ETTUS USRP B205mini-i SDR Performance Assessment

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The following report provides the best performance of an ETTUS USRP B205mini-i SDR in terms of maximum sample rate achievable over its USB3.0 port connection to a Dell Precision 7720 laptop. Collected IQ data is streamed to a 4 TByte SanDisk Extreme 55AE USB3.0 SSD. The Dell laptop is a 64-bit Windows 10 platform. The ETTUS UHD open source software was downloaded and compiled under Visual Studio 2019 Professional which provided a number of executables exercising varies capabilities of the B205mini-i SDR. One executable in particular called "rx_samples_to_file.exe" was called via a custom C# based GUI to record data samples from receive channel 0 to an output file. Figures 2 through 4 show snapshots of the custom C# based GUI with Figure 1 showing the B205mini-i SDR.

The following dependencies / specifics supported compilation of the ETTUS UHD software:

1. Microsoft Visual Studio 2019 Professional
2. Cmake version 3.30.0
3. Boost version 1.85.0
4. LibUSB version 1.0.27.7
5. Python version 3.8.6
6. Mako version 7.1.0
7. Doxygen version 1.11.0
8. NSIS version 3.10.0
9. UHD-master version 4.7.0.0

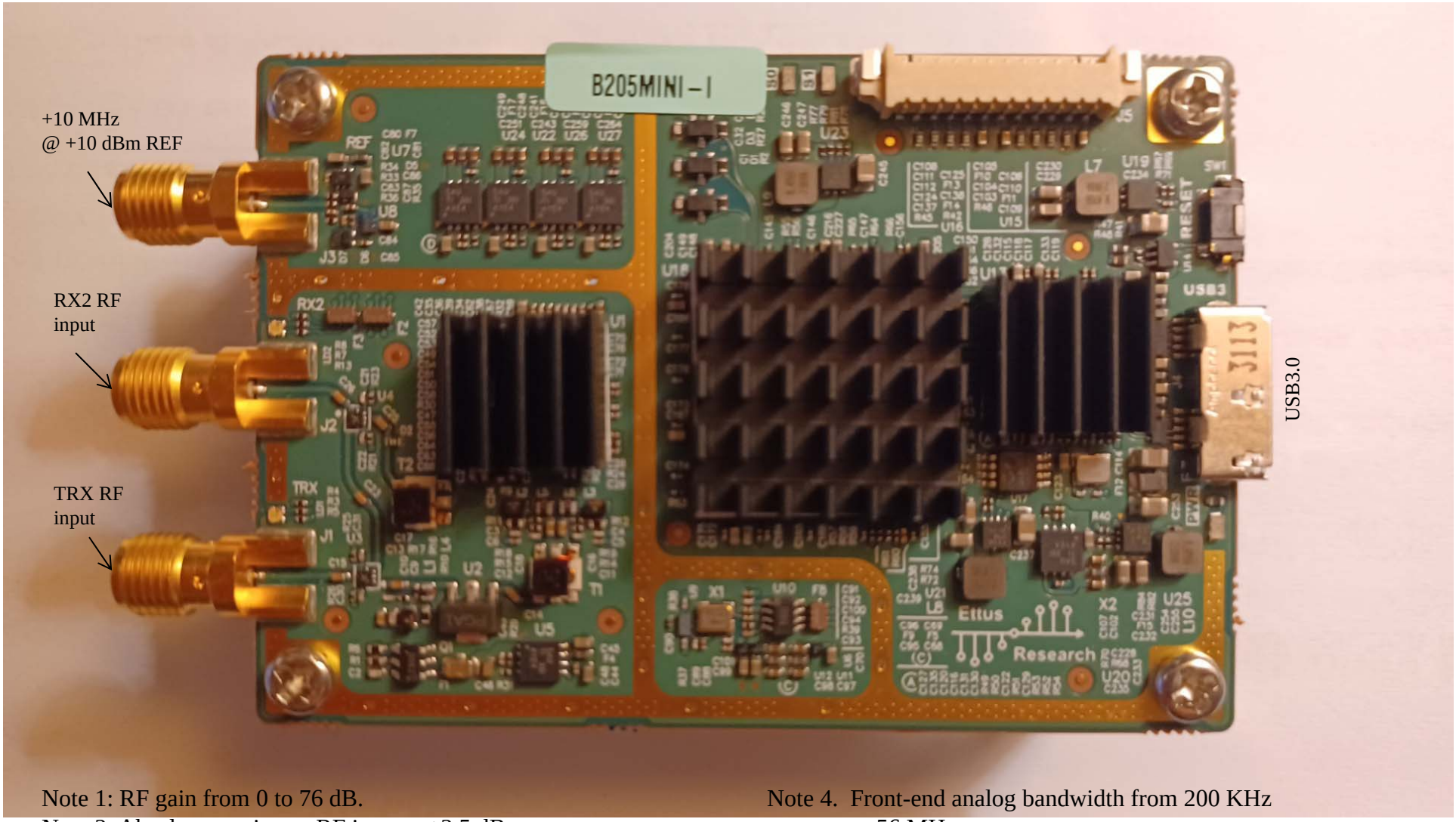
The B205mini-i SDR supports three output IQ formats called “cs16”, “cs12, and “cs8” via the UHD open source code. The SDR front-end provides for 12 bit receive and transmit resolution. The “cs16 format pads 12 bits by 4 bits for 16 bit I and 16 bit Q. Accordingly, each sample consists of 32 bits. The “cs12” format provides no padding for 12 bit I and 12 bit Q; yet the output is identical to the “cs16” mode. The “cs8” mode truncates 12 bits by 4 bits providing 8 bit I and 8 bit Q and like the “cs12” mode has an output identical to “cs16”. Accordingly, despite which format is selected, the output is always 32 bits per sample over USB 3.0; yet, the maximum sample rate is a function of which format is selected. One would think that formats “sc12” and “sc8” would provide 24 bits per sample and 16 bits per sample; but, this is not the case. All sample outputs recorded to file are 32 bits per sample.

Table 1 reports the maximum sample rates and dynamic ranges achievable with 50 dB RF front-end gain and 10,000 samples per USB3.0 receive block for each output format. Details of how these metrics were derived is given further down in the report. Discussion continues on page 7.

Output format	min signal	max signal	dynamic range	Record time	bytes recorded	bit rate	max sample rate
sc16	-110 dBm	-10 dBm	100 dB	10 secs	771,637 KBytes	617.3096 Mbits/sec	20 Msps
sc12	-110 dBm	-10 dBm	100 dB	10 secs	1,013,951 KBytes	811.1608 Mbits/sec	26 Msps
sc8	-100 dBm	-10 dBm	90 dB	10 secs	1,542,945 KBytes	1,234.356 Mbits/sec	40Msps

Table 1. Performance versus output format

Figure 1. ETTUS USRP B205mini-i SDR



Note 1: RF gain from 0 to 76 dB.
Note 2: Absolute maximum RF input = +2.5 dBm
Note 3. Maximum RF input before compression = -15.0 dBm.
Note 4. Front-end analog bandwidth from 200 KHz to 56 MHz.
Note 5. Reference = 10 MHz @ +10 dBm
Note 6. <8 dB receiver Noise Figure

Figure 2. B205mini-i GUI snapshot 1

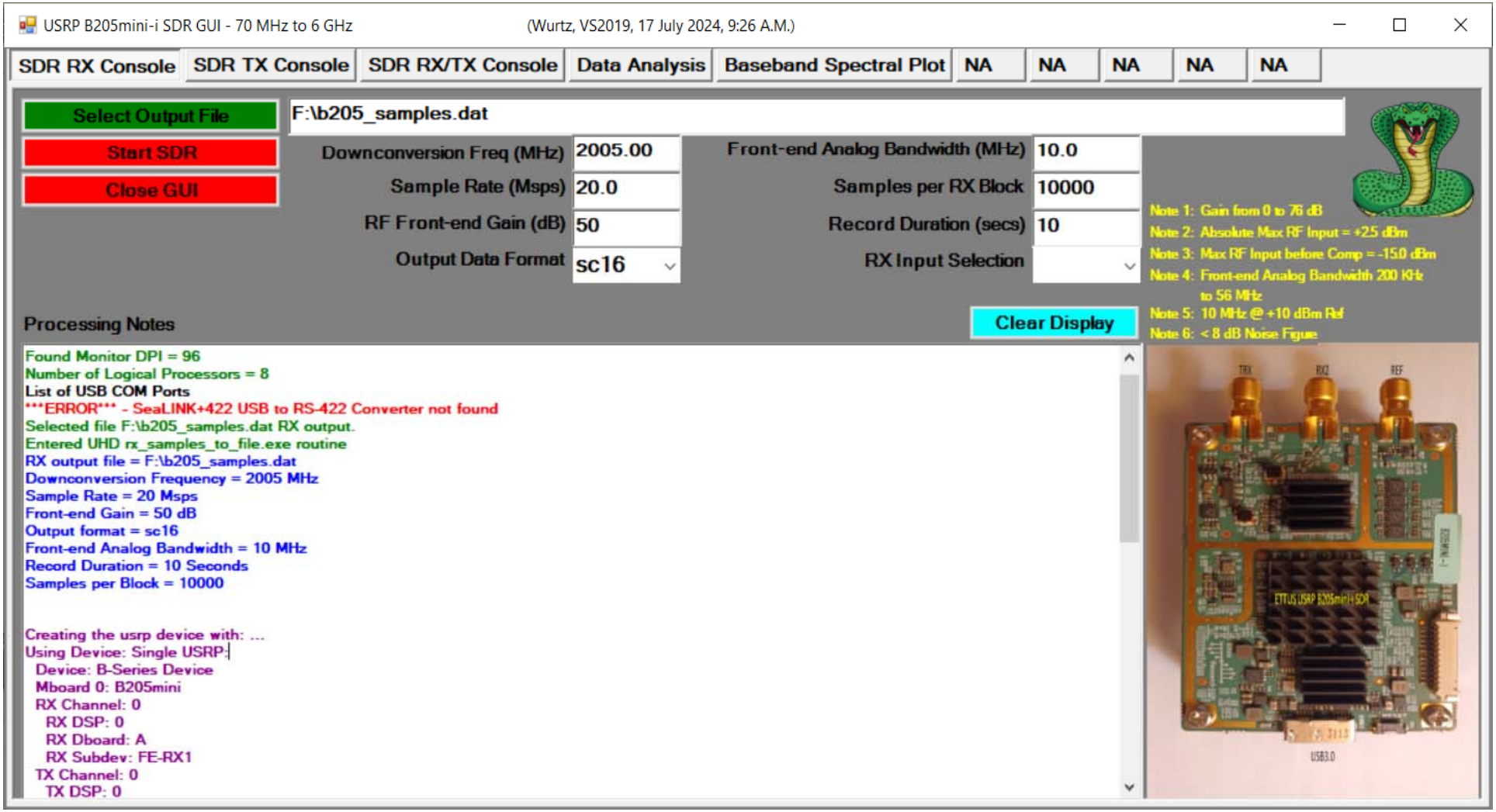


Figure 3. B205mini-i GUI snapshot 2

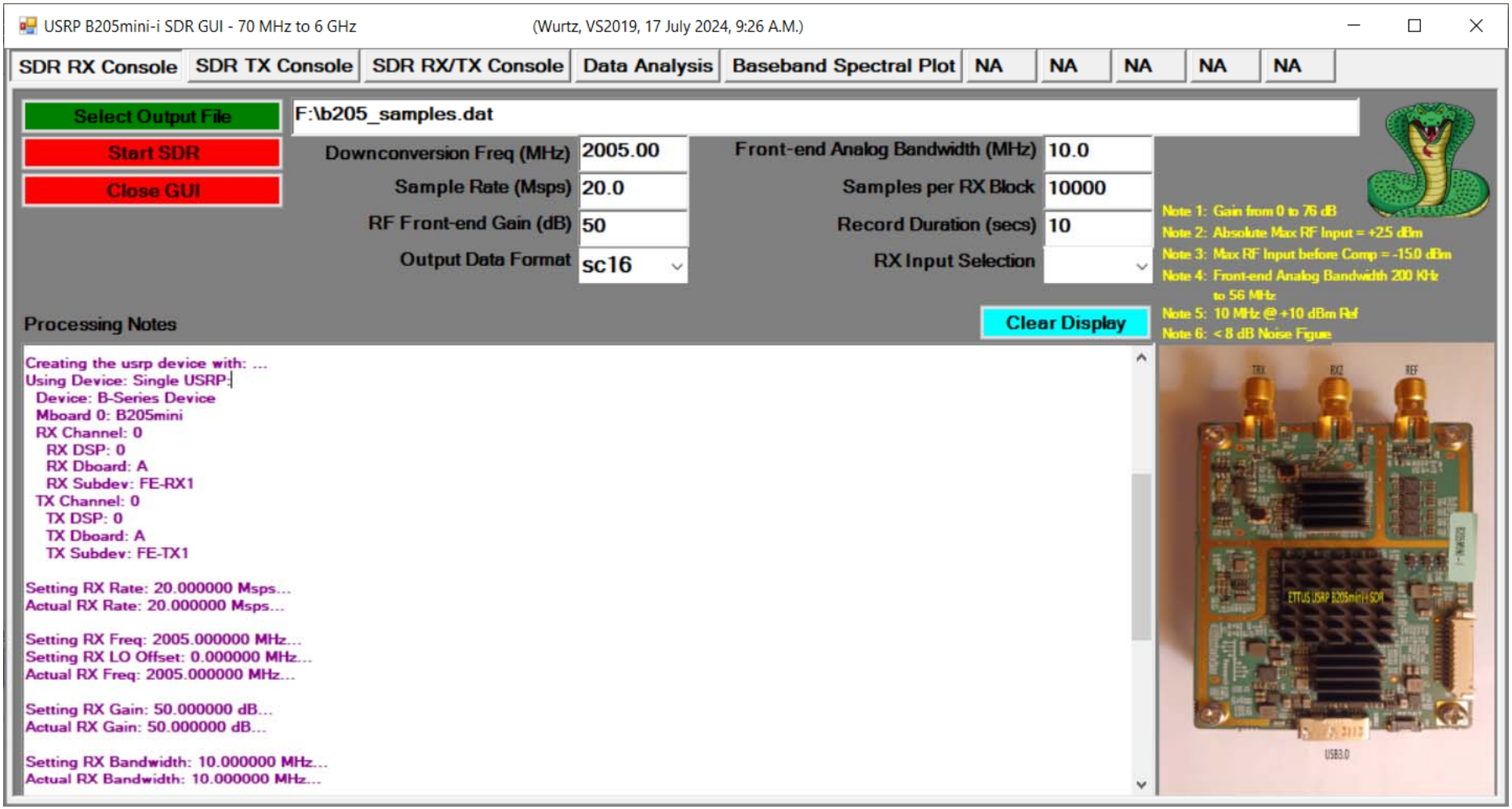
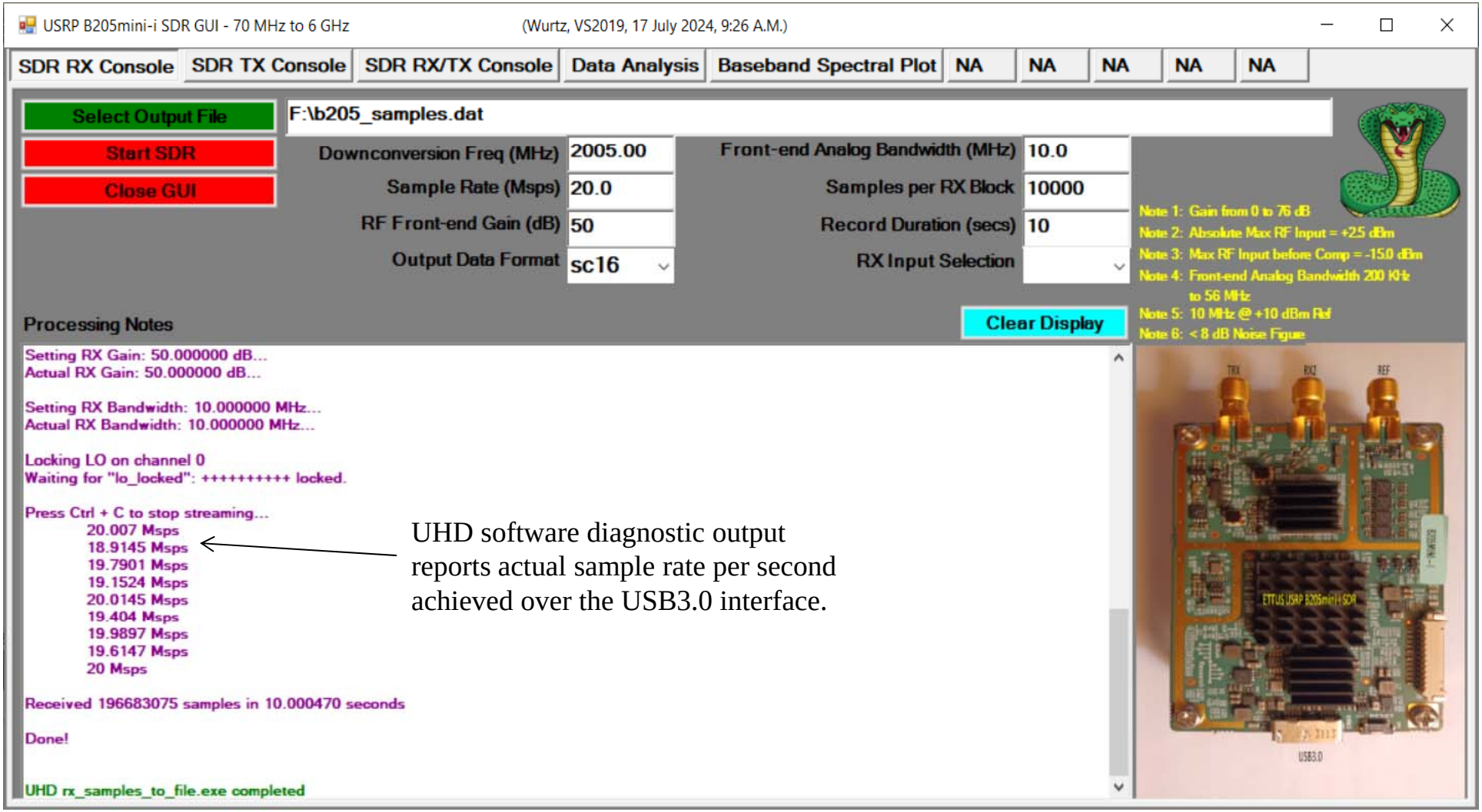


Figure 4. B205mini-i GUI snapshot 3



RF input to the SDR TRX port was provided by an HP8672A synthesized signal generator. Figures 5 though 7 show input spectral plots of interest to the SDR analysis. Discussion continues on page 10.

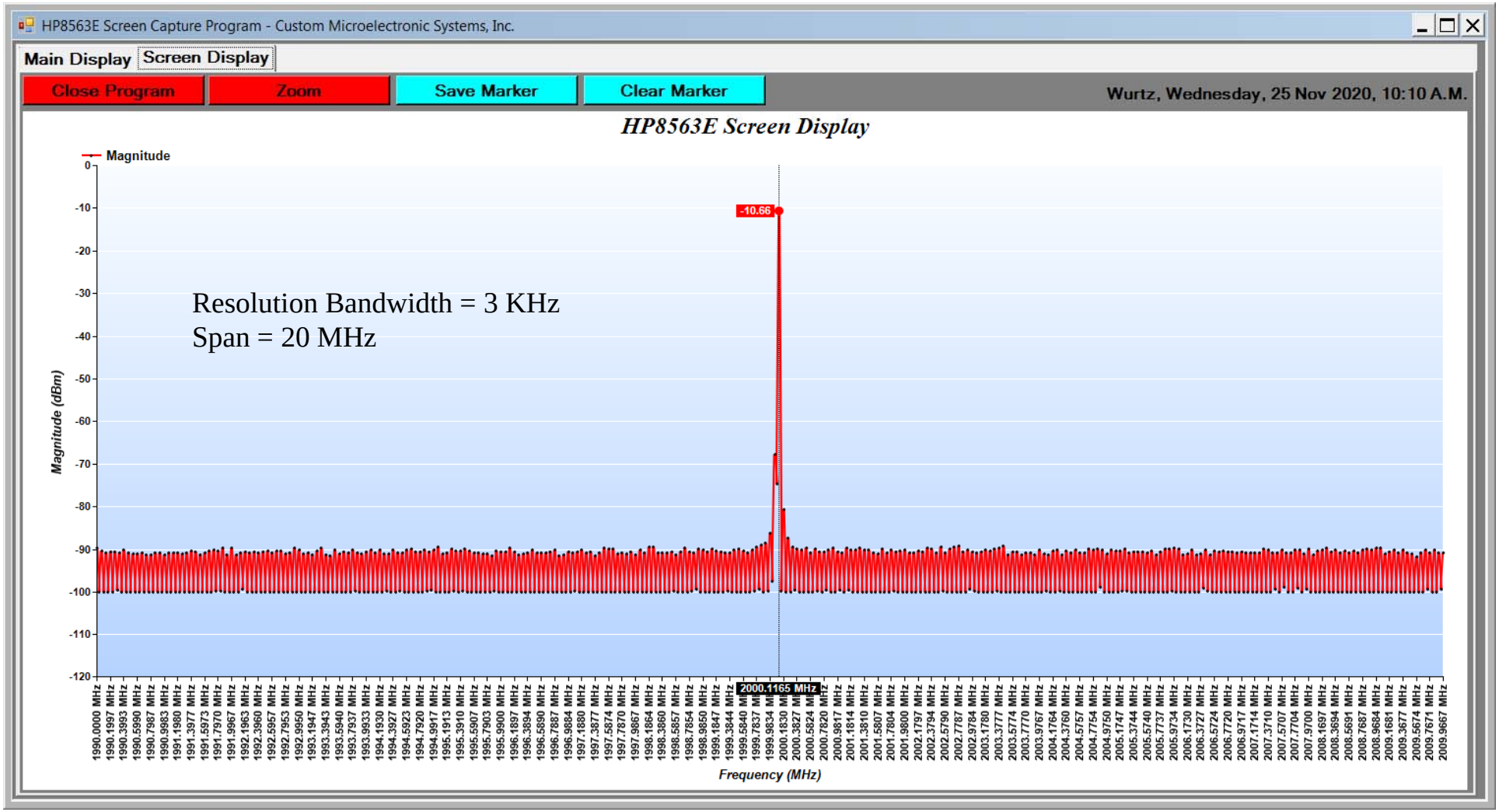


Figure 5. 2000 MHz CW input at -10 dBm

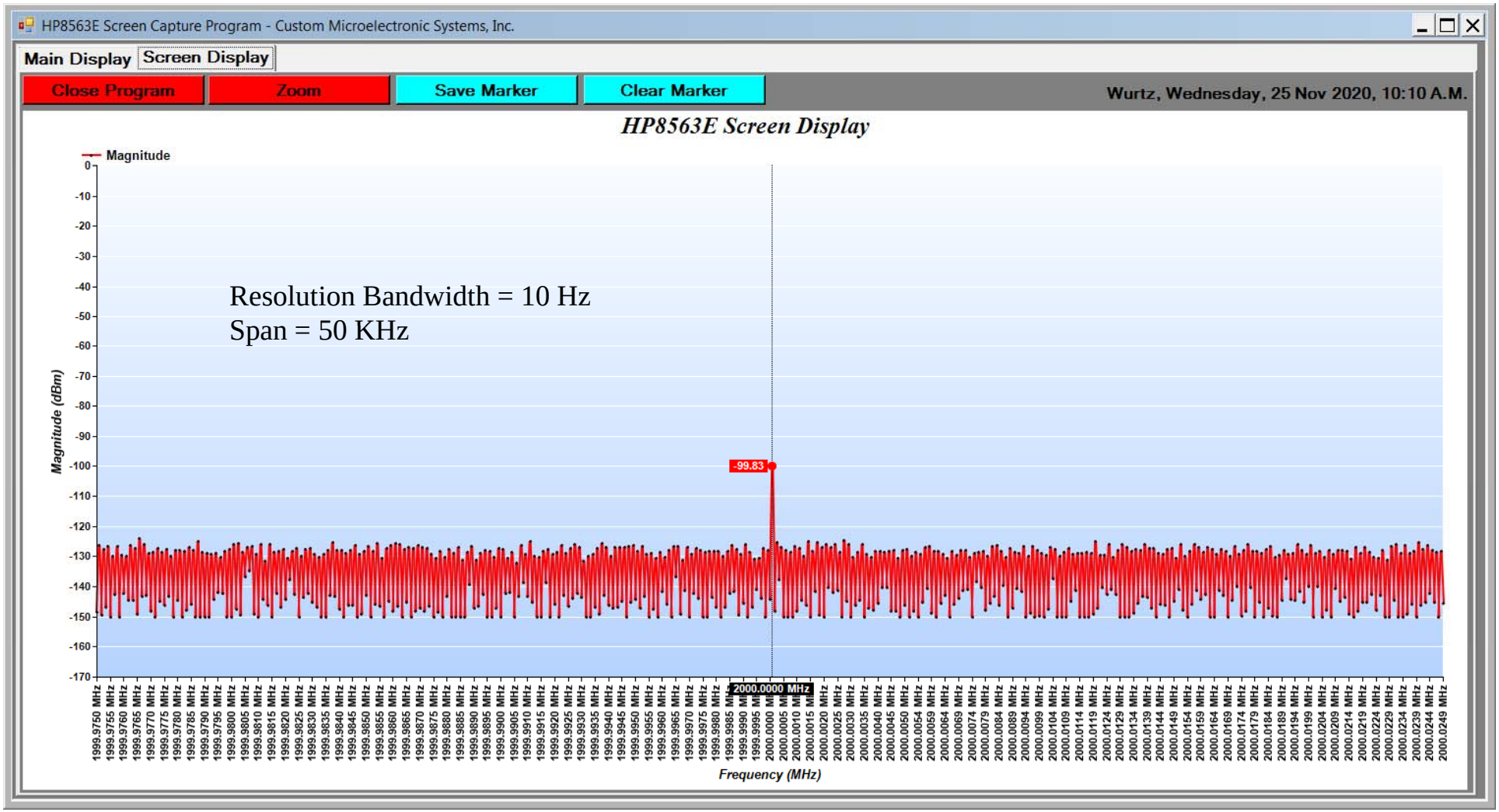


Figure 6. 2000 MHz CW input at -100 dBm

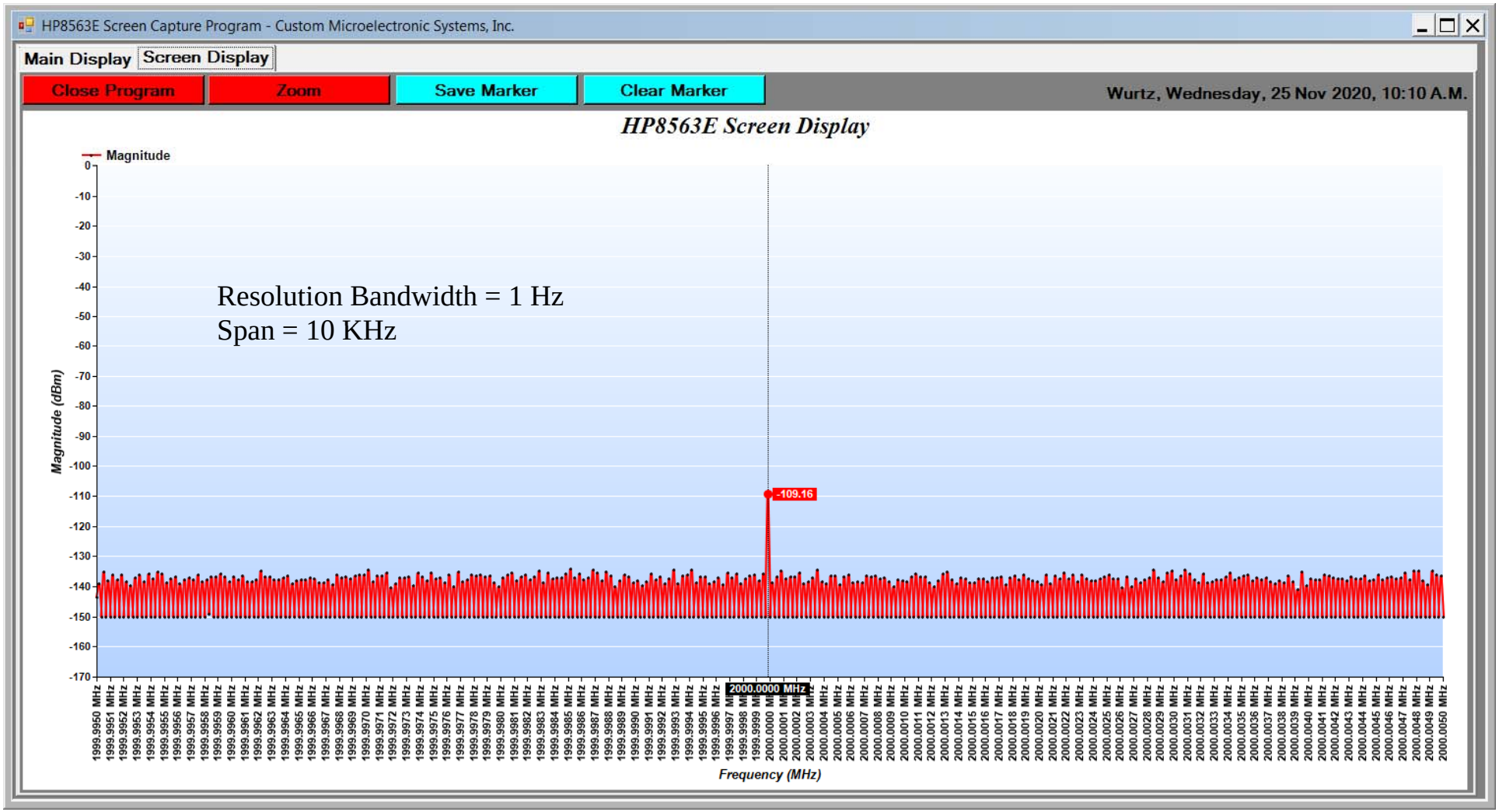


Figure 7. 2000 MHz CW input at -110 dBm

As noted earlier, the B205mini-i SDR using the ETTUS UHD software supports three output data formats: sc16, sc12, and sc8. The sc16 output data format performance will be discussed first.

The methodolgy for testing was to input a 2000 MHz CW signal to the TRX port of the SDR at various power levels to determine dynamic range. The requested sample rate was increased for each output format until the USB3.0 interface essentially "breaks" by monitoring the SDR output sample rate diagnostic shown in figure 4 on page 6. For output format sc16, the maximum sample rate was found to be 20 Msps. By Shannon's sampling theory, the maximum downconverted IF frequency is 10 MHz. The RF front-end analog bandwidth was set to 10 MHz. For this analysis, it was desired to display as much of the lower and upper sideband spectral content as possible; accordingly, the desired IF frequency was selected to be 5 MHz. For a high-side downconversion, the downconversion frequency was set to 2005 MHz.

In short, the test strategy was to preserve as much of the upper and lower sideband spectral content symmetrically around the IF frequency as possible for analysis. The RF front-end gain may range from 0 to 76 dB and was set to 50 dB for the analysis. Figure 8 shows the spectral output with a 2000 MHz -10 dBm CW input. ETTUS documents report an upper RF input of -15 dBm before compression, so -10 dBm was close enough for this assessment. Figure 9 shows the output spectral content with a 2000 MHz -110 dBm CW input. The sc16 output format provides ~100 dB of dynamic range. It must be noted that the B205mini-i SDR was operated for these measurements without an external 10 MHz reference.

The sc12 format output should have similar performance to the sc16 format, in that the receiver provides 12 bits of resolution. Although I and Q are set to 12 bits each per sample, the output across the USB3.0 interface is like the sc16 format with 32 bits per sample. The maximum sample rate was found to be 26 Msps. The high-side downconversion frequency was set to 2006.5 MHz for a primary IF spectral frequency of 6.5 MHz. The RF front-end analog bandwidth was set to 13 MHz. Figure 10 shows the sc12 format spectral output with a 2000 MHz -10 dBm CW input. Figure 11 shows the sc12 format spectral output with a 2000 MHz -110 dBm CW input. The sc12 format output provides ~100 dB of dynamic range.

The sc8 format output truncates the 12 bit receiver resolution by 4 bits for an 8 bit I and 8 bit Q sample. Nevertheless, the output passed across the USB3.0 interface is like that of the sc16 format with 32 bits per sample. The maximum sample rate was found to be 40 Msps. The high side downconversion frequency was set to 2010 MHz. The primary IF output frequency should be 10 MHz. The RF front-end analog bandwidth was set to 20 MHz. Figure 12 shows the sc8 format spectral output with a 2000 MHz -10 dBm CW input. Figure 13 shows the sc8 format spectral output with a 2000 MHz -100 dBm CW input. The dynamic range is ~ 90 dB.

Figure 14 shows a block diagram of the ETTUS USRP B205mini-i SDR.

sc16 format output

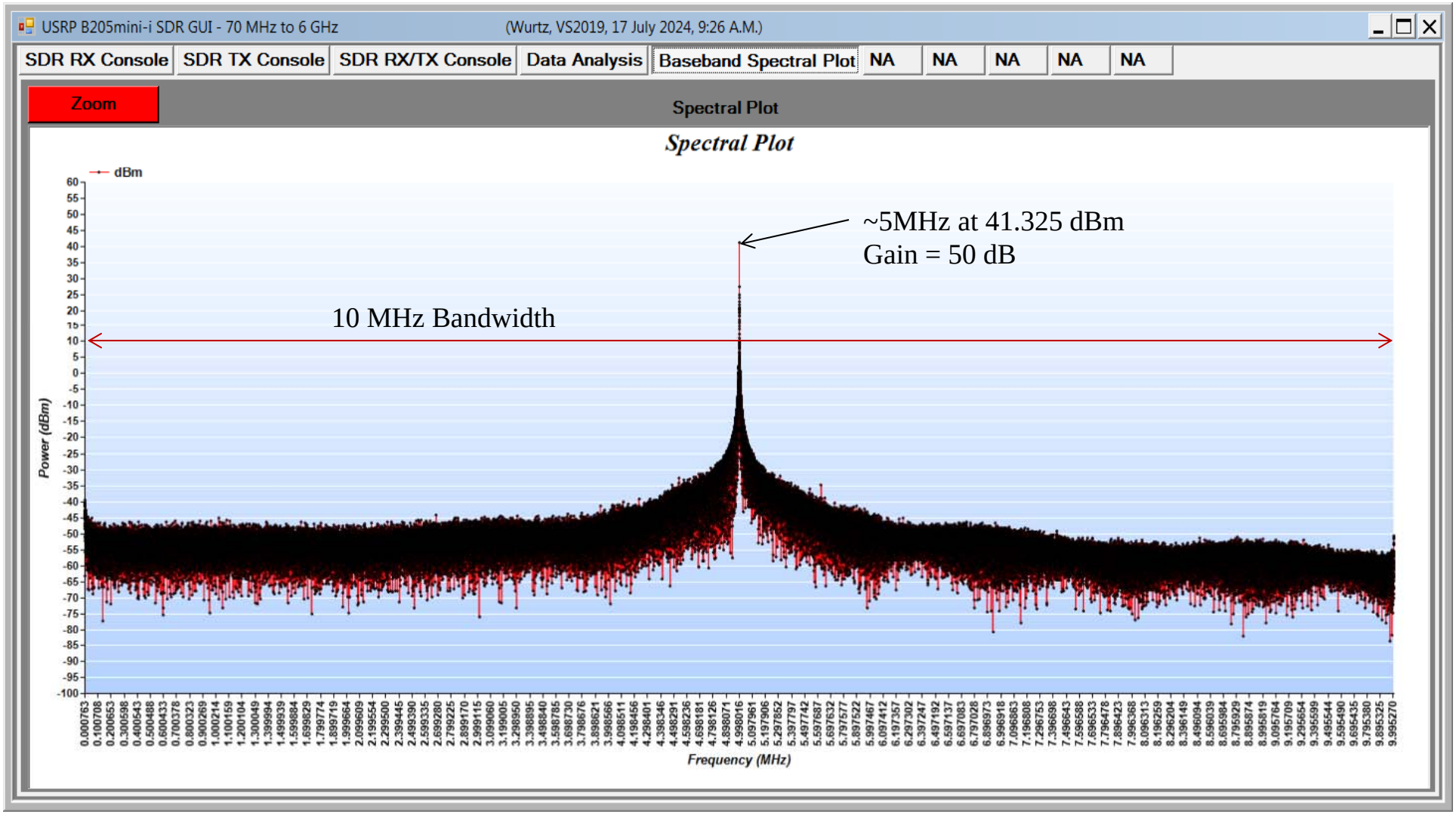


Figure 8. sc16 format spectral output with -10 dBm 2000 MHz CW input

sc16 format output

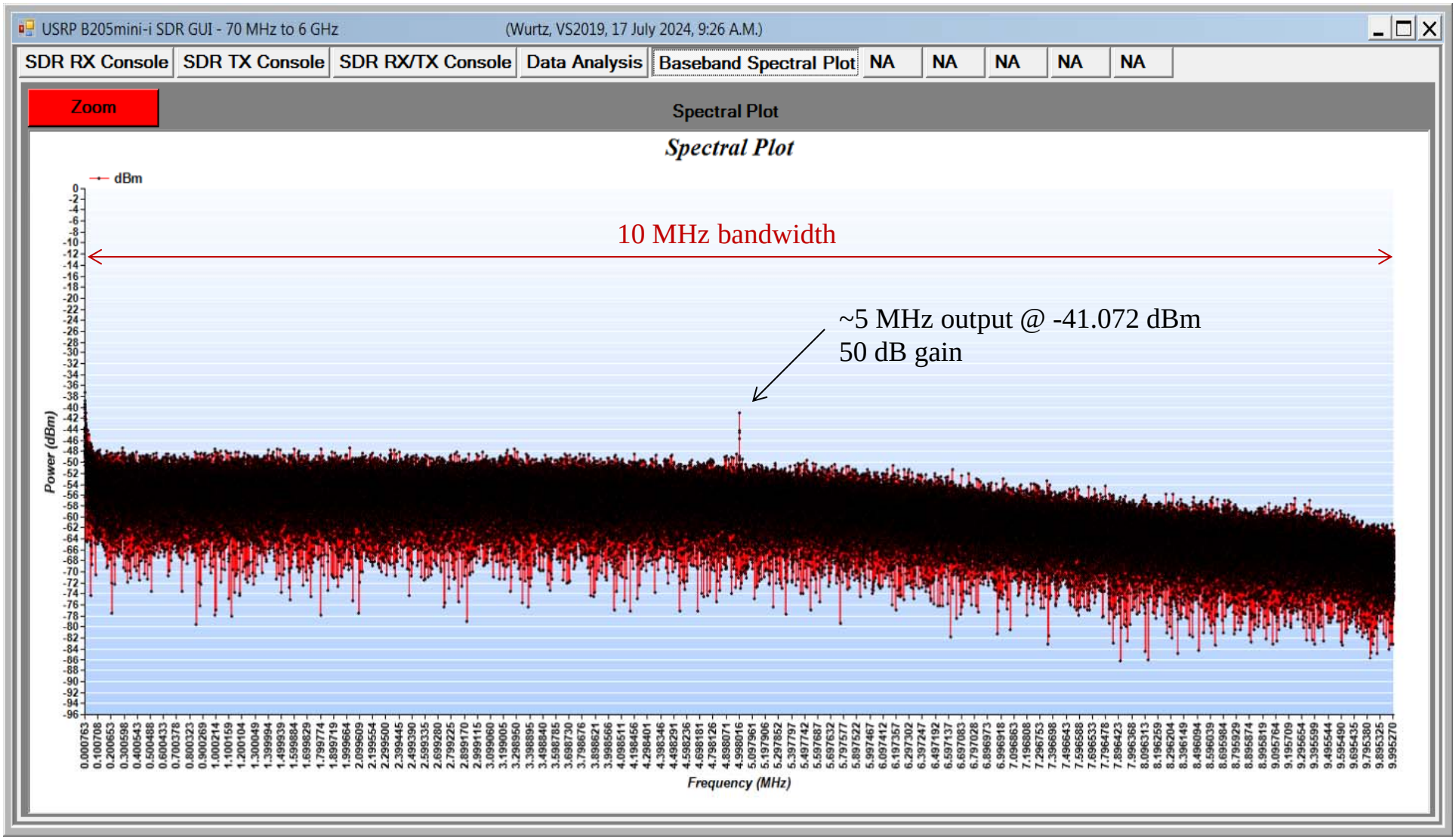


Figure 9. sc16 format spectral output with -110 dBm 2000 MHz CW input

sc12 format output

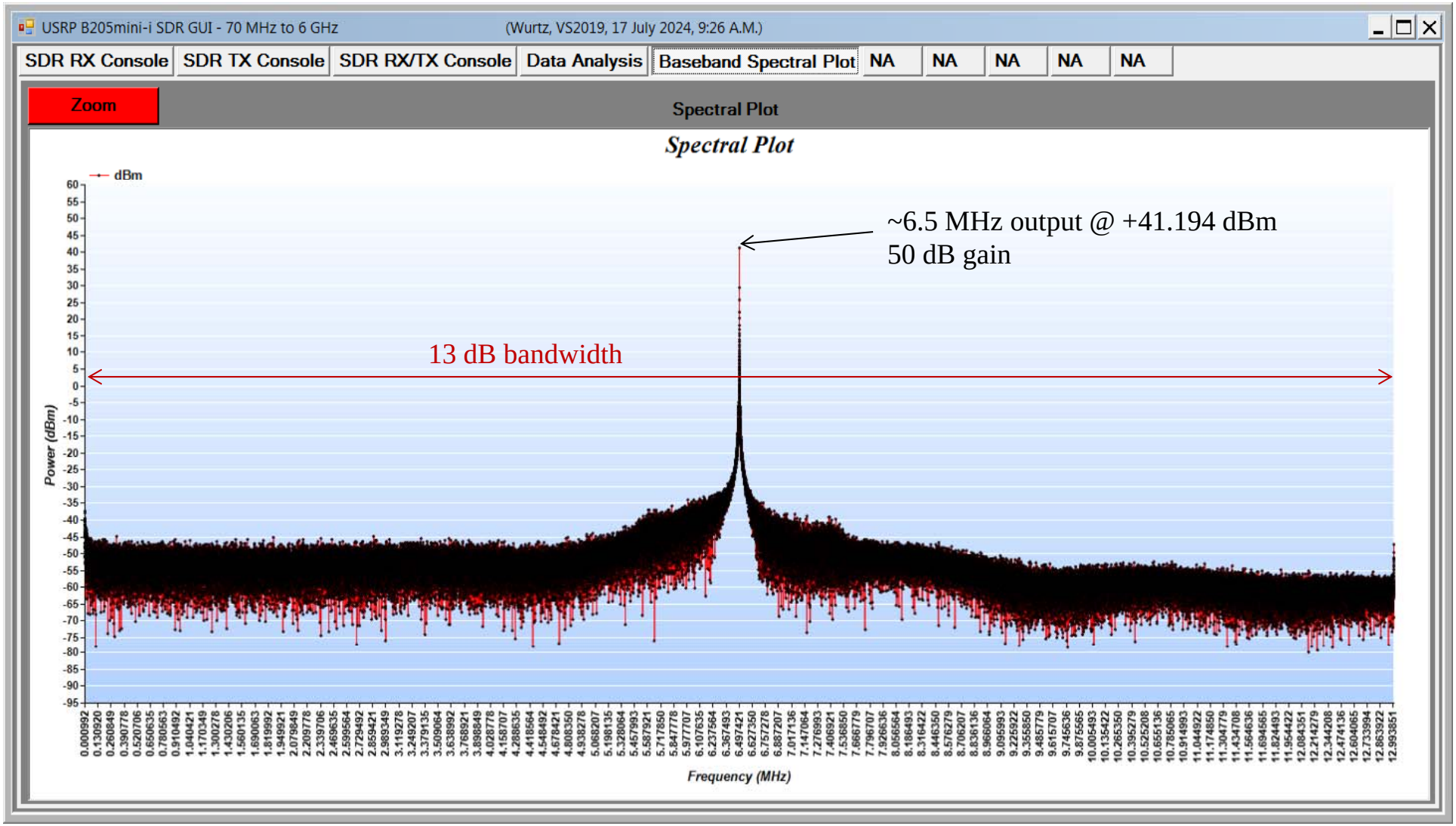


Figure 10. sc12 format spectral output with 2000 MHz -10 dBm CW input

sc12 format output

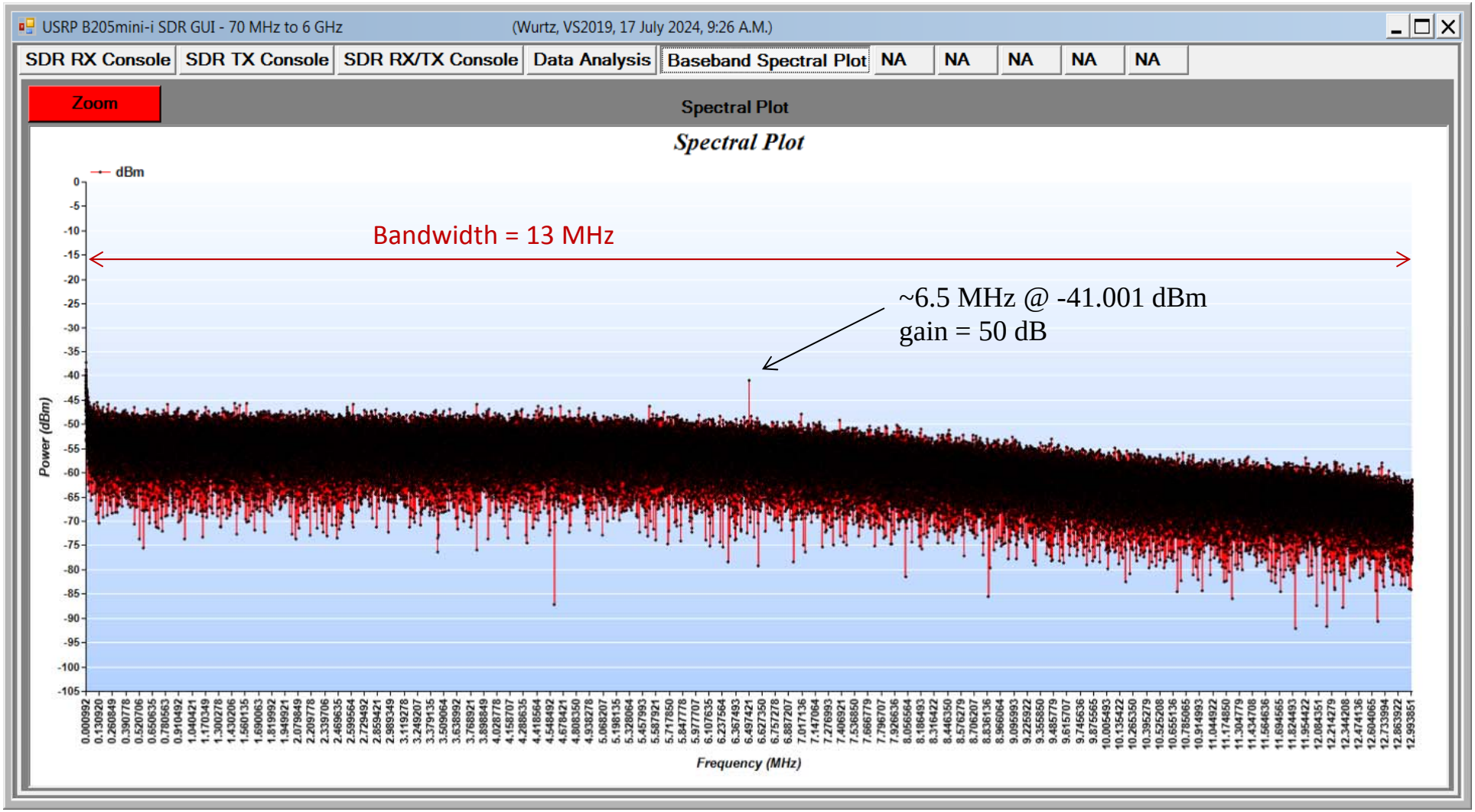


Figure 11. sc12 format spectral output with 2000 MHz CW input at -110 dBm

sc8 format output

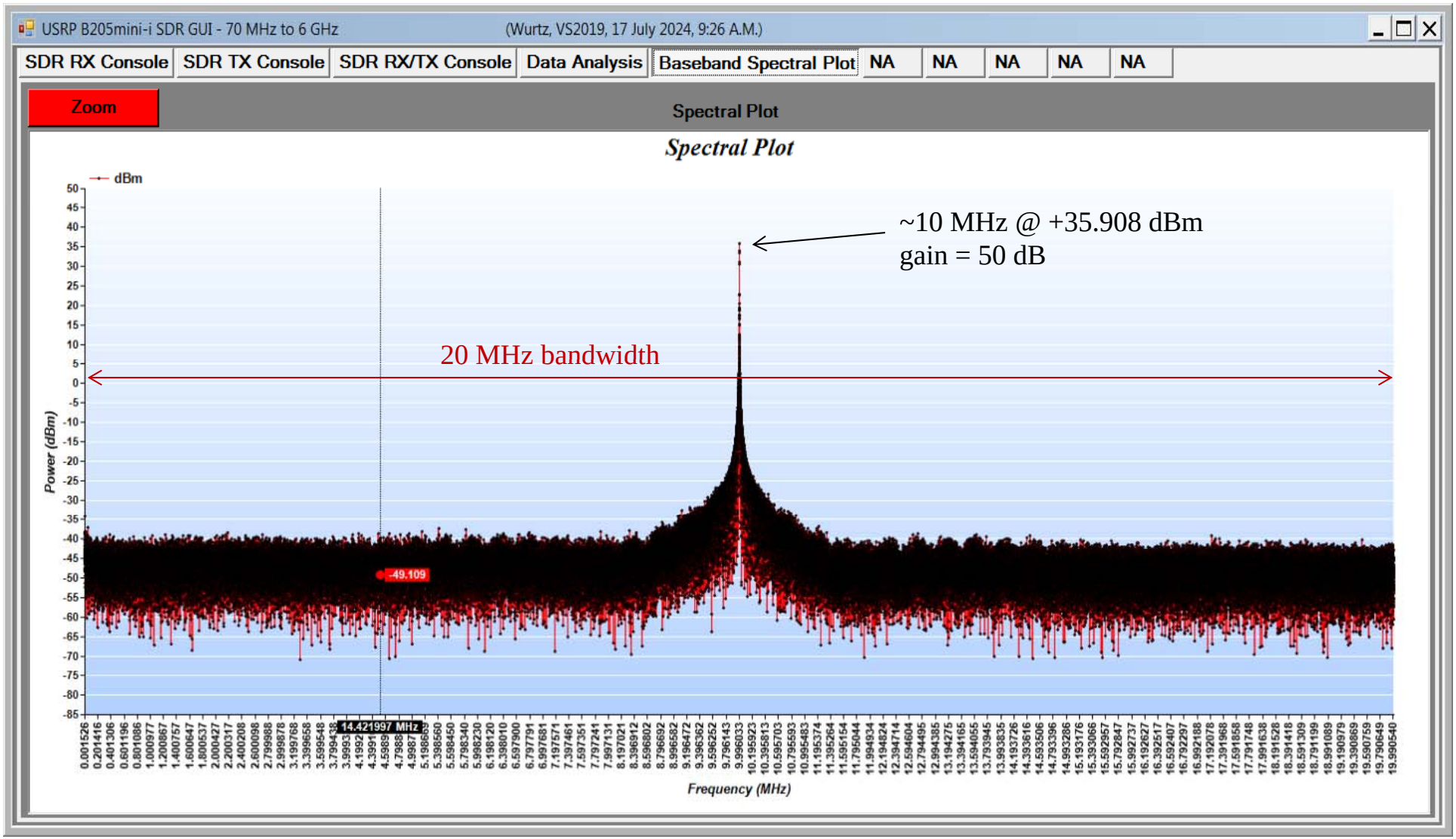


Figure 12. sc8 format spectral output with a 2000 MHz -10 dBm CW input

sc8 format output

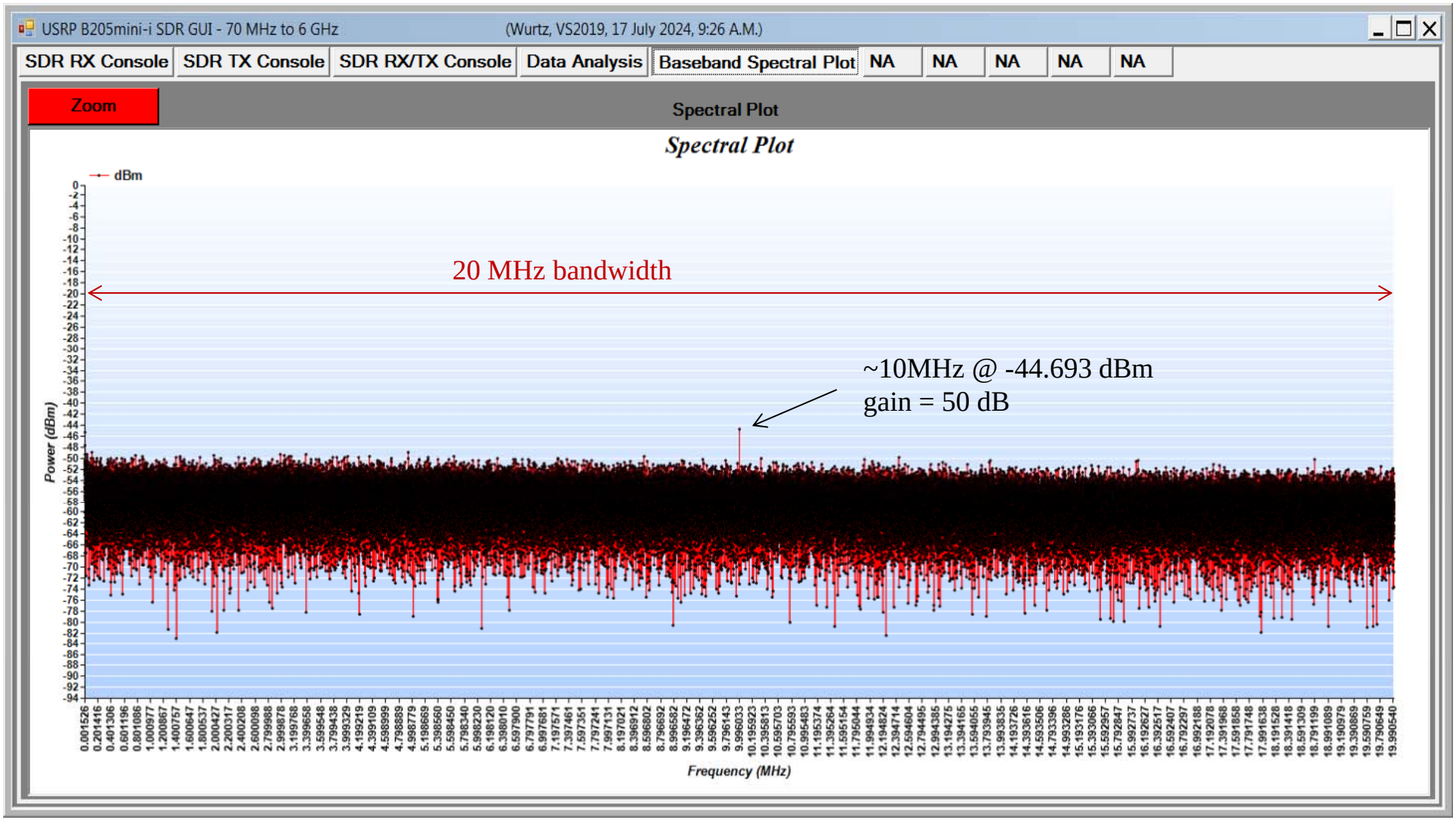


Figure 13. sc8 format spectral output with 2000 MHz -100 dBm CW input

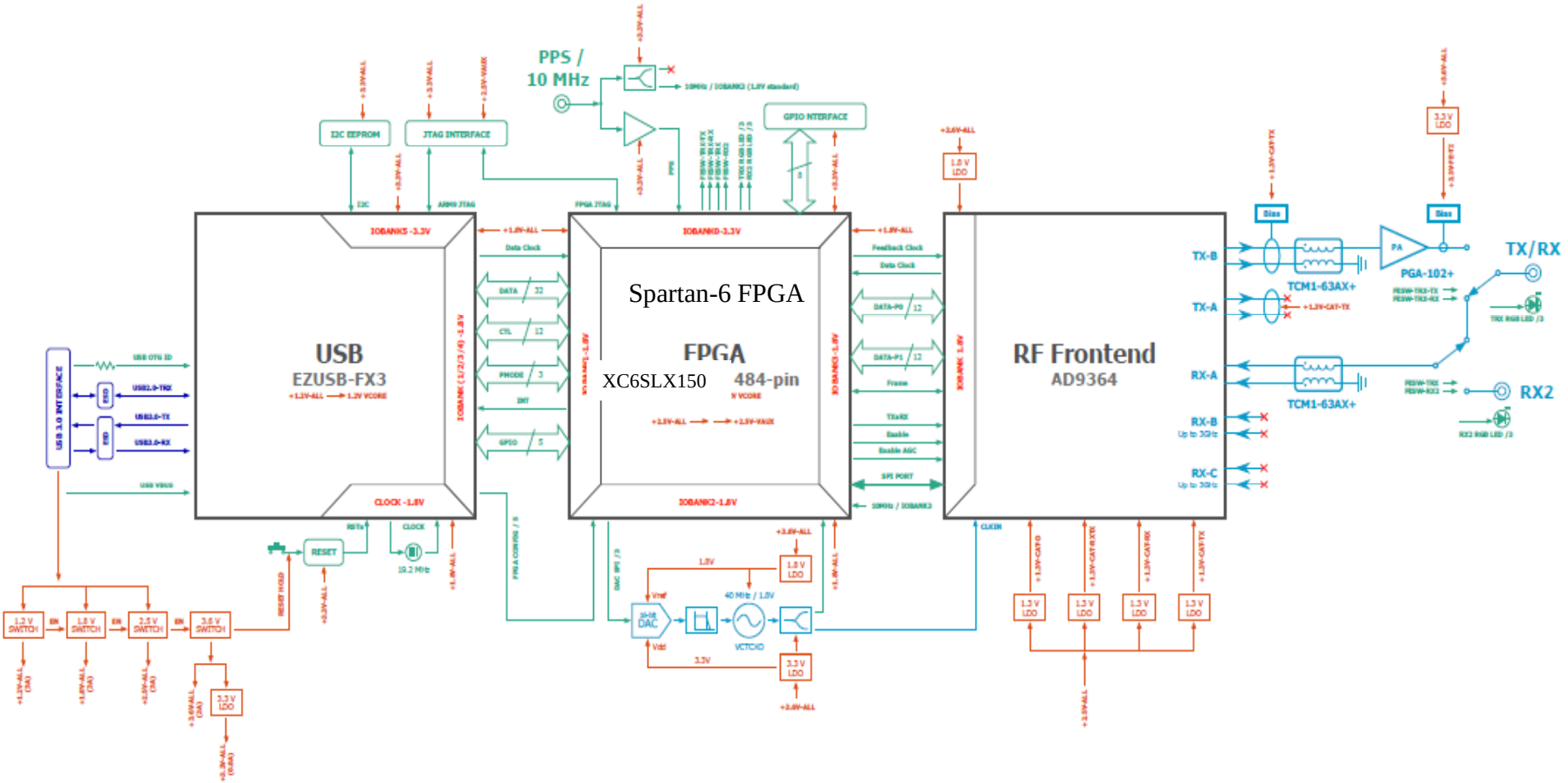


Figure 14. ETTUS USRP B205mini-i SDR block diagram