AN INDIVIDUAL NOTE

Daphne Oram was educated at Sherborne School for Girls, and then, during the war, she joined the BBC in London as a Music Balancer. There she worked with most of the well known international musicians in the fields of chamber music and opera. But, alongside this work, she was intrigued by the possibilities of manipulating magnetic tape sound, and as early as 1948 began to build special equipment for experiments. She was the first to compose an electronic sound track for a BBC television play *(Amphitryon 38)*, all the composing being done in the middle of the night (using quickly assembled equipment) in the deserted Broadcasting House studios.

When the BBC eventually built an experimental studio, the Radiophonic Workshop, Daphne Oram helped to design it and then directed it. In 1959, she decided to leave the BBC to create her own studio in her converted oasthouse at Wrotham, Kent. Since then, she has become internationally known for her work in films, television, theatre and radio; she has presented successful concerts of electronic compositions at the Mermaid Theatre, London, and at the Edinburgh International Festival. She has lectured widely—at London University, Cambridge University Arts Society, The Institute of Physics, Harrow School, Wellington College, Roedean, and at many other Colleges, Schools and Music Festivals. She has also appeared a number of times on television and in films.

For her *Oramics* research work, at her Kent studio, she received two Gulbenkian Foundation Grants.

This is a Galliard paperback. Also available is a study of Arnold Schoenberg by Egon Wellesz, which was first published in 1921 and was re-issued, with an extra chapter written especially for this edition. In preparation is an English edition of the biography of Egon Wellesz by Robert Schollum.

Further titles in this series of books on the music of this century will be announced.

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AN INDIVIDUAL NOTE *Daphne Oram* GALLIARD

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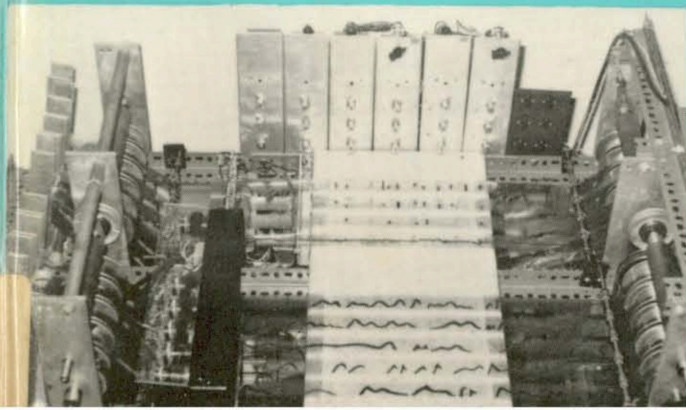
a Galliard paperback

AN INDIVIDUAL NOTE

of **music**

sound

and **electronics**



by Daphne Oram

DAPHNE ORAM

AN INDIVIDUAL NOTE

OF MUSIC, SOUND AND ELECTRONICS

1972

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'. . . these are my own particular opinions and fancies, and I deliver them as only what I myself believe, and not for what is to be believed by others.'

Montaigne: *Essays*. 1580.

May I dedicate this book, in gratitude,
to all those who have given me that
priceless gift—time to muse—
especially to

The Calouste Gulbenkian Foundation

and

J.W. I.W.
F.W.W. D. Mac E.
A.H. N.K.
S.S.G.

who all proved to be perfect impedances!

1

MUSIC, SOUND and ELECTRONICS . . . each of these subjects has been well covered recently by sober academic textbooks; I am certainly not going to write another of those! This book is for amusement. But I want to write that word this way . . . a-*MUSE*-ment.

Looking through my dictionary to see whether the words *MUSE*, *MUSIC* and *AMUSE* come from a common root, I was delighted to find that the Italians have a word *MUSARE*: 'to sniff the air to catch a scent'. It is an appropriate word for this book, for here we shall be sniffing the air in all directions to see whether we can catch a scent or two of intriguing interrelationships between electronics and music, to see whether we can break open watertight compartments and glance anew—from various aspects and in various states of mind.

We will be entering a strange world where composers will be mingling with capacitors, computers will be controlling crotchets and, maybe, memory, music and magnetism will lead us towards metaphysics. Some of the results may even seem to be *AMUSIVE* but . . . what matter? As long as we are seeing afresh and not just blindly accepting, this odd interplay of ideas will surely be justified. We shall, therefore, be exploring aspects of electronics and acoustics in relationship not only to the composition of music, but also to the world in which we find ourselves. We shall allow ourselves to go a-wandering, a-wondering and a-musing so that we may sniff the air expectantly in all directions (and I suspect we may really enjoy, most of all, the pitfalls we fall into . . . when our noses are held far too high in the air!).

Can we enter both the music and the electronic fields at the same time? 'Composers will be mingling with capacitors' . . . an odd combination. Do you think that composers and capacitors have any characteristics in common? Is there a link between musical composition and electronic capacitance? Well it is worth a moment's musing; but we will not tire ourselves with a lot of technical data, for most of us probably have an inkling of how both capacitors and composers work.

Suffice to say that a capacitor is a device for storing electrical energy. The amount of energy it can store depends on its size and materials. It consists of two plates of metal, held apart by a substance of high resistance, such as paper or mica, or the air itself. The plates of the capacitor can be charged by connecting them to a source of electrical energy—a battery. The plate connected to the negative terminal of the battery will become negatively charged, and the other plate, connected to the positive battery terminal, will become positively charged.

Because there is a barrier of insulating material (called the dialectric) between the plates, the negatively charged plate is now embarrassed by an excess of randy electrons, all eager to date the fair positive ions on the other plate! As the battery continues to charge the capacitor, a state of increasing tension is created, and when the battery is removed this state of tension remains. One plate is inducing an effect on the other . . . and vice versa.

If we now connect a wire externally between the two plates a current will flow through the wire, for the electrons will try to get round by this outside path. The wire will have a certain amount of resistance (and other properties), which will determine the time it takes for the electrons to join the positive ions.

If we give this flow of electrons—this current—a great deal of resistance to surmount in the circuit, the capacitor will clearly take an appreciable time to reach equilibrium; its releasing of tension will

occupy a measurable length of time, and during that time the energy will subside in a certain way . . . a definite shaping of outflow, from beginning to end, from one plate to the other.

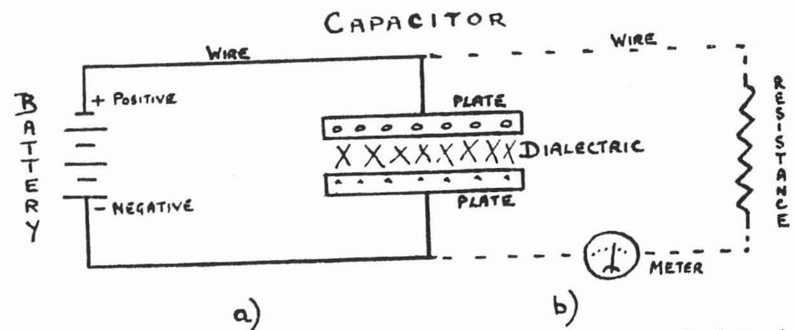


Fig. 1. (a) The capacitor is first connected to the battery in order to be charged. (b) The battery is then removed, and in its place a wire with resistance connects the two plates. A meter in the circuit will now show the flow of electrons gradually ebbing until the plates reach equilibrium.

Has the composer anything in common with this? Could a musical composition be described as a release of tensioned energy, in a specific form, over a determined period of time? A tension which is released in finely controlled 'surges'?

If we draw a graph, with time going from left to right and electron flow (current) on the other axis, we get something like this for the capacitor and fixed resistor:

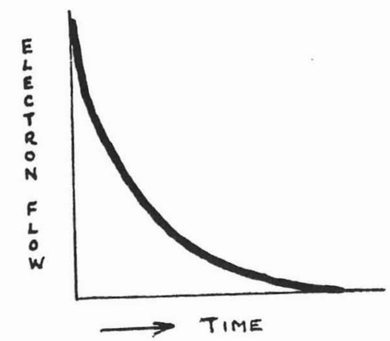


Fig. 2. Capacitor discharging through fixed resistor.

By varying the resistance, during the discharge time, we could control the electron flow, so that it becomes a more interesting pattern.

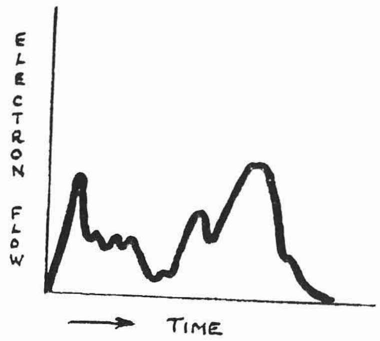


Fig. 3. Capacitor discharging through varying resistor.

This second graph could equally well be a plan of climaxes and relaxations in a piece of music. The time scale would then be extended to some minutes or even hours. Could it not also describe just one note of this music? If the time scale is reduced it could represent just a crotchet, a mere moment of sound, as seen on an oscillograph; for the production of a single note needs the same formula—energy is held in tension and then released through a resistance. The tensioned energy can, of course, be in many forms—a poised drum-stick, a controlled bow, a flexed finger, a held breath; and the resistance—a stretched skin, a column of air, a tightened string, etc. Release the tension and the result is a flow of sound—an ebbing stream of energy-surges, waves of compression alternating with rarefaction which beat against our eardrums; taking a definite period of time before dying away to nothing.

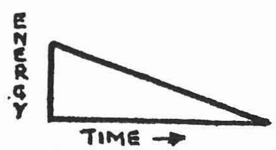
The time taken for a capacitor to discharge its tension may be a fraction of a second; for a trumpet to play its crotchet, a fraction of a minute; for a symphony to complete its statements, a fraction of an hour.

As phenomena they strike me as being surprisingly alike. Each one an interplay of potential, resistance and time resulting in the release of power. Each is achieving its effect on the outside world by disciplining the potential, by creating varying resistance so that the power is modulated in perceptible, finite time.

When we initially connect the capacitor to the battery we find that the plates become charged in quite a short time, sometimes just a moment; yet, if we put a fairly large resistance in its circuit, it may take many seconds for the capacitor to release all this energy.

Similarly, the composer may conceive the germ of the idea for his composition in 'a flash' (Mozart's *Gleich alles zusammen*) but his task then is to bring this *outside time* experience into the reality of time and give it substance and duration, allowing it to achieve its inherent shape and balance. He may release the tension gradually throughout the composition, or find that he is conserving most of it until a climax is reached, when the pent-up tension can burst forth. In this way he can sense and control tensions of rhythm, tensions of tonality or atonality, tensions of spatial relationship and nuance, and so on . . . seemingly his original 'spark' has charged up many capacitors, which are now under his control. But can he vary the resistance in each capacitor circuit so that his musical 'electron flow' creates neither the extreme of chaos nor, on the other hand, the monotony of trite convention?

The initial flash of energy *outside time* is being transduced by him so that it flows now *within time*, until it reaches equilibrium. Fundamentally it is roughly this shape—



but from now on it is being modulated by his will. It starts by being a positive amount and is 'worked out' until at the end of the composition there is nothing left. In other words, it goes from positive towards negative.

But there is much more to a composition than that! The energy and essence of a piece of music is not just the intellectual working out of notes, rhythms and phrases.

Maybe, by pursuing further these analogies between electronic circuits and the composing of music, we will be able to gain a little insight into what lies *between and beyond the notes*; we may be able to glimpse forces at work within the composer (or indeed within any artist or creator), which seem to have counterparts in acoustics and electronics.

Analogy is a process much used in the past. For centuries the myths and legends of Greece and Rome have formed the basis of analogies which have helped people to imagine and describe some of the mysteries of their lives. Religions have served us with rich analogies. Science has also played its part. Now, in the 20th century, when science is so prominent, can it link more closely with imagination? Can science unbend sufficiently to present scientific facts in such a way that they excite artists? Can artistic creations equally excite the scientists? Do both the scientist and the artist need a new range of metaphor, verging on mythology: a new set of analogies which will provide a common meeting ground, giving each a stimulating and enriching glimpse of the other's world?

Can the scientist bear to have his hard learnt 'facts' bent by artistic licence? Will the artist protest if his wildest dreams appear to be scientifically disciplined when they are absorbed and 'put to use' by the scientist?

In the past few years Arts Laboratories have talked a good deal about linking science and art. Have they achieved a unification, by the use of imagination? Have they assisted in the embracing of the two distinct visions to make a unified whole? Their scope, so far, seems to have been far short of this. Instead they seem to be making their main concern the transferring of scientifically made materials and methods from the scientist and technician into the hands of the artist—and even this has only happened in selective fields. Certainly new materials and ideas seem to have revolutionised sculpture and architecture, but they have only just managed to penetrate the musical world. The average musician has very little knowledge of electronics, computers and mathematics, and is even pretty hazy about acoustics!

But that is not a new observation, for Charles Burney was saying much the same thing in 1776:

> 'It seems as if theory and practice were ever to be at strife, for the man of science who never hears music, and the musician, who never reads books, must be equally averse to each other, and unlikely to be brought to a right understanding. . . .'[1]

[1] Charles Burney: *General History of Music*, Vol. I p. 116.

Within the scope of this present book we cannot go far, and in wandering and wondering we shall have to ask the scientist to forgive us if we do not view his discoveries with strict scientific scrutiny; we will also need to ask the forgiveness of the composer if we attempt to bring down to earth some of his difficult aesthetics. Analogy, metaphor and even mythology will, I hope, help us to keep our balance.

Let us return to the capacitor. The capacitor, when charged, is rather like a pendulum which is pulled aside, but not yet released. When you let go of a pendulum it will oscillate, and in this way a pendulum can be used to beat time like a metronome. Although the distance that it swings will gradually be reduced (as its energy dies down), it will, nevertheless, keep strict time. By altering the length of the pendulum we can make it oscillate at, say, sixty times a minute or, with a shorter string, a hundred times a minute. By feeding it with the right sort of energy this oscillation can be kept up indefinitely.

If we now take our charged capacitor and link its two plates with a wire which is twisted into a coil, we find we have an electronic 'pendulum'.

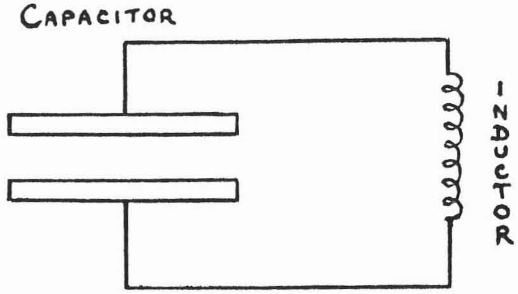


Fig. 4. The capacitor and coil (inductor) make an electronic 'pendulum'.

The excited electrons are no longer so restrained as they were with just the resistance in circuit. Too many eager electrons rush through the coil to the other plate and, finding that there are not enough positive partners to go round they return home only to venture forth again with scarcely less vigour, and as hopeful as ever.

So now the tension dissipates itself in swaying surges—oscillations—until finally a state of satisfied equilibrium is reached. The electrons, when rushing backwards and forwards from plate to plate, keep strict time. Their amorous journey from 'home . . . away . . . home' again, is called one 'cycle' and the number of times an electron does this in one second is called the 'frequency'. Frequency, roughly speaking, is the same as pitch.

By the way, if your refrigerator was cold enough and you could supercool this electronic pendulum, it would go on oscillating for a tremendous length of time, for by supercooling it you would remove its resistance (it could only lose its energy by radiation).

But we have no supercooled refrigerator, so there *is* resistance there, and these oscillations will gradually die out. Not, however, if we can feed the right sort of energy into the circuit and keep its vitality going. With the pendulum we need to give it a slight push every so often; but the push has to be timed to coincide with the pendulum's natural swing, otherwise we damp down its oscillation and badly distort its regular beat.

The regular 'beat' of a capacitor/inductor circuit may be sixty times a minute, but it might well be six hundred times a second. If we insert this electronic 'pendulum' into a special amplifier which will keep it energised, and connect it to a loudspeaker, we find we have transformed this electron activity into audible sound . . . into a musical note . . . D. (We have built an audio frequency oscillator.)

We will find our 600 oscillations a second slightly sharp for D on the treble stave, which oscillates 587 times per second. (D♯ requires 622 oscillations per second.) But this circuit has another attribute: it can be tuned. By altering the size of the capacitor, or the size of the inductor, we alter the pitch (the frequency) of the natural oscillation. In fact, we call this simple electronic circuit a **tuned circuit** . . . a significant mingling of musical and electronic terms.

The tuned circuit is useful in many other ways. In our radio and television sets it allows us to pick up the transmission we want. It can be tuned so that it resonates at the frequency of the required broadcasting station. It then accepts the signal from this selected transmitter; but it can also be placed in a circuit so that it rejects.

To do this we insert it as a barrier, so that the frequency which makes it resonate will be turned away and not accepted.

And this is not all that a tuned circuit can do! We find that, because the wire connecting the capacitor plates is wound into a coil, the current running through the coil creates a magnetic field around itself. As the electrons oscillate backwards and forwards the magnetic field waxes and wanes. There are two separate results from this pulsing magnetic field. Firstly, this action induces in the wire itself more resistance . . . self-induced resistance which is called inductance. Secondly, this waxing and waning magnetic field will induce a current to flow in another circuit which is in close proximity to it. This secondary circuit has to be close enough to be influenced by the changing magnetic field of the first circuit, the primary circuit.

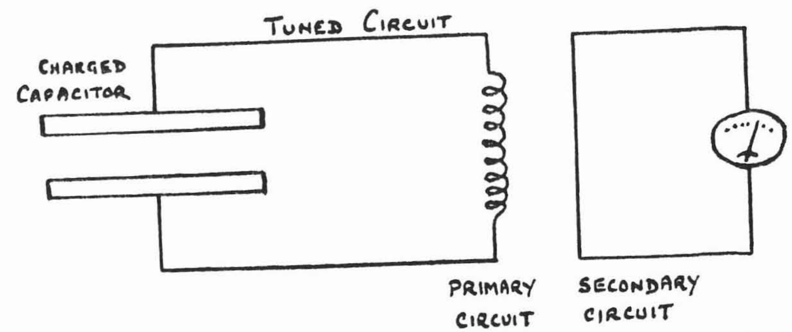


Fig. 5. Every time the electron flow in the tuned circuit changes direction it will induce a flow of electrons in the secondary circuit. (If the wire of the secondary circuit is also coiled, a greater amount of energy will be induced.)

Now let us summarise these points about a tuned circuit—

1. A tuned circuit will act in somewhat the same way as a pendulum. Any energy will dissipate itself over a period of time unless the capacitor is re-energised.

2. If this electronic 'pendulum' is kept in 'motion' by energy from outside, it can be used to produce a continuous signal—an oscillation which can be made audible. (It can also oscillate at frequencies above, or below, the audible range.)

3. The circuit can be made to resonate, at its tuned frequency, by outside influence. It can be used to accept or reject frequencies.

4. By magnetic induction the tuned circuit can induce a current to flow in a nearby circuit.

To all this we should add one more point. If we charge up a capacitor far too much, the barrier between the plates—the dialectric—will break down. The tension will become so great that the energy will suddenly release itself in a great spark, which will burn its way through the dialectric . . . and that will be the end of the capacitor.

Such a sudden release of tension will cause a momentary transmission of electromagnetic energy to radiate in all directions through the 'ether'. This radiated energy can travel a considerable distance and can cause a suitably tuned circuit to resonate, even though this secondary circuit has no tangible connection with the original capacitor (that is, with the capacitor which has just produced its death spark). In fact the secondary circuit may be many yards away from the original capacitor.

So we will now add this fifth point to our summary—

5. By sparking from plate to plate the capacitor can originate an electromagnetic/electrostatic wave which will radiate over a distance, and cause a sympathetically tuned circuit to resonate.

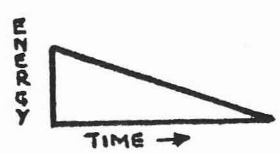
For a little relaxation now, we will turn our attention away from capacitors to the subject of current flow. When you turn on your torch and the current heats up the element of the bulb to give you light, which way do you consider the current is flowing? From the battery's negative terminal, through the bulb and back to the positive terminal; or from the positive terminal to the negative one? The scientists in the early days decided that current goes from positive to negative (+ to −), from the copper pole of a battery to the zinc pole. The scientist these days, while accepting this as the convention, now note that the electron flow is actually from − to +; it is the positively charged ions (resulting from the removal of electrons) which can flow from + to −.

In just such a manner as the scientists, it is fascinating to take a fresh glance at all conventions to see whether there is not another way of looking at them—a way of looking which is exactly the reverse of the usual and yet, perhaps, equally legitimate. The great thinker and essayist Michael de Montaigne had the wonderful gift of seeing things from two directions at once, of looking at both sides of a question, of combining great imaginative powers with complete intellectual honesty. (He lived from 1533 to 1592, so he was just seven years older than that brilliant Englishman, William Gilbert of Colchester, who laid the foundations for the science of magnetism and electricity, introducing the name 'Electricity' from the Greek word for *AMBER*.)

In this book, this book of amusement . . . musing upon electronics and music . . . one of our main concerns is to try to see things 'the other way round'. We might perhaps coin the phrase *to montaigne them*—to consider facts from all directions. 'When I play with my cat' wrote Montaigne, 'who knows whether I do not make her more sport than she makes me?'[1] ('Quand je me jouë à ma chatte, qui scait, si elle passe son temps de moy plus que je ne fay d'elle?')

But we must leave Montaigne with his cat and return to electronics, to our capacitor.

In the capacitor/resistor circuit that we were at first considering, the electrical tension starts from maximum and dies down to nothing, to equilibrium (unless, of course, the circuit is re-energised).



We compared this to the composing of a piece of music, to the energy which the composer controls and works out in musical notes until the composition finishes . . . until it is silent (until the tonal vibrations have subsided into 'equilibrium').

[1] M. de Montaigne: *Essays* (trans. Charles Cotton 1685), 3 vols.

In the composer's 'working out', the shape is, of course, likely to be far more complicated than this diagram implies , but let us, for the benefit of clarity, keep that simple shape as a symbol for this releasing of electrical tension, for this working out of the notes.

But we decided that there is much more to a musical composition than just the notes. I am reminded of Max Harrison's criticism in *The Times*, of a concert at the Queen Elizabeth Hall in October 1968.

'The piano playing . . . was as note-perfect as anyone might wish. Yet the expressive aridity of the major parts of his performance demonstrated—as clearly as anybody could wish—that music lies behind or between the notes, rather than consisting merely of them'.

Behind or between the notes, to which we might add 'and out beyond them', too. While the notes are being worked out this *beyondness* is coming into being.

It will be as well for us to have a symbol for this, too. Could we logically give it this symbol  ? . . . the original symbol  seen from another aspect (through the eyes of Montaigne)?

 denotes the releasing, over a period of time, of the material, electrical, tension, created by the initial 'spark'. I suggest we term it the ELEC.

 denotes the coming into being, over a period of time, of that which is intangible—the gradual re-creating of the *essence* of the initial spark. CELE (the reverse of ELEC) seems to be an appropriate word to coin for this. CELE reminds us of the Greek *KELE* meaning 'swelling' and, too, of the French verb *CELER:* 'to hide'—in this case, what lies hidden, and intangible, gradually emerges . . . it rises into being.

So we have two symbols and two words now, with which we can express the tangible and the intangible. The composer, with his

inspiration, intuition and discipline has to transduce[1] both types of energy if his composition is to be complete.

Of course the ELEC symbol  is a great simplification of the energy flow controlled by the composer. The resulting flow is a complex pattern of tensions and relaxations which evolve as the musical material is worked out. The words 'controlled' and 'worked out' do not really convey what I mean. There seem to be no suitable English words. I am hunting for some word which brings a hint of the skilful yachtsman in fierce mid-Atlantic, guiding and controlling his craft and yet being taken along with it, sensing the best way to manage his vessel, freely changing his mind as unforeseen circumstances evolve, yet always applying the greatest discipline to himself and his seamanship.

Schoenberg disliked the term 'worked out' and used the German word 'durchgeführt' which literally means 'led through'. The composer has to guide and evolve his material in all its aspects.

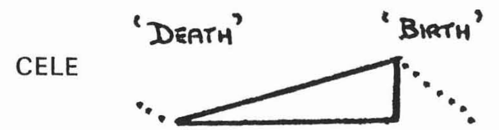
Just as  is a simplification of the ELEC so, similarly, the symbol  is a great simplification of the emergence of CELE,[2] for this also will ebb and flow according to how the composer senses it through and leads it forth.

Now that we have established these words and symbols to signify the tangible and intangible we could well rest awhile, and indulge in a little musing! The intertwining of  and  to make , seems to symbolise much that we meet in life: while one aspect decays the other grows—in fact can it not symbolise life itself? Some people feel that life is no more

[1] Transduce: from the Latin *trans* ('across') and *ducere* ('to draw').

[2] CELE pronounced Sel.

than a gradual decaying away to the point of death. Perhaps this is just the ELEC aspect? Could we not *montaigne* this point of view? Surely there is also a CELE aspect: an emergence into being of something beyond the material, so that both these two symbols are equally relevant.

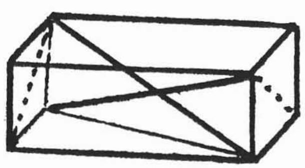


The dotted line in the ELEC diagram is the build up to maturity. This has an analogy in the build up of the transient which begins a musical note. This transient is embryonic too, for it determines, to some degree, the future quality. (We will clarify this point in acoustics later on.)

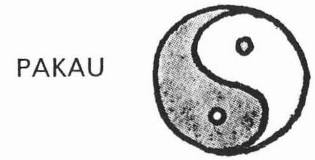
The dotted line in the CELE diagram represents to my mind the reverberation after fulfilment . . . the resonance that incites resonance . . . the radiation (as with the capacitor) that is emitted from the culminating spark. It is the essence of what is bequeathed to future time.

Do you think that civilisations, as well as people, could be represented by such symbols?

The two symbols, integrated together, become a three dimensional structure, which implies the complete whole.



Perhaps this ancient Chinese symbol embodies the same idea more artistically:



To have full consciousness of being, the CELE and the ELEC must, surely, entirely embrace.

2

Halfway through Chapter 1 we were exploring a tuned circuit, and finding out that it could be energised, so that it continued to oscillate at a fixed frequency. The frequency we chose was 600 cycles per second. But nowadays we term this 600 HERTZ. Heinrich Hertz was the young German physicist who, in 1887 at Karlsruhe, carried out a spectacular experiment showing that Clerk Maxwell's prediction of electromagnetic/electrostatic radiation was correct.

Hertz arranged a Leyden Jar, a type of capacitor, as a transmitter, and found that, when it was sparking, it radiated energy which was 'received' at the other end of the physics laboratory.

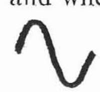
The capacitor he used was not, of course, sparking a 'death spark'. It was not breaking through the barrier between its metal plates: it was not sparking through the dialectric. No, he gave it an external circuit in which to produce the transmitting spark, so that the capacitor could go on making a spark a great number of times a second, without coming to grief. The result was that the capacitor's spark energy was transmitted as electromagnetic waves, akin to invisible light. The remote receiver actually enabled one to see this

transmitted energy, for between the ends of this contraption appeared bright blue sparks. This contraption, the receiver, was just a brass rod bent round into a loop  with the ends almost touching. One end of the brass rod was pointed and the other end round. The blue sparks showed up between these ends. So, thanks to Hertz, electromagnetic transmission was demonstrated for the first time, and the theories of James Clerk Maxwell, who had died seven years before, were proved right.

It was an exciting moment indeed, and doubtless Hertz would have gone on to investigate more marvels if he had not died of cancer at the age of 37—still not realising what a revolution of communication his experiment would bring forth. (It seems strange to think that, had he lived to the age of 80, he could have watched the early BBC television programmes and also seen demonstrations of radar.)

Hertz was dealing, in his famous experiment, with frequencies around 500,000,000 cycles per second, that is 500 megacycles, or rather 500 megaHertz. The tuned circuit we were envisaging oscillates at a far slower speed, for we want it to give us a pitch within the audible range . . . between about 20 Hertz and 20,000 Hertz. We chose 600 Hertz and then decided to re-tune it to 587 Hertz—the note D on the treble clef. We can do this by changing the value of the capacitor.

How long will these oscillations have to be sustained for us to recognise the quality (timbre) of the note and that the pitch is D? Well, if we are very sharp witted, we might recognise the timbre and pitch after $\frac{1}{18}$ of a second, after 33 cycles have occurred (if we give our ears only a very few cycles all we hear is a click).

There are a number of different electronic circuits for producing a sustained oscillation, all of them built around one or more tuned circuits. Some of these oscillator circuits will produce a pure tone—a **sine wave**. A sine wave is a fundamental note without overtones, and when displayed on the screen of an oscilloscope it is this shape . Musically it is not very interesting—it is a thin flute-like sound—but it should not be scorned, for it is the basic building brick of all sound. Early last century, the French mathematician Jean Fourier put forward the theory that an infinite number of resultant waves can be made by mixing together these pure sine waves; and that any sound, however complicated, can be analysed and sorted out into a recipe of its component sine waves.

The sine wave is a fascinating phenomenon. The strange fact is that if you take the graph of one, and cut off part of it, you don't reduce it, you add more sine waves to it!

 is just one fundamental wave at one pitch, but if we cut off the start  (the dotted portion), leaving ourselves with  we find it gives us a sound which is much richer, for it has lots of overtones sounding above the fundamental note. Many frequencies (or pitches) are sounding together—a really complex recipe this one, resulting in a sort of 'chord' which gives a strident timbre (a richer tone quality), far more striking to the ear than the inoffensive, pallid sine wave.

Chopping any bits off a sine wave always results in additional sine waves being added. If we lop off these bits  we again arrive at a very rich sound  which mathematically we find to be (roughly speaking) the fundamental pitch (*e.g.* 100 Hertz), plus 100 Hz multiplied by 3, 5, 7, 9, 11, 13 etc. In other words, by 'squaring' off the sine wave we have added to it its uneven harmonics. Here's an Alice-through-the-Looking-Glass-cum-Montaigne sort of world—you take something away only to make the loser richer!

A sine wave seems an 'about-turn' point . . . you cannot reduce it further in its tonal existence, for it becomes more. Quantum

mechanics seem, to me, to be reaching the same point. But . . . whoa! . . . we had better look out! Are we not holding our noses so high in this rarefied air that we are going to land in a pitfall? . . . Quantum mechanics indeed! We mustn't fancy ourselves as scientists, let alone nuclear physicists. Do you remember what Alexander Pope said?—

> 'To observations which ourselves we make
> We grow more partial for the observer's sake.'[1]

However, just before we come right down to earth, we might allow ourselves a moment's musing. Could this strange behaviour of the sine wave have a metaphysical counterpart in life? Might we find that if we whittled down our vastly complex and hurly-burly lives, until we had focused upon just the essential fundamentals, we would then perceive a different richness presenting itself—a richness governed by natural symmetry and elegance? Not too much of it, mind you, for too much 'fearful symmetry' soon palls—we need a mixture of both worlds, symmetrical and asymmetrical, so that we can jump from aspect to aspect and compare results. We need a certain amount of unforeseen impediment and, later on, we might muse upon the thought of how much aleatoricism (chance happening) is beneficial in filling out the symmetry.

But now, back to the sine wave: Fourier's idea of additive synthesis (mixing sine waves together) and analysis (reducing complexity to single sine wave components) is fine in theory, but, in practice, when we come to music, the sound is never in a steady state waiting to be analysed. It always seems to be in a state of flux—releasing or increasing tension. So when you are moulding it, fashioning it and giving it life you find that you need to caress it, to guide it most carefully, to coax it and then, suddenly, you find you have brought into existence something so alive that it firmly takes over and announces how it will progress! At this point Fourier's mathematical analysis seems as irrelevant as the laws of the Medes and Persians!

[1] Alexander Pope: *Moral Essays*, Ep. I. 11.

Just now, when we cut off the 'top' and 'bottom' of the sine wave curve  we distorted the wave shape so much that we, almost, arrived at this shape . This wavepattern we call a **square wave** and Jean Fourier tells us that it consists of the fundamental and its uneven harmonics (as we have already noted); but he also says that these uneven harmonics have a pleasing symmetry in their amplitude proportions (the proportions governing the volume we hear). It's like this . . . the 3rd harmonic, which is three times the frequency of the fundamental, has $\frac{1}{3}$ of the amplitude of the fundamental, the 5th harmonic $\frac{1}{5}$ of the amplitude of the fundamental, the 7th $\frac{1}{7}$ . . . and so on.

So a graphic 'cookery recipe' for making a square wave would look like this.

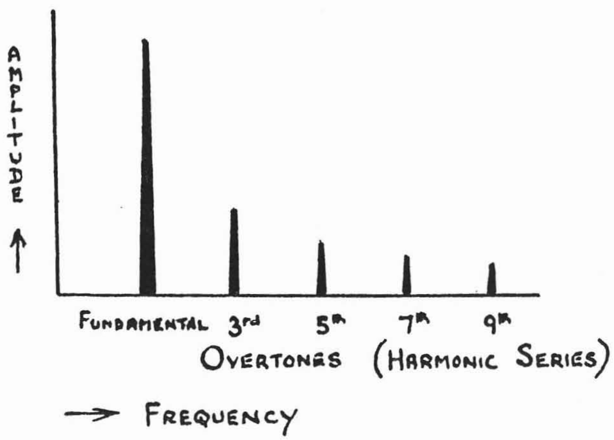


Fig. 6(a). Square wave 'recipe'.

If we happen to have an oscilloscope, we can make it display for us, on its fluorescent screen, the shape of any wavepattern we feed into it, giving us a graph of the amplitude plotted against

time—amplitude usually in the vertical axis, time along the horizontal axis. In this way we would get the familiar shapes  and .

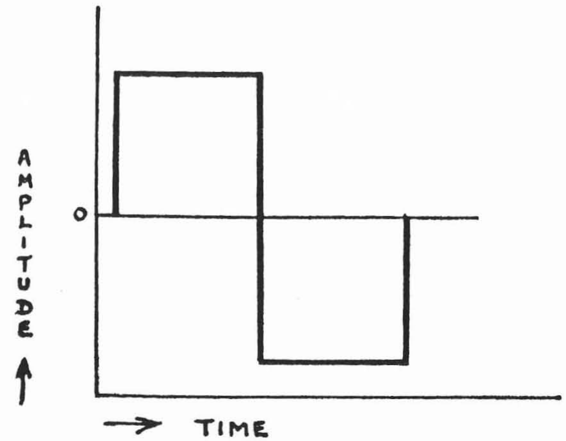


Fig. 6(b). Square wave (oscilloscope trace).

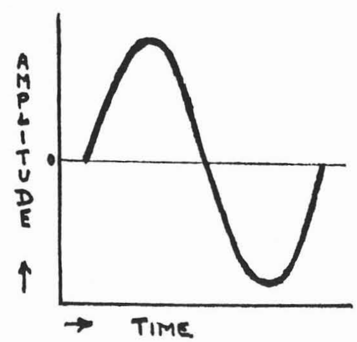


Fig. 7(a). Sine wave (oscilloscope trace).

What would the 'recipe' for a sine wave look like? Pretty simple . . .?

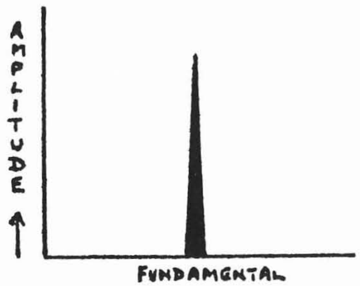


Fig. 7(b). Sine wave 'recipe'.

As we already have a sine wave produced for us by our amplified tuned circuit we could now try our hand at 'cooking up' a square wave. Actually we'll need quite a few sine waves to do the trick. Theoretically it looks as if we will need about 13 of them, and we know that they'll have to be produced in a precise manner so that we have the right amount of sound (the right amplitude) at each frequency. We'll need—

600 Hz at Amplitude 'A'

1800 Hz at Amplitude $\frac{1}{3}$ of 'A'

3000 Hz at Amplitude $\frac{1}{5}$ of 'A'

4200 Hz at Amplitude $\frac{1}{7}$ of 'A'

and so on up to

15000 Hz at Amplitude $\frac{1}{25}$ of 'A'

We could go on up above this frequency, for greater accuracy of squareness, but many ears, amplifiers and loudspeakers get so ineffectual at this high pitch that we might as well stop at 15,000 Hz. Anyhow our recipe tells us that this 15,000 Hz note is, proportionally, very soft—it is only $\frac{1}{25}$ of the amplitude of the fundamental 600 Hz, so if we go higher our next pitch will be even softer and give us still less effect.

But now we will do our bit of sound 'cookery' and mix together the thirteen frequencies in the right proportion. If we start with the fundamental 600 Hz sine wave and add to it the 1800 Hz and then the 3000 Hz and so on . . .gradually . . . we shall hear the sound changing its timbre (its tone colour) . . . getting richer . . . and, seemingly, getting louder. If we are watching the waveshape on the oscilloscope, we will see it get less and less curvaceous, and more and more correct in its squareness, as we go on adding sine wave upon sine wave.

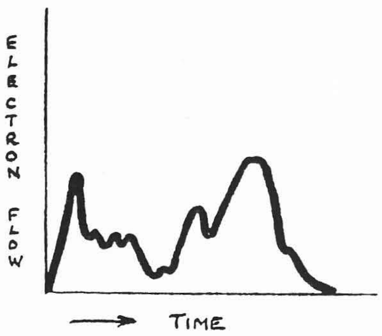
But that's enough of  and  . . . with the whole world of sound to explore, who wants to hear just sine and square waves? It would be rather like eating watery porridge, together with ginger snaps, for every meal! A meagre diet when you think of the range of delectable dishes which are described in most recipe books.

The first thing we could do to change our diet—our 'sound diet'—would be to re-adjust the amplitudes of our 13 oscillating tuned circuits. By doing this we could change the resultant wave-shape quite considerably and the effect to the ear would certainly alter; but our recipe will have to be much more complicated, much more sophisticated than that if we want a really musical result.

During the duration of the sound we shall need to alter the individual amplitudes of the harmonics—some harmonics may not appear at all at the start but will enter, shyly, part of the way through the note. If we want the note to have a sharp attack—to enter decisively—we shall find that we want most of the harmonics present at the start, and the rest of the note will grow out of this, developing some of the harmonic content further, discarding other harmonics once the note is under way.

This vital start to a note is known as the transient—it passes rapidly—yet it gives the note much of its character. We have already referred to it, in regard to the ELEC, as being embryonic. During this fraction of time (perhaps one tenth of a second or so) the harmonics and other overtones, which are going to give the note its timbre, become energised—but not necessarily all at once. However, by the end of the transient period the wavepattern has, as it were, gathered up its energy and settled down into its characteristic form, which may, or may not, be recurrent. (If it is a 'musical' sound it will have some resemblance to a repetitive pattern; if it is a 'noise' it will usually have little that is repetitive.) The energy of the note will dissipate itself in a characteristic shape of outflow. Indeed each component part of the note will have its own characteristic shape of outflow—its own envelope shape.

In Chapter 1 we realised that the graph of the capacitor's outflow of energy—(through a varying resistor)—



could equally well have represented the overall amplitude changes within a single note (the envelope of the note). But we see that we can go further, for this energy/time graph could be a way of showing the amplitude changes of just one of the component overtones of that note!

So now, when synthesizing a note from our thirteen energised tuned circuits we realise that, with thirteen amplitude controls to deal with—just to make one note—this synthesizing business is indeed becoming complicated. And really we have only just started! . . . that is just one small part of the story . . . lots of other aspects (parameters) of the sound have also to be controlled, all at the same time!

These components of a note, these overtones, sometimes lie in the harmonic series and sometimes outside it. What do we mean by the **harmonic series**? For those people who like to think mathematically it is simple. Let us, for instance, take the note C two octaves

below middle C. Its frequency is 65·406 Hz. Multiply this frequency by every number from 1 to 16 and you'll have a progression of frequencies from 65·4 Hz to 1046·5 Hz. These are the first sixteen notes of the harmonic series on C 65·4 Hz (1046·5 Hz is two octaves above middle C).

But if you are musically minded and you want to find these frequencies among the notes of the piano keyboard you will have a little difficulty.

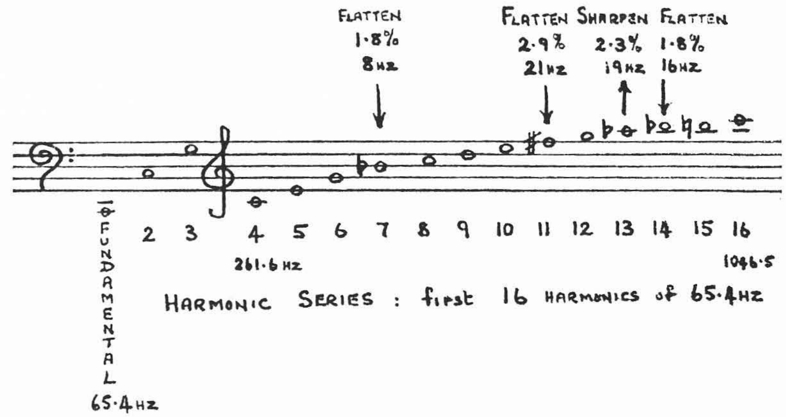


Fig. 8. Harmonic Series. (A quarter tone is 3%. I have tested many lecture audiences with a 'scale' of 1/12th tones—that means changes of 1%—and find that most people in a large hall can detect these 1% changes if they are played in sequence in the middle register. It is said that, under test conditions, the ear can detect changes of 0·3%.)

The B♭ on the piano will be a shade too sharp for the 7th harmonic, and so will the B♭ an octave above, which is the 14th harmonic. Also you will need to flatten the piano F♯ to make it the 11th harmonic, and sharpen the A♭ to make it the 13th harmonic. If you go ahead and do these adjustments not only will your piano tuner be somewhat taken aback but, from now on, you will find that the piano music you play will sound pretty odd—especially when you wish to modulate from one key to another. So I suggest we leave your piano as it was, tuned to the equal tempered scale—a brilliant compromise between nature's 'scale' and the most satisfying scale that mathematicians can envisage.

Now we must get back to our musical recipes. You will find, in many textbooks, these recipes for the sounds of musical instruments. They are usually given in the form of vertical lines, representing (by their height) the amplitude of each overtone—just as Fig. 6a gives a recipe for a square wave. Here is a musical recipe for a violin sound. (Of course it will vary from instrument to instrument, from string to string, and from note to note.)

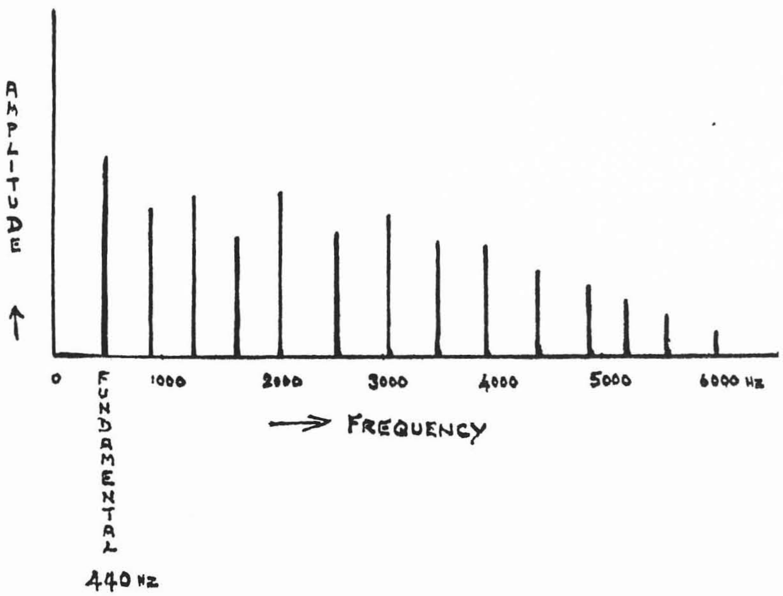


Fig. 9. Violin 'recipe' for the A string.

However, in my experience, interesting musical sounds are far more complicated than this. In my work I am not concerned with synthesizing orchestral sounds—we have excellent orchestras for making those sounds: my interest is in making new sounds which are musical. But I find that the adding of sine waves together in these 'classical recipes' gives a very 'electronic', inhuman sound with a clinical quality, lacking the possibility of subtlety and nuance.

To be human is to have great ranges of expression, to have such infinite range that one moment there can be warmth and the next moment coldness. But what a dreadfully inadequate description that

is . . . it needs a poet to give even a hint of the richness of being human. What words can hope to describe it?

But could we, perhaps, here just attempt an analogy? For it is as if the human being has thousands upon thousands of energy stores, each tuned for a purpose, each charged with a potential which allows it to sound forth. It is as if each human being is an instrument of concord and discord, consisting of thousands upon thousands of finely tuned circuits; each circuit with its own control of pitch and loudness, able to adjust its voice, in harmony or dissonance, in balance and accord, so that it becomes part of the great pattern which makes the individual.

To visualise a human being in this way we would need a most wonderful mixture of fundamentals, harmonics and overtones, all subtly changing from moment to moment . . . a whole spectrum of resonate frequencies which are never at rest, never in a steady state, but are vibrant with pulsating tension. Like the intricate groove of a gramophone record the resulting 'sound track' would be extremely difficult to analyse in all its aspects, for there would be so many components in a state of flux. Yet it would exist as an entity, as a resultant whole, as a vast tangible river of flowing tensions.

Is this picture really so fanciful after all? Could it be that within our material, chemical, make up we have an electrical existence which consists in reality of actual tuned circuits? Is each cell in our bodies itself a tuned circuit (or part of a tuned circuit)?

Let us have a look at the cells of the body. In our muscles, our nerves, and in most other tissues of the body there is, apparently, a varying amount of electrical tension between the inside and outside of each cell membrane. This tension is there when the cell is at rest. It is about 70 millivolts, the inside of the cell membrane being negative compared to the outside.

When the cell is stimulated from outside with a weak stimulus, the inside of the cell becomes less negative with respect to the outside and then, after a slight delay, it restores itself to the resting tension of −70 millivolts. (Rather like our capacitor releasing its tension through a resistor.)

But if the cell is stimulated by a strong stimulus, the inside of the cell rapidly goes from −70 millivolts to +40 millivolts . . . then slowly compensates for this, drifting back towards −70 . . . but it overdoes this compensation for now the inside becomes more negative than −70 millivolts. However, this state of affairs is soon put right and conditions return to the resting state of −70 millivolts.

So this strongly stimulated cell acts a little like our capacitor/inductor circuit—it is too eager for satisfaction, oversteps the mark and has to retrace slightly—in other words it pulsates, in its own special way, rather like a tuned circuit. According to whether the nerve fibre is large or small, the time taken for one pulsation varies from short to long (from about 40 to 60 milliseconds). An oscillation at that rate, if made audible, would have its fundamental rather too low for us to hear as a pitch—it would be a 'double-double bass' note (but as each pulse is a spiky waveshape it would have overtones and we would probably be conscious of a rapid series of clicks).

Having mused upon the possibility of cellular tuned circuits, perhaps we could guess that there might be analogies of capacitor/inductor circuits applying not only to cell energy but also to mental energy, sexual energy . . . even to molecular energy and atomic energy?

Could we expect to find oscillations from the energy within atoms? Oh yes, we do . . . the atoms of most solids and liquids vibrate at just less than 300,000,000,000,000 Hz. A high enough frequency for you? Would you like some higher vibrations still, just to add to our already enormous spectrum?

Well let us take a look at hydrogen. In the 1880s Johann Balmer in Switzerland used a spectroscope to study the series of frequencies emitted from hydrogen. The highest frequency he found to be 3,287,870,000,000,000 Hz. But, more interesting still, he found a sort of musical scale when he studied the relationships of the hydrogen frequencies. The relationships of the hydrogen frequencies (to the top frequency we have just mentioned) are

$$\tfrac{77}{81} \quad \tfrac{60}{64} \quad \tfrac{45}{49} \quad \tfrac{32}{36} \quad \tfrac{21}{25} \quad \tfrac{12}{16} \quad \tfrac{5}{9}$$

which makes an interesting series of 'undertones' (for these frequencies are below the 'fundamental' so I've called them undertones rather than overtones).

If we write this out as a musical scale with A (440 Hz) as the top note, we find the scale has five of its notes crammed together at the top:

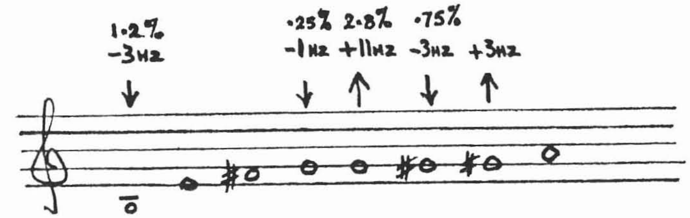


Fig. 10. Hydrogen 'scale'.

How many musical hydrogen atoms have we in our bodies? Well even Winston Churchill was made of 50% water, and water is a compound of hydrogen and oxygen. Also the fat of our bodies has hydrogen atoms in it—so altogether we must be made of quite a few hydrogen atoms giving out their (very high frequency) musical 'scale'! When you think of all the other elements, gases and compounds in our bodies, the chemical 'musical chord' or wavepattern will in itself be amazing.

But there are surely countless other tuned circuits, other than the chemical ones. There will be oscillating circuits giving fundamentals and overtones (and undertones) from a great number of sources—the chemical, the electrical, the mental, the 'CELEtal'.

With all these frequencies 'sounding' at the same time the result will be of such complexity that surely it will be an overpowering *NOISE*. We could build ourselves the analogy of this with electronic components. We could build a circuit which would give an output containing so many frequencies, spread out randomly over the whole spectrum of sound, that the result to the ear would be an overpowering, hissing, roaring sound.

This circuit would be a **white noise** generator. The noise is called white because it resembles the phenomena of white light, which has all the colours of the spectrum (all the colours of the rainbow) present at the same time. Roughly speaking, white noise has all the frequencies of the sound spectrum present at the same time.

Electronically we could build other circuits which would enable us to pick out narrow, or wide, bands of frequencies from this white noise, from this comprehensive sound spectrum. We could pick out a band (a bandwidth) covering all the frequencies within certain defined limits . . . from, say, 500 to 900 Hz; just as we could pick out a band of colours (from, say, yellow to violet) from the complete spectrum of the rainbow.

The circuits, we would need to build, to do this, would be tuned circuits, arranged as acceptor and rejector circuits. All the frequencies in the required band would be accepted and amplified by sympathetic resonance of the acceptor circuits, while all other frequencies would be rejected.

Similarly, 'acceptor circuits' could enable us to split up our huge human spectrum of oscillations into defined bands of frequencies which are more easily handled. I suggest that, for simplicity's sake, we think of just three human bandwidths—the physical, the mental and the celetal.

But, imposed on each of these bandwidths, might we not have further acceptor circuits which would, by sympathetic resonance, define which of the frequencies, within that particular band, should dominate at any precise moment?

Looking back at the musical world is there an analogy there? Yes . . . we find that each musical instrument is rather pernickety as to which frequencies it allows to emanate from it.

The body of the instrument gives definite preference to some frequencies, and when its strings (or its vibrating column of air, or its pulsating stretched skin) give it a fundamental plus overtones to transmit to the air, it has a mind of its own and stubbornly boosts some frequencies and partially mutes others.

Technically we say that each instrument has its pronounced regions of resonance, which are excited by the appropriate frequencies (pitches). These pronounced regions of resonance were given the name **formants** by L. Hermann at the end of the last century.

Try playing middle C on a violin, then on a viola and finally on a cello. The three notes are each of different quality. The fundamental note C with its overtones is being given a different reception in the body of the violin, the viola and the cello. Each of the instruments welcomes the fundamental and overtones in its own individual way, modifies them and then pushes them out into the world bearing the obvious stamp of the parent.

I can best explain it like this, I think: if I made an amplifier with five tuned circuits in it and tuned each circuit to resonate to a specific letter—one tuned to B, one to R, one to O, one to W and one to N—then this amplifier we could call BROWN, for it would prefer those letters above all other letters.

Now if I recite a well known rhyme into this amplifier let us see what the result will be:

ma**R**y had a little lam**B**
its fleece as white as s**NOW**

All the B-R-O-W-N letters are standing out well above the other letters.

But my name is not BROWN it is ORAM so, to show I am a different individual from BROWN, I will alter the tuned circuits—change the formants—the poem will now sound rather different:

MARy h**A**d **A** little l**AM**b
its fleece **A**s white **A**s sn**O**w

And if your name is SMITH see how your formants would recite the rhyme:

Mary **H**ad a l**IT**T**l**e la**M**b
ITS fleece a**S** w**HIT**e a**S** **S**now

Did you notice that this little rhyme had a remarkably different effect on the three 'individuals' reciting it. In BROWN it excites resonance on 4 occasions, in ORAM on 10 occasions, but SMITH gets the most kicks out of it—he gets excited 15 times.

The original sound was the same in all these three recitations, but the interpretation was different each time. BROWN, ORAM and SMITH all showed their individualities in somewhat the same way as the violin, viola and cello did, when we played the same note on each. However this musical note, with all its overtone content, was rather like saying every letter of the rhyme all together at the same time, so making one big chord—yet the instruments were still able to assert their individuality, even in this short space of time and with everything happening at the same moment.

In every human being there will surely be, as we have said, tremendous chords of wavepatterns 'sounding out their notes'.

Do we control them by the formants we build up . . . by tuned circuits which amplify or filter? Are we for ever developing our *regions of resonance* so that our individual consciousness will rise into being—so that we can assert our individuality? In this way does the tumult of existence resolve itself into a final personal waveshape, the embodiment of all one's own interpretations of the art of living?

3

Before we proceed we had better summarise what we have been musing upon so far. Then, having consolidated it, we could allow ourselves to 'sniff the air' once more for further scents.

Our simple tuned circuits seem to have 'humanised' themselves. The resistor/capacitor circuit, energised by a spark from 'elsewhere' has become the analogy for the composer, and other artists, all of whom transduce what is *outside time* into the realm of *material time*. (While the ELEC is working itself out the CELE is coming into being.)

We then decided that if we changed the resistance in the circuit to an inductance we would have a circuit which could be made to produce oscillations. The oscillations could vary, from the pure sine wave, the basic 'brick', to complex waveshapes consisting of the fundamental and many overtones.

We looked at the human being and wondered whether there were thousands upon thousands of oscillations, grouped in various bandwidths, within the human frame—wavebands of the chemical, the electrical, the sexual, the mental and the celetal frequencies. It then seemed as if these bands of frequencies could become individualised in the way a musical instrument confirms its individuality—by imposing on them a formant set of resonators.

In this way it seems that each human being could have more or less the same basic 'material' to start with, yet from this material he would develop those regions which are truly individual to him. This *developing by formant control* could be taking place independently in each waveband, and the results would build together to form a resultant waveshape.

Perhaps we should consider further back in time . . . to the conception of a human being. Maybe each parent provides a formant control, and these two parental-formant-controls form the starting point for the new individual. Nature has already seen to it that the basic human formant shall be present so that the baby has head, body, legs, arms, brain and all the other parts; but the combined personal formants provided by the parents (and indirectly by the ancestors)—these will decide whether the eyes are blue, the hair fair, whether the mind is inclined to be artistic rather than practical, etc. etc. In fact, each parent will provide a formant control for each of the five wavebands.

With these combined formant controls functioning there will now exist, embryonically, tuned circuits of all types within the fertile egg—tuned circuits which will not only determine the personal wavepattern of the baby, but because they are tuned to resonate at certain frequencies they will determine how the baby 'sees' the outside world; they will be ready to welcome some frequencies much more sympathetically than others. Selected energy will therefore be absorbed, physically, mentally and celetally from the environment and from 'beyond', and this process will go on throughout life.

The selection process will determine the individual, and the individual will determine the selection process. A determinate function looked at one way round, but with our *Montaigne* outlook we can feel, equally well, that it is indeterminate at the same time as being determinate.

But this is only half the story . . . more truthfully it's probably not one tenth of the story!

On the one hand we seem to have tuned circuits within us which are producing oscillations modified by our formant circuits, and at the same time we have tuned acceptor circuits within us capable of accepting oscillations from outside and 'beyond', these incoming signals also being modified by our formant circuits. I now suggest that these acceptor circuits do not receive direct signals from outside, but that they receive signals which are resultants . . . the outcome of the internal personal signals intermodulating with the incoming external signals.

Intermodulation—the production of sum and difference frequencies . . . (a subject to keep us 'a-*musing*' for at least the rest of this chapter).

It is said that the human ear is a **non-linear** device—it receives physical vibrations at the eardrum, but it does not faithfully transduce them into electrical pulses to send on to the brain . . . it distorts them en route. (Apparently this distortion takes place in the middle ear.) The effect of this non-linearity is that any two signals received in the ear produce combination tones—the frequencies of the two signals get added together and also they are subtracted one from the other—in other words, as well as the original two signals there are fainter sum and difference tones produced. And that apparently is what our ears are said to do—and some ears do it more than others. (Somewhere I read that the experts say cats can hear as many as 76 combination tones—76 sum and difference tones . . . though how they test the cats to find out I can't imagine. But, if they are right, what a discordant feline world it must be!)

However . . . to get back to human beings . . . now if our ears distort like that, what about our brains? Are we right to assume that they are linear devices? And what about all the other detection devices we have in our bodies?

Could we be altogether non-linear? Could we ever prove it one way or the other?

Practically all . . . well I might as well say ALL . . . transducers are non-linear to some degree; many other electronic devices are non-linear, especially a device known as a ring modulator. This is designed to accept two frequencies and intermodulate them so that the resultant sum and difference frequencies are produced. But I'm sure you haven't a ring modulator handy for experiments, so we had better go into this matter mathematically. (It is all really very simple —just straightforward addition and subtraction—at primary school level, so don't worry if the next few pages have rather a lot of figures drifting across them.)

Let us imagine a fundamental note of 600 Hz plus its 3rd and 5th harmonics, and a second note of 440 Hz, which also has its 3rd and 5th harmonics. If we intermodulate them, every component of one note adds to every component of the other note, and also subtracts from it.

So 440 Hz will add to 600 Hz, giving us 1040 Hz; 440 Hz will also be subtracted from 600 Hz giving us 160 Hz. If we go on working out all the sum and difference tones from these two notes we get a series of frequencies which we find are multiples of 80. We might call 80 Hz the 'unsung fundamental', and then work out the series as harmonics of 80. If you are one of those people who do not like pages of figures here is a diagram (Fig. 11) to show the sum and difference frequencies as harmonics of 80 Hz. Then you need not bother to look at the arithmetic which follows!

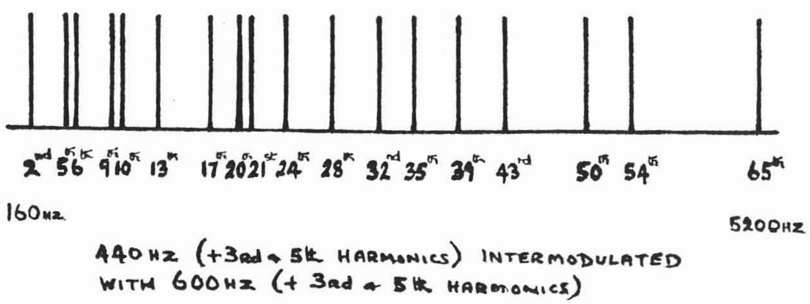


Fig. 11. The 18 sum and difference frequencies of 440 Hz and 600 Hz, shown as harmonics of 80 Hz. (Relative amplitudes are not shown.)

440 Hz & 600 Hz

Sum & difference frequencies

x = 440	3x = 1320	5x = 2200 Hz
y = 600	3y = 1800	5y = 3000 Hz

F = the 'unsung' fundamental = 80

(440 is not a harmonic of F, it is 4·5 F, and 600 is 7·5 F)

y − x =	160 =	2F
5x − 3y =	400 =	5F
3y − 3x =	480 =	6F
3x − y =	720 =	9F
5y − 5x =	800 =	10F
y + x =	1040 =	13F
3y − x =	1360 =	17F
5x − y =	1600 =	20F
5y − 3x =	1680 =	21F
y + 3x =	1920 =	24F
3y + x =	2240 =	28F
5y − x =	2560 =	32F
y + 5x =	2800 =	35F
3y + 3x =	3120 =	39F
5y + x =	3440 =	43F
3y + 5x =	4000 =	50F
5y + 3x =	4320 =	54F
5y + 5x =	5200 =	65F
	Hz	

Harmonics of 80 Hz

As you see, by taking the sum and difference tones of two wave-patterns, each a fundamental with two harmonics (3rd and 5th), we have arrived at a resultant which is 18 rather strangely selected harmonics without a fundamental. Had we used square waves for the two input wavepatterns the resultant would have been even more complex, for we would have had to deal with many more frequencies.

But not only were these input wavepatterns, that we chose, pretty simple—for they had few harmonics and no overtones outside the harmonic series—but also they were fairly far apart in pitch.

Now let us work out the wavepattern we produce if we feed in two sounds much closer in pitch. We will keep 600 Hz, with its harmonics (1800 Hz and 3000 Hz), as our first note, and have as our second note 587 Hz (with the 3rd and 5th harmonics . . . 1761 Hz and 2935 Hz). 600 Hz and 587 Hz are approximately a quarter tone apart.

If we work out our sum and difference frequencies we get an interesting formation, based seemingly on 13 Hz as the fundamental (F). Here first of all is a rough diagram for those who do not want to look at the figures.

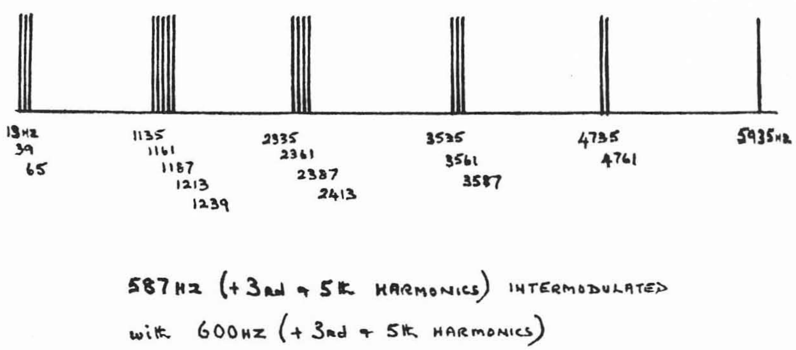


Fig. 12. The 18 sum and difference frequencies of 587 Hz and 600 Hz, showing the formation of 'clusters'. (Relative amplitudes are not shown.)

587 Hz & 600 Hz

Sum & difference frequencies

$x = 587 \qquad 3x = 1761 \qquad 5x = 2935$

$y = 600 \qquad 3y = 1800 \qquad 5y = 3000$

F = fundamental = 13 Hz

(587 is not a harmonic of F, it is 45·1F, and 600 is 46·1F)

$$
\begin{aligned}
y - x &= 13 = F \\
3y - 3x &= 39 = 3F \\
5y - 5x &= 65 = 5F \\
5x - 3y &= 1135 = (x + y) - 4F \\
3x - y &= 1161 = (x + y) - 2F \\
x + y &= 1187 = (x + y) \\
3y - x &= 1213 = (x + y) + 2F \\
5y - 3x &= 1239 = (x + y) + 4F \\
5x - y &= 2335 = 2(x + y) - 3F \\
y + 3x &= 2361 = 2(x + y) - 1F \\
3y + x &= 2387 = 2(x + y) + 1F \\
5y - x &= 2413 = 2(x + y) + 3F \\
y + 5x &= 3535 = 3(x + y) - 2F \\
3y + 3x &= 3561 = 3(x + y) \\
5y + x &= 3587 = 3(x + y) + 2F \\
3y + 5x &= 4735 = 4(x + y) - 1F \\
5y + 3x &= 4761 = 4(x + y) + 1F \\
5y + 5x &= 5935 = 5(x + y)
\end{aligned}
$$

Hz

Imagine for a moment that 600 Hz (plus its 3rd and 5th harmonics) represents an object which you are looking at; while the frequency 587 Hz (plus its 3rd and 5th harmonics) represents you. Your brain, if it is non-linear as we suspect all brains may be, receives a pattern of frequencies roughly like this: III IIIII IIII III II I. But that pattern could only be right if we assume that all the components of your wavepattern, and all the components of the object's wavepattern, are of the same amplitude—sounding at the same volume. This we obviously should not assume. So your brain's impression of the intermodulation would probably be more like this pattern (in which the height of each vertical line shows the relative amplitude of the frequency it represents):

I have traced a line along the amplitude heights because I suspect the brain may scan just these peaks instead of analysing further. It could probably gain all the information it wanted from this:

Or maybe this pattern is more than it needs to know. Perhaps it will employ some of its tuned circuits to filter away part of the pattern, which is superflous, leaving just this:

Perhaps it will become interested in only part of the object, just the part which, in the intermodulation, gives frequencies between 3535 Hz and 5935 Hz. It could use its tuned circuits to boost these frequencies and filter away the other frequencies, so now the brain impression will be:

So, once your personal wavepattern has intermodulated with the incoming signal from the object, your brain can scan the outline of the intermodulated signal either completely, or in parts, according to its fancy. It can, with its tuned circuits, boost or suppress (filter away) parts of the overall scan.

Have you noticed that the resultant intermodulated brain scan, (whether it is filtered or boosted, or not), actually contains no direct

indication of the original frequencies which brought it about? If you look at the series of resultant frequencies, which the brain scans, you will notice that they occur in clusters.

There are three low frequencies 13–39–65 Hz, then a large gap, and then five frequencies starting with 1135 Hz. The original fundamentals 587 Hz and 600 Hz and their overtones are absent. I venture to suggest that, by reason of non-linearity, the signal which reaches our consciousness is only the **amplitude outline of the sum and difference frequencies**, and that the fundamentals and the overtones of the original modulating signals will not be present (unless they happen to coincide with the sum and difference frequencies).

Looking again at the resultant intermodulated signal, you will find that a cluster of frequencies occurs around the 2nd harmonics of 587 and 600, around the 4th harmonics, and again around the 6th, 8th and 10th harmonics. The actual frequencies do not quite coincide with these harmonics. It is as if you get a blurred, distorted, unfocused effect when you 'look at' 600 Hz (and 3rd and 5th harmonics) from such a close viewpoint as 587 Hz (and 3rd and 5th harmonics).

This unfocused effect can be altered by filtering and boosting, but you will still not see the original two wavepatterns—the ones which intermodulated to produce this unfocused result. If you shift your own formants so that your personal wavepattern changes from 587 (+1761 + 2935) to 440 Hz (+1320 + 2200), the resultant wave scan will still not show the original wavepatterns. Look at the resulting 18 harmonics shown on page 37: the original frequencies 440, 1320, 2200 Hz and 600, 1800, 3000 Hz are absent from this resultant.

However much you shift your own wavepattern over the frequency spectrum, will you ever actually *see* the object, with which your own wavepattern is intermodulating?

Is this an analogy of life? Do we ever perceive reality? Is reality always disguised—always an indecipherable intermodulation between ourselves and 'what lies beyond'? Is this what St Paul was referring to when he said: 'The world was created by the word of God so that what is seen is made out of things that do not appear'?[1]

[1] St Paul: *Epistle to the Hebrews*, XI 3.

What, then, will be our personal view of the reality of the outside world? If we sense it by receiving the sum and difference frequencies, produced by the intermodulation of ourselves with the observed world, what a world of stupefying complexity we will find it to be, unless we can keep our own waveshape true to its own character, without any spurious and artificial overtones to distort the resultant.

If we can gain complete formant control of our own wave-pattern . . . have such knowledge of it that we can unfold its various regions of resonance as, and when, we require them . . . it seems that then, and only then, will we be able to gain a glimmer of the reality of the outer world. Perhaps then, and only then, do we find that, beyond the unfathomable complexity there lies a crystal clarity.

4

Can we explore the world of sound—the world of overtones and harmonics, of frequencies and formants—and find any clues to the unravelling of stupefying complexity?

Let us first imagine complexity by representing your personal wavepattern as the frequency 543 Hz, with two overtones in the harmonic series, plus 15 overtones outside the harmonic series. Think of 'yourself' observing that same object that we looked at in the last chapter—600 Hz with its 3rd and 5th harmonics.

What, now, would be the pattern of the sum and difference waves which your brain would have to scan? Well, you can work it out this time, for the arithmetic is too extensive and tedious for me! But I know that, as observer, your brain will be presented with a wavepattern of bewildering complexity, and that you will have an impossible task if you wish to fathom what, in reality, lies behind what you see.

Even if you know that, basically, your own wavepattern (which is modulating the signal from the object) has a fundamental frequency of 543 Hz plus two harmonics, you will still be all at sea, for what about those 15 overtones outside the harmonic series which you also have in your wavepattern—what resultants will they have produced?

What can you do to help the situation? If you have discovered how to control your formant circuits, you can reduce the resonance you have been giving to those 15 inharmonious overtones; you can suppress them for the time being, so that they produce negligible sum and difference tones with the 600 Hz (+1800 + 3000).

Perhaps you could also try reducing the resonance of 543 Hz and make your observation from the vantage point of one of your two harmonics—from 1629 Hz instead. This might give you more insight into the pattern of the 600 Hz waveshape which you wish to observe. You would be viewing it from farther off, seeing it from another perspective. This might be just as well, for trying to get very close to a thing we wish to appreciate, often seems to have the worst possible result. The greatest clash seems to be as we get closer—a musical chord becomes increasingly discordant as the notes get nearer and nearer the same pitch and then horrible interference beats arise; two colours shriek at each other when they do not quite match; blood relations often seem liable to have tremendous family rows, yet these same members of the family avoid quarrels with outsiders.

So being close to an object does not seem to help. How about trying to change your formant until you have the same wavepattern, at the same frequency, as the object you are observing? But it soon becomes apparent that, even if you could change your wavepattern until it was exactly that of the object, it would be to no avail . . . for if the wavepattern of the observer is that of the observed, the observer would no longer have a separate identity, and no observation could be made!

Is there anything, then, that can be done to enable the observer to appreciate more of that which he is observing?

Yes, there most certainly is . . . let us do some more arithmetic to explain it. The object being observed is still 600 Hz (+1800 + 3000). But now you are going to shift and modify your formant circuits. No longer are the frequencies 543 Hz plus 2 harmonics + 15 overtones going to be you. By adjusting the tuned circuits of your formants, you are going to shift the fundamental down to 200 Hz

and just allow this 200 Hz plus 600 and 1000 to resonate and become your personal wavepattern. (You are filtering away those 15 overtones which are not in the harmonic series.)

Now the arithmetic for the sum and difference frequencies is so easy to do that I'll gladly do it for you!

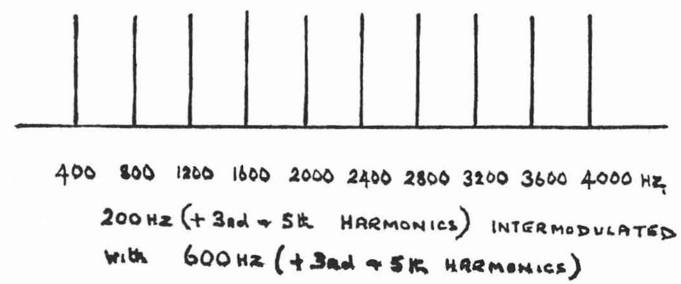


Fig. 13. The 10 sum and difference frequencies of 200 Hz and 600 Hz, showing how evenly they are distributed.

200 Hz & 600 Hz

Sum & difference frequencies

$$x = 200 \qquad 3x = 600 \qquad 5x = 1000$$
$$y = 600 \qquad 3y = 1800 \qquad 5y = 3000$$
$$F = \text{'fundamental'} = 400$$

(200 Hz is the first sub-harmonic of 'F', and 600 is 1·5F)

$$\left.\begin{aligned} y - x &= 400 \\ 5x - y &= 400 \end{aligned}\right\} = F$$

$$\left.\begin{aligned} x + y &= 800 \\ 3y - 5x &= 800 \end{aligned}\right\} = 2F$$

$$\left.\begin{aligned} 3y - 3x &= 1200 \\ y + 3x &= 1200 \end{aligned}\right\} = 3F$$

$$\left.\begin{aligned} 3y - x &= 1600 \\ y + 5x &= 1600 \end{aligned}\right\} = 4F$$

$$\left.\begin{aligned} 5y - 5x &= 2000 \\ 3y + x &= 2000 \end{aligned}\right\} = 5F$$

$$\left.\begin{aligned} 5y - 3x &= 2400 \\ 3y + 3x &= 2400 \end{aligned}\right\} = 6F$$

$$\left.\begin{aligned} 3y + 5x &= 2800 \\ 5y - x &= 2800 \end{aligned}\right\} = 7F$$

$$5y + x = 3200 \quad = 8F$$
$$5y + 3x = 3600 \quad = 9F$$
$$5y + 5x = 4000 \quad = 10F$$

Hz

The resultant wavepattern is a fundamental 400 Hz plus all its harmonics up to 10. Why is it so beautifully simple in structure? Because the observer—you—altered your wavepattern, not to correspond with the object, not to come close to the object, but to be in harmonic relationship with it.

You, the observer, can now start to surmise what the reality is behind your observation. You can adjust your formants so that you

view the object from an emphasised 200 Hz, then from an emphasised 1000 Hz (each time filtering the other two frequencies). Viewed from 200 Hz the resultant will be a fundamental of 400 Hz plus 2nd, 4th, 5th, 7th and 8th harmonics; viewed from 600 Hz it will be the 3rd, 6th and 9th harmonics only, a very simple resultant wave-pattern; viewed from 1000 Hz the resultant will be 400 Hz fundamental plus 2nd, 4th, 5th, 7th and 10th harmonics.

Having now found a way of sensing further reality behind the object, perhaps you are so gifted that you can now *step outside material time* and view the object from all possible perspectives at one and the same moment—in a 'flash' . . . perceiving the CELE as well as the ELEC. Indeed, it may be that, by shifting your formants in this way, you can receive from the object a spark which energises many capacitors within you, so that later on you can transduce this energy into the reality of time . . . you can enjoy the world of creativity.

In trying to explain to you my ideas about sum and difference tones, I have simplified the matter far too much. I have made both the observer and the object simple 'material' things. If the observer is to have strength of character he will, of course, not be just 'a fundamental, two harmonics and fifteen suppressed overtones'. Likewise, for the object to have character and individuality it will not be just a fundamental and two harmonics—it too will be a complex 'structure'.

To recognise the object's individuality the observer will need to have such breadth of character—such a range of overtones to call upon—that he can call into resonance overtones which are distantly concordant with those of the object, and suppress those which are too close and those too unrelated. Thus, if both observer and object are rich enough in overtones the disciplined observer will, throughout his life, be able to find new aspects from which to perceive further realities within and *beyond* the object.

Perhaps, while you have been reading this, your mind has been visualising an object such as a rose . . . maybe a red rose . . . being observed by a human being—the personal wavepattern of the human being intermodulating with that of the rose, and so producing a resultant wavepattern in the brain. Yes, certainly visualise that, but also try to replace the rose with a great painting, or a string quartet, or a Shakespearean play.

Maybe the observer is unable, at first, to comprehend, or appreciate such works of art. He may find that, after many observations the complexity still remains too great to be assimilated. The observer, therefore, may have to extend his own harmonic range—to develop his range of formants—so that he can find some viewing point which is harmonically related to the object, and so gain an insight which, until then, had been impossible.

Once the observer allows his formants to shift so that the new area of resonance is opened up, the incoming wavepattern will itself induce further resonance in the observer's harmonically related tuned circuits. The observer will not have to strive for this—rather the opposite—he will have to relax and allow it to happen. He will have to expose the appropriate part of his tuning circuitry to outside influence, instead of keeping it inhibited. At the same time he may need to inhibit other parts of his circuitry so that they do not cause interference beats.

By repeatedly hearing or viewing this work of art, the newly excited circuitry will become so energised that it will need very little energy to set it into further oscillation. Indeed the observer may now spark off this oscillation by merely remembering the original work of art—the original stimulus.

At this point, it seems to me, we could say that the observer's individual character has been changed—his own wavepattern now has this oscillation as a component. The work of art not only has persuaded him to shift his formants to allow it to be observed, but it has excited sympathetic resonance and created a new facet to his individuality.

In this way are we 'fashioned' by all we ever sense with our five senses? Is our own celetal aspect coming into being as we allow our individuality to expand?

Of course, this 'fashioning by outside influence' is not necessarily linked only to 'that which is of good repute'. We came to the conclusion, some few pages back, that individuality is dependent on the formants—on the size of the areas of resonance, and where they lie in the whole spectrum of possible vibration. Indiscriminate

expansion of these areas of resonance may well allow most undesirable influences to affect the personal wavepattern.

Let us now imagine what would happen if the individual enormously contracted, or enormously expanded, his areas of resonance. To contract the resonance areas he would need to inhibit his tuned circuits; to expand the resonance areas he would need to excite more and more tuned circuits.

If the individual inhibited all areas of resonance he would no longer exist as an individual. He would exist in the most simple and primitive form—its analogy would be as one tuned circuit giving one basic sine wave. If he allowed all areas to become equally excited into oscillation would he also lose his individuality? His range of oscillations would cover the whole spectrum—so, surely, he would indeed have lost all individuality . . . lost it in a hissing roar of white noise. By total *inhibition* he reduced himself to a simpleton, a sine wave; by total *excitation* he disappears into overwhelming noise. Are these merely two aspects of the same thing? Does the ghost of Montaigne whisper 'YES'?

Do we, both humanly and musically, walk a tightrope? If we lean one way we plunge into the futile void of the ineffectual sine wave; if we lean the other way we fall into the abyss of annihilating noise. To keep our balance we must have individuality—individuality of character, individuality of style.

Is any human being so insular that he can remain unaffected by the transmitted energy from objects—both animate and inanimate—which surround him? Perhaps if he can inhibit sufficient of his natural areas of resonance he will achieve this isolation. But do we not call this state madness? To the outside world he appears a simpleton but within himself he is, I think, only able to view the simple sine wave from the opposite aspect—he, within himself, is overwhelmed by incessant, screaming 'noise' . . . the noise of insanity.

Do we not, also in life, meet people who are the very opposite of this—the man who overwhelms everyone with his energies, which he spreads over activities at random—the bullying dictator, the extrovert who is always 'widening his horizons', but, underneath it all, is just a boring simpleton? This, in its extreme, is madness too.

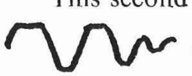
Both these cases come about because of maladjusted formants. Can our formants be adjusted (or maladjusted) by outside influence?

Perhaps a moment's musing upon the possible relationship of drugs and formant control would be interesting. Could we somehow see, in this way, how it is that drugs, such as LSD and cannabis, can give momentary 'enlightenment'?

Drugs seem to be a way of throwing responsibility aside and allowing the personal formant to be expanded or contracted, so that the areas of resonance are either vast or non-existent. If the drug expands the areas of resonance in a random fashion, there will be moments when the 'self' can slip onto an emphasised harmonic of its fundamental, and glimpse a new reality—become attuned so that something of the 'crystal clarity' becomes visible.

However, I rather doubt whether this chemical excitation of the tuned circuits—this violent excitation via the bloodstream—can ever keep the required circuits in resonance for sufficient time to allow balanced and beneficial changes to occur.

Let us try to see what will happen if you take cannabis; let us use an analogy. The 'tuned circuits' or 'pendulums' will be severely jolted, momentarily; unfortunately the pendulums will not be brought slowly and gently into harmonious swing. The drug chemicals in the bloodstream will suddenly over-excite the circuits and then soon die away. Over-excite a pendulum and it will hit against the enclosing wall. Instead of swinging like this  in the manner of our sine wave  it will swing like this .

This second pattern is a sine wave squared off top and bottom  and this squaring off will remove so much energy that the pendulum will soon cease to swing—it will stop far earlier than it would have done had it been gently caressed into oscillation.

By this sudden over-exciting you have changed a single frequency pure wave into a squared wave with lots of overtones. Much of the energy has gone into the overtones and the oscillation soon dies out.

So your rapid injection of a drug is rather like suddenly pushing all your pendulums hard against the back wall. Your personal formant no longer consists of disciplined ranges of tuned circuits,

each tuned circuit accepting just its own single frequency. Now each tuned circuit has gone berserk and momentarily will be distorted into giving out a whole range of overtones.

With all these overtones available at the same moment you will have expanded your areas of resonance enormously. Your personal wavepattern will be raucous with overtones, and its intermodulation with an object will 'engulf' that object with this randomly selected noise.

For a while you may glimpse something *beyond* appearance, something that will be outside your normal experience, something so exciting that it will never let you rest until you find it again. But it will have been only transitory, for it will not have transmitted a 'spark' which you could grasp. Unfortunately, at the time the spark was there to be grasped, all your tuned circuits were too busy pumping out distorted square waves—they were not free to accept, and they were not tuned sympathetically so that they could accept any incoming signal, any incoming spark.

So that spark, which you momentarily perceived, will not have permanently energised any circuit within you, it will not have enriched your wavepattern, nor will it enable you, through memory, to expand your areas of resonance. You will, of course, be able repeatedly to inject drugs into your bloodstream, and each time you will, temporarily, be expanding your formants—expanding them enormously, in fact, for you will be becoming the bullying extrovert in the process of 'widening your horizons'.

You will be using white noise to overwhelm yourself, but the world will see you from the other aspect—to the world you will be becoming a boring simpleton. You will lose all your individuality . . . despite the fact that, between jabs, in your 'conscious' moments, you will do everything in your power to acclaim your individuality! But, finally, you will hardly be able to resist the temptation of residing all the time in that random world of white noise.

You will be pawning your individuality in the hope that the right frequency will turn up among all those random frequencies which constitute white noise . . . the right frequency, the right number of cycles per second, to lift you momentarily into a view of *near reality*. How elusive that right frequency is! You will be tempted to make the white noise more and more truly 'white' until every frequency is sounding—not in random succession, but all at once—until your individuality is completely lost in permanent madness.

5

We have been looking at oscillators, ring modulators, filters and formants and musing upon the possibility of their functions being an analogy of what happens within the human brain and body.

We seemed to sense a relationship between the control of the formants and the growth of individuality; furthermore we saw the abuse of formant control leading to madness. In this chapter I think we should muse upon the role of the arts in relation to what we have already been considering.

There seem to me to be two, somewhat distinct, roles for the arts to play. We have already mentioned the greatest of these roles—that great art presents us with such a rich and perfectly controlled wavepattern that its intermodulation with our own pattern provides us with new aspects of reality—this intermodulation induces resonances which allow us to step aside from our normal rigid viewpoint and uplift us . . . we view afresh with enhanced comprehension.

The induced resonances must occur in all the wavebands—the physical, the mental and the celetal—for the enhanced comprehension to be fully realised. (However, even if resonance is only induced in just one of these wavebands the result is usually pleasurable, as long as the resonance is not too close to the original personal oscillations, for then it produces unpleasant interference—those beat frequencies.)

These induced resonances in all wavebands remain with us, if renewed by memory and repeated experience, so that eventually they become frequencies in our own personal wavepattern. We have now gained this new viewpoint as permanently ours—it was always inherently ours, for it was one of our possible oscillating points, but it needed the signal from outside to induce it to come into sympathetic resonance.

From our newly acquired viewing point we find that we can come back again and again to this work of art, hear it afresh and shift our formants still further, acquiring more and more viewpoints, more and more comprehension. But all three wavebands will need to have their formants shifted at the same time.

Let us imagine that we are at a performance of Bach's *Matthew Passion*. How are our three wavebands affected separately? The physical waveband requires that the sound that reaches our ears shall be well produced, of good timbre, accurate in pitch and rhythm, that we should not be disturbed by extraneous noises such as a coughing neighbour, that the concert hall has pleasant reverberation qualities, that we are warm and not hungry. . . .

The mental waveband wishes to be stimulated by Bach's wonderful powers of musical organisation, his masterly control of form, counterpoint and harmony, his overall sense of architecture, the way in which different performers can re-interpret and yet maintain the balance of structure. . . .

Meanwhile the music is bringing into being its CELEtal quality—its essence, its spirituality. Only if the physical waveband and the mental waveband are pleasurably resonating will the celetal allow itself to be affected. How often do we hear a performance which fails ever to touch us? For the performers are too involved in their mental and physical wavebands to have any chance of transmitting in the celetal band, and we, for our part, are far too worried . . . (by thoughts of unpaid bills, of a difficult week ahead, of rheumatism in our left shoulder?) . . . far too worried to allow our mental and physical wavebands to become acceptor circuits at all. The celetal side will therefore never be present, never be energised, either at transmission or reception, so it is futile to think that on such an occasion there will be any uplift.

However, let us imagine that, halfway through this performance of the *Matthew Passion*, the music begins to 'come alive'. We manage to quieten our brains, forget our rheumatism, and the sheer beauty of sound, the quiet rhythmic detachment of the cello continuo part, the musical phrasing of the oboe player . . . all these make us relax our muscles, calm our nerves. Our own wavepattern in the physical band is being coerced into harmonic relationship with the music—the inter-modulation of the two patterns is becoming a meaningful relationship. It is no longer a jumble of frantically interfering, unrelated overtones—we no longer need to filter away most of the signal reaching the brain: indeed it is becoming so pleasurable that we can shift the formant so that more, not less, of the signal can reach our consciousness. Now we begin to notice other facets of the performance which had till then escaped us . . . it has 'taken hold' of us physically, and now the mental waveband can take over . . . and so to the celetal.

This is no bludgeoning of the senses by sudden overloaded emphasis; this is a gradual awakening from physical to mental to celetal.

Have you noticed that this 'take over' from one waveband to another seems to happen in all walks of life. In the sublime heights of Bach . . . yes . . . but, also in the more humble experiences.

Try watching a thinker at work. He often begins by pacing up and down the room, or by drumming on the table, gently, with his finger tips. In this way he relaxes his physical waveband and imposes on it a soporific rhythm. Next he needs to activate and, at the same time, soothe his mental waveband. He will often doodle symmetrical patterns on his blotting pad or indulge in witty, flippant, sparkling conversation . . . he is 'bringing his brain to heel'. Only then perhaps, can he hope to enter the contemplative world of the CELE.

This gentle pattern can be seen clearly in the rites and rituals of the religious orders, where it is given a solemnity and beauty of its own. But in everyday life it can equally well be not gentle but boisterous and exhilarating. A hard game of rugger, followed by making love, followed by a witty revue at the Arts Theatre, may be more the recipe you require for opening up the region of CELE! Laughter certainly seems to me an excellent stepping stone. But, whatever the path, let it be a mounting rhythm, not a bludgeoning of one waveband only . . . not a battering into senselessness of the physical band, hoping that the other wavebands will, by sheer noise, be forced into resonance. That is the distorted resonance of madness.

Possibly you prefer Pop to J. S. Bach . . . perhaps, then, you can try using the psychedelic lighting, the rhythm of the pop group, the screams of the singer as a quickening of the physical band; perhaps follow this with some mental gymnastics to quicken this waveband too . . . maybe you will then find it possible to emphasise the region of CELE. But beware of becoming benumbed, of being hypnotised, of being 'switched on', or rather 'switched off', for then your individual wavepattern will not be able to play its part; it will gain no lasting benefit and you will find yourself impatiently repeating the experiment over and over again, whenever you want the experience.

Let us now turn from the listener to the composer. When a composer has found that he has a gift for 'tuning in' his wavebands, and that he now wishes to transduce the spark he has received into a musical composition, he has the difficult task of finding a form and of evolving a style which will support all aspects of his endeavour.

Music has, through the hands of many composers, developed wonderful forms, each generation of composers adding to its development in their own particular way. But in recent years the communication between the contemporary composer and his listener seems to have become more difficult, sometimes breaking down altogether. Musical forms seem so different—so formless—that the listener can find nothing to grasp, no helpful basis on which to stand firm. It is because I am often asked, when I give lectures, whether I can give some guidance to listeners, that I felt it would be worth writing a book inviting the would-be listener to muse upon the subjects of music, sound and electronics. But no, I can give no actual advice, for appreciating music is one of those wonderfully personal affairs . . . no one should intrude, let alone tell you how to do it!

It is for this reason that I have used the analogy of personal tuned circuits. For this reason I have emphasised again and again the importance of individuality. If everyone of us has a different personal wavepattern, a wavepattern which is for ever in a state of expansion and contraction, it is for each one of us to say quite independently when hearing a piece of music—'it is great music, for I sense, think and feel it to be so'. (Tomorrow you may feel quite differently about it, for tomorrow your wavepattern may intermodulate with the music quite differently.)

Beware of those busybodies who go around telling you what you should feel, and when you still don't feel it they tell you why you should feel it, and how you should feel it; they write long programme notes and newspaper articles about this work and that performer. If we read all this unnecessary verbiage we find ourselves so preconditioned that we cannot go to meet the music with our own vibrant wavepattern intact; for we are warped and stilted, or else artificially expectant, and, being not true to ourselves, we cannot expect to gain a true impression from the music.

So if I do give any advice, it would be to meet the music without any preconceived ideas. Remember that the signal reaching your consciousness is as much *you* as it is the *music*—it is the sum and difference of you and the music. If you can clarify your own wavepattern and clear it of all irrelevances, before you modulate the music with it, then you have more chance of finding the experience rewarding. If you can become so sensitive to the music, so related to it, that it lifts you to a different region of resonance, then that achievement is almost as much to your credit as it is to the composer.

When you have achieved that, it will be as well to remember to meet the same music next time with no preconceived ideas, no excited expectancy, for your own wavepattern will be different, and who knows, you may either achieve no rewarding intermodulation this time or you may be uplifted to far greater resonance, for truly great music has countless new facets for illumination. In viewing a masterpiece from many angles, from countless aspects, you will not only see *beyond* it but you will also come to know yourself. No one but you can advise yourself how to do that, and no one but you can tell yourself what you are looking for, and where and when. You are an individual and your individuality is to be greatly treasured.

But contemporary music still worries you? . . . you are still worried by the seeming lack of musical form?

Have you ever tried musing in front of a flickering coal fire? The coals form fascinating, grotesque shapes, some fiery red, some sullen black. Tongues of flame, blue and yellow, create crazy rhythms as they dance. You cannot predict what will happen next, yet you feel beneath it all a consuming pulse. You go awandering among these mountains of carbon, through this crevasse, down that valley, catching at each step a new glimpse of a tottering rocky pinnacle. The crazy beat of the flames incites you to join them in a song; so each pathway becomes a musical phrase, each boulder a musical chord. The crescendo reaches a climax as the craggy pinnacle plunges crumbling to its death. The flickering flame is extinguished . . . and all is as silent as dust.

But you know in real life things hardly ever happen in such orderly form. Such an excellent crescendo of rhythm and line that you composed when watching this imaginary coal fire—this crescendo coming to its climax just before the end of the composition and being smothered into silence—how often in life have you met a chain of events which followed such a predictable pattern?

Composers in the past worked out predictable forms on which to base their music. Marvellous forms like the fugue and sonata form. These enabled dull composers to write lots of dull music which was quite 'correct', and, of course, these same forms gave composers of genius architectural structures which supported their greatest inventions.

Life in those days seems to have been more predictable—oh yes, there were the revolutions and the strivings—but the average life was quieter, perhaps more disciplined . . . it thought it knew where it was going. Do you think it is the role of music always to reflect the life of the day? Personally I think it is much more than that—we have already mentioned its role of inducing resonance, its greatest role to my mind—but, as well as that, I think it should not only reflect the life of the day but show the possibilities for the future. It should show all the possibilities . . . the grim ones as well as the pleasant. We should not ask it to wear pink spectacles.

In our arts I think we should reflect and examine the social organisations of today and of the future. The arts should act as an analogy of the possible social and technological systems, so that we can preview and criticise these systems without needing to use the human race as guinea pigs to try them out.

Let me give you an example of how I think it works. Total serialisation in music seems to me to be a 'try-out' of a type of computerisation. In writing his totally serialised music Pierre Boulez, whether intentionally or not, seems to have given us a glimpse of a world where freehand, empirical, human control is withdrawn and everyone (and everything) is submitted to total permutated 'logical' control by computers. It appears an arid, cold, inhuman world to me and not what I would choose; but others may prefer it and certainly in the 1950s it looked as if the world was heading in that direction.

Since then, composers have explored in other directions, where some aspect of the 'machine' seems to hold sway, but more 'freedom' appears to exist—they compose aleatorically. The spin of the coin, the random number table housed in the computer—these keep much of the responsibility out of the freehand human control but escape the regimentation of total serialisation. (My dictionary gives the derivations of this word aleatoric—from the Latin *Aleatorious* for a 'dice-player or gambler', and also from the Greek words *Eleos*, meaning 'crazed', *Ale* meaning 'wandering of the mind, madness', and *Alaomai* meaning 'wander about'.)

This new music has produced some interesting effects. Aleatoricism has given new patterns of pitch and rhythm, new awareness of sound and silence, which has been assimilated by composers—digested by them. All this takes time; we are beginning to hear compositions which are, perhaps, the favourable outcome of this. Having made its point, aleatoric music may now go out of fashion . . . but it has shown us a world of chance which is just as possible in our future lives as the world of strict regimentation.

Music has also taken another path: the composer, having shown in the past how strict regimentation can mould his music, how pure chance can shape his composition, now hands the material to the performer and gives him much of the responsibility for transmuting it. (This music is also sometimes termed aleatoric.)

What of the future? What is the next step? Will the composer disappear altogether? Or will the pendulum, perhaps, swing the other way, making the composer all important . . . and so the performer will disappear? Maybe the performer will take over more and more responsibility on the concert platform, while the composer turns his attention to composing with machines music that needs no

performer. In this field could we hazard a guess that the composer may show us that, after all, the greatest music is composed when the composer has sufficient strength of character to control his forces by his own individuality . . . when his own formants in the physical, mental and celetal regions of his mind reveal such a range of understanding that he too can say: 'this is great music for I sense, think and feel it to be so'.

Will this be a reflection of life as it is being lived today? To my mind . . . yes . . . a new feeling of individuality and responsibility is creeping into life . . . (just in time, I believe, to overcome those insidious horrors of Orwell's 1984) . . . a feeling of individuality which is not arrogant, not conceited, but is based on inner conviction and faith, based on what lies *beyond*.

But you may easily get the wrong impression from what I am saying here. You may quite rightly say that individuality and inner conviction in the world outside the arts can so easily become corruption by dictatorship, persecution by puritanism, and lead to rampant hypocrisy. Outside the arts, perhaps . . . but can great music dictate, persecute and show hypocrisy? . . . that is a point we might well muse upon sometimes.

And now there is another complaint you may make. You may complain about my phrase 'when the composer has sufficient strength of character to control his forces by his own individuality' . . . perhaps you are thinking that that could imply a backward step, instead of a step which can carry us on to the 21st Century. So let me make it clear that 'controlling his forces' will include the control, and exploration of all the technological aids, such as computers which can extend the composer's world. Oh no, do not let us restrict him, or hold him back in any way, for he must explore all that this century can offer him if he is to guide us as to what can be and what might be.

6

One of the devices which the 20th Century offers the composer is the tape recorder, a remarkable piece of technology.

The discovery of the principle of magnetographic sound recording, as tape recording was then called, actually took place as far back as 1888. Oberlin Smith seems to have been the first to discover the principle and proposed that wire, or steel tape (or threads of cotton impregnated with steel dust) should be used as the recording media. By 1898 Valdemar Poulsen had made an actual machine, the 'telegraphone' which could store messages magnetically on steel wire or steel tape, and he demonstrated his machine at the World Exhibition in Paris in 1900.

Since 1900 an immense amount of work has been done to make the tape recorder the versatile instrument it is today. It can be a marvellous tool for the composer, yet many composers appear timid about it. They seem to grow tense in front of the 'new-fangled contraption', and want an engineer to operate it for them. Perhaps they cannot visualise that it is all very simple!

Perhaps they cannot visualise that there are just thousands upon

thousands of tiny bar magnets attached to the shiny plastic tape, quietly waiting for the composer to show them how to arrange themselves; that those yards and yards of tape, pregnantly coiled, are as placid and as inoffensive as the painter's canvas awaiting the first stroke. Each tiny magnet just requires to be orientated, so that patterns are built up, intricate patterns, patterns of waves, ready to be transduced into sound. And later on, these same magnets can be reshuffled—disorientated first of all, and then organised anew into fresh patterns. So the composer has a re-usable 'painter's canvas'. But, also, this 'canvas' has an added dimension—*time*. It has a duration, for it gradually unfolds itself to the listener, unlike the painter's canvas which is viewed 'all at once'.

The composer, in painting his sound colours onto his canvas can gradually build up his composition, taking perhaps ten hours to build one minute of music. Visualising his tape stretched out across the room, he can paint in a note here, strengthen with more tone colour a note there, wash in a background blend, mix together his complex rhythms, and, of course, use his silence as succinctly as his sound. The composition is there in front of him, existing in *concrete* form outside its proper time dimension, ready, finally, to be played back in its true time.

Perhaps the timid composer is worried at the thought that, to make one note lasting one second, he has to organise about 60,000,000,000 magnets in the space of 19 centimetres. Luckily, of course, he only has to issue the instructions!

The recording head, like a fierce headmaster, whips the magnets into their positions and, some 6 centimetres further on, the assembled formations are examined and the result is amplified and . . . 'loudly spoken'. (So the composer can immediately tell, from the loudspeaker, whether his wishes have been faithfully carried out.)

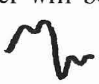
A very superior recording head may have great facility, and be able to discipline some eight, or more, quite separate lines of magnets all at the same time—giving the composer an 'octet' of sound from a single loudspeaker, or eight separate strands of sound from eight specially placed loudspeakers.

But enough of this . . . we all know how a tape recorder works. And many of us will probably have tried our hands at editing tape in order to build up a montage of sound—marking the tape with a soft wax pencil at the precise spot we want to cut, then inserting the tape in a splicing block, and cutting it with a razor blade along the angled slit provided; cutting the other piece of tape in the same way and then joining the required pieces, by butting them together, and putting half an inch of splicing tape (of the same width as the tape) across the join. It is very easy to do . . . the composer soon learns to do it in a 'split second' and thinks nothing of making 50 splices to create a short montage of sound.

The composer will probably want at least two strands of sound, so he will also make a second montage of sound to be played on a second tape recorder; then he will play back both machines together, recording the result on a third tape recorder. This process can be repeated over and over again until many strands of sound are woven together; but there is a snag here: gradually, with repeated re-recordings, more and more background noise will be apparent, for each recording will add to the general hiss and hum—all this being extraneous to the music and a great nuisance.

The composer finds that, when he is re-recording, he has to learn to control very carefully 2 knobs—one is the playback volume knob, which he has to control so that the output from his already recorded tape is sent to the recording machine neither too strong nor too weak, and the second is the record input volume knob.

Too low a playback level means that the record level will have to be brought up to compensate and, because of this, noise from the record amplifier will be introduced into the new recording.

Too high a playback level means that the playback amplifier will probably be producing rather a lot of noise and distortion itself. But the real danger is, with too high a playback level, that the recording amplifier will be overloaded. Loud notes of smooth timbre like this wave  will be squared off like this  and so (remembering the square waves we concocted from numerous sine waves) we shall find lots of uneven harmonics appearing—harmonics which should not be there at all.

Of course we can turn the recording level volume knob down a little to compensate for the high level reaching the machine, but this will not help a great deal, for much of the trouble has already occurred before this volume knob is reached. It is the playback knob of the first machine which needs the discipline.

What happens if, by mistake, we turn the recording level volume knob much too high? Again we introduce harmonics that should not be there; but, despite this, the poor tape will try its best to record it all. In fact, some tapes will record such a high signal that when the tape lies in its spool, hard against the next layer of tape, it will 'print through' to this next layer some of the signal—a 'ghost' sound will be recorded on this adjacent layer of tape.

If you really turn the recording volume knob right up so that the signal to the tape is outrageously high, the millions of bar magnets on the tape just cannot take it—instead of arraying themselves in perfect patterns they become perverse and lie about in neat rows, side by side, displaying no pattern whatsoever. The result is that, during this period of violently overloaded signal, nothing at all will be recorded on the tape. When you play it back there will be an embarrassing moment of silence . . . just where that very loud note ought to be!

I want to call your attention, especially, to these two types of overload distortion—the 'squaring' of the wave pattern which means the introduction of extra harmonics and (with very excessive overload) the 'erasing' of the tape resulting in no signal being recorded. As you have probably suspected, I am going to draw an analogy between these aspects of tape recording and the functioning of the human brain, and these last two points are especially important for our analogy.

But, before we wander off, wondering about all this, I want to mention **tape feedback**.

If you set the speed of your tape recorder to 9·5 cms per second, ($3\frac{3}{4}''$ per sec) and you have the type of recorder which has a playback head separate from the recording head, you can listen to your recording a fraction of a second after it has been recorded. If the distance between the playback head and the record head is 6·33 cms, the delay between recording and playback will be $\frac{2}{3}$ of a second. Now if you feed back to the recording amplifier some of this delayed sound, mixing it in with the signal already being fed to the amplifier, you will impose 'echoes' on the tape, repetitions of the original sound occurring $\frac{2}{3}$ of a second later, and also echoes of these echoes.

A normal acoustic echo—the sort you hear in a cave or between the walls of buildings—is usually a softer, mellowed edition of the original. But with tape feedback echo there is no reason why the echo should be softer than the original sound. It is your hand on the playback volume knob which can control this factor. (You could also alter the tone controls, the filters, of your playback amplifier, and so make the echo very harsh, or very boomy, or distort it in other ways.)

What happens if you turn up the playback volume control fairly high so that the feedback signal reaching the record head is higher in volume than the original signal? Each time the signal goes from playback to record it will be raised in volume and, as we are repeating it over and over again every $\frac{2}{3}$ of a second, it will get greater and greater. The record amplifier will soon find this feedback signal is too high and will start squaring off the peaks of the wavepatterns, thus adding overtones. As well as this, the hiss and hum of the tape and amplifiers will also be raised and raised in volume as the signal is fed back repeatedly. The result will be a terrible howl, which will mount higher and higher in volume, until you cannot stand it any longer. As it screams out of the loudspeaker your ears will be suffering so much that you will have to turn the playback volume knob down, and . . . what a relief . . . the howl will subside and die out. You will soon learn to set the volume knob so that you get just the number of repetitions that you want for your 'echo', at the same time ensuring that the repeat is softer than the original, so that the echoes die out and never build up to a howl.

Tape feedback echo has been used a great deal in the last 15 years both in avant-garde tape music and in pop music. But one can hardly say it is new in conception, for that incredible writer Francis Bacon, writing in about 1624, foresaw something of the sort. When describing, in his *New Atlantis*, the 'Sound Houses' on his imaginary Utopian island, he writes:

> 'Wee have also diverse Strange and Artificiall Eccho's, Reflecting the Voice many times, and as it were Tossing it: And some that give back the Voice Lowder then it came, some Shriller, and some Deeper; Yea some rendring the Voice, Differing in the Letters or Articulate Sound, from that they receyve'.

But let us wander back from Bacon's Sound Houses . . . to tape feedback, and do a little wondering about the human being. About a hundred years ago Karl Von Baer came to the conclusion that we

humans require a certain length of time to become conscious of a stimulus from outside—a sensory impression needs somewhere between $\frac{1}{10}$ and $\frac{1}{20}$ of a second to reach our consciousness. Nowadays, this response time is usually quoted as averaging $\frac{1}{18}$ sec (about 55 milliseconds). (Some fish are said to respond in $\frac{1}{30}$ of a second, but the poor old snail seems to need a $\frac{1}{4}$ of a second, five times as long as we do!)

Could tape feedback be in some way an analogy of brain response? Could this $\frac{1}{18}$ second be not only the time taken for the stimulation to travel along the nerve fibres, but also include the time for it to be 'recorded' and 'played back'? Is there a feedback system so that a thought, resulting from an external stimulus, or a thought resulting from internal reasoning, is retained for as long as it is allowed to feed back? We have, probably, little control over the original 'record level', for we cannot anticipate the extent of this original stimulus, but we probably have great control over the playback volume. I venture to suggest that it is at this playback stage—at this control of feedback stage—that we display our individuality, our will power, our character. For might it not be at this point that we allow the incoming signal to intermodulate with the personal wavepattern and at this juncture—

(a) We have control of the formants decreeing what our personal wavepattern will be at that moment.
(b) We have control of the volume of the intermodulated signal which is being fed back to the recording brain, and so we can decide how many repetitions (echoes) of the signal shall occur and, also, at what volume they shall be recorded.
(c) We have control of the filter circuits (or 'tone controls') which will be able to reduce gradually (during the repetitions) that part of the signal which is deemed to be extraneous or undesirable.

This would give us wide powers of personality, of individuality. We could view the incoming stimulus from any variation of our own personal pattern, so seeing it from various aspects. We could then, having decided how we are going to see this particular stimulus today, decide to reduce it to nothing after very few repetitions, or alternatively, we could keep it energised at a steady rate so that it became self sustained—and at the same time we could filter it and try to fathom it. And when it is something which worries us we could allow it to build up, imprinting itself more and more on our consciousness every time it repeats—every time it feeds back into the circuit (every $\frac{1}{18}$ of a second?).

Does this system of feedback give sustained repetition to thought which is the result of external stimulus and equally to thought which is the result of internal reasoning? Does the personal wavepattern intermodulate with both types of thought? It is sometimes said that women are not able to think as logically as men because they become too personally involved—could this mean that a woman's personal wavepattern is likely to have more amplitude when intermodulating an incoming signal, and therefore an external signal has relatively less effect on her than it would have on him? Might this throw some light on the fact that often women seem to be able to withstand external hardship better than men? Might it also be a reason for the average woman being less domineering, less likely to fight, than a man, because she is less concerned by outside events, less inclined to amplify 'self' in order to dominate these events, for her method of perception already gives her personal wavepattern predominance over the outside signal; but, once the external signal is of far more than normal amplitude, she feels helpless to cope because it then overpowers her own wavepattern—a situation which is abnormal and frightening for her, whereas for the man it is normal and he usually well knows how to assert (amplify) his own wavepattern just sufficiently to keep control of the situation.

When it comes to internal reasoning—to detached thoughts not engendered by immediate outside events—a woman's thought is, likewise, likely to be more coloured by her personal wavepattern than a man's would be. A woman needs a very powerful sense of internal reasoning to keep the amplitude of this reasoning above the amplitude of her personal wavepattern.

(Having read my line of argument, perhaps you would like to *montaigne* this point of view. You will probably find that you can establish just as strong a line of reasoning for seeing it the 'other way round'!)

However, quite apart from any differences between the sexes, I think we might consider that both externally stimulated and internally reasoned thoughts are given sustained repetition by feedback, and then are observed through intermodulation with the personal wavepattern.

Would this sustained feedback repetition be, in a sense, like 'freezing time'—like stopping the TV film and holding it steady on one frame, scanning the same frame over and over again? No, I do not think that that is a good analogy for, in the case of human reaction to an external or internal signal, the everchanging personal wavepattern never allows the brain scan to be repetitive. There is, surely, interaction here . . . for what the brain is scanning will itself be affecting the personal wavepattern . . . in other words, the object will itself be altering the powers of observation.

It needs great detachment and great serenity to watch one's own thoughts without becoming emotionally 'involved'. As Werner Heisenberg said: 'we have to remember that what we observe is not nature herself, but nature exposed to our method of questioning'. Our questioning depends on our personal wavepattern, because it is by using this for intermodulation that we are able to quest at all. So, whether we be men or women, we need to find that tranquillity of mind which allows us to look at ourselves from a stand point which will reveal a truthful observation. We need to learn to control the volume of feedback while, at the same time, shifting the viewing point from harmonic to harmonic of our formant range . . . how can we achieve this? . . . is memory at hand to assist us?

7

What is the memory? Could it consist of hundreds upon thousands of tuned circuits, able to accept those signals which have been reinforced during feedback, reinforced by what we term 'concentration'? We lift the volume level when feeding back signals which we feel are important; are these then printed through on to more permanent feedback circuits, ready for retrieval at any time?

Obviously many of the feedback signals will be allowed to die out very rapidly so that they never get 'printed through' to the longer term memory circuits. You do not, for instance, wish to remember how you spread your marmalade on your toast at breakfast this morning . . . the echoes of that thought would be stifled immediately; but that racy bit of gossip which you read in this morning's paper may be allowed to echo round the feedback circuit for a while, especially if you wish to tell the spicy news to your neighbour this afternoon.

But each time the signal echoes round the circuit it is 'coloured' by the personal formants. It seems that if one is in a mellow mood the incidents of the morning become more rosy as the day proceeds;

whereas, if one is in a spiteful, edgy mood, incidents become more biting and acid. Musical sounds put through a tape feedback process change in just the same way . . . that is, they change according to the settings of the tone controls (or filters) in the feedback circuit. However, the tape recording process itself tends, usually, to have a smoothing, mellowing effect: with repeated re-recordings the higher, shriller, frequencies lose their bite and the startling sforzandos lose their impact; if there are many strands of sound, woven contrapuntally, these gradually become more of an indecipherable 'mush', and only those isolated sounds, recorded with the utmost clarity, seem to retain any brilliance.

Our memory re-recordings appear to follow the same rules. The time lapse of memory, luckily for us, usually has a smoothing, mellowing effect. The memories which seem to last longest are not the complex ones, but are those memories . . . often the childhood ones . . . which were recorded with extreme clarity—isolated events which, at the time, completely held our concentration, for our young brains were not cluttered up with the countless day to day worries of adult life. These childhood events have often been remembered by us, from time to time—so they have been reinforced by retrieval and loud playback, before being returned once again to the memory feedback circuits. Late in life, when we are very old, these childhood events stand out as clear as yesterday . . . if not clearer . . . for they were recorded on 'virgin tape', when the feedback recording mechanisms were in their prime and not overworked, and the recordings were made with the optimum recording level . . . unless, alas, they were recordings of childhood nightmares and miseries, which means that they were probably heavily overloaded when recorded, distorted with self-imposed overtones, and so haunt us for the rest of our lives.

Memory circuits have often been visualised as many layers of recorded tapes. This implies that the memories are there in their original recorded form ready for retrieval. However, if we are considering a feedback loop, with formant-filter control, as a possible memory store, we do not picture a library of recorded tapes with busy librarians flitting to and fro among the shelves. Instead we see millions of tiny feedback circuits each continuing to repeat its echoing signal until its energy dies out.

The feedback (memory) signal from one of these circuits can only be inspected by the consciousness via the particular formants at that moment in control, and the modified signal thus obtained by the consciousness can be made to energise another feedback circuit. In this way the memory signals could be reinforced, and also gradually sorted out into subjects—for instance, all feedback circuits relating to, say, billiards would gradually be situated in a connected area, while those related to, say, geometry would be in another area. (Incidentally, in the case of geometry and billiards, some memory thoughts about angles and deflections might well take up residence in feedback circuits of both areas!)

In sorting out the memory signals, the circuits themselves would not 'move' from area to area of the brain—the energy would, just by sympathetic induction, find itself resonating feedback cells alongside those already concerned with the same type of information. Then one memory thought might resonate many feedback cells in various parts of the brain, because it had affinity with the thoughts stored in these different regions. Its life span of feedback echoing would depend on its initial amplitude and the reinforcement it received from time to time through being retrieved into consciousness. (If it got lost or damaged in one area, it could often be found to reside also in another area, and could be retrieved and re-instated in both.) But retrieval into consciousness always means going through the 'personality formant filters', so the signal might undergo many significant changes in the process.

The brain will probably not bother to retrieve (or even store) every detail of the particular memory thought. It will bring the salient points back into consciousness, but the minor details it will probably fill in from logical reasoning . . . reasoning out consequences and details from the few salient points . . . and this logical reasoning, in the brain's 'rationalising department', will be different on each occasion, because the personal wavepattern in control will vary. So what you remember today of an incident that happened last year, may not be exactly what you remembered of it yesterday—in fact some of today's memories may be significantly coloured by how you remembered the incident yesterday. No wonder we all have difficulty in being 100% reliable as witnesses in a courtroom!

It is perhaps difficult to visualise the speed at which memories could be retrieved, sorted, and re-recorded within the human brain. If you like using your imagination, and like to think of the brain in terms of present technology, I would bring to your notice the gigabit[1]-per-second pulse stream which, at the Bell Laboratories,

[1] Giga = a thousand million (10^9).

can be impressed, by optical modulation, on to a laser beam. There they are using the techniques of electrical multiplexing of four different streams and the speed they can now attain is quoted as being equivalent to the transmission of 200 books per second or a library of 50,000 volumes in about eight minutes. If you wish to muse further on the subject I suggest you relate to the human brain the techniques of holography, as well as optical modulation and multiplexing, and maybe allow it to operate at the speed of tachyons—those particles, which, some scientists suggest, travel faster than light!

Do the various 'bandwidths' of the brain, in the physical, the mental and the celetal, operate at different time speeds? The scientists give the symbol C to the speed of light. C stands for CELERITAS. Does the CELETAL operate at the speed of light or could the celetal perhaps be capable of operating *outside time*?

If geons—the theoretical particles of curved space—consist of solid matter, does curved time equally consist of particles of solid matter? Can space and time both be solid, or do we need to maintain the fluidity of one to 'perceive' the solidity of the other? Have some human brains the ability to *montaigne* space and time—to gain a perspective enabling each to be seen as either solid or fluid?

Such considerations and flights of imagination excite some people, but depress others. Even the advancing technology of today seems to frighten some people, and makes them think that technical ingenuity will outstrip the wonders of the human brain. Perhaps they will be cheered by these words, written by Robert McNamara[1] in 1968 (when he was America's Secretary of Defence), comparing the human brain to the computer—

> 'The human brain is an utterly incredible computer itself, probably the most magnificent bit of miniaturization in the universe. Though it weighs only about 3 pounds it contains some ten thousand million nerve cells, each of which has some 25,000 possible interconnections with other nerve cells. It has been calculated that to build a computer large enough to have that range of choice, would require an area equal to the entire surface of the earth.

[1] Robert McNamara, *The Essence of Security*, published by Harper & Row, New York.

> As St Augustine observed—man looks about the universe in awe at its wonders, and forgets that he himself is the greatest wonder of all'.

A computer, so complex that its circuits would cover the earth's surface, needs very careful discipline and control if it is not to get out of hand. In many ordinary electronic circuits of this type technical faults occur which make the circuit go into a state of self oscillation. This is a state of uncontrolled feedback.

In the human brain this unfortunate state seems to occur if the 'record' and 'playback' circuits are not controlled properly—if the playback volume is allowed to rise too high. This overloading, through having too high a playback volume, is certainly a subject to muse upon . . . it seems to be the bane of our existence. Overload the record amplifier and you square off the curves of the wave-patterns—you introduce overtones which should not be there—the sound gets more strident. These extra overtones foım sum and difference tones with your own personal wavepattern and so more noise is introduced. Everytime the feedback process takes place, that is every $\frac{1}{18}$ of a second, these defects are emphasised and RE-EMPHASISED and RE-EMPHASISED.

If you go on insisting on having the playback volume too high every molehill becomes a mountain, every simple sine wave eventually becomes white noise. Your brain is reeling with the pounding, insistent feedback. The most insignificant acid thought becomes more and more acid, it takes hold of you and will not leave you alone. The greater you concentrate on these thoughts the worse they get.

How do we stop the feedback before we head towards madness? With the tape recorder we just turn down the playback volume knob—but in the human brain that requires a lot of self control. So if it is too difficult to stop the concentration the best thing to do is to divert the concentration on to another subject and hope that this alternative subject will not overload the recording system with the same dire results as before.

But there is another, rather drastic alternative. As we saw in Chapter 6, if we put an extremely heavily overloaded signal into a tape recorder, the recording tape cannot take it and 'records silence'. If the duration of this very heavy overload is longer than the echo reiteration time, then the feedback signal cannot repeat—it will be silenced. Peace will reign at last (until the feedback volume gradually rises again).

Do we find that this overloading-into-silence is applicable to the human brain? 'Overloading' the human brain means giving it a shock—giving it such a sudden, violent jolt that thought is momentarily banished and even the very recent memories are also, momentarily, blanked out. Perhaps nature herself, if left alone, has ways of making the suffering human being blank out his own thought by self-inflicted 'shock treatment'—for a sudden piercing scream emitted by the victim seems to provide a release from the entrapping feedback loop—this certainly seems to be effective for the enraged child. A dowsing in cold water was an old fashioned remedy for the hysterical child—or a sudden, sharp slap. (But, without knowledge of how such remedies were achieving results, the administrators, alas, oft times felt that twenty slaps were twenty times better than one, and so corporal punishment tended to take over.)

It might be interesting to look sometimes at musical composition to see how the maximum effect of shock can be musically administered. For example, Haydn was interested in creating the lulled situation where a surprise would make its greatest effect. Today, Luciano Berio seems to me to be one of the present masters of this craft. John Cage and his followers, can create the boredom of repetition only to shatter it with a commonplace sound—a sound which, in normal circumstances, would have made little or no impact.

Sudden changes of volume, or shattering of boredom, are not the only ways of achieving a feeling of shock. In classical music perhaps the greatest effect is produced by a modulation into a far away key, unrelated to the original home key, and accompanied, in orchestral works, by a change of orchestration which gives the sounds a completely new quality. This type of shock usually gives the listener an excitement—a pleasurable effect, a feeling of purposeful uncertainty and adventure, of sensing from a new aspect.

One wonders whether, in the everyday world, a purposeful change of environment, mingled with some uncertainty, can be arranged to help those suffering from the pounding reiteration of feedback. But no . . . it will need to be a stronger remedy than just a change of habitat and habits. Could it be that music and information theory, allied to technology, will eventually suggest a solution? How wonderful if they can produce a solution which is more refined, less heavy handed than electric shock treatment and leucotomy, and more controllable than drug treatment. (Maybe there is a clue in acupuncture, where the needles seem to administer miniature shocks at the vulnerable point, perhaps at a node or an antinode in the vibrating system? Can uncontrolled feedback produce not only some mental abnormalities, but also some physical ones? Are malignant growths, perhaps, another manifestation of it? Do we tend to find that, within one individual, it can occur either physically or mentally, but rarely in both ways at once?)

We have, so far, been dealing with rather extreme cases of thought feedback—cases where the repetitions mount up in amplitude to produce hysteria or madness. There are many instances in everyday life where thoughts prey on our minds, but luckily never reach the extremes that we have mentioned. In these cases there is a very obvious remedy which, I am glad to say, does not involve cold showers, electric shocks or screaming!

The simple remedy that I am referring to is, of course, this—when a thought worries you too much go and tell it to someone, or write it down in a letter. Perhaps the reason why this is a remedy is that the thought may lose some of its energy when it is transduced into spoken words or into writing. But I think there may be a further explanation. In transducing your thoughts into spoken or written words you are submitting them to a fairly rigid personal censorship—filter circuits are involved which are regulated by you with due regard to the circumstances, to the person you are addressing, and regulated by social training, by shyness, by fear, or by a sense of humour etc. The perceived reactions of the listener, the known attitudes of the reader, may all contribute to the way you regulate your 'output filters', when transducing your thoughts.

When you hear the words you speak, or see the words you write, your thoughts come back to you, through your ears or eyes, as external signals. This means that they are let in only by intermodulating with your personal wavepattern. The personal wavepattern will probably be a variant of the wavepattern which was 'you' at the time you had the original worrying thought; and, furthermore, as we have already mentioned, the signal that now comes back to you from outside is this newly filtered version of the worrying thought—for you filtered it yourself in transducing it into words.

So now the intermodulated resultant will probably vary considerably from the worrying thought held in your memory circuit, for you are seeing the thought from a different angle.

When we see something from two different angles, from two different aspects, we usually gain a more sober and rational view

of it; we have a little more knowledge of it—it is not so unknown—and therefore it is not so likely to be an object of fear and anxiety.

Perhaps there is a musical illustration of this . . . if we listen to twenty violins, all playing the same musical phrase in unison, we hear twenty variants of the phrase all at the same time (for each violinist will be making a slightly different sound). The resulting sound has a pleasing quality which is lacking when that same musical phrase, designed for twenty players, is played by merely one single fiddle. The solo violin can seem stark and naked, while the twenty violins in unison seem warm and rich—the addition of variants has made stark reality more acceptable.

Maybe we could take this musical analogy further and point out that the addition of wider variants will make the reality even more acceptable, for if the musical phrase is harmonised, integrated in a polyphonic structure, or developed in other ways, it will be heard from many 'angles'.

According to these analogies it seems that a worrying thought could be made less obtrusive, less stark, if it is 'worked out' in the reality of words or actions, examined from all angles and combined with variants (or 'harmonisations') of itself. This is, surely, just another way of describing a branch of psychiatric treatment!

8

The authorities have recently published figures showing how many people are likely to be in need of psychiatric treatment in their lifetimes. These figures are truly depressing. It is said that one in eleven of us is destined to spend some part of our lives in a mental hospital.

Could science and music, if they collaborated, assist in helping the mentally healthy members of the community . . . help them to avoid the extremes of 'uncontrollable feedback' and of 'self annihilating white noise'?

Both states seem to come about through the lack of control of energy—through extra energy being allowed either to swamp one particular minute area of the brain, or to run riot randomly over the whole spectrum of the brain.

Certain music, which has been composed in recent years, seems to give a good illustration of rather much energy being allowed to occupy a small and insignificant sector of aural activity. This music employs endless repetitions (or near repetitions) of a trite sound, which the 'composer-cum-performer' attempts to make significant . . . but the listener (perhaps because he is not conversant with a mental

state of uncontrollable feedback?) tends to find the result rather boring and rightly wonders why so much fuss is made of so little. You will also find music in the concert halls these days which will show you the other mental state: in this music, energy runs riot randomly over the whole spectrum of sound.

Does the 'small sector' music soothe those whose minds sometimes tend to run riot randomly? And does the 'run-riot' music appeal to those who tend to get feedback fixations in their everyday thinking? Or do you think it works the other way round (random music appeals to random thinkers . . . etc)? Does the music have a therapeutic effect mentally? Or does it allow indulgence in these abnormal states? Is it asking you to switch off your individuality and enter one of these two states of mental sub-normality? Is it, if it makes you switch off your individuality, preventing you from having constructive thought, and so making it impossible for you to use your critical faculties?

Is the music creating a therapeutic condition, a beneficial state, an antidote to the very condition it portrays? Or do you find that your personal 'areas of resonance' have nothing in common with these particular modern music stimuli, so the music leaves you unaffected? Does the music exist because the creators felt that they just had to create it—never minding about an audience . . . if so . . . why?

We ask why, not because of criticism but because, as we have already observed, music can prophesy future sociological and technical trends and so perform a most beneficial role—but to gain the benefit we must keep asking Why? Why? Why? of every new fashion in music.

So many, many questions . . . and so many points of view on this subject of modern composition. We could spend much of this book musing upon it . . . but, perhaps, we would merely be pre-conditioning ourselves—pre-conditioning ourselves for the music, a state of affairs which we have already deprecated. Perhaps we will do better to go to as many concerts as possible without preconceptions—but taking our individuality along with us most firmly! Even if the music switches off our individuality at the time, we will still have our memory of the event. Days later (better still, weeks later), we shall be able to bring out of our memory circuits those parts of the music which have left their echo there. We can then view these memories at various times, through variants of our formant circuits, so that our individuality can enable us to have various 'views' of the music. Then we can decide either to obliterate it from our minds, or else to increase its amplitude, so retaining it in permanent memory storage.

In this book I am refraining from mentioning actual musical examples within the text. In the Appendix, at the end of the book, I am suggesting many works which I think you will find intriguing listening. In order that you meet these works without preconceived ideas, I am not even suggesting which of the works I relate to certain arguments in this book. Your own opinion about the works is what matters—so do not bother at all to consider which are the works that I, or anyone else, would warmly value or tend to discard. Decide for yourself which you will retain in permanent memory storage, and view these often, so that you gain many viewing points. With no preconceived ideas you will find it so much easier to 'catch the scent' of modern music, and once you are on the scent you will be led down fascinating musical paths, which, intriguingly, have numerous connections in worlds far removed from music.

Memory storage plays a large part in the appreciation of music. It enables us to form, gradually, a deep personal regard for certain works—for when we retain these works firmly in the memory, we find that we return to them with increasing pleasure, finding in them a richer value than was at first apparent; while, on the other hand, we often find that other works do not stand this personal test of many repetitions. (Coleridge, thinking on similar lines, made this comment on poetry: 'Not the poem which we have read, but that to which we return with the greatest pleasure, possesses the genuine power and claims the name of essential poetry. [1])

You will be reminding me that I have already said that memory storage 'colours' a signal—so the music, when brought out from the memory for assessment, after the event, will already be doubly 'distorted'. How clearly Montaigne saw this predicament when he wrote these words nearly 400 years ago:

> 'Our condition always accommodating things to itself, and transforming them according to itself, we cannot know what things truly are in themselves, seeing that nothing comes to us but what is falsified and altered by the senses.'

[1] Samuel Coleridge, *Biographia Literaria.*

I agree that we cannot know 'what things truly are'; but what we can do is to retain our individual right to view them in our own fashion, to transform them according to our own character and thus to gain more insight into ourselves and our own abilities. What matters—what is most important to you—is that you retain the integrity of the personal wavepattern, the knowledge that this wavepattern is under your control—able to be shifted according to your wish and not just at the whim and mercy of any outside agent or any inside abnormality—this integrity of control is the sanity of existence.

Insanity seems to be a turning inwards—the formants in the physical and mental wavebands are barely related to happenings outside the human being, scarcely aware of the environment, because the feedback noise within the brain has taken control of these formants. When *outside* influences, such as drugs, hypnotism, psychedelic happenings, and overwhelming sensory perceptions, take control of the personal formants, we could, perhaps term the resulting condition *outsanity*.

When the personal formants in all three wavebands are under firm personal control we term it *sanity*; and when the person has gained such perfect control of all three wavebands that, whenever he wishes, he is able to remove the main energy in his personal wavepattern from the fundamental to any of the harmonics, and so view life from different aspects, then we would term this *supersanity*.

So far in this chapter we have been relating sanity and insanity to formant control . . . control over those reiterated signals which tend to increase in volume. What about those reiterated signals which have been gradually decreasing in volume? When making a good tape recording we not only have to pay attention to the notes of high volume, but also to those which are so low in volume that they are close to the noise level. Every amplifier produces a certain amount of noise which is extraneous to the signal; a tape recorder not only introduces noise from its amplifier (hum) but also background noise from the tape (hiss).

The tape recorder manufacturer issues a figure to show us how good each recorder is in this respect—the figure is called the signal to noise ratio. We can tell from this when our signal, which is getting softer every time it repeats, will be engulfed in the hiss and hum and no longer be discernible. If we do not want it to lose its identity altogether we must give the signal a boost before it gets too soft; and we must be careful not to boost too much hiss and hum at the same time, for if the signal has lost its validity we will just be amplifying *mush*.

Does the brain have to be careful to check that its precious memory signals do not get too soft and disappear into background mush? Is this what it does while we are asleep? Signals, from a great variety of memory feedback circuits, situated in all sorts of 'corners of the brain', will be getting down in volume dangerously near the noise threshold. While we are asleep does the brain rapidly sort these through? If we were awake the retrieval of these signals into consciousness would mean that they would be automatically amplified and put back into storage. We do not necessarily want that to happen. So perhaps while we are asleep, and consciousness is at its minimum, the brain sorts out which signals are to be boosted. As it will have to examine all the signals which have been reduced to pianissimo, in every area of the memory, it may well have to sort through a seemingly mad variety of signals—perhaps signals about syntax and strawberries and hydroplanes and birthdays, and concubines and ironmongery and Mexicans!

We were wondering, earlier on, whether the memory has a department for rationalising. We thought that maybe our memory circuits did not bother to store all the incidental facts about a matter, but just recorded the salient points; these salient points would then be retrieved when needed and the rationalising department would provide sensible, logical linking material. Now what will happen if, while we are asleep and the brain is hastily sorting through this mad variety of salient points, our consciousness is very slightly roused; does the poor rationalising department, which should be asleep, find itself pressed into service? . . . find itself faced with faint echos of syntax and strawberries and concubines and ironmongery and . . . and . . . and . . . ? Undeterred, it produces some sort of rational jigsaw picture, which it presents to the barely-conscious-consciousness in the form of a dream—or a nightmare! Some of this rationalising spree may be, indeed, so vivid that it gets printed through into the memory circuits . . . and, alas, the remembered dream can then be told, at great length, next morning, to all unwary listeners! It will contain faint echoes of the dreamer's past . . . for that is exactly what it is—a conglomeration of all those memory

echoes which were just about to be engulfed by the general background noise. What dull listening it makes, this inconsequential rigmarole of 'rationalised echoes'!

Dare I suggest that there may be a counterpart to this in modern music today? Performers, quite often now, find that the composer has provided for them no more than strange hieroglyphics—mere faint resemblances to musical notation—dots, dashes, blobs and circles, figures, numbers, catchwords. The performer is asked to bring to bear on these faint 'echoes' the full force of his rationalising department. It is up to him to try to make some sense out of these hieroglyphics. Maybe, when reading these faint echoes, the performer's rationalising department will find that they arouse, upon reflection, quite clear relationships of pitch, rhythm and structure, which are sufficiently strong to be valid in performance; but, alas, if the echoes have no validity, the result for the listener will be the same as we observed in tape recording—the result will be merely amplified *mush*!

You will find that there are concerts these days in which classical music is disintegrated into 'echoes', and then rationalised into 'nightmares' and 'inconsequential dreams'. Such concerts seem to me to be designed mainly for the releasing and exercising of the composer's and performers' brain mechanisms . . . for unclogging their feedback circuits and indulging their rationalising departments. It all smacks of the psychiatrist's consulting room rather than of the concert hall, and so perhaps some composers will soon feel that audiences are irrelevant and should not be encouraged. (Maybe the audiences will feel the same!)

Is this going to be one of the future roles of music—a method of releasing psychic tensions, of bringing into balance the control systems of the brain? 'Do-it-yourself-psychiatry'? To benefit from this, will we all need to be composers and performers? Will such music be performed in the concert hall, or in the home?

Just one small personal plea . . . may we also have some music, please, for those who consider that they are not in need of psychiatric treatment? . . . . . But perhaps such an elite are not going to be permitted to exist?

9

In the last two chapters we have been wondering whether certain trends, in modern music, reflect features which may occur in both tape recording and human memory. As we predicted in Chapter 1, we have been 'breaking open watertight compartments and glancing anew'. But we must be careful that, in so doing, we do not analyse to the point of annihilation. Alexander Pope put it rather well when he wrote—

> 'Like following life through creatures you dissect
> You lose it in the moment you detect'.[1]

From now on in this book we will do well to turn our minds towards **synthesis**, the very opposite of analysis. We shall be thinking of how we can construct rather than how we can dissect.

[1] Alexander Pope: *Moral Essays*, Ep. I. 29.

If we are to construct we must control forces . . . and this is our first problem. How much shall we control and how much shall we leave to chance?

> 'All nature is but art, unknown to thee;
> All chance, direction which thou canst not see;'[1]

So writes Alexander Pope on the subject of chance, and I have a feeling that he is right. We are usually too close in perspective to 'chance' to see that overall 'direction' (though the theory of probability shows us that if we can only step back, and take a view of that chance activity on a large scale, we can predict the behaviour of that activity with much more certainty . . . seen from a distance, from a comprehensive aspect, chance seems to become less chancy).

However, in this chapter, we shall be discussing chance as we meet it in everyday life; and so we can, I think, define it by the dictionary definition, as being undesigned, unforeseen and unforeseeable. It is in this sense that we can apply it to music.

The problem of how much to control, how much to leave to chance, and to whim . . . is not a problem we meet only in music! Obviously educationalists, town and country planners, market researchers, holiday travel agents, and many other people come across it often—how often do you consider it?

Do you like to feel that you control your life 95%? Or 75%? Or 55%? If you take your car out for a pleasant, sunny afternoon drive through the English countryside in May, how much do indeterminate factors affect your trip and how much do you like them to affect it? You decide on your route but how much, of what you actually see, is left to chance? The climate and soil will determine the sort of vegetation and the animal life you see. But within those limits you do not know what to expect round the next corner—you know what not to expect: a camel and a banana tree—but even so there is a very large range of things, which it would not surprise you to find round that next corner! Do you wish to predetermine all the 'happenings' before you set out from home, or is part of the excitement the fact that you only know, within large limits, what will be round the next corner?

As your road enters a glade of trees the colours all around you will be ever changing, according to the light and shade between tree and tree, and sky. The aspect will change according to how you

[1] Alexander Pope: *Essay on Man*, Ep. I. 289.

move your head to take in the view, and the mental image you receive will be coloured by your mental mood—by your calm serenity or your annoyance with the driver ahead. If you come along the same road an hour later your reactions and appreciation may be quite different, for the scene . . . and you . . . will be subtly different.

Having experienced a certain car trip with great pleasure, would you like to be able to repeat it exactly . . . exactly in every detail . . . to repeat it in order to extract more and more from it . . . to take in more each time? Or would you rather that, when repeating it, some aspects should show further variations, while other aspects remain seemingly static?

The vegetation along your car route will gradually change when you repeat the trip every week in May—the bluebells and prunus will die, while the lilac and laburnum come into flower. But last year the same thing happened—the overall scheme of events remains the same each year . . . the same for each yearly repetition . . . but within the scheme there is subtle, and seemingly infinite, variation. Are we pleased to think that the same pattern of spring will occur again next year or would we rather nature became a random process, so that we had no knowledge whatsoever of anything that might happen next year, or of anything that we might meet around the next corner? How aleatoric could your car trip become, and still remain pleasurable?

Look at a red rose . . . it differs from a red peony or a red begonia in its form, and yet no two red roses are identical, for indeterminacy has led to variations in colour-shading, shape and texture, to variations in blemishes and 'incorrectness', all of which give the rose individual life and 'personality'. But the rules of form which make it a rose and not another flower, are rigid enough for us never to be bewildered.

A red rose painted for a railway poster has the right form, in two dimensions, but is dull, having little change in colouring and probably no indeterminacy. The rose painted in a Jan van Huysum painting has the same two dimensional form, but a vast range of colour subtlety within that form, and this enlivens it. It is exquisite, but maybe our imaginations would be aroused more if the form could be kept, if the minute colour difference could be preserved, but, within these rules, there could be more indeterminacy, so that the viewer's eye and imagination has a greater part to play. Visual art, right from the days of impressionism, seems to have been coming to grips with this problem; whereas music seems to me to have entered,

by the 1950/60s, only the preliminary stages, and now in the seventies, to be still looking for a way to create valid forms, while allowing enough indeterminacy.

What do we mean by 'enough indeterminacy'? Is it an 'amount' which we can define? Or do we define it by establishing the borderlines of control and then allowing anything to happen within those borders? Have we any terms of reference for establishing those borderlines? Should we go about it empirically—using our intuition to guide us, or should we try to evolve rules to help us?

When going out for the afternoon's car drive, is it best to keep strictly to the planned route, or do we get more delight if, on sudden impulse, we turn off down an inviting leafy lane to explore the hinterland? (We must, even so, retain some discipline or else the energy—the petrol—will run out before the trip is completed.) Do we like the car drive to evolve so that chance happenings lead us on to more unexpected and adventurous events? We shall hardly like it if the local authorities, finding the roads too overcrowded, give us a form before our trip, dictating exactly the route we must take, its duration, the speed at every moment, the time of day, the car's position in the queue of vehicles . . . etc. We wouldn't even be able to put our foot hard down on the accelerator when we wished to feel the thrill of speed and the freedom of existence! Our car trip would still, despite the authorities, have many aleatoric factors—the vegetation and the sunlight would have their indeterminate factors; but the overall form would be too rigid to allow much pleasure to be gained from these.

So the boundaries of control must not be too cramping; yet complete lack of control would lead to chaos. 'Order is heaven's first law' says Alexander Pope. 'Genius is the talent which gives art its rules' says Kant.

Well, it does not take a genius to see that, in the musical world, there are some boundaries already provided for us. Some established by nature, some by usage. A study of the human ear and the psychology of music gives us some of the first clues, and twentieth century musical 'grammar' shows us that certain usage has outworn its welcome. To establish boundaries regardless of the limits of the ear's comprehension seems just as absurd as establishing boundaries which only allow the clichés of the past (or those of the present day!).

Are there any technical devices which would help us to explore the possibilities of defining boundaries, while leaving the events within these boundaries undefined? The **digital computer**, for instance?

Using a digital computer to control sound sources, we could 'give the computer its head' and tell it to determine the pitch, the volume, the duration, the order and position of every note according to a series of random numbers. If the first random number to occur was 1,056,984,723 what would the computer do? Would it give us a note of 1,056,984,723 Hz for 1,056,984,723 seconds duration? Well, we must first of all give it instructions such as: 'every whole number, in succession, in the random number table is to be used to control an oscillator, so that the equivalent number of Hertz are produced, for the equivalent number of seconds'. Of course, that instruction would have to be stated in unambiguous, precise wording and translated into the appropriate computer language.

Having given the digital computer the appropriate instructions to go ahead, do you realise what you are going to get from the oscillator? Even if you could hear the note of 1,056,984,723 Hz you would hardly wish it to go on sounding for 1747 weeks! Anyhow it is far too high to hear, so neither its pitch nor its duration has any relevance for our ears. Obviously we have to program the computer so that we set up relevant 'boundaries'.

How high, how long, how loud . . . ? What boundaries are we going to impose? What rules and regulations are applicable? Should we say: 'no frequencies above 15,000 Hz or below 30 Hz, no note longer than 8 seconds, or shorter than $\frac{1}{15}$ second'. . . . Those are the sort of decisions we shall need to consider. Having decided on appropriate boundaries, we can re-write our instructions to regulate the output, and then just let the computer 'churn out' results, 'aleatorically', for as long as we like. Gradually we can impose more and more stringent regulations. If we impose a great number of regulations, the aleatoric aspect, the indeterminate factor, will be reduced further and further. Our instructions could, for instance, include rules such as: 'no interval leaps of an octave or a fifth are allowed' . . . the computer would then disregard any number, from the random number series, which, if used to operate the oscillator pitch control, would contravene this rule.

We could give our computer the rules of strict counterpoint, or work out a program for it which would produce a sort of pseudo-18th Century music. The sounds produced by the oscillators, which

it was controlling, could be fed straight to multitrack tape recorders so that complex music 'by the yard' would be produced. Hours and hours of music, days and days of it . . . there is no reason why it should ever stop! It will be as defined or as aleatoric as your program has decreed. Unlike the human performer, the computer has no natural rationalising department. It will not try to 'make sense' of the sounds it is producing, nor will it ever intuitively know when the poor listeners have had enough!

You will have to put into your computer program all the instructions which you think are needed to make the music viable. You are always up against this same problem—how much do you wish to control and how much do you wish to leave to chance?

In using the digital computer with its random store to provide control of the sound sources, we started with broadly indeterminate control and have gradually reduced the indeterminacy: we have gradually given the music individuality.

This process of 'indeterminacy-regulated-towards-individuality' has been used in much of the digital computer music which we hear today. Perhaps we might describe it (with, at the same time, one eye on our present society), as complete permissiveness regulated by minimum rules.

The term 'regulated by minimum rules' is rather a woolly phrase. Surely each of us will have our own opinions as to what are 'minimum rules'. When you listen to digital computer music, you may find yourself disagreeing with the minimum rules, which the composer has imposed, just as much as you may disagree with the minimum rules which, these days, law and society impose. You may wish for much more law and order, or you may find everything much too rigid and restricted. With computer music there is no need to judge the rules themselves, you can judge by the results . . . by the music that is produced.

One of the points to notice in digital computer music is the quality of each note . . . its timbre, its subtlety, its individual shape and phrasing. When you come to program your digital computer will you, mostly, be concerned with the regulation of pitch and rhythm and interval relationship? Will you be able to give time, also, to considering the beauty of each individual note . . . the subtle individuality of each note . . . as well as its place in the main scheme? Will each note, each phrase or melisma, be able to affirm the richness and the character of its own individuality, while it is taking its balanced position in the overall structure?

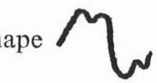
Let us have a look at some of the techniques of digital computer music and see what technical difficulties there are for the composer.

We must get it clear in our minds that there are two types of digital computer music. Firstly, we can use the computer as a controlling mechanism, making it control sound sources which exist in their own right. These sound sources are not part of the computer itself. The output from the computer may be in the form of instructions which can be translated into music notation and then be performed by singers and instrumentalists; or the computer output may be directly linked to a sound source. (For instance, a computer could be linked to a pianola to produce piano music.) In these cases the computer is not producing the sound, it is just giving instructions to the sound source.

In the same way a computer might be linked to your lawnmower and programmed to give all necessary guidance to that lawnmower so that it neatly cuts every blade of grass of your lawns and pathways. The computer is not actually doing the cutting, it is only guiding, and controlling, the lawnmower. Of course the lawnmower would have to be specially adapted, so that it could be controlled by varying voltages. Send it an increasing positive voltage and it would gradually turn, say, to the right; send it an increasing negative voltage and it would turn to the left. All its actions would be related to the varying voltages it received from the computer.

Now let us substitute a sine wave oscillator for our lawnmower. If the computer sends this oscillator an increasing voltage, the frequency of the oscillation could be made to rise equivalently; or the volume (amplitude) of the oscillation could be made to rise proportionally. Pitch and volume are just two of the many parameters which can be controlled by incoming voltages; the computer can be linked to rows of oscillators, and white noise generators, filters and reverberators, ring modulators, and all the other electronic devices we have been mentioning, and every one of these can be controlled by the voltages generated within the computer. But the computer itself is not originating a signal which can, straightaway, be transduced into sound via an amplifier and loudspeaker; in the case we are describing, the computer is merely controlling the devices. The music produced in this way would best be described as computerised-studio music, rather than computer music.

However, the digital computer can actually be used to create—to generate—the sound. This is the second type of computer music, and this music is more truly qualified to be called Digital Computer

Music. How do we 'digitalise' a sound? If we wish to make a wave-pattern of this shape  we could draw it like this  and then measure the height of each dot from the base line. This would give us numerous amplitude readings for one wavepattern. The amplitude readings would consist of a string of numbers (digits) and would be an approximate description of the wavepattern. How many amplitude readings would we need to take in one second, if we want an adequate digital description of the wave? For we want a digital description which we can later turn into an acoustic wave and present to the ear. Will the ear be satisfied with a broad approximation?

The ear is a most remarkable and wonderful instrument. Its sensitivity is incredible. We shall need to use as many as 20,000 digital readings every second if we are going to reproduce fairly high quality sound.

No wonder composers of digital computer music have had some qualms when faced with the problem of controlling the quality of the sound. 20,000 numbers to specify every second! How does the poor composer know which are the right numbers for a particular sound? Well, he is gradually discovering methods of defining the necessary digits . . . but he now runs up against another problem. Generating music from a computer takes time, and time is money. He may easily take 20 computer hours to produce one minute of sound. As the average cost of computer time for this work is approximately £100 per hour, the composer needs to be a rich man, or to be financed by a rich institution!

Building fascinating timbres and intricately moulding individual notes, with a digital computer, needs so much time and money that few can attempt it. The composer usually finds that it is more realistic to devise computer programs which concentrate on the control of pitch, volume and duration, and just make use of the ordinary electronic timbres (such as sine wave, square wave, white noise) which the studio oscillators and generators provide.

So single notes, and groups of notes, are often given little individual colour, shape, or phrasing, for the composer has had to give most of his attention to overall controls—he has created boundaries within which individuality barely counts, for he has neither time nor money to spend on evolving intricate individual aspects. Simple notes, all fashioned in much the same way, will occupy, probably indeterminately, the areas between the boundaries. He can 'process' them according to the way he manipulates those boundaries, but he will have little or no time to consider how an individual note is behaving nor how it could achieve significance. He will have decreed the processing *in absentia* and, once started, the process will run its course whatever the outcome. For, at £100 an hour, he will have little chance of empirical experience, second thoughts will be too costly, last minute inspirations will be inadmissible.

Do we sense an analogy of this situation in the political, sociological and economic lives of the 'advanced' nations? Is the individual human being, almost unknowingly, beginning to play the role of a 'computer's musical note'? With expanding populations and expensive technology, will governments and other establishments have the time, or the money (or the inclination), to do more than 'process' our lives? Can we really retain our individualities? Will we, increasingly, be controlled 'as a herd' . . . 'processed like peas' . . . as well as 'packed like sardines'?

10

We have been examining today's digital computer music and finding that most of it is made by imposing processes (concerned broadly with pitch, volume and duration) on either 'raw' sound (the basic electronic oscillations), or else on digitally defined wavepatterns, which, for reason of time and money, can have little finesse. We noticed that the process often used, takes random conditions and defines the boundaries of randomness.

The programming of a digital computer is a new type of transducing channel for the composer. He has not, until recently, had direct control of the sounds of his music (unless he has himself performed the music); normally he has had to seek the help of an intermediary language and interpreter. This language—the notation on the musical staves of the manuscript paper—has given the interpreter (the conductor, the singer or instrumentalist), great scope for varied interpretations. Through the wisdom of many fine interpreters the greatest music has unfolded itself over the years, and has grown in stature. It has been enriched by human 'transcription'.

Perhaps there is an analogy here. If we substitute for the composer the parliament of a country some 250 years ago do we have a similar situation? Parliament passed the laws and decrees and then handed them over to the local magistrates, judges and administrators who were allowed a certain leeway of interpretation to deal with local conditions (for instance the laws of the Isle of Man, of the Channel Islands, the governing of the Colonies, seem to show something of the wider interpretive powers which, I imagine, prevailed in those days). But in the last hundred years technology has given us astounding communication networks—roads, railways, planes, TV, telephone etc. The government and administrators can be centralised and yet control more firmly than ever. They can check their interpreters at every turn. These interpreters need not necessarily be people of great character and understanding, for now less personal responsibility is involved, less personal interpretation is needed—what is said at the centre tends to go through willy nilly. (Yet, on the other hand, this can have the advantage of curbing any local administrator who might, otherwise, have become a despot.)

Will technology now step in and take over the role of interpreter? Will we have computers in our courts instead of judges and magistrates? Will our TV screens display what we can and cannot do . . . one set of rules and regulations for everyone and everything, everywhere in the country (or indeed everywhere in the continent)? Will there be no chance of individual interpretation? Do you think it will be a free and fair world if we are ruled and judged, directed and organised by machines, programmed by the central government, without human interpretation or intervention?

We have had these '1984' ideas fed to us for many years now, and some of us probably feel that such conditions, as they describe, are not unlikely to occur—in fact they may inevitably occur . . . but I think not.

If we consider that these conditions are really a threat to us, could we not overcome them by changing the methods of technology? If the machines, which replace the human interpreters, are incapable of conveying those aspects of life which we consider the most human, then, however much we may insist that our governments retain a feeling of humanity, the machines will thwart the communication of this humanity. But need machines be so inhuman? Could we so devise a machine that, in the programming of it, all those factors which are deemed to be the most 'human', could be clearly represented?

I think that we can build up an analogy to help us to visualise some of the problems we shall have to solve in designing such a machine; the worlds of music, painting and photography will help to provide this analogy.

We wish to depict a situation where the intermediary human interpreter is removed, and the governing hand is linked directly by machine to that which is to be governed. In musical terms this means that the composer is linked directly by the machine to the sound.

Now our task is to devise that machine so that the composer can control the sound to give the most 'human' result. By 'human' in this context I do not mean that the sound must ape a human voice, or ape an instrument played by a human being. I mean that there are certain human qualities which are difficult to convey by electronic machines. Machines, at their present stage of evolution, do not appear to be designed for conveying this humanising element. It is this humanising element which, to my mind, enables individuality to become apparent and express itself: therefore, in devising this special machine we need to define this humanising element.

For guidance let us look at another branch of the arts—painting and photography. The painter does not have to use an interpreter when transducing his thoughts; so his methods may give us useful clues now that we have removed the musical interpreter. Photography seems to be a less 'humanised', a less individualised, form of art than painting. Perhaps it will help us if we sort out some of the differences between painting and photography. It seems that there are two differences which are more important than any others.

The first difference is that the painter composes and develops his painting by *freehand* methods: he can build up the juxtaposition of forms and colours as his imagination guides him; whereas the photographer may have to make the best of forms and colours which have been already determined. It seems that the painter, because he starts with a blank canvas and employs freehand methods, has more scope for individuality than the photographer.

The second difference is that the painter sees the effect he is portraying on his canvas at the very moment he is painting it, and so the picture *feeds back* information to him which he can take into account as he is developing the picture's detailed structure and overall form. He can, as it were, walk inside his painting and fashion its growth as it is growing. He can watch the individuality of each facet of the painting, allowing its potentiality to unfold; at the same time he can develop each facet as an important integral part of the whole. In painting he has direct control—the paint brush in the hand is an excellent 'interface',[1] between brain and canvas; he is using a technique of normal muscle control developed since childhood. The channel for transducing thought into material substance is clear and uninhibited, and the feedback link, through the eyes, gives an exact visual replica of what has been achieved.

The photographer has an idea, through his viewfinder and by his artistic experience, of what result he will get, but he has no immediate feedback system by which he can confirm the exact outcome; while he is exposing his film he cannot be making adjustments which are dependent on the results actually being registered on his film, for he is not able to examine his film at that moment, so he is unable to build up his picture empirically in the same manner as the artist.

One of the vital factors about a human being is his ability to control his actions according to 'feedback'. For instance, he moves a limb and, by feedback information reaching the brain, he knows when to counteract this muscle movement. (It is a beautiful and intricate system of balance which never fails to fascinate me whenever I think of it.) Mentally, too, he uses feedback, for he adjusts his method of communication according to the messages from his physical-to-mental sensing equipment which tell him whether his communication is conveying what he really means, and whether it is being received and comprehended.

Human beings really do depend on this monitoring feedback enormously. Imagine, for instance, that you have been stone deaf since you were seven years old. How difficult it will be for you now to sing a song. You will have some muscular memory which will guide you in controlling the lungs, vocal chords and mouth; but, without feedback through the ears, you will not know exactly what results you are producing, and I very much doubt whether your vocal effort will be highly appreciated by listeners . . . in fact they will probably find it difficult to endure the performance!

Now imagine your hearing restored, and consider the question of feedback. What aspects of your own voice will you be monitoring—and then adjusting according to the results that you hear? You will

[1] Interface: technical jargon for 'connecting link'.

be checking, I am sure, that the volume of each note is right compared to the note which preceded it and the notes which are to follow. You will check the pitch of the notes, relating each one to what has come before it and also to the 'pitch standard' which you retain in your memory. You will monitor the timbre of the sounds you are producing, so that they have exactly the quality you intend. You will check the length of each note to see that it is rhythmically right (and perhaps you will shorten the note lengths if you find that the acoustic is very reverberant).

Your first rendering of the tune will probably not satisfy you at all. You will try it a number of times before you decide that it is sounding just as you want it. Each time you try it you will be perfecting one aspect, and retaining in your memory the instructions for controlling that aspect. Gradually all the aspects—all the parameters—such as volume, pitch, duration, timbre will have their revised and corrected instructions stored in the memory and you will then be able to give your performance. In this performance you will be 'reading' all the lines of instructions in your memory at the same time, and making each line of instructions control the appropriate parts of the 'mechanisms': the lungs, the vocal chords, the jaw, the lips and the tongue.

Your brain will be interested in seeing that the sense and sensitivity of the song is conveyed by the voice. By subtle interplay of the parameters your brain will find ways of conveying many shades of 'meaning'. Once you have the basic instructions for each parameter firmly established in your memory, you can afford to experiment with small variants in the instructions to see what effect they have—to see whether they assist in conveying more 'meaning'. You will always be able to restore the instructions to their original form if the variant proves to be uninteresting. In this way you will be able to create an individual interpretation of the song, without destroying its value—indeed, you may well be enhancing it through your own perceptive imagination. But, always, you will be relying on your ears to give you feedback information so that you can assess in order to enhance.

Are we now finding that we have one or two clues for this machine we wish to build? We considered the painter and the photographer and decided that the painter has added scope for individuality. He has freehand control and he also has the benefit of immediate feedback. We then considered the singer and his use of feedback when performing a song. It seems that each parameter of the sound is checked and that, maybe, each parameter instruction is stored separately, so that individual interpretation can evolve—evolve by the subtle changing of interplay between the parameters.

So now we could make out a specification for our music machine. We will certainly require these facilities:

1. Freehand drawing of all instructions.
2. Facilities for drawing, separately, the instructions for each parameter.
3. A monitoring system to allow immediate, or almost immediate, 'feedback' of the result.
4. Easy access to the separate parameter instructions so that, after monitoring, alterations can be made and the results re-monitored.

In the next chapter we will visualise the sort of instructions we wish to give our machine—in other words we will work out a new musical notation system.

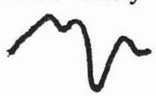
11

We wish to design this machine-with-humanising-factors so that the composer can instruct it by means of a direct and simple language. He will want to transduce his thoughts as quickly as possible, via a channel which is logical.

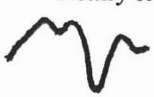
So let us take each parameter in turn and decide what notation will be suitable. The parameters we will consider are volume, duration, timbre, pitch, vibrato and reverberation. If we think of the **volume** (amplitude) of a musical note we might consider that the terms loud or soft would be sufficient to define it. But when we display musical notes on the oscilloscope screen we see that the amplitude graphs of a 'loud' note, played successively on two different instruments, can be strikingly different. One might be this shape  the other this shape 

These we term **envelope** shapes.

The most straightforward way of notating these two different shapes would surely be to draw them just as I have done—to draw a thick black line from left to right to show the change in volume, using the base line as 'silence' and the highest possible point as 'very loud'. So bottom to top (the Y axis) is *pp* to *ff*, and the distance from left to right (X axis) is the **duration** of the sound—we could decide on a convenient time scale of 'so many centimetres to the second'. We have thus written an *analogue* of the sound (we have drawn an 'analogy'). Now we require our machine to read this black line and control the volume accordingly.

Control the volume of what? We shall have to consider how we are going to make a sound . . . a sound of exactly the **timbre** we want. We are not going to be satisfied with just those coldly clinical sounds—the electronic sine and square waves, nor even with waves of this  shape, or of this  shape. We are much more likely to want a splendidly curvaceous wave like this  ; using that for the first three notes, then gradually blending it into this wavepattern  during the next 20 notes.

We could do masses of mathematics and work out, by Fourier analysis, how many sine waves we would need to mix together, and at what relative amplitudes they would have to be, to give us those wavepatterns. Then we would have to operate lots and lots of oscillators, turning all the right knobs precisely the correct amount . . . a laborious, tedious job. Or we could take a complex wave-pattern from an electronic generator and filter away all the components that we do not want, in order to retain those that we do require—this is how those clever 'mighty wurlitzers', the Electronic Synthesisers, make their sounds—but, alas, lots more knobs and dials . . . and will we ever get that blend right?

Really it will be much easier if we can take a pen and just draw  and , and get the machine to scan

these wavepatterns and give us the equivalent sounds. Just a few notes from each pattern will allow us to check, by ear, that these are really the timbres we want. If, however, we find that we do not like the sounds that these patterns produce, then we only have to draw other patterns and so empirically explore, by visual-to-aural means, the countless possibilities of the many waveshapes that we can imagine and draw. It will all be so much easier, so much more humanised, than turning lots of knobs!

The machine will read the patterns just as soon as we present them to it, so we shall hear the results from the loudspeaker straight away. This is fine, for our 'inner ear' is telling us what we want, and we wish to find the sounds before the inner ear's memory fades, so this speed of operation is a great asset. It is most important to hear, immediately, the aural effect that the volume envelope tracks are having on the timbre shapes, and also to be able to blend and alter the timbre within the duration of a single note.

So far we have given our machine instructions about timbre and volume; now we must tell it the **pitch** of every note. Until now we have given it analogue information to read. If we show the pitch of a phrase of music in a similar way, specifying, say, nine notes by this undulating line , we might have difficulty in accurately defining the exact pitch of each note; for we may want notes ranging over the span of seven octaves or more. We shall need some system that is more indicative than an undulating line.

For centuries, in the musical world, we have been defining pitch by putting marks on and around five stave lines. Can we continue to do that for this machine? If we do decide to give our machine ordinary musical notation to read, we shall have to devise a rather clever machine. It will have to recognise the treble and bass clefs, and recognise sharps and flats and leger lines, as well as the ordinary lines and spaces of the stave. Even when we have devised such a machine we may not find this notation adequate, for we may want to write notes and 'swoops' and trills, using pitches which cannot be shown accurately on the treble and bass staves.

So we will invent another notation system (and make it as flexible as possible). We will have a number of lines on which we put marks. These marks will be black dots, which we will call **neumes.** Before we start writing each composition, we will tune the machine so that each of these lines means a certain pitch. We could think of the lines as being the open strings of an instrument. These lines can be easily tuned in any way we like. We could tune them in 3rds, or 4ths, or 5ths, or in strange interval relationships like $\frac{27}{19}$ or $\frac{173}{90}$, (outside our normal chromatic scale). Now, if we put one black dot on a line, we will get from the machine the pitch we have specified for that particular 'open string'.

To get pitches between these 'open strings', we will have some more lines, which will be somewhat like the fingerboard of a stringed instrument. Dots on these lines will raise the pitch of the chosen 'open string'. Each of the 'fingerboard' lines will raise the pitch by a pre-set amount: for instance, a semitone, $\frac{1}{4}$ tone, $\frac{1}{8}$ tone, minor 3rd, or any other interval.

We may not want to think in terms of the normal chromatic pitch. We may prefer to set up our 'open strings' to certain frequencies such as 100 Hz, 249 Hz, 370 Hz and 705 Hz, etc., and set our 'fingerboard' to raise the pitch by any ratios we wish.

By writing our black dots . . . neumes . . . on these 'open string' lines and 'fingerboard' lines, we are now giving our machine simple digital instructions regarding pitch. We are giving it instructions to maintain one pitch (frequency) for the duration of one note. But are we right in doing this? We must remember that we are wishing to 'humanise' this machine. Is it 'human' to maintain anything in a steady state for long? Your limbs, your eyes, your voice, your brain . . . do you hold these in an absolutely steady state for a long period? You get fatigued rather quickly if you try to maintain them so. Musical notes are the same: if we maintain them in a steady state for more than a second or so, they begin to produce fatigue. They are much more interesting, and less fatiguing, if their various parameters (especially their pitch) vary subtly throughout their duration.

With our black dots, our neumes, we have defined the basic pitch of the note: we have defined it digitally. Now we want to modify that pitch slightly, giving it a 'waver', or **vibrato**. We do not want a steady waver, a rhythmic vibrato, for this would be unnatural and far too 'electronic' in its nature. We could, very simply, define

what we want by drawing an undulating line, something like this

. Now our machine will read this undulating line as analogue instructions, and will modify the pitch accordingly.

The music we are instructing this machine to 'play' now has timbre, volume, pitch and vibrato. By drawing more than one timbre wave pattern, and separately controlling the volume from each, we can blend timbres together. So the tone colour can subtly change even within a single note.

What about **rhythm**? Well the volume tracks are giving the duration of each note . . . and of each silence . . . so they are already specifying the rhythm and the accents of the music. If we have a device for introducing **reverberation** (such as an echo room or reverberation plate), we can enhance the sound by using another analogue track to control the amount of reverberation at each moment.

All these analogue tracks are drawn freehand and so are the timbre wavepatterns. In drawing freehand we shall not make our lines absolutely 'accurate'—slight indeterminate factors will creep in, for 'straight lines' will not be quite straight, undulations will have a 'freedom' within the overall form and there will be imperfections. Our own individuality will determine how 'accurate' we wish any parameter to be; some instructions we will draw in with a fast sweep of the hand, with others we may be quite fastidious. So indeterminacy has its place in our machine—it occurs within the overall musical form, which is determined. It adds richness, it confirms individuality.

If we require control by random number series and, furthermore, if we need memory facilities (other than those given by the musical 'score'), we shall have to connect our machine to a small digital computer via an interface and terminal.

Reading all this description of our new musical notation, perhaps makes it sound rather bewildering and complex. I have tried to describe the system in terms which can be easily understood, without worrying that they may not be strictly correct in terminology . . . in fact, throughout this book, I have remembered a saying of Seneca, to the effect that if one tries to be completely accurate one only becomes perplexing.

Although this notation system may not sound simple, in practice it is very straightforward. The graphs are simple to draw and can be amended or erased; the dots (the digits) for pitch control—the neumes—can be quickly written in. What is more, the overall musical 'score' gives an easily comprehended, permanent, visual account of the music, as well as being the instructions for the machine itself.

At the end of the last chapter we gave ourselves some specifications for our machine. The first facility we required was freehand drawing of all instructions; the second facility—each parameter instructions to be drawn separately. Well, we have coped with those—every parameter is now covered by graphical notation (analogue or digital) and there are separate lines of notation for each parameter.

Number three facility is a monitoring system to allow immediate, or almost immediate, 'feedback' of the result. We have an immediate *visual* feedback of what we are writing in our graphic notation, and as we gradually come to know the 'language', our 'inner ears' will let us 'hear' what we are doing; but we need a real *aural* feedback, too. After writing a few notes we shall want to be able to press a button and make the machine play back to us, through the loud-speakers, just what we have written. We shall want it to read all the parameters at once and give us the result—compute the result. (Or we may require it to keep some of the parameters in a steady state, while we hear what effect the other parameters are giving our sound. We must make the machine as sensitive and flexible as possible.)

When we have heard these few notes we have written, we shall want to be able to re-write our notation . . . one note may need to be a little louder, another note shorter, the blend between two timbres may not satisfy us. We must be able to find the exact point in our notation which needs to be changed. It will be best if we can turn back the music, by hand, until we find the point we are looking for; and then be able to erase it and re-write just that particular parameter only—we do not want to alter the other parameters at that point, for they are working well, and it will be a nuisance if we have to re-write those too. When we have made our slight alteration we shall want to be able to hear it straightaway, and go on adjusting and monitoring, and on and on adjusting and monitoring, until finally

the results satisfy that 'inner ear' of ours, which originally conceived the sound.

With those facilities we have completed our original specification. It was a very basic specification and I am sure you can think of many more facilities which would be desirable—it really is rather an interesting line of thought to pursue . . . what are the factors which make us 'human' and how can we 'humanise' the machines around us, so that we can convey more of our individuality through them?

You may be interested in the photographs (pp. 104–7) and diagram (appendix) because they show the machine I have been describing. I spent many years thinking about it and designing it, and then, through a generous grant from the Gulbenkian Foundation, I was able to buy the components and set to work to build it.[1] I have been building it in rather the fashion I compose music—I have 'led it through' and allowed it to evolve. Indeed, it is still evolving all the time, for one lifetime is certainly not long enough to build it and explore all its potential.[2]

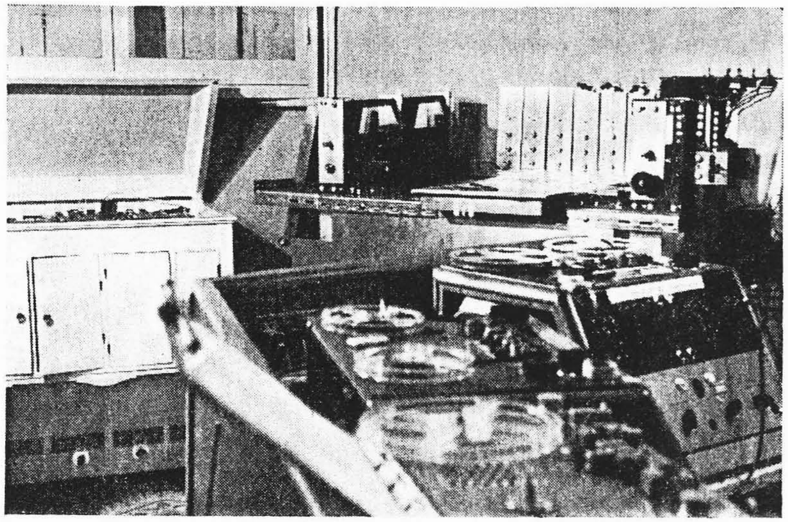
The system (which is nowhere near as costly as the computers we talked about in Chapter 9) is based mainly on controlled feedback and the computing of resultants. It seems to give hints of how some aspects of the human being 'work'—perhaps even hints of how parts of the brain function. It leads me to much musing, and, being no expert, I enjoy a freedom for experiment and thought which an academic approach might well inhibit. Sniffing the air to catch new scents is to me one of the happiest ways to spend one's life, and, if the scents lead me sometimes 'up the garden path', I still enormously enjoy catching them.

(Remembering the Italian word *MUSARE*, do you think I should call myself a *MUSARIAN*?)

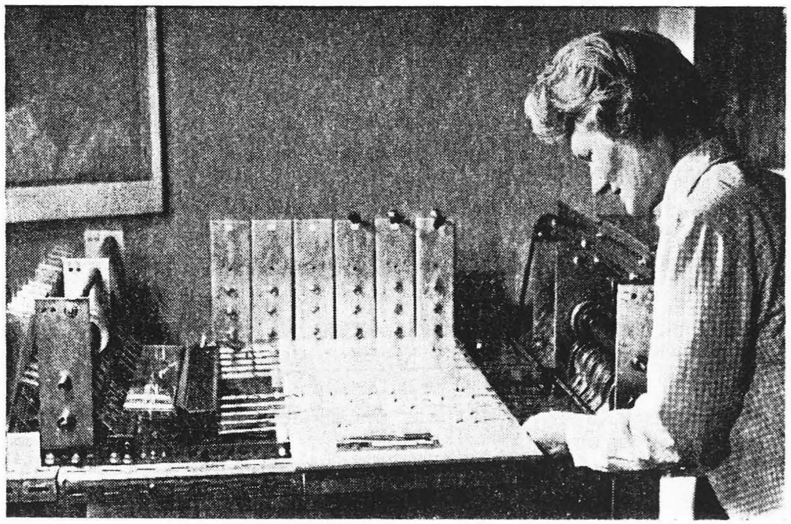
My machine does not really fit into any category, nor does the notation system which goes with it, nor does the music which comes from it. It is a control system which could be applied to many fields, as well as music. I have therefore coined the word O R A M I C S for it . . . and for its philosophy.

1 Now patented.

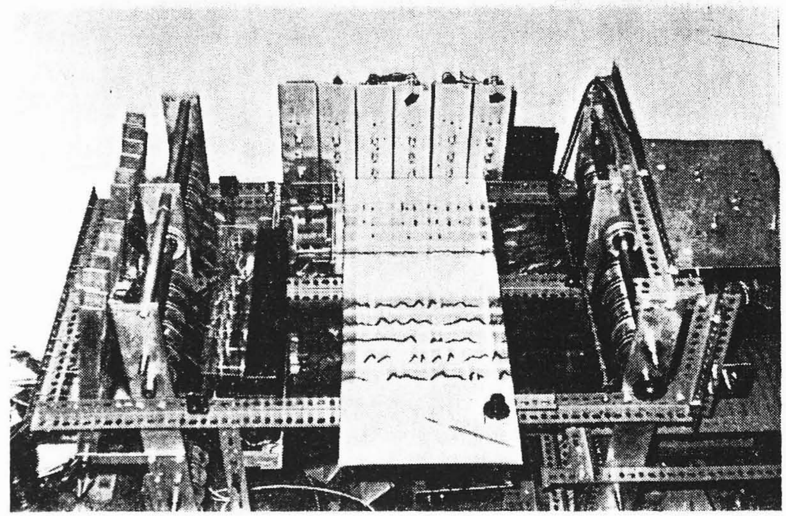
2 *See* Appendix for lists of tapes.



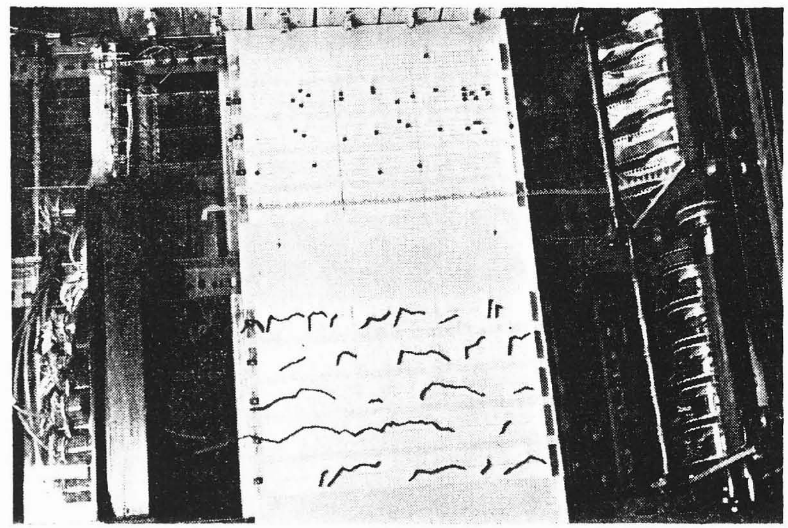
1. Looking across Daphne Oram's studio—Oramics equipment in the background, in the foreground Nagra and Brenell tape recorders.



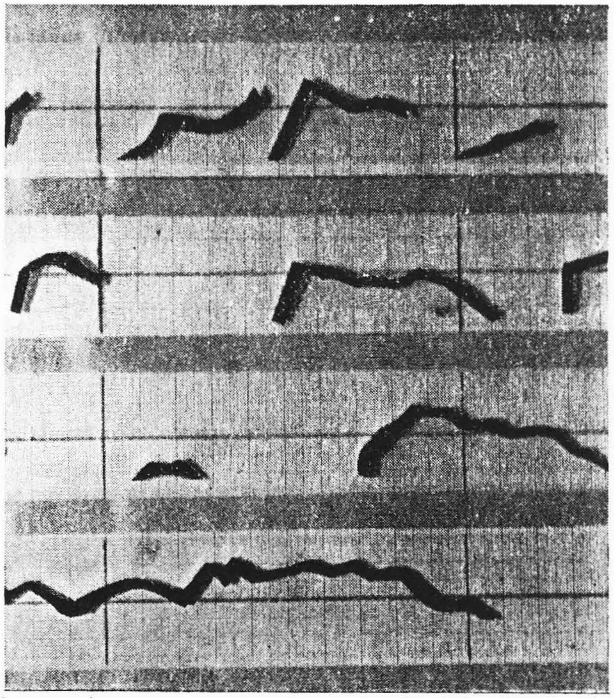
2. Daphne Oram with her Oramics equipment.



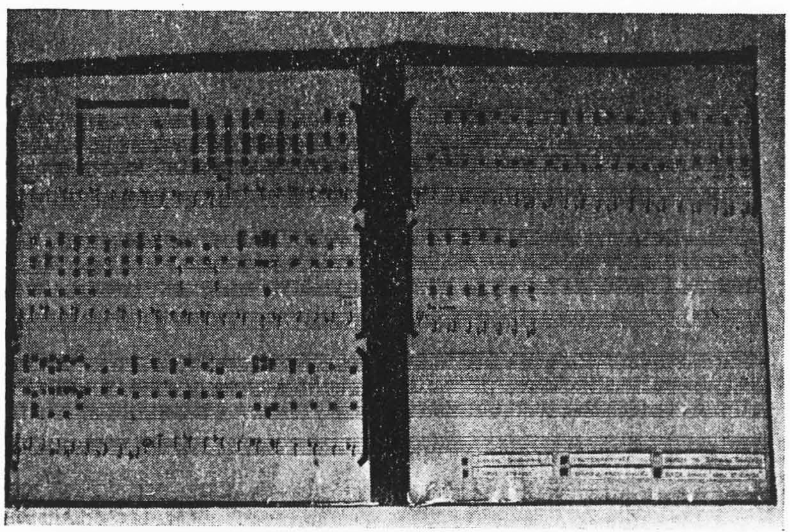
3. Programming equipment.



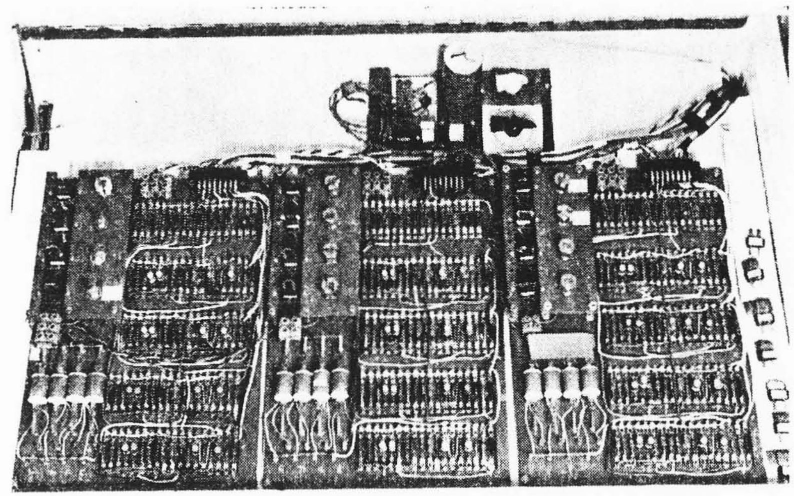
4. Oramics programming equipment—analogue and digital tracks.



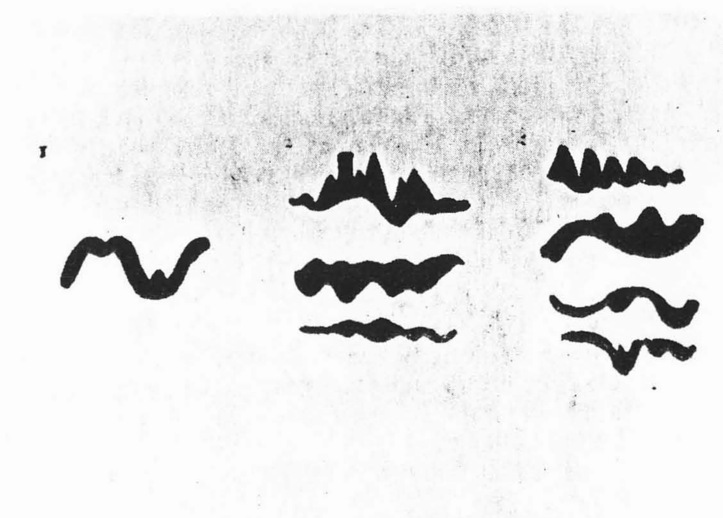
5. Analogue volume tracks—giving envelope shape, duration (rhythm) and volume variations.



6. Notation of pitch for Oramics—a reference book of Neumes.



7. Pitch control circuits.



8. Timbre waveshapes—drawn on transparent slides

12

Since the 1939–45 war many studios have been set up to explore the possibilities of composing electronically synthesized sound. In Hugh Davies' excellent *International Music Catalogue* 1968,[1] he gives the addresses of 148 studios in 39 countries and he lists nearly 5000 compositions. Since 1968 many more studios have been built, and I suspect the number of compositions will have at least doubled. (Besides these compositions committed to tape, there have been many performances using 'live' electronics—the musical material in these performances being evolved by interpretation and improvisation employing electronic equipment actually present in the concert hall.)

The 'classical' electronic music studios such as those of Cologne, Brussels and Milan in the 1950s, consisted of a number of generators, tape recorders, filters, amplifiers and loudspeakers. (Sometimes electronic instruments—like the Melochord and the Trautonium—were also employed.) Much tedious tape splicing was necessary, but,

[1] Hugh Davies: *International Music Catalogue*, 1968. MIT Press, Massachusetts and London.

despite the technical difficulties, some very interesting compositions were created, by such composers as Eimert, Stockhausen, Krenek, Pousseur, Berio, Maderna and Nono (and, in New York, by Luening and Ussachevsky).

Soon studios began to evolve techniques to eliminate these hours of tape splicing. Dr Olson of the R.C.A. Laboratories, New Jersey, developed in 1954 a system of controlling generators by punched paper tape. (Milton Babbitt has composed music of intricate structural precision using this system of synthesis.) Other systems soon appeared, including the Canadian Composertron, and the Russian optical coding system ANS. Then computers were introduced into electronic studios, especially into those attached to universities (Lejaren Hiller at Illinois University, and Max Matthews at Bell Telephone Laboratories were among the pioneers in evolving computer music programmes).

The Mixtur-Trautonium, Melochord and Ondes Martenot, which had been used in the early studios, now gave way to many new types of synthesizers (the later ones being based on the technique of voltage control of modular units)—the Buchla, the Siemens, the Moog, and the British VCS 3, Synthi 100, and Synthi A are some of the most successful.

As well as these extensive developments in sound sources and control techniques, much thought has been given to the layout of suitable concert halls and to the use of multi-loudspeaker systems.

To give further details of the technical developments which have taken place in electronic studios since 1953 is beyond the scope of this book. I suggest that, for more extensive reading, you should refer to books which are, at this moment, being written by Tristram Cary[1] and by Alan Douglas.[2] The excellent Danish book *The New Music Theory* by Bent Lorentzen, which also deals with acoustics, electronics and the psychology of music, will soon appear in English.[3]

To trace the development of compositional techniques, as distinct from purely electronic techniques, you might find it interesting to start with the DGG record of Stockhausen's *Study II* (and

[1] To be published by Faber & Faber Ltd.

[2] *Electronic Music Production*, to be published by Sir Isaac Pitman & Sons Ltd.

[3] Edition Wilhelm Hansen, to be published by J. & W. Chester Ltd.

listen to it while following the score, which was published by Universal Edition: unfortunately the score is now out of print, but it is worth hunting for a copy). This could lead you on to his *Gesang der Jünglinge*, to Pousseur's *Scambi*, Berio's *Omaggio a Joyce*, Milton Babbitt's *Vision and Prayer* . . . and so take you gradually towards works of the present day. You will find it much more interesting if you don't restrict such listening to electronic works only, but notice the position of these works within the overall range of contemporary music. Perhaps the works that I have listed in the Appendix may help you to embark on an individual exploration. I do not wish to impose upon you any preconceived ideas of what you must hear or how you should listen, so I prefer to leave the exploration to your personal whim . . . merely use my suggestions if you feel you must have some guidance.

I have been writing this present chapter with some reluctance, for I feel that many more years should elapse before attempts are made to describe and assess, in textbook fashion, the musical and technical developments which have occurred since 1946. In the previous chapters I have tried to avoid writing a textbook; I have been tackling each subject from an individual angle—making each chapter 'an individual note'—so that my arguments have, I hope, sometimes encouraged you to argue against me, to criticise my point of view, and expound your own thoughts.

When it comes to describing in words music which has a vital essence—music which transduces the celetal—then all attempts to find apposite words seem to me to be illogical and futile, for such essence would not be within the music if it were capable of being transcribed into words. I, therefore, do not wish to attempt to describe such music, nor to analyse the intentions of the composers —you will have your own way of gaining insight into such music, and if, perhaps, in certain works you find no essence at all you will doubtless, like me, give vent to your personal criticism.

But while we are making these criticisms, showing our individual opinions and fancies, and acknowledging what is relevant for us today, do not let us get carried away into thinking that this same music will necessarily be relevant for the world in fifty years' time.

In much the same way, it is very difficult to assess which of the technical developments will be relevant in the future, for we usually have only a vague idea of the possibilities. Inventions can provoke many false and stupid prophesies.

Think for a moment of the way the phonograph and other recording methods have evolved. Sound recording has had a tremendous impact on musical life and standards; it has created great commercial empires, and has now led us into new techniques of composition (and may lead us much further yet). Now read this comment on Edison's phonograph:

> 'It is suggested by the inventors that the phonograph can be used as a means of correspondence, the wax cylinder being transmitted through the post; but it seems much more probable that it will continue to be interesting only as a scientific toy.'

That was written in an encyclopedia some 25 years after Edison had taken out his first patent. It seems incredible that, even 25 years after Edison's ideas were made known, the possibilities were still so unrealised.

It is not much more than 25 years since electronic music (musique concrète) began, so let us refrain from general comments about its future; but don't let us refrain from using our critical faculties to find out what is relevant in it for us today. Let each of us reach our own individual and quite independent opinions about it.

I have just said that it is not much more than 25 years since electronic music began. But I must hasten to qualify that statement, for surely we can trace its history back far earlier than the last war. Do not let us fall into the trap of trying to name one man as the 'inventor' of electronic music. As with most inventions, we shall find that as certain changes in circumstances occurred—as certain new facilities became available—many minds were, almost simultaneously, excited into visualising far-reaching possibilities. New developments are rarely, if ever, the complete and singular achievement of one mind. Yet, when we speak of an invention, we seem to delight in persistently naming one man as the originator . . . I wonder why we want so much to see one man as the hero of the occasion.

(Take for instance the telescope: I have just asked five people the question: Who invented the telescope? Each one has unhesitatingly answered: Galileo. Not one of them has mentioned the work done by the Dutch, in particular Jacques Metius, who may indeed have the strongest claim to the invention.)

The invention of sound recording was one of the most essential features which paved the way for today's exciting developments is music and electronics. We have mentioned Oberlin Smith's and Vlademar Poulsen's work on magnetic recording. The invention of the phonograph (the predecessor of Emile Berliner's gramophone) we usually attribute solely to Thomas Edison; yet it is said that the French poet and scientist Charles Cros (1842–1888) published in 1877 a description of his 'paléophone', which was intended to record and playback acoustical vibrations on a disc covered with lampblack. Charles Cros, strangely enough, termed his machine not only the 'paléophone' but also the 'phonograph'. The description of his invention was sent to the Paris Académie des Sciences in April 1877 and was published on 10 October 1877. Thomas Edison's first application for a patent was dated 19 December 1877. In Edison's patent lampblack was not used, tinfoil being specified instead. In later days, Edison and Tainter made the more advanced model using a cylinder of wax.

(Quite how Charles Cros was going to make his playback system follow the recorded track in the lampblack is not clear to me—maybe he was ahead of his time in dimly foreseeing a photo-electric system which, in those early days, could not be realised into a working machine.)

What does it matter who comes first with an idea? If neither Edison nor Cros had come forward with the invention, someone else would surely have done so, within a very short space of time. Obviously the time was ripe for just such experiments in recording sound. Edison was fortunate in having ways of developing his idea and means of gaining markets and publicity; such facilities were probably not open to others who, nevertheless, foresaw the possibility of recording sound waves.

By the end of the last war, disc recording had reached an advanced stage, and tape recording had just begun, so the time was ripe for new experimental music which would make use of these facilities. By 1950 Pierre Schaeffer had christened such music musique concrète—natural sounds, recorded via a microphone,

were manipulated into new existence by tape techniques. But any sounds could be so transformed—not only the natural ones picked up by the microphone, as in musique concrète, but also the sounds generated by electronic circuits.

(Electronic circuits had already been used to produce musical sounds in such instruments as the Theremin (1920), the Ondes Martenot (1928), the Dynaphone (1928), the Partiturophone (1935), and the many electronic organs such as the Hammond and the Compton.)

Disc and tape recording allied to these electronic circuits opened up new vistas for the imagination—the young composers responded eagerly. Synthesizing sounds electronically was not a new idea, but the possibilities afforded by these recording techniques gave it tremendous impetus.

If you would like to trace some of the influences which seem to have brought about this fusion of music, sound and electronics, I suggest you start in 1624 with Francis Bacon's vision of the music of a *New Atlantis* (*see* Appendix page 127), and then move on to about 1903, when Thaddeus Cahill was synthesizing sounds with his bank of 58 motor-driven sine wave generators (alternators), which he called the 'Dynamophone'.[1] There was little chance, in those early days, of Dr Cahill being able to use the techniques of recording to build up an electronic music composition such as we compose now. Many more minds were needed to contribute further brilliant ideas before that stage could be reached. Such men as Lee de Forest had yet to experiment with the thermionic valve and discover how it could provide amplification.

(You may feel inclined to hail Dr Cahill as the first composer of synthesized music, but it would probably be wiser not to do so, for I am told that back in 1837 a certain Mr C. G. Page wrote an article in the *American Journal of Science* entitled 'The Production of Galvanic Music'. What a splendid title! Who, I wonder, composed this Galvanic Music?)

I doubt whether Dr Cahill's synthesized music, or the Galvanic Music, employed the 'quarter-sounds and lesser slides of sounds' which Francis Bacon envisaged. You will need to trace many influences if you are to find all the paths leading to the microtonal structures and noises of indeterminate pitch—and to the way in which they are organised—in the music of today.

[1] Dr T. Cahill, British Patent 8725, 1897: 3666A, B,C. 1903.

As well as tracing the influence of Anton Webern and other serialists, you will be noting the ideas of Busoni and Honegger, of the Italian bruitists Russolo and Praetello, of Edgar Varèse, Henry Cowell, George Antheil, Percy Grainger, Julian Carrillo, Aloys Hába and many others—a fascinating mixture of well known and lesser known composers, all of whom were visualising new timbres, or scale systems, or rhythmic freedoms, or methods of structural control.

When you have traced the influences right up to the present day, and you begin to wonder who, among living composers, will exert the most influence on the future, you might well look beyond the composers who have their works well patronised by the musical establishment. When I look at the concert programmes, the radio music repertoire, the music magazines and record catalogues, I am reminded of the experience of Wagner in 1842. Here is H. R. Haweis' account of it in his book *My Musical Life*, published in 1886.

> 'Six weeks of ceaseless labour . . . sufficed to complete the music of *The Flying Dutchman*. The immediate result in Paris was ludicrous. The music was instantly judged to be absurd, and Wagner was forced to sell the libretto, which was handed over to a Frenchman, one M. P. Fouché, who *could* write music. It appeared, with that gentleman's approved setting, under the title *Le Vaisseau Fantôme*.' (Grove's *Dictionary of Music* says that M. Paul Foucher—who was later conductor at the Grand Opera—was handed the libretto for versification, and that it was Pierre Dietsch who composed the music. The resulting opera, *Le Vaisseau Fantôme*, was produced at the Grand Opera, Paris, on November 9, 1842.)

Perhaps we should sometimes pause nowadays, and wonder whether some of the composers, whom the musical authorities put forward as worthy leaders, may well prove to be the Pierre Dietschs of today. The Wagners of the present contemporary scene may be far less conspicuous—a fact which makes exploration of present day music a fascinating pursuit.

If you carry out these various lines of exploration which I have outlined, it may make you wonder why so many exciting ideas are thwarted when they are first presented, why so many composers have had to face conditions which were very similar to those at the Paris Opera House in 1842. It seems to me to be a question of outlets . . . and that subject we might tackle in an individual, but electronic, way in the next chapter.

13

When we have an electronic device which is originating (or amplifying) a signal, we have to give it an outlet for this signal. The outlet may be provided by linking it to a loudspeaker or to a recording machine. But if we link it indiscriminately to any loudspeaker or tape recorder, we are likely to be in trouble—for we may be guilty of mismatching.

We find that each electronic device requires the right type of outlet if it is going to function well. The manufacturer of the device has designed it with a certain type of output which must be matched by the input of the equipment to which it is linked. We can probably visualise this clearly by thinking of water pipes. Water, under pressure, running through a pipe one foot in diameter, will 'work best' if it is joined to a pipe of the same diameter. We find that if it is joined to a pipe of only $\frac{1}{4}$ inch diameter the pressure will build up, the flow will be over-impeded, and the pipes may not be able to withstand the greatly condensed energy. On the other hand if the one foot diameter pipe is flowing into a great six foot diameter pipe the situation is rather ridiculous and wasteful, for the water pressure

will dissipate itself to no purpose, making a mere insignificant trickle in this mighty outlet.

Electronic equipment (such as a microphone, a gramophone pickup, an amplifier or a generator) is even more particular about how it is matched. The signal it is originating, or passing on, will become badly distorted if the output is not matched by the required **impedance**. If the signal from the generator or amplifier is extremely large and the outlet is ridiculously small (or there is no outlet at all provided) the generator itself may be actually physically damaged. If the signal from the generator is fed into far too big an outlet, the energy will dissipate itself and scarcely be transferred. We can summarise the results of unmatched impedance as:

DISTORTION—DESTRUCTION—DISSIPATION.

The electronic amplifier can, I think, be seen as an analogy of the dilemma of many inventors, composers, writers and artists, and perhaps, more especially, such an analogy emphasises the dilemma of some of our university students. 'Signals' are being crammed into the student, crammed in at a fearsome rate, ready for the future when he will correlate and amplify them. But what of the future outlets? Where are the matched impedances ready to receive these signals? We spend millions of pounds injecting the signals; could we not spend a similar sum on organising the future outlets so that these outlets have the right impedances? If we do not do this can we expect anything but distortion, destruction and dissipation? Would it not be better to reduce the amplitudes of the injected signals, if the matched outlets are not available? (Or should we change the curriculum so that it mainly consists of studying the art of living, rather than concentrating so much on specific arts and sciences, which may not have the same natural guaranteed outlets?)

Electrical impedance is the opposition presented by a circuit to a flow of alternating current and is composed of resistance, inductance and capacitance.

If the student, emerging into the outside world, finds no outlets—no impedances—to match his own output, he can either do nothing about it (which will result in his output being distorted or dissipated or, in extreme cases, in the destruction of his own individuality), or he can decide to alter his own output impedance to match those outlets which are open to him. To do this he will either have to provoke, or to stifle, his self-induced 'resistance and capacitance'. Either way it will mean that his powers of individuality will be warped.

Probably we have all, at some time, felt the frustration of finding ourselves talking on serious, intelligent matters to someone who has his mind absorbed at that moment by insignificant trivialities. If we are sensitive, we can almost feel physically hurt by his inattentiveness . . . our own words seem to cruelly rebound and strike back at us. This is just a small illustration of unmatched impedances.

If we, who are in the world outside the universities, also maintain our own impedances by self-induced resistance and capacitance, does it not behove us, personally, to do all in our power to present to the graduates the necessary outlets? Do we not, in the university students, see a piquant mirror of ourselves?

When providing outlets we will have to see that the impedances are matched in all the wavebands—physical and celetal as well as the mental. How the student, or graduate, matures will depend greatly on the impedances he meets, and whether these match up to his potential—whether the signals which have been injected into him, ever since his cradle, are allowed to flow forth into outlets that are real and worthwhile.

We have in this book defined ourselves as individual areas of resonance, controlled by formants operating in the physical, mental and celetal wavebands. Self-induced resistance and capacitance—impedance—is surely another way of describing an aspect of formant control; we have a set of defined impedances associated with all our wavebands. We can alter these impedances—these formants—and shift them, allowing the areas of resonance to expand or contract. We can allow our tuned circuits to accept or reject. We present to the world our own personal wavepattern . . . but we also present to it our own personal range of impedances—in other words, we regulate both transmission and reception.

It seems, therefore, that it is in this way dependent on us, and the outlets we collectively offer, as to how the future generations will shape. Our own individuality has much bearing on the young . . . it also has much bearing on everyone with whom we associate, for we decree the input impedances with which we confront them; by our individuality we create the conditions which can engender distortion, destruction and dissipation.

In the same way it seems to be dependent on us how the music of the future will be fashioned. The composer, also, relies on the impedances that are offered to him. He, too, will have to warp his individuality, or resort to distortion or even 'destruction', if he cannot find 'circuits' which have input impedances corresponding to his output. If he distorts music by violent gimmickry and thereby finds an outlet through commercialism, we, as members of the listening public, have each our own individuality to blame . . . for we are providing the outlets and he is matching to them.

Maybe, when we offer no impedances at all—a sort of musical 'super welfare state'—we are providing the worst type of outlets (akin to six foot diameter water pipes) for, if all is acceptable, mediocrity will flow profusely; the normal musical output of a gifted composer may then appear to be an insignificant trickle . . . only those outputs boosted by the most blatant gimmicks and the most publicised 'happenings' will make any effect at all.

This is hardly a healthy situation for either a composer or audience.

If we follow this line of reasoning—this way of visualising impedance matching—we will, I think, come to the conclusion that we each play a large part in creating the world around us. If we strengthen our individuality we find that our role of creativity enlarges. This is not solely a matter of what impedances we offer to those people we meet. I suggest that this creativity-through-individuality extends far beyond just that aspect. Let me remind you of what was said in Chapter 1 about tuned circuits. 'By magnetic induction the tuned circuit can induce a current to flow in a nearby circuit'. A strong personality not only 'creates' by how it accepts or rejects, but also by how it influences.

In the world of acoustics there is a strange phenomenon, reported by Koenig nearly a hundred years ago,[1] which shows the influence of a resonator on the pitch of a tuning fork. (We all know that a tuning fork can influence a resonator, but here we have an experiment showing that a resonator can influence a tuning fork!)

[1] R. Koenig, who was experimenting in acoustics in the 1880s, should not be confused with Gottfried Michael Koenig, the composer, who is now the Artistic Director of the Institute of Sonology at Utrecht University. For further details of R. Koenig's tuning fork experiment see Lord Rayleigh's *The Theory of Sound*, Vol. 1 pp. 85, 166 (Macmillan 1877, revised 1894).

Striking a 256 Hz tuning fork, Koenig found that it would normally vibrate for about 90 seconds. He then added to it a resonator, which was specially made so that its pitch could be varied. With the fork vibrating, he gradually raised the pitch of the resonator towards that of the fork . . . towards 256 Hz. When the pitch of the resonator was still a minor third below 256 Hz, Koenig examined the pitch of the tuning fork and found, to his surprise, that it has risen very slightly . . . the fork was sharp by 0·005. Also, the duration of vibration of the fork, which had been 90 seconds, was now somewhat reduced. The fork continued to rise in pitch and to reduce its duration of vibration . . . until the moment when the resonator actually reached 256 Hz . . . at this moment the fork suddenly reverted to its original pitch. The resonator now gave great reinforcement to the volume of sound from the fork; but, the sound died away after only 8 or 10 seconds.

As Koenig then went on increasing the pitch of the resonator above that of the fork, he found that the fork gradually decreased in pitch and, at the same time, the duration of vibration became longer until, finally, it again lasted for 90 seconds. The greatest frequency change was 0·035. Not a change that our ears would notice, but the point that interests me is the fact that the transmitter (the fork) appears to have been influenced, indeed altered, by the condition of the 'receiver' (the resonator)—altered both in pitch and duration. The greatest alteration was when the transmitter and receiver were very close to 'mutual agreement'. It also seems significant that the transmitter got rid of its energy in $\frac{1}{9}$ of the usual time when it was linked in accord (in unison) to the receiver—this would seem to agree with our thoughts about therapeutic release of tension in Chapter 7.

Before we turn to a slightly different subject, you might like to muse upon the fact that the tuning fork altered its pitch *away* from that of the resonator, when the resonator was approaching the normal pitch of the fork. . . .

Now let us leave the tuning fork and turn our attention to the tuned circuit. Back in Chapter 1 we listed 5 attributes of a tuned circuit. We have considered 4 of them, but not the final one. As this last one displays, to my mind, the greatest scope for creativity, this is the moment, I think, for us to consider it.

You will remember that a capacitor consists of two plates of metal held apart by a substance of high resistance, called the dialectric. If the two metal plates are connected externally by a wire, which is wound into a coil, we have a tuned circuit, which can be energised and made to oscillate at its resonate frequency. We wondered whether the human body consisted of thousands upon thousands of tuned circuits, each energised into resonance. We might now perhaps wonder further—wonder whether the human body is one vast 'tuned circuit' embodying within it all these millions of smaller tuned circuits. (Maybe the spinal column is the coiled wire; maybe the brain . . . (the frontal lobes?) . . . and the solar plexus (with the sexual organs?), are the plates of the capacitor?)

In our electronic tuned circuit, if we allow the tension to become too great, the capacitor will become overcharged, and the energy will break through the dialectric causing a spark—the 'death spark' of the capacitor. This sudden release of energy will mean that an electromagnetic wave will be transmitted in all directions, which will cause any sympathetically tuned circuit to resonate, even though this circuit may be situated some distance away.

What energy within the human body can suddenly 'break through the dialectric' and become transmitted?

Individuality seems to be the formulating of energy, by means of formant control, into a discernible pattern—into an orderly form. By the time we are reaching old age, the orderly forms in our physical and mental wavebands may be becoming disorderly, for the ELEC will have nearly worked its energy out; but the CELE will be reaching its full maturity. Is this the energy which will be transmitted by the death spark—the energy which has been formed by individuality into a personal celetal wavepattern?

If individuality has developed to the full, this celetal wavepattern will be of great significance—it will have sonority . . . it will have a richness of overtones, enveloping a spacious range of harmonics. When such a wavepattern is transmitted, it will surely create resonance in many sympathetically tuned circuits. In this way is it, like all energy, obeying the law of entropy and disseminating itself from one orderly form into smaller, less orderly forms . . . only to start, immediately, the reforming towards new order?

I find it very exciting to think that our own personal wavepatterns may, according to their richness, energise many 'vessels' when we 'die'. How fascinating to feel that part of oneself—perhaps just one of one's overtones—might, 'in a twinkling of an eye', energise by sympathetic resonance an atom or a molecule . . . of an arbutus tree . . . of an amethyst . . . of a sea anemone, of Mount Annapurna, of an antelope, of an Armenian . . . and . . . of the galaxy of Andromeda. What experience it would give 'one'!

Could individuality be viewed as the equal and opposite force which balances entropy? Just as a node balances an antinode? Could the world be a never ending pulsation of energy forming into individuality, then being disseminated by entropy, only to reform into new individuality—a basic pulsation, the very fundamental of all fundamental sine waves?

Do we need to wait for the death spark to feel this basic pulse? Is one not creating resonance and absorbing resonance all the time—an *at one-ness* which, alas, we seldom allow to penetrate our consciousness?

14

In these 13 chapters we have traced sound right through—from the energised tuned circuit, via filters and formants, into the tape recorder, out again with feedback and echo, intermodulated, fashioned by chance, processed or 'humanised', and finally fed to a matching loudspeaker. At the same time we have considered the composer and some of the forces which mould his music—from the initial 'spark' through to the receptive listener.

We have also considered the human elements which seem to correspond to these stages of sound, music and electronics. We have emphasised the tremendous importance of individuality and have tried to visualise how individuality can be maintained in the world of machines. We might easily be led to think that, in humanising machines and in emphasising individuality, we are opening up the road which will take us to a panacea. However, the more we consider it the more we realise that the future still rests with human character and personality. There is no panacea. As we humanise our machines we make them more and more sensitive; they, therefore, are better able to transduce the thoughts of the man who programs them . . .

but . . . what of those thoughts? The more the machine is humanised the more subtle a weapon it can become; the more it can brainwash or mentally torture. Through its immediate feedback system, the man who programs it knows exactly what result he is achieving, and can use it to make the greatest possible impression. The greatest impression of good . . . or of evil. It depends on his thought.

When, in Chapter 3, we were considering how the brain might bring into the consciousness the resultant wavepattern (which occurred through intermodulation) we visualised the brain scanning the amplitude peaks and then being able to focus its attention on one particular area of the scan. It seems to me that, when we think, when we concentrate our thoughts, we can scan whichever part of the vast waveband we choose. Having chosen the waveband, either the physical, the mental or the celetal, we then, to my mind, employ one of three quite distinct modes of thinking—each waveband has its own particular mode.

In the physical waveband the mode of thought appears to be 'sensual'; in the mental waveband it appears to be a rather different type of thought—a case of thinking in words, numbers and graphic representations; while in the celetal waveband I do not feel that we think in words at all. Some psychologists seem to be adamant in declaring that we always and only think in words, so I am here crossing swords with them. But after talking to other artists and inventors, and adding their experience to my own, I would say that there is a mode of thinking which is quite beyond the sphere of words.

Maybe this translation of a saying of Horace[1] supports this view—

> 'Once a thing is conceived in the mind, the words to express it soon present themselves'.

The words . . . 'soon present themselves' . . . implies that the words are not there at the start, and the 'thing conceived' has to be transduced into words. But 'conceptual thinking' does not, to my mind, describe the original mode of thought (and, besides, the word conceptual has now numerous meanings in and out of the art world). I can only go on using the word I have coined—CELETAL.

[1] Horace: *De Arte Poetica*, V311.

When thinking in the CELETAL mode one finds that one cannot worry—no molehill becomes a mountain—one is no longer within the sphere of anxiety and of worry, of hate and of fear. Perhaps in the celetal mode thoughts are not sustained by feedback. Perhaps no disciplined hand is needed on the feedback volume knob to prevent 'howl'; for, maybe, celetal thought is *outside time* and could not be sustained by feedback . . . for the very word feedback implies time.

Is great art one of the few ways in which the human individual can express the celetal in the dimension of time? Could we say that the great scientist and the great engineer also have found ways of expressing the celetal? Is this where art and science meet and understand each other? Yes, I think so . . . but the methods of transducing are so totally different. The processes and the machines which the scientist and the engineer bring into being can so easily dwarf man's individuality, whereas the music of the great composers serves to enhance man's individuality. Can we, in the future, find some way to nurture the celetal so that it can be transduced into the material world in new forms . . . forms which will embody all the greatest attributes of the arts?

The Greeks, in their mythology, have told us the story of Persephone. Seized by Aïdes she was borne away to the hidden realms of the underworld. Her mother Demeter, Goddess of the Earth, stricken with grief at the loss of her daughter, begged the King of Attica to help her. She declared that no fruits nor grain would spring forth from the earth until her daughter was restored to her.

The King built, for Demeter, a Temple at Eleusis, and there she instituted the Eleusinian Mysteries. Due to his wisdom and kindness in helping her mother, the beautiful Persephone was able to rise each year from the underworld, bringing all the flowers into blossom and making the corn once again spring forth from the ground in fullest plenty.

The Earth celebrated. The essence of life, in all its richness, returned . . . . . through the Temple of Eleusis. The wise King of Attica was appointed High Priest of the Mysteries. His name was Celeus.

APPENDIX

NEW ATLANTIS

Wee have also Sound-Houses, wher wee practise and demonstrate all Sounds, and their Generation. Wee have Harmonies which you have not, of Quarter-Sounds, and lesser Slides of Sounds. Diverse Instruments of Musick likewise to you unknowne, some sweeter then any you have; Together with Bells and Rings that are dainty and sweet. Wee represent Small Sounds as Great and Deepe; Likewise Great Sounds, Extenuate and Sharpe; Wee make diverse Tremblings and Warblings of Sounds, which in their Originall are Entire. Wee represent and imitate all Articulate Sounds and Letters, and the Voices and Notes of Beasts and Birds. Wee have certaine Helps, which sett to the Eare doe further the Hearing greatly. Wee have also diverse Strange and Artificiall Eccho's, Reflecting the Voice many times, and as it were Tossing it: And some that give back the Voice Lowder then it came, some Shriller, and some Deeper; Yea some rendring the Voice, Differing in the Letters or Articulate Sound, from that they receyve. Wee have also meanes to convey Sounds in Trunks and Pipes, in strange Lines, and Distances.

Francis Bacon
1624.

Suggestions for listening—

Arel	
Electronic Music No. 1	Sona Nova 1988 (Distributed by Wayne Record Corp. New York)
Babbitt	
Vision and Prayer	
Berio	
Visage	Turnabout TV 34046
	CBS 61079
Différences	Philips 839323 DSY
Epifanie	
Omaggio a Joyce	Philips A 00565 & 4FE 8503
Laborintus II	
Sinfonia	CBS 61079
Momenti	Philips A 00565 & 4FE 8503
Sequenza 4	Philips 6500 101
	Vox STGBY 637
Boulez	
Structures	
Livre	Erato STU 70580
Le Marteau sans Maitre	Philips A 01488
Piano Sonata 2	Philips 6500077 & DGG 2530050
Berg	
Piano Sonata 1	DGG 2530050
Brün	
Non Sequitur 6 *Computer Music*	
Bussotti	
Sette Fogli	
Cage	
Talk by John Cage and excerpts from Fontana Mix	Folkways FT 3704
Fontana Mix	Turnabout TV 34046
Cartridge Music (Cage & Tudor)	
Winter music	
Variations VI 1966	

Cage & Hiller
HPSCHD (1967–69) Nonesuch H71224

Cardew
Octet '61 for Jasper John
February Pieces for Piano

Cary
345 Galliard 4006
Narcissus Galliard 4007

Casserley
Final Desolation of Solitude

Castiglioni
Divertimento

Davidovsky
Study 2 Sona Nova 1988

Davies, Hugh
Galactic Interfaces

Dennis, Brian
Dream Music

Electronic Panorama, includes Philips 6740 001/1–4
Ferrari *Visage V*
Koenig *Funktion Blau*
Kotonski *Microstructures*

Electronic Music by Richter, Mimaroglu, Avni, Carlos
Turnabout TV 34004

Electronic Music by Le Caine, Olnick, Aitken & others
Folkways FMS 33436

Electronic Music III by Berio, Druckman, Mimaroglu
Turnabout TV 34177

Electronic Music by Mâche, Philipott, Bayle & others
Vox STGBY 639

Ferrari
Visage V Philips A 00565–6
Philips 6740 001/1–4

Fiser, Lubos
Fifteen Prints after Duer's Apocalypse RCA VICS 1599

Fucks
Experiment Quatro-Due 1 1963

Gerhard
Collages

Henry
Le Voyage Philips 4FE 8000
Selection of works by P. Henry Philips 4FE 8004

Hiller
Computer Cantata (Hiller & Baker)
Illiac Suite, computer music for String Quartet (Hiller & Isaacson) Heliodor HS 25053

Johnston
String Quartet No. 2 Nonesuch H71224

Kagel
Transicion I Philips A 00566 & 4FE 8503
Transicion II

Koenig
Funktion Blau Philips Electronic Panorama 6740 001/1–4
Klangfiguren II DGG LP 16134

Kotonski
Etude pour un seul coup de cymbale
Microstructures Philips Electronic Panorama 6740 001/1–4

Krenek
Spiritus Intelligentiae. Sanctus DGG LP 16134

Ligeti

Atmospheres	Polydor 2549003
Continuum	Polydor 2549011

Lilburn

Study from one note

Live Electronic music, Concerts given by *Gentle Fire*, *Intermodulation*, *Sonic Arts Union*, and by other groups.

Maderna

Continuo	Philips A 00565 & 4FE 8503

Musgrave

'*From one to another*'	
Soliloquy	DGG 2530–079

Music from Mathematics

Computer Music realised at Bell Telephone Laboratories USA
Brunswick STA 8523

Musique Concrète No. 1 & 2 Panorama
London DTL 93090–93121

Musique Experimental — BAM LD 070 & 071

Nono

Omaggio a Emilio Vedova

Norwegian Electronic Music — Philips 836 896 DSY
by Nordheim, Janson & Fongaard

Pousseur

Electre	UE 13500
Scambi	Philips A 00566

Schaeffer

Solfège de l'objet sonore (illustrates the book *Traité des Objets Musicaux* Editions du Seuil)	ORTF SR2

Sona Nova 1988

Music electronically realised at the Columbia-Princeton Music Center
(Wayne Record Corp. New York)

Stockhausen

Hymnen	DGG 2707039
Klavierstucke IX	Philips 6500–101
(interesting to compare this with a performance on CBS 72592)	
Kontakte (& Gesang der Jünglinge)	DGG SLPM 138811
Gesang der Jünglinge (& Study II)	DGG 16133
Mantra	
Mikrophonie I & II	CBS 72647
Telemusik (& *Mixtur*)	DGG 137012
Prozession	Vox STGBY 615
Stimmung	
Kurzwellen	DGG 139 451/2
	DGG 2707045
Zeitmasse	Philips A 01488

Tilbury

Works and performances by John Tilbury (sometimes with The Scratch Orchestra, London)

Varèse

Works by Varèse	CBS SBRG 72106
	Philips A 01494
	Vox STGBY 643

Webern

Works by Webern	Philips SAL3529
	Philips A 01337
	Philips L 09414/17
	Philips 6500105

Xenakis

Strategie	
Akrata	World Record Club H 71201
Computer Music ST/10–1 080262	

Zinovieff
Zasp Computer Music (with Alan Sutcliffe)
Jazzy Letgo

Zumbach
Etude

Record numbers should be checked in the current catalogue before ordering from your record retailer; if records are not currently available it may be possible to borrow them from gramophone libraries.

Among Daphne Oram's compositions are:

Four Aspects 1959

Excerpts performed at the Mermaid Theatre and at the Edinburgh Festival.

Pulse Persephone

Commissioned for the Treasures of the Commonwealth Exhibition, Burlington House, London. Recently created into a ballet *Alpha Omega*, choreography by Seraphina Lansdown.

Episode Metallic

Four track electronic tape with lighting control. Commissioned by Messrs Mullard Ltd for permanent exhibition at Mullard House.

Contrasts Essconic

Piano and tape. (In collaboration with Ivor Walsworth.) First performed by Joan Davies at the Queen Elizabeth Hall, 1969. Since then broadcast on television and performed widely in Canada. This tape includes the first use of Oramics.

Brociliande

Oramics tape, duration 14 mins.

Sardonica

Piano and Oramics tape. (In collaboration with Ivor Walsworth.) Commissioned for performance in Canada in 1972.

Record:

Listen, Move and Dance (for schools).

Electronic Sound Patterns HMV 7EG 8762

Music for many plays and films, including:

Film *The Innocents* (based on Henry James' *The Turn of the Screw*).

Documentary film *Snow* (for British Transport). A prizewinning documentary directed by Geoffrey Jones.

Documentary film *Trinidad & Tobago* (for British Petroleum).

Mermaid Theatre *Rockets in Ursa Major* by Prof. Fred Hoyle.

Music by Thea Musgrave (the tapes being made in collaboration with Daphne Oram):

Soliloquy for guitar and tape.

From one to another for viola and tape.

Beauty and the Beast for orchestra and tape. Ballet (First Performance 1969 by Scottish Theatre Ballet).

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Chapter 7 MEMORY — RE-RECORDING — FEEDBACK STORAGE — RETRIEVAL — REINFORCEMENT — MULTIPLE STORAGE AREAS — SYMPATHETIC INDUCTION — RATIONALISING DEPARTMENT — COLOURATION — SPEED — CELERITAS — SPACE/TIME — SOLID/FLUID — ROBERT MCNAMARA — UNCONTROLLED FEEDBACK — SELF OSCILLATION — OVERLOAD INTO SILENCE — SHOCK — MUSICAL SHOCK — TRANSDUCING THOUGHTS — DIFFERENT ANGLES — STARK REALITY — WIDER VARIANTS.

Chapter 8 PSYCHIATRIC TREATMENT — CONTROL OF ENERGY — MUSICAL ENERGY — SMALL SECTOR — RUN RIOT — MEMORY STORAGE — SAMUEL COLERIDGE — INTEGRITY OF CONTROL — INSANITY — OUTSANITY — SUPERSANITY — NOISE LEVEL — SLEEP — MEMORY SORTING — DREAMS AND NIGHTMARES — RATIONALISED ECHOES — MODERN MUSIC — HIEROGLYPHICS — VALIDITY OR MUSH — 'DO-IT-YOURSELF-PSYCHIATRY'.

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Chapter 11 MACHINE WITH HUMANISING FACTORS — NOTATION — SEPARATION OF PARAMETERS — ENVELOPE SHAPES — VOLUME — ANALOGUE — TIMBRE — FREEHAND DRAWINGS — BLEND OF TIMBRES WITHIN THE NOTE — PITCH — DIGITAL — NEUMES — OPEN STRINGS — FINGERBOARD — STEADY STATE — FATIGUE — ANALOGUE PITCH — VIBRATO — REVERBERATION — PARTIAL INDETERMINACY — VISUAL ACCOUNT OF THE MUSIC — MONITORING FEEDBACK — 'INNER' EAR — ERASING — HUMAN FACTORS — CONVEY INDIVIDUALITY — MUSARIAN — ORAMICS.

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Guide to Contents by Subject

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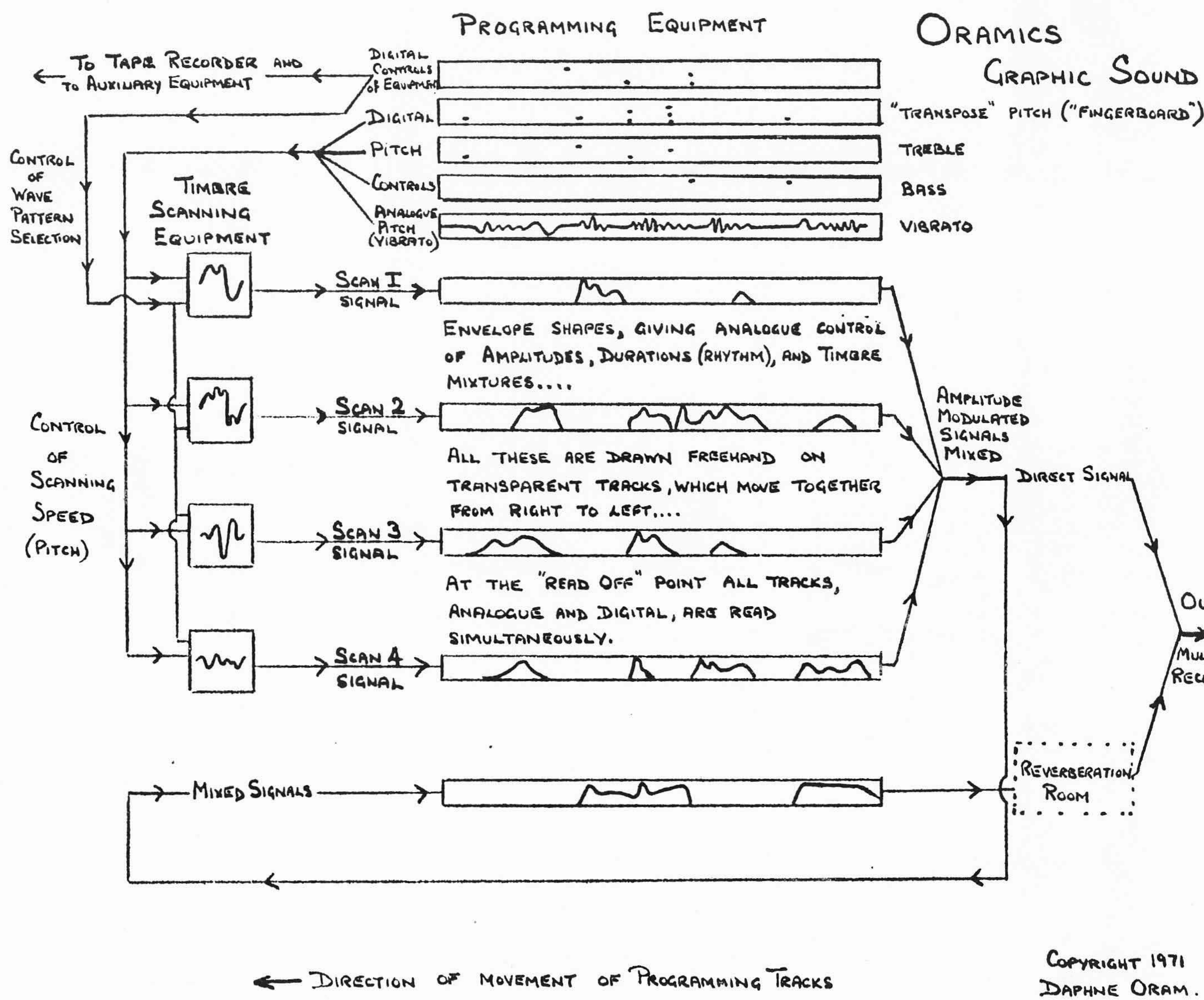
ORAMICS
GRAPHIC SOUND
PROGRAMMING EQUIPMENT
TO TAPE RECORDER AND TO AUXILIARY EQUIPMENT
DIGITAL CONTROLS OF EQUIPMENT
DIGITAL
PITCH
CONTROLS
ANALOGUE PITCH (VIBRATO)
"TRANSPOSE" PITCH ("FINGERBOARD")
TREBLE
BASS
VIBRATO
CONTROL OF WAVE PATTERN SELECTION
TIMBRE SCANNING EQUIPMENT
SCAN I SIGNAL
ENVELOPE SHAPES, GIVING ANALOGUE CONTROL OF AMPLITUDES, DURATIONS (RHYTHM), AND TIMBRE MIXTURES....
SCAN 2 SIGNAL
ALL THESE ARE DRAWN FREEHAND ON TRANSPARENT TRACKS, WHICH MOVE TOGETHER FROM RIGHT TO LEFT....
SCAN 3 SIGNAL
AT THE "READ OFF" POINT ALL TRACKS, ANALOGUE AND DIGITAL, ARE READ SIMULTANEOUSLY.
SCAN 4 SIGNAL
CONTROL OF SCANNING SPEED (PITCH)
AMPLITUDE MODULATED SIGNALS MIXED
DIRECT SIGNAL
OUTPUT TO MULTI-TRACK RECORDER
MIXED SIGNALS
REVERBERATION ROOM
DIRECTION OF MOVEMENT OF PROGRAMMING TRACKS
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