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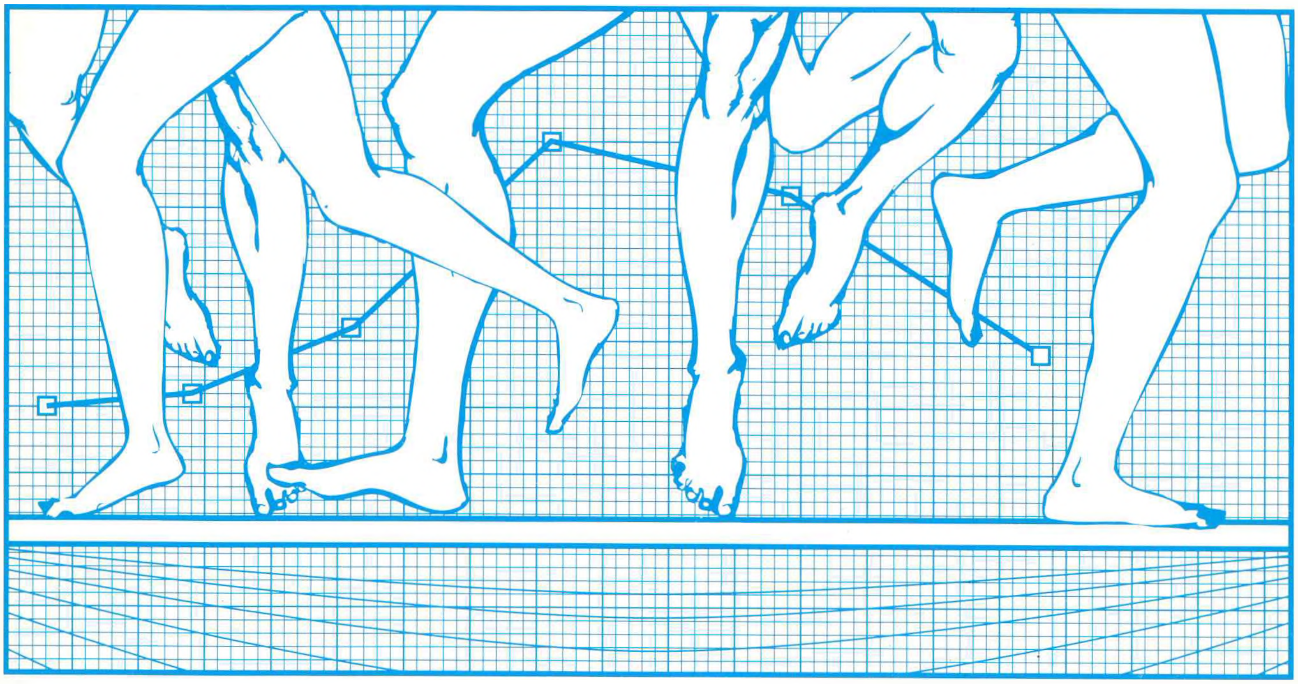

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EDITORIAL

First, may I apologize to readers of Canadian Acoustics for the lateness of the last two issues. This was due to the complicated process of transferring publication to a new editor. It involved finding, taming and educating a new printer. Perversely, it also involved learning about all of the (apparently) new procedures related to dealing with the Post Office (not my favourite company given my recent experiences). We think we have all the problems ironed out and hope to have the journal back on schedule by next issue. Please bear with us.

One consequence of the late publication concerns the questionnaire included in the January issue. Since it wasn't mailed until early April, it was pretty hard to return it by March 31 as requested! The questionnaire appears again in this issue. Please complete and return it as soon as possible.

This issue also contains the announcement for Acoustics Week 90, to be held in Montreal. Given the excellent organizing team, the chosen venue and the interesting seminars on offer, it looks like a great event. I'm sure I speak for all members in expecting the hospitality and gastronomy even to surpass those we enjoyed the last time Acoustics Week was held in la belle province.

Finally, we are actively soliciting articles for the October issue. Any contributions?

J'aimerais d'abord présenter mes excuses aux lecteurs de l'Acoustique Canadienne pour le retard dans l'envoi des deux derniers numéros. Ce retard s'explique par la complexité du transfert de la publication du journal au nouveau rédacteur. Ceci requiert de trouver, de familiariser et de donner les directives au nouvel imprimeur. Il fallait aussi comprendre les (supposées) nouvelles procédures pour faire affaires avec le Bureau de Poste (compagnie qui m'est plutôt antipathique compte tenu de mes récentes expériences). Nous pensons avoir résolu tous les problèmes and nous espérons pourvoir respecter la date de publication du prochain numéro. Nous vous serions reconnaissants d'être indulgents à notre égard.

Une conséquence du retard dans la publication du journal concerne le questionnaire qui apparaît dans le numéro de janvier. Puisqu'il a été posté au début du mois d'avril, il serait difficile de le retourner avant le 31 mars, tel que demandé. Nous apprécierons que vous le complétiez et le retourniez le plus rapidement possible.

Vous trouverez dans ce numéro l'annonce de la Semaine de l'Acoustique qui se tiendra à Montréal. Si l'on se fie à l'excellence du comité organisateur, au lieu choisi et à la qualité des séminaires offerts, cette semaine devrait s'avérer un grand événement. Je parle au nom de tous les membres en espérant retrouver une hospitalité et une gasronomie qui furent grandement appréciées lors de la dernière Semaine d'Acoustique tenue dans la belle province.

Enfin, nous sollicitons activement des articles pour le numéro du mois d'octobre. Désirez-vous contribuer?

Canadian Acoustics / Acoustique Canadienne 18(2) 3-18 (1990)

DYNAMIC LOAD FACTORS FOR PEDESTRIAN MOVEMENTS AND RHYTHMIC EXERCISES

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ABSTRACT

A force platform at the Institute for Research in Construction, National Research Council of Canada, was used to obtain the dynamic load factors for five rhythmic activities for footstep rates below 4 Hz. Two pedestrian movements, walking and jogging, and three rhythmic exercises, jumping, stride jumps and running-on-the-spot, were studied. Load factors for the first four harmonics of the footstep rate were obtained for groups of one, two and four people. For jumping, load factors for eight people were also measured.

The variation of the dynamic load factors with footstep rate and group size is discussed. Load factors suitable for design are suggested for floors subjected to these types of rhythmic activities.

SOMMAIRE

Une plate-forme de charge a été utilisée à l'Institut de recherche en construction, Conseil national de recherches du Canada, pour déterminer les facteurs de forces dynamiques de cinq activités rythmiques à des fréquences de pas en dessous de 4 Hz. On a étudié deux mouvements pédestres, soit la marche et la course, et trois exercices rythmiques, soit le saut, le saut en longueur et la course sur place. Les facteurs de forces pour les quatre premières harmoniques de la fréquence du pas ont été obtenus pour des groupes de un, deux et quatre personnes. On a mesuré les facteurs de forces du saut pour huit personnes.

Ce document examine la variation des facteurs de forces dynamiques en fonction de la fréquence du pas et de la taille des groupes. On y suggère des facteurs de forces adéquats pour la conception de planchers soumis à ce type d'activités rythmiques.

1.0 INTRODUCTION

The National Building Code of Canada 1985 (NBCC) now requires that the dynamic behaviour of a structural system supporting an assembly occupancy be investigated by means of a dynamic analysis when the fundamental frequency of the system is less than 6 Hz (Sentence 4.1.10.4(1)). This is to ensure that overloading of the structural system does not occur as a result of the dynamic response of the system to periodic forces produced by rhythmic activities. The Code also requires that all floor systems be designed so that no significant adverse effects on the intended occupancy of the building result from floor vibrations (Sentence 4.1.1.6.(1)). For assembly occupancies, this serviceability requirement is designed to eliminate floor vibrations induced by rhythmic activities likely to annoy participants or other occupants in the building and thus cause portions of the building to be unacceptable for its intended use. Guidance on performing the dynamic analysis or the serviceability investigation is given in the Supplement to the NBCC 1985, Commentary A, Serviceability Criteria for Deflections and Vibrations (2).

The procedure outlined in Commentary A for assessing the safety or in-use acceptability of a floor system requires knowledge of the dynamic load factors of rhythmic activities that might be performed on the floor system. Dynamic load factors for several rhythmic activities are given in Commentary A. They are taken from a paper by Allen, Rainer and Pernica (3) in which dynamic load factors for several activities were calculated from field tests and direct load measurements. For two activities, jumping and jogging, load factors were ascertained from forces measured on a force platform at the Institute for Research in Construction, National Research Council of Canada (IRC/NRCC). However, only a few of the load factors that were measured on the force platform are presented either in that paper and in others by Rainer and Pernica (4), and by Rainer, Pernica and Allen (5). Load factors for groups of two or more people and for other types of rhythmic exercises are still unreported.

The present paper describes and discusses: the force platform at IRC/NRCC that was used to measure floor forces of rhythmic activities; the experimental procedure followed in making these dynamic force measurements; the dynamic load factors obtained for two pedestrian movements (walking and jogging) and three rhythmic exercises (jumping, stride jumps and running-on-the-spot); and the variation of these load factors with both footstep rate and group size. Load factors suitable for design are suggested for floors subjected to pedestrian movements and rhythmic exercises.

2.0 DESCRIPTION OF FORCE PLATFORM

2.1 *Physical Properties*

The force platform at IRC/NRCC was constructed from a simply supported floor strip 17.04 m long and 2.13 m wide (Fig. 1) consisting of two open-web steel trusses 914 mm deep and 1.74 m apart, topped by 14 non-composite, precast concrete panels. The panels were 1.19 m long, 2.13 m wide and 100 mm thick, positioned on the trusses with about a 25-mm gap between adjacent panel members. A 150 x 50 mm wood plank was placed across the top of the panels directly above the top chord of the trusses. The panels were clamped to the trusses by bolting the wood planks to the top chord of the trusses at every panel gap.

At mid-span of the floor strip a piezoelectric force transducer was placed between the bottom chord of each truss and an adjustable ground support. The force transducers had a sensitivity of 0.23 mV/N, an unloaded resonant frequency of 70 kHz, and a dynamic load range in compression from about 1 N to 22 kN. By adjusting the camber in the trusses each force transducer was pre-loaded to about 4 kN.

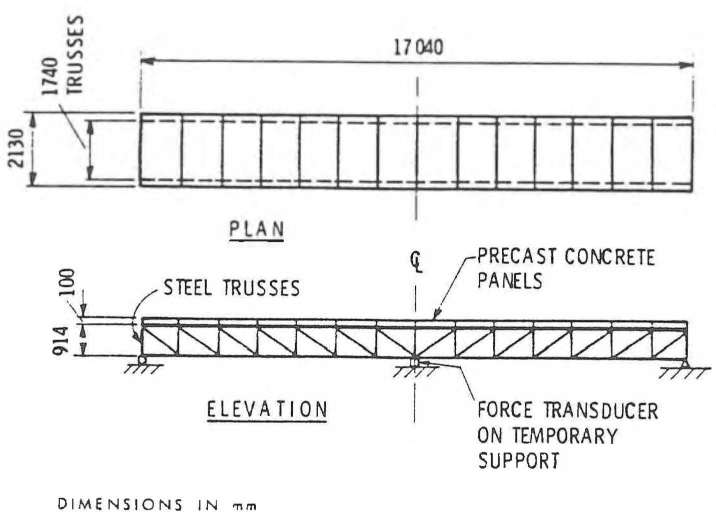

Figure 1. Force Platform

2.2 *Mechanical Properties*

The dynamic properties of the fundamental mode of vibration of the force platform (floor strip with mid-span support) were determined from heel impacts and from forced vibration tests using an electro-magnetic shaker. The force platform had a fundamental frequency of about 13 Hz, a damping ratio of about 2% of critical, and a nearly sine-wave mode shape with nodes at the mid-span and end supports.

2.3 *Correction Coefficients*

For excitation frequencies close to the fundamental frequency of the force platform the dynamic forces measured by the force transducers were too large because of the near-resonant response of the platform. The magnitude of this response was dependent on the proximity of the excitation frequency to the fundamental frequency of the platform and on the fundamental damping ratio. Damping ratio, however, varied with number and location of participants on the platform (6) so that the near-resonant response of the platform changed with each group of participants. To ensure that variations in modal damping would have little effect on response, the dynamic range of the platform was restricted to frequencies below 10 Hz.

To correct for the dynamic behaviour of the platform, response coefficients for the force transducers were determined for excitation frequencies from 2 to 10 Hz using the electro-magnetic shaker. Influence line coefficients for the force transducers were also determined to correct forces for activities in which groups of participants moved horizontally on the platform relative to the mid-span support.

3.0 PARTICIPANTS

3.1 *Composition*

Twenty-two people, 18 men and four women, participated in the experimental program to determine dynamic load factors for two pedestrian movements and three rhythmic exercises. Ages ranged from 20 to 60 for the men and 20 to 30 for the women and weights ranged from 580 to 930 N for men and from 510 to 640 N for women. Each of the five activities was performed by several group sizes (Table 1): with one and two people, activities were performed by at least two different sets of participants; for groups of four and eight people, activities were performed by only one set of participants, except that rhythmic jumping by four people was performed by three sets.

TABLE 1 Group size and range of activity rates for pedestrian movements and rhythmic exercices

Activity	Group Size No. of people	Range of Activity Rate, Hz (Footsteps/s)	
		Normal Range	Measured Range
Pedestrian Movements			
Walking	1, 2 and 4	1.6 - 2.2	1.0 - 3.0
Jogging	1, 2 and 4	2.2 - 3.2	1.6 - 4.0
Rhythmic Exercises			
Jumping	1, 4 and 8	2.0 - 3.0	1.4 - 4.0
Stride jumps	1 and 4	2.0 - 2.6	1.6 - 3.4
Running-on-the-spot	1 and 4	2.2 - 3.2	1.4 - 4.0

Note: Normal ranges for the five activities were determined from the literature and from personal observation of pedestrian movements within buildings and rhythmic exercises in aerobic classes

Participants were initially chosen from the staff at IRC if they appeared to be physically fit. They were re-selected for additional performances only if

1) they displayed reasonable coordination skills in performing physical activities to an audible beat, and

2) they were able to perform an entire program of activity rates without quitting or showing signs of physical distress.

Load factors for some of the activities therefore contain the effects of individuals who had difficulty maintaining the beat or footfall unison with a group.

3.2 *Effective Weight of Group*

Participants who performed the rhythmic exercises were assigned fixed locations on the platform. A single participant performing alone was positioned at the mid-span of the platform so that the participant's effective weight on the force platform (i.e., the weight of the participant as measured by the force transducers) was comparable to the static or scale weight of that participant. Members of groups of two or more were placed symmetrically and as close as possible to the mid-span of the force platform. They were also positioned on the platform so as to minimize differences in their individual effective weights. The total effective weight of a group with members in their assigned positions was determined at the beginning and at the end of each program of activity rates.

For pedestrian movements, the effective weight of a single participant performing alone was also determined at mid-span. For larger groups, effective weight was determined with members at their assigned starting positions on the platform. Members were also positioned so that variation in effective weight while performing the movement was minimized.

4.0 MEASUREMENT PROCEDURE

4.1 Group Activities

Rhythmic exercises were performed with group members remaining at their assigned positions on the platform throughout the prescribed program of activity rates.

For pedestrian movements, single participants began at one end of the platform and moved to the other end at the required activity or footstep rate using a stride length of their own choosing. Groups of two or more pedestrians were handled differently because of space limitations on the platform. Group members were assigned starting positions (mid-span or 1/6-points) on the platform and were asked to move in unison at the required footstep rate in a counter clockwise circle about the centre of the platform. Groups were made up of members having similar height and weight characteristics so that the initial spacing could be maintained throughout the program of activity rates.

4.2 Program of Activity Rates

Activities were performed to pre-recorded pulses played through loudspeakers. A frequency (footstep rate) increment of 0.2 Hz (footsteps/s) was used, resulting in a measurement program of 11 footstep rates for walking, 14 for jogging, 16 for jumping and running-on-the-spot and 10 for stride jumps. The measured range of footstep rates for each of the five activities together with the range normally encountered in practice is shown in Table 1. Normal ranges for the five activities were determined from the literature (7) and from observations of pedestrian movements within buildings and rhythmic exercises in aerobic classes.

Each footstep rate for the rhythmic exercises was performed in unison for 30 seconds. For pedestrian movements, a participant performing alone traversed the length of the platform twice for each footstep rate; groups of two or more completed three circuits of the circular course laid out on the force platform.

4.3 Instrumentation

Signals from the two force transducers were low-pass filtered at 25 Hz, amplified and recorded on an FM tape recorder.

5.0 DEFINITION OF DYNAMIC LOAD FACTOR

Forces produced by rhythmic activities can be represented by the following expression (3);

$$P(t) = W_P \left\{ 1 + \sum_{n=1}^{N_T} \alpha_n \sin(2\pi f t + \varphi_n) \right\} \qquad [1]$$

where

P(t) = forcing function of the activity
Wp = static weight of the group
α_n = dynamic load factor of the nth harmonic (normalized Fourier Coefficient)
n = order of harmonic of activity rate
f = activity rate in Hz (footsteps/s)
ϕ = phase angle of nth harmonic
N_T = total number of harmonics
t = independent variable, time.

The summation term is the dynamic component of the forces produced by the rhythmic activity. The dynamic load factors, α_n, are the Fourier coefficients of the Fourier series representation of the rhythmic forcing function normalized by the static weight of the group performing the activity.

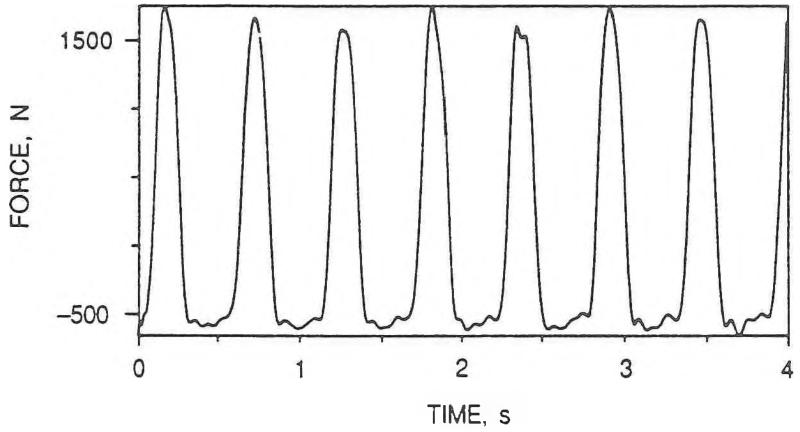

Figure 2. Time Record of Forces Produced by One Person Stride Jumping at 1.8 steps/s (Low-Pass Filtered at 9.0 Hz)

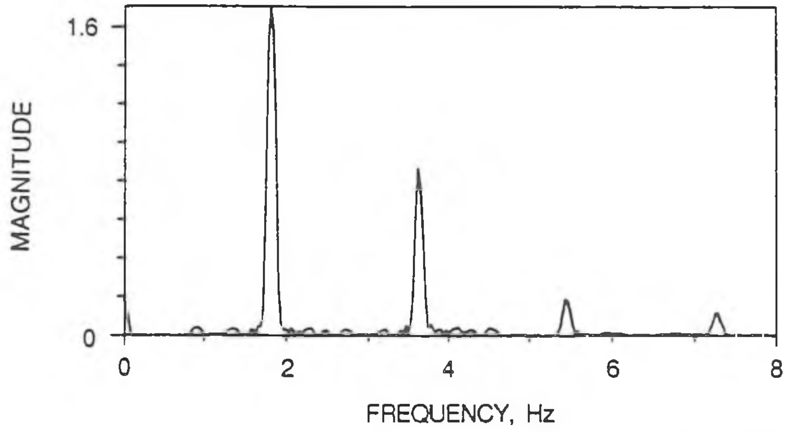

Figure 3. Fourier Spectrum of Forces Produced by One Person Stride Jumping at 1.8 steps/s

6.0 ANALYSIS PROCEDURE

6.1 *Fourier Analysis*

Dynamic load factors for the five activities were determined from Fourier spectra of force transducer signals. Recorded time signals from the two force transducers were added (Fig. 2) and Fourier spectra of the combined signal obtained using a narrow-band (FFT) analyser (Fig. 3). Fourier amplitudes at harmonics of the activity rate were converted to Fourier coefficients, which in turn were divided by the effective weight of the group to obtain dynamic load factors.

6.2 *Fourier Amplitude Corrections*

No influence line corrections of the Fourier amplitudes were required for the three rhythmic exercises since group members did not move on the platform relative to the force transducers. Neither were they needed for pedestrian movement by one person, since only the portion of the force record centred in time over the mid-span support was analysed. Influence line corrections were, however, applied to the spectral amplitudes for pedestrian movements performed by groups of two or more. The corrections accounted for the circular movement of group members on the force platform about the mid-span support.

Dynamic load factors for footstep harmonics above 9.6 Hz were not determined because the dynamic amplifications of these force components were too sensitive to the number, positioning, and physical conditioning of group members. Load factors for harmonics below 9.6 Hz were corrected to take into account the dynamic properties of the force platform.

7.0 DYNAMIC LOAD FACTORS FOR RHYTHMIC ACTIVITIES

Dynamic load factors for the five rhythmic activities are presented in Figs. 4 to 8. Curves for the first and second harmonics of footstep rate are drawn over the measured range of activity rates and for the third and fourth harmonics for harmonic frequencies to 9.6 Hz. Load factors for the first and second harmonics are not plotted for footstep rates of 3.8 and 4.0 Hz in Fig. 5(c) because it was not possible for the four participants to jog on the force platform at the two highest rates with any semblance of unison.

Average load factors are plotted in the figures for group sizes for which there were more than one set of participants. The number of sets (N) from which the averages were obtained is also noted. For the first harmonic, the largest and smallest load factors at each footstep rate are shown with the average curve. Bounds for the second, third and fourth harmonics were omitted because of space limitations within the figures.

Maximum dynamic load factors for each activity and each group size are given in Table 2. The table also shows the footstep rate at which maximum load factors for the first three harmonics were obtained. Footstep frequencies separated by a slash indicate that the harmonic maximum was attained at more than one footstep rate. Those for the maximum of the fourth harmonic were omitted because load factors for the fourth harmonic were fairly constant over the measured footstep range.

Table 2 Maximum Dynamic Load Factors for Pedestrian Movements and Rhythmic Exercises

Group size	Maximum load factor				Activity rate at which maximum occurred Hz (Footsteps/s)		
	Harmonic No.				Harmonic No.		
	1	2	3	4	1	2	3
Pedestrian Movements							
Walking							
1	0.56	0.28	0.16	0.09	2.4	2.6/3.0	3.0
2	0.46	0.19	0.11	0.10	2.4	3.0	2.4
4	0.36	0.07	0.07	0.03	2.4/2.8	1.4	2.6
Jogging							
1	1.50	0.55	0.17	0.09	3.4	3.4	3.0/3.2
2	1.65	0.47	0.16	0.10	2.4	2.4	1.6
4	1.05	0.14	0.11	0.08	2.2	1.6	1.6
Rhythmic Exercises							
Jumping							
1	1.80	1.10	0.47	0.18	2.8	2.6	2.4
4	1.75	0.96	0.28	0.12	2.6	2.4	2.4
8	1.55	0.52	0.11	0.04	2.6	2.2/2.4	1.4
Stride Jumps							
1	1.75	1.10	0.42	0.11	2.6	2.2	2.2
4	1.80	1.00	0.32	0.09	2.2	2.2	2.2
Running-on-the-spot							
1	1.57	0.58	0.26	0.15	2.8	2.8/3.0	1.6
4	1.44	0.38	0.28	0.10	2.4	2.6	1.4

7.1 *Walking*

Maximum load factors for the first three harmonics were primarily associated with footstep rates between 2.4 and 3.0 Hz (Table 2). These rates, which were in the upper half of the measured footstep range, were above the range of normal walking rates (1.6-2.2 Hz). Within the normal range the first harmonic (α_1) increased with footstep rate for all group sizes from about 0.2 at 1.6 Hz to about 0.4 at 2.2 Hz (Fig. 4). Over the measured range, however, α_1 maxima decreased with group size, falling from 0.56 for one person to 0.46 for two and to 0.36 for four people.

The variation of the second harmonic over the normal range reversed as the size of the group increased. Load factors for α_2 went from rapidly increasing with footstep rate for one person to slightly decreasing with footstep rate for four people. The footstep rate of the harmonic maximum also changed location with increasing group size, moving from a suggested location above 3.0 Hz for one and two people to below 3.0 Hz for four people.

Dynamic load factors for the third and fourth harmonics were relatively constant over the measured frequency range irrespective of group size, but overall amplitudes of the two harmonics dropped slightly as group size increased. The third harmonic fell from about 0.07 for one and two people to 0.04 for four people, and the fourth harmonic from 0.05 for one and two people to 0.02 for four people.

The drop in dynamic load factors with rise in group size was not surprising. As people were added to the group, overall group coordination in performing the activity on the platform was reduced as participants found it more difficult to maintain the walking rate and the distance between themselves and other group members. Although this reduction in group coordina-

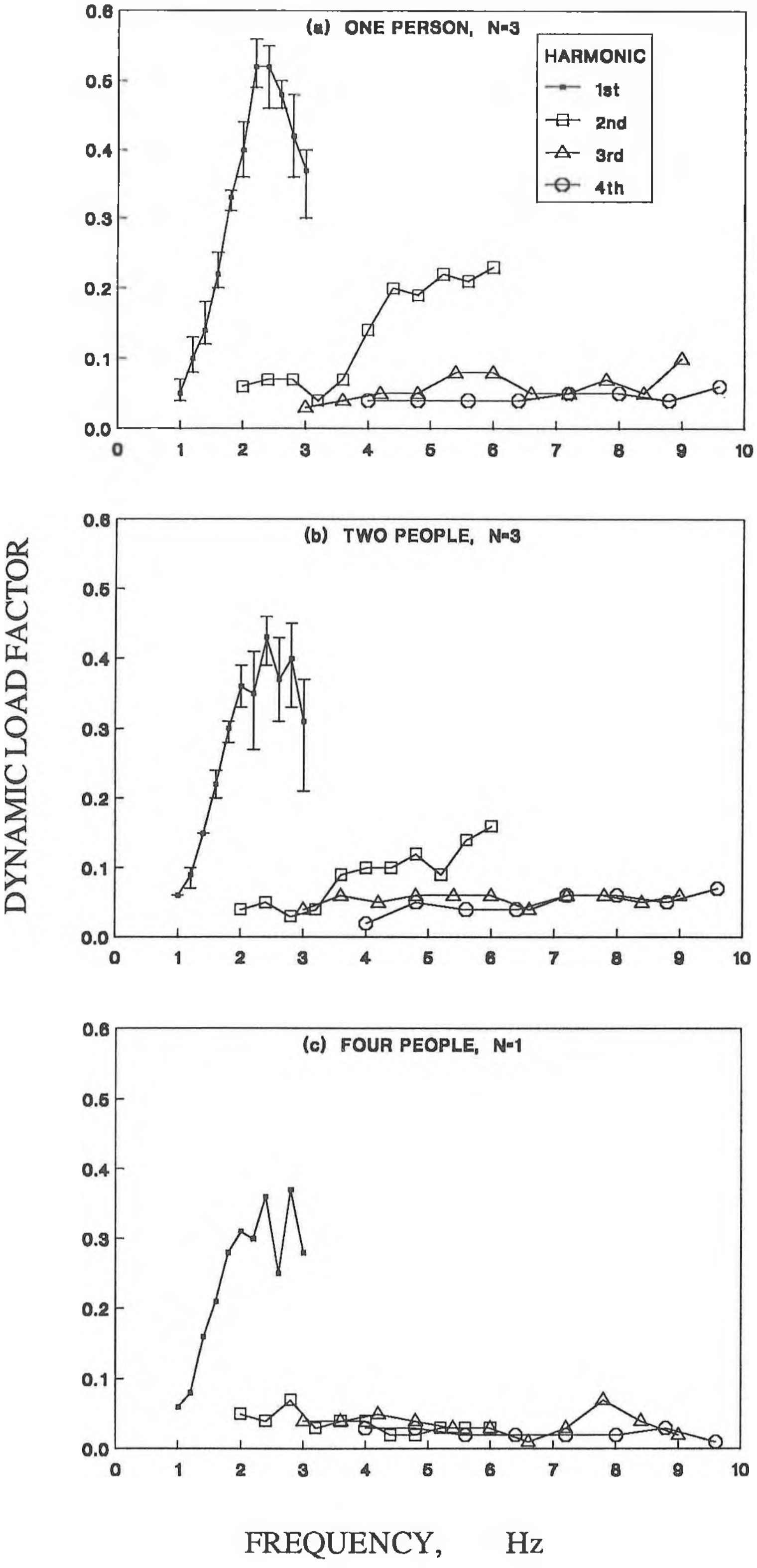

Figure 4. Dynamic Load Factors for Walking

tion appears to be a quirk of the experimental procedure, the same difficulties are apparent for group members under regular walking conditions. Members are forced to adjust their walking characteristics if they wish to walk in unison with and be part of a large group of walkers.

7.2 *Jogging*

Maximum amplitudes for the first harmonic of jogging did not follow the emerging pattern associated with group size; the maximum for two people exceeded that for one person by about 10% (Table 2). The maximum for four people was just as notable, since jogging registered the greatest drop in α_1 maxima of the five activities, falling from 1.5 for one person to 1.05 for four people. Footstep frequencies for these maxima, however, followed the group size pattern closely, sequentially decreasing from 3.4 Hz for one person to 2.2 Hz for four.

Average load factors for the first harmonic also followed a group size pattern in spite of differences in N. First harmonic curves became increasingly flattened and lower over the normal range of footstep rates as group size increased (Fig. 5). The variation in load factors over the normal range dropped from about 20% for one person to 15% for two and 6% for four. The flattening of the α_1 curves and the fall in both the maximum and the footstep frequency of the maximum reinforce what seems intuitively evident that both the level of group unison and the range of footstep rates easiest for joggers to perform fall with increasing group size. These effects of group size may again be partly the result of the experimental procedure used on the platform. As was noted for walking, however, the same difficulties are experienced by individuals trying to jog in unison within a group.

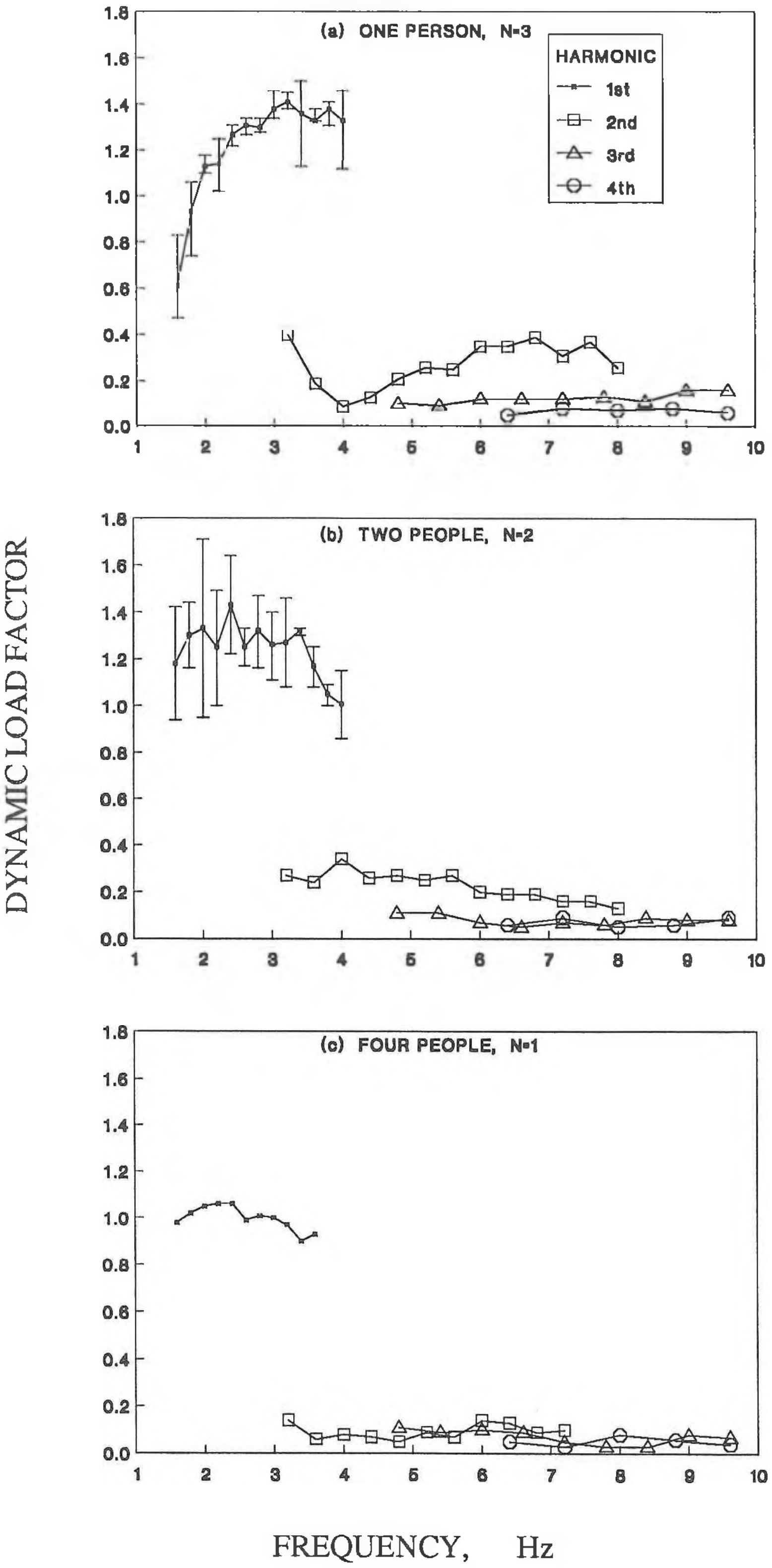

Figure 5. Dynamic Load Factors for Jogging

The decrease in the level of group unison with group size was also apparent in the dynamic load factors of the second harmonic. Maximum load factors for α_2 decreased from 0.55 for one person to 0.14 for four people and footstep frequencies for the maxima from 3.4 Hz for one person to 1.6 Hz for four people. The second harmonic also exhibited (as had the first) decreasing variability with increasing group size over the normal range of footstep rates. The range in α_2 amplitudes in Fig. 5 dropped from 0.13 to 0.35 for one person to 0.07 to 0.13 for four people.

Dynamic load factors for the third and fourth harmonics remained fairly constant for each group size over the measured range of jogging rates. The effect of group size was again evident as the average amplitudes of the two harmonics over the measured range fell, α_3 from about 0.12 for one person to 0.07 for four people and α_4 from about 0.07 for one person to about 0.05 for four people.

7.3 *Jumping*

Dynamic load factors for four people were strikingly similar in shape to those for one person (Fig. 6a,b). Curves for the first three harmonics were convex, with the largest amplitudes located at the centre of the normal range of footstep rates (2.0-3.0 Hz) and the smallest at the lower and upper ends. Within the normal range, average load factors for the first two harmonics were not only fairly constant but those for the first were within 5% of their maximum (Table 2) and those for the second were within 30% of their maxima for groups of one and four people.

Dynamic load factor curves for eight people (Fig. 6c) were more jagged than those for the smaller groups; the curves for eight people were obtained with only one set of participants and those for one and four people were averages of the results for several sets of participants. Load factors for eight people were also

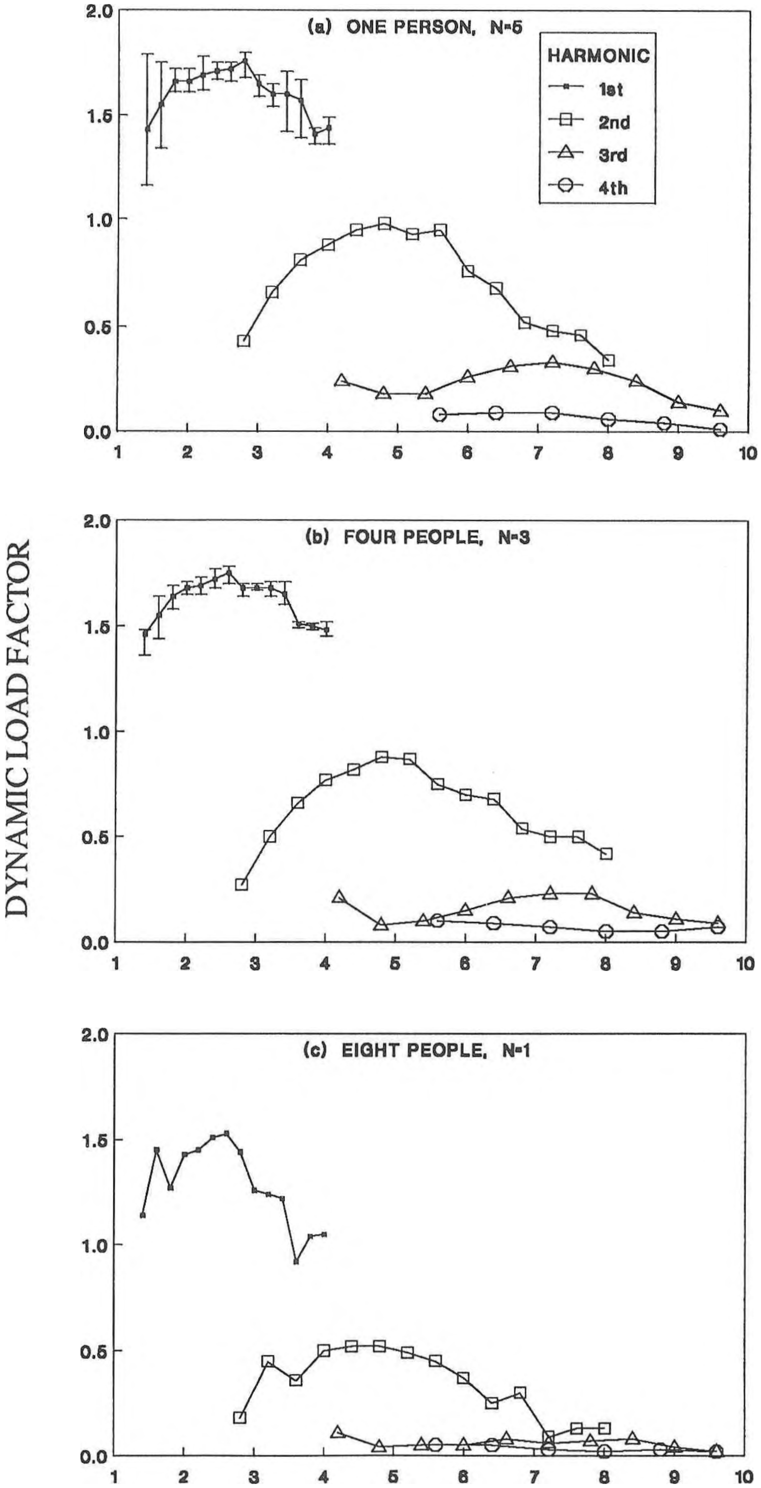

Figure 6. Dynamic Load Factors for Jumping

noticeably smaller than the averages for smaller groups. One reason for the large reduction was the difficulty experienced by one of the participants in the group of eight in maintaining group unison.

Maximum load factors for the four harmonics consistently decreased with increasing group size (Table 2). The size of the decrease also increased with harmonic number, so that forces associated with the first harmonic of the footstep rate became more dominant as group size increased. Ratios of the harmonic maxima of eight people to one person were 0.85 for the first, 0.47 for the second, 0.23 for the third and 0.22 for the fourth. Footstep rates for the maxima also decreased consistently with group size, but remained within the normal range (2.0-3.0 Hz) for the first three harmonics.

7.4 *Stride Jumps (Jumping Jacks)*

Dynamic load factors for stride jumps (also called jumping jacks) were comparable in amplitude and similar in shape to those obtained for jumping (Figs. 6 and 7). This resemblance between the two sets of load factors exists because stride jumps are a type of jumping (although slightly more complex) in which the arms move up with the outward movement of the legs and down with their inward movement within each complete stride jump cycle.

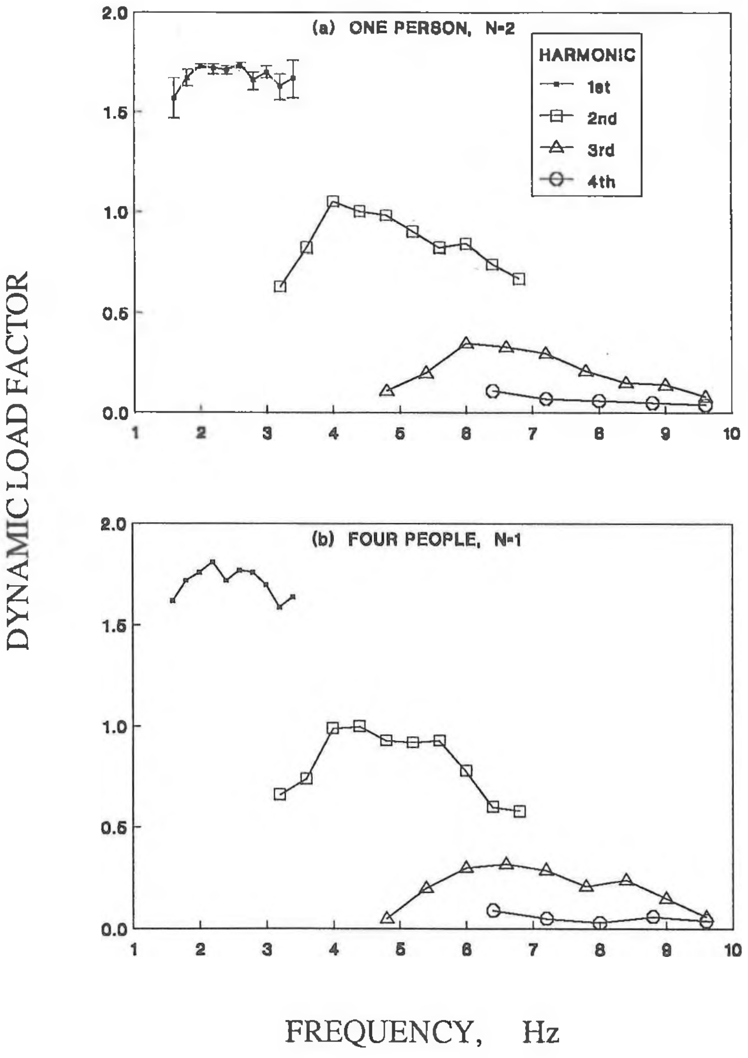

Figure 7. Dynamic Load Factor for Stride Jumps

Dynamic load factors for one and four people were similar in shape and amplitude, suggesting that four people jumped to the broadcast beat with the same degree of harmony as one person. A trend to smaller load factors with increasing group size was suggested by α_2, α_3 and α_4, whose maxima for four people were about 10% smaller than those for one person. However, α_1 countered the trend by registering a slightly larger maximum for four people (Table 2). Footstep rates for harmonic maxima stayed within the normal range (2.0-2.6 Hz) for both group sizes. For α_2 and α_3 the rate remained at 2.2 Hz, while for α_1 the rate fell from 2.6 Hz for one person to 2.2 Hz for four.

7.5 *Running-on-the-Spot*

The shape and distribution of the dynamic load factors were similar to those obtained for jogging (Figs. 5 and 8). This similarity was not surprising since running-on-the-spot is jogging with no horizontal movement. Like jogging, ratios of the second and third harmonics to the first over the normal range of footstep rates (2.2-3.2 Hz) were only about 25% for the second and 10% for the third for both one and four people. This indicated that running-on-the-spot is also a rhythmic activity in which the components of the footstep forces are dominated by the first harmonic of the footstep rate.

Dynamic load factors for running-on-the-spot contained some of the effects of group size already noted for the two pedestrian activities. Curves for the first two harmonics were flatter, although not lower over the measured footstep range (1.4-3.4 Hz); maximum load factors for three of the four harmonics decreased (Table 2); and footstep frequencies of the maxima of the first three harmonics moved downward. These changes with group size, however, were less pronounced than they had been for jogging, suggesting that it was easier for groups of participants to run on-the-spot at a given level of unison than to jog across the platform (with the same level of unison). The difference in group performance for the two activities was probably related to a dual requirement for unison for those who jogged. Participants who jogged were instructed to keep both the beat and the spacing between themselves and other group members on the platform, whereas for running-on-the-spot participants were required only to step to the beat.

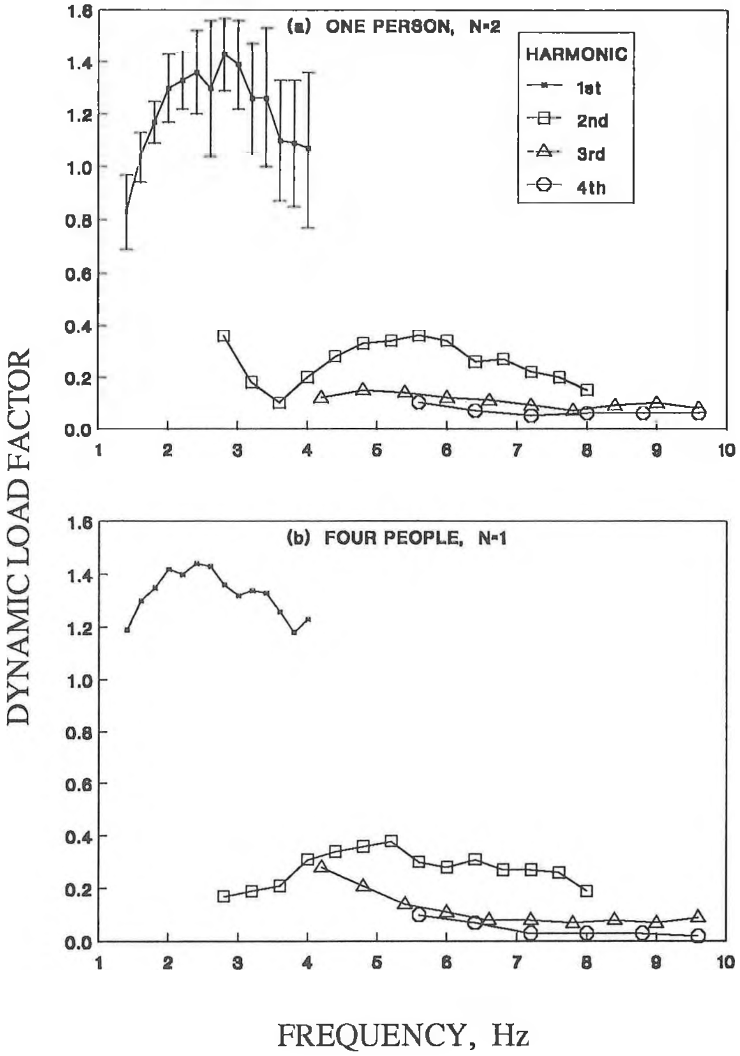

Figure 8. Dynamic Load Factors for Running-on-the-Spot

8.0 DISCUSSION AND SUMMARY

8.1 *Force Platform*

A force platform at the IRC/NRCC was used to obtain the dynamic load factors for five rhythmic activities for footstep rates below 10 Hz. Two pedestrian movements, walking and jogging, and three rhythmic exercises were studied. The 10 Hz upper bound for the platform was not a serious problem since footstep rates for the five activities did not exceed 4 Hz. Footstep rates above 4 Hz were unrealistic for these types of human endeavour.

The 10 Hz frequency bound did, however, limit the number of harmonics for which load factors were obtained to three for footstep rates above 2.4 Hz and to two for footstep rates above 3.2 Hz. This restriction was not a major drawback. Load factors for the third and fourth harmonics were considerably smaller than those for the first and second. In absolute terms, the third and fourth harmonics were also fairly constant over the measured portion of their frequency range. As a result, load factors for the third and fourth harmonics for frequencies above 9.6 Hz could be reasonably interpolated from the existing data without giving rise to substantial error.

8.2 Group Size

Maximum dynamic load factors for the five rhythmic activities decreased with increasing group size. Some amplitude reversals did occur in three of the four harmonics (except the second one) and in four of the activities (except jumping), but the trend to smaller maxima with increasing group size was present in all activities. Footstep rates for the maxima also fell. For the three rhythmic exercises, the rates remained within the normal ranges for the first and second harmonics, but followed no pattern with respect to the normal range for the third one. There was no overall trend for the two pedestrian movements. Rates for the three harmonics of walking remained generally above the normal range, while rates for jogging varied differently with respect to the normal range with harmonic number.

Group size also reduced the variation with frequency in the dynamic load factors of the first and second harmonics of pedestrian movements. The two activities required group members to move across the platform at a specified footstep rate and with about the same stride length. Although group members were of approximately equal height and weight, they did not necessarily have similar walking or jogging gaits. As a result, group members were forced to take smaller (or larger) than normal strides in trying to maintain group unison for each activity rate. The smoothing of the load factors for the first two harmonics may indicate the uncharacteristic movements required of some participants in trying to maintain group unison while traversing the platform. This dual requirement did not arise in the rhythmic exercises since participants did not change position on the platform while performing.

8.3 Harmonic Number

Dynamic load factors for the five rhythmic activities decreased with increasing harmonic number. The rate at which the decrease occurred varied with activity and group size. At one end of the variability spectrum, jumping by one person, the decrease was monotonic. Each of the load factors for a given harmonic of jumping was larger than the set of load factors for each higher harmonic and smaller than the set of load factors for each lower harmonic (Fig. 6). At the other end of the spectrum, walking by one or more people, dynamic load factors for the three higher harmonics overlapped in the frequency domain (Fig. 4), so that the decrease was only visible when harmonic maxima were compared (Table 2).

8.4 Pedestrian Movements

Of the five activities studied, walking had the smallest maximum load factors for the first three harmonics. This was not surprising, considering that walking was the only activity in which one foot was always in contact with the platform. Because of this continuous contact, walking produced smaller footfall impacts than the other four activities in which body contact with the floor was lost during a portion of each footstep cycle. Ratios of harmonic maxima of jogging to walking were about three for the first harmonic, two for the second and 1.5 for the third. Maxima for the fourth harmonic were comparable for one and two people, but with four people that for jogging was significantly larger.

8.5 Rhythmic Exercises

Dynamic load factors for jumping and stride jumps had similar harmonic shapes and comparable amplitudes for identical group sizes (stride jumps are generically jumps with additional leg and arm movements within each jump cycle). The two jumping exercises produced the largest harmonic maxima of the five activities, 1.8 for the first, 1.1 for the second, and 0.47 for the third. Footstep rates for the harmonic maxima of the jumping exercises occurred within their normal ranges of activity rate as these were the easiest to perform.

Running-on-the-spot is a version of jogging in which the position of the participants relative to the floor stays fixed. For one person, dynamic load factors for the two activities were comparable in amplitude and similar in shape. For groups, load factors for running-on-the-spot were much larger than those for jogging because group members did not have to adjust their stride length to maintain unison during the measurement program. For four people, maximum load factors for running-on-the-spot were about 1.5 times as large for the first harmonic and 2.5 times as large for the second and third harmonics.

9.0 SUGGESTED LOAD FACTORS

Suggested load factors for pedestrian movements and rhythmic exercises are contained in Table 3. They are considered suitable for the design of floors in active or assembly occupancies and are based on the maxima obtained for groups of four and eight participants within the measurement program.

Table 3. Suggested Load Factors for Pedestrian Movements and Rhythmic Exercises for Large Groups of People

Activity	Suggested Load Factors Harmonic No.			
	1	2	3	4
Pedestrian Movements	1.10	0.20	0.10	0.05
Rhythmic Exercises	1.60	0.60	0.20	0.10

9.1 Pedestrian Movements

Load factors for pedestrian movements are based on those for jogging since load factors for walking were significantly smaller. Those shown in Table 3 are for groups in which some discord in performing the pedestrian movement will tend to be present. For small or well-coordinated groups of pedestrians the suggested load factors for the four harmonics could be increased by as much as 50% so that the amplitudes reflect the maxima obtained for running-on-the-spot.

9.2 Rhythmic Exercises

Suggested load factors are primarily the maximum for jumping by eight people. Load factors up to 50% larger than those given in Table 3 should be considered for the second and third harmonics for small or well-coordinated groups.

10 ACKNOWLEDGEMENTS

This paper is a contribution from the Institute for Research in Construction, National Research Council of Canada (IRC/NRCC). The floor strip used as the force platform in these experiments was designed by Dr. D.E. Allen of the Building Structures Section, IRC. Claude Pilette and Rock Glazer conducted the measurements on the force platform, and analysed the time records to obtain the dynamic load factors. Their assistance is gratefully acknowledged. The author warmly thanks also the 22 staff members at IRC who gave both time and effort and had the courage to participate in the fishbowl atmosphere in which the measurement program was conducted.

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INFORMATION DU PRESIDENT

Environ 6 mois se sont écoulés depuis le dernier congrès de l'ACA. Le comité des directeurs tiendra sa rencontre bi-annuelle le 3 juin prochain. Les thèmes abordés lors de cette réunion ne reflètent pas nécessaairement les préoccupations des membres en général. De plus, les membres n'ont pas souvent l'occasion de réagir au contenu de cette rencontre avant la tenue de l'assemblée générale annuelle. Le premier problème peut être facilement contourné en publiant l'ordre du jour. J'aimerais par ailleurs formuler une demande ferme: si vous avez des suggestions de thèmes ou des préoccupations spécifiques, soumettez les par écrit à l'un des membres de l'exécutif et demandez lui de l'ajouter à son rapport ou à la liste des nouvelles. Je vous donne ma parole que j'essaierai de présenter les préoccupations et les plaintes le plus fidèlement possible. Le traitement de vos plaintes ainsi que l'issue des autres items discutés apparaîtront dans l'Acoustique Canadienne le plus rapidement possible après la réunion.

Un point majeur qui sera abordé lors de cette réunion sera la venue de Inter-Noise à Toronto en 1992. Les dates n'ont pas encore été fixées mais il est probable que ce congrès ait lieu à la fin de l'été. Plusieurs members de la région de Toronto seront sans doute sollicités pour participer à l'organisation. Commencez à penser à des idées de communications! Veuillez prendre note de l'item de l'ordre du jour concernant l'admission de jeunes non-étudiants dans la catégorie "Prix étudiant" actuelle. Si vous désirez émettre une opinion à ce sujet, informez l'un des membres du bureau. Comment réagissez-vous à l'idée d'admettre des étudiants de niveau baccalauréat dans le concours étudiant?

Vous trouverez ci-joint l'ordre du jour de la rencontre du bureau. Nous vous serions reconnaissants de vérifier s'il y a eu des oublis et si tel est le cas, de nous écrire ou de nous téléphoner.

NOTE FROM THE PRESIDENT

It's been almost half a year since the last CAA conference. On June 3rd, the Board of Directors will have its mid-year meeting. The business carried on in this meeting is seldom sensitive to the concerns of the membership at large. In addition, the membership has not had much opportunity to comment after the fact until the Annual General Meeting. the first concern is easy to address by publishing the agenda. In addition, I'd like to make a strong request that if there are items or concerns you wish addressed, write to a member of the executive and request him/her to include it as a part of his/her report or as new business. Speaking for myself, I will attempt to present concerns or complaints as fairly as possible. The disposition of your complaints as well as the outcome of other items of business discussed will appear in "Canadian Acoustics" as soon after the meeting as possible.

One major item which will be discussed is the holding of Inter-Noise -92 in Toronto. The date has not been set, but the meetings will probably be held in late summer. Undoubtedly, many members in the Toronto area will be asked to help. Start thinking paper submission now! Please note the item relating to including young non-students in what is currently a student-only prize. If you have a strong opinion, let someone on the Board know. What are your feelings about undergraduates being included in the student awards?

Below is the agenda for the board meeting. Look it over for missing items and please write or call.

Bruce E. Dunn

BOARD OF DIRECTORS MEETING, JUNE 3, 1990

AGENDA

1. Report of the President
2. Report of the Executive Secretary
3. Report of the Treasurer
4. Report of the Editor of "Canadian Acoustics"
5. Report of the Membership Chairperson
6. Report of the Convenor of Acoustics Canada '90 in Montreal
7. Progress report on Acoustics Canada '91 in Edmonton
8. Report on International INCE and Inter-Noise '92 - T. Embleton
9. Prizes:
    - Directors Awards - B. Dunn
    - Postdoctoral Prize - S. Abel
    - Bell Prize - L. Brewster
    - Canada-Wide Science Fair - A. Cohen
    - Student Presentations - B. Dunn
10. Other Business
    - Discussion of policy need regarding workshops
    - Change in student presentations - M. Chapman
    - Travel subsidies - C. Andrew/B. Dunn
    - Communication - M. Hodgson
    - Acoustic Centre of Excellence in Halifax
    - National Advisory Board on Scientific Publications
    - Proceedings of panel discussion on the funding of construction R&D in Canada
    - Sheridan College request for information
11. New business brought up at the meeting

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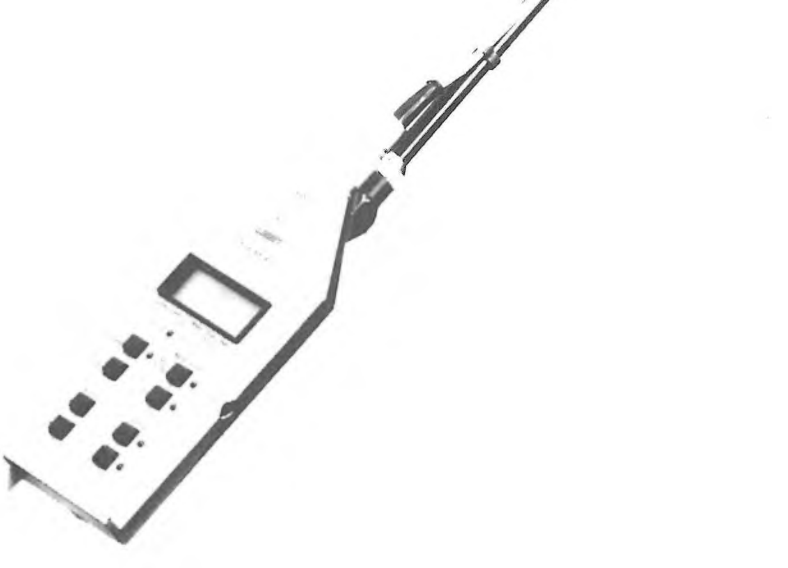

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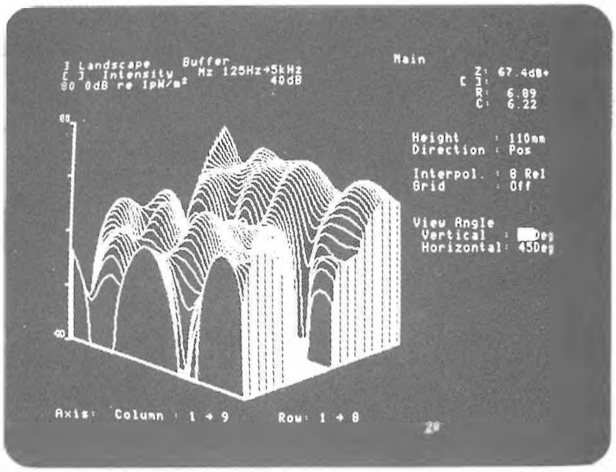

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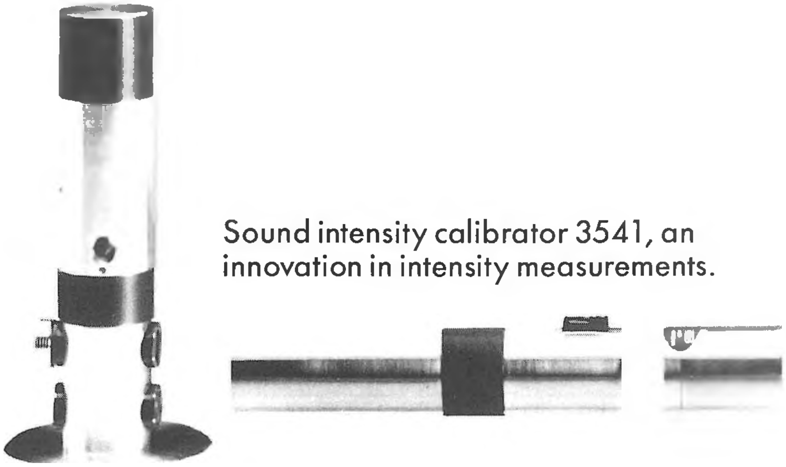

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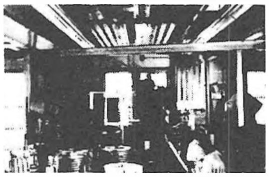

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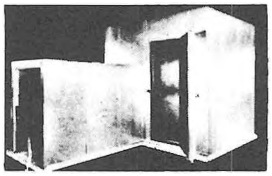

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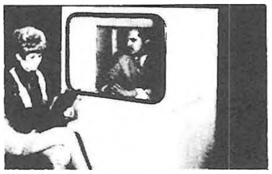

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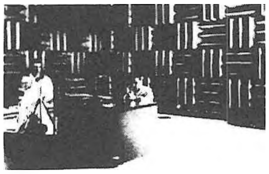

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ABSTRACT

Computer modelling is used to design a two element loudspeaker system ('tripole') capable of generating an accurate cardioid radiation pattern for frequencies below 500 Hz. The model is used to assess the effectiveness of various spherical arrays of such tripoles at cancelling a spherical sound field. One cancelling tripole array is built and found to behave in accordance with the model predictions.

SOMMAIRE

La modelisation par ordinateur est employe dans le concept d'un systeme (tripoles) a deux elements capabale de generer un profil cardioide precis de radiation pour des frequences inferieures a 500 Hz. Le modele est employe pour evaluer l'efficacite des etalages spheriques de telles tripoles afin de reduire le champs spheriques de sonorite. Un etalage tripoles d'annulation est construit et il est trouve que son comportement suit le modele de prediction.

Introduction

The potential for active noise cancellation (ANC) in the area of low frequency noise control has long been recognized (1). ANC is a logical complement to passive noise control methods which are highly effective in middle and high frequency ranges but require unacceptable material bulk to absorb low frequency sound.

Jessel (2) has developed an approach to ANC based on Huygen's principle, in which an array of secondary sound sources is used to generate a sound field which cancels the field of a primary source. The optimum radiation pattern of the individual secondary sources is related to the characteristics of the primary field. For the case of a spherical primary field, the appropriate radiation pattern for the secondary sources is a cardioid (3). A cardioid can be created by the superposition of suitable monopole and dipole fields. An approximate realization of a cardioid field has been achieved using two closely spaced loudspeakers, forming a so called 'tripole' radiator (4). In the present work, a computer program was used to model and study a physically realizable tripole radiator. Spherical arrays of such tripoles were then modelled and their effectiveness at cancelling a tone monopole primary source was evaluated. Finally, a test system with one primary and eight secondary sources was built and its performance compared with predictions from the model.

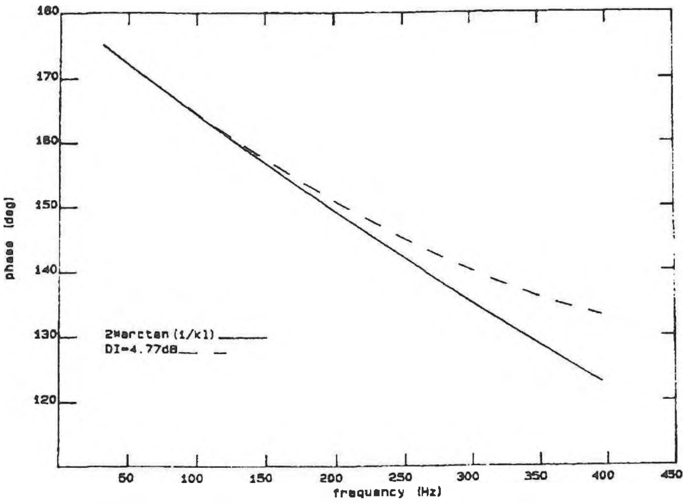

Figure 1. Tripole Phase angle

Computer Modelling Program

The computer model is based on the solution of the wave equation for spherically symmetric sinusoidal waves, and simulates the sound field generated by any collection of monotonic point sources in an inviscid freefield space. Input parameters include the position, frequency, acoustic pressure amplitude and phase of each source. The model calculates for these initial conditions, the amplitude and relative phase of the sound field at any point in space. Ancillary computer model programs calculate sound power (using 40 far field measurement points as per ANSI S1.35-1979), directivity index, and intensity of the generated sound fields. The output data are available in tabular or plot format, or as three dimensional colour contour pictures on a graphics workstation. All computer work was performed using a Syntronics "General Development Tool" (GDT) computer.

Modelled Cardioid Sources

A cardioid radiation pattern can be generated by the superposition of an acoustic monopole and dipole with the following source strength relationship

$$Qm = (i/2)\ k\ l\ Qd \qquad (1)$$

where Qm and Qd are the monopole and dipole source strengths, k is the wave number, and l is the dipole separation. The source strengths are 90 degrees out of phase and simply related by wavelength and dipole separation. The normalized directional factor, $H(\theta)$ for a cardioid pattern is given by

$$H(\theta) = 1/2\ (1 + \cos\theta) \qquad (2)$$

where θ is the polar angle. This radiation pattern has a directivity index of 4.77 dB.

A practical method to implement (1) for a tripole is to drive the two speakers at equal amplitude with a phase difference given by

$$\text{phase difference} = 2\ \text{ARCTAN}(2/kl) \qquad (3)$$

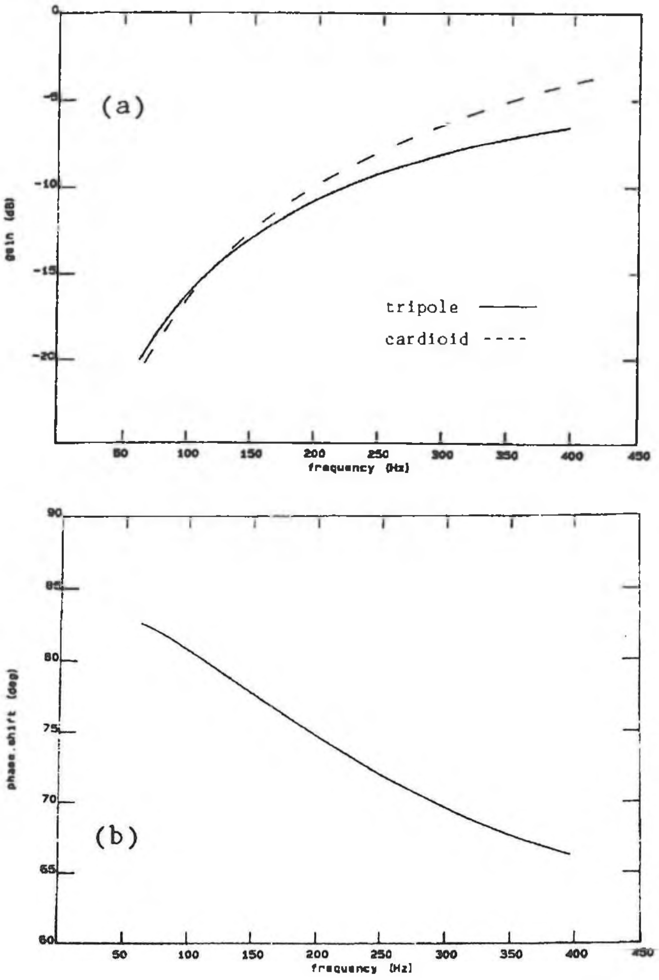

Figure 2. Tripole acoustic response (Model): (a) sound power gain, (b) farfield axial shift.

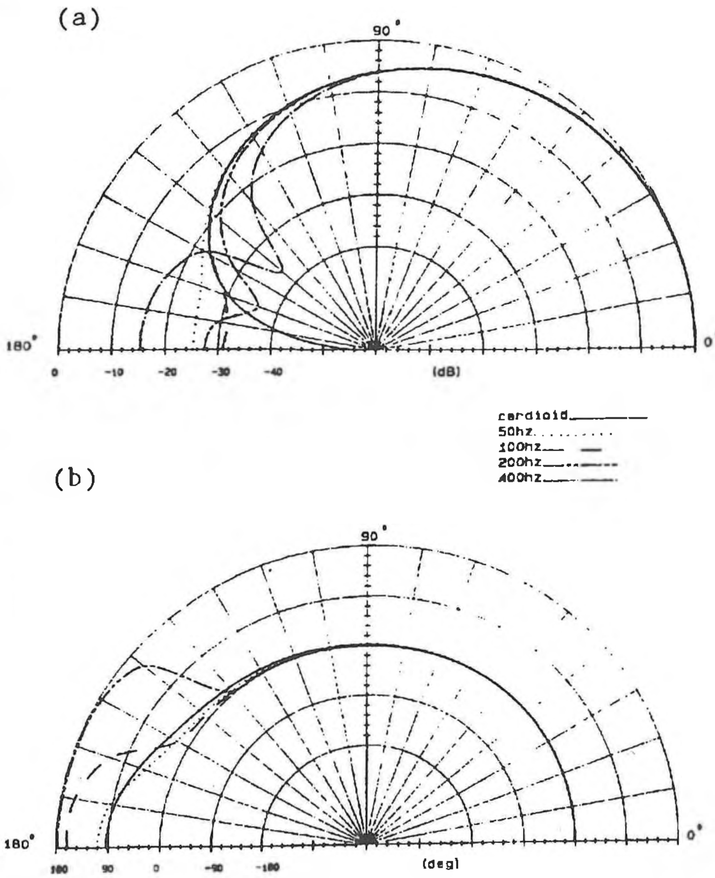

Figure 3. Farfield radiation patterns of tripoles (Model): (a) amplitude, (b) phase.

Computer simulations for a tripole of practical size (l = 0.15m) driven in this manner gave cardioid patterns only for frequencies below 100 Hz. Deviations from the 4.77 dB directivity index were found to increase with increasing frequency. The deviation was believed to arise from the separation distance l, which being non-negligible relative to wavelength at higher frequencies, resulted in distortion of the monopole and dipole field components.

To generate cardioid patterns at higher frequencies, a correction to (3) was determined using the computer model. The phase correction was chosen such that the directivity index of the field of the modelled tripole match that for a cardioid, i.e. 4.77 dB.

For frequencies above about 500 Hz a directivity index of 4.77 dB could not be obtained. The corrected phase relationship is shown in figure 1 and was used to drive both model and physical tripoles in all subsequent work.

The acoustic responses of the modelled tripole and ideal cardioid were determined relative to a monopole of equal sound power input (figure 2). The sound power amplitude of the tripole as compared to the cardioid is seen to diminish moderately with increasing frequency. Over the same frequency range, significant changes in the

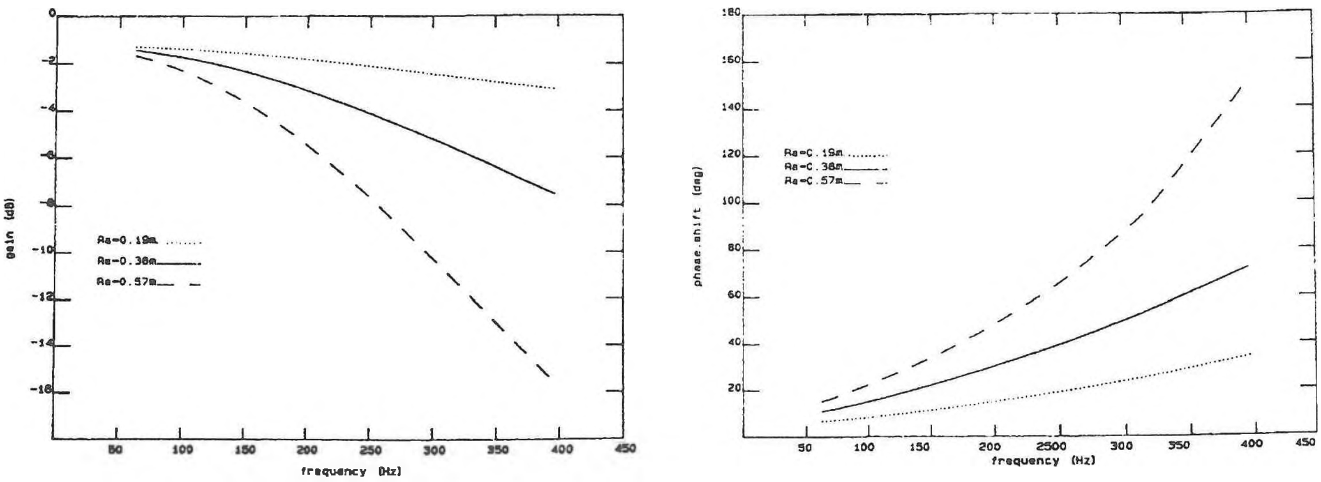

Figure 4. Tripole array response, N= 60 (Model): (a) sound power gain, (b) phase shift at cancellation point.

axial phase of the tripole sound field occur, reflecting the diminishing strength of the dipole component of the tripole relative to the monopole component, with increasing frequency.

The spatial distribution of amplitude and phase of computer modelled tripole sound fields were compared with the ideal cardioid radiation pattern in the frequency range of 50 Hz to 400 Hz. These fields are axisymmetric and are shown in figure 3. It is clear that quite good correlation with the cardioid pattern is achieved for frequencies up to 200 Hz over a polar angle of about 135 degrees. For frequencies up to 400 Hz the sound field in the 'forward' tripole hemisphere is cardioid.

Modelled Arrays of Tripoles

Twelve computer modelled tripole arrays were generated and their resulting sound field amplitude gains and phase shifts investigated. Each array consisted of N tripoles (N = 8,12,20,60) distributed on a spherical surface of radius R (R = 0.19m, 0.38m, 0.57m). The tripoles were located at the vertices of a cube, icosahedron, dodecahedron, and 'football' (a quasi-regular solid with 60 vertices). The amplitude gain was measured as the total sound power output of the array relative to the sum total sound power output of the individual tripoles. The results for the 60 tripole array type are given in figure 4a. For kR less than 2.1, identical results were obtained for all the other array types tested. The array phase shift was measured relative to the axial phase of the individual tripoles. Phase shift results for the 60 tripole array type are given in figure 4b. For kR less than 1.2, the phase shift results for the other tripole array types were identical to the N = 60 case shown. The amplitude gain and phase shift of the spherical tripole array is therefore found to be independent of N when the array radius is less than approximately 1/4 wavelength.

Modelled Active Cancellation of a Spherical Sound Field

The set of twelve tripole arrays described above were used to investigate active cancellation of a spherical sound field. An acoustic monopole was placed at the geometric centre of each tripole array. A cancellation point was selected ten

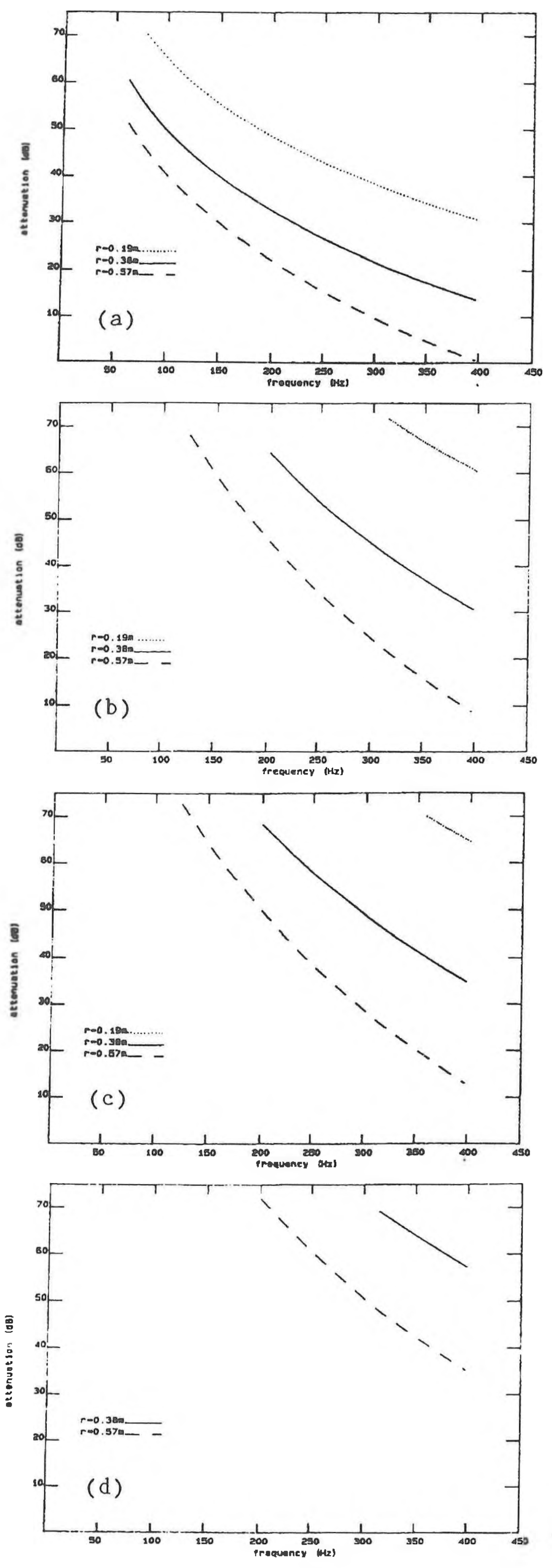

Figure 5. Sound power attenutation of a monopole by tripole arrays (Model): (a) cube, N=8, (b) icosahedron, N=12, (c) dodecahedron, N=20, (d) 'football', N=60.

metres from the monopole. At this point the monopole and tripole array sound fields were compared. Amplitude and relative phase adjustments were made so that the fields were exactly equal in amplitude and opposite in phase at the cancellation point. With the primary and cancelling fields superposed, sound power reductions were measured on a test sphere of radius 100 metres (figure 5). Sound power reductions due to cancellation were found to increase with increasing N and decreasing kR. For kR less than 1.2, reductions were greater than 70 dB for all array types and radii except for N = 8, where reductions for all radii increased from 35dB. The worst test case for each array type occurred for R = 0.57m and f = 400 Hz (kR = 4.2) where sound power reductions ranged from 0dB (N = 8) to 36dB (N = 60).

Recently Nelson, Curtis, Elliott and Bullmore [5] determined the maximum sound power reductions for a monopole field using secondary monopole sources for cancellation. They provided an example of a single cancelling monopole in close proximity to the primary source which gave considerably less attenuation than that for the cubic tripole array. A further example for a tetrahedral array of cancelling monopoles (four secondary sources) also gave less attenuation, however the results were more consistent with those for tripole array cancellation.

Experimental Cubic Cancelling Array

An experimental test system was built and the cancellation results compared to the predictions of the model. The lab system consisted of a cubic array of tripoles (N = 8) mounted on a spherical surface of radius 0.38m at whose centre was an acoustic monopole.

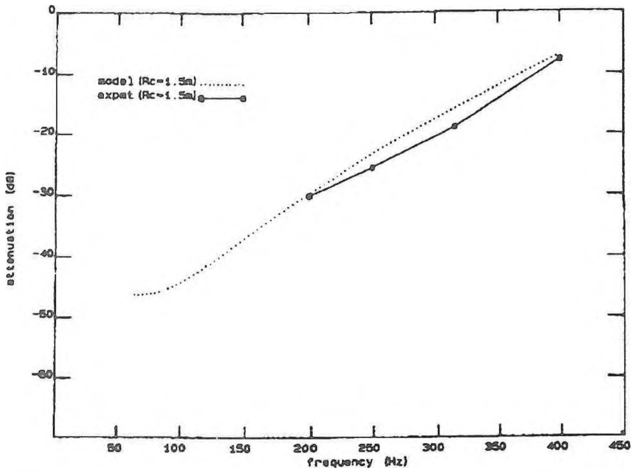

Figure 6. Experimental sound power attenuation of monopole by cubic tripole array.

The monopole unit was constructed of two 5 inch cone type loudspeakers mounted face to face and separated by a cylindrical spacer 0.035m long. The loudspeaker inputs were connected in phase so that a pulsating sphere was approximated when the unit was driven. Each tripole was made of two 5 inch loudspeakers mounted face to face, and separated by a cylinder 0.15m long which was partitioned in the middle to form a separate small cabinet for each speaker. The test system was driven by the GDT computer, one of whose array processors was programed as a multi-channel waveform generator capable of providing the necessary individual amplitude and phase control over the 17 audio signal channels used by the array. The array was tested in a hemi-anechoic room of dimensions 4.9m x 3.8m x 2.6m and cutoff frequency approximately 250 Hz. Sound fields were measured and analyzed with a B&K 4133 1/2 inch condenser microphone, B&K 2032 spectrum analyzer and the GDT computer. Cardioid radiation patterns for the tripoles were generated using the corrected relative phase difference between speakers discussed above. A cancellation point 1.5m from the centre of the monopole was selected and a test sphere of 2.0m was used to measure the sound power reduction of the cancelled monopole field. Tests were conducted using discrete tones at 200 Hz, 250 Hz, 315 Hz, and 400 Hz. The same cubic array, cancellation point and test sphere were run on the computer model. Good agreement between the experimental data and computer simulation were obtained (figure 6), the difference in no case being greater than 3dB.

Conclusion

A good degree of correlation between computer simulation and experiment for active cancellation of a spherical sound field by a tripole array was obtained. This suggests that computer modelling could provide a powerful and practical tool for further investigation in this area. A simple two loudspeaker tripole unit was found to be effective at generating the required cardioid radiation pattern, providing it was used below a critical frequency related to its physical dimensions. A strategy for driving the tripole speaker elements, based on directivity index measurements, has been found to be effective in generating an accurate cardioid radiation pattern. The acoustic response of a spherical array of tripoles was found to be essentially independent of the number of tripoles when the array radius was less than about 1/4 wavelength. Cancellation of a spherical sound field in such circumstances was very effective. It is suggested that the acoustic wavefront generated by the tripole array spatially modulates about a mean shape which is spherical, and the degree of overall cancellation is controlled by the variance of the spatial modulations. This emphasizes the importance of perfect reproduction of the primary sound field by the cancelling array. There are significant practical limitations to the use of tripole arrays for active noise cancellation. Tripoles are not efficient radiators at low frequencies where active cancellation is most effective. Consequently, high gains required at low frequencies to compensate for this inefficiency could result in difficulties avoiding significant distortion of the drivers. Also, it is clear that exact reproduction of the primary sound field is necessary to achieve the noise reduction potential offered by three dimensional active control methods. However, for all but the most simple noise sources, spatial duplication of the resultant sound fields by an array secondary sources would probably be difficult to achieve.

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BOOK REVIEW

Acoustics and the Built Environment
by Anita Lawrence

Assisting the various "built environment professionals to understand the important principles of acoustics that affect their work" is an ambitious undertaking, especially in a book with less than 250 pages. However, a review of the Table of Contents gives the impression that a comprehensive reference is in hand. The diverse perspectives of city planners, architects, HVAC engineers and contractors, all seem to have been considered. Subjects range from community noise prediction and planning to room acoustics and sound transmission concepts applied to specific types of buildings.

The book begins with the compulsory, and in this case very condensed, overview on the nature of sound that is perhaps a little overwhelming for the intended reader. This is followed with a concise explanation of the hearing mechanism which sets the stage for a major premise of the book; most community and building noise situations can be adequately assessed on the basis of A-weighted levels. Since so much emphasis is placed on this throughout the text, it is odd that the relative A-weighting frequency response is only indicated on a low resolution graph.

Chapter Two includes a good general discussion on community noise surveys and introduces the A-weighted equivalent energy level. General prediction procedures based on this descriptor are given for traffic noise and railway operations with some related commentary on annoyance. Aircraft noise is primarily discussed in the context of the NEF and ANEF (Australian version). A brief description of the meteorological effects on noise propagation and a rather esoteric presentation on ground absorption, provides a general understanding of these subjects but little practical design information. The chapter ends with a good discussion on barriers describing Maekawa's method of estimating attenuation.

Chapter Three is primarily concerned with land usage near community noise sources. Numerous worked examples illustrate the application of the various predictive methods presented in the previous chapter. Much of the detail that is required to actually use the formulas is presented for the first time within these examples. This is not typically where one would expect to find this type of information. Continuity would have been much better if Chapters 2 and 3 were combined.

Planners relying solely on these examples may encounter some difficulty in adapting the prediction methods to other circumstances. For instance, the traffic noise example, based on a U.K. standard, fails to describe correction factors for various road surfaces or ground conditions. Even something as essential as the effective source height, for a mix of cars and trucks, cannot be determined without consulting the reference. A similar limitation exists for the prediction of aircraft noise which requires an Australian standard for general use. Some confusion may also arise with the barrier attenuation example, as the prediction procedure that is outlined is not that of Maekawa as previously described. Curiously, a more complicated formula by Feher is introduced without any explanation for the change.

The next two chapters change focus from community noise to building acoustics. These chapters are primarily directed to architects, engineers and contractors with the intention of providing them with a general understanding of architectural acoustics and an awareness of when specialist advice should be sought. Speech and music become the primary sources of interest and are presented in enough detail to provide at least a rudimentary understanding of the subjects. Speech intelligibility/privacy is described using the Articulation Index (A.I.) dot field. More convenient numerical computation methods for A.I. are not mentioned. An interesting anecdotal account on the historical development of music serves to illustrate its fundamental characteristics. Useful design information consists of the dynamic and frequency range of an orchestra and Beranek's well known acoustic criteria for concert halls. Very little is mentioned about more recent descriptors such as lateral fraction or the various early to late energy ratios. The geometrical design of auditoria is covered in uncharacteristic detail illustrating the method of images.

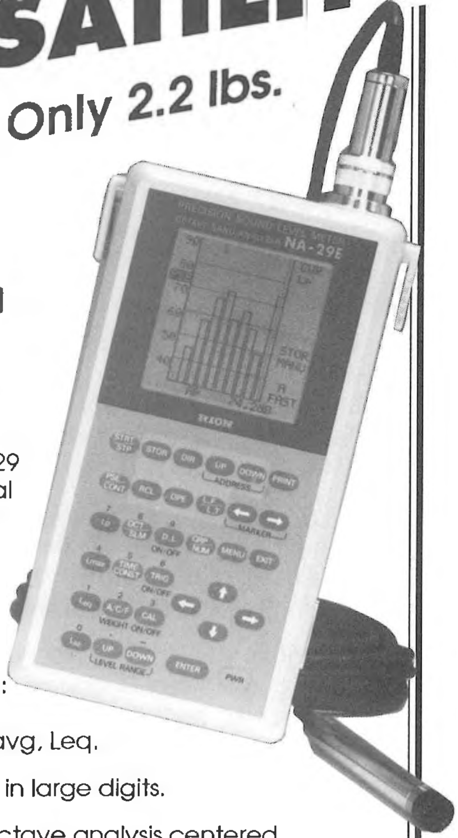
Propagation of sound within rooms is partially explained through the mathematical development of Eyring's reverberation time equation and the fundamental room equation showing the relationship between sound power and pressure. Unfortunately, the author does not mention that this latter equation requires a 10 dB correction when used with British units. This may not be obvious, particularly since equivalencies are typically stated throughout the book.

Transmission of sound and vibration in buildings is discussed in Chapter 5. Sound transmission of homogeneous and multiple skin partitions is presented in such a condensed theoretical fashion that only a vague understanding to an acoustic lay-person is possible. Practical design considerations such as the resilient attachment of leafs, cavity absorption or even a general discussion on stud walls, is completely ignored. A highlight of this chapter is the excellent summary concerning the assessment of airborne and impact noise attenuation, outlining measurement procedures and limitations of single number ratings. A minor error occurs in equation [5.24] where the frequency ratio term in the denominator should have been squared.

The final chapter of the book brings together the numerous aspects covered previously and applies them to various types of buildings. A typical guideline addresses specific design considerations and acoustic criteria pertinent to the occupancy of the building type. Subjects that are referred to include the impact of community noise sources, maximum ambient noise criteria, reverberation times, sound isolation requirements, building layout and a worked example highlighting one or two of these aspects. Once again, when the examples are examined more closely inconsistencies are found between the applied methods and those described in previous chapters where the concept was originally introduced. Nevertheless, this chapter is perhaps the most useful in a practical sense.

Planners, at least in Canada, have access to a variety of planning guidelines and prediction methods that are far more complete than the information contained in this book. It may be interesting supplemental reading but it is certainly not an authoritative resource. Building designers would no doubt achieve a better general understanding of how acoustics affects their work but not to the point where this book could be used as a comprehensive design guide. Many of the design procedures are based on foreign standards which are not fully described. Acoustic principles are often presented in a very theoretical and abbreviated fashion requiring the reader to seek out the references for a better understanding. The book may, however, alert designers to the need for specialist input and in this sense it has fulfilled its objective. Contractors would have very little use for this information. It is disappointing that there are no practical construction details illustrating the acoustic principles that are discussed. Finally, acoustic consultants may find some of the anecdotal comments interesting, many of the references are excellent and many important equations are found within, but the unorthodox organization, lack of detail and sometimes dated information, render it a poor technical reference.

Kelly Kruger, Acoustics Section, Alberta Public Works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INFORMATIONS

CONFERENCES

Quiet Revolutions: Heathrow Penta Hotel, du 9 au 11 octobre 1990. Contacter: Ralph K. Hillquist, (313) 685-2754.

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Inter-Noise 90: Gothenburg (Suède), du 13 au 15 août 1990. Contacter: Tor Kihlman, Department of Applied Acoustics, Chalmers University of Technology, S-412 96 Gothenburg, Sweden. Tél.: (046) 31-72-2211.

Insonorisation et contrôle des vibrations dans l'industrie: Haute Tatra, Tatranska Lomnica, Tchécoslovaquie, du 26 au 30 novembre 1990. Contacter: Stanislav Pavilek.

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Intensité structurale et énergie vibrationnelle: Senlis (France), du 27 au 29 août 1990. Contacter: Centre technique des industries mécaniques, Département d'acoustique industrielle, B.P. 67, F 60304 Senlis (France). Tél.: (33) 44 58 34 15.

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Réunion de l'Acoustical Society of America: San Diego (Californie), du 26 au 30 novembre 1990. Contacter: Frederick H. Fisher, Marine Physical Lab., F-001, Scripps Institute of Oceanography, University of California, San Diego, La Jolla, CA 92093-0701.

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Audiology or Speech-Language, Graduate Level: University of Western Ontario, automne 1990. Contacter: Donald G. Jamieson, Faculty of Applied Health Sciences, Department of Communicative Disorder, Elborn College, London (Ontario). Tél.: (519) 679-2111.

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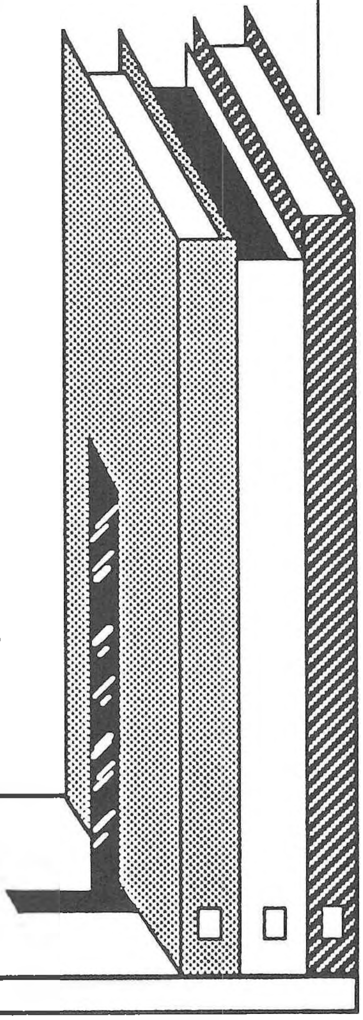

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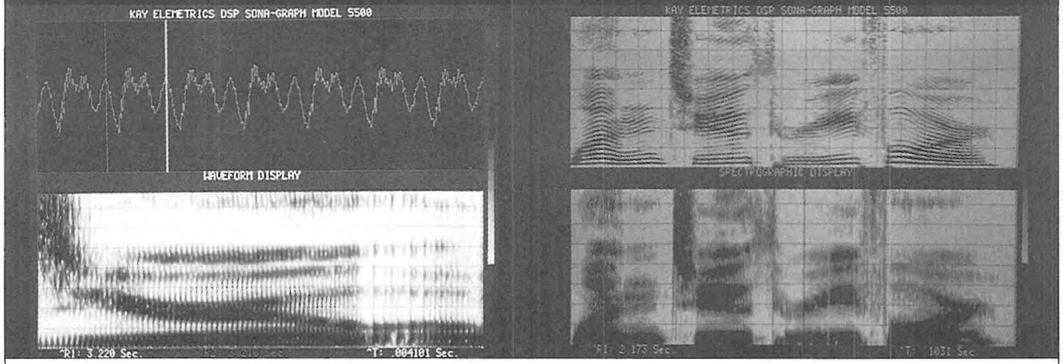

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