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The Determination of Musical Pitch

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The determination of musical pitch has been a major concern of music theory, East and West, in all climes and cultures, throughout the ages. This paper discusses the intricacies of pitch determination from historic, geographic, and scientific perspectives. Its standardization nowadays has permitted the manufacture and tuning of musical instruments on a universal scale.

Keywords: pitch, wave, frequency, vibration, amplitude, scale, tuning

One of the great spiritual quests of Ancient China was the determination of the *Huang Chung* or yellow bell, considered the fundamental tone of the universe. Determining this tone was essential to the construction of their musical instruments and the tuning of scales in ancient China during the legendary reigns of the Three Sovereigns and Five Emperors of Chinese mythology (ca. 2700). In remote antiquity, this pitch was thought to be so important that its tuning was fixed by the bureau of standards. Today, an equivalent pitch approximating *Huang Chung* is situated somewhere in the middle of the piano, wavering around the note *fa* or F.

A Legend

A pre-historic legend relates that every year the Emperor Shun (ca. 2200 B.C.) could be found journeying eastward in order to check upon the condition and standing of his kingdom. How did he do this? Strange as it may seem, he used music as the medium of investigation. He could, of course, have resorted to other methods, evaluating by the standard equivalent of *quality control*—by auditing account books, interviewing officials in authority, or, indeed, by observing the condition of the local populace. He was not ignorant of these statistical methods; yet he did none of them. Emperor Shun chose a different technique to ascertain the political state of his nation: He listened to the *tuning of their instruments*.

Emperor Shun verified the five notes of the pentatonic scale on musical instruments in each province (*i.e.*, gongs, bells, and stones), against the tuning of Huang *Chung* in his possession! And what did he discover? If the tones corresponded to his own, he concluded that all was well. But if not, he anticipated dissension and trouble (Tame, 1984, pp. 33-71). We have yet to grasp the insight and wisdom of Emperor Shun in recognizing the profound relationship between intonation and individual behavior, social order, and political stability (*i.e.*, the

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influence of the pitches used to tune musical instruments, the fixing of scales, and, even, as we shall see the effects of *rhythm* - on the human psyche).

Frequency and Pitch

Pitch is a basic characteristic of tone. Yet, it was not associated with wave frequency before the 17th century. It was the great Italian astronomer, physicist, engineer and mathematician, Galileo Galilei (1564-1642) who discovered the relationship between the physical motion of matter, the frequency of waves as measured in cycles per second (cps) or vibrations per second (Hz) and musical pitch.

But Galileo's interest in the highness and lowness of a sound was not just the disinterested curiosity of a scientist, it was a family matter. His father, Vincenzo Galilei (ca. 1520-1591), an amateur musician with a theoretician's turn of mind, found that if he reduced the tension of a string by a fourth, he could lower its pitch by an octave or 1:2. Nonetheless, Vincenzo was unable to determine a principle on which to base his researches and explain his findings. It was his son, Galileo, who revealed the answer. The reasoning that *pitch* was not based on string length, tension, or thickness, alone, but, rather upon an abstract principle, almost immeasurable at the time—*the frequency of an object's vibration*. It was a remarkable breakthrough.

When we speak of pitch today, we do not rationalize notes and intervals in terms of such particulars as string lengths, tensions, or the materials of which they are made, nor do we think of them in terms of the mathematical ratios of Pythagoras. Valid as these earlier methods are, current technology measures *frequency of vibration* by stroboscopes, in logarithmic units, called cents.

Ultrasonic-Infrasonic

The frequency bands on our radios indicate the speed of radio wave oscillation measured in Hertz units (Hz). Analogous to pitch, these Hz numbers inform us at what *vibration* a given station is broadcasting. The human ear, however, is incapable of detecting these so-called *pitches*, because radio waves produce frequencies far above what our ears are able to detect; they undulate much too rapidly. Such very high frequencies (over 20,000 cycles per second) are called *ultrasonic*.

On the other hand, at the other end of the spectrum, there are also very, very, very slow frequencies (undulating at below 16 vibrations per second), which our ears are, also, unable to pick up and identify. These oscillations are called *infrasonic*.

While vibrations and frequencies may be infinitely high or infinitely low, the world of human aural perception and musical experience takes place between these two extremes: roughly from 16 cycles per second to 20,000 cycles per second. Within the infinity of vibrating undulations, it is an extremely humbling thought, indeed, to realize that our entire sense of audio reality operates within this relatively narrow frequency band.

Absolute Pitch

Today, electronic and computerized instruments are able to measure pitch precisely, in terms of cents, Hz and micro-frequencies per second. But, for most of music history, absolute pitch was a very relative affair. The surest determinates of pitch were material objects made of bamboo pipes, metal bells, and stones.

For the past 1000 years, for the Western world, organ pipes have been used as fixed coordinates in the determination of pitch. But, considered historically, this solution posed numerous problems, simply because, in each town and church of Medieval Europe, organ builders created their instruments independently. They had no objective standard by which to measure pitch. Thus, for example, considerable fluctuation existed in instruments from one place to another, between the actual pitch of the note C or *Do* in one location, compared to that in another location. Not surprisingly, the organs on which Bach played sounded about half-a-tone lower in pitch than today's keyboards; and even Beethoven's symphonies are played nowadays about a half-tone higher than they were when he wrote them.

It was not until 1859, about thirty years after the death of Beethoven, that the Paris Academy fixed European concert pitch at A = 435 cycles per second (cps); and not until 1939, at the International Standards Association Conference in London that the note A was fixed at 440 cycles per second—the accepted pitch at which instruments are tuned today. This standardization has made possible an international music industry, whereby electronic keyboards, produced in Tokyo or New York, sound the note A, for instance, at the same uniform pitch. And yet, the anomaly around the world of major symphony orchestras tuning the note A to higher 442 or 445 cycles per second continues! So much for absolute pitch!

Summary

Tone is a wave created by an oscillation of matter, around itself, that generates a compression of air. These *frequency-pockets* or rocking undulations of air bump into and against one another, transferring vibrations across distances near and far. Such tremors, in turn, when they hit the ear drum are reinterpreted—miraculously as sound.[1] Pitch is the frequency in a given unit or period of time in which those pulsations occur. This is generally agreed upon as a one second (0:01) unit.

Amplitude

On the stroboscope this process is represented as wavy-line images. The distance between the waves is a measure of the pitch (*i.e.*, the more frequent the wavy-lines in a given space-segment, the higher the pitch and vice versa). The vertical height of those waves, however, indicates volume—a sound's loudness, intensity, or amplitude.

This *dynamic value* is indicated by the size of the crest and dip of each wave.

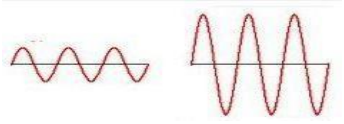

Figure 1. Sound waves viewed visually. The greater the wave the louder the sound.

It is measured in bels or decibels. Amplitude or loudness, however, is a variable, independent of frequency; it does not affect the pitch of a tone.

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[1] A particularly thrilling verse in the Bible—*And the Lord spoke unto Moses saying*, demonstrates the near unfathomable process of transforming cosmic energy into psychic perception—vibration into sound - which in turn becomes transmuted into Word and Voice.

References

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