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A PROPOSED METHOD FOR THE MEASUREMENT OF SPEECH LEVELS WITH SPECIAL REFERENCE TO VOICE ALARM SYSTEMS IN BUILDINGS

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1. INTRODUCTION

The measurement of speech levels is both central to determining compliance with a specification and in the design process itself.

Speech of course introduces complications; firstly it is not a constant or stationery signal in either the time or frequency domain and secondly it might be affected by the rate of delivery and the manner of delivery.

Decisions need to be taken in regard of the following:

1. Weighting descriptor (A, Lin, octave bands etc.)
2. Temporal descriptor (L_{eq}, L_{50}, L_{10} etc.)
3. Response descriptor (slow, fast etc.).

Needless to say the measurements should be relatively routine, simple to make and repeatable.

This Paper explores the various options.

2. WEIGHTING DESCRIPTOR

The first issue is a single figure possibly weighted or an octave band presentation. There are two difficulties with octave band based criteria, firstly it is relatively complicated to measure, secondly it is difficult to state a pass/no pass criteria. There remains the possibility that one or perhaps two octave bands could be cited but this may not work in situations that require a special spectral shaping.

Notwithstanding the above, octave band measurements require rather more care and advanced instrumentation.

The issue seems to be therefore Lin or A-weighting, again for no particular reason other than ease of measurement, availability of equipment and the correlation below A-weighting and loudness, we would chose A-weighting.

3. TEMPORAL DESCRIPTOR

To determine a temporal descriptor we carried out a number of experiments. Firstly we recorded speech as follows:

Sentence 1 - 'She was waiting at my house.'
Sentence 2 - Jo took fathers shoe bench out.'

since these sentences are deemed to include all speech sounds.

Sentence 3 - 'Compared with the earth, how large is the sun?'
Sentence 4 - 'Describe the shoes of a dutchman'.
Passage 5 - Reading from George Bernard Shaw.

Each sentence and the reading was read into a digital editing suite. One version was as recorded and the other was with the periods of silence between words removed.

Each sentence and each version was repeated several times to give a long enough sample to be able to obtain reliable measurements.

The table below gives the results obtained:

Table of Measurements of Speech Levels

Sentence	Talker	With silence			Without silence			Difference		
		L_{A90}	L_{A10}	L_{Aeq}	L_{A90}	L_{A10}	L_{Aeq}	L_{A90}	L_{A10}	L_{Aeq}
1	HG	75.6	88.0	84.0	79.8	89.0	86.0	4.2	1.0	2.0
1	PH	69.6	81.2	77.9	76.2	81.6	79.6	6.6	0.4	1.7
1	SB	71.6	82.7	79.3	76.4	83.8	81.2	4.8	1.1	1.9
1	TS	64.0	83.4	79.7	73.8	84.0	81.2	9.8	0.6	1.5
1	WL	71.2	82.0	78.2	75.0	83.0	80.1	3.8	1.0	1.9
2	HG	77.2	86.8	84.0	82.0	87.8	85.7	4.8	1.0	1.7
2	PH	68.4	82.4	78.4	75.8	83.6	80.0	7.4	1.2	1.6
2	SB	66.4	78.0	75.3	74.6	79.2	77.3	8.2	1.2	2.0
2	TS	61.2	78.2	74.5	74.2	79.2	76.7	13.0	1.0	2.2
2	WL	65.8	76.6	74.3	72.2	77.0	76.0	6.4	0.4	1.7
3	CH	63.6	87.6	82.8	74.6	88.0	84.6	11.0	0.4	1.8
4	CH	68.2	84.4	79.5	72.6	85.2	81.5	4.4	0.8	2.0
5	BS	66.0	86.2	82.8	79.6	87.2	84.6	13.6	1.0	1.8
Average								7.5	0.9	1.8

Table 1

A further experiment was carried out as follows.

The G. Bernard Shaw passage was played (mono) into both sides of headphones and pink noise was summed with the speech signal.

Subjects were asked to set the level of the pink noise such that the speech and noise was judged to be equally loud. Two types of noise was used, broad band (pink) and speech-shaped. Five subjects were used and in each test the subject was asked to increase the noise until equal loudness was achieved and then to decrease the noise until equal loudness was achieved.

The table below gives the results obtained.

Table of Subjective Difference between Noise and Speech for Various Conditions

Silence	Noise	Subjective Difference between Noise and Speech (L_{Aeq})						
		1	2	3	4	5	Av.	SD
With	Broad Band	3.1	3.5	3.3	2.0	0.5	2.3	1.1
With	Speech-Shaped	2.8	0.8	1.5	1.0	1.3	1.5	0.8
Without	Broad Band	2.6	2.6	2.0	1.0	1.4	1.9	1.0
Without	Speech-Shaped	2.7	0.2	1.0	1.2	1.3	1.3	0.9

Table 2

4. DISCUSSION

The choice of a temporal descriptor can only really be between L_{A10} and L_{Aeq} since L_{A90} is not a suitable measure.

Both L_{A10} and L_{Aeq} would be an acceptable measure.

Consideration of the equal loudness results in table 2 suggests that a descriptor which was independent of the periods of silence would be preferable and it can be seen that the difference in L_{A10} with silence and without is less than 1dB.

Accordingly therefore we would lean towards the appropriate descriptor as L_{A10} since not only would this give a reliable and hopefully repeatable measure, it would also give an indication of loudness which would be useful in respect of speech intelligibility calculations.

The argument against L_{A10} is relatively simple in that not all sound level meters are capable of this measurement and we believe this might be an overriding factor.

The measurement of equivalent level however is well understood and nowadays generally available. In common with an L_{A10} reading, L_{Aeq} is a measurement carried out by the sound level meter and does not require human input as would be the case with a meter set to slow.

The disadvantage of an L_{Aeq} measurement is that it understates loudness and furthermore it understates level due to the periods of silence between words.

Accordingly therefore we would propose that a correction be applied to the measured level.

We suggest that a correction of +2dB be applied to take account of the periods of silence (from table 1) and a further +1dB to take account of loudness.

Hence the specified level shall be the measured level (L_{Aeq}) +3dB.

5. PROPOSED METHOD

The proposed method is as follows.

Speech shall be input to the system at a normal operational level delivered at a normal rate (usually 4.8 - 5.2 syllables/sec.). The test speech shall not be less than 1 minute in length.

Measurements of L_{Aeq} shall be made at a representative number of positions at the listening plane throughout the space.

The measurement level shall be rounded up to the nearest whole decibel and then a correction of 3dB applied.

6. SUBJECTIVE SPEECH INTELLIGIBILITY MEASUREMENTS

The correctly measured level L_{Aeq} +3dB shall be used to set the signal level for subsequent post-processing with the addition of the noise of occupancy i.e. set S/N = L_{Aeq} +3dB - noise of occupancy.

Note:

The noise of occupancy is generally simulated by suitable spectral shaping to random noise. The descriptor used would depend upon the type of noise, for football grounds BS7827 specifies L_{A10} most other cases e.g. shopping centres L_{Aeq} might suffice.

7. CONCLUSIONS

We believe the proposed method provides the following:

1. Repeatable measurements.
2. Reliable measurements.
3. Correlation with loudness.
4. Direct use for subjective intelligibility measurements with post-processing.

Note:

The impetus for this work came from the ANC who are currently considering incorporating this or a similar method into an ANC standard. Comments would be most welcome to either authors or the ANC.