Lab #1

Oscilloscope, Spectrum Analyzer

Lab Group #20

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Introduction

The objectives of this lab are:
1. To learn the basic operations of an oscilloscope and the spectrum analyzer.
2. To understand the concept of dBm and dBV.
***Note:** For all signals the sample times follow Nyquist theorem

Section 1

Add a 2V DC signal to a 5KHz, 2V p-p sinusoidal signal. Set the simulation stop time to 10(s). Observe the output on the Scope and the Spectrum Analyzer (you can use one constant, one sine wave block, one Sum block, one Scope, and one Spectrum Analyzer).

a. Include a screenshot of the model you have created in your report.

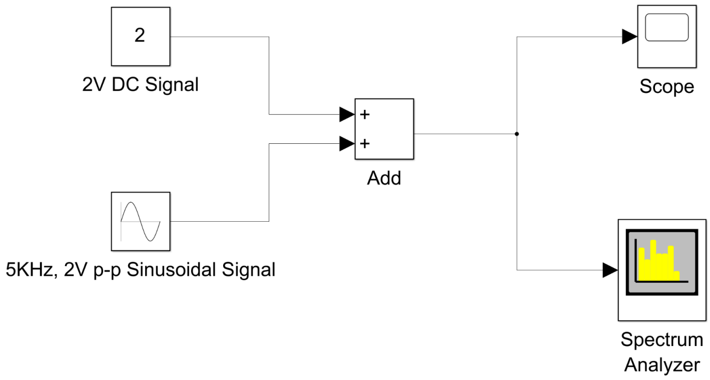


Figure 1.1: Simulink Model

b. Include the figure you observe on the Scope (Make sure that you set the display setting and sample time properly, as explained in Appendix).

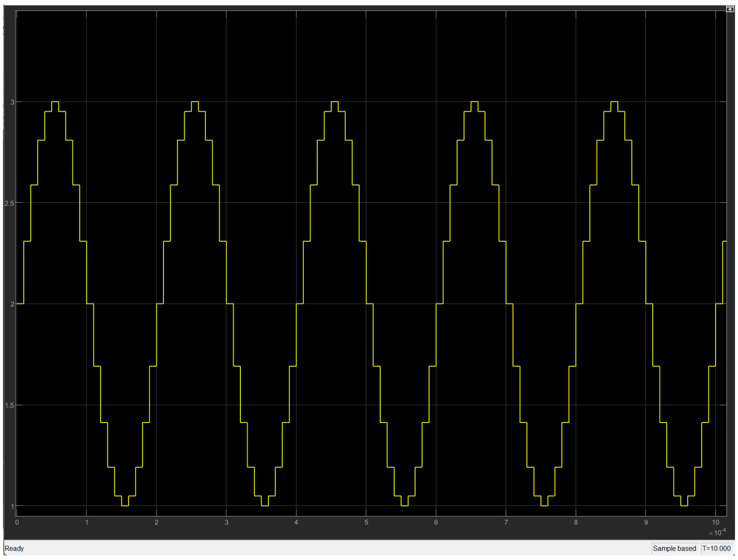


Figure 1.2: Scope

c. Include a screenshot of what you observe on the Spectrum Analyzer (Make sure that you set the display setting and sample time properly, as explained in Appendix)

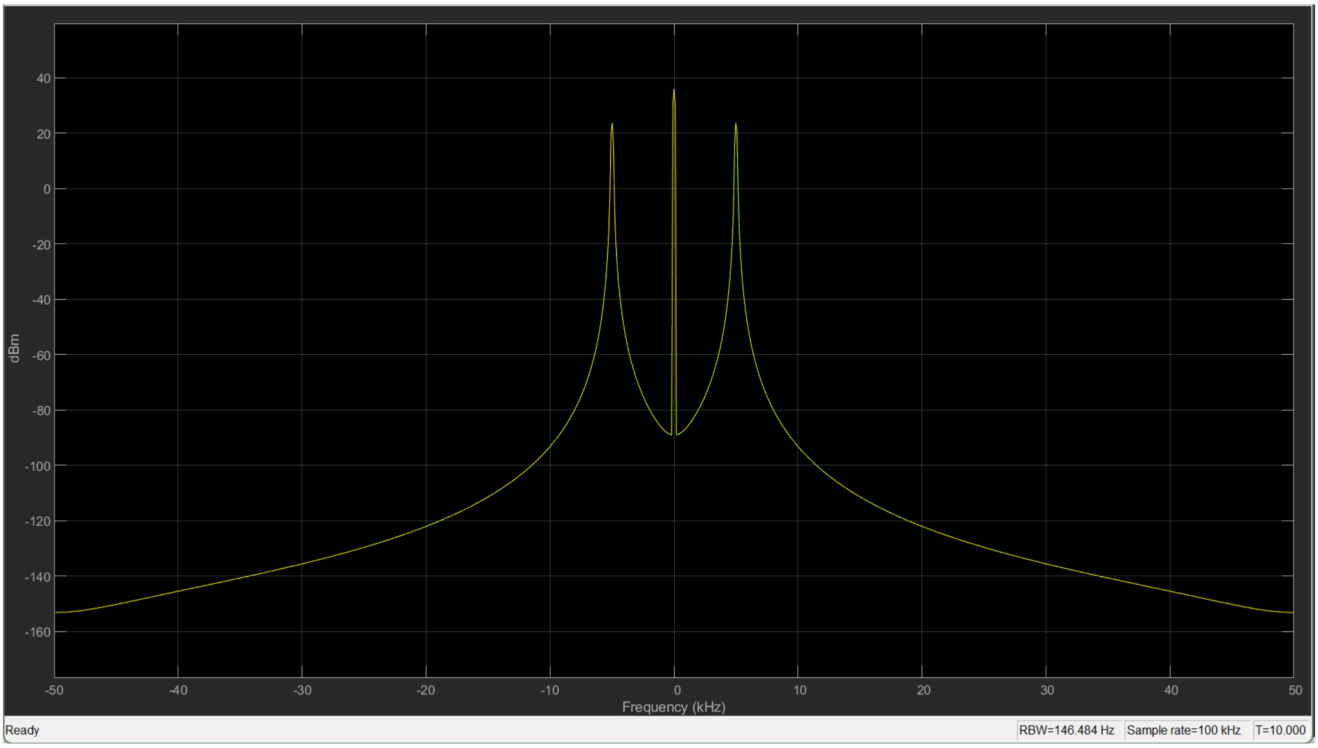


Figure 1.3: Spectrum Analyzer

d. Change the DC signal from 2V to 10V and double the frequency of the Sinusoidal signal to 10 KHz. What changes do you observe in the output of the Scope and the output of the Spectrum Analyzer compared to previous figures? Include the figures and explain briefly.

The output of the spectrum analyzer is similar in shape for both simulations. The difference lies in the value of the peaks and their location on the frequency spectrum. For the 2V DC + 5kHz sinusoid, the largest peak value is 36 dBm, while it is 50 dBm for the 10V DC + 10kHz sinusoidal signal. This is because with more DC offset, the larger the value on the frequency spectrum.
Additionally, the location of the remaining peaks differs for both simulations. For the first simulation, the peaks lie at $\pm$4.98kHz with a value of 23.75 dBm. For the second simulation the peaks lie at $\pm$9.961kHz (almost double the frequency) with a value of 23.07 dBm. This is because the frequency is doubled from the first simulation to the second simulation.
The output of the scope differs between the two simulations. In terms of shape, the first simulation is more curved than the second. This is because…
Additionally, the peak values of the output of the scope differ between simulations. The first simulation has a peak value of 3.00V, while the second simulation has a peak value of 10.95V. This is because the amplitude of the DC signal is increased in the second simulation.

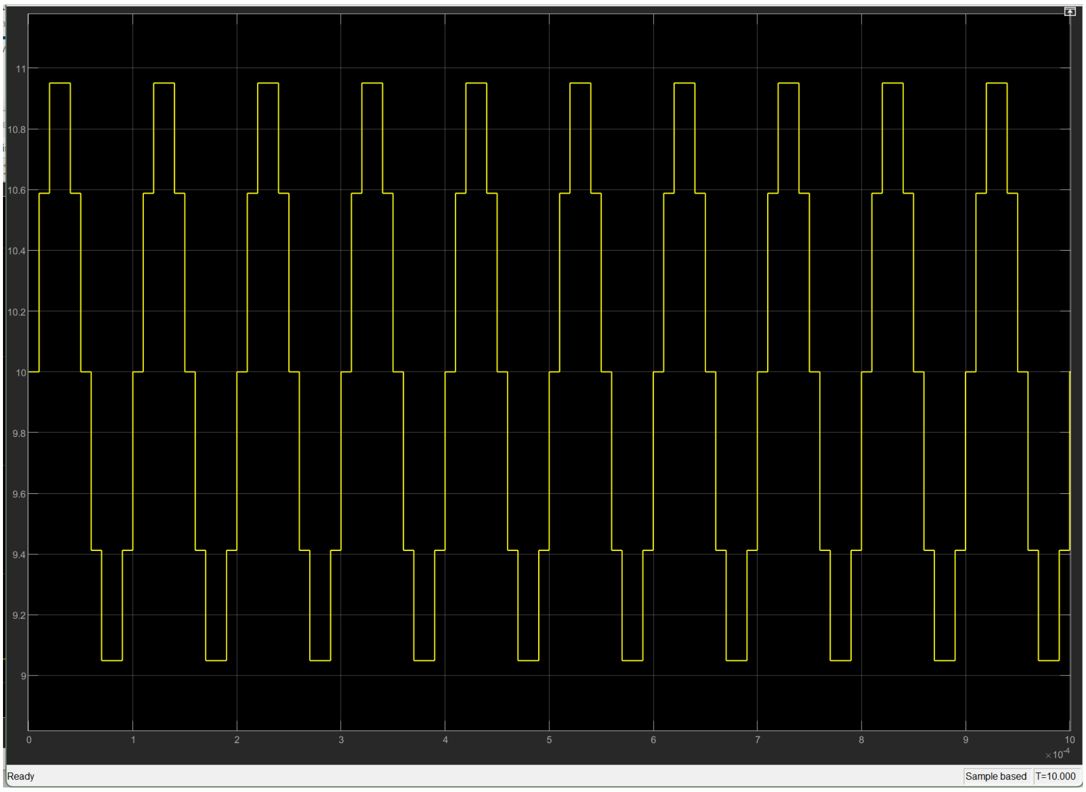


Figure 1.4: Scope

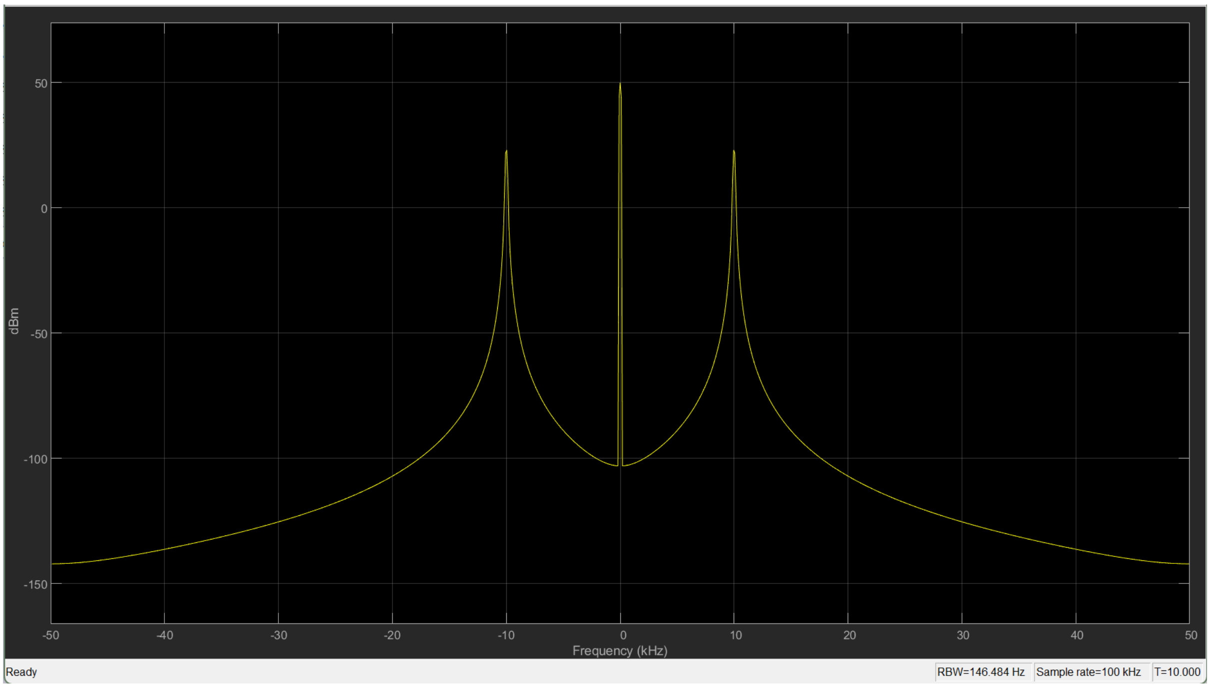
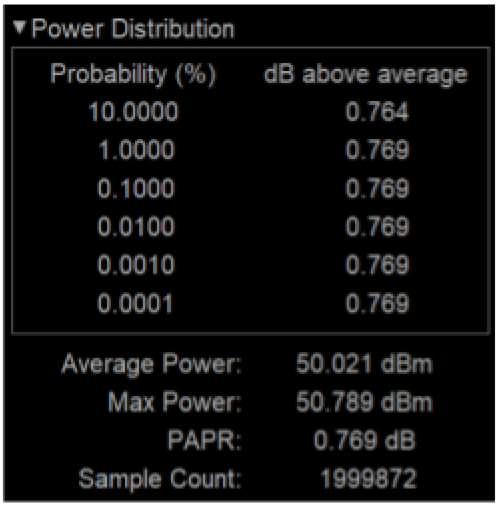


Figure 1.5: Spectrum Analyzer

e. Report the Average power of the signal in dBm (You can observe it using the Spectrum Analyzer. Go to Tools>>Measurements>>CCDF measurements). Change the simulation stop time to 20(s) and report the Average power again. Did you observe any changes? Why?

The average power stays the same regardless of the simulation stop time. Increasing the simulation time results in more samples contributing to the total power. Since both total power and number of samples increase, the average power remains the same.

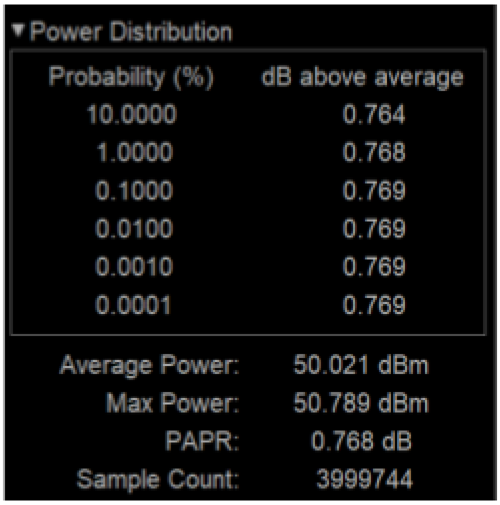


▾ Power Distribution

Probability (%)	dB above average
10.0000	0.764
1.0000	0.769
0.1000	0.769
0.0100	0.769
0.0010	0.769
0.0001	0.769

Average Power:	50.021 dBm
Max Power:	50.789 dBm
PAPR:	0.769 dB
Sample Count:	1999872

Figure 1.6: CCDF Measurements @ 10s



▾ Power Distribution

Probability (%)	dB above average
10.0000	0.764
1.0000	0.768
0.1000	0.769
0.0100	0.769
0.0010	0.769
0.0001	0.769

Average Power:	50.021 dBm
Max Power:	50.789 dBm
PAPR:	0.768 dB
Sample Count:	3999744

Figure 1.7: CCDF Measurements @ 20s

f. Based on your answer in part e, calculate the power of the signal in Watts.

$$P(\mathrm{W}) = 1\mathrm{W} \times \frac{10^{\frac{P(\mathrm{dBm})}{10}}}{1000}$$

Average Power: 50.021 dBm => **P(w)** = 10^(50.021/10)/1000 = 101.485 Watts

Section 2

Add a 5KHz, 1V p-p sinusoidal signal to a 100KHz, 2V p-p sinusoidal signal. Set the simulation stop time to 10(s). Observe the output signal on both Scope and the Spectrum Analyzer. In this part, your output signal is in the following form:

$$\text{Output signal} = A\cos(2\pi f_1 t) + B\cos(2\pi f_2 t)$$
$$\text{Where } A = 0.5, B = 1, f_1 = 5\times 10^3, f_2 = 10^5$$

a. Include a screenshot of the model you have created in your report.

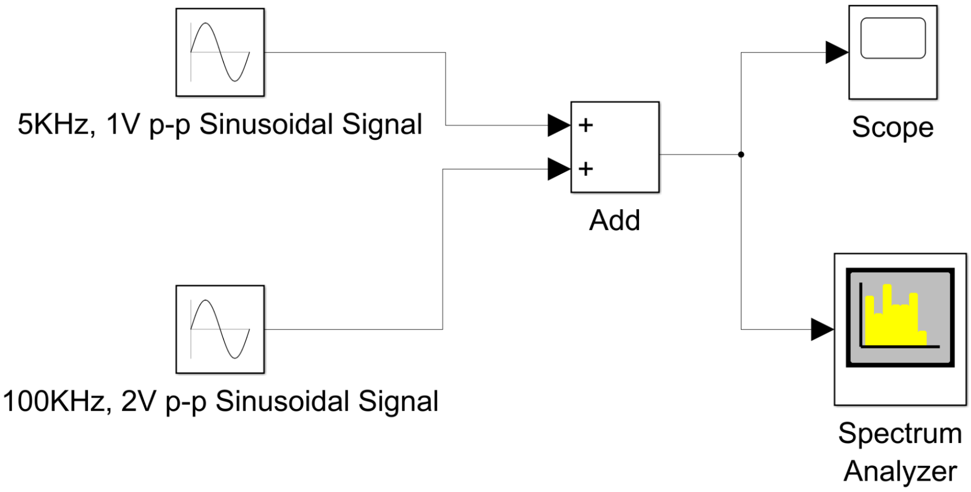


Figure 2.1: Simulink Model

b. Include the figure you observe on the Scope (Make sure that you set the display setting and sample time properly, as explained in Appendix

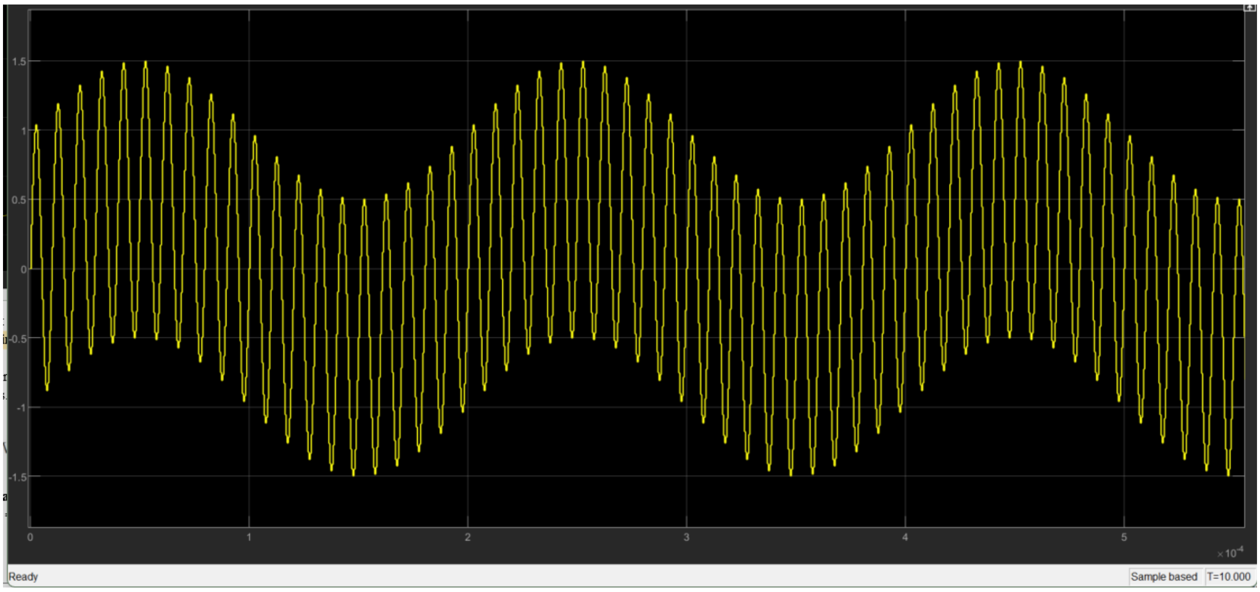


Figure 2.2: Scope

c. Include a screenshot of what you observe on the Spectrum Analyzer (Make sure that you set the display setting and sample time properly, as explained in Appendix).

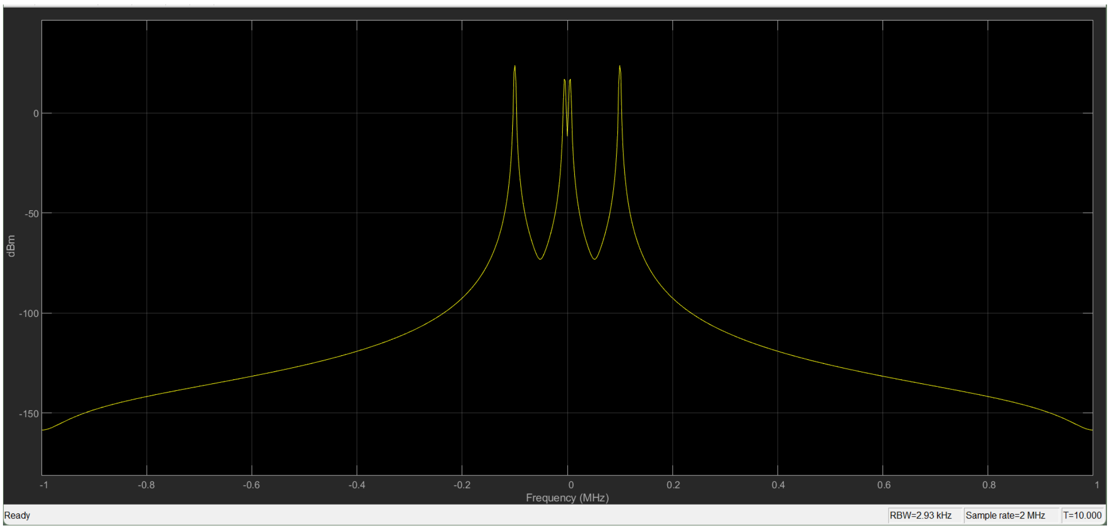


Figure 2.3: Spectrum Analyzer

d. What are the maximum and minimum amplitudes of the output signal on the Scope?

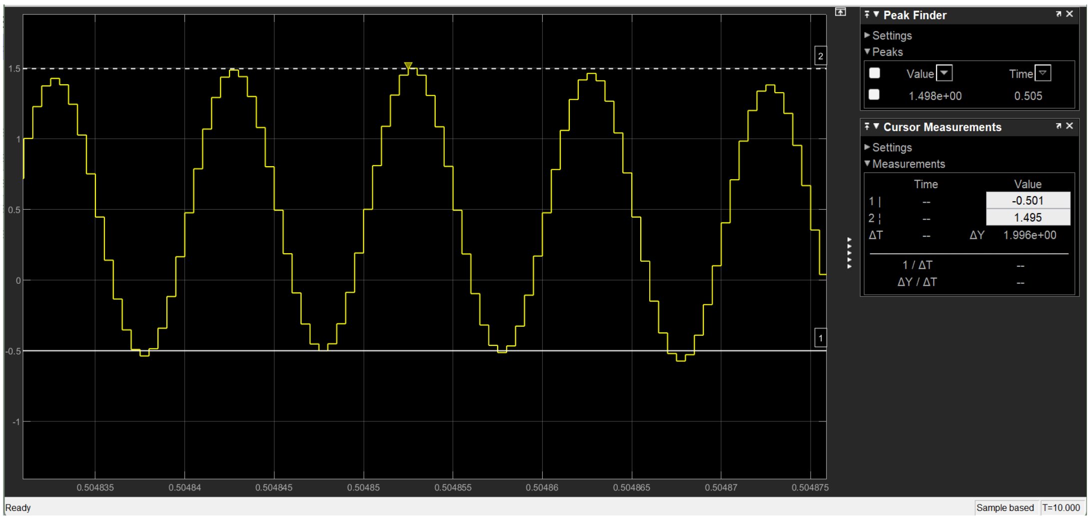


Figure 2.4: Scope Measurements Maximum → Maximum: 1.498V

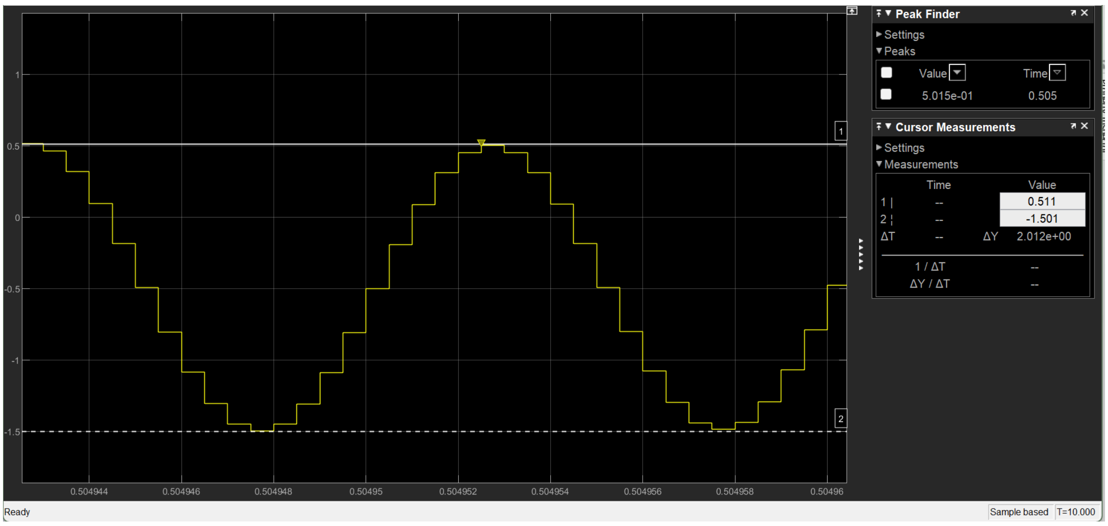
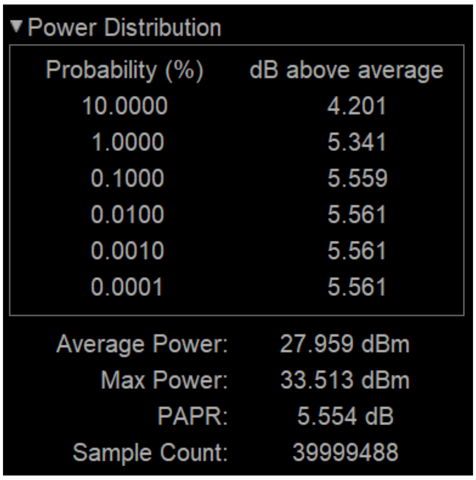


Figure 2.5: Scope Measurements Minimum → Minimum: 0.5015V

e. Report the Average power of the signal in dBm. Calculate the power of the signal in Watts



▾ Power Distribution

Probability (%)	dB above average
10.0000	4.201
1.0000	5.341
0.1000	5.559
0.0100	5.561
0.0010	5.561
0.0001	5.561

Average Power:	27.959 dBm
Max Power:	33.513 dBm
PAPR:	5.554 dB
Sample Count:	39999488

Figure 2.6: Power Distribution

$$P(\mathrm{W}) = 1\mathrm{W} \times \frac{10^{\frac{P(\mathrm{dBm})}{10}}}{1000}$$

Average Power: 27.959 dBm

P(w) = 10^(27.959/10)/1000 =0.62503 Watts

Section 3

Multiply a 5KHz, 1V p-p sinusoidal signal by a 100KHz, 2V p-p sinusoidal signal. Observe the output signal on both Scope and the Spectrum Analyzer. Set the simulation stop time to 10(s) (You can use two sine wave blocks, one Product block, one Scope, and one Spectrum Analyzer)

1. Include a screenshot of the model you have created in your report.

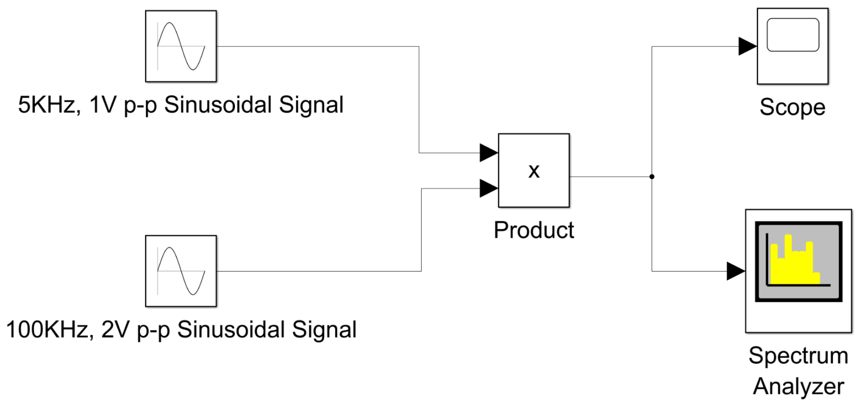


Figure 3.1: Simulink Model

2. Include the figure you observe on the Scope (Make sure that you set the display setting and sample time properly, as explained in Appendix).

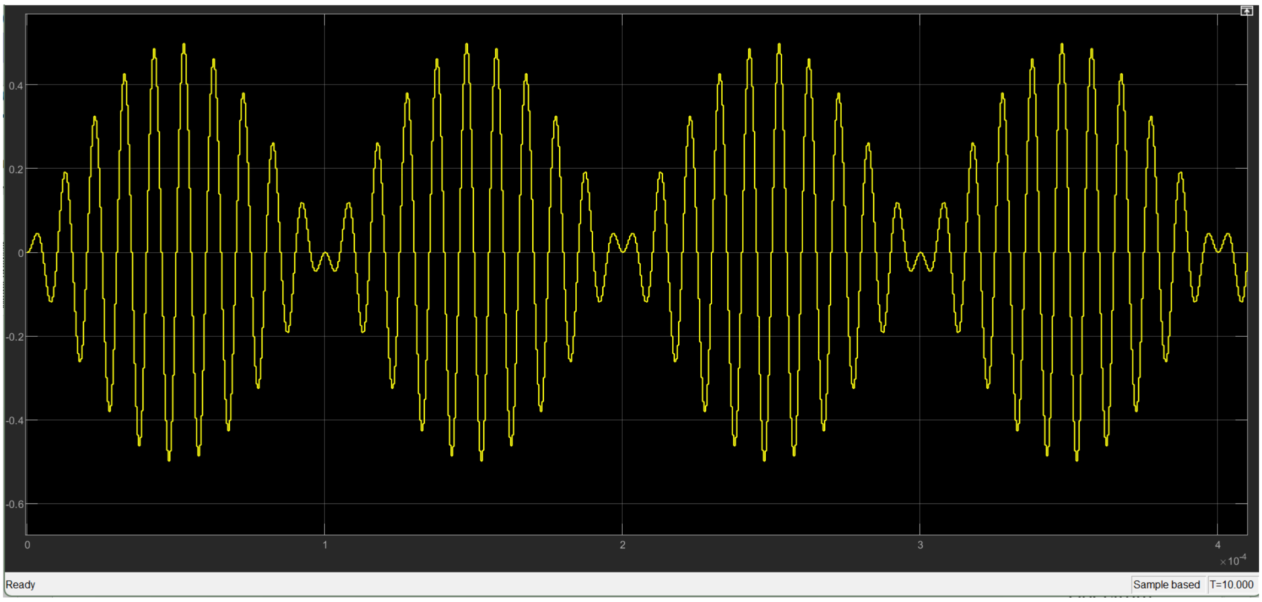


Figure 3.2: Scope

3. Include a screenshot of what you observe on the Spectrum Analyzer (Make sure that you set the display setting and sample time properly, as explained in Appendix)

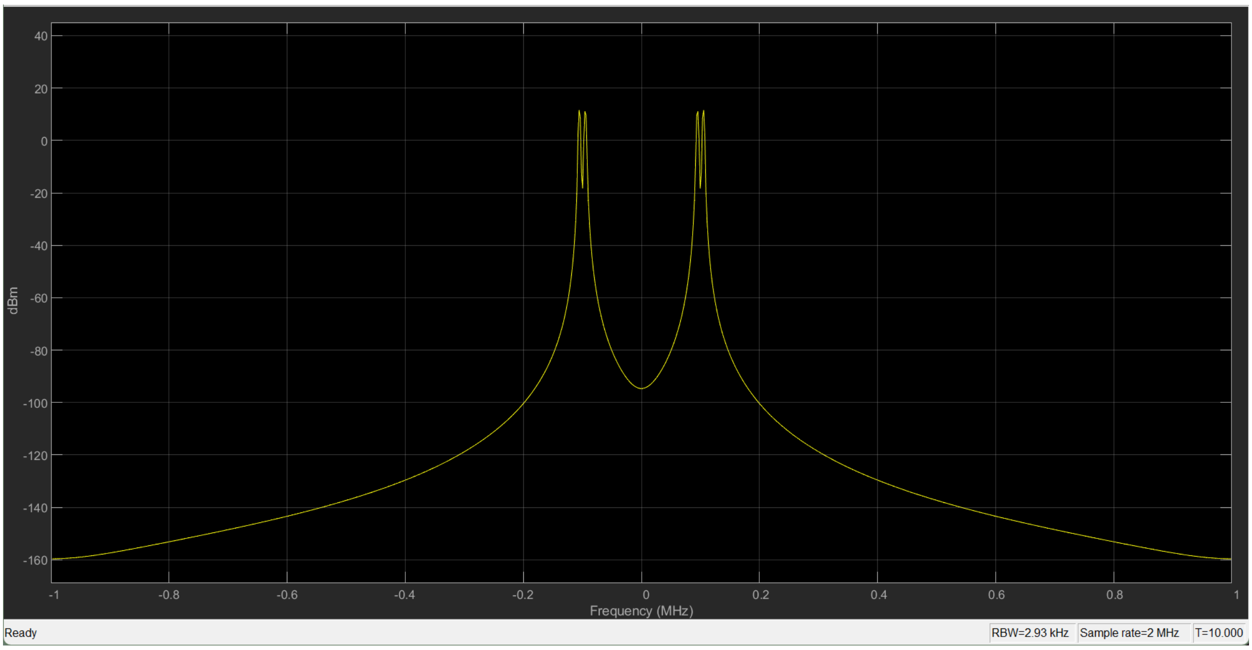


Figure 3.3: Spectrum Analyzer

4. Adjust the Spectrum Analyzer so that you can see the peaks clearly. What are the minimum and maximum amplitudes on the Scope? What is the maximum amplitude observed on the spectrum analyzer?

***Data Displayed on Next Page**

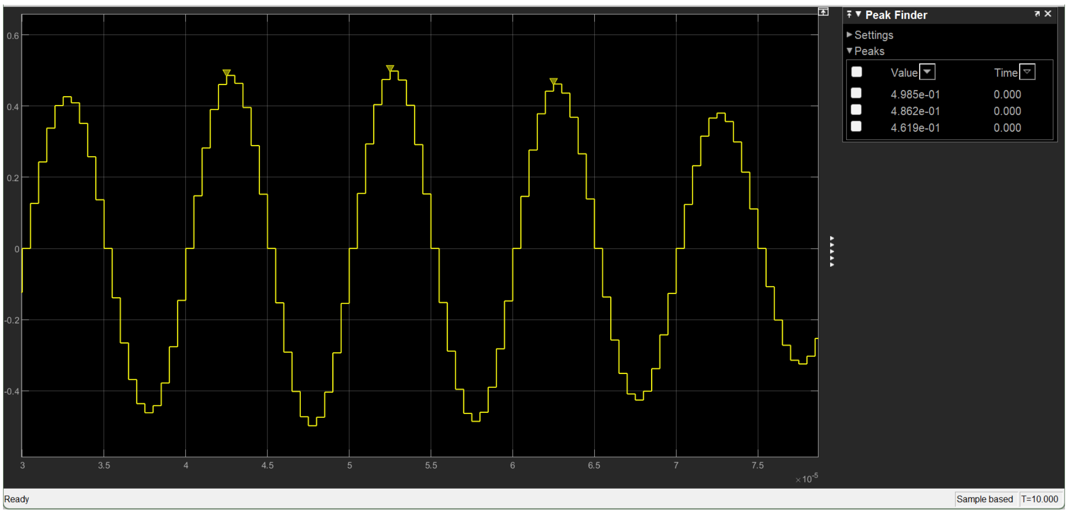


Figure 3.4: Scope Measurements Maximum

Maximum: 0.4985V

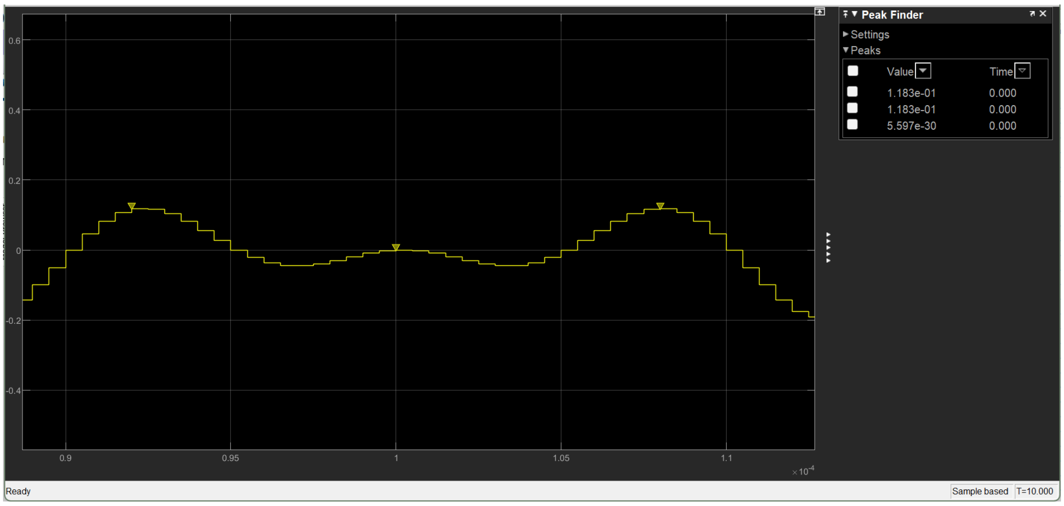


Figure 3.5: Scope Measurements Minimum

Minimum: $5.597\text{x}10^{-30}\text{V} \simeq 0.00\text{V}$

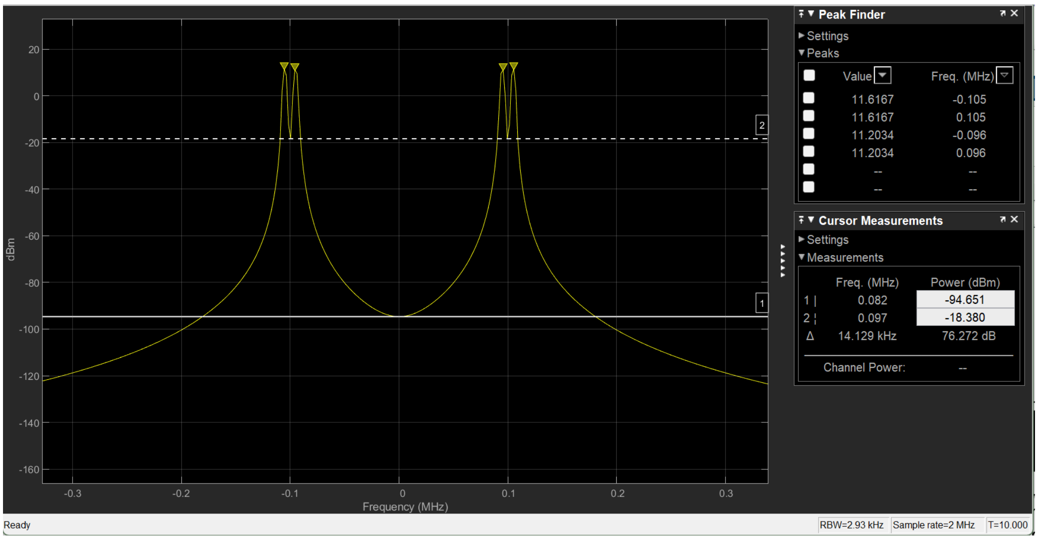
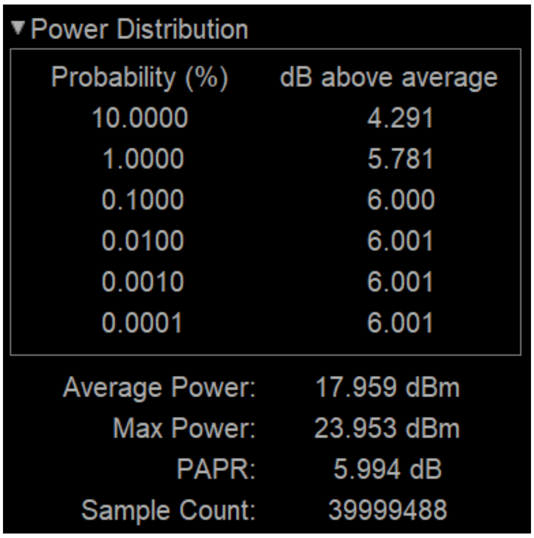


Figure 3.6: Spectrum Analyzer Measurements

Maximum :11.6167 dBm **Minimum:** -18.380 dBm, -94.651 dBm

5. Report the Average power of the signal in dBm. Also, calculate the power of the signal in Watts.



▼ Power Distribution

Probability (%)	dB above average
10.0000	4.291
1.0000	5.781
0.1000	6.000
0.0100	6.001
0.0010	6.001
0.0001	6.001

Average Power:	17.959 dBm
Max Power:	23.953 dBm
PAPR:	5.994 dB
Sample Count:	39999488

Figure 3.7: Power Distribution

$$P(\mathrm{W}) = 1\mathrm{W} \times \frac{10^{\frac{P(\mathrm{dBm})}{10}}}{1000}$$

Average power: 17.959 dB

P(w)= 10^(17.959/10)/1000= 0.0625 Watts

Section 4

An amplifier has a gain of 3dB. What would be the ratio of the output and input voltage?

The amplifier gain can be represented as follows:

$$x = 10\log_{10}\frac{V_2^{\,2}}{V_1^{\,2}} = 20\log_{10}\frac{V_2}{V_1}$$

Since the gain in 3dB then:

$$3 = 20 * log_{10}(\frac{V2}{V1})$$

$$\therefore \frac{V2}{V1} = 10^{\frac{3}{20}}$$

Hence, the ratio of the output and input voltage is approximately **1.41V**