Progress of the Analog LLRF for ALBA

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Outline:

1. **Quick review of the ALLRF design and specifications**
2. **Implementation**
3. **ALLRF performance in error compensation**
4. **ALLRF performance under "Virtual Beam" loading**
5. **"Envelope Simulation" of the ALBA RF system**
6. **Summary**

Specifications

DAMPY cavity parameters

Nominal frequency	499.654	MHz
Tuning range	2	MHz
Shunt impedance	3.3	MΩ
Unloaded Q	28000	
Waveguide cut-off	615	MHz

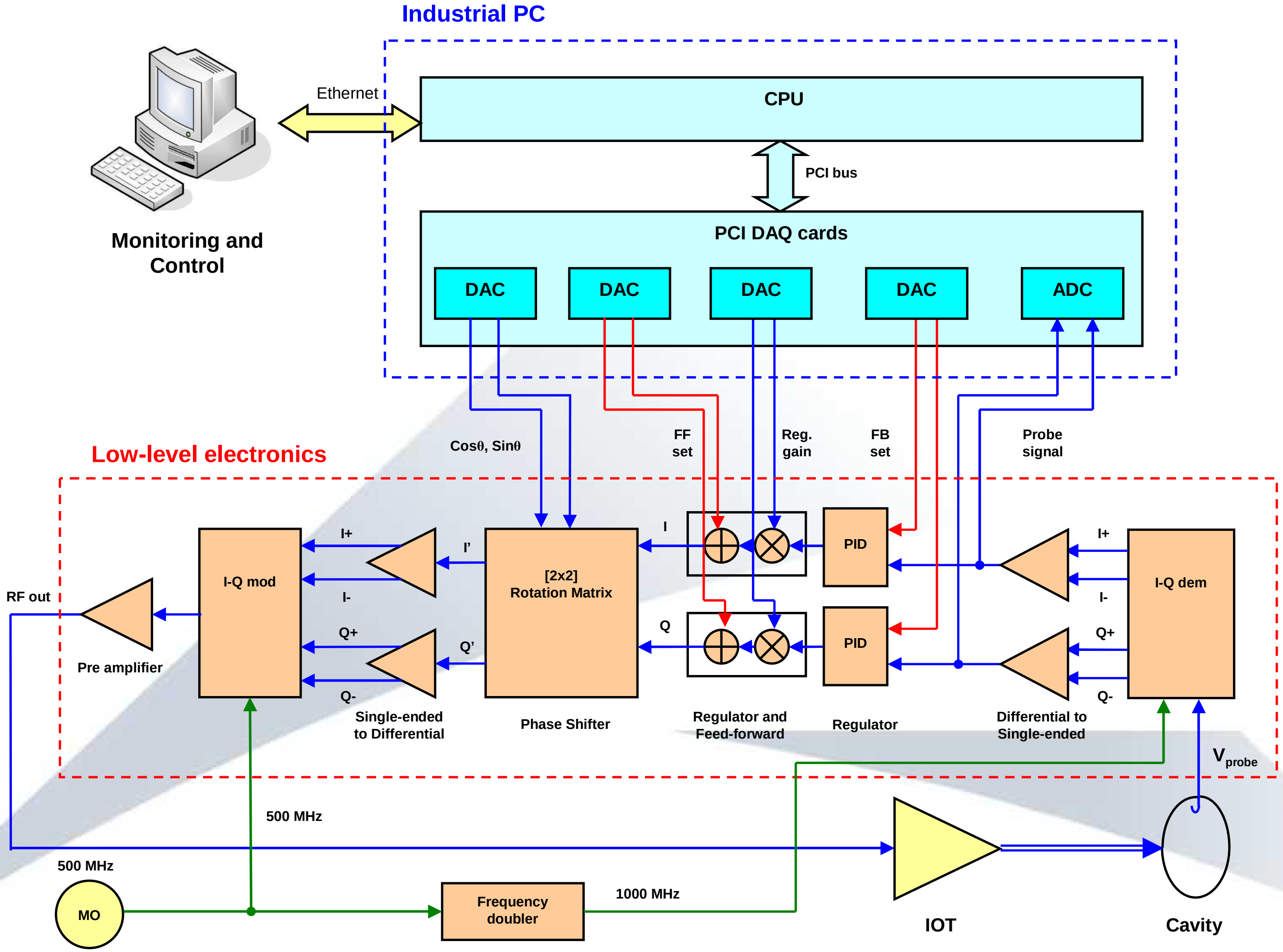
ALBA storage-ring RF specifications

No. of cavities	6	
RF power (per cavity)	150	kW
RF voltage (per cavity)	600	kV
Overvoltage factor	2.8	
Synchroneous phase	159	deg

ALBA ALLRF specifications

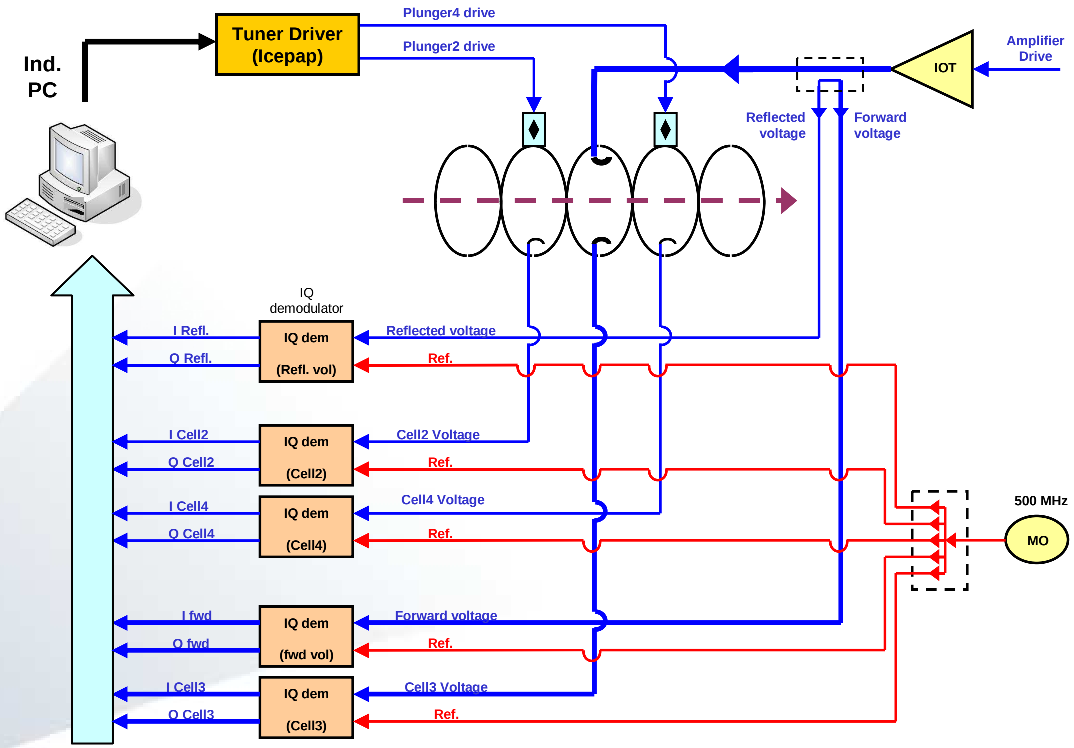
Phase loop		
stability	±1	deg
Bandwidth	1	MHz
No. of bits	16	Bits
DAC throughput	100	kS/s
Loop delay	<1000	ns
Phase control range	0 - 360	deg
Amplitude loop		
stability	±1	%
Bandwidth	1	MHz
No. of bits	16	Bits
DAC throughput	100	kS/s
Loop delay	<1000	ns
Dynamic range	>= 23	dB
Tuning loop		
Bandwidth	~100	Hz
Tuning range	2	MHz
Tuning resolution	0.1 - 1	kHz

Design of the ALLRF (Amp/Ph loops)

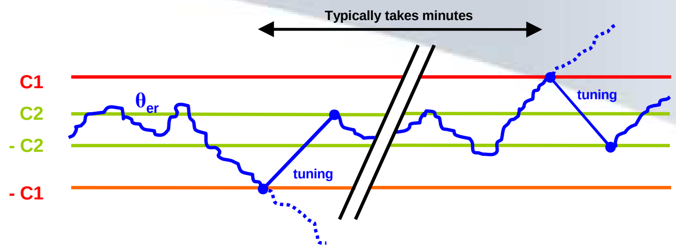


Design of the ALLRF (Tuning/FF loops)

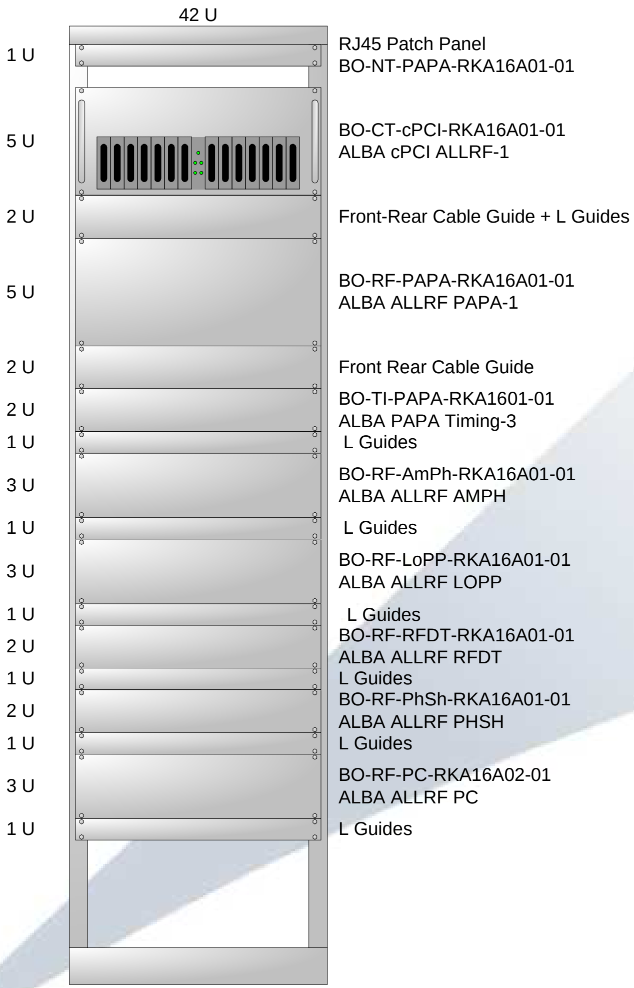
- We measure the phase difference between the forward voltage and the cavity probe voltage by two IQ demodulators and a tag^{-1} operation.
- Depending on the phase error polarity we move both tuners in/out simultaneously to keep the error as small as possible.
- For the booster we only tune the cavity at the peak of the power ramp.
- We have also foreseen the software and hardware for a field-flatness loop but we'll only use it if it proves to be necessary.

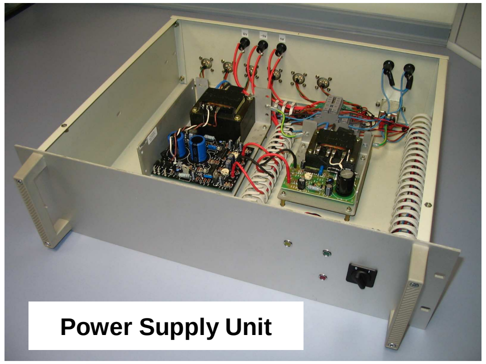


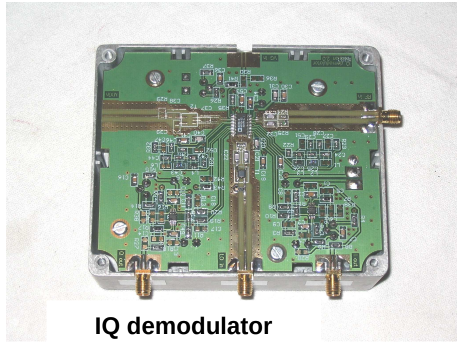
$$\theta_{er} = \theta_{ref} - ArcTan2(I_{fwd}, Q_{fwd}) - ArcTan2(I_{cell3}, Q_{cell3})$$

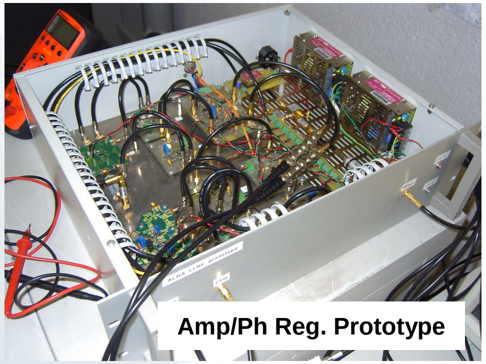


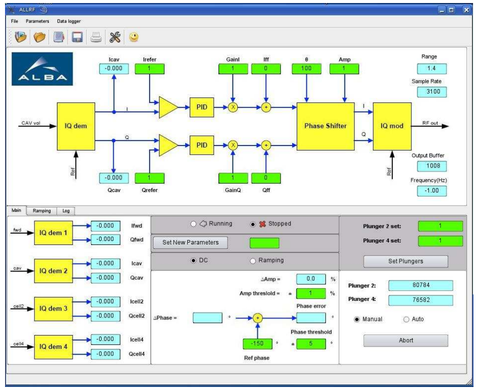
Implementation

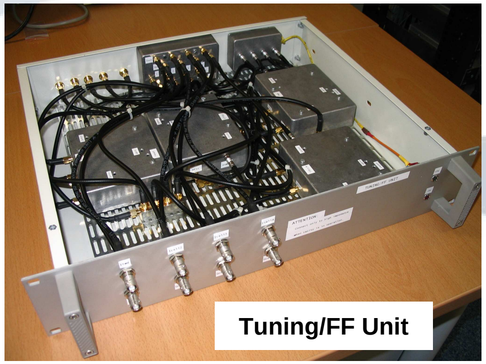


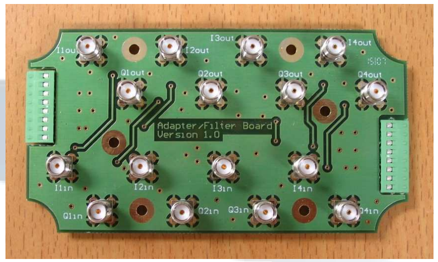

Power Supply Unit


IQ demodulator


Amp/Ph Reg. Prototype


ALLRF GUI

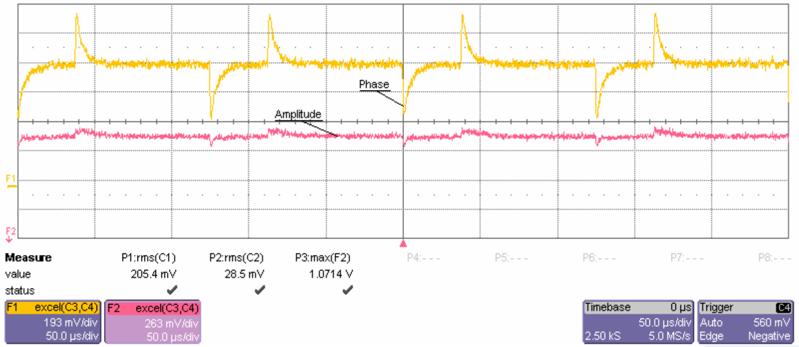

Tuning/FF Unit



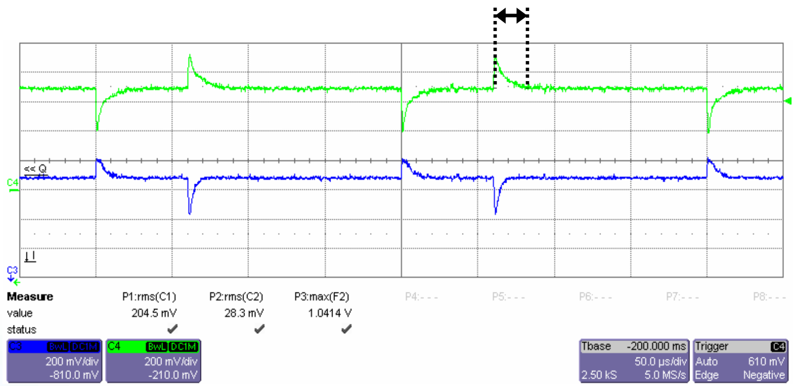
Adapter/Filter Board

ALLRF performance (error compensation)

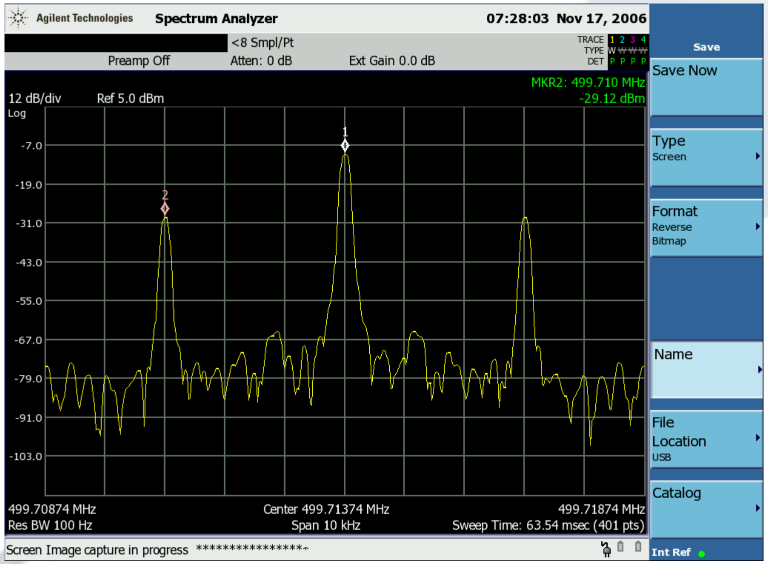
20 µs



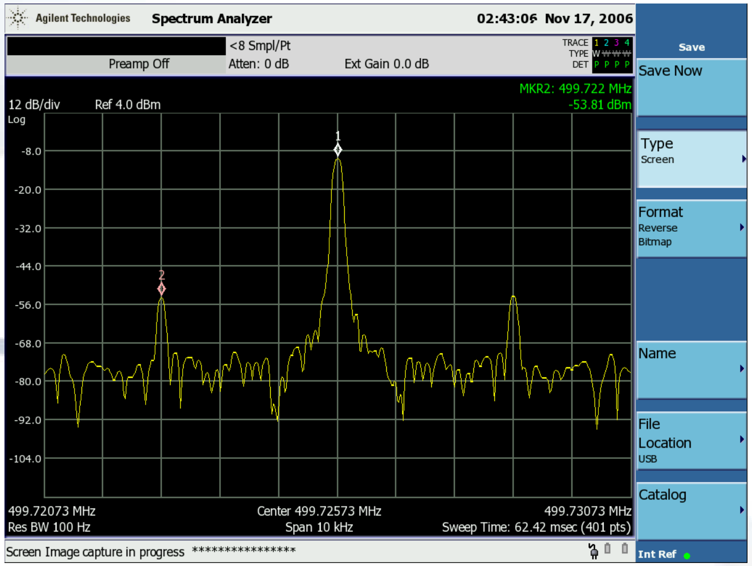
Amplitude / Phase



I / Q

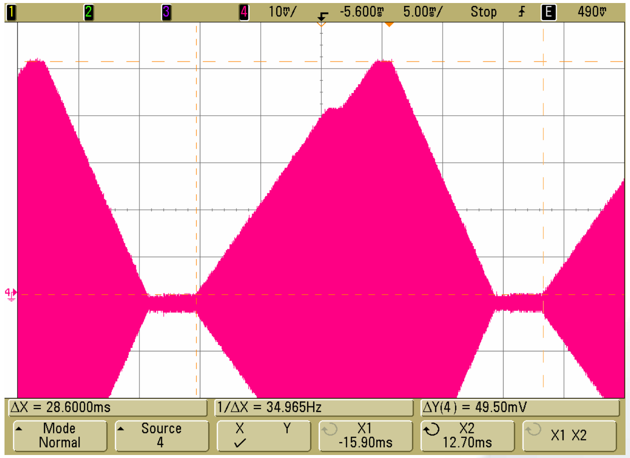


Reg.

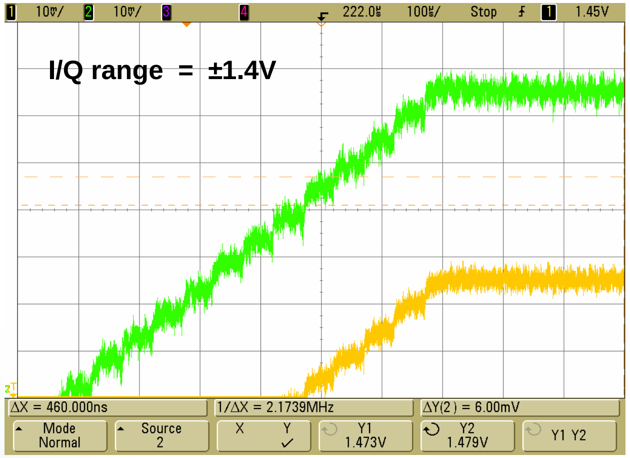


24 dB ripple reduction at f = 3 kHz

ALLRF performance

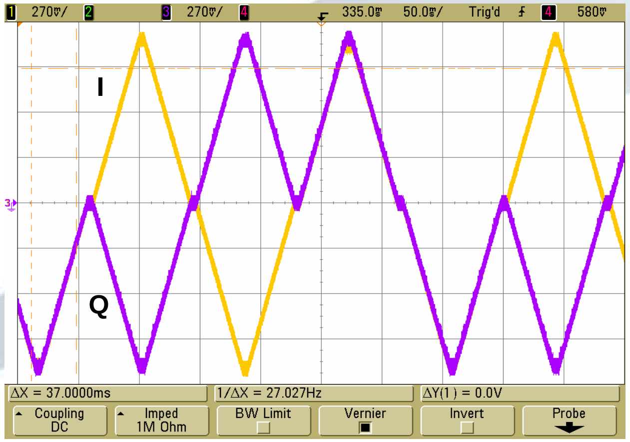


Dynamic range > 26 dB

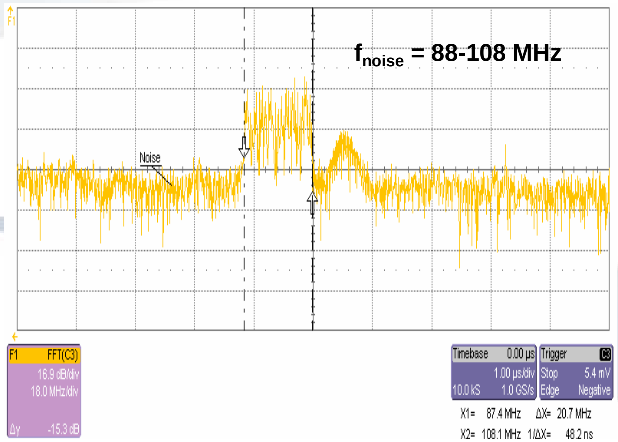


Previous noise on baseband signals ≈ 10mV$_{PP}$

With shielding and a good RF gen. → ≈ 5mV$_{PP}$



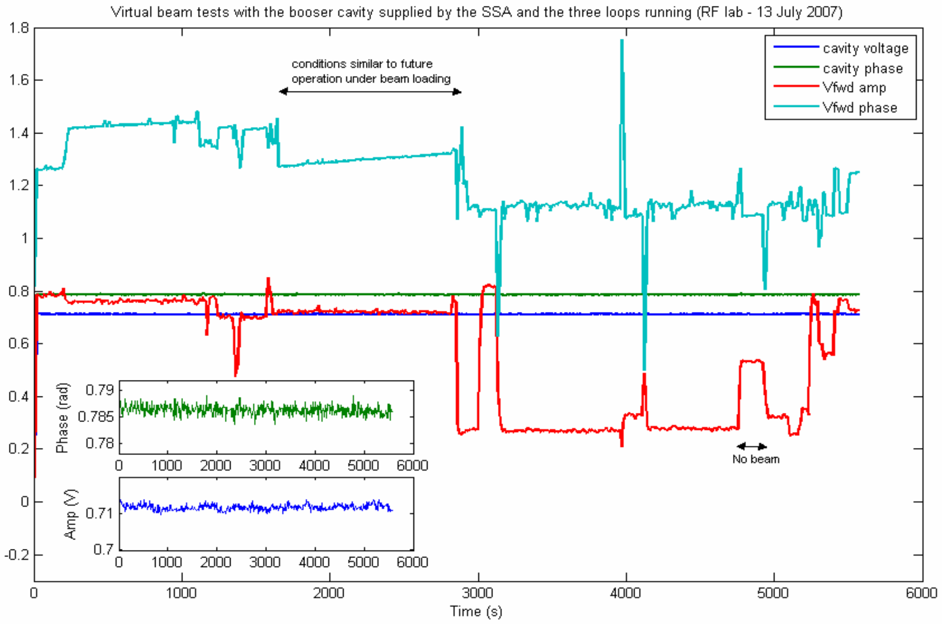
4-quadrant operation

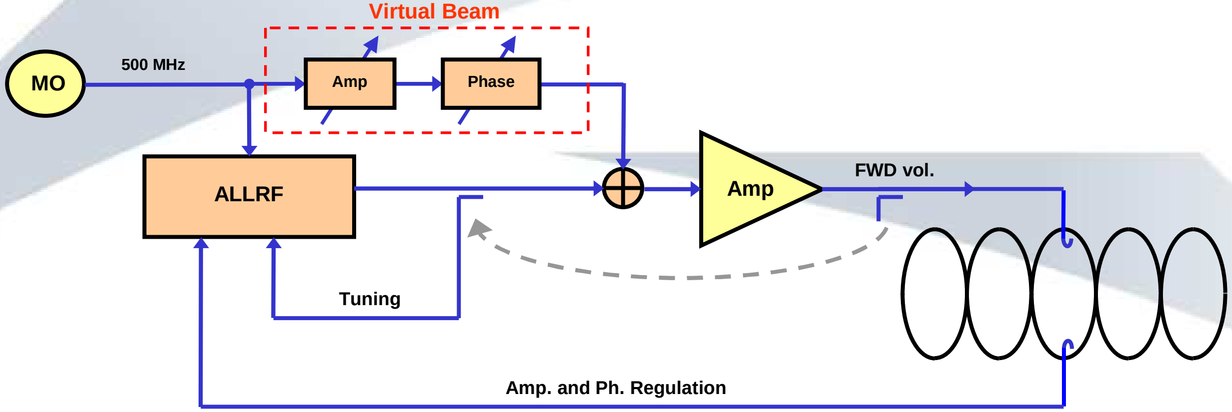


FM disturbance (without proper shielding)

ALLRF performance under "Virtual Beam" loading

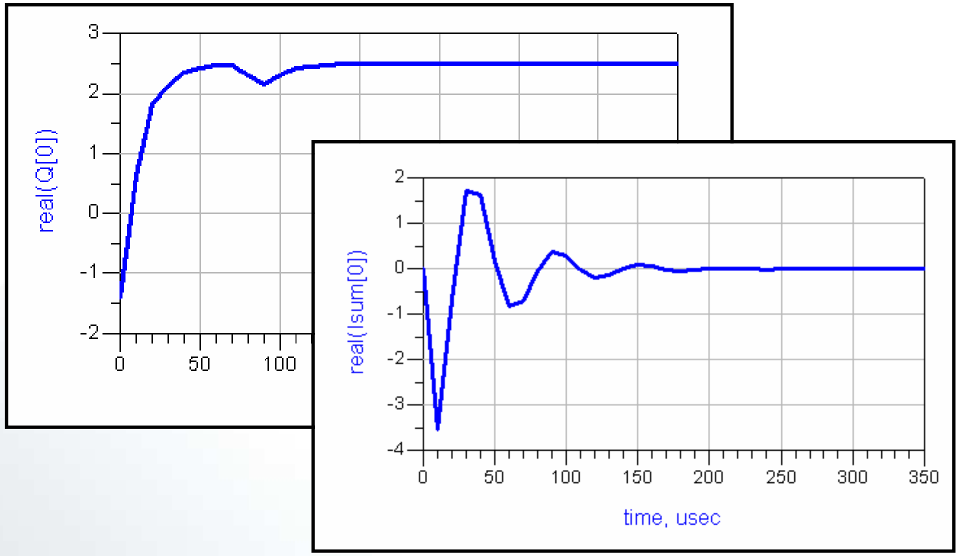
- Beam loading was simulated by adding a 500MHz signal to the amplifier drive and moving the 'FWD vol' measurement point to the ALLRF output.
- The phase of the 'Virtual Beam' was adjusted so that it was acting as a voltage sink thus simulating real beam for LLRF.
- The ALLRF successfully compensated the changes in Amp/Ph and reflected power due to 'Virtual Beam' loading.

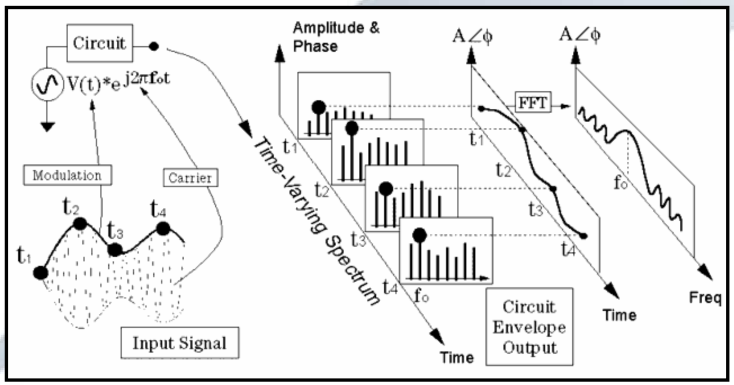


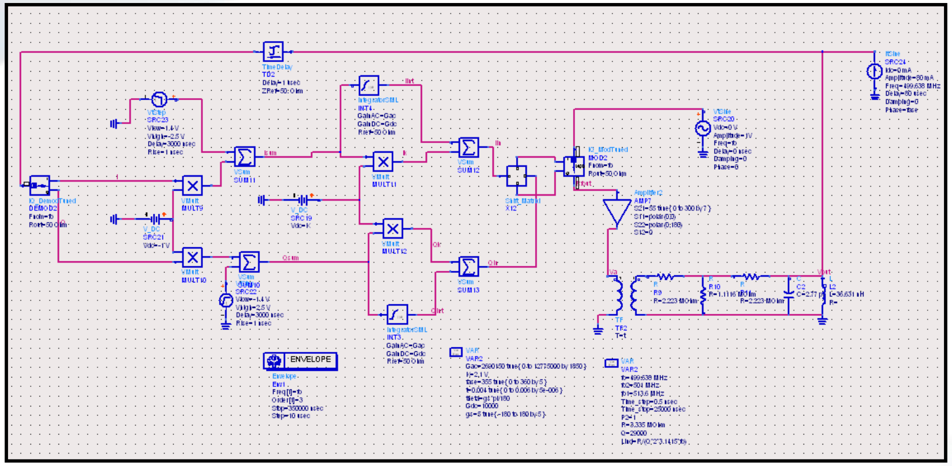


"Envelope Simulations" for the Amp/Ph loops

- **We use ADS software from Agilent to make Envelope Simulations.**
- **As the RF carrier (500 MHz) is not included in the simulations the simulation time is much shorter than conventional methods.**
- **No simplification is made in RF modeling.**
- **Envelope simulations are being done in the framework of a collaboration agreement with the UAB (J. Verdú)**







Summary

- **At ALBA we use IQ technique for the implementation of our RF diagnostics and the regulation loops.**
- **The design and implementation of the LLRF is done in-house.**
- **In the ALLRF tests we achieved an amp/ph stability of at least 2-3 times better than what we had specified.**
- **The loop delay, bandwidth and dynamic range are well within the specifications.**
- **We have developed a new concept called "Virtual Beam" to test our LLRF system under beam-like conditions in the RF lab.**
- **We have made an envelope simulation tool for RF simulations with the ADS software with no modeling simplification but with much shorter simulation time compared to conventional methods.**