Comparison of Inexpensive 10 MHz GNSS Disciplined Oscillators

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1. Introduction

This article compares six inexpensive 10 MHz GNSS Disciplined Oscillators, or GDO, that are used as a reference frequency source. A GNSS is a *Global Satellite Navigation System* of which the *Global Positioning System*, GPS, is the most familiar. In 2017 I evaluated some 10 MHz reference frequency distribution amplifiers {Reeve17} and mentioned a future review of GDOs. I hereby fulfill my intention for that review.

This article is not a comprehensive review; I investigated the GDOs only enough to determine the characteristics that were important to me: Basic frequency statistics; Output signal characteristics; Form factor and dimensions; and Operating voltage and current. My application is the 10 MHz reference frequency input to the software defined radio receivers used in my observatories.

2. Basic GDO Operation

The two most important characteristics of a frequency source are accuracy and stability (figure 1). Accuracy is the measure of how far a frequency is from its true, or nominal, value. Stability is the measure of the variation in accuracy over a period of time. The accuracy can be no better than the stability.

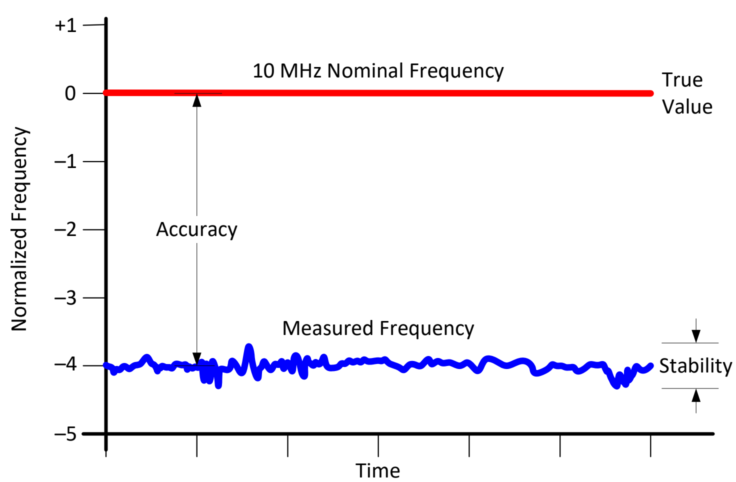

Figure 1 ~ Accuracy and stability of a hypothetical 10 MHz frequency source. The true, or nominal, frequency is shown as the straight red line and the actual oscillator frequency measured over time is shown as the jagged blue line. The stability is a statistical measure of the variations over time and is usually based on a modified version of the Standard Deviation called Allan Deviation (ADEV).

A frequency source consisting only of a quartz crystal generally has very good short term but poor long term accuracy and stability due to aging and environmental factors such as vibration, humidity and temperature. On the other hand, a frequency source derived from a GNSS but without a quartz crystal has very good long term but poor short term accuracy and stability due to jitter and wander. Combining a high-quality crystal oscillator and GNSS receiver provides an almost ideal frequency source that has both high accuracy and high stability. The combination is known by various abbreviations including GDO, GNSSDO and GPSDO.

The oven controlled crystal oscillator (OCXO) and temperature compensated crystal oscillator (TCXO) provide better performance than ordinary crystal oscillators. Rubidium oscillators also are used in GDOs, particularly GDOs that have a *holdover* function. The atomic transitions in a rubidium oscillator *physics package* are used with an RF synthesizer and voltage controlled OCXO to maintain frequency accuracy and stability. None of the units reviewed here use a rubidium oscillator, which is generally more stable but far more expensive than any OCXO or TCXO.

Of course, an oscillator and GNSS receiver cannot be simply slapped together and expected to provide textbook performance. A GDO's performance depends on both internal and external factors. Important internal factors are the quality of the oscillator, the design of the phase locked loop that controls the output frequency and how the GNSS receiver is linked to the oscillator. External factors include signal loss, interference or other disturbances that can cause loss of receiver tracking and jumps in satellite carrier -phase measurements by the receiver. None of the sellers provided any information about the design of the GDOs but I do recall seeing a useless blurry block diagram in one of the listings.

GDOs of the type reviewed here that cost less than 200 USD typically contain old, recycled oven controlled crystal oscillators (OCXO) and have no documentation. Many do not even have a brand or model number. They are not going to perform as well as far more expensive industrial units. Note that the cost of a new OCXO exceeds the cost of any one of the GDOs reviewed.

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3. GDO Descriptions

This section provides information on the six GDOs in terms of the type of oscillator and types of GNSSs supported (table 1). In addition to the GPS, several other GNSS exist including Galileo, GLONASS, Beidou, and QZSS. In some cases, the GNSS must be specified at the time of purchase so the receiver can be programmed appropriately. Although receivers exist that can simultaneously acquire and track all GNSS constellations, the GDOs reviewed here apparently do not have that capability.

Table 1 ~ GDO units being compared. The serial number is an arbitrarily assigned house number. The oscillator manufacturers and model numbers in parentheses were read from the device after removing the GDO enclosure.

Model	**S/N**	**Oscillator, 10 MHz**	**GNSS as advertised** (1)	**Remarks**
BG7TBL-D	001	OCXO (Trimble 72345)	GPS, Galileo	LCD (2)
SatTime	002	OCXO (CTI OC12SC36B)	GPS, BDS, GLONASS, GALILEO, QZSS	(3)
TM4313	003	OCXO (CTI OC5SC25)	GPS, BDS	
TM4313	004	OCXO (CTI OC5SC25)	GPS, BDS	
Mini Precision GPS Reference Clock	005	TCXO (unknown)	GPS, BDS, GLONASS, GALILEO	Abbreviated MPGPSRC
PLL-GNSSDO	006	OCXO (CTI OC12SC36A)	GPS, GALILEO	

<u>Table notes</u>: (1) Not verified; (2) Not an actual model number; see text; (3) Not an actual model number; see text.

The next three sections describe the test setup, evaluation results and a set of images showing the units and their output spectra. All units evaluated cost between 100 and 200 USD and represent only a few of the many different GDOs available from online sellers (primarily located in China).

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4. Test Setup

Frequency measurements were made with a recently calibrated Keysight 53220A frequency/period counter. Other equipment used in the evaluation included a Siglent SSA3032X spectrum analyzer and SPD3303X variable power supply. All measurements were made in a lab environment at a very stable temperature near 20 °C.

The reference frequency input to the counter was provided by the 10 MHz output from a Symmetricom TimeSource 2500 *GPS Primary Reference Source*, a late 1990s industrial unit used in telecommunications applications. The antenna for this unit was located adjacent to an east-facing window with numerous trees outside that partially block the view of the sky.

The TS-2500 has a 1999 vintage GPS receiver that is not very sensitive compared to modern GNSS receivers. As a result, the TS-2500 spent most of the time (about 80%) in *holdover* mode during which the unit's output frequency was determined by a rubidium oscillator. The rubidium oscillator's output frequency is corrected by historic GPS reception data and is very accurate and stable but is not as accurate as when the unit is tracking satellites over a long period. The TS-2500 in combination with the high quality of the frequency counter itself provides a very stable measurement platform. While it may not be as accurate over the long term as a GNSS disciplined oscillator that is actively tracking satellites, I believe it is far more stable than the cheap GDOs evaluated here. Nevertheless, I have not used the estimated stability (ADEV) in my evaluation.

All GDOs were supplied with an active patch-type GNSS antenna of similar design. I used one of these antennas with the GDOs. It was located 2.5 m from the lab workbench in view of the east-facing window. Even though the window does not have a clear view of the sky, as pointed out above, the modern receivers used in the GDOs are very sensitive and always were able to obtain a fix and track multiple satellites (all GDOs have an LED indicator for satellite tracking).

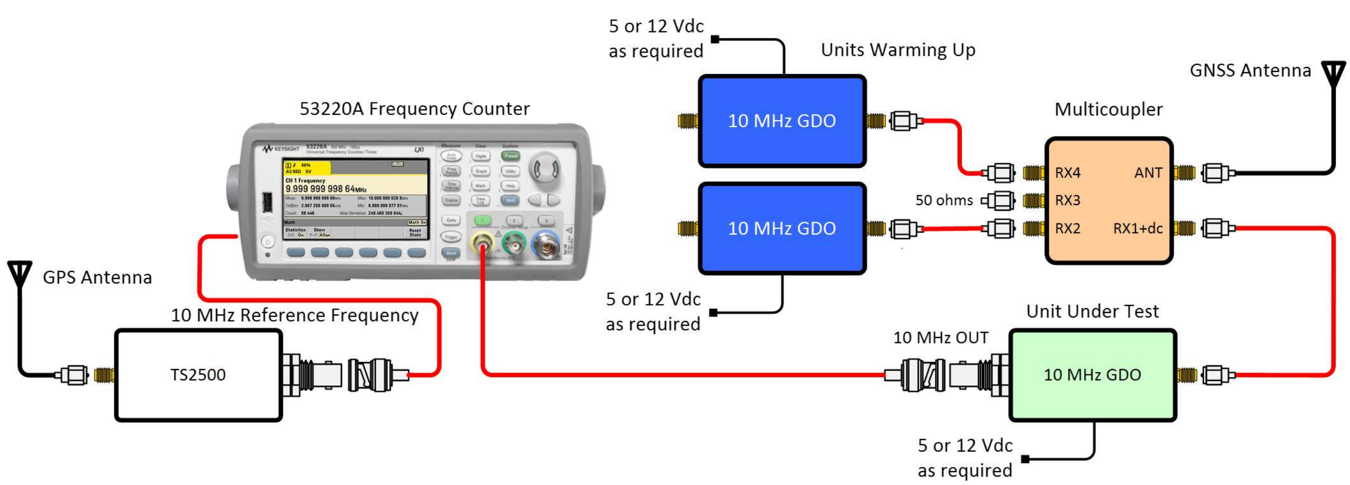

Figure 2 ~ Block diagram of measurement setup. The Unit Under Test (UUT) provides powering voltage to the active GNSS antenna while the other units are warming up and tracking for at least 24 hours. The GDOs were rotated through so that all eventually powered the GNSS antenna as part of the evaluation. Because the frequency counter and UUT used separate receivers and antennas, they operated plesiochronously.

The GNSS antenna was connected through a receiver multicoupler (active 4-port RF splitter) to allow multiple GDOs to track satellites and warmup while awaiting connection to the frequency counter (figure 2). Statistics were collected from the frequency counter for each GDO after at least 24 h of locked satellite operation. Other information was collected including dc input voltage and power plug requirements, start and run current, output spectra from 0 to 200 MHz (20th harmonic), and 10 MHz fundamental output power into a 50 ohm load.

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5. Evaluation

General characteristics: Operational information and features are described for each GDO in this section. Basic dimensional and electrical details are listed in table 2.

Table 2 ~ General characteristics. Dimensions do not include connectors.

GDO	Power Connector	Voltage (Vdc)	Start (A)	Run (A)	Serial Interface	Dimensions (WxHxD, Wt)	Remarks
BG7TBL-D-001	2.1 x 5.5 mm	12	0.56	0.28	DB-9F	107 x 55 x 153 mm, 0.7 kg	Includes LCD
SatTime-002	2.5 x 5.5 mm	12	0.60	0.26	DB-9M	134 x 47 x 123 mm, 0.4 kg	Includes NTP server
TM4313-003	2.1 x 5.5 mm	5	0.78	0.34	Micro-USB	72 x 26 x 110 mm, 0.2 kg	
TM4313-004	2.1 x 5.5 mm	5	0.78	0.34	Micro-USB	72 x 26 x 110 mm, 0.2 kg	
MPGPSRC-005	Mini-USB	5	0.11	0.11	Mini-USB	73 x 40 x 17 mm, 0.05 Kg	Variable frequency output
PLL-GNSSDO-006	2.1 x 5.5 mm	12	0.53	0.16	3.5 mm	64 x 24 x 104 mm, 0.18 kg	Also marked BG7TBL

Brand: The BG7TBL-D does not have a model number or any other markings but some similar looking units sold through eBay and Aliexpress are marked with a date that apparently indicates when it was designed or manufactured. The PLL-GNSSDO also is marked BG7TBL. It apparently was designed or manufactured by the same entity, but it has a completely different form factor than other units with this marking. The TM4313 is unbranded but I believe it is manufactured (or marketed) by a company called TZT in China. Two TM4313 units were evaluated. The SatTime unit has neither a brand nor model number or any other markings. The Mini Precision GPS Reference Clock (abbreviated MPGPSRC from now on) is manufactured by Leo Bodnar Electronics, which is based in Britain and sold direct or through SDR-Kits.net.

Documentation: None of the units included instructions or a user guide of any kind. The minimal online information provided nothing more than repetition of GNSS operational specifications, if that, and no specifications for the actual GDO itself. The MPGPSRC at least has a dedicated webpage with some performance and operation information as well as a software tool for checking satellite tracking and setting the output frequency; some additional application information for this unit is available at {Reeve20}. The MPGPSRC also has upgradeable firmware, something none of the others have or, if they do, it is not advertised.

Load current measurements: All units except the MPGPSRC have an OCXO, which draws more current during starting and warming up than when running. Starting current is the important value because the external power supply must support it. All units with an OCXO showed the same behavior when first powered – the starting current ramped up over several seconds to a peak value and after a few minutes it quickly dropped to the running value.

Another characteristic that affects the current draw is the GNSS receiver transition from searching to tracking satellites. The search function requires more power. I made no attempt to separate the current draw during search and track functions because the difference is small compared to the starting and running currents of the OCXO.

Display and indicators: All units have LEDs that indicate power status, satellites in view (SV) status and satellite fix or tracking status, either through dedicated or blinking LEDs. Only the BG7TBL-D has a liquid crystal display (LCD). The LCD indicates frequency and other information; however, there is no way to turn off or dim the LCD backlight or turn off the display itself without disconnecting the internal LCD cable.

Serial port interface: The BG7TBL-D, TM4313 and PLL-GNSSDO have a serial port interface for monitoring NMEA messages from the receiver but none had instructions on how to use it or how to read the messages. NMEA messages are handy for determining position coordinates and satellites in view and could be used to verify the GNSS that seller advertisements claim the unit uses. The NMEA message type *GSV* identifies the GNSS satellites in view and the number of each. The message is prefixed with GP (GPS), GA (Galileo), GL (Glonass), GB or BD (Beidou), GQ (QZSS) or GN (combined). Many online resources define the various other NMEA messages.

The BG7TBL-D and TM4313 have DB-9F connectors, and the PLL-GNSSDO has a 3.5 mm audio-style jack used for serial communications. I was able to connect to the first two units with the PuTTY software tool, a USB-Serial Converter, straight-through serial cable and 9600, 8N1 COM Port settings and view the NMEA messaging without problems. I have many serial cables that use the 3.5 mm connector but these would not work with the PLL-GNSSDO unless a null modem adapter was inserted between the unit and cable (RXD and TXD on one end of the cable is swapped). These three units tracked numerous satellites with the indoor antenna as described in section 4.

The SatTime has a DB-9M connector marked RS422 but the pinout is undocumented. I was not able to successfully connect to the SatTime unit and did not spend any time trying to determine the connector pinout or any other details about it other than a failed attempt to contact the seller. The MPGPSRC uses a special software tool and does not provide NMEA messaging, but it does show the number of satellites in view and if they are being used in the frequency calculations. The MPGPSRC uses an ordinary USB cable with a Mini-USB connector for serial communications and required no driver installation.

Other functions: Some GDOs have additional outputs including Inter-Range Instrumentation Group (IRIG) timecodes and 1 pulse-per-second (1 PPS), but none of these apply to my immediate needs so I did not evaluate them. The captions on the images in section 6 name the outputs available from each device.

The SatTime unit has a modular jack marked *Ethernet* for its built-in Network Time Protocol (NTP) server function. This means the one unit provides two important functions, a 10 MHz reference frequency source and NTP server. I verified the NTP server functionality by searching the LAN for an unfamiliar IP address and then configuring the NTP client on a PC to use that address. I could not connect to the SatTime's internal web browser interface (if it has one), and the eBay seller did not respond to my inquiries about the unit.

Satellite constellations: The product listings on eBay and Aliexpress indicate the GNSS constellation used by the unit. With some units, either one or two GNSS constellations are to be specified by the buyer during purchase. When given the choice, I chose GPS and Galileo, but I did not verify during evaluation that specific satellite systems were actually being used (successfully tracking satellites was sufficient for my application).

GDOs used in industrial applications are generally designed to meet frequency specifications with only one satellite in view, although some units have increased accuracy with more. The meager information provided with the inexpensive GDOs evaluated here does not specify anything related to satellite-in-view quantity or quality.

<u>10 MHz Oscillator</u>: The 10 MHz output signal from all GDOs is generated by an OCXO except in the Mini Precision GPS Reference Clock. The OCXO in the BG7TBL-D and SatTime units have a well-used physical appearance (scratched or tarnished) and are made by Trimble or CTI. The PLL-GNSSDO uses the same oscillator as the SatTime (CTI) but its physical appearance is much better. The physical appearance of the OCXOs in the TM4313 is better than average.

These oscillators probably were salvaged from obsolete base transceiver stations used in the old 3G cellular systems and probably are *aged out* (that is, natural crystal aging has drifted the crystals beyond their specified frequency limits). Surprisingly, I could not find datasheets for any of the OCXOs, but they have a standard pinout and layout (footprint). The CTI oscillator part number appears to indicate basic characteristics. For example, the CTI OC12SC36B is Oven Controlled (OC) with 12 V operating voltage, SC cut crystal and the long dimension is 36 mm.

The SatTime unit had a noisy OCXO and worked much better after I replaced it (discussed more below and in section 6). Replacing the used OCXOs with new (or newer) devices would likely improve the performance of the other GDOs.

The MPGPSRC advertisements claim it uses a temperature compensated crystal oscillator, TCXO (it is not visible on the unit's PCB). The TCXO works with a synthesizer to provide an output. Although the measurements show the MPGPSRC to have good performance in my lab, which has a constant temperature, the MPGPSRC may not provide performance comparable to a GDO that uses a good OCXO over the operating temperature ranges of my remote observatories (the indoor temperature in my Cohoe Radio Observatory can reach –20 °C during winter).

<u>Workmanship</u>: All GDOs are built on professionally made printed circuit boards and all surface mounted devices appear to be machine-soldered. Surface mounted devices generally are installed on the lower layer with through-hole components (for example, the OCXO and connectors) on the top layer.

<u>Design</u>: There is a potential design problem with all units except the MPGPSRC, and that is the lack of margin in the GDO input voltage compared to the OCXO operating voltage. The voltage range of OXCOs typically is the specified nominal voltage ±5%. For example, for a 12 V operating voltage the input range would be 11.4 to 12.6 V, and for a 5 V nominal input, the range would be 4.75 to 5.25 V. Assuming all units have a polarity guard diode, the OCXOs in units with 5 V input voltage probably are operated below the recommended range and units with 12 V input voltage are operated with little or no margin, both because of diode voltage drop.

It is possible some units do not have a polarity guard diode on the power input but the PLL-GNSSDO does (type SS24 Schottky diode). Further investigation of this unit showed that the oscillator voltage was 11.6 V with 12.0 V at the GDO's power jack. This provides very little margin for variations in the power supply. The margin for this unit may be improved by raising the input voltage to, say, 13 V. Interestingly, the marked input voltage range for the PLL-GNSSDO is 11.4 to 13 V, although the low end is obviously too low. All units are supplied with a regulated ac adapter power supply, either 5.0 or 12.0 Vdc.

The OCXOs in the GDOs have an electronic frequency control (EFC) pin that allows the frequency to be steered over a small range (typically around ±1 ppm or less) to compensate for aging and other drift mechanisms. Presumably, the EFC is ultimately controlled by the 1 PPS signal from the GNSS receivers. I noted that the control voltage on the PLL-GNSSDO was near mid-voltage (6 V) at startup and generally stayed near 1.95 to 1.97 V when tracking satellites. The 12 V OCXOs familiar to me have a full EFC range of 0 to 12 V, so this unit operates near one end of its range at room temperature.

Frequency measurements: All units supplied a 10 MHz output signal when initially powered but with varying amounts of inaccuracy (a satellite fix was not necessary for the unit to provide an output, unlike some industrial units). The frequency drifted as the oscillator warmed up to a running state but before a satellite fix was obtained. After a satellite fix, the frequency appeared to lock into a final nominal value with a small amount of variation as the oscillator stabilized over the next several hours. All oscillators showed tiny frequency variations in the mHz or μHz range after warmup.

I was more interested in comparative frequencies than absolute frequencies. The 53220A frequency counter is easily setup to collect the following statistics: Mean frequency (Favg); Standard deviation (σ); maximum (Fmax) and minimum (Fmin) frequency and Allan Deviation (ADEV). These were collected over a period of at least 24 h for each unit (table 3).

Table 3 ~ Statistics after 24 h of satellite tracking. All parameters except ΔF and Pout were obtained directly from the frequency counter. ΔF is computed as the difference between Fmax and Fmin. Pout was obtained from the spectrum analyzer and is for the fundamental only. ADEV measurements are based on τ = 1 s but they do not provide a useful comparison because of the measurement setup.

GDO	**Favg (MHz)**	**σ (μHz)**	**Fmax (MHz)**	**Fmin (MHz)**	**ΔF (nHz)**	**ADEV (μHz)**	**Pout (dBm)**
BG7TBL-D-001	9.999 999 999 97	293	10.000 000 001 4	9.999 999 998 81	2.59	218.7	12.30
SatTime-002	9.999 999 999 97	2808	10.000 000 012 1	9.999 999 987 60	24.5	2714.7	9.91
SatTime-002 (1)	9.999 999 999 97	944	10.000 000 008 8	9.999 999 994 14	14.7	91.6	10.16
TM4313-003	9.999 999 999 98	2067	10.000 000 028 8	9.999 999 977 87	50.9	249.5	10.66
TM4313-004	9.999 999 999 98	1867	10.000 000 025 6	9.999 999 981 48	44.1	236.9	10.60
MPGPSRC-005 (2)	9.999 999 999 90	636	10.000 000 006 2	9.999 999 997 36	8.84	522.2	8.43
PLL-GNSSDO-006 (3)	10.000 000 000 0	833	10.000 000 004 7	9.999 999 995 00	9.70	168.6	12.08

Table notes:

(1) Measurements were after OCXO replacement described in section 6. For these measurements, the frequency counter reference was changed to the All-in-One package described in section 7 so is different than the previous measurements for this unit;

(2) Pout from the MPGPSRC was with an output drive setting of 8 mA;

(3) The frequency counter reference was changed to the All-in-One package described in section 7.

The mean frequency was not important to me (other than as a cross-check) because of the measurement setup and limitations described above, but the other parameters and the difference between maximum and minimum frequency (ΔF) provided the information I needed. Allan Deviation (ADEV) is an important stability measurement and was recorded as part of the statistics. However, because the reference frequency source for the frequency counter was not always tracking satellites, the meaning of the ADEV measurements was not clear to me and was not used in the evaluation.

<u>10 MHz output spectra</u>: Some GDOs have both sinewave and squarewave outputs. A squarewave has the fundamental frequency as well as numerous harmonics and can be considered to be a very distorted sinewave. I require a low distortion sinewave output to prevent equipment that uses the external reference from locking onto the wrong frequency and also to reduce the number of spurious signals in my lab.

The spectra varied with the type of OCXO as shown in the spectrogram images in the next section. For some applications, the output from a unit with a distorted sinewave or squarewave output may need to be externally filtered to reduce the harmonics. More sophisticated equipment has built-in filters for this purpose.

Note that a 20 dB attenuator was placed on the spectrum analyzer RF input to reduce the chance of damage due to high power, so the vertical scale on the display uses a 20 dB offset to compensate.

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6. Images

<u>BG7TBL-D-001</u>:

Figure 3.a ~ <u>Left</u>: System PCB connected by a ribbon cable to the LCD at bottom of image. Most components are underneath the system PCB. The Trimble OCXO is the large square can in the lower-left of the PCB. Note the well-used and worn appearance of the oscillator. The outputs, antenna input, dc power input jack, serial port interface and LED indicators are on the back panel at the top of the image. The outputs are 1 PPS and 10 MHz sinewave. <u>Right</u>: View of the front panel with the LCD (unpowered).

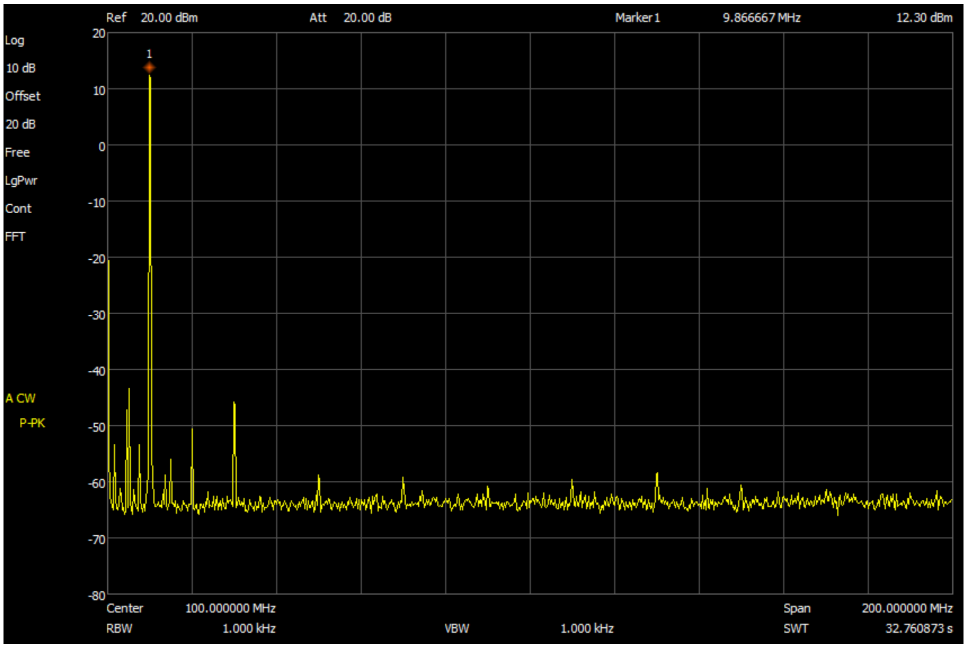

Figure 3.b ~ BG7TBL-D output spectra from 0 to 200 MHz. A 5 MHz subharmonic exists at about –50 dBc and is far enough below the 10 MHz fundamental to not be a problem. A few other spurious signals and harmonics are visible but have lower power. This unit likely would benefit from a new OCXO.

<u>SatTime-002</u>:

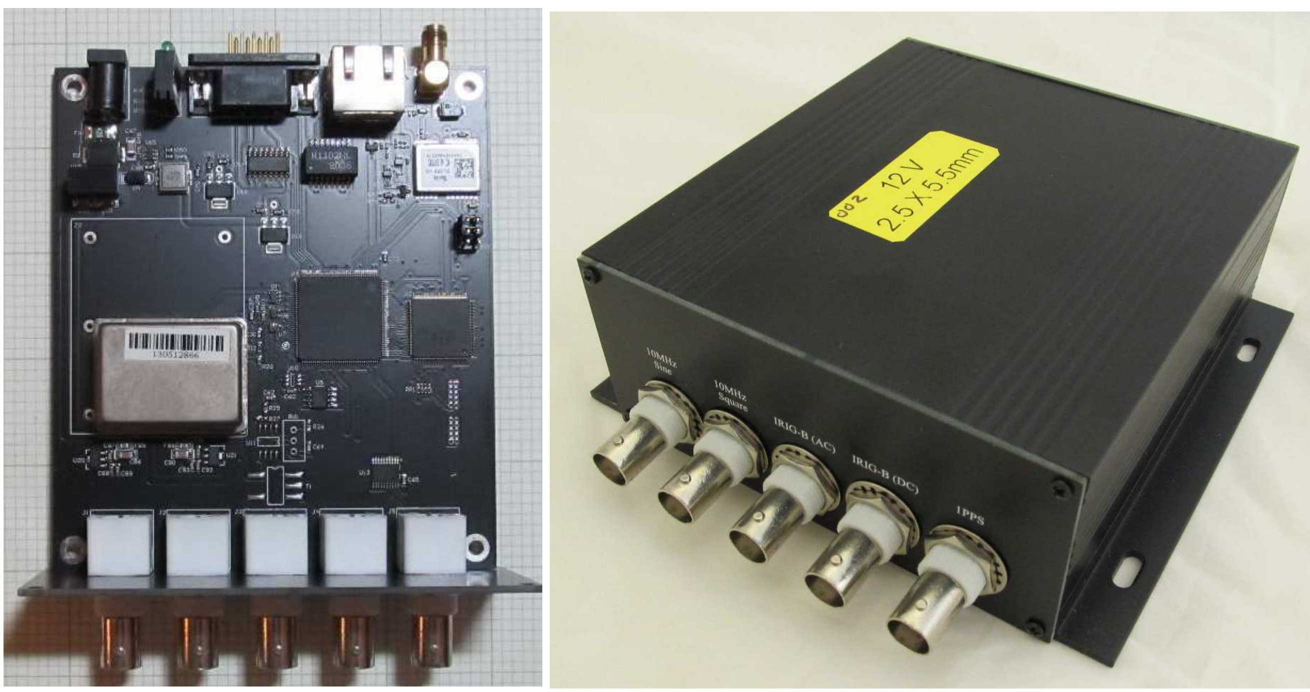

Figure 4.a ~ <u>Left</u>: System PCB. The OCXO is the rectangular silver can near the middle-left of the PCB. This picture was taken before the oscillator was replaced; note the tarnished appearance of the oscillator can. The outputs are at the bottom, and the antenna input, Ethernet modular jack, dc power jack, serial port interface and LED indicators are at the top of the image. <u>Right</u>: View of the output panel. The outputs are 10 MHz sinewave, 10 MHz squarewave, IRIG-B (AC), IRIG-B (DC) and 1 PPS. I only tested the 10 MHz sinewave output.

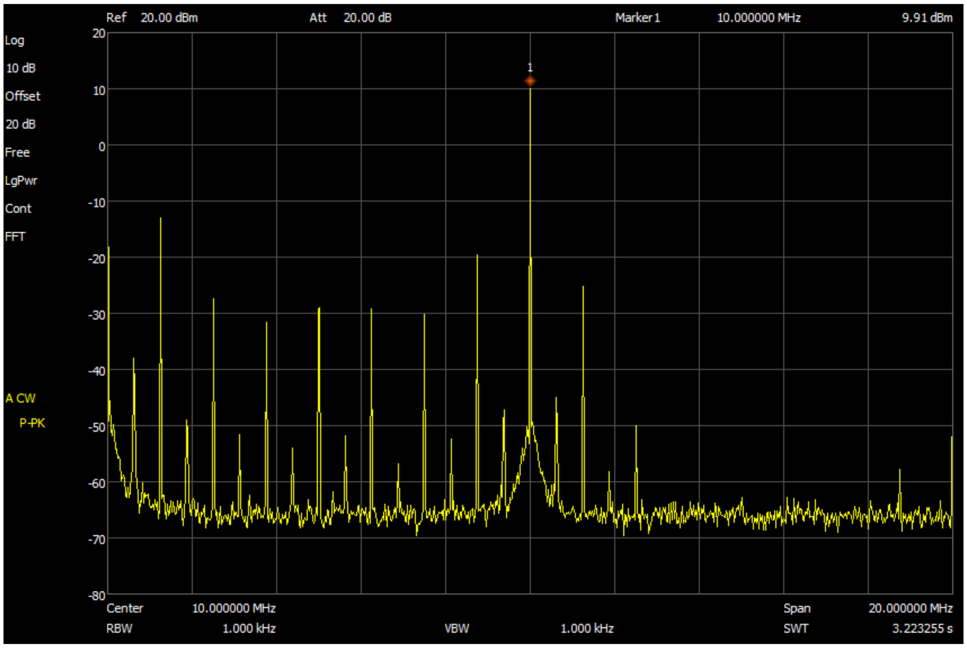

Figure 4.b ~ SatTime output spectra from 0 to 20 MHz as received. The spectra has many subharmonics of the 10 MHz output. The subharmonics start at 625 kHz and continue to over 10 MHz at 625 kHz intervals. The strongest subharmonic is 1.25 MHz at about –20 dBc. The SatTime output is supposed to be a sinewave but the subharmonics indicate the oscillator is defective. The OCXO was replaced and additional measurements below show much better spectra.

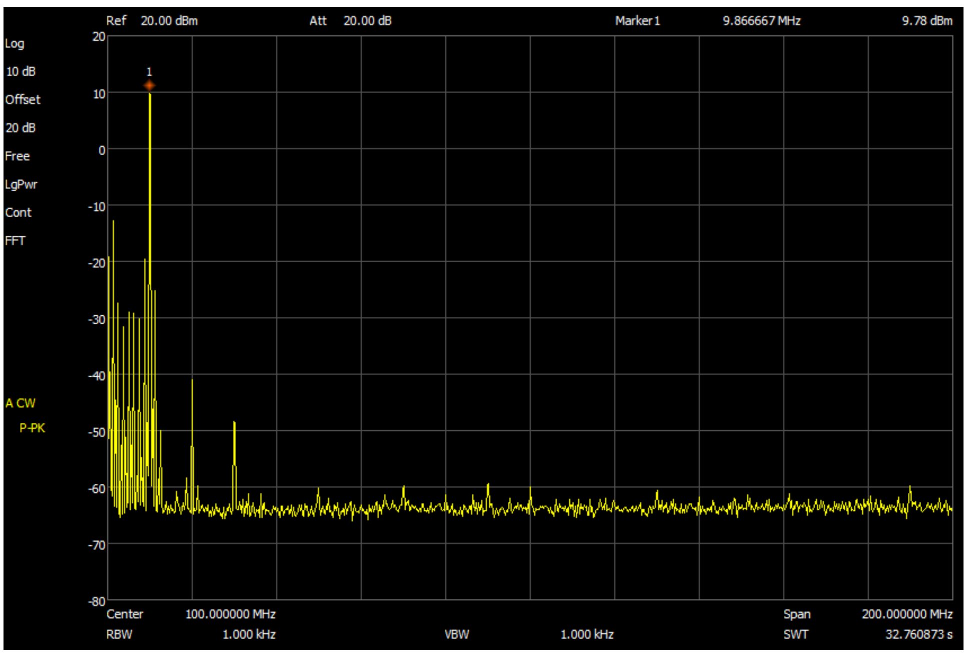

Figure 4.c ~ SatTime output spectra from 0 to 200 MHz before OCXO replacement. The output at frequencies above 10 MHz is clean compared to the subharmonics. The strongest harmonic of 10 MHz is 20 MHz at about –50 dBc.

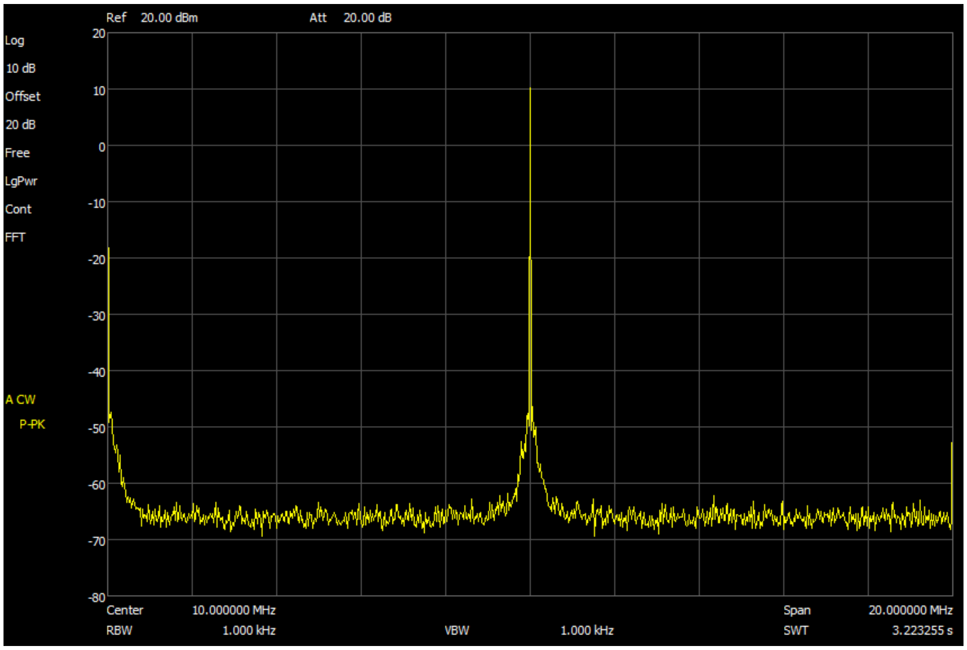

Figure 4.d ~ SatTime output spectra from 0 to 20 MHz after OCXO replacement. Note the complete absence of subharmonics.

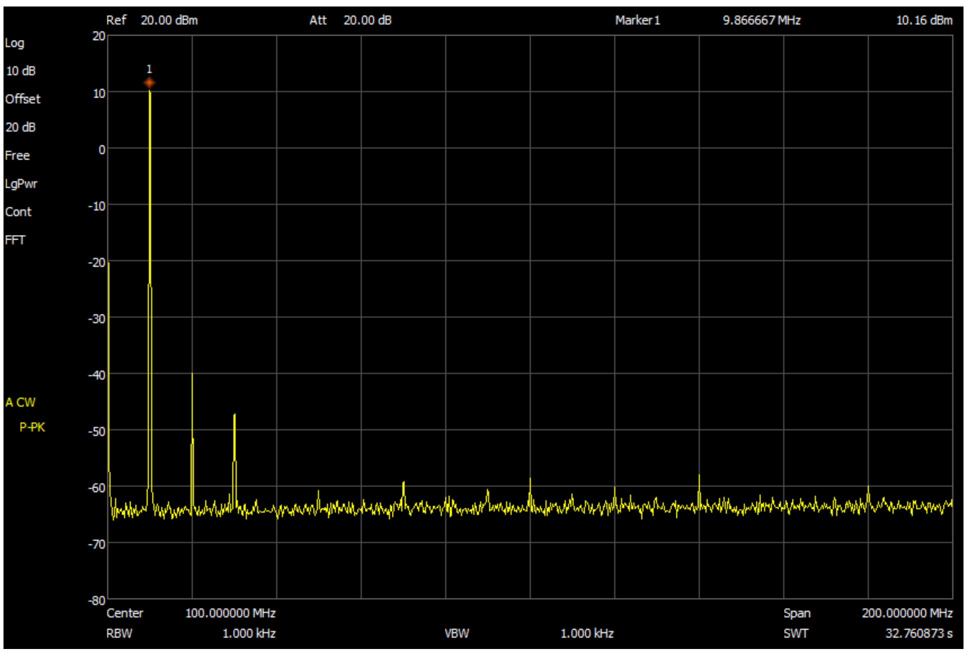

Figure 4.e ~ SatTime output spectra from 0 to 200 MHz after OCXO replacement. The spectrum from 10 to 200 MHz is the same as the original OCXO.

TM4313-003 & TM4313-004:

Figure 5.a ~ Left: System PCB for one of the two units evaluated. The OCXO is the large, square silver can; note the newer appearance than the BG7TBL-D and SatTime (before replacement). The 10 MHz and 1 PPS outputs and antenna input are at the bottom, and the dc power jack, Micro-USB connector and LED indicators are at the top of the image. Right: View of the output and antenna input panel. The outputs are 10 MHz sinewave and 1 PPS.

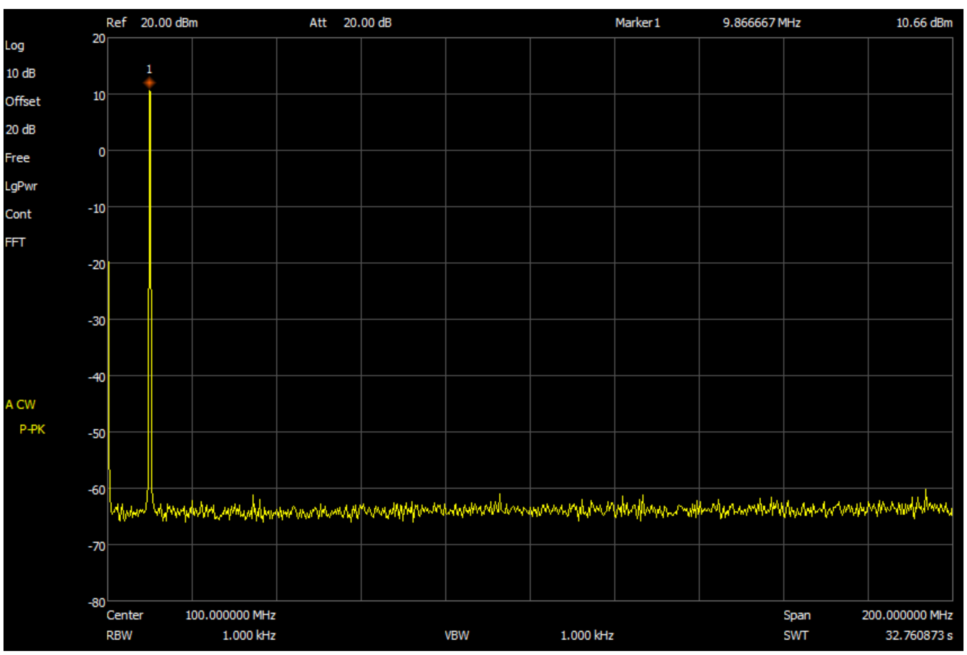

Figure 5.b ~ The TM4313 output spectra is very clean with no visible spurious signals or harmonics with a power level above –75 dBc.

Mini Precision GPS Reference Clock-005:

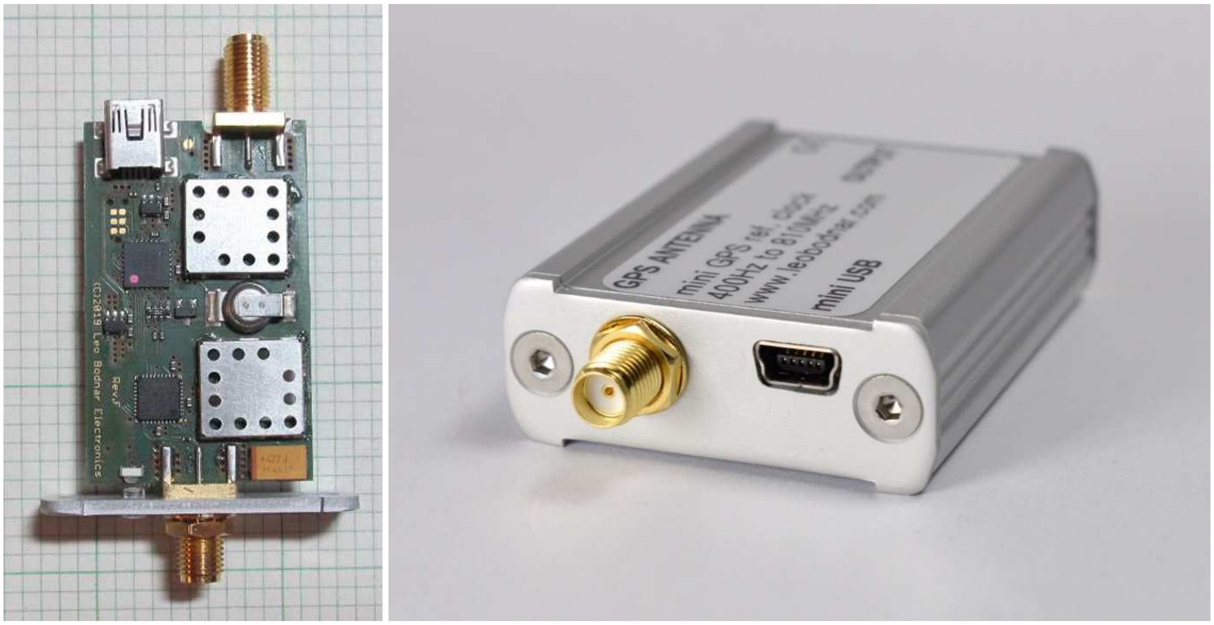

Figure 6.a ~ Left: System PCB. The TCXO is presumably under one of the metal shields. The output is at the bottom and the antenna input and Mini-USB connector are at the top of the image. The only output is a variable frequency squarewave the frequency of which is set by the user; I set my unit to 10 MHz; Right: View of the antenna input and Mini-USB connector panel. Image source: leobodnar.com

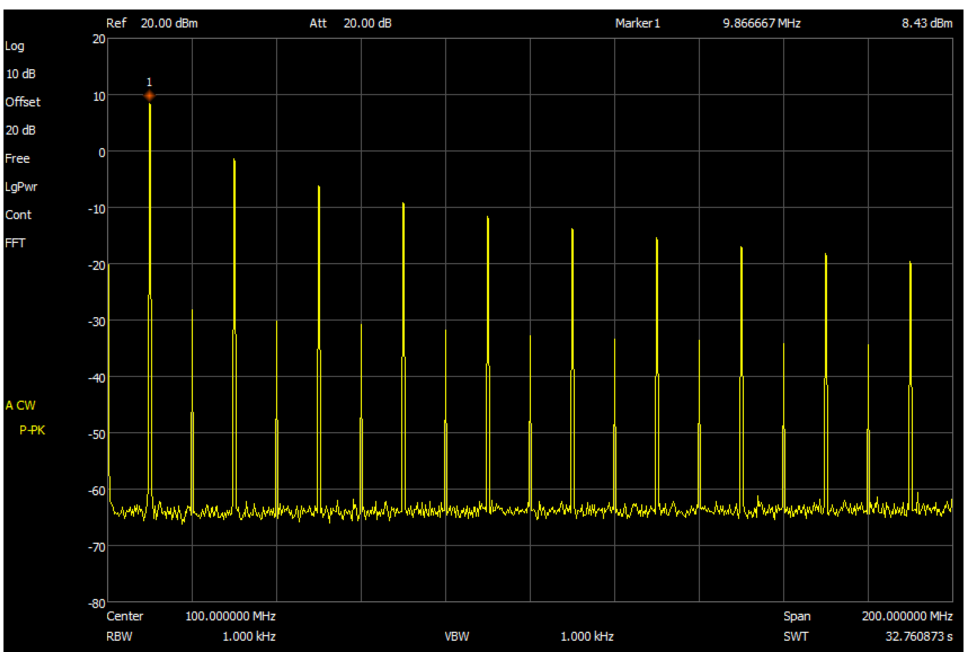

Figure 6.b ~ The MPGPSRC output spectra indicates an offset squarewave with harmonics spaced at 10 MHz intervals. The strongest harmonic is the 3rd harmonic (30 MHz) at –10 dBc.

PLL-GNSSDO-006:

Figure 7.a ~ Left: System PCB, top view showing the OCXO (rectangular silver can in the middle), which is the same model as used in the SatTime GDO. Most components are underneath and not visible in this view. The output BNC-F connectors for the 10 MHz sinewave and 1 PPS and the status LEDs are at the bottom of the image. The antenna input, 3.5 mm serial port jack and dc power input jack are at the top of the image. Right: View of the antenna input, 3.5 mm serial port jack and 12 Vdc input jack panel. The transmit and receive pins on the RS232 (EIA-232) connector are reversed from convention. PCB dimensional tolerances are not particularly good – the nuts on the RF connectors cannot be tightened without warping the panels; the PCB should be redesigned or shims should be used.

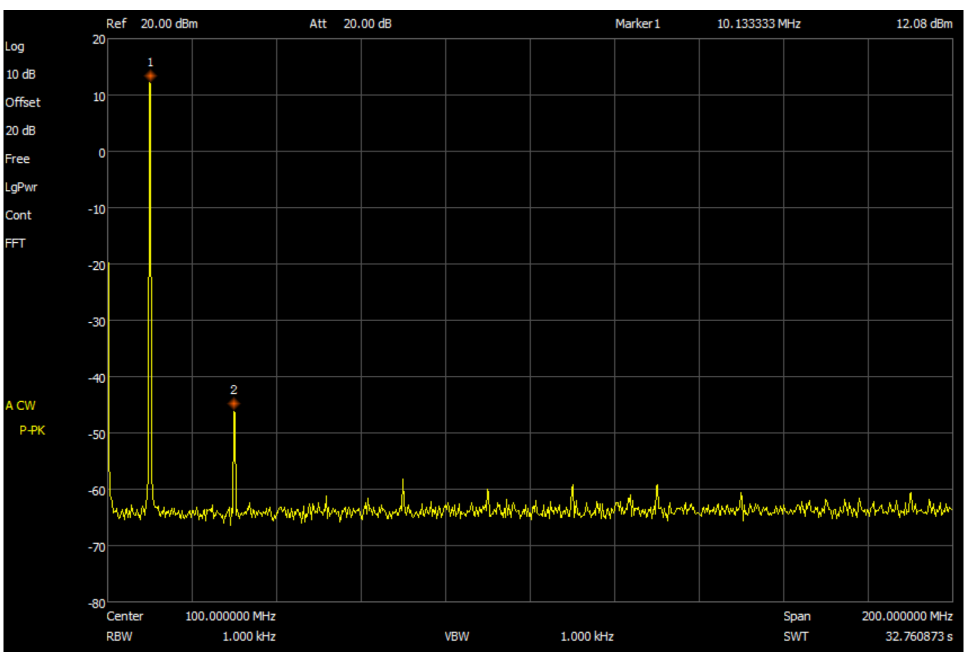

Figure 7.b ~ The PLL-GNSSDO output spectra is very clean with only the fundamental and 3rd harmonic (30 MHz) visible. The 3rd harmonic level is –58 dBc.

7. Discussion

The BG7TBL-D, TM4313 and Mini Precision GPS Reference Clock provide comparable performance but the SatTime (after OCXO replacement), BG7TBL-D and MPGPSRC have the smallest frequency standard deviation (σ) and ΔF. The PLL-GNSSDO performance falls in between. The MPGPSRC output is full of harmonics and, because of the need for an external lowpass filter, is not attractive in my application. The SatTime unit is attractive from the standpoint that it not only has good performance (after OCXO replacement) but it also combines an NTP server and GDO in one box. However, the unit cannot be used more fully without documentation of its features.

I prefer to rigidly mount electronic equipment in 19 in (483 mm) racks or shelves, and the less the required vertical mounting space the better. The TM4313, PLL-GNSSDO and MPGPSRC easily fit in a standard 1-unit (1U) high rack mounted enclosure or shelf, whereas the BG7TBL-D and SatTime units are taller than 1.75 in (44.5 mm) and so require 2U of mounting space. All GDOs use extruded aluminum enclosures that are easily drilled and tapped for screw mounting.

Although the MPGPSRC has better frequency statistics than the TM4313, the TM4313 probably will out-perform the MPGPSRC in other than a lab environment because of their different oscillator types. The MPGPSRC may be set to a frequency other than 10 MHz, which may be needed in some applications but not in mine.

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8. Conclusions

Based on the above discussion, I chose to use the TM4313 GDOs for use in two shop-built, All-In-One NTP Server and GDO packages that are installed in my Anchorage lab and observatory (figure 8).

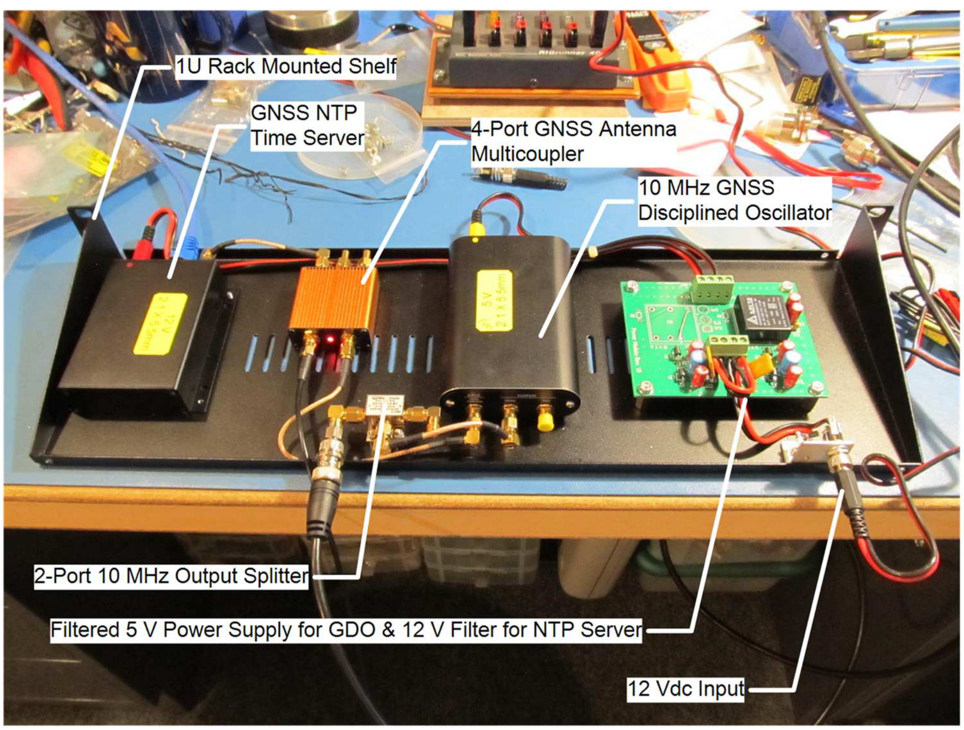

Figure 8 ~ The All-in-One under test. The TM4313 GDO (center) along with an NTP Server (left), are all mounted on a 1U x 6 in (150 mm) shelf. A 4-port multicoupler is used to allow one antenna to serve both units, and it has two extra ports for future GNSS devices. An RF power splitter is used on the GDO 10 MHz output to provide the reference frequency to two SDR receivers. Because the 10 MHz frequency reference signal is so strong (+10 dBm), it is necessary to use very high quality coaxial cables for interconnection to reduce radiated emissions from the source.

The NTP servers in the All-In-One are separate units called *FC-NTP-Mini* and supplement the GpsNtp-Pi units already on the LAN that serves the observatory and lab. The GNSS receivers in the server and GDO are connected to a single antenna through a 4-port GNSS receiver multicoupler that allows additional GNSS receivers to be connected in the future. The PLL-GNSSDO has comparable performance to the TM4312 and will be used in a third All-In-One package to be deployed at my HAARP Radio Observatory.

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9. References

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