**Laboratory 2A:**

**Decibels and Fourier Series**

Read the introduction of the “Decibel” article in Wikipedia: <https://en.wikipedia.org/wiki/Decibel>

*“The decibel (dB) is a logarithmic unit used to express the ratio of two values of a physical quantity. …”*

In this course and further engineering classes, we use decibels very often. We measure with it the voltage or power value of signals. You can either compare two signals, or take one signal and compare to a reference value. For example, comparing the voltage or power of two signals:

or

We can show that these two definitions are equivalent, if you refer to a common resistance value, because:

For

Now, if you measure a voltage signal with respect to a reference voltage of 1V:

Or, if you measure a power signal with respect to a reference power of 1mW:

# Exercise-1 : Refresh Log-Base-10

In order to calculate easily with dB you need to refresh the handling of logarithm on basis 10. For this purpose, fill up the table below. Please solve this without a calculator!

|  |  |
| --- | --- |
| **Powers of 2** | **Powers of 10** |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | **Mixed** |
|  |  |

# Exercise-2 : Measurements in dBV and dBm

Setup the Function Generator (FuGe) to generate an output signal with following characteristics:

Shape: sinus Frequency = 200kHz Amplitude = 1Vrms Load = 50Ω

FuGE + Oscilloscope: single sinus

Connect the output of the FuGe to an oscilloscope using a coaxial cable. Adjust the time base and amplitude, to be able to visualize a few periods. Then answer to the following questions:

1. What is the amplitude value in Vpeak and in Vpp that you expect to measure?
2. What is the input impedance of the oscilloscope? ([Link User Manual for Tektronix TDS 20xx](https://de.tek.com/oscilloscope/tds1002-manual/tds1000-and-tds2000-series-user-manual))

Can you explain the mismatch between the FuGe setting and the reading in the oscilloscope?

1. Change the load setting in the FuGe: Output > Load > **High-Z** > Done

Which amplitude value in Vrms are you measuring now in the oscilloscope?

1. Return the Load setting to **50Ω,** and add a T-joint plus a 50Ohms termination in parallel to the oscilloscope input. Which amplitude value in Vrms are you measuring now in the oscilloscope?
2. Which signal amplitude do you expect to measure in the frequency domain in the oscilloscope? Express your result in dBV.
3. Check your calculation with a measurement using the FFT in the oscilloscope and the cursor (type frequency, source math)

FuGE + Oscilloscope + Spectrum Analyzer: single sinus

Connect now a T-junction in the output of the FuGe, and add a coaxial cable to send the FuGe output in parallel to both the oscilloscope and the spectrum analyzer (SA). The 50Ohm termination from previous exercise is no longer needed. Adjust the spectrum analyzer settings to visualize:

* Frequency range : [10kHz, 2MHz] => Menu freq > start freq / stop freq
* Amplitude (add attenuation) => Menu ampt > RF Att > Manual > 30dB

=> Menu ampt > Ref Level > +20dBm

1. Which signal power do you expect to measure in the spectrum analyzer? Express your result in dBm.
2. Check your calculation with a measurement in the spectrum analyzer. Use the menu marker (or marker →), and the function set to peak.
3. Change the Resolution Bandwidth (RBW under Menu BW) to manual and reduce the value (e.g. 10KHz) to get finer peaks.

# Exercise-3 : Spectrum Measurements

**Spectrum Analyzer: square and ramp signals**

1. Change the FuGe output to a periodic square wave with frequency 500kHz, amplitude 1Vpp, and observe the corresponding spectrum in the spectrum analyzer. Increase the frequency range up to 5MHz, and the RBW to 30KHz.

Check the RMS value in the oscilloscope: A = \_\_\_\_\_\_Vrms

And calculate the corresponding total power in dBm and dBV (relative to Vrms).

1. Which harmonics have a significant amplitude? Check the values both in the spectrum analyzer (in dBm) and in the oscilloscope (in dBV). Note the amplitude values of the first 5 significant harmonics. Ignore harmonics which are 40dB smaller than the fundamental.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Harmonic Nr. | Freq (kHz) | Power (dBm) SpekA. | Amp dBV  In Oscil  Wdw=flattop | Relative amplitude with respect to 1st harmonic  (select either SA or Osc) | Theoretical value based on Fourier Series |
| 1 | 500 |  |  | 1 = 0 dB | Reference 1 =>  0 dB |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

1. Use the Fourier series expression for a periodic rectangle and calculate the theoretical values you expect for the 2nd till 5th harmonics compared to the fundamental (1st harmonic).   
   Fill out these values in the last column of the table above and compare to your measurement “relative amplitude with respect to 1st harmonic”.
2. Change the FuGe output signal to a ramp or sawtooth, and repeat steps (l) and (m). check which harmonics are present in the output spectrum.

Observation: to simplify the comparison with the theoretical Fourier Series, we added on following pages an extract of a Fourier series table from:

**R. Kories, H. Schmidt-Walter, „*Taschenbuch der Elektrotechnik*“,**

Tabelle: Fourier-Reihen aus Kapitel 7.2.6 aus

9., korrigierte Auflage, Verlag Harri Deutsch, 2010.

Observation: The spectrum analyzer sweeps through the frequency measurement range, and measures the power found in each window (RBW). The oscilloscope carries out a numerical algorithm (FFT) to calculate the spectrum of the corresponding signal acquired in the time domain. These 2 methods will have pro/con depending of the application.



