# Rail shielding – influence on noise emission and rail vibration

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## Summary

Calmmoon Rail was approved by the German EBA in 2010 as a rail web damper. By the end of 2015 more than 80 km of track was fitted with this rail shielding technology. In the course of the economic stimulus program II, Calmmoon Rail was redefined as rail shielding due to the way it works. Measurements as part of the economic stimulus program II yielded a noise reduction effect of 3 dB(A) for Calmmoon Rail.

Noise measurements in Switzerland carried out on track of Swiss railway company BLS AG in October 2015 yielded a distinct reduction in the pass-by noise level as a result of rail web shielding (RWS). This was in the region of 1 – 4 dB depending on rail pad stiffness and type of rolling stock. The noise reduction of the shielding is at its greatest when the contribution of the rail determines the rolling noise, and vice-versa is at its lowest when the contribution of the rail to the rolling noise is correspondingly low, which is plausible. The noise mitigation effect is noticeable above 500 Hz and is at its greatest between 800 and 1000 Hz as well as at 2000 Hz. According to theory, this is also the portion of rolling noise that is radiated by the rails.

The measurements of track decay rate and rail vibration show a surprising result. Previously it was assumed that, in contrast to rail web dampers (RWD), rail web shielding (RWS) has no effect on track decay rate and rail vibration. In actual fact though, a considerable difference is evident in the form of higher damping in the track and reduced rail vibrations, especially in the horizontal direction. Therefore, the noise mitigation effect of RWS rests not only on the shielding but also on a reduction in vibration and noise radiated by the rails.

## 1 Introduction

Since 2010 more than 80 km of track maintained by DB AG has been fitted with Calmmoon Rail technology to reduce the noise radiated by rails.

In April 2010 Calmmoon Rail was approved by the EBA (Germany's federal railway authority) for operational trials in Germany. It attenuates the noise radiated by rails and consequently reduces the overall noise level of the railway. Since its initial use on DB AG projects, this light-weight and easy to handle technological product has elicited many questions and new positive findings from customers as well as competitors. A more elaborate field trial carried out in October 2015 on the track of BLS AG in Switzerland led to further new findings regarding the influence of this technology on the track decay rate and the acoustic mode of operation.

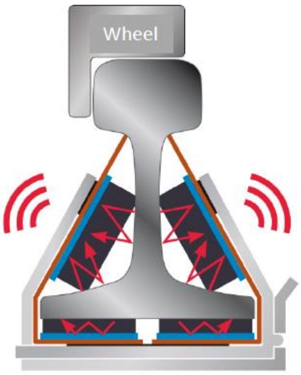


**Figure 1 Calmmoon Rail – rail web shielding technology (RWS)**

# 2 Technology

In contrast to the rail dampening technologies, Calmmoon Rail is not a mass-spring system. It is a light rail web shielding technology. As can be gathered from Fig. 1, this technical term describes the mode of action of it very accurately. This technology works by shielding the rail on both sides of the web as well as the entire foot. This shielding technology came about from an attempt to find an optimum combination of different technologies with regard to noise reduction and the associated production and delivery costs. Calmmoon sheet in the form of 1.3 mm thick noise reduction sheeting is glued onto a steel plate (cover). Then noise-absorbent foam from the automotive industry is applied. At the worksite, this L-shaped "shielding" is attached to both sides of the rail by hand and finally secured reliably and lastingly with two shielding fasteners per rail compartment.

This rail shielding technology weighs around 4 kg per metre of rail when installed. Compared to this, some installed mass-spring systems (RWD) weigh up to around 24 kg per metre of rail. For a kilometre of track, the average installed weight is around 8 tons of this shielding technology or up to around 48 tons of mass-spring system. This material mass needs to be produced, delivered, installed and removed at the end of its service life. For what this may mean with regard to sustainability, one could refer to research by Friedrich Schmidt-Bleek at the Wuppertal Institute.

In the course of installation, any existing LZBs (continuous automatic train-running control systems) continue working without their removal in the rail foot area and remain unaffected by this shielding. At bridges the derailment protection remains unaffected. This technology is installed without having to dismantle or refit the derailment protection.

For the reduction of emitted noise this ensures maximum rail web coverage with regard to the length of the track system.

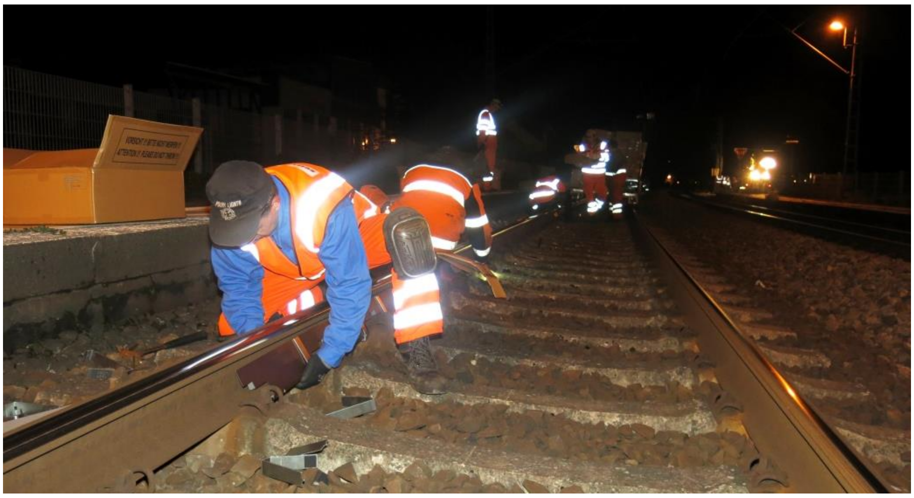

**Figure 2 Installation of Calmmoon Rail on a German Railway track**

# 3 Installation procedure

Once the order has been placed, the rail web shielding is manufactured according to the type of rail, fastening and sleeper, is baled in units of five rail compartments and delivered to the work site in easy to handle packs.

Once the section of line has been released for installation, a small amount of track ballast in the rail compartments is removed quickly by hand using a ballast fork. At the same time, the shielding packs are distributed along the track and opened, ready to be fitted.

After removing the ballast, the cover elements are fitted onto both sides of the rails with the fixings around them.

The track ballast is reinstalled in the rail compartment, the empty cartons are collected, the line section is checked a final time and is handed over to the operator for normal traffic.

# 4 Projects on the network of DB AG

In November 2010 the Schweerbau–SEKISUI bidding consortium was awarded the first contract for the Leipzig-Wahren – Leipzig-Wiederisch project. Two tracks, each 900 m in length, were to be fitted with rail shielding technology.

The work on the first section was carried out in December 2010 in very cold and wintry conditions.

By the end of 2015 more than 80 km of DB track were covered with this technology. Project sites included Rahlstedt/Mariendorf, Hamburg, Bremen, Leipzig, Löf/Mosel, Gau Algesheim, Emmerich/Oberhausen and many cities in the Rhine valley.

**Figure 3 Calmmoon Rail project in Boppard - Germany**


**Figure 4 Calmmoon Rail project in Rhine valley – Germany**

# 5 Results of German economic stimulus programme ll investigations

At the second symposium on noise control at the VDEI railway sustainability forum on 26th and 27th June 2012 in Berlin, the measurement results available on the investigated technologies and their effectiveness in reducing noise were announced by DB (German railways) and the German Ministry of Infrastructures.

The mass spring rail web damper (RWD) technologies showed an average effect of 2dB(A) in noise reduction. A total of 4 RWD technologies were investigated.

Rail shielding showed an average effect of 3 dB(A). This also means that Calmmoon Rail fulfils the requirements of Schall 03 (2012).

As explained above, Calmmoon Rail was approved as a rail web damper by the EBA, but because of the way in which it works was subsequently redefined as rail shielding by the experts in the course of practical tests. It was also shown that a combination of rail grinding, rail shielding and low noise barriers can be expected to reduce the overall noise level experienced by local residents by 10 dB(A). This would correspond to an immediate halving of the noise perceived by local residents.

# 6 Field measurements at the test track of BLS AG

Two 80-metre-long straight sections of the single-track line between Kerzers and Müntschemier were fitted with SEKISUI’s rail web shielding, Calmmoon Rail, to measure its acoustic effect. Following track renewal work in 2014, the section of line is in excellent condition and is ideally suited for the envisaged test, since rail roughness is very low throughout and the influence of the soft and stiff rail pads on the effect of the RWS can be measured. Moreover, passenger and freight trains of varying types run on this section of line.

On both sides of the track there are no trees or other forms of high vegetation along the measured section of line. As there are no reflecting surfaces such as house walls or the like, the ideal propagation conditions of a free sound field exist.

## 6.1 Measurement section and set-up

The section of line located between kilometre markers 24.476 and 24.638 is fitted with stiff rail pads of type Zw 661-6 EVA. Soft rail pads of type Zw 700-b-100kN-EPDM-H-SF150-W are installed from kilometre marker 24.638 onwards. Other than this, both sections of line are ballasted track with a 60 E1 rail profile and B91 concrete sleepers.

The railway embankment is slightly elevated from the surroundings. At the microphone positions the height is between 1 and 2 metres. Accordingly, the ambient conditions meet the requirements of TSI Noise.

The rail web shielding was installed during the night of 26th to 27th October 2015 and was removed one week later.

The measurements could be made under suitable conditions on 19th and 28th October 2015. Besides the noise emission measurements at a distance of 7.5m from the track, on both sides of the track at three measuring cross sections (during normal service over 8 hours), the rail roughness, track decay rates (TDR) and rail vibration before and after installation of the shielding were also recorded.

In addition to the airborne noise that was recorded on both sides, the vibrations in horizontal and vertical direction were recorded at all measuring cross sections, in each case on the southern rail. A light barrier was mounted at each measuring cross section to record the passage of axles and determine the speed of the passing trains.

The ambient conditions such as weather, temperature, humidity, atmospheric pressure and wind speed were recorded several times throughout the measurements.

## 6.2 Rail roughness measurements

The rail roughness was recorded on all measuring cross sections on 19.10.2015 prior to the zero measurement. The upper spectrum limit of acoustic rail roughness according to EN ISO 3095 was clearly undershot on all cross sections. The differences in rail roughness of the three measuring cross sections were minimal.

In addition, the rail roughness on the measuring cross sections fitted with RWS was recorded on 27.10.2015. The change in rail roughness over the period of 8 days was minimal and was at very low roughness levels of -10 to -20 dB in the region of measuring accuracy.

Since the combination of the wheel and rail roughness determines the rolling noise, and wheel roughness for a train passing over the three measuring cross sections can be assumed to be constant and the differences in rail roughness are minimal, the influence of rail roughness on the effect of the RWS can be neglected.

Note: As part of track renewal work in early summer 2014 new rails were fitted over the entire section of line. This was followed by so-called initial grinding in the area of the newly laid rails. Thereafter the rail roughness was slightly too high for TSI Noise measurements. For that reason, at the start of 2015 an acoustic grinding method was used to generate very low rail roughness (singular value of roughness level < 0 dB) in the area of the measuring cross sections.

### 6.3 Equivalent sound pressure level of pass-by measurements

Tables 1 and 2 show the arithmetically averaged pass-by levels, scaled to 80km/h, for the number of trains evaluated (sorted by train type). Here also, the measured values on both sides of the track were averaged. The measurement results at MC0 with a stiff rail pad were chosen as the reference.

- MC0 km 24.580 PROSE reference section with stiff rail pad
- MC1 km 24.520 (± 40m) with stiff rail pad without / with RWS
- MC2 km 24.680 (± 40m) with soft rail pad without / with RWS

**Table 1 Results of pass-by measurements of 20.10.2015, all MC without RWS**

| Train type | No. | Averages [dB(A)] | | | Level difference [dB(A)] (positive values = level increase compared to MC0 | |
|---|---|---|---|---|---|---|
| | | MC0 | MC1 | MC2 | Difference 1-0 | Difference 2-0 |
| Lötschberger | 14 | 75.1 | 75.3 | 78.7 | 0.2 | 3.6 |
| EW3 with Re420 / Re465 | 15 | 79.8 | 79.7 | 82.1 | -0.1 | 2.3 |
| Freight train | 1 | 84.2 | 84.5 | 87.2 | 0.3 | 3.0 |
| Nina | 1 | 75.9 | 75.7 | 78.7 | -0.2 | 2.8 |

It is evident from the values in table 1 that the level differences between MC1 and MC0 turn out small as expected and at most are 0.3 dB, since these sections have the same rail pad stiffness.

Between MC2 with a soft rail pad and MC0 with a stiff rail pad, the differences in pass-by level at between 2.3 and 3.6 dB are distinctly higher. Therefore, at track section MC2 with a soft rail pad, 3 dB higher noise emissions averaged over all types of rolling stock are to be expected.

**Table 2 Results of the pass-by measurements of 28.10.2015, MC1 and MC2 with RWS**

| Train type | No. | Averages [dB(A)] | | | Level difference [dB(A)] (positive values = level increase compared to MC0 | |
|---|---|---|---|---|---|---|
| | | MC0 | MC1 | MC2 | Difference 1-0 | Difference 2-0 |
| Lötschberger | 13 | 74.0 | 72.4 | 73.7 | -1.6 | -0.3 |
| EW3 with Re420 / Re465 | 15 | 79.2 | 77.9 | 79.1 | -1.3 | -0.1 |
| Freight train | 3 | 85.1 | 83.9 | 85.6 | -1.2 | 0.5 |
| Nina | 3 | 77.2 | 74.7 | 76.3 | -2.6 | -0.9 |

After installing the RWS a distinct reduction in the pass-by level is noted at both measuring cross sections MC1 and MC2, and at MC2 with soft rail pads even undershoots for the most train types those of the reference cross section MC0.

**Table 3 Effect of RWS**

| Train type | Level difference [dB(A)] to MC0 zero measurement | | Level difference [dB(A)] to MC0 effect measurement | | Effect due to RWS [dB(A)] positive values = level reduction due to RWS | |
|---|---|---|---|---|---|---|
| | MC1 | MC2 | MC1 | MC2 | MC1 | MC2 |
| Lötschberger | 0.2 | 3.6 | -1.6 | -0.3 | 1.8 | 3.8 |
| EW3 with Re420 / Re465 | -0.1 | 2.3 | -1.3 | -0.1 | 1.3 | 2.4 |
| Freight train | 0.3 | 3.0 | -1.2 | 0.5 | 1.5 | 2.5 |
| Nina | -0.2 | 2.8 | -2.6 | -0.9 | 2.4 | 3.7 |

Table 3 shows the effective reduction in averaged pass-by levels that resulted from the installation of RWS. The effect from inserting the RWS corresponds to the difference in the level differences to MC0 between zero- and effect measurement

With the Lötschberger trains and Nina, the effect with soft rail pads is particularly large since the contribution of the rail to the rolling noise is high in these cases. At MC2 a reduction of almost 4 dB is achieved. Conversely, with freight trains and EW3 with Re420 and stiff rail pads, the contribution of the rail to the rolling noise is low and therefore also the reduction from RWS at slightly above 1 dB.

The noise measurements yielded a distinct reduction in the pass-by levels due to shielding in the expected range of about 1 – 4 dB. The level reduction of the shielding is at its greatest when the rail noise portion determines the rolling noise (in the present case, train type Lötschberger in combination with soft rail pad), and vice-versa is at its lowest when the rolling noise portion of the rails is low (Re420 with EW3 or freight train in combination with stiff rail pad), which is plausible.

In the frequency range, the noise mitigation effect of RWS is noticeable above 500 Hz and is at its greatest between 800 and 1000 Hz as well as at 2000 Hz. According to theory, this is also the portion of rolling noise that is radiated by the rails (see Figure 5)

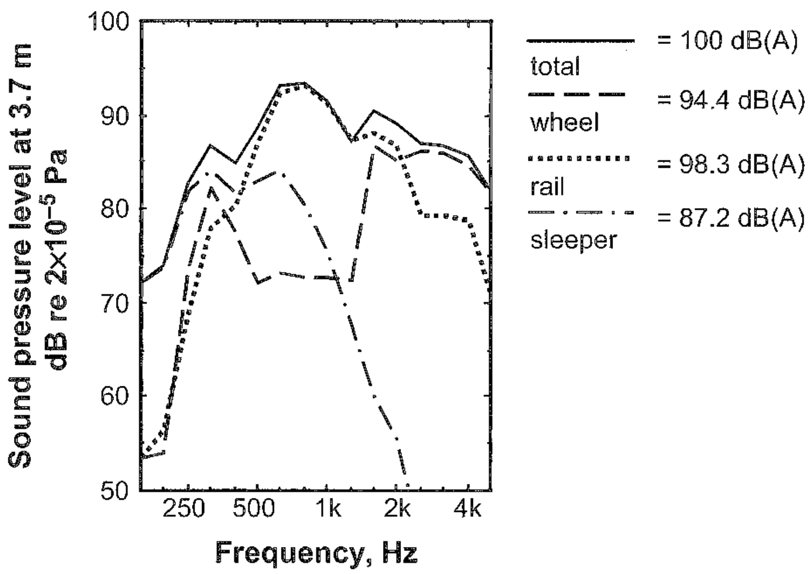


**Figure 6 The contribution of wheel, rail and sleeper to the rolling noise for a freight vehicle at 100 km/h and soft rail pads (Thompson 2009)**

### 6.4 Difference spectra of the pass-by noise

In the course of the measurements, the influence on noise emission of different rail pads with and without RWS fitted was to be shown. To this end, the difference spectra were generated from the ascertained one-third-octave spectra.

The one-third-octave spectra that ensued from the various passing's at reference cross section MC0 were used as reference spectra. In each case the difference spectra between the two other measuring cross sections and MC0 were formed. These are shown in the following diagrams for the two most common types of train on this railway line. Positive values here correspond to an increase in level with regard to MC0.

The effect of RWS in the frequency range is clearly noticeable, especially above 500 Hz up to at least 2500 Hz, with maximum differences of around 6 dB in individual one-third-octave bands, especially with soft rail pads. As already ascertained, besides the stiffness of the rail pad, the type of train also has an influence. In the case of the Lötschberger train with a higher contribution of the rail to the rolling noise, the effect of RWS is distinctly greater, especially in the one-third-octave bands around 2000 Hz.

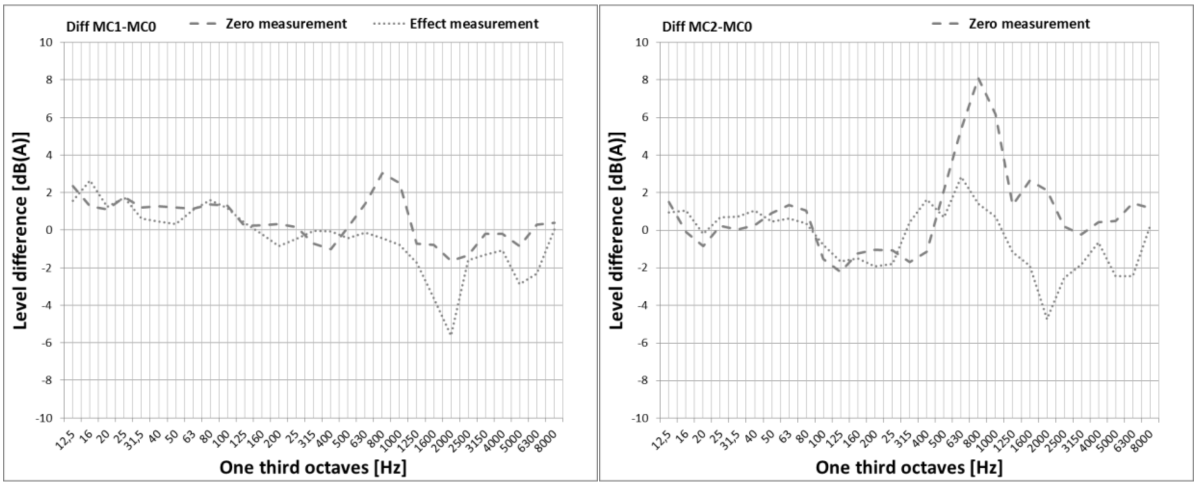


**Figure 7 Difference spectrum for Lötschberger - measuring cross sections 1 and 2 – stiff and soft rail pads**

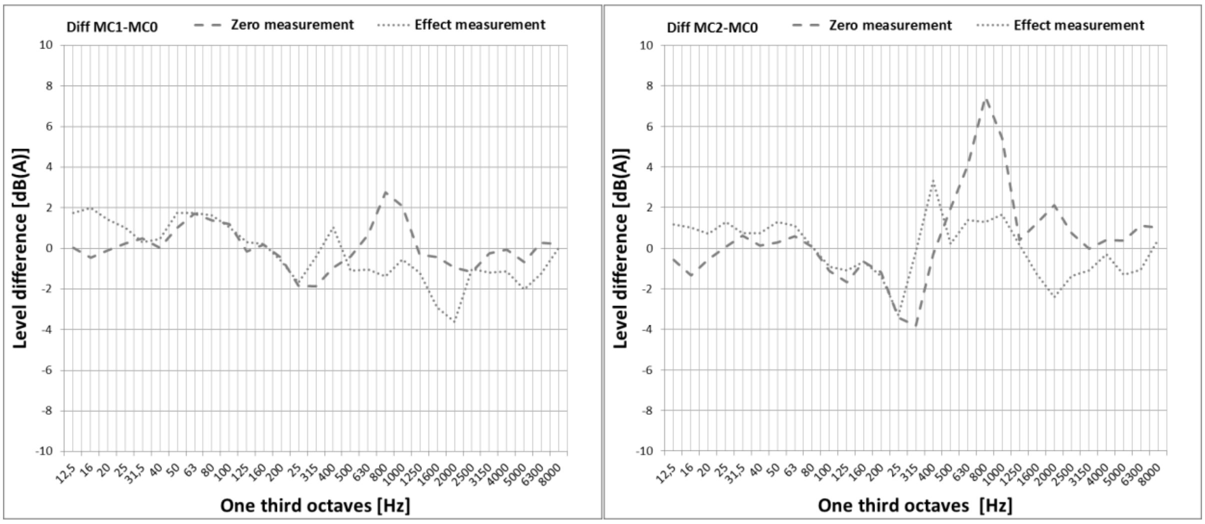


**Figure 8 Difference spectrum for EW3 with Re420/Re465 - measuring cross sections 1 and 2 – stiff and soft rail pads**

## 6.5 Track decay rate measurements

The track decay rate was recorded at all measuring cross sections before the zero measurement on 19.10.2015 (reference MC0 on 02.09.2015) and at the measuring cross sections (MC1 and MC2) fitted with RWS also on 27.10.2015.

Contrary to previous opinion that RWS does not have any influence on the track decay rate, these measurements showed a distinct difference in the track decay rates with and without RWS respectively. There is a distinct difference with stiff (MC1) as well as with soft rail pads, especially for the horizontal track decay rate.

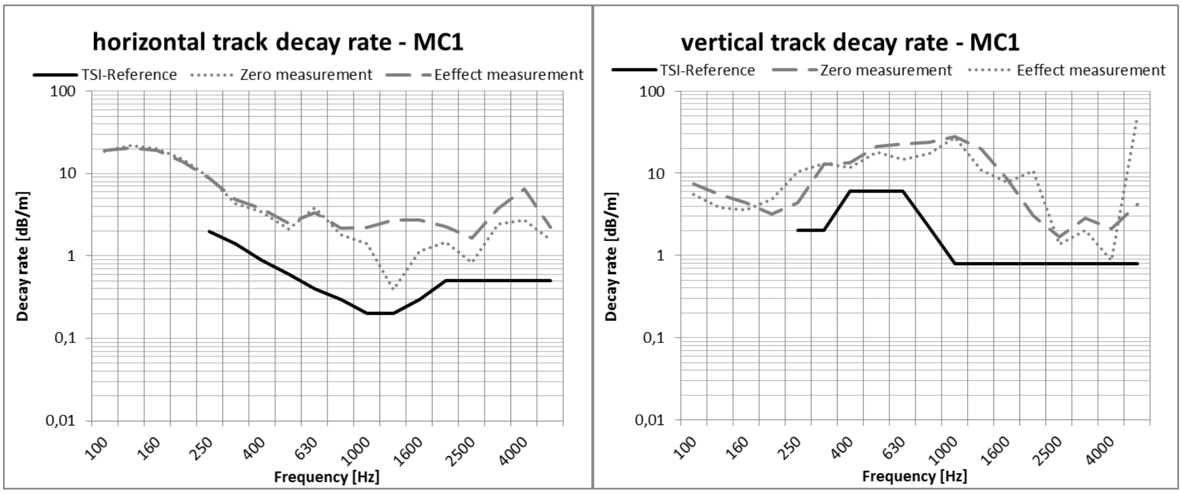


**Figure 9 Horizontal and vertical decay rate MC1 - at km 24.520 - stiff rail pads**

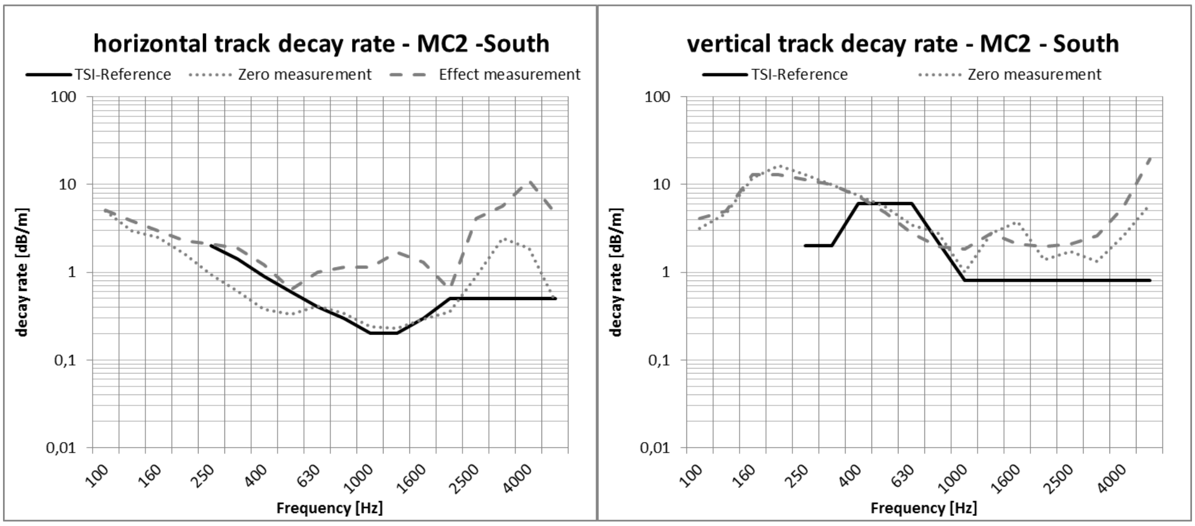


**Figure 10 Horizontal and vertical decay rate MC2 - at km 24.680 – soft rail pads**

## 6.6 Conclusion of field test

The noise measurements yielded a distinct reduction in the pass-by noise level in the expected range of about 1 – 4 dB as a result of the RWS. The level reduction of the RWS is at its greatest when the contribution of the rail determines the rolling noise (Lötschberger in combination with soft rail pad), and vice-versa is at its lowest when the contribution of the rail to the rolling noise is low (Re420 with EW3 or freight train in combination with stiff rail pad), which is plausible.

In the frequency range, the noise mitigation effect of RWS is noticeable above 500 Hz and is at its greatest between 800 and 1000 Hz as well as at 2000 Hz.

The measurements of track decay rate and rail vibration showed surprising results. Previously it was assumed that, in contrast to rail web dampers (RWD), rail web shielding (RWS) has no effect on track decay rate and rail vibration. In actual fact, a considerable difference is evident in the form of higher damping in the track and reduced rail vibrations, especially in the horizontal direction. Therefore, the noise reducing effect of RWS rests not only on the shielding but also on a reduction in vibration and noise radiated by the rails.

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