The Tuning CD
"Using Drones to Improve Intonation"
By Tom Ball

A drone is a sustained tone on a fixed pitch. Practicing while a drone is sounding can help musicians improve intonation through pitch matching, interval tuning, and ear-training. It is most useful for instrumentalists (brass, woodwind, strings) and vocalists who can manipulate a note's pitch up or down slightly.

What is the Tuning CD

The Tuning CD contains a series of 2 minute drones on each of the twelve pitches of the chromatic scale. The musician plays a track of the CD through stereo speakers or headphones while practicing his/her instrument. By practicing intervals, scales, or any piece of music along with the CD, a musician can learn to play with better intonation and improve ear-training skills. At the end of this booklet are some basic exercises and suggestions that can help the player hear pure intonation and play better in-tune.

Tuning CD vs. Tuner

Why use the Tuning CD for this purpose? Isn't it just as helpful to practice with an electronic tuner? No. A tuner is a useful tool for matching a pitch to the A=440 Hz equal tempered tuning system. The problem is that it does not train you to hear when different notes, or intervals, are in-tune with each other or to quickly adjust them. Western European music uses a system of harmony that emphasizes certain intervals within common chords; major 3rd, minor 3rd, major 6th, minor 6th, perfect 4th, perfect 5th and octaves. Since most of the music we play is based off of chords, it is important that musicians learn to play notes in-tune with relationship to the implied underlying harmony. Practicing with a drone on any pitch desired allows a musician to fine-tune his or her intonation skills to a much greater degree. Not only can one improve the ability to play the mentioned intervals but with practice to play all intervals in-tune with greater confidence and adjust with much greater speed when needed.

Intonation

Good intonation should be a goal that musicians strive for at all times. Although this booklet contains some very important information about intonation, it is not intended to be a complete study or technical manual on the subject. This information is given only as a foundation to understanding how pure intonation is a byproduct of nature and simple mathematics. This discussion also touches on some of the more common techniques for tuning intervals and matching pitches using pure (Just) intonation. Using Just intonation, notes of the chord, such as the third and fifth, are slightly higher (fifth and minor third) or lower (major third and minor sixth) than the equal tempered system. Therefore, using a tuner to find where the note is in-tune does not mean it will sound in-tune when played against the underlying harmony.

Equal Tempered Intonation Verses Pure (Just) Intonation

Keyboard instruments and electronic chromatic tuners use a system of tuning called equal temperament. This system divides an octave into 12 equal parts where the distance between each half-step interval is equal. The distance between each half-step is measured as 100 Cents. One octave, therefore, is equal to 1200 Cents. Why can this system create problems? This system of tuning does not occur in nature—it is a man-made compromise. The intervals we use in music also occur in nature as pure mathematical ratios that are often different than intervals created using the equal tempered tuning system. With equal temperament, these intervals are not perfectly in-tune because they are not based off of these pure mathematical relationships. Therefore, only the perfect unison and octaves can be perfectly in tune using the equal tempered system. Some intervals created using the equal tempered system are very close to pure intonation and others are not that close. Because of the acceptance of this tuning system as the norm, our ears have become quite accustomed to the sound of equal temperament when listening to the piano, mallet instruments and electronic music. When listening to acoustic, vocal, orchestral and instrumental wind music however, our awareness of pure or Just intonation is much more acute.

Why do we use the equal tempered system of tuning? The Western-European musical society struggled with different tuning systems until the 1800's when equal temperament became the norm. Many tuning systems have been used and experimented with throughout history but the equal tempered system has become the most acceptable because it allows the composer or player to modulate to different keys and the intonation will stay consistent because in every key, the intervals are identical. The intervals created are, in some cases, close enough to those occurring in nature that our ears accept the discrepancy most of the time. A piano tuned using Just (pure) intonation based on the note C will sound much richer and more beautiful in the key of C compared to equal temperament but as soon as you modulate to a different key, the intonation begins sound sour. The further you travel from the key of C the more out of tune the intervals sound. We have come to embrace how the piano is currently tuned as acceptable and harmonious. A major chord using equal temperament has a slightly flat fifth and a sharp major third compared to pure intervals used in Just intonation which is based on the natural harmonic series. Musicians who do not play with fixed intonation, such as found with the piano, have the ability to adjust the intonation of notes until the interval becomes pure. Fretless string instruments and the trombone are examples of instruments that can most easily adjust the intonation of pitches. Many musicians may adjust notes to be in tune automatically without even much thought. But many musicians struggle to tune some notes in certain circumstances because of not understanding the nature of their own instruments or how their note relates to the underlying harmony. The major third is often the note that is out of tune most often because it is the one that needs the furthest adjustment (down). And because players have become accustomed to playing a note in a certain place, they might even become used to hearing the sharp pitch as normal. We have to adjust chord tones from their normal position which is challenging but possible and necessary for pure intonation. The result of pure intonation is worth every effort.

Wind Instruments

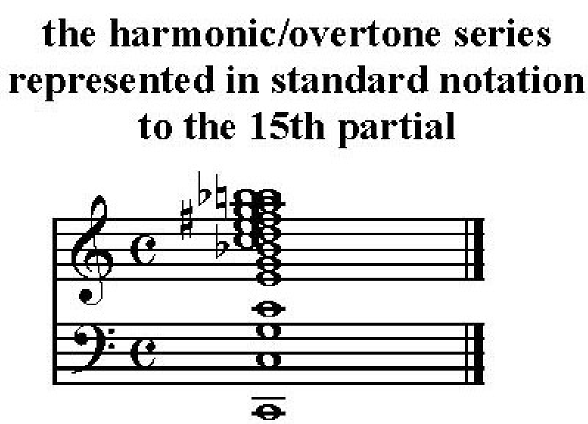
Most of our instruments (woodwind, brass, etc.) are designed to allow as even intonation in all keys as possible. But wind instruments are based off of a harmonic series, or natural overtone series, that is built from mathematical ratios that produce notes that do not quite match equal temperament. When an instrumentalist plays an F on their instrument he or she can learn to match that note with an electronic tuner. If that musician produces that note in exactly the same place over a B flat major chord played or sung by acoustic instruments, the F will then sound flat because a perfect fifth using Just intonation is higher than an equal tempered perfect fifth (as found on a piano). If you then play the same F over a D flat major chord, the F then becomes very sharp sounding because a major third using Just intonation is lower than an equal tempered major third. Using equal temperament, no adjustment of the different chord tones is possible such as found on the piano. You can hear this when playing a major third interval, such as with the notes C and E on a piano. Listen for the beats created. They will be quicker compared to a perfect fifth, such as C up to G where the beats will be slightly slower but still audible. The bottom line is that if you hear beats, the interval is not perfectly in-tune.

Using the consonant intervals, Major 3^{rd}, minor 3^{rd}, perfect 4^{th}, perfect 5th, minor 6^{th}, major 6^{th} and octave, one can most easily hear when interval is out of tune by listening to the beats produced. These beats are heard as a wavering or pulsing that occurs as the notes sound simultaneously. The closer the interval becomes to pure intonation, the slower the beat's waver. When the beating stops, the interval is perfectly in-tune. The frequency of any pitch is measured in vibrations per second called hertz (abbreviated – Hz). If you take two electronic tuners both calibrated to A=440 Hz, playing different notes perfect 5^{th} interval apart, the beats are clearly audible. The tuners would be playing perfectly in-tune but out of tune with each other because the perfect 5th interval created is smaller than that found in the pure, natural harmonic (overtone) series in which the Just intonation system is based.

The overtone or harmonic series

The overtone (harmonic) series is a naturally occurring phenomenon. Whenever a note is played on any instrument, an overtone series is present and is sounding for the duration of the note. All of the notes in the harmonic series of the sounding pitch (the fundamental) vibrate in sympathy with it. Most of these overtones are not individually audible by the human ear, but together they create the timbre or tone color of each instrument or voice. What makes a flute sound different than a trumpet even if they are playing the same pitch is the relative loudness or softness of each overtone in the harmonic series. You can hear some of the overtones clearly on a piano by loudly playing a low note while holding down the sustain pedal. As the sound decays, you can hear the overtones ringing in the string which causes other higher strings to vibrate in sympathy. You can also hear some beats as the overtones clash with the even tempered tuning of the higher strings.

Below is the harmonic or overtone series built from a low C below the bass clef represented through the 15th partial. This tells us what notes will also be sounding when a low C is played although most of the notes are not audible by the ear but make up the "color" or timbre of the sound. Realize that the overtone series continues upward and the intervals continue to become smaller and smaller until they are less than a ½ step and beyond to infinity.



Overtone Series of a String

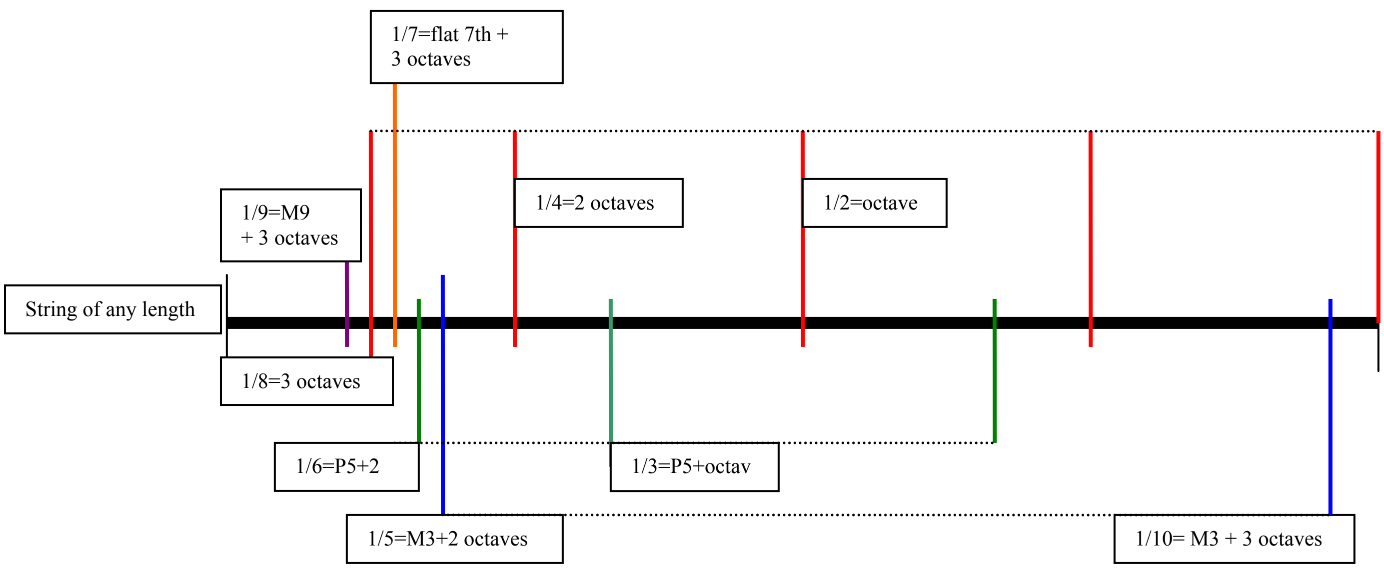
The overtone series can be understood clearer by examining a taut string. If a string is plucked it produces a fundamental pitch. If you divide a string into two equal halves, the resulting pitch from plucking either half has a frequency twice that of the original pitch. The new note vibrates twice as fast as the original note. Thus, a string producing an A at 440 Hz, divided into two would produce another A one octave higher at 880 Hz. The resulting interval of an octave can be represented as the ratio 2:1. If you divide the string into three equal parts, the resulting note will be an octave plus a perfect fifth. This ratio is 3:1. The interval of a perfect fifth without the octave displacement therefore has a ratio of 3:2, meaning, each time the 5th of a chord vibrates 3 times the root or fundamental vibrates 2 times. This information can be examined in the tables below.

These naturally occurring intervals are pure intervals and create a pleasing and harmonious sound to us, as they should. It is fundamental mathematical principles which create these intervals and our ear recognizes this. This is how the harmonic series works for the length of tube of a brass instrument as well. A brass player emphasizes a certain overtone of the harmonic series by buzzing the lips at different frequencies for the length of tubing selected. The tubing length is determined by pressing down valves or moving a slide. Many woodwind instruments work similarly but there are differences in the harmonic series of certain instruments like the clarinet which skips every other partial of the regular overtone series. The intonation idiosyncrasies of a wind instrument are often influenced by the natural intervals present in the harmonic series for the length of the instrument. Also, the manufacturer’s particular design effects the intonation of the overtone series of that particular instrument. This is why some manufacturers’ instruments have different intonation tendencies than another. These factors contribute to the intonation battle that wind instrumentalists face in addition to what chord tone or scale degree each note happens to be at any point.

The following chart lists the fraction of the string and the resulting interval above the fundamental (total string length) note.

Fraction of String length	resulting interval
1/2	one octave
1/3	one octave + perfect fifth
1/4	2 octaves
1/5	2 octaves + major third
1/6	2 octaves + perfect fifth
1/7	2 octaves + flat seventh (very low pitch)
1/8	3 octaves
1/9	3 octaves + major second
1/10	3 octaves + major third
1/11	octaves + augmented 4th
1/12	3 octaves + perfect fifth
1/13	3 octaves + major 6th
1/14	3 octaves + flat seventh (very low pitch)
1/15	3 octaves + major seventh
1/16	4 octaves

Red = Octave
Green= Perfect fifth
Blue= Major third
Violet=Major second
Orange= flat seventh



Mathematical Ratios of Perfect Intervals

What is a perfect interval? Just intonation uses perfect intervals based off of pure ratios. This is explained in more detail in a section below. A diatonic scale using notes derived from pure ratios produces pure intervals that sound in-tune. The intervals produced from the equal tempered system are not the quite same. Below is a table for Just intonation showing the relative ratios of the interval with the fundamental. The intervals highlighted in bold are the simplest ratios and thus the ones that are the easiest to perfectly tune by ear. Notice that there are seventeen intervals in this chart. That accounts for some of the intervals in a naturally occurring overtone series, not a chromatic scale. Remember, the 12 note equal tempered chromatic scale is a man-made scale. But by examining these charts you can see that it is a good compromise that we have learned to live with. Other cultures, such as in India, use some of the notes from the overtone series that we do not to form their scales.

Scale of Just (Pure) Intonation

Interval	Frequency ratio from starting point	Cents from starting point
Unison	**1:1**	**0**
Semitone	16:15	111.731
Minor second	10:9	182.404
Major second	9:8	203.910
Minor third	**6:5**	**315.641**
Major third	**5:4**	**386.314**
Perfect fourth	**4:3**	**498.045**
Augmented fourth	45:32	590.224
Diminished fifth	64:45	609.777
Perfect fifth	**3:2**	**701.955**
Minor sixth	8:5	813.687
Major sixth	**5:3**	**884.359**
*Harmonic minor seventh	7:4	968.826
Grave minor seventh	16:9	996.091
†Minor seventh	9:5	1,017.597
Major seventh	15:8	1,088.269
Octave	**2:1**	**1,200.000**

*Minor seventh that occurs in the overtone series at the seventh partial. It is very flat and unusable in western music.
† Normally used minor seventh.

What a Ratio Tells Us

The Ratio 2:1 means that one note vibrates twice every time the other note vibrates once. This ratio produces a perfect octave. The ratio 5:4 tells us is that for every time the lower note of an interval vibrates 4 times, the higher note vibrates 5 times. This ratio of vibrations produces the interval we call a Major third

Comparison of Just vs Equal Temperament in Ratios

Interval	Ratio to Fundamental Just Scale	Ratio to Fundamental Equal Temperament
Unison	1.0000	1.0000
Minor Second	25/24 = 1.0417	1.05946
Major Second	9/8 = 1.1250	1.12246
Minor Third	6/5 = 1.2000	1.18921
Major Third	5/4 = 1.2500	1.25992
Fourth	4/3 = 1.3333	1.33483
Diminished Fifth	45/32 = 1.4063	1.41421
Fifth	3/2 = 1.5000	1.49831
Minor Sixth	8/5 = 1.6000	1.58740
Major Sixth	5/3 = 1.6667	1.68179
Minor Seventh	9/5 = 1.8000	1.78180
Major Seventh	15/8 = 1.8750	1.88775
Octave	2.0000	2.0000

Comparison of Just and Equal Temperament in Cents

Note	Just Scale	Equal Temperament	Difference
C4	261.63	261.63	0
C4#	272.54	277.18	+4.64
D4	294.33	293.66	-0.67
E4b	313.96	311.13	-2.84
E4	327.03	329.63	+2.60
F4	348.83	349.23	+0.40
F4#	367.92	369.99	+2.07
G4	392.44	392.00	-0.44
A4b	418.60	415.30	-3.30
A4	436.05	440.00	+3.94
B4b	470.93	466.16	-4.77
B4	490.55	493.88	+3.33
C5	523.25	523.25	0

Using *The Tuning CD* During Daily Practice

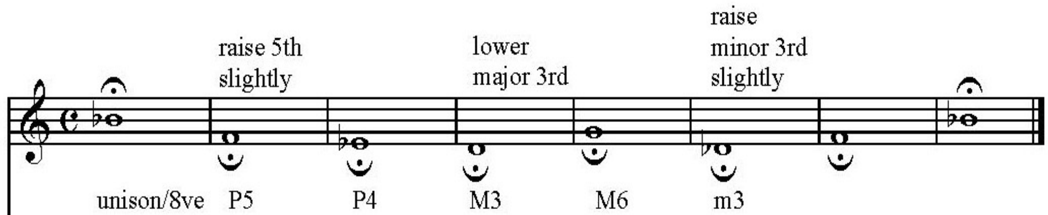
Each note of *The Tuning CD* is tuned to the equal tempered system with A=440Hz. Use the Tuning CD while practicing long-tones, scales, lip slurs, chords, improvising over a pedal point or in a key center, or any piece of music from diatonic to atonal. You can have the note your playing with be the root of a key, scale or chord or any other primary notes within a key like the third or fifth. As a trombonist, I use the Downward Slur Exercise from Buddy Baker Trombone Method or the Remington Warm-Ups at the start of my practice day. It makes great sense to have the root or fifth of the key sounding while working through the lip slurs, long-tones or any warm-up exercises. It gets the ear warmed up for hearing intonation as well as the embouchure muscles for playing. You can play the CD through a stereo or through headphones. It should be loud enough to hear beats but not force one to overplay or become the dominant sound. Use common sense and don't damage the ears.

I also recommend occasionally using a chromatic tuner to compare when your ear tells you your in-tune and where the tuner indicates the pitch is in relation to equal temperament. This is useful in understanding how far up or down certain tones have to be adjusted to really be in-tune within an interval.

Practicing scales over a pedal point can be very useful. I found it effective to have the root or fifth of the scale sound while the player practices each mode of the scale within that key center. For instance, have a C pitch sounding while playing an F major scale. Start with F then play the G dorian (2^{nd} mode of F major scale, then A aolian, etc. Or, one can practice all of the modes of the major scale (or any scale) with C as the root. I usually practice the scales slower at first to make sure that each interval is as in-tune as possible. Improvising using a particular mode or scale while a drone note is sounding is an excellent way to learn to hear the mode with greater clarity.

The Tuning CD
preliminary tuning exercise

Exercise 1. Play with track 1 Bflat drone, hold each note until you achieve perfect intonation.
Transpose down 1/2 step for each subsequent track.



Exercise 2. Play Major Scale, listen to eliminate beats. Transpose down 1/2 step for each subequent track.

*h =adjust note higher than equal temperment
*l=adjust note lower than equal temperment

Play exercise 2 in all keys using all major and minor scale types.