WEB3D 2020

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Tutorial #5, X3D4 Sound and Audio

Sound and acoustics fundamentals

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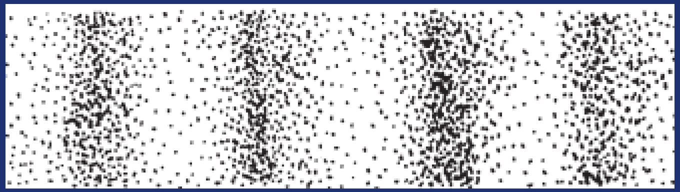
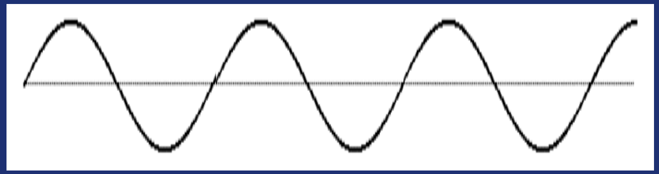
The sound is a wave

Sound is a wave propagating inside a mean like air, water, etc

Variations of the density in the mean



Pressure



Frequency = Speed of sound / Wavelength

Speed of sound in air is almost 340 m/s
So for frequency 20 Hz–20 kHz the wavelength is 17 m - 17 mm

Sound level and intensity

Sound Intensity (dB) = 10 log(I(Watt/m^2)/I_{ref} (Watt/m^2))   in decibels

I_{ref} =10^{-12} Watt/m^2

Sound Power Level = 10 log(W/W_{ref}) decibels

W_{ref}=10^{-12} W

Since Sound (air) Pressure is a parameter easier to measure

Sound Pressure Level (dB) =10 log(P^2/$Pref^2$) in decibels =20log(P(µP)/20µP) in decibels

Sound in open field

For simplification, in some distance from a sound source it may considered as a Point Source

the farther we are from a sound source, the more it behaves like a point source

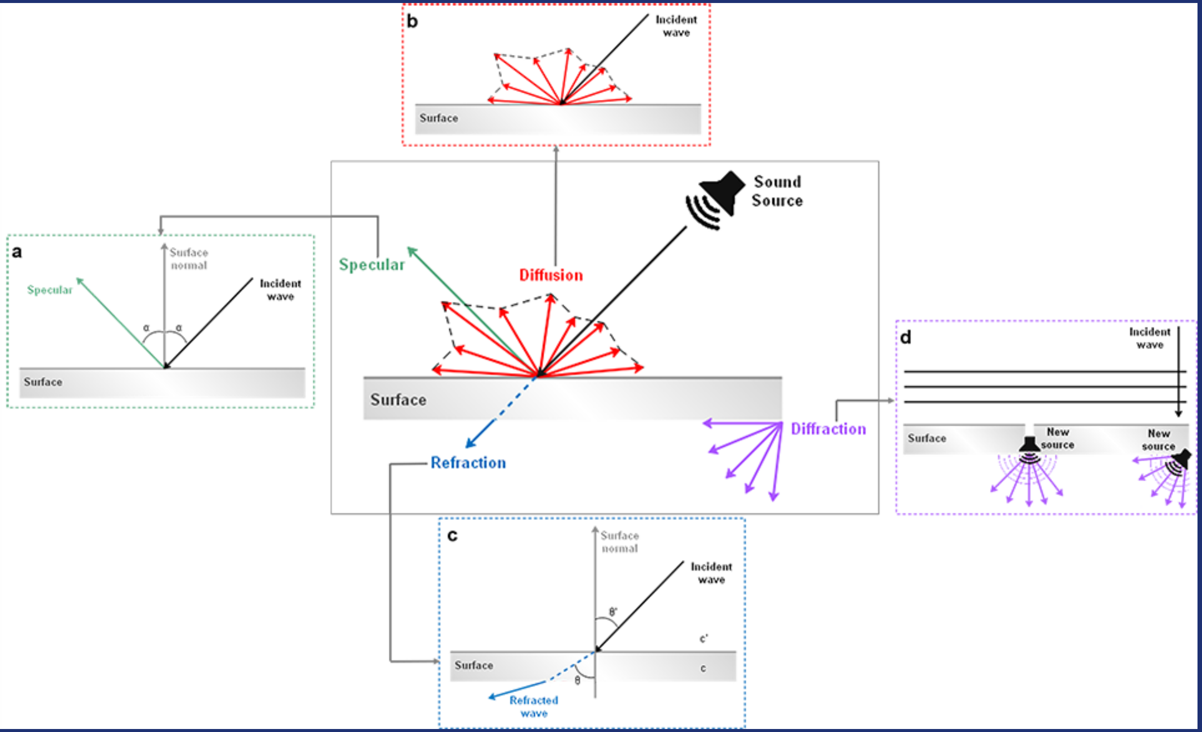
If the sound of a point source has constant uniform intensity (power per unit area) in all directions then Intensity is decreasing by the distance because same sound is spread in wider areas

$I = W / 4\pi r^2$

I = intensity of sound per unit area
W = power of source
r = radius

Sound reaction with surfaces

As we know sound is a wave. Thus propagation and interaction with the environment follows the rules of Wave Physics.



Reflection

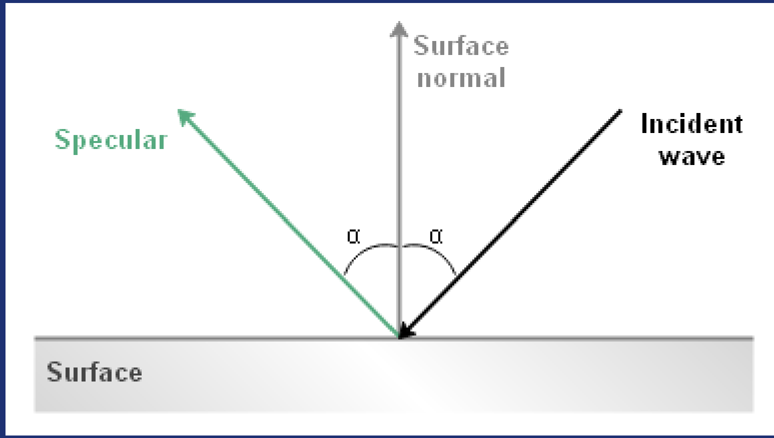
During the propagation of a sound wave in space, the wave strikes a "wide" surface and its free propagation is disturbed. During this strike a portion of the incident wave changes direction. This phenomenon is known as reflection.

Reflection may be **Specular** or **Diffusion**.

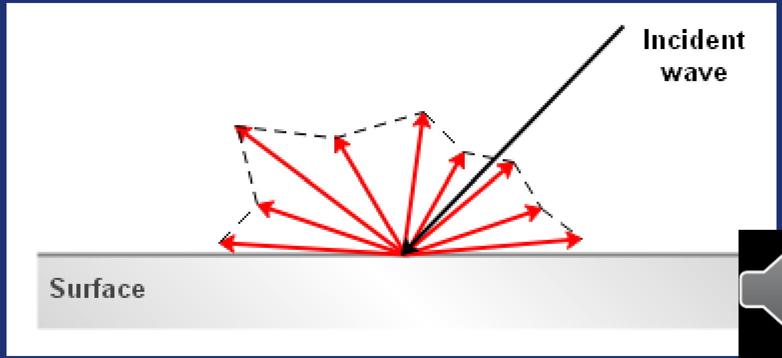
Specular is a reflection where the reflected (specular) wave is changing direction and moved in an angle equal to the angle of the incident wave and the Normal in the surface. The amount of the wave reflected is given by **Specular reflection coefficient** of the surface material.

Diffusion we have when the surface where the wave hits is not reflective and smooth. Is rather rough with anomalies to be deeper that the sound wavelength. In this case we expect reflected wave to be spread into all directions without any particular major direction. The amount of wave diffused is given by the **Diffusion coefficient** of the surface material

Specular Reflection



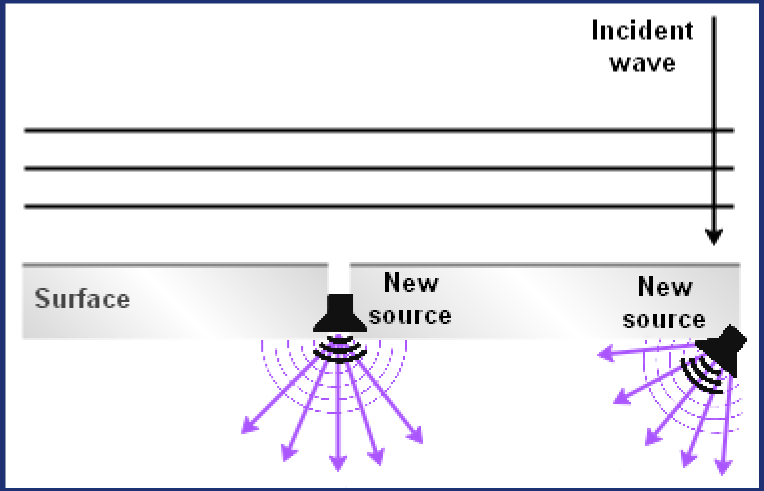
Diffusion



Diffraction

In case that during propagation of sound the wave strikes a narrow surface (few times the wavelength) or in the edge of a surface or finds a hole (also few times the wavelength) then the sound is **Diffracted**. **Diffraction** is acting as a regeneration of the wave in terms of direction and wave propagation characteristics.

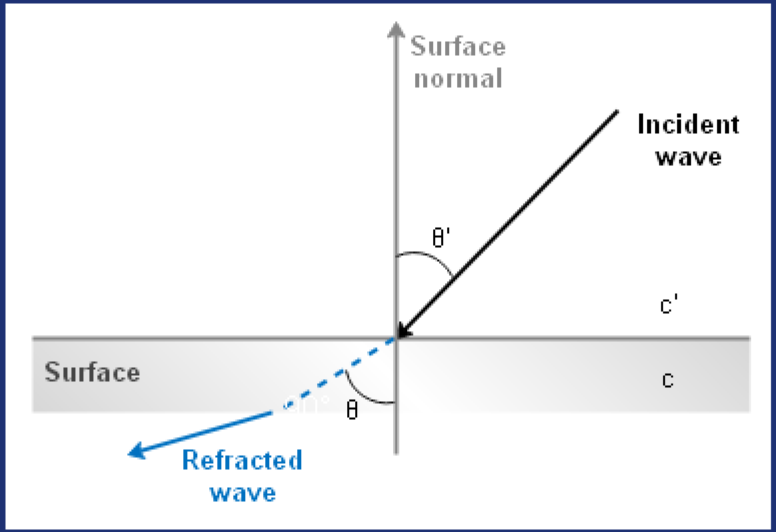
Diffraction



Refraction

Refraction is the phenomenon of a wave to passes from one medium to another and subsequently to change its speed and direction.

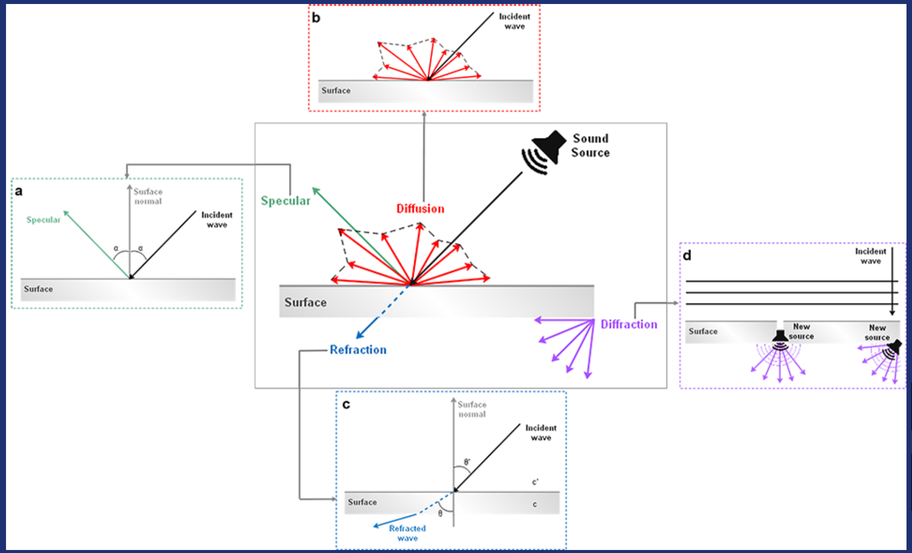
The amount that a wave is refracted by a material is given by the refractive index of the material.



Generic Sound strike into a surface

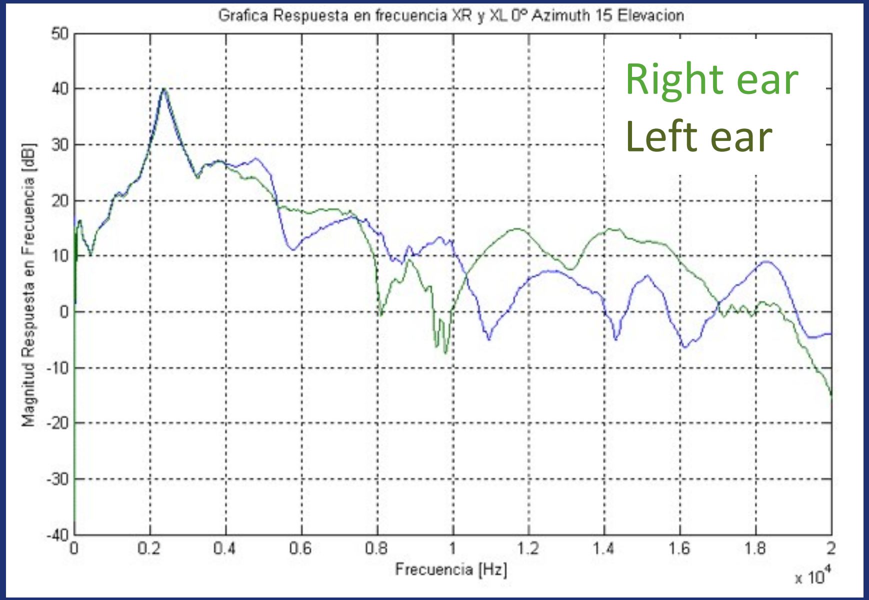
When a sound strikes into a surface, depenting on the material and the geometry of the surface all of the phenomena may appear together

- A portion of wave might be specular reflected (Specular Reflection coefficient)
- A portion might be diffused (Diffusion coefficient)
- A portion might be refracted (Refractive index)
- And if there is a hole or an edge or the surface is narrow enough the wave might be regenerated into a new source (refraction)



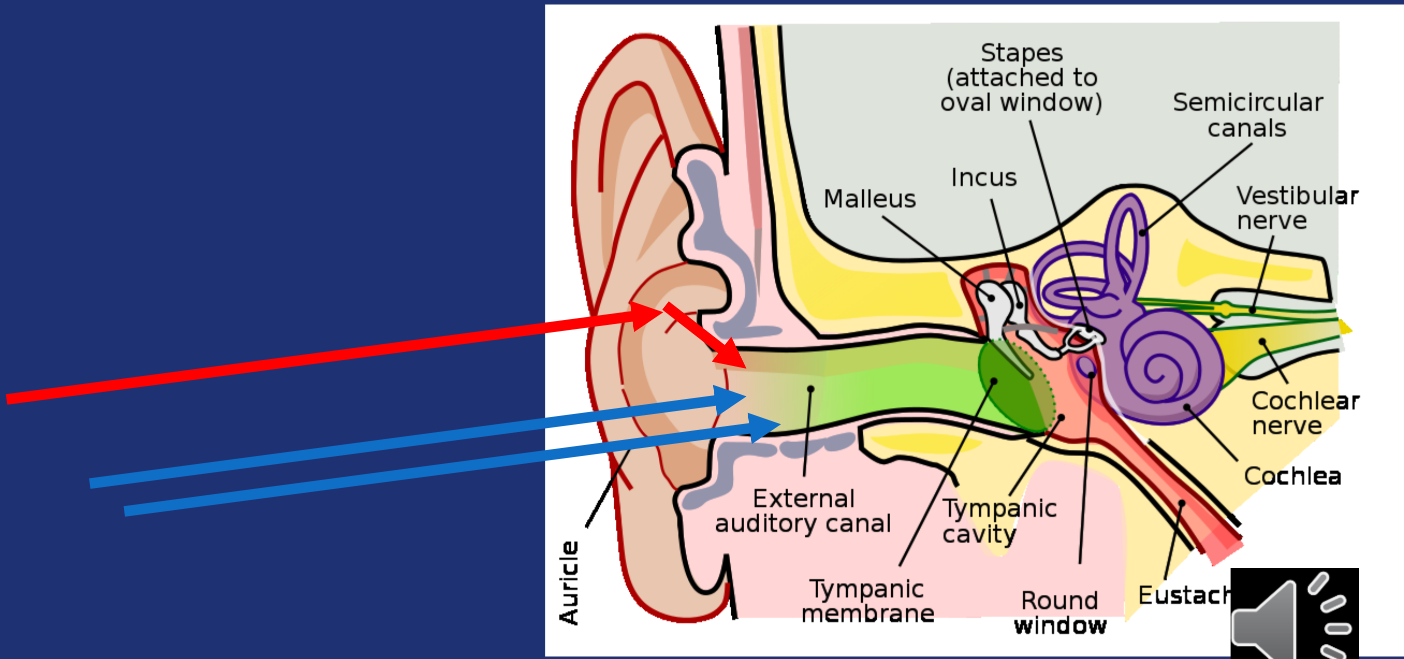
Localization

The perception of the location of a sound source is based on the external ear
Sound reflected in auricle combines with the unreflected direct sound at the entrance to the External auditory canal. This combination goes to the Tympanic membrane and then to the middle and inner ear and finally to the brain for processing.
Localization is affected by the frequency of the sound and the ear transfer function.



Transfer Function

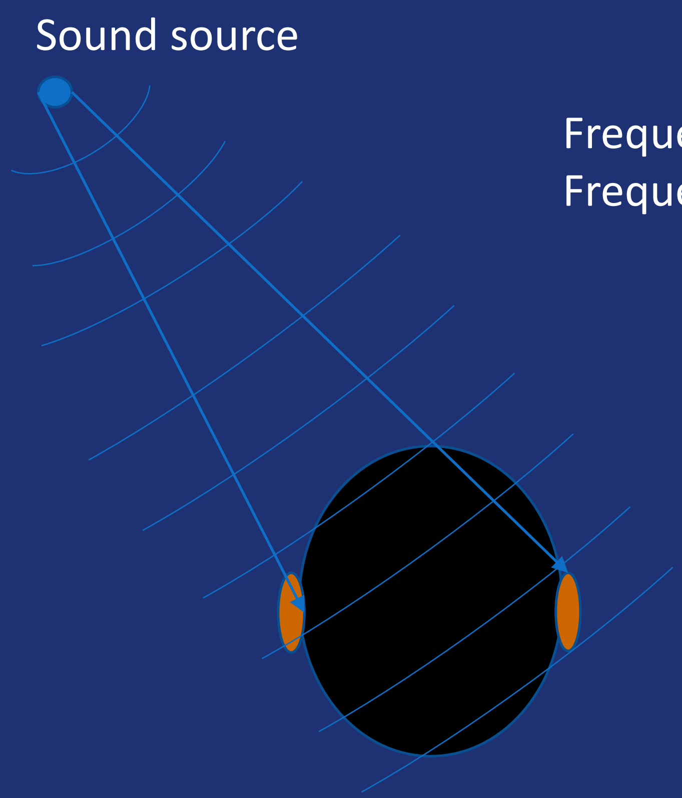
By PeloWisky - Own work, Public Domain,
https://commons.wikimedia.org/w/index.php?curid=5447646



Source wikipedia

Binaural localization

Because of the different distance of each of the ears from the source, the near ear receives sound earlier than the far ear. Also sound may arrive with different intensity between the ears depending on the sound frequency.

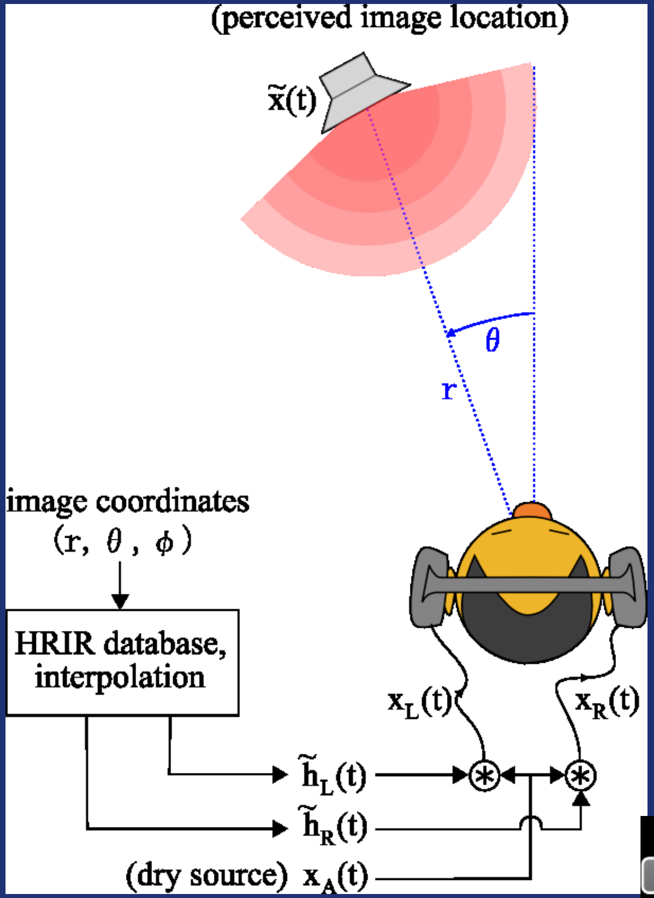


Frequency < 1 kHz -> phase (time) is major
Frequency > 1 kHz -> Intensity is major

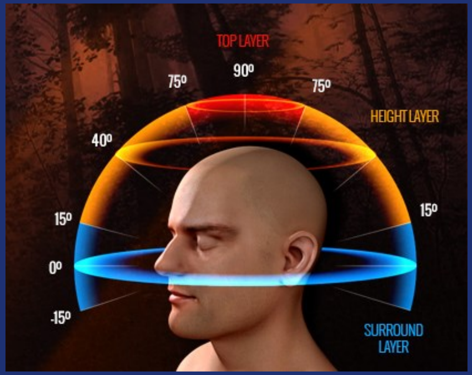
3D audio effects - spatialization

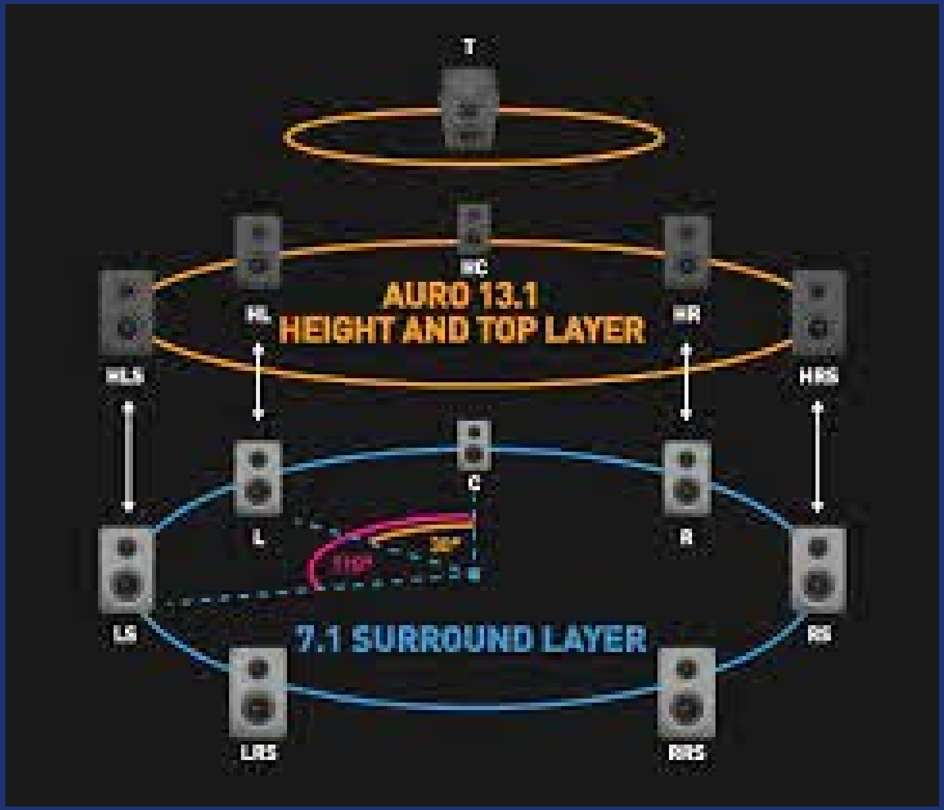
Are effects that synthesizes sound produced by speaker sets. This usually provides the virtual placement of sound sources anywhere in three-dimensional space around the user.

The most common effect is panning that allows an audio stream to be spatialized or virtually positioned in 3D space relative to an listener. This process usually involves the HRTF (Head-related Transfer Function) of the virtual user that usually implemented by a database of human ear transfer functions in several different azimuths and elevations.



3d sound commercial systems- examples

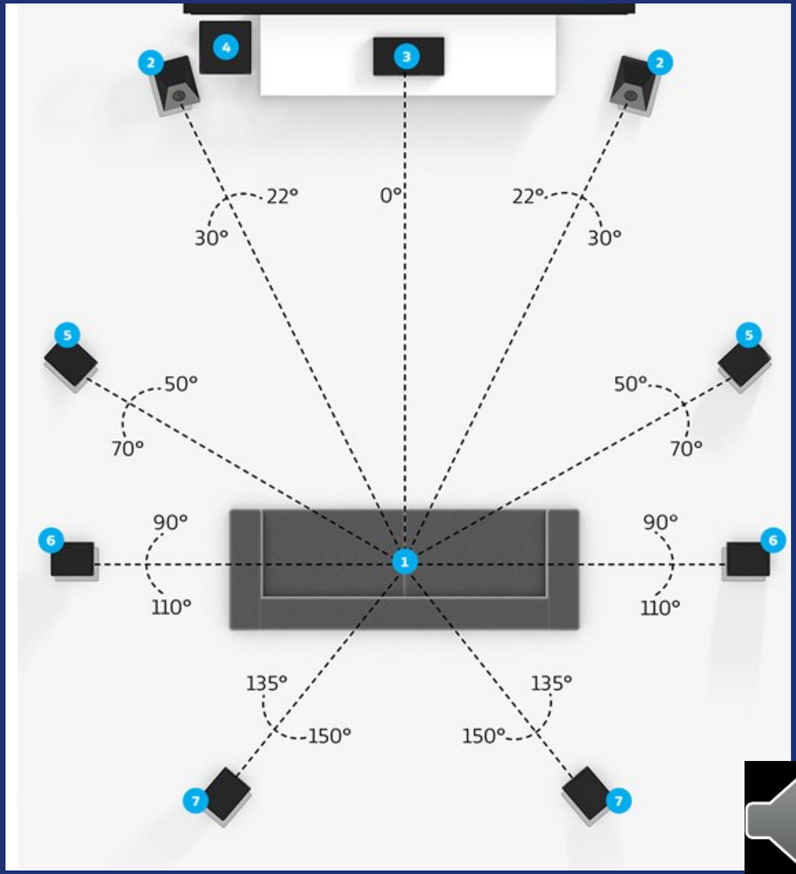




Auro 3D. https://www.auro-3d.com/

3d sound commercial systems- examples

DOLBY atmos
https://www.dolby.com/technologies/dolby-atmos/



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