20

THE MODULAR KEYBOARD

NOVEL TUNING UTILITIES SOFTWARE
For
MIDI-EQUIPED DIGITAL SYNTHESIZERS

By SIEMEN TERPSTRA

For some years I have been intriqued by the idea of applying 53-Equal-Temperament (Quasi-Just Intonation) to the polyphonic keyboard. This Tuning System allows excellant approximations of 3-Limit and 5-Limit ratios as well as good approximations of many 7-Limit intervals. Moreover, being a closed cyclical system, it allows unlimited modulation to all keys. But how can a system of such complexity be represented on a keyboard in a comfortable, playable manner?

One approach is to design a new keyboard especially for that tuning system. I built a cardboard mock-up of Bosanquet's keyboard in order to feel it under my fingers. (The design specifications are described in Helmholtz--ON THE SENSATIONS OF TONE). I found that it was comfortable for 3-Limit patterns,that is , "Pythagorean" type chords and scales; but it was awkward when playing most 5-Limit (Just Intonation) and 7-Limit patterns. Now some modification of the Bosanquet keyboard may indeed be workable, but I directed my efforts back to the standard keyboard. So many people are accustomed to that design. Can 53-E.T. be adapted to the old, black-and-white ivories?

Basically two solutions to this problem have been tried. The first solution I call the "big spread." The pitches are simply spread along the keys without regard to the usual interval layout. The result is less than two octaves of the scale, since keyboards have at most eighty-eight keys and many have less. This narrow range is musically unacceptable. And to make matters worse, even the closed-position chords involve wide and awkward stretches. So this approach is out.

The second, and most common, solution resigns us to the 12 note limit of the keyboard. We may retune those 12 notes per octave any way we want, but to do it we must stop playing and load up the frequency files of the tuning we wish. Now 53-E.T. offers many ways of tuning the chromatic scale--it offers "modes" of the chromatic scale. So we can play in 53-E.T., but always only in some 12 note subset of the system. Hence we cannot modulate freely at will or take advantage of the wider harmonic implications of the system. To move to a more "distant" key we must stop playing, and load up the new intonations. This solution is therefore also unacceptable.

The MODULAR KEYBOARD offers a more versatile solution. It overcomes the above limitations by using a principle akin to

"bar chords" on the guitar. In order to explain the basis of the design, I must delve a little into the structure of 53-E.T.

This tuning system is fundamentally a scale of commas. Consequently, as an easy preliminary notation, the pitches are numbered from 0 to 52. The pitch numbered 0 (which equals 53) stands for our tuning reference pitch "C." This notation is handy, since it gives the size of any given interval in commas. For example, pitch number 31 (G) stands for the interval of the Pure Musical Fifth (ratio 3:2) and is exactly 31 commas in size. The pitch numbered 17 (E) is the Just Musical Major Third (ratio 5:4) and it is 17 commas in size. The Pythagorean Major Third, which is a comma sharp, has comma number 18. And so on. Those of you interested in questions of notation in regard to 53-E.T. and Just Intonation may refer to my article on notation in INTERFACE--JOURNAL OF NEW MUSIC RESEARCH, Volume 14 (1985), Utrecht, Netherlands.

Just Intonation consists essentially of ratios derived from the 3rd and 5th Harmonics. The 2nd Harmonic is considered a "floating" quantity due to the principle of Octave Equivalence. Ratios using the 7th Harmonic are expressed indirectly through 5-Limit approximations. As a result the system may be presented as a tuning matrix derived directly from the 3 * 5 multiplication table. The primary tuning nucleus is shown in Figure 1.

We establish three tuning axes, and hence six tuning directions. The horizontal axis indicates tuning in Pure Musical Fifths and Fourths. The two directions of this axis show tuning in the Dominant direction and the Sub-dominant direction. The oblique axis pointing upward to the right indicates tuning in Just Musical Major Thirds and Minor Sixths (the 5:4 axis). The third axis points obliquely upward to the left. It indicates tuning in Just Musical Major Sixths and Minor Thirds (the 5:3 axis). Thus, for example, the pitch 31 (G) may be tuned from our reference C by tuning up in pitch a Fifth (3:2) or by tuning down a Fourth (3:4). The downward pointing ratios are bracketed. These fractions may be read directly as frequency ratios, or inverted to indicate ideal string lengths on a monochord. They may also be read directly as Harmonics when actually tuning strings. For example, in order to tune G a pure Fifth above C, form a beatless unison between the 3rd Harmonic of the C string, and the 2nd Harmonic of the G string. Viola players know this well.

This nucleus of tuning proceedures may be extended, so that, for example, pitch number 9 (D) can be derived as a 3:2 from G. Or again, pitch 34 (G#) may be derived as a 5:4 ratio above 17 (E). All six tuning directions may be extended indefinitely, theoretically to infinity, but in actual tuning practice there are "natural boundaries" encountered to limit the expansion.

Figure 2 shows the entire field of Quasi-Just Intonation. The natural boundary of the horizontal axis arrives when we encounter the schisma. Tune along the line of fourths-fifths from 0-22-44-13-35 to 4 (the Pythagorean

semi-tone). A boundary is crossed. Now tune from 0-31-9-40 and up a Major Third to-- 4! These two pitches are almost identical. The left-hand side pitch number 4 is a schisma flat of the other pitch 4, which is inside the boundary. Similarly, pitch 49 on the right is a schisma sharp of pitch 49 on the left inside the boundary. Now the schisma is worth about 2 Cents and is generally below our pitch discrimination threshold. This interval is also the difference between the Ditonic comma and the Syntonic comma. The tempering of 53-E.T. eliminates the schisma and uses a "mean" comma midway in size to stand for both types of commas. Hence the boundary to horizontal expansion. Note that any long strand of horizontal tuning leads to a pattern which includes a Just segment. For example, tune 0-22-44-13-35-4-26-48-17. In pure Just Intonation the pitch 17 (E) is a schisma flat of a 5:4. 53-E.T. uses a midway size, about 1 Cent flat of a Just 5:4. Now such temperings are generally below our perception threshold. Hence 53-E.T. is such a good approximation of Pythagorean and Just ratios.

The top and bottom of the field is bounded by the Enharmonic Gateway (pitches 11 and 42). Note the tuning progression 11-25-39-0-14-28-42. The whole pattern turns into a "strange loop". When the circle of Fifths for 53-E.T. is laid out, pitches 11 and 42 are at the opposite side as our generator pitch 0. This boundary to the 5:3 axis results in a closed system of 53 pitches per octave.

One more prominant aspect of Just Intonation. Note the four pitches 29-24-7-46 which inhabit all four "corners" of the field. These pitches are the Harmonic Antipodes. Tuning in practically any direction (except the Enharmonic Gateway) brings us to this area. If we consider 0 (C) as our "north pole", then walking in any direction takes us to the "south pole". Note that pitch 24 approximates the 11th Harmonic ratio (11:8) and 29 is the 11th Sub-harmonic ratio (16:11). The cyclical temperament 31-E.T. preserves the Harmonic Antipodes since it orients around the 5:4 axis, but the 19-E.T. system and the 12-E.T. system eliminate it. The 19-E.T. system orients strongly along the 5:3 axis and the Enharmonic Gateway.

There are many other fascinating strucural features to the 53-E.T. system and the other closely related cyclical temperaments, but we do not need them explained here. Only note the highlighted area on Figure 2. The field naturally divides into three regions. The left-hand region contains comma-lowered intervals, and the right-handed region contains comma-raised intervals. In the central region the intervals are not comma-altered. Here is an important key to a clear notation for the system.

It is important to grasp that this field diagram is planimetric. That is, every type of chord or scale has its own "shape" which is intrinsic to it. To modulate patterns we simply shift them around the diagram. For example, every upward-pointing triangle is a Just Major Triad, and every downward-pointing

triangle is a Just Minor Triad. Hence, the graph has sometimes been called the Web of Just Triads. Not only triads, but any harmonic pattern may be visually represented. I have used this field diagram to organize the Modal Tables for the system.

Our interest now is in chromatic scales for our chromatic keyboard. Now there are many ways to tune a chromatic scale in the system--in fact, there are about 36 "best" modal forms for the chromatic scale. Two representative examples are shown in Figure 3 and Figure 4. Beside the field diagram is the natural application to the keyboard.

The Modular Keyboard Software allows me to build any such chromatic scale and store it on Disk to be loaded up at will. But, you ask, how is this any different from the "second" approach described earlier? Here is the new feature.

Once a desired chromatic scale is loaded up from Disk, it becomes a CHROMATIC MODULE which may be instantly shifted anywhere in the whole field (ie. 53 positions). This shift is accomplished by punching the FIELD NUMBER on the computer keyboard. The intonation of the entire music keyboard is shifted instantaniously. For example, if I load up the module which is Figure 3, then press field number 45, the intonation of the keyboard shifts to that shown on Figure 5. Note that in this shift, some pitches changed, and others did not. For example, the pitch 9 (D) did not change. We may shift to closely related harmonic spaces where only one or two pitches change by a comma, or we may jump instantly to "remote" harmonic regions. Hence we have free modulation anywhere in 53-E.T.

Now I have been concentrating on the 53 system, but this software allows me to set up a field of any number of pitches--any division of the octave (up to 53). Thus it will also provide good access to the other good cyclical temperaments--eg. 31-E.T., 19-E.T., and so on. Needless to say, it also ennables me to play in "bizarre" temperaments like 17 or 23. The same set-up applies. A chromatic module is selected which may be shifted anywhere in the system. Generally this module is a segment of the circle of fifths for that particular tuning system.

Hence this software allows me to explore many harmonic "spaces" both wonderful and wierd! And it allows me to do it in "real time" through my synthesizer. Thanks to some funding through the CANADA COUNCIL, this equipment is now operational. At the present time I'm doing some recording with it.

The main limitation to the design is the restriction to cyclical temperaments only. However, even with this limitation, a vast field is opened up. It is well known that the best cyclical temperaments are 12, 19, 31, 41, 43, 50, and 53. This software has allowed me to personally evaluate these various systems. To my ear, 53 and 31 are the best. The 31 system is especially interesting due to its sonic equivalence to one-quarter comma Meantone tuning. Hence it is very useful for performance of

Renaissance and Baroque music. The "extended meantone" type harmonies of a composer like Gesualdo may be accurately rendered. Thus this software is useful for the performance of "old" music as well as the creation of new forms of harmony.