# Acoustical horns and waveguides

Jean-Michel Le Cléac'h

ETF 2010 Stella Plage, Saturday November 27

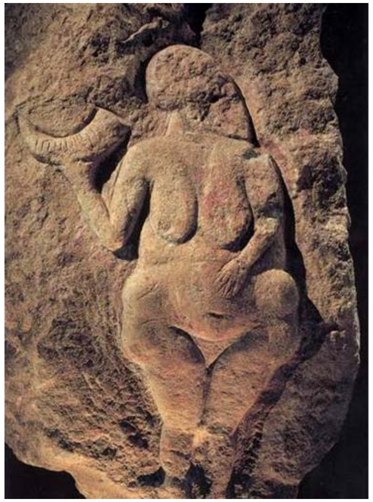
# Horns

**etymology:** **Greek :** **karnon,**
**Latin :** **cornu.**

the *horn* of an animal

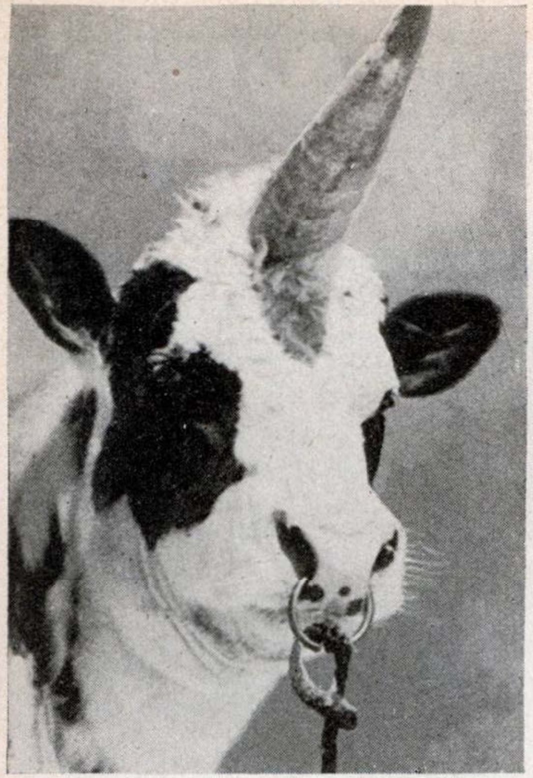
a "wind instrument"
(originally made from animal horns)

reference to car horns is first recorded in 1901.



Neolithic carving
Laussel cave, France

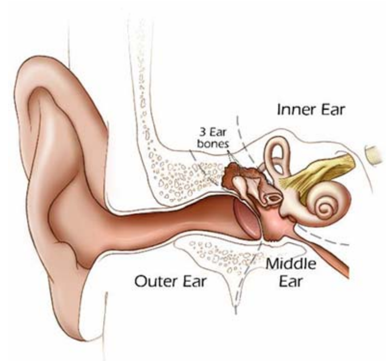
cornucopia



**BULL WITH SINGLE HORN IS MODERN UNICORN**

WHAT might be called a modern unicorn has been produced by Dr. W. F. Dove, University of Maine biologist. From a day-old bull calf, Dr. Dove removed the two small knots of tissue which normally develop into horns. These horn buds he transplanted in the center of the bull's forehead, thereby inducing the growth of a single massive horn. The bull, now nearly three years old, has developed much of the proud bearing ascribed to the mythical unicorn.

# Pavillon de l’oreille, pavillon acoustique (in French)




Etymology of the french name « pavillon »:

Pavillon de l’oreille = part of the external ear which looks like a butterfly
(butterfly = *« papillio »* in latin, *« papillon »* in french)

*An automatic translation may also lead to surprising results like "small house" or "flag"...*

# Definition

a horn is a tube whose cross-section increases from throat to mouth in order to increase the overall efficiency of the driving element = the diaphragm. The horn itself is a passive component and does not amplify the sound from the driving element as such, but rather improves the coupling efficiency between the speaker driver and the air. The horn can be thought of as an "acoustic transformer" that provides impedance matching between the relatively dense diaphragm material and the air which has a very low density.

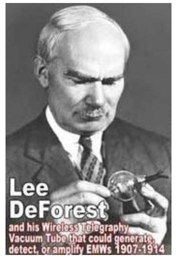
This is important because the difference in densities and motional characteristics of the air and of the driving element is a mismatch. The part of the horn next to the speaker cone "driver" is called the "throat" and the large part farthest away from the speaker cone is called the "mouth“.

# Historical milestones

1876 ____________ Bell's Telephone

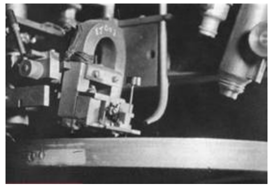
1877 ____________ Edison's Phonograph

1906 ____________ Lee de Forest's triode



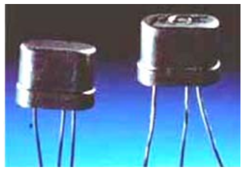

1920____________first commercial radio broadcast

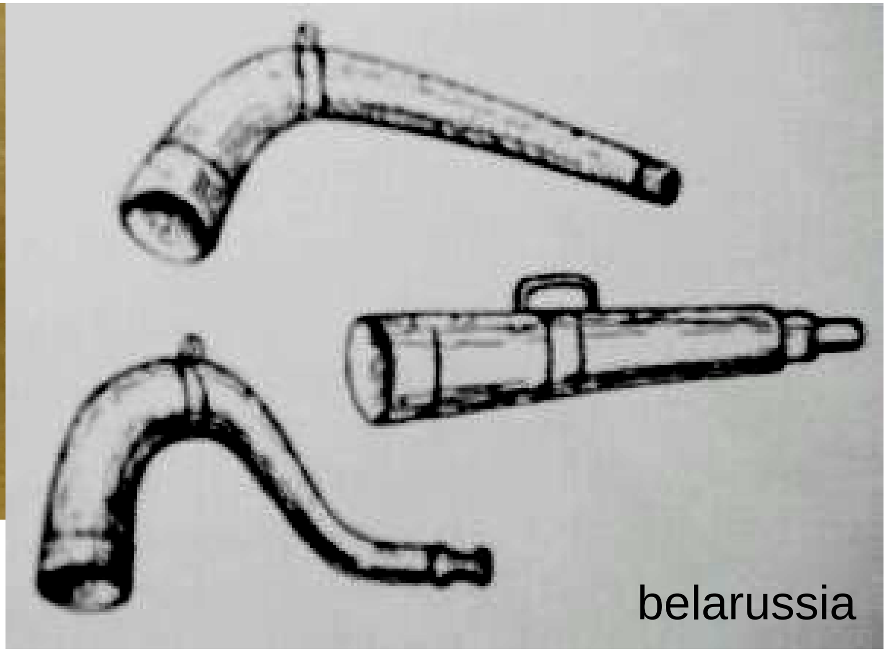
1920____________first commercial electrical recording



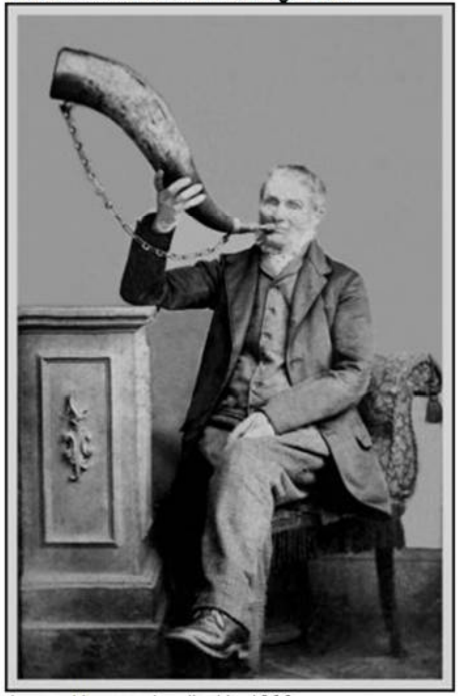
1926 ____________ First commercial talking movie


1953 ____________ Transistor commercialization




*The Hornblower of Bainbridge 1898*



James Horner who died in 1899


## The First Horns

Hunting Horn

Like the simple wooden flute, the bull's horn has been with us for a very long time. We know from ancient accounts that the horn was used to communicate over long distances, but how far a distance? In the aeons before the sort of background noise pollution we have all become accustomed to, the sound of a horn could be heard for miles. As well, sound carries over water- so well, in fact, that on a calm evening, while on the water, normal conversation may carry up to half a mile. And the reflective properties of hillsides and mountains can sometimes carry the sound of a horn a good ten miles and more!

How was a bull's horn used in hunting? There were two ways. No one is certain which of these characteristics came first but the bull's horn was used by hunters to pass on needed information in the conducting of the hunt. As well,

Carved Conque Shell from Nepal with the Godess Kharaccheri in a Mandala.

India

Turbinella Pyrum

Tahitian Pu-Toka

# megaphones

Fisherman using a megaphone

Echo Lake megaphone

Giant megaphone in Brussels

And now she beats her heart, whereat it groans,
That all the neighbour caves, as seeming troubled,
Make verbal repetition of her moans;
Passion on passion deeply is redoubled:
‘Ay me,’ she cries, and twenty times, ‘Woe, woe’,
And twenty echoes twenty times cry so.

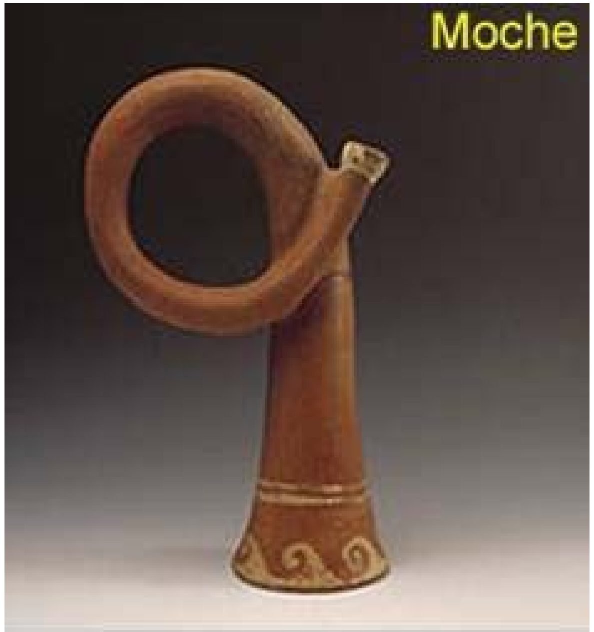
*« Venus and Adonis »*, Shakespeare

# horns as music instruments

- First horns
  - China
  - Oxus
  - Egypt
  - Greece
- Alphorns and thibetan horns
- Brass instruments
- Strings instruments with horns

# First trumpets :

- -4000 BC in China
- -3000 BC in Oxus (Afghanistan-Russia frontier)
- -1500 BC in Egypt
- -300 BC in Greece
- -300 BC in America




Trumpet. 300 CE Larco Museum Collection Lima, Peru.

Peru

Oxus civilization

## ancient Greece

greek *salpinx*

Tutankhamun's trumpets

**Trumpet**

**Egyptian Trumpet**

*"tuuut.....!"*

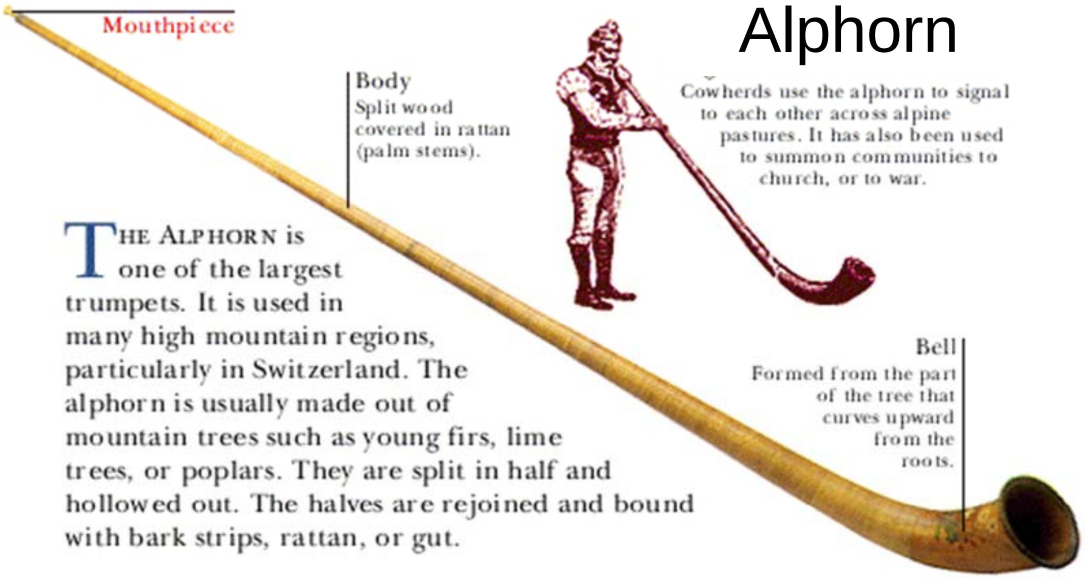
## ancient Egypt

Thibetan horn

Tibetan horn

One of the oldest musical instruments still in use today is the Alphorn,

# Alphorn




Cowherds use the alphorn to signal to each other across alpine pastures. It has also been used to summon communities to church, or to war.

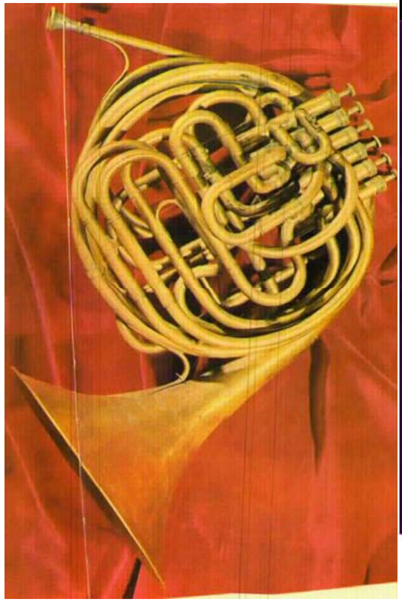
THE ALPHORN is one of the largest trumpets. It is used in many high mountain regions, particularly in Switzerland. The alphorn is usually made out of mountain trees such as young firs, lime trees, or poplars. They are split in half and hollowed out. The halves are rejoined and bound with bark strips, rattan, or gut.

## Horns Made from Tree Trunks Give Odd Musical Tones

HORNS hollowed out of tree trunks are used by native musicians in the Tyrol region of Austria. The novel instruments, said to imitate the tone of a cello, are fitted with stops so that they can play all the notes of the scale. Tree bark is left on the horns in the belief that it has a softening effect on the tones of the instruments.

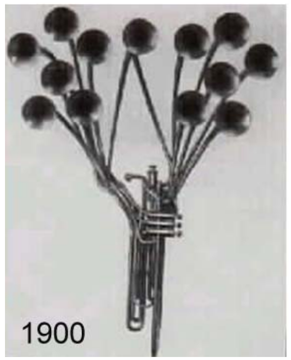
This odd instrument produces tones like those from a cello

A small group of Tyrolese musicians playing on their wooden horns




# Brass instruments from the 19th

METZLER 1860




## The World's Largest Saxophone

THERE is plenty of music in this horn. Standing six feet, seven inches in height, this saxophone is believed to be the largest in the world. In spite of its height it may be played from a sitting position—provided the musician is sufficiently expert.

A tripod support is needed for this saxophone.

## BRASS HORN TWELVE FEET LONG PLAYED BY SIX MIDGETS

Measuring 12 feet in length, a giant horn requires at least two men to play it, as it is so cumbersome that one person cannot carry it. Recently, at a convention in the South, six midget men were necessary to handle the instrument: one at the mouth-

Massive Brass Instrument that Is Played by Two Midgets while Four Others Hold It

piece, another at the keys, and four to support it. This huge band piece was made in Paris and brought to this country about 75 years ago.

brass horn used to load a loudspeaker by Susumu Sakuma

127dB!

vuvuzela

### Vuvuzela: Should the horn be banned from the World Cup?

*June 14, 2010 10:00 AM*

*By POV*

A young soccer fan with a Vuvuzuela horn. (Sebastian Willow/Associated Press)

It's the horn heard around the world, broadcast into living rooms and bars as people tune into the 2010 FIFA World Cup. The vuvuzela, a stadium horn popular with South African soccer fans, has become the symbol of this year's tournament, but not everyone is enjoying the festive instrument's loud sounds.

Some fans have called the noise annoying, especially while watching at home, and those closer to the action are concerned about potential hearing damage.

World Cup organizers are even considering a ban on the 127-decibel horn.

What do you think of the vuvuzela? Should it be banned from World Cup matches?

Should the vuvuzela be banned from World Cup games?

○ Yes

○ No

VoteView Results

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**Violin with Horn for Sounding Box Directs Tone toward Audience**

Built on the same principle as a violin and played in the same manner, a musical instrument with a metal horn instead of the usual sounding box has been patented. Each string is provided with a separate bridge and metal diaphragms to amplify the tone. The sound can be focused directly upon those wishing to hear by pointing the mouth of the horn toward them; greater volume is secured, and the tone, while essentially that of a violin, has something of the quality of a cornet's.

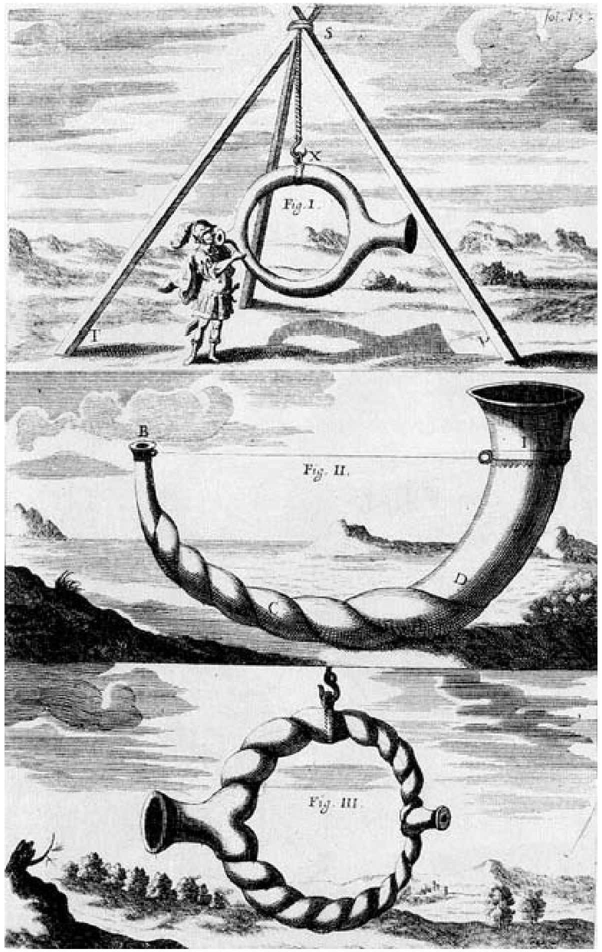
Metal Horn and Diaphragms on This Instrument Give Violin Tones Resonance and Volume




# When strings meet horns

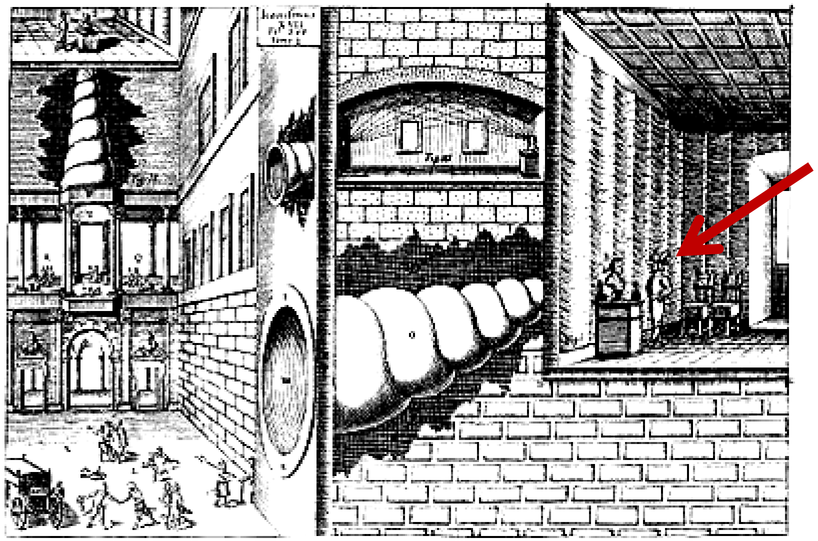

# Non musical purposes

- architectural acoustics
- foghorns
- firemen sirens
- car horns and Klaxon
- military megaphones
- acoustic locators




Propagation Horns
in Phonurgia nova
(Kempten 1673)

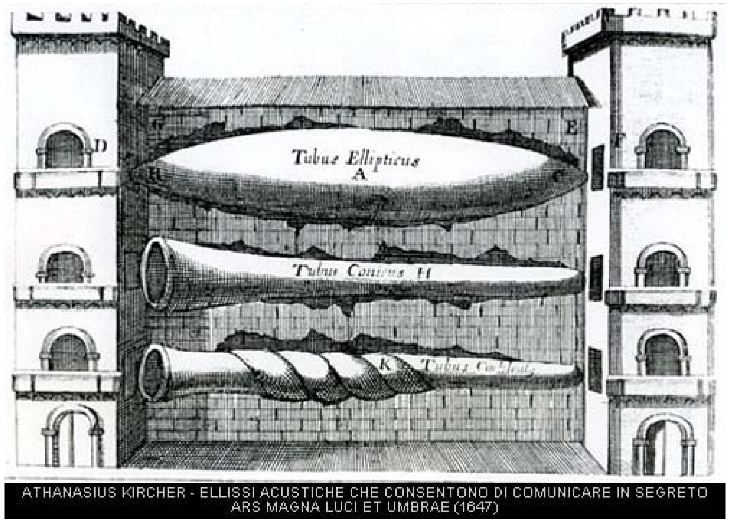
# Architectural purposes



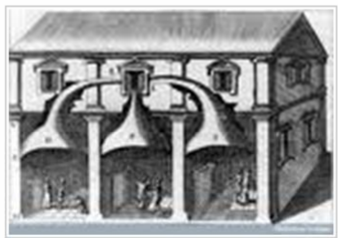
the prince
listening to the
courtiers speaking
outside the
building

Horns used in ancient architecture

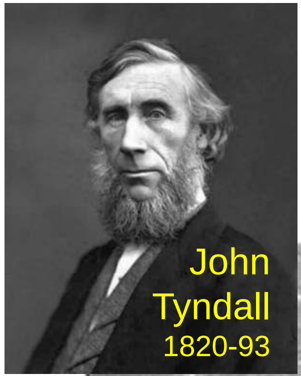

Athanasius Kircher
invented the megaphone
(1608 Germany - 1680 Italy)

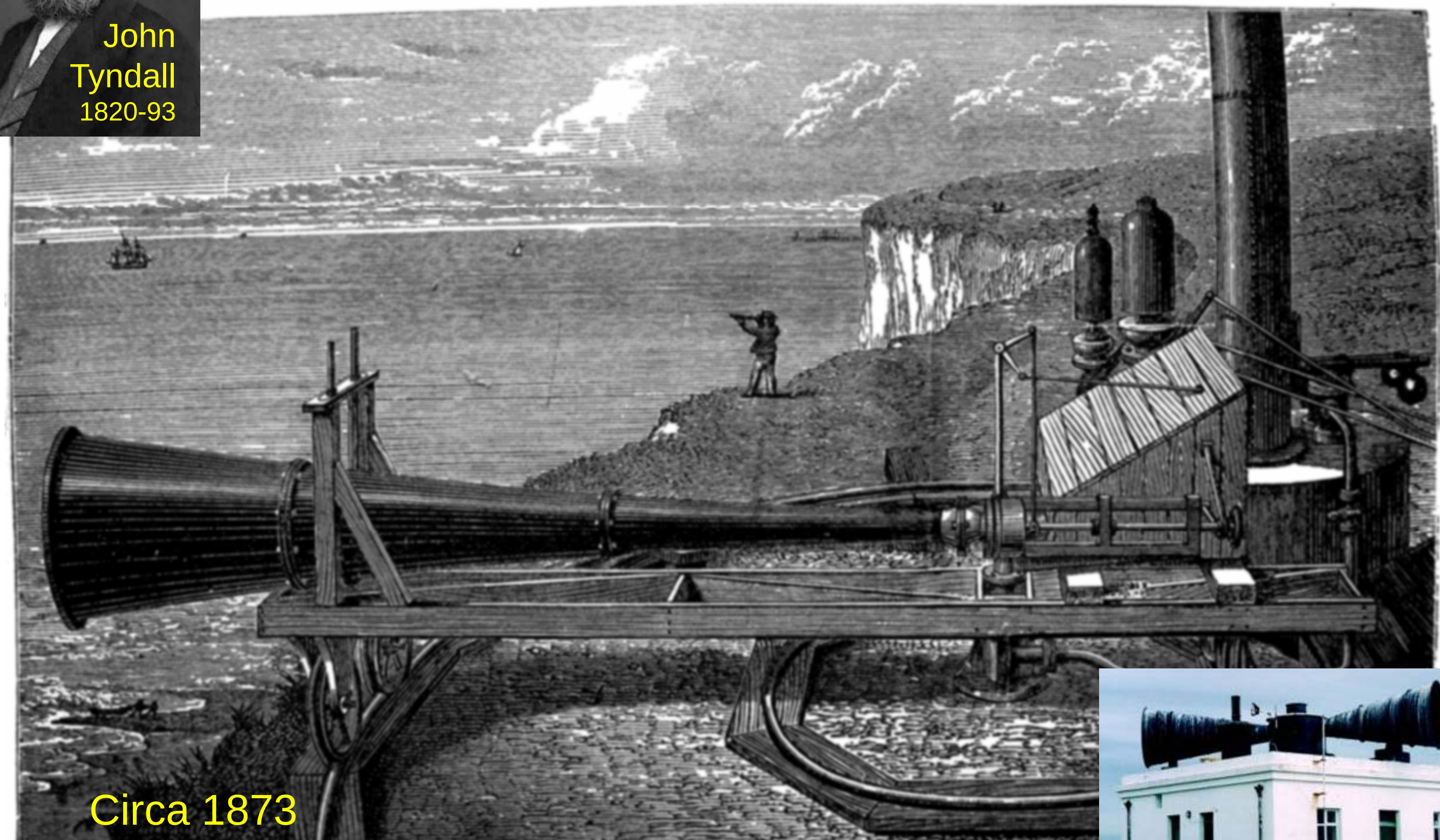






# foghorns




Tyndall's fog-horn

foghorns designed by Lord Rayleigh
Trevose Head Lighthouse, Cornwall (1913)

Edison Uses Klaxons to Warn Men of Fire

A LITTLE more than a year ago the big plant of the Edison Storage Battery Company of East Orange, N. J., burned to the ground.

If another fire should occur today the alarm would be sounded with thirty Klaxon automobile horns installed in various parts of the buildings to warn the employees.

The Klaxons which are a part of the Edison Fire Alarm System are the same kind that Mr. Edison uses on his personal automobiles and that are used today by more than 600,000 other automobilists.

So general is the use of the Klaxon that the word has come to mean "auto horn"—and many horns that are not Klaxons are sold as Klaxons to unsuspecting motorists. The way to be sure is to look for—and *find*—the Klaxon Name-plate.

There is a Klaxon for every kind and size of automobile—for trucks, motor-cycles and motor-boats—from the Hand Klaxonet at $4 to the large Klaxon at $20.

Klaxons are made only by the Lovell-McConnell Mfg. Co., Newark, N. J.

LIFT THE HOOD AND SEE IF THE HORN ON YOUR CAR BEARS THE KLAXON NAME-PLATE.

This nameplate is your protection against substitution

KLAXON

"Mention the Geographic—It identifies you."

Firemen siren


Train horns

# sirens and klaxons

*a siren playing trumpet*


Klaxons

Kopenhagen siren

*victim of pollution*

# military megaphones

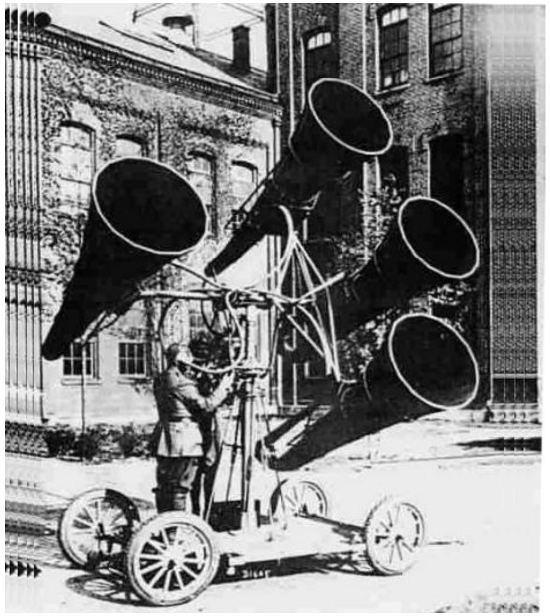
## Bugle Call into Megaphone Gets 'em Up in the Morning

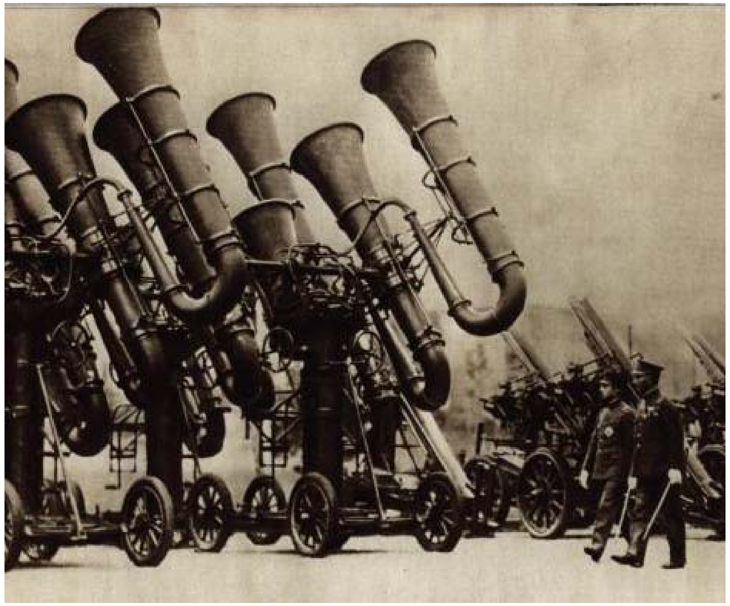
Reveille sounds painfully loud these days to the boys in camp at Fort Jackson, S. C. When the bugler sounds "I can't get 'em up in the morning" he steps to a huge megaphone that blasts his notes throughout the camp. Mess call, he finds, does not require so much artificial amplification.

***The bugler at Fort Jackson, S. C., (left) covers plenty of ground with the help of a big megaphone suspended in a frame at his post***


before radar:

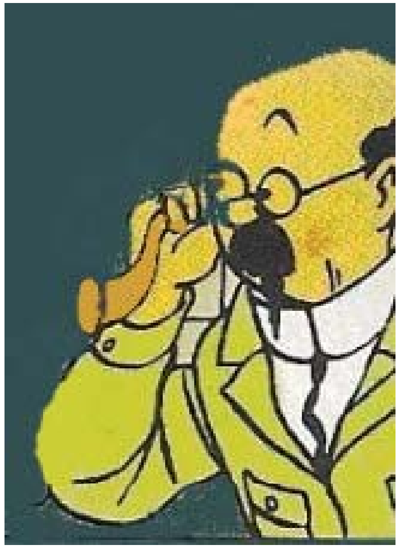
# acoustic locators

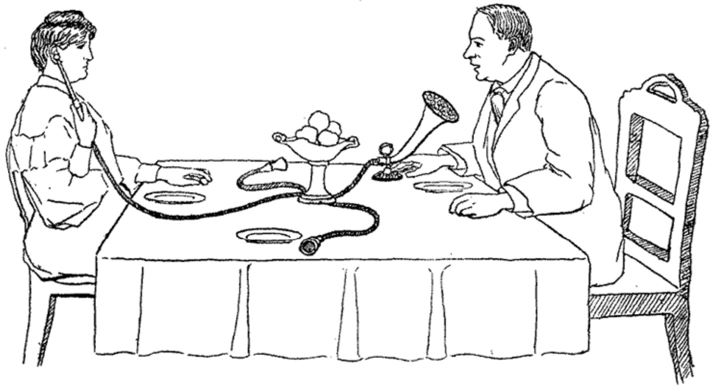




# Hearing aids


In Phonurgia Nova
Athanasius KIRCHER
(1673)





'What, canst thou talk?' quoth she, 'hast thou a tongue?
O would thou hadst not, or I had no hearing.
Thy mermaid's voice hath done me double wrong;
I had my load before, now pressed with bearing;
Melodious discord, heavenly tune harsh sounding,
Ears deep sweet music, and heart's deep sore wounding.

Shakespeare

# Recording and reproducing sounds

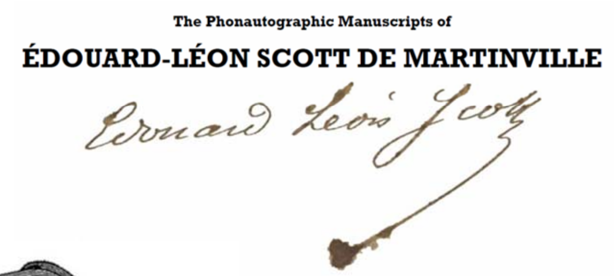
The very first recording of sound was made by Edouard Léon Scott de Martinville with his « phonautographe » before 1857, probably 1854 as written in his writting « *Fixation graphique de la voix* (1857) ». He didn't know how to reproduce those sounds

First successful recording followed by its reproducing (1877) is due to Thomas Alva Edison with his « phonograph ».

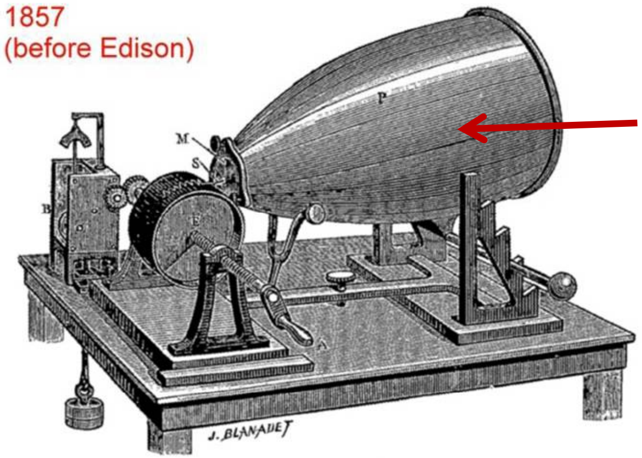
1860-Scott-Au-Clair-de-la-Lune_2.mp3

# Phonautograph


2 phonautograms



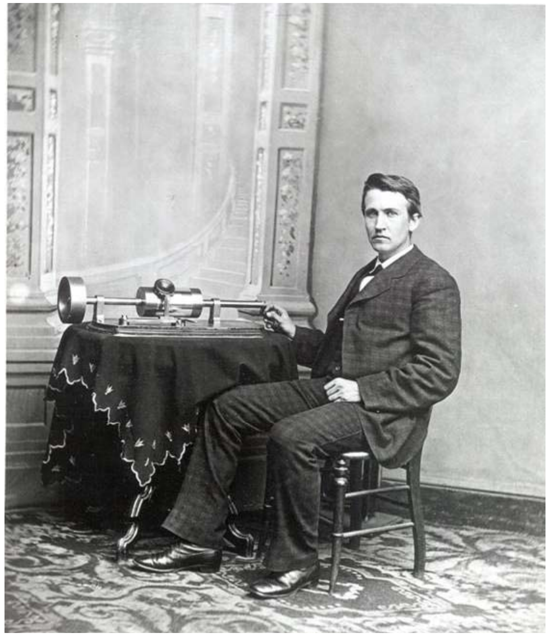

1857
(before Edison)




a simplistic horn

Fig. 17. — Le Phonautographe de Léon Scott de Martinville.

# Thomas Alva Edison



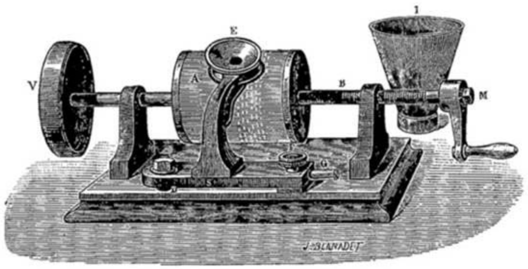


Fig. 20. — Le premier Phonographe d'Édison (1878).

mary_jas_a_little_lamb.mp3

In December of 1877, Edison’s machinist presented him with the completed prototype.

Edison leaned toward the recording horn and shouted out the words “Mary had a little lamb, it's fleece was white as snow, and everywhere that Mary went, the lamb was sure to go.”

It was hardly a moving speech, but then nobody—not even Edison—expected the machine to work the first time.

To his great surprise, a highly distorted but recognizable version of Edison’s words spilled out of the machine when the tinfoil was cranked under the needle once again.

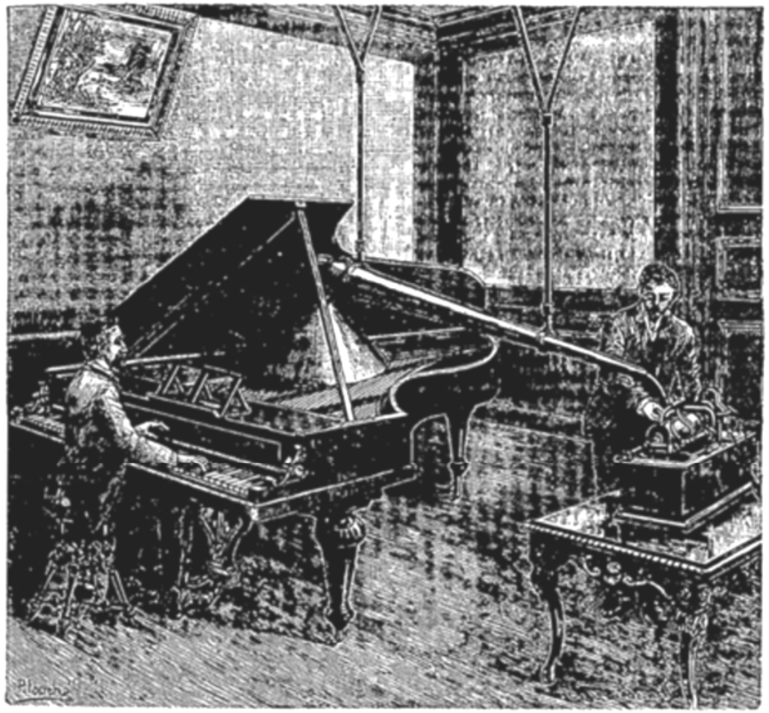
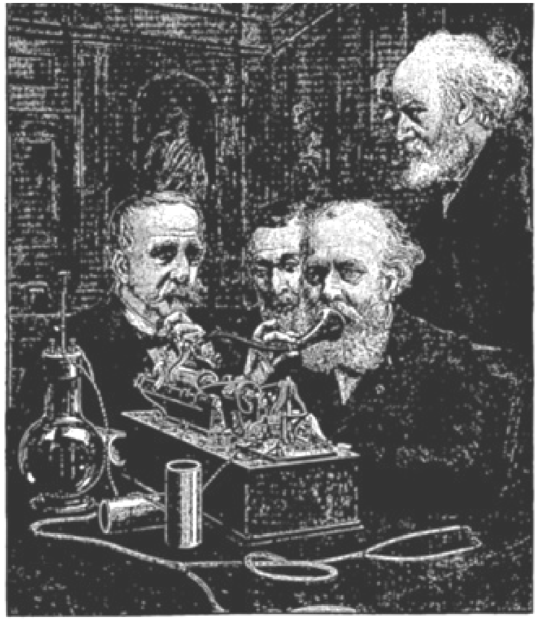


Fig. 31. — Inscription phonographique des sons musicaux.

recording of a piano on a cylinder

Phonograph
Victor V, (1907)

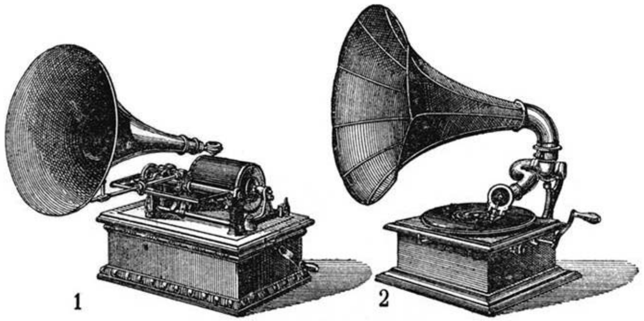
at the French Academy



M. le duc d'Aumale. M. des Cloizeaux. M. Gounod. M. Janssen.
Fig. 72. — Le Phonographe à la séance de l'Académie des Beaux-Arts (27 avril 1889).

Edison Thomas.mp3

recording at Smithsonian



Phonographe : 1. A cylindres ; 2. A disques.

for recording through the horn, the head was replaced by a "recording head"

Dickson first Experimental sound film (1894)

making phonographic record at Smithsonian," 9 February 1916

# Phonographs

Cylinder version

Disk version


*The famous oil painting "His Master's Voice" by Francis Barraud (1895) of the dog Nipper and an Edison-Bell cylinder phonograph, using a horn to load the mechanical transducer to provide the "amplification" necessary to hear the recording.*

**Phonograph Carried as Vanity Case Plays Standard-Size Records**

Carried like a vanity case and about the same size, a collapsible phonograph that plays standard records has been invented.

Portable Phonograph Open to Show Standard-Size Record in Place and Telescoping Horn

The motor is wound by a detachable crank and the horn opens and closes like a telescope so that it can be folded into small space. The entire instrument weighs but little and is said to reproduce tones as satisfactorily as many larger and more expensive machines.

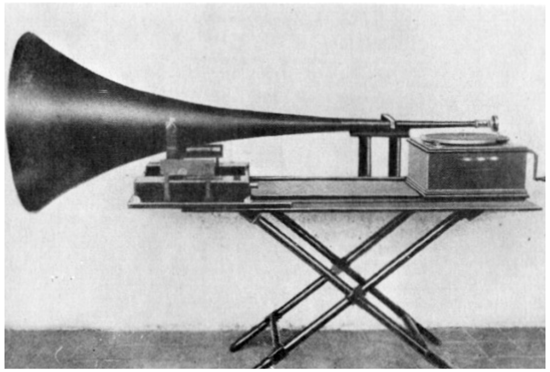
**WATCH-CASE PHONOGRAPH**

CALLED the world's tiniest talking machine, a miniature phonograph has been built into the case of a watch. When wound by the watch stem, a small spring mechanism turns a midget record. Sound is reproduced through a diminutive horn.

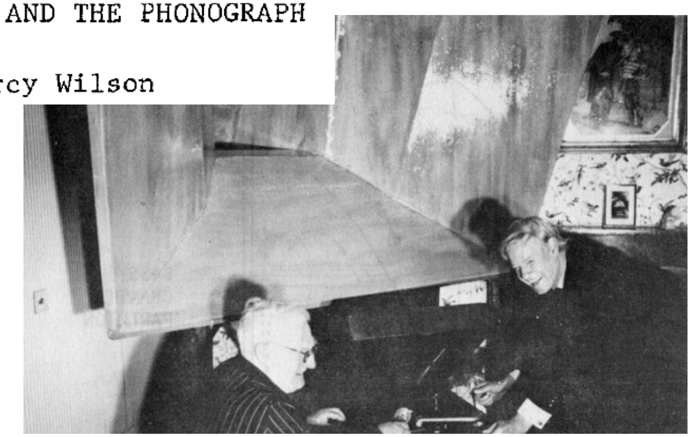

The E.M.G.
Mark Xa
gramophone

HORN THEORY AND THE PHONOGRAPH

Percy Wilson



Balmain Gramophone with 5ft. Straight Horn

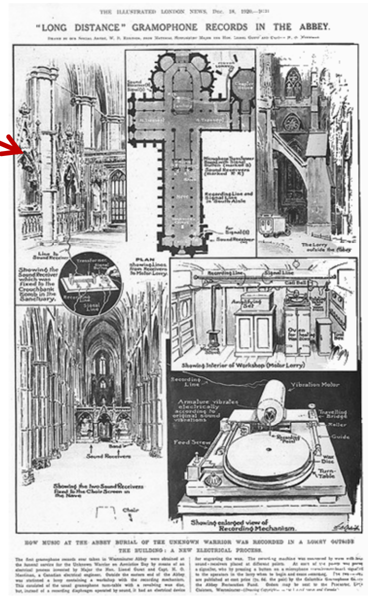


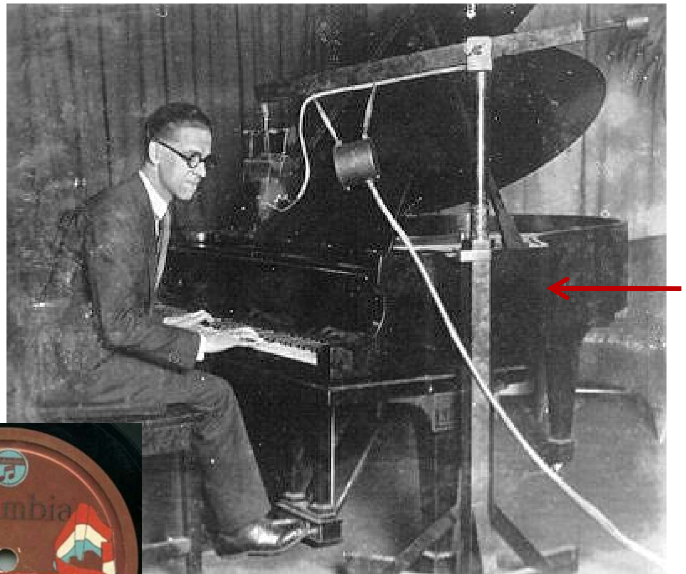
Trapezoidal Horn Fitted to an "Expert" Gramophone

see: « Horn theory and the gramophone »
Percy Wilson in JAES 1974

# Electronic tube time

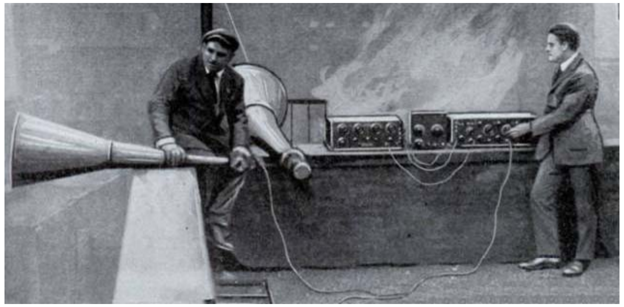
**The world's first commercial electrical recording**
The setup for Guest and Merriman's pioneering electrical recording of the Burial of the Unknown Soldier in Westminster Abbey on 11 November 1920.



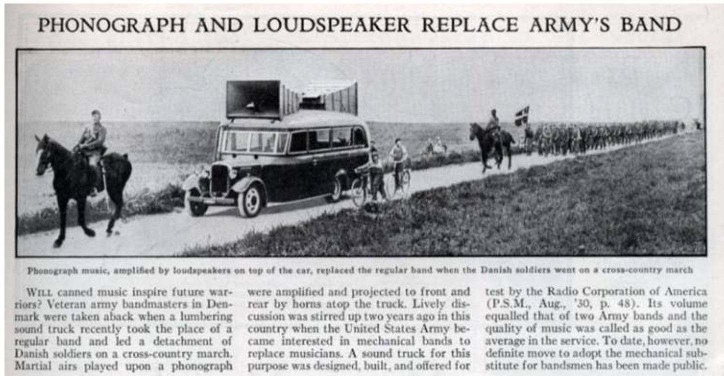




On February 25, 1925, Art Gillham recorded "You May Be Lonesome", a song written by Art Gillham and Billy Smythe.

It was the first master recorded to be released using Western Electric's electrical recording system.

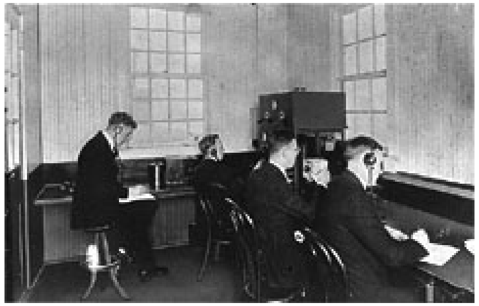
# Radio times

PHONOGRAPH AND LOUDSPEAKER REPLACE ARMY'S BAND

Phonograph music, amplified by loudspeakers on top of the car, replaced the regular band when the Danish soldiers went on a cross-country march

WILL canned music inspire future warriors? Veteran army bandmasters in Denmark were taken aback when a lumbering sound truck recently took the place of a regular band and led a detachment of Danish soldiers on a cross-country march. Martial airs played upon a phonograph were amplified and projected to front and rear by horns atop the truck. Lively discussion was stirred up two years ago in this country when the United States Army became interested in mechanical bands to replace musicians. A sound truck for this purpose was designed, built, and offered for test by the Radio Corporation of America (P.S.M., Aug., '30, p. 48). Its volume equalled that of two Army bands and the quality of music was called as good as the average in the service. To date, however, no definite move to adopt the mechanical substitute for bandsmen has been made public.

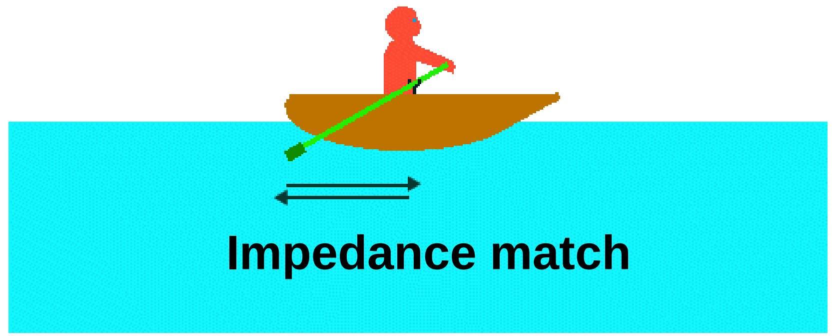


## 1920

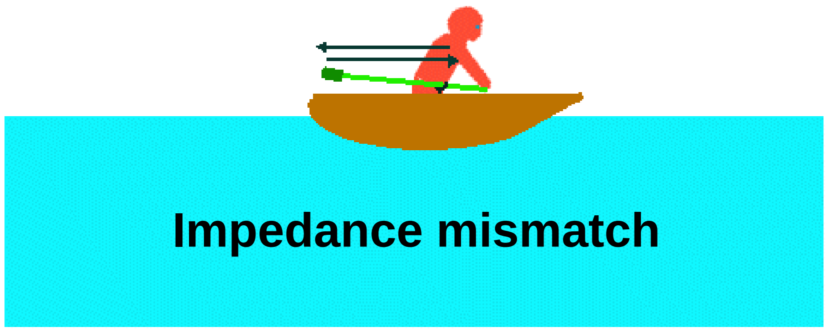
In Pittsburgh, Westinghouse radio station KDKA schedules the first commercial radio broadcast—the Harding-Cox presidential election results.

The first radio broadcast microphone

# a question of conversion efficiency of the energy



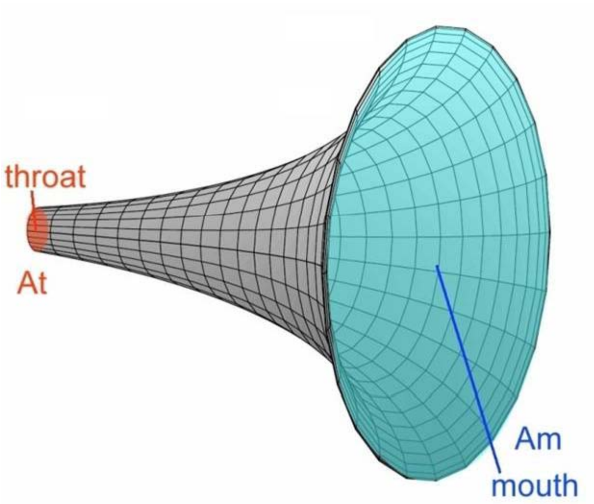

A boat at the interface between air and water.

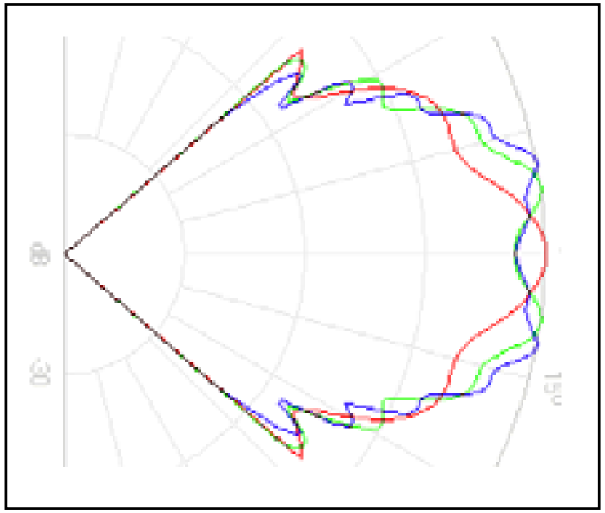



To move the boat it is far more efficient to action the oars inside the water than in the air.

characteristic impedance of air is about 420 Pa s/m
characteristic impedance of water is about 1.5 MPa s/m
(nearly 3600 times higher)

# the purpose of horns



- to progressively adapt the acoustical impedance from the throat to the mouth

- to control the dispersion of the waves outgoing from the horn

The specific acoustic impedance *z* of an acoustic component (in N·s/m$^3$)
is the ratio of sound pressure *p* to particle velocity *v* at its connection point:

$$z = \frac{p}{v} = \frac{I}{v^2} = \frac{p^2}{I}$$

*Where:*

*p* is the sound pressure (N/m$^2$ or Pa),
*v* is the particle velocity (m/s), and
*I* is the sound intensity (W/m$^2$)

**Sound power:**
**if no loss inside the horn:**

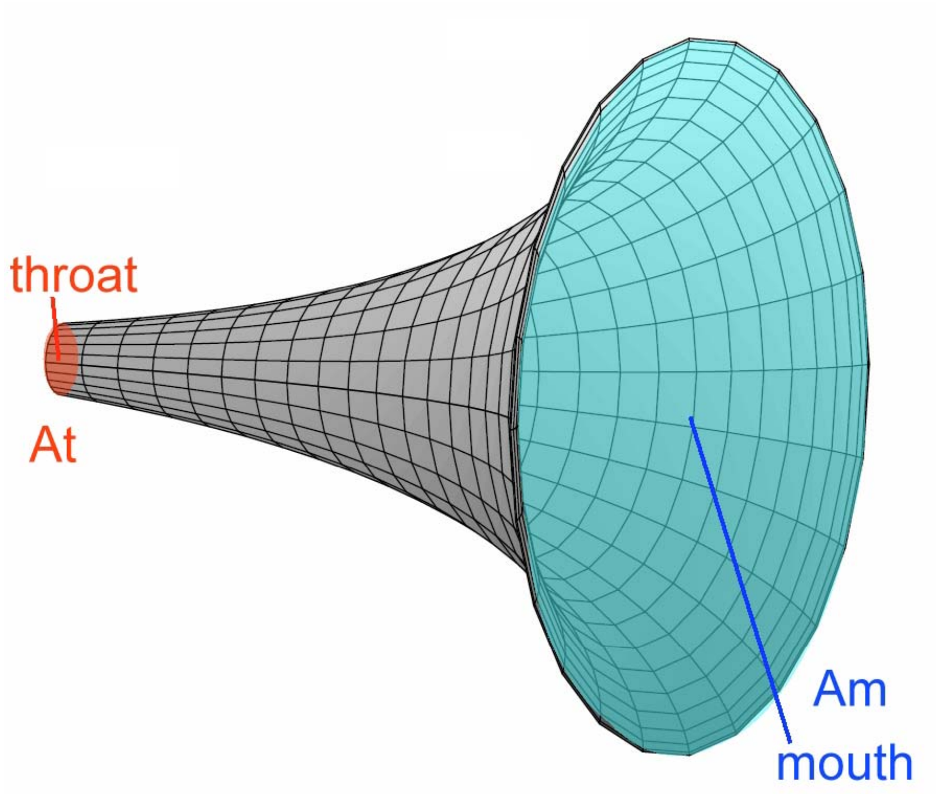
$$Pm = Pt$$

**Sound intensity:**
**it is the sound power per unit area**

$$It = Pt / At$$
$$Im = Pm / Am$$

**Thus:**

$$It / Im = Am / At$$




For a given sound intensity the intensity at throat will be proportionnal to the ratio of the mouth area on the throat area

## acoustical impedance adaptation

the horn creates a higher acoustic impedance for the transducer to work into, thus allowing more power to be transferred to the air.

- increase of efficiency (up to 50% )

  use of low power amplifiers

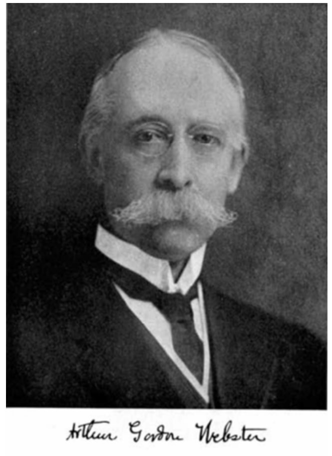
  lower distortion due to smaller displacement of the membrane

- acoustical gain (10dB and more)

## control of the dispersion of the sound waves

- depends on the need of a narrow or a wide spread of the sound in the room

# Webster's equation



Webster's equation for a constant bulk modulus:

$$\frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = \frac{\partial^2 p}{\partial x^2} + \frac{1}{S}\frac{dS}{dx}\frac{\partial p}{\partial x}$$

where :

$$c^2 = B/\rho$$

The only assumption which has been made is that the wave is a function of one parameter

No further assumption is made about the shape of the isophase surfaces. Plane waves, spherical waves, or other wavefront shapes can be assumed within the framework of Webster's equation.

# One parameter hypothesis or 1P hypothesis

1) pressure p depends only on a single coordinate

2) only longitudinal waves propagates from throat to mouth

**Single Mode,**

Wave propagation inside cylindrical pipes can be described by a one-dimensional theory. Waves set up inside approximately cylindrical instruments have plane wavefronts of nearly identical pressure perpendicular to the wall. They propagate just like in open space but are partially reflected and partially transmitted by any change of cross-sectional area within the pipe. They are described by the one-dimensional (z-axis) wave equation

$$\frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = \frac{\partial^2 p}{\partial z^2}. \qquad (3.1)$$

The complex solution for the pressure $p(z,t)$ is

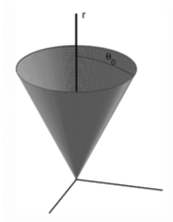
$$p(z,t) = (Ae^{-jkz} + Be^{jkz})e^{j\omega t} \qquad (3.2)$$

with wave number $k$, wave length $\lambda$ while $\lambda = \frac{2\pi}{k}$ and $\omega = 2\pi f$. $A$ and $B$ are the complex amplitudes of the forward resp. backward travelling pressure waves.

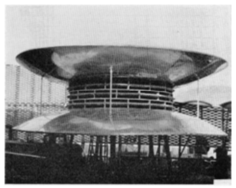
Theory tells us:

only 3 shapes for the wavefront and for the infinitesimal sound duct obey to the 1P hypothesis:

*The cylindrical boundary.*

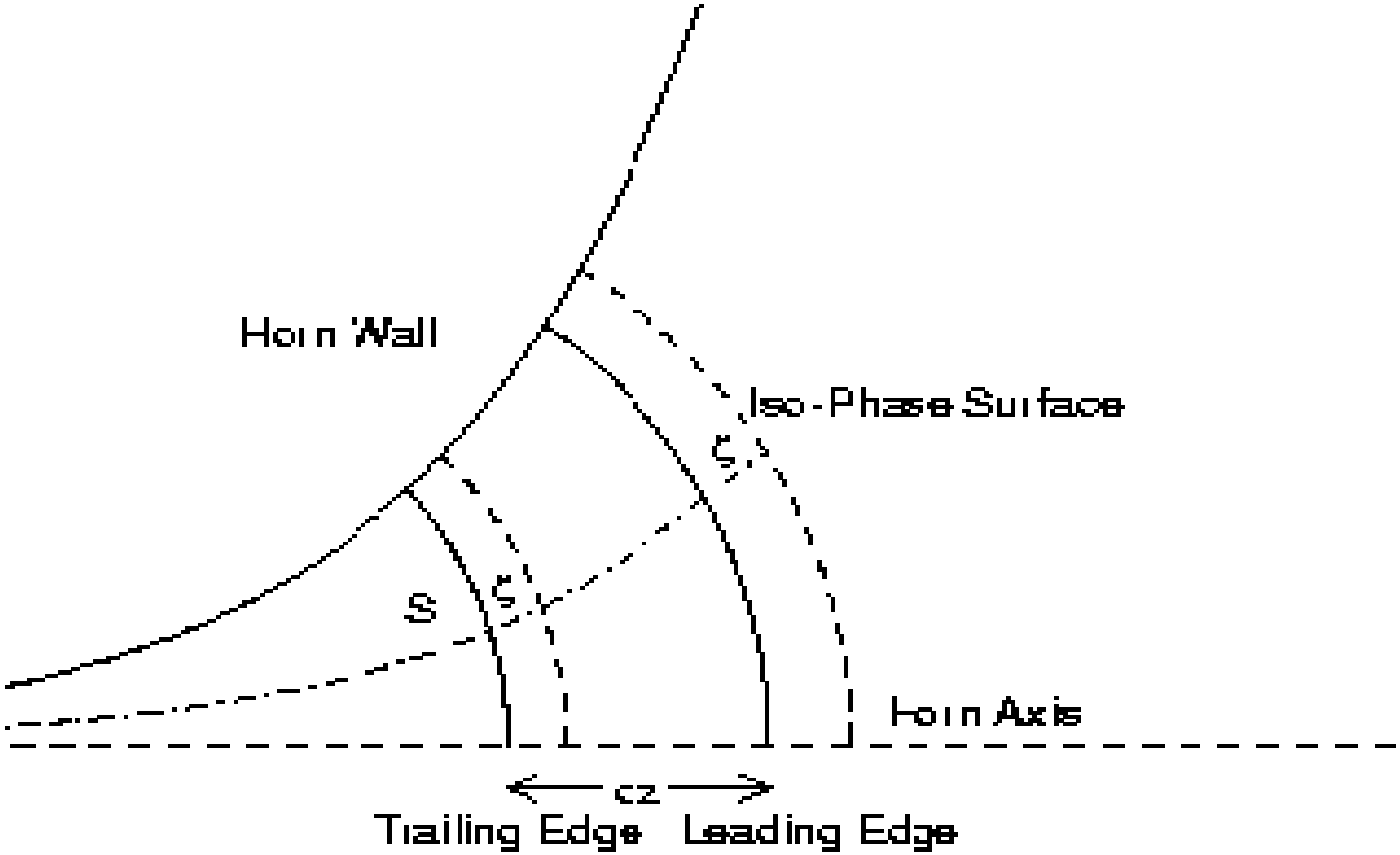


*The conical boundary.*



Complete 360° cylindrical-wavefront speaker.

| wavefront shape: | duct shape: |
|---|---|
| planar | cylindrical tube |
| spherical cap | conical horn |
| cylinder | toroidal horn |




- isophase surfaces are parallel
- isophase surfaces are perpendicular to horn wall
- isobare (= isopressure) surfaces are parallel to isophase

# William Hall (1932)

## COMMENTS ON THE THEORY OF HORNS

By William M. Hall
*Massachusetts Institute of Technology*

Abstract

The present theory of horns makes a number of assumptions and approximations relative to the nature of the motion within the horns. This paper discusses these assumptions and presents the results of an experimental investigation of the sound fields within a conical and an exponential horn. These results show the conditions actually existing in these particular cases, and therefore indicate to a certain extent the validity of the above assumptions and approximations.

at the frequencies measured. Change in its location produced no noticeable effect on the output of another transmitter mounted near it, and the general consistency of the results obtained tend to substantiate the measurements.

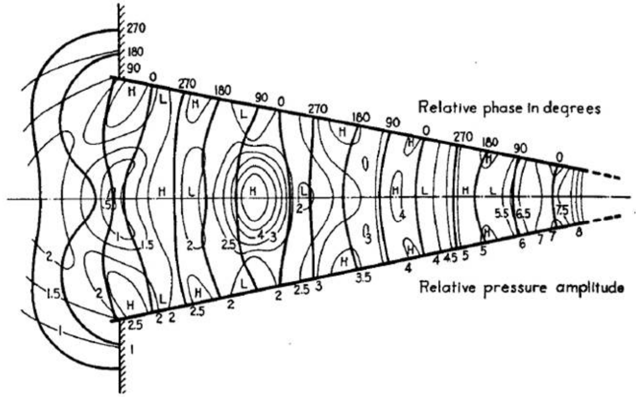



Plate III. *Relative amplitude and phase of pressure within conical horn at 800 c.p.s.*

Diameter of mouth of horn 76 cm.
Length of horn 183 cm.

The investigation was limited to the case of infinitesimal waves. Therefore no information was obtained relative to the assumptions and approximations of the classical theory of sound as they have been outlined above. However, the investigation did give considerable informa-



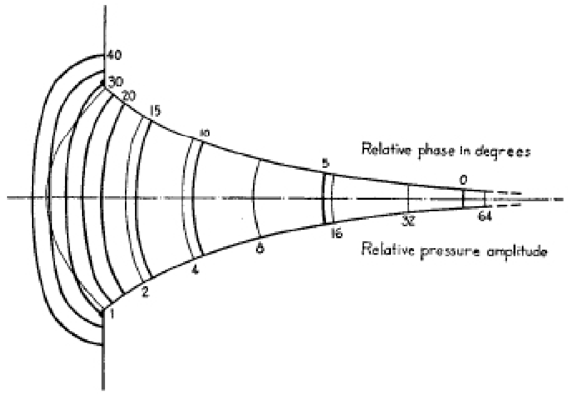



Plate I. *Relative amplitude and phase of pressure within exponential horn at 120 c.p.s.*

Diameter of mouth of horn 72 cm.
Length of horn 173 cm.
Area given by $A = A_0 e^{.046x}$.

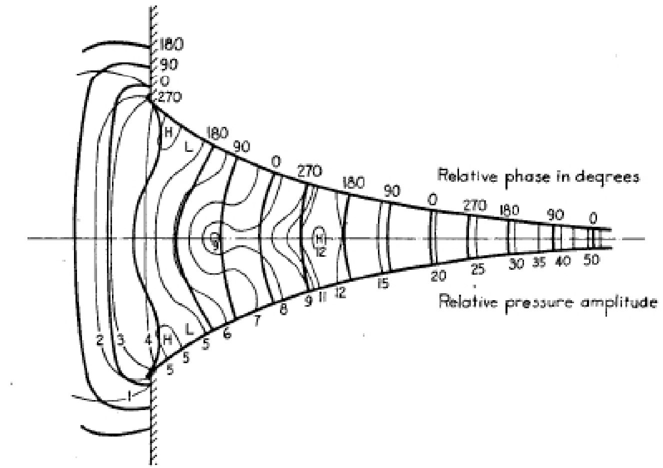


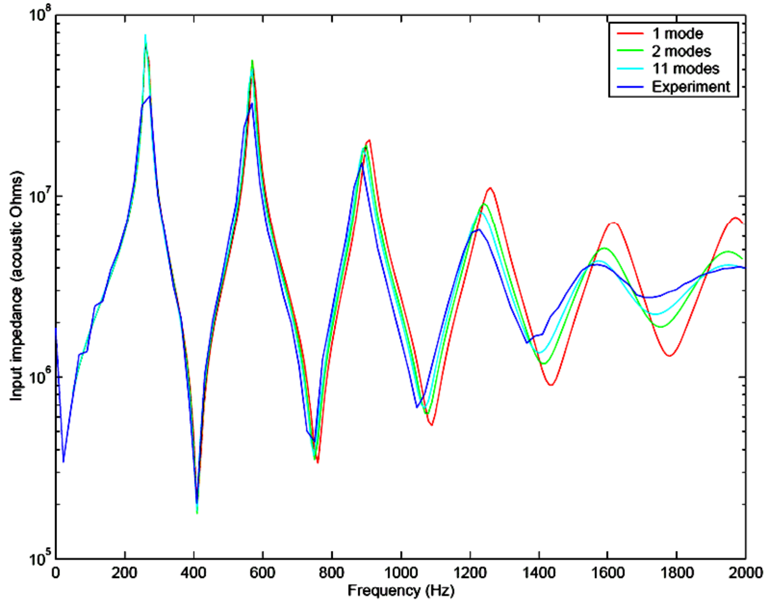

Plate II. *Relative amplitude and phase of pressure within exponential horn at 800 c.p.s.*

# For horns for which p depends on 2 or 3 coordinates we have to take in account high order modes (HOM).

The general solution to the Helmholtz equation in a 2D waveguide can be written

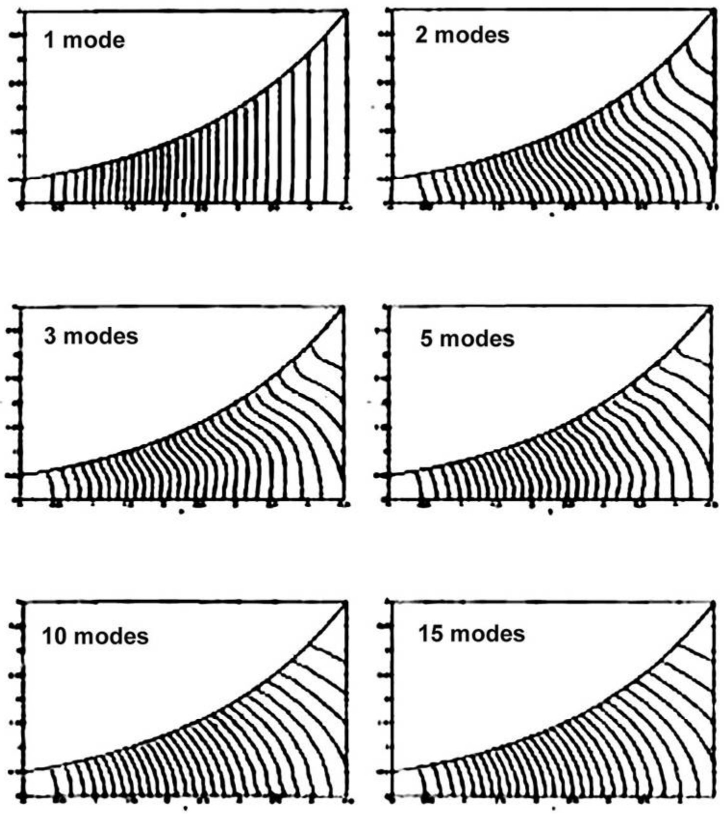
$$p(x,y) = (Ae^{-i\sqrt{\omega^2/c^2-\zeta^2}x} + Be^{i\sqrt{\omega^2/c^2-\zeta^2}x})(Ce^{-i\zeta y} + De^{i\zeta y}),$$

where $\zeta = n\pi c/(2a)$, $n = 0, 1, 2, \ldots$ . The cut-off frequency $f_c$ of a higher order mode is associated with the longitudinal wavenumber becoming imaginary. This occurs at $\omega_c = n\pi c/(2a)$ or $f_c = nc/(4a)$. With $a = 0.05$ m and $c = 345$ m/s, we have $f_c = 1725$ Hz for $n = 1$. At 850 Hz, the amplitude of the first non-planar mode will decay with a factor of around $10^6$ within a distance of $\ell = 0.5$ m. Thus, setting the upper frequency bound to 850 Hz, the higher mode contamination at $\Gamma_{in}$ can thus be expected to be negligible.




Trumpet section input impedance as calculated by Kemp

Isobare curves inside a horn




to take in account the fundamental mode only is not sufficient to rely simulation to measurement

# The quest for efficiency, the quest for loading


The Construction and Performance of a 25ft. Logarithmic Horn.

R.P.G. Denman, "In Search of Quality", Wireless World, Vol. 25 pp97-101 (July 31, 1929)

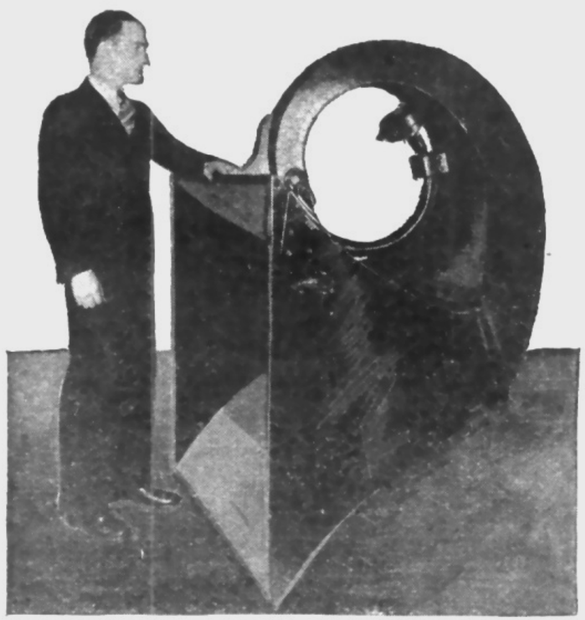
Mr. Kei Ikeda’s listening room


THE LOUDEST OF LOUD SPEAKERS

Western Electric

Julien Sullerot’s WE15A replica on top of an Onken W enclosure

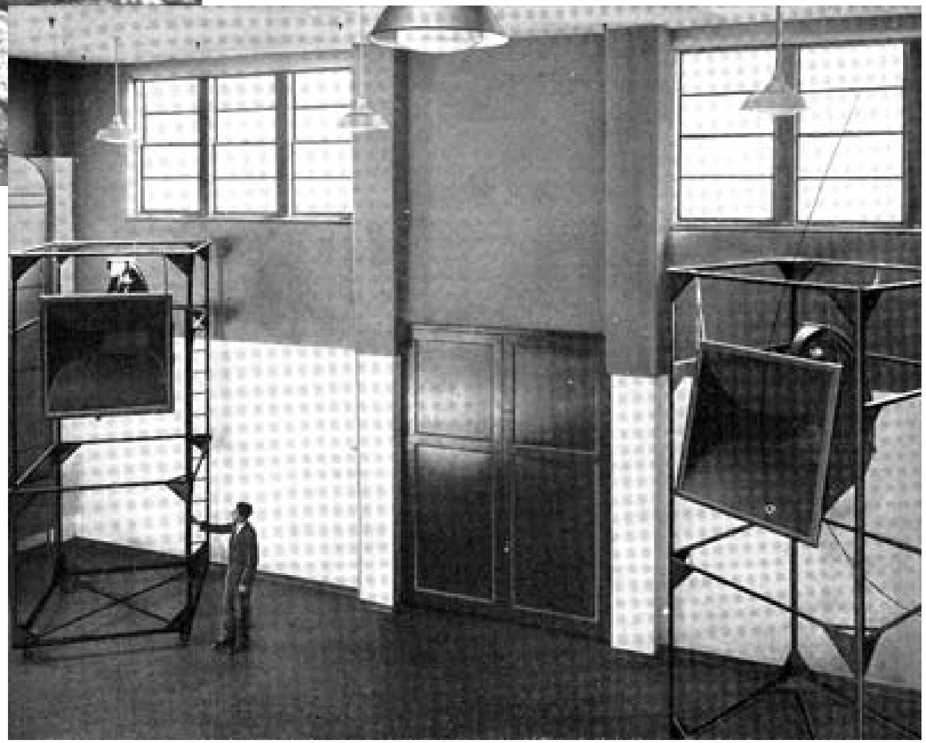
In 1926, the Vitaphone system uses the famous driver WE 555-W coupled to the WE15A horn
(100Hz to 5kHz)



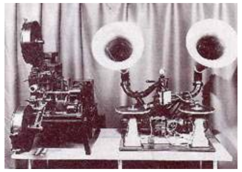
Horns as tall as a man are placed behind the silver screen. This is one of the giants which the audience never sees, but which is vital in making the movies talk.

Acoustic  studies using the WE15A .

See on right Wente's planar waves tube he used to measure the power response of the WE555 driver

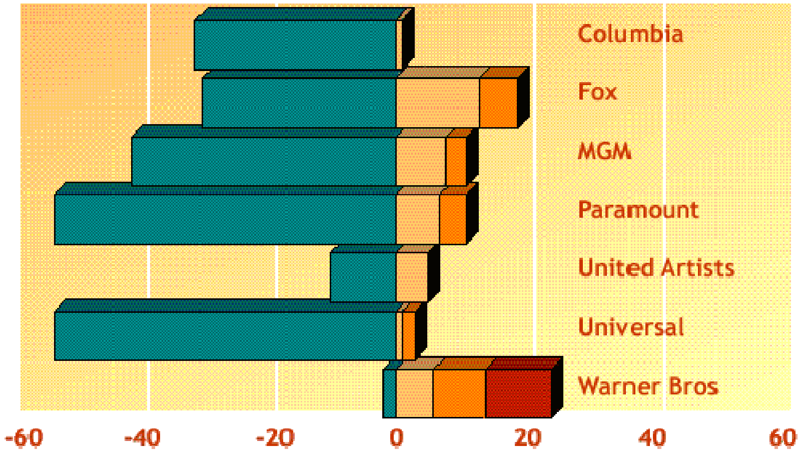


development  of  the *Stereophonic* system (commercially introduced in 1933)

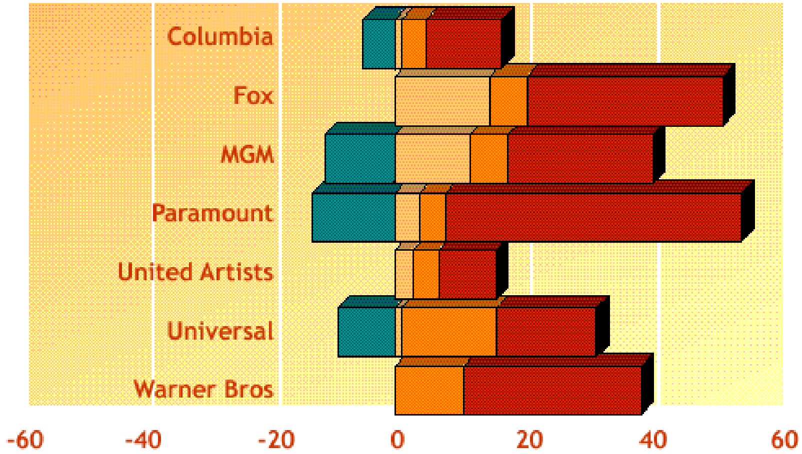


# Hollywood goes for sound
© David Fisher

## Majors' film releases in 1928




## Majors' film releases in 1929

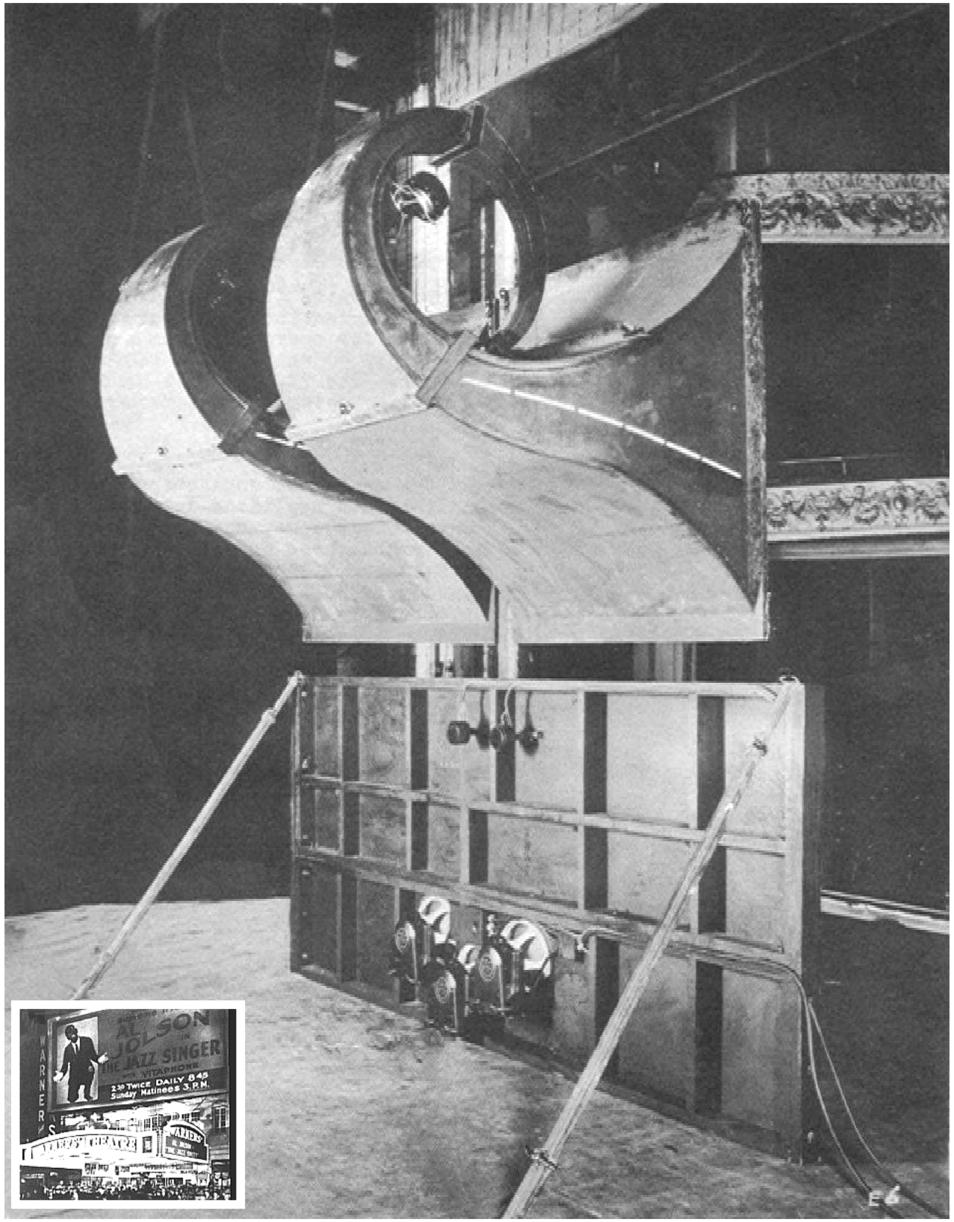



In 1928 the seven Hollywood majors released 220 silent films and 74 sound films, of which 41 had only synchronised music and sound effects, 23 were part talkie and only 10, all from Warner Bros, were all talkie. Universal and Paramount in particular were still heavily committed to silent productions.

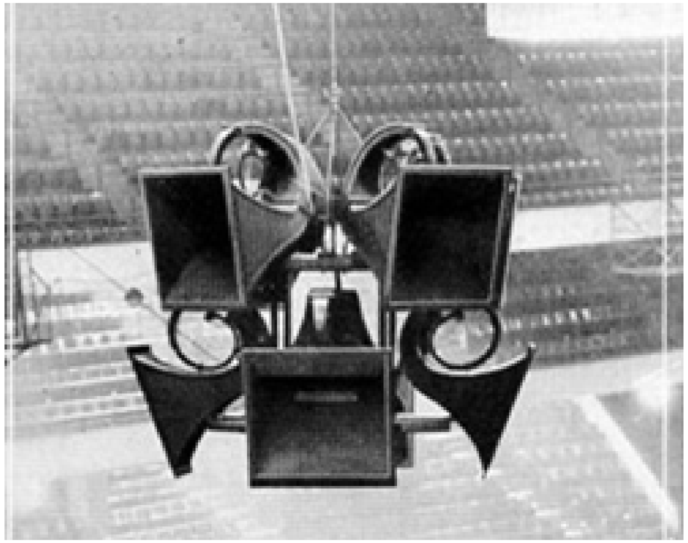
In 1929 the balance had shifted radically. By now there were 166 all talkie releases, 50 part talkie and 36 with only music and effects. Silent releases had dwindled to only 38 out of a total of 290.

silent films — synchronized music and sound effects — part talkie — all talkie

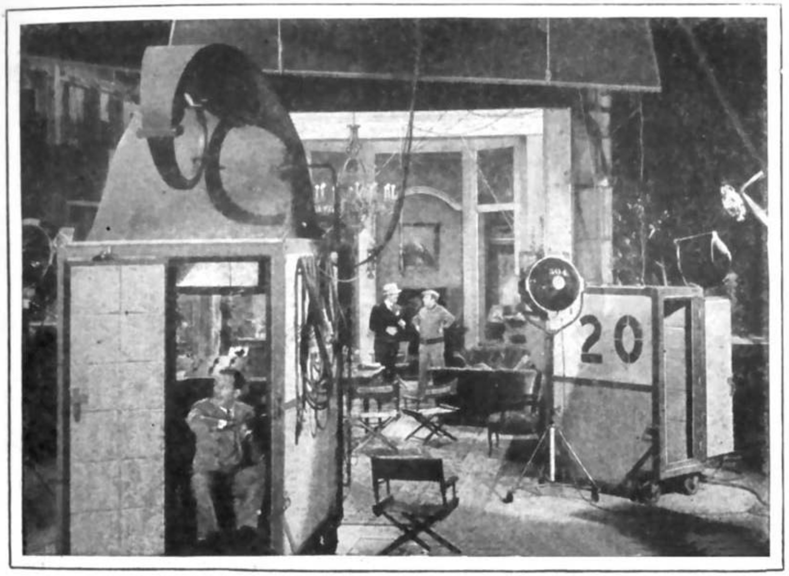

1926 "Don Juan" first talking movie, 1927 "The Jazz Singer"




# Talking Devices are Revolutionizing Movies!



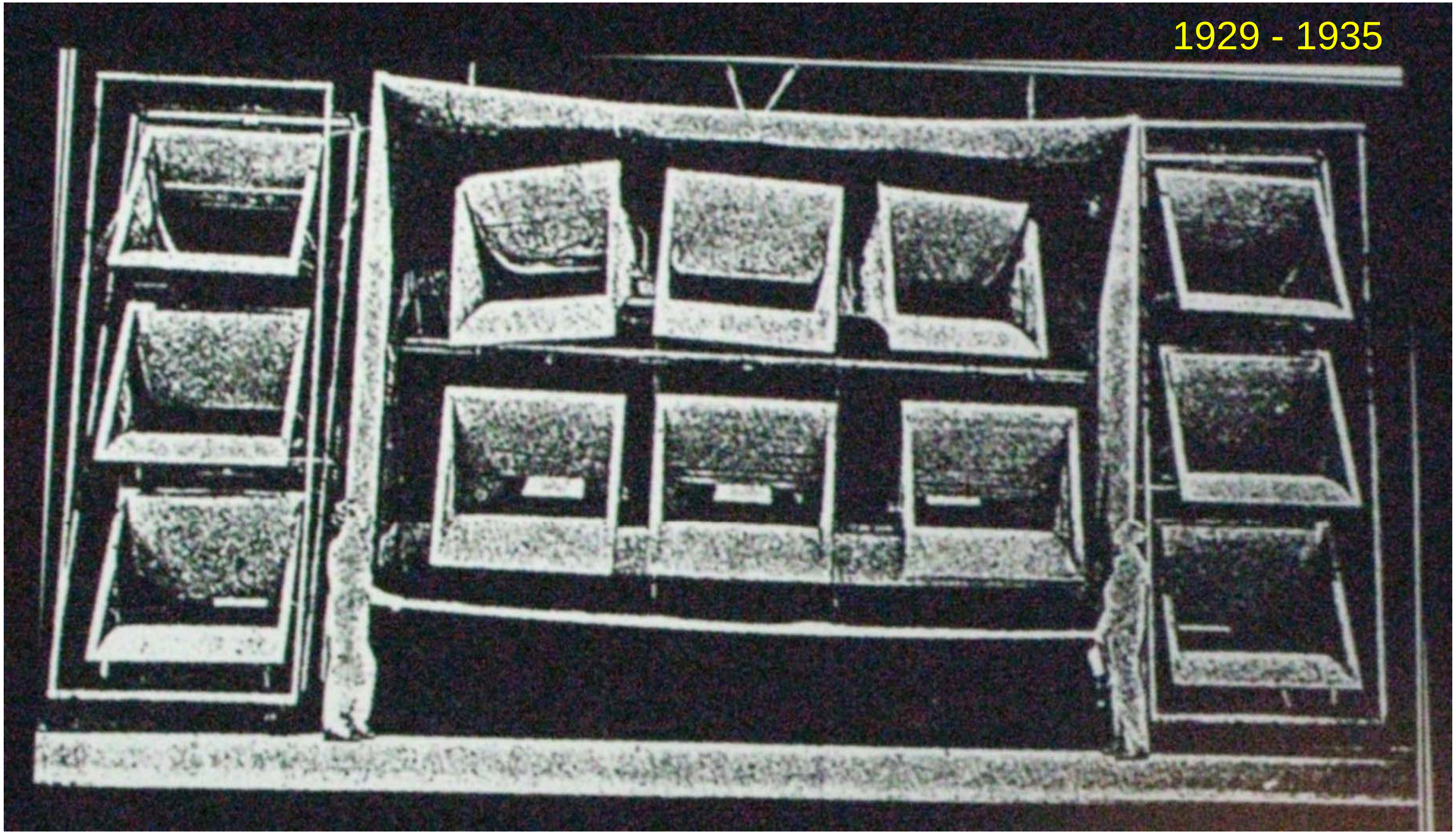
Talkies Created New Movie Jobs, But Put Many Musicians Out of Work



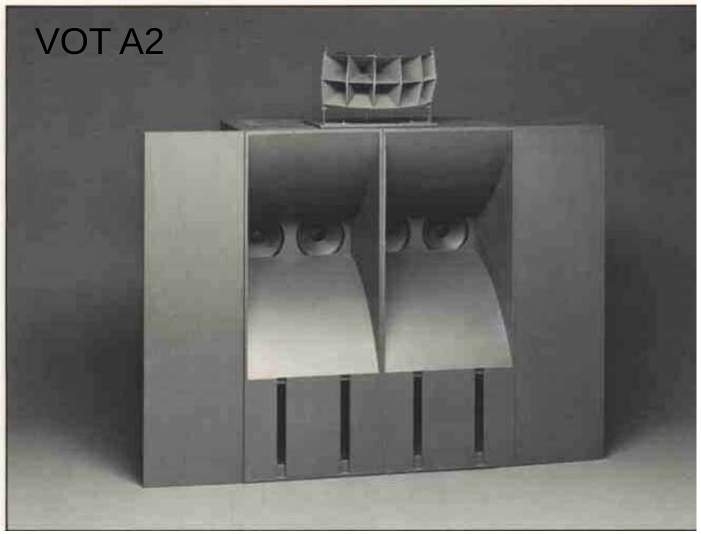
This maze of electrical equipment is used in making sound pictures which have put thousands of musicians out of work, replacing theater orchestras.

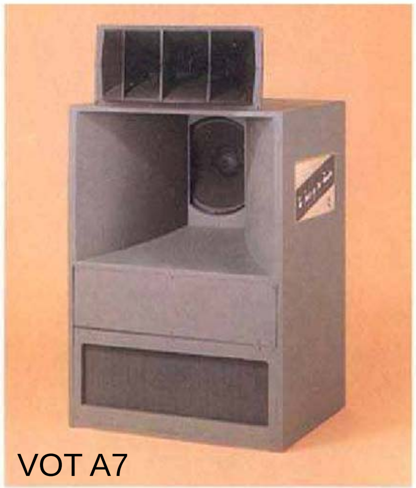
# Talking Devices are Revolutionizing Movies!


1929 - 1935



Sid Grauman's Chinese theater in Hollywood inaugurated in 1927

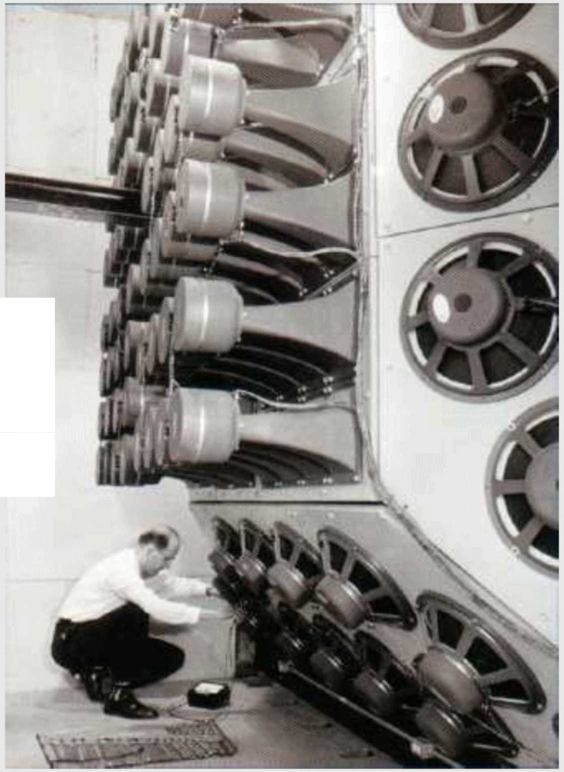


VOT A2


VOT A7

ALTEC LANSING
Voice of the Theatre®

# multiple horns

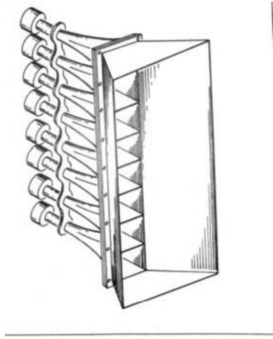
1960s



80 x JBL375
+
40 x JBL150H

600 acoustic watts Generator for vibration analysis

© Harman International, Courtesy Mark Gander and John Eargle



re 16-77 Whelen Engineering horizontal diffraction horn with multiple drivers. (Courtesy Whelen Engineering Co., Inc.)

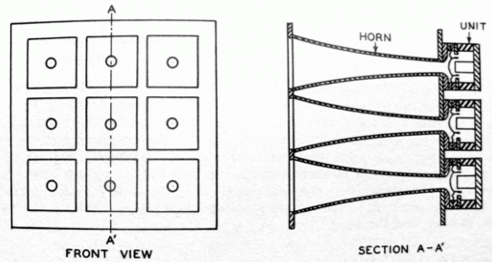
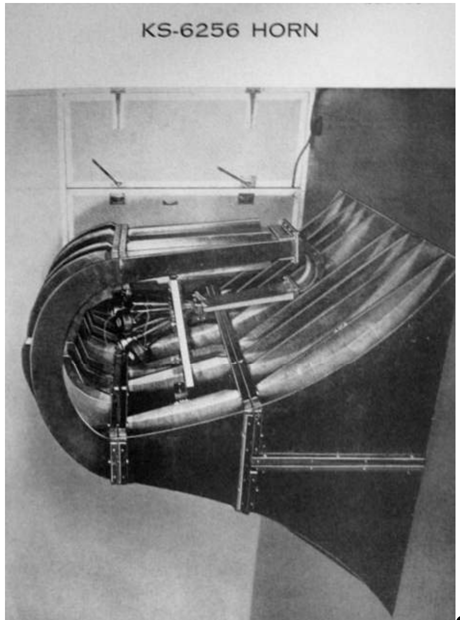
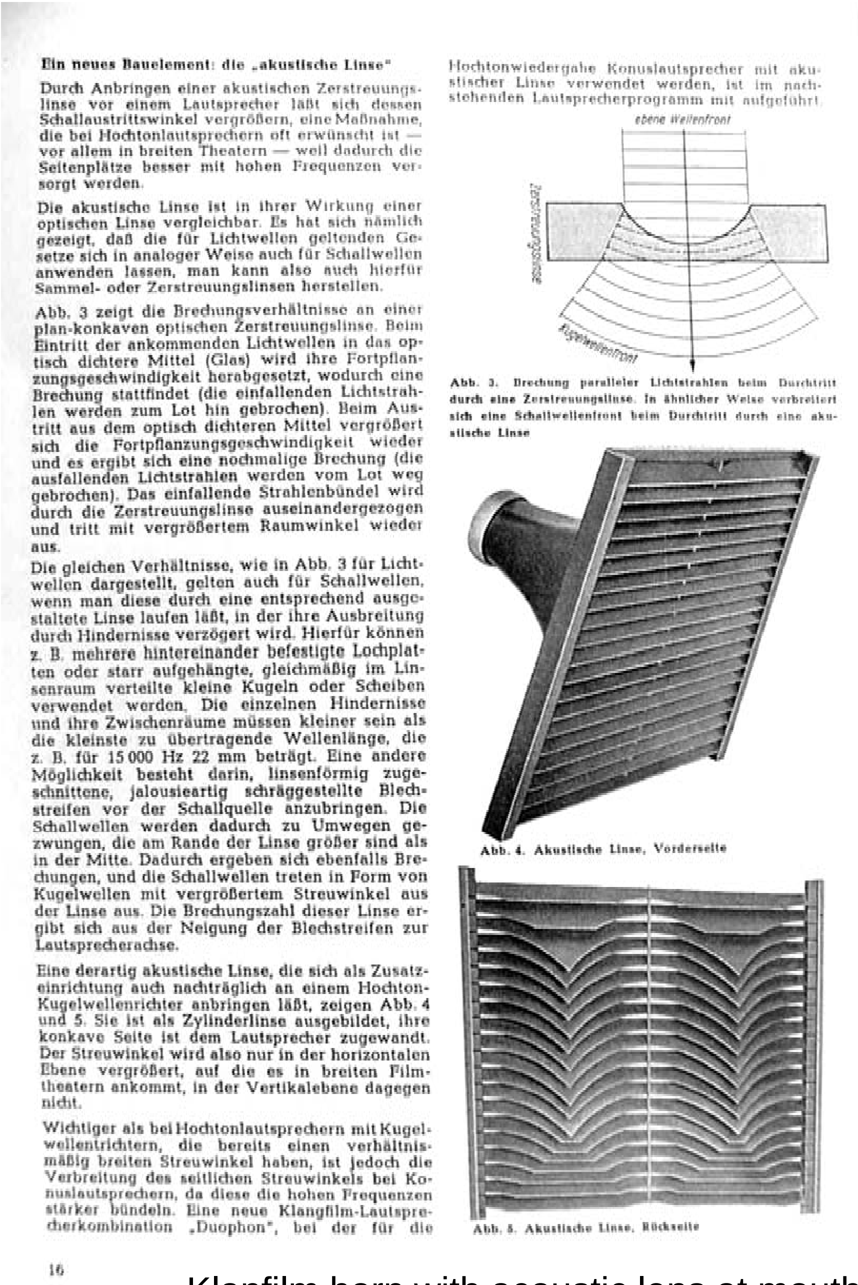



FIG. 7.24. A multiple-horn, single-channel system for high-power announce systems.



# Related to horns

- acoustic lenses
- diffractor couplers (Karlson coupler)
- reflectors



### Ein neues Bauelement: die „akustische Linse"

Durch Anbringen einer akustischen Zerstreuungslinse vor einem Lautsprecher läßt sich dessen Schallaustrittswinkel vergrößern, eine Maßnahme, die bei Hochtonlautsprechern oft erwünscht ist — vor allem in breiten Theatern — weil dadurch die Seitenplätze besser mit hohen Frequenzen versorgt werden.

Die akustische Linse ist in ihrer Wirkung einer optischen Linse vergleichbar. Es hat sich nämlich gezeigt, daß die für Lichtwellen geltenden Gesetze sich in analoger Weise auch für Schallwellen anwenden lassen, man kann also auch hierfür Sammel- oder Zerstreuungslinsen herstellen.

Abb. 3 zeigt die Brechungsverhältnisse an einer plan-konkaven optischen Zerstreuungslinse. Beim Eintritt der ankommenden Lichtwellen in das optisch dichtere Mittel (Glas) wird ihre Fortpflanzungsgeschwindigkeit herabgesetzt, wodurch eine Brechung stattfindet (die einfallenden Lichtstrahlen werden zum Lot hin gebrochen). Beim Austritt aus dem optisch dichteren Mittel vergrößert sich die Fortpflanzungsgeschwindigkeit wieder und es ergibt sich eine nochmalige Brechung (die ausfallenden Lichtstrahlen werden vom Lot weg gebrochen). Das einfallende Strahlenbündel wird durch die Zerstreuungslinse auseinandergezogen und tritt mit vergrößertem Raumwinkel wieder aus.

Die gleichen Verhältnisse, wie in Abb. 3 für Lichtwellen dargestellt, gelten auch für Schallwellen, wenn man diese durch eine entsprechend ausgestaltete Linse laufen läßt, in der ihre Ausbreitung durch Hindernisse verzögert wird. Hierfür können z. B. mehrere hintereinander befestigte Lochplatten oder starr aufgehängte, gleichmäßig im Linsenraum verteilte kleine Kugeln oder Scheiben verwendet werden. Die einzelnen Hindernisse und ihre Zwischenräume müssen kleiner sein als die kleinste zu übertragende Wellenlänge, die z. B. für 15 000 Hz 22 mm beträgt. Eine andere Möglichkeit besteht darin, linsenförmig zugeschnittene, jalousieartig schräggestellte Blechstreifen vor der Schallquelle anzubringen. Die Schallwellen werden dadurch zu Umwegen gezwungen, die am Rande der Linse größer sind als in der Mitte. Dadurch ergeben sich ebenfalls Brechungen, und die Schallwellen treten in Form von Kugelwellen mit vergrößertem Streuwinkel aus der Linse aus. Die Brechungszahl dieser Linse ergibt sich aus der Neigung der Blechstreifen zur Lautsprecherachse.

Eine derartig akustische Linse, die sich als Zusatzeinrichtung auch nachträglich an einem Hochton-Kugelwellenrichter anbringen läßt, zeigen Abb. 4 und 5. Sie ist als Zylinderlinse ausgebildet, ihre konkave Seite ist dem Lautsprecher zugewandt. Der Streuwinkel wird also nur in der horizontalen Ebene vergrößert, auf die es in breiten Filmtheatern ankommt, in der Vertikalebene dagegen nicht.

Wichtiger als bei Hochtonlautsprechern mit Kugelwellentrichtern, die bereits einen verhältnismäßig breiten Streuwinkel haben, ist jedoch die Verbreitung des seitlichen Streuwinkels bei Konuslautsprechern, da diese die hohen Frequenzen stärker bündeln. Eine neue Klangfilm-Lautsprecherkombination „Duophon", bei der für die Hochtonwiedergabe Konuslautsprecher mit akustischer Linse verwendet werden, ist im nachstehenden Lautsprecherprogramm mit aufgeführt.



Abb. 3. Brechung paralleler Lichtstrahlen beim Durchtritt durch eine Zerstreuungslinse. In ähnlicher Weise verbreitert sich eine Schallwellenfront beim Durchtritt durch eine akustische Linse

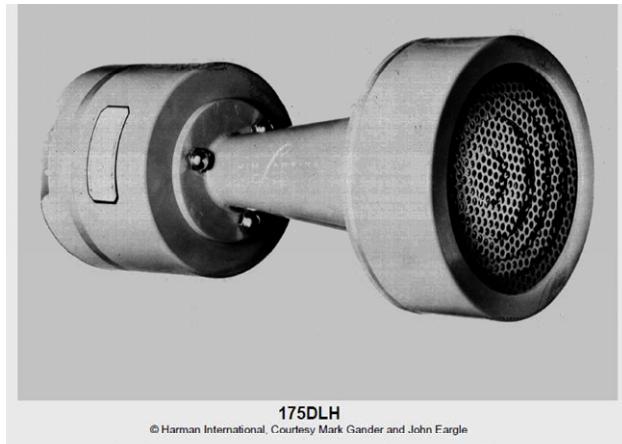
Abb. 4. Akustische Linse, Vorderseite

Abb. 5. Akustische Linse, Rückseite

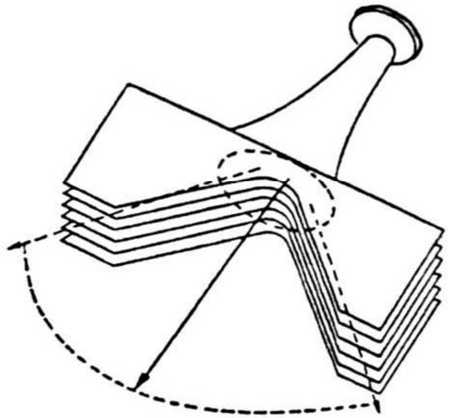
16

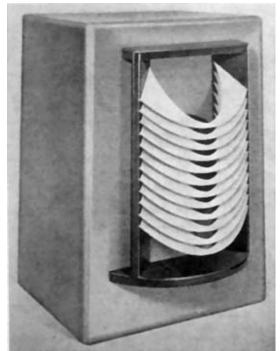
Klanfilm horn with acoustic lens at mouth

JBL "potatoe crusher"

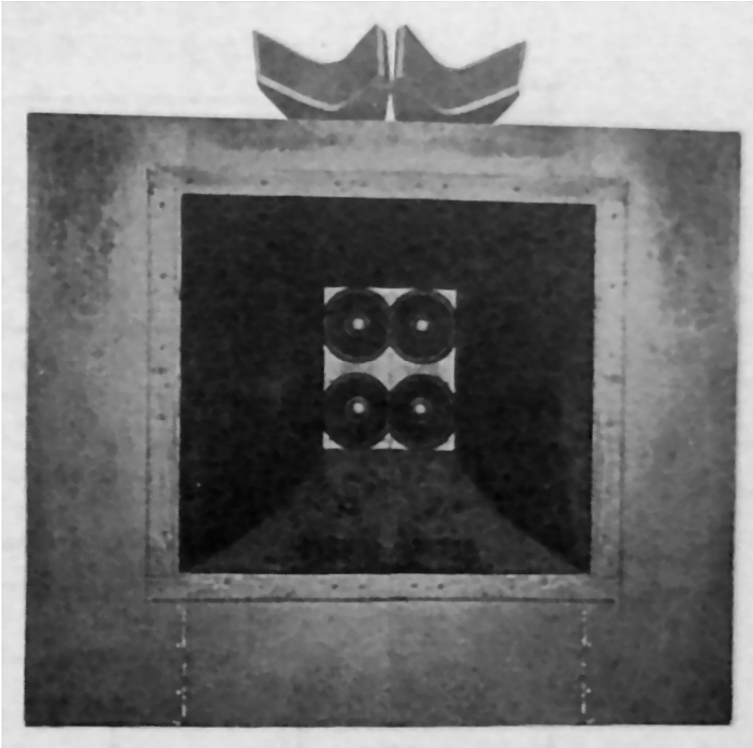



# Acoustic lenses

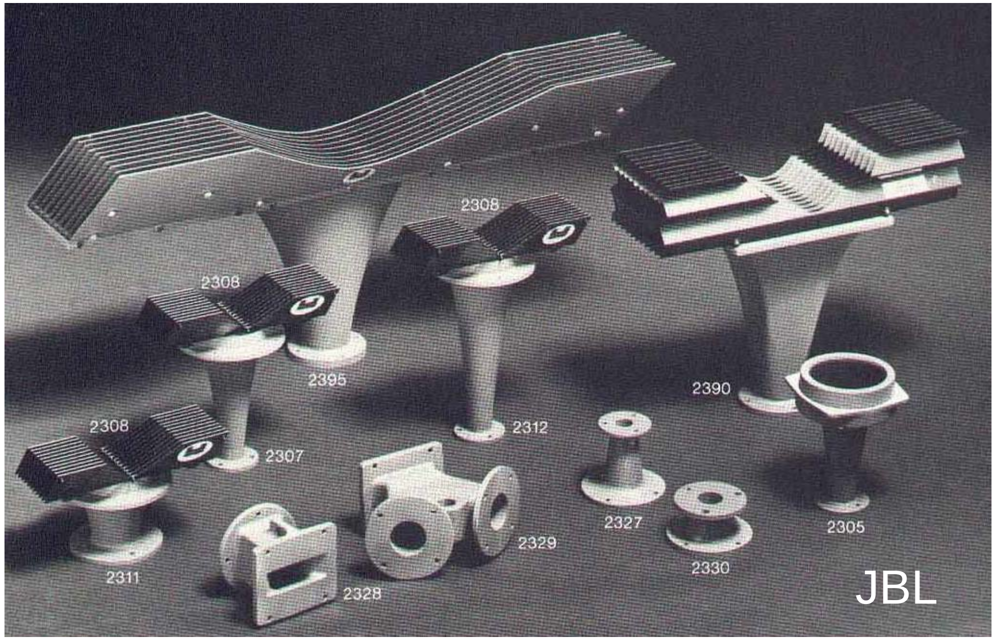




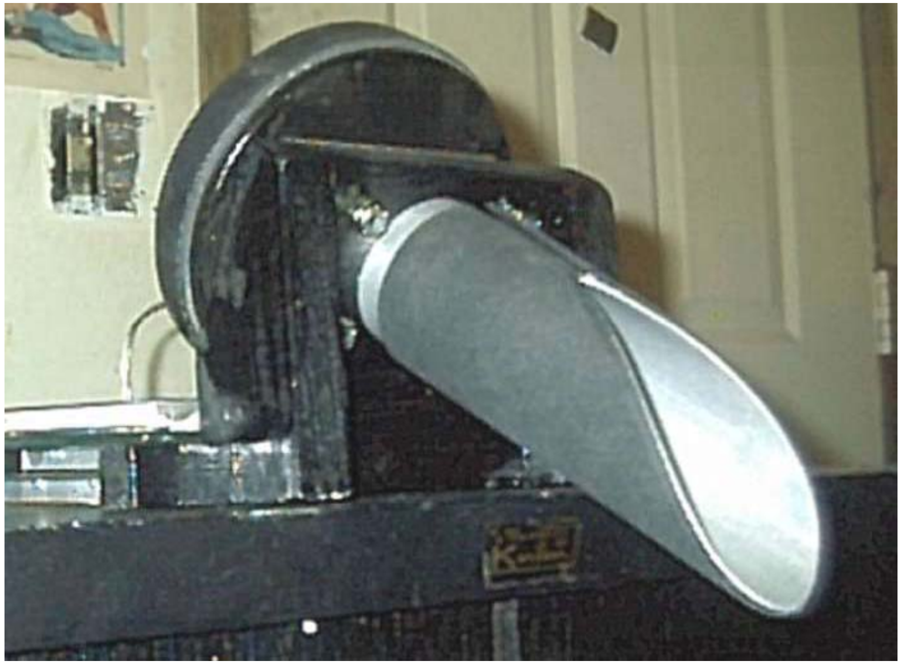
JBL acoustic lens

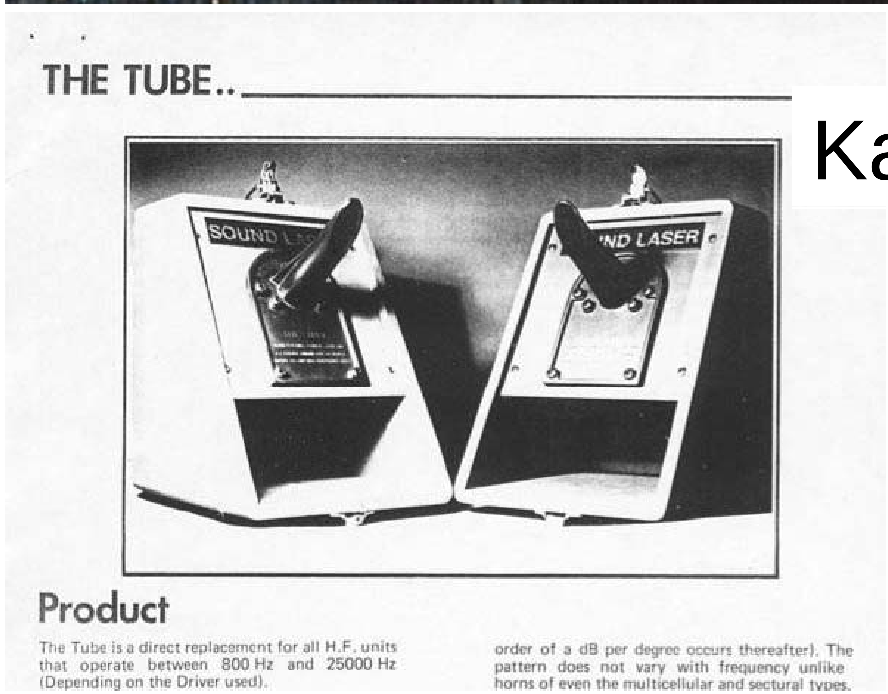



**D30085 Hartsfield**
© Harman International, Courtesy Mark Gander and John Eargle

# Karlson coupler



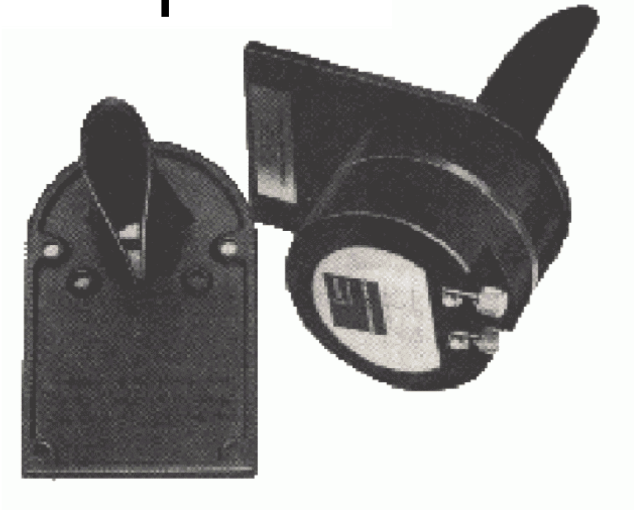


THE TUBE..

SOUND LASER

Product

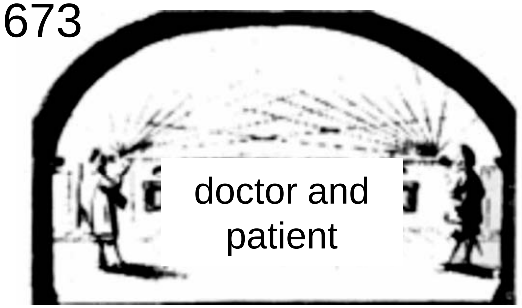
The Tube is a direct replacement for all H.F. units that operate between 800 Hz and 25000 Hz (Depending on the Driver used).

order of a dB per degree occurs thereafter). The pattern does not vary with frequency unlike horns of even the multicellular and sectural types.

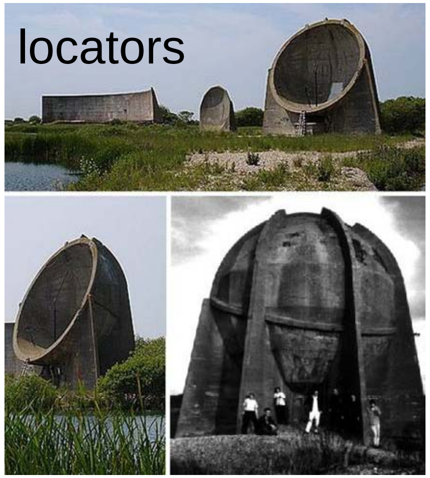


# Elliptical reflectors = acoustic shells

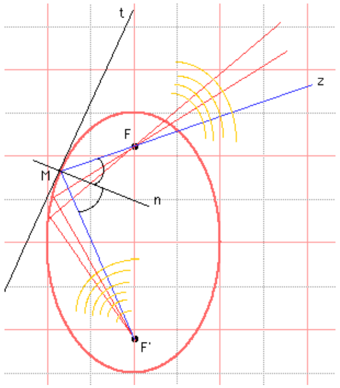
1673

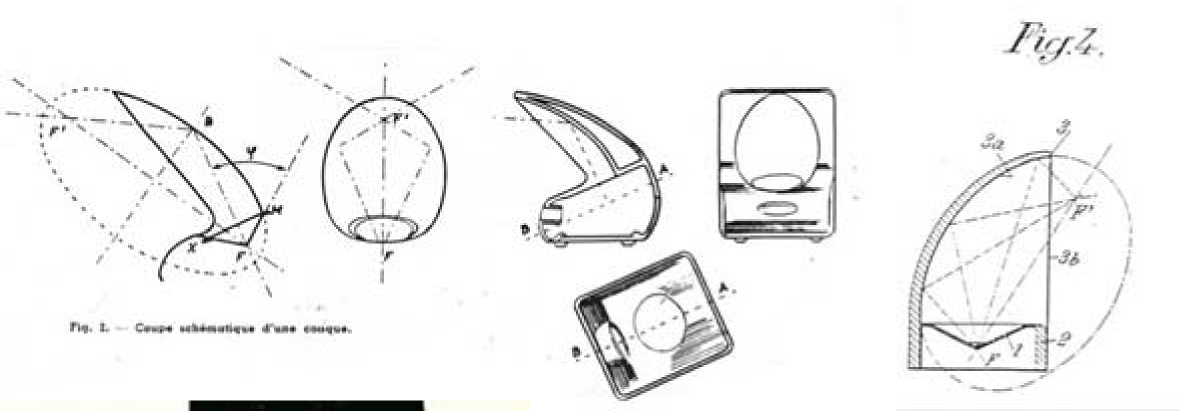


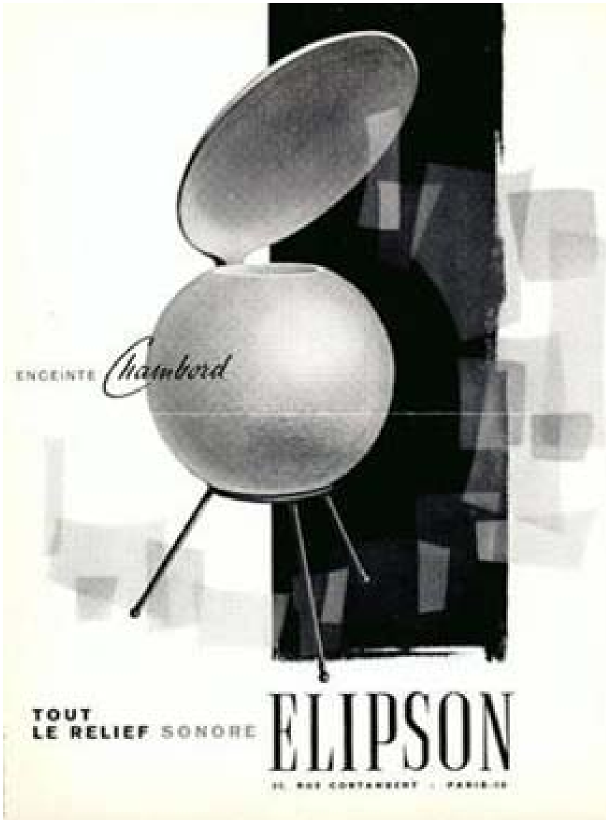
doctor and patient



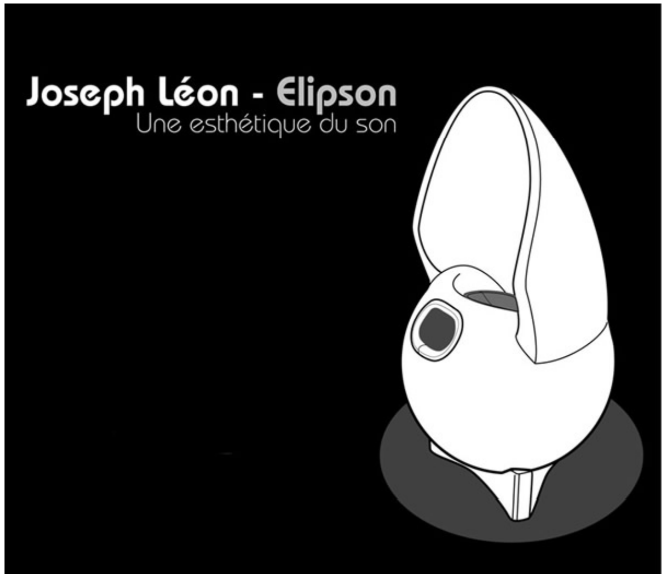
locators



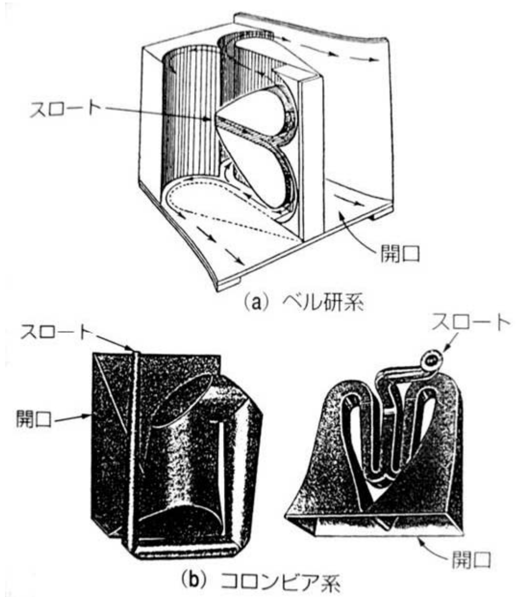

Elipson loudspeakers

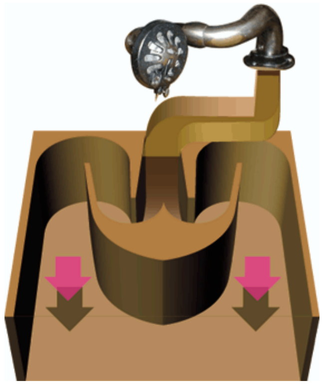


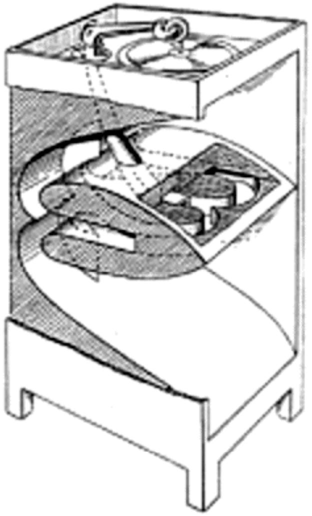
# Folding horns

- In search of miniaturization

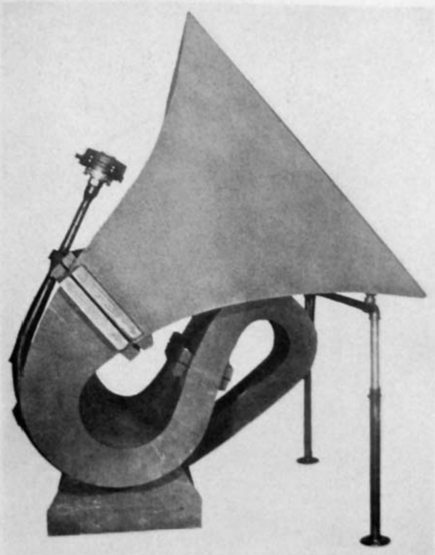
# old folded horns



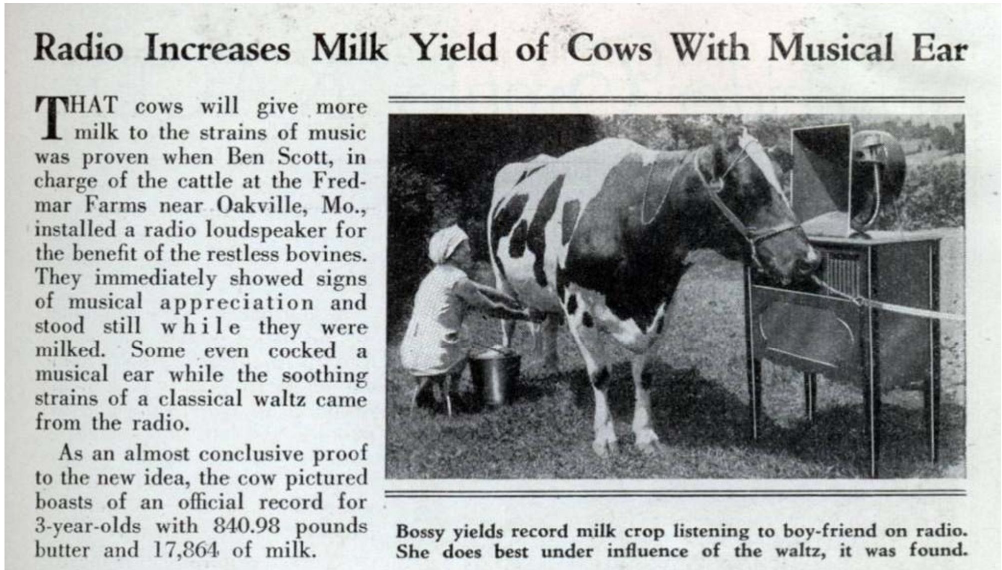





WE 13A horn



1929 - 1935



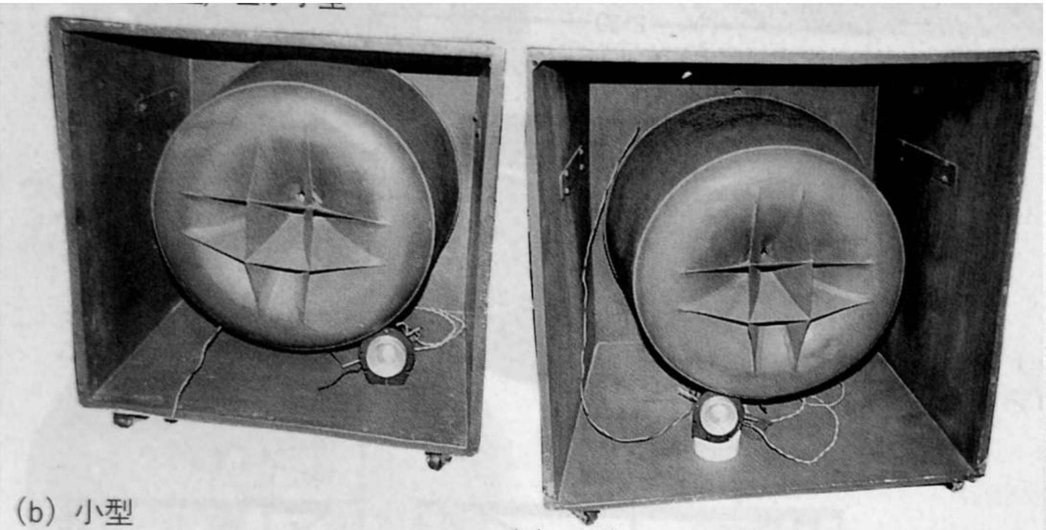
## Radio Increases Milk Yield of Cows With Musical Ear

THAT cows will give more milk to the strains of music was proven when Ben Scott, in charge of the cattle at the Fredmar Farms near Oakville, Mo., installed a radio loudspeaker for the benefit of the restless bovines. They immediately showed signs of musical appreciation and stood still while they were milked. Some even cocked a musical ear while the soothing strains of a classical waltz came from the radio.

As an almost conclusive proof to the new idea, the cow pictured boasts of an official record for 3-year-olds with 840.98 pounds butter and 17,864 of milk.

Bossy yields record milk crop listening to boy-friend on radio. She does best under influence of the waltz, it was found.

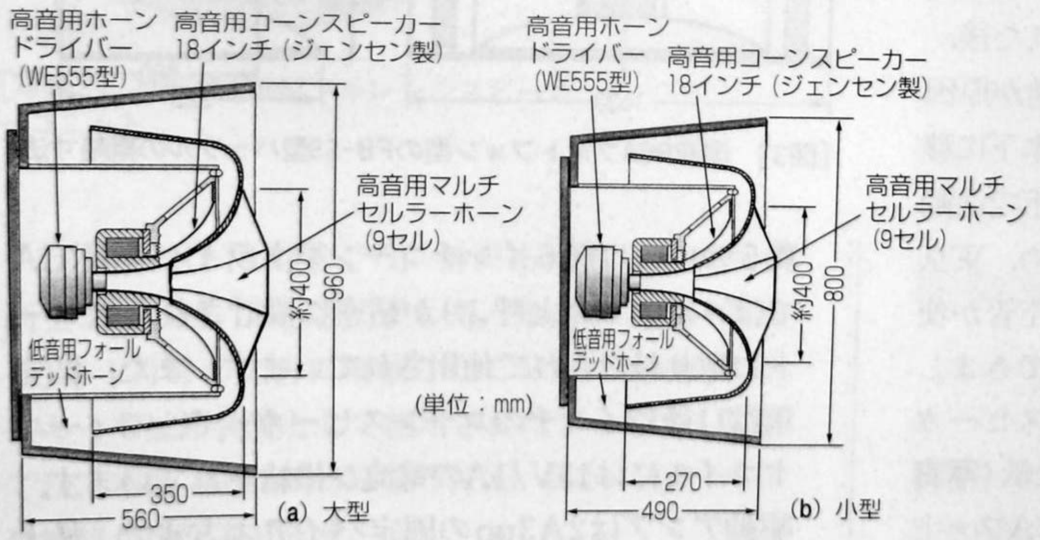
# WE « the Tub », circa 1938



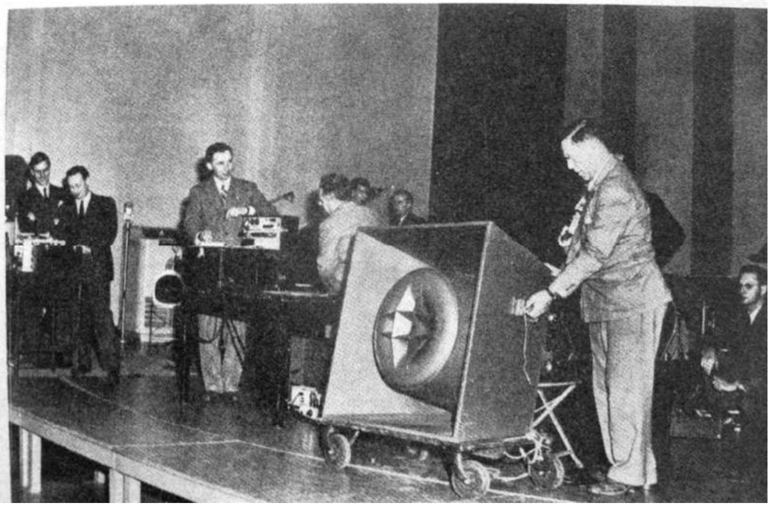
(b) 小型

(c) 大型

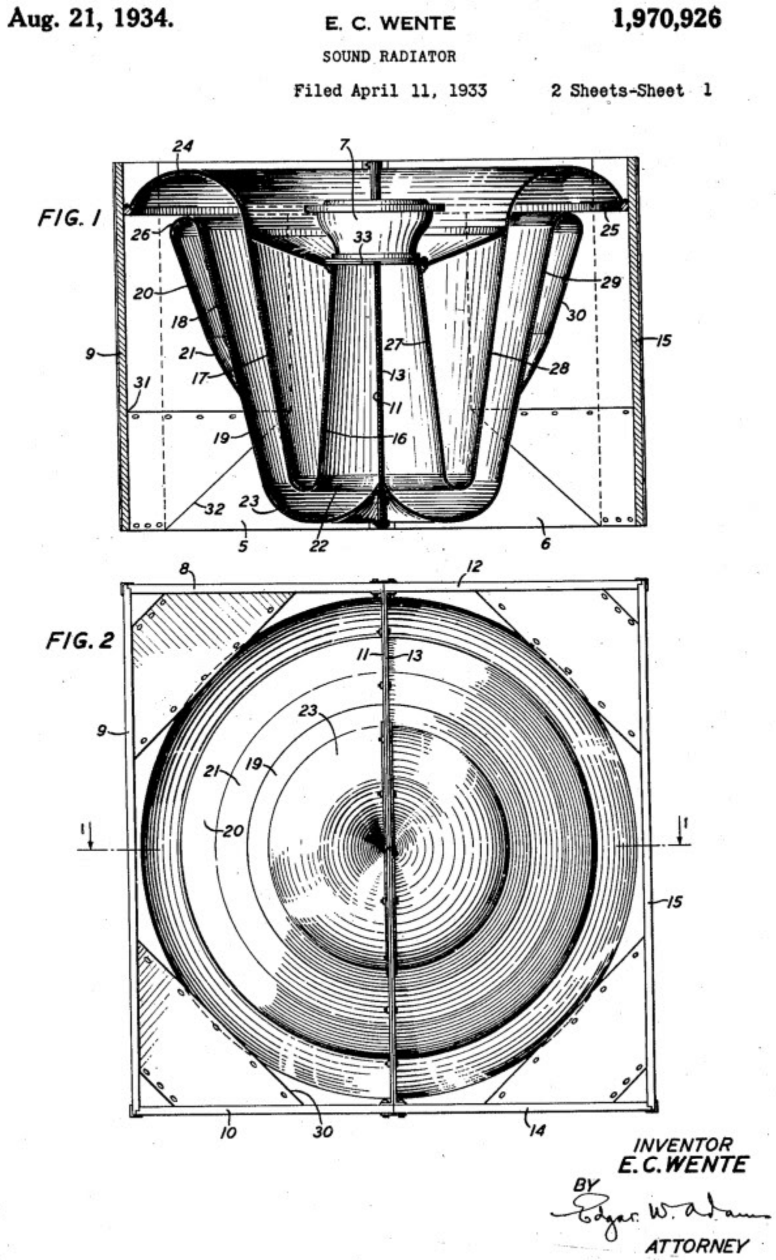
[写真9] 大型と小型の「The Tub」同軸型ホーン型２ウエイスピーカー

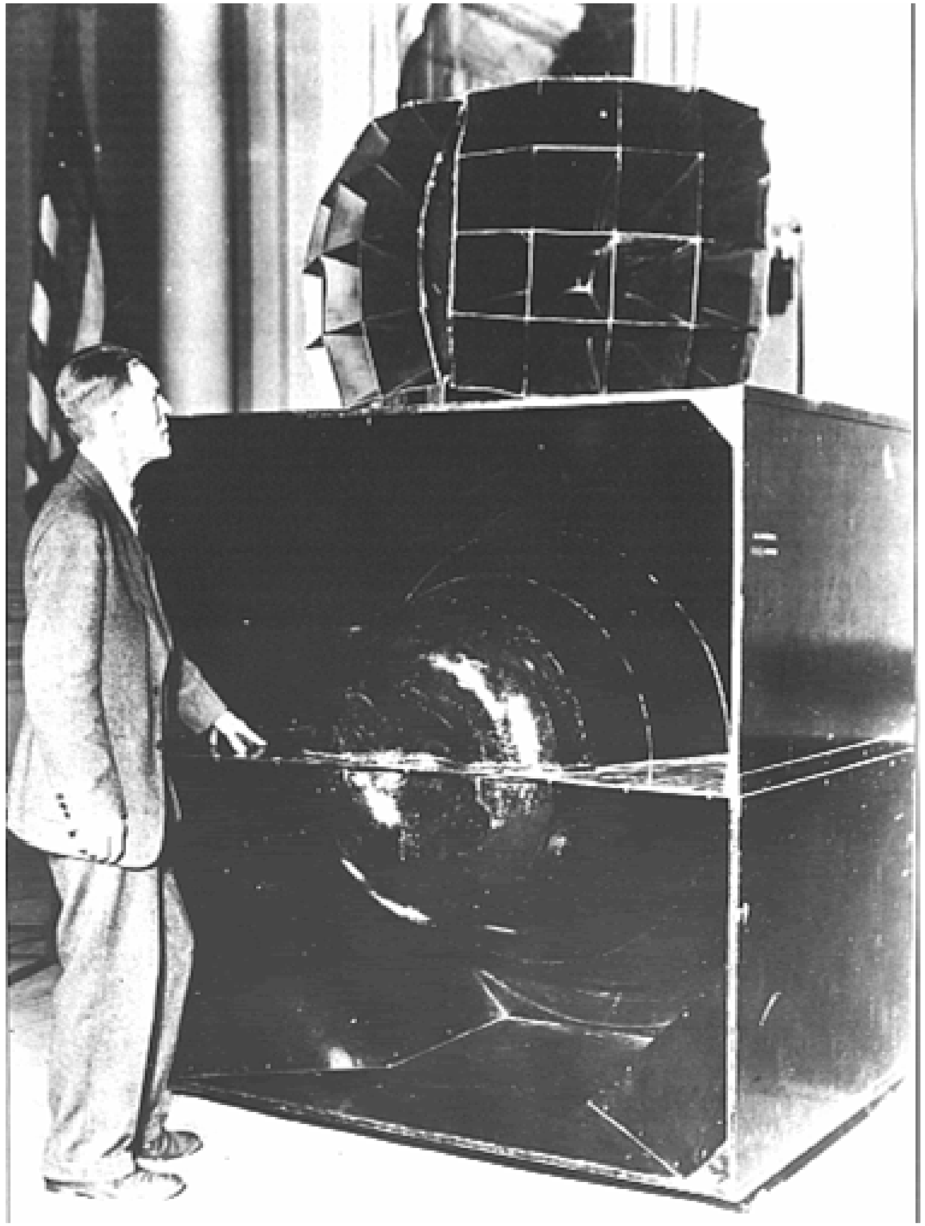



[図4] 「The Tub」の概略構造寸法



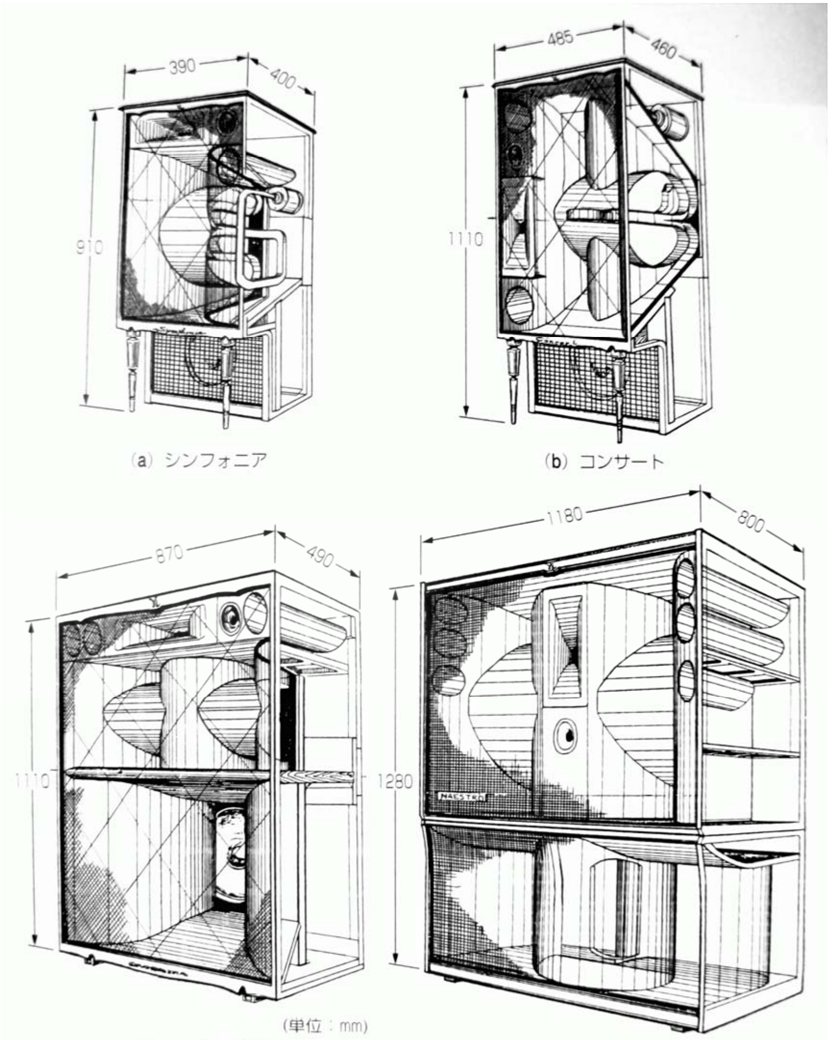
WE collector in Japan



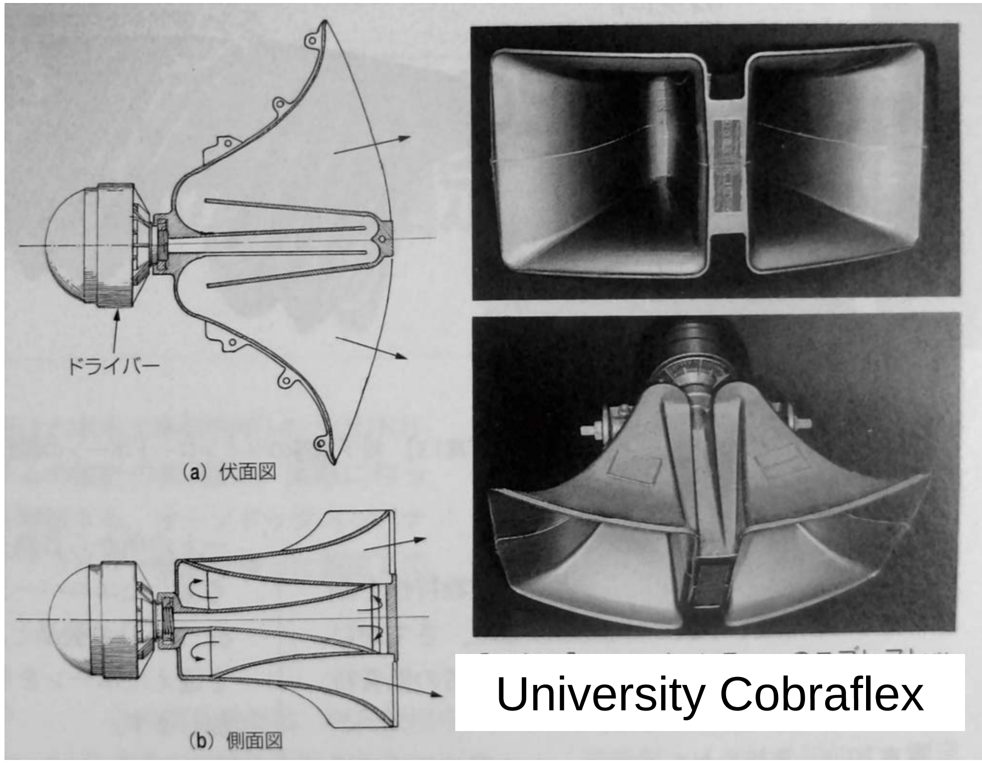



Fletcher system (1933-1940)

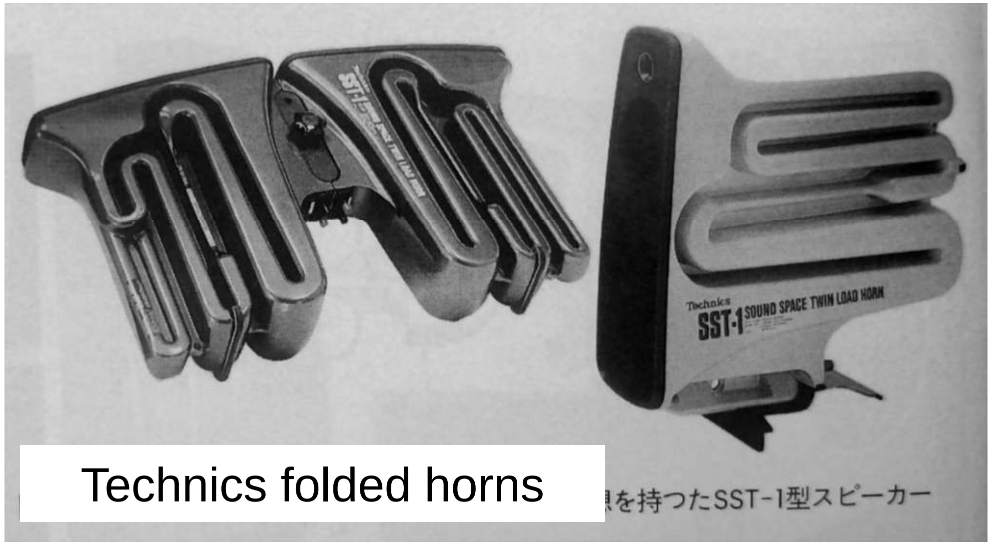
# modern folded horns




YL folded horns (Japan)




University Cobraflex




Technics folded horns

中音用／MB-150

MB-150は、MB-90(II) の音質をそのままに小型化したオールアルミニウム合金製のホーンです。フレヤー部分はデドニング加工により、ホーン鳴りを防止し、開口面も小型で自作キャビネットに手軽に組みこむことができます。

中音用／MB-90(II)

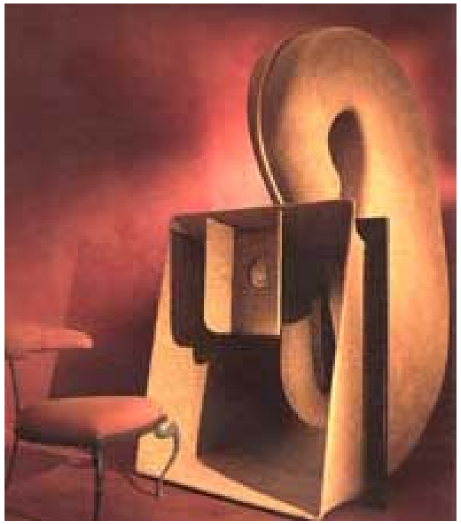
独自の木製ホーンで、低音限界は55系ドライバーと組むと200Hzに、D-75,000 ドライバーでは150Hzと、 2通りに使えます。スペースを取らない折曲型ホーンで、コーンスピーカーでは得られない明瞭なハリのある豊かな再生音が楽しめます。

中低音用／MB-70

中低音D- 75,000 専用に作られたL型ホーンです。フレヤー部分は精密加工の積層

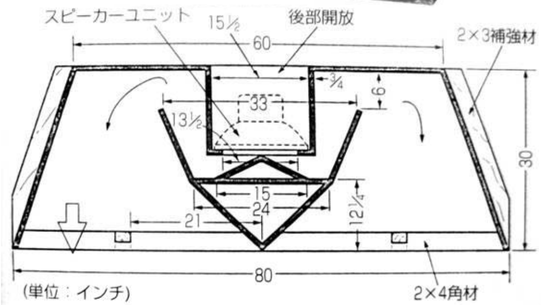
Yoshimura Laboratory, Ale and Goto horns

Nelson Pass's fullrange Kleinhorn

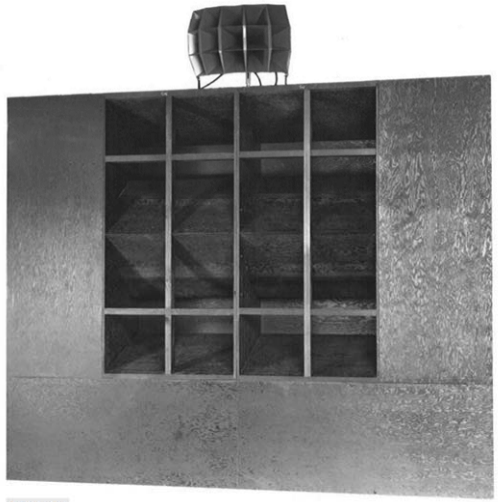


Yamamura fullrange
Churchill  and  Dionisio 32

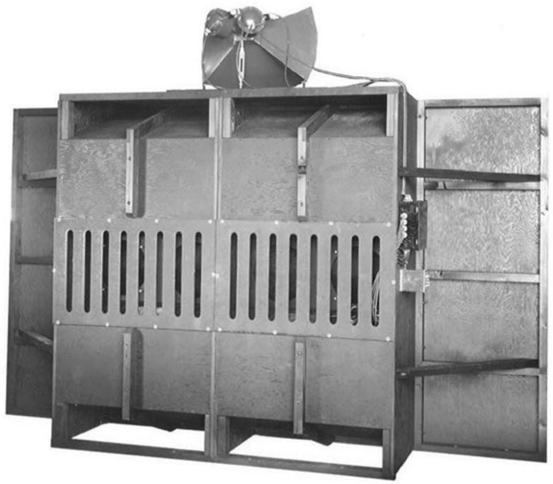
# First folded bass horns




WE TA7396,  1936 -1937



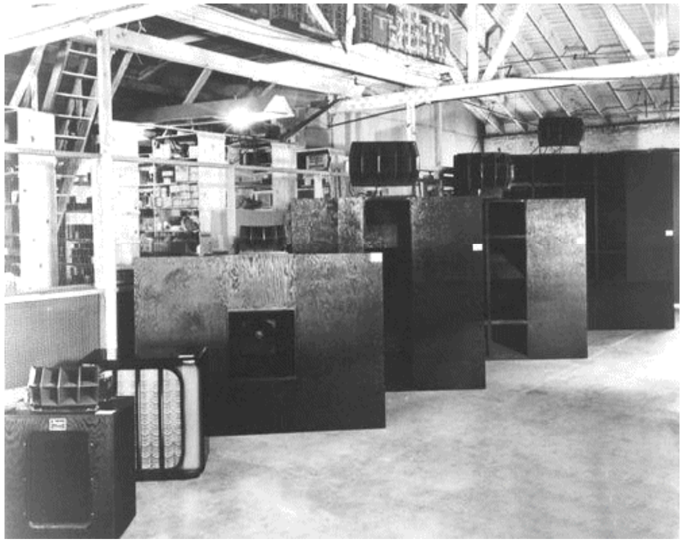
Front



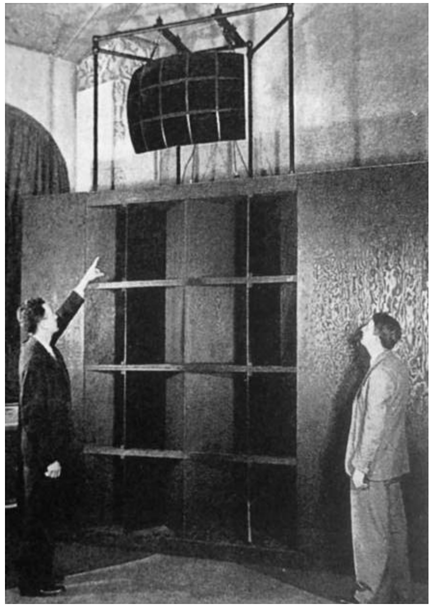
Back

the Shearer horn

Lansing Manufacturing 75W5 Shearer Horn
© Harman International, Courtesy Mark Gander and John Eargle



The Shearer system received a technical achievement award at the 1936 Academy of Motion Picture Arts and Sciences ceremony.



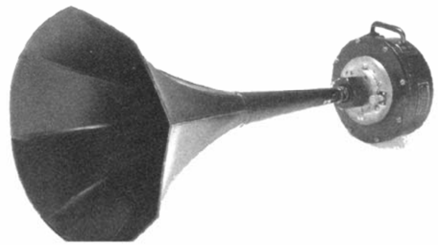
RCA

# Straight horns

# Early exponential straight horns

## Before 1929

my home made crystal radio with a Vitavox E190 horn



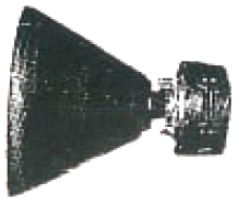
**Western Electric (WE)**

**3A**

This straight horn in a small metal fabrication, it seems to be built in the early 1920s.
The main use of it is in combination with balanced armature-type receiver, as 196w, 549 or 551, for a public address use.

TA 7322 HORN

REQUIRES – ONE 555 RECEIVER

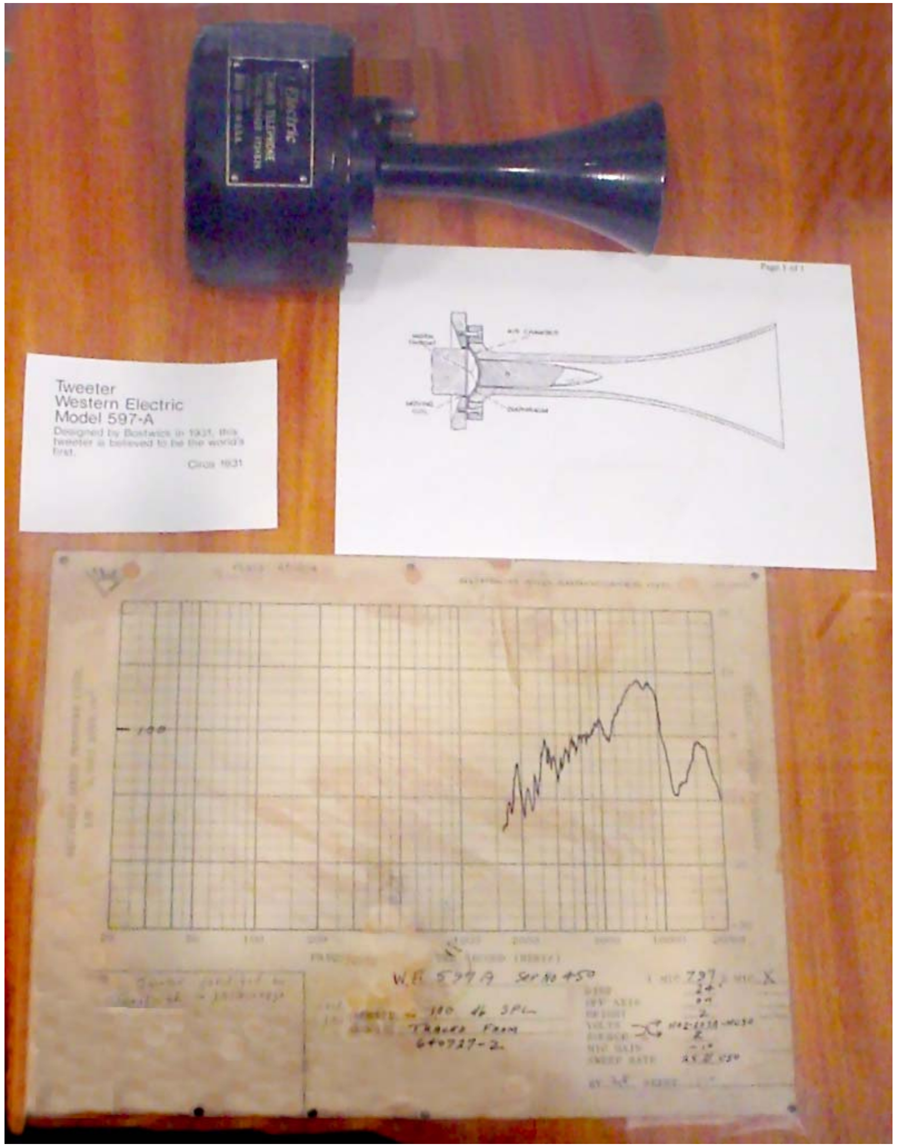


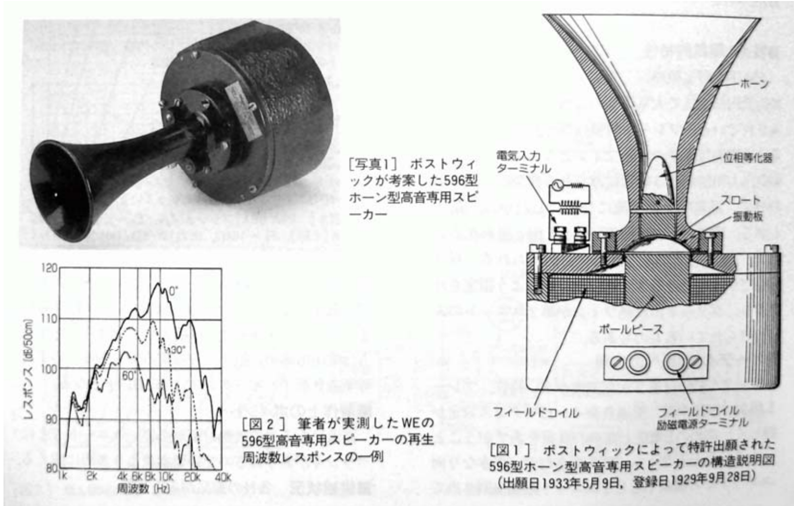
**Western Electric (WE)**

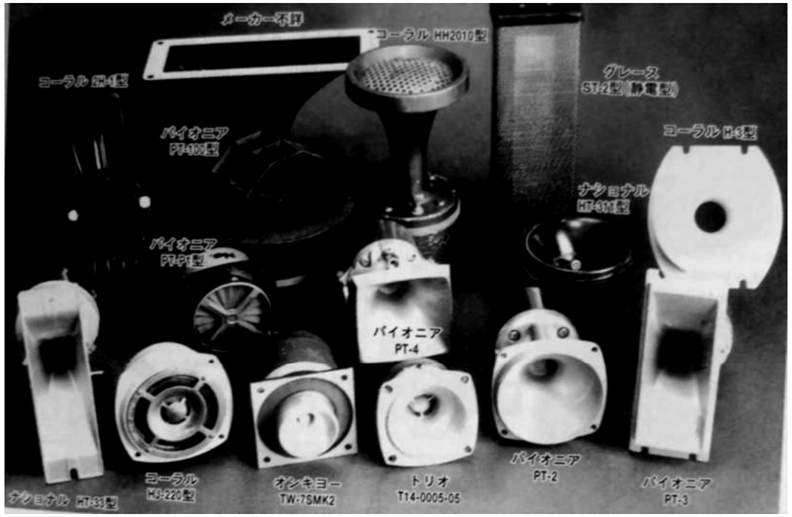
**TA7322**

The wooden horn "TA7322" of this circular type was developed in 1935 for the midrange channel above 600Hz, of the "TA8002" wide range system with WE555 and 2 woofer units type TA4151 for the low frequency)
Size of the horn is diameter 32cm and depth 23cm.
This is probably the smallest genuine horn for the 555 receiver (Doi)

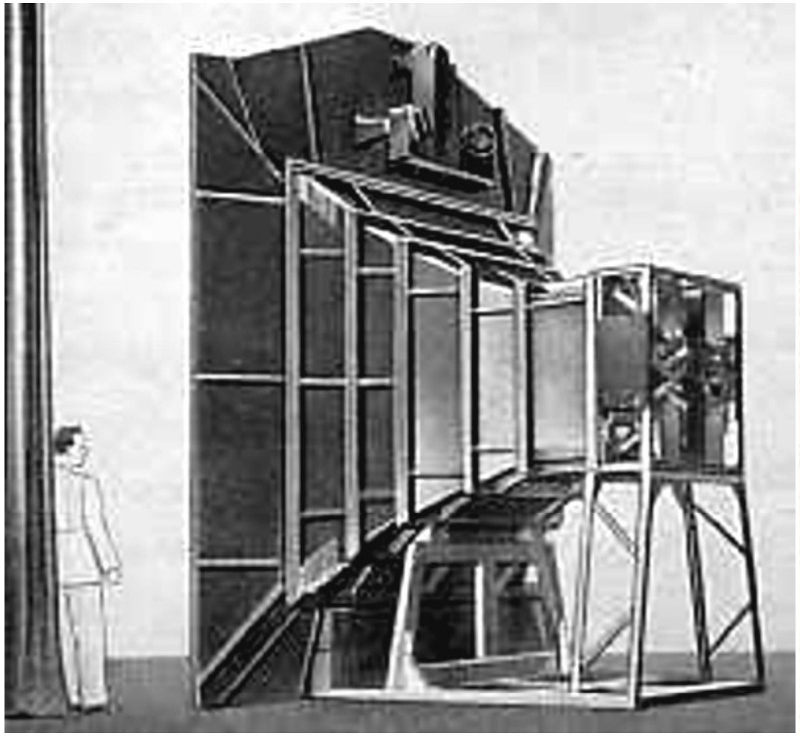
# Horn tweeters



# Klangfilm
# 20 hz Tractrix horn
# Germany, 1951



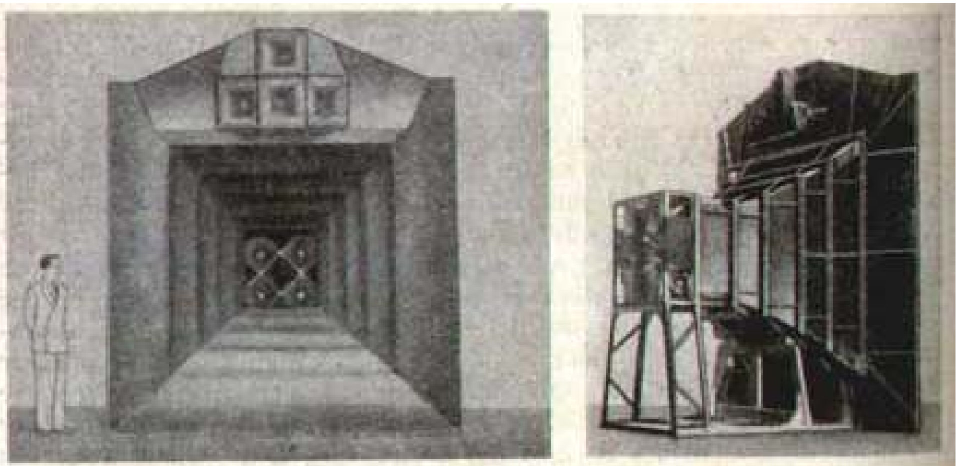
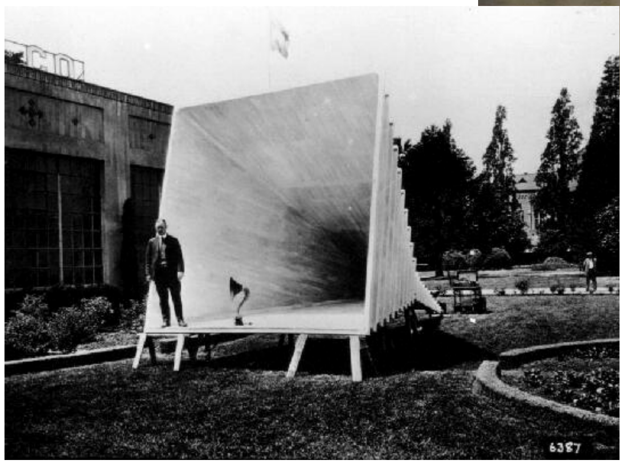


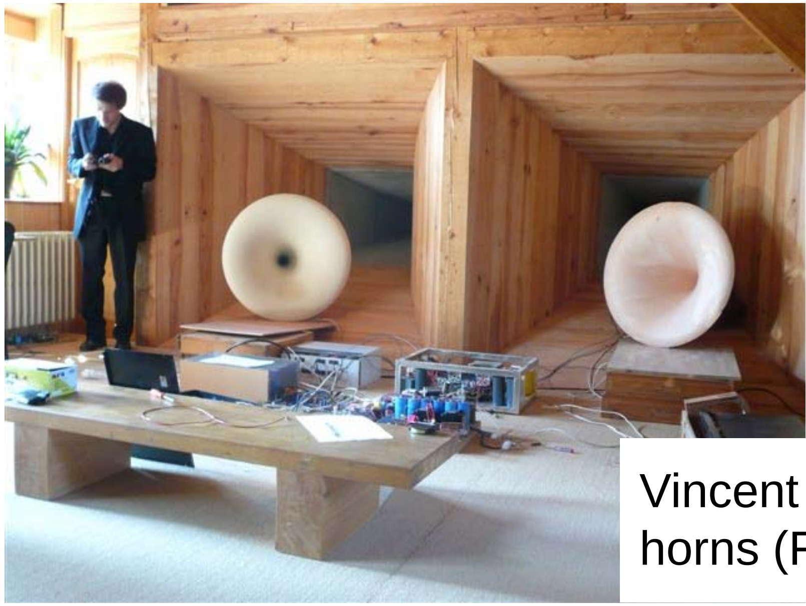
Abb. 211. Die Großlautsprecherkombination der Klangfilm, Euronor II, für Theater bis 1500 Plätze.

Diese Lautsprecherkombination setzt sich zusammen aus einem großen Tieftontrichter mit vier Tieftonsystemen hoher Belastbarkeit und vier darüber angeordneten Höhen-

# Straight bass horns

Bjorn Kolbrek's long throw bass horns

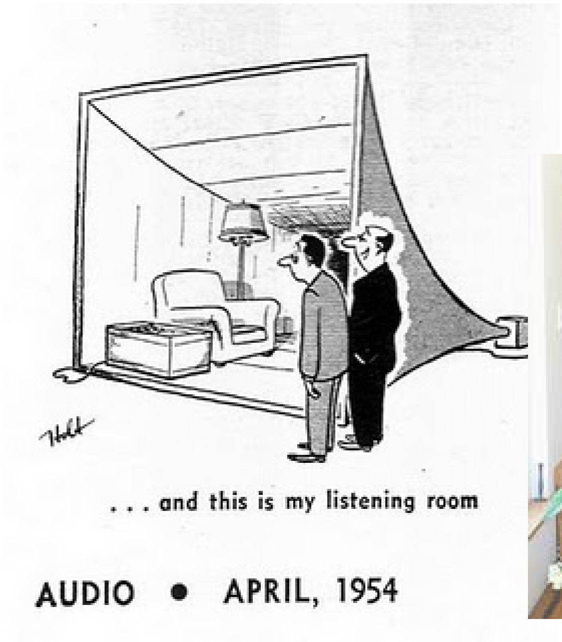



Vincent Brient's 30Hz bass horns (France)


Klaus Speth, full horns with Goto drivers (Germany)

# Quasi cylindrical waves bass horns in France

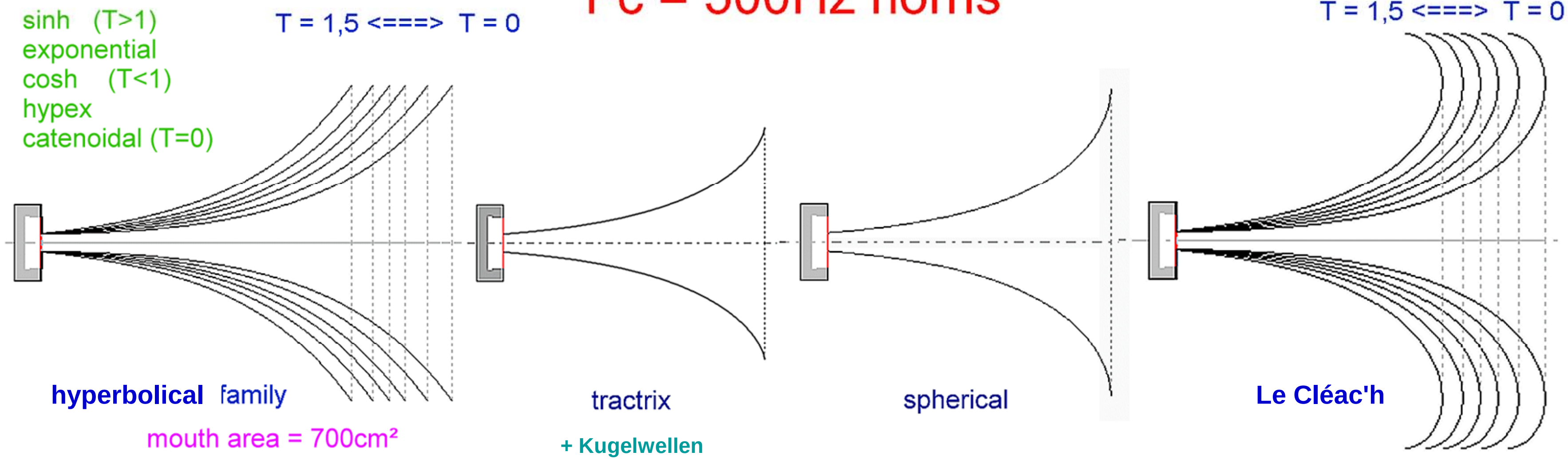




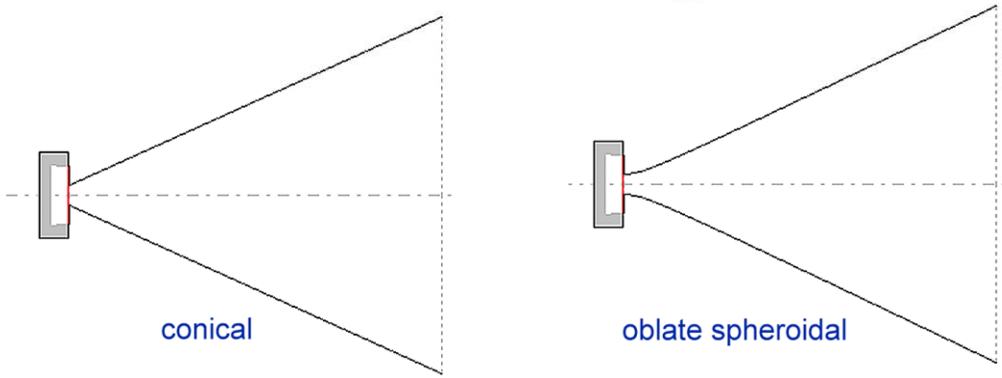

# main families of horns

- Salmon family (exponential, hypex, etc.)
- Tractrix, Kugelwellen and Spherical
- conical
- oblate spheroidal
- Le Cléac'h

# Fc = 500Hz horns




# conical and waveguides




same mouth area and length as the exponential horn

# hyperbolical type

- from catenoidal (T = 0)
- through hypex (0,5 < T < 1)
- and exponential (T = 1)
- to hyperbolic sine (T > 1)

$$Z_1 = \frac{R\cos(\beta L + \theta) + j(X\cos(\beta L + \theta) + \sin\beta L)}{-X\sin\beta L + \cos(\beta L - \theta) + jR\sin\beta L}$$

$$= R^1 + jX^1$$

Formula for the acoustic impedance of an exponential horn

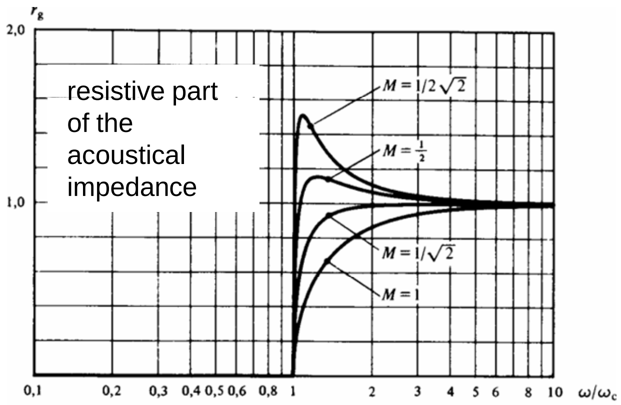



Fig. 4.13

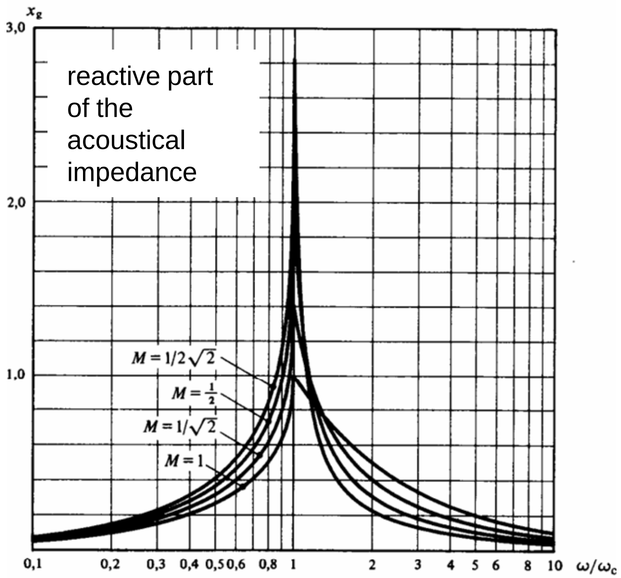


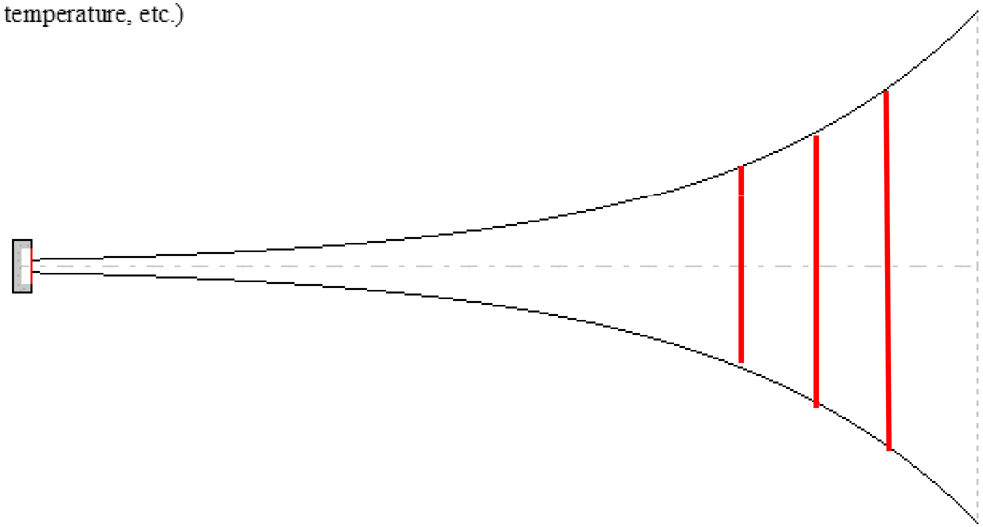

Fig. 4.14

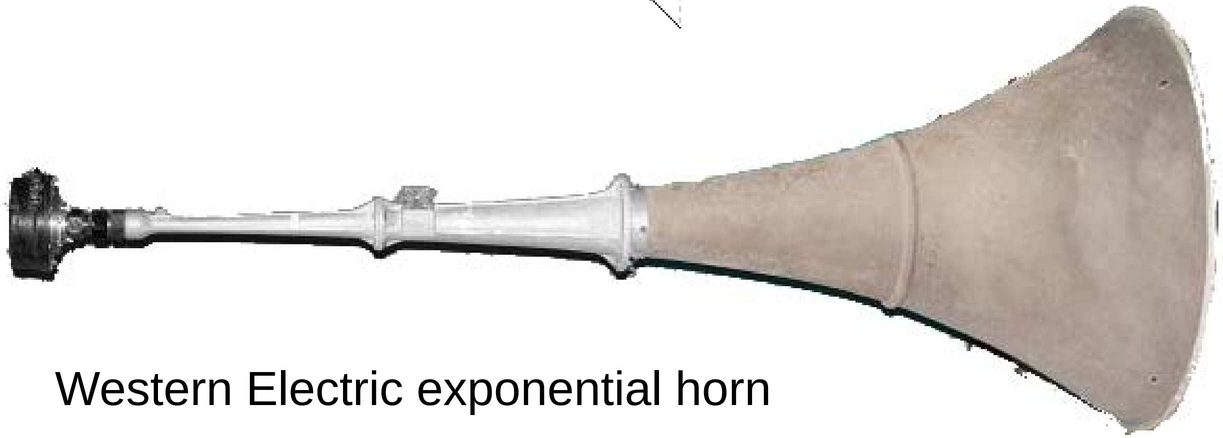
hyperbolic / exponential horns

Area = Throat Area [ cosh ( x*2*Pi*$f$ / c) + M * sinh ( x*2*Pi*$f$ / c) ] ^2

where

- x = distance from throat
- $f$ = the cutoff frequency of the horn
- M = the flare constant - M = 1 is exponential, 0 < M < 1 is hyperbolic
- c = the speed of sound, approximately 13538 inches per second or 344 m/s (depends on temperature, etc.)



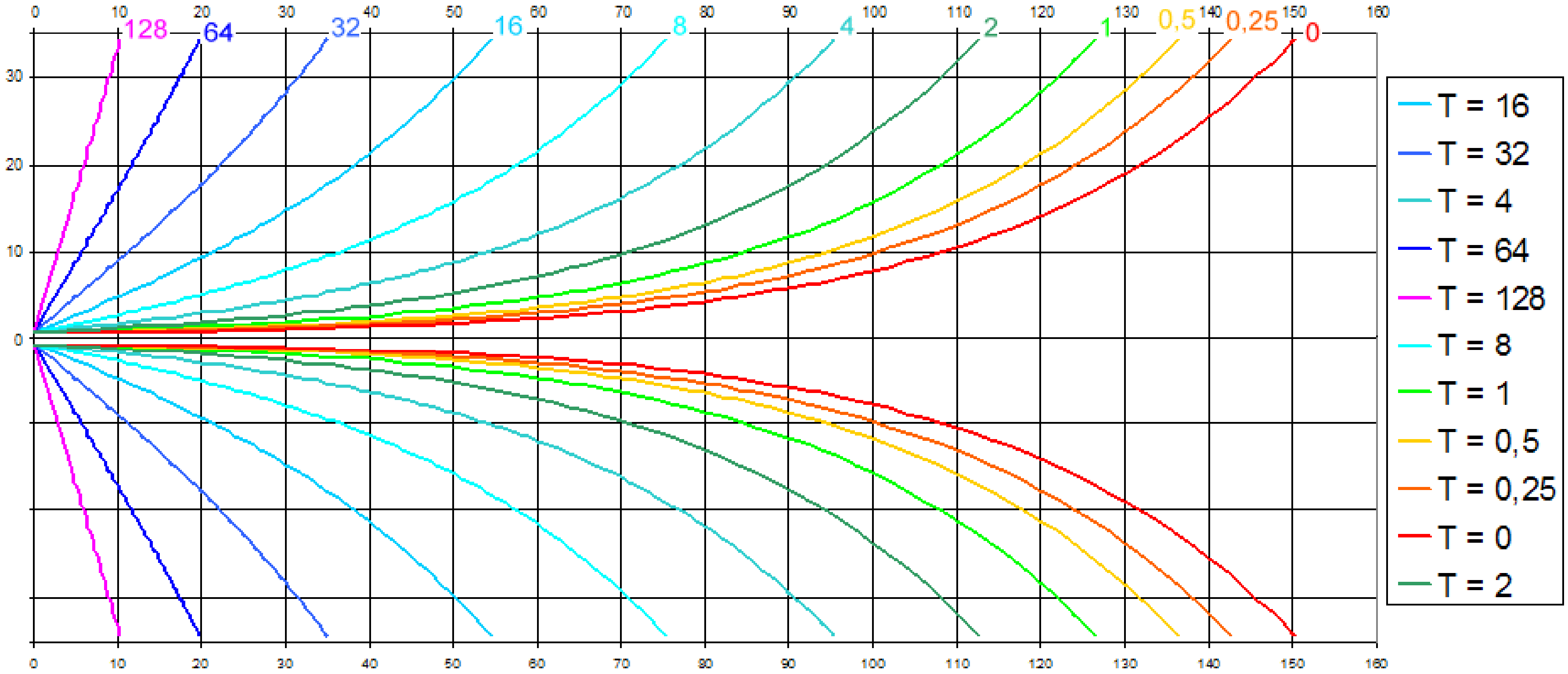


Western Electric exponential horn

$$Ax = Ah\left(\cosh\frac{x}{x_o} + T\sinh\frac{x}{x_o}\right)^2$$

Normal range of T value between 0 and 1
← →

For T>>1 the profile becomes progressively conical



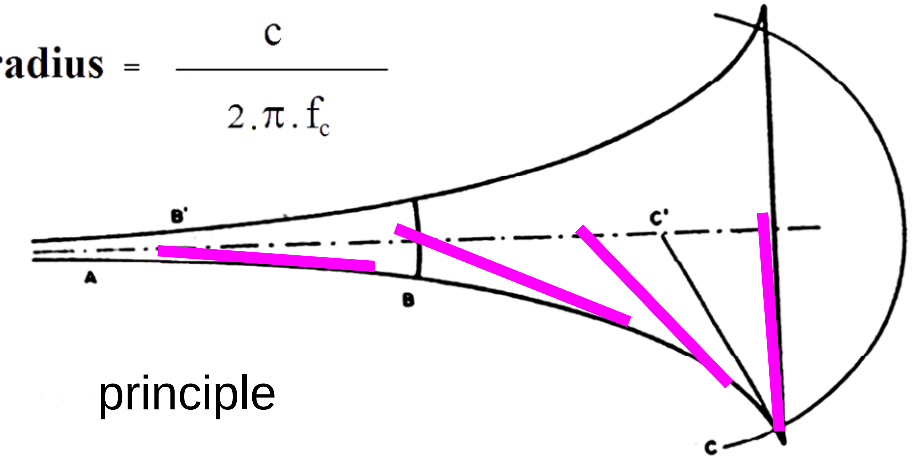

profiles of hyperbolic family horns with T value variation between 0 and 128

# the Tractrix horn

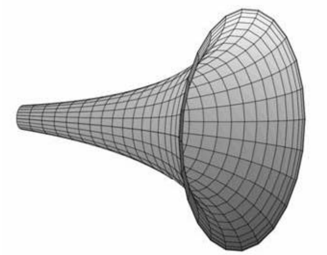
Paul G.A.H. Voigt

( 1902-1981)

$$\textbf{radius} = \frac{c}{2.\pi.f_c}$$



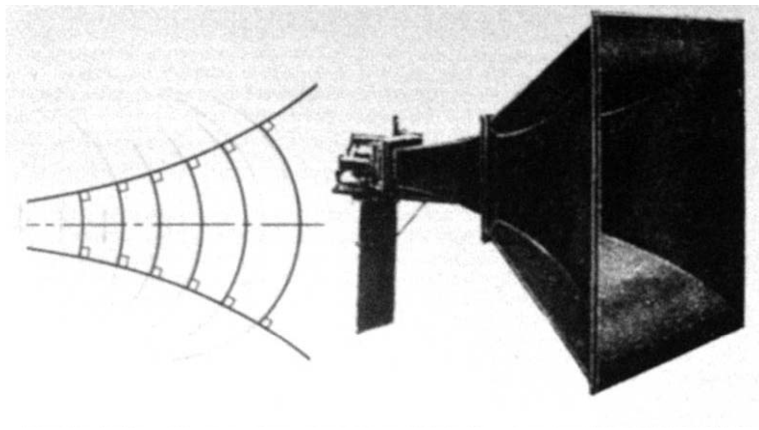

principle



the mathematical pseudosphere

$$x = r_m \cdot \ln\left(\frac{\left(r_m + \sqrt{r_m^{\,2} - r_x^{\,2}}\right)}{r_x}\right) - \sqrt{r_m^{\,2} - r_x^{\,2}}$$

- x is the distance from the mouth
- $r_m$ is the radius at the full Tractrix mouth ( = c / (2 * π * fc) )
- $r_x$ is the radius at distance x from the mouth

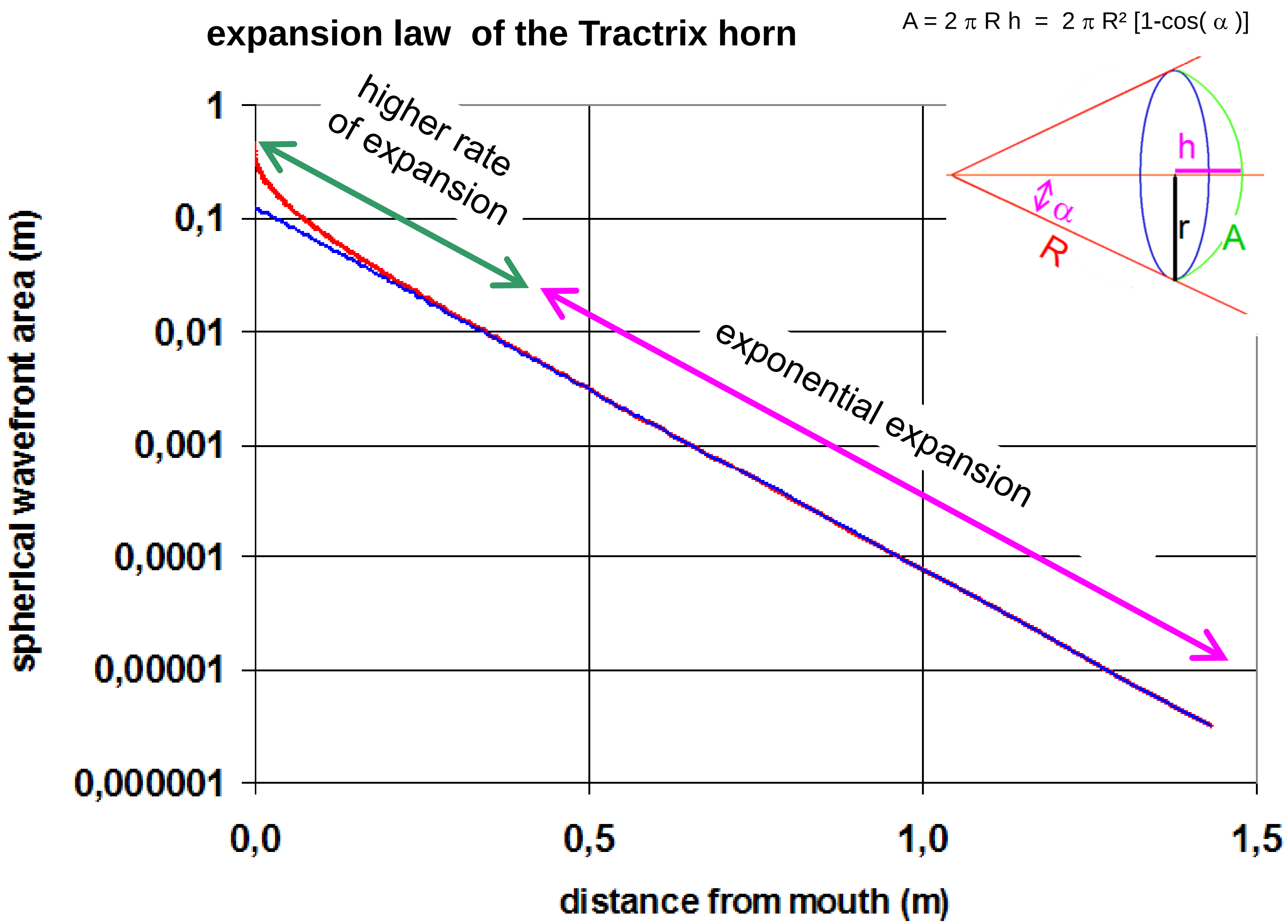


a square tractrix horn built by Edison Bell in England

"The only way that he could figure out to make his driver sound good was to horn load it, but he couldn't understand the mathematics behind the exponential, so he said, "Well, the exponential theory predicts that the wave form going down the horn is plane or flat, but if you look at the physics of the situation, the wave front has to drag along the horn walls. So naturally it's going to be curved. What if I geometrically designed a horn that has curved wave fronts all the way through the horn and see what happens?"


So he did a geometrical construction of a horn that would give him curved wave fronts. *He said that a draftsman looked at what he had done and said, "Oh, that's a Tractrix curve."* The Tractrix curve comes about because if you have one airplane chasing another on a different course, then the chase plane has to change his course to intercept the other plane, and it turns out that's a Tractrix curve."

*Bruce Edgar on Voigt's tractrix*

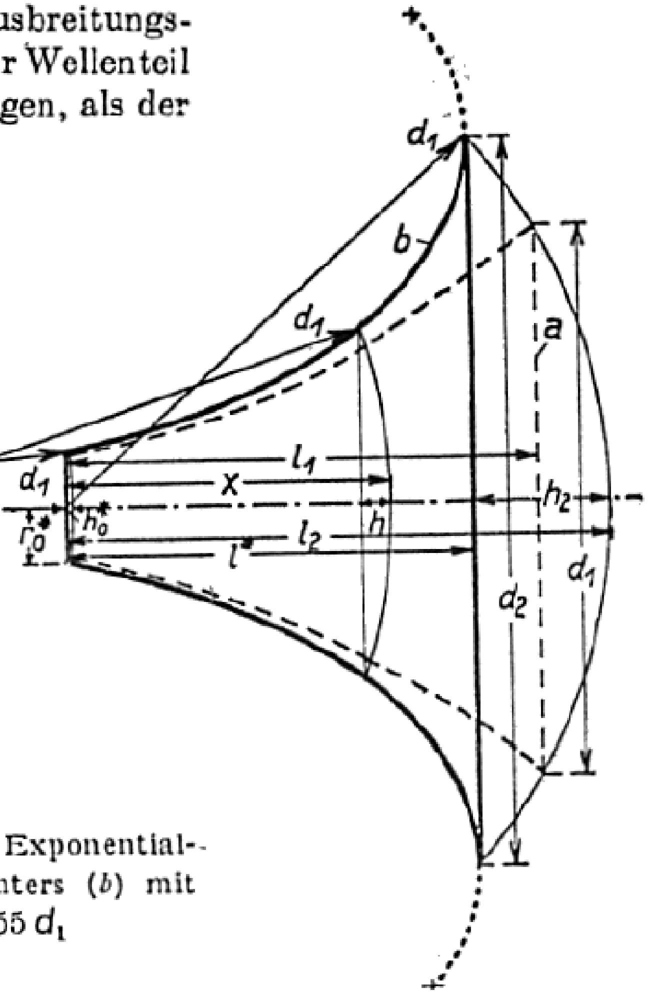

expansion law of the Tractrix horn
A = 2 π R h = 2 π R² [1-cos( α )]
higher rate of expansion
exponential expansion
h
α
r
R
A
1
0,1
0,01
0,001
0,0001
0,00001
0,000001
0,0
0,5
1,0
1,5
spherical wavefront area (m)
distance from mouth (m)

# Kugelwellen

*Rösch ( KLANGFILM laboratories )*

radius is the double of the radius used in the tractrix horn

Kalotte annimmt. Bei gleicher Schallausbreitungs-
geschwindigkeit muß ja in der Tat der Wellenteil
in der Nähe der Achse weiter vordringen, als der

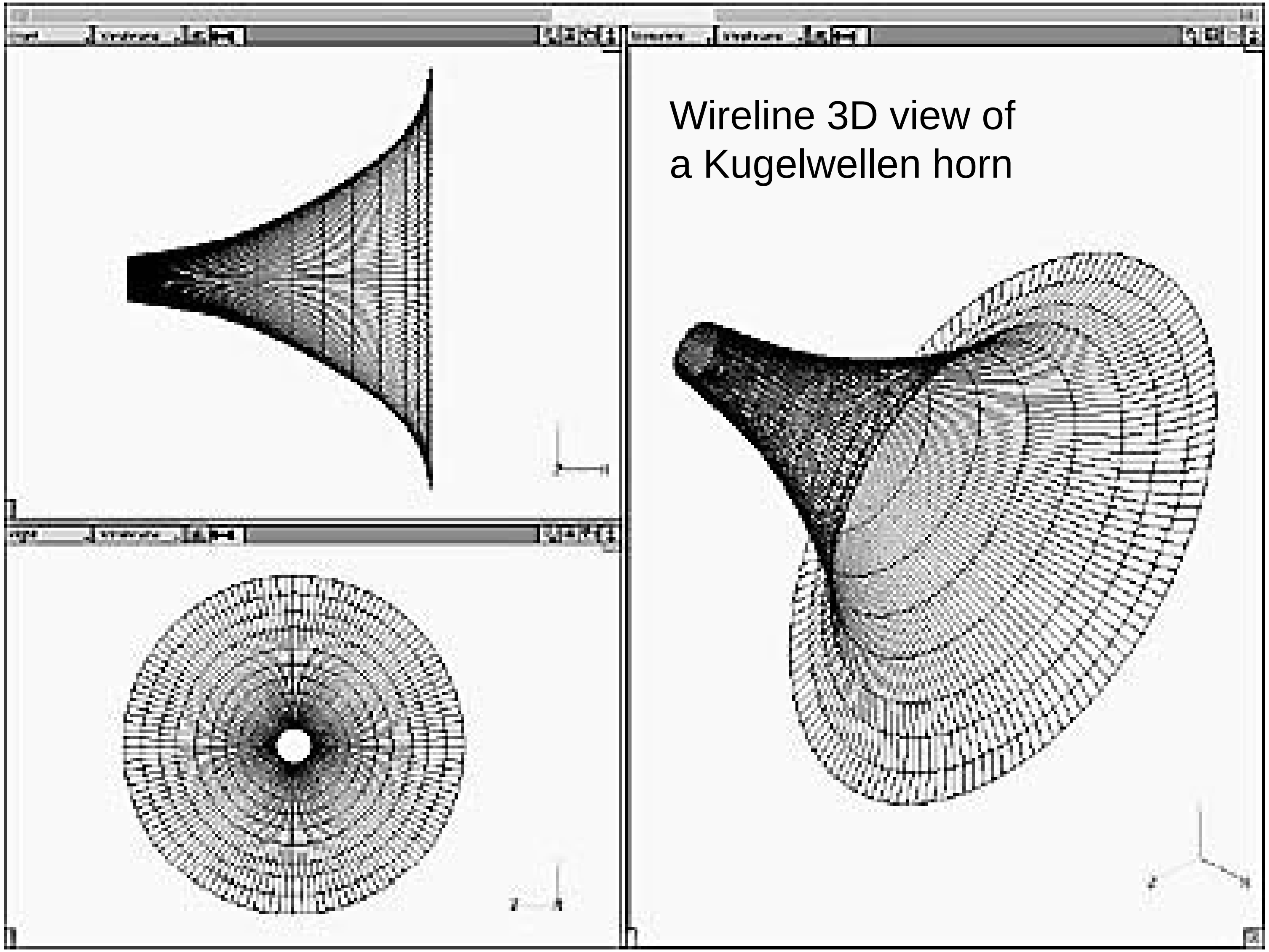



$$\textbf{radius} = \frac{c}{\pi \,.\, f_c}$$

Bild 18f. Mantellinie des bisher üblichen Exponential-trichters (*a*) und des Kugelwellentrichters (*b*) mit einem Anfangsradius $r_0 = 0{,}0955\, d_1$

see also : H.Schmidt: "Über eine neue Lautsprecherkombination" Funk und Ton N°5, 1950, p.226-232

# Kugelwellen



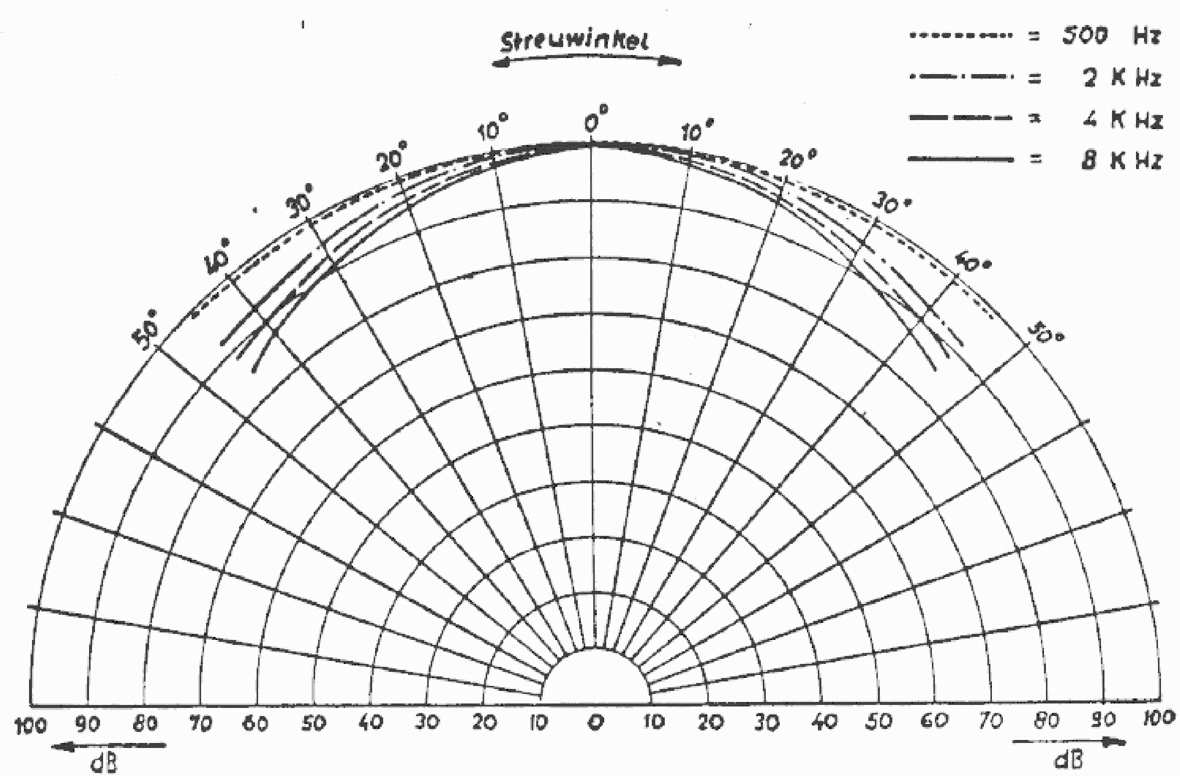
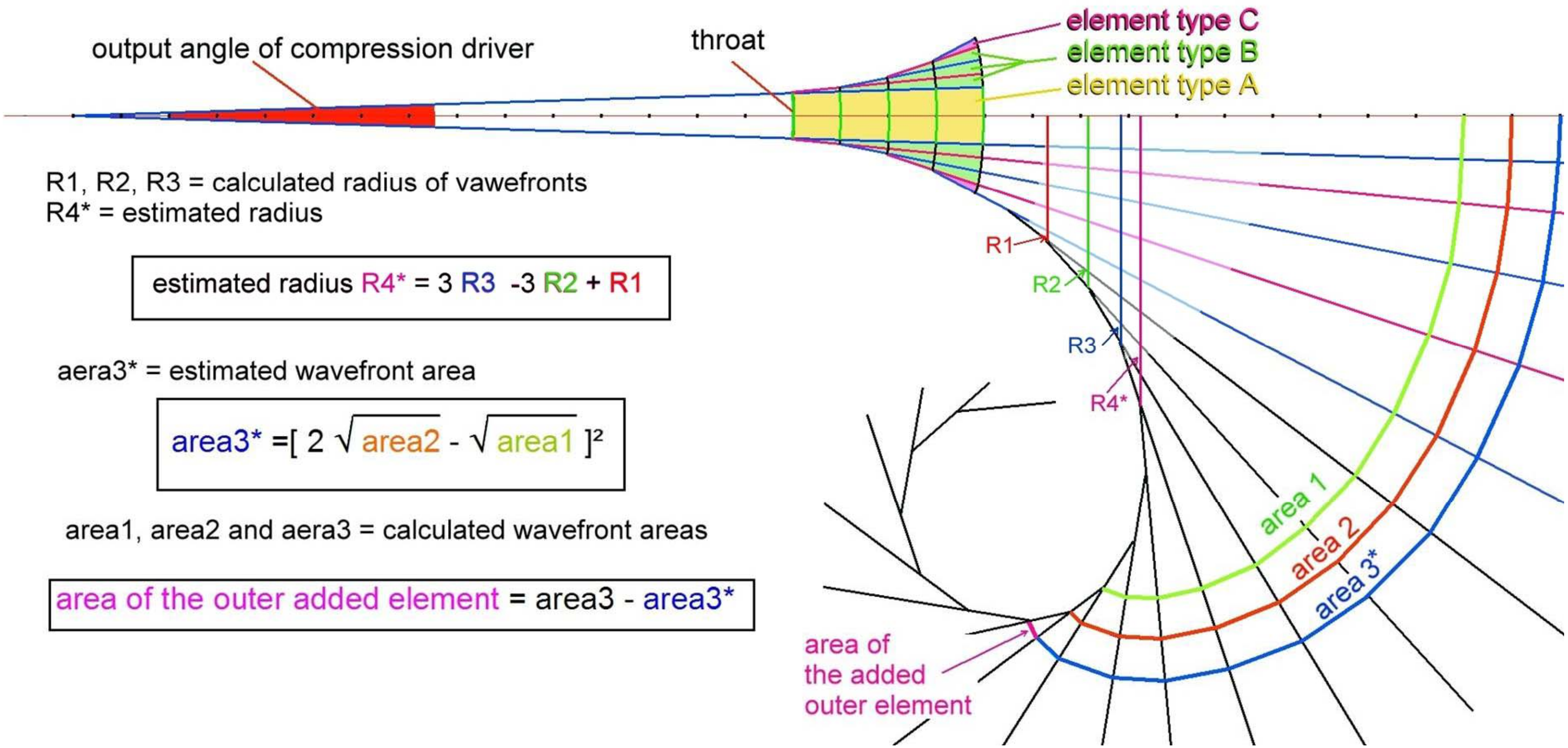



Bild 18ga. Strahlungscharakteristik eines Kugelwellentrichters der Klangfilm G.m.b.H. mit $f_u = 500$ Hz (vgl. [536])

# radiation diagram of the Kugelwellen horn

# "Le Cléac'h" horn

# Le Cléac'h's method to calculate the profile of an horn knowing the relation between the area of the wavefront and its distance to throat




R1, R2, R3 = calculated radius of vawefronts
R4* = estimated radius

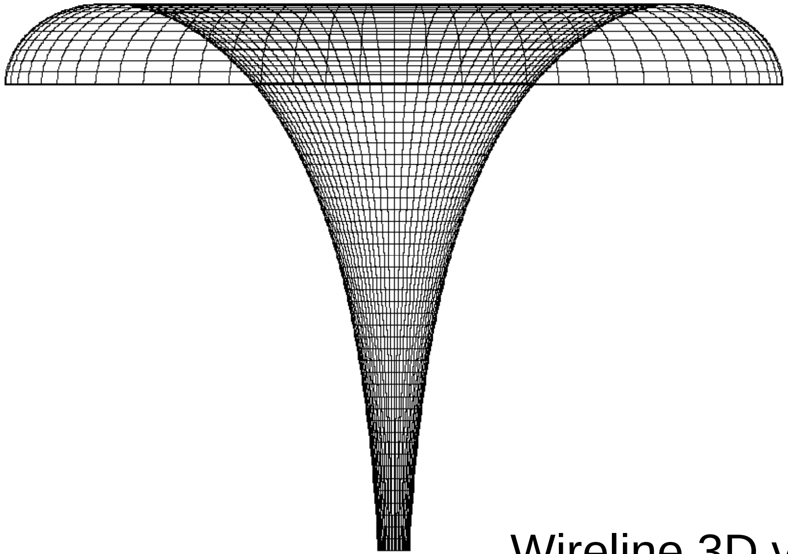
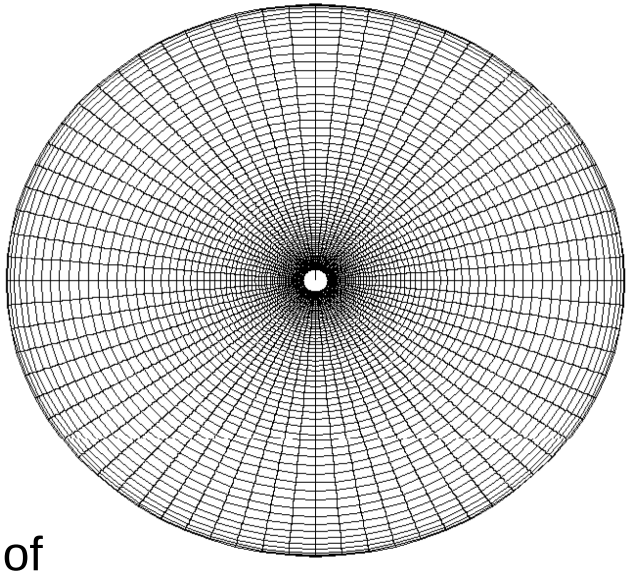
estimated radius $R4^* = 3\,R3 - 3\,R2 + R1$

aera3* = estimated wavefront area

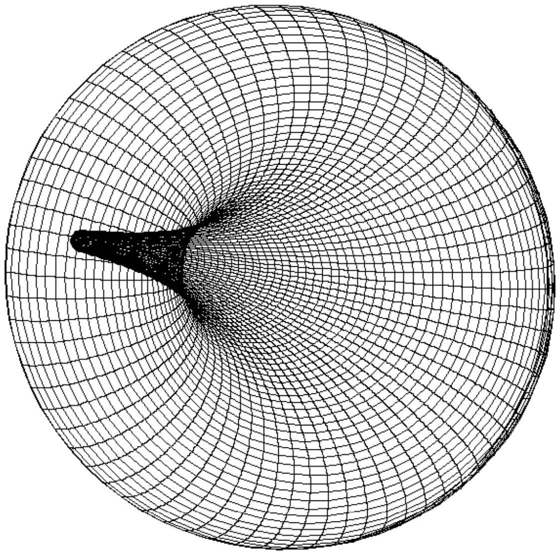
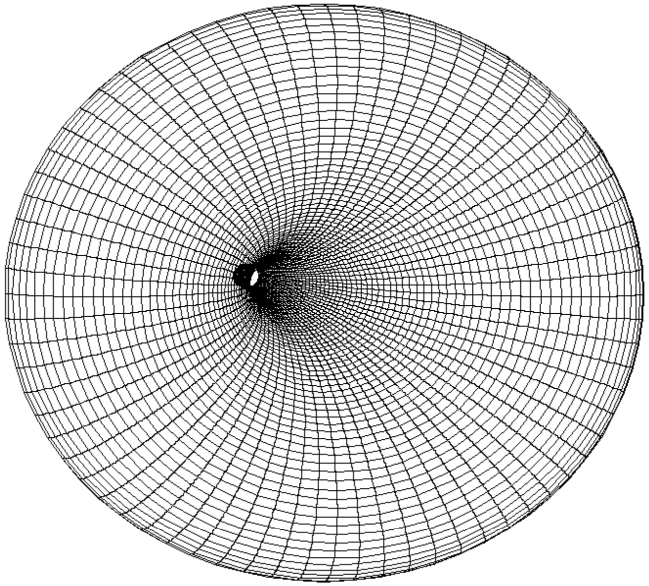
$$area3^* = [\,2\sqrt{area2} - \sqrt{area1}\,]^2$$

area1, area2 and aera3 = calculated wavefront areas

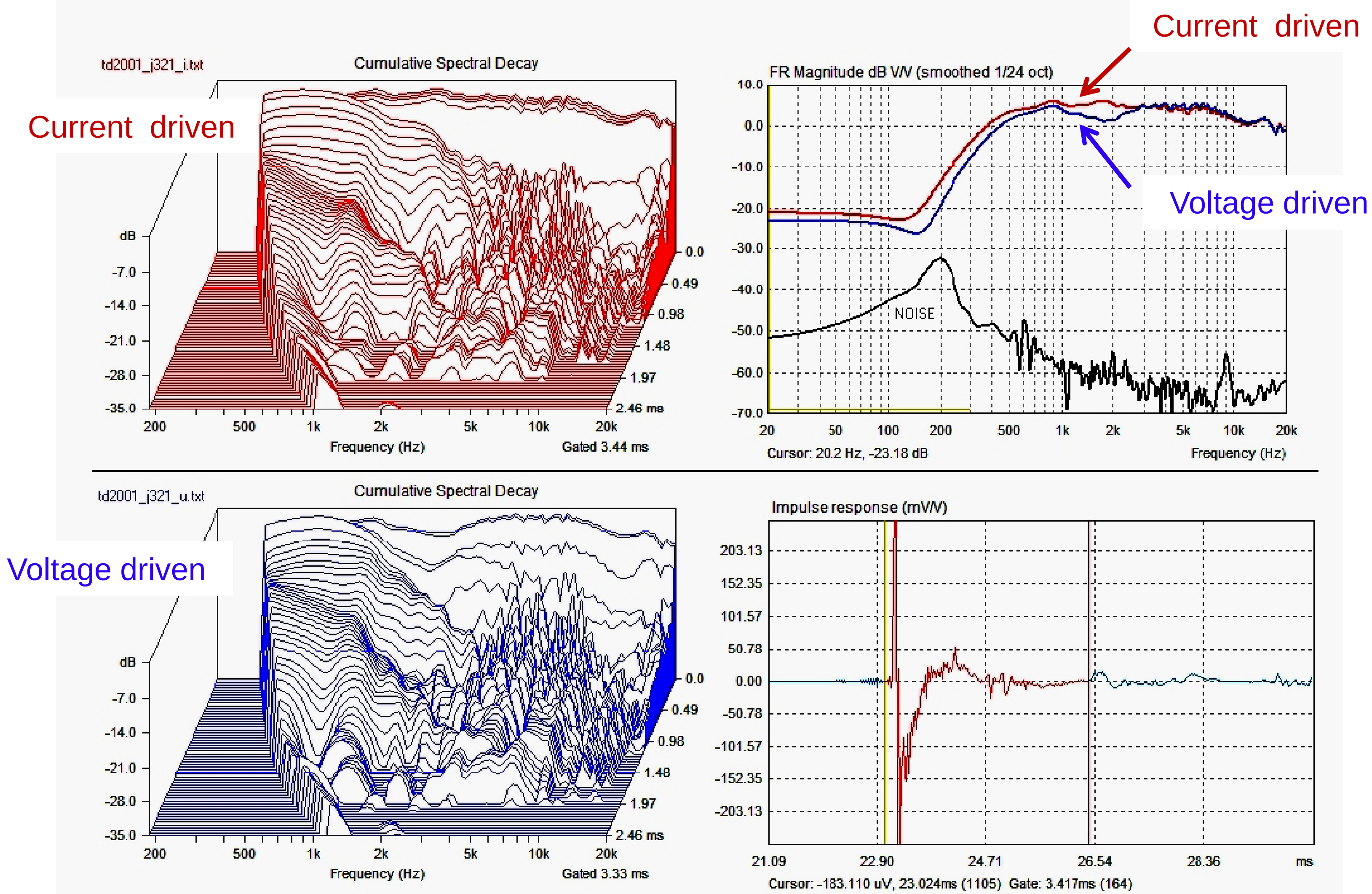
area of the outer added element = area3 - area3*

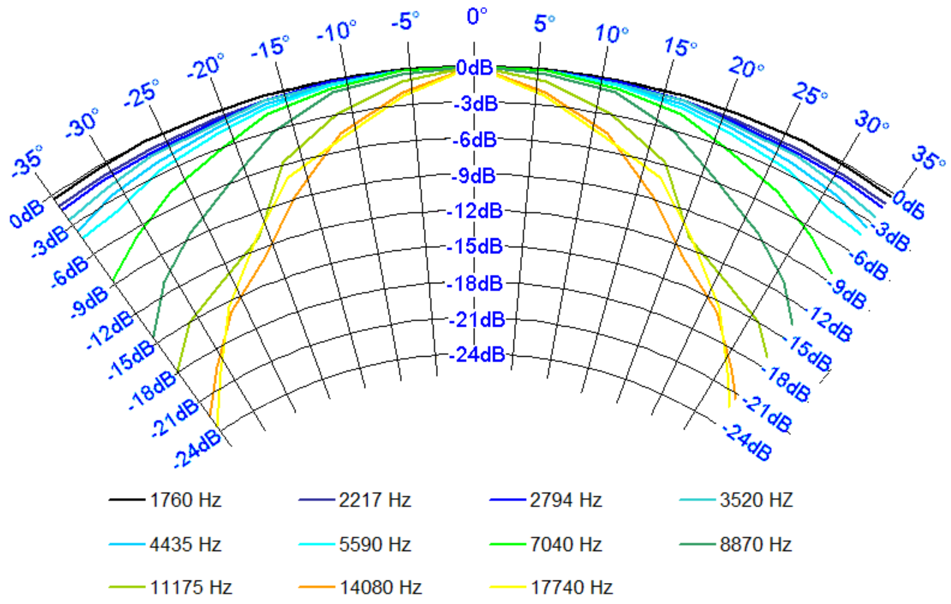
Wireline 3D view of
a Le Cléac’h horn

***Le Cléac'h horns (JMLC) that compromise superb pressure linearity, good bass extension, and time domain behavior. Below example with TAD2001***

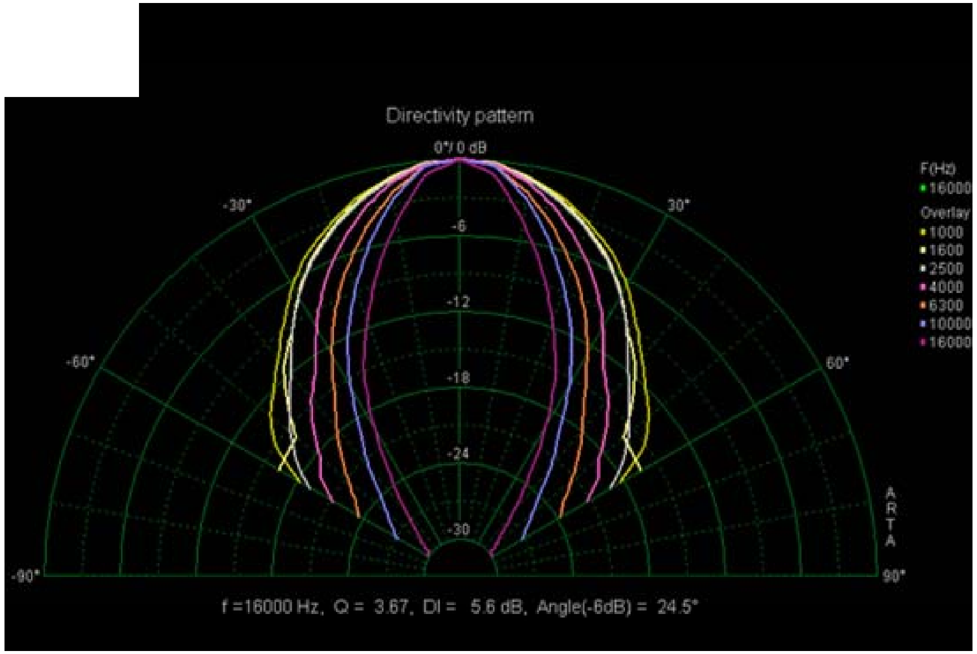



analysis by Jacek Zagaja




J321 (Fc = 320Hz)

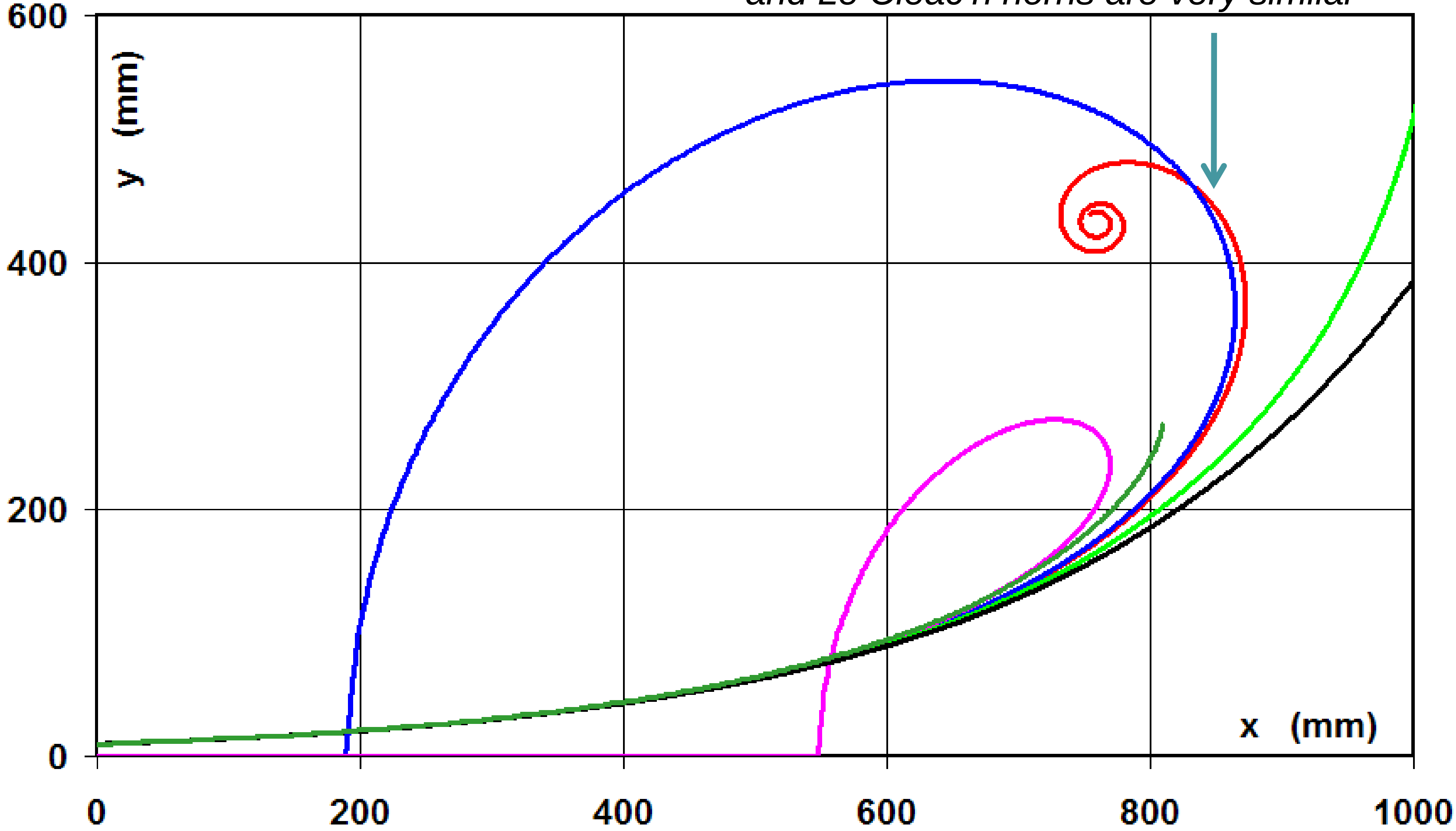
directivity pattern of few
Le Cléac'h horns




J871 (Fc = 870Hz)

# compared profiles of exponential, spherical, Le Cléac'h, Kugelwellen, tractrix, tractrix revisited

*Note how the profiles of the Kugelwellen and Le Cléac'h horns are very similar*



# waveguides

The benefits of the directivity of a waveguide are improved frequency response and SPL levels within the included angle of the waveguide within the operating frequency band of the waveguide.

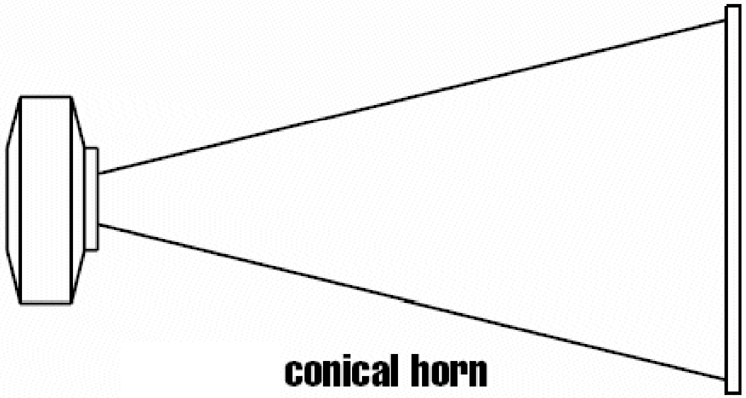
In addition, sidewall and floor bounce reflections are reduced by the controlled directivity

# conical horn

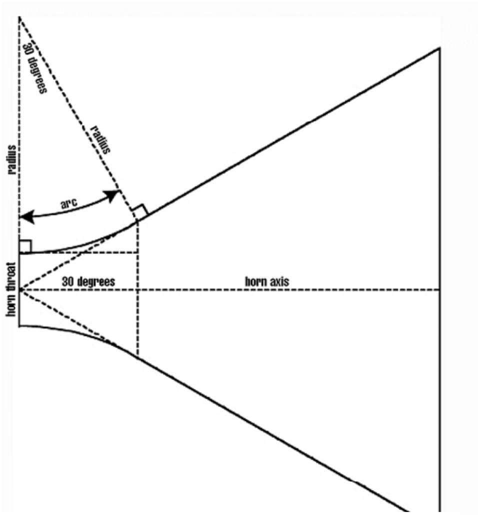
The simple formula for
a conical horn is:

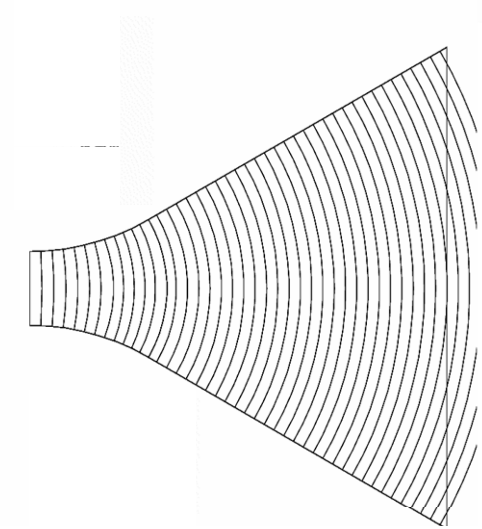
$$S = S_1 x^2$$

$S$ = the area at the horn mouth
$S_1$ = the area at the horn throat
$x$ = the length of the horn



# Oblate spheroidal waveguide



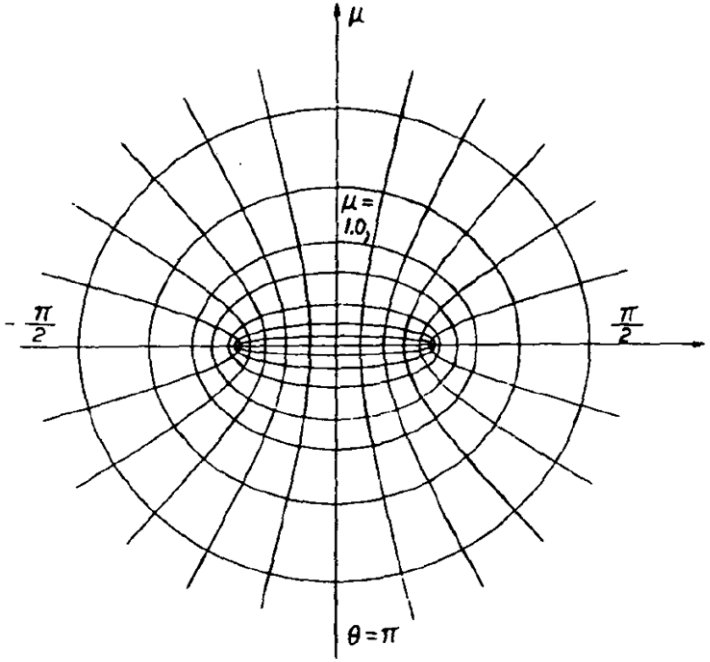



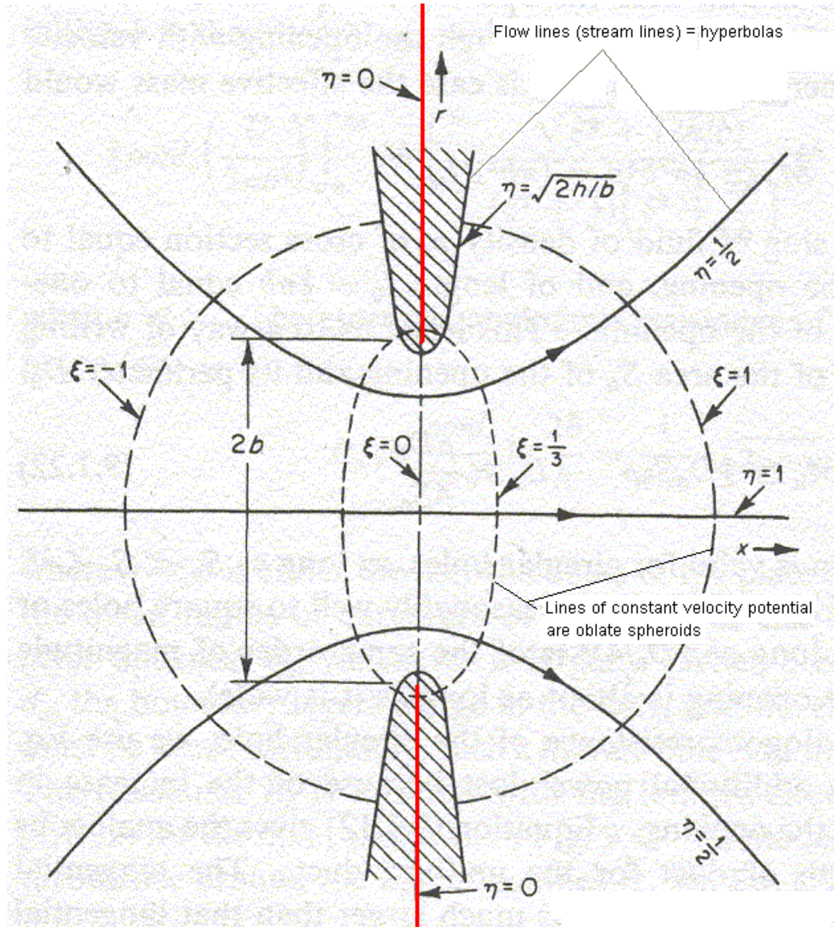
$$S = Ax^2 + B\sqrt{r^2 - x^2} + C$$

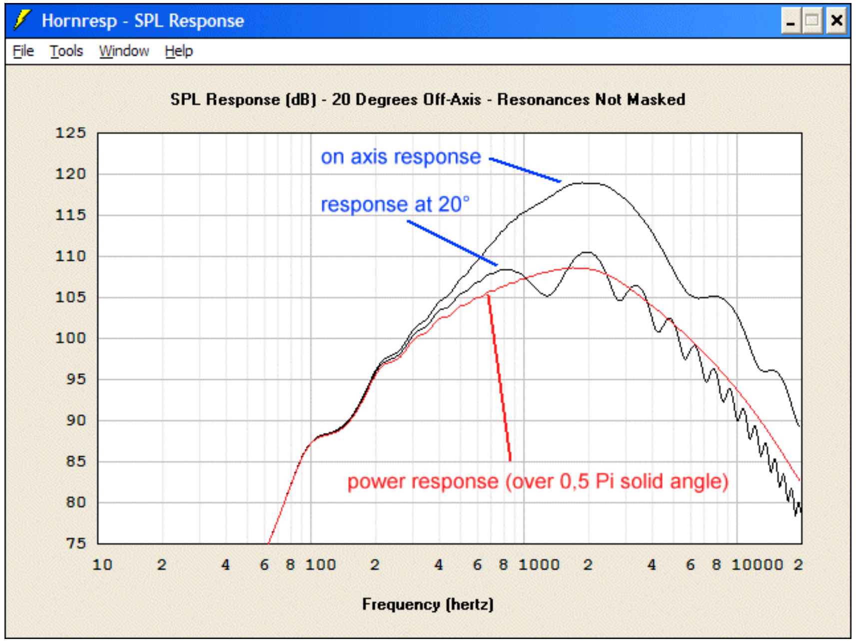
Earl Geddes

"The concept of a waveguide as a direct solution to the wave equation was shown to be capable of exact solution, free of the plane wave assumption of Webster'equation. "

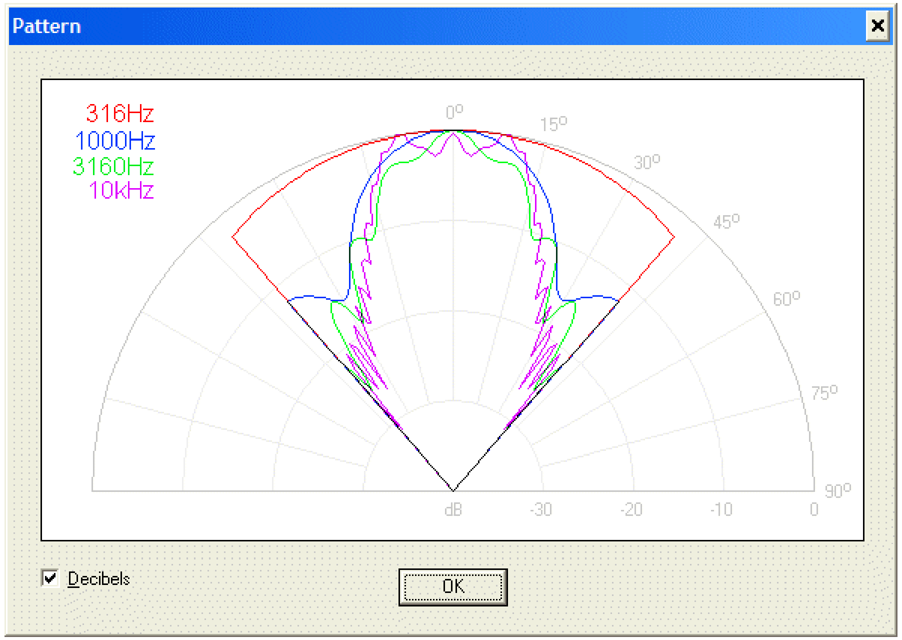
## oblate spheroidal system of coordinates






While the summed power response radiated by the OS waveguide in full space is very smooth, the frequency response curve at any given angle from the axis is never smooth




See measurements of Earl Geddes loudspeaker on page 123.

# modelisation
# and simulation
# of horns

A. H. BENADE et al.: PLANE AND SPHERICAL WAVES IN HORNS. I

ACUSTICA
Vol. 31 (1974)

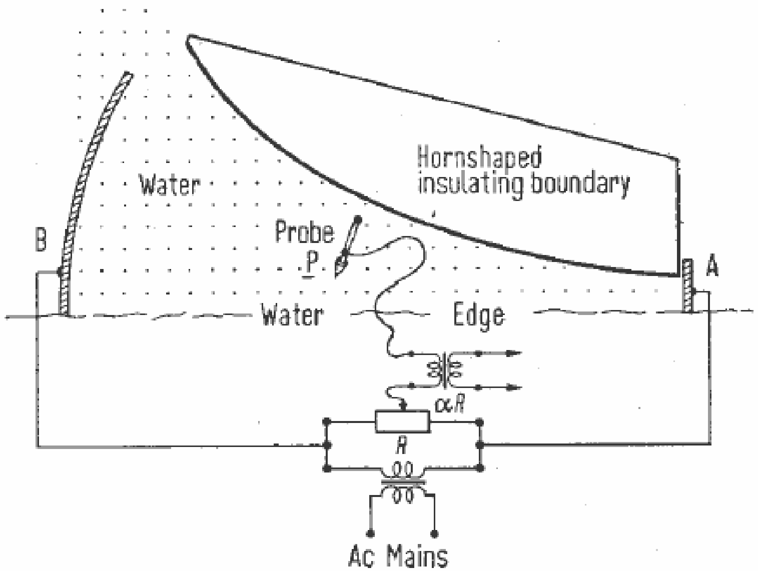



Fig. 4. Schematic diagram of an electrolytic tank field-plotting apparatus provided with a wedge-shaped volume of water. The equipotentials of the electric field are analogous to the low frequency flow equipotentials in an air filled horn.

Shape optimization of an acoustic horn

Erik Bängtsson, Daniel Noreland, and Martin Berggren
Department of Information Technology
Uppsala University
P.O. Box 120
SE-75104 Uppsala, Sweden

May 8, 2002

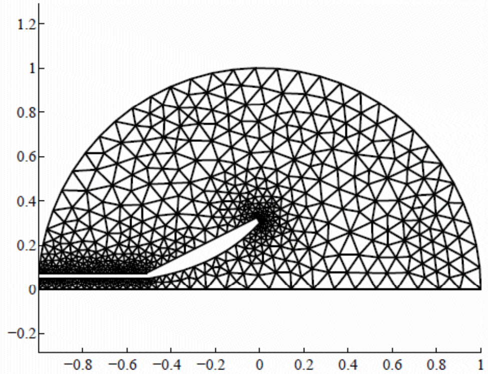



FIGURE 7: The finite element mesh, denoted Mesh I in table 2, on the initial geometry. Note that the $\Gamma_d^{init}$ is different from $\Gamma_d^{ref}$.

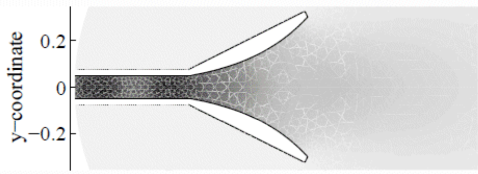



FIGURE 8: The square of the absolute value of the initial sound pressure in the horn, the waveguide, and the surroundings. Note the banded pattern in the waveguide, indicating reflections.

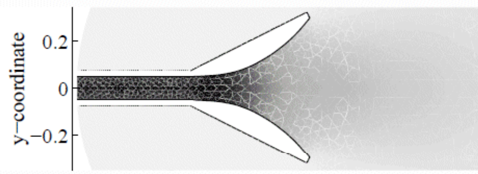



FIGURE 12: The square of the absolute value of the sound pressure distribution at 550 Hz after optimization. Note that the banded structure in the waveguide shown in figure 8 has disappeared.

above: the first models used a tank filled of water.

on right : later finite elements methods were used

## Acoustic Radiation of a Horn Loudspeaker by the Finite Element Method—A Consideration of the Acoustic Characteristic of Horns*

SHIGERU MORITA, NOBORU KYONO, AND SHINICHI SAKAI

*Consumer Products Research Laboratory, Mitsubishi Electric Corporation, Kamakura 247, Japan*

AND

TATSUO YAMABUCHI AND YUKIO KAGAWA

*Toyama University, Toyama, Japan*

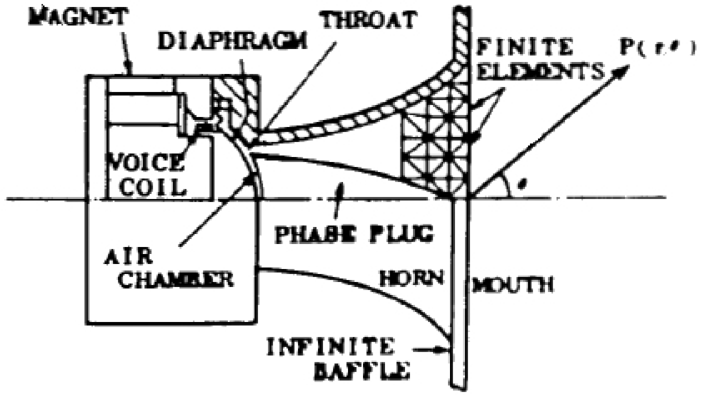



Fig. 1. Sectional view of a horn loudspeaker and finite element division.

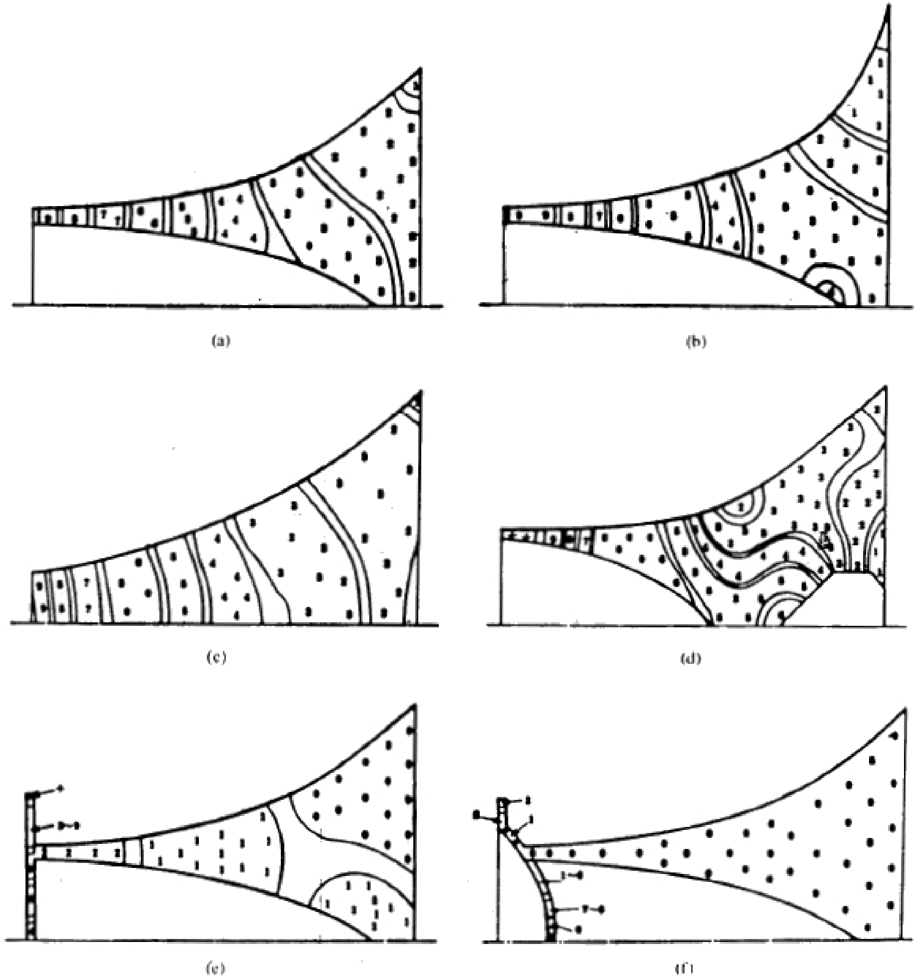
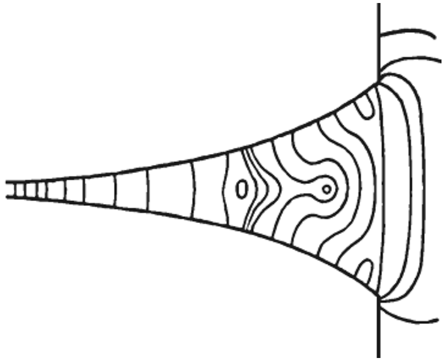
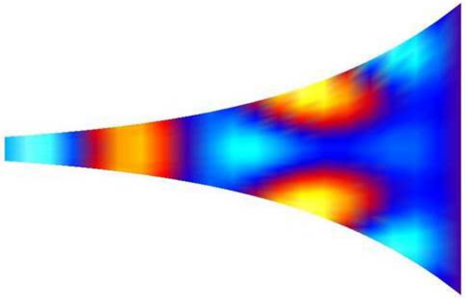



Fig. 8. Sound pressure distribution in the horns. (a) No. 1, frequency 10 kHz. No. 2, frequency 11.7 kHz. (c) No. 3, frequency 10 kHz. (d) No. 4, frequency 12 kHz. (e) No. 5, frequency 12.8 kHz. (f) No. 6, frequency 12 kHz.

one of the first publication on FEM results of the simulation of soundfields in horns

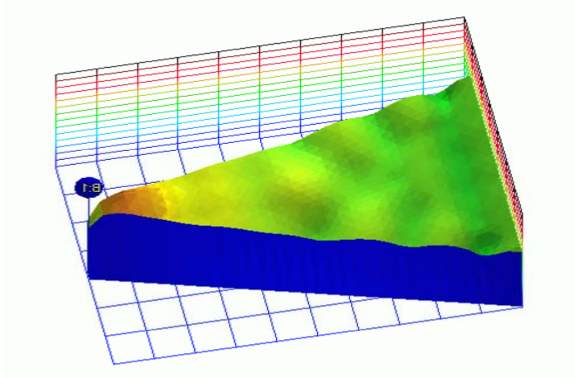


Measurements
performed
by Morse

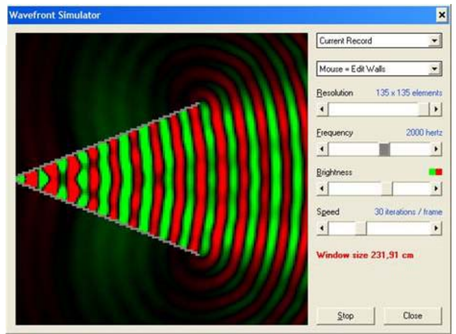


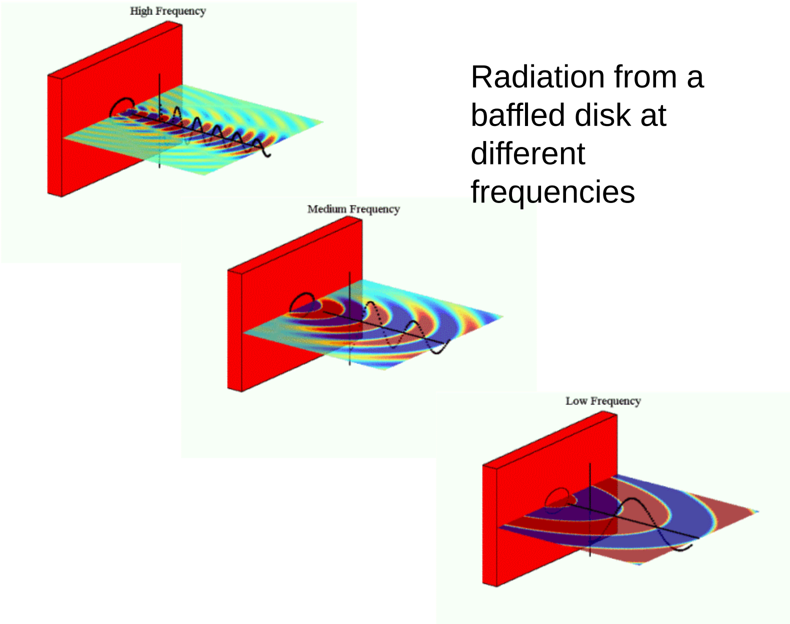
Finite elements analysis of
an exponential horn by John
Sheerin

Analysis using Cara
performed my Michael
Gertsgrasser

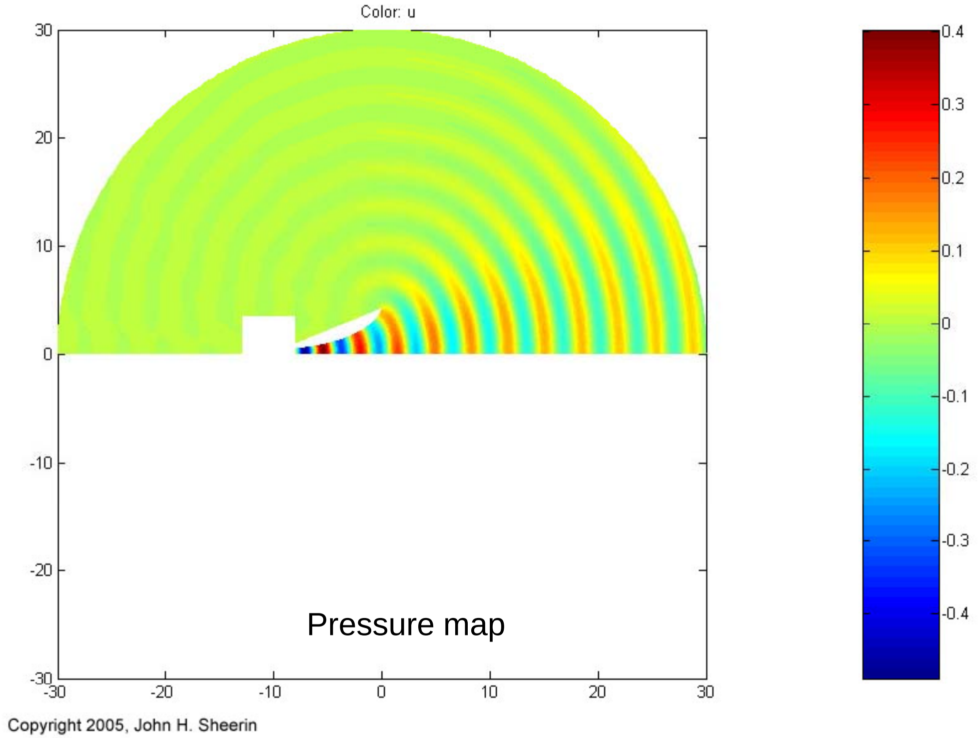


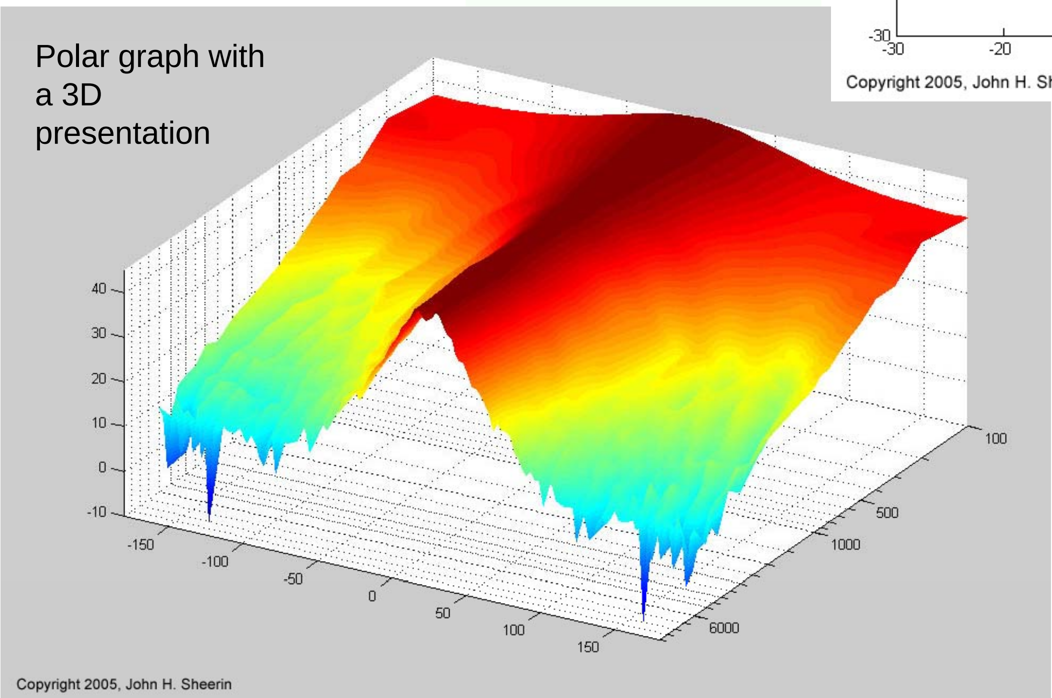
« wavetank » analysis in
David McBean's Hornresp »
software.



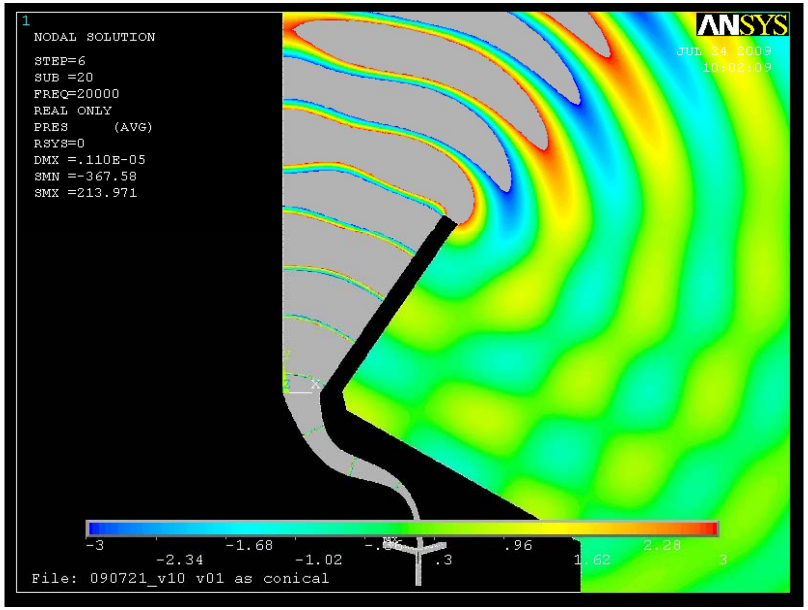


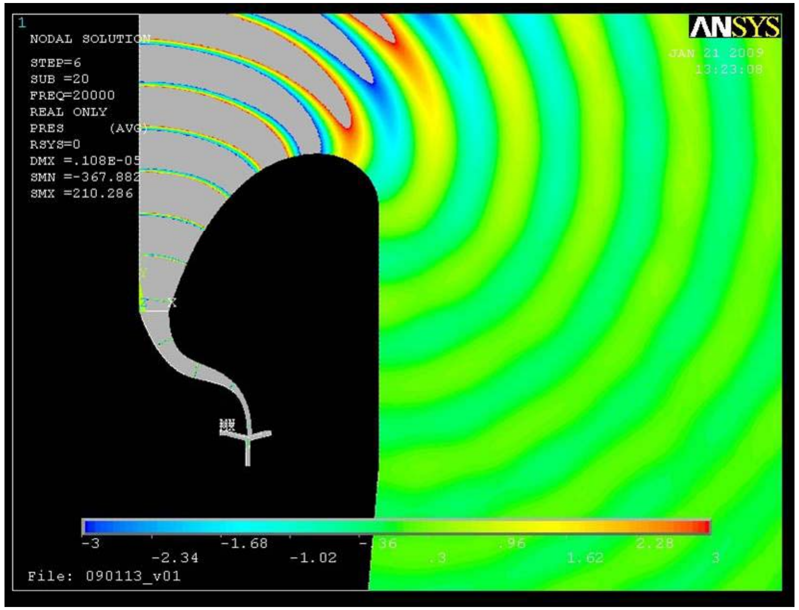

Radiation from a baffled disk at different frequencies




Various simulations of the radiation of a piston and of a horn.




conical horn

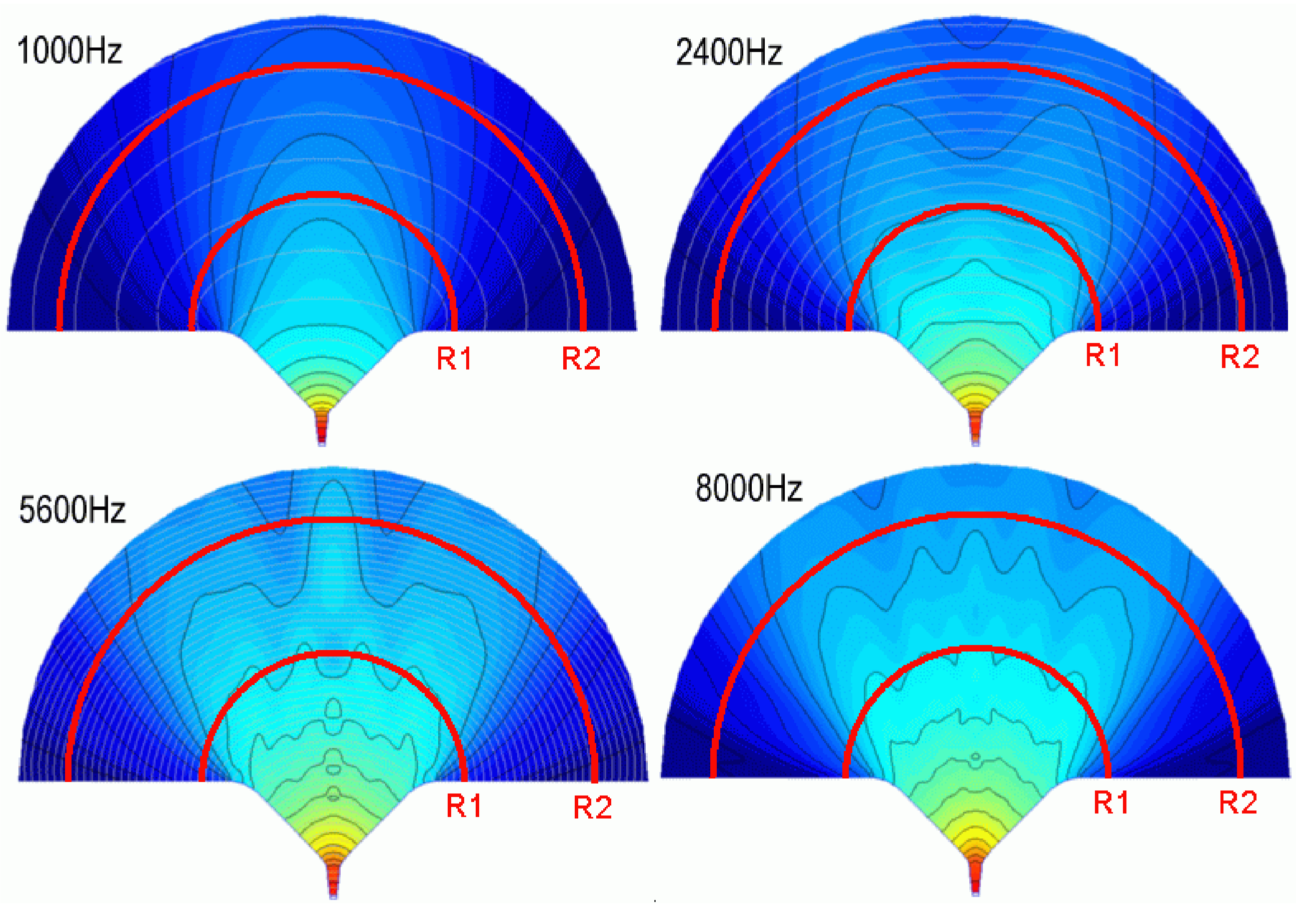
Note the distortion of the shape of the wavefronts

Le Cléac'h horn

Note the very smooth wavefronts

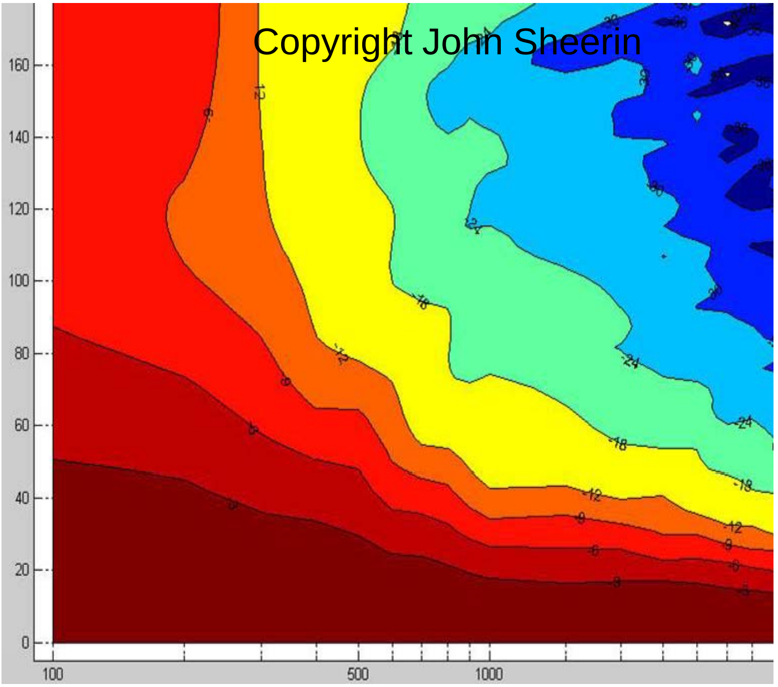
FEM simulations performed by John Sheerin

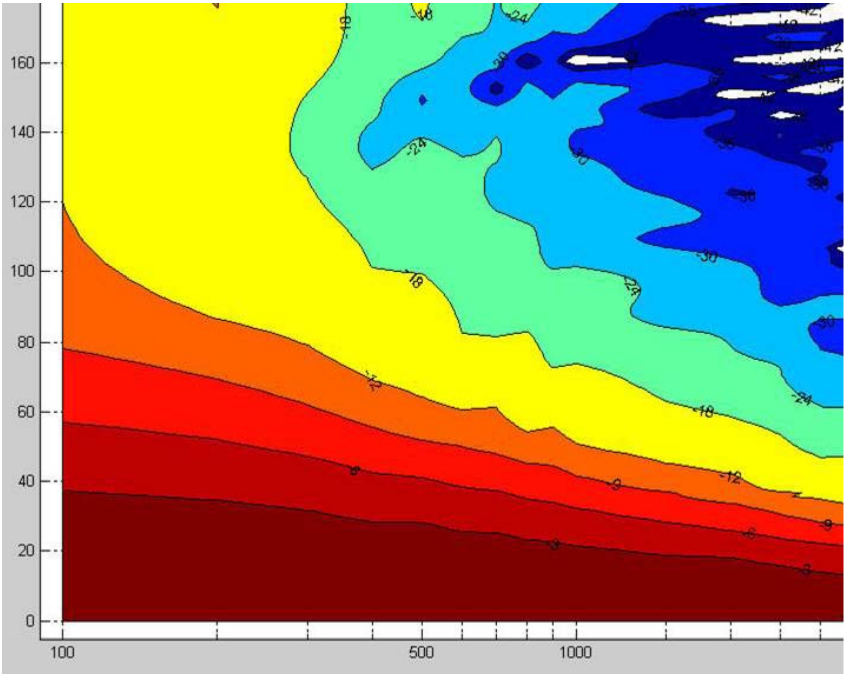
*(Half horn represented only)*




simulations of an OS waveguide at different frequencies

*Note the wavy isobare curves over 2000Hz*

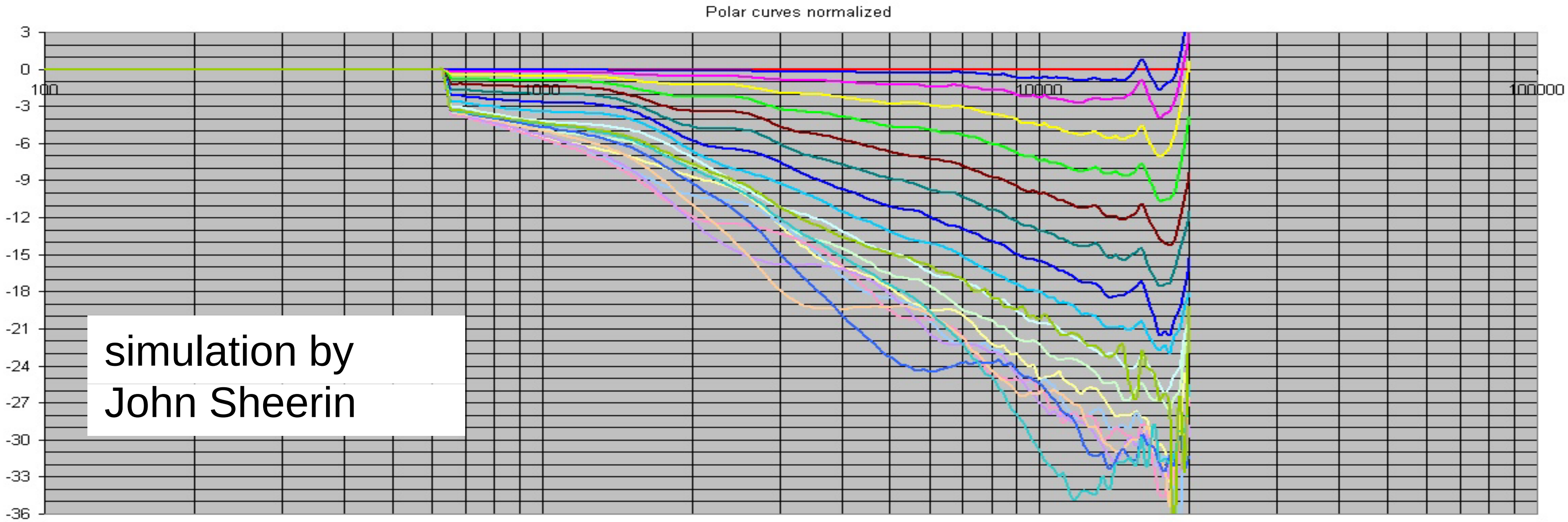


*Note the smoothness and the linarity of the isolevel contours.*

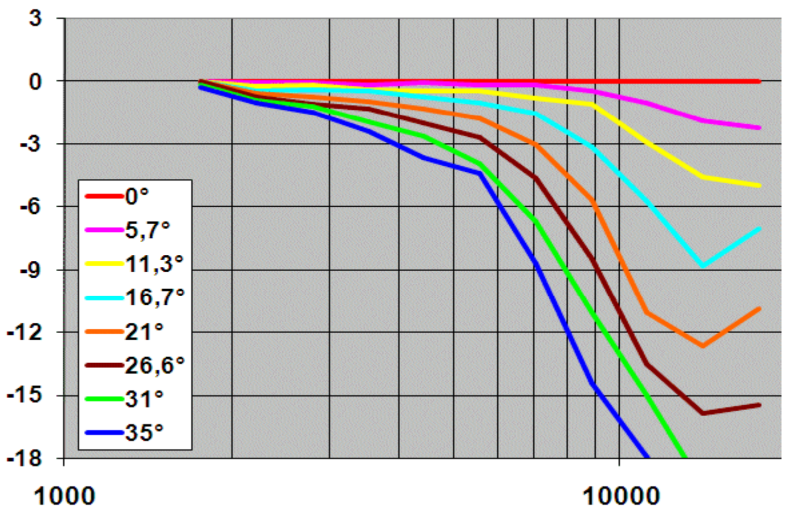
# polars obtained by FEA of a 275Hz tractrix horn and a 275Hz Le Cléac'h horn

FEM simulations performed by John Sheerin




*Note the smooth response curves off axis*

my
measurements on
the J321 horn




Le Cléac'h
horn

# backreflected waves, High Order Modes (HOMs) and stored energy

reflected waves from mouth to throat inside a horn.

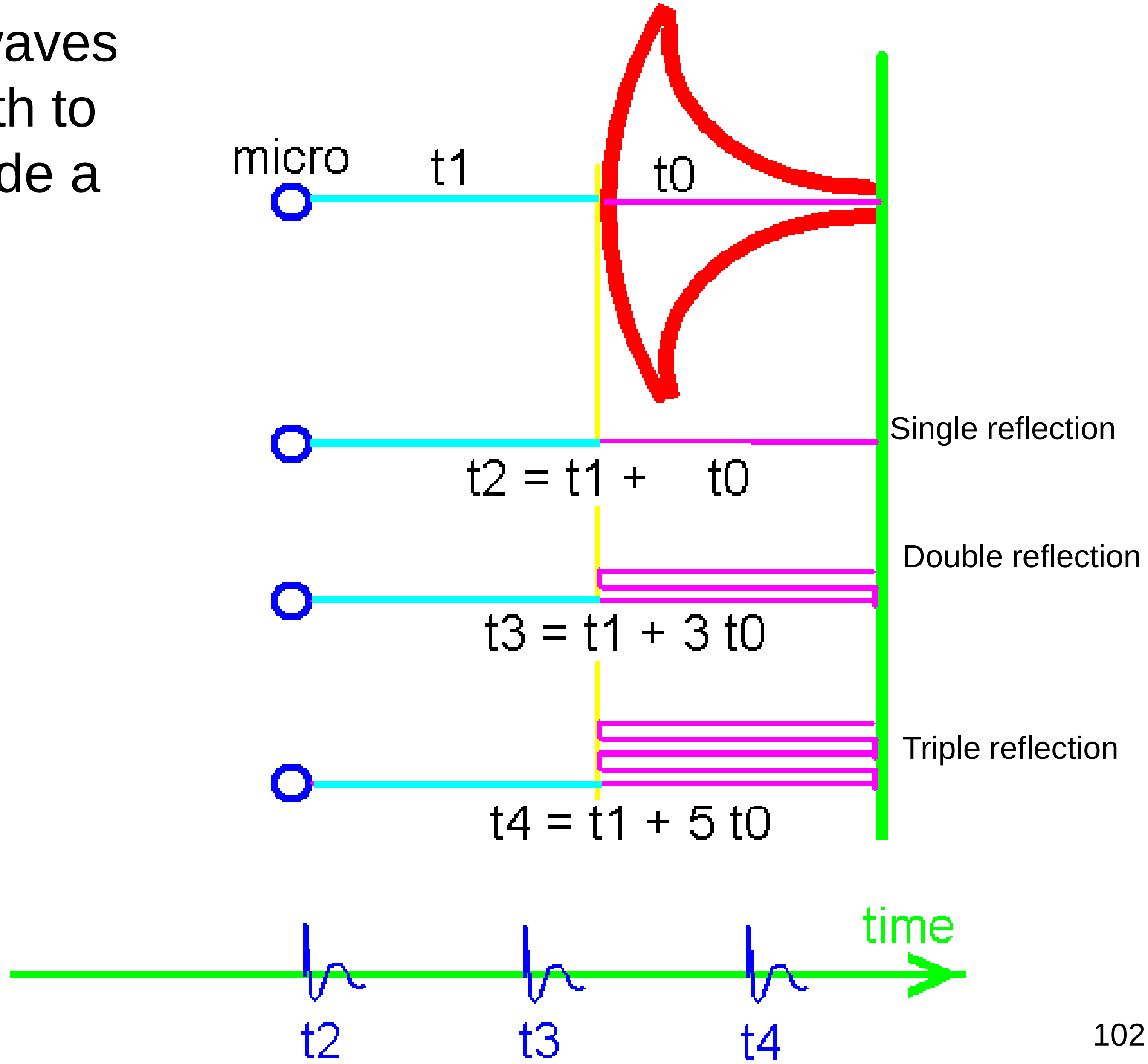
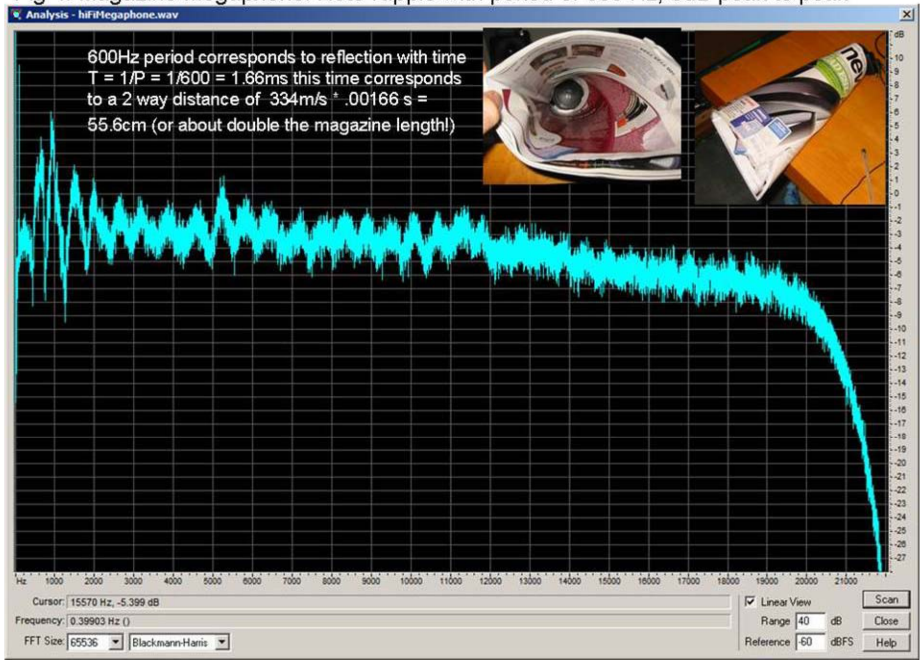


Fig 4: Magazine megaphone: Note Ripple with period of 600 Hz, 5dB peak to peak

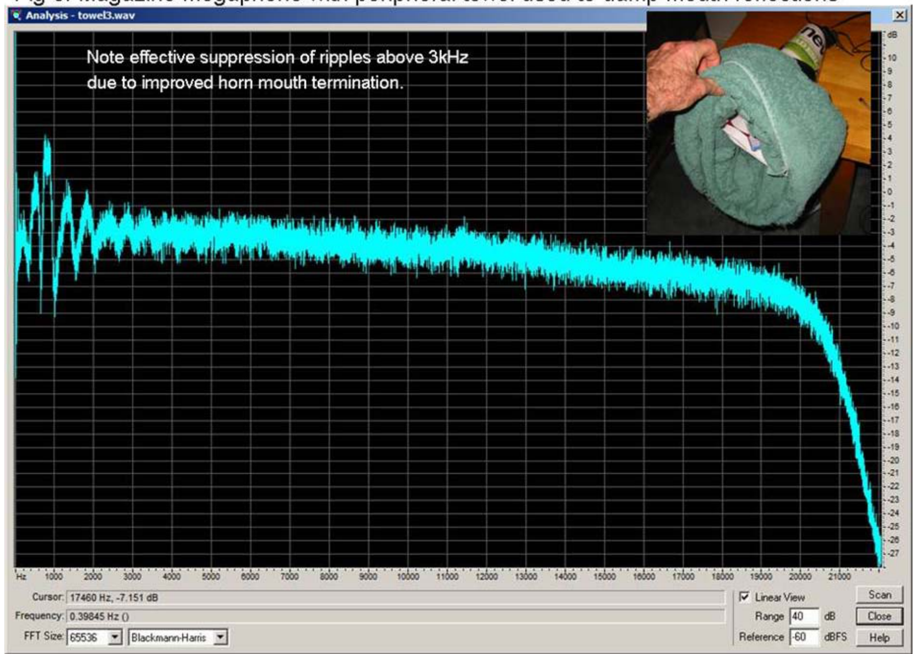



When the pathlength between the direct wave and the reflected wave is equal to a multiple of the wavelength at the considered frequency, we observe a summation of their pressure.

When the pathlength between the direct wave and the reflected wave is equal to a odd multiple of the half wavelength at the considered frequency, we observe a subtraction of their pressure.

easy demonstration of back reflected waves with a PC loudspeaker, a magazine forming a cone and a towel

Fig 5: Magazine megaphone with peripheral towel used to damp mouth reflections



# The Sound of Midrange Horns for Studio Monitors

KEITH R. HOLLAND, FRANK J. FAHY and PHILIP R. NEWELL

J. Audio Eng. Soc., Vol. 44, No. 1/2, 1996 January/February

Table 3. Horn loudspeaker samples grouped according to similarity.

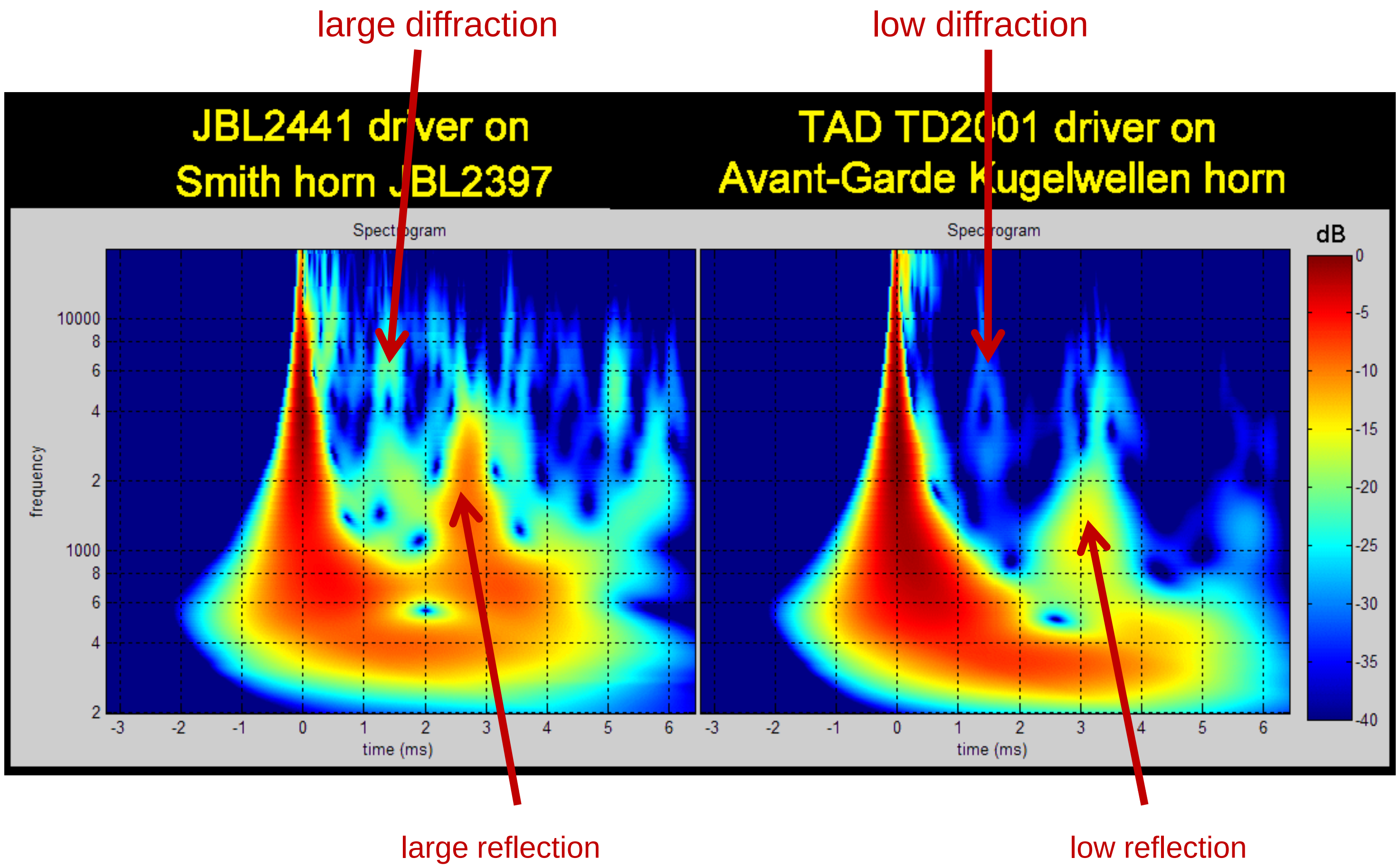
| Sample | Manufacturer/Type | Flare Material | Flare Rate | Length (mm) | Mouth Size |
|---|---|---|---|---|---|
| *Horns with similarity to reference B (Son Audax direct radiator)* | | | | | |
| 1 | Vitavox exponential | Aluminum | Medium | 340 | Medium |
| 4 | AX1 axisymmetric* | Glass-fiber | Low | 230 | Small |
| 5 | Reflexion Arts | Glass-fiber | Medium | 330 | Medium |
| 7 | Reflexion Arts, no lips | Glass-fiber | Medium | 240 | Medium |
| 10 | Fostex sectoral* | Wood | High | 440 | Large |
| 11 | JBL axisymmetric | Aluminum | Low | 250 | Small |
| *Horns with similarity to reference C (Fostex doctoral)* | | | | | |
| C | Fostex sectoral | Alumimum | Medium | 500 | Large |
| 12 | Altec sectoral* | Aluminum | Medium | 530 | Large |
| 13 | Altec multicellular | Aluminum | Low/med | 600 | Large |
| 14 | Starr gramophone | Wood | Low | 650 | Medium |
| 15 | Vitavox sectoral | Aluminum | Medium | 450 | Large |
| 16 | JBL biradial* | Composite | Medium | 400 | Medium |
| *Others* | | | | | |
| 8 | AX2 axisymmetric | Glass-fiber | High | 230 | Medium |
| 9 | Yamaha sectoral | Aluminum | Medium | 350 | Medium |

*Sample 8*: AX2 horn/Emilar EK175 driver (no. 1). Short axisymmetric horn of glass-fiber construction with a rapid flare rate terminating in a medium-sized mouth. Compression driver as sample 1.

*Sample 13*: Altec 806C horn/Emilar EK175 driver (no. 1). Large multicellular horn with eight individual flares of sheet aluminum construction joined to a single throat via a cast aluminum manifold. Compression driver as sample 1.

- Horns do sound different from each other, even when fitted with the same driver.
- The two horns having minimal mouth reflections, one long and one short, were not identified as horns and did not sound similar to the direct-radiating reference.

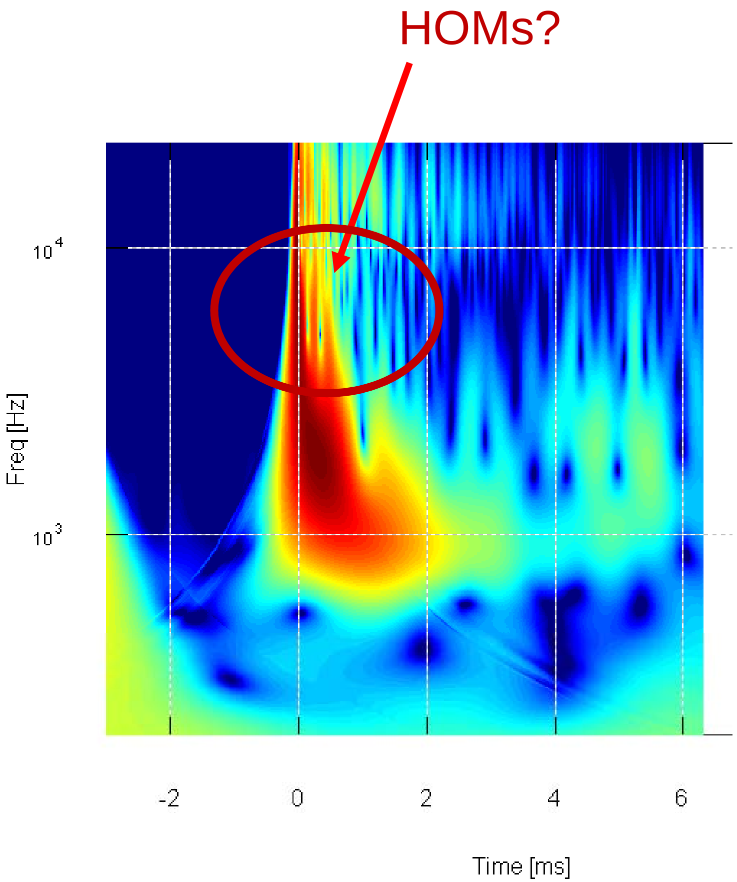
the two horns in the test that produce negligible mouth reflections, samples 8 and 13, neither was ever identified as a horn, and the short horn, sample 8, did not sound like the direct-radiating reference B.

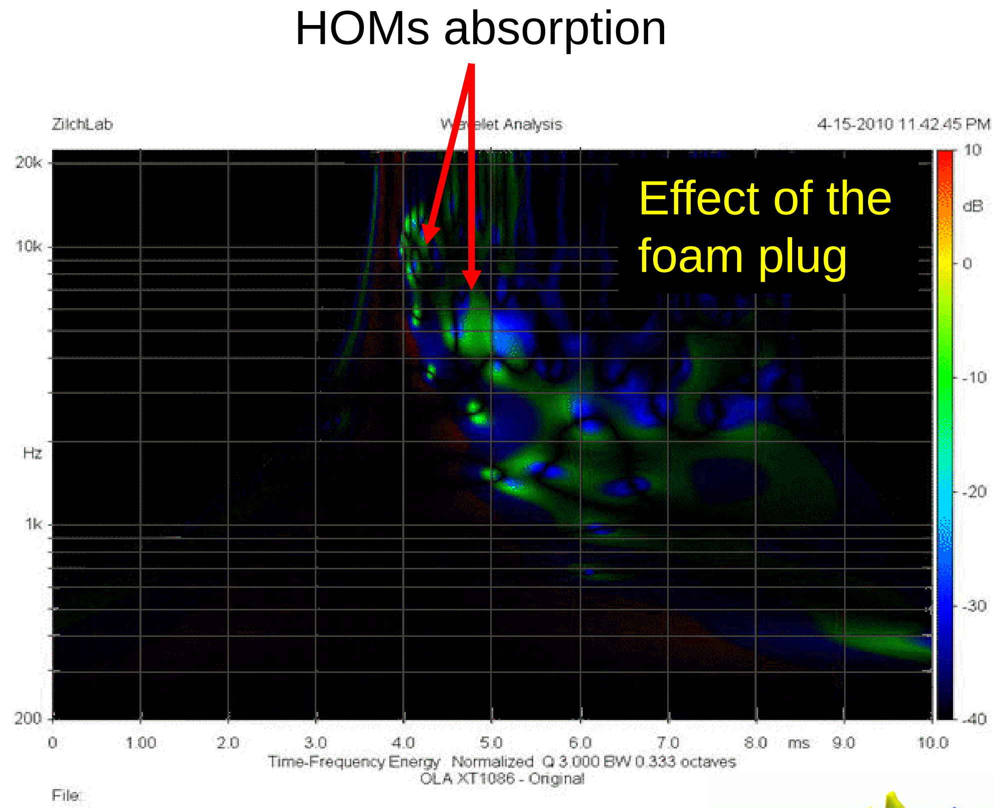



Compared wavelets graphs of 2 horns:

- on left, high reflectance
- on right very low reflectance

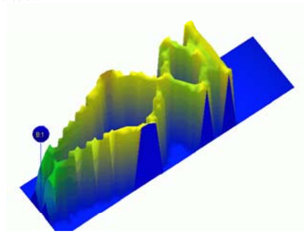
*measurements performed at ETF2010*



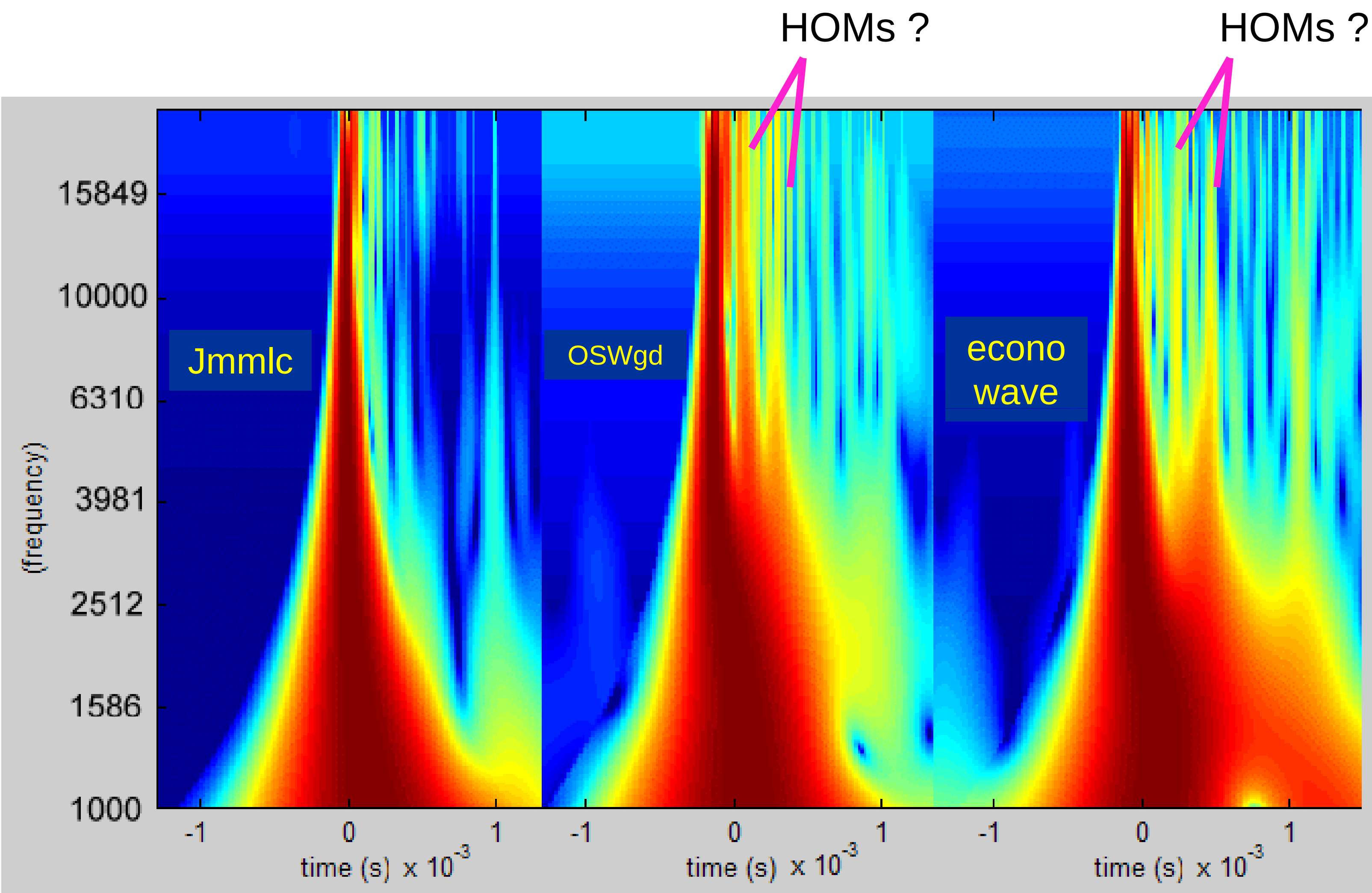




wavelets graph of the oblate spheroidal waveguide

subtraction of the wavelets graph of the OSWGD without its foam plug and with its foam plug



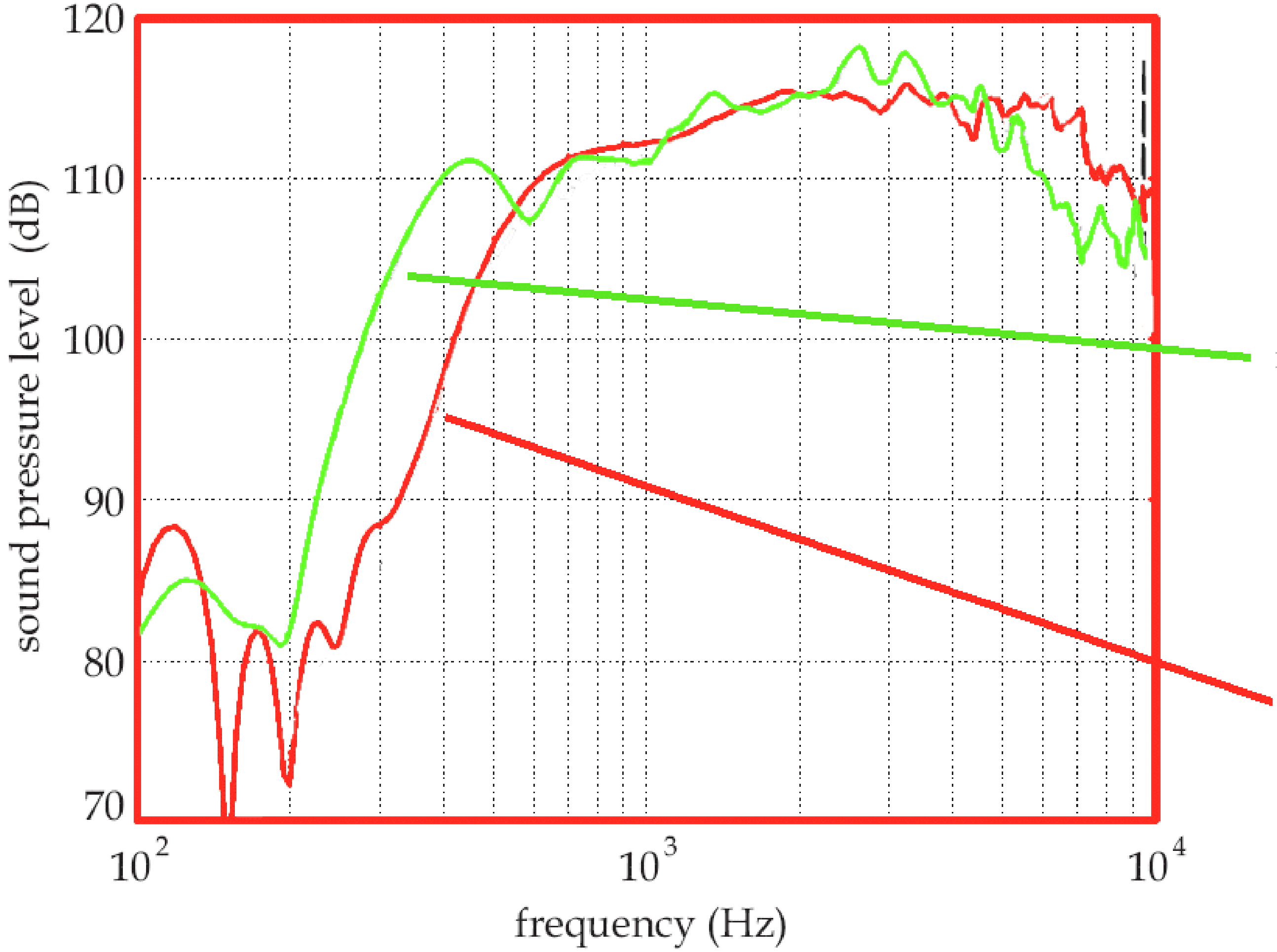
HOMs have non axial travel inside the horn

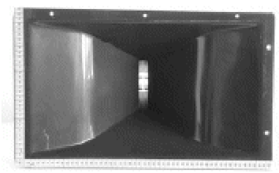



the wavelets graph may be used in order to show the existence of sub-millisecond delayed energy (HOMs?)

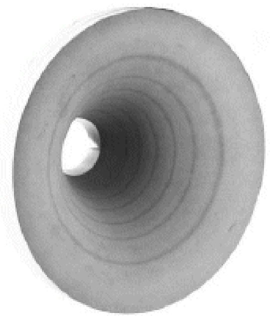
optimization with the goal of a low reflectance

# Electro-Voice DH1A horn driver



Electro-Voice HP 940 CD horn



the used spherical-wave horn.

BEHLER AND MAKARSKI

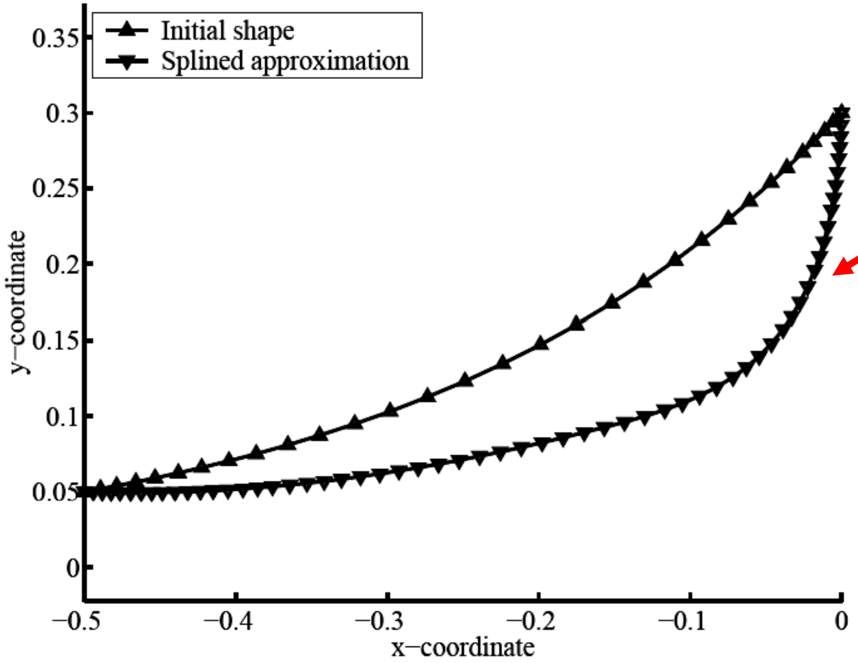
J. Audio Eng. Soc., Vol. 51, No. 10, 2003 October

horns having a lower reflectance at mouth have smoother frequency response curves

Shape optimization of an acoustic horn

Erik Bängtsson, Daniel Noreland, and Martin Berggren

May 8, 2002




note the increased opening angle at throat

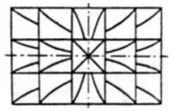
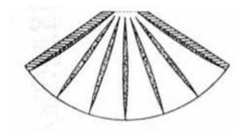
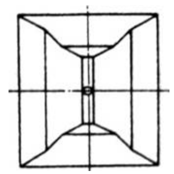
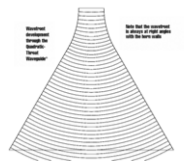
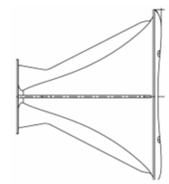
The initial shape and the splined approximation of the optimal shape from the 27 frequency optimization shown in figure 18.

optimized profile for the lowest reflectance at 27 frequencies

# In search of a more constant radiation angle

*The problem of directivity*

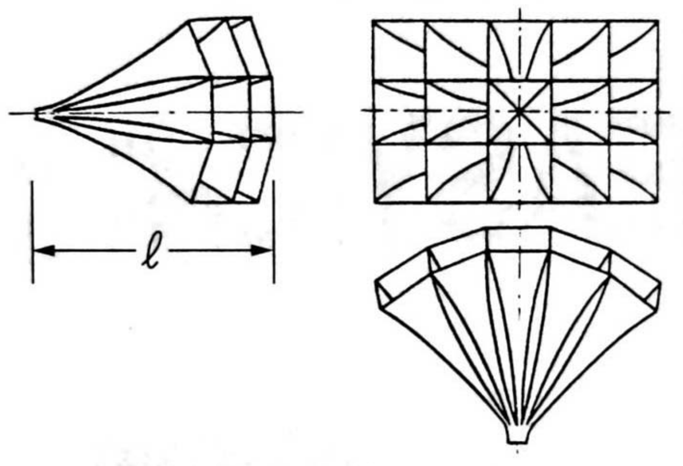
- Multicellular horns
- Multisectorial horns
- Constant directivity horns
- Waveguides
    - Quadratic throat waveguide
    - Oblate spheroidal waveguide

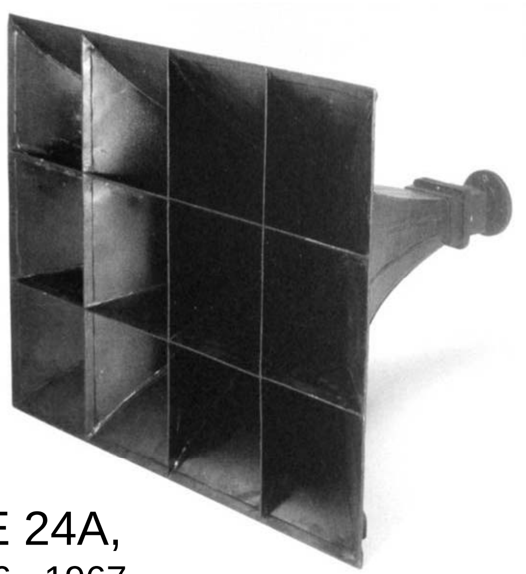
# multicellular horns

– with curved dividers

– with identical cells



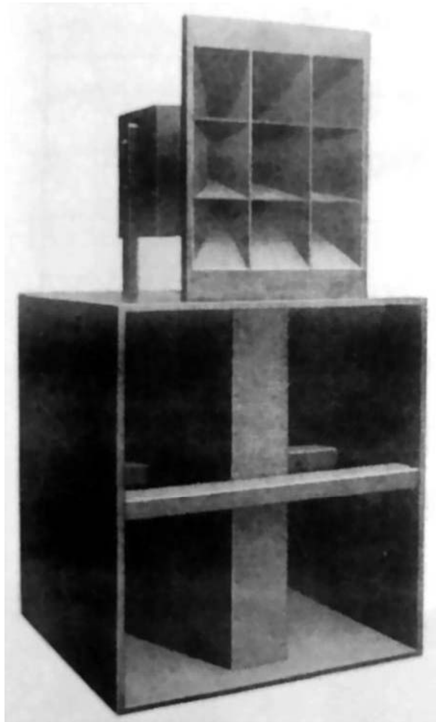

the idea is to split the wavefront near the throat of the horn through several ducts before the wavefront at HF begins to separate from the walls of the horn.



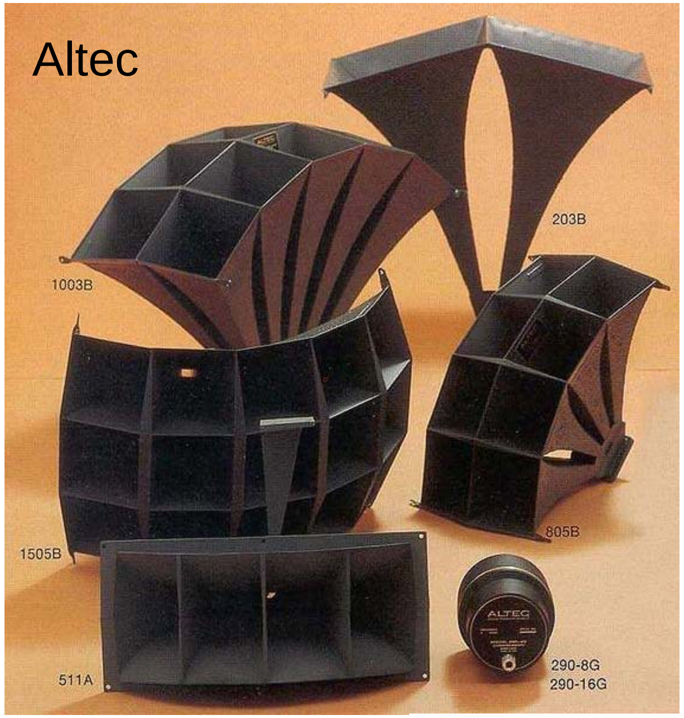
WE 24A,
1936 - 1967

# multicellular horns with curved thin dividers

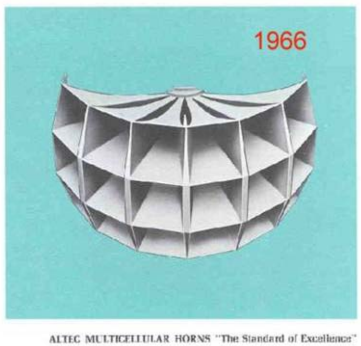
The dividers follow « flow lines ».
Different shapes of cell coexist.
Flat mouth



# multicellular horns with identical cells




Onken  255wood

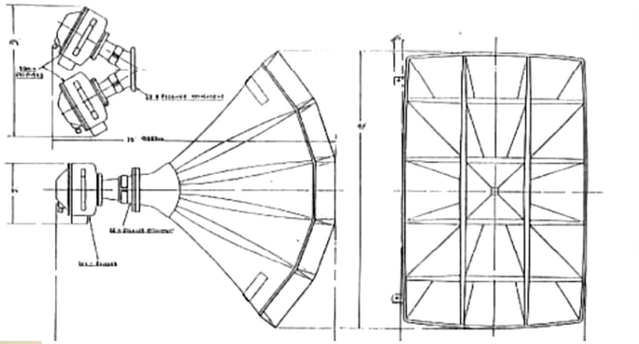



Altec Lansing
H1804B

Onken 255 wood and Onken 455 wood horns  on top of an Onken W bass reflex enclosure

**26A HORN**

USE - STAGE HIGH FREQUENCY
DESCRIPTION - SPHERICAL FACED, 12 CELL, EXPONENTIAL, 3 X 5, ERPI
LAMINATED METAL, BLACK
APPLICATION - USED WITH 1 22A RECVR. ATTACH. & 1 594A LOUDSPR, OR WITH
1 22B RECVR. ATTACH. & 2 LOUDSPEAKERS IN MIRROPHONIC SYSTMS
DIMENSIONS - 25 INCHES HIGH X 37 INCHES WIDE X 32.5 INCHES DEEP
WEIGHT - 125 POUNDS WITH ONE RECEIVER, 150 POUNDS WITH TWO RECEIVERS
FREQUENCY RESPONSE - 300 CYCLES TO 8000 CYCLES/SECOND
HOR. COVERAGE - 110 DEGREES
VERT. COVERAGE - 40 DEGREES
COVERS AUDITORIUM WIDTH OF 75 - 120 FEET

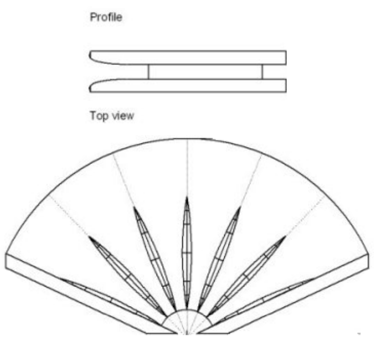


detail of
the assembly
of cells

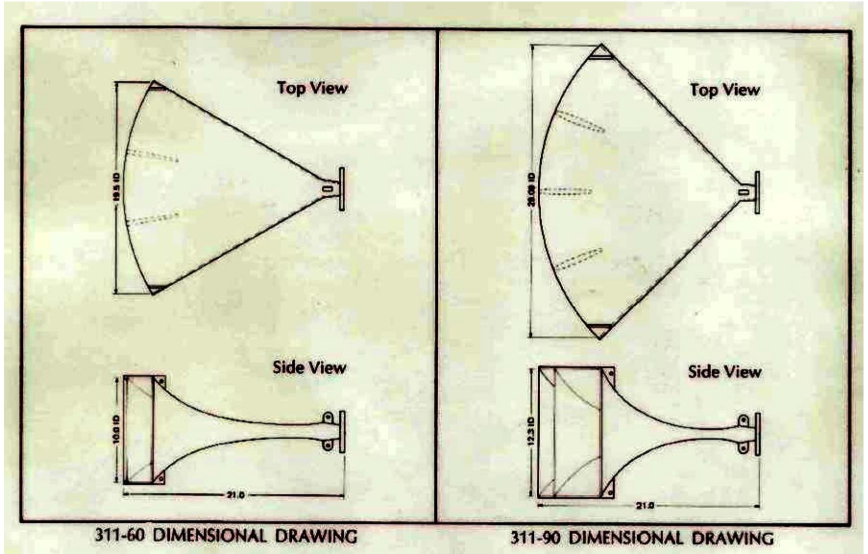
# sectorial horns

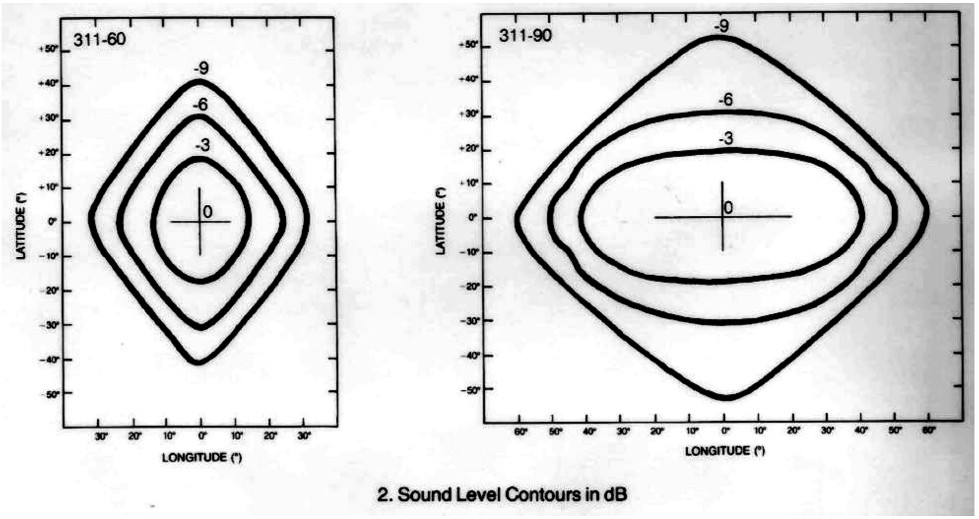
- sectorial horns have linear (« conical ») expansion in one plane and exponential expansion in the other.

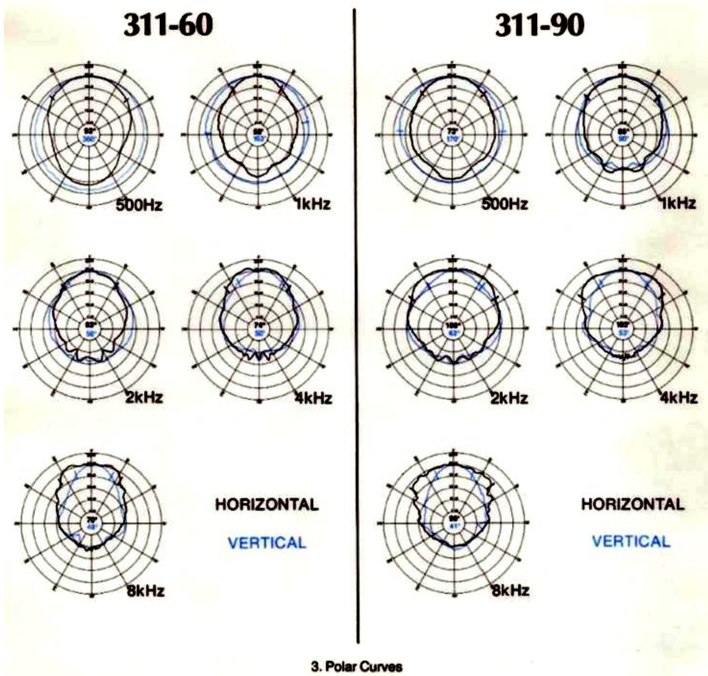
- Dividers can be flat (e.g. Altec 511 and 811) or not (e.g. JBL Smith horn JBL2397)



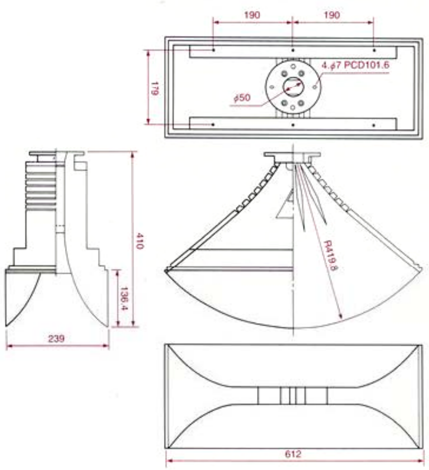

ALTEC LANSING
311-60 AND 311-90 SECTORAL HORNS
Onken 500
311-60
311-90


Top View
Side View
21.0
311-60 DIMENSIONAL DRAWING
311-90 DIMENSIONAL DRAWING

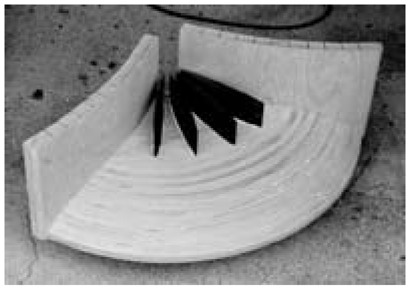

311-60
311-90
-9
-6
-3
0
LATITUDE (°)
LONGITUDE (°)
2. Sound Level Contours in dB


311-60
311-90
500Hz
1kHz
2kHz
4kHz
8kHz
HORIZONTAL
VERTICAL
3. Polar Curves

# Smith horn and related




The TAD TH4001 horn has a Smith horn design at throat



Yuichi Arai's A300 horn

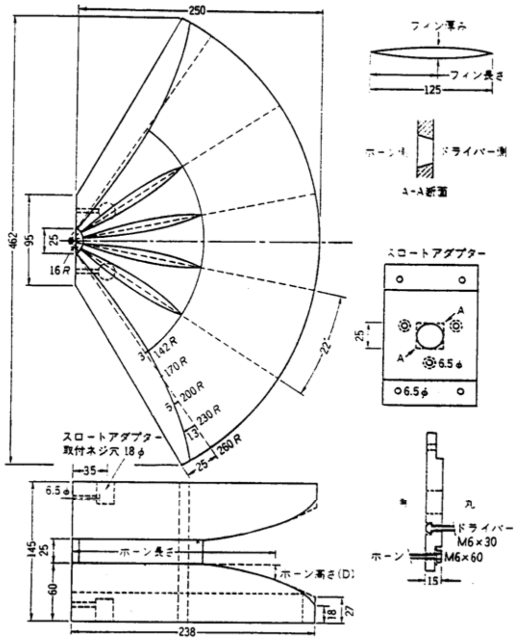



Fig. 1. The Smith-Selsted tweeter unit in combination with a more conventional h-f speaker and a woofer cabinet.

## A Loudspeaker for the Range from 5 to 20 kc

B. H. SMITH* and W. T. SELSTED**

In response to many requests for a description of the unit mentioned in the August issue, the authors provide full design information on this remarkable speaker.

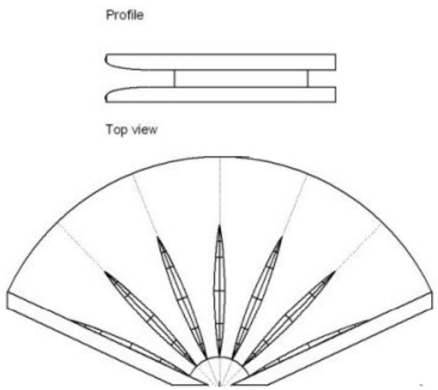

2. The sum of the velocities around any closed loop is zero.

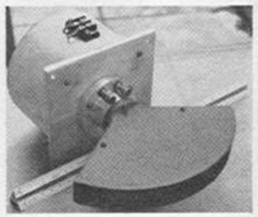
Since the fundamental equations and he combining rules of the two systems re identical, it follows that the soluions of these equations may be obained by identical means. A schematic iagram for the mechanical circuit may e drawn, and a solution may be obained just as it is done for electrical ircuits. For example, consider the echanical circuit of (A) in *Fig.* 3. he schematic diagram and solution re shown at (B).

The quantity $Z_m$ is the mechanical uantity analogous to electrical impednce. Firestone calls this the barnpedance. Before Firestone introduced is force-current analogy, mechanical npedance had already been defined as e ratio of force to velocity. Thus, the ar-impedance is the reciprocal of the onventional mechanical impedance.

**quivalent Circuit for Horn**

We shall now proceed to develop the equivalent circuit of a horn type loudspeaker. As current flows through the



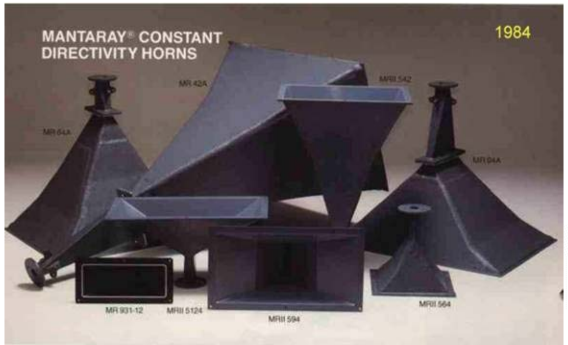



$i = \frac{I}{R}e$

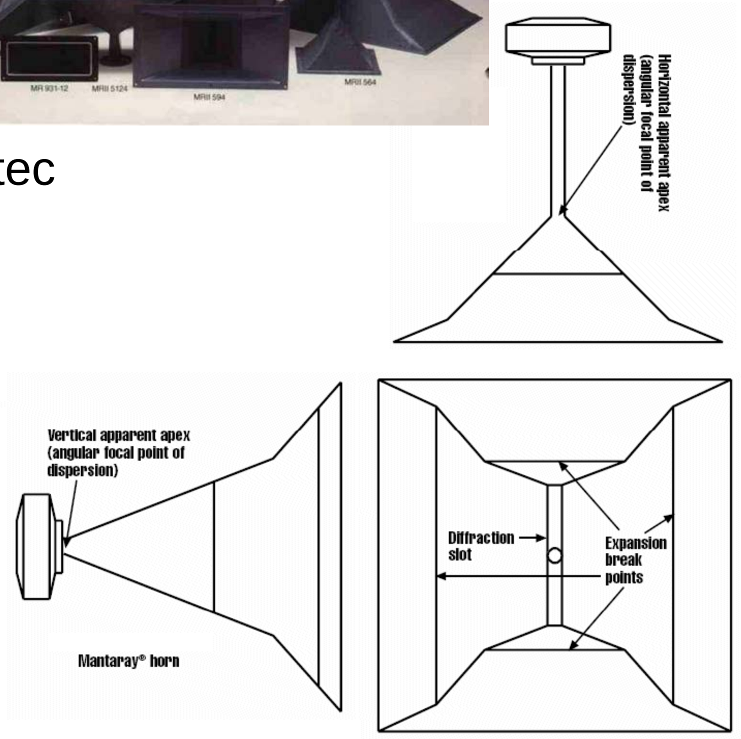
i current
to e voltage
o C capacitance
ous to L inductance
ogous to R resistance
of units is used.
the equations of
of the same form.
r combining these
l. For the elec-
les are known as
h are:
ents entering a junc-
oltages around any
system the com-
ces entering a junc-

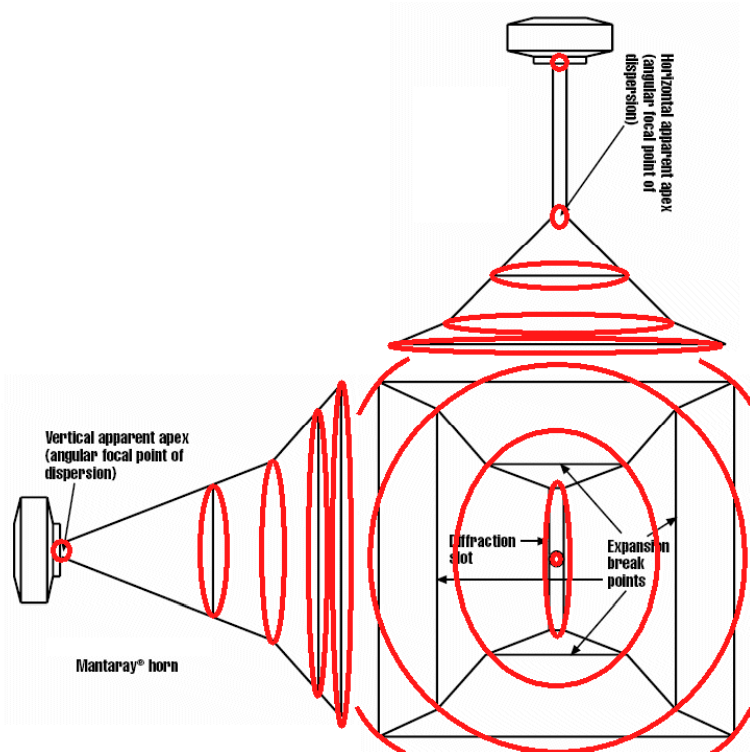
Fig. 2. The tweeter resembles an ordinary high-frequency speaker except for the relatively large field coil housing.

AUDIO ENGINEERING ● JANUARY, 1950




Altec

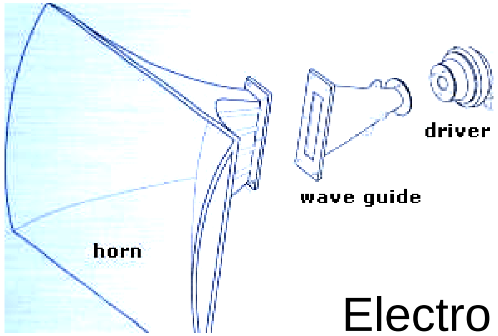



diffraction zones in red

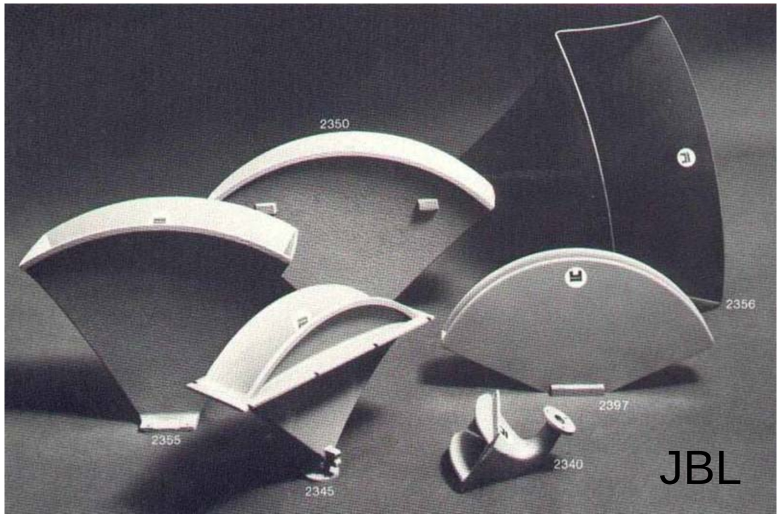
# the Mantaray horn

# from diffraction horns to biradial horns




Electro Voice

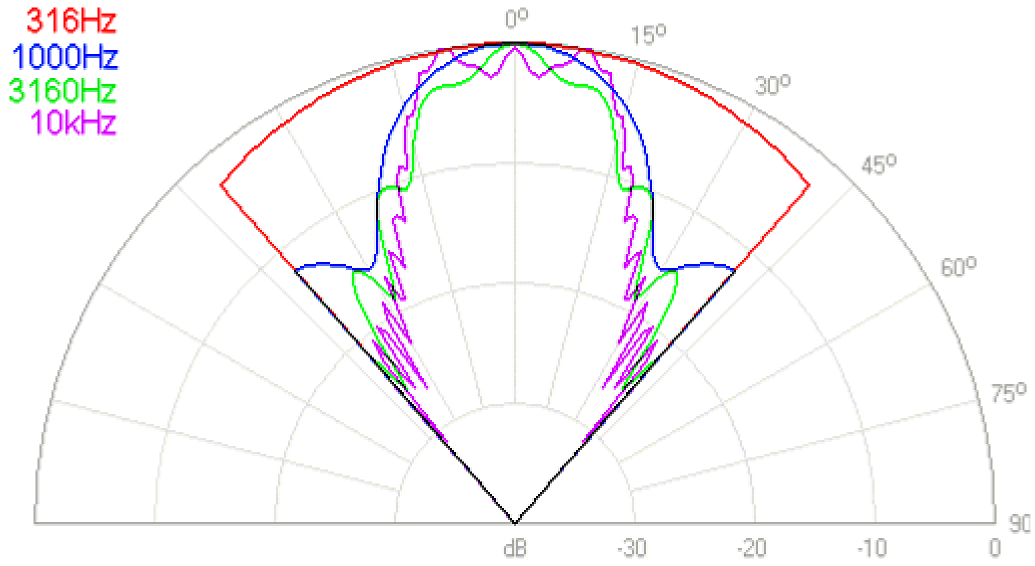
Jim Long and Don Keele in Jim's living room standing on either side of the right-channel HR-9040 "constant directivity" horn mounted over the bass horn designed by Ray Newman. Sept. 2004.

# Directivity control

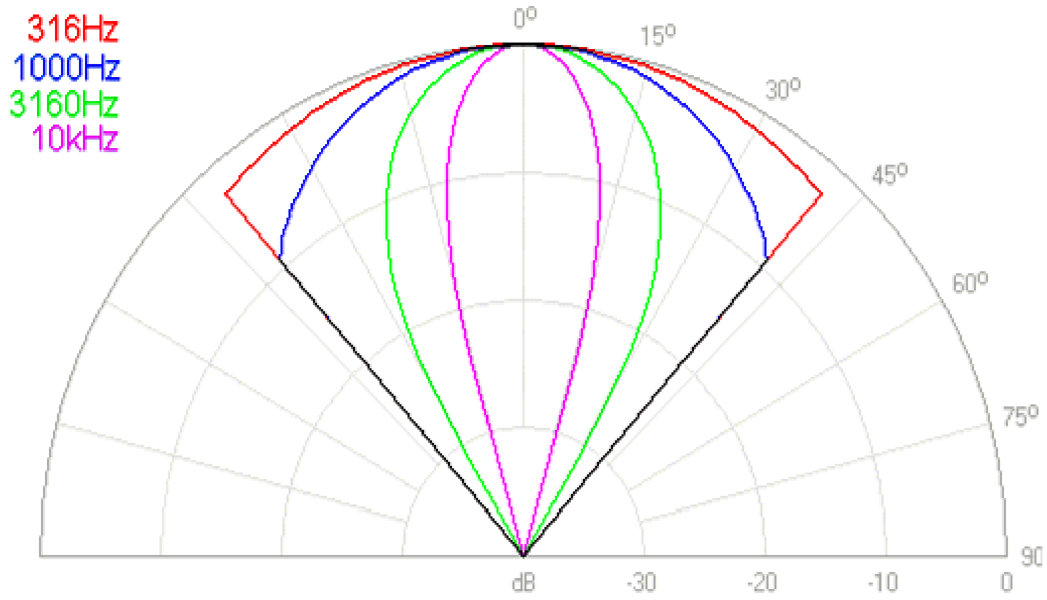
its goal:

to obtain a more constant frequency response over a chosen solid angle




## Oblate spheroidal waveguide

Note the rather constant directivity over 1kHz and the wavy contours

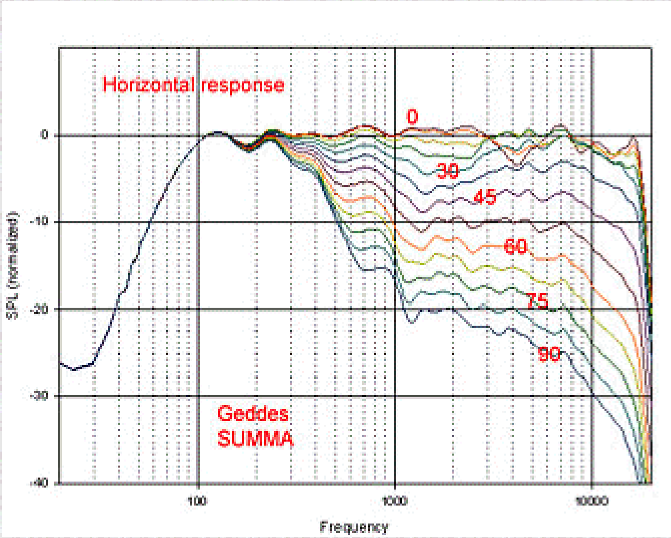


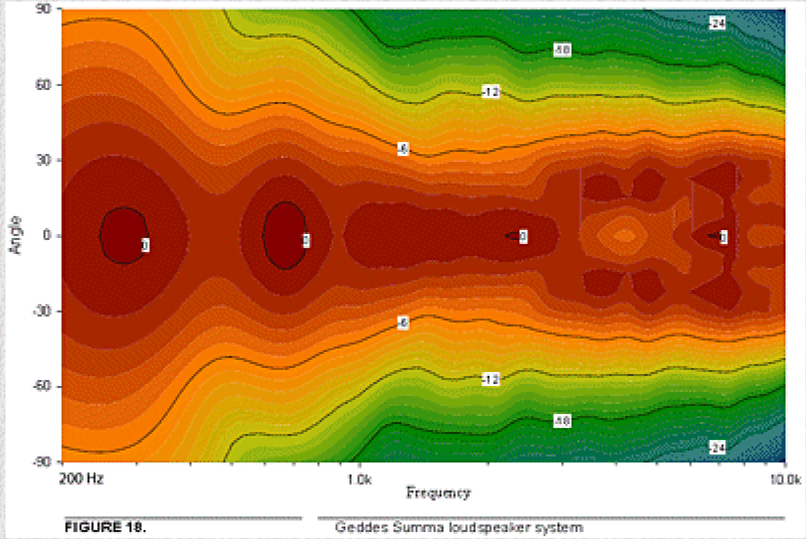

## horn calculated by the "Le Cléac'h" method

Note the directivity regularly increasing with frequency and the smooth contours

*simulations using Hornresp*

# Earl Geddes's « Summa Cum Laudae »
# 2 ways enclosure




See also:

**Acoustic waveguide for controlled sound radiation**
United States Patent 7068805

*Earl Geddes*

TOOLS FOR THE PROFESSIONAL DEVELOPMENT OF

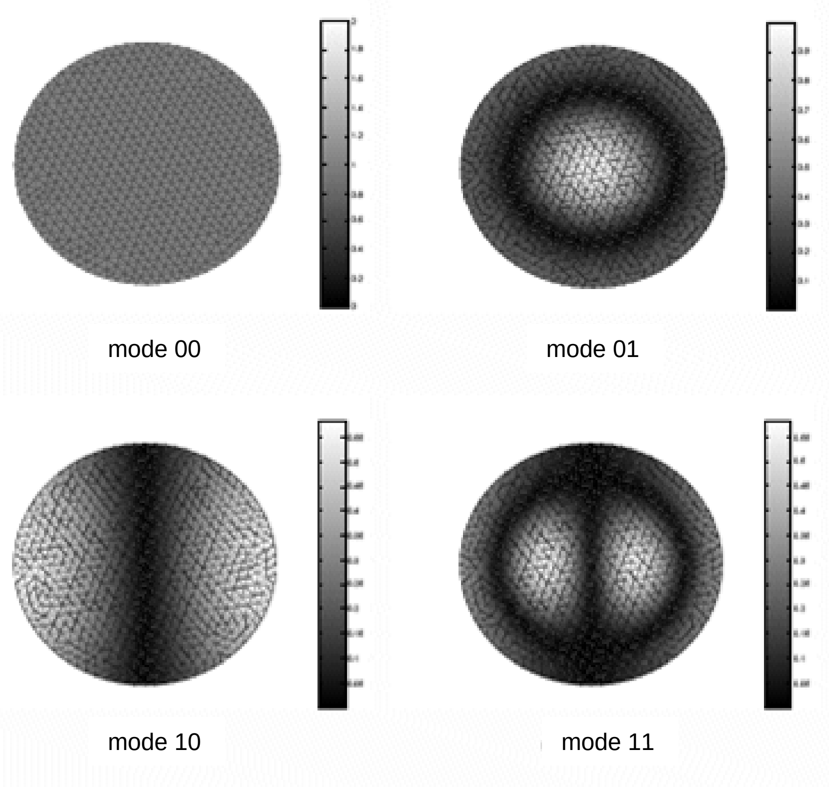
HORN LOUDSPEAKERS

Diplom-Ingenieur

**Michael Makarski**

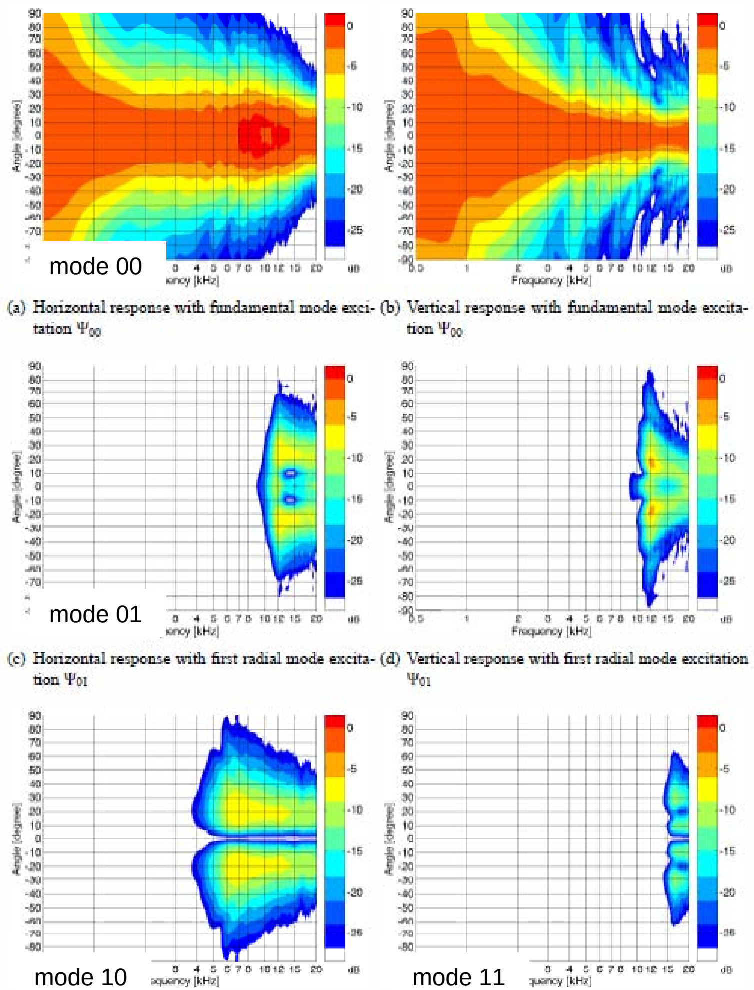
aus Mainz

20. April 2006




only modes 00, 0i, j0 exist with round horns





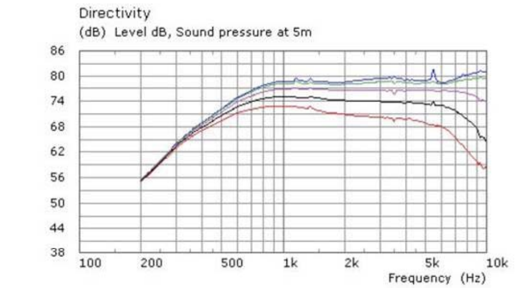

(a) Horizontal response with fundamental mode excitation $\Psi_{00}$ (b) Vertical response with fundamental mode excitation $\Psi_{00}$

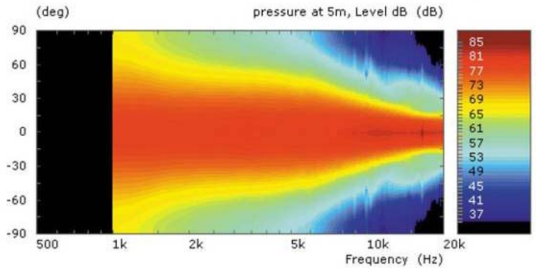
(c) Horizontal response with first radial mode excitation $\Psi_{01}$ (d) Vertical response with first radial mode excitation $\Psi_{01}$

(e) Horizontal response with first angular mode excitation $\Psi_{10sin}$ (f) Horizontal response with the first angular plus radial mode excitation $\Psi_{11sin}$

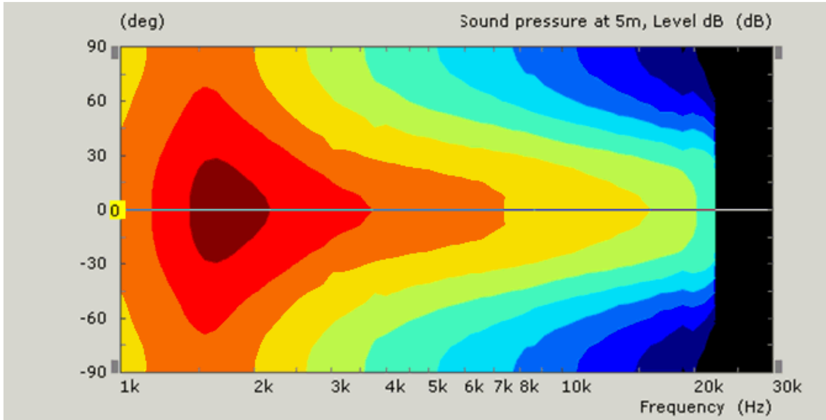
**Figure 5.12:** Modal directivity responses normalized to the 0° frequency response of the fundamental mode

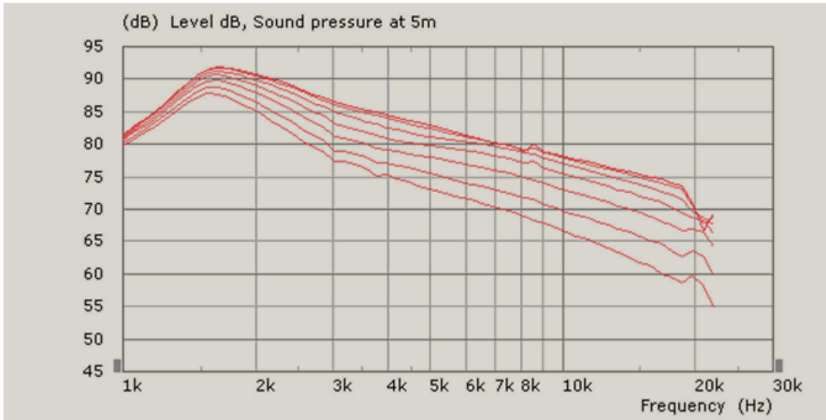
*each High Order Mode has its own cut-off frequency*

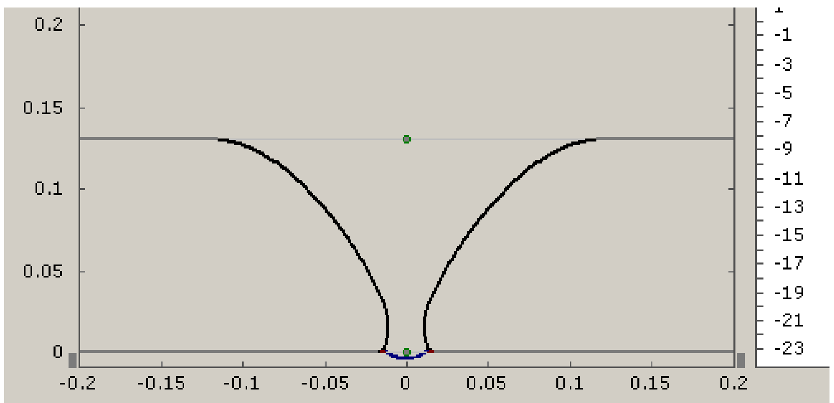




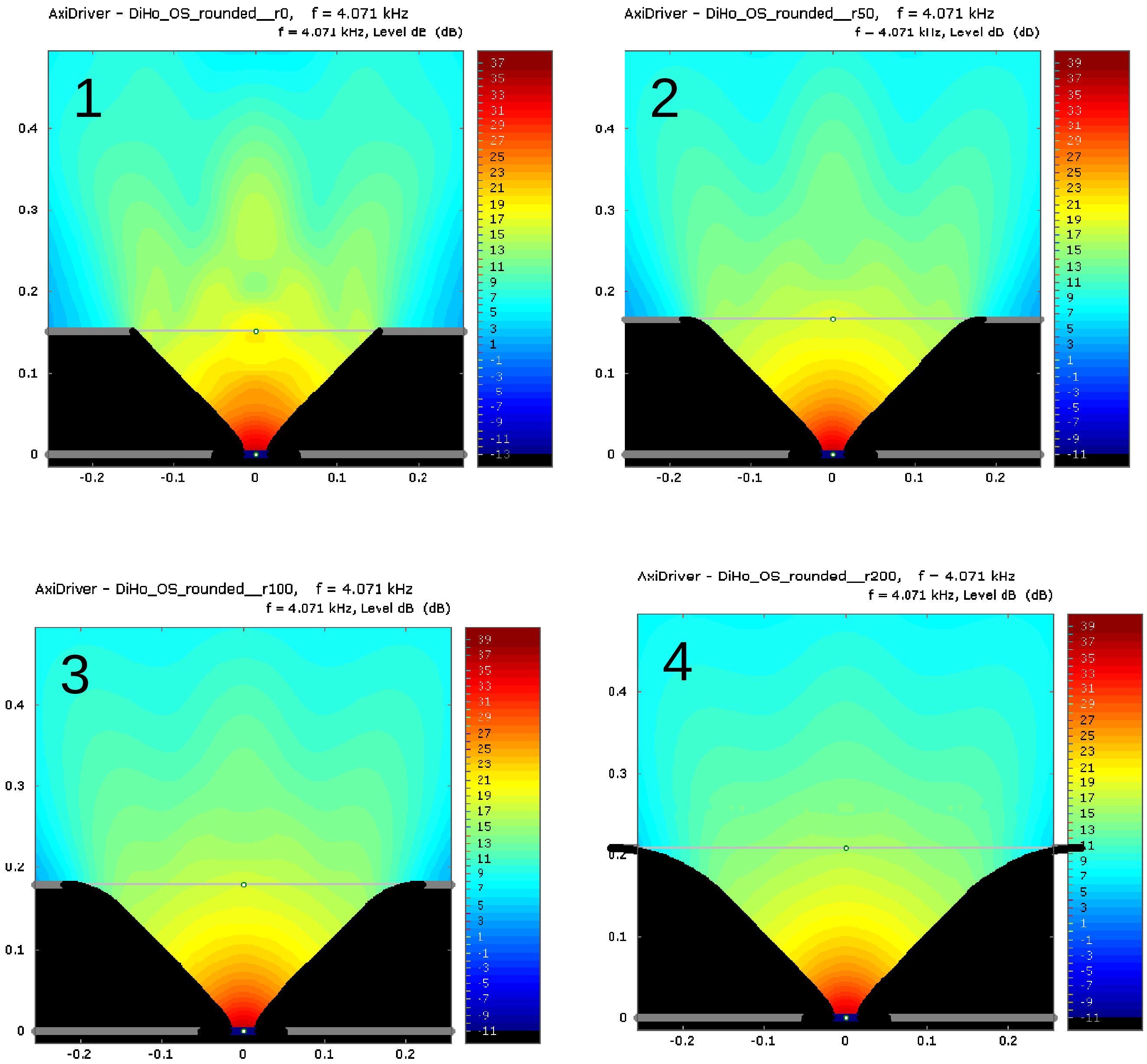



*Minimum phase horns (or short Minphase) by ing. Michael Gerstgrasser*. This are state-of-the-art Gauss optimized horns that offer smoothest sound field with controlled directivity (CD) and good look. Above example with a flat 3" diaphragm.

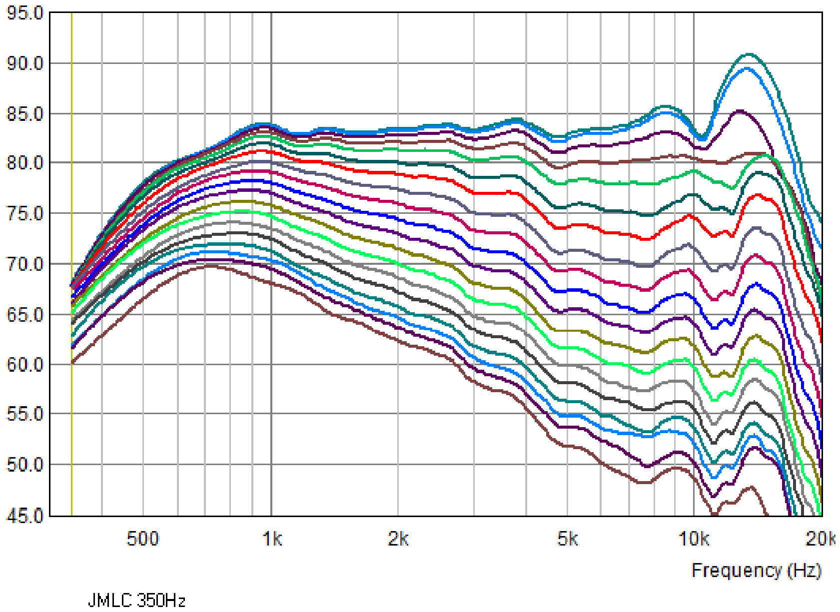
Michael Gerstgrasser'min phase horn is a good compromise between the Le Cléac'h horn and the OS Waveguide



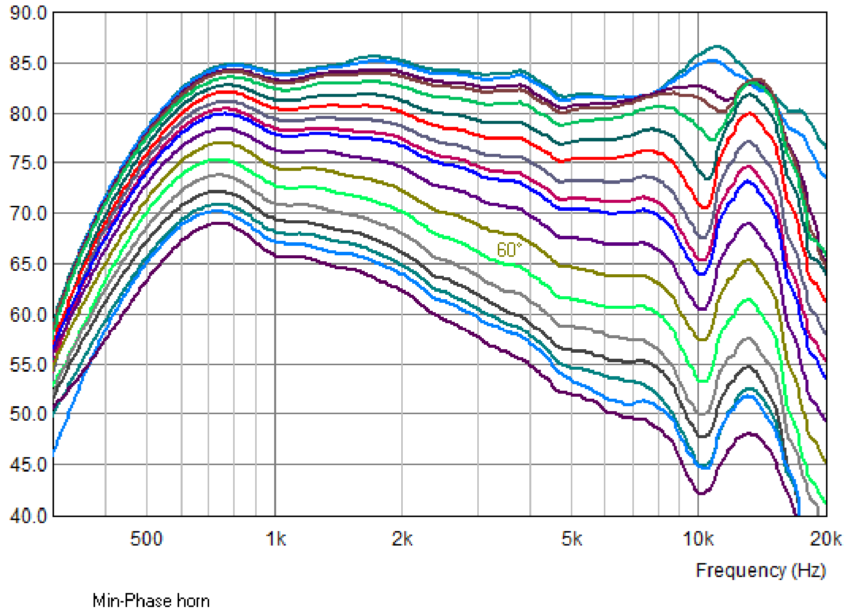

from 1 to 4 the profile of the mouth of an OS waveguide is curved at a nearer distance from the throat

simulations performed by Michael Gerstgrasser using AxiDriver

*from 1 to 4, note the more evenly distributed pressure field* frequency response from 0° on axis to 90°off axis by 5° steps




without equalization



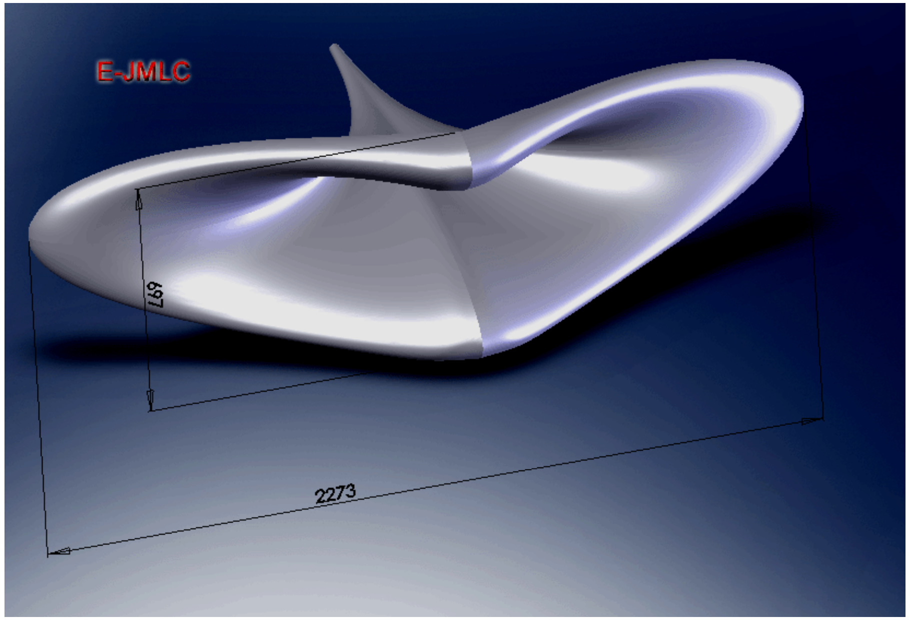

with equalization

## Le Cléac'h horn

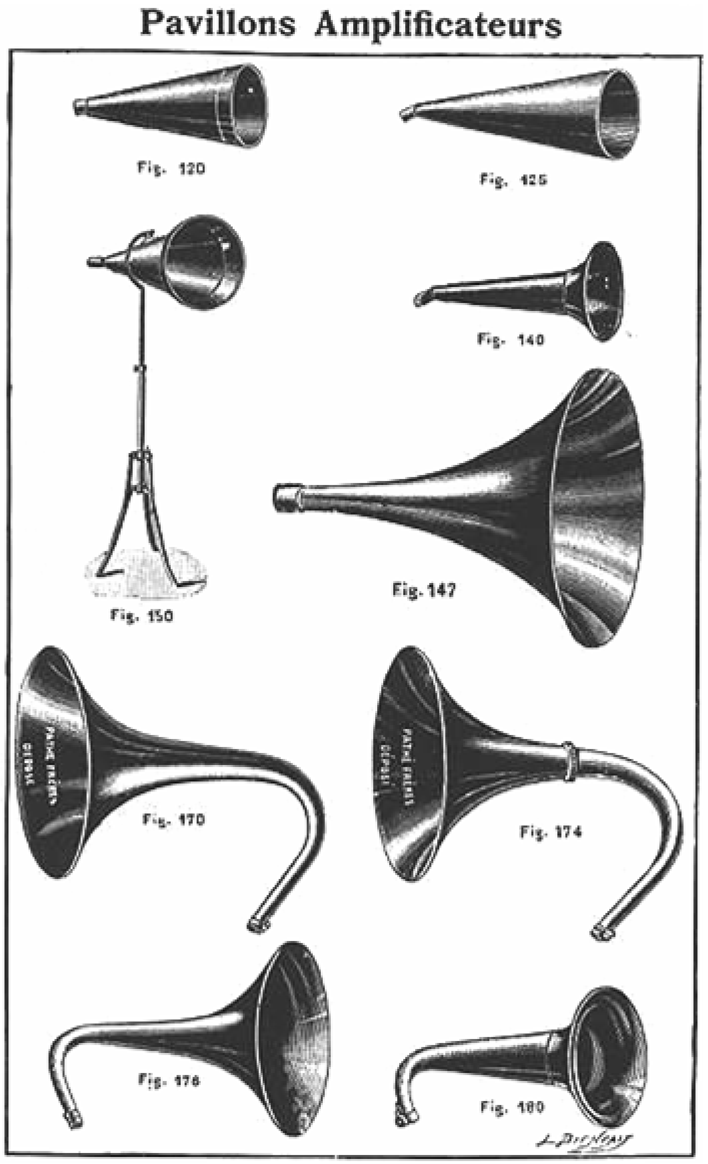
## Min-Phase horn

The Min-Phase horn provides a better directivity control than the Le Cléac'h horn while keeping the smoothness of the frequency response curves on and off axis.

# the END




a new Le Cléac'h horn (2007)




horns commercialized by Pathé (France), 1903