THE STATUS OF COUPLING IMPEDANCE MEASUREMENT FOR THE CSNS/RCS EXTRACTION KICKER PROTOTYPE*

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Abstract

Rapid Cycling Synchrotron (RCS) of the China Spallation Neutron Source (CSNS) is a high intensity proton accelerator, with average beam power of 100kW. In order to high intensity beam operation, the beam coupling impedance of the extracted kickers must be controlled. Longitudinal and transverse impedance of extracted kicker prototype with power supply had been roughly measured by coaxial-wire and dual-wire methods respectively. At the same time, impedance of window has been analyzed theoretically and simulated based on CST PARTICLE STUDIO.

INTRODUCTION

The charged particle beam interacts electromagnetically with its surrounding which is usually described by impedance. Coupling impedance and its instability budget become an important part of designing a high intensity accelerator. Analytical estimation for different vacuum components has been done and it is available in the literature [1]. For standard devices, the estimated impedance should be confirmed by measurement in laboratory. It is easier by measurement than theoretical analysis for complicate components. The standard method of measurement is simulating the beam by a single wire for longitudinal or dual-wire for transverse. The standard method of transverse coupling impedance was first applied by Walling et al [2], and the forward transmission scattering coefficient with a network analyzer S_{21} is measured. The various formulas for the interpretation the measurement have been discussed in the papers [3] [4].

China Spallation Neutron Source (CSNS) is a high intensity proton accelerator based facility, which consists of an H- Linac, Rapid Cycling Synchrotron (RCS) and two beam transport lines [5]. To achieve high beam current, the impedance must be carefully studied. There are eight extraction kicker and they are the main source of RCS impedance. To detailed study kickers, a kicker prototype is manufactured. Figure 1 shows the kicker prototype, and Table 1 gives the main parameters of the kicker [6]. It is difficult to theoretically calculate the prototype impedance since it is complicated structure. Thus studying the impedance by measurement is a relevant method.

The measurement platform and primary result are shown in the paper. In order to comparison the validity of measurement, the corresponding and simple CST simulation model is established, and then comparison between measurement and simulation is introduced. The improved method of measurement will be exhibited.

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Figure 1: The prototype of extraction kicker.

Table 1: The Main Parameters of Kicker Prototype

Inductance(μH)	0.53
Magnetic field intensity(Gs)	560
Effective length(mm)	310
Rise time(ns)	236
Flat time(ns)	608
Loss time(ms)	1
Scale/H*V(mm)	133×206

STANDARD METHOD MEASUREMENT

The assign of measurement is measure longitudinal and vertical impedance of kicker prototype with or without cable on frequency range from 1MHz to 100MHz, which is consistent with bunch length. A naked copper wire of 0.5mm diameter is stretched in the device under test (DUT) with appropriate resistor for matching to 50 Ω cables at both ends. Vector network analyzer (VNA, ADVANTEST R3765CG) is connected to measure the S_{21}, transmission coefficient. The odd mode signal in transverse measurement can be obtained by Hybrid ZFSCJ-2-1-N [7].

Figure 2 shows the schematics of longitudinal impedance measurement with single wire and transverse impedance measurement with two wires. The matching resistor is wrapped by the adaptor, which is circular stainless steel flange. The value of matching resistor is given as [3]

$$R_s = R_c - R_0. \quad (1)$$

with the cable characteristic impedance R_0, the characteristic impedance R_c for coaxial line R_c^L and two wires system R_c^L are given as [8]

$$R_c^L = \frac{60}{\sqrt{\varepsilon_r}} \ln(b/a), \quad (2)$$

$$R_c^T = \frac{1}{\pi}\sqrt{\frac{\mu_0}{\varepsilon_0}} \ln(\frac{2d}{a}). \quad (3)$$

with permittivity ε_0 and relative permittivity of medium ε_r, the radius of reference piper b, copper wire radius a, permeability μ_0, and the space of two wires $2d$.

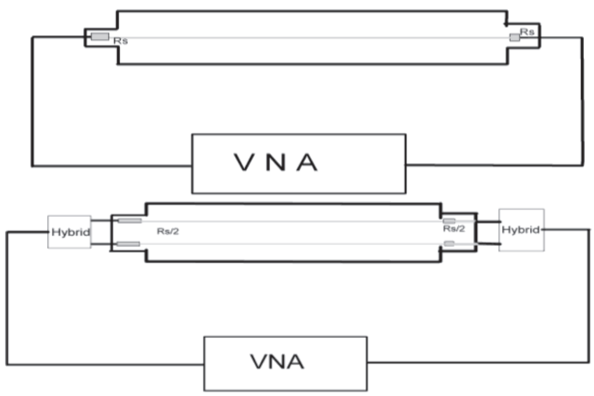

Figure 2: Schematics of longitudinal (top) and transverse (button) impedance measurement.

The transmission coefficient, amplitude and phase, which are obtained by GPIB card and Labview, can be converted to the coupling impedance with the standard formula

$$Z_L = -2R_c^L \ln(S_{21}^{DUT} / S_{21}^{REF}). \quad (4)$$

$$Z_T = \frac{c}{\omega}\frac{Z_{DUT}}{\Delta^2}. \quad (5)$$

with the transmission coefficient of the DUT S_{21}^{DUT} and reference (REF) pipe S_{21}^{REF} respectively.

MEASUREMENT RESULT

The prototype with cable and open termination has not been measured since it has been done power supply experiment. The fast extraction kicker prototype with power supply (no cable) was firstly measured at intermission of power supply experiment in October 2012.

For longitudinal coupling impedance measurement, the kicker is connected with power supply and the measured system is shown in top picture of Figure 3, the button of Figure 3 gives the real part and imaginary part of longitudinal coupling impedance. It can be seen from the imaginary part that the parasitic effect exist and it intensely influence the validity of impedance, which source from matching section [9].

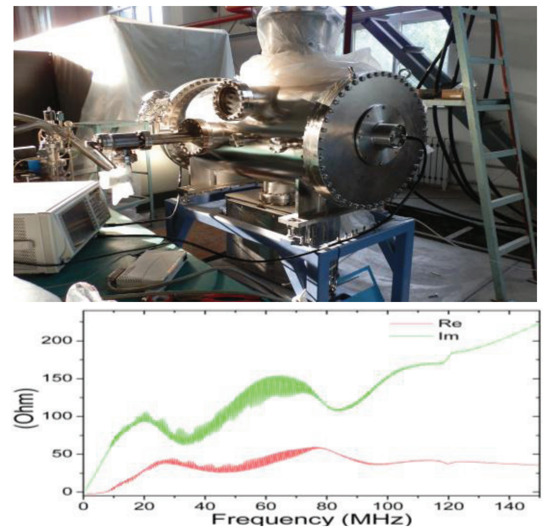

Figure 3: Longitudinal measurement platform (top) and measurement result (button) for CSNS/RCS extraction kicker prototype.

For transverse coupling impedance measurement, the kicker magnet matched with the kicker characteristic impedance at both ends was examined with the two displaced two wires in vertical plane. The result is shown in Figure 4.

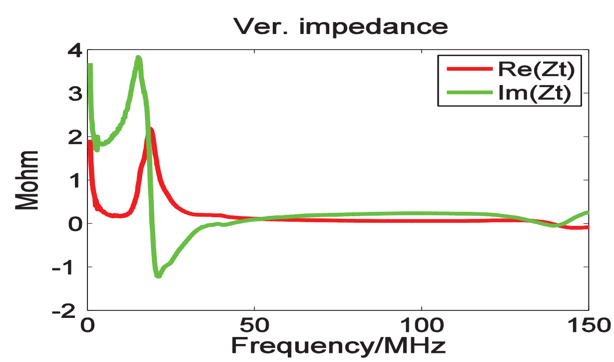

Figure 4: Vertical Z_T of the RCS fast extraction kicker.

COMPARISON WITH CST SIMULATION

In order to make sure the validity of measurement, the impedance of kicker prototype is simulated by CST PARTICLE STUDIO [10]. The comparison of longitudinal impedance between measurement and simulation is shown in Figure 5. It is easy to see that they are totally difference, so the method must be improved. For vertical impedance comparison, simulation result almostly agrees well with measurement result.

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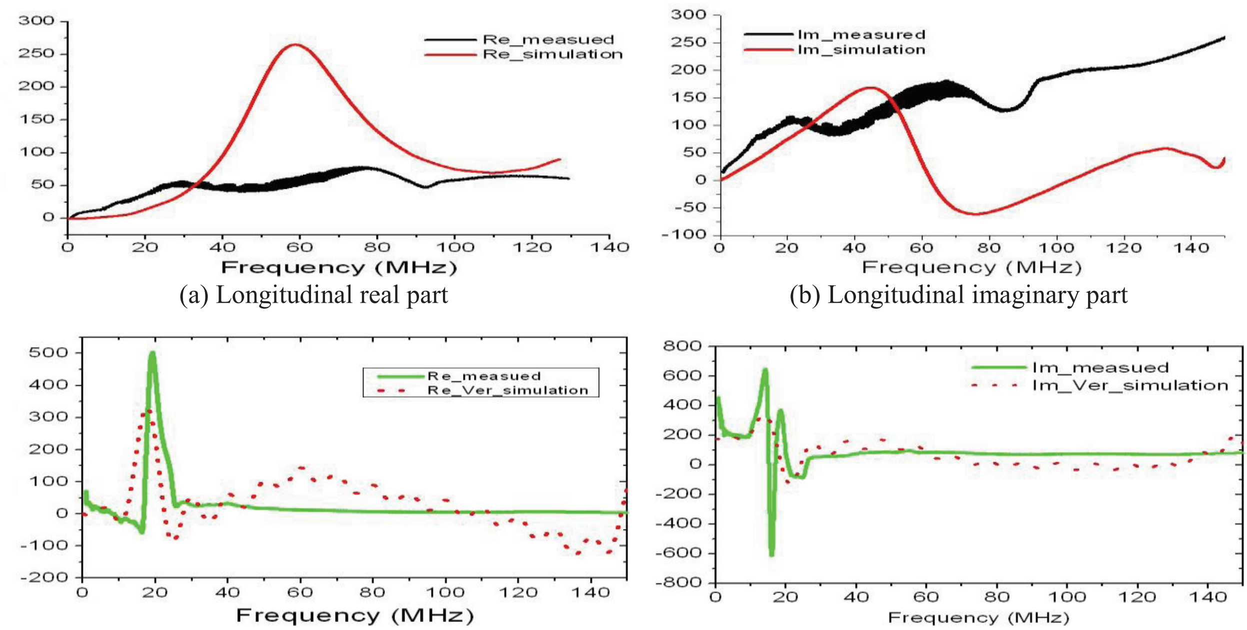

(a) Longitudinal real part (b) Longitudinal imaginary part

(c) Vertical real part (d) Vertical imaginary part

Figure 5: Longitudinal and vertical impedance comparison between measurement and simulation.

IMPROVEMENT

The main question in measurement is parasitic effect, which is source from long and big adaptor, so the upgraded way is replaced the adaptor by SUCOBOX [9] [11], which is shorter. Figure 6 gives the schematics of measurement. The roughly longitudinal measured S_{21} data is governed in Figure 7. The data in Figure 7 shows the parasitic effect is highly decreased although the actual result should be given after measurement kicker prototype.

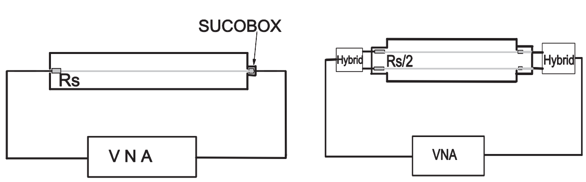

Figure 6: Schematics of longitudinal (left) and vertical (right) impedance measurement with SUCOBOX.

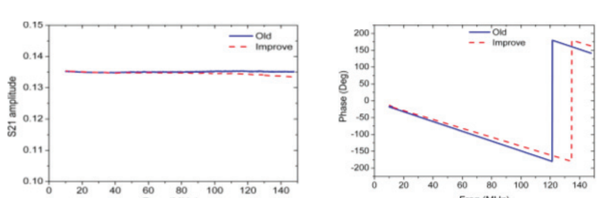

Figure 7: Longitudinal initial data comparison between pre-measurement (old) and improved method.

CONCLUSION

The longitudinal and transverse impedance measurement platform has been established, and roughly measurement results have been obtained. The measured result is different from CST simulation result, especially longitudinal impedance. Moreover, there is parasitic effect in imaginary part of longitudinal impedance for initial measurement system. The system, therefore, must be improved, thus the SUCOBOX is used in upgraded system. The preparatory data of reference is shown that the improved system will be perfect.

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