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Max Mathews at Bell Labs

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AN INTERVIEW WITH MAX MATHEWS

by Loren Means

LM: John Chowning told me that your Radio Baton was the very latest in computer sound controllers.

MM: He's very generous in saying that. The Radio Baton was a fairly early controller of this kind. I've been working on it since the mid-Eighties. But now, there are lots of different kinds of controllers. In fact, we teach a course called HCI, Human-Computer Interface, where we train music students–sometimes they have engineering skills, sometimes not–to make their own controllers, to make their own electronic music instruments. Going down to the Radio Shack and other stores and buying standard components and putting them together. The students use a patch field. You can plug resisters into it, you don't have to solder things.

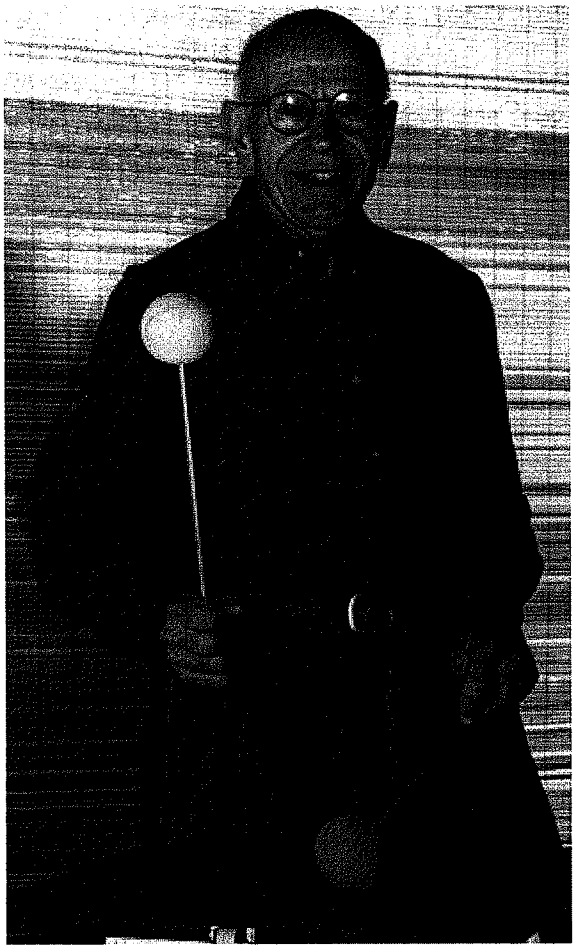


Figure 1. Max Mathews and the Radio Baton.

Here's a picture of me and the old Radio Baton. These are the two batons, and you wave those in the air above this receiving antenna, this plate here. The antennas and the electronics track the motions of these two batons in three-dimensional space. X is top to bottom, Y is side to side, and Z is the height. So that's worked quite well, and there are a number of expressive compositions for this. The idea is to make a device where the electronic musician can perform more expressively than with a traditional keyboard. Anyway, this has been around for ten years or so. When it was made, it was necessary to put wires to the batons to connect them to the electronics box. That's not very pleasant to have wires, so I've been working on a wireless model, and I have a prototype of the wireless baton. Instead of having the oscillator–the radio transmitter, if you will–in the box and a wire taking it to the transmitting antenna, the oscillator is now in the baton. So this is all wireless.

The old version of the antenna is complicated, with wedges. The strength of the signal depends on how thick the wedge is under the transmitter. There's a thick wedge at one end, and next to it a complimentary wedge with the other end thick. So by comparing the strength of these two signals, the computer can tell where it is in X. There are some bars that tell where it is in Y, and a different technique for Z. The program that makes the music is in my laptop. The Radio Baton is actually a MIDI controller. So there's a MIDI interface. You know MIDI, I assume?

LM: MIDI is basically a universal protocol for connecting computers to other devices.

MM: That's precisely what it is. The X-Y signals are encoded in MIDI. They go into the box, and hence by the universal serial port cable into the computer. Then the computer sends out commands to a Roland synthesizer to play music. The model for this particular device is an orchestra conductor. The orchestra conductor waves batons, and if not controls, at least influences the orchestra. And presumably, he controls the expression of the music. But he doesn't have to play the notes. They're on the music paper, and the poor musicians have to do all the expertise of getting the right notes. Here, the score of the music is in the computer memory, and with the one baton, I'm going to beat time, like the conductor does, to set the tempo. With the other baton, I'll use X and Y or some combination of these things to control the loudness and the balance of the voices in the orchestra. There are 127 different timbres in the sample synthesizer. Really they're samples of the 127 different instruments. So sending a number to the synthesizer from 0 to 127 will select an instrument for a given channel. There are sixteen channels, so you have a sixteen-voice orchestra.

I often demonstrate with a Rachmaninov "Vocalise," which I once played with Theramin's daughter. Chowning invited Theramin to come over here, about a decade ago. Theramin was in his nineties, but he was still very bouncy. He brought one of his daughters with him, as well as someone from the Russian music academy, a Communist who was keeping his eye on the situation. We had a good time. This "Vocalise" has a solo part which can be done with a number of instruments, say with soprano. Theramin's daughter did it on a theramin, and I played the accompaniment. My instrument, in many ways, is a grandchild of the theramin, since they both work in radio frequencies. As a matter of fact, they fought each other when we did the concert. Although they don't use the same frequencies, the theramin had such a strong radio signal that it saturated my input amplifiers, so that I couldn't play when the theramin was playing, if the instruments were too close to each other. So we had to move to the opposite ends of the stage, I on one side and the theramin on the other side. But there is one difference between these two instruments. That is that the theramin is the world's most difficult instrument to learn how to play. In fact, very few people have done a decent job of playing it. In this country, Clara Rockmore was the person who became a theramin expert. I think she's still alive, actually, in New York City. And the Radio Baton is the world's easiest instrument to learn to play, because the conductor program does all the technically hard work for you, like getting the right notes. You still have to be musically adept to get the expression you want, make it expressive music, but that's the important and fun part of music, in my opinion.

Computer music started in 1957, the first piece that was synthesized on a computer, which I did on an IBM 7094. The computer was on Madison Avenue in New York City. There were only two of them in the world at that time, one in Poughkeepsie in their research lab, and this commercial one there. I worked for Bell Telephone Laboratories. I was in their Acoustic Research Department. I made a gadget to digitize speech and put it into a computer, so that we could simply write a computer program to try for encoding speech, compressing it so that you could get more voices over the Transatlantic Cable. Instead of spending literally years in building a fancy speech coder, we could spend maybe a month or so writing a program to do that. So we would digitize the speech and put it through this program, and then put it through a Digital-to-Analog converter at the other end, and listen to it to see what the quality and understandability of the speech was. This actually turned out to be a very successful research device, and has led to some remarkable encodings for both speech and music. And, of course, nowdays it isn't just a research tool, it's the way almost all speech is transmitted around the world, in a digital form.

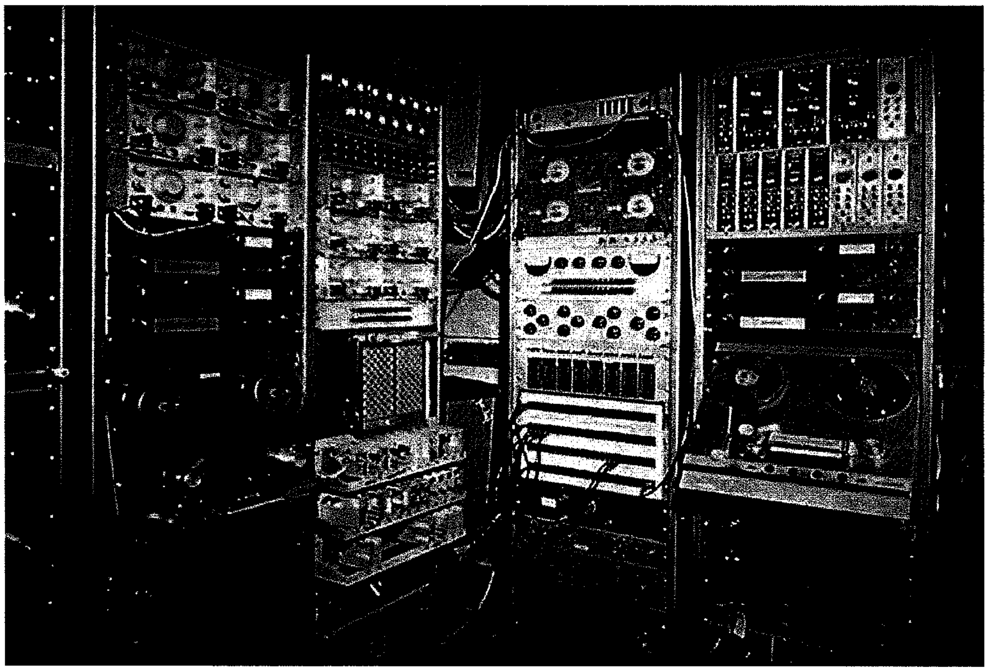


Figure 2. The Entire Groove System Studio

I worked for John Pierce, who died a few years ago. He was probably the world's most famous engineer. The main thing he did was to invent satellite communication, or show that satellites could be used for communication. He was very interested in music. We were at a concert together, and we liked some of it and didn't like other parts of it. In the intermission, we turned to each other and said, "The computer could do better than this." And so he said to me, "Maxwell, I know you're supposed to be working on telephones, but take a little time on the side and write a computer program–you've already made the equipment to get computer numbers converted to sound–let's see what you can get out of it in the way of music." So that got me started in the music direction, and, of course, music has always been one of my great interests. I still play the violin, and enjoy it very much, although I'm not a good violin player. Probably if I were a better violin player, I wouldn't have bothered with computer music.

I wrote five music programs, Music I through Music V, of which the first one was horrible, and the last one is still the pattern for almost all the so-called "studio" music that is made. When I say "studio music," in the beginning, computers were very weak and slow compared to the demands of making sound and music. In other words, it might take an hour to make a minute's worth of music. So there was no possibility of performing with a computer. You made a tape, and then played the tape back for the performance. And you could have the computer compute all night on the tape, and then you could play it back the next day. And that was fine, because in those days a composer might compose a piece, and then he'd wait ten years to get an orchestra to play it. So now, he could at least hear it.

Then along about the mid-1980s, the technology got much, much more powerful. The first power was shown in special-purpose chips, of which John Chowning's FM chip is a very fine example. So that not only did it become much less expensive to own a digital synthesizing device, but it also was possible now to synthesize sound in real time. The DX-7 is the example that the Yamaha company made, that was a very, very successful machine. One of the reasons was simply economic. An entry-level computer music system, using the computers that were available in the Seventies--and these were mostly DEC computers, the PDP-11was a very popular instrument for lots of things–the entry-level cost was about a hundred thousand dollars to get a decent system. So some universities could afford this, but most people couldn't. When Yamaha made their FM chip set, the cost of a DX-7 was about two thousand dollars. So overnight the price came down by a factor of fifty to one, and the number of people who really wanted to use this increased not by fifty to one, but maybe five thousand or a hundred thousand to one. It swept the world, primarily in the popular music domain. Electronic music hasn't changed the San Francisco Symphony very much. They occasionally have an electronic instrument in one of their pieces, but not often.

Nowadays, computers, and even small computers, laptops, have gotten so powerful that you can do everything in one of them. So you can take a laptop on the stage and actually generate the numbers that get converted to the sounds, and do it all in real time,

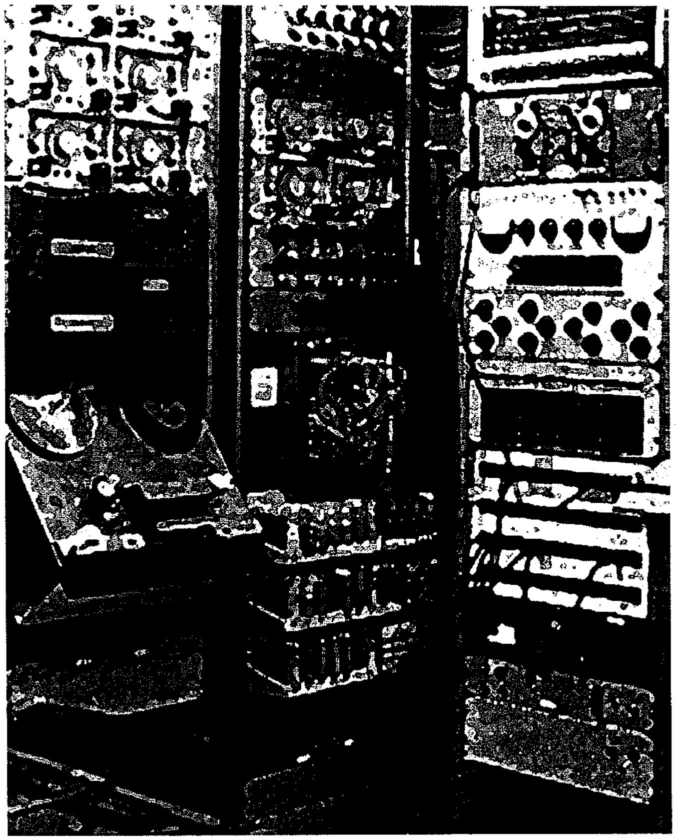


Figure 3. The GROOVE system

and play it like a violin, or play it in the same live manner that you play the violin. It ain't like a violin, it's whatever you make. And whatever you make is mostly the controller, and then the program that you have in the computer.

LM: Where are you teaching the class, teaching people to make instruments?

MM: That's down at Stanford. Music 250A.

LM: You started at Bell Labs as an engineer, working on voice.

MM: That's right, I'm an engineer, really. I'm not a musician.

LM: But you have written some compositions over the years.

MM: Yes, I have. One of my compositions is called "Slider." You know about twelve-tone music? The idea there is to use all the twelve tones equally, and arrange things so that no one hears a sense of tonality anywhere in the music. At least, this is one very pure form of twelve-tone music.

LM: You don't repeat any note until you've played all the others.

MM: Yeah. You do whatever is necessary to keep the listener from believing "Ah, that's the key of C." I wanted to carry this to the ultimate step. I not only wanted to remove all tonality, I wanted to remove all scales, so that there is no C or D or Eb or anything like that, that's recognizable in the music. At the same time, I wanted a strong sense of pitch in the music. So, there are two ways of doing it. One is, you can use narrow-band random noise. Provided you don't make the bands too narrow, you don't have a good sense of pitch, but you can convey a broad sense of pitch that way. But I also wanted to get some very narrow sense of pitch, so I made a piece that is made up entirely of glissandos. Now I have eliminated the scale completely, or I think I have. You can decide for yourself what you think. This was a piece I did in about 1966. It's composed with a graphic score. No notes or anything like that, just a bunch of graphs. To compose the thing, you draw a function. You can either draw it with a pencil and paper, or we had a light pen on a scope that we could draw with, that was directly attached to the computer. You can indicate note durations by dashes, amplitudes with accents, for example, by another line. That was the structure of this piece.

LM: Was the piece realized in real time?

MM: No, that was not realized in real time. That was in the mid-1960s. The computers just weren't quite fast enough to do that then. So you can draw the score on this computer scope, but you had to wait. The first real-time system was a hybrid system which had a digital computer producing control functions, and then had an analog synthesizer, sort of a mongrel-type synthesizer, which had a bunch of Moog modules and a bunch of laboratory oscillators and a bunch of things we built. The computer sent fourteen analog signals that came from fourteen Digital-to-Analog converters to the analog devices, and then you could control that.

This was at Bell Labs, and it was in the late 1960s and early 1970s. There are some Moog voltage-control filters. There's some Moog voltage-controlled amplifiers for attacks and decays, and there are some laboratory oscillators, and then there's a rack where we could build cards out of op amps and other sound generators and plug

Figure 4. Max Mathews using the GROOVE system.

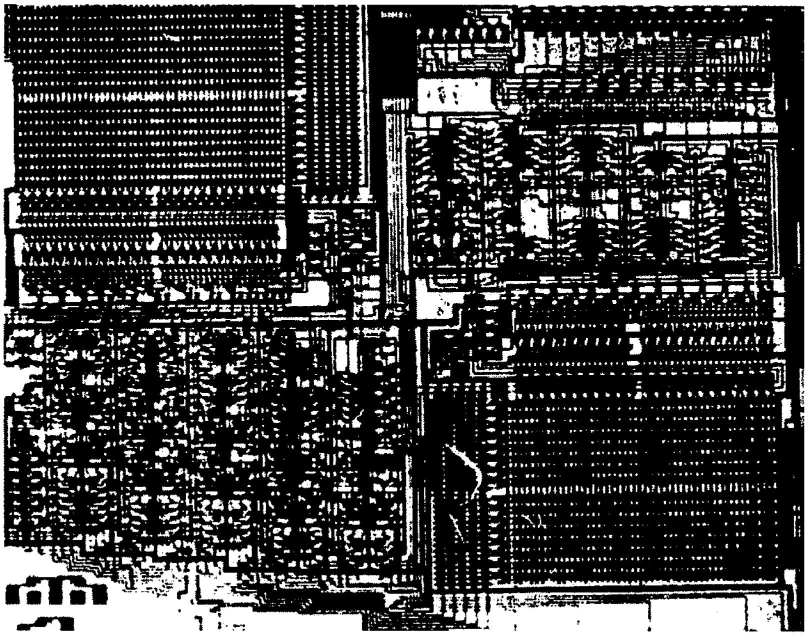


Figure 5. [DX7CHIP]. The DX-7 FM chip.

them in. And then there's a patch panel where we could connect everything together. So when the composer got going at it, each composer could have his own patch field. A composer came in at night when other people weren't using the computer, and he could patch that together. There was nothing very interesting about the computer itself. It had a keyboard. You could only press one key at a time, though. And some buttons. But the really interesting control device was this three-dimensional wand that you can just see behind me. This is the baton.

LM: This is when you were using the GROOVE system [Generated Real-time Output Operations on Voltage-controlled Equipment]?

MM: Yeah. This is the GROOVE system. You can move this wand in three dimensions: up and down, and back and forth. So you could control, for example, loudness with one dimension, and I used timbre for another dimension, and maybe the third dimension for pitch. And in fact, there's a piece that I made on that system. Do you remember Lillian Schwartz?

LM: Sure. She was one of the original YLEM members.

MM: She made the visual part of this piece. She did sixteen millimeter film mostly. I had the visual part converted into a DVD. This was a piece Lillian did called "Papillon". But she has a problem, and I don't know what to do about it. She gave her collection of art, sculpture and everything, to the Ohio State University Archives. And now she can't get ahold of any of the things. She would like to have the sixteen millimeter films converted to DVDs, and so I've written letters saying "She wants this, can you do it? I'd be happy to pay for it." So far I haven't heard that they're willing to let us do it. So be warned: don't give your things to archives until you're dead! My copy of "Papillon", the visual quality is very poor, but the sound quality is quite good. The way I did it, it was an improvisation, where I just simply watched the film and controlled the sound with that three-dimensional wand. It was all done in one night, with the GROOVE system.

LM: Essentially, it's one voice and you're playing with the timbre.

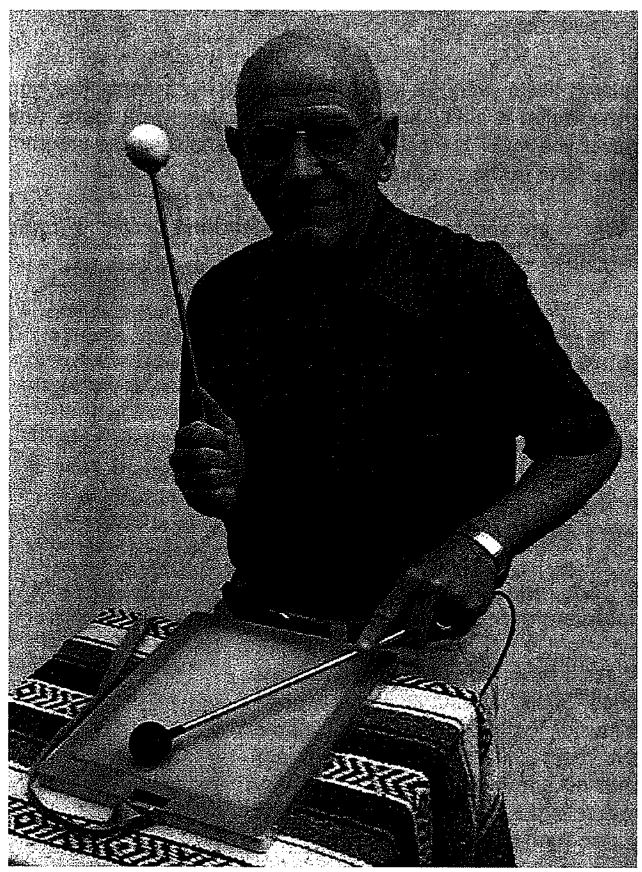
MM: That's right. It's just one voice. It was one timbre axis and one loudness axis, and one pitch access. This does have a scale built into it. The duration of a note was just how long you held the rod in one position until you switched to another pitch, and that marked the end of the note and the beginning of the next one. There were no rests. It's continuous in that sense.

LM: It's like the person never has to take a breath.

MM: That's right. The timbre control was a rectangular wave form, and the X dimension was controlling the factor of the waveform, so the right was a square wave and the left was a narrow pulse wave. It was quite effective. The thing that I most want to get, and I think Lillian most wants to get, is the film either "Running Man" or "The Olympiad". "The Olympiad" is actually the correct name for it. I have a still image from it. She based that film on this Englishman who in the 1800s figured out how to take pictures of running horses....

LM: Eadweard Muybridge. Down at Stanford.

MM: Yeah, down at Stanford. I see that this actually has Ken



Knowland's name on it, as well as Lillian Schwartz's. So he was involved in that, too. I didn't realize that until I looked closely at the thing.

LM: He collaborated with her a few times.

MM: He is a very creative person. We were in the same department for a while. I certainly admired his work very much, and I liked him very much as a person.

LM: It seemed that he started out on the engineer side of the engineer-artist collaboration, and then moved over into the artist side. And it seemed like you sort of did the same thing.

MM: I've now known a lot of composers. I've known them long enough, and admired them so much, that I realize I'm not a composer. I'm really still on the engineering side. But I have enjoyed trying some things, doing some things. Trying to get machines to compose for me.

LM: Apparently it was really a remarkable situation at Bell Labs. All these artists who weren't working on anything having to do with telephones.

MM: Most of them were just using the facilities, and mostly at night, when the facilities were not being used by the research staff. But it was an incredible golden age of many, many things. The transistor, of course, many of the computer programs like C and Unix, that continue to be important. Communication equipment that is now tying the world together incredibly closely. Maybe too closely.

LM: You even put out a record of music from Bell Labs. And Laurie Spiegel was your assistant for a while?

MM: No, she came in, she was a composer, and she did her own thing. I never had any assistants. I didn't really want assistants. I wanted people to come in and be themselves. And I think I made that possible.

LM: I read an article by Lejaren Hiller [*The Computer and Music*, edited by Harry B. Lincoln, 1970] where he talks about what you did, but he makes it sound like he did it first, with the "Illiac Suite."

MM: Well, what I did was different from Hiller. Hiller did the "Illiac Suite" first. This was a composing program that composed the suite. It was played then by a live string quartet. That was really a very difficult feat, much more difficult than what I did. All I did was to make the computer play music. I certainly did that before he got into that domain. I don't know how far he got into it, actually. He was more interested in composing and getting machines to compose.

LM: You were saying you wanted to get computers to compose for you.

MM: Well, I've just done some games, and things like that. Like this graphic scores thing. Most of the compositions that my programs have made, I don't like them. A few of them I like.

LM: John Chowning mentioned that you did a piece where one song metamorphosed into another song, and he was impressed with that.

MM: That was a graphic score. If you're making the melody as a function of time, for one piece, you can also make a different melodic line for another piece, and then you can make a weighted average between these two lines. Just a mathematical statement, saying 90% of this line and 10% of this line, and that will make a melody that sort of falls in between the two. So this particular example is called "International Lullaby." It's by me and a Japanese friend who worked with me for many years, Osama Fujimura. It converts a Japanese melody, a traditional cradle song for babies, into the Schubert "Cradle Song." The Japanese melody is in the pentatonic scale, and the Schubert is in a normal key, I think the key of C. Anyhow, the conversion is in seven steps. The first step is 100% Japanese, and the last step is 100% Schubert, and then you take one divided by seven and figure out how much percentage you go each step.

LM: Hiller mentioned a piece where you used "Johnny Comes Marching Home."

MM: That's another one. These are the two averaging functions. So you start out with 100% "Johnny," and 0% "British Grenadiers," and then you gradually convert to 100% "British Grenadiers," and then you convert back to 100% "Johnny." The "International Lullaby" went in steps, but in this one, the conversion functions are continuously changing. The "Grenadiers" is in 6/8. "Johnny" is in 4/4. The rhythmic transformations are kind of interesting, I think..

LM: One of the better-known things you did was the piece that Stanley Kubrick used in *2001*.

MM: The people who did the interesting parts of that were John Kelly and Carol Lockbaum, because they did the singing. They actually used what is called a "physical model," which in this case is a tube model of the human vocal tract. They took the vocal tract and they simulated its shape with a bunch of sections of cylindrical tubes of different diameters, plotting to the cross-sectional areas of the vocal tract. And then they used some studies of a fellow in Sweden who had studied Russian vowels, and who knew what the shape of the vocal tract had to be to produce various vowel sounds. I guess he also had some data on fricative sounds. This was about 1963. Which is amazingly early for this kind of thing. So that produced the piece with Kubrick was charmed by. It's called "Daisy, Daisy."

LM: How did Kubrick find out about this?

MM: He came around to Bell Labs to find out about telephones and telecommunication equipment for his space station, or his rocket to Jupiter. And John Pierce got ahold of him. Anyone that John grabbed ahold of had to listen to this kind of thing, whether he wanted to or not. Kubrick wanted to, and decided that would be the swan song for Hal, the bad computer.

LM: When did Bell Labs come to an end?

MM: It gradually died. I retired in '87 and came out to Stanford, and have been there ever since.