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

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Abstract

This paper presents two different RF test fixtures developed to reliably and repeatably validate the electromagnetic behavior of the pickup prototypes designed for the Elettra 2.0 button-type beam position monitors. The first one, based on a coaxial-line design that emulates the TEM excitation generated by a relativistic beam, allows the measure of the pickup behavior up to 16 GHz. The second test fixture, employing a wire antenna design, extends the measurement range up to 40 GHz. The so obtained experimental data are compared with the CST and HFSS simulated ones to check the performance achieved by the first 16 prototypes manufactured using glass as dielectric material.

INTRODUCTION

Beam position monitors (BPMs) are integral components of a particle accelerator, fundamental for detecting the position of electron bunches. Their design complexity has progressively increased with the evolution of successive generations of light sources. In the fourth-generation Elettra 2.0 storage ring [1], the BPMs have been designed adopting four button-type pickups with embedded SMK connector (pin contact, according to MIL-STD-348B [2]). Each pickup, shown in Figure 1, is manufactured press fitting the collar C, which defines the SMK connector reference plane, on the pickup body B. The insulator collar, indicated in green, provides mechanical support for the central pin P and ensures vacuum sealing. The pickup essentially behaves as a 50 Ω coaxial line extending from the SMK connector reference plane up to the insulator, where it terminates in the conical button that couples with the beam electromagnetic (EM) field. During operation, the EM energy captured through the gap around the button (beam port), propagates along the coaxial structure of the pickup and is transmitted to the position detection equipment through the SMK connector (RF port).

RF CHARACTERIZATION OF PICKUPS

Button-type pickups can be fully characterized through reflection and transmission measurements performed under test reference conditions by using either time domain (TD) or frequency domain (FD) analysis methods [3]. Direct transmission measurements, however, cannot be performed because the pickup beam port is not designed to be directly connected to measurement instruments. For this reason, a dedicated adapter is required to establish a closed propagation path that starts from the RF port, passes through the beam port and terminates at one or more 50 Ω matched test connectors. Once this propagation path is implemented, transmission measurements can be carried out by injecting a test signal into the pickup through its coaxial connector. This configuration enables the measurement of both the FD amplitude and phase, as well as the TD amplitude and signal arrival time, at the adapter test connectors.

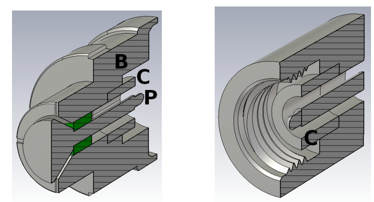

Figure 1: Reference design for the Elettra 2.0 pickups and embedded SMK connector cross sections.

TEST FIXTURES

To ensure reliable and repeatable EM characterization results consistent with simulations, each pickup is mounted on dedicated air-filled aluminum mechanical supports, referred to as test fixtures (TFs). These fixtures integrate RF connectors to perform reflection and transmission measurements under controlled and closed environment conditions. By injecting the test signal through one of the fixture port, the direction of the EM energy propagation through the pickup can be reversed, enabling bidirectional transmission measurements. To define a complete self consistent EM test environment, a reference wire pickup was manufactured using a uniform wire suspended in air as the central conductor. TD and FD characterizations were carried out using a Teledyne LeCroy WavePulser 40iX (TDRMI) operating up to 40 GHz and a Keysight PNA network analyser (VNAMI) operating up to 26.5 GHz, respectively.

Two-Port TF (2PTF) General Description

The simplest type of TF, referred to as 2PTF, is based on a two-port single SMK connector configuration (Figure 2, left). A short wire antenna, coupled with the pickup beam port, is directly mounted on the central conductor of the TF SMK plug type connector. This antenna is aligned with the

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rotational symmetry axis of the fixture. When the device under test is installed, the resulting assembly provides two 50 Ω SMK ports. This configuration enables the measurement of the full 2×2 scattering matrix.

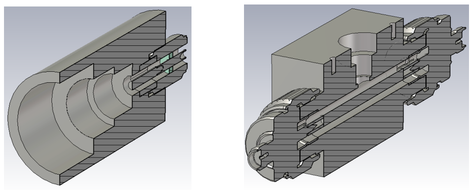

Figure 2: 3D cross view for 2PTF and 3PTF.

2PTF EM Characterization

The assembly of the reference wire pickup mounted on the 2PTF and the corresponding EM model are shown in Figure 3. The connector C2 (RF port of the reference wire pickup) corresponds to the port P2 of the EM model, while the short wire antenna of the 2PTF is connected to the connector C1, corresponding to the port P1. The S_{21} scattering parameter, measured by TDRMI and VNAMI, is shown in Figure 4, which also includes results from numerical simulations performed with CST [4] in TD and HFSS [5] in FD. These results highlight the excellent agreement between experimental and simulated data, confirming both the accuracy of the EM model and the reliability of the measurement setup.

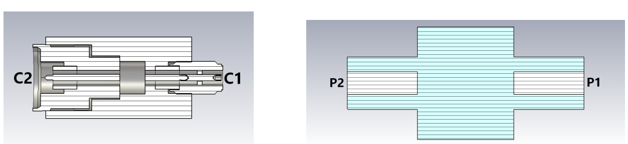

Figure 3: Cross view of 2PTF with mounted reference wire pickup (left) and corresponding EM model (right).

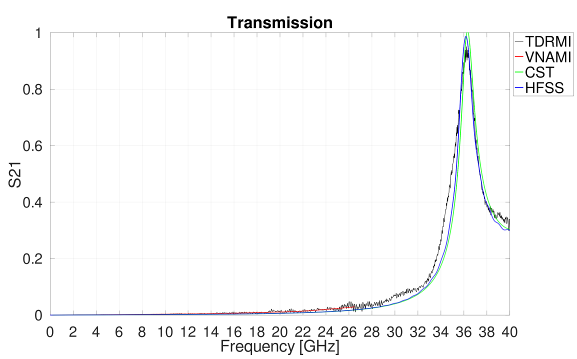

Figure 4: Simulated and measured data for 2PTF with reference wire pickup assembly.

Three-Port TF (3PTF) General Description

The 3PTF is based on a 50 Ω coaxial line [6], designed to couple with the beam port of the pickup under test through an aperture located at its middle length (Figure 2, right). The pickup is mounted orthogonally to the coaxial line, which supports the TEM mode, the same mode excited by charged particle relativistic beams.

Due to practical machining constraints, the outer diameter of the inner conductor is fixed to 3 mm, while the inner diameter of the outer conductor is fixed to 7 mm, according to the IEC 61169-16 standard for N connectors [7]. This geometry results in a characteristic impedance of 50.8 Ω in air. The cutoff frequency of the first higher-order mode (TE_{11}) is approximately 19.5 GHz. 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. Since this value is below the TE_{11} cutoff frequency, it defines the upper frequency limit for the operation of this test fixture.

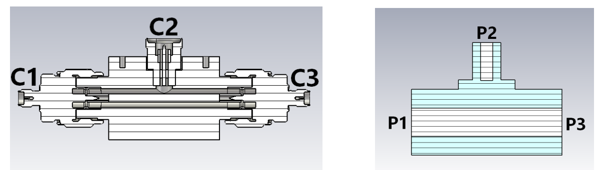

Figure 5: Cross view of 3PTF with mounted reference wire pickup (left) and corresponding EM model (right).

3PTF EM Characterization

The assembly of the reference wire pickup mounted on the 3PTF and its EM model are shown in Fig. 5. The port P1 of the EM model (connector C1) is connected to the coaxial line, the port P3 (connector C3) is terminated on a 50 Ω load, while the port P2 (connector C2) corresponds to the RF port of the reference wire pickup. The S_{21} parameter measured using the TDRMI and VNAMI systems, together with the results obtained from CST and HFSS simulations, is presented in Fig. 6. The comparison confirms excellent agreement between the experimental setup and the EM model.

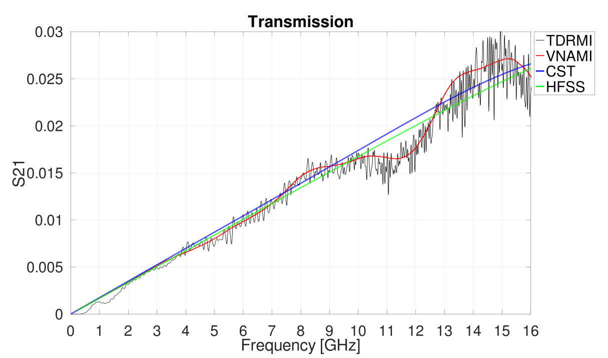

Figure 6: Simulated and measured data for 3PTF with reference wire pickup assembly.

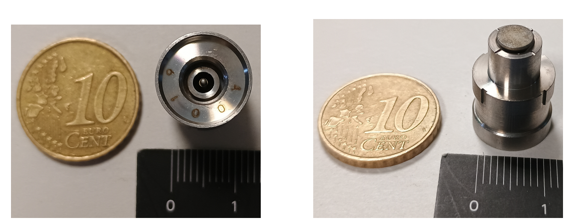

Figure 7: Top and bottom views of the Elettra 2.0 pickups manufactured using glass sealing technology.

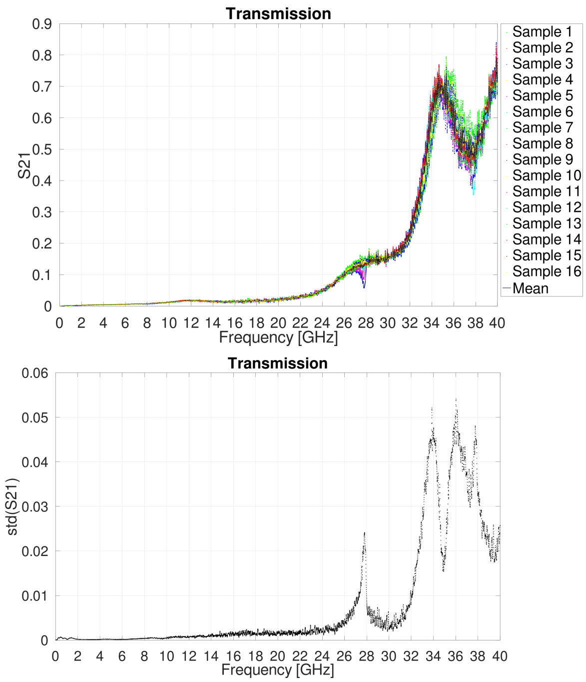

Figure 8: 2PTF measures of Elettra 2.0 pickup prototypes.

PICKUP PROTOTYPES RF CHARACTERISTICS

Following the reference design for the Elettra 2.0 pickups, the first 16 prototypes based on glass sealing technology (used for the insulator collar) were manufactured by Kyocera (Japan) (Figure 7). The central pin is made of molybdenum, while the pickup body and the SMK connector collar are made of AISI 316L. These pickups are electromagnetically characterized through the two presented TFs.

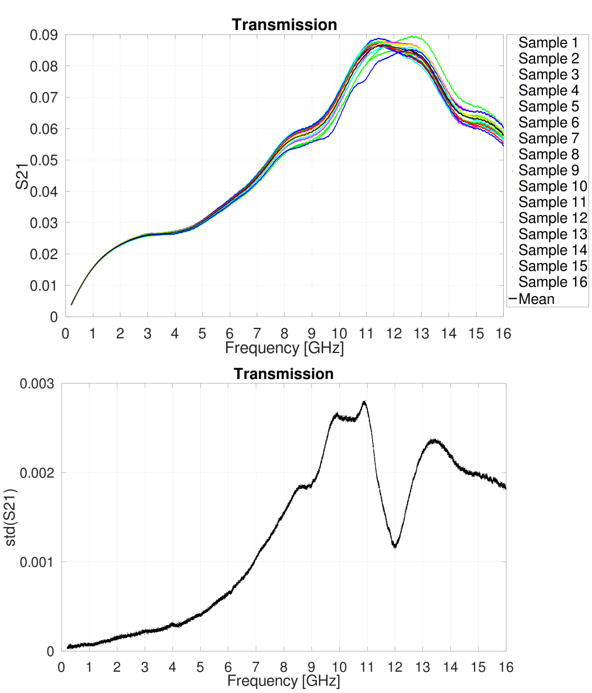

Figure 9: 3PTF measures of Elettra 2.0 pickup prototypes.

Figure 8 (top) and 9 (top) show the S_{21} parameter measured by the 2PTF and 3PTF, respectively, while Figure 8 (bottom) and Figure 9 (bottom) report the corresponding standard deviations over the 16 samples. The S_{21} value obtained from CST/HFSS simulations and the S_{21} mean value calculated from the 2PTF (top) and 3PTF (bottom) measurements are finally compared in Figure 10, using the nominal dimensions of the pickup components and assuming a glass relative permittivity of 4.8. These results demonstrate excellent agreement between simulations and measurements and confirm the high quality and reproducibility of the manufacturing process of these devices.

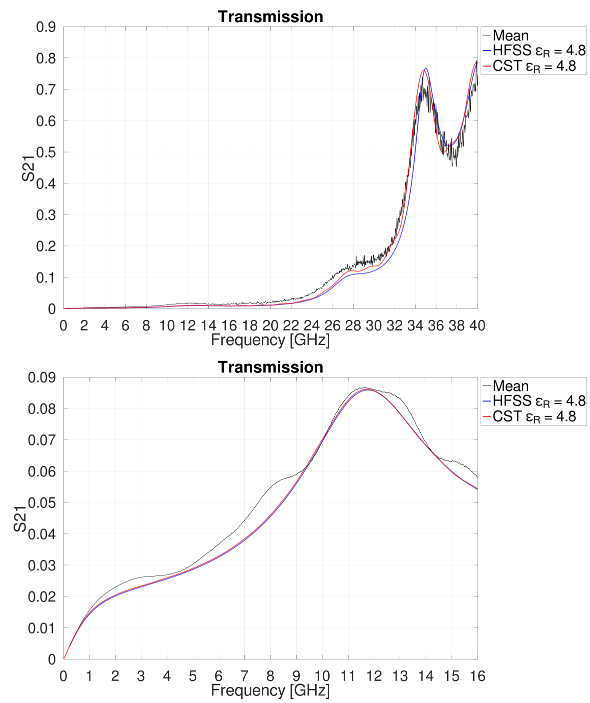

Figure 10: Simulated and measured mean S_{21} value for 2PTF (top) and 3PTF (bottom).

CONCLUSION

Two specific TFs, named 2PTF and 3PTF, have been introduced to obtain reliable and repeatable EM characterization of the button-type pickups for the Elettra 2.0 BPMs. By adopting these fixtures, two main objectives have been achieved. The first, and most significant, objective concerns the assessment of the high manufacturing quality of the pickup devices, which is essential for the proper operation of the entire Elettra 2.0 storage ring. The second objective is the excellent agreement observed between measured and simulated results, obtained using two independent electromagnetic solvers. These results demonstrate the effectiveness of the proposed test fixtures. In particular, the 3PTF can be further exploited as a practical tool for sorting pickups into groups of four with very similar transmission characteristics.

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: `doi.org/10.1016/j.nima.2023.169007`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, 24 March 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.