



Teachers' Resource Pack

SOUNDSCAPES

Exploring electronic music and Karlheinz Stockhausen



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INTRODUCTION

In partnership with EMI and EMI Music Sound Foundation the London Sinfonietta worked with 7 schools from across the UK in March and April 2006. This project aimed to introduce the music of Karlheinz Stockhausen to students from KS4, preparing them for a concert by London Sinfonietta of *Mixtur*.

As part of this project each school received a Teachers Resource Pack to help prepare their students for the concert, as well as an introductory workshop with a London Sinfonietta Education Team. All students and teachers then attend an afternoon event on 24 April 2006 at the National Film Theatre, before attending the evening concert of *Mixtur* by Stockhausen at the Queen Elizabeth Hall, London.

These materials begin with an introduction to the life and work of Karlheinz Stockhausen. They are followed by a range of possible activities for use in the classroom to help gain access to the ideas behind their compositions together with an appendix providing further information about ring modulation as well as some additional web references for further study.

The teachers' activities have concentrated on a few key aspects of the work of the composers – textures and styles, playing and composing techniques. Instead of providing step by step lesson plans, they provide practical 'jumping off' points with a range of ways for exploring the musical aspects and ideas and of thinking about them. The teacher can control their use with perhaps two or three of those ideas with younger students at KS3, with the other ideas to be retained as extension activities. At the same time they allow senior students to explore for themselves and think widely about all or most of the activities. There should be enough ideas and prompts in each activity to keep the most able student still thinking and developing, while each idea is simple enough in itself to engage younger and less experienced pupils.

Teachers will know themselves the nature of the learning in terms of the national curriculum for KS3 pupils and do not need detailed help to justify these activities, and older students can use any of these activities as projects in their examination work. However, a simple statement about the musical learning to be found at the end of each activity is provided as guidance and relevant national curriculum statements are noted to support busy teachers.

We hope the materials will help teachers to think broadly and innovatively about how to approach challenging music in the classroom and help to make it accessible to their pupils.

The Life and Work of Karlheinz Stockhausen

Who is Stockhausen?

"The most innovative and influential German composer of the post war era, Karlheinz Stockhausen laid much of the foundation of modern experimental music; through his pioneering work in electronics, he left an indelible imprint not only in contemporary classic circles but throughout the creative spectrum, where echoes of his genius still reverberate everywhere from the avant-garde to rock to dance music." Jason Ankeny

Karlheinz Stockhausen is perhaps the most influential voice of the post WWII European avant-garde. His music varies widely in style and media, and demonstrates his interests in mysticism, cosmology, science and technology. He is a formidable intellectual and a pioneering composer whose influence is felt by many musical genres.

He was born in 1928 near Cologne in Germany and studied piano from the age of six. His mother was very musical and his father was a farmer. After being orphaned at the age of 13 as a result of the war he immersed himself in music. He was a pianist and oboist and clearly had a very good ear. He took classes at the new music school in Darmstadt with Theodor Adorno and lived in Paris for a while, studying with Olivier Messiaen. He was interested in writing literary texts and poems too and this became an integral part of his musical interests and compositions later. His wartime experience helping in a field hospital also had a very profound effect on him. Later to bring in some income, he played the piano in cafés and night clubs.

After the war, Boulez, Xenakis, Messiaen and Stockhausen were in the vanguard of 'wiping the slate clean' musically (in parallel with the way societies were changing) to forge a new way of thinking about music in the 20th century.

Now nearly 80, he continues to be active, composes still and has a phenomenal catalogue, with over 300 works and 10 volumes of Texts about Music. Since 1975 all his work has been published by Stockhausen-Verlag, his own company. A complete list of all his music can be found on his own website, www.stockhausen.org

Why is his music important?

Stockhausen has approached composition as a more or less scientific process, seeing musical creation as a series of experiments. What is more, he is keen never to repeat his investigations and with each new work has looked forward to new ways of playing, interpreting and listening. This can lead to bewildering frustration on the part of the listener, but the stimulation and confidence this exploratory way of working has given to the wider artistic community is immeasurable.

Arguably, his most influential work has been in the electronic music studio; creating music on tape, for instrument and tape, or combining live instrumental performance with real time transformations or 'live electronics'. He, like others at the time, experimented with the new '*Musique Concrète*'.

From the early 1950s Stockhausen began to work in the electronic music studio of North West German Radio, in Cologne. The music created there, the systematic exploration of compositional process and the lessons learned are of huge importance. He started to experiment with what he called the 'inner' structure of sounds, for example by using wood, glass and metal.

In the exacting environment of the radio studio, he learnt practical skills with microphones and mixing desks. Importantly, he realised that there was an uncharted creative potential for the crude technologies that surrounded him. For example, he saw that the electronic engineer's test equipment, the sine wave generator, could be harnessed as a musical instrument. Its tones could be transposed, recorded, and mixed with others to produce new timbres and a new music.

Who has Stockhausen influenced?

The Beatles, Kraftwerk, Bjork, Miles Davies, Goldfrapp and Frank Zappa all cite Stockhausen as an influence. He connected well to the 60s rock culture and said at one time that John Lennon was '*the most important mediator between popular and serious music of this century*'. Other names that clearly influenced him or were influenced by him include Pierre Boulez, Luigi Nono, Luciano Berio, Edgar Varèse, Olivier Messiaen, Iannis Xenakis and John Cage.

Here are a few reasons to think about why he has had such a great influence:

- Profound artistic integrity
- Never a follower of fashion, always a leader
- Stickler for detail
- Pioneering spirit
- Prodigious invention
- Never restricted by the tyranny of a notation
- Always re-inventing ways to express an idea
- Always ready to take up new technologies

His compositional techniques

We are not short of insights into Stockhausen's compositional intentions – he has written copiously on almost everything that has been produced. This section highlights only a few.

Stockhausen studied the new *12 note serial technique* of Schönberg and Messiaen's technique of applying this to duration, dynamics and timbre as well. This helped him to develop a technique using '*sound points*' and led him to his continuing interest in the structure of sounds themselves.

He was also influenced by the music of Webern, where he is intrigued by the internal structure of the line, which can be followed from one player to the next in the texture of a Webern piece – very difficult to play effectively.

He went through phases of using musical notation flexibly and at other times more formally. He often uses symbols such as +, -, =, to encourage players to interpret the

music themselves with a mixture of formal notation and invented symbols. *Mixtur* was written during such a period. Later he went back to the use of fully notated scores in works like *Mantra* and *Tierkreis*.

From the mid 70s, theatrical modes of presentation and themes became very important to him, with much use of words and mantras. He was enormously inventive about the space he used, including even recording a string quartet in four independent helicopters and relaying their sound electronically to each other and to the ground below (the *Helicopter String Quartet* from *Licht*).

'*Formula composition*' is a term often used for Stockhausen's compositional technique. It usually involves using a single melody, melodic fragment or series of notes, often played at the beginning of a piece. He likens it to a musical seed like DNA which then can be changed, developed and used in intuitive and intelligent ways to grow into a whole.

This excerpt from a CD cover gives a taste of how meticulous he is in the way he thinks about every element in any composition. It is discussing *Mantra*, written in 1970 for two pianists.

"So called ring modulation, which I have employed as a technical process, makes possible a new system of harmonic relationships. To this end, each of the pianists has an apparatus at his left into which a microphone amplifier, a compressor, a filter, a ring modulator, a scaled sine-wave generator and a volume control have been built. The piano sounds are amplified by two microphones and ring modulated by sine-waves. Behind each piano stand loudspeakers, which project the modulated sound simultaneously with the played sound. The modulated sound should be slightly louder than the original sound".

A '*mantra*' is a mystic formula, which Stockhausen uses in other works too, in for example *Stimmung*. It is intended to be repeated and meditated upon. The word comes from the Sanskrit, where it means, approximately, "sacred counsel".

Stockhausen in discussing his work *Ave* gave another insight into his performance practice:

"Since 1970 a new performance practice has developed in my works:

- performance from memory;
- singing and playing without a conductor, knowing the parts of the other musicians from memory;
- stylisation of all movements, often according to detailed notation;
- a 'concert' is either a single work without interruption, or a composition of 'pieces', which are connected to each other by way of a spatial or temporal process;
- designing special costumes for each composition, if possible;
- planning characteristic lighting for each work;
- avoiding all unartistic actions"

Key Works

Almost too many to list, but here are the crucial tracks.

Elektronische Studien I & II (1953 & 1954), electronic music on tape

Gesänge Der Junglinge (1955), electronic music on tape

Kontakte (1958), for electronic sounds, piano and percussion

Microphonie I (1964), for tam-tam, 2 microphones, 2 filters

Mixtur (1964), for orchestra, 4 sine-wave generators and 4 ring modulators

Microphonie II (1965), for choir, Hammond Organ, 4 ring modulators and tape

Telemusik (1966), electronic music on tape

Hymnen (1967), electronic and concrete music on tape

Stimmung (1968), for six vocalists and amplification

Spiral (1968), for soloist and short-wave receiver

Mantra (1970), for 2 pianists, tape, 2 sine-wave generators and 2 ring modulators

Sirius (1975–77), electronic music, trumpet, soprano, bass clarinet and bass

Licht (1977–2003), for solo voices, instruments, dancers; choirs, orchestras, ballet and mimes; electronic and concrete music (includes the *Helicopter String Quartet* for the *Wednesday* section)

In Absentia (2000), film collaboration with the Brothers Quay, for electronics and musicians (the Sospeso Ensemble)

Mixtur

“MIXTUR for orchestra is the first work in which an orchestra is electronically transformed in real time: the genesis of Live Electronic Music.

Starting in 1963 I was the Director of the Studio for Electronic Music of the WDR Cologne. My systematic experiments with the microphoning, filtering and ring modulation of instrumental sounds first of all led – in 1964 – to the work MIXTUR.

Through this, even when using traditional instruments, new timbre relationships (gradual blending, transformations, etc.) and new pitch relationships (in any number of scales which deviate from the division of the octave into 12 equal steps) can be composed, which were – until now – only possible in electronic music.

MIXTUR could be the beginning of a synthesis of instrumental music and electronic music.”

Stockhausen writing for the CD cover of the work.

What is *Mixtur*?

As we have seen, the 1960s saw the introduction of live electronics in performance in works such as *Mixtur* (1964) for orchestra, sine-wave generators and ring modulators, *Mikrophonie I and II* (1964/65), *Prozession* (1967) and *Kurzwellen* (1968).

Mixtur was premiered in Hamburg in November 1965. It is music conceived for four orchestral groups (woodwind, arco strings, pizzicato strings, brass) and three percussionists (each with a cymbal and a tam-tam). These groups are arranged in clusters across the stage from left to right, with the three percussionists on raised platforms at the back. The title refers to the mixing of the sounds of all the groups with sine-waves in ring modulators. The sound is therefore heard by the audience in an entirely different form from what you might expect from a live orchestra. Every player has a microphone and their playing is captured and mixed together with the sounds from other instruments in their group. The four resulting mixes are then fed into four separate ring modulators.

The work is divided into 20 ‘moments’, with different titles such as Points, Calm, Mirror, Pizzicato. The moments are played continuously one after the other, and sometimes the ideas from a previous moment are continued into the next. Most moments are contained on one page of the score, but a few are longer. The effect of these moments accumulating within the mixture of live sound and the electronic manipulation of it is to somehow physically ‘fill’ the space, almost tangibly, with sounds which range from threatening low and penetrating high registers - a great range of timbres or colours of sound. The piece may be played forward as in the score or in a retrograde version and sometimes one version following the other. The composer also makes suggestions where the order of the moments or ‘blocks’ could be varied.

Despite this apparent flexibility, Stockhausen provides meticulous notes to conductors about how to rehearse the piece and even for how long to rehearse it. He is clear that it

should never be combined with another instrumental piece in a concert due to “...*unaccustomed new notation, which has to be learnt, many rehearsals, complex electro-acoustics, particular orchestra set-up and special lighting*”. (See Appendix 4)

Musical time is governed by a common unit, which is expressed as a series of numbers across the top of each page. Each unit is equal to 1/40th of a minute. There is a certain amount of conventional musical notation on each page of the score, but also many opportunities for variation and improvisation. All this is gradually set in rehearsal, so that gestures and textures are fixed by the time of the performance. The oscillators, which produce the sine-waves, are played by four musicians. They follow a very precise score.

What is a Ring Modulator?

A ring modulator is a device that requires two inputs. In the case of *Mixtur* these are one of the four resulting mixes (called the ‘modulator’), and a sine-wave (called the ‘carrier’). Ring modulation is the audio effect that is then produced.

In simple terms, a ring modulator will output a sound that is the consequence of both adding and subtracting the frequencies that make up the ‘modulator’, to and from the ‘carrier’.

For example, if the instrumental mix was of a flute note of a frequency of 440 Hz (the Concert A we typically tune to) and the sine-wave was set at 660 Hz (approximately the E at the top of the treble staff), then the ring modulator would output a sound which comprised both $660 + 440$, which equals 1100 Hz and $660 - 440$, which equals 220 Hz (a C# above the treble staff and an A at the top of the bass staff). (See the pitch and frequency tables in the Appendix 1.)

Of course the pitch of a note (or its frequency) is not the whole story. There are a multitude of other frequencies, which constitute an instrument’s overtones and give it a particular colour, and these too are affected by the carrier sine-wave. Ring modulated sound is subsequently much more complex in timbre than the flute example above, and what’s more, it varies over time as the music unfolds.

Why is *Mixtur* ground-breaking?

In *Mixtur*, Stockhausen was pioneering a synthesis of instrumental and electronic music.

By ring modulating the sound of the orchestra Stockhausen was trying to compose new timbre and pitch relationships. *Mixtur* established real-time live-electronic music as viable.

Now listen to examples of ring modulation in *Mixtur*, on the accompanying CD.

Track 1

HOHES C

In this 'moment' you can hear the ring modulated sound sweep up and down over the string chord, as the sine-waves are changed from 16 Hz to 1568 Hz and then down to zero in one oscillator and from 4160 Hz to 1568 Hz in the other.

This is set against the piccolo playing the 'high C' of the title and ring modulated by a sine-wave that moves up from 82 Hz to 1040 Hz. This final frequency is only slightly more than one octave lower than the sounding piccolo.

Remember that you are not hearing the sine wave itself, but the ring modulated result.

Track 2

PIZZICATO

Listen to shifting timbres as the sine-waves are moved back and forth, getting progressively higher from 6 Hz up to 18 Hz.

The strings play short pizzicato gestures and are made to sound metallic and clangorous by the ring modulation.

Track 3

DIALOG

The sine-wave has to be controlled particularly precisely in this 'moment'. Each brass chord is transformed by a different carrier frequency.

Ideas and Activities for the Classroom

The following are a range of ideas and activities in brief outline which can stimulate an understanding of the way in which Stockhausen has worked over the years. It is not necessary to have a wide range of electronic hardware and software to do most of the activities though more sophisticated results are likely to occur if it is used.

1. **STIMMUNG**

"Stimmung" means 'atmosphere' as well as 'voicing or tuning'. Stockhausen's piece of this name consists of a single static chord that is sustained for over an hour where the singers freely bring into play 'sound models' and 'magic names.' Working in this way gives students a feel for the space and feeling which develops in Stockhausen writing and which is crucial to understanding of his work.

Task. Agree an interesting chord with the students – a ninth or eleventh for example. Make sure everyone can find a note in the chord to sing and practise holding it and re-breathing to hold it as smoothly as possible. (This does work with instruments, particularly strings, but it is better with voices only). From time to time each individual can change their note within the chord, changing again to fill any gaps which may have been left. The important thing is a continuous sound chord. Practise making marked changes in the vowel sound or tone quality of the sound - but do it seamlessly.

Sit in a wide circle and record the sound over a long period of time. Then replay the sound with different qualities, bass up high for example, and sing along with it. Stand up and move about the space while you are singing, and feel how it differs in different places and positions. Build the sequence very slowly and encourage individuals to improvise upon it if confident enough. Pick a theme (e.g. days or months of the year; names of stars and constellations) and students take it in turns very slowly and infrequently to vocalise a word from the theme over the chord whose tone quality should change to reflect the word if possible.

Sing it with eyes closed in a tighter circle, listening more and more intently. Do it in the drama studio in near dark if you can. Use microphones and play with feedback for some of the vocalising. Work to a point where students are concentrating on the feeling of the sound rather than on getting it right.

If you are able to get a recording of *Stimmung*, listen to it in as near dark conditions as you can. It is very long.

Extension or variation: try it with a short chord sequence (always with unresolving chords) or with bass string instruments.

Learning: using and improvising with voices; beginning to **feel** the specialisation which is so important to Stockhausen; using key words as a mantra.

2. DODECAPHONY

"In Octophony I have created timbres with small melodic loops which are produced electronically in a computer and then sped up with enormous speeds. Let's say you have a melodic figure (already rhythmatised) which lasts 2 seconds, and then I speed it up to such a degree that there is a regular pitch, a sustained pitch of let's say a 1000 periods per second, so I would have to speed it up 2000 times to hear a timbre, and the timbre is the result of that particular micro composition. This is my aim, like in nature, to compose timbres like in atomic physics." Stockhausen in interview.

Using Cubase, Reason or Logic Fun, develop 9 short fragments of melodic ideas on different tracks. Find 3 strong chords or timbres which stand alone well and put these down on yet more different tracks. Multiply their range and character by putting down many more tracks of the same fragments at different speeds. Make sure you name them all accurately and sufficiently informatively so that you always know which fragments you are using. Record filter changes over the top to develop the timbres further.

Organise your materials in a slowly unfolding pattern. Using the fragments as many times as you like in as many different speeds and timbres as you like, with a clear shape or direction.

Learning: using fragments of sounds as the basis for an extended composition; the effect on the character of sounds of speeding up and slowing down; making pieces last a long time.

3. PLAYING WITH PIANOS

Using two pianos if possible, and at least two players, set up microphones and replay systems inside and around the piano(s).

Task. Record various resonant and strongly characterised sounds – e.g. bass notes with the pedal on, some rhythmic repetitions of dissonant chords, pedal down and vocal noises or incantations made inside the piano. Make a long recording, which can be played alongside live use of the piano later on.

Develop a few melodic fragments using all available players and decide on a full structure to the piece – i.e. in which order things will happen and how they will link or overlap.

Playback the recording and play the new structural ideas on the piano(s) over it. Record again, discuss, modify, adjust and improve.

Extension and variation: develop a thematic thread, either melodic or vocal; use a pre-existing poem, e.g. Walt Whitman or Blake, or a biblical extract to indicate the metaphysical meaning of the piece.

Learning: combining electronically generated sounds with live performance; exploring the resonance and ambient sounds of the piano; using pre-existing text to bind a pi

4. MUSIQUE CONCRÈTE

If you can find an old reel to reel tape recorder this is a lot of fun and a good insight into the difficulties of early sound manipulation with technology.

Task. Make some Water Music. Record the sounds of lots and lots of drips and flows of water of varying intensity and speed, in hollow containers, pouring out of milk bottles, in sinks, loo cisterns flushing, etc. Play back and pick out what you want to use lots of. Get a feel of how a sound works when it is played backwards by cutting out a bit of tape and sellotaping it back into the gap. This will stimulate lots of conversation about 'sound envelopes' (the shape or graph of a sound). Depending on time, reconstruct the bits of tape in an order of your choice; rerecord the whole, cut it out and play back; layer the sounds on top of each other; play them at a slower speed and rerecord – and so on.

Extension or variation: play a sustained chord sequence on instruments against or over the playback to give it cohesion; record the result; discuss the different effects which happen in each playback.

Learning: the shape or 'envelope' of sounds; using fragments of sounds as the raw materials for composition; live and recorded sound performance together; team work.

5. SCORES

Find a portion of a score of a work by Stockhausen: for example from the front page of website <http://home.swipnet.se/sonoloco2/Rec/Stockhausen/16.html> or any other short piece of score of one of Stockhausen's pieces. (See also Appendix 3)

Task. Try to reproduce the score live. Discuss at length the meaning of all the symbols and different ways in which they can be interpreted. Stockhausen's work is often played in different versions and he clearly enjoys the performers making their own decisions.

Produce your own score of one of the exercises you have done above. Test it out around the group to see how well it works.

Learning: using scores flexibly and notating accurately for others to read; inventing new symbols where necessary; gaining further insight into Stockhausen's compositional process.

6. MUSIC THEATRE COSMOLOGY

Between 1975 and 1977 Stockhausen composed Sirius, a work for an electronic source, trumpet, soprano, bass clarinet and bass that represents the annual cycle and which is one of his early forays into a more theatrical style. He himself has a very strong sense of the spiritual to the point where he has said that he thinks he comes, spiritually at least, from the star Sirius itself. (See the formula for Sirius on the website. <http://home.swipnet.se/sonoloco7/stockhausen/26.html>).

Task: Make music for the cosmos. Group students into four separate groups – it can be done with only four students but it is asking a lot – the groups don't have to be of even size. One group takes the four seasons, another the times of day (morning, afternoon, evening, night), the third can take either the points on the compass or the four elements (earth, air, fire and water). The fourth develops music for the stellar voyages from the stars to the earth, which will bind the whole piece together. Develop a text for the stars and the seasons to be declaimed or sung by individuals at various points throughout the piece.

Together develop a shape of the composition – its formula – and discuss how the four groups might interweave their materials when it is developed. It may be diagrammatic and/or serial.

At least two of the groups should use electronic manipulation of their sound sources and planning needs to take account of how it will all play live. Performance should be in an atmospheric space – the drama studio is ideal – and each group spaced physically separately from each other. Ensure that enough time is allowed to let each element have space to evolve and develop.

Shorter variation: work on one element with common musical fragments for the whole class – stars or times of day - making sure you have a binding element within the structure.

Learning: managing a large live performance with electronic and acoustic sound; weaving text into music as a mantra or declaration; working from a common formula to a cohesive whole; composing to a brief; beginning to understand Stockhausen's spiritual convictions.

7. ACID SAMPLING

For a contest at ACIDplanet, Stockhausen provided Sagittarius from his Tierkreis (Zodiac) as the formula, along with 12 sound samples. Other samples can be easily accessed on ACID software.

Task: choose 12 different samples and label them. Decide on a sequence of pitches as the formula/structure for the piece. Stretch these pitches in time by a factor of eight or another even number. Play around with various versions of the formula and add or superimpose them on the original with a numerical relationship to the original. Develop a structure for where the samples are used and at what speeds. You can introduce live sound too, as well as words or mantras and perform using the performance space to the full. The movement of sound and the speed of sound in space is very important to Stockhausen.

Learning: using and manipulating samples within a structure; discovering the full potential of the software; performance in space; stretching and diminution of speeds.

Here are a few more ideas using more recent technology (most freely available to download) but still within the philosophical ambit of Stockhausen's work

8. **Audiomulch** (available as a free download) – add an exciting complex polyrhythmic layer to a live performance using a live laptop computer with Audiomulch.
9. **Audacity** (available as a free download) – use this program to practise the development of pieces which alter pitch, tempo, reverse sounds, add reverb, insert additional recordings and sounds and manipulate them. Allows for reasonably extended pieces and provides good technical practice for some of the principles of manipulation that Stockhausen espouses.
10. **Use PhotoStory** (available as a free download) – animate 'paintings' or pictures to illustrate a mystical element – e.g. pictures of stars or seasons. Scan pictures into the computer – visually explore the shapes and textures on the surface of the pictures – export them into Windows **Movie Maker** and add your formula music as a soundtrack. You can do the same in a similar way with **Magix Music Maker 7**. This gets close to the heart of Stockhausen's interest in non-musical stimuli although it is not a method he has used himself.
11. **Loop based programmes** such as **Super Duper Music Looper** (very simple free download), **eJay Studio** and **ACID Music** provide an almost limitless library of sounds and samples in a range of styles for students to select, loop, transfer and manipulate so that they can short-circuit the invention stage to get straight to the composition process used by Stockhausen.

APPENDIX I

RING MODULATION, PITCH AND FREQUENCY

Here is part of a bigger table showing musical pitch and its corresponding frequency in Hertz (Hz), where C3 is Middle C.

C1	<i>65.4</i>	C2	<i>130.8</i>	C3	261.6	C4	523.3
C#1	<i>69.3</i>	C#2	<i>138.6</i>	C#3	277.2	C#4	554.4
D1	<i>73.4</i>	D2	<i>146.8</i>	D3	293.7	D4	587.3
Eb1	<i>77.8</i>	Eb2	<i>155.6</i>	Eb3	311.1	Eb4	622.3
E1	<i>82.4</i>	E2	<i>164.8</i>	E3	329.6	E4	659.3
F1	<i>87.3</i>	F2	<i>174.6</i>	F3	349.2	F4	698.5
F#1	<i>92.5</i>	F#2	<i>185</i>	F#3	370	F#4	740
G1	<i>98</i>	G2	<i>196</i>	G3	392	G4	784
G#1	<i>103.8</i>	G#2	<i>207.7</i>	G#3	415.3	G#4	830.6
A1	<i>110</i>	A2	<i>220</i>	A3	440	A4	880
Bb1	<i>116.5</i>	Bb2	<i>233.1</i>	Bb3	466.2	Bb4	932.3
B1	<i>123.5</i>	B2	<i>246.9</i>	B3	493.9	B4	987.8

If the modulator is F#2 and the carrier is 500 Hz, then the resulting ring modulator tones will be:

'carrier' + 'modulator' and **'carrier' - 'modulator'**

$$500 \text{ Hz} + 185 \text{ Hz} = \underline{\underline{685 \text{ Hz}}} \quad \text{and} \quad 500 \text{ Hz} - 185 \text{ Hz} = \underline{\underline{315 \text{ Hz}}}$$

or to put it another way

a **slightly flat F4** and a **slightly sharp Eb3**

Task. Using the information above, calculate the resulting ring modulation frequencies for the following pairs of 'modulator' and 'carrier' inputs.

modulator	carrier
A1	440.0 Hz
F3	481.4 Hz
G#2	532.3 Hz
C3	726.2 Hz
C1	521.9 Hz

APPENDIX II

HELPFUL WEBSITES

www.stockhausen.org

Stockhausen's official site

<http://home.swipnet.se/sonoloco2/Rec/Stockhausen/08.html>

Descriptions, reviews and pictures on *Mixtur*

<http://home.earthlink.net/~alморitz/mixtur.htm>

Further information and discussion about *Mixtur*

<http://home.swipnet.se/sonoloco2/Rec/Stockhausen/16.html>

Score of *Mantra* on front page plus further details on the piece

www.acidplanet.com/contests/stockhausen

Stockhausen competition on Acid.

http://en.wikipedia.org/wiki/Karlheinz_Stockhausen

General biography and other details

http://www.stockhausen.org/beatles_khs.html

The Beatles and Stockhausen

<http://www.acoustics.salford.ac.uk/feschools/waves/super3.htm>

Acoustical detail about noise cancellation and beats

<http://www.mindspring.com/~scottr/zmusic>

Acoustical detail and sound examples on sine waves and the human voice

<http://www.synthfool.com/ringmod.html>

Further information on ring modulation.

APPENDIX III FILM SYNOPSES

In partnership with EMI and EMI Music Sound Foundation the London Sinfonietta ran an afternoon for 7 schools in April 2006. At this event the following films were shown to provide further insight in to the music of Stockhausen.

Helicopter String Quartet

Stockhausen rehearses and talks about his *Helicopter String Quartet* played by the Arditti Quartet in four separate helicopters. The preparations, including test flights, are documented from the first rehearsal to the world premiere, of which excerpts are shown.

The piece is part of a larger piece written by Stockhausen, *Wednesday from Light* and the quartet is the third scene out of four.

The 4 musicians of a string quartet are airborne in four helicopters and synchronously play a polyphonic string quartet. They react to the rhythms of the rotor blades and to the flying of the helicopters by the pilots, who – through adequate rehearsals – can thus influence the playing of the musicians. From time to time the four string players play identical rhythms using the same bowing, although it is clear that they are isolated and kilometres apart.

As they play, the four musicians are transmitted by cameras and microphones to four towers of television screens and four towers of loudspeakers at the ground station for an audience. During this – through the glass cockpits of the helicopters – also the world can be seen from above.

In Absentia

This film is a collaboration between the Quay Brothers and celebrated avant-garde composer Karlheinz Stockhausen, who composed and conducted music for the film. Shot in black and white and projected in CinemaScope, *In Absentia* combines live action and animation with dazzling use of light to convey the mindscape of a woman alone in a room. She is repeatedly writing a letter with broken off pieces of pencil lead, while outside her window vistas of ever changing light register her very emotion. The film is dedicated to 'E.H. who lived and wrote to her husband from an asylum.' *In Absentia* was produced by Keith Griffiths at Konick for the BBC and Pipeline Films' series of short music films 'Sound on Film International.'

(This series also includes film by Neil Hartley, Louis Andriessen, Nicolas Roeg on Adrian Utley if Portishead, and Werner Herzog on John Tavener.)