Title: Spectrum Measurement
Objective: Perform basic spectrum measurements
Equipment: - R&S Vector Signal Generator SMW200A, 100kHz - 20 GHz - R&S Signal and Spectrum analyzer FSW, 2Hz - 26.5 GHz
Remarks: - Never connect a DC coupled source or an active device directly to the SA or to the source unless you are sure it is AC-coupled. When in doubt, use a DC-BLOCK. - Use short cables, account for the insertion loss. - Use Torque wrench

Description:

Part 1: Basic Spectrum Measurements:

1) In this first part, the spectrum of the continuous wave (CW) output of the SMW200A was measured.
2) The RF output of the SMW200A was connected to the input of Signal and the Spectrum analyzer FSW using the Torque Wrench.
3) The resolution and video bandwidth were set to 1 MHz. The start frequency was set to 10 MHz and the stop frequency was set to 6 GHz.
4) The CW test signal frequency was set to 1 GHz and the power (P_{in}) was changed in steps of 10 dBm from – 60 dBm to 0 dBm.
5) The power level at 1 GHz, any harmonic/sub-harmonic at each P_{in} setting, as well as the noise floor, sweep time were recorded.
6) The steps were repeated for RBW = VBW = 100 kHz and 1kHz, and measurements were recorded.
7) The experiment was also simulated in LabView with RBW = VBW = 1kHz, with CW test signal frequency set to 1 GHz and the power (P_{in}) varied in steps of 10 dBm from – 60 dBm to 0 dBm. Results obtained were recorded.

The results obtained for the previous steps are summarized in Table 1. Figures 1, 2, and 3 display the frequency spectrum with RBW = VBW = 1 MHz, 100kHz, and 1kHz, respectively. It should be noted that the P_{in} of the test signal differs in each figure, and the ranges adjusted for clarity: 100 dBm, 110 dBm, 150 dBm, respectively.

Results Analysis

- ***Cable losses***

The power level measurement in the FSW was a few dBm less than the P_{in} set on the SMW. This discrepancy is due to the losses during the transmission of the signal across the short cables. Based on the measurements recorded in the table, the estimated loss is approximately 1 dBm.

- ***Sweep time, RBW, and VBW***

Decreasing RBW and VBW increases the sweep time. This is because the narrower the RBW filter (Gaussian window) is, the longer it takes longer to produce stable results compared to wider filters, hence increasing the sweep time. The VBW is also a filter used to reduce noise on the trace by smoothing or averaging the display trace.

- ***Noise level, RBW, and VBW***

From the table measurements, decreasing the RBW and VBW lowers the noise floor. The noise floor decreases by 10 dBm for every 1/10 decrease in the resolution bandwidth. The VBW, however, does not affect the noise floor.

- ***LabView Simulation***

The last column in the table presents LabView simulation data, which shows only slight deviations from recorded measurements. Importantly, the simulation significantly reduces measurement time compared to manual use of the FSW.

- ***Harmonics***

The second harmonic, occurring at (k× $2\pi(1GHz)$,where k = 2) has a power level of -76.64 dB. It could only be observed when RBW = VBW = 1 kHz, and the test signal Pin ranged from -30 dBm to 0 dBm.

- ***Shape***

As mentioned above, changing the RBW and VBW (from 1MHz to 1kHz) lowered the noise floor, this enabled better observation of the harmonics.

Table 1. Recorded Measurements

	RBW = VBW = 1MHz			**RBW = VBW = 100kHz**			**RBW = VBW = 1kHz**			
Sweep time	12 ms			206.9 ms			2.04 s			
Noise Level	-70 dBm			-80 dBm			-105 dBm			
P_{in} (dBm)	**P_{out} at 1GHz (dBm)**	**Harmonics (GHz, dB)**		**P_{out} at 1GHz (dBm)**	**Harmonics (GHz, dB)**		**P_{out} at 1GHz (dBm)**	**Harmonics (GHz, dB)**		**LabView Simulation Results (dBm)**
0	-0.8	-	-	-1.03	-	-	-0.88	1.9987	-76.64	-0.805
-10	-10.77	-	-	-10.88	-	-	-10.85	1.9987	-76.91	-10.774
-20	-20.76	-	-	-20.86	-	-	-20.8	1.9987	-76.49	-20.769
-30	-30.78	-	-	-30.86	-	-	-30.83	-	-	-30.766
-40	-40.83	-	-	-40.95	-	-	-40.84	-	-	-40.782
-50	-50.79	-	-	-50.93	-	-	-50.83	-	-	-50.771
-60	-60.74	-	-	-61.17	-	-	-60.85	-	-	-60.871

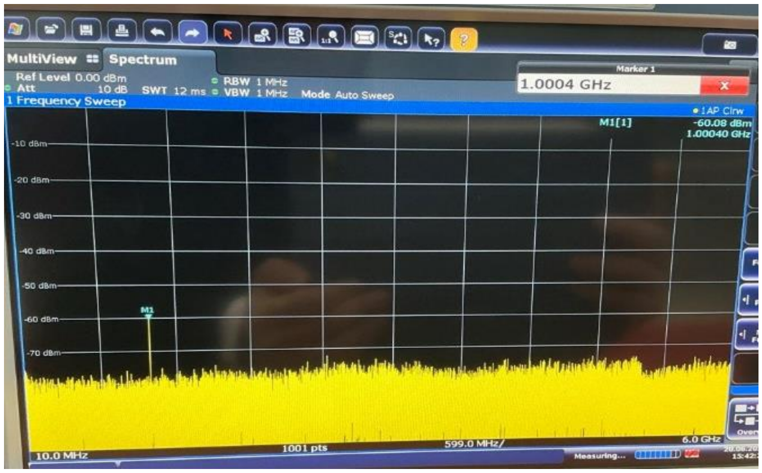

Figure 1. Spectrum Analyzer display with RBW = VBW = 1 MHz.

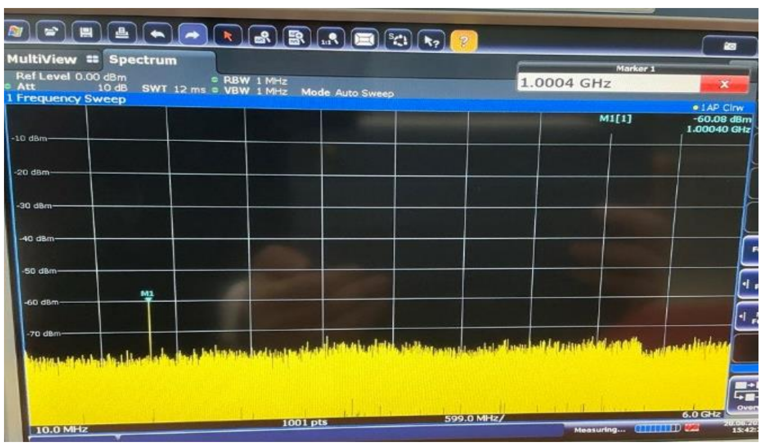

Figure 2. Spectrum Analyzer display with RBW = VBW = 100 kHz.

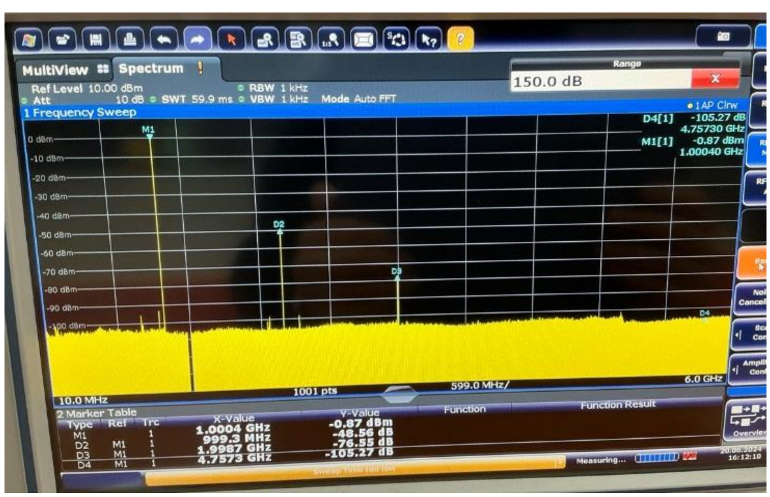

Figure 3. Spectrum Analyzer display with RBW = VBW = 1 kHz.

8) After that, Pin was set to -20 dBm, and the span was reduced to 1 MHz.
9) The frequency spectrum was saved in a (.dat) file and was loaded to MATLAB's workspace.
10) The built-in function `phaseNoiseMeasure` was used to generate the plots shown in figure 4, the power versus the frequency and the phase noise versus the frequency offset.

The phase noise at 100 kHz frequency offset is recorded to be **-118.802 dBc/Hz**. *Note that the phase noise is expected to decrease as the frequency offset increases.*

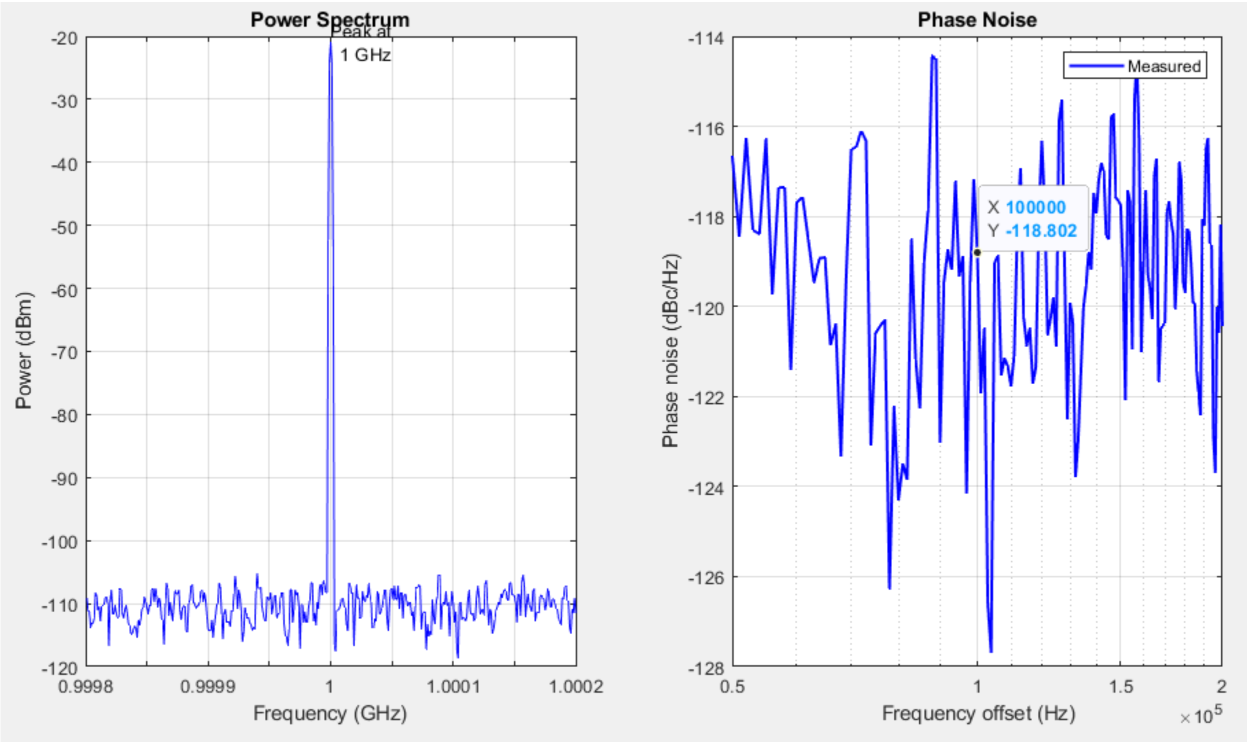

Figure 4. MATLAB simulation results. Power versus frequency plot and phase noise versus frequency offset plot.

Conclusion

In this project, basic spectrum measurements were conducted. The project explored the effect of FSW settings such as the RBW and VBW on signal clarity, noise floor, and sweep time. Subsequently, the frequency spectrum at a given test signal frequency and power level was saved and loaded into MATLAB to generate a phase noise versus frequency offset plot.