

Comparison of the Frequency Spectra and the Frequency Decay of three different Electrical Guitars

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Introduction

The project's goal was to experimentally determine the tonal differences between three different electrical guitars and different pick-ups on one guitar. To do so, I used a computer interface and data acquisition program based on LabView, which computes the frequency spectra using Fast Fourier Transform software.

Connecting a guitar to a computer and picking a string is easy, whereas the analysis of the spectra can be challenging to analyze. First, the frequency spectrum depends on the location of picking the string. For example, if one picks a string exactly in its middle, theoretically just the fundamental is excited; whereas if a string is picked next to the bridge, a high number of harmonics can be observed. Furthermore, if the string is picked on a node of a certain harmonic, this harmonic is not excited.

Second, the output of an electrical guitar also depends on the location of the pick-up. The closer a pick-up is located next to the bridge, the brighter the sound of the guitar will be, whereas a pick-up nearer to the neck will output a more mellow and bassy sound. This is caused by the magnitude of the harmonics amplitudes in different locations on the guitar. For example, the fundamentals maximum magnitude is in the middle of the string and the second harmonics ones are, ideally, on the first and the third quarter of the string. Since the neck pick-up is located closer to those maxima than

the bridge pick-up, it registers a higher amount of these harmonics than the bridge pick-up does.

Third, picking a guitar with a pick (plectrum) results in a brighter sound than picking a guitar with fingers. The reason is on the one hand the width of the picking element, which causes the string to oscillate, on the other hand the different rigidity characteristics of a pick and a finger. The width of a finger plucking the string is often larger than the width of a pick. This results in a sine wave-like shape of the string, whereas a string picked with a pick generates a shape comparable to a sawtooth wave, which has a higher harmonic content than a sine wave-like one. Furthermore, because of the plasticity of a finger, the high harmonics of the string are absorbed if a string is plucked with a finger. It takes more time until the finger is in its initial shape again, whereas the pick reaches its initial shape quite quickly.

Set up for the measurements:

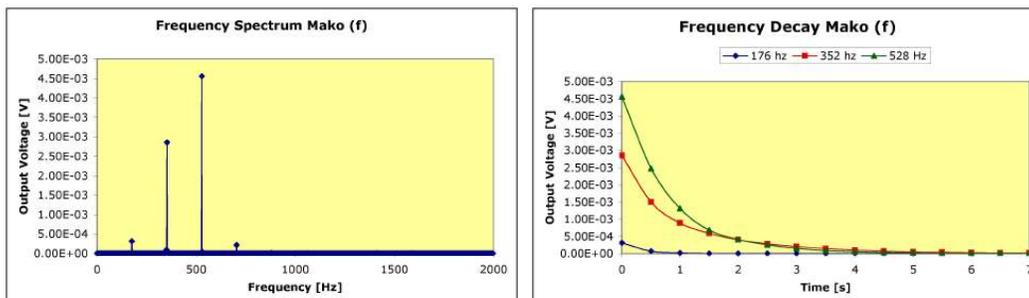
Since the voltage output of higher harmonics was very small, I just plotted the frequency spectrum up to the 4th harmonic. To avoid a node of any of these harmonics being over one of the pick-ups, a capo was set on the third fret. In addition, the string (the d-string was used for all measurements) was picked only on positions where harmonics up to the fourth were excited. I made measurements of three different guitars: A Fender Telecaster, a Fender Stratocaster, and an electrical guitar built by Mako.

Mako

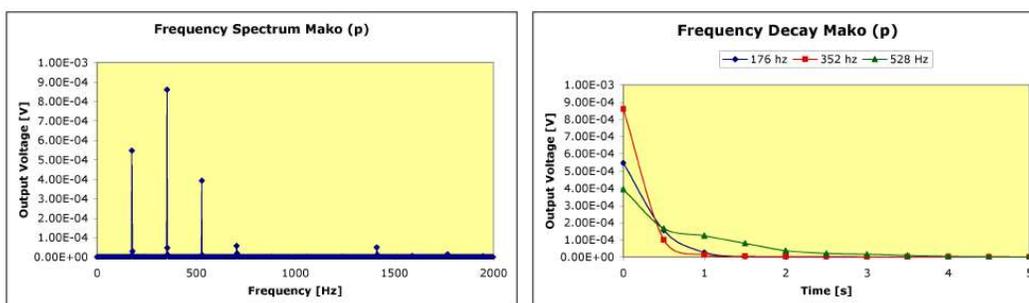
The guitar built by Mako has a humbucking neck pick-up and a humbucking bridge pick-up, therefore the signal output is higher compared to the Fender guitars. For these measurements, both pick-ups were used together.

Prior to the measurements, Prof. Errede suggested to make measurements on the one hand with the non-picked strings damped, on the other hand with them free, to evaluate, if the vibrating string affects the others and these again re-affect the originally vibrating string. Unfortunately this cannot be seen in the charts, although it is very likely that this happens. Therefore I will only display the charts of the first group.

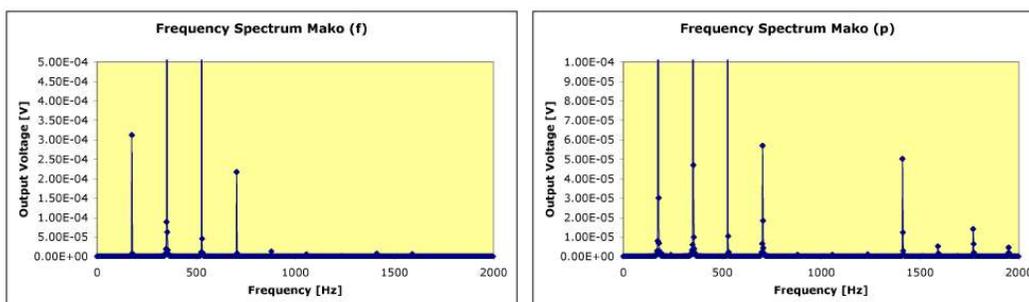
-) d-string with capo in 3rd fret, picked with finger, other strings were not damped



-) d-string with capo on 3rd fret, picked with plectrum



It can be seen that the higher harmonics are excited moreso using a pick than using one's finger:

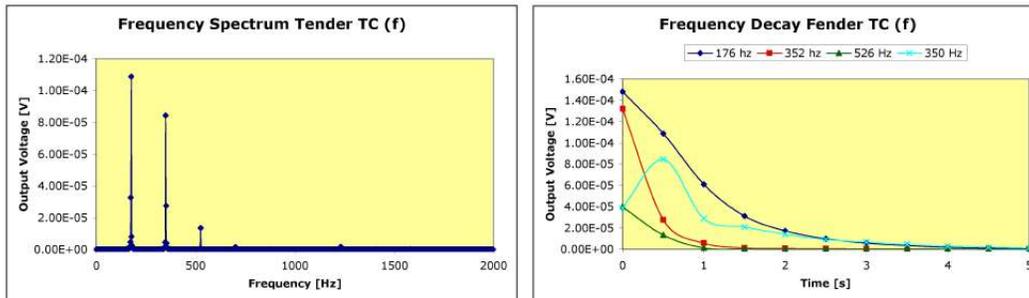


The lack of higher harmonics between 700 and 1400 Hz is due to the location where the string was picked.

Fender Telecaster

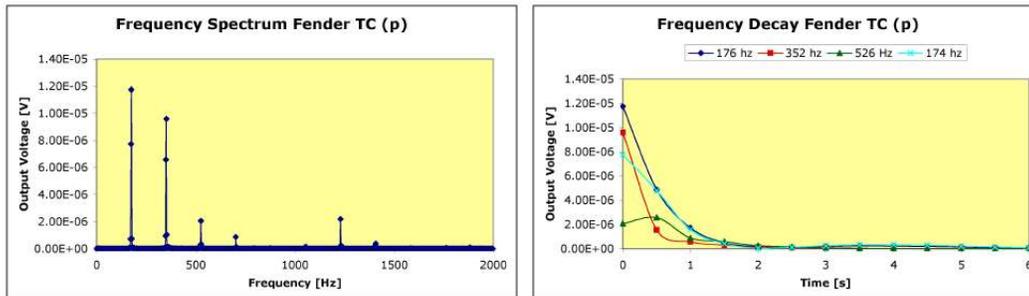
The Fender Telecaster has one single-coil neck and one single-coil bridge pick-up. For the following measurements both pick-ups were again used together.

-) d-string with capo on 3rd fret, picked with finger



It can be seen in the frequency decay chart, that the tune of a picked string is initially slightly higher. Whereas the 350 Hz and 352 Hz slopes are initially almost equal, the 350 Hz slope is significantly higher as time goes on.

-) d-string with capo on 3rd fret, picked with plectrum

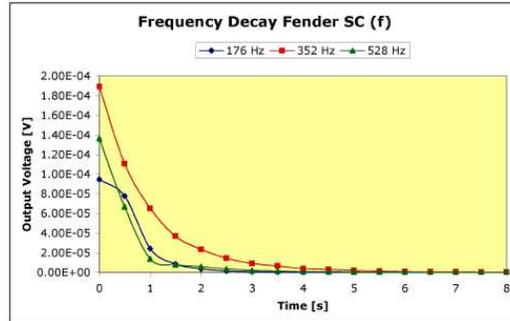
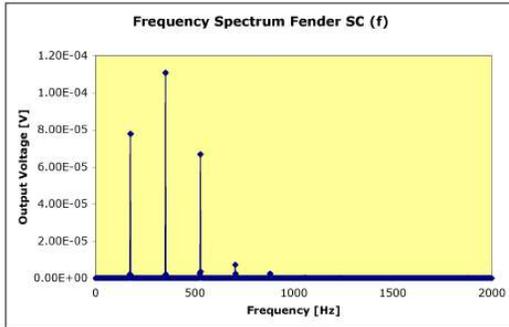


Fender Stratocaster

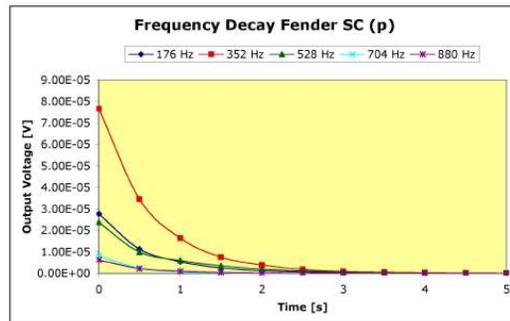
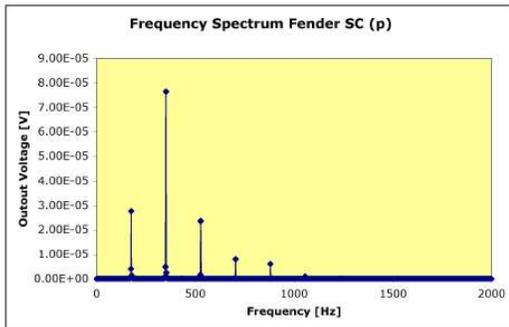
The Fender Stratocaster has three single-coil pick-ups, a bridge, a middle, and a neck pick-up. Since the switch allows, among others, to combine either the bridge and the middle, or the middle and the neck pick-up, both switch

positions were used for the measurements.

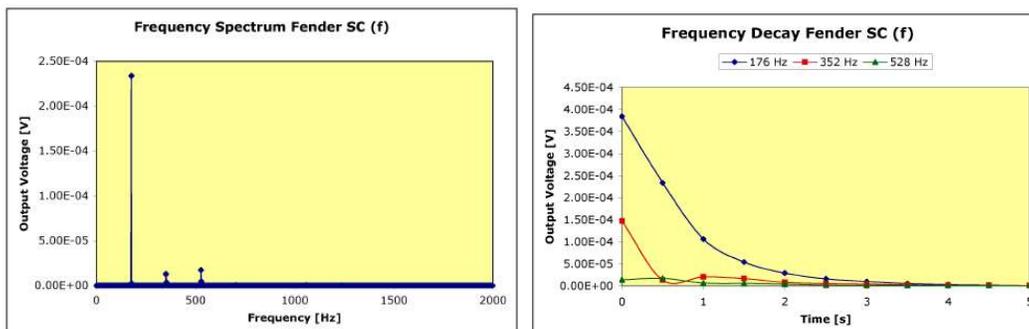
-) d-string with capo on 3rd fret, string picked with finger, bridge and middle pick-up together



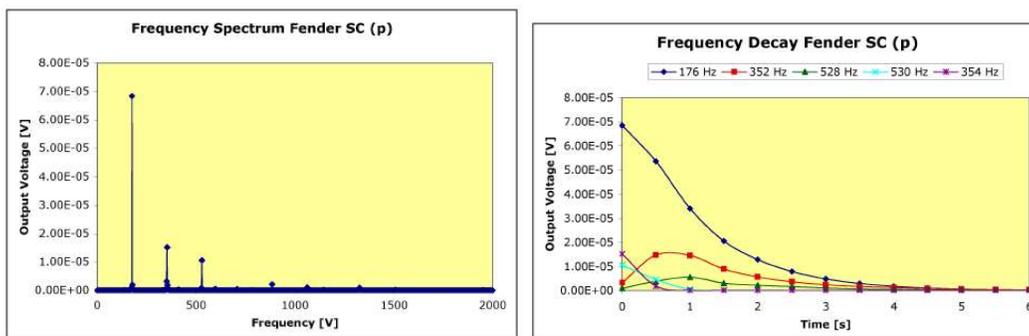
-) d-string with capo on 3rd fret, string picked with pick, bridge and middle pick-up together



-) d-string with capo on 3rd fret, string picked with finger, neck and middle pick-up together

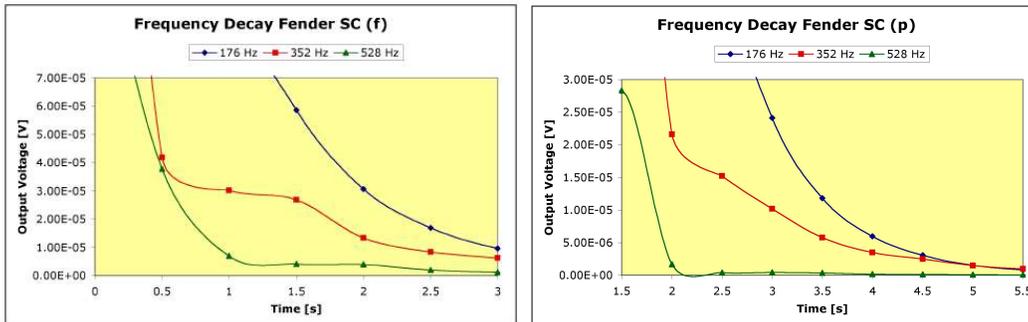


-) d-string with capo on 3rd fret, string picked with plectrum, neck and middle pick-up together



As expected, the frequency spectrum of the neck and middle pick-up is different from the spectrum of the bridge and middle pick-up. Because of the position of the bridge pick-up, the output of higher harmonics is higher than the output of the fundamental, as can easily be seen in the charts, whereas the spectrum of the neck and middle pick-up verifies the bassier sound, since the fundamental has the highest signal output.

Another characteristic of the frequency decay of the Fender Stratocaster can be seen, if the decay charts are looked at. Independent of the pick-up combinations and the way the string was plucked, there is a blip in the decay of the 2nd and the 3rd harmonic which can only be observed at the Fender Stratocaster:



Conclusion(s):

Why different different electrical guitars sound different can be seen in their corresponding frequency spectra. Plucking a string with a plectrum results in the excitement of higher harmonics, whereas the frequency spectrum of a finger-picked string mainly consist of the fundamental and a few higher harmonics. A difference in the frequency spectrum can also be seen for different pick-ups. The spectrum depends on pick-up location. The harmonic spectrum includes only the fundamental and a few harmonics (neck pick-up) or even very high harmonics (bridge pick-up). The audible result of different pick-ups is either a bright and sharp sound (bridge) or a bassy and mellow one (neck). On order to gain a sound comparable to an acoustic guitar, the combination of as much pick-ups as possible is recommended.