Department of Electrical Engineering, IIT Madras

EE 5151: Communication Techniques

Oct. 2017 **Tutorial #2** KG / IITM

1. A 10ppm clock error exists in the incoming signal to the receiver, which in turn has a 5ppm clock error. If the nominal bit-rate is 1Mbps, how much time elapses between (bit-level) slips? If this slip rate must not be greater than 10^{-3} slips/sec, what must be the new spec. on the total clock error?

2. In a system using elastic buffer with 2-frame memory, one frame slip occurs every 36 minutes in a system with a frame rate 150 frames/sec.

a) What is the ppm (parts per million) of the crystal used in the receiver?

b) Now, in order to have only one (frame) slip every 36 hours, what should the ppm be?

3. From "**Wireless Comm. (Electronic Version)**", by T.S. Rappaport, Chapter 2 (pp.25-68), understand equations (2.3), (2.4), (2.8), (2.9)**,** and (2.10) and then re-do the examples 2.1, 2.2, 2.4 **to** 2.7**.** Also, redo example 2.2 by using eqn. (2.10) instead of eqn. (2.9). Comment.

4. Problems from "**Wireless Comm. (E-version)**", Chapter 3, problems **3.12, 3.13*, 3.16, 3.17, 3.20***, and **3.21**. * marked problems are relatively more difficult to solve.

5. Problems from "**Wireless Comm. (E-version)**", Chapter 2, problems **2.1, 2.3, 2.4, 2.5, 2.8*, 2.10*, 2.11, 2.14** (review of Sensitivity), and **2.15**.

6. A signal of bandwidth 2 MHz is radiated through a 16dBi antenna with a power of 10milliWatts. The carrier frequency is 1 GHz, and the receive antenna has a gain of 4dBi.

a) For a required SNR at the detector input of 6dB, and given the receiver noise figure of 5dB, find the receiver sensitivity in dBm. (Assume that the thermal noise power density at the ambient temperature of 300^0K is -174dBm/Hz.)

b) Assuming a path-loss exponent n=3 and a shadow loss that is uniformly distributed between -8dB and +8dB, find the range of SNRs (maximum and minimum values will be fine) that one would see at a distance d=300m from the transmitter. Express your answer in dB scale.

c) Repeat part (b) if (i) n=3, d=3000m, and (ii) n=4, d=3000m.

7. Over wire-line channels, a signal of bandwidth 10KHz is to be transmitted over a distance of 200km. The channel (wire used) that has an attenuation of 2dB/km. Assume that the thermal noise PSD is -174dBm/Hz.

a) Determine the transmit power P_T required to achieve an SNR_0=20dB at the output of the receiver amplifier that has a noise figure F=6dB. Express the desired P_T in dBm as well as in Watts. Is this reasonable?

b) Repeat the calculation when a repeater is inserted every 10km with a gain of 20dB (to compensate the loss) and a noise figure F=6dB, as shown in Figure 2 below. Express the desired P_T in dBm as well as in Watts. How does it compare to (a)? Comment.

Hint: Use the fact when L_i=L and $F_i = F' \; \forall$I, $SNR_0 = \frac{1}{NLF'}\left(\frac{P_T}{kT\Delta f}\right)$

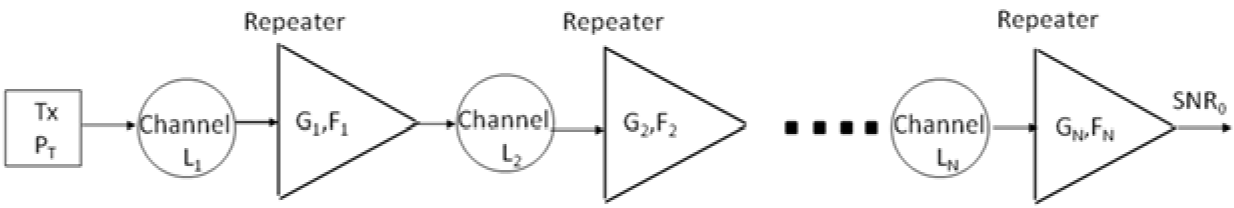

Figure2

8. A 10 MHz signal is to be wirelessly transmitted over a distance of 50km, where the channel has a path loss exponent of n=3. Repeaters are to be used to make this possible where both the Tx and Rx antennas have a gain of 26dBi each , the loss 1meter away from the antenna is L_{1m}=35dB. Assume that the thermal noise PSD is -174dBm/Hz. The power amplifier in each repeater has a gain A=30dB, and noise figure F=6dB.

a) Find the number of hops, N+1, that we need in this case. *Hint:* The PA needs to compensate (only) the "effective" loss per hop so that in the linear scale A/L=1. Use this to find the hop length, and hence number of repeaters N.

b) Determine the transmit power P_T required to achieve an SNR_0=15dB at the output of the N^{th} amplifier output. Express the P_T in dBm as well as in Watts.

9. Now consider another analog repeater design where a 2MHz signal is to be transmitted over a distance of 150km wirelessly, where the channel has a path loss exponent of n=4. Repeaters with Tx and Rx antenna gains of 20dBi each are used, the loss 1meter away from the antenna is L_{1m}=40dB. Assume that the thermal noise PSD is -174dBm/Hz. The power amplifier in each repeater has a gain AdB, and noise figure F=6dB.

a) If transmit power P_T = 10dBm, and N+1 hops, each of length 3Km are used, find A so that SNR_0=10dB is available at the output of the N^{th} amplifier output.

b) If each hop is now to be of length 6Km, what is the new A required?

10. In this problem, we are interested in calculating the bit error rate (BER) of a N-hop link using regenerative repeaters (decode-and-forward relays). For N=12, consider the following cases:
(i) Probability of bit error in each hop is $p=10^{-5}$. What is the overall BER?
(ii) If 8 links have $p=10^{-6}$and the remaining links have $p=10^{-4}$, what is the overall BER?

11. A cellular operator is allotted 12MHz (Downlink) and 12MHz (Uplink) spectrum, to operate in a FDD manner a FDMA network where each full-duplex call consumes 500KHz bandwidth in each direction. The operator decides to employ 4-cell reuse, where omni-directional antennas are used in each hexagonal cell of side R=1Km. The path loss exponent is n=2.2. Use suitable assumptions to answer the following:

(a) Find the best case signal to interference ratio (SIR) in dB.
(b) What is the worst-case SIR in dB?
(c) If 40 users, each with E_u=0.05 Erlangs, are to be supported by the base-station in each cell, what will be the blocking probability P_b at each base-station?

12. From Chapter 8 of "**Wireless Comm. (E-Version)**", please read **Sec.8.7.1** carefully, including equations **(8.28) to (8.33)**, and also look at example **8.9**. Capacity of CDMA in multi-cell case in Sec.8.7.2 is not necessary.

13. A direct-sequence spread spectrum system uses on the uplink a spreading factor of W=128 (i.e., there are 128 code chips per information bit). The system uses a 1MHz bandwidth and the receiver noise figure is F=9dB. Assuming perfect power-control and thermal noise variance as N_o (and noise PSD -174dBm/Hz) the signal to interference plus noise ration (SINR) can be represented by

$$\text{SINR} = \frac{WP}{(N-1)P + FN_0}$$

where P is the power of the received signals from the N users sharing the uplink. If the required SINR=6dB, find the number of users N the base-station can simultaneously support in each of the following cases:
(a) Infinite noise rise (i.e., neglecting the noise term in the SINR expression)
(b) Noise rise = 3dB
(c) Noise rise = 10dB. Comment on your answer.