Flamenco Guitar Sound - Documenting the Heritage

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Abstract

The flamenco guitar as its roots in the accompaniment of singing and dancing, with a focus on percussive sounds. Since the days of Paco de Lucia, the Flamenco guitar has also developed sound features for solo performance, such as sustain or fullness. The documentation project seeks to capture the acoustics of Flamenco guitars over the last 100 years. Along diverse spectral and temporal features, the Flamenco guitar is benchmarked against the classical Spanish guitar.

Introduction

Contemorary flamenco and classical Spanish guitars appear to be similar on the first sight, without typical differences for the scale, the Pantilla, the volume of the enclosed air, or the strings used. On the contrary, in the times of Torres, the Pantillas differed very much from guitar to guitar, and guitars were not necessarily classified flamenco or classical guitars, but rather professional or cheap guitars (Romanillos 1990). And even though flamenco *(FG)* and classical Spanish guitars *(CG)* are much more similar today than ever, most of the Andalusian contemporary guitars makers offer them as specific *FG* or *CG* (Ray, 2014). While interviewing some ten different Granadian guitar makers about the differences most of them claim that there is no difference but the action. The action should allow for easy play in both hands: the lasting play of fast pieces should not tire the left hand, and the striking/plugging combined with the golpe should be ergonomically convenient for the right hand. A few guitar makers claim, that the action also determines the sustain and the modulation of tone, i.e. a higher bridge would cause the modulation and sustain that you want for a *CG*. Another difference is the wood used for the ribs and the bottom. While palisander is the typical wood used for *CG*, the much lighter cypress is the typical wood used for *FG*. Some guitar makers say they would even refuse to build a *FG* with palisandro or a *CG* with cypress, some other guitar makers claim that they can use either wood and tune the sound towards either direction.

This brings up the question about desired sound features for *FG* versus *CG*. Interviewing not only guitar makers but also musicians and in particular professional flamenco musicians in Granada, the desired sound features can be summarized in its most simple form as shown in Table 1.

Table 1: Basic sound features in flamenco versus classical guitars.

guitar	classical *(CG)*	flamenco *(FG)*
main focus	melodic sound	percussive sound
sustain	long	short
sound	rich, full	clear
modulation	strong	no
bass	strong	dry

Apart from that the *FG* has its own typical sound character that cannot easily be described in words, but can be recognized by many players and listeners. A typical element for the percussive play in flamenco is the rasgueado, that is striking the four fingers in a rapid sequence, with as little as some 20 ms between strokes. A *FG* is expected to project such fast sequence with acuity while a *CG* is not. With a *CG*, the four strokes usually kind of merge to just one sound comparable to what a bell does when being hit rapidly. On the other hand, a *CG* can develop a beautiful, modulated and rich tone even while playing only simple melodies or even single notes, whereas a *FG* will not necessarily. And even more, a good *CG* provides a range of voices, or registers, that is, the guitar translates variations of manual action into variations of sound. And while there is an even more differentiated picture on what a *CG* should provide for different epoches of composition, there is a likewise differentiated view on what a *FG* should do for the three main different flamenco performances: accompanying a singer, playing for dance, and playing solo. There are some 30 to 40 styles of singing and some 200 styles of dancing (Ortega, 2011). Some professional musicians claim that these even require three different types of flamenco guitars.

All flamenco musicians interviewed in Spain and in Germany agree that accompanying a singer or playing for dance requires a traditional *FG* made of cypress, whereas the solo play benefits from using palisandro wood, refering to the skilled solo play of Paco de Lucia, who strongly developed the solo play and is still a reference for the virtuosity and the flamenco sound. The musicians also agree that the *FG* apporaches the *CG* in terms of sound features since the days of Paco. This is where the larger question of this research begins: how did the *FG* evolve over the last 100 years? This raises not only ethnological questions (Bethencourt Llobet, 2011), but also acoustical. Measurements were taken from some 70 very good to excellent instruments, including reference instruments of history such as Barranco, Fleta, Pages, Torres, Simplicio, but also best vintage and contemporary guitars such as Barber, Bellido, Conde, Contreras, Devoe, Marin, Reyes, and Wiechmann.

Measurements - Frequency Domain

This short exposition looks at differences between *FGs* and *CGs*, that can be read from measured bridge mobility. Mobility is measured by an impulse hammer, 9 grams, excited at the treble or bass side of the bridge, on the bone, between strings B and e, and strings E and A, respectively. Accelerometer sensors are located at the bridge, at either end, bass or treble. Figs 1 and 2 show the mobility plots of three contemporary *CGs* and three contemporary *FGs*, respectively, made in Granada by the same family, Bellido.

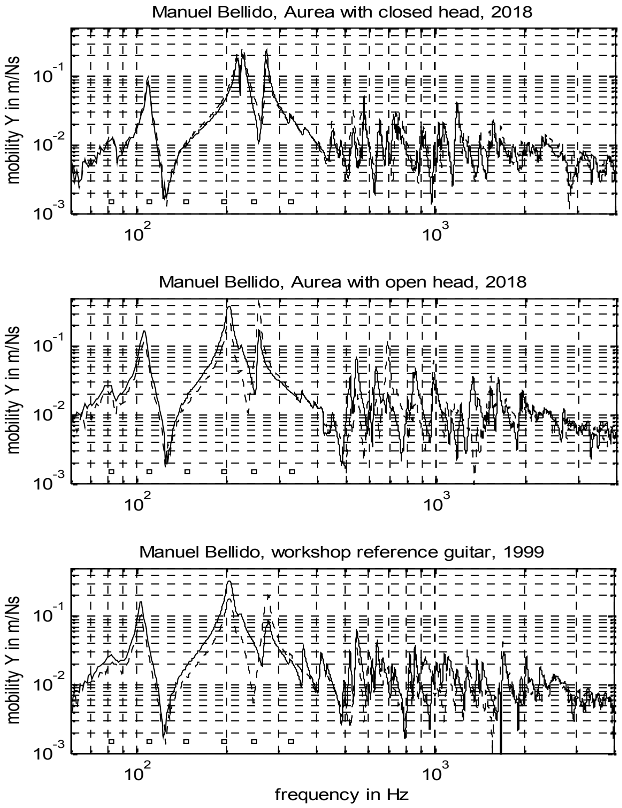

Fig. 1: Mobility of three contemporary Granadian classical Spanish guitars. (—) treble side, (--) bass side, (□) open strings frequency.

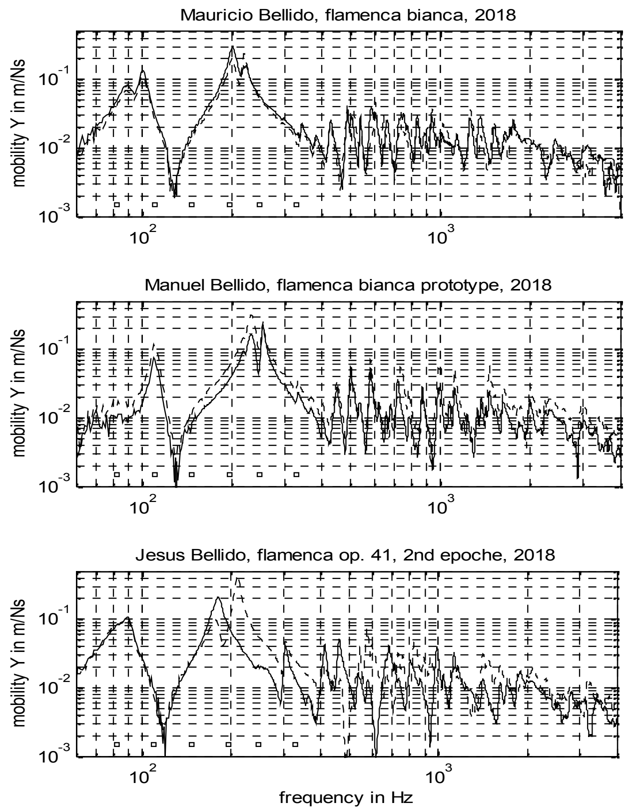

Fig. 2: Mobility of three contemporary Granadian flamenco guitars. (—) treble side, (--) bass side, (□) open strings frequency.

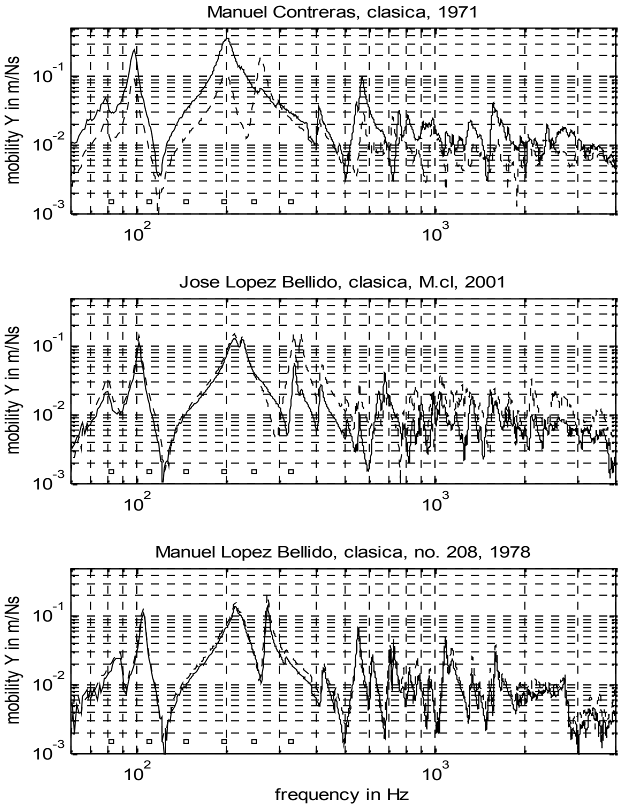

Fig. 3: Mobility of three classical Spanish guitars (vintage collection). (—) treble, (--) bass side, (□) open strings frequency.

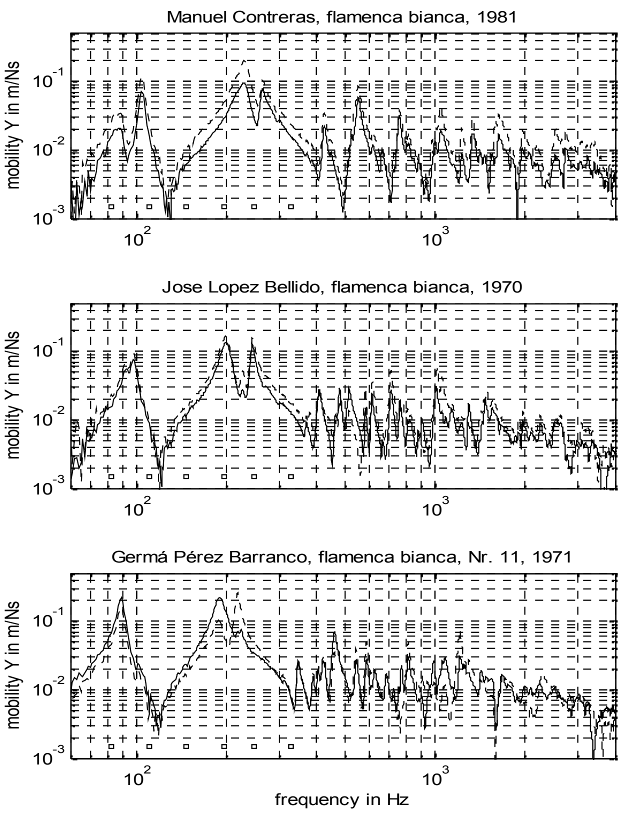

Fig. 4: Mobility of three flamenco guitars (vintage collection). (—) treble side, (--) bass side, (□) open strings frequency.

First of all there is a deterministic region below 400 Hz to 500 Hz, and a statistic region above 400 Hz to 500 Hz. These two regions are also observed in other instruments, such as the violin with a turning point at 700 Hz (Mores, 2014), and the grand piano with a turning point at 200 Hz (Bertaud et al., 2003). In the deterministic region the air resonance at 100 Hz, the fundamental top mode, or (0,0) mode, at 200 Hz and the first cross mode, or (0,1) mode, at 230 to 300 Hz have been reported by many researchers, already (Torres and Boullosa, 2009) (Firth, 1977) (Elie et al., 2012) (Christensen and Vistisen, 1980). While comparing the three *FGs* and the three *CGs*, it is apparent, that the frequency separation between the (0,0) and the (0,1) modes is wider for the *CG* as it is for the *FG*.

When comparing three *FGs* with three *CGs* from a private vintage collection, the frequency separation between the (0,0) and the (0,1) modes is likewise wider for the *CG*. Please note, that Figs. 3 and 4 allow for pair-wise comparison of the two types of guitars from the same manufacturer, in two from the three samples.

The two modes, (0,0) and (0,1), are coupled by air and by wood-internal shearing (Ross, 2010) (Elejabarrieta et al., 2002). Therefore, exiting one resonance will also lead to exciting the other, and vice versa. The -6 dB total width across the two modes is taken as a simple measure for the potential of strong modulation. For example, the Bellido Aurea from 2018, top graph in Fig. 1, peaks at 0.266 m/Ns, and the related -6 dB for the combined modes range from 213 to 274 Hz, taking into account the signals from either side of the bridge.

Fig. 5 summarizes the results for the combined bandwidth, and at the same time for the peak mobility of mentioned two modes. Likewise, the peak and the bandwidth for the fundamental air mode, A0, is also represented in the same figure.

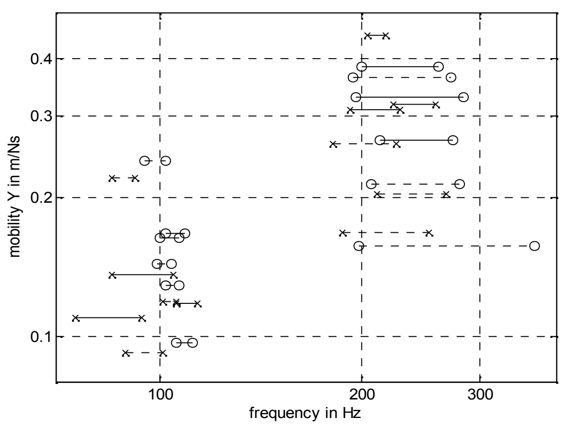

Fig. 5: Mobility versus bandwidth of air cavity modes and main top modes, for (○) classical guitars, (×) flamenco guitars, (—) contemporary, (···) vintage collection.

When ranking the bandwidth of the (combined) main top modes, all but one FG have a smaller bandwidth than all CG, see Table 2. There are two construction differences between CG and FG which may explain this. First, the top of FG is uually somewhat thinner than the top of a CG. Second, the fan bracing is usually somewhat more acute-angled in a *CG*, and somewhat more parallel in a FG. These two difference explein the somewhat greater stiffness in lateral direction working for a higher frequency of the cross mode, (0,1), for the *CG*. The obviously smaller bandwidth in FG translates to what musicians explain by using the descritption of a dry bass, the larger bandwidth in *CG* explains what musicians refer to modulation.

Table 2: Ranking of bandwidths for the combined top plate modes from smallest to largest.

rank	band-width in Hz	type	guitar
1	13	*FG*	Jesus Bellido, 2018
2	35	*FG*	Manuel Bellido, 2018
3	36	*FG*	Mauricio Bellido, 2018
4	44	*FG*	Barranco, 1971
5	56	*FG*	Contreras, 1981
6	60	*CG*	Bellido Aurea (open), 2018
7	62	*CG*	Bellido Aurea (closed), 2018
8	65	*FG*	Jose Lopez Bellido, 1970
9	73	*CG*	Manuel Lopez Bellido, 1978
10	78	*CG*	Contreras, 1971
11	88	*CG*	Bellido workshop ref., 1999
12	164	*CG*	Jose Lopez Bellido, 2001

On the contrary, when ranking the bandwidth of the fundamental air mode, all but one *FG* have a larger bandwidth than all *CG*, see Table 3.

Table 3: Ranking of bandwidths for the fundamental air mode from smallest to largest.

rank	band-width in Hz	type	guitar
1	5	*CG*	Jose Lopez Bellido, 2001
1	5	*CG*	Manuel Lopez Bellido, 1978
1	5	*FG*	Contreras, 1981
4	6	*CG*	Bellido Aurea (closed), 2018
5	7	*CG*	Bellido Aurea (open), 2018
5	7	*CG*	Bellido workshop ref., 1999
5	7	*CG*	Contreras, 1971
5	7	*FG*	Barranco, 1971
9	8	*FG*	Manuel Bellido, 2018
10	12	*FG*	Jose Lopez Bellido, 1970
11	19	*FG*	Jesus Bellido, 2018
12	20	*FG*	Mauricio Bellido, 2018

Ranking the frequency of the fundamental air mode results in a less clear classification. Most *FGs* have a rather low fundamental air mode. A few musicians and one professional trader of *FGs* claim that good *FG* ring at F#, which is at 92.5Hz, whereas *CGs* usually always ring between G, 98 Hz, and A, 110 Hz. This can be explained with the somewhat softer top in *FG*. Jürgen Meyer explained how the air mode declines with increasingly flexible walls while the volume and the open area of the Helmholtz resonator remain unchanged (Meyer, 1985). If it is the flexible top plate, that explains the low frequency of the air mode, then the fundamental top mode, (0,0), should likewise have a low frequency. This is well observable for the rank 1 and 2 guitars (full ranking not shown here), the Barranco and the Jesus Bellido guitars, which have their (0,0) mode clearly below 200 Hz Fig. 2 bottom, and Fig. 4 bottom.

Mobility seems to reveal no classification between *FGs* and *CGs*. None of the types of guitars is generally louder.

Another observation to possibly classify *FGs* versus *CGs* in the frequency domain is the likelihood of *FG* to reveal a deterministic chraracteristic also in the range above 400 Hz to 500 Hz. The Manuel Bellido 2018 shows this characteristic up to 1500 Hz, and the Contreras 1981 shows this characteristic up to 2000 Hz. This might relate to well manufactured top plates, with respect to homogeneity of stiffness across the plate. Andalusian guitar makers carefully check that local stiffness feels to be the same at all plate positions. This is a very important manufacturing procedure, more important than listening to knocking tones, and it seems to be easier to identify non-homogenous areas in the somewhat thinner plates of *FGs*.

Measurements - Time Domain

Concerning the fast rasgueado, one would expect that a fast attack should support such desired temporal acuity of a *FG*. Another supporting factor could be a certain degree of damping which would allow the tone to decline between successive rapid strokes. Fig. 6 summarizes temporal features of the 12 guitars in this investigation. The attack time represents the instant when 50% of the energy of the bridge impulse response has been radiated, with reference to the total energy radiated after 50 ms. The 50 ms reference is taken because the subsequent noise floor after 50 ms differs too much between the various measurement sessions, and roughly 80 % to 95 % of the total energy of an impulse response is radiated within those 50 ms anyway. The damping after 20 ms is the other parameter. It is measured along the fifth-order fitting of a declining exponential function to the envelope of the signal, and, more precisely, to the declining section of this envelope, after peaking. The radition signal is taken at 10 cm above the end of the bridge on either side, bass or treble, while the impulse at the bridge is introduced in the same way and at the same positions as for mobility measurements.

There is a reasonable trend relating attack and damping, well visible, especially for the bass signal, Fig. 6 bottom. There is no clear classification between *FG* and *CG*. However, the three fastest guitars are *FGs* (Jesus Bellido 2018, the Manuel Contreras 1981, and the Jose Lopez Bellido 1970) when checking the treble side, Fig. 6 top. When checking the bass side, again the three fastest guitars are *FGs* (Mauricio Bellido 2018, the Manuel Contreras 1981, and the Jose Lopez Bellido 1970), Fig. 6 bottom. The slowest guitar is a *CG* (Manuel Bellido 1999) when inspecting the treble side, and a *FG* (Barranco 1971) when inspecting the bass side. Apart from this tendency of somewhat faster *FGs* the populations in the temporal maps are rather overlapping, and not clearly featuring attack or damping for the *FGs*. Measures of the temporal map do not correlate with features of the frequency domain.

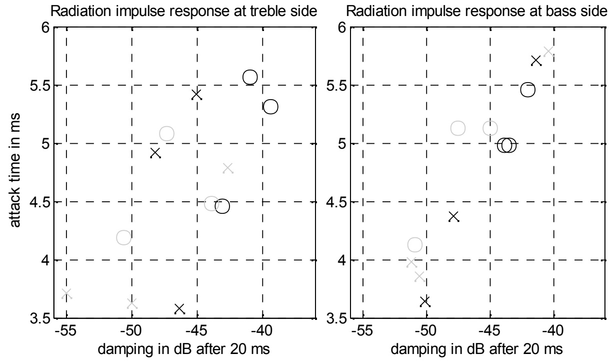

Fig. 6: Attack time versus damping for the radiated bridge impulse response, for (○) classical guitars, (×) flamenco guitars, (black) contemporary guitars, (gray) guitars from the vintage collection.

Summary

Flamenco guitars and classical Spanish guitars reveal differences, more clearly in the spectral domain, and less clearly in the temporal domain. The 6 dB bandwith across the fundamental (0,0) and the first cross mode (0,1) of the top plate taken together is smaller for flamenco guitars than for classical guitars, with only one exception among 12 investigated contemorary guitars and guitars from a vintage collection. In the temporal map - attack times versus damping after 20 ms for radiated impulse responses - the populations of both types of guitars overlap strongly, with only few flamenco guitars being somewhat faster than classical guitars.

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