PRACTICAL EVALUATION OF A CBI AVOIDANCE SYSTEM ON THE SRS

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Abstract

A new system has been developed on the SRS at Daresbury Laboratory to minimise the excitation of Coupled-Bunch Instabilities (CBI), by careful monitoring of the beam and RF cavity HOM spectra. The system allows the RF cavities to be run in a condition which shifts the cavity HOM spectrum such that individual resonances do not coincide with beam frequencies, preventing unstable behaviour of the circulating beam. Strict control and monitoring of the RF cavity temperature and tuner position enables the cavity HOM spectrum to be controlled under all operating conditions. This report details the development work that has been done and the preliminary results obtained in the use of this new system.

1 INTRODUCTION

The SRS has experienced many machine upgrades since its initial commissioning in 1979. As a consequence of many of the upgrade projects, the stability of the circulating beam has been improved dramatically over recent years.

Correction systems are in routine operation to maintain both the electron beam orbit and the photon beam positions to very close tolerances during normal user beam operations[1][2][3]. This has meant that sources for beam instabilities have had to be investigated to ensure continued stable operation. The RF system is a potential source of instability through the RF cavities, particularly the Higher Order Modes (HOM) that can be excited by the beam. These resonances can then act back on the beam, causing beam orbit deviations and consequently photon beam position and angle variations. Depending on the strength of the HOM, its interaction can cause the beam to deviate beyond the limits of the orbit correction systems, giving users a degraded flux and reduced brightness due to the beam energy modulation.

This paper outlines a system that has been devised[4] to detect instabilites in the beam and from which identify whether these are being driven within an RF cavity. The cavities are then scanned for HOMs and on detection of a resonance, the system allows tracking of every cavity HOM, whilst varying of the cavity temperature. This enables the excited HOM to be shifted in frequency away from dangerous beam resonances to an area whereby no other cavity HOM can be excited.

2 SYSTEM IMPLEMENTATION

The system comprises a controlling PC, which is linked to an RF multiplexor and a spectrum analyser via a GPIB interface bus. Various RF signals are then switched through the multiplexor and sampled by the spectrum analyser (see Figure 1).

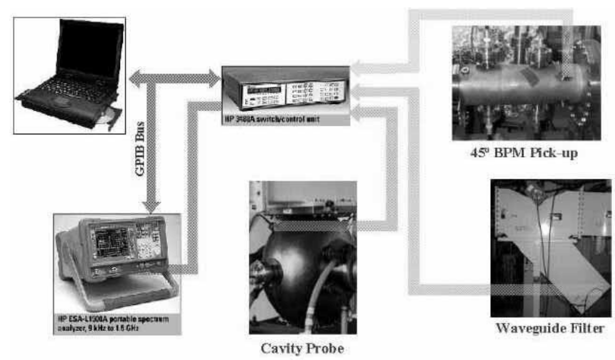

Figure 1. Measurement System.

The beam spectrum is sampled via a BPM pick-up button, which gives a reasonably flat response over the 250MHz baseband acquisition area (500-750MHz). As the BPM pick-up is at 45^o, the beam spectra information contains both horizontal and vertical signatures. It is acquired at a low enough resolution bandwidth such that all orbit harmonic side-bands are sampled. The spectrum is then compared with a similarly acquired stable spectrum that contains no instability resonances. The resulting spectrum difference can then be used to pinpoint the area in frequency space to investigate for cavity HOMs.

2.1 LabVIEW Control System

LabVIEW[5] is a commercial, high level, graphical programming language that is designed for data acquisition, analysis and control. It has an unusual programming methodology, in that software modules are graphically linked. These modules are roughly equivalent to a subroutine in a conventional text based language except that each one is itself fully executable. The graphical approach provides an intuitive understanding for how the program is structured and offers far greater flexibility for alteration. Every module of the software is called a Virtual Instrument (VI). These are the building blocks for every program. Basically, every VI consists of two windows: the first is called the block diagram which is where the code is held and edited and the second is termed the front panel which is the interface with the user.

2.2 SRS Instability Analyser

The front panel for the SRS Instability Analyser is shown in Figure 2.

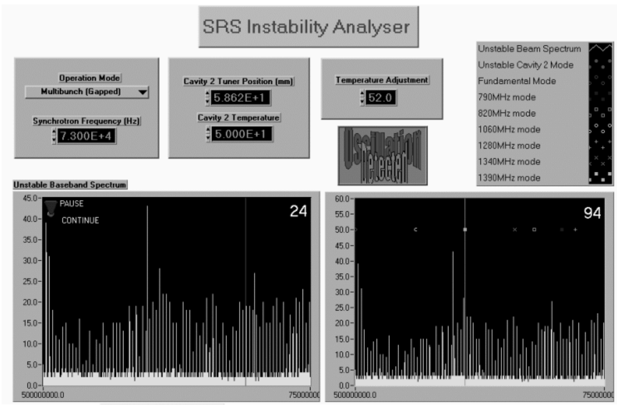

Figure 2. SRS Instability Analyser Control Panel.

It allows the user to enter specific parameters and view acquired data through the many execution cycles of the program. Embedded within the acquisition program are several break point VIs which allow all analysed data to be stored to file on the PC to allow more detailed off-line analysis.

Its execution is sequential, making the program simple and modular. Figure 3 shows how the execution of the program evolves.

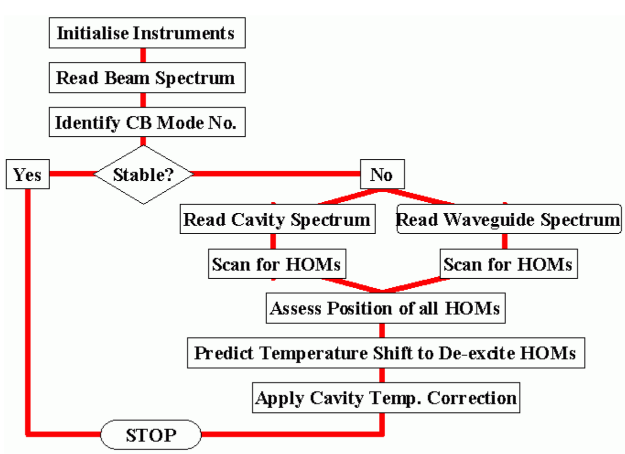

Figure 3. Execution Flow Diagram.

The beam spectrum acquisition needs to contain enough resolution so as to capture all possible side-band resonances. This is done by acquiring a number of small frequency windows and combining them together to form a 250MHz wide, high-resolution frequency spectrum. The spectrum obtained by then subtracting a typically stable spectrum highlights those modes that exist purely when the beam is unstable (see Figure 4).

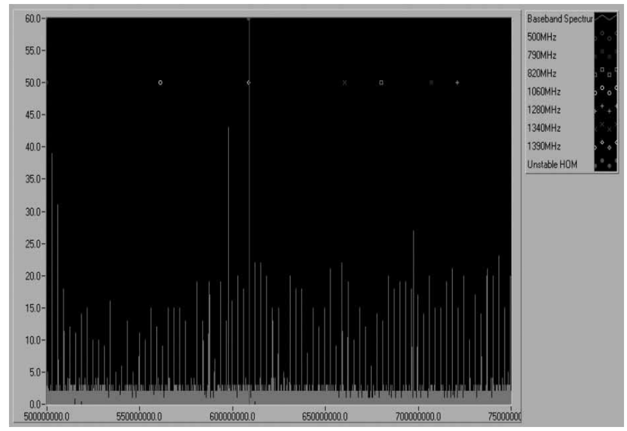

Figure 4. Unstable Beam Resonances.

Each of these unstable resonances are then assessed as to their CB stability using the formula[6]:

$$f_{\mu,n}^{\pm} = nBf_{rev} \pm (\mu f_{rev} + f_{osc}) \qquad 1$$

where:

n = integer
B = number of bunches
f_{rev} = Revolution frequency (Hz)
μ = integer corresponding to the CB mode number
f_{osc} = product of the fractional tune by f_{rev} (Hz)

Should any of these unstable resonances indicate a CB mode number at an integer multiple, then this is flagged as being a CB mode instability.

A cavity probe signal is then switched via the RF multiplexor and read into the spectrum analyser. Knowing the CB mode number, identifying the problematic cavity HOM is relatively straightforward.

The resonances observed on the cavity probe are selective, as it is a magnetic loop coupler, sensitive to strong magnetic fields within the cavity. The longitudinal accelerating modes have peak magnetic fields at the cavity equator, which is where the SRS probe monitors are located. These probes have some sensitivity to the strong dipole modes also and are therefore a good diagnostic for the cavity e-m spectrum. Additional monitor points in the feeder waveguide allow for the detection of those modes that are insensitive to the cavity probe.

Having identified a cavity HOM as causing either synchrotron (frequency modulation) or betatron (amplitude modulation) side bands, the position of all other strong cavity HOMs can be predicted in frequency space, even though they are not being physically excited within the cavity. This is done from precise knowledge of the cavity HOM spectrum and how it deviates in terms of the cavity temperature and tuner position. A cavity temperature adjustment can be predicted, which will move the HOM being excited away from dangerous beam resonances, whilst also ensuring that other cavity HOMs are not excited.

3 SYSTEM EVALUATION

In order to evaluate the system in identifying specific instabilities in the beam, it must be made deliberately unstable by excitation of a cavity HOM. Previous investigations on the SRS have shown that at normal operating beam currents (~250mA), reduction of one of the RF cavity temperatures by 2-3°C excites a monopole mode at 1391MHz[7]. Knowing the e-m field orientation of this mode and also how to excite it, provides a good means of assessing the functionality of the software.

To help with system verification, only the Longitudinal CBIs (LCBI) have been analysed and also only one of the four RF cavities monitored for HOMs. This enabled the program execution to be more easily de-bugged for errors and correct operation.

3.1 Beam Operating Conditions

The harmonic number for the SRS is 160 and normal operation for users is Gapped Beam mode, that is approximately 120 bunches can be filled. With cavity 2 temperature reduced from 52°C to 49°C and sufficiently high beam current (>240mA) to achieve LCBI with μ=125 at n=2 (see equation 1), the prediction software could be tested under real operating conditions.

3.2 Instability Detection

Using the beam Instability Analyser, with the aforementioned beam conditions, indicates that there is a spectral difference, peaking at 608.9MHz (see Figure 4 previously). This frequency coincides with a negative synchrotron side-band about the 35th orbit harmonic. Equation 1 allows the precise pinpointing of the CB mode number associated with this spectral difference, as no cavity HOMs exist around 609MHz. Correctly a CB mode number of μ=125 is indicated, which coincides with the deliberately excited monopole cavity HOM at 1390MHz.

3.3 Cavity HOM Detection

Once the predicted cavity mode is identified, this is then confirmed by collecting the cavity spectrum information from the cavity 2 probe signal. Not only are the excited cavity HOMs observed, but also the storage ring RF frequency and its associated harmonics. These are filtered out in the LabVIEW analysis VIs, isolating purely the cavity HOMs as the source of the beam instability.

3.4 Cavity Temperature Prediction

Knowing both the cavity body temperature and its tuner position, a precise prediction of all cavity HOMs can be made. A shift in cavity temperature can then be simulated, whilst tracking all other HOMs, providing an optimum temperature setting for a particular mode of machine operation and beam current.

Coding has yet to be incorporated to accept the predicted temperature adjustment and have the correction automatically applied through the main SRS control system.

4 CONCLUSIONS

Although this diagnostic system does not stop the onset of CBI on the SRS, it does provide a mechanism for eliminating these instabilities once they are being driven. The use of the LabVIEW interface has proved invaluable in developing the system which copes well with all aspects of the control system, from acquisition through to the analysis and finally to presenting the results.

The system has shown that when operating the SRS under a deliberately unstable condition, driven by a known RF cavity HOM, a correct prediction of temperature adjustment can be made.

Excitations of other cavity HOMs have yet to be investigated and currently only the LCBI coding is implemented. Work is ongoing to refine this mode of operation prior to introducing the Transverse CBI facility.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

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