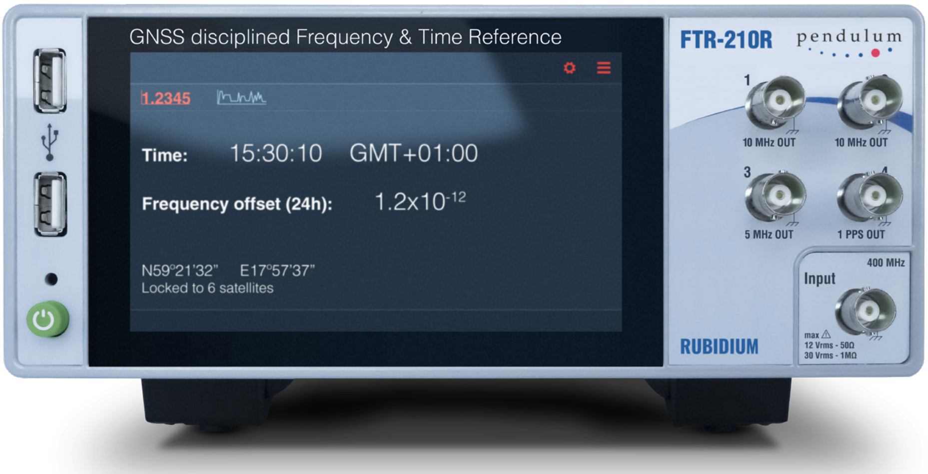
FTR-210R

GNSS disciplined Frequency & Time Reference

DATA SHEET

NEW PRODUCT

- GNSS controlled Rubidium atomic clock
- Primary standard traceability option via built-in calibrator and generation of calibration reports
- Optional Frequency measurement input to 400 MHz with ultra-high resolution (up to 12-13 digits/s)
- Optional Time offset measurements to UTC
- 1x5 MHz and 5x10 MHz ultra-stable frequency reference outputs as standard
- Optional outputs include: 4x10 MHz, 4x1 pps, or 0.1, 1, 5, 10 MHz
- Optional programmable pulse output 0.5 Hz to 100 MHz
- Web server functionality. Control, monitor, and download data from anywhere in the world via ETH.
- Easy to use



The **FTR-210R GNSS disciplined Frequency & Time Reference** is a **multi-output Rubidium Frequency Standard,** with close-to-Cesium stability, thanks to the GNSS control. There are 7 standard outputs (5x10 MHz, 1x5 MHz and 1x1 pps) that can be expanded with up to 4 extra outputs, plus a programmable 100 MHz pulse output option.

The optional integrated indepedent frequency calibrator guarantees true **traceability to GPS-time scale and NIST.** Traceable calibration reports are easily generated.

An optional **input for frequency measurements** to 400 MHz turns the FTR-210R into a one-box ultra-high performance frequency calibrator with up to 13 digits resolution in a second.

Frequency and/or Time standard

When used as a *GNSS disciplined Frequency* standard, the short-term stability is high, and ageing is virtually zero. When used as a stand-alone Frequency standard, in *manual hold-over mode*, the stability is ultra-high. Ageing is less than $5x10^{-11}$/month.

When used as a *GNSS disciplined Time* standard, the 1 pps time reference output, differs less than 10ns rms from UTC. When GNSS disciplining is removed, the hold-over drift is very low; typical 1 µs/24h.

Modular, multi-output configuration

The basic configuration contains 5x10 MHz, 1x5 MHz, and 1x1 pps outputs, to support other instruments, testers, or test objects. If that is not sufficient, 4 additional outputs can be fitted on the rear panel. These outputs are either

- 4x10 MHz
- 4x1 pps
- 0.1, 1, 5, and 10 MHz

Additionally you can enable an optional programmable pulse output, 0.5 Hz to 100 MHz, via a SW license, at any time.

Measurement input for one-box frequency calibration

The ultra-stable frequency reference, combined with the optional DC to 400 MHz measurement input, converts the FTR-210R Frequency Reference to a complete one-box frequency calibrator.

Measurement functions include Frequency, Period, Pulse width, Rise/Fall time, Slew Rate, and Voltage (Vmin, Vmax, Vp-p).

Time offset of an external 1-pps to UTC (GPS), and TIE (Time Interval Error) for 1mHz to 400 MHz, are optional functions (SW enabled).

The performance of the measurement input is state-of-the art. You have 14 ps time resolution (7 ps optional) and 12-13 digits of frequency resolution for 1s gate time. Measurements are gap-free, meaning all individual cycles are counted without any gap.

You can follow short-term and long-term stability of the device under test on the 5" color display, both numerically and graphically. The measurement rate can be set from 1 MSa/s (20M Sa/s optional) up to one sample every 1000 s.

You can store up to 32M measurement samples in each session, and store up to 1G measurements in a non-volatile memory.

The FTR-210R can produce traceable calibration protocols in pdf and csv format of both the internal timebase reference (optional), and the device under test, at any time.

Unique Traceable Frequency Standard for the calibration lab

Off-air frequency standards have existed for decades. But they all have had the same internal architecture (Figure 1). The unit is, in effect, a "black box," with an antenna input and a frequency output. The local oscillator's control process (disciplining) is hidden from the user. Typically, users have used another frequency reference, a timer/counter and a PC for logging the deviation between the "black box" and the external frequency reference.

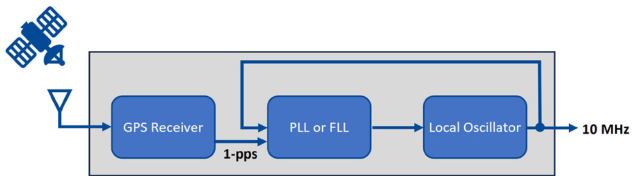


Figure 1: A typical "black box" GPS-receiver (antenna in - reference out). Internal oscillator offset and adjustments are invisible to the user.

The concept of traceability requires an unbroken chain of comparisons to international standards, on a continuing basis, where all comparisons produce documented results with stated uncertainty.

The option 220 in FTR-210R is a documenting frequency comparator/calibrator that is ***independent from the disciplining process***. The received GNSS signal is continuously and gap-free measured against the local oscillator. Phase and frequency deviations are stored internally and can at any time be transferred to any PC, via the Ethernet interface, to almost anywhere in the world.

A traceability record for print-out can be obtained. The unbroken calibration history chain—day by day—is maintained in the non-volatile memory for several years, with the current 24-hour mean offset being displayed continuously on the front panel color display.

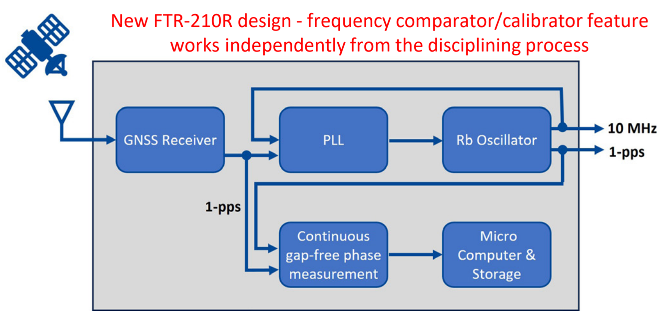


Figure 2: FTR-210R has built-in continuous comparison between the GNSS-receiver and the internal oscillator. The frequency offset is displayed and stored and a traceable calibration protocol can be produced at any time.

Such unique traceability to primary standards means that the FTR-210R never needs to be sent away for traceable re-calibration. Thanks to this design, the very high stability built-in rubidium oscillator is continuously calibrated to the primary frequency standards in the US Naval Observatory, NIST, and ultimately to UTC.

Full flexibility for local or remote control

The FTR-210R is operated manually on the bench via the 5" graphical touch-screen display. You can also connect a mouse, wired or wireless, to one of the front panel USB ports for easier operation.

The FTR-210R comes as standard with a Gbit Ethernet rear panel communication interface, for remote control, monitoring, and data transfer. Using a Wi-Fi dongle in the front panel USB port, enables you to connect FTR-210R to your local wireless network.

You can access and control the instrument from a PC, laptop or tabled, on your lab bench, or from anywhere in the world, using the integrated web server interface function. Or using standard SCPI commands for control in a test system.

Powerful and easy-to-use calibration tools

The optional measurement input converts FTR-210R to a 1-box Frequency Calibrator. Using the MATH function, the Frequency of the device under test can be displayed either as absolute frequency, e.g. "10.000 000 01 MHz", or as deviation from nominal frequency, e.g. "10 mHz", or as relative deviation e.g. "1x10^{-9}".

The FTR-210R is also an accurate 1 PPS calibrator to UTC (SW option). Setting limits for calibration tolerance, with clear pass/fail indicators, further ease the manual or semi-automatic calibration.

Other display formats of the measurement results include Values and time line screens.

Easy-to-use Frequency Offset meter

The optional Frequency Offset Measurement (Option 152F) turns FTR-210R into a dedicated Frequency Deviation meter, and is a very easy-to-use tool of calibrating frequency sources to given limits. The user just enters the desired calibration limits, e.g. "5x10^{-9}", and all other instrument settings are *automatically* set to optimize the calibration. The result of calibration is given as fractional frequency offset from the nominal frequency (automatically found), e.g. as "-1.5 ppb".

If calibration results are outside the set limits, a FAIL message will be displayed.

Disciplined Mode

The frequency deviation between the local oscillator and the received GNSS-signals is used to continuously adjust the oscillator. The resulting 24 h mean freq. offset is displayed continuously on the front panel, and stored together with adjustment data in non-volatile memory every 24 h.

Hold-Over Mode

The internal timebase oscillator is not adjusted. This mode is normally automatically entered when there is no usable received GNSS-signal. This mode can also be activated via the **Manual Hold-over** setting. If there are valid received GNSS signals, the actual frequency offset is calculated and displayed plus stored in non-volatile memory every 24 h.

Front Panel Inputs and Outputs (BNC)

10 MHz Sine Reference Outputs (2x BNC):

Impedance: 50 Ω, nominal
Output level: 1 Vrms in 50 Ω load +/-10%
Freq. Stability: See specs for the oscillator

5 MHz Sine Reference Output (1x BNC)

Impedance: 50 Ω, nominal
Output level: 1 Vrms in 50 Ω load +/-10%
Freq. Stability: See specs for the oscillator

1 pps Time Reference Output (1xBNC)

Impedance: 50 Ω, nominal
Output voltage: TTL-levels in 50 Ω;
Pulse width: approx. 1 ms
Offset to UTC(GPS): 10 ns rms (when disciplined)
Hold-over drift: <1 µs/24 h (typ.)
Jitter: <1 ns rms

Optional Measuring input (BNC, Option 230)

Frequency Range:

- DC-Coupled: DC to 400 MHz
- AC-Coupled: 10 Hz to 400 MHz

Impedance: 1 MΩ // 60 pF or 50 Ω (VSWR ≤2:1 typ.)
Trigger Slope: Positive or negative
Dynamic Range: 0.2 to 10 Vp-p within ±5 V window
Input Signal Attenuation: x1 or x10 selectable
Trigger Level (x1 Attenuation):

- Range: -5 V to +5 V
- Resolution: 1 mV
- Uncertainty: ±(15 mV + 1% of trigger level)

Trigger Level modes: Manual, Relative (to Vp-p), Auto
Auto Trigger Level is set to:

- 50% point of input signal's Vp-p, combined with a wide hysteresis between the 40% and 60% points, for frequency, period average, TIE
- 10% and 90% points, for Rise/Fall Time, Slew rate, with minimum hysteresis
- 50% point with minimum hysteresis for all other functions
- Min. voltage 200 mVp-p

Analog LP Filter: Nominal 10 or 100 kHz selectable
Max Voltage Without Damage:

- 1 MΩ: 350 V (DC + AC pk) to 440 Hz, falling to 12 Vrms at 1 MHz.
- 50 Ω: 12 Vrms

Rear Panel Inputs and Outputs

Multi-GNSS antenna input (TNC)

Supported Systems and Frequencies[1]:

- GPS: L1 C/A, L5
- Gallileo: E1 B/C, E5a
- GLONASS: L1OF
- BeiDou: B1I, B1C, B2A
- NavIC: SPS-L5
- QZSS: L1 C/A, L5

1.Each system/frequency band can be individually enabled/disabled

Active antenna gain: 17 to 50 dB, <+10 dBm at receiver input
DC feed on center pin: +5 V, 100 mA max.

External Disciplining Input (BNC)

Frequency: 1 pps (from external source)
Input levels: TTL levels in 50 Ω

10 MHz Sine Reference Outputs (3x BNC)

See front panel 10 MHz output specs

Optional Pulse Output (BNC, Option 132F)

Pulse mode: Pulse generator, Gate open[2], Alarm[2]
Period range: 10 ns - 2 s in 2 ns steps
Pulse width range: 4 ns - 2 s in 2 ns steps
Output impedance: 50 Ω (nom.)
Output level: 5 V HCMOS in open output

2.Requires Measurement input option, Option 230

Optional Ref. Frequency outputs (4x BNC)

Option 210: 4x10 MHz (sine)
See front panel 10 MHz output specs
Option 211: 0.1, 1, 5, 10 MHz (sine)
See front panel 10 MHz output stability specs
Option 213: 4x1 pps (pulse)
See front panel 10 MHz and 1 pps output specs

Measuring Input Functions (Opt. 230)

Frequency and Period:

Range: DC to 400 MHz
Resolution: 12-13 digits/s
Accuracy: see timebase oscillator specification

TIE (Option 151F):

Range: DC to 400 MHz
Resolution:
14 ps/timestamp, standard
7 ps/timestamp, optional (option 121F)

Frequency offset (Option 152F):

Dedicated Frequency Difference measurement mode with ultimate ease-of use. User inputs desired calibration limits only, all other measurement, math, limits and other settings are automatically set.

Time offset to UTC(GPS) (Option 153F):

Frequency Range: 1 PPS (Pulse Per Second)
Accuracy: <10 ns rms
Resolution:
14 ps/timestamp, standard
7 ps/timestamp, optional (option 121F)

Pulse width, rise/fall time:

Range: 1.5 ns to 1000s
Repetition rate:
up to 1 MSa/s standard,
up to 20 MSa/s optional (option 122F)
Resolution:
14 ps/timestamp, standard
7 ps/timestamp, optional (option 121F)

Slew rate:

Calculation (V/s): (80% of Vp-p) / (rise/fall time)
Min pulse width: 1.5 ns

Voltage (max, min, p-p):

Frequency range: DC, 1 Hz to 200 MHz
Resolution: 1 mV
Uncertainty (sine, typical):

- DC, 1 Hz to 1 kHz: 1% +15 mV
- 1 kHz to 20 MHz: 3% +15 mV
- 20 to 100 MHz: 10% +15 mV
- 100 to 200 MHz: 30% +15 mV

Statistics

Functions: Maximum, Minimum, Mean, Δmax-min, Standard Deviation and Allan Deviation
Display: Numeric or frequency distribution graph
Sample Size: 2 to 16M samples (depending on measurement function)
Max. Sample rate:

- up to 140 kSa/s calculated
- up to 1 MSa/s captured, std.
- up to 20 MSa/s captured (option 122F)

Limit alarm

Graphical indication of limits with Pass/Fail message on front panel,
Limit Qualifier: OFF or Capture values above, below, inside or outside limits

Sample Interval (Gate time)

The Sample Interval sets the measuring time (gate) in Freq./Period measurement modes, and the time between measurements/samples in all other modes

Range: OFF, or 1 µs to 1000 s, std.
OFF, or 50 ns to 1000 s (option 122F)

Mathematics

Can be used to display the difference to the nominal frequency for frequency calibration, either in absolute terms (µHz), or relative terms (e.g. 10^{-12})
Functions: OFF, (K*X-L)/M, (K/X-L)/M, X/M-1
X is current reading, and K (Scale factor), L (Nulling value) and M (Reference value) are constants

Other Functions

Restart: Aborts current measurement and starts a new
Run/Hold: Switch between RUN (continuous measurements) and HOLD (Freezes result, until a new measurement is initiated via Restart)
Auto Set: Makes "best settings" for current measurement function

Save and Recall Settings and Measurements

Measurement Set-ups can be saved/recalled. Set-ups saved to internal memory can be user protected.
Measurement results (RAM) can be accessed by connected PC, and/or saved in internal non-volatile memory, and moved to USB flash drive.
Max. Measurement Speed and Storage size (RAM):
1 MSa/s: 32M samples, standard
12.5 MSa/s: 32M samples, option 122F
20 MSa/s: 16k samples, option 122F
Max. Speed to remote controller:

Block mode:	up to 170k readings/s
Individual results:	up to 425 readings/s

Internal Traceable calibration (Opt. 220)

Internal Traceability Data Storage

24 h-freq. offset (10 MHz):
>4 years data, Non-volatile memory
Phase data (1 pps):
>4 years data, Non-volatile memory

Display of calibration data (selectable)

Numeric on screen:
Phase and/or Frequency offset over 30 s, 1 h, 24 h
Graphic on screen:
Phase and Frequency offset vs. time
Phase and Frequency offset distribution
Graph tools:
Smoothing of data
Pan and zoom in graph vs. time
Cursor readouts (x, y, Δx, Δy, Δy/Δx) in graph vs. time

Calibration protocol of internal timebase

Can be generated at any time and exported as pdf file for direct print out. The file is update once/24h at 00h:00m:00s UTC(GPS), and has the following information.

- Header with general traceability information
- Instrument's ID (serial number, configuration, specific user input data)
- Data field consisting of 6 columns:
  - Date range (selectable by the user)
  - 1 pps phase offset (24 h avg.) vs. UTC(GPS)
  - Calculated uncertainty
  - Freq. offset (24 h vg,) vs. UTC(GPS)
  - Calculated uncertainty
  - Comment

The raw phase data that is used to compute the phase and frequency offset can be downloaded as csv file for further analysis.

Calibration protocol of external unit under test

Can be generated and exported as csv file for direct print out. The file has the following information.

- Header with general traceability information
- All measurement settings
- Device ID (model, serial number, other data, to be input by the user)
- ID of FTR-210R (serial number, configuration, specific user input data)
- Data field consisting of 4 or 5 values:
  - Date
  - Calculated Freq. offset OR 1 pps Phase Offset to UTC(GPS) (depending on selected function)
  - Calculated uncertainty
  - Comment

Remote interfaces

Remote operation

Programmable Functions: All front panel accessible functions

Data Output format: ASCII, IEEE double precision floating point, or packed

USB interface

USB version: 2.0

Connectors:

Front panel: 2x Type A; (Host) used for FW updates, mouse/keyboard connection, external result storage, and installation of SW licences

LAN & WLAN interface

Speed: 10/100/1000 Mbps

Capabilities:

- Web server
- SCPI over HiSLIP protocol, compatibility with VISA

Supported WiFi USB-dongles: TP-Link TL-WN321G, TP-LINK Archer T4U v.2, TP-LINK Archer T4U v.3

General Specifications

Display

Display: Graphic screen for menu control, numerical read-out, status information, plus distribution, trend and time-line graphs

Resolution: 1280x720 pixels

Type: Color Touch 5" TFT LCD display with backlight

Front panel accessible tools: Graph smoothing, pan and zoom, cursor read-out

Environmental Data

Class: MIL-PRF-28800F, Class 3

Installation category: II

Operating Temp: 0°C to +50°C bench-top, 0°C to +40°C rack-mount

Storage Temp: -40°C to +71°C

Vibration: Random and sinusoidal according to MIL-PRF-28800F, Class 3

Shock: Half-sine 30G per MIL-PRF-28800F; Bench handling

Transit drop test: According to MIL-PRF-28800F

Safety: EN 61010-1:2011, pollution degree 2, installation/over voltage category II, measurement category I, CE, indoor use only
CSA C22.2 No 61010-1-12

EMC: EN 61326-1:2013-06, increased test levels according to EN 61000-6-2:2008, Group 1, Class B, CE

Power Requirements

Max. Version: 90 to 265 Vrms, 47 to 63 Hz, < 70 W

Dimensions and Weight

Width x Height x Depth: 210 x 90 x 395 mm (8.25 x 3.6 x 15.6 in)

Weight: Net approx.3.5 kg (7 lb)
Shipping approx. 5 kg (11 lb)

Ordering information

Basic model:

FTR-210R GNSS-Controlled Traceable Standard Rubidium Frequency Reference: 5x10 MHz, 1x5 MHz, and 1x1 pps outputs

HW input/output options[4]

Option 211 4 additional 10 MHz outputs[5]
Option 212 Multiple reference outputs – 0.1 MHz, 1 MHz, 5 MHz and 10 MHz sine outputs[5]
Option 213 4 additional 1 pps pulse outputs[5]
Option 230 Measurement input; DC to 400 MHz

4: These options need to be ordered from start and can not be retro-fitted by the user.
5: These options are mutually exclusive. Only one can be installed at at time

Other options (SW license enabled)[6]

Option 220 Traceability option to UTC(GPS) with calibration report generator.
Option 121F: Upgrade resolution of option 230 from 14 ps/timestamp to 7 ps/timestamp
Option 122F: Upgrade measurement speed of option 230 from 1M measurements/s to 20M meas./s
Option 132F: Enable pulse output 0.5 Hz to 100 MHz
Option 151F: Add TIE measurements to option 230
Option 152F: Add Easy-to-use Frequency Offset measurement function to option 230
Option 153F: Add Time Offset to UTC(GPS) to option 230

6: These options can be installed at any time by the user

Included with Instrument:

- 2 year product warranty[7]
- Line cord (*dependent on destination country*)
- Link to User documentation (PDF)
- Certificate of Calibration
- Important information document

7: Warranty period is extended to 3 years, at no cost, by registering the product within 1 year from delivery.

Optional Accessories

- **Option 01/200** Multi-GNSS Antenna, L1 & L5 bands, N-connector
- **Option 02/20T** Antenna Cable, 20 m, N to TNC
- **Option 02/50T** Antenna Cable, 50 m, N to TNC
- **Option 02/130T** Antenna Cable, 130 m, N to TNC
- **Option 22/90:** Rack-Mount Kit - 1 unit
- **Option 22/05:** Rack-Mount Kit - 2 units
- **Option 27:** Carrying Case - soft
- **Option 27H:** Heavy-duty Hard Transport Case
- **Option 90/07:** Calibration Certificate with Protocol; Rubidium oscillator
- **Option 90/07A:** *Accredited* ISO 17025 Calibration Certificate with Protocol; Rubidium oscillator
- **Option 95/05:** Extended warranty 2 extra years
- **OM-210:** User's Manual English (printed)[8]

8: Always available as download from the Pendulum website

Time Base Oscillator

Mode		Disciplined	Free run
Time base type:		Rubidium	Rubidium
Uncertainty due to: -Aging per 24h per month per year -Temperature variations: 0˚C to 50˚C 20˚C to 26˚C (typ. value)		$<1x10^{-12}$ (3) $<1x10^{-12}$ (3) $<1x10^{-12}$ (3)	$5x10^{-12}$ (3) typ. value $<5x10^{-11}$ (3) $<5x10^{-10}$ (3) $<3x10^{-10}$ $<3x10^{-11}$
Short-term stability: τ =1 s (Allan Deviation) τ =10 s τ = 24 h		$<5x10^{-11}$ $<2x10^{-11}$ $<1x10^{-12}$	$<5x10^{-11}$ $<2x10^{-11}$
Phase noise stability (typ. value) at - 10 Hz / 100 Hz / 1 kHz /10 kHz offset from carrier:		<-95 / -125 / -135 / -140 dBc	<-95 / -125 / -135 / -140 dBc
Frequency retrace (after 24h OFF time): - After 1 h ON time - After 7 min. ON time . Time to lock:		<6 minutes	$<3x10^{-11}$ $<5x10^{-10}$ <6 minutes
- Free run: Typical total uncertainty at 2σ (95%) confidence interval, averaged over 24h, for temperature 20˚C to 26˚C, up to 1 year after last calibration/adjustment			$<6x10^{-10}$

(3) After 24h of continuous operation

01.08,2025 FTR-210R rev. 9

Specifications subject to change or improvements without notice.
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pendulum