LONGITUDINAL BROADBAND IMPEDANCE MEASUREMENT SYSTEM *

Huang Gang, Zheng Shu-xin, Huang Wen-hui, Tong De-chun, Lin Yu-zheng
Tsinghua University, Beijing, P.R.China
Zhao Zhen-tang, Institute of High Energy Physics, Beijing P.R.China

Abstract

A broadband longitudinal impedance measurement system based on coaxial line method is constructed in Tsinghua University. A special designed connector and a pairs of tapers are used in the system to achieve a good transmission performance. The system is calibrated by the measurement of a pillbox cavity. Three bellows of different shielding status are measured.

1 INTRODUCTION

Impedance of vacuum components in a storage ring is one of the most important reasons causes beam instabilities. Many kinds of instabilities can be understood in the view of impedance. Find out the impedance of components is a powerful method to analyse the instabilities. Careful design and minimizing the impedance of the components is one of the targets during the design stage.

The impedance of components can be estimated by analysis, calculation or bench measurement during design procedure. The calculation of the impedance can be done by 2D or 3D codes, such as URMEL, URMELT, MAFIA and HFSS etc. The bench measurement of impedance can use bead-pull method or coaxial-line method.

The Coaxial Line Method was first developed by Sands and Rees[1]. Several laboratory constructed their own measurement platforms after that,. This method uses an electric current pulse on an inner conductor to simulate the electron bunch pulse behaviour. The inner conductor forms a coaxial system together with the Device Under Test(DUT) or reference tube(REF). Measuring the S parameter of such coaxial systems $S_{21,REF}$ and $S_{21,DUT}$, we get the coupling impedance Z(w) by the following relationship[2][3]:

$$Z_w = 2R_0 \frac{S_{21,REF} - S_{21,DUT}}{S_{21,DUT}} \qquad (1)$$

where R_0 is the characteristic impedance of the transmission line.

Such a longitudinal impedance measurement system has been constructed in Tsinghua University. The system includes an HP8720B vector network analyser, a GPIB card, a personal computer and software written by LabView, together with related microwave measurement components, as shown in Figure 1.

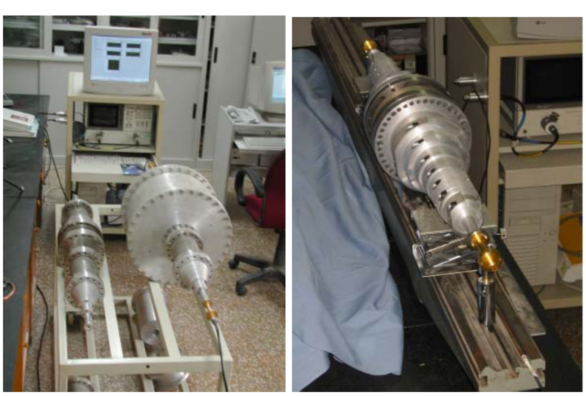
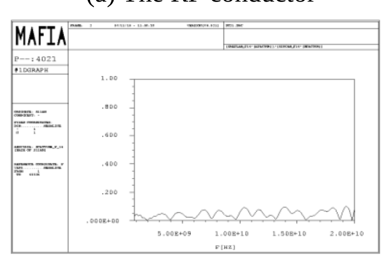


Figure 1: Longitudinal Coupling Impedance Measurement System

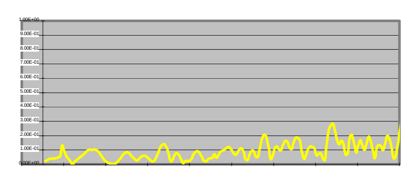
2 MICROWAVE MEASUREMENT SYSTEM OPTIMIZATION[4,5]

The relationship between coupling impedance and the S parameter shown in formula (1) is applicable only when the whole microwave transmit system outside the DUT is a matching transmission, and the inner conductor

(a) The RF conductor



(b) Calculated S_{11}



(c) Measured S_{11}

Figure 2: The Special Designed RF Conductor

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(a) taper for BEPC beam pipe shape (b) taper for SSRC beam pipe shape (c) the inner surface of the taper

Figure 3: The taper matching section

is thin enough and strained.

A special RF connector and a pair of tapers are designed to accomplish the requests above.

2.1 The RF connector [4]

MAFIA is used to design the special connector. A structure with two discontinuities is applied in the connector. The appearance of the connector is shown in Figure 2-a. The RF connector can strain the inner conductor to keep it straight. It has good transmission parameters over a wide frequency range from 130MHz to about 17GHz. The calculated S_{11} of the connector is less then 0.1 below 20GHz, as shown in Figure 2-b. The connector is manufactured and measured with a network analyser. The measurement of the connector performance is shown in Figure 2-c. S_{11} of the connector is less then 0.2 below 17GHz with only some point exceptions.

The structure of the design can ensure the electric boundary of the connector is fixed during straining the inner conductor. So, the connector has a good repeatability. A movable inner conductor is designed in the connector to strain the thread (inner conductor) of the measurement system by a screw thread.

2.2 The taper

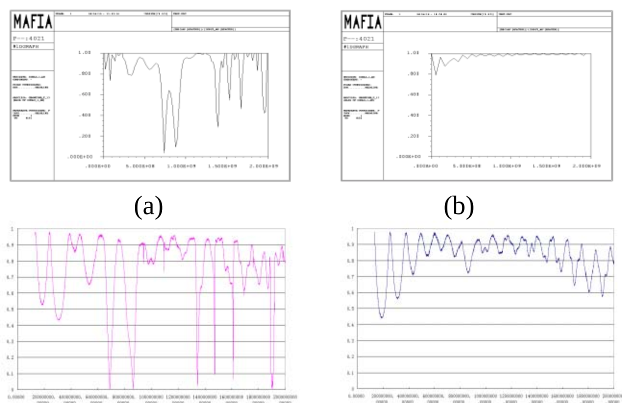
Most vacuum components are connected with the beam pipe directly, such as bellows. The beam holes of them are similar to the shape of beam pipe. Normally, the shape of beam pipe is designed to suit the flat beam. The section view of BEPC beam pipe is runway shape and that of SSRC beam pipe is octagon shape. A pair of tapers has to be added between the components (DUT) and the normal microwave measurement system.

New tapered matching sections are designed to fit the vacuum chamber of IHEP and SSRC, as shown in Figure 3-a, 3-b. Each generating line of the taper is designed with the double cosine function as the transmission function. And the taper can be regarded as a parallel of them. The tapers are fabricated by the CIMS center of Tsinghua University. Figure 3-c is quarter of the inner surface of the taper.

3 CALIBRATE BY A PILLBOX CAVITY

A pillbox cavity is measured and the result is compared with the MAFIA calculation. Such result is used to calibrate the measurement system.

The calculation models include the pillbox cavity or the reference tube, two drift sections, and two tapered matching sections. The calculated S_{21} is shown in Figure 3-a and 3-b. It is shown that there is a slight reflection in the lower frequency range when the reference tube is connected. And when the pillbox cavity is connected into the measurement system, there is much reflection at the frequency of modes of the cavity. The same results can be achieved from measurements as shown in Figure 3-c



(a) (b)

(c) (d)

Figure 4: Calculated and Measured result of the Pillbox Cavity
- (a) Calculated S_{21} of the system with pillbox
- (b) Calculated S_{21} of the system with reference tube
- (c) Measured S_{21} of the system with pillbox
- (d) Measured S_{21} of the system with reference tube

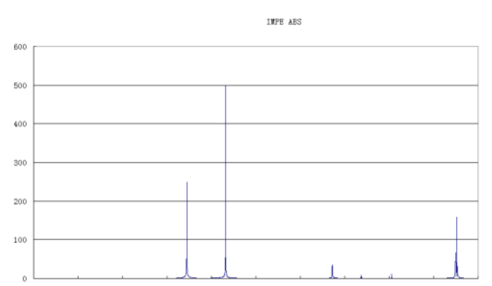


Figure 5: calculated impedance of the pillbox cavity

and 3-d. There are several coaxial modes separated about 150MHz. They all can be subtracted from the measurement of the reference tube. The difference in valley values comes from the reflection of the connector.

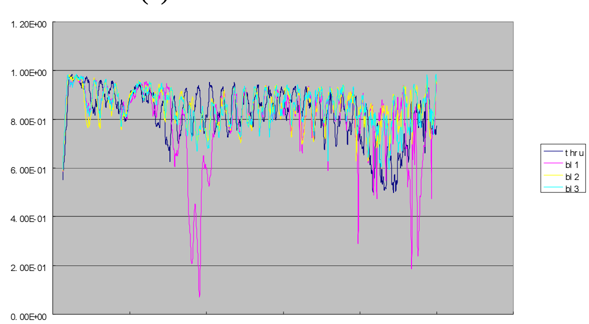
The impedance of the pillbox cavity can be calculated by formula (1) with the data of the measured S_{21}. The calculated result is shown in Figure 5.

4 MEASUREMENT OF THREE KINDS OF BELLOWS

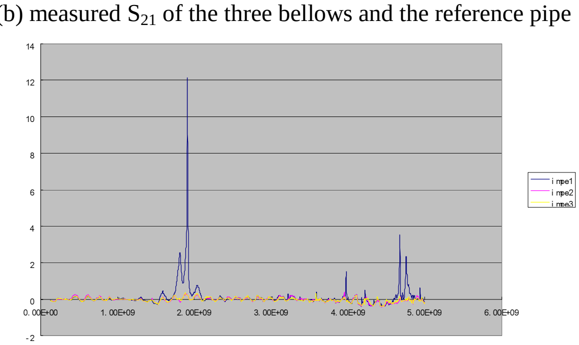
Bellows are wide distributed around the storage ring. The broadband impedances of them are related to some kinds of instabilities.

Three kinds of bellows designed for BEPC are measured. The first one has some parasitic cavity at each flange. The parasitic cavity can be shield by some extra plates. The second bellow is the shielded bellow. Another kind of bellow with slip finger is the third kind of bellow.

(a) the three kinds of bellows



(b) measured S_{21} of the three bellows and the reference pipe



(c) The impedance of the three kinds of bellows

Figure 6: the measurement of three kinds of bellows

The three kinds of bellows is shown in figure6-a. The measured S_{21} of the three bellows and the reference pipe are shown in figure 6-b. The impedance of the three kinds of bellows are shown in figure 6-c.

We can find out from the measurement that the parasitic cavity induced great impedance into the system. The other two type bellows doesn't have obvious difference.

5 RESULTS

- A broadband impedance measurement system is constructed in Tsinghua University
- Several components of the measurement system are redesigned:
  a.The RF connector is designed to achieve straining the inner conductor and good broadband transmission property
  b. The new taper is designed to make the system can measure more vacuum components easily
- New generation instruments, HP8720B Vector network analyser, and new software, labview, are used in the measurement system
- The measurement system is calibrated by pillbox cavity and got a good result
- Bellows measurement is started and some results are obtained

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