IEE1711 Applied signal processing

Exercise 1

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Timetable

Thursday

10:00-11:30	**10:00-11:30 - practice** **1-16** IVEM22 weeks: **even** teadur Julia Berdnikova U02-206	
14:00-15:30	**14:00-15:30 - exercise** **1-16** IVEM21, IVEM22 weeks: **odd** teadur Julia Berdnikova U02-206	**14:00-15:30 - practice** **1-16** IVEM21 weeks: **even** teadur Julia Berdnikova U02-206

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IEE1711 Final grade

The final grade will be formed as the sum of the three grades: **practices, individual work and written exam**.

Final Grade = Practices (25%) + Individual work (25%) + Exam (50%)

PREREQUISITES FOR FINAL EXAMINATION:

Five practices and individual work with presentation are assessed.

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Practice

- The practical assignments must be presented in order to be able to take the exam.

- Each student is given **five** individual assignments. Each assignment gives a maximum **5 points** and presenting all lab assignments will give a maximum of **25 points (25 %)** which will count towards the final course mark.

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Practice

Practical work is given maximum points if:

- - the assignment is done correctly, possible errors and shortcomings are corrected
- - the assignment is presented on time (presenting the assignment 2 weeks late will give a maximum of 3 points and presenting more than 2 week late will give a maximum of 0 points)

Penalties for late submission will count towards the final course mark

- The results of the lab assignments are presented in a report form.

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Individual work (project)

- Assessment preconditions: The project is submitted to the supervisor on time in the way and format the supervisor requests. Deviations need to be agreed with the supervisor before the deadlines.
- Individual work should be **presented.**

- Assessment: **The individual work will be assessed** by the supervisor if all the learning outcomes are fulfilled and will give a maximum of **25 points (25 %)**

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Presentation of the individual work

Assessment preconditions: The presentation is given on time in the way and format the supervisor requests. Deviations need to be agreed with the supervisor before the deadlines.

Exercises (Matlab software and board)

- The main aim is to prepare students for a practice and individual work
- To show the methods and applications that could be used in practice

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Exercise 1
Communication system

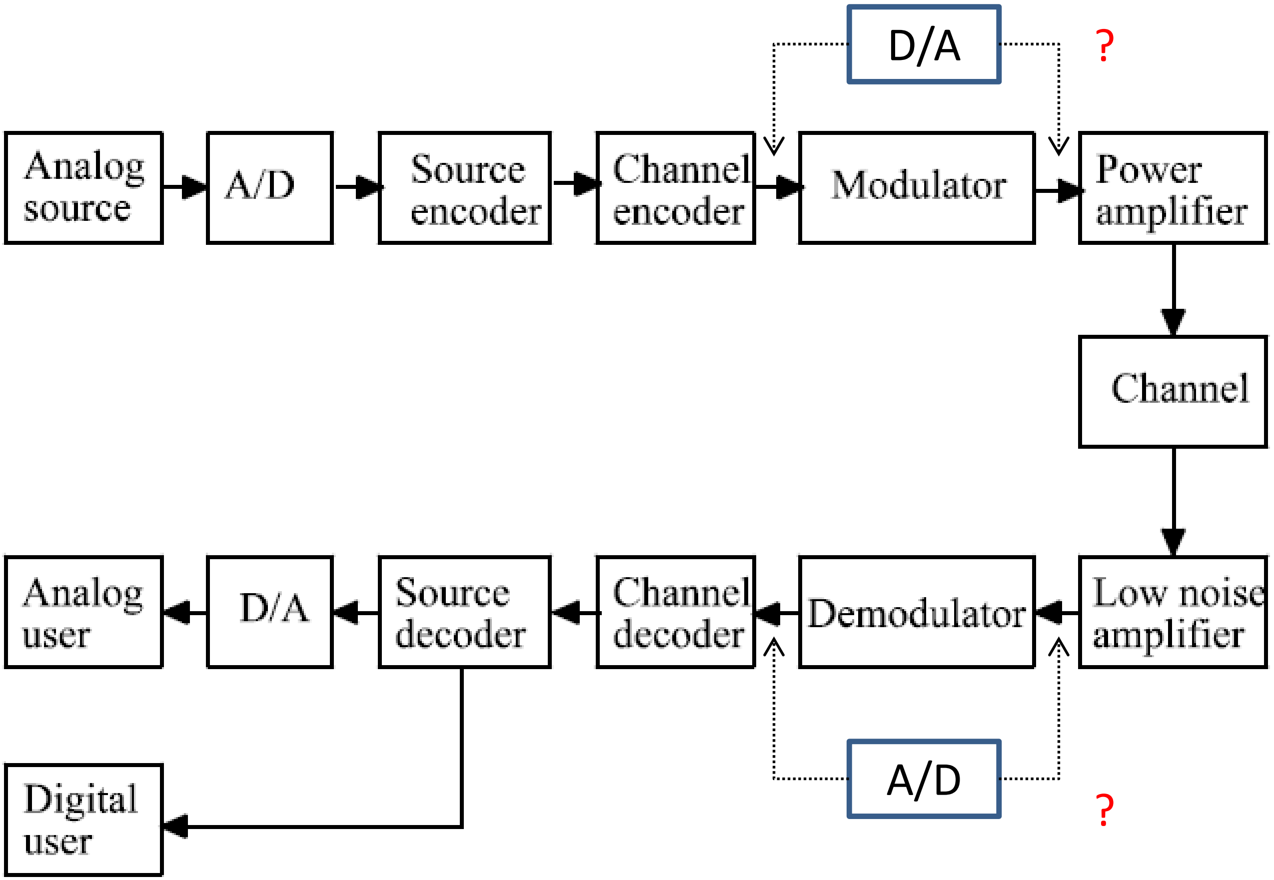

Figure 1.1 Block diagram of a typical digital communication system.

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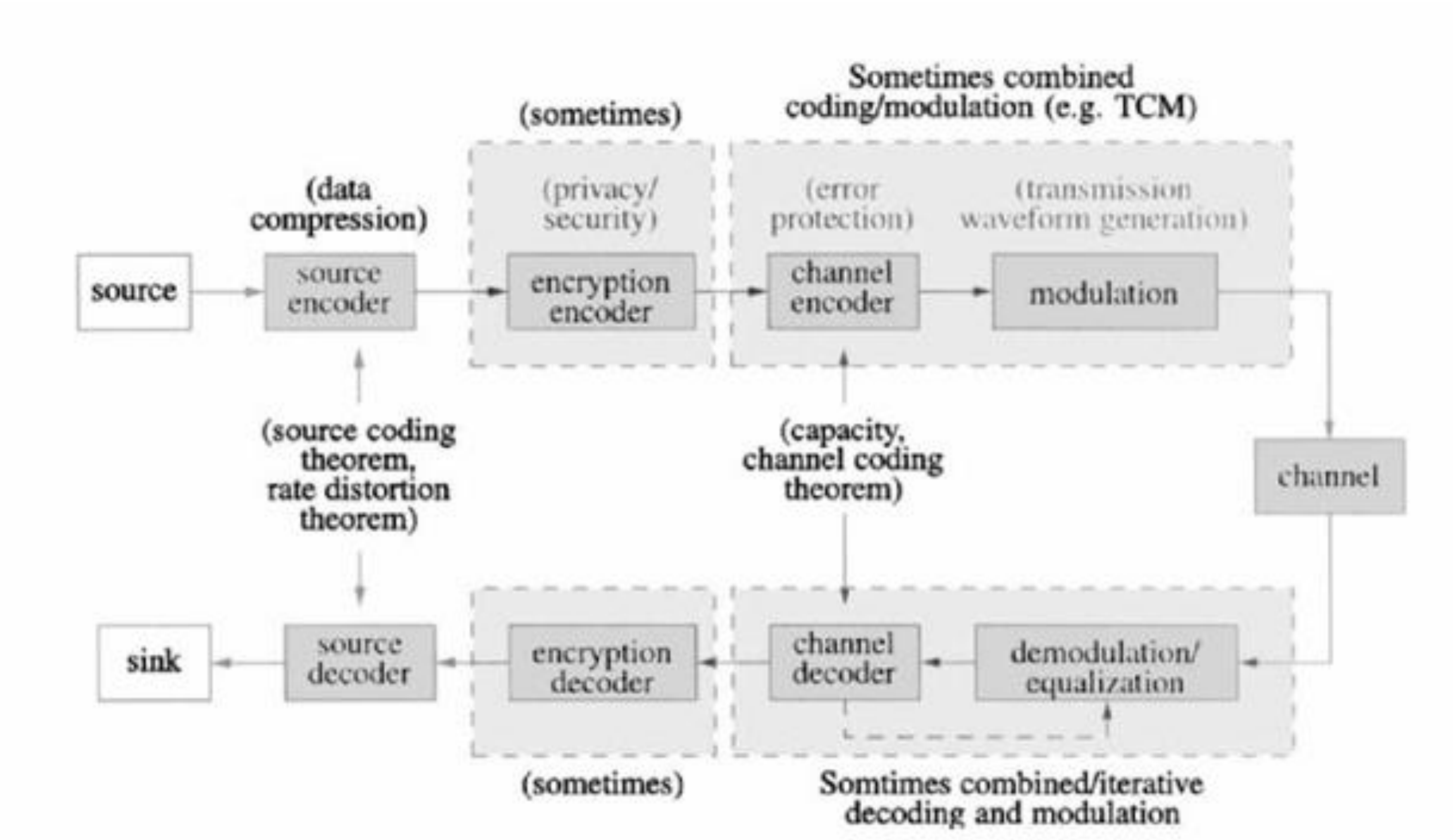
Fuqin Xiong . Digital modulation techniques . Boston (Mass.) ; London : Artech House, 2006

Communication system



Moon, Todd K., "Error Correction Coding : Mathematical Methods and Algorithms"

Communication theory

Shannon–Hartley theorem AWGN channel (*Aditive White Gaussian Noise*)

$$C = W \log_2\left(1 + \frac{S}{N}\right)$$

C is *channel capacity* (*bits per second,* bit/s), (*maximum rate)*

W - bandwidth (Hz)

S is the signal power over the bandwidth (W või V^2)

N is the average power of the noise and interference over the bandwidth (W või V^2)

S/N is the signal-to-noise ratio (SNR) or (*CNR – carrier-to-noise ratio*) (linear relation)

Communication theory

Bandwidth Efciency, Spectral efficiency

$$\eta = \frac{\text{Transmission Rate}}{\text{Channel Bandwidth}\, W} \;\; [\text{bits}/s/Hz].$$

Shannoni limit

Fundamental limit: For infinite amounts of bandwidth, *i.e.*, $\eta_{\max} \to 0$, we obtain

$$\frac{E_b}{N_0} \geq \lim_{\eta_{\max} \to 0} \frac{2^{\eta_{\max}} - 1}{\eta_{\max}} = \ln(2) = -1.59\text{dB}$$

This is the absolute minimum signal energy to noise power spectral density ratio required to reliably transmit one bit of information.

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http://en.wikipedia.org/wiki/Spectral_efficiency

Source encoding

Data compression:

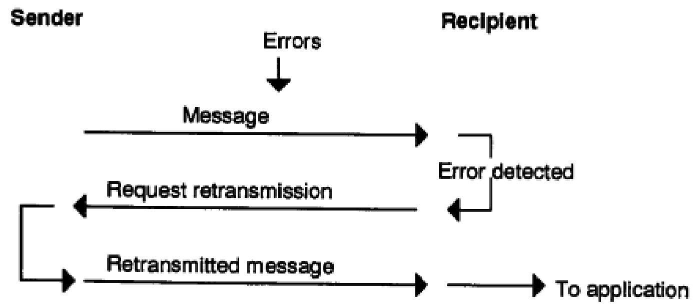
- Files (ex. .zip, jpg)
- Audio codecs
- Video codecs
- etc

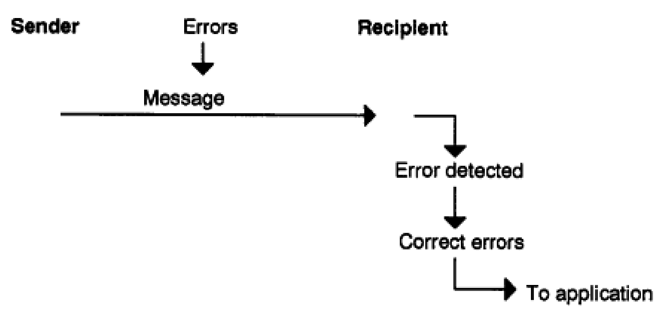
Channel coding

- *Error detection coding*
  - Repetition codes
  - Parity bits
  - Checksums
  - Cyclic redundancy checks (CRCs)
  - Cryptographic hash functions
  - Error-correcting codes
- *Error corrected codes*
  - *Convolutional codes or block codes*
  - *ARQ*
  - *Hybrid schemes (FEC+ARQ)*

EEC (error-correcting code)
FEC (forward error correction)

Automatic repeat request (ARQ)





Channel models

Analog channel models

- *Noise model, for example Additive white Gaussian noise (AWGN) channel*
- *Phase noise model*
- *Interference model, for example cross-talk (co-channel interference) and intersymbol interference (ISI) Distortion model, for example a non-linear channel model causing intermodulation distortion (IMD) Frequency response model, including attenuation and phase-shift Group delay model Modelling of underlying physical layer transmission techniques, for example a complex-valued equivalent baseband model of modulation and frequency response Radio frequency propagation model, for example Log-distance path loss model*
- *Fading model, for example Rayleigh fading, Ricean fading, log-normal shadow fading and frequency selective (dispersive) fading*
- *Doppler shift model, which combined with fading results in a time-variant system*
- *Ray tracing models, which attempt to model the signal propagation and distortions for specified transmitter-receiver geometries, terrain types, and antennas*
- *Mobility models, which also causes a time-variant system*

Digital channel models (memory or memoryless) (symmetric or non-symmetric)

- *Binary symmetric channel (BSC)*
- *Binary bursty bit error channel model, a channel "with memory“*
- *Binary erasure channel (BEC)*
- *Packet erasure channel*
- *Arbitrarily varying channel (AVC)*

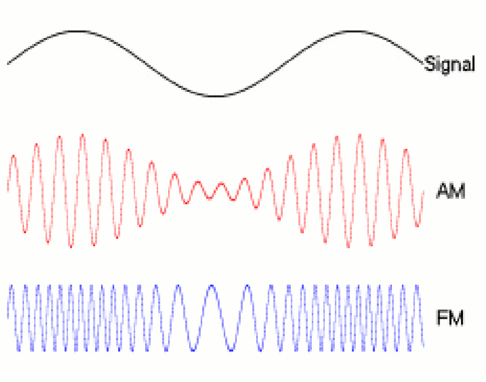
https://en.wikipedia.org/wiki/Communication_channel

Modulations

- Amplitude modulation (AM)

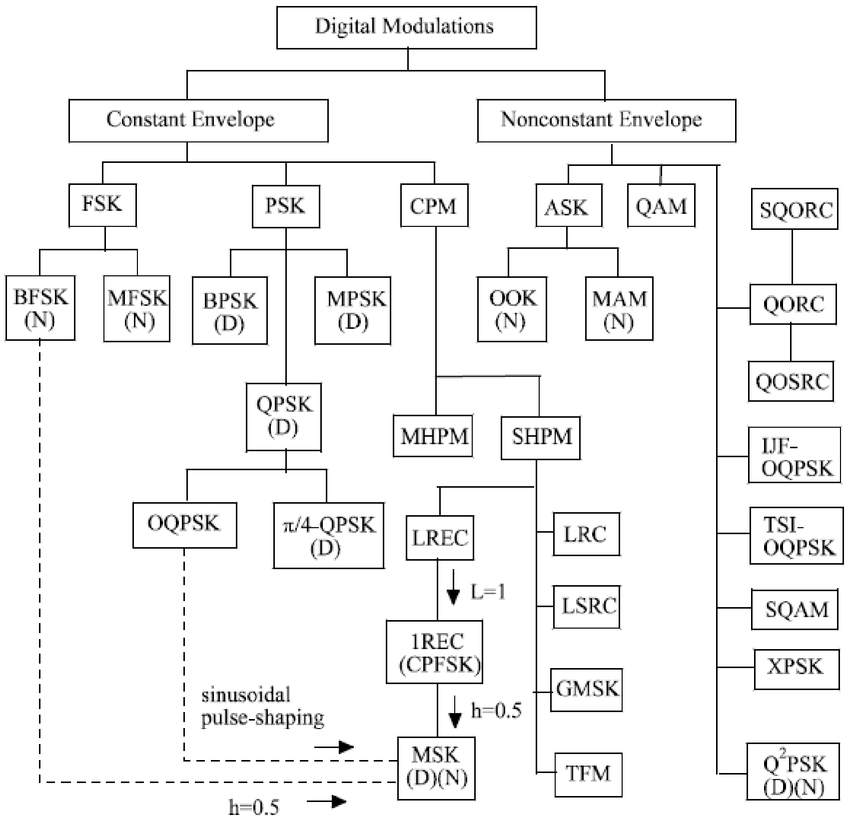
Angle modulation:

- Frequency modulation (FM)
- Phase modulation (PM)



https://en.wikipedia.org/wiki/Modulation

Digital modulations



N –noncoherently

D – differentially

Digital modulations

Abbreviation	Alternate Abbr.	Descriptive Name
Amplitude and Amplitude/Phase Modulations		
ASK		Amplitude Shift Keying (generic name)
OOK	ASK	Binary On-Off Keying
MASK	MAM	M-ary ASK, M-ary Amplitude Modulation
QAM		Quadrature Amplitude Modulation
Frequency Shift Keying (FSK)		
BFSK	FSK	Binary Frequency Shift Keying
MFSK		M-ary Frequency Shift Keying
Phase Shift Keying (PSK)		
BPSK	PSK	Binary Phase Shift Keying
QPSK	4PSK	Quadrature Phase Shift Keying
OQPSK	SQPSK	Offset QPSK, Staggered QPSK
$\pi/4$-QPSK		$\pi/4$ Quadrature Phase Shift Keying
MPSK		M-ary Phase Shift Keying

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Digital modulations

Abbreviation	Alternate Abbr.	Descriptive Name
Continuous Phase Modulations (CPM)		
SHPM		Single-h (modulation index) Phase Modulation
MHPM		Multi-h Phase Modulation
LREC		Rectangular Pulse of Length L
CPFSK		Continuous Phase Frequency Shift Keying
MSK	FFSK	Minimum Shift Keying, Fast FSK
SMSK		Serial Minimum Shift Keying
LRC		Raised Cosine Pulse of Length L
LSRC		Spectrally Raised Cosine Pulse of Length L
GMSK		Gaussian Minimum Shift Keying
TFM		Tamed Frequency Modulation
Nonconstant Envelope Modulations		
QORC		Quadrature Overlapped Raised Cosine Modulation
SQORC		Staggered QORC
QOSRC		Quadrature Overlapped Squared Raised Cosine Modulation
Q^2PSK		Quadrature Quadrature Phase Shift Keying
IJF-OQPSK		Intersymbol-Interference/Jitter-Free OQPSK
TSI-OQPSK		Two-Symbol-Interval OQPSK
SQAM		Superposed-QAM
XPSK		Crosscorrelated QPSK

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Digital modulations

- ***ASK*** *(Amplitude-Shift Keying)*

$$s_i(t) = A_i\, p(t)\cos(2\pi f_c t), \quad 0 \le t \le T \qquad i = 1,2,\ldots M$$

- ***FSK*** *(Frequency-Shift Keying)*

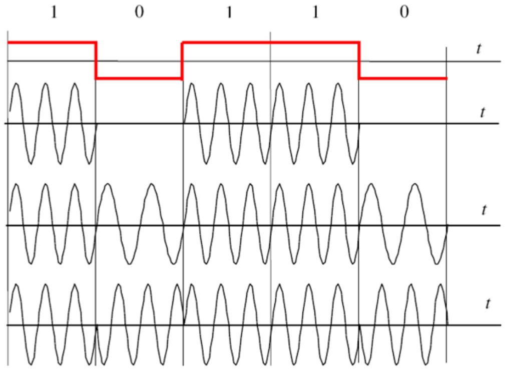
$$s_i = A\cos(2\pi f_i t + \Phi_i) \qquad i = 1,2,3,\ldots M$$

- ***PSK*** (*Phase-Shift Keying)*

$$s_i(t) = A\cos(2\pi f_c t + \theta_i), \quad 0 \le t \le T$$

$$i = 1,2,\ldots,M \qquad \theta_i = \frac{(2i-1)\pi}{M}$$

ASK
FSK
PSK



SNR and BER

Signal to noise ratio:

- **SNR** (linear or dB) - Ratio of signal power to noise power
- **Eb/No** - Ratio of information bit energy per symbol to noise power spectral density
- **Es/No** - Ratio of information symbol energy per symbol to noise power spectral density

Bit error rate: BER – the number of bit errors divided by the total number of transferred bits

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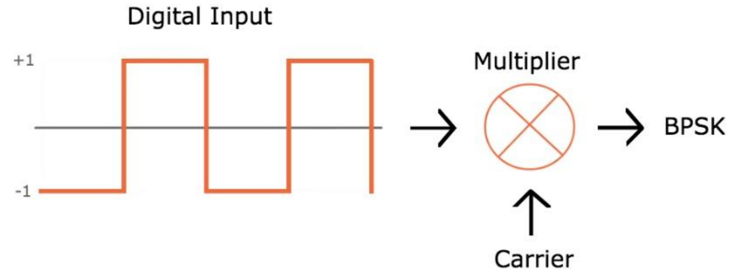
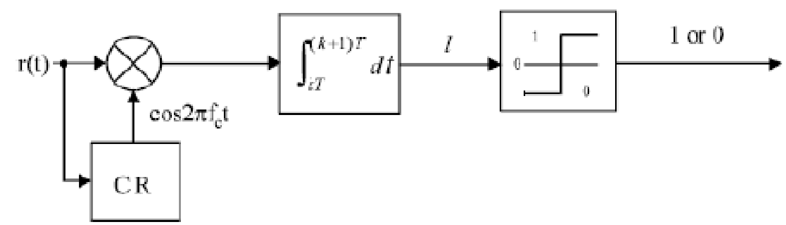
Modulator / Demodulator

Example: BPSK modulation

Modulator:



Demodulator (coherent):



carrier recovery (CR)

Bit error probability (coherent):

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \text{ or } P_e = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$$

https://www.allaboutcircuits.com/uploads/articles/BPSK_hardware_v1_clean.jpg

Criteria of Choosing Modulation Scemes for Communication Systems

- power efficiency (bit error rate or bit error probability)
- bandwidth efficiency,
- system complexity.

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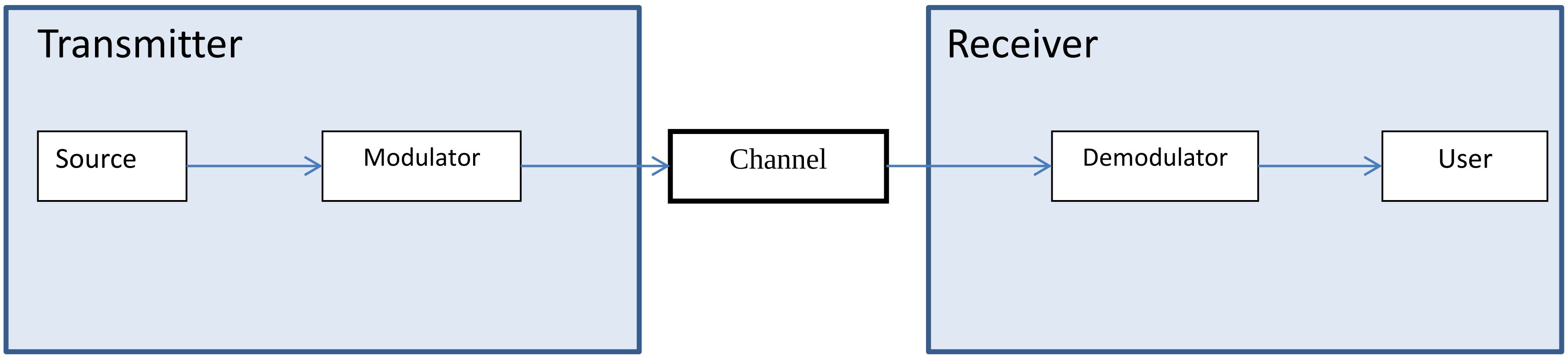
Communication model in Matlab
Task 1.

- Run **bertool** application in Matlab

- Calculate BER curves for BPSK, QPSK, QAM and FSK modulations (AWGN channel)

Task 2.
Simplified communications model



- Generate known binary sequence (length <20)
- Modulate sequence with BPSK modulator and send it to the AWGN channel
- Receive the sequence with demodulator
- Calculate BER
- Change the transmitter sequence to a random binary sequence (length >1000) and calculate BER