Tonic strains of a chamber orchestra

Dipl.-Ing. Alfred Wettklo
Dr.Ing.h.c.F.Porsche AG
Weissach

Abstract:

This paper deals with the acoustic behaviour of classical string instruments. The subject to be examined with the acoustic camera is a classical chamber orchestra including two violins, one viola and one cello. First each musician was asked to play the concert pitch. This note, the a’ corresponds to 440 Hz which is equivalent to a wavelength of 75cm. Then different tones, strains and different accents were played and measured.
And now the questions are:
What is the way of the tonic strains in the room ? Are there maybe any sensitive spots on the surface of the instruments ? Where does the strains come from ? Are there differences between the instruments ? What about the harmonic emission of notes ? This paper should give an answer to these questions and should open the awareness for room acoustics.

1 INTRODUCTION:

From the viennese classical period until todays time the string quartet with two violins, one viola and one violoncello is the most significant form and type of the classical chamber music.
The most significant period of the classical string quartet was the viennese classical period (approx.from 1780 to 1827). The viennese classical became a stylistic direction of the European art music.
Well known composers of the viennese classical period are Joseph-Haydn, Wolfgang Amadeus Mozart and Ludwig van Beethoven.
This work, tonic strains of a chamber orchestra, was possible with the help of a string quartet during an exercise evening in a lecture hall. First a short introduction of the music instruments will follow .

2 MUSIC INSTRUMENTS

2.1 The violin

(figure1)

The violin (figure1) is a bowed string instrument with four strings tuned in perfect fifths. It is the smallest and highest-pitched member of the violin family of string instruments, which also includes the viola and cello. First precursors of the violin came from the spanish-moorish area in the 8th century. The first documents mentioning violins date back to 1523. The shape has basically not changed since then. The origin is upper Italy. Well known italian violin makers, also called Luthiers, are for example Andrea Amati and Antonio Stradivari.

The violine and its parts:
neck: approx. 13 cm length
fingerboard: approx. 27 cm length
body: up to 36 cm length
The belly (provided with the f-holes) is usually made from fir wood. The back is usually manufactured from maple wood.

The fading time of the violine lasts between 30-60ms. In literatur the sound is described as clear and brilliant.

2.2 The viola

(figure2)

The viola (figure2) is a string instrument which represents a larger form of the violin. The sound is deeper than the violin. So the viola represents the alto voice of the violin family. Usually the body of the instruments have a length between 38 and 45, 46, 47 cm, most of them are between 40,5 and 43 cm. The fadingtime of the viola lasts between 40–80 ms.

The sound of the viola is described as full, smooth, dark up to the highest register, always a little bit melancolic and smoky.

Its own sound is due to the fact that the body of the viola is a little bit to small for the register it is used with. The sound is a perfect fitfth deeper than that of the violin. (ratio of Frequency 2:3) So the body has to be bigger in the same proportion than the 36 cm body of the violin. This means a length of 54 cm. The small body mutes the higher overtones.

2.3 The violoncello

(figure3)

The violoncello (figure3) is also a string instrument that belongs to the *Viola-da-braccio*-family.
The cello is built nearly in the same way as the violin. But it is bigger and the sides are in proportion higher than those of a violin.
The cello is played with a bow. In diffenrence to the violin and viola the instrument rests on a tailspike placed at its bottom, the neck is up and the body stands between the legs of the musician.
length of the body: 750–760 mm
hight of the sides: 111 mm
swinging length of the string: 690 mm
stringdiameter: 0,8–2 mm
The fadingtime time of the cello lasts between 60ms and 100ms.

Because of the high sides the sound spectral analysis shows the enforcement of particular tones, especially the first harmonic overtone . This is why the the cello develops its special sonority.

3 MEASUREMENT AND ANALYSIS

3.1 Measurement and analysis of the violin

The measurement shows the a‘ vibrato. Figure 4 on the right side shows the overall level and its emission. Figure 5 on the left side shows the time signal where the amplitude and its modulation can be seen. Figure 6 on the right side shows the spectral analysis with a lot of harmonic overtones of the concert pitch a‘, which are caracteristic for the range of sounds of the violin.

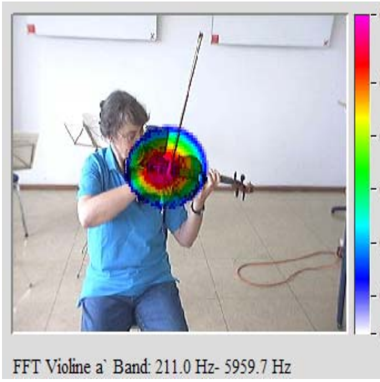

figure4:overall level

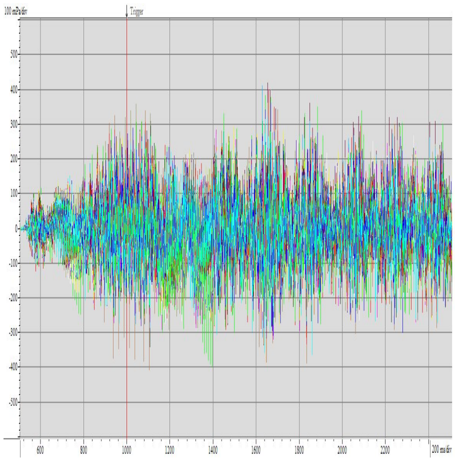

figure5:time signal a‘

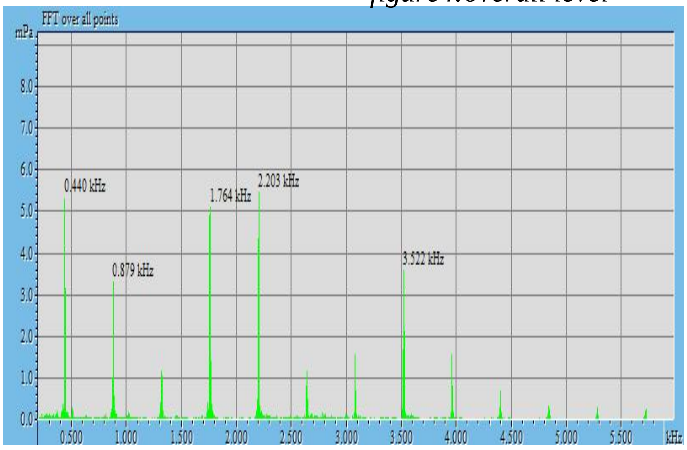

figure6:spectral analysis of the a‘

The following analysis shows the tonic strains of the a‘. With a dynamic range of 3dB one can find interesting relations between the wavelength and the geometrical extents.

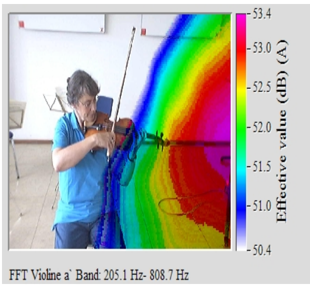

figure7:440Hz=>76cm

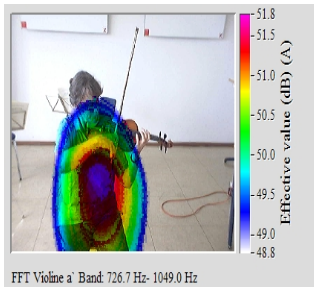

figure8:880Hz=>38cm

The tonic of the a‘ builts a standing wave in the room (figure7). The maximum of the sonic pressure of the first harmonic (figure8) is located at the torso of the musician. The emission of the third harmonic strain (figure9) is located in front of the f-holes.

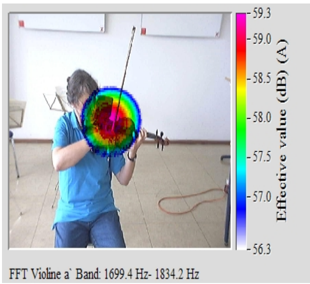

figure9:1760Hz=>19cm

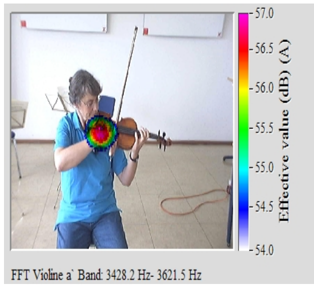

figure10:3520Hz=>10cm

3.2 Measurement and analysis of the viola

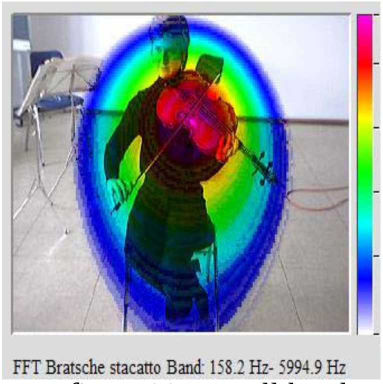

figure11:overall level

The measurement shows the c‘ stacatto. Figure11 on the right side shows the overall level and its emission.
Figure12 on the left side shows the 2 seconds lasting time signal where each stacatto part can be seen. Figure13 on the right side shows the spectral analysis with less harmonic overtones than the violin. The tonic is dominating which is caracteristic for the sound of the viola.

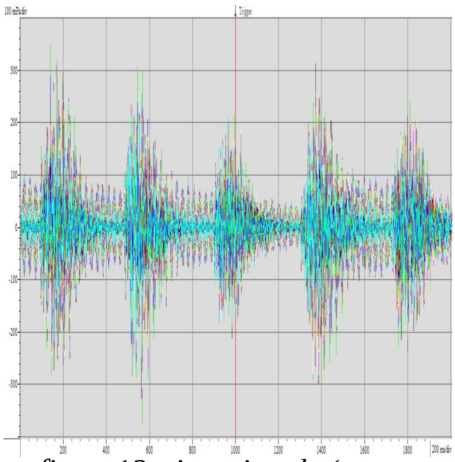

figure12: time signal c‘ stacatto

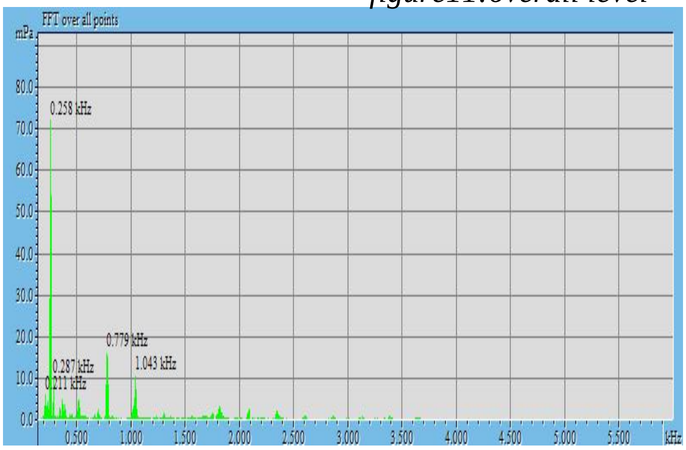

figure13: spectral analysis of the c‘

The following analysis shows the tonic strains of the c‘. With a dynamic range of only 1dB one can find interesting relations between the wavelength and the geometrical extents.
The maximum pressure of the tonic (figure14) builts a reflection on the ground . The second harmonic strain (figure15) shows the belly of the viola as the emission source. The sixth harmonic strain (figure16) is concentrated near the f-holes and the tenth harmonic strain (figure17) is radiated from the strings. In this case the wavelength corresponds to the distance between the fingers and the bridge.

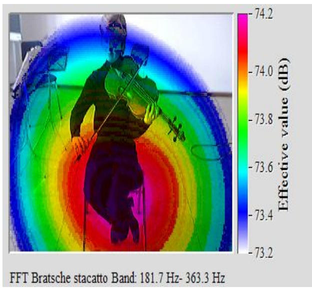

figure14:1260Hz=>130cm

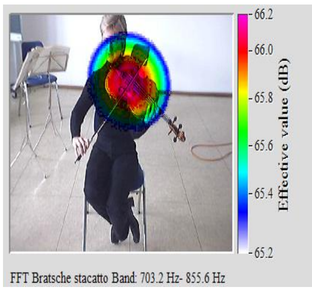

figure15:780Hz=>43cm

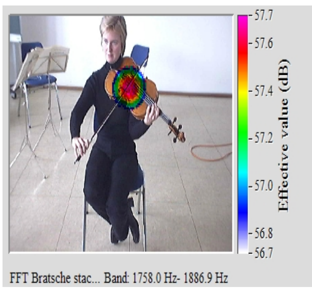

figure16:1820Hz=>18cm

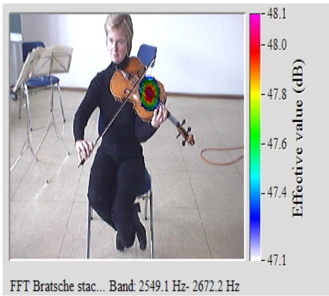

figure17:2600 Hz=>13cm

3.2 Measurement and analysis of the violoncello

This measurement shows the concert pitch a‘. Figure18 on the right side shows the overall level and its emission, a standing wave between musician an the ceiling.
Figure19 on the left side shows the 3 seconds lasting time signal where the modulation of the tone can be seen. The complicated nature for resonancys of the cello‘s body with its irregular harmonic dissipation are responsible for the so called cantable sound of the cello. Figure20 on the right side shows the spectral analysis of the concert pitch a‘ which is equivalent to 440 Hz.

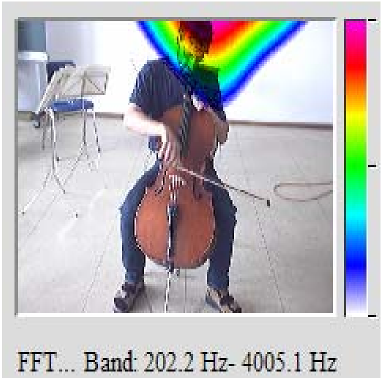

figure18:overall level

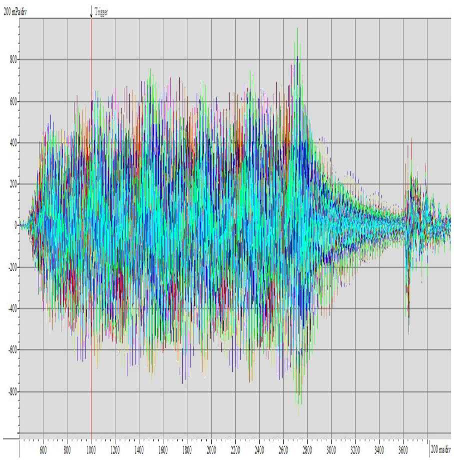

figure19: time signal c‘ stacatto

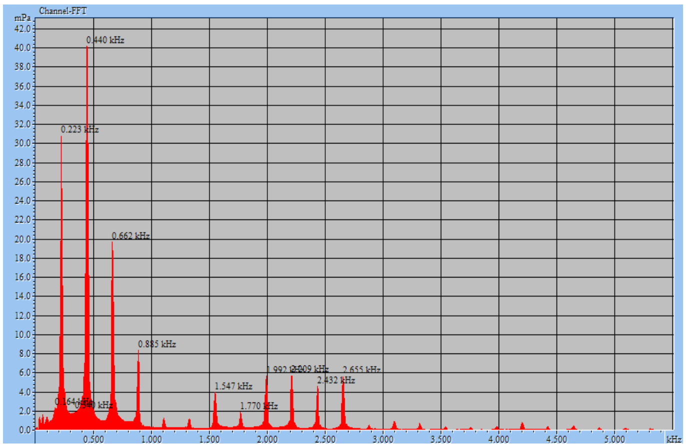

figure20: spectral analysis of the c‘

As it can be seen in the frequency analysis of the concert pitch a‘, the tonic sound dominates.
Interesting are the subharmonic tones of the a‘ which lead also to the cantabling sound of the cello.

The following figures show the analysis of the tonic strain a‘. Figure 21 shows the tonic strain with a wavelength of 76cm, which builts a standing wave between the musician and ceiling. The first harmonic tone is radiated from the top bout of the cello. The second harmonic radiation spot (figure23) is located at the f-holes and figure24 shows the sixth harmonic tone at the tailpiece, where the strings are fixed.

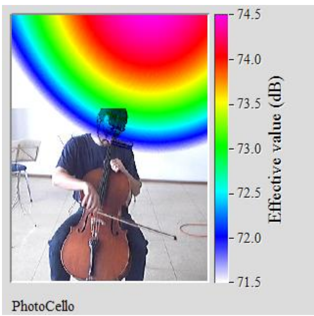

figure21:440Hz =>76cm

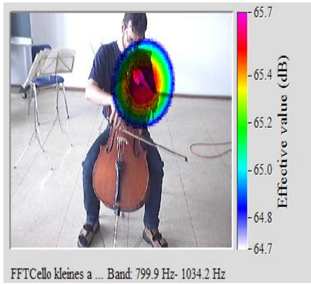

figure22:880Hz=>38cm

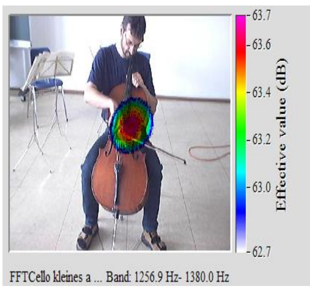

figure23:1320Hz=>25cm

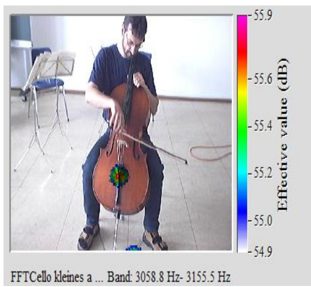

figure24:3100Hz=>11cm

The recordings were made with the acoustic camera, developed by the association for applied informatics „Gesellschaft für angewandte Informatik“ (GfaI)“ in Berlin

I would like to thank the musicians, specially Mrs. Eva Mänz who arranged our meeting and made this recordings possible.

References

[1] Winfried Pape, Wolfgang Boettcher: *Das Violoncello. Bau, Technik, Repertoire*. Schott, Mainz 1996, 2005 (2. Aufl.), ISBN 3-7957-0283-6 (Standardwerk zu Geschichte, Technik und Repertoire)

[2] Cremer, Lothar: „Physik der Geige“, (Hirzel Verlag) Stuttgart 1981, ISBN 3-7776- 0372-4.

[3] Fletcher, N.V.; Rossing T.D.: „The Physics of Musical Instruments“, (Springer Verlag), New York 1991, ISBN 0-387-96947-0.

[4] H. Kutruff : "Room acoustics", Applied science publishers, London 1979