湖南省计量检测研究院

HUNAN INSTITUTE OF METROLOGY AND TEST

The Application of Dual-antenna Radar Velocimeter on High-speed Train

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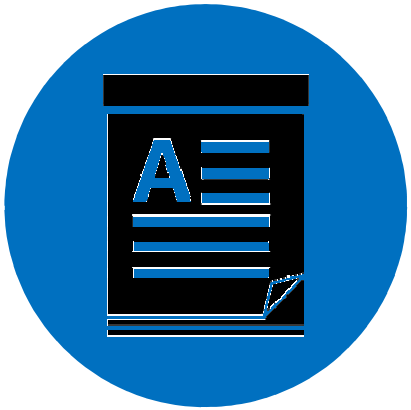

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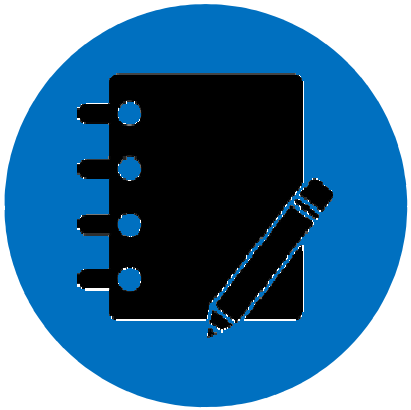

Equipment Introduction

Test Results

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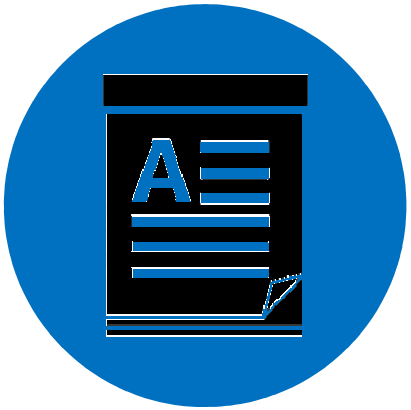

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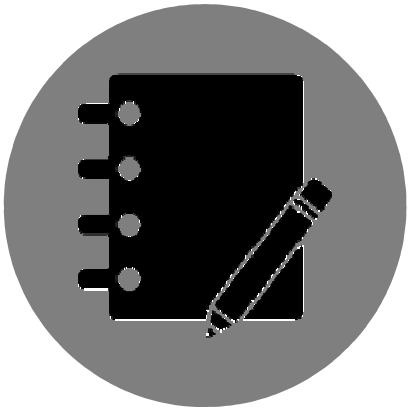


Equipment Introduction

Test Results

Background

As we all known, China is a veritable high-speed superpower. By the end of 2015,China's high-speed rail extends over 19,000 kilometers, accounting for more than 60% in the world.

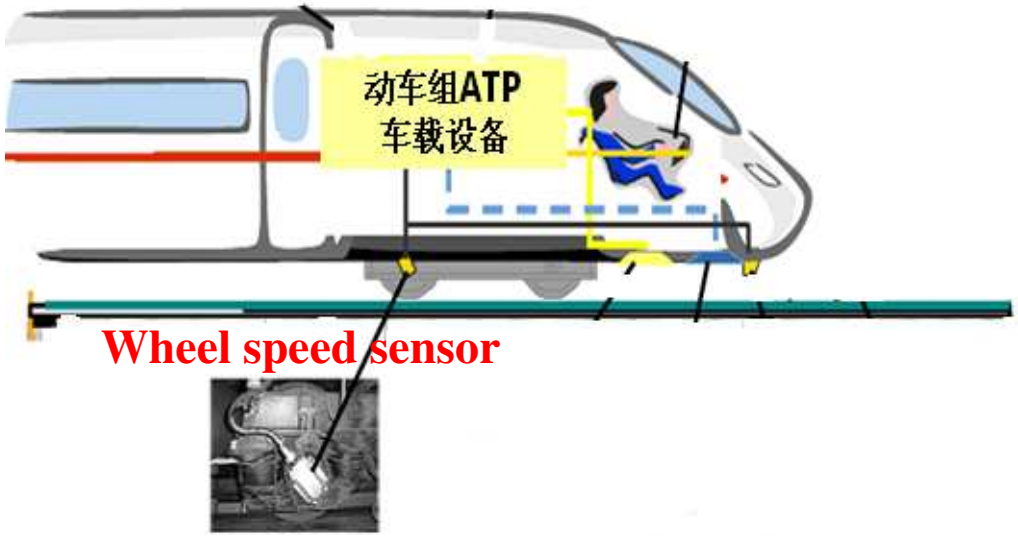
Background

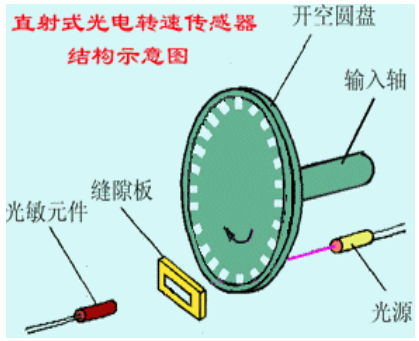
Accurate speed is 394km/h ?

Maybe the speed is 393 or 395 km/h

According to the CTCS-3 (Chinese Train Control System Lever 3), the speed measuring error of High-speed train must be less than 1km/h.

Background





Wheel speed sensor { Magnetoelectric, photoelectric, centrifugal, Hall

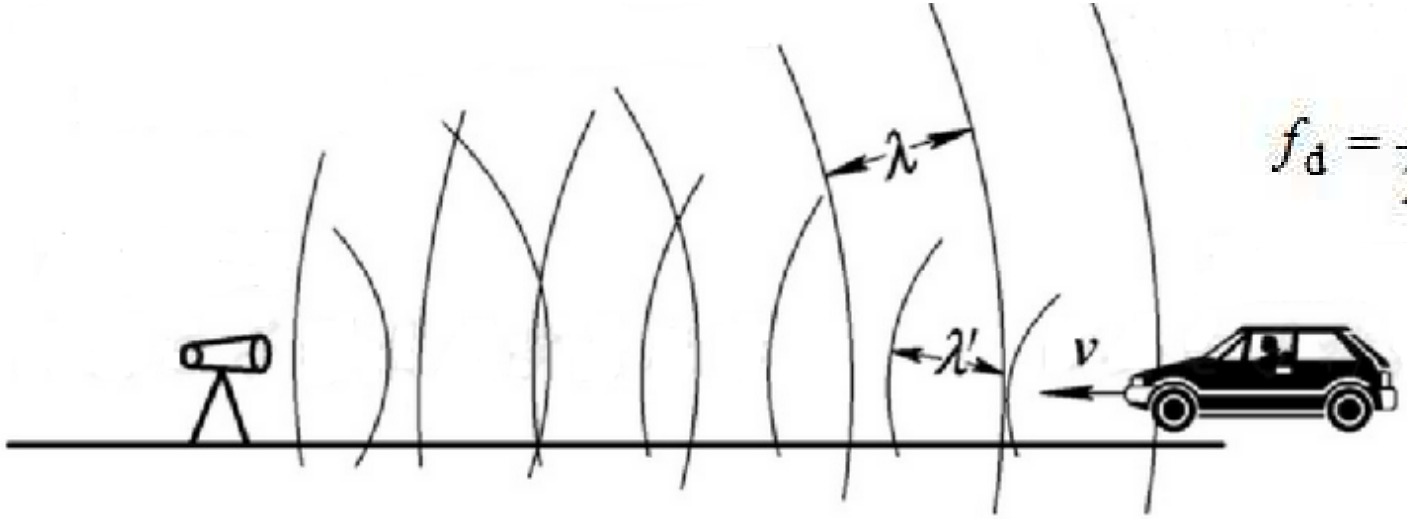
$$v = \pi D n / 3.6$$

D **is the diameter of the wheel**

n **is the rotate speed of the wheel**

Background

When the wheel slipping, invalid impulses will be recorded and the result is error. Another speed measuring method — Doppler radar may be a good way.



$$f_d = \frac{1}{2\pi}\frac{\Delta\varphi}{\Delta t} = \frac{v}{\lambda}\cos\theta$$

According to the CTCS-3 （Chinese Train Control System Lever 3), the new radar velocimeter containing **two planar antennas and DSP** will be built up, and we call it "Dual-antenna Radar Velocimeter. "

Background

1

Reliability

Two planar antennas will work together, so the date will be compared second by second.

2

Integrity

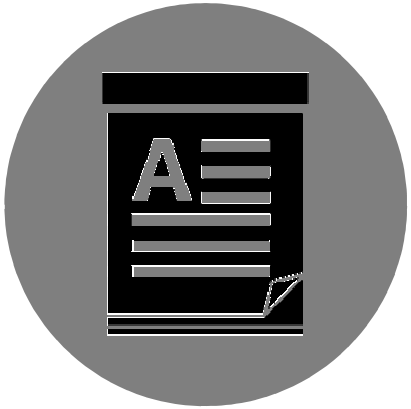
One antenna mainly measures low-speed, and another one mainly high-speed.

3

Accuracy

The abnormal data will be removed, and the output value will be cross-checked.

Contents



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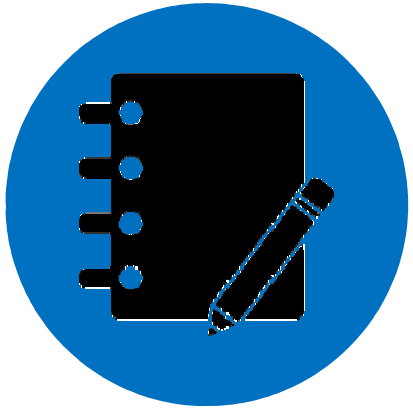
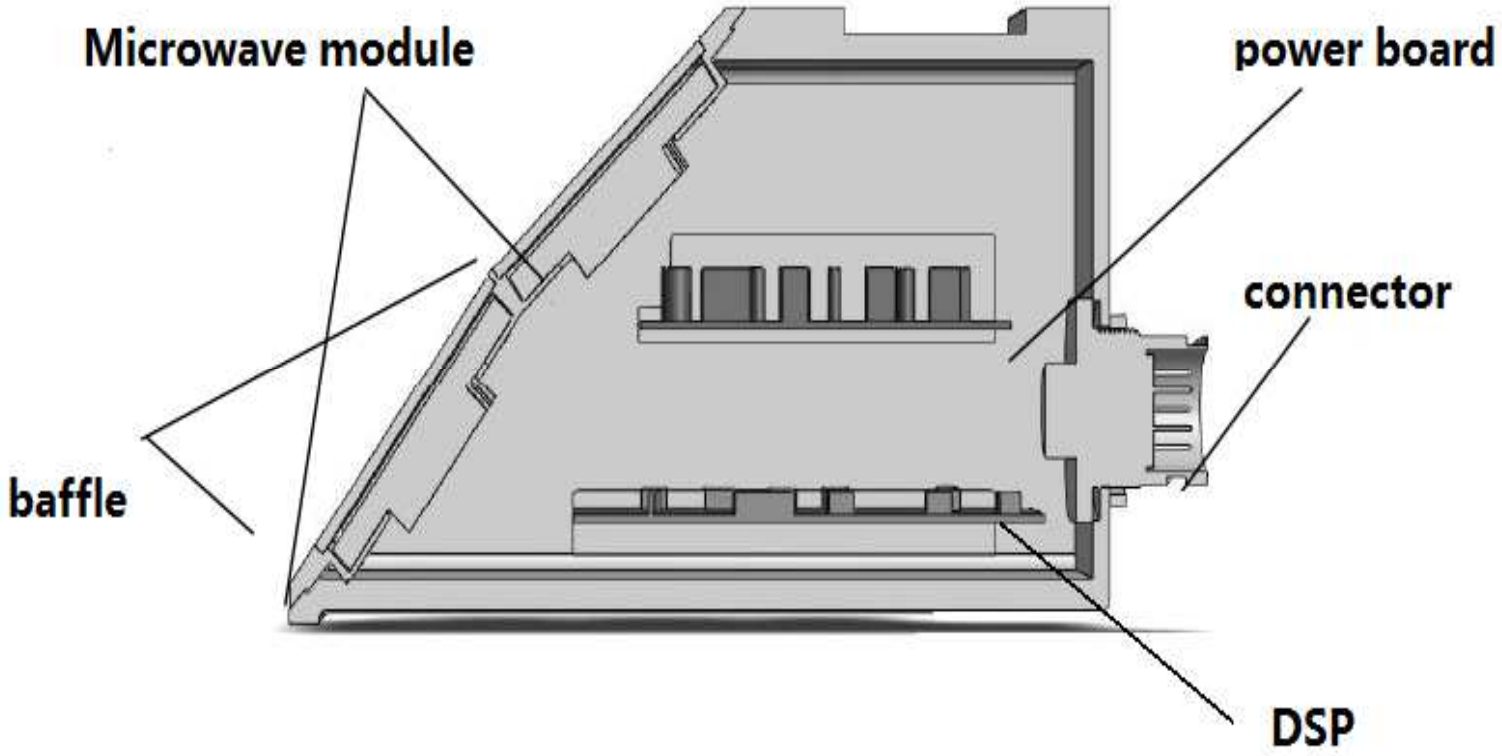


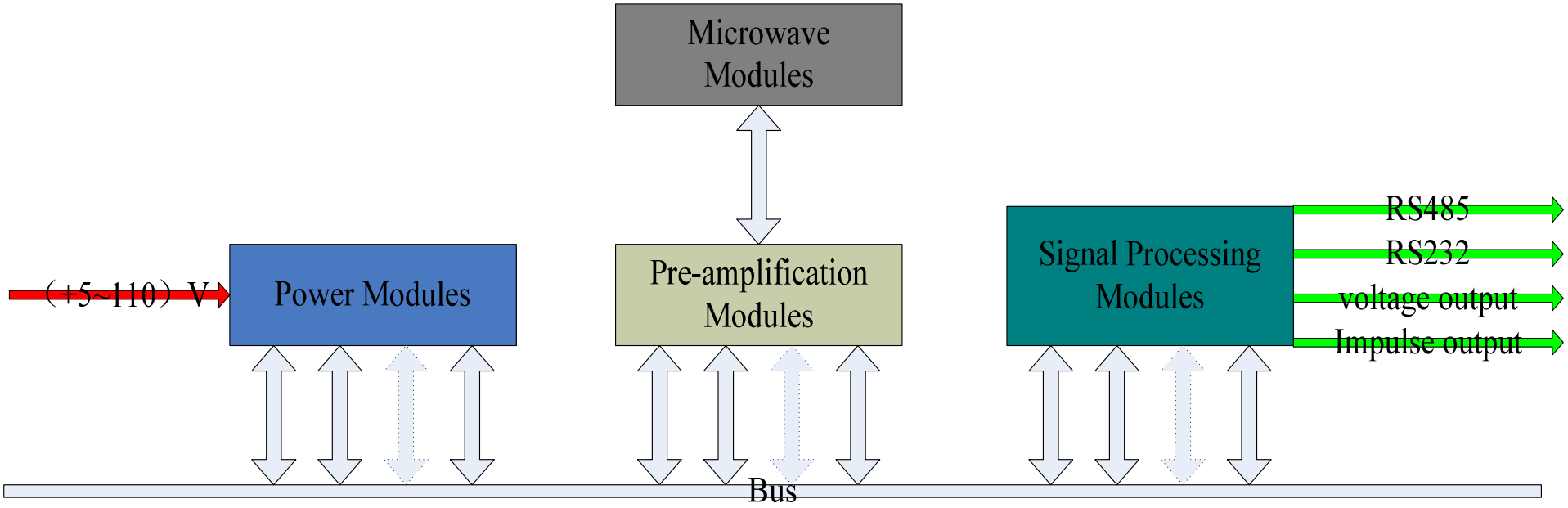
Equipment Introduction

Test Results

Equipment Introduction



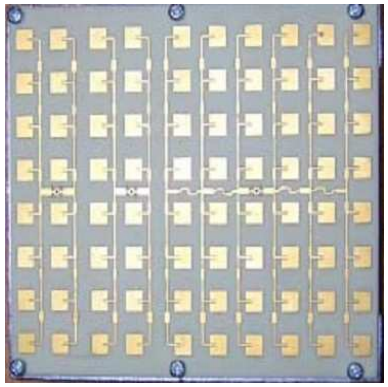
Equipment Introduction



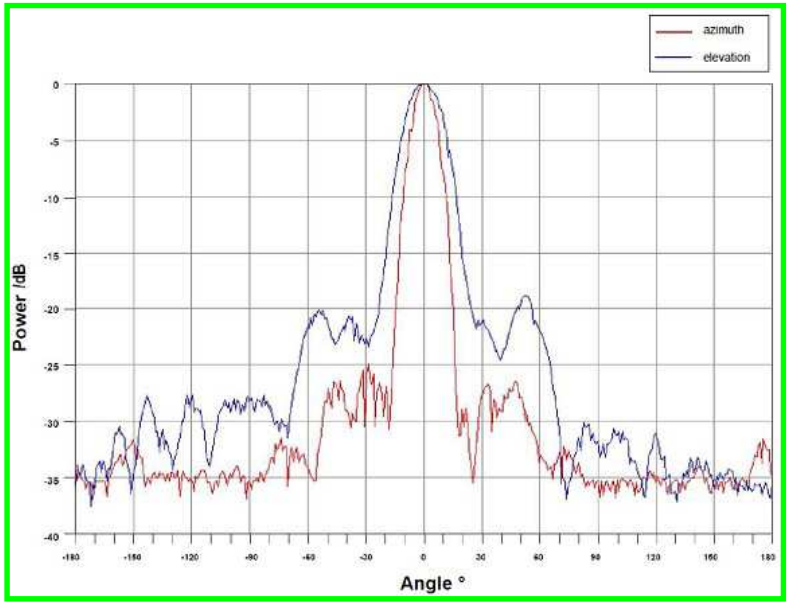
There are four modules: microwave modules, power modules, pre-amplification and signal processing modules.

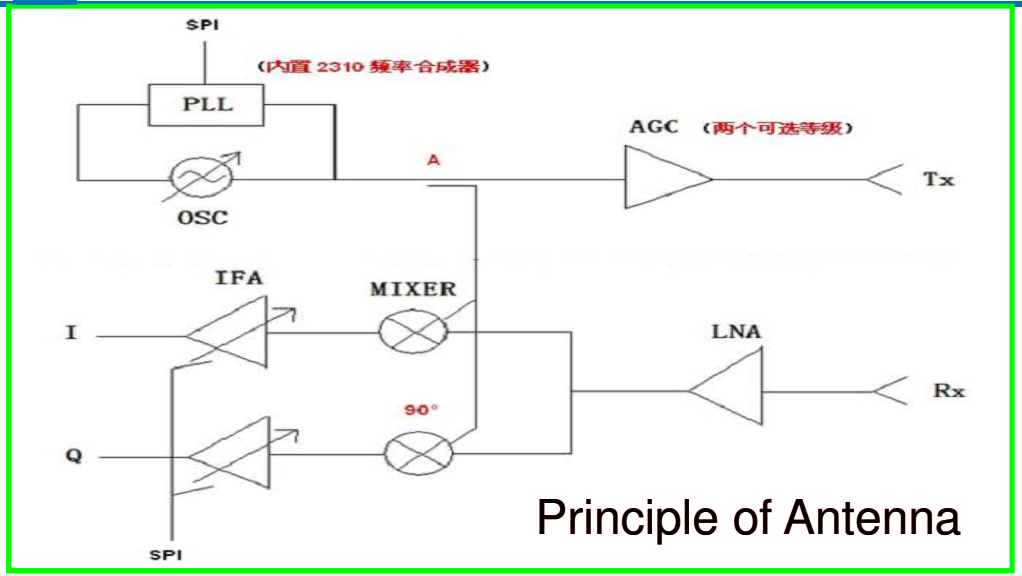
Equipment Introduction

Microwave modules



Microstrip array antenna

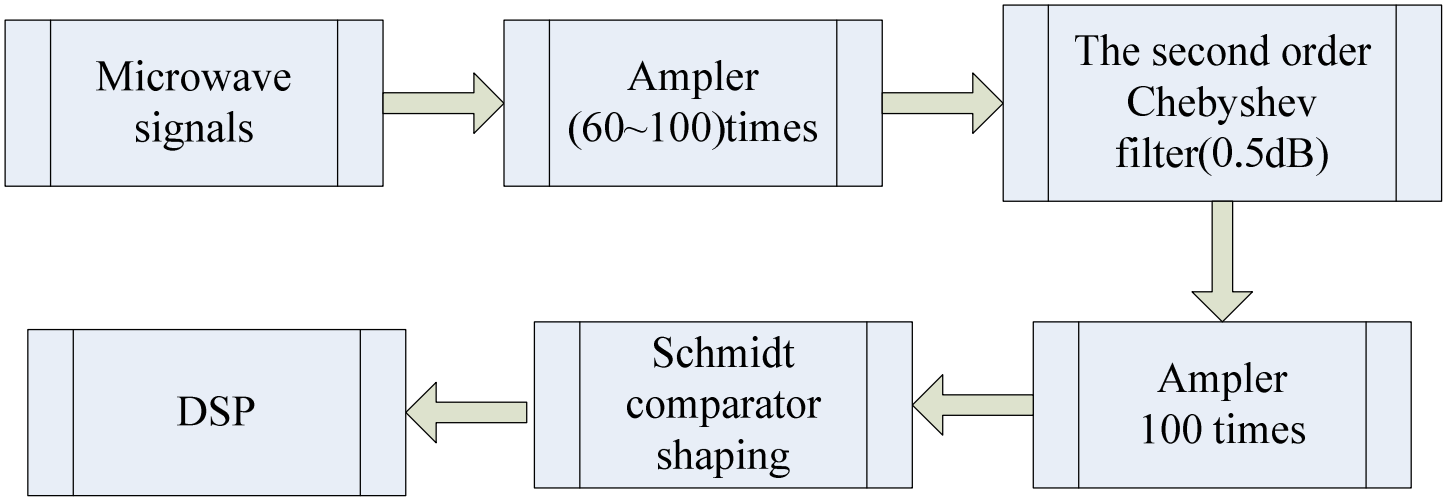




Principle of Antenna

1. K band, Antenna Angle：horizontal 23degrees vertical 13degrees;
2. VCO radar transceiver based on MMIC technology;
3. Working mode :CW/FSK/FMCW;
4. Separate transmit and receive path, the biggest gain can be obtained ;
5. Four reception channel s:I1、Q1、I2、Q2;
6. Dimension ：(70 × 70 × 10)mm

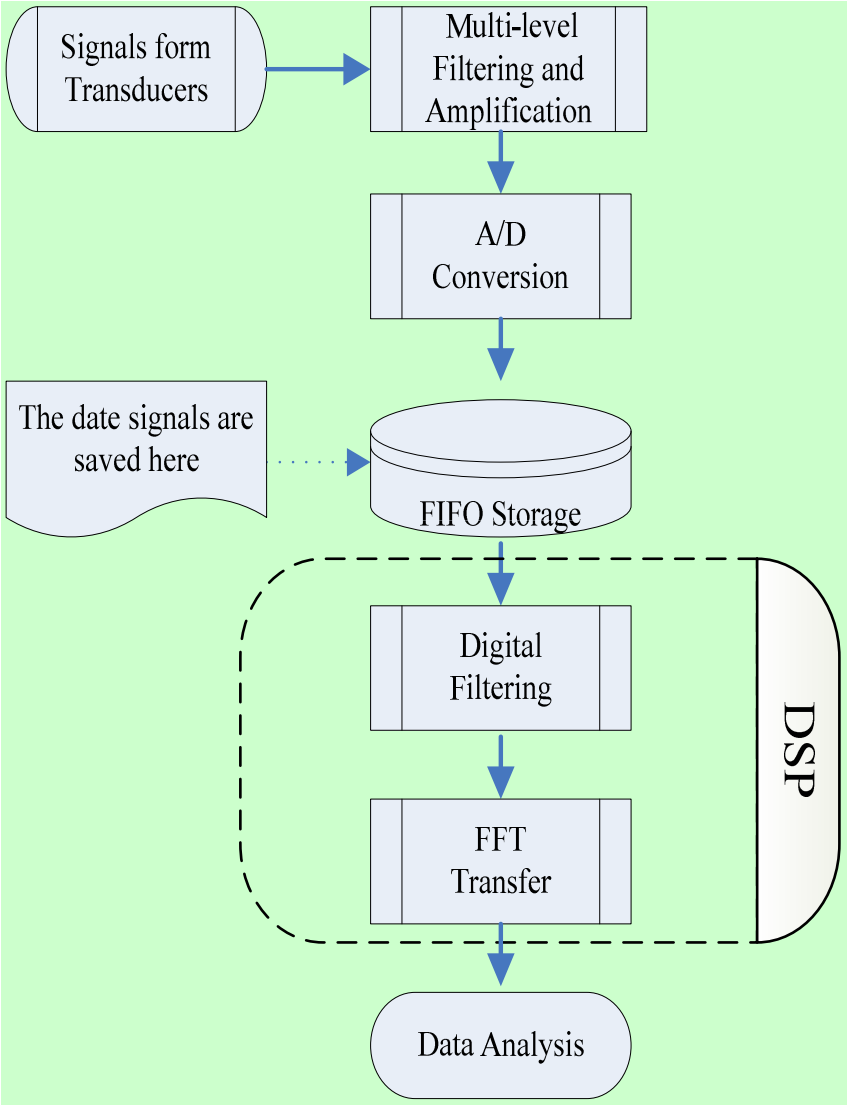
Pre-amplification modules



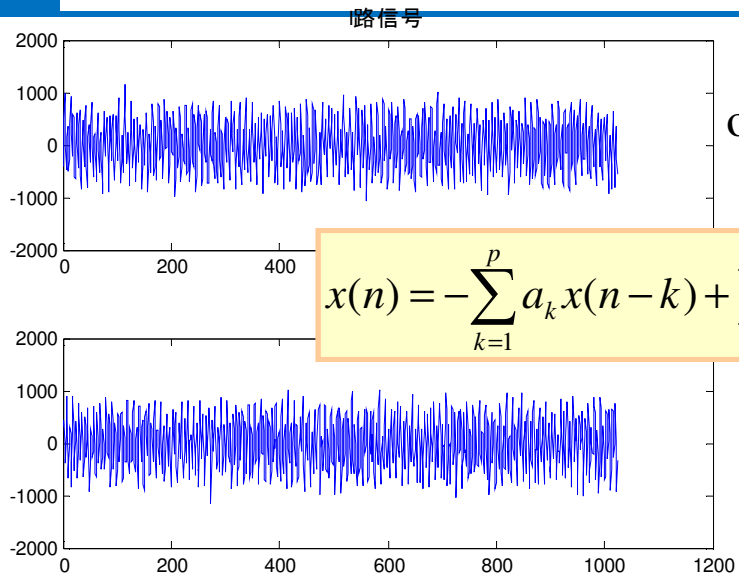
Pre-amplification modules: The MC33079 operational amplifier is used to amplify the weak sine signals about 60~100 times from the microwaves, and then the 50 Hz interference signals will be removed by the second order Chebyshev filter, and then 100 times will be amplified, and will be shapinged by Schmidt comparator, finally the TTL singles will be send to DSP.

Equipment Introduction

Signal processing modules



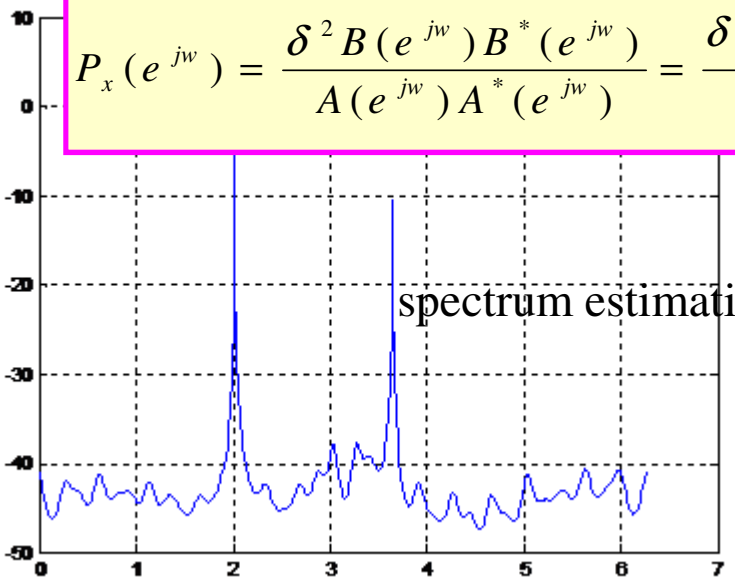
Flow Chart of Signal Processing



original signals

$$x(n) = -\sum_{k=1}^{p} a_k x(n-k) + \sum_{k=0}^{q} b_k u(n-k)$$

$$P_x(e^{jw}) = \frac{\delta^2 B(e^{jw}) B^*(e^{jw})}{A(e^{jw}) A^*(e^{jw})} = \frac{\delta^2 \left| B(e^{jw}) \right|^2}{\left| A(e^{jw}) \right|^2}$$

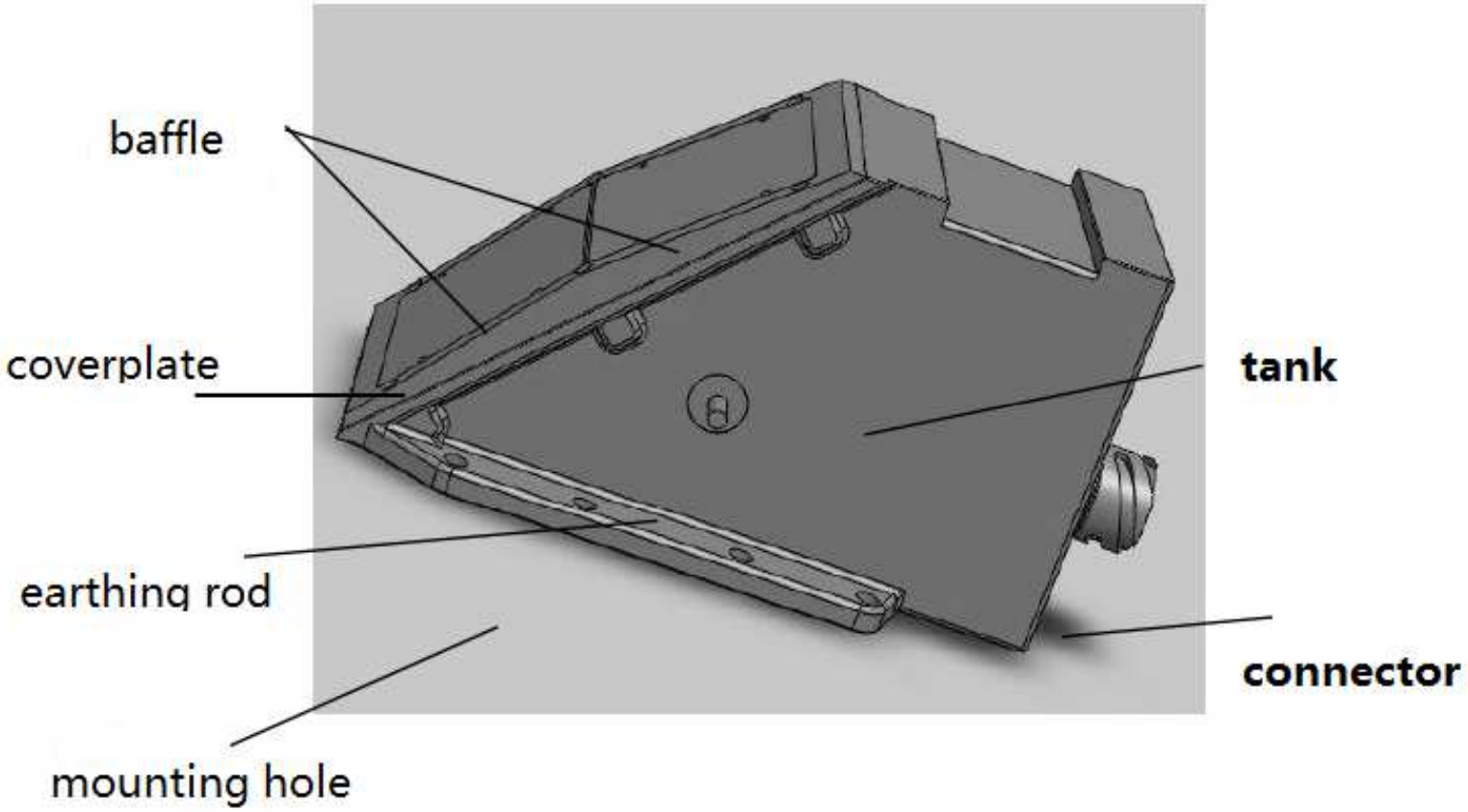


spectrum estimation curve

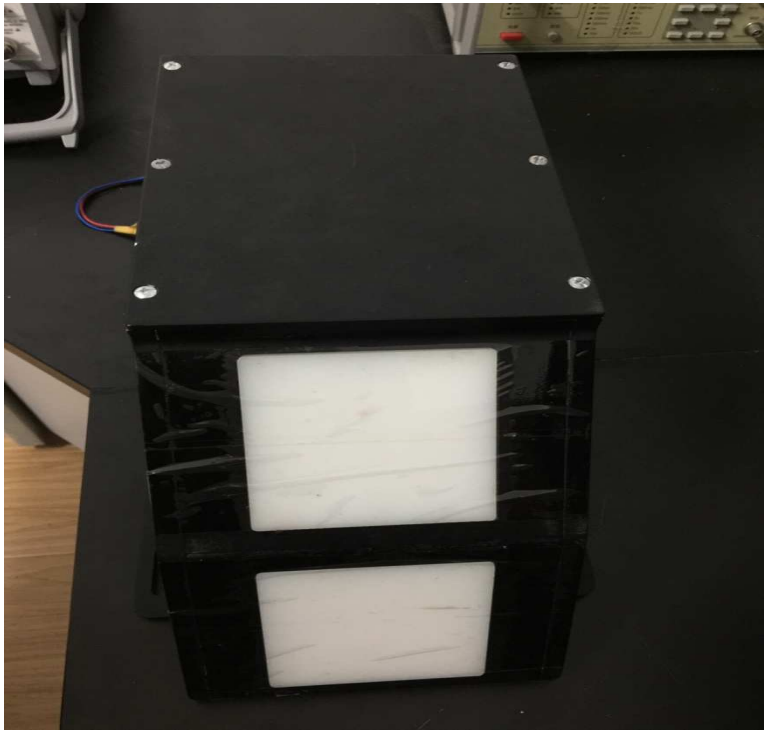
Technical Index

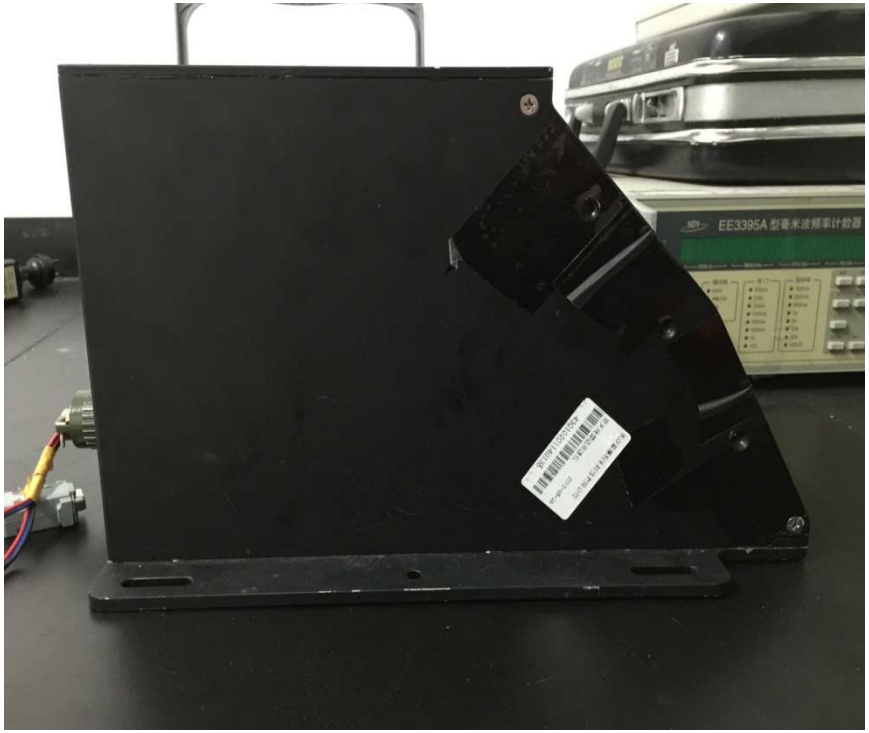
- **Measuring range：**
  （10-400）km/h
  blew 100km/h，MPE:±1km/h；
  above 100km/h，MPE:±1%.
- **Anti-knock；**
- **Bulletproof；**
- **Antifouling；**
- **Electromagnetic compatibility .**

Equipment Introduction



Equipment Introduction





Photos of Prototype

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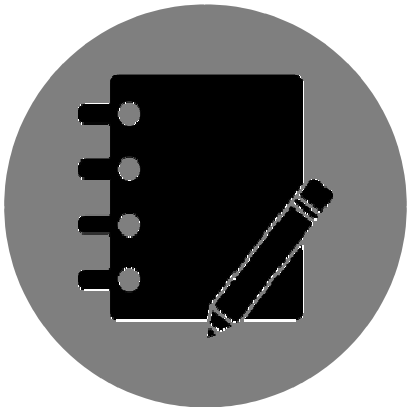
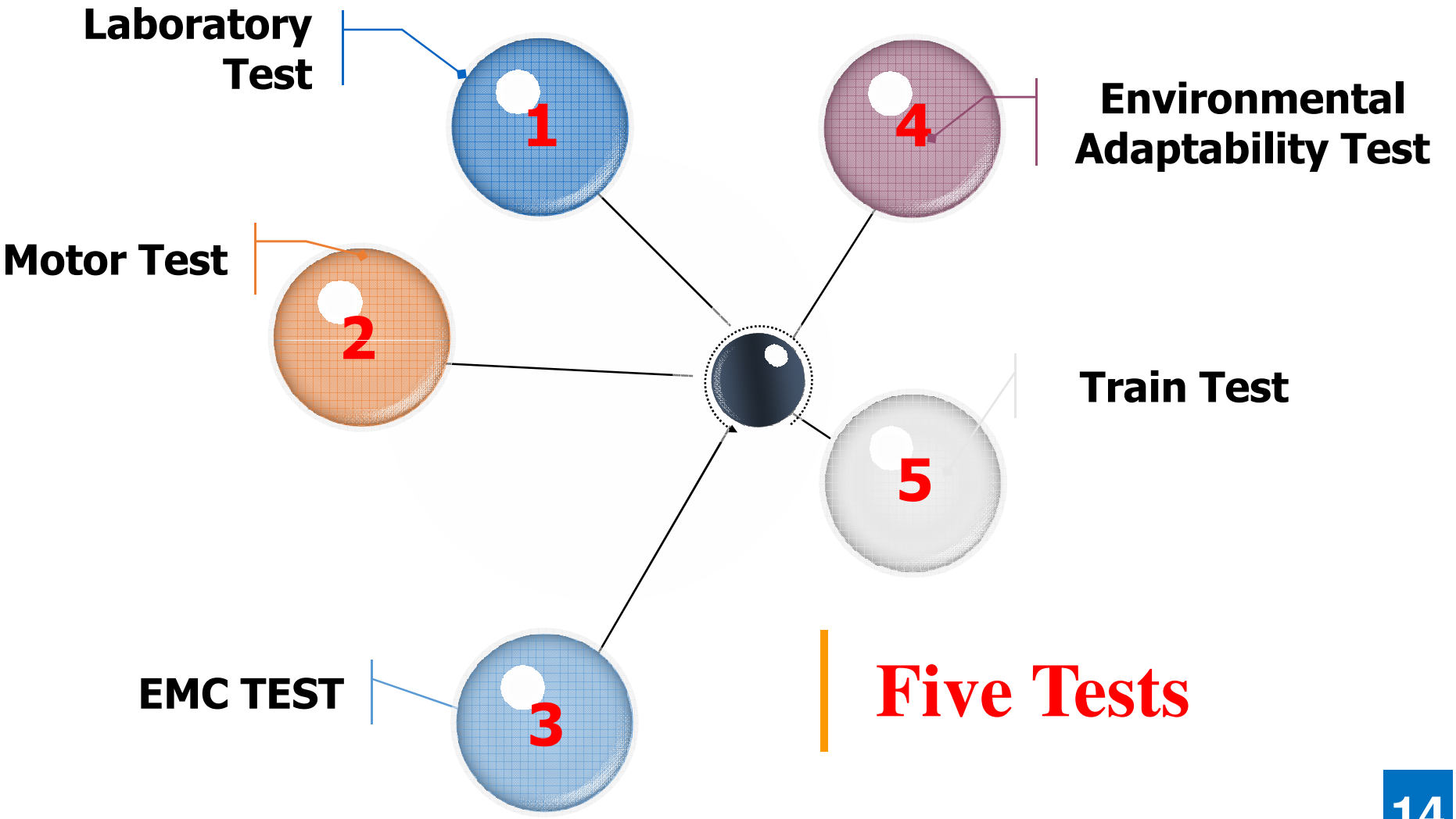
Background



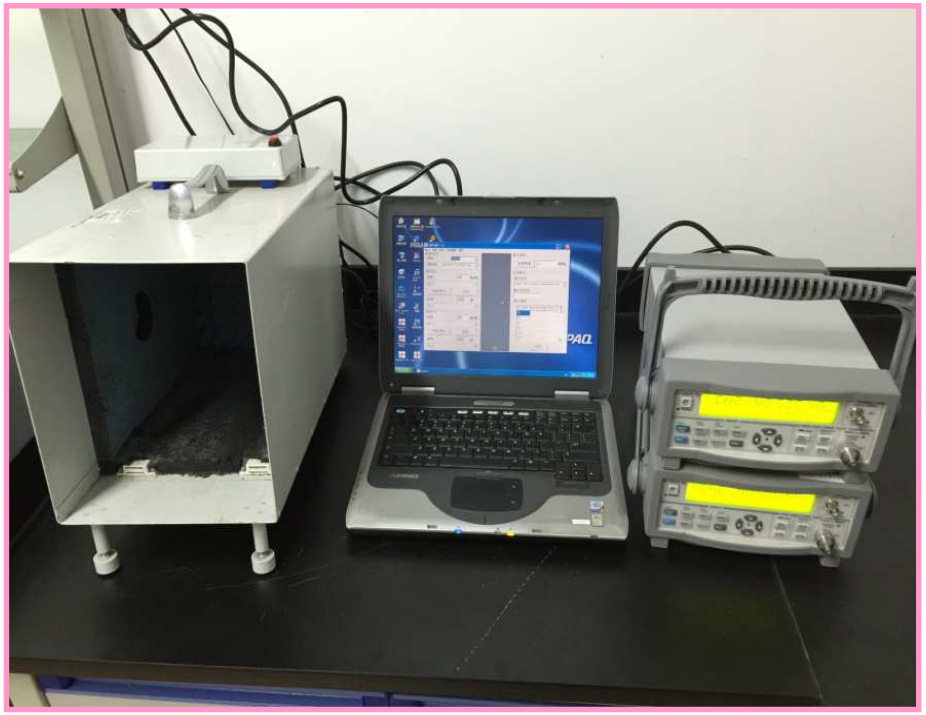
Equipment Introduction

Test Results

Test Results



Laboratory Test



1、Composition：

(1)f =24G Radar calibration module;

(2) Millimeter wave frequency counter;

2、Technical Index：

(1) Range：X、K: (10～400) km/h;

(2) Uncertainty :$U \leq 0.1$km/h, (k=2)；

Test Results

Unit : km/h

Standard	Antenna 1	Antenna 2	Standard	Antenna 1	Antenna 2
10	10.01	10.01	140	140.17	140.17
20	20.02	20.02	150	150.18	150.18
30	30.03	30.03	160	160.19	160.19
40	40.04	40.04	170	170.20	170.20
50	50.05	50.06	180	180.21	180.21
60	60.07	60.07	190	190.23	189.92
70	70.08	70.08	200	200.24	199.94
80	80.09	80.09	210	210.25	209.95
90	90.10	90.10	220	219.96	219.96
100	100.12	100.12	230	229.97	229.97
110	110.13	110.13	240	239.98	239.98
120	120.14	120.14	250	250.00	250.00
130	130.15	130.15	260	260.01	260.01

Test Results

Unit：km/h

Standard	Antenna 1	Antenna 2	Standard	Antenna 1	Antenna 2
270	270.02	270.02	400	400.18	400.18
280	280.03	280.03	/	/	/
290	290.05	290.05			
300	300.06	300.06			
310	310.07	310.07			
320	320.08	320.08			
330	330.09	330.09			
340	340.10	340.11			
350	350.12	350.12			
360	360.13	360.13			
370	370.14	370.14			
380	380.16	380.16			
390	390.17	390.17			

Motor Test

1、Composition：

(1) Standard Velocity Meter L-350;

(2) Multi-channels Data Acquisition DAS-3;

(3) Test vehicle

2、Technical Index：

(1) Range： (10～250) km/h;

(2) Uncertainty : $U \leq 0.1$km/h, (k=2);

Test Results

Test vehicle

Multi-channels Data Acquisition DAS-3

Testing site

Standard Velocity Meter L-350

Test Results

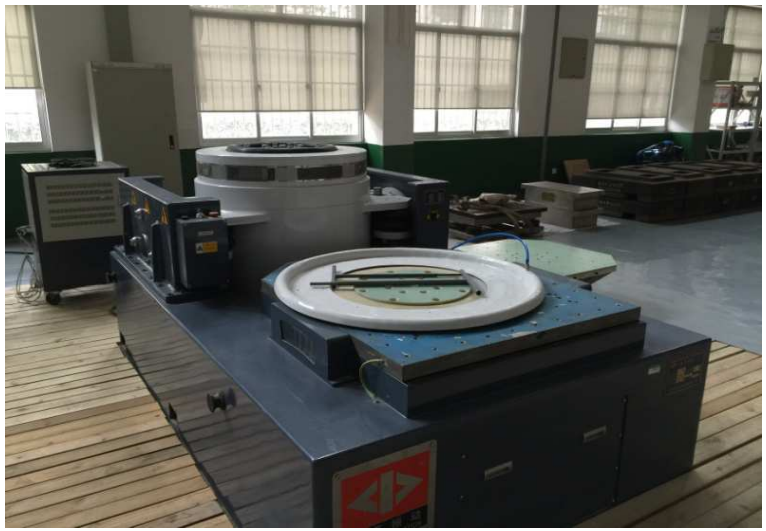
Unit : km/h

Standard	Antenna 1	Antenna 2	Standard	Antenna 1	Antenna 2
21.36	21.53	21.53	25.68	25.88	25.89
32.65	32.99	32.96	36.88	36.90	36.90
41.28	41.58	41.60	45.13	45.62	45.63
50.09	50.28	50.28	56.37	56.42	56.45
61.89	62.03	62.12	66.50	66.87	66.89
72.35	72.85	72.80	76.25	76.42	76.53
83.46	83.95	83.91	86.34	86.45	86.95
90.02	90.25	90.58	96.02	96.22	96.72
100.26	100.31	100.82	105.43	105.81	105.90
110.31	110.54	110.54	116.30	116.33	116.52
120.84	120.95	120.95	125.68	125.92	125.90
130.25	130.61	130.61	135.55	135.85	135.80
141.46	141.93	141.90	146.23	146.73	146.86

EMC Test

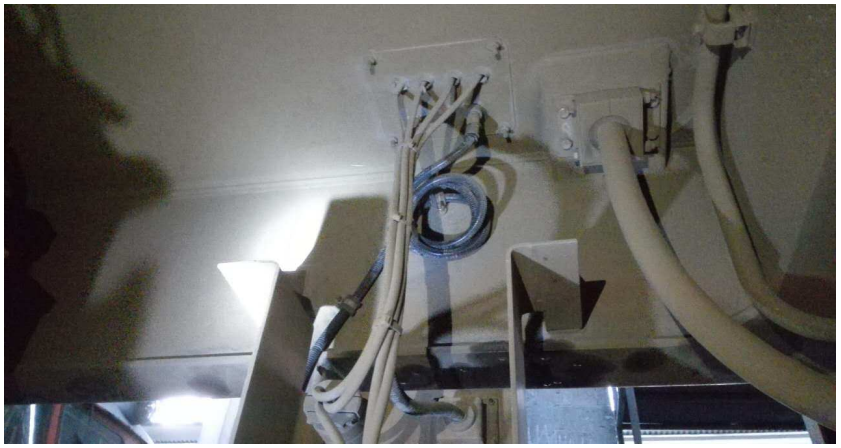
According to general requirements of railway products, the electromagnetic compatibility test should be finished before mass production.

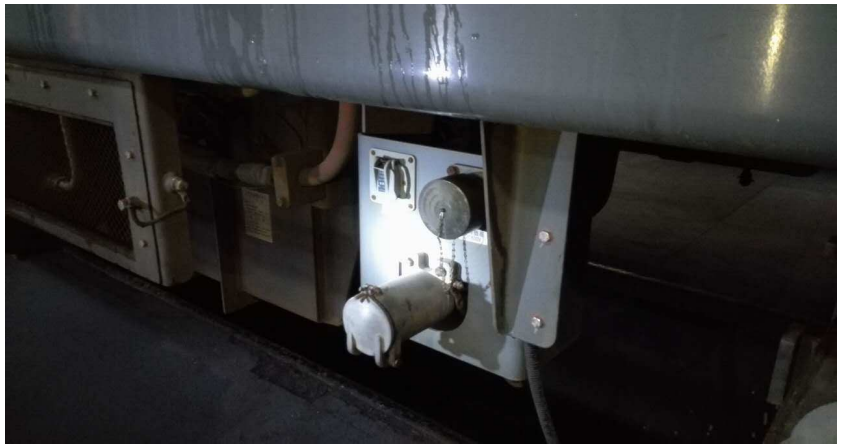
Environmental Adaptability Test



To ensure that the environmental adaptability of the product, the vibration test, impact test, high -low temperature test, sand and dust test, salt spray test must be finished.

Train Test





The test is now under way, so there are no enough test data.

Thanks for listening !