THE LONG STRING INSTRUMENT

Designed and built by Ellen Fullman

The standard string instruments derive their sound from the transverse vibrations of the strings. In these strings the predominant vibrational movement, the one which produces most of the sound, is that of the string moving back and forth in a direction perpendicular to its length. But transverse vibration is not the only dance that strings can do: there are other modes of vibration, most notably the longitudinal.

In longitudinal vibration the direction of movement is along the length of the string. The vibration is caused by waves of compression and decompression of the material of which the string is made, comparable to waves in the air or in a liquid medium. In a string which is fastened at both ends, the waves will travel from end to end, bouncing back and forth, and causing any given point on the string to oscillate as the waves pass through. Longitudinal vibrations can be excited by an impulse given to the string in the direction that the waves travel, such as rubbing the string lengthwise with sufficient friction. The frequency of vibration -- the rate at which a given point on the string moves back and forth lengthwise in response to the waves of compression and decompression -- is determined by the length of the string and the velocity at which waves travel through the string's material, according to the formula $F=V/2L$. This means -- and it does work out this way in practice -- that the tension on the string has no effect on the rate of vibration, as long as the string is held taut. Given a string of a certain material, the sole variable determining the rate of longitudinal vibration is the length of the vibrating portion of the string.

By itself a string vibrating longitudinally cannot be heard, since it will move only negligible amounts of air. But, as with conventional

ELLEN FULLMAN PLAYS THE LONG STRING INSTRUMENT

Photo copyright Pieter Boersma, Amsterdam stringed instruments, the string can be attached to a resonator such as a soundboard, which will move enough air to give ample volume. A string vibrating longitudinally readily makes an efficient coupling with a soundboard if it is attached perpendicular to the plane of the soundboard. The connection then is as direct as can be (as with a harp, no bridge intervenes) and, unlike strings vibrating transversely, the primary direction of vibration of the string is the same as that of the soundboard.

So why have instrument designers in the past not made more use of longitudinally vibrating strings? There is a very practical reason.

Longitudinal waves travel through different substances at varying, but generally very high speeds. The velocities at which they travel through the materials of which strings can be made are in the range of tens of thousands of feet per second. If you look back at the formula given above for determining the frequency of a string vibrating longitudinally, you will see the implication of these velocities: in order to produce fundamental tones which are within the range in which we can identify musical pitches, the strings must be outrageously long. Ellen Fullman provided the chart below, showing the length of string necessary to produce certain pitches for certain materials.

(Fullman has found the figures given in this chart to be somewhat inaccurate, but they do provide a broad picture.)

VELOCITY OF LONGITUDINAL WAVES THROUGH WIRES OF VARIOUS MATERIALS AND WIRE-LENGTHS REQUIRED TO PRODUCE SOME SAMPLE PITCHES.

MATERIAL AND DIAMETER OF WIRE	VELOCITY OF WAVE IN FEET/SECOND	LENGTH AT WHICH THE WIRE SOUNDS A SAMPLE PITCH	
0.012" Iron	22,421 ft/sec	A-440	25' 6"
0.0135" Iron	22,110 ft/sec	A-440	25' 3 1/2"
0.0135" Bronze	11,513 ft/sec	A-220	26' 2"
0.014" Brass	10,908 ft/sec	A-220	24' 9 1/2"
0.013" Brass	10,972 ft/sec	A-110	49' 10 1/2"

It becomes clear that, in order to exploit the musical possibilities of longitudinally vibrating strings, one must have a very large parlor.

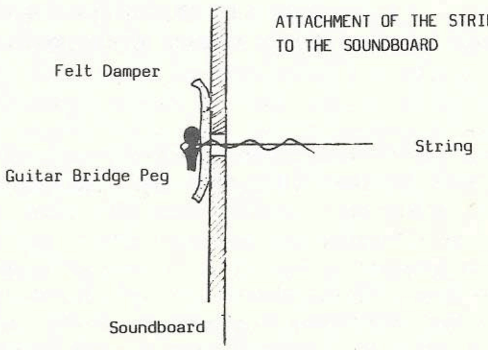
FULLMAN'S INSTRUMENT -- DESIGN AND CONSTRUCTION

With her Long String Instrument Ellen Fullman has created a working longitudinal vibration string instrument. A description of the instrument follows, and Fullman's own account of the project's progress from a chance observation to a fully functional (though still evolving) musical construction appears a few pages hence.

The specific form of the Long String Instrument varies from one installation to the next. The most recent manifestation of the instrument has fourteen strings in two groups of seven. Their full length (as opposed to their sounding length) is ninety feet. At one end the strings are attached to some stable surface, such as a wall. On earlier versions of the instrument the strings were held taut at this end -- but not tuned, since tension does not effect tuning -- by means of several sets of machine pegs made for string basses. Fullman has since discovered that the job can be done more effectively by a wratcheted infinitely-turning winder, a device made in Belgium and used by European farmers for stringing fence wire.

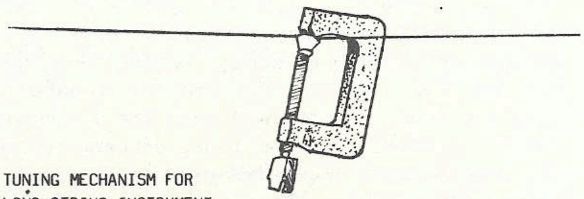
At the opposite end the strings are secured to a rectangular soundboard, eight inches by fifty-nine inches, made of spruce. Each string passes through a hole in the soundboard and then through a damper of felt, and is tied to a guitar peg on the far side. The tension on the string pulls the peg fast against the soundboard, and the damper between prevents buzzing.

ATTACHMENT OF THE STRING TO THE SOUNDBOARD



Fullman, with input from others, is currently redesigning the soundbox that supports the soundboard. The soundboard and soundbox arrangement has taken several forms as the instrument has evolved. Earlier versions were far heavier and larger. But the smaller, lighter board, though seemingly out of proportion to the great length of the strings, is appropriately proportioned for the frequency and intensity of the vibrations it is designed to project. It produces a sound that is louder and warmer than larger boards, and reproduces the detail of the strings' overtone content more clearly.

The strings are tuned by adjusting their sounding length. Fullman does this with C-clamps. They are clamped on the string and left suspended there at the point where the vibration should stop in order to produce the desired pitch. One can calculate this point using the frequency formula given above. It seems surprising that the clamp,



THE TUNING MECHANISM FOR THE LONG STRING INSTRUMENT resting on the string and affixed to nothing rigid, would be sufficient to stop the vibration in such long strings. But if the mass of the clamp is equal to or greater than that of the string it can function as a nearly-fixed termination, and it does not take a very large clamp to equal the mass of the relatively thin (.0125" diameter) string.

PLAYING TECHNIQUE

To sound the instrument, the player uses violin bow rosin on both the strings and the hands, and strokes the strings lengthwise. The strings sound best with a moderately light touch. Fullman compares it to the way one coaxes the tone from a wine glass by running a finger around the rim. The optimal speed for the stroke is, to use another of Fullman's metaphors, slow like the movements of T'ai Chi. The player walks back and forth along the strings as she plays, giving performances a choreography shaped by the music.

TUNING

Fullman has evolved a tuning system designed to fit the form of the instrument and its playing technique, and which feeds directly into her processes of composition and improvisation. The strings are grouped in two or more sets of several strings -- the precise numbers have varied from one installation of the instrument to the next. Within the sets the strings are spaced closely enough that two or more strings can easily be played simultaneously. Fullman tunes the strings within each set to intervals which she determines will work well together for her compositional purposes, considering the relationships both of fundamentals and overtones. Adjacent strings are not tuned to adjacent scale steps, but to selected harmonic intervals. The other sets of strings are tuned to the same relative intervals, but at different pitch levels, allowing for a form of modulation and for some complex harmonies.

TIMBRE

The Long String Instrument derives much of its flavor from a peculiar attack and decay and the equally peculiar behavior of the overtones. The fundamental -- the object of all those calculations concerning the rate at which the wave travels through the medium -- is always clearly present. But a mix of very prominent overtones shifts dramatically according to where the player strokes the string. The nearer the strokes to one or the other end, the higher are the overtones that predominate. Toward the middle of the string one gets all the lower overtones very clearly and recognizably. If the stroke begins very near one end and moves toward the center, a waterfall of high overtones tumbles out over the fundamental in the first moments of the tone, descending rapidly. The descent continues, but ever more slowly, with the movement toward the center, as the fundamental remains more or less constant.

Like a bowed instrument, the long strings sing as long as the stroke lasts. But unlike with transversely vibrating strings, whose vibration will die away slowly if they are not muffed, the longitudinal vibration ceases abruptly after the stroke ends. In Fullman's instrument, a quieter echo of fairly fast decay can then be heard; it is the vibration in the soundboard giving up the ghost a trifle more reluctantly.

THE MUSIC

The Long String Instrument lends itself to long tones and sustained harmonies, and this is reflected in Fullman's composition. Her pieces are built around predetermined sets of harmonic relationships within which performers can improvise using certain strings and their overtones for a period of time and then moving on to the next set of relationships. Two players usually perform together, engaging in their T'ai Chi walk along the length of the installation as the music dictates. Fullman has performed at galleries in New York and has brought the instrument -- dismantled for the journey, needless to say -- to performances in Europe as well.

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Recordings of the Long String Instrument are not commercially available at present. A gallery in Holland has made tentative plans to produce a record within the next year or so which will probably be available through New Music Distribution Service (500 Broadway, New York, NY 10012).

For more information about the instrument, performances and the like, Ellen Fullman may be reached at 17 Kent Ave., Brooklyn, NY 11211.

ARNOLD DREYBLATT AND ELLEN FULLMAN AT THE LONG STRING INSTRUMENT
Photo by Peter Cox, Eindhoven, Netherlands

ELLEN FULLMAN WRITES ABOUT THE EVOLUTION OF THE LONG STRING INSTRUMENT

For the past several years I have been developing an installation, "The Long String Instrument". In 1981, in St. Paul, Minnesota, I was stretching long lengths of string using various materials and tying them to metal containers. The containers acted as resonators and were amplified with contact microphones. I bowed the string and put water in the containers, moving them and listening to the resonance change. One day I brushed against one of these strings and it made a loud clear sound. I began stroking it lengthwise with my hands. I sensed that what I was discovering had a lot of potential but I needed to learn what was happening scientifically to be able to control the sound produced. I was unable to find the kind of information that I needed in Minnesota, although I'm sure it exists there. I saw evidence of there being more integration of art with technology in New York City, and decided to move there.

For about a year in New York I took false steps in relation to the project. I wanted a warm, low sound, and to be able to tune the strings. I tried using a better contact microphone and tried to modify the sound by electronic filtering. I was now using very large containers of water and setting up the strings on the roof of my building, the only place large enough. One afternoon Steve Cellum, and engineer, explained to me how the string was vibrating. We had on hand a large board, originally used to reflect the sound. Steve suggested that we attach the string directly to it. We drilled a hole, put the string through, tied it to a washer, then tightened it against the board. The string produced a loud, rich sound without amplification.

Soon after, I set up the project in a better location and began building test resonator boxes. At this time my friend Arnold Dreyblatt, a composer, brought over his friend Bob Bielki, an engineer, to look at what I was doing. Steve was also there, and we tried several experiments which greatly clarified the procedure I was to take. In a physics handbook they found a formula which was to become my method of tuning. We also discovered that by using brass wire, I could lower the frequency produced. It seemed that the next step was to build a large box resonator that would sustain the sound longer than only a board.

My next studio space was the Terminal New York Show which was to begin a month later. I spent the intervening time reading about musical acoustics, planning the box, and gathering materials. In the show I had a very large area to work in and built a large plywood box. I suspended the strings from this in clusters of four, tuning the groupings to equally tempered chords. I spent this period listening to different combinations of tones and thinking about the musical possibilities.

When the show was over some friends let me use their basement to work in. The strings ran through a doorway and into another room with the bass section extending down a long hallway. At this time I met David Weinstein, a composer, and we began a series of sessions in which David taught me about just intonation. Since overtones are so clearly present in this instrument, a tuning system using just intervals seemed more appropriate and more interesting.

I tuned the instrument in various ways, listening to ancient systems and generating my own. I settled on a just 12-tone chromatic scale based on F. Rather than in chromatic sequence, the strings were laid out in a pattern in which each string has a simple harmonic relationship to its adjacent strings. This was done so that while playing one string, others beside it could be touched also, adding a harmonic density. I added a second section of twelve strings in the same pattern of adjacencies but tuned in a perfect fifth relationship to the first section.

David and I began playing long, sustained, slowly shifting tones. Our playing was really random, as I didn't know much about musical intervals. In time I began learning more, laying out charts in which I could see the mathematical relationships in chord structures. I realized that, since the overtone series is swept through in each string as it is played, complex, shifting chordal relationships would occur when two or more strings are played at once. I began building chord sequences in which I stroked the same strings walking away from the soundbox and returning, listening to the shifting of the chords in the overtones. Now I'm interested in dealing with time in a more precise way than that delineated by the player's footsteps.

The project has become for me my personal music school. It leads me to read and study, as the information I seek gets put to use in very practical ways. The piece is like a microcosm of the history of music. The lessons I learn materialize in a very graphic form. There is a quality of its being a science project that displays principles of musical acoustics. I am an outsider to music, and it's as if now I am seeing the inner workings, the gears, pulleys and bricks that build music, and it's my intention to affect the listener the same way.