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PURE TONE GENERATION AND HIGH DIRECTIVITY-INDEX OF A 36 HZ RESONANCE IN A FLY-OVER BY A WIND-SPEED OF 10 M/S

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ABSTRACT
The wind under a fly-over generates in the Helmholz resonators tones from $35 - 37$ Hz. At great distance from the fly-over a frequency of 36 Hz is found from a place 60 meters behind the fly-over. This type of source is hardly recognizable in the field because the place of the source is not at the place of the construction.

1 - INTRODUCTION

Nearby some fly-overs is a generation of a wind-induced low frequency pure tone heard. In this example the pure tone is registered by a wind-speed of 10 m/s. In the dwellings the tone is about 60 dB at 36 Hz and is in a steady state during the hours the wind is blowing.
The people living in the dwellings tried to find out the source of the pure tone generation without success. They suggested that the piles of the power-line could generate the tone. By doing sound pressure and vibration measurements it was clear that the power-line construction had nothing to do with the 36 Hz tone.
The fly-over was vibrating at 36 Hz, in particular the crash-bar (125 dB ref. 10^{-9} m/s). The fly-over concrete is vibrating with a velocity of 95 dB (ref. 10^{-9} m/s). Below the fly-over, at the railroad, the maximum sound pressure level is 100 dB at 36 Hz. The sound pressure level at 150 m distance is 90 dB so it was not clear how these two sound pressures did relate to each other. Figure 2 gives the situation and the measured sound pressure levels at 36 Hz. Figure 1 gives the measured tone at 200 m distance.

2 - PLACE OF THE SOURCE

By going from a distance of 500 m meter in the direction of the fly-over the increase of the sound pressure levels gives a source place at a distance of about 60 m before the fly-over. From this point to the fly-over there is a negligible chance in sound pressure. At some meters (10 m) at the wind-side of the fly-over the tone cannot be recognized.
To give a sound pressure level of 90 dB at 90 m distance from the source the monopole strength of the source is 140 dB, but the directivity index is high. The sound energy is transmitted in 1/8 sphere and the reflecting plane gives a 6 dB amplification of the pressure. So the power level should be in the order of 125 dB (ref. 1 pW) at a place where no object is located (acoustic hologram).

3 - THE CONSTRUCTION OF THE FLY-OVER

The fly-over is built of 19 I-beams with a length of 20 meter and a width of 1.2 meter. The flange of the underside of the beam has a slit of about 0.08 m (medium) and a depth of 0.16 m. The inside volume is 9.9 m^3. Figure 3 gives the slice view.
At the top of the fly-over deck are safety bars and crash bars. The eigenfrequency of these bars is between 30 and 50 Hz. At two places the frequency of 36 Hz is found. After removing this construction the pure tone was still present so the only source could be the 18 slits below the fly-over (Helmholz resonators).
By measuring the sound pressure in the slit the frequency is varying and not stable at 36 Hz. (see figure 4). There is also found the turbulence (vortex) by the wind which gives a tone of about $1 - 5$ Hz with

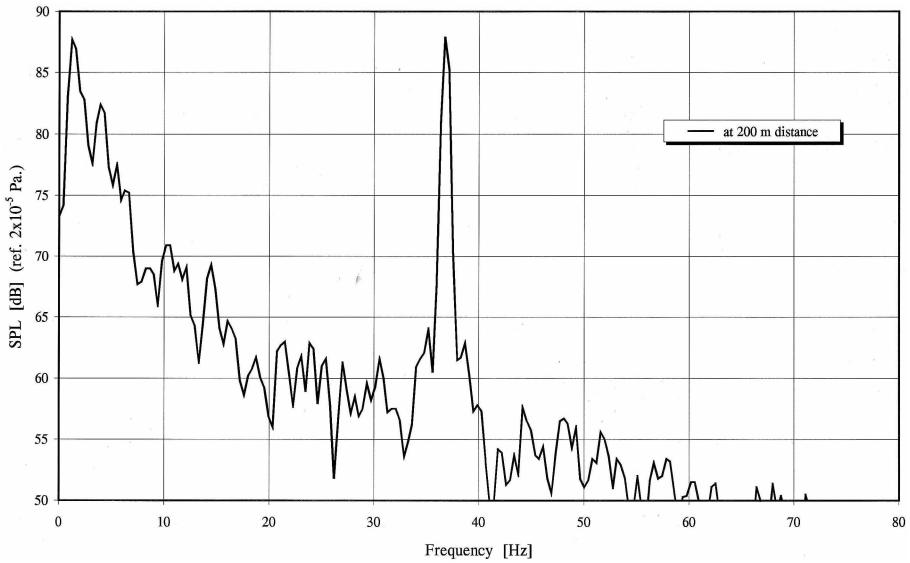

Figure 1: Measured sound pressure level at 200 m from the fly-over.

a sound pressure of more than 100 dB under the fly-over deck. Figure 4 gives the sound pressure levels in the slit and under the beam.

4 - FREQUENCY OF THE HELMHOLZ RESONATOR IN STEADY STATE CONDITION AND IN FLOWING AIR

The expected frequency is:

$$f_0 = \frac{c_0}{2\pi} \cdot \frac{S}{V\,(1 + \Delta l_i + \Delta l_0)}$$

with

$$\Delta l_i = \frac{b}{\pi}\,(\ln\,(c_0/fb) - 0.107)$$

and

$$\Delta l_0 = \begin{cases} \Delta l_i & \text{with no wind influence} \\ 0 & \text{at a high wind speed} \end{cases}$$

- c_0 = velocity of sound
- S = neck area
- V = volume
- l = length of neck
- b = neck width
- f = frequency
- no wind speed: $f_0 = 33$ Hz; high wind speed $f_0 = 39$ Hz

The measured frequency at 10 m/s is $35 - 37$ Hz in the slits.

5 - ACOUSTIC HOLOGRAM

All 18 slits are in phase generating a tone because of the vortex frequency with a very long wave length. Through the wind gradient the 18 spatial slits are giving a source at the earth surface as an acoustic hologram. The total real source is located at 60 meters with the wind direction behind the fly-over. The source has the strength of the sum of the 18 slits together.

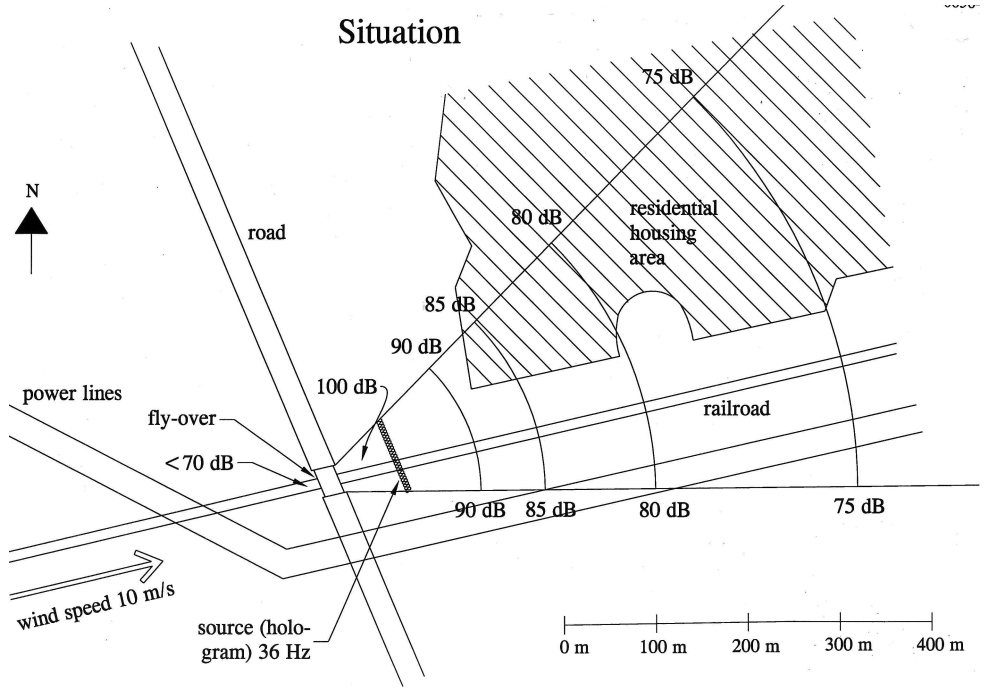

Figure 2: Situation and measured sound pressure level at 36 Hz.

6 - CONCLUSION

The vortex frequency is generating in the 18 slits at 1.2 meter separating distance at the same moment a pure tone varying between 35 and 37 Hz. The wind gradient gives with this spatial sources an acoustic hologram at a great distance behind the object, so the place of the source could not be recognized in the field. After sealing the slits the pure tone disappeared.

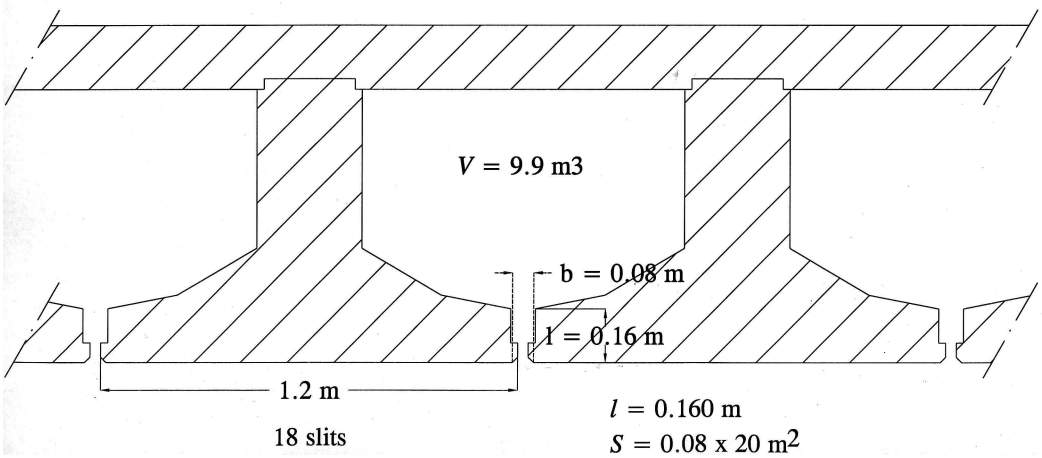

Figure 3: View of the construction.

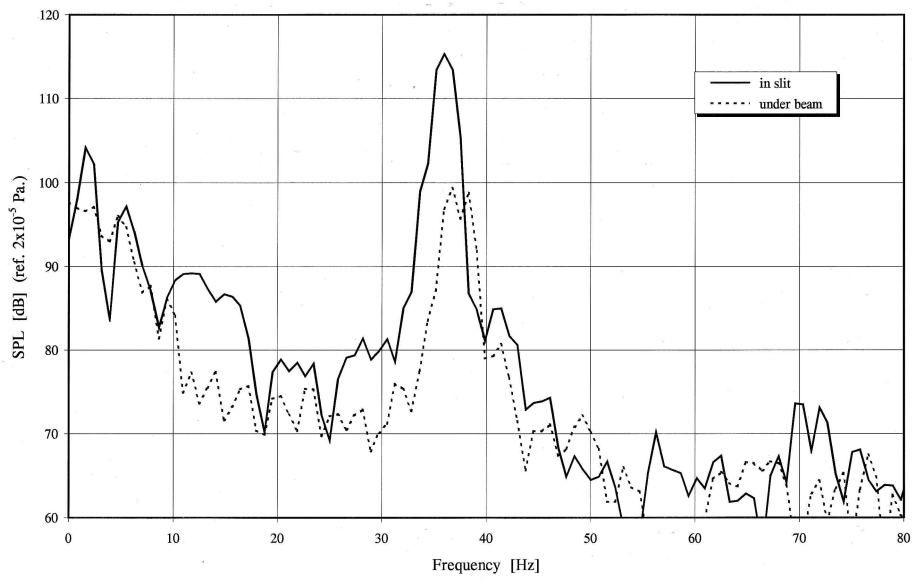

Figure 4: Measured sound pressure level in the slits and under the beam.

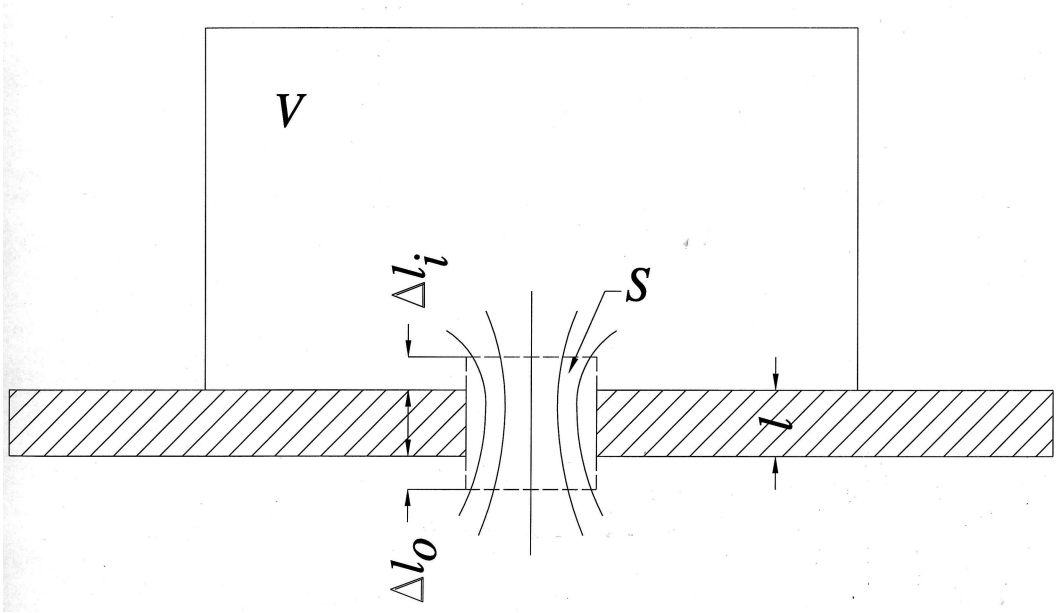

Figure 5: Helmholz resonator.