

**Z38XX**

**GPS Disciplined Reference**

**Software**

by

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**Manual by**

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## 1. Introduction

Z38XX is a PC monitor program for GPS Disciplined References (GPSR) which communicates using the SCPI Protocol<sup>1</sup>. The program provides real-time monitoring of the operation of the GPSR, including status information, GPS satellite information, timing and control information, holdover prediction, reference Allan Variance and even a UTC clock with second accuracy. It also displays various logs, and stores all measurements on file for later analysis.

Devices which utilize the SCPI protocol are widely used in the telecommunications industry, and since they are now becoming available on the surplus market, GPS Disciplined References are also popular with amateurs and others not directly related to the telecom industry.

Currently Z38XX does not operate with GPSR devices (such as the Trimble Thunderbolt) which use TSIP or other protocols, but future versions may support TSIP.

The SCPI protocol is unfortunately loosely defined, and varies from one manufacturer to another, and even from one model to another – not just in the commands supported, but in the exact syntax of the commands! Thus the program is designed to identify the model of device to which it is connected, and from this determines which commands to use, and how to interpret the responses.

This manual described Z38XX Version 20090719. There will be slight differences in other versions. The version number is shown on the program banner.

### What You Need

Clearly, you need a GPSR which uses the SCPI Protocol and is supported by the software. You need to carefully identify the serial communications information from the User Manual for the device – data bit rate, and especially the parity. It will help to have a copy of the User Manual available. The devices which are specifically supported by Z38XX V20090719 are:

Agilent/HP/Symmetricom	Z3801A Z3805A Z3815A
Jackson	Firefly Fury
Samsung	GCRU-D

You also need a suitable power supply and GPS antenna for your GPSR. Follow the guidelines in the GPSR User Manual.

The computer which operates the software needs to be at least a Pentium 1 200MHz with 48MB memory and an 800x600 screen, although a faster computer is recommended. It also needs a working serial port (or USB port and serial adaptor). Performance will be sluggish on a low

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<sup>1</sup> Standard Commands for Programmable Instrumentation (see <http://www.ivifoundation.org/scpi/default.aspx>)

specification computer, and chart visibility limited to one at a time, but such old computers (especially laptops) are ideal for monitoring your GPSR long term, as they consume little power.

The program operates with Windows™ 98, 2000 and XP. It probably does not operate with Windows Vista. It operates well using WINE under LINUX.

A suitable serial communications cable with connectors for your computer and GPSR is required. The program will also operate with USB to serial adaptors in addition to conventional serial ports. You need to check with 'System Information' or 'Control Panel' to be sure which COM Port to use.

### What the Software Does

Z38XX communicates with the GPSR using the SCPI Protocol. It sends a group of messages every 10 seconds, and so generates all the charts and statistical information based on responses to this 10 second cycle. SCPI is designed as a question-and-answer protocol: the GPSR does not broadcast messages; in other words it only replies when correctly formatted questions are asked of it. This can lead to considerable confusion, as the unit will not respond if the bit rate and parity are wrong, or the device ID is not recognised by the software.

Every 10 seconds the software requests the following data:

- The receiver identity.
- EFC value (Electronic Control Voltage - voltage control to the GPSR's 10MHz reference oscillator).
- 1pps TI (difference between the GPS receiver 1pps time mark derived from the satellite time information, and the GPSR locally generated 1Hz time base).
- The UTC time from the GPS receiver
- The GPSR error status
- The GPSR Receiver Status Message.

Some units do not support all the above messages, and so the software retrieves what it can from the Receiver Status Message instead. This is a large message which consists of a page of information in a (nearly) fixed format. The message contains satellite information (azimuth, elevation, signal strength, whether tracked or not, how many satellites are in view and tracked), position and time information, in addition to GPSR reference controlling status information.

The Receiver Status Message is interpreted by Z38XX in order to provide further data for logs and displays, since some information is not readily available from all devices in any other way (i.e. by explicit messages), and anyway, the Receiver Status Message is a convenient single message that carries a wealth of data in ASCII form. Unfortunately the message varies in detail from one device to another.

Once the data is collected, it is stored in a database file<sup>2</sup>, from where it is collected for display and analysis on various charts. Future versions may use a more flexible file naming scheme which may limit the maximum file size. Because the data is stored, the program can be stopped and restarted

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<sup>2</sup> The file naming convention is as follows: the file name is 'Z38XXDataYYYYCWZZ.Txt', where YYYY = year, ZZ = current calendar week. A new file is written to each week.

some time later, and the charts will continue to display correctly, simply with a gap for the duration of the time the program was stopped.

### Limitations

As previously mentioned, not all receivers have the same commands available, and so some data is not available from some units. In addition, some units (notably the Samsung GCRU-D) report 0ns TI when locked and the TI is < 100ns.

The clock is also not available with the Samsung GCRU-D. The 'LIFE' parameter is missing from some units. The program is also limited in use to the units that it knows about (listed in the introduction).

The program updates every 10 seconds, so changes faster than this are under-sampled. It is also not possible to measure Allan Variance with Tau shorter than 10s.

Graphs have no averaging built in, so when data contains considerable noise or dithering, it may not be easy to see what is going on. Selecting a shorter time frame or increasing the span of a particular graph may help.

### A word of caution concerning serial echo

If you have successfully setup Z38XX as described in the next section but nevertheless communication between the program and the GPSR seems **not** to run faultless, i.e. some commands from Z38XX are not recognized from the GPSR and/or Z38XX receives no answer from the GPSR<sup>3</sup>, then the problem may be that the GPSR echoes serial characters.

This is not allowed for Z38XX! Serial echo is nice for use with a terminal program but is a real nightmare for automated communication. Unfortunately the SCPI syntax for switching serial echo off is different between different manufactures so that Z38XX cannot handle the situation completely on its own (serial echo may hinder Z38XX to find out which device from which manufacturer is connected to it). You must help Z38XX in finding out whether serial echo is enabled with your GPSR and if so to disable it. Some receivers may need to receive a command like

```
SYST:COMM:SER1:FDUP 0
```

while devices from Jackson Labs need a

```
SYST:COMM:SER:ECHO OFF
```

command. Both commands are included in the dropdown listbox of Z38XX's "Manual Command Entry" window. Other GPSRs may need something completely different. Check your GPSR's manual to find out which command is needed for your device.

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<sup>3</sup> This condition may be observed in detail using Z38XX's "Debug Window"

## 2. Setup

### Installation

Installing the software is very simple. Download the latest version of Z38XX<sup>4</sup>, and unzip it into a new empty folder on your computer. If installing over a previous version, it is best to move all the existing files in the folder to an archive so that the program has a clean start.

Create a shortcut to the program, and drag it to your desktop or menu system.

Connect up the GPSR (which has preferably been running some time and operating stably), and check which COM port it is connected to. Start the Z38XX program by using the new shortcut.

When the program starts you see the main screen and graphs (see Fig. 2), labelled at the top (the 'banner') with the program name and version. Directly under this is a row of menu items. Select **Parameters**, and another small window will pop up.

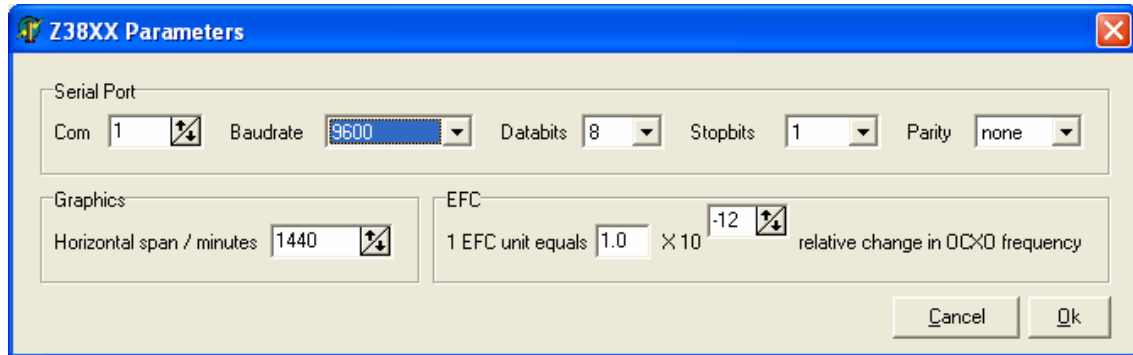


Fig. 1. The **Parameters** pop-up window

### Serial Communications

In this window enter the COM Port number, the bit rate, number of data bits, stop bits and parity currently used by your GPSR. For example, some default values are:

Model	Bit Rate	Data	Stop	Parity
Agilent Z3815A	9600	8	1	none
Chongho GPSR-A	19200	8	1	none
HP Z3801A	19200	7	1	ODD
Samsung GCRU-D	9600	8	1	none

### Chart Speed

This same pop up window allows you to set the chart speed, which affects all charts with time as the abscissa (x-axis). This value is in the box labelled 'Graphics'. The default value, 1440 minutes, allows the graphs to present 24 hours at a time. If the program has been running less than the time in the specified chart span, the abscissa is stretched to show all the available range; if data for more than the specified horizontal span is available, the charts show the latest data at the right, and available data for the specified span stretching back to the left.

<sup>4</sup> From <http://ulrich-bangert.de/Z38XX.zip>

Once the program has been running for some time (even if it has been interrupted occasionally), the chart speed can be changed up and down to show detail as required, although the information shown will always have the latest data on the right (you can't show historical data - older than the time span - except by setting a high horizontal span or by experimenting with the **Chart Editor** feature).

### EFC Gain

The final item on the **Parameters** menu item pop-up window sets the relationship between the EFC (Electronic Frequency Control) voltage and frequency. The default value is that for the Z3801A, where one EFC unit represents a frequency change of  $1 \times 10^{-12}$ . Your unit may be different, and if so, enter the value here.<sup>5</sup>

This information is only used by the OCXO ageing drift calculation, which can be determined from the change in EFC values over time. It affects only one value reported in the **EFC Statistics** view, and it won't matter to program operation if the EFC gain value for your unit is unknown or not exact.

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<sup>5</sup> The value also varies slightly between units of the same model, and with different EFC voltages.

### 3. Main Window

When the program starts up, only the main window appears. You may need to drag it around the screen (drag the banner), or resize it to suit your needs (drag at the corners or edges). You will note that the graph in the centre of the window resizes automatically as you change the window size.

Please note that screen-shot examples in this manual were generated using either a Samsung GCRU-D or Symmetricom Z3815A. Using Z38XX with a different unit will most probably produce graphs that look significantly different. In addition, the values shown for various displayed parameters could well be different to those of other units, even of the same model.

When the program is first started, before invoking any of the pull-down menu items from the main window (described below), wait at least 20 seconds for the software to establish communications and identify the unit. Otherwise you may find that some menu items are greyed out or do not work.

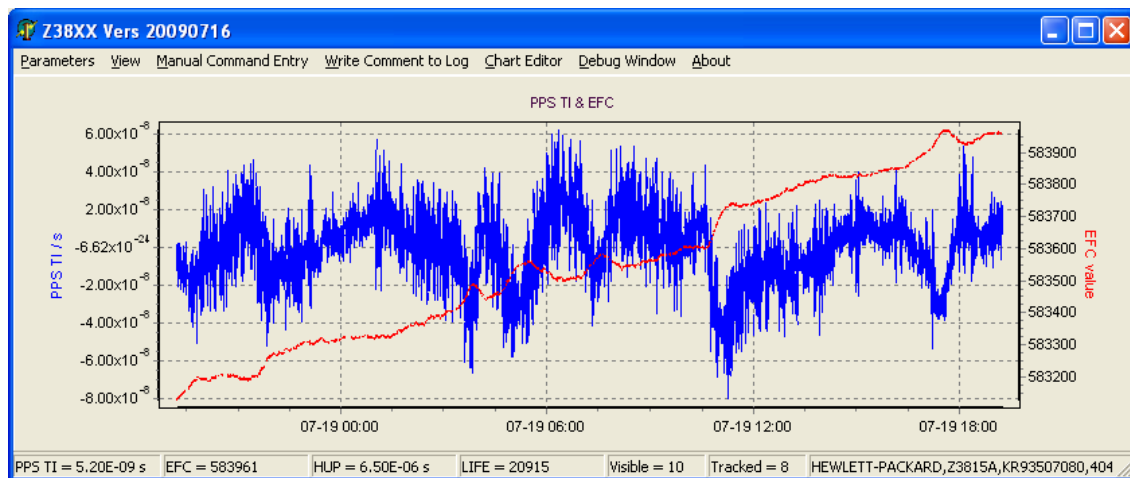


Fig. 2. The Main Window

#### Zooming & Panning

One thing that is not obvious with most of the graphic displays is that they allow zooming and panning of the displayed data. Zooming is initiated by pressing the left mouse button at the upper left corner of the area to be zoomed, and – with the mouse button kept pressed – moving the mouse to the lower right corner of the area to be zoomed.

You will notice a white frame that borders the zoom area. As soon as you release the left mouse button the display will show the zoomed area. Zooming may be applied as often as you like. Un-Zooming is done by a “zoom action into the opposite direction”, i.e. you open a zoom area starting in the lower right corner and drag it to the upper left corner. All zooms that you may have done in the meantime are undone by a single Un-Zoom.

While in a zoomed state you see data with a higher resolution, but clearly now some data is invisible because it is outside the zoomed area. Instead of Un-Zooming and then again zooming into another area, you may as well “pan” data into the zoom area by pressing the right mouse button, and – with the button kept pressed – moving the mouse around. You will notice how the data “follows” your mouse movements. All panning actions are undone by a single Un-zoom action.



## Status Line

At the very bottom of the main window (see Fig. 2) is a line of text which displays various items of interest. When you first start the program, it's a good idea to check this line, as at the right it should show the identity of the GPSR you are using. If you don't see it displayed after 20 seconds or so, you may not have correct communication with the GPSR.

### Hint:

If you are using a computer with a small screen, or have made the main window smaller, you may not be able to see the ID without resizing the window.

Other items shown on the status line are (from the left):

PPS TI	The current GPSR time interval difference from UTC or GPS
EFC	The current EFC tuning value
HUP	The current Holdover Uncertainty Prediction from the GPSR <sup>6</sup>
LIFE	The total power-up time (hrs) that the GPSR has experienced
Visible	The number of satellites which should be above the horizon
Tracked	The number of satellites which are used to determine the position and time

## Main Graph

The main graph shows the EFC (Electronic Frequency Control) digital control value (scale on the right) in red, and the GPSR 1pps TI (compared with the mean GPS derived 1pps) in blue (scale on the left). The graph is auto-scaling on both parameters.

The horizontal axis is elapsed time with the most recent samples at the right. The sample period is 10s and all data available within the selected span is displayed.

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<sup>6</sup> The GPSR estimates from its own performance how much in error it might to be, if forced into holdover for 24 hours (for example if the GPS antenna fails).

## View Menu

Referring back to the menu line at the top of the main window, clicking on the **View** item presents a drop-down list of other views which can be used:

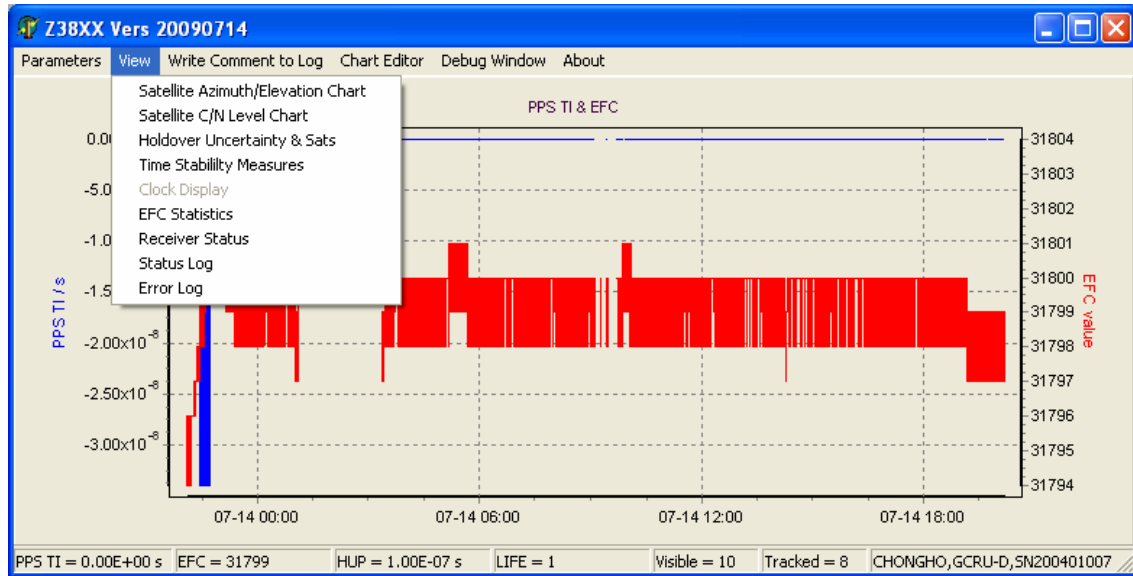


Fig. 3. The **View** drop-down menu

- Satellite Azimuth/Elevation Chart
- Satellite C/N level Chart
- Holdover Uncertainty & Sats
- Time Stability measures
- Clock Display
- EFC Statistics
- Receiver Status
- Status Log
- Error Log

## Manual Command Entry

This menu item brings up a small window which acts as a communications terminal. It allows you to send direct SCPI commands to the unit, and receive the results. You can select from a drop-down list of pre-defined commands, or type your own, if you know the exact format required.

Because the program continues to communicate with the unit, there are times when it is not possible to send manual commands. Please wait for the yellow dot at the top to be displayed before pressing the **Send** button. This window closes automatically after three minutes of inactivity.

### Note:

Do not use this feature unless you know exactly what you are doing, and what you expect to happen. Check your manual first. There are some commands in the drop-down list which may not work on your unit, or may cause trouble if used incorrectly, such as loss of lock, loss of position fix, reset or even serious damage such as loss of the unit's operating program.

### Write Comment to Log

Using this feature you can write a text comment which is placed in the log file (Z38XXStatus.Txt) at the current point in time.

### Chart Editor

Z38XX uses a generalized chart generation function for many of the windows it displays. On these windows you will see **Chart Editor** as a menu item. Using this feature you can change the way the graph is displayed. For example you can change the horizontal or vertical span of the graph to view detail, you can change to log axes, change the graph appearance and the data items displayed.

It is suggested that you leave the **Chart Editor** alone unless you are confident that you know what you are doing! Fortunately, if you really mess things up, the chart will return to the default settings if you close and reopen the program. You can also use the pan and zoom features described earlier.

One of the quirks of the chart function is that in auto-scale mode, bipolar graphs tend to have no 'zero'. Instead, an impossibly small value (e.g.  $4.07 \times 10^{-20}$ ) is shown. Just pretend that this means zero!

### Debug Window

When selected, this window presents a list of all the messages to and from the GPSR as they happen. It can be used to debug communications with an unknown GPSR or communications setting. If you need assistance, capture this information (**File/Log to File**) for a few minutes and send the resulting log (Z38XXDebug.Txt) to Ulrich<sup>7</sup>, along with the other files in the same folder.

### About

Tells you who wrote the software, reminds you of the source web site, and what the rights and limitations on the software are.

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<sup>7</sup> df6jb@ulrich-bangert.de

## 4. Satellite Azimuth/Elevation Chart

This interesting graph shows a birds-eye view of the current satellite constellation as red dots on a polar graph, using the azimuth and elevation data from the GPR Status message. It plots only the tracked satellites. Note that you can display each satellite's PRN and C/N by moving the mouse of the corresponding dot.

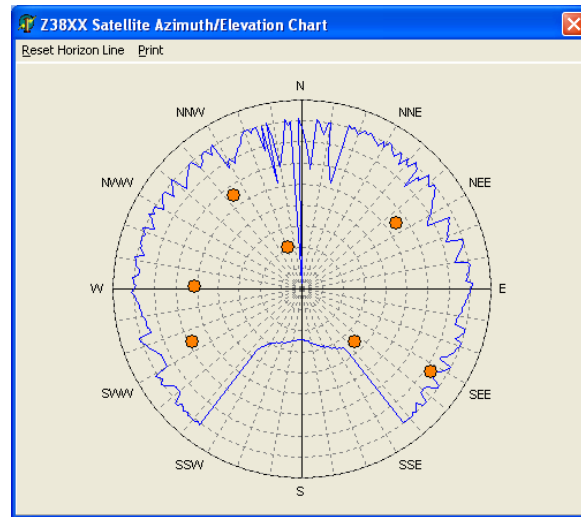


Fig.4. The Satellite Azimuth/Elevation Chart

The chart also draws a 'horizon line', a series of blue lines which slowly build up a view of the elevation at which the satellites become viable at different azimuths, and is essentially a simplified polar diagram of the GPS antenna being used. It takes at least 12 hours to build up a useful diagram, as the satellites need to move position in order to survey the sky<sup>8</sup>.

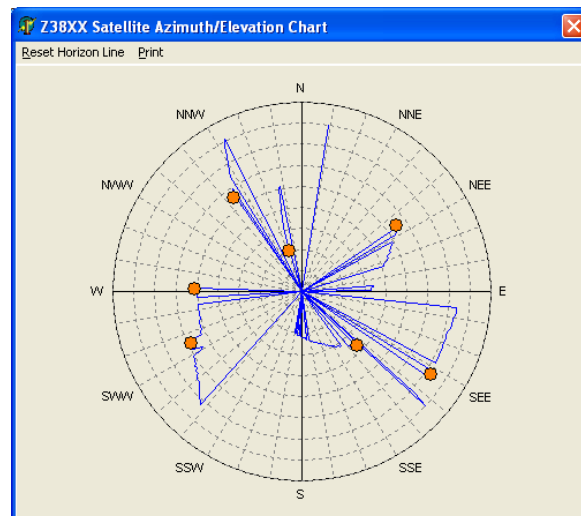


Fig. 5. Building the polar pattern

<sup>8</sup> The GPS satellite orbital period is about 12 hours, so they appear to move quite slowly.

The example in Fig. 4 is about three days old, while that in Fig. 5. is only two hours old. While you can see how the graph is being constructed, as illustrated by the blue lines, it is not so useful until it has been running a while longer.

The horizon line can be reset (a warning is given, since it does take a while to build a new horizon line), and the chart can be sent to a printer.

**Hint:**

You will note in Fig. 4 that there is a large bite taken out of the horizon line towards the south. This is not because of antenna limitations, but simply because the GPS satellite orbits are inclined 55° and so do not move near the poles. Because this recording was made in the southern hemisphere (37°S), the gap is in the south. In the northern hemisphere, the gap is to the north, and increases in size as you approach the poles. Near the equator, the effect is less noticeable.

If you need to place your GPS antenna near an obstruction, try to place the antenna to the south (northern hemisphere) or north (southern hemisphere) of the obstruction in order to least affect the polar pattern.

### 5. Satellite C/N Level Chart

This is a simple bar graph which displays the C/N (carrier to noise ratio) of the satellites currently being tracked. The measurements depend on the GPS engine used, and vary from unit to unit, so it isn't easy to compare one with another.

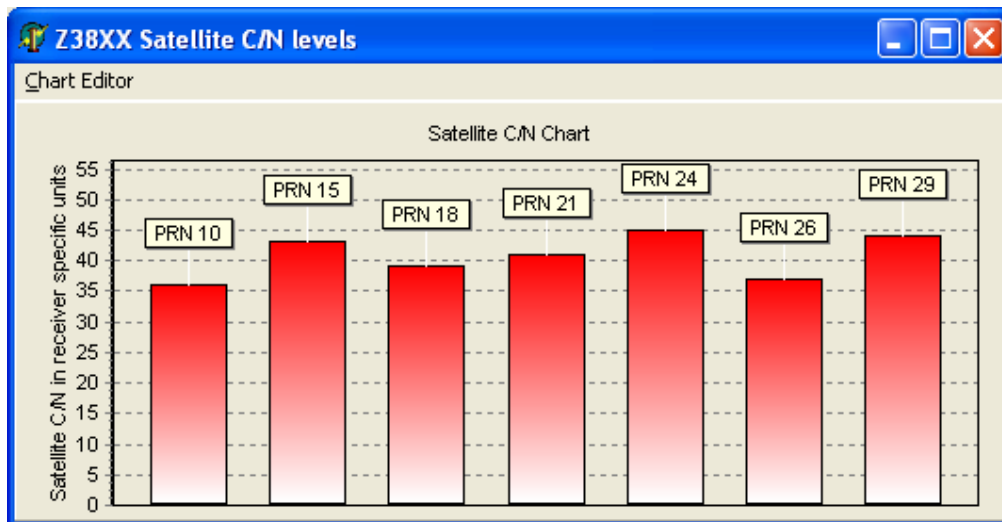


Fig. 6. Satellite signal level chart

The left axis title 'Satellite C/N in receiver specific units' reflects the non-traceable nature of this measurement.

## 6. Holdover Uncertainty & Sats

Two easily understood but unrelated parameters are plotted against time on this chart.

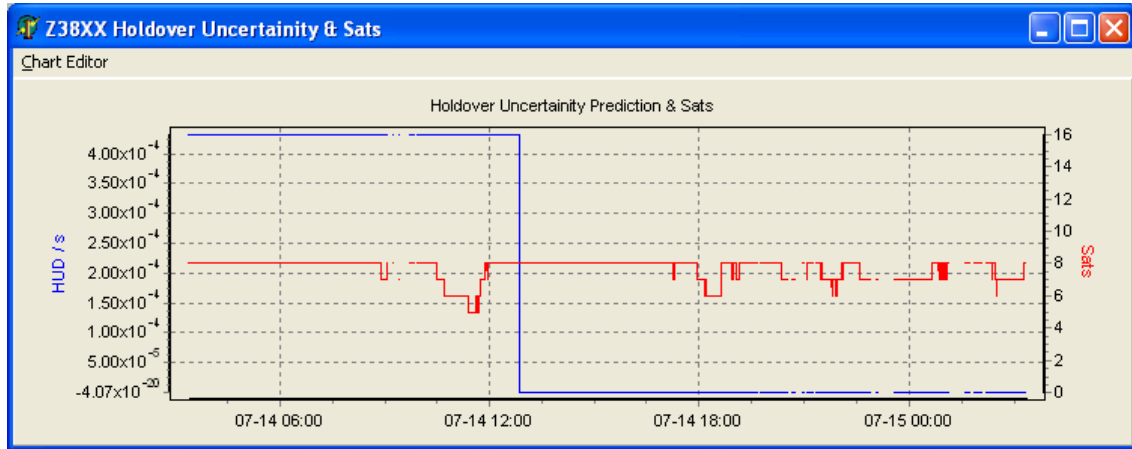


Fig. 7. Holdover Uncertainty and Number of Satellites

### The Holdover Uncertainty

The Holdover Uncertainty Prediction (abbreviated HUD, blue line, left scale) indicates the predicted performance over the next 24 hours if the GPS reference was lost at that time. The value is typically in seconds, and relates to the error in the regenerated 1pps output of the GPSR relative to the GPS or UTC 1pps event.

Check with your GPSR Status message (**View/Receiver Status**) to determine the units of the Holdover Uncertainty. The Holdover Uncertainty Prediction reflects the quality of GPS reception and 1pps TI control over the previous few days.

Note in Fig. 7 that the left scale starts at  $-4.07 \times 10^{-20}$ . Just pretend that means zero – even if you manually change the scale minimum to zero, it won't change the way the graph scale is displayed!

### Satellites

The number of satellites being tracked (red line, right scale) gives a reasonable indication of how well the GPS receiver section of the GPSR and its antenna are performing. Bear in mind that the maximum possible number may well be less than the maximum on the default fixed 0 – 16 scale. For example, the HP Z3801A has a 6-channel GPS engine and therefore can never track more than six satellites at once. Most other units have at least 8-channel engines.

With a good antenna, there should be the maximum number of satellites (or at least eight on 12-channel engines) most of the time. If you regularly have periods with fewer than four satellites, consider replacing or moving the antenna to a better location. Fig.7 shows typical behaviour of an 8-channel receiver on a good well-placed outdoor antenna. Refer to the Satellite Azimuth/Elevation Chart (Fig. 4), which will also help diagnose potential antenna placement problems.

## 7. Time Stability Measures

In order to understand this chart, you need to know about Allan Deviation<sup>9</sup> and its application to high stability oscillators. The **Time Stability Measures** chart displays the results of several different types of measurements, which have slightly different properties. Fig. 8 shows two, the conventional Allan Deviation (blue line) and the Modified Allan Deviation (green line).

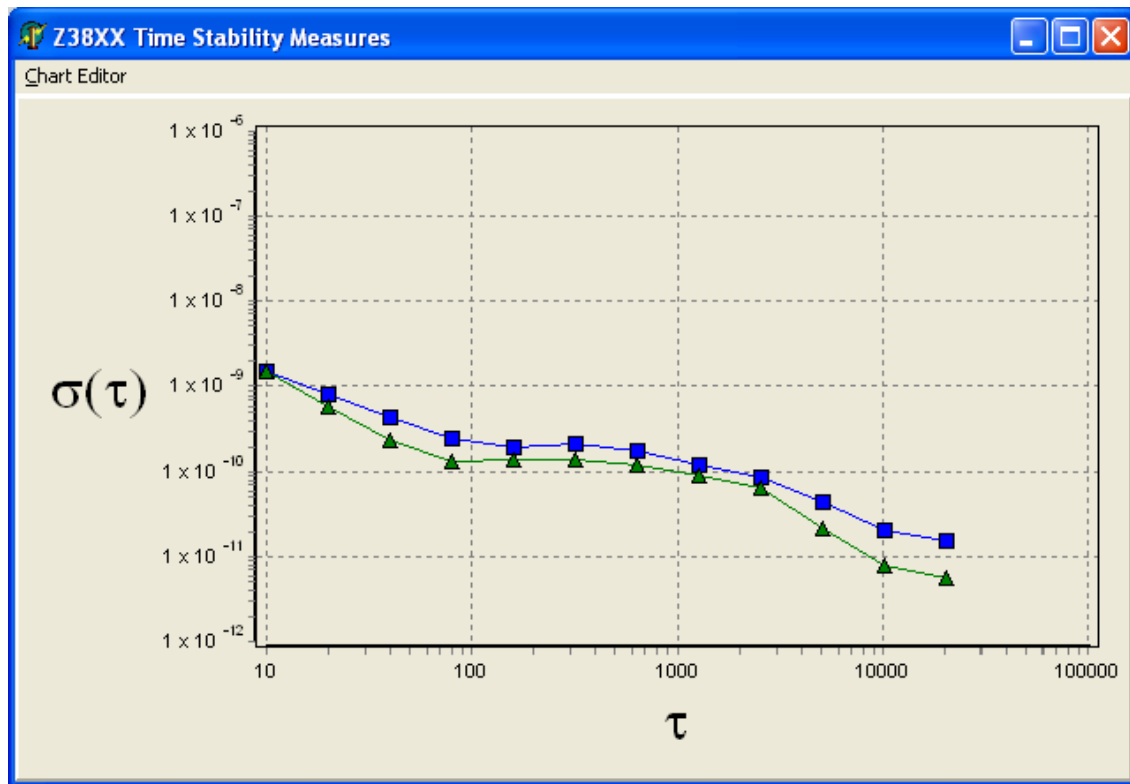


Fig. 8. The Time Stability Chart

By default this chart shows all the possible measurement techniques, and also shows a legend to the right which allows you to select and deselect what is displayed (Fig. 9). In Fig. 8 this legend has been turned off using the Chart Editor feature, and all but two of the options also disabled.

Calculation of these results is computationally intensive, and can slow down an older slow computer. In addition, the values for 10s Tau (left of chart) are not calculated until at least 100s have elapsed since the program started, and the graph slowly builds to the right as more data is collected. In order for the 100,000s Tau values to appear, the program needs to be running continuously for over one million seconds, or nearly two weeks. The chart is not refreshed as the program continues to run, so to view the latest performance, close and re-open this chart.

When just one of the possible calculation techniques is displayed, an additional list of the Time Stability performance is shown (see Fig. 9). Stretch the window vertically to ensure that the bottom part of this additional table is not lost.

<sup>9</sup> See <http://www.allanstime.com/AllanVariance/>

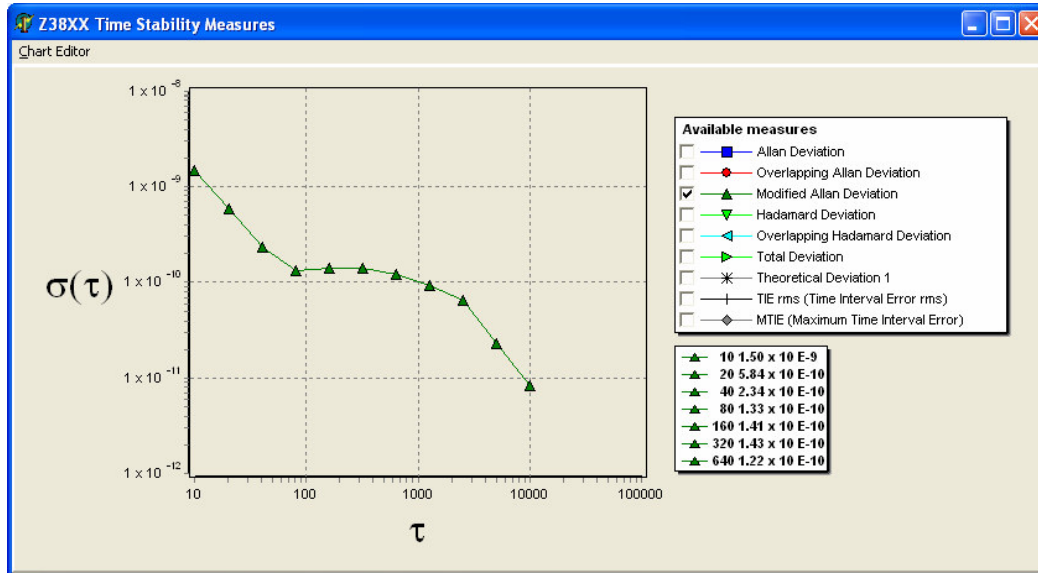


Fig. 9. Time Stability Chart, legend on, one measure selected

The chart cannot show stability for Tau less than 10s, since the unit is only interrogated every 10s. The results are generated by analysis of the 1pps TI information. The **View/Time Stability Measures** chart menu item is greyed out if the GPSR unit does not provide correct 1pps TI information.

It is important to note for the interpretation of the Time Stability Measures that what you see is computed from 1pps TI values measured inside the device. The PPS measurements involved compare:

- A 1pps signal locally generated from the OCXO by means of a frequency divider
- The receiver's 1pps (derived from the satellite constellation)

The comparison of these two PPS signals is the **input information** to the unit's frequency standard control loop. Because this **input information** is dominated by the GPS 1pps jitter (resulting largely from GPS receiver and propagation limitations), do not be fooled into thinking that the Time Stability Measure presented here is that of **your frequency standard**. It is only an internal value which indicates overall system performance (including the GPS reception). For reliable stability measurements, you should make independent measurements against a local high stability reference. The task of the frequency standard's control loop is to 'marry' the high short-term stability of the internal OCXO with the high long-term time stability of the GPS system. For this reason the 10MHz output of your unit will have significantly better stability (for short observation times) than the values indicated in the Time Stability Measures chart.

## 8. Clock Display

It is not difficult to guess the function of this window! It displays UTC or GPS date and time (depends on the setting of the unit) from direct interrogation of the unit's time stamp message. The displayed time should be accurate to within  $\pm 1s$ .



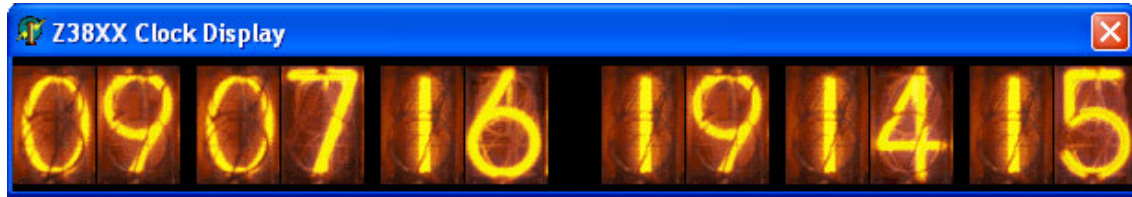


Fig. 10. The 'Nixie Tube' clock display: date (left) and time (right)

Just for fun the clock (Fig. 10) is displayed using 'Nixie Tube' characters, a simulation of the gas discharge displays on old frequency counters. The clock always sits over the top of other charts, so if it is in the way, simply move it (drag the banner) or close it again.

The latest version of the program shows the date to the left, in Y/M/D format, and the time to the right, in H/M/S format. Older versions only display the time. The clock view menu item **View/Clock Display** is greyed out if the unit does not support the time stamp request.

## 9. EFC Statistics

The **View/EFC Statistics** menu item brings up a small additional window which displays an analysis of the Electronic Frequency Control of the unit's OCXO reference. When the window is activated, it also calculates a linear least-squares fit on the data visible in the main chart, which is then displayed as a black line on the main chart. A small legend pops up at the same time. The fact that the fit is made on the *visible* data in the main chart allows you to zoom into the data and compute the fit on smaller segments than originally displayed.

The linear fit line and statistics are not subsequently updated. When you close the EFC Statistics view, the linear fit line and legend disappear. To update the linear fit and statistics, simply close this view and reopen it later.

## 10. Receiver Status

Every SCPI GPSR unit has a status message, which is like a comprehensive page of human-readable data. It carries information about the synchronization process, GPS fix acquisition, the position of tracked and untracked satellites, shows the UTC or GPS time and position, plus other information relating to the position survey, time and frequency reference quality and Holdover prediction, and various self test parameters.

This message is requested and used internally by Z38XX, but you can also view the message using the **View/Receiver Status** menu item. This display refreshes every 10 seconds, as a result of the software interrogating the unit. Once you understand what it tells you, this is perhaps the most useful of all the real-time displays.

## 11. Status Log

The Status Log is generated by Z38XX, and records changes of status of the program with respect to the GPSR unit. It is not directly a record of the GPSR Receiver Status (see item 10 above). The Status Log is also stored as 'Z38XXStatus.Txt'. You can view this log file with the **View/Status log** menu item.

## 12. Error Log

The error log is also generated by Z38xx, but records errors reported by the GPSR. The log is saved as 'Z38XXError.Txt'. The **View/Error Log** menu item simply displays this log. The Error Log records any errors reported by the GPSR in communication, rather than faults in the GPSR itself.