SYSC 5608 TERM EXAM 1 13 Feb 2020

Q1) Short Questions

a) The use cases in the first four generations have been around the (smart) phone. For the first time, 5G targets ~~[illegible]~~ use cases beyond the smart phone — in the vertical industries.

b) FTN: Faster-than-Nyquist. In FTN signaling, the symbol rate is higher than ~~[illegible]~~ that which results in no-ISI. FTN signaling results in ISI.

c) $P_W = \int_{-\infty}^{\infty} S_w(f)\,df = \int_{-\infty}^{\infty} \frac{N_0}{2}\,df = \frac{N_0}{2}\int_{-\infty}^{\infty} df = \infty$

However, the noise power experienced by the receiver is P_N, which is the noise power in the signaling bandwidth. $P_N = \int_{-\infty}^{\infty} \tilde{S}_N(f)\,df = \int S_w(f)|H_{RX}(f)|^2\,df$

$= \frac{N_0}{2}\int_{-\infty}^{\infty}|H_{RX}(f)|^2\,df = \frac{N_0}{2}E_b < \infty.$

d) In the 4G context, delay-sensitive means real-time applications such as voice or video. For those, 200 msec latency is sufficient. Some applications in 5G require much lower latency. Ex: XR: 20 msec; connected vehicles: 1 msec. These are the applications in the URLLC class (ultra-reliable low latency comm).

e) Is the PSD has a tail extending to infinity, the "absolute BW" will be ∞. This is misleading as the amount of power beyond some frequency may be negligable for all practical purposes, although the absolute BW definition will suggest ∞ bandwidth.

p2

f) $T_1 = 21°C = 294°K \rightarrow T_2 = 30°C = 303°K$

$SNR_1 = \frac{P_S}{P_{N_1}} = 10^{1.31}$ $\quad SNR_2 = \frac{P_S}{P_{N_2}} = \frac{P_S}{P_{N_1} \times \frac{303}{294}}$

$\therefore SNR_2 = SNR_1 \times \frac{294}{303} =$

$= \underbrace{10^{1.31}}_{20.42} \times \frac{294}{303} = 19.81 = 12.97\ dB$

g) $\int_{f_1}^{f_2} S_X(f)\,df$ = Power contained from f_1 Hz to f_2 Hz which has to be +ve.

$\therefore S_X(f) \geq 0$ to prevent negative power levels.

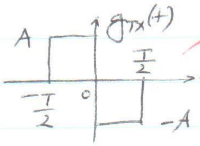
h) when $n_{BS} \gg n_{UE}$, BS can use the MU-MIMO (multiuser MIMO) technology; in this way, the network capacity can be increased while the link capacity will be limited by $\min(n_{TX}, n_{RX})$.

If $\frac{n_{TX}}{n_{RX}} = K$, then K links each with n_{RX} antennas at the UE can be supported. As such, as n_{TX} increases, more UEs can be supported concurrently (on the same resource block).

i) Zero-forcing equalization: ISI is supressed in its entirety. This is not necessarily the optimum strategy, as ZF results in noise enhancement. That is, ZF is optimal wrt ISI, but not optimal overall.

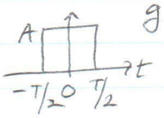
j) $R_{max} = \min(8,4) \times 40\,10^6 \times \underbrace{\frac{3}{4} \times \log_2(256) \times \frac{1}{1+0.2}}_{SISO\ SE\ =\ 5\ b/s/Hz} = 800$ Mbps

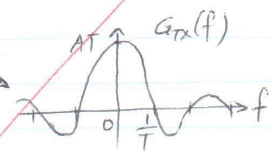
Q2) ISI

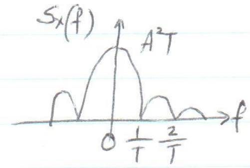


$x(t) = \sum x_k\, g_{TX}(t - kT)$
$\hookrightarrow \pm 1$

Remember





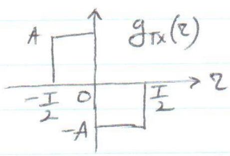


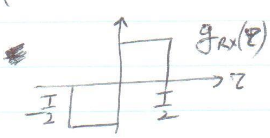
$S_x(f) = \frac{1}{T}\left|G_{TX}(f)\right|^2$

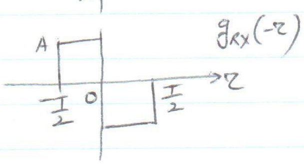
Null BW $= \frac{1}{T}$

a) Note that
$g_{TX}(t)$ is composed of two pulses each of which has a width of $\frac{T}{2}$ $\Rightarrow$ Null BW $= \frac{2}{T}$

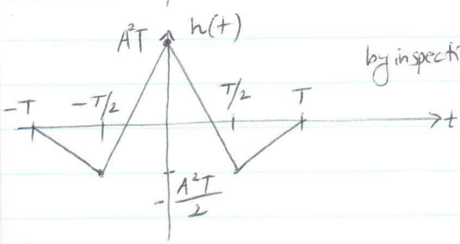
b) $g_{RX}(t) = g_{TX}(-t)$ $\left(= -g_{TX}(t) \ldots \text{due to odd symmetry} \right)$







$h(t) = g_{TX}(t) * \underbrace{g_{CH}(t)}_{\delta(t)} * g_{RX}(t)$
$= g_{TX}(t) * g_{RX}(t)$
$\triangleq \int_{-\infty}^{\infty} g_{TX}(\tau)\, g_{RX}(t-\tau)\, d\tau$



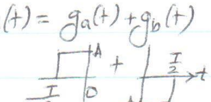
by inspection

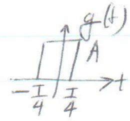
$h(t) \overset{?}{=} \begin{cases} 1, & t=0 \\ 0, & t=kT, \quad k=\pm1, \pm2, \ldots \end{cases}$

Assuming A^2T can be set to 1, this system will not result in ISI.

c) $h(t) = g_{TX}(t) * g_{RX}(t)$
$= g_{TX}(t) * -g_{TX}(t)$
$H(f) = -G_{TX}^2(f)$

$g_{TX}(t) = g_a(t) + g_b(t)$





$g_{TX}(t) = g(t+\frac{T}{4}) - g(t-\frac{T}{4})$
$G_{TX}(f) = FT\{g(t+\frac{T}{4})\} - FT\{g(t-\frac{T}{4})\}$

Q3) Link Adaptation

P4

$h(t) = \alpha\,\delta(t)$

$\alpha_n = 0.5\,\alpha_{n-1}$, $n = i+1, \dots, i+5$.

$\alpha_{i+1} = 0.5\,\alpha_i$

$\alpha_{i+2} = 0.5\,\alpha_{i+1} = 0.5^2\,\alpha_i$

$\alpha_{i+5} = (0.5)^5\,\alpha_i$

$SNR_i = 29.7\,dB = 10^{2.97} = 933.25$

$$\frac{P_{S,i}}{P_N} = 933.25$$

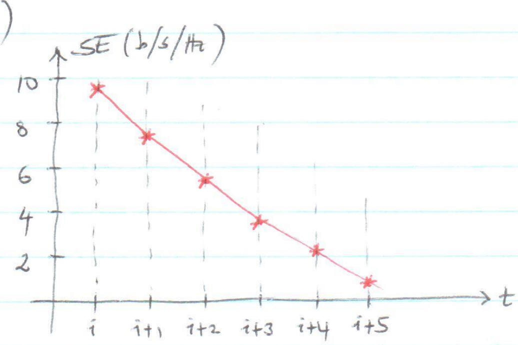
$P_{S,i} = P_{TX}\,\alpha_i^2$

$P_{S,i+1} = P_{TX}\,\alpha_{i+1}^2 = \frac{1}{4}\alpha_i$

$SNR_n = \frac{1}{4} SNR_{n-1}$, $n = i+1, \dots, i+5$

	i	$i+1$	$i+2$	$i+3$	$i+4$	$i+5$
SNR	933.25	233.31	58.33	14.58	3.65	0.91
SE	9.87	7.87	5.89	3.96	2.22	0.93

↳ $\log_2(1+SNR)$



Note that when SNR is high, SE $\sim \log_2 SNR$

When SNR is reduced by 4, SE goes down by 2:

$$SE_{i+1} - SE_i = \log_2 SNR_{i+1} - \log_2 SNR_i$$
$$= \log_2\left(\frac{SNR_{i+1}}{SNR_i}\right)$$
$$= \log_2\left(\frac{1}{4}\right) = -2$$