Infrasound and Ultrasound

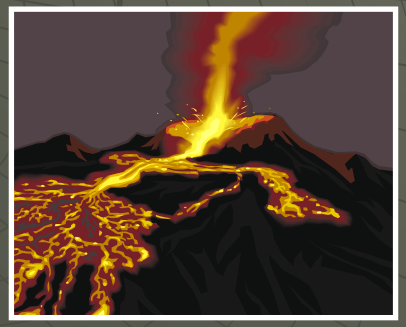
Exposure and Protection

Ranges

- Classical range of audible frequencies is 20-20,000 Hz
- <20 Hz is infrasound
- >20,000 Hz is ultrasound
- HOWEVER, sounds of sufficient intensity can be aurally detected in the range of both infrasound and ultrasound

Infrasound

- Can be generated by natural events
  - Thunder
  - Winds
  - Volcanic activity
  - Large waterfalls
  - Impact of ocean waves
  - Earthquakes



Infrasound

- Whales and elephants use infrasound to communicate

Infrasound

- Can be generated by man-made events
  - High powered aircraft
  - Rocket propulsion systems
  - Explosions
  - Sonic booms
  - Bridge vibrations
  - Ships
  - Air compressors
  - Washing machines
  - Air heating and cooling systems
  - Automobiles, trucks, watercraft and rail traffic

Infrasound

- At very specific pitch, can explode matter
  - Stained glass windows have been known to rupture from the organ's basso profunda
- Can incapacitate and kill
  - Sea creatures use this power to stun and kill prey

Infrasound

- Infrasound can be heard provided it is strong enough. The threshold of hearing is determined at least down to 4 Hz
- Infrasound is usually not perceived as a tonal sound but rather as a pulsating sensation, pressure on the ears or chest, or other less specific phenomena.

Infrasound

- Produces various physiological sensations
- Begin as vague “irritations”
- At certain pitch, can be perceived as physical pressure
- At low intensity, can produce fear and disorientation
- Effects can produce extreme nausea (seasickness)

Infrasound: Effects on humans

- Changes in blood pressure, respiratory rate, and balance.
- These effects occurred after exposures to infrasound at levels generally above 110 dB.
- Physical damage to the ear or some loss of hearing has been found in humans and/or animals at levels above 140 dB.

Infrasound: effects on humans

- Primary effect may be annoyance
- At 127-133 dB, a pressure sensation is felt in the middle ear
- Other effects include vertigo, imbalance, intolerable sensations, incapacitation, disorientation, nausea, vomiting, bowel spasm, and resonances in inner organs, such as the heart

Infrasound

- Can also cause sleep disturbances
- Feelings of fatigue, apathy, depression, loss of concentration, drowsiness, reduced wakefulness
- Pressure in the ears
- Vibration of internal organs
- Increased diastolic BP, decreased systolic BP and pulse rate
- Altered time perception

Animal studies/infrasound

- Effects in behavior, brain chemistry, and on blood vessels
- Cochlear damage, which can be substantial with high level exposures
- Reduced physical endurance
- Effects on nervous system, liver, and other organs

Infrasound as a War Weapon?

- Cannot be heard: a distinct advantage for a defense system
- Effects can be felt
- Symptoms come on rapidly and unexpectedly
- Pressure waves impact against the entire body
  - Heart, lungs, stomach, intestinal cavity can be wracked with painful spasms even after exposure
- Pressure against the eyes and ears, nearly unbearable
  - Eyesight can be affected for days
- Increased intensities can result in death

Walt Disney and his artists

- Were once made seriously ill when a sound effect was slowed down several times on a tape recorder and amplified through a theater sound system
  - Original sound source was a soldering iron with 60-cycle hum; was lowered 5x to 12 cycles
- Produced a lingering nausea that lasted for days

Kokomo, IN

- Several individuals in this community have complained of subjective non-specific symptoms including annoyance, sleep disturbance, headaches, and nausea. These symptoms are perceived by the individuals to be due to a low-frequency hum-like noise in and around their homes that is not clearly audible to everyone.

Exposure limits: Infrasound

- Currently, there are no US or international standards defining Permissible Exposure Limits to infrasound
- Infrasound that is not subjectively perceived in some way, has no effect on performance, comfort, or general well-being*

American Conference of Government Industrial Hygienists (ACGIH)

- Recommends that, except for impulsive sounds (duration < 2 sec.) 1/3 octave levels for frequencies 1-80 Hz should not exceed a SPL ceiling limit of 150 dB
- No time limits are specified

Infrasound: proposed limits *

- 8 hour PEL's range from 136 dB at a low frequency of 1 Hz. , to 123 dB at the upper end of the infrasonic range of 20 Hz.
- Limits may be approximately adjusted for longer or shorter duration exposures by using a 3-dB exchange rate

Health Protection Agency (UK)

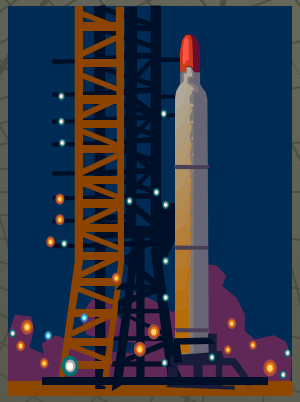
- Study began in 2005 to assess health effects of infra and ultrasound
- May lead to PEL's

Danish EPA

- Limits exposure to infrasound to 85 dB for 8 hour period

NASA

- Limits exposure in space craft and space stations to 120 dB for 24 hour exposure to 1-16 Hz.



Infrasound and Ultrasound

- Usually don’t occur in the absence of sounds within the normal range of audibility due to the nature of the processes by which such sounds are generated

Ultrasound

- Can be generated by a variety of industrial processes
  - Cleaning
  - Drilling
  - Welding plastics
  - Mixing
  - Emulsification

Ultrasound Exposure limits

- Have been recommended by a number of national and international organizations
- Criteria are similar, typically limiting exposures to 75 dB SPL for frequencies at and above 20 KHz; and 110 dB SPL for frequencies at and above 25 KHz.

Ultrasound PEL's

- Criteria for high audio frequencies (up to about 18K) are based upon subjective and psychological rather than auditory effects
- Ultrasound can cause unpleasant sensations such as aural fullness or pressure, headaches, in-head localization, and possibly nausea and fatigue

HPD attenuation: Infrasound

- Available data from one study only that looked at attenuation characteristics of earmuffs at low audio and infrasonic frequencies
- Done by Air Force
- Used both subjective (real ear attenuation thresholds at 35-500 Hz) and physical (microphone in earmuff, 1-500 Hz) measurement methods

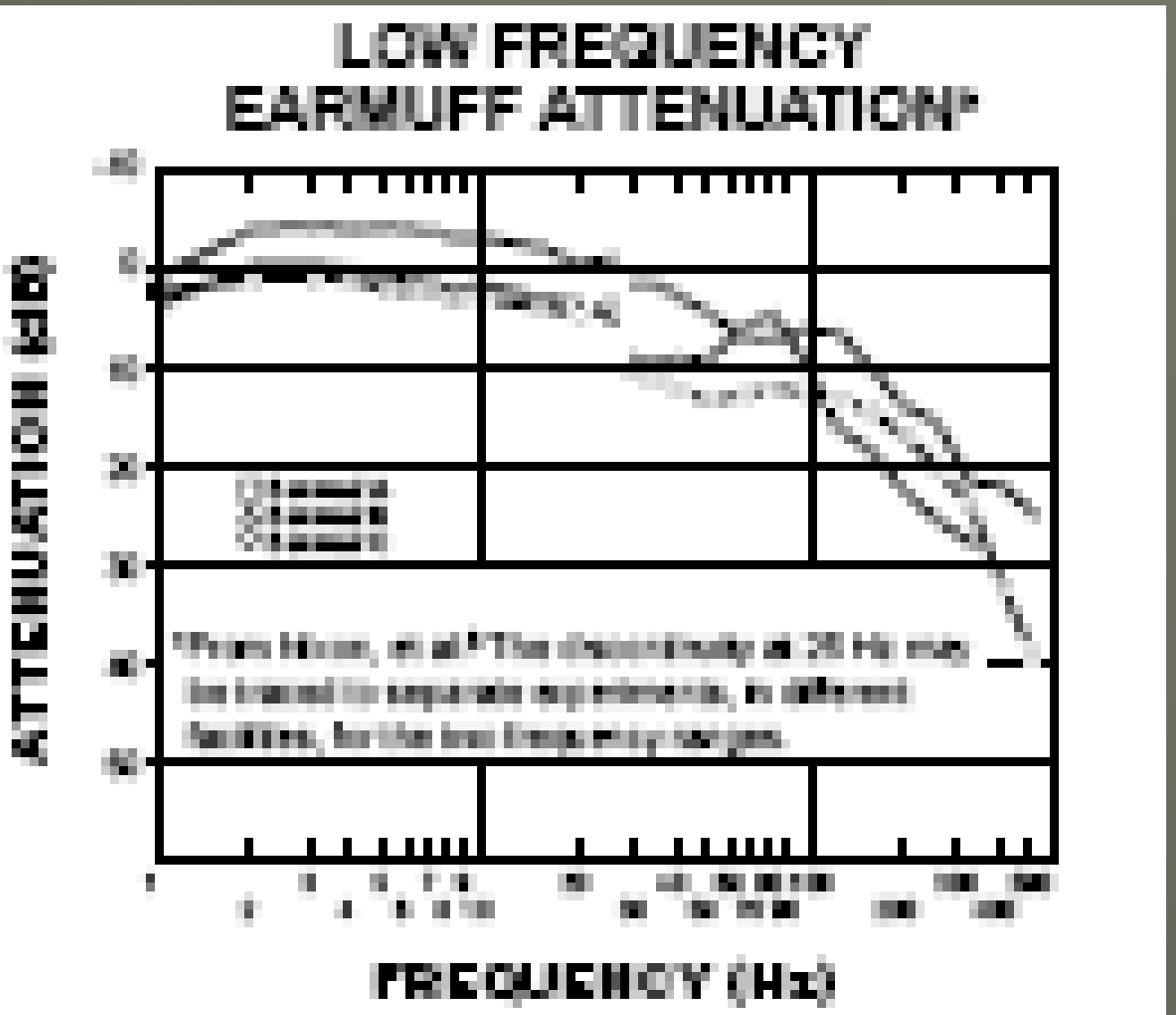

LOW FREQUENCY
EARMUFF ATTENUATION*
ATTENUATION (dB)
FREQUENCY (Hz)

Figure 1

Data show:

- Generally constant attenuation 30-100 Hz
- Very limited protection, or even amplification, for the infrasonic frequencies
- Confirmed by subjective impression

Insert protectors

- Most test standards do not require testing below 125 Hz.
- Some authors have tested as low as 50 or 80 Hz
- Results from AEARO labs show little difference in attenuation between 80 and 125 Hz.

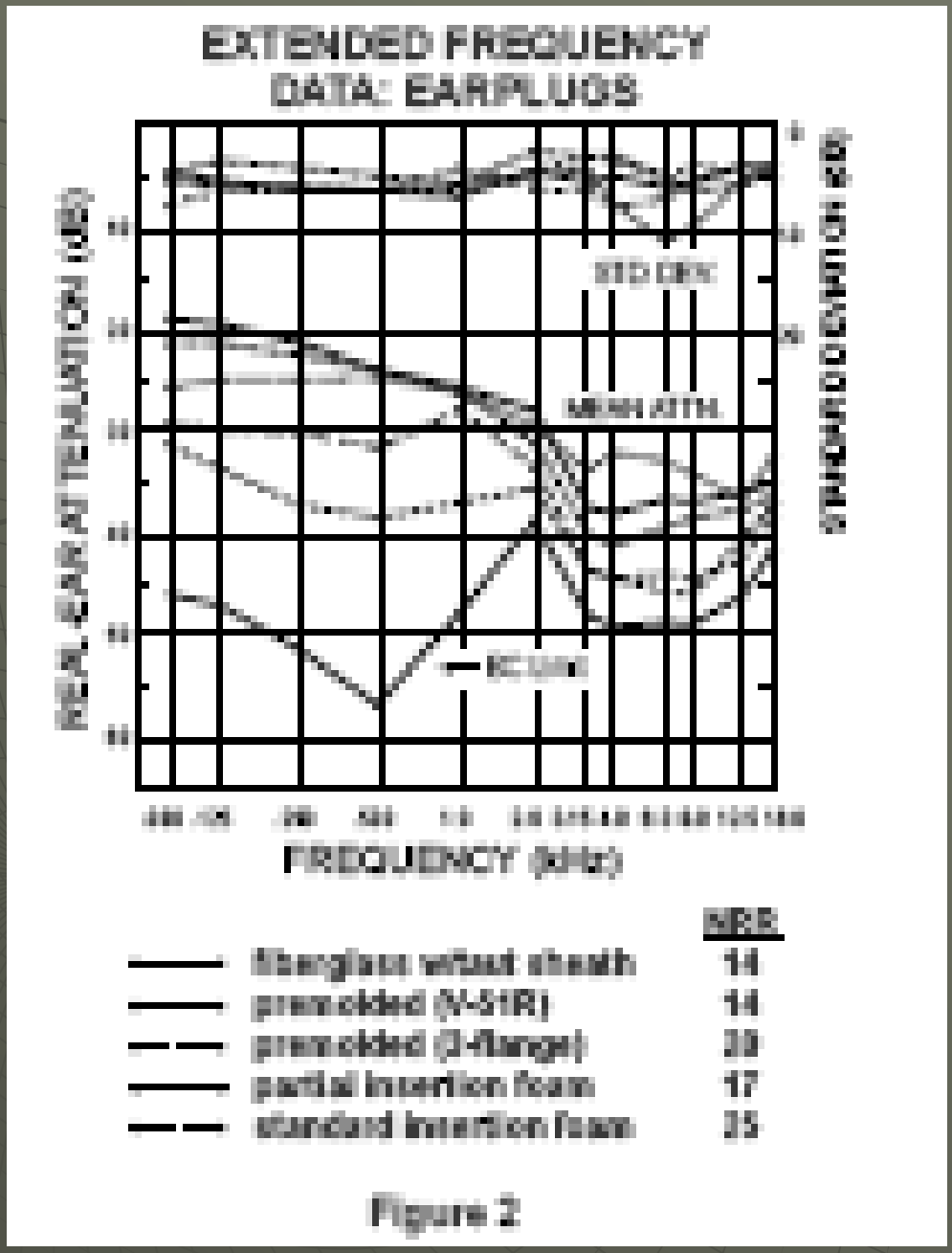

EXTENDED FREQUENCY
DATA: EARPLUGS
STD DEV
MEAN ATTN
FREQUENCY (kHz)
NRR
fiberglass w/out sheath 14
premolded (V-51R) 14
premolded (3-flange) 39
partial insertion foam 17
standard insertion foam 35

Figure 2

Hearing sensitivity

- At the upper end of the audio range, hearing sensitivity decreases at the rate of approximately 100 dB/octave, compared to 10-20 dB/octave for low audio and infrasonic frequencies.
- Most HPD's provide relatively good attenuation at high frequencies
- Makes generation of ultrasonic acoustical stimuli at a level sufficient to be detected by a subject wearing HPD's very difficult

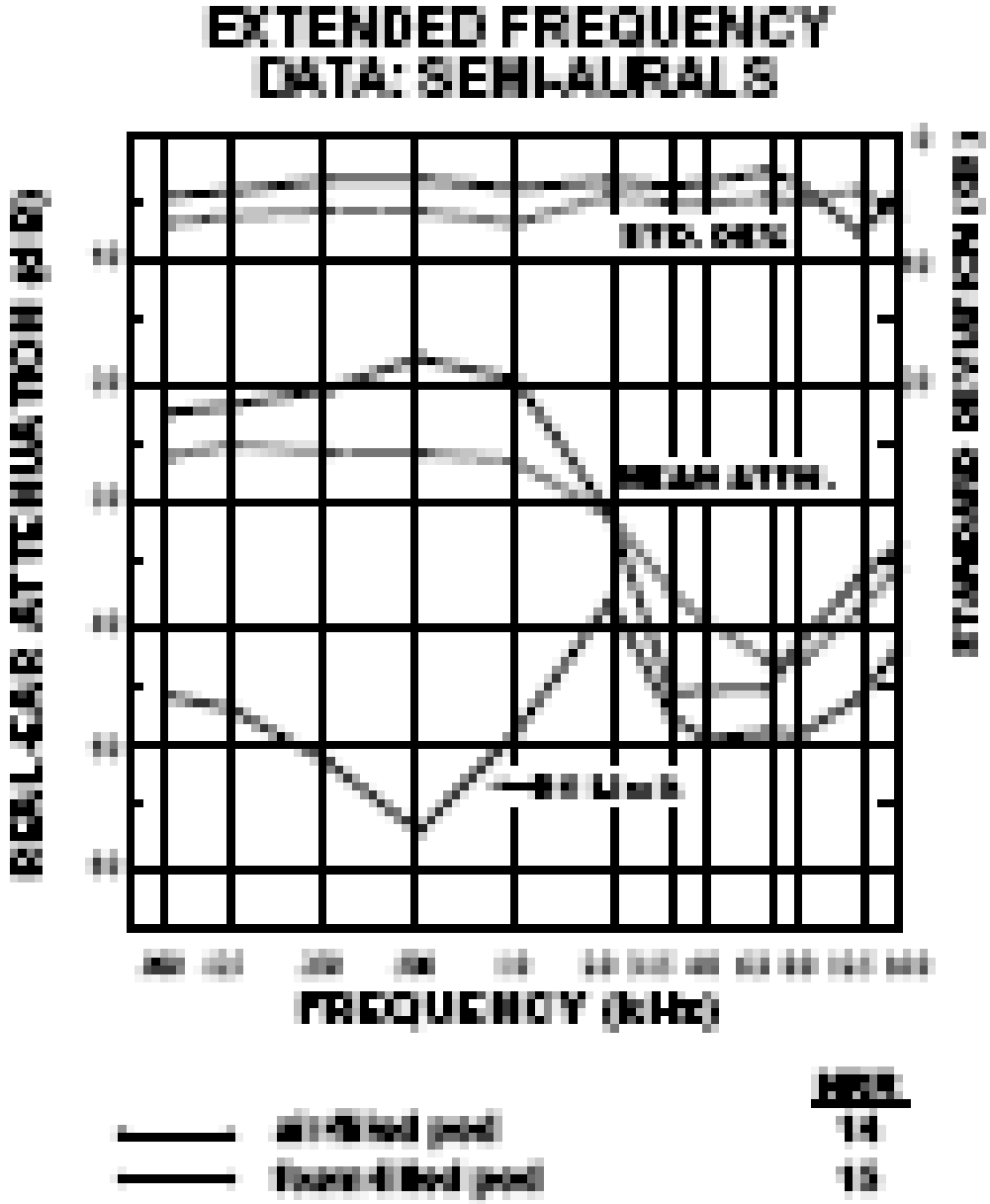


Figure 3

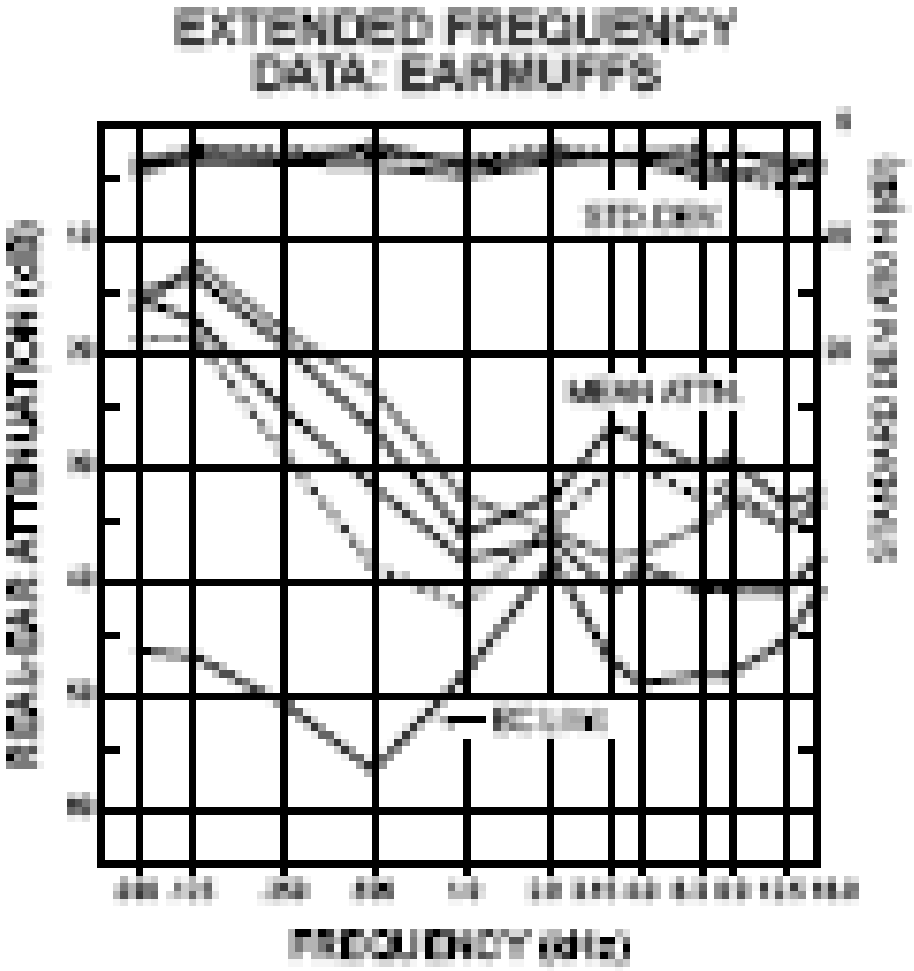

EXTENDED FREQUENCY
DATA: EARMUFFS
REAL-EAR ATTENUATION (dB)
STD DEV
MEAN ATTN
FREQUENCY (kHz)

Figure 4

Brger

- Also evaluated a plug + muff combination and found that in the frequency range 2-16 KHz, the measured performance was essentially equal to the BC limits

Conclusions

- HPD attenuation at low audio frequencies (down to about 50 Hz) can be estimated to an accuracy of approximately 5 dB by assuming it is equal to 125 Hz. data
- At high audio frequencies (up to 17.8 KHz) all HPD's tested were very effective, providing at least 32 dB of noise reduction

Conclusions

- At infrasonic frequencies earmuffs provide little or no protection, and may even amplify sound
- Properly fitted plugs should provide appreciable protection
- It is reasonable to assume that most HPD's will provide the same protection at frequencies up to 32 KHz as they do in the high frequency range (8-10K)