Controlling directivity in loudspeakers

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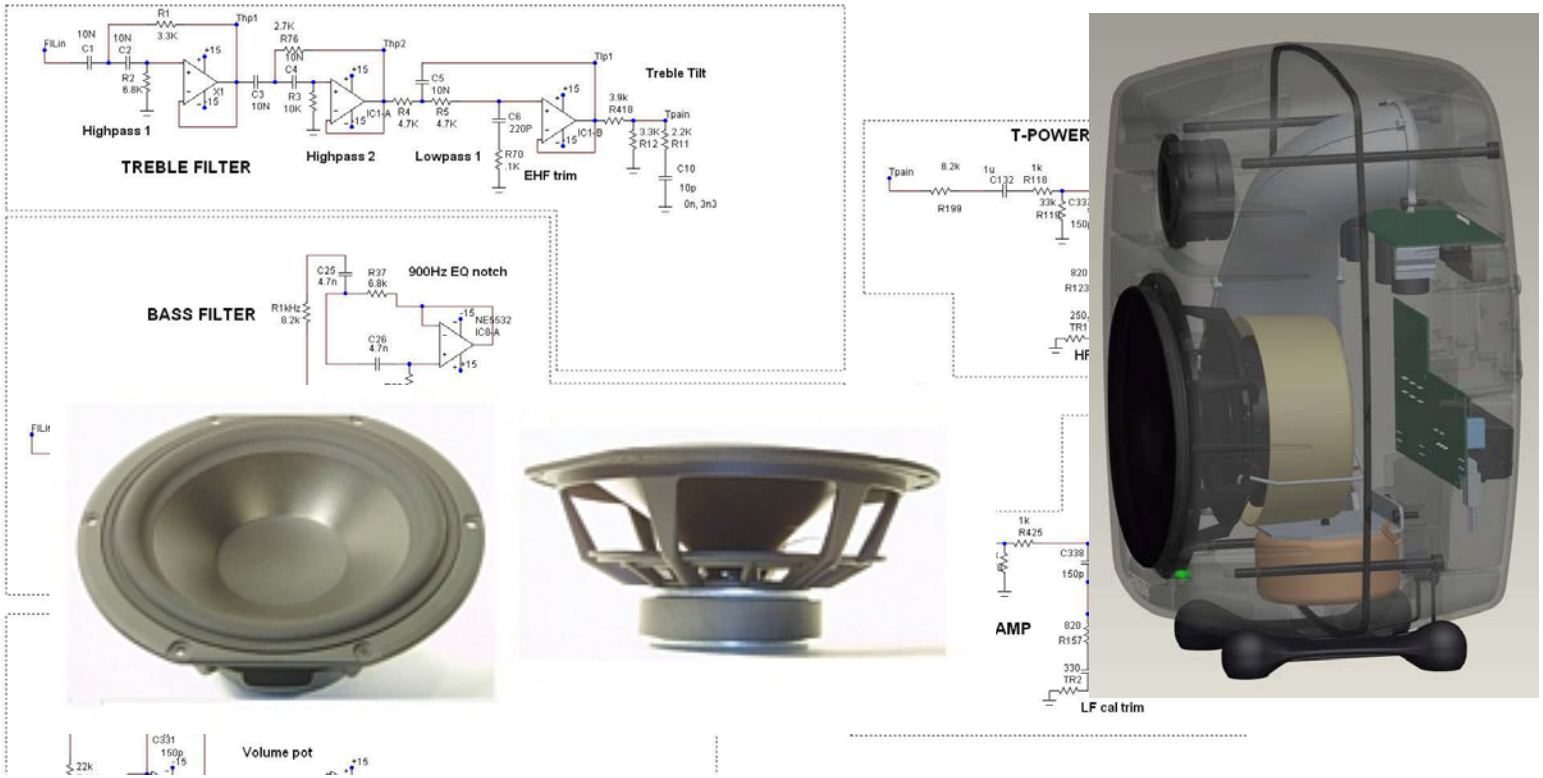
What is a good loudspeaker?



A loudspeaker that is faithful to the input signal.

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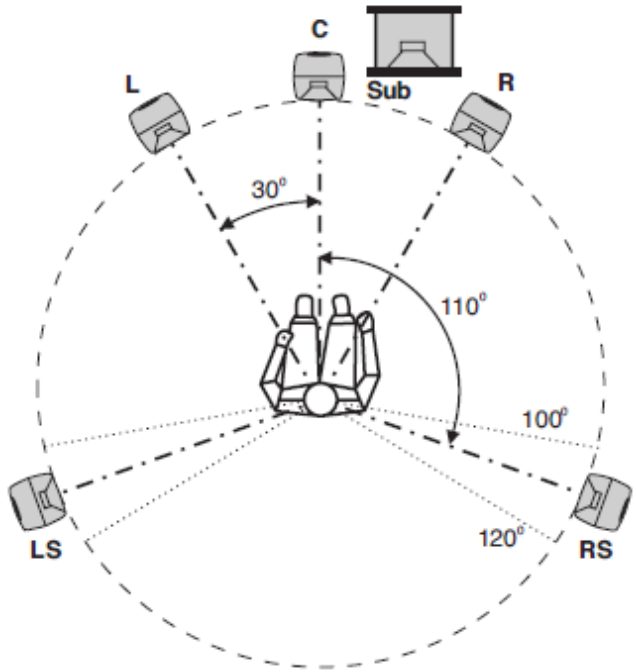
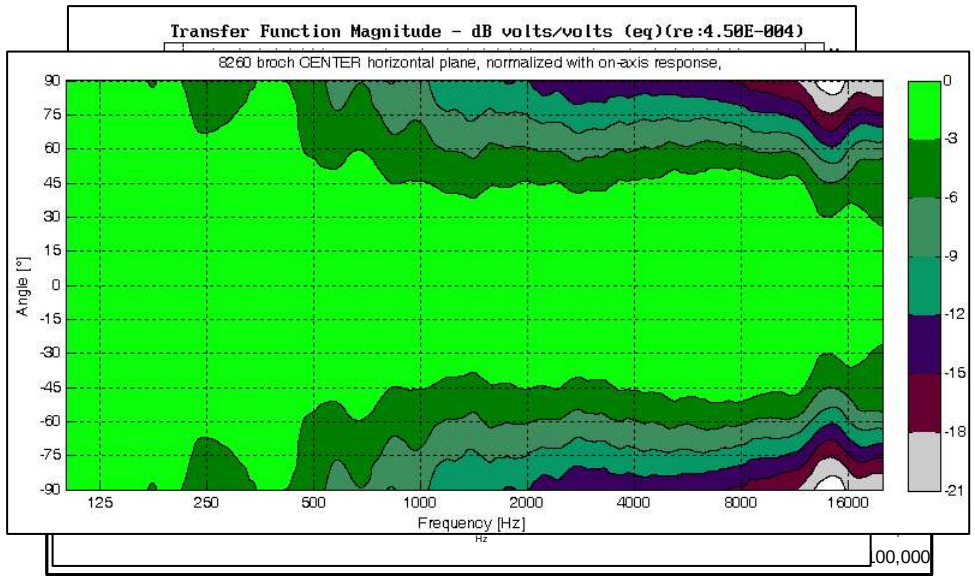
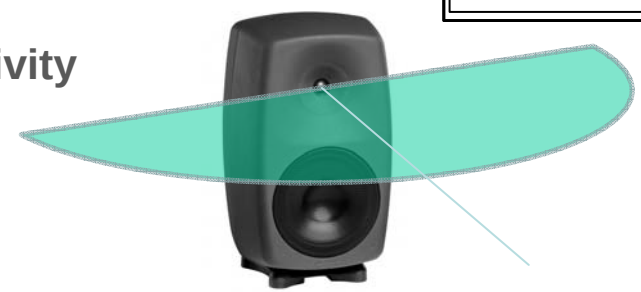


5.1 surround setup
ITU-R BS.775-1

How to get there?

- **Flat on-axis frequency response & sufficient frequency range**
- **Smooth off-axis frequency response**
- **Low distortion**
- **Sufficient sound pressure capability = Dynamics**
- **Controlled directivity**





Directivity

”How effective the speaker is at taking the sound it produces and sending it in one particular direction instead of all directions.”

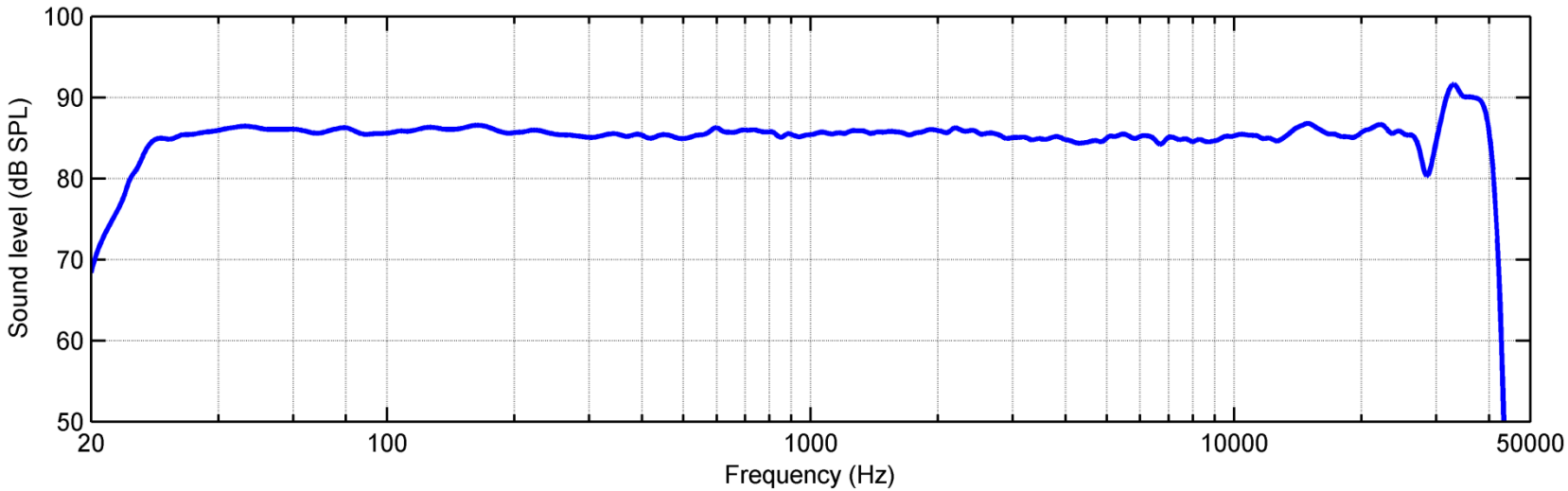
This is the area where the majority of loudspeakers lie in terms of directivity.

POINT SOURCE = no directivity

HORNS = very directive

In anechoic room you wouldn’t need to worry about the directivity behaviour of loudspeakers.

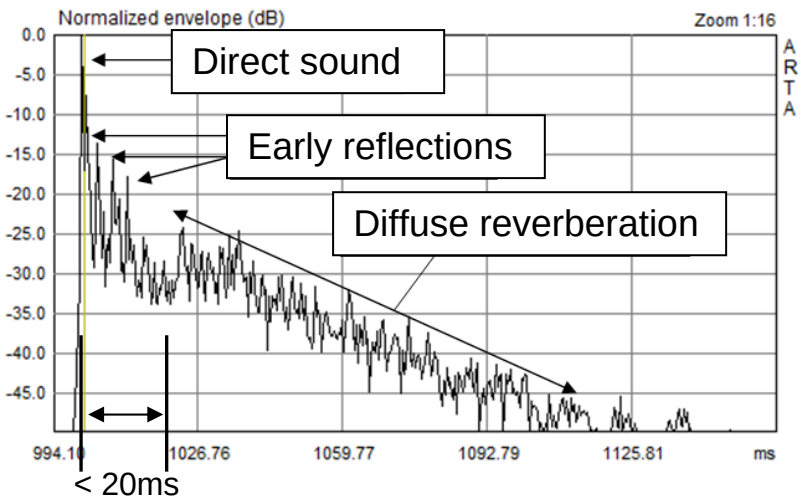
You would only hear the on-axis sound of the loudspeakers which in some cases is almost perfect.



On-axis response of a Genelec 8260A loudspeaker

In real-life listening rooms the situation is quite different.

You are hearing a mix of direct and indirect sound.
Depending on the room size and listening location the reflections play a significant role.



Direct sound is the only thing that is dependent on the on-axis response of the loudspeaker.

The total subjective listening experience is highly dependent on how the loudspeaker is radiating sound around itself.

Early reflections

The reflections forming soon after the direct sound:

- First wall reflections from sidewalls, ceiling and floor
- All the reflecting surfaces near the loudspeakers

Acoustical treatment in these reflection points offer big improvements:

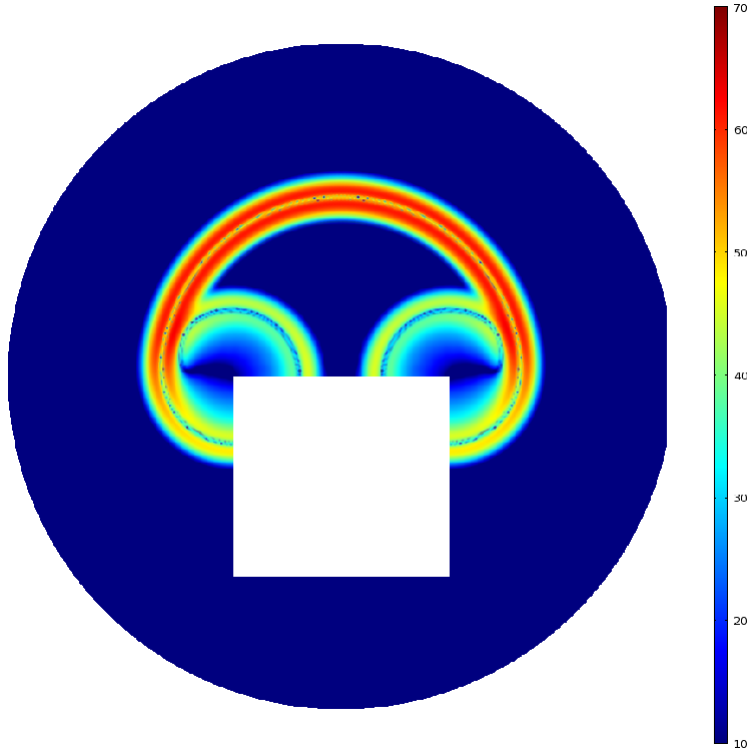
- Enhanced clarity of sound
- More precise stereo image with sharply defined locational cues

By controlling the directivity of the loudspeaker we can further decrease the amount of sound energy traveling towards the wall surfaces → further emphasize the improvements !

Diffraction should me minimized

All discontinuities and abrupt changes in shape around the original sound source causes diffraction.

Diffraction causes problems in the frequency response and impair the stereo image.



Screen capture of a FEM simulation of diffraction at sharp corners

Practical implementation

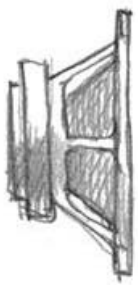
A typical flat baffle loudspeaker with:

- 25mm Tweeter & 165mm Mid / Woofer
- Crossover frequency at 4000Hz

Fundamental problem is related to the size of the drive units.

”A driver starts to become directive when it’s diameter is equivalent to one wavelength”

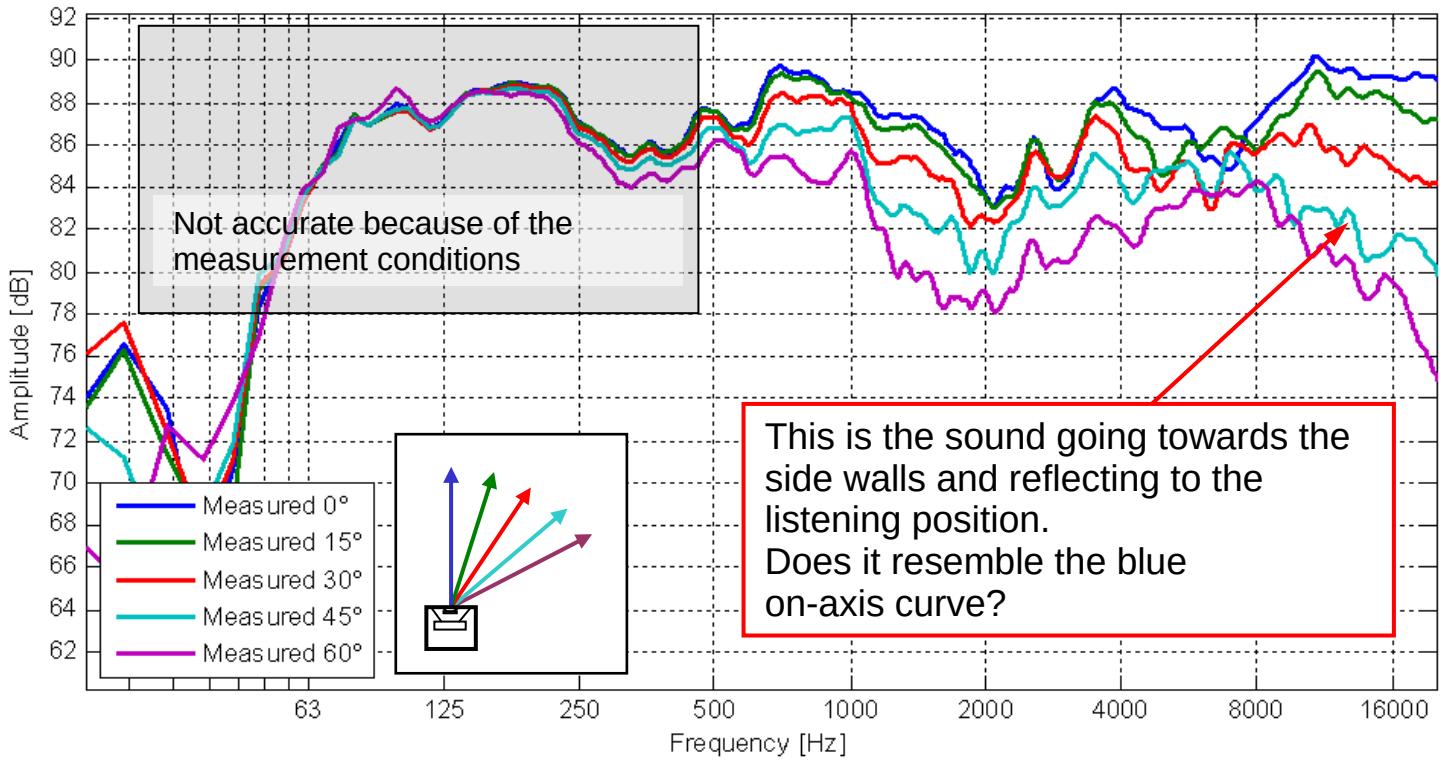
With a 25mm diameter tweeter the sound energy is effectively spread to all directions below 8000Hz



With a 165mm Mid / Woofer the directivity is gradually increasing above 2000Hz

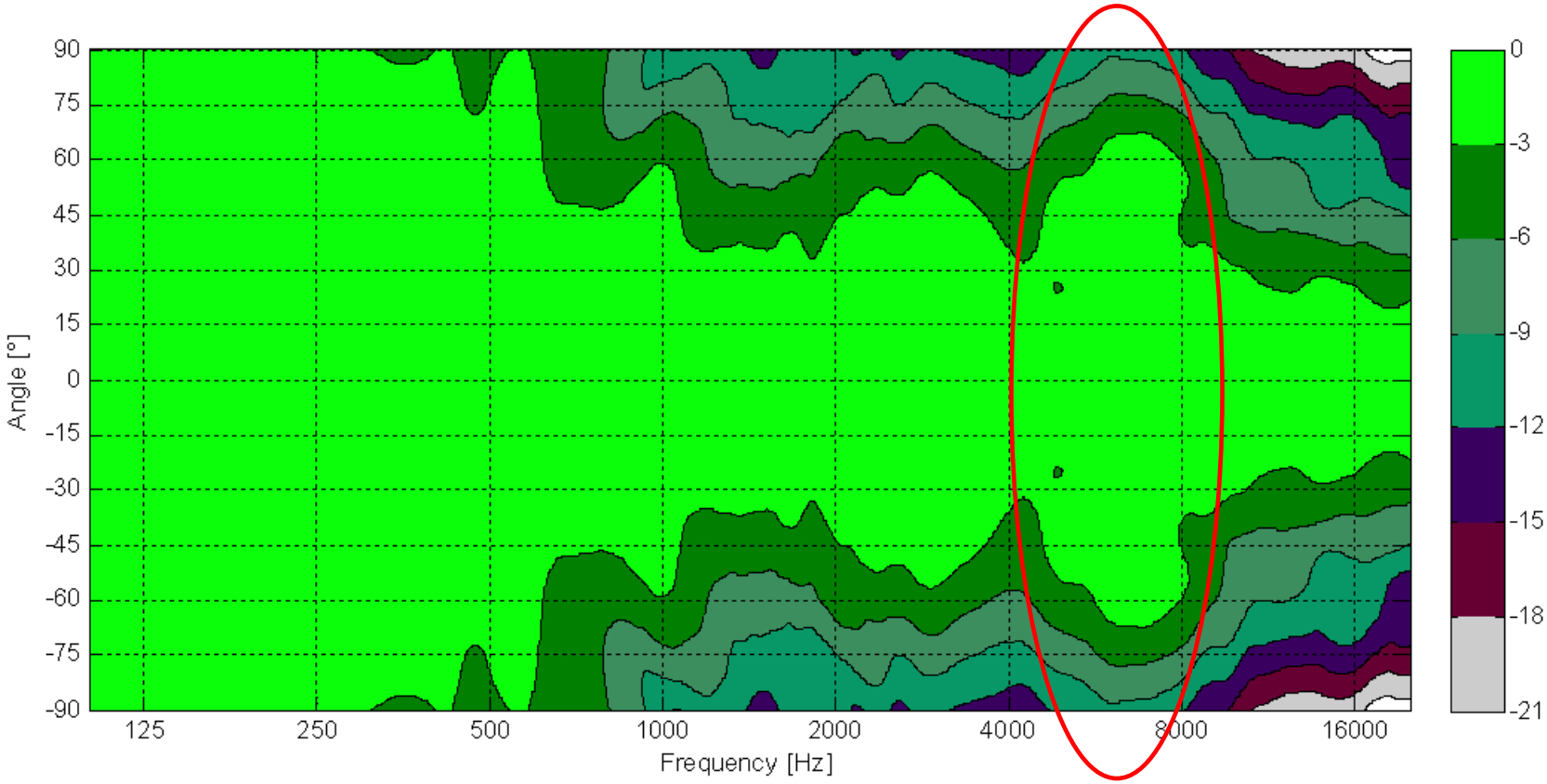
No directivity control

The problems are very visible in the frequency response at different horizontal angles around the loudspeaker.



No directivity control

Directivity is lost around 7000Hz



Horizontal plane directivity (normalized with on-axis)

Practical implementation closer to the goal

A loudspeaker with waveguide and using:

- 25mm Tweeter & 205mm Mid / Woofer
- Crossover frequency at 1850Hz

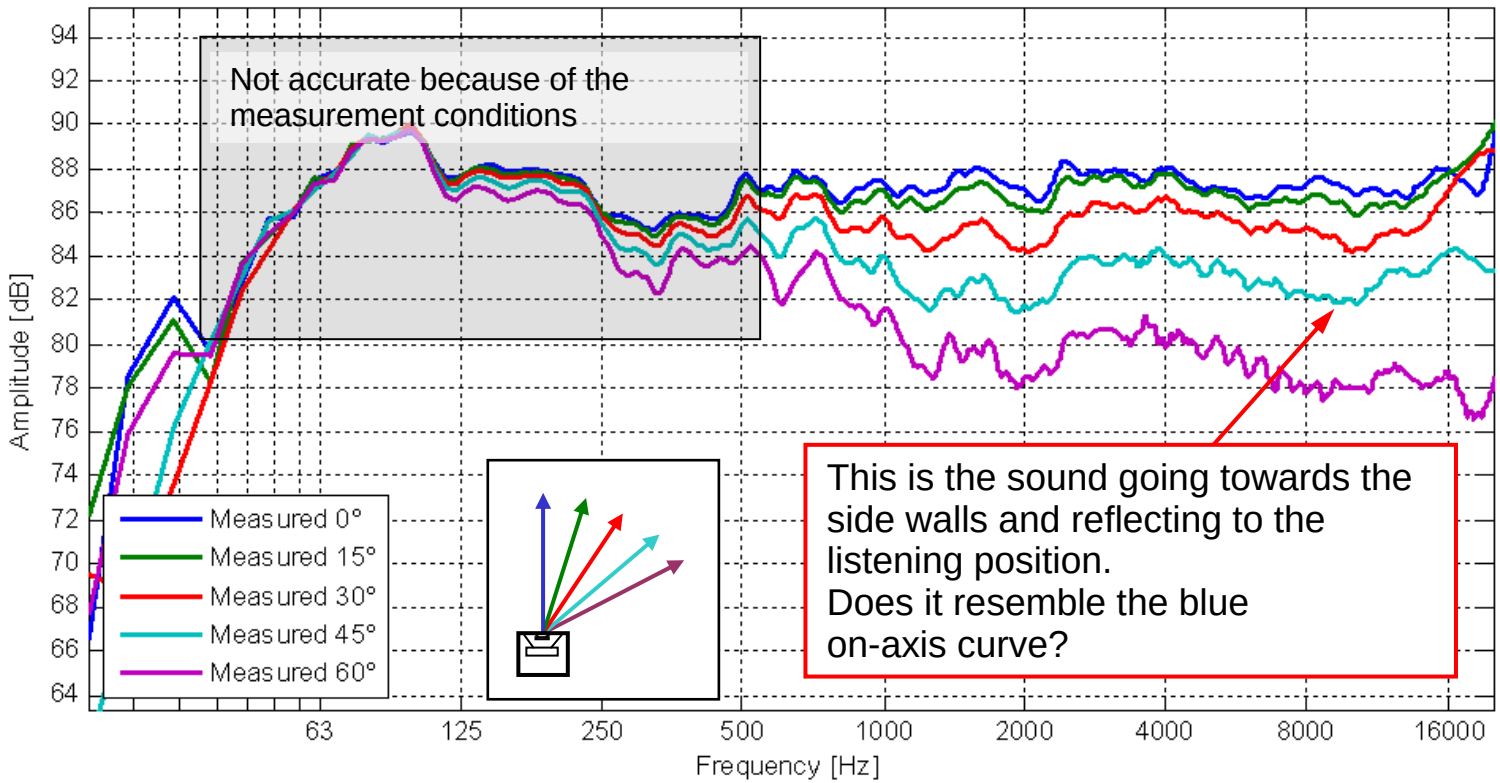
Even more demanding case as the crossover frequency is now as low as 1850Hz. The tweeter has no directivity at those frequencies.

For more that 30 years Genelec has used a solution to improve the directivity of the tweeter (and midranges). This is called a directivity control waveguide (DCW™).

Curved cabinet edges and smooth baffle surface minimize diffraction.

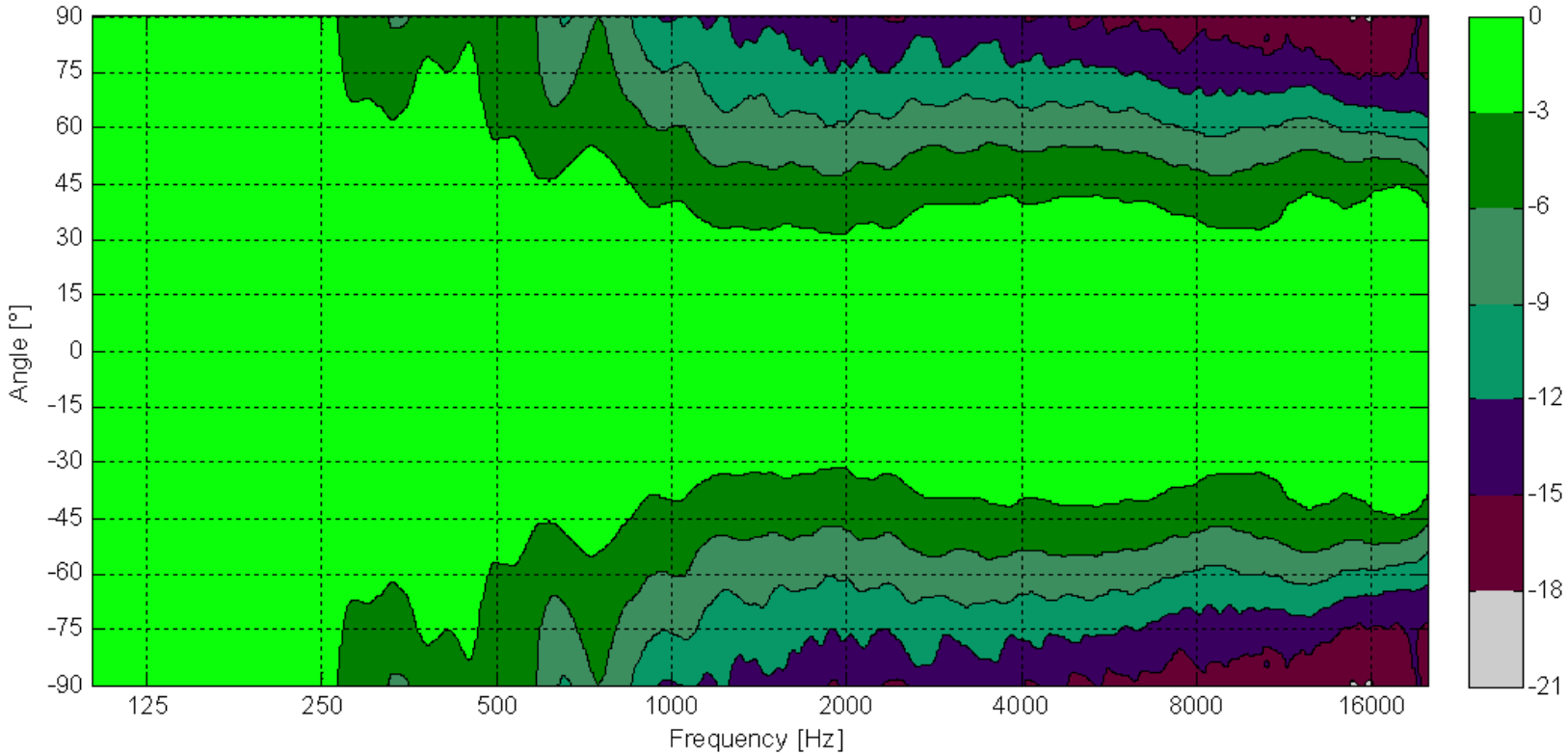
With directivity control

The curves are flat and only the level drops when moving off-axis.



With directivity control

No sudden changes in directivity behaviour → Sound energy is well controlled to all directions



Horizontal plane directivity (normalized with on-axis)

Benefits of DCW

- The DCW increases the efficiency of the tweeter by ~6dB compared against flat baffle mounting
  - Lower distortion with the same output level
  - Larger SPL capability → improved dynamics
- Less sound energy is radiated on the baffle surface → less diffraction
- Lowers the level of early reflections → improved stereo image
- Larger listening area where the sound colour does not change

s o u n d p a s s i o n