# The Experimental Studies on High-speed Railway Noise Field Vertical Distribution and propagation characteristic

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**Summary**
The studies on high-speed railway noise field vertical distribution characteristic and propagation characteristic are the basis for drawing up environmental management, the relative standards and the noise reduction measures. The related tests have been carried out in the Wuhan-Guangzhou High-speed railway and Beijing-Shanghai High-speed Rail. By analyzing the experimental data, the vertical distribution characteristic when the Multiple Units running in a high speed and the law as the noise attenuated with distance are achieved.

## 1. Introduction

By the end of 2013, the revenue kilometers of our country's high-speed railway sums to 11028 km. There is 12,000 km high-speed railway under construction in China. We have become the country with longest high-speed railway operation mileage and the largest construction scale in the world. However, the environmental problem of noise effect caused by the higher speed and higher density of railway transportation has increasingly drawn the attention of people from all walks of life. According to the features of their own high-speed railway, the Union of European Rail way industries and Japan have built the model of the noise directivity and the sound field distribution in operation of the trains, and they have applied the models to noise prediction and the control analysis of relative measures. Since China hasn't built the sound field distribution model of high-speed railway, the experimental study on vertical distribution characteristics is able to offer basic data for formulating and improving relevant standards and technical base for developing the design of environmental management and noise reduction facilities, thus to promote sustainable development of railway construction.
In this paper, combined with the high-speed railway testing and commissioning, the corresponding experimental study was carried out in typical bridge and subgrade section of the Wuhan-Guangzhou high-speed railway and Beijing Shanghai high-speed rail.

## 2. The Experiment Overview

Wuhan-Guangzhou high-speed railway is located in Hubei, Hunan and Guangdong provinces. This railway leads from Wuhan station and ends up Guangzhou South station. The line runs 1069 kilometers with15 stations. Beijing-Shanghai high-speed railway runs 1318 kilometers with 24 stations and leads from Beijing South Railway Station and ends up Shanghai Hongqiao Railway Station. It runs through Beijing, Tianjin, Shanghai three municipalities which directly under the central government and Hebei, Shandong, Anhui and Jiangsu four provinces.
The design speed of Wuhan-Guangzhou high-speed railway and Beijing Shanghai High-speed railway is 350km/h. The line spacing is 5.0m, and the minimum radius of curve of general is 7000m.The maximum gradient is 20 per thousand.

### 2.1. Measurement section line conditions

The table I lists the comparison of line condition of the two high-speed railways bridge measurement section. According to Table I, there are some big differences in line conditions between Wuhan Guangzhou and Beijing-Shanghai high-speed railway, such as the width of the bridge beam and protective wall height. [1-3]

Table I. The comparison of the two high-speed railways bridge measurement section

| Name of high-speed railway | Protective wall height | The bullet train models | Bridge beam width | Bridge height | Ballastless track type | Bridge beam type | Fastener type |
|---|---|---|---|---|---|---|---|
| Beijing-Shanghai | 0.7 m | CRH380AL | 12.2 m | 9.9 m | CRTS II plate | 32m Simply supported box girder | Vossloh300 |
| Wuhan-Guangzhou | 1.0 m | CRH2C | 13.4 m | 11.5m | CRTSI bi-block slab | | |

## 2.2. Layout of measurement points

Testing work carried out on Wuhan-Guangzhou high-speed railway and Beijing-Shanghai high-speed railway bridge and embankment section. The surrounding of measuring points is flat with no houses or other obstacles, which basically meets the condition of half free sound field.
Arrangement of measurement points is shown in figure 1 and figure 2 [1-3].

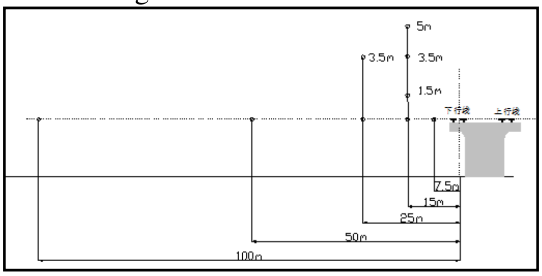


Figure 1. arrangement of measurement points on bridge section

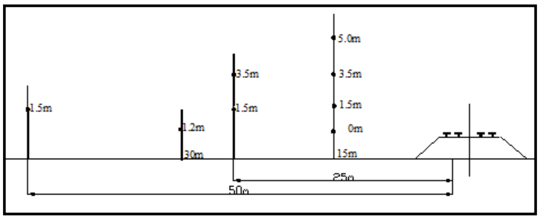


Figure 2. arrangement of measurement points on subgrade section

### 2.3. Measurement method

Using multichannel noise data real-time acquisition and analysis system for recording each train time domain noise signal. The measurement of noise by train is in accordance with the rules of 《Acoustics-Measurement of noise by railbound vehicles》(IS03095—2005).

## 3. Vertical distribution characteristic of radiated noise

### 3.1. Vertical distribution characteristic of radiated noise on bridge section

（1）The Beijing-Shanghai high-speed railway [2-3]

When CRH380AL bullet train passed through the bridge measurement section of Beijing-Shanghai high-speed railway at different speed, the variation trend of TEL(sound exposure level of running train) relative value along with speed change, outside the center line of the track 15m and at the height above the orbital plane 0m、1.5m、3.5m、5m, can be seen in figure3.

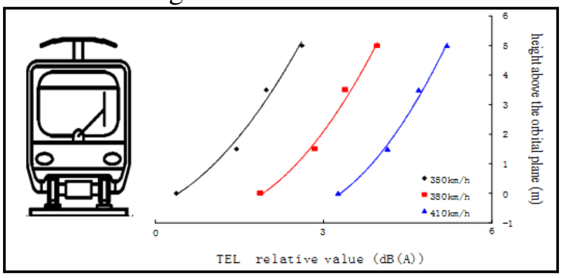


Figure 3. Vertical distribution characteristic of noise by train on bridge section

Through the above experimental results, relations of TEL(sound exposure level of running train) and orbital plane height when the bullet train pass the bridge section can be obtained as below:

a. When the train speed is 350km/h:

$$TEL = -0.0414h^2 + 0.629h + C_1 \quad (2.1)$$

b. When the train speed is 380km/h:

$$TEL = -0.0385h^2 + 0.589h + C_2 \quad (2.2)$$

Where H is the height above the orbital plane in formula.
From figure 4, in 15m away from the outside track center line and 0m~5m above the orbital plane, radiated noise level is gradually increasing with the increase of the orbital plane height, which approximately equal quadratic function. Minimum noise level exists on the orbital plane. With the testing point height (0m~5m range) increase, the sound level increased gradually. Overall, the noise level of each testing point increased with the

increase of speed. The vertical distribution characteristic at different speed is similar.

When CRH380AL bullet train running at 350km/h, train radiated noise frequency characteristic is shown in figure 4.

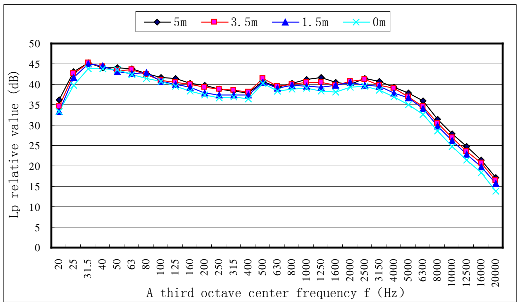


Figure 4. noise frequency characteristics at different heights（CRH380AL，350km/h）

According to Figure 4, train radiated noise spectrum presents broadband characteristics in the 20~4000Hz range, the maximum sound level mainly focused on low frequency 31.5~125Hz, the high frequency component decreases rapidly above 4000Hz.

（2）Wuhan-Guangzhou high-speed railway [1]

When CRH2C bullet train passed through the bridge measurement section of Wuhan-Guangzhou high-speed railway at different speed, the variation trend of TEL(sound exposure level of running train) relative value along with speed change, outside the center line of the track 7.5m and at the height above the orbital plane 0m、1.5m、3.5m、5m, is shown in figure 5.

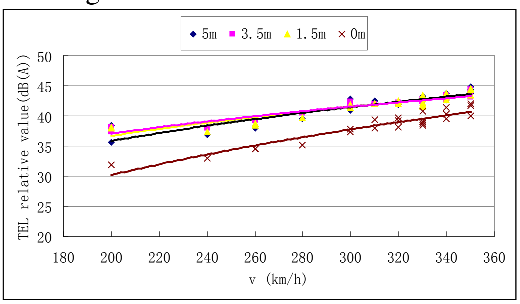


Figure 5. trend of TEL relative value along with speed change at the different height on bridge measurement section

From figure 5:

1）outside the center line of the track 7.5m, at different height above the orbital plane, TEL increases along with the speed increase.

2）the Wuhan-Guangzhou high-speed railway protective wall is 0.7m，which is 0.3m higher than the Beijing-Shanghai high-speed railway, and 0.3m higher than orbital plane. Because of the shielding effect of the protective wall, compared with Beijing-Shanghai high-speed railway, the total sound pressure level in wheel-rail area is lower than other regions on Wuhan-Guangzhou high-speed railway bridge testing section.

3）Compared to upper train aerodynamic noise, the set of electric system noise is faster growing along with the speed increase [4,5].

### 3.2. Vertical distribution characteristic of radiated noise on subgrade section

When CRH2C bullet train passed through the subgrade measurement section of Wuhan-Guangzhou high-speed railway at different speed, the variation trend of TEL relative value along with speed change, outside the center line of the track 17m, at the height above the orbital plane 0m、1.5m、3.5m、5m, is shown in figure 6.

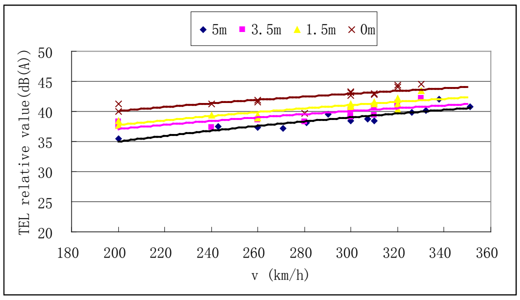


Figure 6. trend of TEL relative value along with speed change at the different height on subgrade measurement section

According to the figure 6, when the CRH2C bullet train at different speeds passed through the Wuhan-Guangzhou high-speed railway subgrade measurement sections, from outside the center line of the track 17m, above the orbital plane 0m ~ 5m, radiated noise level decreased gradually with the increase of orbital plane height. The maximum noise level which is bigger than the radiated noise level at 5m above the orbital plane about 3~4 dB(A) exists at 0m orbital plane. Overall, With the increase of speed, the radiated noise level of each testing point increases accordingly and the increase rate is similar.

When CRH2C bullet train running at 350km/h, train radiated noise frequency spectrum characteristic with 17m from outside track center line and 3.5m above the orbital plane is shown in figure 7.

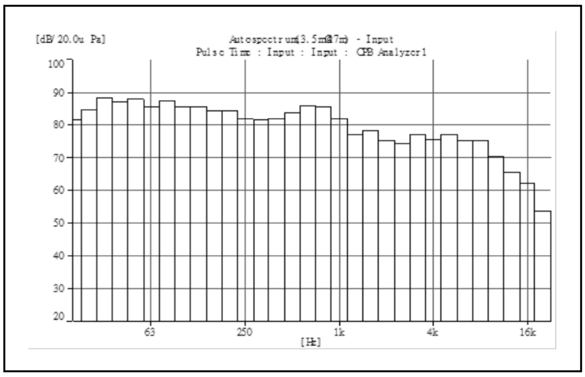


Figure 7. Wuhan-Guangzhou high-speed railway noise frequency characteristics on subgrade section (V=350km/h)

When bullet train is running at 350km/h, Wuhan-Guangzhou high-speed railway noise spectrum on subgrade test section presents wide band characteristic. The peak of frequency mainly focus on low frequency (f=31.5~63HZ) and intermediate frequency (f=500~1Khz).

## 4. Propagation characteristic of the radiated noise

### 4.1. Propagation characteristic of the radiated noise on bridge section

When CRH380AL bullet train at 350~410 km/h speed passed through the bridge measurement section of Beijing-Shanghai high-speed railway, the trend of TEL relative value along with speed change , outside of the center line 7.5m、15m、25m and 100m, meanwhile at the same height with the orbital plane, is shown in figure 8 [2-3].

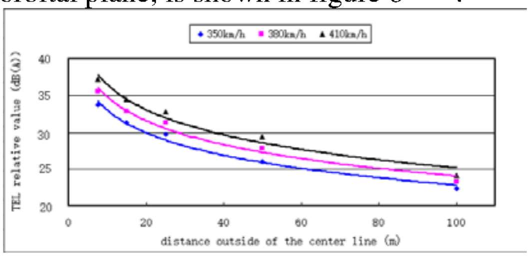


Figure 8. noise propagation characteristic on the bridge section.（CRH380AL）

By the test result, when the train passes through the bridge section of Beijing-Shanghai high-speed railway, the attenuation formula of TEL goes with the distance as below：

a. When the train speed is 350km/h：

$$TEL = -10.2 \times \lg\left(r/r_0\right) + C_3 \qquad (3.1)$$

b. When the train speed is 380km/h：

$$TEL = -10.8 \times \lg\left(r/r_0\right) + C_4 \qquad (3.2)$$

where r as the horizontal distance from the center of rail lines, reference distance $r_0 = 30m$.

By the above formula, on the bridge measurement section of Beijing-Shanghai high-speed railway, with double distance from outside the center line of the rail, the sound level attenuation about 3 dB (A), within the scope of the near field approximation meet infinite long term source with the attenuation law of distance.

According to the above formula, at the bridge measurement section of Beijing-Shanghai high-speed railway, when the distance from the center line of outside rail doubles, the sound level decays 3 dB(A). Within the scope of near noise field , it can meet the attenuation law of infinite long sound source with distance approximately.

### 4.2. Propagation characteristic of the radiated noise on subgrade section

When CRH2C bullet train passed through the subgrade measurement section of Wuhan-Guangzhou high-speed railway at 200～350 km/h speed, the variation trend of TEL relative value along with speed change , outside of the center line 17m、25m and 50m, meanwhile at 1.5m height above the orbital plane, is shown in figure 9 [1].

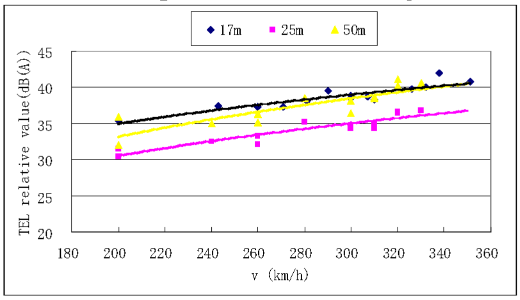


Figure 9. trend of TEL relative value along with speed change at the different distance from the center of rail line on subgrade measurement section

According to the test result, when the train passes through the subgrade section of Wuhan-Guangzhou high-speed railway, the attenuation formula of TEL goes with the distance as below：

a. When the train speed is 300km/h：

$$TEL = -13.3 \times \lg\left(r/r_0\right) + C_5 \qquad (3.3)$$

b. When the train speed is 350km/h：

$$TEL = -12.6 \times \lg\left(r/r_0\right) + C_6 \qquad (3.4)$$

where r as the horizontal distance from the center of rail line, reference distance $r_0 = 30m$ .
According to the regression relation, on the subgrade measurement section of Wuhan-Guangzhou high-speed railway, with double distance from outside the center line of the rail, the sound level attenuation about 3~4 dB (A), within the scope of the near field approximation meet infinite long term source with the attenuation law of distance.
According to the above formula, at the subgrade measurement section of Wuhan-Guangzhou high-speed railway, when the distance from the center line of outside rail doubles, the sound level decays 3 dB(A). Within the scope of near noise field , it can meet the attenuation law of infinite long sound source with distance approximately.

## 5. Conclusions

The test result of high-speed railway noise field vertical distribution characteristic and propagation characteristic prove that:
(1) Noise level is gradually increasing with the increase of the orbital plane height（within the range of 0～5m）on bridge section, approximately equal quadratic function. Train radiated noise spectrum presents broadband characteristics in the 20~4000Hz range, the maximum sound level mainly focused on low frequency 31.5~125Hz, the high frequency component decreases rapidly above 4000Hz.
(2) Noise level decreased gradually with the increase of orbital plane height（within the range of 0～5m）on subgrade section. Noise spectrum presents wide band characteristic. The peak of frequency mainly focus on low frequency (f=31.5~63HZ) and intermediate frequency (f=500~1Khz).
(3)On the bridge and subgrade measurement section, when the distance from the center line of outside rail doubles, the sound level decays 3~4 dB(A).Within the scope of near noise field , it can meet the attenuation law of infinite long sound source with distance approximately.

## References

[1] China Academy of Railway Sciences. The testing report of environment noise, vibration and noise barrier in Wuhan-Guangzhou high-speed testing and commissioning.2009.

[2] China Academy of Railway Sciences. The comprehensive test study of Beijing Shanghai high speed railway report nine: a study report of high-speed railway environment effects The ninth part of research report of Beijing-Shanghai high speed railway comprehensive test——the report of high speed railway environment effect . 2011.

[3] China Academy of Railway Sciences. The general report of comprehensive test study on the Beijing Shanghai high-speed railway. 2011.

[4] China Academy of Railway Sciences. The research report on noise, vibration characteristics on ballastless track and control measures of Beijing-Tianjin intercity train. 2008.

[5] Yin Hao, Li Yaozeng, Gu Xiao'an. Study of the Noise Characteristic of Running Trains of High-speed Railroad. The railway labor health and environmental protection, 2009 (5): 221~224.