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Compensation of the 50 Hz ripple on the extracted beam

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During slow $\frac{1}{3}$ integer extraction with r.f. off at 200 GeV/c, the only noticeable modulation on the extracted beam is 50 Hz. This can be seen in Fig.1a, which is a photograph of the spill detected by the BSI-610316 and also in Fig. 2a, which shows the spectrum of the spill analyzed with a Solartron spectrum analyzer. Simultaneous observations of the spill time structure and of the 50 Hz modulation of the mains showed that the phase relationship between the maxima of the two signals is constant from pulse to pulse. This suggested that it should be possible to compensate for the ripple by superposing, to the normal pulse of the main F-quadrupole power supply, a small signal at 50 Hz, synchronous with the mains, and with a phase and amplitude to be determined experimentally. This was done, and, after rather critical adjustments of the amplitude and of the phase, we reached an optimum where the ripple modulation was nearly completely compensated. Fig. 1b shows a photograph of the spill after compensation; the spike in the spill comes from a somewhat unstable situation, but it is not relevant to the present experiment. The spectrum analysis with 50 Hz compensation in Fig. 2b shows that the amplitude of the 50 Hz modulation had decreased by a factor of 10 (20 db) compared to the no compensation case. The amplitude of the compensation, relative to the F-quadrupole strength at 200 GeV/c, is 2×10^{-6} peak to peak, i.e. a maximum Q modulation of $\pm 2.5 \times 10^{-5}$.

The spectrum analyses were done on the BSI signal in BA6. Each spectrum was averaged over 16 samples, to reduce background. Fig. 3 shows the spectrum with r.f. on at 710 kV, without servo spill and after 50 Hz compensation. The signal shows that no new significant frequencies appear, compared to the r.f. off case (Fig. 2b); the 50 and 100 Hz modulations are small. As the r.f. voltage is increased the spectrum becomes richer in low-frequency harmonics, but the amplitudes of the harmonics remains small above 10 Hz. In the r.f. on case, the spill became shorter ($\sim$200 msec), so that frequencies below $\sim$ 15 Hz are influenced by the spill length.

Conclusion: After 50 Hz compensation, the amplitude of the ripple modulation for frequencies higher than 10 Hz is small even with r.f. on. It should therefore be possible in the future to obtain a good spill with a servo system of limited bandwidth. Given the small amplitude of the 50 Hz modulation (2×10^{-6}), the effectiveness of the compensation should be checked as a function of time, over periods of several hours.

We took advantage of having the experimental apparatus set up for the experiment we have just described, to observe the response of the extracted beam to a sinusoidal variation of the betatron wave number. This function is important for the design of the servo-system. We added a modulation to the main F-quadrupole supply and observed the response of the spill as a function of the amplitude and frequency of the modulation. The results are difficult to interpret because of pulse-to-pulse fluctuations of the spill time structure and of the inherent inaccuracy of the method. The measurements indicate that the threshold for 100% modulation of the spill is of the order of 2×10^{-5} peak-to-peak, normalized to the normal F-quadrupole strength, for frequencies up to 100 Hz. We propose repeating the experiment, using a different technique, in the near future.

Reported by: M. Cornacchia

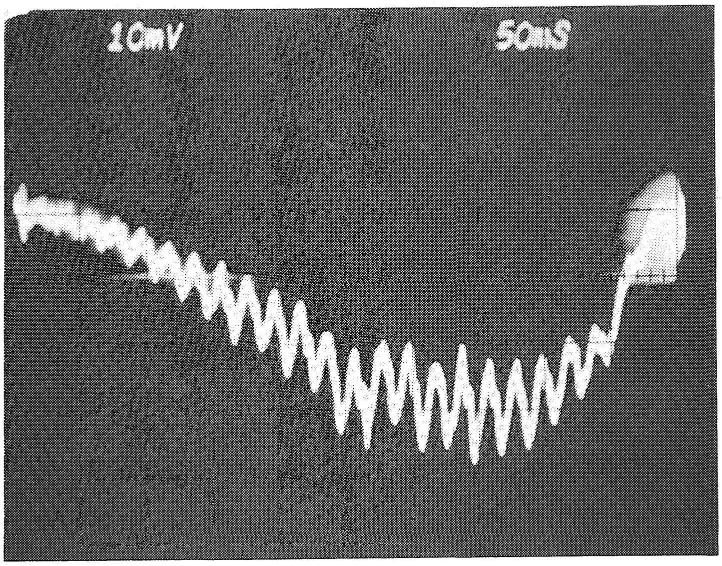

Fig. 1a - Spill without 50 Hz compensation

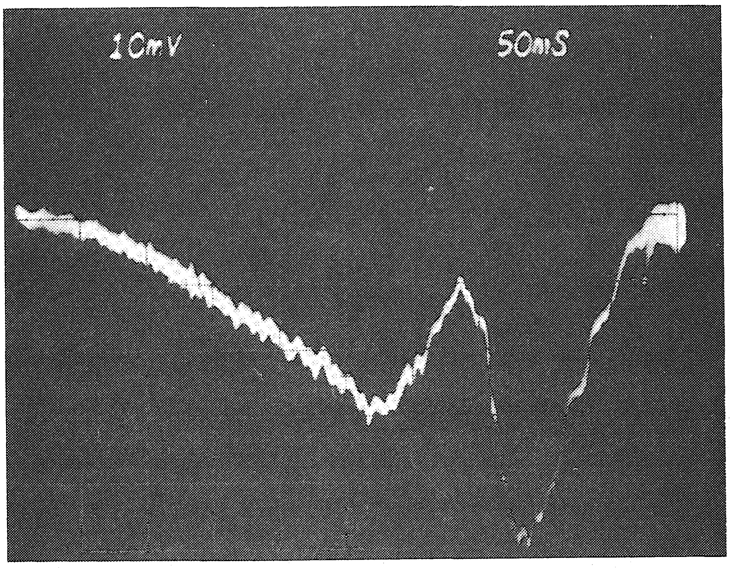

Fig. 1b - Spill with 50 Hz compensation

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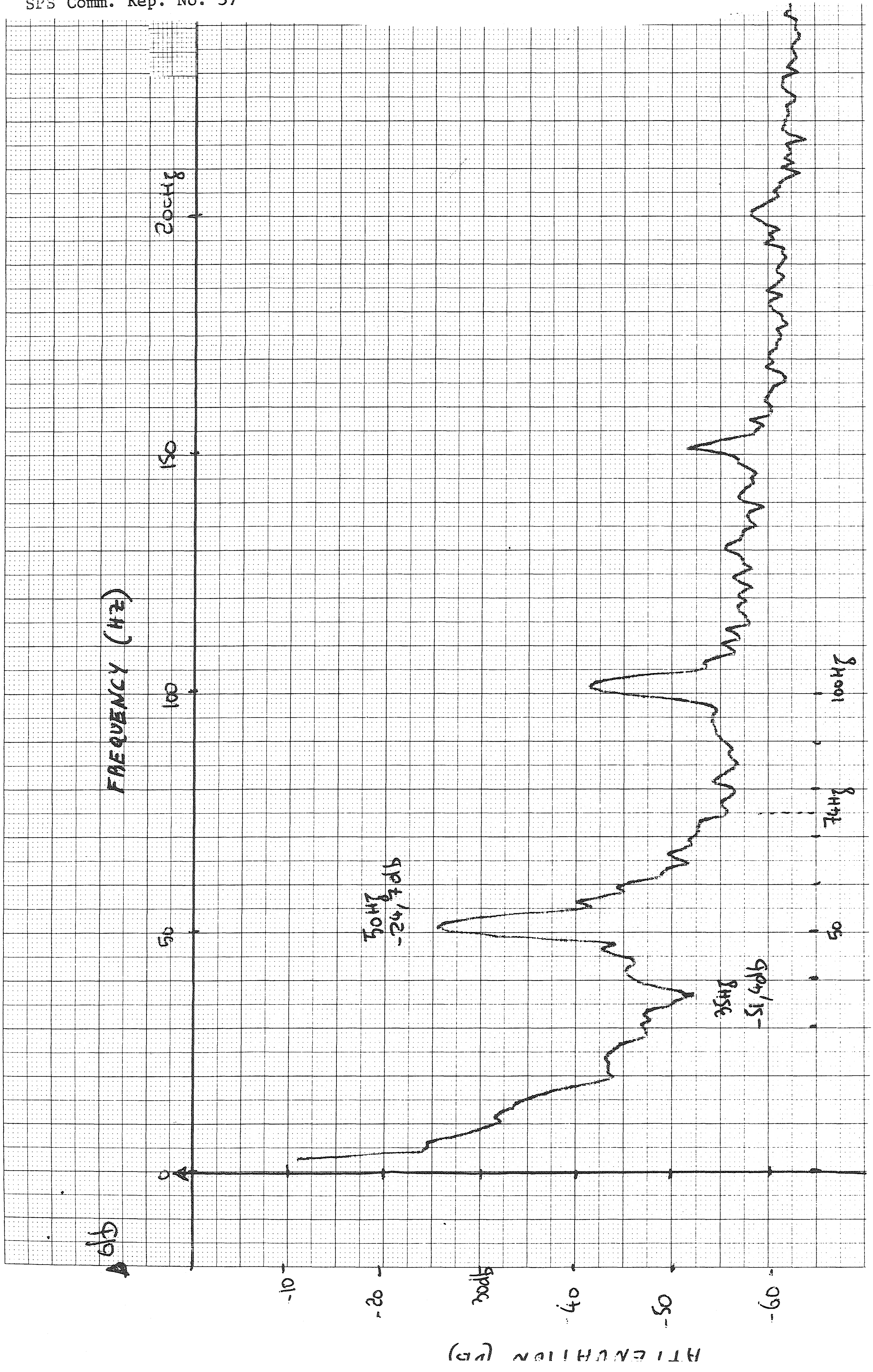

Fig. 2a - Spectrum analysis of the spill without 50 Hz compensation

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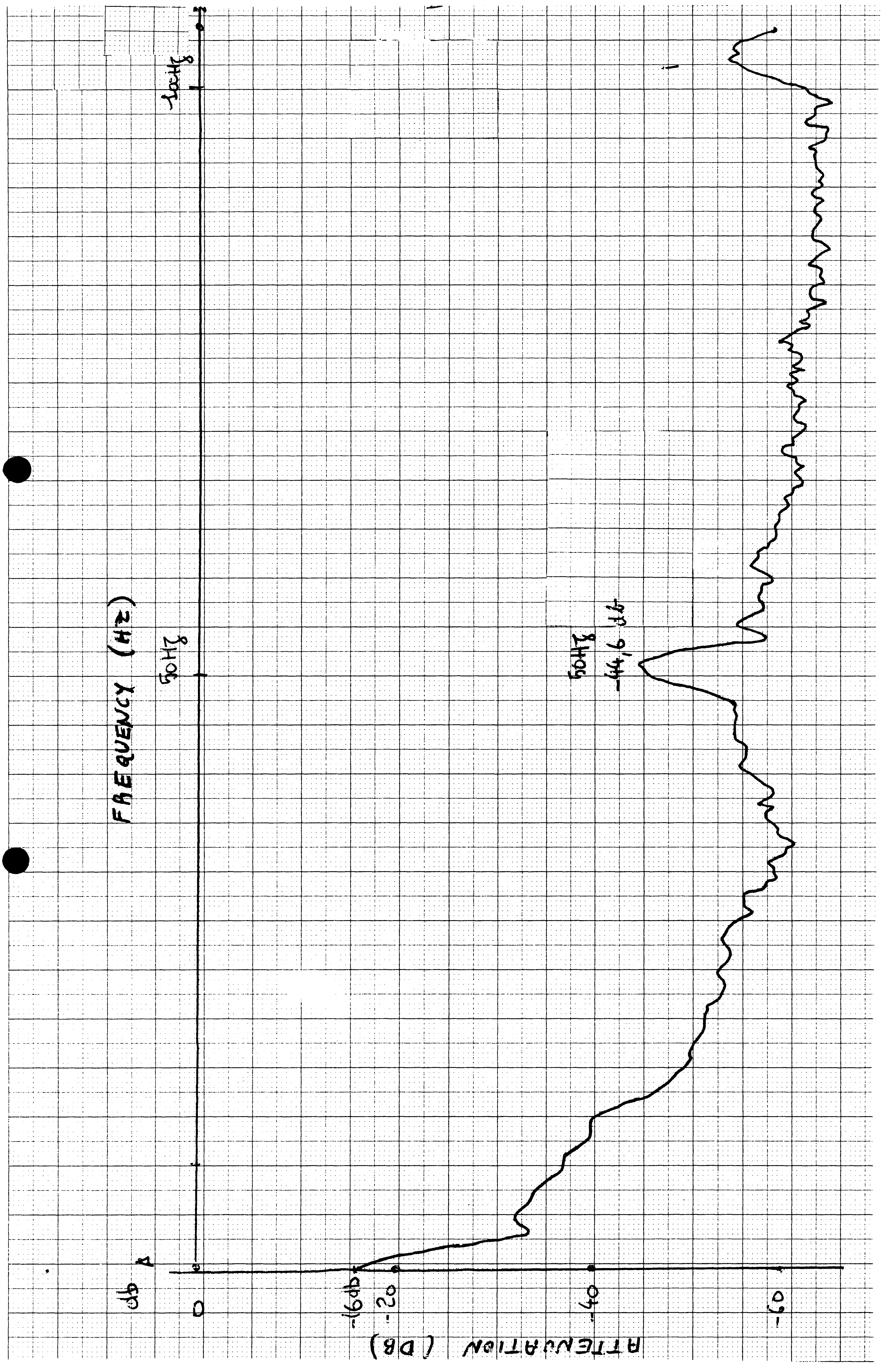

Fig. 2b - Spectrum analysis of the spill with 50 Hz compensation

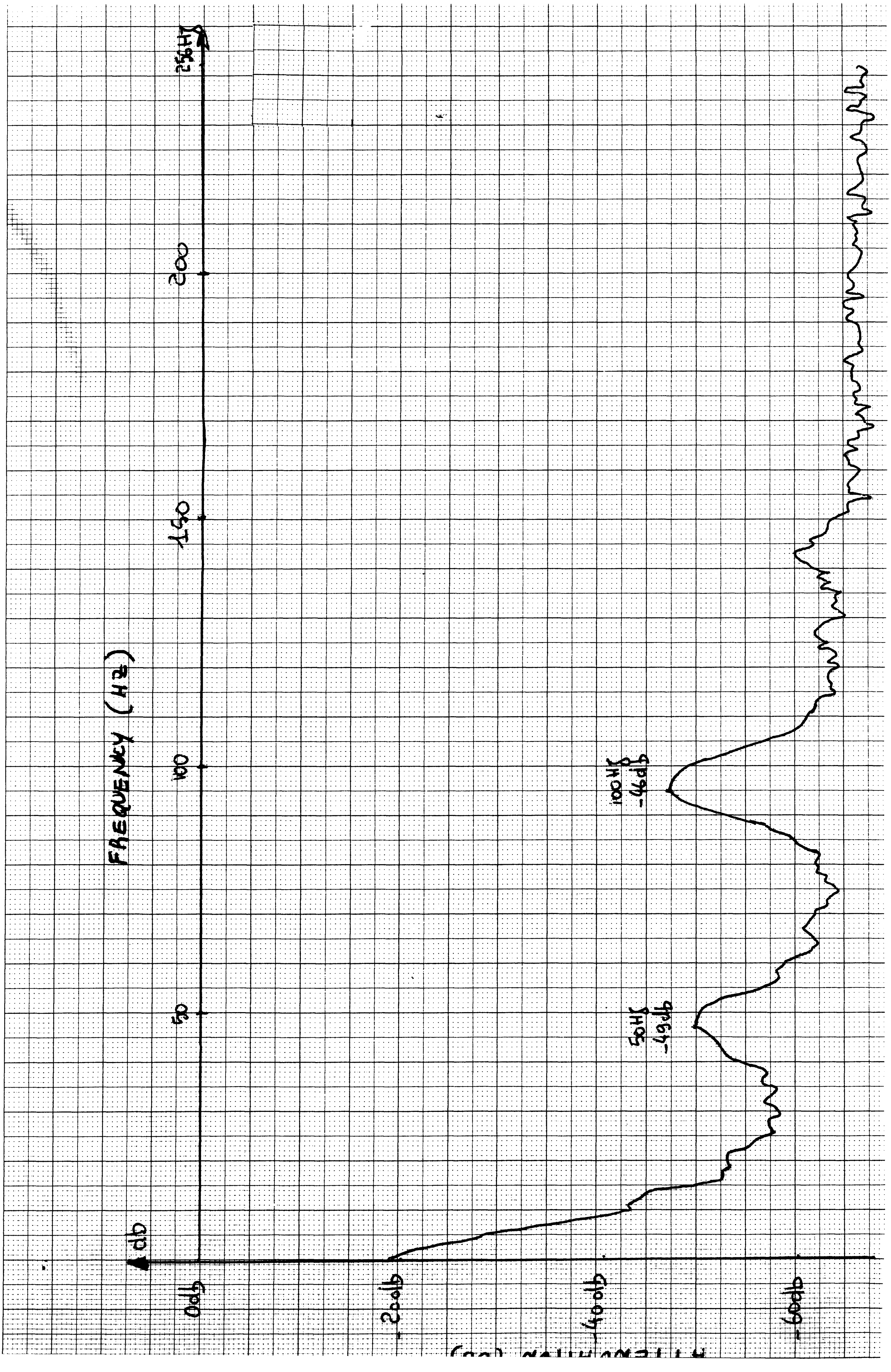

Fig. 3 - Spectrum analysis of the spill with r.f. on (710 kV), after 50 Hz compensation