S-72.610 Mobile Communications Services and Systems

Tutorial 4, December 3, 2004

1.The co-channel CIR must be at least 9 dB. Estimate the CIR along the diagonal of the cell. Select for the attenuation factor in the system values $\alpha = 3.5$ and 4.5.

1. From the previous exercise we get that the reuse diatance in case of $\alpha = 3.5$ should be bigger than $k \geq 5.38$. First allowed *k* value satisfying this requirement is 7 and for $\alpha = 4.5$ $k = 4$.

From $k \geq \frac{1}{3}\left(\frac{D}{R}\right)^2$ we get $\frac{D}{R} = \sqrt{3k} \Rightarrow D = R\sqrt{3k}$. Also we know an equation for estimating CIR at the cell border $\frac{C}{I} \geq \frac{1}{6}\frac{(D-R)^\alpha}{R^\alpha}$. Inserting D into it

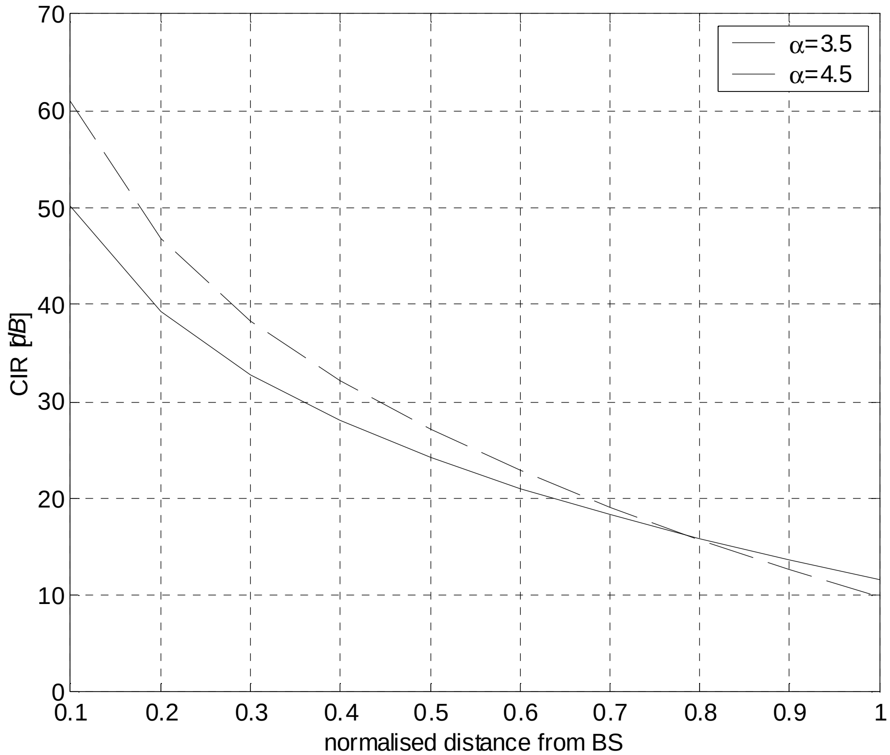
$$\frac{C}{I} \geq \frac{1}{6}\frac{\left(R\sqrt{3k}-R\right)^\alpha}{R^\alpha} = 14.5 \Rightarrow 11.6\ dB.$$

For $\alpha = 4.5$ $\frac{C}{I} = 9.8$

We normalise the cell radius to 1.

The worst case estimation of the CIR along the radius of cell can be calculated when D is kept constant and we change the radius distance r along the radius. Since maximal radius is normalised to 1 we change $r = 0 \ldots 1$. $\frac{C}{I} \geq \frac{1}{6}\frac{\left(\sqrt{3k}-r\right)^\alpha}{r^\alpha}$

R	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
CIR [3.5]	50.0	39.1	32.6	27.9	24.1	21.0	18.3	15.8	13.6	11.6
CIR [4.5]	60.9	46.8	38.3	32.0	27.0	22.8	19.1	15.7	12.7	9.8



70
60
50
40
30
20
10
0
CIR [dB]
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
normalised distance from BS
α=3.5
α=4.5

2. Compare the impact of GPRS and EGPRS coding to the data capacity. Show the cell areas where different coding classes are used. What is average data rate in the system? The system parameters for reuse distance are same as in previous exercise. The target CIR and user datarates are given in the tables below for EGPRS

Coding Class	MCS1	MCS2	MCS3	MCS4	MCS5	MCS6	MCS7	MCS8	MCS9
kbit/s	8.8	11.2	14.8	17.6	22.4	29.6	44.8	54.8	59.2
CIR [dB]	9	11	12	16	20.5	24.5	31.5	39	42

GPRS

Coding Class	CS1	CS2	CS3	CS4
User Data Rate	9.05	13.4	15.6	21.4
Required CIR $[dB]$	9	13	15	23

2. At distance *r* the system uses the maximal code rate for which the CIR requirement is satisfied. Now we know for a code the required CIR value and can calculate the distance from BS where this code can still be used. Set this distance to be r_{MCS}

$$CIR_{MCS} = \frac{1}{6}\frac{\left(\sqrt{3k} - r_{MCS}\right)^{\alpha}}{r_{MCS}{}^{\alpha}}$$

$$r_{MCS} = \frac{\sqrt{3k}}{\sqrt[\alpha]{6 \cdot CIR_{MCS}} + 1}$$

Normalised distances where different coding classes of EGPRS can be used

Coding Class	MCS 1	MCS 2	MCS 3	MCS 4	MCS 5	MCS 6	MCS 7	MCS 8	MCS 9
Normailsed Distance $\alpha = 3.5$	1.14	1.03	0.98	0.79	0.62	0.49	0.32	0.20	0.16
Normailsed Distance $\alpha = 4.5$	1.03	0.96	0.92	0.79	0.66	0.56	0.41	0.29	0.25

Normalised distances where different coding classes of GPRS can be used

Coding Class	CS1	CS2	CS3	CS4
Normailsed Distance $\alpha = 3.5$	1.14	0.93	0.84	0.53
Normailsed Distance $\alpha = 4.5$	1.03	0.89	0.82	0.59

From the results we see that it is always possible to use higher data rate than the minimum data rate. It is obvious since the MCS2 coding requires atleast 11 *dB* CIR ratio but at the cell border (in case of $\alpha = 3.5$) we have CIR 11.6 *dB*.

The average user data rate is calculated by summing over different user rates weigthed with the area where corresponding rate is used.

For example MCS9 coding is used at the distances $0 \ldots 0.2$ from BS. The corresponding area is $\frac{\pi \cdot 0.2^2}{\pi \cdot 1^2} = 0.04$. For MCS8 the distance is from 0.2 to 0.4 and the area is $\frac{\pi \cdot \left(0.4^2 - 0.2^2\right)}{\pi \cdot 1^2} = 0.12$. Evaluating so for each coding and weighting the user data rate with the correspongin area we get as the sum $28.4 \frac{kbit}{s}$.

Average user data rate in the cell

	$\alpha = 3.5$	$\alpha = 4.5$
EGPRS	22.07 kbit/s	23.82 kbit/s
GPRS	16.01 kbit/s	16.02 kbit/s

3. Study the possible logical channel combinations in given GSM signaling channel [reference: GSM 05.01, Figure of Channel organization for 51 frame multiframe.].

a) The channel combination is BCCH + CCCH + 4*SDCCH/4. How many pagings are possible in one signalling frame (51 frames - multiframe)? Assume that all the pagings are implemented by using TMSI - in one CCCH 4 users can be paged simultaneously.

b) The network parameter BS_AG_BLKS_RES is set to 1 and in the cell is used same channel combination as in a). How many calls can be paged in one signalling frame (51 frames)?

c) Paging can be implemented bu using TMSI or IMSI. Why it is preferable to use TMSI?

d) In case a) combination two frames are missing. What is transmitted in those places?

e) Network parameter BS_PA_MFRMS is set to 4. How ofter mobile station should be activated to decode paging frame? Used channel combination is BCCH + CCCH + 4*SDCCH/4.

AGCH Access grant channel

BCCH Broadcast control channel

CCCH Common control channel

SDCCH Stand alone dedicated control channel

BS_AG_BLKS_RE Parameter indicating number of blocks on each CCCH reserved for access grant message

TMSI Temporary Mobile subscriber enetity

IMSI International mobile subscriber entity

F: TDMA frame for frequency correction burst
B: TDMA frame for BCCH
D: TDMA frame for SDCCH
R: TDMA frame for RACH
S: TDMA frame for synchronization burst
C: TDMA frame for CCCH
A: TDMA frame for SACCH/C

Figure 3: Channel organization in the 51-frame multiframe

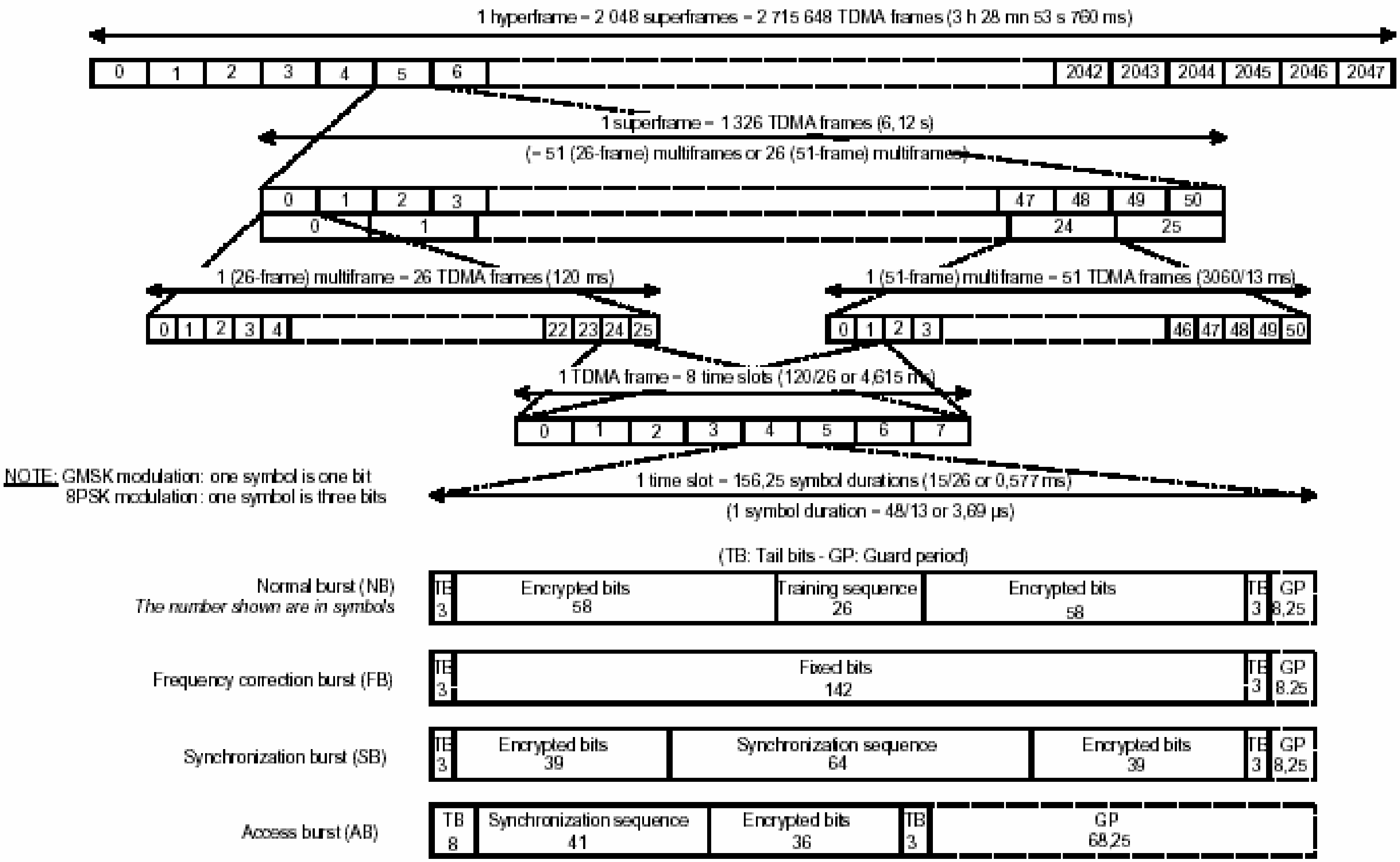


Figure 1: Time frames time slots and bursts

Figure. GSM TDMA frame structure.

3. Solution

Study the possible logical channel combinations in given GSM signaling channel [reference: GSM 05.01].

a) The channel combination is BCCH + CCCH + 4*SDCCH/4. How many pagings are possible in one signaling frame (51 frames - multiframe)? Assume that all the pagings are implemented by using TMSI, in one CCCH 4 users can be paged simultaneously.

   Because of channel coding one CCCH-block occupies four frames. CCCH in downlink direction contain PCH and AGCH. AGCH reserves CCCH accordingly its need. In maximum all three CCCH-blocks from combination of BCCH + CCCH + 4*SDCCH/4 contain paigings. One burst can contain paiging messages to four calls, in which case during one multiframe 3*4=12 mobiles can be called.

b) The network parameter BS_AG_BLKS_RES is set to 1 and in the cell is used same channel combination as in a). How many calls can be paged in one signaling frame (51 frames)?

   Now one burst is fixed for the access grant information, and therefore in one multiframe can be called 2*4=8 mobiles.

c) Paging can be implemented bu using TMSI or IMSI. Why it is preferable to use TMSI?

   TMSI is shorter than IMSI → it allows to fit many mobile users into one burst. Additionally if TMSI is used users identify information is not transmitted over radio interface.

d) In figure used in case a) two bursts are missing. What is transmitted in those frames?

   F and S, in other words FCCH and SCH: s-burst and f-burst.

e) Network parameter BS_PA_MFRMS is set to 4. How often mobile station should be activated to decode paging frame? Used channel combination is BCCH + CCCH + 4*SDCCH/4.

Duration of one 51 frame multiframe is 3060/13=235.38 ms. The calls of paging grouping are repeated in every multiframe → 4*235,38 ms = 941,52 ms.

4. Two spreading signals in vector form are $s_1 = [-111-1]$ and $s_2 = [1-11-1]$ with the chip length $\tau_1 = 1$.

calculate the cross correlation function between the spreading sequence $s_1(t)$ and signal $s_{11}(t)$ that is bit sequence $[11]$ spread by $s_1(t)$.

calculate the cross correlation function between the spreading sequence $s_1(t)$ and signal $s_{10}(t)$ that is bit sequence $[-11]$ spread by $s_1(t)$.

calculate the cross correlation function between the spreading sequence $s_1(t)$ and signal $s_{21}(t) = [11]$ spread by $s_2(t)$.

calculate the cross correlation function between the spreading sequence $s_1(t)$ and signal $s_{20}(t) = [-11]$spread by $s_2(t)$.

4. Solution

The spreading signal is described as sequence of values ± 1. Our spreading code has length four and we can express it as sum of four unit pulses

$s_1(t) = \sum_{n=0}^{3} s_1(n) p(t - n\tau_1)$, where $s_1(n)$ is the *n* element of the spreading signal vector, and $p(t - n\tau_1)$ is a unit pulse beginning at 0 and ending at **Error! Objects cannot be created from editing field codes..**

Multiplying the bits of the s_{11} with the spreading sequence generates is generates the spread signal

$$s_{11}(t) = \sum_{n_b=0}^{1} a\left(n_b\right) p_b(t - n_b T_1) \left(\sum_{n_s=0}^{\tau_1} s_1\left(n_s\right) p_s\left(t - n_s \tau_1\right) \right),$$

where n_b, n_s stand for the bit and chip numbers accordingly. $p_b(\ ), p_s(\ )$ are unit pulses with the bit and chip length accordingly and $a\left(n_b\right), s_1\left(n_s\right)$ stand for the bit and chip amplitudes.

The cross correlation function $R_{xy}(\tau)$ between two signals $x(t)$ and $y(t)$ is defined as

$$R_{xy} = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} x(t) y(t - \tau) dt.$$

Since we are dealing with a finite length signal the integration can be limited only to the values which are different from zero for out signal it would be interval $0 \ldots 7$.

For our signal when τ is integer the correlation function can be written as sum of every chip of spread signal $s_{11}(t)$ and reference signal $s_1(t)$

$$R(\tau) = \frac{1}{4\tau} \int_{0+\tau}^{7+\tau} s_{11}(t + \tau) s_1(t) dt$$

Since the signals are compounded from triangular impulses we can calculate the correlation only for integer values of τ and between those $R(\tau)$ is given by a linear function connecting two neighboring values.

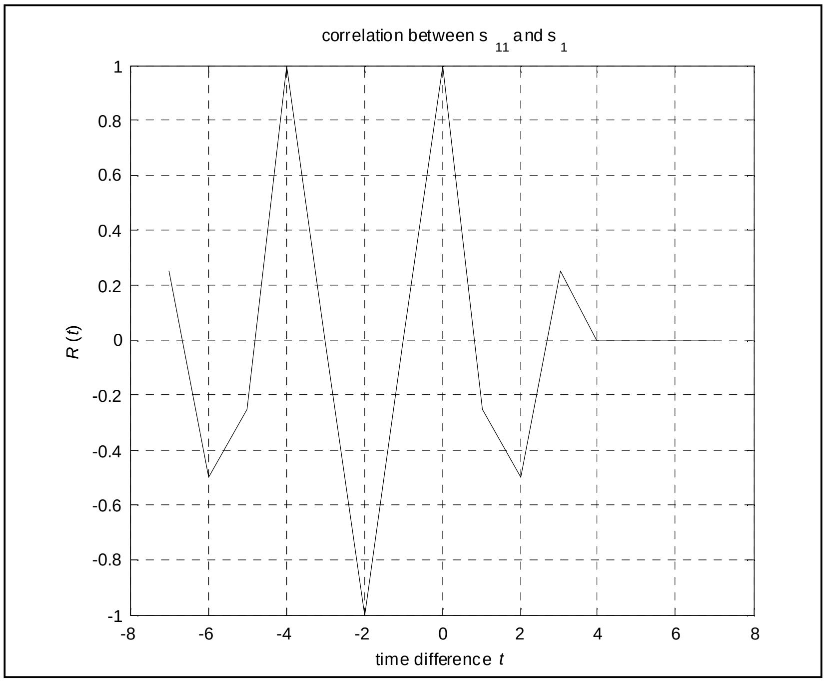
For integer τ_{int} values $R(\tau_{\text{int}})$ is calculated as:

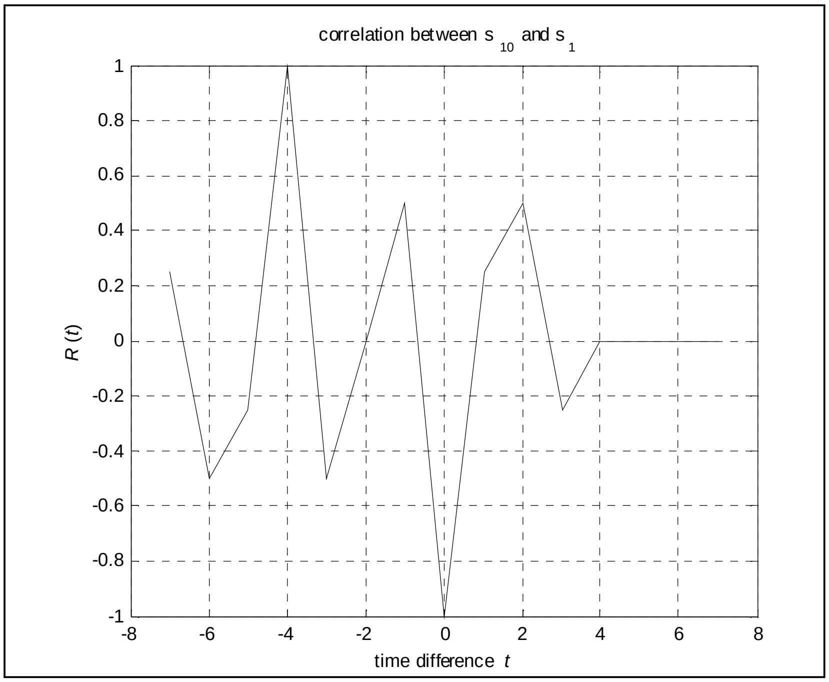
$$R(\tau_{\text{int}}) = \frac{1}{4\tau_1} \sum_{m=0+\tau}^{7+\tau} s_{11}(m+\tau_{\text{int}}) s_1(m)$$

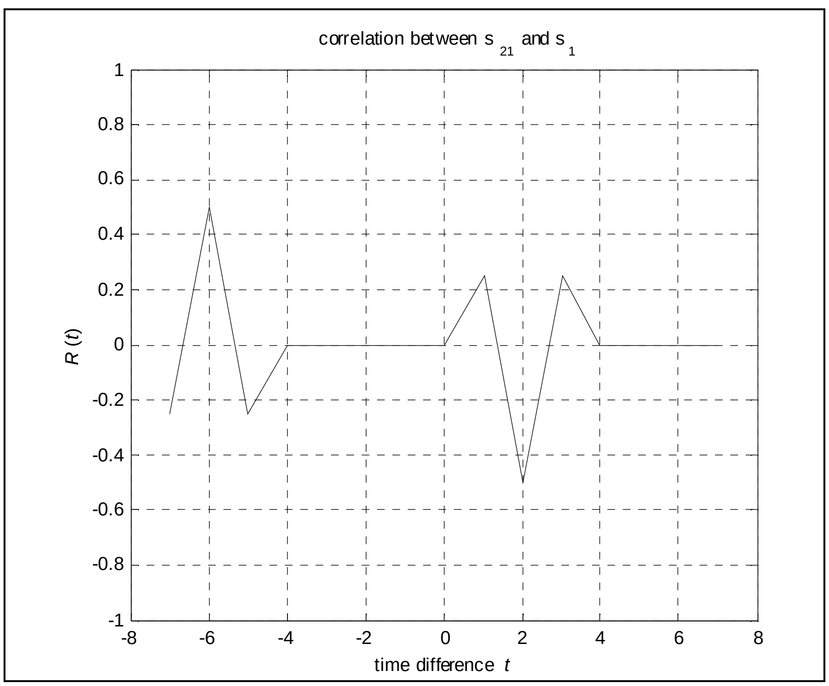
Between these values we use linear function

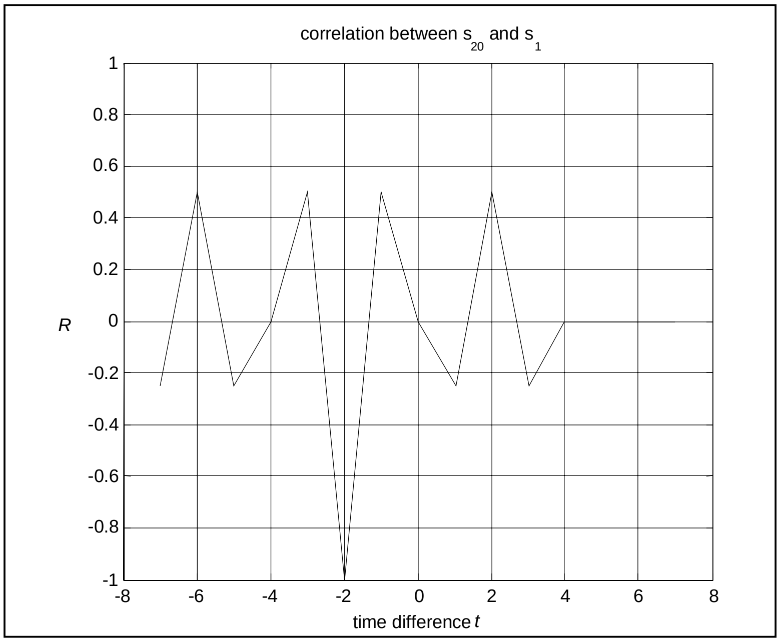
$$R(\tau) = \left(R\left(\lfloor\tau\rfloor\right) - R\left(\lceil\tau\rceil\right)\right)\left(\tau - \lfloor\tau\rfloor\right) + R\left(\lfloor\tau\rfloor\right).$$

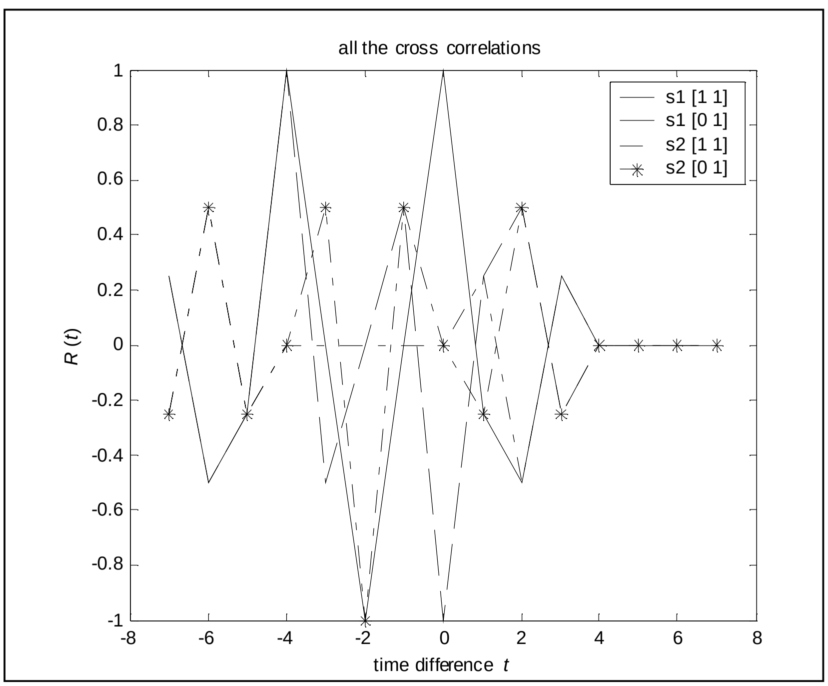
Where $\lfloor\ \rfloor, \lceil\ \rceil$ stand for the nearest smallest and highest integer respectively. We evaluate all the correlation functions with the "Matlab".




correlation between s 10 and s 1
R (t)
time difference t
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-8
-6
-4
-2
0
2
4
6
8


correlation between s 21 and s 1
R (t)
time difference t
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-8
-6
-4
-2
0
2
4
6
8


correlation between s_{20} and s_1
R
time difference t
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-8
-6
-4
-2
0
2
4
6
8


all the cross correlations
s1 [1 1]
s1 [0 1]
s2 [1 1]
s2 [0 1]
R (t)
time difference t
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-8
-6
-4
-2
0
2
4
6
8

5. CDMA capacity

DS-CDMA system has spread code rate 3.84 Mchip/s. User data rate is 30 kbit/s. How many users can one cell serve when the required error probability should be at least 10^-3 (corresponding CIR target is 3 *dB*)?
Consider also neighboring cell interference given by a factor 0.5.

5. The capacity in CDMA system is interference limited. The interference per bit is described as energy per bit divided by total interference in the transmission bandwidth. In CDMA all other users generate the interference in communication bandwidth. We assume that the interference is characterized as a zero-mean AWGN process.
In CDMA the total interference power presented to each user's demodulator is $I = (k_u - 1)P_s$.

(1)

i.e. number of other users k_u multiplied by the signal power to one of the users. We assume here that at the receiver all the users have the same signal power P_s.

The noise density received by each user demodulator is, $I_0 = \frac{I}{W}$

The energy per bit is, $E_b = \frac{P_s}{R}$

By inserting these into Eq. (1) we get,

$$k_u - 1 = \frac{I}{P} = \frac{W/R}{E_b/I_0}.$$

(2)

This equation contains only the interference from the host cell. The interference from the other cells is f times the interference from the host cell. In order to overcome the interference from other cells we have to increase the energy per bit from 1 to $(1+f)$.

$$k_u - 1 = \frac{I}{P} = \frac{W}{R}\frac{I_0}{E_b}\frac{1}{(1+f)}.$$

(3)

Where $\frac{E_b}{I_0} = SNR$.

In what follows we assume that the main source of the noise is multiple access (other users) interference. Accordingly to this assumptions we can assume that $SNR = SIR$.

The term $\frac{W}{R}$ is called coding gain. $\frac{3.84 \cdot 10^6}{30000} = 128$

inserting this values into Eq. (2) and (3) results

$$(2) \quad k_u = 128 \cdot \frac{1}{10^{3/10}} + 1 \simeq 65$$

$$(3) \quad k_u = 128 \cdot \frac{1}{10^{3/10}(1+0.5)} + 1 \simeq 43$$