COUPLED BUNCH MODES MEASUREMENT SYSTEM AT ELETTRA

A. Fabris, C. Pasotti, P. Pittana, M. Svandrlik, Sincrotrone Trieste, Italy

Abstract

Elettra operates with a controlled longitudinal coupled bunch excitation in order to provide the required lifetime. A constant control of this excitation is required to avoid deterioration of the light quality. A fast and reliable measurement of the Coupled Bunch Mode oscillation amplitudes is obtained by means of automatic acquisition software that allows to characterize the full beam spectrum in 4 minutes for the longitudinal plane and 10 minutes for the transverse one. The system is fully integrated with the ELETTRA control system. It provides real time results which can also be saved for post-processing purposes. Options for full spectrum measurement or single coupled bunch mode measurements in time are available. A further option is implemented to allow measurements for different filling patterns of the ring. The measurement set up and specification as well as some measurements on the ELETTRA machine are presented.

1 INTRODUCTION

In circular accelerators, the electromagnetic field generated by the bunched beam, the wake field, interacts with the surrounding and, under certain circumstances, can be amplified and can act back on subsequent bunches. Disturbances grow and so-called collective beam instabilities arise [1]. The machine environment is seen by the bunch as a frequency dependent impedance, that can be sampled by the beam spectral components [2].

A single bunch beam usually performs small oscillations along the unperturbed single particle orbit, or stationary trajectory. Therefore at a fixed location along the machine, the signal of a single bunch has the frequency components [2]:

$$f_{m,p} = pf_0 + mf_0$$

in which f_0 is the revolution frequency, p is an integer running $-\infty < p < +\infty$, number of beam turns. The index m is the single bunch mode of oscillations that assume positive values: m=0 means a stationary bunch, m=1 oscillations of dipole mode (rigid bunch), m=2 quadrupole mode, m=3 sextupole and so on.

If the ring is filled with M uniform equally spaced bunches, the motion of each bunch can coupled together in M different modes of oscillations:

$$f_{m,n,p} = pMf_0 + nf_0 + mf_s$$

where n= 0, ... , M-1 indicates the n^{th} Coupled Bunch oscillation Mode (CBM).

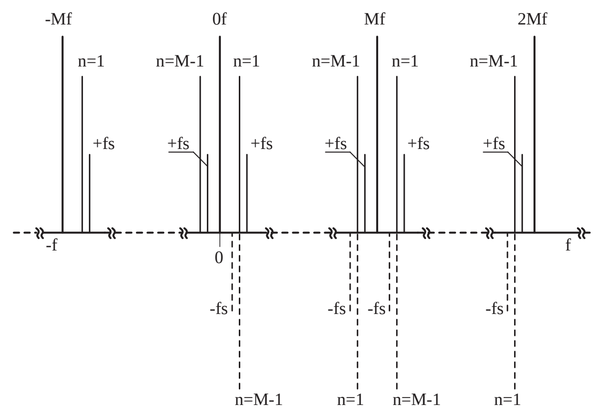

Fig 1: Sketch of the frequency lines for the p=-1,0,+1 values. The pattern repeats running from $-\infty$ to $+\infty$. Dashed lines represent the frequency lines p=-1 aliased in the positive range, p=1.

The frequency lines for M bunches for the m=1 case are sketched in fig. 1. Both positive and negative sidebands in the positive, physical, frequency range are measured on the spectrum analyzer. So measurements of either the positive and the negative sidebands around the same carrier signal can be made, providing that the right CBM number is associated with the respective frequency:

$$f_{1,n,p} = (pM + n)f_0 + f_s \qquad n = 0,\ldots,M \qquad p = 0,\ldots,\infty$$

$$f_{1,n,p} = (qM + n')f_0 - f_s \qquad n' = M - n,\ldots,0 \qquad q = -p = -1,\ldots,-\infty$$

These equations show that it is possible to measure all the CBM numbers along half the beam spectrum when M is even. The full beam spectrum becomes for p=1:

$$f_n = (M + n)f_0 + f_s \qquad n = 0,\ldots, M/2$$

$$f_n = (2M - n)f_0 - f_s \qquad n = (M/2)+1, \ldots, M-1$$

For the transverse case the bunch mode number m can have zero, positive and negative integer values [1]. The frequency lines are:

$$f_{m,n,p} = pMf_0 + nf_0 + |m|\, f_s + Q_T\, f_0$$

where Q_T represents the horizontal or vertical machine tune.

Due to the high quality factor and shunt impedance [3], the High Order Modes (HOM) of the ELETTRA cavities can cause instabilities when $f_{HOM} \approx f_n$, that is when the sharp peaks of the HOM longitudinal impedances have the same resonant frequencies at the beam spectrum lines. For example, the CBM number 86 at the periodic p=3, has frequency $f_{86,3}$=1598.4 MHz, that is close to the longitudinal mode L5.

2 THE CBM AUTOMATIC ACQUISITION PROGRAM

The ELETTRA full beam spectrum characterisation requires amplitude measurement of the 432 CBM frequencies in the frequency range 500 MHz to 750 MHz. In the control room several beam analog signals coming from stripline, buttom and annular pickups are available. According to the kind of measurement, the proper beam signal pickup is connected to the spectrum analyzer remotely controlled by the CBM automatic acquisition software. The program runs from the control system workstation. The instrument performs the CBM spectrum scan by measuring the amplitude of the peaks at the CBM frequencies f_n. The value of the revolution frequency f_0 is first checked by measuring the 432 harmonic frequency, the f_s or f_Q are given by default. Usually the annular electrode signal is used to measure the coherent oscillations in the longitudinal plane and the stripline signal the oscillations in the transverse planes, both horizontal and vertical.

The current program version runs under the assumption that the multibunch instabilities are due to the rigid bunch oscillation mode m=1, but it can be easily extended to different bunch oscillation modes m.
The measurement in the longitudinal plane is faster. The synchrotron frequency at 2.0 GeV is 11.0 kHz. A frequency span of 100 kHz on the spectrum analyzer allows to measure simultaneously both the positive and the negative sidebands. For the transverse planes the default betatron frequencies are $f_{\beta h}$=347 kHz and $f_{\beta v}$=231 kHz, so only one measurement with a span of 100 kHz is made. With a sweep time of 500 ms the longitudinal spectrum measurement lasts 4 minutes, the transverse measurements last 10 minutes.

The beam spectrum is measured by a Rohde & Schwarz FSEA20 spectrum analyzer. The resolution bandwidth is 1 kHz and the measurement level error is equal to 0.5 dB. The user cannot change the instrument settings, except for the number of averages over the selected trace: in case of a stationary coherent beam oscillations the averages increase the measurement accuracy at the cost of a longer measurement time.

The program is written with the development language HP Visual Engineering Environment VEE 3.21, running on the HP 9000 Serie 700. The instrument is remotely controlled via a GPIB bus, connected to the ELETTRA control system LAN via the HB E2050A LAN/HB-IB gateway.

As soon as each CBM number oscillation is measured, its level is shown on a graphical display. The longitudinal oscillation amplitudes are shown in degrees θ_m, referring to a phase modulation of the sideband with respect to the 432 harmonic, the CBM number 0:

$$\theta_m[\deg] = 2\frac{A_{side}}{A_0}$$

where A_{side} is the measured amplitude, in dB, of the CBM m and A_0 is the amplitude of the CBM number 0. For the transverse case the CBM intensity is not correlated to the 432 harmonic one. The results, always displayed on the graphical output, are simply shown in terms of dB with respect to the minimum level that the instrument can measure with the wanted accuracy.

The program runs with default input data during user operation to check the status of multibunch instabilities. During the shifts dedicated to the machine studies, the user can change the synchrotron and betatron default frequencies as well as the number of the filled machine buckets depending on the current machine status.

To improve the operational flexibility of the acquisition system, three modes of measurement are available via pop-up menus: to measure all the CBMs, to measure only a selected group of CBM and to perform a repetitive measurement of a single selected CBM. The last option is helpful to investigate the stability of the detected CBM excitation. When its amplitude is stable the beam performs coherent stationary oscillations, see fig. 2. On the contrary, low frequencies beam oscillations occur when the CBM amplitude is continuous changing. Two pop-up panels showing the measurements of the longitudinal beam spectrum and the amplitude of the excited CBM number 86 are outlined in figures 1 and 2.

ACKNOWLEDGEMENTS

The authors would like to thank Fabio Radovcic for the program installation and the useful discussion on the user interface panels.

REFERENCES

[1] Pedersen F., “Multibunch Instabilities”, Proceedings of Joint US-CERN school “Frontiers of Particle Beams: Factories with e^+e^- Rings” pg 269, Springer-Verlag, New York 1992.
[2] Chao A., “Physics of Collective Beam Instabilities in High Energy Accelerators”, Wiley-Interscience Publications, New York 1993.
[3] M. Svandrlik et all, “Improvements in curing coupled bunch instabilities...”, in *Proceedings of the 1997 Particle Accelerator Conference*, Vancouver.

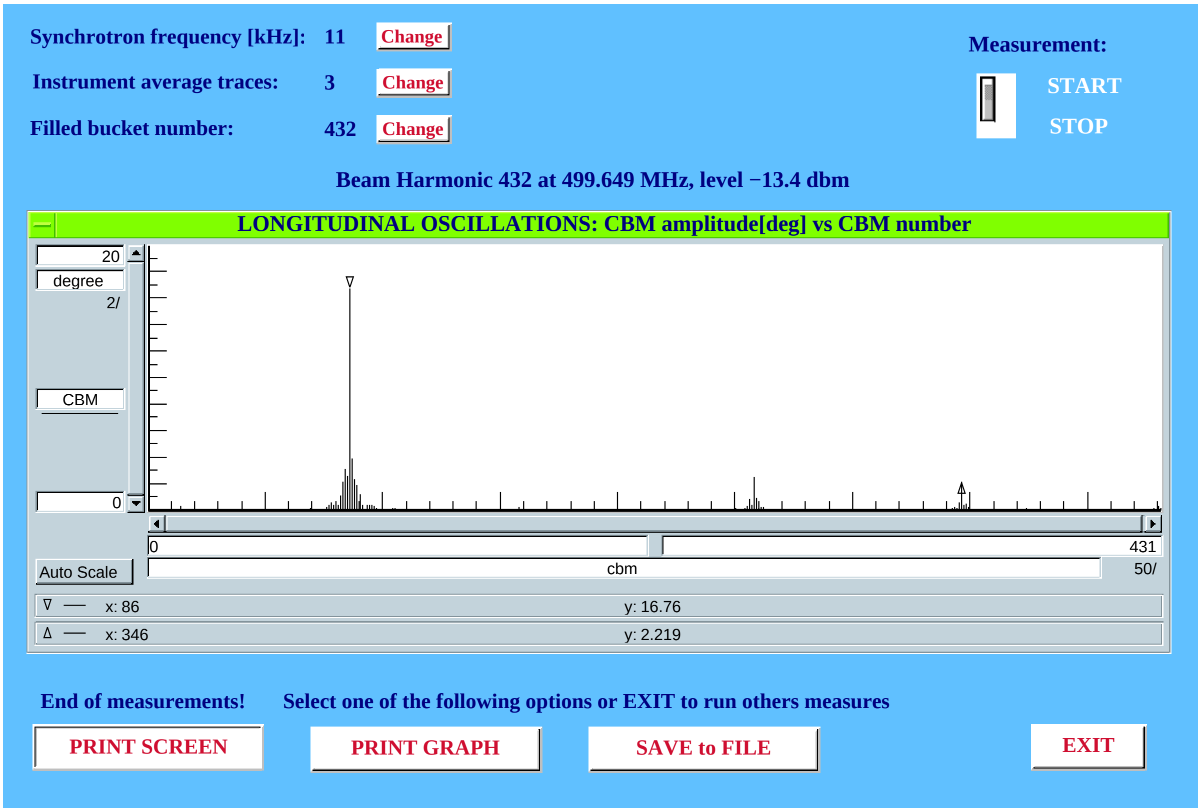

Figure 1: Automatic acquisition system panel showing a beam longitudinal spectrum measured during a user dedicated shift. The CBM 86 is excited providing the required beam lifetime.

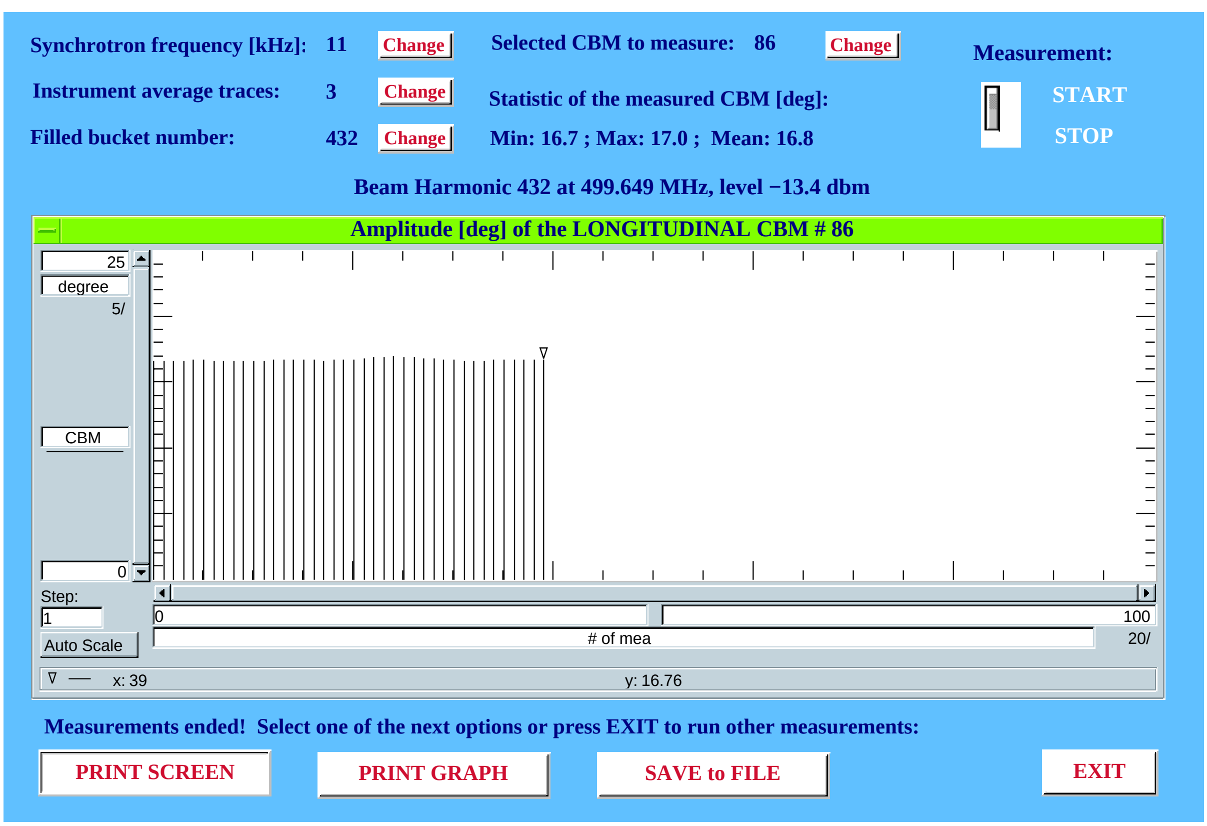

Figure 2: Panel of the single repetitive measurement of the same CBM. The data are measured during a user dedicated shift: the excitation level of the CBM 86 is constant, no low frequencies oscillations occur and the beam is stable within the induced oscillation.