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EMI Caused by A Grounding Loop

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Abstract

EMI caused by a grounding loop was described, investigated and controlled. After having this lesson, a new grounding system was designed and has shown that it is a successful design for EMC.

Introduction

Engineers who design electronic circuits and systems should be very familiar with grounding because in every circuit and system they have to handle where and how grounding points are placed. That is why grounding is instructed and described as detail as possible in education books and electromagnetic compatibility design handbooks ①②③④⑤⑥. When I read these books, I think they describe this concept clearly and I seem to understand how to set grounding for a circuit, black box, subsystem and system. I am getting confused when I have to decide where and how grounding points are going to be put.

It is found in some guidance books that grounding is classified so detail that engineers have to identify grounding points for structure, safety, power supply, signal, noise, system and lightning. I am bewildered by these books so much that I have no idea for grounding at all. For example, one grounding point can be considered for signal, but it also can be functions for safety and power supply. Should I set three grounding points in different places if done according to this guidance? Once a time, I analyzed a system in that there were grounding points for power supply, safety, signal, noise, system and so on, separately. It was found that this system could operate normally when the grounding point for power supply was taken out. I was getting doubt then if this grounding point for power supply did really be needed for this system.

"There are six(n) electrical or electronic engineers in a closed room, there are often as many as five(n-1) grounding experts"⑦. It is true that there are many different approaches for grounding when they are working for the same piece of PC board, black box or system. That is why grounding is so deceptively simple in concept and dishearteningly complex in application and endless in discussion and argument.

Single-point and multi-point grounding are very popular in engineering. In some special cases, both of single-point and multi-point grounding may reach the same requirements. That means a circuit can operate normally and EMI is controlled under a level in the specification . In the other case, the situation may be changed. The single-point grounding may be better than the multi-point one, or conversely. Which one is the best choice among single-point, multi-point and hybrid ? This is a question engineers would like to know and which is very difficult to be answered . Usually, it is depend on the special goal to be accomplished, as related to the function of the grounding arrangement wanted to reach. In order to dispose of grounding well, I think more literatures of theory and engineering should be read, and theory should be combined with practice. In the following, I have a real story from that I have learnt a lesson.

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EMI Phenomenon

Some years ago, a computer was imported and would be installed in our lab that located in the second flow of a building. Engineers from that computer company did not care how the power supply network was distributed in our lab. They arranged this installation only according to their documentations. In order to control EMI from the power supply network and keep safety of the computer, a three-phase 380V/50Hz transformer(see C in the lower part of Fig. 1) was installed and an earthing pile for safety grounding(see D in Fig. 1) was set up in the South of the building. The earthing resistance had to be less than 2 Ω specified in their documentations. In this environment the computer had operated well for several years.

We had a simulation test of software and hardware in a system. Doing this test, signals from the system should visit the computer through cables connected between them, and the computer would response these signals immediately. Before linked, the computer and system run very well individually. Unfortunately, an unbelievable phenomenon appeared at the moment when they just started to communicate. Neither the computer operated, nor the system

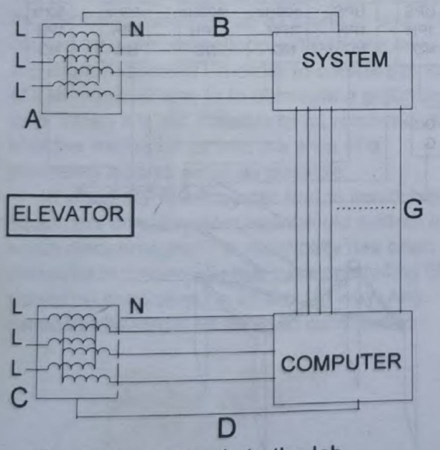

Fig. 1 Power supply to the lab.

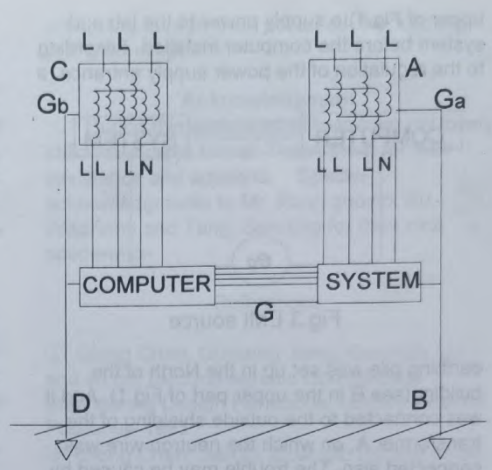

Fig. 2 The grounding loop

run. They only could operate separately. After linked, they were incompatible and could not run together at the same time. What was wrong with them? Why could not they be compatible? This strange phenomenon made us puzzled and we had tried many times to remove this phenomenon.

Investigating and removing

Because there was an elevator closed to the computer and system, it was suspected that EMI signals come from the relay array in the elevator effected this test. Then this test was repeated when the elevator was shut down. The strange phenomenon could not be eliminated. As the building was on the side of a heavy traffic road, then we tried to test them at the midnight. The interference could not be removed away. After above experiments, we began to find EMI sources within the computer and system. At first, couplings between power supply wires were suspected, then EMI filters were installed in proper places within these wires. This disaster EMI still could not be controlled. Facing this situation, a careful investigation was conducted. We found that there was an other three-phase 380V/50Hz transformer (see A shown in the upper of Fig.1)to supply power to the lab and system before the computer installed. According to the regulation of the power supply entrance, a

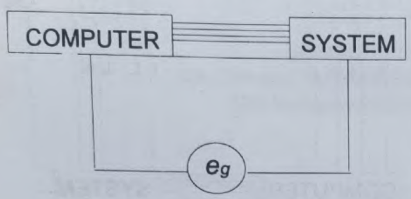

Fig.3 EMI source

earthing pile was set up in the North of the building(see B in the upper part of Fig.1). And it was connected to the outside shielding of the transformer A, on which the neutron wire was connected also. The trouble may be caused by both earthing pile of B and D. If Fig.1 was shown in Fig.2 identically, it was getting very clear that B (earthing Pile for the transformer A), G_a(Safety grounding point of the lab.), G(grounding reference between the computer and system), G_b(safety grounding point of the computer), D(earthing pile for the transformer C) surrounded a grounding loop. Because the distance between D (or G_b) and B (or G_a) was around 15 meters, and the distance from G_b (or G_a) to D (or B) was at lest 3 meters, the grounding loop was around 45 square meters. It was large enough to cause serious EMI. For removing this EMI trouble, the action we only needed to be taken was to break the earthing pile at the point G_a(or G_b). After this magic treatment, this computer had matched the system very well because the B-G_a-G-G_b-D-B grounding loop was eliminated. And EMI produced by the grounding loop was removed.

The effect of a grounding loop could be abstracted and shown in Fig.3. An inducted voltage *e* would be created if an alternative field through the loop B-G_a-G-G_b-D-B. It might be estimated as the following

$e = -d\ \phi/dt = -sdB/dt$

s --- the loop area, m^2

dB/dt --- the intensity of magnetic flux, which through the loop vertically.

When the amplitude of an inducted voltage was getting large enough, it was able to interrupt any circuit which linked to this loop. If the computer or system operated, there must be an alternative electromagnetic field through the loop. An inducted signal potential would be created along the loop path. The potential e_g at the point g on the loop could be estimated as the following

$e_g = i_g(r_g + j\ \omega\ l_g) - sdB/dt$

i_g --- the moment current in the loop

$r_g + j\ \omega\ l_g$ --- reactance at the point g referred to the earth

In order to know how large the amplitude of the inducted voltage was, we tried to observe it through an oscilloscope. The ground point of the oscilloscope connected as close to G_a in Fig.2 as possible, and the input of the oscilloscope run as close to linked cables as possible. Observed signals were random and could not be synchronized with the oscilloscope. Its maximum amplitude was more than 3 V, It was too large to believe.

To Learn this lesson

The simulation lab including the computer and system would be moved to a new building. In order to control EMI from a grounding loop,

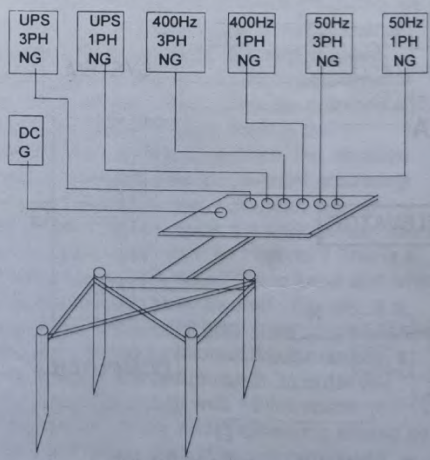

Fig.4 The new grounding system

we drew this lesson and designed a new grounding system very carefully. The first step we took was to pile 4 brass sticks of the diameter 20mm and length 3 meters into soil, which located outside of the lab. They consisted of the earthing pile. The second step was to link all of 4 sticks by soldering brass ribbons of the width 20mm and thickness 3mm. Some trees were planted around this area to keep soil damp. The grounding resistance was 0.6 ohms when measured by the method of three points. The third step was to set up a grounding bus inside of the lab. Then the earthing pile and grounding bus were connected by copper ribbons of the width 200mm and thickness 3mm as shown in Fig.4. The fourth step was to install EMI filters in proper places within power supply networks.

Since 1991 a lot of simulation experiments have been tested in this lab, and sometimes more than one system have to communicate with the same computer. No any EMI have been observing so far. It is shown that this grounding system design was compatible.

Conclusion

A grounding loop is possible to exist in any PCB, black box, subsystem and system. When a system is getting larger and larger, for example, the electronic system in an air plane or ship, EMI caused by a grounding loop will become more and more noticeable. In order to control this kind of EMI, the best way is to eliminate a grounding loop. When it is not possible to be removed, the effective method is to limit the area of a grounding loop as small as possible.

It is usually to encounter that to insert new equipment or subsystem into the old system in which electromagnetic compatibility has been approved in practice. In this case controlling EMI should be considered in all around way. Any carelessness might be liable to surround a grounding loop by their power supply, cabling and grounding.

Acknowledgment

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