Experiment 2
Signal Spectrum Measurement

Objectives

1. To get familiar with the user interface of spectrum analyser

2. To get familiar with important spectrum analyzer parameters.

3. To perform frequency domain signal measurements of periodic signal.

Equipment

R&S FSV Spectrum Analyser
Tektronix TDS1012B Digital Oscilloscope
TG1010 Function Generator

Procedure

Caution

The Spectrum Analyser has a **maximum allowable input power** of 1 W (30 dBm).

To avoid potential damage, please make sure that **you have set the voltage level of the input signal to the Spectrum Analyser as instructed.**

To display signal spectrum using spectrum analyser, we need to specify the frequency range to be displayed on the spectrum analyser by setting the **Start** and **Stop** frequency or **Centre frequency** and **Span** on the Spectrum Analyser as shown in Figure E2.1.

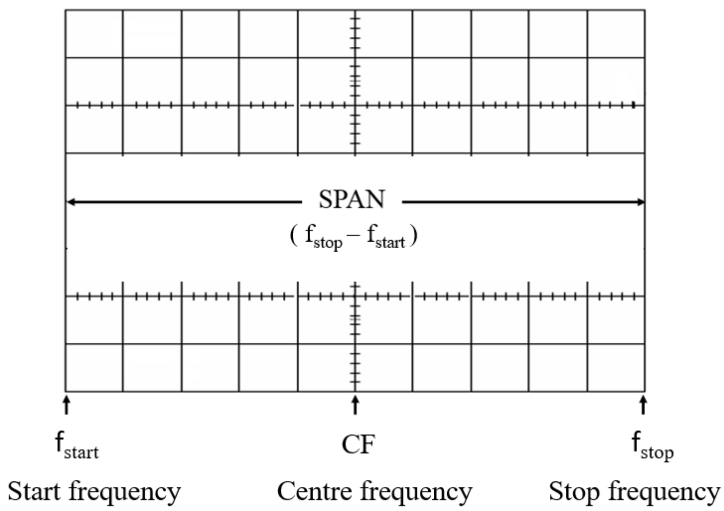

Figure E2.1 Spectrum Analyser CRT screen

You will use the **two** methods to display the spectrum of a signal:

- Method 1 - set **Start and Stop** frequency
- Method 2 - set **Centre** frequency and **Span**

A. Measure frequency and power of a 100 kHz and 600 mV$_{pp}$ sine wave signal

1. Input a sine wave signal of 100 kHz and amplitude of 600 mV$_{pp}$ to the spectrum analyser through a RF cable as shown in Figure E2.2.

Important
Make sure that you have set the input signal voltage level as instructed before connect the signal to the spectrum analyser.

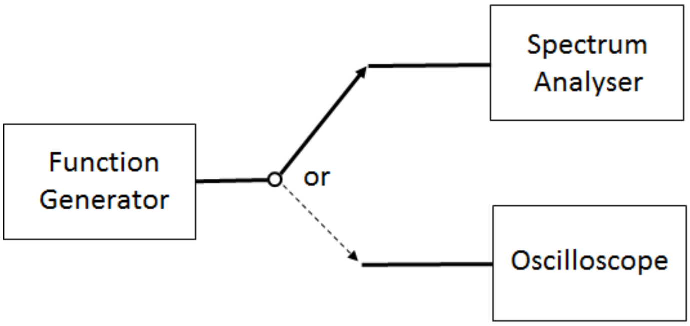

Figure E2.2 Connection diagram

2. Measure the frequency and power of the sine wave:

   FREQUENCY ➔ CENTER ➔ enter 100 kHz ➔ SPAN ➔ enter 200 kHz

3. Adjust the reference level (refer to appendix):

   AMPLITUDE ➔ Ref Level ➔ enter 0 dBm

4. Press PEAK SEARCH to place a marker (**M**1) on the frequency component. Record down the frequency and amplitude of the sine signal below:

   Frequency: ____________________.

   Amplitude: ____________________.

Question 1: How many frequency components does a sine signal have? ____

Question 2: What is the expected frequency of the component?

Expected frequency: ______________

B. Display and measure the spectrum of a rectangular wave

1. Input a 200mV_{p-p} rectangular wave with a period of 5μs and a pulse width of 1μs to the spectrum analyser (the timings must be exact).

2. Based on what you have learnt in Chapter 2, sketch the **single-sided** spectrum of the rectangular wave up to the 7th harmonic below. Indicate the frequency of each component but not their amplitudes.

3. Display the spectrum of the rectangular wave up to the 7th harmonic (from fundamental frequency to 7th harmonic) on the spectrum analyser using **Method 1.**

   a) Determine **Start** frequency**,** $\mathbf{f_{start}}$:

   Start frequency**,** Calculated f_{start} = 200 kHz (to display the fundamental frequency component)

   Note: The actual Start frequency, f_{start} should be chosen slightly smaller than 200 kHz, usually the difference is $\boldsymbol{\Delta F}$, so that the fundamental component will be fully included within the display window:

   $\boldsymbol{\Delta F}$ **= 10% ×** $\mathbf{f_0}$ **(fundamental frequency)**

   Chosen $\mathbf{f_{start}}$ = Calculated $\mathbf{f_{start}}$ - $\boldsymbol{\Delta F}$ = 180 kHz

   b) Determine **Stop** frequency, $\mathbf{f_{stop}}$:

   Stop frequency, f_{stop} =1400 kHz (to display the 7th harmonic component).

Note: The actual **Stop** frequency, $\mathbf{f_{stop}}$ should be chosen slightly larger than 1400 kHz so that the 7th harmonic component will be fully included within the display window.

Chosen $\mathbf{f_{stop}}$ = Calculated $\mathbf{f_{stop}}$ + ΔF = 1420 kHx

Now you can display the spectrum using the **chosen Start** and **Stop** frequency:

FREQUENCY ➔ Start ➔ enter **180** kHz ➔ Stop ➔ enter **1420** kHz.

4. Display the spectrum using **Method 2**

a) Determine **Center** Frequency:

CF = (Calculated f_{start} + Calculated f_{stop}) / 2 = 800

b) Calculate Span:

Span = Calculated f_{stop} – Calculated f_{start} = 1400 – 200 = 1200 kHz.

Note: The actual Span should be chosen slightly larger than the calculated Span so than the first and the last components will be fully included within the display window.

Chosen Span = Calculated **Span** + 2ΔF = 1240 kHz

Set the spectrum analyser to display the spectrum:

FREQUENCY ➔ Center ➔ enter 800 kHz ➔ SPAN ➔ enter **1240** kHz.

5. Measure the frequency and amplitude of each frequency component

a) Record down the reading of the amplitude and frequency of the frequency components in the table below.

MRK-> ➔ Peak ➔ Next Peak, and so on

Note: You can also turn the knob manually to measure component by component using PEAK SEARCH.

	Fundamental	2^{nd} Harmonic	3^{rd} Harmonic	4^{th} Harmonic	5^{th} Harmonic	6^{th} Harmonic	7^{th} Harmonic
Frequency (kHz)							
Amplitude (dBm)							

Question 3. While maintain the frequency of the rectangular wave constant, slowly increase the SYMMETRY until it reaches 50%. Describe and explain the change in the spectrum.

Observation: ______________________________

Explanation: ______________________________

____

C. Display and measure the spectrum of a Sawtooth wave

1. Change the signal to a sawtooth wave while mantaining all other values unchanged.

2. Record down your reading on frequency and amplitude of the frequency components in the table below.

	Fundamental	2^{nd} Harmonic	3^{rd} Harmonic	4^{th} Harmonic	5^{th} Harmonic	6^{th} Harmonic	7^{th} Harmonic
Frequency (kHz)							
Amplitude (dBm)							

Question 4: Compare the spectrum of the rectangular wave and the sawtooth wave, describe and explain the difference.

Observation: ______________________________

Explanation: ______________________________

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D. Practice

1. Practice 1

Display the spectrum of a 400mV$_{p-p}$ rectangular wave with a period of 10µs and a pulse width of 3µs up to the 9th harmonic. Show how you calculate and choose Start and Stop frequency, SPAN and Centre frequency. **Show the spectrum to your lecturer.**

Method 1

Start frequency = __________

Stop frequency = __________

Chosen Start frequency = __________

Chosen Stop frequency = __________

Method 2

Center frequency = ______________

Calculated **Span** = ______________

Chosen Span = ______________

2. PRACTICE 2

Display the spectrum of a 500 mV$_{p-p}$, 250 kHz square wave, showing the **3rd and 5th harmonics only**. Show your working below. Measure the frequency and power of each component. Show how you calculate and choose Start and Stop frequency, or SPAN and Centre frequency. **Show the spectrum and measurements to your lecturer.**

Method 1

Start frequency = __________

Stop frequency = __________

Chosen Stop frequency = __________

Chosen Stop frequency = __________

Method 2

Center frequency = ______________

Calculated **Span** = ______________

Chosen Span = ______________

E. TEST

Without referring to the lab sheets, set the functional generator to generate the waveform shown in Figure E2.3. Display the spectrum up to 5th components on the spectrum analyser. **Show your results to your lecturer.**

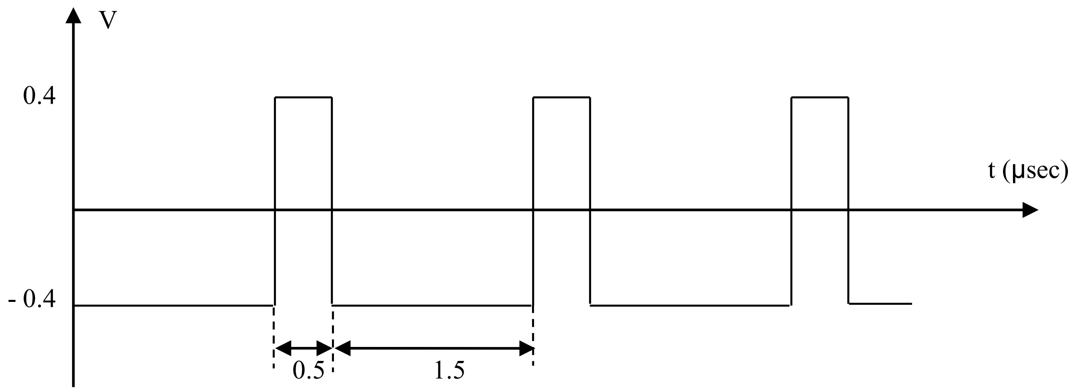

Figure E2.3 A rectangular waveform

Determine the following **before** you start:

Frequency :________________________

Amplitude :________________________

SYMMETRY (Duty cycle) :________________________

Appendix

1. REFERENCE LEVEL (Ref LVL) (check if change required)

The REFERENCE LEVEL (REF LVL) must be set to an appropriate value. Look at the spectrum displayed on the CRT screen. Can you see the peaks of all the frequency components of the input signal? If yes, then you don't need to change the REF LVL setting. If the displayed spectrum does not appear correctly on the screen, you need to adjust REFERENCE LEVEL .

Follow this sequence to adjust the REFERENCE LEVEL (RFF LVL): AMPLITUDE ➔ Ref Level ➔ Rotate the "SPINNER" to move the displayed spectrum ↑ or ↓ until the peaks of all the frequency components are clearly displayed.

> **Note**: *You will notice that each vertical line representing a frequency component is a bit rounded. This is normal and is due to the way the spectrum analyzer works.*

Five settings of reference level are available i.e. 20 dBm, 10 dBm, 0 dBm, -10 dBm and -20dBm. The Ref LVL should be set to a value slightly higher than the power of the input signal expressed in dBm. Since we do not know the input power, we have been setting the Ref LVL by trial and error.

If you know the input power in dBm, then you should set the Ref LVL to the next higher level. For example if the input power is +15 dBm, set the REF LVL to +20 dBm. If the input power is -15 dBm set the Ref LVL to -10 dBm.

2. DC COMPONENT

Spectrum analysers cannot display DC component

3. OTHER SETTINGS

a) The resolution Bandwidth (RBW) will be set to the optimum every time when the span selection is changed. But, it can be set manually to see a fine spectrum by pressing the following buttons in sequence: BW ➔ RBW ➔ enter XXX Hz/ kHz/MHz.

b) You can place a triangle-shaped marker on the peak of a frequency component to find the frequency and amplitude (power) of that component. Follow the sequence blow to get the reading of all frequency components. The Marker Readout is the frequency and amplitude of the component (Marker Readouts of amplitude and frequency appear in the upper-right corner of the display).

MKR-> ➔ Peak ➔ Next Peak