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STUDIO REPORT

Spatialization of Karlheinz Stockhausen's COSMIC PULSES

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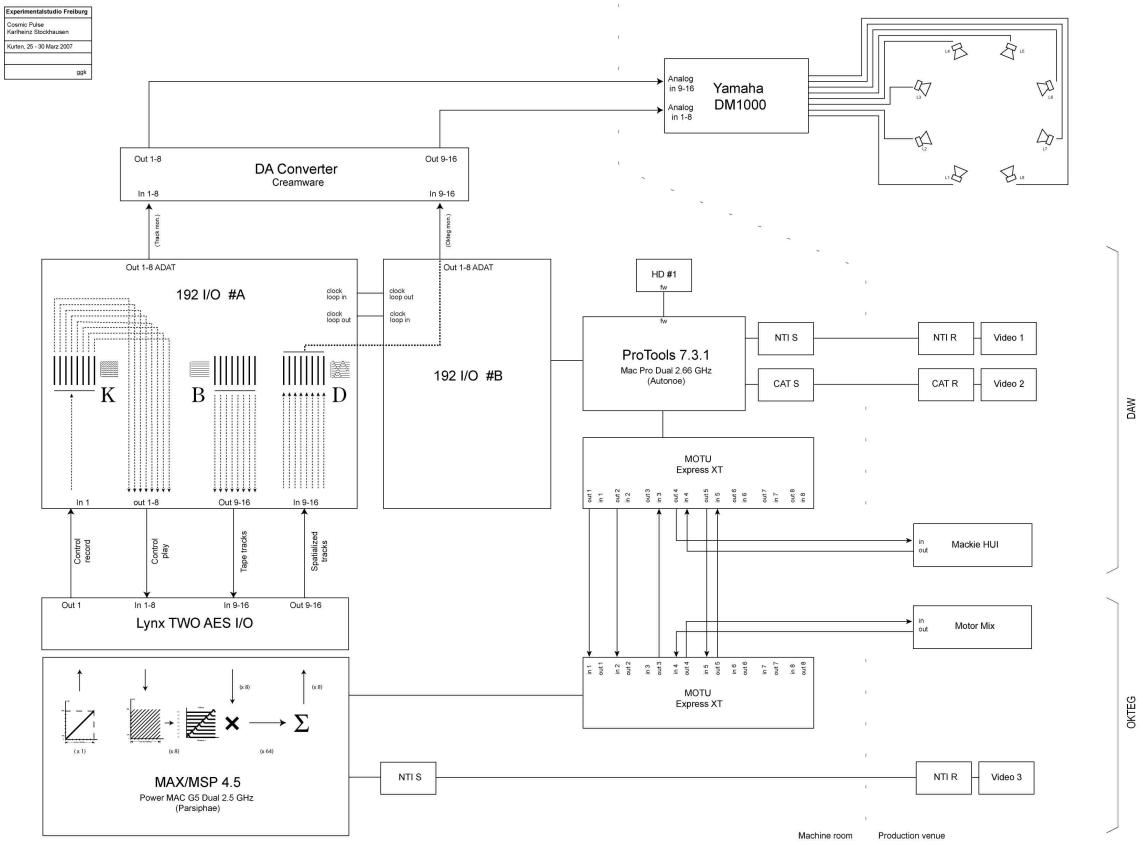
This report describes the final stage of the production of Karlheinz Stockhausen´s COSMIC PULSES, an eight-channel electronic music piece conceived as the 13th hour of the cycle KLANG (SOUND), the 24 hours of the day [1]. For this project, the *Experimentalstudio für akustische Kunst* in Freiburg [2] was commissioned by Stockhausen to produce the spatialization of 24 sound layers over 8 channels, according to a series of 241 rotations. These layers -in forehand produced by the composer- were made up of synthesizer recordings of about 24 minutes each. During the course of the piece, each of these layers should rotate according to given sets of loudspeaker series, synchronized with specific time cues. The production of this project was carried out by Joachim Haas and Gregorio Karman at the *Experimentalstudio* in Freiburg, between December 2006 and April 2007, in constant communication with the composer, while the spatialization itself took place at Stockhausen´s installations in Kürten between the 25th and 31st of April 2007. Spatialization techniques employed by Stockhausen in previous similar projects were studied, and several alternative plans were put to consideration regarding the strategy to follow and the choice of spatial engines and interfaces, with special concern on the design of the production process itself.

System overview

The system developed for COSMIC PULSES is based on a spatialization device –the OKTEG– handling the real-time panning of eight simultaneous layers, coupled together with a Digital Audio Workstation (DAW) in charge of layer playback, trajectory recording and mixing tasks. The core of the OKTEG is a *Max/MSP* [3] patch that implements eight variable-law amplitude-panning modules, each of them driven by a sequencer with its own tempo control. These eight sequencers are controlled by means of messages managed by an execution queue, containing the rotation data. The tempo of each sequencer is adjusted in real-time by means of motor faders. A salient feature of this design is that spatial performance is encoded as a frequency-modulated audio-rate sawtooth and recorded as a standard audio track in the DAW, providing an integrated and sample-accurate trajectory recording environment.



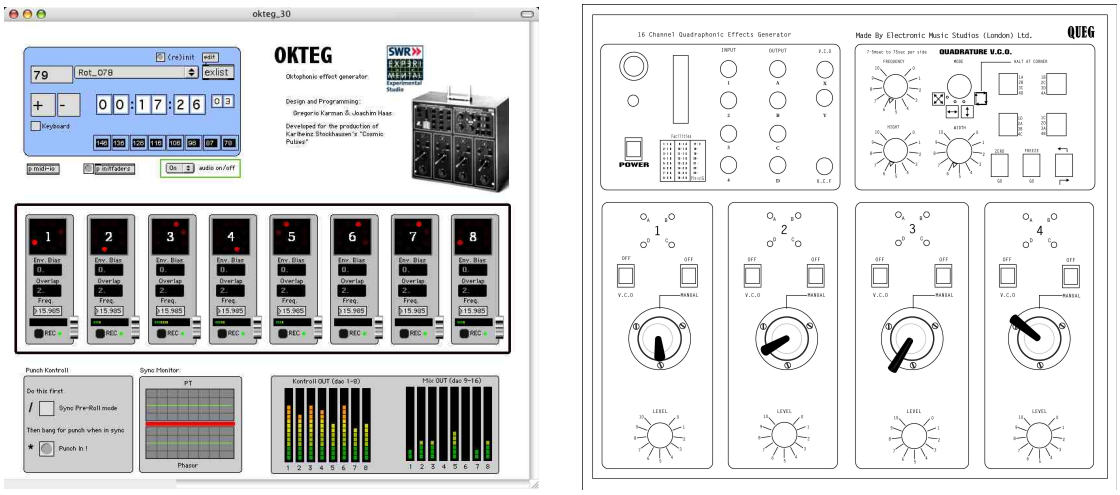
[Fig. 1. System diagram and signal flow]

The diagram above shows an overview of the implementation and signal flow of the system used. For the recording of trajectories a *Mac Pro* based *ProTools HD* system with two *192 I/O* 16-channel interfaces was chosen. Layer playback, sequence triggering and routing for audio monitoring are also performed within the same *ProTools* box. The OKTEG behaves as an eight-channel insert processor, running on a *Power MAC G5* computer shipped with a *Lynx TWO* PCI card with 16 digital I/O channels. Further hardware involved a mixing desk for signal monitoring, two motor fader control surfaces, USB + video monitor extenders, and eight high-end audiophile quality loudspeakers. The specific details of signal flow and interaction between the control bus (K) and the raw layers (B) as well as the downmix (D) tracks are explained below.

The OKTEG

The OKTEG is an eight-channel spatialization unit for positioning eight simultaneous signals over eight loudspeakers, purposely designed for the production of COSMIC PULSES. It merges different ideas present in former devices such as the QUEG, the *Rotationsmühle,* or the *Rotationstisch*, all related to previous works composed by Stockhausen. The QUEG (*Qadrophonic Effects Generator*), a four-channel spatialization unit -designed by Tim Orr and

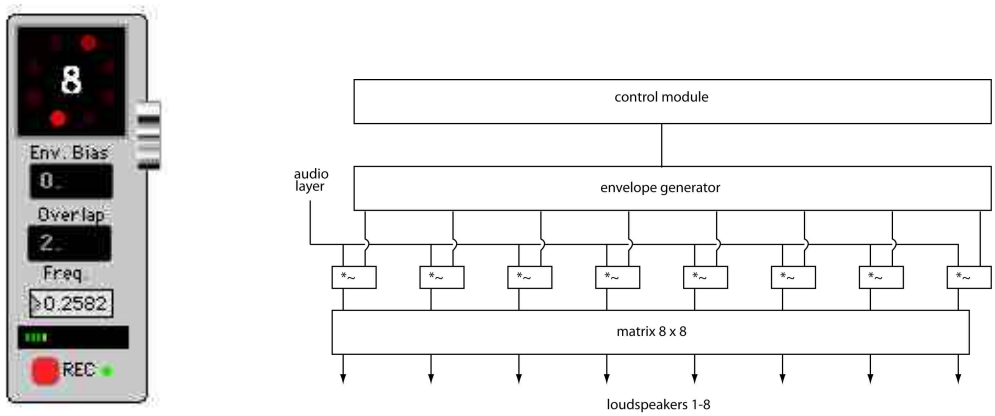
manufactured by *EMS* in 1975- was used by Stockhausen in OKTOPHONIE (1990/1991). The OKTEG resembles the QUEG for being a spatial step sequencer, as well as in its LED-based visual feedback system. However, the new design allows for an optimised production process when compared to the overdubbing-downmixing procedure described in the foreword of the latter score [4]. Like in the *Rotationsmühle* –a device used in the spherical auditorium at the World's Fair in Osaka and later implemented as output stage of the *Klangwandler* [5]- the OKTEG provides the performer with manual control of rotation velocity, and different routings are accomplished by means of matrix programs. The *Rotationstisch,* first used as a spatializaton instrument in KONTAKTE, was later further developed for exploring the artifacts which appeared at very high rotation speeds [5, 6, 7]. Following this idea, the OKTEG provides with sample accurate trajectories and arbitrary high rotation speeds, assisting the exploration of a continuum linking space and timbre. When sound trajectories get close to the upper velocity range of 16 rot/sec in the composition of COSMIC PULSES, the perception of movement is gradually transformed into a diffuse and vibrating spatial quality. Higher rotation frequencies manifest themselves as audible modulation effects. Further alternatives including graphical input of trajectories, or more complex virtual space simulation techniques were also discussed, but didn't prove to be adequate for materializing Stockhausen's spatial conception for this composition.



[Fig. 2. Screenshot of the OKTEG´s MAX patch interface (left). Illustration of the front-panel of the EMS QUEG (right)]

The figure below shows the graphical interface of a single OKTEG module, with LED monitoring of active loudspeakers, envelope-shaping controls (*Bias/Overlap*), numerical display of rotation frequency, position within the cycle (horizontal level-meter), and recording and sync

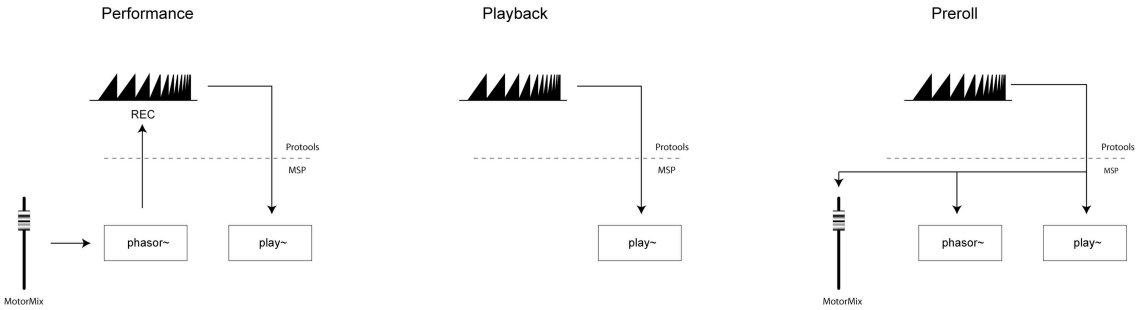
lights. The illustration on the right schematizes the block diagram of one OKTEG channel consisting of a control module, an envelope generator and an 8x8 matrix.



[Fig. 3. Graphical interface (left) and functional diagram (right) of a single OKTEG channel]

Control Module

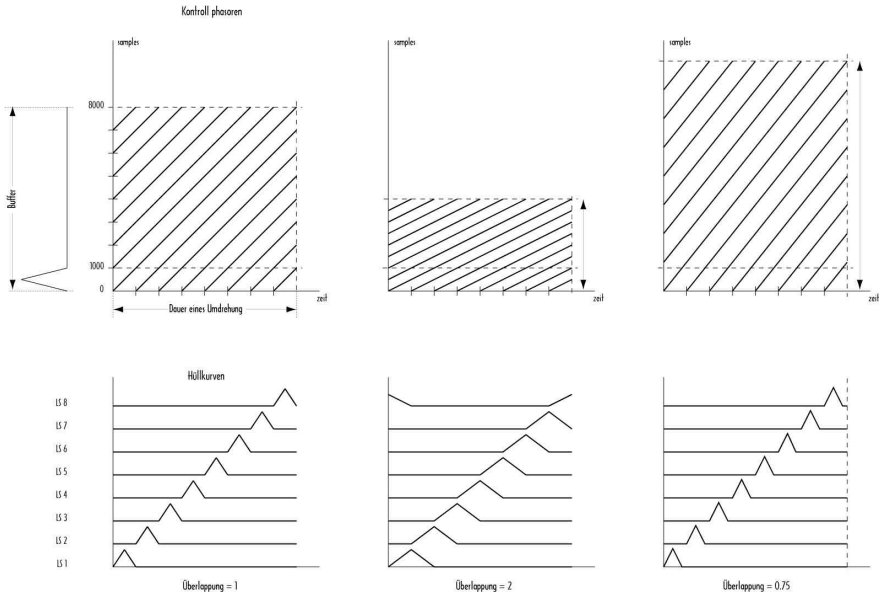
The Control Module is in charge of generating the driving signal, which directly controls the cycle rate of the space sequencer. In the *Max/MSP* patch, an oscillator, whose frequency is controlled by means of a physical fader, generates the audio-rate control sawtooth. During performance, this signal is recorded as an audio track in *ProTools*, registering an imprint of the performed speed variations. Once recorded, the control module switches to playback mode, using the recording instead as control source for the envelope generator. For eventual corrections of the spatial performance, a punch-in mode is provided. In this mode, a *phase locked loop* compares the frequency of the recorded sawtooth with the local oscillator during pre-roll time, adjusting both oscillator frequency and motor fader position for smooth trajectory punch-in.



[Fig. 4. Control flow in *Performance*, *Playback* and *Preroll* modes]

Envelope Generator

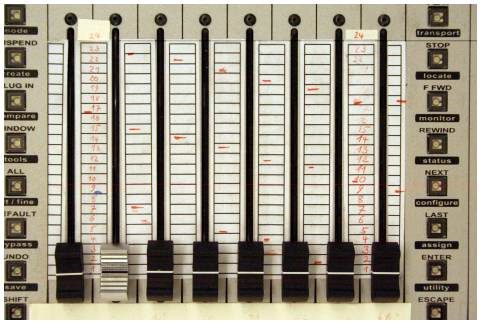
The Envelope Generator module is responsible for turning the modulated sawtooth coming from the control module into an eight-channel envelope signal. The incoming sawtooth is split into eight channels by shifting and applying the modulo-operator. The resulting phasors are then used to read the panning function (Fig 5). Further parameters that can be adjusted at this stage are *overlapping*, and continuous envelope shaping or *bias*. For COSMIC PULSES an *overlapping* value of 2, and a squared sinus envelope shape ($\sin^2$) were judged to be the most adequate settings throughout. In the final stage, the multi-channel envelope is multiplied with the sound fed to the OKTEG, and sent through the matrix to obtain the desired loudspeaker sequence.



[Fig. 5. Eight time-shifted phasors (above) are used to read the envelope function stored in a buffer for obtaining the multichannel envelope (below). Overlapping = 1 (left), Overlapping = 2 (middle), Overlapping = 0.75 (right)]

Rotation range and tempi scale

Different tempo "tunings" and ranges were discussed during the production stage of the OKTEG. The slowest rotation period chosen in the end was 16 seconds, and the fastest 0.0625 seconds (i.e. 16 rot/sec). Tempo for each OKTEG channel can be varied continuosly within these two boundaries by means of motor-faders. A tempo scale with 24 steps was defined, for being used used in COSMIC PULSES as "tempo keynotes" for each one of the 24 of the layers. Consecutive tempi within this scale are related by a ratio of $1:\sqrt[23]{256}$, an interval between a major third and a perfect fourth.



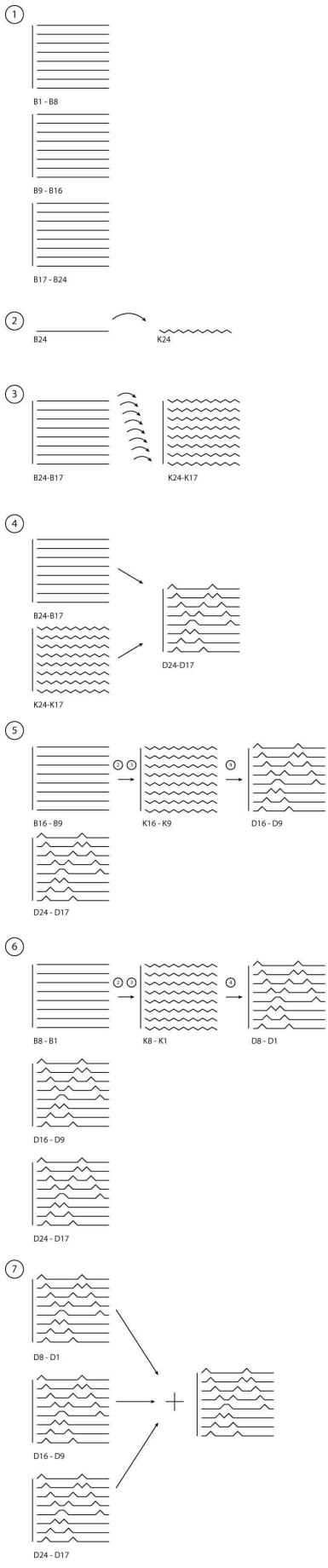
OKTEG tuning used for Cosmic Pulses

	Rotation period [seconds]			Frequency [rot/sec]		
	Perfect fourth	Major third	OKTEG	Perfect fourth	Major third	OKTEG
	$\frac{3}{4}=0{,}75$	$\frac{4}{5}=0{,}8$	$\frac{1}{\sqrt{256}}=0{,}7857672331$			
Layer						
1	16	16	**16**	0,0625	0,0625	**0,0625**
2	12	12,8	**12,57227573**	0,083333333	0,078125	**0,079540095**
3	9	10,24	**9,878882314**	0,111111111	0,09765625	**0,101226026**
4	6,75	8,192	**7,762502022**	0,148148148	0,122070313	**0,128824443**
5	5,0625	6,5536	**6,099519736**	0,197530864	0,152587891	**0,163947334**
6	3,796875	5,24288	**4,792802746**	0,263374486	0,190734863	**0,208646183**
7	2,8476563	4,194304	**3,766027353**	0,351165981	0,238418579	**0,265531794**
8	2,135742188	3,3554432	**2,959220893**	0,468221308	0,298023224	**0,337926784**
9	1,601806641	2,68435456	**2,325258813**	0,624295077	0,37252903	**0,430059654**
10	1,20135498	2,147483648	**1,827112184**	0,832393436	0,465661287	**0,547311768**
11	0,901016235	1,717986918	**1,435684885**	1,109857915	0,582076609	**0,696531677**
12	0,675762177	1,374389535	**1,12811414**	1,479810553	0,727595761	**0,886435126**
13	0,506821632	1,099511628	**0,886435126**	1,973080737	0,909494702	**1,12811414**
14	0,380116224	0,879609302	**0,696531677**	2,630774316	1,136868377	**1,435684885**
15	0,285087168	0,703687442	**0,547311768**	3,507699088	1,421085472	**1,827112184**
16	0,213815376	0,562949953	**0,430059654**	4,676932118	1,776356839	**2,325258813**
17	0,160361532	0,450359963	**0,337926784**	6,23590949	2,220446049	**2,959220893**
18	0,120271149	0,36028797	**0,265531794**	8,314545987	2,775557562	**3,766027353**
19	0,090203362	0,288230376	**0,208646183**	11,08606132	3,469446952	**4,792802746**
20	0,067652521	0,230584301	**0,163947334**	14,78141509	4,33680869	**6,099519736**
21	0,050739391	0,184467441	**0,128824443**	19,70855345	5,421010862	**7,762502022**
22	0,038054543	0,147573953	**0,101226026**	26,27807127	6,776263578	**9,878882314**
23	0,028540907	0,118059162	**0,079540095**	35,03742836	8,470329473	**12,57227573**
24	0,021405681	0,09444733	**0,0625**	46,71657114	10,58791184	**16**

Division of the range 1/16 – 16 rot/sec in 24 steps. ($3{:}4 < \sqrt{256} < 4{:}5$).

[Fig. 6. (above) Annotated motor-fader surface after the production, and rotation velocity scale]

[Fig. 7. (left) Production workflow]



Workflow

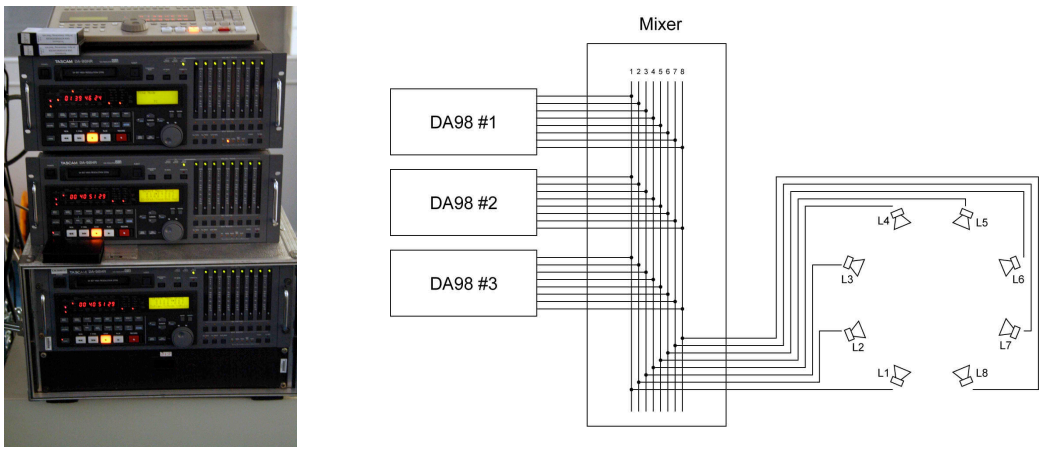
In this section, the spatialization procedure that was followed is described (Fig.7). Initially the *ProTools* project is loaded with the 24 raw sound layers to be spatialized (1). The first step in the production is processing layer -*B24*- through the OKTEG. Playing the OKTEG involves real-time performance of rotation speed and level during the length of the layer by means of motor faders. The spatial information, encoded as a frequency-modulated sawtooth, is recorded in track *K24* (2), while dynamics are stored as standard level automation data in track *B24*. This action is repeated eight times for each of the subsequent tracks (3), while hearing the previously performed layers as in an

overdubbing process. Spatial movements are rendered live through the OKTEG insertions, thus speed and level corrections can be made before downmixing the first 8-packet to the eight *D-tracks* (4). Once consolidated, the original *B-layers* and the control *K-tracks* are deactivated in order to free resources, but still if any adjustments should be needed after bouncing, the tracks could be effortlessly made active again. The same process described in steps (2) and (3) is repeated with the second 8-packet -*B16* to *B9*- (5) in order to obtain the second downmix. Again, the process is repeated for the last eight layers, *B8* to *B1* (6). Finally, the relative levels of the resulting three packets are adjusted by means of VCA automation.

Master Tapes

Two different Master sets of COSMIC PULSES were produced. In the first version, the resulting 24 *D*-tracks from the final *ProTools* session were directly transferred to three *Tascam DA98* digital tape recorders, attached to the TDIF ports of the *ProTools* interfaces. The three resulting DTRS tapes of the digital transfer contain:

TAPE 1: spatialized layers 1-8
TAPE 2: spatialized layers 9-16
TAPE 3: spatialized layers 17-24



[Fig. 8. Tascam DA98 used for the recording of the the master tapes (left), and track-loudspeaker relation for sound projection (right)]

These tapes are to be played with three *DA98* machines running simultaneously (time-code synced), which should be combined in an external mixing console for projection over eight loudspeakers according to the before given routing diagram (Fig. 8). The second master set is based on the eight-track reduction of the 24 *D-tracks* (7). The downmix was digitally transferred

to one *DA98* to produce an eight-track version master tape. Each of the eight tracks of this tape corresponds, one-to-one, to each of the loudspeaker channels.

After the master tapes of COSMIC PULSES were finished, a further production stage was to be carried out at request of Professor Stockhausen. The level automation of the individual layers should be neutralized (while keeping the original spatial performance recorded for COSMIC PULSES) and each of the 24 layers bounced separately to be used for the production of further electronic materials for KLANG (Fig. 16.). The 192 (24x8) resulting audio files (24bit @ 48 KHz), were labelled with the layer and loudspeaker tags (*layer_#24_LS1, layer_#24_LS2, layer_#24_LS3… layer_#23_LS1, layer_#23_LS2*, etc.), and delivered in 12 single-layer DVDs to *Stockhausen-Verlag* at the beginning of July 2007.

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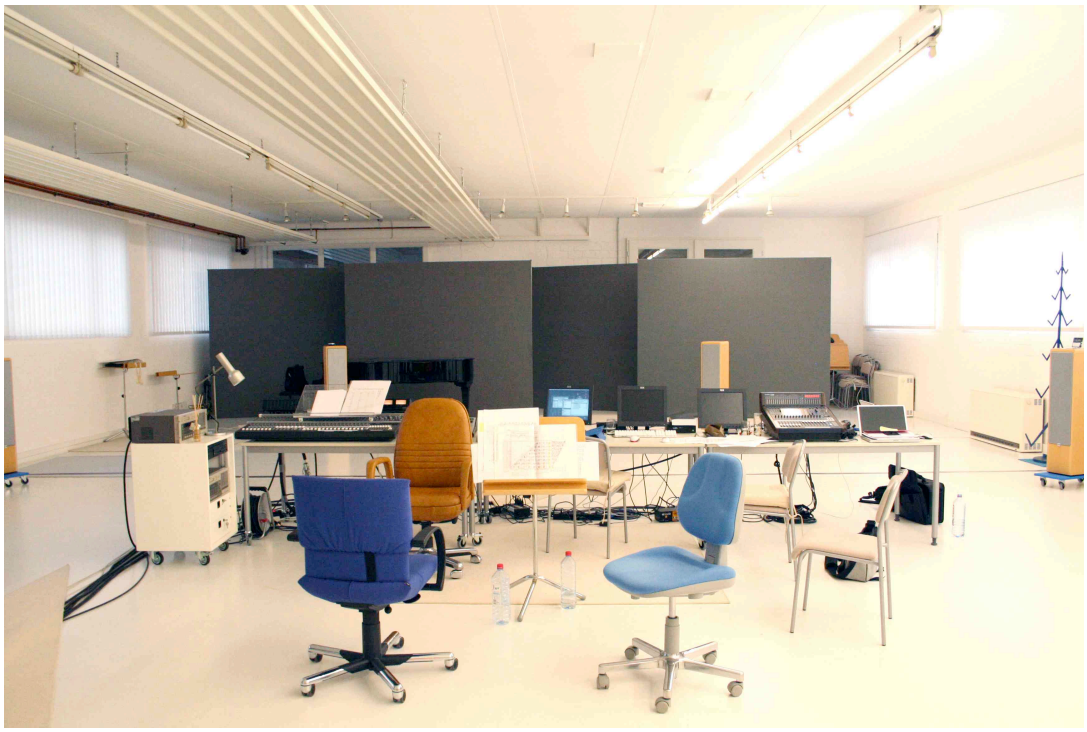
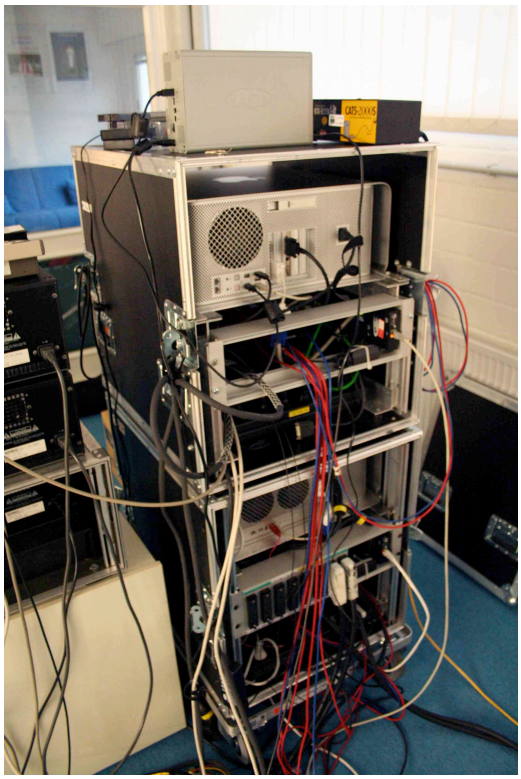
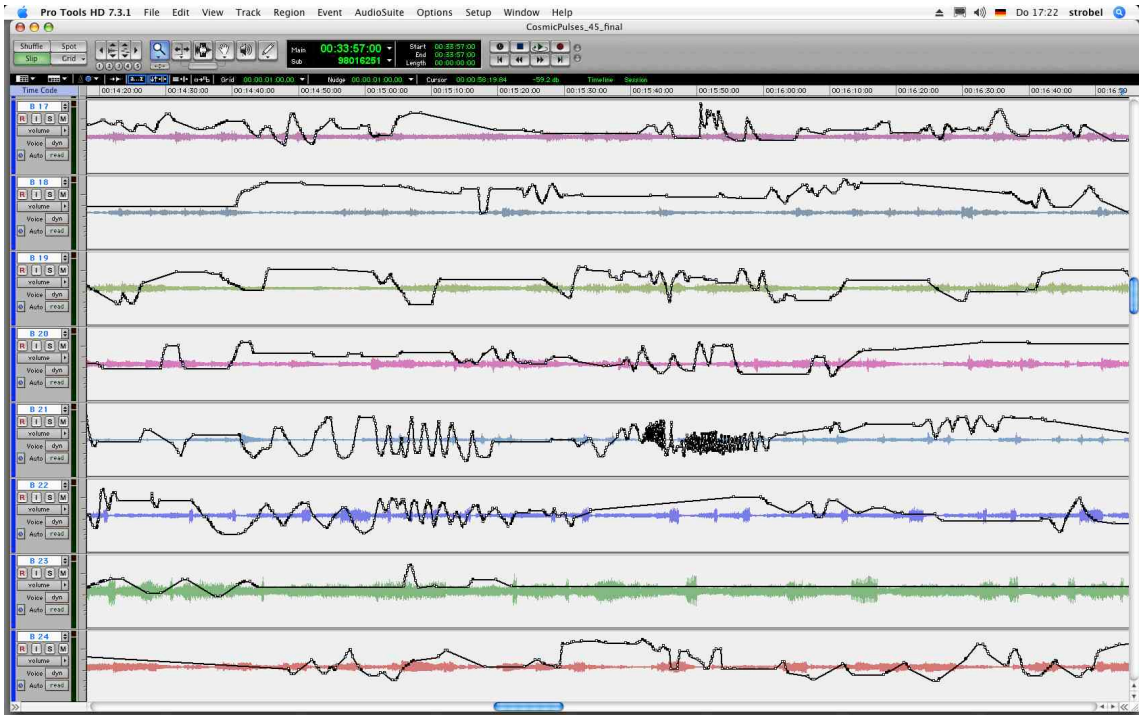
[Fig. 9. Production venue at Stockhausen's facilities in Kürten]



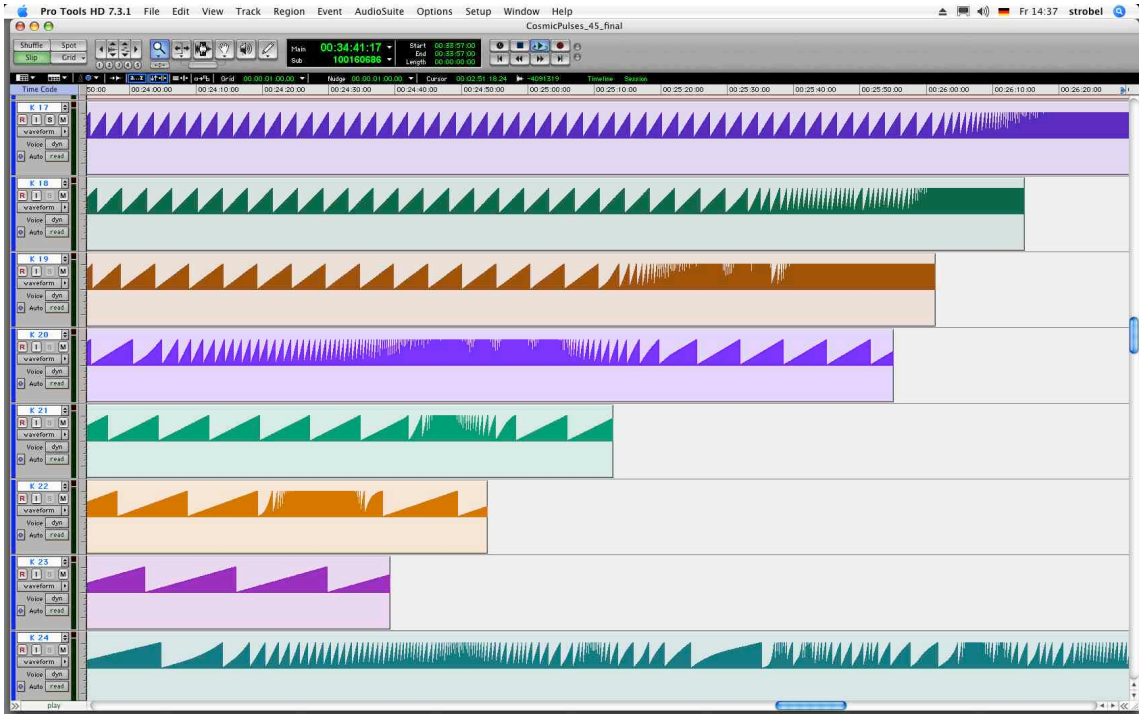
[Fig. 10. Machine Room – *Experimentalstudio's* computers used for the spatialization of COSMIC PULSES]



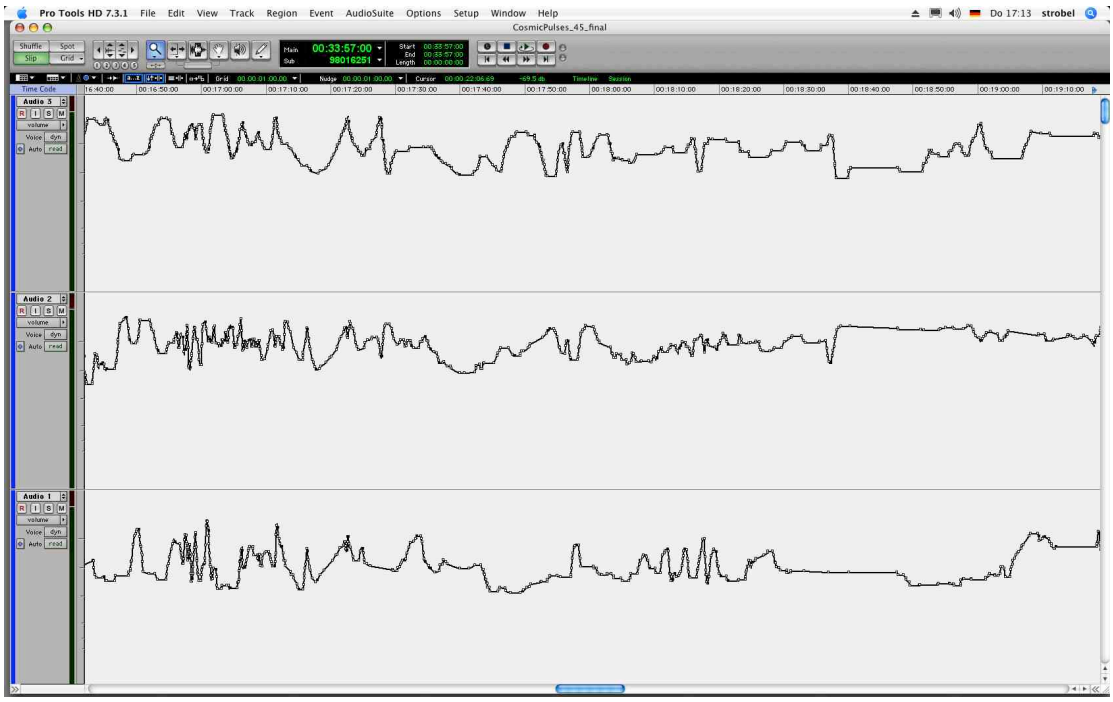
[Fig. 11. Excerpt of recorded volume envelopes of layers 24 to 17 (14'20"-16'50")]



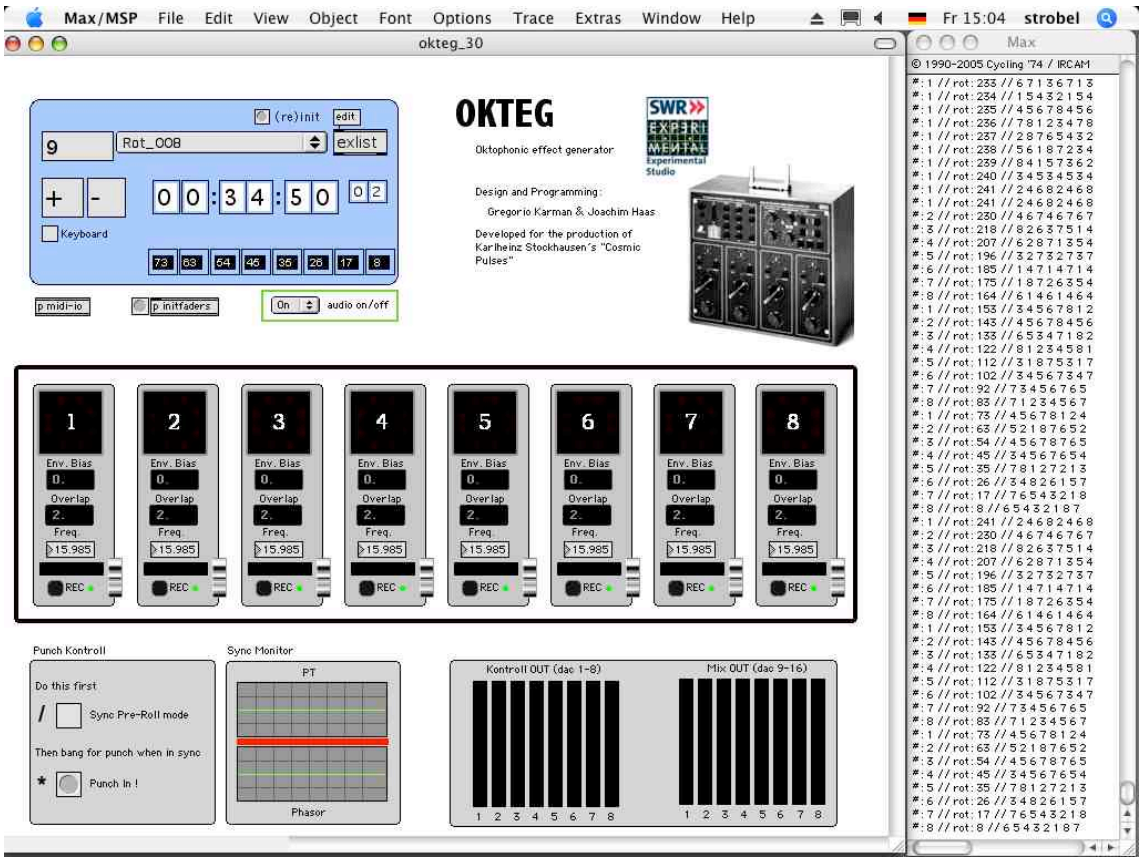
[Fig. 12. *K- tracks* excerpt from Stockhausen's spatialization performance of layers 24 to 17 (23'50"-26'30")]



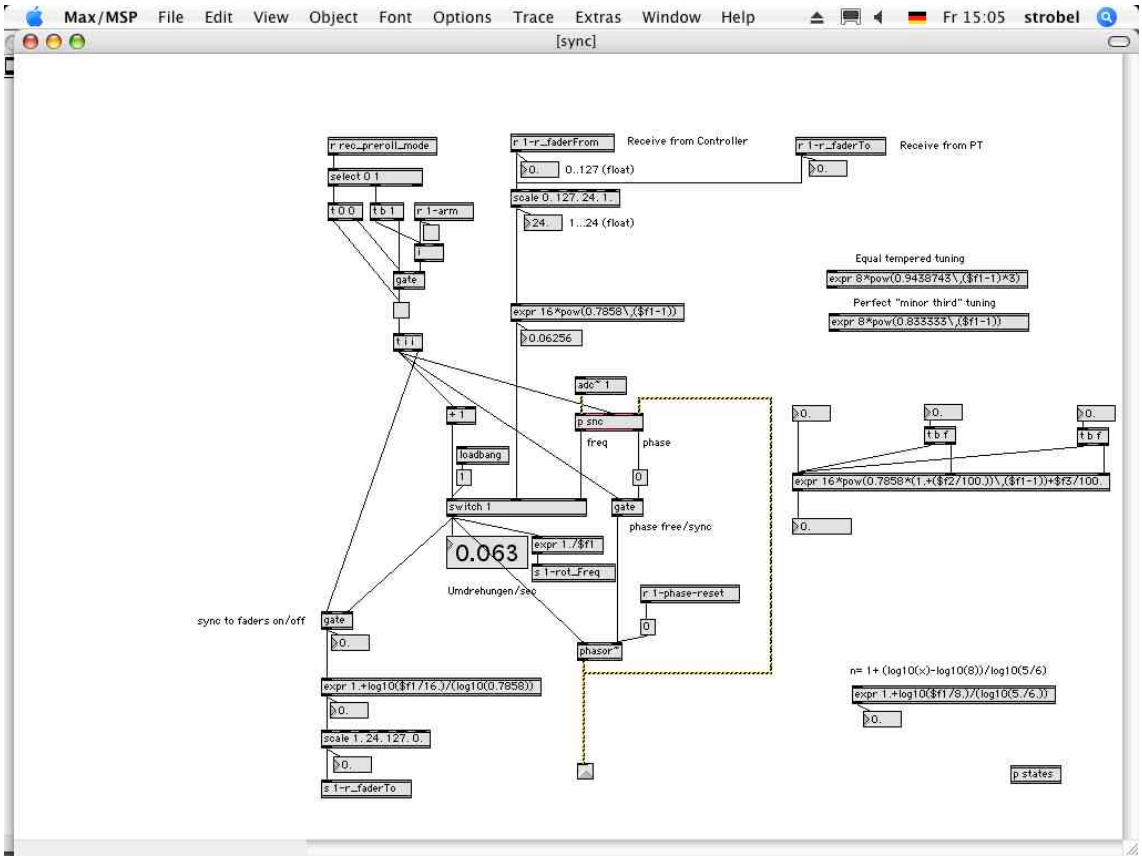
[Fig. 13. Dynamics automation corresponding to the three spatialized eight-packet groups (16'40"-19'10")]



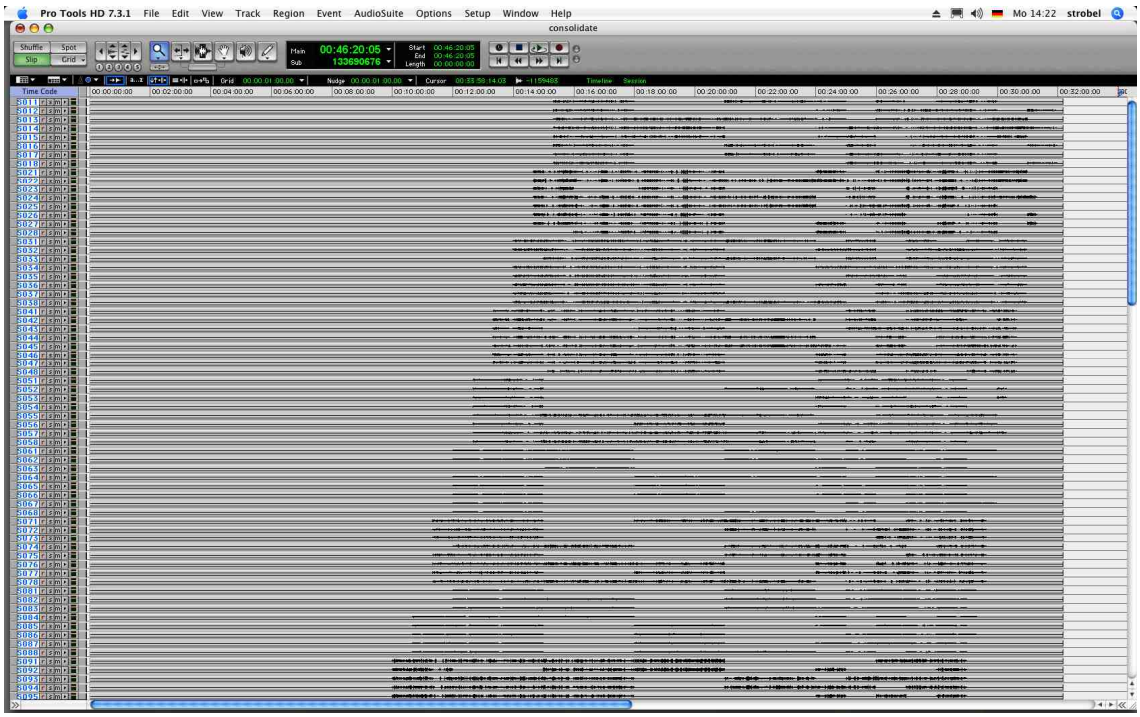
[Fig. 14. OKTEG´s graphical interface]

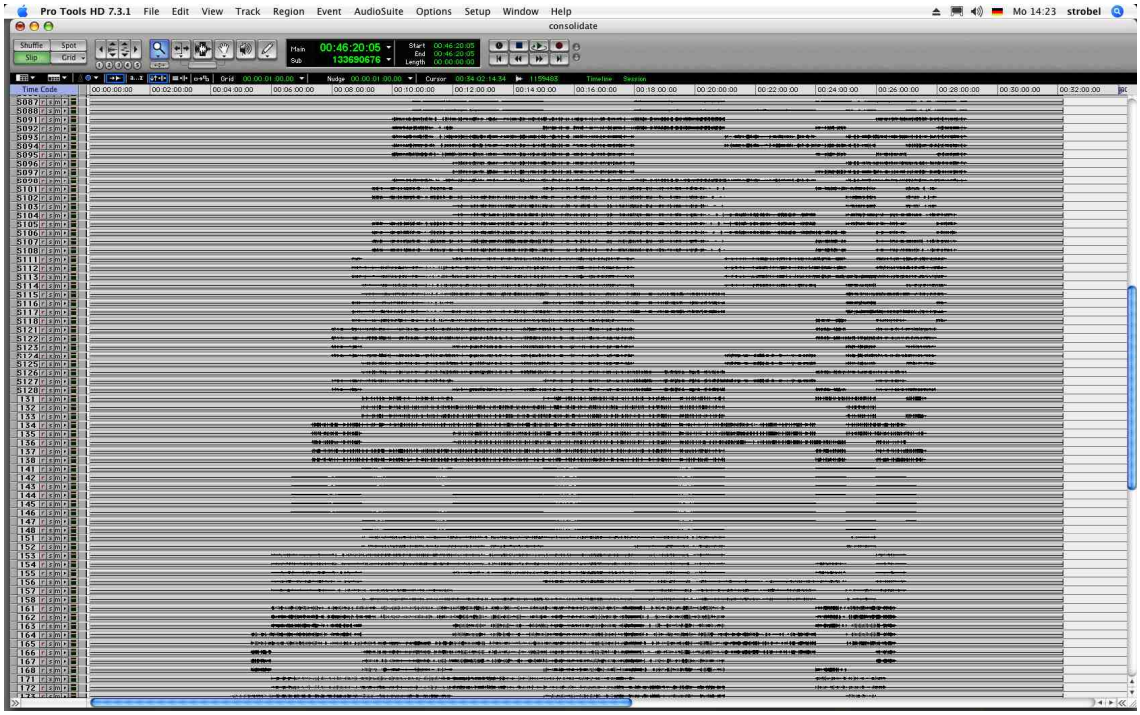


[Fig. 15. OKTEG's patch detail]



[Fig. 16. Individually spatialized layers (192 tracks) for KLANG]

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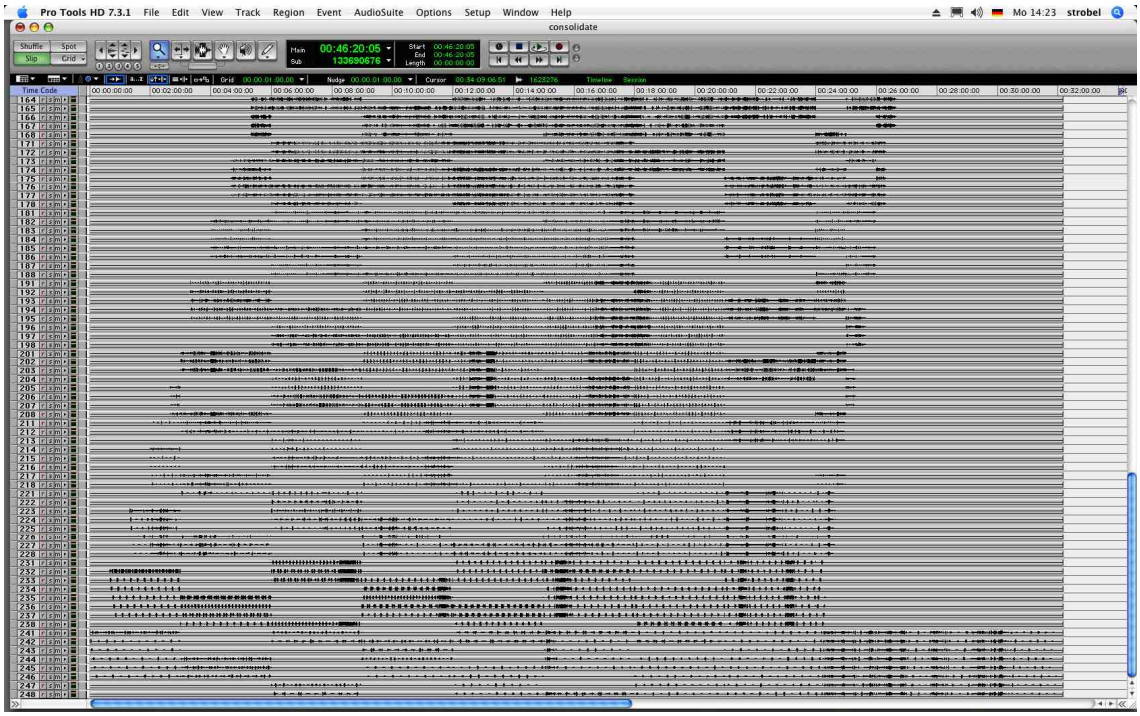
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References

[1] <http://www.stockhausen.org/cosmic_pulses.html>

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[7] Nauck, Gisela: *Musik im Raum – Raum in der Musik*: ein Beitrag zur Geschichte der Seriellen Musik. Stuttgart: Steiner, 1997, p. 192.