Ex2

February 10, 2019

```
In [1]: #%matplotlib inline
        import numpy as np
        import matplotlib.pyplot as plt
```

1 Exercise 2: Quantisation of different signals, SNR

a) Generate a signal vector xSine that contains a discrete-time, zero-mean sine signal $x[k] = Asin(k)$ with normalised discrete-time angular frequency $= 2f/fs = 2/50$ and a variance $^2_x = 1/2$ (as a time average measure) for $0k < 50000$.

```
In [2]: k = np.arange(0, 50000)
        A = 1
        Om = 2*np.pi / 50
        var_sine = 1/2
        xSine = A * np.sin(Om * k)
```

b) Generate a signal vector $xNorm$ that contains a discrete-time, zero-mean, normally distributed noise signal (randn()) with a variance $^2_x = 0.0471$ for $0k < 50000$. By doing so the signal amplitudes are mostly within the range $1xNorm1$ and theo- retically only 1 sample out of 100,000 samples has a larger amplitude $|xNorm| > 1$ that would clip the quantiser modeled in exercise 1

```
In [3]: var_norm = 0.0471
        xNorm = var_norm * np.random.randn(50000)
```

c) Generate a signal vector xUniform that contains a discrete-time, zero-mean, uniformly distributed noise signal (rand()) with a variance $^2_x = 1/3$ for $0k < 50000$. By doing so the signal amplitudes are theoretically within the range $1xUniform1$

```
In [4]: var_uniform = 1/3
        xUniform = var_uniform * np.random.rand(50000)
```

d) Generate a signal vector $xLaplace$ that contains a discrete-time, zero-mean, noise signal following the Laplace distribution (laprnd()) with a variance $^2_x = 0.0236$ for $0k < 50000$.

```
In [1]: import laprnd
        var_lap = 0.0236

        xLaplace = laprnd.laprnd(50000, sigma=var_lap)
```

e) Generate fig. 2: apply the 4 generated signals to the quantisation with xq = my_quant(x,N) from exercise 1 for different numbers of bits and calculate the signal-to-noise ratio in dB as ... using the quantisation error signal $e[k] = xq[k]x[k]$. Note that your simulation results for the noise signals may differ depending on the state of the used random number generator (i.e. how many samples have amplitudes $|x[k]| > 1$). To validate your code use the sine signal as reference. Then compare your results with the theoretical SNRs:

zero-mean, uniformly distributed with $^2_x = 1/3$: SNRdB = 6.02 dB ů w

zero-mean, full scale sine signal with $^2_x = 1/2$: SNRdB = 6.02 dB ů w + 1.76 dB

zero-mean, normally distributed noise with $^2_x = 0.0471$: SNRdB = 6.02 dB ů w 8.5 dB

zero-mean, Laplace distributed noise with $^2_x = 0.0236$: SNRdB = 6.02 dB ů w 9 dB

In [6]:
```
def my_quant(x,N):
    #limit
    x = np.copy(x)
    idx = np.where(np.abs(x) >= 1)
    x[idx] = np.sign(x[idx])

    #quantization
    Q = 2/(N-1) #quantization Stepsize
    xQ = Q * np.floor(x/Q + 1/2)
    return xQ

def my_quant_even(x,N):
    #limit
    x = np.copy(x)
    idx = np.where(np.abs(x) >= 1)
    x[idx] = np.sign(x[idx])


    #quantization
    Q = 2/N #quantization Stepsize
    xQ = Q * np.floor(x/Q + 1/2)
    #increase last quantisation step
    iqdx = np.where(x > (1-Q))
    xQ[iqdx] = 1-Q

    return xQ
```

In [7]:
```
def calcSNR(x, xQ, varX):
    e = xQ - x
    varE = np.var(e)
    SNR = 10 * np.log10(varX/varE)
    #SNR = 10 * np.log10((np.var(x)/varE))
    return SNR
```

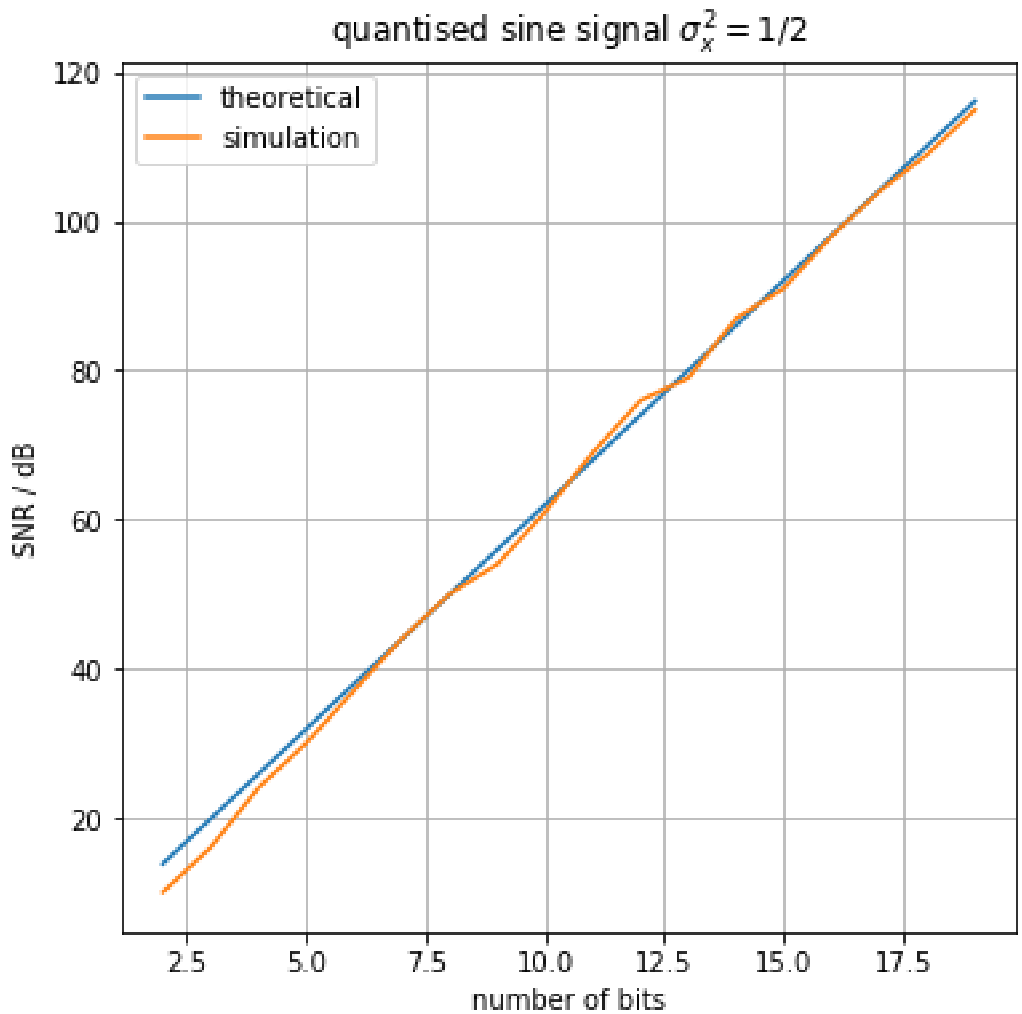
In [8]:
```
def quantize_SNR_For_N_Steps(x, N, varX):
    #select Quantization function
```

```
        if N%2 == 0:
            xQ = my_quant_even(x,N)
        else:
            xQ = my_quant(x,N)

        #return SNR
        return calcSNR(x, xQ, varX)
```

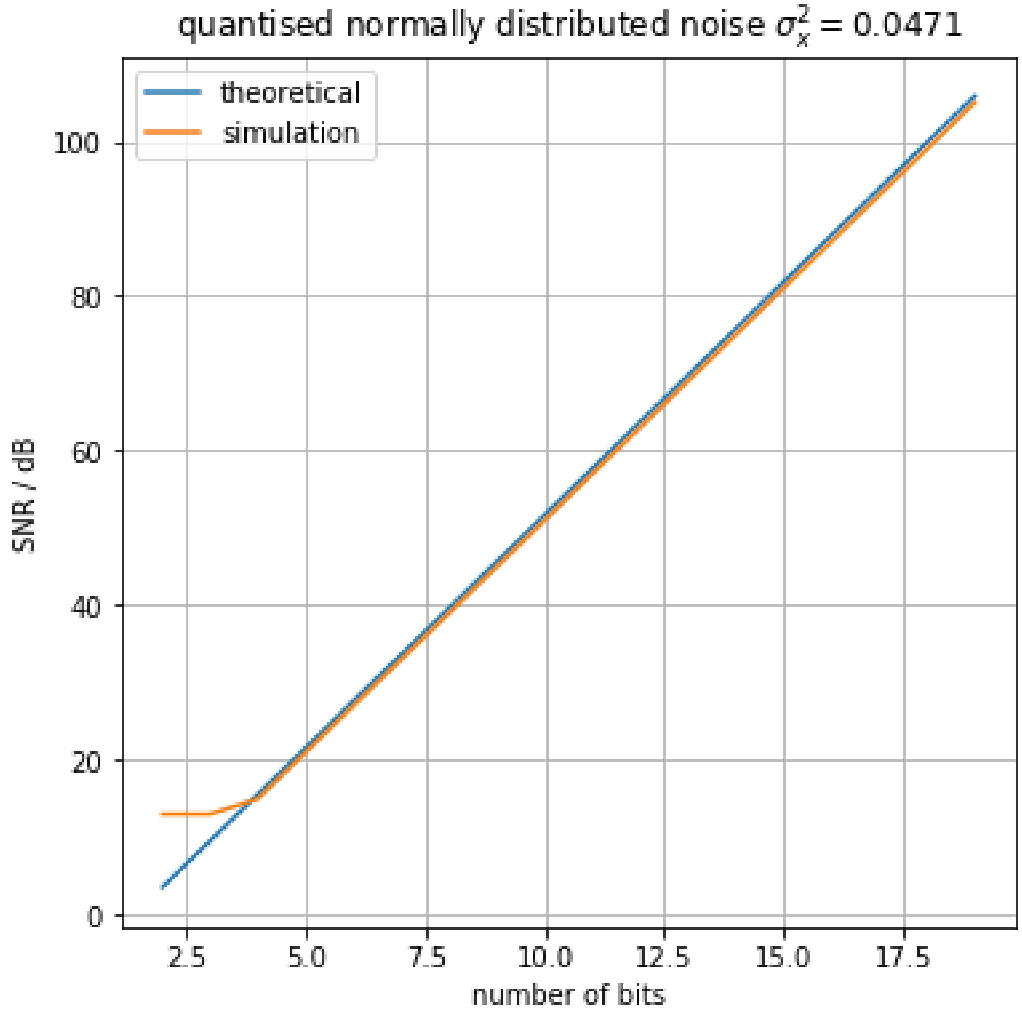
In [9]:
```
def plot_SNR(w, sim_plot, theo_plot, titel):
    plt.figure(figsize=(6,6))
    plt.plot(w, theo_plot, label=r'theoretical')
    plt.plot(w, sim_plot, label=r'simulation')
    plt.xlabel(r'number of bits')
    plt.ylabel(r'SNR / dB')
    plt.grid()
    plt.legend()
    plt.title(titel)
```

In [10]:
```
#max_Steps=1048576
max_Bits = 19
w = np.arange(2,max_Bits+1,1)

#theoretical signals
theory_sin_snr = 6.02 * w + 1.79
theory_uniform_snr = 6.02 * w
theory_norm_snr = 6.02 * w - 8.5
theory_lap_snr = 6.02 *w - 9
```

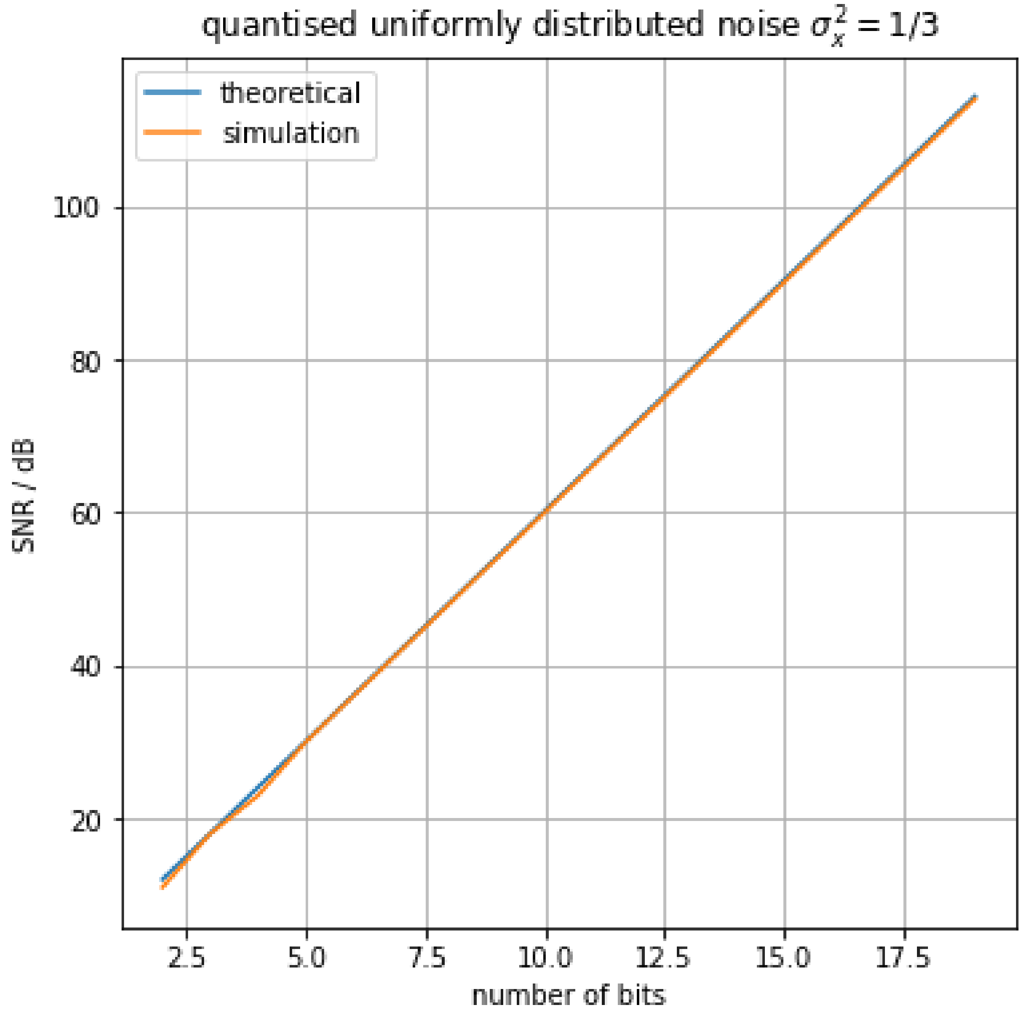
In [11]:
```
#Sine
sin_snr = np.arange(2,max_Bits+1)
for n in range(2,max_Bits+1):
    sin_snr[n-2] = quantize_SNR_For_N_Steps(xSine, np.power(2,n), var_sine)
plot_SNR(w, sin_snr, theory_sin_snr, r'quantised sine signal $\sigma^2_x = 1/2$')
```



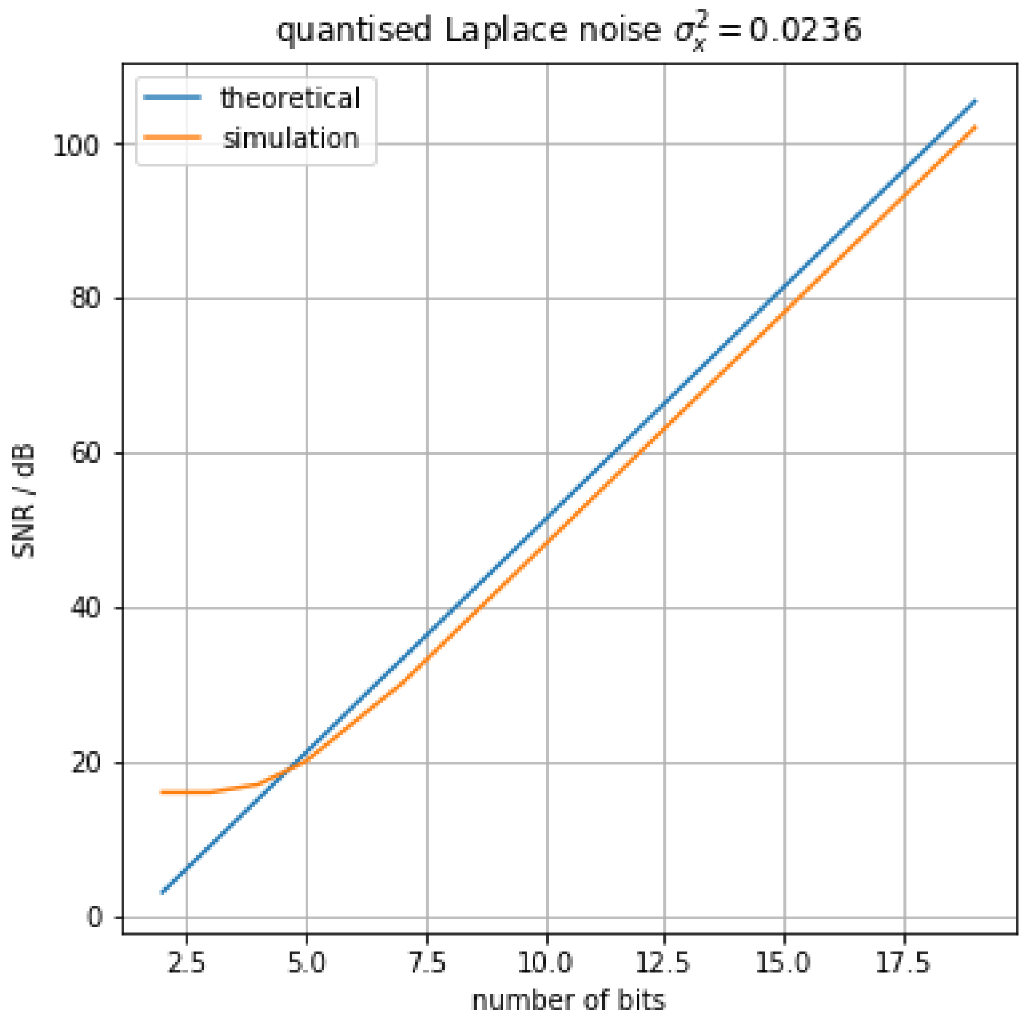

```
In [12]: #Normal Distributed
         norm_snr = np.arange(2,max_Bits+1)
         for n in range(2,max_Bits+1):
             norm_snr[n-2] = quantize_SNR_For_N_Steps(xNorm, np.power(2,n), var_norm)
         plot_SNR(w, norm_snr, theory_norm_snr, r'quantised normally distributed noise $\sigma
```



In [13]:
```
#Uniformly Distributed
uniform_snr = np.arange(2,max_Bits+1)
for n in range(2,max_Bits+1):
    uniform_snr[n-2] = quantize_SNR_For_N_Steps(xUniform, np.power(2,n), var_uniform)

plot_SNR(w, uniform_snr, theory_uniform_snr, r'quantised uniformly distributed noise $
```




```
In [14]: #Laplace
         lap_snr = np.arange(2,max_Bits+1)
         for n in range(2,max_Bits+1):
             lap_snr[n-2] = quantize_SNR_For_N_Steps(xLaplace, np.power(2,n), var_lap)

         plot_SNR(w, lap_snr, theory_lap_snr, r'quantised Laplace noise $\sigma^2_x = 0.0236$')
```



Abweichungen zur Lösung konnten nicht gefunden werden. Vermutung: übersetze Larplace Funktion funktioniert nicht richtig.

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In [ ]:
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In [ ]:
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