4G LTE and 5G mmWave Model Simulation Program

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What, Why and How?

- ## What?

  Developed a Simulation Program That Accurately and Quickly Predicts Coverage
  - mmWave and Microwave Frequencies
  - Accounts for Blocking (Building Walls) and Shadowing

- ## Why?

  5G Networks Will be Characterized by Diverse Access Technologies, e.g., Both Traditional Microwave and Newer mmWave Access Points. A Simple GUI-Based Tool to Predict Coverage Would be Useful for Network Planning

- ## How?

  Python-Based GUI to Avoid Need for a MATLAB License or Complicated NS3 Installations/Programming
  - Based on the Latest Technical Report 3GPP TR 38.901 Version 15.0.0 Release 15 (2018-07)
  - Covers Broad Frequency Range of 0.5-100 GHz and Models Propagation Effects Such as Path Loss, Shadowing and Wall Penetration

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What Can You Do?

- Choose an Environment (e.g., Rural, Urban)
- Choose the Size of the Environment to be Analyzed
- Insert Buildings at Chosen Location, of Different Sizes
- Insert Base Stations/Access Points; Specify
  - Center Frequency (0.5-100 GHz)
  - Bandwidth
  - Transmit Powers
  - Height
- View Coverage
  - Total Power in dBm (Sum of All Received Powers)
  - and/or SINR Heat Map (in dB)
  - Specify Granularity of the Simulation

Example 1 – Microwave Frequency Conditions

- **Environment**: Rural
- **Bandwidth**: 500 [MHz]
- **Size of the Grid**: 200 by 200 [m]
- **Accuracy (Length of Each Block):** 10 [m]
- **Obstacle1:**
  Center Location: (60,60)
  Length: 40 [m]
- **Obstacle2:**
  Center Location: (-80,-80)
  Length: 20 [m]
- **Height of Receiver:** 1.5[m]
- **BS1:**
  Power: 30.0 [dBm]
  Center Frequency: 6.0 [GHz]
  Location: (-80,80)
  Height: 35.0 [m]
- **BS2:**
  Power: 30.0 [dBm]
  Center Frequency: 6.0 [GHz]
  Location: (80,-80)
  Height: 35.0 [m]

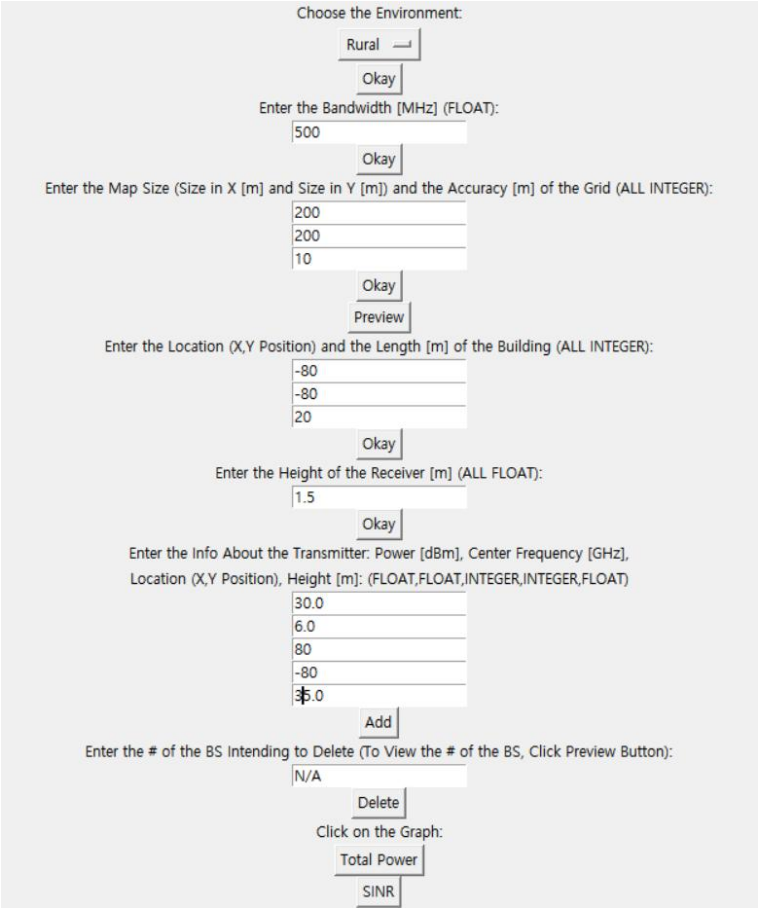

Figure 1. GUI With Conditions Entered

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Example 1 – Microwave Frequency Results

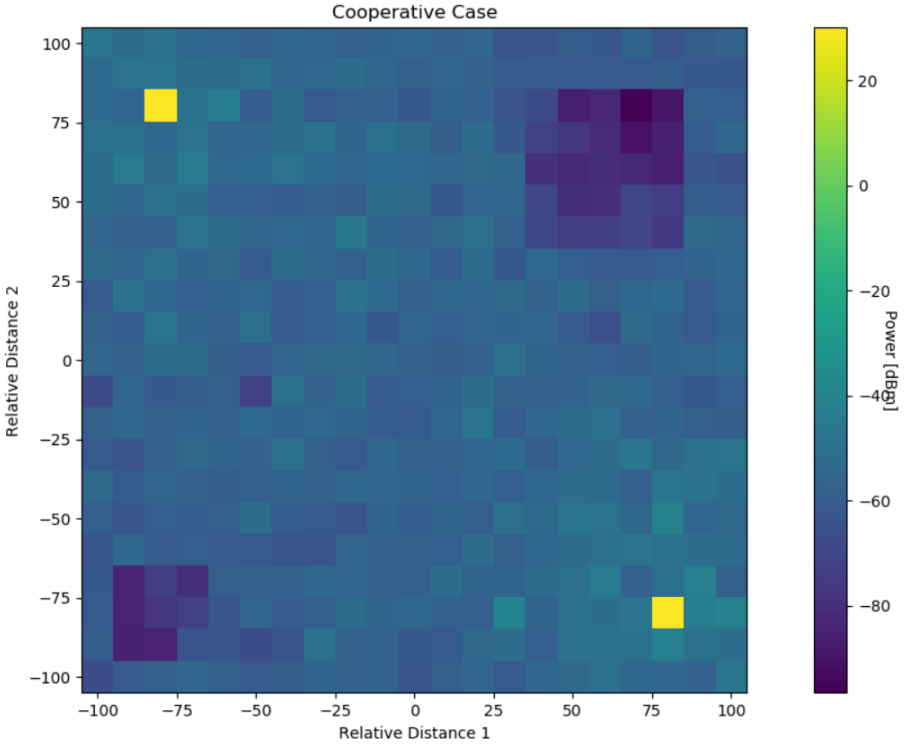

Figure 2. Cooperative Heat Map

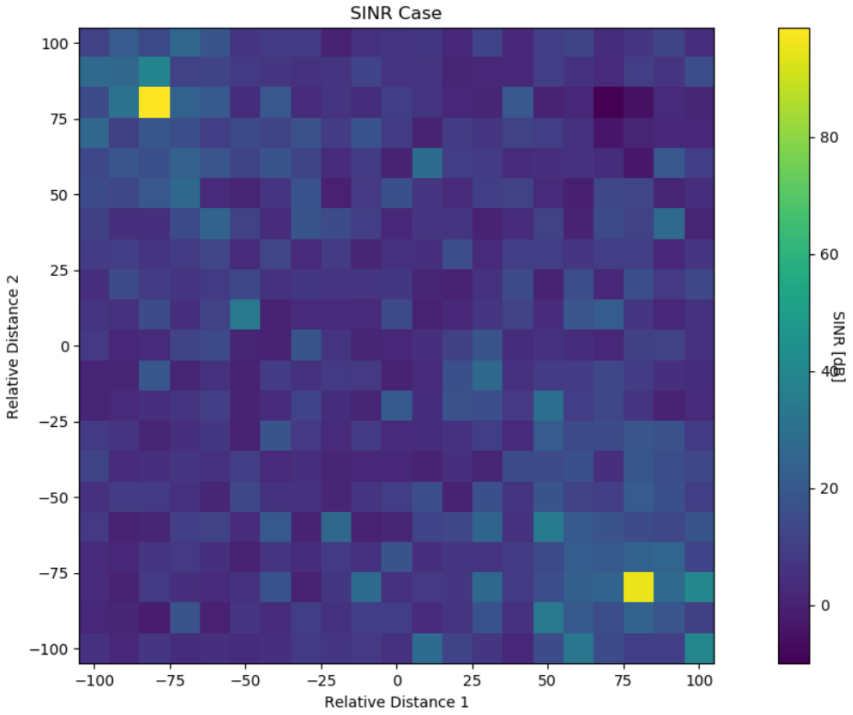

Figure 3. SINR Heat Map

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Example 2 – mmWave Frequency Conditions

- **Environment**: Urban
- **Bandwidth**: 2000 [MHz]
- **Size of the Grid:** 200 by 200 [m]
- **Accuracy (Length of Each Block):** 10 [m]
- **Obstacle1:**
  Center Location: (60,60)
  Length: 40 [m]
- **Obstacle2:**
  Center Location: (-80,-80)
  Length: 20 [m]
- **Obstacle3:**
  Center Location: (0,80)
  Length: 20 [m]
- **Obstacle4:**
  Center Location: (0,-80)
  Length: 20 [m]
- **Height of Receiver:** 1.5 [m]
- **BS1:**
  Power: 30.0 [dBm]
  Center Frequency: 28.0 [GHz]
  Location: (-80,80)
  Height: 35.0 [m]
- **BS2:**
  Power: 30.0 [dBm]
  Center Frequency: 28.0 [GHz]
  Location: (80,-80)
  Height: 35.0 [m]

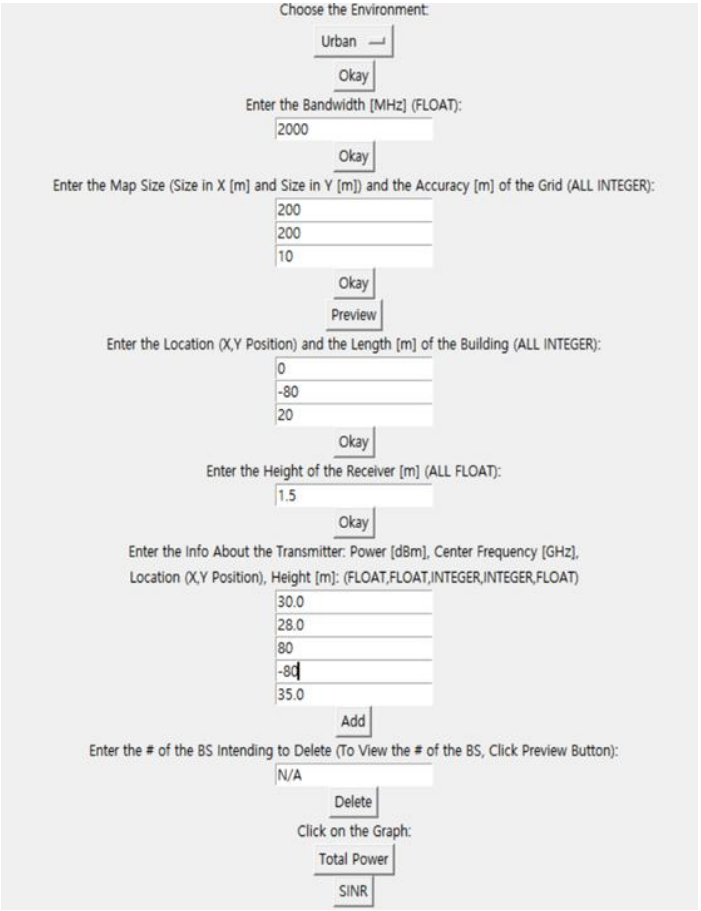

Figure 4. GUI With Conditions Entered

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Example 2 – mmWave Frequency Results

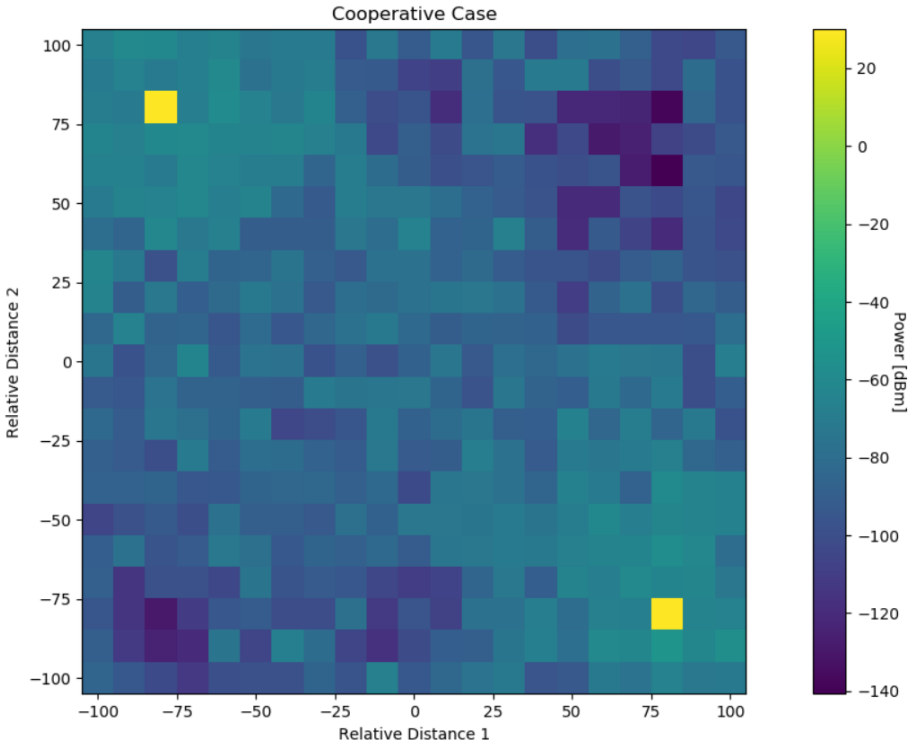

Figure 5. Cooperative Heat Map

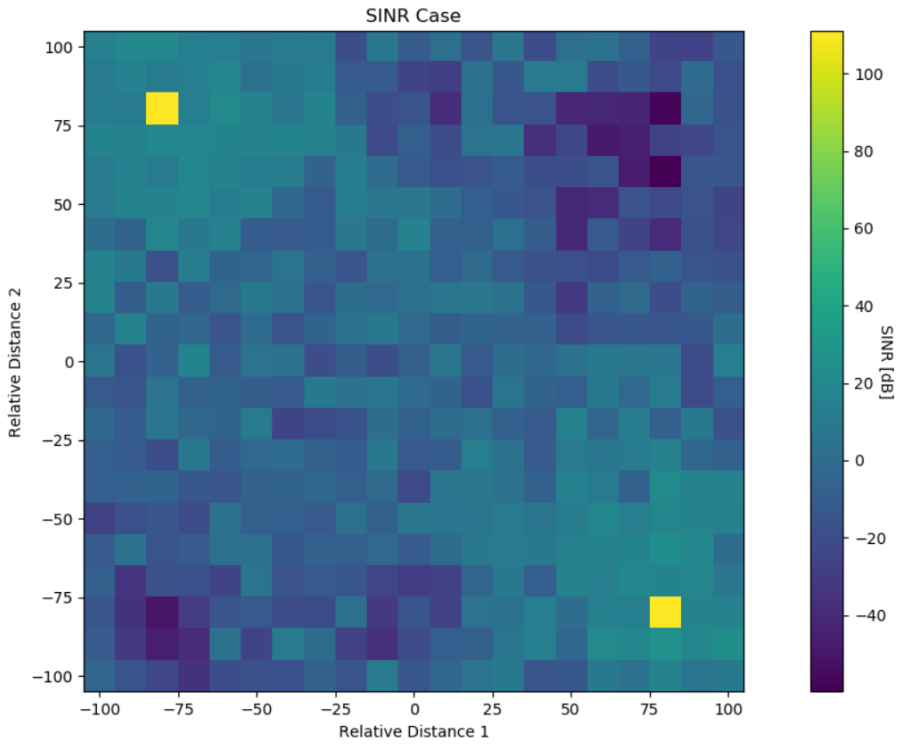

Figure 6. SINR Heat Map

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Example 3 – Microwave/mmWave Frequencies Conditions:

- **Environment**: Urban
- **Bandwidth**: 2000 [MHz]
- **Size of the Grid:** 200 by 200 [m]
- **Accuracy (Length of Each Block):** 10 [m]
- **Obstacle1:**
  Center Location: (0,60)
  Length: 40 [m]
- **Obstacle2:**
  Center Location: (0,0)
  Length: 20 [m]
- **Obstacle3:**
  Center Location: (0,-60)
  Length: 40 [m]
- **Height of Receiver:** 1.5 [m]
- **BS1:**
  Power: 30.0 [dBm]
  Center Frequency: 6.0 [GHz]
  Location: (-80,0)
  Height: 35.0 [m]
- **BS2:**
  Power: 30.0 [dBm]
  Center Frequency: 6.0 [GHz]
  Location: (80,40)
  Height: 35.0 [m]
- **BS3:**
  Power: 30.0 [dBm]
  Center Frequency: 28.0 [GHz]
  Location: (50,-40)
  Height: 5.0 [m]

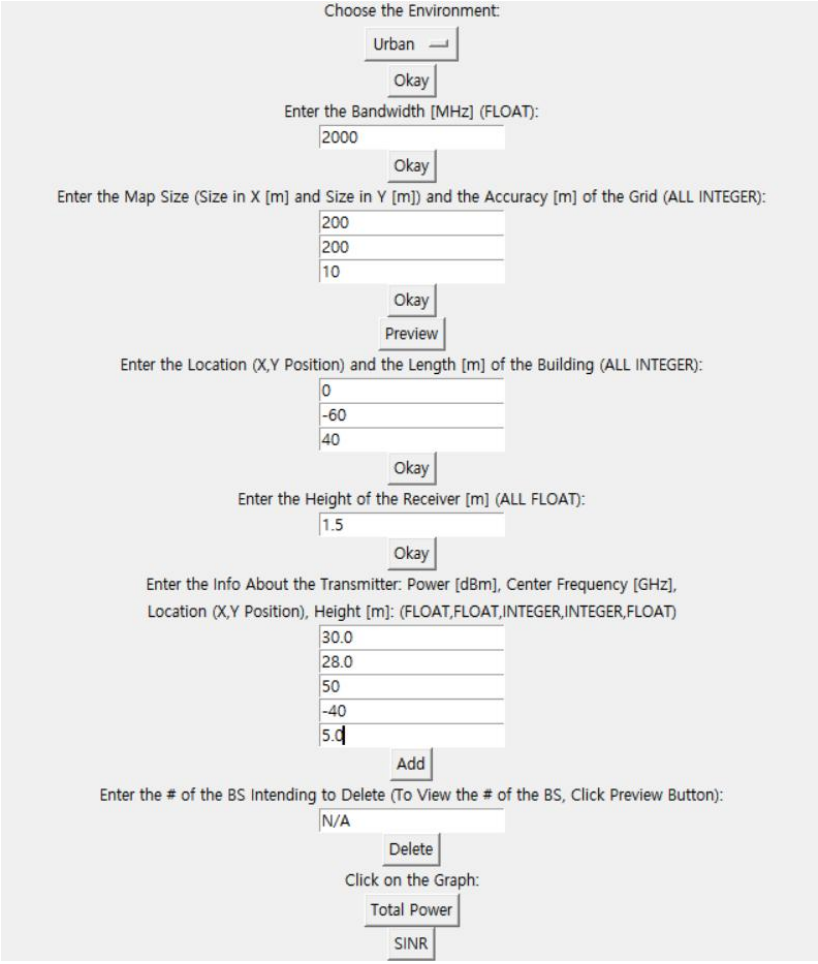

Figure 7. GUI With Conditions Entered

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Example 3 – Microwave/mmWave Frequencies Results:

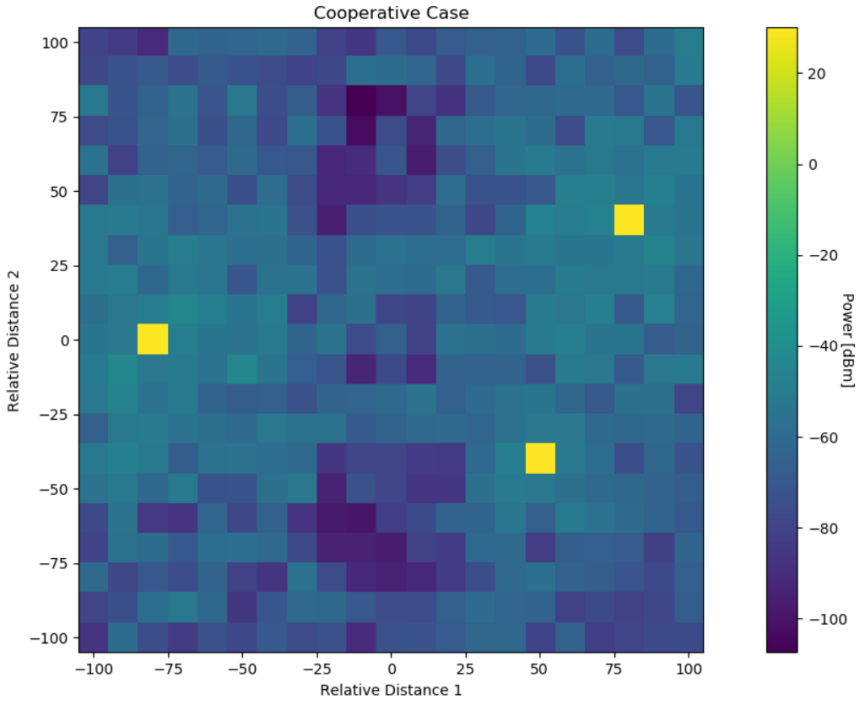

Figure 8. Cooperative Heat Map

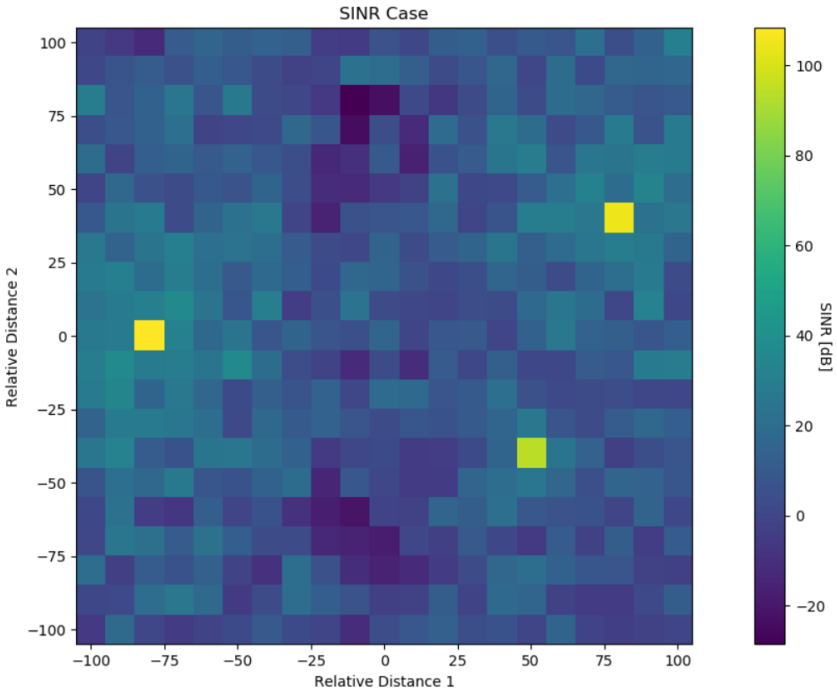

Figure 9. SINR Heat Map

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What are the Challenges?

- **Accuracy**

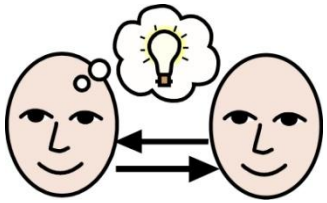
  How to Produce Results That Correlate With Real World Outcomes?

- **Speed**

  How to Implement a Time-Efficient Simulator?

- **Ease of Use**

  How to Make the User Interference Easy and Intuitive?



Solutions – Accuracy/Speed

- Accuracy: Carefully Consider All Possible Propagation Paths
  - Especially When Buildings are in the Simulation
  - We Have Outdoor-to-Indoor and Outdoor-to-Outdoor, But Past Walls to Consider
- Speed: Calculate Power on a Grid Only
  - e.g., on a 20 x 20 [m] Map With Grid Block Length of 10 [m], Calculate Power Only on (-10,10), (-10,0), (-10,-10), (0,10),…

Solution – Ease of Use

- Use Graphical User Interface (GUI)
- Instructions:

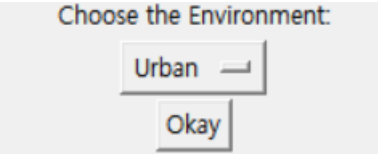
1. 

Fig. 11 UI for Choosing Environment

Click the Button and Choose the Environment: Rural or Urban.

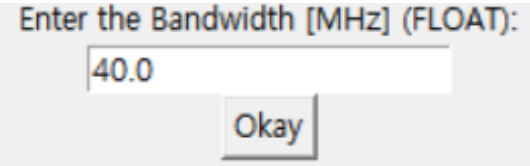
2. 

Fig. 12 UI for Choosing Bandwidth

Enter the Total Bandwidth Being Used in GHz.

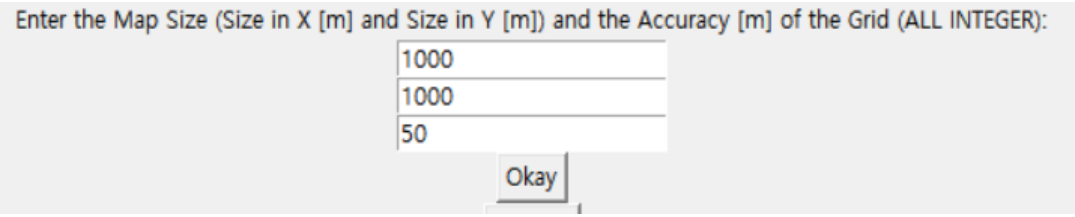
3. 

Fig. 13 UI for Choosing the Size of the Map and Viewing the Preview of the Map

Enter the Dimensions of the Map: (Length in X) x (Length in Y) [m]. Also Enter the Length of Each Block [m]. User Can Click on "Preview" to View the Grid of the Map and See the Locations of the Existing Obstacles and Base Stations.

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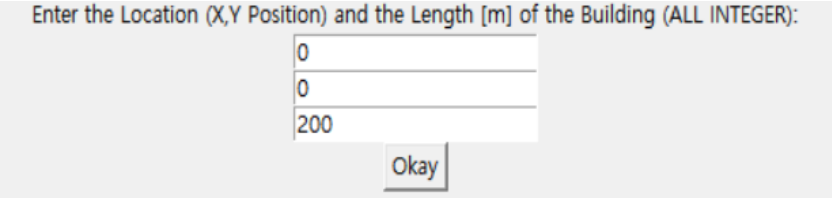
Solution – Ease of Use Continued

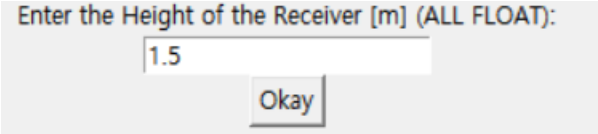
4.



Enter the Center X,Y location and the Length of Each Side [m] of the Building. If the User Wants to Add Multiple Buildings, Press "Okay" Every Time the Information of Each Building is Saved.

Fig. 14 UI for Choosing Building

5.



Enter the Height [m] of the Receiver.

Fig. 15 UI for Choosing Height of the Receiver

6.

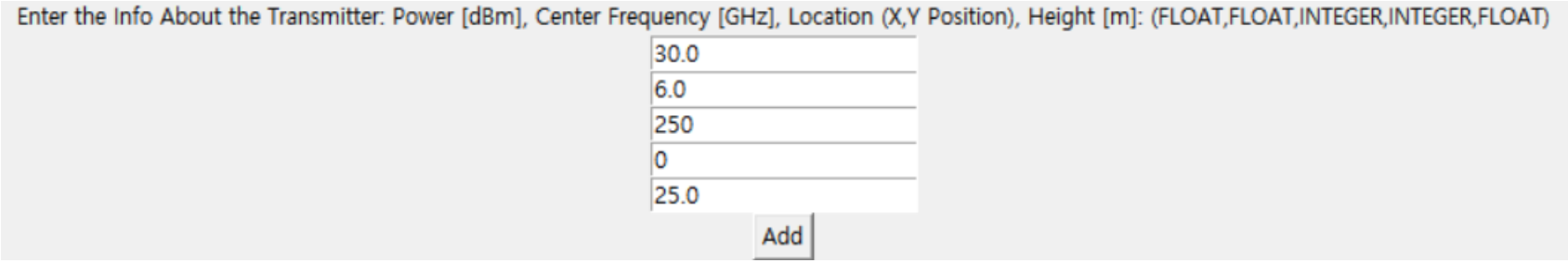


Fig. 16 UI for Adding Base Station(s)

Enter the Information About the Base Station: Transmitted Power [dBm], Center Frequency [GHz], X,Y Location and Height [m]. If the User Wants to Add Multiple Base Stations, Press "Add" Every Time After Entering This Information and the BS Parameters are Saved.

Solution – Ease of Use Continued

7.

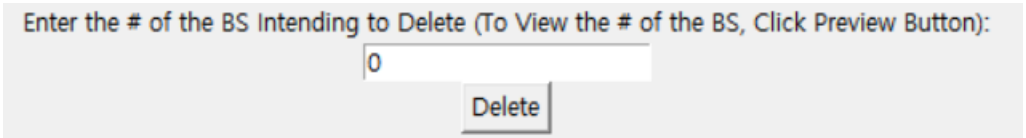


Fig. 17 UI for Removing Base Station(s)

If the User Wishes to Delete a Base Station, This Can be Done by Entering the Number Here. The BS Number Can be Obtained by Clicking on "Preview".

Simple Demo Using Example 3 From Slides 8-9:

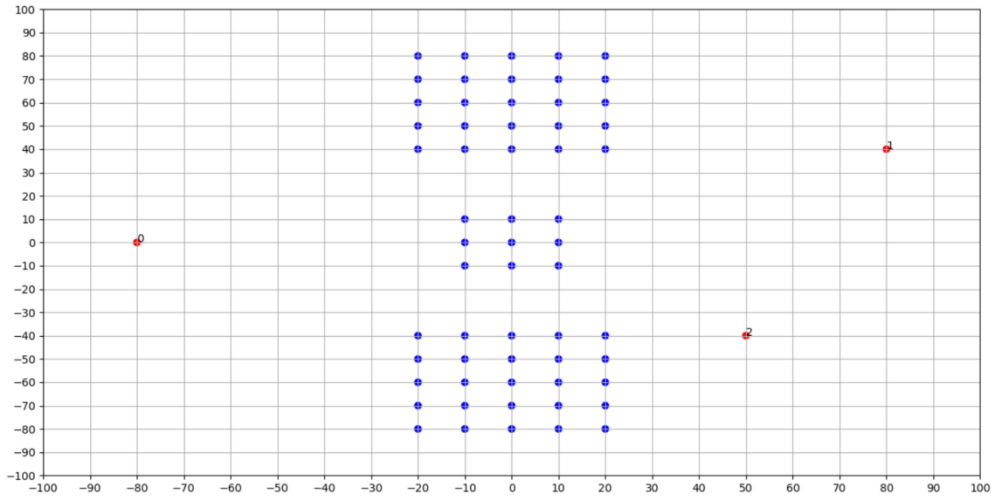


Fig. 18 Preview of the Map for Example 3

1. Preview of the Map Before a Base Station is Removed.

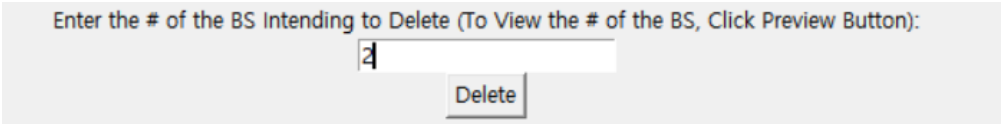


Fig. 19 UI for Removing Base Station(s); Intending to Remove Base Station #2

2. Entering "2" to Remove Base Station #2.

Solution – Ease of Use Continued

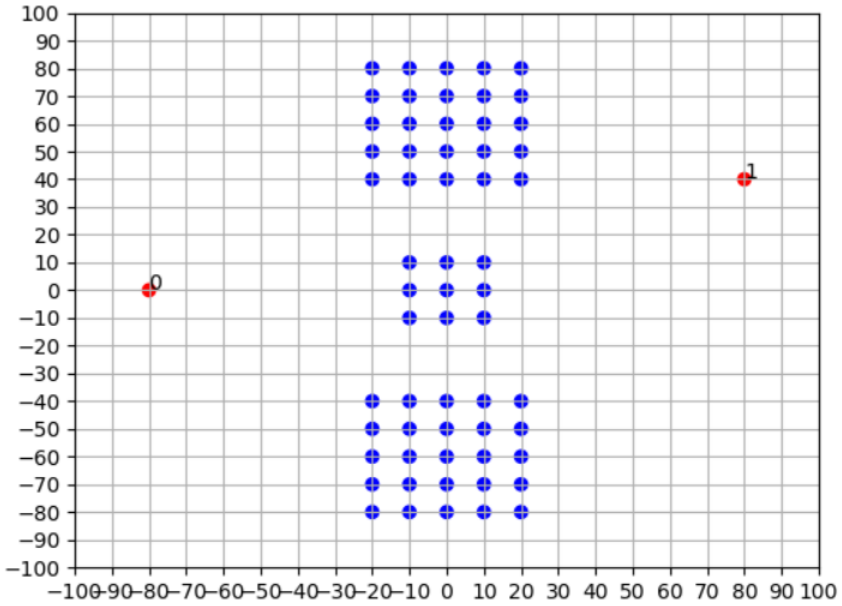


Fig. 20 Preview of the Map After Deletion of Base Station #2

3. Preview of the Map After Base Station #2 Has Been Removed

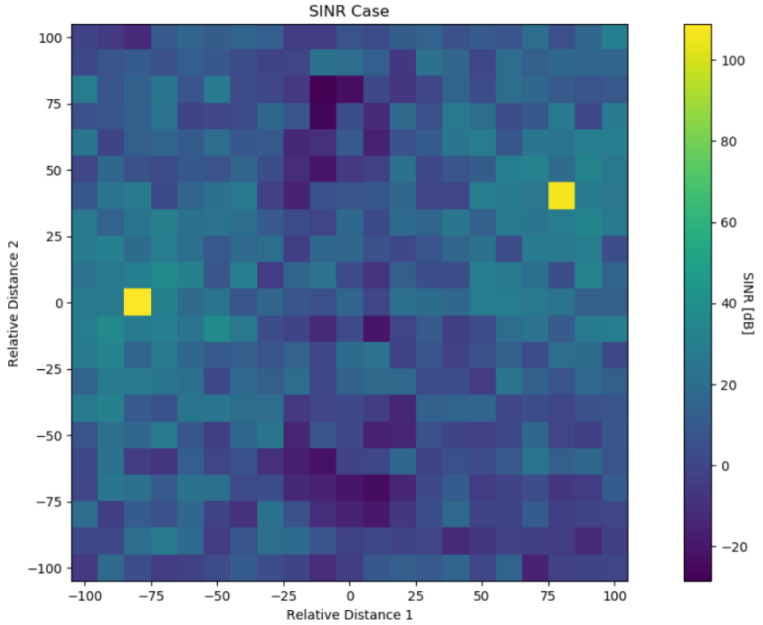


Fig. 21 SINR Heat Map After Deletion of Base Station #2

4. SINR Heat Map After Base Station #2 Has Been Removed

These "Add" and "Delete" Functions Can be Very Useful to Find the Most Efficient Ways to Organize the Base Stations in an Environment Being Investigated, as Access Points (BSs) Can be Easily Removed or Added.

Solution – Ease of Use Continued

8.

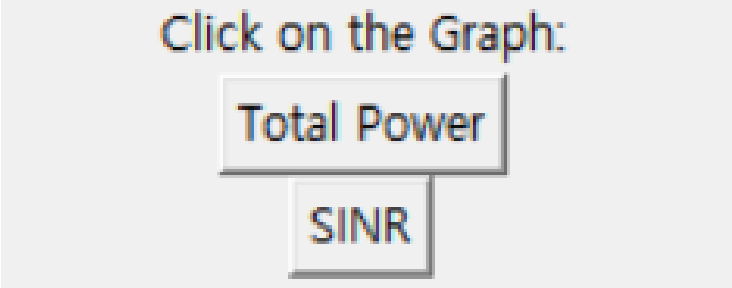


Fig. 22 UI for Choosing the Wireless Coverage Heat Map

Click on "Total Power" to View the Heat Map Corresponding to Total Power Received at a Point (If All BSs Cooperate)
Click on "SINR" to View the SINR heat map.

9.

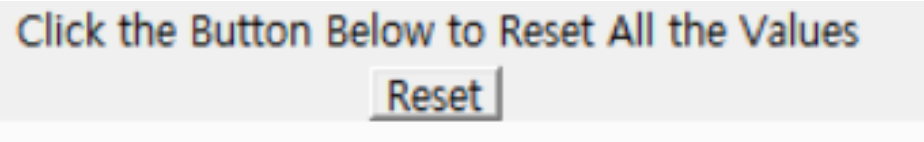


Fig. 23 UI for Clearing All the Entered Values

Click on "Reset" to Reset All Values From the Previous Simulation and Restart.

We are Happy to Consider Implementations of Extensions as Desired

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Thank You