RF systems: feedbacks, filters, spectra

Mikrofalony

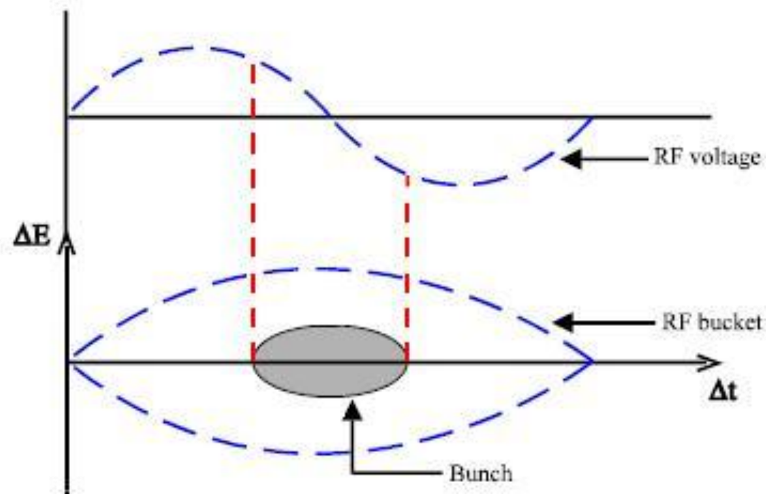
Jacek Jagosz, Julia Żuławska

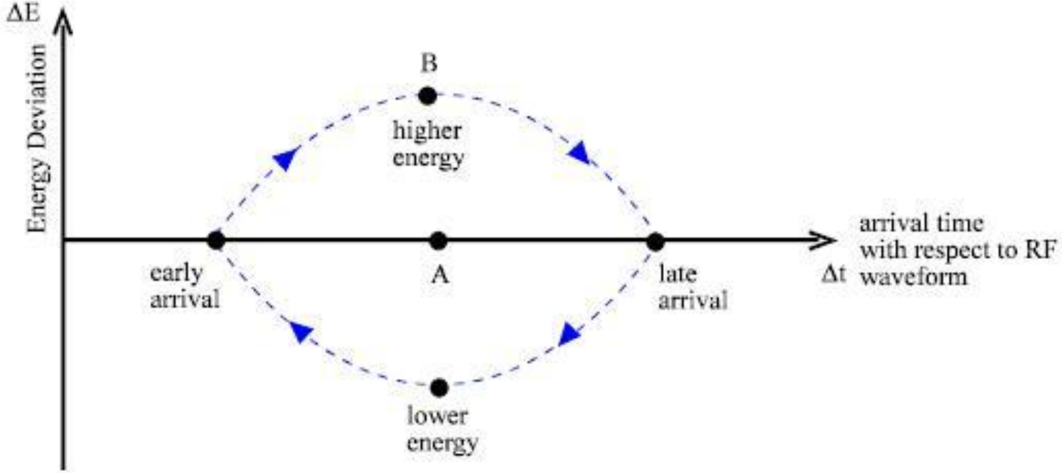
Machinery - how are waves generated?

SPS Travelling Wave Structure - almost an RF Cavity

SPS 200 MHz RF Combiner

Standing wave in RF cavities





Images from Accelerators for pedestrians, Baird, S, CERN. Geneva. AB Department

Some cool calculations

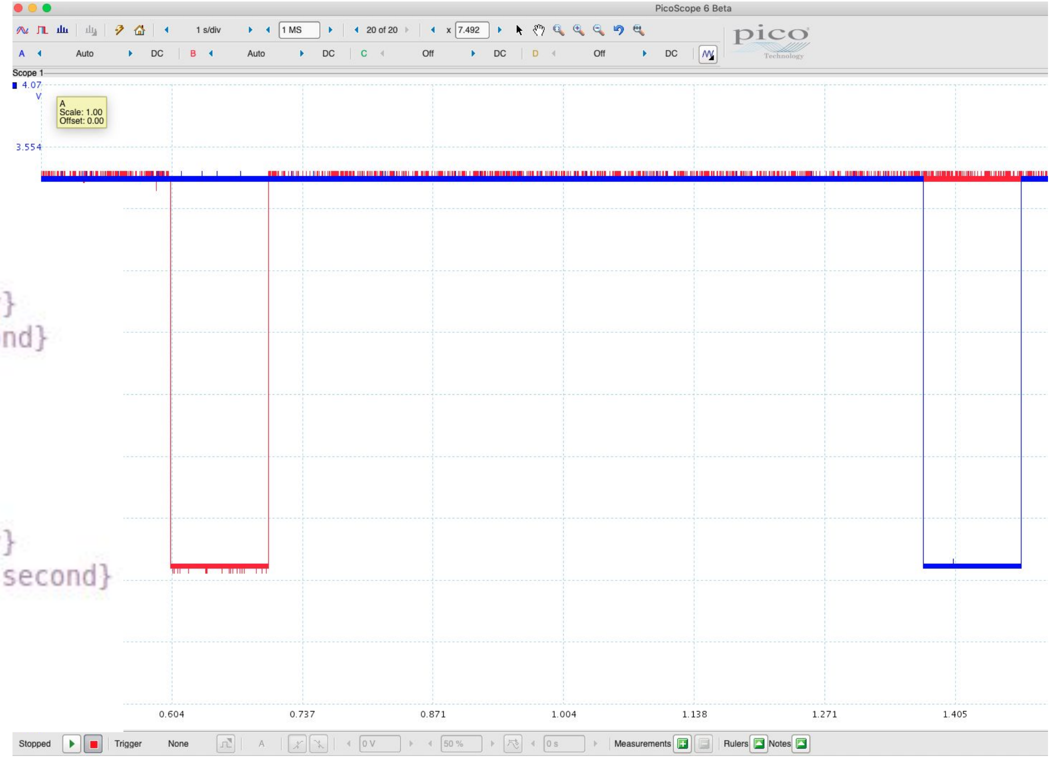
```
import math

V = 1.5*10**6 #voltage amplitude in RF cavities
c = 3*10**8
fi = 2*math.pi/180 #phase shift of a bunch (2 deg)
L = 26659 #length of the accelerator

energy_gained = V*math.sin(fi) #energy gained in one cavity (in eV)
E = 7*10**12 - 450*10**9 #energy difference between SPS and LHC
n = E/(8*energy_gained)
t = n*L/c
print(t/60) #time needed to accelereate one bunch (in minutes)
```

```
23.163929773314138
```

Synchronisation of time

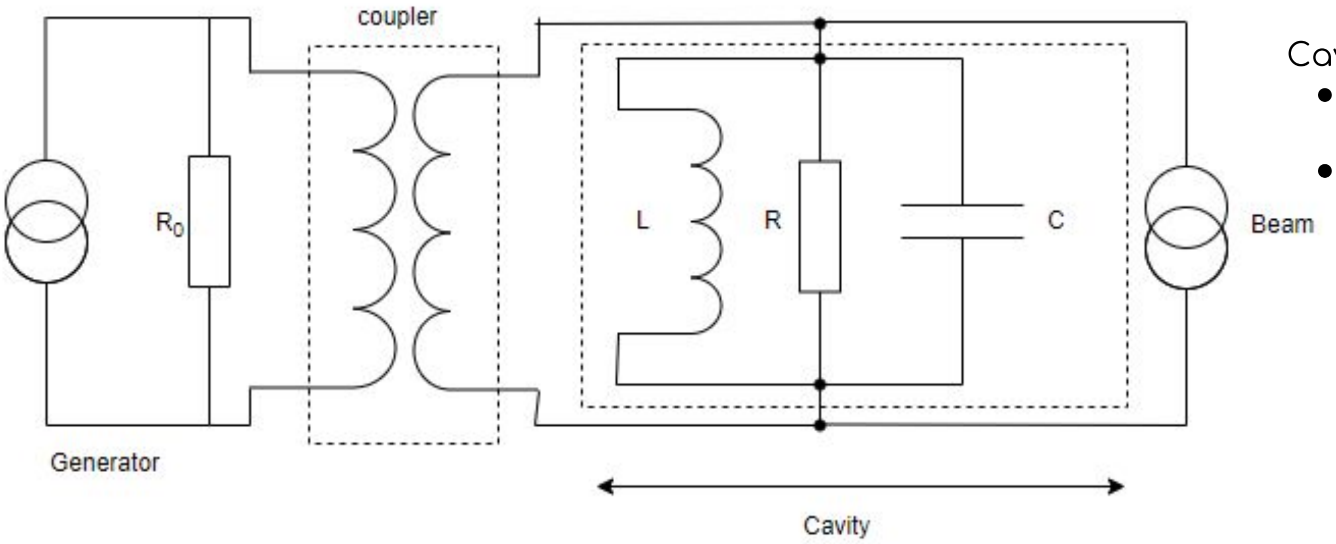
```
now=datetime.datetime.now()
for hosts in HOSTS:
    now=datetime.datetime.now()
    msg=f"setdate {now.year} {now.month} {now.day}
{now.weekday()} {now.hour} {now.minute} {now.second}
{int(round(now.microsecond/1000))}"
    print(msg)
    print((hosts, PORT))
    s.sendto(str.encode(msg), (hosts,PORT))
now1=now+datetime.timedelta(hours=0,seconds=10)
msg1=f"trigger {now1.year} {now1.month} {now1.day}
{now1.weekday()} {now1.hour} {now1.minute} {now1.second}
{int(round(now1.microsecond/1000))}"
print(msg1)
for hosts in HOSTS:
    s.sendto(str.encode(msg1), (hosts,PORT))
```

Python code of a client



Synchronisation of time from the Internet

Tuning RF cavity to achieve impedance match



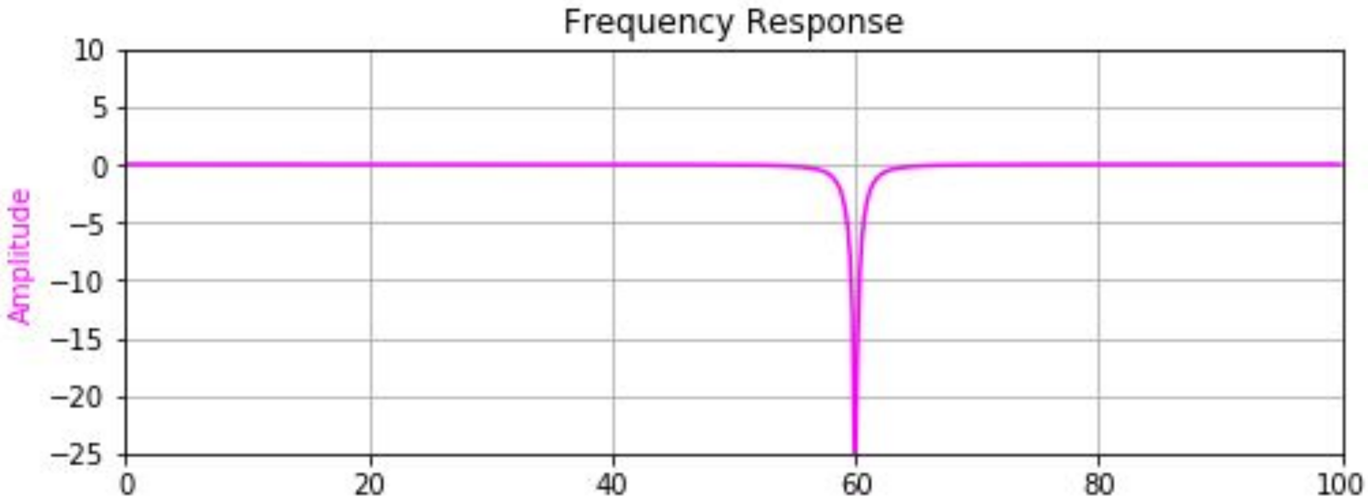
Cavity tuner:

- observes voltage and current
- changes the shape of the cavity using a motor

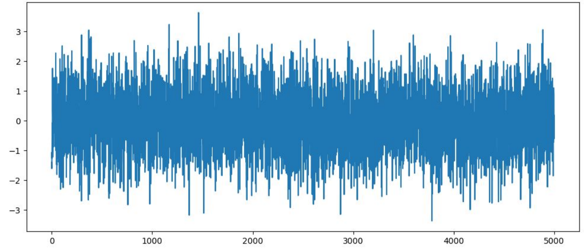
$$P = \frac{U^2 R_0}{(R + R_0)^2}$$

$$\frac{dP}{dR} = \frac{U^2(R + R_0)^2 - 2U^2 R_0 (R+R_0)}{(R + R_0)^4} = 0 \Rightarrow R_0^{\ 2} = R^2$$

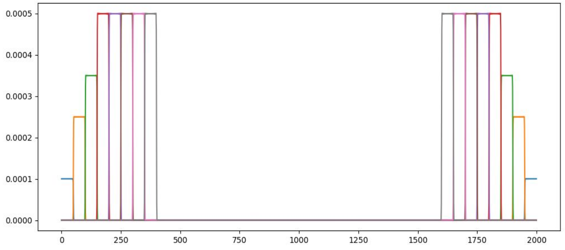
Digital filters - how & why?



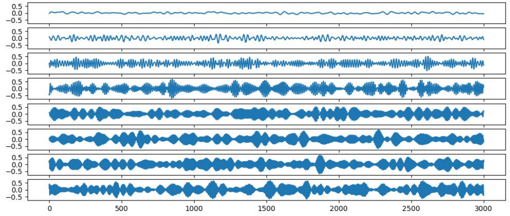
Example of a notch filter

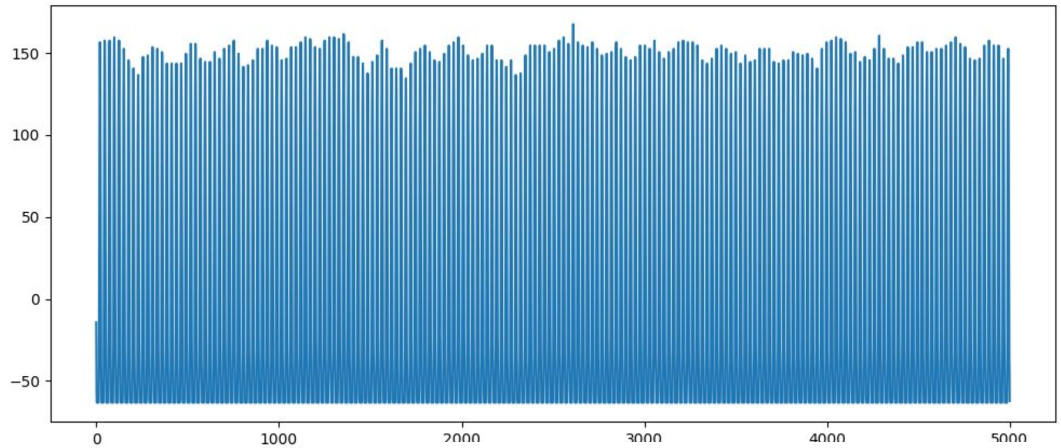


Some random signal



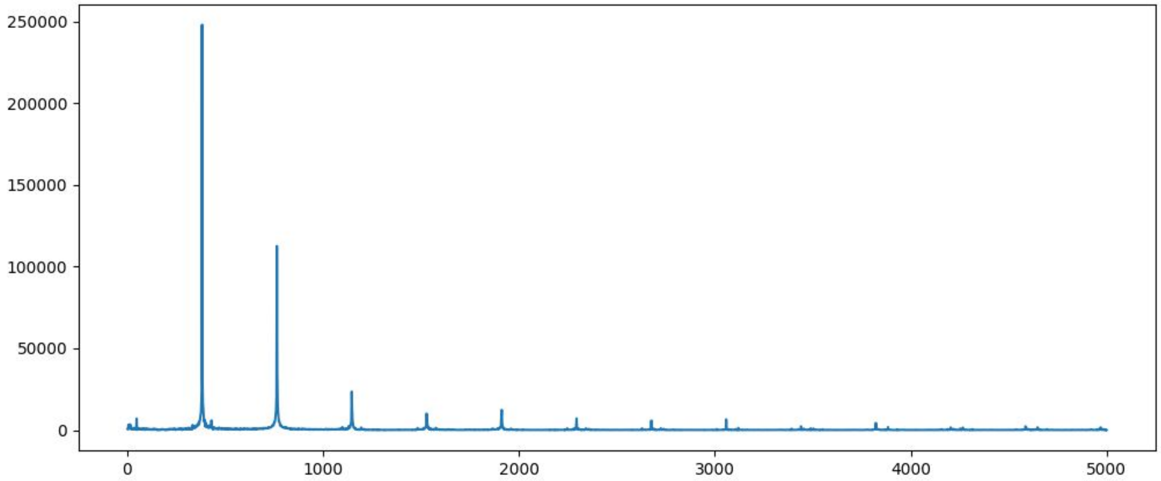
Bandpass FIR filters generated by us



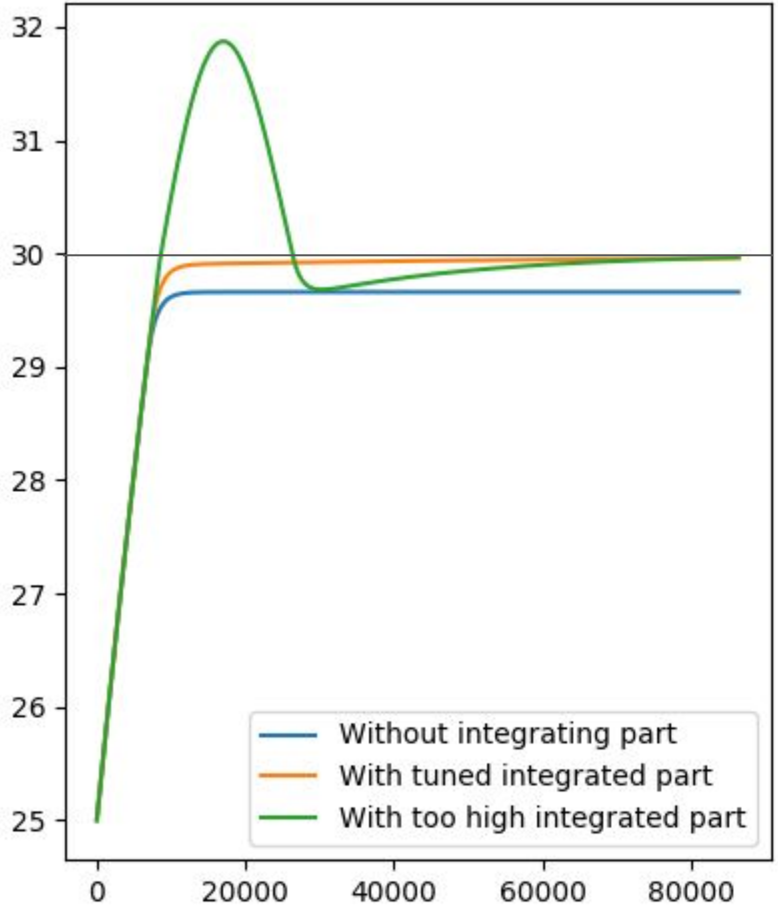


Registered signal (300 Hz sine)

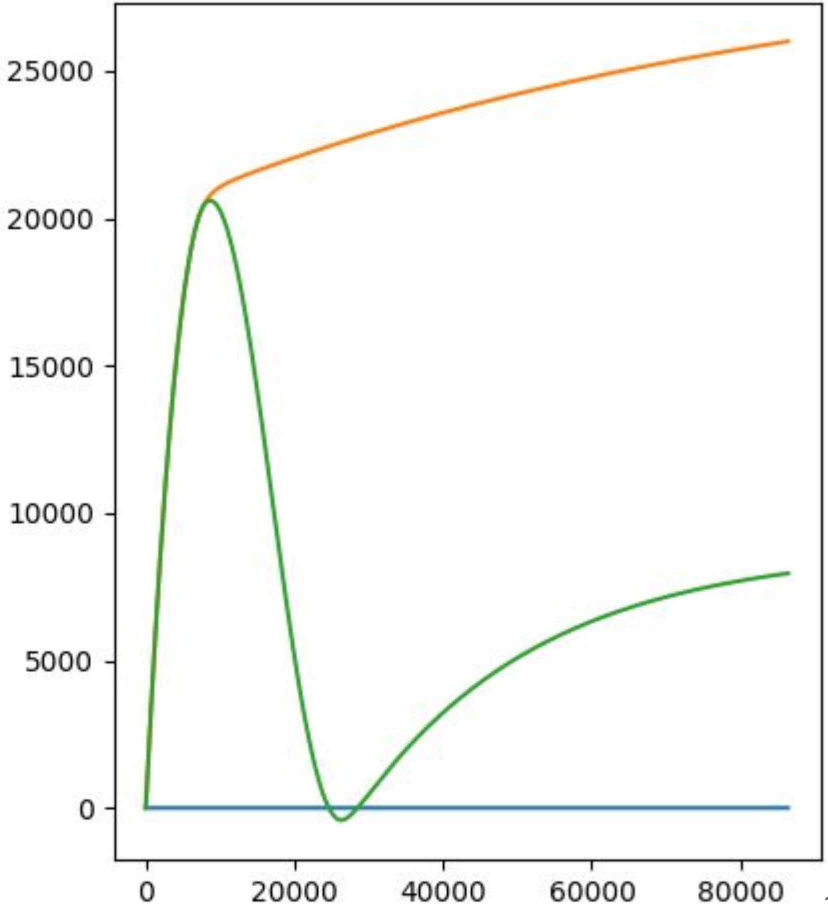
And its spectrum after Fourier transform



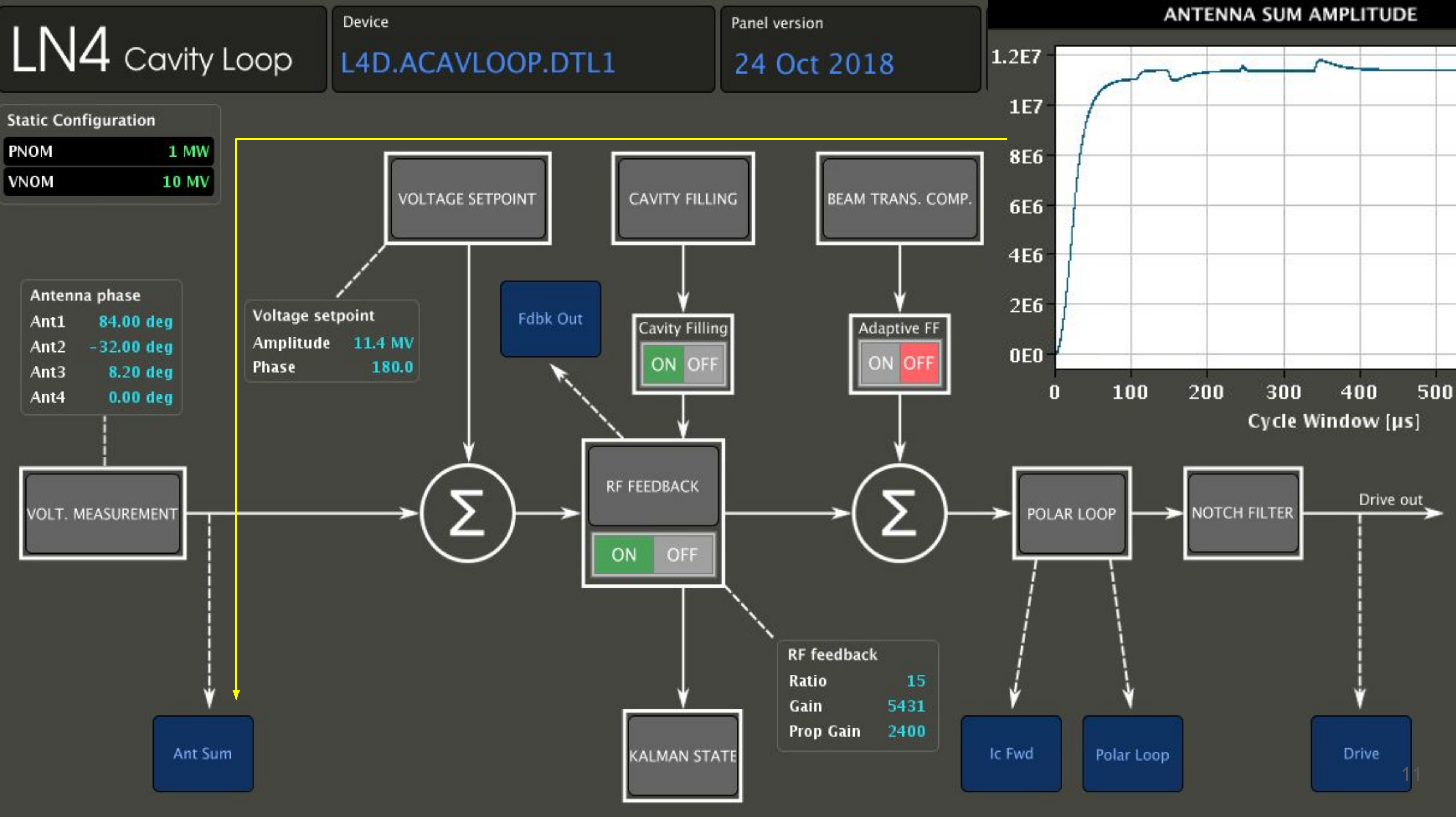
Feedback loop - simulated aquarium

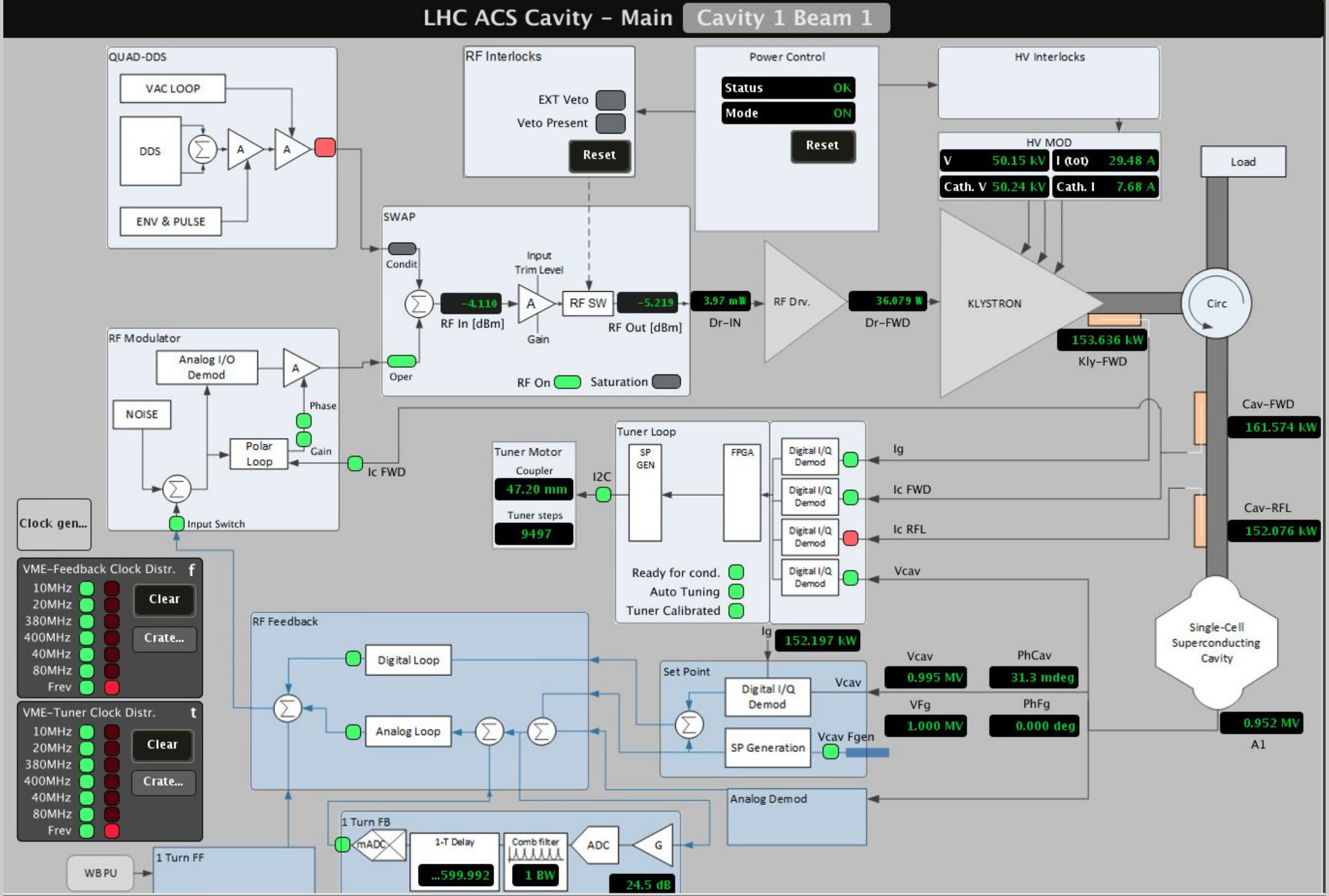


Temperatures

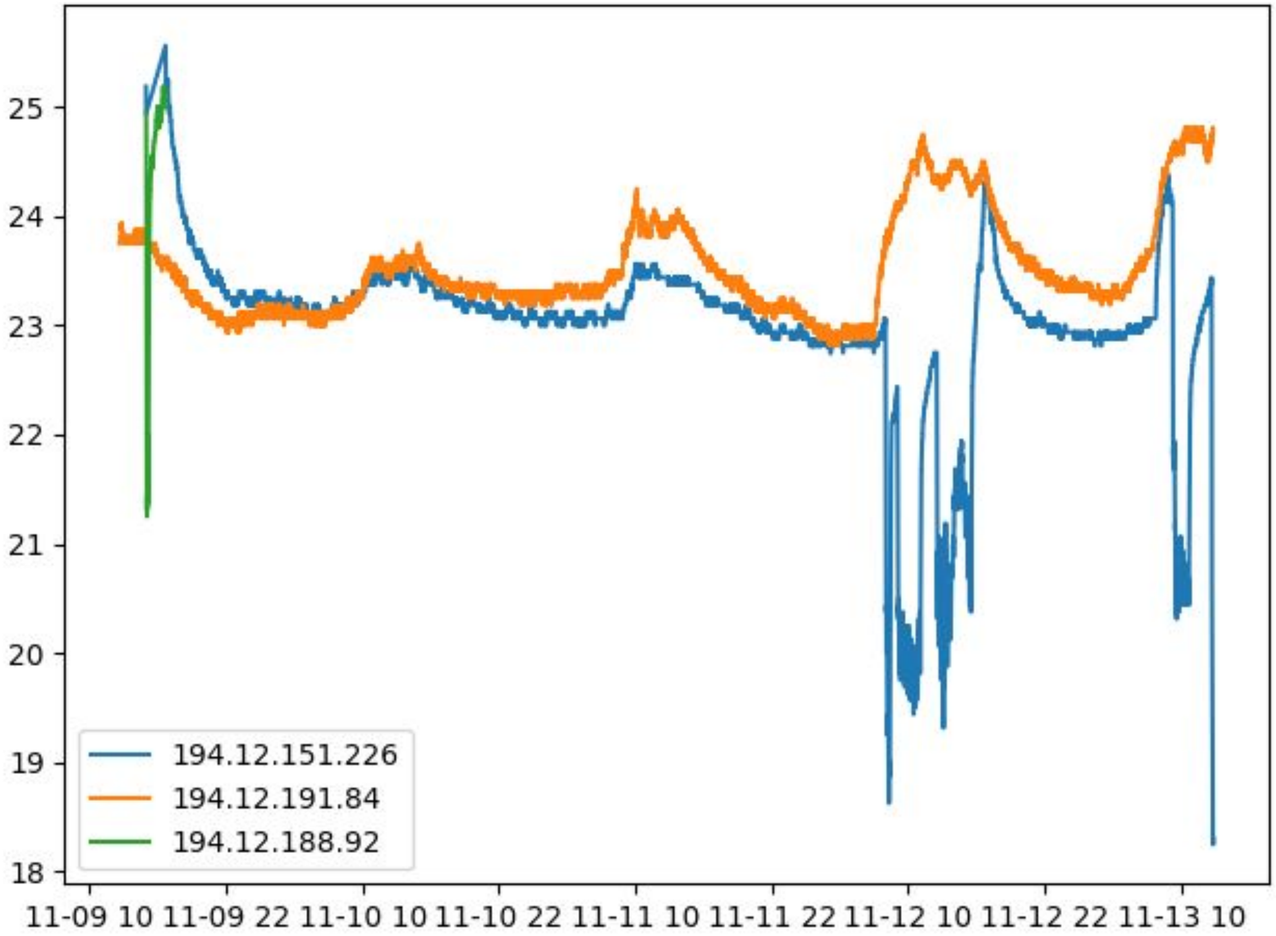


Integrated error value

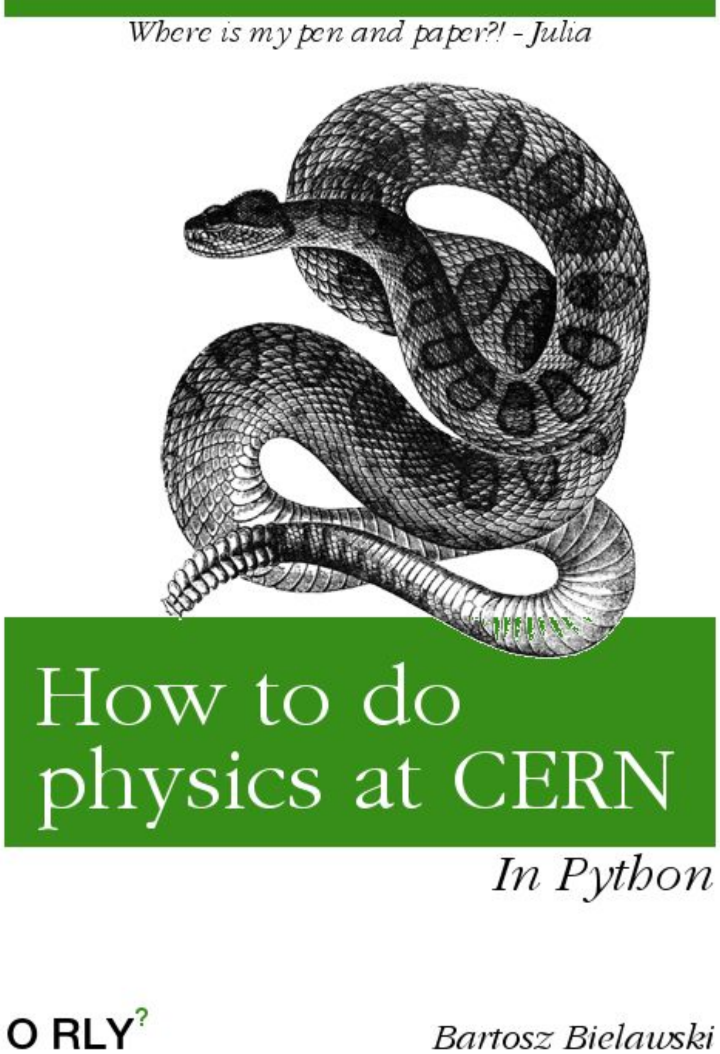

LN4 Cavity Loop
Device
L4D.ACAVLOOP.DTL1
Panel version
24 Oct 2018
ANTENNA SUM AMPLITUDE
1.2E7
1E7
8E6
6E6
4E6
2E6
0E0
0
100
200
300
400
500
Cycle Window [µs]
Static Configuration
PNOM 1 MW
VNOM 10 MV
VOLTAGE SETPOINT
CAVITY FILLING
BEAM TRANS. COMP.
Antenna phase
Ant1 84.00 deg
Ant2 -32.00 deg
Ant3 8.20 deg
Ant4 0.00 deg
Voltage setpoint
Amplitude 11.4 MV
Phase 180.0
Fdbk Out
Cavity Filling
ON OFF
Adaptive FF
ON OFF
VOLT. MEASUREMENT
RF FEEDBACK
ON OFF
POLAR LOOP
NOTCH FILTER
Drive out
RF feedback
Ratio 15
Gain 5431
Prop Gain 2400
Ant Sum
KALMAN STATE
Ic Fwd
Polar Loop
Drive


LHC ACS Cavity - Main
Cavity 1 Beam 1
QUAD-DDS
VAC LOOP
DDS
A
ENV & PULSE
RF Interlocks
EXT Veto
Veto Present
Reset
Power Control
Status OK
Mode ON
Reset
HV Interlocks
HV MOD
V 50.15 kV
I (tot) 29.48 A
Cath. V 50.24 kV
Cath. I 7.68 A
Load
SWAP
Condit
Input Trim Level
-4.110
RF In [dBm]
Gain
RF SW
-5.219
RF Out [dBm]
Oper
RF On
Saturation
3.97 mW
Dr-IN
RF Drv.
36.079 W
Dr-FWD
KLYSTRON
Circ
153.636 kW
Kly-FWD
RF Modulator
Analog I/O Demod
Phase
NOISE
Polar Loop
Gain
Ic FWD
Input Switch
Cav-FWD
161.574 kW
Tuner Loop
SP GEN
FPGA
Digital I/Q Demod
Ig
Ic FWD
Ic RFL
Vcav
Cav-RFL
152.076 kW
Tuner Motor
Coupler
47.20 mm
Tuner steps
9497
I2C
Ready for cond.
Auto Tuning
Tuner Calibrated
Clock gen...
VME-Feedback Clock Distr. f
10MHz
20MHz
380MHz
400MHz
40MHz
80MHz
Frev
Clear
Crate...
VME-Tuner Clock Distr. t
10MHz
20MHz
380MHz
400MHz
40MHz
80MHz
Frev
Clear
Crate...
RF Feedback
Digital Loop
Analog Loop
Ig
152.197 kW
Set Point
Digital I/Q Demod
Vcav
SP Generation
Vcav Fgen
Vcav
0.995 MV
PhCav
31.3 mdeg
VFg
1.000 MV
PhFg
0.000 deg
Single-Cell Superconducting Cavity
0.952 MV
A1
Analog Demod
1 Turn FB
mADC
1-T Delay
...599.992
Comb filter
1 BW
ADC
G
24.5 dB
1 Turn FF
WB PU

Data collection - temperatures in offices



Conclusion:


Where is my pen and paper?! - Julia
How to do physics at CERN
In Python
O RLY?
Bartosz Bielawski