Chapter 7
Seating Arrangement in the Concert Hall

7.1 Customary Positioning of Instrument Groups

There is no uniform rule for seating arrangements within an orchestra; the placement of individual instrument groups is handled in many different ways. Thus, tonal as well as performance technical reasons play a role, and finally, the shape and size of the available floor space also are important factors. The latter naturally is especially relevant in orchestra pits of opera houses; however, also for concert stages, which generally provide adequate expansion possibilities for ensembles there is no seating arrangement universally recognized as optimal.

The reason for this can be seen in the fact that acoustical conditions differ from hall to hall and that there will always be an attempt to adjust the orchestra arrangement to the given room acoustic circumstances. Naturally this is the case for the local concert hall, which is mainly used by one orchestra on a routine basis, however, it is certainly not ignored during tours. Thus, for example, it is well known that W. Furtwängler insisted on corrective changes in seating arrangements in various halls during rehearsals, while on tour with the Berlin Philharmonic (Furtwängler, 1965). Other conductors, however, for sound esthetic reasons, insisted on the same seating arrangement, which appeared optimal to them, for each orchestra with which they performed, even when the relevant orchestra was accustomed to a different arrangement (Boult, 1963). The seating arrangement preferred, naturally depends on the personal interpretation style and the subjective tonal perception of the conductor.

The importance ascribed to the grouping and arrangements of performers by composers and contemporary musicians is shown by a look at the history of performance practice (Schreiber, 1938; Hoffmann, 1949; Becker, 1962; Paumgartner, 1966). Thus, already J. Mattheson in the publication "Der vollkommene Capellmeister," (1739) addresses this question and J. J. Quantz, 1752, demands of an "Anführer der Musik" that he "knows how to group, position, and locate the instrumentalists," he also then gives exact directions for positioning of performers, where naturally the location of the harpsichord of the conductor as the central location is understandable for the end of the era of the *basso continuo*. R. Wagner, had a new podium constructed for a performance of the 9th Symphony by

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L. van Beethoven in Paris, in order to arrange the orchestra in steeply rising steps, according to his own system (Wagner, 1911). In his writings about conductors, with many details, Hector Berlioz considers the effectiveness of raised podiums and sound reflecting surfaces, and demands sufficient distance between similar instrument groups which are to enter into a dialogue-like interchange (Berlioz, 1864). A. Melichar (1981) considers the arrangement of the strings in great detail, especially the situation with the second violins, and in doing so quotes A. Toscanini, who considers the two violin groups as a pair of shoulders: “Like shoulders, they must be equally strong and equivalent.”

For the seating arrangement within the orchestra, which is currently found in concert halls, the strings are almost always located in front of, and to the side of the conductor and occupy the full width of the podium. The woodwinds and horns are located directly behind, them usually a step up; the final row is formed generally by the heavy brass and the percussions in front of the rear wall of the hall. Within the strings and the wind groups the arrangement of the individual voices can vary considerably.

The currently customary arrangement of the strings is schematically represented in Fig. 7.1. For the sake of clarity, all instruments within one group are drawn as parallel to each other; in practice of course all desks are oriented so that the players have the conductor in their field of view. The so-called German or European seating of the strings, as indicated, represents the longest tradition. Within that tradition, the placing of instrument groups is characterized by the fact that the first and second violins are seated opposite each other on the podium, while the celli are located directly in front of the conductor and slightly to the left of the first violins. The violas fill the space between the second violins and the celli, the basses continue on the left wing toward the rear of the celli. The earliest historical precursors of this seating arrangement can be found in the Mannheim church orchestra under Abbé Vogler (around 1777), who introduced the separation of the two violin groups to the right and left side. In his arrangement the general bass group forms the center. Locating the two violin voices on both sides of the conductor was subsequently adopted relatively quickly in a series of other orchestras. However, the European seating arrangement of the form represented in Fig. 7.1 was not spread universally until the second half of the nineteenth century.

From a purely performance technical standpoint this arrangement has the advantage that the contact between the concert master and the solo cello is very good because they are so close. The contact between celli and basses is also very favorable, which is particularly advantageous for critical common entrances (e.g., at the final presto of the 4. symphony by R. Schumann, in measure 211). To a certain extent the two violin groups are seated as partners opposite from each other, the difference between these two voices can be recognized through a certain “stereo effect” in the tone picture which lends much greater transparency especially to passages within which the motif is exchanged. A further advantage of this seating arrangement is noticed in passages where the first violins and the celli play in unison as for example in the last movement of the first symphony by J. Brahms (score example 11). Placing these two groups as neighbors merges these two voices into a total sound better than if they were separated from each other.

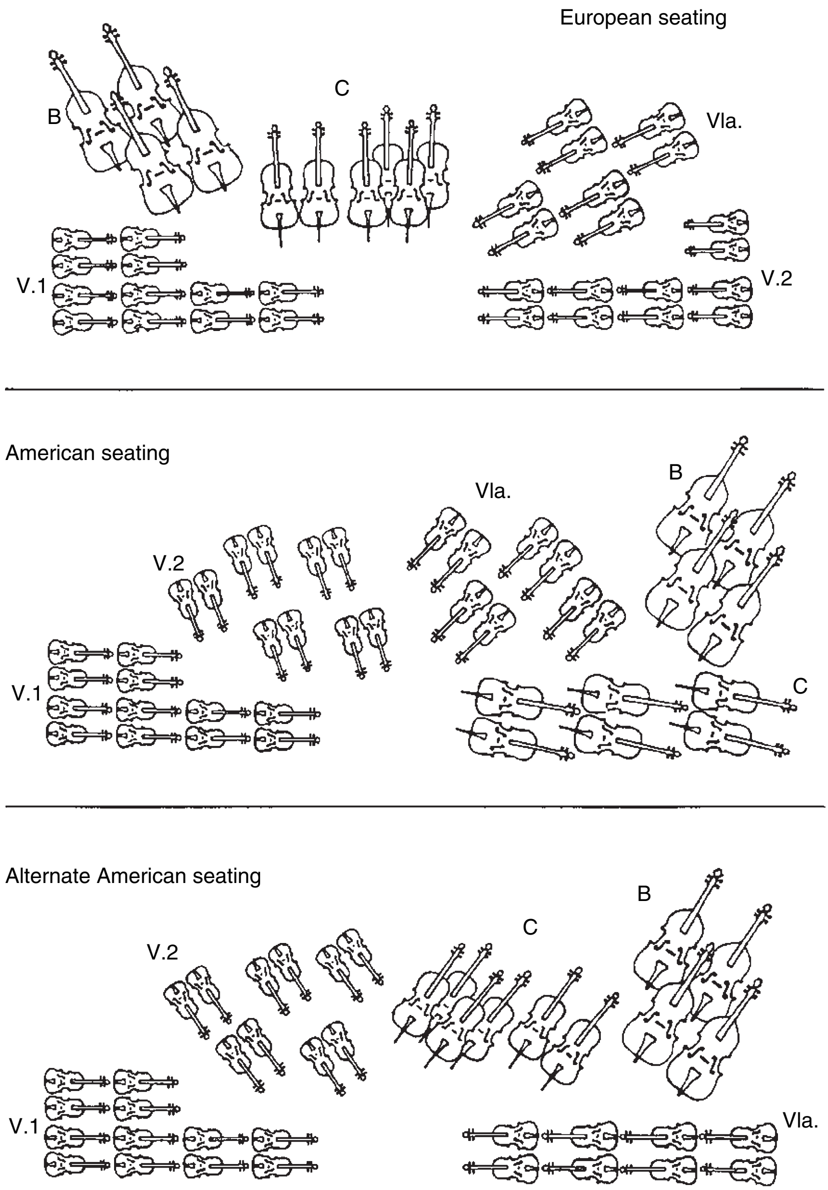


Fig. 7.1 Schematic representation of the currently used seating arrangement of string players in a symphony orchestra. For the sake of clarity all instruments belonging to one voice are represented in parallel fashion

Score example 11 J. Brahms, 1st symphony, 4th movement measure 185 ff. Score excerpt without winds and percussion

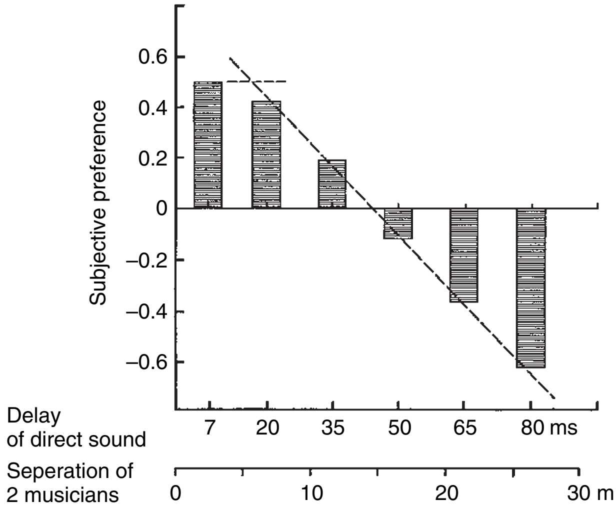


Fig. 7.2 Ease of playing together without visual contact, in dependence on distance between performers (after Gade, 1989a)

With increasing demands for precision in playing together, the requirements for mutual contact increase for the spatially separated arrangement of the two violin groups: acoustically this is supported when the strings are located beneath a nearly horizontal reflection surface (see Fig. 6.14); optically it is supported if the rear desks are slightly raised. The importance of visual contact for players is shown in an experiment by Gade (1989a). He had two musicians perform in separate nearly anechoic rooms. Mutual contact between the two players consisted only in having the sound performed for each by means of a microphone and a speaker; in the experiment, varying delay times could be introduced into the electroacoustic connection. The result is shown in Fig. 7.2: the subjective ease of performing jointly, as judged by the performer, is entered above the delay time; furthermore, the horizontal axis indicates the separation between performers which corresponds to the delay time, or the traveling time between performers when located in the same room.

As evident, performing together becomes increasingly difficult when the traveling time between players becomes longer than approximately 20 ms; this corresponds to a distance between players of about 7 m. Considering, that for an orchestra, a width of about 17 m and a depth of about 12 m is not uncommon, it becomes clear how indispensable visual contact is, especially between players located at the outer edge, as well as with the concert master. In this context it should be mentioned that in a discussion about questions of orchestra seating arrangements P. Boulez represented the standpoint that the difficulties of playing together only arise because of the large orchestra size currently customary. It can easily be overcome with seating limited to eight players within a section (Meyer, 1987).

During the second half of the twentieth century, the so-called American seating was found predominantly. It was initially introduced on a trial basis in the 1920s to make concessions to the initially very primitive recording techniques for radio and recordings. It was then propagated by L. Stokowski, and rapidly entered international concert halls (Melichar, 1981). In this seating, the celli are located to the right side of the podium, while the second violins follow the first violins toward the middle, the violas and the basses take up the space between the second violins and the celli; occasionally the basses are pulled toward the front of the podium following the last desk of the celli. This seating arrangement which rapidly began to become important in the 1950s in Europe, corresponds to the arrangement of the string quartet in a linear voice sequence. However, one should not overlook the essential difference, that in a quartet the first and second violins receive individual tone formation both in regards to performance technique and especially through the vibrato, while these characteristics totally lose their differences.

An advantage of this seating arrangement is of course the good contact between the two string groups which supports critical common passages or entrances. The linear arrangement of strings also appears especially logical in such places where a motif is repeated through all four voices in a rising or falling line, because the time sequence now also corresponds to a spatial sequence and sequence in register. As typical of such passages the score example 12 gives an excerpt from the Scherzo of the 7th symphony by L. van Beethoven; the last movement of this work contains similar locations, where, however, the violas and the celli move together. For this seating arrangement, however, the less than optimal contact between the concert master and the solo celli is a disadvantage, the contact between the celli and the basses also suffers, especially when the latter are not drawn toward the front of the podium.

This deficiency is largely equalized with the variation of the American seating arrangement which was introduced by W. Furtwängler and has since been adopted by many orchestras. The celli and the violas exchanged positions, so that again a closer connection exists between the celli and the basses. The contact between solo cello and the concert master is also improved without having to abandon the performance technical advantages of seating the two violin groups together. This

Score example 12 L. van Beethoven, 7th symphony, 3rd movement, measure 24 ff. And excerpts from the 4th movement, measure 307 ff. (without winds and percussion)

seating arrangement, however, has a disadvantage, especially when due to placement across the entire width of the orchestra, common accompanying figures played by the second violins and violas cover the first violins, particularly when these do not play a closed melody line (e.g., F. Schubert, 7th symphony, 2nd movement, measure 267 ff) (Creuzburg, 1953). Thus the conductor faces a difficult task, at least in the dynamic layering, which for spatial voice separation would not be so critical.

The woodwinds are usually distributed in the two rows behind the strings in a manner such that the flutes and the oboes are in front, and the clarinets and bassoons behind, at least for sufficiently large numbers of players. In this arrangement, the first voices of each group are placed toward the middle so that the quartet of the four solo performers is located with correspondingly good mutual contact in a limited space. Specifically the flutes are generally located toward the left as seen from the position of the conductor, the oboes to the right, while the arrangement of clarinets and bassoons varies.

For a small number of winds, in most cases all musicians can be accommodated in one row, where the highest instruments usually are placed to the left and the additional woodwinds down to the bassoon follow toward the right; the horns are then located at the end. Depending on instrumentation, it sometimes makes sense for individual compositions to depart from this steady rise in pitch. A typical example for this is the symphony in B flat minor by Joh. Chr. Fr. Bach, in which the flute and bassoon both play in opposition to the two clarinets in all movements;

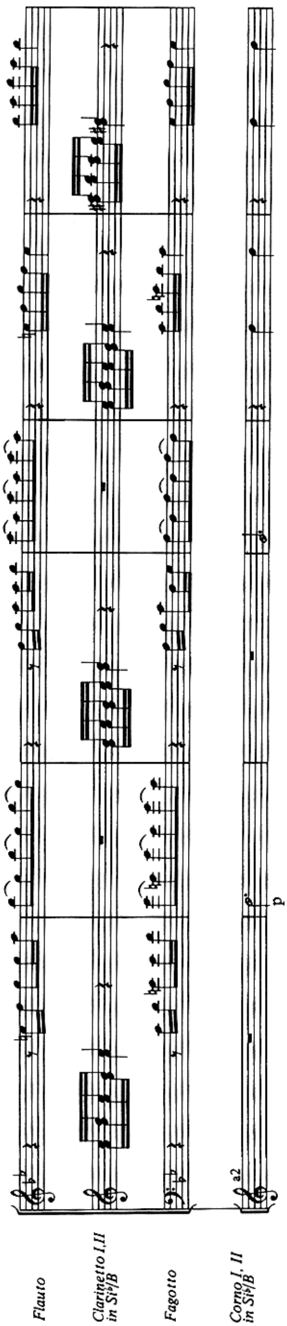
two horns complete the winds (score example 13). In this case it is desirable to place the flute and the bassoon together and not separate them by the clarinets. It thus remains a question of interpretation, to decide whether the "stereo effect" between the woodwind pairs is to be reinforced so that sometimes even the horns are placed in the middle.

A good connection between the bassoon and the cello group is of course important, however this also demands seamless mutual performance with the violins which occurs in many classical works with a so-called Vienna unisono with its octave parallels between violins and bassoons (see score example 14). An excessive separation between the two instrument groups can lead to unpleasant sound effects, since it not only influences mutual listening, but can also lead to a stereophonic separation. In works with smaller numbers of winds, as for example in the early symphonies of J. Haydn and W. A. Mozart this problem is already solved by the fact that all winds are sitting in a row next to each other and the distance between the bassoon and the strings is correspondingly diminished.

The horns are located to the right or left of the woodwinds. The performance technical advantages and disadvantages of both possibilities are difficult to assess, since on the one hand the woodwind group is shifted to one or the other side by the choice of location of the horns, and on the other hand the tonal balance of the remaining brass instruments and the mutual performance with them must be considered. In particular performance technical difficulties arise when the horns are located directly in front of the trombones because the players in both groups will hear the other instruments louder than their own and thus the danger always exists that the loudness level will be raised. Finally the horns, or at least the solo horn must have good contact with the celli, since frequently unisono-instrumentation of these two groups are found, and this often in melodic passages. Contact with the concert master, which is particularly important at the conclusion of the slow movement of the 1st symphony by J. Brahms, will at any rate be only possible visually, so that in this case, positioning the horns to the right side will unquestionably be more advantageous.

In the presence of two to four horns, the heavy brass is generally positioned on the same step with the second row of the woodwinds. When there are eight horns, the trumpets, trombones, and tuba are moved further to the rear, and they are then found in the same line with the timpani and the remaining percussion instruments. For reasons of tonal symmetry a position near the central axis of the orchestra is often preferred for the timpani however there are also seating arrangements for which the timpani are located in a rear corner of the podium. This is the case for example when the basses are positioned in the last row in front of the rear wall.

When positioning percussion instruments it is especially important not to overlook the fact that the traveling time of the direct sound to the more distant musicians of the orchestra can certainly be of the order of 30 ms, so that playing together with desired precision based solely on hearing is no longer possible and visual contact and optical connections through the conductor alone meet rhythmic needs. For difficult joint passages of individual musicians, the choice of seating arrangement with view toward least separation and good visual connection is of the utmost



Score example 13 J. Chr. Fr. Bach, symphony in B^b major (1794), 1st movement, measure 73 ff. (without strings)

Score example 14 J. Haydn, symphony No. 94, first part of the trio in the minuet

importance. In this context those percussion instruments are especially important which have their essential tone contribution at higher frequencies as for example small drums, xylophones, or the wooden block. If, for example, the direct sound during its path past the musicians of the orchestra is additionally damped because of its high frequency, it can be attenuated so strongly in comparison to the ceiling reflection that the sound from the percussion instrument is perceived as coming from the ceiling with its corresponding delay determined by the additional path length. This effect particularly adds to the difficulty when a soloist (e.g., clarinet concerto by C. Nielsen) or the concert master is expected to play simultaneously with the corresponding percussion instrument. The score example 15 shows a typical passage for this from the 15th symphony by D. Shostakovitch. For such cases positioning the percussion instruments closer to the front within the orchestra can be an advantage. Also, in the first parts of the Bolero by M. Ravel such a positioning of the small drum is advantageous for the rhythmic precision and dynamic shaping.

The choice of seating arrangement also plays an important role from an acoustical standpoint since the individual instrument groups, depending on their orientation, radiate their sound more strongly or weakly into the hall and thus can also change the tone color. The relationship between the intensity of the direct sound, the early reflections, and the diffuse field which is essential for the clarity of the tonal picture can be influenced by the orchestral seating arrangement because of the connection with the directional characteristics of the musical instruments. This opens valuable possibilities for adapting the tonal body to the room acoustical environment when a musical concept is to be realized in the performance. At the location of the conductor the tonal effects of different seating arrangements are hardly noticeable, since all orchestra musicians are oriented to face the conductor, and thus in all cases the radiation directions remain the same relative to the conductor. However, they are clearly noticeable to the audience.

As a measure to indicate how pronounced the directional dependence of the sound radiation for individual instrument groups is, the range of the statistical directivity factors for three representative frequency ranges is represented in Fig. 7.3. These regions encompass the values for all directions; the maximum value which applies to the direction of strongest sound radiation is of particular

Score example 15 D. Shostakovitch, symphony No. 15, 1st movement, measure 337 ff

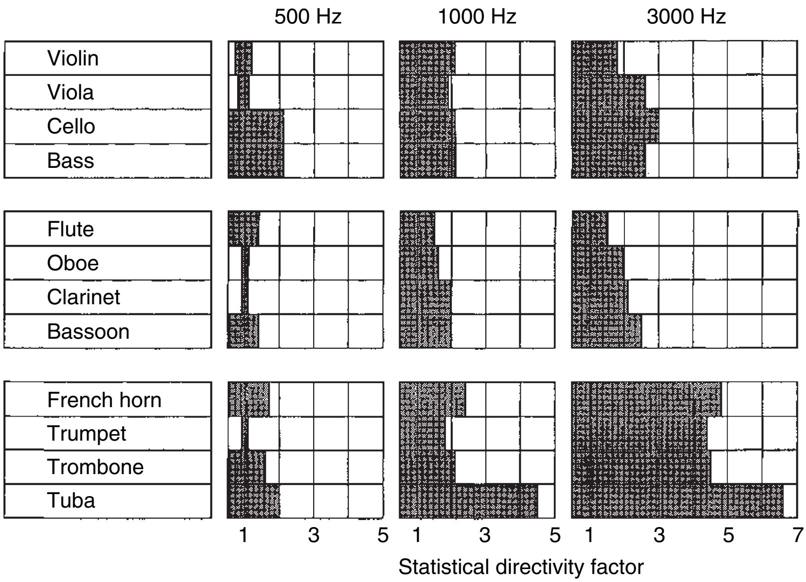


Fig. 7.3 Variation range of the statistic directivity factors of orchestra instruments at three frequencies

importance. In this representation it should be noted that the directional effect for string instruments at higher frequency is more pronounced than for woodwind instruments – it is naturally still far surpassed by brass instruments. The influence of these directed sound radiations on the tonal effect in the hall will be treated subsequently in detail, with its consequences related to performance practice.

7.2 The Tonal Effect in the Hall

7.2.1 String Instruments

7.2.1.1 Violins

The angular regions of preferred sound radiation for violins were already represented in Figs. 4.17–4.19 in the form of histograms. In Figs. 7.4 and 7.5 the essential characteristics of directional effects are once again collected in a schematic overview. They represent those angular regions for which the sound level does not drop by more than 3 dB below its maximum value in a horizontal plane and in a vertical

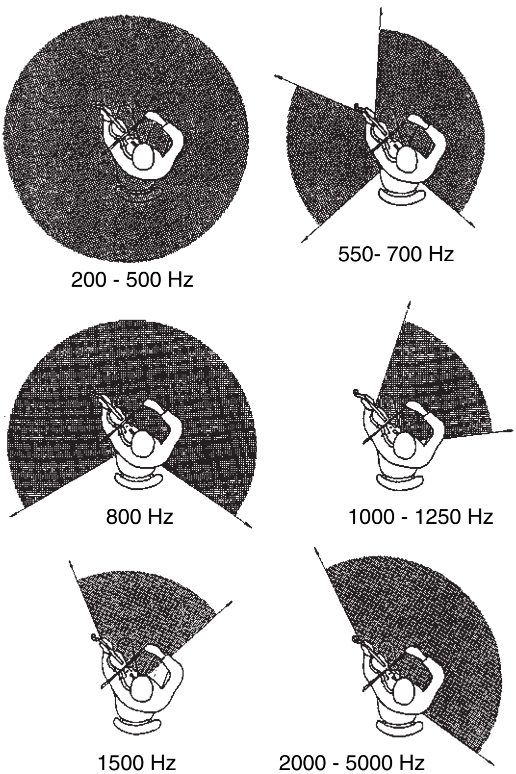


Fig. 7.4 Principal radiation directions (0...−3 dB) of violins in the horizontal plane

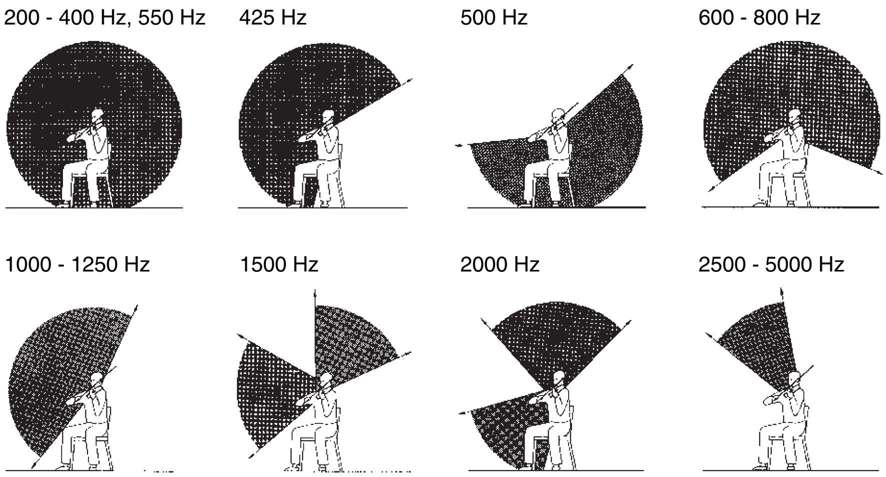


Fig. 7.5 Principal radiation directions (0...−3 dB) of violins in the plane of the bridge

plane, with a figure representation of the performer indicating the spatial orientation. These representations are designed to form the foundation for a comparison of tonal effects of the two violin groups under different spatial conditions for varying orchestral seating.

For the first violins, which are seated to the left of the conductor, the angular region which is directed toward the audience is marked in red in Fig. 4.18, in order to emphasize the tonal difference between the two violin voices in the German seating. Correspondingly the region in Fig. 4.17 is marked in red for which the sound radiated from the first violins reaches the audience directly or by a reflection from the ceiling. In contrast those angular regions are colored in blue for which the direct sound of the second violins is important in the German seating arrangement. A comparison of the red and blue areas thus clearly illustrates the tonal difference between the two string groups.

A very pronounced difference appears in the frequency region between 1,000 and 1,200 Hz, which belongs to the high a(ah)-formant and is thus responsible for a strong, bright tone color. In the German seating arrangement, these components are very advantageous for first violins, in contrast, they are radiated significantly more poorly by the second violins. Also, the higher frequencies from 2,500 Hz on upwards are more effective for the first violins, and the tone color receives its brightness and brilliance. Furthermore, it is precisely these high frequencies which in large measure contribute to the clarity and precision of fast passages.

In contrast, sound radiated by second violins has an advantage in the range of o(oh)- and å(aw)-formants, as well as for the nasal contributions (around 1,500 Hz) as perceived by the audience. Thus the tonal effect of the second violins in contrast to the first violins is darker and more covered; the timbre is shifted in the direction toward the violas. This difference in tone color is observed especially clearly in two passages of the 1st movement of the 6th symphony by L. van Beethoven (measure 155 ff and 201 ff), where within four measures, sustained notes of equal pitch are exchanged between the two violins. The duration of these tones is sufficient to enable an audible distinction between the details of the differing tonal structures.

While all this primarily includes the direct sound and the ceiling reflections, Fig. 7.6 makes it possible to include the first side wall reflections in these considerations. In analogy to Fig. 6.9 those frequency regions are represented, for which the side walls of a rectangular hall (as seen to the left or right of the audience) fall within the main radiation region of the string instruments. With reference to the violins it is recognized that for the German seating arrangement strong reflections from the left side wall are to be expected from the second violins, which melt the two violin groups more strongly to a single whole for the audience than apparent at the location of the conductor. At the same time, these representations clarify the significance of the left, and especially the right side wall, for the sound of the first violins, which contributes to the spaciousness of the orchestral sound by appropriate reflections, provided the walls do not diverge excessively.

As can already be seen from Figs. 4.17–4.19 and 7.4 to 7.5 the tonal difference between the two violin groups in the American seating is relatively small. For this seating arrangement relatively good radiation conditions can be expected, even for the high-frequency contributions around 4,000 Hz, provided there is nothing to prevent them from spreading freely. This assumption is confirmed by measurements (from the year 1967) in the Beethoven hall in Bonn, where measurements were performed to determine by how much the sound level of the violins in various locations in the hall is less than the level at the location of the conductor. The result is shown in the diagrams of Fig. 7.7. It is noted, that in most locations the drop for the second violins is not significantly different from that of the first violins. Only in the left portion of the front on the main floor, the performance of the first violins effect some shadowing of the second violins which are seated further back. The relatively even frequency dependence which occurs for the first violins is particu-

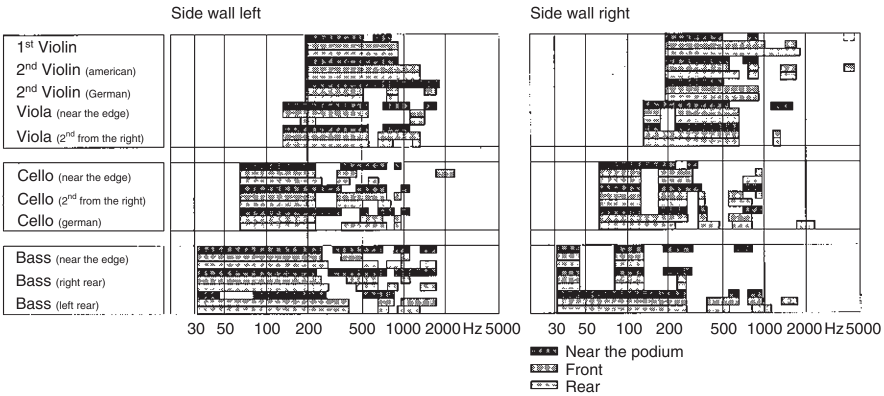


Fig. 7.6 Frequency regions of preferred side wall reflection for strings

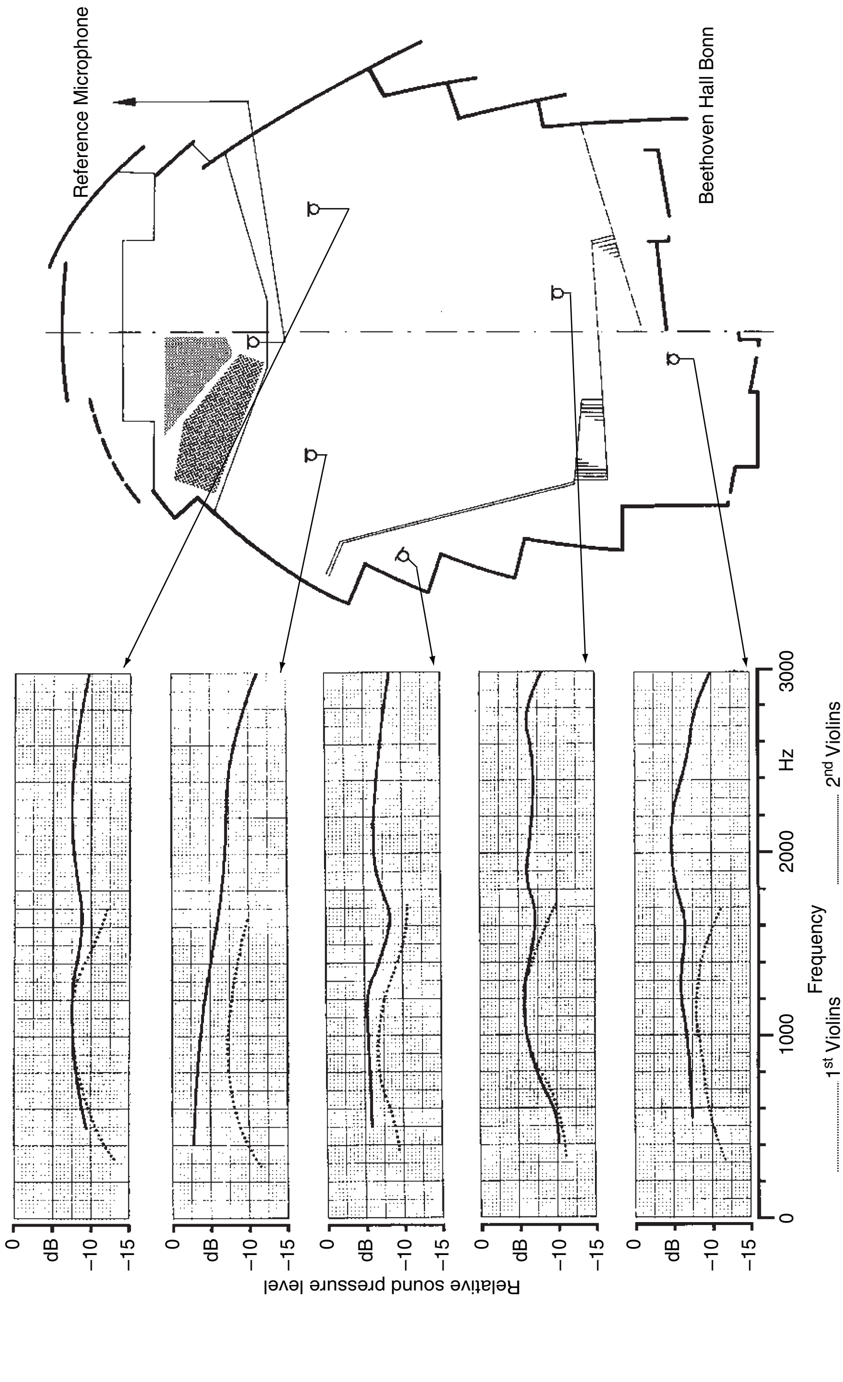


Fig. 7.7 Sound level difference of violins at different locations in the hall compared to the level at the conductor

larly noticeable in these results. Only in the front left of the main floor, are the directional characteristics dominated by the lower components, while the higher frequency components, which are preferably radiated in an upward direction, are not reflected adequately to the front seats of the audience by the ceiling. From an energy standpoint this is an advantage for the rear of the hall. For this reason, the podium in concert halls should not be too high, so that even the front rows receive some of the high portions of the violin sound.

This objectively measured result suggests the conclusion that the tonal effect of the second violins – considered as an individual group – should be significantly better when located next to and behind the first violins, than is the case for the German system. This approach, however, ignores an important psycho-acoustic consideration, which makes these relationships more relative, where the connection to the combined sound of the entire string group has yet to be considered. On the other hand, the tonal difference between the two sections can in many cases have a positive influence on the total impression and should also help the clarity of the voice mixtures. This is particularly the case when both violins have the same, yet temporally displaced motif, which is exchanged, back and forth between the two voices. Score example 16 includes two excerpts from symphonies by J. Haydn and L. van Beethoven, where in each case only the two violins are represented. The upper passage is concerned with the simultaneous performance of the two motifs, which are exchanged between the two voices. When the violin groups sit next to each other the listener has the impression that the one voice only plays eighth notes and the other repeats the motif several times, which consists of quarter notes and one-half note. This certainly does not correspond to the tonal impression intended by the composer. Similarly, the figure grouping of the lower example would become washed out in the American seating arrangement. Furthermore, many tone combinations for two simultaneous melody lines appear less dissonant when the violins are distributed on both sides and both voices can be followed independently, as for example in the first movement of the Jupiter Symphony by W. A. Mozart (measure 220 ff). A missing voice separation in the introduction of the last movement of the first symphony by J. Brahms becomes especially noticeable, where the difference between the alternating 30-s note figures in *forte* and the continuing *piano* parts lose their dramatic effect (score example 17).

Score example 16 *Top:* J. Haydn, symphony No. 103, 4th movement, measure 368 ff *Bottom:* L. van Beethoven, 4th symphony, 4th movement, measure 293 ff. Violin parts

Score example 17 J Brahms, 1st symphony, 4th movement, measure 23 ff. Violin part

The tonal differences between the two string sections under given room-acoustic circumstances of different concert halls naturally depend not only on the direct sound radiation and the reflection of the hall ceiling above the audience but also on the reflections by the rear wall of the stage and the stage portion of the ceiling. For the first violins the reflections from the rear portion of the stage play a role, especially at frequencies between 500 and 700 Hz as well as 1,500 and 2,000 Hz. While the former contributions are partially absorbed by the players behind them, they are still reflected by the rear wall and the ceiling, and thus they, along with the components between 1,500 and 2,000 Hz, can reach the hall after double reflections.

For the second violins it is particularly the important contribution around 1,000 Hz, as well as the very high frequencies, which in the German seating arrangement are radiated upward toward the rear. To what extent they are still effective in the hall depends on the height of the hall (in relationship to the distance of the player from the rear wall). Inasmuch as these components are radiated in relatively narrow bundles, below about 45° upwards, very different reflection effects result, depending on hall height. As the schematic representation in Fig. 7.8 shows for high halls, the strongest sound portions initially hit the rear wall and are subsequently reflected into the hall by an additional ceiling reflection. A slight tilt of the reflection surface is particularly advantageous. If in contrast, the distance of the player from the rear wall is greater than the height of the hall, the frequencies under consideration come back to the orchestra, and even a tilted ceiling cannot avoid this. In such cases, therefore, in the German seating, special attention needs to be paid to the dynamic balance of the two violin groups. In contrast, it is advantageous in high halls to keep the distance of the strings from the rear wall at a minimum when seated in a symmetric arrangement, at the very least it needs to be smaller than the height of the ceiling above the stage.

At first glance the previously named advantages of the German seating, however are placed in question when the tonal effect of audience seating behind the orchestra is considered. The tonal difference between the two violin groups could be perceived as illogical when the second violins have a more brilliant sound than the first violins and thus become unintentionally dominant. In this case the overall impression for the rear seats would be better if the lack of high frequency tonal components becomes as evident for the second violins as for the first, whereby nevertheless the seats behind

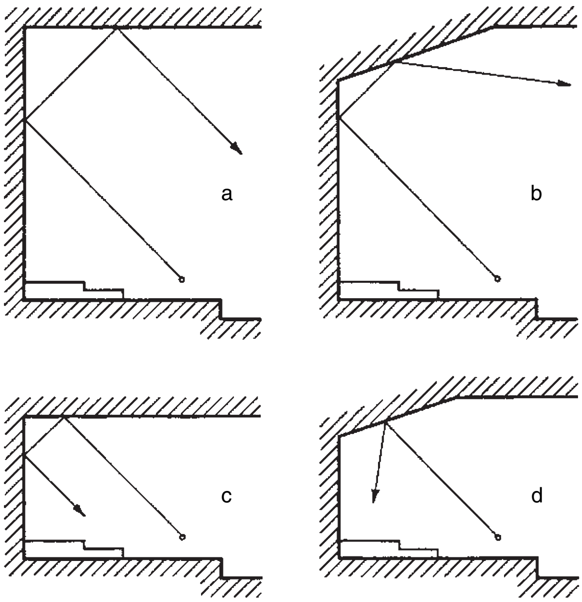


Fig. 7.8 Reflection relations for the very narrowly bundled radiation of high frequencies of the second violins (for German seating) for different hall conditions

the orchestra would not be equivalent to those in the normal direction. At very best, certain compensation can be achieved through appropriately angled reflectors hung from the ceiling. In view of the main radiation angle at high frequencies these must not be located directly above the violins, but rather slightly in front of the orchestra (i.e., in the 0° direction of the bridge plane of the violin). Under such conditions the German seating appears justified even in halls with an audience behind the orchestra, particularly when the points to be considered in Sect 7.2.1.5 are included in the overall sound of the strings.

7.2.1.2 Violas

There are few options in relationship to the normal seating of violas on the concert stage. Locating this section at the right wing of the orchestra leads to the fact that in addition to the components below 500 Hz, which are uniformly radiated in all directions, the components between 600 and 700 Hz are radiated favorably into the audience. These components determine the sonority of the instrument, which also corresponds to the vowel color of a dark å(aw). The frequencies around 1,000 Hz which are responsible for the brilliance of the sound and a certain brightening of the tone, i.e., in the range of the a(ah)-formant, on the other hand, are directed in preference toward the right of the player. The higher partials around 4,000 Hz exhibit a similar characteristic. This means that these components reach the main portion of the hall predominantly by reflections from the rear wall of the hall and the ceiling above the podium. The degree of their effectiveness thus depends on the hall height and the distance of the player from the rear wall in line with the representation for second violins in Fig. 7.8.

For listeners behind the orchestra the directional characteristics of violas result in a tonal change opposite to that of the violins (from the German seating arrangement only for first violins). The comparatively bright viola sounds and the relatively dull violin sounds approach each other in character, while the contrast to the lower cello and bass group increases. It is, however, unmistakable that the violas considered as an individual group develop a very clear and beautiful tone from this direction as can be observed, for example, in certain seats in the Berlin Philharmonie.

The angular region, which, from a tonal standpoint, is evidently very favorable, is directed toward the audience only for special orchestral arrangements without violins. Thus, for example, in the 6th Brandenburg concerto by J. S. Bach, the violas occupy the podium toward the left of the conductor. Also in the A major serenade op.16 by J. Brahms, the violas are often located there. However, in this work winds frequently occupy the position of the first violins. Likewise, the soloist in a viola concerto naturally takes the position at that side so that the instrument radiates a clear tone into the hall.

In contrast, solo viola players within the orchestra most often need to settle for a position in the right wing. For symphonic works with viola soloists (like, for example, the Haydn symphony No. 15, or "Don Quixote" by R. Strauss), however, it does not appear to be a disadvantage to arrange the strings in such a way that the soloist, if possible, is located at the left side. Thus, occasionally a seating arrangement is used, in which the two violin groups find themselves opposite each other on the podium with the violas, – in contrast to the German system – located behind the first violins.

7.2.1.3 Celli

The principal radiation regions for celli are represented in Figs. 7.9 and 7.10 for a horizontal as well as vertical plane. Results for the plane located vertically in the room clearly show the importance of the ceiling reflections for the tonal effect of this instrument group, since the angular regions of especially strong intensities include the ceiling of the hall for all frequencies. This is also one of the reasons why the reflection ceiling in the Philharmonic Hall in New York in its original form, which largely absorbed low frequencies, were such a disadvantage for the cello in the orchestral sound (E. Meyer and Kuttruff, 1963; Beranek et al., 1964).

In detail, these figures show that the radiation at 200 Hz, and in the region from 350 to 500 Hz, occurs predominantly toward the front, so that both floor and ceiling reflections become effective. From 800 Hz on upwards the preferential regions are so steep that the audience is no longer included. Since the upward directed cone becomes narrower with increasing frequency, the tilt of the ceiling, or possibly reflectors hanging above the orchestra, play an important role for these components. This means that in contrast to violins, for which the most important reflection regions of the ceiling are located deeper in the hall, the celli depend on that part of the ceiling directly above the players for reflections. The very high frequencies

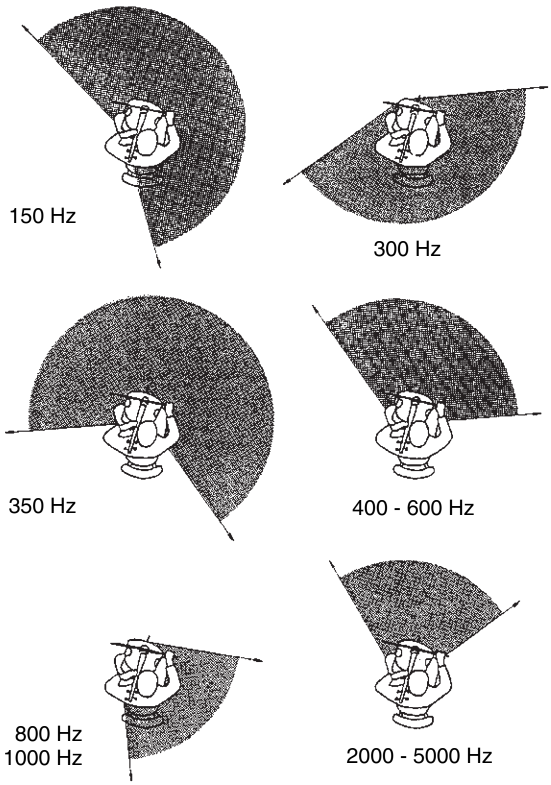


Fig. 7.9 Principal radiation directions (0...−3 dB) of celli in the horizontal plane

are furthermore radiated in a very shallow direction toward the floor and the front where they are also reflected into the hall unless they are blocked by other players.

The question, concerning the seating of the celli directly in front of the conductor or toward the right on the edge of the podium is of great significance for the tonal effect in the hall. To illustrate the different tonal effects, the angles in Fig. 4.23 (page 319) which in the German and the American seating arrangement are oriented directly toward the audience, are indicated in different colors. A comparison of the yellow and the blue areas clearly indicates, that for the German seating, the high frequencies, which are important for the clarity of fast passages are radiated more favorably into the hall. However, also in the frequency region of 350–600 Hz which includes the region of the o(oh) – formant, which therefore contributes strongly to the sonority of the sound, the frontal radiation is more favorable than the radiation toward the side. It should also be noted that the high register of the A string, used frequently with the fundamental notes of *cantabile* passages, falls into this frequency region. A further advantage of the frontal seating arrangement can be seen in the fact that strong reflections can be expected from both sides for the low frequency contributions below 200 Hz and the tonal contributions in the region from 400 to 500 Hz which are important for the sonority. This means on the one hand, that the tonal effect of the celli is more equalized for

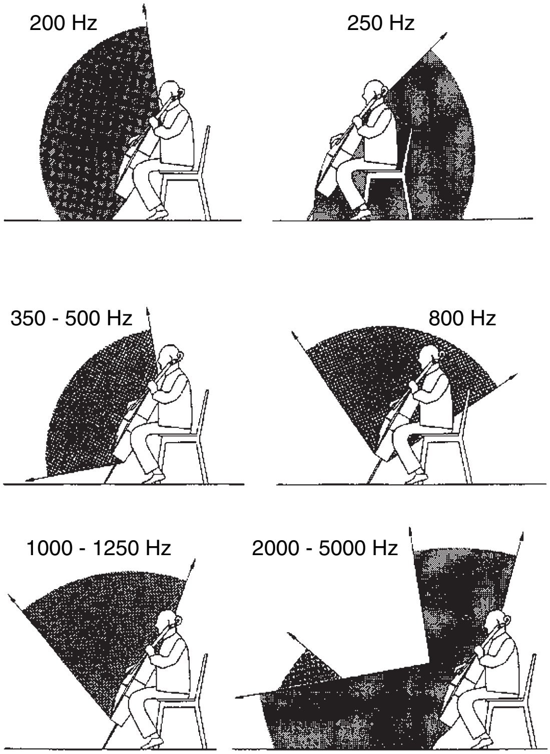


Fig. 7.10 Principal radiation directions (0…−3 dB) of celli in the vertical plane

different seats in the hall, and on the other hand, that the spatial broadening of the tone for a *forte* is more pronounced. As the representation of the principle radiation regions and the reflection surfaces lying within these angles show in Fig. 7.11, this symmetry is not achieved by placing the celli toward the edge, so that the sound in the hall is not as full and voluminous.

As is seen in Fig. 7.9 the seating arrangement toward the side leads to stronger contributions in the regions from 250 to 300 Hz and from 700 to 900 Hz; the tone color, therefore, becomes darker. However, it should be emphasized that placing the celli toward the edge certainly does not lead to a louder impression in the hall. This is again supported by recent investigations by Winkler and Tennhardt (1993).

In this context, recent investigations by Prince and Talaske (1994) are very interesting. They measured impulse responses for various positions of a sound source on the stage for sound sources with various directional characteristics in a hall for an audience of 1,200. These results show, among other things, that at least in the middle frequency region the direct sound of the celli is attenuated by 6 dB on the average, when they are placed to the right of the conductor, rather than directly in front. In both cases, the strongest reflections from the stage region have the same intensity, however for frontal arrangement they are slightly delayed. They are clearly weaker than the direct sound (toward the right by about 3 dB, in the center by about 9 dB because of the stronger

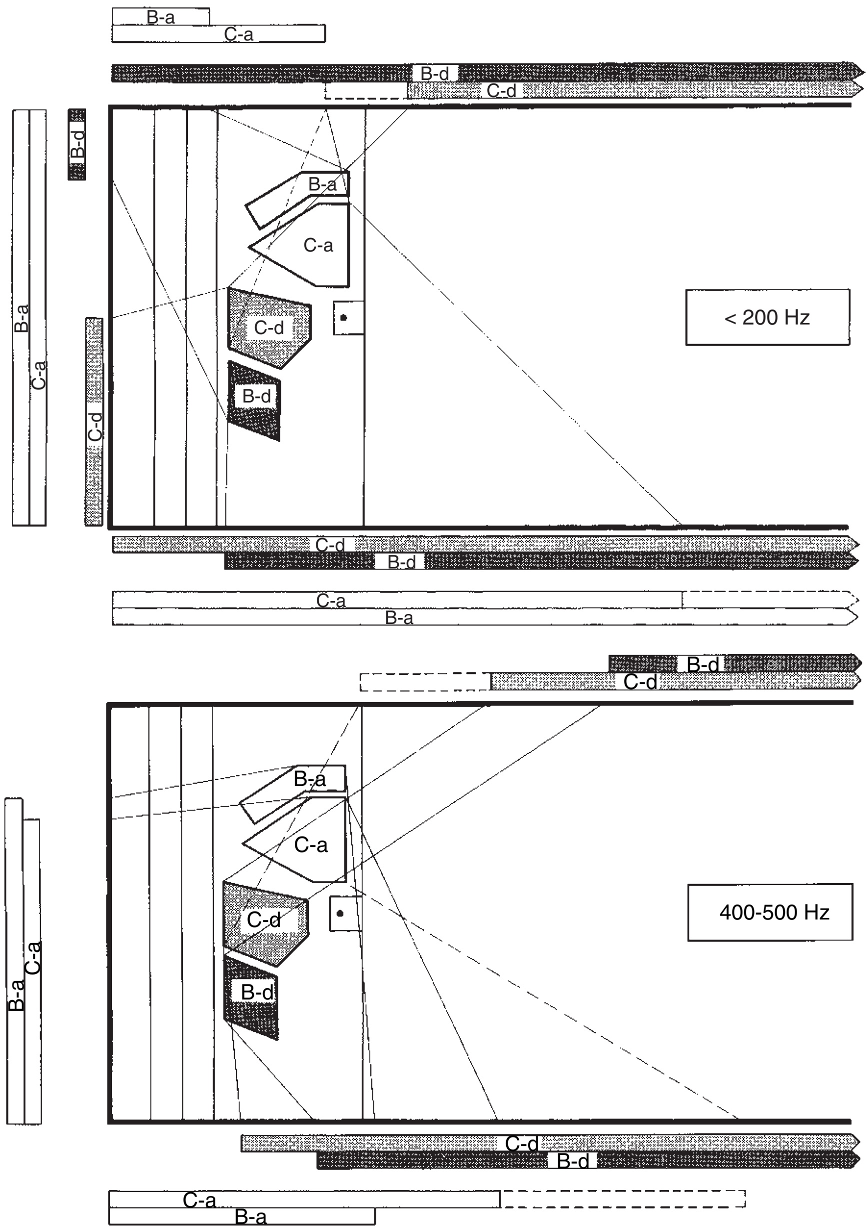


Fig. 7.11 Preferred reflection regions for celli and basses for those frequencies below 200 Hz for which the radiation is not spherical, as well as for the frequency region around 400–500 Hz for two different seatings

direct sound). These results again show the advantages of the frontal arrangement both by reasons of energetic considerations as also the precision. In comparison, the direct sound of the second violins, when placed to the right of the conductor, are lowered only by 4 dB when compared to the frontal arrangement, which is also compensated by the fact that the strongest reflections from the region of the stage (with a delay of about 25 ms) are by 2 dB stronger, and thus exceed the direct sound slightly.

A further problem for celli seating at the side in wide halls lies in the fact that the strongest sound intensity is directed toward the left wall of the hall as seen from the audience, and thus a clear echo is audible when there is no direct sound coming from the left wing of the orchestra. A typical example for this is given in score example 18 where the forte entrances of the celli and the basses are totally open.

The tonal effect at different locations in the hall for American seating is represented in Fig. 7.12 in several diagrams, which again represent the level difference in relation to the position of the conductor. In these results it is particularly noticeable that the celli on the right side of the main floor, i.e, relatively close to the players, are most strongly attenuated in the important frequency region around 400 Hz and are thus strongly influenced in their sonority. In contrast, on the left side of the main floor, i.e., in the direction of sight for the players, the higher tonal contributions are especially pronounced. In the gallery portion located immediately in front of the celli, the tonal effect is very balanced, while in the rear of the main floor a drop in the region of the o(oh)-formant is present which must be judged negatively. These examples demonstrate the advantages of the seats located directly in front of the players, in contrast to those located toward the side. Considerations of the uniform tonal effect for violins, as shown in Fig. 7.7, indicate that the reason for this rests with the sound radiation of the celli and not the nonuniformities of the room acoustics.

The fact, that the components which are responsible for the sonority and the richness of sound are radiated better into the hall for a frontal seating, effects not only the tone of the cello group as a single instrument, but this also is an advantage when playing in octaves or in unison with violins. The theme in the last movement of the 1st symphony of J. Brahms (score example 11), which is initially introduced by the violins only (measure 61 ff), but then appears in unison with the first violins and celli, receives a more closed tonal character for the German seating arrangement than when the celli are located toward the side. The celli enhance the sound of the violins through the strong components in the region of the o(oh)-formant, a frequency range which violins characteristically do not radiate strongly. The overall impression thus gains in tonal richness and expression without darkening the timbre by overemphasizing the low frequency contributions. Reference was already made to the effect that, for the American seating arrangement, the two instrument groups are not blended as well as a result of the stereo effect.

The preferential radiation of high frequencies for the frontal seating is particularly advantageous for fast passages, which therefore gain clarity and precision. However, even in slower passages the plasticity of the melodic line increases, while the initial transients are more easily recognized. The higher frequency com-

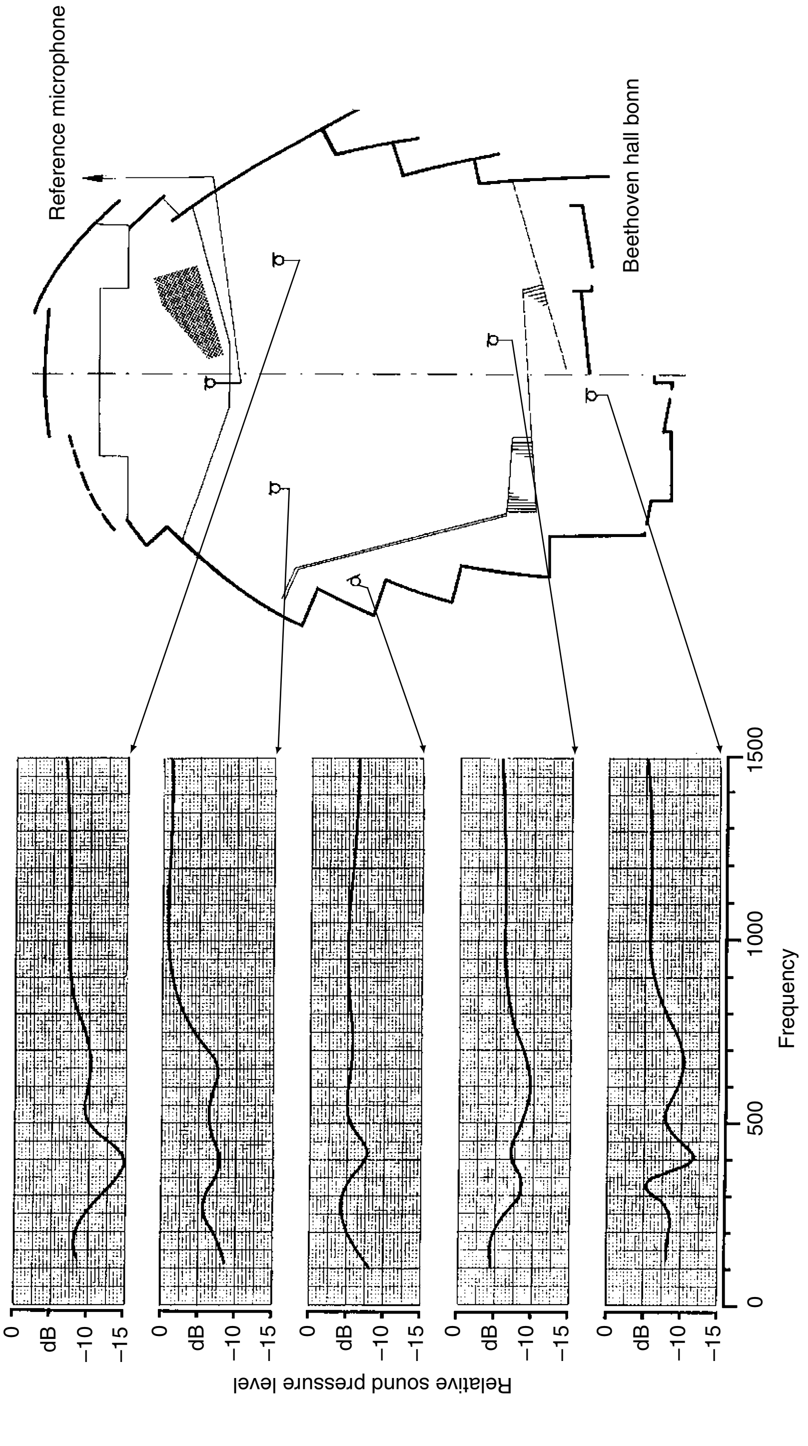


Fig. 7.12 Level differences of Celli at various locations in the hall in comparison to the level at the location of the conductor.

ponents are of course especially important for rapid repetitions of the same note, since for them the rhythmic structure only becomes audible through the articulation of the attack.

As an example for such a passage, several measures from the 2nd movement of the 5th symphony by L. van Beethoven are given in score example 19. (According to the metronome notations, added by the composer later, the 1/32 notes are to follow each other with a separation of 1/6 s) It should also be noted, that in a previous parallel passage (measure 38) for the same execution by the upper strings, the celli play the E as a continuing note; on occasion, it is very difficult to make this difference audible, particularly in large halls.

The Furtwängler variation of the American seating offers similar tonal conditions for the celli in comparison to the German seating, since generally the first or the second chairs sit nearly directly in front of the conductor. For the rear desks, high frequency absorption by players sitting in front, increases at any rate. Consequently, a stepwise rise of the individual rows is not a disadvantage, however, many concert stages do not provide that option.

Score example 18 L. van Beethoven 8th symphony, 4th movement, measure 277 ff

Score example 19 L. van Beethoven, 5th symphony, 2nd movement, measure 87 ff. Score excerpt without horns and bassoons

7.2.1.4 Double Basses

Situating the double basses toward the left or right rear corner of the orchestra means a change of the angular region directed toward the audience by approximately 90°. The difference between these two positions, expected by reason of the directional characteristics, can be noted from the representations of Fig. 7.13; it can also be noted from the recorded angular regions of preferred sound radiation, that rear wall reflections can enhance the sound from the bass especially in the frequency regions between 200 and 250 Hz as well as 500 and 800 Hz.

An additional strengthening effect is noted for very low frequencies, when the instrument is less than a wavelength away from the wall. Under those circumstances the reflection interacts with the instrument itself so that for certain frequencies the radiated energy increases and for others, decreases (Skudrzyk, 1954). In Fig. 7.14 the increase or decrease of this sound power level, in dependence on frequency is represented. The individual curves refer to different wall constructions; an instrument to wall distance of 75 cm is assumed. The broken curve shows that a "hard" stonewall has the effect of strengthening the sound for

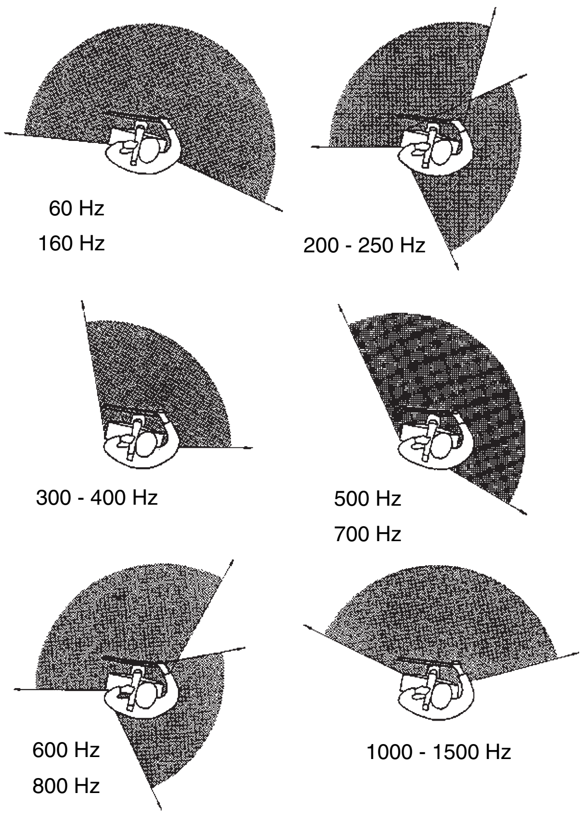


Fig. 7.13 Principal radiation directions (0…−3 dB) for basses in the horizontal plane

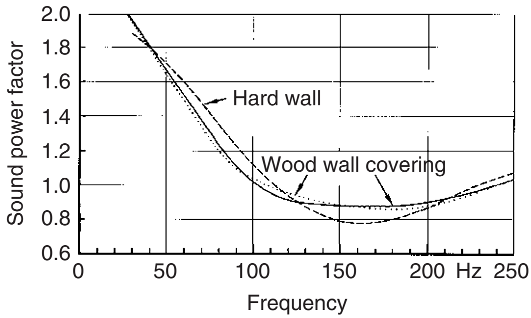


Fig. 7.14 Change of radiated sound power for a source located 0.75 m in front of a wall. *Dashed curve*: hard wall. *Dotted curve*: wood paneling (α = 0.7 at 125 Hz), *Continuous curve*: wood paneling (α = 0.7 at 160 Hz)

frequencies below 100 Hz, that, however, in the region of 150 Hz the sound power drops. If the rear wall is covered with wood paneling, which has an absorbing effect at these frequencies, a curve is flattened without decreasing the strengthening at lowest frequencies. Thus the bass gains intensity at the low end, where evidently the wood paneling is more favorable than the hard wall.

The effect decreases as the bass is moved further from the wall; at the same time the drop is shifted toward lower frequencies. At a distance of 1.5 m it is moved to the region of the air resonance of the instrument, and thus the energy decrease is equalized. For a distance of 3 m, it moves to 40 Hz where precisely those notes which are to be enhanced are weakened. For all this to be effective, the wall naturally has to be sufficiently high to reflect low frequencies. In order to achieve effectiveness down to 250 Hz, a height of at least 3 m is required, depending on the distance from the bass. For frequencies to 30 Hz, 4–5 m are required (Meyer, 1975). The result of all this is, that, as a matter of principle, from a standpoint of tonal quality, it is not desirable to place the basses so that they do not have a rear wall.

In this connection, the question arises concerning the importance of platforms or supports, capable of vibrating, placed below celli or especially basses. While early measurements (E. Meyer and Cremer, 1933) suggest that a sympathetically vibrating floor has no effect on the sound level in the hall, because the contribution of the radiated energy is too small, more recent investigations (Askenfelt, 1986) certainly recognize the possibility of sound enhancement. It should be noted that these experiments were carried out with extremely thin floor material (12.6 mm plywood). As shown in Fig. 7.15, a level rise (in the hall) as compared to a rigid floor by about 3 dB near 50 Hz and about 5 dB at higher frequencies was measured. Inasmuch as the ear is particularly sensitive to level differences at lower frequencies (see Fig. 1.1), these differences in tonal impressions are clearly noticeable. The psychological feedback for the player should also not be underestimated since the performer senses the floor vibrations as room resonances-even when the floor does not contribute significantly to the radiated sound.

It is thus not surprising when in recent times – as e.g., in the Morton H. Meyerson Hall in Dallas - a floor, capable of vibrating is installed above a special hollow room in the region of the podium, where usually the celli and basses are found. Naturally the acoustic effects of such a construction are tied to a very specific orchestral seating arrangement. This reduces flexibility in relation to seating arrangements.

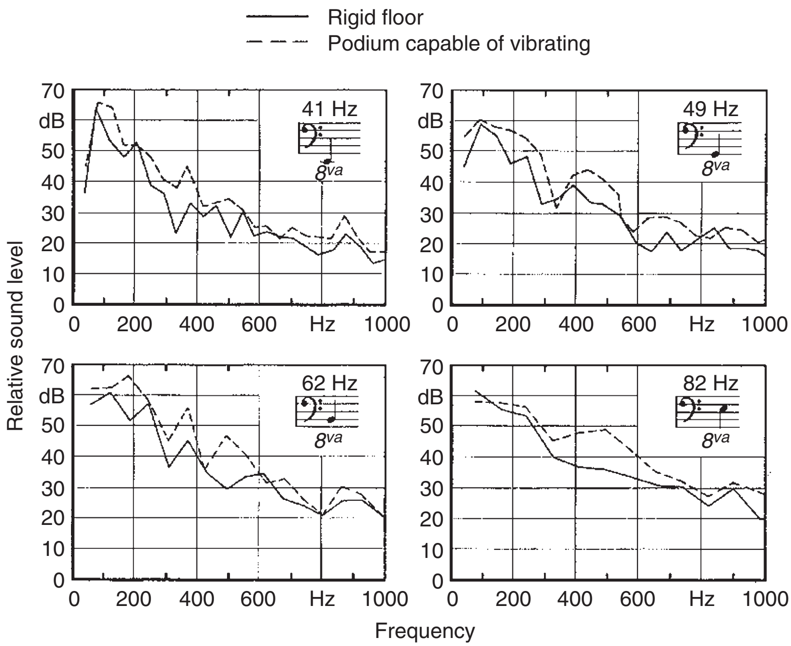


Fig. 7.15 Influence of a podium capable of vibrating on the sound radiation of a bass (after Askenfelt, 1986)

From another standpoint it should not be overlooked that a level rise in the hall by 3–5 dB means that at least the same amount of energy, as that radiated into the air is transmitted through the tail pin into the floor. This means an additional energy loss for the instrument for which bowing technique can compensate, which in turn leads to a more rapid decay for *pizzicato* playing and thus a dryer sound. This could certainly be perceived as a disadvantage for a vibrating podium.

The angular regions oriented toward the audience in the diagrams (Fig. 4.24, page 319) are again emphasized by red and blue coloring in order to clarify the tonal effects of basses for differing seating arrangements. It can be noted that the colored areas are relatively equivalent for wide frequency regions, especially for the high frequencies nearly equal portions fall into both angular regions. Only between 300 and 500 Hz and in the regions around 700 and 1,000 Hz the red areas dominate. Thus the direct radiation is slightly preferred for seating on the left side at these frequencies. The region from 300 to 500 Hz includes parts of the u(oo)- as also of the o(oh)- formants and therefore contributes characteristically to the dark and full nature of the bass sound.

The advantage of locating the basses on the left side, however, becomes very clear when considering reflection conditions in Fig. 7.11. Similar to the case with the celli, utilizing both sidewalls for relatively strong reflections at low frequencies contributes to the spatial fullness of the sound.

The higher frequency contributions are generally not as important for the bass, since basses frequently double the celli and occasionally bassoons. In these cases, the tonal picture is at any rate supplemented by those instruments which are rich in overtones and most often are played an octave higher. For passages which do not provide enhancement by other instruments, good radiation possibilities for the entire bass spectrum is important. This refers either to independent bass voices, as for example the introduction of the 1st movement of the 7th symphony by F. Schubert (measure 17 *ff*, here the melody is shared by celli and violas) or to thematic changes, as for example in certain places in the fugue of the Jupiter symphony. In this example, the difficulty lies in letting the entrance of the basses (e.g., measure 50) stand out sufficiently clearly against the four upper voices where the higher frequency tonal contributions play an essential role. Naturally, for such passages the somewhat greater intensity of the lower components, with an arrangement of the basses toward the left, becomes an advantage. Reference should also be made to the fact that the position of the basses near the left wing is an advantage for the solo bass player, when, for example, in several Haydn symphonies (No. 6, 7, 8, 31, 72), solo passages or an entire solo variation is to be performed. Finally, it is also an advantage for the solo in the 3rd movement of the 1st symphony of G. Mahler, when the solo bassist is not located at the outer edge of the orchestra, but more toward the middle, otherwise the performance with the timpani falls apart.

Also, the way in which the Vienna Philharmonic positions the basses next to each other in front of the rear wall of the podium (see Fig. 6.1) is advantageous for the radiation of the entire spectrum, particularly since the reflection possibilities of the rear wall are optimally utilized. However, this increases the distance to the celli so that the contact with this group is somewhat more difficult. In particular, when there is no wall located at the side of the podium this arrangement provides a very effective adaptation for the basses in acoustically unfavorable halls.

If, however, the basses are placed on the right side behind the violas, or possibly the celli, clear up to the front edge of the podium, a loss of high frequencies in the direct sound results, as seen from Figs. 4.24 and 7.12. The intensities also drop slightly in some of the lower registers, which becomes all the more significant since these frequency contributions are already weakened when considering the propagation of the sound into the audience. In addition, these intensity reductions are especially noticeable because of the characteristics of the ear (as a result of the narrow spacing of curves for equal loudness). Since for this seating arrangement the instruments, including especially the first desk, are unfavorably turned inward in relation to the direction of sight, a shallow tone effect cannot be avoided.

7.2.1.5 Combined Sound of the String Sections

Up to this point the predominant concern was the tonal effect of the individual instrument groups. Yet, the distribution of voices on the podium is also important for the combined sound of the strings. The German seating, with violins distributed equally on both sides and the celli oriented toward the middle, comes close to a symmetric arrangement, especially since the basses in the left wing can be brought closer to the conductor than in the American seating. This symmetry naturally relates predominantly to the direct sound of the individual instrument groups relative to the audience; it is, however, also supported by the early wall reflections, which effect the spatial broadening of the tone. On the other hand, this means that halls of lesser acoustic quality (with lower spaciousness) are more critical in relation to the geometric tone balance.

Especially during the Romantic period, there was no lack of attempts to perfect this symmetry. Thus, H. Richter located the eight basses in two groups of four in the even divided both the celli and the basses into two halves, which were located on both sides of the conductor behind the violins (Becker, 1962). This division of the low voices was also frequently observed in early classical orchestras. Even today several Swiss orchestras, as well as the Vienna Philharmonic, locate their basses in front of the rear wall of the podium over the entire width of the orchestra.

The division of the two violin groups onto both wings of the orchestra provides a pronounced octave performance, or a unison of the two groups in a characteristic fashion, since, at least in the region of low frequencies, very dense and temporally stretched reflection sequences from both side walls supplement the radiated direct sound, which is already very broad (see Fig. 8.2). It is this spatial emphasis in the tonal effect, which Gustav Mahler likely intended when he stated: "Permitting the bright and dominant passages of the second violin to run in unison with the first violins leads to a significant improvement of the tonal effect and to the achievement of a convincing tone brilliance of the violins. This cannot be explained only by the increase of the numbers, but must rest on the acoustic principle which creates such a vital tone and brilliance effect resulting from the two sound waves which meet from both sides" (Paumgartner, 1966). Thus, in Mahler's 6th Symphony there is a passage in which the two violin sections are playing in unison, however are annotated with opposite crescendi and decrescendi so that the tone receives a spatial motion (shortly before the conclusion of the 3rd movement; "always with a feeling of motion, increasing and decreasing.")

The instrumentation of the 14th part of the Bolero by M. Ravel (score example 20) suggests an effort to obtain a spatially broad and uniform tonal effect. Here the violins play the theme in a four-voiced parallel passage beginning with a major triad doubled in octaves. It is particularly noteworthy that the division is not intended to have the first

Score example 20 M. Ravel Bolero measure 219 ff. excerpts: strings and second violins each take two voices but instead both groups are divided into four sections. When all violins are seated together this division loses its significance, while, when the violins are spread over the entire width of the podium, a closed tonal effect of great spaciousness is achieved. Similar instrumentation is also found in the first movement of the *Symphonie Fantastique* by H. Berlioz (measure 410 ff and 428 ff).

In contrast, the linear American seating arrangement leads to a strong bass emphasis of the right wing and a concentration of the high voices on the left side. While this means greater clarity in relation to the distinction of the instrument groups for the listener, on the whole it leads to geometrically not very even tonal balance and consequently to a less fused complete sound. This division of the high and low string voices proves especially crucial in passages such as the excerpt from the beginning of the Finale of the 5th symphony by P. Tchaikovsky shown in score example 21 where, after the full sounding string entrance, the sound of the E in the second measure suddenly only comes from the right wing even though this note is an integral component of the motif.

From the standpoint of radio recording techniques, there are those who reject this linear seating arrangement, for a number of reasons, among them the artistic argument, because a true stereophonic sound is not fully utilized, but rather an impression is given which approaches a pseudostereophonic effect achievable by frequency differences (Briner-Aimo, 1966).

Furthermore, arranging the bass group toward the side leaves some seats in the audience near the orchestra with an unsatisfying tonal picture, because of the emphasis on the bass. The proximity of the second violins in the German seating order can also lead to excessive emphasis on accompanying figures in many compositions; however, this disadvantage should generally be less important than the excessive emphasis on the bass.

Beyond these objectively measurable differences in relative to sound radiation for different seating arrangements, a psycho-acoustic effect also plays an important role for the tonal impressions of these two string groups for the audience. The brilliance of the first violins does depend, among other things, also on other voices

Score example 21 P. Tchaikovsky 5th symphony, 4th movement. Beginning (without winds) located in close proximity: when the first violins are located in front of the celli and the basses, their sound is perceived as clear and more brilliant than when they are located in front of the second violins, even though nothing has changed in their sound from a purely physical standpoint. The relevant concept is the more or less strong masking of the higher frequency components for the direct sound of the first violins by the sound of the other instruments (Meyer, 1987). This phenomenon is illustrated by a number of sound power spectra of *forte*-sounds represented in Fig. 7.16. Since the power spectra of string instruments are essentially not changed with intensity, but practically are shifted only up and down, the following considerations can also be transferred to different dynamic levels.

Considering, for example, the overtones in the region of 3,000 Hz for notes in the middle register (see the arrow in Fig. 7.16), one observes that the level of the cello is approximately 20 dB below that of the violin. In addition, it is noted that for the violin, the level below the 3,000 Hz region rises by 5 dB per octave, or alternatively sinks, when one moves to a higher, or correspondingly lower register. In contrast, the level for the 3,000 Hz region in the cello practically does not change between the low and mid registers; in the high register, however, it rises by nearly 10 dB. The level of the bass still lies clearly below the curve for the cello at these high frequencies. With the assumption that the number of first violins is approximately equal to the sum of cellos and basses, the first violins dominate against the low strings by an order of 15–20 dB at the high frequencies in the direct sound of the orchestra.

When the first violins are seated in front of the second violins, a dominance of only about 5 dB results for the first violins at the 3,000 Hz components when the two voices are separated by approximately an octave, which becomes even less for narrower voicing. This causes a partial mutual masking in the ear for the high tone

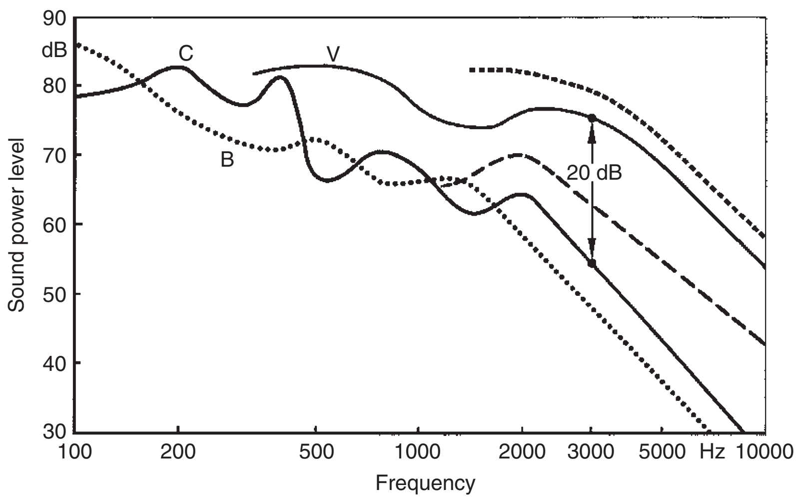


Fig. 7.16 Envelope of sound power spectra of string instruments for *forte*. *Continuous*: midrange (Vl and Vc). *Dashed*: high register (Vl and Vc)

contributions in the direct sound: they are perceived as weaker than when heard from the first violins alone. This means a reduction in brilliance. When in contrast the first violins are seated in front of the low strings, such masking for the sound of the violins does not occur because of the larger level difference of 15–20 dB, and the brilliance of the first violins is preserved. On the other hand, even the high tonal contributions of the second violins are masked in the audible sound impression when both violin groups are seated together. In this the more advantageous sound radiation of the second violins in comparison to the German seating is compensated at least in part. And in fact in a direct comparison of the American and German seating arrangement it is astonishing to experience how unexpectedly clear the second violins sound for an audience in the hall. In this context it is also noteworthy, that the second violins – as emphasized by Herbert Blomsted – are forced to be more independent, and use more initiative (Blomstedt, 2000).

Finally, it is naturally always a question of personal conception, which seating arrangement is preferred. In all this, certainly, the fact plays a role, that, since the changes in the 50 s, a new generation of conductors (and music critics) have come, who have only known the seating arrangements of that period. Since then, increasingly opportunities have arisen to hear orchestras, particularly with internationally renowned conductors, which place the two violin sections on opposite sides. Thus, the beginning of the twenty-first century is characterized by a clear change in the trend towards spatial tone balance as represented by the German seating.

7.2.2 Woodwind Instruments

7.2.2.1 Flutes

Since the sound radiation of flutes does not only depend on frequency but also on the order of partials, it is not possible to represent the angular regions of preferred sound radiation as simply as for other instruments of the orchestra. Thus in Fig. 7.17 the principal radiation regions of the first four partials of the not overblown notes, i.e., for the positions of C_5 to D_6, are recorded and are supplemented by the preferred regions at frequencies 3,000 Hz and 8,000 Hz; where the two images on the right in the upper and middle row apply for the first and second partial of the overblown notes E_6^b to D_7.

Since the directional characteristics of the flute are essentially rotationally symmetric, conclusions about the radiation upward can be drawn from the schematic representation of the individual frequency regions of the horizontal plane, when the shadowing effect of the head of the performer is considered. As noted from the pictures, this effect is observable in the horizontal plane approximately from 1,000 Hz on upwards toward the rear and toward the left side of the musician. One must also count on a level decrease in the upward and rearward directions in comparison to the free radiation toward the front. However, there is no noticeable shadowing effect vertically upward.

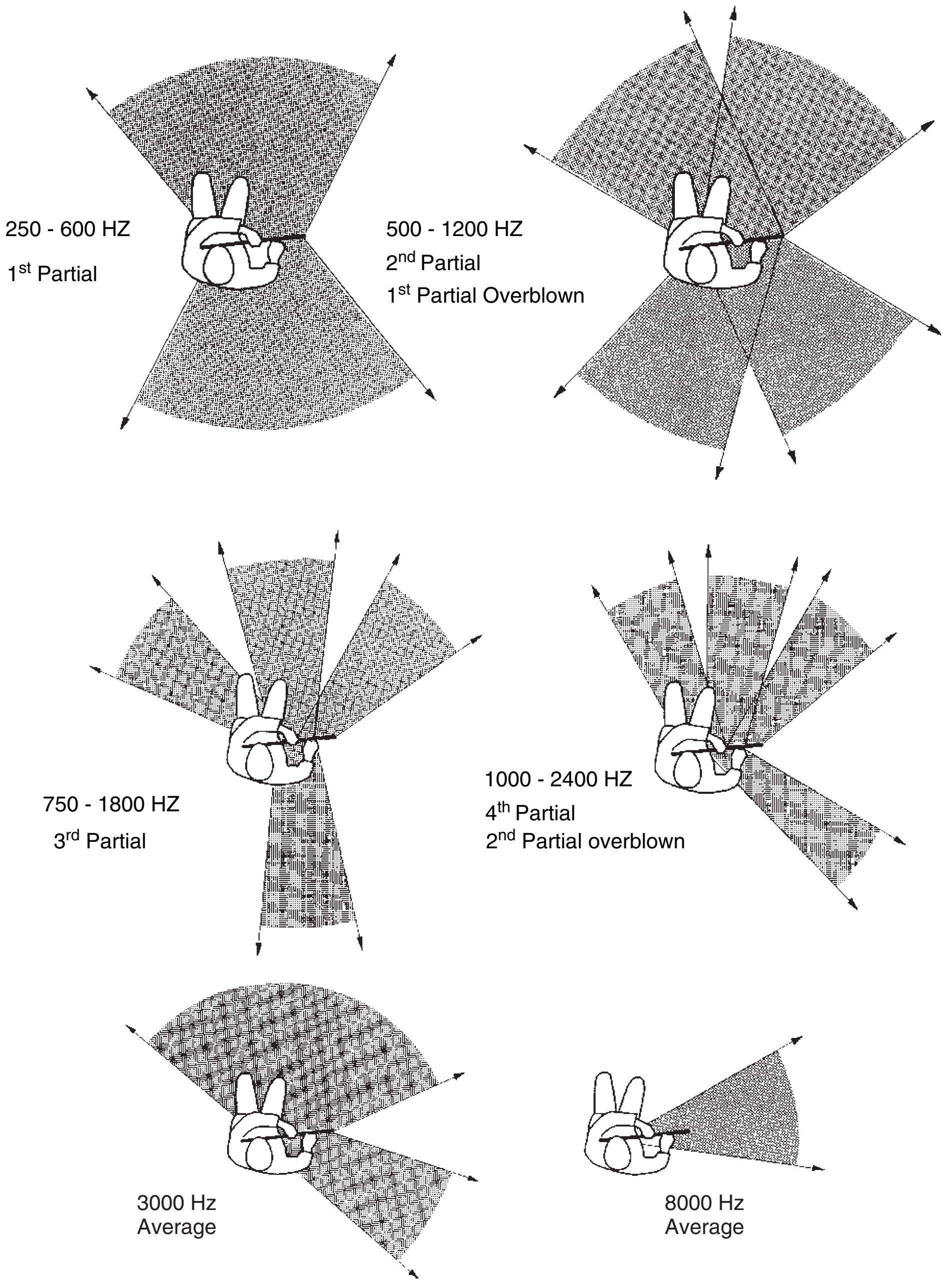


Fig. 7.17 Principal radiation directions (0…−3 dB) of flutes

A review of the images of Fig. 7.17 shows that the sound of the flute is radiated very strongly into a relatively broad angle toward the front (naturally also into the corresponding upward directions). While a closed region of high amplitude is present only for the fundamental, the separation into several maxima for the overtones is not clearly noticeable in the tonal effect in large halls. Only for very high frequencies are the harmonic partials preferentially radiated toward the right side, while all other tone contributions are weaker in this direction than in the direction of sight. Since the highest frequencies are most pronounced at great loudness levels, the *forte* easily receives a certain sharpness toward the right side of the performer. In contrast, the very high frequency noise contributions, since they predominantly come from the mouth-hole, are radiated more strongly in the direction of sight, than toward the side, so that the articulation becomes more clear toward the front than toward the side (see Fig. 4.9).

Because of these directional characteristics, the generally customary seating arrangement of flutes on the concert stage with the viewing direction turned toward the audience is considered acoustically favorable. The free radiation toward the front can, however, be impeded more or less by the string groups sitting in front, when the stage is high and the stepping of the rows of winds is flat, or the flutes possibly even sit at the same level as the strings. However, even in these cases, reflections from the hall ceiling are still effective, since it lies within the angular region of preferred sound radiation. In contrast, placement to the left of the conductor as it is occasionally found in works without violins (i.e., Serenade Op. 16 by J. Brahms), or for pure wind compositions, is not advantageous since the flute sound loses in substance.

Sound reflections from the rear wall behind the orchestra do play a role in the standard frontal seating arrangement for flutes, especially at low frequencies; they can reinforce the fundamentals and the first overtones in the low register, for higher passages this reinforcement is essentially limited to the fundamental. Consequently, the rear wall reflections not only effect an increase in loudness, but also support the round tone of the flutes to the extent that they are not shadowed by the winds sitting behind them. As the summary in Fig. 7.18 shows, sidewall reflections for flutes

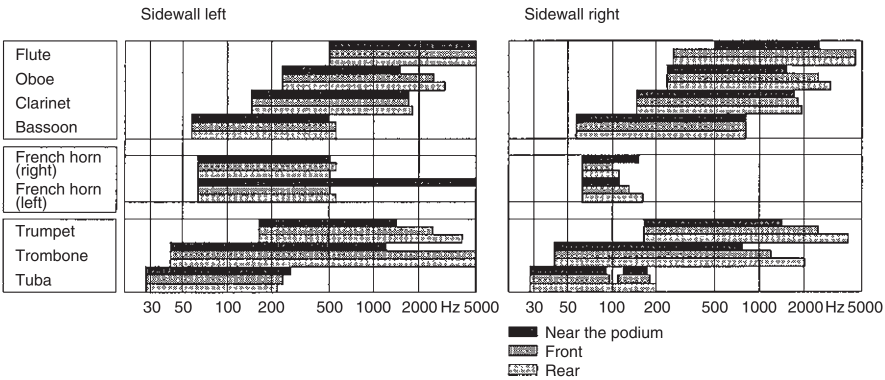


Fig. 7.18 Frequency regions of preferred side wall reflections for winds

include that frequency region which for all woodwind instruments mostly extends upwards. Thus, strong reflections from the left side (as viewed from the audience) reflect the less desirable very high components into the hall. However, this occurs only when the sound is not absorbed by a performer sitting in front or toward the side, as is the case for very wide stage dimensions where sidewalls also diverge in the direction of the hall.

For a soloist, standing in front of the strings, rear wall reflections naturally only play a minor role, the soloist therefore relies especially on the favorable radiation of the direct sound. With reference to the directional characteristic, it therefore appears advantageous when the soloist faces the audience, provided contact with orchestra and conductor is not compromised. The sound is stronger and fuller than when the open end of the flute is turned toward the audience. An additional gain can be achieved through the reflecting floor surface in front of the performer, provided there is at least an expanse of 2 m in the direction of sight.

7.2.2.2 Oboes

The principal radiation directions of the oboe are assembled in Fig. 7.19 for several frequencies. These representations are based on the directional characteristics of the instrument as given in Fig. 4.10, yet at the same time they take into consideration the shadowing of the sound by the performer as expressed in the diagram of Fig. 4.11. As can be seen, the tonal components in the region of the principal formant, which lies near 1,000 Hz, are quite advantaged as far as radiation into the hall is concerned. The principal region extends approximately from the horizontal to an angle of 50° upward so that the audience is reached directly as well as by a reflection from the ceiling. Also at 2,000 Hz, the direct sounds proceed horizontally and in a slightly angled direction toward the audience, however, the reflections from the ceiling depend very much on its inclination. If the ceiling is horizontal, the reflections primarily return to the orchestra. However, if there are angled reflectors, sound reflection toward the audience is also possible.

At higher frequencies, sound radiation occurs primarily toward the floor so that the intensity reaching the audience depends largely on the reflectivity of the floor covering. Within the orchestra these tonal contributions are also rather strongly absorbed by the musicians sitting in front. The resulting unavoidable weakening of the highest tonal components, however, is certainly aesthetically pleasing, since the oboe sound otherwise becomes too shrill and cutting. For frequencies near 4,000 Hz, a special reference needs to be made concerning the distance of the reflection surface in front of the player. In this frequency region, a very steeply reflected sound bundle occurs, which reaches the audience only after a further reflection from the ceiling, provided the ceiling has the appropriate angle.

The increasing shadow effect toward the rear by the performer not only affects the weaker sound for the audience possibly located there – even for a rising angle of 30° the front-back ratio retains a value of approximately 15 dB for the important frequency contributions – but it also means that the reflection wall

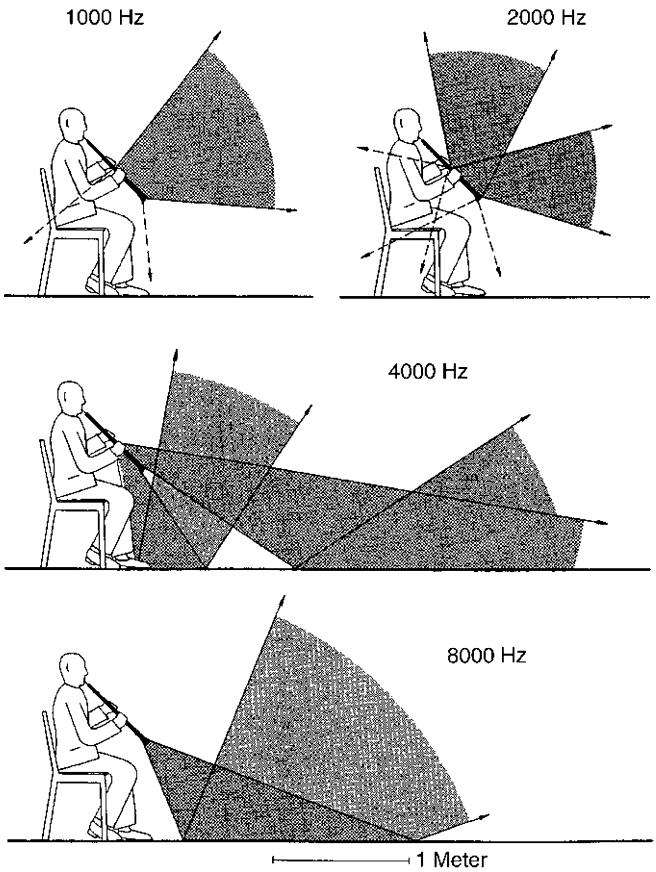


Fig. 7.19 Principal radiation directions (0...−3 dB) for oboes

located behind the player does not have very great significance for the oboe. Consequently, the unimpeded sound spreading toward the front and upwards is essential for a good tone development.

The weak radiation of the oboe into the angular region behind the player, with particular damping of the high frequency components, offers the possibility in concert halls, where there is no separate and acoustically usable location for the oboe from the distance (*"lontano"*), as in the 3rd movement of the *Symphonie Fantastique* by H. Berlioz, to perform these passages from the orchestra stage. When the oboist is seated with his back facing the conductor – which, because of the free location of this duet passage, should not influence the ability to perform with the orchestra – the reflections from the podium rear wall and the ceiling dominate strongly for the audience, so that the tonal picture obtains the desired spatial indifference, without localizing the instrument within the orchestra. This effect, however, can only be achieved because the oboe has a much weaker sound radiation toward the back than in the direction of sight of the player; for example, for a flute this would not be possible, furthermore the audience seated behind the orchestra would observe an opposite effect.

Since the radiation of the oboe toward the side is by nearly 5 dB weaker, reflections from the sidewall next to the orchestra are only marginally significant, while in long stretched halls, reflection surfaces which lie deeper in the hall, have a reinforcing effect. Locating the oboes next to the conductor, as might be suggested, for example, for the Serenade for Winds, Celli, and Basses by A. Dvorak, the decreasing intensity of the instruments toward the side would also become noticeable. A frontal placement for the oboes (highest section in this work) should therefore be preferred, especially in large halls. Corresponding considerations naturally are valid also for compositions for winds only.

7.2.2.3 Clarinets

As shown in Fig. 7.20, the angular regions of strongest sound radiation for the clarinet are similar to those for the oboe; only in the frequency region near 2,000 Hz, the upward directed sound bundle is missing, furthermore, the radiation in this region is directed in a slightly more flat direction downward, by reason of the slightly more steep orientation of the instrument. When the clarinets are seated in the orchestra facing the audience, the essential tone contributions up to above 1,000 Hz, as is the case for the oboe, are radiated favorably directly toward the audience as well as by a reflection from the ceiling. Since this involves the components in the region of the o(oh) and a(ah) formants, this directional effect partly explains the full round tone color of clarinets in large halls. Naturally, for this, free radiation without excessive shadowing by performers seated in front is necessary, since otherwise the intensity relationship between the direct sound and the sound reflected by the ceiling is shifted in favor of the latter so that the instrument is no longer located with the desired spatial precision. On the other hand, as is the case for the oboe, the shadowing of the sound toward the rear can also be used to advantage when an echo effect is desired as indicated in the 3rd Movement of the Symphonie Fantastique by Berlioz for the clarinet, which is merely specified as *pppp* and not intended for an additional performer at greater distances.

Rear wall reflections are of relatively little importance for the tone of the clarinet as a whole. They are limited essentially to the fundamentals of the low register, the reinforcing effect is here slightly more pronounced than for the oboe. Furthermore, sidewall reflections by surfaces near the stage can contribute to the overall sound picture slightly more effectively than for oboes. On the other hand, audience seating behind the orchestra is equally disadvantaged for both instrument groups.

The juxtaposition of two-tone spectra in Fig. 7.21 clearly shows the strong influence of floor reflections on the tonal effect for clarinets. Both were recorded in an anechoic chamber with a distance of 1.7 m of the microphone in front of the performer and a height of 1 m. The upper picture shows the tonal relations without

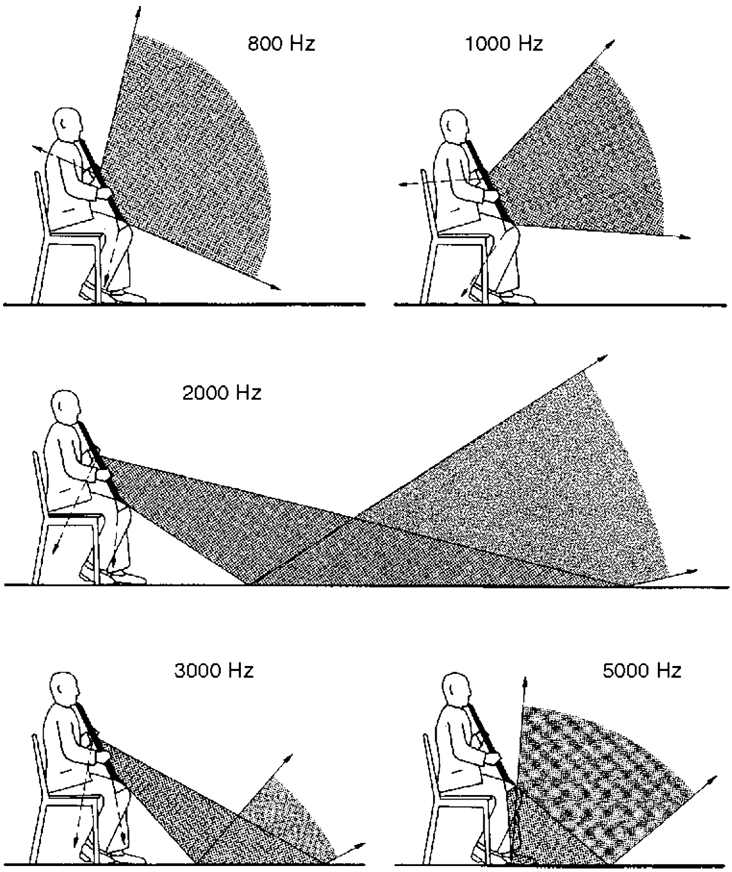


Fig. 7.20 Principal radiation directions (0...−3 dB) for clarinets

reflecting floor, the lower one with reflecting floor. Ignoring the fact that, because of the relationship of the microphone distance to the wavelength of the note played, the third partial is weakened by the out of phase reflected wave, one can see a significant intensity increase of the components above approximately 1,500 Hz. The level of the attack noise (in the region of 2,000 Hz) has also increased. Therefore, the tone of the clarinet has increased in brilliance as well as precision; thus, the timbre has become crisper without raising the overall loudness significantly.

The absorption of high frequencies in the hall does not permit this effect to become equivalent for all listeners, however, for microphone recordings of oboes and clarinets, one needs to be aware that even relatively small position changes lead to noticeable changes in the tonal picture because of the variations in radiation angle for the different regions at higher frequencies. In this context, reference again needs to be made to the fact that in the axial direction as well as the direction

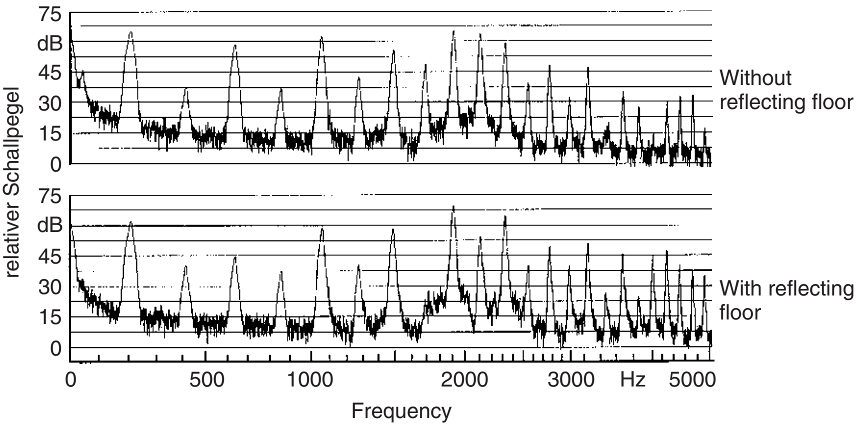


Fig. 7.21 Influence of floor reflections on the tonal spectrum of the clarinet (tone played: A_4) recorded in anechoic chamber, microphone distance 1.7 m, elevation 1 m

perpendicular to that, dips in the directional characteristics which lie by more than 10 dB below the maximum (See Fig. 4.12) are present in the frequency region between 1,500 and 2,000 Hz.

7.2.2.4 Bassoons

By reason of the upwardly directed orientation of the instrument, and its size, different radiation conditions than for the remaining woodwind instruments are given. As seen from Fig. 4.12, the intensity up to approximately 250 Hz is equal in all directions. The preferred directions for higher frequencies are represented schematically in Fig. 7.22. As clearly apparent, the radiation in the region near 300 Hz is very strong in the horizontal plane in all directions, so that reinforcing reflections are to be expected from a rear wall behind the player as well as from side walls of the hall (see Figs. 7.12 and 7.17), reflections from the floor are also possible. In the frequency region of the strongest components of the bassoon (near 500 Hz), the sound is also oriented directly toward the audience, however, the energy also reaches the hall by side wall reflections. In contrast, the rear walls play a lesser role. However, with appropriate angles of the ceiling, reflections from the region above and behind the player can also be effective, reflections from ceiling portions located further in the rear of the hall near the audience can also be expected. The tonal components in the region of the principal formant are thus radiated into the hall with particular advantage.

The structuring of the preferred angular regions into four radiation bundles in the subsequent frequency region up to above 1,000 Hz also leads to strong ceiling and rear wall reflections and also contains contributions directed toward the audience, provided the audience floor rises appropriately. For a level audience floor, these components reach the audience mostly by reflections and will therefore be some-

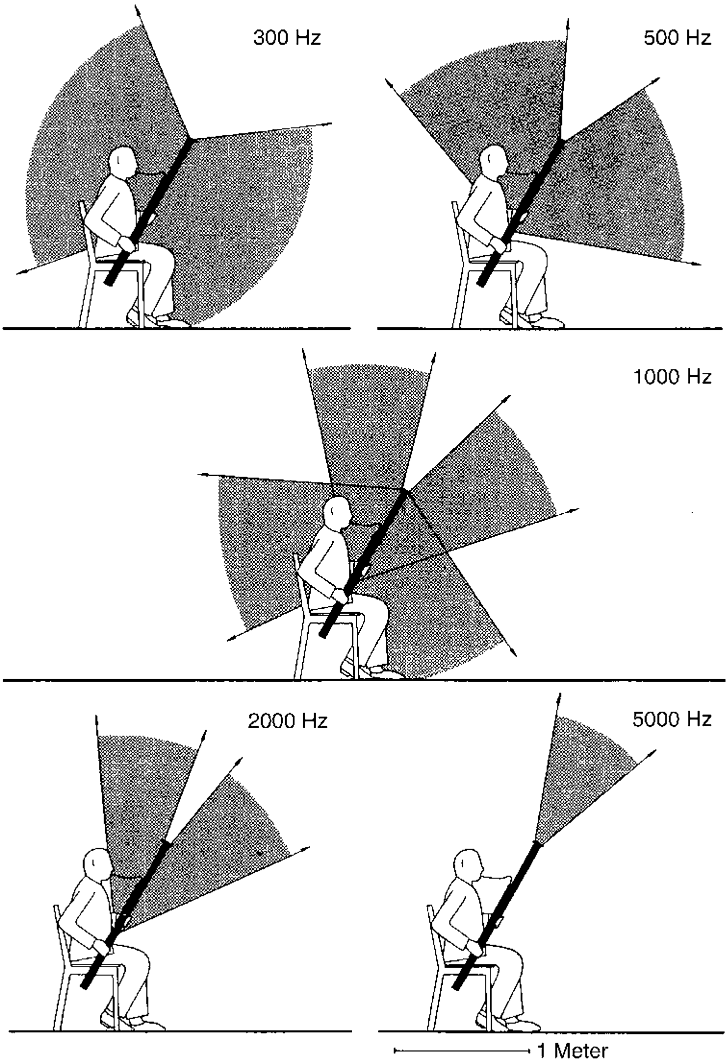


Fig. 7.22 Principal radiation directions (0...−3 dB) for bassoons

what weaker. Thus, the sound of the bassoon loses somewhat in strength and brightness. This effect can certainly be desirable for Baroque music, in view of the timbre of contemporary bassoons, in contrast, for musicians of the Classic period, a possibly bright tone color is desired (Meyer, 1968). Consequently, the portions of the frequency region around 1,000 Hz which are directed toward the rear, should be reflected into the hall if possible, while it is certainly not harmful if the low components around 300 Hz are absorbed by the rear wall. A lowering of the intensity at these frequencies would shift the main formant slightly higher so that it more nearly approximates the historical tonal impression.

At the highest frequencies, which occur mostly for very loud tones, the strongest components are concentrated in a relatively narrow angular region upward. However, an amplitude dip is formed above 2,000 Hz in the neighborhood of the instrument axis. At times this dip even exceeds a value of 10 dB in depth (see Fig. 4.12).

With increasing height of overtones the radiation cone closes. At 5,000 Hz the bundle only includes an angle of about ±20° relative to the axis. These very high components, which for tone aesthetic reasons should not reach the audience with excessive intensity, are mostly conducted by ceiling reflections. Thus, it can become dangerous when the bassoon addresses certain reflecting surfaces which are concentrated toward the public because the tonal balance between the high and low contributions is disturbed and the timbre receives an unpleasant hardness and crispness.

Locating the microphone along the extension of the instrument axis is especially undesirable because of the directional characteristics. The position of the microphone should at least be far enough from the player so that also the 500 Hz cone is included, (thus flatter than 45°). In order to avoid these difficulties for recording purposes, a bassoon with a bell bent at the bottom is used for the solo parts in concerts. For an instrument of such construction the high, noise-like contributions, do not stand out.

7.2.2.5 Combined Sound of the Woodwind Sections

The different angular regions for preferred sound radiation by individual woodwind instruments and the difference in the effectiveness of wall and ceiling reflections lead to difficulties in achieving a good balance between the wind voices for all seats in the hall under complicated room acoustic conditions. An example for the tonal effect of two oboes and two bassoons for a very flat seating arrangement, with winds behind the strings, is given for two different seats in the concert hall in Fig. 7.23.

At a location in the upper main floor (see Fig. 7.41), wall and ceiling reflections can arrive from all sides without obstructions, while only few reflections are expected, or can be expected in the gallery, and thus the direct sound contributes more strongly to the overall impression. As recognized from the octave diagrams, the level value for individual chords of this passage is larger in the upper main floor in the lower frequency regions and around 4,000 Hz, while around 1,000 and 2,000 Hz larger values are found in the gallery. This means that in the upper main floor the bassoon can be heard more loudly. In contrast, in the gallery it is the oboe, as can easily be deduced from the tonal characteristics of the two instrument groups.

The reason for this variation in intensity relations lies in the directional characteristics. The bassoon stands out wherever wall and ceiling reflections play an important role for the room acoustical picture. In contrast, the oboe is heard better wherever the direct sound can arrive without obstruction and is not attenuated along the path to the audience. Under given hall conditions, a better

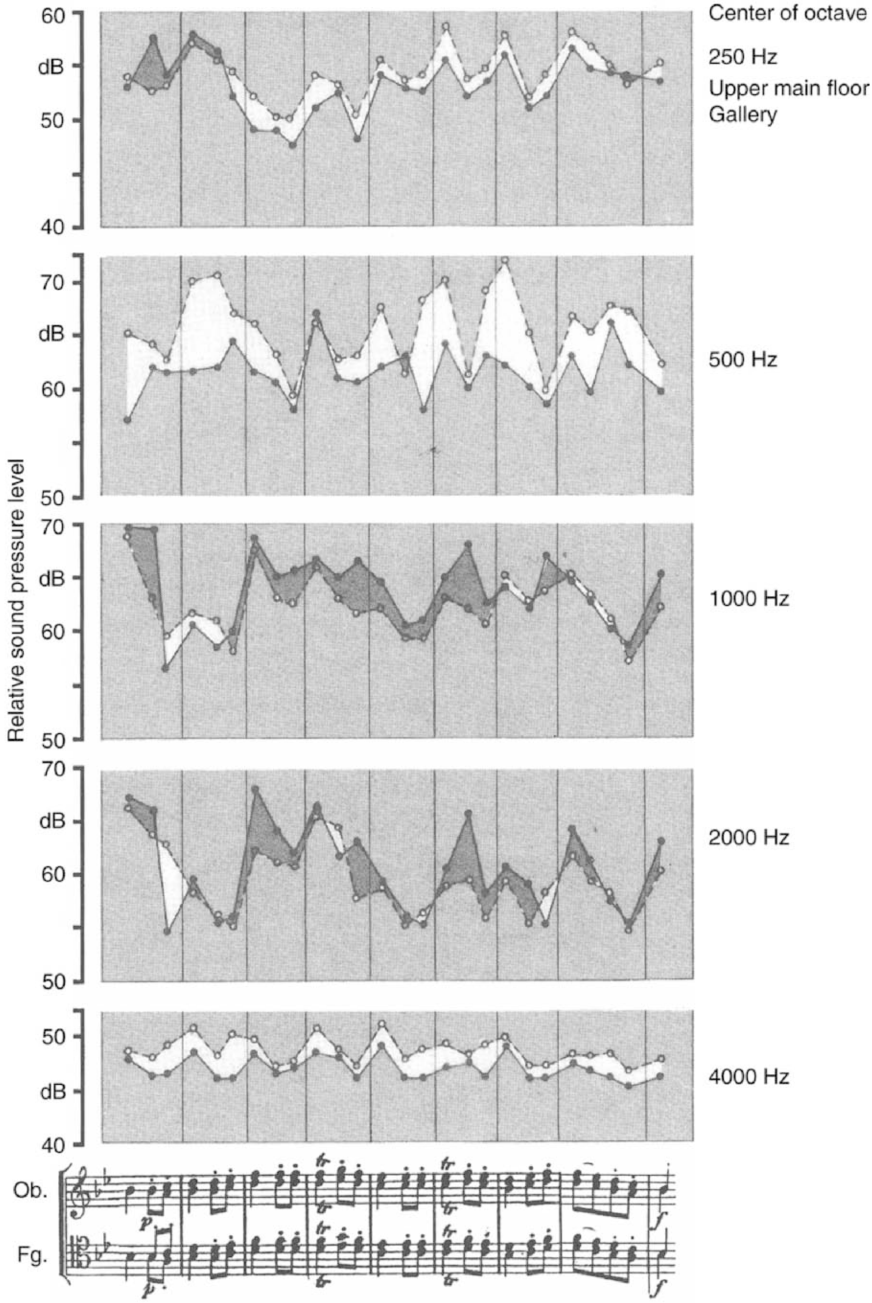


Fig. 7.23 Octave level analysis of a passage for two oboes and two bassoons (W.A. Mozart, Symphony B^b major, K319, 4th Movement, measure 336–344) in two locations in the large hall of the Stadthalle Braunschweig

balance can be achieved by placing the oboes appropriately higher to permit free radiation to the main floor.

With regards to the positioning of the four woodwind groups, this example shows that it is advantageous for a balanced overall sound, to flank the bassoons by clarinets and horns, or possibly trumpets, instead of locating them near the edge, in order to reduce wall reflections. This is particularly important when the orchestra does not occupy the entire width of the podium, leaving a free space between the performers and the side walls. In this case the wall reflections of the bassoon are not attenuated by the string players for a portion of the audience, and thus the bassoon appears louder in some parts of the hall than in the remaining seats.

Since free sound radiation is important for clarinets, two levels for woodwind rows are acoustically better than having all players seated at the same level. The question whether clarinets should be located to the left or right of the bassoons is immaterial for the tonal effect of woodwinds. Locating the clarinets is thus primarily determined by the choice of seating the horns. In most halls, even the seating arrangement of oboes and flutes in the front row is of no importance for the acoustic effect in the hall. It could merely happen that a piercing piccolo can influence the tonal symmetry of the orchestra when seated near the outer edge: in such a case switching flute and oboe group positions is occasionally advisable, however, it is very important to consider the character of the composition.

7.2.3 Brass Instruments

7.2.3.1 Horns

The simplified sound radiation relationships for horns are represented in Figs. 7.24 and 7.25, for the horizontal plane as well as for two vertical planes. In addition it should be remembered that the intensity for frequencies below 100 Hz is uniform in all directions. The tone contributions between 150 and 250 Hz, as well as those between 300 and 500 Hz are radiated in the horizontal plane (Fig. 7.24) approximately in the width of a semicircle, while the frequencies located between those two regions are concentrated in a slightly narrower angle. Above 600 Hz the largest amplitudes occur only in a more or less narrow region oriented toward the right rear. These components reach the audience predominantly by wall reflections.

The general preference of the right side, as well as the rear facing direction, is clearly expressed in the figure representations for the vertical plane (Fig. 7.25). Beyond that, these characteristics show a pronounced radiation concentration toward the front and the upper direction: this can reach the audience in the hall through ceiling reflections. Below 600 Hz, this preferential region reaches at least down to the horizontal plane, so that these components, which also include the principal formant of the horn, are radiated directly toward the audience. Furthermore, an additional maximum toward the back of the performer in the region from 1,000 to 1,300 Hz is noteworthy. This can become effective through double

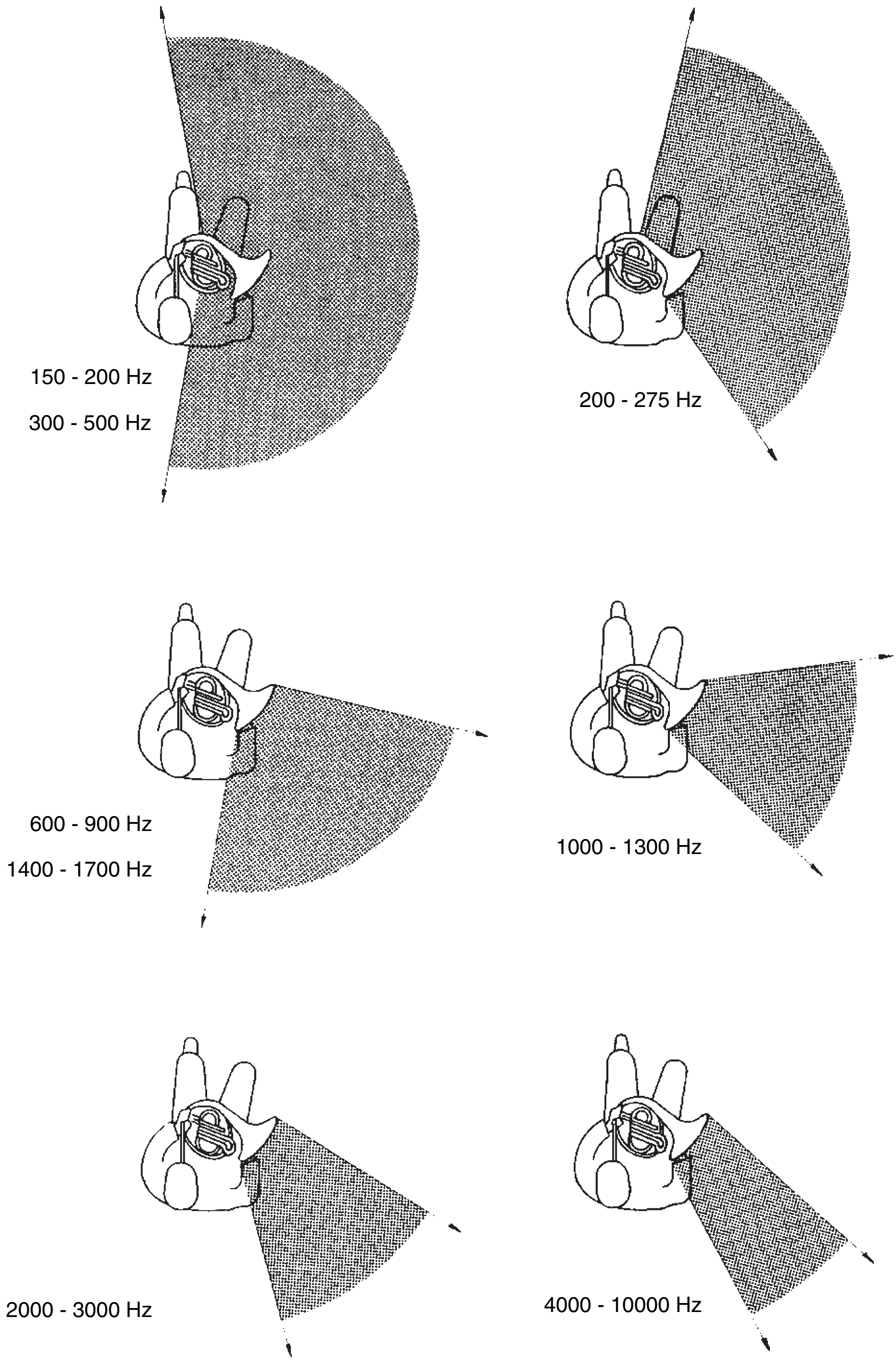


Fig. 7.24 Principal radiation directions (0…−3 dB) for horns in the horizontal plane

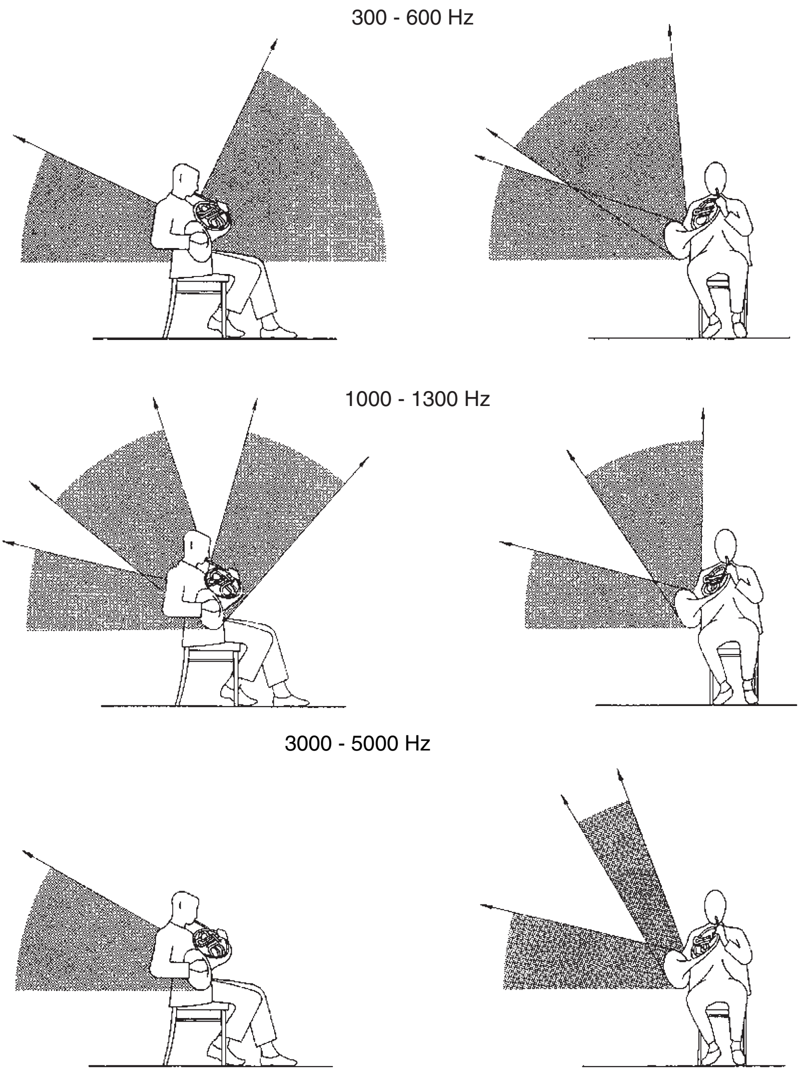


Fig. 7.25 Principal radiation directions (0. . .−3 dB) for horns in two vertical planes

reflection from ceiling and rear wall. Corresponding to its location near the high a (ah)-formant it enhances the forceful tonal characteristic of the instrument.

Toward the right side, an increasing separation into two preferred regions occurs as frequency rises. These in turn also become narrower. Consequently, in addition to sidewall reflections, sound reflections from the ceiling also are significant. These regions of ceiling reflection need to be located at an angled orientation above the player. The dynamics of the performance can increase significantly when the highest frequencies, which occur only for increased loudness are advantageously directed toward the audience, otherwise a *forte* can remain too dull. For unfavorable room acoustic conditions, forced blowing can compensate for this phenomenon, at least partially.

The extraordinarily different tonal effect of the horn is also expressed in the juxtaposition of two sonagrams in Fig. 7.26, where one gives the tonal picture in front of the player, the other one toward the right next to the player. In this representation, the frequency of the overtones is recorded from bottom to top, the intensity is given by the degree of darkening, where the individual grey steps represent level differences of 6 dB. As even a cursory glance reveals, a tone picture much richer in overtones is formed to the right of the player than toward the front. When considering the initial transients of tongued *staccato* eighth notes, a very dense sequence of contours is noted, represented by a very rapid rise in amplitude.

The highest intensity at frequencies below 1,000 Hz is reached within approximately 20 ms. For some tones, the higher contributions have a longer transient than the lower ones. This phenomenon is very pronounced for some of the *staccato* eighth notes (e.g., F_6 and $F_6^{\#}$ in measure 4), especially for notes of longer duration. This *crescendo* within the note is only weakly perceived by the player, since the overtones only reach up to 1,500 Hz.

A tonal difference also results for the connected E_6, which appears more strongly separated toward the right hand of the performer, while the connection (this case deals with a valve connection) results in a softer impression in front of the player. For the last three notes, the loudness is raised to a metallic timbre: toward the side of the player the overtone contributions reach up to about 8,000 Hz, while in front it barely reaches 4,000 Hz. In this context it is worth noting how the player attacks those notes, which by overtone content are related to the *staccato* eighth notes, and thus, thereafter, rather suddenly again achieves the metallic sound. Certainly the

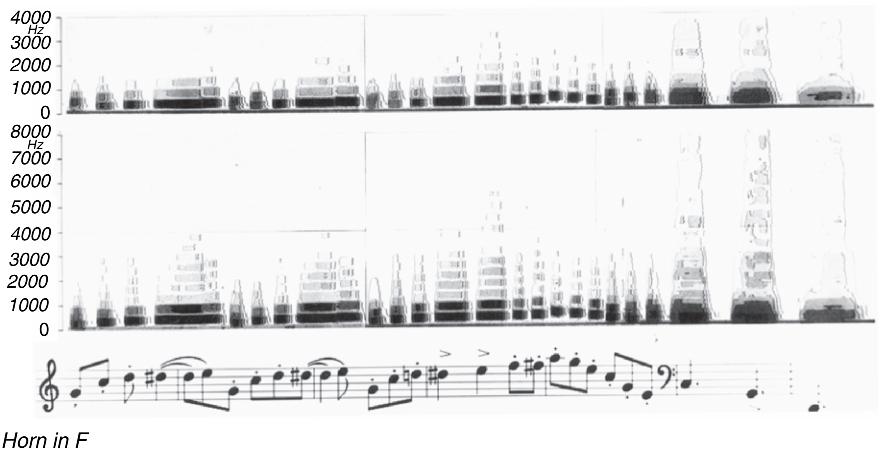


Fig. 7.26 Sonagrams with of the horn theme from R. Strauss' "Till Eulenspiegel's Merry Pranks" recorded in an anechoic chamber, microphone distance 3.5 m. *Top*: in front of the player. *Bottom*: to the right, next to the player

same dynamic tendency can be recognized in both directions; however, the expressivity toward the front is far less. Finally, a valve noise (between C_6 and G_5 in the 5th measure) is noted, which is observed more clearly toward the right of the player in several frequency regions, while it is not observed in front of the player.

Naturally, rear-wall reflections play a particularly important role for the sound of the horn. Consequently, the front-back ratio is represented in Fig. 7.26, above the level increase for comparison, with a hard, sound reflecting wall behind the player. Ignoring variations through interference phenomena at some low frequencies, one clearly recognizes the reinforcing effect of the rear wall in the lower diagram. In the low frequency region, the level rise amounts to approximately 6 dB, and has a maximum of about 15 dB in the region from 1,500 to 2,000 Hz; at still higher frequencies the effect again becomes less. Thus, the sound of the horn generally gains intensity through the reflection effect of the rear wall, where the lower region of the nasal components is strengthened least. The brightening tone contributions in the region of the vowel color "e(eh)" are especially brought out. For all commonly used horns (except for the horn in high F) these form a characteristic side formant.

The spectral broadening is also recognized in the sonagram of Fig. 7.27. The *staccato* motif not only contains more overtone contributions in the presence of rear wall reflections, but even at lower frequencies presents larger amplitudes, as is noted by the total number of darkness steps. Even the particular intensity increase in the region around 2,000 Hz is clearly visible for several of the notes. Inasmuch as in this case, as for the sonagram of Fig. 7.25, the clarity of the attacked notes is more determined by the greater frequency range than by the special processes of tone

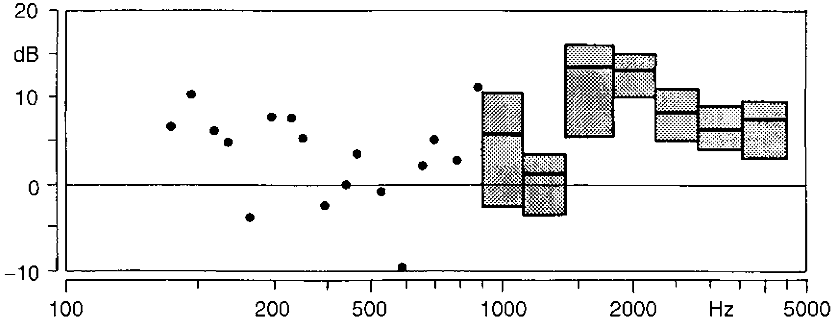


Fig. 7.27 *Top*: front-back ratio of the directional characteristic of the horn. *Bottom*: level rise in front of the player caused by a reflecting rear wall with 1 m distance from the bell

development, it certainly can be said that the rear wall gains in significance, especially for a larger orchestra. When the spectrum is excessively limited, a pronounced soft sound results, however the danger increases that the horns are covered by other instruments in the context of the entire sound. On the other hand, a stylistic comparison with the sound of valveless concert horns (German: Invention Horn) of Mozart's time leads to a conclusion, that especially for compositions of this time period, the brightening effect of the rear wall is advantageous, provided players make allowances for excessively hard attacks in an attempt to equalize the dynamics relative to other instrument groups.

Generally, horns are seated toward the right or left next to the woodwinds; when there are six or eight horns, the entire group is occasionally located as a third wind row behind the clarinets and bassoons. The higher the horns are seated above the strings, and the closer they thus come to the rear wall of the stage, the brighter their tone color becomes, and the more precise they become in their attacks. In contrast, locating them next to the oboes or bassoons is more favorable for a softer tone presentation, since the shadowing by other players especially effects the higher frequencies. It is thus recommended to surround the horn group by other players, in order to achieve the round and sonorous sound of the horns, as demanded, for example, in the symphonies of Brahms and Bruckner, while smaller horn sections in classical symphonies already lead to the fact that horns obtain a more free, and thus brighter tone radiation.

The question, of locating horns preferably in the right or left side of the orchestra is also related to the spatial conditions of the podium. In rectangular halls or also for a nearly rectangular stage, both seating arrangements are possible, since the side wall reflections partly return to the orchestra and are partly attenuated by the string players sitting before them. However, it is important that the first horn is located at the very edge when placed on the left side as seen from the conductor so that that instrument presents the most brilliant sound within the section. Within the framework of meaningful possibilities, this arrangement leads to the brightest sound of the horns. It thus appears to be predestined for classical compositions. It is interesting to note that especially in France this arrangement is frequently used, where also horn designs move in a direction to achieve similar tonal effects.

When the horn section is placed on the right wing, the first horn can sit either inside or outside. On the inside, it is located more closely to the solo players of the other wind groups, which supports mutual contact, and a unison with the cello also works very well. On the other hand, when located on the outside, the first horn can be heard well by the other sections and its influence on intonation and uniform tone development of lower voices is made easier. From a performance technical standpoint, placing the horns toward the right side is also advantageous in cases when the first horn plays together with the solo violin as is the case for example in the slow movement of the 1st symphony by Brahms, since visual connection with the left side is not possible.

When the stage opens cone-like toward the hall, locating the horns on the left side of the orchestra is not advisable. In similar fashion, as already explained for the bassoon, the pronounced side wall reflections reach the hall without obstruction because of the opened flank of the instrument. For a portion of the audience, the horns thus sound significantly louder and more cutting than expected by the conductor, and as perceived in other seats of the house. It thus is certainly possible that the higher frequency tone contributions reflected by the wall – in consequence of directional characteristics – are stronger than the direct sound and therefore the sound source is perceived as coming from a reflecting wall and not from the player. Thus, with increasing loudness, the sound from the horns is spatially separated from the remaining orchestra. This uneven spatial effect of horns in the room is significantly less when the horns are seated toward the right since they then turn their side of least sound radiation toward the open flank of the orchestra.

For a soloist standing in front of the strings, naturally the tonal contributions radiated toward the rear are strongly absorbed, so that the direct sound becomes of increased importance. Some players utilize the possibility of influencing the tone by turning the bell toward the audience during fast passages, i.e., passages of a lively and rhythmic strongly accentuated character, while they adjust their orientation for cantabile portions of compositions, in such a way, that the timbre becomes rounder and softer. This technique, however, can not be used for a horn quartet functioning

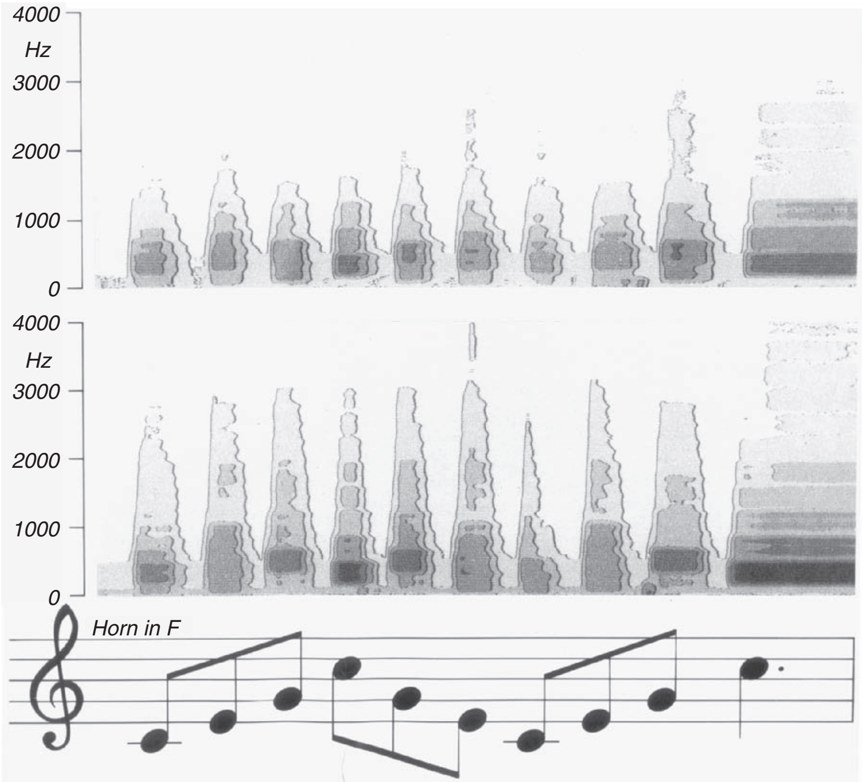


Fig. 7.28 The sonagram of the *staccato* tone sequence recorded at 3.5 m distance in front of the layer in an anechoic chamber. *Top*: without reflecting rear wall. *Bottom*: with reflecting rear wall

as a solo instrument. It is thus more favorable, and this not only in view of the dynamic balance, for works such as the Concert Piece for 4 Horns and Orchestra by R. Schumann, to place the soloists behind the orchestra, though slightly to the side, but somewhat raised. A reflecting wall behind the players can also be used to raise the brilliance.

7.2.3.2 Trumpets

Sound radiation patterns for trumpets are significantly less structured than for horns, as the two representations for the vertical and horizontal planes in Figs. 7.28 and 7.29 show. Following the frequency region of the spherically uniform radiation, which in the low register includes frequencies up to approximately 500 Hz, the stronger energy contributions are concentrated toward the front in an angular region, which approximately fills the frontal hemisphere. Accordingly, at these frequencies the sound reaches the audience not only directly but also by reflections from large sections of the ceiling and the side walls, provided they do not diverge excessively in the region of the audience. Floor reflections are also possible, where, however with increasing size of the orchestra, absorption by musicians sitting in front becomes ever more noticeable. In contrast, reflections by the rear wall of the stage, as well as the portion of the ceiling directly above the player, only plays a very subordinate role at these frequencies.

However, this changes near 800 Hz where the representation for both planes visualizes the significance of the higher portions of the rear wall and the entire ceiling. From 1,000 Hz on upward, the increasing concentration for the trumpet leads to the circumstance that in addition to the direct sound, reflections are only effective for far distant portions of the ceiling or side walls (in long halls). This fact is noteworthy particularly because the strongest tone contributions of the trumpet lie in this frequency region, which is responsible for the typical timbre, and primarily gives strength to the sound. Since this also dominates the spectrum for a *piano* sound, the directional characteristic means that trumpets – in contrast to many other instruments – radiate their sound in a relatively concentrated manner even for low loudness levels.

Above 1,500 Hz the concentration of the sound radiation becomes so narrow that only little value can be attributed to side wall reflections and even ceiling reflections. From 4,000 Hz on upwards, the principal intensity is only directed toward the audience sitting on the main floor. The narrow radiation region of the relevant partial pictures also indicates how important it is to have the player sufficiently elevated in relation to orchestral seats located in front of the trumpet, so that the brilliance of the *forte* is not influenced. The related effect of the music stand, and performance with raised bell, will be treated in a later section (see Sect. 8.3.3).

The fact that reflections from the rear and side walls of the stage are only important for the lowest tone contributions becomes noticeable, especially when large choral works are performed. While most instruments are influenced in inten-

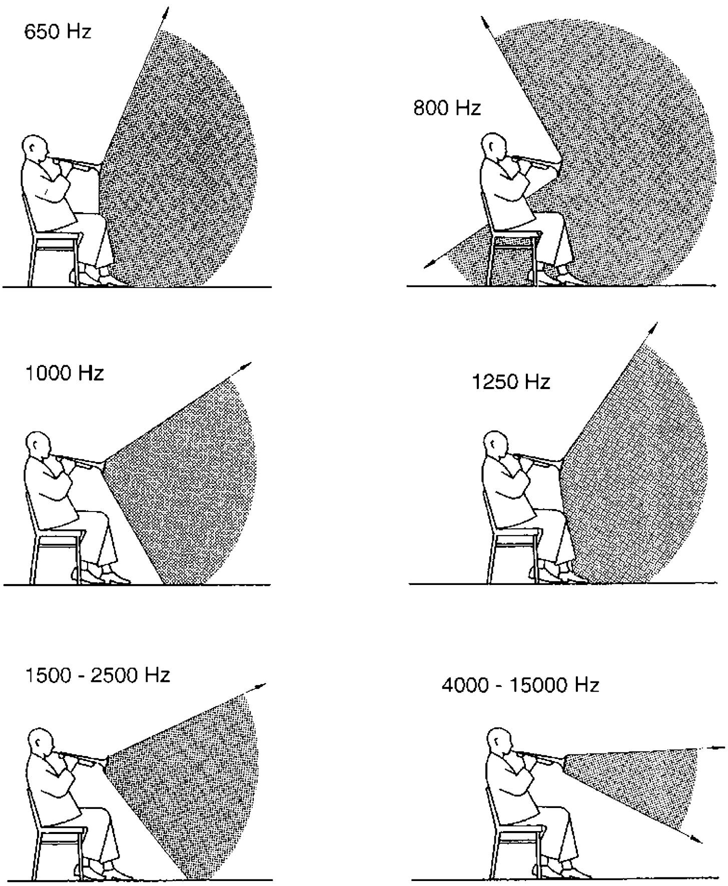


Fig. 7.29 Principal radiation directions (0. . .−3 dB) for trumpets in the vertical plane

sity and especially brilliance by the absorption effects of the choir, the timbre of trumpets are essentially preserved for the audience in the hall.

The especially sharp directional characteristics of trumpets naturally results in the fact that in wide concert halls, or halls for which the audience is also seated behind the orchestra, the sound is not perceived with the same brilliance and clarity in seats toward the side and the rear, as it is for seats in the direction of sight of the performer. This is less noticeable in definite solo passages than in passages for which the trumpets are to stand out with a rhythmic motif from the total orchestral sound. As an example for this, a tonal analysis of an excerpt from the 9th symphony by A. Bruckner is given in Figs. 7.30 and 7.31.

Figure 7.30 shows two models of sound levels in octaves for measures 51–71 of the 1st movement; the time sequence is shown in the associated score. The center frequencies of the octave band filters used are noted at the left edge. Accordingly, the low frequencies are located at the rear, the high frequencies at the front. The

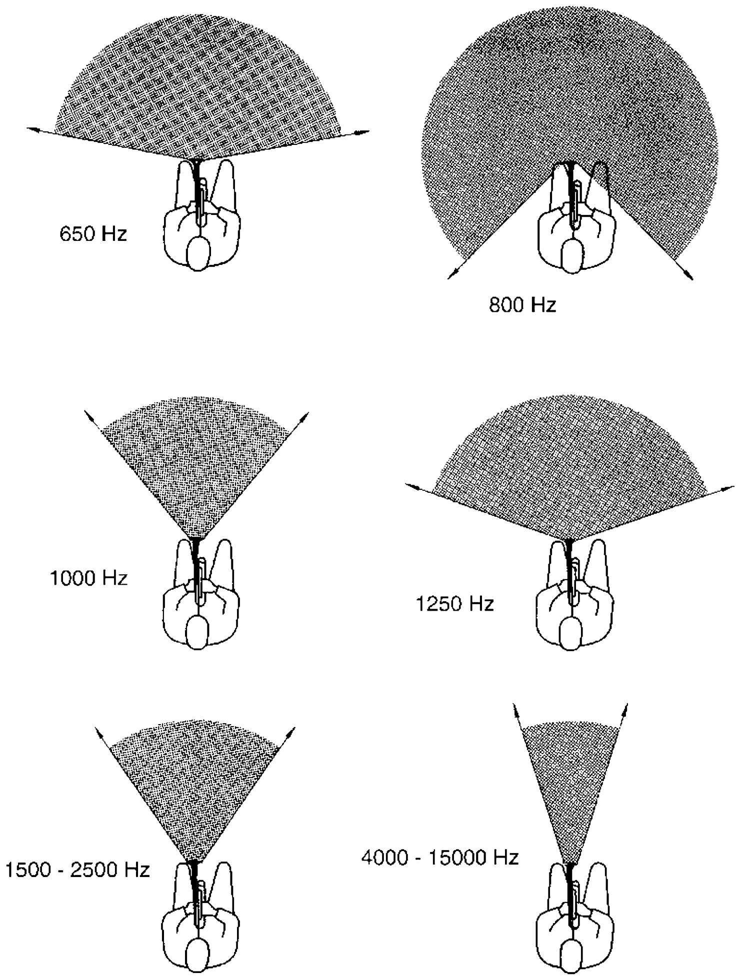


Fig. 7.30 Principal radiation directions (0...−3 dB) for trumpets in the horizontal plane

intensity of the individual filter regions is represented on the vertical axis. While the lower model represents the tonal picture at an audience location in the 5th row from the front, approximately in the middle of the hall, the upper model represents the sound relations at the location of the conductor.

In both examples, the same structure of the tonal process is recognized, from the exchange between *piano* and *pianissimo* (twice) at the beginning, over the large *crescendo* with the entrance of the low instruments, to the rhythmically marked theme in the right portion of the picture. However, certain differences are also noted between the models, especially the greater richness in overtones at the position of the conductor. In the context of the previous discussion, the last four measures of the *crescendo*, where the trumpets have to play *staccato* 1/8 notes, deserve particu-

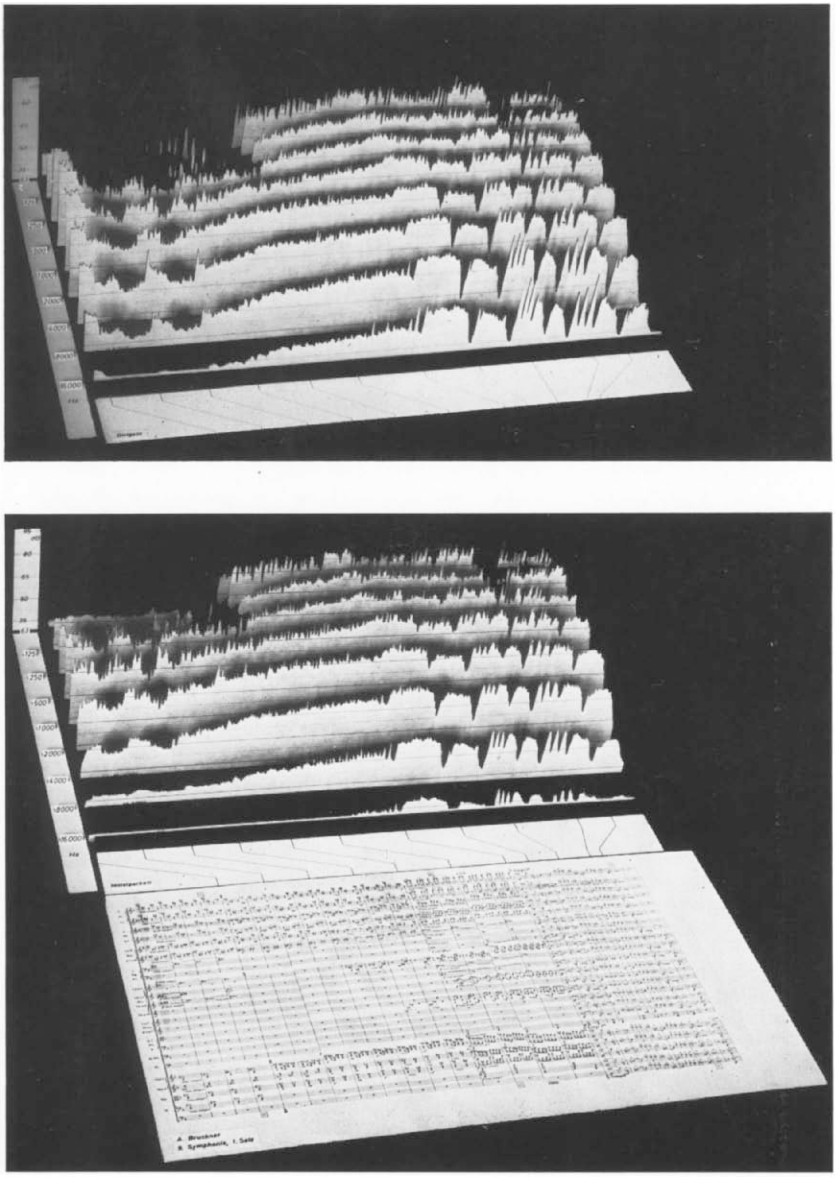


Fig. 7.31 Octave level models of the orchestral sound in the Stadthalle Braumschweig (A. Buckner, 9th symphony, 1st movement, measure 51–71). *Top*: sound at conductor location. *Bottom*: sound in the 5th row of the main floor

lar attention. In the upper model, these figures are not clearly recognized in any filter region (as equally spaced sharp peaks), which is connected to the fact that at the location of the conductor the strings located in close proximity radiate strong components at high frequencies with their tremolo. In the lower model, however, the trumpet 1/8 in the 8,000 Hz region are noticed as regular peaks even though the trumpets are slightly shadowed by musicians sitting before them for this audience location. This is because the high tone contributions of violins are received only weakly in these front audience seats as shown in Fig. 7.7 (different hall, however).

The difference in the effectiveness of trumpets becomes especially clear when a location, which is still within a diffuse-field distance, is compared with one toward the side. For this purpose, the interesting measures, are given, with sound levels in octaves for an 8,000 Hz filter, while identifying the recording locations in the floor plan. In this frequency range, trumpets stand out most clearly (if at all) from the orchestra sound. The score excerpt includes only those voices which can deliver sufficiently strong tonal contributions at those high frequencies. The time base on the recording strips is given by connections to the measure bars in the score, thus one can clearly recognize that the individual level peaks in the lower diagram correspond to sharply attacked 1/8 notes.

Since the seats in the audience rise relatively steeply in front of the rear wall, a relatively good view of the wind groups is obtained from there. The trumpets are not shadowed by other performers, and thus stand out sharply from the total sound. This is not only the case for the *staccato* 1/8 before letter C but also in the clearly separated entrance in the 2nd measure after letter C. At the location on the side, beyond the diffused-field distance, the individual 1/8 notes, however, are no longer uniquely identifiable, even though the distance to the player is only half as large, and furthermore, the other high voices arrive with relatively low overtone content because of the placement of the two violin sections and the flute on the left side of the podium.

It should, however, be especially emphasized, that a maximum in intensity in the region of highest frequencies is not necessarily to be considered as desirable for trumpets in principle. This requirement is primarily only valid for the higher dynamic levels, as can be seen from the dependence of the spectral composition on the loudness. For smaller orchestras, a less cutting trumpet tone also merges better into the overall tone. Nevertheless, it will always contribute less to the spatial representation of the total orchestra sound than all other instruments, and will stand out from the overall tone because of the precision of its spatial location.

7.2.3.3 Trombones

Concern for equalized tonal effects at high frequencies is even more important for trombones than for trumpets since this instrument group easily has a harsh sound in slow passages and misses the desired sonority. As seen from schematic representations in Figs. 7.32 and 7.33 the concentration of the radiated sound of a trombone plays an important role. As is the case for trumpets, the radiation is directed mostly toward the front and the ceiling which contributes to an intensity increase by reflections for frequencies below approximately 1,100 Hz, at least at far distances. Since the components directed toward the floor experience strong absorption by the

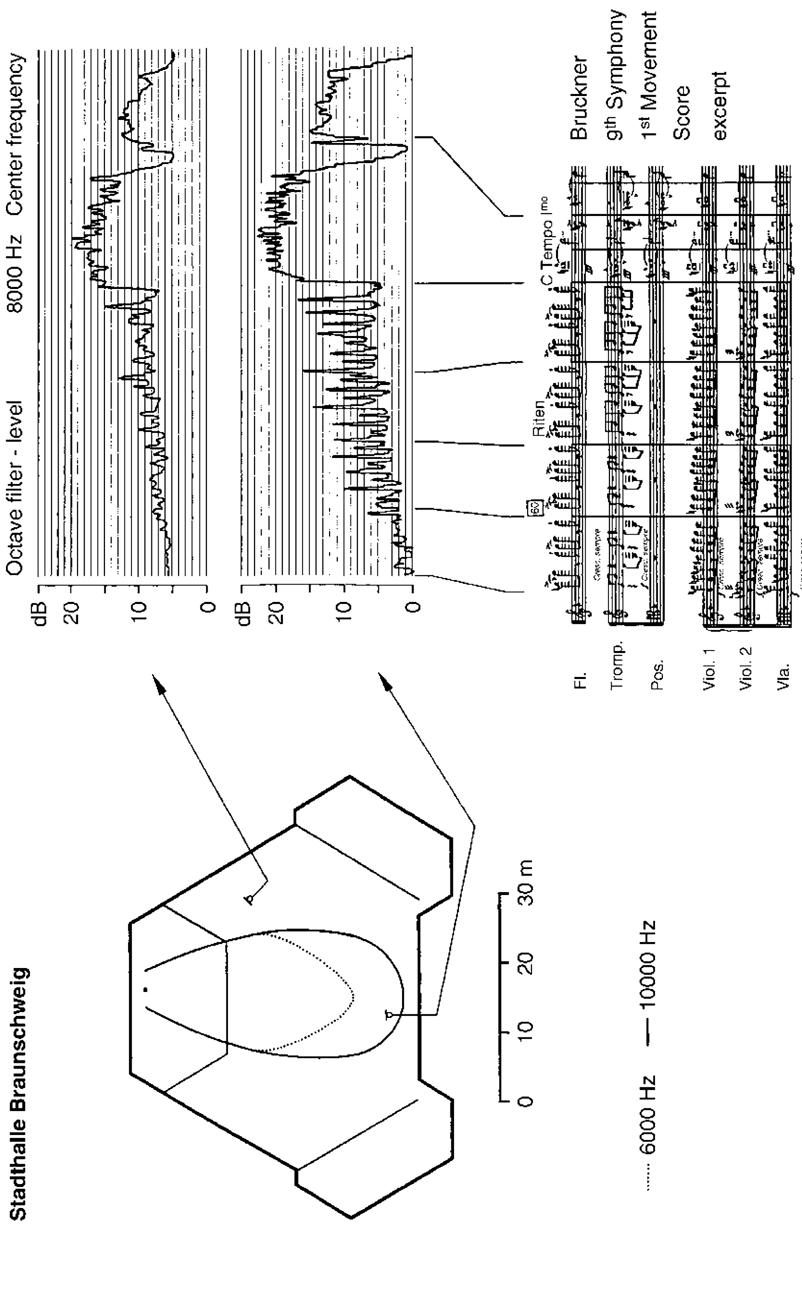


Fig. 7.32 Tone effect of the trumpets at two locations in the Stadthalle Braunschweig

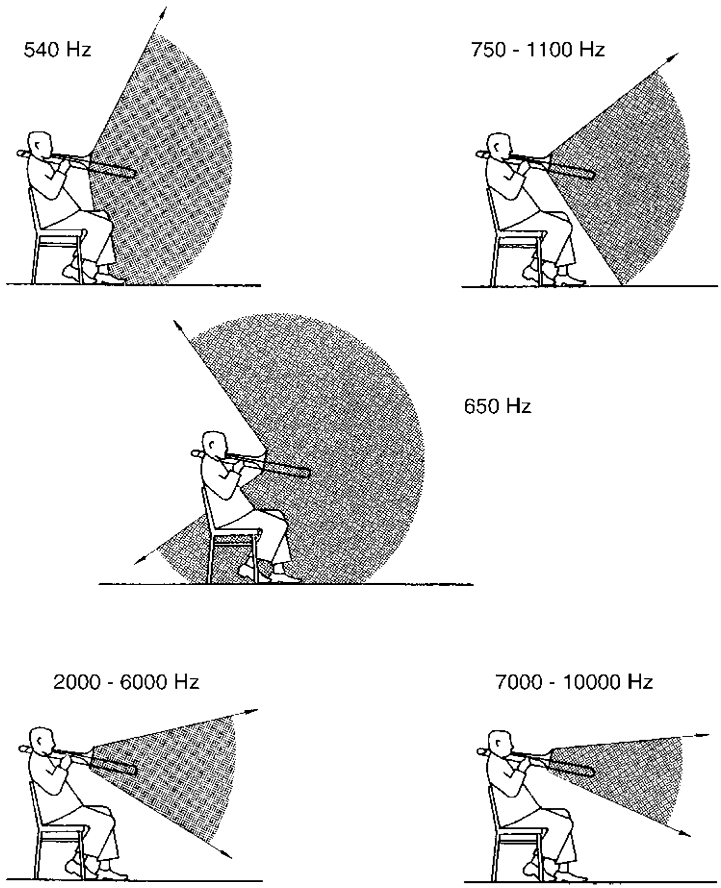


Fig. 7.33 Principal radiation regions (0...−3 dB) for trombones in the vertical plane

musicians sitting in front, the tonal effect in the hall, for high frequencies is especially dominated by the direct sound.

This is also shown in the representation for the horizontal plane, where, for frequencies above 2,000 Hz, an angular region of only 45° width of the audience space of the concert hall lies within the principal radiation region; and above 7,000 Hz, i.e., for components, which only in *fortissimo* exhibit greater intensity, a narrowing to 30° occurs. However, for trombones the side wall reflections below about 1,100 Hz and especially below 700 Hz play an important role. In contrast to trumpets, where the strongest energy in a given frequency region is radiated with relatively sharp concentration, for trombones, the principal formant lies in the frequency region for which the intensity toward the side of the player is attenuated only by approximately 3 dB in comparison to the direction of the instrumental axis. These important tone contributions are thus radiated relatively broadly into the hall.

Naturally, in the directions toward the side a somewhat softer tone picture results from the weakening of the higher frequencies in those directions, in comparison to the direction of sight: however, this effect can be advantageous for the sonorous and majestic tonal effect of trombones. In this context Sir Adrian Boult should be remembered, who suggested (1963) the possibility of orienting trombones on the concert stage in such a way that they play at a right angle toward the middle rather than into the hall directly, since then their tone can be more easily merged into the overall sound. This merging of individual instruments within a group, or into the overall sound of the orchestra, is to be understood to mean that trombones should not draw attention by pronounced transients, but rather join a chord unobtrusively by a soft attack without playing with lessened intensity.

The relatively broad radiation of trombones in the frequency region of their principal formant requires special attention in concert halls for which the podium is wider than the area occupied by the orchestra. As already mentioned for other wind instruments, for such cases the danger exists that the intensity for some audience seats is especially high by reason of unimpeded wall reflections, while in other areas of the hall the loudness balance is more equalized. This effect is especially noticeable when the side walls of the podium are not parallel but open in the direction of the hall. Since this effect is more strongly pronounced for trombones than for other wind instruments because of their directional characteristics, it is recommended under such spatial circumstances to locate the trombone section at the highest level not toward the edge, but toward the middle. In rectangular halls or for a rectangular stage such difficulties do not occur.

Since the trombones most frequently are seated in the last row of the orchestra, the question of the influence of a reflecting wall behind them on the tonal impression in the hall naturally arises. Frequently the technical possibility exists to increase the absorptivity by means of a curtain, to the point that sound reflections from the rear wall are practically eliminated.

As expected from the directional characteristics (see Fig. 4.4), rear wall reflections only influence the sound in the hall up to a frequency region of approximately 400 Hz. In analogy to the representation for corresponding conditions in the horn (Fig. 7.26), Fig. 7.34 shows the level increase which can be achieved with a trombone by a hard rear wall; the difference is clearly recognizable. Dampening of the rear wall thus merely affects a decrease of the lower tonal contributions for the trombone, which leads to a somewhat brighter tone color, while the timbre with a reflecting rear wall has more of the nature of the fundamental. However, the principal formant is practically not influenced, so that the loudness is not noticeably changed.

This modification of the tone picture in the hall and also at the position of the conductor need not coincide with the aural impression of the player. Since by virtue of the directional characteristics, the higher frequency contributions already reach the player's ear relatively weakly, an increase of these components by a rear wall reflection is certainly sensed. This in turn has the consequence that the player performs somewhat more softly and the tonal effect in the hall becomes more dull.

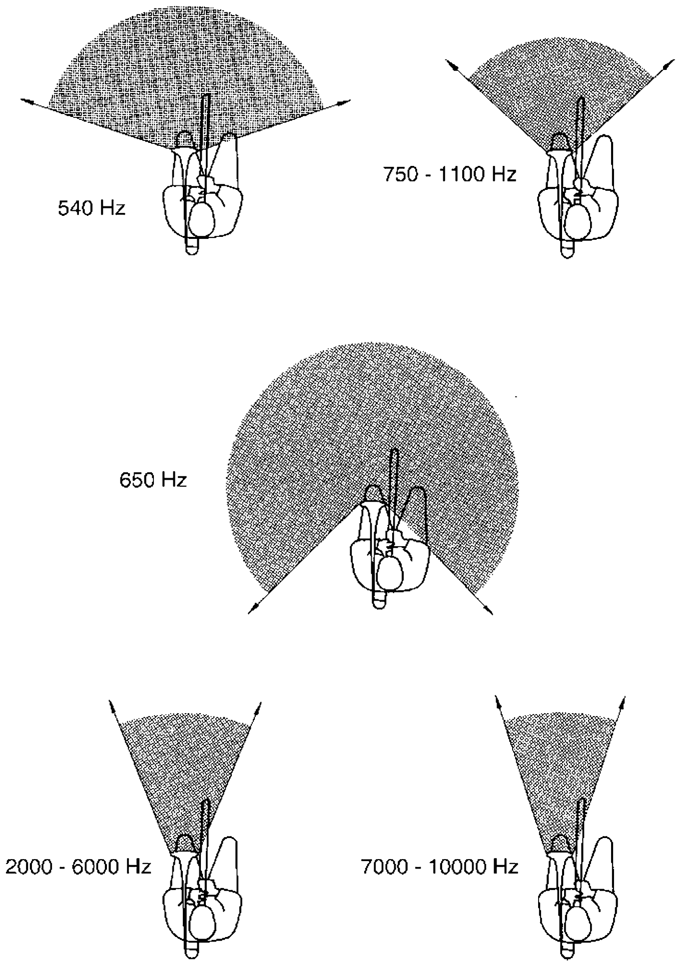


Fig. 7.34 Principal radiation regions (0...−3 dB) for trombones in the horizontal plane

7.2.3.4 Tubas

The angular regions of preferred sound radiation for a tuba are represented for three frequency regions and two different vertical planes in Fig. 7.35. In consequence of the slightly angled orientation of the bell axis, slightly different half value widths result for these two planes. Furthermore, it is noted as a reminder, that at frequencies up to approximately 75 Hz the radiation is uniform in all directions. As recognized from the pictures, the direct sound radiated to the audience has special importance in the region of lowest frequencies, where the shadowing by musicians seated before them is certainly minimal. Already in the region of the principal formant the intensity in the horizontal plane is by 3 dB less than toward the top. With increasing frequency the concentrating effect becomes more pronounced;

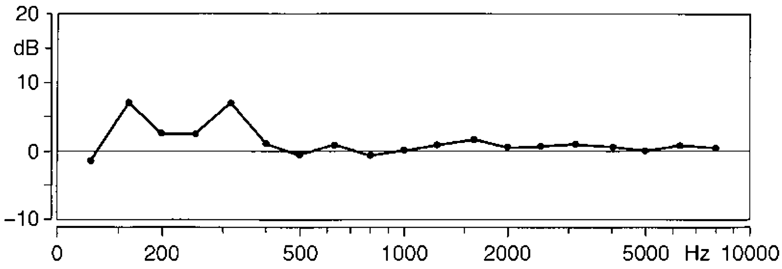


Fig. 7.35 Level increase in the direction of the player by a reflecting rear wall (trombone)

components above 800 Hz are radiated toward the ceiling more strongly by 20 dB than in the horizontal plane.

In view of the low range, as well as by reason of the full and round sound of the tuba, overtones of these frequencies must be considered as very high: this means that they are frequently perceived as undesirable rather than as enriching for the tonal picture. This phenomenon can be noted as annoying when occasionally unfavorably oriented reflection surfaces are responsible for sending the sound contributions of higher frequencies into seats of a limited audience area. Since in this region of higher frequencies, relatively annoying noise mixtures are present, the tone receives a rather rough and strange character. Furthermore, the danger of erroneous localization can arise, i.e., the listener receives an impression localizing the instrument near the ceiling behind the reflecting surface, because the low frequencies with a strong direct sound contribution contribute almost nothing to a sense of direction.

Inasmuch as the reflection surfaces above the orchestra are of great importance for most other instruments, it follows from these considerations that generally considerations of tuba playing technique must include awareness of reflectors, thus no higher dynamic level than *mezzo forte* should be blown to achieve a full, steady tone. Furthermore, consideration should be given to limited absorption possibilities above this portion of the orchestra in light of the narrow concentrations of high frequencies for the tuba, particularly since the trombones, which are frequently seated next to the tubas, would not profit by reflections from the ceiling.

7.2.3.5 Combined Sound of the Brass Sections

There are primarily two considerations for locating the individual brass sections on the concert stage: one is the tonal balance between the French horns and the heavy brass, the other is the spatial effect associated with exchange of motifs. The intensity balance is easily influenced when the trombones are seated behind the French horns. Since, based on directional characteristics, players in both sections hear the instruments of the other section as louder than their own, they are inclined to force the tone – especially at louder dynamic levels. Many horn players consider this seating arrangement, particularly for *fortissimo* passages, only acceptable for doubly occupied horn chairs. The dominance of the other section, as perceived by

Score Example 22 A. Bruckner, 4th Symphony, 3rd movement, measure 9 ff. Excerpt without strings and wood winds

the players, also leads them to regard conductor instructions to reduce volume, as inappropriate in their case. Therefore, placing the trombones behind the woodwinds appears more favorable than behind the French horns, particularly since this also makes it possible to place the first chairs of the trumpets and the trombones close to the wood wind solo players. Thus, for example, for decades, the customary seating for the Vienna philharmonic in the large Musikvereinssaal is as follows: (as seen by the conductor from left to right): Tuba, Trombones (3–2–1), Trumpets (1–2–3), French Horns (1–2–3–4).

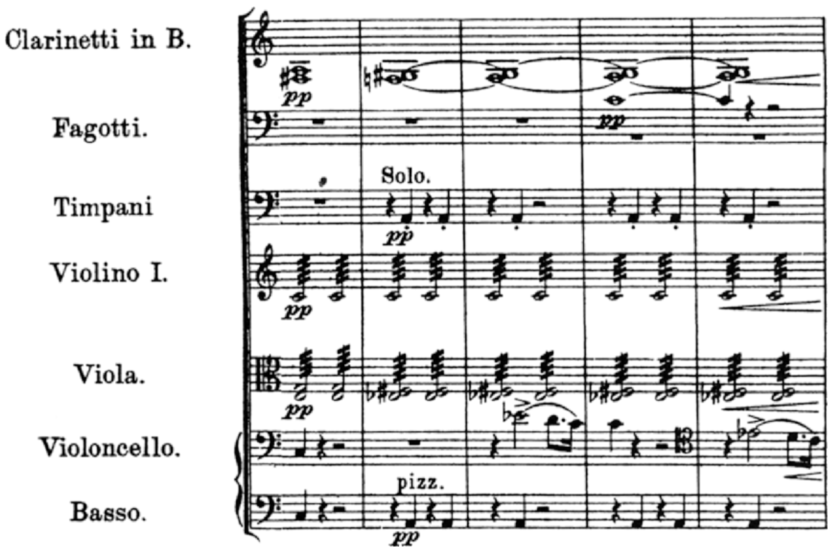
The sideways separation of the French horns from the heavy brass also has the advantage that the exchange of motifs occurring between French horns and trumpets, or Trombones, as they jump back and forth, results in greater dimensionality. In fact, even for listeners which are seated farther that 30 m from the orchestra stage, such a spatial effect is clearly sensed. A typical example of this seating technique is given in the Scherzo of the 4th Symphony of A. Bruckner (score example 22), where, however, it should be noted that the third trumpet occasionally coincides with the French horns; it should therefore not be separated too much from that section. In the Sinfonia de Requiem by B. Britten the French Horns are also brought to pronounced opposition with the other brasses in several places, where in part a thematic exchange is carried on between the trumpets and trombones. In that setting, the desired contrast effect can only be achieved by distributing the brass players over the entire width of the stage.

7.2.4 Timpani

In spite of the low pitch, timpani are easily localized by the audience because of the time structure of the sound, and this not only for hard blows. For placement within the orchestra, therefore, the question of cooperative sound with other instrument sections becomes as important as the choice to locate the timpani in the middle, behind the orchestra for tonal symmetry. The tonal connection with trumpets in Baroque and Classical music is a natural consequence for this position. The combination with basses is more difficult, be this as opposing voices (see Sect. 7.2.1.4.), or in unison as in the slow introduction of the Freischütz Overture by K. M. von Weber (score example 23). Particularly in this example, it is certainly a question of interpretation, whether the pronounced tone formation accomplished by proximity of the two instrument sections, or the undistinguished tonal effect of spatial separation is preferred, since the latter possibly can express the eerie feeling of this passage more appropriately. Furthermore, the spatial effect of the rolling thunder at the conclusion of the 3rd movement of the Symphonie Fantastique by Berlioz can be increased by distributing the four timpani equally over the entire width of the orchestra.

Certainly the positioning of the timpani in C. Nielsen's 4th Symphony is a problem, since, according to instructions in the score, two pairs of timpani are to be placed on the right and on the left in front of the orchestra, so that "until the end, even when performing at *piano,* a certain threatening character is to be maintained." Without a doubt, this would be an impressive tonal effect, however, in loud passages the timpani would make technical playing situations for strings significantly more difficult, especially for the violins. A possible compromise, though somewhat costly, would be to double the timpani and have the loud passages performed in the rear corners of the orchestra and the soft ones, in contrast, by the timpani in front of the orchestra.

By reason of dynamic balance, timpani, when serving as solo instruments, are better placed behind, rather than in front of the orchestra, particularly since the reflecting rear wall can have an advantageous effect on the harmonic contributions of the timpani sound. For example, this is valid for the concerto for trumpet and timpani by S. Matthus. To visualize this, the principal radiation regions of the most



Score example 23 C.M. von Weber, Der Freischütz, overture, measure 25 ff important components are represented in Fig. 7.36. While the lowest (inharmonic) ring mode is radiated uniformly in all directions, the harmonic partials show clear concentrations with maximum values in the horizontal plane, where the radiation upward for the radial vibrations with increasing index becomes ever more flat. Consequently the rear wall behind the player enhances the concentration of the harmonic partials more than that of the lowest ring mode: thus the tone becomes pure and the pitch more clearly recognized, an effect which is naturally lost when a choir is seated behind the orchestra.

Side wall reflections support the second, however, not the first radial mode, so that the fifth is enhanced in sound in comparison to the sound of the principal mode.

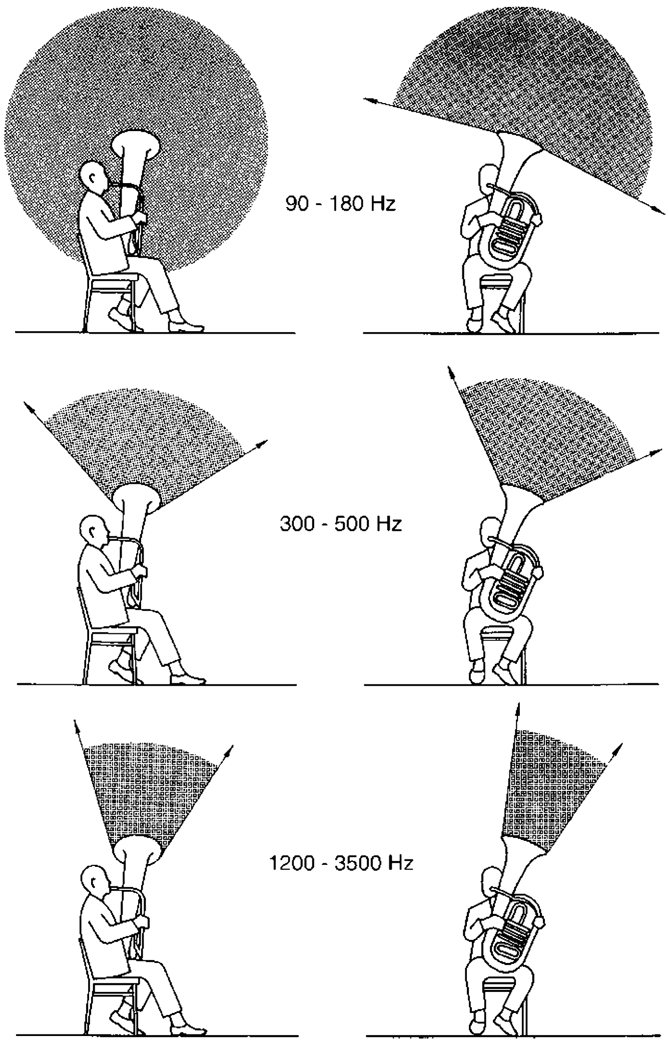


Fig. 7.36 Principal radiation directions (0…−3 dB) for a tuba in two vertical planes

Reflections especially include the lowest ring mode and possibly contribute more toward a dull and less pure sound of the timpani. For this, however, it is important that the reflectivity of the ceiling reaches down to 150 Hz, which is often not the case when the ceiling is divided into individual reflectors, or when the ceiling contains large openings for lighting.

When the podium itself, by virtue of its vibration capability, is in a position to enhance the sound of the timpani through structure born sound transmission, this primarily involves the lowest ring mode. For this membrane resonance, the force is transmitted in equal phase to the entire circumference of the kettle rim, and can be transmitted to the floor through the stand. The dull impact noise, though stronger during the attack, will decay more rapidly. This effect, however, is not very pronounced because of the mass difference between the membrane and timpani body.

7.2.5 Grand Pianos

Piano sound receives its characteristic on the one hand by the precision of the attack and on the other hand by the slow decay. Both characteristics are weakened in their aesthetic effects by excessive reverberations in the hall. Consequently, strong direct sound contributions, as well as the stronger partials and the high overtones, which transmit the precision, are essential for convincing sound impression in the audience. Within limits, this even applies to the noise contributions due to articulation. As the representation of the principal radiation angles in a vertical plane show in Fig. 7.37, these conditions, for a grand piano with raised lid are best met for the audience seated toward the right of the performer, whereby the high registers can see additional improvement for an audience seated on a slightly rising floor. In contrast, the higher registers are clearly disadvantaged toward the back of the instrument. Reflections from the hall ceiling enhance the low frequency contributions and thus give the instrument its fullness. Reflections from the ceiling above the stage especially enhance the attack noise as transmitted by the sound board and thus can be annoying both to the audience and to the performer, especially when the delay of the reflection is too long. The unfavorable intensity relation for these directions, between attack noise and harmonic partials, was already mentioned in connection with Fig. 4.27.

The directional effect in the horizontal plane leads to the fact that, for an audience seated outside a preferred region of approximately $\pm 30°$ width, the clarity and transparency of rapid tone sequences decreases, even though the subjective overall loudness is only changed slightly. Since, above all, the low tone contributions are largely preserved, a masking of other instruments by the piano can occur for the seats located further toward the side, where, however, these passages no longer possess the desired precision. The optimal tone picture of the piano with its full brilliance thus can only be heard in the very narrow region of the hall of a width of approximately $\pm 5°$ from both sides of the central axis.

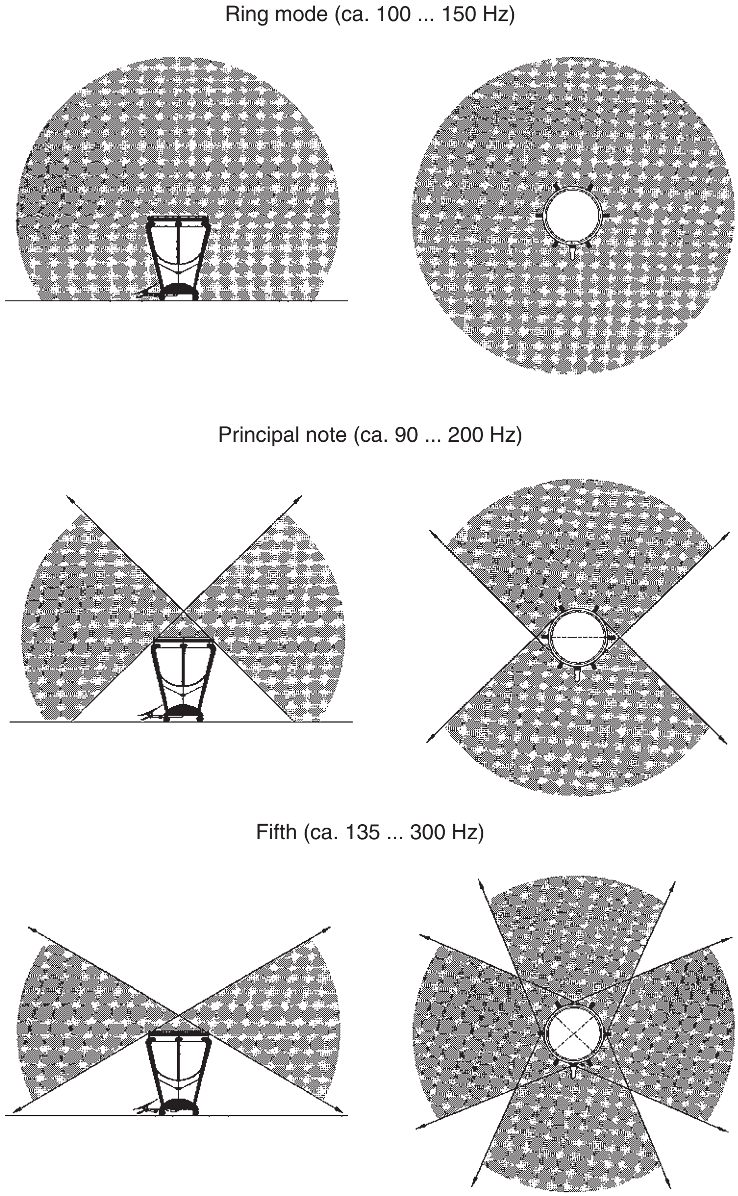


Fig. 7.37 Principal radiation directions (0. . .−3 dB) for timpani in a vertical as well as horizontal plane

Since the directional characteristics result from a cooperation of the direct sound and floor reflections (from the sound board), naturally they are not valid for the near field region in which the pianist, and for piano concertos with orchestras also the conductor, is located (Grützmacher and Lottermoser, 1936). Especially at the location of the conductor, the high tone contributions are largely blocked by the piano lid, so that the conductor hears the piano relatively loudly, but with a dull tone color. However, this effect is slightly diminished when the conductor is not located in the middle behind the piano, but rather approximately toward the extension of the keyboard, as preferred by some conductors, even though this makes eye contact more difficult.

Difficulties concerning positioning occur mostly for works with two pianos. For performance technical reasons pianists value a setting which places keyboards along one line. Of course, this presents the danger that the second piano is blocked in rather strong measure by the lid of the first when this one is open. If, however, the first lid is only half raised, the masking of the second is somewhat reduced, and the high tone contributions of the first are somewhat weakened so that a balance can be reached for the tonal impression in the hall. If, on the other hand, the lid of the first piano is removed entirely, an excessive decrease in high frequency has to be expected. In this case the danger exists that the audience perceives the second piano as more brilliant than the first. However, the tonal impression in the immediate vicinity of the instruments is certainly different from that in the hall.

Under circumstances where sufficiently large and appropriately oriented ceiling surfaces are present, considerations could be given to removing both lids. For this, however, it is a requirement for a good tonal effect, that the ceiling or the reflectors hanging above the instruments are not too high. For ceiling heights above 10 m, precision of the tone entrance is affected in the front portion of the hall by the delayed reflections. Furthermore, the tone can assume an uncomfortable hardness when the attack noise is repeated after a short pause of approximately 10 ms by the delayed reflection. This is especially unpleasant when the relevant surfaces reflect predominantly higher frequencies, because in that case the longer lasting low frequency attack noise (duration around 100 ms) no longer masks the shorter high frequency attack noise (duration around 40 ms) and its reflection, and thus no longer fills the pause between the two (see Fig. 3.21).

For this type of sound radiation by the instruments it is also possible to arrange both pianos in nested fashion such that the pianists face each other. This solution does have the advantage that the sound of the second piano reflected by the floor is not blocked by the other instrument, yet this positioning is not as convenient for the players since it makes precise playing together more difficult.

When the piano is used as an orchestral instrument as is occasionally the case, especially in contemporary compositions, it is generally located further toward the back of the podium. The orientation of the instrument then results from a requirement that the pianist must be able to see the conductor. Choice of position then is closely connected to the nature of the composition of each piece, that is, to the question, to which instrumental section the piano is assigned by the structure of the composition. Frequently it is the percussion section, often also the celeste or harp, which are to merge into a uniform sound with the piano. For the brilliance of the piano sound, it is naturally advantageous to locate the piano with open lid on the left side of the orchestra (as seen by the conductor). On the other hand, removal of the lid is recommended when the piano is located on the right side even though at that location the tonal effect is not as precise or bright and for many piano models the high registers then simply no longer sound right. Even for compositions for which a close contact between piano and harp on the one hand and basses on the other is required, as for example in the Sinfonia da Requiem by B. Britten, it is advantageous from a tonal standpoint, to place the piano on the left side of the stage, which, however, would demand so-called European seating of strings or a positioning of the basses in front of the rear wall of the podium.

7.2.6 Harps

Traditionally the harp is placed on the left side of the orchestra behind the violins. This may be partly for tonal reasons which relate above all to playing with violins or – for European seating – also with celli. Certainly the optical impression also plays a role: the instrument is shown in its full form, the head of the player and the music stand are located behind the harp; in contrast, frontal positioning would be less attractive.

As the principal radiation regions show, (represented in Fig. 7.38 for the horizontal plane) the sound radiation is largely symmetrical. Only in the middle frequencies the left side of the player is slightly preferred. It is, however, noteworthy that in this frequency region, which is particularly important for tone color and loudness impression, the frontal sound radiation dominates over the side. The most encompassing spectrum is radiated at an angle toward the front. It would therefore be optimal for a soloist to be seated at an angle of just under 45° with respect to the edge of the podium. In front of the player, by reason of the weaker radiation above 2,000 Hz, the harp sound is less hard in the attack, and thus possibly even somewhat rounder, which at least for recording purposes can be of interest.

For the customary positioning within the orchestra the wall behind the performer, which is most often the left side wall of the hall, presents the most important reflection surface for the harp. Walls which are located toward the side as seen by the player are less effective. Ceiling reflections especially support a middle frequency region from about 400 to 1,000 Hz and thus contribute to the fullness of the sound. However, all these acoustic aspects are not of sufficient importance to prevent primary consideration of the overall sound cooperation with other instruments like the celeste, piano, or basses as already discussed in Sect. 7.2.5.

7.2.7 Combined Sound of the Orchestra

7.2.7.1 Balance Between Sections

The multiplicity of instruments, with their different tonal ranges and tone colors, as well as differing preferred radiation directions, combine into the orchestral "body of sound." From an acoustical standpoint, this results in a very complicated sound

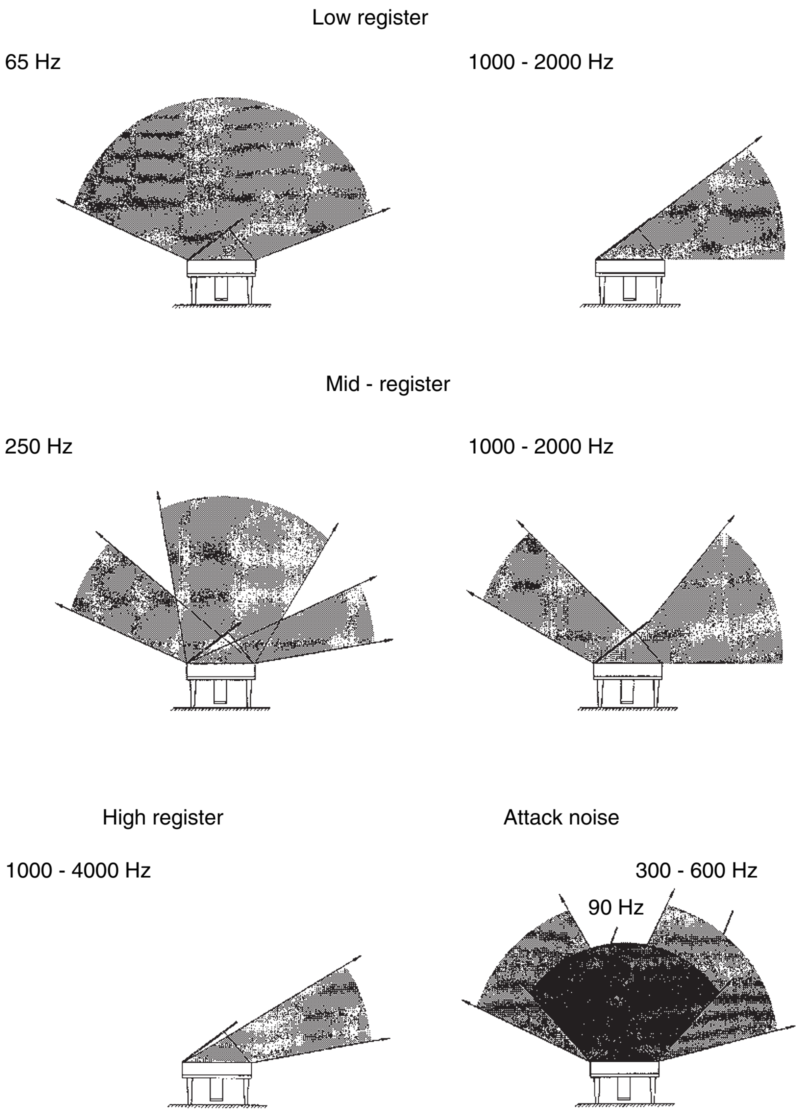


Fig. 7.38 Principal radiation directions (0...–3 dB) of a concert grand piano for the most important partials and the attack noise

source. Added to that is the fact that a portion of the instrumental voices are occasionally represented by only two players while others are formed by larger groups. Finally, the spatial spread of the orchestra on the podium also plays a role. In particular, different distances of individual instruments from the conductor result in a tone picture at the conductor's desk which is often sensed as essentially different than that at various locations in the audience.

In spite of that, the listener expects a balanced orchestral sound which conveys the composition in the interpretation of the conductor as convincingly as possible. This balance is essentially related to three factors: the intensity or loudness, the tone color, and the clarity. These three components should possess the "right" balance between the individual instrument groups. This must not change throughout the hall, so that the tone picture is not misrepresented.

In the earlier context of discussing sound radiation relationships for individual musical instruments, preferred directions, and thus directions for which greatest clarity is expected in the hall, were singled out. This should not lead to the immediate conclusion that maximum clarity for all instrument groups of the orchestra is basically to be considered as a tonal optimum; rather, different composition styles place different demands on the transparency of the sound.

Inasmuch as increasing concert hall size diminishes clarity, the task is given to create a balance in large halls by appropriate seating within the orchestra, wherein on the one hand preferred directions of instruments are utilized, and on the other hand the mutual blocking by musicians is reduced by increased tier elevations. Figure. 7.39 shows the podium of the large Musikvereinssaal in Vienna in which even the strings are seated in elevated tiers. As a whole, the elevation difference within the podium is 1.8 m; in the old Berlin Philharmonic – destroyed in the war – the elevation tiers even covered a level difference of 2.8 m (Winkler and Tennhardt, 1993). All such possibilities for increasing the clarity should be utilized for performance in large halls, especially for the performance of classical works (originally written for and performed in smaller halls), which, by their very nature, require a

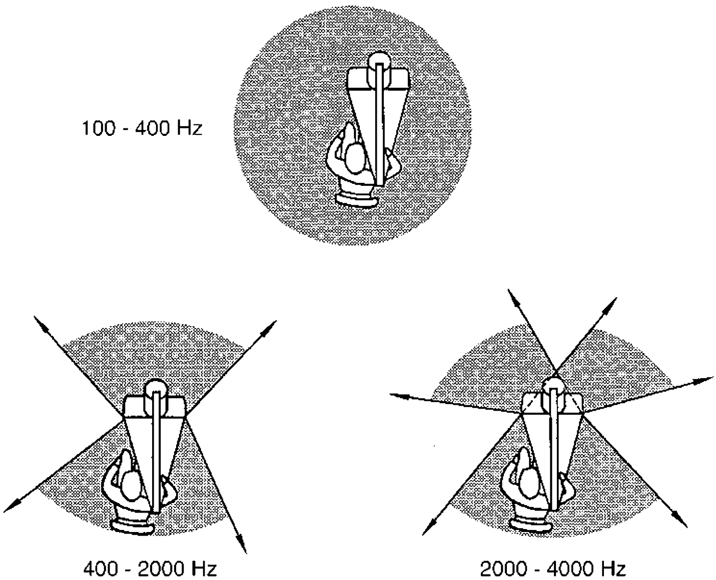


Fig. 7.39 Principal radiation directions (0...−3 dB) of a harp in the horizontal plane

transparent tonal picture. In contrast, for romantic music, a more uniform overall sound results, with slightly masked initial transients.

A steeper tier arrangement on the podium naturally also influences the loudness relationships between individual sections. The higher the winds are seated, the freer the path of the direct sound is toward the audience in a flat, main floor, and the stronger they will appear there, in comparison to the strings. This means, that for a small number of strings, the danger of brass dominance can occur and thus a more flat seating on the stage is an advantage for the balance. For a larger number of strings, in contrast, higher tiers for the brass make it easier to create a dynamic balance.

Circumstances are somewhat different when the audience seats rise steeply or galleries are present. The audience in elevated seats always have the advantage of receiving the direct sound of the winds directly (as long as they are not seated to the side of or behind the orchestra). In that setting, the steepness of the tiers on the podium, only plays a minor role. Nevertheless, the tonal picture should not deviate too much from that, on the main floor. Therefore, under such hall conditions, it is absolutely important to provide good direct sound for the flat rows in the audience, thus the wind steps need to be tiered more steeply. Furthermore, blocking by strings can also be reduced by having them seated at different levels. With small numbers of strings the winds naturally must adapt their intensity to that of the strings.

If a large portion of the audience seats are located behind the orchestra then naturally steep tiers of wind rows lead to increased blocking of the strings. With regards to intensity balance, this is nevertheless not perceived as detrimental, since the largest portion of wind instruments radiate sound preferable in the forward direction and are thus heard relatively softly behind the orchestra. Thus, for sufficiently steeply rising audience seats, a relatively even balance can be achieved, even behind the orchestra, provided the horns are placed as close to the middle as possible so that they are shadowed toward the back by other players; furthermore, the horns have to be treated very carefully with respect to dynamics. As a last resort one could also consider placing sound absorbing structures behind this instrument group.

Some investigations which were carried out in the mid 1960s in the Stadthalle in Braunschweig will show in detailed form to what extent the balance between individual instrument sections can be influenced by changing the seating arrangements and the podium step arrangement. The goal of these investigations was to find an optimal arrangement for this hall, which was new at the time. Figure. 7.40 shows the distribution of players on the podium in a floor diagram, as well as sections through the elevation arrangement, as used initially at the time of hall dedication, and as it was changed after the first acoustical measurements. Initially all strings sat at the same level (1.15 m above the main floor) – according to the Furtwängler seating, all woodwinds and horns were located on the first step, percussion and heavy brass on the second level. The tonal effect of the orchestra in the hall was investigated at four different locations in the audience and compared with the relationship at the location of the conductor. These four audience positions are marked by microphone symbols in Fig. 7.41 in the floor plan portion of the figure.

Fig. 7.40 Orchestra stage in the Vienna Musikvereinssaal. The center of the first step is removed for the piano

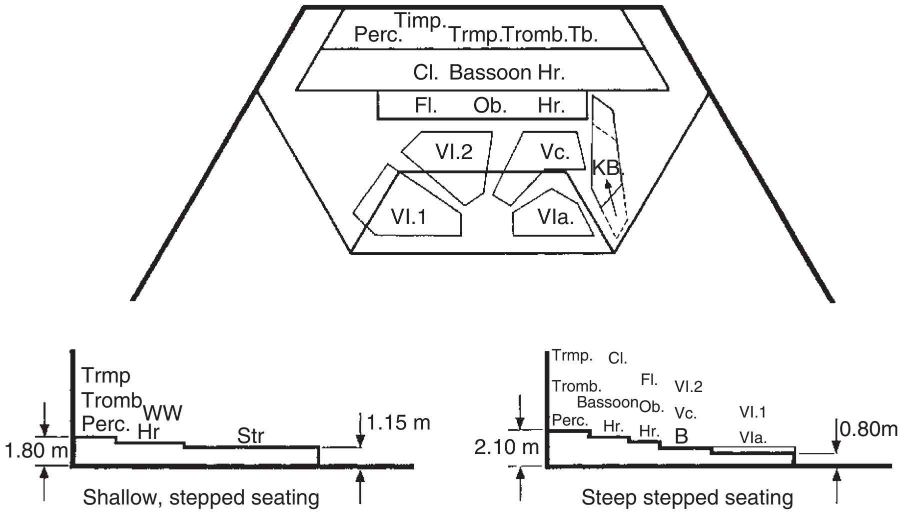


Fig. 7.41 Orchestral arrangement on the podium of the large hall of the Stadthalle Braunschweig

Beginning with the assumption that the tone picture at the location of the conductor is essentially responsible for the dynamics of the performance of the individual groups, the sound level difference for the most important instruments between the conductor and the individual audience locations was determined. The results are shown in the small diagrams for violins (I and II), the cellos and basses, the woodwinds, and the horns. In contrast to the violins and celli in the Beethoven Hall (Figs. 7.7 and 7.42) the frequency dependence is not represented here. The size of the individual blocks merely corresponds to the sound level difference in dB between the level at the conductor's podium and the relevant seat in the audience.

It is noted that in the rear portion of the rising main floor and especially in the gallery, the strings arrive relatively weakly, in the gallery the bass section is by almost 15 dB softer than at the conductor's position. In contrast, the winds are less attenuated in both audience locations. It appears especially loud on the right side of the main floor since the sound is reflected by the angled side walls of the hall for these seats.

In order to obtain an objective measure for the balance between individual instrument groups at the different audience locations, i.e., a value, which does not depend on the loudness of the individual voices, in each case the difference between the results for the most and least attenuated instrument groups is indicated next to the diagrams. At the location of the conductor this value would be 0 dB: in the central front of the main floor a shift of the dynamic balance by 3.8 dB occurs in comparison to the tonal impression of the conductor where the violins retreat most strongly and the horns stand out most loudly. The greatest change in balance of 5.6 dB occurs in the gallery, as indicated.

These tonal disadvantages can be significantly diminished by some changes in the seating arrangement and level adjustments on the podium. The new arrangement is shown in the small drawings on the right of Fig. 7.40. The strings are seated on two levels, with the lower dropped to a level of 0.8 m above the main floor. The woodwinds and horns are positioned on an additional step, and the players of the

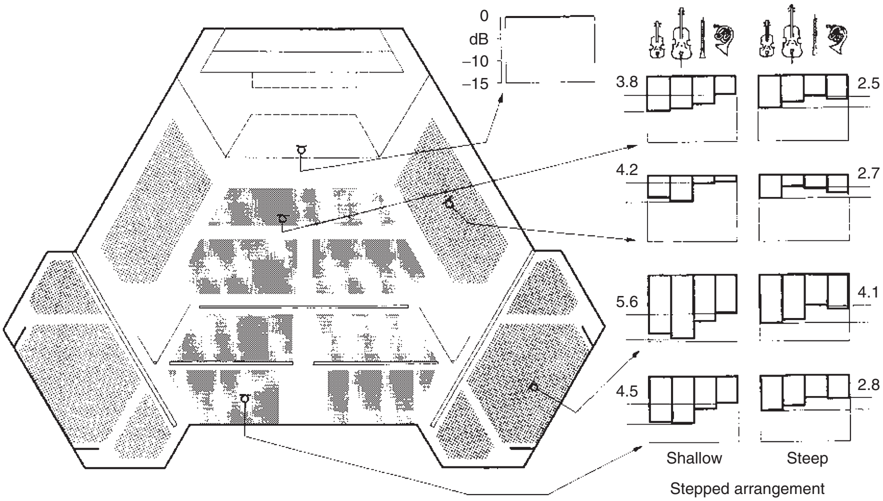


Fig. 7.42 Level differences between different audience locations and the location of the conductor for four instrument sections and two types of orchestral seating (Stadthalle Braunschweig)

heavy brass and percussion are placed on the fifth step. When only two or four horns are used, the trumpets and trombones move forward a row, and are thus placed next to the bassoons.

The floor plan is hardly changed, only the basses are moved as far as possible to the rear which not only aids their own tone but also brings about that the horns are shadowed slightly in relationship to the right side wall. Thus, the undesirable reflections are reduced to a more suitable measure. This steeper step arrangement especially improves the freer sound radiation of the strings, but it also affects the tone of the woodwinds favorably.

The improvement of acoustical conditions achieved by these changes (without construction efforts) is expressed in the diagrams on the right of Fig. 7.41. In the upper ground floor and the gallery, the intensity of the violins and the low strings is raised by several dB, the winds also become somewhat stronger. Thus, the frequently criticized disadvantage of the first arrangement, namely insufficient loudness at these locations, is significantly ameliorated. In contrast, the winds experience significantly stronger damping in the area of the side main floor for the second arrangement and thus no longer dominate as strongly in the overall sound. However, the bass group has become louder which can be considered as undesirable from the tonal standpoint: however, this is the only disadvantage resulting from this change considered for the 16 values for four instrument groups at four locations. In particular, these balanced values, which lie below 3 dB except for the galleries, point to the increased even balance of the orchestral sound.

When the intensity of each instrument group is compared for the four different locations in the hall, a positive influence of the change in orchestral arrangement can also be noted. In particular, the level of the winds differed in the first seating arrangement by 7 dB while the differences for the second seating arrangement were reduced to 3.5 dB. In this regard, even for the strings, an improvement is noted.

In the level considerations so far, the spectral structure of the sound was not considered. However, the freer radiation of violins and woodwinds also raises the overtone contribution of the sounds in addition to the overall level, and thus the brilliance of the instrument, as perceived in the hall. Thus, for violins for example, in the upper main floor in the gallery, a gain in level of 5 dB is noted for components above 1,000 Hz which contrasts with an increase in overall level of only 3 dB. The free radiation of the oboes as observed in the front rows in the main floor also shows an additional rise from 2–3 dB for the higher frequency contributions.

As an example for the frequency level dependent changes caused by the alternative seating arrangement the intensity differences at the individual audience locations for the celli and basses is represented in Fig. 7.43. Again the location of the conductor is the reference point – i.e., the zero line in the diagram. The tonal changes can be explained by the orchestral seating arrangement as follows:

Central main floor: Since the basses are pulled back from the edge, the distance to the audience in these seats increases, consequently the lowest tone contributions become weaker. The steeper seating arrangements on the other hand give freer radiation to the celli, so that the higher frequencies arrive more strongly, and the tone as a whole is somewhat brightened.

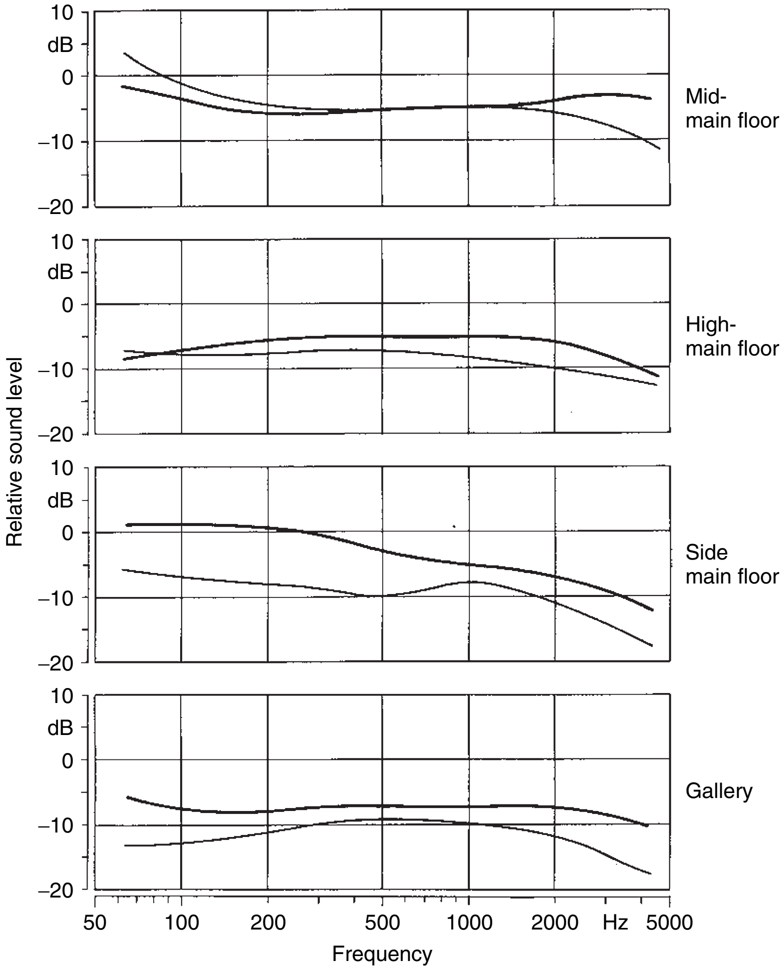


Fig. 7.43 Level difference of celli in different hall locations in relationship to the level at the location of the conductor. (Stadthalle Braunschweig). *Thin line*: seating with shallow steps; *thick line*: seating with steep steps

Upper main floor: Turning the basses, as determined by the new placement, leads to an advantageous radiation of the low components in the direction of this audience location. The steeper arrangement of the celli, furthermore, effects a level gain in the mid and high frequency regions.

Side main floor: Turning the basses leads to an increase of the low tone contributions, which, however, as mentioned, in this location is evaluated as negative. However, the higher frequencies of the celli reach this location more strongly. Since the basses are moved further back, the shadowing of the celli is reduced

Gallery: Turning the basses and the higher seating of the celli affects – as in the upper main floor – a level gain at all frequencies.

Disadvantages of a flat orchestral seating arrangement are not only noticeable in the relationship to the intensity balance between instrument sections, but also in the precision of the tonal onsets. In Fig. 7.44 the structure of the beginning chord of a Mozart symphony (score example 24) is given by means of sonagrams taken at the five relevant locations in the hall. Here again the frequency of the overtones is recorded in the upper direction while the intensity (in the relatively wide filter regions) is characterized by the degree of blackness. As the time scale shows, these partial pictures, in each case, barely show the first quarter of the first measure.

While at the location of the conductor the entrance of all frequency regions – and thus for all instrument groups – occurs at the same time and sounds correspondingly precise, the front edge of the sonagrams for the other locations in the hall shows different delays at different frequencies. In the center of the main floor the B_5^b (with a fundamental around 950 Hz) arrives somewhat later than the lower voices. The reason for this, in the case of strings, lies partially in the *arpeggio* beginning, which has the upper note appearing slightly later, but partially also in the fact that components at around 1,000 Hz are predominantly radiated toward the ceiling. The fact that the *arpeggio* delay – in contrast to the location of the conductor – is so pronounced, also lies in the circumstance, that the 1st oboe, which also plays this $B_{5,}^b$ is shadowed for the middle main floor by performers sitting in front and is thus heard predominantly by the delayed ceiling reflection.

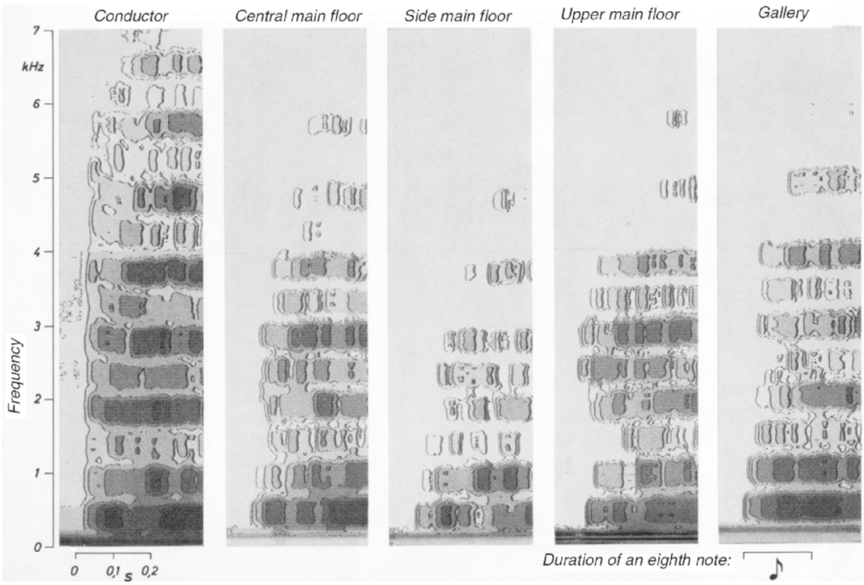


Fig. 7.44 Sonagram of a beginning chord of the 1st movement of Symphony K319 by W.A. Mozart (see score example 24) recorded at five different locations in the hall

Score example 24 W.A. Mozart, Symphony B^b major K 319 beginning of the 1st movement

This effect is even more pronounced in the side of the main floor where the bass group (including the horns) enters especially strongly and early. The delay time of approximately 1/16 s again points toward shadowing and the detour via ceiling reflections.

In the upper main floor the entrance sounds relatively exact: at this location, as expected from the directional characteristics and the location of formants, strong direct sound portions in the region around 3–4 kHz arrive here from the winds, while the principal energy of the violins is directed to this location by a ceiling reflection. The bass group is delayed only slightly so that the chord receives a closed tonal entrance.

In contrast, the sound of the bass group arrives in the gallery first, which can be ascribed to the spatial separation of the instrument groups in the orchestra: the delay of about 1/30 s for the upper voices is quite small and is hardly noticed as disturbing. By reason of the fact that violins as well as woodwinds are directed toward the higher lying gallery with strong direct sound contributions, a relatively precise tone entrance results.

As a whole, these investigations show that a podium elevation of approximately 80 cm is acoustically more advantageous for the front string desks than a height of more than 1 m, and that a multileveled orchestra podium leads to a better tonal balance and greater clarity of the tone picture in the hall. These experiences were also confirmed by more recent studies in the Berlin Schauspielhaus (Winkler and Tennhardt, 1993): experienced test listeners attest to a clear improvement of balance and clarity for increased stepping and lowering of the front podium area to 80 cm, a further, though only slight improvement, was brought by additional, slightly downward angled edge elements protruding above the podium. This kind of steeper steps also brings advantage for mutual listening of orchestra musicians, particularly for the sound impression of woodwinds on the strings. Contact between celli and first violins is also easier for the American seating, while second violins and violas hear each other less (Winkler and Tennhardt 1994).

7.2.7.2 Newer Seating Arrangements

Considerations so far all began with the classical seating arrangement which finds the strings in front and the winds in steps behind. Naturally, new groupings can be considered for which this system is either totally or partially abandoned. The principal effort of L. Stokowski was directed toward enabling the best possible sound radiation for all instruments within the orchestra into the hall. This means the preference of the direct sound in the overall sound and aims at the same time toward an unimpeded transmission of the entire tonal spectrum, especially as high frequency components. This naturally still leaves the problem of dynamic balance between instrument groups of differing strengths.

Building on the intentions of Stokowski, Veneklasen (1986) proposed and carried out experimental tests of several variations for orchestral seating. These experiments included current understanding of sound power and directional characteristics of the individual instruments. In this context it is particularly interesting to consider a comparison between the customary American seating and a seating arrangement for which, in each case the first desk of the string groups is located as usual, close to the conductor, however, additional strings are positioned on steps generally reserved for winds. To the left of the conductor, seated behind the concert master, are the woodwinds (with the first chair always near the edge), to the right behind the first cello chair are the horns followed by the heavy brass). In comparison to the standard seating, this seating arrangement resulted in the following changes in regards to loudness balance in the audience (Seattle Opera House): the horns, as the strongest group among the brasses become weaker by 3 dB, since they have to make due without rear wall reflections. The brass group as a whole was reduced by 5 dB, not least because they had to perform in the direction perpendicular to the hall axis. In contrast, the strings did not lose intensity. The balance therefore was perceived as improved: problems of mutual listening were not considered in this context.

Another experiment conducted during a season opening concert in the same hall extended the Stokowski string sequence, however, grouped the strings to the left only to slightly past the middle, so that the celli faced toward the front. Four woodwind groups sat to the right of the conductor on risers behind each other: horns and heavy brass were seated in steps toward the rear on the right third of the podium. The concert public was impressed by the choir-like total sound of the strings which even for *tutti* performance at the higher dynamic levels was not squelched. No measurements were taken for this experiment. Because of marginal acceptance by musicians, this seating was not continued after the premier performance. No detailed reasons were given.

A not yet realized seating arrangement even departs from the central position of the conductor; the conductor is located close to the right wall of the stage. Seated on the front level (with sight direction toward the right) are the woodwinds in four rows behind each other followed by horns, heavy brass, and the timpani, which form the end at the left edge of the front. On the first higher step – on which the conductor stands toward the right – the eight chairs of the 1st violins are positioned behind each other. On three additional steps, the 2nd violins, violas, and celli in appropriate width. The basses are found toward the left rear.

All these variants reveal an effort toward dynamic balance within the orchestra, emphasizing a choir-like string sound. They evidently depart strongly from a striving toward special balance, which is typical for the orchestral sound of the Classical and Romantic repertoire. How far this brings new perspectives or new development is still an open question.

7.2.7.3 Spatial Effects

While treating several instrument groups, a number of examples were already shown, for which a spatial separation of the voices permits an increased transparency of the tonal picture for thematic exchanges. In similar fashion it is naturally also possible that themes between instruments of different groups are exchanged as in a dialogue, and a corresponding spatial sound effect becomes desirable. However, even for a single run through a motif from high to low instruments (or in the opposite direction), in spite of varying tone colors, a spatial wandering or possibly jumping of the sound source within the orchestra can present a certain charm. Thus, recently even for electronic music reproductions, spatial effects have been deliberately introduced. In this context the separation of performers on the stage does not necessarily have to be large, particularly when single instruments are considered, for the ear can already sense an angular change of the incoming sound of approximately 3° (compare Sect. 1.2.4.).

A typical example for such a passage is represented by the excerpts given in score example 25 from the Concerto for Orchestra Op. 38 by P. Hindemith. To achieve the tonal effect of this passage it is certainly recommended that flutes, clarinets, and trumpets are placed adjacent to each other (even if they are located at different levels on the podium), and not directly behind each other. Otherwise, the listener has difficulties to follow the individual voices, particularly after the triplet run, even if they are clearly distinguishable in tonal character. Likewise, the dialogue between flute and trombone in A. Copland's 3rd Symphony only reaches its full effect when both players are not located behind each other but side by side.

On the other hand, of course, the task is often given to form a new tone color with closed and uniform effect from several individual instruments. Typical examples of different combinations of this nature are found in the Bolero by M. Ravel, such as in the 6th pass through the theme, with trumpet (*con sordino*) and flute in octaves, or the instrumentation with horn, piccolo, and celeste as given in score example 1. In such cases a spatially close contact is demanded for tonal reasons, but naturally also to make a rhythmic and intonation precise combined playing easier to achieve. A combination of low voices is less critical in the context of spatial-tonal con-

Score example 25 P. Hindemith, Concerto for Orchestra, beginning of the 4th movement, score excerpt without timpani siderations, especially when instruments with full and round tone color are involved. A combination of a wind voice with strings is also less critical – at least in concert halls where the audience sits only in front of the orchestra – since these groups are not localized as sharply because of their wide distribution on the stage. However, a narrow separation is required by the technical demands in many classical works for the trumpets and the timpani, especially when rhythmic accents occur which are placed into an already existing orchestra chord, as for example the third attack of the large fermata shortly before the end of the 1st movement (measure 332) of the 8th symphony by L. van Beethoven.

Particular spatial effects can be achieved (and usually are intended by the composer), when compositions are written for two orchestras or instrument groups. For example, the symphonies for two orchestras by Joh. Chr. Bach or the Concerto for two string orchestras by M. Tippett belong in this category. Both composers place two instrumental bodies in opposition to each other without giving one of them a dominant position. Consequently the players would be most advantageously located symmetrically on the two halves of the podium. This lateral separation by an imaginary central line already is sufficient for a spatial effect which however can still be somewhat increased by moving the violins on both sides by 1–2 m away from the conductor, which is particularly advantageous in large halls.

As is the case for the two string sections of orchestras with German seating arrangement, for this two sided distribution of both instrument bodies, the high strings of the first orchestra (the left one as seen by the conductor) receives more brilliance than the corresponding voices of the right orchestra. This phenomenon also differentiates the tonal picture and it is therefore important to be aware that the low strings and possibly the winds must be adapted to this tonal picture. Certainly the basses sound more open from the left side if they are located in the two rear corners of the podium, however, for the front facing celli of both groups, a particular dynamic adaptation is required, since they are not differentiated from each other by their timbre. For the Bach symphonies it would also make sense to provide for a freer radiation possibilities for the flutes of the first orchestra (in Op. 18, No. 1 and 3) than for the flutes of the second orchestra, while for the symphony Op. 18, No. 5, the balance between the two groups is taken care of automatically by the tonal difference between the oboes and the flutes.

Similar relationships for strings also exist in the Petite Symphony Concertante by F. Martin, or for the Music for String Instruments, Percussion and Celeste by B. Bartok, however, in this case the separation on two sides of the string bodies are additionally enhanced in their spatial effect by locating the keyboard and percussion instruments as well as the harp, predominantly in the middle. For reason of intensities, the harpsichord should occupy the more favored position in comparison to the piano in the Martin composition. In the Bartok composition, the central group should be positioned to be as small as possible and located on the lowest level since the two voices of the string bodies are not always treated as opposite poles (as for example at the beginning of the 2nd movement), but often performed in unison.

In contrast to this, for the Serenata Notturna K239 by W. A. Mozart, which in the subtitle is designated as a serenade for two orchestras, a horizontal separation is inappropriate. Since the "first orchestra" only involves four strings in solo fashion, rather, a tonal spatial broadening of the central core in the direction of the overall sound is approached, as is characteristic of baroque concerti grossi for strings. However, for a sufficiently large number of strings in the main orchestra it is advantageous in the Mozart Serenade to position all four soloists on the left side of the conductor, which is an advantage for the viola and, above all for the bass (playing without cello support).

In contrast, a larger spatial separation is required for those pieces for which instruments are placed as an echo in opposition to the main orchestra, as for example in the Divertimento for two string trios by J. Haydn for which the passages of the first group are repeated by the second group with different delays. This compositional technique is shown in yet increased form in the serenade for four orchestras K286 by W. A. Mozart for which each section contains strings and two horns.

In an ideal case, a concert hall provides the possibility for such works to locate the echo orchestra in different, distant, musician galleries, as is the case for the Berlin Philharmonic. On the other hand, when arranging the echo orchestra near the main group is unavoidable, one should attempt to weaken the direct sound of the echo by movable walls and by correspondingly unfavorable orientation of musicians so that the echo is clearly differentiated from the original sound by a greater reverberation. In that case, however, if at all possible, the echo group should not consist of fewer players than the main orchestra, since a smaller ensemble with its more transparent sound would contradict the less precise distance impression of an echo.

A more reverberant sound naturally also is created when the respective instruments perform in a staircase or a foyer and the sound (including the reverberation from the side room) reaches the actual concert hall through an open door or studio window. This procedure is also very well suited for individual instruments whose sound in the sense of the composition comes from a distance. Well-known examples for this are given by the trumpet signals in the 2nd and 3rd Leonore Overture by L. Beethoven. The posthorn solo in the 3rd symphony by G. Mahler or the oboe "from the distance" in the Symphonie Fantastique by H. Berlioz, as already mentioned can be performed very expressively in this fashion. Likewise, the excessively direct effect of the second horn pair in the echo symphony in E^b major by Stamitz is removed by such an arrangement, since, based on the directional characteristics, even the first pair of horns include the reverberation of the hall very strongly in the tonal picture.

When direct visual connection with the conductor is not possible, such contact can be established by a TV monitor, however, for reasons of intonation it is absolutely imperative that the performer of the echo hears the orchestra with sufficient loudness and overtone content which in extreme cases can be achieved by a loudspeaker or earphones (compare the comments in the section about stage music, Sect. 9.4.2). On the one hand, the distance impression of the echo can be influenced by having the player orient the more or less strong direct sound portions toward the opening into the hall, which for example in the 3rd Leonore Overture can be used to increase the effect when repeating the trumpet signal. On the other hand, it is often also possible to make the actual location of the echo source more obscure by opening several doors. Furthermore, the reverberation of the ante-room can be adapted to the desired tonal demands with appropriate curtains or carpets. Finally, the distance impression can be enhanced by means of a curtain in front of the opening to the hall which weakens the high frequency components of the echo.

7.2.8 Singing Voices

7.2.8.1 Choirs

For oratorios, and for symphonic works with choir, in addition to the problems of the orchestra, the question of the arrangement of singers also arises, and in many cases this can also become the principal concern. Thus, the clarity of the tonal picture as received by the listener, as well as the loudness, especially in larger halls, i.e., the transmission of sound energy, plays an important role for the vocal soloist. For choirs, on the other hand, above all clarity and tone color – both with sufficient homogeneity – are significant.

A choir consists of a multiplicity of incoherent sound sources; a choir's sound thus possesses a character which is not spatially differentiated and the individual singers are acoustically not separately located. Even localizing the individual voice groups of a choir in space often becomes difficult at great distances. The overall sound primarily gives the impression of filling the room, which is also supported by reflections from side walls. Nevertheless, depending on arrangement of vocal sections, a difference is perceived with regards to spatial tone balance. When female voices are located in the front and male voices behind, a higher degree of symmetry in the tonal picture is achieved than when voices are arranged from left to right in the sequence of soprano-alto-tenor-bass. The latter arrangement, however, corresponds better to the American orchestral arrangement.

Since a choir is always located behind the orchestra, floor reflections are almost never effective for singers. Ceiling reflections and especially side wall reflections, however, can contribute to enhancing high frequency contributions as a look at angular regions of strongest sound radiation shows (see Fig. 4.33). Wall surfaces which lie within an angle of approximately $\pm 60°$ of the direction of sight of the singers are particularly effective. Hanging ceiling reflectors must be located sufficiently high that they are no longer in the field of view of the singers. Disregarding the fact that relatively low reflector positions direct important reflections toward the audience, they are perceived by choral singers as extremely disadvantageous when they convey the feeling that a portion of the sound above the reflectors vanishes and is lost to the sound in the hall (Burd and Haslam, 1994).

In order to insure free sound radiation toward the front, and to avoid mutual shadowing by choir members the steps for the individual rows of singers should rise at an angle of approximately 45° in the optimal case i.e., they should be as high as they are wide. At the same time, this provides an unimpeded sound spreading in the direction of the reflecting side walls.

The more shallow the choir is arranged, the less favorable the sound radiation of the strongest tone contributions, directed downward – by reason of directional characteristics. Clarity and precision of the choral sound and articulation suffer especially since the reflections from the ceiling, which are not energetically influenced, gain in intensity, as perceived in the hall, in relation to the direct sound. Thus a larger portion of the radiated sound energy falls into the reverberation of the hall; in halls with very little reverberation this can be seen as positive while then the excessively direct tonal impression is reduced. A flat choral arrangement is decidedly unfavorable in very high halls because there the delayed ceiling reflection influences the clarity of the articulation when the direct sound is weakened by the rows of singers standing in front of each other. The critical limit for hall height (above the level of the singer risers) lies at around 8–10 m depending on the spatial arrangement of the audience region.

For the listener, the wall behind the choir enhances especially the middle and low frequencies. Portable walls which are designed to shield the singers from the empty room behind the choir should extend at least 0.5 m above the heads of the last row of singers. For mutual listening of singers, rear wall reflections are especially important, particularly when there are no additional close wall or ceiling reflections. As already explained, reflection surfaces with distances to the singers of 2.5–6 m especially support the acoustic contact.

The influence of a more or less tightly spaced choir on mutual listening is rather limited since only the direct sound of the immediate neighbor stands out above the sound of the entire choir (Ternström, 1991b). The "individual diffuse-field distance" of the individual singer, i.e., the distance for which the direct sound of the singer has the same level as the statistical sound field of all partners, lies, depending on choir size at one-third to one-fifth of the normal diffuse-field distance for the corresponding hall, i.e., for a concert hall between 1.7 and 1.0 m. This means that placing the singers more closely, the number of directly audible vocal colleagues is only raised minimally. The influence on the uniformity of the choral sound in the hall lies within very narrow boundaries.

7.2.8.2 Vocal Soloists

For positioning vocal soloists, depending on special circumstances, there are three possibilities: in front of the orchestra next to the conductor, behind the orchestra raised in front of a rear wall, or in the middle of the choir gallery. Advantages and disadvantages of these positions must be evaluated from the point of view of sound radiation (loudness, vocal color, and clarity) as also from the standpoint of contact with the choir or spatial separation from the choir.

Placement next to the conductor, in addition to good contact with the conductor, offers the opportunity of proximity to the audience and utilization of energetically valuable floor reflections: the latter, however, does require a free distance from the stage edge of at least 2 m. For the singer, the proximity to the supporting voices of the orchestra conveys a feeling of security. To what extent the sound in the hall supports the singer's feeling for vocal control depends on the reflection characteristics of each room and thus can not be evaluated in general for this location near the podium. Reflections from surfaces at a distance of up to 6 m are desirable though not absolutely necessary for the soloist; however, later reflections which establish the connection to the reverberation of the hall are important.

For the audience seated at the side of the orchestra, this vocal soloist position is a disadvantage as is the case for many audience seats located on the sides of very wide halls: as determined by the directional characteristics of the voice, an optimal tonal effect can be expected in the angular region of approximately ±45° relative to the direction of sight. This region which opens conically into the hall reaches the side walls in a 20 m wide hall at approximately 11 m in front of the podium. In a 40 m wide hall it does not reach the wall until 22 m. Furthermore, for seats in the side of the hall the spatial separation of soloist and choir is noticeably annoying when a closed tonal impression of all vocal voices is expected by the composition as for example in the Rhapsody for Alto, male chorus and orchestra by J. Brahms (score example 26).

When vocal soloists are positioned in front of a reflecting rear wall, the direct sound is strengthened at least in the low and middle frequency region by 4–5 dB, by the unnoticeably delayed reflections, so that the diffuse-field distance of the singer is apparently nearly doubled. This increase of the reach of the singer, compensates acoustically for the greater distance to the audience – when compared with placement in front of the orchestra. Particularly in wide halls, this positioning can reduce the number of unfavorable audience seats noticeably, and even for locations to the side of the orchestra the tone quality is improved. On the other hand, naturally, the

Score example 26 J. Brahms, Rhapsody for Alto, male chorus and orchestra, measure 166 ff. (without strings) visual impression of closeness to the singer is very desirable for the audience, consequently more distantly located soloists need to be optically emphasized as for example by special lighting or color control of the surroundings.

For the singer, the position behind the orchestra differs from the position in front of the podium by the fact that behind the orchestra the hall sound of the voice and the direct sound of the instruments are perceived as coming from similar directions. This makes vocal control more difficult, unless, in addition to the rear wall reflection already mentioned, additional strong reflections, especially from the ceiling, support the impression from the voice. Regardless of the acoustical aspects, one can also imagine situations where the organizer does not want to present a prominent singer at a distance greater than absolutely necessary and thus will insist on positioning the singer next to the conductor.

Positioning the vocal soloist in the center of the choir gallery also combines the advantage of reaching the audience at the side well and the possibility of the tonal integration of the choir and soloist. To what degree the latter is essential, or on the other hand not desirable, depends on the compositional structure of each work. For the soloist it is here also an advantage to have a reflecting rear wall, which for example can be accomplished by the structure of an organ or movable walls. For the singer personally, the reduced distance to the hall ceiling provides an advantage over a location directly behind the orchestra in view of the hall sound coming from above so that the tonal impression of the solo voice is not covered as strongly by the orchestra.