THE WIRE POSITION MONITOR (WPM) AS A SENSOR FOR MECHANICAL VIBRATION OR THE TTF CRYOMODULES

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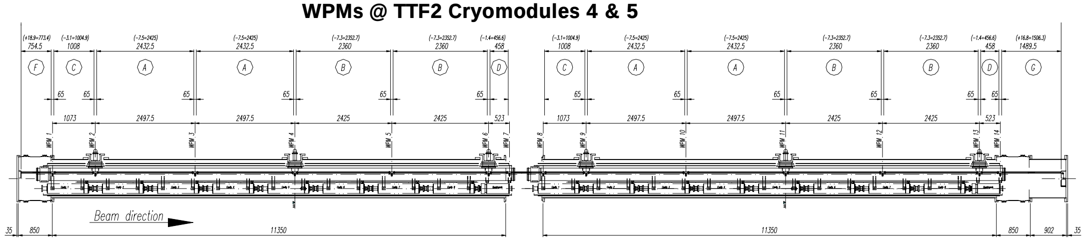
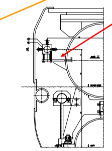
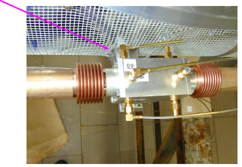
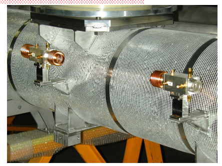
WPMs @ TTF2 Cryomodules 4 & 5

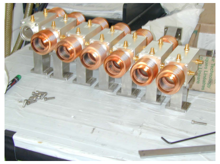


The last cryomodule generation has a single chain of seven detectors (placed in critical positions: at each end, at the three posts and between the posts), screwed through a support to a stainless steel arm which is welded to the gas return pipe (GRP).







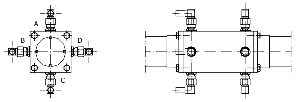


A WPM is a sort of microstrip four channels directional coupler. A 140 MHz RF signal is applied on a stretched wire placed (nominally) in the center of the monitor bore. The de-modulated electrical signal (D_x and Dy) is converted in cold mass displacement (x and y) via a two dimensional 3rd order polynomial.

$$D_x = \frac{V_B - V_D}{V_B + V_D} \qquad D_y = \frac{V_A - V_C}{V_A + V_C}$$

$$x = a_{10} D_x + a_{30} D_x^3 + a_{12} D_x D_y^2$$

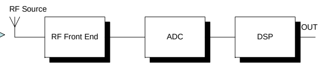
$$y = a_{01} D_y + a_{03} D_y^3 + a_{21} D_x^2 D_y$$

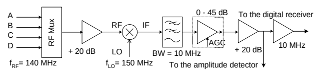


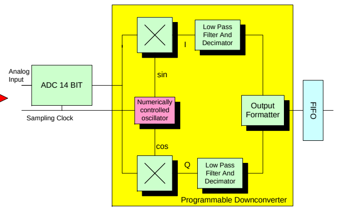
WPMs as Vibration Detectors

- The low frequency vibrations of the cold mass amplitude modulate the RF signals picked up by the microstrips.
- The microphonics (and the sub-microphonics) can be recovered de-modulating the microstrip RF signal.
- The de-modulated signals are converted into positions via the same two dimension 3rd order polynomial, used to convert the WPM electrical signals (D_x and D_y) into cold mass displacements (x and y).
- Only transverse vibration in the horizontal and vertical planes can be detected.

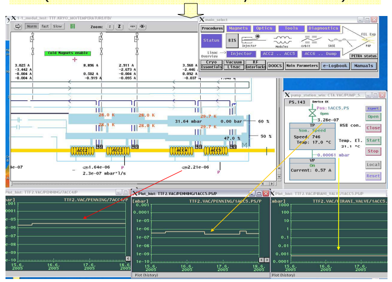
- The WPM control electronics has been upgraded inserting a 4 channel Digital Receiver Board, which recovers the base-band signal like a sort of AM software radio. The vibration detection system is a super-heterodyne receiver, where the base-band demodulation is made digitally.
- Two WPM readout electronics boards have been modified to work as the RF front end circuitry for the digital receiver. The function of the RF front end is to read the four microstrips of the selected WPM, and to down-convert the RF signal to the 10 MHz IF signal, together with amplifying and filtering.
- The IF signals from the RF front end enter the QDR, where they are first filtered, and then sampled. The Analog Devices 14 bit AD9644 analog to digital converter, mounted on a mezzanine board is used for the A to D conversion. The rest of the processing is done in a digital way. The Digital Downconverter (DDC) translates the carrier to base-band and then applies filtering and decimation, gain scaling, resampling and Cartesian to polar coordinate conversion.

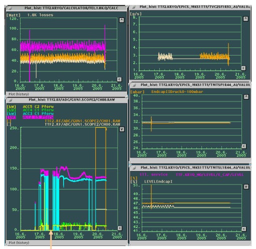






Status of the cryo and RF system when data were taken (between 2 and 4 P.M. of Friday 17 June 2005)





Klystrons off when data were recorded

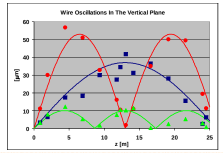
Microphonic vibrations spectral lines on module 4 and 5

- The wire proper vibration spectral lines (fundamental and harmonics) overcome the cold mass mechanical vibration lines.
- On the other hand, being their frequencies well predictable by VSE which completely agrees with the experimental data, it's easy to filter them when processing the data.

Vibrating string equation (VSE)

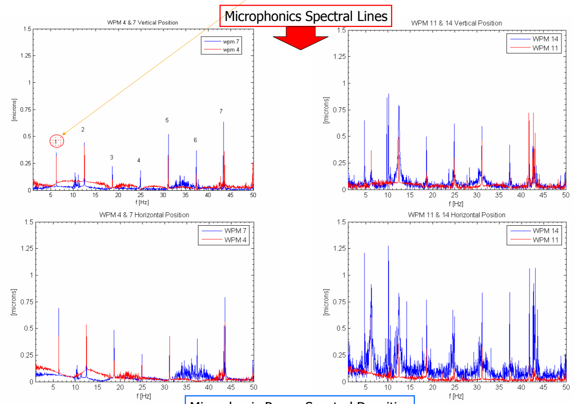
$$f_n = \frac{n}{2\ell}\sqrt{\frac{F}{\rho A}} = n \cdot 6.4\ \text{Hz}$$

- **Wire: (CuBe) Berylco-Cabot BERYLCO 25**
- Density (ρ): 8.25 g/cm^3 = 8250 kg/m^3
- Cross Section (A): 0.196 mm^2
- Stretched Wire Length (ℓ) 25.950 m
- Tensile Strength: 18 kgp = 176.58 N

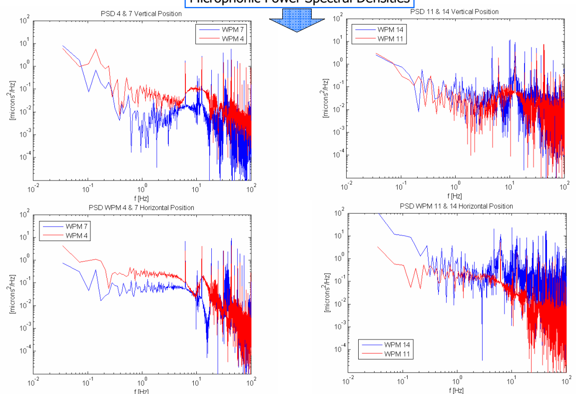


Measured spatial pattern of the streched wire harmonics (in the vertical plate) for the first three harmonics.

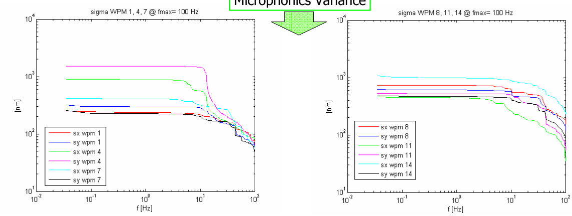
Microphonics Spectral Lines



Microphonic Power Spectral Densities



Microphonics Variance



WPMs 4 and 11 are close to the central post were all the cold mass is constrained.

WPMs 7 and 14 are at the end of the corresponding cryomodules.

Wire eigenvalues spectral lines are still present, though heavy filtered. Filter operation, though easy from the implementation point of view, is a delicate operation because often wire oscillation amplitudes can be up to a hundred of µm, against hundreds of nm maximum amplitude of microphonics. Often microphonic noise is superimposed on wire oscillation spectral losses. So to avoid to cancel useful informations, we have preferred to not filter completely the wire oscillation lines, stopping when noise signal is readable.

Looking to the blue line spectra of WPM 14, a significant amount of noise is present between 10 Hz and 30 Hz, 30 Hz and 40 Hz, due to the proximity of vacuum pumps and similar devices, and under 10 Hz, possibly due to the cryogenic system.

On the contrary, the spectra of the WPM 11 signals, which is at the central post position, shows only the harmonics (filtered) of the wire oscillations.

The effect is less pronounced on the cryomodule 4 (WPMS 4 and 7) where the noise coming of both WPMs is comparable, though pumping spectral lines are present on the monitor close to the cryomodule end.

The data was acquired with acquisition time T = 30 s at sampling frequency f_s = 5 kHz (nominal). The spectral bandwidth is df ≈ 0.035 Hz.

Unexpected noise at very low frequency has been found on the signals coming from WPM 4. Further test must be done to understand if this is a real noise or is a common mode interference.
(The WPM electronic rack is very close to the klystrons).

WPM 1 & 8 are at the beginning of the cryomodule 4 & 5 respectively.

The variances of WPM 4 is dominated by the low frequency noise as shown in the PSD.

For all the WPMs, a small contribution to the variance comes from the spectral losses of the wire self oscillations lines. A more efficient procedure to remove these contributions is under study.

Equations:

Spectral bandwidth df ≈ 0.035 Hz

FFT coefficients

$$G\left(\frac{n}{N\tau}\right) = \frac{2}{N}\sum_{k=0}^{N-1} g(k\tau)\cdot e^{-j\frac{2\pi}{N}nk} \qquad n = 1\ldots\frac{N}{2}-1$$

$$G(0) = \frac{1}{N}\sum_{k=0}^{N-1} g(k\tau) \qquad n = 0$$

Power Spectral Density

$$PSD\left(\frac{n}{N\tau}\right) = \frac{\frac{1}{2}\left|G\left(\frac{n}{N\tau}\right)\right|^2}{df}; \quad df = \frac{f_S}{N} = \frac{1}{T}$$

Variance

$$\sigma\left(\frac{n}{N\tau}\right) = \sqrt{df \cdot \sum_{l=n}^{\frac{N}{2}-1} PSD\left(\frac{l}{N\tau}\right)}$$