S-72.3275 Cellular Radio Network Planning and Optimization

Exercise Set 1

Solutions

Spreading and Modulation 1

A direct sequence spread-spectrum system is used to resolve the multipath signal components in a two-path radio signal propagation scenario. If the path length of the secondary path is 300m longer than that of the direct path, determine the minimum chip rate necessary to resolve the multipath components. How would WCDMA cope with the situation?

[If the two paths would be received within a time of one chip, the paths could not be resolved; hence only one rake-finger would be allocated to the paths. To be able to distinguish between the paths, the chip time T_{chip} has to be

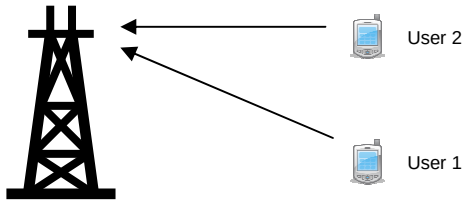
$$T_{chip} = \frac{\Delta d}{c} = \frac{300\text{m}}{3 \cdot 10^8 \text{m/s}} = 1\ \mu\text{s}$$

$$\Rightarrow R = \frac{1}{T_{chip}} = 1\ \text{Mcps}$$

WCDMA chiprate = $3.84*10^6$, hence it can resolve path length differences bigger than 78.1 m. This is a good value to keep in mind!]

Spreading and Modulation 2

Consider the uplink of a CDMA system with two synchronous users received as shown in picture below.



User 1 spreads its bipolar data signal d1 with the sequence
C1 = [–1 –1 –1 +1 –1 +1 +1 +1].
User 2 spreads its data signal d2 Î {-1, +1} with the sequence
C2 = [+1 +1 –1 +1 +1 -1 -1 -1].
The received values for the chips of the first bit are
y = [0 0 -2 2 0 0 0 0].

1. What is the spreading factor? What is the spreading gain in dB?

[SF = 8, spreading gain = 9dB]

2. Are the sequences C1 and C2 orthogonal to each other?

[C1*C2T = -4, signals not orthogonal]

3. Perform the despreading operation for the first bit of user 1. What is the estimated bit?

[Result of despreading: 4, estimated bit: +1]

4. Perform the despreading operation for the first bit of user 2?. What is the estimated bit?

[Result of despreading: 4, estimated bit: +1]

5. Determine the SIR for user 1.

$$\left[SIR_1 = \left| \frac{\mathrm{ACF}_1(0)}{\mathrm{CCF}(0)} \right|^2 = \left| \frac{8}{4} \right|^2 = 4 = 6 \text{ dB} \right]$$

6. What would be the SNR if the distortion to user 1 would be thermal noise (instead of user 2) with the same power?

[SNR = SF or in decibel domain 10*log(SF)]

7. Why is there a difference between the SNR and the SIR values? What is the possible range of SIR values?

[SIR depends on the CCF between the two sequences; possible range: 0 dB (identical sequences) .. +inf dB (orthogonal sequences).]

Spreading and Modulation 3

Consider the uplink of W-CDMA. Given a spreading factors of 64 for DPDCH and 256 for DPCCH, an information bit rate of 15.6 kbps (12.2 kbps + 3.4 kbps for data and control correspondingly), and a power ratio of 1/9 between control and data channel:

1. What is the symbol rate for DPDCH?

$$\left[symbolrate = \frac{W}{SF} = \frac{3840\text{Mcpc}}{64} = 60ksym/s \right]$$

2. What is the spreading gain for DPDCH in dB?

$$\left[10\log(SF) = 18.1 \text{ dB} \right]$$

3. What is the processing gain considering the whole transmission?

$$\left[PG = 10\log\left(\frac{W}{R_{info}} \right) = 23.9 \text{ dB} \right]$$

[Here R_{info} is naturally the whole information bit rate, including control information!]

4. Give the relation between SNR, CINR and PG.

[SNR = CINR + PG]

5. A practical task where you utilize your expertise gained from solving last four problems:

In our example now, a reliable signal reception requires E_b/N_0 = 5 dB. The properties of DPDCH and DPCCH remain the same. Assuming a noise floor of -103 dBm, what is the required signal strength of the whole signal at the NodeB receiving end? Consider the signal as whole, do not separate data and control parts.

[P_{RxMin} = P_{n+I} + Ec/N0
= P_{n+I} + (Eb/N0 - PG)
= -103 dBm + (5dB – 23,9 dB)
= -121,9 dBm]

What is the required RX power of DPCCH?

[Relation between data and control =1/9

- ⇨ DPDCH power = 9/10*total power
- ⇨ DPCCH power = 1/10*total power
- ⇨ $P_{RxMin,dpcch}$ = P_{RxMin} – 10 dB = -131.9 dBm]

Spreading and Modulation 4

Consider the uplink of a WCDMA system. There are 15 users transmitting information bits at a rate of 12,2 kbps. The required E_b/N_0 to achieve sufficient performance is 6 dB. All users are received with equal power of 1mW. The thermal noise power at the receiver is 5mW.

1. Determine the carrier-to-interferer-and-noise ratio CINR at the receiver.

[CINR = 1mW/(14 mW + 5 mW) = 1/19 = -12.8 dB]

2. What is the processing gain?

[PG = chip_rate/bit_rate = 3.84 Mcps/12.2 kbps = 25 dB]

3. Is the Eb/N0 value sufficient?

[E_b/N_0 = CINR + PG = 12.2 dB > 6 dB => E_b/N_0 value is sufficient!]

4. What is the minimum receive power per user such that the required Eb/N0 is satisfied? (still all users are received with the same power)

[
Minimum required CINR = E_b/N_0 - PG = -19 dB = 0,0126

Let x denote the minimum receive power per user:

$$\frac{x}{14x + 5\ \text{mW}} = 0{,}0126 \Rightarrow x = 0{,}076\ \text{mW}$$
]

5. What is the maximum number of users that can be received with sufficient performance if an infinite receive power is allowed (pole capacity)?

[
Infinite receive power => thermal noise power can be neglected.

$$\frac{x}{(a-1)\,x} = 0{,}0126 \Rightarrow a = 1/0{,}0126 + 1 = 80$$
]

6. How much should the processing gain be increased to allow for doubling the number of users?

[3 dB, remember that WCDMA is a typical case of interference limited capacity. Doubling the amount of users is possible either by
1. Implementing a system that supports the considered service with 3dB less Eb/N0, or
2. Implementing a system that needs for considered service “3 dB” less information bit rate yielding doubled processing gain.]