Body Woods and an Electric Guitar's Frequency Spectrum

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ABSTRACT

There are many theories as to what significance particular wood species contribute if any to the overall tone of an electric guitar. In this paper two differing wood types are studied, ash and alder, and a method are investigated to determine their tonal spectrums. Analysis of the data shows that in an electric guitar the body wood type does not contribute significantly to the sound of the amplified instrument.

I. Background and Introduction

It is widely held and documented that the tone woods that go into the construction of an acoustic guitar affect the overall sound of the instrument drastically. An acoustic guitar's tone is defined by three factors, its strings, the resonance box, and the air contained within the volume of the box (Sundberg 154). Therefore the woods that comprise the resonance box do indeed define the color of the instrument. In contrast, an electric guitar lacks a direct correlation to the resonance box and the volume of air. Its sound is defined by the string, the electromagnetic pickup and the amplifier. From this it seems then, that no other constituent parts of the electric guitar contribute to the overall sound of the instrument. However, there is much anecdotal evidence purporting to be truth as to what significance a given body wood type contributes to the overall tone of an electric guitar. Most who have played electric guitar for some time will most certainly acknowledge that body woods do in fact influence the sound of the instrument. While some would say there is an effect based upon differing construction materials there are those that argue otherwise. For instance Halliday states that the solid body of the instrument in fact has no resonance (2001, 716). The lack of information and studies on this topic are what has influenced this further investigation into what potential contribution certain wood species make if any.

To make a special note; music is a subjective art and as such it is not the intent to question personal preference by making assumptions on what is a "good" sound for a given instrument. That judgment rests solely with the players and their audiences. The intent is however, to aid musicians in understating the complexities of their instruments and give them more information when selecting a particular component or instrument.

In this paper, the experimental setup and method are detailed. Also, results and conclusions from the research are discussed.

II. Experimental Setup and Method

A single experimental method was used to investigate the tonal contributions of differing wood species. Specifically, the analysis of the two bodies was conducted using a microphone and an electromagnetic pickup separately. The signals from both the microphone and pickup were routed to a sound card for capture via a line analyzer and the resultant waveform and corresponding data was captured and plotted for analysis. The specifics of this method are detailed further.

The Bodies

The choice of woods, alder and ash, were chosen for the fact that they are the two most popular wood choices available for aftermarket electric guitar bodies. They also have different densities. Ash is approximately 0.638 g/cc while alder is roughly 0.38 g/cc (Seeley). Ash is also a very porous wood while alder is a closed pore species. The characteristics of the wood species are noted for reference but could not be proven for significance for the purpose of this testing. Both of the guitar bodies for this research were purchased from USACG and manufactured identically using a CNC machine. Due to the manufacturing process both bodies can be assumed to be identical other than composition. Figure 1 shows the two bodies side by side for comparison.

Figure 1: Alder and Ash bodies

Microphone

The microphone was provided by the university and the specifications are unknown. Its sensitivity is of the normal audible range. The microphone was suspended above the guitar neck by a stand at approximately the 12^{th} fret. This location was chosen as a result of trial and error placement for getting the most volume for the recorded signal. The microphone was plugged directly into the lab computer's sound card.

Electromagnetic Pickup

The electromagnetic pickup used was a single-coil type typical for the guitar style body used. It was a bridge pickup which was attached directly to the bridge. The pickup is set at a 45 degree angle to the strings. The resistance of the pickup was 9.6 kΩ. The pickup leads were attached to test leads which were in turn attached to the standard ¼ inch output jack that is used on most electric guitars. For capturing data using the pickup a slightly different routing method was used. Instead of going directly to the PC's sound card an intermediate usb external soundcard was used. The soundcard was a Tascam® U122 model. The reason for this was to match impedances and also that the volume that could be achieved by plugging directly into the computer's onboard soundcard was not sufficient enough had the usb device not been used. The recorded signal would have had to have been amplified via software to compensate for this and that principle potentially could have added other residuals to the signal which may have colored the sound.

Computer Software

Various pieces of software were used for the project. For the capture of the audio signal with the microphone a program named "Spectrum Analyser" was used. This software was available via the university and was written by a previous student, Paul Kellett. Resolution was set at 43 Hz with a max frequency of 5 kHz and a max level of 0 db to 100 dB. For the acquisition of data via the pickup method, a freely available program called "Audacity" was used. This software was used off the lab premise when the pickup measurements were taken. The "Audacity" program functions in a manner very similar to the "Spectrum Analyser" program except that it performs the spectrum analysis from a recorded sound file rather than in real-time.

General Testing Setup

To conduct the testing a complete guitar was constructed using the alder body. This process was repeated identically for the ash body as well. The construction consisted of a maple neck, neck plate, neck screws, 3-saddle bridge, bridge screws, set of .10 gauge strings, and a ¼" input jack. For this testing setup all the components, other than the bodies, were kept were kept constant. This was done to minimize the variation to that of the bodies only to better evaluate their qualities.

The style of guitar studied was modeled after a Fender Telecaster®. It was chosen for a couple of reasons. The first reason is that is one of the simplest on the market, and this simplicity allowed the study to be unencumbered by unnecessary components and systems. The second reason was that due to its popularity. As a result there were many components available for testing.

For both the pickup and microphone tests all six strings of the guitar were measured. Each string was plucked with a pick between the neck and bridge pickup areas. The strings were plucked open, which means the strings were not fretted and did not contact the fretboard.

III. Results and Discussion

Data that was collected was imported into Excel for analysis and graphing. Initially the data was to be analyzed by completing a Design of Experiments but due to the amount of data collected it was deemed not feasible. A qualitative review of the signal waveforms was reviewed for patterns. In Figures 2 through 7 at the end of this section, individual strings were graphed, showing both the alder and ash bodies, and compared between the microphone and pickup measurements. It can be seen from the successive graphs that the data collected via the pickup appear to be more consistent between the alder and ash samples. It appears that in the case of the microphone the electric guitar appears more like an acoustic and as such exhibits tendencies in which the body does affect the spectrum. From this visual inspection of the charted microphone data it appears that the alder body resonates with more overtones than that of the ash as evidenced by the charts. The pickup it also seems has a smoothing effect on the spectrum and minimizes the differences that body materials may cause. This results in a more predictable spectrum, which essentially can be tuned per the pickup manufacturer's process or by tweaking other electronic components such as the tone and volume potentiometers to achieve a musician's desired spectral response (Helmuth).

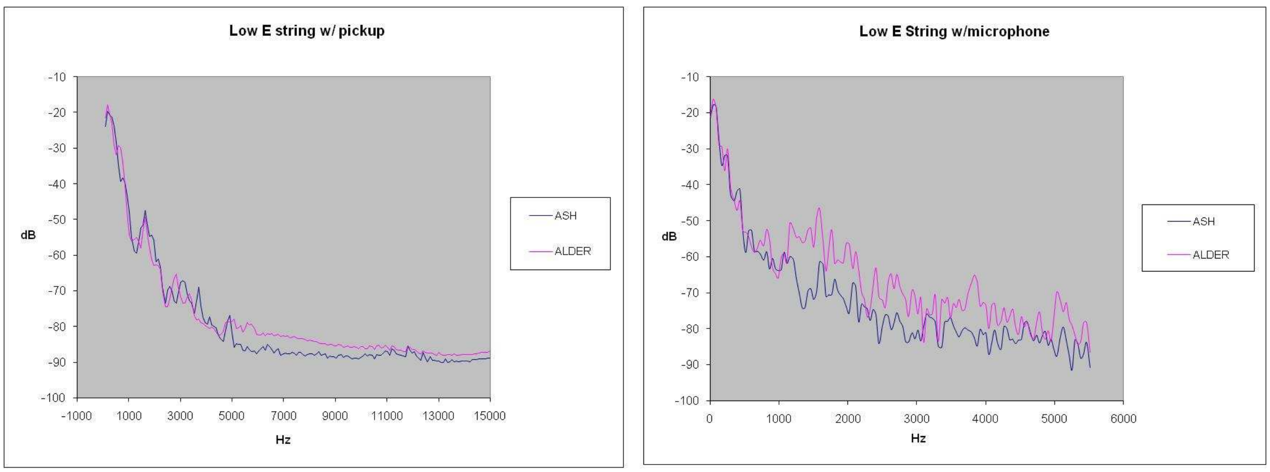

Figure 2: Comparison of waveforms from pickup and microphone for low E string

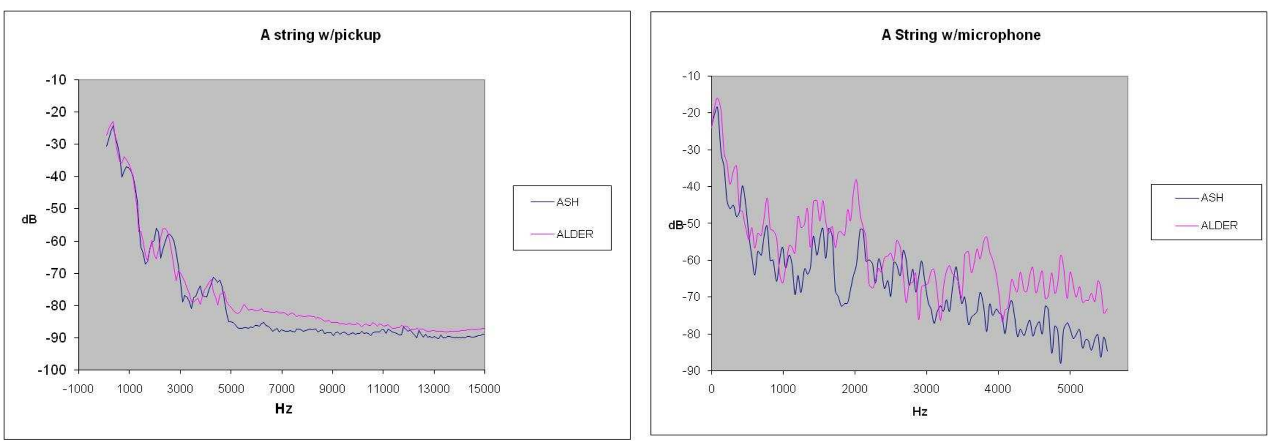

Figure 3: Comparison of waveforms from pickup and microphone for A string

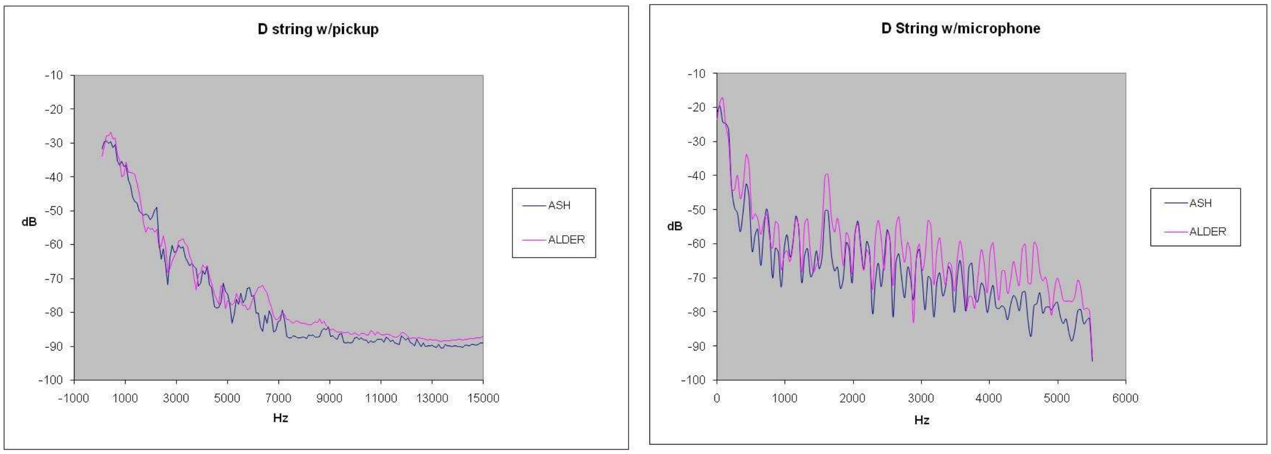

Figure 4: Comparison of waveforms from pickup and microphone for D string

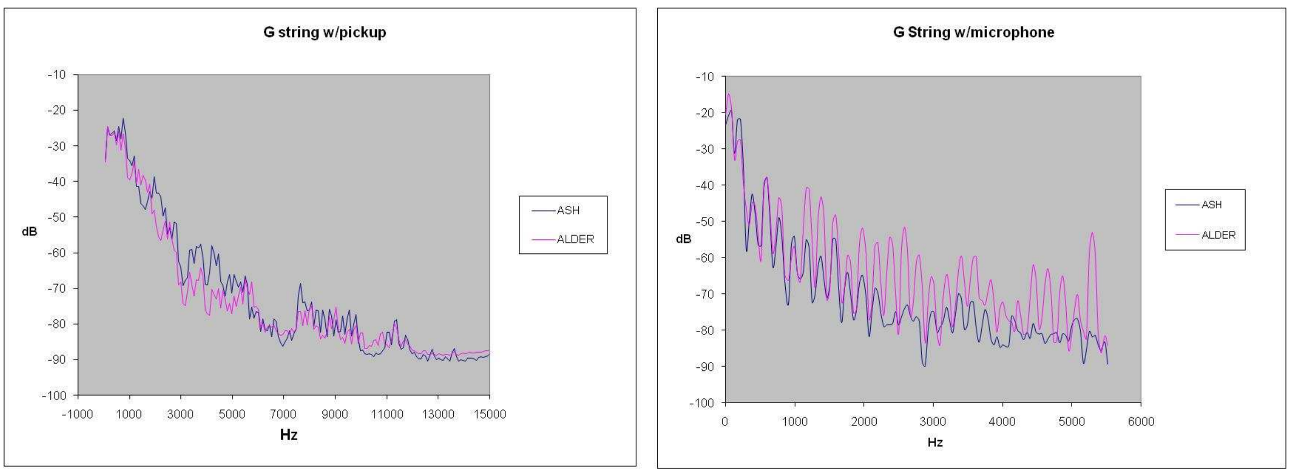

Figure 5: Comparison of waveforms from pickup and microphone for G string

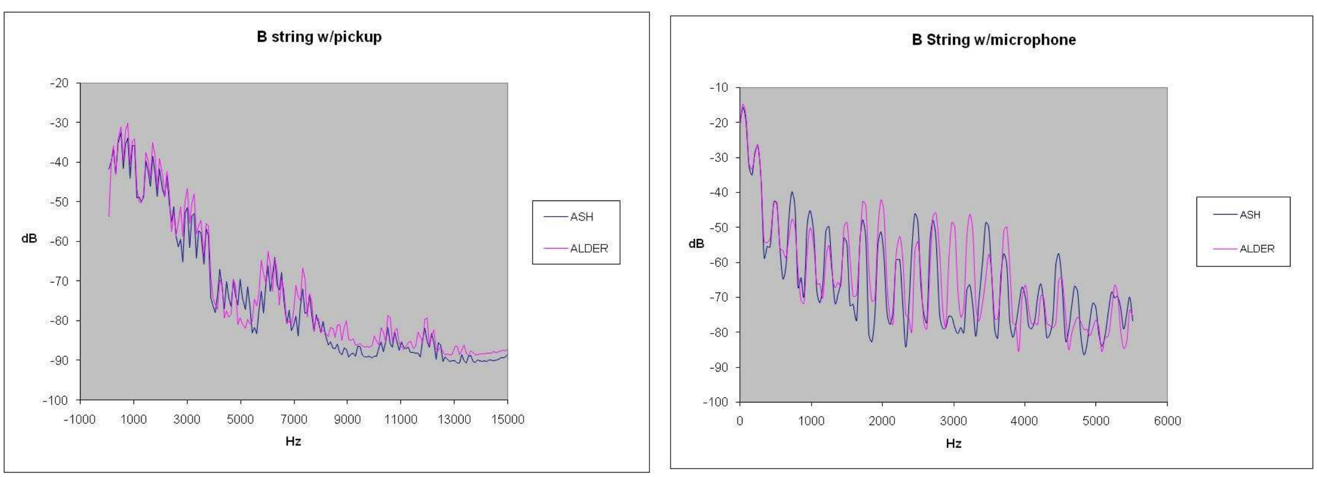

Figure 6: Comparison of waveforms from pickup and microphone for B string

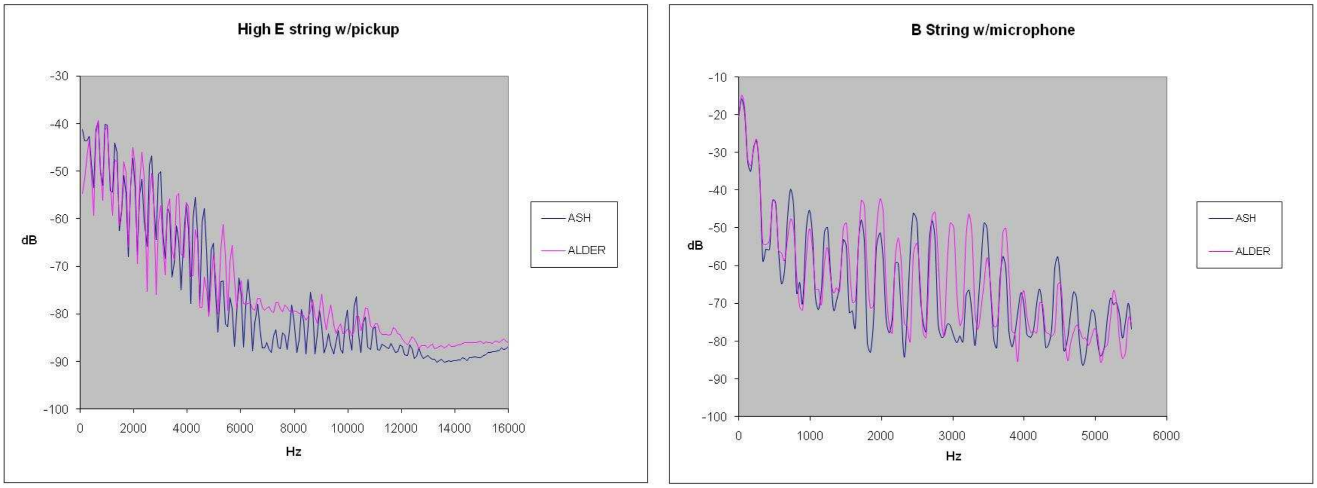

Figure 7: Comparison of waveforms from pickup and microphone for high E string

IV. Conclusions

Through the course of this research it seems that there is proof to the statement made by Halliday in that the body of an electric guitar does not have resonance. Of course this is both correct and incorrect. From the stand point of the electric guitar's purpose of being amplified the statement is correct. However, the guitar body does in fact resonate and when it is not plugged in, the body is noticed to color the sound. This observation explains why some would say they can hear a difference in the wood. When playing an electric guitar unplugged the tonal qualities of the wood are apparent as the ears perceive what the microphone "hears". These perceptible variations however, appear to get lost when the volume of the amplified signal takes over.

V. References

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