2F1212 Musical Acoustics project work, spring 97.

Analysis of a Cymbal

Andreas Ersson and Andreas Andersson
Royal Institute of Technology, School of EE

Abstract

This paper describes the difference in the sound from a cymbal with respect to how hard it is struck. It also gives pointers on how to synthesize the sound.

Introduction

During the construction of an analog drum machine, we found out that simulating cymbals/hi-hats with analog circuits was harder than we thought. We therefore set out to find some better way to synthesize a cymbal using a source-filter method. To do that we needed to analyze a real cymbal.

Background

Most of the literature regarding percussion instruments concerns membranes whose edges are rigidly restrained, i.e. drum heads (Hall 1991 chapter 9, Askenfelt 1983 pages 72-77). Here we make the assumption that a cymbal can be described as a very stiff membrane whose edges can vibrate freely (Hall 1991 page 166). This leads us to expect a spectrum consisting of a number of disharmonic partials.

Method

The recording of the cymbals was done in a well-damped room at the Department of Speech, Music and Hearing, KTH. Using a DAT, we recorded two different kinds of cymbals three times each at high, medium and low striking force.
The tone of the first cymbal proved to be highly dependant on where it was struck. Since we were mainly concerned with spectrum differences related to different striking forces, we concentrated our efforts on the second one, a Zildjan 10" splash cymbal.

The recorded sounds were then transferred to a PC using a DSP board and the sound editing program Swell. For normalizing of the samples and spectrum analysis, we initially used Sound Forge 4.0b. Because of a shortcoming in Sound Forge, we were unable to get satisfactory data on the spectrum envelope of the samples, so we later used our own program Pfft instead (which has numerous shortcomings too, just not the same ones).

To get a decent source-filter model we made one long FFT over almost the whole waveform (not including the attack part of the waveform) to obtain the source characteristics and a series of short FFTs to obtain the variation of the filter characteristics over time.

Results

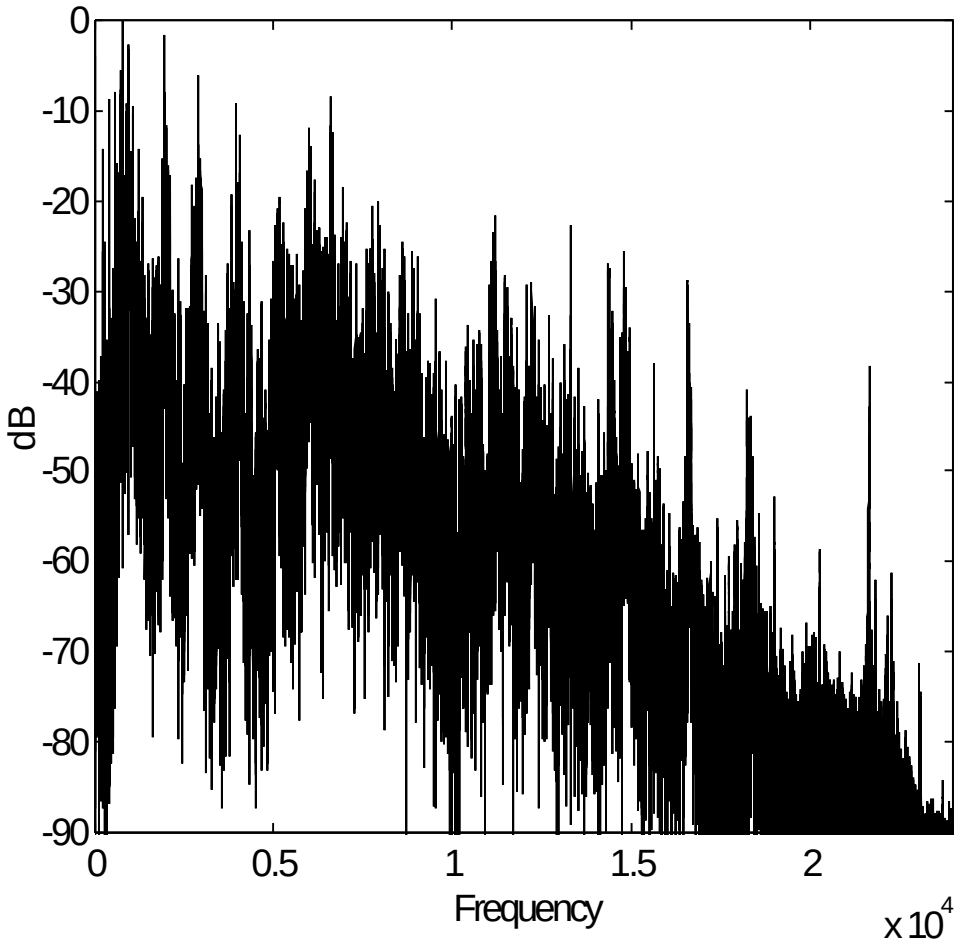

Figure 1 The spectrum of the cymbal when struck hard. Obtained from analyzing a long segment of the sample. As can be seen above the spectrum consists of a large number of partials. They are even present beyond normal hearing range.

Figures 2.1-2.3 show spectrum envelopes at different times in the sample. The top solid curve is the envelope at the beginning. Later curves follows, spaced 1/48000*8192=0.1707 seconds apart.

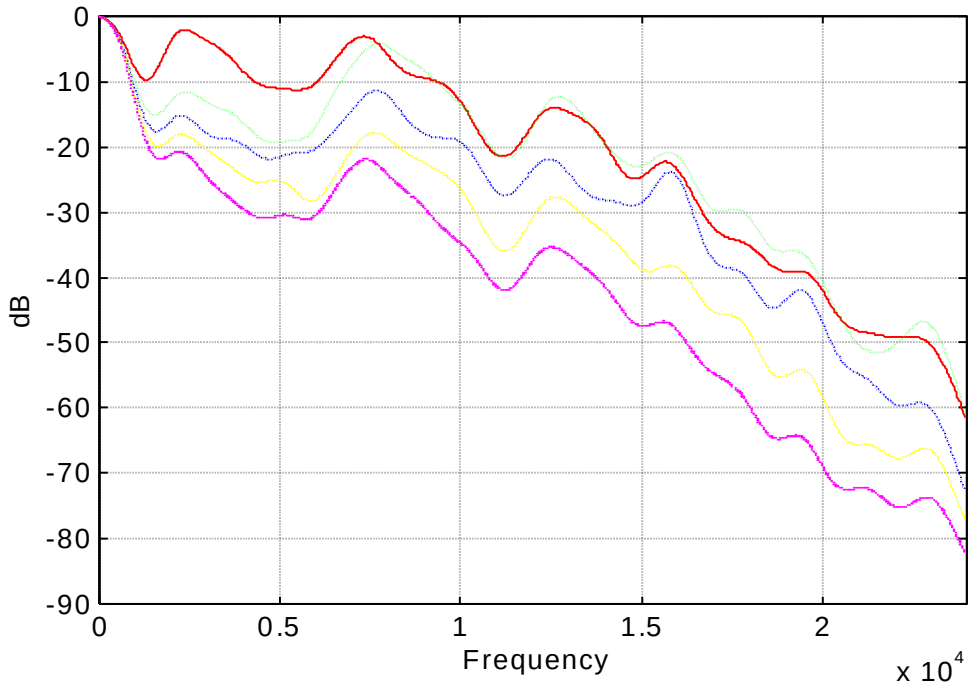

Figure 2.1 The spectrum envelopes of the cymbal when struck hard.
Initial spectrum slope -28 dB/octave. Final spectrum slope -40 dB/octave.
Change in slope -18 dB/octave/s (dB per octave per second).

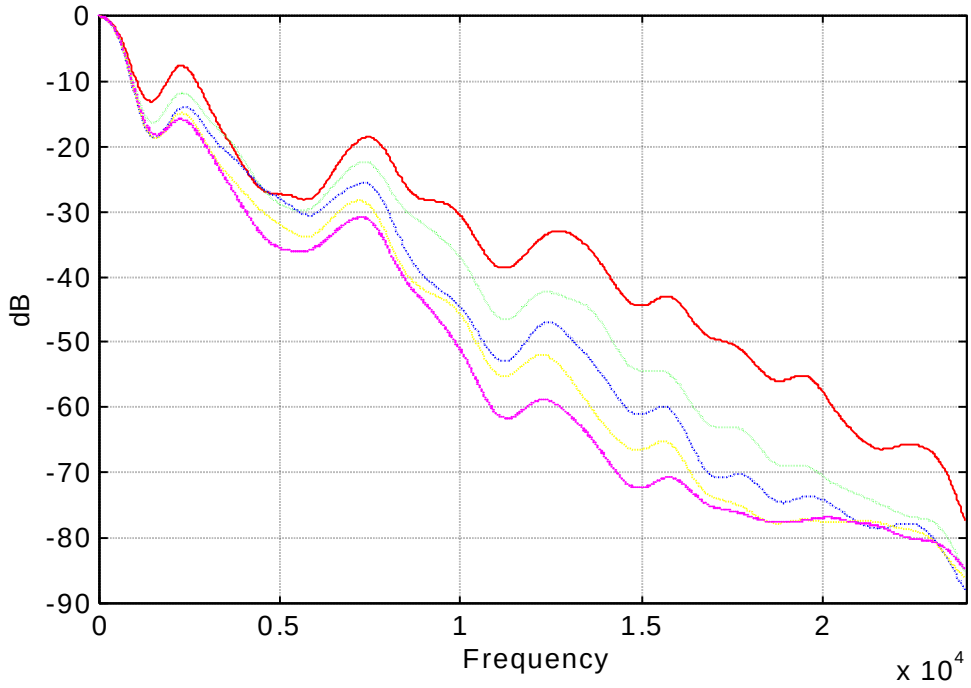

Figure 2.2 The spectrum envelopes of the cymbal when struck medium hard.
Initial spectrum slope -34 dB/octave. Final spectrum slope -54 dB/octave.
Change in slope -29 dB/octave/s.

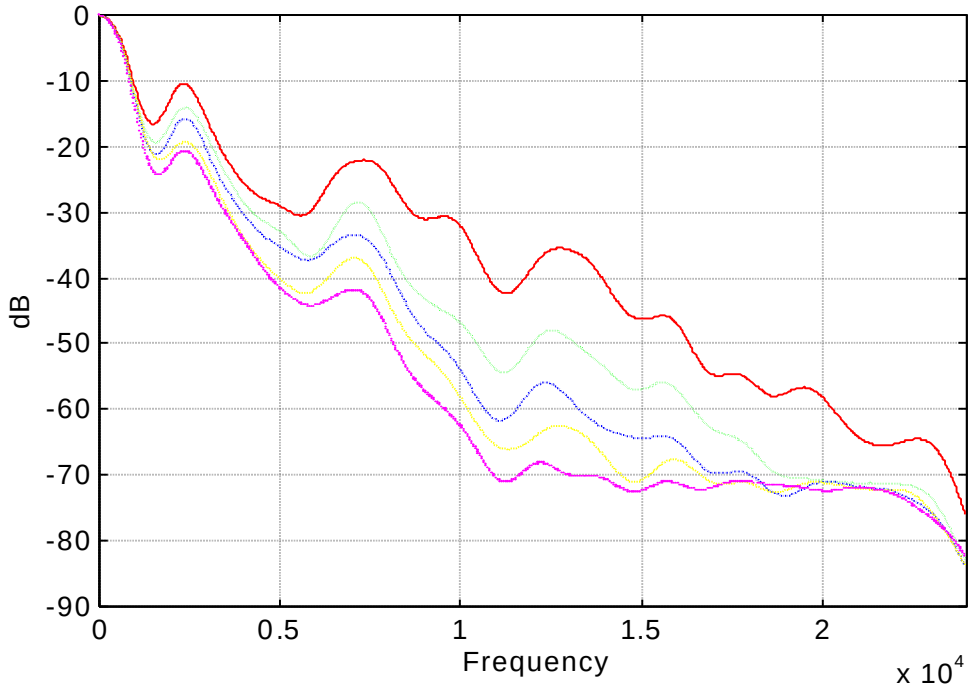

Figure 2.3 The spectrum envelopes of the cymbal when struck not so hard.
Initial spectrum slope -31 dB/octave. Final spectrum slope -61 dB/octave.
Change in slope -44 dB/octave/s.

Discussion

An interesting observation to be made in fig 2.1 is that the high frequency components (above 7-8 kHz) are more strongly excited after 170 ms than they are at the beginning. Since this does not occur in fig 2.2 and 2.3 we draw the conclusion that there are non-linearities in the cymbal that only show up when it is struck hard.
It also seems (as could be expected) that there is more overall high frequency content in the spectrum during the attack when the cymbal is struck harder.

Conclusions

Due to the overwhelming number of partials and their inharmonic nature, we found it hard to make a good source model for our synthesis. It would seem that the best way to synthesize a cymbal is by using a sample of a real cymbal and applying different time-dependent filters for different striking forces. This is bad news for us, since we were looking for a way to do this without the use of samples.

The relationships between how hard the cymbal is struck and the filters needed are:

Hard	Soft
Higher cutoff	Lower cutoff
Shallower slope	Steeper slope
(fewer dB/oct)	(more dB/oct)
Slower change in slope	Faster change in slope

Since we had no way of measuring striking force, we are reluctant to give absolute numbers. The values that appear in Results are more to be seen as a starting point for further experimenting than some kind of absolute, final truth.

References

Askenfelt Anders:	"Något litet om"	Department of Speech, Music and Hearing, KTH (1983)
Hall Donald E.:	"Musical Acoustics" 2nd Ed.	Brooks/Cole Publishing Company, Pacific Grove California (1991)

Acknowledgments

Thanks to:

Anders Friberg, our supervisor.

Sofia Dahl, for lending us the cymbals at such short notice.