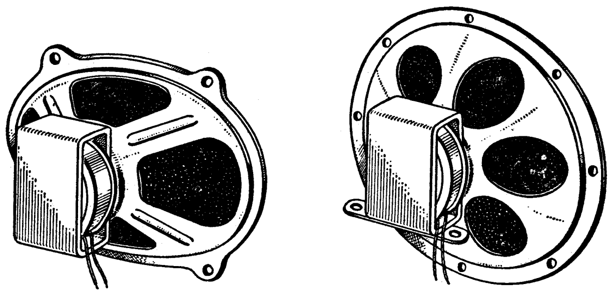

Figure 5.25: Oval and round loudspeakers.

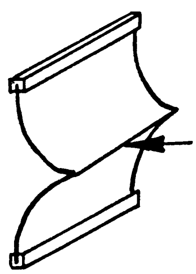

Figure 5.26: Diaphragm of a folded loudspeaker.

# 6 Horn loudspeakers

The horn-loudspeaker evolved from the funnel shaped loudspeaker. In order to make the funnel shaped speaker more efficient, it must be made longer. As the dimension of a horn loudspeaker grew too large, so it was folded like a musical instrument. See figure 6.1. Modern folded horn in figure 6.2.

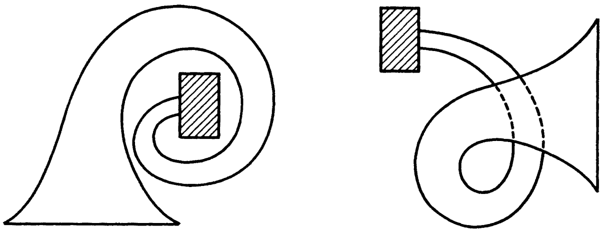

Figure 6.1: The transition from funnels to horn-loudspeakers.

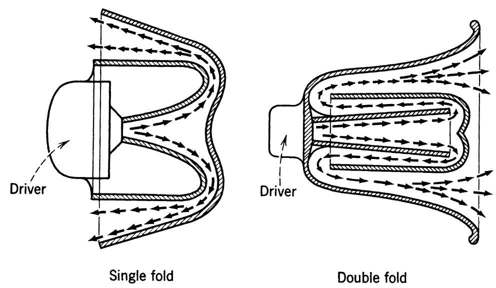


Figure 6.2: Modern folded horn-loudspeaker.

In principle, there is a (modern) horn speaker with a small dynamic moving coil system, a sound chamber (pressure chamber), and a funnel or horn that is connected through a small opening at the sound chamber, Figure 6.3.

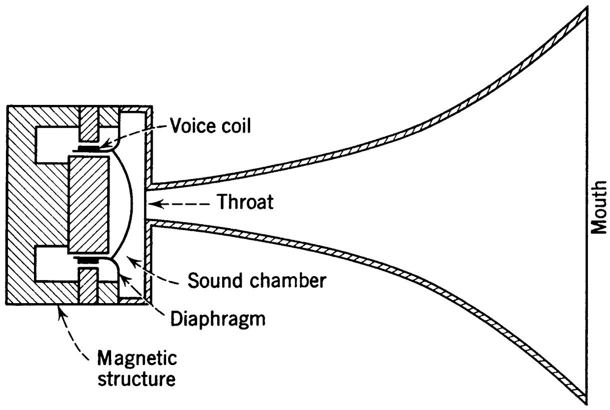


Figure 6.3: Basic components of a horn-loudspeaker.

The funnel is used to transform the acoustic impedance from the sound transducer to the impedance of the air. This concerns, in particular, the transition from the sound chamber to the horn, Figure 6.4.

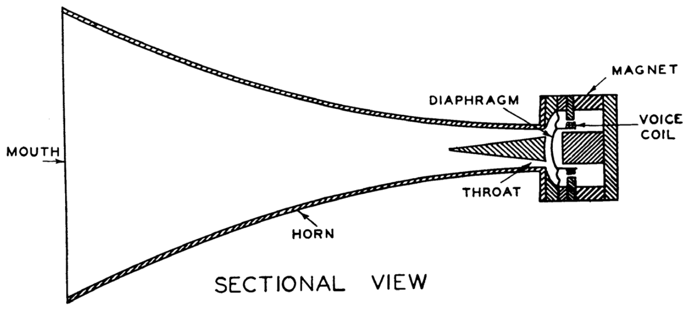


Figure 6.4: Cross-section of a horn-loudspeaker.

The transducer generates high pressure acoustic waves. The horn serves as a matching network to match the open sound field. The longer the Horn, and the wider the horn mouth, the lower the achievable cut-off frequency of the horn. Figure 6.5.

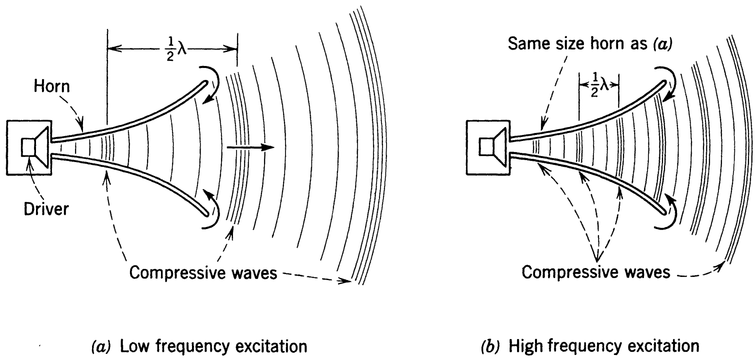


Figure 6.5: The lower frequency limit of a horn loudspeaker; At lower frequencies, which is to say at longer wave lengths, the reflected back wave (curved arrows) cancels the radiated wave, thereby decreasing volume.

The lower frequency limit depends equally on the length of the horn and on the width of the horn mouth, Figure 6.6.

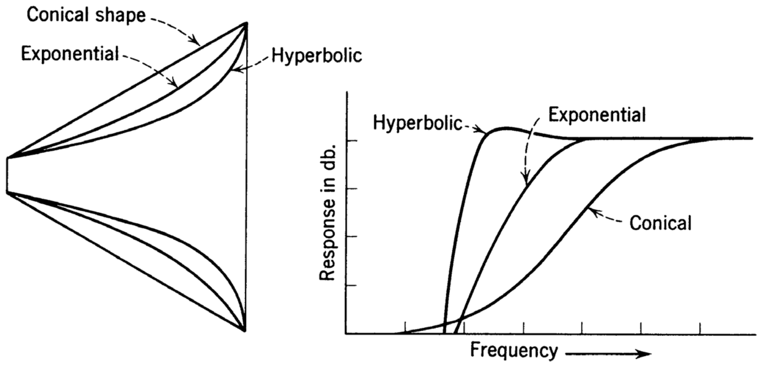


Figure 6.6: The low frequency cutoff of a horn-loudspeaker depends on it's shape.

The hyperbolic form is optimal. The original straight-sided cone form performs poorly.

## 6.1 Drive systems for a horn-loudspeaker

There are basically two types. The "annular" type has a ring-shaped diaphragm, which tends to eliminate standing-wave patterns because of it's narrow shape. The "dome" type differs with it's cap that is domed inward, figure 6.7 and 6.8.

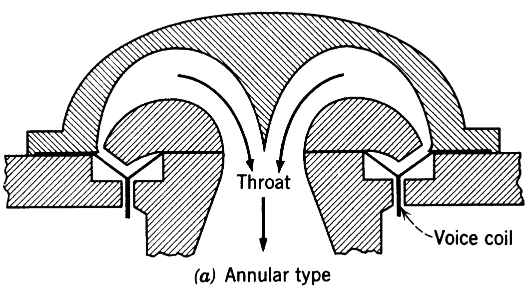


Figure 6.7: Drive system of a diaphragm.

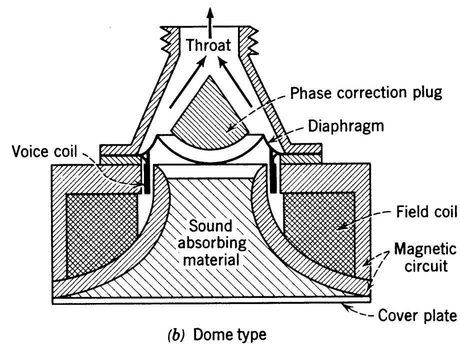


Figure 6.8: Drive system with inverse dome diaphragm.

The means to transform the acoustic impedance between the diaphragm and the horn is also visible. Horn-loudspeakers of the 1920's were realized with four-pole magnetic drive systems, Figure 6.9. The acoustic matching and the necessary acoustic transformation were not yet complete.

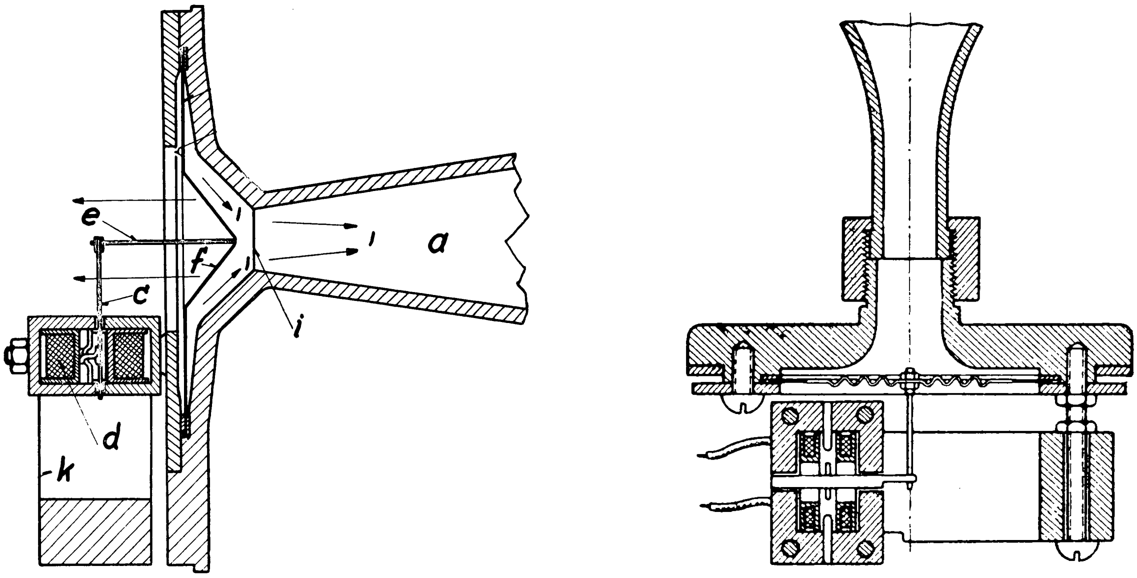


Figure 6.9: Four pole magnetic drive system in horn loudspeakers.

The modern application of the Horn-loudspeaker covers the high frequencies on the one hand, and "Public address" loudspeakers on the other. In the 1920's, only the horn-loudspeaker could produce loud volumes. Figure 6.10.

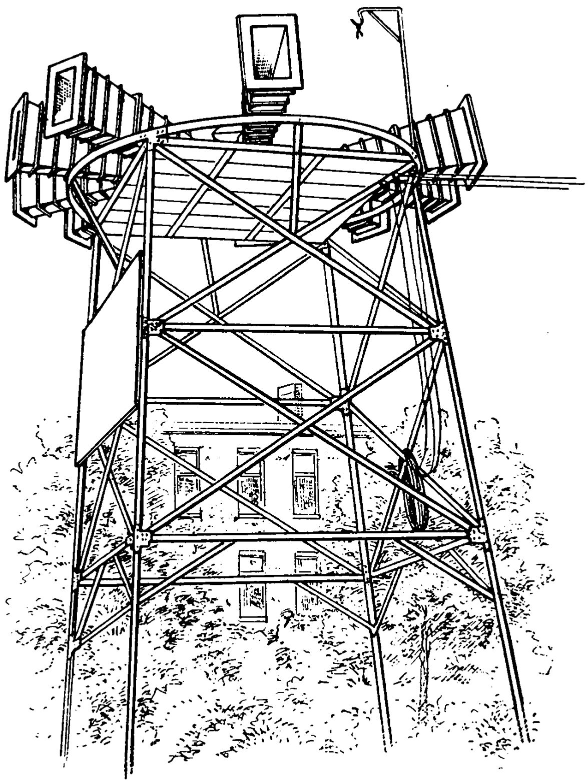

Figure 6.10: Horn megaphone from the 1920's.

# 7 Special forms

## 7.1 Electrostatic Loudspeakers

Electrostatic loudspeakers are, in principle, capacitors, in which an electrode is free to move and can convert an alternating electric field, which is biased by a DC field, Figure 7.1.**1

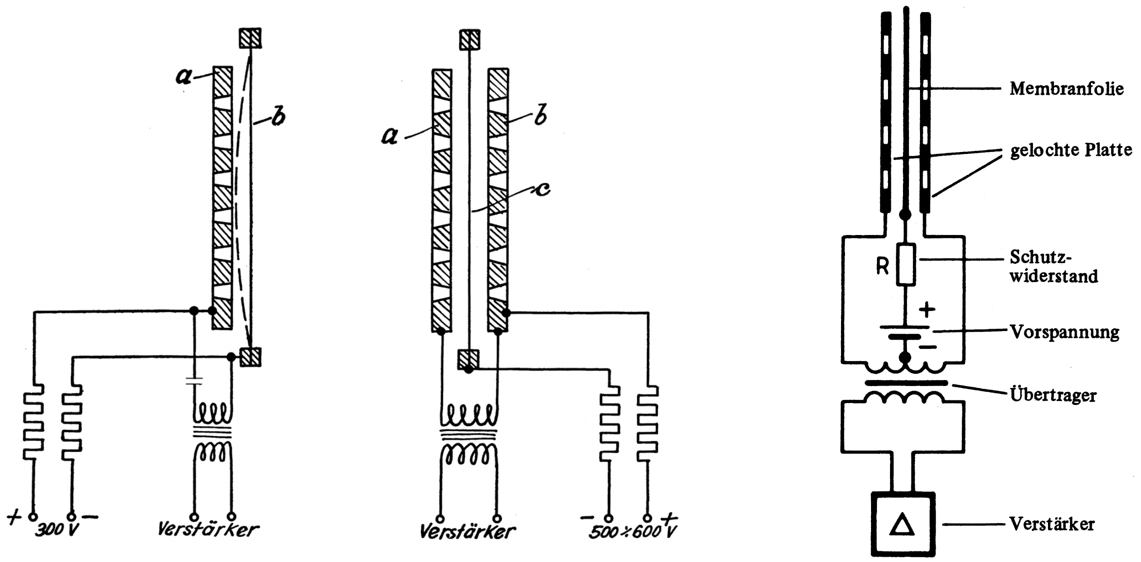


Figure 7.1: Principle of the electrostatic loudspeaker.

From Figure 7.1 it is seen that only the symmetrical arrangement has relevance in a practical speaker application, because the diaphragm is free from a mechanical fixed tension at rest.

## 7.2 Crystal loudspeakers

Crystal loudspeakers use the piezoelectric principle, Figure 7.2. They are applied mostly as tweeters.

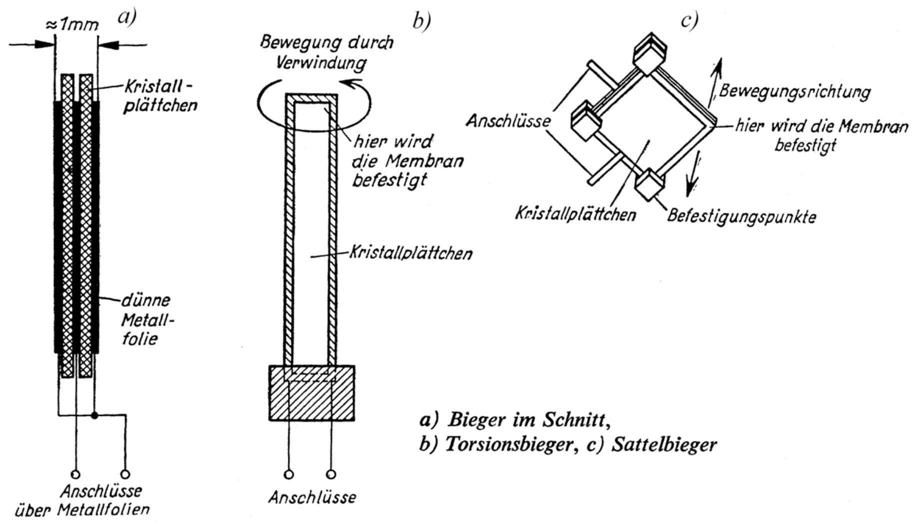


Figure 7.2: Drive system of a Crystal loudspeaker.

The connections to the diaphragm of piezoelectric speaker are shown in figure 7.3.

**1The electrostatic transducer has it's greater application in "condenser microphones", which are constructed on the same principles.

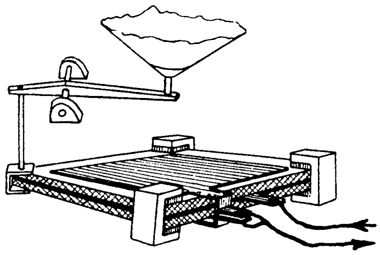

Figure 7.3: Drive system of saddle-bender.

## 7.3 Ionic loudspeakers

Ionic loudspeakers need a high-frequency corona discharge, Figure 7.4. The radio frequency discharge varies with amplitude modulation of the high-frequency oscillations and thus emerges the audio signal. As these vibrations take place almost without inertia, ionic loudspeakers are usually designed as tweeters.

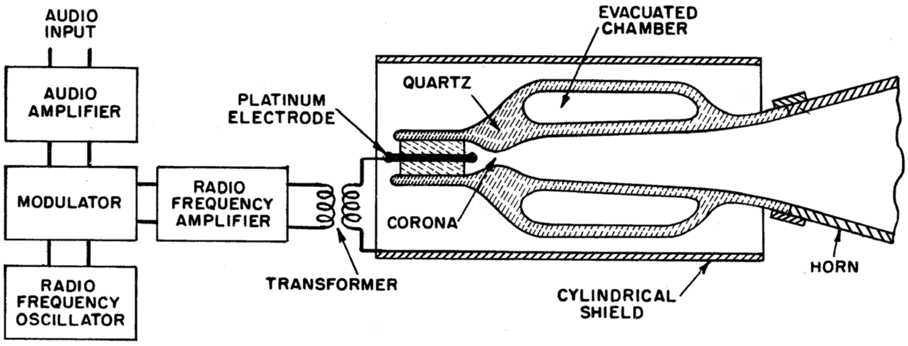


Figure 7.4: Principle of the ionic loudspeaker.

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