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Abstract: [This contribution describes 60GHz propagation measurement of several condition.]

Purpose: [Contribution to VHT/mmW TG3c joint meeting.]

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60GHz Applications and Propagation Characteristics

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Summary

- TG3c has adopted CM2.3 channel model for NLOS residential environments – this was created by eliminating LOS component from LOS channel model, and, later the real measurements validated this as a good channel model for severe communications environments.

- This CM2.3 is good for beacon signal transmission from PNC (Picone coordinator) with Omni antenna at both PNC and Device up to 10 m coverage (typical coverage of WPAN).

- NLOS environments could be defined in many other ways according to different applications such as beaconing, desktop environments, intra room communications, long transmission with very high antenna gain – which generates very few delay spread.
Agenda

- Introduction

1. CM2.3: A valid NLOS channel model
   i. Metal shadowing: Cabinet shadowing
   ii. PC shadowing

2. Various NLOS environments and measurements
   i. Common mode: up 10 m with Omni antenna - beaconing
   ii. Long transmission: Door penetration
   iii. PC Peripheral: Desktop penetration

3. High antenna gain applications
   i. Delay spread
   ii. Beam forming antenna

Conclusion
CM2.3: A valid NLOS channel model

NLOS residential measurement

Floor plan of residential environment
Example PDPs (Power delay profile) in NLOS residential environment (Beam width: Tx=30, Rx=30)

- Direct-path component remains in NLOS measurement
- TSV model can model NLOS residential channels

NLOS direct-path component with the penetration loss of the door

Clusters
Metal Blocked: Example of Delay profile
Both antenna faced to each other

40 dB down due to shadowing
Almost same with/without shadowing object
Metal Blocked: Example of Delay profile

Both antenna faced to wall

- Relative power [dB]
- Excess delay [ns]

40 dB down due to shadowing
Non-direct path reflected on the wall:
Independent on the object
PC Blocking: Measurement environment

LoS environment

NLoS environment

Shadowing object: PC's

Antenna
- Conical horn antenna
- Beam width: 30° (16dBi)
- Polarization: V, H, C
- Antenna height: 1m

Transmission (TX) antenna

Reception (RX) antenna
Materials
- Wall, floor: Concrete
- Window: Glass
- Door: wood
- Desk, White board, Refrigerator: Metal
- TV, PC: Plastic + Metal

Antenna
- Conical horn
- Beam width: 30° (16dBi)
- Polarization: V, H, C
- height: 1m

Measurement condition
- Distance: 1, 2, 3m
- Rotation every 10 degree
PC Blocking: NLoS environment

Materials
- Wall, floor: Concrete
- Window: Glass
- Door: wood
- Desk, White board, Refrigerator: Metal
- TV, PC: Plastic + Metal

Antenna
- Conical horn
- Beam width: 30° (16dBi)
- Polarization: V,H,C
- Height: 1m

Measurement condition
- Distance: 3m
- Rotation every 10 degree
NLOS: Door - Measurement environment

- **Distance**: 1-3 m
- **Door**: obstacle between Tx and Rx
- **Antenna Height**: 1.1 m
- **Controller**
- **Network Analyzer**
- **Tx**
- **Ceiling Height**: 2.47 m
- **Wall side**
- **Window**
- **3.57 m**
- **6.85 m**

Floor plan of NLOS residential environment

- **Rotation Table (Step 5°)**
Measurement conditions

<table>
<thead>
<tr>
<th>Instrument</th>
<th>HP8510C VNA</th>
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<tbody>
<tr>
<td>Center frequency</td>
<td>62.5 GHz</td>
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<tr>
<td>Bandwidth</td>
<td>3 GHz</td>
</tr>
<tr>
<td>Time resolution</td>
<td>0.333 ns</td>
</tr>
<tr>
<td>Distance resolution</td>
<td>19.1 cm</td>
</tr>
<tr>
<td># of frequency points</td>
<td>801</td>
</tr>
<tr>
<td>Frequency step</td>
<td>3.75MHz</td>
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<tr>
<td>Times of average</td>
<td>128 times</td>
</tr>
</tbody>
</table>

- Calibration performed with 1m reference separation
- Time resolution and distance resolution were determined by bandwidth
Measurement conditions (cont’)

- **Antenna**: Conical horn antenna
- **Polarization**: Vertical
- **Beam-width**: Tx:30 and Rx 30

Conical horn antenna
Beam-width 30 deg
Penetration loss was measured to be more than 50 dB. TX antenna: Omni(4dBi), RX antenna: 15 degree(22dBi)
Penetration measurement
~ Low wooden desk ~

Without desktop (Direct) : -42.2 dB

<table>
<thead>
<tr>
<th>Position</th>
<th>Received Power[dB]</th>
<th>Loss [dB]</th>
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<tbody>
<tr>
<td>0</td>
<td>-52.7</td>
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<td>-60.5</td>
<td>-18.3</td>
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<td>7</td>
<td>-64.9</td>
<td>-22.7</td>
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<tr>
<td>8</td>
<td>-77.0</td>
<td>-34.8</td>
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</tbody>
</table>

Delay Spread : 0.26 nsec

Penetration loss: 10dB
NLOS: Penetration measurement
~ meeting desk ~

Without desktop (Direct) : -41.0 dB

<table>
<thead>
<tr>
<th>Position</th>
<th>Received Power [dB]</th>
<th>loss [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-65.19</td>
<td>-24.19</td>
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<tr>
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<tr>
<td>12</td>
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<td>-33.9</td>
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</tbody>
</table>

Delay Spread : 0.51 nsec
RMS delay spread analysis of CM2.3

- 30 dB cut-off and no cut-off thresholds (*) give no difference in RMS delay spread
- Continuous channel and discrete channels generated from the continuous give no difference in RMS delay spread
- CM2.3 ($W_{Rx}=30$ deg with -30 dB cut-off threshold) (same result as previous)
  - 90th percentile of CDF: 12.5 ns, and 100th percentile of CDF: 30.8 ns
- $W_{Rx}$ of 15 deg with -30 dB cut-off threshold
  - 90th percentile of CDF: 7.7 ns, and 100th percentile of CDF: 18.8 ns

$D_{rms}$ CDF with 30 deg (Original CM2.3)  $D_{rms}$ CDF with 15 deg
High Antenna Gain applications

To transmit LONG distance such as 30 m, a 30 dBi antenna gain will be required.

In such case, the measured delay spread is very small (a couple of ns with 5 degree HPBW antenna)

Direct as well as reflective wave is good enough for communications

TG3c specification includes beam forming to track the best and 2\textsuperscript{nd} best beam for more reliable communications
Conclusion

NLOS environments may be defined in various ways according to different applications.

CM2.3 channel model has been validate as a good channel model for beacon signal transmission to cover up to 10 m in NLOS environments with Omni antenna.

Beam forming antenna will resolve delay spread issue a lot.