SOUND INTENSITY POWER AND PRESSURE LEVEL ADDING SOUNDS

MU610A: ACOUSTICS & PSYCHOACOUSTICS

EDWARD COSTELLO

FUNDAMENTAL ITEMS

- The 3 ways to measure energy of sound present and be able to define each relationship between loudness and intensity
- Weber-Fechner Law
- Linear VS Logarithmic
- Sound Intensity Level (SIL)
- Sound Power Level (SWL)
- Sound Pressure Level
- Correlated and uncorrelated sound sources and their relationship with phase

SOUND ENERGY

- There are three ways to measure the amount of sound present in a wave
  1. Power: How much energy is transferred per unit time ie: the number of joules per second that propagate
  2. Intensity: how much power is delivered per unit area (sound occupies space)
  3. Pressure: the amount of pressure variation at a given point

SOUND INTENSITY

- A measure of how much power is delivered per unit area.
- Intensity takes into consideration that sound occupies space
- Intensity also has a direction: perpendicular (90 degrees) to that of the flow of acoustic energy

LOUDNESS AND INTENSITY

- Loudness and intensity do not have a linear relationship (ie: they are not proportional)
- However, they do have a clear relationship, the perceptual response depends on the ratio of the two.
- Weber-Fechner Law: *"The increase in intensity needed to produce a given increase in perceived loudness is proportional to the pre-existing intensity"*

LOUDNESS AND INTENSITY

- For example: An increase in intensity from an arbitrary unit of 1 to 10 provides the same increase in perceived loudness as a rise from 10 to 100.
- Thus we perceive changes in sound intensity (and power/pressure) logarithmically.

LINEAR AND LOGARITHMIC PHENOMENA

- There are 2 main modes of perception: linear and logarithmic
- Linear implies a constant amount of change based on the difference between values.
- For example, the changes from 5m to 6m is perceived to be the same as the change from 2m to 3m. It takes the same amount of change for both to occur (+1 metre)
- Thus we perceive distances linearly.

LINEAR AND LOGARITHMIC PHENOMENA

- Logarithmic phenomena are perceived on the basis of the ratio of the values (not the differences). We perceive changes in sound intensity/power/pressure logarithmically.
- For instance, a change from a 'loudness' of 1 to a 'loudness' of 10 will be perceived to be the same increase as a change from 10,000 to 100,000. It takes the same amount of change for both to occur (x10)

WHAT'S COMING NEXT!

- Sound Intensity Level (SIL): How much energy is delivered per unit area.
- Sound Power Level (SWL): energy transfer per unit time.
- Sound Pressure Level (SPL): the amplitude of a wave at a certain point.

SOUND INTENSITY LEVEL (SIL)

- As intensity is a relative scale (based on ratios, not differences), we need to use a reference value if we want an absolute scale.
- The reference intensity used is the intensity at the threshold of hearing (for a tone at 1KHz):
- A change in intensity of 1dB corresponds roughly to the minimum change we can hear. Note the subjectivity here

SOUND POWER LEVEL (SWL)

- Sound Power Level is the total energy being radiated in all directions per unit time
- SWL is measured in watts (as opposed to watts per area, as previous), and is an absolute measurement taken in relation to the threshold of hearing
- SWL is a measure of total acoustic power, it does not have direction, as SIL does.

SOUND PRESSURE LEVEL (SPL)

- The measurement of sound pressure is a way of describing the amplitude of a wave at a certain point
- Pressure is a force that can be associated with sensation of something pushing against us in some way
- Sound pressure can be thought of as the amount of air molecules are getting 'pushed around'

SOUND PRESSURE LEVEL (SPL)

- Pressure waves coming from a sound source reach our ears. The air molecules at the ear are vibrating due to this pressure.
- These small vibrations cause us to experience sound.
- Note the word "experience"

ADDING SOUNDS

- Sound often arrives from multiple sources, in which case they must be added. For example perhaps multiple instruments are playing. Sound will also reach a listener after being reflected off walls/objects in a listening room. Also, many modern listening situations involve multiple loudspeakers.

ADDING SOUNDS

- Two distinct situations should be considered when adding sounds:
  1. Correlated sound sources: again, several sound sources, but this time, they are related, for example sine reflections (arriving within a short delay time) or similar loudspeaker signals (common electrical sources).
  2. Uncorrelated sound sources: again, several sound sources, but this time, they are unrelated. For example, different instruments playing together (even the same instruments playing together will be different), or a signal arriving at a listener directly and after a long delay. This may occur, for example, after several reflections.

SOUND PRESSURE LEVEL (SPL)

- SPL is the usual measure for amplitude of a sound wave.
- SPL used the threshold of hearing for its reference. The threshold of pain is 20 pascals.

CORRELATED SOURCES

- Correlated sources add together simply. For example, the total pressure of the sum of a number of correlated pressure waves is:

$$P_{total}(t) = P_1(t) + P_2(t) + \ldots + P_n(t)$$

CORRELATED SOURCES

- In this case, as the sources are correlated, they will all be the same frequency. Also, the result is a function, so will vary with time (as the pressure function will change with time).
- This time delay mentioned previously between the correlated sources become crucial for periodic/ repeating waves. Short delays in time correspond to phase shifts, which alter the result of adding waveforms.

CORRELATED SOURCES

- Take for example 2 sinusoidal waves. If they are 'in phase' at the same phase point with respect to time. They add, point by point, to result in twice the original pressure variation.
- At the other extreme, consider two sinusoidal waves that are 'anti-phase'. This can be considered as one wave being delayed by one half period.
- Performing the point by point addition, the output is zero, as the waves cancel

UNCORRELATED SOURCES

- The addition of uncorrelated sources on the other hand is not as straightforward as correlated sounds. In this case we must add the powers of the individual waves together
- The power in a waveform is proportional to the square of the pressure levels so in order to sum the powers of the waves we must first square the pressure amplitude, then add them.
- Note for uncorrelated sound sources, phase cancellation is not an issue

SUMMARY

- There are 3 ways to measure the amount of sound present in a wave/the sound energy
- Sound Power Level: energy transfer per unit time.
- Sound Intensity Level: How much energy is delivered per unit area.

SUMMARY

- Sound Pressure Level: the amplitude of a wave at a certain point.
- Sound 'loudness' levels are perceived logarithmically.
- The deciBel scale is used to represent relative sound levels.
- Correlated and Uncorrelated sounds are added differently