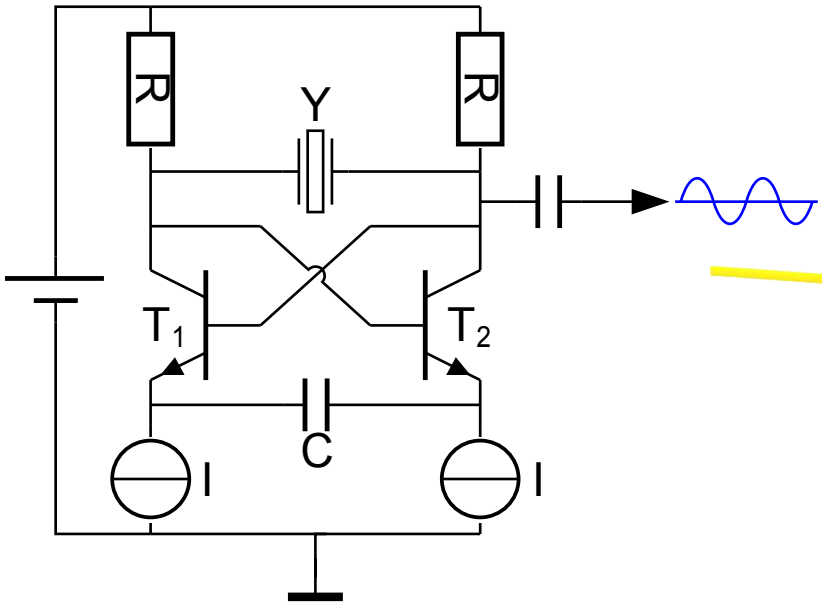
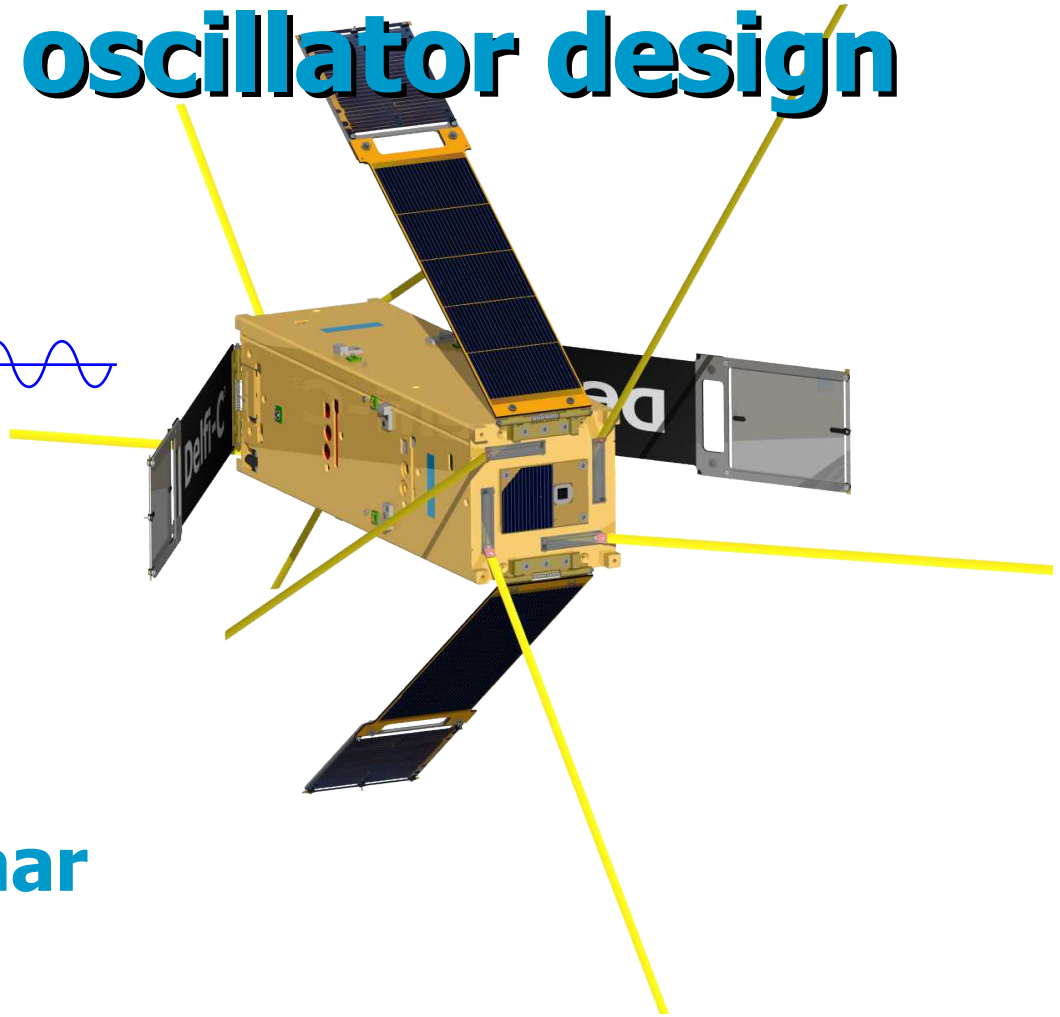
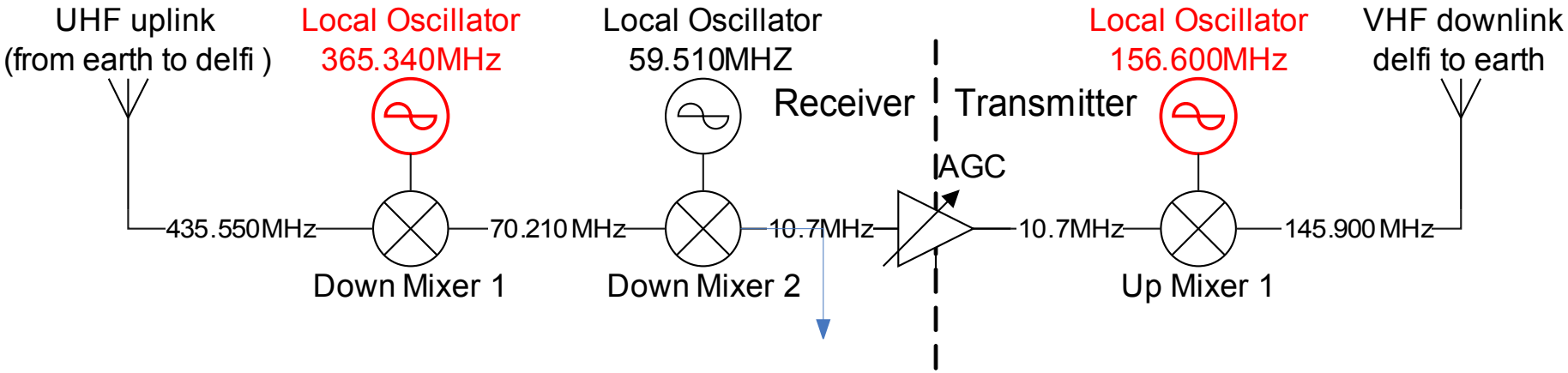
Delfi-C3 local oscillator design

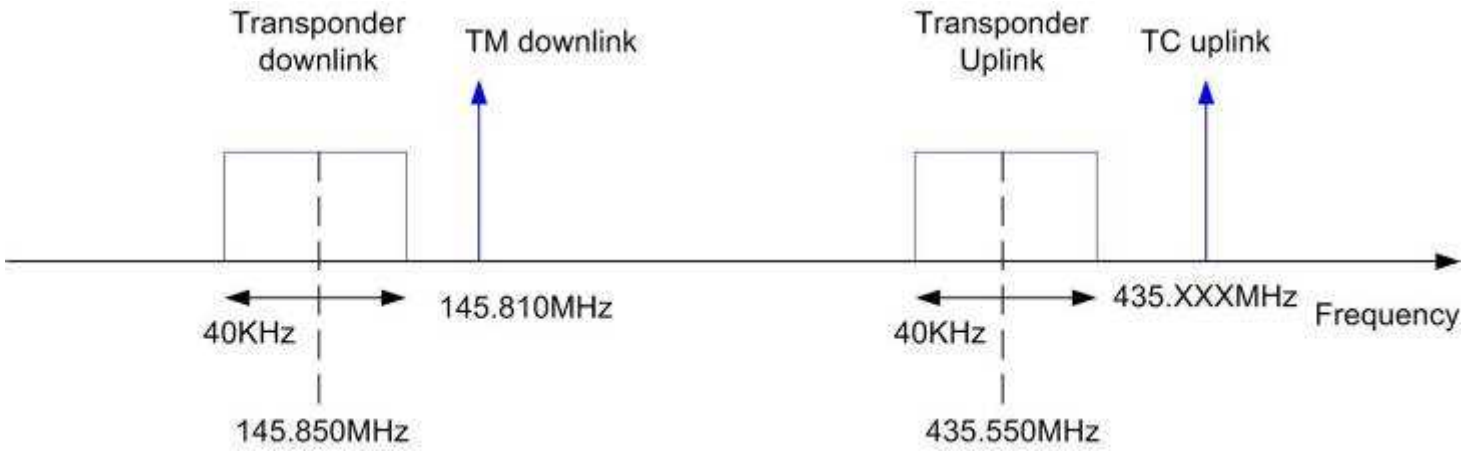




Wouter Weggelaar
PA3WEG

Transceiver



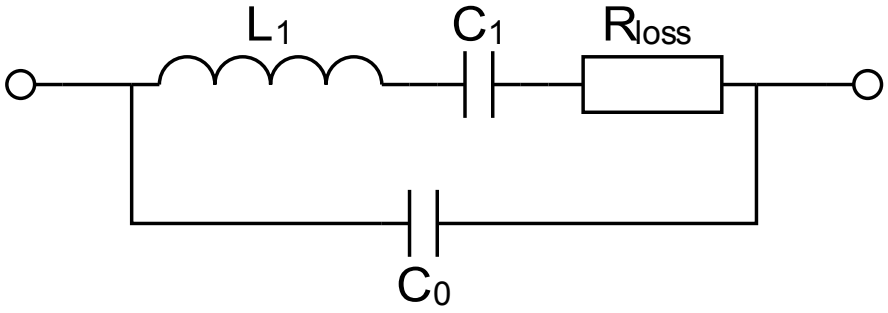


What are oscillators?

- An oscillator is a system that can generate a periodic signal out of constants
- There has to be a minimum of one timing component
- Order
  - First
  - Second
  - Third

Crystals

- Thin piece of (synthetic) quartz crystal
- Piezo-electric effect
- Mechanical resonance is coupled to electrical resonance
- Overtone resonance
- High Q-factor

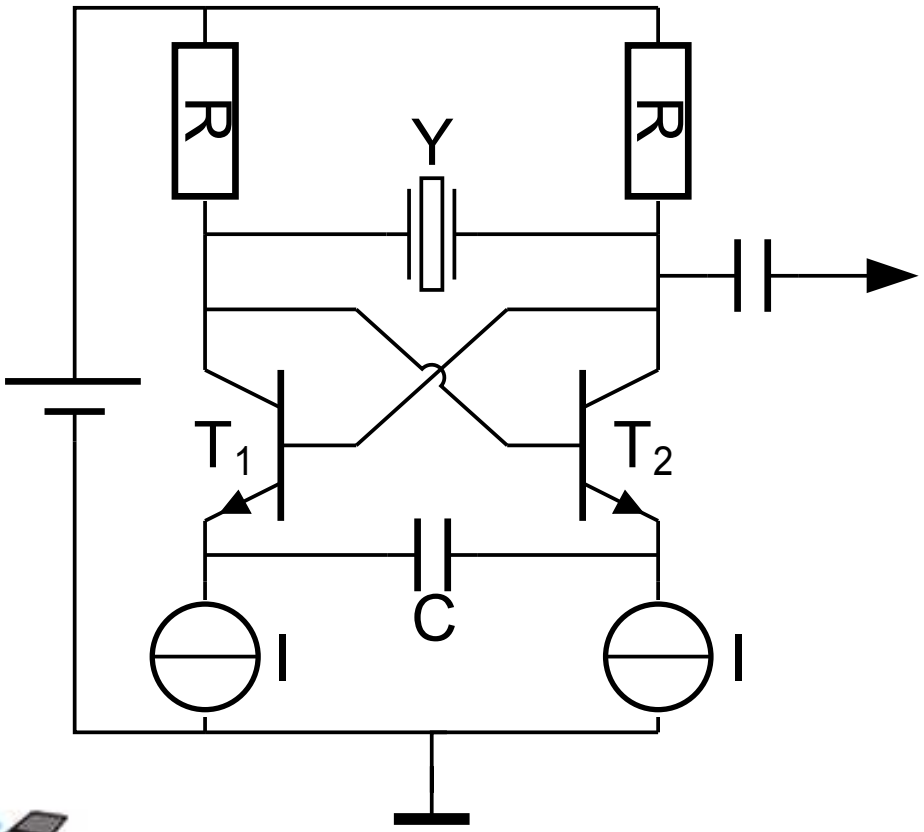


Local Oscillator requirements

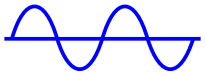
Parameter	Value
Frequency	156.600MHz, 365.34MHz
Output level	+7dBm
Output impedance	50 Ohm
Power	50mW
Temperature range	-20 - +60 ºC
Supply voltage	3V3 or 5V

- Small, lightweight and preferably SMD
- Can handle vacuum, radiation, vibration and shock

Why a Resonator synchronized emitter coupled relaxation oscillator?



- Only a few components
- Crystal dominates behaviour (no suprises!)
- small "board space"

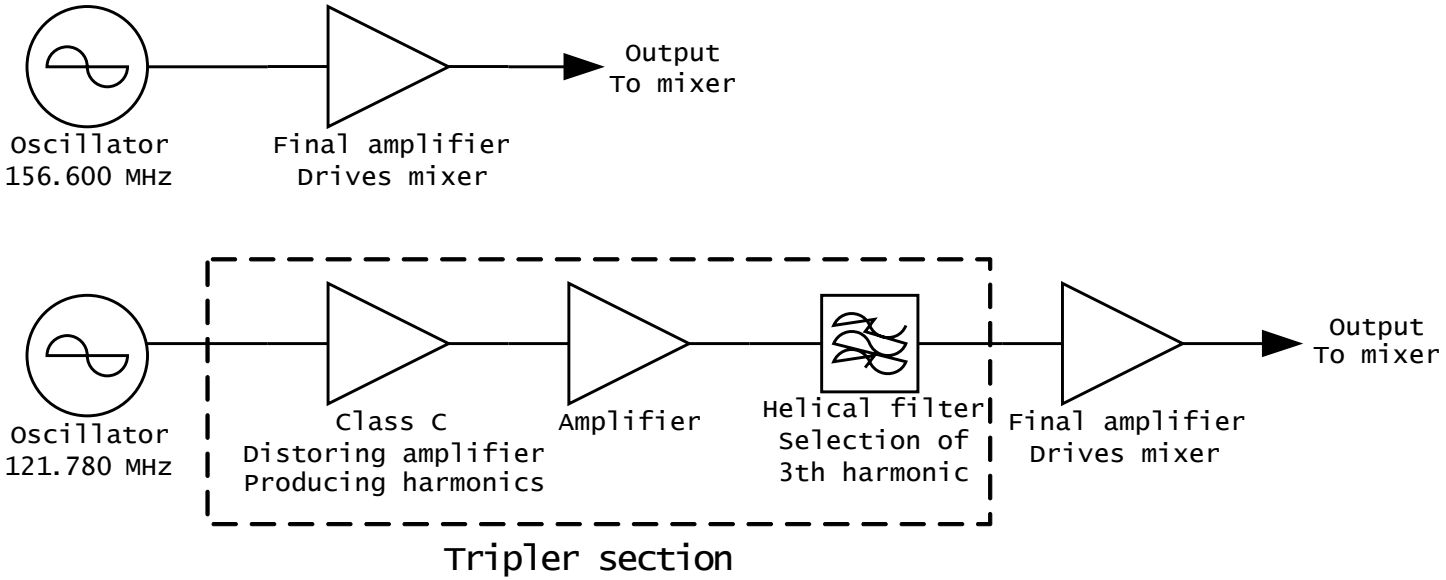


- First order behaviour

Downsides:

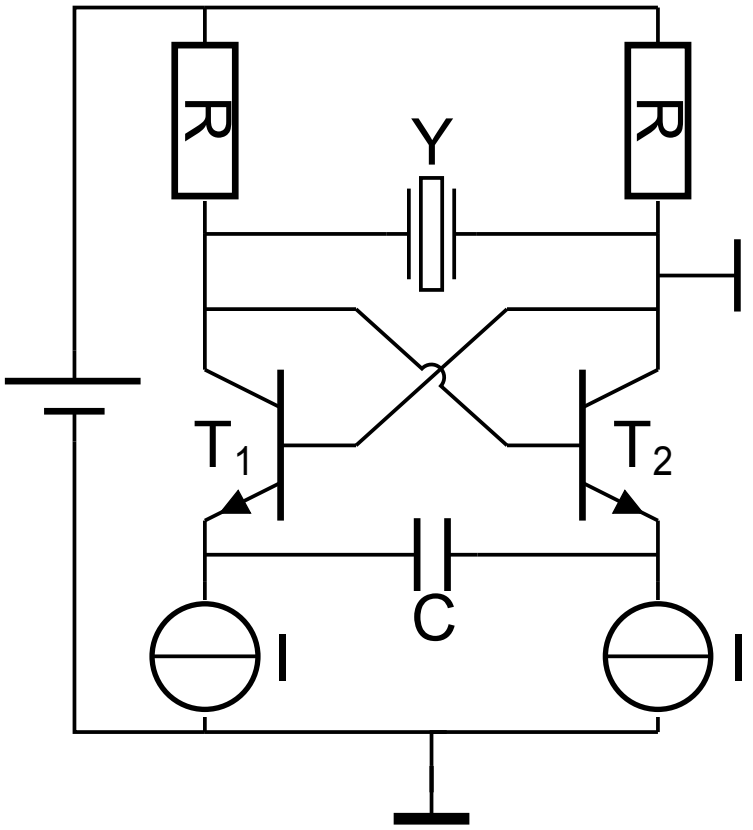
- New concept
- Has never flown in space!

Transmitter (TX) and Receiver (RX) LO

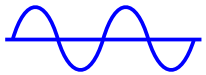


- TX LO directly on 156.600MHz
- RX LO on 121.78MHz multiplied by 3 by the tripler circuit

Relaxation oscillator



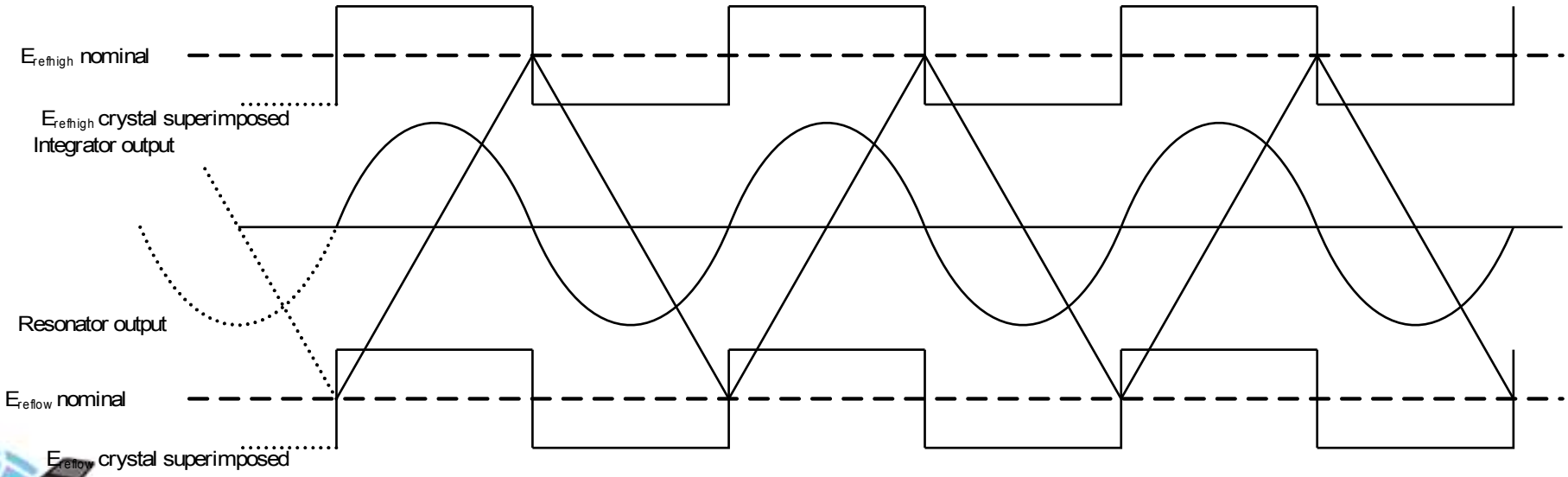
- T1 and T2 form a schmitt-trigger



- C as integrator defines the time constant

Relaxation oscillator

- Crystal can "alter" the threshold of the schmitt-trigger
- Transitions can take place earlier
- Crystal dominates the timing

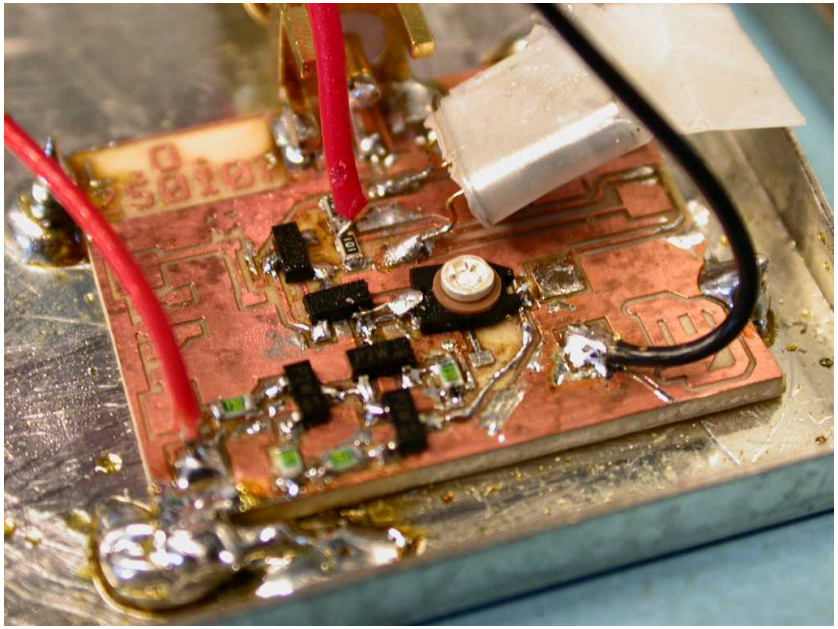


Tripler block

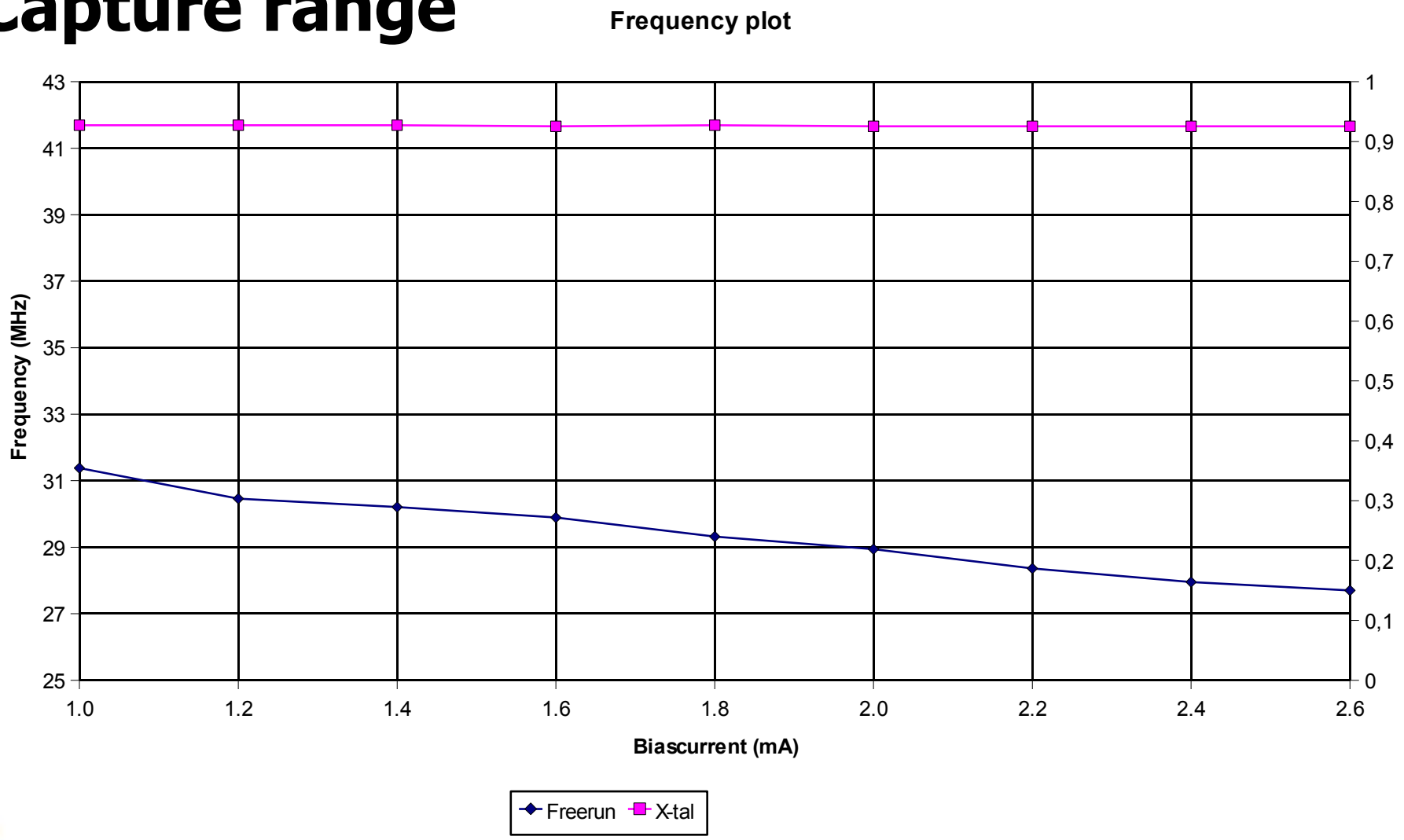
- Multiply frequency by 3
- Class C clipping amplifier
  - Harmonics
- Filter the correct harmonic using a helical filter
- Amplify signal (BFR92A, BFR380)

Capture range

- At which freerunning frequency does the crystal "lock"?
- Has transistor biasing any influence?



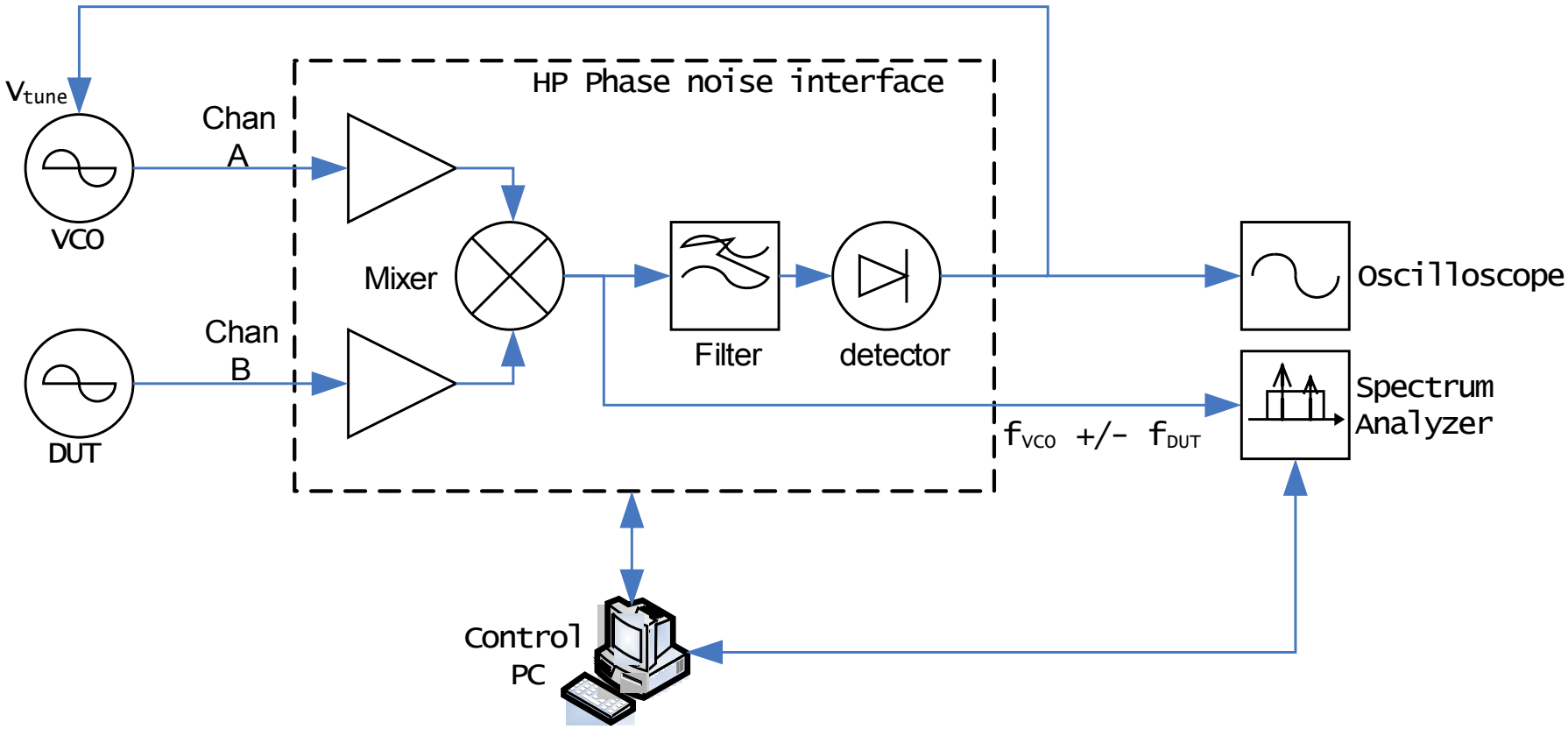
Capture range

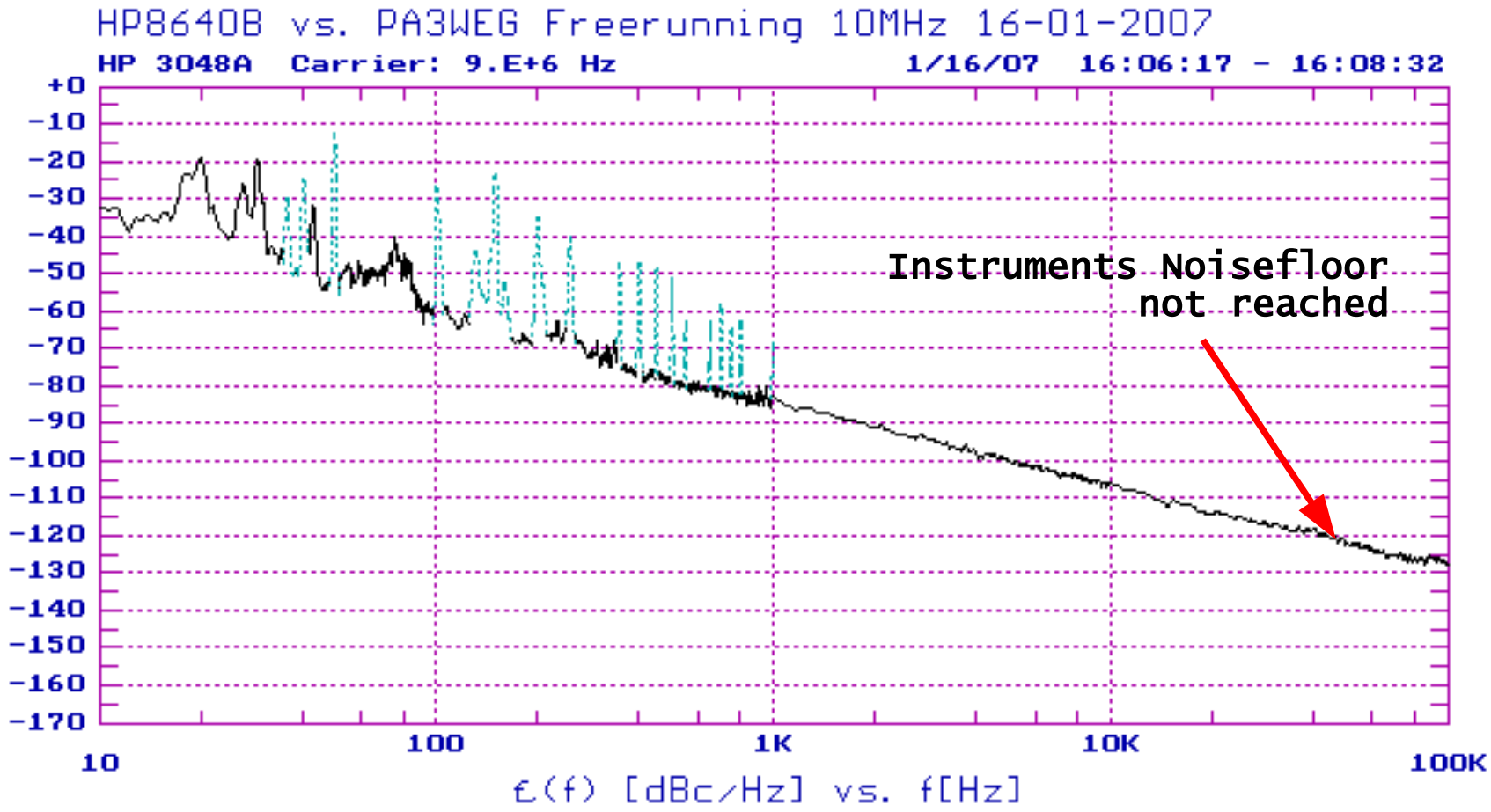


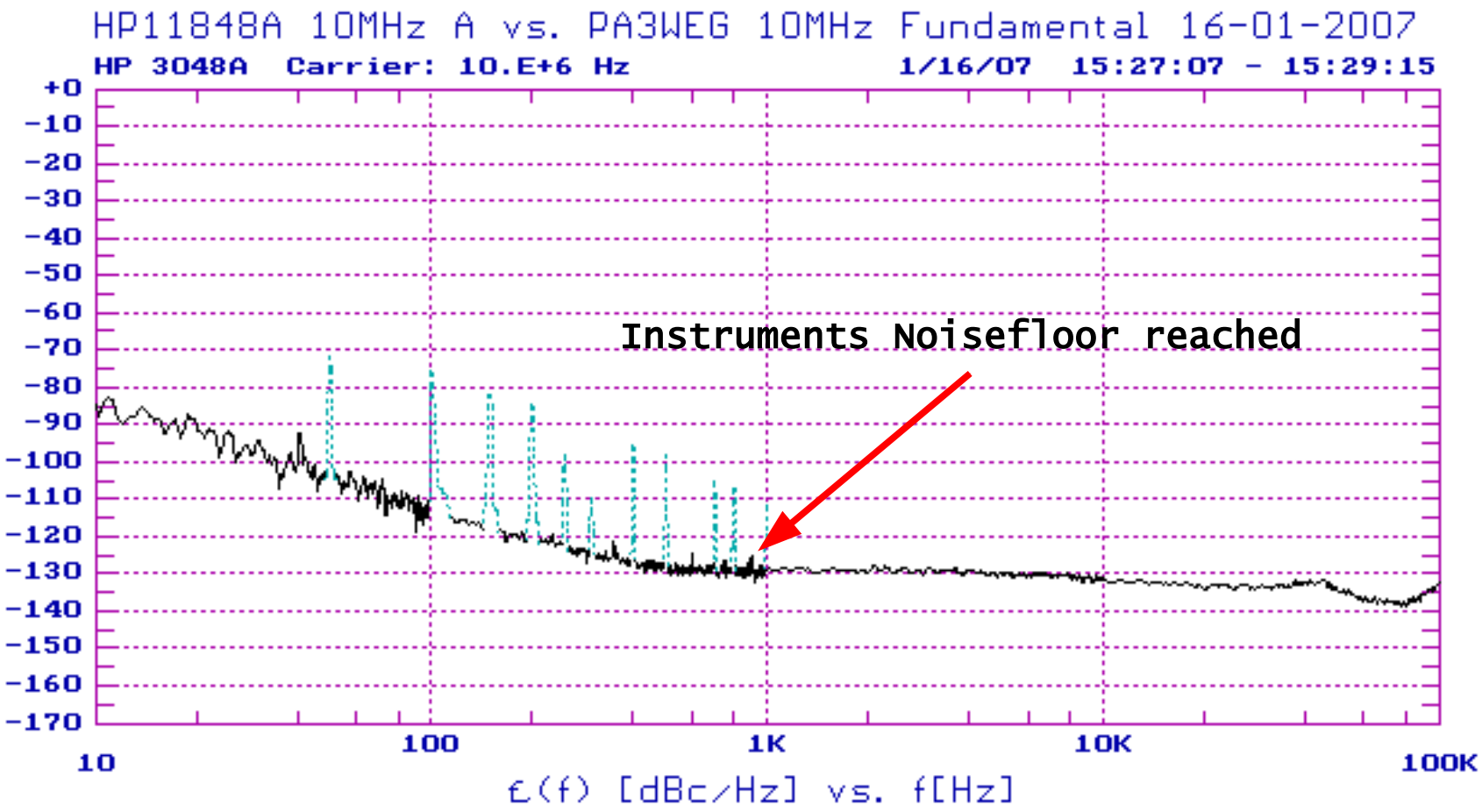
Phase noise

- Change of phase compared to the desired LO
- Can be mixed and demodulated
- Reciprocal mixing!

Measuring Phase Noise

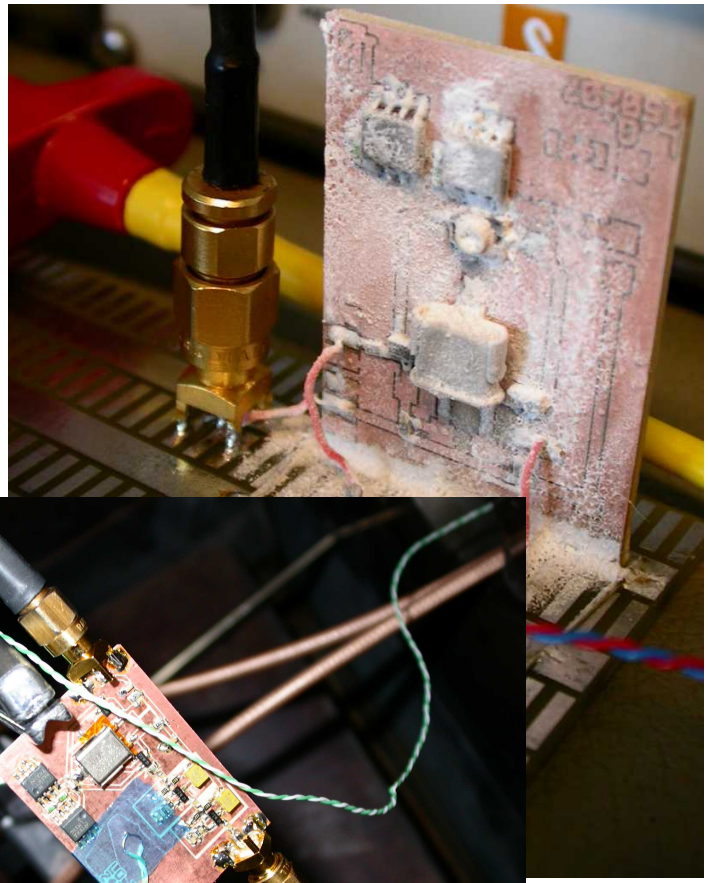


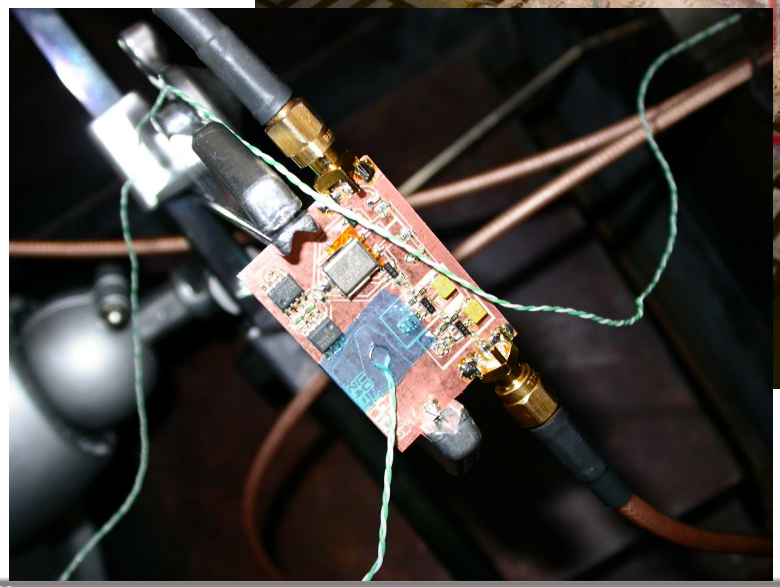

HP8640B vs. PA3WEG Freerunning 10MHz 16-01-2007
HP 3048A Carrier: 9.E+6 Hz
1/16/07 16:06:17 - 16:08:32
+0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
10
100
1K
10K
100K
ℒ(f) [dBc/Hz] vs. f[Hz]
Instruments Noisefloor
not reached

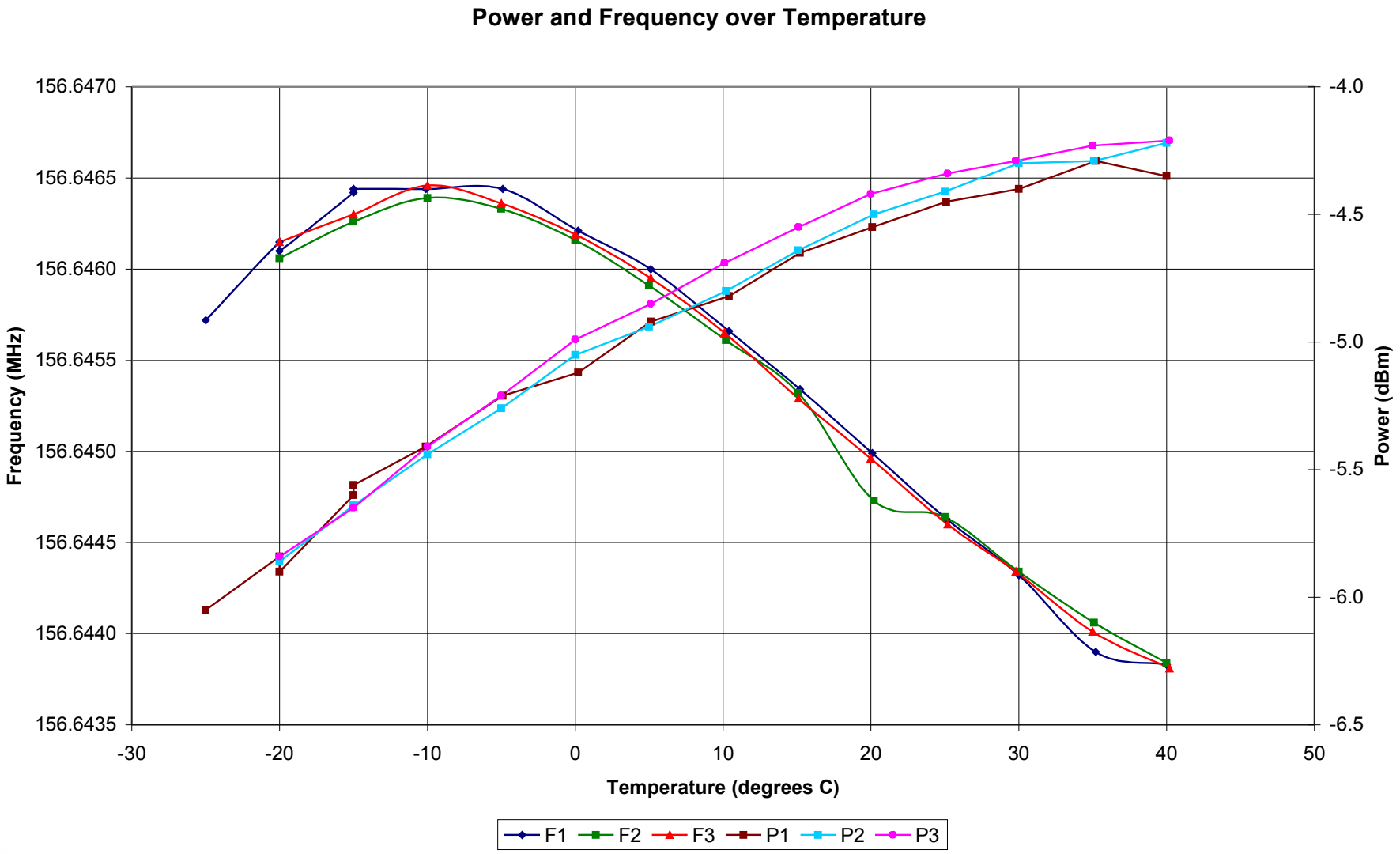

HP11848A 10MHz A vs. PA3WEG 10MHz Fundamental 16-01-2007
HP 3048A Carrier: 10.E+6 Hz
1/16/07 15:27:07 - 15:29:15
+0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
10
100
1K
10K
100K
Instruments Noisefloor reached
ℒ(f) [dBc/Hz] vs. f[Hz]

Temperature measurements

- -20 to +50°C
- Measured:
  - Frequency
  - Output level
  - "Look" at the signal on a scope
  - Temperature on the crystal measured

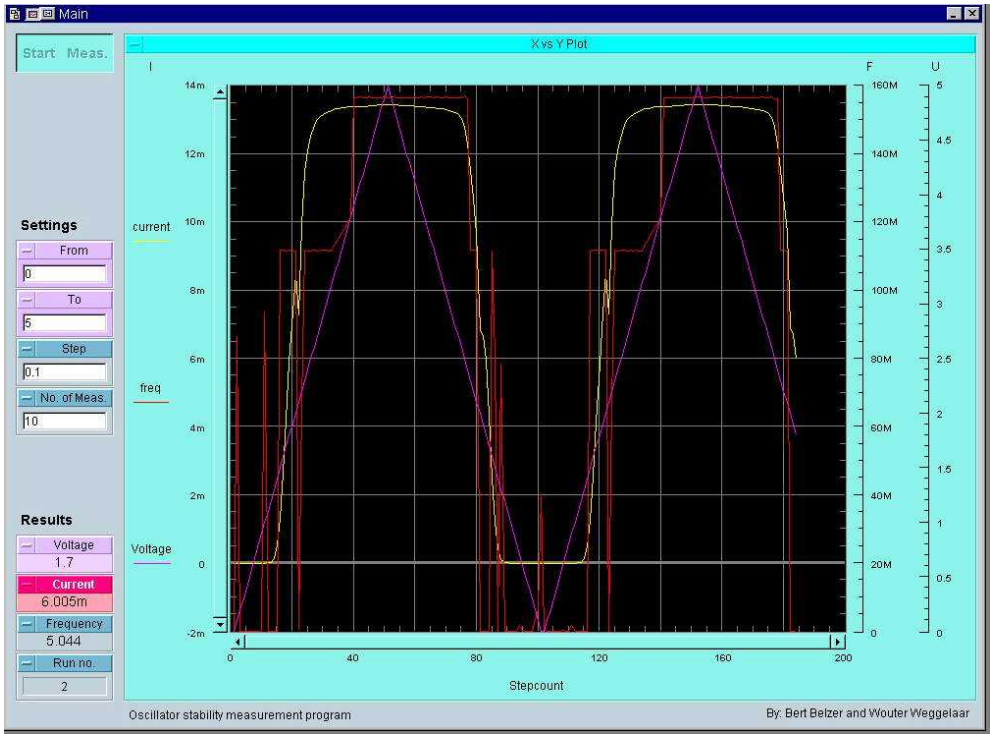


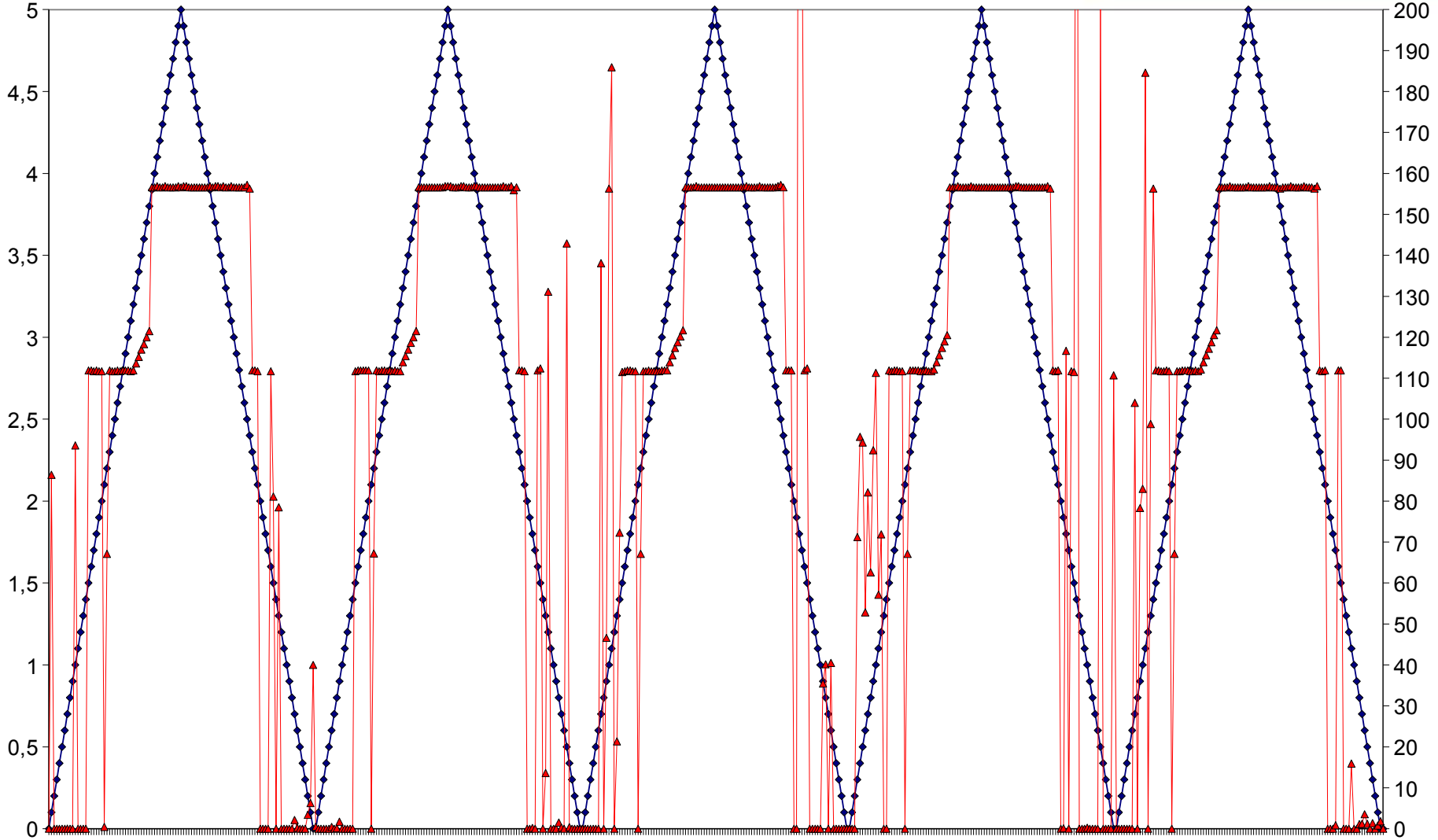



Power and Frequency over Temperature
156.6470
156.6465
156.6460
156.6455
156.6450
156.6445
156.6440
156.6435
Frequency (MHz)
-4.0
-4.5
-5.0
-5.5
-6.0
-6.5
Power (dBm)
-30
-20
-10
0
10
20
30
40
50
Temperature (degrees C)
F1
F2
F3
P1
P2
P3

Power Supply vs Frequency

- How does the circuit react to different supply voltages
- Measurement by computer
- HP-VEE program




5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

results

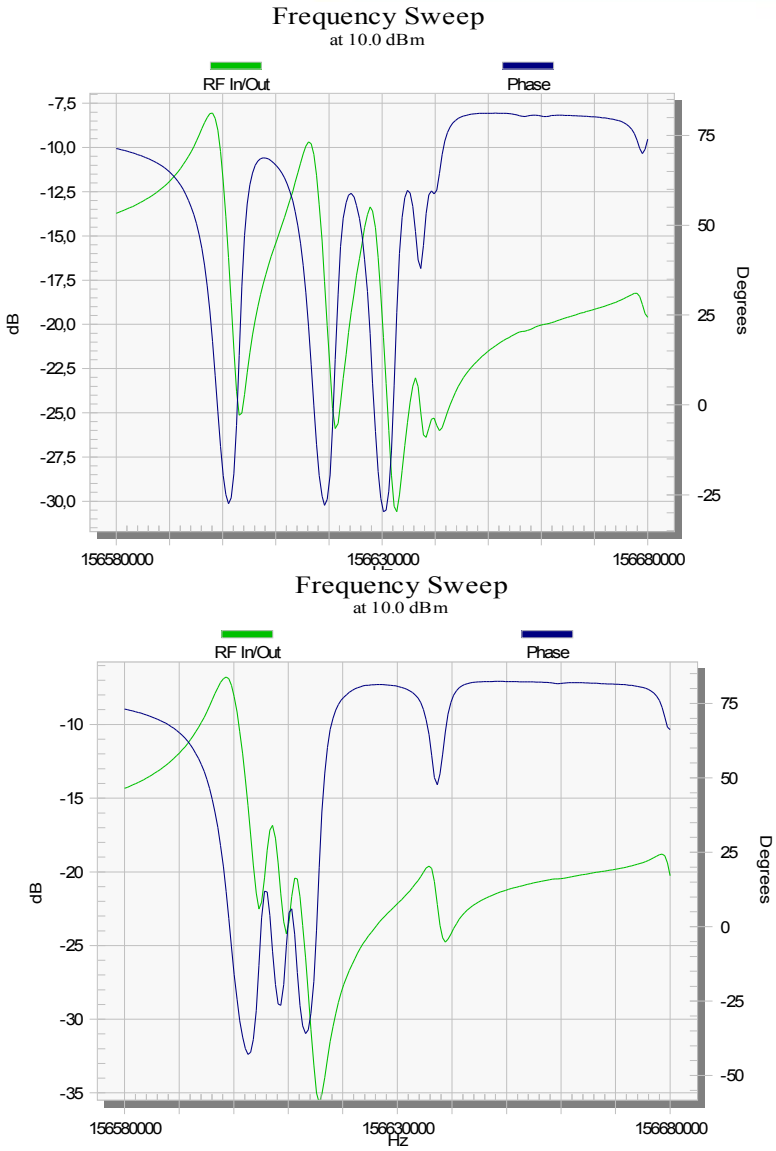
- Minimum supply voltage known
- Adjust freerunning frequency if supply is to be lower
- Proves lock and hold range theory

Problems faced

- Lay-out
  - Undesired signal pickup
  - Print capacity
  - Crosstalk between TX and RX
- LO overdrives mixer
- Parasitics in the crystal

Parasitics

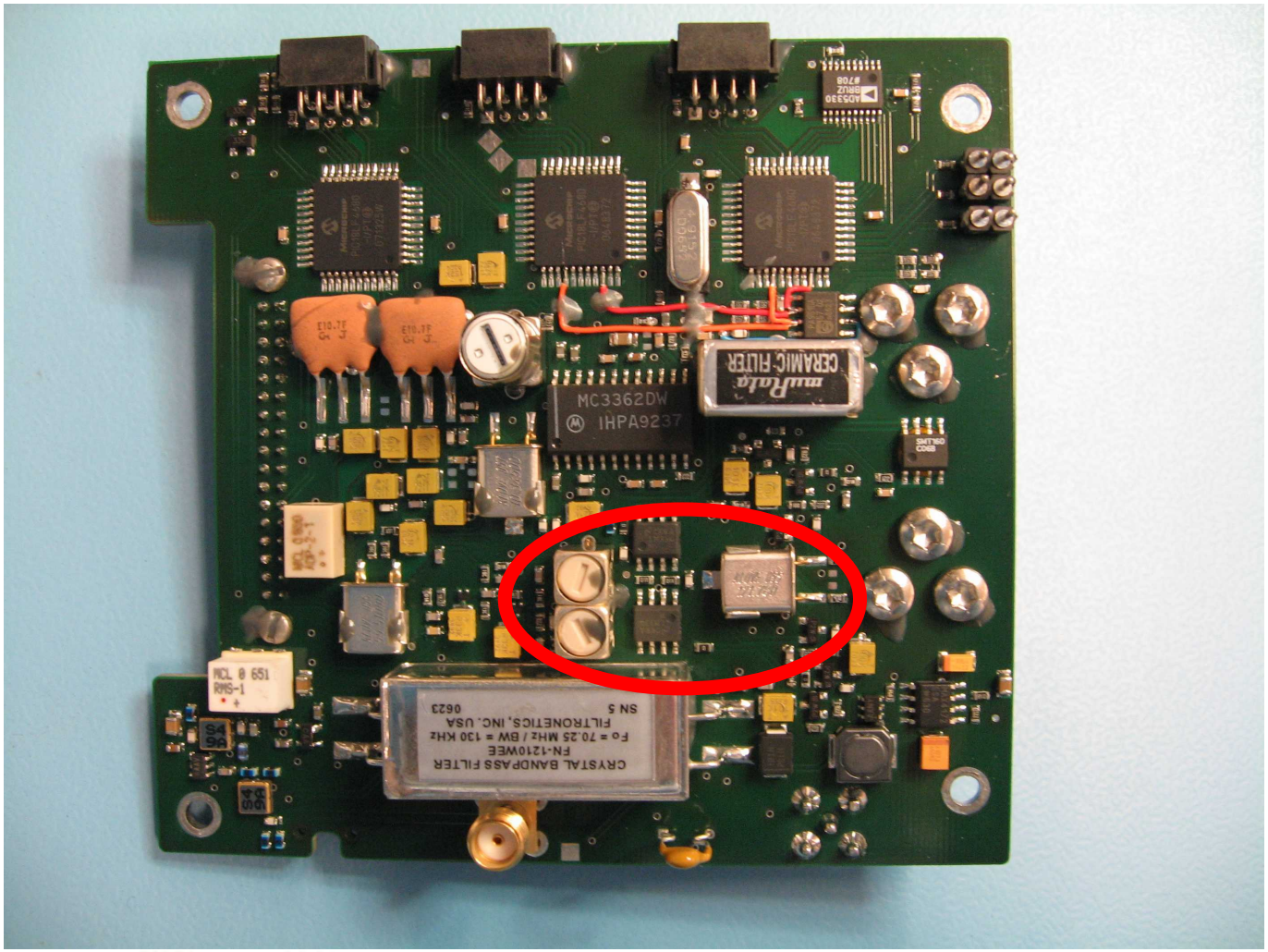
- Undesired resonance close to the desired frequency
- Dust and dirt
- High-Q parasitics means trouble!
- Selection from a batch of crystals



Parasitics

- Crystals for 156MHz now produced at 7th overtone and not on 5th
- Another Factory
- 5th overtone 156MHz was beyond manufacturers capabilities (but they tried anyway)

Results


MC3362DW
IHPA9237
CERAMIC-FILTER
CRYSTAL BANDPASS FILTER
FN-1210WEE
Fo = 70.25 MHz / BW = 130 KHz
FILTRONETICS, INC. USA
SN 5 0623

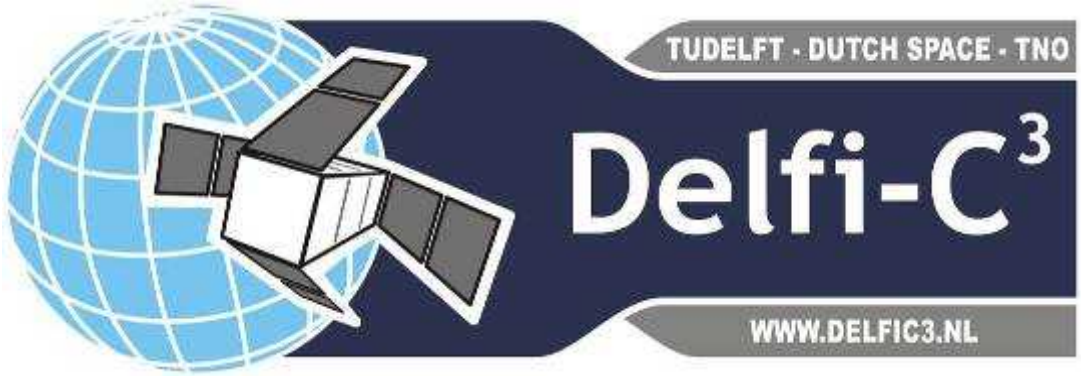
Results

- ✔ Flight hardware successful and operating in space
- ✔ Voltage output
- ✔ Impedance of less importance
- ✗ More Power consumption than estimated
  - ✔ No problem on power-budged

Parameter	Value specified	Value realized
Frequency	156,600MHz, 365,34MHz	156,600MHz, 365,34MHz
Output level	+7dBm	0,7V over mixerdiodes
Output impedance	50 Ohm	Not important
Power	**50mW**	**66mW**
Temperature range	-20 - +60 ºC	-20 - +50 ºC tested
Supply voltage	3V3 of 5V	3V3


Which results in THIS!
And soon a 5 by 9 from JO21ex!

QSL?



www.delfic3.nl

pa3weg@delfic3.nl