Bass Guitar Investigation

Physics 498, Physics of Music

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1. Introduction

This report is an investigation into what causes the audible characteristics of the bass guitar. The attributes investigated were the location of the pickups, the frequency response of the strings, the frequency response based on playing position and the modal resonances of the body of the bass guitar.

2. Experimental Setup and Procedure

2.1 Pickup Location

Equipment:

- Ruler
- Bass Guitar

The distance along the guitar of the neck pickup and bridge pickup were measured.

2.2 Frequency Response of Strings

Equipment:

- 24-bit sound recorder
- Matlab wave analysis program
- Bass Guitar

The 24-bit sound recorder was used to record the four open strings, EADG, as well as E5(5th fret), E12, A5, A12, D5, D12, and G12. Once the sounds were recorded, they were transferred to the computer for analysis using a wave analysis program in Matlab.

2.3 Frequency Response based on playing position

Equipment:

- Tektronix Oscilloscope
- Unity Gain Guitar Amplifier
- Labview
- Bass Guitar

The bass guitar was connected to the unity gain guitar amplifier, which was connected to the oscilloscope. After playing a note on the guitar, the frequency response

was recorded on the oscilloscope and then transferred to the computer for storage and processing. This investigation measured the response of different playing positions for the Low-E string. The playing positions chosen were close to the neck, at the neck pickup, in between the pickups, at the bridge pickup, and close to the bridge.

2.4 Modal Resonances

Equipment:

- Model SR830 DSP Lock-In Amplifier (x2)
- 20 MHz Function/ Arbitrary Waveform Generator
- Piezoelectric Transducer (x2)
- Small weights
- Large Rubber Band (x2)
- Foam Block
- Bass guitar

The waveform generator was used to create signals from 10 Hz to 1,000 Hz that were sent to the first piezoelectric driver creating a mechanical vibration at the bridge of the bass guitar. The piezoelectric was resting on the bass guitar with the help of a small weighted disk. A second piezoelectric was located at one of five different positions to pick up the modal resonances of the body of the guitar. The guitar meanwhile was suspended from two 2x4s that are clamped to a laboratory table using c-clamps with rubber in between the table and the 2x4s to dampen the vibrations from the lab table. To suspend the guitar a wire was used at the bottom of the guitar where the neck strap is normally attached and the rubber bands were wrapped around the neck of the guitar. A block of foam was placed in between the neck and the strings of the instrument to mute the strings. The signal picked up by the second piezoelectric was sent to the two lock-in amps, which were also connected to the waveform generator to measure the frequency, the real and imaginary portions of the signals and the corresponding phase relation.

Figure 1: Bass Guitar Modal Vibration Experiment Setup.

3. Results and Discussion

3.1.1 Pickup Locations on Yamaha RBX-170

The distance along the guitar of the neck pickup and bridge pickup were measured. The scale length of the guitar is 34". The neck pickup was found to be 28" and 29" in for the first and second pickup respectively. The bridge pickup was at 31.75". The neck pickup was roughly at a third harmonic anti-node, while the bridge pickup was roughly at an anti-node of the eighth harmonic. The Yamaha RBX-170 is closest to a '96 Fender Am Deluxe P-Bass of the bass guitars measured [Figure 2]. The two basses have their pickups at the same anti-nodes.

3.2.1 Frequency response of strings on Yamaha RBX-170

The first examination into the frequency response of the strings involved recording the notes of the four open strings,the note of the open strings fretted on a lower string and the 12th fret on each of the strings. The sounds were recorded using a 24-bit sound recorder

then transferred to the computer for analysis. A problem with the Low-E recording caused the Matlab analysis program to fail due to a lack of bits caused by an unexpectedly low response from the fundamental harmonic.

To investigate why the fundamental harmonic was magnitudes lower than expected, the 24-bit sound recorder was analyzed using white noise to measure its frequency response. The sound recorder was found to behave as expected and successfully recorded the full range of the white noise produced without any abnormalities in the signal. To investigate further why the fundamental harmonic on the Low-E string was magnitudes lower than expected, a possible human error was assumed in the playing position of the musician on the bass. To investigate the playing position, a simpler frequency response analysis was performed and is discussed in Section 3.3 of the Results and Discussion Section.

To boost the fundamental harmonic in the Low-E string, the bass was recorded a second time with the Low-E string being plucked closer to the center of the string to excite the first partial. However, when this sound recording was analyzed in the wave analysis program there was still a failure due to insufficient amount of bits in the fundamental. Although the Low-E string could not be analyzed, useful data was recovered for the other strings on the bass guitar.

In line with the investigation into the Low-E string the reason it couldn't be analyzed, it was observed that the fundamentals of the open strings on the Yamaha bass were magnitudes smaller in amplitude compared to the same note fretted on a lower string. A possible explanation for this is the location of the pickups, which are not in the center of the string and thus would pickup the fundamental on a shorter note better than on the open string.

The majority of the energy in the recordings is in the first four partials. By the fifth partial, all of the recorded notes have greatly diminished amplitude and it can be extrapolated that the higher harmonics are relatively insignificant. One exception to this is G12 in which the fifth partial is a dB higher than the third harmonic and 3 dB higher than the fourth. There are no modal resonances in the body at the fifth partial of G12, which is at 980 Hz. Perhaps something to do with the string thickness, how they vibrate, or the impedance of the pickups could account for this phenomenon.

An interesting occurrence can be seen in the sound recording of A0 [Figure 3]. The third partial is varying considerably in magnitude, yet the vibrational energy doesn't seem

to be going into any of the other first four harmonics. Looking at the phases of A0 [Figure 4], there isn't a harmonic that is oscillating out of phase with A0.

Observing the phase relations of the different recordings, the most noticeable observation is that the 5th partial of the 12th fretted notes tends to vary wildly in phase while the other harmonics are relatively stationary [Figure 5]. The 5th partial of the 12th fretted notes also vary wildly in amplitude and in frequency after several seconds after playing the note [Figure 6]. One hypothesis for what is physically occurring with the 5th partial is that while it rapidly decays it is still being sustained by the lower harmonics, and in particular the 4th partial which varies in amplitude while the 5th is oscillating. The effect is not seen to the same degree in the open and 5th fretted notes. Another phenomenon of phase can be observed in G0 where the fundamental was constantly changing in phase with respect to the other harmonics [Figure 7]. G0 is the only note in which this was observed for the Yamaha.

3.3 Frequency Response based on playing position

An investigation into the frequency response based on playing positions was performed on the Low-E string. The playing positions chosen were close to the neck, at the neck pickup, in between the pickups, at the bridge pickup, and close to the bridge. Playing close to the neck gave larger amplitude (RMS volts)^2 in the fundamental and second partial and a diminished response in the higher harmonics than playing at the bridge. This is intuitive based on the more mellow sound produced when playing closer to the neck and the concept behind axial mode resonances. Playing over the neck pickup produced a signal that had a larger second harmonic peak, a fundamental that was several magnitudes lower than the second harmonic and overall a steeper decline in the amplitude for higher harmonics. The bridge pickup showed a peak in the third and fourth harmonics that were several magnitudes higher than the fundamental harmonic.

3.4 Modal Resonances

This investigation measured the mechanical resonance of the three basses.

'76 P-Bass

Resonance at all points on the bass at 145Hz and 355Hz.

Large Neck resonance at 108Hz.

2003 Music Man Sterling Bass

Resonance at all points on the bass at 56Hz, 160Hz, and 325Hz.

Yamaha RBX-170 Bass

Resonance at all points at 145Hz and 371Hz.

4. Conclusion

There are other variables between bass that are not accounted for, like the strings. One of the ways that we showed that this is an important factor to consider was performing the same wave analysis on a bass with two different sets of strings. One set of strings was made out of an unknown material while the others were steel hybrid slinkys. It is very clear from the plots of D0 and D5/D4 on the music man that the unknown strings are much brighter. Also, the fundamental is held out longer while the other partials decay compared to the hybrid slinkys.

Pick-up placement is very important to the sounds produced. For instance the forth harmonic on any string fretted at the 12th is very low compared to the fundamental. One the reasons for this is, is that the pick-ups are very close to the middle of two different antinodes that are 180degrees out of phase. Because the pick-ups are set in series the two voltages induced cancel each other out.

No good correlation could be made between harmonic amplitude and modal resonance. There were no characteristics among the data that could suggest a modal resonance either amplified or attenuated a certain partial.

There was also plentiful phase relationship data between partials as well as between piezoelectric driver and piezoelectric pick-up. Because no conclusions could be made about the magnitudes no phase data was included.

Appendix

Bass Guitar PU Locations

Last Updated: 103:00hr April 4, 2009 {SME}

	Nominal Scale Length	Neck PU1 Location	Neck PU2 Location	Neck PU <Location>	Bridge PU1 Location	Bridge PU2 Location	Bridge PU <Location>
'76 Fender Precision Bass - VW	34.0000	28.0000	29.1250	28.5625			
'04 Fender Precision Bass - Blnd	34.0000	28.0000	29.1250	28.5625			
'82 Fender Bullet P-Bass Deluxe	34.0000	28.7500	29.8125	29.2813			
Fender CS Vintage '56 P-Bass	34.0000	28.0000	29.1250	28.5625			31.3750
USA Fender J/P-90 Bass	34.0000	28.0000	29.1250	28.5625			31.1875
'96 Fender Am. Deluxe P-Bass	34.0000	28.0625	29.1875	28.6250	31.5000	32.1875	31.8438
'64 RI Fender CS Jazz Bass	34.0000			27.8125			31.3750
MIM Fender Jazz Bass	34.0000			27.8125			31.3750
MIM Fender Jazz Bass V	34.0000			27.7500			31.3125
Yamaha RBX-170 P/J-Bass	34.0000	28.0000	29.0000	28.5000			31.7500
'99 Ibanex SD GR P/J Bass	34.0000	28.5000	29.5000	29.0000			32.1875
LPB USA Lakland Decade Bass	34.0000			25.5000			31.2500
'78 Gibson RD Std. Bass	34.0000			26.7500			31.3750
'64 Gibson EB-3 Varitone Bass	30.0000			22.2500			28.5000
'66 Gibson EB-0 Bass	30.0000			22.2500			
'69 Gibson EB-1 Bass	30.3125			22.3125			
'68 Gibson Kalamazoo Bass	30.0000			22.3125			

Calculates the Locations of Electric Guitar Pickups

Place PU's at anti-nodes of certain harmonics, and/or nodes of other ones...

L_scale = 34.0000 inches

Harmonic #	Node	Anti-Node		Bridge-Side Node	Bridge-Side Anti-Node	
1	x	L/2		x	17.0000	
2	L/2	L/4		17.0000	25.5000	<= Fart-in-the-bathtub tone!
3	L/3	L/6		22.6667	28.3333	
4	L/4	L/8		25.5000	29.7500	
4	2L/4=L/2	3L/8		17.0000	21.2500	
5	L/5	L/10		27.2000	30.6000	
5	2L/5	3L/10		20.4000	23.8000	
6	L/6	L/12		28.3333	31.1667	
6	2L/6=L/3	3L/12=L/4		22.6667	25.5000	
7	L/7	L/14		29.1429	31.5714	
7	2L/7	3L/14		24.2857	26.7143	
8	L/8	L/16		29.7500	31.8750	
8	2L/8=L/4	3L/16		25.5000	27.6250	
8	3L/8	5L/16		21.2500	23.3750	

Get nodes @ L/n, 2L/n, 3L/n, ...

Get antinodes @ L/2n, 3L/2n, 5L/2n, ...

Figure 2: Bass guitar Pickup Locations.

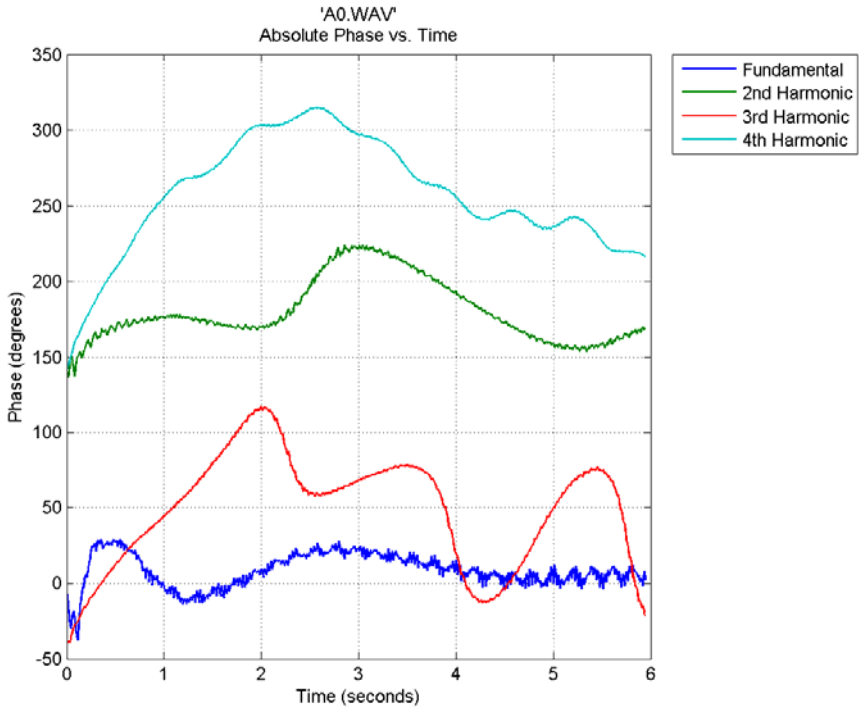
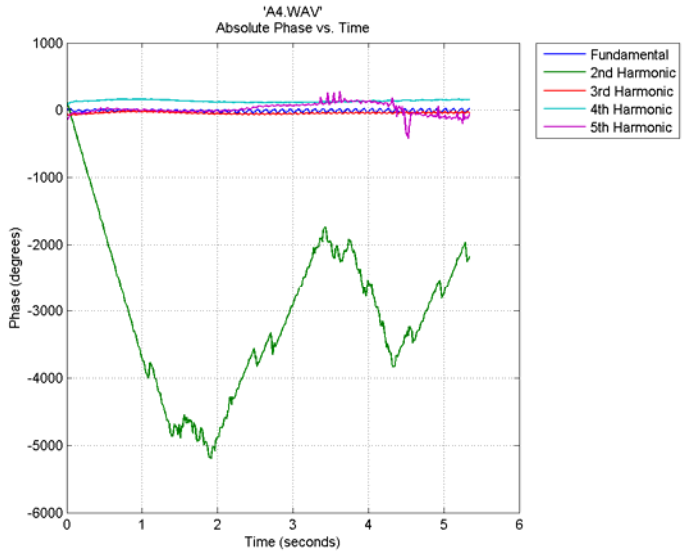
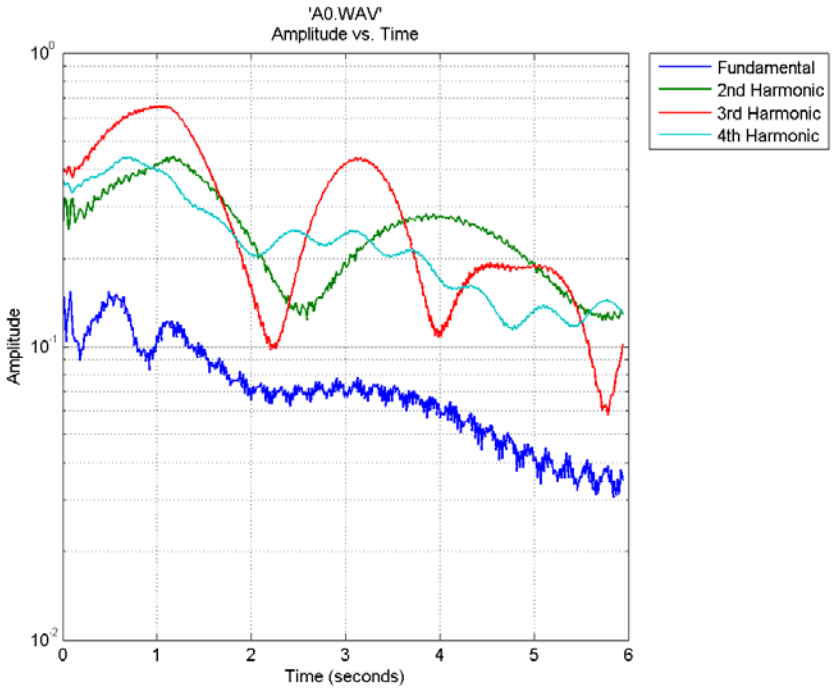


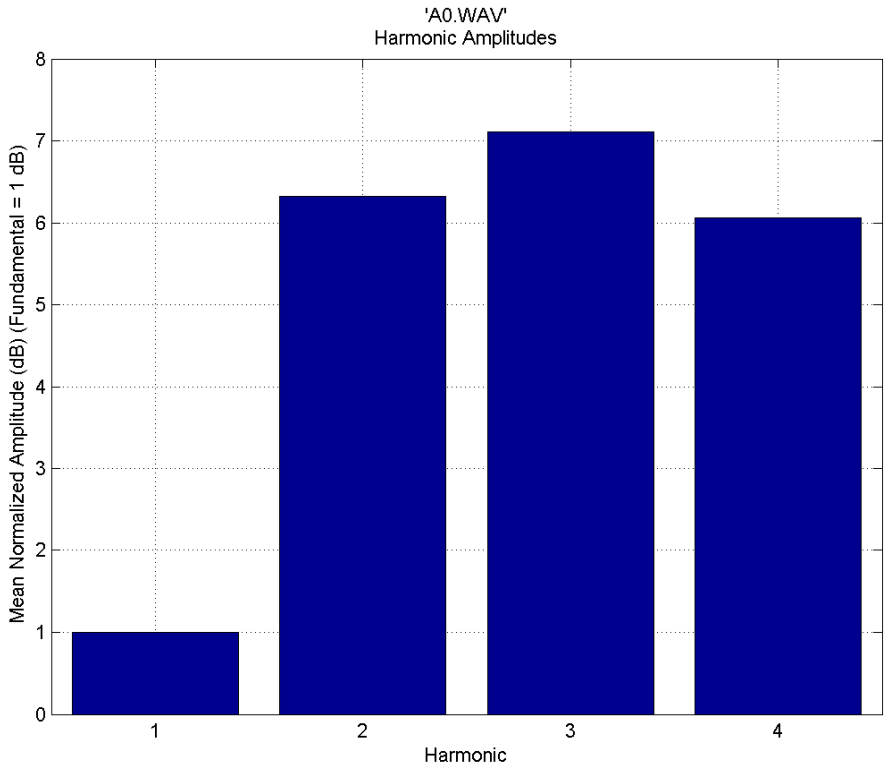
Figure 3.1.2: A0 Absolute Phase vs. Time for Yamaha RBX-170.

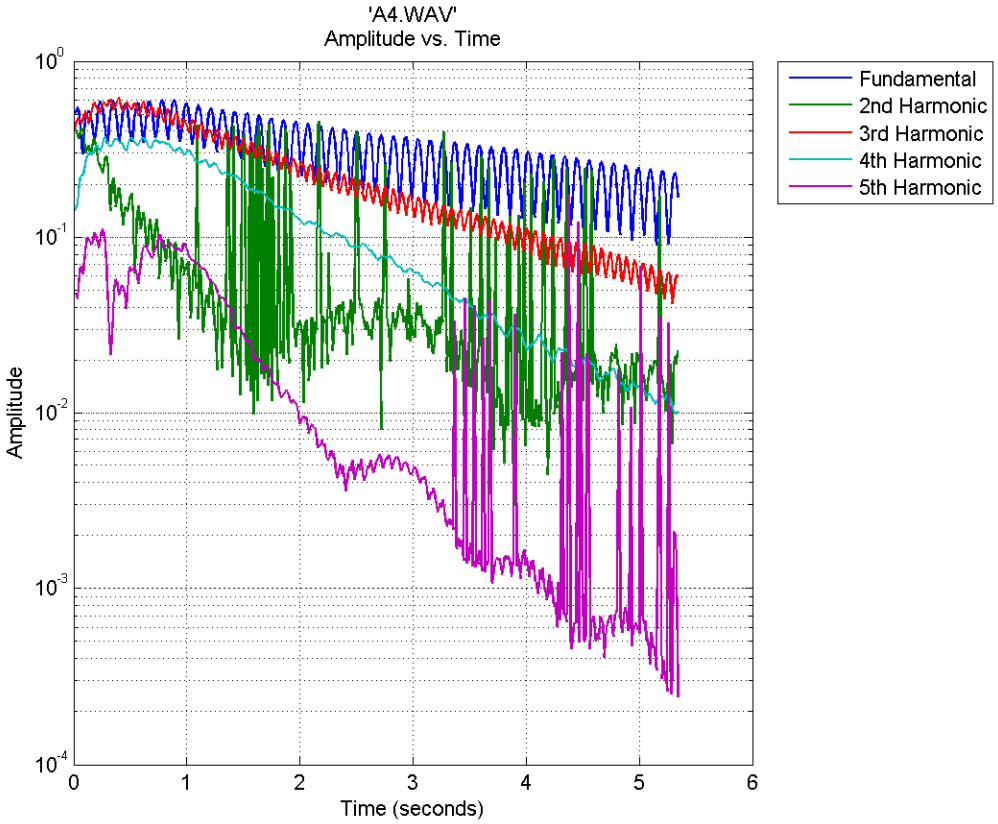


Wave Analysis and Mechanical Resonance

3. Yamaha RBX-170



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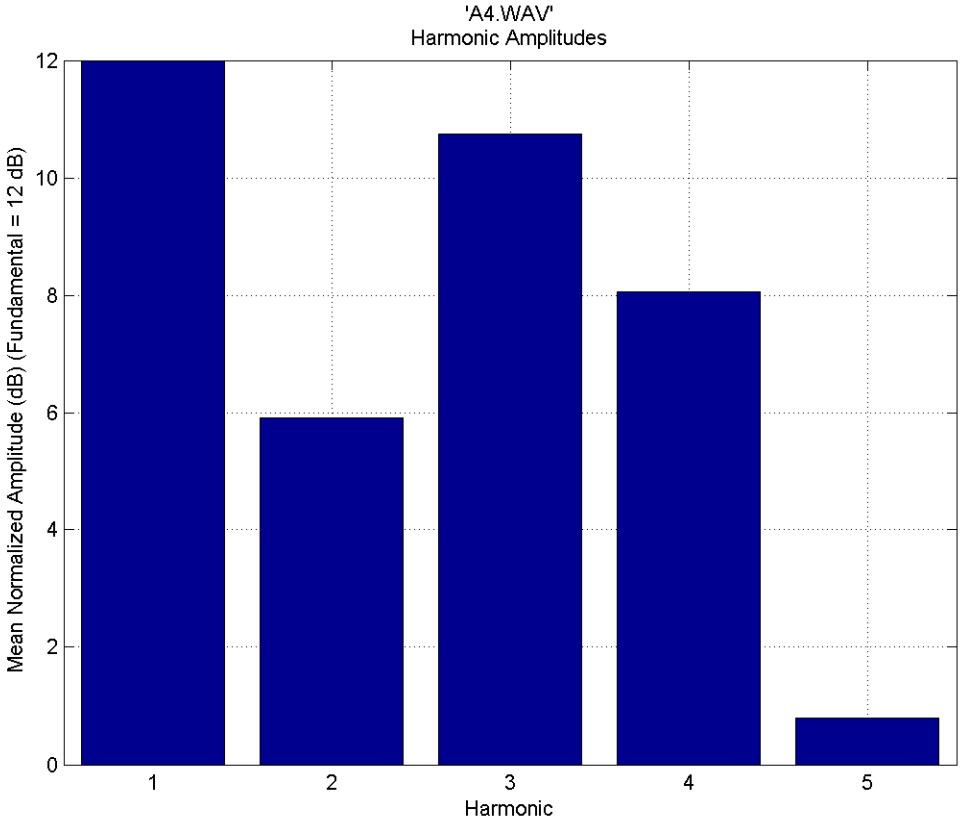
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic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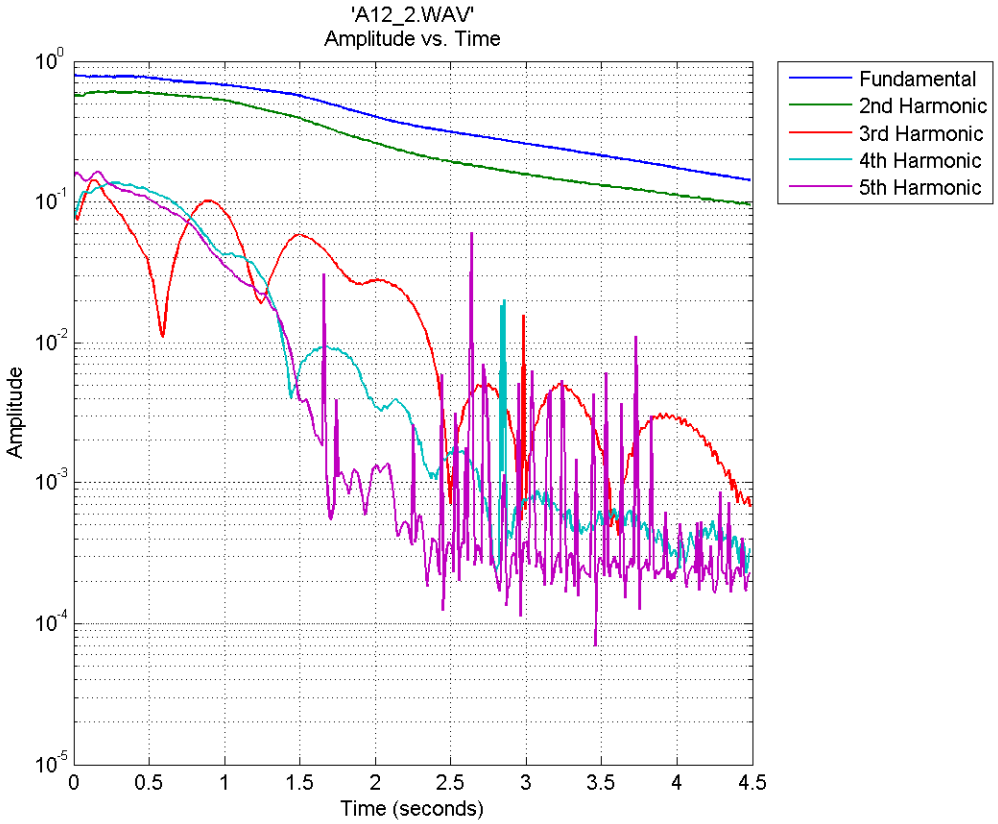
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 12 dB)
Harmonic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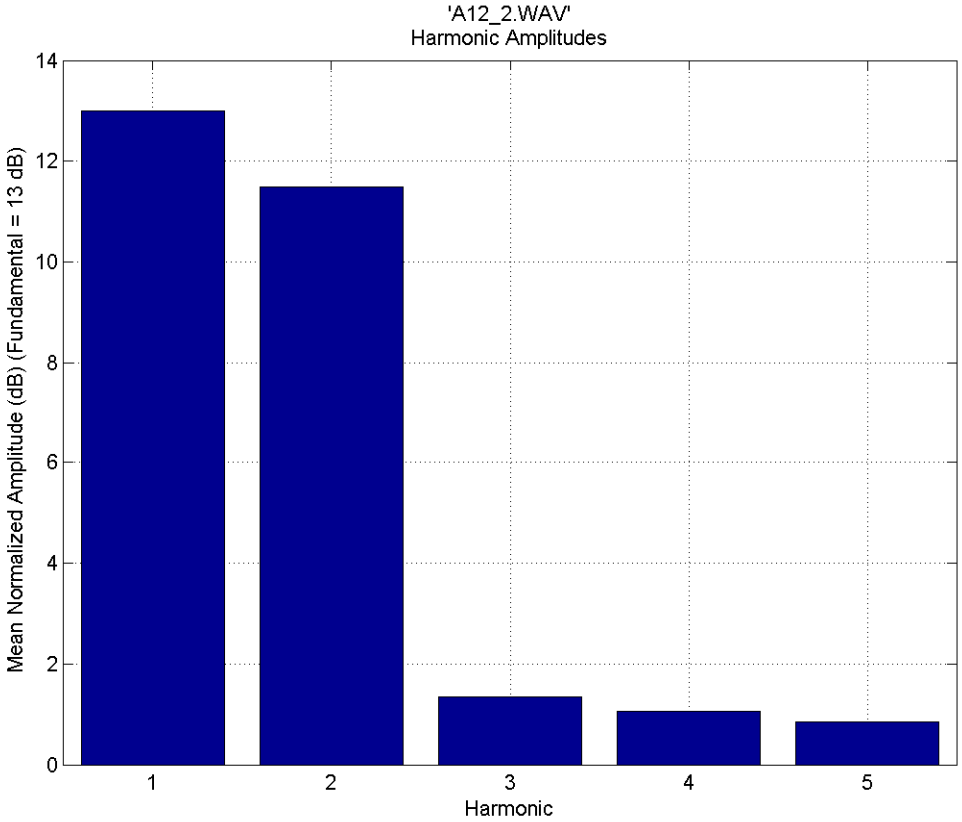
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)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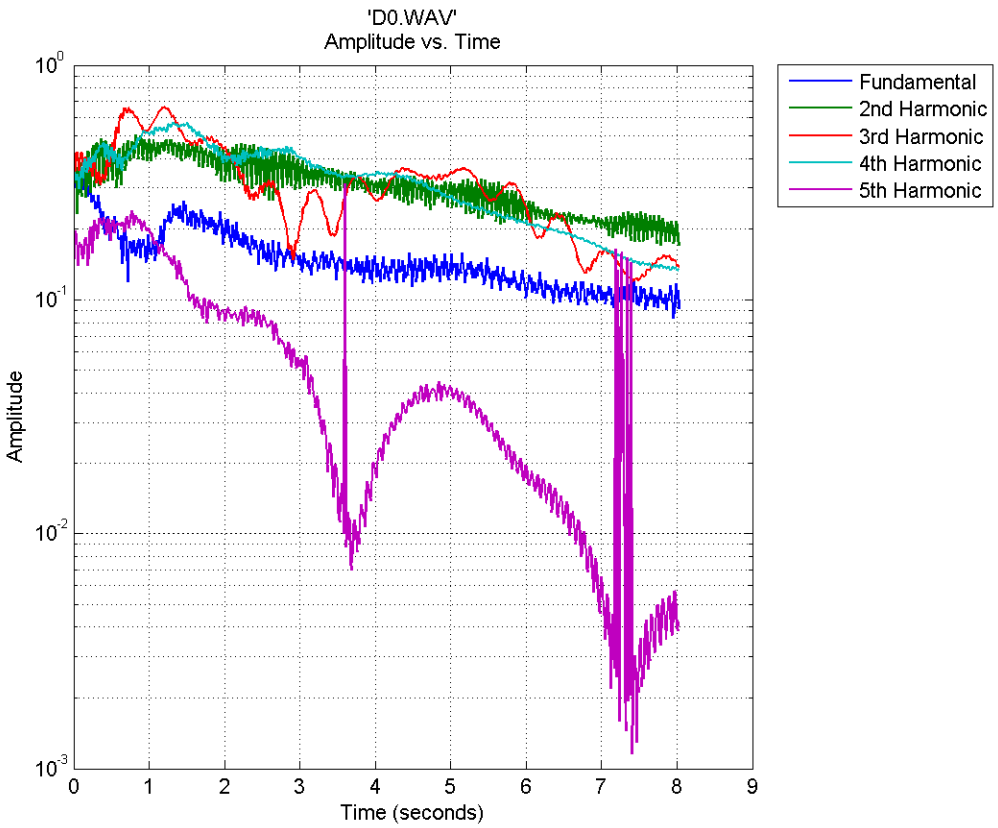
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 13 dB)
Harmonic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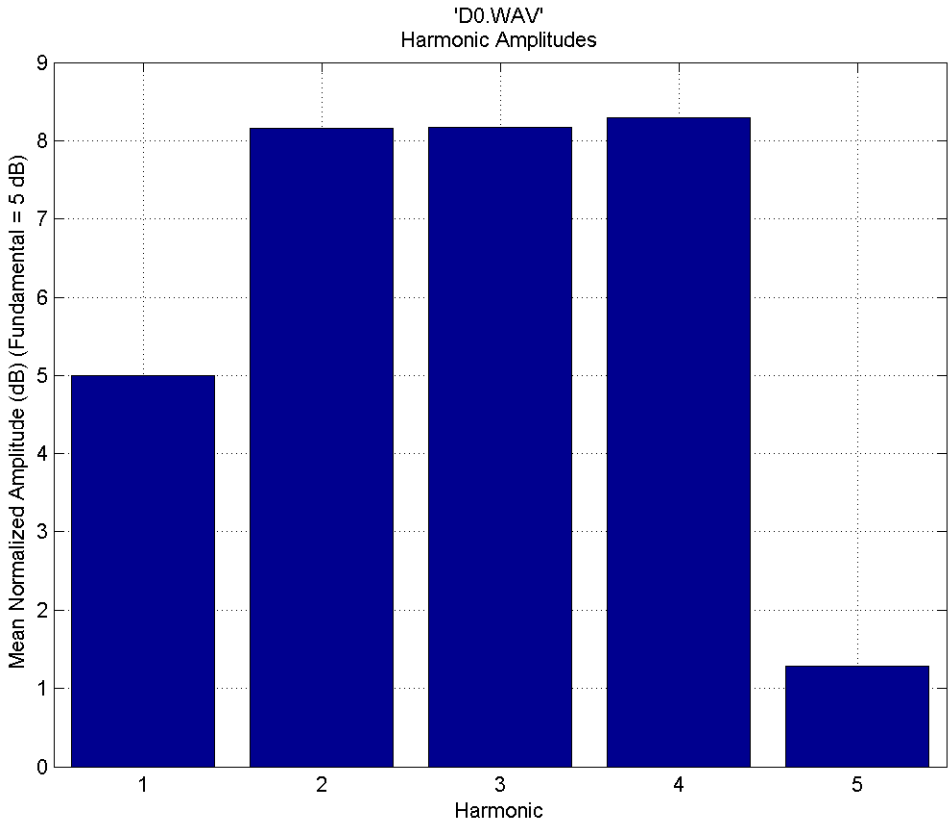
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic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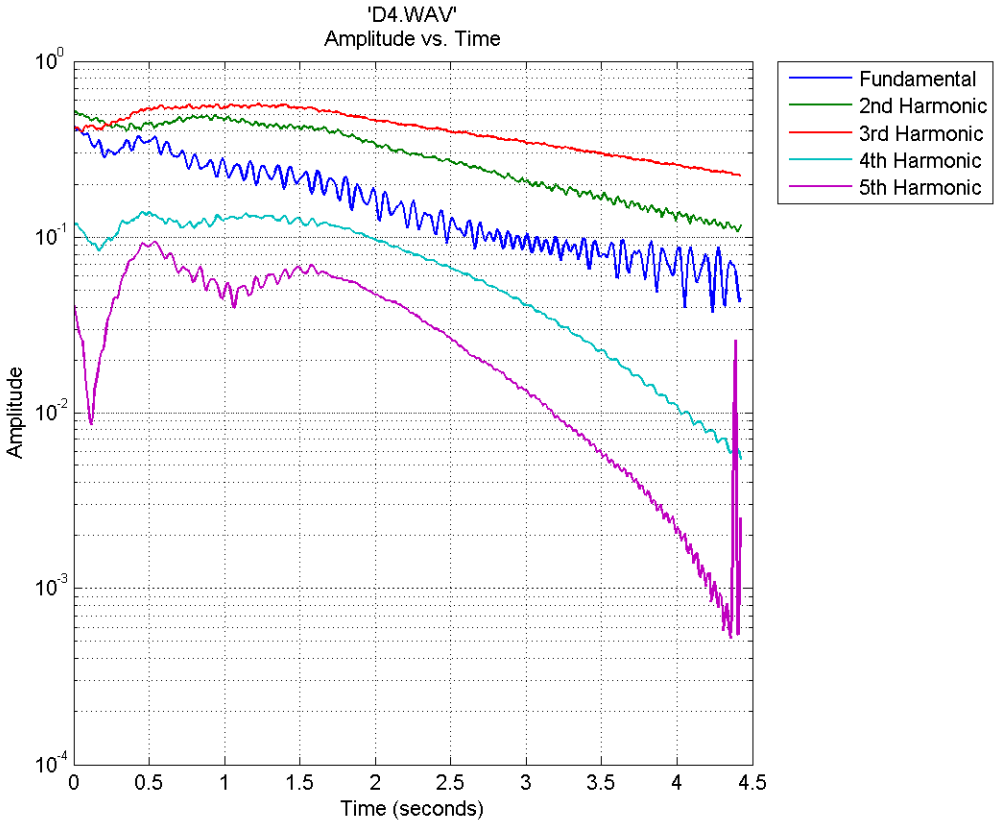
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 5 dB)
Harmonic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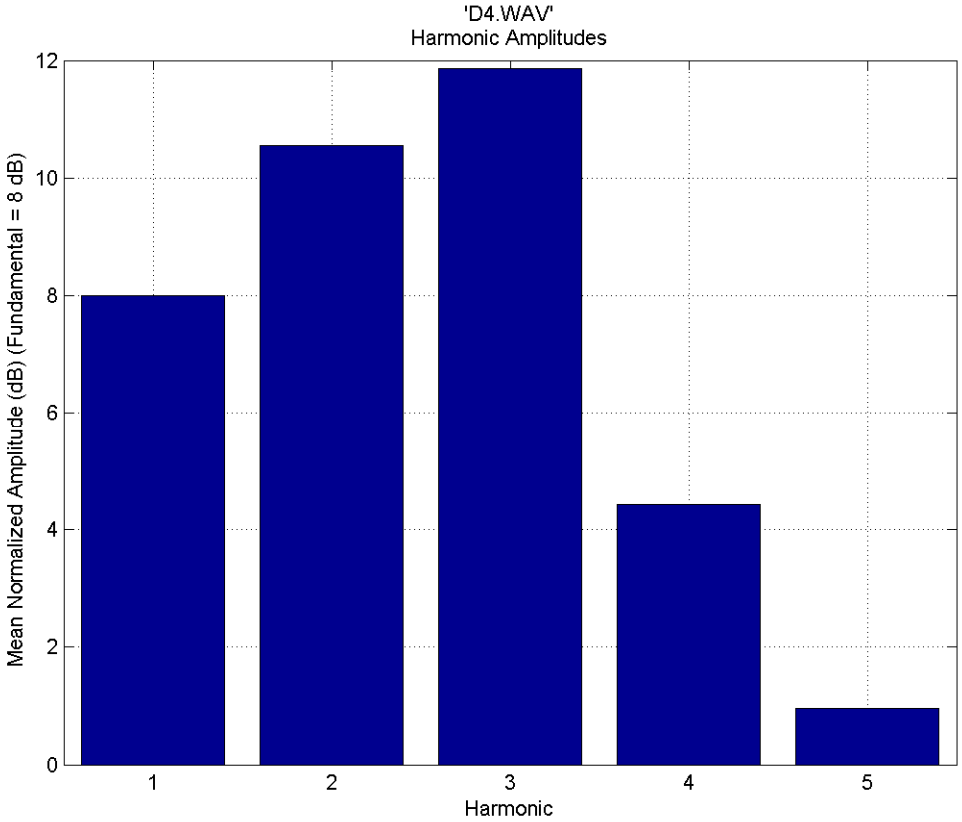
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)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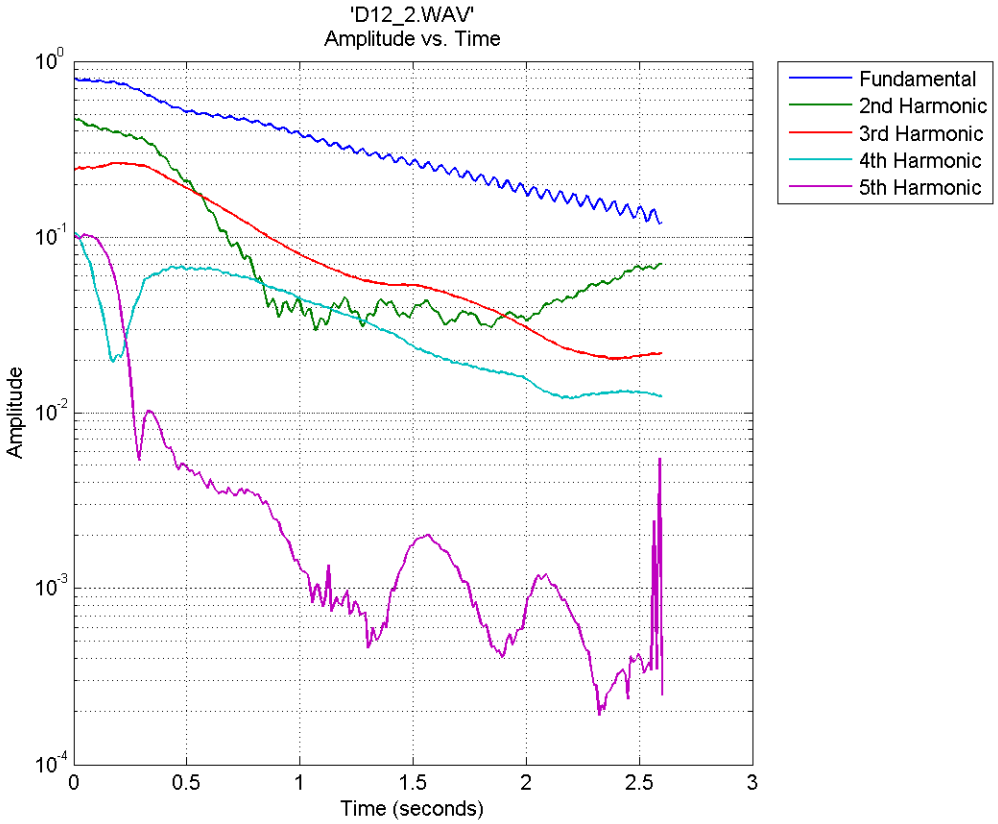
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 8 dB)
Harmonic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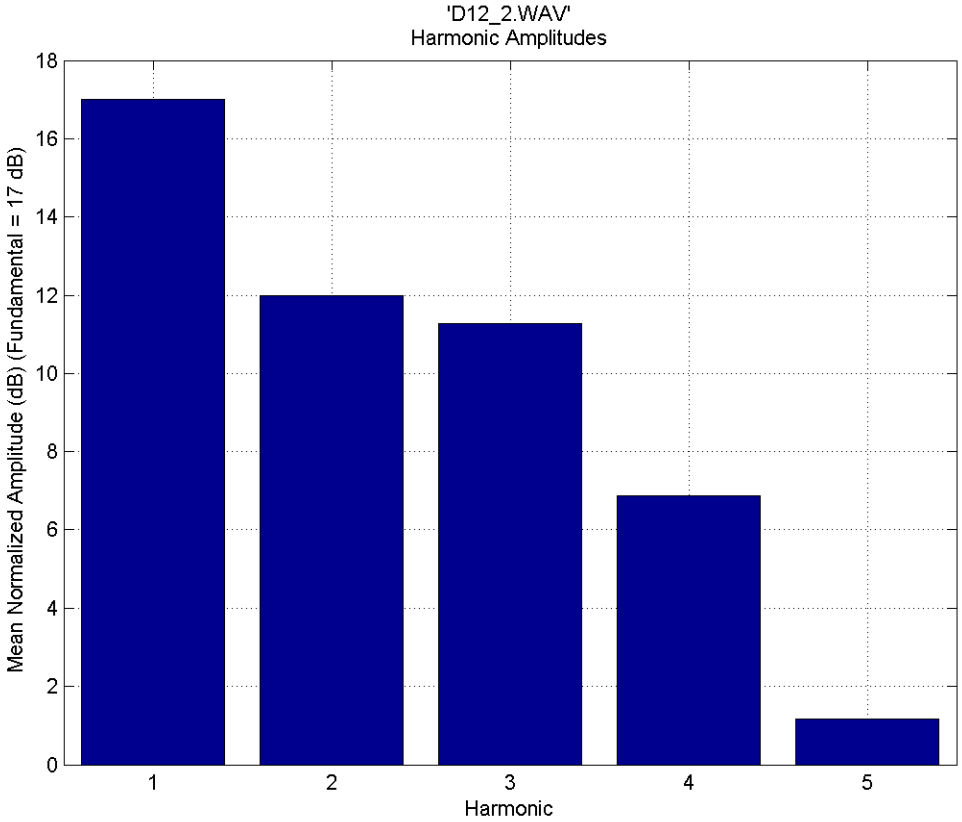
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic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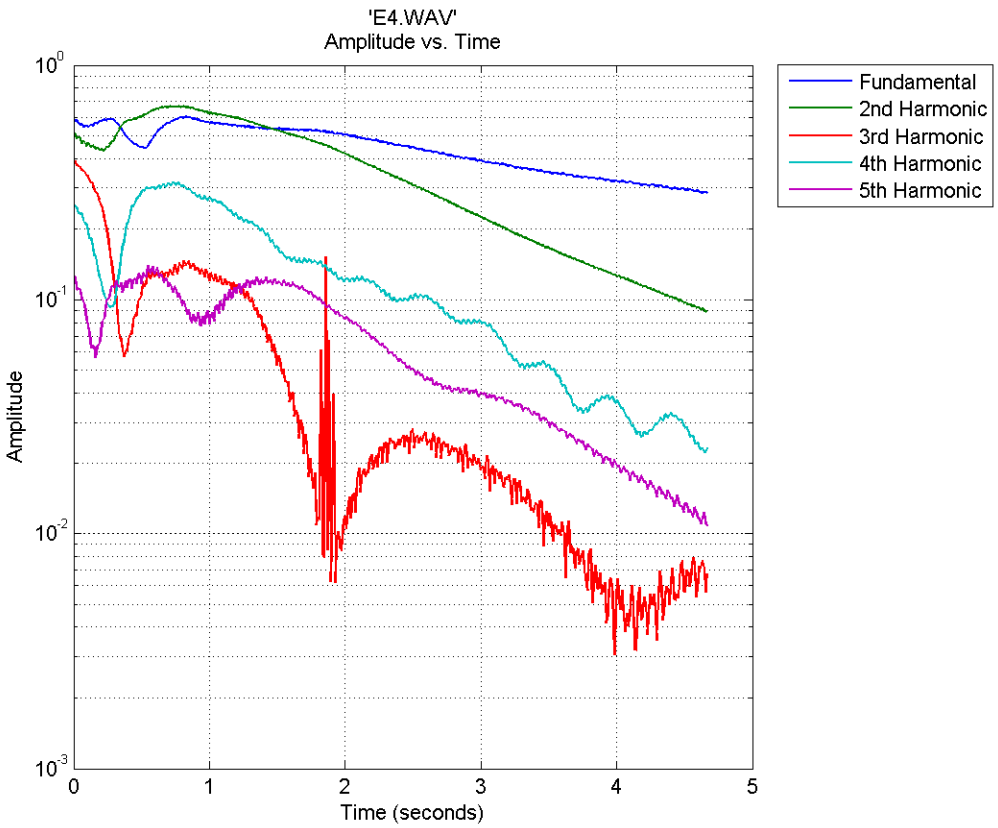
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 17 dB)
Harmonic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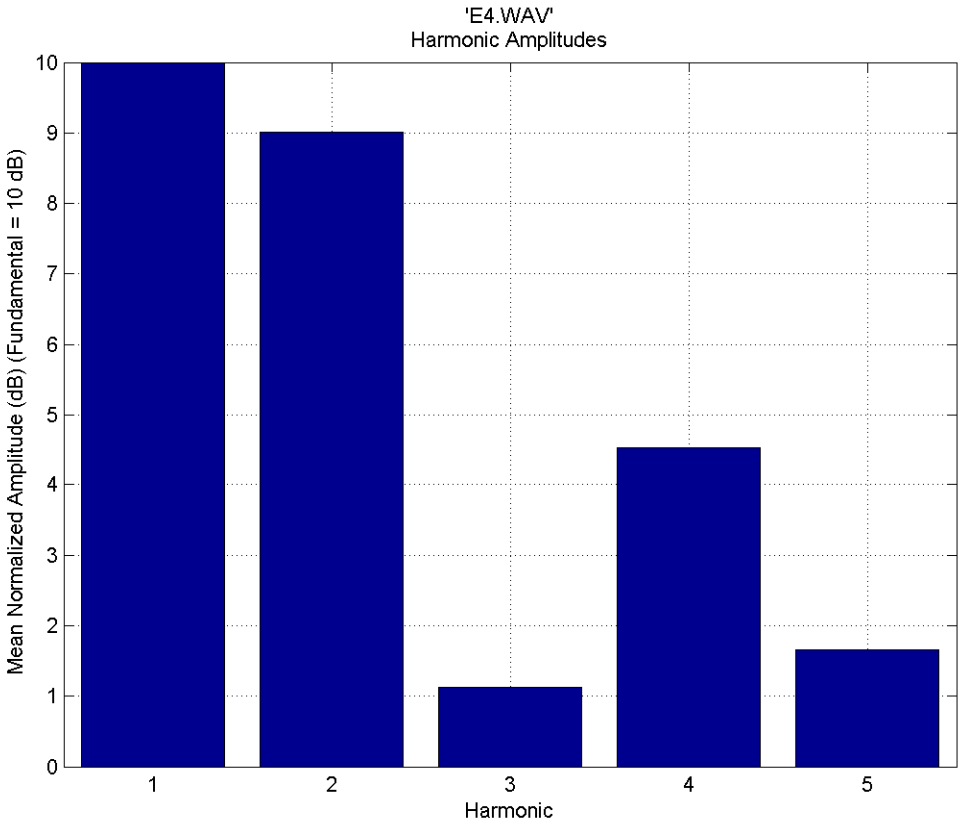
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic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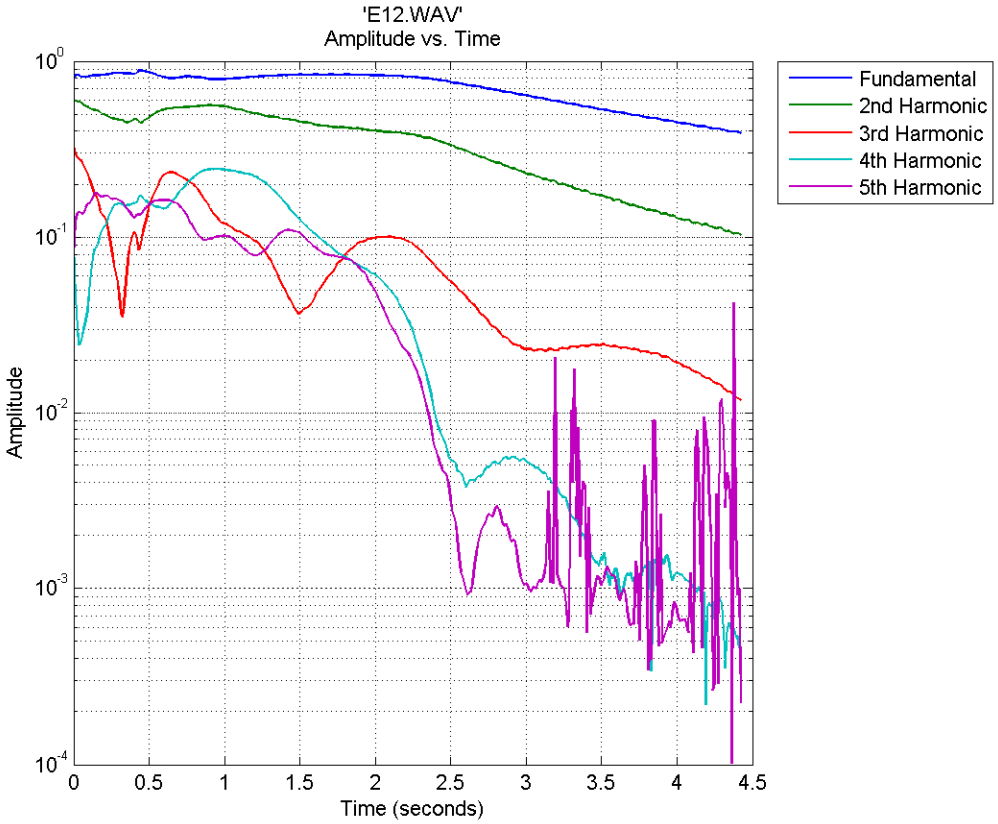
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 10 dB)
Harmonic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Fundamental
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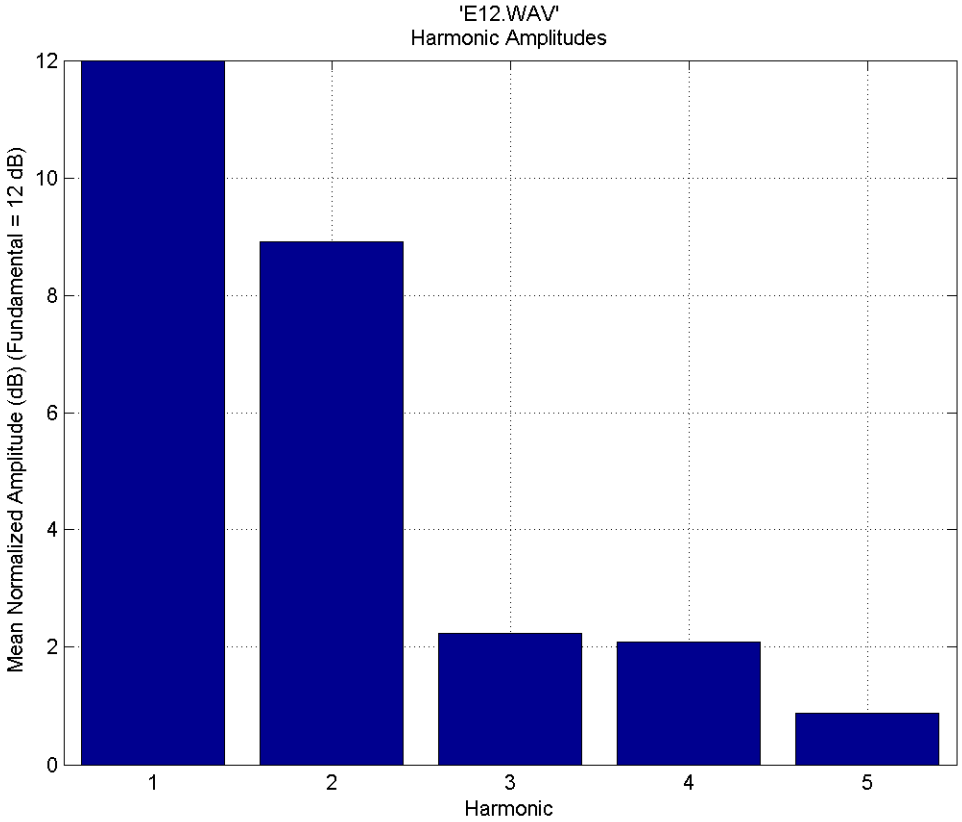
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)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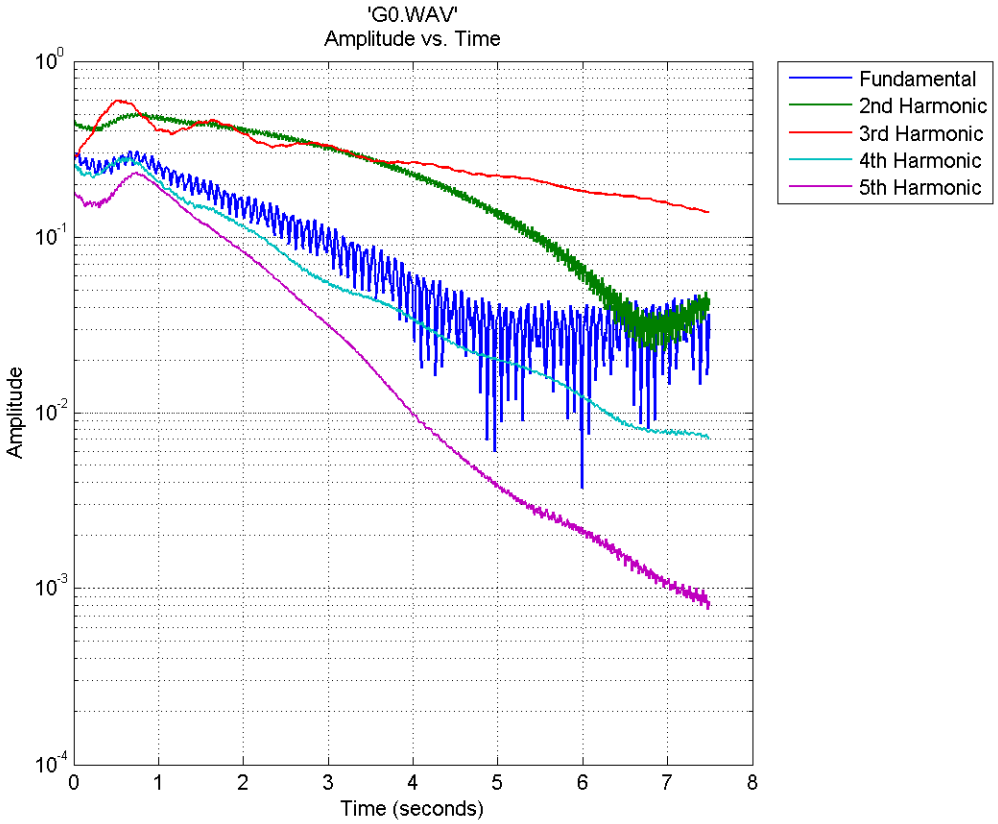
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 12 dB)
Harmonic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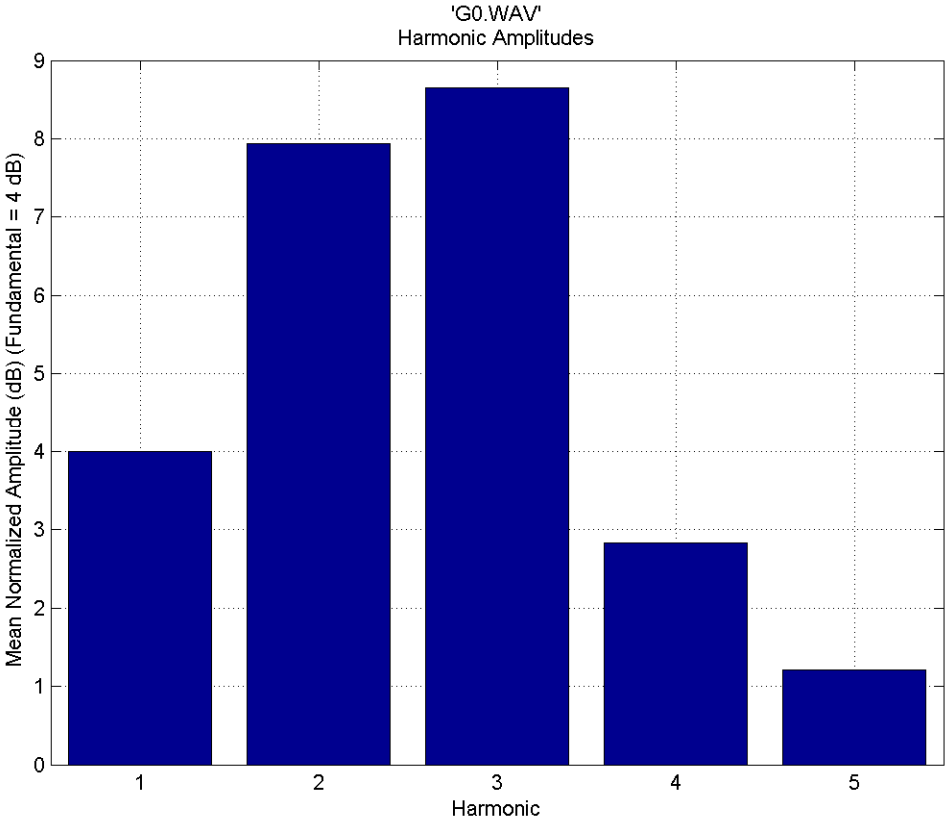
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic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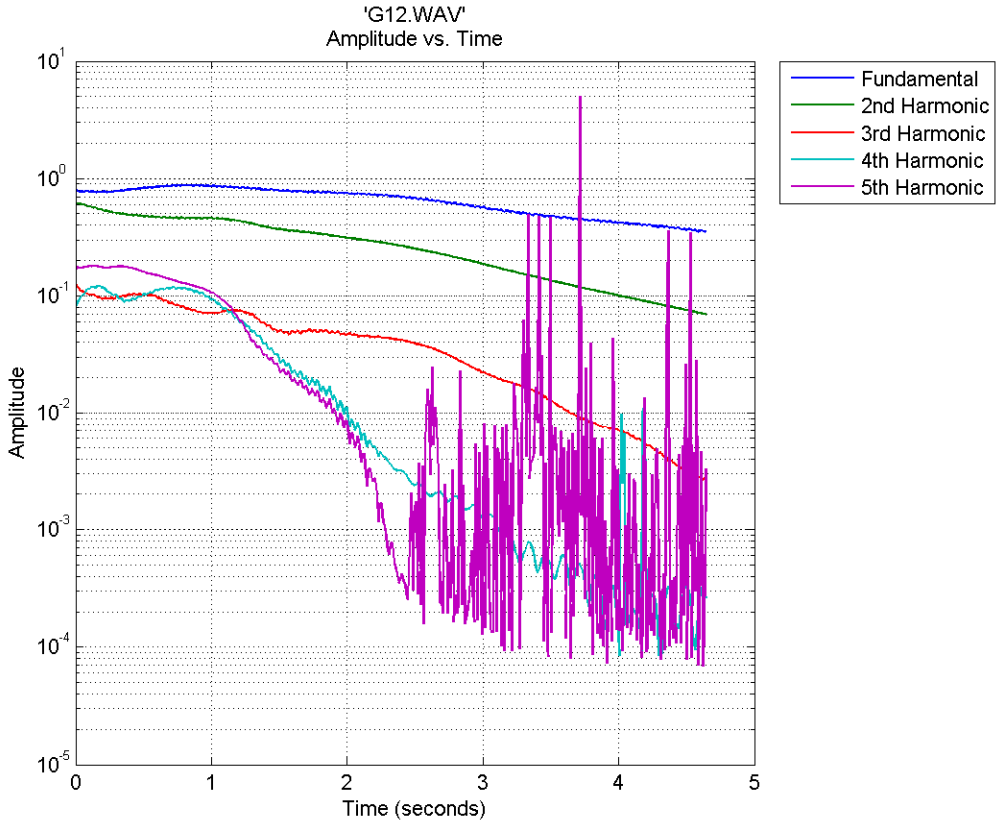
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 4 dB)
Harmonic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Amplitude
Time (seconds)
Fundamental
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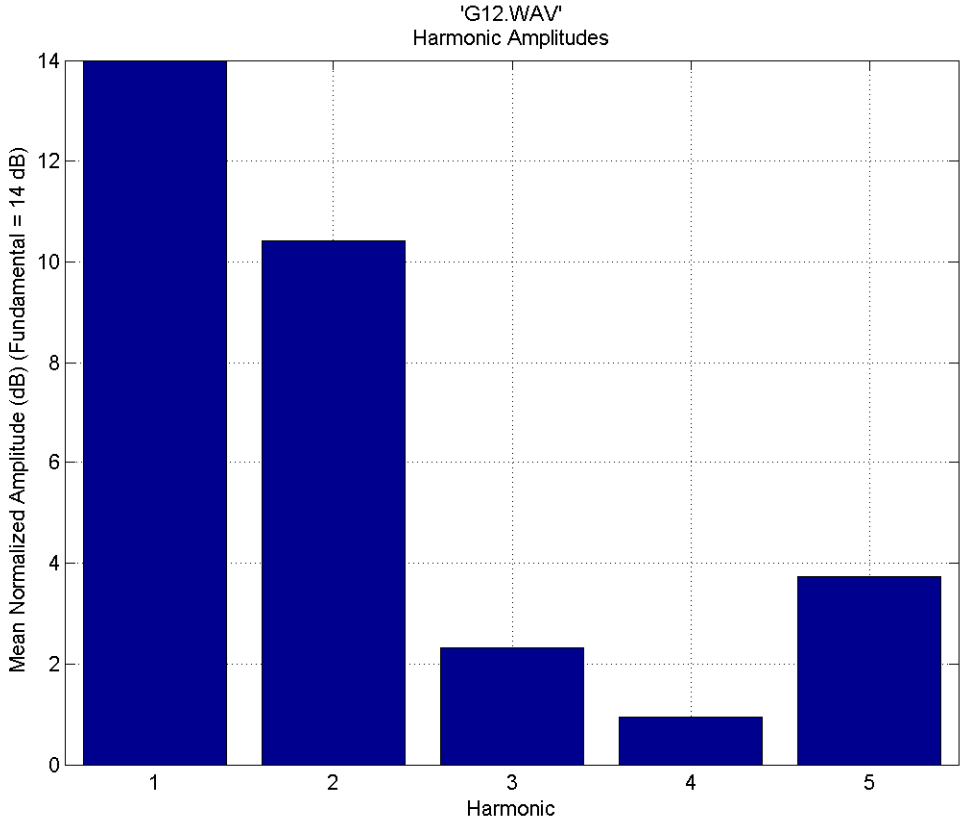
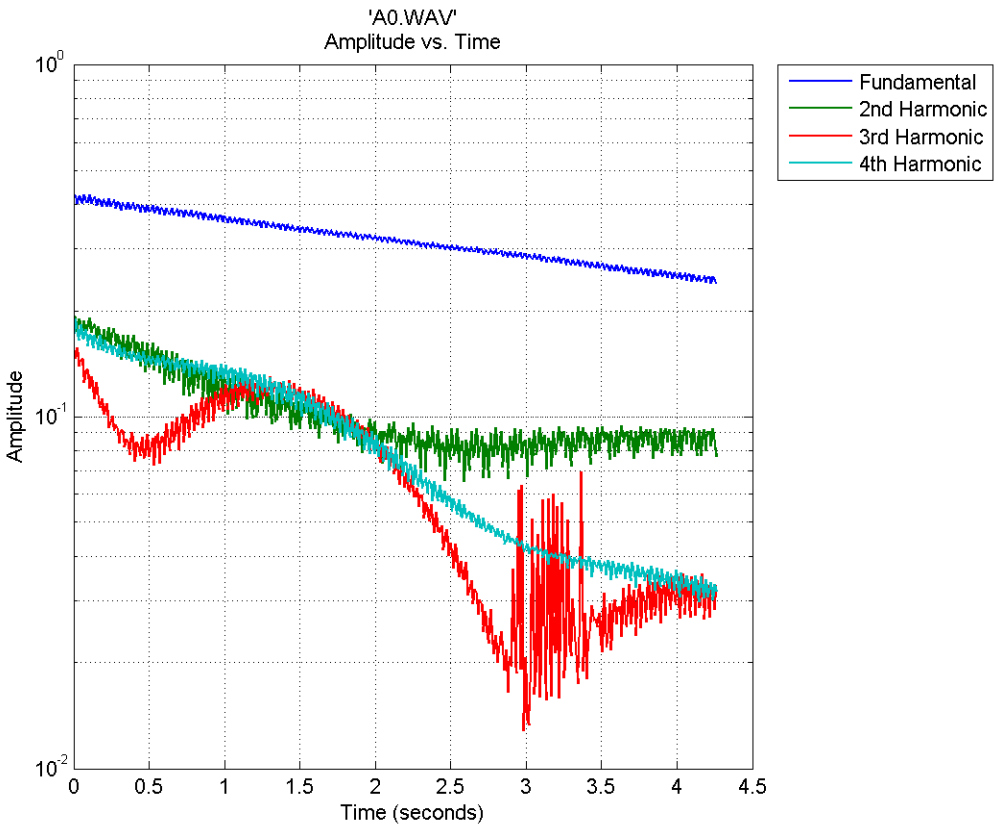
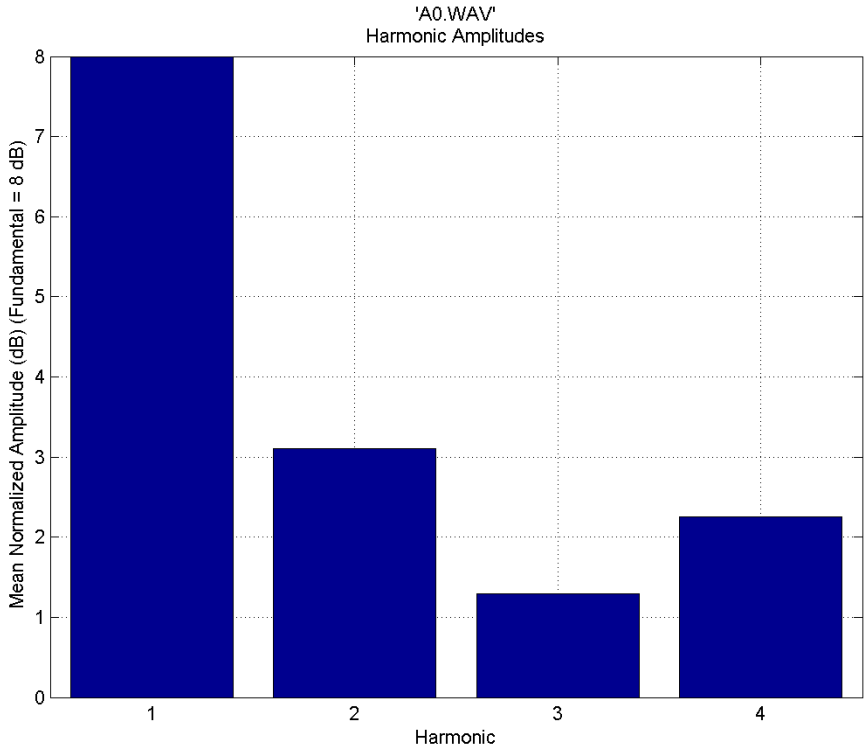
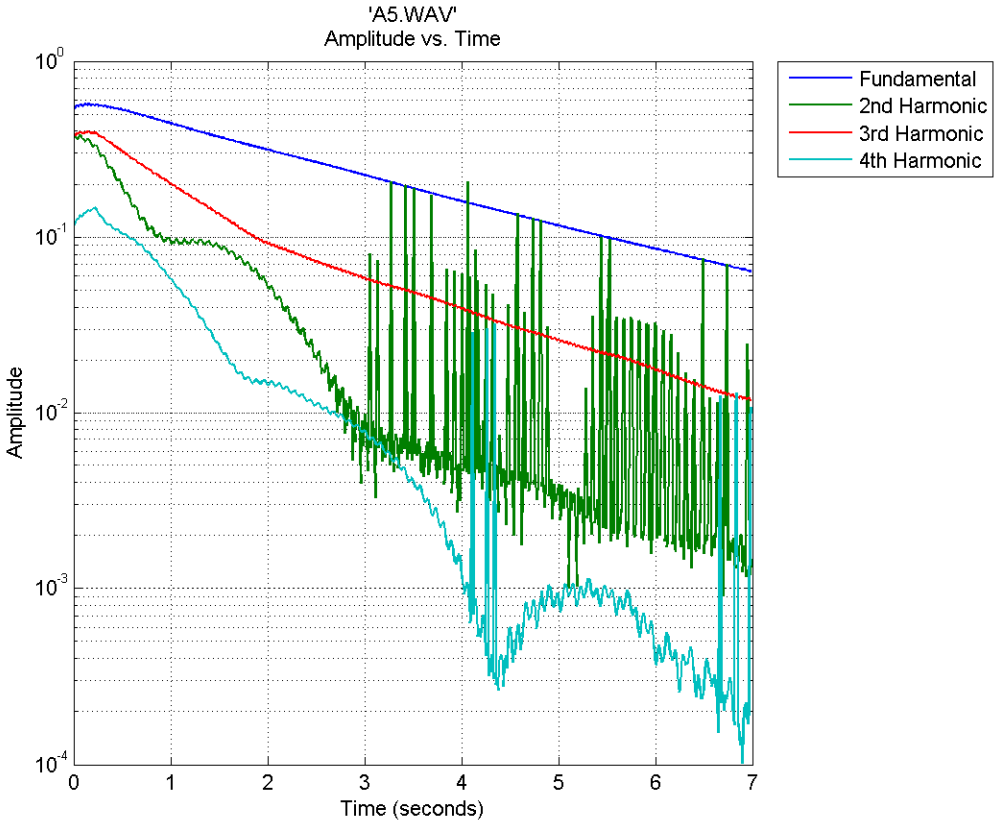
3rd Harmonic
4th Harmonic
5th Harmonic

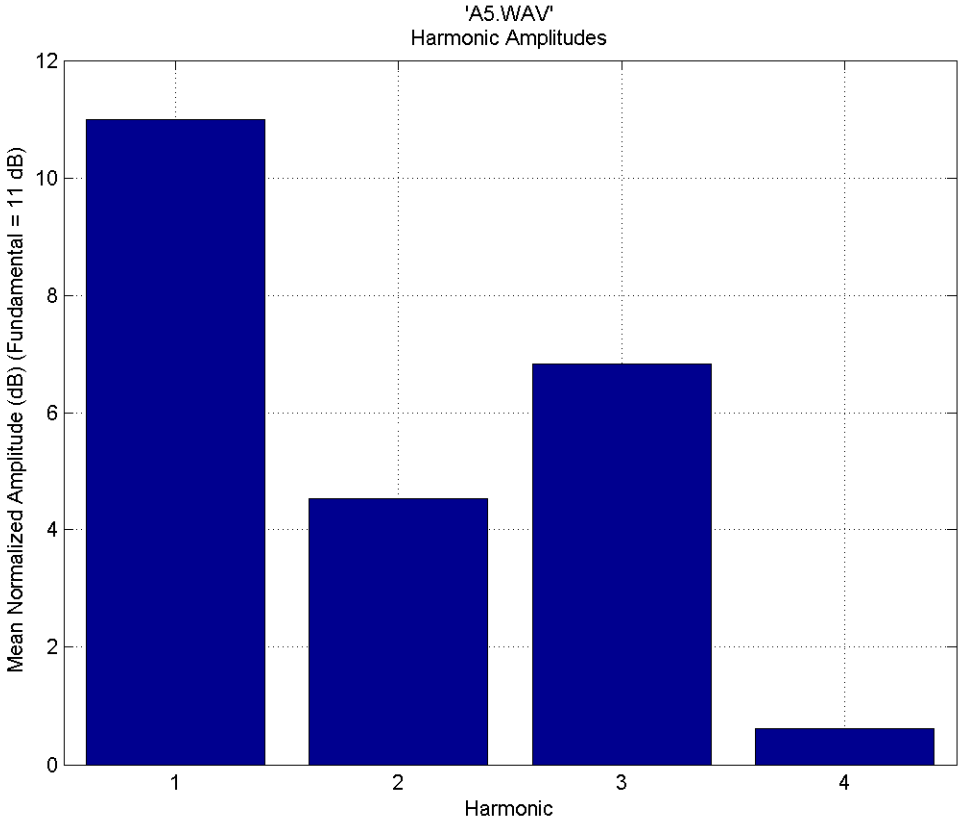

'G12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 14 dB)
Harmonic

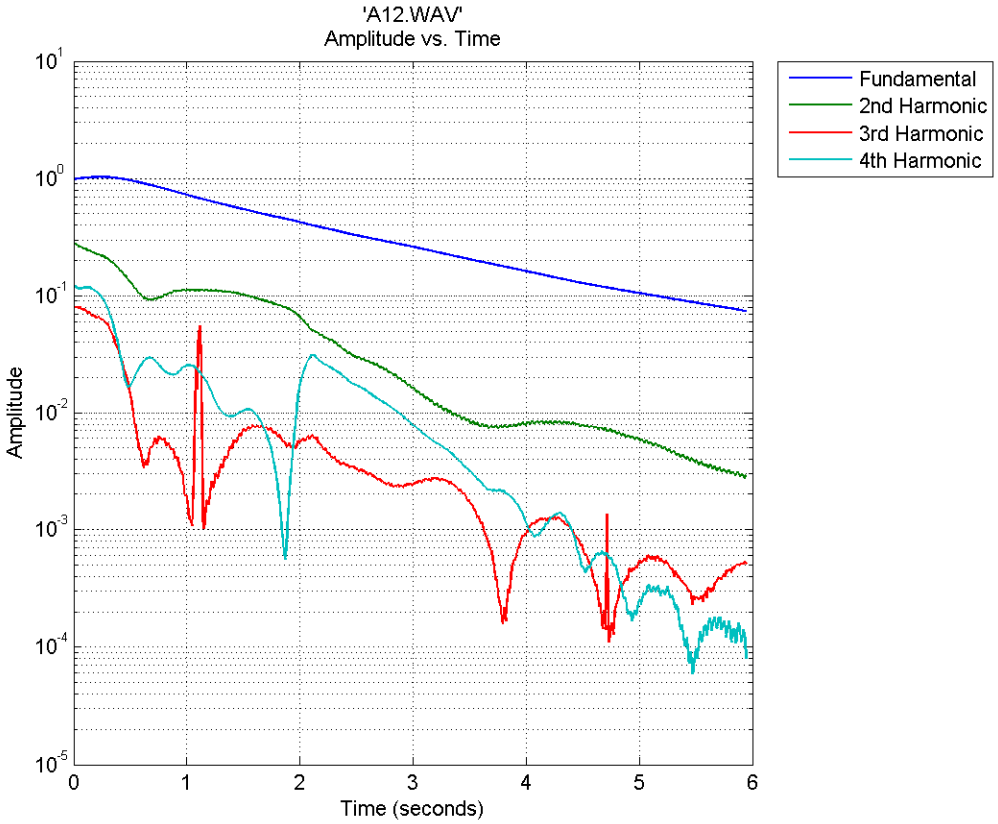
4. 1976 Fender P-Bass

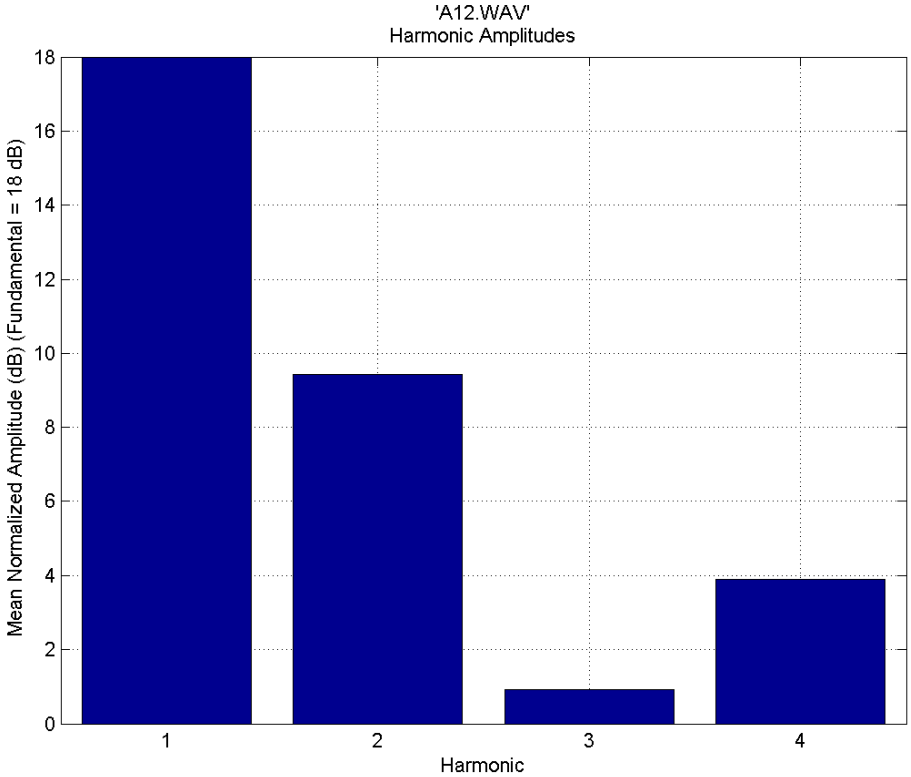


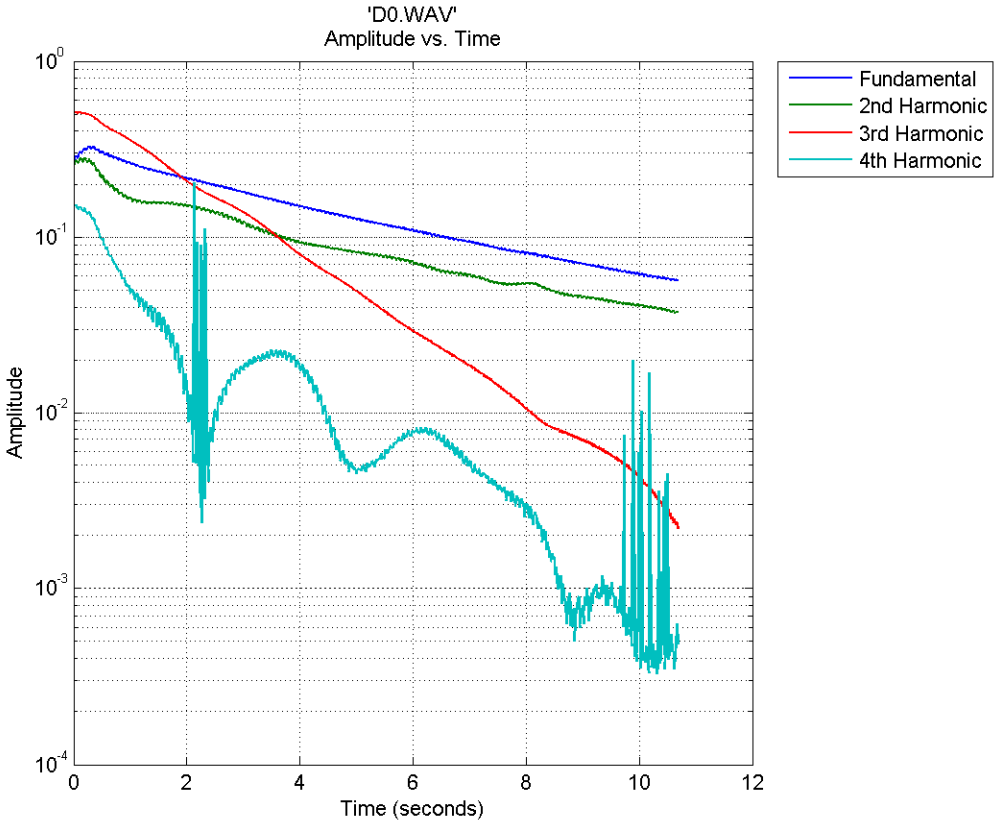


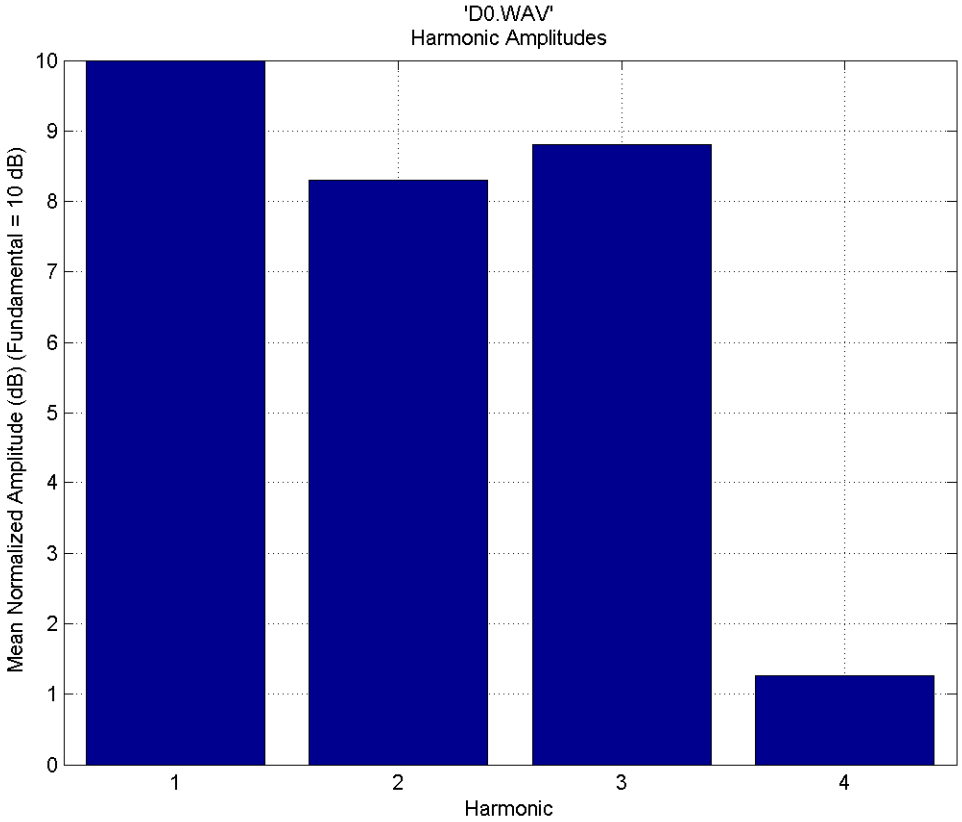

'A5.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

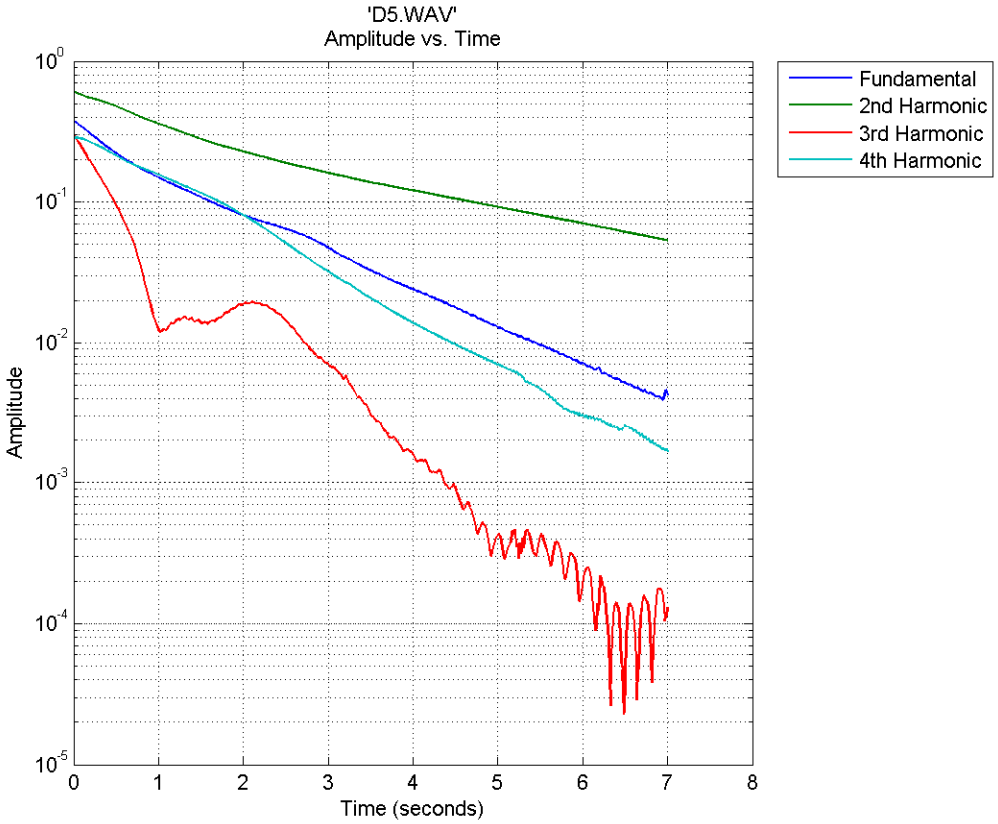

'A5.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 11 dB)
Harmonic

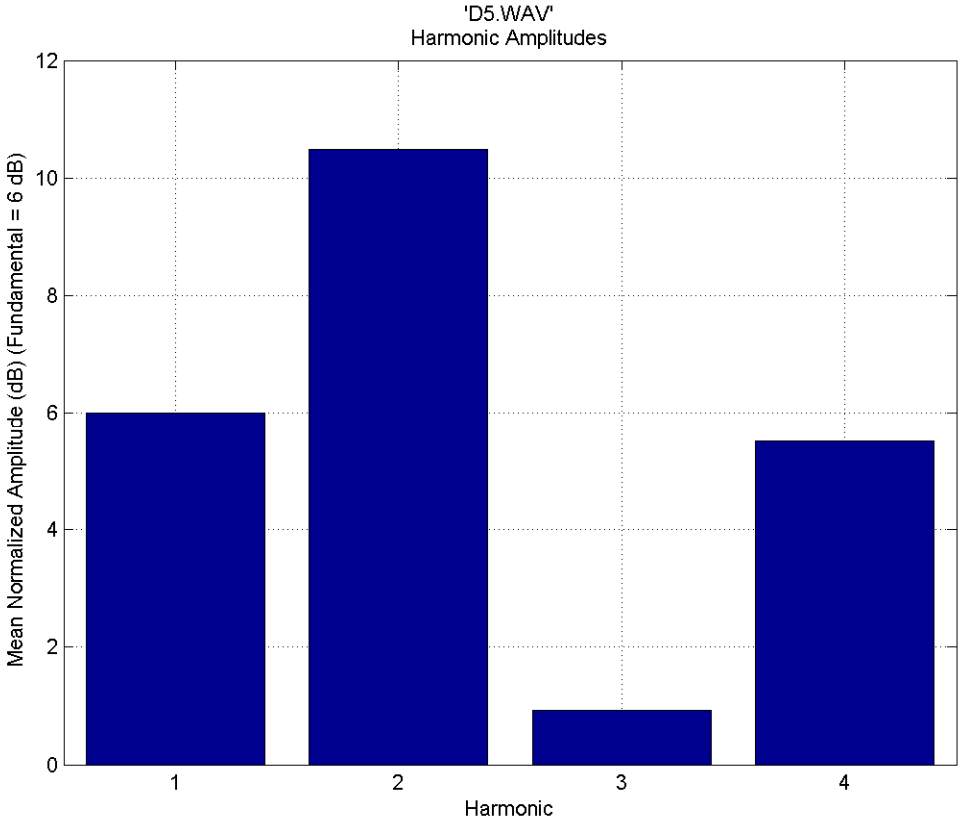

'A12.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

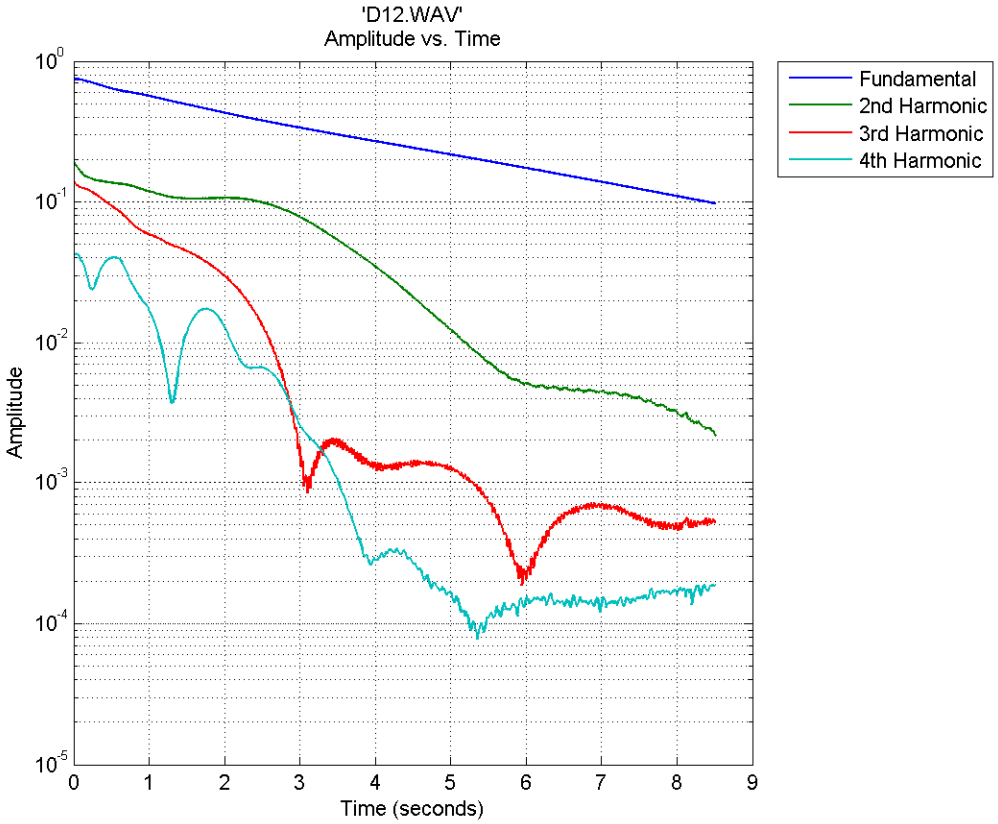

'A12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 18 dB)
Harmonic

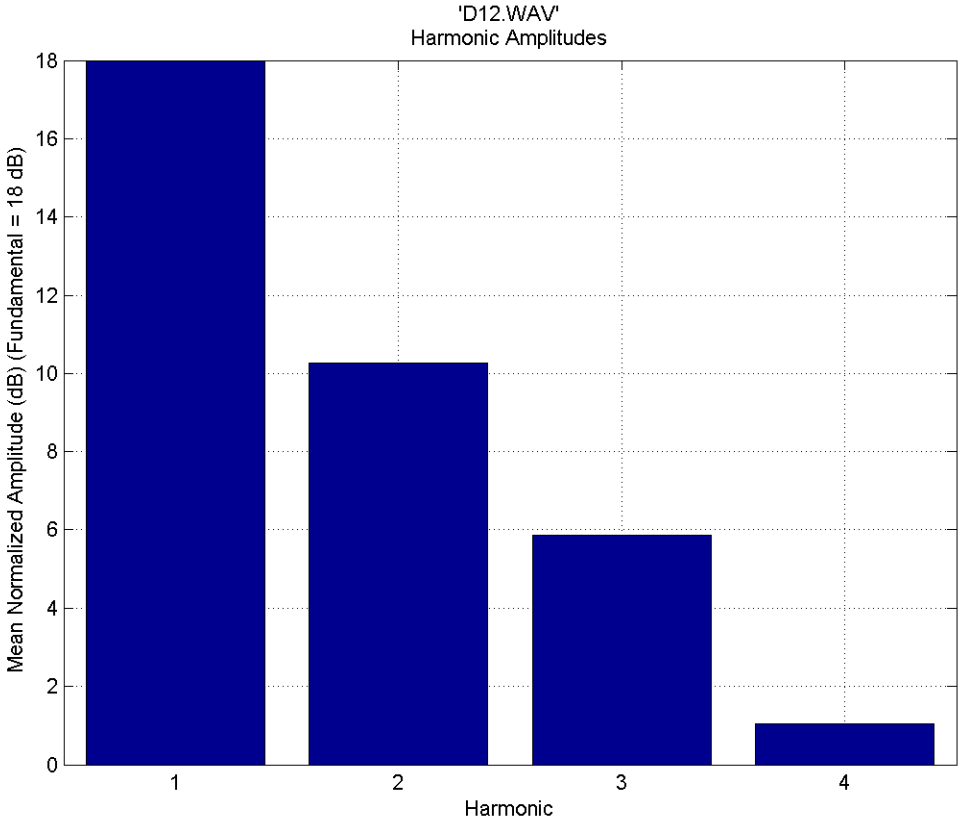

'D0.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

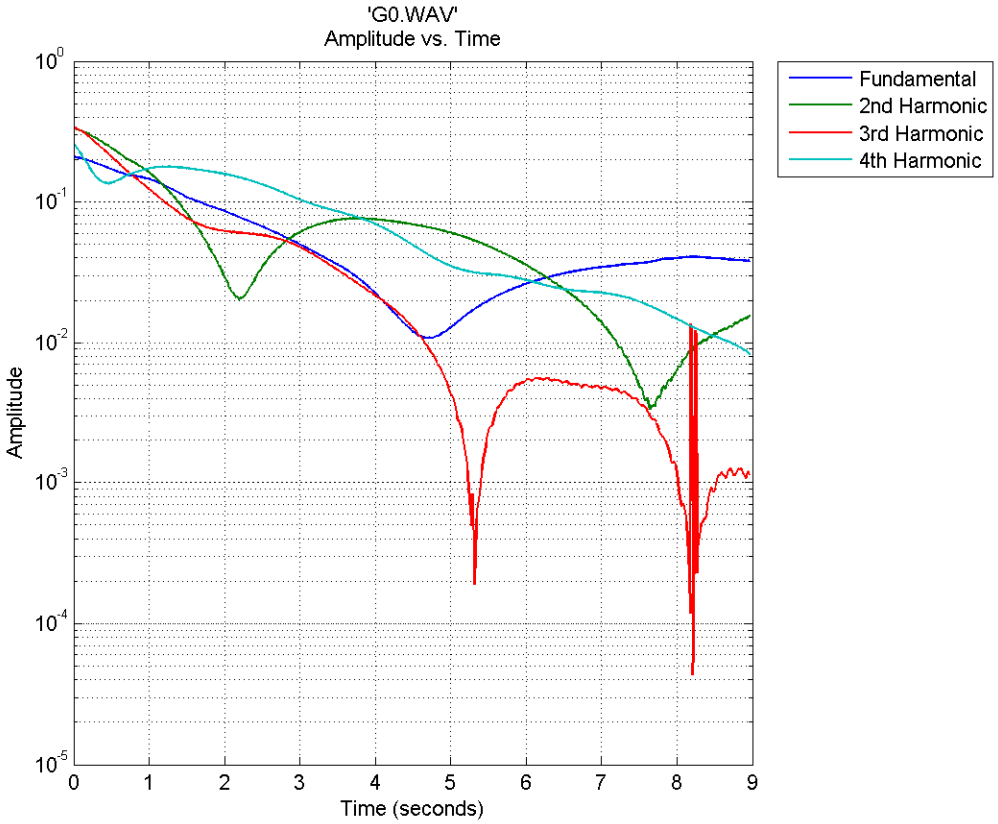

'D0.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 10 dB)
Harmonic

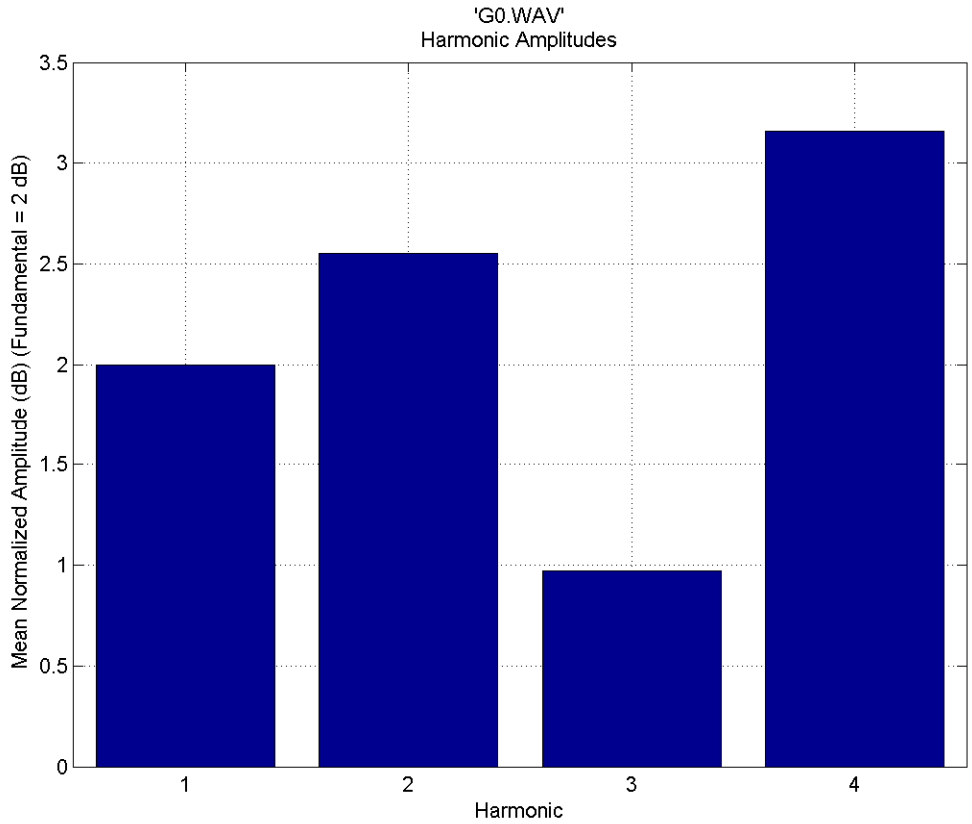

'D5.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

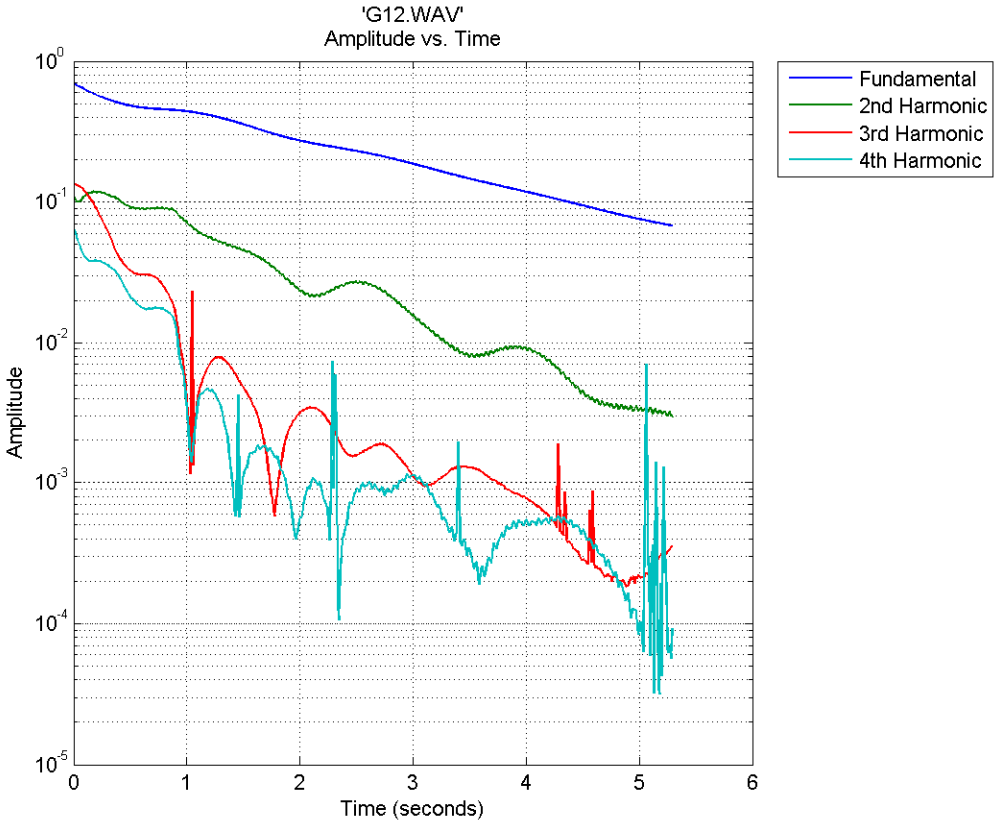

'D5.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 6 dB)
Harmonic

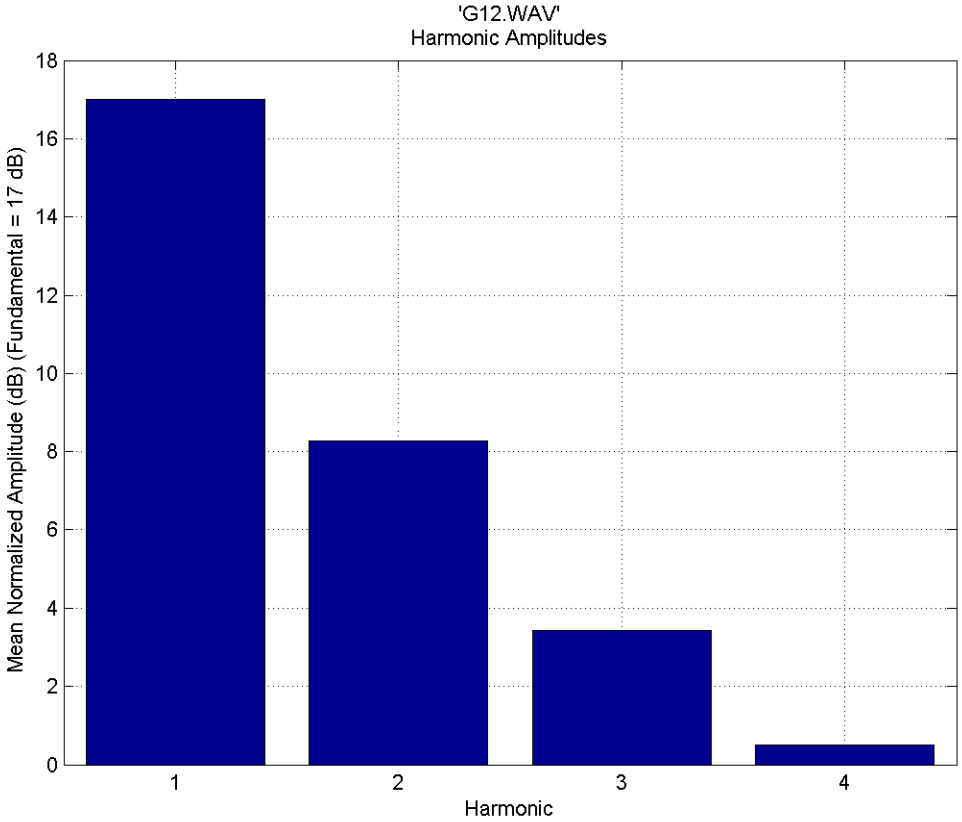

'D12.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)


'D12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 18 dB)
Harmonic

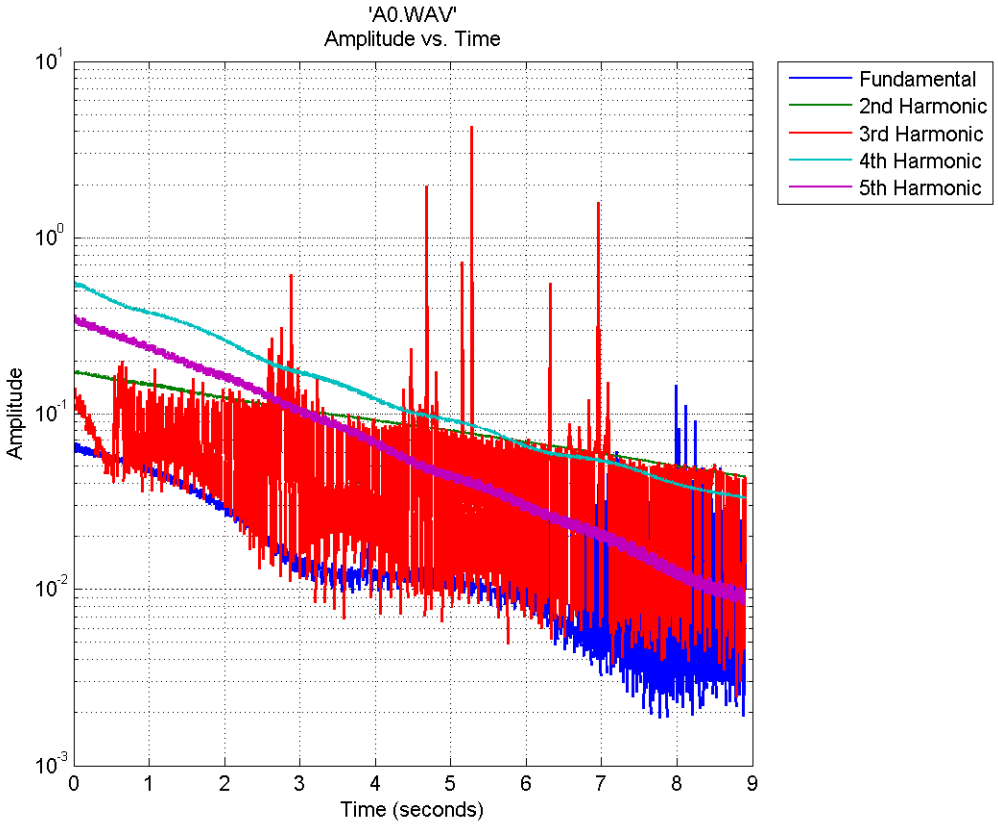

'G0.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

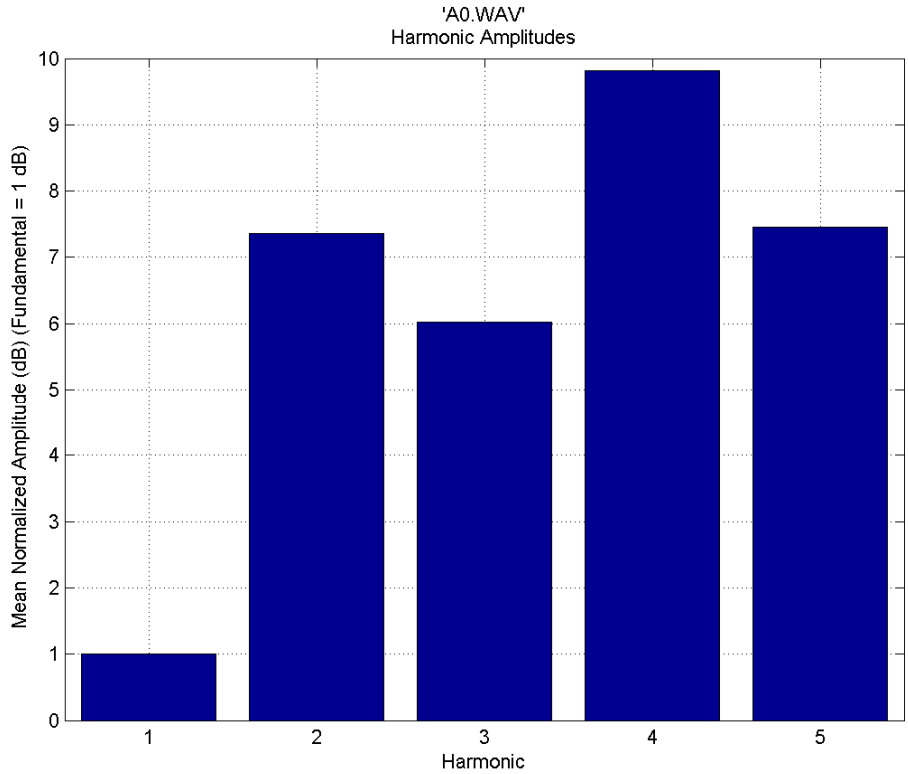

'G0.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 2 dB)
Harmonic

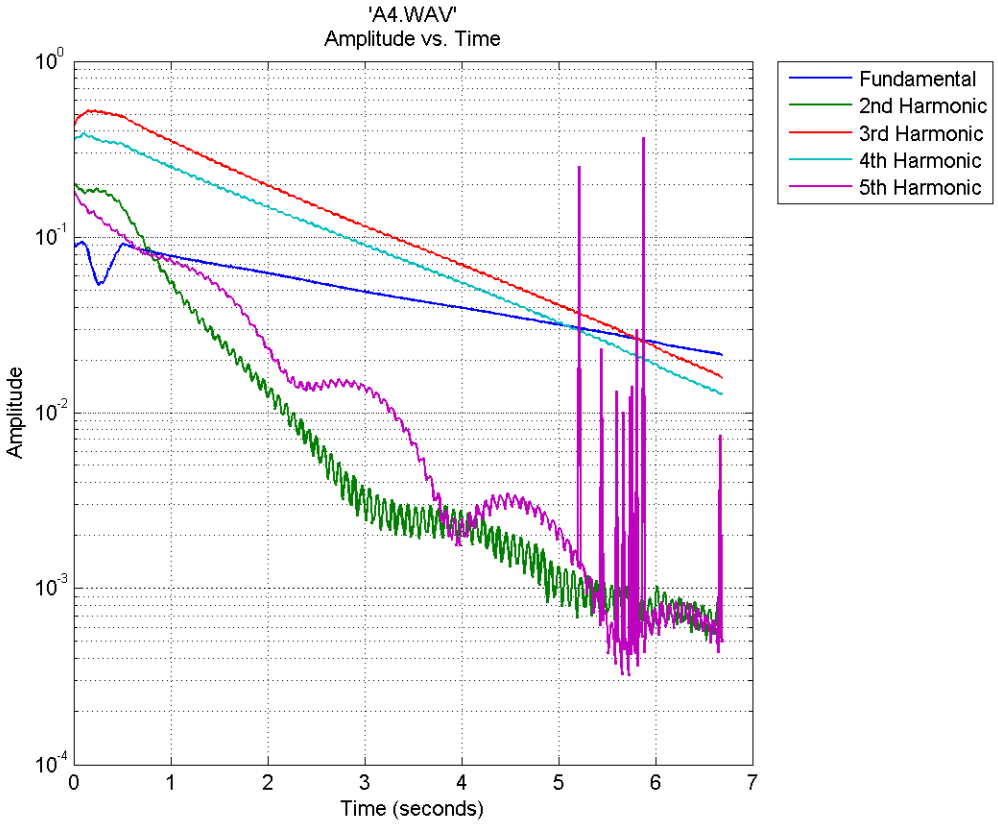

'G12.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

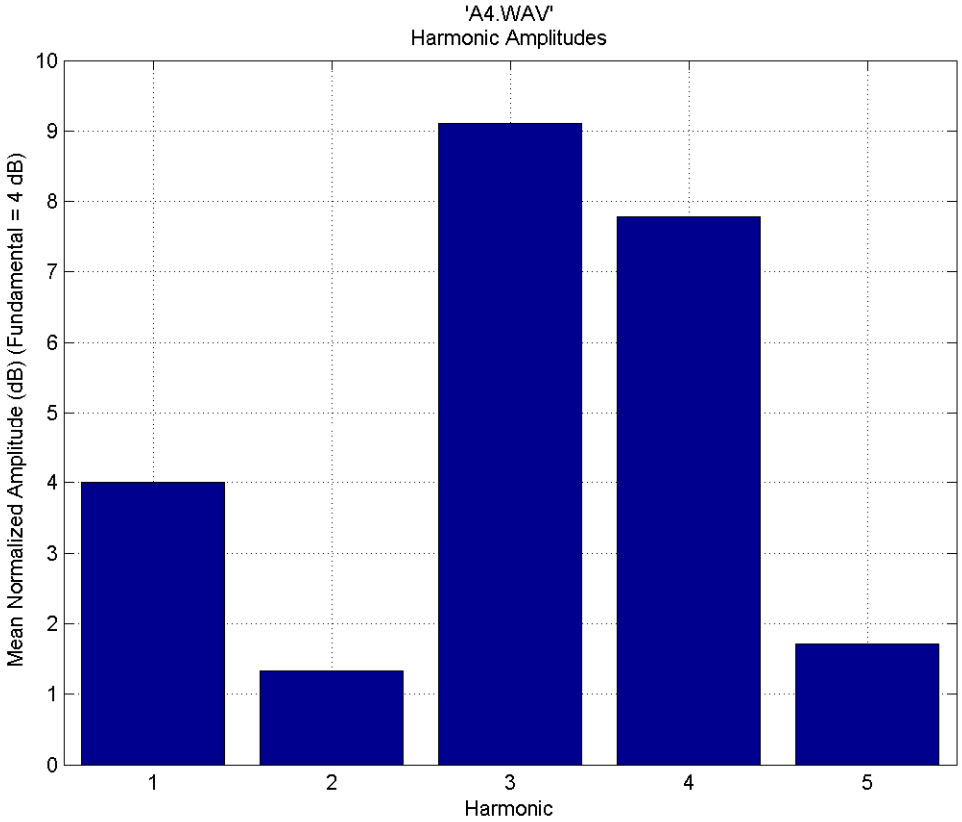

'G12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 17 dB)
Harmonic

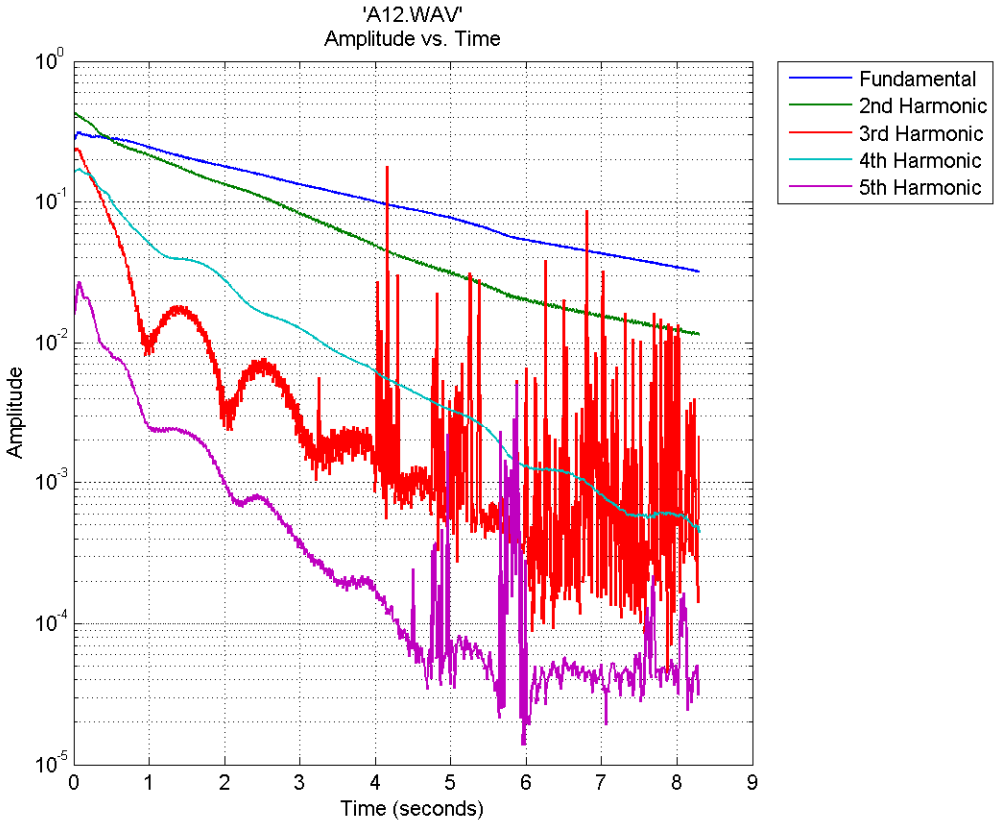
5. 2003 Music Man Sterling with bright strings

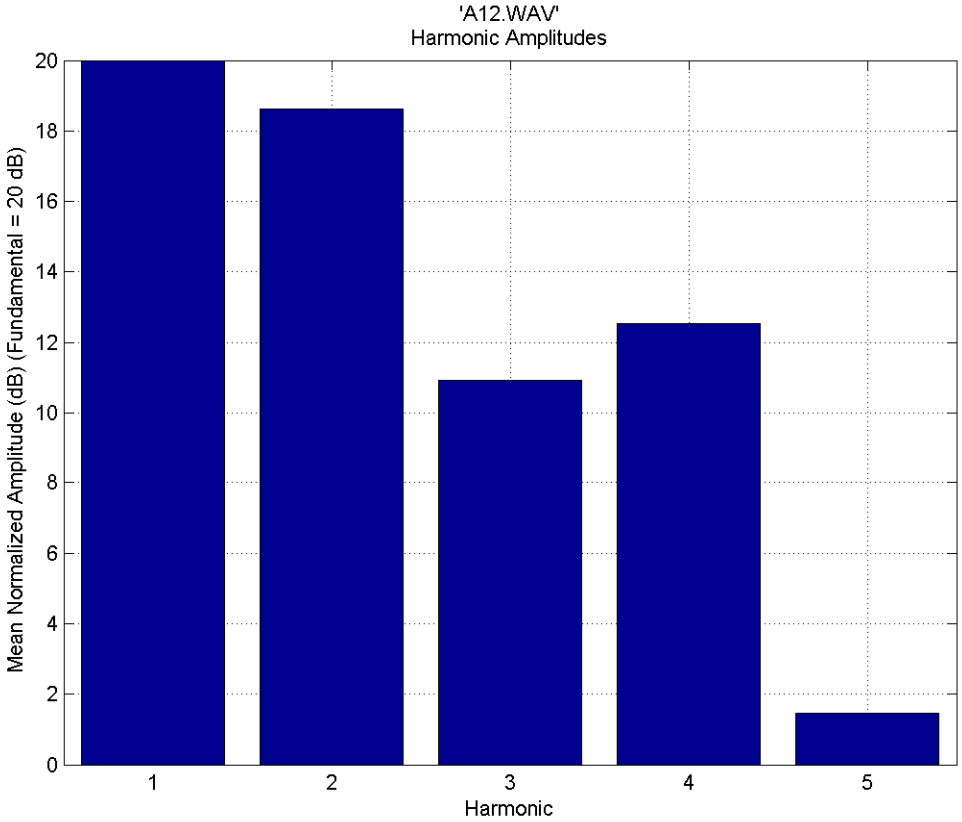


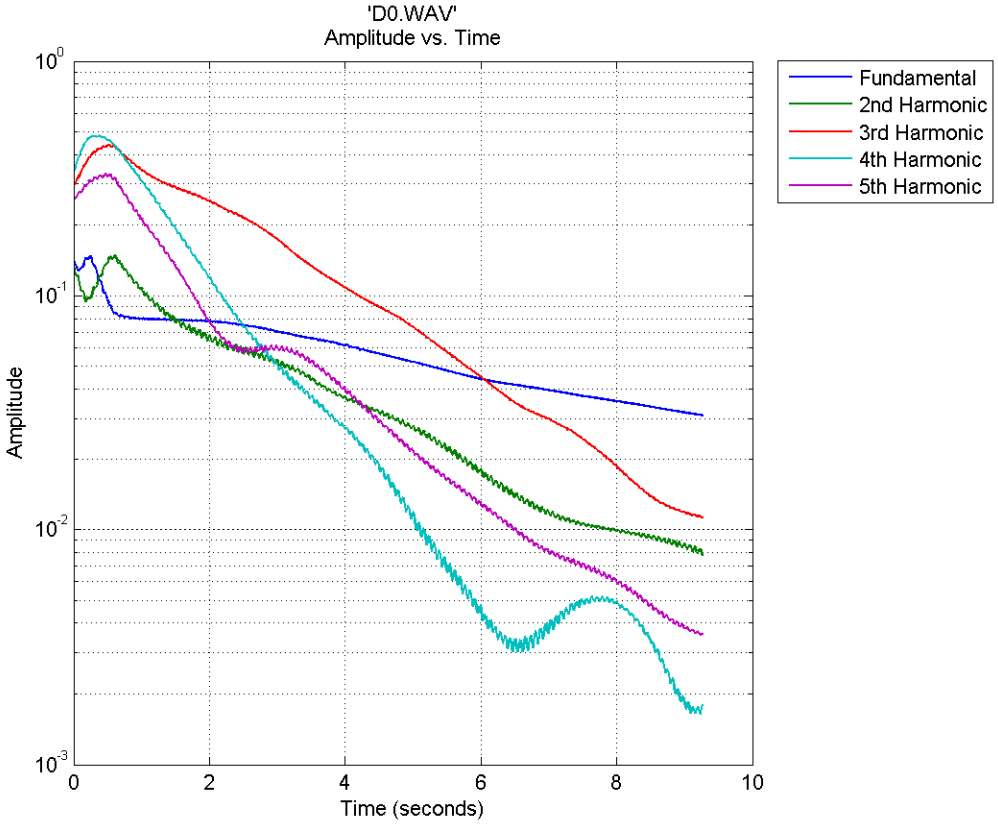


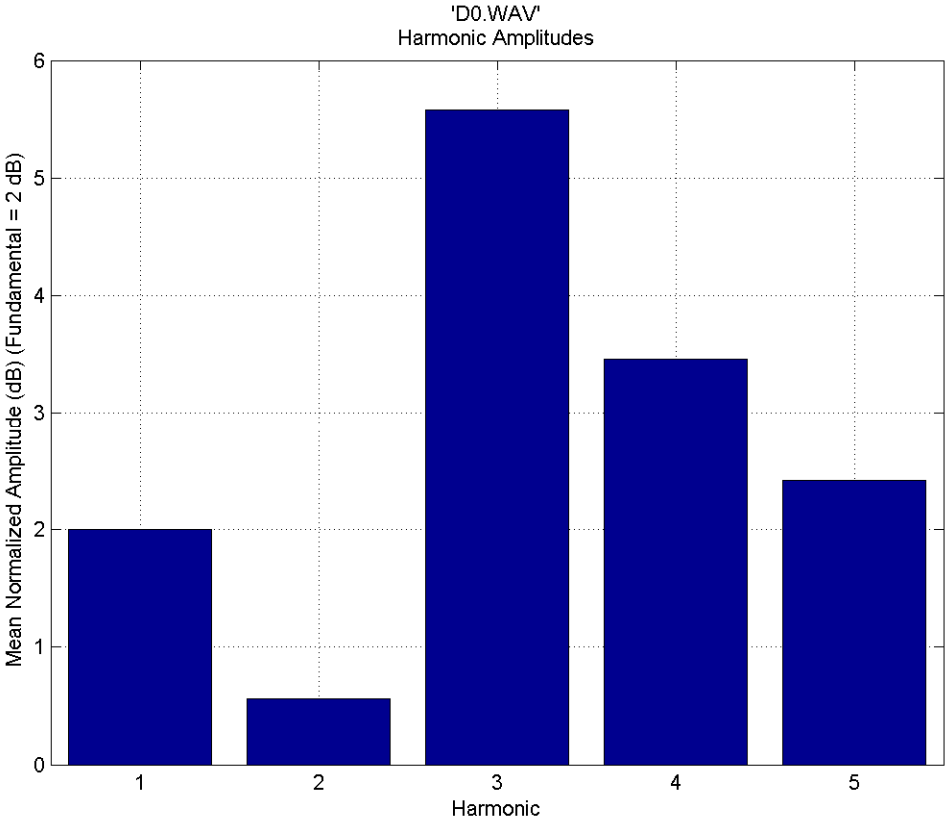

'A4.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)

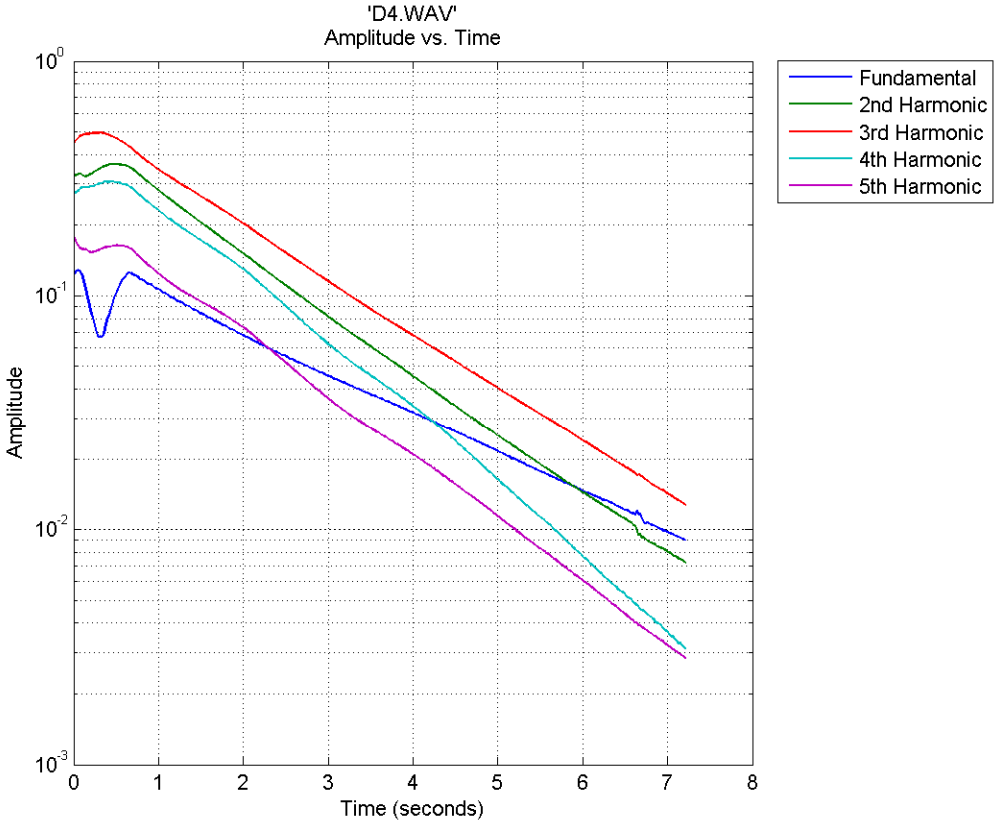

'A4.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 4 dB)
Harmonic

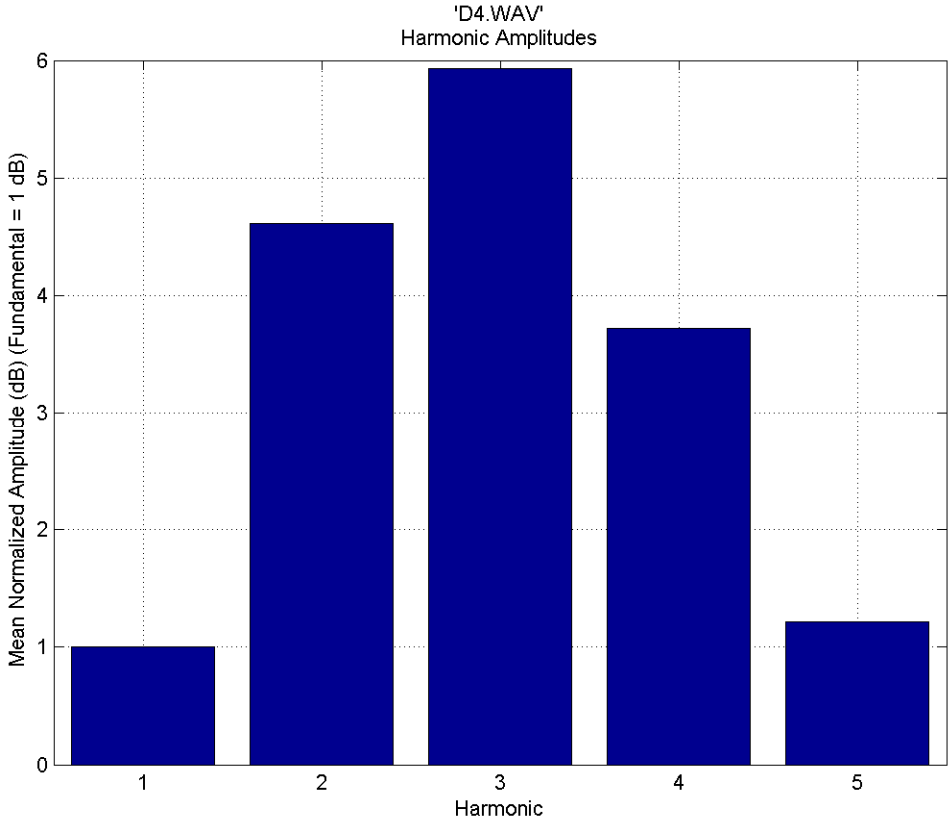

'A12.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)

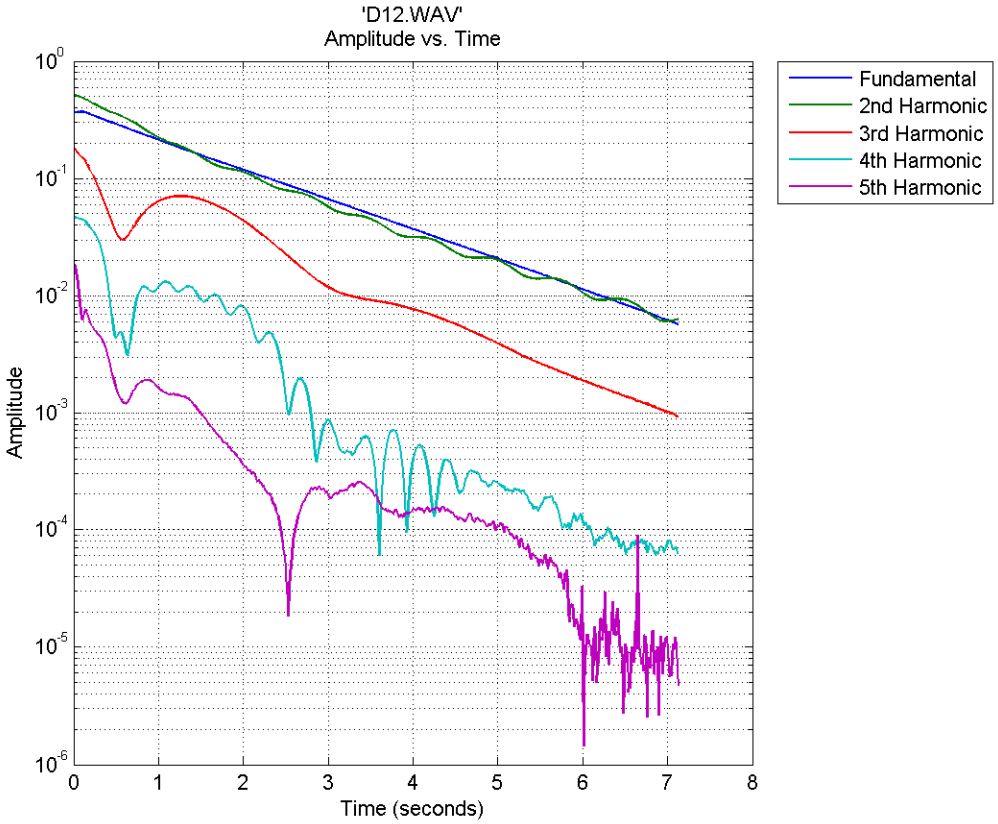

'A12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 20 dB)
Harmonic

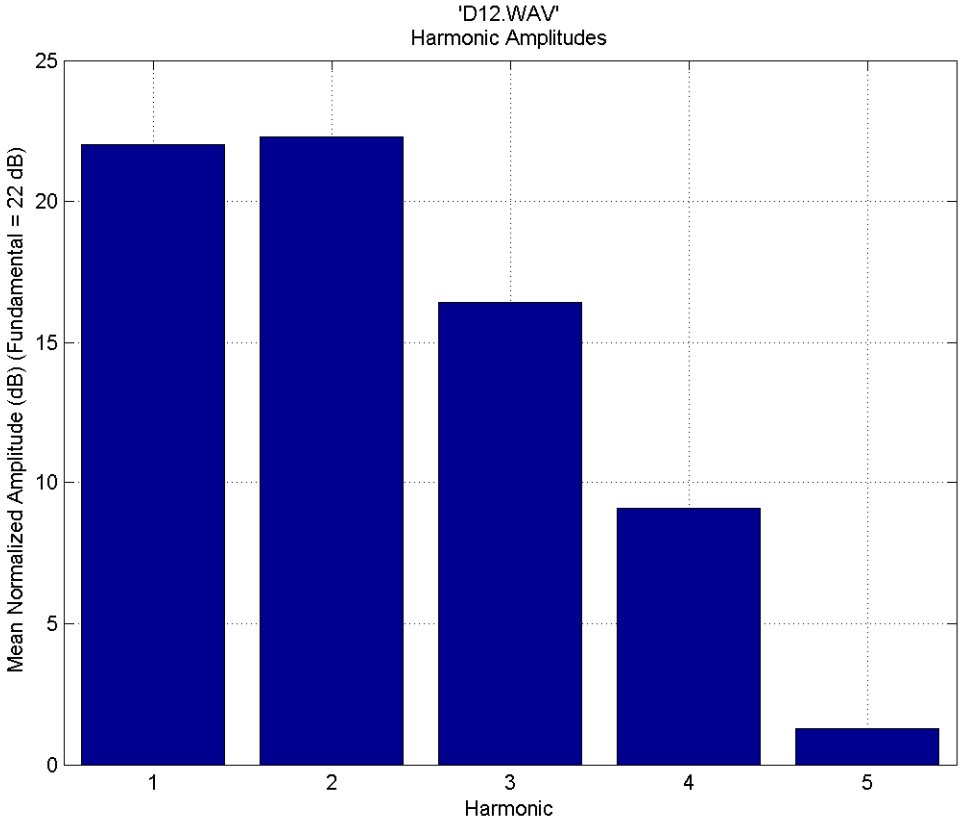

'D0.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)

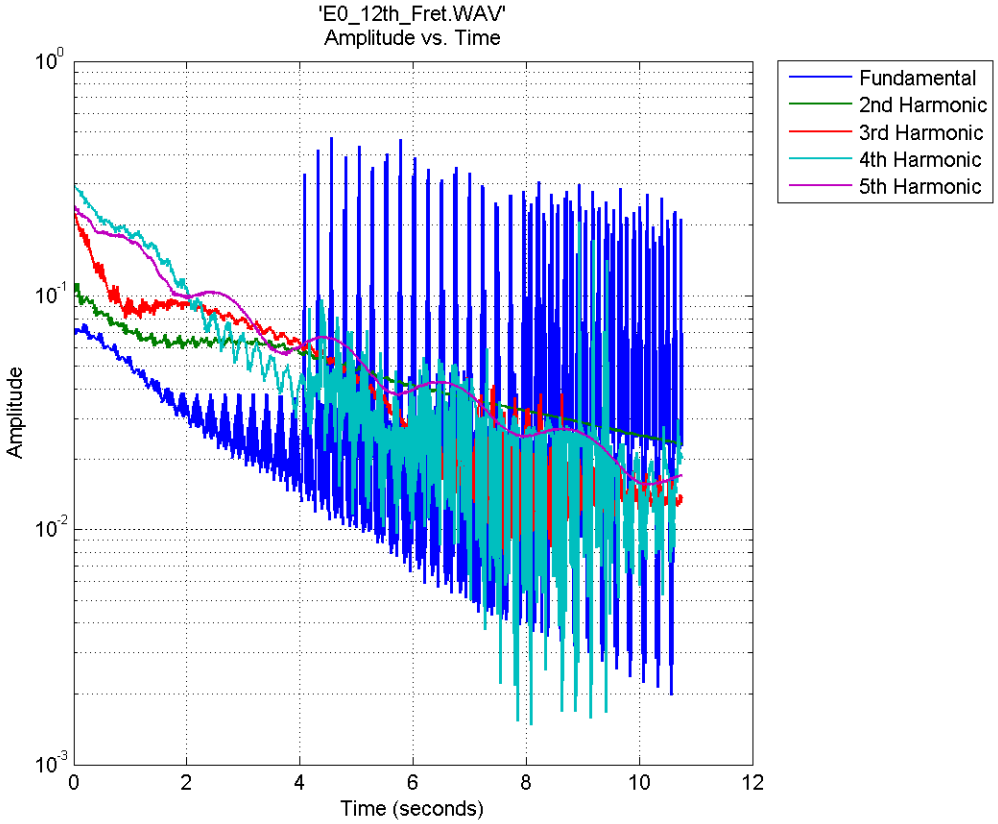

'D0.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 2 dB)
Harmonic

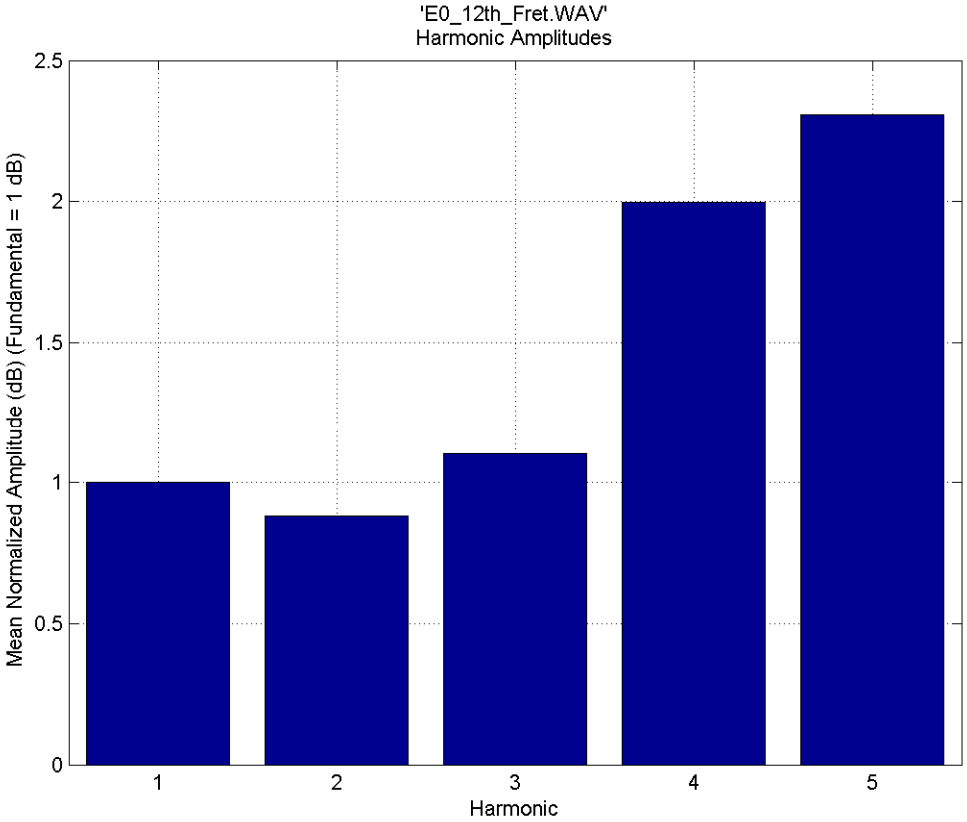

'D4.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic

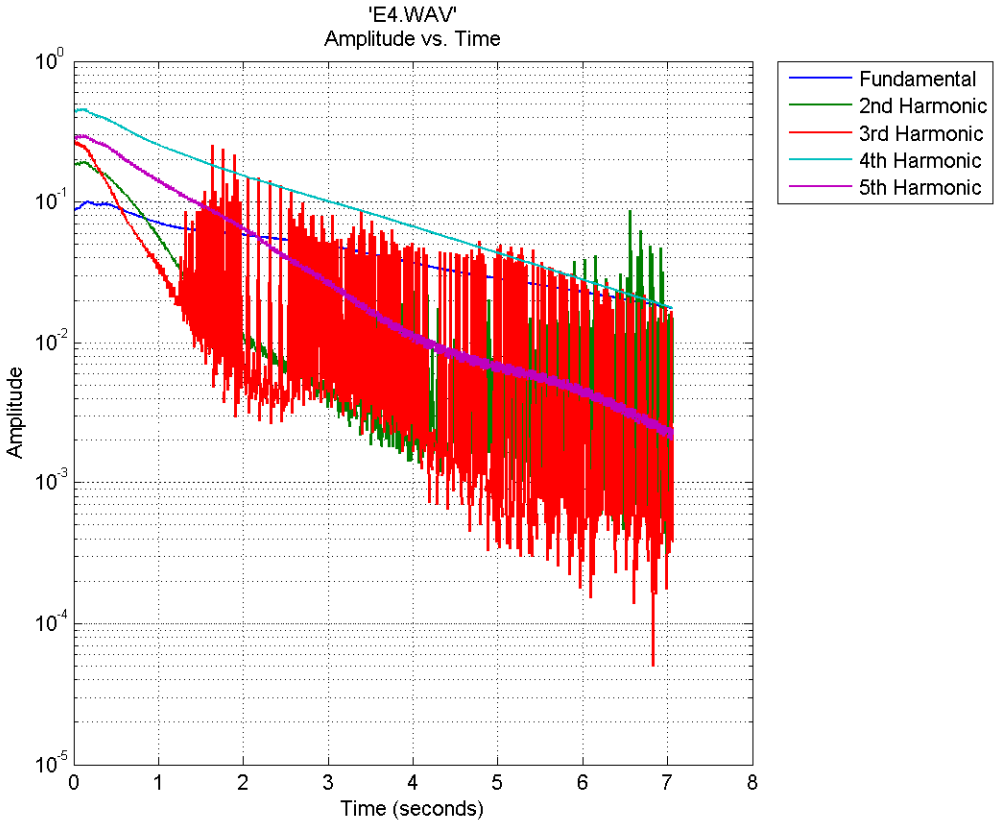

'D4.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 1 dB)
Harmonic

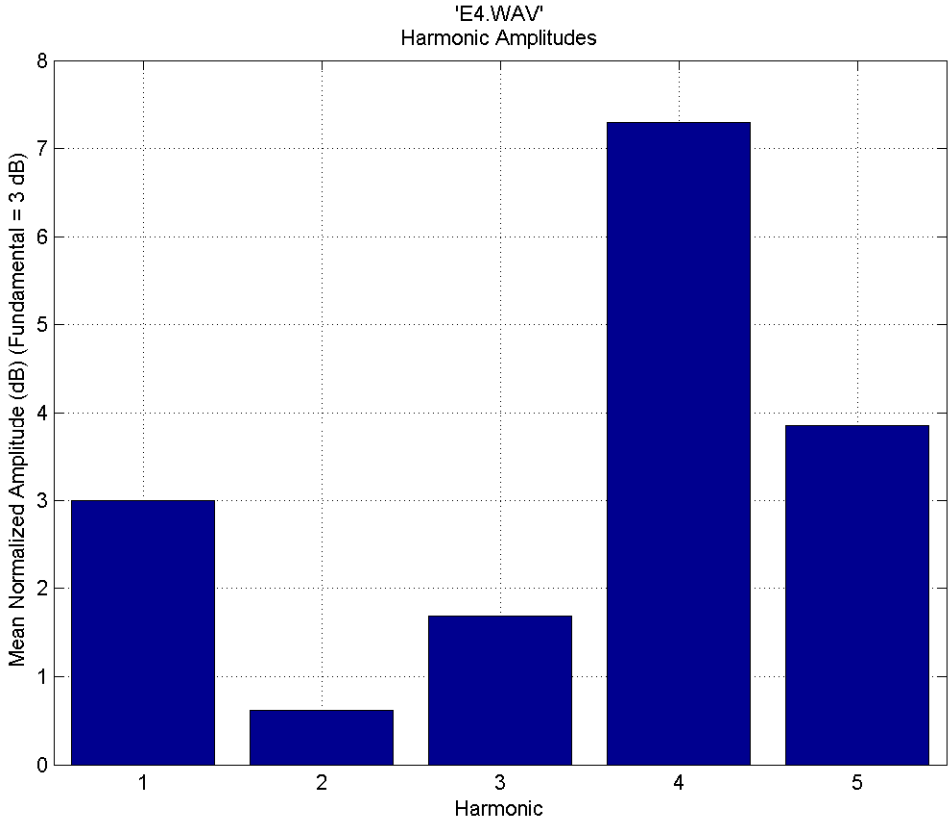

'D12.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic

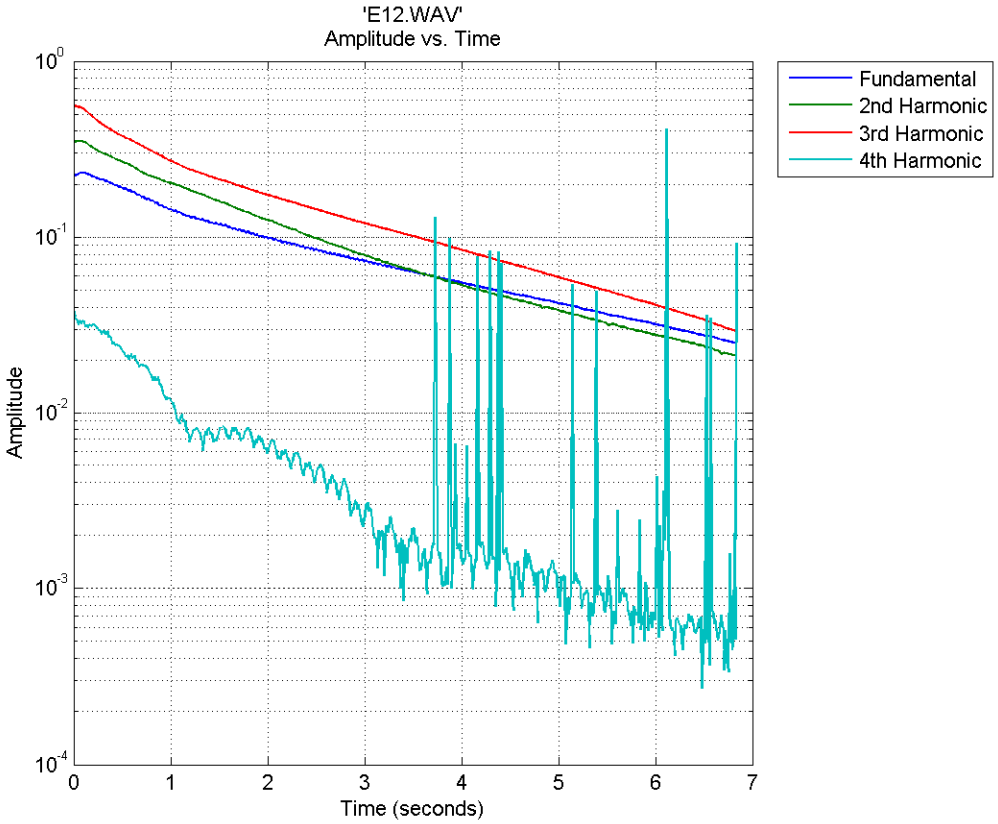

'D12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 22 dB)
Harmonic

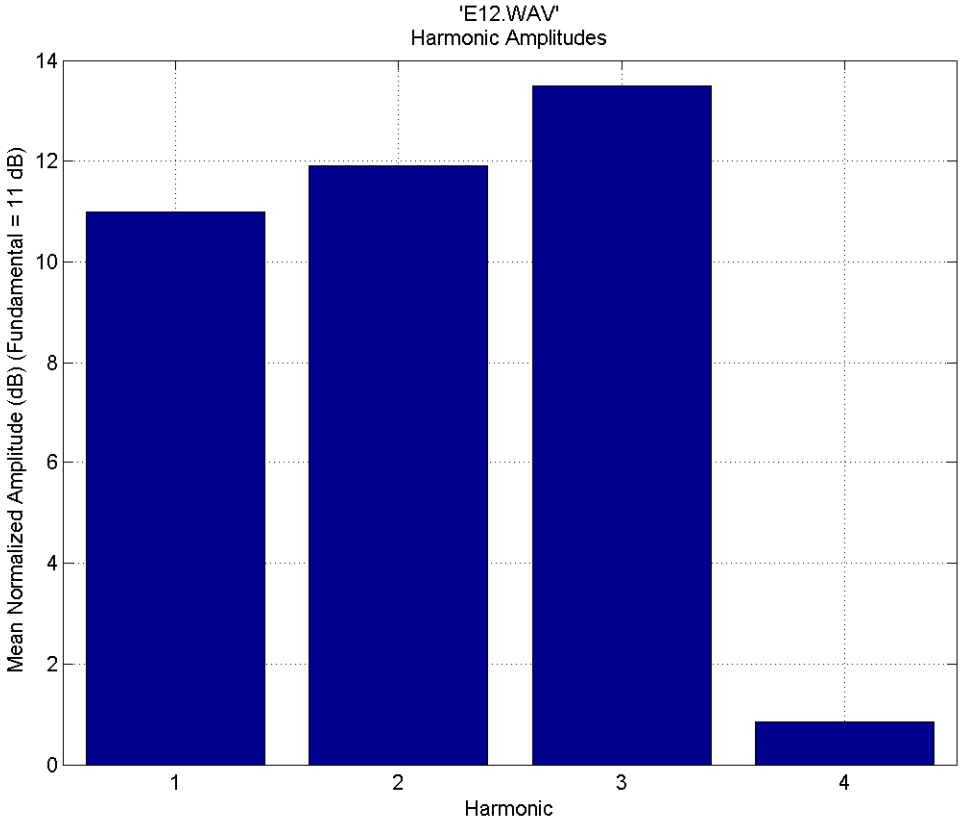

'E0_12th_Fret.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic
Amplitude
Time (seconds)

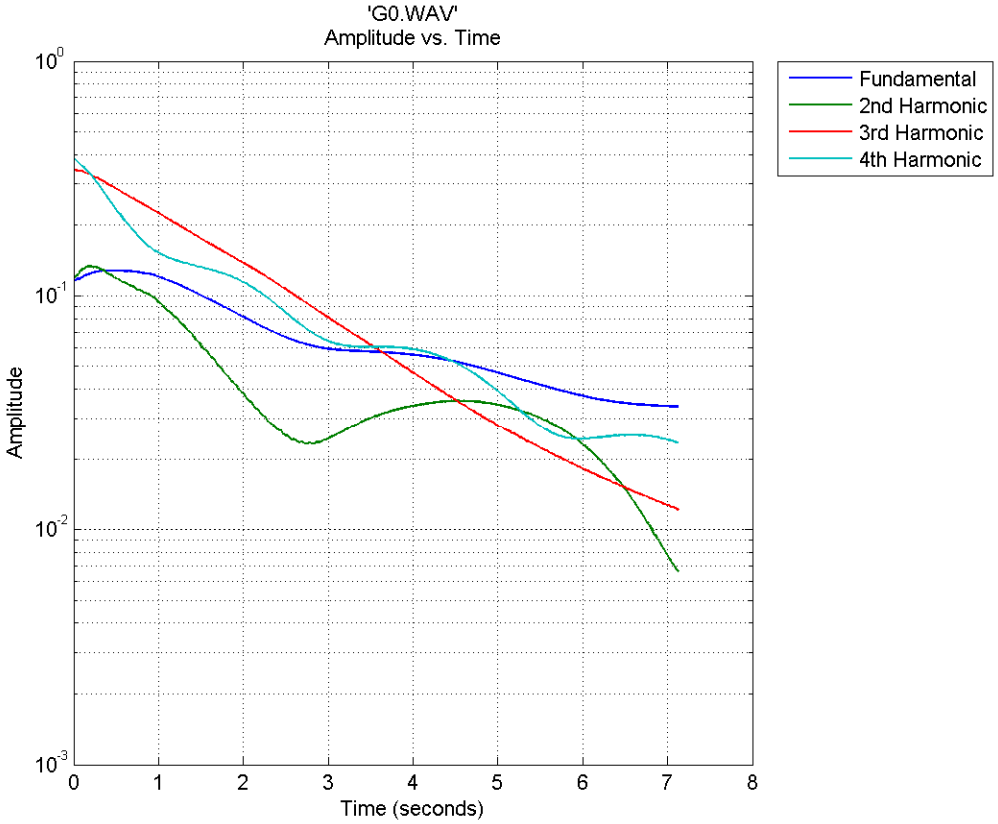

'E0_12th_Fret.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 1 dB)
Harmonic

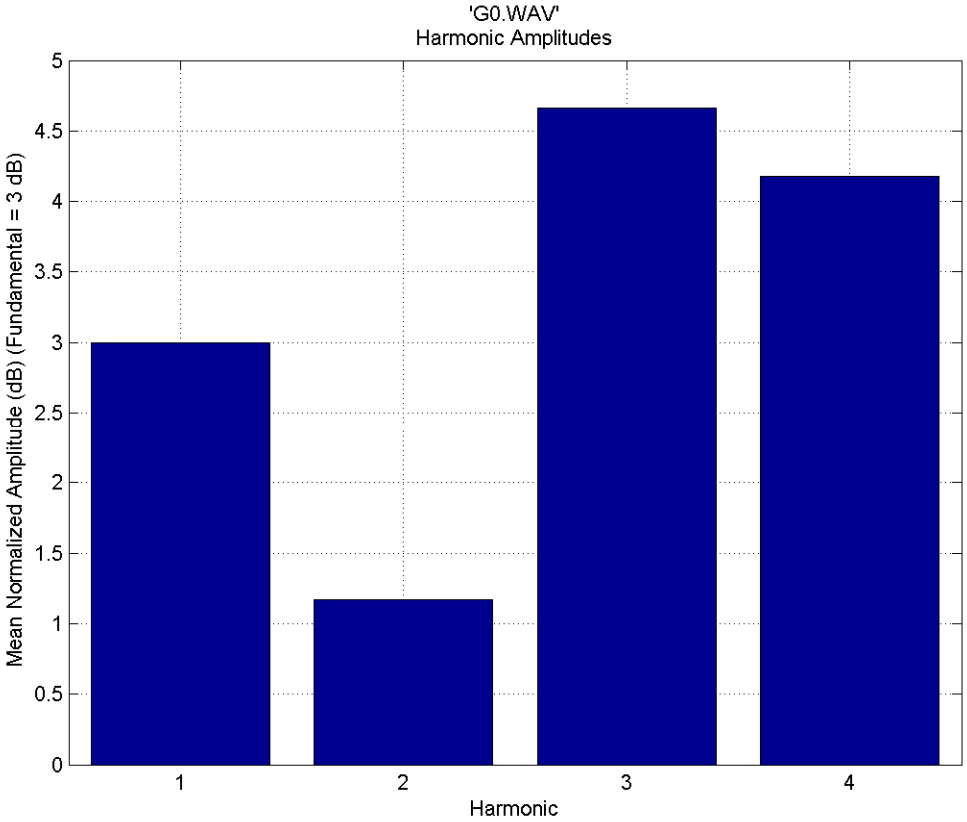

'E4.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
5th Harmonic

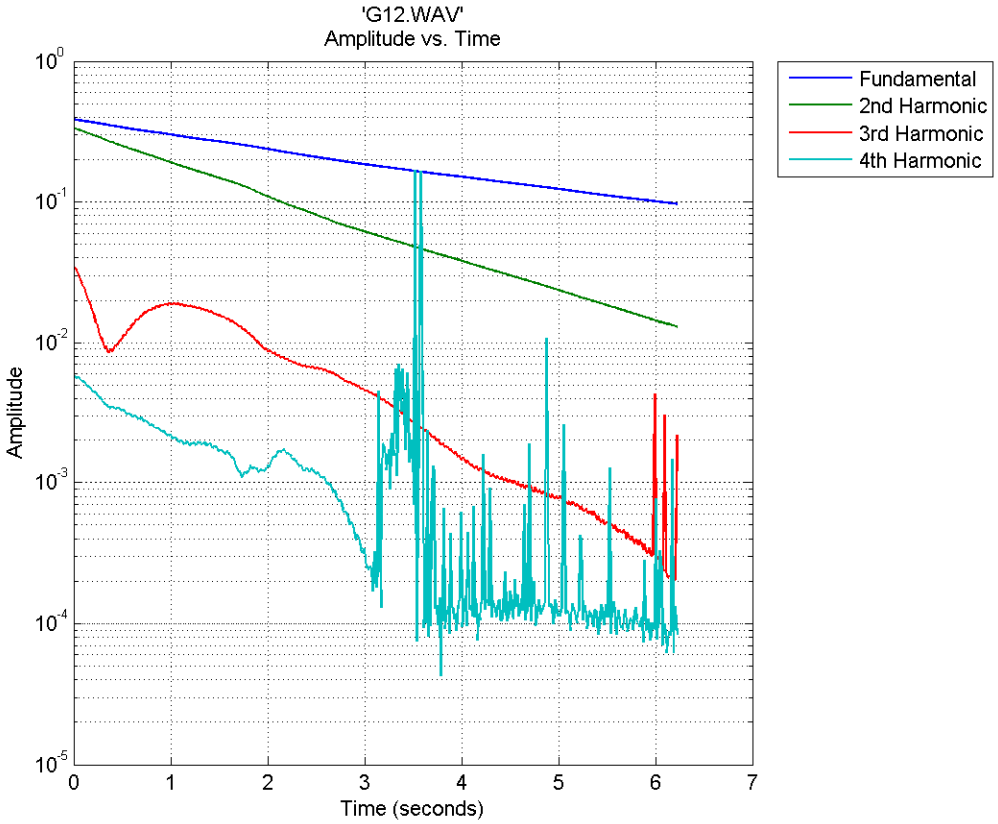

'E4.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 3 dB)
Harmonic

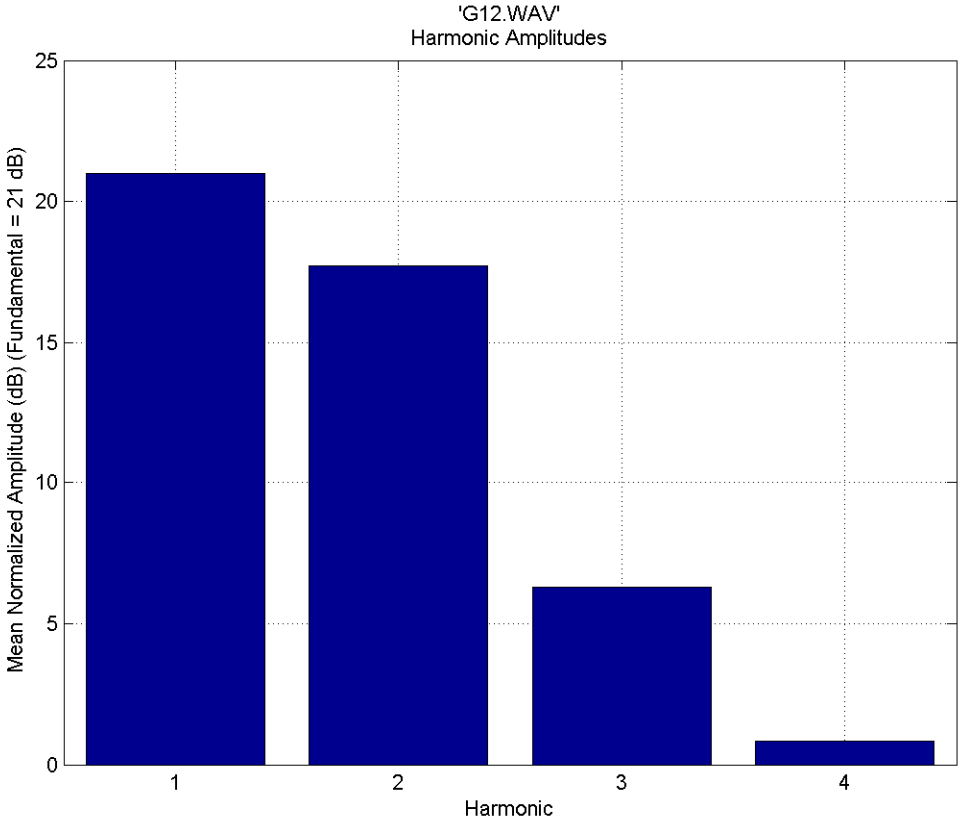

'E12.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)


'E12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 11 dB)
Harmonic

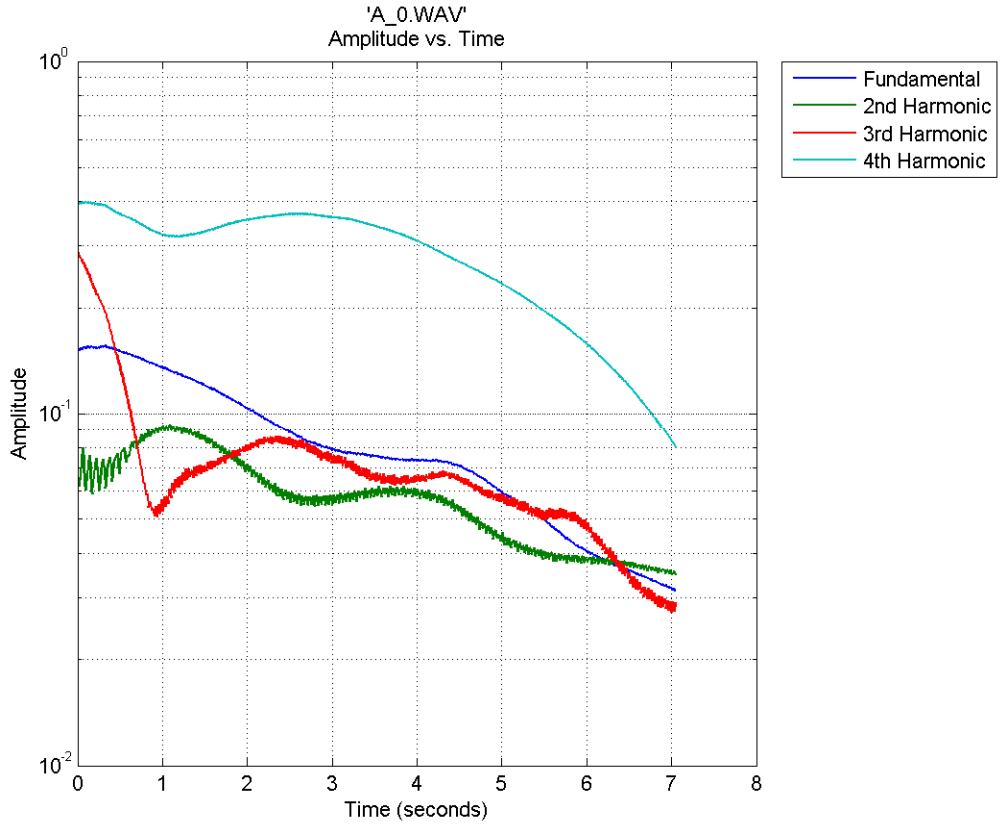

'G0.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

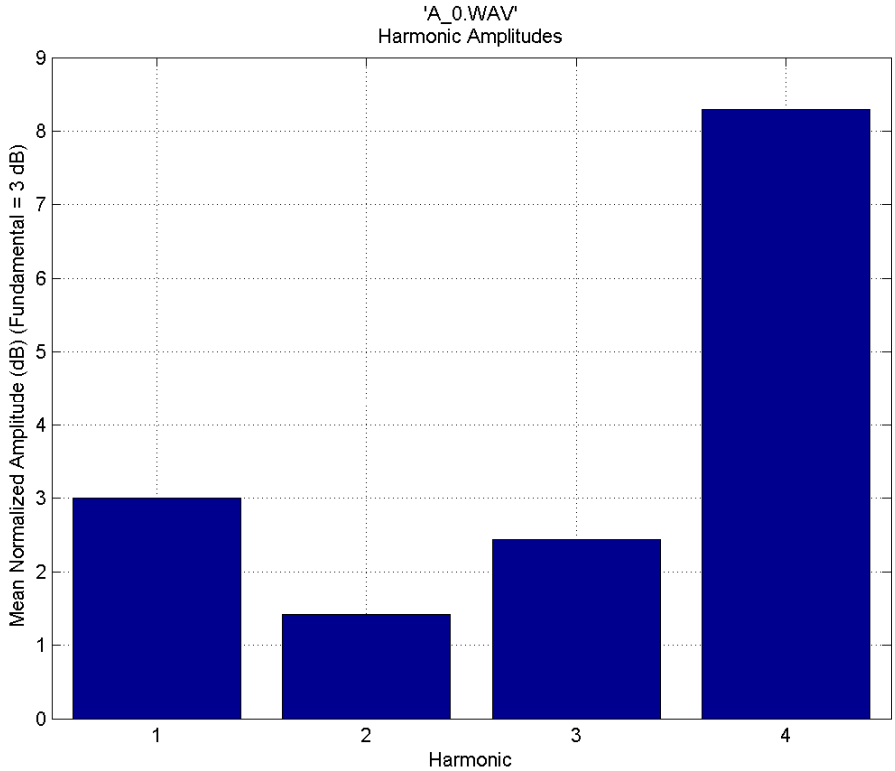

'G0.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 3 dB)
Harmonic

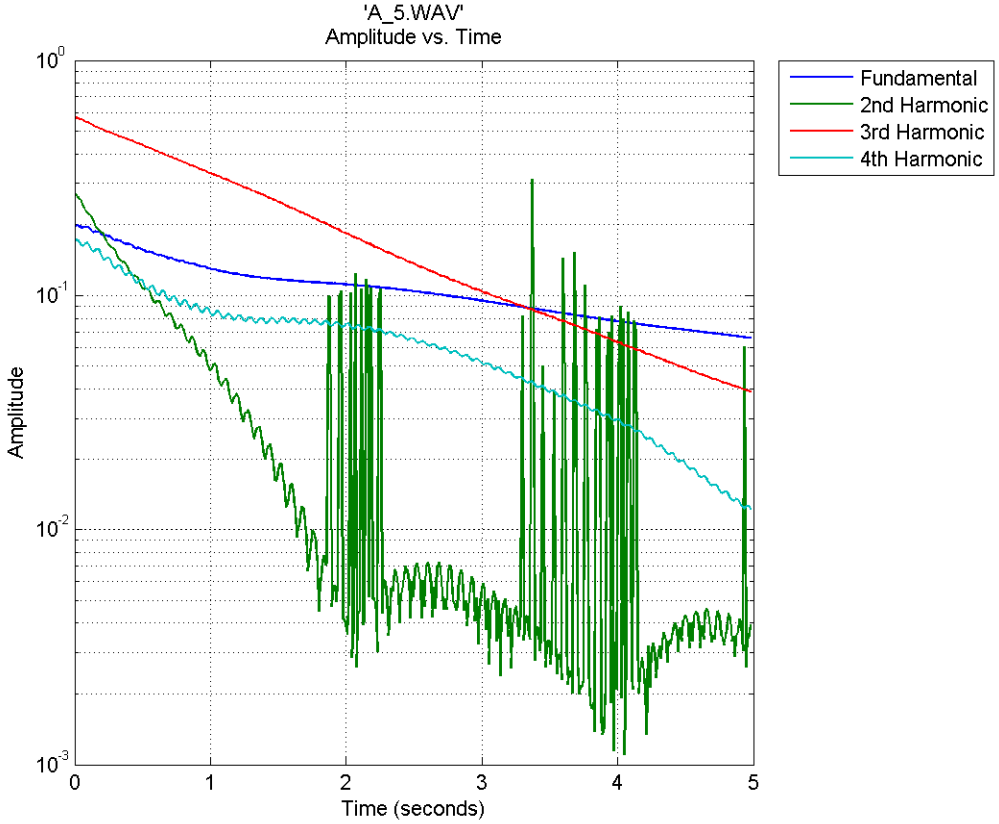

'G12.WAV'
Amplitude vs. Time
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
Amplitude
Time (seconds)

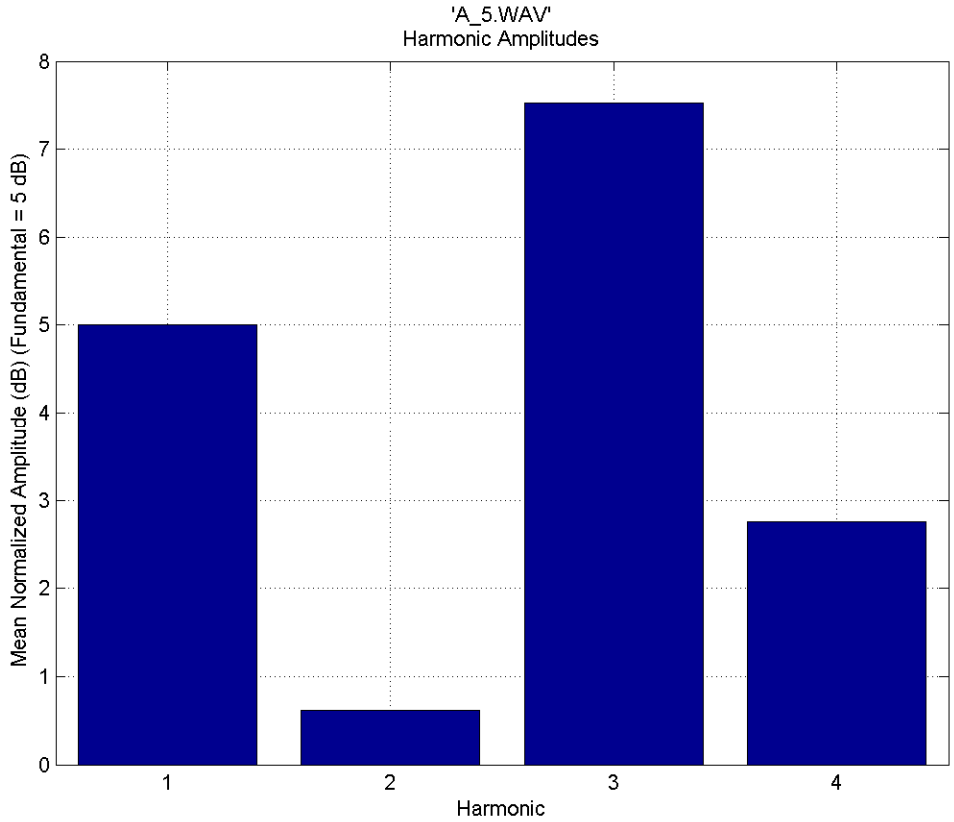

'G12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 21 dB)
Harmonic

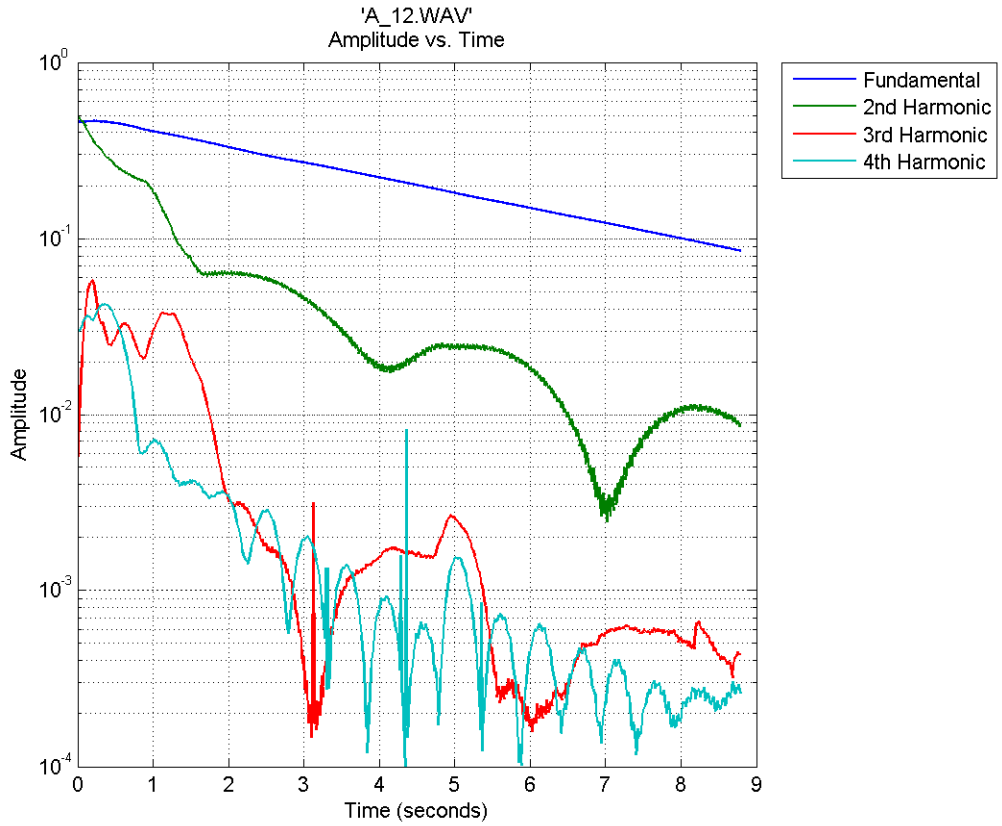
6. 2003 Music Man Sterling with hybrid slinky Strings

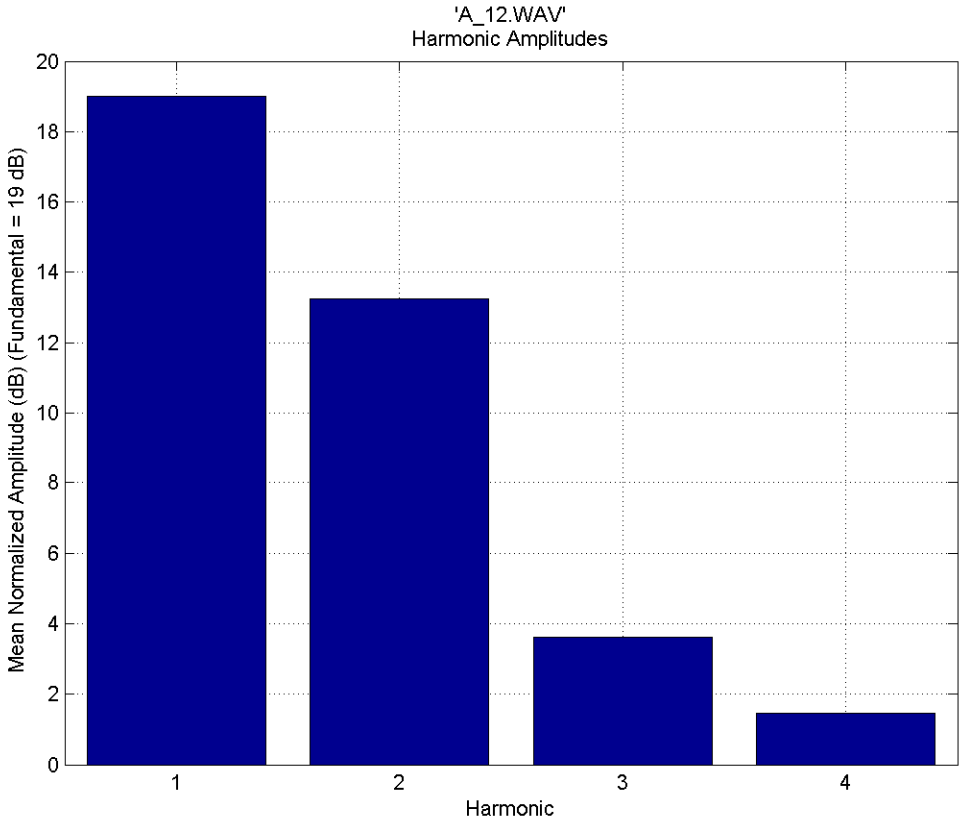


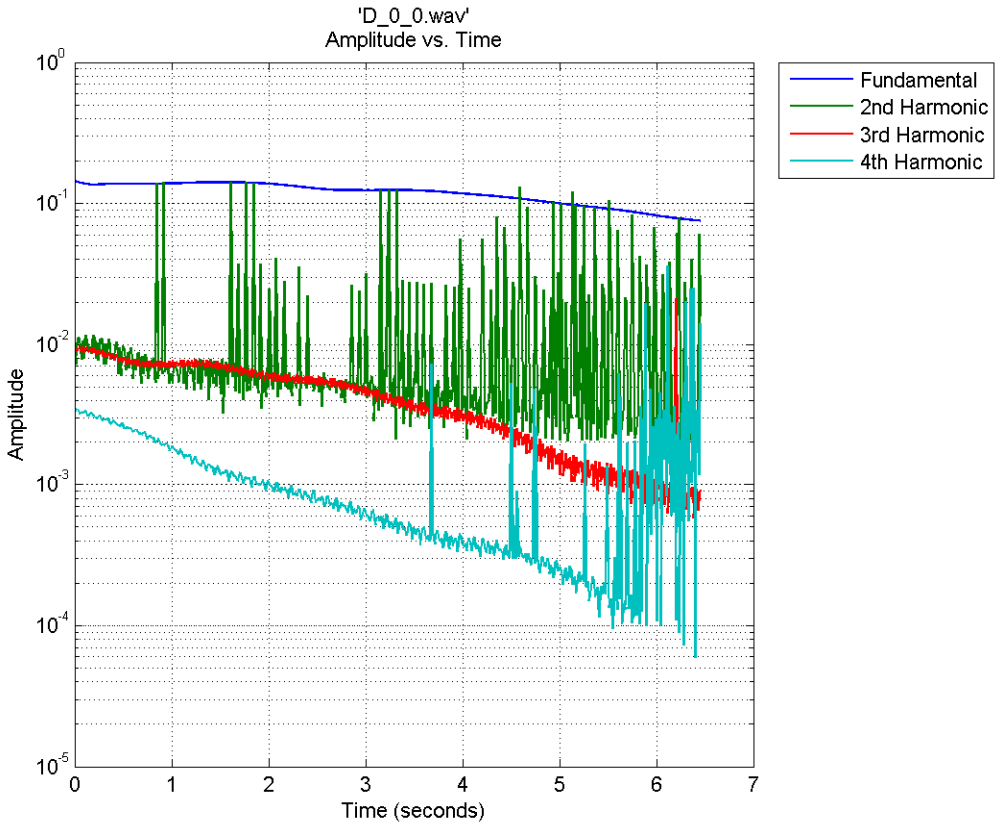

'A_0.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 3 dB)
Harmonic
0
1
2
3
4
5
6
7
8
9
1
2
3
4

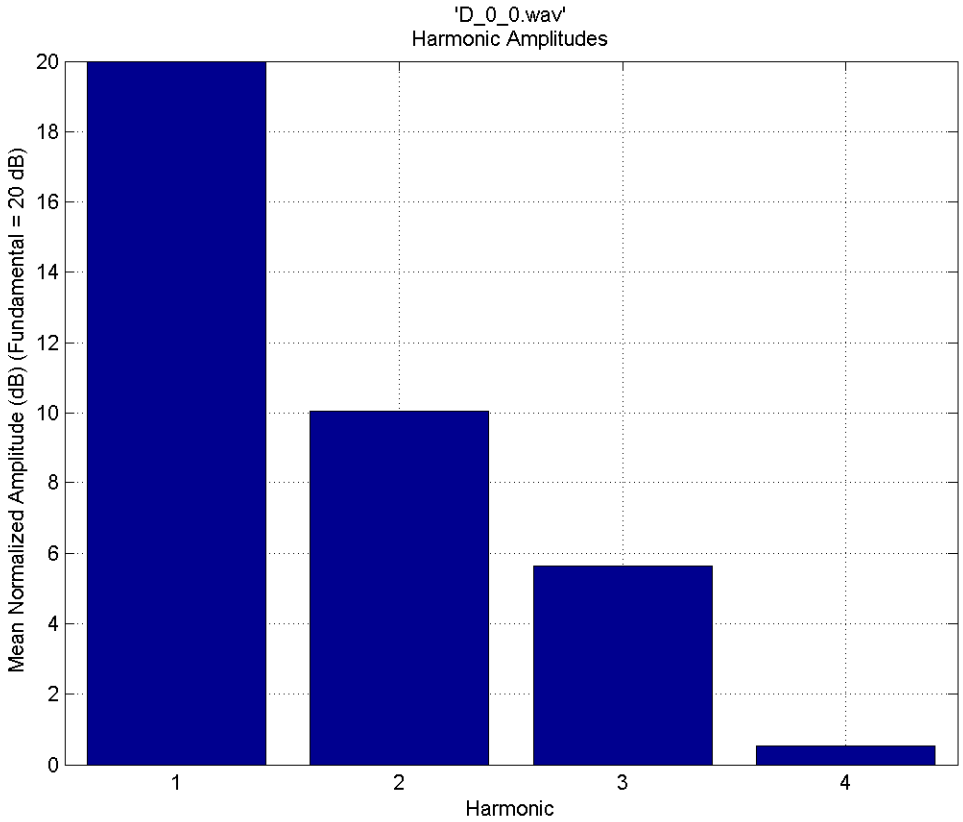

'A_5.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5

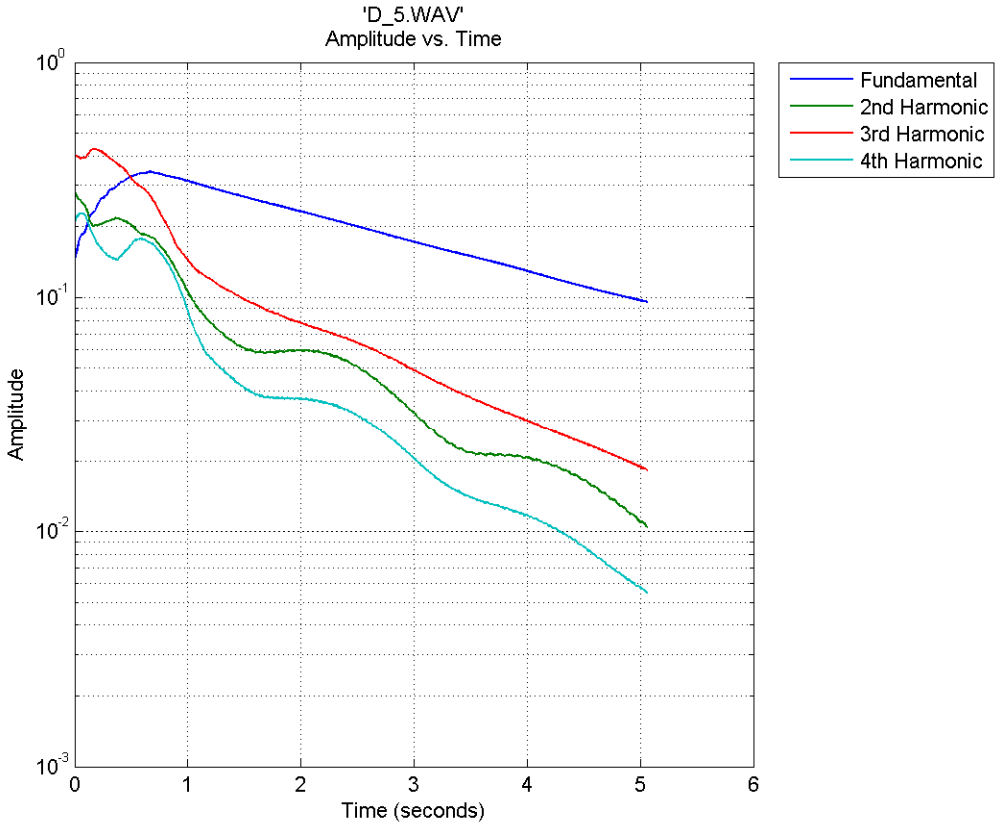

'A_5.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 5 dB)
0
1
2
3
4
5
6
7
8
1
2
3
4
Harmonic

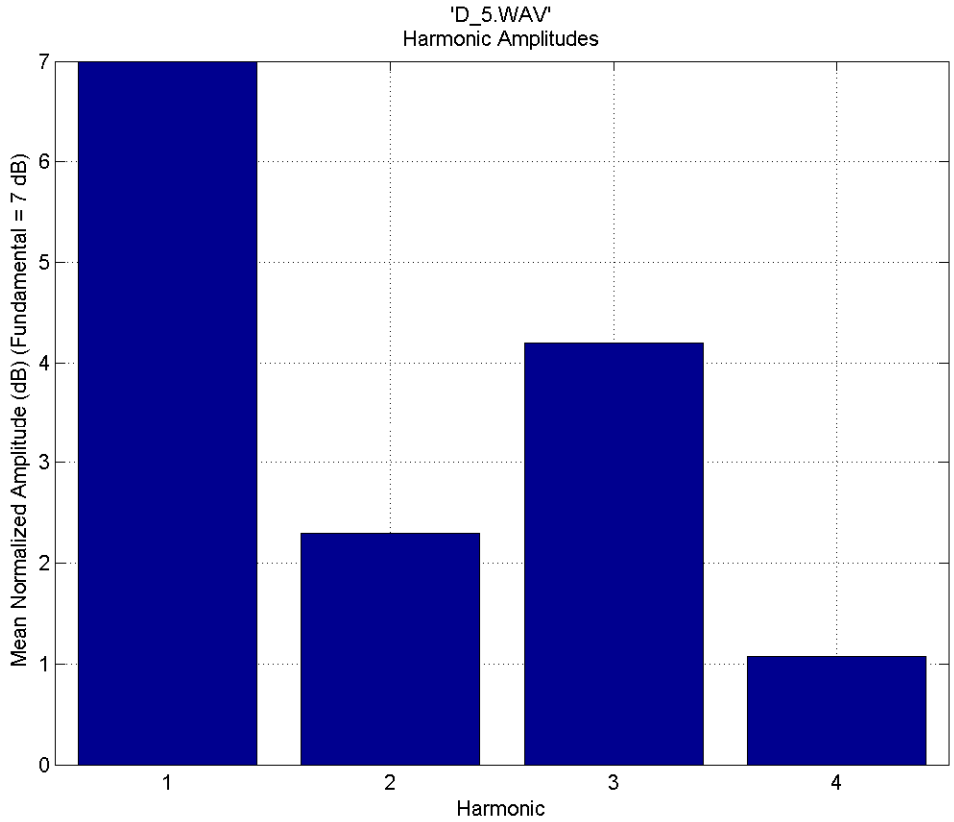

'A_12.WAV'
Amplitude vs. Time
Amplitude
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
1
2
3
4
5
6
7
8
9
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic

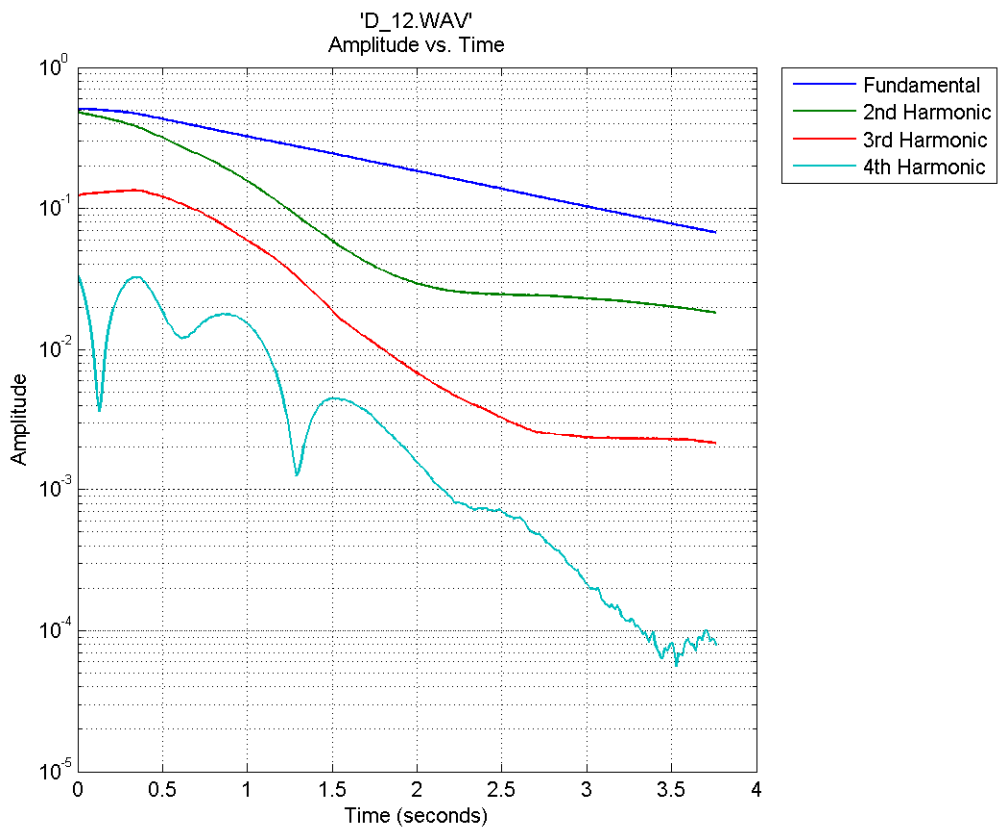

'A_12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 19 dB)
Harmonic
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4

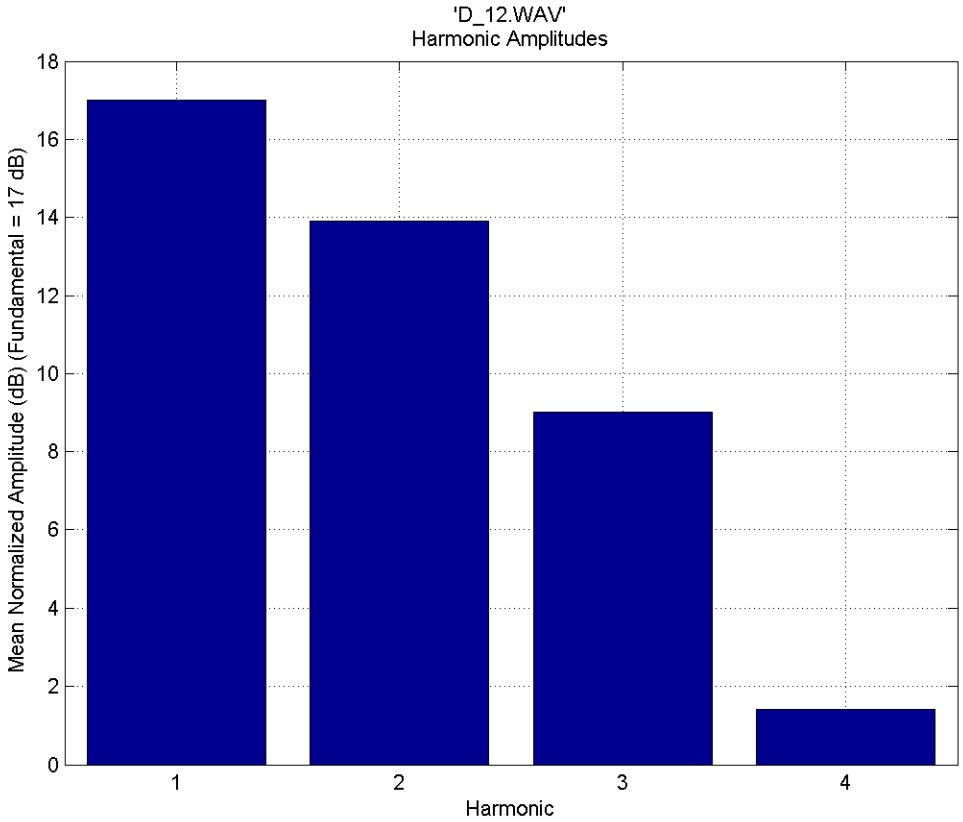

'D_0_0.wav'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
1
2
3
4
5
6
7

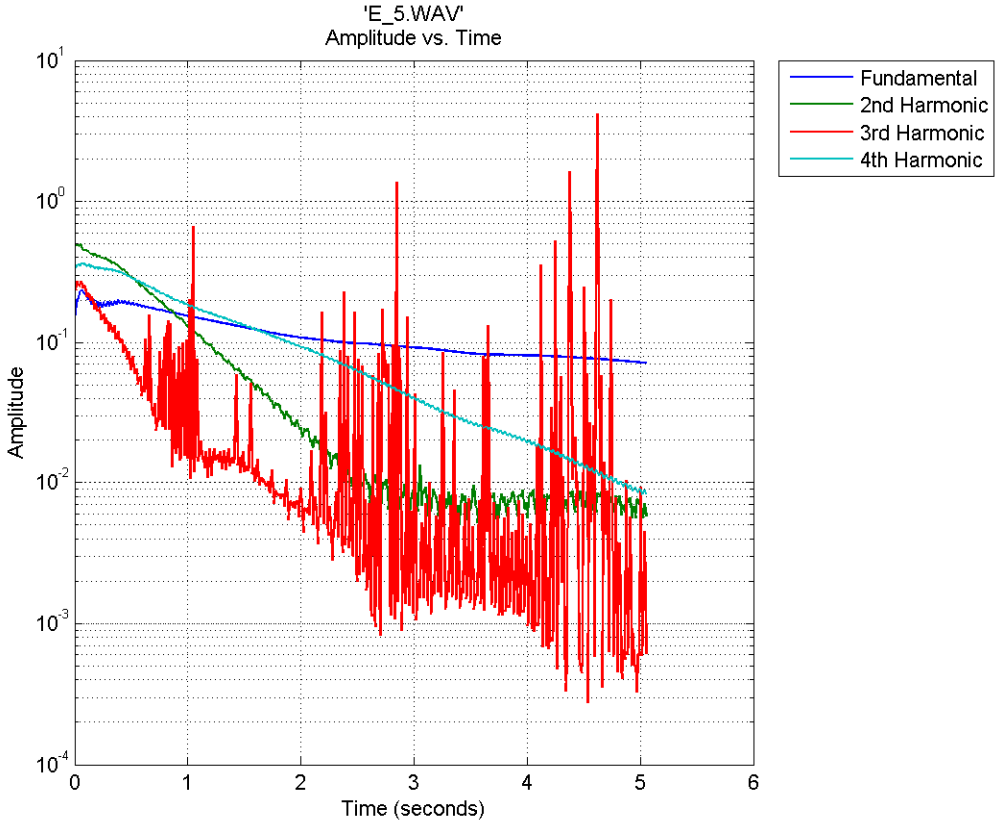

'D_0_0.wav'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 20 dB)
Harmonic
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4

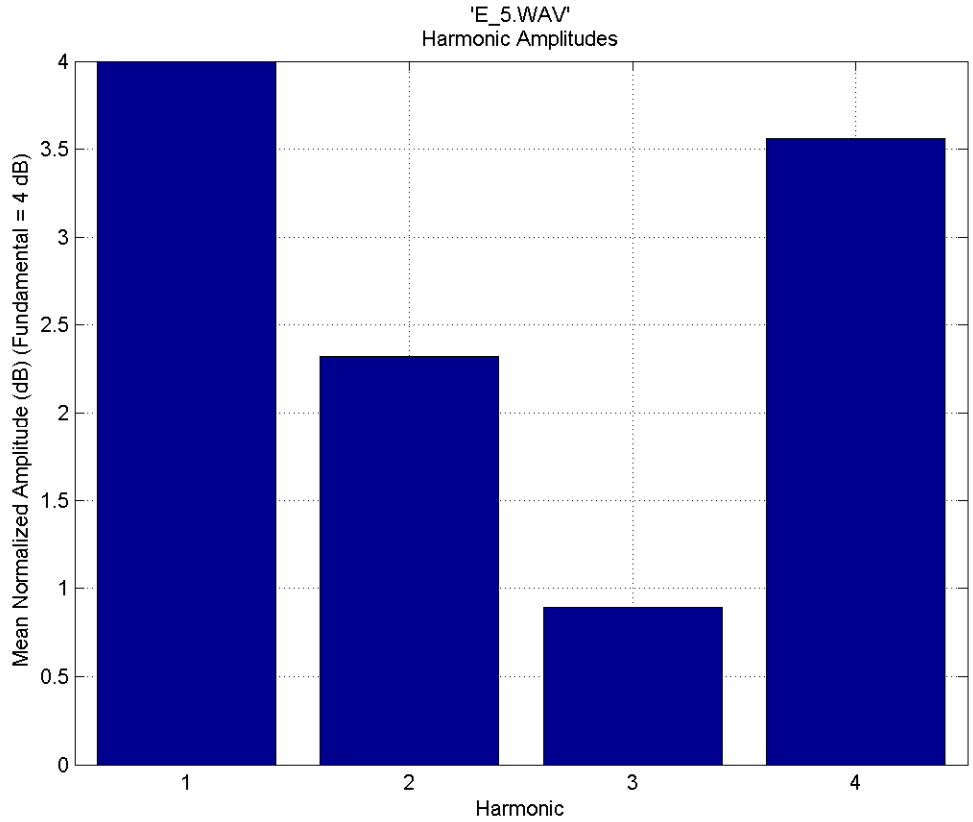

'D_5.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5
6
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic

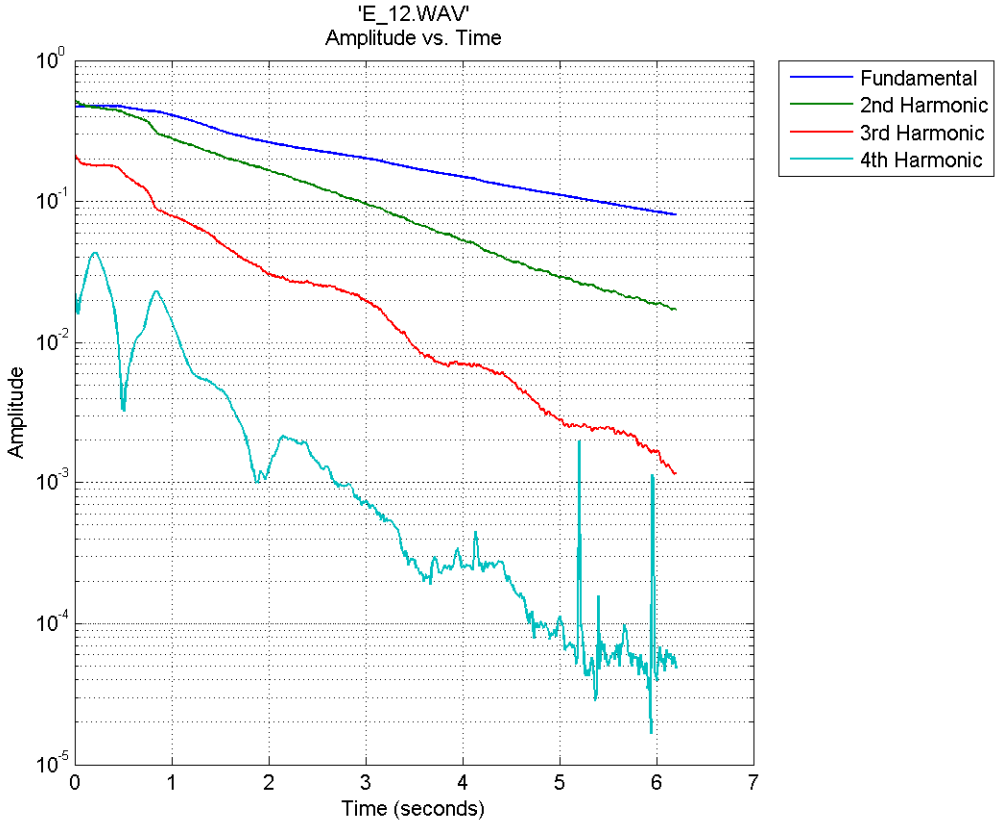

'D_5.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 7 dB)
0
1
2
3
4
5
6
7
1
2
3
4
Harmonic

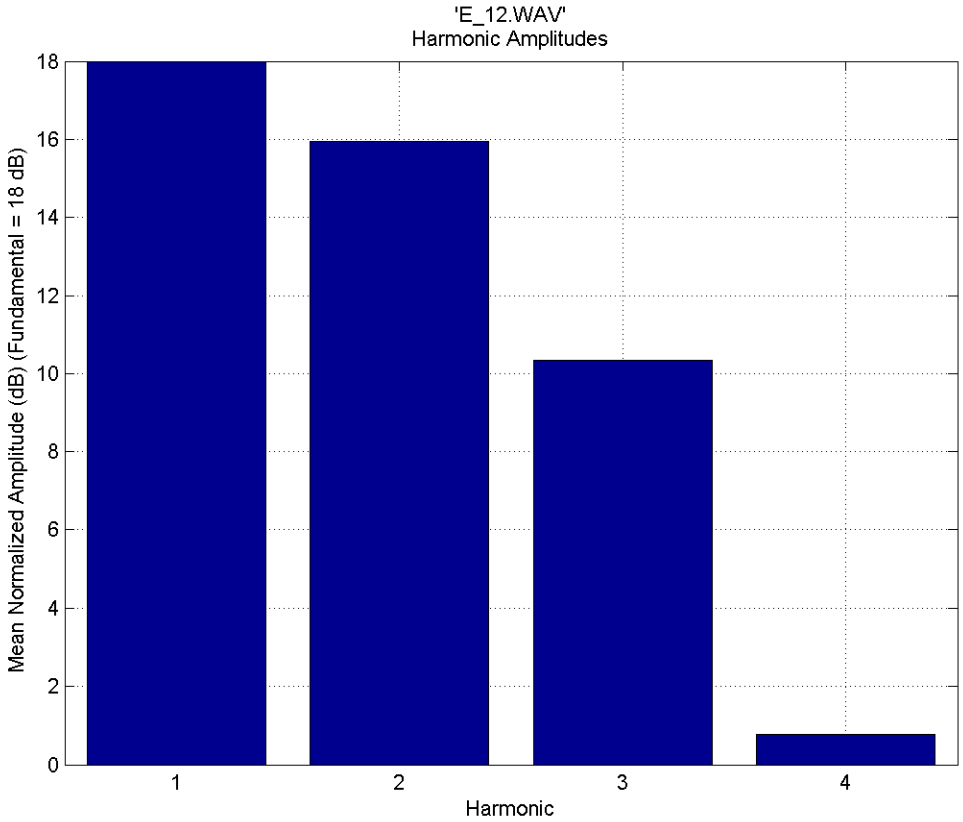

'D_12.WAV'
Amplitude vs. Time
Amplitude
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic

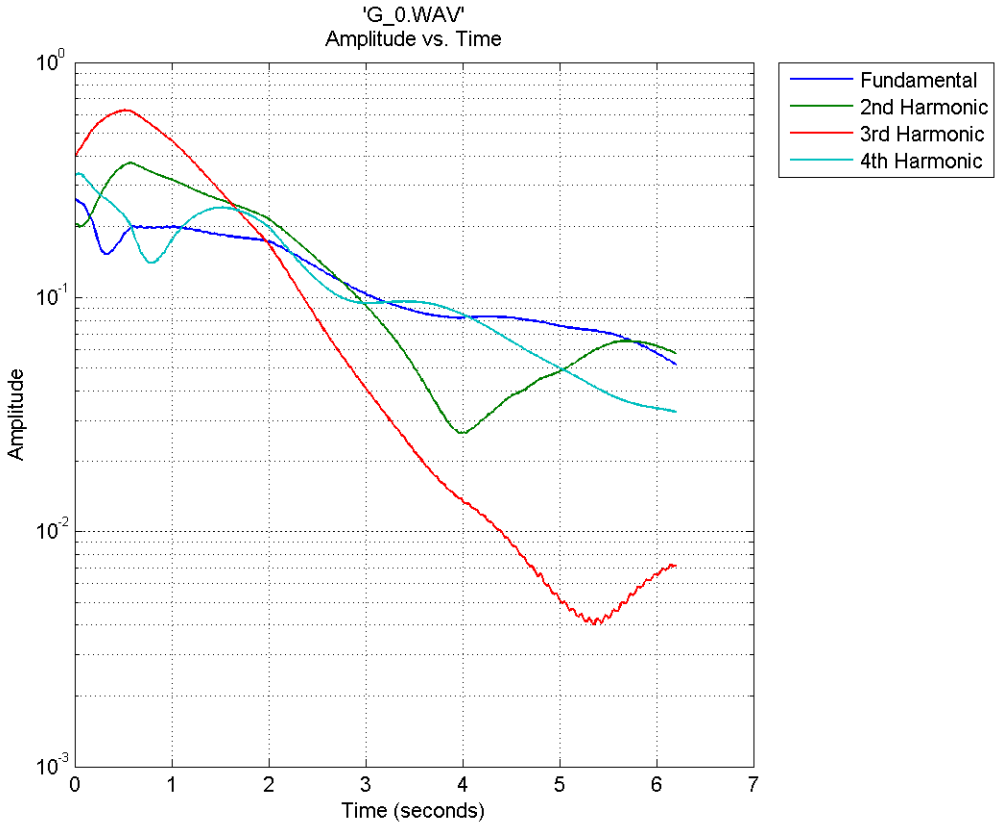

'D_12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 17 dB)
Harmonic
0
2
4
6
8
10
12
14
16
18
1
2
3
4

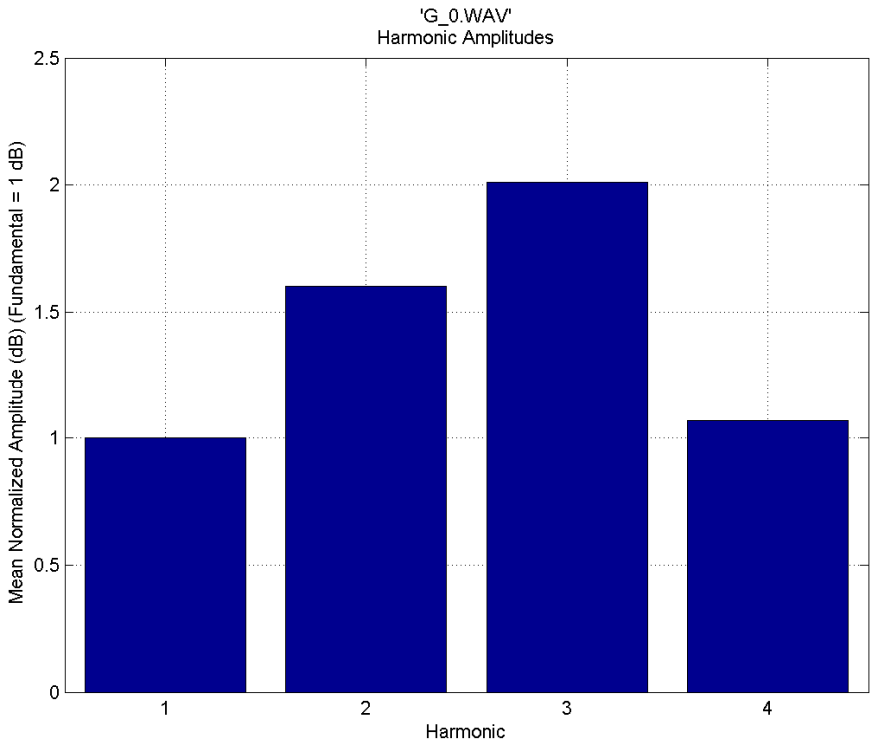

'E_5.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
1
2
3
4
5
6

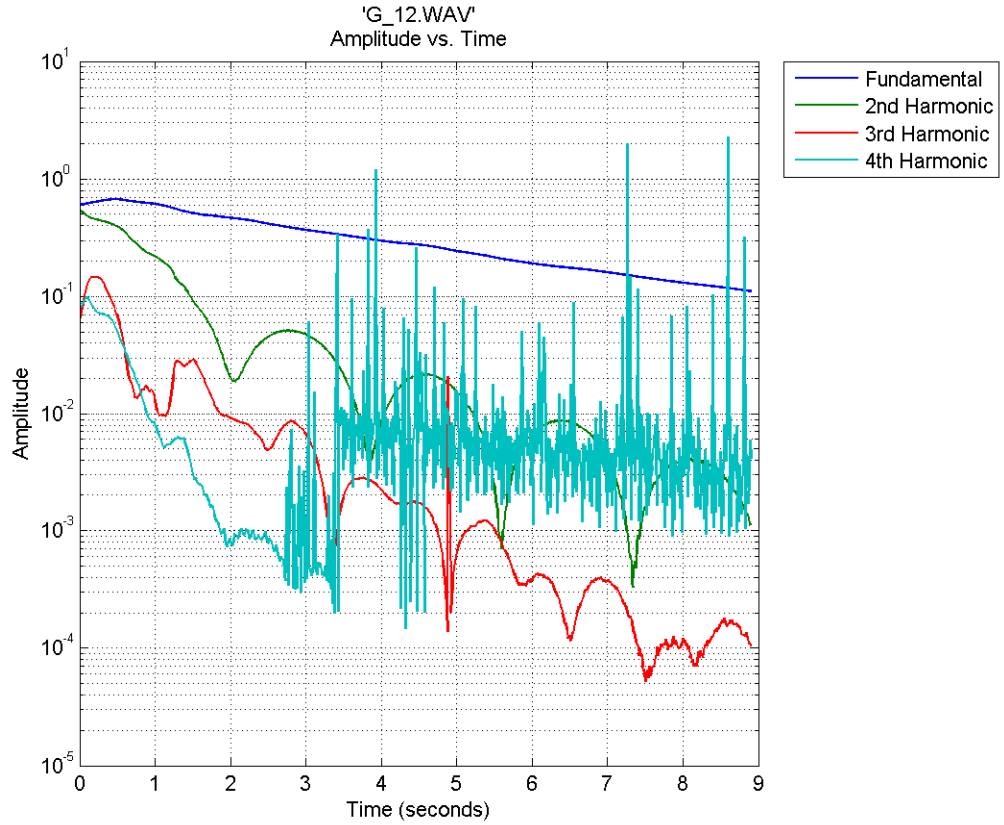

'E_5.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 4 dB)
Harmonic
0
0.5
1
1.5
2
2.5
3
3.5
4
1
2
3
4


'E_12.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
1
2
3
4
5
6
7


'E_12.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 18 dB)
Harmonic
0
2
4
6
8
10
12
14
16
18
1
2
3
4


'G_0.WAV'
Amplitude vs. Time
Amplitude
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5
6
7


'G_0.WAV'
Harmonic Amplitudes
Mean Normalized Amplitude (dB) (Fundamental = 1 dB)
2.5
2
1.5
1
0.5
0
1
2
3
4
Harmonic


'G_12.WAV'
Amplitude vs. Time
Amplitude
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
1
2
3
4
5
6
7
8
9
Time (seconds)
Fundamental
2nd Harmonic
3rd Harmonic
4th Harmonic

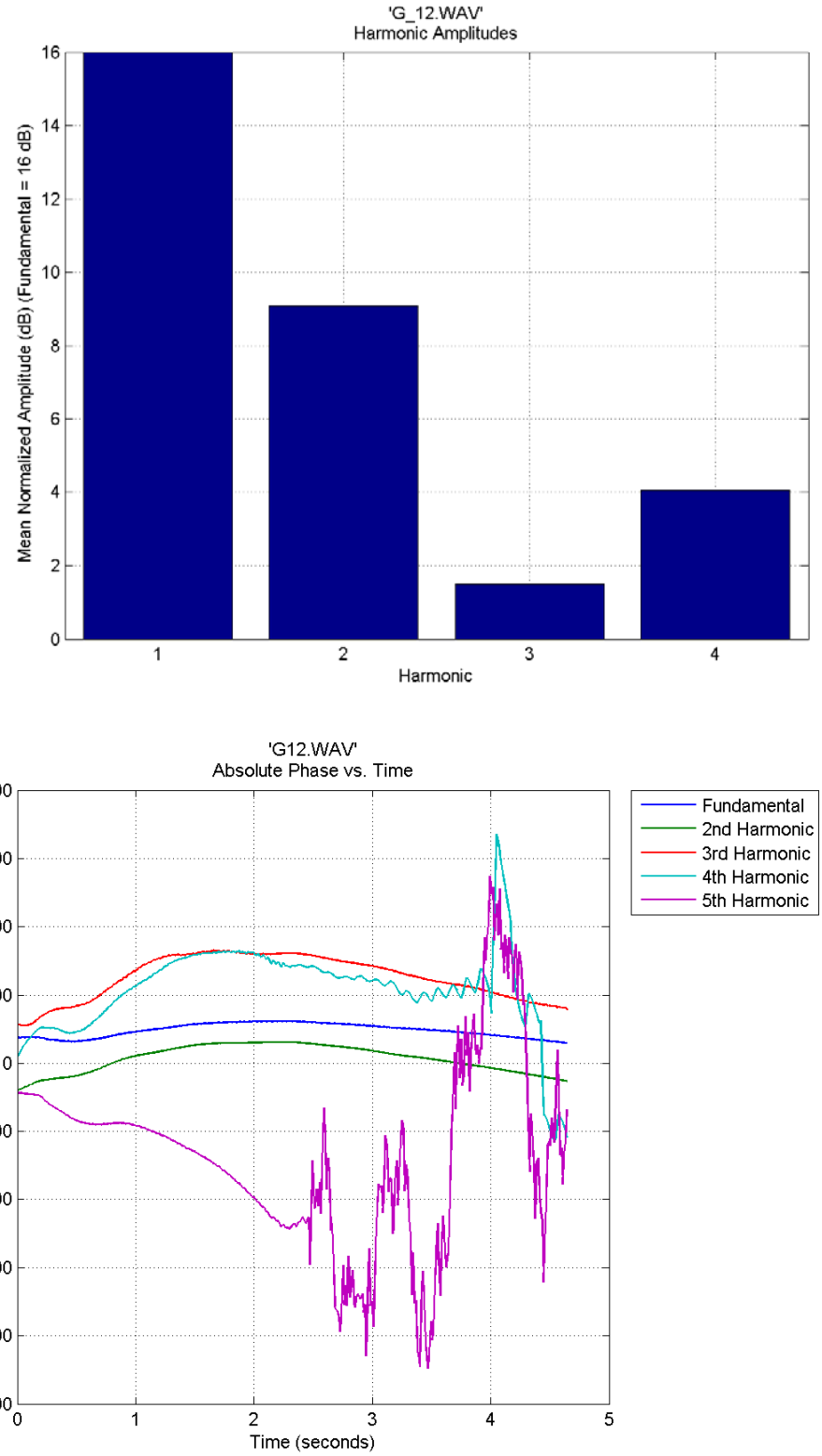


Figure 5: G12Absolute Phase vs. Time for Yamaha RBX-170.

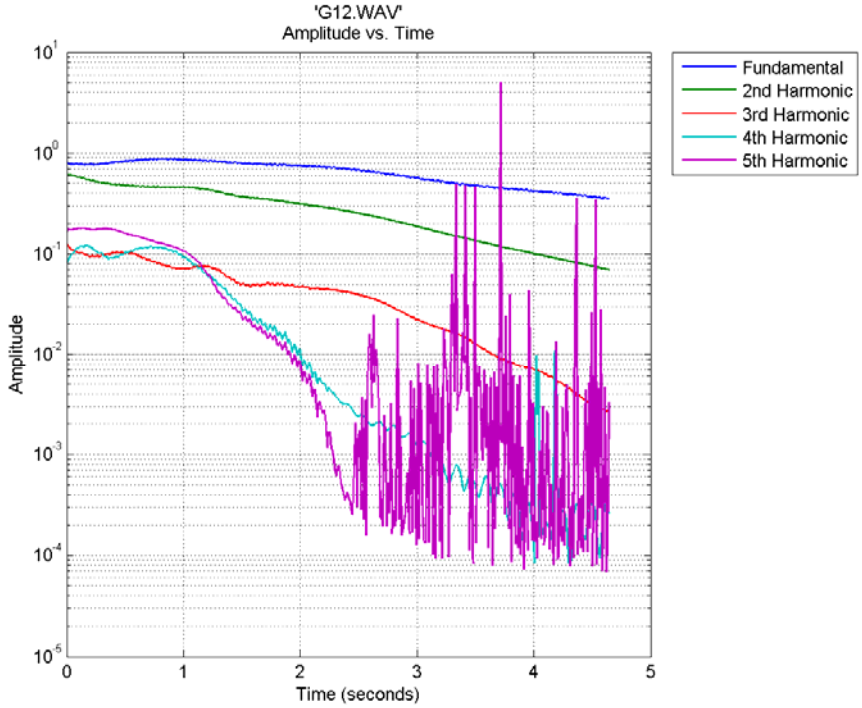


Figure 6: G12Amplitude vs. Time for Yamaha RBX-170.

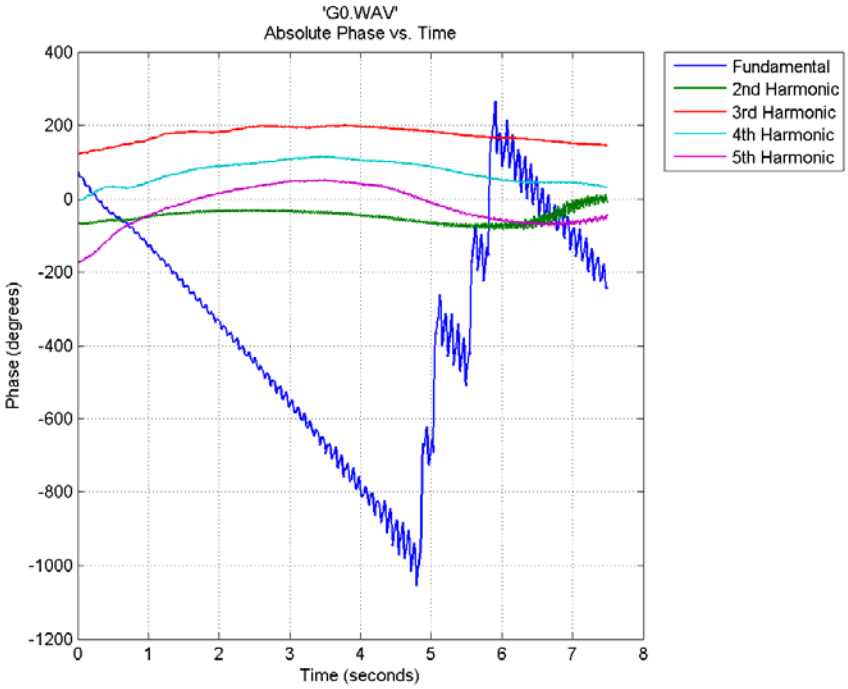
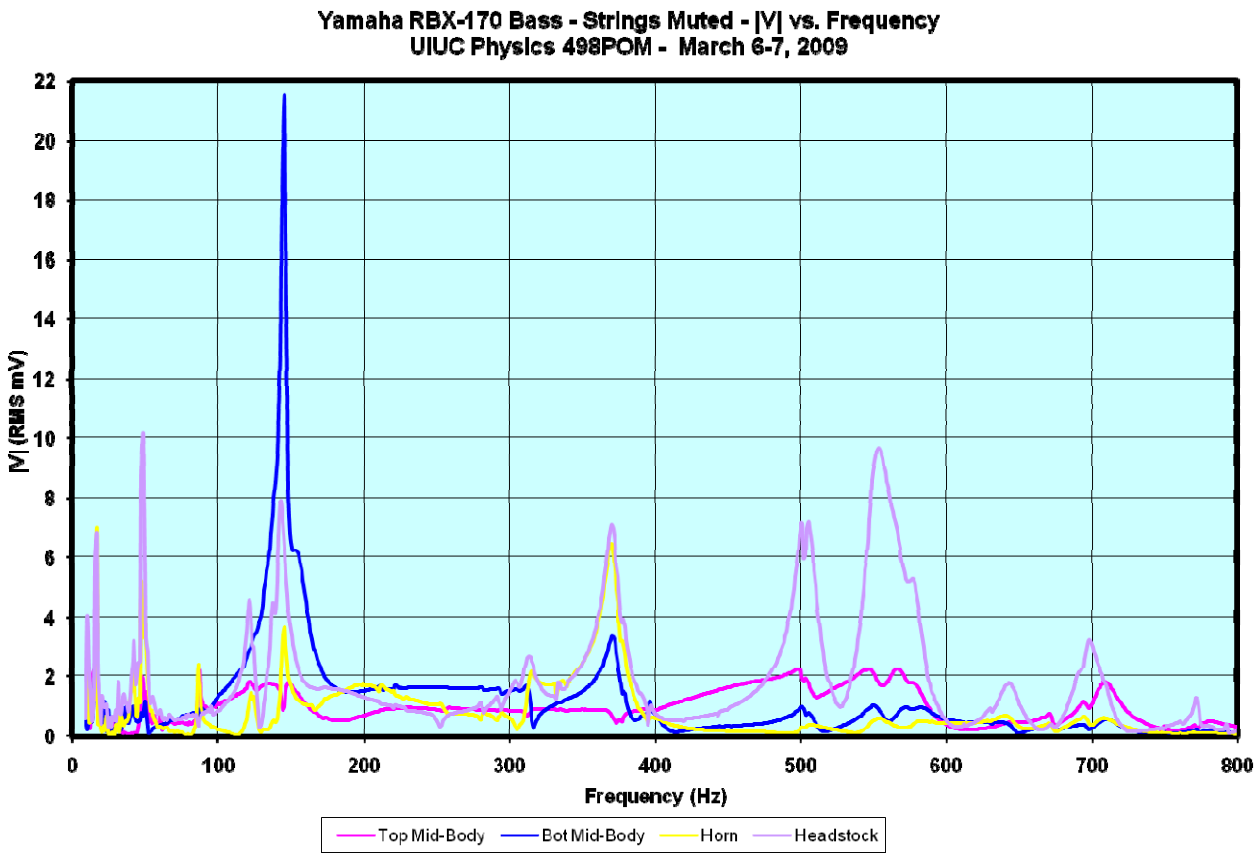
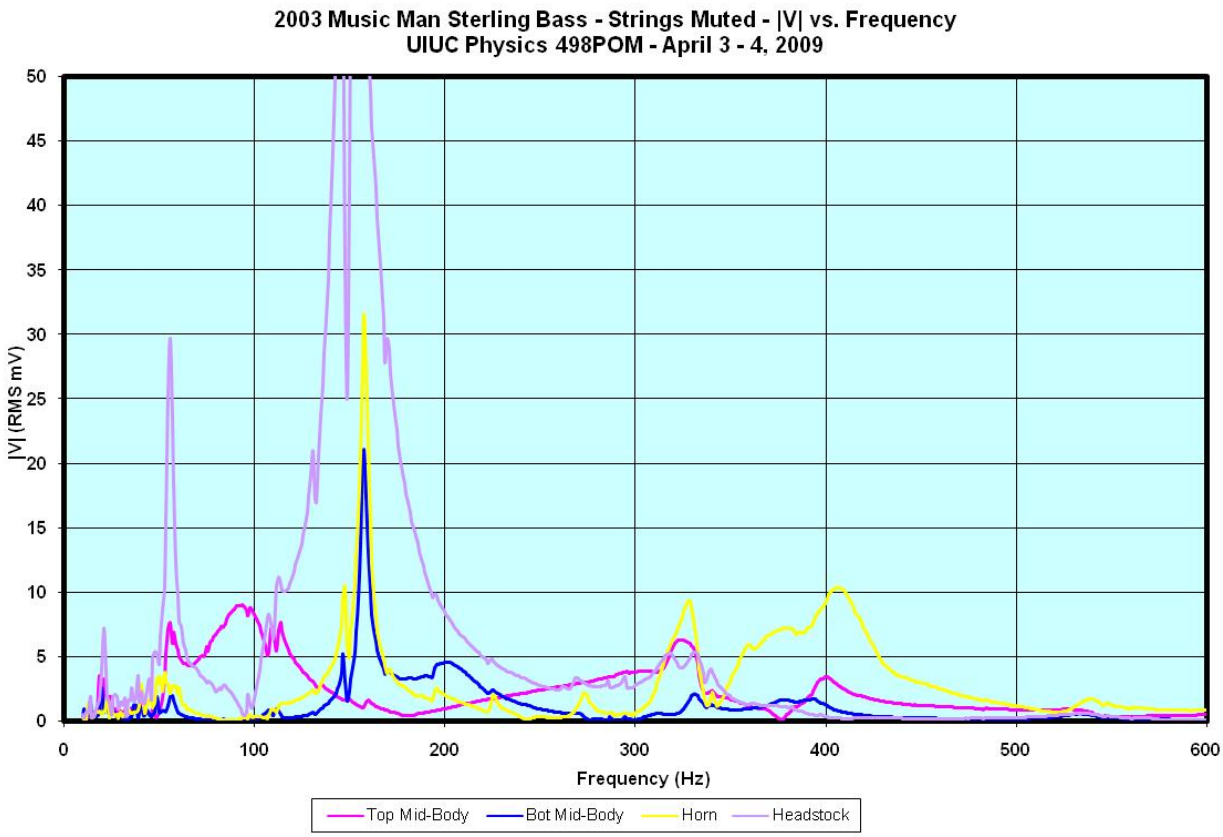
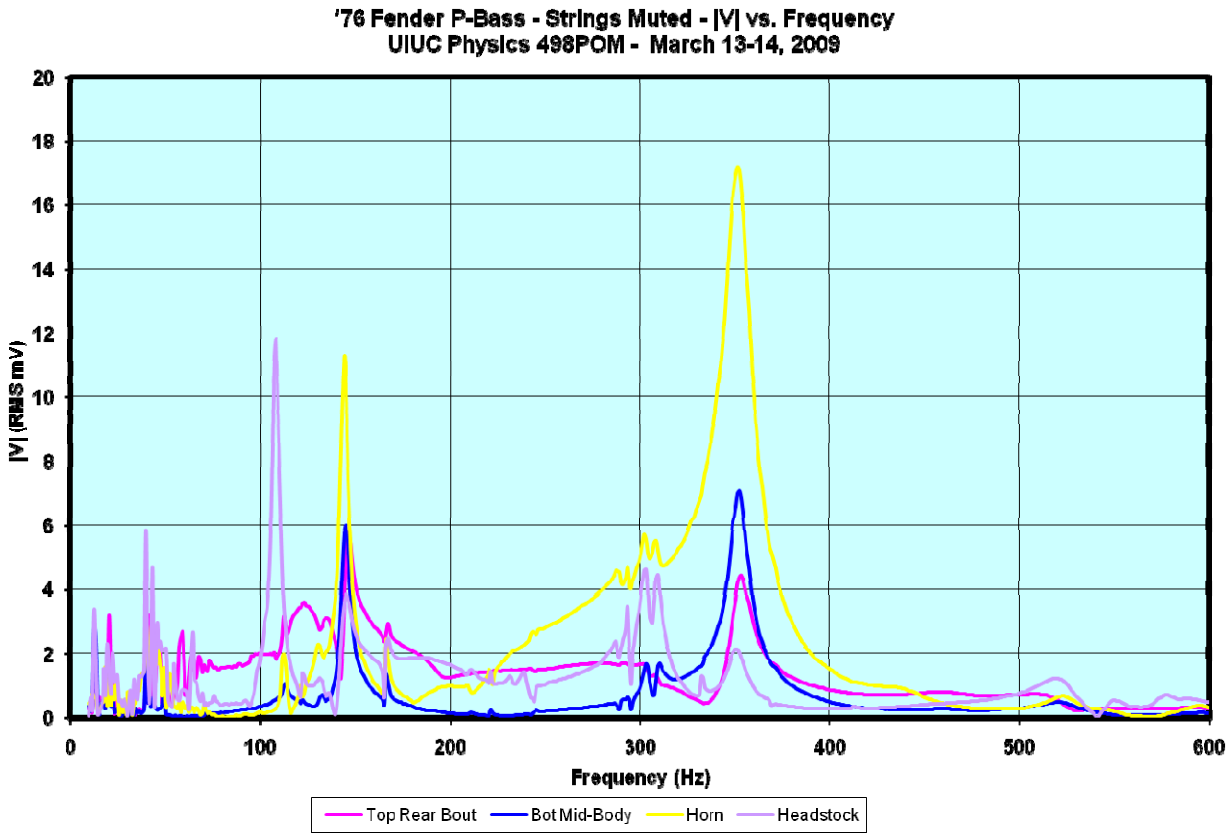


Figure 7: G0 Absolute Phase vs. Time for Yamaha RBX-170.

Figure 8: Modal Resonances of the Yamaha RBX-170


Yamaha RBX-170 Bass - Strings Muted - |V| vs. Frequency
UIUC Physics 498POM - March 6-7, 2009
|V| (RMS mV)
Frequency (Hz)
0
2
4
6
8
10
12
14
16
18
20
22
0
100
200
300
400
500
600
700
800
Top Mid-Body
Bot Mid-Body
Horn
Headstock


2003 Music Man Sterling Bass - Strings Muted - |V| vs. Frequency
UIUC Physics 498POM - April 3 - 4, 2009
|V| (RMS mV)
Frequency (Hz)
Top Mid-Body
Bot Mid-Body
Horn
Headstock


'76 Fender P-Bass - Strings Muted - |V| vs. Frequency
UIUC Physics 498POM - March 13-14, 2009
|V| (RMS mV)
Frequency (Hz)
Top Rear Bout
Bot Mid-Body
Horn
Headstock