



**Faculty of Engineering and Technology**

**Electrical and Computer Engineering Department**

**WIRELESS AND MOBILE NETWORKS**

**ENCS5323**

**Online Calculator for Wireless and Mobile Networks**

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**Section:** 3

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In this project, we implement a calculator using React to solve 5 types of questions:

1. The number of bits and rate of the sampler, quantizer, source encoder, channel encoder, and interleaver.
2. The number of bits and rate for resource elements, OFDM symbol, Resource Blocks, and maximum transmission using parallel resource blocks.
3. Power transmitted in a flat environment based on the transmitter and receiver specifications.
4. Throughput in percent of Multiple Access techniques.
5. Design of cellular system.

Main page :

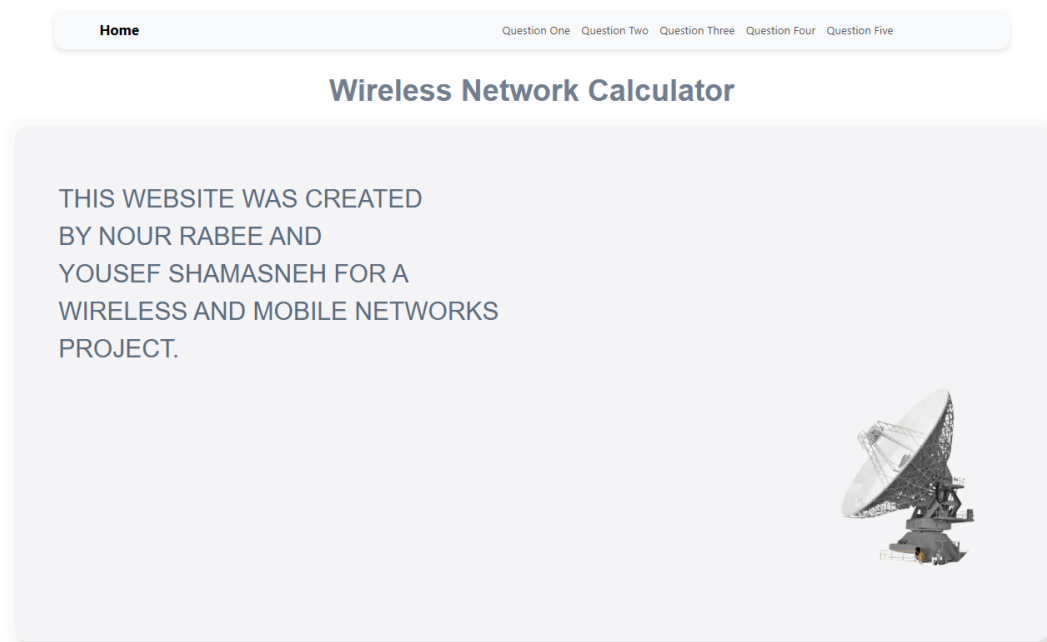


Figure 1: Menu Page

**Note that our website is not responsive; components sizes may change when screen's size change. To run the code, you need to install the following libraries: react-router-dom and react-bootstrap.**

## Question One

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Bandwidth

Hz ▾

Quantizer Levels

Compression Rate (RS)

Code Rate (RC)

Interleaver Bits

Calculate

Sampling Rate

Bits of the Quantizer

Bit Rate at the Output of Quantizer

Bit Rate at the Output of Source Encoder

Bit Rate at the Output of Channel Encoder

Bit Rate at the Output of Interleaver

Figure 2: First Calculator "question one"

The user will enter the bandwidth (BW), number of quantizer levels (L), compression rate (Rc), code rate (Rs), and interleaver bits. Upon clicking the “Calculate” button, six outputs will be computed. First, the sampling rate which is  $2(BW)$ . Second, Bits of the Quantizer which is  $\log_2 L \text{ bits/sample}$ . Third, the bit rate at the output of the quantizer (input to the source encoder), which is the sampling rate multiplied by the number of bits of the quantizer. Fourth, the bit rate at the output of the source encoder (input to the channel encoder), which is the input to the source encoder multiplied by the compression rate. Fifth, the bit rate at the output of the channel encoder (input to the interleaver), which is the input to the channel encoder divided by the code rate. Finally, the bit rate at the output of the interleaver remains the same as its input, since the number of bits of the interleaver does not affect the bit rate.

## Scenario 1

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Bandwidth

KHz ▼

Quantizer Levels

Compression Rate (RS)

Code Rate (RC)

Interleaver Bits

Calculate

Sampling Rate

Bits of the Quantizer

Bit Rate at the Output of Quantizer

Bit Rate at the Output of Source Encoder

Bit Rate at the Output of Channel Encoder

Bit Rate at the Output of Interleaver

Users can select the unit for the bandwidth (BW) between Hz and kHz. All the results are correctly calculated and presented as mentioned earlier.

## Scenario 2

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Bandwidth

KHz ▼

Quantizer Levels

Quantizer levels should be a power of 2 (e.g., 2, 4, 8, 16, 32, ...)

Compression Rate (RS)

Code Rate (RC)

Interleaver Bits

Calculate

Sampling Rate

Bits of the Quantizer

Bit Rate at the Output of Quantizer

Bit Rate at the Output of Source Encoder

Bit Rate at the Output of Channel Encoder

Bit Rate at the Output of Interleaver

If the user enters a value in the quantizer levels field that is not a power of 2, an error will occur. This is because the logarithm base 2 of a nonpower of 2 value results in a float, but the number of bits for the quantizer must be an integer.

### Scenario 3

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Bandwidth

4

KHz

▼

Quantizer Levels

256

Compression Rate (RS)

0.25

Code Rate (RC)

0.5

Interleaver Bits

256

Calculate

Sampling Rate

8KHz

Bits of the Quantizer

8

Bit Rate at the Output of Quantizer

64Kbps

Bit Rate at the Output of Source Encoder

16Kbps

Bit Rate at the Output of Channel Encoder

32Kbps

Bit Rate at the Output of Interleaver

32Kbps

Changing the number of interleaver bits does not affect the bit rate of the interleaver output, as shown in the Figure above.

## Question Two

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Bandwidth  
 Hz

Subcarrier Spacing  
 Hz

OFDM Symbols per Resource Block

Duration of Each Resource Block  
 s

Number of Assigned Parallel Resource Blocks

Calculate

Modulation Technique  
1024-QAM

Number of bits per Resource Element

Number of Subcarriers

Number of bits per OFDM Symbol

Number of bits per OFDM Resource Block

Max Rate for One Resource Block

Max Rate for Assigned Parallel Resource Blocks

In this calculator, users input several parameters including bandwidth (BW), subcarrier spacing, number of OFDM symbols per resource block, duration of each resource block, and select one of five modulation techniques: BPSK, 16-QAM, 64-QAM, 256-QAM, or 1024-PQAM. Upon clicking the "Calculate" button, the system computes six key outputs. Firstly, it determines the number of bits per resource element based on the chosen modulation technique, calculated as the logarithm base 2 of the number of bits specific to that modulation scheme. Secondly, it calculates the number of subcarriers by dividing the bandwidth by the subcarrier spacing. Thirdly, it computes the number of bits per OFDM symbol by multiplying the bits per resource element by the number of subcarriers. Fourthly, the system determines the number of bits per OFDM resource block by multiplying the bits per OFDM symbol by the number of OFDM symbols per resource block. Fifthly, it calculates the maximum rate for one resource block by dividing the number of bits per OFDM resource block by the duration of each resource block. Finally, it computes the maximum rate for n resource blocks by multiplying the maximum rate for one resource block by n.

## Scenario 1

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Bandwidth

180

KHz

Subcarrier Spacing

15

KHz

OFDM Symbols per Resource Block

7

Duration of Each Resource Block

0.5

ms

Number of Assigned Parallel Resource Blocks

4

Calculate

Modulation Technique

1024-QAM

Number of bits per Resource Element

10

Number of Subcarriers

12.00

Number of bits per OFDM Symbol

120.00

Number of bits per OFDM Resource Block

840.00

Max Rate for One Resource Block

1680000.00 bps

Max Rate for Assigned Parallel Resource Blocks

6720000.00 bps

Users can select the unit for bandwidth (BW) and subcarrier spacing, choosing between Hz and kHz. Also, they can select the unit for the duration of each resource block from options including ms, sec, and microseconds ( $\mu$ s). All calculations are accurate and presented as previously described.

## Scenario 2

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Bandwidth

180

KHz

Error: Bandwidth must be divisible by subcarrier spacing without remainder.

Subcarrier Spacing

16

KHz

OFDM Symbols per Resource Block

7

Duration of Each Resource Block

0.5

ms

Number of Assigned Parallel Resource Blocks

4

Calculate

Modulation Technique

1024-QAM

Number of bits per Resource Element

Number of Subcarriers

Number of bits per OFDM Symbol

Number of bits per OFDM Resource Block

Max Rate for One Resource Block

Max Rate for Assigned Parallel Resource Blocks

As mentioned earlier, the number of subcarriers is determined by dividing the bandwidth (BW) by the subcarrier spacing. Therefore, users must enter values that divide evenly without any remainder, as the subcarrier spacing must be an integer and cannot accept floating-point numbers.

### Scenario 3

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Bandwidth  
180 KHz

Subcarrier Spacing  
15 KHz

OFDM Symbols per Resource Block  
7

Duration of Each Resource Block  
0.5 ms

Number of Assigned Parallel Resource Blocks  
5

Calculate

Modulation Technique  
256-QAM

Number of bits per Resource Element  
8

Number of Subcarriers  
12.00

Number of bits per OFDM Symbol  
96.00

Number of bits per OFDM Resource Block  
672.00

Max Rate for One Resource Block  
1344000.00 bps

Max Rate for Assigned Parallel Resource Blocks  
6720000.00 bps

In this scenario, the user selected the modulation technique 256-QAM and chose to use 5 parallel resource blocks instead of 4. The calculations are as follows: the number of bits per resource element is 8 bits (since  $\log_2 256 = 8$  bits); the number of subcarriers remains unchanged; the number of bits per OFDM symbol is 96 bits (8 bits per resource element multiplied by 12 subcarriers); the number of bits per OFDM resource block is 672 bits (96 bits per OFDM symbol multiplied by 7 OFDM symbols per resource block); the maximum rate for one resource block is 1,344,000 bps (672 bits per OFDM resource block divided by 0.5 ms duration); finally, the maximum rate for 5 resource blocks is 6,720,000 bps (1,344,000 bps multiplied by 5).



## Question Three

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Path Loss  
 dB

Antenna Feed Line Loss (Optional)  
 dB

Noise Temperature (K)

Frequency (Hz)

Other Losses (Optional)  
 dB

Link Margin  
 dB

Distance (m)

Fade Margin (Optional)  
 dB

Modulation Technique  
8PSK

Transmit Antenna Gain (Optional)  
 dB

Transmitter Amplifier Gain (Optional)  
 dB

Bit Rate Error Rate  
10<sup>-6</sup>

Receive Antenna Gain (Optional)  
 dB

Receiver Amplifier Gain (Optional)  
 dB

Data Rate (bps)

Noise Figure Total  
 dB

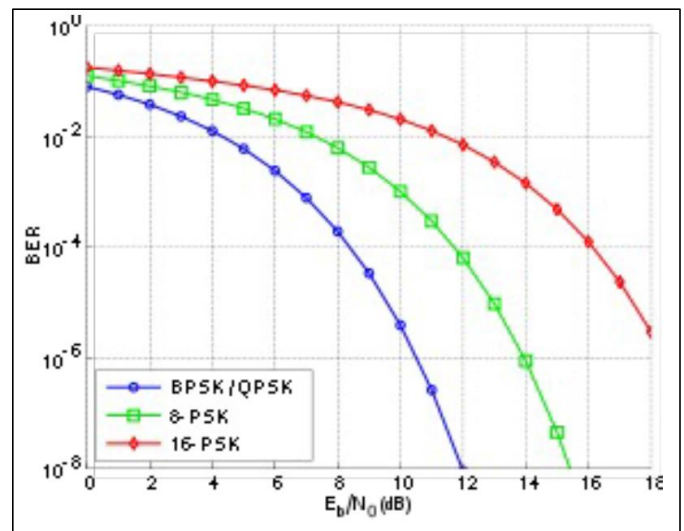
Power Transmitted  
 dBm

This calculator computes the transmitted power and displays it in three units: dB, dBm, and watt. The formula used is:

$$P_{t,dB} = K + T + N_{f,total} + R + (E_b/N_o)_{req} + L_p + L_f + L_o + F_{margin} + M - G_t - G_r - A_t - A_r$$

All values in this equation are in dB. The required  $(E_b/N_o)$  is calculated based on the modulation technique and the specified Bit Error Rate (BER) value intersection. Any gain or loss (except path loss) that is unspecified will be assumed to be 0 dB and not included in the calculation.

Also, if the user enters the path loss value, the fields for frequency and distance will be disabled. Conversely, if the user enters the frequency and distance, the path loss can be calculated from these inputs.



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Path Loss  
140 dB

Antenna Feed Line Loss (Optional)  
12 dB

Noise Temperature (K)  
290

Frequency (Hz)

Other Losses (Optional)  
20 dB

Link Margin  
8 dB

Distance (m)

Fade Margin (Optional)  
8 dB

Modulation Technique  
8PSK

Transmit Antenna Gain (Optional)  
8 dB

Transmitter Amplifier Gain (Optional)  
dB

Bit Rate Error Rate  
10<sup>-4</sup>

Receive Antenna Gain (Optional)  
0 dB

Receiver Amplifier Gain (Optional)  
24 dB

Data Rate (bps)  
9600

Noise Figure Total  
6 dB

Calculate

Power Transmitted  
9.84669 dB

In this scenario,  $(E_b/N_o)_{req} = 12$  which is the intersection between 8psk and  $10^{-4}$ .

$$P_{t,db} = K + T + N_{f,total} + R + (E_b/N_o)_{req} + L_p + L_f + L_o + F_{margin} + M - G_t - G_r - A_t - A_r$$

$$= -228.6 \text{ dB} + (10 \log_{10} 290 = 24.623 \text{ dB}) + 6 \text{ dB} + (10 \log_{10} 9.6 \text{ k} = 39.8 \text{ dB}) + 12 \text{ dB} + 140 \text{ dB} + 12 \text{ dB} + 20 \text{ dB} + 8 \text{ dB} + 8 \text{ dB} - 8 \text{ dB} - 0 - 0 - 24 \text{ dB}$$

## Scenario 2

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Path Loss  
140 dB

Antenna Feed Line Loss (Optional)  
12 dB

Noise Temperature (K)  
290

Frequency (Hz)

Other Losses (Optional)  
20 dB

Link Margin  
8 dB

Distance (m)

Fade Margin (Optional)  
8 dB

Modulation Technique  
16PSK

Transmit Antenna Gain (Optional)  
8 dB

Transmitter Amplifier Gain (Optional)  
dB

Bit Rate Error Rate  
10<sup>-4</sup>

Receive Antenna Gain (Optional)  
8 dB

Receiver Amplifier Gain (Optional)  
24 dB

Data Rate (bps)  
9600

Noise Figure Total  
6 dB

Calculate

Power Transmitted  
5.84669 dB

In this scenario, we have switched to 16PSK modulation with a BER of  $10^{-4}$ , resulting in an intersection value of 16 dB. Additionally, the receive antenna gain has been adjusted to 8 dB.

$$P_{t,db} = K + T + N_{f,total} + R + (E_b/N_o)_{req} + L_p + L_f + L_o + F_{margin} + M - G_t - G_r - A_t - A_r$$

$$= -228.6 \text{ dB} + (10 \log_{10} 290 = 24.623 \text{ dB}) + 6 \text{ dB} + (10 \log_{10} 9.6 \text{ k} = 39.8 \text{ dB}) + 16 \text{ dB} + 140 \text{ dB} + 12 \text{ dB} + 20 \text{ dB} + 8 \text{ dB} + 8 \text{ dB} - 8 \text{ dB} - 8 \text{ dB} - 0 - 24 \text{ dB}$$

### Scenario 3

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Path Loss
140
dB
Antenna Feed Line Loss (Optional)
12
dB
Noise Temperature (K)
290

Frequency (Hz)
Other Losses (Optional)
20
dB
Link Margin
8
dB

Distance (m)
Fade Margin (Optional)
8
dB
Modulation Technique
16PSK

Transmit Antenna Gain (Optional)
8
dB
Transmitter Amplifier Gain (Optional)
dB
Bit Rate Error Rate
 $10^{-8}$

Receive Antenna Gain (Optional)
dB
Receiver Amplifier Gain (Optional)
24
dB

Data Rate (bps)
9600
Noise Figure Total
6
dB

Calculate

Power Transmitted
17.84669
dB

In this scenario, we have switched to 16PSK modulation with a BER of  $10^{-8}$ , resulting in an intersection value of 20 dB, and the receive antenna gain has been adjusted to 0 Db again.

$$P_{t,db} = K + T + N_{f,total} + R + (E_b/N_o)_{req} + L_p + L_f + L_o + F_{margin} + M - G_t - G_r - A_t - A_r$$

$$= -228.6 \text{ dB} + (10 \log_{10} 290 = 24.623 \text{ dB}) + 6 \text{ dB} + (10 \log_{10} 9.6 \text{ k} = 39.8 \text{ dB}) + 20 \text{ dB} + 140 \text{ dB} + 12 \text{ dB} + 20 \text{ dB} + 8 \text{ dB} + 8 \text{ dB} - 8 \text{ dB} - 0 \text{ dB} - 0 - 24 \text{ dB}$$

## Question Four

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Data Transmission Bandwidth 'R' (bps)

Maximum Signal Propagation Time 't' (sec)

Frame Size 'bits'

Frame Rate 'fps'

Multiple Access Technique

ALOHA

Calculate

Throughput

In this calculator, users input several parameters including data transmission bandwidth (R), maximum signal propagation time (taw), frame size, frame rate, and select one of multiple access technique: ALOHA, SLOTTED ALOHA, UNSLOTTED NONPERSISTENT CSMA, SLOTTED NONPERSISTENT CSMA, UNSLOTTED 1-PERSISTENT CSMA, SLOTTED 1-PERSISTENT CSMA. Upon clicking the "Calculate" button, the system computes the throughput.

For example, to calculate the throughput using ALOHA,  $S_{th} = G e^{-2G}$

$G = gT$ ;  $g$  = frame rate,  $T$  = frame period

$T = T_b * \text{frame size}$

$\text{Alpha} = taw/T \rightarrow$  used in other multiple access techniques such as UNSLOTTED NONPERSISTENT CSMA

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Data Transmission Bandwidth 'R' (bps)

Maximum Signal Propagation Time 'τ' (sec)

Frame Size 'bits'

Frame Rate 'fps'

Multiple Access Technique  

Unslotted Nonpersistent CSMA ▾

Calculate

Throughput

The throughput of un-slotted non-persistent csma:

$$S_{th} = \frac{Ge^{-2\alpha T}}{G(1+2\alpha) + e^{-\alpha G}}$$

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Data Transmission Bandwidth 'R' (bps)

Maximum Signal Propagation Time 'τ' (sec)

Frame Size 'bits'

Frame Rate 'fps'

Multiple Access Technique  

ALOHA ▾

Calculate

Throughput

The throughput of aloha:

$$S_{th} = Ge^{-2G}$$

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Data Transmission Bandwidth 'R' (bps)

20000000

Maximum Signal Propagation Time 't' (sec)

0.00004

Frame Size 'bits'

10000

Frame Rate 'fps'

5000

Multiple Access Technique

Slotted ALOHA

Calculate

Throughput

0.20521

The throughput of un-slotted aloha:

$$S_{th} = Ge^{-G}$$

## Question Five

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Area of the City  
 m2

Number of Subscribers

Average Number of Calls per Day

Average Call Duration  
 h

Minimum SIR (dB)

Measured Power at Reference Distance  
 dB

Reference Distance (m)

Receiver Sensitivity  
 uW

Timeslots per Carrier

Path Loss Exponent  
2

Number of Co-Channel Interfering Cells  
1

Target Call Drop Probability  
0.2

Maximum Distance Between Transmitter and Receiver for Reliable Communication

Maximum Cell Size Assuming Hexagonal Cells

Number of Cells in The Service Area

Traffic Load in The Whole Cellular System in Erlangs

Traffic Load in Each Cell in Erlangs

Number of Cells in Each Cluster

Minimum Number of Carriers Needed in The Whole System

Calculate

In this calculator, users input various parameters such as the area of the city, number of subscribers, average number of calls per day, average call duration, minimum SIR, measured power at reference distance, reference distance, receiver sensitivity, timeslots per carrier, path loss exponent (values between 2-4), number of co-channel interfering cells (6, 2, or 1), and target call drop probability. When the “Calculate” button is clicked, the system computes seven key outputs.

Firstly, the Maximum Distance Between Transmitter and Receiver for Reliable Communication is calculated by multiplying the reference distance by  $(\text{measured power at that reference distance} / \text{receiver sensitivity in watt})^{1/\text{path loss exponent value}}$ .

Secondly, the Maximum Cell Size Assuming Hexagonal Cells is calculated using the formula:  $\frac{3\sqrt{3}}{2} R^2$  where R is derived from the first output.

Thirdly, the Number of Cells in The Service Area is determined by dividing the area by the cell size.

Fourthly, the Traffic Load in The Whole Cellular System in Erlangs (Au) is calculated by multiplying the average number of calls per hour by the average call duration in hours, and then calculating  $A = UAU$ , where u is the total number of subscribers.

Fifthly, the Traffic Load in Each Cell in Erlangs is obtained by dividing the Traffic Load in The Whole Cellular System in Erlangs by the number of cells.

Sixthly, the Signal to Interference Ratio (SIR) is calculated by  $\frac{1}{3}(\text{number of co-channel interfering cells} * 10^{SIR/10})^{1/2}$  / path loss exponent value.

Finally, the Minimum Number of Carriers Needed in the Whole System is determined using the Erlang B curve. The intersection between the probability of a call being blocked and the traffic intensity per cell gives the number of channels per cell. Dividing this number by the timeslots per carrier gives the number of carriers needed per cell. Multiplying this by the number of cells in the system gives the minimum number of carriers needed in the whole system.

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Area of the City  
 Km2

Number of Subscribers

Average Number of Calls per Day

Average Call Duration  
 m

Minimum SIR (dB)

Measured Power at Reference Distance  
 dB

Reference Distance (m)

Receiver Sensitivity  
 uW

Timeslots per Carrier

Path Loss Exponent

Number of Co-Channel Interfering Cells

Target Call Drop Probability

Maximum Distance Between Transmitter and Receiver for Reliable Communication

Maximum Cell Size Assuming Hexagonal Cells

Number of Cells in The Service Area

Traffic Load in The Whole Cellular System in Erlangs

Traffic Load in Each Cell in Erlangs

Number of Cells in Each Cluster

Minimum Number of Carriers Needed in the Whole System



## Scenario 2

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Area of the City  
4 Km2

Number of Subscribers  
80000

Average Number of Calls per Day  
8

Average Call Duration  
3 m

Minimum SIR (dB)  
16

Measured Power at Reference Distance  
-22 dB

Calculate

Reference Distance (m)  
10

Receiver Sensitivity  
7 uW

Timeslots per Carrier  
8

Path Loss Exponent  
3

Number of Co-Channel Interfering Cells  
6

Target Call Drop Probability  
0.02

Maximum Distance Between Transmitter and Receiver for Reliable Communication  
96.60 m

Maximum Cell Size Assuming Hexagonal Cells  
24243.01 m<sup>2</sup>

Number of Cells in The Service Area  
165 cell

Traffic Load in The Whole Cellular System in Erlangs  
1333.33

Traffic Load in Each Cell in Erlangs  
8.08

Number of Cells in Each Cluster  
13

Minimum Number of Carriers Needed in the Whole System  
330

In this scenario, we increase the SIR value to 16. This change primarily affects the number of cells in each cluster (N), which also increases as the SIR value goes up. An increased signal-to-noise ratio means reduced interference, which is achieved by adding more cells to each cluster, thereby increasing the distance between clusters.

## Scenario 3

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Area of the City  
4 Km2

Number of Subscribers  
80000

Average Number of Calls per Day  
8

Average Call Duration  
3 m

Minimum SIR (dB)  
13

Measured Power at Reference Distance  
-22 dB

Calculate

Reference Distance (m)  
10

Receiver Sensitivity  
7 uW

Timeslots per Carrier  
8

Path Loss Exponent  
4

Number of Co-Channel Interfering Cells  
6

Target Call Drop Probability  
0.02

Maximum Distance Between Transmitter and Receiver for Reliable Communication  
54.79 m

Maximum Cell Size Assuming Hexagonal Cells  
7800.15 m<sup>2</sup>

Number of Cells in The Service Area  
513 cell

Traffic Load in The Whole Cellular System in Erlangs  
1333.33

Traffic Load in Each Cell in Erlangs  
2.60

Number of Cells in Each Cluster  
4

Minimum Number of Carriers Needed in the Whole System  
513

In this scenario, increasing the path loss exponent from 3 to 4 impacts several outputs. The “Maximum Distance Between Transmitter and Receiver for Reliable Communication” decreases because the formula depends on the path loss exponent. So, the cell radius “distance Between Transmitter and Receiver” decreases since the signal attenuates more quickly, reducing the effective communication distance.

Also, the number of cells in each cluster decreases. This is because a higher path loss exponent means less interference between cells using the same frequencies, allowing for a smaller reuse factor ( $N$ ).