Room Acoustics

Experiment: Modes in room

- Use loudspeaker w/ Fcn Generator at 1KHz (wavelength about 30cm)
- Have people close one ear and move head around
- Find nodes in room by moving head around.
- **problem:** this may not represent a simple source, and many modes are being oscillated
    - although it should be possible to find points where they cancel each other out (superimposition of modes)

- Clearly affects the perceived frequency response of room.

- If ear is at node of a pressure wave (remember eardrum responds to air pressure), very quiet.

- Even if speaker, instrument, etc has good freq response, what listener hears will not reflect this: there's lots of peaks and dips in response.

- Chan centre-- upper balconey-- moving back 2 ft causes distinct and large change in audibility of sound from stage.

Perceived loudness-

- to properly hear a mode, ear must not be at node (pressure node, not velocity node-in different places).

- Also instrument will excite that mode only if it is not at a pressure node *of the room*. (just as plucking string or striking drum response depends on where you strike it, so response of room mode depends on where you excite it.

- so both listener and instrument must be at relative max of a mode if a listener is to hear the mode well.

- Can get situation where the modes which are strong at listener are weak at the instruments and vice versa. Both give poor response.

- the excitation of a mode is maximized by not only the positioning of the sound source relative to the rooms nodes, but also by the sources driving frequency being matched to the mode frequency
    - these highly excited modes will ring for a very long time, with high relative Q (decay very little)
    - if the source frequency is adjusted, the modes present will change, and thus the positions of nodes and antinodes will change
    - depending on where someone sits, and where the source is located, different modes may be audible, and thus the sound perceived may be different

Decay

- modes should decay. If they ring too long all sounds just mush together

- DECAY TIMES:
    - decay time= time for ampl to decay by 60dB
    - reverberation time: time required for averaged pressure amplitude to die out to one thousandth of its initial amplitude (10*10*10 times amplitude = 10+10+10

dB=30dB)

- decay time characteristics are very similar to build-up of sound characteristics

- if the frequency spectrum (draw one) has many wiggles, it will ring longer (more harmonics)

Reflection

- sound intensity dies out over distance by inverse square law

- sound travels at constant speed (speed of sound), and so is delayed depending on distance to perceiver

- the perceiver in a room will also hear the echo resulting from the walls, ceiling, and floors

- as discussed earlier, low frequency sounds tend to have lower efficiencies due to their being below the knee frequency, and the ear is less sensitive to lower frequencies, so it is perceived that they don’t travel as far as high frequency sounds

- Harmonics of a single sound travel differently
  - low frequency partials of a sound travel with equal strength in all directions, and have strong uniform echoes for simple uncluttered rooms
  - high frequency partials are strongly forward directed, resulting in smaller, inconsistent reflected sounds

- the amplitude of the echoes is diminished by the additional distance that the sound travels, it’s relative efficiency, and the absorption by the wall (say if it's porous)

- an initial wave that hits someone’s ear may still be dieing out as the reflected wave arrives, resulting in distorted sounds (think about loud music in a gym)

- reflections off flat solid walls will preserve the initial sound wave, but people, seats, furniture will refract and scatter the waves, changing their shape

Ear has astonishing ability to factor out room

- ear has the amazing capability of discriminating between pitch, loudness, and tone colour

- can “make sense” out of complicated signals

- seems as if everything is just as it should be, and often have to pay really close attention to realize the node/antinode dependence. (as noted from experiment)

Brain's perception of a sound

- Nervous system function
  - has the capability of assessing the partials of a sound perceived by both ears, and performing an averaged measurement
  - also capable of making a “running average”, summing up information over a short period of time and averaging it (to correct for movement in the room of the perceiver or something else)
  - even the slight movement of the perceiver or player can add information to this averaging

- ”Precedence effect” : Ear combines reduplicated sound sequences and hears them as one entity if the arrive within 35ms of each other (if sounds are alike)

  - first sound to arrive will seem to be the location of the sounds origin, with the other sources (reflection, speaker, etc) will augment the sound – as long as the later arriving sounds are not three or more times greater in amplitude

- Initial reflection delay time affects perception
  - Brain uses initial transients of sound to determine location and intelligibility of sound
  - Want first reflection to be delayed by at least 10msec

- Problem with electronic amplification—
  - sound emitted by speaker near you before initial sound arrives from stage.
  - Confuses brain, and makes intelligibility much less.
  - Need electronic delay so sound from speakers delayed to just after direct sound from stage, even if direct sound is much quieter than from speakers.
    - Common problem in halls-- putting speakers around hall can make it less intelligible than without, even though it's louder
    - This is also why loud speakers tend to be placed behind speakers, rather than distributed.
    - Also why ceilings tend to be high in a good hall (delays reflection from ceilings).

Different materials absorb different frequencies to different degrees

- Main absorbers at surfaces (walls, floors, ceilings) absorb differently.

- concert hall changes significantly due to presence of audience.
  - the presence of furniture and people in a room will rearrange the frequencies of the various modes and certain frequencies will be more readily absorbed than others
  - People (full audience) are good absorbers of most freq. (once again depends on whether a person is at node or antinode)
  - Clothing-- fur coats vs bare skin changes absorption
  - Attempt to create chairs with same absorpotion as people to make hall less sensitive
  - soft seats as much for sound as for comfort of audience.

Surroundings should be tailored to depend on the type of sound used

- Number of perceived modes is proportional to the square of the excitation frequency

- directly proportional to the volume of the room
  - find volume ratio to determine the factor increase of modes

- old stone cathedrals ring for long time
  - decay times of up to 10 sec.
  - good for a slow organ music; as long as there are very slow changes of pitch
  - but terrible for fast music or for speech

- for speech, require a shorter decay time of order of 1 sec

- up to 2.5 seconds for music decay time

- If the decay time is *too short*, all sounds very dry and hard to hear
  - ie: outdoor arenas, where the sound never reflects

- Chan centre
  - huge curtains which can be lowerd along walls to increase absorption of mid

frequencies at walls

- concrete reflects everything. Curtains do not absorb low freq well