Determination of directional echograms and application in room acoustics

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Echogram: definition

A diagram showing the distribution of the acoustical energy at the receiver, as a function of time arrival. (whatever the direction of incidence)
Echogram: applications in room acoustics

Room acoustics parameters:
- T30, EDT
- SPL
- C80, D50
- ...

Room impulse response

Auralization
Directional Echogram: definition

\[ h_{SR}(\theta,\phi,t)d\Omega \]

A diagram showing the distribution of the acoustical energy at the receiver, as a function of time arrival, in a particular direction of incidence.
The directional echograms are evaluated by ray-tracing, at each listener’s position. The 3D space around the listener’s head is divided into 26 solid angles, simulating 26 directional microphones.
Directional echograms: computation in two «academic» room acoustics problems
Example 1: Room A (ref. Hodgson, JASA, 89(2), 1991)

Cubic room

- side length: 27.5m
- absorption coefficient of all faces: 0.068
- scattering coefficient of all faces: d=0 or d=1

Source

Z Y X
Room A: Directional echograms at one receiver position, 5m away from the source, diffusing surfaces.
Room A : Directional echograms at one receiver position, 5m away from the source, specular surfaces.
Room A: Directional echograms at one receiver position, 5m away from the source.
Example 2: Room B (ref. Hodgson, JASA, 89(2), 1991)

Long disproportionate room
-55m x 110m x 5.5m
-absorption coefficient of all faces: 0.068
-scattering coefficient: d=0 or d=1
Room B : Directional echograms at one receiver position, 5m away from the source, diffusing surfaces.

d=1
T30=4.3s
Room B: Directional echograms at one receiver position, 5m away from the source, specular surfaces.
Room B: Directional echograms at one receiver position, 5m away from the source.
Room B: Energy decay curve at one receiver position, 5m away from the source.

\[ T_{30} = 16.4\text{s} \]  
\[ T_{30} = 4.3\text{s} \]
Room B: T30 directional at one receiver position, 5m away from the source.
Conclusion of the analysis of two « academic » problems

The directional echograms can afford interesting additional information, especially for:
- disproportionate rooms,
- weak diffusing surfaces,
- asymmetrical distribution of acoustical absorption.
Directional echograms: application in a room acoustics project
Project:

Renovation of an ancient horse-riding school into a cultural polyvalent hall.

Théâtre du Grand Manège (Namur)
Long disproportionate room -55m x 110m x 5.5m

- absorption coefficient of all faces: 0.068
- scattering coefficient: d=0 or d=1

Seats absorbing roof
reflecting walls
Polyvalent hall, original situation:
Echogram and energy decay curve at one receiver position.
Polyvalent hall, original situation:
Directional echograms at one receiver position, 1 kHz.
Polyvalent hall, original situation:
Directional energy decays at one receiver position, 1 kHz.
Polyvalent hall, original situation:
Directional T30 at two receiver positions, 1 kHz.
Théâtre du Grand Manège
(Namur)

First acoustical treatment:
Absorbent and diffusing surfaces on the left wall
(when looking from the scene)
Polyvalent hall, first acoustical treatment:
Directional echograms at one receiver position, 1 kHz.
before treatment : T30=5.6s
after treatment : T30=1.9s

Polyvalent hall:
Directional energy decays at one receiver position, 1 kHz.
Théâtre du Grand Manège
(Namur)

Horizontal audience surface
Polyvalent hall, horizontal audience surface:
Echogram and energy decay curve at one receiver position.

EDT = 2.3s
T30 = 6.2s
Polyvalent hall, horizontal audience surface: Directional energy decays at one receiver position, 1 kHz.

tilted audience surface: $T_{30}=1.9s$

horizontal audience: $T_{30}=6.2s$
Conclusions

- Directional echograms can give original information in non-diffuse acoustical fields.

- They are particularly useful in the detection of potential flutter echos, lack of diffusivity and asymmetrical distribution of absorption.

- They can explain significant differences between T30 and EDT, as a result of nonlinear energy decays.

- They can suggest optimal placement of absorbent and/or diffusing material to attenuate reverberation.