THE RADIATED EMI ISOLATION FOR TPS KICKER MAGNET*

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Abstract

Electromagnetic interference (EMI) is a critical problem for electronic equipment, especially for those sophisticated measuring sensors using in TLS (Taiwan Light Source). Therefore, lots of efforts have been made to isolate the electromagnetic noise from the kicker magnets system. In this article, we performed an experiment by using different thicknesses of aluminium plates to block off the specific frequency of radiated electromagnetic wave. Furthermore, the different widths of slits simulated the necessary openings on kicker assembly. According to the results, some parameters were obtained for the enclosure design of kicker magnet in TPS (Taiwan Photon Source). According to the experiment results, these parameters provided a believable guideline in the beginning status of TPS kicker system.

INTRODUCTION

Electromagnetic interference is an existing problem in the pulsed magnet system of TLS for years. Due to the confined space for installation and top-up mode operation, it is difficult to carry on any further improvement to reduce the electromagnetic interference in TLS. Because of the TPS will adopt the same injection mode in the future, the EMI issue should be taken into consideration in advance, and a well-designed structure must be implemented to avoid similar dilemma. Generally speaking, the EMI could be classified with Conducted Emission and Radiated Emission. All kinds of wires and cables, whether connecting to control systems or power systems, could probably provide the path for EMI conduction. By using different band of filters and good grounding networks, the Conducted EMI could be greatly suppressed. As for Radiated EMI, building a seamless enclosure will isolate the receptor from a large amount of electromagnetic wave power from radiation source.

According to the experiment results, some geometrical parameters were obtained to construct the Radiated EMI enclosure of pulsed magnet in TPS. Furthermore, different sizes of slits were applied to simulate the necessary openings between magnet system and vacuum chamber (shown as Fig. 1). The results of small scale experiment showed that these parameters will provide at least 95% of power reduction.

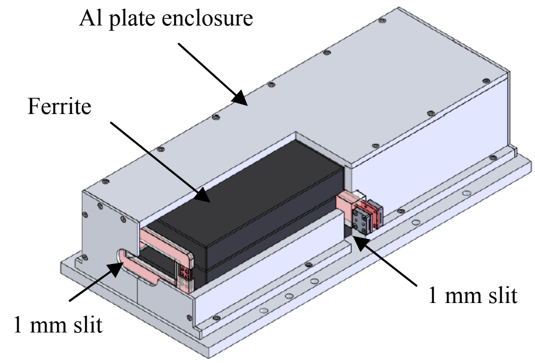

Figure 1: EMI enclosure engineering drawing.

EXPERIMENTAL METHODS AND APPARATUS

The experimental apparatus is set up as shown in Fig 2. A 100 MHz RF signal is generated by RF signal generator, Agilent N9310A. After amplification by power amplifier (SMC25), the signal transmits to the TEM cell to establish EM field. The commercial RF meter, NARDA EMR-300, is installed into the TEM cell to measure the electromagnetic field. At first, the magnitude of electromagnetic wave is large enough to be measured by EMR-300. While the probe encircles by shielding plates, the magnitude of electromagnetic wave becomes too small to be detected. Therefore, a Hall probe has been used to receive small signals in order to ensure the completeness of this measurement. The detection frequency of NARDA EMR-300 ranges from 100 kHz to 3 GHz. The experimental results show a detection limit once the E-field is less than 0.5 V/m. In this case, the Hall probe mentioned above is used to replace the EMR-300.

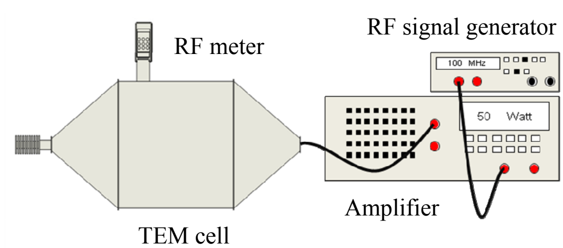

Figure 2: The radiated EMI experimental setup.

A sheet of aluminium 6063 had been cut into several 12x12 cm^2 boards. These Al boards were combined to be shielding boxes with some conditions. The complete scheme of shielding box with RF probe is shown as Fig. 2.

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Figure 2: EMR-300 enclosed by Al 6063 boards and different sizes of Hall probes.

EXPERIMENTAL RESULTS

Thicker substance provides more shielding ability against electromagnetic wave. Taking the strength and the shielding efficiency into considerations, the thickness of enclosure must exceed 3 mm. According to Fig.3 (y-axis is logarithmic scale), the shielding box assembled by 3 mm thick Al boards reduces the E-field to nearly 0.3 V/m (Represented by green line). That is almost 99.7% reduction compares to No-shielding case (Represented by blue line). The red line shows if the thickness of Al boards reduces to 1.5 mm, the electromagnetic wave penetration percentage will increase slightly from 3% to 4%.

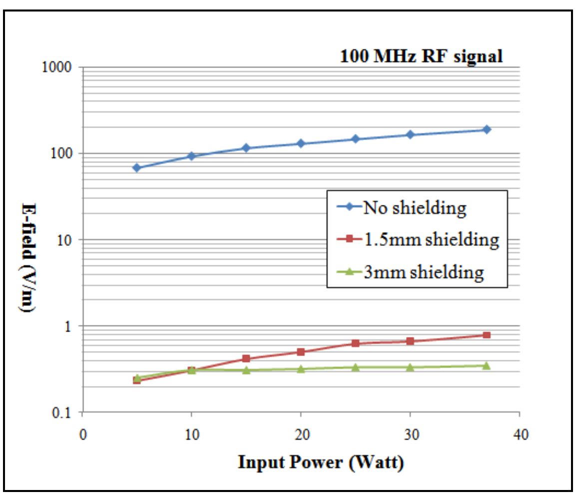

Figure 3: 100 MHz EM wave incident to different thickness of shielding.

In order to clarify the upper limit of slit width, that still provided enough shielding ability. One of the enclosure surfaces had been cut with a 1 mm or 2 mm slit. Meanwhile, the slit had been set in different locations to imitate the various direction holes. From Fig. 4, it can be seen easily that the magnitude of electromagnetic waves is beyond the detection limit of RF meter. The E-field strength could not be measured with a reasonable value except the 2 mm slit case (Represented by red line).

Therefore, a Hall probe was used to collect these small signals (as shown in Fig. 5). The power ratio of shielded to non-shielded is around 3%, which is almost equal to the result of Fig. 3.

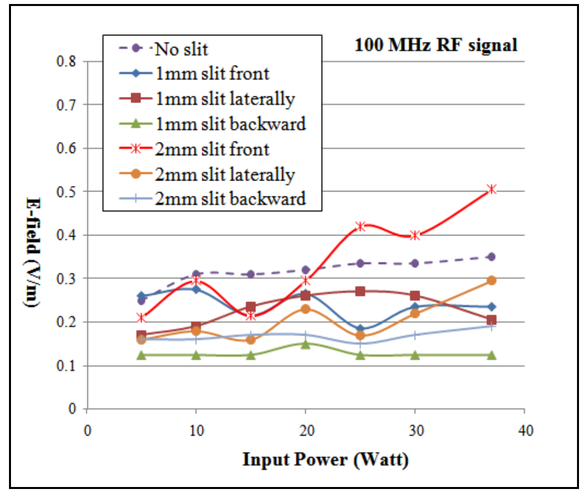

Figure 4: E-field power measured by EMR-300. (Under detecting limitation).

Fig. 6 shows the comparison of energy penetration between 100 MHz and 1 GHz RF source. It is obviously that the electromagnetic wave with higher frequency could penetrate Al board more easily.

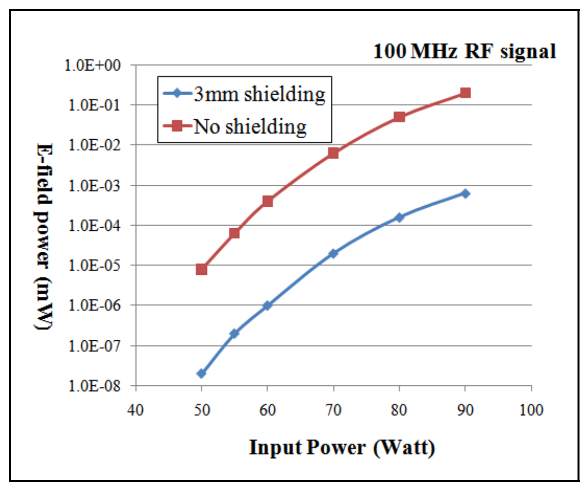

Figure 5: E-field power measured by Hall probe.

A nearly 0.35 V/m E-field was measured by using 100 MHz electromagnetic wave. Once the frequency increased to 1 GHz, the field strength increased to 1.7 V/m as well. Although the through magnitude increased as the frequency rising up, however, the field strength ratio of shielded to non-shielded remains less than 1.3%. That means a 1 GHz, 100 V/m EM wave only 1.3 V/m could be detected under 3 mm Al shielding, and this value is still within our goal, 5% of reduction.

As so far, it has been verified that the enclosure which assembled with 3 mm thick Al boards could provide at least 98% reduction in field strength. The following data will show the effect of opening direction on enclosure. In order to fine tune the position of pulsed magnet, the magnet cannot be fully encircled in real situation.

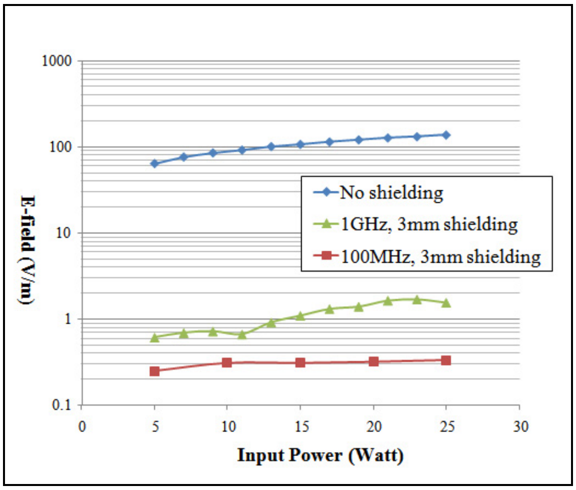

Figure 6: 1 GHz EM wave incident to different thickness of shielding. (Higher frequency leads to more penetration.)

As a result, the following tests were proceeded to find out the proper width on enclosure (shown as Fig. 7). A 2 mm slit was cut on one of the enclosure surfaces, and then repeat the same measurement. The slit was set in some cases: in front of the 1 GHz RF source (red line), lateral to the RF source (green line) and backward to the RF source (purple line). The E-field ranged from 115.4 V/m to 138.8 V/m without any shielding. If the slit confronted to the RF source directly, the E-field could be seen by the magnitude of 3.97 V/m to 5.27 V/m. In other words, nearly 3.4% to 4.0% of EM wave penetrated the breached enclosure. It is not surprised that EM wave passes through a breached structure, but the direction of slit will also affect the outcome. A lateral slit confined the transmission of RF wave, and led to less than 2.5% of penetration. For this reason, any unavoidable opening could be accepted as long as it is not facing to the pulsed magnet directly.

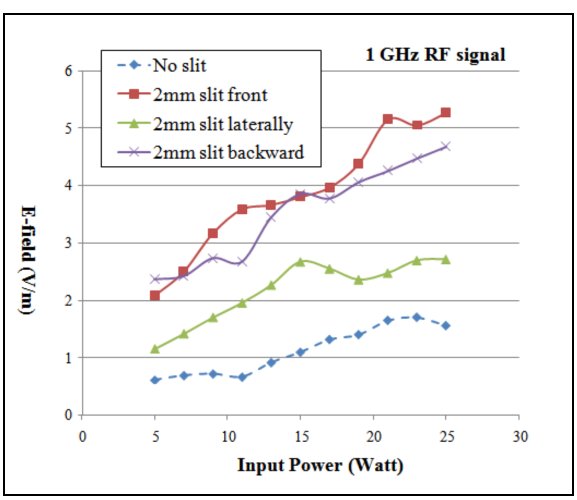

Figure 7: Direction of slit affects the shielding ability.

CONCLUSIONS

After testing several cases, the reduction of radiated EMI of pulsed magnet in TPS had been confirmed. The enclosure assembled by 3 mm thick Al boards and less than 2 mm wide slit could provide sufficient protection from 100 MHz to 1 GHz EM waves. In TPS project, enclosures for pulsed magnets were assembled by 10 mm thick Al boards, and all possible slits were narrower than 1.5 mm. In other words, the enclosures which were designed for TPS project could prevent the instruments those are close to the pulsed magnet from electromagnetic noise affection. According to this paper, this well-designed enclosure could reduce the power of EM wave about 97% to 96% of original value. Even if a slit exist in front of it, nearly 95% of reduction could be observed as well.

Furthermore, the Hall probe was used to collect small signals which may be hidden in the detection limit of EMR-300. This measurement showed the same result as former test. Almost 3% of reduction had been measured once the Hall probe was enclosed within the shielding box. Combined these data, it could be concluded at least 95% of power reduction by using 3 mm thick Al boards.

To provide sufficient isolation, the junctions of enclosure must be well joint. In this paper, as long as the slit was smaller than 2 mm, the electromagnetic field reduced to 3% ~ 5% of its original value. But it is very interesting that a backward slit and a front slit let the same amount of field pass. That means if a blank placed in front of slit, there will be enough isolation, too. All the parameters in this test will be implemented in TPS project.

REFERENCES

[1] Y.-H. Liu et. al., "Analysis and reduction electromagnetic interference to ICTs caused by pulsed power supply excitation in NSRRC.", EPAC06, 2006.

[2] "International Standard IEC 61000-4-3", International Electrotechnical Commission.