LLRF Control System for the Diamond Storage Ring

Alun Watkins
Senior RF Engineer
Diamond RF Group

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Diamond SR LLRF: talk outline

- *Summary of key specs*
- *MO distribution*
- *LLRF hardware and software*
- *Commissioning procedure*
- *First results*
- *Technical challenges*
- *Future work*
- *Conclusions*

Key specifications

Parameter	Value	Comment
Technology	Analogue IQ	EPICS software
RF Frequency	499.654 MHz	
Cavity voltage range	0.125 to 2.5 MV	(per cavity)
Amplitude regulation	0.5 % rms	Over 14 dB range
Phase regulation	0.2 º rms	Over 14 dB range
Phase control range	± 180°	
Loop bandwidth	10 Hz to 100 kHz	Open loop unity gain
Loop gain	0 to 40 dB	variable

Designed and manufactured by: ACCEL Cryoelectra

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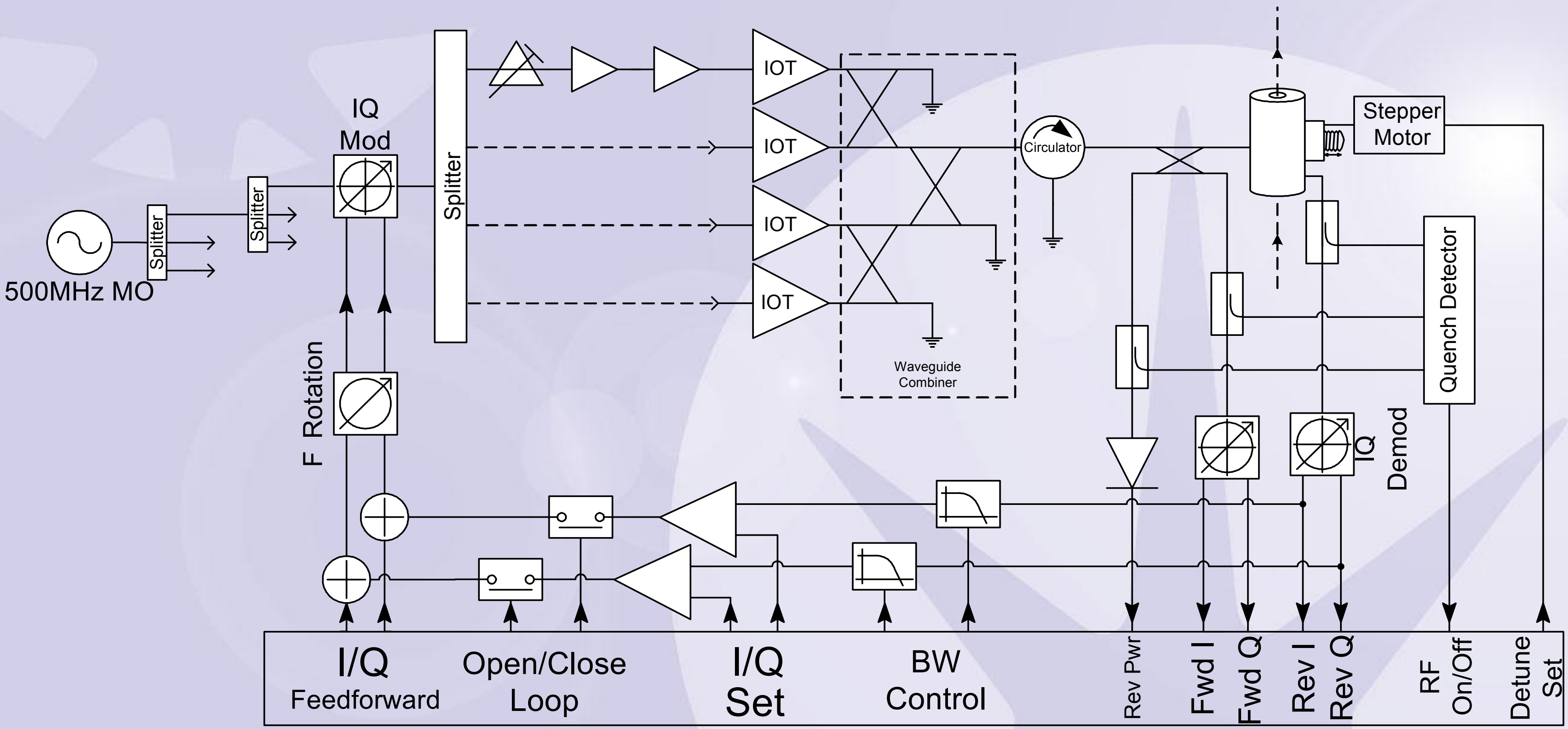
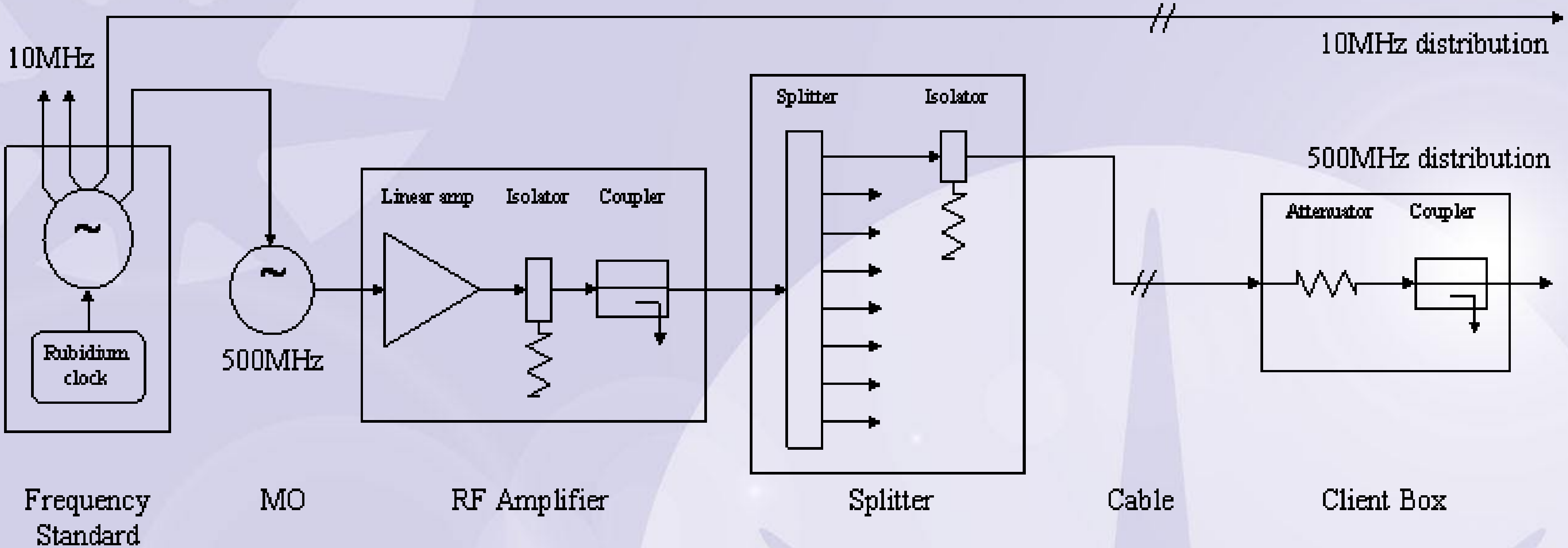
RF plant block diagram
(1 of 3 amplifiers)



Master Oscillator RF distribution



Destination	*Cable Length*
Linac	10m
Booster	40m
Optics Hutch	80m
Diagnostics CIA	155m
RF Hall	275m

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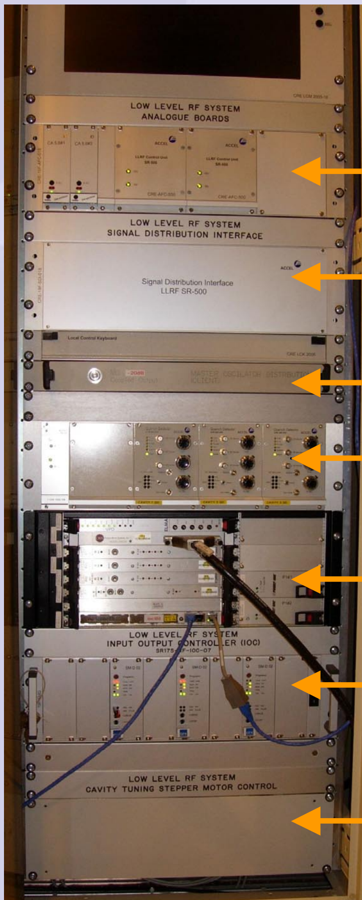
Master Oscillator RF distribution

- IFR 2040 signal generator
  - 130ms phase/frequency transient, even for 0.1Hz step!
  - IFR looking into the problem (normal noise mode OK)
- In-house built 5W amplifier and splitter
  - ASC311 amp to be replaced with Aerial Facilities unit, due to one failure and internal switcher noise.
- LDF4.5RN-50 phase stabilised cable
  - 275m cable to RF Hall gives approx -1.2º/ºC (= 6 ppm)
- So far, amplitude and phase stability of MO signal OK
- LDF1 for 10 MHz
  - reference signal useful for locking instrumentation to the MO

LLRF Hardware



LLRF electronics

LLRF/VME interface

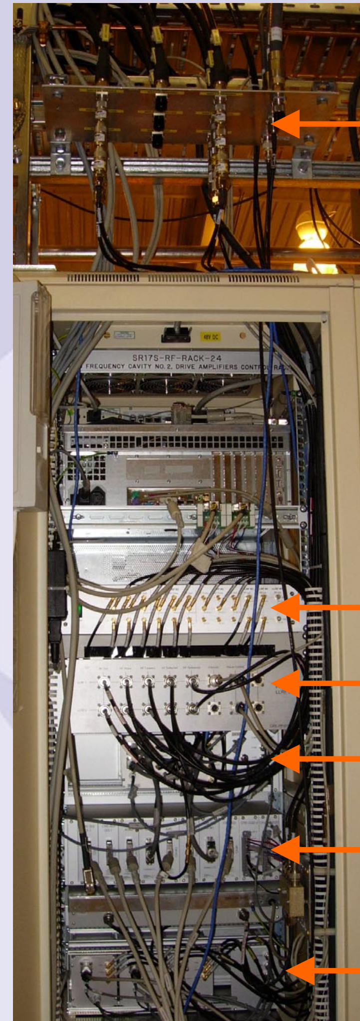
MO Monitor

Quench detector (QD)

Hytec IOC

Stepper motor driver

Stepper motor PSU's



Cavity signal patch-panel

RF preamp & signals to QD

LLRF IO panel

LLRF

LLRF/VME interface

QD

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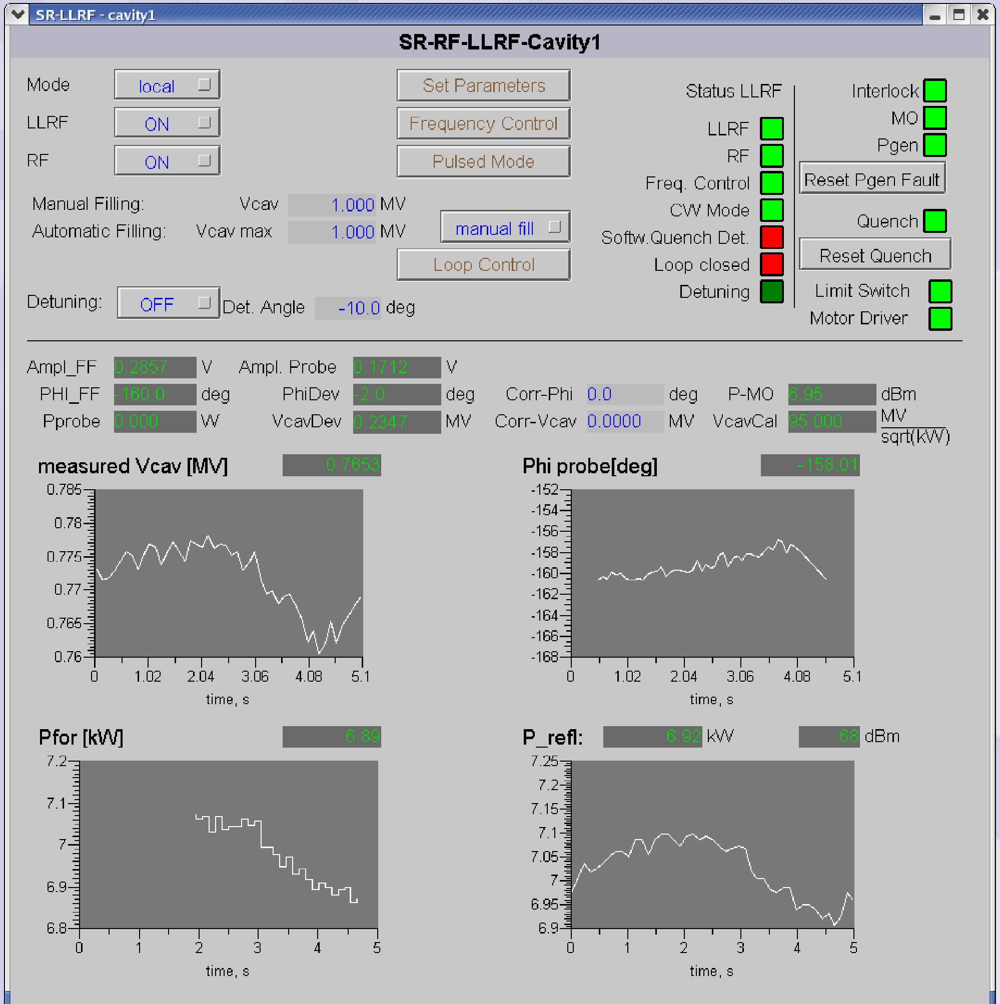
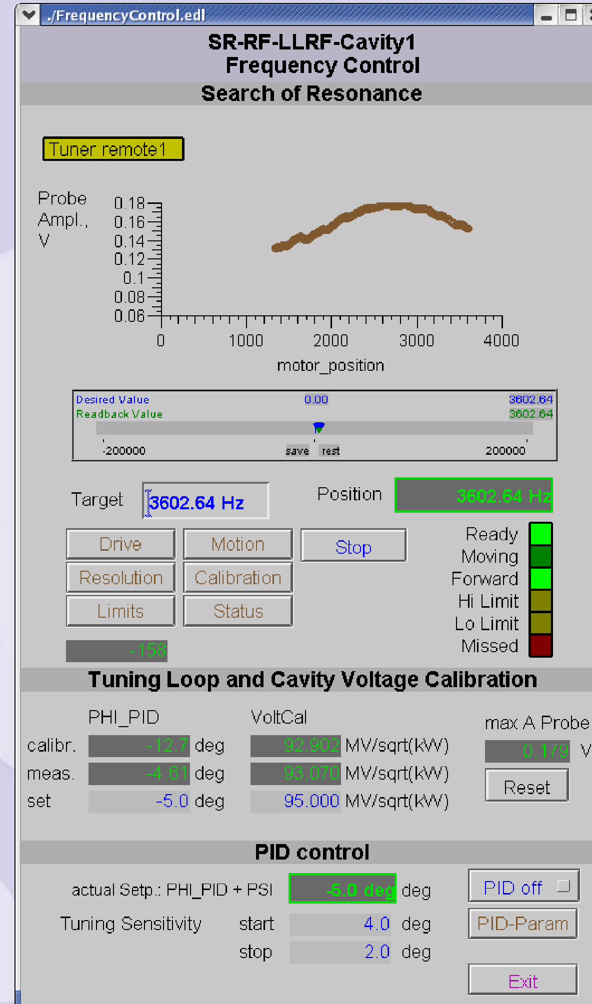
LLRF Software





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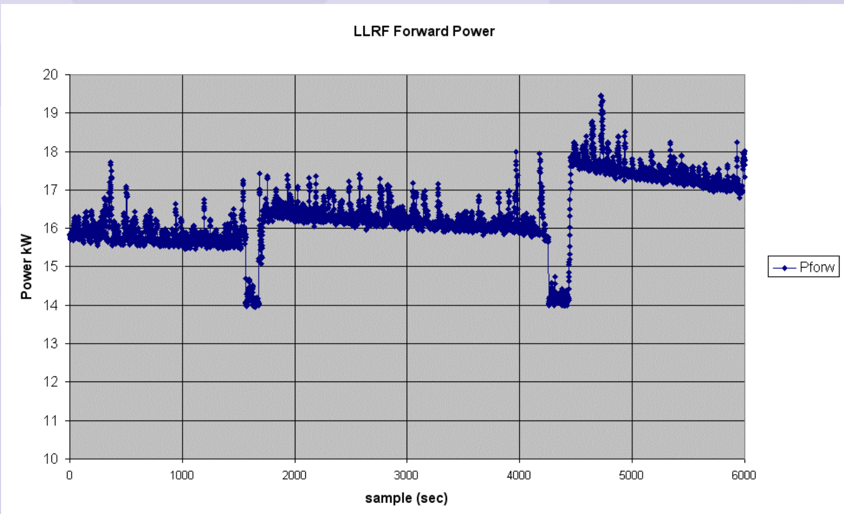
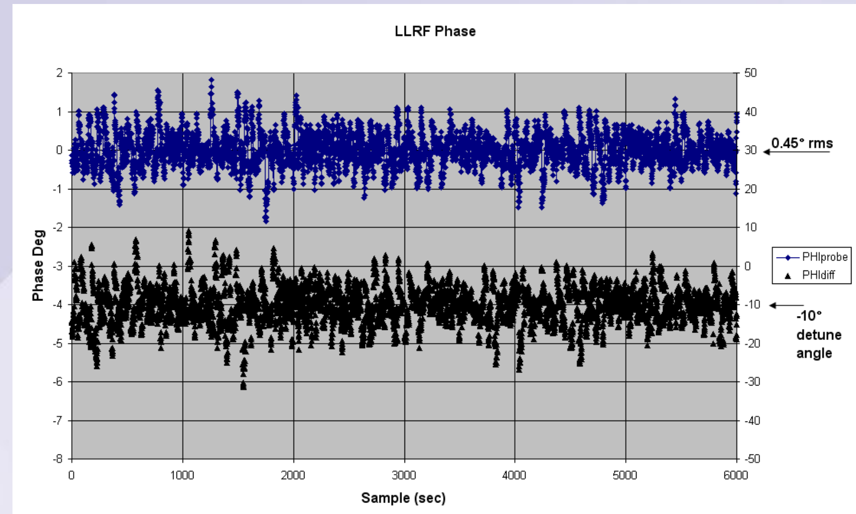
Commissioning procedure

- Calibrate modulator and demodulators
- Calibrate RF paths (pickup cables and amplifier gain)
- Measure cavity tuner step/Hz
- Optimise PID parameters and motor speed in motor record
- Zero phase between forward and probe signals at resonance
- Determine ‘Voltcal’ factor for the cavity probe:
  - Voltcal = Vcav/√ Probe
  - Vcav is found from $\sqrt{4 * Pfor * R/Q * Q_0}$ at resonance
- Verify correct detuning operation

First results

Results using EPICS 'strip tool' (1sec sample rate):





Settings	Amplitude Stability		Phase Stability	
	rms	pk-pk	rms	pk-pk
LLRF only	0.09%	-	0.05°	-
1.35 MV IQ gain=50, BW=0	0.12%	0.86%	0.53°	4.80°
1.0 MV IQ gain=70, BW=0.5	0.13%	0.86%	0.23°	2.06°
1.0 MV, IQ gain=70, BW=0.5 Detune = 20°	0.12%	1.15%	0.18°	1.53°

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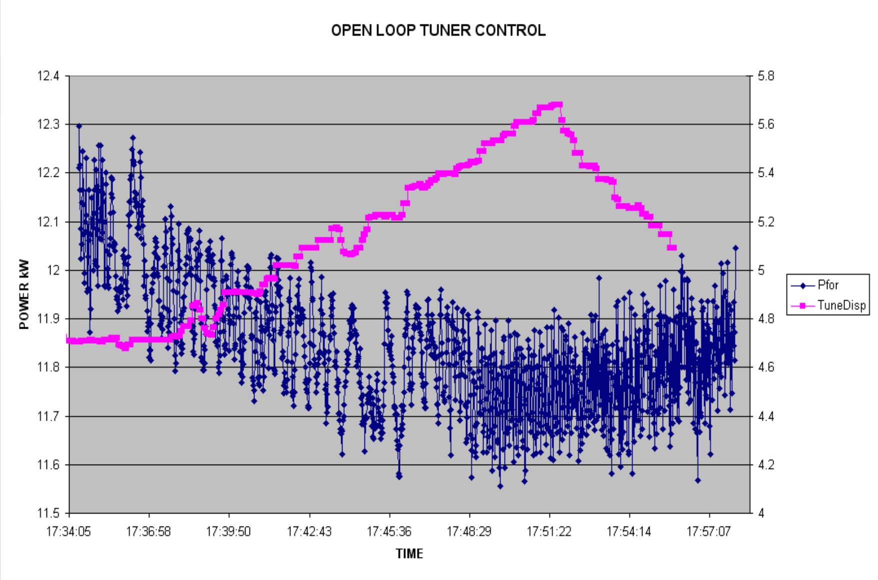
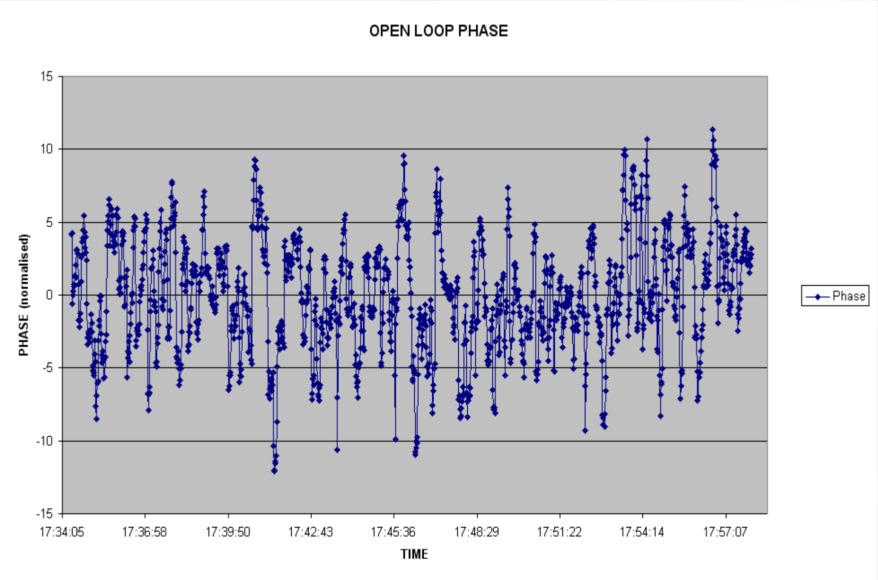
First results



Forward power variations of >10 %
- need to reduce

Phase stability under tuner control ~ ± 15 ° : need to investigate contributions from tuner, cryogenics, amplifier etc.



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Technical challenges

- Tuner problems: backlash, hysteresis, EPICS motor record not easy to master.
- Amplifier gain change with power and temperature
  - open loop error in predicted power output from the LLRF
  - also gain change with IOT configuration (e.g. 2 or 4 IOT's)
- Closed loop error: ~100 kV, analog offsets (and no dc integrator term?)
- Accurate power calibration: coupler, calorimetric, LLRF
  - which one is giving the true reading?
- Loop gain and BW dependant offset
  - can we add a look-up table?

Future work

- Improve operation of tuner loop
- Optimise loop gain and BW for regulation
  - requires better measurement of amplitude and phase stability than through EPICS
- Look for interaction with beam on higher BW settings
- Develop ‘Operator friendly’ control screen
  - combined within a combined Storage Ring RF plant screen?
- Improve calibrations of forward power and cavity voltage
- Reduce noise on Pforward and Pprobe phase readings
- Provide training and operating instructions

Conclusions

- Tuner improvement is the most urgent requirement
- Target spec of 0.5%, 0.2° rms was realistic (for an analog system)
- Offsets and values that require ‘tweaking’ may be the main drawbacks of our analogue system
- Require the development of a simplified operator interface
- Hardware reliability has been excellent

Acknowledgements

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