III. Computer Music

     During the years 1961-64, Tenney worked at Bell Labora-
tories in New Jersey, and was, I believe, the first composer
to utilize the music synthesis programs (MUSIC IV) that Max
Mathews had been developing. It is curious that even though
Tenney's articles (such as the one in the (Yale) Journal of
Music Theory, 1963) were really the first technical explana-
tions of digital synthesis procedures available to com-
posers, he is not often cited as one of the pioneers of the
field in the literature I have seen. Only two of his com-
puter pieces, Noise Study and the Stochastic String Quartet
are available on record, and a rather obscure one at that.
I have observed that among composers, he seems to be better
known for his work in computer music than any other field,
yet few know the music itself (how could they?). These
pieces are, if not the first computer generated works, at
least among the first, and the astonishing fact is that in
terms of compositional intelligence, they are still rather
advanced.   They age well, especially in light of the trend
toward building better and better hardware and
synthesis/processing software, and the virtual lack of
interest in compositional algorithms (one has only to pick
up a copy of the Computer Music Journal or attend a computer
music conference to realize this). The tremendous advances
of Tenney's music in the early sixties have yet to be prop-
erly acknowledged or appreciated.
     Luckily, Tenney has written at length about his work at
Bell Labs ("Computer Music Experiences," 1969), and good
tapes exist of all the pieces (I believe that there is a
strong possibility of putting several of the pieces on a CRI
record, but at this writing this is still in the works). In
this regard, I don't need to analyze the pieces themselves
in any detail, for Tenney has already done so in the above
mentioned paper, which should be required reading for anyone
interested in computer music. However, I would like to
offer some reactions to the work in general and say a few
words about each of the pieces.
     There are several philosophical currents running
through this music. One is that Tenney felt that the com-
puter should be used to show him new things about music,
perception, and the nature of composition, rather than to
simply execute a set of pre-composed musical-dramatical
ideas.   In this respect, all the pieces are, like much of
his later music, tasks for the listener given a set of known
compositional criteria. The computer provided Tenney with a
means to create perceptual domains whose environment he
could predict and structure, but whose detail, and even mid-
dle level characteristics could in turn structure him,
teaching him about his own perceptual processes. This seems
to be essential to the very nature of artificial

intelligence, as well as its primary interest. Tenney was not primarily interested in the computer as a powerful synthesizer, although his many experiments with timbre made full use of that exciting technical domain. Rather, he deeply felt Cage's influence, and the way in which he responds to Cage's ideas, through his compositional programs, is fascinating. In these pieces, for the first time in his music, he chooses to relinquish control over various aspects of the music, and by doing so opens up a rich new area for musical experiment. Another somewhat peculiar aspect of Tenney's music that surfaces in these pieces is his love of all things noisy. This is evident not only in the Noise Study, but in the particular timbres and structures he chose to experiment with - structures which would produce, and did result in, ungainly, dense and noisily unpredictable sonorities. Even in his experiments with vibrato, he comes to the comclusion that random elements must be introduced into several parameters of the timbral synthesis, and only in this way will "more natural" sounds be produced. He has always sought to in some way emulate things not directly musical in his forms and timbres, believing, I think, that the most interesting manifestations of the various musical parameters (rhythm, timbre, pitch, and even structure) occur not by human design, but as part of some natural process. He has in particular, always been interested in the human voice and in speech, and many of his compositions either show this directly (like the Three Indigenous Songs) or indirectly (like the rhythmic "feel" of Monody or Seeds). Noise, in either its simplest timbral connotation or in its more abstract one involving the ordering and transmission of information, is ever present in the environment, but its occurrence there is often the last thing we imitate when we imitate nature. For Tenney, it has usually been one of the first.

A third idea of importance in this music is the use of stochastic processes, in rather sophicticated ways, to structure each of the pieces. Tenney had already written META≠HODOS at this time, and so had at his disposal a rich and complex theory of musical form which lent itself naturally to the use of stochastic methods in composition. The full ramifications of that paper, and of the later ones in the "series" (META≠HODOS and "Hierarchical Gestalt Perception...") have yet to be realized compositionally, though many composers have felt their influence (Charles Ames' recent string orchestra work, Crystals, is a good example). Briefly, the concept of a stochastic process is one in which certain parameters of a random distribution are specified, and these parameters can be shifted to affect the general shape (or color) of the random events. In this case, Tenney found that by specifying the mean and range of various parametric levels over given time intervals, he could create large and complex forms whose overall structure was determinate, but whose microstructure at any given moment was

indeterminate. Tenney implemented this in a hierarchical fashion, in which large-scale means were used to randomly select smaller scale means within them, and thus a hierarchically nested gestalt structure is created (more about this in the discussion of his theoretical work, in Chapter XVI). All of the pieces that he composed at Bell Labs use these ideas in some way, and it should be noted that along with Iannis Xenakis (who was exploring somewhat similar ideas in Europe at about the same time) and Lejaren Hiller, with whom Tenney had studied at Illinois (but who used the notion of stochastic distributions in a completely different way), Tenney is one of the first composers ever to seriously deal with these ideas in a formal and compositional setting. They have since become, more through the influence of Xenakis than anyone else, part of the common parlance of contemporary composition, but at the time they were quite revolutionary and radical concepts, no less so than the aleatoric ideas with which Cage shocked the musical establishment.

Tenney describes the context of his work at Bell Labs in the following excerpt from "Computer Music Experiences" (better than I possibly could):

"I arrived at the Bell Telephone Laboratories in September, 1961, with the following musical and intellectual baggage:
1. numerous instrumental compositions reflecting the influence of Webern and Varèse;

2. two tape-pieces, produced in the Electronic Music Laboratory at the University of Illinois - both employing familiar, 'concrete' sounds, modified in various ways;

3. a long paper ("Meta/Hodos, A Phenemenology of 20th Century Music and an Approach to the Study of Form", June, 1961), in which a descriptive terminology and certain structural principles were developed, borrowing heavily from Gestalt psychology. The central point of the paper involves the clang, or primary aural Gestalt, and basic laws of perceptual organization of clangs, clang-elements, and sequences (a high-order Gestalt-unit consisting of several clangs).

4. A dissatisfaction with all the purely synthetic electronic music that I had heard up to that time, particularly with respect to timbre;

5. ideas stemming from my studies of acoustics, electronics and - especially - information theory, begun in Hiller's class at the University of Illinois; and finally

6. a growing interest in the work and ideas of John Cage.

I leave in March, 1964, with:

1. six tape-compositions of computer-generated sounds - of which all but the first were also composed by means of the computer, and several instrumental pieces whose composition involved the computer in one way or another;

2. a far better understanding of the physical basis of timbre, and a sense of having achieved a significant extension of the range of timbres possible by synthetic means;

3. a curious history of renunciations of one after another of the traditional attitudes about music, due primarily to a gradually more thorough assimilation of the insights of John Cage.

In my two-and-a-half years here I have begun many more compositions than I have completed, asked more questions than I could find answers for, and perhaps failed more often than I have succeeded. But I think it could not have been much different. The medium is new and requires new ways of thinking and feeling. Two years are hardly enough to have become thoroughly acclimated to it, but the process has at least been begun."

(pp. 23-24)

In my discussion of Tenney's computer music, I will follow this paper's sequence and will quote freely from it (citing page numbers where a direct quote is used). Hopefully, someday soon these pieces will be put on record, and the listener will be able to fully enjoy and experience this remarkable music.

Noise Study (Dec. 1961)
    This was Tenney's first piece at Bell Labs, and he describes its genesis below:

"For several months I had been driving to New York City in the evening, returning to the Labs the next morning by way of the heavily traveled Route 22 and the Holland Tunnel. This circuit was made as often as three times every week, and the drive was always an exhausting, nerve-wracking experience, fast furious,.... The sounds of the traffic - especially in the tunnel - were usually so loud and continuous that, for example, it was impossible to maintain a conversation with a companion. It is an experience

that is familiar to many people, of course. But then something happened, which is perhaps not so familiar to others. One day I found myself <u>listenening</u> to these sounds, instead of trying to ignore them as usual. The activity of listening, attentively, to 'non-musical', environmental sounds was not new to me - my esthetic attitude for several years had been that these were potential musical material - but in this particular context I had not yet done this. When I did, finally, begin to listen, the sounds of the traffic became so interesting that the trip was no longer a thing to be dreaded and gotten through as quickly as possible. From then on, I actually looked foward to it as a source of new perceptual insights. Gradually, I learned to hear these sounds more acutely, to follow the evolution of single elements within the total sonrous 'mass', to feel, kinesthetically, the characteristic rhythmic articulations of the various elements in combination, etc. Then I began to try to analyze the sounds, aurally, to estimate what their physical properties might be - drawing upon what I already knew of acoustics and the correlation of the physical and the subjective attributes of sound.

From this image, then, of traffic noises - and especially those heard in the tunnel, where the over-all sonority is richer, denser, and the changes are mostly very gradual - I began to conceive a musical composition that not only used sound elements similar to these, but manifested similarly gradual changes in sonority. I thought also of the sound of the ocean surf - in many ways like the traffic sounds - and some of the qualities of this did ultimately manifest themselves in the Noise Study. I did not want the quasi-periodic nature of the sea-sounds in the piece however, and this was carefully avoided in the composition process. Instead, I wanted the aperiodic, 'asymmetrical' kind of rhythmic flow that was characteristic of the traffic sounds."

(pp. 24-25)

How similar this is to Varèse's love for the noises of the city (as in <u>Amèriques</u>, <u>Déserts</u>, <u>Ionisation</u>, ...) and to so many of the ideas implicit in Cage's use of noise. It is interesting that the very first "instrument" Tenney constructed at Bell Labs was the very thing that much of electronic music tries to eliminate: a complex noise generator. The instrument itself is of the amplitude modulation type, with the ability to select a center frequency, amplitude, and bandwidth, and to interpolate over a given duration

between selected initial and final values for these parameters. The tape has up to fifteen of these instruments at some points, though this is a result of the combination of three different speeds of an initial tape (on which only five instruments are used). Tenney described the large scale structure as follows:

> "The piece is divided into five sections, the durations of the sections decreasing, progressively, from the first to the fifth. The piece begins slowly, with relatively wide noise-bands whose center frequencies are distributed evenly throughout the pitch range, approximating a white noise. As the average intensity and temporal density increase (in the second and third sections) the noise bandwidths decrease, until the sounds of each instrument are heard as tones with amplitude fluctuations, rather than as noise-bands. The beginning of section 4 is marked by a sudden change to a lower temporal density (i.e., longer note-durations), wider bandwidths, and a new amplitude envelope is introduced, with percussive attack followed by a decreasing - then increasing - amplitude. During this fourth section the average intensity is maintained at a high level. The fifth section begins at a lower intensity, which decreases steadily to the end of the piece. This return to the conditions of the beginning of the piece is manifested in the other parameters also, except for the temporal density, which increases during the last two sections from a minimum (like the beginning) to a maximum at the end. Thus, except for this note-duration parameter, the over-all shape of the piece is a kind of arch."
> (p.28)

Temporal density is, in Tenney's usage, roughly equivalent to tempo. More precisely, the temporal density of a given "temporal gestalt unit" is the number of lowest level ("element") events it contains "per unit time", so that, for example, a phrase that contains ten notes over ten seconds has a higher temporal density than one which contains eight over the same duration.

Because Tenney's own description of these pieces is so complete, I will refer the reader to his own paper for details. The following chart (Example III.1, from page 31) shows the way in which the three tapes were timed and mixed together to form the total piece.

Noise Study is quite an effective, short piece, in which Tenney was just getting started in some of the aesthetic directions which he would later develop more fully in pieces like Phases.

Example III.1

Temporal Density

Intensity

Double-Speed Tape

Original Tape

Half-Speed Tape

Double-Speed Tape

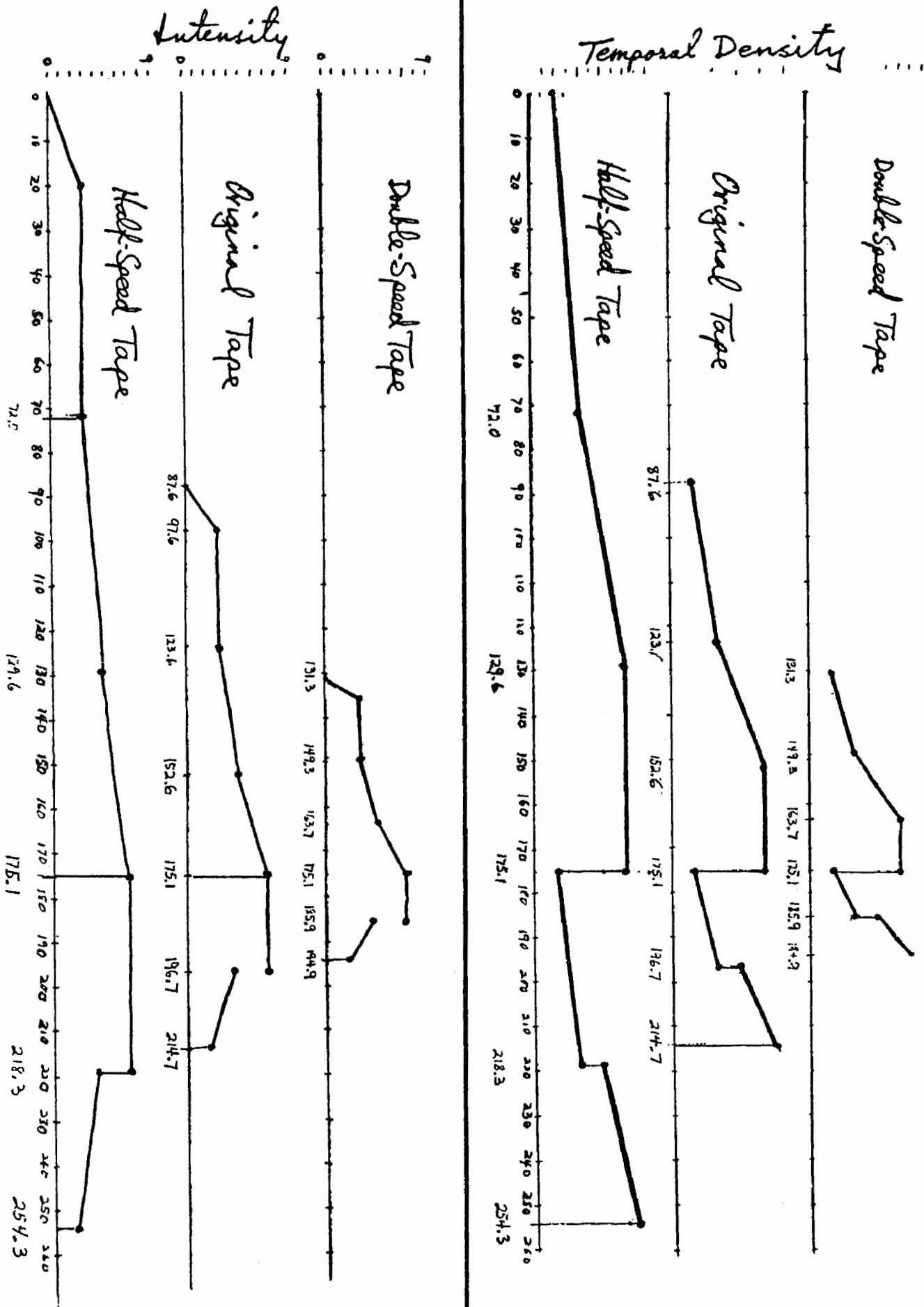Original Tape

Half-Speed Tape

Figure 4. Superimposition of the three analog tapes in the Noise Study.

Psychoacoustic Experiments

Since most of Tenney's later music in some way or another involves an exploitation of psycho-acoustic phenomena, the nature of his early research in this area is interesting to consider. Although we would expect that it would in some way concern itself with either intonation and spectral information, speech, or the perception and distinction of form, it does not. Instead, he made a careful exploration of two aspects of timbre: modulation and rise-time. In particular, he became interested in those factors of amplitude and frequency modulation which would most likely produce "natural" sounding envelopes and timbres. To do this, he rather meticulously isolated several factors in the creation of a digitally synthesized vibrato (or frequency modulation), in the hopes of better understanding the relationships between particular uses of FM and resultant timbral perception. Subsequently, he investigated the use of random amplitude modulations to add life to tones. Some of Tenney's conclusions about the way FM and AM might be applied to various segments of a spectrum, and the higher level fluctuations in the rates of modulation are, to my knowledge, quite ahead of their time, at least in the musical community. Though timbral experiments with computers have indeed come a long way since then with the greater ease and accuracy in synthesis techniques, Tenney's experiments still stand as interesting and important early ventures in the field, and are notable for the fact that he was one of the only people at the time interested in what later became such a popular experimental realm. After some experiments with standard values for rates and ranges of frequency modulation, and then some experimenting with the use of time-variant values and envelopes for these, Tenney began to investigate the use of random fluctuation:

"A sort of 'mechanical' quality still persisted in these tones, however, and in order to overcome this I began to experiment with random frequency modulation, both with and without some amount of periodic modulation. The nature of the interpolating random number generator is such that, in order to give the impression of a modulation of a range and rate similar to the periodically modulated tone, higher values in both parameters are necessary (+/- .5 % to 2.0 % at 16-20/sec.).

Using random modulation by itself produces an interesting tone, but it does not sound like a conventional 'musical tone' with normal vibrato. The combination of random with periodic modulation, with enveloping (as described above) on the ranges of each, does, however, produce an effect so 'realistic' that I felt I had achieved one of the partial goals I had set for myself in these tests, when I heard the results. The relative proportion of the

range allotted to the two modulation sources does not seem to make very much difference, just so long as there is a 'perceptible' amount of each, and the sum of the two ranges does not exceed the range considered 'good' for a periodic modulation (about .5 + .5 = 1.0 % in my work).

With amplitude modulation, I found that the effect of a periodic modulation was not very interesting, did not even seem to be needed with the more interesting random amplitude modulation, to simulate the kind of fluctuations of amplitude that give 'life' to most instrumental and vocal sounds. Only with such sounds as those of the flute, vibraphone and bell does a periodic modulation of amplitude seem perceptually important."

(pp. 33,35)

Tenney's rise-time experiments led him to a rather different conclusion, in short that his scientific experiments with the rise-time of a tone were not as useful as his own more or less subjective ability to classify this timbral parameter.

"It is questionable whether such tests as the one described, carried out in very artificial laboratory conditions, and divorced from any musical context, can ever be of much use to the composer. And for this reason, primarily, I have not done any more experiments of this kind. Instead, I have tried to gain an understanding of such physical-to-psychological correlations more directly - by listening to the sounds in a musical context. What this approach lacks in precision (and - sometimes, unfortunately - communicability), it more than makes up for in efficiency. Only after giving up all intentions of dealing with these problems in the strict ways of the psycho-physical laboratory has it been possible for me to produce compositions with any degree of fluency."

(pp. 39-40)

Four Stochastic Studies and Dialogue (1962)

"If I had to name a single attribute of music that has been more essential to my esthetic than any other, it would be variety. It was to achieve greater variety that I began to use random selection procedures in the Noise Study (more than from any philosophical interest in indeterminacy for its own sake), and the very frequent use of random number generation in all my composing programs has been to this same end. I have tried to increase this

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variety at every Gestalt 'level' - from that of
small scale fluctuations of amplitude and frequency
in each sound (affecting timbre), to that of extend-
ed sequences of sounds - and in as many different
parameters of sound as possible (and/or practica-
ble). The concept of entropy has been extremely
useful as a descriptive 'measure' of variety, and
several important laws of musical structure have
been derived in terms of entropy relations (see the
memo "On Certain Entropy Relations in Musical Struc-
ture" included with my articles). The composing
programs described below represent various attempts
to combine the clang concept developed in Meta/Hodos
with more recent ideas about these entropy relations
and stochastic processes in general."
(p.40)

In the programs written for these pieces, Tenney for
the first time constructs the compositional model for the
gestalt formation processes outlined in META / HODOS.   This
motivated the first use of compositional subroutines in the
MUSIC IV context, an idea which has proved invaluable ever
since.   Simply put, the basic MUSIC IV and all subsequent
sound synthesis programs of its genre are primarily "per-
formers" - their main function is the generation of sound
given certain parameters, in much the same manner as an ana-
log synthesizer.   The composer does this, rather tediously
in most cases, by specifying values for all the parameters
of his software-constructed computer instruments - each set
of values constituting a "note".   While this procedure gives
the composer the type of control that he is perhaps most
accustomed to in the traditional manner of writing a score,
it does not take into account the use of the computer as an
aid to compositional intelligence. Tenney very quickly saw
the need for this, and with Max Matthews, developed the
necessary software for incorporating compositional subrou-
tines written in high-level languages (which at the time was
FORTRAN, of course) into the MUSIC IV system. The synthesis
program would then get the data it needed from the composi-
tional program, where this data was "composed" by composer-
specified and written algorithms.

The basic compositional idea Tenney was interested in
was the ability to specify mean and range values for certain
parameters (in this case note duration, amplitude and fre-
quency), and have the computer select random values around
these fixed ones. Given a fixed (or variable) begin-time
and end-time, such a statistical specification creates what
Tenney calls temporal gestalt units (TGs).   The means and
ranges would of course vary from TG to TG, and this speci-
fied progression of values in a sense determines the piece.
He called a TG comprised of small level (element) values a
clang. He also specified that at least one of the three
parameters in any clang should "be variable over its entire

range, whereas the other parameters might be varying (temporarily) over a narrower range" (page 42). Tenney also gave the program the total number of "clangs" it was to generate, along with extreme values for their durations (or an overall duration range), the number of voices to be generated per clang, the rest probability for each voice, and the FM range for each voice. By changing values for the above, four different pieces were generated, called the Four Stochastic Studies.

Dialogue (1963) represents certain improvements or extensions to the program he used for the studies. One such modification was to make it possible for a larger hierarchical form to be superimposed on the clang by clang chain of events. To do this, Tenney specified initial and final mean values for a given "sequence" (which was composed of clangs in the same way that clangs are composed of elements), and then the computer used interpolated values (from the clang starting times) to stochastically compute means for the clangs. This in a sense replicates the choice process within the clangs themselves, and ensures "that some sense of 'direction' could be given to longer sequences, while still allowing the smaller details to vary randomly" (page 44). The actual instruments used in Dialogue were of a different sort as well, in that they either produced noise bands or tones in response to a given probablity input. Three more parameters are also added to the instruments' repertoire.

"These are amplitude-modulation rate (which becomes noise bandwidth for faster rates), amplitude-envelope function-number, and waveform function-number. The two types of stored functions are arranged in arbitrary 'scales' and controlled in essentially the same way the other parameters are. (The arrangement of the function-number scales is not entirely arbitrary: for wave-form, the spectra with more energy in the lower harmonics were given the lower scale-values, and for amplitude-envelope, those with the shorter rise-time were given the lower values. Thus, a sequence could change, gradually, from less to more 'penetrating' and/or 'percussive' timbres, for example.)"

(p. 44)

The piece is, in form, a dialogue between noise-bands and pure tones. The diagram (Example III.2a,b; pp. 47-48) shows the complete form of the piece, and accurately reflects the input to the computer program. The first diagram shows the graphs for the mean values of tonal parameters, and the second shows similar parameters for the "noise-tones". One thing of interest in this program, is that we see a very early usage of what has become an important technique in modern digital sound synthesis, the use of
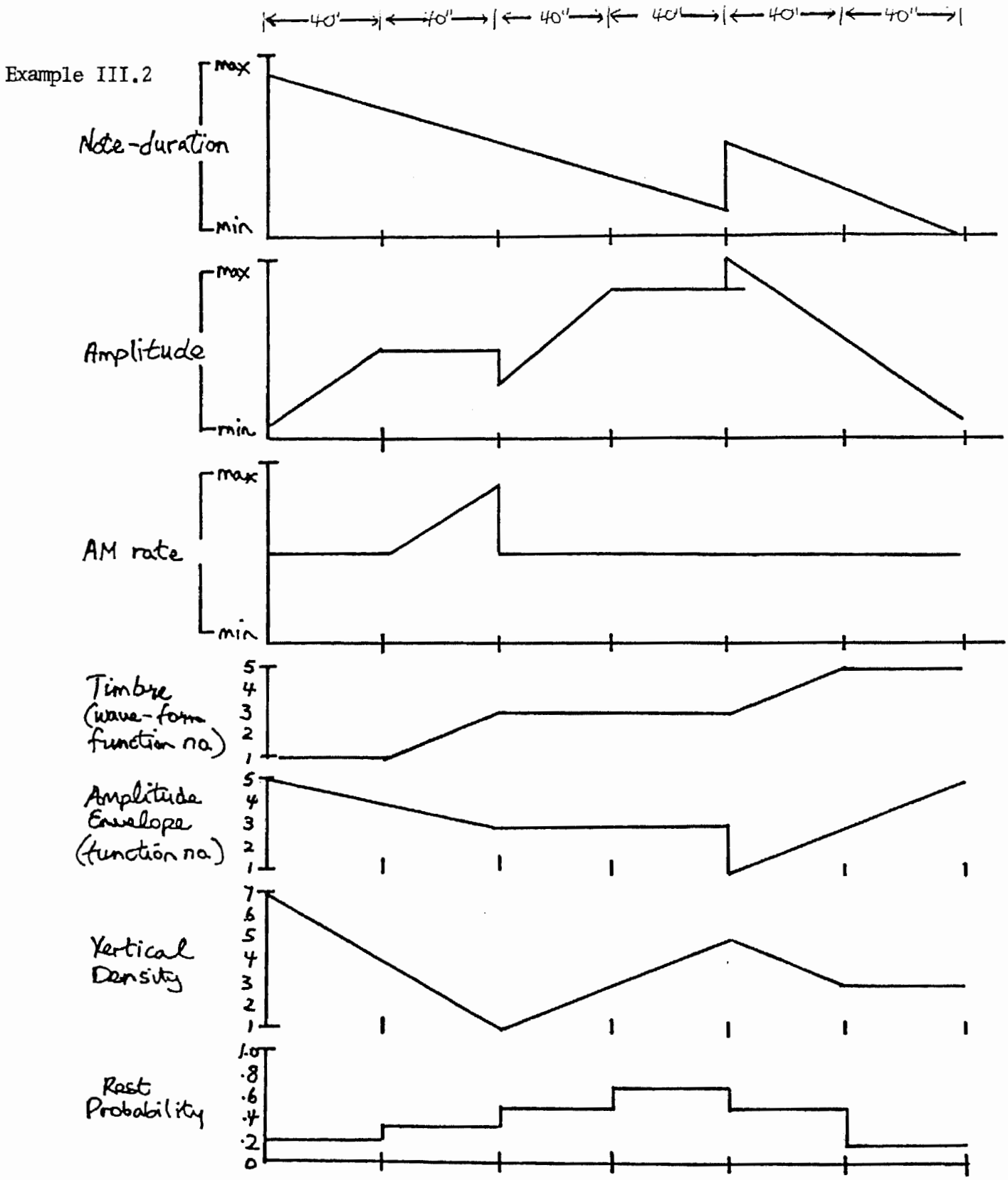
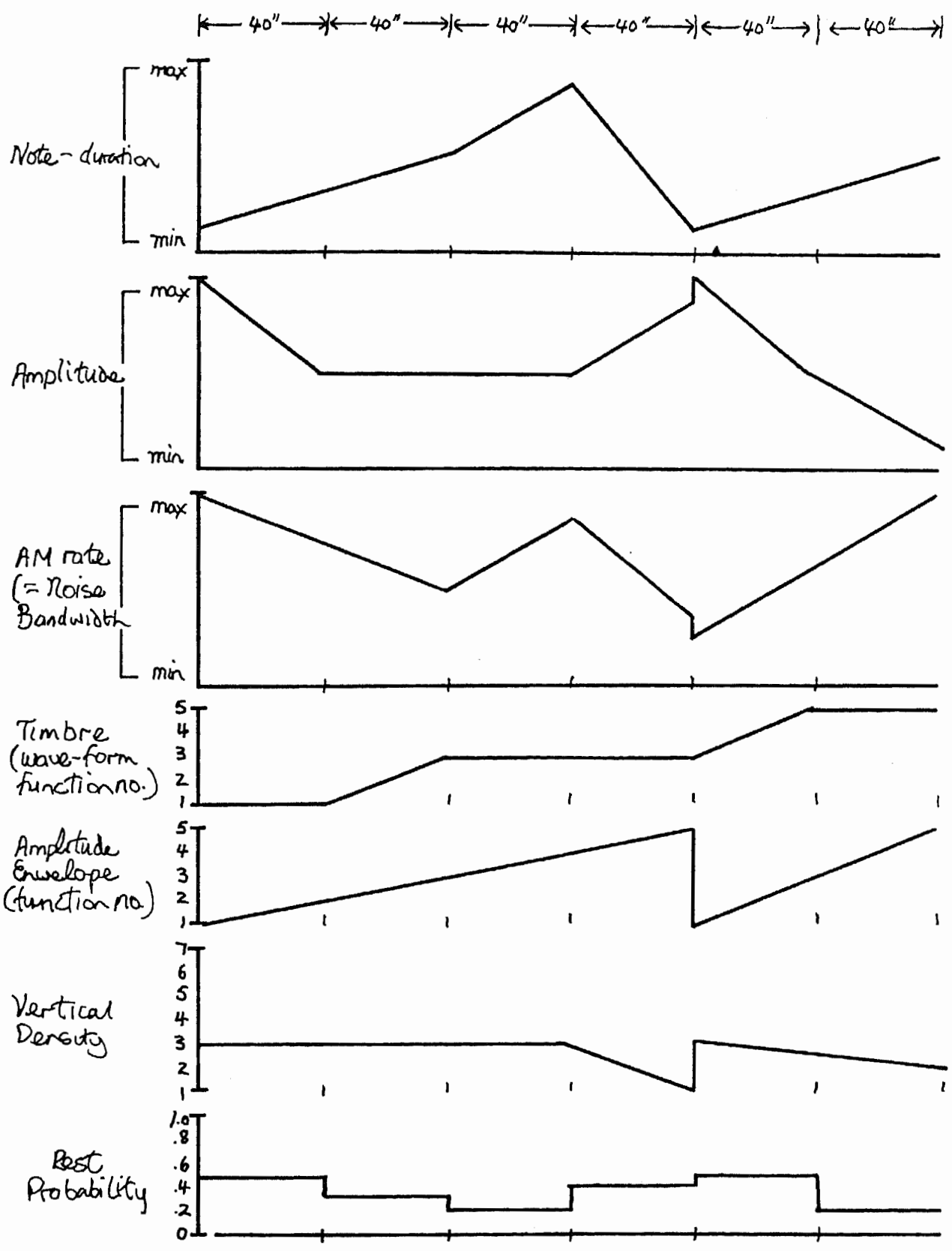Figure 11a.   Parametric Means for "Dialogue" (tonal stratum).

Figure 11b. Parametric Means for "Dialogue" (noise stratum)

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wave-tables - preset functions that a composer can call up
himself to use in a variety of ways. Intelligent structur-
ing of systems of these functions, that is, how to order
them perceptually, remains a fruitful field for investiga-
tion (note that Tenney's ordering of the timbral space is
quite ingenious, and this type of thinking at such an early
stage is quite striking to those of us who are just now
beginning to deal with these same questions!).

Stochastic(String)Quartet

It is difficult, as usual, to improve upon Tenney's own
description of the composition of this piece. The work was
a "request" from a professional string quartet, and Tenney
siezed the opportunity to use the computer to compose a
piece for traditional instruments, along the same lines as
Hiller's Illiac Suite (which really has little in common
with Tenney's music other than the use of stochastic
processes). He devised some means for translating the clang
generation process into a program which would output values
readily translated into musical notation. The real problem,
as he describes at some length, occurs in the time parame-
ter, and he developed an algorithm which would deal with
successive subdivisions of beats to produce complex but
notationally feasible rhythms.

His later problems with the piece's performance and
players' reactions to it led him to some wonderfully candid
and philosophical musings about his own work, computer
music, and miscellaneous musical items which should be
quoted here in full:

"Since the first quartet was completed I have twice
begun a new program for instrumental music, and
twice abandoned the work before a piece was fin-
ished. The reasons for this were not clear to me
until recently, and involve not only the experiences
in writing the programs and listening to the (syn-
thetic) results on tape, but also the experiences in
trying to get string-players to play the first quar-
tet, and other, more general, changes in my musical
attitudes in these last several months.

In the first quartet the complexities of the notated
parts were such that a string player would have had
to practice his part diligently, and even then the
ensemble would probably have needed a conductor to
keep it together. Now if every detail in the score
were part of some 'musical idea' (in a 19th century
sense) that needed to be realized precisely, such a
situation might be justified. But this was not the
case. Each detail in the score was the result of a
random selection process that was being used only to
insure variety, and might thus have been - within
limits - anything else than what it was and still

have fulfilled the conditions I had set up in the beginning. (At Bennington, I tried to explain this, and to assure the players that their 'best approxi-' mation' to the part as notated was really suffi-cient. But the very appearance of the score itself contradicted me!)

Thus, it began to be clear to me that there was an enormous disparity between ends and means in such a piece, and I have more recently tried to find a way to get that variety – in the 'human', instrumental situation – in ways more appropriate to the situa-tion itself, in terms of the relationship between what the player sees and what he is expected to do.

Another problem arose with this quartet which has led to changes in my thinking and my ways of work-ing, and may be of interest here. Since my earliest instrumental music ('Seeds', in 1956), I have tended to avoid repetitions of the same pitch or any of its octaves before most of the other pitches in the scale of 12 had been sounded. This practice derives not only from Schoenberg and Webern, and 12-tone or later serial methods, but may be seen in much of the important music of the century (Varèse, Ruggles, etc.).

In the programs for the Quartet and the Dialogue, steps were taken to avoid such pitch-repetitions, even though this took time, and was not always ef-fective (involving a process of recalculation with a new random number, when such a repetition did occur, and this process could not continue indefinitely). In the Quartet, a certain amount of editing was done, during transcription, to satisfy this objec-tive when the computer had failed.

But certain things about all this began to bother me: (a) it represented a kind of negative aspect of a process that was supposed to make 'everything' possible; (b) it was a constraint applied only to one parameter – pitch, whereas almost all other operations in the program were common to all parame-ters; and finally, (c) it used up a lot of computer-time (that might have been used to make more music, rather than less). Also, I had noticed that in the Dialogue, where the pitches are selected from a continuous scale (as opposed to the quantized scale of the Quartet), the pitch repetitions (two pitches within a very small interval of each other or of one's octave) that got by the exclusion-process in the program did not seem to decrease the variablility of the music, or interrupt the flow in

the way they did in the Quartet. This suggested that the unison-octave avoidance was needed only when the pitch-scale was quantized as traditionally - only, that is, when the entropy of the pitch distribution had already been severely limited by such quantization. Accordingly, I no longer find it necessary to avoid any pitch, at the same time that I intend never to leave undisturbed - even when working with instruments - the traditional quantized scale of available pitches. It is not too difficult to get around this with instruments (except for such as the piano) - it's mainly a matter of intention and resolve."

(pp. 50-52)

Ergodos I (for John Cage) (1963)
    The concept of an ergodic information domain, one in which (put rather simply) any given slice of the material is equivalent statistically to any other slice, has become of great importance to contemporary composers since the early work of people like John Cage, LaMonte Young, and Tenney. The effects of such an environment on our perception, and the choice of how to create such an auditory phenomenon has remained an idea of tremendous interest. In a way, the current use of the term minimalism (as usual, to describe a trend that peaked several years before the term took hold among critics, academics, etc.) is a special case of music whose large form often has no real direction, or at least an extremely simple one, but whose intricate (or even simple) microstructure is of immediate sonic importance. Justifiably, composers and listeners have been fascinated by such works, and have experimented both with the concepts of apparent change along specific parametric axes (like Cage's Music of Changes), or with very slow and steady modification of one parametric axis. Tenney's characteristic response to these ideas, was to first try to more or less scientifically explain it to himself, and then to create music which utilized that property of ergodicity which removes any vestiges of "dramatic intent" from its resultant structures.

"Both the String Quartet and Dialogue made use of programming facilities enabling me to shape the large-scale form of a piece in terms of changing means and ranges in the various parameters in time. Now my thoughts took a different turn - an apparent reversal - as I began to consider what this process of 'shaping' a piece really involved. Both the intention and the effect here were involved in one way or another with 'drama' (as in Beethoven, say) - a kind of dramatic "development" that inevitably reflected ('expressed') a guiding hand (mine), directing the course of things now here, now there, etc.

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What seemed of more interest than this was to give
free reign to the sounds themselves, allowing any-
thing to happen, within as broad a field of possi-
bilities as could be set up. One question still
remained as to the possible usefulness of my con-
trols over the course of parametric means and
ranges: are there ways in which the full extent and
character of the 'field' may be made more percepti-
ble - more palpable - by careful adjustments of
these values?"

(p. 52)

The structure of Ergodos I is simple: two ten minute
monaural tapes which may be played in either direction,
alone or together, or in any combination (there are 10 such
possible). The outside two minute sections of each tape
were given some statistical shaping - an increase (or
decrease) of both tempo and intensity towards the mean
(midrange) levels for these parameters. The resultant shape
is thus a kind of trapezoid with a six minute static sec-
tion.

"During the middle six minutes of sound on each
tape, all the parametric means are constant near the
middle of their respective scale-ranges, and these
ranges are at their maximum. Thus, the sounds on
each tape are nearly ergodic, and thus the title -
'ergodos'".

(p. 53)

In addition, certain measures had to be taken so that the
various versions of the piece (that is the various tape com-
binations) would also be ergodic - that one would not result
in a greater statistical distribution of any given parameter
than any other. This included ensuring that all envelopes
occurred with the equal probability of their retrogrades.
Great care was taken to determine the proper time length of
the ergodic section ("did the field of possibilities get
used up?") and to slightly juggle the means and total ranges
of the various parameters, which are the same as those used
in Dialogue. Tenney did this by setting the parameters for
the first ten minute tape on the basis of some preliminary
tests, and then listening to the entire ten minute piece and
adjusting the parametric values slightly according to his
own perception of what was needed. The final ten minute
tapes are combinations of the two sets of computer runs and
in this way the changes in the parametric values are "bal-
anced out".
The table below gives the values for the initial
parametric means, and the values to which Tenney felt he had
to change them. Note that these values are meant to produce
a certain effect: that of a random distribution of sonic
events over our perceptual space, and so the magnitude of

the changes is of some interest.

	First Run	Second Run
Minimum note duration	1/16 sec.	same
Maximum note duration	4 sec.	5.3 sec.
Mean values for note duration (log scale)	1/2 sec.	same
Note/rest probability	.33	.5
Average vertical density (# voices)	less than 3	3
Noise probability	.5	.67

(Note that a duration value of 1/2 second is, on a base 2 log scale, exactly the mean of 1/16 and 4).

Phases   (for Edgard Varèse) (Dec. 1963)

To me, Phases is the most beautiful and interesting of the works of this period. It is impossible to describe the ungainly, almost other-worldly effect that it has, but it often seems as if it were not composed by either man or machine, but by some goblin-hybrid of the two. It remains, as well, one of the strangest and least accesible of Tenney's compositions, as it seems to exist for its own purposes entirely. Listening to it, I often feel that I am in the position of eavesdropping on a strange and beautiful conversation. It has not become a well-known piece, but this is not surprising, for it makes few compromises to any of the criteria yet formed for "good" music - it goes its own way with a deep sense of inner coherence, but coherence on a larger level than we are yet able to easily perceive. I think that in this piece, and also perhaps in Ergodos II which followed it, Tenney realized his goal at Bell Labs, to have the computer-produced work do things that he could not foresee, and as such to advance his own musical thinking.

On another level, the sheer sound quality is equally exciting. The word that comes to mind when I hear it, and a word that I seldom use with respect to computer music, is "funky". The subtle use of noise, pitches just on the level of audibility, miniscule glissandi that remind one of the inner patterns in rice paper, are all in their own ethereal way, quite moving. It is as if Phases is a window on a perceptual and sonic space that is always going on, but one that we are seldom allowed to hear.

A lot of this has to do with the further extensions Tenney made to his instrumental repertoire in Phases:

"One of the most obvious aspects of many of these environmental sounds was their frequency instability - 'glissandi' and 'portamenti', as well as faster modulations. The sounds in Dialogue and Ergodos I had some frequency modulation, but no frequency 'en-

veloping', and this now seemed a necessary extension
of the list of variables. Filling in the gap
between tones and noise-bands was achieved simply by
allowing intermediate values to occur in the parame-
ters affecting the noise - the range and rate of
random amplitude modulation. In addition, it seemed
desirable to envelope the AM rate so that the
bandwidth of the noise could vary within each
sound."

(pp. 55-56)

Another important factor in the generation of more com-
plex and varied tones was the use of a rather complex ampli-
tude compensating band pass filter in the stored functions,
to produce an enormous range of spectral variation on a lim-
ited set of basic waveforms. The complexities of this
filter have more to do with the mechanics of digital sam-
pling than anything else (and indeed seems quite simple when
compared to the digital "comb" filters in use today) but
what is important is that its bandwidth and center frequency
could be modified continuously in time, independent of the
fundamental frequency, creating a powerful instrument for
spectral shaping and manipulation. (It is interesting to
note that Tenney refers to this as a formant filter, a term
that has more to do with the acoustics of speech than the
current term "band-pass"). Thus, Tenney was searching out
each timbral parameter and more or less applying the same
idea: that their functions should be controlled by the sto-
chastic processes that govern TG formation.

Formally, the Phases program incorporates still one
higher level of TG determination, what Tenney calls the sec-
tion, and so now not only parametric means of clangs are
determined by the machine, but also the parametric means and
ranges of sequences, which previously had to be input by the
composer. This extends the hierarchical process to four
levels (element, clang, sequence, section). Tenney's graph
(Example III.3) shows the shapes which the parametric vari-
ables took in several of what he considers to be the most
important parameters. One can easily see both the simple
elegant form and the genesis of the title, for the functions
are each sinusoids of varying wavelenths, and as such change
phase with each other. These slow moving sinusoids create
the perceptual effect of a clear overall movement but imper-
ceptible change, and only if the listener focuses his atten-
tion on a given parameter (and this is difficult to do!) can
he percieve the direction and nature of the parametric evo-
lutions.

Ergodos II (for John Cage) (1963-64)
This was the last work Tenney completed at Bell Labs,
and it is a fitting, zen-like conclusion to the nature of
his formal and aesthetic investigations. It is eighteen
minutes long, and may be played in either direction. The

Example III.3

Figure 13. Parametric Means and Ranges (dotted lines) for "Phases."
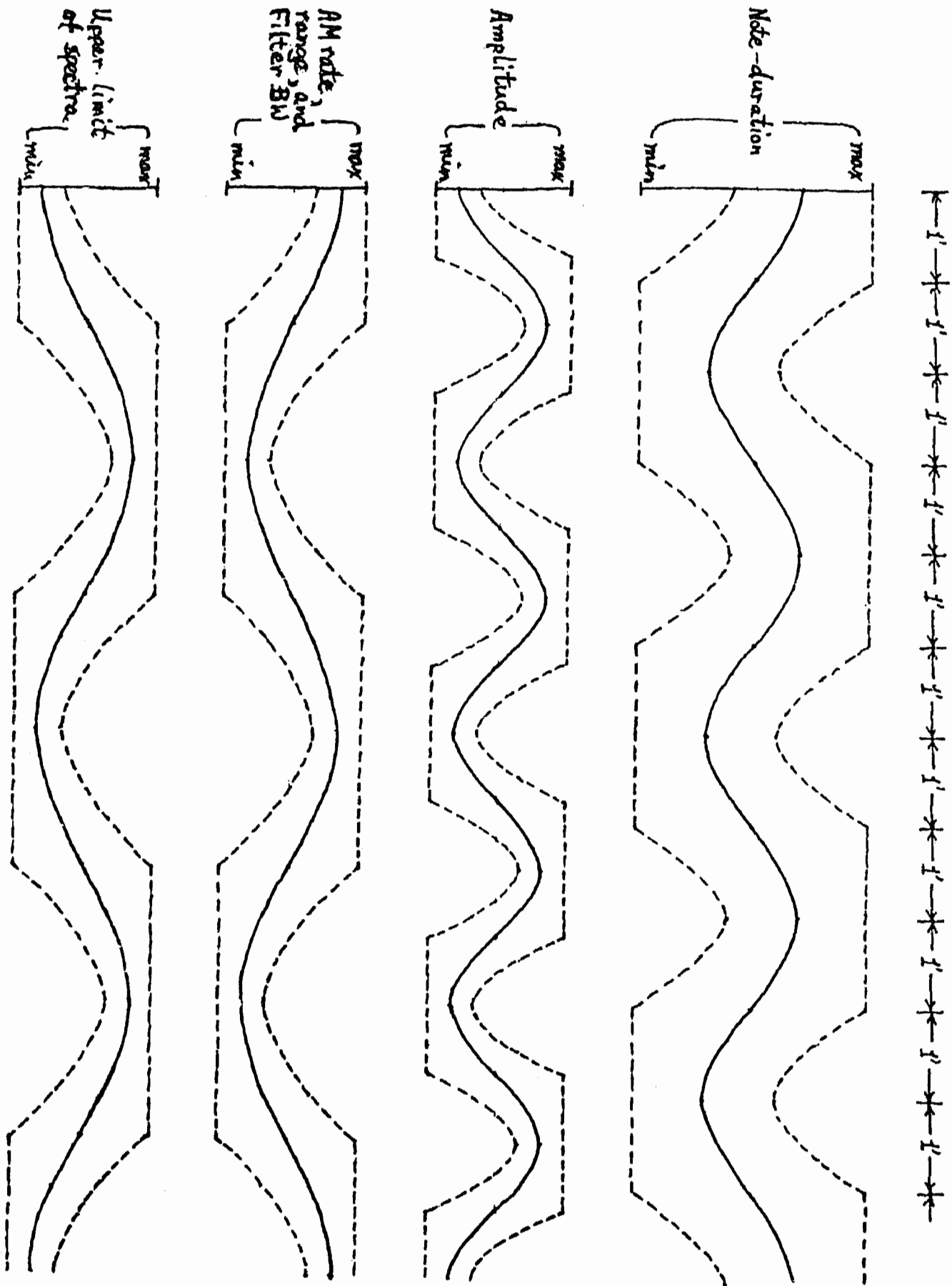
tape "might be subdivided into two or more segments of approximately equal length, and these segments played simultaneously (over one to N pair of loudspeakers, for N segments)". Tenney later used Ergodos II with the Tone Roads ensemble as the tape basis for the piece Instrumental Responses. In addition, Ergodos II is the first piece to use the stereo facilities that had recently been programmed into the music language. Predictably, Tenney adds the spatial distribution of the sounds into the list of parametric variables that are subject to stochastic distribution. The instruments and algorithms are almost identical to Phases, and it has the same rich and beautiful quality, but there is finally complete ergodicity. There is, in any way that we might reasonably define it, no form. The musical effect is quite startling. Ergodos II seems to have been an almost required piece, the final step in a series of investigations into the perceptual unknown. In this regard, I have always been curious about the last sentence in Tenney's paper, where he somewhat cryptically states:

"Another piece was begun after its completion, but abandoned when my dissatisfaction with the early test results made it clear that I would not have time to complete it before leaving."

(p. 60)

Though the reader might wonder, as I did, what could possibly follow Ergodos II, Tenney has informed me that it eventually became Fabric for Che (see Chapter IV).

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