# The delayed Phantom of the Opera

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False localisation/image shift is observed in many otherwise excellent opera halls, from San Francisco through Europe to St Petersburg. Such "phantom sources" are often considered as "something we should just avoid" in acoustic design, and the effect is not covered by common room acoustic criteria. However, a controlled amount of false localisation might be useful, to broaden the apparent orchestra width/height, and: if we did not have any false localisation, parts of the audience would not hear most of the treble part of the opera orchestra. This paper focuses on a special version of disturbing "phantom-sources" that not only gives false localisation, but also a **rhythmic distortion (“delayed Phantom of the Opera”)** between the bass and treble instruments of the orchestra. This disturbing effect was observed at some seats in the (otherwise excellent) Munich Opera.

## IMAGE SHIFT=PHANTOM

An image-shift/phantom-source describes that a sound is not perceived to arrive from its real localisation (see Barron [1]). Such false localisations are commonly reported for high pitched instruments in orchestra pits. Actually, most of the sound from these instruments should not be heard in the stalls of an opera house, as most of the audience do not see them.

Meyer [2] gives interesting results of how the treble part of the orchestra is reduced in the stalls of an opera house. However, these results do not indicate direction and time delay of the treble components received.

In order to set the acoustic criteria for the new opera in Oslo, we visited a number of opera houses, from S. Francisco, Metropolitan through Europe (Covent Garden, Bastille, Lyon, Frankfurt, Munich, Berlin, Dresden, Gothenburg, Helsinki), to St. Petersburg (Kirov). In all these houses we observed some kind of false localisation from the orchestra. The impression of this effect ranged from *“perhaps OK for most of the public”* to *“problem”,* but on the other side: *“excellent!”*, indicating that the false localisation actually gave a needed *“broadening of the apparent orchestra source width and horizon”*. Most of these opera houses are covered in literature on acoustics, but without much comment on “false localisation”.

Okano [3] shows investigations of image shift, mostly for concert halls and for symmetrical situations. We observed that perceived false localisation in opera houses are often far from symmetrical, even for seats close to the centre line of the hall, this also due to the asymmetrical position of the orchestra in the pit.

Svensson [4] gives a model for investigation of the diffraction of the orchestra due to the pit-rail, used by Dammerud [5]. This confirms why treble instruments do not “climb over the pit rail as easily as the bass”.

## TYPICAL TYPES OF PHANTOMS

*Typical time **delay $\Delta t$** and **angle of arrival $\Phi$** (clockwise) of “image shift” from an opera orchestra in the pit are given for typical seats to the right, 2/3 back in the stalls of horse shoe shaped opera halls of moderate size.*

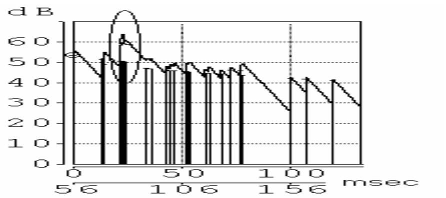
1) From a low reflector over the proscenium $\Phi=0^0$, $\Delta t=$ *ca 2 - 10ms*. The “Apparent Source” of the orchestra is raised, almost as if the orchestra appears to be situated on the stage. Not noticeable as a “phantom source” for most listeners, but might disturb the stage/pit balance and the ability to discriminate the vocal line. For seats at the rear of stalls, the $\Delta t$ might be as small as to give “Box-klangfarbe” [6].

2) From the proscenium side-walls $\Phi=15^0$, $\Delta t=$ *ca 15-20ms*, typically from upper parts of the walls between proscenium walls and ceiling/reflector (proscenium splay), or from “wedges” on these surfaces (Gothenburg, Helsinki, and Bastille, with longer $\Delta t$).

3) From frontal parts of (curved) sidewalls $\Phi=15$-$30^0$. $\Delta t=$*ca 10-20ms.* (S. Francisco, Metropolitan etc). If one forgets that the orchestra should be perceived from the pit, some phantom sources of this type are not always that annoying. Rhythmically, the reflections in 2) and 3) are almost in time/direction with the “bass/rhythm” from the pit. Such reflections might give an excellent broadening of the apparent orchestra source width (Dresden) but might give very strange effects like “flutes hanging high up along the sidewalls or snare drums under the balcony”.

4) From the middle part of sidewalls $\Phi=75$-$120^0$ $\Delta t=$ca25ms. Often such phantom reflections have passed more than one surface. Example: A source in the orchestra pit is reflected from the underside of the first balcony, then from the side wall and down to the stalls. This often sounds like a bad loudspeaker, due to the limited high-frequency range transmitted.

When the Munich Opera was rebuilt, the acoustic consultant [7] proposed diffusing elements on the sidewalls at floor level of auditorium (stalls), but this was not possible. The overall acoustic impression of this opera house is excellent, but there have been some remarks of focusing for seats at the sides at the back of the stalls. We had the opportunity to examine these seats, and found that they did not only give focusing, but also a clear **rhythmic distortion**. The bass (diffracted over the pit-rail) and the treble was not received “in rhythm”. At these seats we received a divided orchestra: Bass from the pit, and Treble arriving later from the side/back, with a time delay that gave severe rhythmical problems (Bizet: Carmen, Troubadour-March). A computer study shows that Δt for these sideways reflections in Munich are clustered between 23-25 ms.




This is shorter than the 50ms often referred to as the integration time of our hearing organ/"echo-limit", but still dramatic, as it splits the orchestra into 2 layers, and gives a **delayed Phantom of the Opera.**

In musical notation Bizet´s up-tempo-march was perceived almost like this:

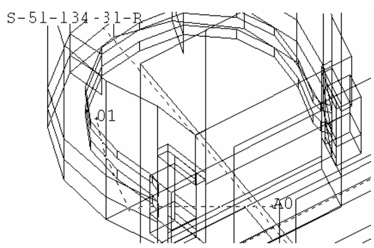
where the upper staff indicates the perceived delayed phantom (picc.flute/tambourine etc.) which should be "in rhythm" with staff 2. The fact that the delayed / treble part ("staff 1") of the orchestra was received from the back/ side, $\Phi$=90-120$^0$, made our listening experience even more disturbing.

<u>5) From sidewalls/rear walls close behind the listener</u> (San Fransisco, Nat.Theatre Oslo). $\Phi$ *>+/- 130$^0$,* Δt= 5-20ms. Such Phantoms might give some disturbances for orchestra, but on the other hand extra clarity for vocal/speech, some uncertainty about localisation and Box-Klangfarbe [6].

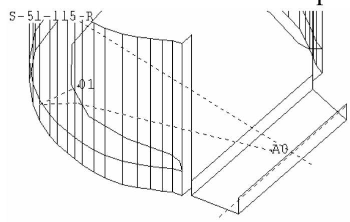
<u>6) Reflections from the opposite side of the hall,</u> <u>**Echos**</u> $\Phi$=-(90-120)$^0$, Δt ca. >50 ms. (Kirov, St. Petersburg), and for some seats in Covent Garden. Such echoes will not be discussed further in this paper.

## COMPUTER MODELLING OF PHANTOMS

The sidewalls of the Munich Opera are almost circular. This gives a problem for computer modelling. An overall model, with a small number of surfaces might give good results for most common acoustic criteria, given the right diffusion/scattering coefficients.




However, to visualise the observed focusing effect, we need to divide the sidewalls into many small surfaces, to show the direction of the focusing "phantom" observed in the Munich Opera.




This model gives some 20 reflections clustered between 23-25 ms (shown in the "echo-gram" above). However, such a detailed room-model for all surfaces might not give correct results for the overall acoustic criteria.

## CONCLUSION

Phantom sources from the orchestra pit are common in most opera houses, and should be controlled as part of the acoustical design. A controlled broadening/ heightening of the orchestra "apparent source width/height" might be beneficial. Image shifts of single instruments and specific frequency ranges should however be avoided, especially if received from the side/rear, giving rhythmic distortion.

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