A New Wall Current Monitor for the CERN Proton Synchrotron

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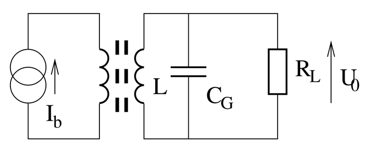
Abstract

Wall Current Monitors are the devices of choice to observe the instantaneous beam current in proton accelerators. These entirely passive transformers deliver a high-fidelity image of the beam intensity in a bandwidth spanning from about 100kHz up to several GHz. They serve as a signal source for a diverse set of applications including Low Level RF feedback and longitudinal diagnostics such as bunch shape measurements and phase-space tomography. They are appreciated for their excellent reliability, large bandwidth and unsurpassed dynamic range. We describe the design of a new Wall Current Monitor for the CERN Proton Synchrotron with a useful bandwidth of 100kHz to 4GHz. Two such devices have been installed in the PS machine and are now used in regular operation. Some usage examples will be shown.

Introduction

In the CERN Proton Synchrotron, Wall Current Monitors (WCMs) are the preferred signal sources for longitudinal diagnostics and RF feedback. A WCM is a single-turn beam current transformer with the beam in the role of the primary 'winding', the beam pipe and surrounding shell as the secondary and some ferrite toroids as the core.



$$U_o = \frac{I_b s L}{s^2 L C_G + s \frac{L}{R_L} + 1} \qquad (1)$$

Figure 1: Simplified electrical circuit model.

A simplified model represents the WCM as a parallel combination of a resistor for the collective effect of the eight feedthroughs, a parallel inductor for the outer shell with the ferrite toroids and a parallel capacitor representing the gap (1). The beam is represented as a pure current source (Fig. 1).

This model is sufficiently accurate for the low-frequency end, but falls short for the high-frequencies, where electro-magnetic cavity effects dominate the response. Simulation is more helpful there.

Mechanical construction

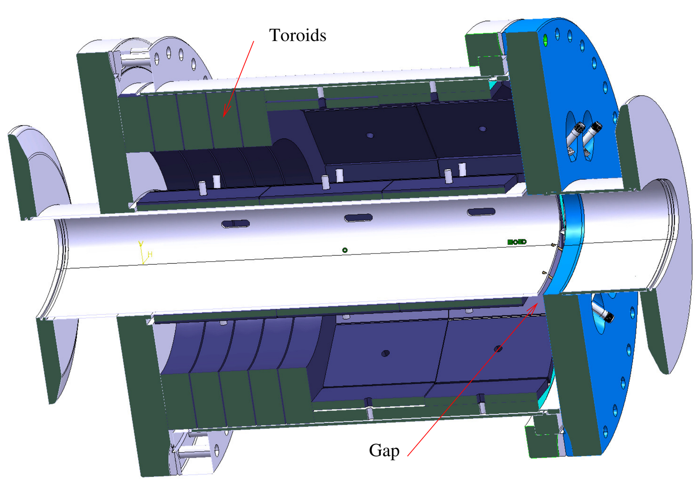


Figure 2: Cross section view of the WCM.

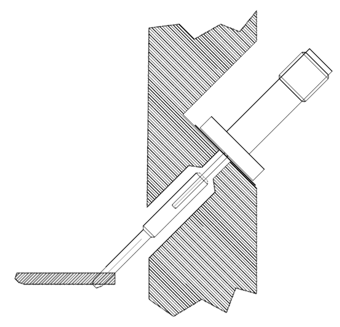


Figure 3: Detail of a feedthrough.

The WCM is basically a cylinder between two ConFlat DN250 flanges, traversed by the PS standard oval vacuum chamber (Fig. 2). The gap is between the right-side flange and the inner chamber. Eight vacuum feedthroughs traverse the right-side flange under an angle to join the edge of the inner chamber across the gap (Fig. 3, 4). The inner chamber edge and the feedthrough probe pins are gold-plated to ensure good electrical contact. The outside of the inner chamber, as well as the inside of the outer chamber, is covered with Ferroxcube 4S60 type ferrite tiles to absorb the energy propagating in the coaxial space between the beam pipe and the shell (Fig. 6, 9).

Five Ferroxcube T240/160/20-8C11 toroids stacked in the bottom of the shell provide the 10μH of inductance required to extend the bandwidth down to 100kHz (Fig. 7, 8).

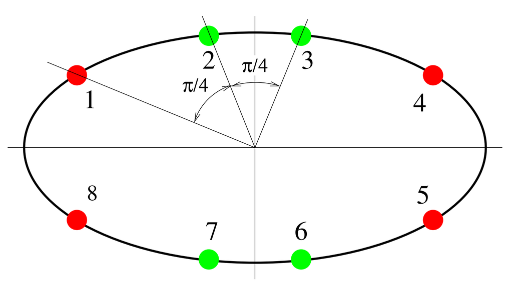


Figure 4: Eight probe points around the tube perimeter.

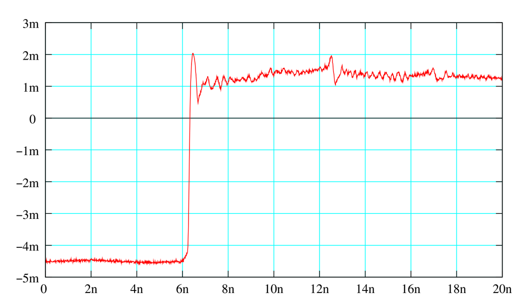


Figure 5: Step response of the final WCM output. Risetime is 60ps.

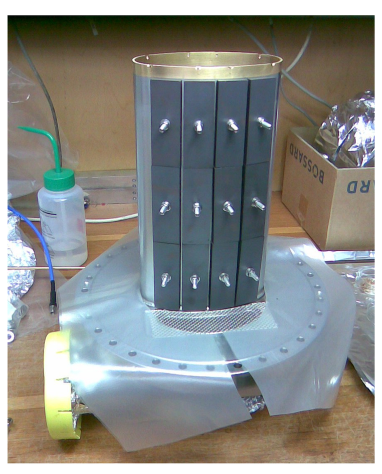


Figure 6: The inner chamber with its 4S60 absorbtive tiles.

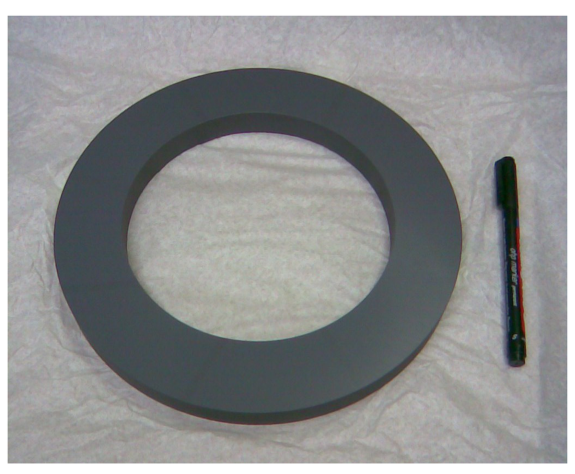


Figure 7: One of the T240/160/20-8C11 toroid cores

Absorbing ferrite tiles are mounted inside two hoops that are slid into the WCM shell (Fig. 9). The hoops are consolidated by leaf springs and a retainer ring with a spiral RF gasket. The tiles on the inner chamber are held in place on threaded studs. Spring washers protect the brittle ferrite tiles against excessive forces.

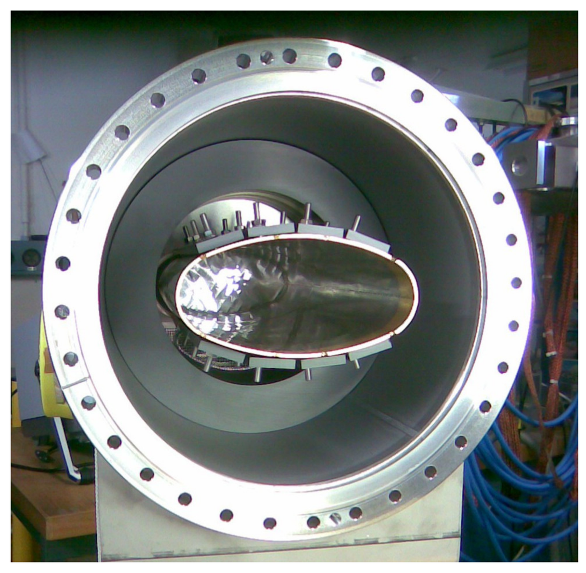


Figure 8: The toroids in the bottom of the sump.

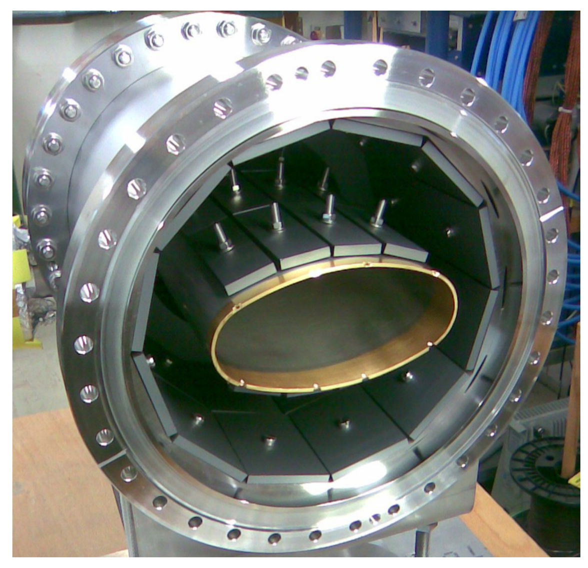


Figure 9: A view of the insides of the WCM.

Figure 10: Elementary 4-port combiner.

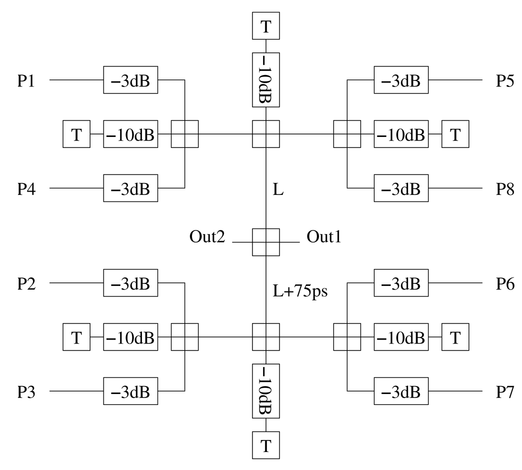


Figure 11: Combiner tree.

A tree of seven elementary combiners (Fig. 10, 11) creates two identical —approximately position-independent— output signals from the eight probe signals. Attenuators spread out signal power and damp transients arising from asymmetries.

Simulation model

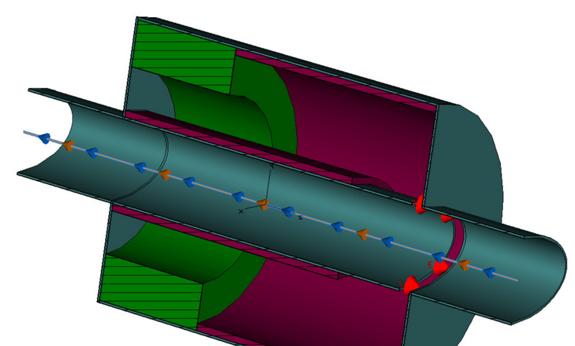


Figure 12: CST Microwave Studio simulation model.

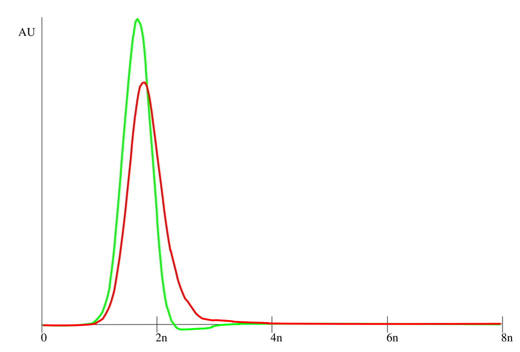


Figure 13: Simulated impulse responses.

Simulating all the small details of the WCM, especially in the area of the vacuum feedthroughs would lead to prohibitively long simulation times and very large data files. The model (Fig. 12) therefore has several simplifications with respect to the actual WCM:

- The five ferrite toroids are modelled as a single barrel.
- The tiles are modelled as a homogeneous smooth internal layer.
- The feedthroughs are modelled as simple 50Ω ports, neglecting all small detail. Part of the feedthrough was the subject of a separate dedicated simulation.
- Gaps, seams, ridges, shims and other such mechanical details have been omitted.

Figure 13 shows the simulated output of one each of the two sets of ports, one for a 'near' port (green) and one for a 'remote' port (red). The response of a 'near' port is faster and larger, due to its smaller charge collection area and its proximity to the beam.

Conclusions

Two WCM's were installed in the PS. The better signal quality and greater bandwidth of these WCMs have significantly improved the clarity of the tomograms. As an example, Fig. 14 shows a longitudinal phase space picture produced by the Tomoscope.

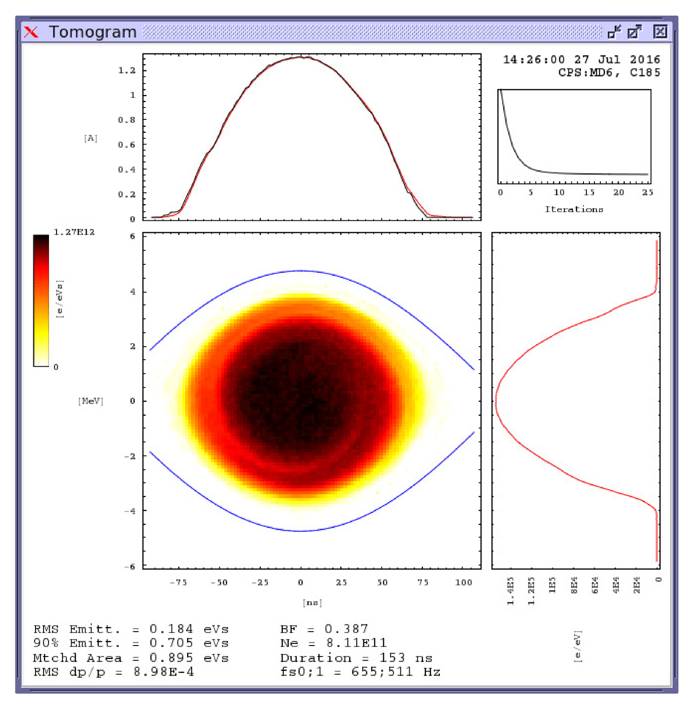


Figure 14: A tomoscope picture.

Acknowledgements

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References

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