INSTITUTE FOR NUCLEAR STUDY
UNIVERSITY OF TOKYO
Tanashi, Tokyo 188
Japan

INS-TH-144
Feb. 1982

NOISE REDUCTION IN THE BEAM CURRENT MONITOR

SHIGEAKI ARAI

INS-TH-144
Feb. 1982

NOISE REDUCTION IN THE BEAM CURRENT MONITOR

SHIGEAKI ARAI

Institute for Nuclear Study, University of Tokyo
Tanashi-shi, Tokyo 188, Japan

Abstract

A simple noise reduction system using a pulse transformer and a pair of L C low pass filters has been introduced to the beam current monitor of a current transformer type at the INS electron linac. With this system, the pick-up noise has been reduced to be 1 % of the noise without noise reduction. Signal deformation caused by this system is relatively small and the beam current pulse down to 20 mA is successfully monitored in the actual accelerator operation.

§1 Introduction

Ferrite core monitors of a current transformer type[1)] are now being used as a beam current monitor of the INS (Institute for Nuclear Study, University of Tokyo) electron linac. The linac beam has a pulse width of 2 μsec and its current intensity is usually in the region of 50 mA ~ 250 mA. The output signal of the core monitor is displayed on the oscilloscope at a control room which is about 15 m away from the core monitor. Since the signal amplitude is relatively small and there are many noise sources around the accelerator, the reduction of the pick-up noise in the monitoring system becomes an important subject. The main noise sources at the linac are the thyratron switch tubes used in the high voltage pulse modulators for the electron gun and the klystron. The noise is picked up by the coil wound around the ferrite core and by the cable which sends the signal from the core monitor to the oscilloscope. In order to propagate the fast pulse signal, the coaxial cable is currently used. When the output of the core monitor is directly connected to the oscilloscope with the coaxial cable, the signal-to-noise ratio is not large enough to monitor the present beam current.

To increase the signal-to-noise ratio, an amplifier is generally used at the proximity to the core monitor. The pick-up signal is once amplified with the amplifier and is send to the oscilloscope with the long coaxial cable. However, the amplifier set near the core monitor is apt to be damaged by the radiation and the change of the amplifier gain becomes a serious problem. Therefore, in order to simplify the maintenance by improving the reliability of the monitor, another method using a pulse transformer has been introduced for the reduction of the noise. In the present paper, this approach in the beam current monitor of the electron linac is described.

§2 Beam Current Monitor with the Noise Reduction System

A schematic diagram of the beam current monitor using ferrite core is shown in Fig. 1. The principle is simple. When the pulsed beam passes through a core monitor, the voltage proportional to the beam current is induced at both ends of a shunt resistance of the coil wound around the ferrite core.

When the rectangular pulsed beam with a width of t_w passes through the core, the induced voltage is given as follows;

$$V(t) = \frac{R\ I_o}{N} e^{-(R/L)t} , \quad (0<t<t_w)$$

and

$$V(t) = \left(\frac{R\ I_o}{N} e^{-(R/L)t_w} - \frac{R\ I_o}{N}\right) e^{-(R/L)(t-t_w)} , \quad (t_w<t) \qquad (1)$$

where N is the number of turns in the coil around the core, I_o is the beam current, R is the shunt resistance and L is the inductance of the coil. The droop of the pulse top is defined approximately by $R \cdot t_w/L$. When the number of turns in the coil is small, the signal voltage increases but the droop of the waveform becomes large. Therefore the number of turns is finally decided from the tolerance of the droop.

When the amplifier is not used, the shunt resistance is matched to the impedance of the transmission line of the output signal and is chosen usually to be 50 Ω. However, with this simple configuration, the signal displayed on the oscilloscope is illegible because the signal-to-noise ratio is so small. Then, the following method using the pulse transformer and LC-filters has been employed for the noise reduction. A circuit of the system is shown in Fig. 2. The signal from a core monitor is divided into two signals which has opposite polarities with each other. The signals are sent with two coaxial cables to the pulse transformer which is set just before the oscilloscope. Since two primary coils of the pulse transformer are wound in opposite directions, the noises with the same polarities on two coaxial cables are canceled each other and two signals with the opposite polarities are superposed to reproduce the original signal. The high frequency component of the noise, which is not canceled effectively by the transformer, is cut by means of low pass filters composed from an inductance and a capacitance. They are set immediately before the pulse transformer.

Although the shape of the output signal from the pulse transformer changes somewhat in comparison with that of the input signal,[2)] this deformation can be suppressed by choosing parameters suitably as small as tolerable. The change of the waveform by the pulse transformer appears as a droop of the pulse top. From a equivalent circuit shown in Fig. 3, the droop is given by a form,

$$\text{droop} = R_G R_L t_w / L_P (R_G + R_L) , \qquad (2)$$

where R_G is the source impedance, R_L is the load impedance and L_P is the primary inductance of the pulse transformer. In this case, the droop is negligible because R_G is a coil resistance of the ferrite core monitor and is very small. Dullness of the rise time caused by the pulse transformer can be neglected too, since the distributed capacitance and leakage inductance of the coils of the pulse transformer are small, respectively. However, the dullness of the rise time by the LC-filter can not. The rise time t_r is given approximately by

$$t_r = \frac{\pi}{\sqrt{2}} \sqrt{L C} . \qquad (3)$$

As a core of the pulse transformer, Tokin permalloy (TMH) is used which has dimensions of 10 mm in thickness, 25 mm in inner diameter and 35 mm in outer diameter. The number of turns in the primary coils is 10 and that in the secondary coil is 20.

§3 Experimental Results

At first, in order to investigate the dullness and the droop due to the core monitor and the noise reduction system, the rectangular pulsed current of 100 mA has been fed to a one-turn coil wound around the core monitor and the shape of the output pulse has been observed. The result is shown in Fig. 4. The upper signal shows a test input pulse and the lower signal shows an output signal. The droop is about 3 % and the rise time is about 0.3 μsec, which are quite acceptable for the present purpose of beam monitoring.

In the next place, effectiveness of the system for noise reduction has been investigated experimentally by using the actual beam from the electron linac. The waveforms of the output signal in the case of beam current 150 mA are shown in Figs. 5(a) and 5(b). Figures 5(a) and 5(b) show the waveforms monitored with noise reduction and without noise reduction, respectively. Figure 5(c) shows the waveform of the noise wihtout noise reduction. By comparing these figures, it is noted that the pick-up noise in the beam monitor with noise reduction is reduced to be 1 % of that without noise reduction. The noise amplitude after noise reduction is equivalent to the beam current of about 20 mA.

In conclusion, the above described method is very useful for the reduction of the pick-up noise and is applied successfully in the beam current monitor at the INS linac.

Acknowledgments

The author would like to express his sincere thanks to Dr. H. Okuno and Dr. K. Yoshida for reading the manuscript and for their valuable comments.

References

1) R. Yamada, Japan. J. appl. Phys. 1 (1962) 92

2) J. Tanaka and H. Baba, INS-TH-69 (1971)

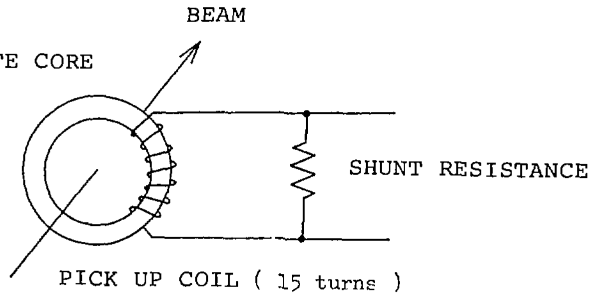

Fig.1 Ferrite core monitor

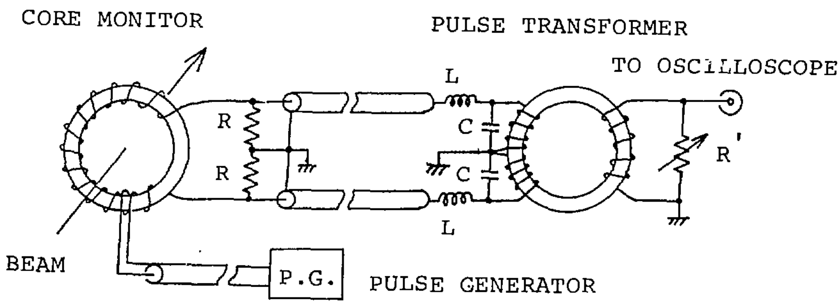

Fig.2 Schematic diagram of the noise reduction system where $R = 50\ \Omega$, $L = 1.6\ \mu H$, $C = 570\ pF$ and $R' = 50\ \Omega$.

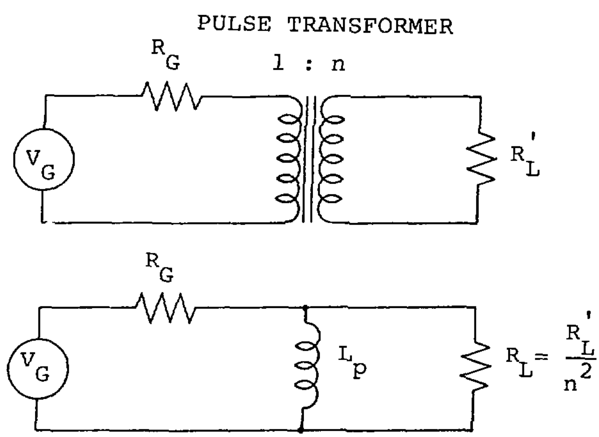

Fig.3 Equivalent circuit for the low frequency component.

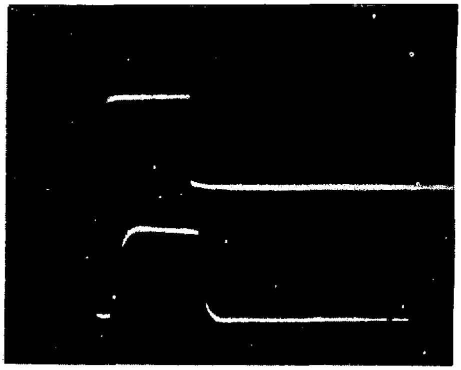

Fig.4 Dullness and droop due to the core monitor and noise reduction system.
Upper and lower signals show the test input pulse and the output pulse, respectively
Time scale = 1 μsec/div. and amplitude scale = 50 mV/div.

Fig.5(a) Output waveform with noise reduction.

Time scale = 2 μsec/div. and amplitude scale = 50 mV/div.
Beam current = 150 mA.

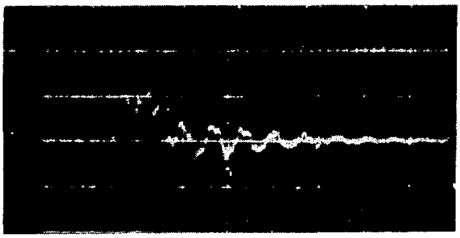

Fig.5(b) Output waveform without noise reduction.

Time scale = 2 μsec/div. and amplitude scale = 1 V/div.
Beam current = 150 mA.

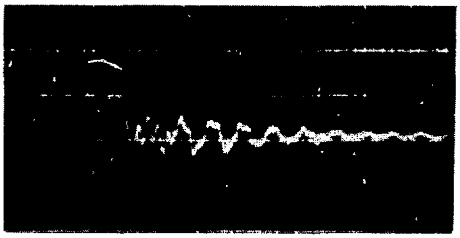

Fig.5(c) Noise waveform.

Time scale = 2 μsec/div. and amplitude scale = 1 V/div.