WB-SG1 Wideband RF Signal Generator

Whitham D. Reeve

1. Introduction

The WB-SG1 wideband RF signal generator (figure 1) is built by the same individual (or company) that makes the 8-channel, 10 MHz distribution amplifier, which I reviewed in {Reeve10MHz}. These devices are marked with the model number and the text BG7TBL, which I presume is a Chinese amateur radio call sign. The signal generator operates from 12 Vdc and can be used in portable applications.

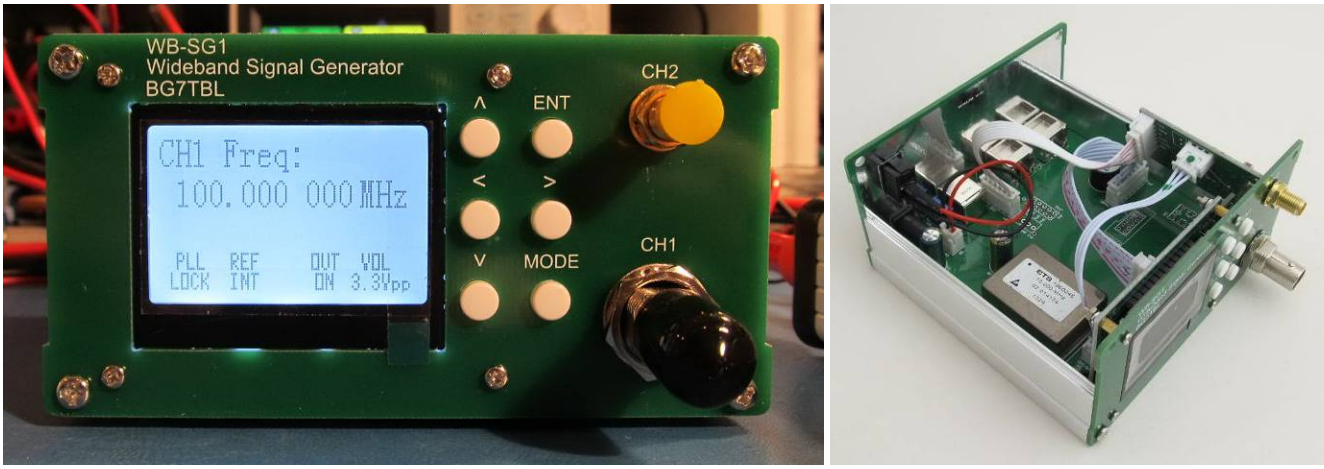

Figure 1 ~ BG7TBL WB-SG1 wideband RF signal generator front view (left) and with top cover removed (right). The dimensions are 106 W x 55 H x 106 L mm (not including connectors) and the weight is 0.35 kg. The connectors for the two output channels, six push-button controls and liquid crystal display are located on the front panel. Images © 2020 W. Reeve

Unlike many inexpensive RF signal generators, the WB-SG1 does not require a computer for operation, and its frequency range extends from 1 Hz to 8 GHz. I purchased it to use as a signal source for field and lab work. This article is a follow-on to my article about the FA-VA5 Vector Antenna Analyzer and RF Explorer WSUB1G+ Spectrum Analyzer {ReeveVA5}. It describes the WB-SG1 and provides the results from a series of measurements I made on the unit in April 2020.

I purchased the signal generator through eBay from a Chinese vendor for 150 USD. The package included the signal generator and an ac adapter power supply, but it did not include documentation. I contacted the seller who provided a weblink to a 14-page manual with text in both Chinese and English. The manual is usable but I spent more time trying to understand the broken English than learning how to use the unit. The unit itself is simple enough that with some effort, its operation eventually could be figured out without the instructions. I decided to rewrite the manual in plain English and reduced its length to 6 pages.

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2. Description

The WB-SG1 has two RF output channels that can be used simultaneously. Channel 1 uses a type BNC-F connector and has a frequency range from 1 Hz to 200 MHz with 1 Hz step size up to 19.999 999 MHz and 10 Hz step size from 20 to 200 MHz. Channel 1 can be used to modulate channel 2 in an on-off or amplitude shift keying (ASK) mode (I did not test this feature). Channel 2 has a frequency range of 35 MHz to 8 GHz and its output is through a type SMA-F connector. The step size of channel 2 is 500 Hz up to 4 GHz and 1 kHz from 4 to 8 GHz. Except as noted, the signal generator has no provisions for any type of modulation. The output impedance of both channels is 50 ohms. The output waveforms are not sinewaves, so external lowpass filters would be required for applications that require low distortion signals.

The output power levels from the two channels are not adjustable, but they can be turned off from the front-panel controls. However, I noticed that the channel 2 output actually is on whenever channel 1 is displayed even though channel 2 has been manually turned off. That is, channel 2 can be turned off only when channel 2 is displayed. The outputs are independent, so for most applications this operating quirk should not be a problem.

Channel 1 output is specified in terms of voltage as 3.3 $V_{pk\text{-}pk}$. The user guide does not state if this is an open-circuit or loaded voltage but it appears to be open-circuit, although my measurements showed a lower value (see next section). Channel 2 output is specified as 0 dBm into 50 ohms. External attenuators are needed if the WB-SG1 is to be used as a variable RF source.

The signal generator construction is similar to other products by BG7TBL. The enclosure uses a clamshell extruded aluminum body. The front and rear panels are made from single-sided printed circuit board (PCB) material with a solid tinned-copper back in direct contact with the metal enclosure. Silkscreen labels are placed on the outside for the controls and connectors. The electronics are on three high-quality PCBs. The main PCB (figure 2) slides into the enclosure and is interconnected to the other boards with ribbon cables. One of the other PCBs is mounted on the display module and the third PCB is mounted at an angle to the front panel by its type SMA-F connector for the higher frequency output channel 2 (figure 3).

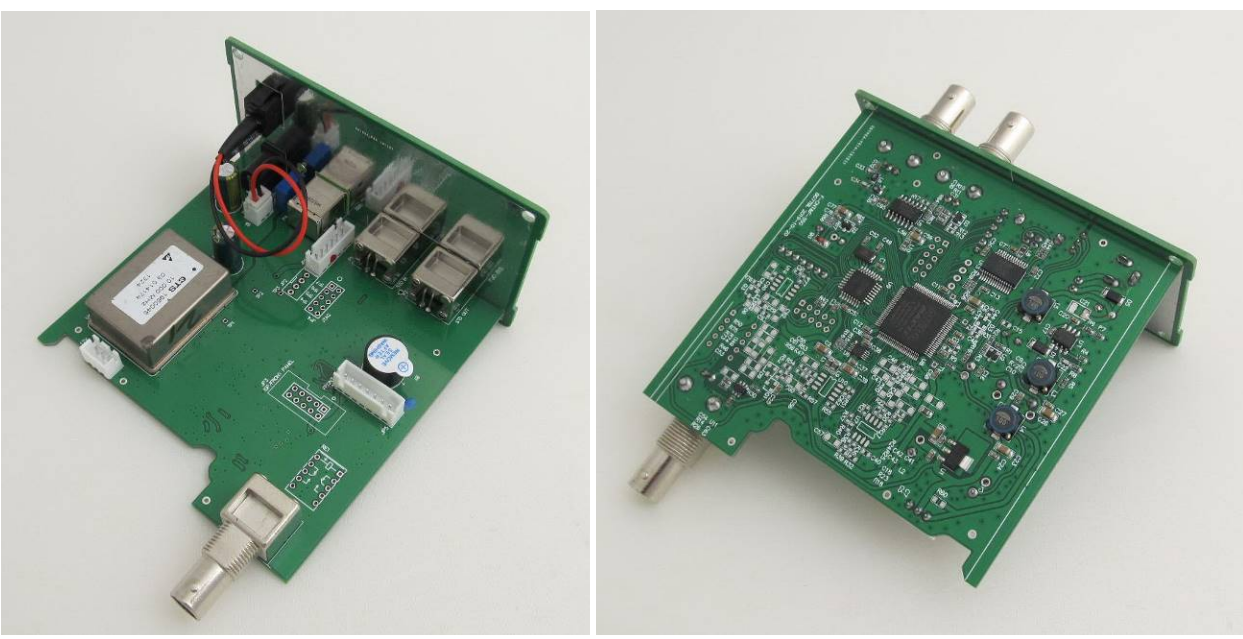

Figure 2 ~ Main printed circuit board top (left) and bottom (right) views, both with the PCB fastened to the rear panel (it is removeable). All components on the main PCB except the oven-controlled crystal oscillator, piezoelectric beeper and ribbon connectors are surface mounted devices on the bottom. The oven-controlled crystal oscillator is the rectangular metal box on the left side of the left image. The type BNC-F connector in the foreground of the left image is the channel 1 output. An *Altera MAX* complex programmable logic device is seen in the middle of the right image. Images © 2020 W. Reeve

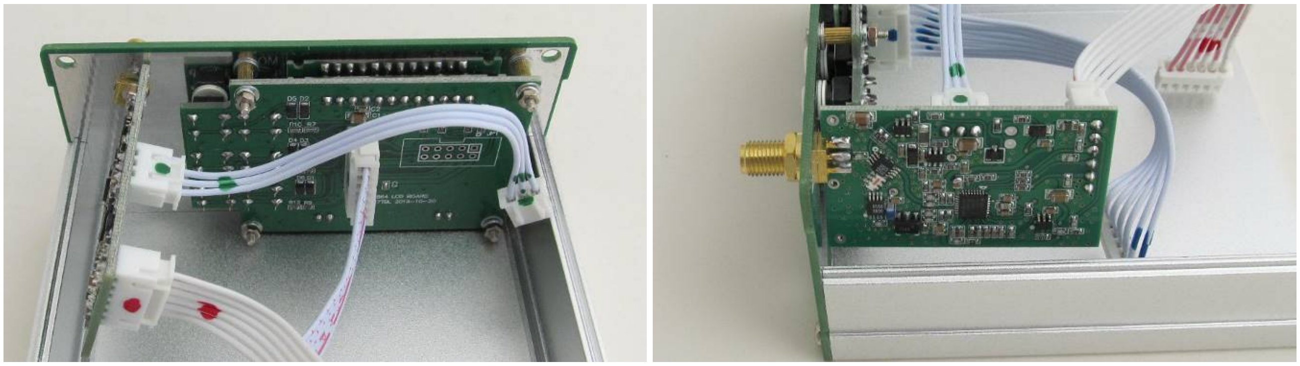

Figure 3 ~ Display PCB (left) and Channel 2 RF PCB (right). Before disassembly, I marked the ribbon cable connectors with a little finger nail polish to ensure I reassembled everything properly; however, the connectors are different sizes so mistakes are improbable. The type SMA-F connector visible in the right image is soldered to the PCB and also mechanically fastens the PCB to the front panel. Images © 2020 W. Reeve

The WB-SG1 is designed for stand-alone operation and normally is controlled by six push-button switches on the front panel in conjunction with a 128 x 64 pixel liquid crystal display (LCD); however, a USB port is provided on the rear panel, which allows the unit to be controlled from a terminal emulator program (for example, Tera Term or PuTTY) on a PC using a virtual COM port. The port requires the FTDI virtual COM port driver be installed on the PC. I am unaware of any graphical user interface (GUI) software; instead, the user sends ASCII character strings to the unit to set the frequency and other controllable functions. I did not test the USB control feature.

The user manual includes a block diagram, which indicates the RF functions for channel 1 are produced in a *complex programmable logic device*, or CPLD. I noted the device has an Altera brand on it (MAX series), so the device is a few years old (Altera was bought and absorbed by Intel in late 2015). The CPLD is controlled by a microprocessor, labeled MCU in the block diagram, which also controls the display and takes inputs from the push-buttons. The channel 2 output is generated on a separate PCB and uses a doubler circuit above 4 GHz to produce the specified 8 GHz output. The internal power supplies use a dc-dc converter to produce 5 Vdc and a low drop-out (LDO) voltage regulator on the dc-dc converter output produces 3.3 Vdc.

The unit has an internal oven-controlled crystal oscillator (OCXO) that on my unit was preset quite accurately (see next section). If necessary, the frequency can be trimmed through a screwdriver adjustment on the rear panel but I did not have to use it. The user guide does not state the warmup time for the oscillator to meet a certain accuracy, but my measurements indicate that OCXO temperature and frequency stabilizes after about 20 min. The OCXO can be synchronized to an external reference source through a type BNC-F connector on the rear panel. Another BNC-F connector on the rear panel can be used to daisy-chain the reference source. The connectors are labeled 10 MHz Ref Input and Output, respectively.

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3. Measurements

The input voltage requirements of the WB-SG1 are stated to be rather stringent at 11.7 to 12.5 Vdc; the manual cautions to never exceed 12.5 V. The OCXO is responsible for most of the input current during a cold start. The instruction manual says the cold start load is 0.5 A decreasing to 0.25 A when the oscillator temperature stabilizes.

I used a *JouleScope* to measure the dc load. The load current was 0.455 A during two cold-starts with the lab ambient temperature at +20 °C (figure 4). After a couple minutes, the current decreased rapidly over a couple seconds to 0.330 A and then dropped slowly to 0.289 A over a period of about 20 min. After several hours the load current was 0.286 A, and it never decreased below that over the following 24 h period.

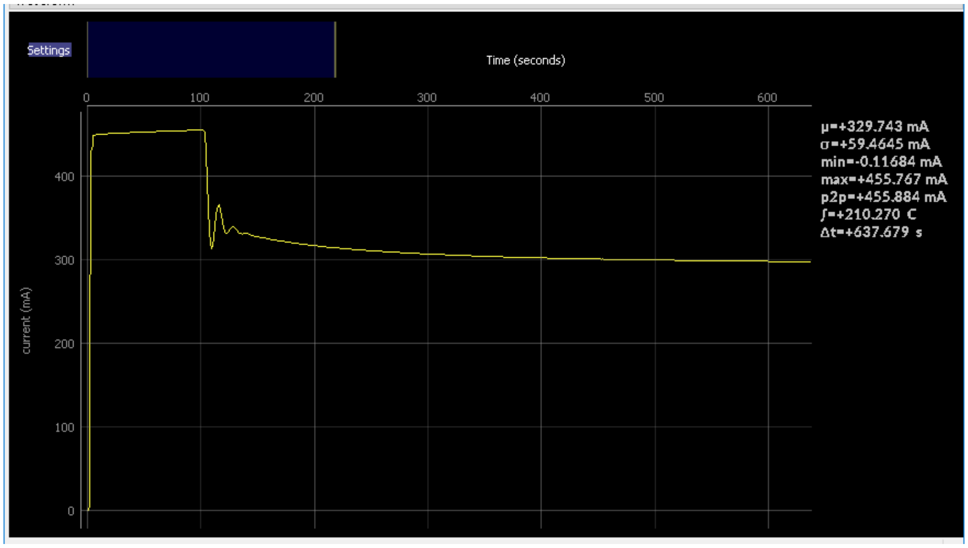

Figure 4 ~ Screenshot from the JouleScope application software showing the WB-SG1 load current (vertical scale in mA) over time (horizontal scale in seconds) for the first 10.5 minutes. The plot starts a few seconds before the signal generator was turned on. The initial warmup period lasts about 2 minutes (left side of plot) and then the current steps down. It subsequently slowly decreases as the OCXO temperature stabilizes.

I also made a series of RF measurements with a Siglent SDS2302X oscilloscope, Keysight N9917A FieldFox Microwave Analyzer (setup in spectrum analyzer mode) and a Keysight 53220A frequency counter. For all scope and spectrum analyzer measurements, the WB-SG1 was synchronized to an external 10 MHz reference source that is traceable to the Global Positioning System (GPS). Also, for the spectrum measurements, I inserted a 20 dB attenuator in the output circuit for channel 1 and a 30 dB attenuator for channel 2 to ensure that the analyzer input would not be overloaded. When reading the marker levels shown in the spectrograms below, the indicated values should be adjusted accordingly.

Only a few of the measurements are shown in this section; see **Appendix** for the full set of measurements at 1 kHz, 10 kHz, 100 kHz, 1 MHz, 10 MHz, 100 MHz and 1420 MHz. Note: The Appendix is included only in the online version of this article at {ReeveWBSG1}. Frequency measurements are discussed later.

At lower frequencies the output is displayed as a square wave on my oscilloscope (figure 5) and the spectrum shows strong odd harmonics and weak even harmonics (figure 6). The scope has 300 MHz bandwidth so waveforms with frequency components above about 60 MHz are not properly displayed because the harmonics are not accurately processed. For example, a 10 MHz square wave has significant harmonics above 60 MHz and its displayed waveform is not square (figure 7). However, the displayed fundamental frequency voltage level is accurate. The spectrum for 10 MHz shows the same characteristics as lower frequencies (figure 8).

In terms of power amplitude, the channel 1 output is flat within about 0.5 dB throughout most of its frequency range up to approximately 100 MHz but the output drops off above that. I noticed some dc offset at 100 MHz on channel 1 (the waveform was not symmetrical around 0 V). The output levels from channel 1 are stable over time.

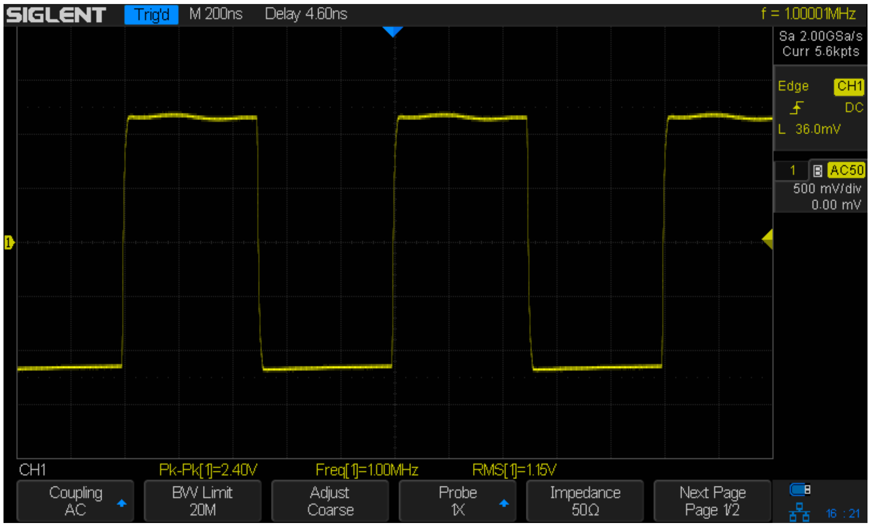

Figure 5 ~ Oscilloscope screenshot of voltage (vertical scale) over time (horizontal scale) showing the measured output waveform at 1 MHz. For this measurement, the scope's vertical channel impedance was set to 50 ohms, and the signal generator output was connected directly to the scope vertical channel. Note the vertical scale is 500 mV/div and the actual peak-peak voltage is 2.40 V (not 3.3 V as specified in the user guide). The horizontal scale is 200 ns/div.

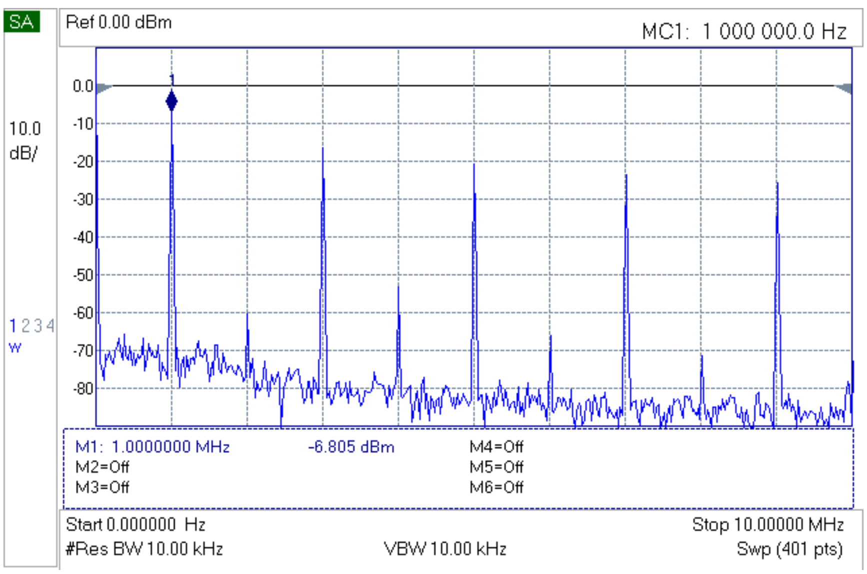

Figure 6 ~ Spectrum analyzer screenshot showing the signal generator channel 1 output when tuned to 1 MHz. The horizontal scale indicates 0 to 10 MHz. Nine harmonics can be seen, primarily odd harmonics indicating a good square wave. The 3rd harmonic is about 10 dB down from the fundamental. The spectrum analyzer was connected through a 20 dB attenuator so 20 dB needs to be added to the vertical scale. Horizontal sweep is from 0 to 10 MHz.

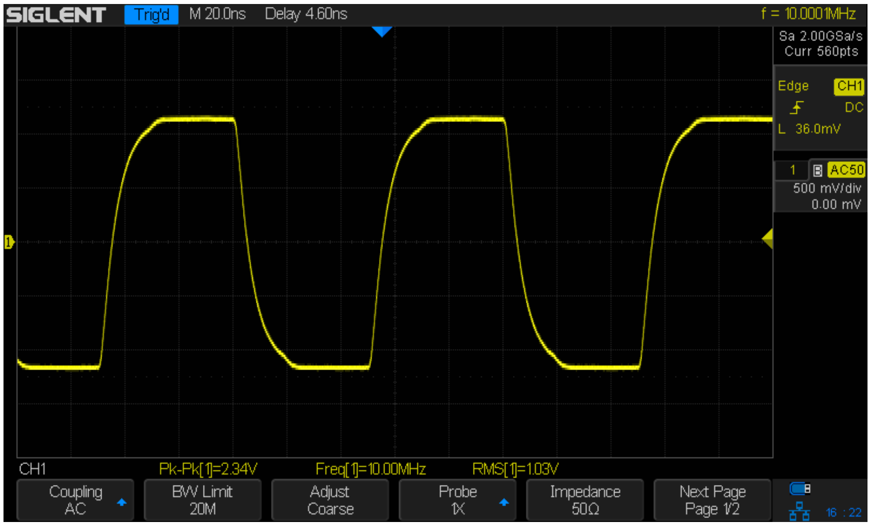

Figure 7 ~ Oscilloscope screenshot showing the measured output waveform at 10 MHz. The measurement conditions are the same as above. The peak-peak voltage has decreased slightly to 2.34 V compared to 2.40 V for 1 MHz. The vertical scale is 500 mV/div and the horizontal scale is 20 ns/div.

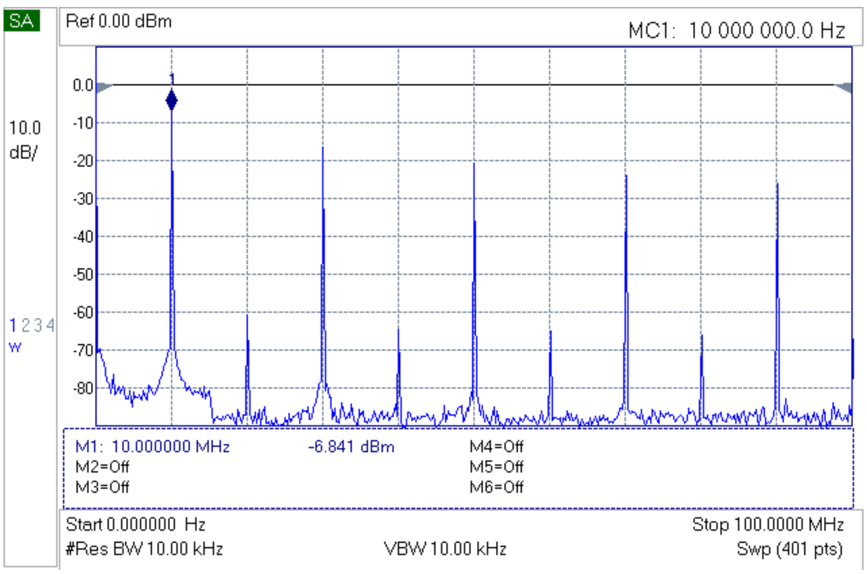

Figure 8 ~ Spectrum analyzer display for the 10 MHz output on channel 1 with the frequency span set to 100 MHz. The spectrum analyzer was connected through a 20 dB attenuator so 20 dB needs to be added to the vertical scale measurements. Horizontal sweep is from 0 to 100 MHz.

I measured –1.0 dBm on the output of Channel 2 at 1 GHz (the specifications in the user guide state 0 dBm). There are some variations across the frequency range. I also checked channel 2 output at 1420 MHz with the spectrum analyzer (figure 9). The 2nd harmonic is about 19 dB below the fundamental and the 3rd harmonic is about 11 dB below. The presence of a 2nd harmonic indicates the waveform has some asymmetry. As with channel 1, the output levels from channel 2 are stable over time.

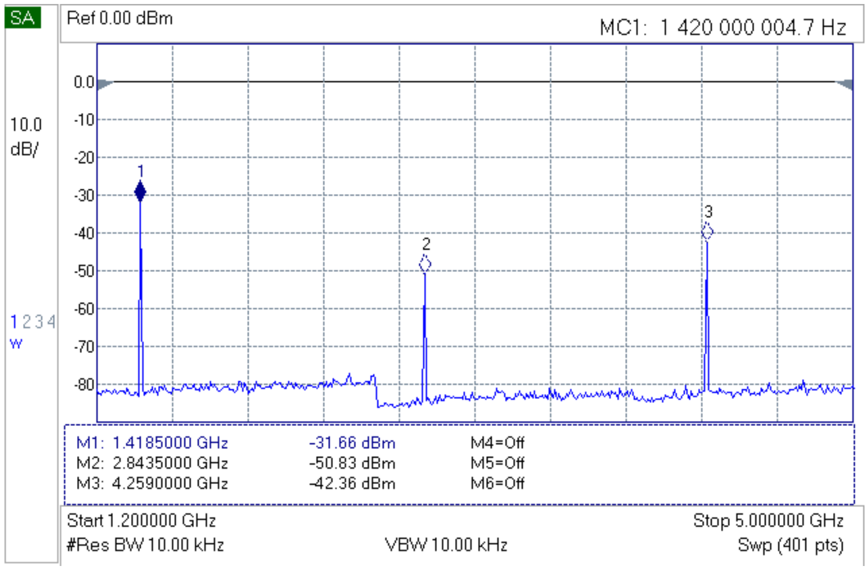

Figure 9 ~ Spectrum analyzer screenshot of showing 1420 MHz fundamental and 2nd and 3rd harmonics. Add 30.5 dB to the marker levels to account for the external attenuator on the spectrum analyzer input and loss in the connecting coaxial cable. The step in the noise floor just before the 2nd harmonic is from the signal generator. The frequency span is from 1200 to 5000 MHz.

I measured channel 1 and channel 2 frequencies with the WB-SG1 in both free-run and synchronized modes. The synchronizing frequency reference source was the lab 10 MHz reference. The counter was synchronized to the same reference source for all measurements. When both the counter and signal generator use the same frequency reference, the measurements indicate the relative accuracy of the WB-SG1 frequency-following circuits compared to the professional frequency counter. All frequency measurements were made after a 1 h warmup time.

Figure 10 ~ Screenshots of the frequency counter browser interface showing the 100 MHz output from the signal generator channel 1 (upper) and 1420 MHz output from channel 2 (lower). The left two images are the measured frequencies with the signal generator in free-run mode and the right two images are with the generator synchronized to the external frequency reference source. For these measurements, an external 20 dB attenuator was used on the channel 1 output and a 30 dB attenuator on the channel 2 output.

I connected the WB-SG1 channel 1 output to the frequency counter channel 1 input and the channel 2 output to the frequency counter channel 3 input (my 53220A frequency counter has the optional 6 GHz input channel 3). I measured only two signal generator frequencies, 100 MHz on channel 1 and 1420 MHz on channel 2 (figure 10). With the WB-SG1 in the free-run mode, the measured frequency error was about 1.4 Hz at 100 MHz (14 parts per billion, ppb) and 20 Hz at 1420 MHz (14 ppb). With the signal generator synchronized to the external reference, the frequency errors were zero, as expected.

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4. Conclusions

The WB-SG1 RF signal generator is a good value. Its 1 Hz to 8 GHz continuous frequency range is very wide and the unit does not require a computer for operation. For 150 USD, it is not surprising the WB-SG1 lacks features available on far more expensive signal generators such as low distortion sinewave and variable power outputs and fancy modulation modes. However, as a portable, variable frequency signal source, it can be quite useful for many types of field and lab measurements and applications.

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5. References

{Reeve10MHz} Reeve, W., Observatory 10 MHz Reference Distribution Amplifier, 2017, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_10MHzDist.pdf

{ReeveVA5} Reeve, W., FA-VA5 Vector Antenna Analyzer and RF Explorer WSUB1G+ Spectrum Analyzer, 2020, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_FAVA5-RFE.pdf

{ReeveWBSG1} Reeve, W., WB-SG1 RF Signal Generator, 2020, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_WB-SG1_SigGen.pdf

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Appendix

Measurements at 1 kHz, 10 kHz, 100 kHz, 1 MHz, 10 MHz, 100 MHz and 1420 MHz

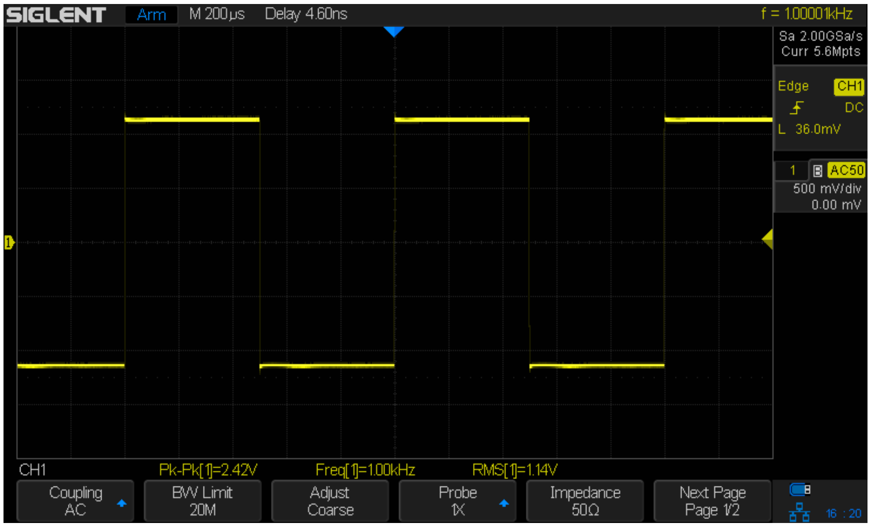

Figure A.1 ~ 1 kHz oscilloscope screenshot. Vertical scale 500 mV/div and horizontal scale 200 µs/div.

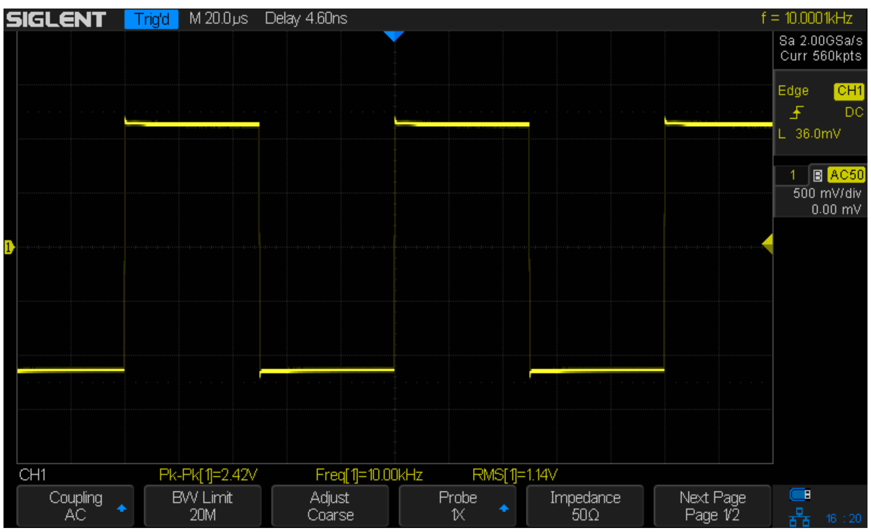

Figure A.2 ~ 10 kHz oscilloscope screenshot. Vertical scale 500 mV/div and horizontal scale 20 µs/div.

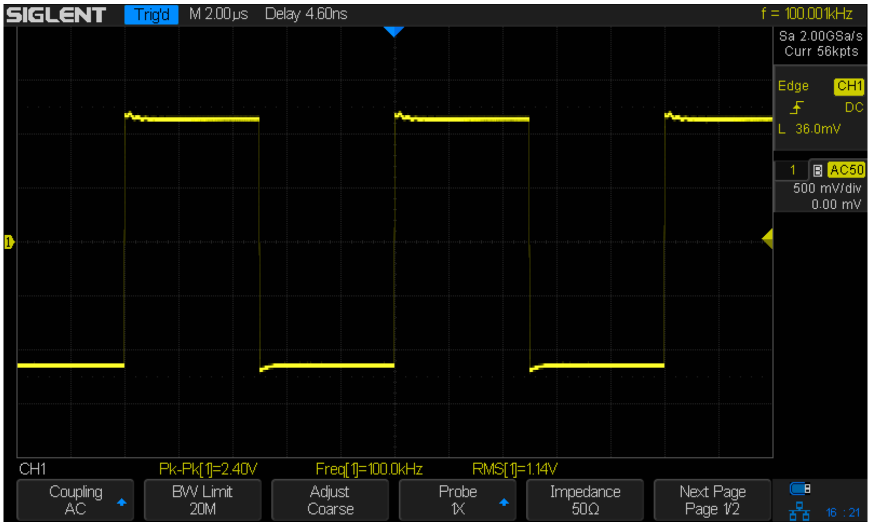

Figure A.3 ~ 100 kHz oscilloscope screenshot. Vertical scale 500 mV/div and horizontal scale 2 µs/div.

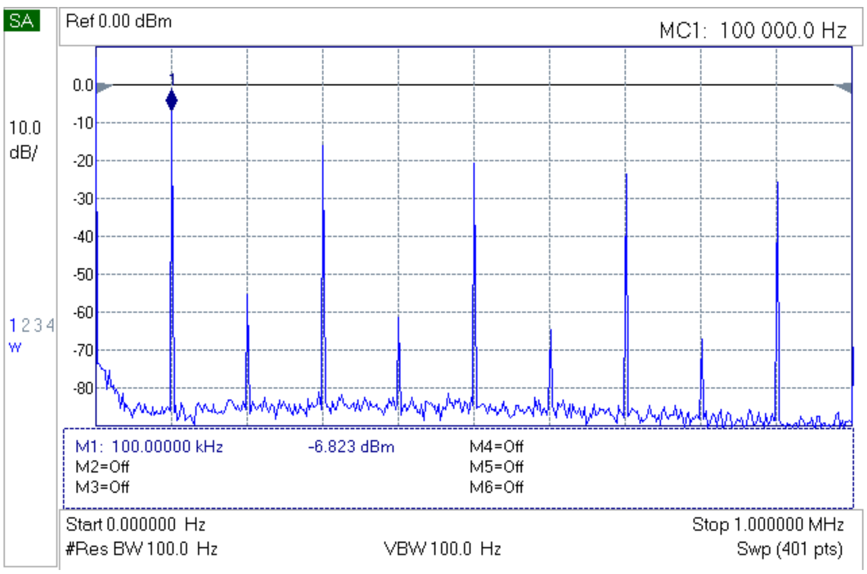

Figure A.4 ~ 100 kHz spectra with 20 dB attenuator between the output and spectrum analyzer. Horizontal sweep is from 0 to 1 MHz.

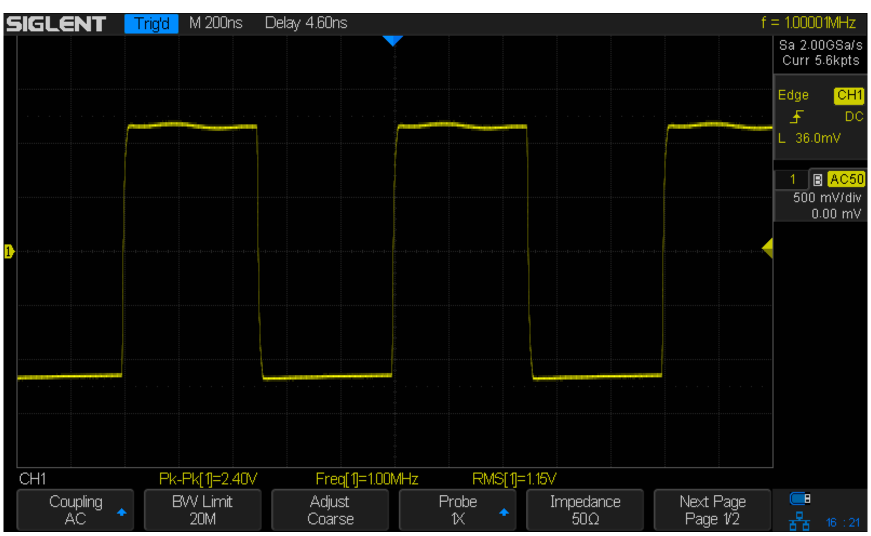

Figure A.5 ~ 1 MHz oscilloscope screenshot. Vertical scale 500 mV/div and horizontal scale 200 ns/div.

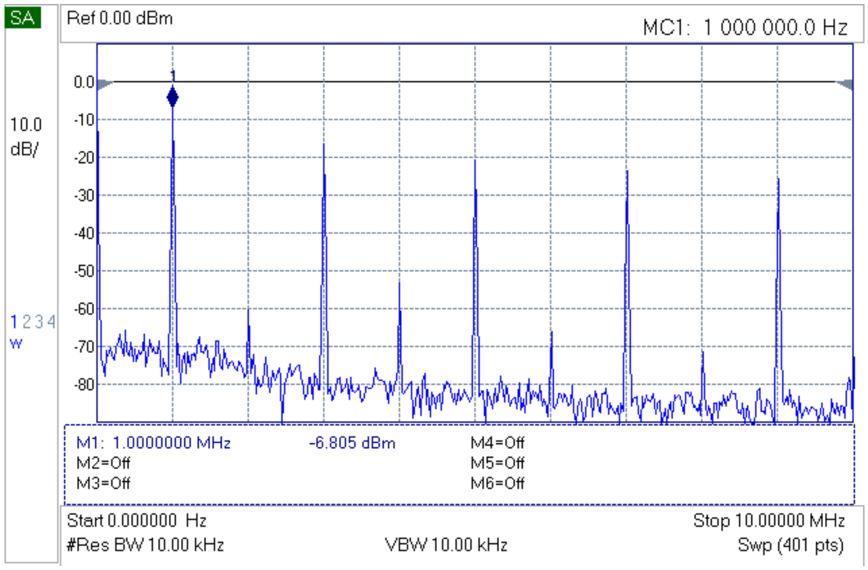

Figure A.6 ~ 1 MHz spectra with 20 dB attenuator between the output and spectrum analyzer. Horizontal sweep is from 0 to 10 MHz.

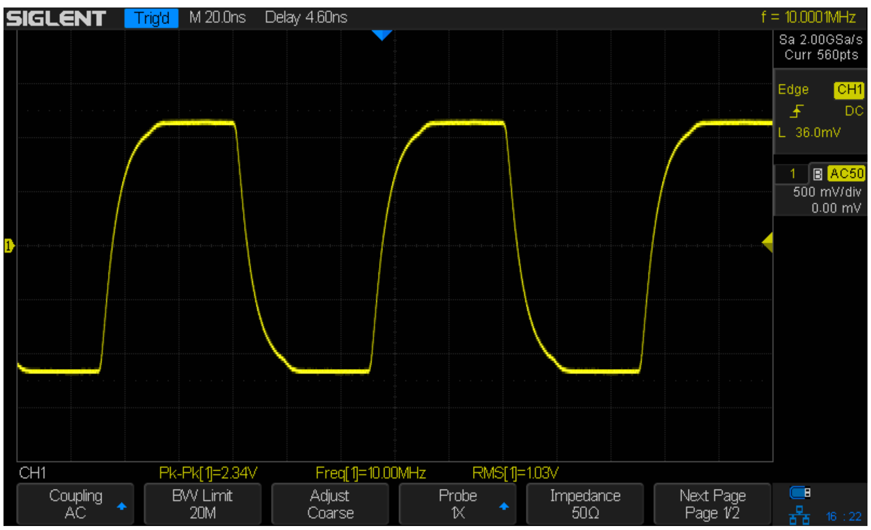

Figure A.7 ~ 10 MHz oscilloscope screenshot. Vertical scale 500 mV/div and horizontal scale 20 ns/div.

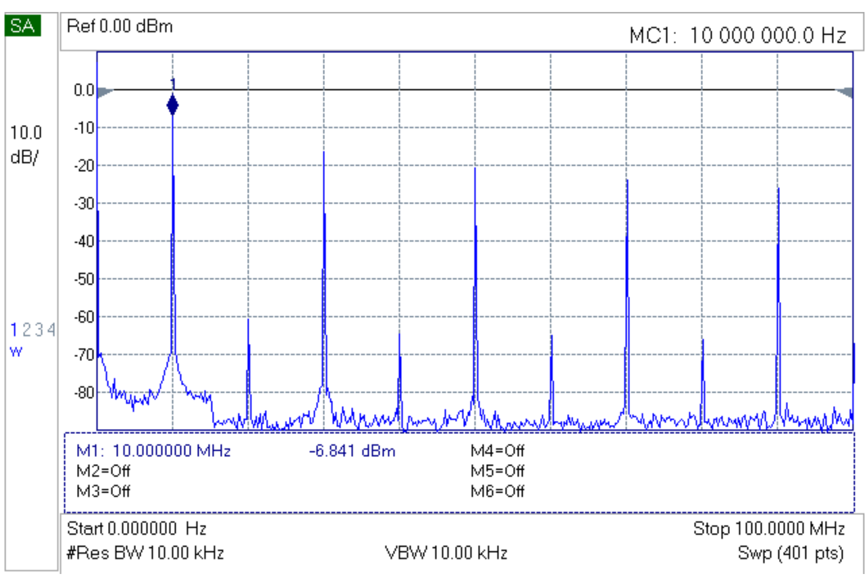

Figure A.8 ~ 10 MHz spectra with 20 dB attenuator between the output and spectrum analyzer. Horizontal sweep is from 0 to 100 MHz.

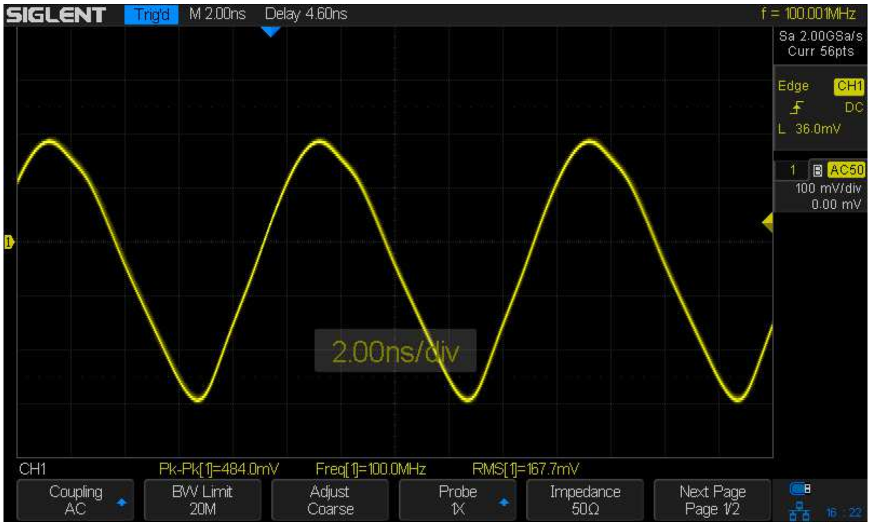

Figure A.9 ~ 100 MHz oscilloscope screenshot. Some, or maybe all, of the harmonics are suppressed by the oscilloscope input circuits. Vertical scale 100 mV/div and horizontal scale 2 ns/div.

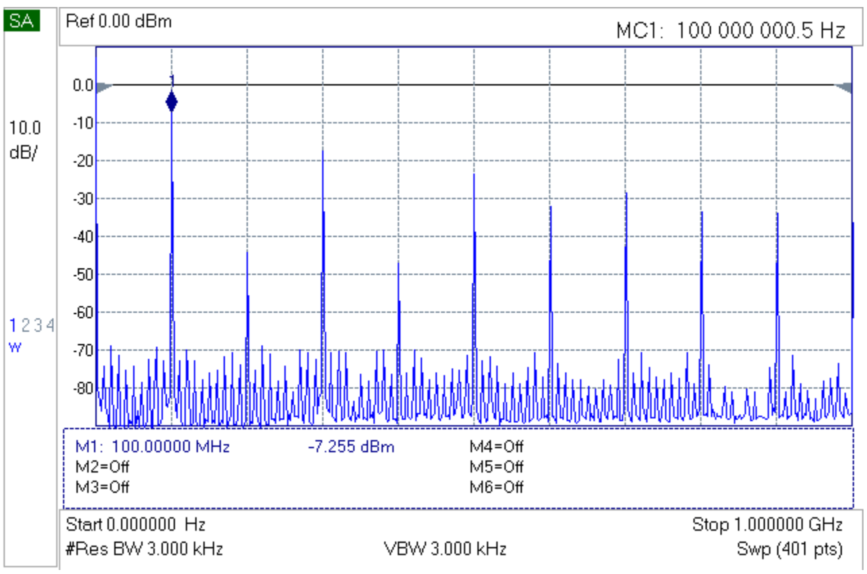

Figure A.10 ~ 100 MHz spectra with 20 dB attenuator between the output and spectrum analyzer. Note the many low-level (approximately –60 dBc) spurious signals compared to lower frequencies.

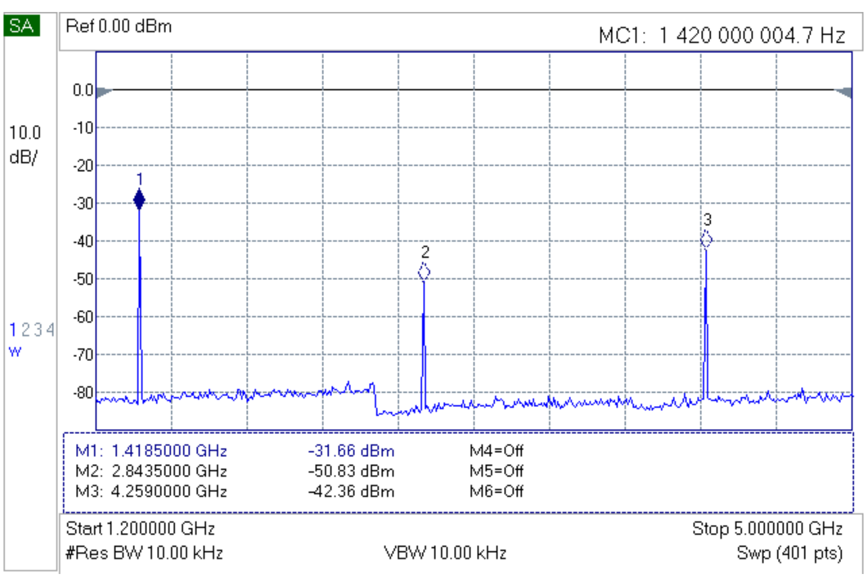

Figure A.11 ~ 1420 MHz spectra with 30 dB attenuator between the output and spectrum analyzer. Horizontal sweep is from 1200 to 5000 MHz.

Document information

Author: Whitham D. Reeve

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0.1 (Added all measurements, 12 Apr 2020)
0.2 (Added input current measurements, 13 Apr 2020)
0.3 (Added conclusions, 10 May 2020)
0.4 (Completed 1st draft, 13 May 2020)
0.5 (Distribution, 14 May 2020)
0.6 (Added reference to FA-VA5 and WSUB1G+, 01 Aug 2020)

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