Radiated Emission from a Lift Control Panel Based on an IGBT Inverter

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ABSTRACT

Modern elevator systems more often than not would consist of high-speed microprocessor and fast switching power devices in its inverter circuitry, where high efficiency and comfortable riding can be achieved. Nevertheless, it could be a possibility that due to these fast-switching devices, for instance, the Insulated Gated Bipolar Transistor (IGBT) to result in Radio Frequency (RF) radiated and conducted emission. With the introduction of Electromagnetic Compliance (EMC) regulations, the EN81 (Safety Rules For The Construction And Installation Of Lifts – Part 1: Electric Lifts) has encompassed EMC standards such as EN12015 (Electromagnetic Compatibility – Product Family Standard For Lifts, Escalators and Passenger Conveyors – Emission) and EN12016 (Electromagnetic Compatibility – Product Family Standard For Lifts, Escalators and Passenger Conveyors – Immunity) to ensure elevator system compliance to the EMC requirement. Most of the elevator vendors, if not all, have to overcome this unavoidable yet invisible problem. Here, this paper shall present the EMC evaluation facilities and the result of radiated emission from an elevator system, utilizing to an IGBT drive inverter.

1. INTRODUCTION

For modern elevator system, in order to achieve highly efficient control and sophisticated functions, high-speed processors are implemented as the main control logic circuit. Furthermore, in turn to realize comfortable riding and energy saving function, high-performance IGBT inverter topology is employed. Though it is advantageous to incorporate these fast-switching devices, there is a high possibility of noise emission generated from these switching devices.
In recent years, portable microelectronics and radio apparatus, such as notebook type personal computer, mobile phone, have dramatically increased in popularity. Although it does not invokes the actual problem immediately, the chances of interference between these portable microelectronic apparatus and the inverter unit of the elevator system, which is generally housed in the machine room, may actualize. To meet such an environmental transferal, EMC standards (EN12015, EN12016) for elevators are enacted in Europe. The trend of EMC regulation has also started to embark on Asian countries.

This paper outlines the various EMC testing and evaluation equipment, established to comply with the EMC standard. The obtained test results of an elevator control panel, together with the noise reduction methodology applied, are also reported.

2. EMC STANDARDS FOR ELEVATORS

2.1 EMC Challenges

Generally, electromagnetic compatibility engineering composed of two basic topics, namely, emission & immunity. Radio interference by the unnecessary radiation generated from an electric device is known as Electromagnetic Emission or Interference (EMI) problem. Whereby the noise-tolerance capability against the noise generated from the other equipment is identified as Electromagnetic Immunity or Susceptibility (EMS) problem. And it is precisely the purpose of EMC standards to ensure a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances.

The main sources of emission noise of an elevator system are illustrated in Figure 1. The emission noise in an elevator includes the conducted emission that leaks through the main power supply lines, and the radiated emission that is emitted from the control panel and lift car equipment. On the other hand, the elevator system had to be immunized from the conducted noise invades from the main power supply lines, and radiated noise due to radio apparatus.

In the aspects of EMC, the main focus for elevator system is conventionally emphasized on the disturbance noise generated by the power supply harmonics, which can be broadly classified under conducted emission noise. Extensively research had been carried out in the area of conducted emission noise [Gary 1999]. However, research based on radiated emission had not been fully explored.

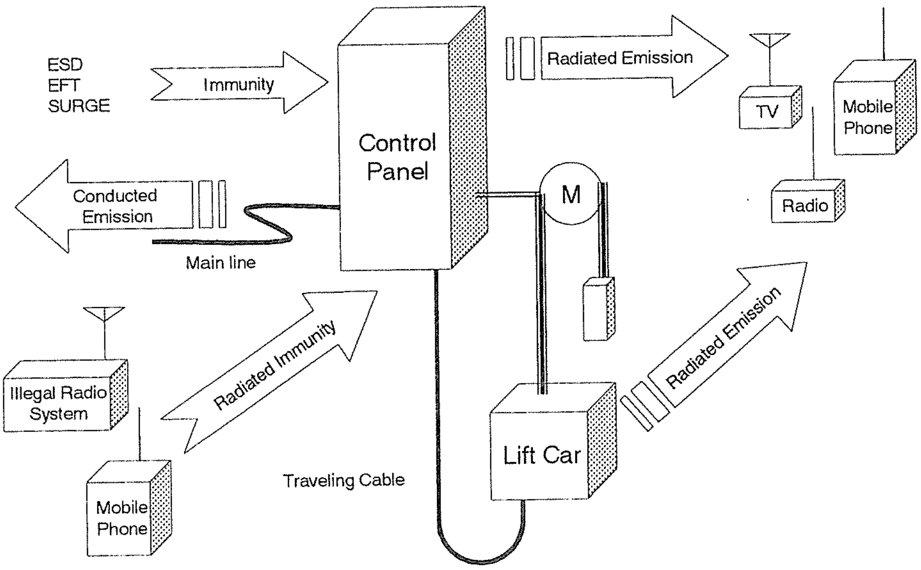


Figure 1 Emission and Immunity at an elevator system

2.2 European Norm (EN) Standards [EN12015 and EN12016]

Different product family would have to comply with the respective product family EMC standards. For the elevator, escalator and passenger conveyor, the governing EMC standards are EN12015 [EMI 1998] and EN12016 [EMS 1998], which spelt out the emission and immunity requirements correspondingly.

The comparison of the emission limit value between EN12015 and the typical EN50081 (Generic Emission Standard) standard is appended in Table 1. As reflected in Table 1A, for an inverter-driven lift system, based on the current rating capacity, it is clearly exemplified that the limits for conducted emission are conformable. As reflected in Table 1-B, the limit value for radiated emission as spelt out in EN12015 is comparable to those of general electronic apparatus as listed in the generic standards.

In addition, EN12015 had also explicitly defined the extrication of an elevator system for the EMC evaluation purposes, as highlighted in Figure 2. The elevator system is overall breakdown into the machine room equipment; lift car and landing floor apparatus for the necessary EMC assessment, in consideration of the physical size of an elevator structure.

Table 1 Emission Limit Value of EN12015

(A) Conducted Emission

Frequency Range (MHz)	Main Input Current	EN 50081-2		EN 12015	
		Vq (dBuV)	Va (dBuV)	Vq (dBuV)	Va (dBuV)
0.15 ~ 0.5	<25A	79	66	79	66
	25-100A			100	90
	>100A			130	120
0.5 ~ 5	<25A	73	66	73	60
	25-100A			86	76
	>100A			125	115
5 ~ 30	<25A	73	60	73	60
	25-100A			90- 70	80 - 60
	>100A			115	105

(B) Radiated Emission

Frequency Range (MHz)	Distance	EN 50081-2 Vp (dBuV/m)	EN 12015 Vp (dBuV/m)
30 ~ 230	10m	40	40
230 ~ 1000	10m	47	47

Vp: Quasi peak value Va: Average value

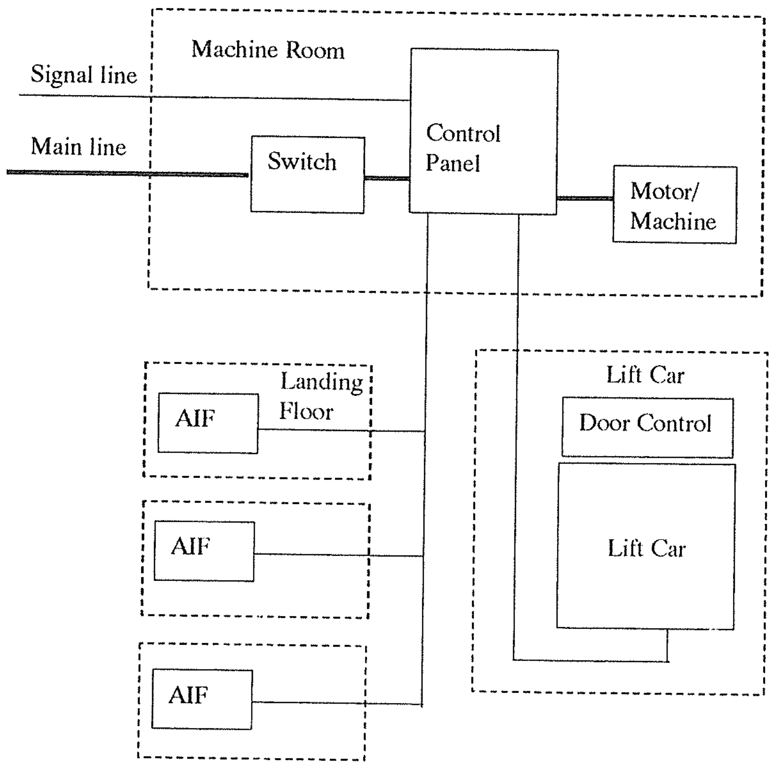


Figure 2 Breakdown of an Elevator System for EMC Assessment

3. FACILITIES FOR EMC TESTING

The foremost requirements for performing EMC testing of an elevator control panel required a high capacity power supply and a load motor to emulate similar site condition. Due to this reason, it is difficult to have any EMC test to be conducted at any accredited laboratory. Consequently, we had decided to establish EMC testing facilities, suitable for EMC testing of an elevator system.

3.1 EMC Evaluation Laboratory

A general layout of the newly established EMC testing laboratory is exemplified Figure 3. The laboratory basically comprises of a semi-anechoic chamber, motor chamber, measurement chamber and the office. The semi-anechoic chamber, reflected in Photograph 1, is equipped with a high capacity power supply as appended in Table 2. The stipulated attenuation of the semi-anechoic chamber is designed based on the Federal Communications Commission (FCC) standard. Moreover, the turntable within the semi-anechoic chamber is linked with the measurement system, whereby measurement can be accomplished automatically. A load motor and auxiliary apparatus (AE) are installed in motor chamber as illustrated in Photograph 2.

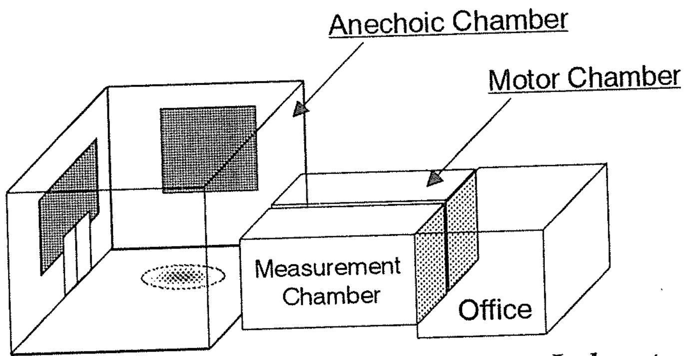
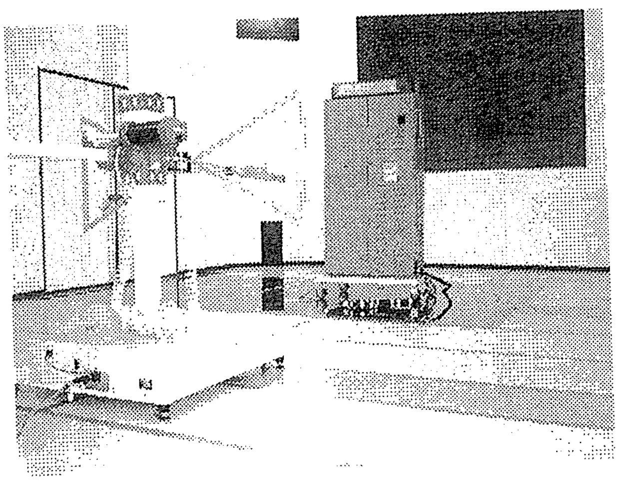
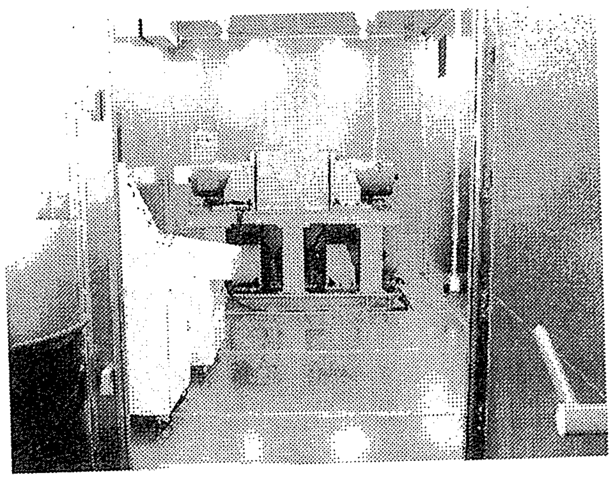


Figure 3 Layout of EMC Evaluation Laboratory



Photograph 1 Semi-anechoic Chamber



Photograph 2 Motor Chamber

Table 2 Semi-anechoic Chamber Specifications

Term	Specification
Chamber	Semi-anechoic Type
EM Absorber	Grid Type Ferrite
Turntable	2m in diameter
Shielding	30MHz-2GHz: 100dB
Site Attenuation	Conformity with ANSI C63.4-1992
EM Uniformity	Conformity with IEC61000-4-3
Power Supply	3Phase 400V 100kVA
	Single Phase 100V 15kVA

Table 3 EMC Measurement Equipment

Equipment	Specification
EMI Receiver & Spectrum Analyzer	20Hz - 7GHz (Integrated Type)
LISN	3Phase 440V/100A
	Single Phase 15A
Antenna	Bilog-antenna: 30MHz-2GHz

3.2 Testing Equipments

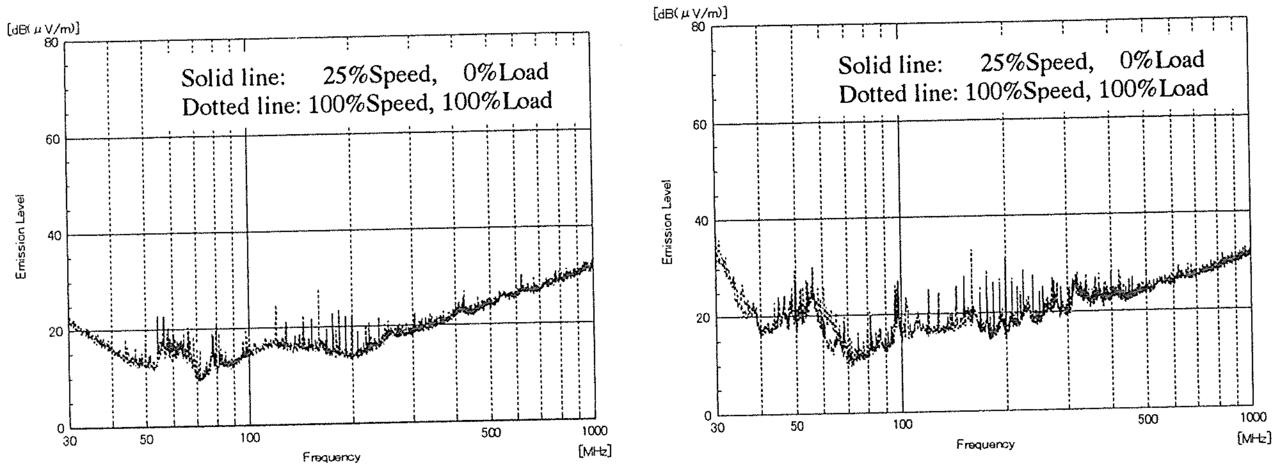
The main measuring equipment for emission measurements are the antenna, spectrum analyzer, and an EMI receiver. A super-wide range antenna that covers 30MHz - 2GHz is chosen, so as to reduce the unnecessary time spent on the switching of different type of antenna for different frequencies range measurements. Concurrently, with the implementation of highly computerized, automatic measurement software, anyone could conduct the emission measurement easily. A list of emission measurement equipment is listed in Table 3 as follows:

4. EMISSION MEASUREMENT OF CONTROL PANEL

4.1 Determination of Measurement Condition

It is vital to determine the operating condition of an elevator system that generates the maximum emission noise. However, the status of an operating elevator varies with the variation in the number of passengers and/or speed patterns. Thus, the speed and load characteristics of an elevator system, with reference to the radiated emission, are studied to determine a realistic measurement condition.

The radiated emission measurement results based on two distinct speed and load characteristics are detailed in Figure 4. In the first case, the speed is set to one quarter of the rated speed, with no loading level. In contrast to the preceding operating condition, the elevator is operated at the rated speed and rated loading effect. The spectrums of horizontal and vertical waves are identical, across the entire frequency bands for both operating conditions. Hence, it is proven that radiated emission is not dependent speed and load characteristics at all. Consequently, the no-load operating condition is chosen as the most appropriate measurement condition for radiated emission noise, as it is comparatively easy to set up. In addition, operating at no-load condition may be beneficial to the test efficiency and the reproduce of the measurement results at site is made possible.



(A) Horizontal wave (B) Vertical wave

Figure 4 Speed and Load Characteristics of Radiated Emission

4.2 Emission Measurement

The spectrum of radiated emission from the IGBT-based inverter system is shown in Figure 5. The elevator system is operated under constant speed at no-load condition. The control panel does not have any particular shielding.

Although the switching frequency of an inverter is up to 10kHz, the maximum spectrum level of radiated emission appears around 100MHz, and spectrum has spread to 1GHz. Since the main circuit of an inverter is designed as low inductance using the bus bar etc., it has very high resonance frequency. It is surmised that radiated emission 100MHz or more occurs, when a steep voltage change generated by diode recovery operation impresses to this resonance circuit. Actually, the high frequency current in agreement with radiated emission is observed around the inverter.

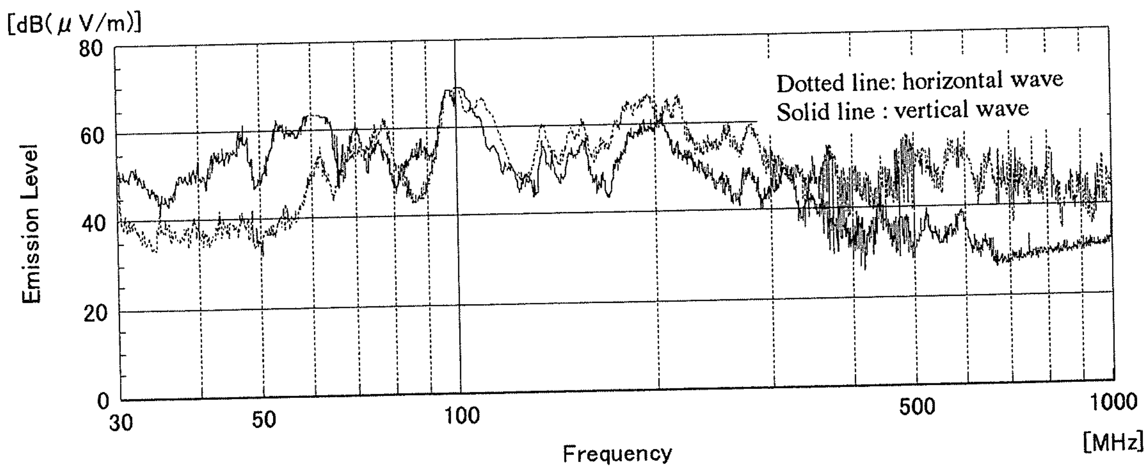


Figure 5 Original Radiated Emission

5. EMISSION REDUCTION MEASURE

EMI suppression device such as EMI filter can be applied to effectively reduce the emission for low voltage printed circuit board (PCB). However, it is not realistic to employ EMI filter for large current circuitry such as those of an inverter. Therefore, practical emission reduction measures are (1) shielding of a cubicle, (2) proper grounding, (3) suppression of noise source.

5.1 Shield Effect of Cubicle

Figure 6 illustrated the experimental cubicle for the verification of the shield effect of a cubicle. This cubicle has equipped with EMI gasket and the metal mesh, to improve the shield effect. Nevertheless, the drawer hole of the cable at the base of the panel remains.
An oscillator is placed in the cubicle and acts as a radiated noise source within the cubicle. The radiated emission measurement data captured when the door is opened and closed are stated in Figure 7 and 8 respectively.

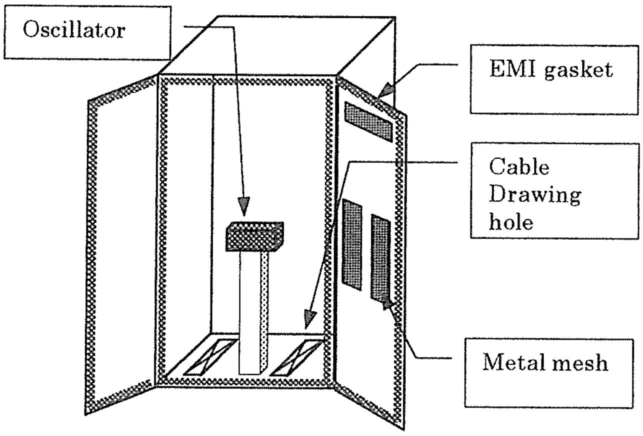


Figure 6 Cubicle for the Shielding Evaluation

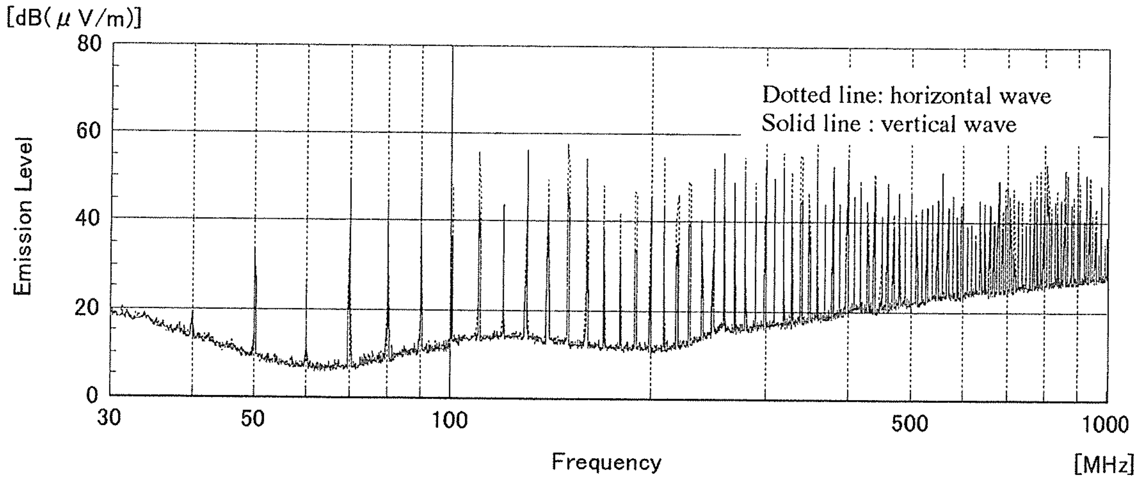


Figure 7 Radiated Emission under Door Open

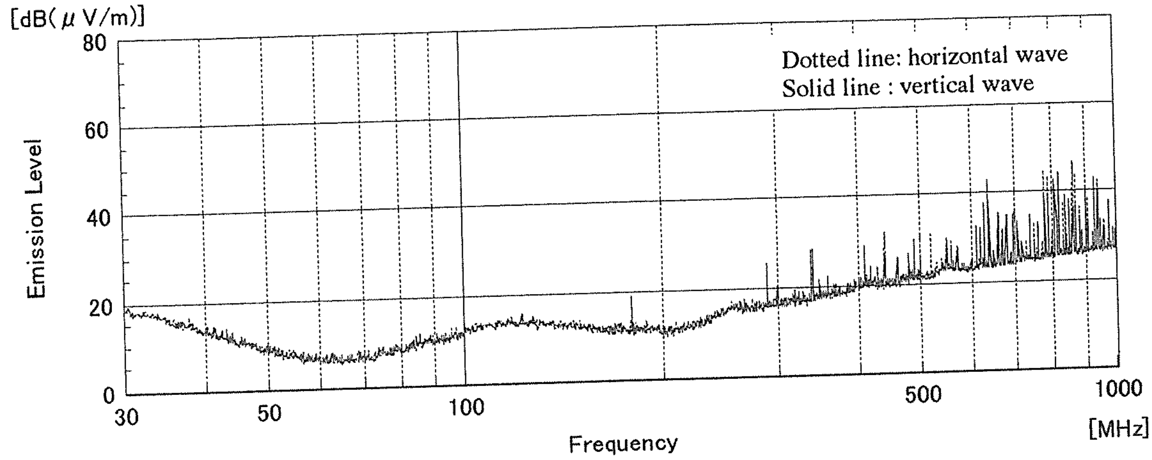


Figure 8 Radiated Emission under Door Close

Extract from Figure 8, it had assure that the shield effect is achieved until 500MHz Above 500MHz, a leak in noise was observed and the cause could be attributed from noise via the drawer hole.

The experimental measurement obtained until now is carried out without any cable installation, which is not a practical case. Thus, another assessment is initiated with the cable installation. As observed in Figure 9, a degradation of about 10dB shielding effect is discovered in the 150MHz frequency band. Consequently, a greater depth of degradation is expected in an actual control panel, since numerous cables would be routed in and out from the cubicle.

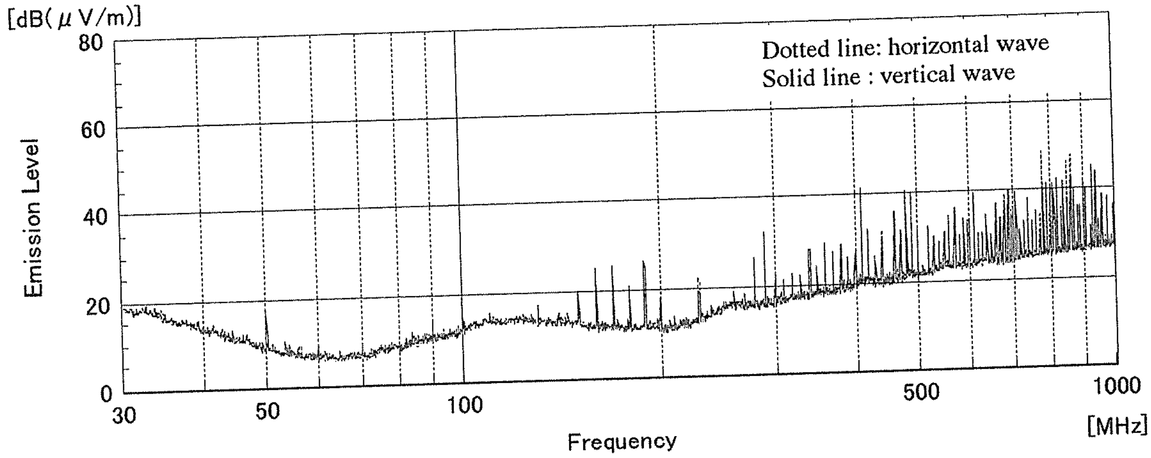


Figure 9 Radiated Emission with a Cable

5.2 Radiated Emission Results of a Shield Cubicle

The radiated emission measurement results for a shielded cubicle that includes the inverter unit are captured in Figure 10. In this case, shielded cables are applied in those identified "noisy" wiring areas. In addition, the grounding system is re-evaluated and enhanced. It is found that in comparison with Figure 5, a reduction of about 20dB in the radiated emission noise had been effectively attained for almost all over the frequency band.

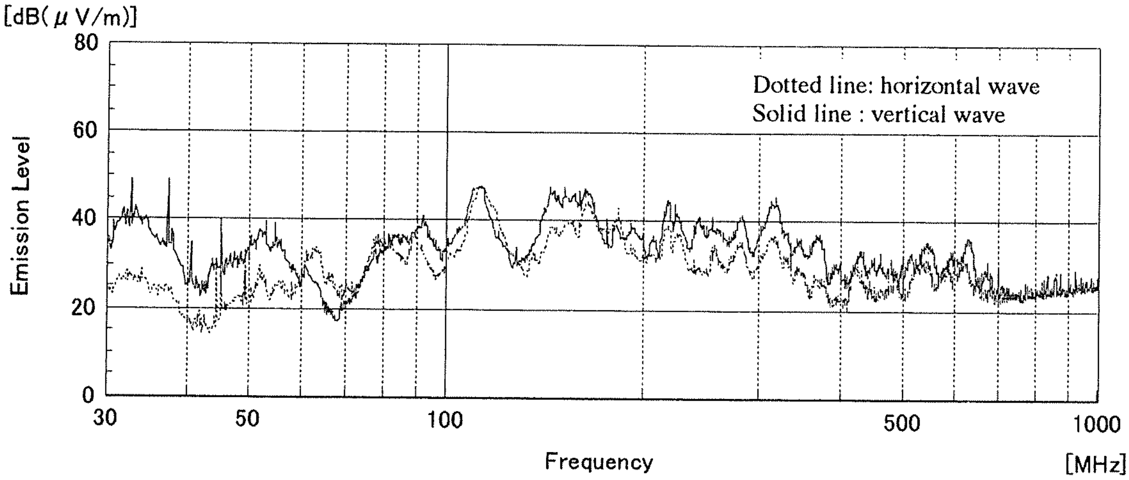


Figure 10 Radiated Emission with Shield Cubicle

5.3 Reduction of Radiated Emission by Soft-Switching

As mentioned in the preceding section, it is deduced that the resonance phenomenon of the inverter main circuitry, accompanied by diode recovery operation is considered to be the major cause of the emission problem. The soft-switching technique is recommended as the fundamental emission noise reduction method to control the undesired effect of the diode recovery operation. Soft switching is considered to be effective not only in conducted emission but in radiated emission as it diminished the ripple or surge voltage level. Next, study is made to observe the difference in the radiated emission by making the switching speed sufficiently slow is experimented.

As appended in Figure 11, soft-switching technique could realize a remarkable reduction in the noises generated via radiated emission. Though soft-switching of inverter can heap desired results, prudent consideration must be made when introducing this reduction measure, as it affects the basic switching operation of the inverter circuitry.

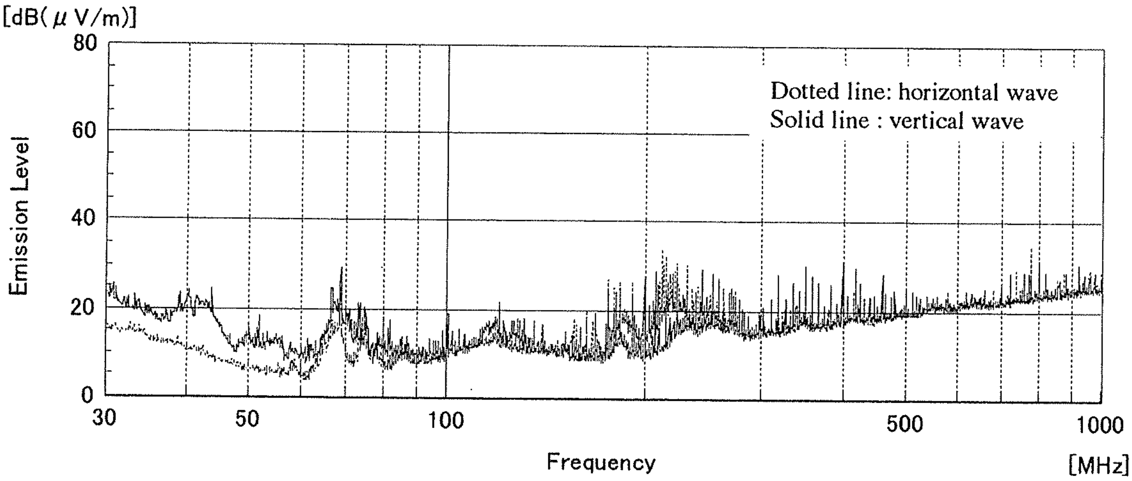


Figure 11 Radiated Emission using Soft-Switching Technology

6 CONCLUSIONS

Inverter-driven elevator can provide a comfortable vertical transportation system, in which high energy efficiency and flexible controllability can be easily attained. On the other hand, it generates the same radiated emission level as in a general electronics apparatus.
The operating condition of elevator system for EMC assessment on radiated emission measurement has been studied, and it had proven that the radiated emission noise does not had any dependability on neither the speed nor the load characteristics.
Subsequently, the effect of some emission reduction measure such as shielding and soft-switching techniques had been shared. By combining these techniques, it is found that a radiated emission reduction can be clearly attained.
We will carry out the elucidation of the mechanism of radiated as a future work.

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