ELECTROMAGNETIC TEST-BENCH EVALUATION OF PICKUP PROTOTYPES FOR THE ELETTRA 2.0 BUTTON-TYPE BEAM POSITION MONITORS

S. Cleva*, M. Barnaba, S. Bassanese, G. Brajnik, R. De Monte, D. Pozzecco, R. Sergo
Elettra-Sincrotrone Trieste S.C.p.A., Trieste, Italy
A. Passarelli, Istituto Nazionale di Fisica Nucleare, Napoli, Italy
M. Comisso, University of Trieste, Trieste, Italy

Abstract

To reliably and repeatably validate the electromagnetic behavior of the pickup prototypes designed for the Elettra 2.0 button-type beam position monitors, two different radio-frequency test fixtures have been developed. The first test fixture, based on a coaxial-line design that emulates the TEM excitation generated by a relativistic beam, allows to measure the transmission performance of the pickups up to 16 GHz. The second test fixture, employing an antenna-launcher design, extends the measurement range up to 40 GHz. This paper presents a comparison between measured and simulated data, with particular focus on the electromagnetic validation of the first 16 prototypes manufactured using glass as the dielectric material.

INTRODUCTION

Figure 1 shows the reference design for the Elettra 2.0 [1] button-type pickups, together with the SMK connector (pin contact, according to MIL-STD-348B [2]) embedded in the pickup body. Such device is manufactured press fitting the collar C (that implements the reference plane of the SMK connector) on the pickup body B. The insulator collar, indicated in green, fulfils two functions: it provides mechanical support for the central pin P and it ensures vacuum sealing. The pickup is basically a 50 Ω coaxial line from the SMK connector reference plane up to the insulator, which terminates in the conical button that couples with the EM field of the beam. In normal operation, the electromagnetic (EM) energy captured by the gap around the button (the beam port), propagates along the pickup coaxial structure and is delivered to the position detection equipment through the SMK connector (the radio frequency (RF) port).

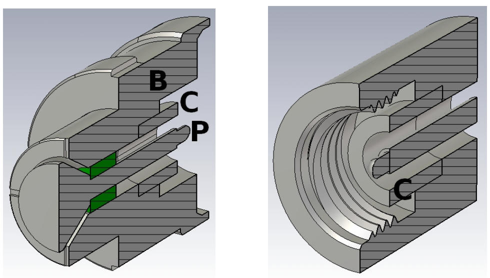

Figure 1: Reference design for the Elettra 2.0 pickups and embedded SMK connector cross sections.

* stefano.cleva@elettra.eu

RF CHARACTERIZATION OF PICKUPS

The behavior of any kind of button-type pickup can be fully characterized by reflection and transmission measurements performed under test reference conditions, using time domain (TD) or frequency domain (FD) signal processing methods [3]. Transmission measurements can not be directly executed because the beam port of the pickup is not intended to be directly connected to measuring devices. For this reason a dedicated adapter is required to create a completely closed propagation path that, starting from the RF port of the pickup, passes through the beam port and terminates on one or more 50 Ohm matched test connectors. Once such propagation path has been physically realized, transmission measurements are executed injecting a test signal in the pickup through its coaxial connector and measuring the amplitude and phase (FD) or amplitude and time of arrival (TD) of the signals detected on the adapter's connectors.

TEST FIXTURES

To get a reliable and repeatable EM characterization comparable with simulation, each pickup is mounted on dedicated metallic mechanical supports made of aluminum, named test fixtures, that host RF connectors to perform both reflection and transmission measurements under closed environment test reference conditions. The dielectric material inside the test fixtures is air. Injecting the test signal through a test fixture port the flow of the EM energy that propagates through the pickup can be reversed, allowing bi-directional transmission measurements. In order to define complete self consistent EM test environments, a reference wire pickup has been manufactured using a uniform wire suspended in air as central pin. For the experimental measurements, a Teledyne LeCroy WavePulser 40iX (TDRMI) was employed for time-domain analysis (transmission and reflection up to 40 GHz). For frequency-domain characterization up to 26.5 GHz, a Keysight PNA network analyser (VNAMI) was used.

Two Ports Test Fixture General Description

The simplest type of test fixture, indicated as "2PTF", is based on a two ports, single SMK connector configuration, see Fig. 2 (left). A short wire antenna, that couples with the beam port of the pickup, is directly mounted on the central conductor of the test fixture's SMK connector (plug type). This antenna is aligned along the rotational symmetry axis of the test fixture. Upon mounting the pickup under test, the resulting assembly is equipped with two SMK connectors, each possessing a nominal characteristic impedance of 50 Ω. This configuration allows the measurement of the full 2 × 2 scattering matrix.

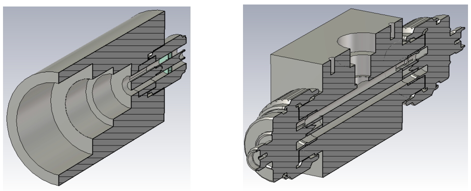

Figure 2: Two ports and three ports test fixture 3D cross views.

Two Ports Test Fixture EM Characterization

The assembly of the reference wire pickup mounted on the 2PTF, together with the corresponding EM model is shown in Fig. 3. The connector C2, the RF port of the reference wire pickup, corresponds to the port P2 of the EM model. The short wire antenna of the 2PTF is connected to the connector C1, which corresponds to the port P1. The comparison between simulated and measured S_{21} scattering parameters measured by TDRMI and VNAMI is shown in Fig. 4. In the same figure the data simulated by CST [4] in TD and HFSS [5] in FD are reported. The excellent agreement between measured and simulated data demonstrates the correspondence between the EM model and the real measurement setup.

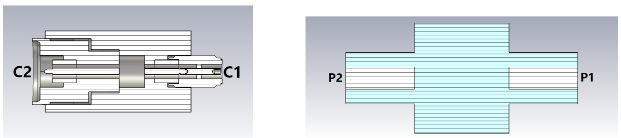

Figure 3: 2PTF with mounted reference wire pickup cross view (left) end the corresponding EM model (right).

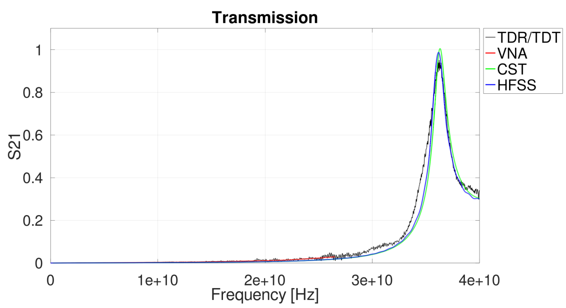

Figure 4: Comparison between simulated and measured transmission data for the assembly 2PTF plus reference wire pickup.

Three Ports Test Fixture General Description

This device [6] is based on a 50 Ω nominal characteristic impedance coaxial line that, through an aperture located at its middle length, is able to couple with the beam port of the pickup under test, see Fig. 2 (right). The pickup is mounted orthogonally to the coaxial line, which supports the TEM propagation mode, the same excited by charged particle relativistic beams. Due to practical machining constraints, the outer diameter of the inner conductor has been fixed to 3 mm, while the inner diameter of the outer conductor has been fixed to 7 mm, according to the IEC 61169-16 standard for N connectors [7]. The ratio between these value is 2.33, corresponding to 50.8 Ω in air, with cutoff frequency of the first high order mode (TE_{11}) equal to 19.4874 GHz. The commercial N to SMA adapters (N-MALE to SMA-F) mounted to support the inner conductor of the coaxial line have a maximum operative frequency of 16 GHz that, being lower than the frequency of the TE_{11} mode, is set as the maximum operating frequency for this kind of test fixture.

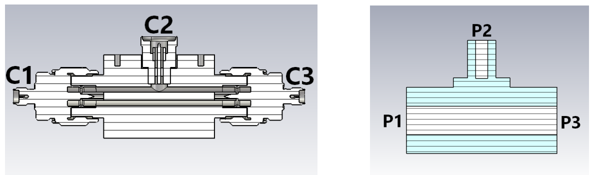

Figure 5: 3PTF with mounted reference wire pickup cross view (left) end the corresponding EM model (right).

Three Ports Test Fixture EM Characterization

The assembly of the reference wire pickup mounted on the 3PTF, together with the corresponding EM model is shown in Fig. 5. The connector C1, corresponding to the port P1 of the EM model, is connected to the coaxial line. The connector C3, corresponding to the port P3, is terminated on a 50 Ω load. The RF port of the reference wire pickup, that is the connector C2, corresponds to the port P2. The comparison between simulated and measured S_{21} scattering parameters measured by TDRMI and VNAMI is shown in Fig. 6. In the same figure the data simulated by CST in TD and HFSS in FD are reported. The excellent agreement between measured and simulated data demonstrates the correspondence between the EM model and the real measurement setup.

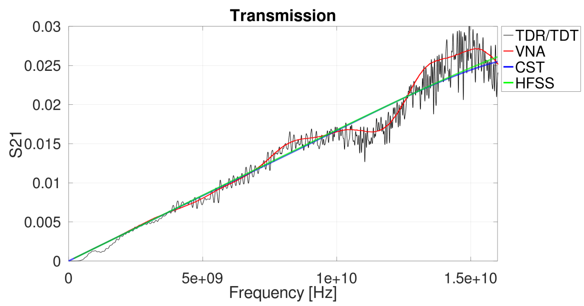

Figure 6: Comparison between simulated and measured transmission data for the assembly 3PTF plus reference wire pickup.

PICKUP PROTOTYPES RF CHARACTERISTICS

According to the reference design for the Elettra 2.0 pickups, the first 16 pickup samples based on glass sealing technology (used for the insulator collar) have been fabricated by Kyocera (Japan), see Fig. 7. The central pin is made of molybdenum, the pickup body and the SMK connector collar are made of AISI 316L. Following the same procedures adopted for the reference wire pickup, these pickups have been electromagnetically characterized through the 2PTF and 3PTF test fixtures. Figures 8 (top) and 9 (top) show, respectively, the frequency response of S_{21} measured by the 2PTF and 3PTF. The corresponding standard deviations, calculated on the population of 16 samples, are shown, respectively, in Figs. 8 (bottom) and 9 (bottom). The low value of the standard deviations is indicative of the excellent quality of the manufacturing process of these devices.

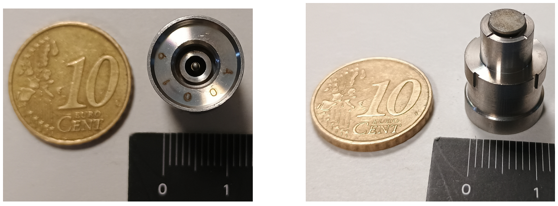

Figure 7: Top and bottom views of the Elettra 2.0 pickups manufactured using glass sealing technology.

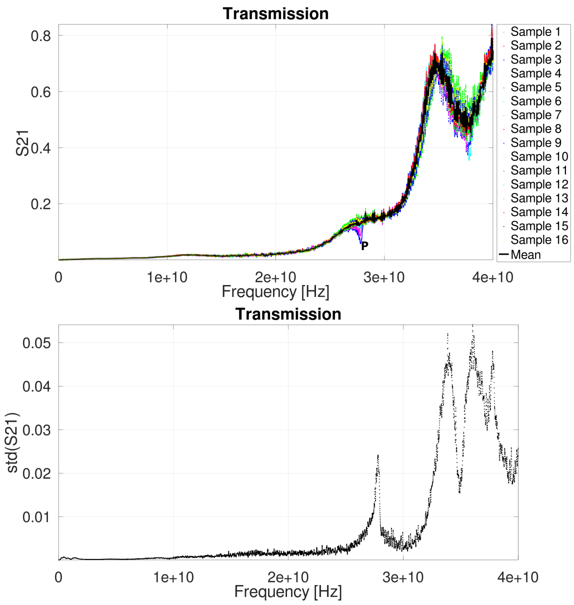

Figure 8: 2PTF characterization of the Elettra 2.0 pickup prototypes.

Taking for granted the nominal dimensions of the pickups components and assuming the electric permittivity of glass equal to 4.8, Fig. 10 shows the comparison between the simulated (CST (TD) - HFSS (FD)) and measured mean value of S_{21} using the 2PTF (top) and 3 PTF (bottom) test fixtures. Even in this case the agreement between measured and simulated data is very good.

CONCLUSION

The introduction of both 2PTF and 3PTF test fixtures has enabled the reliable and repeatable electromagnetic characterization of the button-type pickups for the Elettra 2.0 beam position monitors, while also assessing the high quality of the pickups' construction process. Furthermore, the 3PTF is an excellent tool for the practical sorting of pickups in groups of four with very similar signal transmission characteristics.

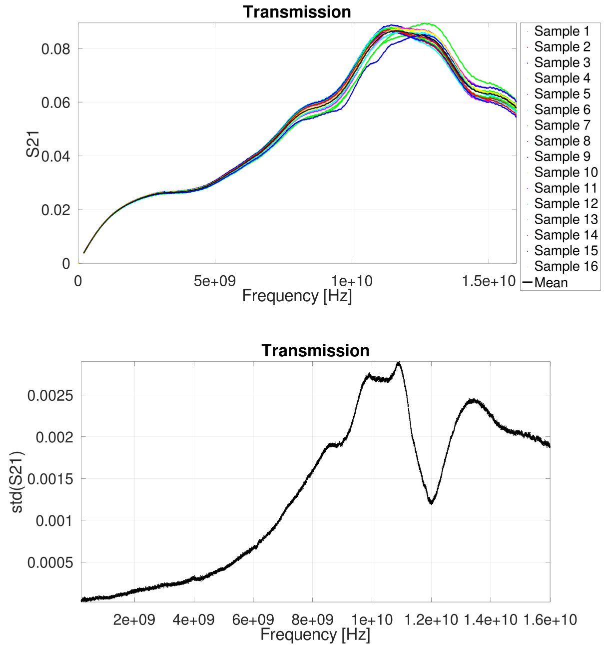

Figure 9: 3PTF characterization of the Elettra 2.0 pickup prototypes.

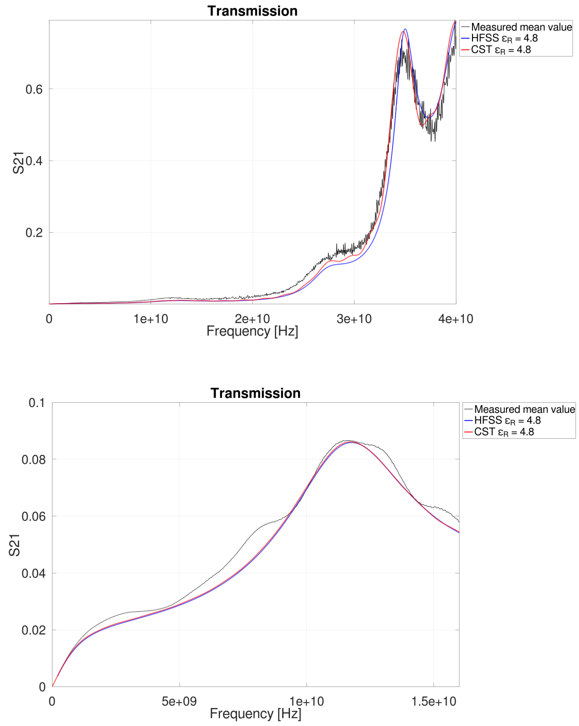

Figure 10: 2PTF (top) and 3PTF (bottom) comparison between the simulated value of S_{21} and its measured mean value.

REFERENCES

[1] E. Karantzoulis, S. Di Mitri, F. Barbo, W. Barletta, S. Bassanese, R. Bracco, G. Brajnik, A. Buonanno, D. Caiazza, A. Carniel, D. Castronovo, M. Cautero, S. Cleva, M. Comisso, I. Cudin, S. Dastan, R. De Monte, B. Diviacco, A. Fabris, R. Fabris, G. Gaio, S. Grulja, L. Gregoratti, A. Gubertini, S. Krecic, S. Lizzit, G. Loda, M. Lonza, K. Manukyan, B. Mazzucco, M. Milani, D. Millo, M. Modica, L. Novinec, G. Pangon, C. Pasotti, A. Passarelli, L. Rumiz, S. Sbarra, G. Scrimali, N. Shafqat, G. Simonetti, M. Svandrlik, F. Tripaldi, M. Veronese, R. Visintini, E. Yousefi, and M. Zaccaria, "Design strategies and technology of Elettra 2.0 for a versatile offer to the user community", *Nucl. Instrum. Methods Phys. Res. A*, vol. 1060, p. 169007, 2024. doi:10.1016/j.nima.2023.169007

[2] U.S. Department of Defense, *MIL-STD-348B: Radio Frequency Connector Interfaces*, 1993.

[3] S. Cleva, "Electromagnetic characterization of the first 16 pickup prototypes for the Elettra 2.0 BPMs", presented at the *13th Diagnostics Experts of European Light Sources (DEELS)*, Paul Scherrer Institute, Villigen, Switzerland, Mar. 2026. Available at: https://indico.psi.ch/event/17840/contributions/62374/

[4] CST, *CST Studio Suite*, 2025. Available at: https://www.3ds.com/

[5] Ansys, Inc., *Ansys HFSS, Release 2025 R2*, Canonsburg, PA, USA, 2025. Software for full-wave electromagnetic simulation. Available at: https://www.ansys.com

[6] F. Marcellini, "The SLS 2.0 button BPM: Definitive design", presented at the workshop *Button BPMs for Synchrotron Light Sources*, ALBA Synchrotron, 11–12 December 2024. Available at: https://indico.cells.es/event/1542/contributions/2924/

[7] International Electrotechnical Commission, *IEC 61169-16: Radio-frequency connectors – Part 16: Sectional specification – RF coaxial connectors with inner diameter of outer conductor 7 mm (0.276 in) with screw coupling – Characteristic impedance* 50 Ω *(*75 Ω, International Electrotechnical Commission, 2006. IEC 61169-16:2006.