The Analyses and Measurements of Electromagnetic Fields for the Urban Maglev Prototype Vehicle

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ABSTRACT: This paper describes the electromagnetic field measurements for the Korean maglev prototype vehicle for urban applications. The vehicle was built in 1997 and has been under several tests on 1.3 km test track in KIMM (Korea Institute of Machinery and Materials). The electromagnetic fields were measured at several points inside the cabin and outside of vehicle. Also the electromagnetic fields were measured close to the levitation magnets. The measurements were performed at various speeds up to 46 km/h. The measured frequency range of electromagnetic fields were from DC to 300 GHz. The measured electromagnetic field data were compared with those of a conventional subway system. It was confirmed that the electromagnetic fields of the Korean maglev prototype vehicle satisfy the ICNIRP guidelines for electromagnetic field exposure.

1 INTRODUCTION

Although the electricity provides easy and fast life for modern society, electromagnetic field exposure to people from varieties of electronic products has been concerned for a part of environmental issue.

An electric railway, which is running for public transportation now, takes the same electric power system as the urban transit Maglev does. The traditional railway relies on the friction between the train and the rail; however, the Maglev uses non-contact system utilized by magnetic forces. The Maglev at a constant distance of approximately 10mm from the guide way (track) gets propulsion force from linear induction motor. Because of its light weight transporting advantage compared to heavy one, the Maglev can be utilized for the branch lines between the main lines. Also, due to the low noise and vibration production from the train, it can be constructed on the elevated state from the ground. Since it has advantages for planning line construction for these reasons, the government can minimize the land compensation money for removal.

The Maglev systems are divided into levitation control, propulsion control, braking, power conversion, and current collector system. The levitation control system is separated into levitation magnet for levitation force, chopper for supplying electric power to electromagnet, and levitation controller for controlling levitation condition. The propulsion control system is composed of linear induction motor for generating propulsion force, inverter for supplying electric power to electromotor, and converter which is transferring DC 1,500V from ground electric source to vehicle's electric sources.

Figure 1. Urban Transit Maglev(Prototype)

Above systems are harmonically driven with each others. Also, the levitation control system is supplied by voltages of DC 100V, DC 300V, and AC 110V from the converter. The power conversion system is made up of the converter and inverter. The converter uses DC 1,500V input for generating DC 100V, DC 300V, and 3 dimensional AC 220V auxiliary electric source inside vehicle. The inverter converts DC 1,500V input to 3 dimensional AC 1,280V for driving linear induction motor.

In this paper, we investigated and analyzed the electromagnetic field exposure from the Maglev train as a fact of environmental influence, and compared the measured data with WHO/ICNIRP guidelines.

2 ELECTROMAGNETIC FIELD MEASUREMENTS

2.1 Measurement methods

The electromagnetic fields from the Maglev train were measured under the standard electromagnetic field measurement method of KRRIS (Korea Research Institute of Standards and Science) and the measurement equipments which were accredited by KRRIS Electromagnetic Metrology Center were used for fair measurements. According to the standard electromagnetic field strength measurement, the low frequency band means a range of 0Hz ~ 10kHz, and the high frequency band means a range of 10kH ~ 300GHz.

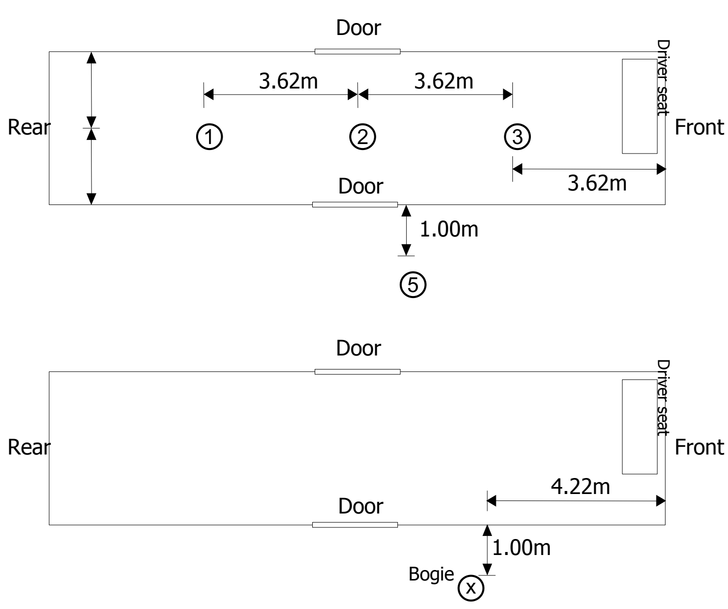

Figure 2. Position of measurements, up is inside cabin, down is outside

Three different measurement points were uniformly fixed inside the vehicle because there are 3 bogies in the low part of the vehicle. Individual bogie has eight levitation magnets and two linear induction motors. The inside of the tested vehicle is shown in Figure 2. DC/DC converter is attached underneath of point ①, filter reactor of propulsion controller is equipped in point ②, and VVVF inverter, which is a propulsion controller, is located on point ③. Point ⑤ is fixed according to the base distance and height of waiting platform. Point X is spotted on standard height for maintenance. The survey was done by measuring the highest value of electromagnetic fields at the time of lending and completion of levitation at a stop. Also, the measurement was taken when the train was passing through point ⑤ at maximum speed.

2.2 Measuring equipments

The AC magnetic field measuring equipments are listed in Table 1 (high frequency measuring equipments) and Table 2 (low frequency measuring equipments). These equipments were officially inspected by KRRIS.

Table 1. List of measuring equipments for high frequency

Name of Equipment	Model	Range of Frequency
Spectrum Analyzer	Agilent 4407B	9kHz to 26.5GHz
Amplifier	Sonoma 310	9kHz to 1GHz
Amplifier	HP 8349B	2GHz to 20GHz
Rod Antenna	Electro Metrics	10kHz to 32MHz
Biconical Antenna	R/S HK 116	30MHz to 300MHz
Log-Peridodic	R/S HL 223	200MHz to 1GHz
Horn Antenna	Electro Metrics	1GHz to 18GHz
RF cable		
Tripod for Antenna		

Table 2. List of measuring equipments for low frequency

EFA-200	EFA-300
Integrated coil system(B field)	Integrated coil system(B field), electrode(Etofield module)
Triaxial (isotropic) or monoaxial	
5Hz to 2kHz, 30Hz to 2kHz, 5Hz to 32kHz or 30Hz to 32kHz	
15Hz to 2kHz	
RMS value (averaging time = 1sec) or peak value (with proper phase)	
4nT(100cm^2 probe) to 32mT	4nT(100cm^2 probe) to 32mT, 0.7V/m to 100kV/m
5Hz to 32kHz	
< 0.4% to 200%	< 0.4% to 200% (H field) < 5% to 200% (E field)
5Hz to 2kHz or 40Hz to 32kHz	

0.01 Hz or 0.1Hz	
3600 single value or 22 spectral analyses	3600 single values or 22 spectral anaylses (each for B field or E field)

2.3 A standard electromagnetic strength

The standard electromagnetic strength for the public is shown in Table 3.

Table 3. Guidelines for limiting exposure to time-varying electric and electromagnetic fields (up to 300GHz)

Frequency range	**E-field strength (V/m)**	**H-field strength (A/m)**	**B-field (μT)**	**power density (W/m^3)**
up to 1Hz	-	3.2×10^4	4×10^4	
1Hz~8Hz	10,000	$3.2\times10^4/f^2$	$4\times10^4/f^2$	
8Hz~25Hz	10,000	4,000/f	5,000/f	
25Hz~0.8kHz	250/f	4/f	5/f	
0.8kHz~3kHz	250/f	5	6.25	
3kHz~150kHz	87	5	6.25	
150kHz~1MHz	87	0.73/f	0.92/f	
1MHz~10MHz	$87/f^{1/2}$	0.73/f	0.92/f	
10MHz~ 400MHz	28	0.073	0.092	2
400MHz~2,000MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	f/200
2GHz~300GHz	61	0.16	0.20	10

3 RESULTS

3.1 Measurement results at the low frequency band

The electromagnetic field data from test Maglev train (UTM-01) during levitation and lending at a stop were shown in Table 4.

Table 4. Measured at static state (f : 40Hz~32kHz)

Measuring Position	Measuring level 0cm(μT)		Measuring level 55cm(μT)		Measuring level 80cm(μT)	
	landing	levitated	landing	levitated	landing	levitated
①	1.34	1.96	0.29	0.41	0.20	0.26
③	0.17	0.17	0.13	0.11	-	-
⑤	-	-	0.15	0.16	0.10	0.11
⑤-0	-	-	0.15	-	-	-
boggie	-	-	-	-	0.15	0.18

Electromagnetic field strength at the bottom of point ①, where the DC/DC converter is located, was 1.96μT at the frequency band range of 40Hz ~ 32kHz. The value of electromagnetic field at potential transformer of converter was higher than other parts. Table 5 shows the electromagnetic field distributions of 55cm levitation at a stop, and in the case of 60Hz frequency, the data was measured as 0.55μT which is much lower than general public exposure to time-varying electric and electromagnetic fields of 83.3μT.

Table 5. Measured at static state (f : 60Hz)

Measuring Position	Measuring level 0cm(μT)		Measuring level 55cm(μT)		Measuring level 80cm(μT)	
	landing	levitated	landing	levitated	landing	levitated
①	-	-	0.15	0.15	-	-
③	-	-	0.05	0.05	-	-
boggie	-	-	-	-	0.03	0.12

The electromagnetic fields inside the vehicle at the running condition are shown in Table 6. Likewise, since the maximum measurement results at the running speed of 46km/h was 0.51μT(60Hz), it is determined that the electromagnetic field environment is safe enough to satisfy the ICNIRP guidelines.

Table 6. Measured running state (f : 60Hz)

Measuring Position	Measuring level 0cm(μT)		Measuring level 55cm(μT)		Measuring level 80cm(μT)	
	landing	levitated	landing	levitated	landing	levitated
①	-	-	0.15	0.30	-	-
②	-	-	0.01	0.51	-	-
③	-	-	0.04	0.22	-	-

3.2 Measurement results at the high frequency band

The electromagnetic field exposure of UTM-01 at the high frequency band (10kHz ~ 300GHz) was measured by installing standard antenna on 3 different parts of inside the vehicle as shown in Figure 2 and 3. Table 8 shows those data. As shown in Table 8, the highest value at the high frequency band was 0.115V/m(25kHz) at a central point of boggie side under the train. The value at the high frequency band is 1/756 of the ICNIRP guidelines. (87V/m).

In the case of 30MHz ~ 300MHz, the highest measurement value was 0.038V/m (30MHz), which is 1/1350 of the ICNIRP guidelines.(28v/m). Also, only outside noises, such as FM and TV broadcasting signal, were captured.

Table 7. Results of measured values at high frequency range

Measuring Position	Measuring value (Max.)		Guideline
	Frequency	E-field strength	Public (V/m)

		(V/m)	
Static state ⑤			
landing	2.3MHz	0.005	57
levitated	1.0MHz	0.040	87
	30MHz	0.034	28
Inside cabin ①			
landing	1.0MHz	0.071	87
levitated	1.0MHz	0.079	87
Inside cabin ②			
landing	1.0MHz	0.071	87
levitated	1.0MHz	0.071	87
Inside cabin ③			
landing	1.0MHz	0.079	87
	31.1MHz	0.032	28
levitated	1.0MHz	0.063	87
	30MHz	0.038	28
Running state (inside ②)			
	1.0MHz	0.071	87
Boggie side ⊗			
landing	25kHz	0.115	87
levitated	25kHz	0.012	87
	31.9MHz	0.038	28

The electromagnetic fields generated by Maglev (UTM-01) were measured on 1.3km test track in KIMM (Korea Institute of Machinery and Materials) at a maximum speed of 46km/h, and the measurement results indicated that the electromagnetic field exposure is extremely small and does not exceed the guideline from ICNIRP.

Also, further electromagnetic field measurements will be continued for UTM-02.

6 REFERENCES

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