No materials, no calculator. Prepared by and return to: Mikko Valkama

NB 1: If you wish to take the Full Exam, answer to all the questions 1-6. If you wish to take only the Second Midterm Exam, answer only to the questions 4-6.

NB 2: Please pay special attention to clear handwriting. If I cannot read your text with reasonable effort, your paper cannot be unfortunately graded. So, please, try to write in a clear manner. Thank you.

NB 3: For Second Midterm, only one full response sheet is allowed. For Full Exam, two full response sheets are allowed.

1. Explain shortly the following concepts in the context of electrical or electromagnetic communications: a) spectrum, b) intermodulation distortion, c) correlation function, d) spectral density, e) thermal noise. No need to dwell on finest details, rough explanations which show your understanding are enough.

2. Explain the general concept of I/Q modulation. Illustrate the principle by drawing a block-diagram of an I/Q modulator, and some example spectral contents of the relevant signals in different stages. How does I/Q modulation utilize the structure of a general bandpass signal, sketched below. Explain also how the receiver can recover the I and Q components. Finally, explain the concept of lowpass or baseband equivalent and how is it related to I/Q modulation.

$$x_{BP}(t) = A(t)\cos(\omega_C t + \varphi(t)) = x_I(t)\cos(\omega_C t) - x_Q(t)\sin(\omega_C t)$$

3. Explain shortly the fundamental core elements or processing stages that every digital communication system contains and what are their basic roles/purposes. Explain also shortly what are the most fundamental parameters or features that define the external operation of a digital communication system.

4. Suppose you are to design an I/Q modulated single-carrier M-QAM digital communication system where the target physical-layer bit rate is 1 Gbit/s, and that you have 200 MHz bandwidth available around a center-frequency of 30 GHz. Design the system in terms of the needed QAM symbol alphabet size, symbol rate and feasible nonzero excess bandwidth (rolloff) factor for a raised-cosine pulse. Draw also an elementary block-diagram of the transmitter, starting from the transmit bit sequence towards the high-frequency I/Q modulated waveform.

5. Explain briefly the basic ideas of multicarrier modulation / OFDM and multi-antenna / MIMO communications. Discuss also shortly the benefits of OFDM compared to single-carrier PAM/QAM/PSK, and the corresponding benefits of multi-antenna/MIMO compared to single-antenna systems.

6. Explain shortly what is meant by (*i*) information, (*ii*) entropy and (*iii*) mutual information, in the context of electrical or electromagnetic communications. Explain also what is meant in this context by channel capacity. Assuming a bandlimited additive white Gaussian noise (AWGN) channel, what factors are determining the channel capacity ? Give also a feasible numerical example.

Maximum points, Full Exam: 6 x 5 = 30p

Maximum points, Second Midterm Exam: 3 x 5 = 15p