## ETTN01 Advanced Digital Communications, (max: 30p)

Examination, April 19, 2023

Passing grade (3): 15; grade 4: 20p; grade 5: 25p. Thresholds may be adapted.

Tools: Everything (books, old exams, notes, etc etc)

# Problem 1

Answer the following questions with either 'true or 'false. For each correct answer, you get one point. For each incorrect answer, one point is deducted.

Note: If some part of the statement is underlined, then it is this part of the statement that your answer should relate to. The not underlined part is either assumptions or valid statements.

If you do not wish to answer a particular subproblem, you don't have to.

No explanations please, only true/false.

True a. The bandwidth efficiency of 16QAM is larger than that of 4QAM.

False b. The largest possible minimum distance, $d_{min}^2$ , for any constellation is 2, which is, e.g., achieved for antipodal signaling.

True c. Given a received signal r(t) of the form $r(t)=s_j(t)+n(t)$, where n(t) is white Gaussian noise, we can project r(t) onto the basis functions of the signal space, <u>and then we have no further use of r(t)</u> (if the goal is to detect the transmitted message).

True d. The number of signal space dimensions of M-FSK is M

False e. The number of signal space dimensions of M-QAM is $\log_2(M)$

False f. The number of signal space dimensions of PPM (pulse position modulation) is $2^M$

True g. The number of signal space dimensions of M-PAM is 1

False h. $d_{min}^2 = 2$ for 2-PPM (PPM with two messages)

False i. Let $s(t) = 3\phi_1(t)+ 4\phi_2(t)$, where $\phi_k(t)$ are orthonormal basis functions. The energy of s(t) is then $\sqrt{3^2+4^2} = \sqrt{25} = 5$

False j. The bandwidth efficiency of OFDM is linearly proportional to the number of subcarriers.

True k. The coherence time must exceed the symbol time in OFDM if the system should function as intended.

False l. The inverse of the coherence bandwidth must exceed the symbol time in OFDM if the system should function as intended.

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True m. The IFFT/FFT used in OFDM are algorithmic implementations of IDFT/DFT that are very fast.

False n. The BER of a system with diversity is typically behaving as BER/L, where L is the diversity order.

False o. For a Rayleigh fading channel, BER is given by $Q(\sqrt{A^2 d_{min}^2 E_b/N_0})$ where A is the average channel gain

True p. Slow fading and frequency non selectivity is not always possible to achieve.

False q. Capacity is proportional to $d_{min}^2$

True r. The capacity with infinite power is unlimited while the capacity with infinite bandwidth is limited.

False s. If W->0 but P is constant (which implies that P/W->∞) then capacity is converging to a non-zero value.

True t. Waterfilling allocates more power to strong channels than to weak channels.

False u. At very high SNR, Waterfilling concentrates the allocated power to the strongest channels.

True v. In an OFDM context, Waterfilling assumes that the transmitter can adapt the constellation and coding rate across the subcarriers, i.e., different frequencies may have different constellations.

False w. Consider an OFDM system with M-QAM at all subcarriers. Assume that the transmit power per carrier is adjusted in such a way so that the BERs at all carriers are equal. This power allocation is produced by the Waterfilling algorithm as M->∞.

True x. Consider two signals x(t) and y(t). If $\int x^2(t)dt = 10, \int y^2(t)dt = 5\,, and \int \left(x(t) + y(t)\right)^2 dt = 15$, then it follows that x(t) and y(t) are orthogonal.

True y. The main application area of OFDM is situations where the channel impulse response is of significant length.

False z. Transmitting a repetition of the data over the same channel is known as diversity.

False aa. Assume that I (Fredrik) **always** takes my umbrella when it rains, but **never** when it does not rain. Consider the following formula and decide if it is true or false. Prob(rain outside **and** Fredrik carries umbrella) = Prob(rain outside)*Prob(Fredrik carries umbrella)

True bb. Let x be Gaussian, zero mean and variance 1. Is the following true: Pr(x<5) = 1 – Q(5)

False cc. Let x and y be independent Gaussians, zero mean and variance 1. Is the following true: Pr(3<x<5 **or** 2<y<6) = Pr(3<x<5) + Pr(2<y<6)

True dd. Without knowledge of the bitmapping, the BER cannot be calculated from the symbol error rate.

True ee. Assume a signal of the form $r(t)=s_j(t)+n_{in}(t) + n_{out}(t)$, where $n_{in}(t)$ is noise that can be represented in the signal space and $n_{out}(t)$ is noise that cannot. Further, let $n_{out}(t)$ have a power which is $10^9$ times the power of $n_{in}(t)$. Consider now the two signals

$r_1(t)=s_j(t) + n_{in}(t) + n_{out}(t)/10^9$ and $r_2(t) = s_j(t) + n_{in}(t)(1-1/10^9) + n_{out}(t)$

Then, the BER stemming from $r_2(t)$ is lower than that of $r_1(t)$

False

True