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Growth Rate of Longitudinal Instability on 1.77 GeV (2.71 GeV Total) Flattop

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Subject: Growth Rate of Longitudinal Instability on 1.77 GeV (2.71 GeV Total) Flat Top

Observations & Results

The purpose of this study was to measure the growth rate of the longitudinal coupled bunch instability that occurs at f_{rf} = 4.182 MHz as a function of the bunch length. Previous studies (#244 and #251) had given a growth rate of 24 sec^{-1} at 8 x 10^{12} with a bunch length of 70 μsec. By using the chopper, it was possible to obtain bunches of ≈ 46 μsec duration on a 1.77 GeV flat top where f_{rf} = 4.182 with intensities of at least 1.6 x 10^{12}. Some difficulties with transverse instabilities were encountered during the set up but these were overcome by changing the tune.

In addition to measuring the growth rate, an attempt was made to measure the spectrum of the oscillating part of the charge distribution. Two spectrum analyzers were employed; one tuned to the 11th harmonic of the rotation frequency (348 kc) to monitor the amplitude of the instability growth and the other tuned to any other line in the spectrum [f_0 (n + k • 12) + mf_s]. Initially, the bandwidth of the analyzers was set to 10 kc which meant that any signal at (n + 12k)f_0 due to unequal bunch populations would be seen along with the signal separated by ± f_s ≈ 1.65 kc due to the instability. At first, there was appreciable unequal bunch signal so it was decided to reduce the bandwidth to 1 kc (in the fixed tune mode) so as to separate the two signals. Since previous measurements (not with a spectrum analyzer) had identified the mode as n = 1, one of the analyzers was tuned to (11 f_0 - f_s) with no result. However, when it was tuned to 11 f_0 + f_s, the growth of the coherent line was observed. Some time was devoted to check and recheck this result but there was no doubt that the mode was a n = 11 (or n = -1) mode but not the n = 1 mode as defined by Sacherer. The previous identification using a mountain range display (#249) was in error by a factor of -1 i.e., since the phase shift from bunch to bunch was -30°, it should have been called either n = -1 or n = 11.

Figure 1 is a plot of the line at ($11\ f_0 + f_s$) which gives a growth rate of 48 sec^{-1} at 1.6×10^{12} with a bunch length of ≈ 46 μsec. There was not enough time remaining to measure the perturbed charge spectrum since this would have required individual fine tuning around each line. Instead, the intensity was lowered to the threshold of the instability, i.e., to ≈ 10^{12} and the spectrum of the unperturbed charged distribution was obtained (Fig. 2). No attempt was made to set up to measure the growth rate at a longer bunch length due to time limitations.

Conclusions

From the measurements of the growth rate for two different bunch lengths (ratio of 1.52:1), it is possible to estimate the frequency of the resonator causing the instability. Also, from the measurement of the threshold intensity and the unperturbed bunch spectrum, an estimate of the space charge Z/n for low frequencies can be made. The details of these calculations will be presented in an AGS Tech Note. We obtain a Z/n ≈ 158 Ω assuming a longitudinal phase space distribution ~ $(1 - r^2)^{3/2}$ which has a spectrum similar to that shown in Fig. 2. For the resonator frequency, we obtain a value of ≈ 15.6 MHz. However, this assumes that the observed growth rates are due solely to a single resonance. We note that since the mode number is n = 11, the 40 accelerating gap impedances could contribute since they will be detuned above $12\ f_0$ by beam loading. This effect will be greatest for the long bunch 8×10^{12} intensity case since the amount of detuning at 1.6×10^{12} will be much smaller. In fact, beam induced voltage at ($11\ f_0 + f_s$) and ($13\ f_0 - f_s$) was observed for the latter case where equal amplitude are expected. At higher currents, the signal at the ($13\ f_0 - f_s$) line should be greater and hence the net effect of 40 gaps could account for some fraction of the observed growth rate. Any correction for this effect would increase the calculated resonator frequency.

Finally, we must reexamine the results of Study #251 since we have an n = 11 not a n = 1 mode. Assuming again a fixed resonator frequency, the next mode that would be excited as the energy is raised would be the n = 0, m = 1 mode. However, this would be damped by the accelerating cavities and the low level rf control system. The n = 0, m = 2 mode would also be influenced by the main cavity impedance as the upper sideband would see more impedance than the lower. Since the unknown resonator apparently has a much narrower bandwidth, it could excite this mode at some value of f_{rf}. In fact, a very strong n = 0, m = 2 quadrupole mode was observed at 4.2658 MHz on 4/12/89 but at the time, this was attributed to the rf system itself and the bunch damper shape was used to suppress it. If, however, we assume that this was due to a resonance at 4 f_{rf} = 17.06 MHz, then we note that for the initial n = 11, m = 1 mode at 4.182 MHz one has 4 x 4.182 + 4.182/12 = 17.07 MHz. Thus an $f_{res} \approx 17$ MHz would be consistent with the above bunch length estimate for f_{res}. We note, however, that one should have observed an n = 10, m = 1 instability at f_{rf} = 4.0944 MHz whereas the 4/12/89 measurements went down as low as 4.0 MHz without finding this mode. In view of these results, a repeat of the energy scan study should be considered.

1.6×10^{12} 45.4 MeV Bunch [illegible] 1180 = 4.8360

FIGURE 1

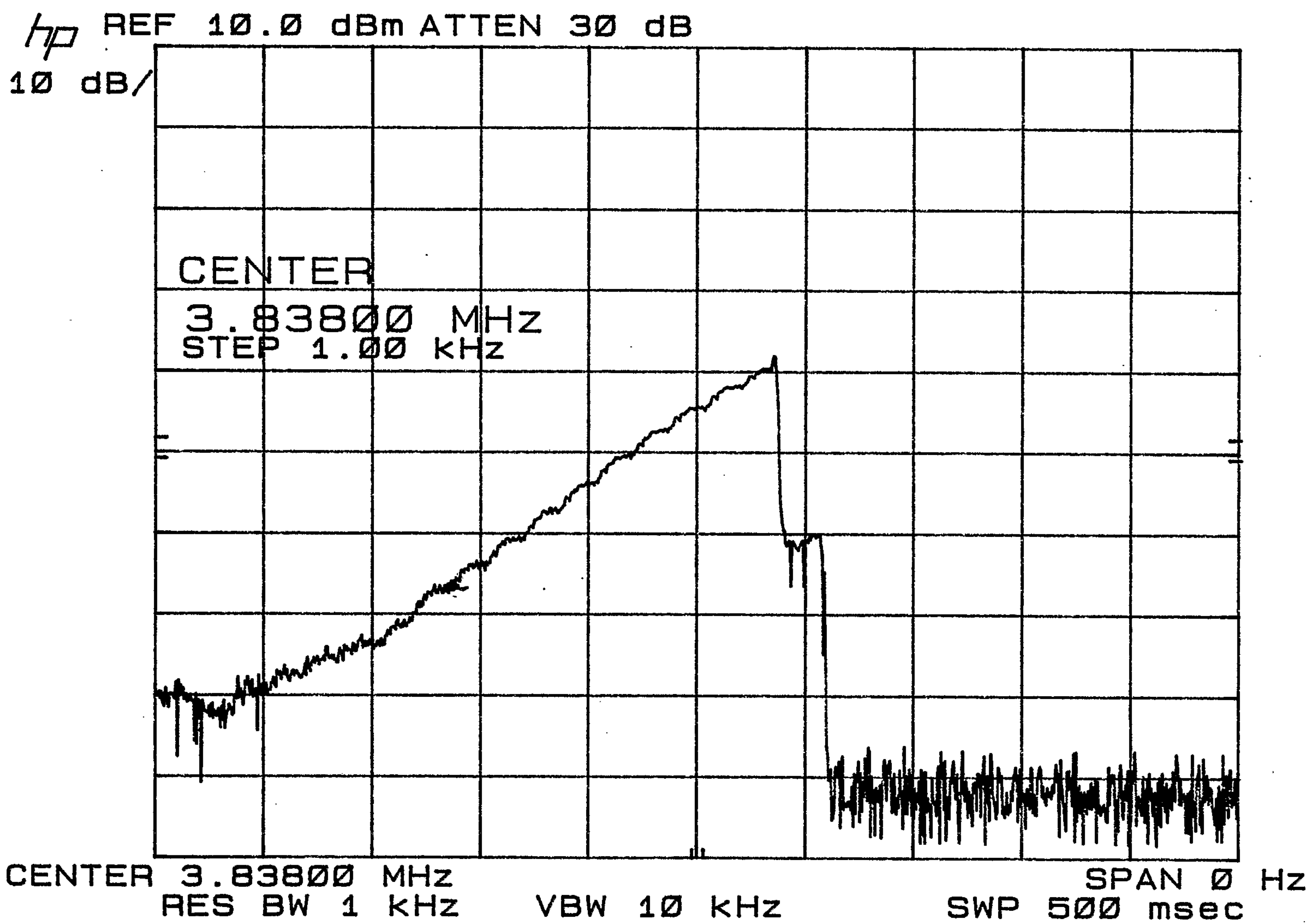
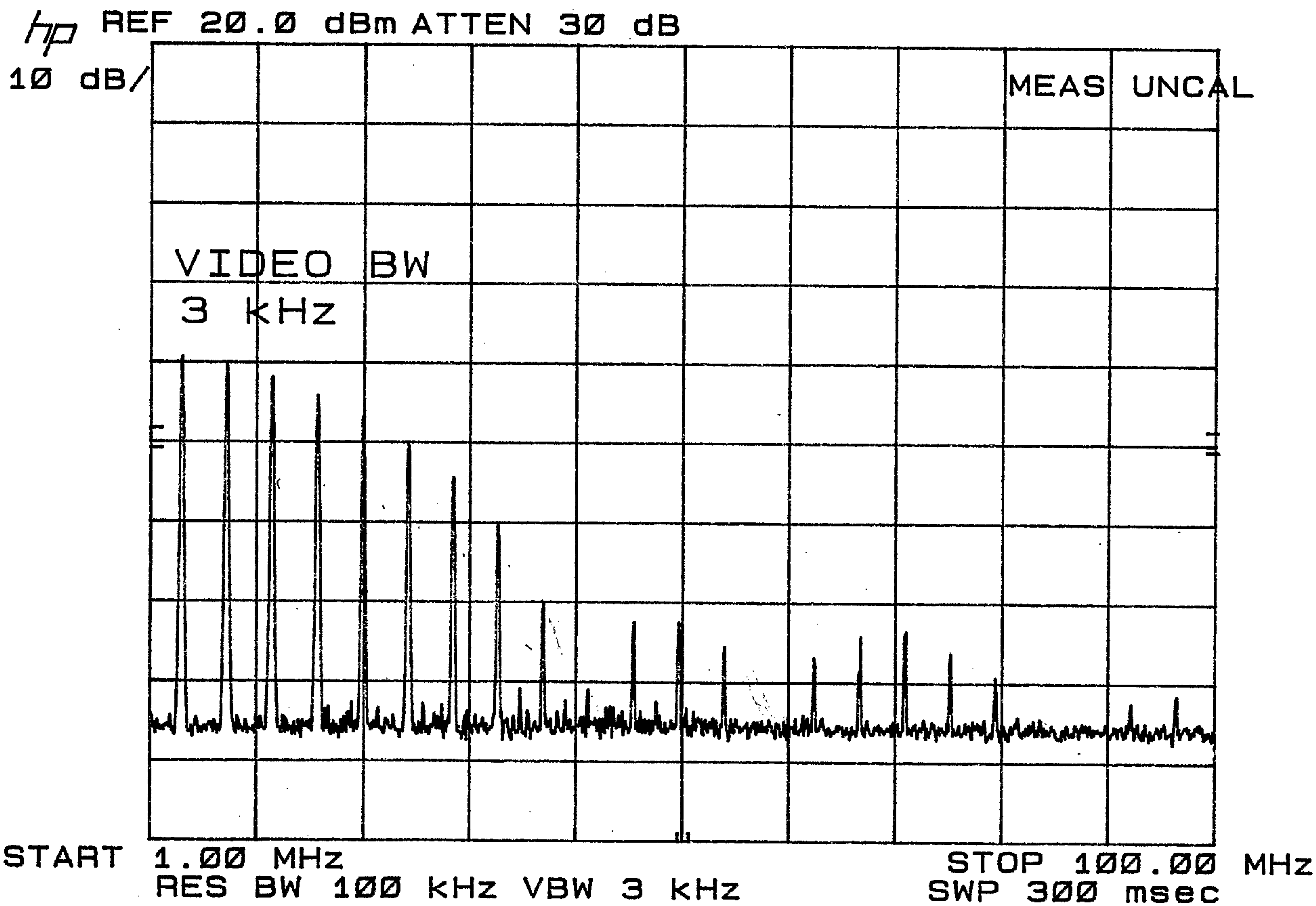


FIGURE 2


REF 20.0 dBm ATTEN 30 dB
10 dB/
MEAS UNCAL
VIDEO BW
3 kHz
START 1.00 MHz
RES BW 100 kHz VBW 3 kHz
STOP 100.00 MHz
SWP 300 msec