Department of Electrical Engineering

EC-305 : Communication Systems

Nov. 2009 **Tutorial #3** 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. A digital multiplexer has 16 incoming streams, each with 2.048MBps rate and clocks with ±10ppm. The multiplexer adds a 32-bit framer (unique word) and a 16-bit CRC, and then stuff-bits (and the stuff-bit length indicators) are inserted to assemble a frame every 1sec.

   (a) Assuming that this operation is done so that each of the 16-streams are multiplexed bit-by-bit, what will be the multiplexed bit-rate? Make a rough sketch of the frame indicating the various fields.

   (b) If the frame duration is reduced to 10msec, but with the framing and CRC overheads remaining the same, what will be the output bit-rate? Comment with reference to your answer in (a).

   (c) Supposing elastic buffers with byte-level memory is used (byte is 8-bits), and the 16-streams are multiplexed byte-by-byte, what will be the multiplexed bit-rate for the case when frame duration is 1sec? Again, compare your answer with that in (a) and comment.

4. In a intermediate level digital multiplexer, 4 input streams arrive with rates and clock ppm given as follows: 5Mbps (1ppm), 10Mbps (1ppm), 10Mbps (2ppm), and 5Mbps (5ppm). If a 32-bit frame header and a 32-bit CRC are added to every 100msec frame assembled by this multiplexer along with appropriate stuff-bits (and indicators), answer the following:

   (a) Describe a simple bit-by-bit multiplexing strategy.

   (b) Make a rough sketch of the assembled frame, indicating the various important fields.

   (c) What is the output bit-rate?

5. 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.

6. Over <u>wire-line</u> 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′ □I, $SNR_0 = \frac{1}{NLF'}\left(\frac{P_T}{kT\Delta f}\right)$

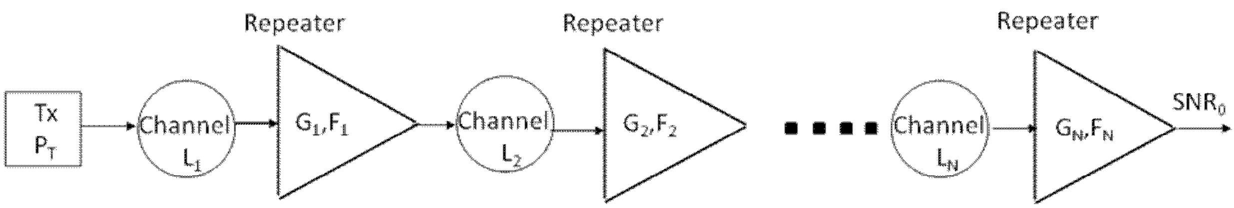

Figure2

7. 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.

8. 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?

9. Reading from **<u>"Wireless Communications – Principles & Practice" 2nd Ed.,</u>** by T.S. Rappport, Chapter 3-"The Cellular Concept – System Design Fundamentals" pp.57 to 104. It is also recommended that you (at least) browse thro the first two chapters in this book to answer some of the problems from the text book given below.

10. Problems from "**<u>Wireless Comm. 2nd Ed.</u>**", by Rappaport,chap.3(pp.97-104): **3.1,3.4,3.5*, 3.6,3.7, 3.9,3.10*,3.11 & 3.26**(revision of Erlang-B; use tables), **3.13,3.16,3.22** (Revision of Rx sensitivity) , and **3.28*.**