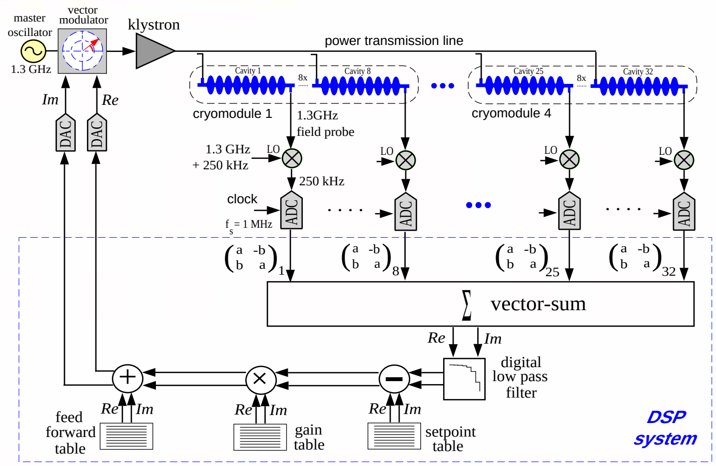
LOW LEVEL RF

TESLA DESY

Principle of RF Control



Introduction

Superconducting cavities exhibit a high susceptibility to mechanical perturbation due to the narrow bandwidth of the cavities. Significant phase and amplitude errors can be induced by the frequency variations excited by microphonics and Lorentz force detuning. The dynamical Lorentz force detuning of cavities operated in pulsed mode at high gradients (> 15 MV/m) can approach the cavity bandwidth thereby demanding substantial additional power for field control. Considerable experience of rf control at high gradients with pulsed rf and pulsed beam has been gained at the TESLA Test Facility in which presently 16 cavities have been driven by one klystron. The rf control system employs a completely digital feedback system to provide flexibility in the control algorithms, precise calibration of the vector-sum, and extensive diagnostics and exception handling capabilities.

RF System Requirements

Amplitude and Phase Stability:

- Keep bunch-to-bunch energy spread to less than 10^{-4} (rms). Correlated error requirements are therefore of the order of 10^{-4} for amplitude and 0.1° for phase. Uncorrelated error requirements are relaxed by $\sqrt{N}$ in the associated linac section, where N is the number of klystrons.

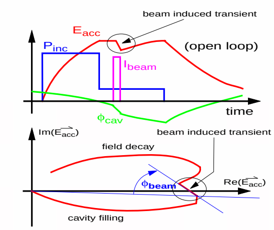
Calibration of the Vector-Sum

- The components of the vector-sum must be calibrated to better than 10% in amplitude (gradient) and 1° in phase for microphonic noise levels up to ±10°. This will result in energy gain fluctuations of less than 2.7×10^{-4} (rms) for an ensemble of 32 cavities

Contributions to Energy Fluctuations

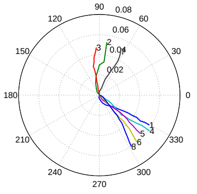
1. Lorentz Force
2. Microphonics
3. Bunch-to Bunch Charge Fluctuations
4. Calibration error of the vector-sum
5. Phase noise from master oscillator
6. Non-linearity of field detector
7. Klystron Saturation
8. RF curvature (finite bunch length)
9. Wakefield and HOMs

Beam Based Calibration

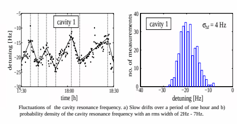


for $\Delta t \ll \tau_{cav}$:

$$\Delta V_{ind} = I \cdot \Delta t \cdot \left(\frac{r}{Q}\right) \cdot \pi \cdot f$$

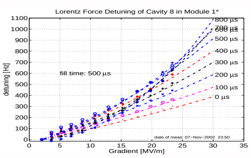


Microphonics

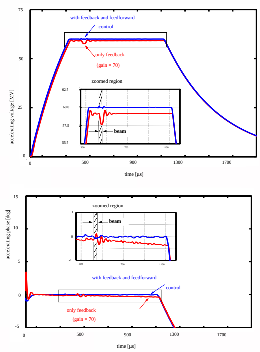


Fluctuations of the cavity resonance frequency. a) Slow drifts over a period of one hour and b) probability density of the cavity resonance frequency with an rms width of 2Hz - 7Hz.

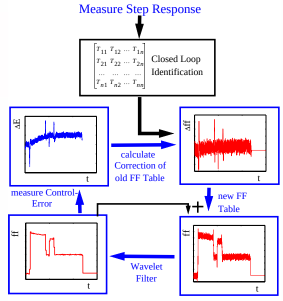
Lorentz Force Detuning



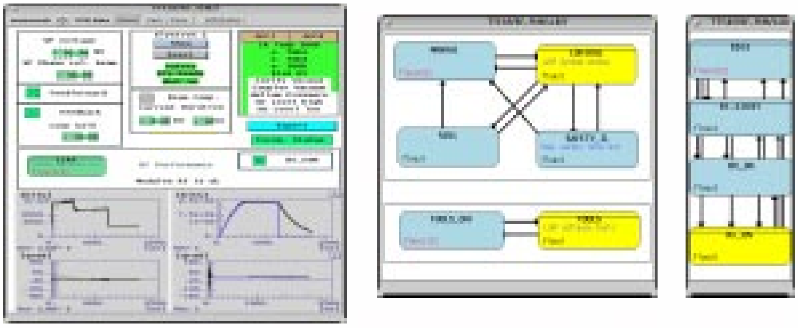
RF Control Performance



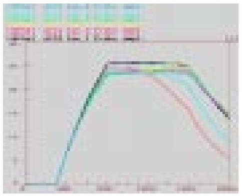
Adaptive Feedforward



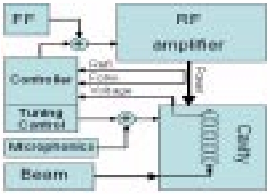
Automated Operation by Finite State Machine



Exception Handling

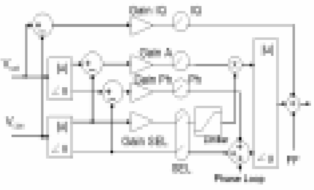


RF Sub-systems and Interconnections

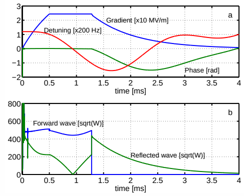


Simulations

Controller Scheme



Example



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Oct 2003