CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC5608 – Wireless Communications Systems Engineering – Winter 2020

TERM EXAM **13 February 2020 – Prof. Halim Yanikomeroglu**

Closed-book exam. One-page single-sided aid-sheet is permitted. No smart phones, no internet access. Write answers in the space provided on the question sheet. If necessary, use both sides of a page. Write legibly, and state any assumptions that you make. Time = 80 mins.

Name: **Student No:**

Question 1 [100 pts] – Short Questions

a) What is the main difference of 5G in comparison to the previous generations?

b) What does FTN stand for? How does FTN signaling improve the rate? What is the main challenge (i.e., price paid) in FTN signaling?

c) According to the AWGN model, calculate the total white noise power at the receiver front end, P_W. Are you concerned about the calculated P_W value in relation to SNR at the receiver?

d) 4G LTE already supports delay-sensitive applications, such as real-time video-conferencing (ex: FaceTime). Then, why is there so much emphasis in 5G on reducing the latency (delay)?

e) Why is the "absolute bandwidth" definition not suitable in some signaling schemes?

f) SNR of a signal is measured as 13.1 dB when the temperature is 21°C. If the temperature were 30°C, what would the SNR be?

g) The PSD of a signaling scheme must be non-negative; that is, $S_X(f) \geq 0$, for all f. Why?

h) The multi-layer (also known as the multi-stream) MIMO gain is equal to $n = \min(n_{\mathrm{TX}}, n_{\mathrm{RX}})$, where n denotes the number of antennas. Often, $n_{\mathrm{BS}} >> n_{\mathrm{UE}}$. Therefore, the rate of the link between a BS and a UE will be limited by n_{UE}. Then, what is the point of having many more antennas at the BS?

i) What does zero-forcing equalization mean? (Describe in a qualitative manner.)

j) What is the maximum bit rate achievable when a turbo-coded 256-QAM with a code rate of 3/4 is used in conjunction with root-raised-cosine pulses with a roll-off factor of 0.2, in a bandwidth of 40 MHz, in the presence of a 8x4 MIMO array?

Q2 [50 pts] – Inter-Symbol Interference (ISI)

The IEEE 802.3 standard (Ethernet) uses an antipodal encoding scheme known as the Manchester code: $g_{TX}(t) = A, \quad -T/2 < t \leq 0;$
$= -A, \quad 0 < t \leq T/2.$
In the above, T denotes the bit duration.

Let $x(t)$ represent the transmitted signal for a random bit-stream: $x(t) = \sum x_k\, g_{TX}(t-kT)$, where x_k is an uncorrelated and equally-likely sequence with values +1 and -1.

It is given that the channel exhibits the characteristics of an all-pass filter: $g_{CH}(t) = \delta(t)$. The receiver filter is matched to the transmitter filter; i.e., $g_{RX}(t) = g_{TX}(-t)$. Let $h(t) = g_{TX}(t) * g_{CH}(t) * g_{RX}(t)$.

a) Through inspection (i.e., by examining $g_{TX}(t)$), estimate the null-bandwidth of the signaling scheme $x(t)$.

b) Sketch $h(t)$. Does this system result in ISI? Substantiate your answer through a time domain analysis.

c) Obtain and sketch $H(f)$. <u>(Needs a fair amount of effort. Solve only if you have time.)</u>

Q3 [50 pts] – Link Adaptation

Consider a wireless transmission system which employs link adaptation. Assume that the channel is ideal with $h(t) = \alpha\, \delta(t)$, where the channel gain α changes at every TTI (transmission time interval). Let n be the discrete index for TTIs.

Consider a situation when the channel starts transitioning from a good-state to a bad-state at TTI $n = i$ as follows: $\alpha_n = 0.5\alpha_{n-1}$, $n = i+1, i+2, \ldots, i+5$.

Assume that the system uses a perfect AMC (adaptive modulation and coding) scheme with the following spectral efficiency at TTI n: $\mathrm{SE}_n = \log_2(1+\mathrm{SNR}_n)$ b/s/Hz.

If SNR_i = 29.7 dB, sketch SE with respect to n, for $n = i, i+1, \ldots, i+5$.