# LOW FREQUENCY ELECTROMAGNETIC INTERFERENCE AND SHIELDING OF POWER CABLE STRUCTURES IN BUILDING

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## SUMMARY

This paper is a case study of the electromagnetic interference of power cable structure in building. As increasingly electronic devices are utilized within modern buildings; the electromagnetic performances of buildings become important. Low frequency magnetic field interference was causing screen jitters and malfunctions of the computer system in a library. Several shielding approaches were employed to reduce the interference. The success and failure experiences are reported. Some useful suggestions on the shielding design are verified through the field trial.

## INTRODUCTION

In a modern building, more and more electronic devices are utilized to ensure security of communication and smart control facilities. Recently, the electromagnetic performance of the building has become a concern for the occupants (TURNER, 1997). The electromagnetic environment created within a building could also be harmful to communications and operation. Various governing bodies have imposed several sets of regulations that must be met for the product. On the other hand, the building itself has to meet the electromagnetic requirements in the environment, too.

The characteristic of electromagnetic wave is strongly related to its frequency. High frequency wave is used for digital equipment and communication devices. The building performance is concerned with the electromagnetic compatibility of facilities within the building.

The wavelength of high frequency electromagnetic wave is quite short; consequently, reflection is the major mechanism of shielding. For example the Federal Aviation Administration building in Oklahoma City had been designed (MANKIN, 1994) to shield from external electromagnetic field. It was found that protecting the building from a broad range of electromagnetic fields was very helpful.

Low frequency interference is mainly caused by power lines, control devices, various motors and power facilities in buildings. The low frequency interference may be induced from radiation and conduction.

The suspension frame of power line is common in modern buildings. The power lines of lower floor are close to the person and the equipment on the floor above. Sometimes, it causes significant interference.

## CASE STUDY

The building under investigation is a library that is built by reinforced concrete. The schematic diagram is shown in Figure 1; (a) is the suspended power transmission line near the ceiling of the ground floor, (b) is the concrete and steel structure, (c) is the table on the upper floor and (d) is the computer.

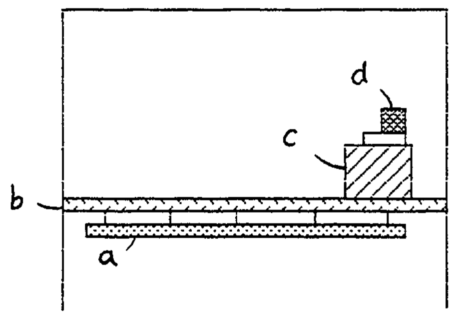



Figure 1. The schematic diagram of power line structure in the library.

High current of the power lines caused computer screen jitters on above floor. The computer screen continuously shifted. People were tired easily while working with the monitor.

**Shielding material selection**

Understanding of the emitting source and the receptor of interference, the major improvement step is to reduce the coupling between the emitting source and the receptor elements. The magnetic field is usually reduced by using shielding plates and enclosures.

Some research had been focused on the new shielding materials; such as metal, composite and ferromagnetic material. Depositing metal on injection molded thermoplastic enclosure of electronic industrial is the state of the art in building barrier against radio frequency interference. The selective deposition of aluminum by evaporation approach was reported in (GWINNER, 1996). The evaporation source was designed so that several microns of aluminum were deposited, achieving high electromagnetic wave attenuation by reflective losses.

For lightweight ceiling consideration, shielding metal fiber composites were developed. The composite was prepared by impregnating highly dispersed short metal fibers into a UV curable polymer matrix. These metal fiber composites offer electromagnetic shielding over a wider frequency range. Although those materials have their advantages, its price is still high.

The shielding mechanisms are based on reflection and absorption. Each time a wave strikes a metallic barrier, a part of its energy passes into the barrier, while part of the energy is reflected. Absorption loss occurs after the wave has entered the shield material, and the absorption loss is independent on the type of wave (electric and magnetic) that struck the shield. The reflection loss of low frequency magnetic field is small, hence the major shielding mechanism is the absorption. The absorption loss is (IEEE, 1997)

$$A = 1.314 \sqrt{f \ \mu \ \sigma} \cdot d \quad \text{dB}$$

where

- $A$ is the absorption loss in dB
- $f$ is the frequency in Hz
- $d$ shielding thickness in centimeters
- $\sigma$ conductivity relative to that of copper
- $\mu$ permeability relative to that of air

The relative permeability of iron is 1000 and the conductivity of iron is 0.17. The 26 Gauge Iron (single layer) has 5.2 dB absorption loss in 60 Hz (IEEE, 1995). It was chosen to shield the suspension frame. A construction method for achieving double-isolated shielding system was also developed in industry. One of the combination is 24 Gauge Galvanized Steel and 3 oz Copper. This is a high performance system using an outer galvanized shield and an inner 3 oz copper shield. The shielding performance of this material for magnetic field at 60 Hz can be 8 dB.

**Approaches and trial**

There are several possible approaches to implement the shield.

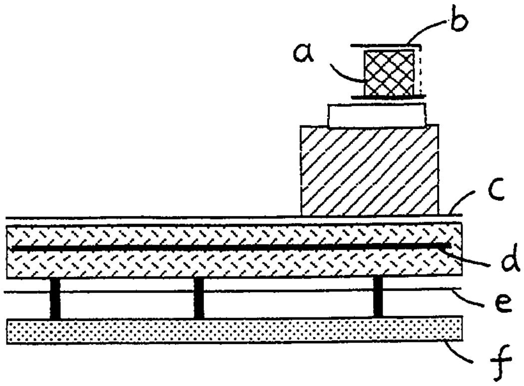



Figure 2 The possible shielding approaches in the trial phase.

All the possible approaches (shown in figure 2) were evaluated in the trial phase. The characteristics of them are listed below.

(a) Monitor with a sensor

The sensor measures field intensity within the monitor, and system circuits generate another opposite field to cancel the interference. As shown in figure 3, this approach requires special circuits and a sensor within the monitor; therefore, this approach needs more engineering effort.

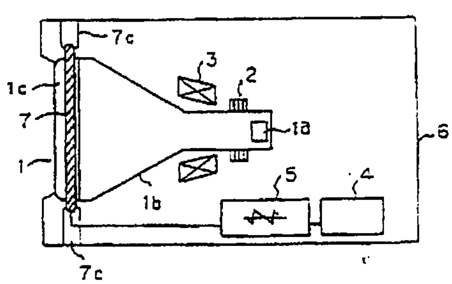



Figure 3. The magnetic field sensor and circuit.

(b) Shielding on the monitor chassis

A shielding enclosure with good absorption characteristics was selected. The enclosure consisted of double metal layers. The measure results showed that the interference was only slightly decreased. Leaving large opening of the screen reduced the effectiveness of shielding.

(c) Shielding on the floor

Several pieces of metal plate were placed on the floor under the table, but the measured result showed the magnitude of magnetic field did not change. It is quite difficult to shield the floor because of the area is too large.

(d) Metal frame in the concrete structure

The effects of the metallic frame of the building on electric and magnetic fields were investigated (RAN, 1996). It was found that the frame can reduce the electric field but has little effect on the low frequency magnetic fields.

(e) Shielding on the ceiling

Some of the shielding structures had been developed. As shown in Figure 4, the Instar Shielding System used a snap-in panel composed of standardized factory prefabricated components to form the shield enclosure. The ceiling area of the library was too big to shield; therefore this approach was omitted.

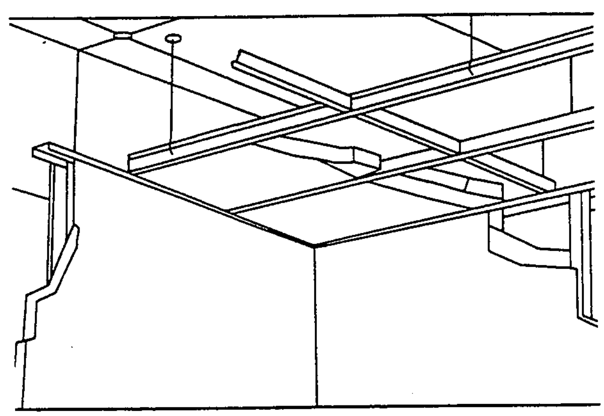


Figure 4 The shielding structure of the ceiling

(f) Shielding the suspension frame.

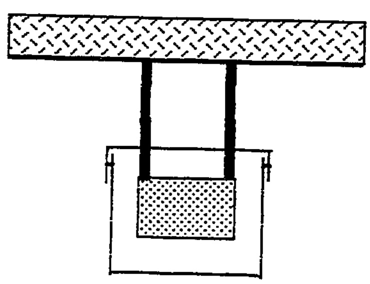
This approach controlled the interference in source region and it was more realistic for the present case. More detail treatments are discussed in following.

## FIELD INSTALLATION

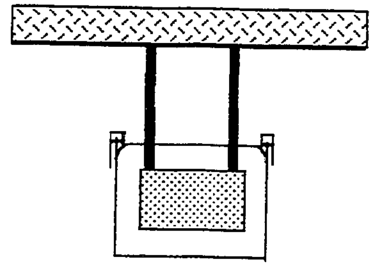
The initial trial was carried out by placing iron plates on the top of the suspension frame. The width of the plates was 2 times wider than that of the frame. The field measurements were carried out by using a HP spectrum analyzer and a loop antenna. The radius of the loop antenna was 5 cm. The probe was sensitive to magnetic fields that point straight into the loop. The spectrum analyzer swept over the frequency range and recorded the maximum receiving intensity. The magnetic field intensity decreased only 2 dB. The screen jitters on the monitor were not improved, either. The finite size of the shielding plate limited the effect of shielding.

The shielding mechanism was also effected by induced current through the shielding materials. The induced current generated another magnetic field to cancel the existing interference. Base on this consideration, an enclosure that surrounded the suspension frame was designed (figure 5.a).

The enclosure had a top part and a removable base part, two parts were connected by screws to ensure the proper electrical contact. This design achieved 5 dB shielding.



(a)



(b)

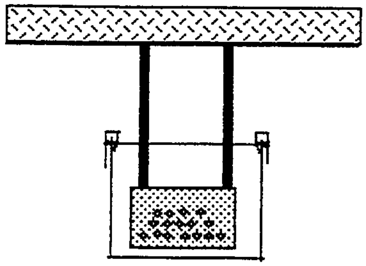
Figure 5. (a) The schematic diagram of shielding enclosure of power cable, (b) the modified approach to enhance the contact.

**Troubleshooting**

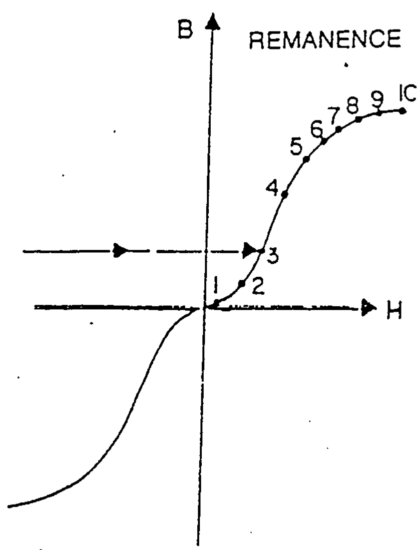
The design in Fig.5.a was installed to observe its reliability. Some failures occurred after 15 days. The resistance measurement showed the contact resistance between top and bottom enclosure was high. Corrosion of the metal surface decreased the electrical conductivity between two parts.

The enclosure was redesigned as figure 5.b to solve the problem. By adding several contact springs between the top and the base surface, the electrical contact and the shielding performance were enhanced.

During the field trial, some of the sections had lower shielding effectiveness. It was found that the power cables were placed near the bottom of shielding enclosure (figure 6.a). While the power cables were placed near the enclosure, the field intensity on the iron plate became high. Figure 6.b shows the B-H curve of a typical iron material. The permeability of the material equals the remanence B divided by the field intensity H.



(a)




(b)

Fig. 6 (a) The placement of power cable within the enclosure (b) typical B-H curve of iron

As shown in figure 6.b, the slope of the curve (the permeability of the metal) decreases when the field intensity becomes larger. Therefore, the shielding effectiveness decreases as the power cable is close to the shielding materials. Base on this observation, the power cables were relocated to central region of the shielding enclosure.

## CONCLUSION

The low frequency magnetic field interference from power cables is one of the major interference source in buildings. The success and failure experiences show the complexity of shielding treatments. Good electrical contact is quite important to ensure a good shielding. Performance of a specific shielding enclosure is also related to the field intensity. The saturation of material reduces the shielding performance. Most modifications that tread the transmission structure and the building floor are generally more costly and cumbersome than if they had been incorporated in an early design phase.

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