Detection and Localization with Encapsulated Microphones

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Introduction

Detection and localization of gun noises with microphones have been performed for several decades and efficient acoustic devices are now produced. However, for the detection and localization of snipers it is difficult to conciliate the measurement of signals of high level(Mach wave of the projectile) and low level (muzzle wave at a distance) level in a given background noise environment. To work out this problem we propose to put two microphones in a same macro-sensor. The characteristics of the first microphone are chosen to fit the parameters of the high level shock wave (Mach wave of the projectile), those of the second microphone to fit the parameters of the low level wave (muzzle wave at a distance). The microphones are enclosed in cavities which are designed to have frequency characteristics corresponding to the main frequency domain of the two signals. This macro-sensor allows, while having a low sampling rate, to assess the physical characteristics of the two waves (peak pressure, wave duration). Furthermore, the microphones that are encapsulated in a cavity with very little openings are protected from external agents. A prototype has been made in order to validate the principle. Experimental results are compared to those obtained with classical microphones.

Signature of a small weapon

Gun noises are characterized by two kind of waves. The first one is associated with the supersonic projectile flight and is called the Mach wave (or N wave). The second wave is an expanding blast wave generated at the gun muzzle (muzzle wave).

Mach wave

The Mach wave is a shock wave generated by the moving source (projectile) and exists as an expanding conical wavefront with the projectile at the vertex. This a N shaped wave (see figure 1) and it can be regarded as the result of a linear distribution of acoustic monopoles. It is seen that, with the usual supersonic projectile velocities, the Mach wave is confined to approximately a 130° angle to the front of the weapon. The angle of the cone increase to 160° with projectile Mach number of 6. At Mach 1.5, the angle cone decreases to about 100°, and at Mach 1 it vanishes altogether.

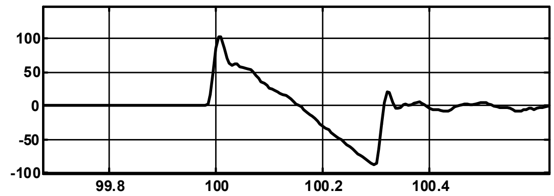

Figure 1: Example of a Mach wave (N wave) in the vicinity of a small projectile trajectory.

Muzzle wave

In the far field, a small arm weapons muzzle wave can often be treated as a simple acoustical monopole source [1]; that is, its sound diverges as a symmetrical sphere. It is seen that the cumulative sound signal impulse is directly proportional to the volumetric gas flow rate at the source. The positive and the negative sound pulses represent, respectively, an increase and a decrease in gas flow rate. Further, since a given increase in gas flow must eventually be followed by an equal decrease in gas flow, it follows that a transient signal must necessarily consist of both a positive and a negative portion. Each, however, may be variously distributed throughout time. For the blast wave, in each case the sound pressure decreases exponentially with time. The rate of decrease depends on the flow parameters of the source. An example of muzzle wave due to a small arm weapon is showed in figure 2.

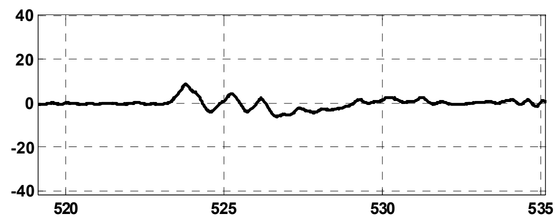

Figure 2: Example of a muzzle wave due to a small arm weapon at large distance.

Use of encapsulated microphone

Difficulties encountered with measurement

Because these two waves have different origins, they present different time and frequency characteristics which are used for detection and localization systems. This is important to obtain good information about the two signals simultaneously at the same position.

The amplitude of the Mach wave is often greater than that of the muzzle wave. This difficulty leads to a compromise for the choice of the suitable microphones.

A second difficulty is the different frequency range of the two waves as seen on figure 3. The frequency range of the muzzle wave is often lower than that of the Mach wave.

A third difficulty is the very short duration of the Mach wave which needs a high sample rate.

The last difficulty is the need of "in situ" measurements in "all weather conditions" which implies that the microphones must be protected.

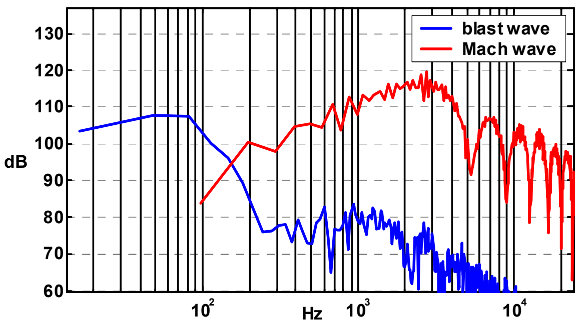

Figure 3: General spectral components of (a) Mach wave and (b) muzzle wave.

Solutions: encapsulated microphones in cavities

To solve the problem of the difference in amplitude, we made a macro-sensor with two microphones. Each of them is encapsulated in a resonant cavity communicating with holes with the outside (see figure 4). One cavity has a frequency range close to the spectrum of the muzzle wave (low frequency) and the other close to Mach wave spectrum (high frequency). This solution enables to increase the dynamics of the muzzle wave without saturation from Mach wave.

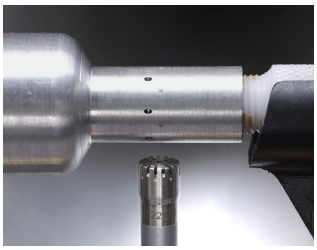

Figure 4: Two cavities system. A ¼'' microphone is put in front of the holes. On the right we can see the support of the microphone encapsulated in the high frequency cavity (Mach wave) and on the left the more important volume of the cavity dedicated to low frequencies (muzzle wave).

The third difficulty evoked before (i.e.: short duration of the Mach wave) is also overcome even with a relatively low sample rate. As the physical characteristics of the cavity are well known they allow a good reconstruction of the time signal (see figure 5) in the cavity.

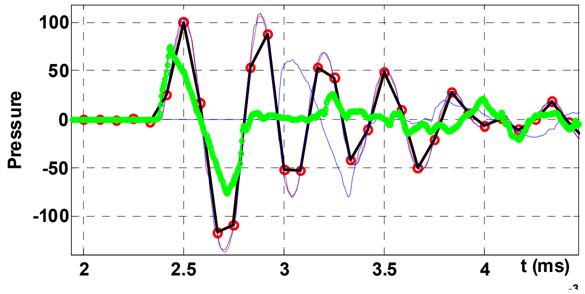

Figure 5: N wave measured with an external microphone up to 100 kHz (green solid line) and measured with the cavity microphone (line with red circle, sampling rate 12 kHz).

Thus it is possible to get information on the real shape (real amplitude) of the N wave (see figure 5) even with low sampling rate.

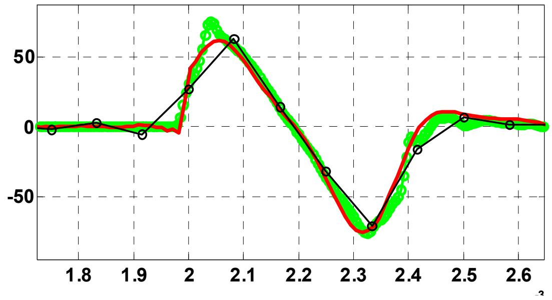

Figure 6: N wave measured with the cavity microphone and reconstructed (red solid line) and measured with an external microphone (line with green circles, sampling rate 200 kHz, line with black circles sampling rate 12 kHz).

The last advantage of this macro sensor is that the microphones are protected from external agents (like rain) without lost of information.

The double cavity presented in this paper seems to be the future solution for improvement of sniper detection system.

References

[1] Morse, P.M., Vibration and Sound. New York: McGraw-Hill Book Co.,Inc. (1948),p312.