Hydra: a noise radar to automatically track down excessively noisy vehicles in real traffic conditions

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ABSTRACT

The developments made by Bruitparif since 2016 around sound source localization technologies applicable to the field of environmental noise resulted in the launch on the market of a patented combined acoustic and imaging sensor called "Medusa". An article of law was voted in France at the end of 2019 in order to enable the experimentation of noise radars in order to punish drivers causing significant noise nuisances by their behavior. The evaluation process includes track trials, roadsite tests and a final phase with fines. We will describe this national experimentation and the context in which it takes place. We will then detail the prototype called "Hydra" that we have developed for this purpose, and will present case results showing how it solves the major difficulties of the legal measurement of the pass-by noise of vehicles in real traffic conditions.

1. INTRODUCTION AND CONTEXT

Road traffic is a major source of noise pollution in the Ile-de-France region, with 30% of the region's residents quoting it as the primary cause of noise annoyance when they are at home. Among vehicles, motorised two-wheelers are clearly the ones that generate the most complaints. Thus, 27% of Ile-de-France residents consider the noise emitted by motorised two-wheelers to be the transport-related noise that annoys them the most, ahead of the noise from private vehicles (cited by 18% of Ile-de-France residents) and the use of horns (17%), according to the results of the "Well-being and noise pollution in Ile-de-France" study carried out by Crédoc for Bruitparif in 2021, to be published shortly [1]. 35% quote the noise of scooters, mopeds and motorbikes as one of the three sources of noise pollution that have annoyed them the most at home over the last twelve months.

The focus on noise complaints about motorised two-wheeled vehicles is largely due to the fact that the noise standards in application for the approval of these vehicles (specified in European Regulation No. 41) are often exceeded in actual traffic conditions, due to offending behaviour and illegal transformation of the vehicles. According to modelling carried out by Bruitparif, a scooter with an unapproved exhaust system would wake up more than 11,000 people if it were circulating at night in Paris between the Place de la Bastille and the Place Charles-de-Gaulle Étoile [2]. The same applies to motorbikes whose drivers have removed the silent baffle and/or who push their machines to very high regimes, as well as to certain sports cars or cars specifically "customized" by their owners to make noise on purpose.

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These excessive noise peaks produced by certain vehicles often represent the majority of the ambient noise measured during the day, as shown by the results of measurements carried out by Bruitparif along the departmental road 91 in the Vallée de Chevreuse (Yvelines). This winding road is very popular with motorcyclists, which leads to recurrent complaints from its residents. Bruitparif carried out a detailed analysis of the data collected by the "Medusa" sensors deployed at three locations on this road (at Saint-Lambert-des-Bois, Saint-Forget and Senlisse) during the spring 2021 (period from 15 April to 31 May). This analysis made it possible to determine the daily number of vehicles, the vast majority of which are motorised two-wheelers, which generate more than 80 dB(A) at a reference distance of 7.5 m from the center line of the road. Theoretically, this level should not be exceeded if the homologation limit values (results of the tests carried out in motion) were respected in real traffic conditions [3]. The results are clear: while noise events of more than 80 dB(A) represent on average only between 4 and 15% of the vehicles detected, depending on the site, they account for 37% to 54% of the overall noise measured, and this contribution can even reach 75% on certain sunny weekend days in the sectors most used by motorcyclists (at Saint-Forget and Senlisse). On such days (Saturday 8 May 2021, Sunday 30 May 2021, for example), some 700 noise peaks exceeding 80 dB(A), 10% of which even exceed 90 dB(A), were recorded by the sensor deployed in Saint-Forget. For the residents of this sector, this represents an average of one noise disturbance per minute between 8am and 9pm.

There is no doubt that combating abnormally noisy driver behaviour could therefore have a significant impact on overall road noise and the tranquility of local residents.

Sanctions for noise pollution against drivers who use their engines at excessive speeds or who have tampered with their vehicles are a constant demand from residents living near roads, who are victims of noise pollution that can have a long-term impact on their health (stress, fatigue, concentration difficulties, sleep disturbance, cardiovascular diseases, anxiety and depression, etc.) [4]. A majority of them (59% of the French [5], 60% of the inhabitants of Ile-de-France [1]) said they are in favour of installing noise radars and 18% of the inhabitants of Ile-de-France even consider this action to be a priority in the fight against road noise [1].

Today in France, the police has the possibility of fining drivers for excessive noise. This can be done by a simple ear test or, more generally, by measuring the noise of the vehicle intercepted, in order to avoid any subsequent disputes. This measurement is then carried out when the vehicle is stationary, in neutral and at a medium to high engine speed as indicated in box U.2 of the vehicle registration certificate. The noise level is measured by the police using a sound level meter (SLM) positioned in the immediate vicinity of the exhaust system. The driver is then fined if the level recorded during such a check exceeds the value entered in box U.1 of the registration certificate by more than 5 dB(A), (value determined at the time of the vehicle's approval by a test carried out when stationary). This value varies according to the type of vehicle and can easily exceed 80 dB(A) or even 100 dB(A) for certain models of large motorbikes.

However, this possibility of sanction is rarely used in practice due to a lack of human and material resources (few brigades have approved SLM to carry out such checks).

In addition, certain excessively noisy driving behaviours in real traffic conditions (over-speeding, driving with music blasting, etc.) cannot be sanctioned by means of the noise level check carried out at a stationary location.

In order to address these issues and to be able to increase the number of checks, the French government introduced new provisions in the Loi d'Orientation des Mobilités (LOM – Mobility orientation law) at the end of 2019 to allow the automated control of vehicle noise emissions levels to be tested in real traffic conditions.

2. THE FRENCH EXPERIMENTATION

The LOM, officially promulgated on 24 December 2019, includes a number of provisions to combat noise pollution. In particular, it introduced, in its Article 92, the experimentation of automatic control of vehicle noise emission levels by radars.

In 2020 and 2021, the Ministry of Ecological Transition carried out a phase to identify the technical solutions that could be adopted for the development of noise radars. At the end of this period, which included two series of tests carried out on the track of the Gustave Eiffel University in Bouguenais (44), in autumn 2020 and spring 2021, three prototypes of radars developed by by three different French manufacturers including Bruitparif were selected to take part in the experimentation.

This experimentation officially started on 4 January 2022 following the publication in the Journal Officiel of decree n°2022-1. It runs for two years and is implemented in seven pilot communities:

- In urban areas, the cities of Nice, Toulouse and Paris.
- In peri-urban areas, the cities of Bron, Villeneuve-le-Roi and Rueil-Malmaison.
- In rural areas, the Community of Municipalities of the Haute Vallée de Chevreuse.

The experiment consists of two phases.

The first phase, which began in January 2022, is a "blank" test phase with no offences recorded or fines issued. The data collected by the noise radar prototypes developed by the three manufacturers and installed in the different pilot sites (see figure 1) are transmitted to secure servers for the purpose of studying and analysing the performance of the systems in real conditions.

Figure 1: The noise radar prototype developed by Bruitparif installed in three of the pilot sites in Paris (on the left), in Villeneuve-le-Roi (in the center) and in Vallée de Chevreuse (on the right)

At the end of this phase, a ministerial order will complete the decree 2022-1, by setting the control threshold(s) that must meet the conditions for placing the various categories of vehicles on the market, while taking into account the results of the experiment.

During the second half of 2022, manufacturers will have to take the necessary steps with the Laboratoire National d'Essais (LNE) to have their model of noise radar approved from the point of view of legal metrology, which will require them to carry out a certain number of additional tests and trials on a track or in laboratory conditions.

The second phase of the experiment will then begin in April 2023, and will involve the devices that have met the requirements of legal metrology: this time, the radar models will be used for recording offences. The files containing the elements constituting an offence prepared by the noise radars will then be sent by remote transmission to the centers authorised to record offences within the pilot territories participating in the experiment. The offence will then be punished by a 4th class fine, as provided for in Article R318-3 of the Road Code. This corresponds to a fixed fine of €135, reduced to €90 if paid within 15 days.

At the end of the experiment, an evaluation and assessment will be made by the Ministry of Ecological Transition. If they prove conclusive on the regulatory and technical aspects, the legislation will then be amended, paving the way for the larger-scale deployment of noise radars in France.

3. THE "HYDRA" NOISE RADAR PROTOTYPE

Designed by Bruitparif, the "Hydra" radar prototype combines two acoustic devices using the patented "Medusa" technology and all the technical elements to detect road noise infringements (see figure 2).

Each "Medusa" acoustic device consists of four microphones able to calculate noise levels and angles of origin 25 times per second. Each sensor is enclosed in an acoustically transparent metal cage to protect it from potential vandalism.

The "Hydra" also incorporates a wide-angle camera (180°) to capture the entire scene at the time of the potential infringement, as well as two cameras dedicated to automated number plate reading (ANPR) from the front and rear of the vehicle or in each direction of travel. The prototype also includes additional devices dedicated to various environmental measurements: pressure, humidity, temperature, wind speed, rain.

All the components of the "Hydra" are installed in a metal structure which also contains the central processing unit and the secure and encrypted remote data transmission. All processing is carried out within the device and does not require any external system.

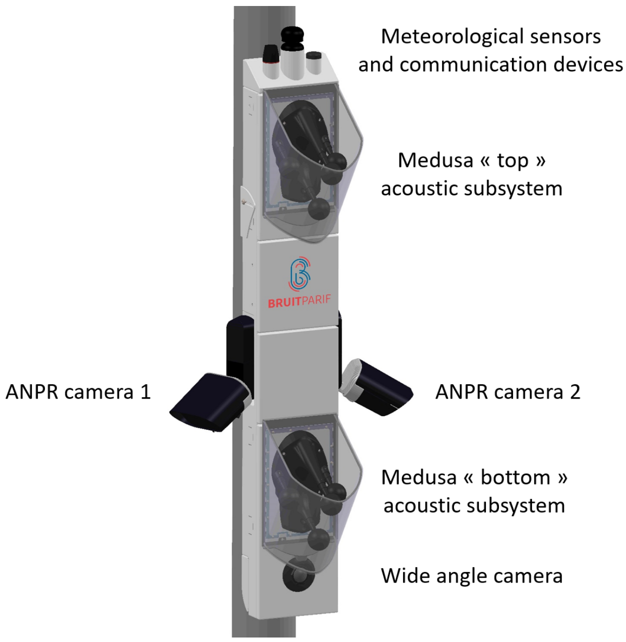

Figure 2: "Hydra" noise radar prototype designed by Bruitparif

3.1 Real-time computer processing

The first processing carried out consists of cross-referencing the information from the two acoustic devices to determine the noise level generated by the dominant noise source every 40 ms, as well as the distance at which it is located. This allows the noise emitted by the vehicle to be determined as if it were measured at a standard reference distance (7.6 m). For the determination to be valid, both acoustic devices must focus simultaneously on the same source (see Figure 3), for a sufficient number of measurement points along the path taken by the vehicle with regard to the representativeness criteria integrated in the processing chain.

When this noise level "readjusted" to 7.6 meters exceeds the set trigger threshold, if the environmental conditions are met (no or low wind, dry road), a potential infringement file is opened within the "Hydra". The automated processing then recovers, from the wide-angle camera, a few seconds of video before and after the moment considered most significant for the infringement. It automatically analyses all the images in the sequence to determine the position of all the vehicles in the scene at each moment in order to reconstruct their trajectory.

The trajectories found from the image analysis are then reconciled with the dominant acoustic trajectory to determine which vehicle is causing the noise excess. During this reconciliation, potential confusion situations are eliminated. Thus, the device does not take into account situations where several vehicles are at a given moment in the direction of the acoustic source detected as dominant, nor does it take into account situations where there are no vehicles in the direction in question, etc.

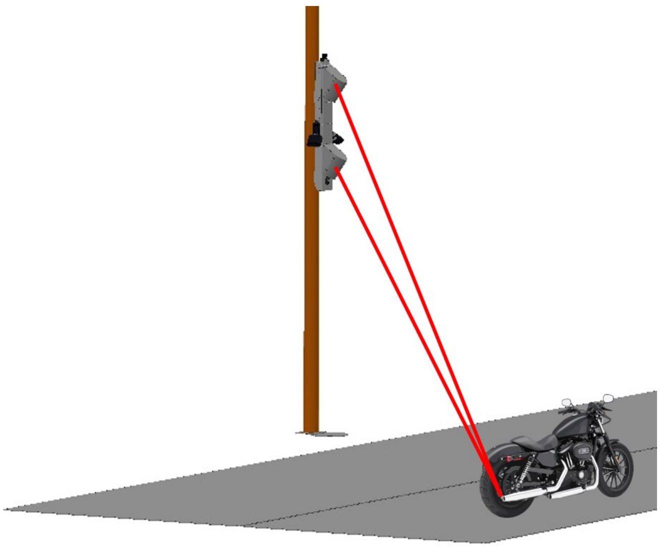

Figure 3: Focusing principle operated by Hydra with its two acoustic modules

3.2 Characterising the infringement

If there are enough valid measurement points left in the overtaking with a well identified vehicle, the infringement can be considered as constituted. A context image (see Figure 4) is therefore extracted and added to the file. This image shows a frame around the vehicle responsible for the excess noise as well as the area of origin of the dominant noise (in the form of a point surrounded by a circle), which materializes the fact that it is indeed this vehicle that is the source of the excessive noise emission.

The processing then interrogates the ANPR cameras to retrieve images of the vehicle concerned with its readable number plate. The number plate is also read automatically. All of these elements are added to the potential infringement file, which can then be transmitted in encrypted form to secured servers as part of the first phase of the experiment, and then eventually to the centers that will be authorised to control this type of noise infringement.

Figure 4: Example of a context image taken by Hydra

4. TWO MAIN TECHNOLOGICAL CHALLENGES

4.1 The necessity to determine pass-by noise at a standard reference distance

The first challenge is related to the ability of the device to correctly assess the distance to the source of the excessive noise emission (exhaust, engine, tyre-road contact, horn...). This information is crucial because it allows the compensation of the noise attenuation effect according to the distance and thus, the adjustment of the noise level generated by the vehicle at each moment at a standard reference distance (7.6 m), enabling to compare the value thus obtained with the threshold that will be used to establish the infringements. In this way, a basis for finding infringements is available that does not depend on the distance the vehicle passes, which makes it possible to treat all the vehicles present equally, even if they are travelling on different lanes. The cross-referencing of information on the source of the noise delivered by the two "Medusa" acoustic devices integrated into "Hydra" makes it possible to meet this first challenge.

4.2 The necessity to isolate vehicule noise

The second challenge concerns the precise evaluation of the noise generated by the vehicle that is most likely to be in noise violation. It is a question of being able to measure the noise emission of the vehicle in question, without taking into account the other noise sources present (other vehicles present, parasitic noise sources, etc.). The simple measurement of the ambient noise, which includes all the noise sources, as carried out by a conventional SLM, cannot therefore be used to evaluate the noise linked to the passage of the vehicle in question, as illustrated in Figure 5 below. The black line represents the noise level that would be measured by a SLM when five vehicles pass in three lanes of traffic in a period of a few seconds. By cumulating the noise emitted by the different vehicles at each moment, such a measurement would be unable to determine the value of the noise level emitted by each vehicle in isolation as it passes and would systematically overestimate it. The expert data processing algorithm developed by Bruitparif, which takes advantage of the presence of four microphones within each acoustic device "Medusa", makes it possible to meet this first challenge through two essential functionalities:

- The first is the ability to determine, at each moment, which vehicle is the noisiest via the analysis of the angles of origin of the dominant noise. In the example given in figure 5, the analysis of the angles carried out by "Hydra" would enable the system to focus successively on the green scooter (for T between 1.5 and 2.5 s), then on the light blue motorbike (for T between 2.5 and 3 s) and finally on the dark blue motorbike (for T between 3 and 4 s). However, this feature would still be insufficient if the overall noise level measured at these times were used, which would overestimate the noise of the three vehicles passing by, as it would be interfered with by the noise of other vehicles.
- The second essential functionality is the ability to combine the signals from the different microphones to correctly evaluate the level of each of the vehicles that, over a given period of time, is the most sonically prominent in the scene. The noise level thus obtained after this combined processing of the signals (in red in the figure) appears to be very close to the noise emitted by each individual vehicle, which is the aim of automated control.

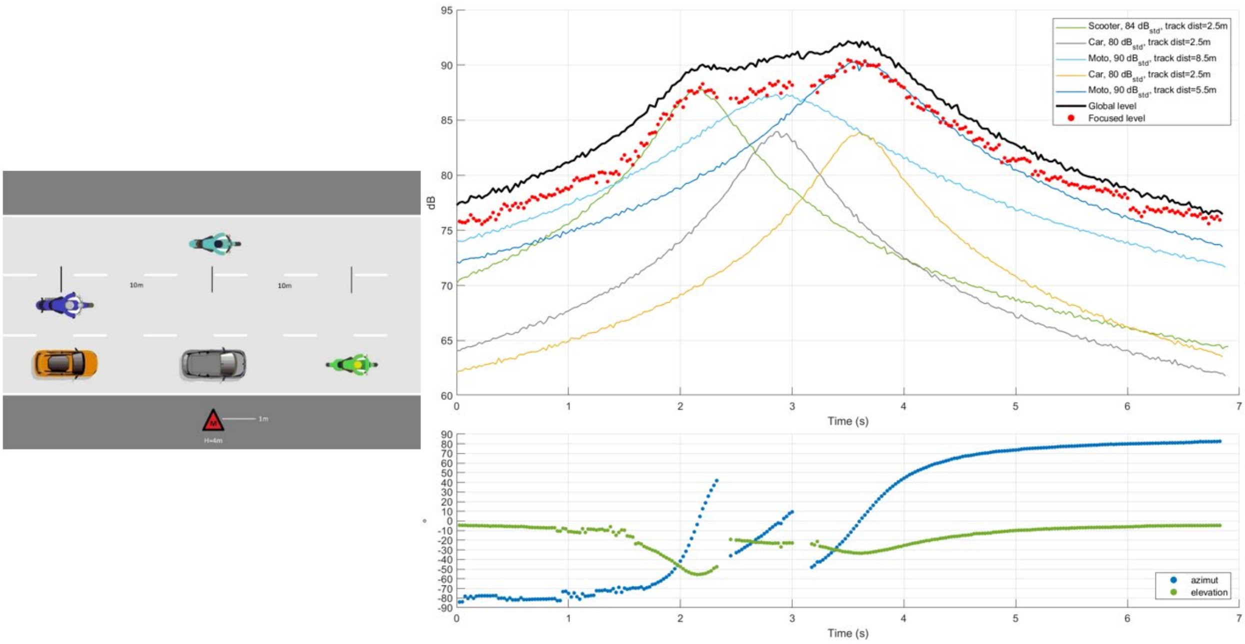

Figure 5: Example of complex but realistic scenario with five vehicles passing in front of the “Hydra” noise radar. The curves in colours show the pass-by noise emitted by each vehicle as if it were taken alone, the black curve shows the total noise like a SLM will measure it, and the red dots show the noise levels calculated by “Hydra” for the three noisiest vehicles detected thanks to azimut and elevation angles.

A noise radar must also meet a number of other requirements, such as being able to correctly identify the number plate of potentially infringing vehicles, being able to withstand the weather and being sufficiently robust to resist any attempts at vandalism.

5. CONCLUSIONS

The experimentation underway in France with devices designed to automatically control vehicle noise emissions in real traffic conditions is a response both to societal demand, with many local residents complaining of noise peaks generated by excessively noisy vehicles, and to a need to simplify control procedures and save time and resources for the police.

The emergence of this type of device along the roads, in addition to the capacity to reinforce controls and sanctions against drivers disrespectful of public tranquility, will undoubtedly also make it possible to develop the awareness of the general public and local actors of the importance of the damage caused by noise on the health of the neighbouring populations. Complementary devices of a purely informative nature, such as educational noise radar (see figure 6), are beginning to be deployed in several European countries (Germany, Switzerland and France in particular) and should certainly be multiplied in the future, as is already the case for speeding.

Figure 6: Educational noise radar designed by Bruitparif and installed in Juvisy-sur-Orge in France

From a technological point of view, the developments made in the design of noise radars for enforcement purposes are also making it possible to advance the techniques for analyzing ambient noise and to improve understanding of the respective contributions of the various types of vehicles, traffic conditions and driving behaviours.

6. REFERENCES

[1] CRÉDOC, BRUITPARIF (2021) – à paraître en juin 2022. Qualité de vie et nuisances sonores : opinion et comportements des Franciliens.
[2] https://www.bruitparif.fr/video-sur-le-bruit-des-deux-roues-motorises/
[3] BRUITPARIF (Juin 2021). Analyse des données de mesure du bruit le long de la RD91 – Période allant du 15 avril au 31 mai 2021.
[4] WHO. (2018). Environmental Noise Guidelines for the European Regions
[5] IFOP, JNA (2022) – Enquête Bruit et santé - les décibels de la discorde.