

# CM533 Multimedia Time-based Assets: Psychoacoustics 2

Dr Paul Vickers

# Auditory illusions

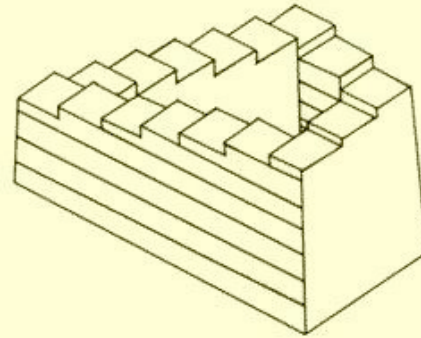
- ▶ Virtual pitch
- ▶ Infinitely rising/falling pitch
- ▶ Tritone paradox
- ▶ Infinitely increasing tempo
- ▶ And some others..

# Virtual pitch

- ▶ If a set of frequencies are presented that are all integer multiples of some lower (but absent) tone, we hear a tone with a pitch equal to the missing frequency.
  - ⦿ e.g. hear a 100Hz pitch when presented with a stimulus consisting of the sum of the frequencies of 700, 800, 900, & 1000Hz: all four tones are harmonics of 100Hz



# Rising/falling pitch



- ▶ Shepard/Risset tones sound like they're continuously rising or falling in pitch
  - ◉ Partial of harmonic sounds related arithmetically
  - ◉ Partial of a Shepard tone related geometrically using Weierstrass functions where  $M$  = no. partials and  $\beta$  = geometric relationship between two adjacent partials

$$w(\beta t) = \sum_{k=0}^M \cos(\beta^{k+1} t) = \sum_{k=1}^{M+1} \cos(\beta^k t)$$

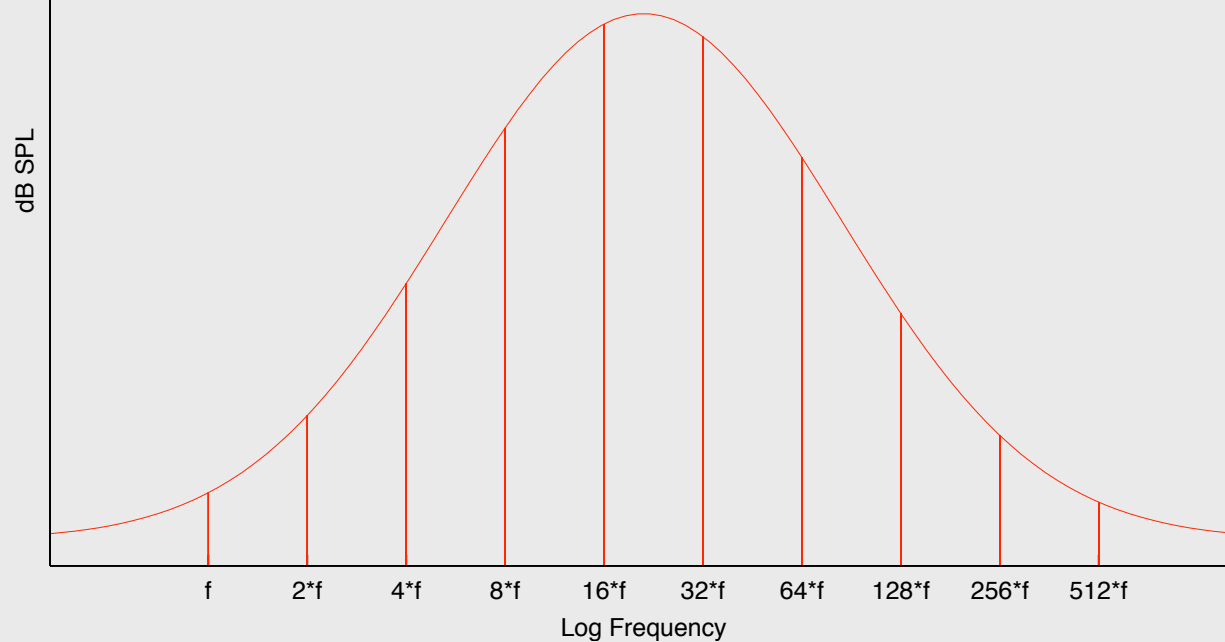
- ◉ Essentially, the partials are a Gaussian distribution of octaves
- ◉ The function doesn't change the 'body' of the tone but only the boundary conditions.



# Shepard tone

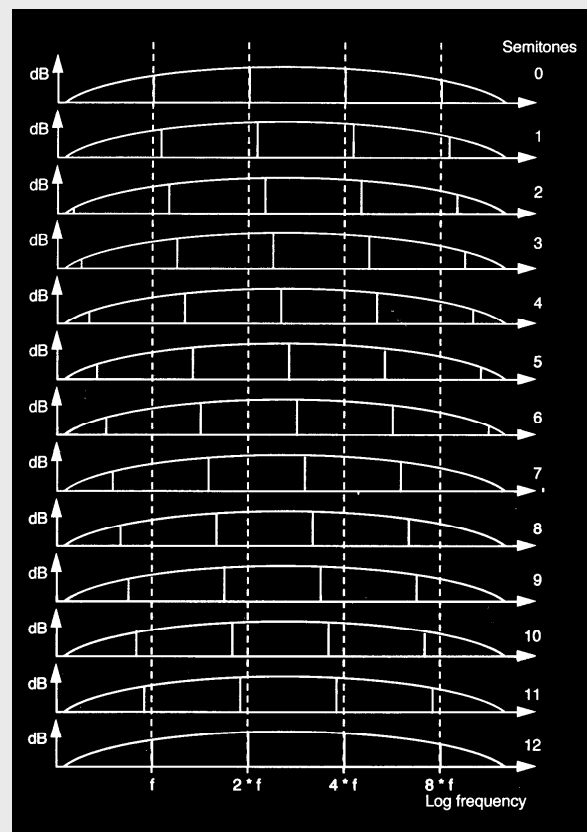
▶ Example harmonic distribution

frequency	f	2f	4f	8f	16f	32f	64f	128f	256f	512f
Hz	50	100	200	400	800	1600	3200	6400	12800	25600



# Shepard tones

- ▶ Iteratively increase pitch of each partial by 1 semi-tone



# Tritone paradox

- ▶ Created by Diana Deutsch (famous music/audio psychologist)
- ▶ Two Shepard tones exactly half and octave apart are played. This interval is called a tri-tone as in musical terms it is three whole diatonic tone steps (e.g. C-F#)
- ▶ The two tones, when played sequentially are heard as either a rising interval (C up to F#) or a descending interval (C down to lower F#), but never both at same time
- ▶ Deutsch found
  - ⦿ effect related to absolute pitch of frequencies involved: an individual will always tend to hear the same tone as higher or lower even when order of presentation is varied
  - ⦿ British subjects tended to resolve the ambiguity one way whilst Californian's heard it the other way

# Accelerando

- ▶ An illusion related to the rising/falling tones, but this time we hear an ever increasing tempo



CM533

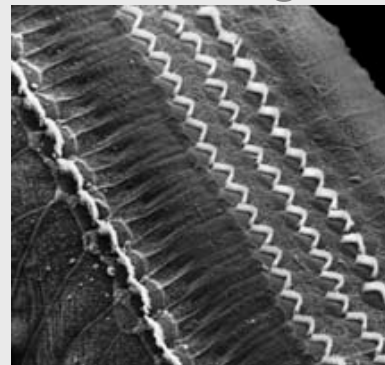
Multimedia Time-based Assets

©2005, Paul Vickers

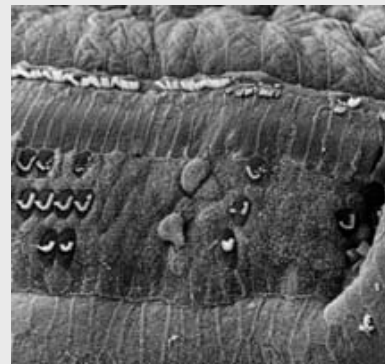
# Hearing loss

- ▶ Exposure to loud noises can cause hearing loss. But how loud and how long?

Continuous dB	Permissible Exposure Time
85 dB	8 hours
88 dB	4 hours
91 dB	2 hours
94 dB	1 hour
97 dB	30 minutes
100 dB	15 minutes
103 dB	7.5 minutes
106 dB	3.75 min (< 4min)
109 dB	1.875 min (< 2min)
112 dB	0.9375 min (~1 min)
115 dB	0.46875 min (~30 sec)



Normal inner ear "hair" cells



Damaged inner ear "hair" cells

[www.hei.org/news/facts/nihfact.htm](http://www.hei.org/news/facts/nihfact.htm)

**Concert/disco = 110-120 dB**

**iPods etc = 112 dB**

**We measured London Underground @ 95 dB!**