

Investigations about the sound radiation characteristic at different types of girders

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Abstract

In the year 2003 sound measurements were carried out on the maglev line in shanghai and on the test facility in Emsland (Germany) to compare both systems about their sound characteristics. This lecture describes the acoustic measurement method and gives a overview about the results of this investigations.

1. Introduction

The acoustic characteristics of the Transrapid high-speed system depend, irrespective of the system-specific sources, quite naturally to a large extent on the aerodynamic design of the vehicle (but also of the guideway) and on the geometric design of the overall system.

The cross-sectional design of the vehicle/guideway interface has proven to be a very decisive impact factor: The different conditions existing between Emsland and Shanghai in this respect have led to very different noise levels. For this reason, sophisticated observation and new measurement methods were drawn up and applied.

2. The measurement configuration

As a possible significant difference between TVE- and SHA-systems the lower part of the guideway may lead to a difference in sound levels. The different cross sections for the SHA-girder-type and the TVE-girder-type are explained in chapter 4. The sound energy coming from the area between guideway and vehicle may be reflected by the shape of the girder to the side for the SHA type and may be reflected by the ground with less influence on the side for the TVE type of guideway girder. So to evaluate the different directivity the system of “vehicle – guideway” should be measured. Similar to the measurement of sound power a lot of microphones are positioned in a cross section around the area of sound source, in this case not for minimising the influence of the directivity as it is made for measuring sound power, but to get the information of the directivity. So during the measurements two lines of microphones were positioned near the area below the vehicle, so the half of the lower area is covered. Each line consists of 13 microphones. The arrangement is shown in Fig. 1 for TVE conditions.

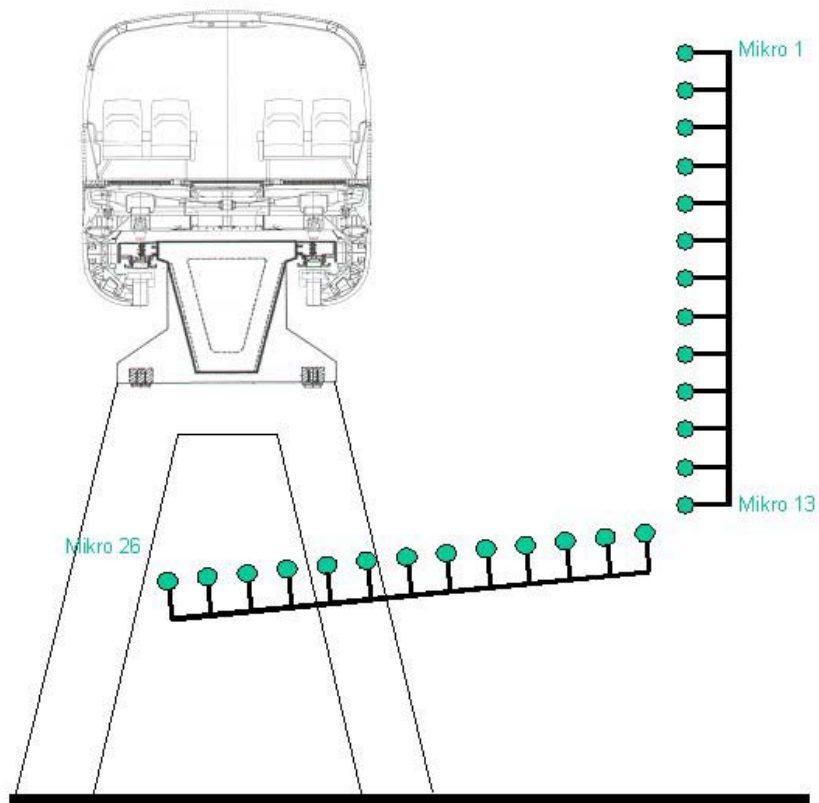


Figure 1: measurement arrangement

The measurement chains and the devices which were used are shown in Figure 2. With this constellation it is possible to measure in a frequency range of 25 Hz to 8 kHz. All time signals were digitalized online with two IMC musyacs measurement frontends. All chains were calibrated in the morning before measuring and in the evening after measuring. The calibration method includes the complete measurement chain. All calibrations were recorded and documented.

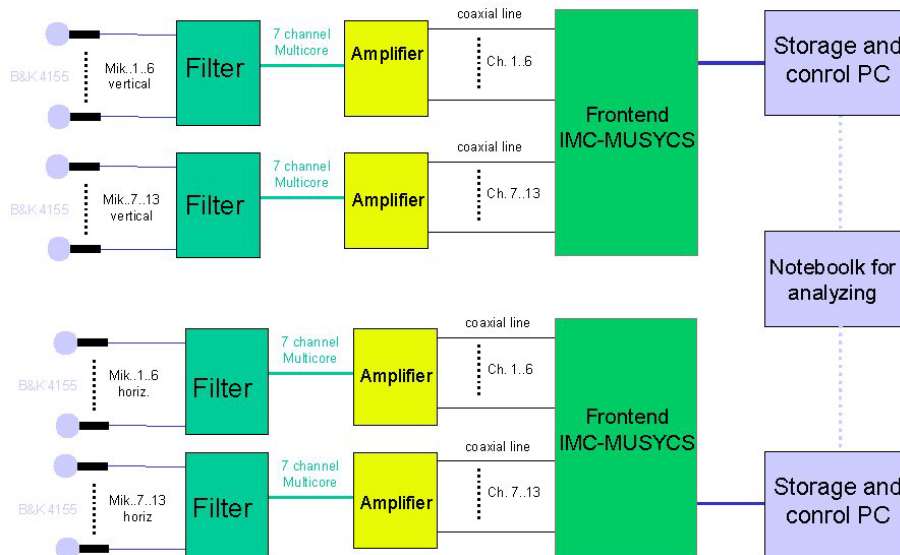


Figure 2: measurement equipment

A typical measurement assembly for the radiation characteristic measurement is shown in Figures 3. The vertical microphones are fixed on a portable tower. On one side the horizontal microphone configuration is fixed on the vertical microphone constellation and on the other side on a mobile measurement tower. With this construction to fix the microphone there are no reflecting parts behind the microphone and no disturbing parts between the vehicle and the microphones.



Figure 3: typical measurement location

3. The evaluation method

As the microphones are positioned relatively close to the passing vehicle the signals are filtered with a highpass ($f_u = 25 \text{ Hz}$; 40 dB per decade) to avoid an influence of the pressure wave of the vehicle. The signals of all the microphones are recorded separately. Before using the signals for calculation the signals are corrected by a factor which is derived from the calibration signal (a different factor for each microphone). A typical time history of the sound pressure, only filtered with the high pass filter, is shown in Fig. 4.

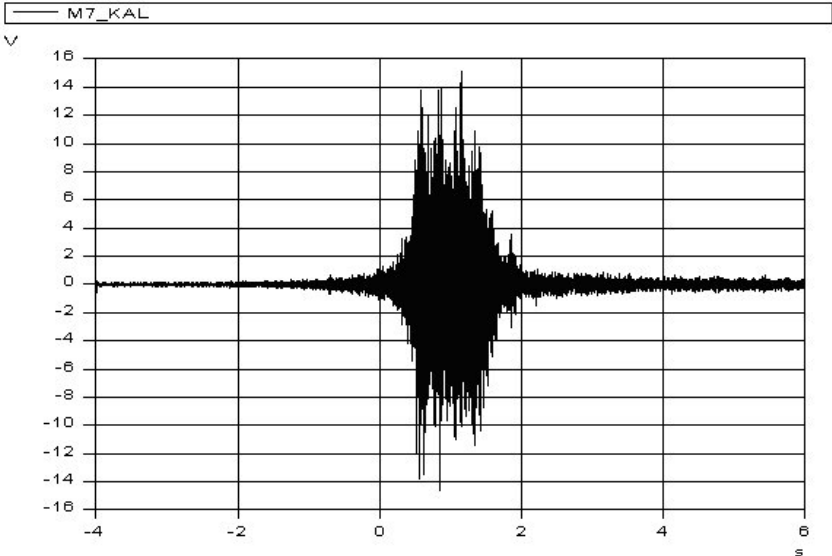


Figure 4: Typical time history of the sound pressure during the pass-by of the vehicle

The signals are weighted in the same way as the signals from conventional freefield measurements, in the frequency domain by a A-weighting and in the time domain by the FAST weighting. Fig. 5 shows the time history of the weighted signal and the time period for the pass-by. The averaged level within this period is the pass-by level for the microphone position. The same procedure as for calculating the pass-by level for a single microphone was taken to calculate the pass-by level for each microphone.

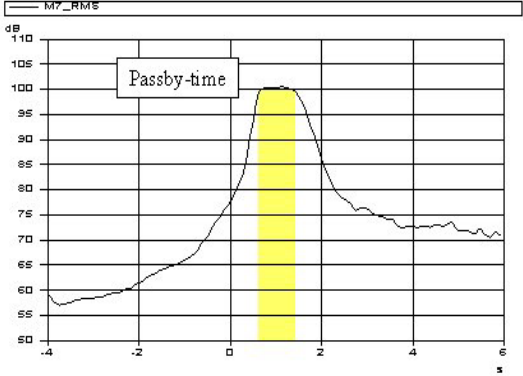


Figure 5: Typical time history of A-weighted and FAST weighted sound pressure, marked with the period of passing vehicle.

The microphones are arranged on two lines. So the distance to a certain sound source is not equal for the sensors. Therefore the levels have to be increased or decreased according to the distance to get a realistic directivity of the sound source. It was decided to take in the horizontal direction the middle of the guideway and for the vertical direction the middle of the levitation magnets as the position of a the virtual sound source. This procedure takes into account that earlier measurements have shown that the strongest sound sources are always situated in the lower region of the vehicle and especially in the region between the vehicle and the guideway where the two boundaries are very close together. So all levels were corrected with the assumption of a line source (in the longitudinal x-direction), with a decreasing of 3 dB for doubling the distance.

To get a similar impression for the several results and to keep them comparable all the signals were related to the signal with the maximum level of the 26 microphones per result. In the case of more than one directivity pattern per diagram the levels of all position are related to the maximum of all levels (for example in Fig. for the hybrid guideway with several modifications)

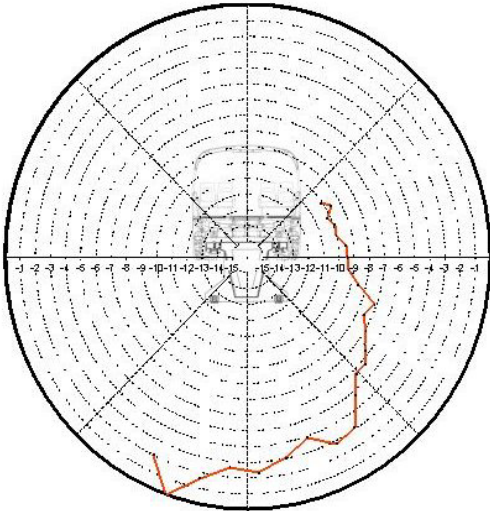


Figure 6: Typical result of the multi-microphone-arrangement

4. The Types of Guideways

4.1 The TVE Guideways

In Figure 7, the cross-sections of the types of guideway are shown, which were investigated by means of the measurements carried out at TVE. For each of these types of guideway, comprehensive measurements on the radiation characteristic were performed and evaluated. The results and the insights gained will be looked at in greater detail later in this presentation.

Concrete guideway

The elevated concrete guideway is the most used guideway type on TVE.. The measured guideway types are 25 m in length of. The cross section of the girder is shown in Fig. 7a.

Steel guideway, prototype I

This guideway type represents the actual status of a steel girder for the elevated guideway. The construction is a double span beam with a length of 2 x 25 m. In Fig. 7b the cross section of this type is given. The cavity in the middle of the girder is filled with small ballast of foamed ceramic pieces to reduce the levels of the lower frequencies.

Hybrid guideway TVE

The latest development for girder types on TVE is the construction of the hybrid guideway type. The middle part is made of concrete and the functional parts (stator, guidance rail and sliding rail) are designed as modules with a length of 3 m and fixed to the concrete part. The length used for this prototype at TVE is 62 m. This type is the most similar type to the SHA girder type. The cross section is given in Fig. 7c.

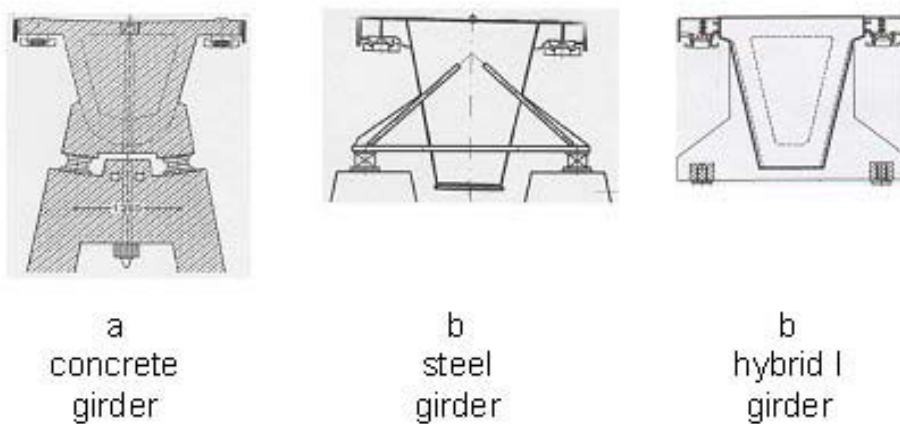


Figure 7: TVE guideway types

4.2 The Shanghai Guideways

In Figure 2, the cross-sections of the two types of guideway investigated in Shanghai are shown. For both types of girders, comprehensive measurements on the radiation characteristic were performed. The results will be looked at later in this presentation.

Steel guideway

Some girders in Shanghai are steel girders. The construction is a double span beam with a length of 2 x 25 m. In Figure 8 a the cross section of this type is given.

hybrid guideway in Shanghai and for the hybrid guideway with absorber material stuck to it in Shanghai. In all cases, the passing speed was 400 km/h. On the (TVE) concrete guideway, the predominant amount of sound energy is radiated downwards and absorbed by the ground. At the hybrid guideway (SHA), much sound is reflected on the bottom flange of the girder, so that the sound level radiated to the side is up to 3 dB louder than for the concrete guideway. In this way, the louder emission levels measured in Shanghai at a distance of 25 m can be explained. The blue curve shows the radiation characteristic of the hybrid girder with the sound absorber boards fixed to the outside surfaces.

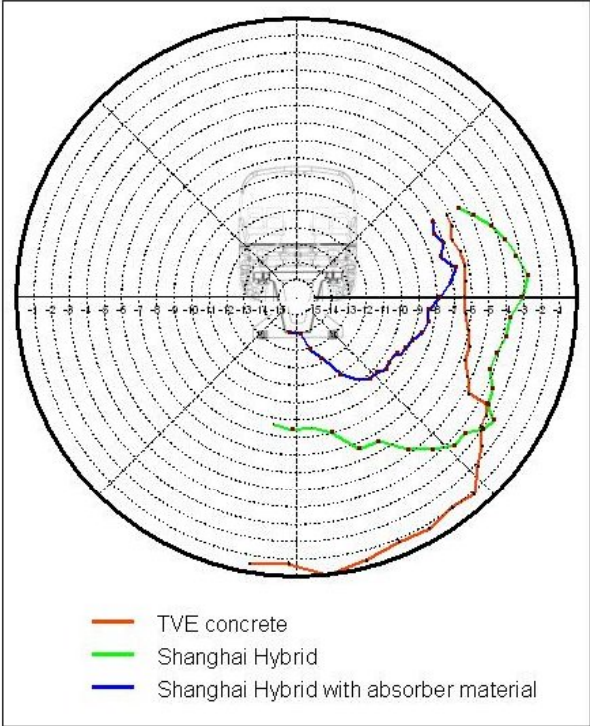


Figure 10: Comparison of different guideway types

The next two figures show in a direct comparison the radiation conditions for the steel guideway (SHA) and the hybrid guideway (SHA) with different modifications. In order to show the influence of the vehicle speed, the measurement runs with $v=200$ km/h and $v=400$ km/h were selected. In Figure 11 ($v=200$ km/h) what is shown again is that the clearly larger proportion of sound energy is radiated downwards in the box-shaped steel guideway in contrast to the hybrid guideway and thus the laterally radiated noise level on average is 4 dB higher for the hybrid guideway than for the steel guideway. If the two figures are compared, it becomes clear that at $v=400$ km/h the noise proportion caused by the aerodynamic components (carriage body and nose flow) increases. The noise level reductions of 0.5 - 1 dB reached as a result of the longitudinal gap covers at $v=200$ km/h are no longer identifiable at $v=400$ km/h in the outdoor noise, because the noise proportion caused by the aerodynamic components (carriage body and nose flow) is more dominant than at lower speeds. Moreover, the radiation characteristics for the girder covered with absorber material are shown. As a result of this measure, reductions of 6 dB at 400 km/h and 8 dB at 200 km/h are achieved for the levels radiated laterally. By means of the increasing domains of the above-described aerodynamic components, the relative level reduction at high passing-by speeds is smaller.

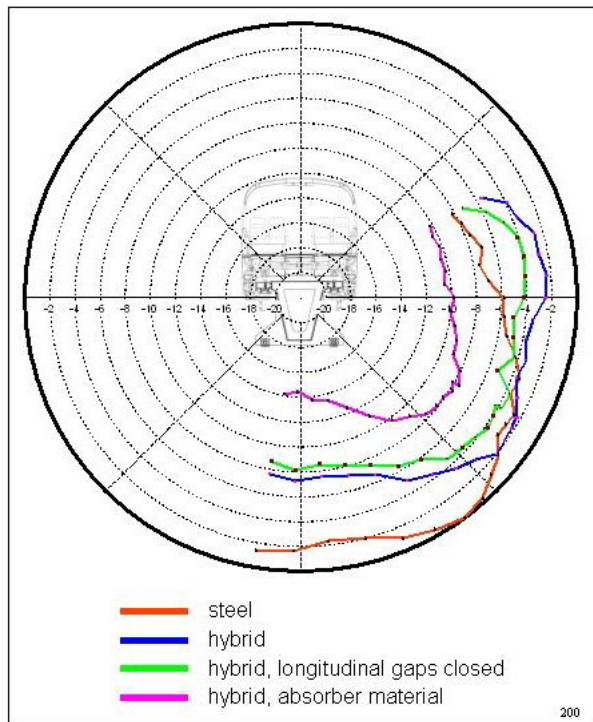


Figure 11: Comparison of different guideway types

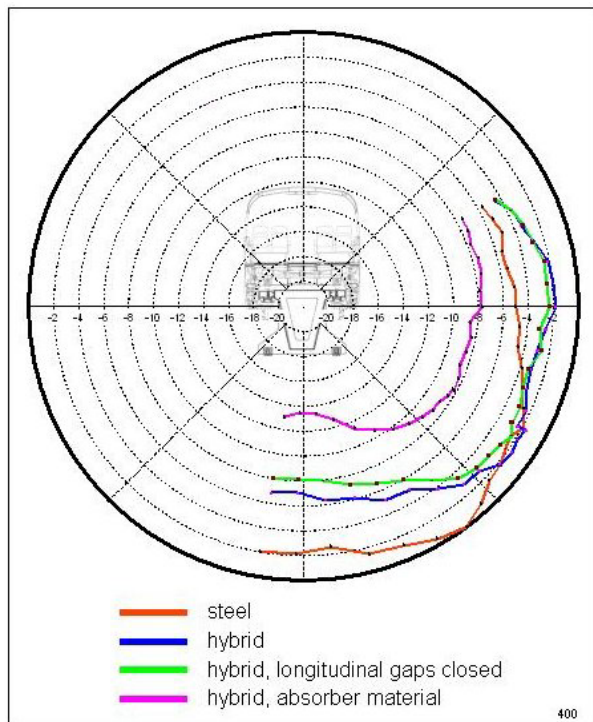


Figure 12: Comparison of different guideway types