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SOUND ATTENUATION BY A VEGETAL SCREEN EXPERIMENTAL MODELS

A. Dziedzic

Laboratoire de Physiologie Acoustique
I.N.R.A. - 78350 Jouy en Josas - France -

An experiment was designed to determine how the interposition of a vegetal screen between a sound source and a reception site can modify the acoustic level on this site. Its main results will be described and the respective contributions of various meteorological and dendrological parameters on the observed modifications briefly analyzed.

Material and method

Two experimental settings were adopted : one to measure the acoustic level on the site (EX1), the other to determine the effect of the vegetal mass on the acoustic wave crossing it (EX2).
The vegetal screen is composed of 150 Thuya atrovireps (4/4.5 m). The site studied is an open plot of plane grassland. Two differently structured screens were tested : the first is formed with 5 jointed rows of maximum plantation density (surface : 30 x 5 m^2) ; the second has 9 alternated jointed rows (surface : 25 x 9 m^2).
The mean dendrometric caracteristics of the screens were determined with 5 randomly selected trees.

The signal, either a white or a pink 1/3 octave filtered noise, is emitted 1 m from the screen and 2 m from the ground. The two channel emission (2 x 80 W) covered a 100 - 10.00 Hz frequency band. The screen and a 14 m distant space, directly in front of it, limited the spot where the measures were performed (see Figure).

Sound levels were successively recorded on 21 different points of the spot : in EX1, simultaneously with 4 microphones held on a movable mast at 0.5, 1.2 and 4 m from the ground ; in EX2, with 3 microphones fastenned 50 cm from each other on a square plywood panel (side = 1 m, thickness : 2 cm) lying on the ground and moved from point to point right behind the screen.

If possible during the same day, the experiment with screen was completed with the same paradigm without screen the different output and recording points being transferred on the same side of the screen.

For each recording points, acoustic measures were completed with meteorological readings. Six variables could affect the acoustic level on the site : temperature : x(1) ; hygrometry : x(2) ; wind on site : x(3) ; wind projected on the acoustic ray : x(4) ; geometrical weakening and impedance of the ground : x(5) ; vegetal mass crossed by the acoustic waves : x(6).

The range covered by the meteorological variables during the whole experiment (which lasted more than two years, 1978-80), is given in the following table :

$\bar{x}$ (1)	$\bar{x}$ (2)	$\bar{x}$ (3)	x (4)
14° (- 3° to 25°)	75.6 % (48 to 100 %)	3 m/s (0 to 5 m/s)	0 to 360°

A multiple linear regression model has been chosen to determine the effect of each of these variables on the acoustic level of the experimental spot, the transfer function of the vegetal system was used to study the influence of the vegetal mass on the acoustic beam.

Results

Effect of the variables on the acoustic level of the site (EX1)

If Y is the difference between the emitted an received sound levels of the examined frequency band, the following model can express its variations :

$$Y = \begin{bmatrix} Yo \\ Y1 \end{bmatrix} = \alpha o + \sum_{i=1}^{5} \alpha_i \cdot X(i) + \alpha 6 . X(6) + \varepsilon$$

where Yo corresponds to the measures without the vegetal screen ; then x(6) = 0 .

Y1 corresponds to the measures with the vegetal screen ; then x(6) = 1

ε = residue of the rule $N_o (0, \sigma^2)$

$\alpha 1$ = coefficient caracterizing the influence of x(i) on Y.

- First note that the multiple correlation coefficient r, between the x(i), shows that the adaptation of the model is not constant function of the frequency.

- The temperature x(1) and the hygrometric x(2) effects on Yo start being noticeable at 2.500 Hz ; this influence is more important, but also more irregular on Y1. In both cases, $\frac{d\alpha 1}{dv}$ and $\frac{d\alpha 2}{dv}$ are negative.
- The wind's influence on Yo is greater than Y1 but, in both cases, anemometric readings at 50 cm of the ground enhance the variability of $\alpha 3$ and $\alpha 4$.

The effet of x(5) is always significant ; α 5 greatly varies for

$630 \leqslant \nu \leqslant 2.500$ Hz ($0.421 \leqslant \alpha 5 \leqslant 1.51$) but $\alpha 5 \simeq 1$ for $\nu > 2.500$ Hz.
- Its only from 630 Hz that the vegetal mass has an effect on Y1 (therefore, this frequency constitutes the inferior limit of our study, initially started at ν = 100 Hz). Notice that negative values for $\alpha 6$ were only obtained with the screen containing maximal plantation density and for $\nu \leqslant 1.600$ Hz.
A linear regression of $\alpha 6$ on the logarithm of the frequency gives a good approximation (explained variance ⩾ 92 %) of the variation rule $\alpha 6$ (ν).
The coefficients of the regression line for each of the two studied structures are :

STRUCTURES	DENSITY MAX.	QUINCUNX
a dB/g/cm^2	0.41	0.39
b dB/g/cm^2	- 0.31	- 0.52

The following table gives the variation range of the coefficients for the 6 studied variables (and of r)

	r	α 1	α 2	α 3	α 4	α 5	α 6
Yo	0.420 to 0.523	-0.40 to 0.05	-0.46 to 0.46	-0.27 to 3.70	-0.54 to 0.51	0.421 to 1.51	
Y1	0.93[illegible] to 0.9[illegible]1	-0.4[illegible] to 0.0[illegible]	-0.72 to 0.52	-0.11 to 0.72	-0.22 to 0.55	0.94 to 1.31	-0.13 to 0.51

Transfer function of the vegetal mass (EX2)
Computations were done with 100 ms white noise sequences (sampling period : 20 kHz) where the transfer delays of the wave accross the vegetal channel were corrected.
As the sound was recorded on ground level only, the direct and the diffusion waves, inside the screen, were considered.
Three transfer channels (A, B, C), with a respective length of : 4.77 m, 7.80 m, 15 m and vegetal mass factor of : 14.51 g/cm^2, 21.87 g/cm^2, 37.2 g/cm^2, have been considered. The mean response of each channel was given by the responses of the 3 microphones on the plywood panel.
The autoregressive (AR) (all-pole) method was choosen to model the tranfer system. This method is based on the resolution of the following temporal equation :

$$y_t + a_1 y_{t-1} + \ldots\ldots + a_p y_{t-p} = G.e_t$$

where e_t and y_t are discrete values of the input and output signals, G the gain of the system and of the transfer function :

$$S(z) = \frac{G}{A(z)} = \frac{G}{1 + a_1 z^{-1} + \ldots + a_p z^{-p}}$$

e_t's lack of whiteness has been corrected as follows :
a - computerizing the AR model on e_t with a white input εt
b - filtering y_t with the inverse of the obtained model and,
c - identifying the investigated model on y_t, previously filtered.
In this case, e_t, has a constant spectral density and the obtained transfer function is equivalent to the spectral power density (S.P.D.) of the filtered y_t.
A linear regression of the S.P.D. on the logarithm of the frequency for each octave band, between 1 and 8 kHz, has given the following results :

POINT	A			B			C		
Micro.	1	2	3	1	2	3	1	2	3
1 to 2	1.61 (0.94)	[illegible] (0.77)	- 0.81 (0.81)	0.47 (1.0)	- 2.20 (0.83)	- 13.43 ([illegible])	- [illegible] (0.41)	- 9.98 (0.57)	- 1.69 (1.17)
2 to 4	- 2.90 (1.16)	- 10.70 (0.49)	- 11.60 ([illegible])	- 2.28 ([illegible])	- 16.26 (1.02)	- 7.33 (1.05)	- 16.34 ([illegible])	- 7.90 (1.99)	- 16.92 (1.86)
4 to 8	- 18.77 ([illegible])	- 9.69 ([illegible])	- 3.61 ([illegible])	- 17.71 ([illegible])	- 20.71 ([illegible])	- 20.49 (1.75)	- 19.04 (1.81)	- 25.82 (2.68)	- 14.66 (1.09)

- Slope of the regression lines of the S.P.D. by octave band, on the frequency logarithm (within bkt : standard deviation of the regression error).

The values of the exceeding absorption coefficients (in dB/g/cm^2), for each of the 3 examined frequency bands, are then as follows :

Point	A	B	C	Mean
1 to 2	0.057	0.692	0.670	0.473
2 to 4	1.739	1.229	1.093	1.353
4 to 8	2.210	2.377	1.616	2.234

- These values are to be compared with the coefficient of the first experiment (a = 0.41).

Results obtained in EX1 are statistically significant for the whole experimental site and all usual meteorological conditions met in the Parisian district. However, those in EX2, are only reliable for the vegetal screen with no consideration for meteorological conditions.

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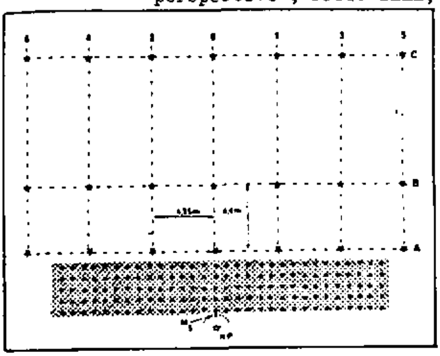

Experimental site in EX1

HP : Loud speaker
M5 : ref. microphone
* : measurement points