DIGITAL ANALYSIS OF BEAM DIAGNOSTIC NOISE

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Abstract

A digital coherence analysis has been performed to analyze the origin of the noise observed on several beam diagnostics. By correlating different channels from the same electronics or from different monitors, the instrumental or physical origin of the noise can be deduced.

INTRODUCTION

This paper presents some results about the origin of the noise observed using different diagnostics systems either on Proscan, a 250Mev proton accelerator medical facility, or on the 590 MeV proton accelerator. The origin of the noise is always a question that arises when interpreting the experimental data. Is it simply a noise from the measurement system (instrumental noise) of does it really reflect some physical fluctuations of the parameter that is being measured ("physical" noise)? Coherence analysis using digital signal processing has been used to address this issue.

Coherence analysis [1] compares the spectral content of two signals and indicates how well the signal frequency components are correlated. It is a function of the power spectral density ($P_{xx}(f)$ and $P_{yy}(f)$) of x and y and the cross power spectral density ($P_{xy}(f)$) of x and y and is defined as: $C_{xy}(f)=\frac{|P_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$. For the results presented here, the coherence has been computed with MATLAB applying the Welch method with 50% overlap.

NOISE ANALYSIS FOR CURRENT MEASUREMENTS

Logarithmic amplifier electronics (LogIVs) [2] is extensively used to measure the current signals from beam current monitors or harp monitors [3, 4] for PROSCAN.

VME LogIV-32 instrumental noise

A 32-channel VME LogIV electronic board has been developed for the harp monitors. The possible cross-talk between channels has been investigated by using a 150pA test source as input for all 32 channels and by calculating the coherence spectra of the sampled data. The sampling frequency was 5kHz and the spectral resolution was 9.8Hz. Altogether 496 spectra have been computed. The coherence spectra between most of the channels indicate no statistically significant cross-talk (see Fig. 1 the coherence spectrum between Ch.1 and Ch2). However, the coherence exhibited values above 0.5 over the whole frequency range for a few cases (see Fig.2). The cross-talk could be traced back to the capacitive line coupling between the log amplifier voltage output and the current input of a nearby log amplifier for some specific channels.

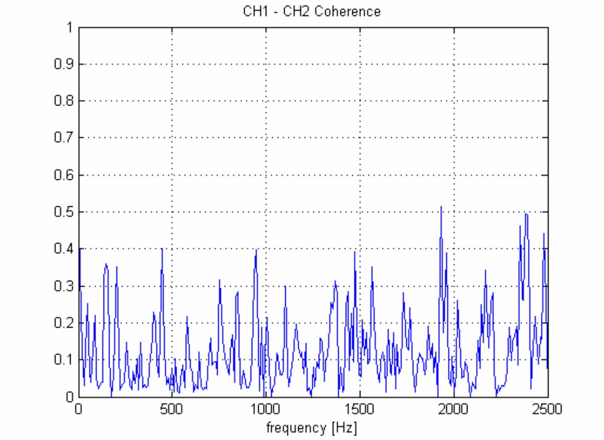

Figure 1: Typical coherence spectrum between VME LogIV-32 channels, in this case, Ch.1 & 2.

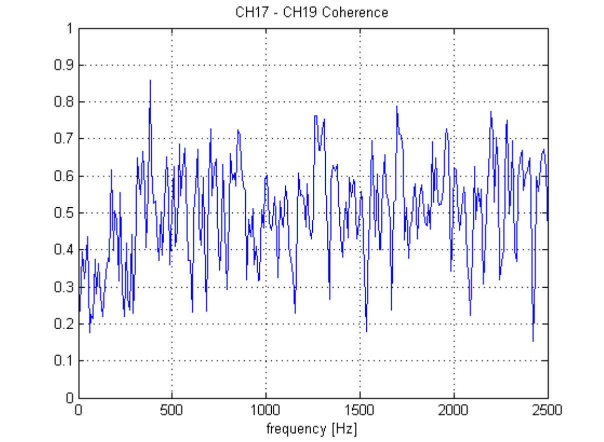

Figure 2: Evidence of cross-talk between channel 17 & 19

As a result of this capacitive coupling, the noise of a few channels increases at very low current measurements (<1nA) though the DC value is not affected. For larger current (>1nA) the coupling is negligible.

Beam noise

PROSCAN beam current measurements (see Fig.3) exhibit significant noise level (50% is not unusual). The coherence analysis has been applied to exclude any instrumental origin and to possibly identify the origin of the observed noise. 2 VME LogIV-4x4 boards were used for the beam current monitors MMAC1 & MMAC3 whereas a CAMAC LogIV-16 was used for the harp measurements. The analogue outputs of the electronics have been sampled at a frequency of 100kHz; the use of a datalogger allowed us to record more than 131’000 samples (up to 512000 samples have been recorded for some cases) leading to spectral resolution better than 13Hz.

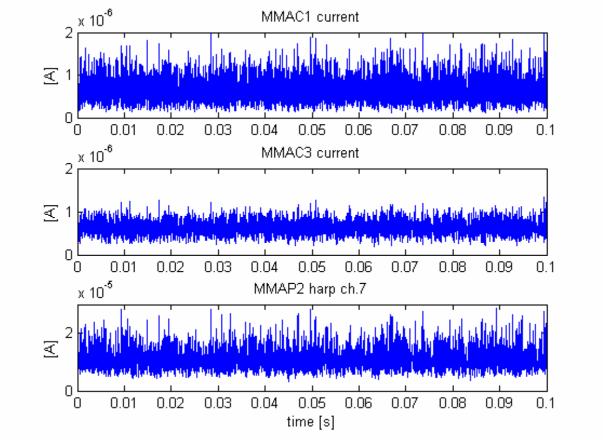

Figure 3: PROSCAN beam signals

The coherence spectrum between the two beam current monitor signals (Fig.4) exhibits an excellent correlation for frequencies up to 40kHz. Excellent correlation is also observed between beam current monitors and harp signals (Fig.5).

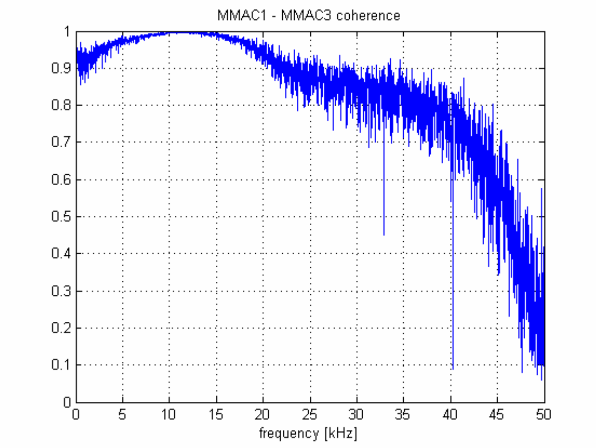

Figure 4: Coherence spectrum of beam currents

Since the signals have been measured using different electronics boards (2 VME and 1 CAMAC) the correlated noise cannot be attributed to the used electronics. The current monitor fluctuations reflect beam intensity fluctuations whereas harp signals are in addition sensitive to beam position variations. This implies that the observed noise is due to beam intensity fluctuations the most probable noise source being the ion source itself.

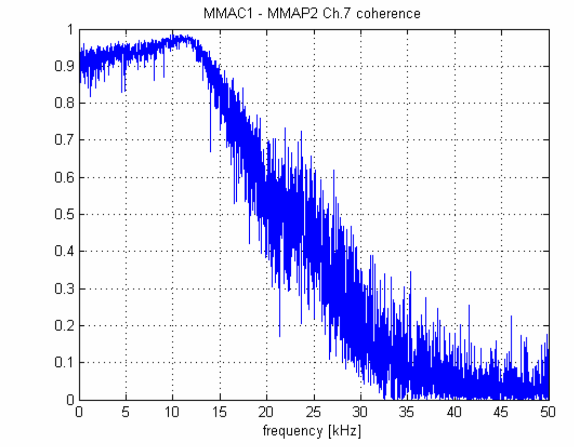

Figure 5: Coherence spectrum between a beam current and a harp monitor signal.

BEAM POSITION MONITOR NOISE

The beam position monitor (BPM) systems [2] are based on digital receiver technology and use the signals from 4 pick-up coils. The RF 2nd harmonic (101.26MHz) signals (beam signals) are directly frequency down-converted (no analogue LO), and the online measurement of individual channel overall gain using 101.31 MHz pilot signals. The beam position is deduced from the difference over the sum of the normalised signals: $\Delta x \,\alpha\, \dfrac{S_n^+ - S_n^-}{S_n^+ + S_n^-}$ with $S_n^{+(-)} = \dfrac{S_{beam}^{+(-)}}{S_{pilot}^{+(-)}}$ the normalized sensor + or -.signal.

Some preliminary results have been obtained as far as the noise analysis from BPM signal is concerned. The MXS3 BPM has been used for these measurements at a beam current of 1.97 mA. The effective sampling frequency was 1kHz. The beam and pilot signals are well correlated for the horizontal direction (Fig.6). Similar results have been obtained in the vertical direction. However no correlation has been observed between horizontal and vertical signals.

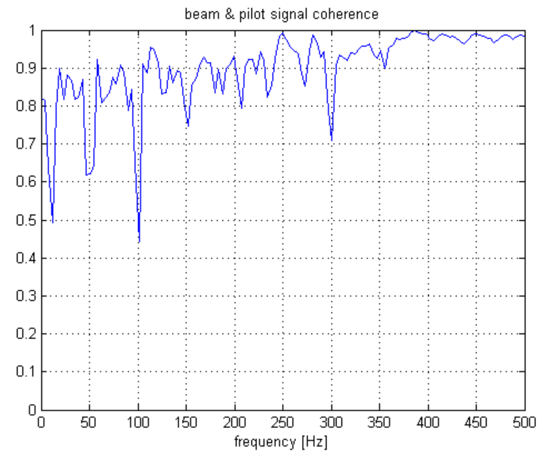

Figure 6: Beam & pilot signal coherence spectrum.

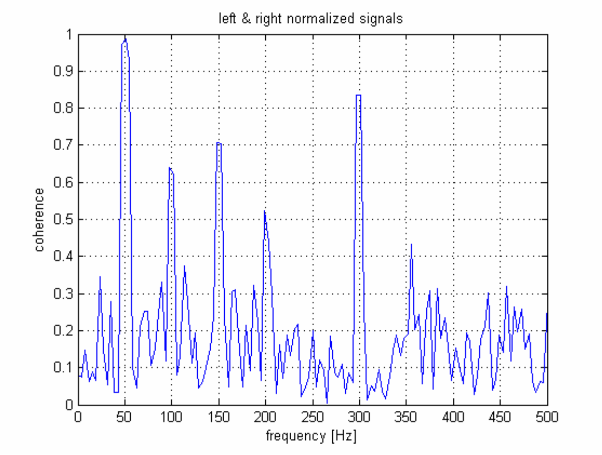

Figure 7: Normalized signal coherence spectrum.

This suggests that the observed beam or pilot signal noise is of instrumental origin, most probably generated by the RF preamplifiers. It is interesting to notice that the normalized signals exhibit some correlation only for the 50Hz harmonics (Fig.7). The interpretation of the normalized signal coherence spectra is more difficult. Indeed, the power spectrum of a normalized signal is the result of the convolution of two spectra. It can be shown with some simulations that the raw data coherence may be lost with the signal normalization. The observed instrumental noise is expected to be removed with the second version of the RF preamplifier which is being presently developed.

REFERENCES

[1] J. S. Bendat, A. G. Piersol, “Engineering Applications of Correlation and Spectral Analysis”, John Wiley & Sons, p.72.

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[3] R. Dölling, “Ionisation Chambers and Second Emission Monitors at the PROSCAN Beam Lines” in Beam Instrumentation Workshop-2006, Batavia, AIP Conference Proceeding vol. 868, pp.271-280.

[4] R. Dölling, “Progress of the Diagnostics at the Proscan Beam Lines” this conference.