A wireless method for beam coupling impedance measurements of the LHC goniometer

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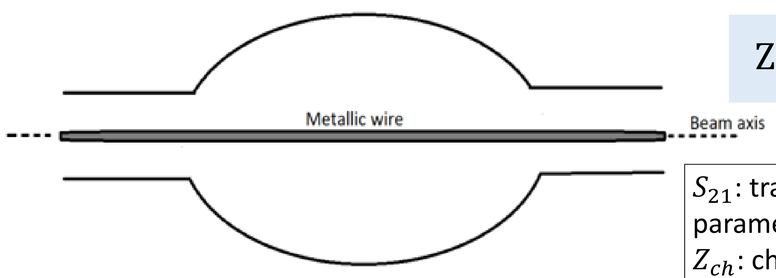
Abstract

The **beam coupling impedance** (BCI) of an accelerator component should be ideally evaluated exciting the device with the beam itself. However, this scenario is not always attainable and **alternative methods** must be exploited, such as the **bench measurements techniques**. The stretched Wire Method (WM) is a well established technique for BCI evaluations, although nowadays its limitations are well known. In particular, the stretched wire perturbs the electromagnetic boundary conditions. Therefore, the results obtained could be inaccurate, especially below the cut-off frequency of the beam pipe in the case of cavity-like structures. To overcome these limitations, efforts are being made to investigate alternative bench measurement techniques that will not require the modification of the device under test (DUT). In this framework, a **wireless method** has been identified and tested for a pillbox cavity. Its potential for more complex structures, such as the **LHC crystal goniometer** is explored.

Standard bench methods and limitations

- Ideally the **beam coupling impedance** should be evaluated by exciting the device with **the beam itself**
- Beam based measurements of the **impedance** are not always possible
  - alternative methods : bench measurements
  - The **stretched wire method** is a well-established technique [**1**]



$$Z_{\text{long}} = -2Z_{ch} \ln \frac{S_{21}^{DUT}}{S_{21}^{REF}}$$

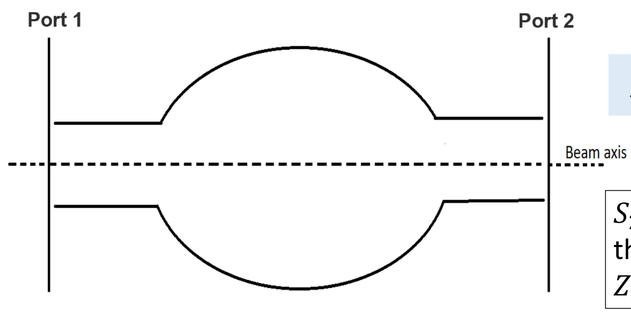
S_{21}: transmission scattering parameter
Z_{ch}: characteristic impedance of the equivalent transmission line

- The **wire perturbs the EM boundary conditions** : artificial propagation of the TEM mode through the device

- Nowadays the **limitations** of this technique **are known** [**2**] → **techniques without the modification of the DUT,** such as the **wireless method**

The wireless method

- **Wireless method idea:** longitudinal beam impedance**: energy loss of the em wave** propagating in the structure → ***S* parameters** [**3**]



$$Z_{\text{long}} = f(Z_{mode}, S_{21}^{DUT}, S_{21}^{REF})$$

S_{21}: transmission scattering parameter of the TM mode
Z_{mode}: mode impedance

- **Wireless method approach:** study the first propagating **TM mode** of the DUT, instead of the TEM mode
  - Tested analytically and in simulations for resistive wall beam chambers [**3**]

- **Wireless method implementation:** implementation of a **real excitation** of the TM mode consistently with the simulations

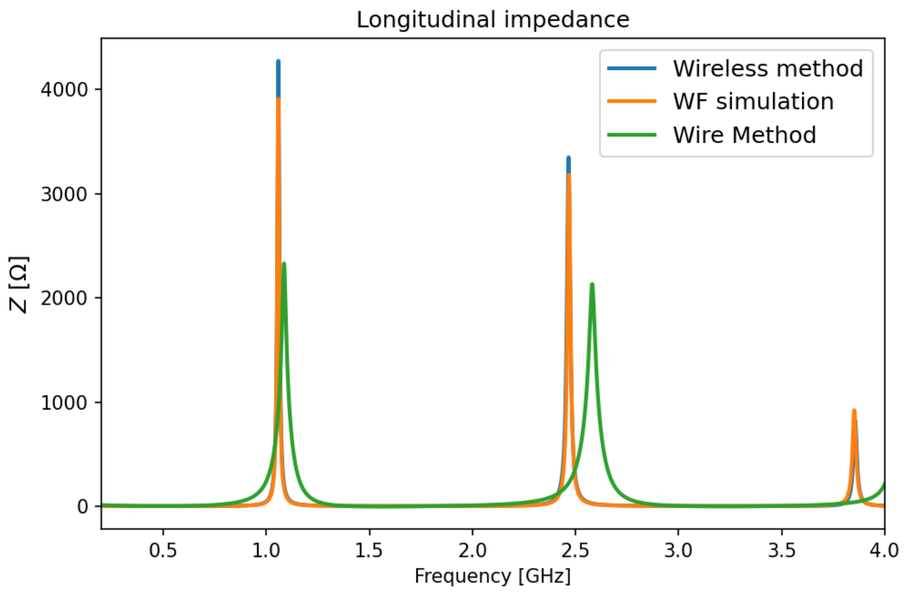
The wireless method for resonant structure

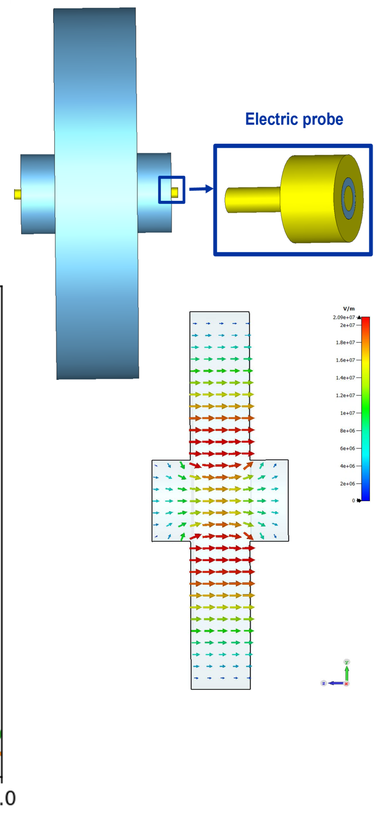
- **Wireless method formula:**
  The scattering parameter can be related to the beam impedance, similarly to the case of the wire method [**4**]

$$Z_{\text{long}} = \frac{Z_{mode}}{2\pi}\left(1 - \frac{|S_{21}^{DUT}|}{|S_{21}^{REF}|}\right)$$

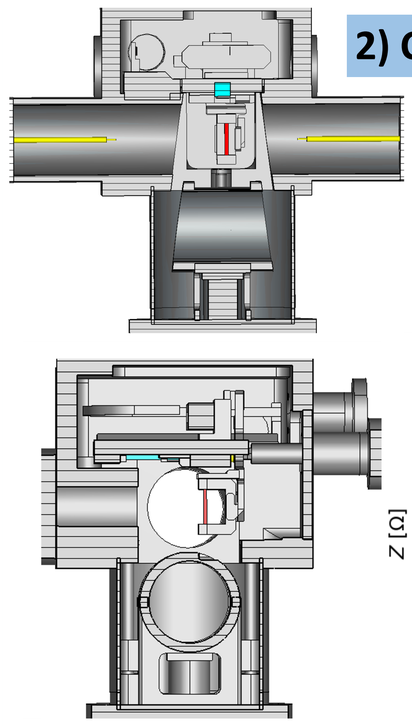
- **Wireless method implementation:**
  Electric probe setup as a **real excitation** of the DUT

1) Simple case : pillbox cavity

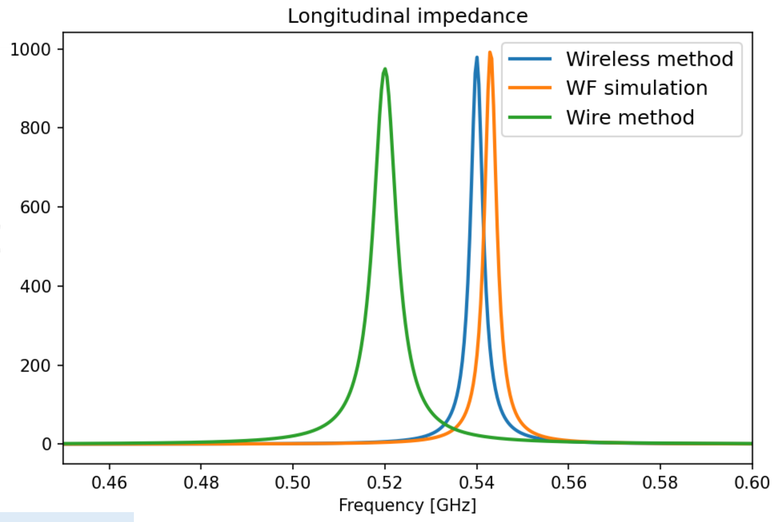




2) Complex device : LHC crystal goniometer



- **Preliminary studies** on a complex device show **again promising results**



- **Very good agreement** between the wireless method and the expectations
  - The advantage compared to the wire method is evident

Conclusion and outlook

➢ **Conclusion**
- Promising virtual measurement results
  - Advantage compared to the wire method

➢ **Outlook**
- Implementation of a real bench measurement setup

[1] V.G. Vaccaro, "Coupling impedance measurements: an improved wire method, INFN sez. di Napoli, Nov. 1994.
[2] M.R. Masullo, V.G. Vaccaro, M. Panniello, "Coupling impedance measurements: an improved wire method, *Proceedings of Linear Accelerator Conference LINAC*, 2010, Tsukuba, Japan.
[3] C. Antuono, " Improved simulations in frequency domain of the Beam Coupling Impedance in particle accelerators", CERN-THESIS-2021-026.
[4] G. R. Lambertson, A. F. Jacob, R. A. Rimmer, and F. Voelker, "Techniques for Beam Impedance Measurements Above Cut-off", in *Proc. EPAC'90*, Nice, France, Jun. 1990, pp. 1049– 1052.