Comments on Barrier Buckets
Experience from the Fermilab Recycler
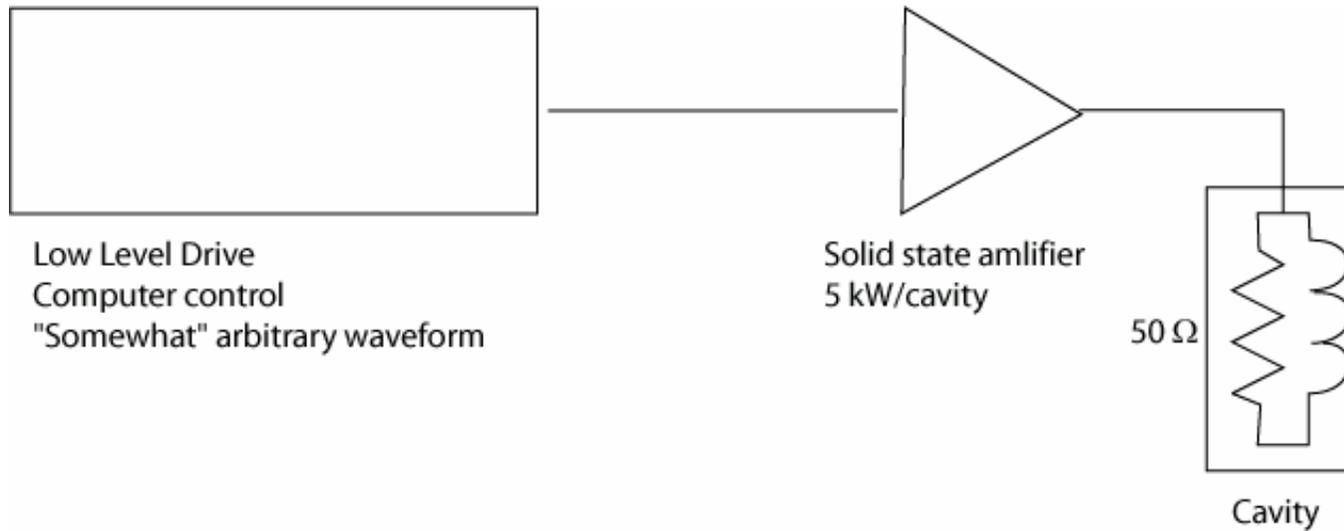
John Marriner

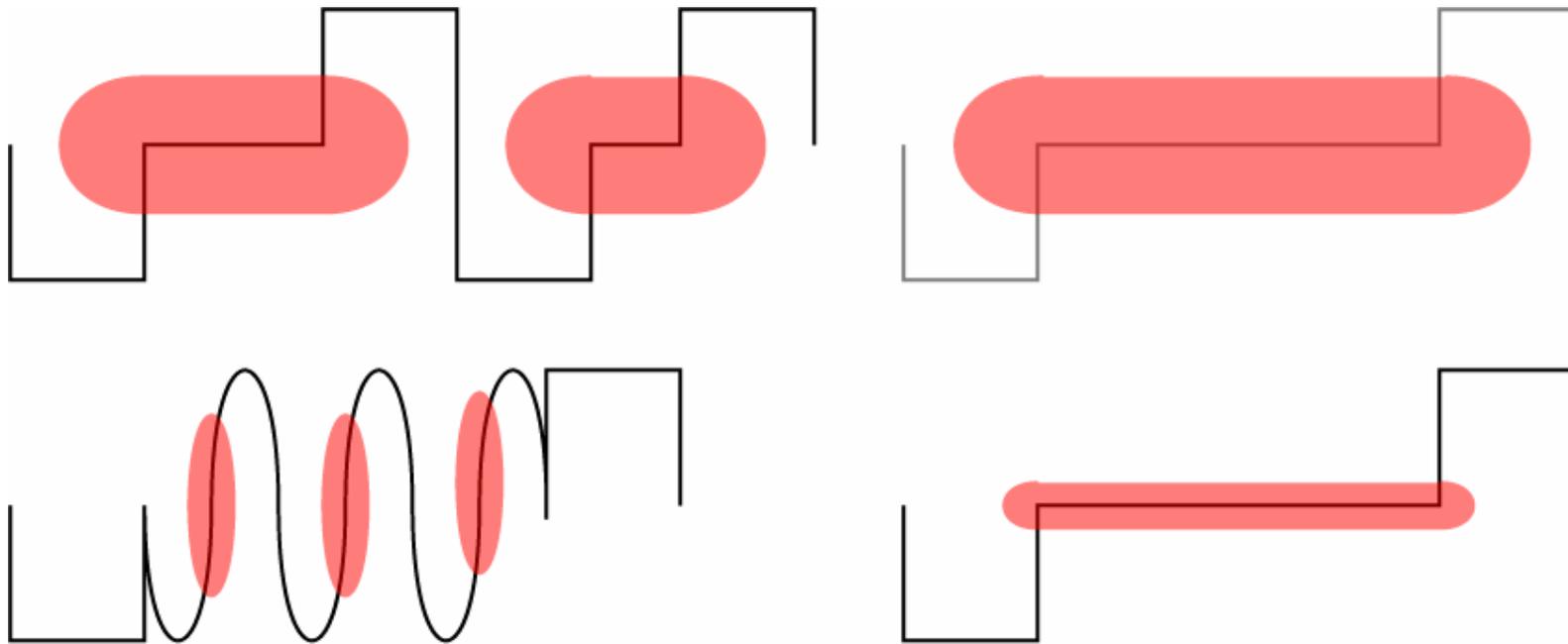30 October 2002

f

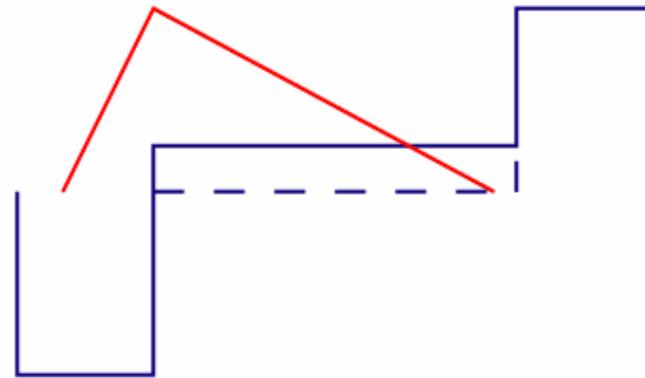# **f** What is the rf system?

Low Level Drive
Computer control
"Somewhat" arbitrary waveform

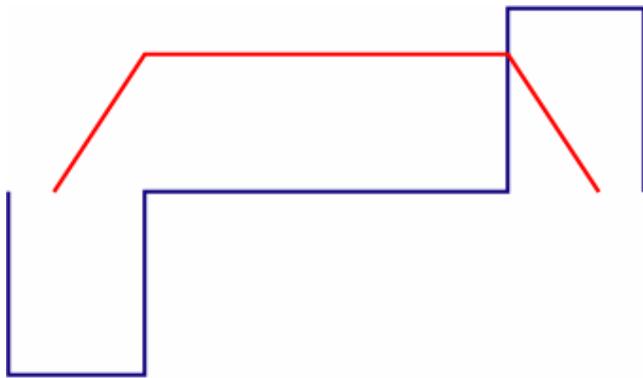Solid state amlifier
5 kW/cavity

50 Ω

Cavity

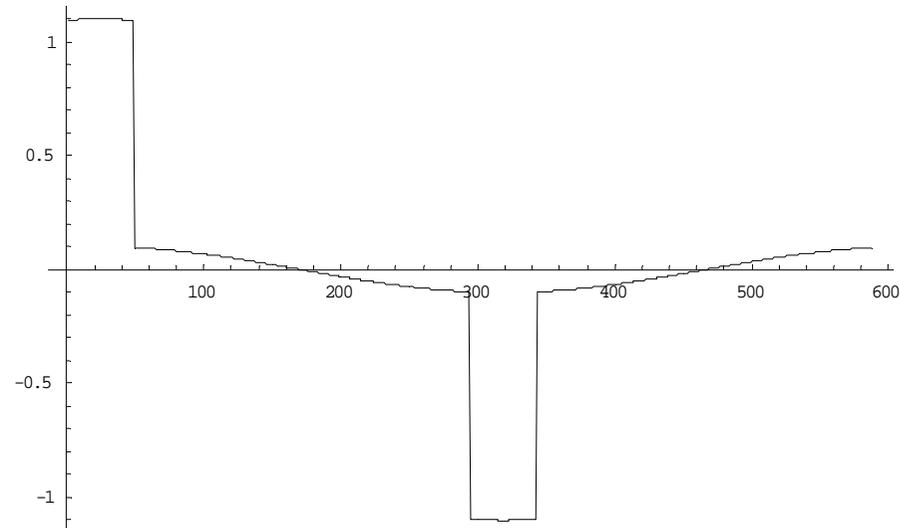**f** Basically, it does work…

f Sensitivity to Waveform

f Sensitivity to waveform

- Require a uniform transfer function at harmonics of the revolution frequency (100 KHz) up to about 10 MHz

- Want voltage between barriers (nominally 0) to be less than 1% of peak
  - □ Want Gain flat to 1/4 dB
  - □ Phase flat to 2 degrees

f The fundamental difference

- Particles captured by sine wave rf have oscillation frequencies near a non-zero value known as the synchrotron frequency.
- Particles capture by a barrier bucket have oscillation frequencies in a spread around zero.

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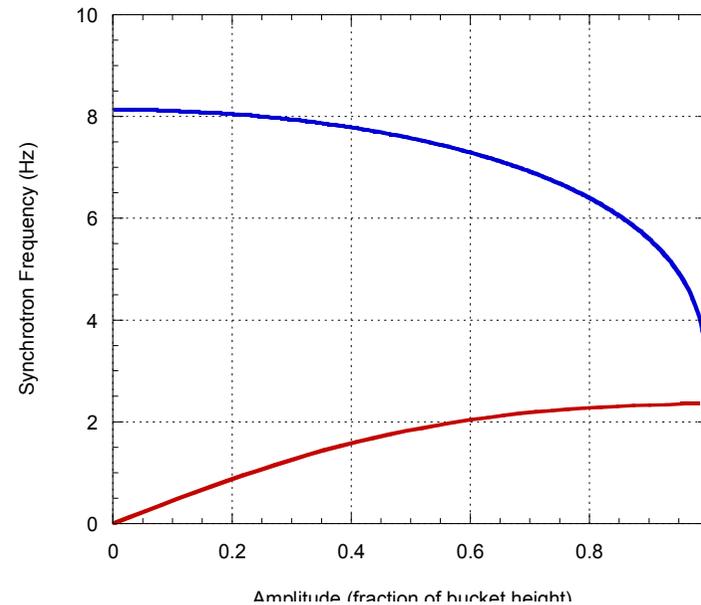
f The other fundamental difference

- Sine wave rf has only two variables: amplitude and phase. Mathematics is vector addition or multiplication of complex numbers.

- Barrier rf has quasi-infinite number of variables. Mathematics is Laplace transform.

f Consequences for the Recycler

- Synchrotron motion is coupled to the Main Injector ramp
  - The accelerators share the same tunnel and stray magnetic fields from the Main Injector (<1 G) modulate the orbit length.
  - The modulation frequency is in the band of synchrotron frequencies.
- The resulting emittance growth in the Recyler is much bigger than what is acceptable (3x worse).
- Storage machines are more susceptible to this effect.

f   RF Feedback

- Conventional rf systems are rarely (if ever) true sine waves.

- A typical rf system is a modulated sinewave, where the bandwidth is typically larger than the synchrotron frequency spread to include features such as:

  - ☐ Radial position and phase feedback
  - ☐ Quadrupole
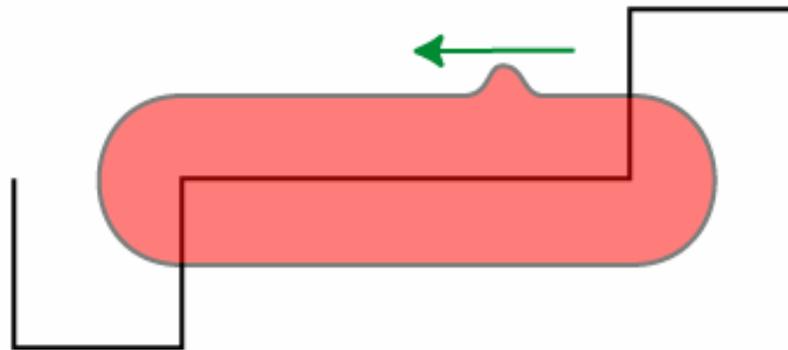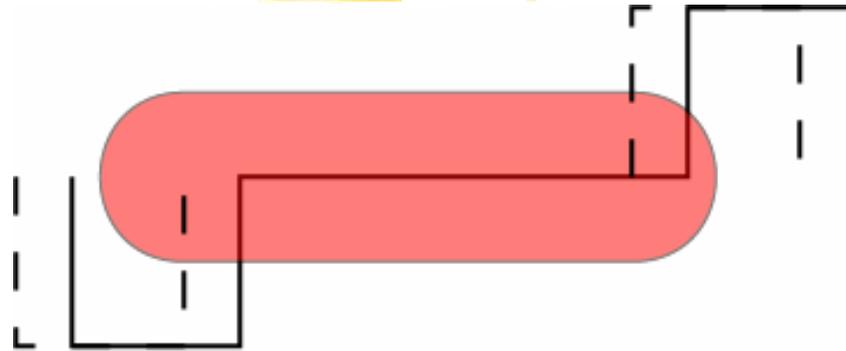 - ☐ Tuning circuits
  - ☐ Beam loading compensation

f Feedback with barriers

- Beam oscillations are very noticeable on the bunch profile displayed on an oscilloscope.
- We have identified two possible approaches
  - ☐ Narrow-band phase feedback system
  - ☐ Broad-band phase feedback system

f Feedback System Concepts

f Conclusions

- Attention to the precise waveform is important for the FNAL Recycler.
- Barrier bucket beams are susceptible to low frequency noise.
- Feedback systems may be required.
  - The requirements have not be fully explored.
  - The wide system bandwidth is both a problem an an opportunity.
  - Stability and effectiveness of these systems need study.
- We are early in the learning process.