A method for unattended railway pass-by noise measurements

Anders Genell and Erik Nyberg
Swedish National Road and Transport Research Institute (VTI), Regnbågsgatan 1, SE-41755 Gothenburg, anders.genell@vti.se

Measuring pass-by railway noise for use as source data for community noise modeling can sometime be challenging and costly due to the man-hours required to capture a statistically valid number of passages for each train configuration. One way to reduce cost is to employ autonomous measurement equipment that does not require operators' attendance while measuring. Several "noise monitoring" solutions exist on the market, but most of them lack the ability to collect all data required to obtain rolling stock noise source data for community noise modelling. In the current project an unattended measurement setup has been developed with the aim to manage measurements suitable for obtaining rolling stock noise source data. Microphone positions correspond to those in EN 17936:2024 "Railway applications. Acoustics. Measurement of source terms for environmental noise calculations". To obtain data on type of rolling stock, speed and direction etc. the project has been given access to the network of RFID-readers deployed by the Swedish Transport Administration to ca 1500 places along the Swedish railroad network. The RFID readers detect RFID data from each passing rail vehicle containing a unique identification number which can be used to obtain vehicle data such as axle/boggie construction, braking system, dimensions et cetera. The RFID readers are combined with axle detectors which allows for precise determination of speed as well as of direction. A prototype has been placed at a suitable measurement site along one of Sweden's most heavily utilized tracks, adjacent to a RFID reader and axle detectors. Audio is recorded from two microphones at different heights, rail vertical vibration is recorded from the nearest rail and data from the RFID-system has been obtained through an API provided by the Swedish Transport Administration. Synchronization between RFID and audio recordings is based on time stamps in the respective data files. Some issues have been experienced with the sensors for sound and vibration and with the shielding from external electronic noise affecting the measurement signal on one or several recording channels. Preliminary results from measurements indicate that the method is promising to be successful in providing rail vehicle noise source data.

1 Introduction

In Sweden measurements were performed 2018 – 2022 [1-5] in order to determine railway source data for CNOSSOS-EU [6] as well as for Nord2000 [7]. These measurements were performed manually by one or two technicians at several different measurement sites spread out around Sweden. During the measurements it became clear that in addition to manual measurements for noise source determination, there was use for long term measurements that could either be used to analyse noise emission trend over time, or to capture noise emission from a certain type of train that passes by infrequently and irregularly. Performing such measurements manually is impractical due to inefficiency and related personnel cost so some form of automation would be useful. Through dialog with the Swedish Transport Administration and a limited literature review it became clear that in Sweden an autonomous measurement station would ideally be combined with the vast network of existing detectors in the Swedish railway system.

1.1 Similar work

The Austrian Federal Railway (Österreichische Bundesbahnen, ÖBB) have employed stationary unattended measurement stations for railway noise in order to determine the effect in overall trailway noise emission from implementing the Technical Specifications for Interoperability (TSI) presented in EU regulation 2019/774 of 16 May 2019 [8], where railway segments of at least 20 km with an average of more than 12 nighttime freight trains are designated to become "Quieter Routes" by reducing nighttime railway noise exposure. The main reduction is achieved by replacing the cast iron brake blocks that cause a rough wheel rolling surface which is responsible for high levels of rolling noise, with composite brake blocks that do not cause significant wear on the wheels. The measurements in Austria were performed to monitor the efficacy of the reduction in noise emissions [9] using automated photo-based identification of rail vehicle types, and as a side effect Dr. Günter Dinhobl at ÖBB who was responsible for the measurements saw the need for a standardized method for unattended measurement of railway noise emission [10].

1.2 Applicable standards

Traditional manual measurements of pass-by railway noise adhere to applicable parts of ISO 3095 [11] regarding microphone positions in relation to the track where the rail vehicles of interest pass by. As a complement to ISO 3095 an additional European standard, EN 17936:2024 [12], has been developed by CEN/TC 256/SC 4/WG 3, led by Dr. Michael Dittrich, with the aim to provide a method for determining railway noise source terms for noise prediction calculation methods such as CNOSSOS-EU. The method includes instructions on how to determine the combined effective roughness of wheel and rail through vibration acceleration measurement on the rail in order to separate noise radiated from the rail and noise radiated from the wheel. Two separate standards handle properties of the rail infrastructure; EN 15461 [13] regarding measurements of Track Decay Rate and EN 15610:2025 [14] regarding rail and wheel roughness. Dr. Günter Dinhobl at ÖBB has been realizing the idea of a measurement standard for unattended measurements through a subgroup within CEN/TC 256/SC 4/WG 3 by leading the work on a Technical Specification called "Railway applications — Acoustics — Unattended and automated measurements of noise emitted by railbound vehicles in operation". It is not yet published, but a draft available to the author reveals what is required for a measurement setup:

- IEC 61260-1 class 1
- Microphone positioned at 7.5 m from center of track and 1.2 m above top of rail.
- Time acquisition
- Axle detection
- Speed detection
- Driving direction detection
- Track occupation detection if double or multi-track layout at measurement site
- Recording meteorological / environmental conditions
- Rail roughness assessed according to EN 15610 at least once a year.
- Track decay rate according to EN 15461

In Sweden, all non-acoustic properties should be able to be obtained from the existing RFID-system.

1.3 Railway RFID system

There are more than 1400 Radio Frequency Identification (RFID) sensors in Sweden, maintained by the Swedish Transport Administration. The sensors are positioned along the Swedish railway network, registering RFID-data for each RFID-tagged rail vehicle passing the sensor. The railway RFID tags and sensors are designed according to a European railway industry standard, and many rail vehicles in Europe are equipped with an RFID tag. The tags basically only transmit a single vehicle identification number, and data about each vehicle of interest can be obtained from a vehicle database. Currently vehicle data is registered nationally, although freight cars are frequently used across all European countries sharing the 1435 mm standard-gauge railway. Thus, rail car passages may be registered but will be marked as "unknown" if no valid RFID tag was registered and will show vehicle identification number but no detailed data if the vehicle is not included in the national Swedish rail vehicle database.

In Sweden the RFID detectors are always combined with a pair of axle counters and a wheel-bearing temperature sensor for identification of brake drag or worn-out bearings. In a few places there are also rail load detectors that can identify flat spots on passing wheels.

2 Method

2.1 RFID logger

Data from the RFID network is mainly shared to train operators as a service from the Transport Administration via a data API. The data variables names and contents are in part decided by the RFID industry standard. The system is setup so that an operator is issued a certificate that is used to authenticate the computer that is requesting data. As the system expects a fixed IP address from which the request is sent, it is not suitable for implementation in a temporary measurement setup such as the one described in this paper. Thus, the RFID data is logged separately, and timestamps of the measurements are then matched to RFID timestamps to synchronize measurements with the RFID data. In addition to RFID-data, the project also has access to a subset of a database containing all Swedish-registered rail vehicles in operation, providing information about vehicle brake system (such as cast iron or composite), wheel diameter, vehicle class etc.

2.2 Acoustical data logger

In accordance with the CEN draft technical specification, a weatherproof microphone was positioned at 7.5 m from track centre and 1.2 m above top of rail. Additionally, a microphone was positioned at the same distance but at 3.5 m height as required by ISO 3095 as well as by EN 17936. The CEN draft technical specification states that the scope of the system is long term trends of noise emissions, but by adding the extra microphone the suitability of the measurement setup for source term measurements can also be investigated.

There is a double track passing by the measurement site and in order to capture noise contribution from both tracks, one accelerometer was placed on the closes rail of each track, although the distance between the farther track and the microphones does not fulfil the requirements in ISO 3095 or EN 17936.

The two microphones, MicrotechGefell MMS 212, are IP67-rated, rugged, IEPE-driven ½-inch measurement microphones. The accelerometers are two Dytran 3055F3 IEPE accelerometers equipped with Brüel & Kjaer UA-0559 mechanical filters. The sensors are connected to two Measurement Computing Corporation MCC 172 IEPE Measurement DAQ HAT data acquisition units for the Raspberry Pi SoC minicomputer. A Raspberry Pi 3B+ serves as central data logger. A Python program initiates the data acquisition units and starts time signal recording, either continuously or triggered by the accelerometer signal reaching above a custom threshold.

2.3 Peripherals

The Raspberry Pi with the data acquisition units is placed in a weatherproof casing together with a 5G mobile network router, a security camera and a weather station. The camera can be set to automatically capture video if e.g. someone approaches and by manipulating the settings most of the passing trains can trigger the camera, providing an opportunity for visually inspect the surroundings if there is something that seems be amiss with the recordings.

The 5G router both allows for accessing the camera cloud storage for uploading images or video as well as for cloud storge of weather data from the Ecowitt WH2650-WIFI4DA2 weather station. The router is also set up to receive incoming connections, allowing for remote control of the system. The weather station, camera and main casing are all mounted on a aluminium pole placed in a stand supported by a heavy base.

2.4 Measurement site

The measurement site is positioned in Rörvik in the southeast of Sweden, along the southern main route which is oen of the more heavily used rail tracks in Sweden. There are wheel temperature detectors, axle counters as well as a small shed containing all the electronic equipment related to the wheel temperature sensor, axle counter or RFID receiver. The shed is also equipped with outdoor power outlets that powers the noise and vibration measurement station.

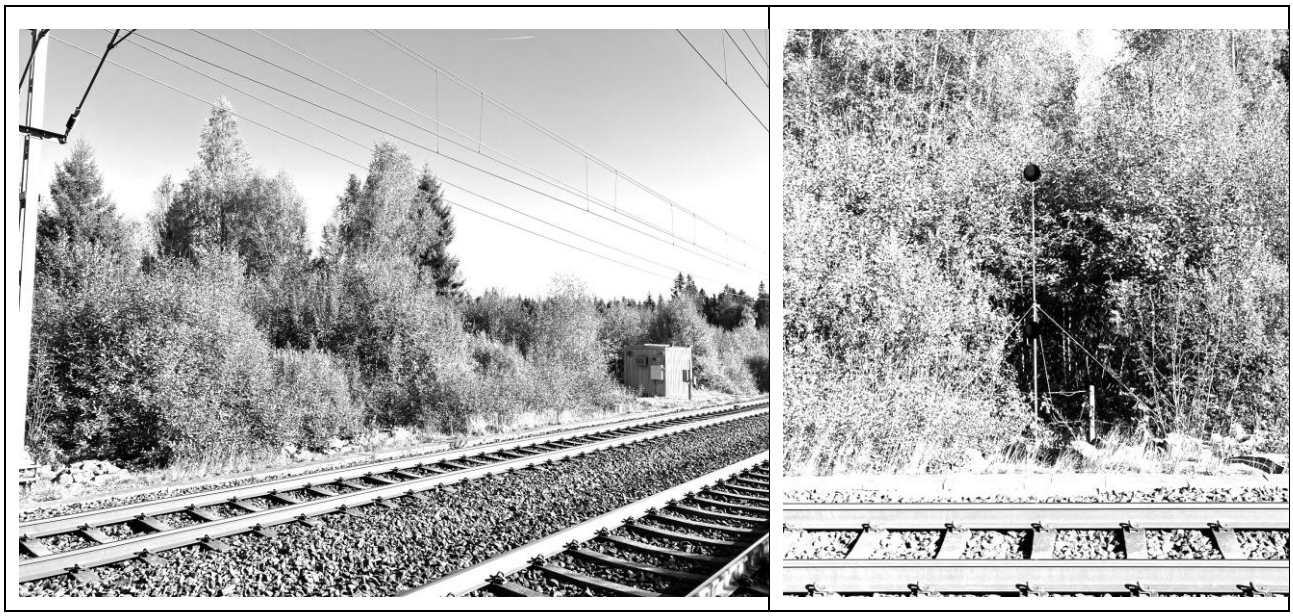

Figure 1. The measurement site along the southern main line with the electronics shed close to the southbound track (left) and with the two microphones mounted inside large wind shields on a bespoke microphone pole (left) closest to the southbound track.

Before starting measurements, the rail head roughness was measured on a section of the track closest to the microphone position. This was done in accordance with EN 15610 using a Corrugation Assessment Trolley (CAT), giving one value per mm along the track and a vertical resolution of 10 nm. Figure 2 shows results from the CAT measurements at the site, with the ISO 3095 smooth rail limit curve as reference. The rails of both southbound and northbound tracks is a relatively similar to the ISO3095 reference curve, validating the site as suitable for measurements.

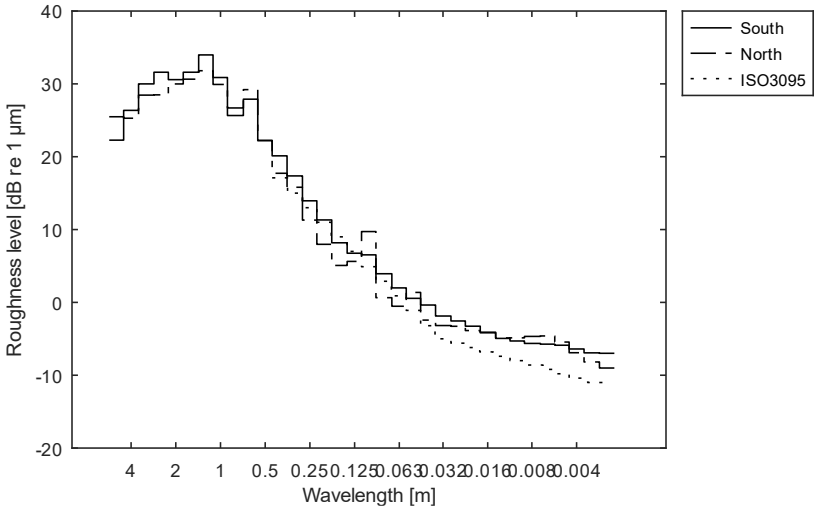

Figure 2. One-third octave band wavelength levels. The

3 Results

3.1 Noise and vibration measurement

During the period 2026-01-01 to 2026-01-22 a grand total of 1944 individual train passages with a total of 3544 vehicles with a valid RFID tag were recorded at the measurement site. Figure 3 shows an example of recorded sound and vibration levels for a one freight train passage. Only data for the accelerometer on the track in use is included in the graph. The vertical lines in the graph represent points in time for the first and the last axles passing, obtained from the RFID-data. As the RFID data is based on timings around either the axle counters, the wheel temperature detectors or the RFID sensor, and since the microphones were placed ca 45 north of the wheel temperature detector, matching the RFID data with measurements is an ongoing process that will hopefully result in consistent automatic datamining.

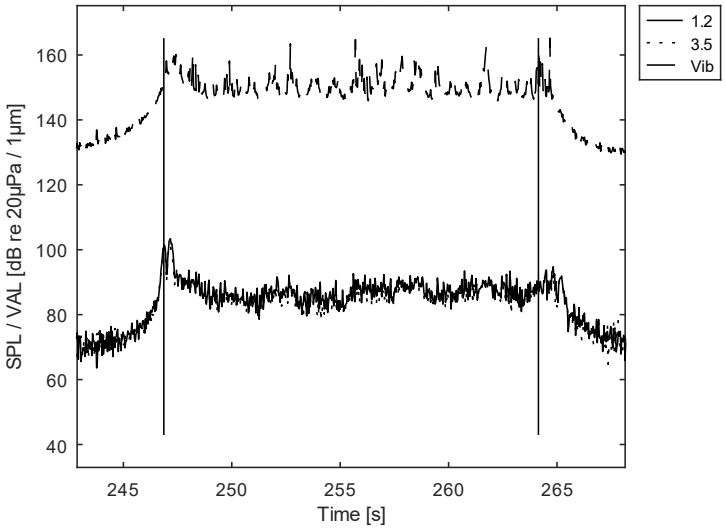

Figure 3: Sound pressure level (SPL) recorded at microphone heights 1.2 m and 3.5 m above rail head surface, and rail vertical vibration acceleration level (VAL) for accelerometer placed under the foot of the rail. Vertical lines represent first and last axle passage from the RFID and axle detector data.

The corresponding RFID and axle counter data is presented in Table 1. As can be seen, the recorded train set comprised 18 wagons pulled by an Rd class locomotive. Three of the wagons seem to lack RFID-tag and thus only axles passing were registered. Of the remaining 14 rail cars only 5 were included in the Swedish railway vehicle database. All in all, 72 axles passed the measurement station at a speed of 90 km/h. The “Train number” has been omitted as it may be regarded as sensitive data.

3.2 Number of vehicles and number of axles

The data obtained from the RFID and axle detector systems is delivered in the form of one row per passing axle. Each passing axle is connected either to a valid RFID tag vehicle number, or if not available, to a string describing the vehicle type as “Unknown X-axle vehicle (n)”, where X is the identified number of axles belonging to the same vehicle and n is the ordinal number of the individual vehicle of the same type. In the data from the period of interest 40 2-axle vehicles without valid RFID tags were identified and correspondingly 24 4-axle vehicles and 22 6-axle vehicles were similarly identified. As no system is perfect there were also occasions where a large number of axles were identified as belonging to one vehicle, resulting in vehicles with 18, 52, 56, 92, 106, 110 and 114 axles respectively. This is of course not correct, and it will also affect the ability to correctly calculate the number of passing vehicles. In order to estimate the number of vehicles, the ratio of correctly identified 2, 4 och 6-axle vehicles were calculated and the total number of passing axles were then divided by the weighted average of vehicle type, resulting in 23750 vehicles without valid RFID tag. 12 different electric locomotive types, 2 different diesel locomotive types, 32 different freight wagon types, 3 different passenger electric multiple unit types, 2 different passenger diesel multiple unit types and one special measurement wagon type were registered during the period of interest.

Table 1: Vehicle data obtained from the database via the RFID vehicle identification number. The first two rows contain data for the whole trainset, and the following rows contain data on individual vehicles.

Number of vehicles	Speed [km/h]	Number of axles	Length [m]	Train number	Direction
19	90	72	432	XXXXX	S*
Vehicle no in train set	**Vehicle identification number**	**Axles**	**Type**	**Class**	**Brakes**
1	917400011313	4	Locomotive	Rd	-
2	247442205628	4	Freight car	-	LL-block
3	247442181340	4	Freight car	-	LL-block
4	238029411671	2	-	-	-
5	Unknown 2-axle vehicle (1)	2	-	-	-
6	338027437197	4	-	-	-
7	315627707138	4	-	-	-
8	338027431364	4	-	-	-
9	338027433634	4	-	-	-
10	338027433311	4	-	-	-
11	Unknown 4-axle vehicle (2)	4	-	-	-
12	838027454142	4	-	-	-
13	338527407823	4	-	-	-
14	338027432610	4	-	-	-
15	247442204928	4	Freight car	-	LL-block
16	338527400216	4	-	-	-
17	Unknown 4-axle vehicle (3)	4	-	-	-
18	247442208267	4	Freight car	-	LL-block
19	247442204878	4	Freight car	-	LL-block

* Direction is determined as traveling along the normal direction of travel on a southbound track.

4 Discussion

An unattended measurement station has great potential for obtaining data on long-term trends that are difficult to measure manually without being very costly. The current ongoing project has developed a measurement setup that reliably can perform measurements unattended; however, a number of issues were identified during testing of the different parts of the setup. Initially a set of MEMS microphones were used for audio recording, but at least one seemed to succumb to the poor weather conditions at the site, and both were swapped out for the current more rugged microphones. The accelerometers were mounted using strong mounting magnets, which have been working well, but the accelerometers were found to unscrew from the magnetic mount due to the intense vibrations caused by the passing trains, and since the rail traffic needs to be stopped and the track needs to be blocked off in order to re-attach the accelerometers, getting to accelerometers to stay mounted is essential. Some thread compound was added which drastically improved the reliability. There are still some issues with electrical disturbance which is likely due to lack of proper shielding and grounding. The setup has been upgraded to improve the signal to noise ratio and testing is currently ongoing.

Also, work obtaining the most useful RFID data is currently ongoing. There are different data sets that need to be requested separately through the API and that may contain a few critical variables. Combining a few variables from separate data sets should provide all necessary data to adhere to the method described in the draft of the CEN Technical Specification.

During the spring simultaneous manual measurements will be done at the measurement site in order to determine if the unattended measurement setup can be used for source term measurements in addition to the long term trend measurements the method is intended for.

References

[1] Jerson, T - Mätserie 1 - Grund för indata tågbuller, Mätningar av bulleremission från tågpassager vid fyra platser i Västsverige, *Technical Report*, WSP, Sweden, 2019.

[2] Jerson, T - Mätserie 2 - Grund för indata tågbuller, Mätningar av bulleremission från tågpassager vid 7 olika platser på svenska järnvägar, *Technical Report*, WSP, Sweden, 2020.

[3] Jerson, T - Mätserie 2B – Tillägg Flixtrain persontåg, Mätningar av bulleremission från tågpassager vid Torp, *Technical Report*, ELTON, Sweden, 2022.

[4] Jerson, T - Mätserie 2C – Tillägg snabbtåg X2, Pilotstudie bulleremission från livstidsförlängda X2-tåg vid Torp, *Technical Report*, ELTON, Sweden, 2023.

[5] Jerson, T - Mätserie 2D – Tillägg ståltåg med olika bromssystem, Pilotstudie av bulleremission från godstågspassager vid Storvik, *Technical Report*, ELTON, Sweden, 2022.

[6] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise; 2002.

[7] Jonasson, H. G., Storeheier, S. Å., Nord 2000. New Nordic Prediction Method for Rail Traffic Noise. Version 1.0. *SP Rapport 2001:11*, SP Sveriges Provnings- och Forskningsinstitut, Sweden, 2001.

[8] European Union: Commission Implementing Regulation (EU) 2019/774 of 16 May 2019 amending Regulation (EU) No 1304/2014; see URL: http://data.europa.eu/eli/reg_impl/2019/774/oj, 17.4.2023.

[9] Land Kärnten, ÖBB-Infrastruktur AG (Hg.): Monitoring Schallemissionen Eisenbahnverkehr Wörthersee. Bericht 2022; Klagenfurt / Wien: Land Kärnten, *Technical Report*, ÖBB-Infrastruktur AG, 2023.

[10] Dinhobl, G., Railway noise long term monitoring: experiences and standardisation, *Proceedings of 10th Convention of the European Acoustics Association*, Turin, Italy, 2023.

[11] EN ISO 3095:2025 Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles, International Standards Organization, Geneva, Switzerland, 2025.

[12] EN 17936:2024 Railway applications - Acoustics - Measurement of source terms for environmental noise calculations, European Committee for Standardization, Brussels, Belgium, 2024.

[13] EN 15461, Railway applications — Noise emission — Characterisation of the dynamic properties of track sections for pass by noise measurements

[14] EN 15610:2025, Railway applications — Acoustics — Rail and wheel roughness measurement related to rolling noise generation