Department of Electrical Engineering, IIT Madras

EE5141 : Fundamentals of Wireless and Cellular Communications

KG/IITM **Tutorial for Lesson #7** **Mar. 25, 2022**

1. A Direct Sequence (DS) CDMA system with spreading factor T/Tc = W=256. For each of the following scenarios, compute the number of uplink users this system can be simultaneously supported using pseudo-noise (PN) codes. Use the uplink capacity expression discussed in class. Neglect impact of other cell interference, and voice activity detection. Let SINR=5 in linear scale for the weakest link.
(a) Under strict equi-power control, all user signals arrive with power P. What is the pole capacity?
(b) All users arrive with the same power P. How many users can be supported when the noise rise allowed is: (i) 3dB, (ii) 6dB, and (iii) 10dB.

2. In the DS-CDMA system as above, we now allow half the users can arrive at power P, and the other half to remain at power P/2.
(a) In this case, what is the pole capacity?
(b) For a noise rise of 3dB, how many users will this system support?
(c) If at power P, one can support 50% more rate in bits/sec when compared to power P/2, which of these two systems described in Q.1 and Q.2 can support higher sum rate at pole capacity?

3. Now consider a 10MHz DS-CDMA system with W=1024. Assuming perfect uplink power-control, the aim is to compute the uplink power P required from each user at the base-station. Assume that on the linear scale the SINR required is 5, and the receiver noise variance is σ^2, answer the below:
(a) For N=1, what is the P required (as a function of σ^2) ?
(b) What is the pole capacity N_P of this system?
(c) For $0<N<N_P$, what is the expression for the set-point of P?
(d) Repeat (a) & (c) for the narrow-band W=128 example, with the same SINR=5 required for each uplink. Compare your results and discuss.

4. Assume that the thermal noise power spectral density at the DS-CDMA base-station receiver can be taken as -174dBm. The path-loss exponent is n=3, and the 1m loss at the Tx end of the mobile station can be taken to be 35dB. Both the Tx and Rx use ideal omni antennas with gain of 0dBi. It is also given that the Rx noise figure is 5dB, and the required post-processing SINR = 9dB for the considered modulation. The Frequency-Division-Duplexed (FDD) communication link uses a one-way bandwidth of 2MHz, and the (peak) uplink transmit power is P_T =15dBm. The system uses a spreading factor of W=256 to send a 9.6kbps bit-stream over the given bandwidth.
(a) Find the value (in dBm scale) of the thermal noise (power) variance σ_n^2 at the receiver.
(b) Let the pole capacity of this DS-CDMA system be N_P. Recall that the number of users $N< N_P$ that can be practically supported on the uplink is a function of the allowed noise rise, L. The required power control setting P_R at the base-station receiver for a given N is therefore a function of L. Find the expression of P_R in terms of L, N_P, and σ_n^2.
(c) For an allowed noise rise of 6dB (i.e., L=4), find the *maximum link distance* in meters that this DS-CDMA base-station can support on the uplink.

5. A cellular TDMA base-station is required to serve users who are up to 9km away on the uplink. The RF bandwidth used by this system is W=2MHz, sync pulses are used to produce the 8-PSK encoded waveforms. The frame duration is 6msec with 5 slots per frame of 1.2msec duration each.
(a) Find the symbol duration, and the number of symbols per slot.
(b) What is the number of guard symbols required on the uplink MAC channel to compensate for the worst-case time of flight difference?
(c) What is the effective (useful) bit-rate per user, if 10% of the slot duration is given for pilot symbols and other control overheads? What is the useful spectral efficiency in bits/sec/Hz ?
(d) Now, the RF bandwidth is increased to 20MHz and 50 slots are planned in every 6msec frame duration (with all other parameters as before). What is the new value of useful spectral efficiency?