UNIVERSIDAD POLITÉCNICA DE MADRID

E.T.S.I.S. TELECOMUNICACIÓN

ATHENS COURSE UPM94

Practice

Design of a Cinema Theater with digital multichannel sound and THX certification

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DEPARTAMENTO DE INGENIERÍA AUDIOVISUAL Y COMUNICACIONES

1. INTRODUCTION

The design of a cinema theater with digital multichannel sound that complies with the requirements of the THX - DOLBY 7.1 certification is intended. The cinema is a large room, with a capacity of approximately 750 seats and is located in a multiplex cinema complex isolated from other types of buildings.

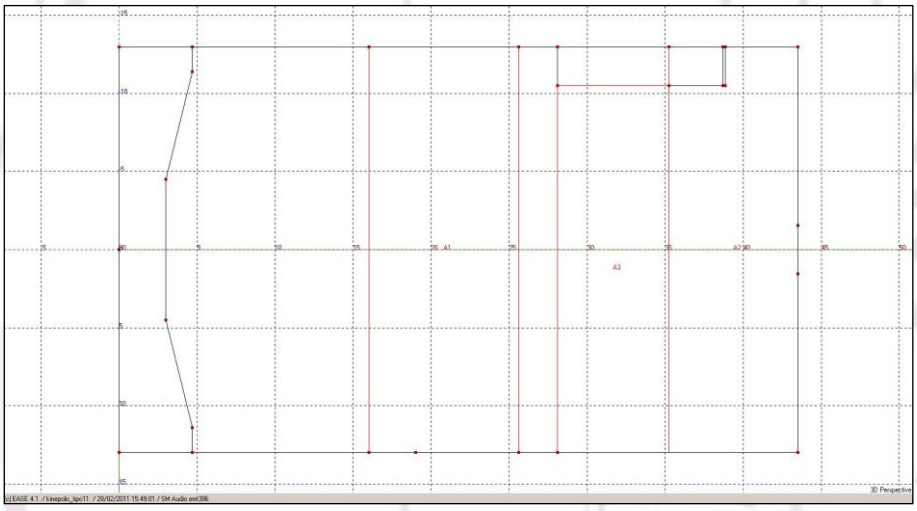
We have EASE 4.3.5 program and the file **kinepolis_6_7.ppj** that contains the original data of the room are available (both construction and acoustic conditioning).

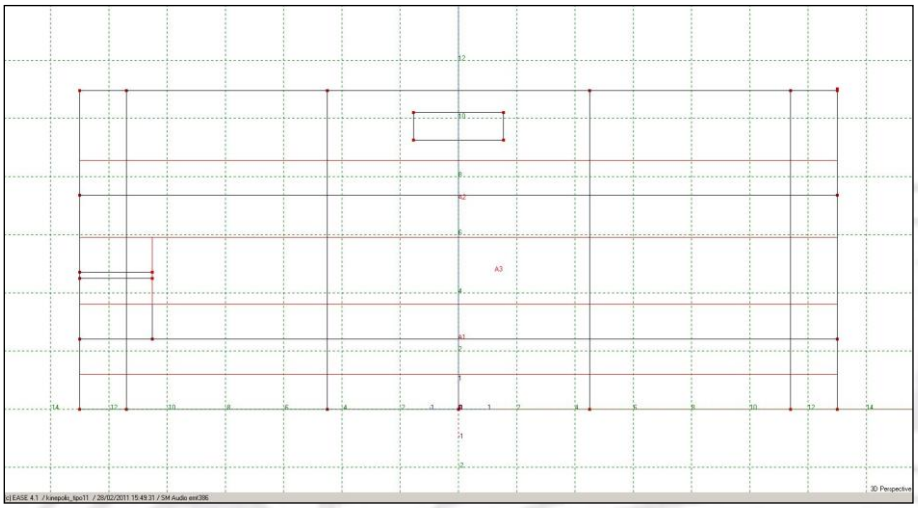
The main objective is that students modify the room to the requirements of the THX certification in relation to the room dimensions, screen dimensions, number of seats, reverberation time, indoor noise conditions, of acoustic isolation conditions, etc. Also, the student should select speaker system that considers appropriate (certified THX) depending on the volume of the room to make a projection in the Dolby Digital 7.1. The speaker system must specify screen channels, subwoofer channels and surround channels, as well as the required amplification system, possible processors (filters and equalization) and dimensioning of wiring. It is recalled that THX certified makes explicit reference to the placement of the speakers in a sound wall behind the screen.

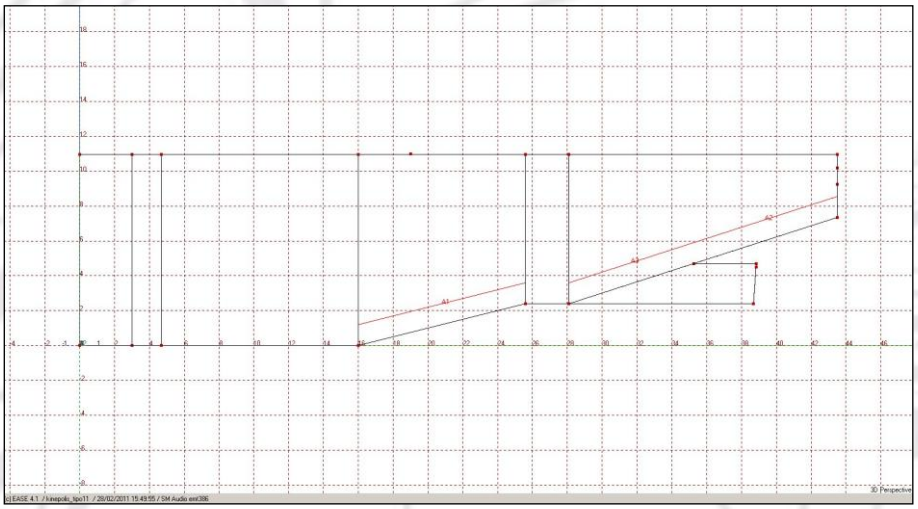
Finally, the equalization of the room as specified with the curve X (ISO-2969) must be done.

The selection of the speaker system must be decision by the student, and so must choose the brand deemed more convenient between the data available in EASE (in existing or either via web).

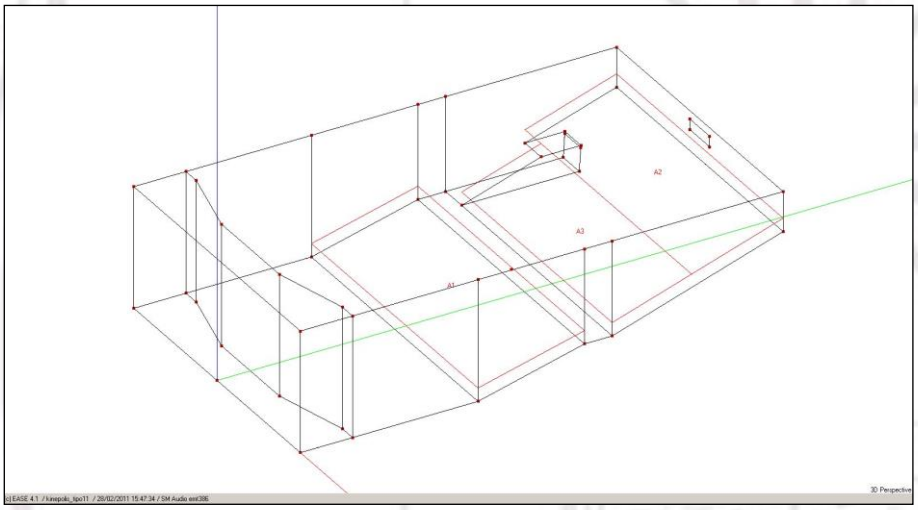
In the room will be mounted a screen with dimensions of 22 m x 10 m, which allows a projection of digital films in Scope format (2.35:1).







Floor and elevations view in the cinema theater



Tri-dimensional view in the cinema theater

2. PRACTICE DEVELOPMENT

Acoustic Features

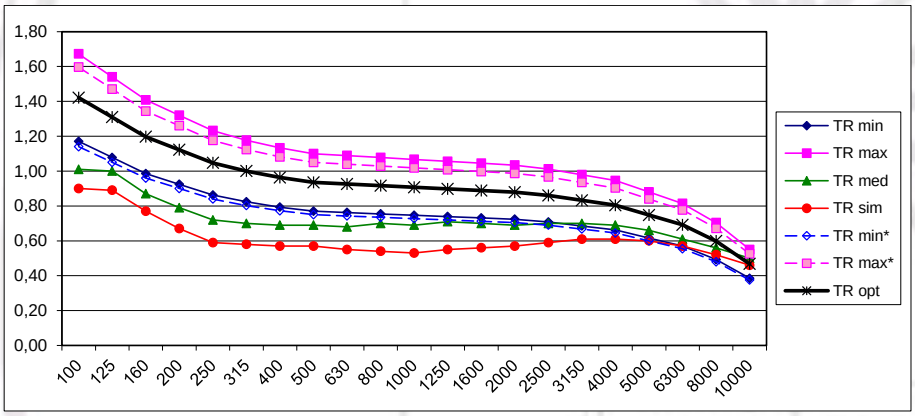
First of all, room data conditions in which it is delivered must be obtained in order to be able to have an idea of the problems that it presents. Information of the existing reverberation time and free room volume must be obtained. Also must get information

from the acoustic characteristics of the room surface materials (in the provided room the acoustic characteristics of the material of the walls of the room were modified in order to adjust the reverberation time of agreement which are actually measured in the room).

The process to be followed will be at first calculate the reverberation time according to proposals studied in theory (Sabine, Eyring, etc.), starting by adjusting the $TR_{500}Hz$ depending on the size of room and adjusting it to the other third octave bands, according to the frequency variation of RT. It should be remembered that this adjustment is made on the basis of the room volume, or what is the same as the number of seats that will have the cinema theater. As it is known, this parameter of $TR_{500}Hz$ is going to find inside a gauge of values. You should compare the ideal setting of the reverberation time with the time that initially has the room. Then we will know how to act to get closer to the ideal situation of adjustment. Remember, that EASE has reverb time setting curves (Standard, Dolby and THX).

TR500 (s)	0,77	1,1						
TR500* (s)	0,75	1,05						
TR500 0pt(s)		0,94						
Volumen:	10018m3	Volumen:	353993ft3					
Volumen*:	8922m3	Volumen*:	315077ft3	* descontando el volumen de detrás de la pantalla				

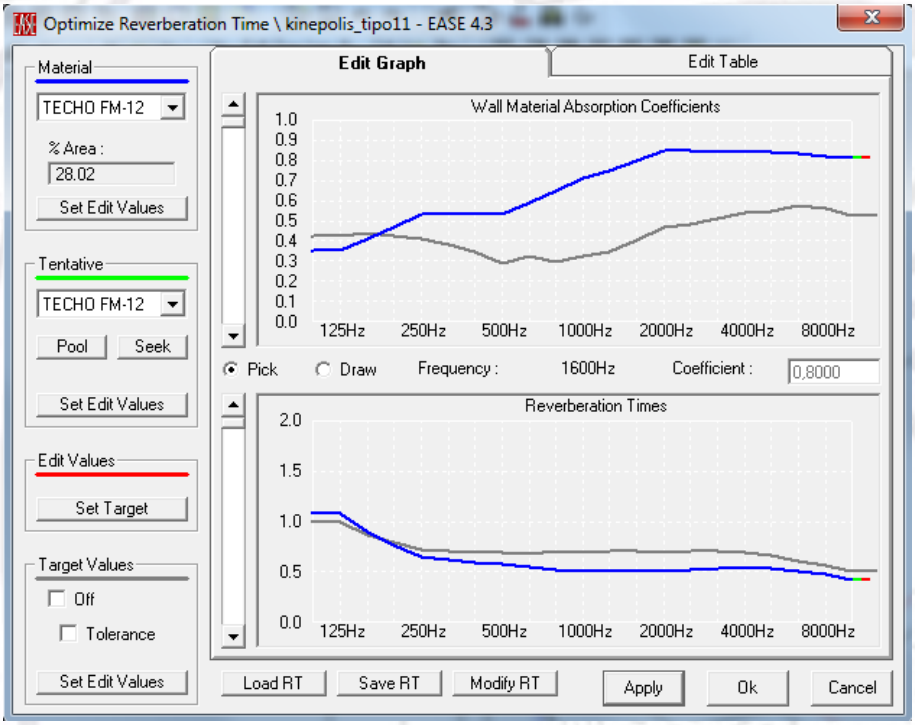
Banda	TR500 ratio	TR min (s)	TR max (s)	TR min* (s)	TR max* (s)	TR medido (s)	TR simulado (s)	TR opt (s)
100	1,52	1,17	1,67	1,14	1,60	1,01	0,90	1,42
125	1,40	1,08	1,54	1,05	1,47	1,00	0,89	1,31
160	1,28	0,99	1,41	0,96	1,34	0,87	0,77	1,20
200	1,20	0,92	1,32	0,90	1,26	0,79	0,67	1,12
250	1,12	0,86	1,23	0,84	1,18	0,72	0,59	1,05
315	1,07	0,82	1,18	0,80	1,12	0,70	0,58	1,00
400	1,03	0,79	1,13	0,77	1,08	0,69	0,57	0,96
500	1,00	0,77	1,10	0,75	1,05	0,69	0,57	0,94
630	0,99	0,76	1,09	0,74	1,04	0,68	0,55	0,93
800	0,98	0,75	1,08	0,74	1,03	0,70	0,54	0,92
1000	0,97	0,75	1,07	0,73	1,02	0,69	0,53	0,91
1250	0,96	0,74	1,06	0,72	1,01	0,71	0,55	0,90
1600	0,95	0,73	1,05	0,71	1,00	0,70	0,56	0,89
2000	0,94	0,72	1,03	0,71	0,99	0,69	0,57	0,88
2500	0,92	0,71	1,01	0,69	0,97	0,70	0,59	0,86
3150	0,89	0,69	0,98	0,67	0,93	0,70	0,61	0,83
4000	0,86	0,66	0,95	0,65	0,90	0,69	0,61	0,80
5000	0,80	0,62	0,88	0,60	0,84	0,66	0,60	0,75
6300	0,74	0,57	0,81	0,56	0,78	0,61	0,57	0,69
8000	0,64	0,49	0,70	0,48	0,67	0,56	0,52	0,60
10000	0,50	0,39	0,55	0,38	0,53	0,50	0,46	0,47



Cinema room reverberation time

EASE-simulated reverberation time

Where the reverberation time does not fit to the recommended, the student shall propose changes which should be in the room. Materials of room limit surfaces must modify to adjust the reverberation time to values obtained in the previous step. At least must get that the variation of the reverberation time versus frequency is more like studied in theory as possible.



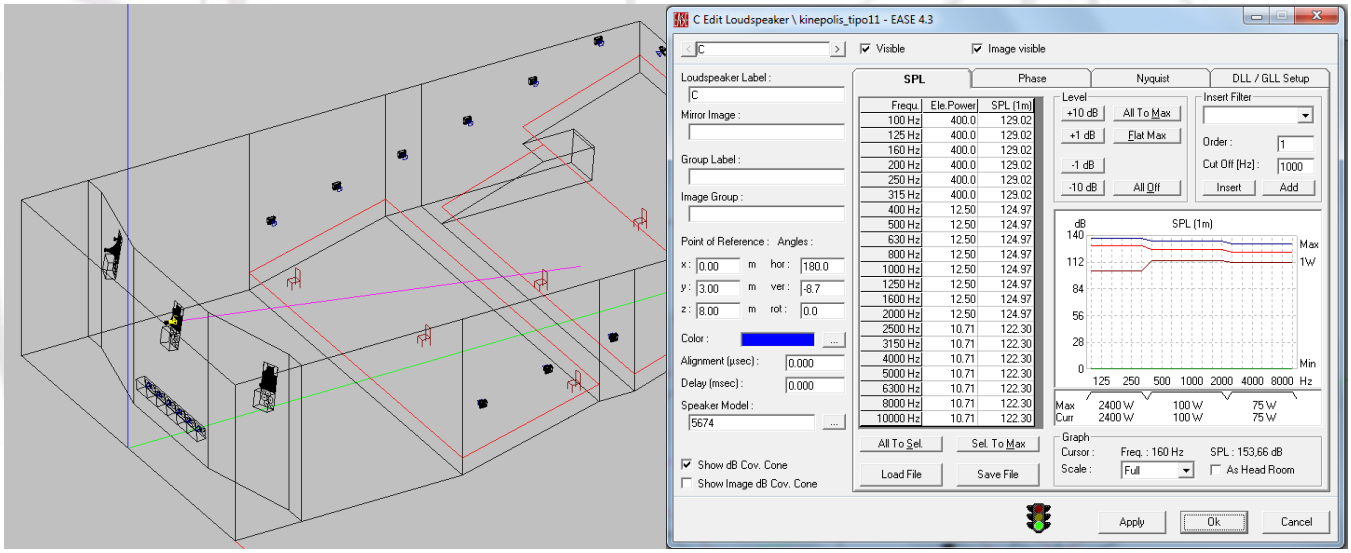
EASE Optimize RT tool

Once achieved the reverberation time setting, you must select the speakers from the database of EASE and depending on the size of the room.

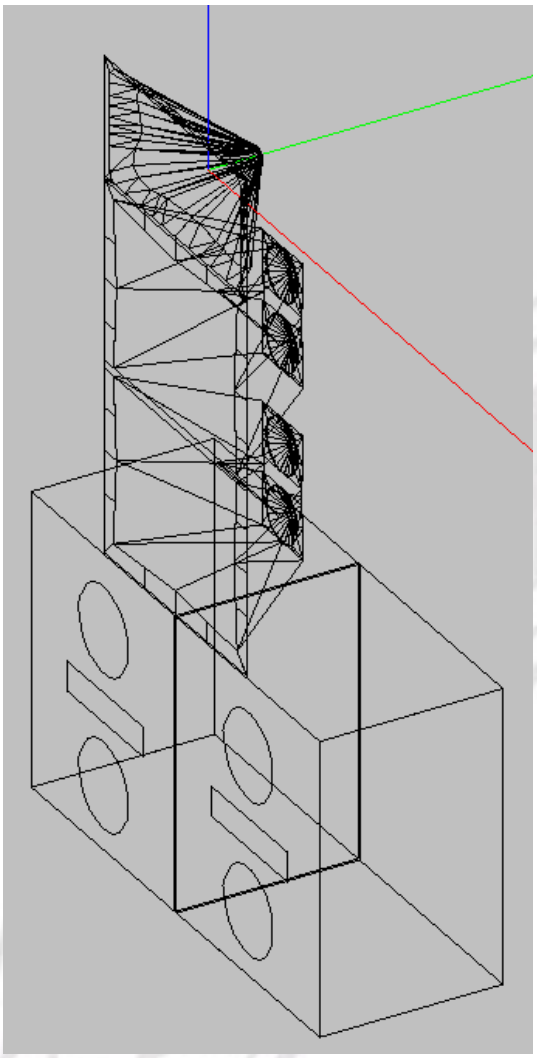
Absorption coefficient of materials

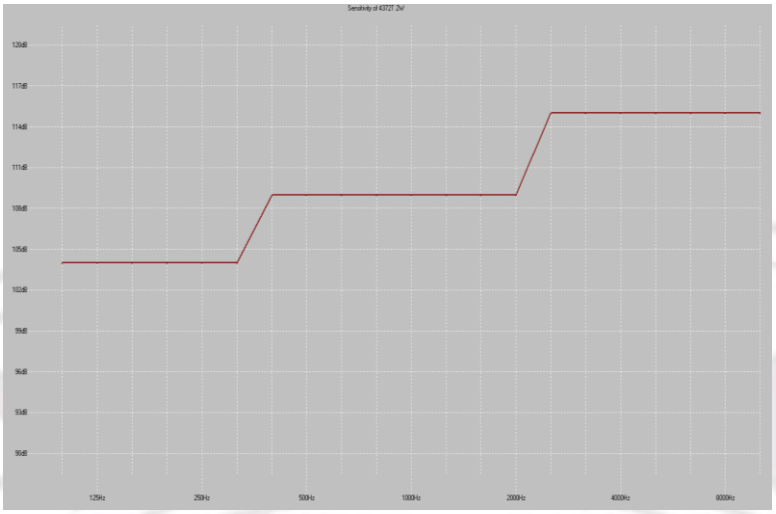
Screen Channels

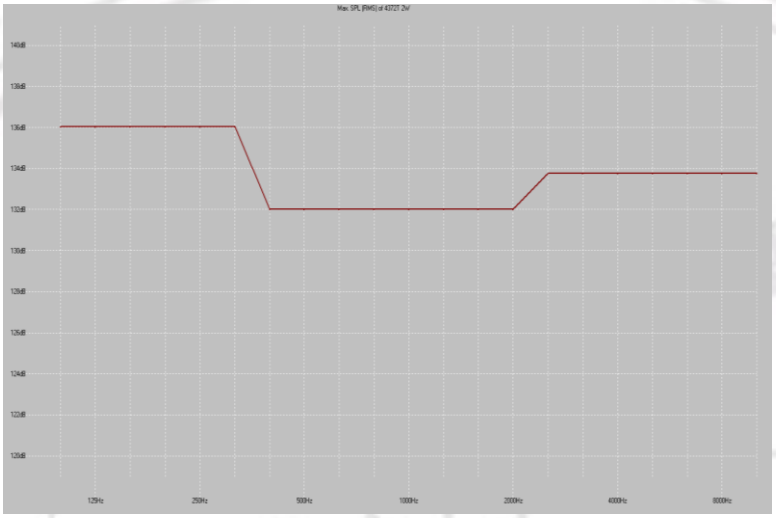
It will start screen channels (L, C, R) must compulsorily select three-way multi-amplified systems. As a design idea, and given the dimensions of the room, screen systems should be, for example, 5000 Series or Screen Array of JBL (trying to facilitate the choice of speakers to the extent possible and not waste excessive time, some speakers of screen systems, with some modifications are provided; the following models have been proposed: 4372T-1 Screen Array with a bass unit; 4372T 2W Screen Array with two bass units; 5674 Series 5000 - the first two systems are based on the technology of asymmetric horns and the third model is based on technology from conventional horns). The sound reinforcement should start with speakers to maximum power, making the first calculations in the 1 kHz band, to subsequently adjust the power to meet the requirements of the standard. This is achieved by using the command *All To Max* in the Loudspeaker Properties Window. This command puts a flat excitation signal frequency with the same summation power that the nominal power of the speaker. With multi-way speakers *All To Max* command puts at maximum each band separately.

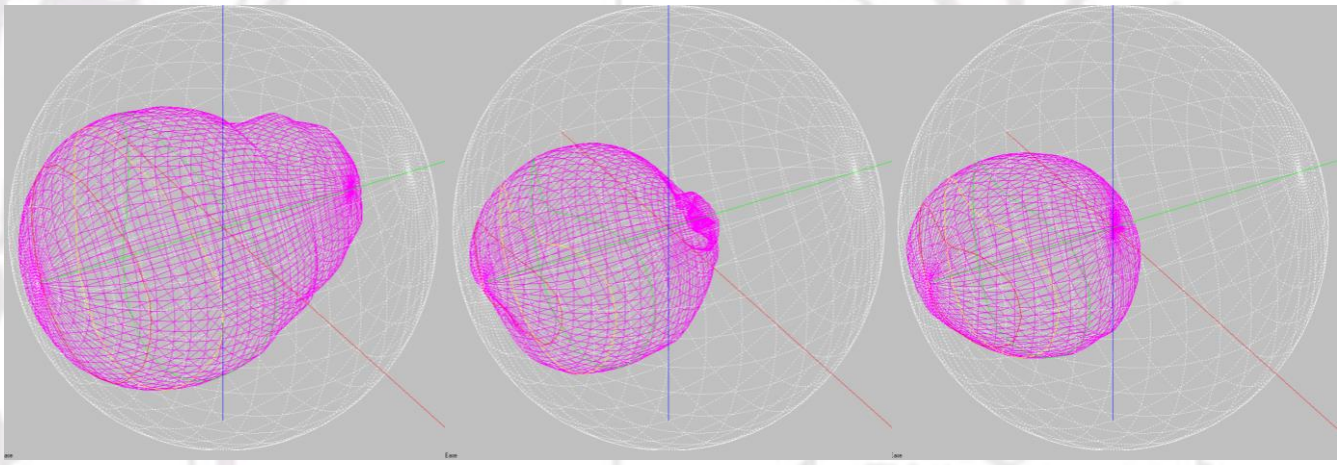


Screen channel C

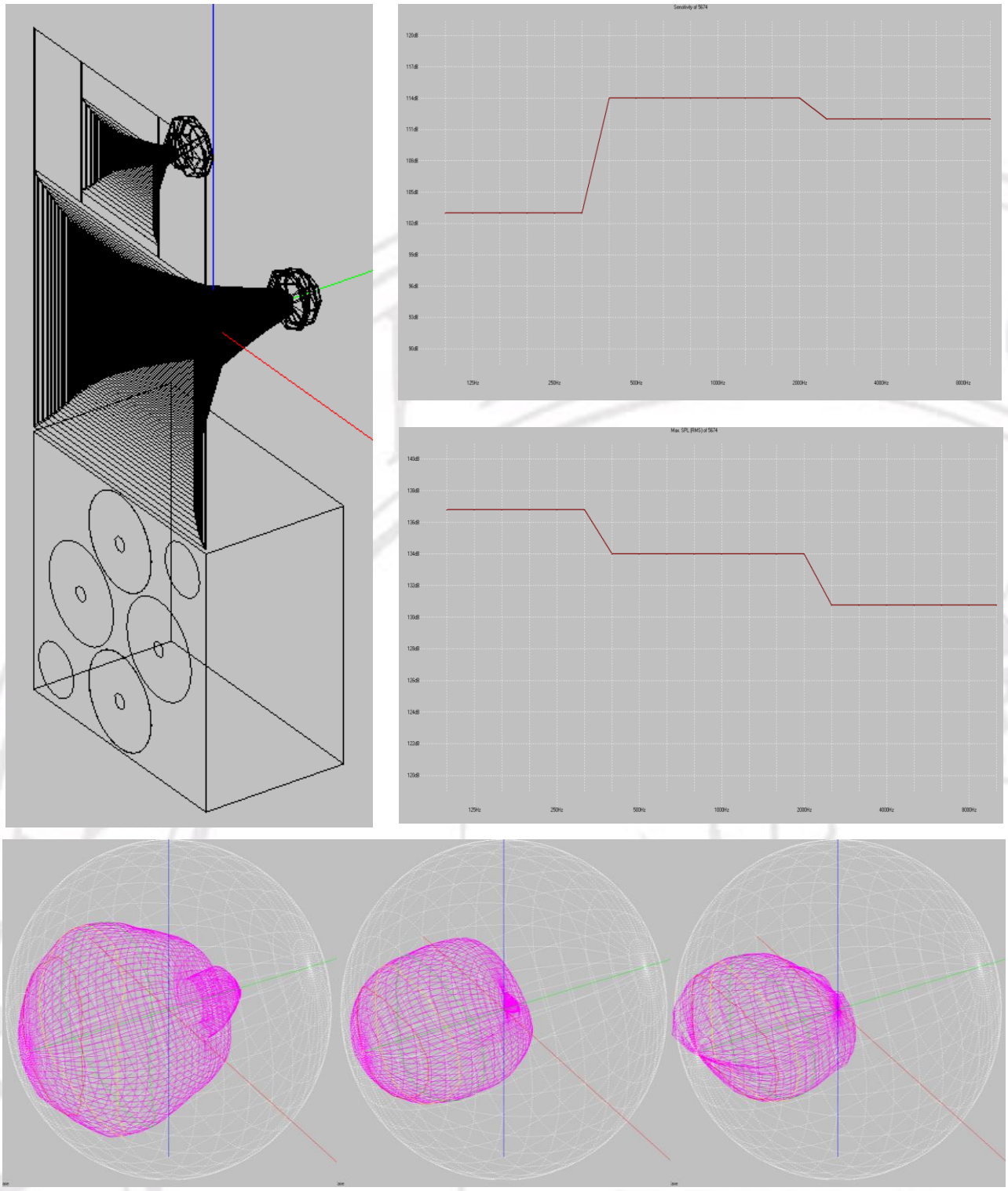








JBL 4372T 2W

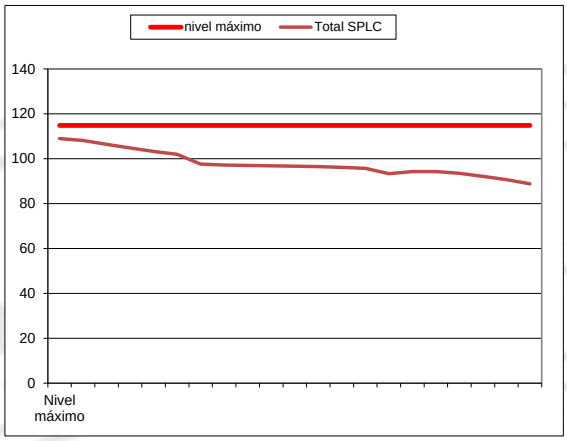


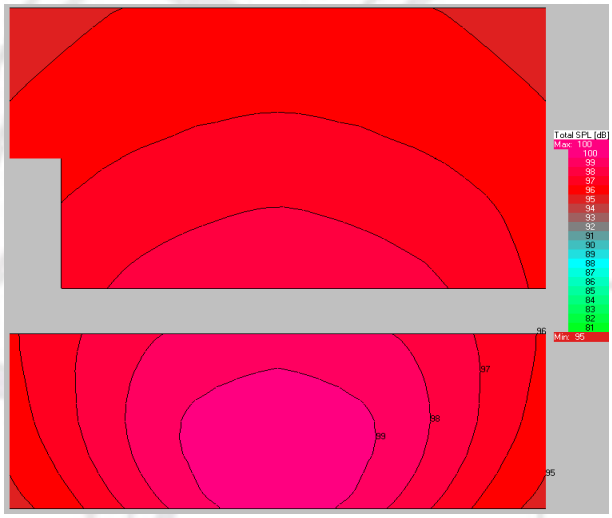
JBL 5674

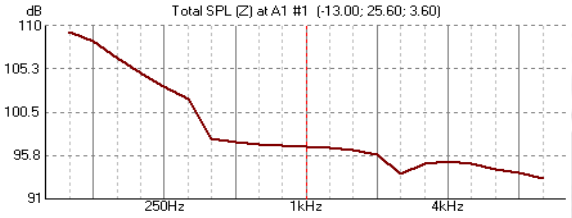
Although screen systems should be recessed into the wall, in order to facilitate the work of the students, will be allowed that they are positioned against the wall which lies behind the screen. The dimensions and weight of screen systems should be specified in order to get an idea of the design of the structure that must support them. Treble of screen channels systems pointing should not be made directly to the last row of seats and were pointing at the point of equalization to 2/3 of the total length of the room. Aiming of screen channels systems should not be made directly to the last row of seats and were aiming at the point of equalization (sweet point) to 2/3 of the total length of the room. It must be tried to achieve a uniform distribution of the total sound pressure level (SPLT) in the room, with a variation of ±4 dB (with all screen systems working). Check if the room has an equivalent free-field behavior and get a direct/reverberant field distribution. Speakers/amplification systems should be sized to obtain 105 dBC peak levels per channel

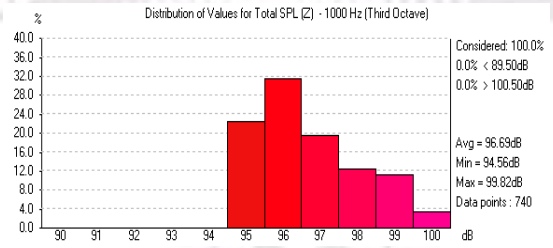
at the sweet point (2/3 of the total length of the room), before the equalization.

Altavoz C inicial				
Frequency	Direct SPL	Total SPL	curva C	Total SPLC
100 Hz	99,7	109,25	-0,30	108,95
125 Hz	99,69	108,34	-0,17	108,17
160 Hz	99,27	106,47	-0,08	106,39
200 Hz	98,85	104,83	-0,03	104,80
250 Hz	98,42	103,26	0,00	103,26
315 Hz	98,29	101,97	0,02	101,99
400 Hz	94,11	97,59	0,03	97,62
500 Hz	93,97	97,15	0,03	97,18
630 Hz	94,14	96,99	0,03	97,02
800 Hz	94,3	96,85	0,02	96,87
1000 Hz	94,47	96,69	0,00	96,69
1250 Hz	94,2	96,55	-0,03	96,52
1600 Hz	93,92	96,29	-0,09	96,20
2000 Hz	93,62	95,87	-0,17	95,70
2500 Hz	91,41	93,64	-0,30	93,34
3150 Hz	91,8	94,76	-0,50	94,26
4000 Hz	92,12	95,09	-0,83	94,26
5000 Hz	91,64	94,76	-1,29	93,47
6300 Hz	90,95	94,14	-1,99	92,15
8000 Hz	89,94	93,77	-3,05	90,72
10000 Hz	88,59	93,22	-4,41	88,81
	Nivel en banda ancha [dBC]			114,86

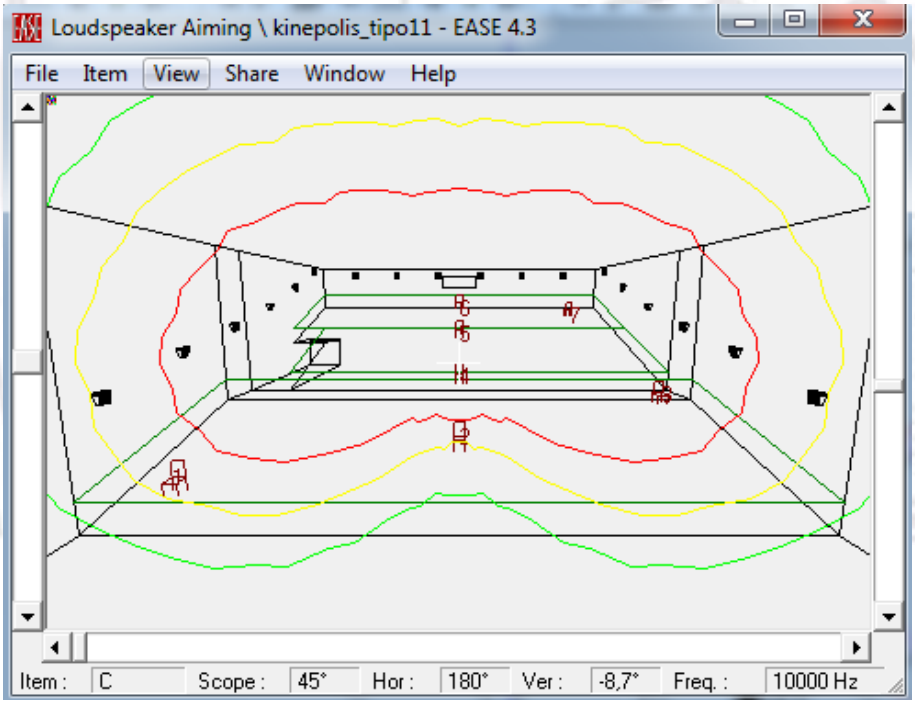


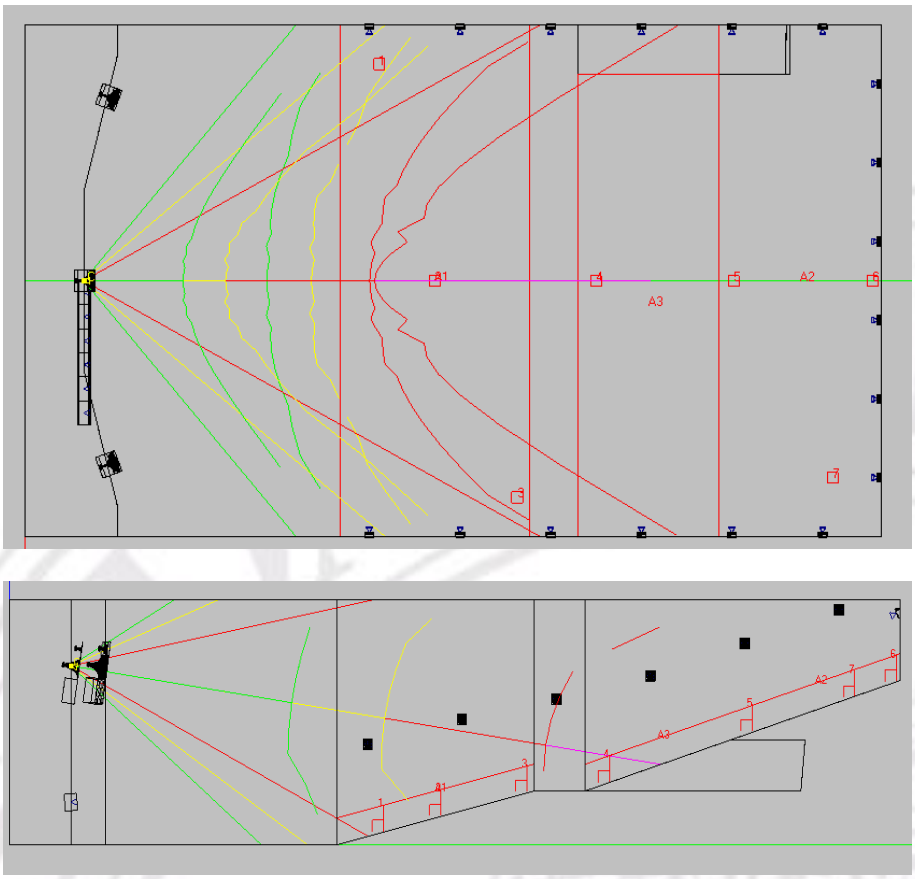






Channel C and maximum level coverage check





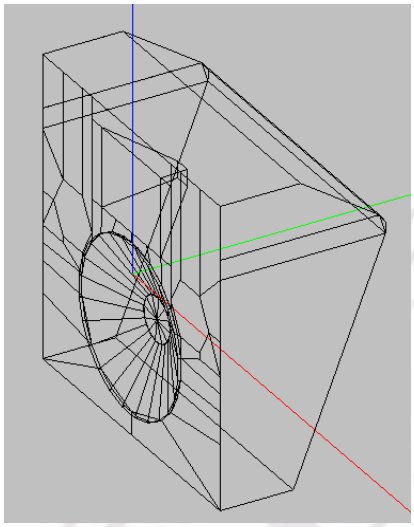
Aiming and coverage of the C-channel

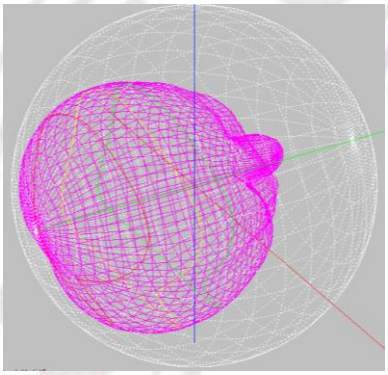
Surround Channels

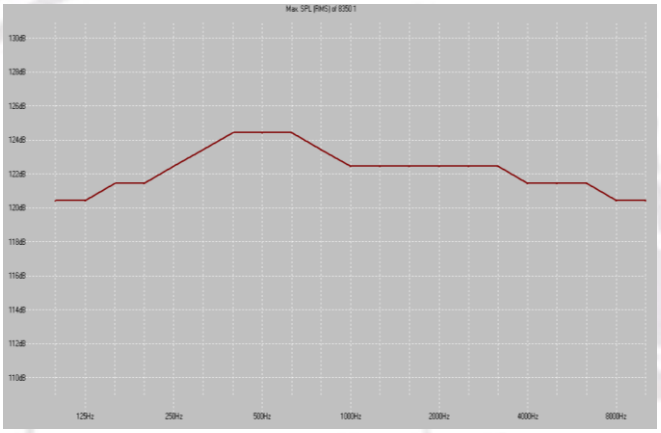
Continue with the design of surround systems, leaving them predesigned for performance with Dolby Digital 7.1. As a design idea, and given the dimensions of the room, it would be desirable that surround systems were at least 250 W and with indirect tweeter systems (in this case intends to use the models JBL 8350 1, 350 W power).

Surround systems aiming will be tried to satisfice the condition of pointing to the center of the opposite audience zone where they are placed (remember that the speakers surround boxes already comes with a vertical inclination of –15 °). They will be positioned about 4 m height above the audience area (in the 2/3 posterior parts of the room) and following the geometry of the audience area, whenever possible (suggested consider turn surround speakers in the horizontal plane –rotation- so that they remain parallel to the audience areas, rather than always being parallel to the ceiling of the room (in our case the completely horizontal). Since the configuration requested is 7.1, it will be impossible to balance four surround channels, so the rear surround channels must be a different setting from the side surround channels (at least we will try that if the film becomes a configuration of Dolby Digital EX, surround back channel is the more balanced as possible with respect to the side surround channels - same number of speakers on each channel). You must try to achieve a uniform distribution of the sound pressure level total (SPLT) in the room, with a variation of ±2 dB, all surround systems working (information from the coverage of total field that has each surround channel separately, but without trying to make the coverage of ±2 dB, shall be delivered though if the percentage of audience that is under these conditions and where is located in each case is indicated). Check if the room has an equivalent free-field behavior and you'll get a direct/reverberant field distribution. Surround system amplification should be sized to obtain 102 dBC peak levels per channel, before the equalization. In the sizing of surround systems amplification is must justify the

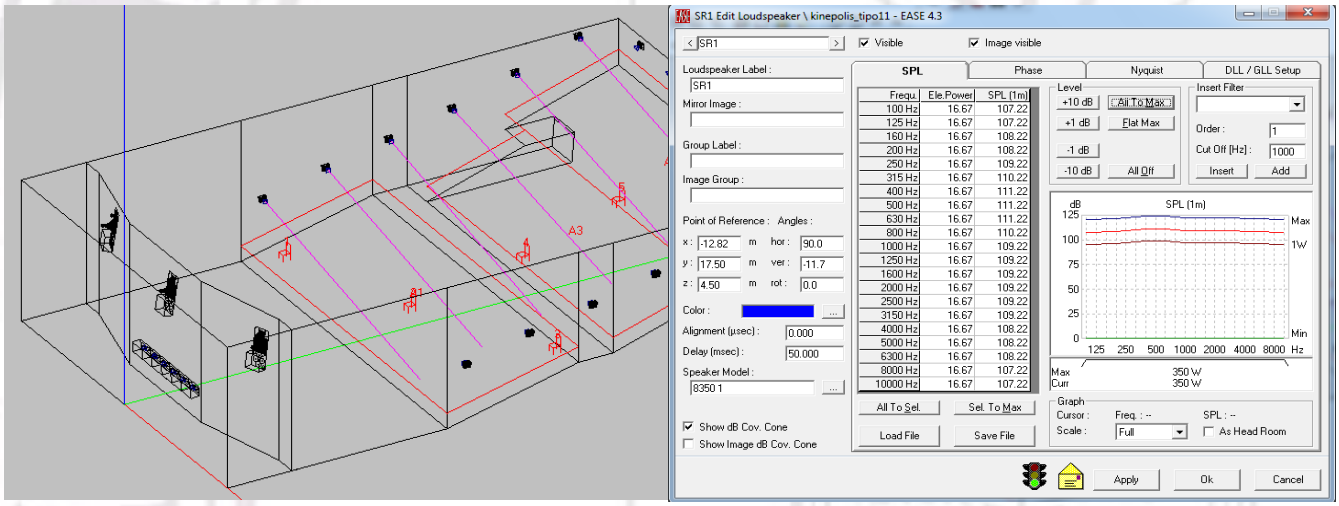
choice and number of amplifiers, as well as the possibilities of connecting more than two speakers to each amplifier or to each channel of the amplifier).



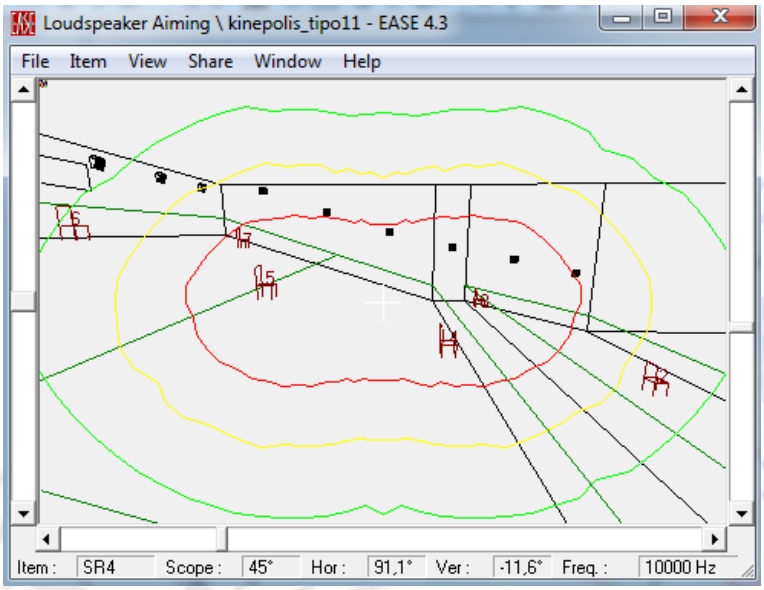




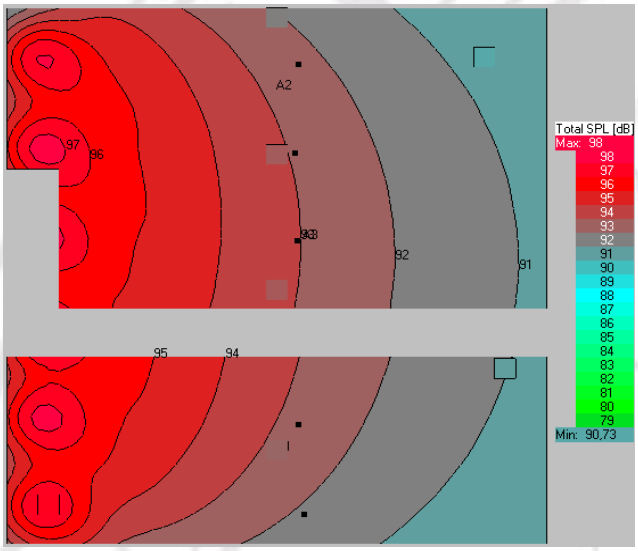
JBL 8350 1

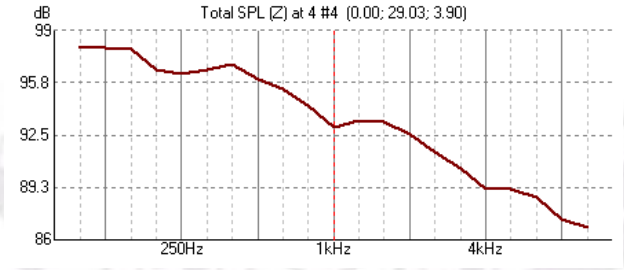


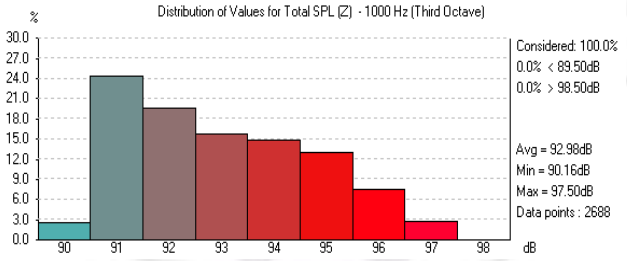
Surround Channel SR



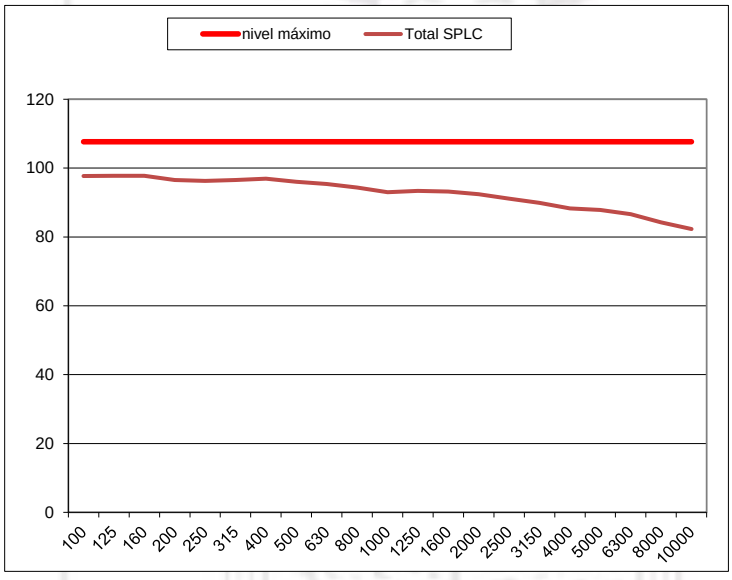
Aiming and coverage of the surround cannel







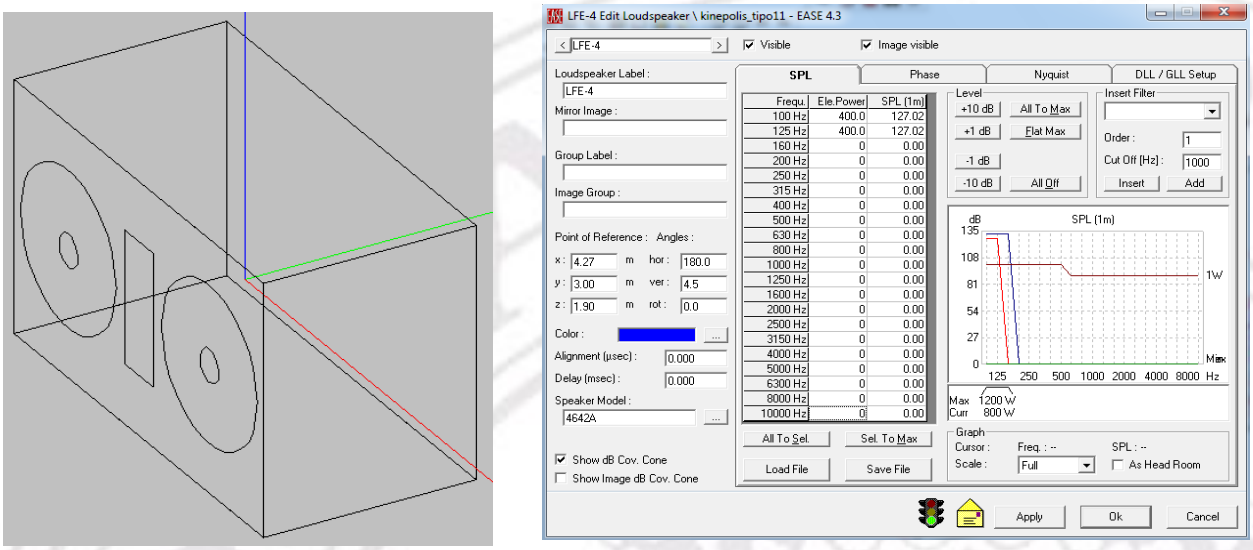
Altavoz SR inicial				
Frequency	Direct SPL	Total SPL	curva C	Total SPLC
100 Hz	90,27	98,02	-0,30	97,72
125 Hz	90,46	97,95	-0,17	97,78
160 Hz	91,49	97,83	-0,08	97,75
200 Hz	91,30	96,58	-0,03	96,55
250 Hz	92,14	96,30	0,00	96,30
315 Hz	93,03	96,55	0,02	96,57
400 Hz	93,80	96,88	0,03	96,91
500 Hz	93,28	95,99	0,03	96,02
630 Hz	92,81	95,36	0,03	95,39
800 Hz	92,05	94,35	0,02	94,37
1000 Hz	90,93	92,98	0,00	92,98
1250 Hz	91,27	93,41	-0,03	93,38
1600 Hz	91,22	93,28	-0,09	93,19
2000 Hz	90,58	92,57	-0,17	92,40
2500 Hz	89,73	91,43	-0,30	91,13
3150 Hz	88,81	90,43	-0,50	89,93
4000 Hz	87,52	89,14	-0,83	88,31
5000 Hz	87,49	89,12	-1,29	87,83
6300 Hz	86,99	88,61	-1,99	86,62
8000 Hz	85,65	87,27	-3,05	84,22
10000 Hz	85,06	86,73	-4,41	82,32
Nivel en banda ancha [dBC]				107,69



Surround channel SR and maximum level coverage check

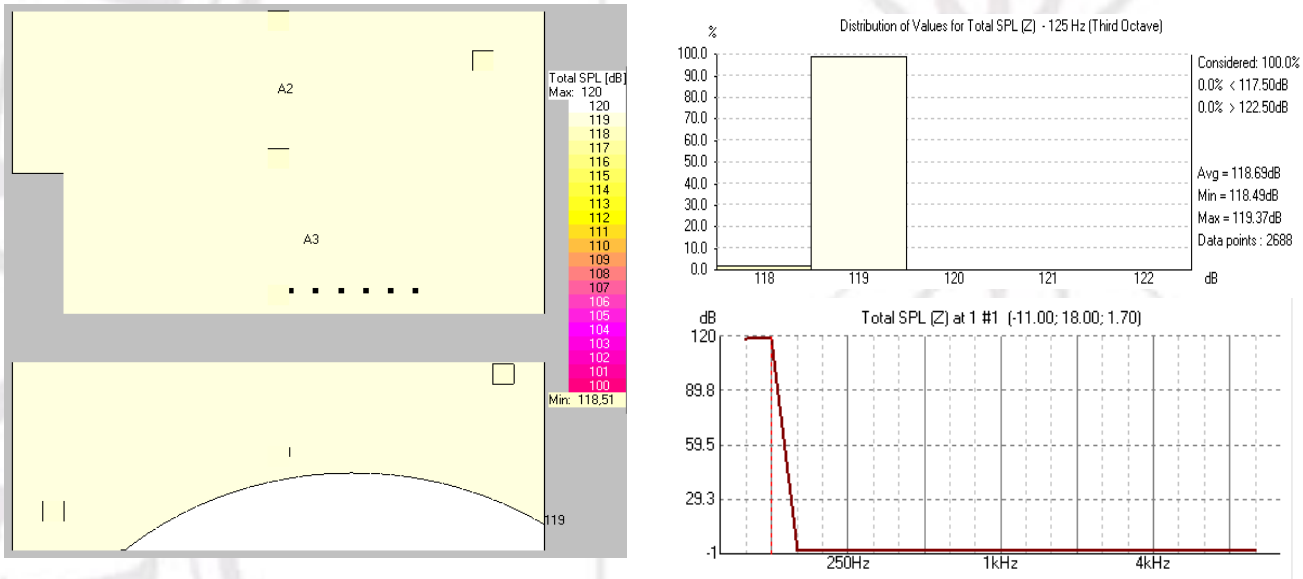
LFE Channel

Finally, the subwoofer system (LFE) will be designed, taking into account the characteristics of the room must be used boxes that fit two cones of 18 "and a few 800W (intends to use the model 4624 JBL A 1200W). Speakers of the LFE channel systems must filter at EASE so that they cover only the specified working band (125 Hz).



JBL 4624A

The subwoofer equalization curves will be stored. The allocation of these systems will take place at the bottom of the screen, as close to the edge of the ground, whenever it is possible for safety reasons (suggested not placing the LFE channel speakers centered on the room and move them with respect to longitudinal axis of the room). Amplification systems must be sized for peak of 115 dBC levels per channel, on his work bandwidth for Dolby Digital.



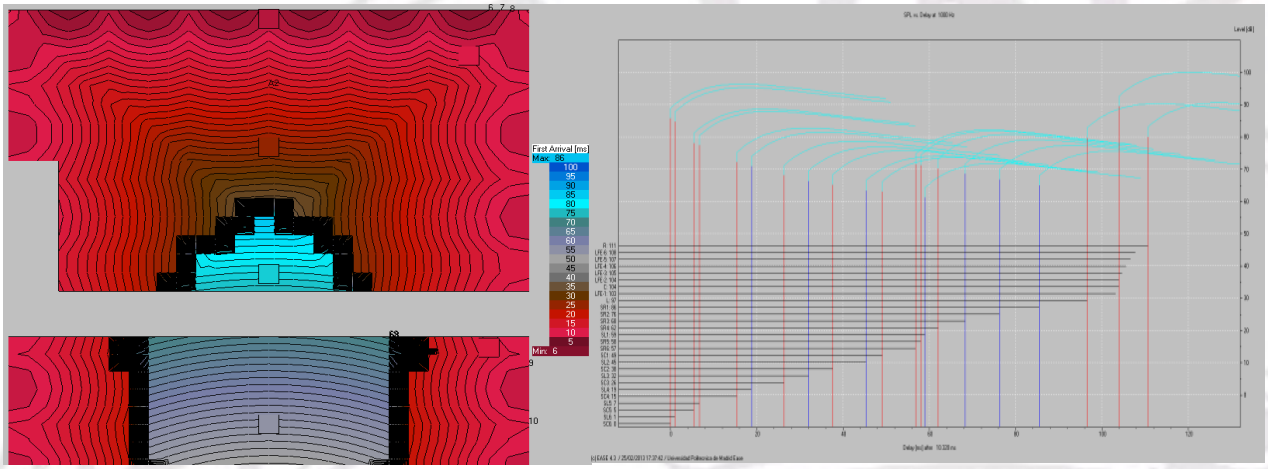
LFE channel and maximum level coverage check

Delays

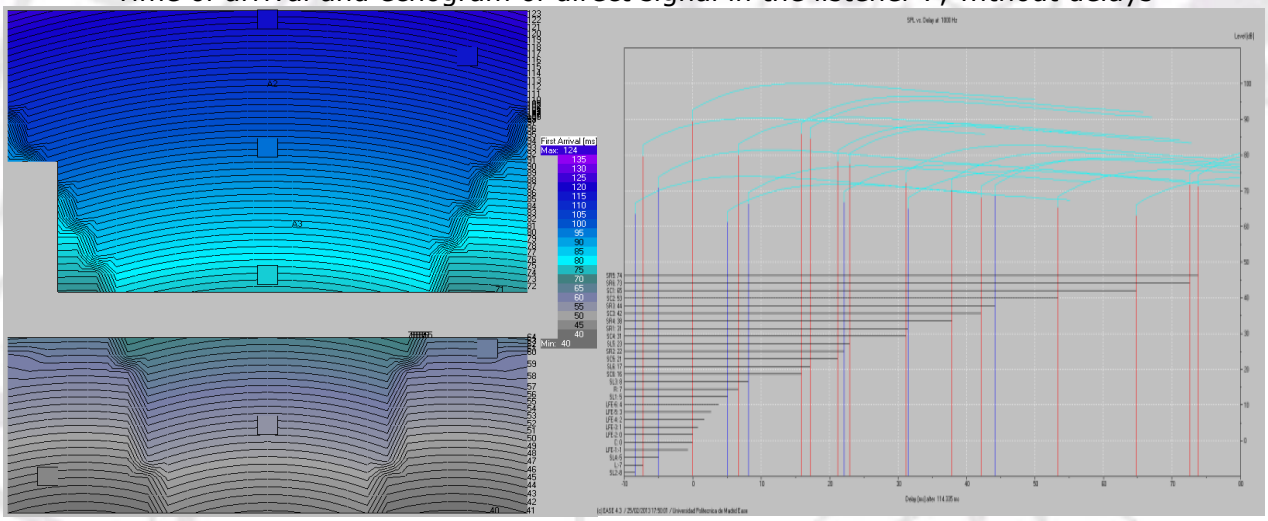
In the design of sound reinforcement system electronic delays are used to control the time response of the room. The time response of a room influences the subjective perception of sound the same. The time response of the room determines also the

subjective localization of the sound source. In cinemas is convenient to the main sound event (excluding possible "sound effects") seems to come from the area front the listener (should be considered is the central channel of screen which contains the information in the dialog).

In conventional cinema is usually only delay the surround channels to achieve focus the sound image to the screen. This is achieved by making screen channels arriving before the surround channels to any listener in the room. It is creating "sound precedence" from the screen to meet what is known as the "law of the first wave front" or "precedence effect".



Time of arrival and echogram of direct signal in the listener 7, without delays



Time of arrival and sonogram of direct signal in the 7, with delays (50 ms and 120 ms, 80 ms) listener

When electronic delays are used to create the "precedence effect" can occur that the time response in certain places, lengthen in excess causing a sharp decline in intelligibility and a possible appearance of echoes. This negative effect typically occurs in areas near the screen speakers, where you can hear it to surround speakers with excessive delay.

It must take into account that EASE considers direct field all those signs that come in a range of 80ms after the arrival of sound considered as precedent (sound screen systems). We must take this into account when defining surround systems delays. As it has already been studied, current processors only allow the introduction of a delay for all channels of surround (which is calculated as average of all surround speakers delay). It must justify the number of delays employed, in case that you decide not to use in that it comes in processors by default (recommended, unless it can be justified economically, surround speakers be grouped together when it comes to applying them delays and there are no independent delays for each surround speaker).

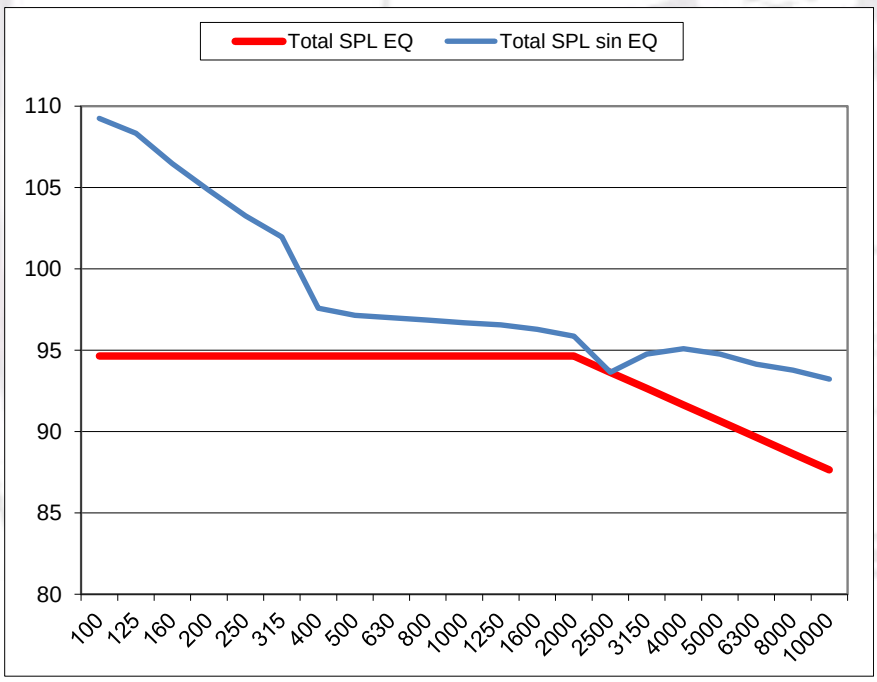
Equalization

The next step is the equalization of the room according to the curve X (ISO-2969). Equalization will be held separately with each sound system channel (7 in our case, since the LFE channel does not follow this Equalizer curve). Keep the files of Equalization of speakers at EASE .exf format, in order to not have to make the Equalization of each speaker independently, thus also to be able to follow the evolution of the power radiated by the speakers in the different steps of adjustment of the system in EXCEL).

The column "Total SPL without EQ" contains the average value of the SPLT exported from EASE room. The "Smoothing" column represents the attenuation values to be applied to the speaker C to get the average desired after the equalizer. If, as in our case, it is working with the speaker to maximum power, the Equalization must be negative (or zero) in all bands. To achieve this is proposed to begin to equalize from third octave of the average lower in the cave X of EQ flat area (100 Hz - 2000 Hz). If the repetition of the formula, to the rest of the rows in the column "Attenuation", remains some positive value, that value to the entire column will be subtracted. In the case of the previous table, has begun by the third octave of 2500 Hz and the following expression has been applied in the calculation of the value of attenuation: P$ 17 + Q17 - Q$ 17.

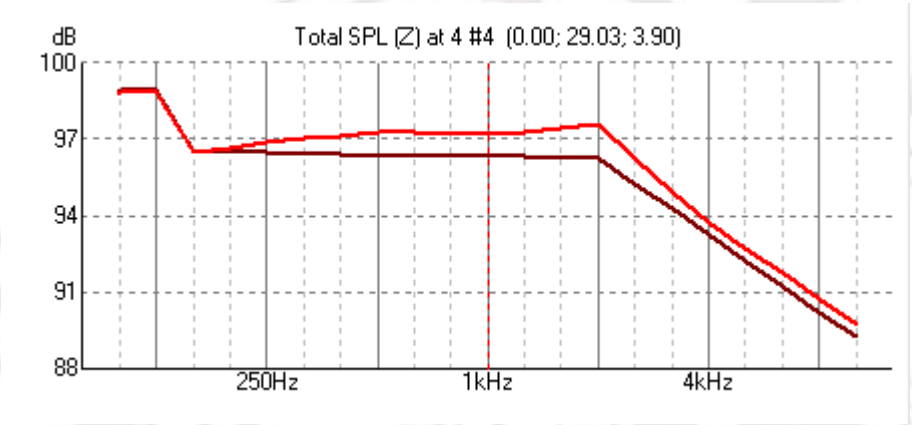
Frequency	Total SPL sin EQ	CurvaX	Atenueación	Total SPL EQ	SPL 1m sin EQ	SPL 1m EQ	Total SPL EQ
100	109,25	0	-14,61	94,64	129,02	114,41	94,64
125	108,34	0	-13,7	94,64	129,02	115,32	94,64
160	106,47	0	-11,83	94,64	129,02	117,19	94,64
200	104,83	0	-10,19	94,64	129,02	118,83	94,64
250	103,26	0	-8,62	94,64	129,02	120,4	94,64
315	101,97	0	-7,33	94,64	129,02	121,69	94,64
400	97,59	0	-2,95	94,64	124,97	122,02	94,64
500	97,15	0	-2,51	94,64	124,97	122,46	94,64
630	96,99	0	-2,35	94,64	124,97	122,62	94,64
800	96,85	0	-2,21	94,64	124,97	122,76	94,64
1000	96,69	0	-2,05	94,64	124,97	122,92	94,64
1250	96,55	0	-1,91	94,64	124,97	123,06	94,64
1600	96,29	0	-1,65	94,64	124,97	123,32	94,64
2000	95,87	0	-1,23	94,64	124,97	123,74	94,64
2500	93,64	-1	0	93,64	122,3	122,3	93,64
3150	94,76	-2	-2,12	92,64	122,3	120,18	92,64
4000	95,09	-3	-3,45	91,64	122,3	118,85	91,64
5000	94,76	-4	-4,12	90,64	122,3	118,18	90,64
6300	94,14	-5	-4,5	89,64	122,3	117,8	89,64
8000	93,77	-6	-5,13	88,64	122,3	117,17	88,64
10000	93,22	-7	-5,58	87,64	122,3	116,72	87,64

Table of equalization for the screen channel C



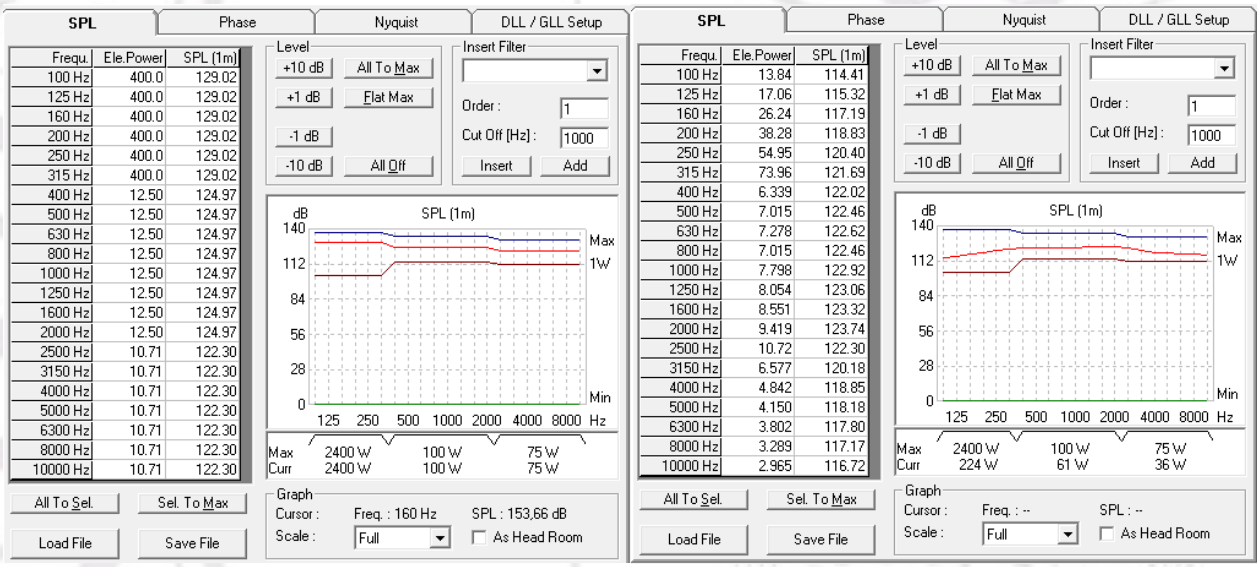
Screen Channel C SPL_T before and after the equalization

It should be noted that the Equalization process is usually done from the average curve of the SPLT levels in the room. If the level had been used in the set point (sweet point) 2/3 of the length of the room, it is possible that the average level of equalized and equalized at that point do not coincide. Normally, although the standard only specifies that the curve must be adjusted Equalizer at the point X, when you fit a reality movie theater, several points around the sweet point measures are averaged to obtain the value of equalization (either of the two procedures would be valid, but should be explained by what has been chosen and the differences between both appreciated).



Comparison of the SPLT with all systems in the sweet point (red) and the average of the room (Brown)

Once the equalizer curve has been obtained, you must apply to the corresponding speaker. To attenuate a speaker should introduce the absolute power (or SPL) 1 m in the corresponding band. To do this, and as Edit Loudspeaker window commented previously, in the level curve must be stored prior to equalize (.exf format) and import it into Excel (column "SPL" 1m without EQ) table. Applies the corresponding to the column "Smoothing" Equalization and gets the "SPL 1m EQ" column, whose values must be entered again in the Edit Loudspeaker window, and save the new curve EQ (.exf format), if it is necessary to use it for other speakers (as it would be the case of surround systems).



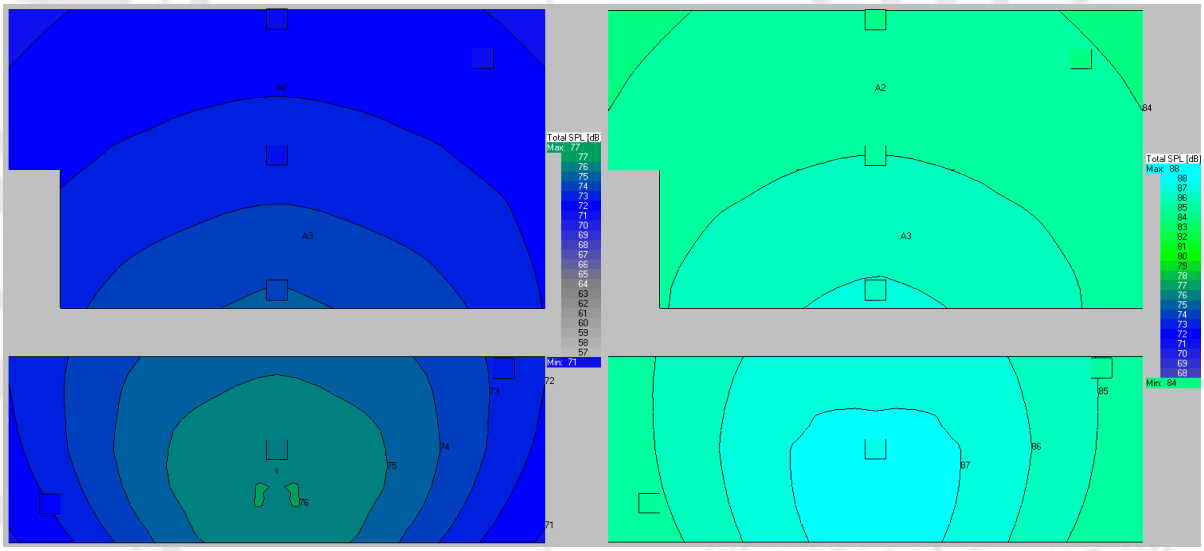
Levels of the screen channel C before and after equalization

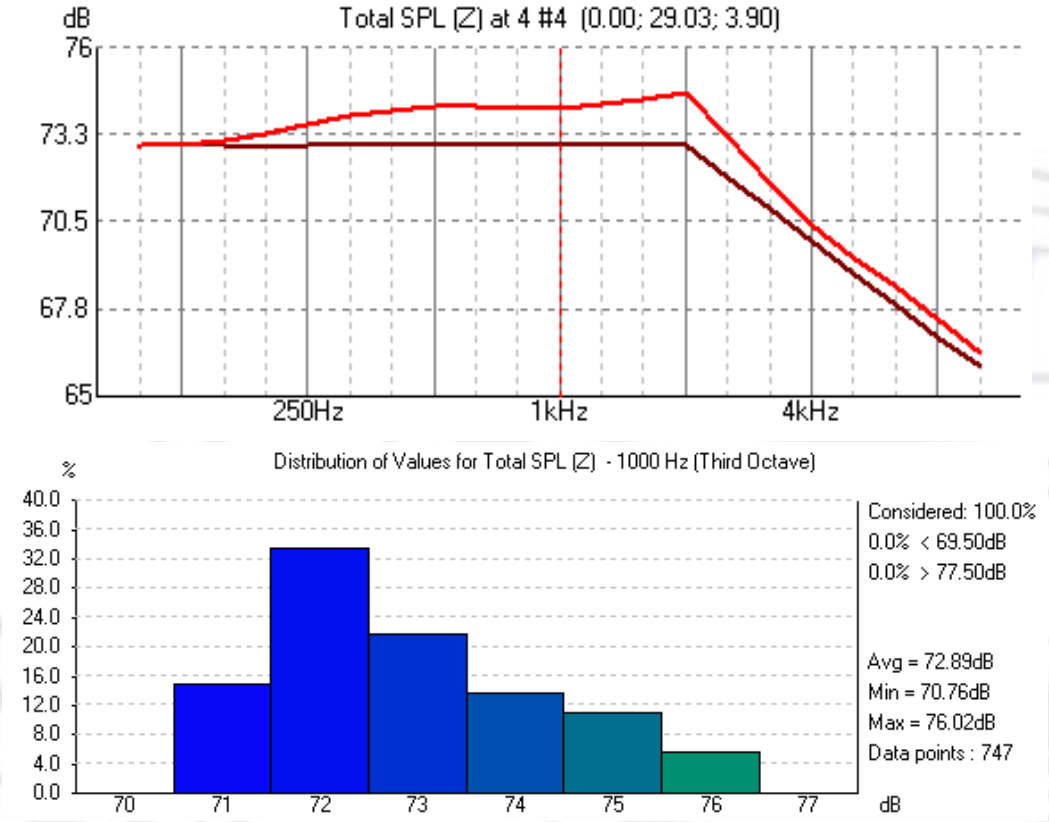
Once the equalizer to all speakers of each system independently is applied, will be good to check the behavior of the set of all systems of the cinema and see if it fits to the response of the curve X. This is not usually done in the cinemas, then the signal from each channel independent and not it will be possible to check the joint operation of the systems when it applies the same signal to all (something that will never happen in a cinema).

In addition, and given the impossibility of defining the surface of the screen in EASE, you must specify how should be treble of screen systems units filters, although not apply to the properties of the speakers at EASE, to take into account the effect of dimming the screen (this step is necessary to select the screen type that is to be mounted always keeping in mind that the screen will be micro-perforated type). Also, if someone decides to do so, it is possible to define an electrical filter that simulates the effect of dimming of the screen is selected and then set the compensation of the treble of screen channels via filter (keep in mind that in reality it must always offset the effect screen and selecting the tweeter system that is to be mounted. We will have to take into account that it is possible in high frequency bands having a gain up to 12dB with respect to the gain of the filter unit). You must save the curving of filtering (treble) screen systems, screen dimming curves and curves of Equalization of each of the channels. Remember that this section should be performed at maximum power of the speaker. After setting each system channel equalization separately, should be checked the room equalization curve with all systems working.

Level setting

Once the room is equalized (with each channel separately) should be the final level adjustment for each channel with the values specified above according to SMPTE and THX recommendations. It will first display systems adjust independently at the sweet point (2/3 of the length of the room), to have a level of 85 dBC broadband. Each channel of the surround system shall be adjusted so that at the point of equalization (2/3 of the length of the room), 82 dBC have per channel. The sizing of subwoofer systems will be adjusting them to 95 dBC in his working band for Dolby Digital. The final level adjustment should be over already-equalized systems. Check the effect of sound system working in full (will take into account that this check is only to have a general idea of the acoustic behavior of the cinema, since in reality the sound in cinema is independent channels that do not carry the same excitation signal).

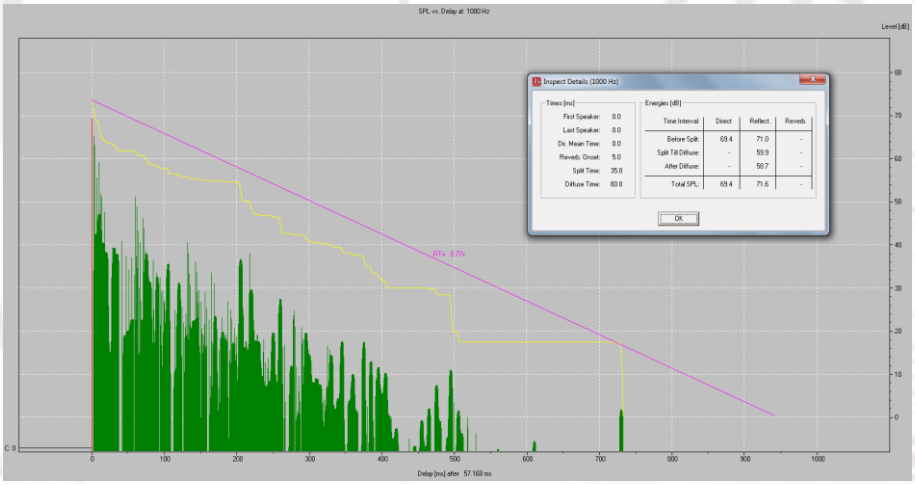




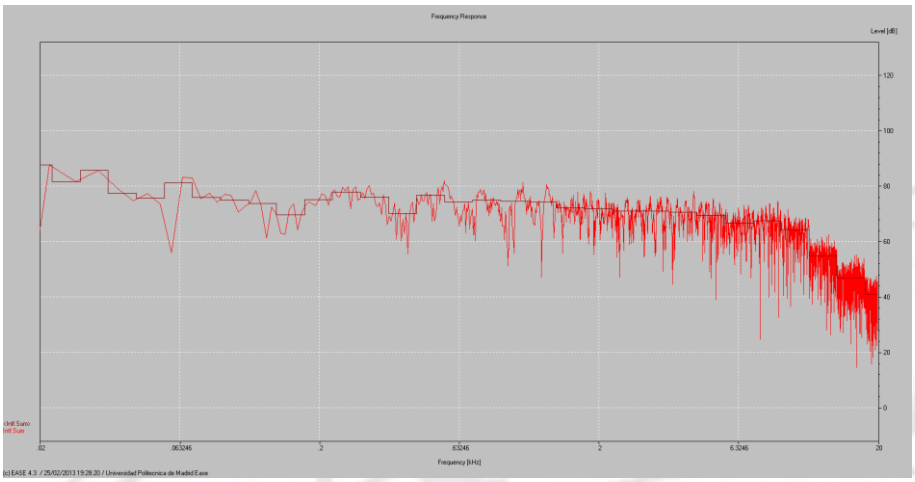
Screen channel C setting

Calculation of the maps from the time response

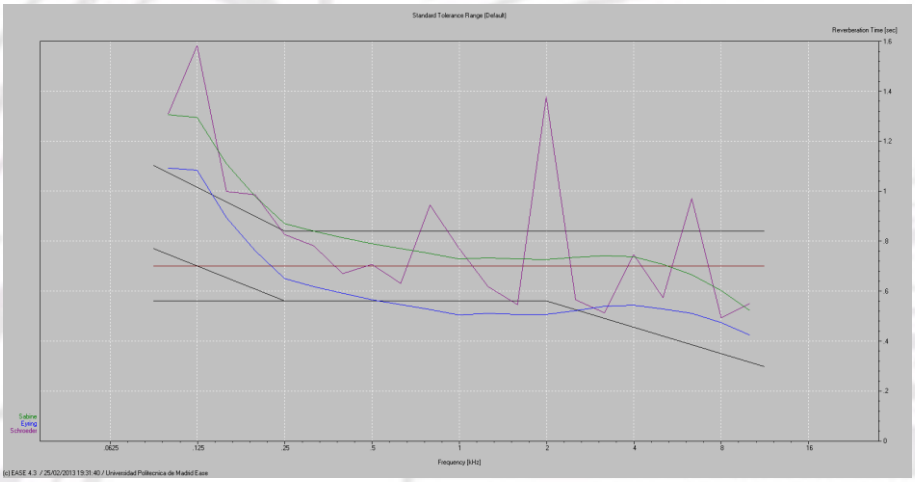
The behavior of the system according to the psychoacoustic effect criteria should study precedence and annoying echoes. At this point will be evaluated the design of a system of delays for surround channels more sophisticated that which currently allow the film processors available in the market. As for the criterion of effect precedence just performs a echogram of signals direct from each one of the systems that make up sound of the cinema (place a "Probe" in the positions of selected listeners). For the verification of the criterion of annoying echoes will be necessary to get a detailed echogram for each channel separately (it is advisable method AURA of EASE, or failing that a impacts ray tracing). This method allows you to obtain the impulse response of each channel in order to subsequently auralize designed cinema when a multi-channel test signal available.



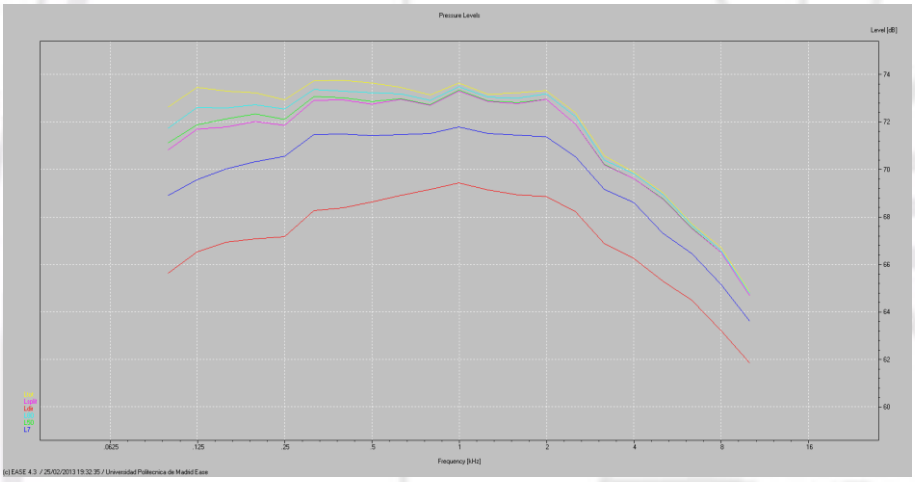
Reflectograma channel C-listener 1



Frequency response channel C-listener 1



Reverberation time channel C-listener 1



Expected levels channel C-listener 1

Equipment, blocks and connection diagram

Finally should be a scheme of connection, specifying the selected computers and by sizing the power amplification. The characteristics of the selected computers, providing the documentation which will be available in electronic format is must detail. Those jobs that specify in a clear and detailed the connection between different processors, and active filtering systems, and amplification systems and between these and the speakers of the various channels will be valued very positively. Remember that in order to obtain THX certification is required the inclusion of filter THX (1138 or 3147 of Lucas Film Inc.), although using another system of filtered asset of higher quality (JBL, for example DSC280). Those works that propose innovative routing, amplification and signal processing solutions will also be assessed positively.