ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ
им. Г.И. Будкера СО РАН

V.A. Lebedev, P.K. Lebedev,
V.V. Parkhomchuk, V.D. Shiltsev

TRANSVERSE VIBRATIONS OF ELECTRON BEAM AND GROUND MOTION MEASUREMENTS AT VEPP-3 STORAGE RING

BUDKERINP 92-39

НОВОСИБИРСК

Transverse Vibration of Electron Beam and Ground Motion Measurements at VEPP-3 Storage Ring

Lebedev V.A., Lebedev P.K., Parkhomchuk V.V., Shiltsev V.D.
Budker Institute of Nuclear Physics,
630090, Novosibirsk, Russia

ABSTRACT

This paper is devoted to measurements of electron beam vibration at VEPP-3 storage ring. We measured simultaneously the beam vertical position by synchrotron radiation monitor, floor and magnetic quadrupole lens vibrations.

The analysis of spectra of power and correlations points on strong connection of mechanical vibrations of lenses and beam movement at frequencies below 40 Hz and on definitive influence of current supply fluctuations in the frequency range above hundred Hz.

These results could be applied for design of various accelerator facilities such as SR sources, B-factories and large future colliders.

АННОТАЦИЯ

В работе приводятся результаты измерений вибрации пучка ВЭПП-3. Вертикальные перемещения "центра тяжести" сгустка определялись по детектору СИ с точностью лучше 1 микрометра. Одновременно измерялись вибрации пола в зале ускорителя и колебания одной из квадрупольных линз. Анализ спектров мощности и корреляций разных сигналов в полосе 0.1 - 1250 Гц выявил прямую связь механических вибраций линз и пола с изменением положения пучка при частотах ниже 40 Гц и определяющее влияние нестабильностей электропитания на пучок в диапазоне от сотни Герц до килоГерца. Новизна полученных результатов в расширенной до более чем 1 кГц полосе частот и корреляционном анализе различных сигналов. Данные измерений могут быть использованы при расчете и проектировании источников СИ, В-фабрик и больших ускорителей будущего.

1. INTRODUCTION

Since the beginning of linear supercolliders design [1] it was realized that there are significant influence of vibrations on their work. The measurements of vibration levels at Protvino region where linear supercollider VLEPP is planned to be build were presented in papers [2,3].

As appears [4] the vibrations must be taking also into account in design and operation of large circular machines with small beam sizes since they lead to emittance growth and orbit distortions.

Measurements of vibrations at small existing machines allow to estimate their influence at "usual accelerator conditions" for future colliders.

In the case of VEPP-3 with revolution frequency $f_0 \approx 4$ MHz the most significant contribution goes from "low" frequency noise fluctuations of transverse position of magnetic elements and currents which produce a closed orbit distortions (COD) in a storage ring point A accordingly to well known formulae :

$$\Delta X_A = \frac{\beta_A^{1/2}}{2\cdot\sin(\pi\nu)} \sum_i \beta_i^{1/2} \theta_i \cos(\phi_i - \phi_A - \pi\nu) \qquad (1)$$

where Σ is the sum over all sources of distortions i, β_A and β_i - values of beta-functions in the point A and i, $\phi_i - \phi_A$ is betatron phase advance between the points and ν is the betatron tune, θ_i - beam angle deviation due to imperfection.

On the other hand for large accelerators like Superconductive SuperCollider (SSC) with $f_0 \approx 3.4$ kHz the region of frequencies about one kHz is very dangerous due to "heating of beam" - growth of transverse emittance [4].

Thus, mesurements of COD at a small ring allow to estimate roughly a damage of "real condition" vibrations for supermachines.

2. EXPERIMENTAL

General scheme of the set up is shown at Fig.1 . The synchrotron radiation beam (SR) from one of VEPP-3 dipoles passes through the vacuum channel approximately 8 meters long and achieves the SR beam position monitor (BPM), placed in a vacuum box outside the hall of VEPP-3 storage ring.

The measured by BPM displacement of SR beam is R times greater than the displacement of the electron beam ΔX_A in the point of radiation due to the angular deviation of the beam :

$$\Delta X_{SR} = \Delta X_A + L\cdot\Delta\Theta_A \; ; \; R = \frac{|\Delta X_{SR}|}{|\Delta X_A|} \approx (1 + L/\beta_A) \qquad (2)$$

For experiments discussed below L=8 m ,β_A=16 m and factor R is not very large R≈1.5.

The BPM is sensitive to photo current appeared after high energy photon conversion on thin aluminum plates. The difference of the currents from two closely spaced plates (horizontal gap about 100 micrometers) is proportional to SR beam vertical displacement from medium plane.

The monitor was calibrated by displacement of BPM as a whole by the usage of precise micro mover . The sensitivity was equal to 40 mV/micrometer at electron current in the VEPP-3 of about 80 mA.

The power density of "white noise" of the BPM electronics was equal to 10^{-4} micrometer**2/Hz in the frequency band 0 - 1800 Hz or 0.5 micrometer . Estimations shows that Schottky noise at similar band gives about 0.02 micrometer.

Seismological equipment which we used consists from the commercial probes of two types : SM-3KV and TAF . The velocimeter SM3-KV type with frequency range from 0.05 Hz to 100 Hz was described in details in our papers [2,3]. Pair of those vertical probes were placed - one on the VEPP-3 quadrupole lens and another one on the concrete floor of accelerator hall .

The sensitivity of three component piezoelectrical accelerometer TAF type was 0.5 mV/m/sec^2 in the range 1.0 - 1300 Hz and has the dynamic range of 100 dB relatively to the acceleration of the gravity. The only TAF was placed on the quadrupole.

Digital part of the set up was based on 10 bit 4 channel CAMAC ADC-101SK which allows to measure four signal simultaneously and record them in 4K ADC memory with a toggle frequency 2500 Hz. After the memory filling all data were directed to IBM PC/AT.

The calculated spectra of all signals and 12 possible spectra of

correlations were avereged for about 150 -200 times and saved in in PC memory too.

Spectrum of correlations of two signals $X(t)$ and $Y(t)$ (or *mutual correlation spectrum*) we used here is defined as :

$$K(\omega) = \frac{< X(\omega)\cdot Y^{*}(\omega)>}{[<|X(w)|^2>\cdot<|Y(\omega)|^2>]^{1/2}} \qquad (3)$$

Here brackets <...> means averaging over the time of measurements, $X(\omega)$ - Fourier image of $X(t)$. Coherence mentioned below is equal to a module of complex value of $K(\omega)$.

For long period measurements we used toggle rate 500 Hz and lower. In this casethe data were written to IBM PC/AT memory directly and analyzed later.

3. RESULTS

The most of results presented below were obtained during two days of measurements :February,28 and March, 1 , 1992.

Long term drifts of the beam position which as appears to be rather significant are presented in Fig.2 together with the calibration of BMP. One can see that 20 min beam vertical shift is about 100 μm. For 40 sec measurements the r.m.s. displacement was about 5 μm.

Fig. 3 shows power spectra of SR beam motion and of the ground and VEPP-3 quadrupole vibrations in the frequency range from ≈0.2 Hz up to 1250 Hz measured during these two days.

Fig. 4 presents r.m.s. values of these vibrations in frequency band [f-1250] Hz as a function of frequency f ,i.e.

$$\delta X = [\int_f^{1250} \mathrm{Spectrum}(f)\cdot df\,]^{1/2} \qquad (4).$$

There are several remarkable features of these pictures :

1. the difference in values of ground and quad vibrations as it seems is due to *quads' support* (ten meter iron beam) which amplifies ground oscillations ;

2. the decrease of SR beam spectrum ($\approx f^{-0.5}$) is significantly slower than the ground and quad's one ($\approx f^{-4}$) ;

3. the set of power supply frequency harmonics is clearly seen in all spectra;

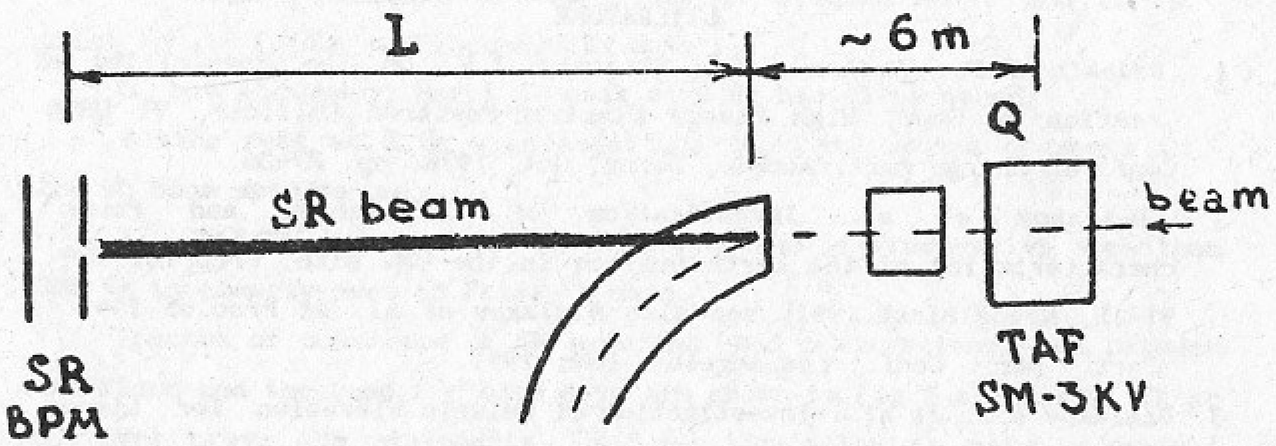

Fig. 1. Layout of the experiment.

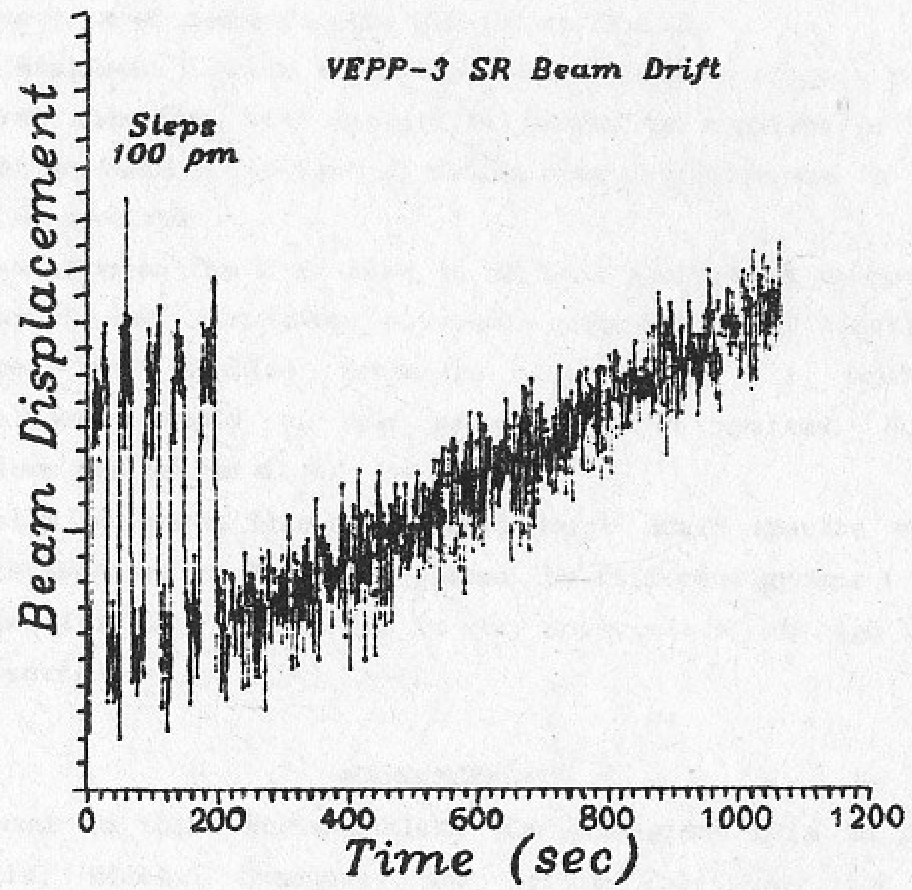

Fig. 2. Slow VEPP-3 beam displacement.

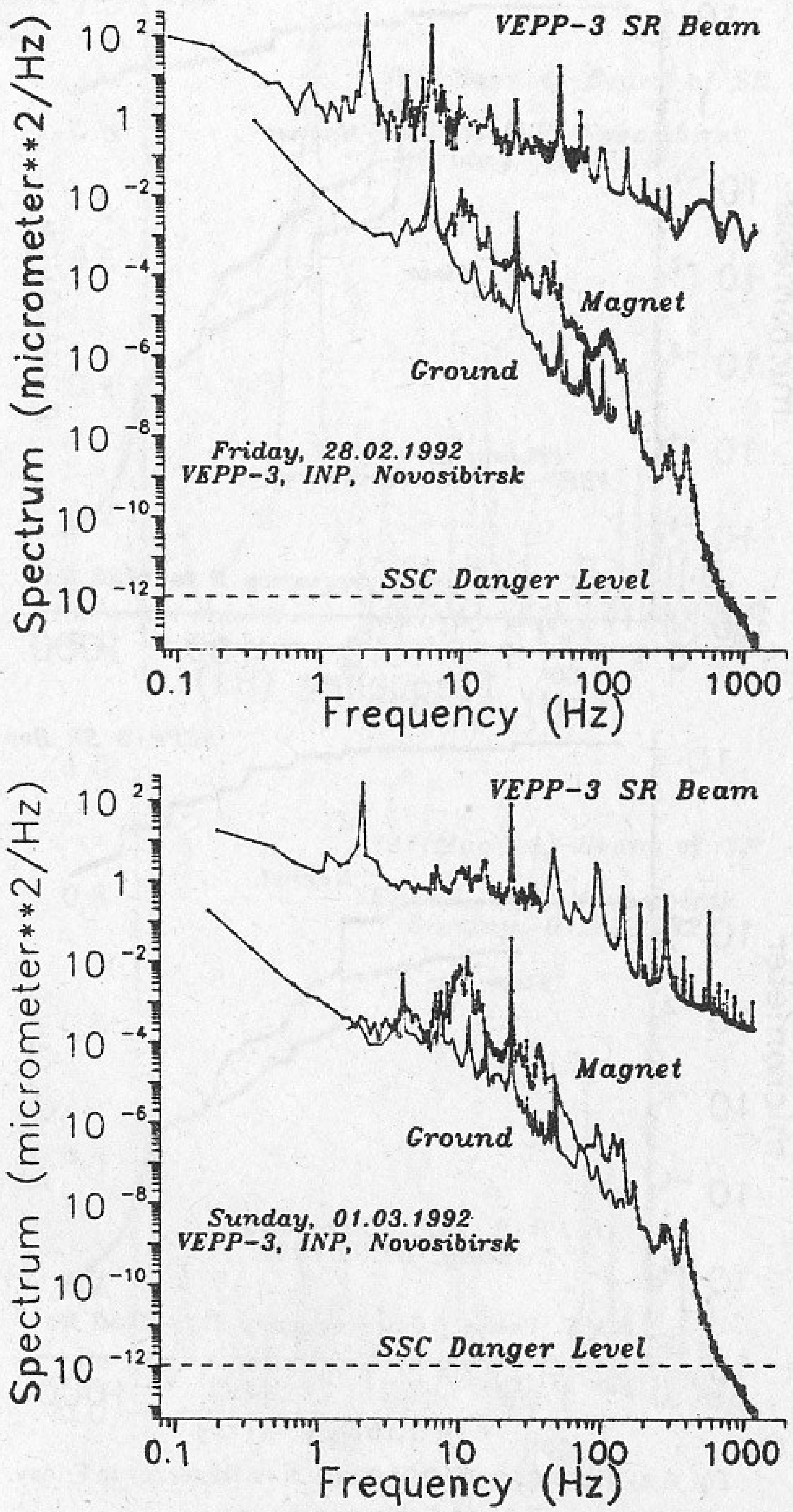

Fig. 3. a) The vibration spectra measured in Friday, February, 28;
b) the vibration spectra measured in Sunday, March, 1.

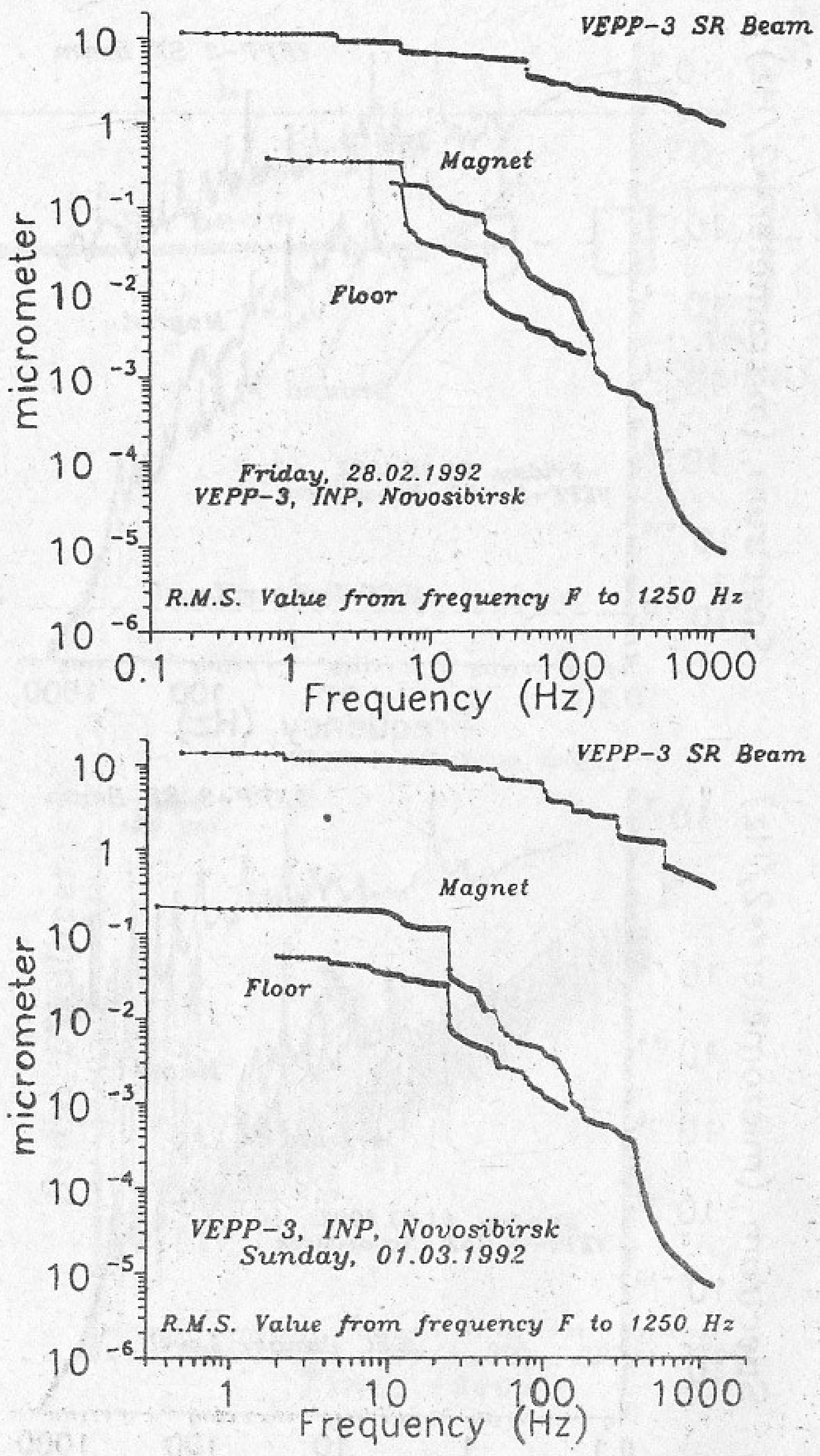

Fig. 4. a) The displacement of the beam vs. frequency in Friday.
For definition see the text.
b) The same as in Fig. 4a but measured in Sunday.

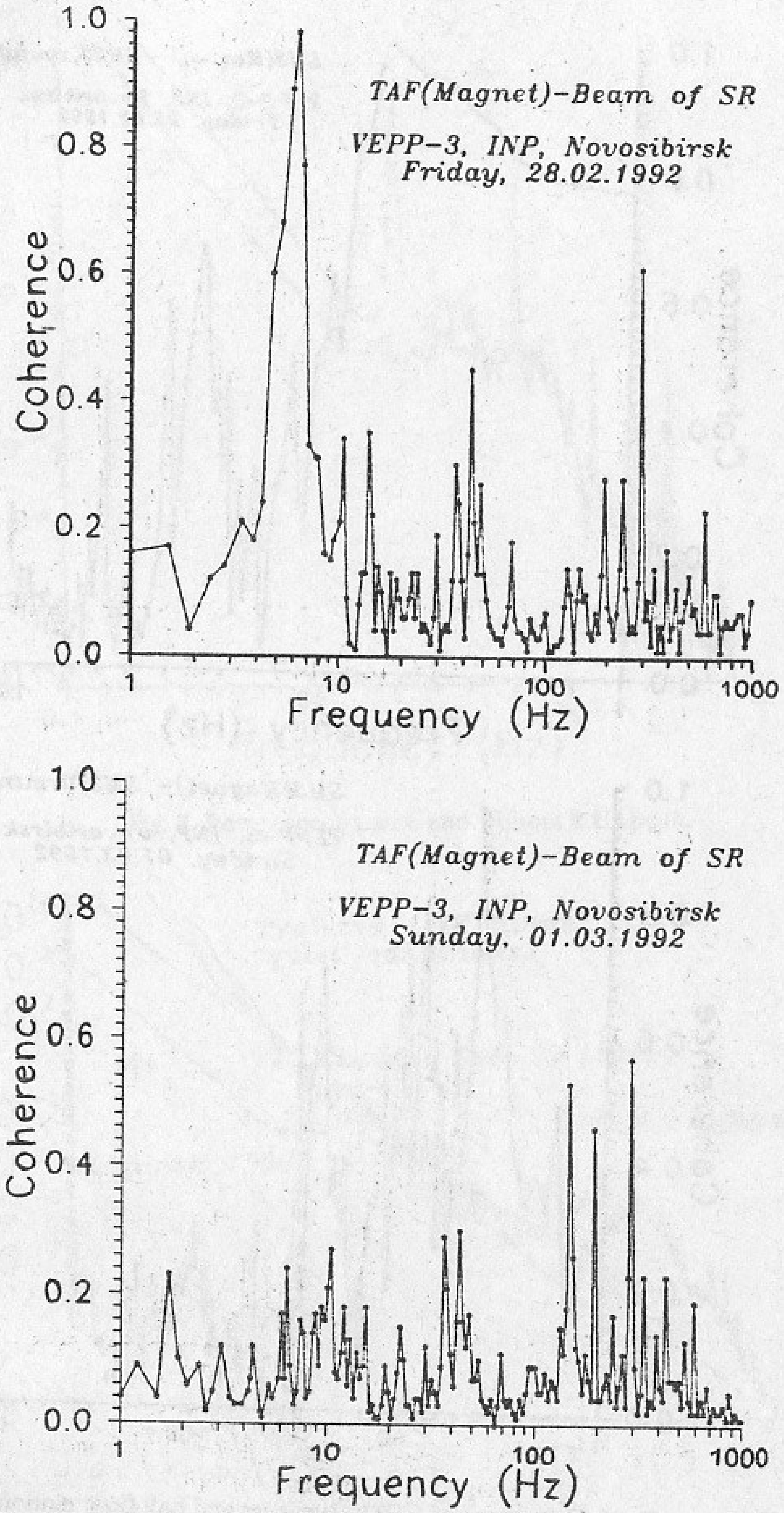

Fig. 5. Coherence of VEPP-3 magnet and SR beam motion in Friday (a) and in Sunday (b).

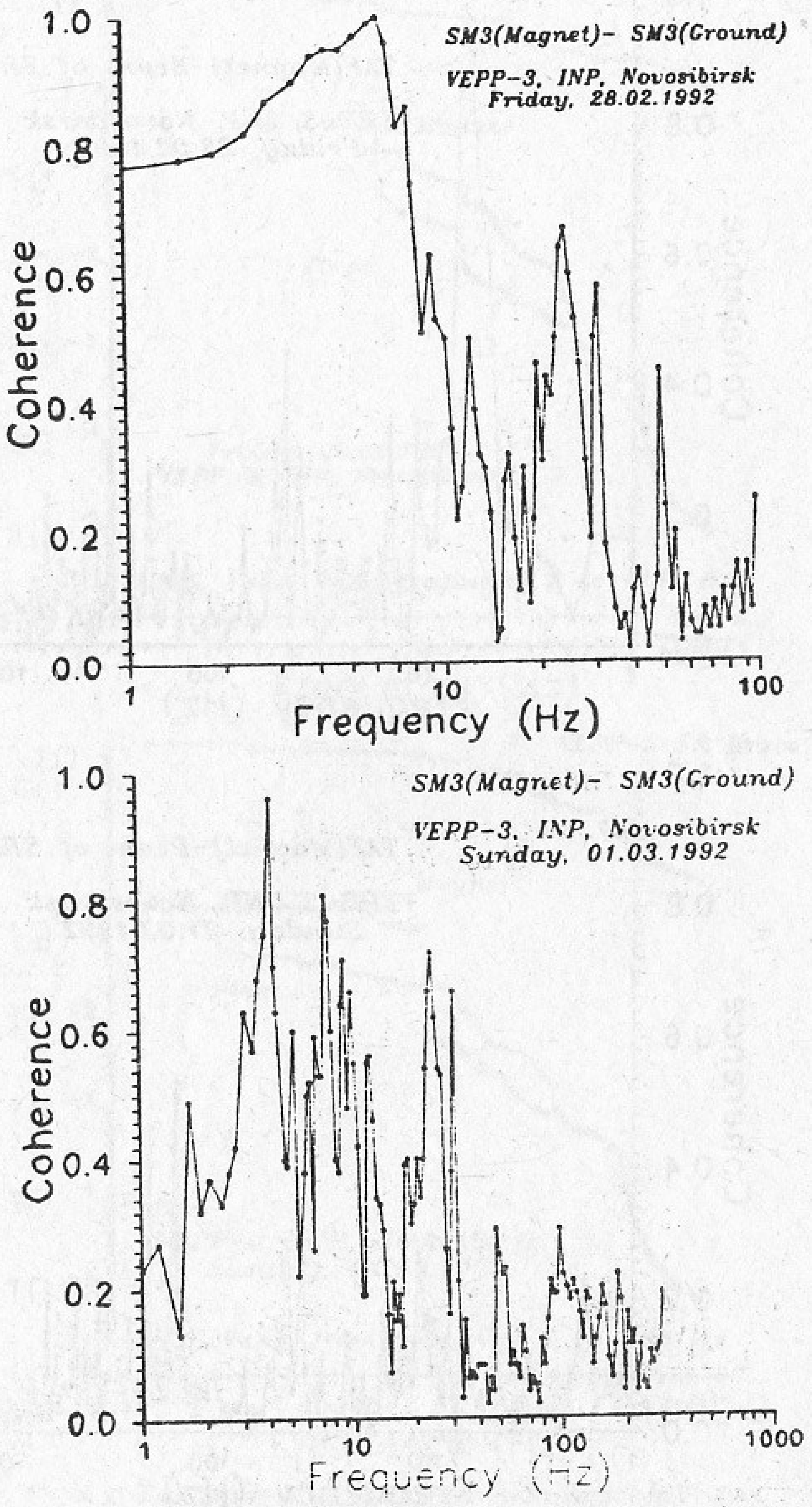

Fig. 6. Coherence of VEPP-3 magnet and hall floor motion in Friday (a) and in Sunday (b).

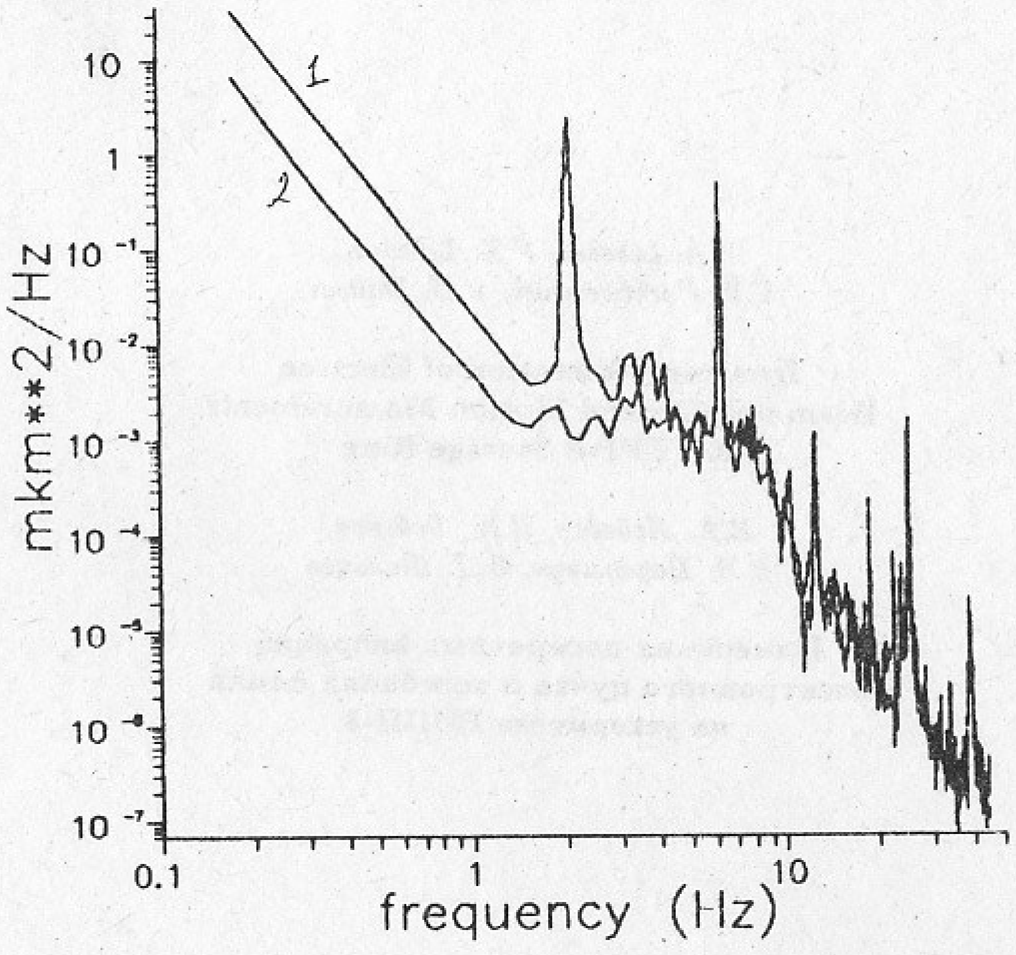

Fig. 7. Power spectra with and without 2 Hz peak.

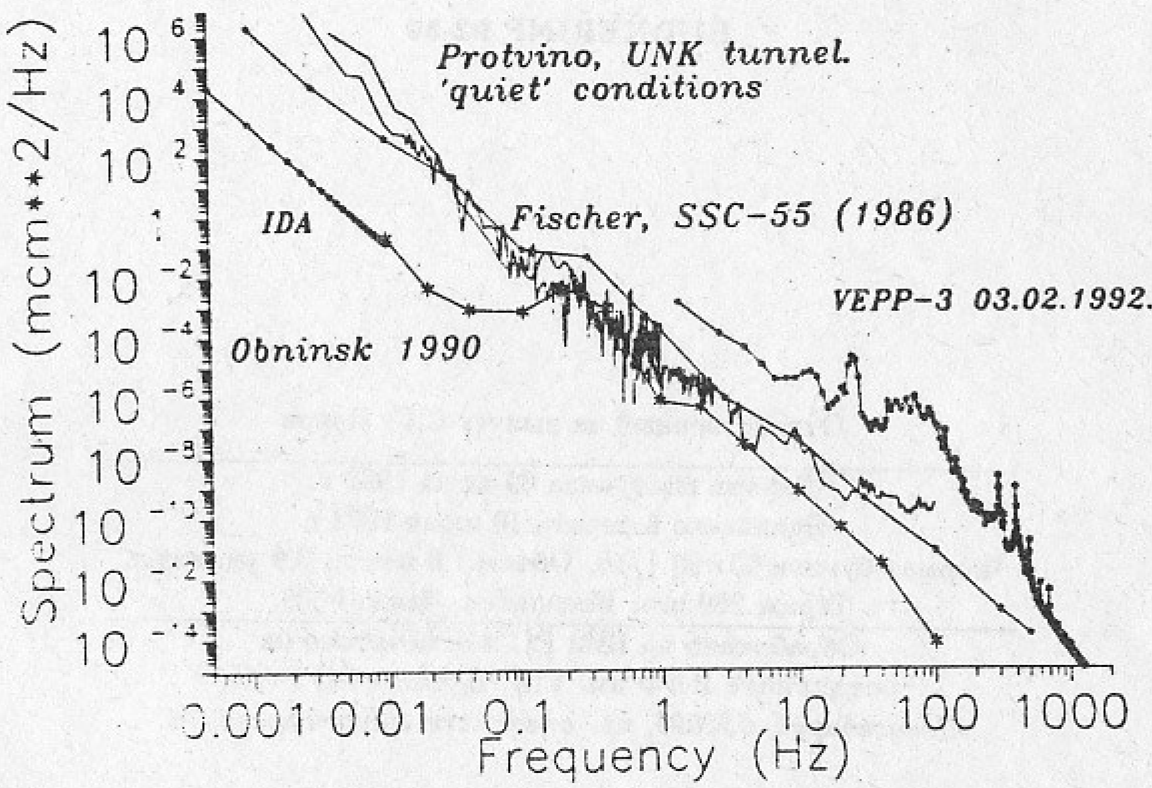

Fig. 8. Comparison of power spectra measured in various places in the world with VEPP-3 hall spectrum.

V.A. Lebedev, P.K. Lebedev,
V.V. Parkhomchuk, V.D. Shiltsev

Transverse Vibration of Electron Beam and Ground Motion Measurements at VEPP-3 Storage Ring

В.А. Лебедев, П.К. Лебедев,
В.В. Пархомчук, В.Д. Шильцев

Измерения поперечных вибраций электронного пучка и колебаний земли на ускорителе ВЭПП-3

BUDKERINP 92-39

Ответственный за выпуск С.Г. Попов

Работа поступила 09 июня 1992 г.
Подписано в печать 10 июня 1992 г.
Формат бумаги 60×90 1/16. Объем 1,0 печ.л., 0,9 уч.-изд.л.
Тираж 200 экз. Бесплатно. Заказ N 39.

Обработано на IBM PC и отпечатано на ротапринте ИЯФ им. Г.И. Будкера СО РАН,
Новосибирск, 630090, пр. академика Лаврентьева, 11.