MODELLING OF EXCESS NOISE ATTENUATION BY GRASS AND FOREST

Michael U. Onuu
Department of Physics, University of Calabar, P.M.B 1115, Calabar, Cross River State, Nigeria
(E-mail: michaelonuu@yahoo.com)

(Submitted: 24 September, 2006; Accepted: 30 November, 2006)

Abstract

*A wide-range of acoustical measurements have been conducted in the open field, guinea grass (**panicum maximum**) and forest which comprises iroko (**milicia ezcelea**) and white afara (**terminalia superba**) trees in the ratio of 2:1 approximately. Excess noise attenuation spectra have been plotted for the grass and forest for various distances. It was observed that the grass introduces excess noise attenuation about twice that of the trees (or forest) throughout the octave band centre frequencies. Excess noise attenuation curves for both media indicate three distinct parts. Results have further shown that the grass and the trees can find applications in environmental noise control and the built environment. The proposed best models for excess noise attenuation versus octave band centre frequency in this study are logarithmic (or linear) for the grass and power law for the forest.*

Keywords: *Excess noise attenuation, grass, forest andctave band centre frequency*

1. Introduction

Work on ***Jungle Acoustics*** dates back to 1946 with the investigation by Eyring (1949). Many other research workers have conducted studies of sound attenuation and absorption by trees, shrubs and grass. Their findings include excess attenuation by trunks and branches (Embleton, 1963; Martens, 1980, 1981; Bullen and Fricke, 1982 and Fricke, 1984) and scattering and absorption by foliage (ISO/DIS, 1913a, 1913b; Burn, 1979; Tang et al., 1980; Martens, 1981; Martens and Michelson, 1981 and Martens and Roebroek, 1986). A semi - empirical model to predict the ambient noise due to vegetation was presented by Fégeant (1999a). His second paper (Fe'geant, 1999b) on measurements of noise spectra from aspen, birch and oak showed that spectra exhibited an emission peaks around 4,000-5,000 Hz. Onuu (2003), investigated the effects of atmospheric attenuation and shielding of road traffic noise along some Nigerian highways. He found that for the majority of the results for the four sites, the sound pressure band level is at its peak at 32- 63 Hz and decreases with increase in frequency at the rate of 5-12 dB per decade above 2,000 Hz. Investigation of sound propagation over grass (Onuu, 2000) showed a display of absorption and attenuation spectrum with dips at low and mid-frequencies (32-63 and 500-2,000 Hz with emission peak at 250 Hz), a steady excess increase in attenuation from 2,000 Hz and characteristic dips at 1.8m above grass, among others. Study of spectral characteristics of traffic noise attenuation by vegetation belts in Delhi (Tyagi et al., 2005) showed a significantly higher relative attenuation of more than 24dB characteristically at 3.15 kHz at all the vegetation sites. Sound diffraction by multiple wedges, barriers and polynomial-like shapes was investigated by Kin et al. (Kim et al., 2005) who proposed a theoretical formula that is based on the geometrical diffraction.

This investigation is part of our ongoing programme in the study of grass and vegetation in relation to use in environmental noise control. Other objectives of the study are to compare excess noise attenuation by the grass and trees, develop their spectral characteristics and empirical models for the prediction of excess noise attenuation by the grass and trees.

2. Sites, Measurements and Data Reduction

The sites are located at Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State, Nigeria. They are grass and forest respectively on the right and left sides of the road leading to the Faculty of Engineering and the Animal facing the generator house. The forest comprised iroko (***milicia ezcelesa***) and white afara (***terminalia superba***) trees in the ratio of 2:1, approximately. The forest was less dense, less thick and had some undergrowth and evergreen trees.

One of the sites (grass) and noise sources are those used in an earlier study (Onuu, 2000) except that the grass had grown taller. Sound of horn from a Mecedes Benz car was also used as a secondary noise source. This was to ensure that the data were reproducible. The 500kVA generator was a continuous source of noise but the horn was sounded only when instruction to do so was given by the wave of hand during measurements in the open field and grass by one of the field attendants. During measurements in the forest, a whistle was blown to signal that the horn should be sounded at distances greater than about 100m because of trees that constituted a barrier.

Noise level and noise spectra measurements were made in the open field, grass and forest at specific distances and octave band centre frequencies using the precision sound level meter (B & K Type 2203) and 1/3 octave band filter (B & K Type 1613). Measurements were made at distances of 50,100,150,and 200m from the sources where edge effects in the forest was insignificant, or before noise from other sources became prevalent. Subsequently, noise reduction was carried out . This involved comparison of measurements in the open with those in grass and forest. Then excess noise attenuation due to grass, ΔL_g, and trees (forest), ΔL_t as functions of distance and frequency were determined. A lot of data were discarded before arriving at those used in the analysis. These were those that constituted unreasonable scatter as the graphs were being fitted. Occasional peaks and picks were also ignored as the graphs were being fitted. This was because the trend of the graphs were of utmost importance in this investigation.

3. Results and Discussion

3.1 Effect of frequency and distance

Results show that frequency and distance have a marked effect on excess noise attenuation by grass and trees (or forest) (Figs. 1- 4 and Table 1). The curves show three distinct parts. Excess noise attenuation /Hz by grass shows rapid decrease at octave band centre frequencies of 31.5-8,000 Hz., gradual decrease at 8,000-16,000 Hz and constant decrease above 16,000Hz. The difference in excess noise attenuation by grass, ΔL_g, between 100m and 50m; 150m and 100m; 200m and 150m increases from 3.5 to 5.8 dB at 1,000 Hz until a constant value of 5 to 7 dB at 16,000 Hz (Fig. 1 and Table 1). Thus, excess noise attenuation by grass is more pronounced or highest at low frequencies and, as should be expected, increases with distance from the source. These results are similar to those obtained by Beranek and Kurze (1979) who reported that shrubbery and grass offer high noise attenuation which usually increases roughly at the rate of 5 dB per 100m for each doubling of frequency.

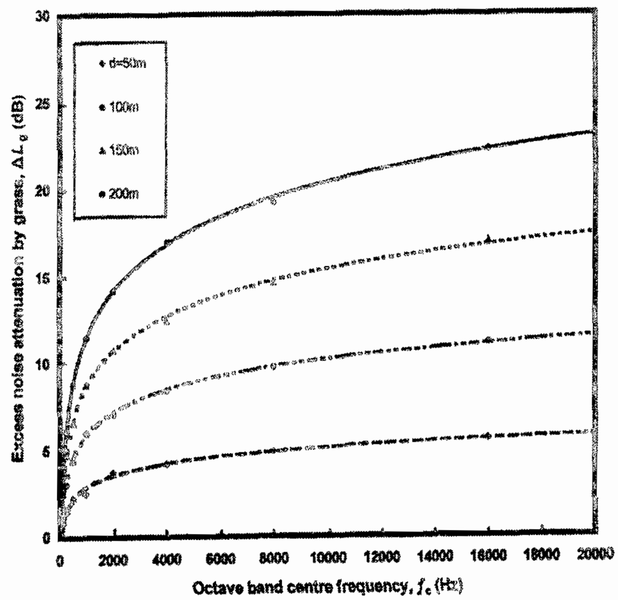

Fig.1: Excess noise attenuation by grass at vaious octave band centre frequencies and distances

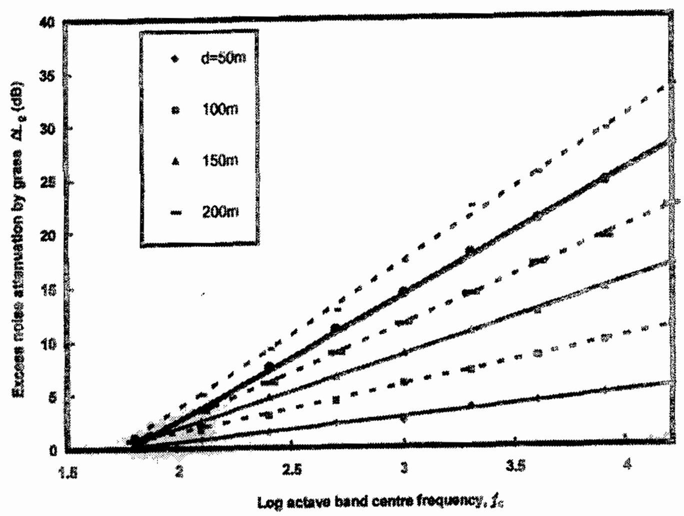

Fig.2: Semi log plot of excess noise attenuation by grass at various octave band centre frequencies and distances

The three (3) distinct parts are also prominent in the curves for excess noise attenuation by trees at the particular octave band centre frequencies and distances (Fig. 3) as were observed in the case of grass (Fig. 1). From Fig. 3 and Table 1, it is shown that excess noise attenuation by trees increases from 1.3 dB at 1,000 Hz to a constant value of about 4dB at 16,000 Hz per same distance difference of 50m. Thus, (trees or forest) are not as effective noise barrier as grass. It was also reported (Krocher and Kessler, 1975) that trees form a poor barrier against noise. Researches conducted in Canada, Russia, America and German (Crocker and Kessler, 1975) led to the following conclusions: excess noise attenuation of 10 to 25 dB per 100m at frequencies below 2,000 Hz for thick forests; excess noise attenuation of 5 to 12 dB per 100m at these frequencies for less thick forests, and excess noise attenuation of 0 to 5dB per 100m for deciduous trees without leaves (bare). Excess noise attenuation by forest in this investigation was found to vary from 0.5 to 3.5 dB/100m at the same frequencies and is about 6dB/100m above 16,000 Hz. These results which lend credence to those of previous workers (Beranek and Kurze, 1979) are also corroborated by those of Crockers and Kessler (1975) who found that excess noise attenuation at the frequency of 1,000 Hz vary from 25 dB/100m for dense evergreen woods to 3 dB/100m for bare trunks above absorbing ground.

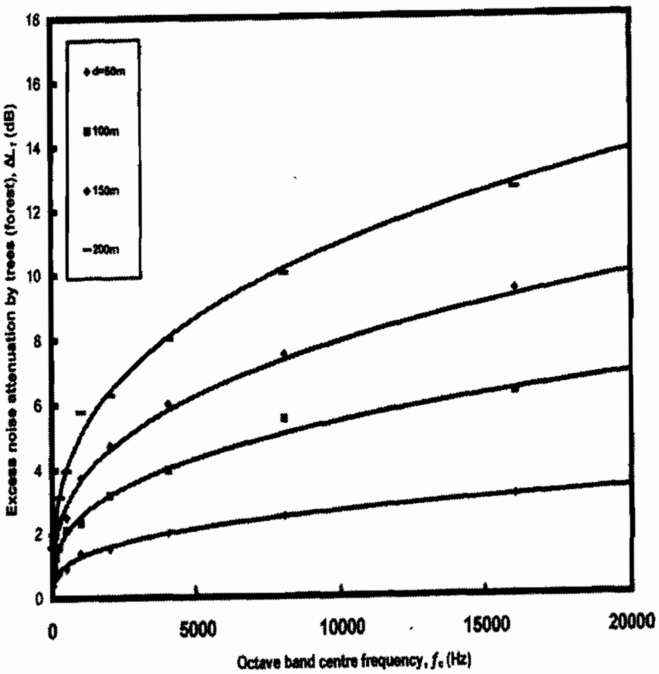

Fig.3 : Excess noise attenuation by trees (forest) at various octave band centre frequencies and distances

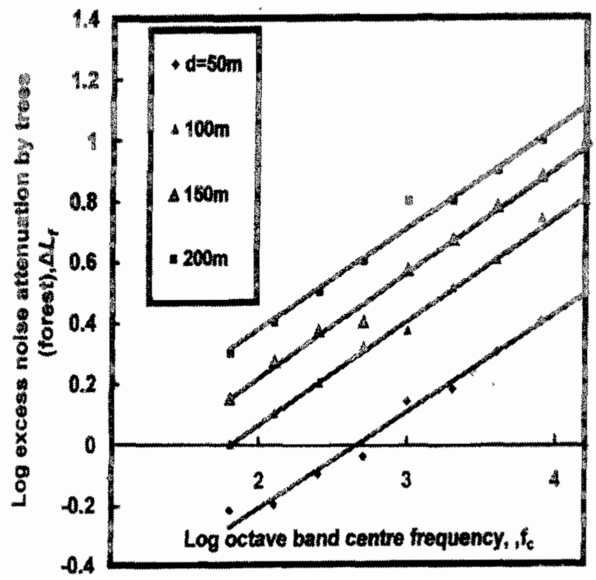

Fig. 4: Log-log plot of excess noise attenuation by tress (forest) at various octave band centre frequencies and distances

3.2 Empirical Relationships

Excess noise attenuation by grass, ΔL_g, and trees, Δl_t, were regressed on the octave band centre frequency, f_c, in order to establish the empirical relationships between them at various distances (Table 2). These relationships (Table 2) can generally be expressed as follows:

In eqns. (1) -(5) d_1 (d), a_o(d), b_1(d), m(d) and k^1(d)

$$\Delta L_g = a_1\,(d)\ \text{In} f_c + a_o\,(d) \qquad (1)$$

$$\Delta L_g = b_1\,(d)\ \log f_c + a_o\,(d) \qquad (2)$$

$$\therefore \Delta L_g = [2.31 b_1\,(d)]\text{In} f_c + a_o\,(d) \qquad (3)$$

From eqn. (3), it is clear that eqns. (1) and (2) are similar.

Also,

and $$\Delta L_t = m\,(d) f_c^n \qquad (4)$$

$$\Delta \text{Log}\ \Delta L_t = k \log f_c + k^1\,(d) \qquad (5)$$

are functions of distance while n and k are constants having average value of 0.3333 or 1/3.

Equations (1)-(5) are the best relationships between the variables ΔL_g, ΔL_t and f_c as indicated by the values of the regression coefficients of the various curves proposed.

The proportion of the variance of the dependent variable that can be attributed to its regression can be described as r^2; then r calculated (Table 2) indicates that nearly 100% of the variance of the dependent variables, excess noise attenuation by grass, ΔL_g and trees, ΔL_t, are explained by the independent variable, octave band centre frequency, f_c. Thus, the curves fit the data well implying that the relationships between excess noise attenuation by grass and octave band centre frequency and that by trees and octave band centre frequency are logarithmic (or linear) and power law, respectively.

Similar relationships have been found to exist between excess noise attenuation and frequency in Hertz (Crocker and Kessler, 1975):

$$(A^3)_{\text{Shrubbery or grass}} = (0.18 \log f \ 0.31)\, r, \quad \text{dB} \quad (6)$$

and

$$(A^4)_{\text{Forest}} = 0.01(f)^{1/3}\, r, \quad \text{dB} \quad (7)$$

where r is path length through shrubbery (or over grass) or forest in metres.

Table 1: Summary of excess noise attenuation by grass and trees (forest) at various octave band centre frequencies and distances.

Distance, d(m)	Octave band centre Frequency, f_c (kHz)	Excess noise attenuation, ΔL (dB)		Distance, d (m)	Octave band centre Frequency, f_c (kHz)	Excess noise attenuation ΔL (dB)	
		Grass ΔL_g	Trees (Forest) ΔL_t			Grass ΔL_g	Trees (forest) ΔL_t
50	1	2.0	1.0	150	1	9.0	3.8
	2	2.5	1.3		2	10.3	4.5
	4	3.0	1.5		4	12.5	6.0
	8	3.8	2.5		8	14.8	7.3
	16	4.3	3.0		16	17.0	9.5
100	1	5.5	2.3	200	1	11.3	5.0
	2	6.0	3.0		2	14.3	6.3
	4	8.3	3.8		4	16.0	7.8
	8	10.0	4.8		8	19.8	8.0
	16	10.3	5.8		16	22.0	12.5

Table 2: Summary of empirical relationships between excess noise attenuation by grass and trees (forest) and octave band centre frequencies at various distances

Regression parameters	Distance from source, d(m)	Regression coefficient		Correlation coefficient, r	Relationship
$\Delta L_g/f_c$		a_o	a_1		
	50	-8.9284	0.9825	0.9976	$Lg = 0.9825 \ln f_c \ 3.9284$
	100	-7.2342	1.8959	0.9988	$Lg = 1.8959 \ln f_c \ 7.2342$
	150	-11.558	2.9281	0.9998	$Lg = 2.9281 \ln f_c \ 11.58$
	200	-15.291	3.8771	0.9999	$Lg = 3.877 \ln f_c \ 15.291$
$\Delta L_g/\log f_c$		a_o	b_1		
	50	-3.9484	2.2687	0.9976	$Lg = 2.2687 \log f_c - 3.9484$
	100	-7.2687	4.3776	0.9987	$Lg = 4.3776 \log f_c - 7.2687$
	150	-11.612	6.7612	0.9998	$Lg = 6.7612 \log f_c - 11.612$
	200	-15.362	8.9523	0.9999	$Lg = 8.9523 \log f_c - 15.362$
$\Delta L_t/f_c$		m	n		
	50	0.1372	0.3224	0.9962	$L_t = 0.1372 f_c^{0.3224}$
	100	0.254	0.333	0.9985	$L_t = 0.254 f_c^{0.333}$
	150	0.3619	0.3349	0.9975	$L_t = 0.3619 f_c^{0.3349}$
	200	0.505	0.334	0.9984	$L_t = 0.505 f_c^{0.334}$
$\text{Log}\, \Delta L_t / \text{Log}\, f_c$		k	k^1		
	50	-0.8485	0.3186	0.9946	$\text{Log } L_t = 0.3186 \log f_c - 0.8485$
	100	-0.6075	0.337	0.9984	$\text{Log } L_t = 0.337 \log f_c - 0.6075$
	150	-0.4672	0.3434	0.9968	$\text{Log } L_t = 0.3434 \log f_c - 0.4672$
	200	-0.2836	0.3313	0.9945	$\text{Log } L_t = 0.3313 \log f_c - 0.2836$

4. Conclusion

From the investigation, the following conclusions could be made:

1. Grass introduces excess noise attenuation about twice that of forest at all frequencies.
2. Grass and trees are considered a fairly good noise barrier and so could be used for noise control especially at frequencies between 1,000 and 4,000 Hz where the normal human ear is very sensitive.
3. Excess noise attenuation rate by grass and trees are characterized by three district parts namely rapid decrease, gradual decrease and constant decrease at octave band centre frequencies of 31.5- 8,000 Hz, 8,000-16,000 Hz and above 16,000 Hz respectively.
4. The best models for excess noise attenuation and octave band centre frequency is logarithmic for grass while power law is the most appropriate for the family of curves for excess noise attenuation by trees or forest.

Acknowledgments

The author acknowledges the efforts of the final year students (2001/2002 session) of the Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria, during data acquisition and the school authorities for the generator.

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