Chair of Distributed Systems and Security
School of Computation, Information and Technology
Technical University of Munich

# Computer Networking and IT Security (INHN0012)

Tutorial 2

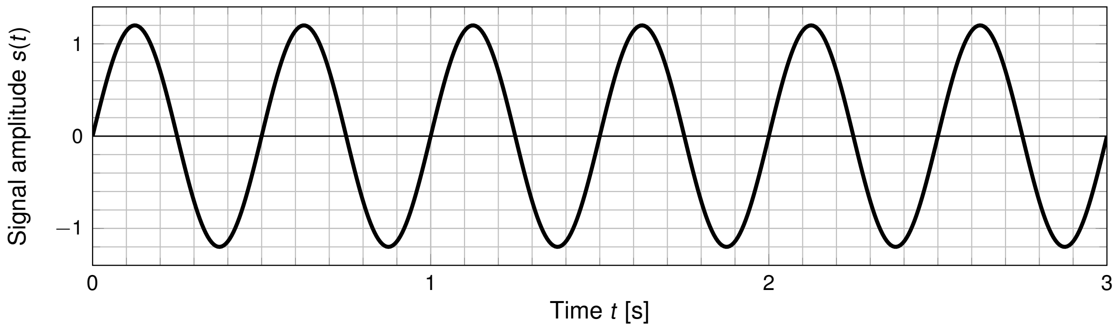
## Problem 1 Signal Analysis and Synthesis

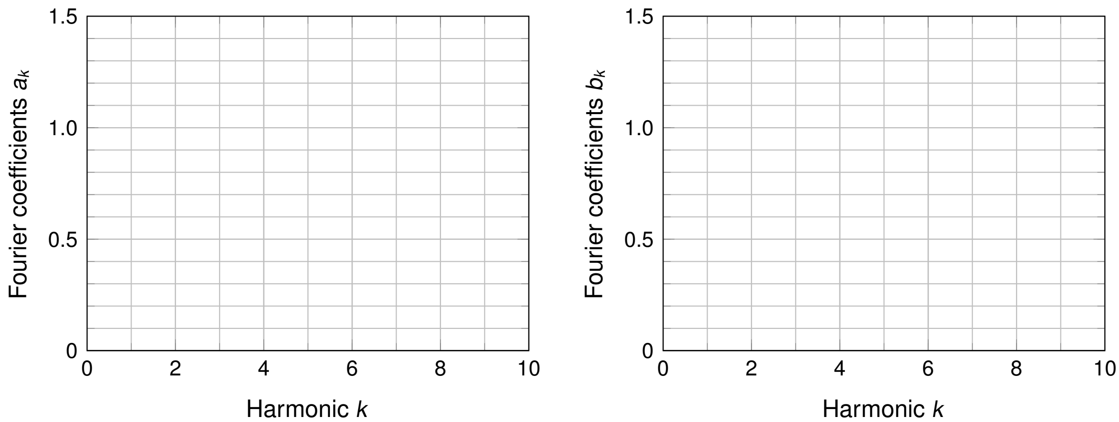
In general, signals can be represented either in the *time domain* or in the *frequency domain*. These two representations can be transformed into each other through Fourier analysis or synthesis. The given signals are periodic in the time domain; therefore, their frequency spectrum can be analyzed using the Fourier series.

a) For what reason is the spectrum of a signal or its representation in the frequency domain of interest?

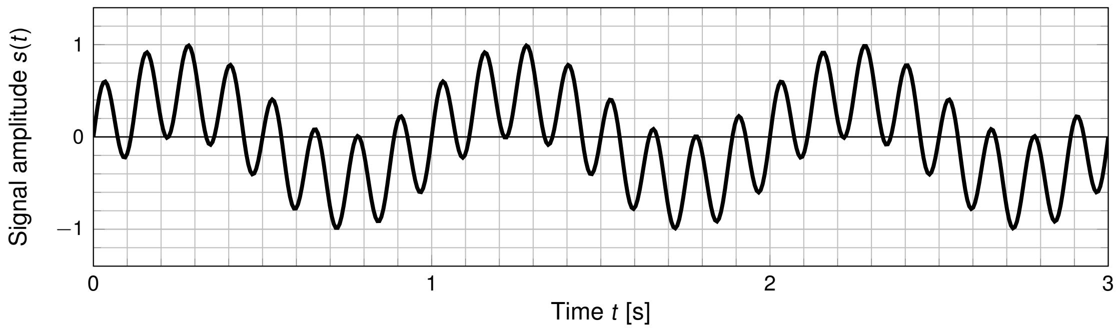
### Analysis

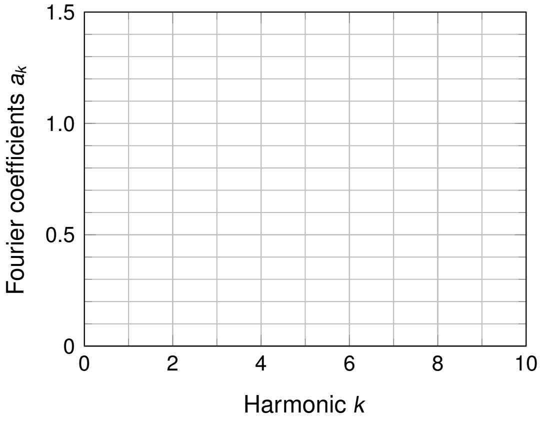
b) Given the periodic time signal $s(t)$ shown below, with $\omega = \frac{2\pi}{T}$ and $T = 1$ s. Draw the spectrum corresponding to $s(t)$ in the solution field.

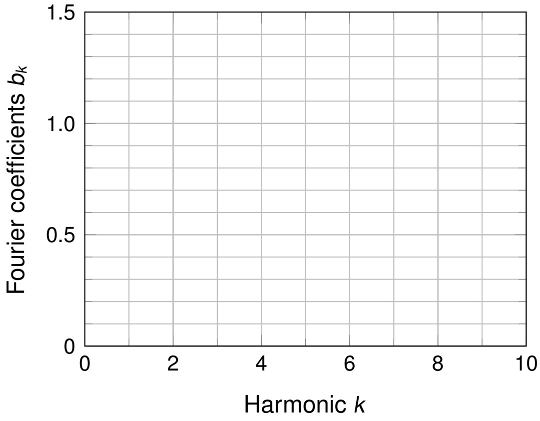


c) Given the periodic time signal $s(t)$ shown below, with $\omega = \frac{2\pi}{T}$ and $T = 1$ s. Draw the spectrum corresponding to $s(t)$ in the solution field.

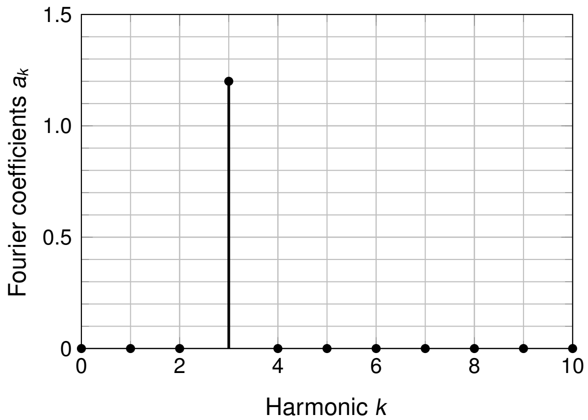


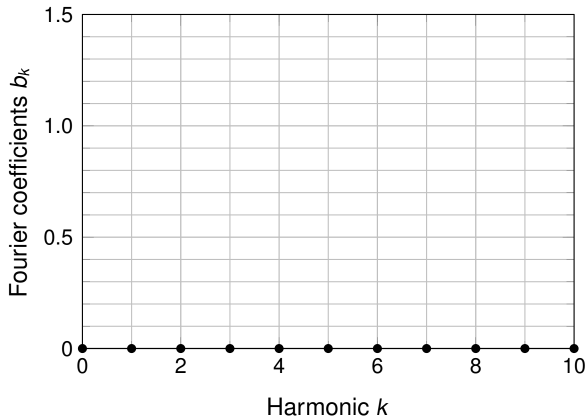



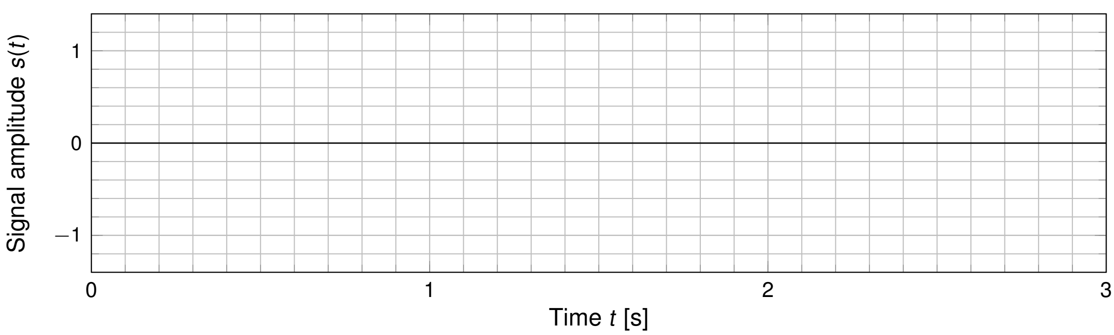




**Synthesis**

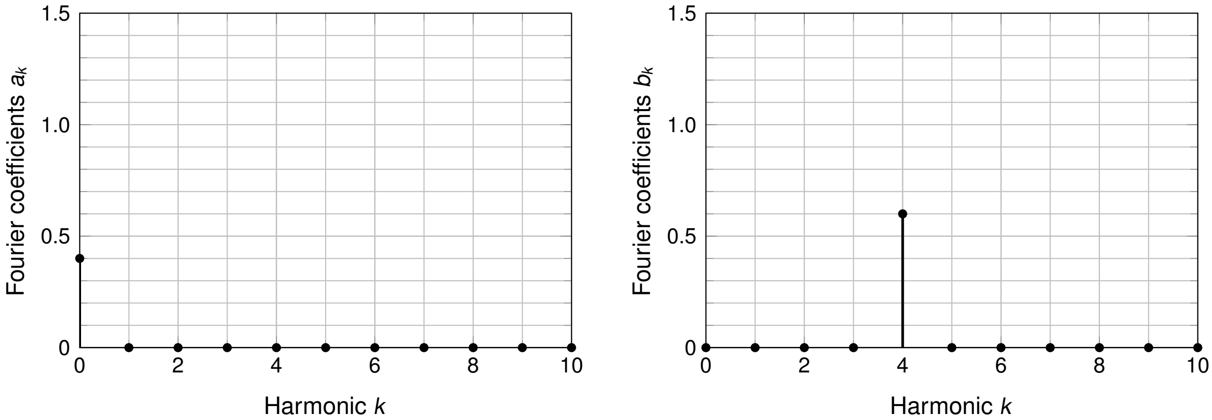
d) Given the spectrum of a Fourier Series shown below. Draw the corresponding time signal $s(t)$ in the interval $[0, 2]$ in the solution field. The constants are again $\omega = \frac{2\pi}{T}$ and $T = 1$ s.

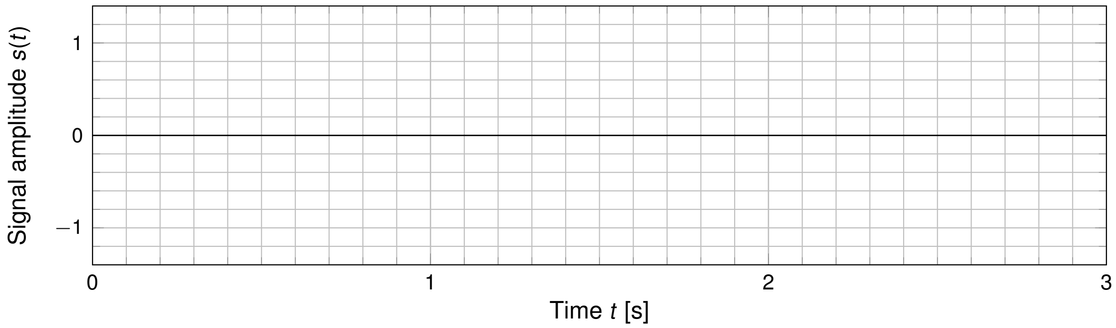


e) Given the spectrum of a Fourier Series shown below. Draw the corresponding time signal $s(t)$ in the interval $[0, 2]$ in the solution field. The constants are again $\omega = \frac{2\pi}{T}$ and $T = 1\,\mathrm{s}$.



## Problem 2 Quantization and channel noise

In this task, we want to quantize a temperature curve and investigate the influence of noise on signals. For this purpose, we consider temperatures in the range of $-40$ ℃ to 70 ℃. The measured values are to be mapped linearly, with a step size of at most 0.5 ℃.

a)* Explain the difference between sampling and quantization.

b)* What is the minimum number of bits required to digitize a single temperature value? Give reasons for your answer.

c) According to subproblem b), which step size can be used to determine the temperature based on the number of bits used?

d) Determine the maximum quantization error with respect to the calculated step size from subproblem c) assuming that mathematical rounding is used.

If you have not solved previous subproblems, assume 256 quantization levels.[1]
The baseband signal used uses exactly one symbol for each temperature level. A channel capacity of 10 kbit/s should be achieved.

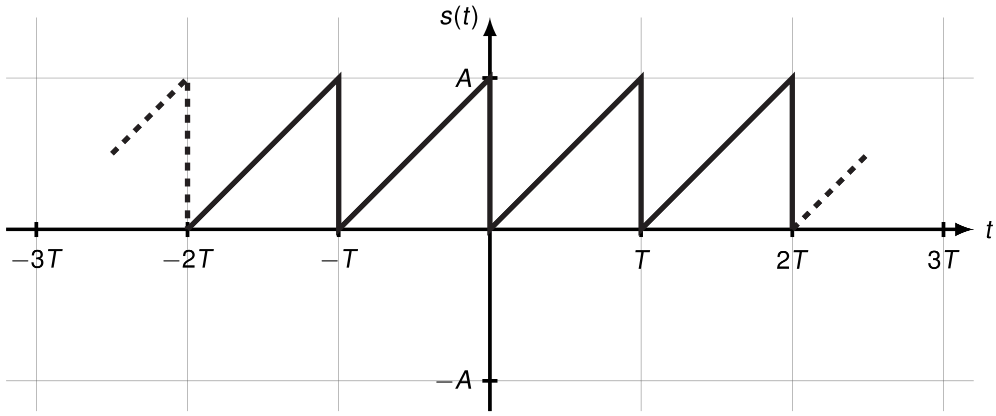
e) Determine the minimum bandwidth that is required for a noise-free channel to achieve the specified channel capacity.

f) To what value would the channel capacity decrease, assuming that the same bandwidth is used and a SNR of 35 dB is applied?

[1] In the written exam, tasks basically build on each other, i. e., intermediate results of previous subproblems are to be used. For longer tasks, we — when appropriate — sometimes give substitute values so that reentry is possible.

## Problem 3 Fourier Series

Given the following $T$-periodic time signal $s(t)$:




a)* Find an analytical expression for $s(t)$ in the interval $[0, T]$.

The signal $s(t)$ can be developed as a Fourier series, i. h.

$$s(t) = \frac{a_0}{2} + \sum_{k=1}^{\infty} \left(a_k \cos(k\omega t) + b_k \sin(k\omega t)\right). \tag{3.1}$$

The coefficients $a_k$ and $b_k$ can be determined as follows:

$$a_k = \frac{2}{T} \int_0^T s(t) \cdot \cos(k\omega t)\, dt \;\text{ und }\; b_k = \frac{2}{T} \int_0^T s(t) \cdot \sin(k\omega t)\, dt. \tag{3.2}$$

b)* Which coefficient in formula (3.1) is responsible for the constant component of $s(t)$?

c) Determine the constant component of the signal $s(t)$ through calculation.

d)* Could you have guessed the result from the previous subtask *by inspection*?

e)* Determine the coefficients $a_k$.
**Note:** You do not need a calculation here. Instead, compare the symmetry of $s(t)$ with a cosine oscillation. Can a weighted cosine contribute to the overall signal?

From now on, we assume $T = 1$ for simplicity.

f)* Determine the coefficients $b_k$.
**Hints:** $\int_0^1 t \sin(ct)\, dt = \dfrac{\sin(c) - c \cdot \cos(c)}{c^2}$ and $\omega = 2\pi/T$.

g) **Homework:** Using the results so far, sketch the DC component $a_0/2$, the first two harmonics and their sum for $A = \pi$ in a coordinate system.