Práctica 3
Refuerzo sonoro de una sala

Javier Rodrigo López

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1. Introducción y comentarios

En este informe se presentan los resultados del diseño de un sistema de refuerzo sonoro distribuido para una sala multiusos que denominamos SEA. Los requisitos que se piden son los siguientes:

1. Uniformidad de campo sonoro directo en las zonas de audiencia A1 y A10 por cada canal principal del sistema, de modo que $\Delta \text{SPL}_d < 10\,\text{dB}$ en la banda de 1 kHz.
2. Ecualización del campo total para que el promedio entre ambas curvas de audiencia siga la curva de referencia X.
3. Nivel total mínimo (D + R) de $90\,\text{dB}_{\text{SPL (A)}}$ en promedio en las zonas de audiencia A1 y A10.
4. Retardos adecuados para cada altavoz de modo que se cumpla el efecto precedencia en el punto más alejado de la sala (punto de escucha 3).

2. Resultados, mapas y gráficos

2.1. Modelos de altavoz

Teniendo en cuenta que la sala es simétrica, que se requiere un sistema estereofónico y que un sistema centralizado ya es capaz de proporcionar una buena respuesta en la zona de audiencia, se decide utilizar un par de altavoces para el escenario y otro par de altavoces para mejorar la respuesta en la zona de audiencia del palco superior (zona A10).

En concreto, se utilizan los siguientes modelos de altavoz:

- Los dos altavoces ubicados en el escenario son unos Avant 15A de la empresa D.A.S. Audio, de dos vías (aunque no permiten configuración independiente, se ajustan como una sola vía) autoamplificados.
- Los altavoces del palco superior son unos TRAP JR 6K de la empresa Renkus-Heinz. Presentan dos vías configurables y necesitan amplificación externa. El fabricante recomienda el uso del amplificador de potencia Renkus-Heinz P3500 amplifier.

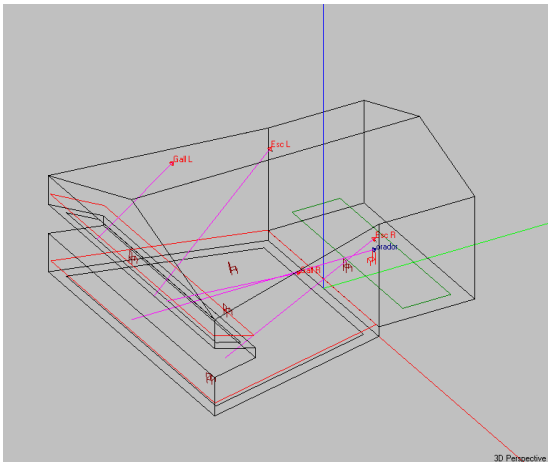
Las especificaciones técnicas de estos pueden encontrarse en el Apéndice A al final de este informe.

2.2. Colocación de los altavoces

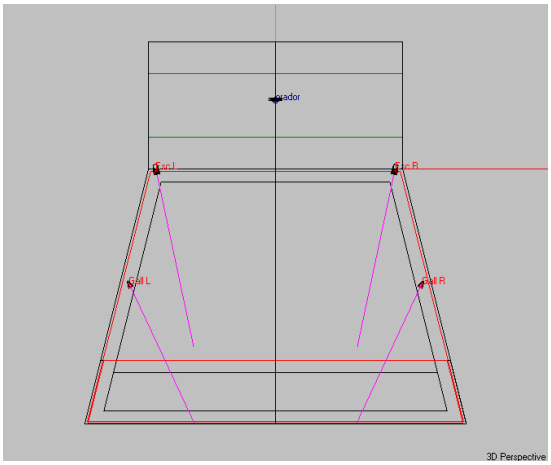
En la Figura 1 aparece la disposición de los altavoces en la sala SEA.

Tabla 1: Datos sobre la disposición de los altavoces

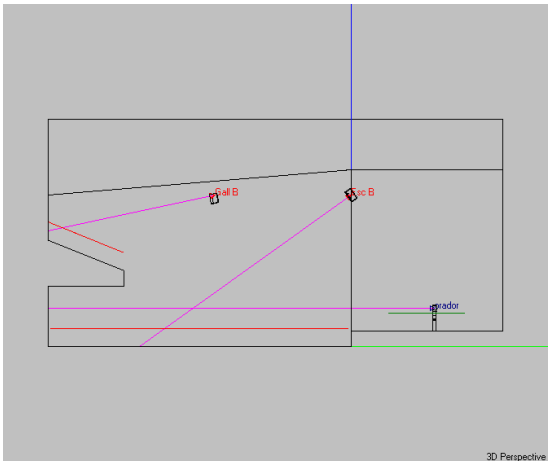
Item	Esc L	Esc R	Gall L	Gall R
Speaker Model	AVANT 15A	AVANT 15A	TRAPJR/6K	TRAPJR/6K
Delay [ms]	0	0	25	25
Alignment	0	0	0	0
x [m]	-9.40	9.40	-11.50	11.50
y [m]	0	0	-9.00	-9.00
z [m]	10.00	10.00	10.00	10.00
Hor [°]	12.0	-12.0	2.50	-2.50
Ver [°]	-35.0	-35.0	-11.0	-11.0
Rot [°]	0	0	0	0



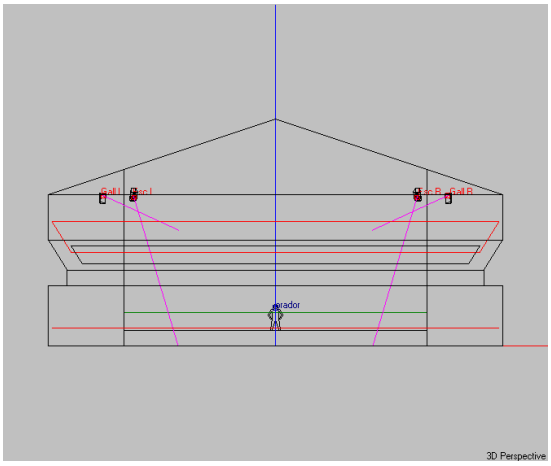
(a) Vista 3D



(b) Planta



(c) Perfil



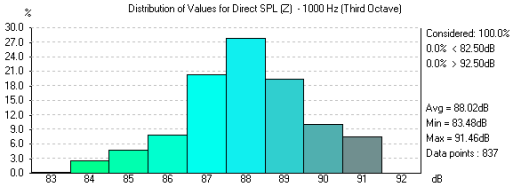
(d) Alzado

Figura 1: Colocación de los altavoces en la sala

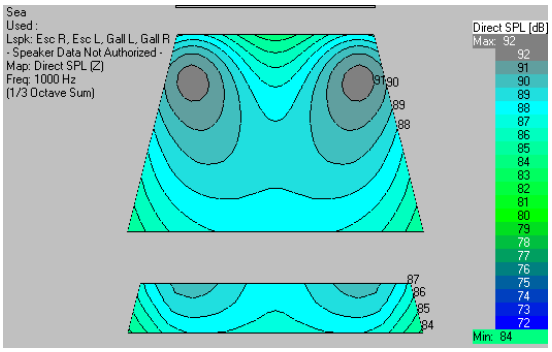
2.3. Ajuste de la uniformidad de campo directo a 1 kHz

El requisito de uniformidad se cumple, ya que en la banda de 1 kHz la diferencia entre el nivel de presión sonora máximo y mínimo es menor a 10 dB. Concretamente, usando los datos de la Figura 2a:

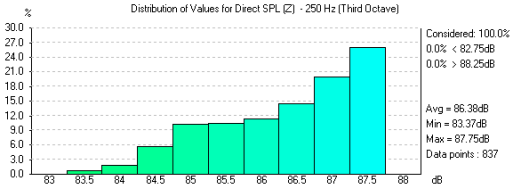
$$\Delta \mathrm{SPL}_d = \mathrm{SPL}_{\mathrm{máx}} - \mathrm{SPL}_{\mathrm{mín}} = 91{,}46\,\mathrm{dB_{SPL}} - 83{,}48\,\mathrm{dB_{SPL}} = \boxed{7{,}98\,\mathrm{dB}} < 10\,\mathrm{dB}$$



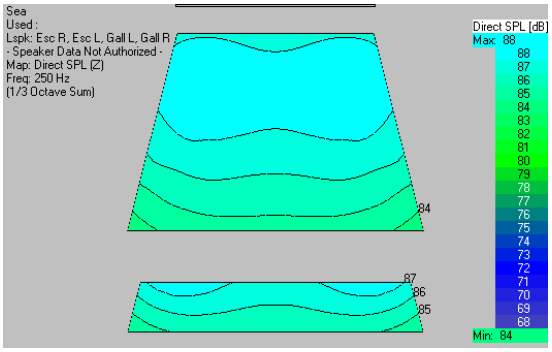
(a) Distribución del campo directo a 1 kHz



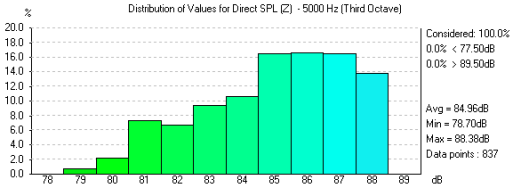
(b) Mapa del campo directo a 1 kHz



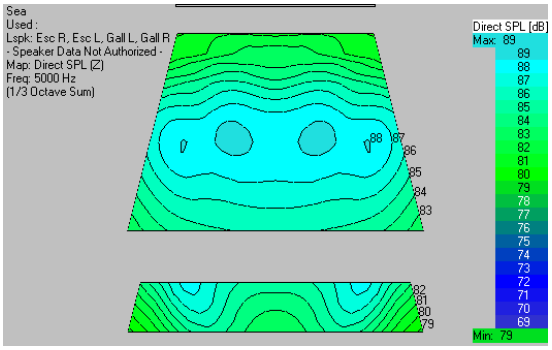
(c) Distribución del campo directo a 250 Hz



(d) Mapa del campo directo a 250 Hz



(e) Distribución del campo directo a 5 kHz



(f) Mapa del campo directo a 5 kHz

Figura 2: Representación de los niveles de presión sonora debidos a campo directo en la sala SEA para varias frecuencias significativas.

2.4. Balance de potencia

En la Tabla 2 aparecen representados los niveles de presión generada por cada altavoz. Si se quisiera obtener la potencia eléctrica que se debe suministrar a cada altavoz, habría que utilizar la sensibilidad aportada en las

especificaciones. En total, Esc L y Esc R utilizan 519 W cada uno, la vía de graves de Gall L y Gall R utiliza 28 W y la vía de agudos de estos utiliza 6.2 W.

Tabla 2: Niveles SPL generados por cada altavoz a 1 m, por bandas

Frequency	Esc L	Esc R	Gall L	Gall R
100 Hz	106.13	106.13	100.04	100.04
125 Hz	105.78	105.78	99.69	99.69
160 Hz	106.51	106.51	100.42	100.42
200 Hz	107.37	107.37	101.28	101.28
250 Hz	107.69	107.69	101.60	101.60
315 Hz	108.27	108.27	102.18	102.18
400 Hz	109.10	109.10	103.01	103.01
500 Hz	108.54	108.54	102.45	102.45
630 Hz	109.92	109.92	103.83	103.83
800 Hz	110.48	110.48	104.39	104.39
1 kHz	112.01	112.01	105.92	105.92
1.25 kHz	112.53	112.53	106.44	106.44
1.6 kHz	114.53	114.53	108.44	108.44
2 kHz	115.28	115.28	109.19	109.19
2.5 kHz	113.81	113.81	107.72	107.72
3.15 kHz	112.64	112.64	106.55	106.55
4 kHz	112.31	112.31	106.22	106.22
5 kHz	111.21	111.21	105.12	105.12
6.3 kHz	111.13	111.13	105.04	105.04
8 kHz	110.22	110.22	104.13	104.13
10 kHz	110.17	110.17	104.08	104.08

2.5. Ecualización. Niveles promedio de banda ancha con y sin ponderación A

En la Figura 3 aparecen las curvas resultantes de la ecualización (cálculos adjuntos en el documento de Excel). En la Figura 4 aparecen las respuestas en frecuencia en cada punto de escucha por bandas.

2.6. Retardos

En la Tabla 1 aparecen los diferentes retardos que se han aplicado a cada altavoz. En la Figura 5 el mapa de *Arrival Time*.

2.7. Inteligibilidad

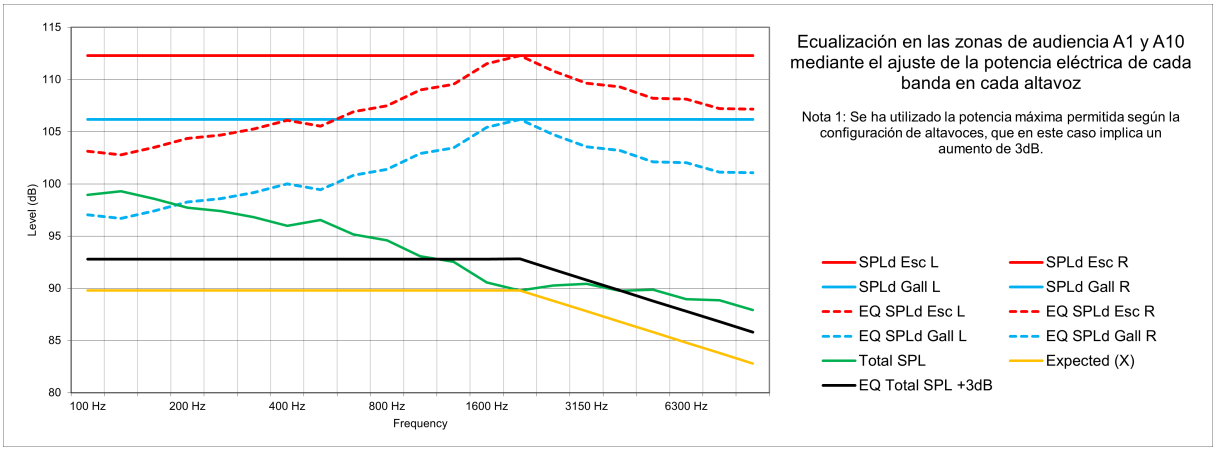


Figura 3: Curvas de ecualización

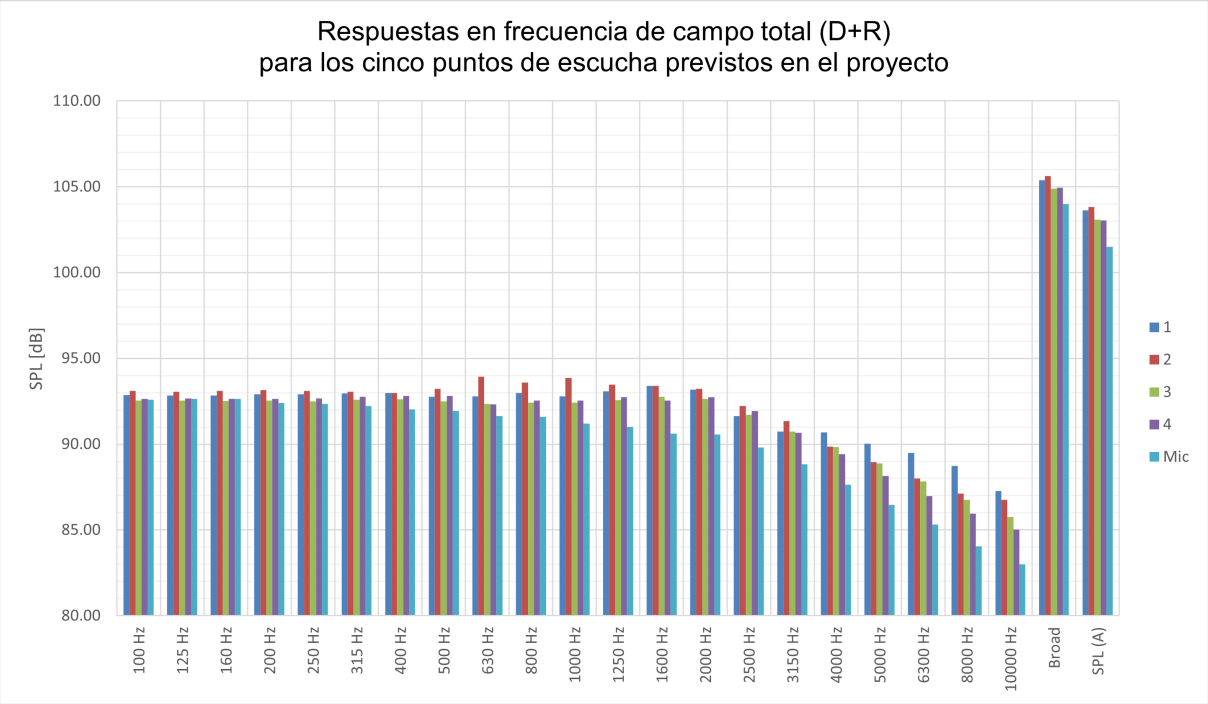


Figura 4: Respuesta en frecuencia en cada punto de escucha por bandas

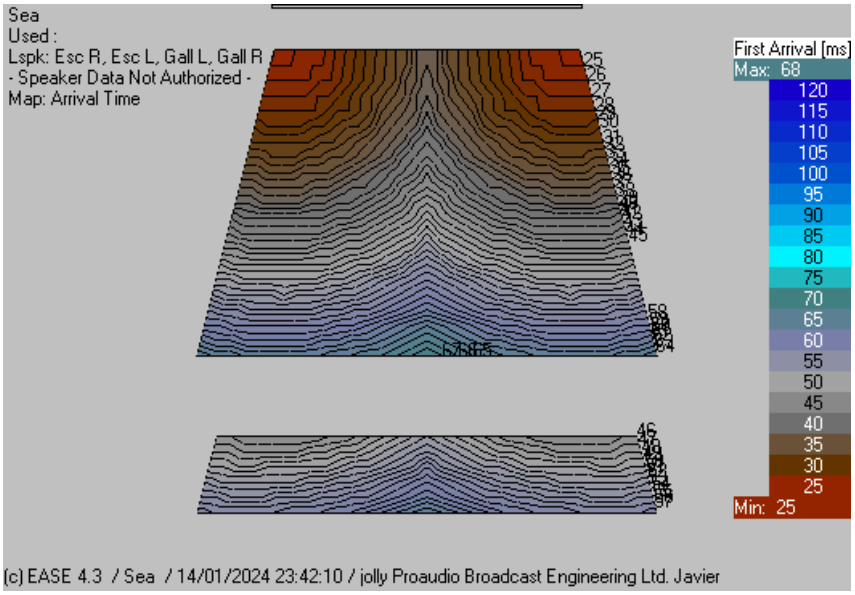


Figura 5: Mapa de Arrival Time calculado con AURA

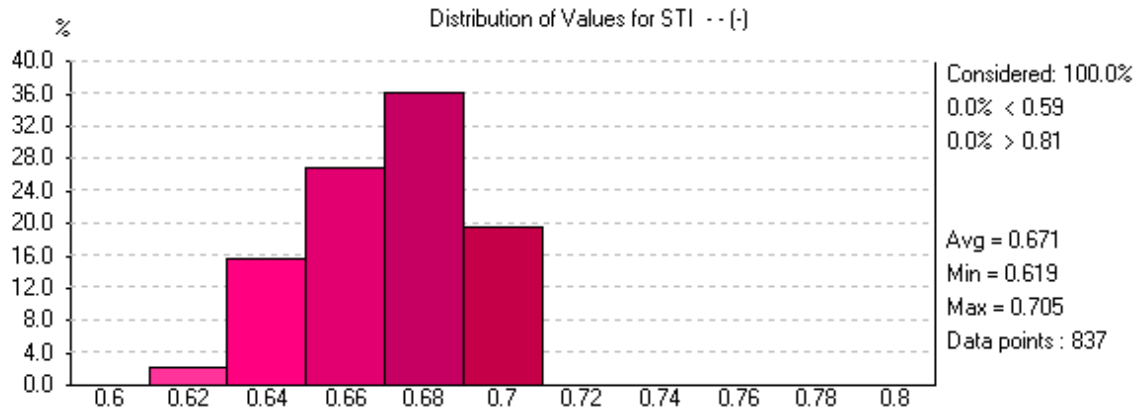


Figura 6: Distribución de STI mediante Standard Mapping

A. Especificaciones técnicas de los altavoces

En las siguientes páginas se incluyen las especificaciones de los altavoces utilizados en este proyecto.

avant 15A

Powered, bi-amplified portable system

- **» Biamplified 2-way system**
- **» 500 W low frequency 3rd Generation Class D power amplifier**
- **» 100 W high frequency 3rd Generation Class D power amplifier**
- **» 15" speaker (3" voice coil)**
- **» 2" diaphragm neodymium compression driver**

The Avant 15A provides the musician, DJ or A/V professional with a system that redefine the meaning of portable PA.

The loudspeaker components of the Avant 15A include a 15AV4, high efficiency 15" cone transducer with 3" voice coil and one M-50N neodymium compression driver with 2" titanium diaphragm. The driver is attached to a 80° x 50° rotable horn.

The two-way 3rd Generation Class D amplifier offers 500 W for the low frequency transducers and 100 W for the high frequency section. The amplifier provides extended bandwidth, improved dynamic range and exceptionally low distorsion.

The efficiency of the Avant amplifiers measures more than 90%. This ensures cool operation so that no fans or bulky heatsinks are needed. The low idle consumption also offers an easy way to reduce overall power use.

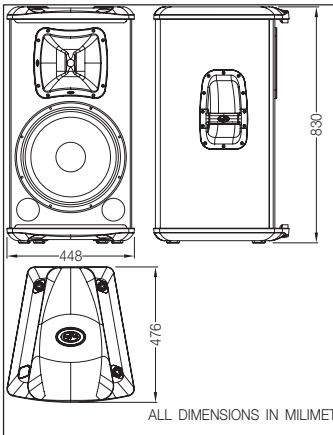
Signal processing is accomplished by way of a powerful 24 bit DSP providing unparalleled control over critical signal parameters.

The Avant 15A is protected by two types of limiters-an instantaneous peak limiter to safeguard the systems against spikes and a sonically transparent RMS limiter that controls excessive overpowering and thermal damage to components.

Technical Specifications

Low Frequency Power Amplifier [1]	1000 W_{peak} - 500 $W_{continuous}$
High Frequency Power Amplifier [1]	200 W_{peak} - 100 $W_{continuous}$
Input Type	Balanced Differential Line
Input Impedance	Line: 20 kohms
	Mic: 20 kohms
Sensitivity [2]	Line: 1.95 V (+8 dBu)
	Mic: 20 mV (-32 dBu)
On-axis Frequency Range (-10 dB)	45 Hz - 20 kHz (EQ Flat)
Maximum Peak SPL at 1 meter [3]	133 dB
HF Horn Coverage Angles (-6 dB)	80° x 50° (Rotatable)
Enclosure Material	Birch Plywood
Finish	Black Paint with ABS Plastic Endcaps
Transducers/Replacement Parts	LF: 1 x 15AV4/GM 15P4
	HF: 1 x M-50N/GM M-50
Connectors	INPUT: Female XLR-Jack
	LOOP THRU: Male XLR
	AC INPUT: Male IEC
AC Power Requirements	115 V, 50 Hz/60 Hz
	230 V, 50 Hz/60 Hz
Dimensions (H x W x D)	83 x 44.8 x 47.6 cm
	(32.7 x 17.6 x 18.7 in)
Weight	30 kg (66 lb)
Accessories (optional)	ANL-5
	TRD-5
	TRD-2

Dimensions

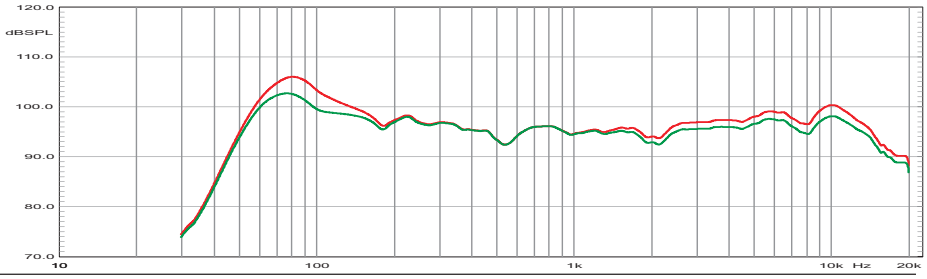


ALL DIMENSIONS IN MILIMETERS

1. Continuous power at driver impedance.
2. Level control at maximum.
3. Measured maximum peak level.

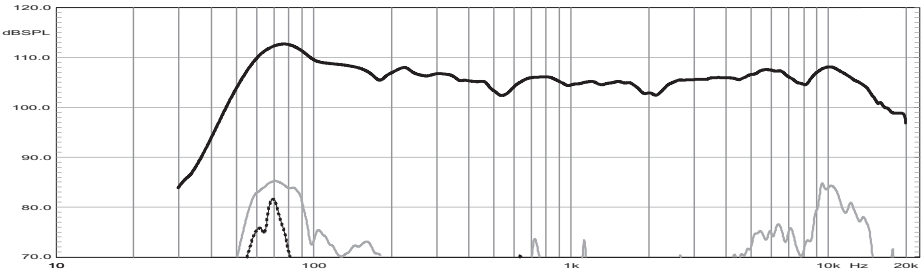
Frequency Response

Shows the frequency response at 1 m of a unit radiating to an anechoic environment and driven by a swept sine wave signal (-20 dBu input). Green: Flat EQ. Red: Boost EQ



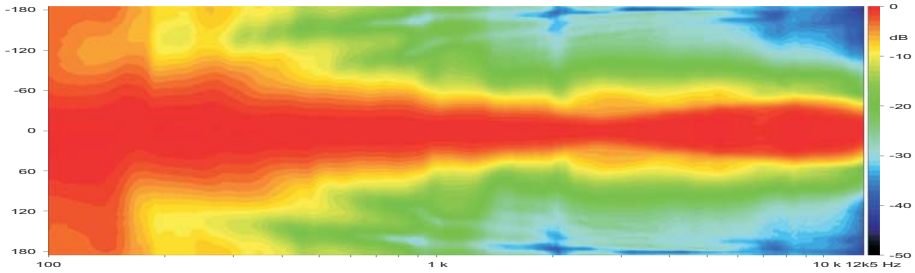
Distortion

Shows the Second Harmonic Distortion (grey) and Third Harmonic Distortion (dotted) curves for a unit driven by a swept sine wave signal (-10 dBu input).



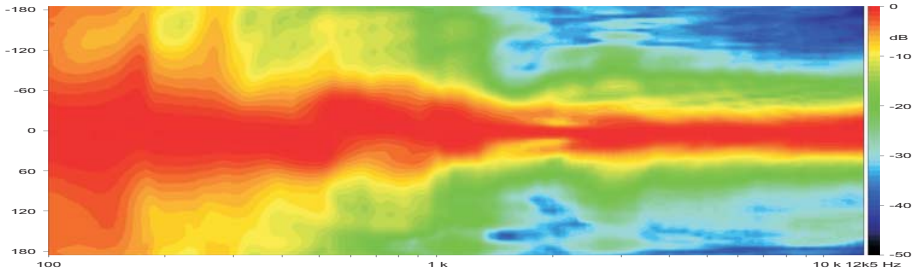
Horizontal Directivity

Shows normalized horizontal isobar plot.



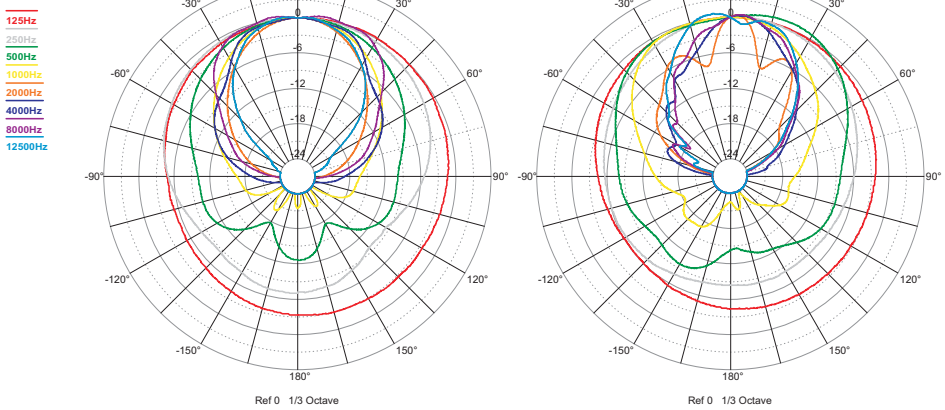
Vertical Directivity

Shows normalized vertical isobar plot.



Polar Response

Shows the 1/3 octave band horizontal (left) and vertical (right) polars for the indicated frequencies. Full scale is 30 dB, 6 dB per division.



NOTES. 1.Frequency response: referred to 1 m; low end obtained through the use of near field techniques; one-third octave smoothed for correlation with human hearing. 5.Polars were acquired by placing the unit on a computer controlled turntable inside our anechoic chamber. Measurement distance was 4 m.

Product improvement through research and development is a continuous process at D.A.S. Audio. All specifications subject to change without notice.

D.A.S. Audio S.A.
C/ Islas Baleares, 24
46988 Fuente del Jarro
Valencia - SPAIN
Tel. 961 340 525 - Tel. Intl. +34 961 340 860
Fax 961 340 607 - Fax Intl. +34 961 340 607

D.A.S. Audio of America Inc.
Sunset Palmetto Park - 6816 NW 77th Court
Miami, FL. 33166 U.S.A.
Tel. 305 436 0521 - Fax. 305 436 0528
Toll Free: 1 888 DAS 4 USA

D.A.S. Audio Asia Pte. Ltd.
25 Kaki Bukit Crescent # 01-00/ 02-00
Kaki Bukit Techpark I - Singapore 416256
Co. Reg. No. 200704134E
Tel. +65 6742 0151 - Fax. +65 6742 0157

www.dasaudio.com

TECHNICAL SPECIFICATIONS
All specifications are with loudspeaker specific processing

TRAPJR/6K LOUDSPEAKER

SENSITIVITY:	99 dB (1w/1m) @ 300 Hz
MAXIMUM PROGRAM SPL:	127 dB pgm, 130 dB peak
DISPERSION:	40° H by 60° V
FREQUENCY RESPONSE:	50 Hz to 18,000 Hz
HIGH FREQUENCY DRIVER:	1" SDA202-8 driver, 40 W RMS at 8 Ohms, 80 W program.
LOW FREQUENCY DRIVER:	12" SSL15-8K woofer, 300 W RMS at 8 Ohms, 600 W program.
CROSSOVER POINT:	1600 Hz
ENCLOSURE	13 ply hardwood, heavily braced with perforated metal grille and moisture resistant foam insert
CONNECTORS:	Neutrik 4-pin
FINISH OPTIONS:	Black, white or custom color paint, natural, weather resistant
DIMENSIONS:	26 1/2" H x 14 3/4" W x 16 1/4" D (67.3 cm x 42.2 cm x 59.1 cm)
NET WEIGHT:	63 Lbs.

P 3500 AMPLIFIER

OUTPUT RATINGS: (20 Hz to 20 kHz < 0.25% THD)	500 w/ch at 8 Ohms 750 w/ch at 4 Ohms 900 w/ch at 2 Ohms 1500 Watts, 4 Ohms bridged
FREQUENCY RESPONSE:	+0.0, -.5 dB, 20 Hz to 20 kHz @ RPO
THD (at 1kHz) **DISTORTION:**	< 0.1% at RPO (4 Ohms)
SMPTE IMD:	< 0.2 %, 500 w at 8 Ohms
HUM & NOISE:	-100 dB (referred to RPO @ 8 Ohms,
CROSSTALK:	> 60 dB @ 400 Hz
INPUT SENSITIVITY:	1.5 V for RPO (at 8 Ohms)
INPUT IMPEDANCE:	20 K Ohms, balanced
VOLTAGE GAIN:	42
SLEW RATE:	> 35 v/usec
DAMPING FACTOR:	>100 for loads of 2 Ohms or greater, 20 Hz to 20 kHz
MAX. VOLTAGE SWING:	+/-105 V Peak @ 8 Ohms RPO
POWER REQUIREMENTS:	100/120 VAC, 50/60 Hz (Dom.) 200/230 VAC, 50/60 Hz (Export) (1440 VA)

ARCHITECTS' AND ENGINEERS'S SPECIFICATIONS

The loudspeaker cluster shall be a Renkus-Heinz Model {TJ3K(T)} {TJ4K(T)} {TJ5K(T)} or approved equal pre-engineered RPA array providing true point source performance.

The loudspeaker cluster shall include (3)(4)(5) Renkus-Heinz TRAPJR/6K loudspeakers and all necessary hanging hardware.

Each loudspeaker shall consist of an extended-range 1" HF driver coupled to a single Complex Conic high frequency waveguide plus a heavy-duty 12" woofer, all mounted in a 40° trapezoidal enclosure. The woofer shall have a 4" edge wound voice coil and a Kevlar reinforced fiber cone. Each loudspeaker shall include a built-in crossover having a 600 Watt program power rating at 8 Ohms and provide 40° H x 60° V coverage.

Sensitivity shall be no less than 98 dB @ 1w,1m with a maximum SPL of at least 127 dB and a frequency response of 50 Hz to 18 kHz.

The enclosure shall be trapezoidal in shape and constructed from 13 ply hardwood, heavily braced and lined with fiberglass to suppress resonances. It shall be no larger than 26 1/2" high and 14 3/4" wide, be no deeper than 16", and weigh no more than 63 Lbs. A matching perforated metal grille backed with protective foam shall be included. The finish shall be (black carpet) (black paint) (white paint) (natural) (weather resistant). Connectors shall be 4-pin Neutrik.

The loudspeaker array shall be equipped with factory pre-engineered flying hardware, Renkus-Heinz model (TJ3-RHANG) (TJ4-RHANG) (TJ5-RHANG).

Power for the array shall be provided by a Renkus-Heinz P3500 amplifier equipped with an appropriate PK-A loudspeaker controller modules.

The power amplifier shall have an FTC output power rating of at least 750 Watts per channel into 4 Ohm loads (900 Watts into 2 Ohms) at less than 0.25% THD from 20 Hz to 20 kHz. Overall frequency response shall be within + 0.0 dB, - 0.5 dB over the same frequency range at all power levels up to rated power output. Hum and noise level shall be at least -100 dB referred to RPO @ 8 Ohms.

Binding posts and a 4-pin Neutrik connector shall be provided for output connections. Input connectors shall be 3-pin XLR type. Front panel controls shall include the input level attentuators and power on/off switch.

The plug-in controller modules shall be calibrated to match the equalization, protection and delay requirements of the associated loudspeaker array. They shall provide separate fourth-order, 24 dB per octave crossovers, low frequency signal delay circuitry, and protective circuitry for the associated loudspeakers. The protective circuits shall be designed to prevent damage to the loudspeakers from overheating (thermal overload), from over-excursion and from high-level transients].

RENKUS-HEINZ
19201 Cook Street, Foothill Ranch, CA 92610-3501
Tel: 949-588-9997 Fax: 949-588-9514 E-mail: Sales@renkus-heinz.com Web: www.rh.com

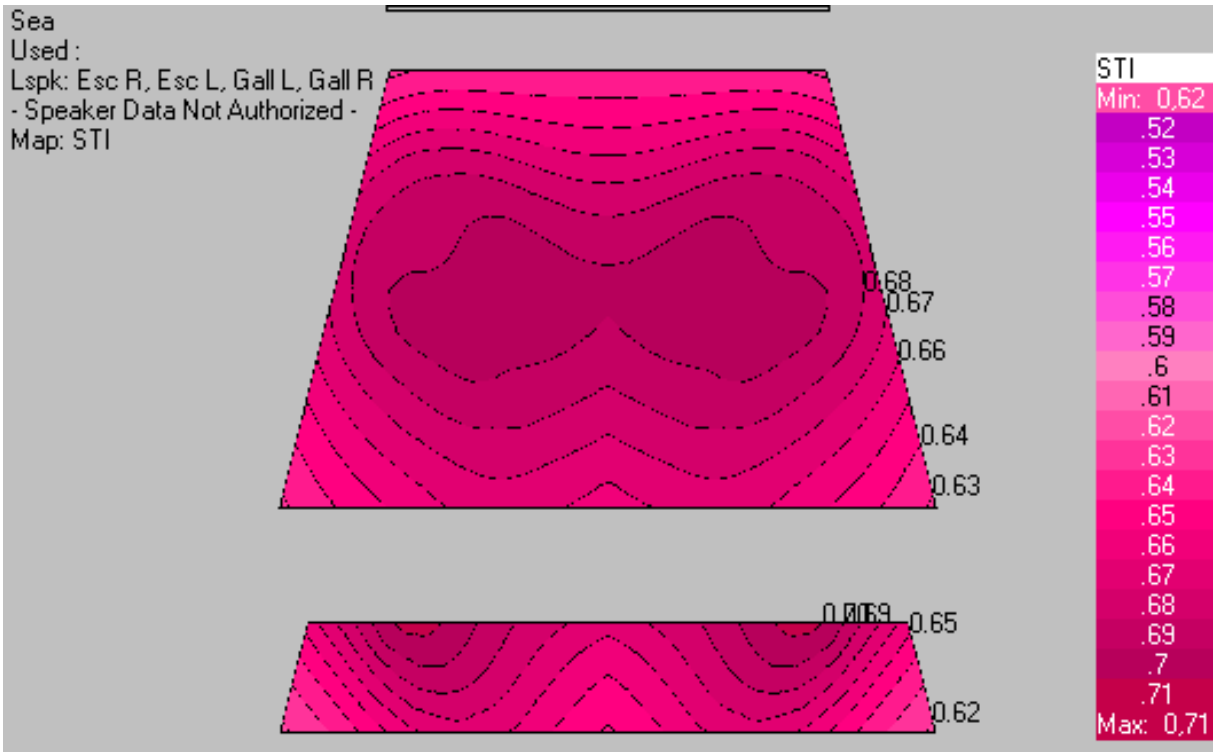


Figura 7: Mapa de STI mediante Standard Mapping