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AUDIO POWER AND DYNAMIC HEADROOM REQUIREMENTS FOR PUBLIC ADDRESS AND ELECTRO-ACOUSTIC REINFORCEMENT SYSTEMS

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INTRODUCTION

The design of public address systems involves a number of tasks - one such task is the determination of the audio power requirements. This is particularly difficult when the space is not acoustically well defined and there is the likelihood of a high ambient noise levels.

The problem may be considered from a number of standpoints. The most common is to estimate the ambient sound pressure level and from this determine from a consideration of the transducer type and placement the electrical power requirements. This involves a number of assumptions and hence increases the degree of uncertainty in the calculated values.

The problem may, however, be approached another way by equating the power requirements directly.

THEORY

In situations of moderate or high ambient noise, the following statement may be used:

System Acoustic Power Requirement = Ambient Noise Source Acoustic Power + Acoustic Power Margin..(1)

The acoustic power margin relates to an excess power requirement to allow for acoustic losses and programme peak-to-mean ratio together with the requirements for signal-to-noise ratio for good speech intelligibility.

Hence in practical terms, the expression (i) above becomes:

System Acoustic Power (dB) = Noise Source Acoustic Power (dB) +Signal-to-Noise for Intelligibility (dB) +Headroom for Programme Content (dB)

Since

System Electrical Power = System Acoustic Power x Electro-Acoustic Conversion Efficiency + Electrical Losses

it is therefore possible to estimate the electrical power requirements.

SOURCE ACOUSTIC POWER

In the case of spectator-type venues, the ambient noise is almost certainly caused by shouting. A resume of the text and data books gives the power of a loud shout to be in the region of 1mW. Hence a crowd of 10,000 spectators would generate (if they all shouted at the same time) 10 Watts. It may be in the light of experience that this product needs to be modified on the basis that not all would be vocal at any time.

Hence: Total Acoustic Power of Source = Power of Single Element x Number in crowd x Diversity modifier

i.e. $Pwl_s = Pwl_u + 10\text{Log}_{10} N + 10\text{Log}_{10} F$

where
Pwl_s = Sound Power Level of Source
Pwl_u = Sound Power Level of Crowd Unit
N = Number in Crowd
F = Diversification Modifier.

SIGNAL-TO-NOISE FOR INTELLIGIBILITY

The maximum achievable intelligibility depends heavily upon the signal-to-noise ratio between the system acoustic signal and the ambient noise.

Fig. 1 below shows the maximum achievable[1] %AL_{cons} for varying signal-to-noise ratios.

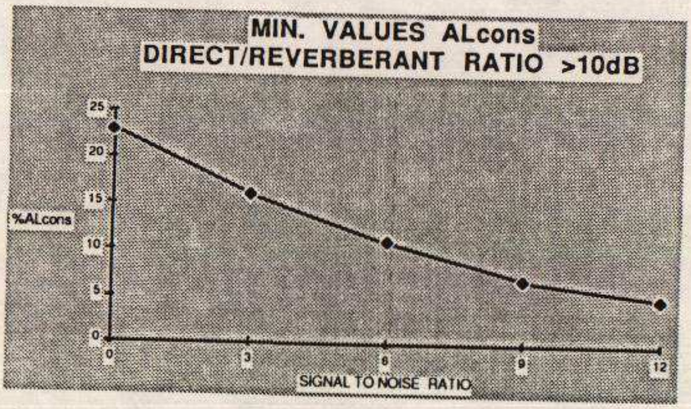

FIG 1

It would seem reasonable that the absolute minimum signal-to-noise ratio would be 3 dB and that a suitable practical acceptable value might be 6 dB

ACOUSTIC LOSSES

The acoustic losses depend heavily upon the type of transducer employed, its placement and the architecture of the venue. We refer to the amount of power that is radiated to the rear of the unit and hence makes no useful contribution. Fig. 2 shows an example of the radiation in terms of power from a 90 x 40 constant-directivity horn.

From fig. 2 it can be seen that for the rated dispersion angle (i.e. 90 x 40) the useful to non-useful(or front-to-back) radiation is in the region of +1 dB which means that a little under half of the power is wasted i.e. in the region of 3 dB. The more directional the device, the worse the situation becomes - a 40 x 20 constant-directivity horn is around unity over its rated dispersion angle. However, in practice the useful radiation is not necessarily only confined to the manufacturers quoted dispersion pattern. We may define 'useful' as that portion of the radiated power that is directly incident on the primary absorptive surface e.g. the audience.

[1]Based on the Peutz prediction model.

For most applications this would be contained in a $90^0 \times 90^0$ angle. In some cases the useful angle would be greater. This is especially true with large audience areas. Taking into account such losses for a variety of units a typical figure of 3 dB would not seem unreasonable.

ELECTRO-ACOUSTIC CONVERSION EFFICIENCY

This loss will depend upon the type and form of transducer employed. The table below gives typical conversion efficiencies for commonly used units.

Unit Type	Efficiency
CD Horn	15%
Re-Entrant Horn	5%
Cone	2%

These figures will depend to some extent upon the make of unit but may be regarded as typical.

OTHER ELECTRICAL LOSSES

These losses refer to cable and transformer losses or 0.5 dB without transformers. In a typical well designed system, these losses should be less than 2.0 dB.

HEADROOM FOR PROGRAMME CONTENT

This is rather more difficult to quantify since it will essentially depend upon both the type of programme and may be affected by the type of amplifier used. Fig.3 shows the formation of a multi-syllable word.

Where the peak-to-mean ratio is in the region of 12-15 dB this is further corroborated by long term samples of running speech as shown in fig. 4. This data suggests a peak power capability of approximately 12 dB is required within the system design which typically may result in a 7-8 dB short term rms power requirement. We would therefore suggest that +10 dB was reasonable.

SUMMARY

The following table provides the results for a system for a 30,000 capacity ground.

	Power dB (re 10^{-12} Watts)		Power Watts	
Requirements	**Factor** (dB)	**Total dB** (re10^{-12}Watts)	**Factor** (Multiplying)	**Total Watts**
Acoustic Power of Loud Shout		90.0		0.001
No. of Spectators (30,000)	44.8	134.8	30,000	30.0
Total Crowd Power		**134.8**		**30.0**
Losses/Allowances				
Headroom for Intelligibility	6.0		4.0	
Cable and Transformer Losses	2.0		1.6	
Device Headroom	10.0		10.0	
Losses Due to Non-Containment	3.0		2.0	
Total Losses/Allowances	21.0		125.9	
Total Acoustic Power Required		**156**		**3777**

Transducers Used	Efficiency %	Total Electrical Power Required	Electrical Power in Watts/Person to nearest 0.5W
CD Horns	15	25,200	1.0
Re-Entrant Horns	5	75,500	2.5
Cone Devices	2	180,000	6.5

DISCUSSION OF RESULTS

The foregoing is, of course, an approximation with a considerable number of assumptions. However, the figures give fair agreement with current practical examples.

The concept of estimating the electrical power requirements based on the number of spectators and the device types is not unreasonable and does provide a ready and quick method.

The largest area of uncertainty is in the allowances for programme content since the actual required rated power of the amplifiers will depend upon the type of amplifier employed and its ability to provide a short term excess of power.

It is important to note that in most practical examples, due to the topography of the system, amplifiers are not fully loaded and hence the total system power is not the sum of the amplifier power. For large distributed systems a 25% redundancy in amplifier power is not uncommon.

The simplicity of this method of estimating power requirements lies in its independence of the acoustics of the space.

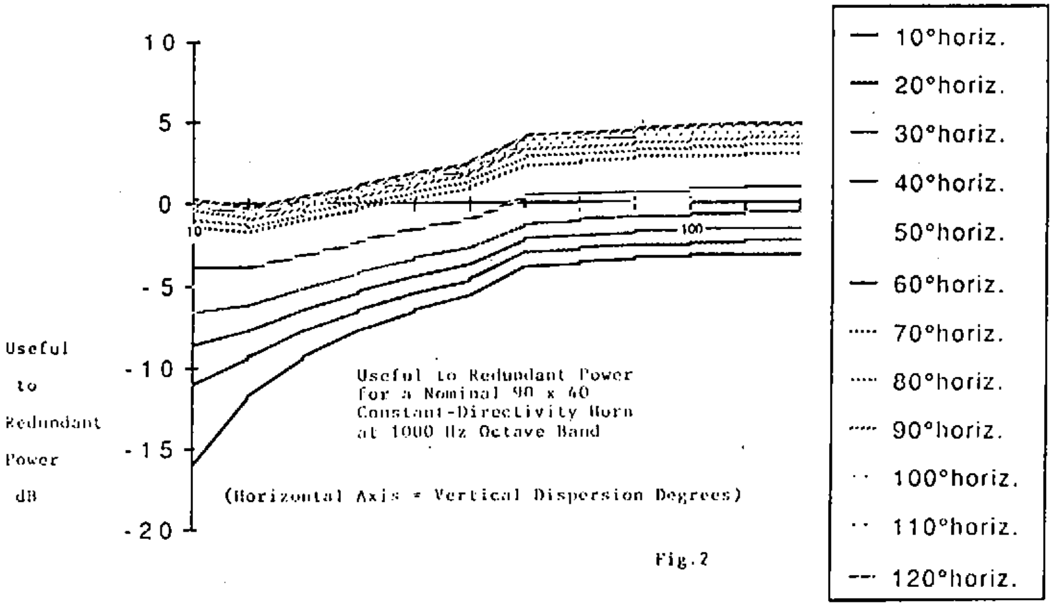

Fig.2

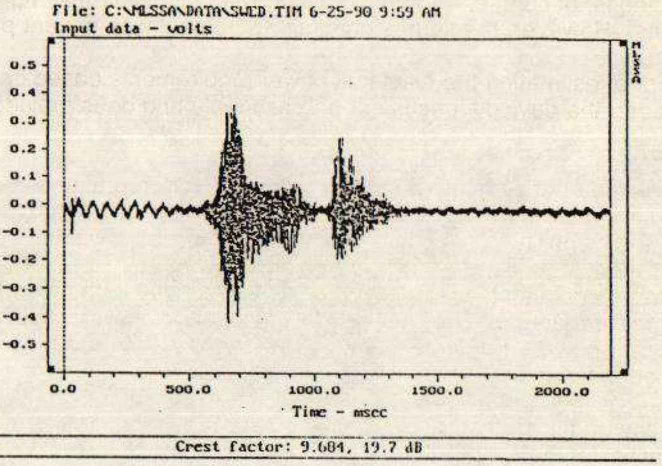

Fig. 3

Male Speech Peak and rms Levels

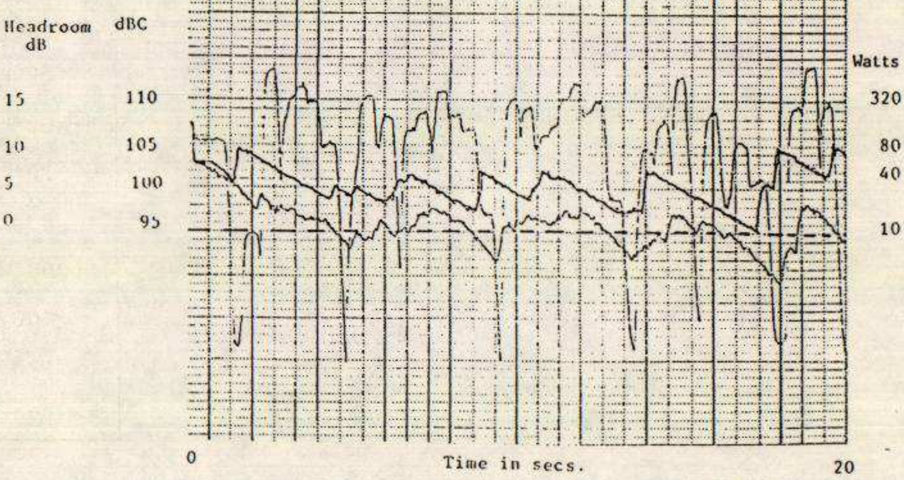

Fig. 4