ANALYSIS AND REDUCTION ELECTROMAGNETIC INTERFERENCE TO ICTS CAUSED BY PULSED POWER SUPPLY EXCITATION IN NSRRC*

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Abstract

The purpose of this paper is to eliminate the Electromagnetic Interference (EMI) from kicker power supply. Analysis of the EMI source and the propagation path are the beginning missions. The radiated and conducted EMI both affected the Integral Current Transformer (ICT) normal operation because of the space limitation for TLS in NSRRC. The ICT is to measure injection efficiency, thus, ICT located just behind the kickers and using the common girder. The EMI signals therefore are much higher than the electron beam currents and the integral values of the sensor are not correct. For reducing and eliminating the interference of electromagnetic waves, a hybrid segregation and grounding method was used [1]. The EMI wrapper was enclosed the ICT and its high frequency amplifier separately to prevent the radiated EMI from the space. The grounding paths provided the possible stray current dredge to the ground loop. It reduced the stray current spread to the subsystems next to the kickers. The conducted and radiated EMI therefore reduced over 95% and the injection efficiency could be calculated successfully. The elimination of the EMI from kicker itself will be the next step in the future.

BACKGROUND

Electromagnetic Interference is one of the TLS issue because of the limit space in TLS. The electron beam will produce strong electromagnetic field, especially obviously interference occur while injecting. When the electron beam is injected, the kicker need kick electrons from booster to storage ring. The kickers were excited by pulsed high current, such pulsed current induced conducted and radiated EMI. The situation is more serious while the top-up mode operate in TLS.

ICT DESCRIPTION

The ICT (Integrated Current Transformer) is for examining the injection efficiency. The sensors locate separately in the beginning, middle, and the end of the transport line (BTS-Booster to Storage ring). The position of the ICT3 is illustrated in Fig. 1. It is installed in the end of the BTS, located next to Septum. The position of ICT3 is in the front of the Kicker1 and Kicker2 (relatively close to Kicker2). Because of locating nearby the kickers, the ICT3 suffered tremendous influences from the Kicker firing. The noise of the signal is higher than the electron beam current, therefore the injection current can not be quantitatively analyzed.

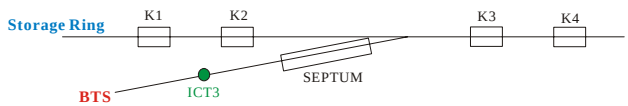

Figure 1: Relative position of the ICT3.

Fig. 2 is the photo of the ICT3. The signal of the integrated current passed through the radio frequency amplifier, and transferred to the control room. The Instrument & Control group received the signals and converted the currents to the injection efficiency.

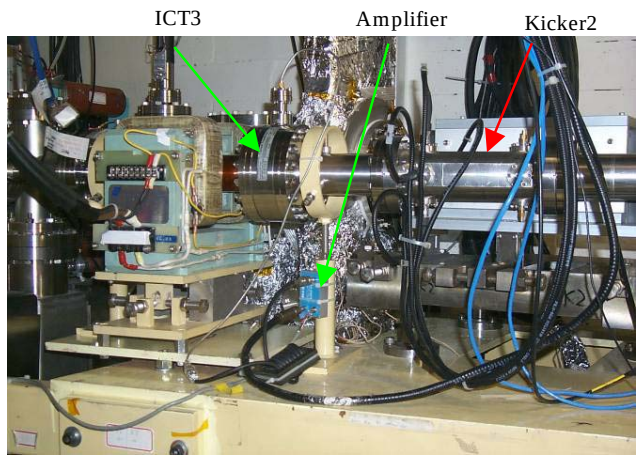

Figure 2: The photo of the ICT3.

EMI OF ICT

Fig. 3 is the signals measured by the ICTs during injection. The blue line is the signal of ICT1, which located in the beginning of the BTS. The red line is the signal of the ICT2, which located in the middle of the BTS. The voltage drop is about 1.8 V and the duration of the electron current is about 200 μsec. The green line is

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the signal of the ICT3, where there is high frequency noise in front of the beam current. The noise is induced by high pulsed current (kicker power supply). The pulsed power supply extracted EMI and pick up by the nearest sensor - ICT3. Because of the electron beam current is integrated value; the measured signal is highly influenced and could not set the trigger level. Thus the correct beam current could not be found.

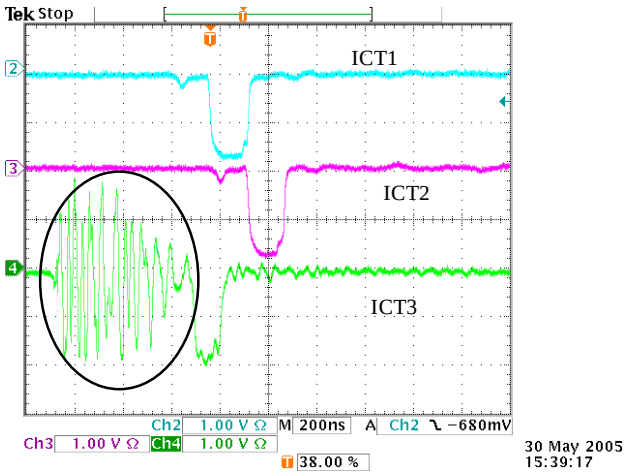

Figure 3: The signals measured by ICTs.

According to the experimental results, the source of the noise must be confirmed. First, excited Kicker1 to Kicker4 separately, observed the affection to the ICT3 during machine study period. The electromagnetic environment is the simplest situation during machine study period. The results shown that while K2 firing, the noise received by ICT3 is biggest. K1 is the next. There is rare influence to ICT3 while K3, K4 and Septum firing. It is sure that the noise received by ICT3 majority caused by K1 and K2 firing, and the noises include the conducted and radiated EMI.

REDUCE RADIATED EMI

Although the ICT3 locates next to the Kickers, there must be some radiated EMI affected the received signal. In order to reduce the radiated EMI, the EMI wrappers were used. The material of the EMI wrapper is frame-resistant UL94VTM-0 fabric. The shielding effectiveness is approximately 50 dB and depends on frequency. Because the EMI wrapper is being a fabric, the material could cover and EUT of any shape or cable.

Next, the wrap ways and locate the position of the EMI wrapper were tried during machine study. Enclosed the ICT3 and radio frequency amplifier separately, shown in Fig. 4, formed the best performance. The effect of enclose the ICT3 and amplifier separately is better than enclose ICT3 and amplifier together. The conclude noise is shown in Fig. 5. This is the signal picked up by ICT3 without electron beam current. The noise dropped tremendously, especially frequency higher than 30 MHz. It match the EMI wrapper specification, and the EMI wrapper is effective with high frequency radiated EMI.

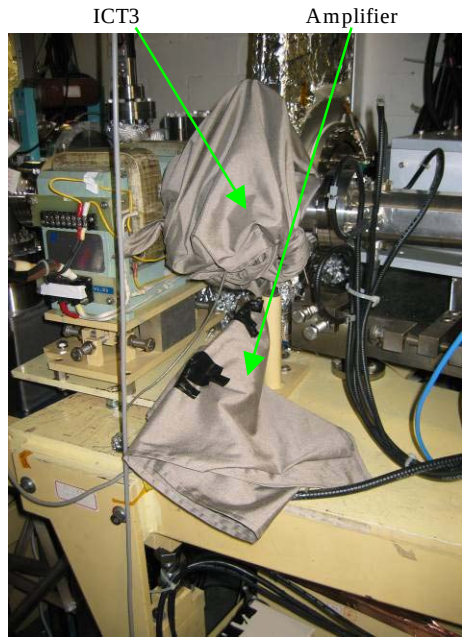

Figure 5: EMI wrapper enclosed the ICT3 & amplifier.

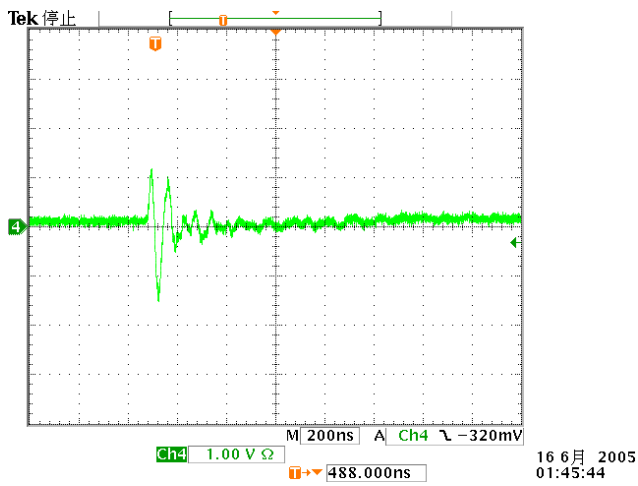

Figure 5: Noise picked up after EMI wrapper enclosed.

The electromagnetic noise is reduced by using EMI wrapper. The performance is good in the frequency higher than 30 MHz. The spectrum of Fig. 5 showed that the noise almost approach to zero in high frequency, and the frequency of the noise lower than 30 MHz could not be eliminated by EMI wrapper. Compare with the current measured by electron beam, the noise still too high. In order to further eliminate the electromagnetic interference, the analysis of the ground condition nearby the ICT3 is needed.

REDUCE CONDUCTED EMI

In the section of BTS to storage ring, K1, K2, Septum and ICT3 use the same girder to support these parts. The girder is made of stainless steel. The conducted EMI

could possibly transmit to the ICT3 or the amplifier while kicker firing. The conducted EMI is spray to the local position nearby the kicker power supply and kicker itself. In order to reduce the spray current excited by kickers, increase the spray routes directly to the local ground could reduce the spray current [2]. The kicker supports to girder and the girder to the ground routes were added after the evaluating the conducted EMI situation, shown in Fig. 6.

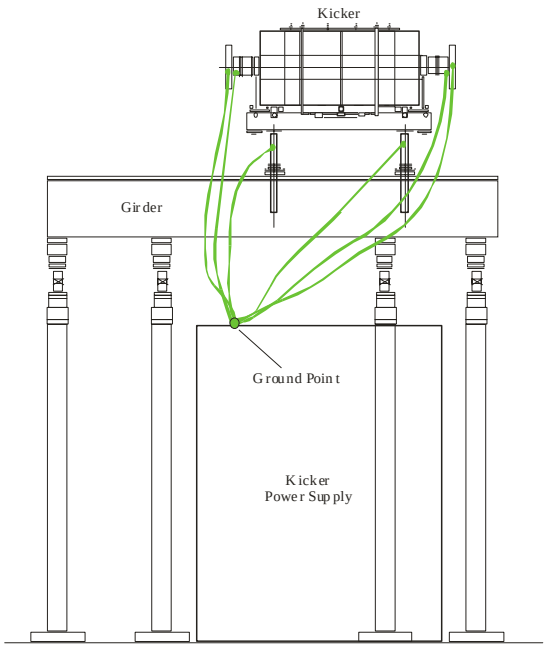

Figure 6: Kicker Ground Routes.

The noise signal measured by ICT3 after adding the spray ground routes is shown in Fig. 7. The pick to pick value of the noise reduced from 2.8 V to 1.2 V after doing EMI eliminating procedure. Compare with the electron beam current, the ICT3 signals could be accommodate correctly. The trigger level can be set easily and the kicker fire induced EMI have time shift with the electron beam current.

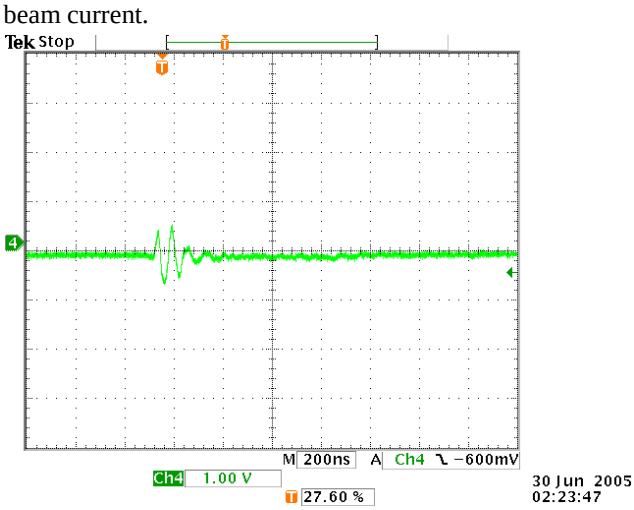

Figure 7: Noise picked up after add the spray ground routes.

FINAL PROFORMANCE

The injection efficiency is measured and recorded in the History server. The one day injection current is shown in Fig. 8 after eliminating the EMI. The red line is the current measured by the ICT1, and the green line is the current measured by the ICT2. The experimental results show that the beam currents are increase during injection and reveal after injection. The blue line is the current recorded by the ICT3 after the EMI accommodation. The electron beam current was recorded successfully, and the signals were triggered and operated normally. According to the beam current amplitude, one can calculate the injection efficiency from the beginning of the BTS to the end of the BTS. This is an important clue to evaluate the top-up mode operation performance, and provide the Beam Dynamic team and Operation team to evaluate the beam condition. Increasing injection efficiency could effective reduce the radiation dosage. Thus, the normal operation of ICT will directly influence the parameters of the accelerator.

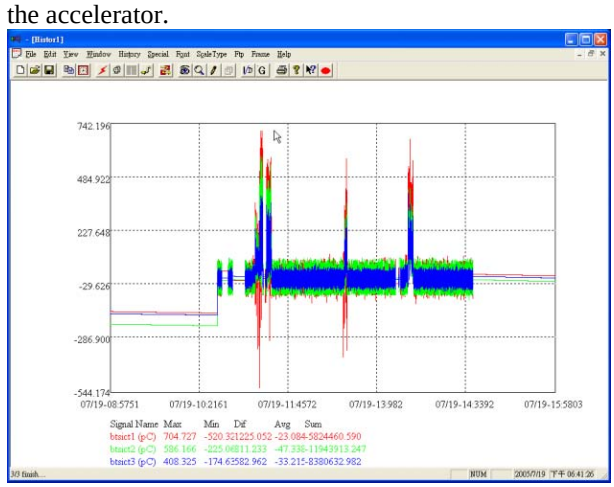

Figure 8: Signal after EMI reduction.

CONCLUSIONS

The radiated and conducted EMI both affected the Integral Current Transformer (ICT) normal operation because of the space limitation. The EMI wrapper was enclosed the ICT and its high frequency amplifier separately to prevent the radiated EMI from the space. The grounding paths provided the possible stray current dredge to the ground loop. It reduced the stray current spread to the subsystems next to the kickers. The EMI therefore reduced over 95% and the injection efficiency could be calculated successfully.

REFERENCES

[1] J. Carwardine, Electrical Systems and Grounding at The APS, APS Power Supply Group, February 2001.
[2] J.A. Carwardine and J. Wang, “Analysis of the electrical noise fromthe APS kicker magnet power supplies