How Musicians Can Utilize the Guitar's Acoustic Properties

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Abstract:

Guitars are extremely versatile instruments due to the myriad of ways in which the player can alter the timbre. This study explores how the timbre of the acoustic guitar is affected by alterations in the string type and gauge, the excitement location, pick versus pluck excitements, and the placement of the capo. A theoretical understanding of the previously mentioned changes can justify and direct a guitarist's artistic decisions in Flamenco, Irish Traditional, and Country/Folk music. Understanding the connection between the technical and artistic aspects of the guitar can guide a musician in creating the effects appropriate for each genre.

Introduction:

This study on how the use of different strings impacts the timbre of a guitar can prove very useful for musicians. By learning more about the effects on the timbre, a musician will be able to fine tune their craft and further delve into the sound that they want to create for others. Many guitarists become familiar with their instrument through experimentation, and it can take years for them to create the sound they want. This research project explores the physical reasons behind various guitar properties and directly connects them to musical genres. Musicians can then utilize this information to make informed decisions about how to develop the perfect sound.

The properties measured in this project include:

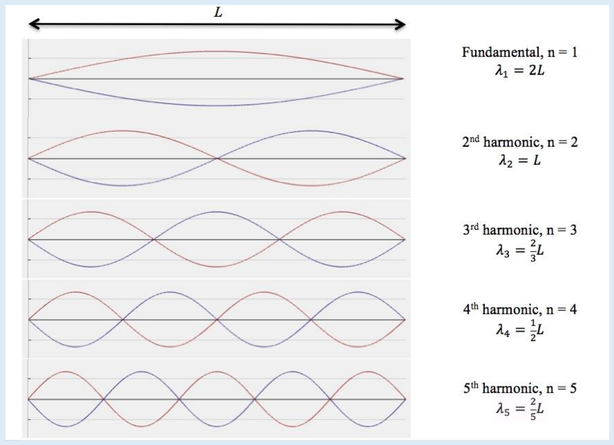
•String type and gauge: Unknown, Cobalt - 9 gauge, Nickel-Steel - 12 gauge, Nylon - medium gauge

•String excitement location: L/2, L/3, L/4

•Capo versus no capo: placed capo at the second, fourth, and sixth fret

•Pick versus pluck: thumb pad, soft pick (0.3mm), hard pick (3mm)

Theory:



The strings on a guitar are standing waves that are attached to two fixed ends. Each string is a different note, but the effective length of each string is the same. The data for this research includes exciting each string at the approximate lengths, L/2, L/3, and L/4. These were chosen to incorporate the locations where players excite the strings for different sounds in various musical genres. When a string is excited at L/n, where n is an integer, the corresponding missing harmonics occur at multiples of n. Measuring these different excitement locations, among other properties, ultimately alters the timbre of the guitar. The timbre is dependent on the harmonics and the percent fundamental. The amount of harmonics present defines the timbre, and the percent fundamental is the ratio of the first harmonic over the sum of the other harmonics. The wave equation, which includes many of the variables included in this study, is:

$$v = \sqrt{(T/\mu)} = \lambda f = 2L f$$

This wave velocity equation provides a lot of information that is useful for our research. The μ is the mass density of the string and is related to the thickness of the string. The T represents tension of the strings and can be altered via the rotating the tuning peg or by bending the string while playing. Lambda, λ, represents the wavelength of the sound wave and is related to the length of the string. The frequency is associated with the pitch of the note, so a higher frequency means a higher pitch. The L stands for the length of the string, which stays constant and is measured from the bridge to the nut of the guitar. Lastly, the V is the velocity of the sound wave that is created once a player plucks a string.

Methods:

A Vernier Lab Pro with microphone and analysis software comprised the data acquisition equipment. Our procedure and measurements consisted of the following items:

• String spectra were taken in exciting the strings at three locations: L/2 (the octave fret), L/3 (at the end of the neck), and L/4 (near the normal playing location). For each string type, the spectra were recorded for each string, from E2 to E4.

• We restricted our measurements to the following types of strings: (i) an unknown string set, (ii) cobalt (Co), (ii) Ni plated steel (Ni-St), and (iv) nylon. The gauges of strings will be 9 (Co) and 12, the most common, for the others.

• The effects of a capo on the timbre were tested on the nickel-steel strings. The capo will be placed at frets 2, 4, and 6 to test how the resulting different lengths and tensions of the strings affect the timbre.

• The impacts of using a pick versus finger plucking were tested on the nickel-steel and cobalt strings. Both a soft pick (0.3mm) and a hard pick (3mm) were used.

• In order to test the accuracy of our original data taken at Loyola, we repeated a sample of the measurements in the anechoic chamber at Northwestern University.

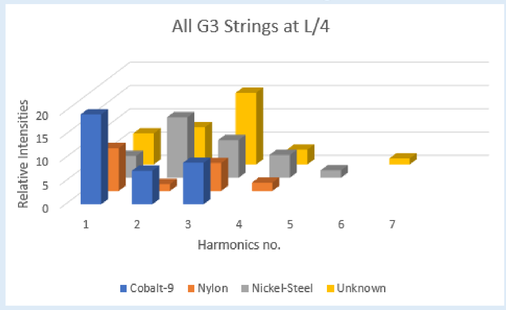
Results:

String types:

When comparing across the four string types, there were consistent similarities between the Unknown and Nickel-Steel strings, as well as similarities between the Nylon and Cobalt-9 strings. Looking at the tensions and percent fundamentals demonstrates this observation.

Variable	Unknown	Co-9	Ni-Steel	Nylon
Harmonics	OK	OK ±15%	Except $\frac{L}{4}$	Except D_3
Tension (N)	149 ± 13	79 ± 17	147 ± 13	75 ± 11
Percent Fund.	36	46	25	45

In addition to this, both pairs of strings have comparable timbres. The Cobalt and Nylon strings have dominant fundamentals which correlates with a higher percent fundamental. The Nickel-Steel and Unknown strings have dominant second and third harmonics and their percent fundamental is lower. This means that the Cobalt and Nylon strings have a purer sound while the Nickel-Steel and the Unknown have a brighter tone.



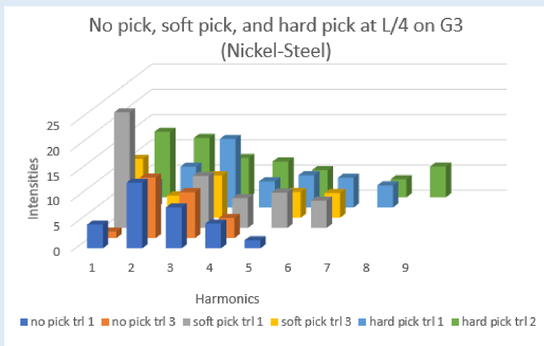
Excitement Location:

For each string type except for Nylon, the percent fundamental decreases by 10 percentage points when moving from L/2 to L/3 to L/4, meaning that as the string is excited closer to the sound hole the sound becomes less pure and brighter. For the Nylon strings, the string excitement location has no impact on the timbre.

% fundamental average for each location	L/2	L/3	L/4
Unknown	46.7	36.3	24.1
Ni-Steel	57.0	46.4	38.9
Co-9	58.9	45.4	37.9
Nylon	45.3	44.1	45.0

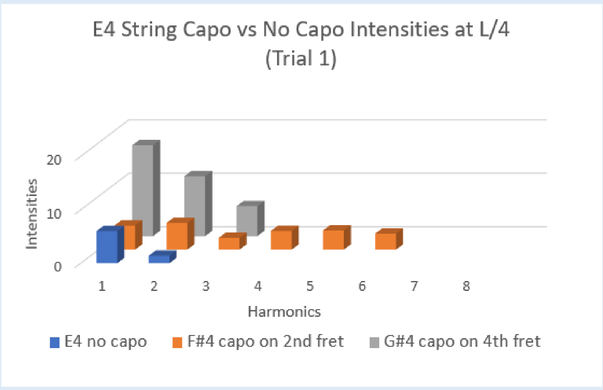
Pick vs. Pluck:

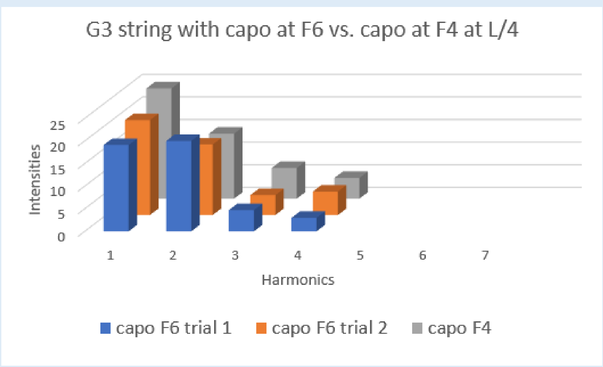
Using a pick, instead of one's thumb pad, will excite more harmonics. Compared to the soft pick, The hard pick excites the most harmonics and exhibits the brightest tone.



Capo:

Compared to playing without a capo, playing with a capo will excite more harmonics. Placing the capo on the second fret will produce the brightest tone. When the capo is moved further down the neck to the fourth and sixth fret, the harmonics for both are nearly equivalent and produce a warmer tone than when the capo is at the second fret.





Northwestern Anechoic Chamber: Various measurements were retaken at Northwestern's anechoic chamber in order to verify the consistency of the data. The anechoic chamber eliminates background noise that may interfere with data collection. We were able to conclude that the measurements taken at Loyola were consistent with the data taken at Northwestern.

Conclusion:

Musicians can use these results to make decisions when trying to produce a specific sound. Applying this data to three different musical genres will guide musicians as to how they can use the guitar's various physical properties to their advantage.

Flamenco: This Spanish style of music is very emotive and is focused on story telling through lyrics, instruments and dancing
String Type: Nylon

Capo: Use capo (Cejilla) at the second fret

Pick: Fingerstyle, no pick

Irish Traditional: A very lively and upbeat style where the guitar is used as accompaniment
String Type: Nickel-Steel

Capo: Use capo at the second fret

Pick: Use a hard pick

Country/Folk: These American-based genres pair guitar and vocals to tell stories that everyday people can connect to
String Type: Nickel-Steel or Nylon

Capo: Use capo at the second fret

Pick: Fingerstyle, no pick OR use a soft pick

Future Considerations: Potential future studies may include replicating these measurements on different styles of guitar such as an electric, bass, or classical guitar. Another approach could focus on applying results to other genres of music. More in depth measurement could also be taken such as comparing the impact of varying gauges of one string type or analyzing the effect of different capos.