Just Intonation

Western ears are well used to the twelve note octave that has dominated our music for centuries. But our ears are capable of so much *more*. **Ian O'Brien** provides an overview of an alternative system of intonation that can be used to radically change the way we compose music.

Freedom of Choice

The tuning system known as **equal temperament**, used by the majority of Western musicians and composers, is stifling the ability of these people to express themselves through music. Would writers restrict themselves to only half the words in the dictionary? By the same token, musicians using a tempered scale are bound to a limited resource.

Tuning systems and how they work are often a grey zone in the knowledge base of many musicians. Indeed, many are unaware that alternatives exist or even why they use the system that they do. There is an alternative which has been with us for many centuries and is based upon the very nature of sound itself — **just intonation**.

As the twentieth century draws to a close, Western art music (for want of a better description) finds itself at the end of nearly a century of pushing boundaries, breaking rules, inventing and reinventing systems and otherwise experimenting at a staggering pace. Unfortunately, many of these experiments have used the tempered scale as their language, a scale that was initially designed for instruments of fixed pitch.

Some contemporary pioneers, such as Harry Partch, Ben Johnston, La Monte Young and Karlheinz Stockhausen, have experimented towards the development of a musical dialect based not on equal temperament, but upon just, or natural, intonation. Just intonation is infinite in its adaptability and variation. It is capable of not only traditional dissonances and consonances, but many more that are outside the capabilities of our restrictive twelve note system.

Most systems are, at best, an approximation of the natural behaviour of sound and its associated qualities. When the nature of sound is compromised, the choices left to composers and musicians are severely restricted. Sound is, after all, a thing of infinite possibilities, as music should be. A system which allows merely twelve unnatural divisions of the octave, such as Western music's equal temperament, must limit the creative avenues available to us.

Just intonation is an accurate way of using sound and its natural physical properties to create music. The make-up of the human aural system is highly attuned to receive sounds created in this way. Indeed, Just Intonation is naturally used by singers and wind players when free of fixed pitch instruments and is also used in many folk genres. The so-called blue notes in blues music are the most familiar example of a just interval that have great emotive qualities but are ignored within a fixed pitch, twelve note environment.

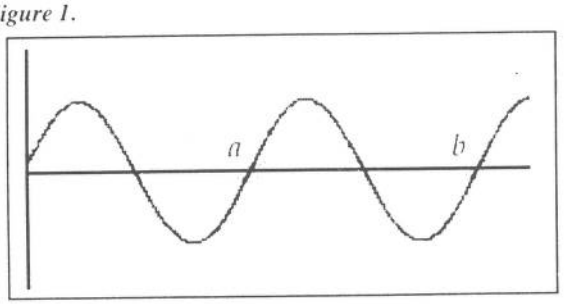
What Is Tuning, Anyway?

If we can accept an *extremely* general definition of music as the organisation of sound, then tuning may be defined as one of the basic building blocks for this organisation. To understand the nature of tuning and its associated problems, one must first understand the nature of sound, and then how each system deals with the organisation of sound into units that can be turned into music.

Firstly, there is what we hear. Sound is made up of vibrations which are picked up by our ears and interpreted by the brain. The human ear can perceive pitches from bass to treble across what is known as the **frequency spectrum**. We can hear pitches within this spectrum from roughly 20 to 20 000 cycles per second, or **hertz**.

In Concert Pitch, any note can be defined as being a particular frequency. For example, the note *A* on the second space of the treble clef is defined as 440 hertz. This simply means that it vibrates 440 times a second. These vibrations are most often represented as **wave forms**, such as in Figure One.

Figure 1.



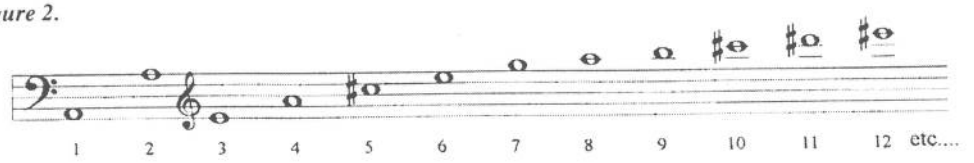
When a note vibrates it travels one full cycle of the wave (from a to b in Figure One). *A* does this 440 times a second, hence *A*=440 hertz. *A* above the treble clef vibrates 880 times in a second and the *A* above that vibrates 1660 times and so on. In other words, an octave above a given pitch vibrates at twice the speed.

All notes and sounds can be represented in some way by the

harmonic series, the beginning of which is roughly illustrated using conventional notation in Figure Two.

The harmonic series can be better understood in a simple mathematical sense. If the bottom note, or **fundamental**, is for the sake of argument *A*=110 (or *A* two octaves below *A*=440) then the second degree of this harmonic series will be

Figure 2.

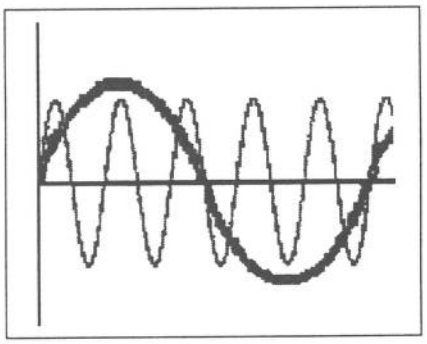


220 hertz. The third degree (*E*) will be 330 hertz, the fourth 440 (*A*), the fifth 550 (*C#*), and so on to the infinite. Each of these degrees are said to be in phase with each other. This means that if their waves were superimposed, they would divide exactly into each other. Figure Three might make this somewhat clearer. The larger wave shown is our fundamental, *A* (110 hz), and the smaller is the fifth harmonic, *C#* (550 hz).

Notice the way the smaller wave vibrates *exactly* five times for each single vibration of the fundamental. If the smaller wave did *not* divide exactly into the fundamental it would become **out of phase**. The actual sound that this would create would be beats between the two notes, an effect all too familiar to musicians trying to play in tune.

The importance of the harmonic series cannot be understated. Any note is either a fundamental or one of the degrees of a series. The **timbre** of any note is usually dictated by which degrees of the series (or partials) are present in the sound.

Figure 3.



To provide an example of how keyed in to the harmonic series the human hearing mechanism is, take the fact that if you were to wear a set of headphones with one of the lower degrees of the series playing exclusively to one ear and another degree playing exclusively to the other ear, your brain would supply the fundamental, i.e. you would hear three tones (Doty 16).

Unless they are tempered, all instruments, except ideophones (instruments which use struck metal or wood as their sound source), have the harmonic series as their foundation (Doty 65). The series also exists virtually everywhere there is air and vibration...take the rim of a wine glass or the wind on a telephone cable, for example.

Equal Temperament

Equal temperament forsakes all of the intervals dictated by the harmonic series with the exception of the octave. It is best described as the division of the octave into twelve equal semi-tones. The unit of measurement used to define the semitone is known as the **cent**, which was invented by Alexander J. Ellis, a nineteenth-century physicist (Doty 24). Basically, each semitone is worth one hundred cents, and there are twelve hundred cents in the octave. Theoretically, this ensures that on a fixed pitch instrument, such as a piano, each octave is precisely in tune.

The equally tempered scale is a rough approximation of a scale worked out by Pythagoras. This is known as the **Pythagorean Ditone Scale** and is based upon the pure (or just) perfect fifth, rather than the octave. The reason the Pythagorean scale was adjusted (or tempered) was to remedy a problem encountered within Pythagoras' system known as a ditonic or Pythagorean comma.

The Pythagorean comma is a discrepancy that occurs when you complete a circle of fifths in just, or pure, fifths. For example, if you start at *C*, then ascend a perfect fifth to *G*, and then to *D* and so on around the circle of fifths until you end up at *B#*, this *B#* will be sharper than the original *C* by a Pythagorean comma, or 23.5 cents (Doty 34).

This obviously caused great problems for composers writing for a fixed pitch instrument, particularly if they modulated too far away from a given tonic. In an environment where keyboards and fretted instruments dominated, as well as an increasing tendency to remote modulation, a system was required to overcome this anomaly.

Equal temperament's solution was to spread this error equally throughout the scale, flattening each fifth by around 1.96 cents. While this seems an insignificant amount, the result is that all intervals within equal temperament, with the exception of the octave, are slightly out of tune and therefore slightly out of phase, corrupting the harmonic relationships between the notes. It is this corruption that leaves equal temperament incapable of achieving the colour and complexity experienced with purely tuned intervals.

Even though Western music has been using equal temperament virtually exclusively for the last two centuries, our ears still seek out the pure harmonies of just intervals. A choir will naturally use just intonation, as will brass and wind players. This is the reason why the harmonies of a brass quintet or a barbershop quartet sound much sweeter than the same harmonies played on a piano or another equally tempered instrument.

Just Intonation

In its most simple form, Just Intonation is the tuning of intervals to avoid beats occurring between the notes. As already mentioned, beats occur when two notes are played together and their wave forms become out of phase. Just intonation can also be described as being a system where all of the intervals between all of the notes can be represented as a whole number ratio (e.g. 3:2).

Within Just Intonation particular intervals are represented as ratios. For instance, 3:2 represents the just perfect fifth. If you refer back to the harmonic series in Figure Three you will

notice that the **third** degree is a perfect fifth above the **second** degree, hence 3:2. This same equation can also be represented numerically. If the E is 330hz and the A is 220, then 330 divided by 220 is equal to 3/2, or 3:2.

By the same reasoning, it is easy to pick out other just diatonic intervals from the harmonic series, such as the major third (5:4), the major second (9:8), the minor sixth (8:5), the octave (2:1) and so on. The number of different intervals available is as endless as the harmonic series and it is not necessary to travel too far up the series to find intervals not represented by equal temperament, such as 7:6, which is known as the septimal minor third (the so-called blue third).

This is essentially the basic structure of just intonation. In developing systems with which to use Just Intonation, composers and theorists talk of using **limits**. A **five limit** system, for example, is one made up of intervals created by chaining together a series of intervals using any ratios whose pair of numbers can be factored (or divided) to prime numbers of five and under. A five limit system takes a fundamental and stacks just major thirds (5:4) and just perfect fifths (3:2) above and below the fundamental, resulting in a huge range of useable pitches over the musically useful pitch range. The higher the limit the greater the number of useable pitches, but with this comes increasing complexity. For a more complete discussion, refer to the recommended books at the conclusion of this article.

Clearly, this is not a system that is capable of use on a fixed pitch instrument, such as the piano or, to a large extent, the fretted guitar. The simple act of changing keys away from the fundamental causes many intonational problems.Equal temperament, however, is suited to use on these instruments due to the fact that it is for precisely these instruments that the system was designed in the first place. As a result, musicians using instruments of non-fixed pitch have been struggling to effectively use a system that is alien both to their ear and to their instrument.

So How Do You Use It To Make Music?

Just Intonation can be, and is, used by many of us in day-to-day music making. It is quite clear when performers are using pure intervals and equally obvious when they are not. To truly exploit Just Intonation, however, one must design the music with this system in mind from the outset.

Just Intonation theorists have provided a number of models and frameworks with which to create music with Just Intonation as its basis. These vary in complexity and usability. Unfortunately, a universally accepted system is yet to be established. As a result, composers tend to create their own system and often their own instruments to reap the benefits of a more expressive musical language. As long as this experimentation continues, there will eventually arise a useable and workable system to replace equal temperament, which has long been more a yolk around the neck of music makers than an aid to expression. (8~)

Sources and Recommended Texts

Doty, David B. *The Just Intonation Primer*, 2nd Ed. Other Music Inc.:San Francisco, July 1994.

Doty, David B. *The Just Intonation Network*, http://www.dnai.com/~jinetwk, 1996.

Partch, Harry *Genesis of a Music*, 2nd Ed. Da Capo Press:New York, 1974.

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books

Violin Music in the Age of Shopping

Jon Rose and Rainer Linz
NMA Publications: P.O. Box Burnley VIC 3121, 1994
(ISBN: 0-646-18105-X)

With Jon Rose poised to give a series of what are becoming increasingly infrequent Australian appearances, it's timely to reconsider this book, his second collaborative work with Melbourne's Rainer Linz. Together, Rose-the-belligerent-loon and Linz-the-sardonic-wit make quite a testing team, tilting at dragons and windmills alike with equal deadpan candour. Who among us dares to mock cover versions that are the stock-and-trade of John Zorn, or reveal the shocking truth that is the James Moribund Big Band? Verily, the Emperor's new clothes are none too flash and the court musicians sound fucking woeful.

For me, this book is some kind of uproarious companion to Jacques Attali's Noise: The Political Economy of Music. The likeness is not so much Mad magazine parody as Mad Max supercharging. Rose and Linz share Attali's committed Marxist politic and, like Attali, their visions culminate in improvisation and the possibilities of new technology. But where Attali is dry and turgid, Rose and Linz are engaging and jocular. Their gentle whimsy and caustic satire is familiar to me from my rural adolescence, for it is the vernacular of Australian humour.

In its way, Violin Music provides some small proof of a whole secret history of Australian music: the vitality of Australian improvisation in recent years, the forgotten visits by David Moss and Eugene Chadbourne, the records on the Fringe benefit label. But this is history viewed through the refracting prisms of a kaleidoscope. More correctly, this is a historical "version", peopled by that gallery of roguish virtuosos--the apocryphal Rosenberg family. This mongrel dynasty of idiot-savant composers and theorists first came to public attention in the pages of Rose and Linz's previous book, The Pink Violin. Violin Music elaborates on that book, but it takes broader task with the world, dropping all before it in a withering line of fire. Consider these words from "Country and Western Shopping", Conway Chadwick's report to the Nashville