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Data and Signal Analysis

5th Exercise Sheet
Winter Semester 2024/2025

Submission unit 17/01/2025 1 p.m. CET

1. Exercise: Christmas Exercise (20 Points)

The Frequency Shift Keying (FSK) method is a digital signal transmission technique that is used, for example, in fax[1] transmission. Bit sequences are divided into individual packets, called symbols. These symbols are represented by transmitting multiple frequencies simultaneously, where the combination of frequencies defines the transmitted symbol. Individual symbols are separated by pauses in the signal transmission.

In the example considered here, eight frequencies are to be used. This allows combinations of 4 bits (four zeros or ones) to be represented. The following table shows the used frequencies and their meanings:

	Bit 1	Bit 2	Bit 3	Bit 4
Value 0	697 Hz	770 Hz	852 Hz	941 Hz
Value 1	1209 Hz	1336 Hz	1477 Hz	1633 Hz

Two consecutive symbols can transmit 8 bits, which equals 1 byte. Here, the first symbol represents the first four bits of a byte (low-order bits), and the second four bits are the last four of the byte (high-order bits). This order is often referred to as the *little-endian byte order*. The following example is intended to illustrate the encoding:

In a spectrum, the four frequencies 1209, 770, 1477, and 1633 Hz are initially identified: This corresponds to the bit sequence 1011. After a short pause in which the spectral maxima disappear (no transmission), a different frequency combination is observed: 697, 1336, 1477, and 941 Hz (bit sequence 0110). Together, this results in: 10110110. If the bit sequence is interpreted in increasing order of significance, it results in the decimal number 1 + 4 + 8 + 32 + 64 = 109. In the ASCII character set, this number corresponds to the letter *m*.

In the file `message.txt` in the `Exercise Sheets` folder, you will find a time series containing a message encoded according to the procedure described above. The sampling rate is 8000 Hz. The transmission times of the symbols (frequency combinations) as well as the pauses between them are at least 50 ms.

a) Decode the message.

b) Describe your approach and the reasons for choosing this approach in DETAIL.

[1] Fax is an ancient technology for transmitting messages before the time of e-mail. It is considered a symbol of Germany's slow digitalization.

Note: The `scipy.signal` library contains a function for the Short-Time Fourier Transform. Read the documentation of this function thoroughly.