Second Workshop of India-EU Collaboration on Standardization for Select Technologies [5G,NFV/SDN and ITS]

tsdsi
India's Telecom SDO

Path Loss Modeling for Indian Terrain

5th Nov, 2015

Hemant Kumar Rath

Tata Consultancy Services

TSDSI

Gulmohar Hall, India Habitat Centre, New Delhi, India

Outline

- Introduction
- Need for Path Loss Model
- Path Loss Models for the Existing Cellular Technologies
  - Existing Schemes
  - Comments on the existing schemes
- Drive tests for Path Loss Analysis
  - Statistical modeling and validation
- Proposed Steps
- Path Loss Modeling for 5G

Path Loss Models

- **Deterministic Approach**
  - Accounts for limited number of known measurable influencing factors
  - Requires enormous computational effort for tailor-made models for each site
  - Uses geometric information of each coverage cell
    - Simple mathematical formula can be used
- **Empirical Approach**
  - Uses field measurements
    - Generalization is based on statistical properties
  - Implicitly accounts for all influencing factors (known and unknown)
  - Lesser computational time and effort

Need for Path Loss Models

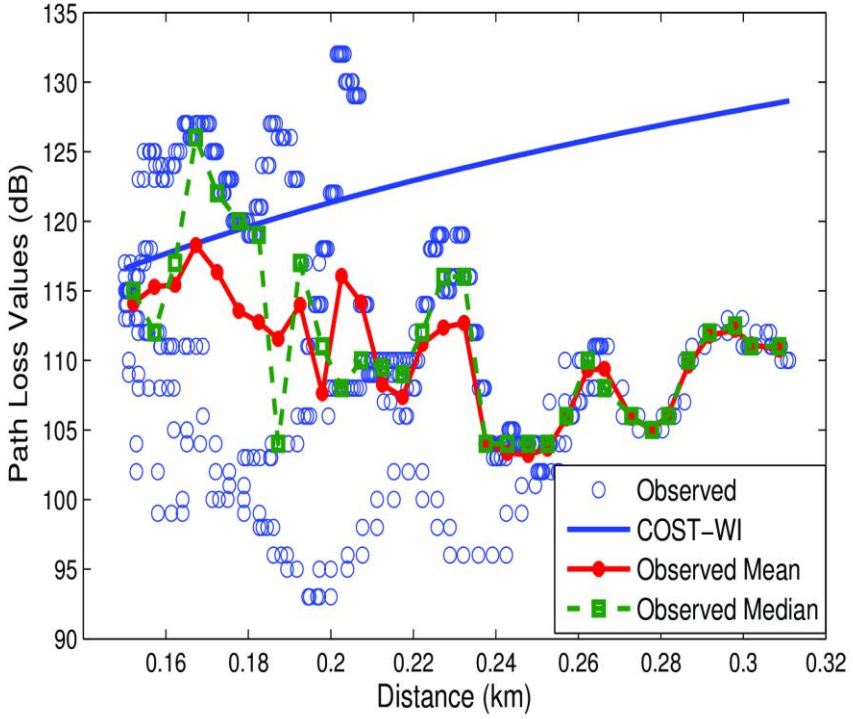
- **Cell Coverage Estimation**
  - **Important from business and regulatory perspective**
    - Maximum coverage is required with minimum investments
    - Exiting as well as 4G/5G technologies require this
  - **Cell shape and size depends on**
    - Max. transmit power: Fixed by Regulatory Bodies (TRAI in India)
    - Min. received power: Fixed (depends on the device sensitivity)
    - Antenna gains: Fixed (depends on the Tx and Rx antennas installed)
    - Max. feeder losses : Fixed (Hardware dependent)
    - Dynamic loss due to – buildings, foliage, over-bridges, stadiums, movement of heavy equipments, etc
- **Necessity of Drive Tests**
  - **Observation changes over time due to change in the landscape**
    - More drive tests are necessary resulting in increasing cost of operation

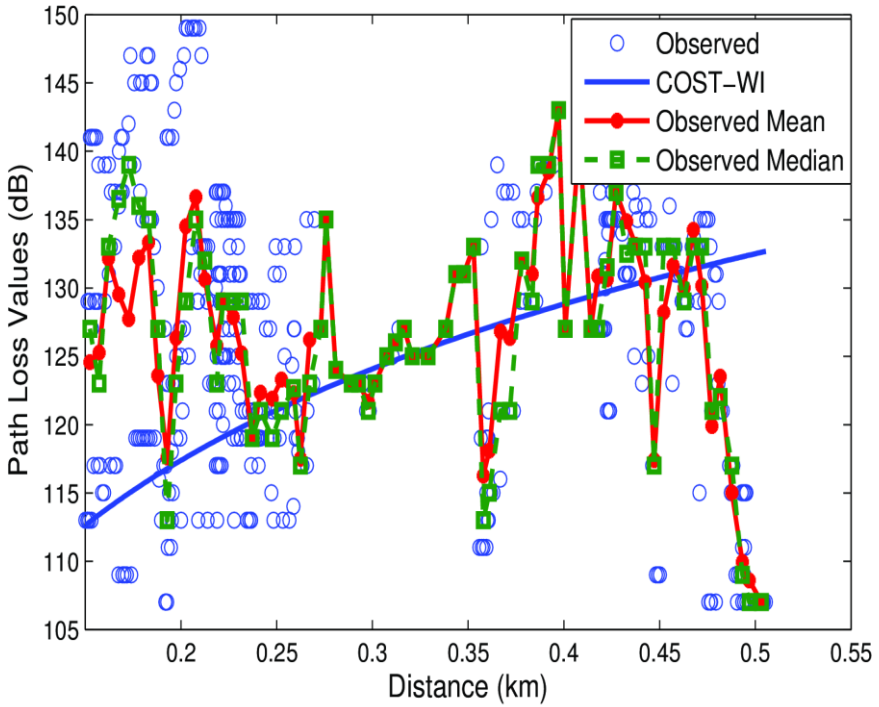
Existing Path Loss Models for Cellular Technologies

- **Based on empirical measurements in and around Japan/USA/European countries**
- **Basic outline used** $PL = k_1 + k_2 \log \mathrm{f} + k_3 \log \mathrm{h_b} + k_4 \log \mathrm{d} + k_5 \log \mathrm{b} + k_6 \log \mathrm{w}$
- **Popular models – Okumura Hata, COST 231, COST 231-WI**
  - **In India COST 231 – WI model is extensively used, applicable for 800 to 200 MHz**
- **Unsuitability of these models in India**
  - **Terrain conditions in Japan/US/Europe radically different from that in India**
  - **Building material, building heights, and road patterns radically different as well**
  - **Lack of planning – patches of urban/suburban/open areas, everywhere**
    - **Typical scenario – Indian cities**
- **For 5G, work has started**

Accuracy of the Existing Models

- **Empirical studies behind classic models do not emulate foreign propagation conditions**
  - **Far from accurate modeling, 10 -20 dB difference**





Existing Path Loss Models - Observations

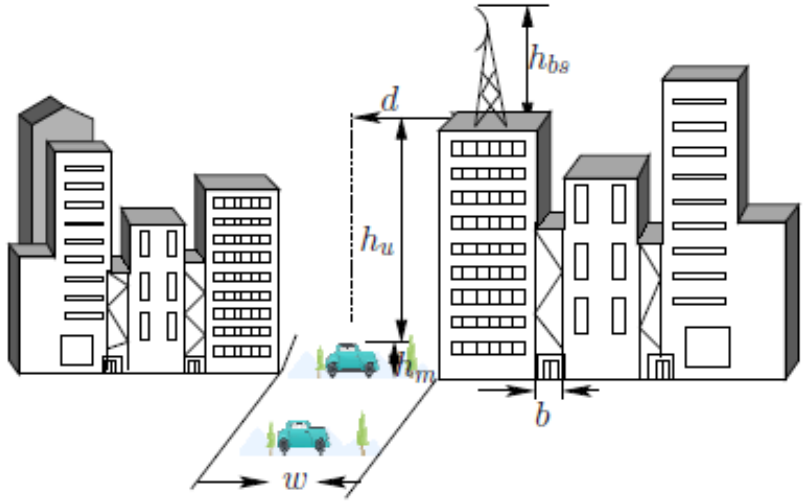
- **Classic COST-WI model unsuitable (expected)**
  - **RMSE > 4 dB (threshold to avoid ping-pong effect)**
- **Simple addition of clutter loss factor is insufficient**
  - **SDE not close to zero**
- **COST-WI cannot be considered an unbiased estimator**
  - **RMSE and SD values do not match**
- **Simple classification as 'urban', 'suburban', etc is insufficient.**
  - **Significant variations in RMSE (upto 12dB) and SDE (upto 11 dB)**
- **Solutions practiced**
  - **Extra factor to the path loss model based on MSE: 10-15/20-30 dB – urban/rural**
  - **Tweaking few coefficients k_n in the path loss equation**

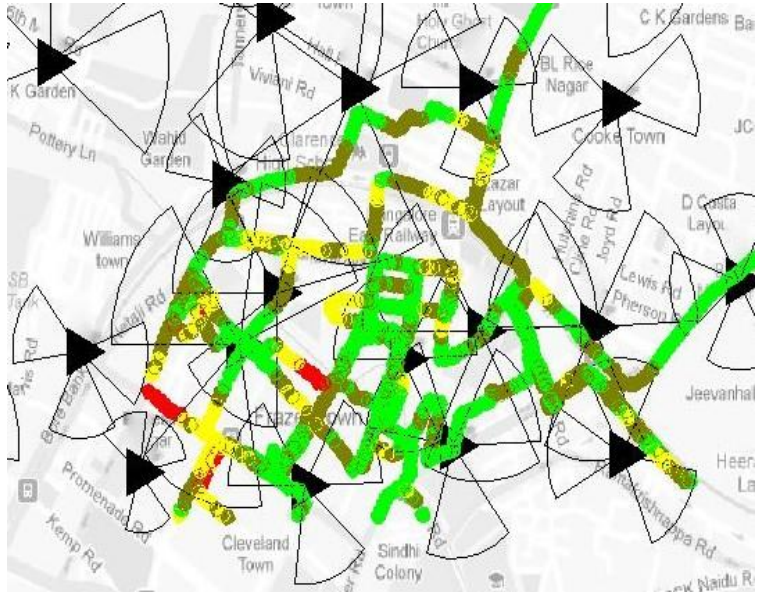
Towards a New Path Loss Model…

- **Conducted field measurements of signal strength in Bangalore**
  - **Drive tests conducted using both smartphones and commercial tools (TEMS)**
    - **Bangalore East, Whitefield, Jaya Nagar, etc**
  - **Both day time and night time drive tests**
    - **Walking & driving (2-50 km/h)**
- **GPS resolution**
  - **Major source of concern, data needs to be filtered out**
- **Speed vs. coherent time**
  - **Varies inversely with speed and with vehicle separation on the road**
    - **Decrease with the separation**

Towards a New Path Loss Model… (contd.)

- **Dense Urban and Semi-urban cases**
  - **Urban - max 300 m radius**
  - **Semi-urban - max 500 m radius**
- **Operating conditions**
  - **BTS Tx power - 20 W**
  - **Building - 3+ storey buildings with less than 1 m separation**
  - **Road width - 6 m to 20 m**
- **Data sets**
  - **Covered more than 60 BTSs**
  - **30 BTSs data used for analysis**
  - **Rest used for validation**





New Path Loss Model – 1800 MHz, Bangalore

- **Loss categorization**
  - **Segment 1: As a function of frequency of transmission**
  - **Segment 2: Empirical loss due to environment, typical city planning**
- **Segment 1**
  - **Path loss due to LoS and NLoS, COST-WI model parameters can be used**
    - **LoS - due to simple propagation loss along a street**
    - **NLoS - free space loss, scattered loss and diffraction loss**

$$PL_{S_1}(dB) = \Big\{ p_{los} \times 20\log 10(f) + (1 - p_{los}) \times \Big[20\log 10(f) + 10\log 10(f) + 15\left(\frac{f}{925} - 1\right)\log 10(f) \Big] \Big\},$$

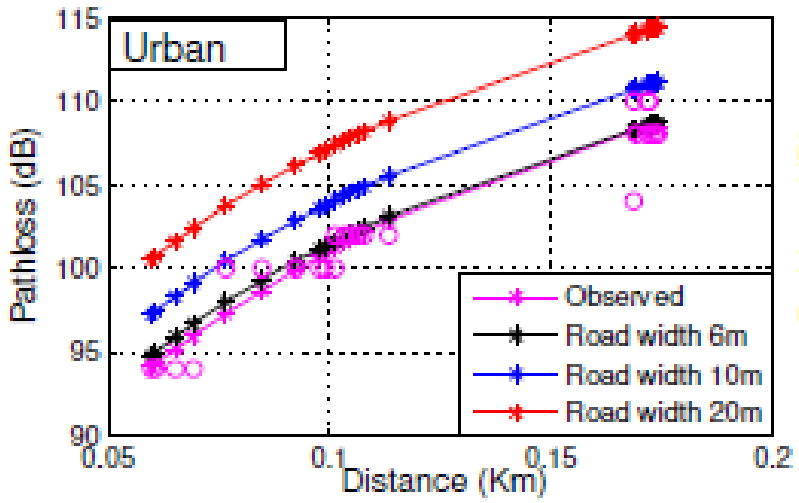
$$p_{LOS} = \left(\frac{h_{bs} - h_{roof}}{h_{bs}}\right) \times \left(1 - \frac{d}{h_o}\right)$$

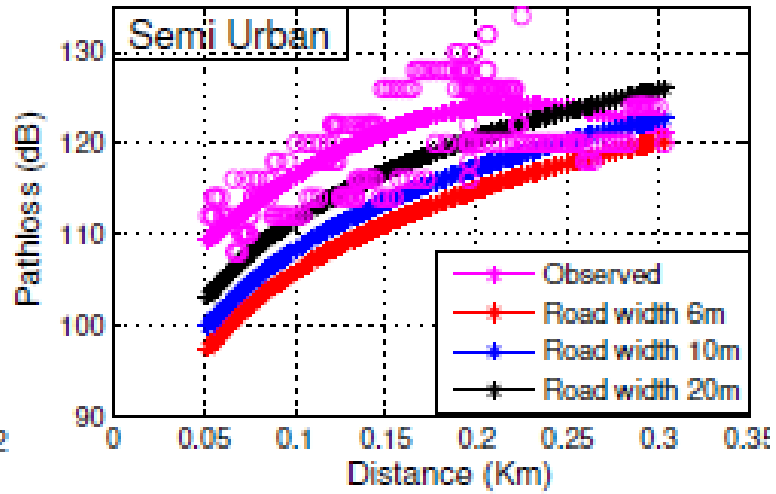
New Path Loss Model – 1800 MHz, Bangalore (cont…)

- **Segment 2**
  - **Major contribution from our side**
  - **Empirical loss due to variation in signal path**
  - **Separation of the fixed and variable components and then statistical modeling using curve fitting**
    - **Major factors: distance, road width, building separation, BTS height and user height**
    - **Obtaining the values of k_n is the key**

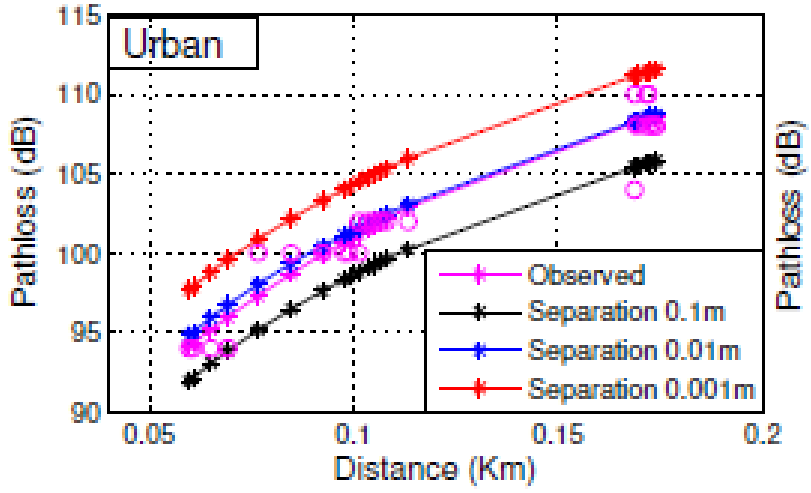
$$PL_{S_2}(dB) = \Big\lfloor 30\log 10(d) + K_a \log 10(w) + K_b \log 10(b) + K_c \log 10(h_{bs}) + K_d \log 10(h_u) \Big\rceil,$$

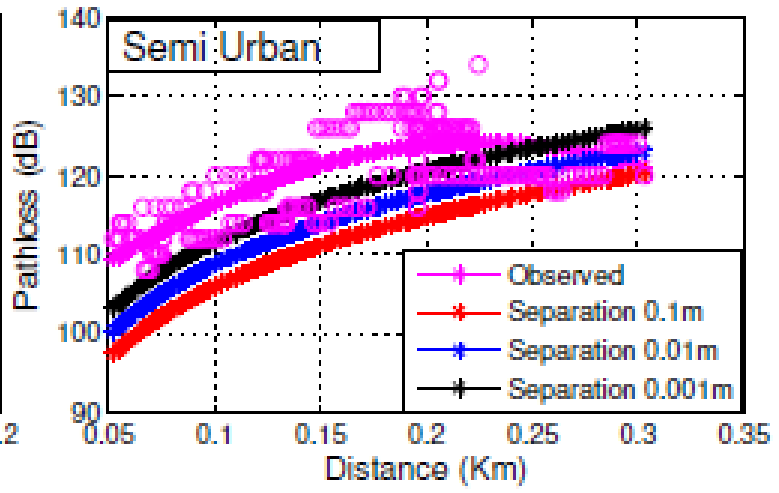
Evaluating the Proposed Model





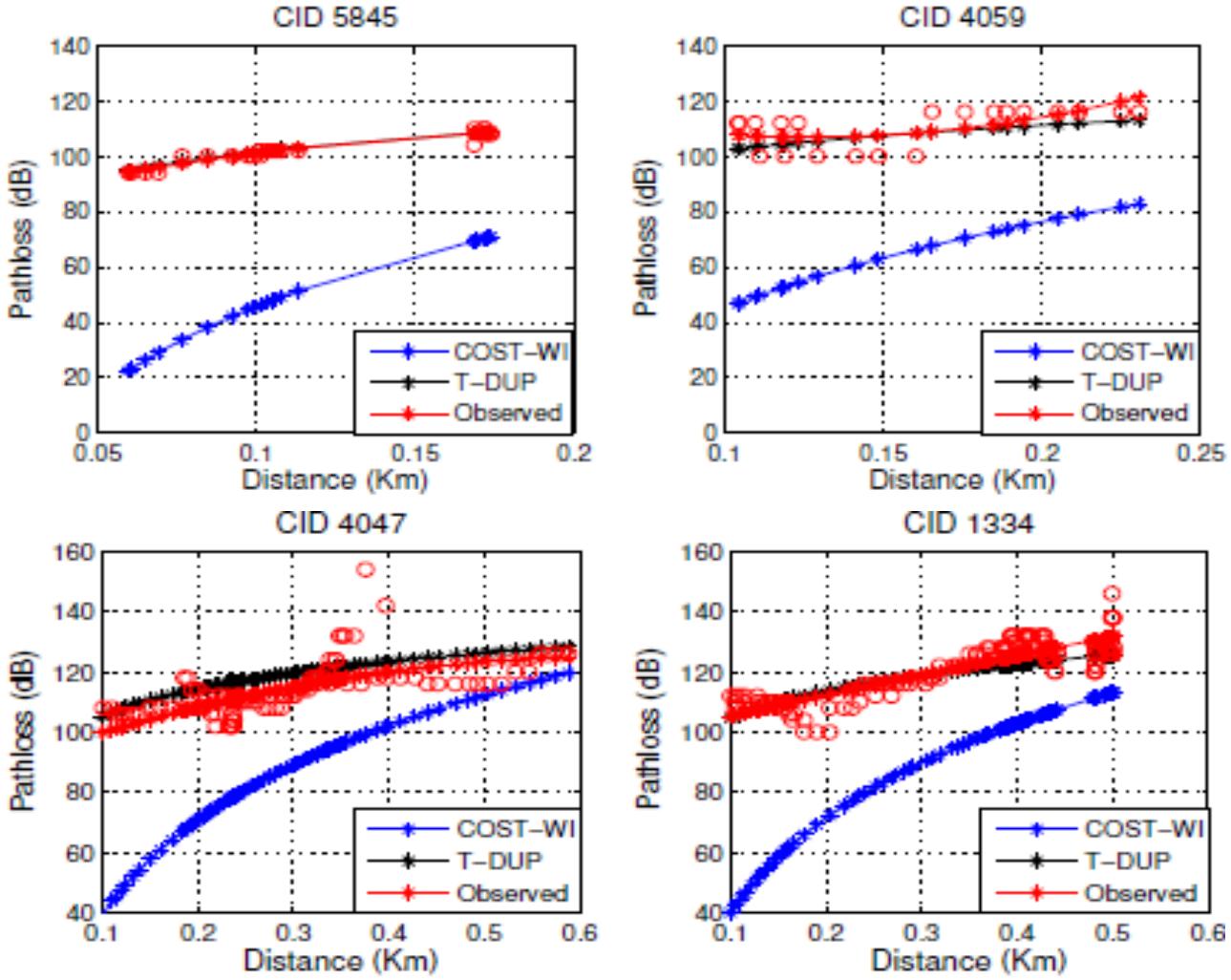
Road width on path loss values





Building separation on path loss values

Evaluating the Proposed Model (cont…)



Dense Urban

Dense Semi-urban

What Next?

- **Path loss model for Indian terrain - SI Item under TSDSI**
  - **500 MHz (TV bands), 2 GHz cellular bands, existing bands (800/1800 MHz)**
- **Channel models in different parts including Himalayan and NE regions**
  - **Specific path loss component for high rise buildings, over bridges, congested areas**
    - **Involving IITs and IISc for the data collection and modeling, crowd sourcing**
- **Terrain re-classification**
  - **Re-defining of terrains – dense urban, urban, rural**
  - **Loss component depending upon the building materials**
- **Operator assistance**
  - **Network topology and drive test data need to be shared**

Path Loss Modeling for 5G - Challenges

- **Path loss modeling for mm-wave bands – SI Item under TSDSI**
  - **High path loss at this frequency, NLoS component is the key, more sensitive to blockages**
    - **Building material – India specific losses !!**
- **Major challenge 3D channel and path loss modeling**
  - **Angular offset based on drive tests required**
  - **Small scale fading modeling based on drive tests**
- **Mobility providing realistic correlations characteristic between different links is needed**
- **D2D path loss modeling**
  - **Both Tx and Rx antennas are at low height with very low Tx power**
- **V2V path loss modeling**
  - **Vehicle type, antenna mounting positions, impact of shadowing**
  - **What about the vehicles parked on the road side?**

Path Loss Modeling for 5G - Notes

- **Free space path loss**
  - **More antennas can be fit into the same physical area => higher antenna gain**
    - **Not subject to larger free space loss when multiple antennas are used**
  - **20 dB extra loss due to aperture can be managed by large arrays**
- **Diffraction**
  - **No diffraction for mm-wave**
- **Reflection and Scattering**
  - **Specular reflection transmission mechanism is fairly consistent**
    - **Most reliable means of obtaining signals in NLOS conditions**
  - **Roughness of materials relative to the wavelength is important**
    - **Diffuse reflection is enhanced relative to the cm-wave range and could help to extend the coverage range, can help in reaching the NLOS areas**

Path Loss Modeling for 5G - Notes (cont…)

- **Material penetration**
  - **Loss will increase as the frequency is increased**
    - **Increased isolation between indoor and outdoor to reduces interference**
- **Oxygen and water absorption, rain loss**
  - **No more than 6.0 dB in the very worst case rain events for 100-150mts**
- **Foliage Loss**
  - **Will be high, but can be managed with reflections and re-routing**
  - **Wind direction and speed can modify the path loss values…**
    - **What about the path loss during Monsoon or during storms?**
- **Ready to take up path loss modeling in collaboration with a few academic institutions in India and we will be happy to partner with a collaborator in EU if interested**

References

- Prasad, et. al., "Path loss modeling for Indian cities - some observations," in Proc. of the 20th IEEE National Conference on Communications (NCC), March 2014
- Sharma, et. al., "Modified Approach to Estimate the Propagation Path Loss in Urban Area," UACEE International Journal of Advances in Electronics Engineering, vol. 2, no. 3, pp. 453–360, 2011
- Saveeda, et. al., "Received Signal Strength (RSS) Calculation for GSM Cellular System at BSNL Pondicherry using Modified Hata Model," in International Journal of Science, Engineering and Technology, vol. 2, pp. 043–047, 2013
- Nadir, et. al., "Seasonal Pathloss Modeling at 900MHz for OMAN," in International Conference on Telecommunication Technology and Applications, 2011
- Rappaport, et. al, "Millimeter wave mobile communications for 5G cellular: It will work!" IEEE Access, 2013

Thank you