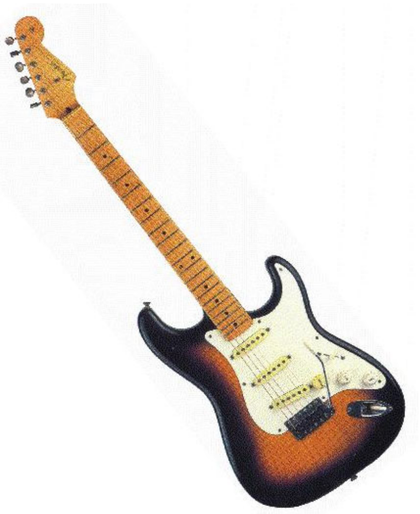
Acoustic Timbre Enhancement of Guitar Pickup Signals with Digital Filters



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CONTENT

How to make a guitar pickup signal sound natural ?

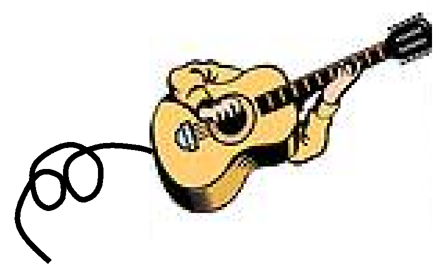
- WHY ??
- REASON
- SOLUTION
  - Methods
  - Measurement setups
- Changing the perceived size of a guitar body
- Discussion and future work
- Conclusions

WHAT'S THE PROBLEM ?

Quality reproduction of guitar pickup signals can be problematic in concert situations

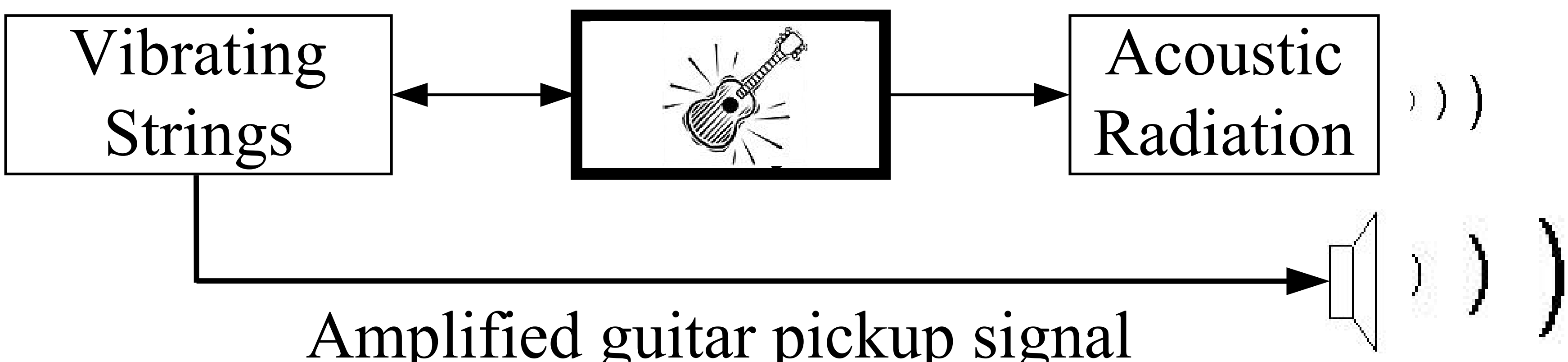
- External microphone
  - \+ ***Natural timbre***
  - – Acoustic feedback
  - – Crosstalk
  - – Cannot move freely

- Internal microphone
  - – ***Unnatural timbre***
  - \+ Less acoustic feedback
  - \+ NO crosstalk
  - \+ Free to move



REASON

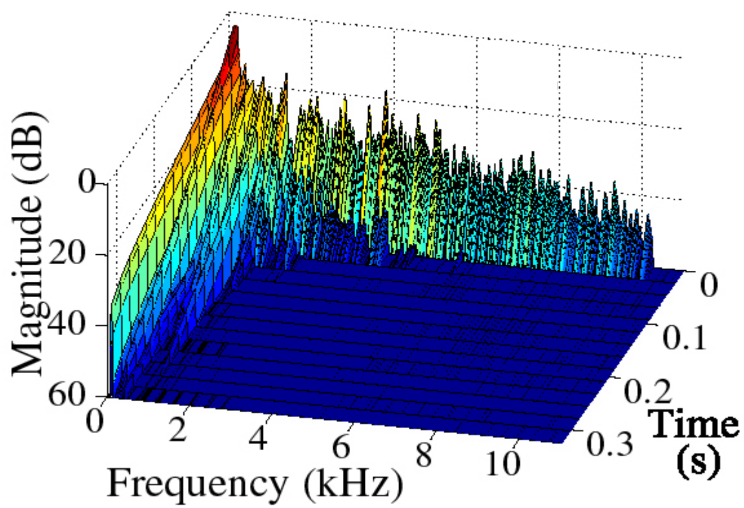
A guitar pickup does not notice the guitar body



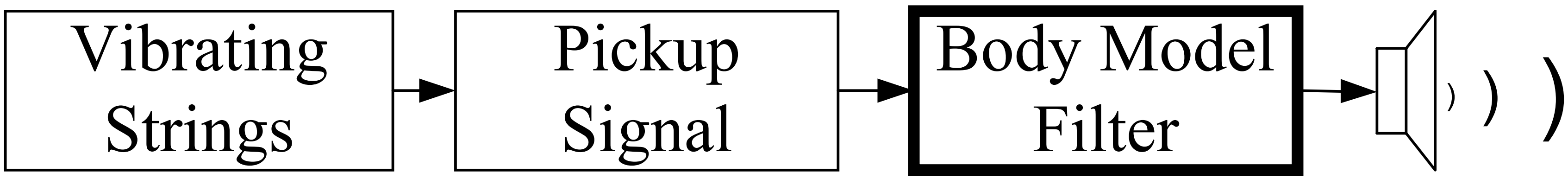
WHAT ARE WE MISSING ?

EFFECT OF GUITAR BODY:

- Amplifies and colors string vibrations
- Typically two strong body resonances (80-200Hz)
  - Size does matter ~ SIZE DEPENDENT
- At high frequencies more resonances



SOLUTION

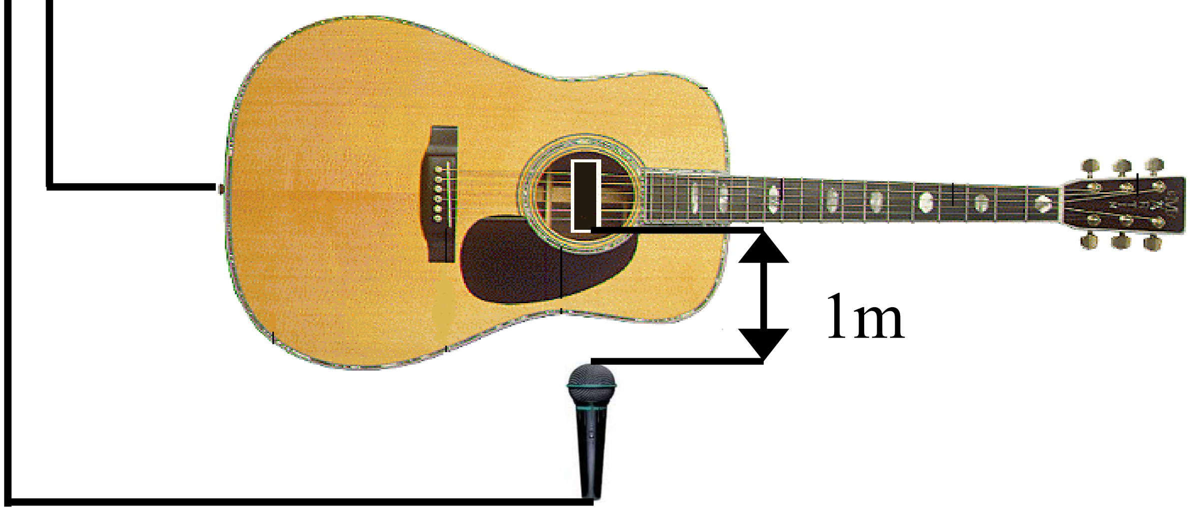


- A body model filter approximates the important characteristics:
  - Discrete resonances (low frequency)
  - Reverberation (high frequencies)
- Implemented with digital filters

MEASUREMENT SETUP

Two signals are recorded simultaneously

1. Microphone 1 m in front of soundhole
2. Bridge pickup



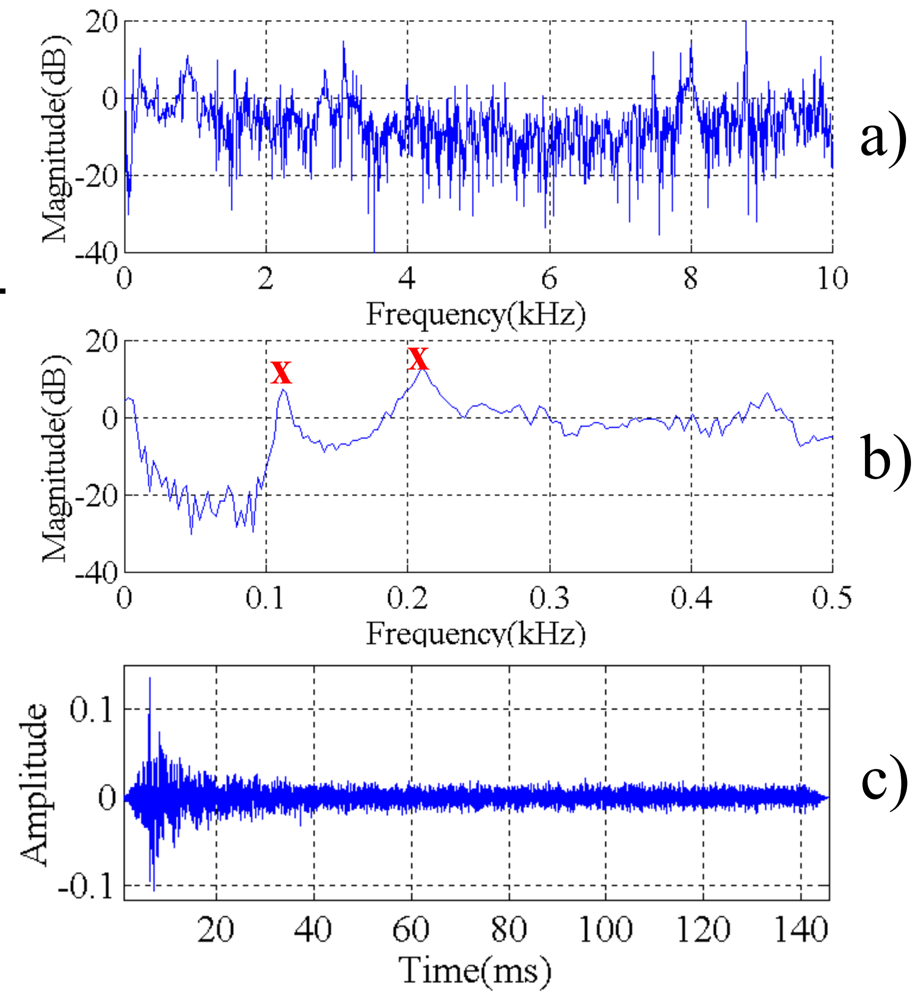
Calculate transfer function between two signals

RESPONSES PART I

Body model filter for steel stringed acoustic guitar

Steel stringed

Microphone
Guitar pickup
Filtered



SAME THING BUT WITH NYLON STRINGS

Body model filter for classical acoustic guitar

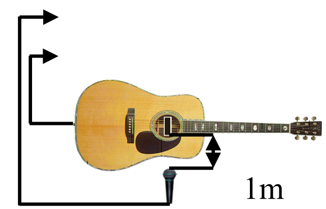
Classical guitar

Microphone
Guitar pickup
Filtered

TRANSFORM AN ELECTRIC GUITAR TO AN ACOUSTIC ONE

I) Same measurement setup as before

- DIFFERENCE: magnetic pickup
  (works only for steel strings)



OR

II) Modified Impulse Response (MIR)

- Boost high frequencies
  (both steel and nylon strings)

- Magnetic pickup behaves as a lowpass filter (*fc* = 2-5kHz)
  - Body models reverse this effect

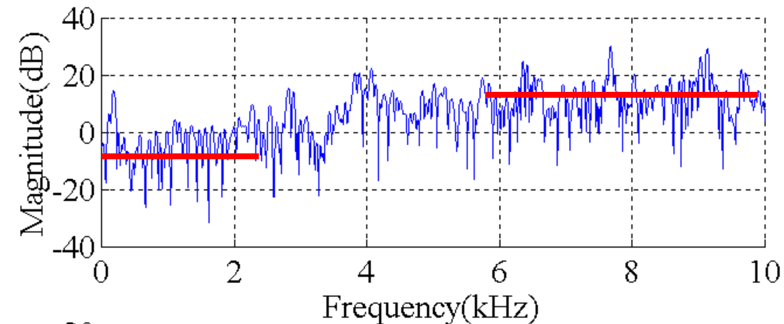
RESPONSES PART II

THE RETURN OF THE RESPONSES

Body model filter for electric guitar

Steel stringed acoustic
Electric guitar
Filtered (II, steel stringed)
Filtered (II, nylon stringed)
Filtered (I)

Distorted & clean
(no filtering)
Distorted & clean
(Stereo = I & II)



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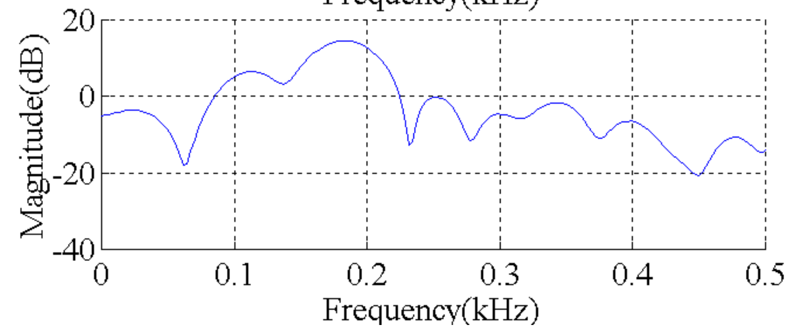

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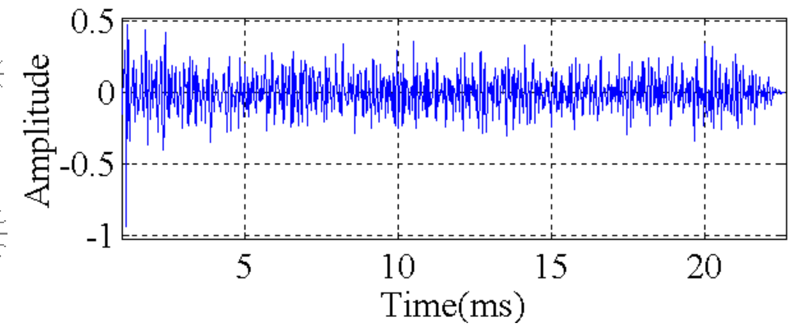

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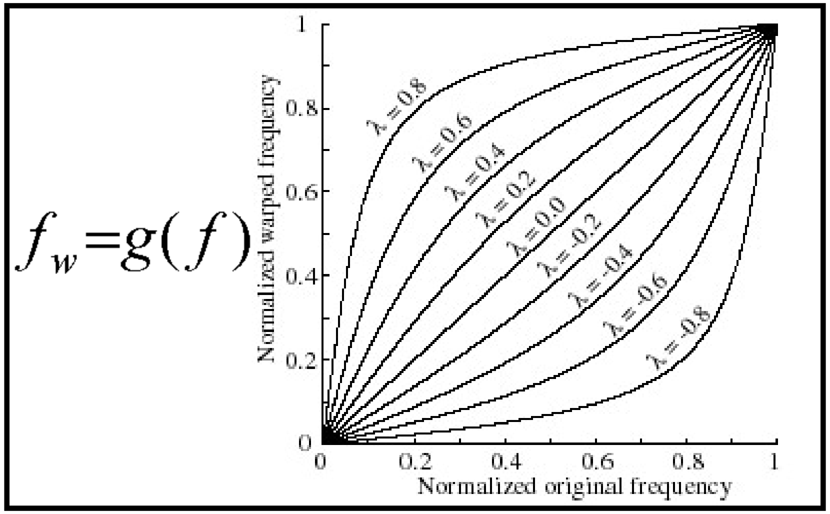
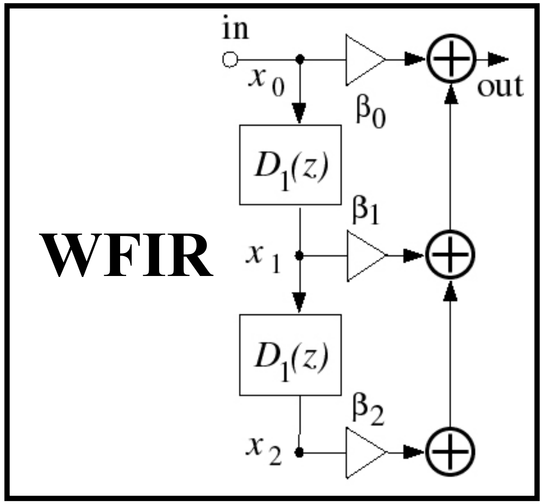
DIFFERENT FILTER STRUCTURES

- Finite Impulse Response (FIR) filters
  – Orders 300 to 5000 (typical 1000)
- Infinite Impulse Response (IIR) filters
  – Design methods: Linear prediction and Prony’s method (orders 300 to 1000)
- FIR is the best

DIFFERENT FILTER STRUCTURES II

- Frequency-warped filters (WFIR & WIIR orders 100-200)
  - Unit delays replaced with allpass sections
  - Frequency resolution can be altered
  - Improves performance of IIR filters
  - Further improved by cascading two warped filters





DIFFERENT FILTER STRUCTURES III

- Reverb algorithms can also be used
  - Short delay lines produce a colored response
  - Computationally very efficient
  - Accurate control not possible

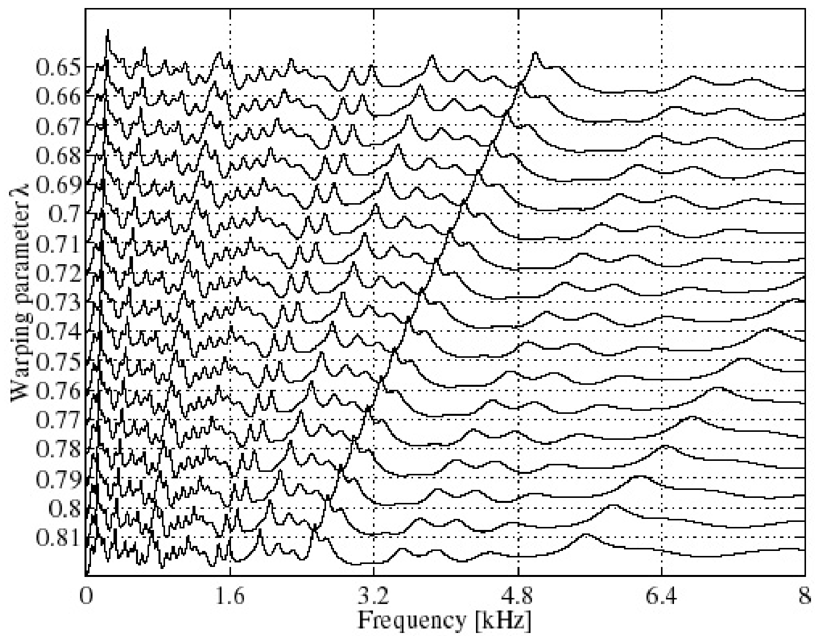
  Original Reverb I Reverb II

- Model separately the two low frequency modes
  - Improve control and efficiency

CHANGING THE PERCEIVED SIZE

- Low frequency resonances size-dependent
- Alter frequency resolution with frequency-warped filters (WIIR)

- Resonance frequencies are changed with ONE parameter
- Listening tests confirm
- Possible but not straightforward



CHANGING THE PERCEIVED SIZE II

- Musically two concepts

I) Stepwise: change after a measure of a riff

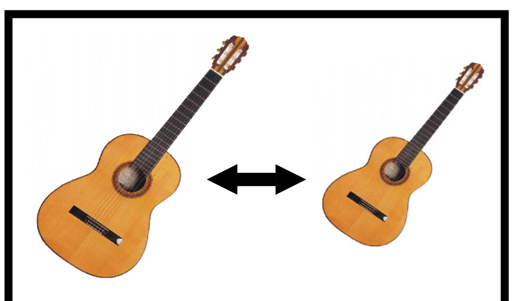
Original $\rightarrow$ Smaller

Original $\rightarrow$ Larger

II) Continuos: resembles the phaser-effect

Electric guitar with a truly

flexible and time-variant body



DISCUSSION &FUTURE WORK

- Anechoic vs. reverberant conditions
- Directional hearing
- Measurement setups and microphones
- Acoustic feedback during live performance
- Model for string finger/nail/plectrum interaction
- Only for guitars ?

CONCLUSIONS

- The response of a guitar body can be modeled and applied for pickup signals
  – Improve the response of an acoustic guitar & make the electric guitar sound more like an acoustic guitar
- Improve the sound quality in live performance situations
  – No need to switch between guitars (electric guitar)
- The perceived size of a body can be altered
- Sound effects that run in real-time