B3 (LLRF & HPRF): Homework Problems

Q1: The rf systems (1300 MHz) of the main linacs of the ILC must provide rf power for 7280 cavities. Each rf station at the ILC consists of 1 klystron driving 26 cavities. With a linac energy gain of 245 GeV, and a beam current of 9 mA calculate:

a) the average gradient of the cavities (cavity length 1.038 m).
b) the rf klystron power required for each rf station if the complete power is transferred to the beam
c) The loaded Q required to achieve the matched condition in (b).
   Note 1: matched conditions are achieved when the beam induced voltage is equal to the operating voltage.
   Note 2: It is assumed that the Lorentz force detuning is compensated with the piezo tuners.

Q2: The 10 MW multibeam klystron is replaced by a single beam klystron with an efficiency of 65%.

a) What is the perveance of the klystron and what the operating voltage ?

Q3: The microphonics noise level is 10 Hz rms at a loaded Q of 3e7. The linac is operated with single bunches with a bunch charge of 8 nC (i.e. practically no beam loading).

a) What feedback gain is needed to achieve a field stability of 0.1 deg. ?

Q4: An rf controller for 1300 MHz employs a digital field detection scheme with an IF frequency of 50 MHz which is sampled at 75 MHz. The ADC clock at 75 MHz has a timing jitter of 5 ps (rms).

a) What is the noise on a single cavity phase measurement if the clock jitter is the dominating noise source ?
b) What clock jitter is required if the phase must be measured with an accuracy of 0.1 deg. for a single measurement and when averaging over 100 measurements ?
c) how does the results change if one takes into account the ADC quantization resolution of 14-bit (assuming a peak input voltage of 50% of the full range) ?

Q5: How does the latency in the feedback loop effect performance ? Estimate the latency in the rf control loop for ILC ?. Take into account cables, waveguides, klystrons, data conversion/processing etc. .

Q6: Describe the differences between correlated and uncorrelated field errors in the main linac with 7280 cavities ?

Q7: The cavities in the bunch compressor are operated 20 degrees off crest at a gradient of 31.5 MV/m.

a) What is the energy gain of an rf station with 26 cavities ?
b) What is the necessary klystron power for (i) a tuned ($\Delta\omega$=0 Hz) cavity and (ii) for cavities at optimum detuning angle ?

Q8: The local reference distribution uses a coaxial cable with a temperature coefficient of 1 ppm/deg.C.

a) What is the phase change over 100m cable length for a 1 deg. temperature change at the frequency of 1300 MHz.

Q9: Voltage fluctuations of the HV-power supply modulate the phase of RF drive signal of the 26 cavities (QL=3e7) by 15 deg./1 kV. Assuming a low frequency of the voltage fluctuations (less than the cavity bandwidth) determine:

a) the required stability of the klystron HV to obtain a field stability of 0.1 deg. with a controller feedback gain of 100.
b) the required HV stability if we take into account microphonics of 10Hz.
c) the corner frequency above which the fluctuations are reduced by the low-pass characteristics of the cavity in the closed loop case.