AUTOHARP TUNING THEORY AND PRACTICE

Introduction

First the bad news ---- you will never get all the strings of your Autoharp perfectly in tune. Now the good—there is, in music based on the scales used in the Western World, no such thing as being tuned "perfectly," but, by understanding why this is so, you can achieve a delicate balance of harmonies so pretty that no one will know the difference.

In the early eighteenth century, J.S. Bach decided he wanted each key symmetrically in tune so he devised a method of adjusting the pitches of notes called "equal temperance" in which each semi-tone is proportionately the same. This system has continued to this day in the tuning of keyboard instruments and in the mechanics of the electronic tuning machine.

When you tune the strings of an Autoharp to a piano or to the zero point of an electronic machine, you are actually putting each note equally out of tune. Because of the short length of the strings of an Autoharp relative to, say, a piano or classical harp, the discordant overtones sound particularly nasty. Also, the notes of the Autoharp are at fixed pitches and can't be "bent" to produce more pleasing harmonies which is partly how other string and wind instruments deal with the discrepancies.

Starting with the basics

Let's start at as basic a level as possible. Sound is produced when something causes changes in the pressure of the air that hits the eardrum. If these pressure changes are regular, like ripples emanating from the spot where a stone has been tossed into a pond, we perceive it as pitch; the faster the rate, the higher the note. As a string is plucked and moves the air around it, there is also a series of minor vibrations or "partials." It not only vibrates in one piece but in two pieces, or three, or more all at the same time. These lesser vibrations have exact mathematical relationships. If the whole string is vibrating 262 cps or *cycles per second* (not to be confused with cents or cts which are 1/100ths of an equal-tempered semi-tone), we call it "c." The two halves of the string are going twice as fast (524 cps) which produces a "c" note an octave higher "c^2" expressed as a ratio 2:1 (524:262). The string's thirds are going 786 cps (3:2 or 786:524) producing "g^2" an octave and a half above the original "c." The beat goes on:

Portion of String Vibrating	Note	Ratio	Multiply Cycles	CPS
1 / 1	c^1	1:1	1 x 262	262
1 / 2	c^2	2:1	2 x 262	524
1 / 3	g^2	3:2	3 x 262	786
1 / 4	c^3	4:1	4 x 262	1048
1 / 5	e^3	5:4	5 x 262	1310
1 / 6	g^3	6:4	6 x 262	1572
Etc.				

Harmonics: Tuning By Ear

You can demonstrate this phenomenon yourself. Lightly touch the lowest c string on your autoharp at exactly the halfway point. Now pluck it near the string anchor, simultaneously lifting your finger. The first c harmonic (c^2) is produced. Repeat 1/3 of the way up = g^3 , 1/4 of the way up = c^3 (same note two octaves higher), 1/5 of the way up = e^3 , etc.

Now this sequence of notes should look familiar. That's right: it's the good old 1 3 5 steps of the C major scale which, when combined, make the C chord.

Chart of String Harmonics

(X marks the spot on string where harmonic will sound)

e^3 c^3 g^2 c^2

pin______________X___X_____X___________X______________________________________ball end

1/5 1/4 1/3 1/2

5:4 4:1 3:2 2:1

You can tune the octaves, fifths, and thirds to the harmonic produced by the corresponding lower string. In other words, get higher c, e, and g notes from the harmonics on the #3 c string. Tune the other notes by octaves (you have to work backwards for the e's). The result is a chord tuned to "just intonation":

Note	**String**	**Ratio**	**= Harmonic on string**	**note : note**
c^2	#12	2:1	#3	c:c
g^2	#19	3:2	#3	c:g
g^2	#19	2:1	#8	g:g
c^3	#24	4:1	#3	c:c
c^3	#24	2:1	#12	c:c
e^3	#28	5:4	#3	c:e
g^3	#31	3:2	#12	c:g
g^3	#31	2:1	#19	g:g
c^4	#36	2:1	#24	c:c

The string numbers above correspond to the array on a standard chromatic 36 string autoharp.

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Generating Chords from Multiplied Tonic Tones

So it seems one could tune perfectly around the abbreviated diatonic circle of fifths (f-c-g-d-a-e-b) and wind up with the scale perfectly in tune, right?

Wrong. I guess it's just one of those Mysteries of Nature.

Let's see why it doesn't work. Here is how the harmonic tuning described above works out mathematically.

The cps (cycles per second) of a perfect fifth is obtained by multiplying the tonic by 1.5 giving the desired 3:2 ratio ---- c^2 (524 cps) X 1.5 = g3 (786 cps). To get the cps for the middle octave g^2, simply take half of g^3 [786 x .5 = 393 cps]

Going around the circle of fifths in this manner (multiplying a tonic by 1.5 to obtain the fifth):

d 589.5 cps
a^2 884 cps
e^3 1326 cps

But wait a minute. Earlier we have seen that to have the third step in the scale ("e") perfectly in tune with the tonic c , the cps should be in a ratio of 5:4 from the bass string or 1310 cps, The e obtained through the circle of fifths sounds very sour when played in the C chord; it is sharp by 16 cps.

So let's try a different angle. We can tune the IV chord (F) and the V chord (G) by the same harmonic-based method we used to get the I chord (C) .
[tonic of chord x 1.5 = the fifth
tonic of chord x 5 divided by 4 = the third]

In other words, we are building the major triad by figuring the sympathetic cps (cycles per second) generated by the bass string of the chord and achieving a harmonically pure chord.

In this manner we get the following values:

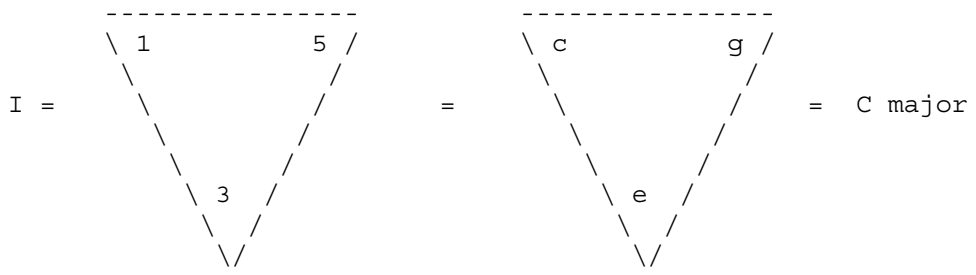
c 262 cps
d 294.75
e 327.5
f 349.4
g 393
a 436.75
b 491.25
c 524

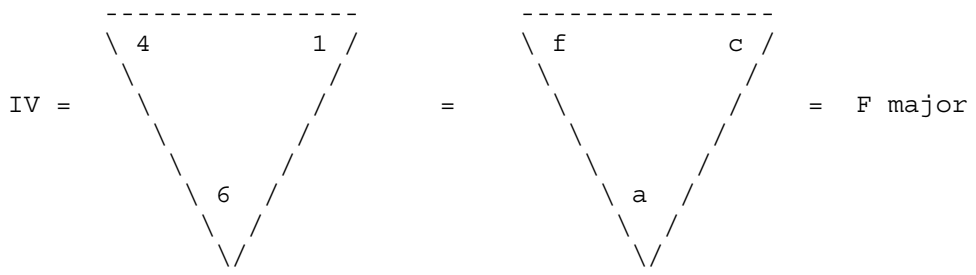
Now all three major chords I, IV, V (C, F, G) and two of the minor chords VIm, IIIm (Am, Em) are in tune in perfect mathematical proportion. Unfortunately, when you try to match up the fifth interval (d - a) contained in the IIm (Dm) chord, the house of cards falls apart. The a note obtained from the f string works out to 436.75 cps, but when you find a perfect fifth from the d string, multiplying by 1.5, you get 442.125 cps, a noticeably discordant difference of about 6 cps .

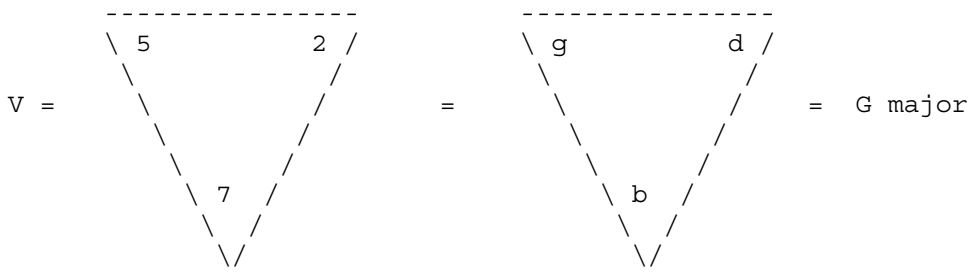
The crux of the problem

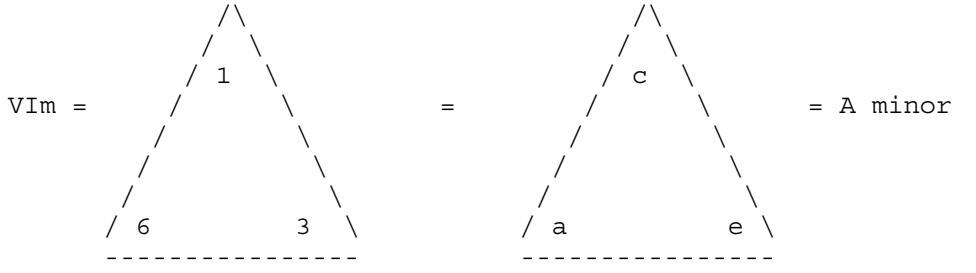
Here is the crux of the problem: in order that a major chord made up of the scale's 1-3-5 steps sound in perfect tune the #3 step should be lower than it would be in equal temperament (e.t.). For example, if the c and g notes (I-V steps in the C scale) read out at zero on the tuning meter, the e note should read less than zero. The opposite is true for the minor chords --- the minor third (m3) middle note needs to read out higher than the I and V. For example, in an Am chord, the c should be at zero on the meter that shows the a and e lower than zero.

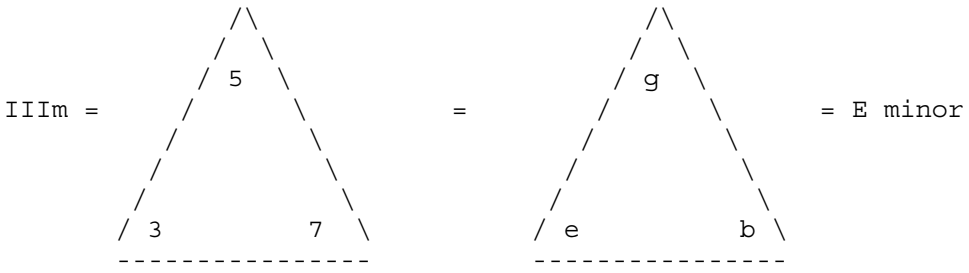
Below are the notes that make up the primary chords of a scale in the Key of C and their ideal relative pitches adjusted from e.t. (cardinal numbers referring to scale step; i.e. l = c, 2 = d, etc.)

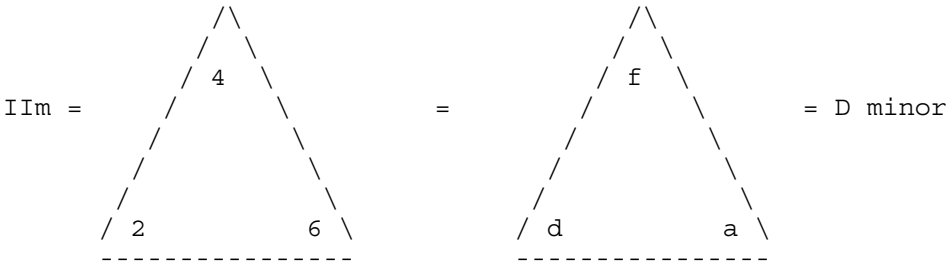








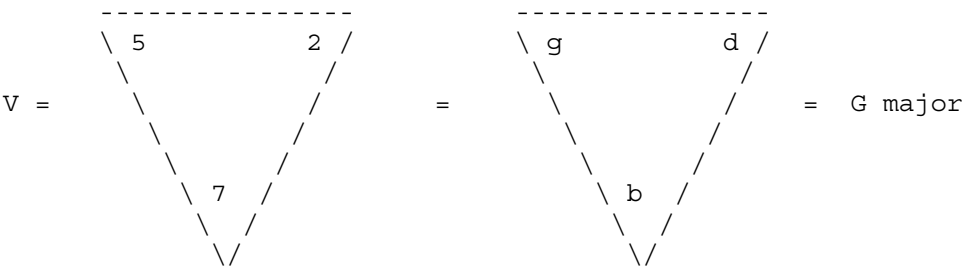




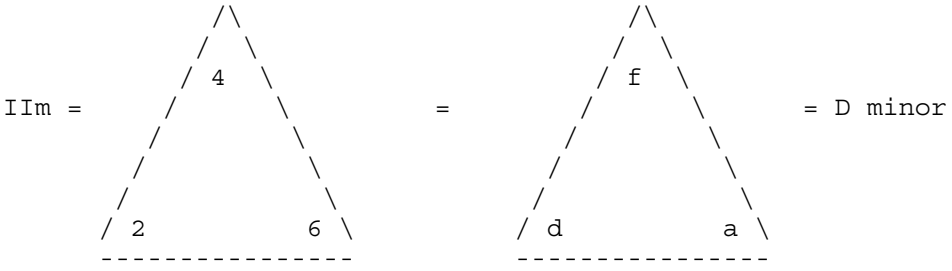
So if the tuning of the steps is adjusted in this manner:

1 2 4 5
3 6 7

All the notes are set in what is known as "just intonation" (j.i.) There is only one small problem. The #2 note (d) which works great in the top row for the V chord:



needs to be in the bottom row for the IIm chord:



If you want to use this chord (and most of us do), and if you want your 'harp tuned in more than one key (i.e. if you're chromatically inclined), and unless you've got a gig in the Garden of Eden, a compromise or two must be made. Something's got to give. C'est la vie.

There are probably as many ways of making this compromise on the Autoharp as there are Autoharp players. Which note or notes will be the sacrificial lamb(s)? What are the relative values of the chords? I'll try to keep subjective opinions out of this discussion as much as possible. I don't want to ruffle any feathers. However, you should know that when you tune the 'harp by ear, even as Mama Maybelle did back in the days b.c. (before computers), strumming the various chords and adjusting the notes in common to make sure they don't clash too much. what you're doing is making this very same compromise.

"Let's re-state the problem: in "equal temperament" (e.t.), the notes that make up the major thirds in the I, IV, and V chords are too high; in "just intonation" (j.i.) you go unacceptably out of tune when you try to switch keys or play a IIm (or partial II7) chord. Therefore, in order to find a middle ground both pleasing to the ear and practical to play, the #3, #6, and #7 scale steps (e, a, and b in the key of C, the major thirds of I, IV, and V) have to be raised (sharpened) from j.i. or lowered (flattened) from e.t. Also, the #2 note (d in the key of C) needs to be flattened from e.t. to more closely harmonize with the #6 (a) from j.i.

Just knowing that these are the directions in which you want to be heading is a great help when you're trying to make adjustments either by ear or machine. Of course, how far you adjust the intervals depends on your personal musical requirements. A chromatic player jamming with other instruments is not going to want to stray too far from e.t.; whereas, the solo diatonic player will favor the justly intoned end of the spectrum.

Ah, but how much should the thirds be flattened and the 2-5 interval bent into shape? It's a puzzle where if you tighten up one part, it causes something else to come loose. Let's see how far we have to go; i.e., by how many "cents" (1/100ths of a semi-tone) the j.i. notes vary from the same ones in e.t.

… to be continued

JUST INTONATION VERSUS EQUAL TEMPERAMENT

Key of C: Variance of just intonation from equal temperament (in cents)

c	0
d	+4
e	-14
f	-2
g	+2
a	-16
b	-12

It makes more sense if you think of it in two cycles of fifths:

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    4       d
  2       g
0     c
-2 f


-12 b
   -14 e
      -16 a
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Now straighten the top line at zero

f c g d = 0

And straighten the bottom at minus 12:

b e a = -12

This compromises the pure chords somewhat but does tighten that pesky d - a interval, although not really to an acceptable degree. You could tune thus, leave out II chord(s), and have a sweet-sounding instrument.

Now if you flatten each fifth by 3.4 cents until both lines stand on end, “d” comes even closer to meeting up with “a”

f	+3.4
c	0
g	-3.4
d	-6.8
a	-10.2
e	-13.6
b	-17

Everybody has had to suffer, but at least “d” and “a” are friends again, i.e. closer than with a justly-intoned scale, and a kind of harmony has been restored to the group as a whole. The added bonus is that the rest of their chromatic buddies are welcome at the party as long as they fall into their assigned places:

d#	+10.2
a#	+6.8
f	+3.4
c	0
g	-3.4
d	-6.8
a	-10.2
e	-13.6
b	-17
f#	-20.4
c#	-23.8
g#	-27.2

This is an example of a kind of "mean-tone" tuning (loosely defined).

As you can see, the thirds are at their "just" interval of -13.6 from their tonic (although the fifths are no longer as close), and all the usual chords for the standard Autoharp keys of F,Bb,C,G,D, and A are reasonably in tune, so everything should run smoothly unless those troublemaker chords, Ab and B7*, show up. Ab's g# and d# notes are going to clash something awful, and B7 would be okay except his d# is so sharp somebody could get hurt. Why don't you substitute his more compatible cousin, Bm, or those other minors: Fm, Cm, or F#m. They fit in better. The diminished sevenths can augment the fun too, although each will contain a faulty minor third; the suspenseful moments they create can be resolved.

*These chords are sometimes included on factory stock 21 button models

THE 2.5 CENT SOLUTION

If I might interject a personal opinion here, I would separate the mean-tone fifths by units of 2.5 cents rather than 3.4. It is much easier to read the needle on the tuner as it bounces between quadrants of the meter's 10 cent demarcations, and, at -10 rather than -13.6, the thirds sound, to my ear, just as sweet. Most important, it tightens the fifths which had been stretched to their limit.

The two bass strings, f and g, should probably be tuned by ear since the lowest frequencies are particularly hard for the machine to read (most likely because of all the overtones). Many players like to tune bass and lower octave strings a little flat of the upper octaves, possibly because the thicker strings tend to vibrate slightly faster when first struck.

d#	+7.5
a#	+5
f	+2.5
c	0
g	-2.5
d	-5
a	-7.5
e	-10
b	-12.5
f#	-15
c#	-17.5
g#	-20

This is the essentially the way most of the mean tone systems work, even if there is talk of the syntactic comma, etc., etc. You can use different and/or unequal increments, but in general you shave the fifths until you arrive at an acceptable third for each chord.

A NEW APPROACH TO DIATONIC AUTOHARP TUNING

The problem with all the historic tempering systems is that they are designed for tuning scales and are meant to account for any combination of intervals within those scales. However, last time I looked, the autoharp is ONLY made up of chords. In general, you play the notes of a melody by selecting one of the chords available for a given note. The harmony is whatever other notes are contained in the selected chord. Therefore, the premium should be placed on having the chords in tune with themselves, not the scale.

If you have a 'harp set up in a diatonic scale, the justly-intoned notes within the chords will all be harmonious except the #2-#5 (d-a in the C scale) found in the IIm and partial II7 chords, as well as other "color" chords.

Here is one method of dealing with this dilemma.

If you assume that it's more important to have certain chords in better tune than others, you can favor those with sweeter intervals. (By extension, in a chromatic autoharp setup - some keys are more important, some chords within those keys are more important, and some intervals within those chords are more important – and the temperance can be adjusted accordingly.) What results is that, when you play a musical piece, as the progression moves away from the harmonic center, the chords become less "in tune". A dissonant tension is created and is subsequently resolved when you return "home" to the I chord at the end of the piece, as most musical compositions do.

Considering diatonic chords only, the order of importance from the most to the least, is:

I – V – V7 – IV – VIm – IIm

(the IIIm will take care of itself once the others are adjusted)

Here is a system of temperance based on those assumptions and is a modification of the fifths at "0", thirds at "-12" approach discussed earlier:

STEP	NOTE	CENTS
1	c	0
2	d	0
3	e	-10
4	f	+2.5
5	g	0
6	a	-5
7	b	-10

This made sense to me theoretically, but in practice the system I ended up using for years was simpler but with a slightly greater compromise of the thirds.

STEP	NOTE	CENTS
1	c	0
2	d	-2.5
3	e	-7.5
4	f	0
5	g	0
6	a	-7.5
7	b	-7.5

Displayed as a circle of fifths:

STEP	NOTE	CENTS
4	f	0
1	c	0
5	g	0
2	d	-2.5
6	a	-7.5
5	e	-7.5
7	b	-7.5

And this worked reasonably well both in playing solo or with groups, the adjustments being slightly altered depending on circumstances.

A RADICAL DEPARTURE

Since I first started tuning autoharps, I knew they could sound better. This was back in the days before electronic tuners, so approaching it as a guitarist, I would tune by ear using the string harmonics as my guide. I was in for a lot of frustration. But I blundered through, and by listening closely and reconciling the various chords with their component notes, I made the best of it. Of course, this is how Maybelle and Sara Carter, Kilby Snow, and all autoharp players that had come before had done it – and with satisfactory results.

It was also my good fortune to be around Bryan Bowers right after he had first diatonized his 'harps and tuned them by his exceptional ear. I remember sitting in the kitchen of the Prism Coffeehouse and slowly strumming the chords on his harp. It was like buttah. I had heard the gold standard of autoharp tuning up close. That was many years before I did the math and worked through the thought processes detailed above, though I had also discovered that if you were planning to record a song in a given key, you could optimize the compromises for that one performance.

THE QUEST FOR TRUE HARMONY (or Pythagoras' Revenge)

But if you are in quest of the true harmony most pleasing to the ear, which in theory as well as practice is the mathematically sympathetic vibration, you still have not only the IIm conundrum but this central problem with equal temperament: even when both notes of a fifth are fixed at "0" on the electronic tuning meter, THEY ARE STILL OUT OF TUNE.

The "perfect" fifth is actually 1.91 cents sharp of the tonic (go ahead, call it 2 cents). If you try to build this into your temperance for the tonic, dominant, and subdominant, you will be forced to make even greater compromises further down the line. This will be an insurmountable obstacle unless …UNLESS you have two different "#2 d" notes. Again, because of the peculiarities of the diatonic autoharp, this can be accomplished with a little radical "open harp" surgery.

A standard autoharp has 36 strings arrayed in a mostly chromatic series of notes – in the middle octave you have all 12 notes to work with. By setting up a diatonic arrangement with just seven notes - for example in the key of C - you remove the accidental steps (c#, d#, f#, g#), thus providing some leftover strings. These notes are doubled to increase volume and the likelihood of hitting one's target. Usually the logical notes to double go according to their importance in the scale and frequency of appearance in the various chords – i.e. the tonic, dominant, and subdominant. The "2" note is most often left single. However, if you have it doubled, you can tune one to fit the V triad (5-2-7) and one to fit with the IIm (2-4-6) and cut your chord bar felts accordingly.

There are still compromises to be made, but … oh, what a difference a "d" makes. If you want to preserve the "open chording" technique which increases speed and can provide pleasing harmonic effects (and most diatonic players would), you have to keep the two "d's" close enough in pitch so that they are not jarringly dissonant.

Therefore, I arrived at the following configuration:

STEP	NOTE	CENTS
4	f	-2
1	c	0
5	g	+2
+2	+d	+3
-2	-d	-5
6	a	-8
5	e	-8
7	b	-8

You may have noticed that the 6-5-7 fifths of this arrangement, all at -8 cents, though not perfect, are still superior to the flatted fifths of most mean tone temperaments. [Note: the +d note is moved up just

one cent – a compromise to keep it closer to the –d note]

Here is how the temperaments for the various chords work out:

CHORD	STEP	NOTES	CENTS
C	I	c, e, g	0,-8,+2
F	IV	f, a, c	-2,-8,0
G	V	g, b, +d	+2,-8,+3
Am	VIm	a, c, e	-8,0,-8
Em	IIIm	e, g, b	-8,0,-8
Dm	IIm	-d, f, a	-5,-2,-8
G7	V7	g,b,+d,f	+2,-8,+3,-2
D7*	II7*	-d, c, a	-5,0,-8

*partial chord

To get the minor chord fifths perfect, you could go with:

STEP	NOTE	CENTS
4	f	-2
1	c	0
5	g	+2
2+	d+	+6
2-	d-	-14
6	a	-11
5	e	-8
7	b	-5

But the +6 d and the -14 d, would be, to put it charitably, noticeable. If you try to push the thirds even lower towards just intonation, the second step spread becomes even more pronounced. Still, if you have arrangements which only used closed position chords (i.e. chord bars pressed down) and no fear of hitting the un-tuned double note, this could work, especially for slow tunes in minor keys.

In conclusion, the proof of the tuning is in the playing. My 'harps have never sounded better and are a joy to pick up and swat away at. Since they are better in tune to start with, it takes longer for them to go really off. And it is easier to make an adjustment to a single sour note by ear. Consequently, I end up playing them more, which is both a good and bad thing. But mostly good.

Will Smith, Nolensville TN
April 23, 2006

Much of Part I and an earlier version of Part II of this disquisition was used for a workshop during the Augusta Heritage Autoharp Week at Davis Elkins College in 1988

MISCELLANEOUS TUNING TIPS

1) *Find a quiet place*

First, find someplace quiet. I know this is obvious, but I couldn't leave it out. And ceiling fans, in particular, disturb the sound waves and make the notes waver.

2) *Stretch the strings*

Make sure your strings have been stretched if the 'harp has been sitting a while, especially if it is new. This is a tedious process: tune reasonably close to standard pitch, push and pull on the string, check the tuner, then tune again; repeat this procedure until it holds, usually two or three times. (Often this method can be used to "fine-tune" a note, lowering it 2.5 cents or so.)

3) *"Rough tune" first*

Do a rough tune first, putting all the notes "in the neighborhood", before trying to fine-tune; this will evenly distribute the tension on the 'harp.

4) *Go through the circle of fifths*

If tuning by ear, go around the circle of fifths, starting with f, using the harmonics to give you the perfect fifths and octaves. Keep in mind the d,a,e, etc. should be flattened slightly so they will fit in as thirds. You could also do this by obtaining the #1 and #5 notes for each major chord and then tuning the middle third note to the other two.

5) *Favor high needle jumps*

If you're using a tuning machine, tend to favor the higher jumps of the needle because in melody playing the initial onset of the note is what you'll hear most often. This is especially true of the bass notes since as the vibrating string returns to stasis, the meter will show a progressively lower pitch – so if the "settling" point is lower than its octaves, the initial wider vibrations will be closer in pitch.

6) *Install a fine tuning system*

A set of fine-tuners (available from a number of parts dealers/repairmen) is expensive and takes a while to install but saves time and anxiety in the long run.

7) *Clip your wrench*

If using a clip-on tuner pickup or alligator-type clasp, fasten it to the shaft of your tuning wrench or fine-tuner Allen wrench. This will transfer string vibrations fairly accurately and save you from having to move it around to different spots on the harp for the various notes.
(Tip of the Hat to Drew Smith)

8) *Zero point is arbitrary*

When you start tuning, check the different notes to see where they have settled and remember that the less you have to alter the better, and that, unless you are playing with other instruments, it does not matter which note is assigned the "zero" point as long as all are in tune *relative* to each other. Strings have a "memory" and will want to return to previous tension, so the less you have to change it, the more likely it is to hold.

9) *Check m7 arpeggios*
Once you think you've got things right, check by playing minor 7th arpeggios made up of notes from the I and VIm chords
(C+Am = c e g a = Am7; G+Em = g b d e= Em7, etc.)
You don’t actually have to have an Am7, for example, just pick the strings from the chord and let them ring. They should not clash too much.

10) *Clean your strings*
From time to time, use some kind of commercial solvent (like Fast Fret or a spray-on-cloth type for guitar strings) to get the grease and grime off your wires. Assuming you pluck with your fingernails to get the note and/or tune with harmonics, the oils from your grubby little mitts get on your autoharp. The build up can cut down the vibrations and distort the readings of your strings. So wash your hands before tuning. Actually, wash your hands anyway to keep from catching a cold.