THE EMI REDUCTION OF PULSED MAGNET IN NSRRC*

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Abstract

The purpose of this paper is to reduce the Electromagnetic Interference (EMI) from kicker and its pulsed power supply. Analysis of conducted and radiated EMI is the beginning mission. Different frequency range of radiated EMI was measured by different sensors. A hybrid shielding method was used to test reduction of radiated EMI. The copper and μ-metal enclosure was used on kicker magnet to prevent the radiated EMI. The reduction of electromagnetic field showed the effect of different material. Besides, the conducted EMI was also tested and eliminated by adding grounding routs. For decreasing grounding noise to other systems, the individual grounding bus was installed. The experimental results showed significant effect. In the future, TPS (Taiwan Photon Source) injection magnets will design higher performance, lower EMI than TLS (Taiwan Light Source). Therefore reducing and eliminating the interference of electromagnetic waves will be a very important issue. All the EMI prevention schemes will implement in the new project.

INTRODUCTION

Electromagnetic Interference is one issue of TLS because of the limited space and top-up mode operation. For TPS project, top-up mode injection will also be the basic operation mode in the future. Therefore, injection magnets will produce conducted and radiated EMI similar to TLS existing condition. For eliminating and reducing interference between injection sections, a good EMI design should be implement in the beginning. Firstly, a good impedance match between pulsed power supply and magnet (load) should be notice carefully. The co-axial or tri-axial cable will use to reducing radiated EMI. The connectors should be bond very carefully. Secondly, the grounding scheme will design based on the TLS experience. Every kicker will have exclusive grounding bus directly connect to grounding networks. The spray current will also collect by several routs in order to increasing efficiency. Finally, the EMI enclosure is proved effective and will implement to kicker magnet and its pulser. All three steps are the total solutions to reduce conducted and radiated EMI of TPS pulsed magnets.

RADIATED EMI TESTS

The first step to clarify radiated EMI of kicker was tested the magnetic field using different sensors. The low frequency range of magnetic filed was measured by ELF Gauss/Tesla meter, which test Extremely Low-frequency filed (ELF) from 25 Hz~2 kHz. The high frequency range of EMI was tested by magnetic field probe, which measure frequency range from 100 kHz to 3 GHz.

In order to reduce radiated EMI from pulser and pulsed magnets, the EMI shielding enclosure is the best way. The copper and μ-metal enclosure was used on kicker magnet to prevent the radiated EMI. First, the high frequency EMI was tested by using NARDA EMR-300. The magnetic field probe was used E-field Type 8, which frequency range is from 100 kHz ~ 3 GHz. The experimental results showed the background EMI noise level was about 0.5 V/m, which the base line in blue color was shown in Fig. 1. The background condition means the system was OFF during testing. All the systems including power supply and pulser were off during measuring.

Before shielding, the magnetic field was 2.0 ~ 4.5 V/m during firing (15 kV pulse test) in variety positions, which was blue line shown in Fig. 1. The magnetic field was various in different locations, probably because of different magnetic field direction and EM wave propagation. After shielding, the magnetic field was reduced to 2.0~2.5 V/m, which was green line shown in Fig. 1. The shielding efficiency was good in some location and bad in other place. The reduction percentage of E-field was 50%~0% in different locations.

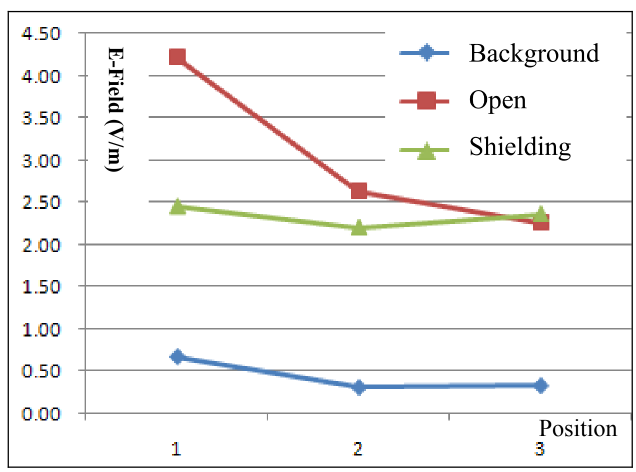

Figure 1: High frequency radiated EMI.

The TPS prototype kicker copper shielding enclosure was shown in Fig. 2. The thickness of copper was 5 mm, which was made to enclose the kicker magnet. There were only two holes open where the ceramic chambers will locate. The shielding efficiency was various probably because of the open holes in beam direction or other small gaps between copper enclosures or the cable connecting point.

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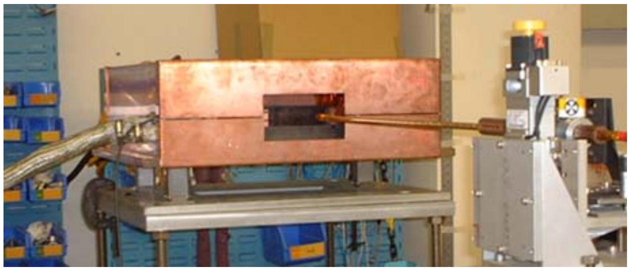

Figure 2: Kicker copper enclosure.

At the same time, the low frequency magnetic filed was also measured by Gauss/Tesla meter (F.W. BELL Model 4190). The frequency range is from 25 Hz ~ 2 kHz. The background of EMF was about 0.11 mG everywhere, which the base line in blue color was shown in Fig. 3. The EMF was about 0.12~0.16 mG during firing (15 kV pulse test), which was red line shown in Fig. 3. After μ-metal enclosure, the EMF was reduced to 0.10~0.07 mG, which was green line shown in Fig. 3. The ELF magnetic filed was even smaller than background level. The reason could be μ-metal is very effective to shield low frequency noise. On the other hand, the low frequency EMF had no big difference between on and off. It implied that the kicker radiate high frequency EMI while firing. And the high frequency enclosure to kicker is more important than low frequency EMI.

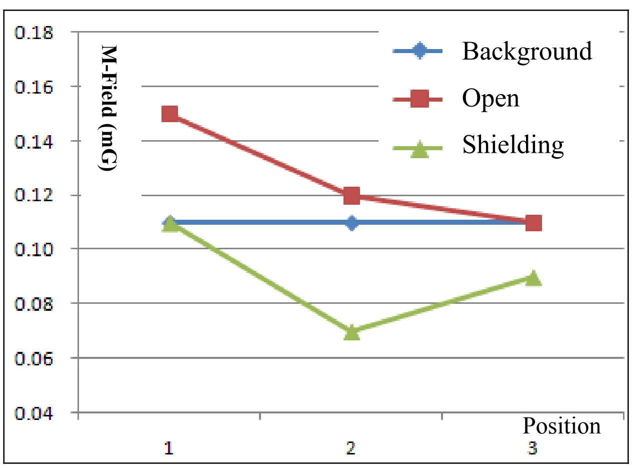

Figure 3: Low frequency radiated ELF.

The experiments showed that the radiated EMI could be shielding by using different materials. The high conducted material such as copper was suit to shielding higher frequency EMI. It is needed to be noticed that the enclosure gap between holes and connector points. The heat problem therefore caused by shielding was also needed to be noticed. SLS suggested opening a gap in kicker to reduce the temperature inside, the water cooling will be one of the options to reduce the heating problem. Besides, the low frequency ELF shielding was also tested by using μ-metal. The μ-metal is high permeability material, which is suitable to reduce the low frequency magnetic field. Although the μ-metal actually reduces the ELF, the difference between shielding was not significant. The necessity using μ-metal needed under evaluation.

GROUNDING SCHEME

The grounding scheme of TPS injection section will design based on the TLS experience. Every kicker will have exclusive grounding bus directly connect to grounding networks. The spray current will also collect by several routs to increase efficiency.

In order to reduce the spray current excited by kickers and septum, increasing spray routes directly to the local ground bus could reduce the spray current [1]. The spray current induced by pulser should retrieve by several routs back to pulser ground point. Thus, paths of spray currents have no interchange between other subsystems. The routs of kicker supports and the ceramic chamber to the ground bus are shown in Fig. 4.

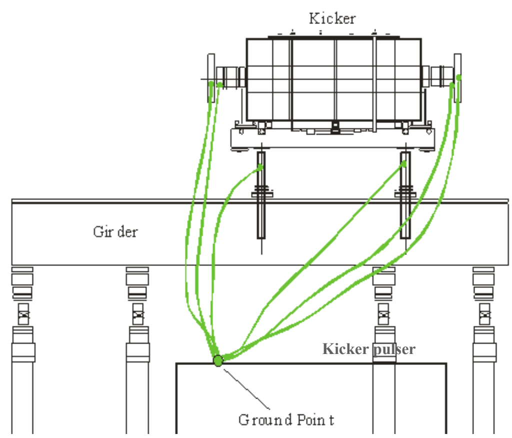

Figure 4: Kicker ground routes.

Next, each kicker will have exclusive grounding bus directly connect to grounding networks. Figure 5 showed the TLS grounding bus for one of the kicker. The exclusive grounding bus was directly connected to grounding box and insulates to the circulation Cu bus in the storage ring. In order to avoid the fault current flow to each other, the kickers need individual support. That means girder should separate to kickers and septum each other. The experimental results showed that the separation of 4 kickers and septum grounding bus eliminated the mutual spray fault currents.

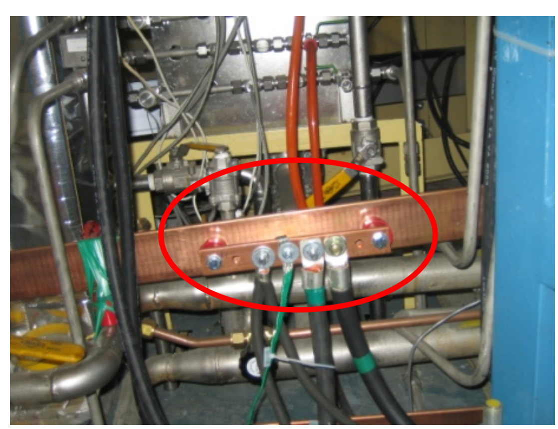

Figure 5: Exclusive ground bus.

Figure 6a showed the spray current during injection before modification. The grounding routs were all bond to copper bus which was encircled to the whole storage ring. During injection, the grounding current measured located in Cu bus was increased up to 1.2 A. After injection, the grounding current revived to the base line ~ 70 mA. The significant difference between injection and normal operation indicated the spray current flow by Cu bus. Thus, the spray currents scatter by any possible routs nearby and could possibly affect the sensors or instruments nearby the injection section. There was one example ICT (Integral Current Transformer) which was affected by injection spray current [2].

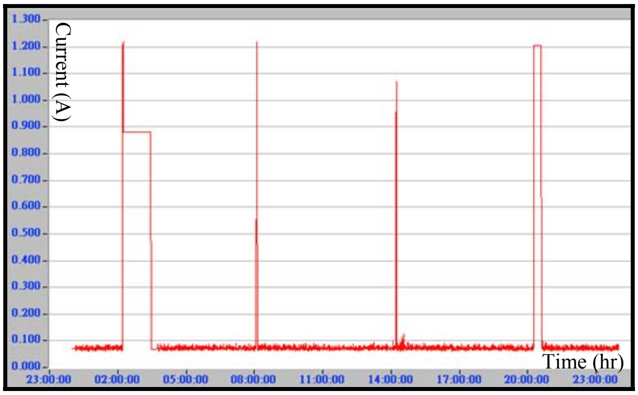

Figure 6a: Current on Cu bus before modification. (24 hr) (Max. spray current up to 1.2 A)

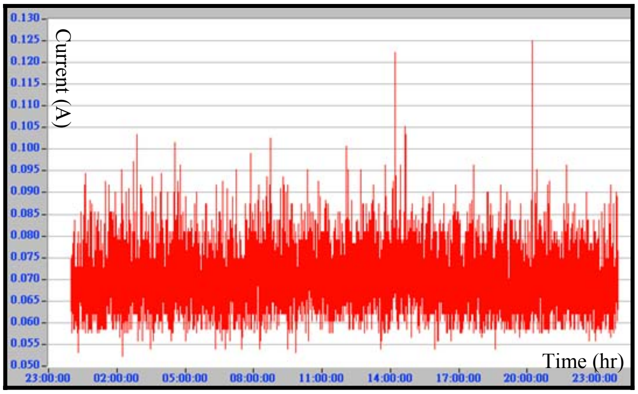

Figure 6b: Current on Cu bus after modification. (24 hr) (Average spray current ~70 mA)

Figure 6b showed the spray current during injection after modification. The grounding buses for 4 kickers and septum were separate. Each pulsed magnet had exclusive grounding bus directly connected to grounding box. The experimental results showed that the spray current almost have no difference between injection and normal operation. The maximum current was not exceeded to 120 mA and approach to the base line ~ 70 mA. It means the fault currents were revived back to pulser themselves rather than spray to other systems. The conducted EMI was recovered by planed routs directly go back to the source point/pulser. The experimental results showed the good performance by using exclusive grounding bus.

EMI REDUCTION SCHEME

The EMI reduction scheme of pulsed magnet in TPS will show in Figure 7. First, a good impedance match between pulsed power supply and magnet should be very important. The EMI shielding cable will use to reducing radiated EMI. Second, every kicker will have exclusive grounding bus directly connect to grounding networks. The spray current will also collect by several routs in order to increasing efficiency. Third, the EMI enclosure will implement to kicker magnet and its pulser. All three steps are the total solutions to reduce conducted and radiated EMI of TPS pulsed magnets.

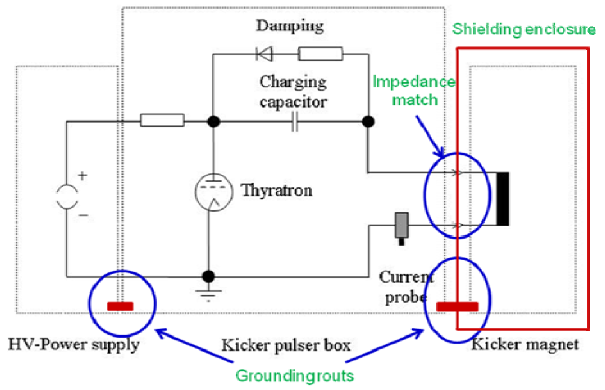

Figure 7: EMI reduction scheme.

CONCLUSIONS

After different testing, the reduction of radiated and conducted EMI of pulsed magnet in TPS got some results. The copper and μ-metal enclosure was used on kicker magnet to prevent the radiated EMI. The reduction of electromagnetic field showed the effect of different material. Besides, the conducted EMI was also tested and eliminated by adding grounding routs. For decreasing grounding noise to other systems, the individual grounding bus was useful reducing conducted EMI. In the future, TPS injection magnets will design higher performance, therefore reducing and eliminating the interference of electromagnetic waves will be a very important issue. All the EMI prevention schemes will implement in the new project.

REFERENCES

[1] J. Carwardine and J. Wang, "Analysis of the electrical noise from the APS kicker magnet power supplies.

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