Vergelijkende metingen 10MHz

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PE1FOD

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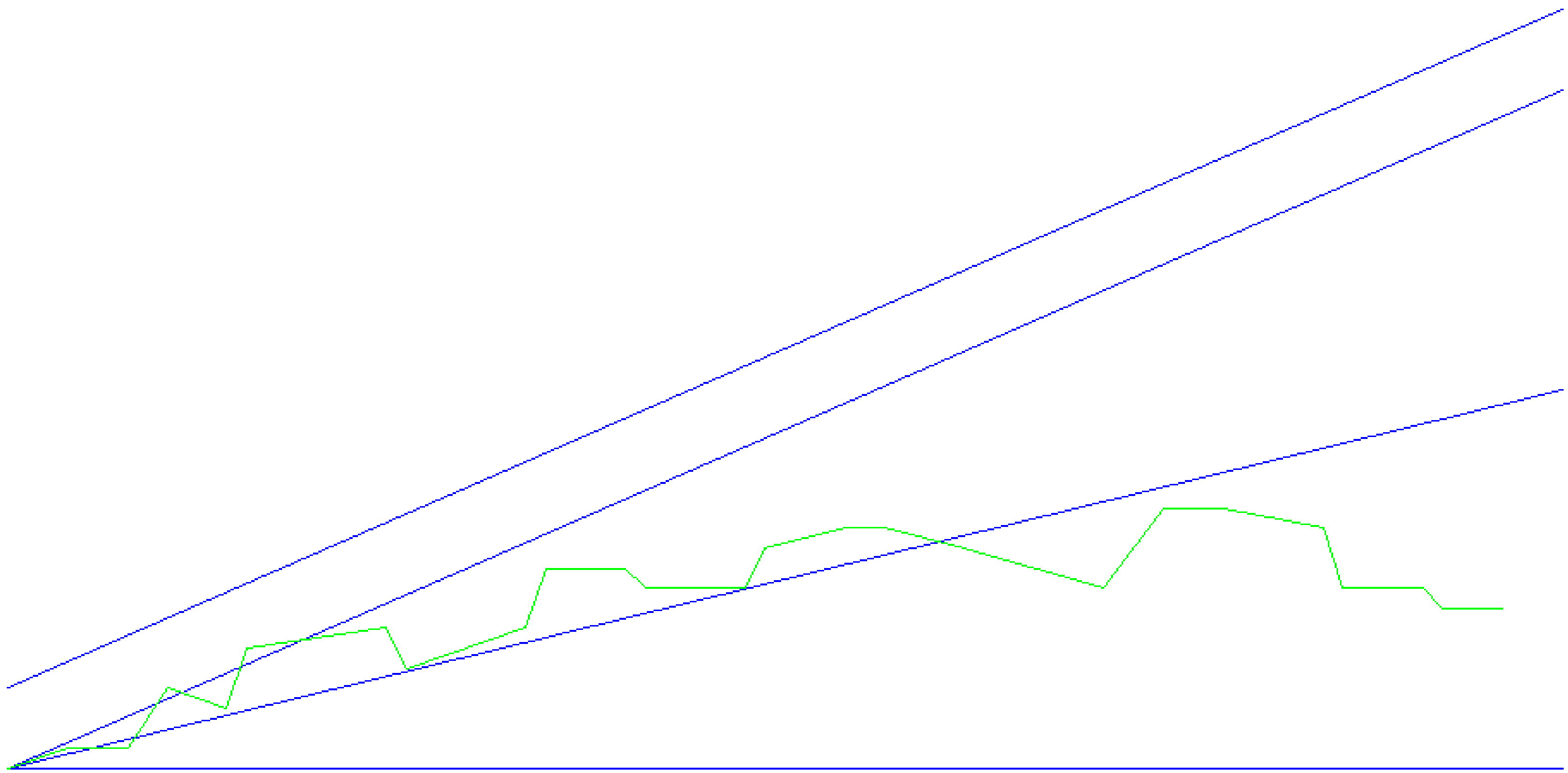
Basics van frequentiemeting

- Resolutie
  - denk aan aantal cijfers   10 000 000.000 (000)
- Nauwkeurigheid of accuratesse of juistheid
  - denk aan benadering van de werkelijke waarde

    10 000 001.000
- Stabiliteit, Presiecie of reproduceerbaarheid
  - denk aan procentuele afwijking per tijd, verloop

Stabiliteitsgrafiek



Frequentie meten

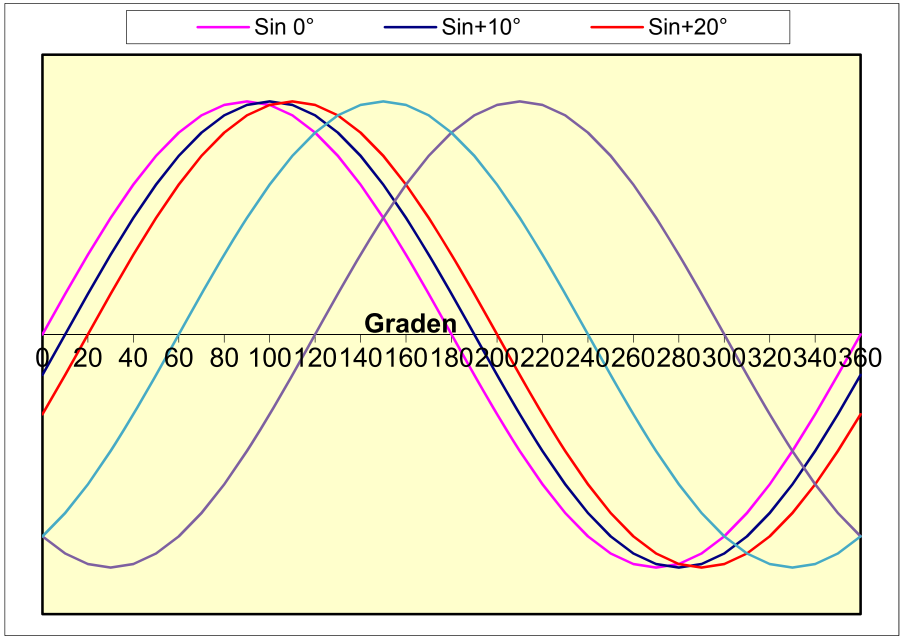
- Frequentieteller
  - Vergelijke van twee bronnen
    - Referentiefrequentie
    - DUT frequentie

Plaatje frequentiemeter

- Nauwkeurige en stabile referentiebron

Fasemeting

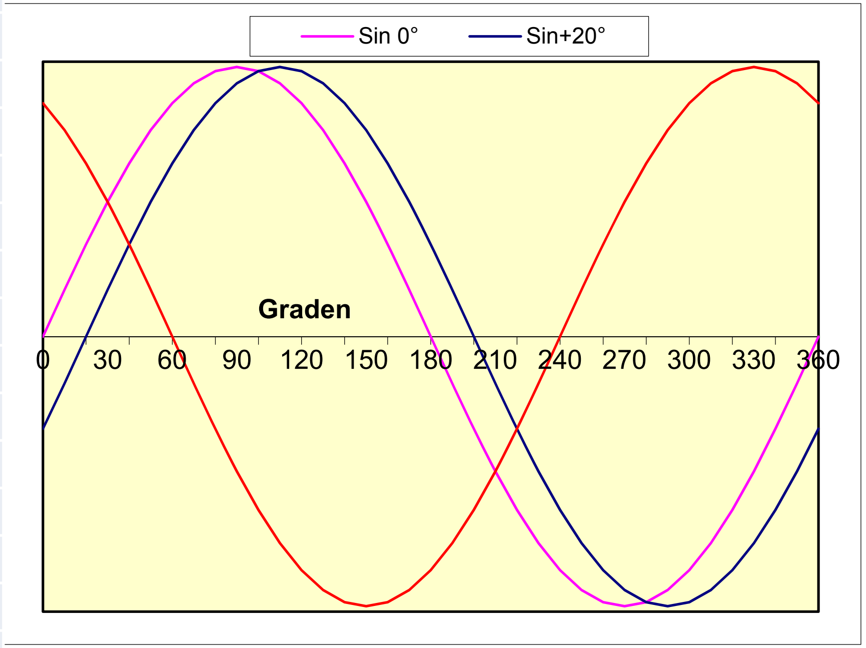
- Fasemeting
  - Fase vergelijking van DUT t.o.v, referentiesignaal
  - Hoe groter het faseverschil per tijd, hoe groter de frequentieafwijking
    - $\Delta\omega = \Delta\phi / \Delta t$
    - $\omega = 2\pi f$
    - ϕ in radialen
    - t in seconden



Fase verschill

10MHz

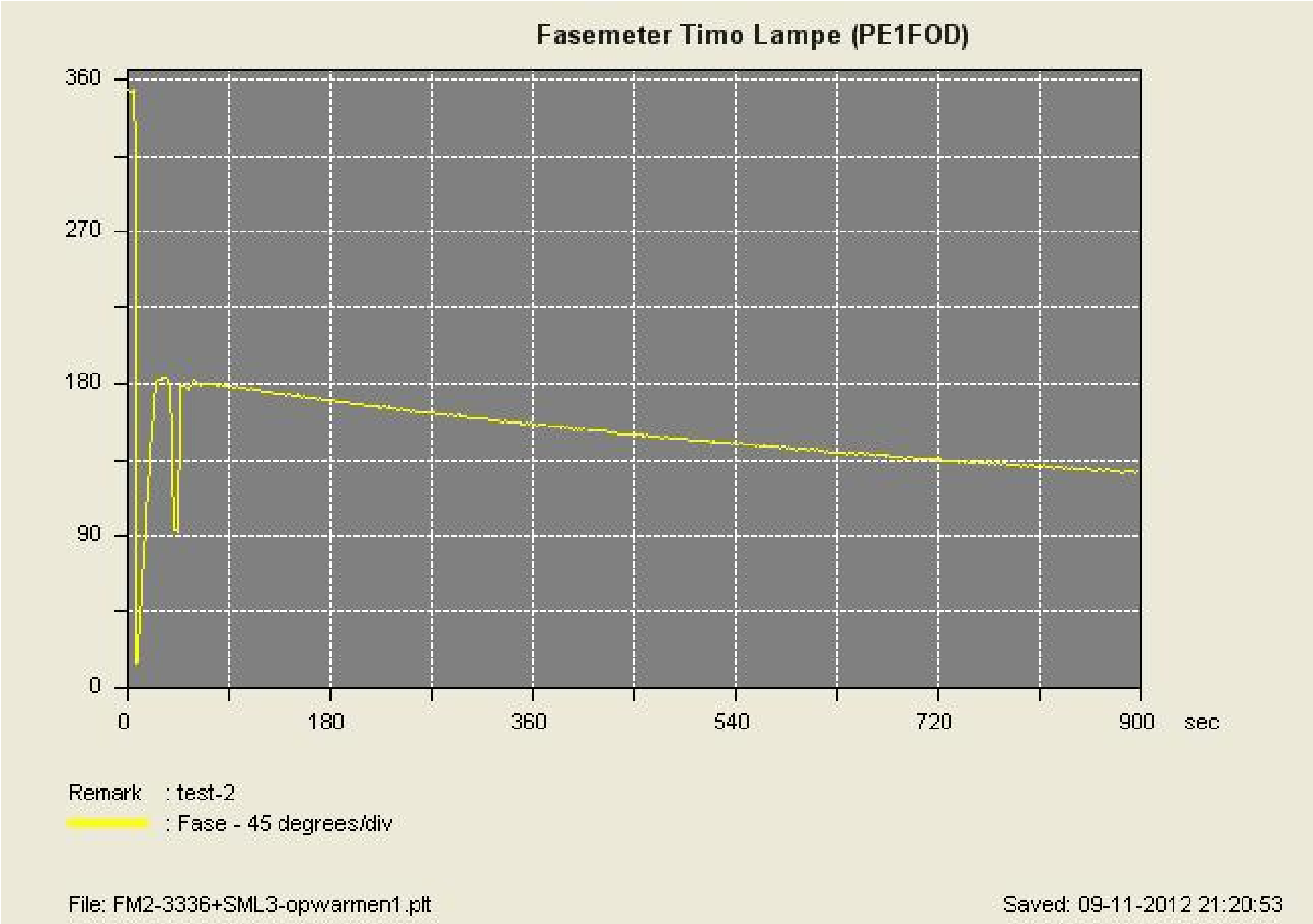
°	1	10	100	1000	Sec.
1	2.78E-10	2.78E-11	2.78E-12	2.78E-13	
2	5.56E-10	5.56E-11	5.56E-12	5.56E-13	
3.6	1.00E-09	1.00E-10	1.00E-11	1.00E-12	
5	1.39E-09	1.39E-10	1.39E-11	1.39E-12	
6	1.67E-09	1.67E-10	1.67E-11	1.67E-12	
7	1.94E-09	1.94E-10	1.94E-11	1.94E-12	
8	2.22E-09	2.22E-10	2.22E-11	2.22E-12	
10	2.78E-09	2.78E-10	2.78E-11	2.78E-12	
20	5.56E-09	5.56E-10	5.56E-11	5.56E-12	
36	1.00E-08	1.00E-09	1.00E-10	1.00E-11	
60	1.67E-08	1.67E-09	1.67E-10	1.67E-11	
120	3.33E-08	3.33E-09	3.33E-10	3.33E-11	
180	5.00E-08	5.00E-09	5.00E-10	5.00E-11	
360	**1.00E-07**	1.00E-08	1.00E-09	1.00E-10	
720	2.00E-07	2.00E-08	2.00E-09	2.00E-10	
1080	3.00E-07	3.00E-08	3.00E-09	3.00E-10	
1440	4.00E-07	4.00E-08	4.00E-09	4.00E-10	



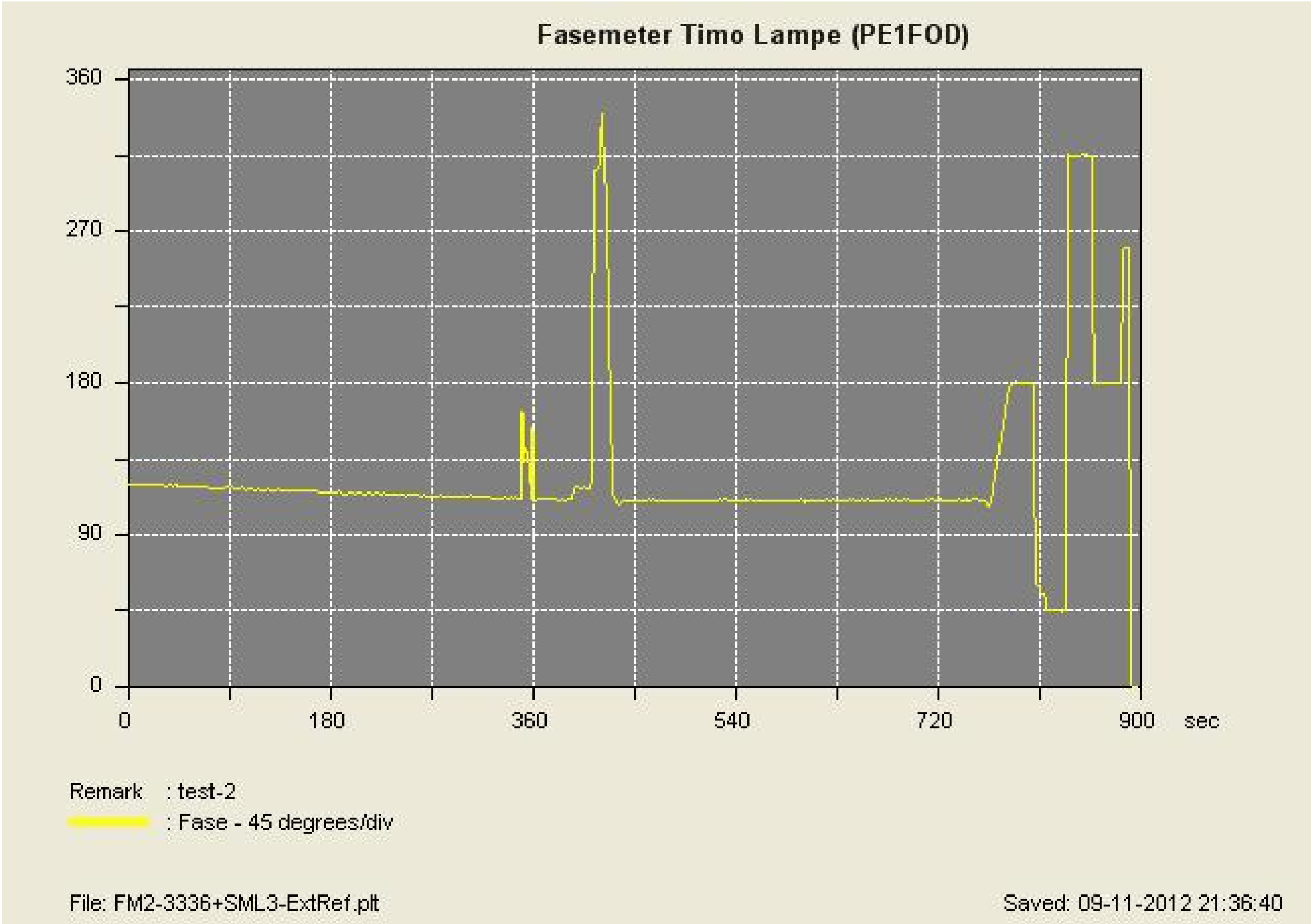
Tijdintervalmeting

- Meten van tijdverschil
- Met HP5370B, Racal 1992, Fluke 6680....
  - Tijdverschil tussen
    - Referentiesignaal
    - En DUT signaal
      - Meet tijd(fase, op de nuldoorgang)

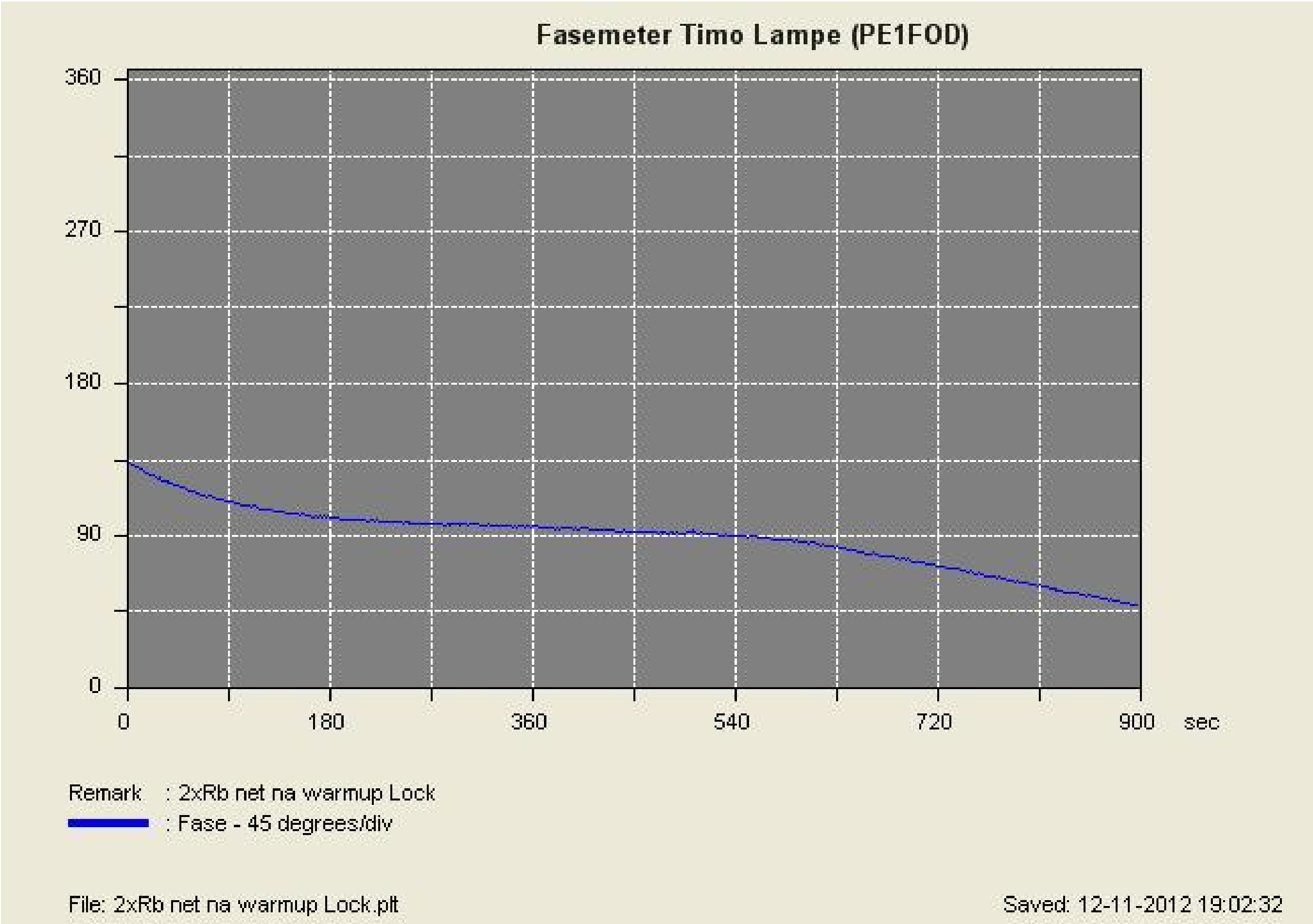
Fase meting SML03 <> Rb-FOD



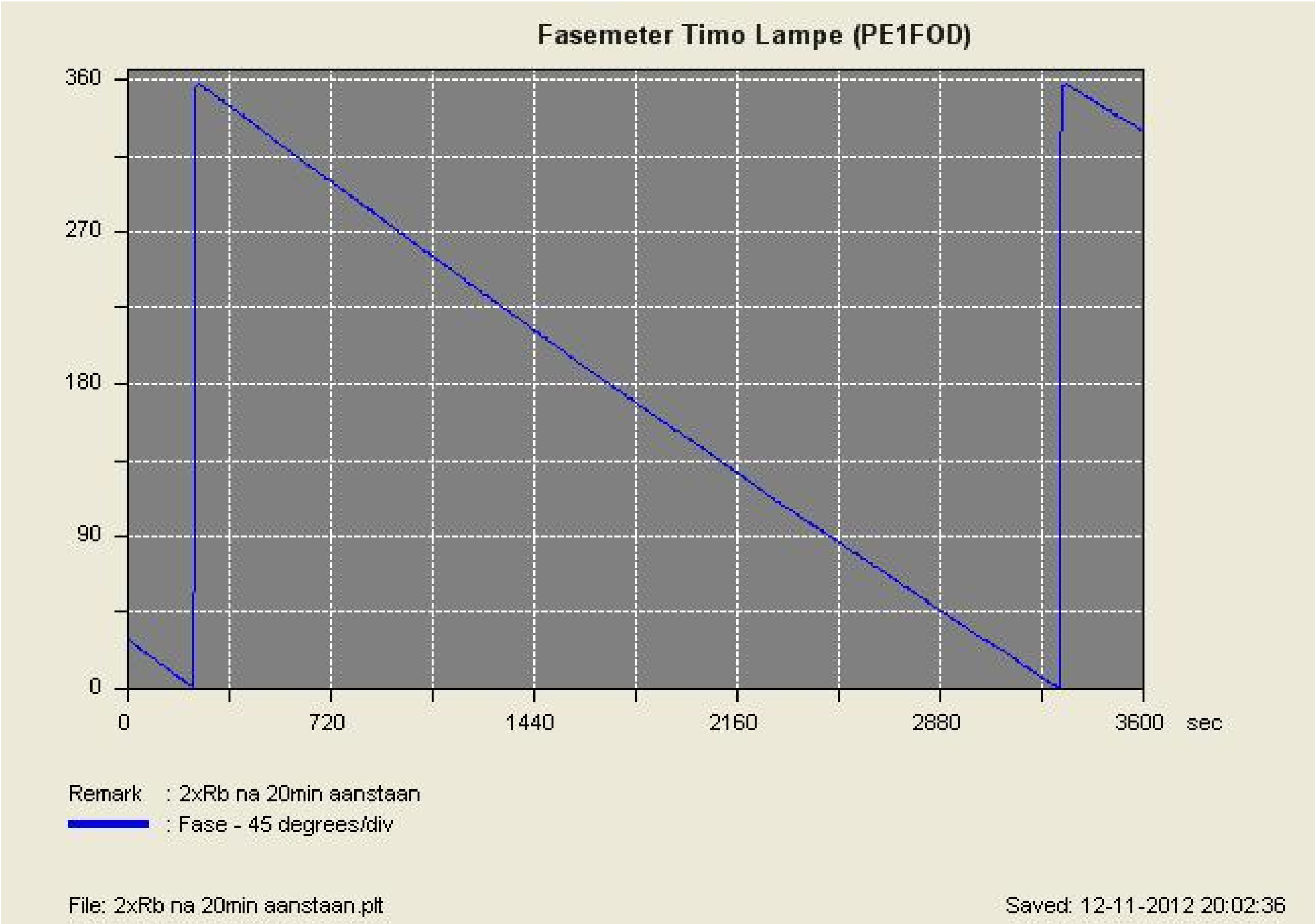
Fase meting SML03 <> Rb-FOD



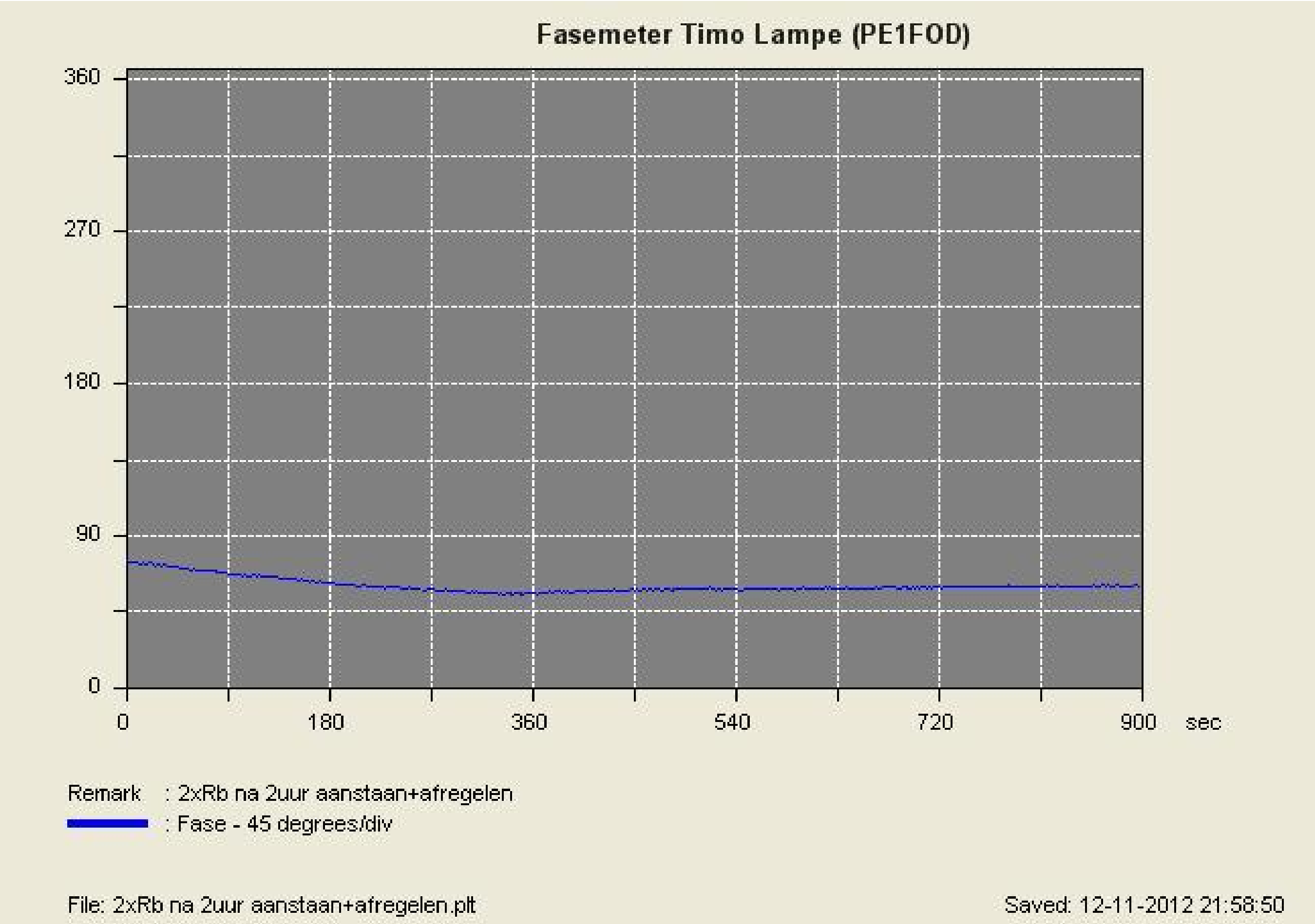
2x Rb Kort na warmup



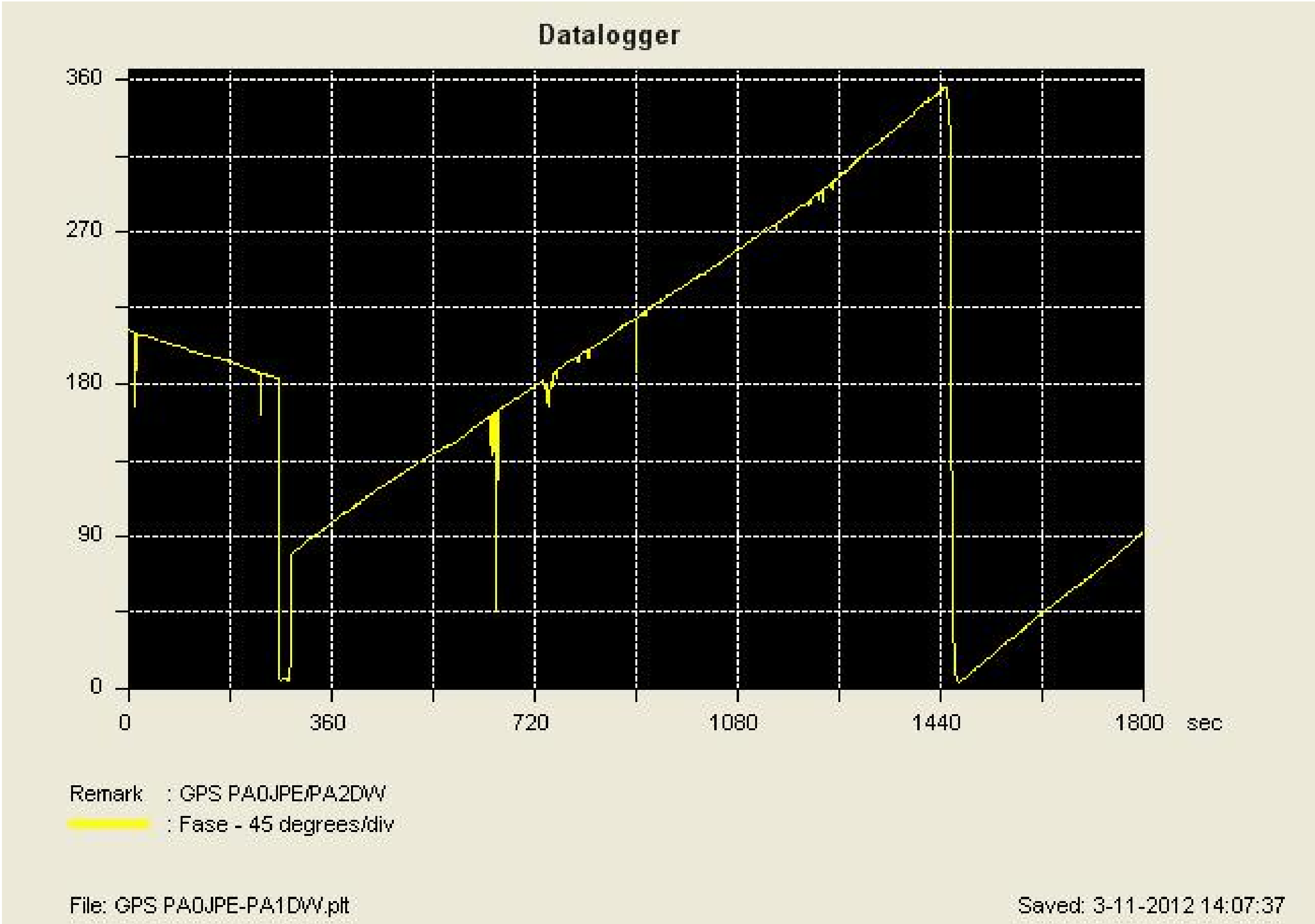
2x Rb na 20 min.



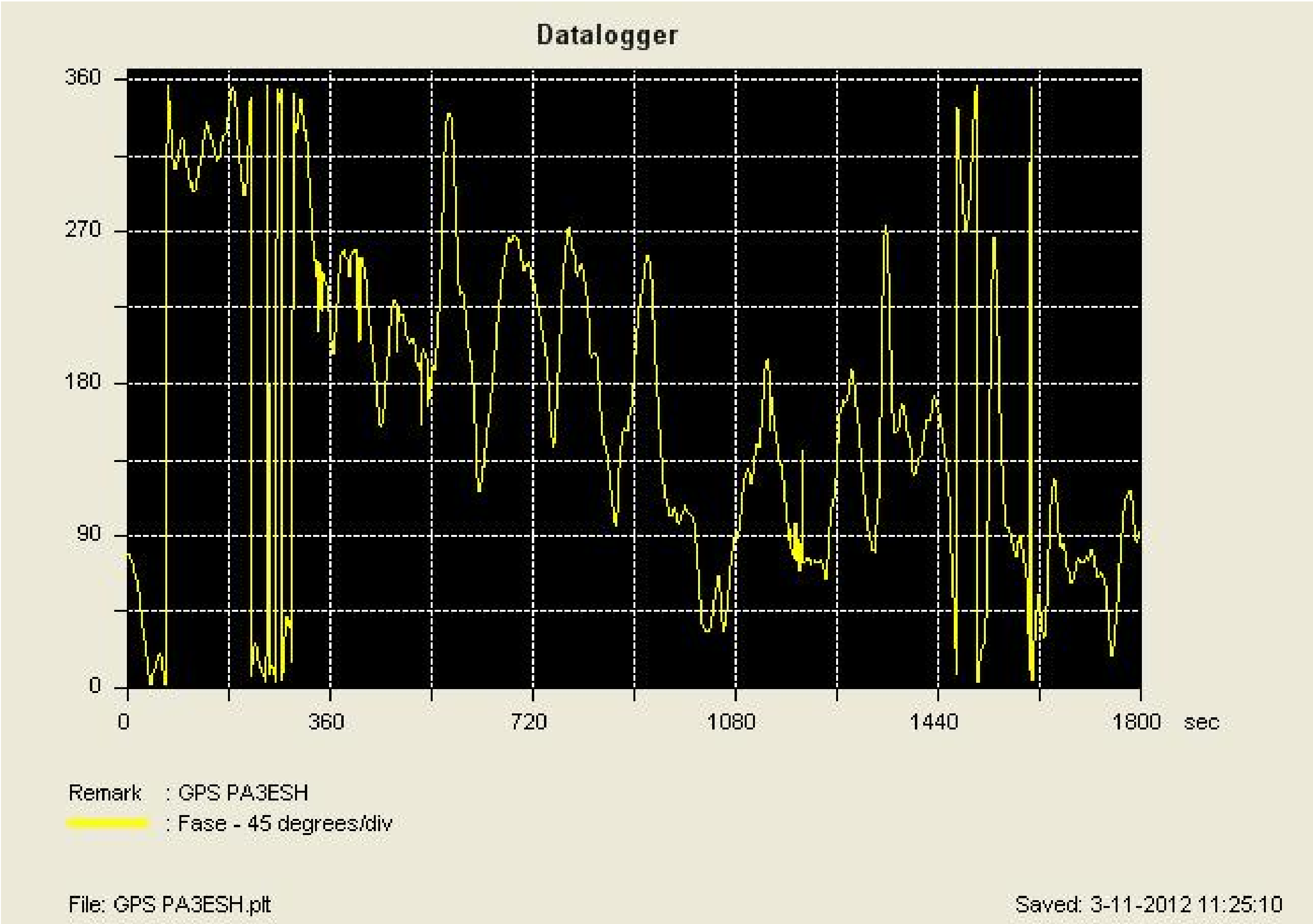
2x Rb na 2 uur + correctie bij 360°



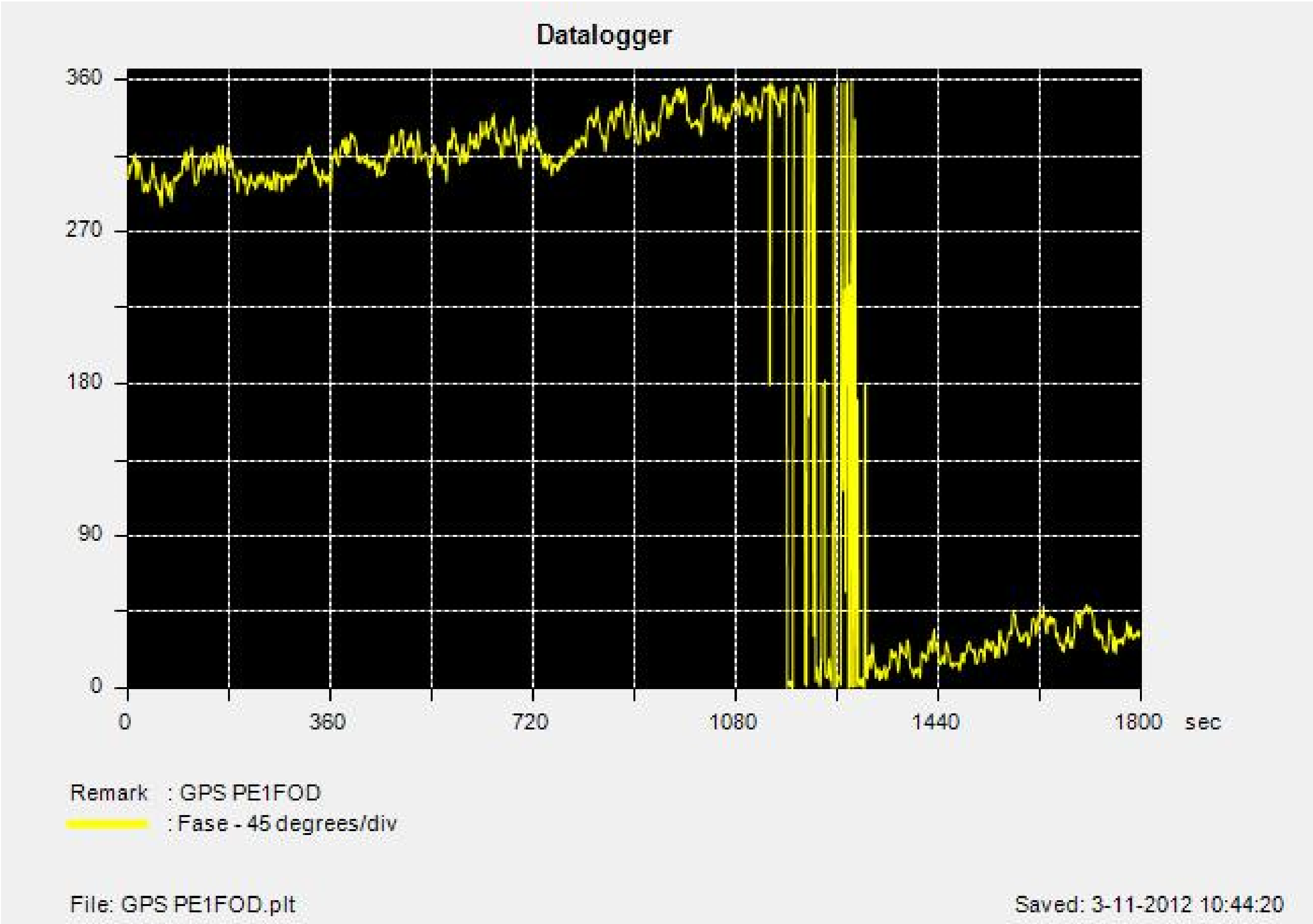
Rb-FOD <> Rb PA0JPE en PA2DW



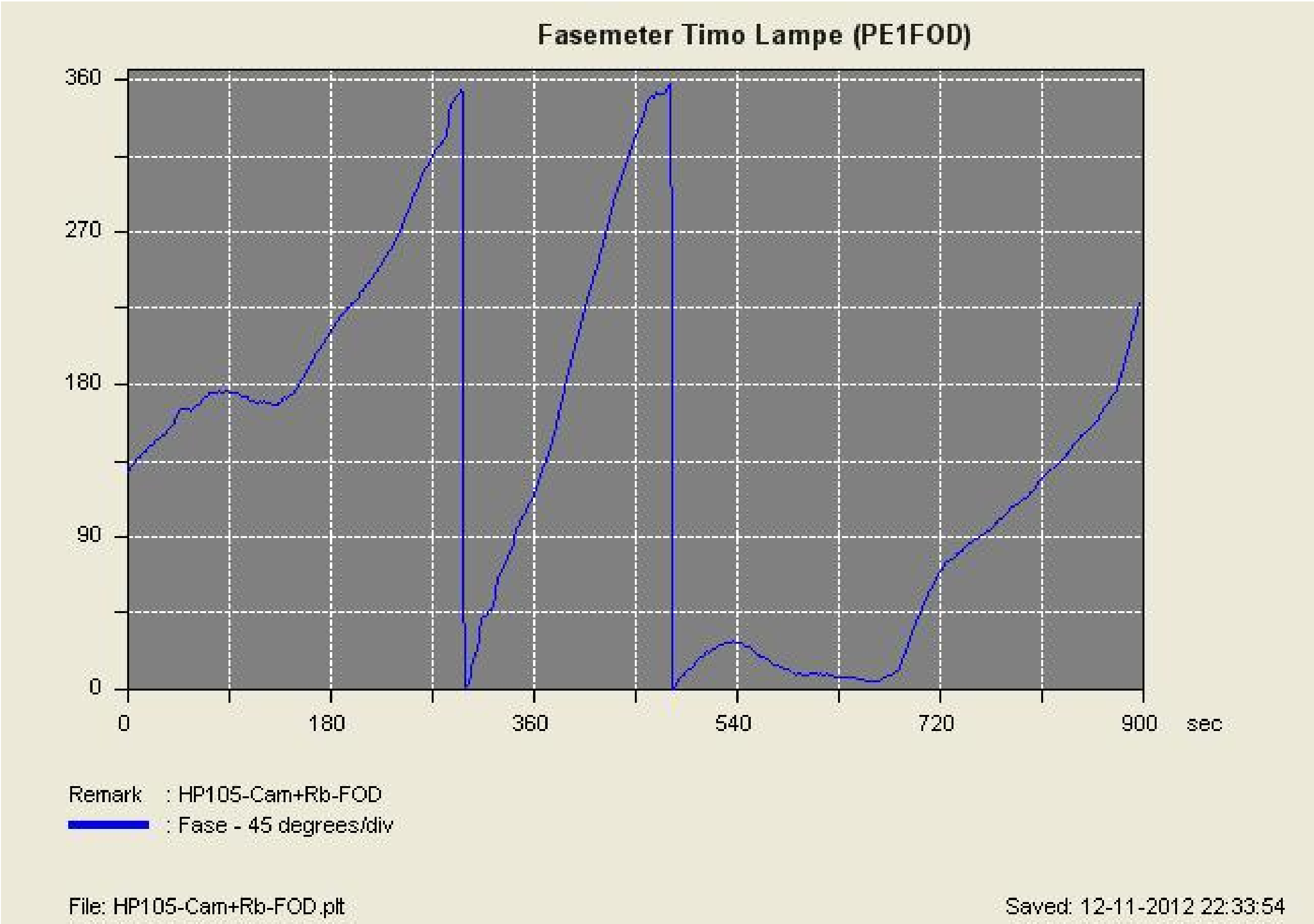
Rb FOD <> Jupiter GPS Lock 10MHz, PA3ESH



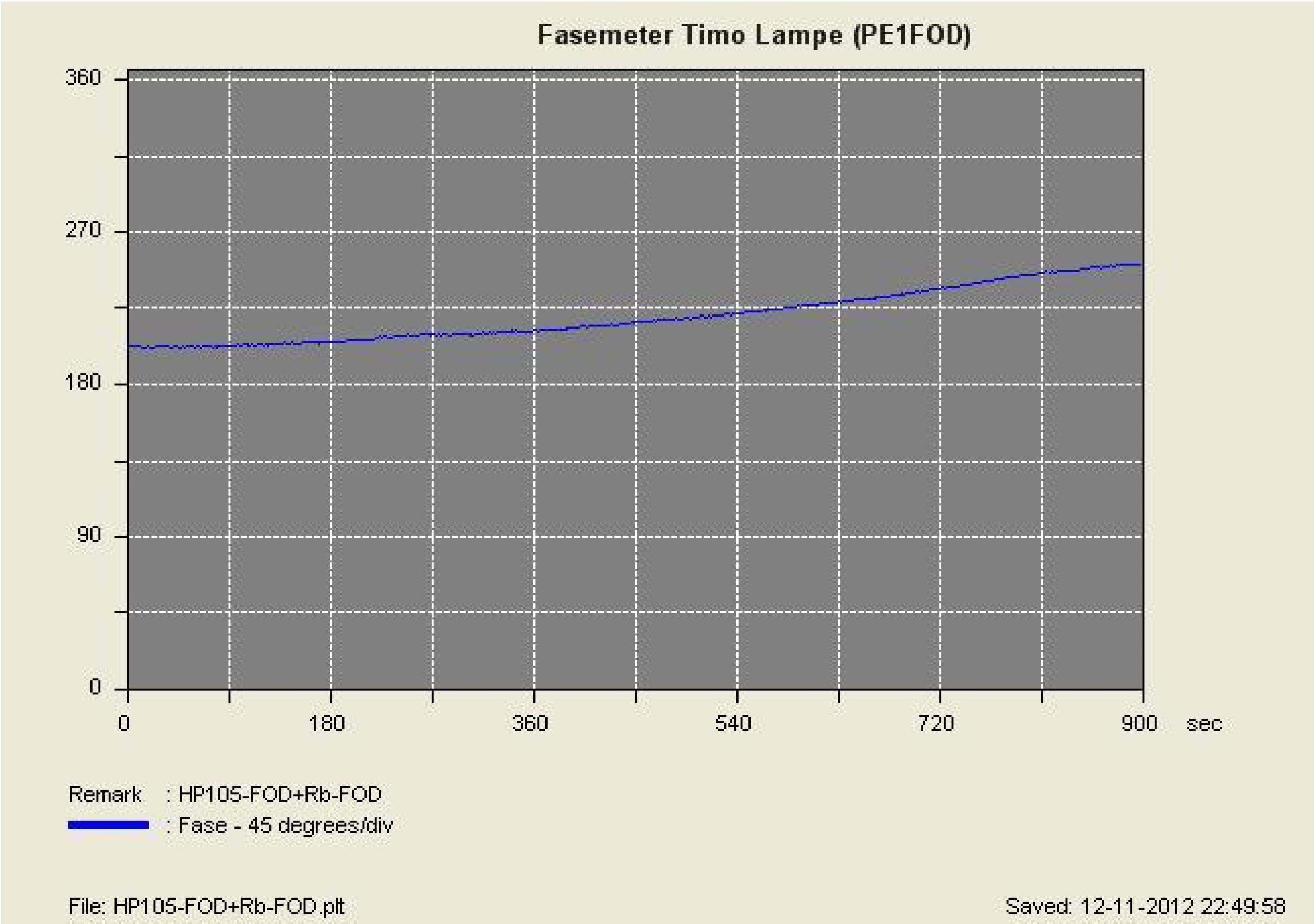
Rb FOD <> Navsync GPS Lock 10MHz, PE1FOD



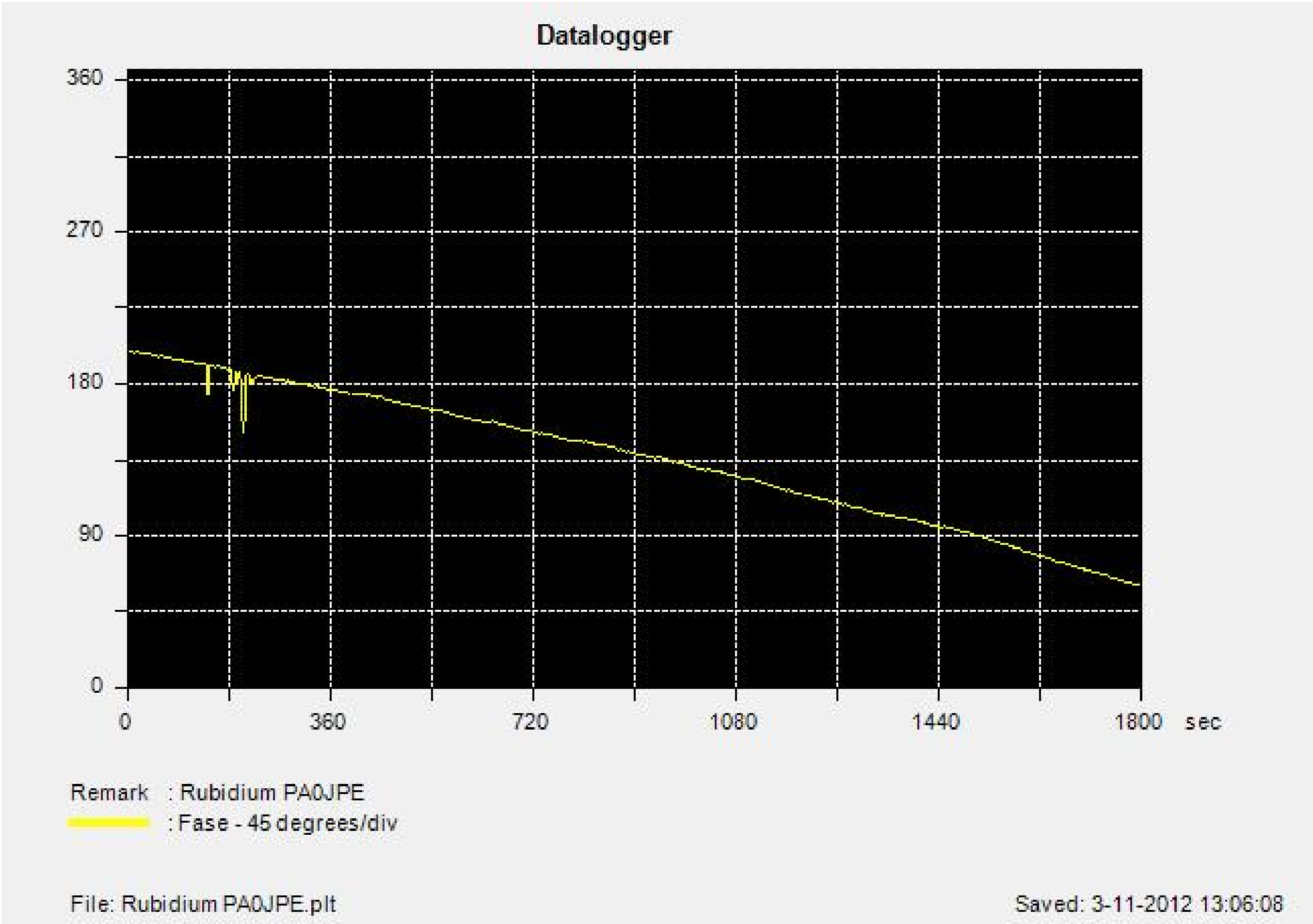
Rb-FOD <> HP105B CAMRAS



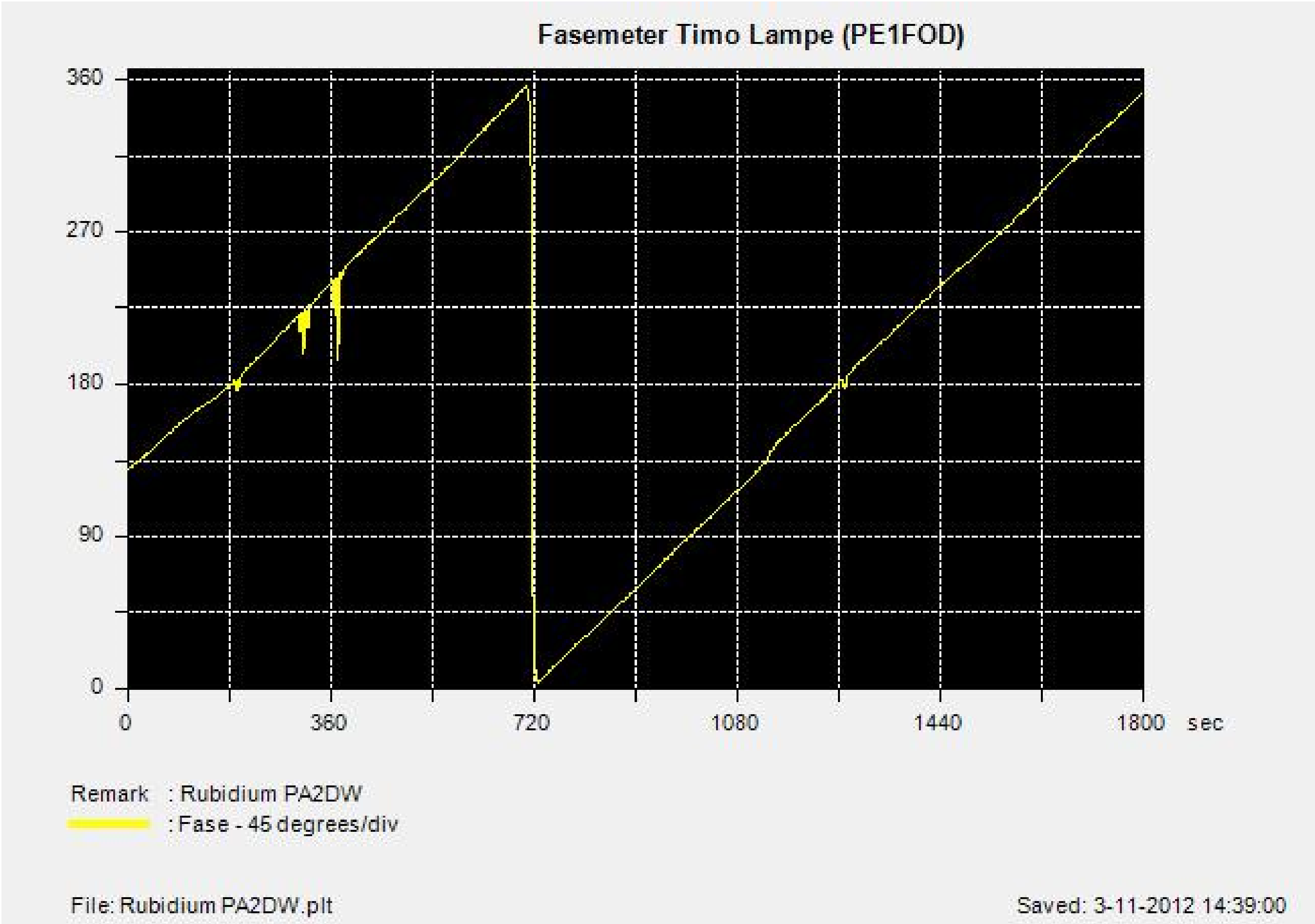
Rb FOD <> HP105B PE1FOD



Rb FOD <> Rb PA0JPE



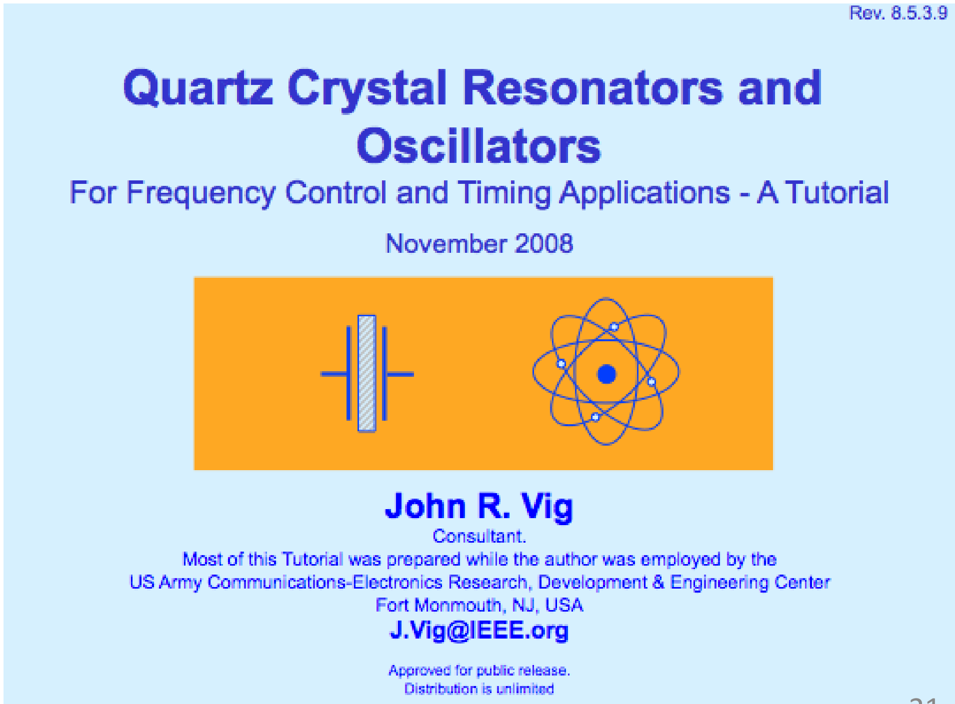
Rb FOD <> Rb PA2DW



Alles valt en staat met:

- Stabiele, nauwkeurige referentiebron

Zie tutprial vig3.ppt van John R. Vig



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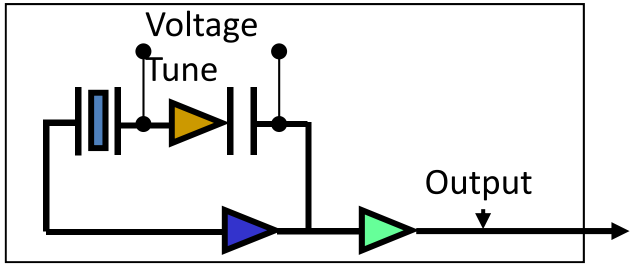
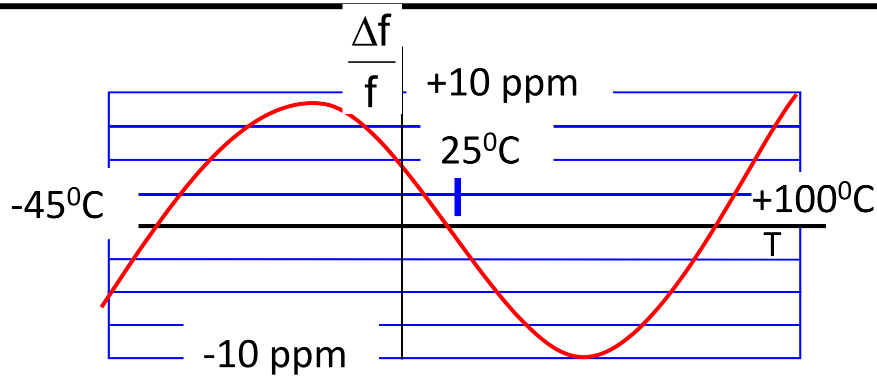
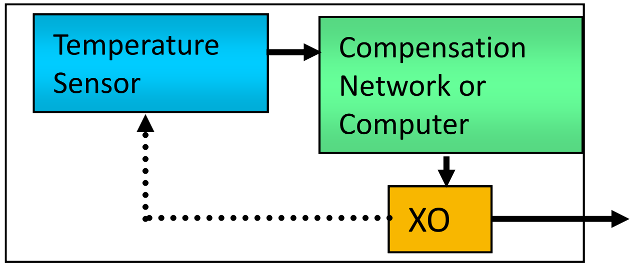
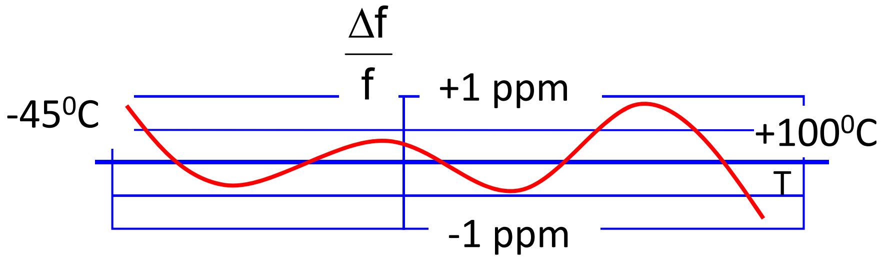
Crystal Oscillator Categories



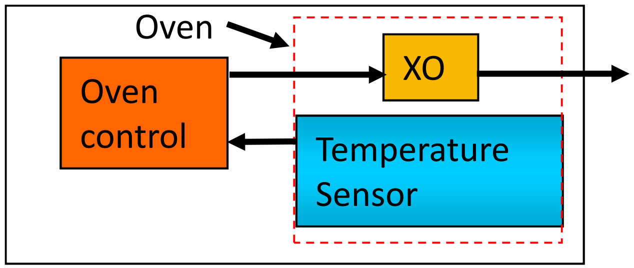


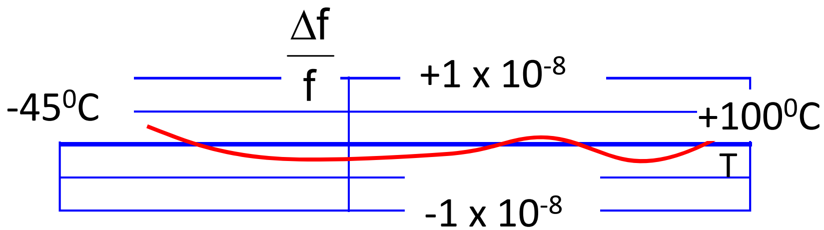
- Crystal Oscillator (XO)





- Temperature Compensated (TCXO)





- Oven Controlled (OCXO)

Hierarchy of Oscillators

Oscillator Type*	Accuracy**	Typical Applications
• Crystal oscillator (XO)	10^{-5} to 10^{-4}	Computer timing
• Temperature compensated crystal oscillator (TCXO)	10^{-6}	Frequency control in tactical radios
• Microcomputer compensated crystal oscillator (MCXO)	10^{-8} to 10^{-7}	Spread spectrum system clock
• Oven controlled crystal oscillator (OCXO)	10^{-8} (with 10^{-10} per g option)	Navigation system clock & frequency standard, MTI radar
• Small atomic frequency standard (Rb, RbXO)	10^{-9}	C^3 satellite terminals, bistatic, & multistatic radar
• High performance atomic standard (Cs)	10^{-12} to 10^{-11}	Strategic C^3, EW

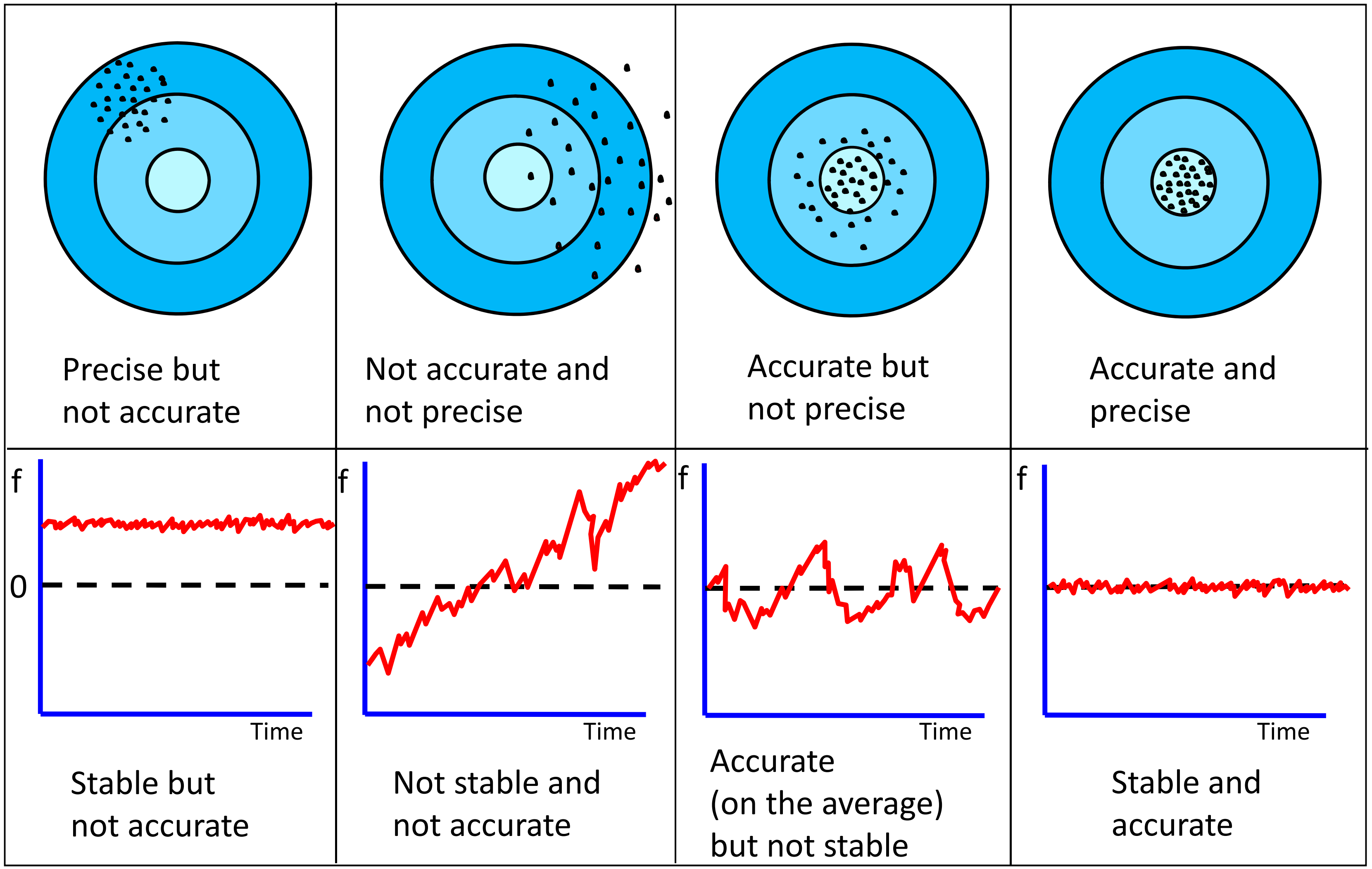
* Sizes range from <$1 cm^3$ for clock oscillators to > 30 liters for Cs standards
Costs range from <$1 for clock oscillators to > $50,000 for Cs standards.

** Including environmental effects (e.g., -40°C to +75°C) and one year of aging.

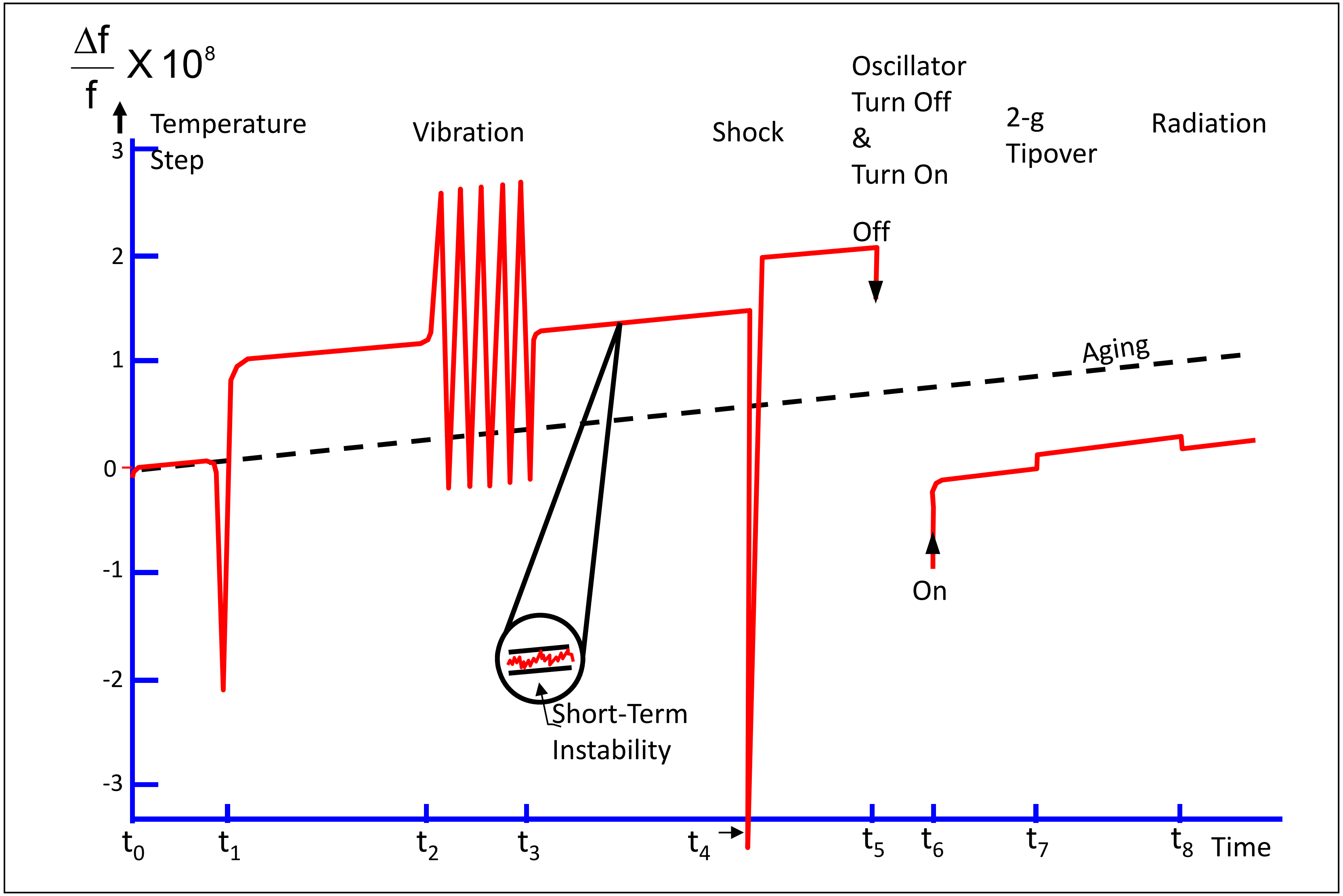
The Units of Stability in Perspective

- What is one part in 10^{10} ? (As in 1×10^{-10}/day aging.)
  - ~1/2 cm out of the circumference of the earth.
  - ~1/4 second per human lifetime (of ~80 years).
- Power received on earth from a GPS satellite, -160 dBW, is as "bright" as a flashlight in Los Angeles would look in New York City, ~5000 km away (neglecting earth's curvature).
- What is -170 dB? (As in -170 dBc/Hz phase noise.)
  - -170 dB = 1 part in 10^{17} ⍰ thickness of a sheet of paper out of the total distance traveled by all the cars in the world in a day.

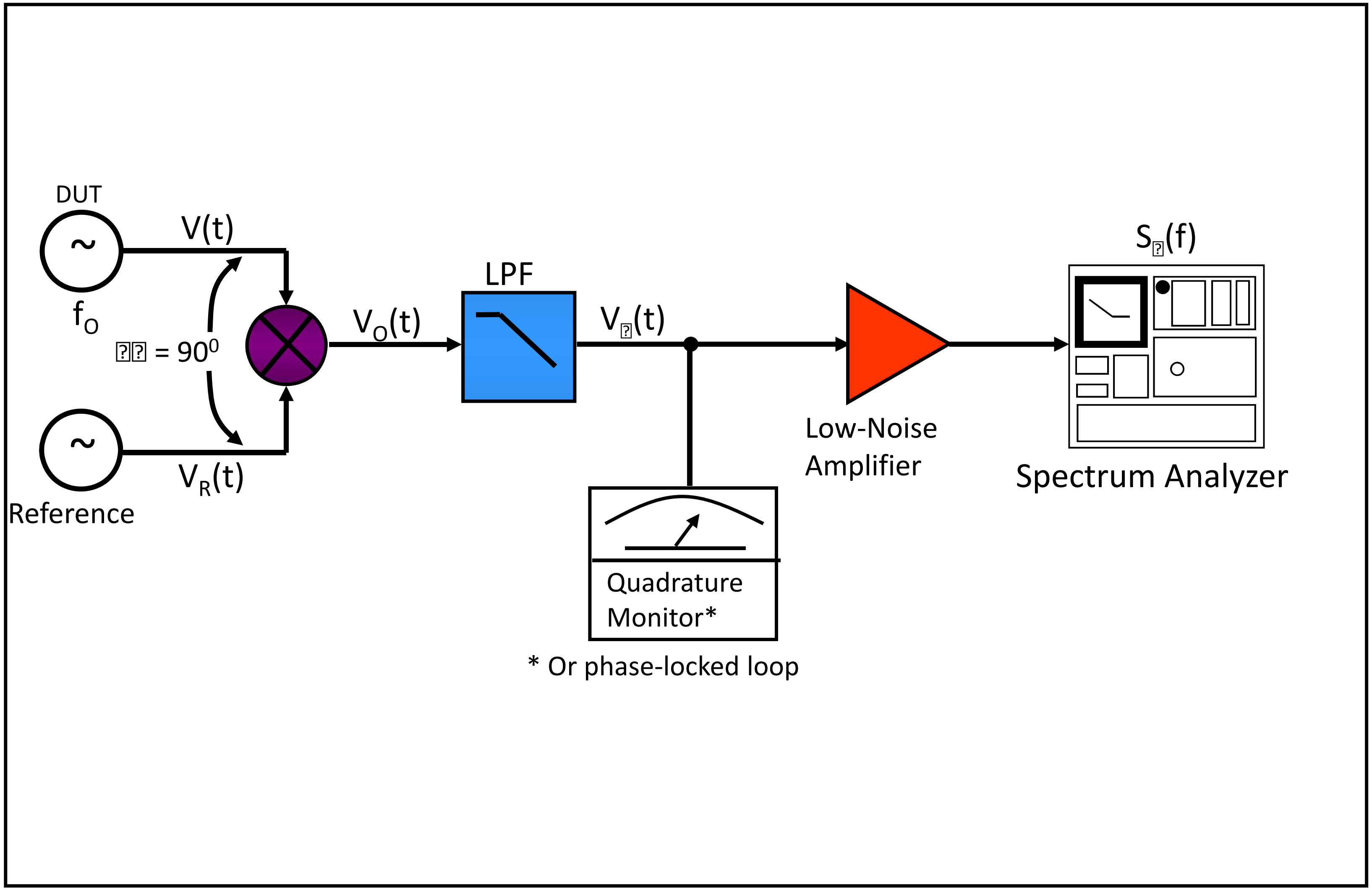
Accuracy, Precision, and Stability



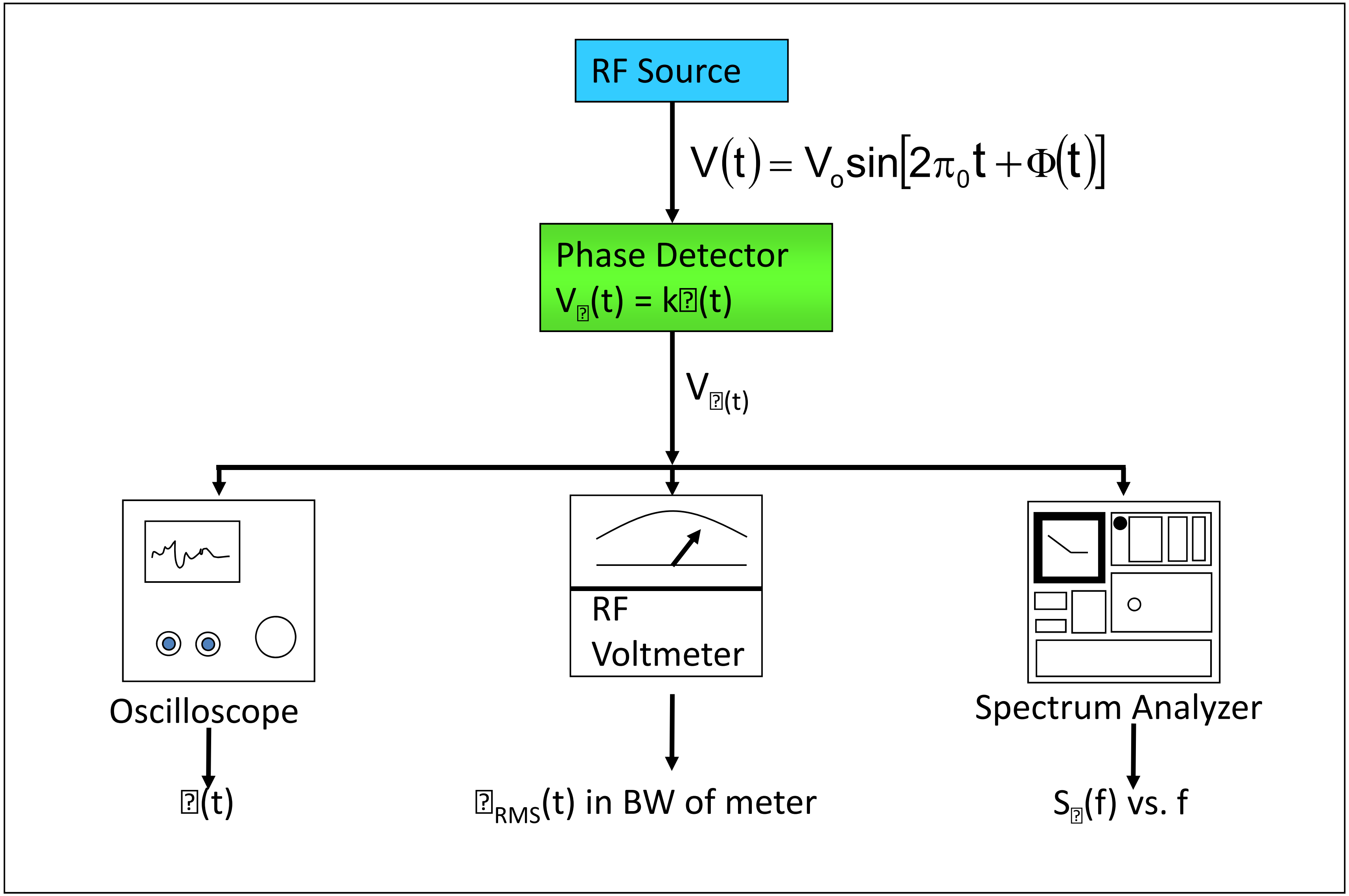
Idealized Frequency-Time-Influence Behavior



Phase Detector



Phase Noise Measurement



Precision Frequency Standards

- Quartz crystal resonator-based ($f \sim 5$ MHz, $Q \sim 10^6$)
- Atomic resonator-based

  Rubidium cell ($f_0 = 6.8$ GHz, $Q \sim 10^7$)

  Cesium beam ($f_0 = 9.2$ GHz, $Q \sim 10^8$)

  Hydrogen maser ($f_0 = 1.4$ GHz, $Q \sim 10^9$)

  Trapped ions ($f_0 > 10$ GHz, $Q > 10^{11}$)

  Cesium fountain ($f_0 = 9.2$ GHz, $Q \sim 5 \times 10^{11}$)

Oscillator Comparison

	Quartz Oscillators			Atomic Oscillators		
	TCXO	MCXO	OCXO	Rubidium	RbXO	Cesium
Accuracy * (per year)	2×10^{-6}	5×10^{-8}	1×10^{-8}	5×10^{-10}	7×10^{-10}	2×10^{-11}
Aging/Year	5×10^{-7}	2×10^{-8}	5×10^{-9}	2×10^{-10}	2×10^{-10}	0
Temp. Stab. (range, ^{0}C)	5×10^{-7} (-55 to +85)	3×10^{-8} (-55 to +85)	1×10^{-9} (-55 to +85)	3×10^{-10} (-55 to +68)	5×10^{-10} (-55 to +85)	2×10^{-11} (-28 to +65)
Stability, $\sigma_y(\tau)$ (τ = 1s)	1×10^{-9}	3×10^{-10}	1×10^{-12}	3×10^{-12}	5×10^{-12}	5×10^{-11}
Size (cm^3)	10	30	20-200	200-800	1,000	6,000
Warmup Time (min)	0.03 (to 1×10^{-6})	0.03 (to 2×10^{-8})	4 (to 1×10^{-8})	3 (to 5×10^{-10})	3 (to 5×10^{-10})	20 (to 2×10^{-11})
Power (W) (at lowest temp.)	0.04	0.04	0.6	20	0.65	30
Price (~$)	10 - 100	<1,000	200-2,000	2,000-8,000	<10,000	50,000

* Including environmental effects (note that the temperature ranges for Rb and Cs are narrower than for quartz).

The end