

# What sort of sound should we be aiming for? And can we tell if we have it?

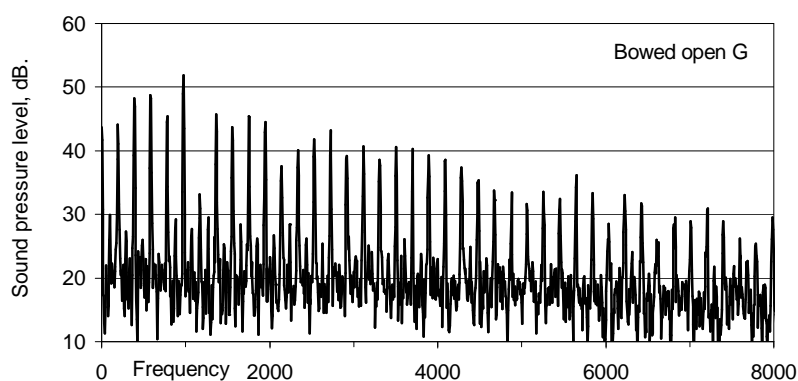
by Nigel Harris

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*Progressive violinmaking requires that one should make small changes to one's model and adopt those that bring tonal improvement and reject those that do not. To do this requires that the maker change one thing at a time and keep all other factors constant, and have a clear tonal objective in view. This paper discusses the tonal objectives of violin making and methods of tonal assessment.*

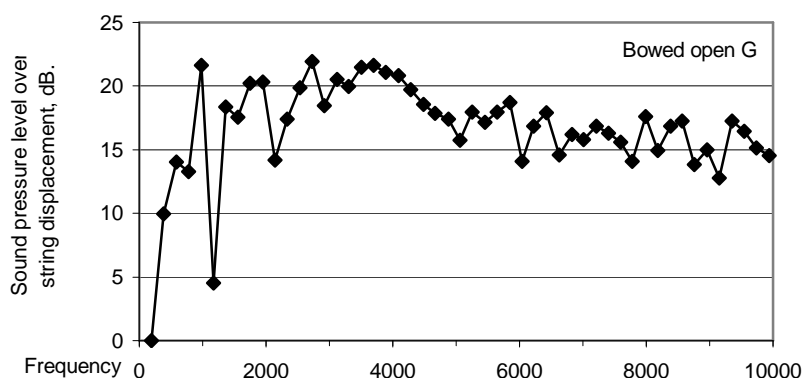
## Getting a picture of the sound

When we bow a string it is gripped and pulled sideways until the force exceeds the friction grip and then the string flies back until gripped again. In a matter of microseconds the frequency of this “stick-slip” mechanism settles down to a predictable note that depends on the mass and tension in the string, and of course its length. The string vibration produced has a waveform that looks very like a saw tooth and can be resolved into a large number of harmonics.



play a scale on a violin the tonal quality will be slightly different on every note because of the variation in the relative strength of the lower harmonics but because of subjective infill these tonal differences are minimised. There is a factor common to all the notes that is the characteristic tonal quality of that instrument. It is not likely therefore that the overall tone of the violin will be affected significantly by where, in the frequency range, the resonance frequencies of the low frequency body modes occur. The method of thickening plates to stiffness criteria [1] advocated by me does permit some variation in the resonance frequencies of these modes. Our ear seems to be much more responsive to the strength of the high harmonics compared to the low frequency harmonics and this has a pronounced effect on the brightness of the sound.

The relative height of the harmonic peaks depends on the relative size of the force on the bridge from the vibrating string, and on how efficiently the violin can radiate sound from that force. The force on the bridge is proportional to the displacement of the string so we can get a clearer picture of how the radiation efficiency varies with the frequency by dividing the radiated sound by the transverse displacement of the string. This is shown in fig 2.



**Fig 2. The radiated sound pressure level per unit transverse displacement of the string (uncalibrated). The harmonic peak heights are shown as dots and are joined up by lines to improve clarity. Shown for the bowed open G string used in fig 1.**

In this graph the peak heights are shown as dots, and for clarity they are shown joined by lines. The general shape shown in this graph tends to apply to all notes on the violin and tells us about how the radiation efficiency varies with the frequency. The first thing to note is that it does not vary all that much. Most of the points lie within the range of about 12 decibels (approximately a doubling of subjective loudness), so the violin is a more uniform radiator of sound than is often suggested. It is characteristic of the low notes on the G string that the first harmonic is a very poor radiator. The modes of vibration of the body below 1000Hz are widely separated, so the harmonics up to 1000Hz tend to vary in their strength and this variation is different for every note. From 2000Hz to 5000Hz there is a low broad hill with a summit at about 3000Hz. Beyond this the response very slowly tails off at a lower level. Fig 2 is called a response spectrum, but it only provides valid information at the harmonics (shown as dots). A continuous response spectrum can be made by tapping the bridge and measuring the response. This is called a frequency response function or frf (familiar to many violinmakers), but it may not give a reliable indication of the response of the violin when the string is actually bowed. Attempts to identify desirable characteristics in the shape of the frf have been made by comparing the frf of violins of varying quality. Very expensive violins have been shown to have strong body peaks and a high hill, but that is little more profound than saying they are powerful. The resonance frequencies of the body modes vary even among the best violins.

Attempts have been made to synthesise tone by combining the tones of the constituent harmonics electronically. Had that worked, it may have been possible to find the ideal response spectrum. But these attempts have shown that it is very difficult to distinguish the synthesised sound of a violin from that of an oboe or a mouth organ, so there is little chance of distinguishing good violin tone from bad by this means. It is clear that violin tone cannot be defined solely by the relative heights of the constituent harmonics, although some makers still think it can.

### **Effect of transients on tonal quality**

A note played on the violin has a beginning and an end. The start of the note involves a very short period of random noise that within a few microseconds settles down into a steady tone. This period of change is called a transient (or attack). If we remove the transient period from the sound of musical instruments a listener finds it difficult to say what the instrument is, but with the transient included it is readily identifiable. Measurements of the relative peak heights in the tone show no consistent difference between old and new violins, but the difference is readily identifiable to the player's ear. This probably has much more to do with the transient sound than the steady tone of the instrument. Comparative tests show that listeners can tell if a player is using steel strings. Steel strings tend to have a shorter transient period than other strings, but they usually have less harmonicity.

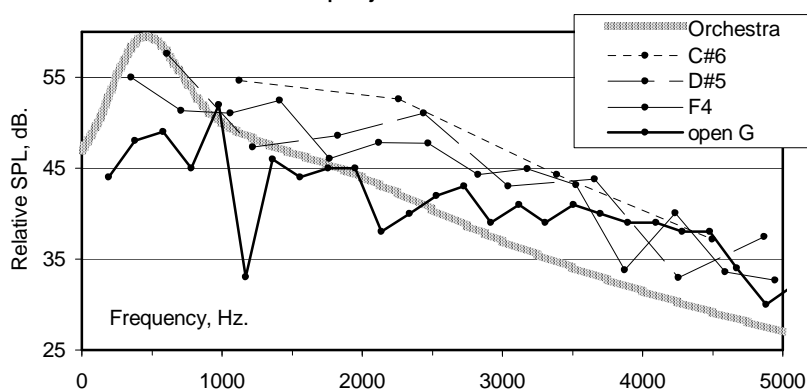
### **Effect of harmonicity on tonal quality**

The harmonic peaks in musical tone are spaced at simple multiples of the first harmonic frequency and this is called harmonicity. But the harmonicity is never quite perfect so the simple multiple is slightly out. This inharmonicity probably originates from the stiffness of the string. New unstretched gut cored strings have their windings jammed up close together in anticipation of the string stretching and this probably raises their stiffness. There is some evidence that inharmonicity makes the tone less clear. The vibration of the string is not entirely independent of the vibrations of the body. I replaced a violin body with a rigid mass so that the tail gut and nut were firmly fixed. The bridge was set on rubber mounts that simulated the elasticity of the violin body at the bridge. The string was then bowed and its vibration measured. The string was then placed on a real violin and again it was bowed and the vibration measured. The ratio of the height of the harmonic peaks to their width was found to be from 2 to 2.5 times greater for the string on the real violin than the string on the rubber mounted bridge. It was established that damping was not the explanation. This suggests a greater stability of harmonicity during the period that the motion was sampled by the analyser. The improved harmonicity has come from the interaction of the string with the body. The string and the body are most closely coupled through LSV (longitudinal string vibration) [2]. Low EAR violins [2] tend to sound woolly and unclear in tone and in the higher registers to sound metallic. Again the tone can be made much clearer by optimising the EAR. A violin with an unclear sound may have a too low EAR and can be helped by fitting a bridge with a closer distance between the feet [3].

### **Carrying power**

Carrying power is not just a matter of total loudness. A violin has carrying power if it produces the type of sound that enables a listener to hear it above competing sounds. Perhaps the ultimate test for violin carrying power is playing a concerto with an orchestra. Players find it very difficult to judge if an instrument has carrying power and this often leads to making grievous mistakes when buying violins. Eventually over many decades the names of certain makers (often Italian) begin to emerge as having made violins with carrying power. Players then seek these names thus driving up the prices. It is great carrying power or projection that is the most desirable quality of violins and upon which the reputations of Stradivari and Guarneri

del Gesu rest. If a violin has this ability it seems to follow that the tone quality will at least be acceptably good. They may be uneven and often are, but a player can adjust to that. Players often talk about carrying power, and are aware that some instruments have it and some don't. It is worth then taking a look at what measurable features of the tone cause it to have projection.



**Fig 3. Comparison of the frequency distribution of sound pressure level of an orchestra with that of 4 notes spread across the violin. The shape of the orchestral curve has not been altered, but to facilitate comparison its level has been adjusted to equate approximately the sound pressure made by the open G string.**

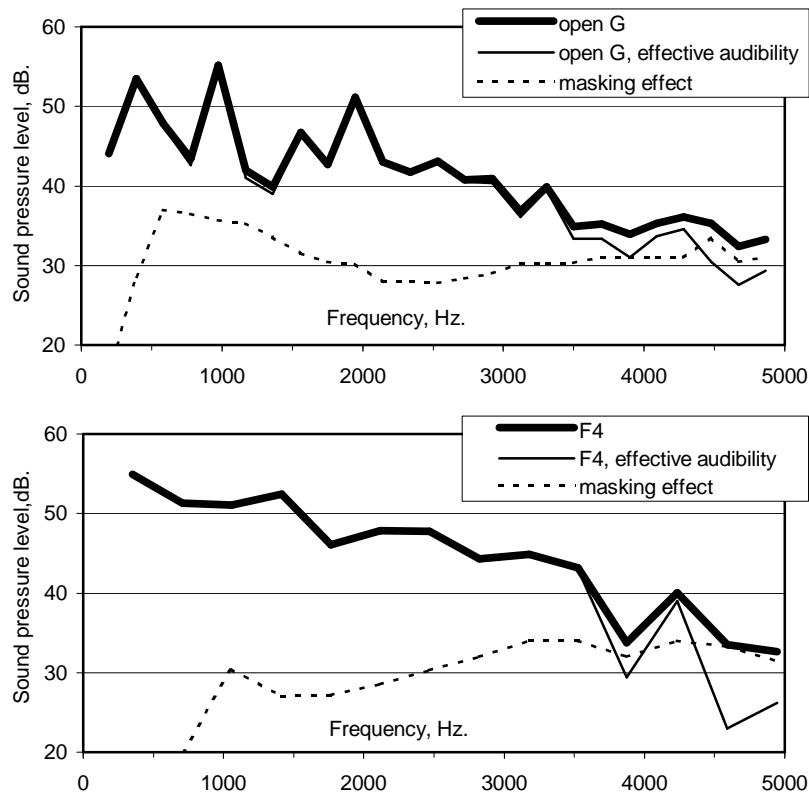
Fig 3 shows lines joining the harmonic peak heights for four notes played on the violin, the open G (as is also shown in fig 1), F on the D string, D# on the A string and C# on the E string. It will be seen that as the pitch rises the peaks are stronger. However the note will not sound any louder because there are fewer peaks because they are further apart. The broad line in fig 3 is an approximation of the shape of the frequency distribution of orchestral sound (from Johan Sundberg). This curve must vary in shape depending on the orchestration, and in its strength depending on how loudly they play. I have shown the orchestral curve placed at a level that enables us easily to compare its shape with that of the sound pressure level of the open G string. It will be seen that the high note C#6 can be heard easily over our orchestra. D#5 is just in the clear also, but the lower harmonics of F4 would be submerged and most of the open G string harmonics below 2000Hz would disappear. This explains why it is the lower notes on a violin that are most easily drowned out by the orchestra. The considerate composer writes a thinner orchestral texture in solo passages and often places extended passages at the top end of the violin. Solo violas and cellos are of even lower pitch making the situation worse, but this is partly compensated by their increased sound power.

If we look at the frequency distribution of the open G compared to the orchestra it can be seen that the harmonics below about 1500Hz have no chance of being heard but the harmonics above about 2500Hz will be heard. The listener will hear this sound as G, as in the first harmonic but the timbre will be very bright because the listener cannot hear the low frequency harmonics. If one thinks about what you actually hear at a concerto concert, the solo violin sounds much brighter than would the same violin played solo in a room. If the orchestral sound level in fig 3 is increased, it is clear that the lower harmonics of most of the notes will be submerged and the listener will be dependant on the high harmonics. There is little chance of beating the orchestra in the lower harmonics, so given that a violin can only produce a limited amount of sound it is apparent that the concerto violin is most likely to be heard if the sound is concentrated in the higher harmonics. We can now see the importance of a strong response above 2000Hz. It contributes greatly to the carrying power of the instrument. I have previously shown [2] that building the arching to the optimum EAR can boost the radiated sound in this area. In a later paper I will show that the varnish is important in the high frequencies.

Chamber music players do not compete with an orchestra, so do they need the same type of violin? I believe the answer is yes, for two reasons. At a concert the listener wants to feel real presence in the sound, as though they are sitting very close to the players. An upfront hi-fi sound rather than a distant sound. It just makes communication between the players and the listener much more alive. Secondly, the listener should feel able to listen individually to the players, in say a string quartet, and this requires a transparency of texture in the sound. We can learn something from the cocktail party situation. It can be difficult to hear what someone is saying to you with everybody talking loudly around you. People who have high frequency hearing loss find this very difficult. Our ability selectively to listen to a sound is enhanced if it contains high harmonic components, provided that the listener can hear them. Similarly a string quartet will have greater transparency of texture if the instruments have good high harmonic sound output. The characteristics that make a Strad very suitable as concerto instrument would enable it to serve very well as a chamber music instrument also.

### **Why the player finds tonal assessment difficult**

No player would be happy with hearing only the high harmonic components that the listener hears in a violin concerto. So we want a good balance between the lower and higher harmonics. If the lower are strong relative to the higher, the instrument will be described as mellow or dark; and of course, the reverse applies. Now if the instrument is strong in the high harmonics it will have good projection, but the balance between the lower and upper harmonics may have been skewed because the lower harmonics are not strong enough to give a good balance. Will the player like it? Fortunately the player does not hear the same sound as the listener. This is usually explained as being partly because the sound of a violin is quite directional and the player will not hear all the radiated sound equally, and partly because the louder a sound is, the more sensitive our ears are in the range 2000Hz to 5000Hz. But this effect is very small and since the player hears the greatest sound volume he should be hearing a slightly greater response in the 2000 to 5000 range but in fact the reverse is the case. In a powerful violin the player does not hear the high harmonics as easily as the listener. I am often surprised when people come to try violins I know well, that the sound I hear the players produce is much brighter than the sound I hear when I play. I believe this can be explained by masking. We all know that a loud sound will make it difficult to hear other sounds. This phenomenon is called masking. Generally a sound will tend to mask those sounds above it in pitch much more than those below it. The sound from the lower harmonics tends to mask that from the higher harmonics. By using published tables of the effect of masking at various frequencies, I have been able to estimate the effect of masking on the sound heard by a player.



**Fig 4. Frequency distribution of sound pressure for G3 and F4, indicating the possible effect of masking, and the resulting effective audibility.**

Fig 4 shows (the heavy line) the frequency distribution of the sound pressure for G3 and F4, recorded near a player's ear in a moderately reverberant room. The effect of masking at each frequency is also shown (dotted). By subtracting the masking effect from the recorded sound an effective audibility is estimated (because of the non-linear sound scale the subtraction is not a simple arithmetic reduction). At the lower harmonics, the sound is too strong to be masked but from about 3,500Hz the sound is weaker and its audibility can easily be masked. These curves are not shown beyond 5000Hz because I did not have any information on the effect of masking above 5000Hz. However, by projecting these trends beyond 5000Hz it seems likely that the audibility will be almost completely degraded. I did the same for the higher notes but this showed that masking mainly affects notes below the open A string. The effectiveness of the masking increases very considerably with a rise in the masker sound and decreases very considerably with a fall in masker sound (this is called a non-linear effect). For the player, the non-linearity means that a small increase in the sound pressure of the lower harmonics could very noticeably mask the high harmonics to the player, making the violin sound quite mellow, and similarly if the lower harmonics were weakened the audibility of the higher harmonics would be increased and the player would think the violin very bright. If played in a concert hall with competing instruments the listener would only hear the higher harmonics and notice no difference. This explains why some old violins can sound quite mellow under the ear but still have the ability to carry very well. If we want projection we must have a strong response in the 2000 to 5000Hz range. A violin with this alone, would sound very bright. This brightness can be reduced by strengthening the low frequencies, which is the right way to do it. But all too often it is done by reducing the high frequencies. The ear is much less sensitive to the total volume of sound, than it is to the balance between the lower and the higher harmonics. The old radios used to have a one-knob tone control. When the tone was turned to the bass setting all it did was to cut the highs, and when it was turned to treble it simply restored the highs.

The choice of varnish used can degrade the high harmonics thus giving the violin an apparently mellower sound but only at the expense of the carrying power. The resonant modes of a violin are quite widely spaced below about 1000Hz and much closer above this. In general this makes the harmonic distribution curves for the notes on the lower two strings of the violin much more variable in the low harmonics than the higher ones. If one only heard the lower harmonics of the G, it would not only sound rather mellow, but because of the many weak harmonics, it would also sound rather thin and much more variable in quality from note to note. If the high harmonics are added the sound will be much brighter but this extra information can be used by the brain to identify the missing harmonics and subjectively fill them in, thus making the sound fuller. I can demonstrate this to myself very simply by turning off my hearing aid, thus weakening the harmonics above 3500Hz. The sound I hear then is not just mellowed, but it is thinner in quality.

### **National tonal preferences**

It is the player who buys a violin and not the listener, so naturally players satisfy their own requirements before giving much consideration to what the listener might hear. Over many years violinmakers have addressed the question of giving the players what they want to hear. Players differ, but it is apparent that there are in fact national tonal preferences. We tend to be very conditioned by early childhood experiences. Our earliest experience of sound comes from the tonality of the language spoken to us by our mother. We British would perhaps characterise the French language as light and nasal, German as hard, and Italian as bright and resonant. Foreigners have assured me that English sounds rather flat and mellow. It is perhaps not surprising that these qualities seem to appear in the tone quality of singers from various countries. But perhaps more surprisingly, I am informed that the same tendencies are apparent in the organs built in the various countries, and even the pianos. Certainly, many string players would agree that the string instruments follow this pattern also. These tonal preferences result mainly from the choice of the surface treatment applied, and these treatments have become deeply embedded in the making tradition of each country. The national tonal preferences are probably more rooted among the less good professional players and amateurs, but historically it is probably these people that have been the buyers of new violins and had the most influence on the makers. Very experienced professional players may modify their earlier instinctive preferences and move towards a more international consensus of good tone.

Of all these national groups an Italian is most likely to be happy with a very bright sound, and an Englishman the least happy. The traditional Italian varnish system does tend to encourage the high harmonic response and the English approach has traditionally tended to subdue it (I hope to address these matters in a later paper). English players have not generally preferred Italian violins to English violins when they are new, although new Italian violins seem to be very acceptable to Italians and can be seen in good numbers in the Italian orchestras. Strads are very bright sounding violins to the player, even today, and are known to sound much fuller to the listener than the player (subjective infilling). What would they have been like when new? Sandys and Forster [4] write that "one Cervetto a professional cellist, said his father before he entered the musical profession, had been an Italian merchant, and had dealt with Stradivari himself in musical instruments, and brought some of his make over to England; but as he could not obtain as much as five pounds for a violoncello, they were taken back as a bad speculation." The English makers were making and selling new instruments that met the tonal preferences of the English player. The change brought about by many years of playing will make the Italian instrument sound more congenial to the player. The effects of ageing give more benefit to the player than the listener who would probably be less aware of the

difference. To the listener it is less a matter of old versus new violins, but rather, good versus poor violins.

Many dealers have reported that players usually want a violin that sounds like the one they already have. We tend to get used to a certain sound. People who have played a good modern instrument become very happy with a bright sound and have no desire to exchange for an old violin, but the reverse is also true. A competition judge is likely to be a very experienced player who is used to playing an old Italian instrument. When judging new instruments the absence of the 'old' sound is likely to have a significant effect on the judge. Under these circumstances the judge may be more comfortable with a violin that has the highs clipped off. Some contemporary Italian makers have felt their tone is discriminated against in international competitions and certainly it is the Italian making tradition that produces instruments that in some respects sound the least like old ones. Perhaps a good new violin should not be judged by how accurate a pastiche it is of an old violin, both tonally and visually, but rather how well it stands as a new violin. People writing about 100 years ago, predicted a great future for certain contemporary English and French makers and made no mention of the Italian makers of the day, but the better Italian instruments of that period are now sought by players and cost much more. As makers we have to live with the preferences of players, make instruments that will sell, and hope that in a hundred years time we are still being talked about. It can be difficult to satisfy all these requirements.

Small violas often have very weak low harmonics when the low notes on the C string are played, but provided the high harmonics are strong, even and extended in range, these notes may sound quite full and project very well. The case for large violas is not as strong as is often argued, and is based on overestimating the importance of the low harmonics. Viola players are more inclined to make the mistake of pursuing a deep dark sound and finding this in instruments with weak high harmonics. Such instruments would have poor projection and a wide tonal variation from note to note. Instruments with a low EAR tend to sound hollow in tone and less clear [2]. The hollowness gives a slightly melancholic quality and psychologically a sound of depth. These qualities are often found in violas that players like. Hence the woolly dark viola with no projection, which gives rise to viola jokes. It has been said that British makers have tended to have more success with viola making than the other instruments, and this would be consistent with the British tradition in making and the particular preferences of many viola players. Cellists on the other hand are more likely to enjoy a bright clear sound.

### **How does one test a violin**

It is a fact that players hear a considerable variation in tone between violins, which is much less audible to listeners; and listeners hear many things in a violin that are inaudible to players. There are many tests one can make of an instrument. In most cases we judge a violin from playing it in a room, and this makes it very difficult to be sure how well it will carry. The presence of strong high harmonics is very difficult for the player to judge because of the effect of masking and the dominating effect of the balance between the lower and upper harmonics. A bright sound might just be an indication of weak lower harmonics rather than real strength in the high harmonics. If a listener goes further away and says the violin sounds fuller at a distance than close up (as the masking disappears) then it is a good sign. Another good sign is if the strings feel very firm under the bow. Not flabby. This is an indication that the arching of the plates is working well and the LSV is strongly coupled to the body. A simple rule is that good instruments feel tight to the player and sound loose, and poor ones feel loose and sound tight. Great clarity is also a good sign.

It is no good going into an empty Albert hall with several violins trying them solo and asking your friend in the back row what they think. There will be differences but they will all be heard. Have a friend listen while you play a sonata with a piano. Play

particularly the lower strings. The second movement of the Caesar Frank sonata is a good test. A piano can easily drown the lower strings of a violin. Play with others. Ask your quartet how it sounds to them. The ultimate test is to play a concerto, but for most of us that is not so easily arranged.

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