**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:

 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:



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. *Hint:* you do not need a calculator!

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

# Exercise-1 : Measurements in dBV and dBm

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

* Sinus shape with frequency 200kHz
* Peak-peak amplitude of 1Vpp

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 output impedance of the FuGe?

Obs.: depending on the oscilloscope which you have available, you might have or not two possible settings for the input impedance. Take the high impedance setting.

1. Which amplitude value in Vpp are you measuring in the oscilloscope?
2. What is the input impedance of the oscilloscope? Can you explain the mismatch between the FuGe setting and the reading in the oscilloscope?
3. Which signal amplitude do you expect to measure in the frequency domain in the oscilloscope? Express your result in dBV.
4. 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 the output to a spectrum analyzer and answer the following questions:

1. What is the input impedance of the spectrum analyzer? Which effect does it have on your measurement in the oscilloscope?
2. Which signal power do you expect to measure in the spectrum analyzer? Express your result in dBm.
3. Check your calculation with a measurement in the spectrum analyzer. Adjust the frequency settings to visualize from 50KHz to 500KHz. Use the marker, and the function set to peak (evtl set to next peak).
4. Change the Resolution Bandwidth (RBW under Menu BW) to manual and reduce the value to get finer peaks.

**Spectrum Analyzer: square and ramp signals**

1. Change the FuGe output to a periodic square, and observe the corresponding spectrum in the spectrum analyzer. Increase the frequency range up to 5MHz.
2. Which harmonics have a significant amplitude? Note the amplitude value of the first 5 visible harmonics in dBm.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Freq (kHz)** | **Harmonic Nr.** | **Power (dBm)** | **RMS-Amplitude Measurement (dBV)** | **Relative Amplitude with respect to 1st harmonic** |
|  |  |  |  | 1 = 0 dB |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

1. Compare the last column of your measurement (relative amplitude with respect to 1st harmonic) to the theoretical values. Use the Fourier series expression for a periodic rectangle.
2. Change the FuGe output signal to a ramp or sawtooth, and check which harmonics are present in the output spectrum. Compare to its Fourier series expression.

# Exercise-2 Fourier Series Table

1. Run and study the code of the Matlab demo files implementing the Fourier synthesis of different periodic functions:

*Fourier\_series\_3D\_graph\_step\_1.m*

*Fourier\_series\_3D\_graph\_step\_2.m*

What are the difference between these two scripts? Which effect does this difference have?

On the following pages, you find 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.

1. Compare the f(t) equations from the table to the expression of a Fourier series with real coefficients ak and bk. Determine the coefficients ak and bk for at least 4 functions, and verify your ak and bk expressions by modifying the corresponding lines in the Fourier synthesis Matlab script.
2. Now study the following Matlab script: *Fourier\_series\_3D\_graph\_step\_3.m*

Here the single harmonics are stored in separated lines of a matrix. These harmonics are then plotted in a 3D plot in script: *Fourier\_series\_3D\_graph\_step\_4.m*

Modify the step\_4 script to implement one of the functions you tried out in item (b).

1. Expand the script step\_4 to calculate the following coefficients:

* Ak and phik : Fourier series Real coefficients in polar notation
* ck : Fourier series complex coefficients

1. Then generate a plot of the single sided and double sided spectra.

Tip: Define an k vector which you can use for horizontal axis. For example for the single sided spectrum k = 0:1:M;

The complex coefficients ck can be approximated via a numerical calculation with the FFT function (fast fourier transformation). The FFT function is based on the DFT algorithm (discrete Fourier Transformation) which we will learn in the following weeks.



