RHIC/AP/7

Comparison of the Bellows Impedance Calculation with Measurement

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I. Introduction

The longitudinal coupling impedance of bellows was measured on the bench using the wire method. The measurements were compared with the numerical calculations done using the time domain module T2 in MAFIA [1]. The results of measurements and calculations are presented below.

II. Measurement

The parameters of the bellows are its total length (l), number of corrugations (N), depth of the corrugation Δ, and beam pipe radius b. The measured bellows have l = 17.3 cm, N = 32, Δ = 0.7 cm b = 3.65 cm [Figure 1]. These dimensions are similar to those of RHIC bellows.

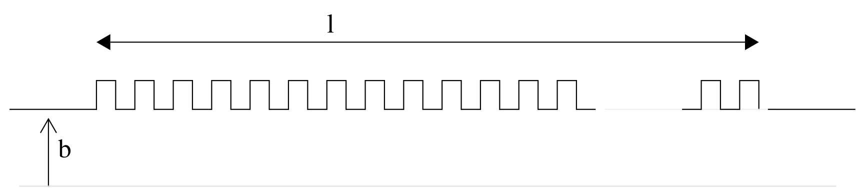

Figure 1. Bellows

The impedance is measured on the bench with a wire placed on the axis of the beam pipe and determining the scattering parameters of the system. The device is placed in between two side pipes of radius 3.65 cm. The wire pipe coaxial system is connected to the Network Analyzer through a 50 ohm cable [Figure 2]. The radius of the wire is 1.6 mm, and the characteristic impedance of the wire pipe system is 188 ohms. The TRL calibration method was used to correct for the mismatch between the 50 ohm cable and the 188 ohm pipe wire system.

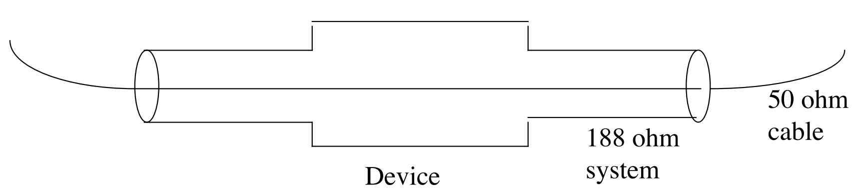

Figure 2. Measurement Setup

Figure 3 gives a plot of the scattering parameters of the uncalibrated device and Figure 4 gives the scattering parameters calibrated with TRL.

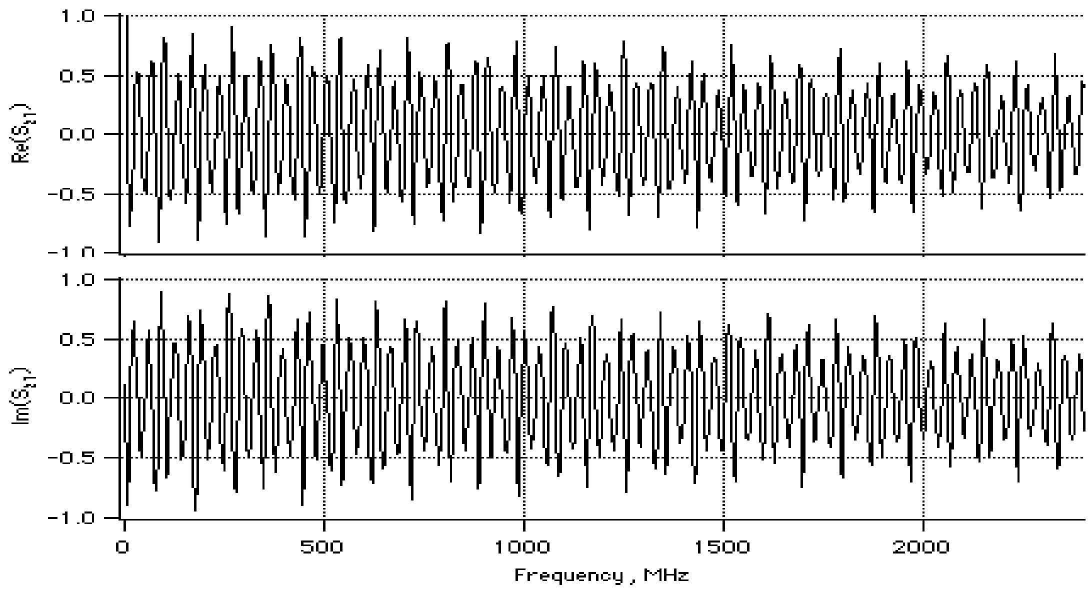

Figure 3. Uncalibrated S_{21} Parameters of Bellows

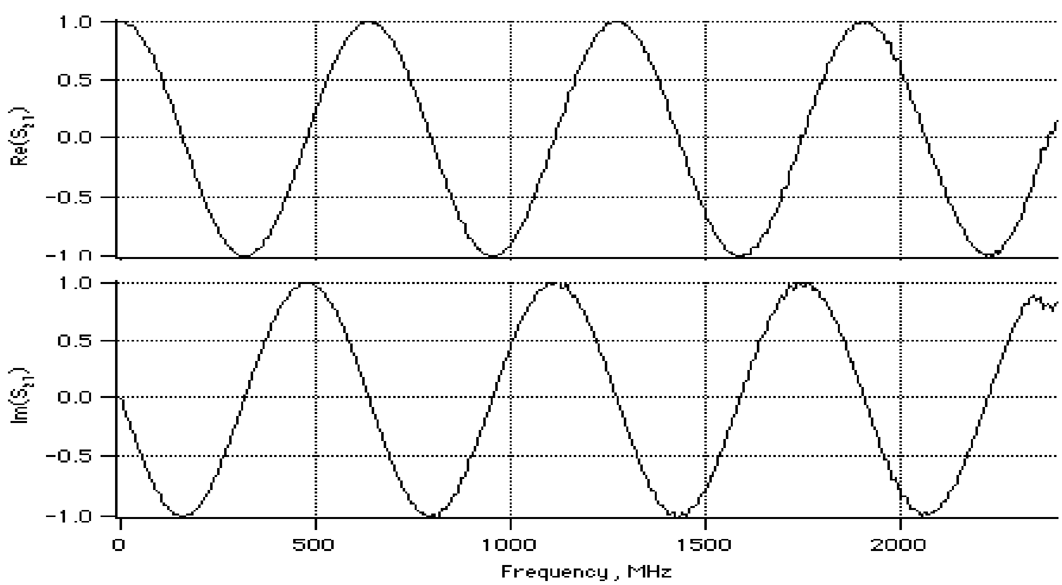

Figure 4. S_{21} Parameters of Bellows Calibrated with TRL

The impedance is obtained from the transmission coefficients as follows [2]

$$Z(\omega) = 2Z0\frac{(S_{21}(REF) - S_{21}(DUT))}{S_{21}(DUT)}$$

The solid line in Figure 5 gives a plot of the measured impedance upto a frequency of 2.5 GHz.

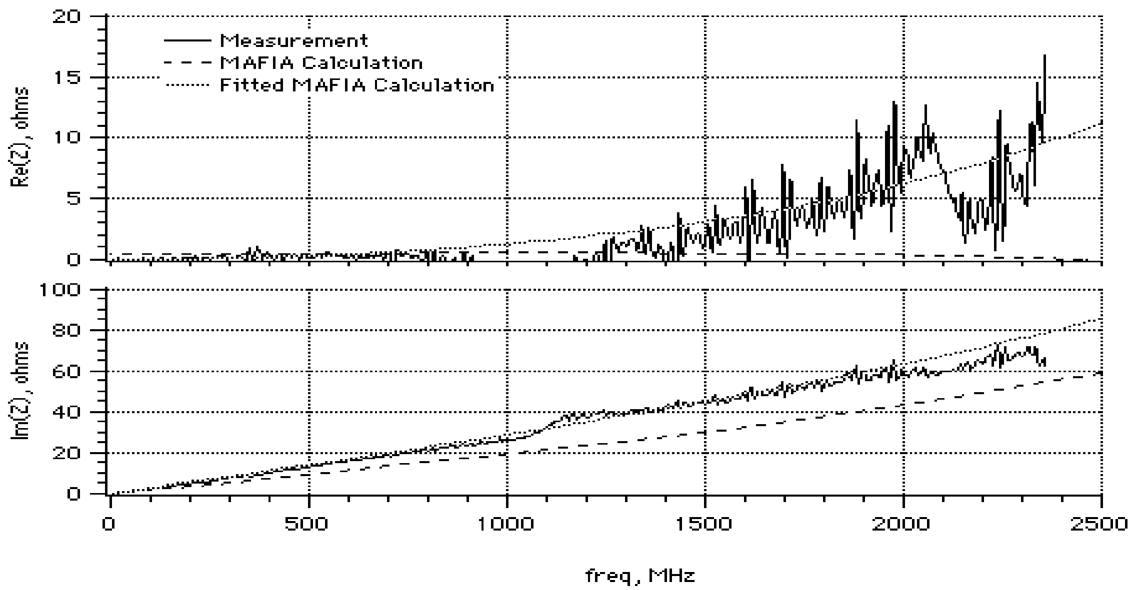

Figure 5. Impedance of Bellows

III. Numerical Calculation

The measurements are compared with numerical calculations done with the time domain module T2 in MAFIA. The wakepotential is obtained for a Gaussian charge distribution traversing the bellows with perfectly conducting walls and monopole mode. The fourier transform of the wakepotential divided by the fourier transform of the charge distribution gives the impedance. The dashed line in Figure 5 gives the numerically calculated impedance.

The calculated result shows a broad resonance and is fitted to the following resonator model

$$Z(\omega) = \frac{R}{1 + iQ\left[\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega}\right]}$$

where R is the shunt impedance, Q is the quality factor and ω_r is the resonance frequency. This is described in more details in an earlier paper [3]. It was also determined that the resonance frequency satisfies the following empirical relation

$$f_r = \frac{1.69}{2\pi}\left(\frac{c}{\Delta}\right)\left(\frac{\Delta}{b}\right)^{0.43}$$

The above mentioned bellows are fitted to a resonator with R = 658 ohm, Q = 4 and f_r = 5.8 GHz [Figure 6]. The dotted plot in Figure 5 gives the calculations fitted to the resonator model. This is in good agreement with the measured response.

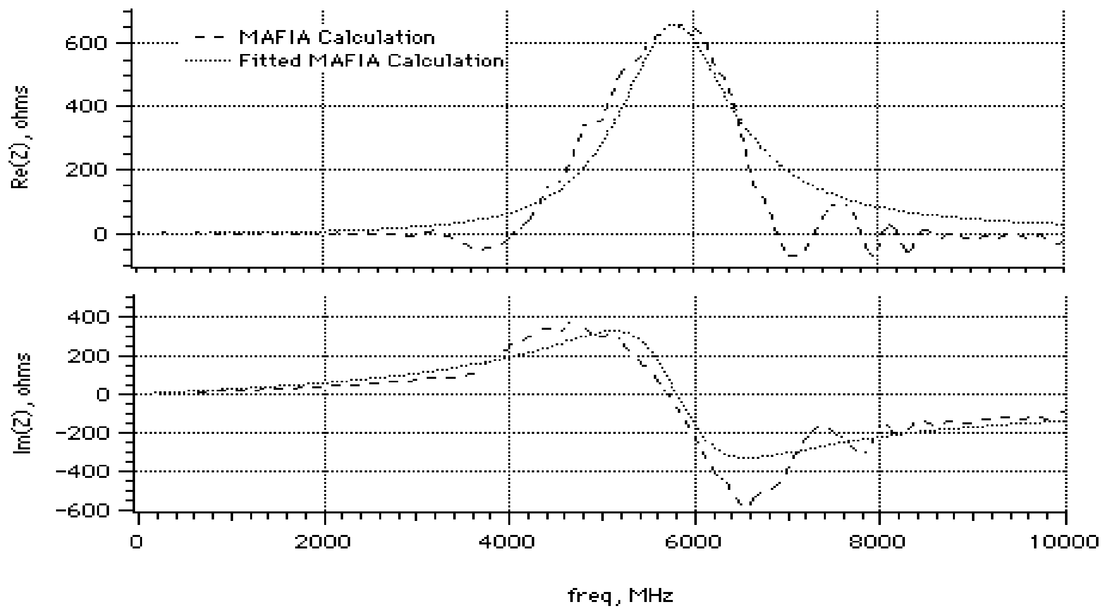

Figure 6. MAFIA Calculation Fitted to Resonator

Note that the calculations are done for a perfect conductor and in the measurements the effect of the wire is not taken into account. Both these effects have a small contribution, due to the low Q nature of the device. The real part of the impedance is noisy above 1.5 GHz and has to be investigated.

IV. Conclusion

In RHIC there are 408 bellows in the cold region and 144 bellows in the warm region. The impedance of the RHIC bellows had been calculated numerically with MAFIA, and it was found to contribute to more than half of the RHIC broadband impedance. Therefore, it has been decided to shield the bellows. The measurements and numerical simulations are plotted in Figure 5. The calculations were published in an earlier paper [3], and are in good agreement with the measurements.

V. Acknowledgments

The author would like to thank R. Sikora, T. Shea and W. Mackay for their help with the measurements.

VI. References

[1] T. Weiland, Particle Accelerators 15 (1984), pp. 245-292

[2] H. Hahn, F. Pedersen, BNL 50870, April 1978

[3] V. Mane, BNL 48375, May 1993