# 21.4 MHz / 1.7 GHz Tevatron Shottky Automated Tune Fitters Upgrade Proposal

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September 22, 2003

## Introduction and Purpose

Our goal is to report to the Tevatron betatron tunes periodically and automatically, such that it can be data-logged for further analysis. Such tune fitters could be called "virtual, or soft" instruments because it involves no new instrumentation hardware per-se, as it consists of various software packages, tightly integrated and, of course, some computing equipment. The betatron tune is a rather fundamental property of any synchrotron, and the Tevatron has stringent accuracy requirement to understand the lattice and adverse beam-beam effects. We believe that reporting tunes reliably without direct assistance from operators is important and achievable. A response rate of ~ one Hertz would be adequate. Finally, Such information could in principle be used to provide a tune tracker, that is, a way to control the tunes automatically.

A prototype of such a system has been assembled during FY03, based on signal coming from the 21.4 MHz Shottky. This project is described at http://www-bd.fnal.gov/tevtune/ , and a contribution to PAC03 has also been posted. (http://warrior.lbl.gov:7778/pacfiles/papers/WEDNESDAY/PM_POSTER/WPPG052/WPPG052.PDF).
Meanwhile, a prototype of a digital signal analyzer looking at all 4 signals from this 21.4 MHz system has been assembled. The Vertical Proton signal has been recently studied and compared to the signal obtained from the HP3561a. Preliminary results are encouraging. More work is clearly needed to fix the aliasing problem, most likely due to an unreasonably low digitization frequency (33 MHz) (See Document number #830 in the Document database for further details ). Nevertheless, we propose to retire the HP3561a analog signal analyzers and adopt such digital techniques, and upgrade the computers on which the fits are performed.

The reason for this upgrades are:

a. The HP3561a devices cannot be easily controlled remotely. That is, a known configuration cannot be downloaded via the GPIB upon power cycles, or after change made to the HP3561a front panel, in a timely fashion. Although this is in principle possible, Charlie Briegel from Controls/BD tried and found this task a bit too cumbersome.
b. HP3561a Signal Analyzer can still be purchased on e-Bay, along with all sorts of obsolete equipment and other antics that required special skills to operate or maintain. As Fermilab personal is our most valuable asset, we should not waste it!
c. Most important, data is transferred via a slow GPIB interface, limiting the number of spectra we can fit in a timely fashion.

The new 1.7 GHz Shottky monitor has also been built during FY03. See http://warrior.lbl.gov:7778/pacfiles/papers/THURSDAY/PM_POSTER/RPPB023/RPPB023.PDF
Signals from this instrument have been recently made available via a GPIB interface to the VSA generating frequency spectra and a Vax Console application has been written, where users can perform Gaussian fits of the down-converted signal upon demand. We plan to automate such fits, and write the necessary D.A. and control software such that this application no longer runs on an unacceptably slow Micro-Vax and automatically reports betatron tunes to ACNET.

This document is organized as follow. Based on prior experience with such prototypes and requirements from Beam Physicists, a set of high level requirement are listed. The overall architecture of these "soft" instruments is described. We then briefly describe the hardware that we plan to retire. We propose new hardware and give a preliminary M&S cost. We conclude by giving a rough estimate of the man-power required to upgrade the software and a very tentative schedule.

**High Level Requirement**

The Tevatron tune foot-print typically cover ~ 0.02 fractional tune units, centered around 0.575. A change of the fractional tune of 0.001 often has significant –usually adverse-consequences on the stability of the beams, we therefore require the tune fitter accuracy to be a few $10^{-4}$. Note that such an accuracy might be difficult to achieve with the 1.7 GHz Shottky, because of the possible lack of a coherent signal lasting for a fraction of one second, or conversely, if the device works in true Shottky mode, we might not have a signal to noise ratio good enough to provide average spectrum over a long period. The above accuracy requirement is only valid for "best case" scenarios. An accuracy of 0.001 is the least minimum acceptable.

During machine tuning, with uncoalesced beams, the tune fitters must report tunes every seconds or so, commensurate with the Nyquist frequency given a base betatron frequency of ~27 kHz and the precision requirement stated above, and reasonable performance of achievable digitizers, Fast Fourier Transform (FFT) and fitting software. For coalesced beams, and for tune measurement for every bunch in the machine, the performance might degrade to ~ 0.1 Hz..

There shall be two distinct tune fitter package, one for each type of signal sources: 21.4 MHz and 1.7 GHz. Such devices are indeed complementary: the former is able to measure tune very precisely, but given the relatively high Q of the pick-up (~300 ), it integrates over many 53 MHz bunches. The latter is able to see individual bunches, provided they are separated by ~ 400 ns, but might not provide highly accurate measurement. It is hoped however that beam-beam tune shifts of ~0.005 will be adequately measured by this second tune fitter package. This remains to be demonstrated.

Both "soft" instruments will automatically report data to ACNET, such that tunes can be data-logged, both periodically and in SDA. These systems will be maintained the

Instrumentation Dept and/or the Controls Dept., such that they report data during normal RunII operations. The software will be maintained in central repositories.

The Tune Fitters must also be able to deliver "raw data" (the frequency spectrum) to casual users, on demand, over the network, for monitoring purposes. This can be achieved either with dedicated LabView ancillary programs that works over the network, or conversely via Java Server Pages.

Desirables:

a. The Tune fitters, in principle, can deliver information about the chromaticity, by looking at the width of the tune lines, or synchro-betatron relative intensities, or by comparing the "Q" vs "1-Q" signals. We consider such analysis of great interest.

b. Tune Tracking: at a later stage, one could envision building a tune tracker, with a response time of a few second, to control the actual tune of the machine.

**Proposal**

1. Hardware for the 21.4 MHz system:
   a. A/D convertsion and FFT. Purchase a 4 channel, 16 bit (24 bit preferred) A/D converter, with at least a 100 Khz sample rate (for each channel). An antialiasing filter is also required. This board will be interfaced to either VME or PCI. Two vendors are suggested :
      i. The ICS-110BL (http://www.ics-ltd.com/info/ProductInfo.cfm?ID=9). This is an 8-channel, max 108 kS, 24 bit.
      ii. The NI PCI-6120 (http://www.ni.com/pdf/products/us/ni6120.pdf) This is a 200kS, 16 bit device, 16 channels.

Depending on the choice VME vs PCI, we will have to purchase either a PC to host the PCI board, or a VME crate equipped with 2401 Power PC VME card to perform the data transfer and execute the FFT fits.

   b. Again, depending on the preferences, either two additional PC, dual processors, 2 GHz , with 512 MGb memory to perform the root fits for all 4 channels, concurrently. Such a processing power is required to achieve the 1Hz rate for un-coalesced beams, and ~0.1 Hz for difficult spectra. If the FFT are performed on a PC board in a VME crate, we have two option to implement the hardware for the tune fitter per-se: either we buy two standalone PC or we purchase additional Power PC VME cards. (or equivalent) Again, this choice belongs to the Instrument and/or Control Dept. It should be noted that Controls/BD prefers SUN system as opposite to "open market" PC running Linux. However, they are considering supporting Linux, for cost saving mostly. Again, we will run on the systems we are given…. We have a preference for Linux.

We refrained from making the choice, VME vs PCI. This currently prevents us to make a firm plan. All in VME will likely to be prohibitively expensive. A likely compromise is to install the item a) in a VME crate and install the tune fitter on cheap commodity PC.

2. Hardware for the 1.7 GHz system. As we plan to keep the VSA which delivers frequency spectra of interest, we only need to purchase one or two PC, again, dual processor for cost savings. The exact number remains to be determined, based on the measured performance of that tune fitter. For instance, we do not know yet for how long coherent signals persist, if long enough, many synchro-betatron lines should be recognizable. If so, such lines can be fitted and a more precise value for the tune could in principle be obtained. At a cost of some additional – and unknown for now - computing resources, of course.

3. Software.
    a. Small DAQ and Control system for the 21.4 MHz digital signal analyzer, (consisting of the A/D converter and FFT programs). Again here, specific solution could either be LabView, or home-build small DAQ software based on free-ware (like the Comedi software at http://www.comedi.org/
    b. Small DAQ and Control system for the 1.7 GHz VSA. Currently, a Vax Console application controls the VSA, sets which bunch is being gated, extract the frequency spectrum and fit upon demand. This application will be phased out and replace by a modern D.A/Control part (running on VxWork, or Unix, somewhere…) and the tune fitter per-se.
    c. Tune Fitter Software. This is evidently homegrown software. It is currently maintained by Paul Lebrun (CEPA/CD) and Denise Finstrom (Controls/BD) under CVS (http://www-bd.fnal.gov/cgi-acc/cvsweb.cgi/misc/c_src/fits/TevTuneMeter/) We plan to extend this software to support the 1.7 GHz system.

## Cost

Although software & methods will be shared for both 21.4 MHz and 1.7 GHz systems, we will cost them independently from each other.

a. 21.4 MHz – Signal Analyzer

| | |
|---|---|
| ICS-110B 8 channel 24-bit digitizer | $5k |
| ICS software drivers | $1k |
| VME crate | $1.7k |
| VME 2401 Power PC card | $2.3k |
| | ------- |
| Total | $10k |

The PCI option is a bit cheaper since we save the cost of the VME crate. However, if we choose to run LabView, a software "Pro" (capable of running remotely and on multiple systems ) is about 4k.

b. Computers to run the fitters . Here, the cost is uncertain by ~ factor two. For instance, we never ran the tune fitter on a 2400 Power PC to benchmark. So we quote here one of the cheapest – hardware wise – option, regardless of the hidden cost of software support. CD may have a better option, we are in good contact with them. Let me simply quote a randomly chosen vendor, Dell, and mentioned that a dual CPU PC, 2 GHz, 512 M. memory server cost 2,800. A better quote from the CCF/CD dept. (thanks to Steven Timm) is lower, about $1800 per system, which includes:

Dual Intel Xeon CPU's 2.66 GHZ/ 533 MHZ Front Side Bus
2 GB of DDR SDRAM
Dual gigabit ethernet ports
20 Gb system disk
120 GB data disk

See http://www-oss.fnal.gov/scs/qualify2003/eval_bench.html for details on various benchmarks and evaluation. We would need three such systems, at a cost of $5400. (Cost of the Rack is not included).

It should be noted that a SUN option in the same VME crate is also doable. It would be easier to establish communication between the fitter and the engines that deliver the frequency spectra. It comes at a high cost: For roughly the same compute power (i.e. UltraSparcIIIi chip, dual, 1.2 GHz, and oodles of memory we don't really need...) at http://www.themis.com/products/hardware/USPIIIi.htm , the price tag is $19,000 (quote from the vendor, no negotiation…)

## Man Power estimate:

We think the 21.4 MHz new D.A. can be assembled with ~ 4 man month of effort. The team should include a D.A. expert from either CEPA/CD or Instrumentation/BD. Likewise, the rewrite of the Vax Console application supporting the 1.7 GHz VSA configuration should also 4 to 6 man months. The fitting package for the 1.7 GHz system could be assembled in less than a month. The clean-up and support of the tune fitter for the 21.4 MHz is on going, and much of it is directly applicable to the 1.7 GHz system.

A reasonable goal would be to deliver these soft instrument ~6 months after delivery of the computer hardware.

As this work is a collaborative effort between Instrumentation/BD, Controls/BD, Tevatron/BD and CEPA/CD, the details are a bit sketchy as we need first to establish proper roles and responsibilities. Evidently, proponents must have a say in choosing the equipment they will support. *Therefore, comments on this draft document are welcome. In fact, we have received comments from Jean Slaughter and Stephen Pordes, which have been included in this draft. Thanks Stephen and Jean.*

## Critical Path

As hinted just above, the plan looks a bit sketchy. So let us think about what needs to be done next to get going:

a. We are discussing with CEPA/CD, BD/Controls, BD/Instrumentation to identify the major tasks and responsibilities. We could agree on splitting the project into two distinct areas: (i) the engines that provided the spectra (ADC/digitizer and FFT, or VSA, with Control and D.A) and (ii) the engines that perform the fits. For cost saving measure, the technology (Bus and I/O peripherals) could and probably be different (VME vs commodity PC based farms.)

b. Meanwhile, we will analyze the existing 1.7 GHz Vax-Console application, and extract the Control requirement from this analysis and other specification, based partly on limitation of a single VSA. (A second VSA system for the 1.7 GHz could probably double the rate at which we can update the tunes for each bunch.) We plan to write a short note, an appendix to this document in fact, specifying this little VSA-Control application.

c. Again, it should be noted that both OAA/CEPA/CD and Instrument/BD have expertise in building such small Control and D.A. engines. Once the responsibilities for each sub-system is clearly defined on both (21.4 MHz and 1.7 GHz D.A. engines), we will make the critical decisions concerning D.A. software and hardware configuration (VME vs PC based ADC cards).

d. If available soon, try again to collect the 4 spectra for the 21.4 MHz on the VME system based on the ICS-110B card. (BD/Instrumentation may have bought a spare).

## Summary

Automated Betatron tune measurements for the Tevatron beams (coalesced and uncoalesced) are essential to proper tuning of the machine and study adverse beam-beam effects. We propose to install tune fitter software for both the 21.4 and 1.7 GHz pick-ups, as they are complementary. In addition, we would like to phase out obsolete D.A. equipment for the 21. 4 MHz system. The total cost is of the order of $25k. Once hardware is in place, automated tunes could appear within 3 months.

**Appendix : Existing sub-systems to be retired:**

The 21.4 MHz based tune fitter system consist of two HP3561a signal analyzers, connected to two distinct GPIB, themselves connected to some e-Net boxes. A dedicated Open Access Client (OAC) reads these devices and writes small files that contain the frequency spectrum to be fitted. It is proposed to retire the HP3561a, and provide a higher band-with between the fitting package and the data source (the digital signal analyzers), by implementing faster data paths (dedicated point to point links, or via file sharing) between the engine that provide the frequency spectra and the computer that performs the fit.

The Vax Console application performing fits of the 1.7 GHz signal will also be retired. (We propose to write a dedicated tune fitter package and a small Control/D.A. system to drive which bunch on which the signal is to be gated and to perform other similar control functions.)

The following computers currently "on-loan" will be returned to their owners (who probably have forgotten of their existence, but that does not matter…) : (i) "bdtev10", formally a desk-top computer for SDA analysts, previously owned by the Technical and Office Computing Support, in CD and (ii) "dpe13", a SUN Tetras computer owned and maintained by Controls/CD