



**FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF COMPUTER ENGINEERING
Wireless and Mobile Networks - ENCS5323**

Project – Online Calculator for Wireless and Mobile Network

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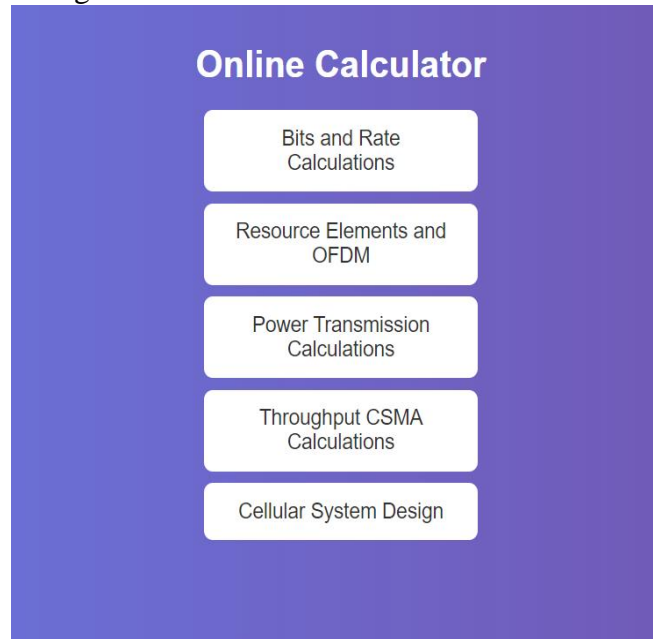
ID: 1200308

Instructor: Dr. Mohammad K. Jubran

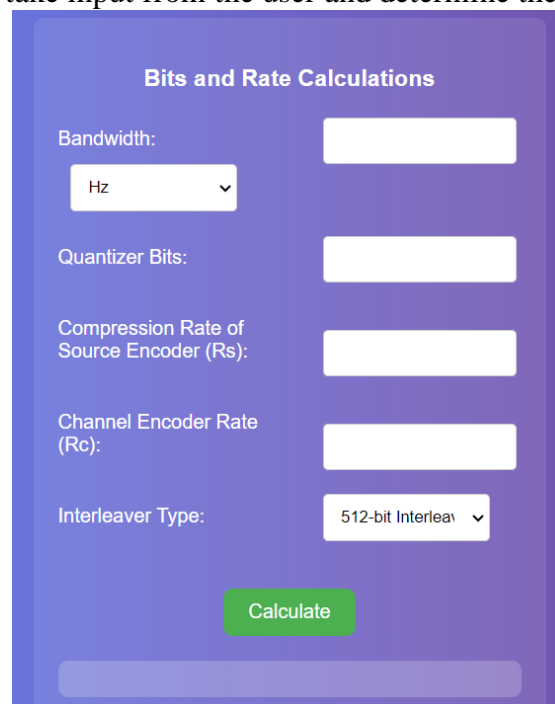
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The project aims to assist in various network calculations. It enables users to enter system characteristics to calculate bits and rates for various encoders, calculate resource components and OFDM parameters, analyze power transfer, evaluate throughput for multiple access modes, and design cellular networks. This website allows accurate calculations to know the infrastructure of wireless and mobile networks.

- The general design is built as follows:



- ❖ When click on **“Bits and Rate Calculations”** the screen appears as follow, which contains spaces to take input from the user and determine the bandwidth scale

The image shows a purple rectangular box with the title "Bits and Rate Calculations" at the top. Below the title, there are five input fields, each with a label and a corresponding input area. The labels are: "Bandwidth:", "Quantizer Bits:", "Compression Rate of Source Encoder (Rs):", "Channel Encoder Rate (Rc):", and "Interleaver Type:". The input areas are white rectangles. Below the input fields, there is a green button with the text "Calculate". At the bottom of the box, there is a long, thin, light purple horizontal bar.

The interface asks the user to enter the bandwidth, quantizer bits, compression rate of source encoder (R_s), a channel encoder a rate (R_c) and select the type of interleaver depends to number of bits and it print the results as it obvious in the figure above.

In this part, it uses the following steps and equation

1. Sampling frequency = $(2 * BW)$
2. The number of quantization levels = $2^{\text{quantizer bits}}$
3. The bit rate at the output of the source encoder:
 - Should calculate the input bits of the source encoder
 - = F_s (sampling frequency) * number of bits per sample
 - then find the output bits = the input bits * R_s
4. The bit rate at the output of the channel encoder
 - = the output bits of the source encoder / R_c
5. The bit rate at the output of the interleaver
 - = the same bits of the output of the channel encoder

In the first scenario, the values of the exam question entered to test and examine the system and found that it worked correctly and it actually gave the expected outputs as follow:

The screenshot shows a web interface titled "Bits and Rate Calculations" with a purple background. It contains several input fields and a "Calculate" button. Below the button, a box displays the calculated results.

Parameter	Value
Bandwidth	4 kHz
Quantizer Bits	8
Compression Rate of Source Encoder (R_s)	0.25
Channel Encoder Rate (R_c)	0.5
Interleaver Type	1024-bit Interleaver

Calculated Result	Value
Sampling Frequency	8.00 KHz
Number of Quantization Levels	256
Bit Rate at the Output of Source Encoder	16.00 Kbits/sec
Bit Rate at the Output of Channel Encoder	32.00 Kbits/sec
Bit Rate at the Output of Interleaver	32.00 Kbits/sec

The next scenario, the inputs entered with these values, and it gets the correct results as the figure below:

The screenshot shows a web form titled "Bits and Rate Calculations" with a purple gradient background. The form contains the following input fields and values:

- Bandwidth: 20
- Unit: MHz (selected from a dropdown)
- Quantizer Bits: 16
- Compression Rate of Source Encoder (Rs): 0.5
- Channel Encoder Rate (Rc): 0.8
- Interleaver Type: 1024-bit Interleaver (selected from a dropdown)

A green "Calculate" button is located below the input fields. Below the button, a light purple box displays the calculated results:

- Sampling Frequency: 40.00 MHz
- Number of Quantization Levels: 65,536
- Bit Rate at the Output of Source Encoder: 320.00 Mbits/sec
- Bit Rate at the Output of Channel Encoder: 400.00 Mbits/sec
- Bit Rate at the Output of Interleaver: 400.00 Mbits/sec

The last scenario, the inputs entered with these values, and it gets the correct results as the figure below:

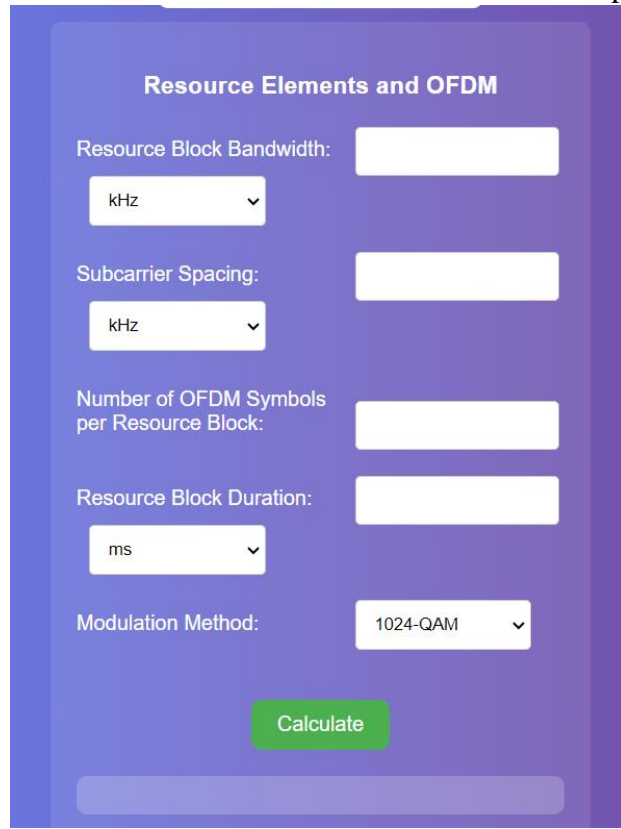
The screenshot shows the same "Bits and Rate Calculations" form with the following input fields and values:

- Bandwidth: 5
- Unit: MHz (selected from a dropdown)
- Quantizer Bits: 8
- Compression Rate of Source Encoder (Rs): 0.75
- Channel Encoder Rate (Rc): 0.9
- Interleaver Type: 2048-bit Interleaver (selected from a dropdown)

A green "Calculate" button is located below the input fields. Below the button, a light purple box displays the calculated results:

- Sampling Frequency: 10.00 MHz
- Number of Quantization Levels: 256
- Bit Rate at the Output of Source Encoder: 60.00 Mbits/sec
- Bit Rate at the Output of Channel Encoder: 66.67 Mbits/sec
- Bit Rate at the Output of Interleaver: 66.67 Mbits/sec

❖ When click on “**Resource Elements and OFDM**” the screen appears as follow:



The interface asks the user to enter the resource block bandwidth, the subcarrier spacing, number of OFDM symbols per resource block, each resource block duration and select modulation method (1024-QAM, 64-QAM, QPSK)

In this part, it uses the following steps and equation:

1. The number of bits per resource element = number of bits recording the modulation method
2. The number of bits per OFDM symbol = resource element * subcarrier

the subcarrier = $B.W / f$ (The subcarrier spacing)
3. The number of bits per OFDM resource block

= number of bits per OFDM symbol * symbols per resource block
4. The maximum transmission rate for the user when assigned a n parallel resource blocks continuously = $(n * \text{number of bits per OFDM resource block}) / \text{resource block duration}$

In the first scenario, the exam question values were entered to test, and it was discovered that it worked appropriately and produced the expected results, as seen below:

The screenshot shows a web-based calculator titled "Resource Elements and OFDM". It features several input fields with labels and units, a "Calculate" button, and a results section. The inputs are: Resource Block Bandwidth (180 kHz), Subcarrier Spacing (15 kHz), Number of OFDM Symbols per Resource Block (7), Resource Block Duration (0.5 ms), and Modulation Method (1024-QAM). The results displayed are: Bits per Resource Element: 10 bits, Subcarriers: 12.00, Bits per OFDM Symbol: 120.00 bits, Bits per OFDM Resource Block: 840.00 bits, and Max Transmission Rate: 1.68 Mbits/sec.

Parameter	Value
Resource Block Bandwidth	180 kHz
Subcarrier Spacing	15 kHz
Number of OFDM Symbols per Resource Block	7
Resource Block Duration	0.5 ms
Modulation Method	1024-QAM
Bits per Resource Element	10 bits
Subcarriers	12.00
Bits per OFDM Symbol	120.00 bits
Bits per OFDM Resource Block	840.00 bits
Max Transmission Rate	1.68 Mbits/sec

The second scenario, the inputs are filled in with these values, and the right results are obtained as shown in the picture below:

The screenshot shows the same "Resource Elements and OFDM" calculator interface, but with different input values. The inputs are: Resource Block Bandwidth (360 kHz), Subcarrier Spacing (30 kHz), Number of OFDM Symbols per Resource Block (7), Resource Block Duration (0.5 ms), and Modulation Method (64-QAM). The results displayed are: Bits per Resource Element: 6 bits, Subcarriers: 12.00, Bits per OFDM Symbol: 72.00 bits, Bits per OFDM Resource Block: 504.00 bits, and Max Transmission Rate: 1.01 Mbits/sec.

Parameter	Value
Resource Block Bandwidth	360 kHz
Subcarrier Spacing	30 kHz
Number of OFDM Symbols per Resource Block	7
Resource Block Duration	0.5 ms
Modulation Method	64-QAM
Bits per Resource Element	6 bits
Subcarriers	12.00
Bits per OFDM Symbol	72.00 bits
Bits per OFDM Resource Block	504.00 bits
Max Transmission Rate	1.01 Mbits/sec

The third scenario, two numbers whose division result is not a integer was entered, and this is not within the logic of the solution so a warning appears as the figure below:

The image shows a warning dialog box with the text: "Invalid input: Resource Block Bandwidth must be an integer multiple of Subcarrier Spacing." and an "OK" button. Below the dialog is the "Resource Elements and OFDM" form. It has two input fields: "Resource Block Bandwidth" with the value "180" and a unit dropdown set to "kHz", and "Subcarrier Spacing" with the value "14" and a unit dropdown set to "kHz".

❖ When click on **“Power Transmission Calculations”** the screen appears as follow:

The image shows the "Power Transmission Calculations" form. It is divided into two columns. The left column contains: "Path Loss (Lp):" (input field), "dB" (dropdown), "Transmit Antenna Gain (Gt):" (input field), "dB" (dropdown), "Receive Antenna Gain (Gr):" (input field), "dB" (dropdown), "Data Rate (R):" (input field), "bps" (dropdown), "Antenna Feed Line Loss (Lf):" (input field), "dB" (dropdown), and "Other Losses (Lo):" (input field), "dB" (dropdown). The right column contains: "Receiver Amplifier Gain (At):" (input field, Default: 0), "dB" (dropdown), "Receiver Amplifier Gain (Ar):" (input field, Default: 0), "dB" (dropdown), "Noise Figure Total (Nf,total):" (input field), "dB" (dropdown), "Noise Temperature (T):" (input field), "Link Margin (M):" (input field), "dB" (dropdown), "Modulation Method:" (input field, 1024-QAM), and "Maximum Bit Error Rate:" (input field, 10^-1). A green "Calculate" button is at the bottom right.

The interface asks the user to enter the path loss, frequency, transmit antenna gain, receive antenna gain, data rate, antenna feed line loss, other losses, a fade margin, receiver amplifier gain, receiver amplifier gain, noise figure total, a noise temperature, link margin, maximum bit error rate and the select modulation method (1024-QAM or 64-QAM or QPSK).

It is calculating the total transmit power required of modulated signal with the maximum bit error rate as follow:

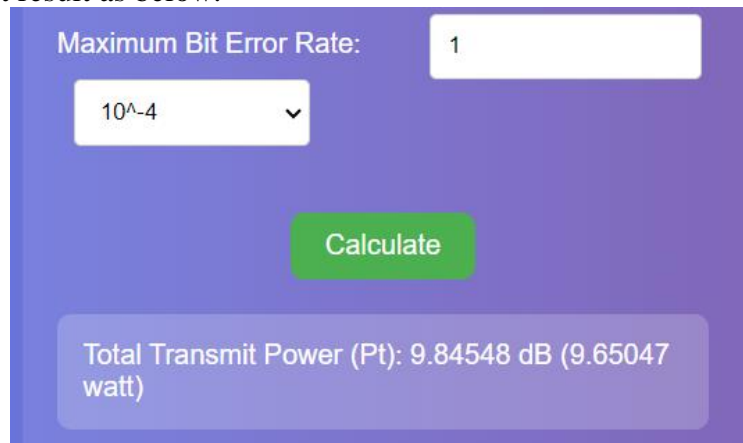
Use equation: $P_r = P_t + G_t + G_r + A_t + A_r - L_p - L_f - L_o - F \text{ margin}$

To find P_t it finds P_r first, from the equation which represent by M.

And the (E_b/N_o) value it determinate from table which that includes the data after entered them from the graph, regarding the modulation method and the numbers at the both axes.

The exam scenario, $L_p = 140$ dB, $G_t = 8$ dB and $G_r = 0$ dB, $R = 9.6$ kbps, $L_f = 12$ dB, $L_o = 20$ dB, a F margin = 8 dB, $A_r = 24$ dB, $N_{f,total} = 6$ dB, $T = 290$, and $M = 8$ dB and 8- PSK modulated signal with a maximum bit error rate of 10^{-4} .

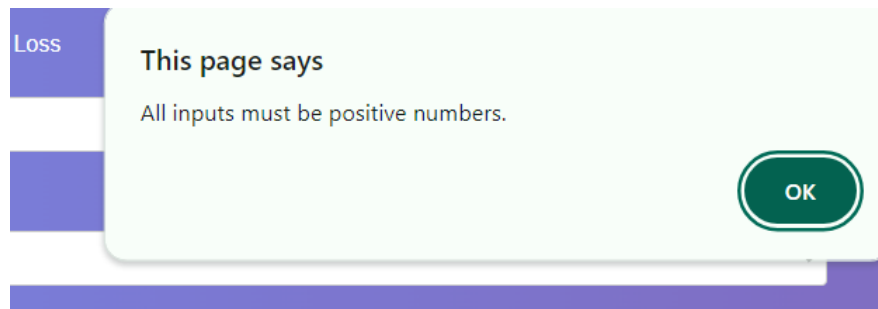
And got the correct result as below:



Maximum Bit Error Rate:
 ▾

Total Transmit Power (Pt): 9.84548 dB (9.65047 watt)

In other scenario, when enter the path loss a minus number, it gives an error as follow:

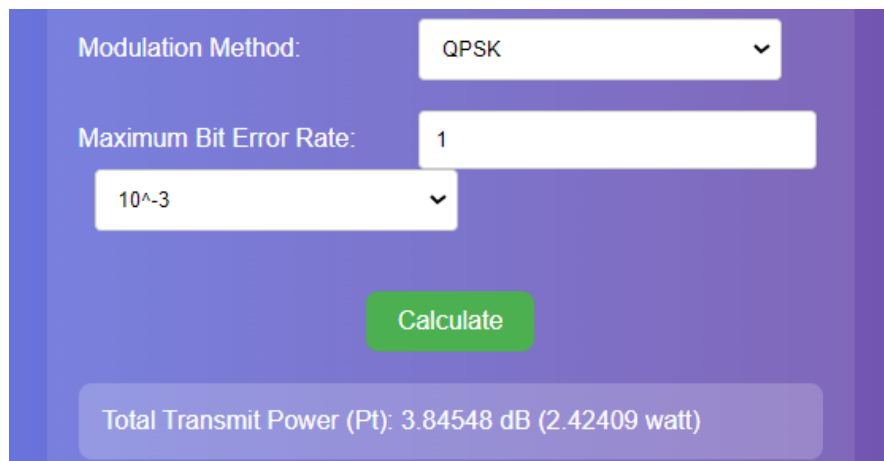


Loss

This page says

All inputs must be positive numbers.

In the last scenario, the values changed to $L_p = 140$ dB, $G_t = 10$ dB, $G_r = 0$ dB, $R = 9.6$ kbps, $L_f = 12$ dB, $L_o = 20$ dB, F margin = 8 dB, $A_t = 24$ dB, $A_r = 0$ dB, $N_{f,total} = 6$ dB, $T = 290$ K, and $M = 8$ dB and QPSK modulated signal with a maximum bit error rate of 10^{-3} .



Modulation Method: ▾

Maximum Bit Error Rate:
 ▾

Total Transmit Power (Pt): 3.84548 dB (2.42409 watt)

❖ When click on “Throughput CSMA Calculations” the screen appears as follow:

The screenshot shows a web interface titled "Throughput CSMA Calculations". It contains the following fields and controls:

- Data Transmission Bandwidth (B.W):** A text input field with a dropdown menu currently set to "bps".
- CSMA Method:** A dropdown menu currently set to "Unslotted Nonpersistent CSMA".
- Maximum Signal Propagation Time (τ):** A text input field with a dropdown menu currently set to "s".
- Frame Size:** A text input field with a dropdown menu currently set to "bits".
- Frame Rate (g):** A text input field with a dropdown menu currently set to "frames/sec".
- Calculate:** A green button.
- Throughput:** A light blue bar at the bottom, currently empty.

The interface asks the user to enter the data transmission bandwidth, the maximum signal propagation time from one node to another (τ), frames size, frame rate (g) and select which CSMA method that used in the MAC layer

Then it determines the throughput in percent by the following equations:

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

$$T_b = 1 / B.W$$

$$G = g * T$$

$$\alpha = \tau / T$$

then apply all of these in the appropriate rule for S depending on the method chosen.

The exam scenario, was tested and the system give a correct exact output as follow:

This screenshot shows the same interface as the previous one, but with numerical values entered and the result displayed:

- Data Transmission Bandwidth (B.W):** 20 (Mbps)
- CSMA Method:** Unslotted Nonpersistent CSMA
- Maximum Signal Propagation Time (τ):** 40 (us)
- Frame Size:** 10 (kbits)
- Frame Rate (g):** 5 (kframes/sec)
- Calculate:** Button
- Throughput:** 67.22%

The second scenario, the inputs are filled in with these values, and the correct throughput value are obtained as shown in the picture below:

Throughput CSMA Calculations

Data Transmission Bandwidth (B.W):
Mbps

CSMA Method:

Maximum Signal Propagation Time (τ):
ms

Frame Size:
bits

Frame Rate (g):
frames/sec

Throughput: 29.63%

In the third case, the inputs are filled with these values using Slotted 1-persistent CSMA, and the right throughput value is produced, as seen in the figure below:

Throughput CSMA Calculations

Data Transmission Bandwidth (B.W):
Mbps

CSMA Method:

Maximum Signal Propagation Time (τ):
ns

Frame Size:
kbits

Frame Rate (g):
frames/sec

Throughput: 2.00%

❖ When click on “Cellular System Design” the screen appears as follow:

It takes from the user the timeslots per carrier, the area of the city, the number of subscribers, the average of calls per unit time (λ), the average call duration (H), a call drop probability that the quality of service (GOS) for Erlang B and the minimum SIR needed to correctly provide the service (SIR), the measured power, the reference distance, base stations the path loss exponent and receiver sensitivity.

It uses this equation to find d
$$P_r = P_0 \left(\frac{d}{d_0} \right)^{-n}$$

Then use cell size
$$\frac{3\sqrt{3}}{2} (R^2)$$

The number of cells = The area of the city / cell size
take it an integer

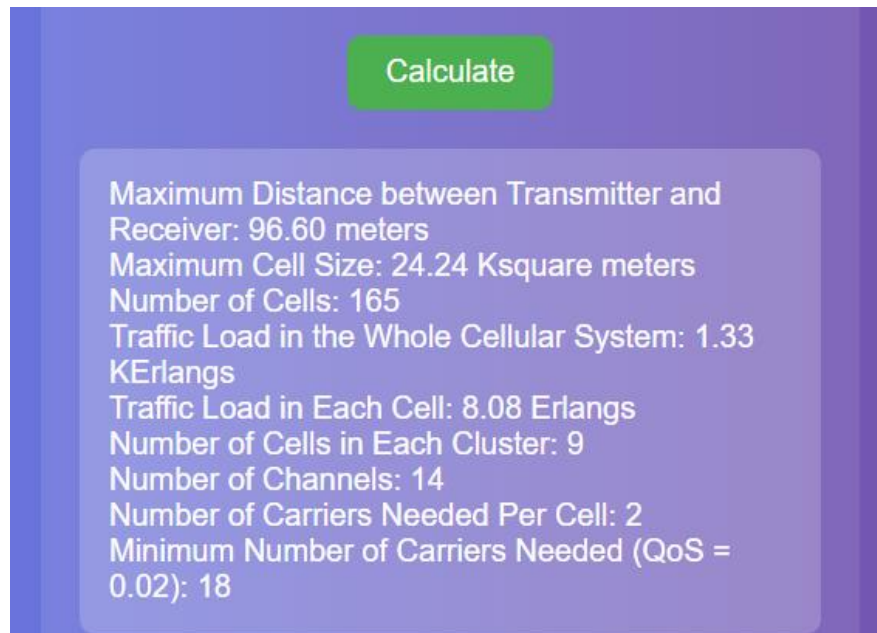
Then calculate traffic load in whole cellular = $U * \lambda * H$
Acell = the total traffic load / number of cells

Then apply SIR equation
$$\Rightarrow \text{SIR} = \frac{(\sqrt{3N})^n}{N_b} = \frac{Q^n}{N_b}$$

Then from its equation and N_b already known (6), it finds N and it should round the resulting number to the closest possible number that includes this number or is greater of the possible values of N (1, 3, 4, 7, 9, 12, 13, 16, 19, 21, 28).

The sheet scenario, was tested, and the system gave the identical output as follows:

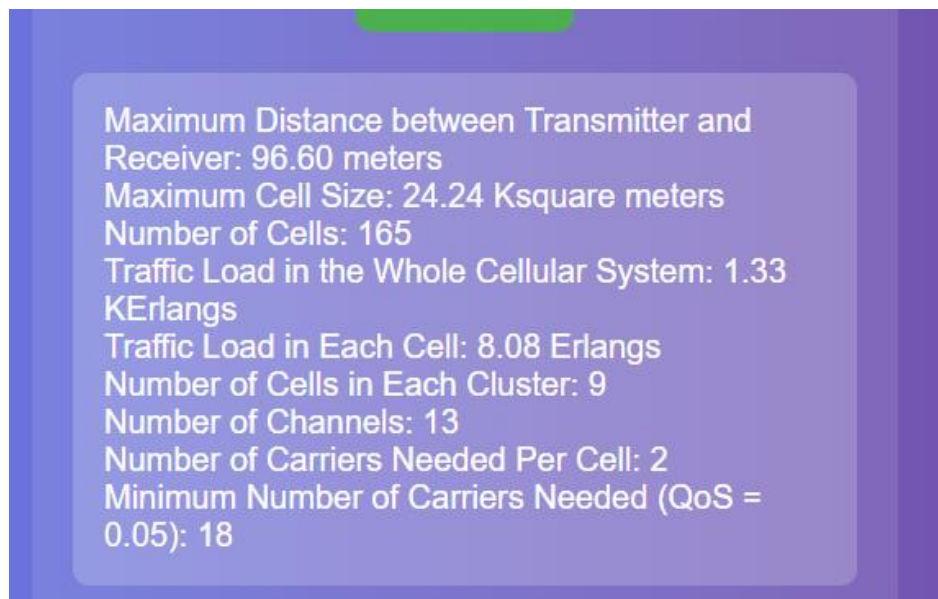
- When the Call Drop Probability (GoS) for Erlang B = 0.02:



A screenshot of a software interface with a purple background. At the top center is a green button labeled "Calculate". Below it, a white rounded rectangle contains the following text:

Maximum Distance between Transmitter and Receiver: 96.60 meters
Maximum Cell Size: 24.24 Ksquare meters
Number of Cells: 165
Traffic Load in the Whole Cellular System: 1.33 KErlangs
Traffic Load in Each Cell: 8.08 Erlangs
Number of Cells in Each Cluster: 9
Number of Channels: 14
Number of Carriers Needed Per Cell: 2
Minimum Number of Carriers Needed (QoS = 0.02): 18

- When the Call Drop Probability (GoS) for Erlang B = 0.05:



A screenshot of a software interface with a purple background. At the top center is a green button. Below it, a white rounded rectangle contains the following text:

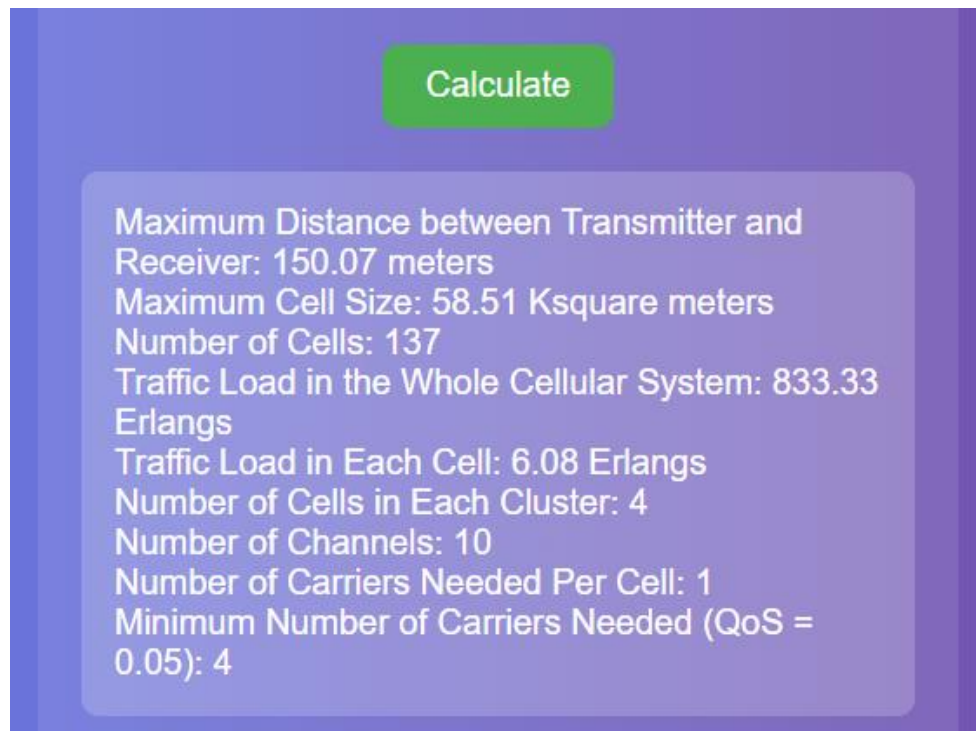
Maximum Distance between Transmitter and Receiver: 96.60 meters
Maximum Cell Size: 24.24 Ksquare meters
Number of Cells: 165
Traffic Load in the Whole Cellular System: 1.33 KErlangs
Traffic Load in Each Cell: 8.08 Erlangs
Number of Cells in Each Cluster: 9
Number of Channels: 13
Number of Carriers Needed Per Cell: 2
Minimum Number of Carriers Needed (QoS = 0.05): 18

There is different in the number of channels but when calculate the number of carriers and round them; they are equal.

In another scenario, the inputs entered as follow:

- Number of Timeslots per Carrier: 10
- Area of the City: 8 km²
- Number of Subscribers (U): 120 thousand
- Average Number of Calls per Unit Time (λ): 5 per Day
- Average Call Duration (H): 2 mins
- Call Drop Probability (GoS) for Erlang B: 0.01
- Minimum SIR: 15 dB
- Measured Power at Reference Distance (P0): -18 dB
- Reference Distance (d0): 20 meters
- Path Loss Exponent (n): 4
- Receiver Sensitivity: 5 μ watt

And the system gives a correct and logical answers as shown below:



The screenshot shows a green 'Calculate' button at the top. Below it, a list of calculated values is displayed in a light blue box with a dark blue border. The values are:

- Maximum Distance between Transmitter and Receiver: 150.07 meters
- Maximum Cell Size: 58.51 Ksquare meters
- Number of Cells: 137
- Traffic Load in the Whole Cellular System: 833.33 Erlangs
- Traffic Load in Each Cell: 6.08 Erlangs
- Number of Cells in Each Cluster: 4
- Number of Channels: 10
- Number of Carriers Needed Per Cell: 1
- Minimum Number of Carriers Needed (QoS = 0.05): 4

▪ Note:

To find all details about the call drop probability (GOS), the table entered as array and the system search in the data specific to the selected probability from user. And when it finds the closest number that includes number (Ac), here it finds number of channels.

Then it finds the number of carriers needed per cell = number of channels / timeslots per carrier

Finally, the number of carriers the whole system is = the number of carriers needed per cell * N