Calculated Basic Sound Level as a Derivation of Measured Sound Levels of Freight Trains

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Introduction

Railway rolling noise depends largely on wheel and rail roughness. Therefore the MEASURED sound level may differ at different measuring points along the rail. But also the wheels have different roughness, especially wheels of freight trains.

However, the Grundwert (basic sound level) defined in the German directive Schall03 may be valid for intercity coaches and average good rail conditions, and does not take into account these variations.

In this paper, sound levels of freight trains measured at different measuring points are used to reverse calculate the actual basic sound level under the specific conditions of each measurement.

Memorable illustrations show the shortcoming of the Grundwert as defined in the directive. These illustrations form the basis for an open discussion about a lawful and generally accepted COMPUTABLE definition of the basic sound level of freight trains that is derived from many measurements. Such a definition has to be a solution of a number crunching problem. We look for one value - the basic sound level for freight trains - which describes the noise for all species of freight trains with their individual and independent wheel roughness, and for all species of rails with their individual roughness.

The aim is to find such a definition that is adequate for use in future directives and guidelines.

Different Rails and Wheels

freight rail roughness

Railway rolling noise depends largely on wheel and on rail roughness. Therefore the measured sound level may be different at different measuring points.

Figure 1 shows the basic sound level at 63 measuring points. At each of these measuring points the range of basic sound levels is visible: If at one of these measuring points m the basic sound levels of 95% of all passed freight-trains are higher than a level $p_{r,m}$, then we define:

Definition: Level $p_{r,m}$ is called the freight-rail-roughness of a measuring point m at the period of measurement.

At the measuring point 110 we used 257 measurements which were made during a short period, and 5% of these measurements have a basic sound level less than 44 dB(A). We assume a constant surface-quality during this period, therefore the freight-rail-roughness is $p_{r,110} = 44\, dB(A)$.

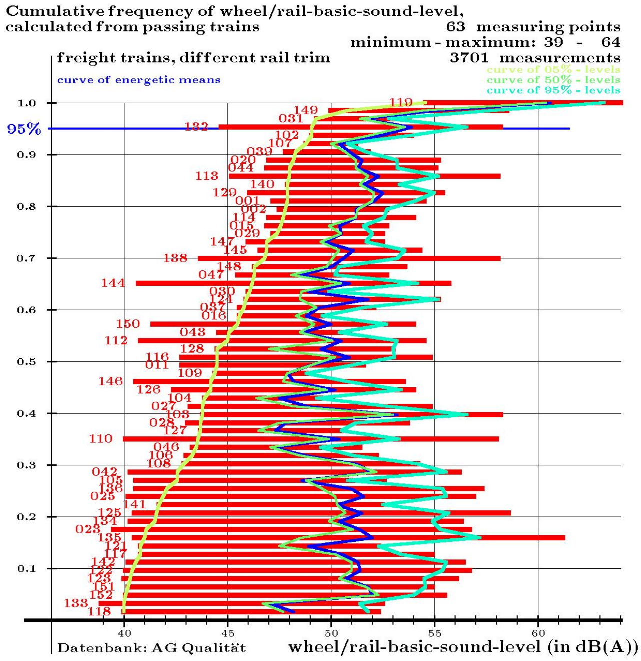

Figure 1: measured basic sound (or noise) levels $B_{SL,w,r}$ of 63 different measuring points, arranged by the 5%-level ($40\,\text{dB(A)} \leq$ 5%-level $\leq 49\,\text{dB(A)}$)

freight wheel/rail-basic-sound-level

Using the abbreviation $B_{SL,w,r}$ for the resulting wheel/rail-basic-sound-level, the emission per hour (Emissionspegel in the german Schall 03) $L_{m,E,1\,hour}$ of one freight train, which passes in a distance of 25 m and 3.5 m above the rail surface with a speed v, is defined as the result of a calculation:

$$L_{m,E,1\,hour} = B_{SL,w,r} + D_{Fz} + D_D + D_l + D_v + D_{Fb} + D_{Br} + D_{Bü} + D_{Ra}.$$

If we assume

- freight train ($D_{Fz} = 0$)
- 100% of the freight wagons have block brakes ($D_D = 10 \cdot \lg[5 - 0,04 \cdot p] = 10 \cdot \lg[5] = 7$)
- $D_{Fb} = 2$ (wooden- or concrete sleeper)
- $D_{Br} = 0$ (no bridge)
- $D_{Bü} = 0$ (no street-crossing)
- $D_{Ra} = 0$ (radius > 500 m)

then

$$\begin{aligned} L_{m,E,1\,hour} &= B_{SL,w,r} + 0 + 7 + D_l + D_v + 2 \\ &= B_{SL,w,r} + D_l + D_v + 9 \end{aligned}$$

$L_{m,E,1\,hour}$ is the emission with respect to one hour, but we are interested in the emission $L_{m,E,\text{pass}}$ during the time t_{pass}:

$$\boxed{L_{m,E,\text{pass}} = B_{SL,w,r} + 30 \cdot \lg[v] + 39}$$

With this formular it is easy to measure and/or to control the wheel/rail-basic-sound-level $B_{SL,w,r}$ (and $L_{m,E,\text{pass}}$).

Remark:
Schall 03 ([3]) determines: $B_{SL,w,r} = 51\,dB(A)$.

rail grinding

Freight-rail-roughness $p_{r,m}$ is not a constant with respect to time (see [4]):

decline in dB(A) = A · lg [*1+B · (days after grinding)*]

where

a) the decline is proportional to the number (and the weight) of freight trains
  - in contradiction to figure 2 from *EBA* ([1]). The results published by EBA are not acceptable for a theory of the decline of rail-roughness.

b) A and B are reals.

Therefore we use the decline-of-rail-theory from [4].

Eisenbahnbundesamt (EBA):

Measurements of upgrade/stagnancy/decline of rail roughness after grinding
in three test series Donauwörth - Augsburg

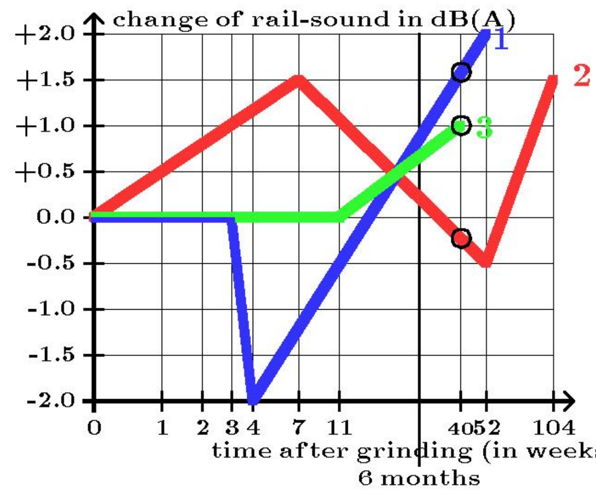

Figure 2: Eisenbahnbundesamt (EBA):
3 examples of upgrad/stagnancy/decline of rail roughness
1: Tabelle 6, 2: Tabelle 5 3: Tabelle 7

example

assumption 1: 500 freight trains pass within 24 hours the measuring point 110 of figure 1 (140 during the night).

We will look for a period of about two years - that means we consider

$$500 \cdot 360 \cdot 2 = 360\,000 \text{ freight trains}$$

assumption 2: Figure 3 describes the decline of the rail roughness at measuring point 110 (case (1) or (2)).

From figure 3 we see that
- 32 400 freight trains pass during the first 61 days,
- 126 000 freight trains pass during the last 226 days before grinding.

From figure 1 we see that at x days after grinding
- $B_{SL,w,r,110,5\%,x\,days} = 44\,dB(A)$
- $B_{SL,w,r,110,100\%,x\,days} \leq 57\,dB(A)$

Therefore at x days after grinding at the measuring point 110 there is a difference $\Delta_B = 13\,dB(A)$.

assumption 3: The difference between the freight rail roughness $p_{r,110}$ and
- the 5%-level is constant equal to 2 *dB(A)*, $B_{SL,w,r,110,5\%} = 2\,dB(A)$
- the maximum is constant equal to $2 + \Delta_B$, $B_{SL,w,r,110,100\%} = 15\,dB(A)$

with respect to the time between two sequenced grindings.

Therefore we have to decide at what time of decline the measurement took place.

curve of decline during passing of 360000 freight trains
increase of rail roughness: 20 dB(A) after 652 days

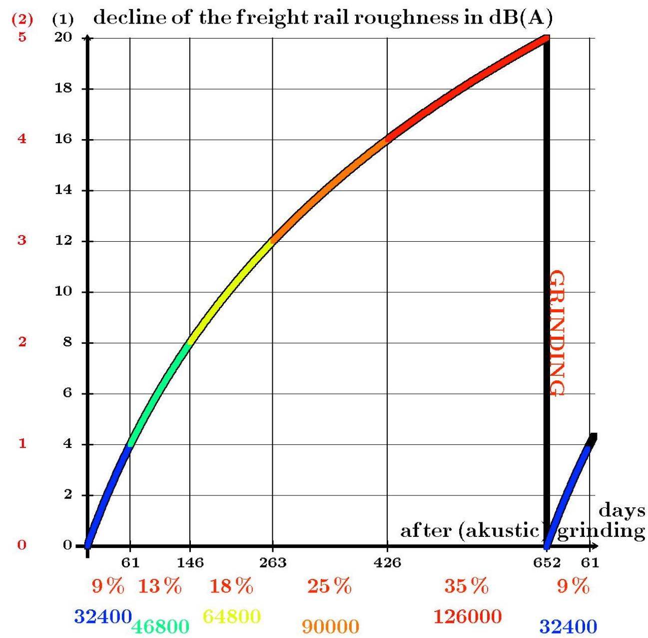

Figure 3: two cases of decline at measuring point 110
decline in dB(A) $= A \cdot \lg\,[1 + B \cdot (\text{days after grinding})]$
$A(1) = 28.2$, $A(2) = 7.05$ and $B = 0.00632$

assumption 4: The period of measurement was 0 days after grinding ($x = 0$).

Then we have for $p_{r,110,0\,days} = 44\,dB(A)$:
- $B_{SL,w,r,110,min,0\,days} = 46\,dB(A)$
- $B_{SL,w,r,110,max,0\,days} = 59\,dB(A)$
- $B_{SL,w,r,110,max,652\,days}(2) = 59 + 4 = 63\,dB(A)$
  or $B_{SL,w,r,110,max,652\,days}(1) = 59 + 16 = 75\,dB(A)$

Figure 4 shows incase (2):
- during the period of 2 years in the majority of freight trains (41 818 trains) we have
  $$B_{SL,w,r,110}(2) = 54\,dB(A),$$
  that is one train per 22 minutes with this noise
- in the fifth period (226 days) there are 8 568 trains
  - or more than one train per two hours - with
  $$B_{SL,w,r,110}(2) = 62\,dB(A).$$

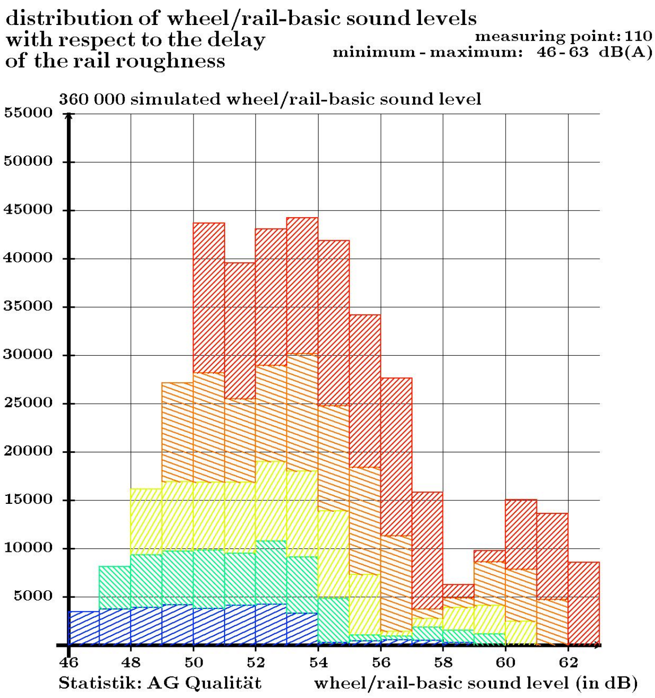

Figure 4: 5 groove-steps (case (2))

There is a very great difference between the Schall 03-determination (with $B_{SL,w,r,Schall\,03} = 51\,dB(A)$) and the simulated basic sound levels.

annoyance and arousal

The preceding results of figure 4 are number crunched, because we assumed statistical equipartition - and that may be wrong:

In the paper [2] of the Forschungsverbund *Leiser Verkehr* we find , that - with respect to annoyance - the most noise-sensitive space of daytime (from 06 am to 10 pm) is from 06 pm to 10 pm.

With respect to arousal it is necessary to know at what time the freight trains pass during the night. But additional it is necessary to know how many of these freight trains will arouse the residents: the dependence on the wheel/rail-basic-sound-level is shown in figure 5 (see [5]).

If we are interested in the annoyance and in the arousel of the noise of freight trains which pass a measuring point during a time-period, then it is important

- to split the time up to day/evening/night and in weekday/weekend
- to take into account the time/noise-relation for each freight train as shown in figure 5 (during he night).

Remark: The Schall 03 defines the day-mean of freight-train-emission as

the energetic mean of all emissions $L_{m,E,1\,hour}$
which occur during all 365 days (06 am to 10 pm)
of one year

and analogous the night-mean.

All influences we had mentioned before are neglected.

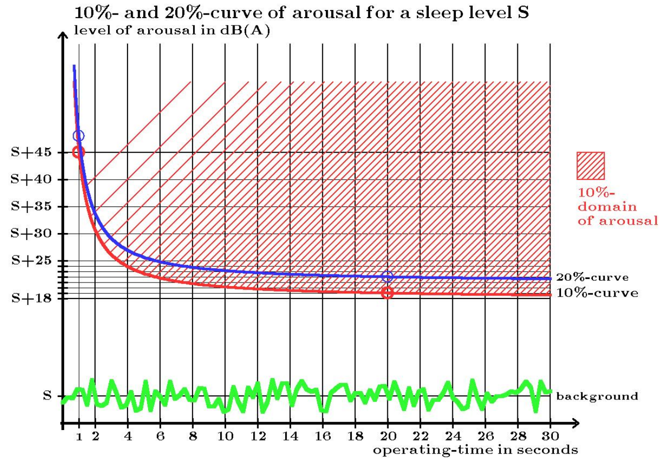

Figure 5: arousal (from [5]), depending on noise-level and operating-time (personal $S = 64\,dB(A)$: 10% of residents wake up if they hear in their bedroom for 20 seconds a (real) sound-level of $S + 19 = 83\,dB(A)$)

Therefore the simulation of figure 4 has to be carried forward with respect to time- and train-splitting.

evaluation of rail-noise

energetic-mean-level

The scatter of the wheel/rail-basic-sound-level $B_{SL,w,r}$ as shown in figure 1 is very important for the determination of an emission value for a freight train. The levels $L_{m,E,1\,hour}$ and $L_{m,E,pass}$ depend linear on the level $B_{SL,w,r}$; therefore these levels scatter in the same way.

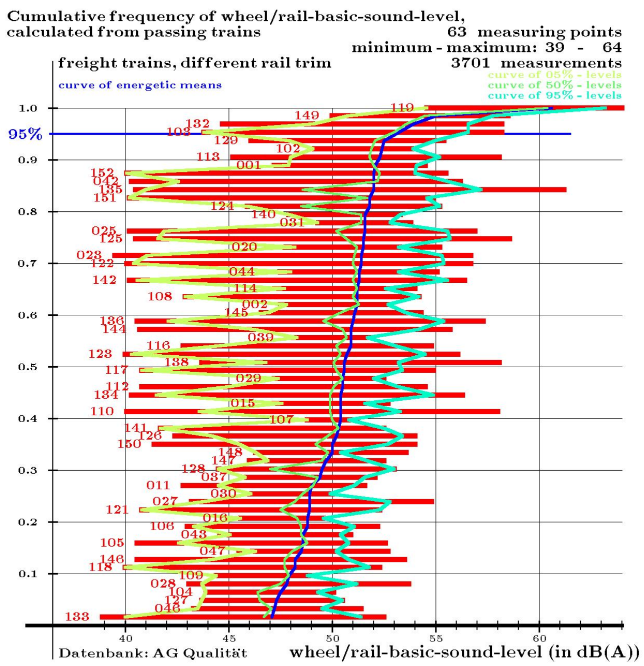

Figure 6: measured basic sound (or noise) levels $B_{SL,w,r}$ of 63 different measuring points, arranged by the energetic mean (47 dB(A) $\leq$ *energetic mean*-level $\leq$ 53 dB(A))

The figure 6 shows the result of a measurement at a few days between two sequenced grindings:

For each of the 63 measuring points we calculated
the lowest level, the 5%-level, the energetic mean,
the 95%-level and the highest level
of the wheel/rail-basic-sound-levels. Then we arranged the 63 measuring points by the value of the the energetic mean.

For the determination of the location with the largest energetic mean we use the measuring point 108 with energetic mean 53 *dB(A)* (accepting 5% defective measurements).

Then we can say:

> At 95% of 63 different locations,
> at a few days between two sequenced grindings
> the means of the wheel/rail-basic-sound-levels
> of the passing freight trains
> was lower than $B_{SL,w,r,all,norm(mean)} := 53\,dB(A)$.

But in the same way as before we have to consider that these data are produced at a few days - and therefore we need theory about the remaining time between two sequenced grindings. If we use the assumption 2 (decline of the freight rail roughness), then we get

$$B_{SL,w,r,all,norm(mean)} = 53 \pm 20\,dB(A).$$

If a resident at the location of measuring point 110 asks for the noise, then the answer will be:

the energetic mean is $B_{SL,w,r,110,norm(mean)} = 50\,dB(A)$
(this is the energetic mean at the measuring point 110). But this answer is incomplete because

- it describes a mean of the energetic means only of measuring point 110 at an arbitrary date
- it does not take into account the decline of the rail roughness
- it does not take into account the scatter of wheel-roughness.

95%-level

In figure 7 we used figure 1, but the data are arranged by the 95%-level - and we can see:

At 95% of 63 different locations
at a few days between two sequenced grindings
the wheel/rail-basic-sound-level
of 95% of the passing freight trains
was lower than $B_{SL,w,r,all,norm95} := 57\,dB(A)$. or
of 5% of the passing freight trains
was higher than $B_{SL,w,r,all,norm95} := 57\,dB(A)$.

But in the same way as before we have to consider that these data are produced at a few days - and therefore this 95%-level does not take into account the decline of the rail roughness.

In this moment (in the year 2009), we should define an active09 freight wheel/rail-basic-sound-level

$$\boxed{B_{SL,w,r,all,active09} = 57\,dB(A),}$$

but we wait for an update using new measuring points (or new results for some of these 63 locations). if there is an additional measurement, this may be wrong.

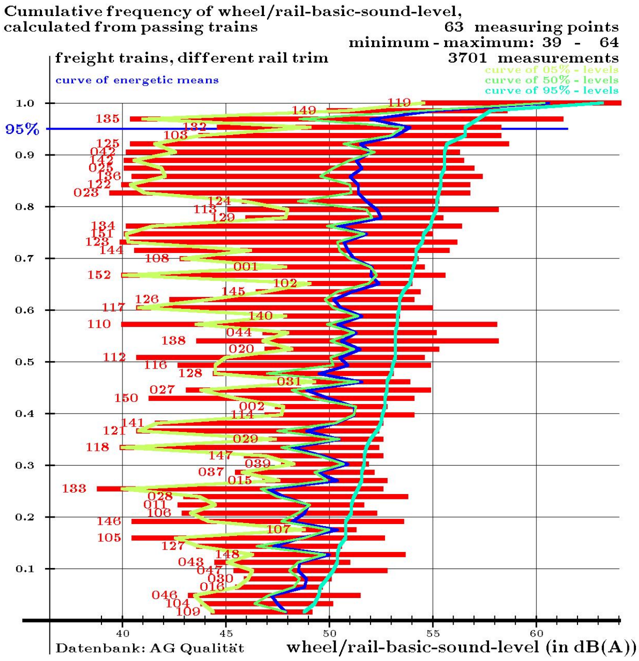

Figure 7: measured basic sound (or noise) levels $B_{SL,w,r}$ of 63 different measuring points, arranged by the 95%-level (49 dB(A) $\leq$ 95%-level $\leq$ 57 dB(A))

After any additional measurement it is necesary to calculate active10 freight wheel/rail-basic-sound-levels $B_{SL,w,r,all,active10}$ for all situations mentioned before.

References

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Anlage 1a zur Verfügung Pr.1110 Rap/Rau 98, S. 30f., Tabelle 5, 6 und 7

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