On Playing "Harmonics" (Flageolet Tones)

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INTRODUCTION

For the string player, "harmonics" means tones where the string's fundamental frequency and some overtones are suppressed by a lightly touching finger. One of the `partials then becomes the new fundamental, and a set of partials harmonically related to this new fundamental remains as overtones. At the point where the finger touches, the new fundamental and its overtones must have a node.

As a professional double-bass player I have puzzled over harmonics more than once. In particular, contemporary music provides many challenges, both as far as technique and interpretation of the score are concerned. Quite often composers ask for a harmonic, notated in a high position on the string, whereas the surrounding notes have to be played in low positions, or vice versa. As a performer, I will then naturally be looking for alternative ways of executing that same pitch. The following question arises:

AT HOW MANY PLACES ON THE STRING CAN THIS PARTICULAR HARMONIC BE PLAYED?

By touching an open string lightly at its midpoint, I define its second harmonic as its "new fundamental". If wanting a triple raise in frequency, I have two alternatives: I can touch the string one-third from either end. At all times the nodes are placed in intervals equal to half the wavelength of the new fundamental, but now the complications start. For a fourfold raise in frequency (two octaves) I cannot choose freely between the three existing nodes (positioned at 1/4, 2/4, and 3/4 of the string length), because touching the node at half string length doubles the frequency, raising the pitch one octave only. After having given it some thought, some years ago I came up with the following answer as to how many useful nodes, N, exist in each case:

$$N = \prod_i \left(\mathrm{Prime}_i^{p_i} - \mathrm{Prime}_i^{p_i - 1}\right). \qquad (1)$$

This means that if I want to play a harmonic that has a fundamental frequency n times higher than the open string, I can factorize n in prime numbers (Prime_i) and powers (p_i), like this:

$$n = \mathrm{Prime}_1^{p_1} \times \mathrm{Prime}_2^{p_2} \times \cdots. \qquad (2)$$

N is then found as the product stated in Eq. (1):

$$\left(\mathrm{Prime}_1^{p_1} - \mathrm{Prime}_1^{p_1 - 1}\right) \times \left(\mathrm{Prime}_2^{p_2} - \mathrm{Prime}_2^{p_2 - 1}\right) \times \cdots.$$

For the lowest ten harmonics (i.e., n = 2, 3, 4,... 11), the numbers of useful nodes are thus:

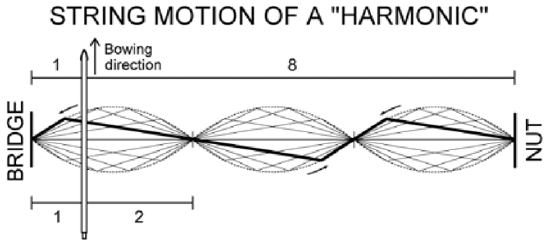
N = 1, 2, 2, 4, 2, 6, 4, 6, 4, 10, which, admittedly, was not my initial guess when addressing the problem.

With several fingering alternatives, a next question naturally arises:

DO THEY ALL SOUND THE SAME?

When playing harmonics the lightly touching finger causes a partial reflection at the point it touches the string (the finger should then preferably be seen as a "resistive" by the string, not to cause inharmonicity). A good fraction of the wave amplitude should be reflected at the finger, which is usually placed "on top of the string", leaving both the string and the finger free to vibrate somewhat in the bowing plane (with high-impedance double bass strings, however, it is often better to place the finger on the string's "side", since a light finger does not always provide enough resistance when touching the string from above. Inadequate reflection results in long transients with strong elements of the original fundamental frequency—the "tuba syndrome"). Well, if the finger provides adequate reflection, there is still something to choose between the different nodes. The further away from the bridge the node is fingered, the longer the transient lasts, and a more "remote" sound is experienced (two major frequencies interfere here: the fundamental of the open string and the fundamental of the string between the bridge and the touching finger). The musical context must decide which sounds better where the fingering is not defined by technical limitations.

Figure 1. When a harmonic is played, the string forms several sections separated by "nodes". Within each section a Helmholtz corner is rotating.



HARMONICS AND BOW SPEED

Schelleng found expressions for minimum and maximum bow force for a given position and speed of the bow [1, 2]. If we reorganize his equations slightly, we get for the lower bow speed limit:

$$v_b \geq \beta \frac{F_Z(\mu_s - \mu_d)}{Z_0}, \quad (3)$$

where:

μ_s and μ_d are the limiting static, and the dynamic (sliding) friction forces, respectively
β = bowing position relative to the string length
Z_0 = characteristic wave resistance of the string
v_b = bow speed; F_Z = bow force (often termed "bow pressure")
R = string-termination resistance (representing all losses).

The minimum bow speed is seen to be proportional to β.

Figure 1 shows the string's motion during a harmonic that raises the pitch an octave and a perfect fifth, i.e., increases the fundamental frequency three times. There are two nodes, both of them usable, which separate the string into three "lively" sections. Within each of these, a Helmholtz corner is rotating. If positioning the bow as shown in Fig. 1, a change from the open-string fundamental to the harmonic thus implies a change of β from 1/9 to 1/3. In theory the minimum bow speed is hence three times higher for the present harmonic.

Practice has shown that the following turns out to be quite a good rule-of-thumb: "When going from an open string to a 'harmonic', or vice versa, adjust the bow speed proportionally to the respective fundamental frequencies." Said another way: "Play the 'harmonic' as you would have played the same pitch on the fingerboard without changing the bow's position or 'pressure'."

HARMONICS AND INTONATION

Harmonics are commonly known as sounding flat. The few times I have measured such, they have nonetheless either been mathematically correct or *sharp* (!)—as they should be if bending stiffness is present. I can, however, think of several reasons why they are perceived as flat, all of which likely to play a part:

(1) Preference for stretched octaves. As long as the ear prefers intervals to be larger than the mathematically correct (brilliantly demonstrated in the CD of ref. [3]), non-adjustable harmonics representing relatively high pitches often appear flat compared to the "preferred pitch"—in spite of "mathematical correctness".

(2) Absence of high partials fools the ear. Art Benade once made the experiment to have an audience compare pure sine tones to shrill sounding ones composed of harmonically related partials (I cannot recall where he documented it, but I have repeated his experiment on several occasions). The task would be to match pitches between tones of different timbres. His audience (as mine) was fooled into matching the sine tones with shrill tones of slightly lower frequencies. Lack of overtones made the sine tones sound flat by comparison.

(3) Difference between true and tempered pitches. Harmonics based on the fifth and seventh partials (often asked for in cello and double bass) cause problems, especially when played in combination with the tempered scale of the piano. While the seventh partial is flat by any measure, the fifth (raising the pitch two octaves and a major third) represents the "true pitch", which is nearly 14 cents lower than the tempered pitch of the piano (e.g., the harmonic F#$_5$ on a cello D-string in combination with F#$_5$ of the piano gives nearly six "beats" per second). My own simple solution to this problem was always: "Omit the conflicting piano tone unless it is melodic".

(4) Pitch distortion. If using open strings when tuning, these are susceptible to pitch distortion, i.e., the pitch rising as function of string amplitude, or rather string stretching [4, 5]. Since harmonics give Helmholtz corners that are rounded over a relatively larger part of their rotational path, relatively less string stretching takes place, which results in better pitch stability. Consequently harmonics do not get pushed up as much as ordinary tones during normal playing.

(5) String players tend to gradually raise the pitch during performance.

SOME NOVEL TECHNIQUES

Several novel techniques involving harmonics have emerged over the last decades, many of them thought out by clever jazz bassists. I will list only a few:

(1) Chords involving harmonics are now most often played by fingering the nodes in low positions and flogging the strings with the right-hand fingernails close to the nut. This gives a clearer sound with more emphasis on overtones, since the impact is percussive, and given with a harder and more pointed

object. Combined with amplification, the sound is quite impressive.

(2) "Multiphonics" may be played by touching the string lightly at the highest node of the harmonic wanted, while bowing the string at the fingerboard side of the touching finger. This results in swift changes between the fundamental and the harmonic sound.

(3) When playing melodic lines the following technique is recommended for pizzicato in combination with "artificial harmonics" (i.e., harmonics played on stopped strings): Finger the string as usual at a pitch one octave below the desired pitch. Place the right-hand index finger lightly at the octave node, while plucking the string against the fingerboard (usual jazz pizzicato) with the middle finger. This is easier to carry out and produces a brighter sound than the "classical" way, where the thumb is touching the string lightly at the node while plucking with a free finger (as employed by harpists). Plucking against the fingerboard gives better sustain (less damping) of high frequencies, apparently due to lower bridge mobility at this angle.

(4) The first time I experienced the combination of a natural (i.e., "open-string") harmonic and *glissando*, my reaction was exactly the same as when I first time heard a pitch bend on the vibraphone. I didn't! My ears refused to accept something that I intellectually knew was impossible! But the solution is simple, and the execution pretty much the same for these two very different instruments: In order to achieve a tone bend on the vibraphone, the player places one mallet firmly at one of the stave's natural node lines (i.e., over one of the ropes) while striking the stave with another one. The stave's natural frequencies can then be lowered by moving the first mallet—and then to some extent the effective node line—toward the stave end, thus increasing the distance between the two node lines. In a double bass it is carried out like this: Start the harmonic in the usual way, using one of the lower nodes, where there is fingerboard beneath. At the instant the harmonic is established, quickly press the node finger firmly against the fingerboard, and perform the slide in either direction. If properly done, the remaining node pattern is left unaffected—even as the distance between nodes is altered.

The last technique has a snag: After having pressed the node down to the fingerboard, there is no lightly touching finger to provide partial reflections anymore. This makes no difference if the tone was played pizzicato. With "arco", however, a successful continuation depends on a sensitive bowing hand.

MAINTAINING THE HARMONIC WITHOUT TOUCHING THE STRING

If removing the lightly touching finger after a harmonic's transient has expired, the string most likely returns to its ordinary fundamental mode quite quickly. This happens because in practice Schelleng's bowing-parameter criteria for the harmonic and for the fundamental mode are likely to overlap, while only the latter provides sufficient stability. Harmonics are stable only as long as all string flybacks are equal in velocity—and it does not take much to lose that track when the partial reflection vanishes. The way to get around this problem is to give the bow a slight acceleration and/or gradually reduce the bow force. With that technique the slip/stick pattern is maintained even with minor differences in the flyback magnitudes. ■ C A S J

REFERENCES

[1] Schelleng, J. C., 1970, Pressure on the bowed string: Catgut Acoust. Soc. Newsletter #13, p. 24-27.

[2] Schelleng, J. C., 1973, The bowed string and the player: J. Acoust. Soc. Am. Vol. 53, p. 26-41.

[3] Houtsma, A. J. M., Rossing, T.D., and Wagenaars, W.M., 1987, "*Auditory demonstrations*" (CD), Philips 1126-061, tracks 31 and 32.

[4] Pickering, N., 1989, Pitch rise with amplitude in violin strings: Catgut Acoust. Soc. Journal Vol. 1, No 4, II (Nov. 1989), p 19.

[5] Wall, E., 1995, "Mathematician's Corner": Catgut Acoust. Soc. Journal Vol. 2, No 8, II (Nov. 1995), pp 34, with follow-up in Vol. 3, II (May 1996), pp 50.