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GENERAL ACOUSTIC FEATURES OF STRING INSTRUMENTS

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Abstract: *String instruments are among the oldest and most popular musical instruments in the world. They all have a similar construction and close phonic qualities. The acoustic features of string instruments are of critical importance in recording and reinforcement in order to achieve maximum sound quality. Knowledge of pollar pattern, frequency and dynamic range are very important for any sound engineer. For composers and conductors is equally important to know and understand the acoustic features of strings. This article aims to help everyone whom it may cocern and to provide useful practical information to all the music professionals.*
Keywords: *acoustics, frequency, decibel, dynamic range, sound, timbre, sound propagation*

The term "string instrument" could be filled with the most varied meaning depending on the criteria and the taco-nomic model used in the classification and research of the musical instruments. According to the nature of sound reproduction, these may be acoustic or electroacoustic instruments, according to the cultural and civilization condition, these are folk and professional instruments, according to the way of sound reproduction these are bows, harps and percussion, etc. In this article, string instruments will be understood as the classic string bow musical instruments, established as the main part of the symphony orchestra and the main instrumentation in classical music - violin, viola, violoncello, double bass. The acoustic features of the instruments reflect their constructive, sound-reproducing and sound-emitting parameters in terms of quality, composition and distribution of their sound.

The family of violins, as they called this group of instruments, have more or less similar constructive arrangements of individual representatives with a major difference in spatial dimensions and scale. Each string instrument is made up of more than 70 separate parts, illustrating the complexity of the acoustic vibrating system it represents. The qualities of the materials and the method of processing have a significant impact on the acoustic characteristics of the strings. When selecting wood for the casing, a number of factors are taken into consideration such as the location of the annual rings, the qualities and vectors of the veins, the wood's own sound, the vibration of the board, the timing of the tree cut, the chemical qualities of the material, and so on. Next of great importance is the technology of processing the material, the way of cutting and gluing of the individual plates, the setup and the tests, and all the techniques of the luthiers masters, which make the creation of a musical instrument a form of art.

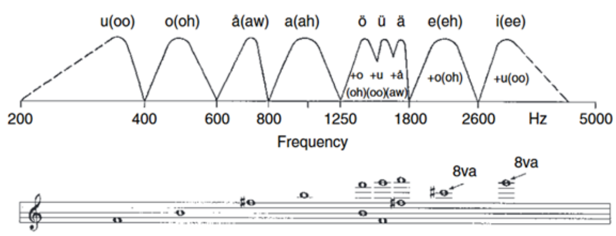
The Renaissance masters of violins such as Stradivari, Amati and Guarneri are almost legendary. There are three common circumstances that determine the incredible phonic qualities of the Renaissance string instruments. First of all, this is the preliminary preparation of the tree, which gives it durability and resistance to changes in temperature and humidity. It is found that the mineral composition of the wood by the old masters is very different from that of the natural untreated wood - there is a greater amount of silicon, calcium, manganese and aluminum and a reduced sodium content. This requires long-term treatment with various chemical solutions, the main purpose of which is to achieve micro-changes in the cellular structure of the wood, resulting in the wood becoming more solid and durable, and increases its sound qualities in the direction of clarity and vibrational flexibility.

The second "mystery" of Renaissance luthiers was identified with regard to the base or primer used on the wood before the lacquer coating was applied. The primer layer is a solid layer evenly applied to the instrument substance, which is approximately ten times the thickness of the lacquer layer. According to modern studies and experiments, the exceptional qualities of the primer are the reason for the inimitable sound of the Stradivari and the Amati's violins. The most important thing again is a combination of certain chemical substances such as silicon, aluminum, phosphorus, sulfur, calcium, titanium and others. Probably the Italians have used a similar mixture, obtained by connecting limestone with vinegar, water and a binder. The primer thus formed protects the tree very much and gives it more resistance and better sound. Most notable is the fact that these qualities have remained unchanged for four centuries.

The third unique feature of Renaissance violins lies in the composition and qualities of the thin lacquer coating. The lacquer is very important for the sound properties of the material, increases the mass and stiffness of the boards, as a result of which the fundamental resonance frequency shifts in ascending direction, increasing the wave resistance. Besides the extremely small coating thickness - less than 0.01 mm - the other important feature of the Renaissance lacquer is the presence of nitrogen of chitin or protein origin.

The main acoustic determinants of each musical instrument include the physical parameters and the spatial behavior of the sound they emit. The acoustic parameters can be summarized in several categories - frequency response, dynamics, polar characteristics. The homogeneous structure and the similar phonic qualities of the strings family allow a common examination of the phenomena.

The tone and frequency range of the sound spectrum are one of the main quality features of musical instruments. They match the size and pich of the instruments. The concept of spectrum very accurately describes the frequency content and the ratios between harmonics in the sound. The initial vibrations are created by the strings, but the sound radiated in the space is determined by the resonator properties of the body. Due to the complexity and multiple resonance systems, as well as the different vibrational phases of the individual components, the strings have a complex frequency spectrum. The main distinctive quality is the presence of formant zones - the resonant amplified zones of frequencies - which are stabil and permanent, regardless of the pitch. Formants are among the most important criteria for the timbre of the instrument. The exact frequency positions of the formats are indicated by Jürgen Meyer [4]



Позиция на формантите на гласните звуци в немски език (по Юрген Майер)

Picture 1.

There are several resonance regions in the string sound spectra, that shape the different sound characteristics. The low-frequency formants are in the range of 100-400 Hz, due to the air resonance of the instrument housing, as well as the resonance of the body itself, give the sound a density, sonority and a basic sound color. For the violin, the lowest formant is around 400 Hz, by the viola it is around 220 Hz with an additional maximum of 350 Hz. Consequently, by the cello this format is around 110 Hz combined with additional 250 Hz formats and between 300 and 500 Hz, whereas for the bass, the most important low-frequency components are in the range between 70 and 350 Hz.

The formats found in the next range between 500 and 1500 Hz have an extraordinary impact on the color of the sound, especially high instruments. The exact frequency position of the vocal "a" - 1000 Hz is critical in terms of the density and the nuances of violin sound, and this is also the strongest formanf of the instrument. For example, a comparison between Guerneri's instruments, where the maximum is between 1000 and 1200 Hz, makes the sound brighter and exuded, and Stradivari's violins, where this formant is always under 1000 Hz, creating their characteristic with a pronounced dark, rich timbre. The presence of formant areas around 1500 Hz emphasizes the so-called nasal components in the composition of sound, especially by viola and cello.

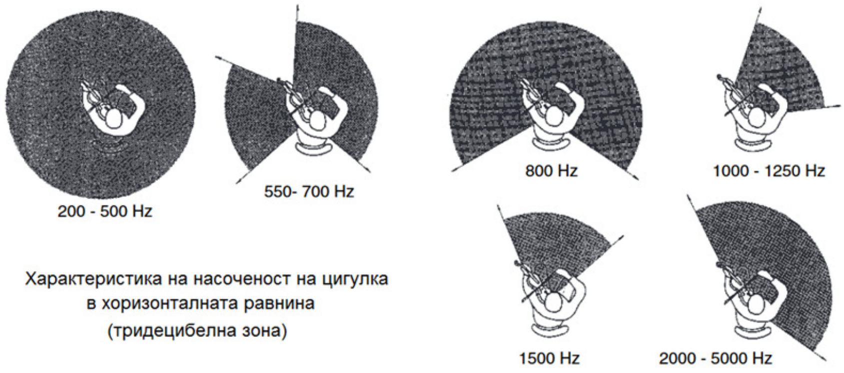
High-frequency formats in the range of 2000 - 4000 Hz have a direct impact on brightness and brilliance of the sound. Each of the string instruments, with the exception of double bass, has more or less pronounced formants in this area. The brilliant sound of the violin is largely due to the presence of two resonance maximums around the vocals "e(eh)" and "i(ee)" respectively 2300 and 3500 Hz. For the violla, the high frequency formality is around the frequency of 3200 Hz, whereas in the cello it is fluctuating to a fairly wide range and can be detected between 2000 and 3000 Hz.

Timbre and intensity of the sound depends on how the performer plays, which changes various parameters, such as the bow's moving speed, the bow pressure, and the position of the point of contact between the bow and the string. The intensity of sound reproduction has a direct relation to the content of the sound spectrum, increasing the amplitude proportionally increasing the range and number of harmonics.

In regard to dynamics, strings are far from being the strongest sound sources in the classical orchestra. This is illustrated empirically in the tradition of building the symphony orchestra, where against the single wind instruments acoustically opposes a chorus of strings. The dynamic range of a musical instruments is expressed in the difference between the quietest and the loudest possible dynamics. Dynamic range values are given in decibels on the absolute scale, measuring the sound pressure level. Again, the way of playing is important.

The overall dynamic range of strings lies from just under 40 dB in the violin to 25 - 30 dB for the bass. For the violin, the dynamic range is around 30-38 dB, with the maximum pianissimo values varying between 58-74dB SPL, and between 95 and 99dB SPL for the fortissimo. The violla has an interesting acoustic phenomenon - regardless of the size increase with a factor of 1.2, the maximum sound intensity is a few decibels lower than the violin. The reason of this is the mathematical ratios between the body size, the length and the tension of the strings, and the tone range. Maximum quiet dynamics lies between 63 and 67 dB SPL, while the strongest fortissimo ranges from 88 to 95 dB SPL, which forms a dynamic range between 25 - 32 dB. For cello, the values are between 63-74 dB SPL for pianissimo and 90-98 for fortissimo, which outlines a range of 30-35 dB. For double bass can be summarized a dynamic range of about 25 - 30 dB, with a wide range of pianissimo dynamics (66 - 79 dB SPL) and forte values of 92 - 96, even 100 dB SPL for individual tones. It can be noted the significant relation between the dynamics and the timbre in the contrabass, which is expressed in a serious difference in the amplitude between the low-frequency and the high-frequency components as a function of the intensity of movement and the pressure of the bow.

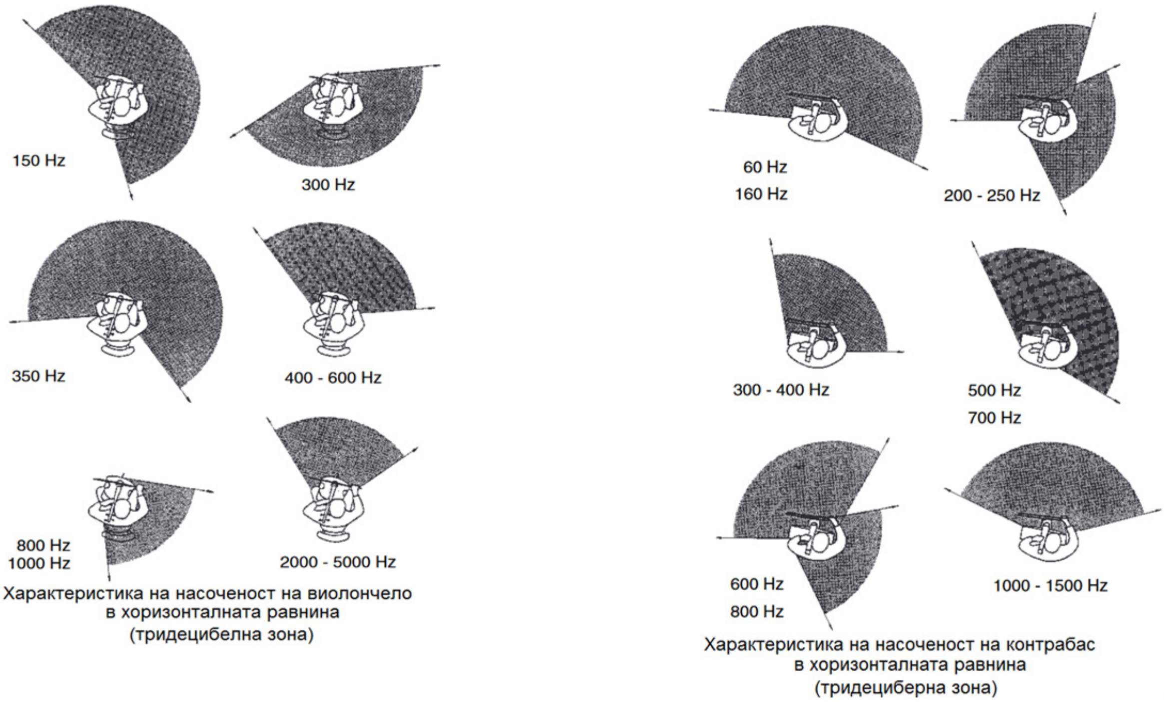
The third major acoustic feature of musical instruments is polar pattern. the characteristic of directionality. It describes the amount of radiated sound energy in space as a function of a particular physical vector. The direction of each sound source has an irregular spatial shape with one or more main directions of maximum energy concentration. The main reason for this is the fact that the individual structural elements of the instrument vibrate with different phases and different amplitudes, creating a sound pressure gradient in the space around the source. Sound propagation is considered separately in the horizontal and vertical plane, and separately for the different frequency domains as it is marked by serious differences and dependencies. Around each sound source two areas of significant importance are outlined - these are the three-dB and ten-dB angular zones. In these, the intensity of the emitted sound decreases by a maximum of three (e.i. ten) decibels relative to maximum value. The three-dB area marks the most informative spatial zone around the instrument with relative radiation stability and a maximum level of the corresponding frequency components. One should look for the microphone's position in this area in order to achieve maximum quality and full-range sound recording.



Picture 2.

Strings are characterized as the most undirected instruments with multiple directions of sound energy concentration and uneven distribution of general vector. In the low-frequency region, each of the instruments has an undirected radiation, i. is defined as a point sound source. Trimming of a three-dB zone area only occurs when the sound wavelength for the corresponding frequency becomes comparable to the instrument's spatial dimensions. Generally, the main vectors of polar pattern by strings concentrate in the orthogonal direction parallel to the top of the body and outline a relatively wide angular area, sometimes with two or more equivalent spatial directions radially outwardly of the upper acoustic plane.

Picture 2 shows a violin orientation in the horizontal plane with shaped angular areas of maximum sound concentration for the particular frequency segment. Obviously, there is an inverse trend between increasing the frequency and narrowing of the three-dB area. For violas the data are almost identical.



Picture 3.

For cello and double bass, there is a significant change in the position of the instrument relative to the body of the performer, but this does not alter the fundamental radiation properties inherent in all strings. As illustrated in Picture 3, there is a significant dependence between the frequency and magnitude of the richest angular area.

The acoustic principals that have been examined so far in this article have only scratched the surface of the overall complex and multi-layered picture. The current article has not the capability and does not aim at a maximum comprehensive presentation of the issues involved. Some of the important acoustic characteristics of musical sound such as the construction of transient processes, the development of quasi-stationary processes and the corresponding time deviations, as well as the impact of spatial laws in the distribution of sound in halls, remained out of focus. There is undoubtedly the great practical importance of this matters in terms of concert practice, sound reinforcement and recording of classical instruments. The detailed knowledge of strings acoustics is a sine qua non for achievement of competent and quality results by any professional who is involved in acoustic or soundrecording.

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