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SPEECH PRIVACY EVALUATION OF SOUND MASKING IN OPEN PLAN OFFICES

Mr David Luck
Hyder Consulting (Australia), Acoustic Services Division
116 Miller St, North Sydney, NSW, 2060
david.luck@hyder.com.au

Dr. John Challen
University of New South Wales
Department of Mechanical and Manufacturing Engineering
Kensington, NSW, 2052
j.challen@unsw.edu.au

1 INTRODUCTION

Traditional office design has is recent years undergone a number of changes which are reshaping the workplace. One of these trends has been the increased use of the open plan office. The continuing trend towards open plan offices has resulted in a new series of workplace problems. In the open plan office, noise has been identified as a major problem. Numerous noise sources, such as phones ringing, office machinery and loud conversations all contribute to a less productive work environment [1, 2].

The intelligibility of received speech depends upon the level of the accompanying background noise. Noise levels in open plan offices tend to be low because of the absorptive environment. This results in diffuse noise from adjacent workstations being both audible and distracting. In such cases, it is common to introduce electronic random noise generators feeding loudspeakers hidden in the ceiling plenum to raise the level of the background noise. This treatment is termed ‘sound masking’ a precisely contoured, constant broad band, low level background sound that masks conversational distractions and unwanted noise.

A typical sound masking system consists of the masking noise generator, an equaliser, one or more power amplifiers and a group of special loudspeakers installed above a dropped ceiling. Sound masking systems generally consist of electronic devices that generate a sound signal, shape or equalise a signal. This signal is then distributed to an array of speakers that are normally positioned in the ceiling plenum [3.]

Despite enthusiasm for sound masking as a means of decreasing speech intrusion, there is some contention as to the cost-effectiveness and necessity for sound masking. The practice of reintroducing sound into spaces already designed to achieve acceptable air conditioning noise levels remains an issue of debate. As mechanical plant and sound masking sound similar in character, it may be argued that air conditioning noise alone can provide sufficient background noise to enhance speech privacy. However the level and spectrum of air conditioning noise can vary from workstation to workstation, and in many buildings, cycles on and off. Noise masking is designed to provide constant evenly distributed sound in an open plan area. The use of a graphic equalizer allows shaping of the sound, particularly in the speech frequencies (250-4000 Hz), where speech intrusion affects workers productivity.

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Speech privacy testing was conducted in four open plan areas on Level 11 and 12 of the Campus MLC building, North Sydney. This 12-storey building has undergone an internal refurbishment, which included the installation of sound masking on all floors. A unique feature of the new design is that all staff, including management, are located in the open plan areas to facilitate team working.

The sound masking system located in ventilation riser shafts consists of a masking noise source and an Electrovoice 31 band 1/3 Octave Band Equalizer. This system is mounted in a rack with 240V power supply. Each speaker volume in the ceiling plenum is controlled from the main volume control on the graphic equalizer[4].

The main aim of this study was to determine the subjective speech privacy performance the Campus MLC masking system. This was conducted using assessment techniques provided in Australian Standards 2822-1985 [5]. The main test scenarios were evaluated for this study were as follows:

1) Normal Masking (graphic equalizer volume +9) and air conditioning noise;
2) No Masking – air conditioning noise only;
3) Maximum Masking (graphic equalizer volume +12) and air noise conditioning.

Secondly, a contour map of sound masking was constructed to identify and demonstrate areas of uneven coverage and potential installation problems

2 METHODOLOGY

This study was conducted using the 'Subjective Assessment' method in AS2822-1985. Subjective testing was conducted using a test crew consisting of one talker and two listeners. This involved the talker reading a list of 50 monosyllabic target words to the two listeners, at seated distances of 4-7m, and 15m.

The vocal effort of the talker was set to 60 dBA (conversational voice) at 1m from a CEL593 sound level meter. During delivery of the test material, each test word was embedded in a sentence "The word is…". This enabled a reverberant sound field to be established in the office area prior to the reading of each target word. Both talker and listener were located behind a Unifor workstation, which consisted of a 1.25m double- sided absorbent barrier screen.

The average panellist age was 30.3 years, ranging from 17 to 49 years. This consisted of 5 males and 5 females, with no notable hearing impairment. To minimise disruption in the MLC workplace, tests were conducted after hours although some workers and cleaners were present during testing.

The number of words correctly perceived by the listener was converted to a percentage of the test words to give the Speech Intelligibility (SI%). The SI% was then used to determine the

Articulation Index (AI). This measure was then used to determine the speech privacy conditions for each test as shown in Table 1.

Articulation Index	Speech Communication	Speech Privacy
0.00 0.05	None	Confidential
0.1		Normal
0.15		Unsatisfactory
0.2		
0.25	Fair	
0.3		
0.35		
0.4		
0.45	Good	None
0.5		
0.55		
0.6		
0.65	Excellent	
0.7		
0.75		
0.8		
0.85		
0.9		
1.0		

Table 1 Relationship between Articulation Index and Speech Privacy (AS2822-1985).

Following the delivery of the test words, a broadband 1-minute L_{Aeq} was measured at the ear level of the listener workstation, using 'Slow' response. In addition, a broadband impulse response reverberation time was determined using balloon bursts.

In addition, spatial coverage of the masking system was conducted to detect 'hot spots' or areas of uneven sound coverage in each office. Noise measurements were taken at seated ear level at a series of grid points 2m wide by 5m long. In some cases, the presence of workstations or office furniture obstructed the exact measurement location. In such cases the nearest location relative to the grid point was used. Each measurement was conducted using a Bruel and Kjaer 2231 sound level meter using Slow response L_{Aeq} for 20 seconds duration. Measurements were paused during periods not associated with the steady state office noise. Each reading was marked onto a grided test sheet and retained for further analysis. Spatial coverage was interpolated and plotted using Surfer contour software in 1 dBA intervals [6].

3 RESULTS

3.1 Acoustic Environment

The results of measurements conducted in the office spaces during these tests are presented below in Table 2. Measurements with the masking on varied by 3.2 dBA between offices. Overall normal and maximum masking levels were consistently above Australia/New Zealand Standards 2107-2000[7] (AS/NZ 2107-2000) for open plan offices of 40-45 dBA. In addition maximum masking was clearly intrusive, and was described by panellists as an annoying 'hiss'. With no masking, air conditioning and office machinery were the predominant steady state noises.

Test Scenario	Range (L_{eq})
Masking On	45.1-48.3
No Masking	43.0-48.4
Maximum Masking	47.9-51.1

Table 2 Office Noise Measurements dBA.

Mean office reverberation times in octave bands presented in Table 3 Broadband values were below AS2107-2000 recommended values for open plan offices of (0.4 to 0.6 seconds). This was indicative of increased levels of absorptive treatment, namely mineral fibre ceiling tiles, absorbent workstation barriers and carpet.

Broadband (Hz)	63	125	250	500	1k	2k	4k	8k
0.31	0.35	0.35	0.38	0.32	0.24	0.23	0.22	0.22

Table 3 Mean office reverberation times (seconds).

3.2 Speech Privacy Evaluation

Following the compilation of the panel test results, speech privacy of the open plan areas presented in Figures 1-3. At 4-7m AIs in all scenarios were well above values required to achieve norma0l privacy and were in all cases were deemed 'Unsatisfactory' (See Table 2.1). However speech privacy clearly improved with the addition of sound masking. At 15m, the addition of sound masking was more effective, resulting in 'Normal' privacy conditions for bot normal and maximum masking tests. Although during maximum masking tests it was noted that the vocal effort of the talker increased by 1.2 dBA. Overall results for combined distances indicate the addition of masking did not achieve normal privacy conditions, although privacy conditions were substantially improved with the addition of masking.

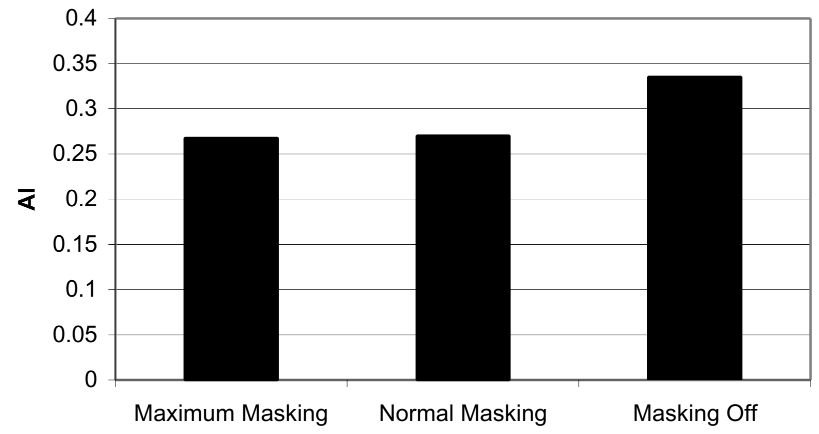

Figure 1 Speech Privacy Test Results - 4-7m

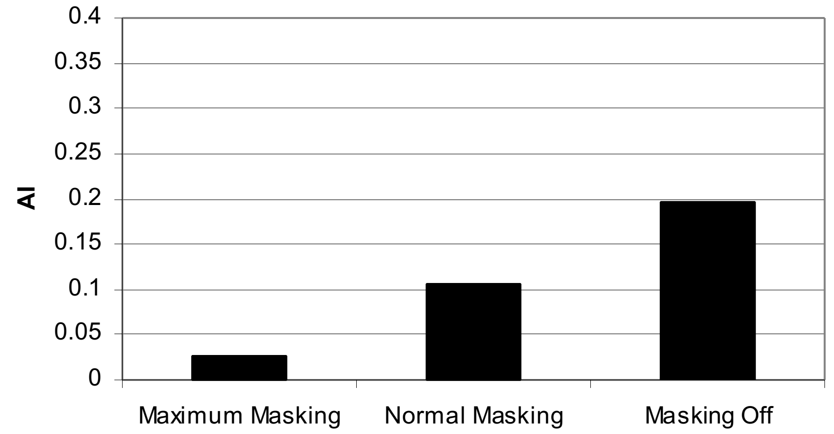

Figure 2 Speech Privacy Test Results - 15m

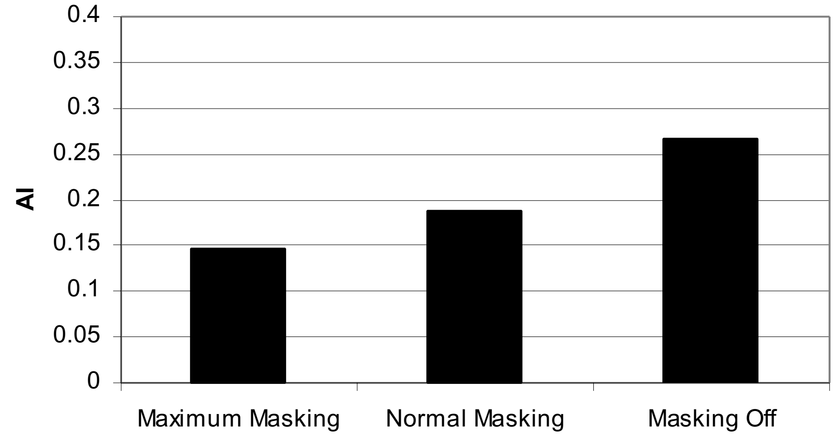

Figure 3. Speech Privacy Test Results - all distances

3.2 Spatial Coverage

Following interpolation of noise level grid points in each office, key areas of uneven sound masking coverage were determined. Overall, 'hot spot' areas were prevalent near return air grilles located close to the ceiling mounted speakers. In some areas this resulted in noise levels above 50 dBA, and was characterised by a subjectively annoying high frequency 'hiss'. In some cases this was directly below workstation areas as shown in Figure 4. Other identified hot spot areas were computer cable tray penetrations or loosened ceiling tiles.

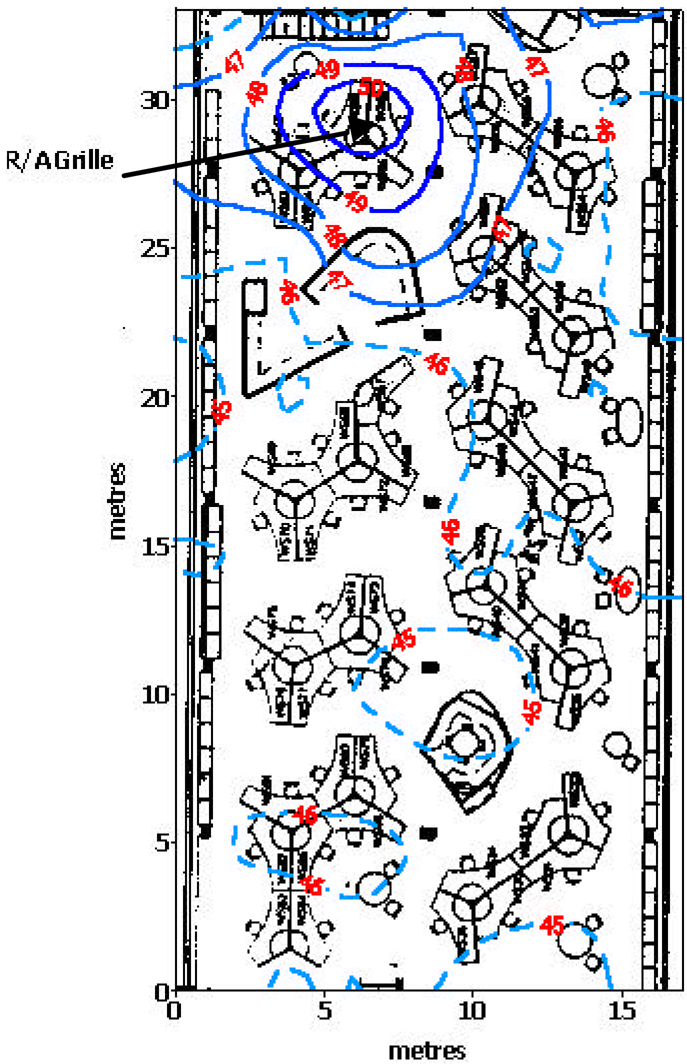

Figure 4 Spatial coverage of Level 11 South wing, showing return air (R/A) grille 'hot spots'. Contour values = 1 dBA.

4 DISCUSSION

Evaluation of the office acoustic environment determined masking noise levels in these offices were above recommended design levels, however this was counterbalanced by a highly absorbent surface finishes. The 'Unsatisfactory' privacy results at 4-7m suggest that direct field effects in these offices have not been adequately treated. This was probably due to a combination of low workstation barrier heights and limited floor space. Moreland (1987)[8] for example, determined that optimum floor areas of 10 to 25m^2 were required to achieve normal privacy. In these offices, the average floor workspace floor area was only 11m^2. In addition, workstation barrier heights of 1.25m were below Moreland's recommended 1.5m to 2.3m. This design was not clearly effective in some providing privacy in some office areas. During testing several workers commented their open plan areas were already overcrowded and distracting. Satisfactory levels of privacy were particularly difficult to achieve during sensitive phone conversations.

At 15m, the effects of direct field speech intrusion were not predominant, and distance attenuation effects combined with sound masking system greatly improved privacy conditions. More distant workstation noise was largely eliminated with masking noise added.

In the absence of sound masking, air conditioning noise was less effective in providing speech privacy and its ability to mask speech was strictly limited. Panellists also indicated that target words were clearly more audible in the absence of masking. Subsequent spectral analysis air-conditioning noise determined deficiencies in the speech frequencies, particularly between 500 to 2000Hz.

Only small differences in speech privacy were determined between normal and maximum test scenarios (AI=0.04). This small difference is likely due to a number of factors. Firstly, the normal setting on the graphic equalizer was already set towards higher masking volumes. Secondly, the higher background noise resulted in the talker speaking more loudly during test material delivery. The mean vocal effort increased by 1.2 dBA during maximum masking testing. Masking levels of 48-51 dBA can achieve desired levels of privacy, however this can also result in the background noise becoming intrusive, requiring greater vocal efforts to maintain communication.

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5 CONCLUSION

Overall speech privacy was best achieved at distances of 15m. At closer distances, direct field effects resulting from low workstation barrier heights degraded speech privacy. Clearly the effects of the masking system at Campus MLC would be enhanced with increased barrier heights. Masking volumes between 48-51dBA although effective were counter productive to the office environment.

Spatial coverage evaluation identified a number of sound 'hot spots' in each open plan area. This has resulted in certain parts of the office possessing a characteristic 'hissing' sound, degrading the acoustical environment. Sound masking may be viewed as an electrical installation issue, and acoustical issues such as speaker coverage and location need to be clearly identified during installation. Installers should avoid inappropriate location of speakers near ceiling penetrations and return air grilles.

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