Estimating Partial-Overtone Decay-Times in a Freely Vibrating String

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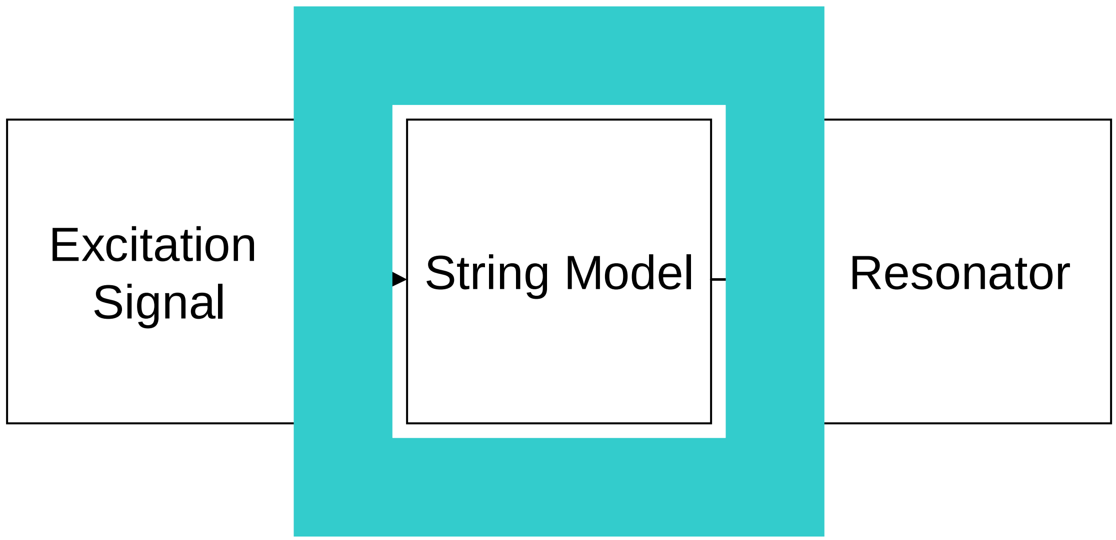
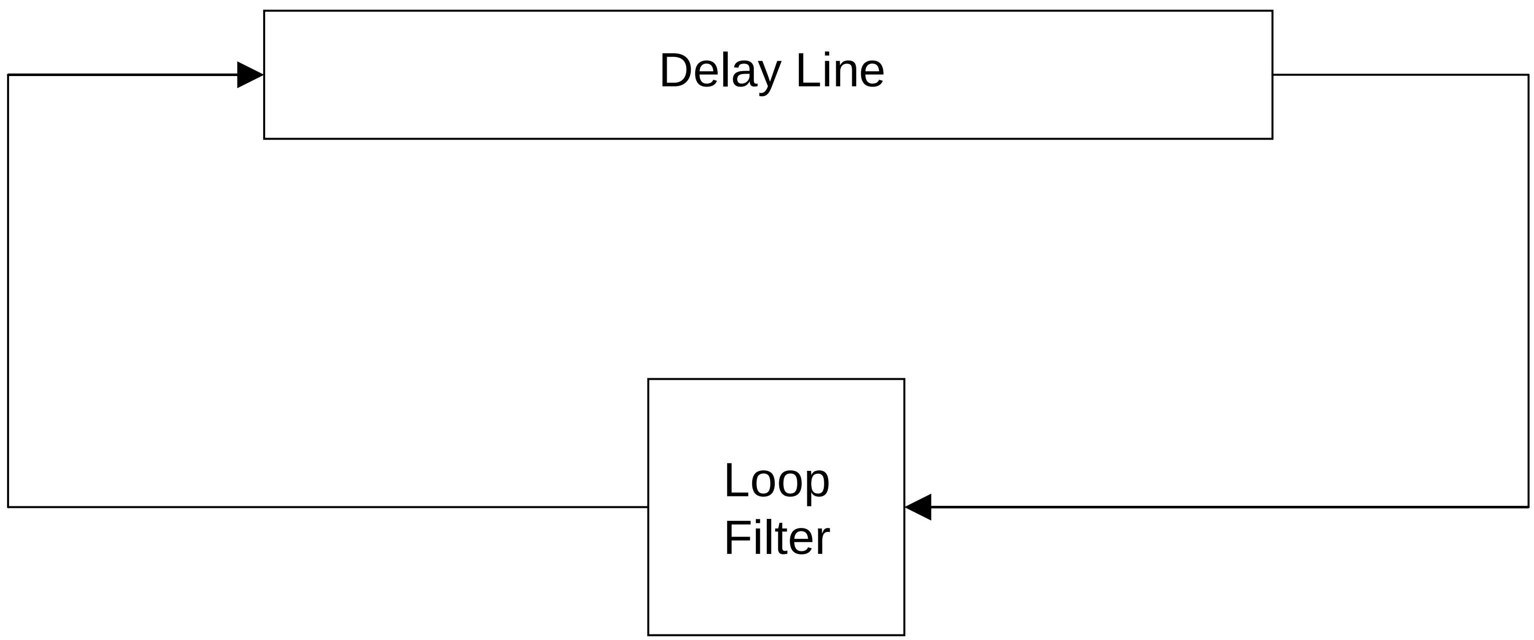
Problem Domain

- Developing high-fidelity guitar synthesizers
- Focus on classical guitars
- Using Waveguide Synthesis

Synthesis Model



String Model



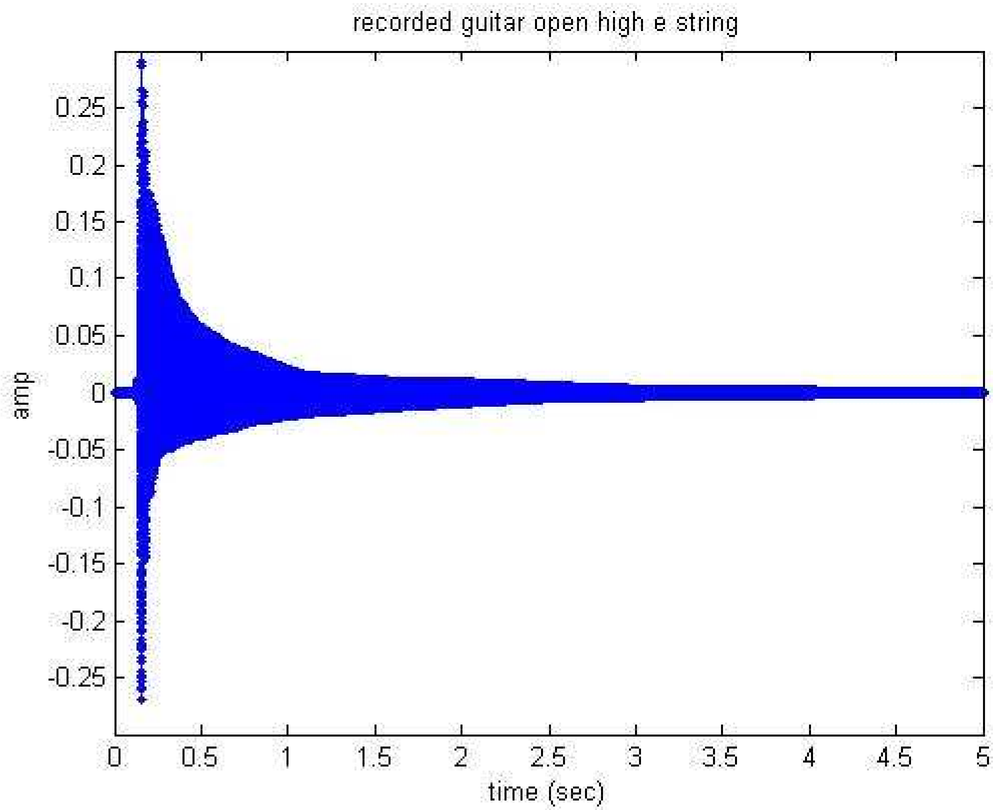
Previous Work

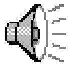
- Most used magnitude response
  - Data Noisy
- Energy Decay Relief
  - “Model-Based Analysis and Resynthesis of Acoustic Guitar Tones” by Tero Tolonen (Helsinki University of Technology)
  - EDR briefly mentioned
  - Comparison between using magnitudes and EDR not made

Energy Decay Relief

- Generalized Energy Decay Curve (Schroeder, 1965)
- Computes backward integration on STFT of time domain signal (Jot, 1992)
- Original use in reverberation

Recorded Signal

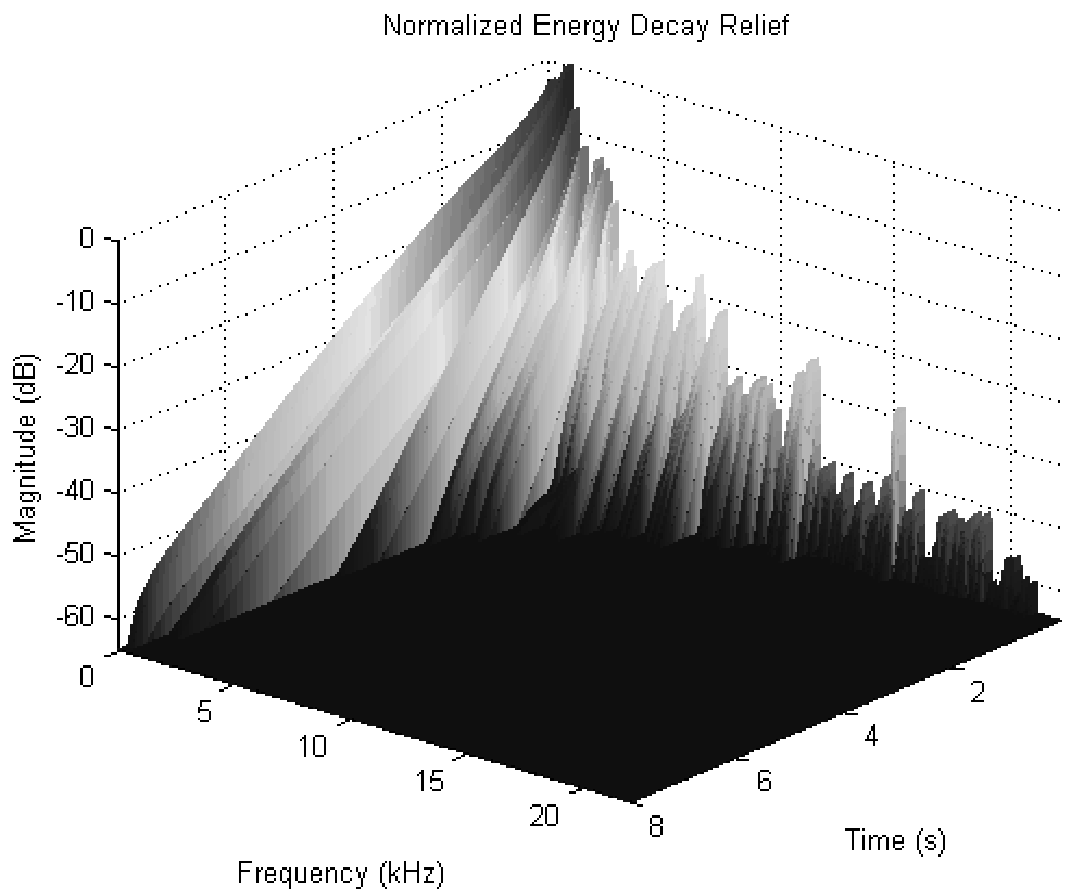




Original

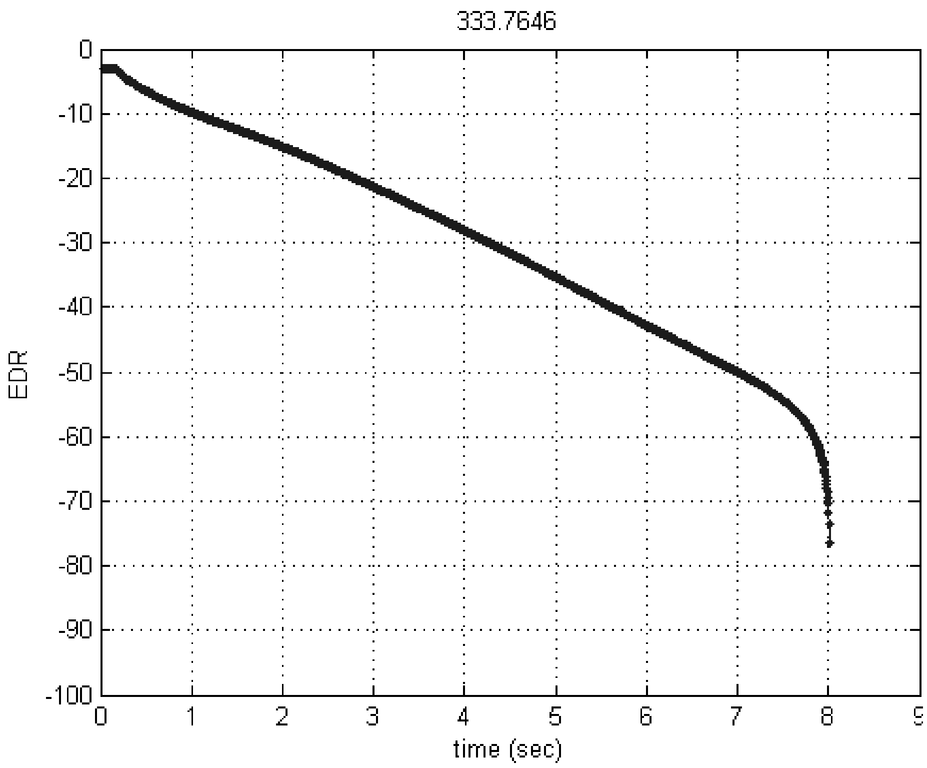
Energy Decay Relief

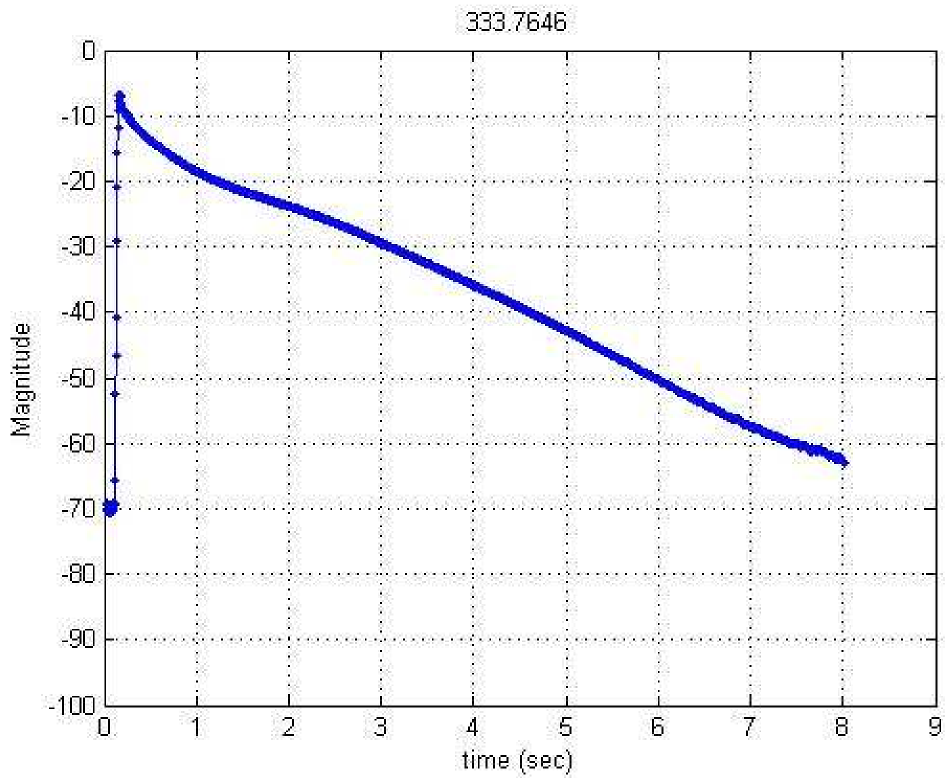
$$\mathrm{EDR}(t_n, f_k) \triangleq \sum_{m=n}^{M} \left|H(m,k)\right|^2$$



Energy Decay Relief

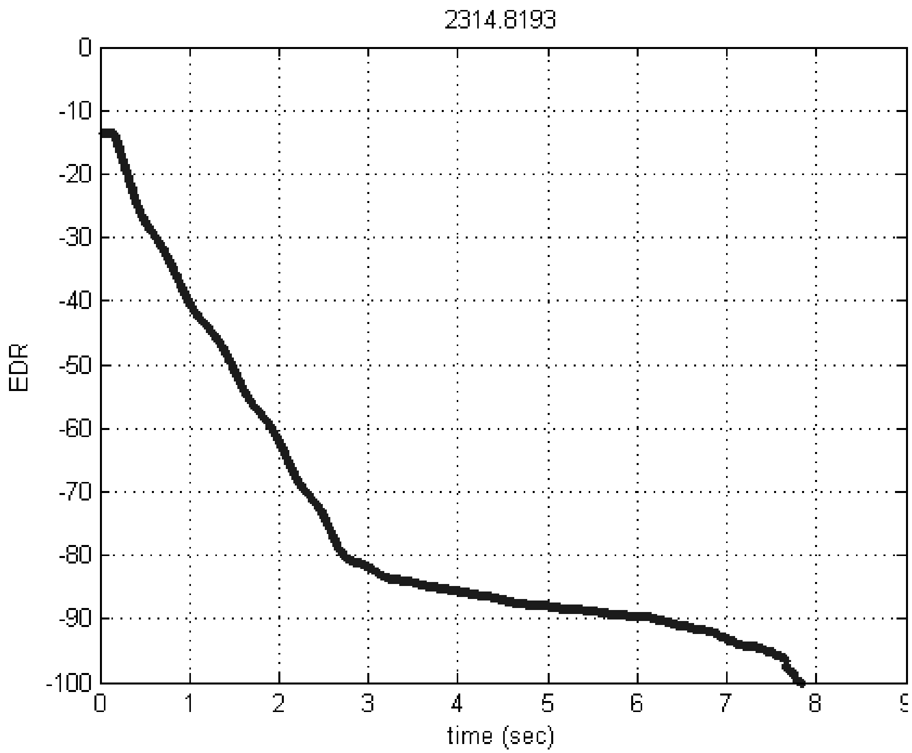
- Examining The Fundamental

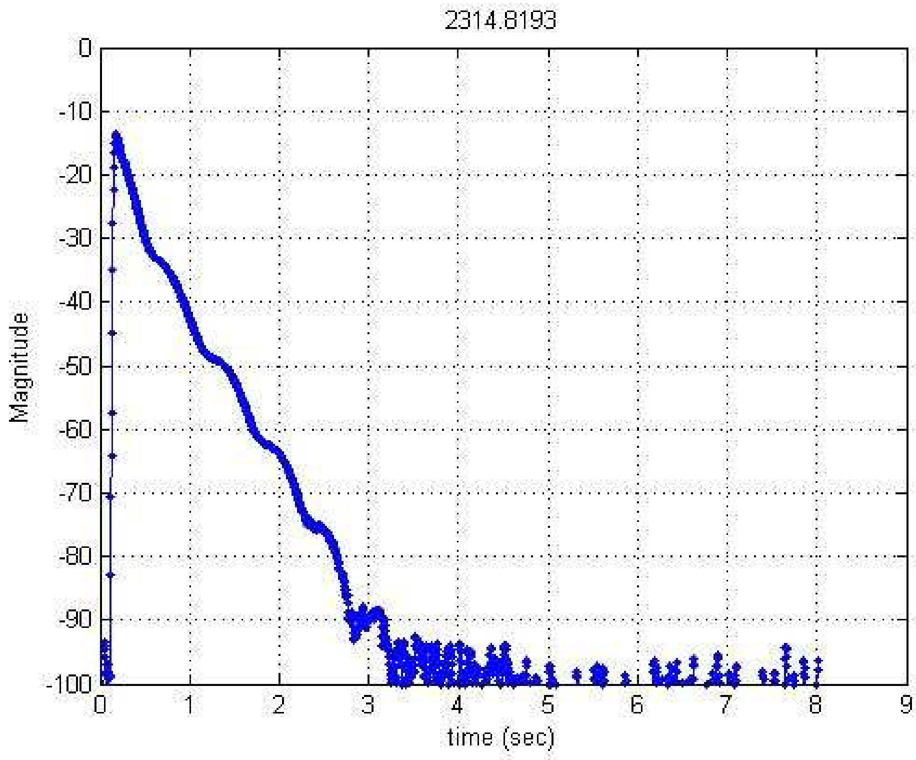




Energy Decay Relief

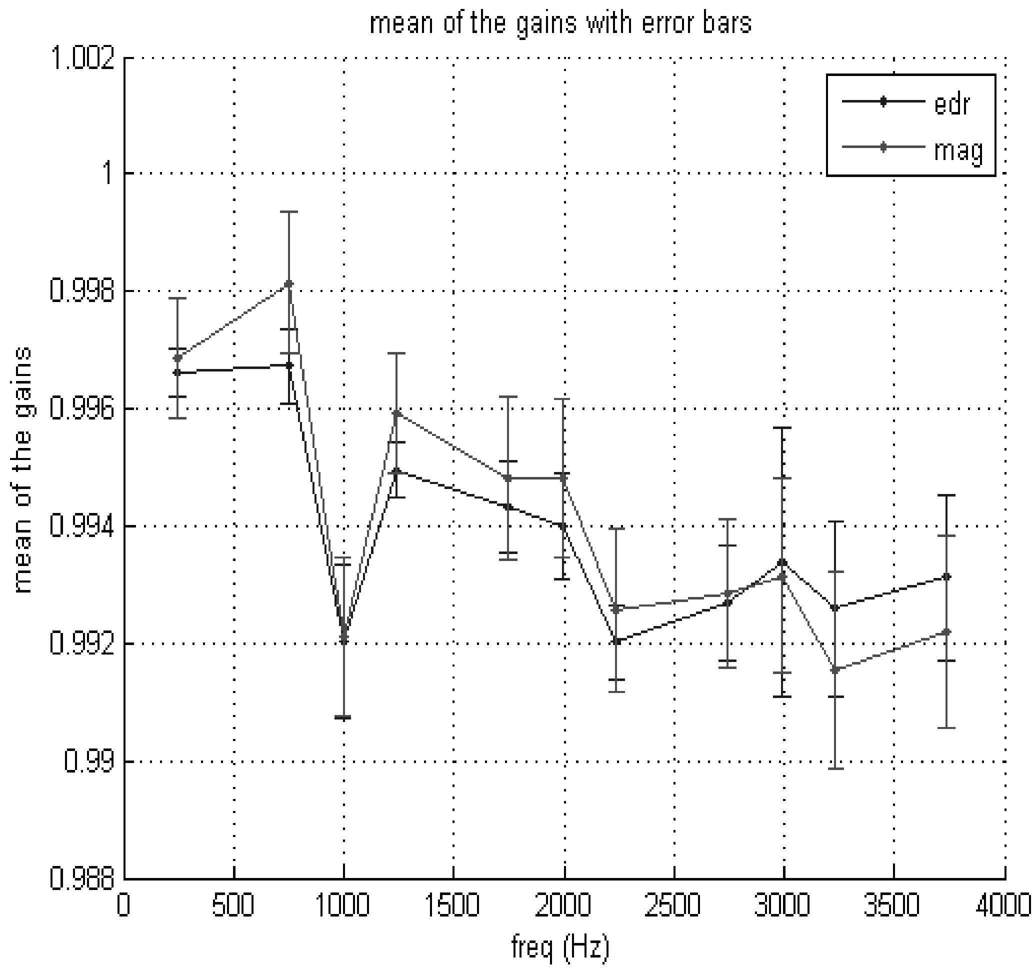
- Higher Harmonics





Energy Decay Relief

- Parameter Estimation using 14 different plucks of the same note
- Parameter mean and standard deviation for first 11 harmonics



Conclusions

- Energy Decay Relief less noisy than magnitude
- Resulting in better parameter estimation
- Energy Decay Relief matches slope of magnitude
- http://ccrma.stanford.edu/~jos/pasp/EDR_Based_Loop_Filter_Design.html

Synthesized Original

Math

$$c = \frac{20\log_{10} DR(n+1) - 20\log_{10} DR(n)}{\Delta t}$$

$$\Delta t = \frac{HOPSIZE}{f_s}$$

$$c\Delta t = 20\log_{10}\frac{DR(n+1)}{DR(n)}$$

$$10^{\frac{c\Delta t}{20}} = \frac{DR(n+1)}{DR(n)}$$

$$\gamma \equiv 10^{\frac{c\Delta t}{20}}$$

$$DR(n+1) = \gamma DR(n)$$

$$DR(n+1) = \gamma(|H(n)| + DR(n+1))$$

Math

$$|H(n)| = DR(n+1)(\frac{1}{\gamma} - 1)$$

$$|H(n-1)| = DR(n)(\frac{1}{\gamma} - 1)$$

$$|H(n-1)| = (|H(n)| + DR(n+1)|)(\frac{1}{\gamma} - 1)$$

$$|H(n-1)| = (|H(n)|)(\frac{1}{\gamma} - 1) + (DR(n+1)|)(\frac{1}{\gamma} - 1)$$

$$|H(n-1)| = (|H(n)|)(\frac{1}{\gamma} - 1) + (H(n))$$

$$|H(n-1)| = (|H(n)|)(\frac{1}{\gamma} - 1 + 1)$$

$$|H(n-1)| = (|H(n)|)(\frac{1}{\gamma})$$

$$|H(n)| = \gamma(|H(n-1)|)$$

$$g_{f_i} = 10^{-3M/(f_s * -60/c_i)}$$

$$M = f_s/fund$$

Minimum Phase Spectrum

- Excitation signal
  - Inverse filtering
  - Energy of excitation filter
    - Concentrated at time 0
  - Reduces complexity of excitation filter

Same Magnitude, Min. Phase

- http://ccrma.stanford.edu/~jos/filters/Creating_Minimum_Phase_Filters.html
- Well-developed methods with few caveats