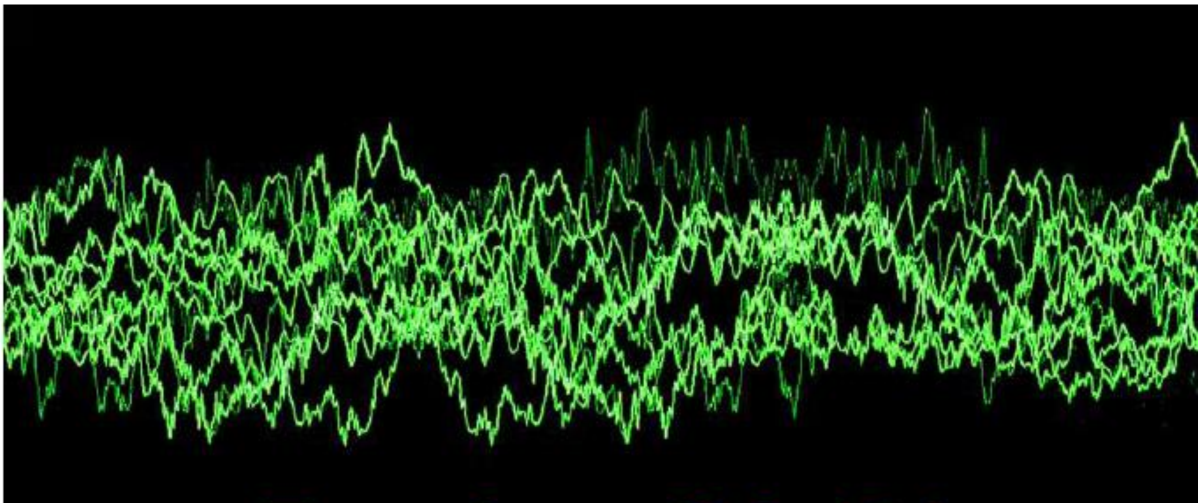


Tune in to ISO 16 !

The long and oscillating history of standard tuning frequency

by Tor Halmrast

The theories of tuning musical instruments have been discussed since Pythagoras. However, these early discussions included only the relative frequencies, called intervals.

Even after the western world simplified tuning into the strict system of semitones of equal size, as in Bach's *Das Wohltemperierte Klavier*, there was no decision regarding reference tuning frequency.

In the long and " oscillating " history of tuning frequency, the first question was : what tone (" chroma ") should be used for such standardization ? Of course " A " had an advantage, from the alphabetic structure of the tonal names (somewhat disguised by the mid-European/German misspelling of H for B), and for its position in the middle of the common 𝄞-clef, and thus in the middle of the tonal range (" ambitus ") of most melodic instruments.

The middle " C " has been a challenger, but the middle " A " (A4) has been the most common tone for tuning instruments.

In Europe, the reference pitch has fluctuated some five to six semitones over the past 400 years. Haynes spends 560 pages including 36 graphs on the many sidetracks in the history of " A ".

Figure 1 shows a smaller selection of found tuning frequencies from 1350 to today. This is adapted from Ellis, and some of the data have been questioned. It looks like someone has fired a shotgun, although some trends in the " inflation " of frequencies might be seen towards 1900.

String instruments are rather easily tuned to +/- a whole tone, somewhat depending on the material used for the strings and the neck. String instruments tended to be tuned rather high, to give a louder and broader sound.

Wind instruments also have tuning flexibility, but to a lesser degree than string instruments. Between 1300 and 1400, the tuning frequency often changed from occasion to occasion, and from city to city. The lack of standardization of tuning frequency became clear when keyboard instruments such as the clavichord, harpsichord, fortepiano and, most of all, the organ were played together with woodwind instruments.

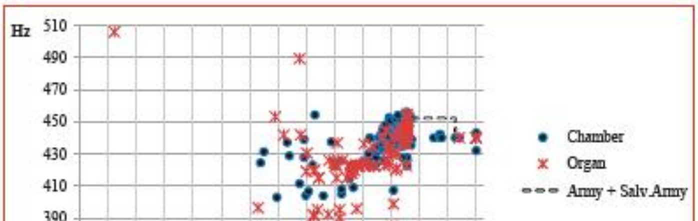


Figure 1 : *Tuning frequencies from 1350 to 2000.*

Almost all the findings from before 1700 in Figure 1 are taken from church organs/pipes. We see that the spread is so huge that they could be called transposing instruments. The difference between organs in the same city could be up to five semitones.

One argument for tuning church organs rather low is that it is relatively easy to cut the length or hammer the pipes inwards to raise the frequency, while it is not as easy to lower the frequency. An argument for tuning organs high is, of course, that the pipes will be shorter/cheaper and need less space.

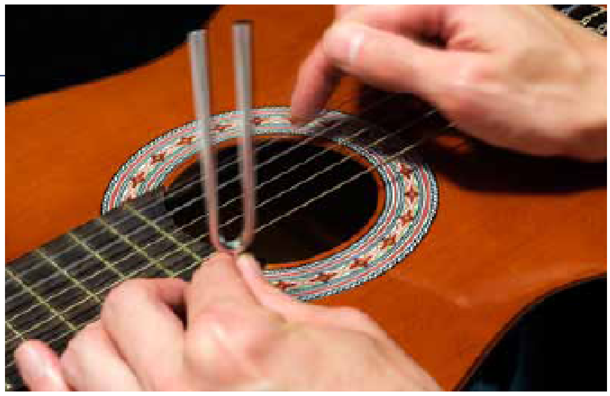
One of the first pitches mentioned as some kind of standard was the *mezzo punto* in Venice, Italy, around 1550, and *tutto punto*, which actually was 440 Hz, like our ISO standard today. In the 18th century, we might, with the danger of simplifying, put the tuning frequencies into the following groups:

- Cornet-thon 465 (A_{+1} 435-479)
- Chor-thon 440 (A_{+0} 428-452)
- Cammer-thon 415 (A_{-1} 409-427)
- Opera-thon 390 (A_{-2} 384-397)

The brackets indicate the regions for approximate pitch levels used by Haynes. The ratios between the main numbers for the different tunings indicate that the tunings are close to semitones apart, and skilled organists transposed "on site".

The tuning fork and the oboe

The first standard tuning fork was made by John Shore in 1711 and had a frequency of A4=423.5 Hz. Of course Heinrich Hertz himself knew nothing about this, as he was born in 1857, but some tuning forks from those days have been found.



Why use a fork? It is not even harmonic! Luckily, the frequency of the first overtone is way above the fundamental, about 6.25 times, and it is rather weak, so most of the energy goes to the fundamental.

The main reason for using a fork is that it is stable and solid. In its principal mode, the prongs move of phase so the audience will not hear it. The handle of the fork moves up and down, so it can be held without dampening the vibrations severely. This up/down movement also makes it possible to place the end of the handle on a resonating table or a box, to amplify the sound. Alternatively, the end of the handle can be placed on the mastoid bone behind the ear, enabling structure-born vibrations to be transmitted directly into the inner ear. (In this way, an audiologist can diagnose any mechanical or neural hearing loss.)

The choice of the oboe as the source when tuning an orchestra is not obvious. It is not an almost "pure sine" source like the fork, but it is actually easier to judge the pitch of such a tone richer in overtones. The fact that the oboe itself is quite hard to intonate is a disadvantage. The choice may be more down to tradition, as the "hautboy" was the first wind instrument to join the string orchestra, and has a penetrating, strong sound.

Fluctuations toward a standard

The troublesome evolution of tuning frequency up until the publication of the International Standard, ISO 16:1975, *Acoustics – Standard tuning frequency (Standard musical pitch)*, (at 440 Hz) is described in many books and papers. Almost none of them agree. A simplified overview might look like Figure 2.

Around 1800, the most common tuning was the "Classical Pitch" of A=422 Hz, which is said to be the one in which Mozart wrote. However, this was not a standard by our definition, and there was a rise in the following years: two tuning forks from the Dresden opera house are found to give A=423.2 (1815) and 435 (1826).

In 1859, the French government established by law the "Diapason Normal" of A=435 Hz at a temperature of 15°. The alteration of a fork due to heat is scarcely perceptible, but wind instruments, and particularly organs, rise because sound travels faster as the temperature rises.

From the time of the French Diapason, there have been discussions on whether the temperature was given in Réaumur or Celsius, and some suggested corrections have led to new mistakes. (Possibly the measurements should be performed at 15°R≈19°C, and not 15°C, so that the French tuning of 435 in fact should correspond to some 439.)

The first standard tuning fork was made by John Shore in 1711.

Other countries gradually followed the French, with the United Kingdom the last in line. The tuning history of the United Kingdom was a bit troublesome, as the Philharmonic Society had already decided on A=433.2 Hz. Forks for this vibration number, stamped "Philharmonic", were sold as late as 1846, but in or about that year the performing pitch of the Society and many organs had actually reached the "High Pitch" of 452.5 Hz.

In 1885, Queen Victoria sanctioned the French standard for her private band and state concerts. The Philharmonic Society adopted the "Diapason Normal" in 1896, but military bands and brass bands did not go along. In fact, they went gradually higher.

In 1896, the Society decided upon A=439 Hz ("New Philharmonic") at 68° Fahrenheit (20° C). The "High Pitch" of 452.5 Hz remained for military and brass bands, preserved as the standard for the Military Training School Hall in 1890. This high pitch also remained in some churches with large concert organs not yet lowered.

Bands in France, the United Kingdom and the USA also used this "High Pitch". Most remaining horns from the US Civil

War (1861-1865) are high pitched (A=454). In fact, the USA "military high pitch" often turned out even higher, to A=457 Hz.

In Germany, bands and orchestras in the mid- to late-1800s tuned to A=440 Hz. Around the turn of the century, the use of this low pitch became more common in the USA, too. Brass horns were often offered with slides to allow the musician to play in either pitch.

In 1917, the American Federation of Musicians followed A=440 as the "official" pitch for the USA, and it became known as "American Standard Pitch". Following World War I, a little known provision of the Treaty of Versailles (1919) adopted A=440 as the standard pitch, and the production of horns with accessory slides for high pitch declined.

The A440 standard was endorsed by the British Standards Institution (at a meeting organized by the International Federation of National Standardizing Associations/ ISA) in 1939, and by ISO in 1955 and 1975.

In 1964, the Salvation Army asked its manufacturers to produce brass instruments only in the "low" pitch. Some older instruments were of such good quality that a number are still in use today.

Scientific alternatives and solutions

The French standard of A4=435 Hz gives C4≈258.65 Hz. This gave the idea of a "mathematical" tuning frequency of C = 2^8 = 256 Hz, so that all the Cs would be a power of two, but A4=435 Hz won.

The previously mentioned question of correcting for temperature in the 435 standard could result in 439 Hz, so this number was also suggested, but superseded by 440 Hz after complaints that 439 was a prime number and thus difficult to reproduce in a laboratory. In the "analogue age", 440 Hz could already be generated from a high-precision 1 MHz piezo-electric crystal, using some multiplication with 11/55.

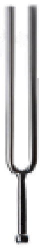
Most instruments today are tuned to 440 Hz, following ISO 16. But not the major orchestras!

Absolute/relative pitch and psychoacoustics

Reference pitch is common for many singers and musicians. They are familiar with the different types of intervals and can judge "any" tone once they hear a reference.

Absolute pitch means that the person needs no such reference tone. Since Mozart was said to have absolute pitch, and the standard tuning frequency has changed since then, absolute pitch might be impressive but is somewhat meaningless.

For a future revision of ISO 16, there might be more detailed discussions about subjects such as temperature. For ensembles of contemporary music and rock bands, tuning to a sine-wave-like synthesizer or tuning machine, it might also be considered that the perceived pitch for pure tones actually depends not only on frequency, but also on sound pressure level.



Do we follow the standard today?

The majority of today's "ordinary" instruments are by default tuned to 440 Hz. However, most symphony orchestras on the European continent today use 442 Hz, while 440 Hz still is most common in the United Kingdom, the USA and Japan. When an orchestra from mid- or northern Europe visits "the Proms" in London, a grand piano tuned to 442 Hz needs to be leased.

Some concert halls have two grand pianos in different tunings. Herbert von Karajan wanted 445 Hz for the Berlin Philharmonic.

Luckily, modern digital instruments are easily retuned to other tuning frequencies, but the non-standard tunings of symphony orchestras give problems for guest musicians with instruments not easily tuned to a different frequency, such as the accordion and Hammond organ.

Ensembles with wood instruments in tropical countries have problems keeping any standard pitch due to huge changes in humidity and temperature.

Some ensembles specializing in early performance praxis might use 415 Hz for baroque music (about a semitone lower than 440 Hz, see Figure 2), 430 Hz for classical music, and 438 Hz for romantic music. ■

Thanks to Jens Holger Rindel.

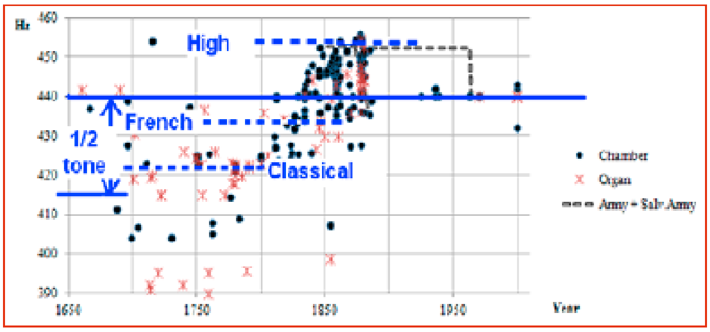


Figure 2 : *Tuning frequencies.*

About the author

Tor Halmrast is Head of Acoustics at Statsbygg (Norwegian Directorate of Public Construction and Property), Associate Professor at the University of Oslo's Department of Musicology and an award-winning composer of works for symphony orchestras, opera, and electroacoustic music. He has been a member of several ISO and Standards Norway committees on acoustics.