PAPER

Environmental Magnetic Fields in the Yamanashi Test Line

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In this paper, we report on environmental magnetic fields in the Yamanashi Test Line. Magnetic field levels measured in several points are within the objective value of environmental protection and agree with assumed magnetic field levels. Based on this measurement, we show that the magnetic fields has main spectrum at the frequency corresponding to bogie pitch and assess environmental magnetic fields at 500km/h .

keyword : environmental magnetic fields, Yamanashi Test Line, Superconducting magnetically levitated trains

1. Introduction

Recently, influence of magnetic field with Extremely Low Frequency (ELF) to electronic equipment and humans has been attracting peoples' attention. In addition to power supply lines and electric equipment, linear motor cars (including magnetically levitated trains) can be considered as a source of alternating magnetic field. Therefore, it is important to clarify the magnetic field levels of linear motor cars in the development process.

Superconducting magnetically levitated trains use SuperConducting Magnet (SCM) for levitation, guidance and propulsion of vehicle, which is an essential part of this system. The magnetic field pertaining to this SCM moves with vehicles and, therefore, this magnetic field is observed as an alternating (AC) magnetic field in the environment of track. Propulsion current flowing in propulsion coils of Linear Synchronous Motor (LSM) might be another source of (alternating) magnetic field in environments. However, the alternating magnetic field originating from propulsion coils is negligible compared with the one from SCM because of difference in the magnitude of current of both sources, therefore, we will focus on the magnetic field by SCM hereafter.

In addition, the maximum frequency of magnetic field anticipated in the environment is about 50Hz at a vehicle speed of 500km/h. This frequency range belongs to ELF. This magnetic field does not have the property of electromagnetic wave and decreases more rapidly according to the distance between current source and observatory point.

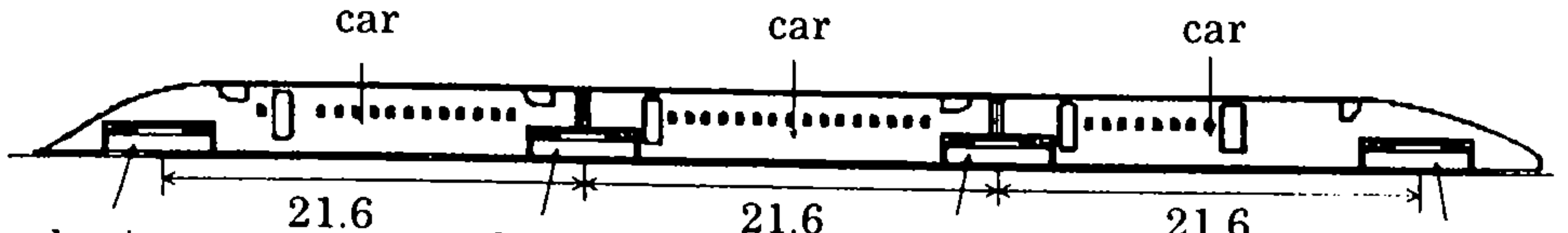


Fig. 1 Vehicles used for the Yamanashi Test Line (unit : m)

2. Yamanashi Test Line and vehicle

Fig.1 shows vehicles used for the Yamanashi Test Line (first train set)[1] . This train set consists of three cars and four bogies. One bogie contains eight SuperConducting coils (SC coils). Each SC coil is energized into the direction opposite to its adjacent SC coil on the same side, but two SC coils which constitute a pair on both sides are energized into the same direction. Arrows in Fig.2 mean the direction of energization of each SC coil. Table1 shows the specification of each SC coil[2]. Based on this SC coils' configuration, we estimate the levels of alternating magnetic field in the Yamanashi Test Line, when vehicles run.

Fig 3 shows the cross section of standard viaduct of the

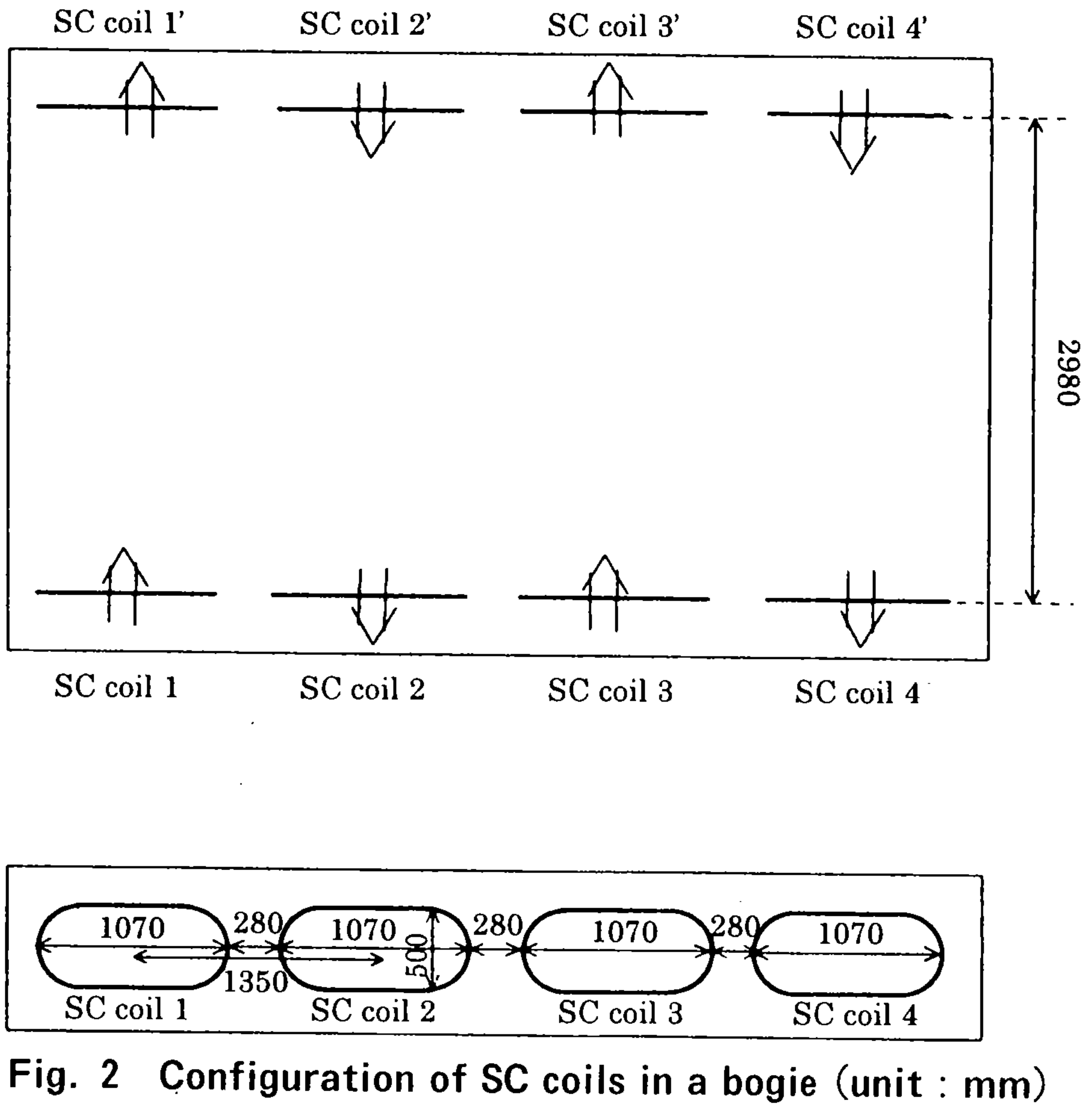


Fig. 2 Configuration of SC coils in a bogie (unit : mm)

Table 1 Specification of each SC coil

Shape	racetrack
Length 1.07m,	height 0.5m
Exciting current	700kA

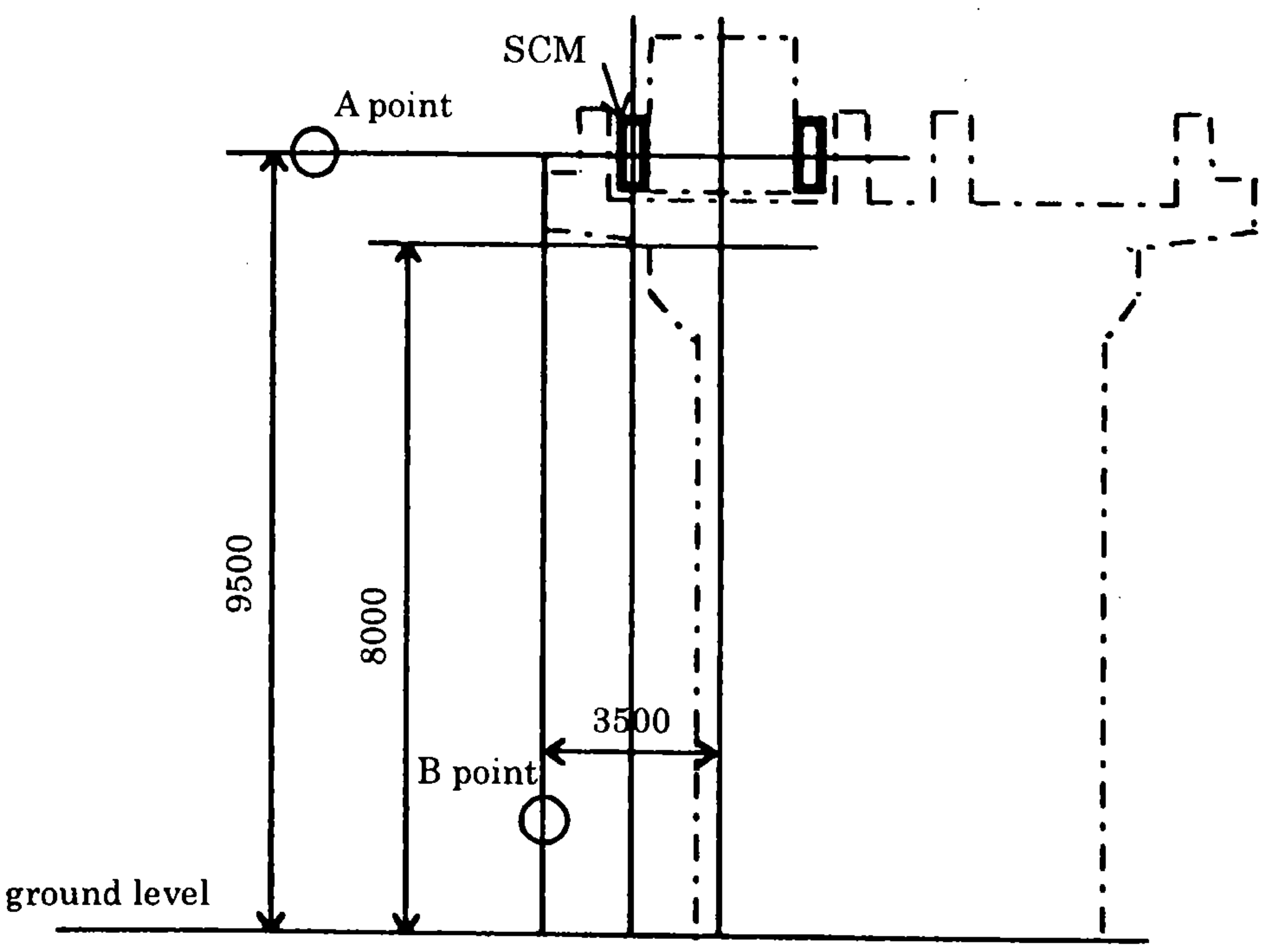


Fig. 3 Cross section of standard viaduct (unit : mm)

Yamanashi Test Line. Measurement was performed at the same level as that of SCM (point A) and directly under the end of track formation (point B). The point B is selected because its magnetic field level is higher than that of other observation points at the same height.

3. Measurement result

To measure magnetic fields, we use MultiWave System II (Electric Research and Management Inc. in US), which

Table 2 Specification of MultiWave System II

Precision	0.56 m Gauss (DC) and 0.02 m Gauss (AC)
Range of frequency	DC -3kHz
Range	0.05 m Gauss - 5.75 Gauss
Sensor	tri-axial fluxgate type

was used to measure static and alternating magnetic fields in Transrapid in Germany and TGV in France.[4] We show the specification of this instrument in table 2.

Fig.4 shows measurement positions in the Yamanashi Test Line. Measurement was performed at five measurement positions of ①,②,③,④ and ⑤ in Fig.4 on March 10 and 14, 1997, with the presence of Yamanashi prefecture office and Yamanashi University. A sensor was set at the same level (height) as that of SCM in positions ① and⑤ , set at the height of 1.5m from the ground level in position ④ and set at the ground level in positions ② and ③. Fig.5 shows a picture of measurement in position ③. Fig.6 shows measured and estimated (calculated) environmental magnetic field wave forms at position ①. Bx, By, Bz and | B | mean the component of direction of travel, direction of guidance, vertical direction and composed value (s.t. $|B| = (Bx^2+By^2+Bz^2)^{1/2}$) of magnetic field, respectively. Fig.6 (a) is an observed wave form of magnetic field. The wave form is composed of two components. One is static (DC) field (bias), which exists regardless of whether vehicle exists or not. The other is alternating magnetic field originating from SCM, which is superimposed on the static field. Fig.6 (b) shows the wave form of the magnetic field in Fig.6 (a) from which the static field (bias) is subtracted. Fig.6 (c) is a wave form calculated by Biot-Savart formula. From this Fig., we conclude the following.

1) Fig.6 (b) and (c) are in agreement.
2) Four wave cycles are observed, each corresponding to one bogie (with eight SC coils).

Thus, the fundamental frequency of this alternating magnetic field can be regarded as $21.6/v$ (Hz), where v is

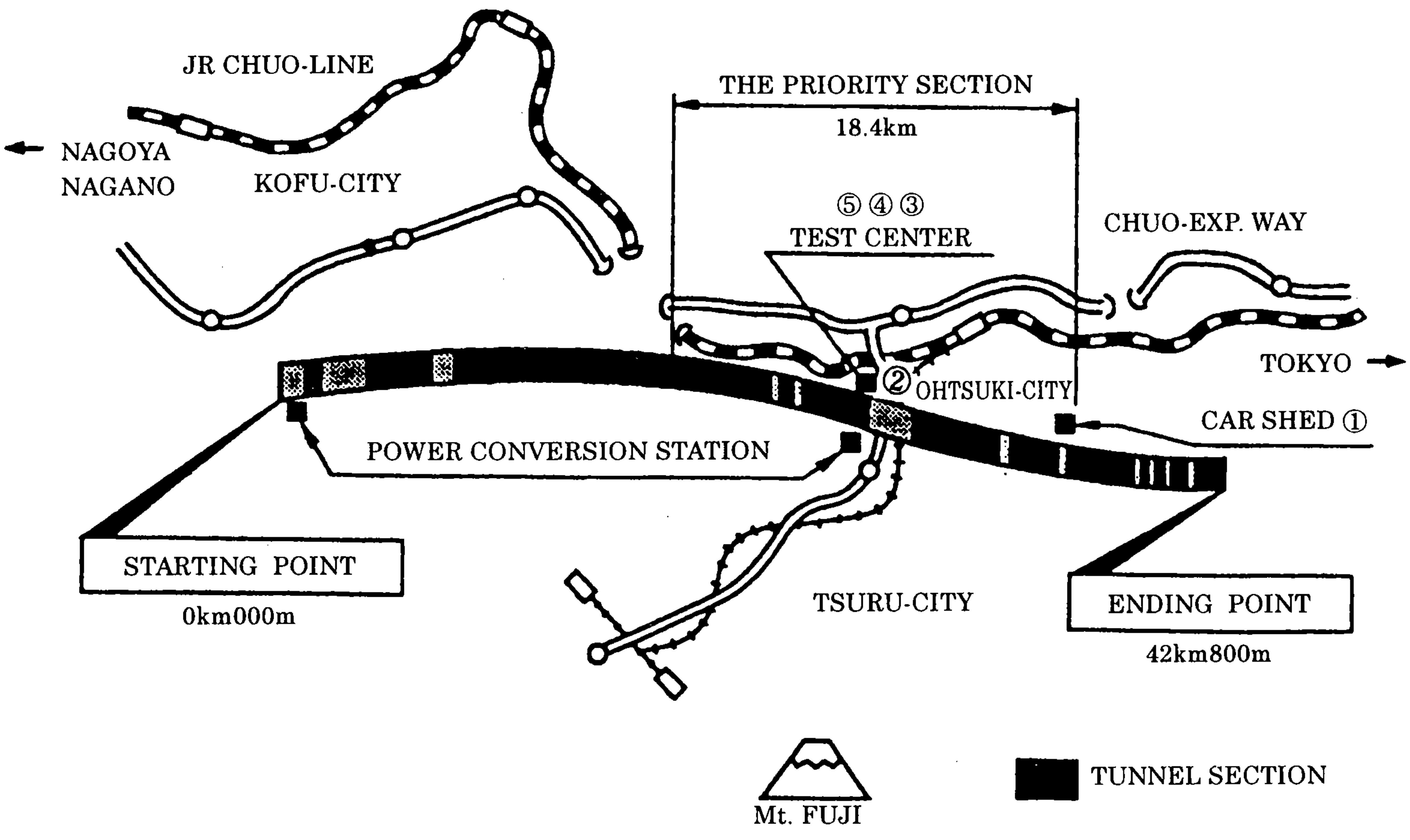


Fig.4 Yamanashi Test Line and its measurement positions

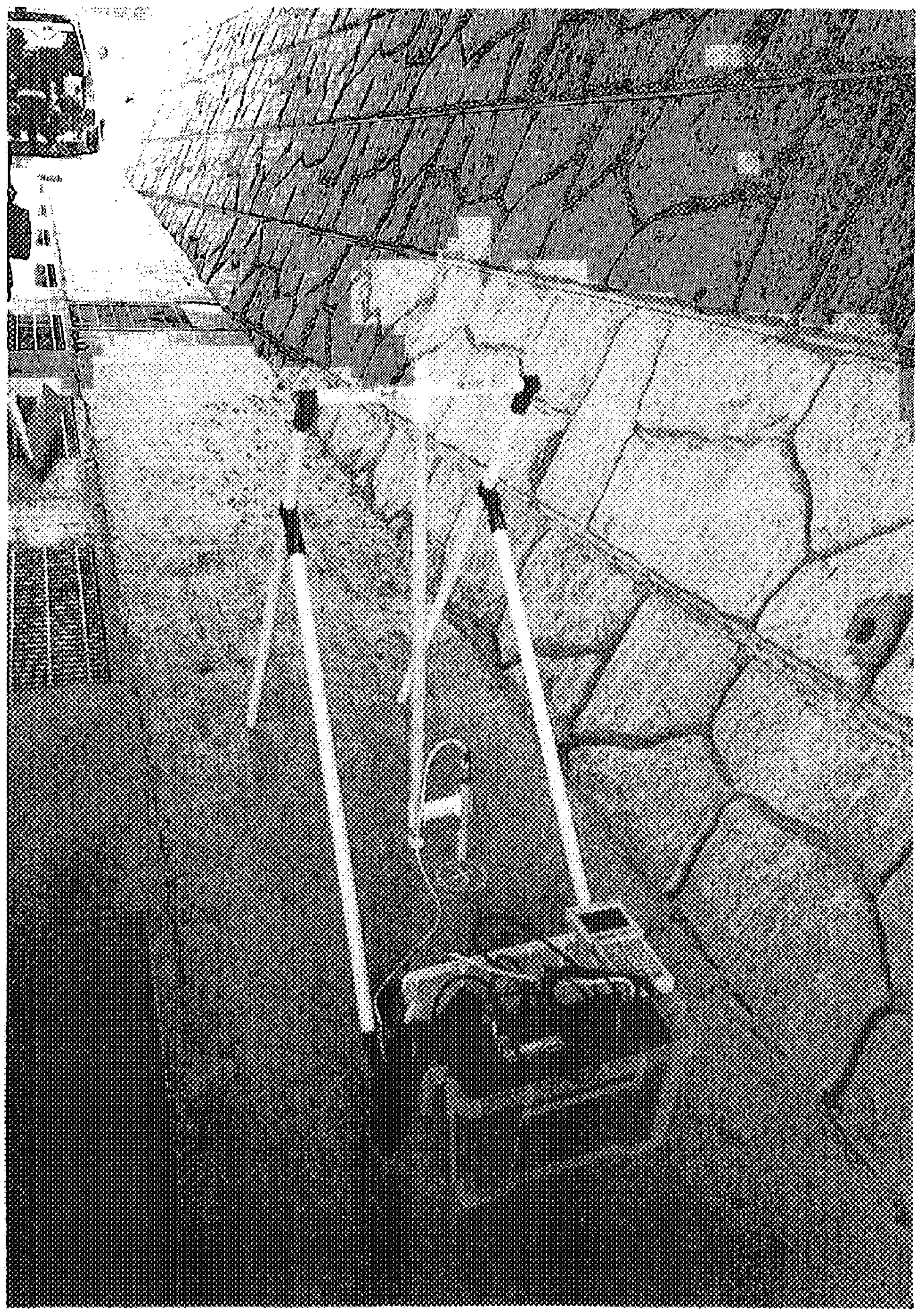
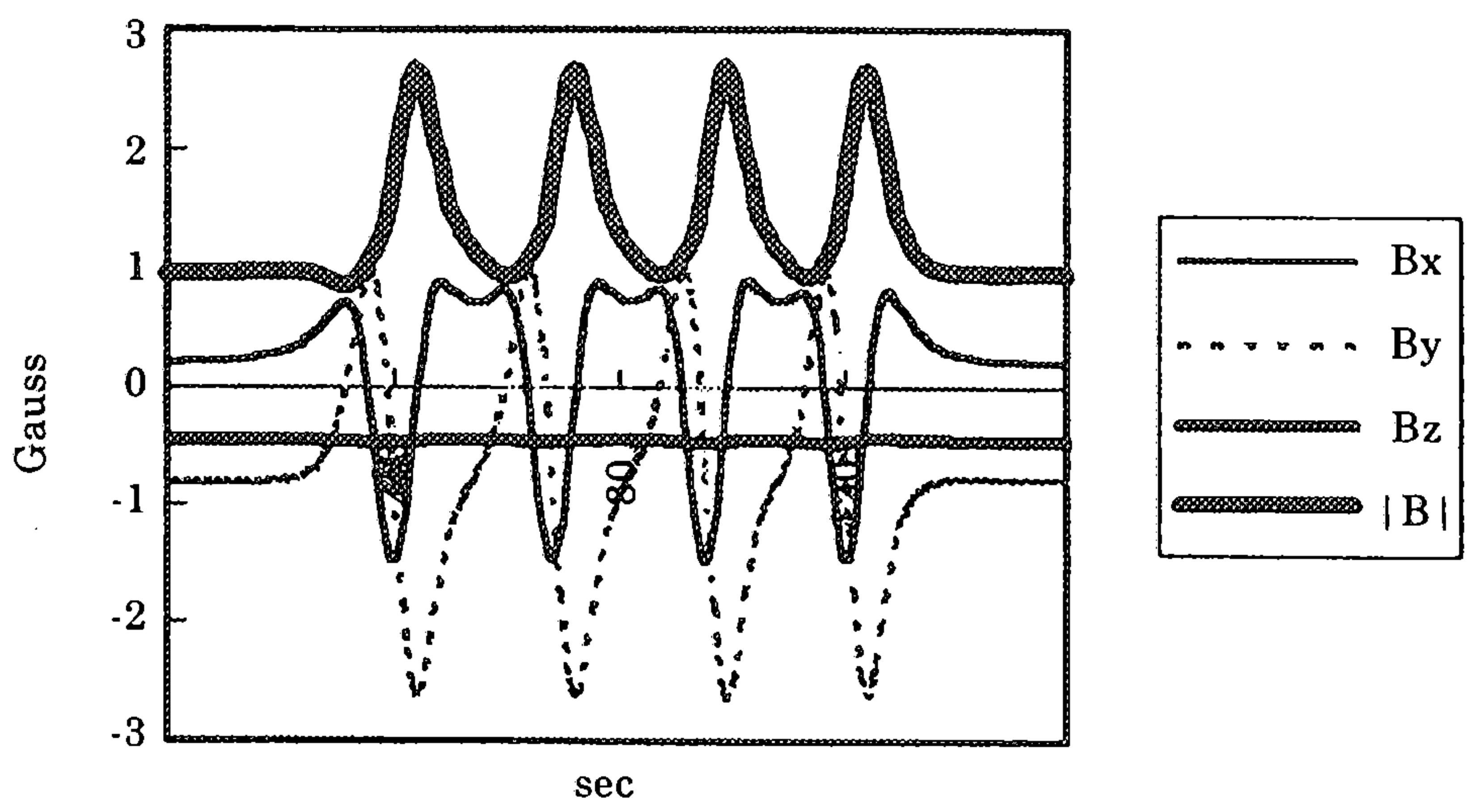
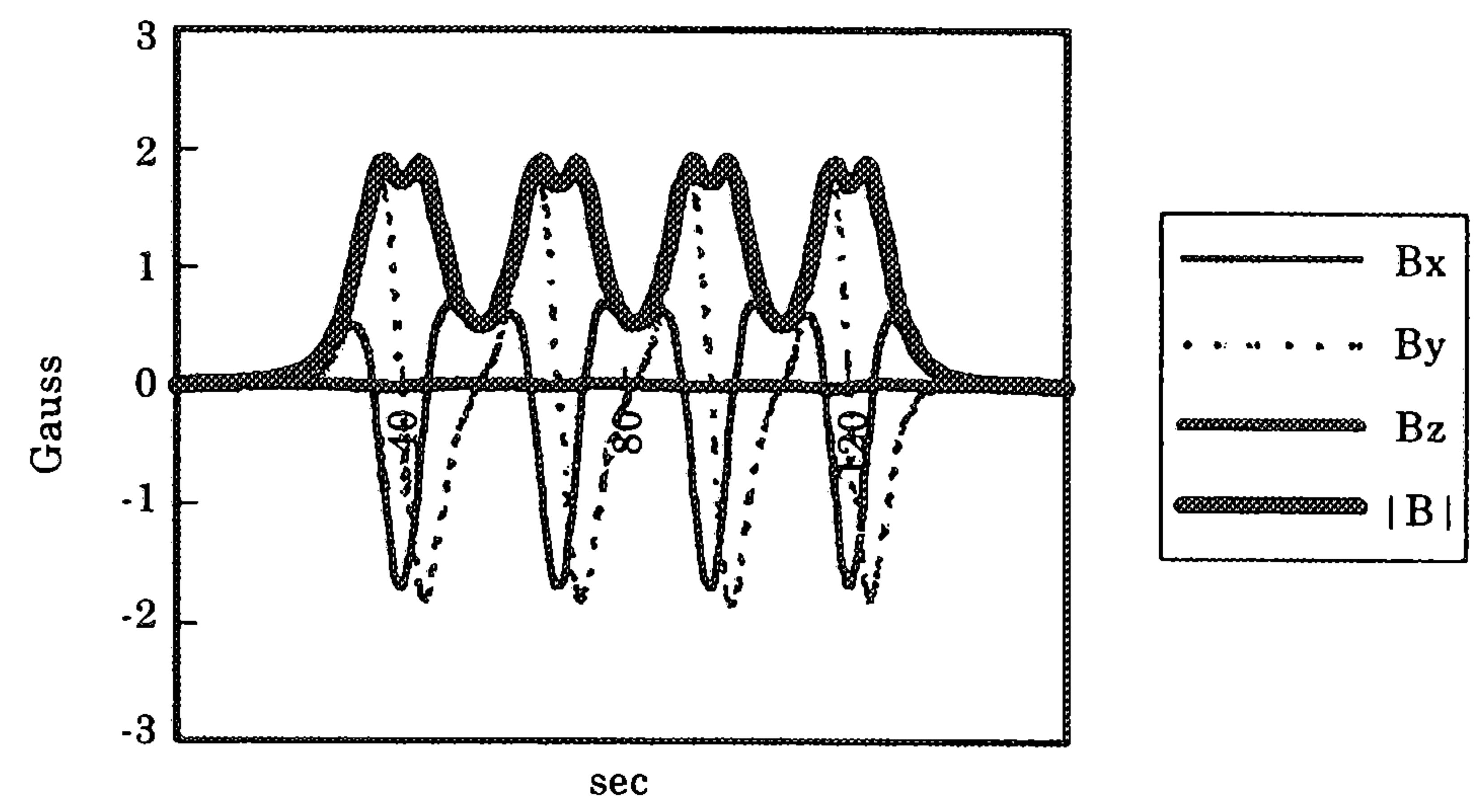


Fig. 5 Picture of measurement in position ③



(a) Observed wave form of magnetic field



(b) Wave form with the static bias subtracted

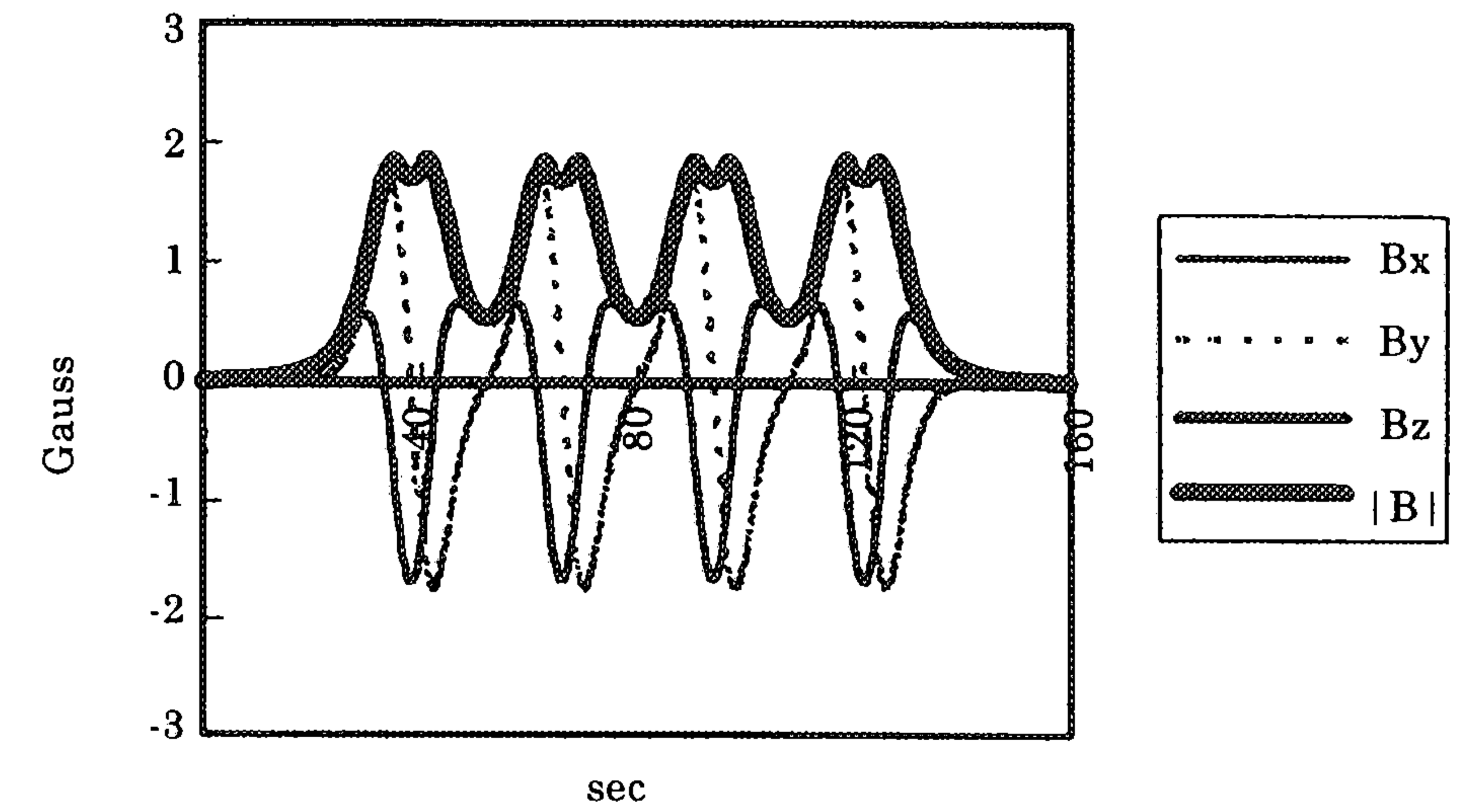


Fig. 6 Magnetic field wave form at position ①

vehicle speed and 21.6 (m) is the interval between two bogies (See Fig.1.).

Table 3 shows measurement results of environmental magnetic field at five positions of Yamanashi Test Line in Fig.4. 'Vertical distance' means the vertical distance from the center of groud coil (which nearly equals to the center of SC coil) to the measurement point and 'Horizontal distance' means the lateral distance from the center of vehicle to the measurement point. 'Measured magnetic field' means the maximum value of | B | in Fig.6 (a) and 'Measured magnetic field by vehicle' means the maximum value of | B | in Fig.6 (b).

In all measurement positions, the maximum of measured magnetic field by vehicle is less than 2.41 Gauss to satisfy the objective level of environmental magnetic field required for the Yamanashi Test Line (less than 20 Gauss) [3].

In ordinary viaducts (8m girder), the vertical distance from the center of ground coil to observatory positions at 1.5m height from the ground level is about 9m-10m. Therefore, '4.6m' in position ④ is the minimum value in the neighborhood of viaduct structure accessible by ordinary people. In the case of positions ① and ⑤, ordinary people are prevented from entering the area within about 4m from the end of track formation (s.t. the area in which the horizontal distance is less than about 7.5m) by a fence.

4. Spectrum of alternating magnetic field at a speed of 500km/h

In this chapter, we assess the environmental magnetic field at the maximum vehicle speed (500km/h).

In commercial operation, one train set consists of a number of cars (14-16 cars). The peak of wave form in Fig.6 will repeat further when the train set becomes longer. So we suppose periodic magnetic fields at every pitch of bogie (21.6m, see Fig.2) and calculate Fourier coefficient of this periodic magnetic field as below. The expression (1) shows this periodic (alternating) magnetic field by SCM expanded into Fourier mode.

Table 3 Measurement results of environmental magnetic field in Yamanashi Test Line

Position		Vertical distance Zdirection unit : m	Horizontal distance Ydirection unit : m	Measured magnetic field unit : Gauss	Measured magnetic field by vehicle (calculated) unit : Gauss	Vehicle speed unit : km/h / Transmission system
①	Entrance of car shed	0.0	7.5	2.68	1.89 (1.83)	3 / Pulled by diesel car
②	Under the viaduct	19.0	3.5	0.45	0.02 (0.015)	15 / Linear synchronous motor
③	Under the viaduct	9.2	3.5	0.50	0.19 (0.20)	15 / Linear synchronous motor
④	Under the viaduct	4.6	3.5	1.76	1.41 (2.0)	15 / Linear synchronous motor
⑤	Vehicle level	0.0	7.0	2.70	2.41 (2.43)	8 / Pulled by diesel car

$$B(t) = \Sigma_{i=1}^{\infty} \{B_{ci} \times \cos(2\pi \times (v/21.6) \times i \times t) + B_{si} \times \sin(2\pi \times (v/21.6) \times i \times t)\} \quad \cdots\cdots\cdots(1)$$

where i is degree of Fourier mode; v is speed of vehicle; t is time (sec); B_{ci} and B_{si} are constant vectors (Fourier coefficients). When vehicle speed=500km/h, v=138.89m/s.

We show calculated magnetic field by SCM expanded by Fourier mode at a vehicle speed of 500km/h in Fig.7. The calculated point corresponds to position ① in Fig.4 and Table 3. In this case, the fundamental frequency is 6.4Hz (138.89/21.6) and the amplitude of harmonic frequency decreases rapidly, as frequency increases.

In addition, environmental magnetic field by SCM is intermittent in contrast to that of power supply line. In the case of commercial operation (we suppose that trains composed of 14 cars and 15 bogies run 12 times per hour in one direction.), the ratio of time when alternating magnetic field is generated by SCMs is as follows (at a speed of 500 km/h),

$$(21.6 \times 15/138.89) \times 12 \times 2(\text{double track})/3600 = 0.016. \quad \cdots\cdots\cdots(2)$$

Namely, it is less than 2%.

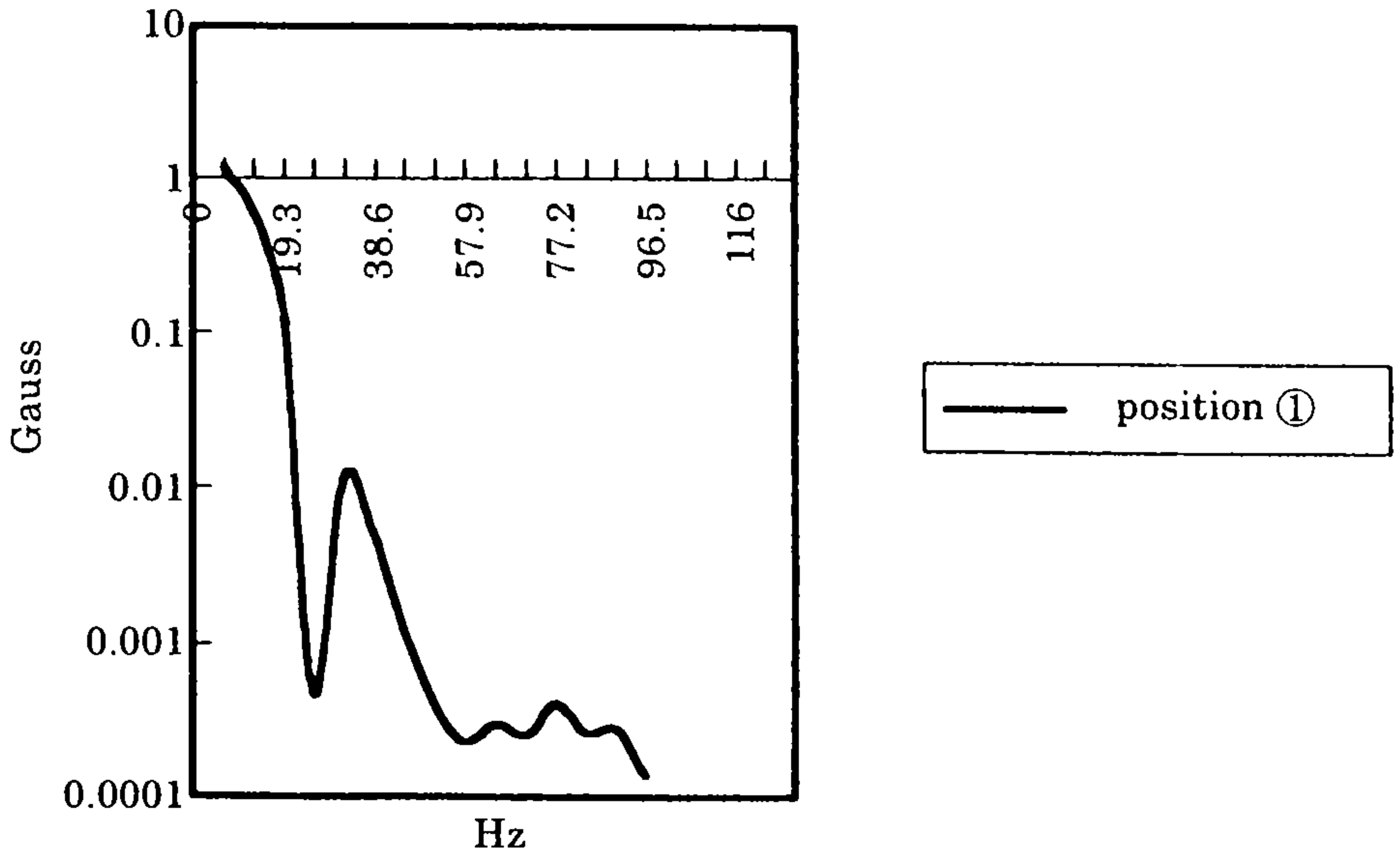


Fig. 7 Spectrum of magnetic field at position ① at a vehicle speed of 500km/h

5. Conclusion

We performed a measurement of environmental magnetic field at the Yamanashi Test Line. We conclude that the specification of Yamanashi Test Line guarantees environmental magnetic field level within the objective level required. And main frequency component is 6.4Hz at a vehicle speed of 500km/h, which is low compared to that of power supply line.

Acknowledgment

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References

1) Takao, K. and Takahashi, K. : "Vehicles for Superconducting Maglev System on Yamanashi Test Line", Quarterly Report of RTRI, Vol.35, No.3, pp.150-157, 1994
2) Suzuki, E. et.al.:"Superconducting Magnet for Maglev Train", Quarterly Report of RTRI, Vol.35, No.3, pp.158-163, 1994
3) Nakagawa, M. : "Electromagnetic Fields Issue with EDS Maglev System", RTRI Report (in Japanese), Vol.6, No.4, pp.3-9, 1992
4) Safety of High Guided Ground Transportation Systems, Comparison of Magnetic and Electric Fields of Conventional and Advanced Electrified Transportation systems, USDOT/FRA/ORD-93/07, Final Report, August 1993.