Forum Acusticum 2011

BREKKE STRAND

Magne Skålevik
Brekke & Strand, Oslo, Norway
www.akutek.info

Cross-over wanted

SCHROEDER FREQUENCY REVISITED

About the presentation

- What is the significant properties of the two frequency regions?
  - Low frequency region – Modal Region
  - High frequency region – Schroeder Region
- Why care?
- Common misunderstandings
- The Schroeder Frequency
- Suggesting a revised cross-over region
- Handling the non-diffuse cases

The two frequency regions

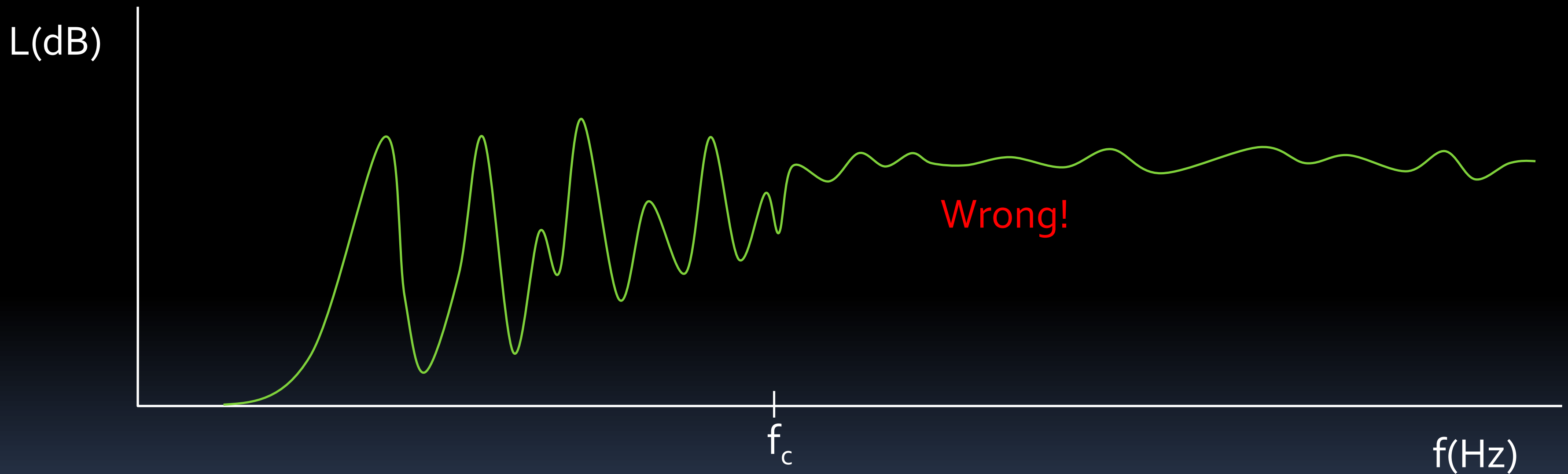
- Low frequency region – Modal Region
  - Dominated by separate modes, but clusters of overlapping modes may occur
  - Lowest mode in room of length L — $f = 170/L$
  - Half-power mode bandwidth — $B = 2.2/T$
  - Average mode spacing — $\Delta f = \frac{c^3}{4\pi V f^2}$
- High frequency region – Schroeder Region
  - Dominated by stochastic level outcome from overlapping modes
  - Best described by statistical properties
  - Average spacing between maxima — $\Delta F_{avr} = 4/T$
  - Average peak-to-dip level difference — $\Delta L_{avr} \sim 10dB$

Why care?

- In the high frequency region, energy-based prediction methods can work well, sound is well described as particles or rays
- In the Modal Region, single modes dominates

Common misunderstanding

- Smooth frequency response in the HF region



The Schroeder Frequency

- A room of volume V and reverberation time T
- The low limit of the high frequency region

$$f_c = 2000\sqrt{\frac{T}{V}}$$

corresponding to 3-fold modal overlap

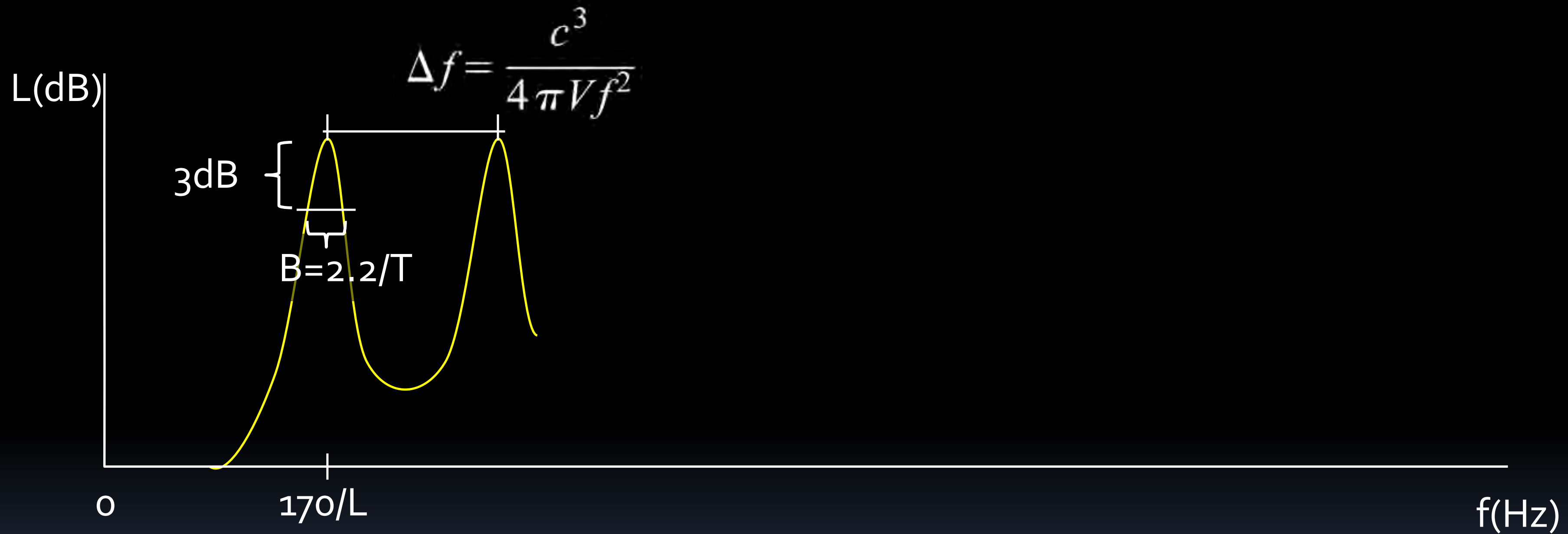
  - Originally, Schroeder, Kuttruf and Thiele suggested 10-fold overlap and the factor 4000, but after collecting more data, Schroeder in 1962 recommended the limit as expressed above

Validity of f_c

- High frequency properties can be expected above f_c, according to Schroeders' intention
- However, it is not established that the same properties can NOT be found below f_c
- f_c was not designed to determine the upper limit of the Modal Region
- Further discussion of the cross-over region follows

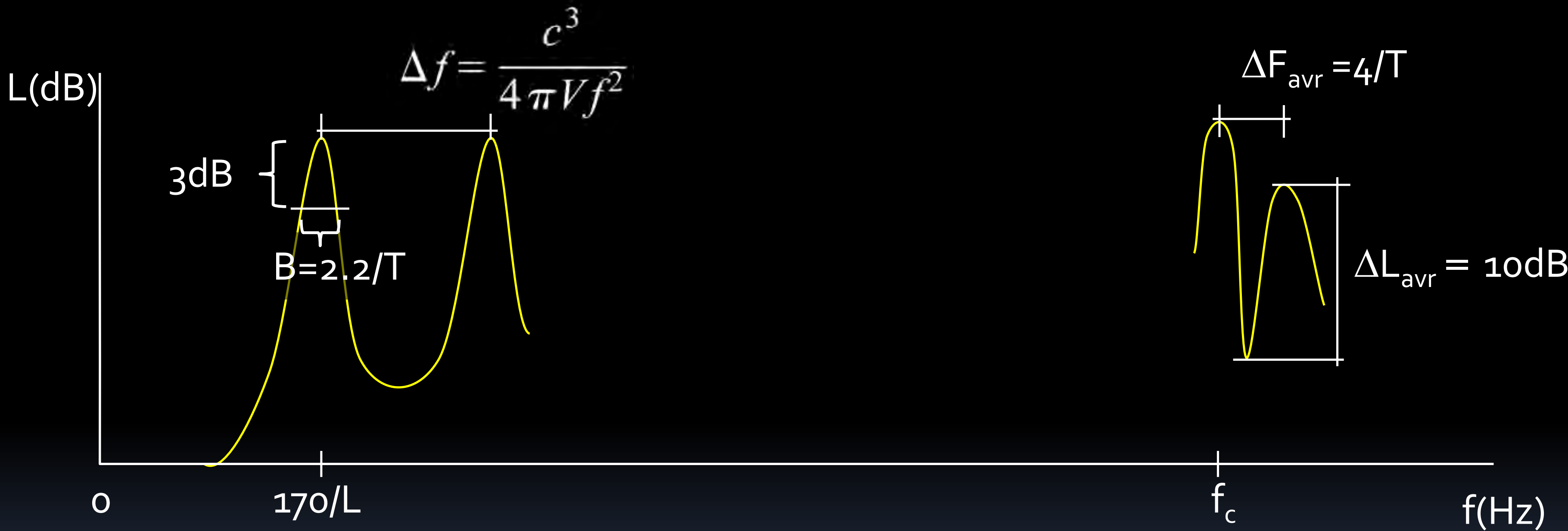
Modal Region

Frequency Response (Transfer Function)



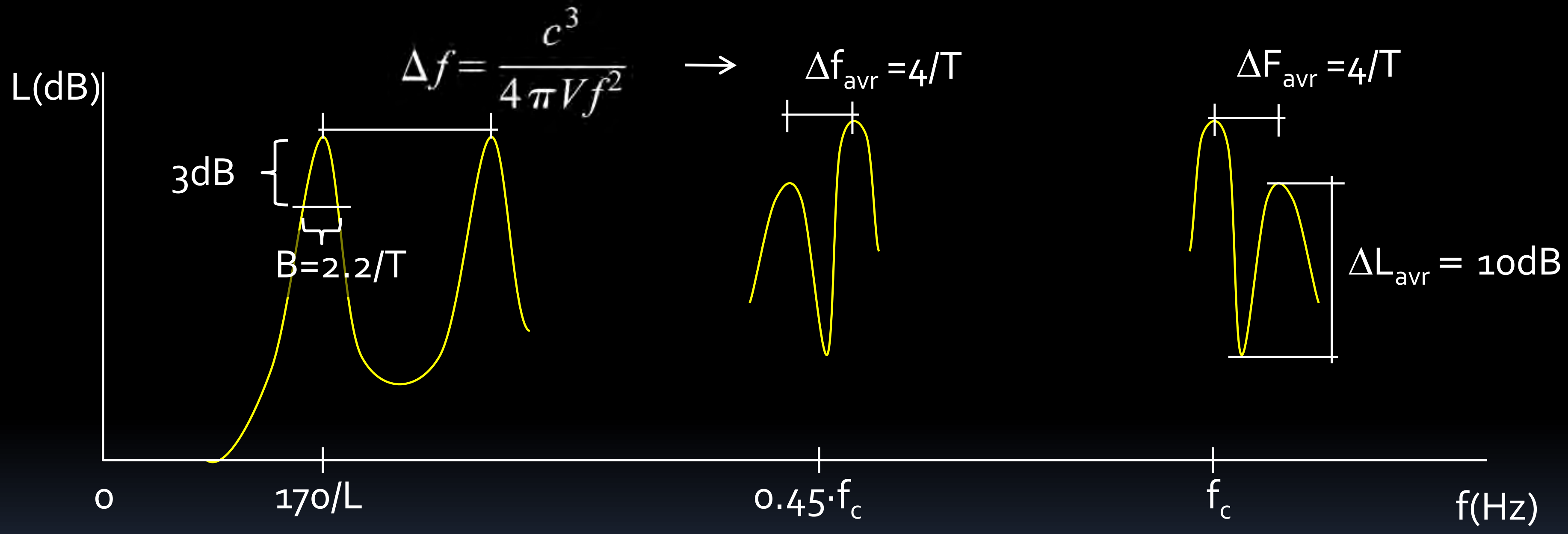
Introducing Schroeder Region

Frequency Response (Transfer Function)

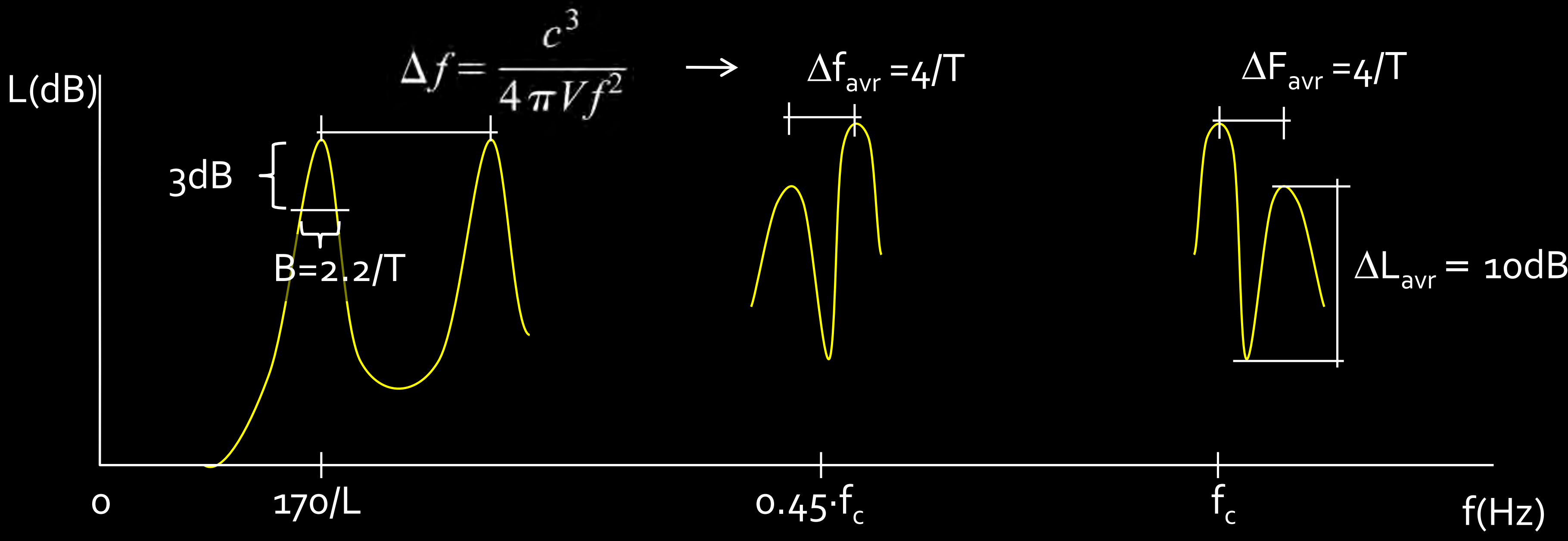


Possible cross-over region

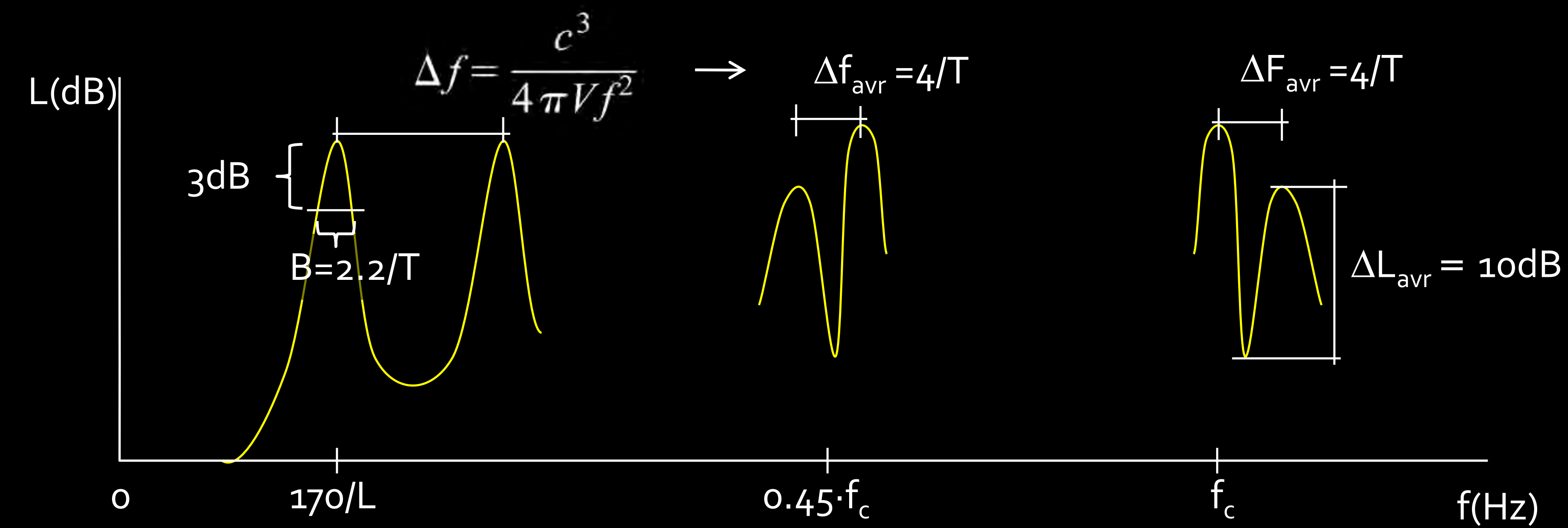
Frequency Response (Transfer Function)

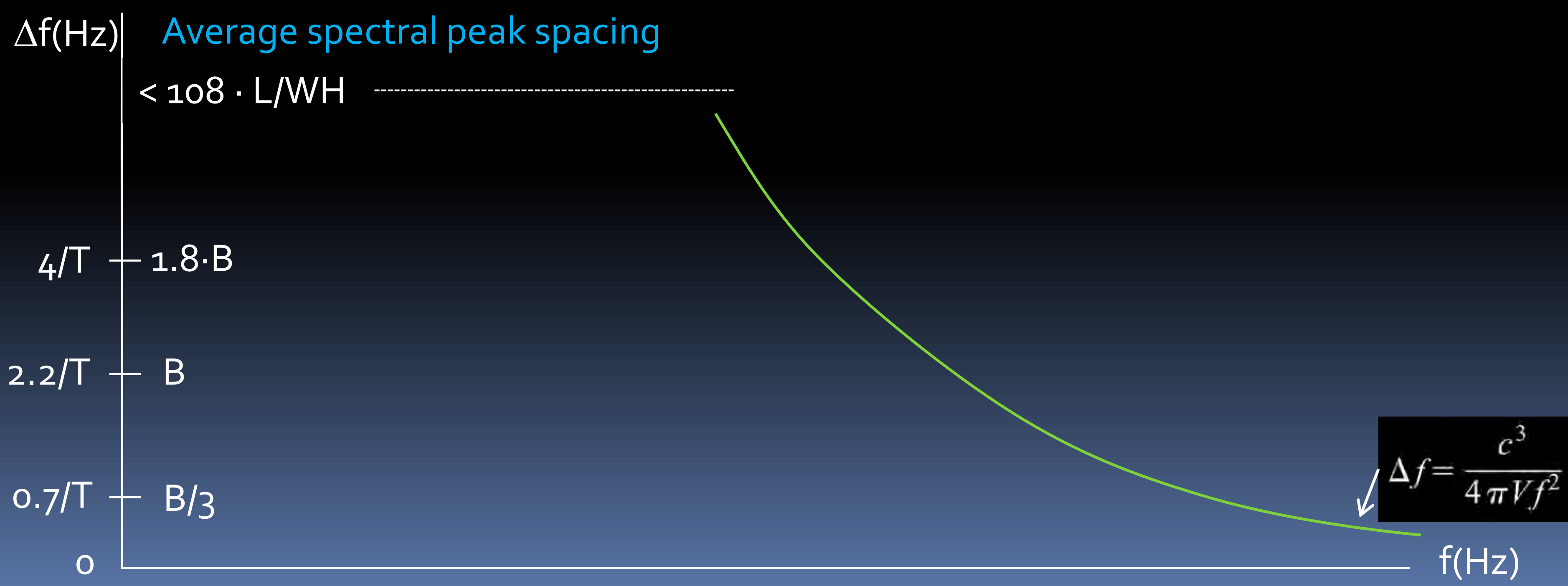


Frequency Response (Transfer Function)

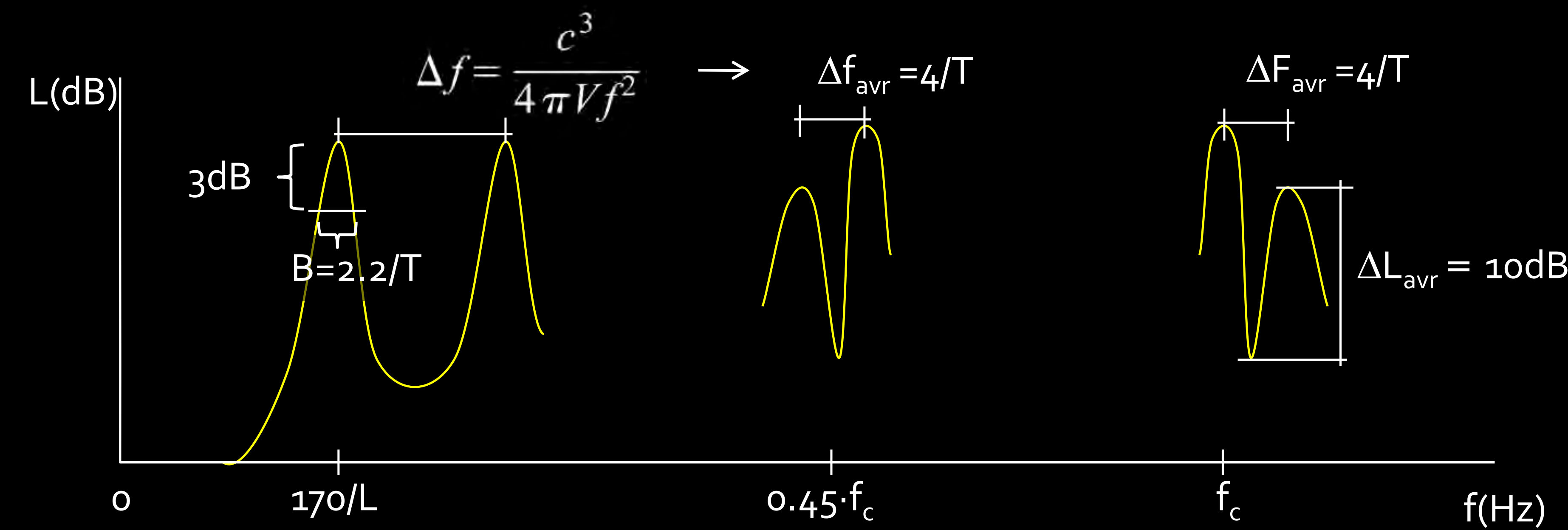


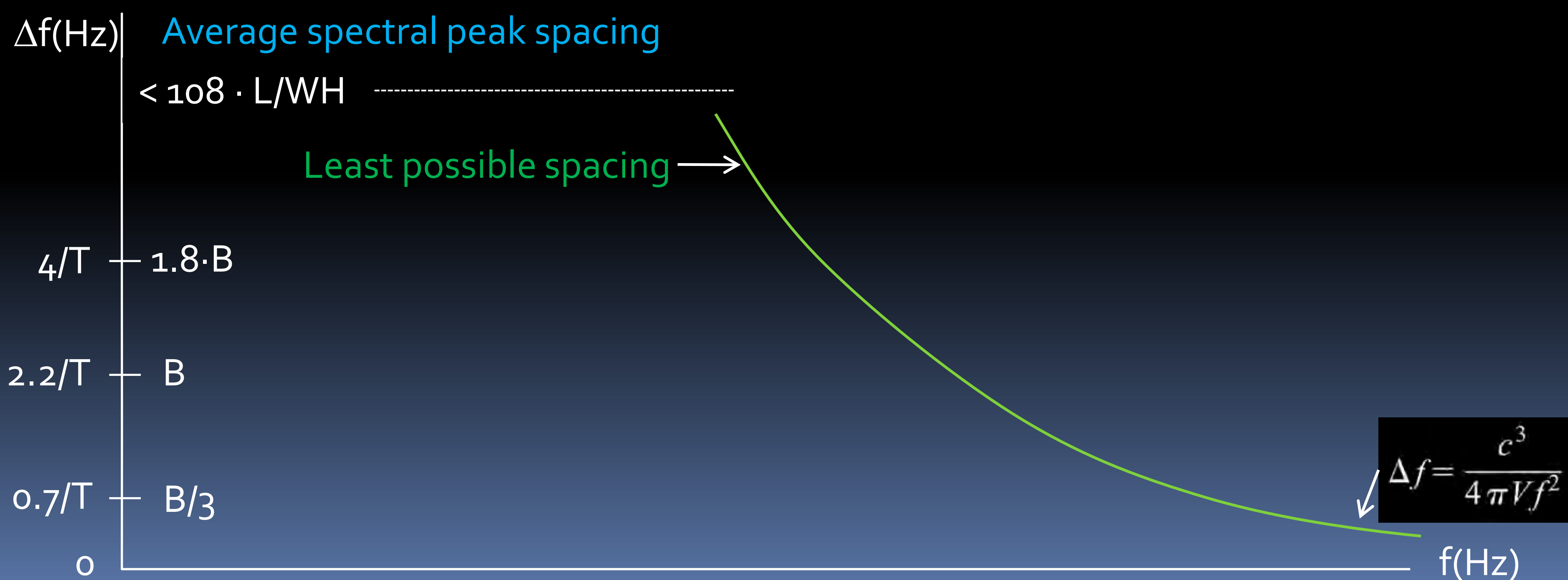
Frequency Response (Transfer Function)



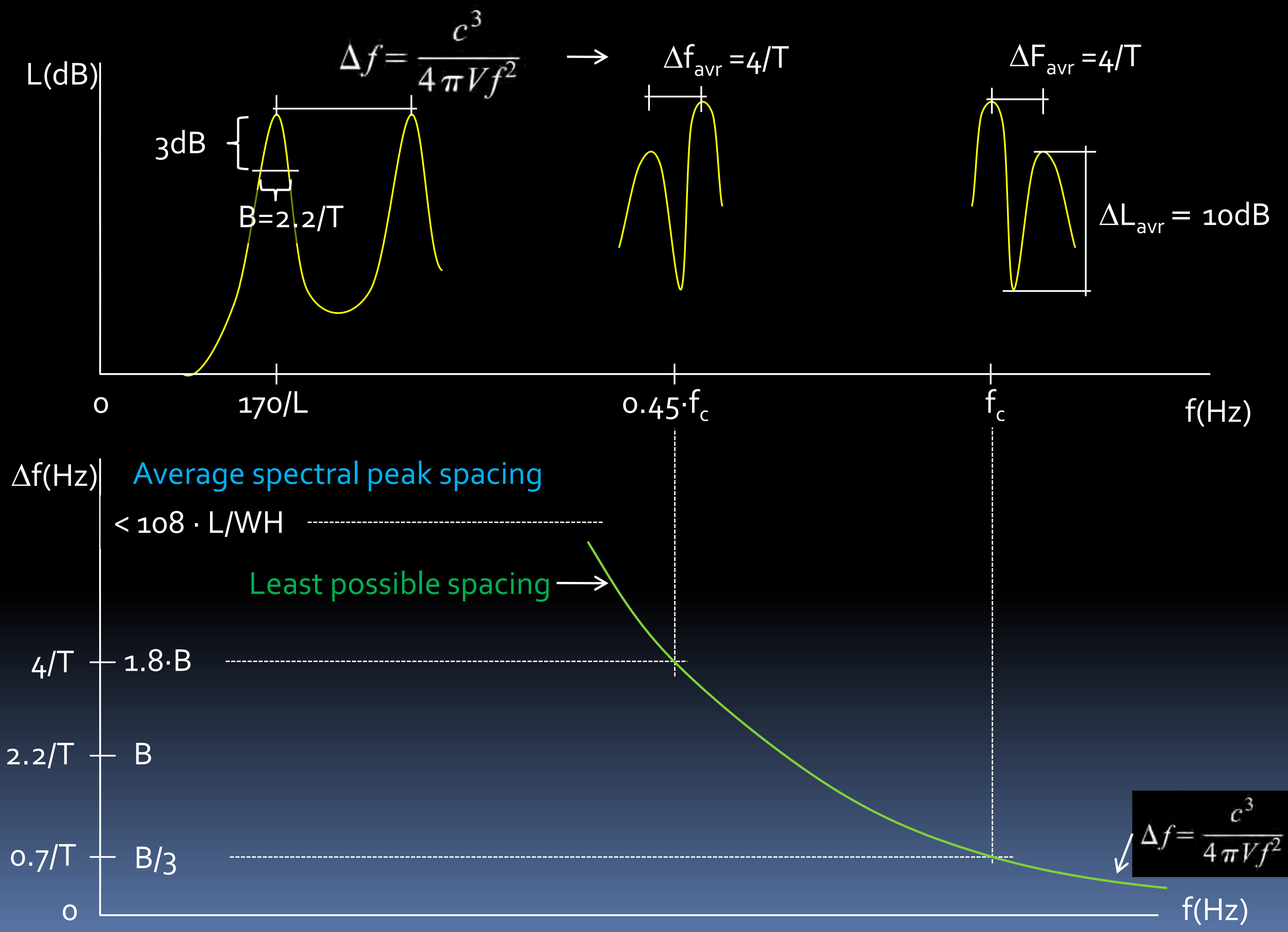


Frequency Response (Transfer Function)

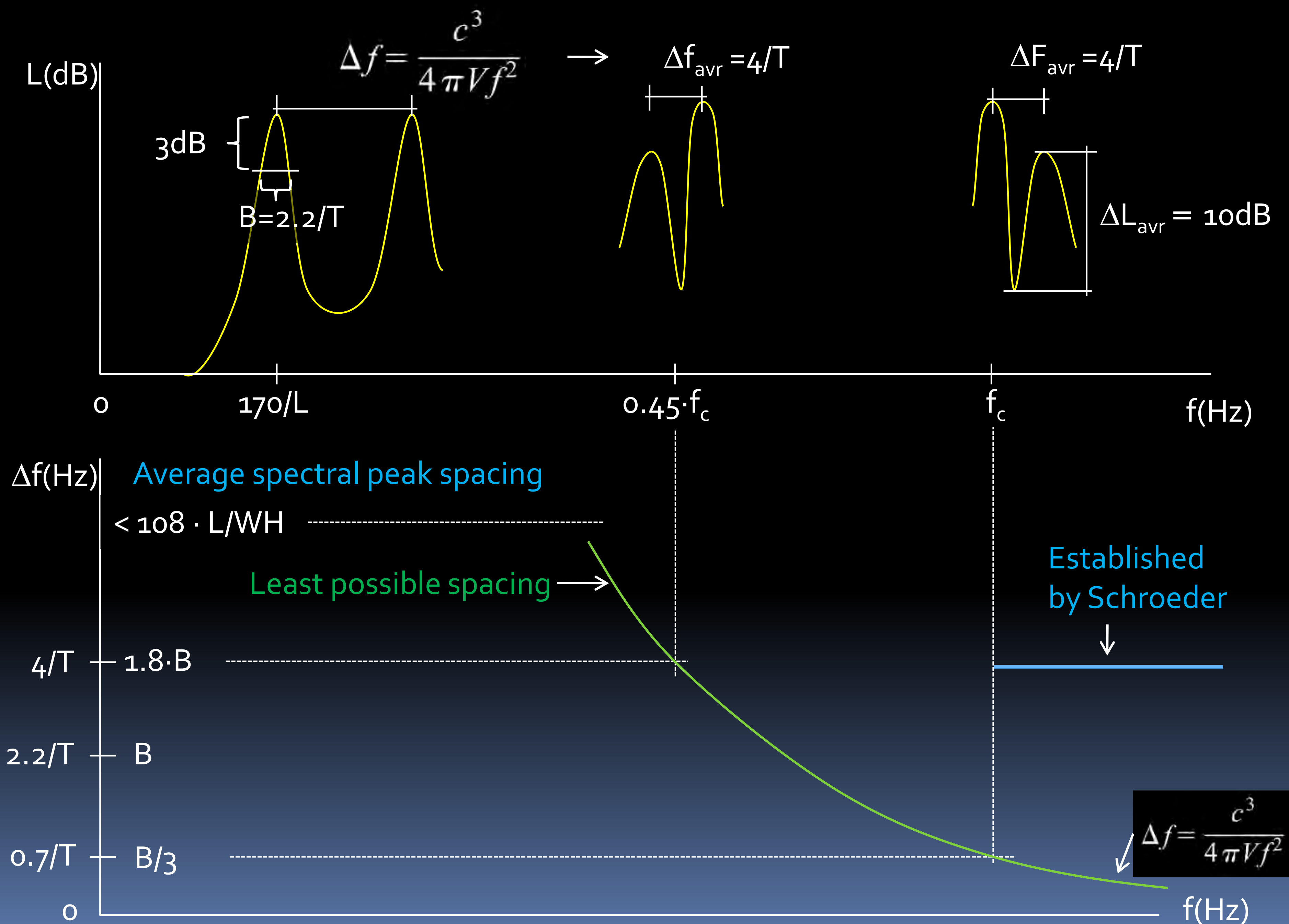




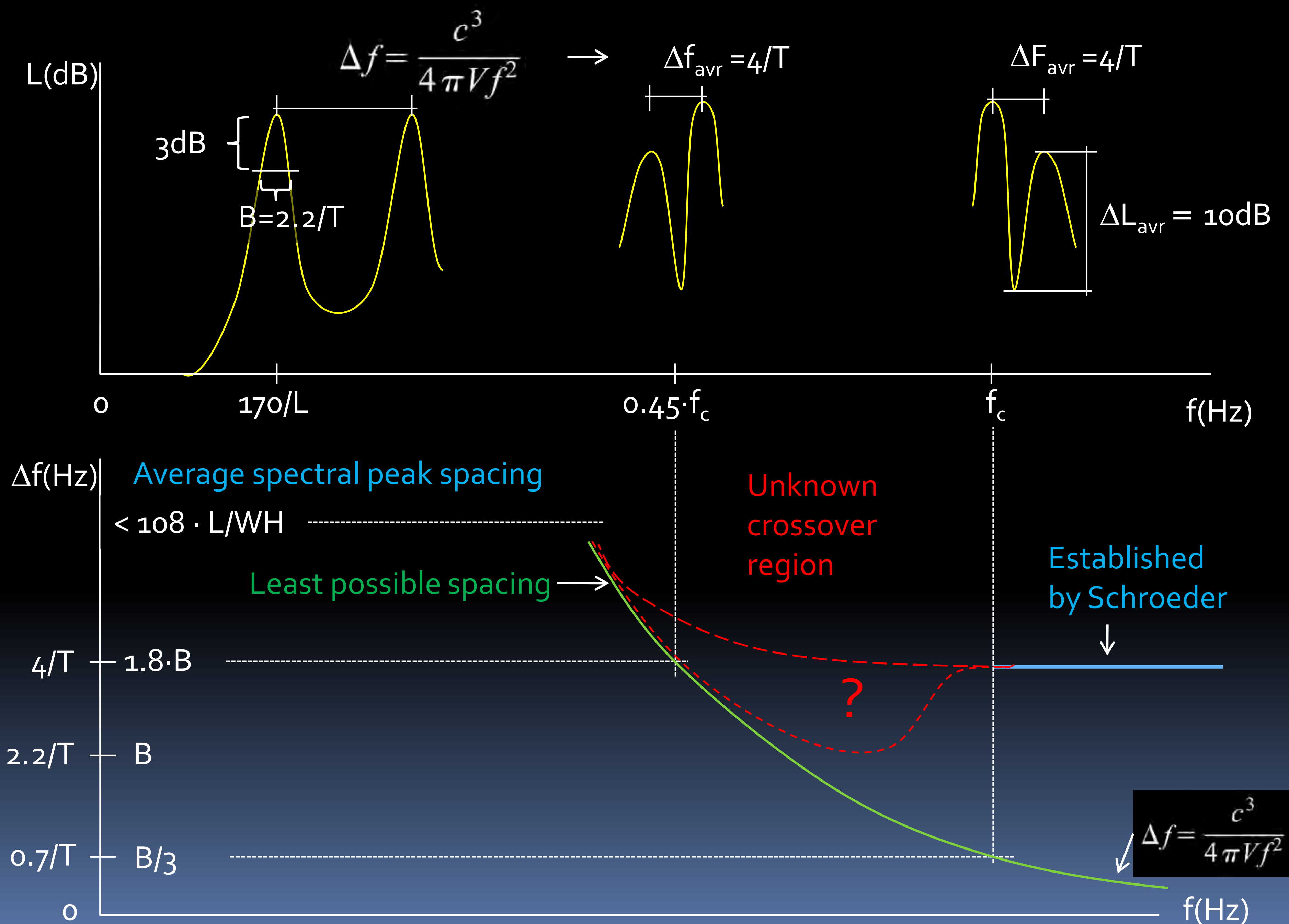
Frequency Response (Transfer Function)



Frequency Response (Transfer Function)



Frequency Response (Transfer Function)



What cross-over?

- Either the cross-over is a single frequency limit or a frequency region, we require:
- It should be measurable!
- In particular, since $0.45 \cdot f_c$ has an average peak spacing, 4/T, characteristic for the high frequency region, we require either:
  - Average level fluctuation around $0.45 \cdot f_c$ must differ from those of the high frequency region (This can be decided by further measurements)
  - Or, $0.45 \cdot f_c$ must be the lower limit of the Schroeder Region

Conclusions & Further Work

- A measurable cross-over between the Modal Region and the Schroeder Region remains to settle
- In further work, the transition between $0.45 \cdot f_c$ and f_c will be investigated
- Cases of prominent modes in the Schroeder Region should not be used as argument for further extension of the cross-over region
- Instead, one should question whether the conditions for f_c are fulfilled
- For example, an effective absorbing ceiling may create a 2-D horizontal field. The lower modal density would imply less modal overlap, thus high frequency properties can not be expected
- Complex harmonic modes (pitch) may be perceived above f_c

Annex: $f_{c,2D} = 12500 \cdot T/S$

- 2-D sound field (tangential,horizontal, x-y) in cuboid with floor area S=XY and a sound-absorbing ceiling; Number of modes derived from eigenmode-space, $N=\pi S(f/c)^2$, shall increase by 3 in a frequency interval equal to the modal bandwidth $B=\ln 10^2/(\pi T)$, which occurs at the limit frequency

  $f_c = 3c^2 \cdot T/(2S \cdot \ln 10^6) \quad \sim 12500 \cdot T/S$

  inserting Sabine's $T=\ln 10^6 \cdot 4V/(cA)$, where $V=S \cdot H$, H room heigth, and A the absorption area, the critical wavelength becomes

  $\lambda_c = A/(6H)$

Thank you

More about high frequency acoustics, follow these links:

http://akutek.info/articles_files/stochastics.htm

http://akutek.info/articles_files/stochastics_2.htm

www.akutek.info

The www center for search, research and open sources in acoustics

magne.skalevik@brekkestrand.no