Addendum to the Beam Pipe Heating Calculation

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In the calculation of power deposited in the beam pipe by rf components of the beam, the argument is made that for reasonable gaps between injected booster batches, the fundamental rf frequency component and its integral harmonics account for about 96% of the total heating. If the booster batches are not all of equal intensity and if there are other variations in the bunch charges, then a greater fraction of the heating may arise from harmonics of the 47.7 KHz rotation frequency.

An estimate of the fraction of beam pipe heating which results from rotational harmonics can be made by examination of the spectrum of a normally full main ring. The spectra shown in the accompanying figure were taken with 13 booster batches in the main ring at 100 GeV. The top picture covers a frequency range from 0 to 470 MHz. The fundamental rf component near 50 MHz and its harmonics are the salient spectral lines in the picture. (The sixth harmonic is nearly zero because the bunches are not truly Gaussian in shape, and there is a $\frac{\text{Sin } X}{X}$ term in the Fourier expansion of the bunch shape.) The vertical scale in the picture is 10 db per division so the spectral amplitudes are directly related to power dissipation. It is clear that the regions between the rf harmonics are rich in rotational harmonics at a reduced level.

In the second picture, horizontal scale is 500 KHz per division centered on 50 MHz. The 47.7 KHz rotational harmonics are clearly visible, and it is evident that every 13th line is accentuated about 10 db above its neighbors. These lines are the result of the 13 booster batches in the main ring and there are 84 such lines in each 53 MHz

interval. The spectral density between rf harmonics consists of two bands, the larger containing 84 lines and, almost exactly 10 db lower, a more dense band, containing approximately 1000 lines.

The third picture spans a frequency range of plus and minus 50 MHz centered on 50 MHz. In this picture one can see that the larger of the intermediate bands varies from about 30 db below the rf line near 50 MHz to a minimum of about 40 db down, half-way between the lines. The lower band follows the same contour, 10 db below. If the higher of the bands has an average decrement of 36 db then the average power per line is a factor of 5×10^{-3} (0.5%) below the rf line. Since there are 84 such lines the total power in this band appears to be about 4.2% of the rf frequency power. In this same manner the remaining lines represent an average power per line of 0.05% of the rf line, and 1000 such lines represent the power of 5%. It is reasonable to conclude from these data that harmonics of the rotation frequency other than the integral harmonics of the rf frequency may contribute between 9 and 10% as much power to the beam pipe heating as do the rf harmonics. Considering the uneven character of the injected beam, this conclusion does not in any way disagree with the above calculation.

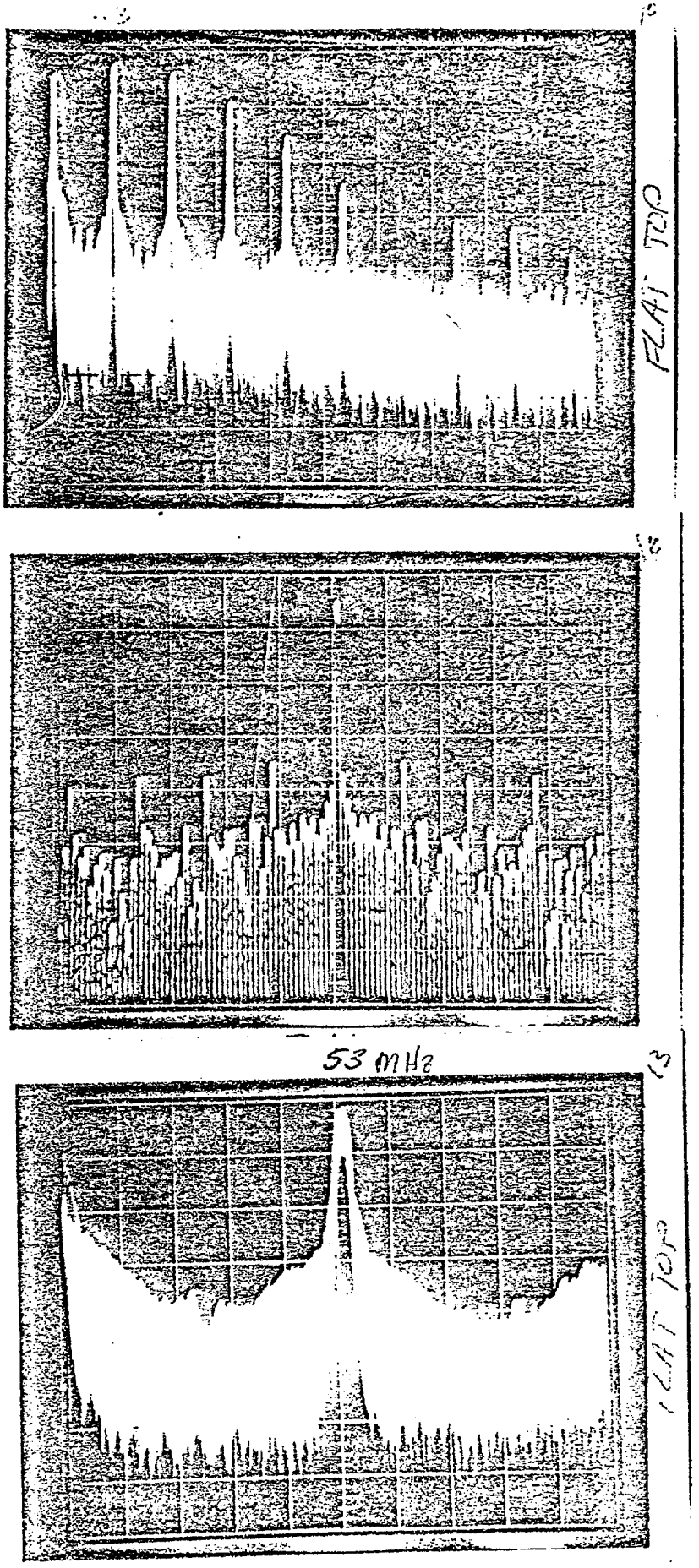

Figure Beam spectra taken at 100 GeV with a normally filled main ring. a) 50 MHz per division and 10 db per division; b) 50 KHz per division; c) 10 MHz per division.