“Cellular consept”

Task 1. Derive the reuse factor *Q* for hexagonal cells with a cluster size *N*=4 and *N*=3.

Solution:

$$\text{N=4: } Q = \frac{D}{R} = \frac{\sqrt{(3R)^2 + \left(2\frac{\sqrt{3}}{2}R\right)^2}}{R} = \sqrt{12} = \sqrt{3N} \text{ . OK}$$

$$\text{N=3: } Q = \frac{D}{R} = \frac{3R}{R} = 3 = \sqrt{3N} \text{ . OK}$$

Task 2. Consider Example #2 once again, having now different environments in consideration: *n*=2, *n*=2.5 and *n*=3.5. How many cells are required for each case?

Solution:

First, we need some ErlangB curves. With Matlab, one can draw that for example as follows:

$$p_B = \frac{E^M / M!}{\sum_{i=0}^{M} E^i / i!}$$

```
M=7; %number of traffic channels
facM=factorial(M);
for E=0:50,
    summa=0;
    for i=0:M,
        summa=summa + (E^i)/factorial(i);
    end
    result(E+1)= E^M / facM / summa;
end
semilogy(0:50,result);axis([0 50 0.0001 1]);grid
xlabel('traffic, E')
ylabel('blocking probability')
```

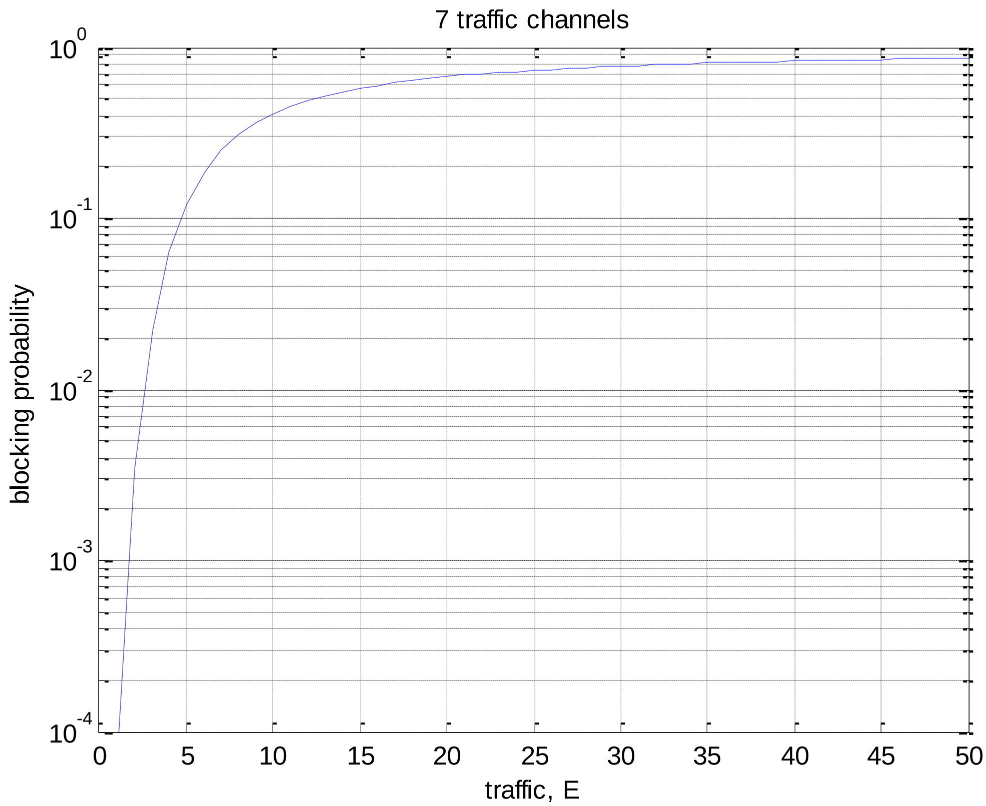
The initial requirement is the same: the system should be able to carry 250Erl traffic. To find out the cluster size, we need:

$$\frac{S}{I} = \frac{(D/R)^n}{6} = \frac{\left(\sqrt{3N}\right)^n}{6} \Rightarrow N = \frac{(6 \cdot S/I)^{\frac{2}{n}}}{3}$$

For different *n* this gives:
n=2 → N=50,2
n=2,5 → N=18,4
n=3,5 → N=5,8

Case n=2: In this case the cluster size would be 51. Since we only have 40 carriers, the maximum cluster size is 40 (that is, 1 carrier can be used in each cell). If we select that, it actually means that the SIR=14 dB requirement can not met, but should be reduced to SIR=13dB.

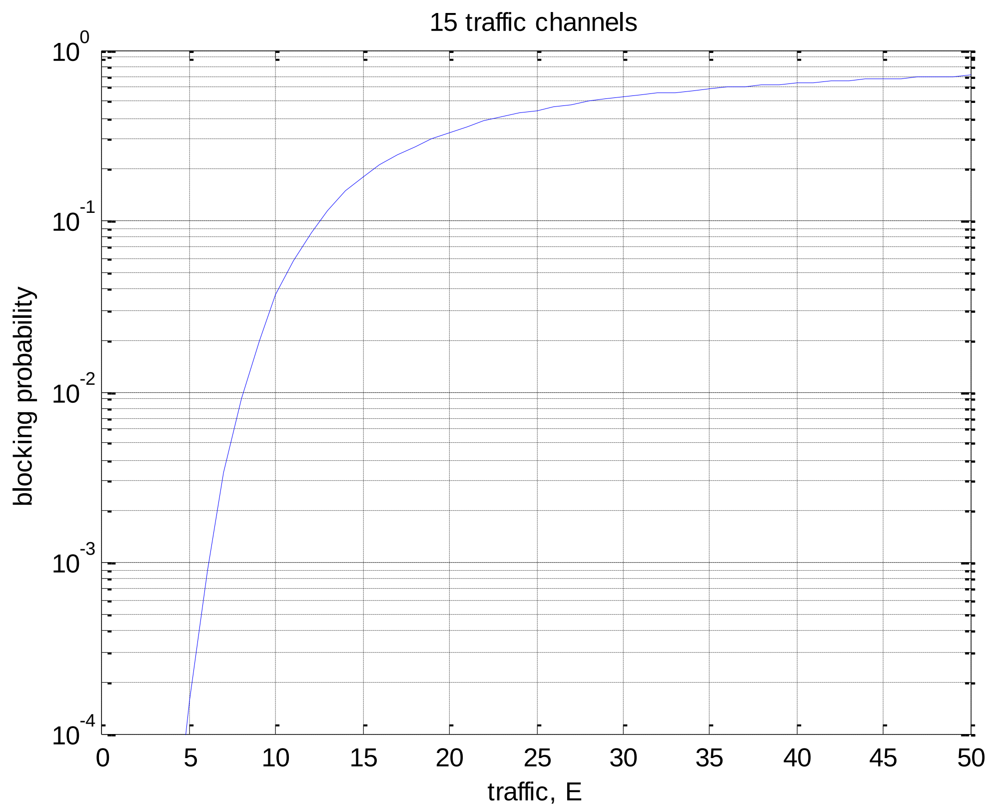
In GSM each carrier frequency can support 8 users (traffic channels). Lets reserve 1 for signaling purposes, i.e we have 7 traffic channels in use.



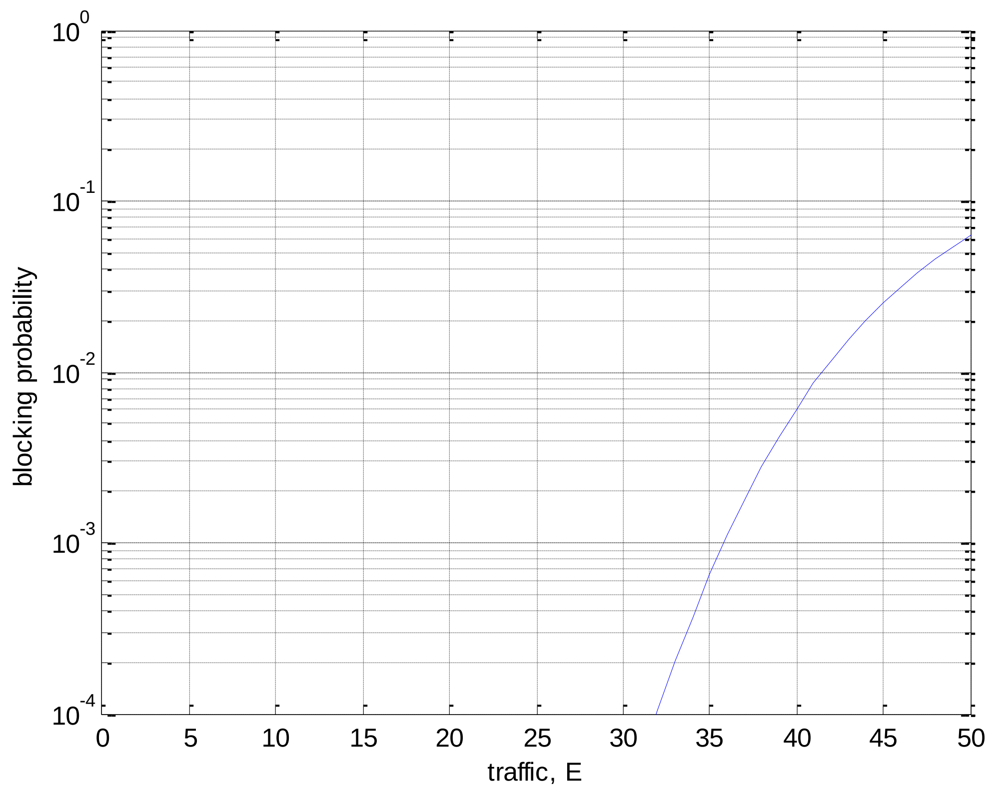
From the figure we see that 7 traffic channels can support 2.5 Erl of traffic with 1% blocking probability. Hence, 250 Erl / 2.5 Erl/cell = 100 cells.

Case *n*=2,5: In this case the cluster size would be 18,4 → 19. Hence, we would have is 40/19 = 2,1 carriers per cell. Lets fix it equal to 2 (that is, cluster size equal to 20), which would mean that we improve the SIR requirement to SIR=14,4 dB.

With 2 carriers per cell we have 16 traffic channels (let's reserve 1 for signaling). From the next figure we see that 15 traffic channels can support 7 Erl of traffic with 1% blocking probability. Hence, 250 Erl / 7 Erl/cell = 35,7 cells → 36 cells required.

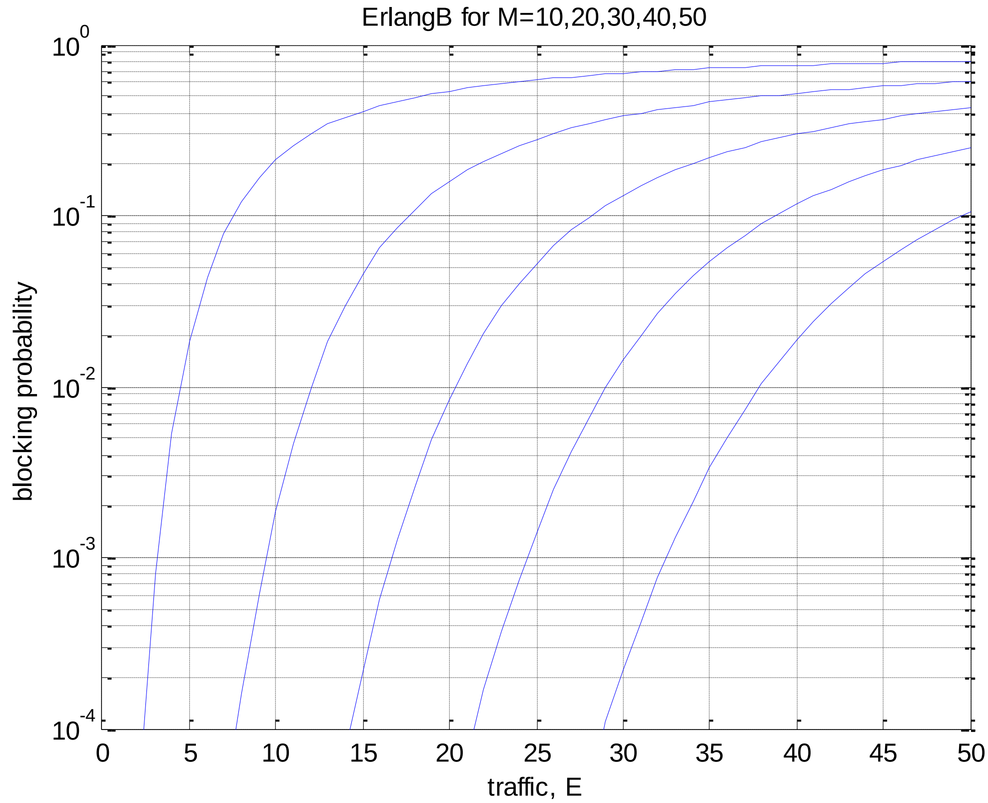


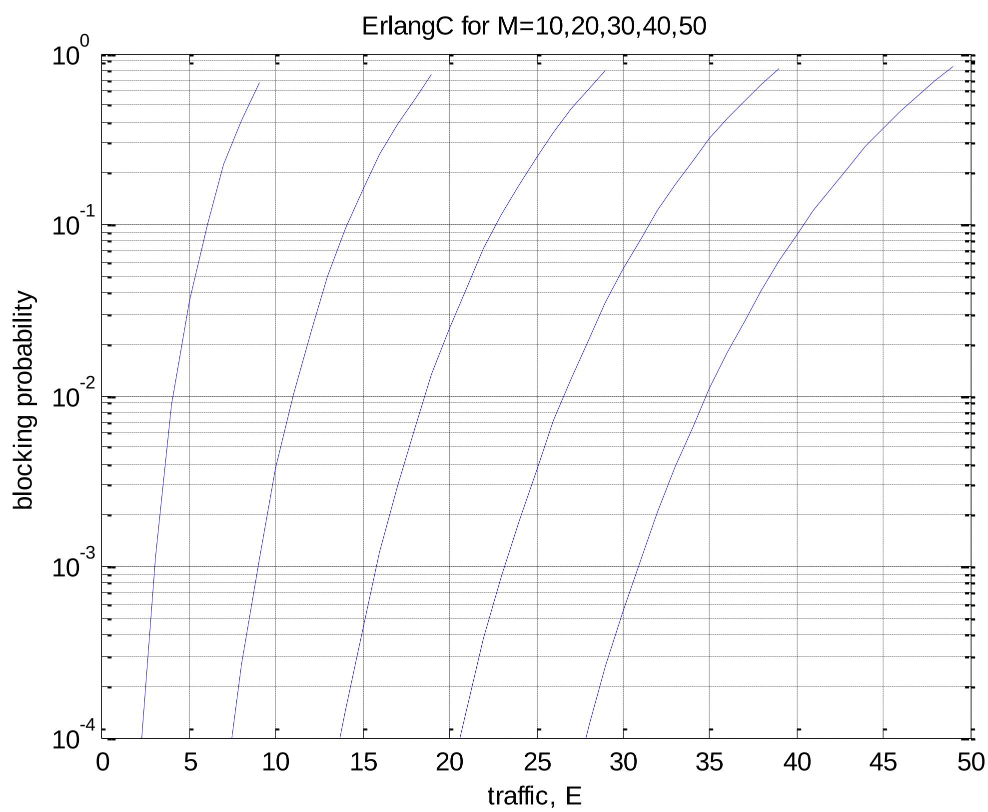
Case *n*=3,5: In this case the cluster size would be 5,8 → 6. Hence, we would have is 40/6 ≈ 7 carriers per cell. With 7 carriers per cell we have 56 traffic channels (lets reserve 2 for signaling). From the figure (next page) we see that 54 traffic channels can support 42 Erl of traffic with 1% blocking probability. Hence, 250 Erl / 54 Erl/cell = 5,9 cells → 6 cells required.



Task 3. Plot the figures for Erlang C formulas for 10,20,30,40 and 50 channels. How the figures are different from Erlang B figures ?

```
for M=10:10:50;
    facM=factorial(M);
    for E=0:50,
        summa=0;
        for i=0:M-1,
            summa=summa + (E^i)/factorial(i);
        end
        yla=(M*E^M)/facM/(M-E);
        ala=yla+summa;
        result(E+1)=yla/ala;
    end
    semilogy(0:50,result);axis([0 50 0.0001 1]);grid
    xlabel('traffic, E')
    ylabel('blocking probability')
    title(['ErlangC for M=10,20,30,40,50'])
    hold on
end
```


ErlangB for M=10,20,30,40,50
blocking probability
traffic, E
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
5
10
15
20
25
30
35
40
45
50


ErlangC for M=10,20,30,40,50
blocking probability
traffic, E
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
5
10
15
20
25
30
35
40
45
50

”WCDMA Introduction”

Task 1. Two DS-CDMA spreading codes are s_1=[-1 1 1 -1 1] and s_2=[1 -1 1 -1 1].

a) Are the codes orthogonal ?
b) Suppose a BS is sending user #1 bits [-1 1] with a code s_1 and user #2 bits [1 -1] with a code s_2 at the same time. Generate the data that a BS is sending at the chip level.
c) Suppose that the channel is ideal, so there is no noise and the users receive exactly what was sent by the BS. Detect the bits for user #1 and #2 using their own codes. Are the bits going to be detected correctly?

Solution:

a) < s_1 , s_2 > = -1*1 + 1*(-1)+1*1+(-1)*(-1)+1*1 = 1 → not orthogonal, so we should expect some interference between user’s signals.

b)

code s_1	-1	1	1	-1	1	-1	1	1	-1	1	
sent chips for user #1	1	-1	-1	1	-1	-1	1	1	-1	1	bits [-1 1]
code s_2	1	-1	1	-1	1	1	-1	1	-1	1	
chips sent for user #2	1	-1	1	-1	1	-1	1	-1	1	-1	bits [1 -1]
signal sent by BS	2	-2	0	0	0	-2	2	0	0	0	

c)

user #1 despreading	-2	-2	0	0	0	2	2	0	0	0	
user #1 integration	-2	-4	-4	-4	-4	2	4	4	4	4	
user #1 decision					-1					1	--> OK
user #2 despreading	2	2	0	0	0	-2	-2	0	0	0	
user #2 integration	2	4	4	4	4	-2	-4	-4	-4	-4	
user #2 decision					1					-1	--> OK

Task 2: Suppose that bits [1 -1 1 -1] are spread with a DS-CDMA code s1= [-1 1 1 -1]. Calculate the amplitude of the signal and the interference for every bit if the channel response is the following:

Path amplitude:	0.5	0.3	0.2
Path delay in chips:	0	1	2

Assume that the correlator is tuned to the first path, that is, the first path is considered as the “information” and the other remaining paths give the “interference”.

Solution:

The chip sequence at the receiver is locked into the first path. When this path is despread, also the other paths will be despread, but the timing for those two paths will be incorrect ! For this reason the other paths cause interference when despreading the first path.

In the next page you can see the chips sent and received. In the final stage, if we should do the decision of the symbols, we should check the sign of the total received amplitude: 1,3 : -1,3 : 1.3 : -1.3. Hence, we would end up with the correct symbol estimation +1, -1, +1, -1.

transmitted chips:	-1	1	1	-1	1	-1	-1	1	-1	1	1	-1	1	-1	-1	1		
received chips from path #1:	-0,5	0,5	0,5	-0,5	0,5	-0,5	-0,5	0,5	-0,5	0,5	0,5	-0,5	0,5	-0,5	-0,5	0,5		
received chips from path #2:		-0,3	0,3	0,3	-0,3	0,3	-0,3	-0,3	0,3	-0,3	0,3	0,3	-0,3	0,3	-0,3	-0,3	0,3	
received chips from path #3:			-0,2	0,2	0,2	-0,2	0,2	-0,2	-0,2	0,2	-0,2	0,2	0,2	-0,2	0,2	-0,2	-0,2	0,2
chip sequence at the receiver:	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1		
despread chips from path #1:	0,5	0,5	0,5	0,5	-0,5	-0,5	-0,5	-0,5	0,5	0,5	0,5	0,5	-0,5	-0,5	-0,5	-0,5		
despread chips from path #2:	0,0	-0,3	0,3	-0,3	0,3	0,3	-0,3	0,3	-0,3	-0,3	0,3	-0,3	0,3	0,3	-0,3	0,3		
despread chips from path #3:	0,0	0,0	-0,2	-0,2	-0,2	-0,2	0,2	0,2	0,2	0,2	-0,2	-0,2	-0,2	-0,2	0,2	0,2		
integrator (path #1)	0,5	1,0	1,5	2,0	-0,5	-1,0	-1,5	-2,0	0,5	1,0	1,5	2,0	-0,5	-1,0	-1,5	-2,0		
integrator (path #2)	0,0	-0,3	0,0	-0,3	0,3	0,6	0,3	0,6	-0,3	-0,6	-0,3	-0,6	0,3	0,6	0,3	0,6		
integrator (path #3)	0,0	0,0	-0,2	-0,4	-0,2	-0,4	-0,2	0,0	0,2	0,4	0,2	0,0	-0,2	-0,4	-0,2	0,0		
Amplitude of the signal:				2,0				-2,0				2,0				-2,0		
Amplitude of the interference:				-0,7				0,6				-0,6				0,6		

Task 3. Suppose there exists 5, 10, 15 or 20 simultaneous connections of 12.2 kbps data rate in a single WCDMA cell, and each connection has 5dB target for SINR. Determine the total received power by the BS when the noise power at the BS equals -102 dBm.

It is assumed that the received powers from each user are the same (power control) and equals to p_{rx}. Then we have:

$$\frac{\frac{W}{R}p_{rx}}{(K-1)p_{rx}+N}=\rho \Rightarrow \left(\frac{W}{R}-\rho(k-1)\right)p_{rx}=\rho N \Rightarrow p_{rx}=\frac{\rho N}{\frac{W}{R}-\rho(k-1)}.$$

The total power at BS is the sum of user powers and the noise:

$$P_{tot}=K\cdot p_{rx}+N=\frac{K\rho N}{\frac{W}{R}-\rho(K-1)}+N=\frac{K\cdot 10^{0,5}\cdot 10^{-10,2}}{\frac{3{,}84\cdot 10^{6}}{12200}-10^{0,5}(K-1)}+10^{-10,2}$$

For K=5,10,15 and 20, the total received power at the BS equals, respectively, -101.8 dBm, -101,5 dBm, -101,3 dBm and -101,0 dBm

Homework (Pole capacity)

Polecapasity = W/(rhoo*R) +1 =100,53

```
rhoo = 10^0.5;
N = 10^(-10.3);
R = 12200;
W = 3.84*10^6;

for k=1:100
    power(k+1)=rhoo*N/(W/R-roo*(k-1));
end

semilogy(power)
```