

CERN-SPS WIRE SCANNER IMPEDANCE AND WIRE HEATING STUDIES

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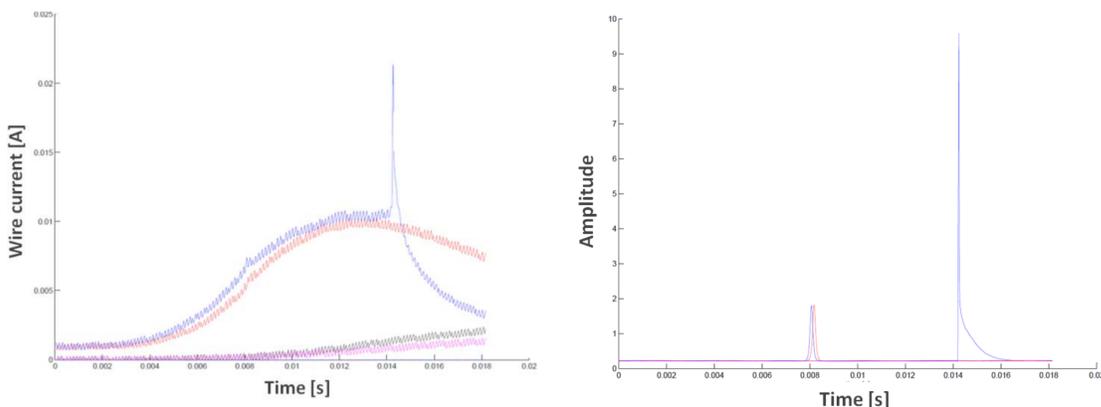
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Abstract: This article describes a study performed on one of the CERN-SPS vertical rotational wire scanners in order to investigate the breakage of the wire, which occurred on several occasions during operation in 2012. The thermionic emission current of the wire was measured to evaluate temperature changes, and was observed to rise significantly as the wire approached the ultimate LHC beam in the SPS, indicating the possibility of strong coupling between the beam's electromagnetic field and the wire. Different laboratory measurements, complemented by CST Microwave Studio simulations, have therefore been performed to try and understand the RF modes responsible for this heating. These results are presented here, along with the subsequent modifications adopted on all of the operational SPS wire scanners.

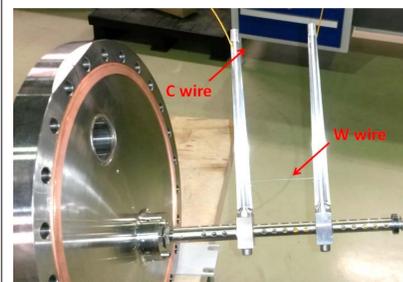
SPS wire breakage mechanism

The CERN-SPS rotational wire-scanners are used on a regular basis by machine operators to perform beam size measurements to verify and optimise the beam emittance. During the run in 2012, there were many more abnormal wire breakages during the use of these scanners compared to previous years. There were observations of a large current induced in the wire when the scanning fork was in its parking position. This was finally explained by radio-frequency (RF) modes developing in the scanner tanks with the wire acting as an antenna.



Scanner 416 vertical wire current versus time during four movements around the time of wire breakage (left) and corresponding profile measurement (right).

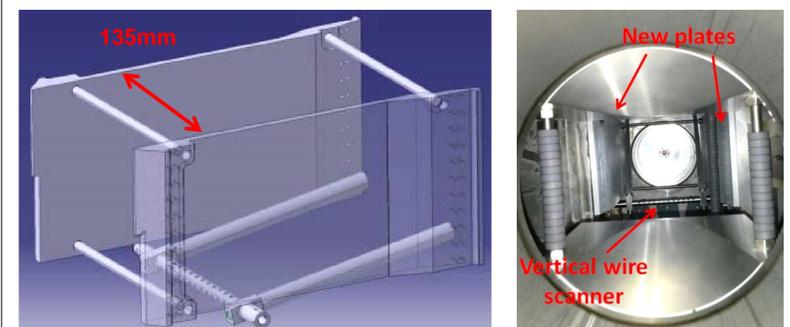
Solution proposed



The first modification was the installation of a tungsten wire of 0.5mm diameter placed across the fork at a distance of 40mm from the shaft.

The idea behind this thicker, more robust tungsten wire was to try use this as an additional coupling antenna to "deviate and absorb" some of the higher RF modes generated in the tank cavity and dissipate the energy in the body of the fork/shaft structure. This would then reduce the RF coupling to the carbon measurement wire, leading to a lower induced current.

The second modification adopted was intended to decrease the overall RF power building up in the vacuum tank. Two vertical, aluminium plates were installed to avoid discontinuities and reduce the volume of the tank seen by the beam.



Laboratory measurements

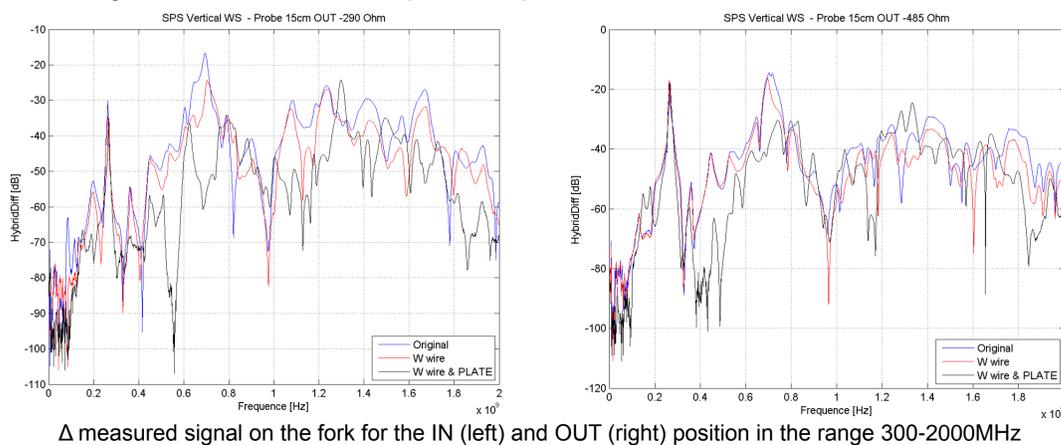


Both proposed modifications were applied to the SPS 416V scanner for tests in the laboratory. The scanner was also equipped with a probe antenna powered by a Vector Network Analyzer (VNA) in order to excite the high frequency modes in the beam spectrum. The two ends of the carbon wire were connected to a Δ - Σ RF hybrid coupler [2], with the resulting sum (Σ) and difference (Δ) signals measured by the VNA. The difference signal being the eventual signal that would generate a current in the carbon measurement wire. Measurements were taken in all configurations with the fork in both the IN and the OUT (parking) positions. The delta signal is assumed to be proportional to the induced current on the carbon wire.

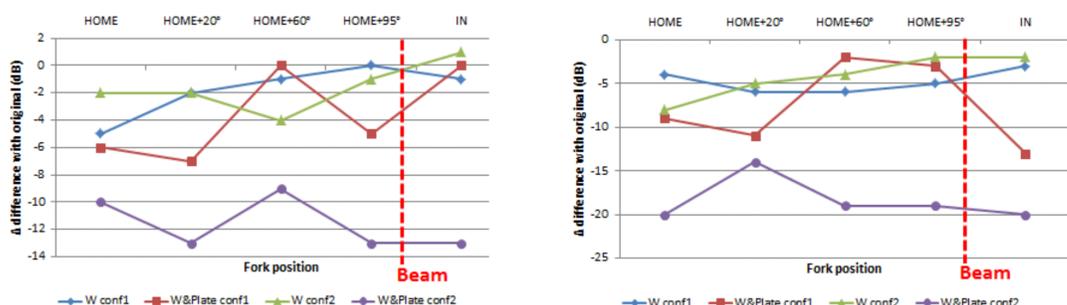
Two regions of high coupling can be identified, one between 200 MHz and 400 MHz and the other between 600 MHz and 800 MHz.

Measurements were performed for three different configurations:

- the original unmodified wirescanner
- with a tungsten wire added to the fork
- with a tungsten wire added and vertical plates incorporated



Δ measured signal on the fork for the IN (left) and OUT (right) position in the range 300-2000MHz

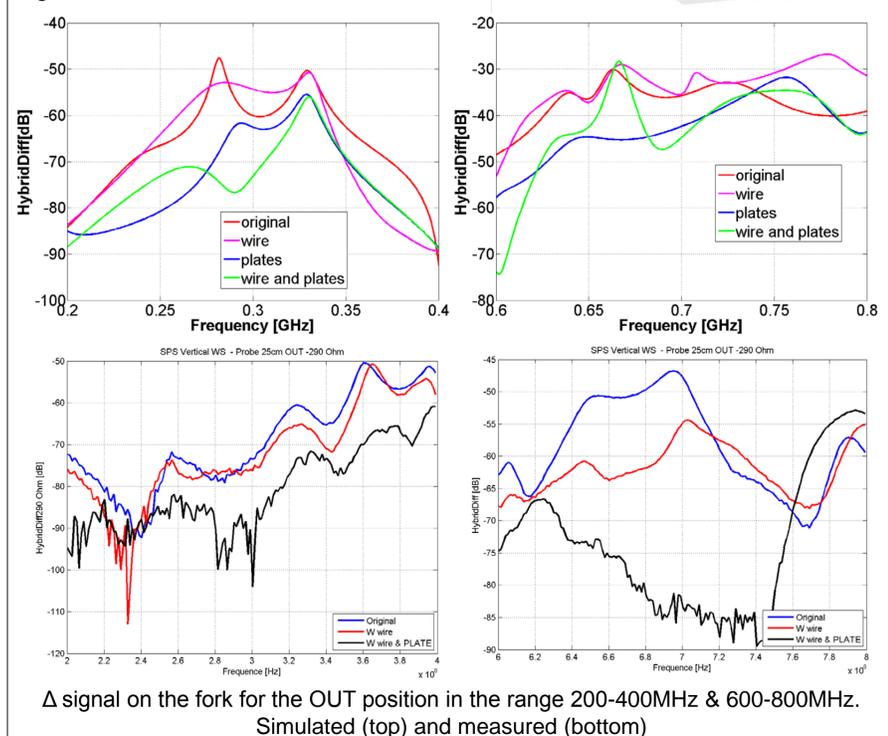
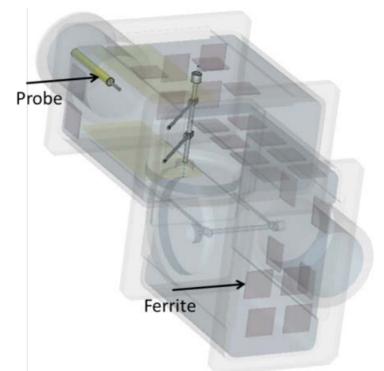


Δ signal difference in the range 200-400MHz and 600-800MHz in two different probe configurations

CST Simulation

The measurement set-up was also simulated using the CST STUDIO SUITE [3], with the 3D model used for the simulation.

The model contains all the main features of the device, including the measurement probe and the carbon wire with its connecting wires with the fork. The sum and difference signals were simulated using the frequency domain solver of CST Microwave STUDIO with tetrahedral mesh cells. The results show two resonant peaks in the 200-400MHz range and a broader resonance in the 600-800MHz range in good agreement with the measurements.



Δ signal on the fork for the OUT position in the range 200-400MHz & 600-800MHz. Simulated (top) and measured (bottom)

Conclusions and perspectives

Laboratory measurements and simulations have been performed to try and understand the wire breakage of the SPS wire scanners during high intensity operation, thought to be linked to beam induced currents in the measurement wire. A good agreement is observed, with significant RF coupling expected in the case of the original tank set-up. A marked reduction in the RF power absorbed by the structure is also seen by both measurement and simulation when adding a tungsten wire to the fork and vertical shields to the tank. Both modifications have now been carried out on the installed SPS scanner 416 vertical and the tungsten wire on all the wire scanners. The effect on wire lifetime will be investigated during the 2014 and 2015 SPS runs.

References

- [1] F. Caspers, B. Dehning, E. Jensen, J. Koopman, J.F. Malo, Roncarolo F., "Cavity mode related wire breaking of the SPS Wire Scanners and loss measurements of wire materials"; Proceedings of DIPAC 2003, Mainz, Germany.
- [2] F. Roncarolo, "Accuracy of the Transverse Emittance Measurements of the CERN Large Hadron Collider", PhD Thesis (2005); <http://lphe.epfl.ch/publications/theses/these.fr.pdf>
- [3] CST Microwave Studio <http://www.cst.com>