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DETERMINATION OF LOUDSPEAKER SOUND POWER AND DIRECTIVITY OF REVERBERATION AND ANECHOIC CHAMBER METHODS

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1. INTRODUCTION

For most voice system design it is paramount that the direct-to-reverberant ratio within a space (at various positions) is known. Errors of as little as 3dB can, under certain conditions, have a profound effect on the system performance especially speech intelligibility.

Much therefore depends upon the loudspeaker data supplied by the manufacturers or their test houses.

The calculations to deduce direct-to-reverberation ratio (D/R) may be applied from a variety of starting points but they all revolve around the same set of equations.

We know that:

$$L_{p,d} = L_w + 10\text{Log}\left(\frac{Q}{4\pi r^2}\right) \qquad \text{[1]}$$

where: $L_{p,d}$ = direct sound pressure level dB re 20µPa
L_w = Sound Power Level dB re 10^{-12}Watt
Q = Directivity factor
r = distance from source (m).

Further that:

$$L_{p,r} = L_w + 10\text{Log}\left(\frac{4}{R_c}\right) \qquad \text{[2]}$$

where: $L_{p,r}$ = reverberant sound pressure level dB re 20µPa
L_w = Sound Power Level dB re 10^{-12}Watt
R_c = Room constant (m^2).

From equation [1] for a given $L_{p,d}$ a knowledge of either Q or L_w allows deduction of the other and further, a knowledge of L_w and R_c allows deduction of $L_{p,r}$ and hence D/R.

Hence we need to determine either L_w or Q but in any case the measurement of one of the quantities must be equivalent to a measure of the other.

Traditionally, sound power level is determined in a reverberation chamber and directivity in an anechoic chamber but in fact either parameter may be deduced from a measurement in either chamber. In fact the measurement of directivity in an anechoic chamber is in fact a measurement of the sound power of the device which is subsequently used to determine directivity index (10LogQ) and hence directivity factor Q.

Hence we may understand that both parameters L_w and Q are interchangeable and for brevity most of the measurements for comparison given in this Paper are for L_w.

2. EXPERIMENTS

To test the reciprocity of L_w and Q for each method, reverberant and anechoic, we carried out sound power level measurements in AMS Acoustics' reverberation chamber and also deduced sound power level from the polar plot in AMS Acoustics' anechoic chamber.

The chamber data is given below:

Chamber	Volume	Mid-Frequency RT
Anechoic	$85m^3$	N/A
Reverberant	$38m^3$	7 secs.

The results for a single cone driver device mounted in free space are given in fig. 1.

It can be seen that there are differences at both low and high frequency. We could not explain the high frequency difference but thought that the low frequency discrepancy was due to the small volume of AMS Acoustics' reverberation chamber.

We decided to repeat the experiment but using BRE chambers. We found that the differences still existed. there was no difference between the anechoic measurements and only a small difference between reverberation measurements (see fig. 2). Surprisingly there was minimal difference at low frequency. It should be noted that we tested several different types of single cone devices in both sets of chambers and the differences between BRE and AMS were slight.

3. INVESTIGATION OF THE ERROR

We were convinced that the apparent error lies in the polar method and felt that it was a resolution problem.

We should state that the polar method used was 10 deg. intervals using the Davis area weighting.

We decided to remeasure the chart at 5 degs. and to process the data by the Gerzon area weightings.

We retested two simple single cone projector loudspeakers and obtained the results shown in figs. 3 and 4.

Again we obtained differences at low frequency and there appeared to be little difference between the different weighting and angular resolution.

To further investigate the problem we carried out an additional test using a 7mm ceiling loudspeaker mounted in a half space baffle. The results are given in fig. 5.

It can be seen that the low frequency anomaly is apparently reduced but the high frequency difference remains. It also suggests that the higher angular resolution gives closer agreement with the reverberant method.

4. DISCUSSION

Considerable care was taken when carrying out the measurements since we were aware that small differences could be significant. We remain slightly concerned that the AMS reverberant chamber is apparently able to produce the same low frequency results as BRE. Fig. 2 however provides the BRE reverberant chamber results as a comparison with AMS anechoic chamber; the low frequency discrepancy is apparent.

Of considerable importance is which method is correct.

Instinct suggests that it is the traditional reverberant chamber method which is closer to reality. the potential errors are in pressure level measurement, error in RT measurement and error in volume measurement. Certainly errors in volume or RT would need to be gross to have a material effect and in any case the correlation between BRE and AMS reverberant chamber is good where there is different volumes and different RTs.

The errors in anechoic measurements are different, firstly there is the error of actual pressure measurement, which we would expect to be much the same as for the reverberation chamber method. Then there are errors in regard of angular displacement, distance from the rotational centre and the relative distance between the transducer and the rotational centre.

The relative distance between the transducer and rotational centre might account for the differences between Projector A and Projector B which were different sizes (same diameter, different volume).

The rotational errors might account for the differences between the projectors and the ceiling loudspeaker. In the case of the free space projector the loudspeaker was rotated and in the case of the ceiling loudspeaker, the microphone was moved.

The next consideration is the magnitude of the difference. A difference of only 3dB translates to a Q directivity error of x2 which is unacceptable.

5. CONCLUSIONS

Although we have not at the time of writing solved the problem of the discrepancy or indeed which method is to be preferred, we have however determined that these differences can exist but would not be noticed if both methods were not employed.

On the premise that the reverberant chamber method is more reliable then there is some evidence to suggest that 5^0 resolution is better than 10^0 and that Gerzon weightings are to be preferred over Davis.

The exercise has also highlighted the importance of rigor when carrying out the measurements. Normal experimental errors can result in significant differences in calculated directionality (or sound power) which can translate into differences in predicted performance especially in terms of RASTI and on this subject it might be that the current precision to predict RASTI is better than that to measure and define loudspeakers.

It is hoped that this Paper, although not conclusive might provide the impetus for further work or thoughts and it might that a working party by one of the learned societies might be set up.

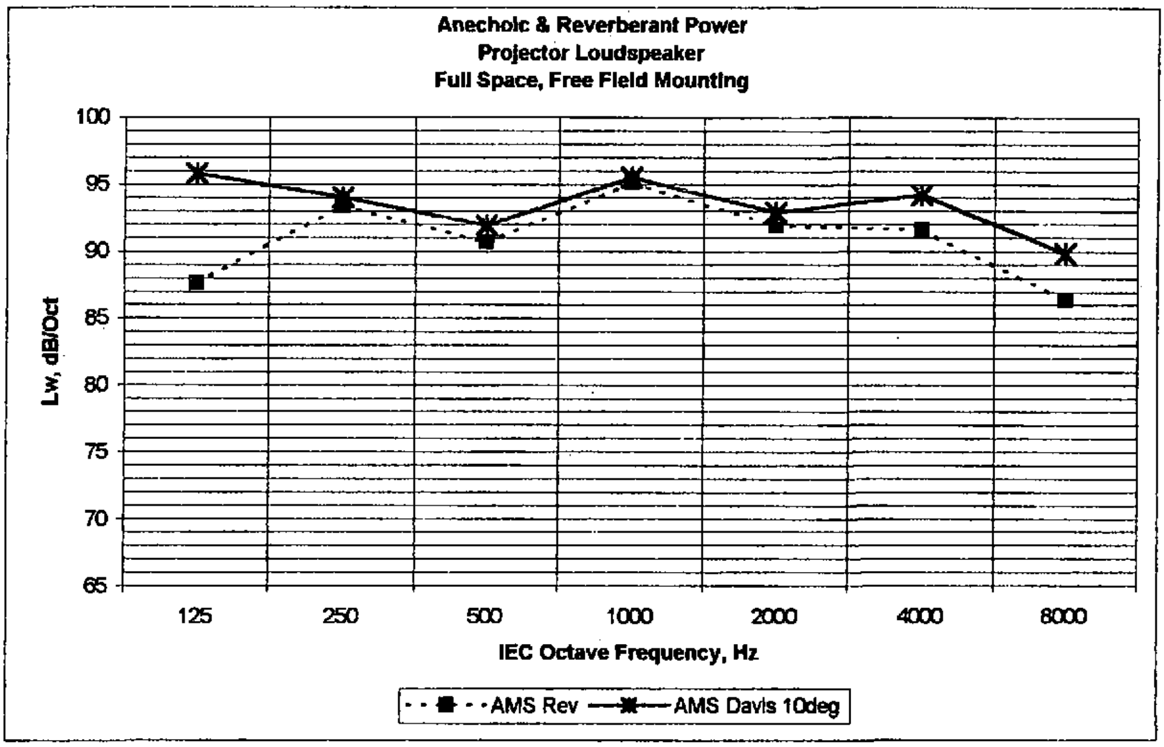

Figure 1

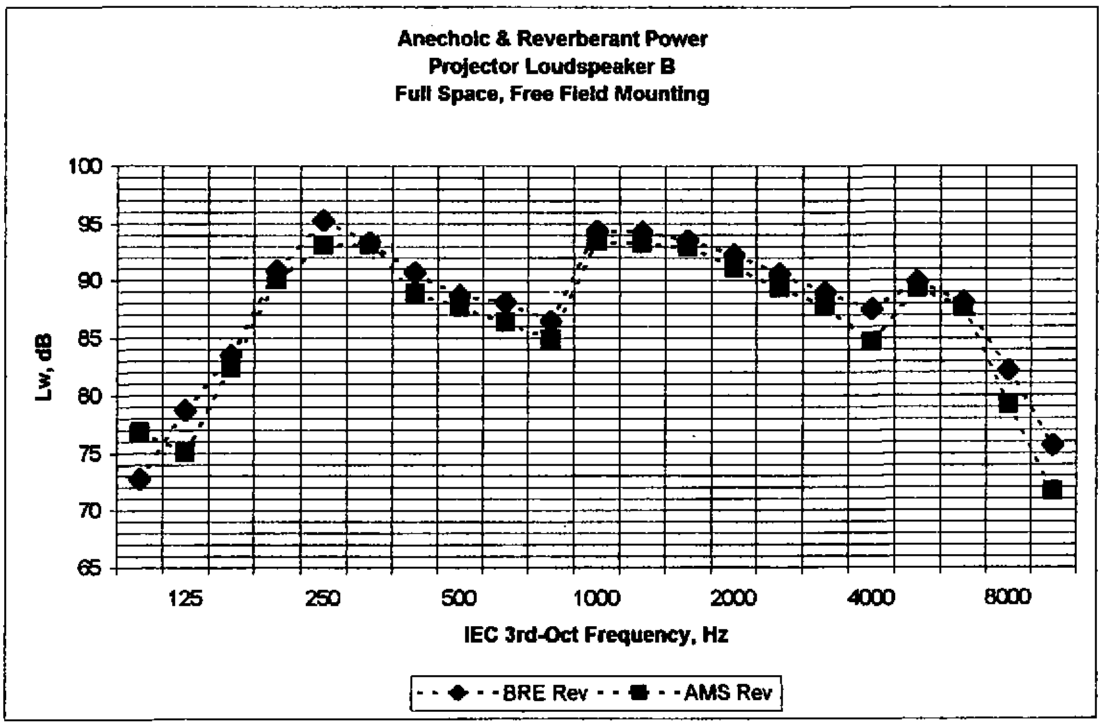

Figure 2

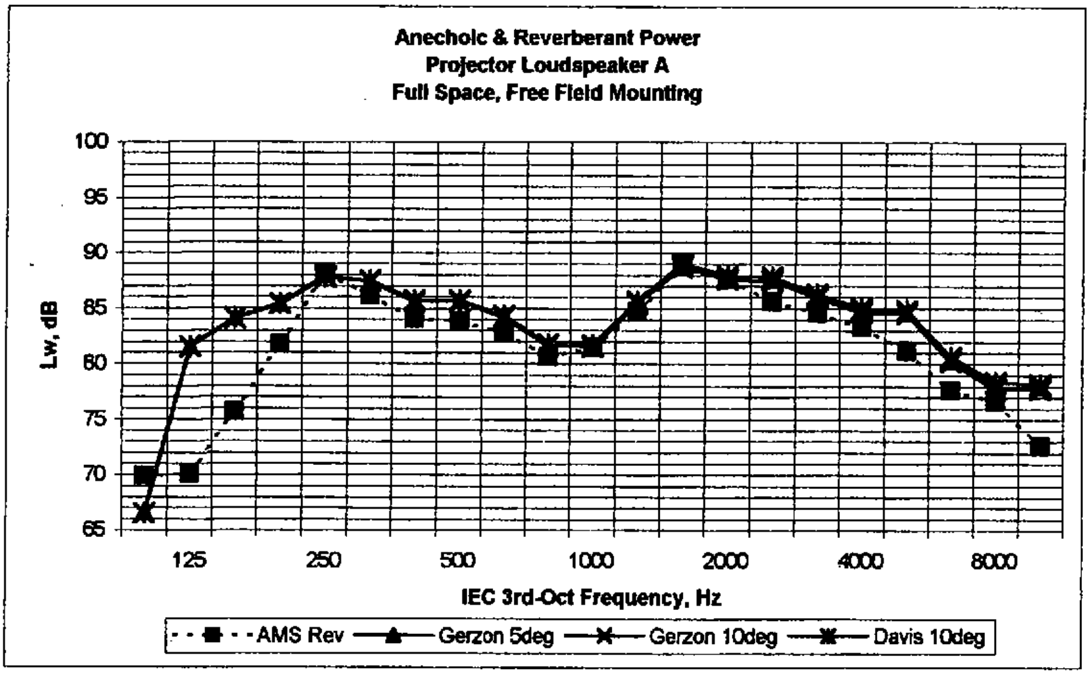

Figure 3

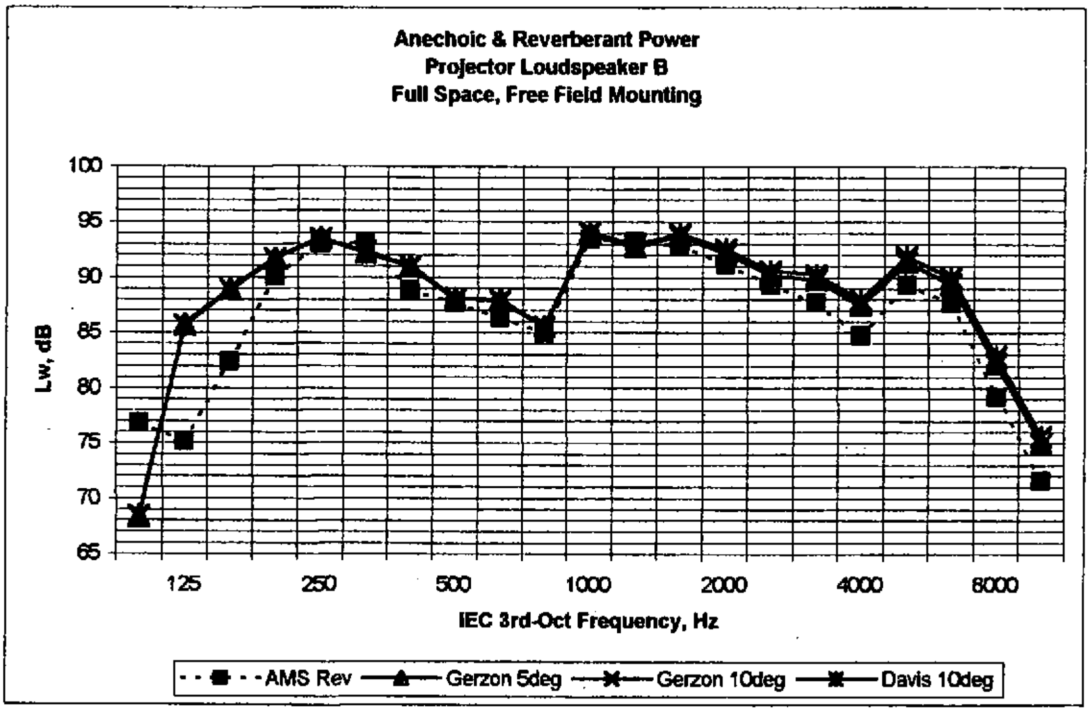

Figure 4

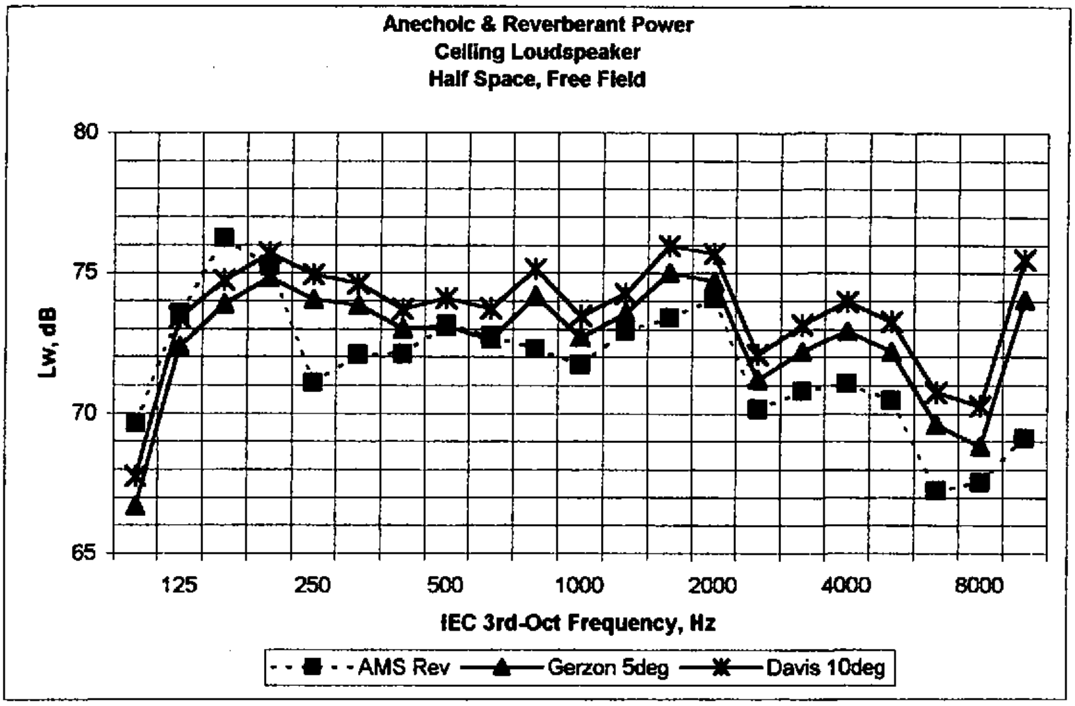
Anechoic & Reverberant Power
Ceiling Loudspeaker
Half Space, Free Field
80
75
70
65
Lw, dB
125
250
500
1000
2000
4000
8000
IEC 3rd-Oct Frequency, Hz
AMS Rev
Gerzon 5deg
Davis 10deg

Figure 5

Table 1

Ceiling Loudspeaker (AMS Rev)

	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
LpT Mean (dB)	744	784	81.0	809	77.2	786	787	798	793	787	77.9	786	783	786	743	744	740	724	684	67.3	67.9
LpT Deviation (dB)	1.4	20	08	08	06	08	08	06	07	04	03	05	02	03	01	03	02	02	02	01	06
RT Mean (secs)	80	7.0	68	7.8	84	86	83	83	7.9	7.5	68	60	51	46	42	37	31	24	20	1.5	1.2
RT Deviation (secs)	02	06	1.0	08	1.8	1.0	1.1	05	02	02	04	03	01	02	01	02	01	01	01	01	01
LwMean (dB PWL)	697	736	782	753	71.1	721	721	731	728	723	71.7	729	734	741	702	708	71.1	705	67.2	67.5	691
LwDeviation (dB PWL)	1.5	24	1.4	1.1	1.5	1.4	1.4	08	09	05	06	07	03	05	02	05	03	03	04	03	08

Projector Loudspeaker A (AMS Rev)

	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
LpT Mean (dB)	744	781	821	884	947	984	91.2	91.0	899	87.5	87.9	906	943	926	900	886	885	837	790	787	71.5
LpT Deviation (dB)	1.7	09	1.4	1.8	25	1.6	1.0	06	05	08	02	04	05	03	.03	02	01	02	04	05	07
RT Mean (secs)	7.8	100	101	98	92	103	94	93	90	82	7.3	63	56	51	44	40	33	28	21	1.6	1.2
RT Deviation (secs)	03	1.0	23	07	06	1.4	04	02	04	03	02	02	01	00	01	01	01	00	01	00	01
LwMean (dB PWL)	699	701	757	81.8	882	881	841	838	828	808	81.5	847	890	876	856	846	833	81.2	77.7	768	726
LwDeviation (dB PWL)	1.9	1.4	24	21	28	24	1.2	07	07	1.0	03	05	06	03	04	03	02	03	05	06	1.0

Projector Loudspeaker B (AMS Rev)

	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
LpT Mean (dB)	81.7	809	890	986	993	999	959	952	939	91.8	999	994	985	981	987	91.3	87.1	905	87.9	783	693
LpT Deviation (dB)	05	1.7	1.1	1.8	09	1.5	01	1.1	1.2	03	02	05	03	03	02	01	02	02	02	02	04
RT Mean (secs)	84	94	105	96	86	91	93	100	99	83	7.4	69	58	50	43	36	28	21	1.6	1.3	09
RT Deviation (secs)	08	08	1.9	07	06	03	02	05	01	04	01	00	03	01	01	00	00	02	00	00	00
LwMean (dB PWL)	788	751	824	901	930	931	888	87.7	883	849	984	982	929	91.1	893	87.7	847	893	87.7	792	71.6
LwDeviation (dB PWL)	09	21	1.9	22	1.2	1.7	02	1.4	1.3	05	02	05	05	04	02	01	02	06	03	02	06

Projector Loudspeaker B (ERE Rev)

	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
LpT Mean (dB)	67.7	734	783	856	894	882	853	831	822	802	87.8	87.4	881	843	820	795	77.1	782	752	67.5	596
LpT Deviation (dB)	1.1	07	05	02	06	01	01	02	01	04	03	01	04	04	04	03	05	03	07	08	1.2
RT Mean (secs)	203	187	183	17.6	149	17.1	161	152	141	127	11.9	109	96	85	7.3	60	48	35	26	1.8	1.3
RT Deviation (secs)	1.9	05	1.6	09	03	05	01	04	03	01	04	02	02	01	02	01	01	01	01	00	01
LwMean (dB PWL)	727	787	835	909	953	983	907	887	881	865	944	943	936	923	906	889	87.5	899	881	822	756
LwDeviation (dB PWL)	1.5	08	09	04	06	02	01	03	02	04	05	02	05	05	05	03	06	05	08	09	1.4