LucyScaleDevelopments present:

LucyTuned Guitars

The first practical LucyTuned guitar was the Mk V, which was first made in 1986. It has twenty-five frets per octave.

The story of its design and construction can be found in [chapter one of *Pitch, Pi, and Other Musical Paradoxes*](#) . This is the design used by Arc-Angel and there are now a few hundred copies which have been made in all parts of the world. Although the design was patented, permission has been given for their non-commercial production for personal use. The design details have been evolving, and it is now proposed that new users start with the nineteen fret per octave model, and with experience add twelve further frets to make it thirty-one frets per octave.

Playing LucyTuned guitars

[Diagram of LucyTuned and 12tET frettings](#)

This design is intended to make the evolution from 12tET to LucyTuning as easy as possible for experienced musicians and new players. Although all frets, except the octave, are at different positions; the dots or marks found on the neck and fretboard of a conventional guitar are found at directly comparable positions on LucyTuned guitars. The familiar "landmarks" usually found at the 3, 5, 7, 9, and 12th frets on 12tET guitars, are placed at the bIII, IV, V, VI, and VIII positions. (i.e. C, D, E, and F# for the A (5th) string. This enables new users to use familiar open tunings and immediately navigate around the fretboard using familiar fingering.

When playing with more than 19 frets per octave you will use pairs of close frets. Placing your fingers **below** (towards the nut from) **the pair** will sound the **flatter** note. Playing **on the pair** will sound the **sharper** of the two notes.

You will notice that all the **sharper** of the notes sounded from the pairs will be in **sharp keys**; the **lower of the pair** being in **flat keys**.

Tuning LucyTuned guitars

Any tuning of the open strings may be used: conventional (EADGBE), slack key, alternative etc. yet each string will need to be referenced to A4 = 440 Hz. and other notes fine tuned (+/- a few cents). This may be done by matching to frets on adjacent strings, using "harmonics", or an electronic tuner. The tuning needs to be very precise, yet when you have got correct, it will be very apparent, for chords you play will sound very "in tune".

Using conventional tuning the changes are:

Open String	**. . . 6 . E**	**. . 5 . A**	**. 4 . D**	**3 . G**	**. . . . . 2 . B**	**. . . 1 . E**
Change (cents)	4.5 cents **flat** (**b**)	**same** as 12 tET **110 Hz.**	**4.5** cents **sharp** (#)	**9.0** cents **sharp** (#)	**9.0** cents flat (**b**)	**4.5** cents flat (**b**)

Getting *your own* LucyTuned guitar

There are a number of options.

New Neck and fretboard

New necks can be manufactured for most solid guitars with any specified fretting by: John Carruthers, 346, Sunset Ave, Venice, California 90291. Phone 1 (213) 392-3910 contact Jim Hetal.

Magnetic Fretboard Kits

Mark Rankin, (last seen in Phoenix, AZ.), mail at: Franklin City, Greensbackville, VA 23356, phone contact numbers 1 (714) 688-9894 and 1 (415) 658-1889 can provide a kit for interchangeable fretboards, which are held in position by a magnetic laminate.

DIY: You can produce your own, using magnetic laminate available from: Magna Visual Inc. 9400, Watson Road, St. Louis, Missouri 63126-1598: Voice 1 (314) 843-9000 or Fax 1 (314) 843-0000. ($15 for two sheets .045" x 12" x 24"). You will need to remove all frets and plane or sand down your fretboard to glue on a thin metal sheet (I have used thin galvanised roofing material), then cut the laminate to size, and attach the frets to the laminate.

You can then use the guitar fretless, or with a variety of interchangeable fretting systems.

Refretting

You can get an existing guitar refretted by any competent luthier. I use and recommend: Colin Noden at

Andy's Guitar Shop, Denmark St. London W1. He is very experienced and usually busy, yet does an excellent job. Most luthiers will charge a couple of hundred dollars for the work, and will need the exact fret positions which depend upon your nut to bridge distance.
In the US, you might also try Glen Peterson.
If your instrument has other than 650 mm from nut to bridge, you will need to pro-rata the distances, or EMail to Charles Lucy from here. (lucy@ilhawaii.net) with your nut to bridge distance (in inches or millimeters) to get the AmigaBasic or spreadsheet program or a file of the output.

DIY: Doing it yourself is the least expensive route. Remove all the frets. Fill the holes with Plastic Wood. Allow to dry overnight. Sand the board and stick masking tape over it so that you can mark out the fret positions. Draw a straight line from the centre of the nut to the centre of the bridge as a reference for fret alignment, and mark each fret position. Cut fret grooves; remove the masking tape, insert the frets; secure them; trim; file; dress; set up guitar and enjoy playing your LucyTuned guitar.

I suggest 19 frets per octave initially, so that you can add more frets later as you gain playing experience. Use mandolin fretwire for the second octave, so that there will be space for the extra frets later.

Fret positions for LucyTuned 19 & 31 frets per octave instruments.

Intervals	Ratio	Cents
Large (L)	1.116633	190.9858
small (s)	1.073344	122.5354

Distance from Nut to Bridge = **650** (millimetres)

(for other other nut to bridge distances, values can be pro-rated)

Diagram of LucyTuned and12tET frettings

Note Name Guitar Fifth String (* = marks)	Scale Position	Distance Nut to fret First Octave	Fret No. of **19** for **First octave** (0-19)	Fret No. of **31** for **First octave** (0-31)	Large (L) and small (s) Intervals from nut. Add (5L+2s) for second octave	Distance Nut to fret Second Octave	Fret No. of **19** for **Second octave** (19-38)	Fret No. of **31** for **Second octave** (31-62)
A	I	-	Nut	Nut	Zero & 5L+2s	325.0	19	31
Bbb	bbII	019.9923	-	1	2s-L	334.9962	-	32
A#	#I	025.1987	1	2	L-s	337.5994	20	33
Bb	bII	044.4160	2	3	s	347.2080	21	34
Ax	xI	049.4295	-	4	2L-2s	349.7103	-	35
B	II	067.8928	3	5	L	358.9464	22	36
Cb	bbIII	085.7970	-	6	2s	367.8985	-	37
B#	#II	090.4595	4	7	2L-s	370.2298	23	38

*C	bIII*	107.6696	*5	8*	L+s	378.8348	*24	39*
Dbb	bbIV	124.3503	-	9	3s	387.1751	-	40
C#	III	128.6942	6	10	2L	389.3471	25	41
Db	bIV	144.7283	7	11	L+2s	397.3641	26	42
Cx	#III	148.9038	-	12	3L-s	399.4519	-	43
*D	IV*	164.3163	*8	13*	2L+s	407.1581	*27	44*
Ebb	bbV	179.2546	-	14	L+3s	414.6273	-	45
D#	#IV	183.1449	9	15	3L	416.5724	28	46
Eb	bV	197.5042	10	16	2L+2s	423.7521	29	47
Dx	xIV	201.2436	-	17	4L-s	425.6218	-	48
*E	V*	215.9462	*11	18*	3L+s	432.5231	*30	49*
Fb	bbVI	228.4242	-	19	2L+3s	439.2121	-	50
E#	#V	231.9081	12	20	4L	440.9541	31	51
F	bVI	244.7676	13	21	3L+2s	447.3838	32	52
Ex	xV	248.1164	-	22	5L-s	449.0582	-	53
*F#	VI*	260.4773	*14	23*	4L+s	455.2387	*33	54*
Gb	bbVII	272.4580	15	24	3L+3s	461.2290	34	55
Fx	#VI	275.5781	-	25	5L	462.7890	-	56
G	bVII	287.0943	16	26	4L+2s	468.5472	35	57
Abb	bbVIII	298.2564	-	27	3L+4s	474.1282	-	58
G#	VII	301.1632	17	28	5L+s	475.5816	36	59
Ab	bVIII	311.8925	18	29	4L+3s	480.9462	37	60
Gx	#VII	314.6866	-	30	6L	482.3433	-	61
**A	VIII**	325.0000	19**	31**	5L+2s	487.5000	38**	62**

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an extract from:

Pitch, Pi, and Other Musical Paradoxes (A Practical Guide to Natural Microtonality)

by Charles E. H. Lucy ISBN 0-9512879-0-7

Chapter One.

IS THIS THE LOST MUSIC OF THE SPHERES?

After twenty five years of playing, I realised that I was still unable to tune any guitar so that it sounded in tune for both an open G major and an open E major. I tried tuning forks, pitch pipes, electronic tuners and harmonics at the seventh, fifth and twelfth frets. I sampled the best guitars I could find, but none would "sing" for both chords. At the risk of appearing tone deaf, I confessed my incompetence to a few trusted musical friends, secretly hoping that someone would initiate me into the secret of tuning guitars, so that they would "sing" for all chords. A few admitted that they had the same problem, but none would reveal the secret.

I had read how the position of the frets was calculated from the twelfth root of two, so that each of the twelve semitones in an octave had equal intervals of 100 cents. It is the equality of these intervals, which allows us to easily modulate or transpose into any of the twelve keys.

Without realising it, I had begun a quest for the lost music of the spheres. I still secretly doubted my musical ear, but rationalised my search by professing an interest in microtonal music, and claimed to be searching for the next step in the evolution of music. First stop library, where I found Helmholtz's book *On The Sensations Of Tone*. He introduced me to thousands of alternative tunings. The only universal 'truth', on which all tunings agreed was that halving the length of a string doubles the frequency, and produces a ratio of 2.00000:1 which is known as an octave. This octave was subdivided in three basic ways;

1) By a geometric progression, with any number of equal intervals.Eg. 12 (as on conventional guitars) [100 cents per semitone or interval]; 31 as advocated by Huyghens (1629-1695) [38.71 cents per interval], or 53 by Mercator and Bosanquet (1876 Treatise) [22.64 cents];

2) By low whole number ratios. Eg. (Just Intonation) 3:2 for the Vth; 5:4 for the major third etc.

3) By cumulative fifths. Eg. Pythagorean Tuning 3:2 for the Vth; but 81:64 for the major third.

There are also hybrids of the other three, Eg. Meantone Temperaments .

If the only point of agreement is that the octave ratio should be exactly two; how do we explain the phenomenon of stretched octaves, used by some piano tuners?

The Pythagorean system , instead of arriving at the octave after 12 steps i.e. (3^12)/(2^18) becomes 531441/262144 = 2.0272865 instead of 2.0000 as we assume when tuning a guitar by fifths at the seventh fret. This difference or error is known as *Pythagoras' lemma*. Every system seems to be an imperfect compromise, which is probably why mathematicians and musicians have devoted millions of hours to searching for the perfect scale.

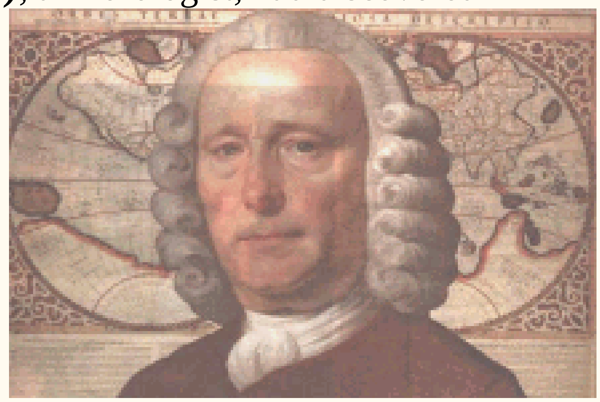
Initially, the idea of 53 notes on a geometric progression seemed to be a sensible solution, and I read that

Bosanquet's harmonium on this scale had been in the Kensington Science Museum since the 1880's. I went to find it, but it was in storage. Instead I found Mr. Chew. I told him of my quest and that I had a hunch that the solution was in some way connected with the music of the spheres and the Greek letter " Pi ".

π

"That's what Harrison thought."

I enquired further and discovered that **John Harrison** ***(1693-1776)***, an horologist, had discovered longitude and won a £20,000 prize from Parliament after the personal intervention of George III. I was directed to the Clockmakers' Library in the Guildhall, and there found a treasured copy of *A Description concerning such Mechanism as will afford a nice, or true Mensuration of Time; together with Some Account of the Attempts for the Discovery of the Longitude by the Moon; and also An Account of the Discovery of the Scale of Musick*, harrison.zip only to be refused permission to photocopy any of it, due to its antiquity. I eventually acquired photocopies of the relevant pages from another source. Harrison had written in such an obscure style that I suspected that he intended to hide its secrets from all but the most diligent enquirer.



The essence of what Harrison said is as follows:

"The *natural scale of music* is associated with the ratio of the diameter of a circle to its circumference." (i.e. pi = 3.14159265358979323846 etc.)

"This scale is based on two intervals;"

1) The *Larger note* as he calls it; This is a ratio of 2 to the 2*pi root of 2, or in BASIC computer terms 2^(1/(2*pi)), which equals a ratio of 1.116633 or 190.9858 cents, approximately 1.91 frets on a conventional guitar. (L)

2) The *lesser note*, which is half the difference between five *Larger notes* (5L) and an octave. i.e.(2/(2^(1/(2*pi)))^5)^(1/2), giving a ratio of 1.073344 or 122.5354 cents, an interval of approx. 1.23 frets. (s)

The equivalent of the fifth (i.e. seventh fret on guitar) is composed of three Large (3L) plus one small note (s) i.e. (3L+s) = (190.986*3) + (122.535) = 695.493 cents or ratio of 1.494412.

The equivalent of the fourth (IV) (fifth fret) is 2L+s = 504.507 cents.

Harrison discovered this scale experimenting with monochords and a viol, and trained a church choir in Lincolnshire to sing it.

From this information I constructed a number of computer programs to explore all the possible permutations and combinations which could generate a practical scale. My problem was to decide which of the hundreds of intervals which I calculated by addition and subtraction of multiples of the Large (L) and small (s) interval should be used. Faced with pages of possible results, I decided to select intervals by finding which notes would match if I constructed a circle of fifths using the ratio of 1.494412.i.e. (1.494412^2)/x.........to.....(1.494412^n)/x. x being an exponential of 2, the use of which as a divisor would give a result between 1 and 2 and hence in the first octave. Although I had originally intended to use MIDI pitch bend for the scale, I dreamt of an instrument which would be simple to play, in any key of up to 7 sharps or flats, for any competent guitarist.

The following morning my feet led me to Denmark St. where I casually mentioned that I had dreamt about this very strange guitar, and asked how I could make one. The only guitar I owned, liked, and was willing to modify was a Westone Raider II. I agreed a price with Graham Noden of Andy's, and rushed home to calculate the fret positions. I listed the note names, frequencies in Hertz, ratios, and fret positions for 20 frets per octave and a total of 35 frets; and delivered the Westone, instructions, and a detailed explanation of the mathematics to determine the fret positions.

On Christmas eve, Graham phoned me to say that he had started on the guitar, but that the ninth fret seemed to be in the wrong place, so would I please check my calculations. I did, and called him back with the position for an extra fret, between what had previously been the ninth and tenth frets.

When I called to pick up the finished job, Graham had already left for Christmas. I took home the first instrument to play the scale a renowned genius had first described two hundred and eleven years earlier. The tuning had to be done by ear, as only the open fifth string would be the same as any other guitar at 110 Hertz. I set it from a tuning fork, tuned the others from the appropriate frets, and slowly strummed an open G Major. The intervals sound foreign, but this chord certainly sings. Now for an open E; the same result. It works. Harrison must have imagined this moment when he wrote his book for some future generation to decipher. I spent the next two hours trying chords and melodies which I had previously only played on a conventional guitar. It was difficult at first to remember that sharp and flat notes must conform to the key of the piece, but with a little practice everything became playable except for the frets between the ninth and the octave, where something was definitely wrong. I checked the measurements. They matched my instructions exactly. Graham had certainly done his part perfectly. I checked the ratios against the fret positions; perfect up to the ninth, but between 10 and the octave nothing made sense. Two hours later I realised my mistake.

I had selected the wrong intervals, because my program had listed six fret positions on each line and after nine, I had counted the intervals out of synchronisation with the fret positions. Back into the computer. Two days later I had cracked it, and added a few extra frets on my instruction sheet. Lucy Guitar Mark V has twenty-five frets to the octave and a total of forty-five. It can be played in any key of up to 11 flats or 11 sharps.

Initially the layout of the Mark V looks confusing, for there are six pairs of close frets in each octave, and above the first octave, it was essential to use mandolin wire as the adjacent frets are very close. Although the guitar sounded harmonically perfect I found the average guitarist was initially intimidated by Mark V.

Details and specifications of LucyTuned guitars

This apprehension resulted in Lucy guitar Mark VII with nineteen frets to the octave by eliminating the least used of the frets in pairs. Mark VII is easier to play, but lacks the tonal versatility of Mark V, for it limits the number of keys which may be used to up to 7 flats or 9 sharps, or any conceivable key, if an error of (2L - 3s) = 14.367 cents between sharps and adjacent flats is tolerable. By compromising and replacing the pairs of frets on the Mark V by a single midpoint fret, this error may be reduced to 14.367/2 = 7.2 cents. Any pitch is sharpened or flattened by adding or subtracting the difference between a Large and a small interval i.e. (L-s) = 68.451 cents.

Applying the scale to synthesisers, I found that if the *black* keypads were all assigned to appropriate sharps or all to flat pitches, the system sounded consonant. Mixing sharps and flats caused interesting effects, but contradictory altered notes tended to sound dissonant.

To produce the most viable use on keyboard instruments of only twelve keypads per octave, the appropriate pitches for the *black* keys need to be programmed, or fast-loaded, from a selection of choices dependent upon the tonality of the piece to be played, but for some experimental keyboards of 31 or 53 keypads per octave the tunings may be fixed, and modulations between sharp keys and flat keys achieved.

LucyTuning using pitchbend and MIDI

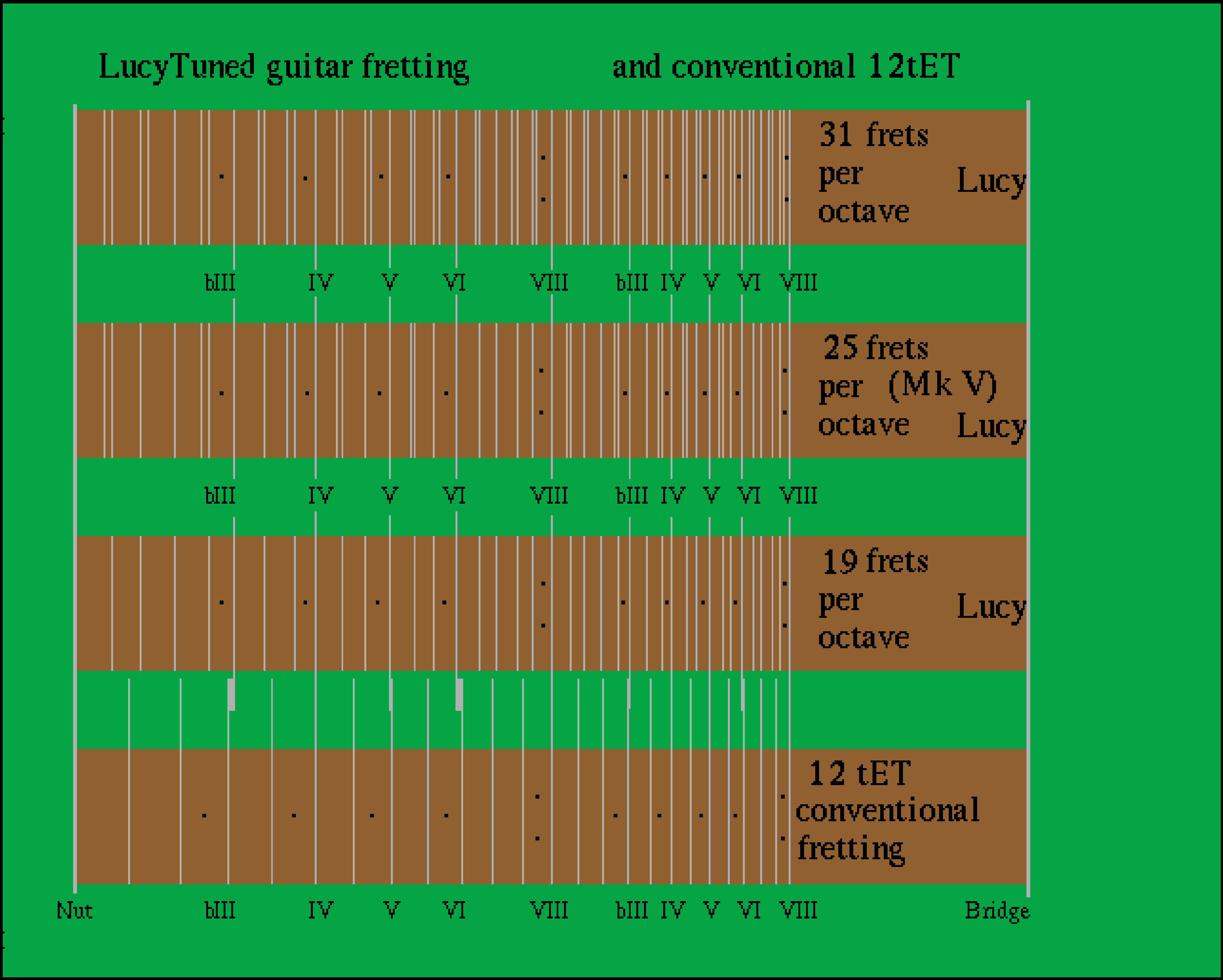
This book is a constantly evolving document, to also report progress to readers. Many instruments, including harmonicas, banjos, basses etc. have now been produced, tuned or modified to this scale. The 19 frets per octave guitar has served its purpose as a starting point for timid players, but the limitations and tuning compromises soon became apparent. The 25 fret guitar has become the most versatile fretted instrument as all the notes are 'in tune', but this I'm sure will also evolve as musicians reach further into new tonalities. (as it has) As hundreds of people are now using these discoveries, research continues particularly into the connections to physics, mathematics, topology, and to music other than equal temperament for composition and performance.

Download Chapter One and associated files as Adobe (.pdf) format for view and print

|synopsis and order info. for this book| |Chapter Two| |Chapter Three| |To view table of more than sixty scales and their codes| |Recipe to build a physical model|

|LucyTuning homepage|

Fretting patterns for 12 tone Equal Temperament and LucyTuned 19, 25, and 31 per Octave



The diagram above only shows the positions for 12tET and LucyTuned 19, 25, and 31, frets per octave.
The MS Works 4.0 spreadsheet which may be downloaded below lists exact values for 19, 31, and 53 fret positions for LucyTuned instruments for 650 mm nut to bridge fretboards. If you have MS Works 4.0 it may be adjusted to give fretting positions for any nut to bridge distance, and any meantone, LucyTuned, or equal temperament tunings.

Download Microsoft Works 4.0 Spreadsheet - worksfret.zip

|Fretting Specifications and Instructions| |More diagrams about LucyTuning| |LucyTuning homepage|