IMPROVEMENT OF INTONATION AND PLAYABILITY OF GUITAR FINGERBOARDS

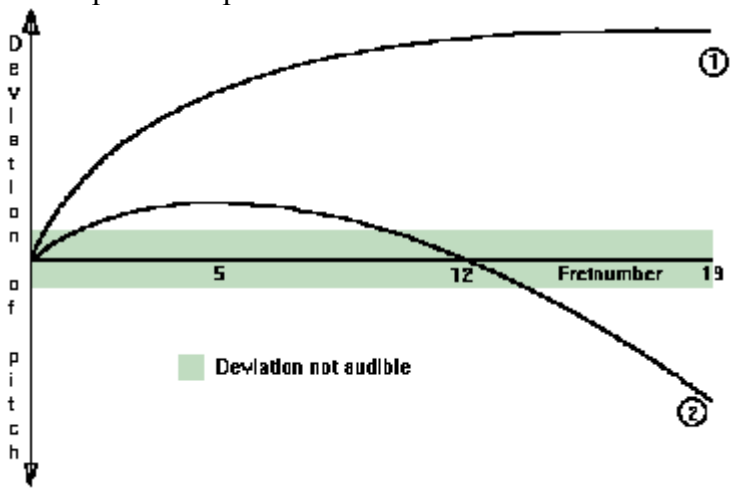
In the history of the development of the concert guitar, there have been many highlights, but also pauses. With Antonio de Torres the guitar became a respected classical instrument. Later, some have called Santos Hernandes the last great successor of Torres in Spain. Then, while Llobet, Pujol and the young Segovia contributed to the growing reputation of the guitar in the whole world, the art of guitar making seemed to enter a long sleep in Spain, certainly not unrelated to the circumstances under the Franco-regime.

In Germany the situation did not look much better: after Herrmann Hauser I. hardly any novelty regarding the sound of the guitar appeared. After the second world war, new impulses were set in Paris by Robert Bouchet and later by Daniel Friedrich. The "guitar boom" of the seventies brought new impetus to the art of guitarmaking. Slowly the Spanish methods of construction began to leak out into the world again, and since then the development of the concert guitar has taken place on an international level. While during the eighties the tendency towards increasingly louder instruments was obvious, nowadays guitarists are no longer willing to pay for volume with quality of sound.

A neglected issue in the course of this development has been the design of the finger-board - which is astonishing considering how important it is for intonation and convenience of playing. Long ago the quality of the strings has reached a standard that justifies much higher demands in this respect. Only a few years ago, I have advised customers who complained about the bad intonation of their (in conventional terms correctly adjusted) guitar to switch to playing the violin. What a sad conclusion for a guitarmaker.

In the generally customary construction of fingerboards the scale length is divided by way of calculation. This procedure, however, does not take into account that more tension is put onto the string when it is pressed down, which raises the pitch. The instrument maker usually compensates this effect by "lengthening" the string, i.e. moving the bridge backwards, in order to achieve a lower tone again. How far the bridge needs to be shifted is determined by comparing the open string with the tone played in the twelfth fret: it should represent the exact octave to the open string. But is this an adequate measure for correcting all the other tones?

Unfortunately this is not the case. The deviation of the pitch is graphically illustrated below: diagram 1 shows the deviation that would result without compensation at the bridge; diagram 2 shows the change achieved through the procedure mentioned above: at the beginning of the finger-board as well as around the twelfth fret the result is satisfactory - the strongest deviations are apparent around the fifth fret and toward the end of the fingerboard. Consequently this approach is not in the least a universal solution to the compensation problem.



Schrottstr. 18 ■ D-80686 Munich ■ fon: ++49-(0)89-58 58 93 fax: ++49-(0)89-1590 9323
www.stenzel-guitars.de ■ email: sebastian@stenzel-guitars.de

In concert guitars the level of this "built in" disharmony lies just in the audible realm. Unfortunately, there are other sources of incorrectness in addition: one of them lies in the fact that the temperated tuning itself implies compromises; also the conventional method of compensation even in the best case is balanced out over all six strings and therefore not quite exact (except when special bridges are used, like those used on electric guitars). The strings are never completely accurate in tone (quintrein); besides, the string is almost always slightly distorted in a lateral direction when pressed down. Finally, imprecisions result from the marking of fret positions by hand, which is frequently practised in the construction of expensive handmade guitars.

All these insufficiencies combined have caused some violin players to disqualify the guitarists as hearing impaired musical philistines. Here the guitarmaker is asked to do everything in his power to avoid what can be avoided. The guitarist, after all, can do nothing but tune his guitar and place his fingers cleanly in order to improve the intonation.

In addition, how much the disharmonies are audible is also dependant on the degree of overtones heard in the guitar, which is quite different from one instrument to the other. The stronger and the more numerous the overtones of two tones forming an interval are, the more precisely the tone interval is heard. Also changes in the fret position have a stronger effect on the overtones than on the basic frequency of a tone. Among other factors, the material of the string determines to what degree the pitch is raised when the string is pressed down. Certainly the synthetic strings of a concert guitar are less problematic here than metal strings, but on the other hand synthetic strings lie relatively high. Here a new problem arises: the six strings react differently according to their material: with or without winding, and the strings of one brand react differently from those of another.

With all these difficulties in view, let us return to our initial consideration: the conventional method of compensation ensures a sufficient exactness at the top of the fingerboard and around the twelfth fret, but does not constitute the entire solution to the compensation problem. It can only be solved if the necessary correction of the individual fret's position is calculated for each fret separately. The factors involved are - as mentioned above - the distance of the string to the fret, over which the string is pressed down, as well as the material and consistency of the string.

As far as the correction of the fret position is concerned, there have been attempts to find a solution through empirical experimentation in the past. However, because the theoretical foundation was incomplete and the quality of the strings was less good than today, no convincing results were achieved with this method. After all, in order to determine the right fret correction, it is first necessary to know the exact distance of the string to each fret and to be aware of how the string's pitch changes with its extension.

Let us leave the intonation aside for a moment, as the distance between fret and string leads us to the subject of playability of the fingerboard. This distance should be fairly small - the strings being positioned low, so that as little force as possible is required to press them down while playing. On the other hand the strings should not buss at any tone even when played forte.

So how does the finger-board need to look alongside the string to fulfill both requirements? Up to now, in answer to this question there were merely rules of thumb circulating among instrument makers, which often were far from the optimum.

The engineer Ernst Frisch has dedicated his dissertation to the above described problems - the complexity of which can only be indicated here - and thereby has made a significant contribution to the improvement of all instruments with fingerboards. I have verified the correctness of his findings through experiments with the monochord, and since then have successfully put them into practice in the construction of many instruments.

In summary: The aim is to create an easier playability and better intonation. If we know the optimal height profile of the finger-board, meaning the distance of each fret to the string, the required fret correction can be calculated, provided we know the "behavior" of the string when it is extended. This

leads us to the most complicated problem, for which Ernst Frisch however has found a very good solution:

He has developed a simple measuring procedure that serves to determine a parameter specific to the string, and contains all factors necessary for calculating the correction of the fret position. We know then what each individual string "does". As mentioned above, each string behaves differently, and also the E6-string, for example, needs an all in all higher position (action) than the e1-string. Consequently, for each string a different fret correction would be required. There are instrumentmaker who recommend corresponding fingerboards, but in most cases they have in mind to make the use of pure, Pythagorean or other scales possible. Meanwhile it is questionable wether the enormous effort involved in creating these fingerboards is justified if one has already accepted the compromises of the temparated tuning.

The engineer Ernst Frisch wanted to keep straight, parallel frets as well. Under this predisposition, the best solution to the problem of the different fret positions for each string was to maintain the compensation at the bridge for the twelfth fret and to balance out the remaining differences.

The method was established in a computer program, which - after informations about scale length, measuring data of the strings and position (action) of strings are entered, calculates the corrected fret positions, the required compensation at the bridge, and finally a complete height profile of the finger-board. The height profile calculated in this way allows for a string action that is 25% lower compared to a straigth fingerboard! In addition, the program provides an evaluation of the remaining inaccuracy resulting from the process of balancing out the differences between the strings. For example, it is possible to create fret positions for the e1- and the h2-strings that are very exact, while tolerating small inaccuracies in the high pitches of the E6-string.

As mentioned earlier, another problem is posed by the variations among corresponding strings of different manufacturers. I prefer the use of everage values drawn from various commonly used brands. The growing quality consciousness of guitarists will hopefully inspire some of the string manufacturers to produce strings that reduce these remaining inaccuracies to a minimum.

Conclusion: There is a new method to improve the intonation and playability of fingerboards significantly. A special advantage of this method lies in the possibility of adjusting the finger-board to the selected strings and to the individual technique of the player. Optimizing the height profile of the fingerboard is worth the effort for almost all instruments. In order to improve the intonation, however, the finger-board needs to be exchanged or the frets re-positioned. This effort is certainly only justified for guitars of high quality.

To avoid acquiring a reputation for splitting hairs I would like to emphasise that one can certainly live with a conventional fingerboard, provided it is precisly made. Also, a lot depends on what one is used to hear: many of my customers have not heard the improved intonation until playing there old guitar again. I hope to have shown that even on the level of theoretical foundation there are still possibilities for improving the techniques of construction of concert guitars.

Schrottstr. 18 ■ D-80686 Munich ■ fon: ++49-(0)89-58 58 93 fax: ++49-(0)89-1590 9323
www.stenzel-guitars.de ■ email: sebastian@stenzel-guitars.de