Basics of Noise and Its Measurement

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Some Key Terms

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Sound Terminology

- Decibels
- Octaves
- Decades
- Bandwidth
- Wave-number
- Tones
- Pink noise
- White noise
- Weighting

Tones & Octave

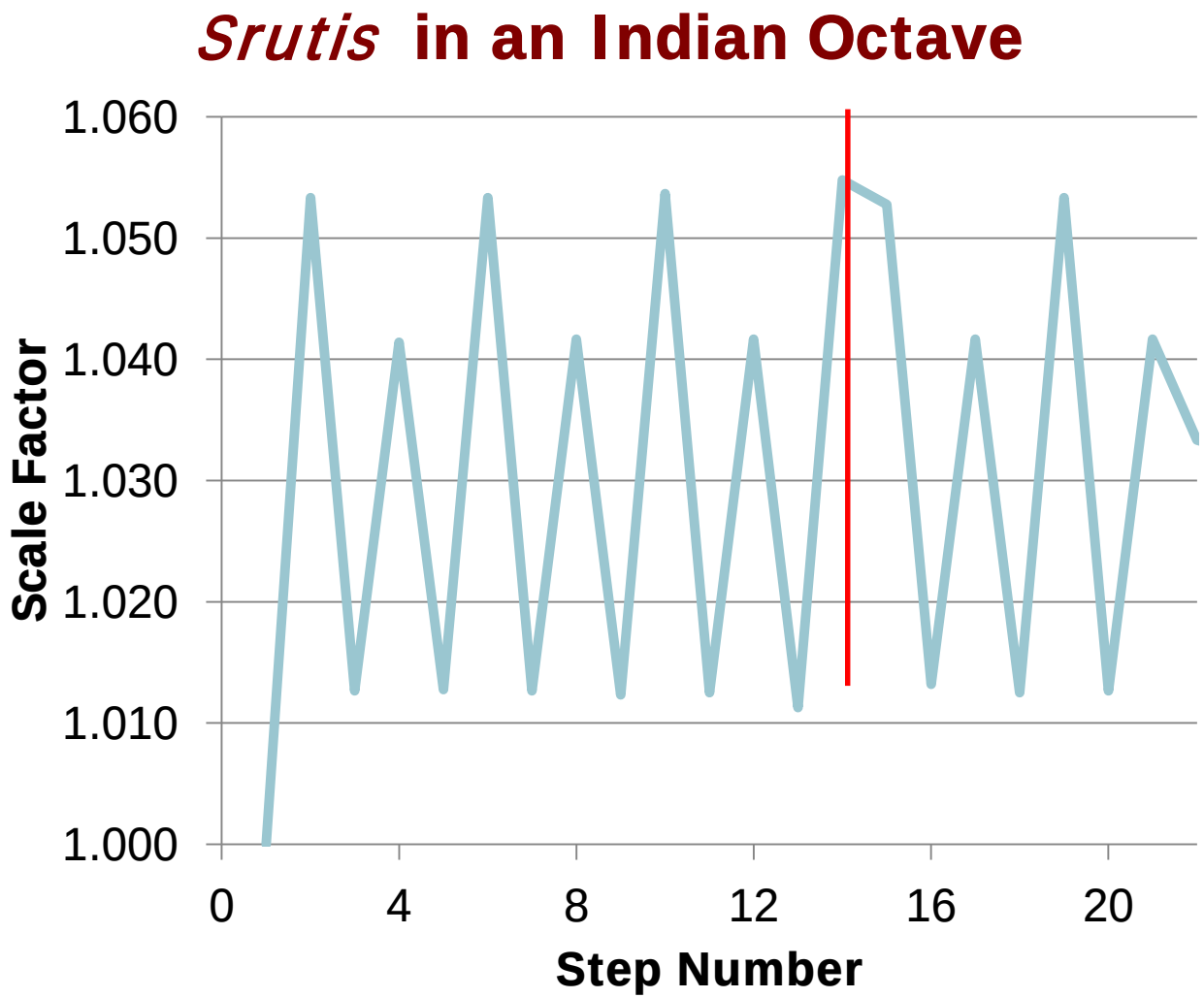
- Ear sensitivity – on a geometric scale
  - Frequency: 20 – 20,000 Hz
  - Pressure: 2×10^{-5} to 20 N/m^2
- Octave - Interval between two sound pitches (frequencies), separated by a factor of two
- Decade – Interval between two sound frequencies separated by a factor of 10

An Octave in Western Classical Music

Hz	Ratio	Name
240.0		**C**
254.3	1.0595	C sharp or D flat
269.4	1.0595	**D**
285.4	1.0595	D sharp or E flat
302.4	1.0595	**E**
320.4	1.0595	**F**
339.4	1.0595	F sharp or G flat
359.6	1.0595	**G**
381.0	1.0595	G sharp or A flat
403.6	1.0595	**A**
427.6	1.0595	A sharp or B flat
453.1	1.0595	**B**

Equally Tempered Scale

An Octave in Indian Classical Music



Sargam

Shadaj

Rishabh

Gandhaar

Madhyam

Pancham

Dhaivata

Nishaad

Just Tempered Scale

Octaves & Decades

- Logarithmic frequency scale
  - Why?

- Octaves & decades refer to frequency ratios
  - Octave: $f_2/f_1 = 2$
  - Decades: $f_2/f_1 = 10$
  - One-third octave: $f_2/f_1 = 2^{1/3} \approx 1.26$

Preferred Frequencies	
1/1	**1/3**
1	1 - 1.25 - 1.6
2	2 - 2.5 - 3.15
4	4 - 5 - 6.3
8	8 - 10 - 12.5
16	16 - 20 - 25
31.5	31.5 - 40 - 50
63	63 - 80 - 100
125	125 - 160 - 200
250	250 - 315 - 400
500	500 - 630 - 800
1000	1000

Bandwidth & Wave Number

- Bandwidth - difference between upper and lower frequencies in a contiguous set of frequencies
  - Center frequency
  - Audio bandwidth: 20 to 20,000
    - Bass
    - Middle
    - High

- Wave number (k) = $2\pi/\lambda = 2\pi f/c = \omega/c$
  - Used to dimensionalize distance and size
    - $kd >> 1$ is acoustically far or large
    - $Kd << 1$ is acoustically near or small

Tones and Noise

- Tone - purely sinusoidal sound wave

- Noise - mixture of all frequencies
  - White noise - equal power within a fixed bandwidth for any center frequency
    - i.e. constant power spectral density
  - Pink noise - power spectral density is inversely proportional to frequency
    - Equal power in each octave
    - Also called 1/f-noise

White & Pink Noise (example)

frequency	Power Spectral Density	Power Pink	Power White
1	1		
2	0.5	0.75	0.75
4	0.25	0.75	1.5
8	0.125	0.75	3
16	0.0625	0.75	6
32	0.03125	0.75	12
64	0.015625	0.75	24
128	0.007813	0.75	48
256	0.003906	0.75	96
512	0.001953	0.75	192
1024	0.000977	0.75	384
2048	0.000488	0.75	768
4096	0.000244	0.75	1536
8192	0.000122	0.75	3072

References

- Acoustics, Beranek Leo L., Acoustical Society of America, 1993.
- Introduction to Acoustics, Finch Robert D., Pearson Prentice Hall, 2005.
- Fundamentals of Acoustics, Kinsler Lawrence E., et al, 4th ed., John Wiley & Sons, 2005.
- Sound and Structural Vibration, Fahy Frank, et al, 2nd ed., Academic Press 2007.