Submission Title: [NLOS office channel model based on TSV model]
Date Submitted: [November, 2006]
Source: [Hirokazu Sawada, Yozo Shoji, Chang-Soon Choi, Katsuyoshi Sato, Ryuhei Funada, Hiroshi Harada, Shuzo Kato, Masahiro Umehira]
Company [National Institute of Information and Communications Technology]
Address [3-4, Hikarino-Oka, Yokosuka, Kanagawa, 239-0847, Japan]
Voice:[+81.46.847.5096], FAX: [+81.46.847.5079], E-Mail:[sawahiro@nict.go.jp]
Re: []

Abstract: [This contribution describes NLOS office channel model based on TSV model.]

Purpose: [Contribution to mmW TG3c meeting.]

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NLOS office channel model based on TSV model

Hirokazu Sawada, Yozo Shoji, Chang-Soon Choi, Katsuyoshi Sato, Ryuhei Funada, Hiroshi Harada, Shuzo Kato, and Masahiro Umehira

National Institute of Information and Communication Technology (NICT), Japan
Agenda

- Background
- Measurement procedure and results
- Extracted TSV model parameters
Background

- Channel model for NLOS office environment was released. However the parameter for only omni antenna is available

Purpose

- To provide re-analyzed NLOS office channel model based on TSV model, and to extract the parameters for the directional antenna
Measurement condition

• Polarization : Vertical
• Antenna height : 1.1 m
• Antenna separation : 10 m
• Tx antenna: always fixed
• Rx antenna: rotated from 0 to 360 with 5 degree step

Ref. Doc 06/12
Measurement environment in office
Measurement environment in office (cont’)
Measurement environment in office (cont’)
Measurement environment in office (cont’)

Floor plan of office environment
Measurement condition (cont’)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Room size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office (NLOS)</td>
<td>Floor: 22 × 12.5 m² Ceiling height: 3.5m</td>
</tr>
</tbody>
</table>
Measurement conditions

<table>
<thead>
<tr>
<th>Instrument</th>
<th>HP8510C VNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>62.5 GHz</td>
</tr>
<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>3.75 MHz</td>
</tr>
<tr>
<td>Times of average</td>
<td>128 times</td>
</tr>
</tbody>
</table>

Time resolution and distance resolution were determined by bandwidth.
Measurement conditions (cont’)

- Tx: Pyramidal horn antenna (3dB beam-width:30 deg) and Omni directional antenna
- Rx: Pyramidal horn antenna (3dB beam-width:15 deg)
- Calibration performed with 1m reference separation
### Measurement Data List

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Antenna beam width</th>
<th>Angle [deg]</th>
<th>PDPs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tx [deg]</td>
<td>Rx [deg]</td>
<td></td>
</tr>
<tr>
<td>Office (NLOS)</td>
<td>Omni</td>
<td>15</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0,5,…,355</td>
<td>72※</td>
</tr>
</tbody>
</table>

- Not available data
- ※ 95deg
Example PDPs in office environment
(Beam width: Tx=30°, Rx=15°)

Direct-path component with diffraction loss of obstacles (PC, LCD…)

- Direct-path components remain in NLOS environment
- TSV model can model NLOS office channels
Impulse response

NLOS direct-path component with diffraction loss of obstacle

Cluster Rician factor ($\Delta K$)

Ray Rician factor ($\Delta k$)

S-V model response

$\Gamma, \Lambda, \gamma, \lambda$

TSV model can generate channel response for NLOS environment by setting $\Gamma_0 = 0$
TSV model for NLOS office environment

- For LOS desktop environment (06/297)
  TSV model = Statistical two-path component + S-V components
  \[ h(t) = \beta \delta(t) + \sum_{l=0}^{L-1} \sum_{m=0}^{M_l-1} \alpha_{l,m} \delta(t - T_l - \tau_{l,m}) \delta(\varphi - \Psi_l - \psi_{l,m}) \]
  \[ \beta [\text{dB}] = 20 \cdot \log_{10} \left( \frac{\mu_d}{d} \right) \sqrt{G_t G_r} + \sqrt{G_{t2} G_{r2}} \Gamma_0 \exp \left( \frac{2 \pi h_i h_2}{\lambda_f} \right) \right] - PL_d(\mu_d) \]
  Statistical factors in both two-path and S-V

- For NLOS office environment
  Reflection coefficient: \( \Gamma_0 \equiv 0 \)

Modified TSV model = Direct-path component + S-V components

\[ h(t) = \beta \delta(t) + \sum_{l=0}^{L-1} \sum_{m=0}^{M_l-1} \alpha_{l,m} \delta(t - T_l - \tau_{l,m}) \delta(\varphi - \Psi_l - \psi_{l,m}) \]

\[ \beta [\text{dB}] = 10 \cdot \log_{10} (G_t G_r) - PL_d(\mu_d) \]

Statistical factors in only S-V

Refer to Appendix A for each parameter
# Extracted TSV model parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TSV Model</th>
<th>Small Rician effect</th>
<th>S-V model oriented parameter</th>
<th>Number of cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Omega_0(d)@10m$ [dB]</td>
<td>$k$ ((\Delta k))</td>
<td>$\Gamma$ [ns]</td>
<td>$1/\Lambda$ [ns]</td>
</tr>
<tr>
<td>Tx:360 Rx:15</td>
<td>-109</td>
<td>4.37 (19.0 dB)</td>
<td>109.2</td>
<td>30.8</td>
</tr>
<tr>
<td>Tx:30 Rx:15</td>
<td>-107.2</td>
<td>4.43 (19.2 dB)</td>
<td>134.0</td>
<td>35.9</td>
</tr>
</tbody>
</table>

Channel model for NLOS office environment was reanalyzed

*Refer to Appendix B*
Path loss measurement for NLOS office

Fig. Floor plan to measure the path-loss
Path loss in direct-path component in NLOS office environment

\[ PL_d(\mu_d)[dB] = PL_d(d_0) + 10n_d \log_{10}(\mu_d / d_0) \]

Path loss in direct-path component

- **Path loss at** \( d_0 = 3 \text{m} \) distance
  \[ PL_d[dB] = 20 \log_{10}\left(\frac{4\pi d_0}{\lambda_f}\right) + 5.56 \approx 77.5 \]
  \( \lambda_f \approx 4.8\text{mm} \) \( (f = 62.5 \text{GHz}) \)

- **Path loss exponent**
  \[ n_d = 3.35 \]

\( PL_d \) includes diffraction loss (Attenuation for NLOS office environment: \( A_{NLOS} = 5.56 \text{dB @ 3m} \)

Fig. Path Loss in direct-path
Summary of available LOS / NLOS channel models

<table>
<thead>
<tr>
<th>Location</th>
<th>LOS</th>
<th>NLOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Available (NICT)</td>
<td>Available (NICT)</td>
</tr>
<tr>
<td>Residential</td>
<td>Available (NICT)</td>
<td>Available (NICT)</td>
</tr>
<tr>
<td>Desktop</td>
<td>Available (NICT)</td>
<td>N/A</td>
</tr>
<tr>
<td>Library</td>
<td>Available (IMST/Intel)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

These parts are now available based on TSV-model
Summary

- The parameters for NLOS office channel model was reanalyzed based on TSV-model

- Channel models for all LOS/NLOS environments (residential, office, desktop) based on TSV model are now available
Appendix A: Definition of TSV model (modified)

CIR:  \[ h(t) = \beta \delta(t) + \sum_{l=0}^{L-1} \sum_{m=0}^{M_l-1} \alpha_{l,m} \delta(t - T_l - \tau_{l,m}) \delta(\phi - \Psi_l - \psi_{l,m}) \]

(Complex impulse response)

\[ |\alpha_{l,m}|^2 = \Omega_0 e^{-T_l/\Gamma} e^{-\tau_{l,m}/\gamma - k[1 - \delta(m)]} \sqrt{G_r(0, \Psi_l + \psi_{l,m})}, \angle \alpha_{l,m} \sim \text{Uniform}[0, 2\pi] \]

Two-path parameters (4)

\[ \beta [\text{dB}] = 20 \log_{10} \left( \frac{P_r}{d} \sqrt{G_r G_t} \right) + \frac{2 \pi k h_l}{\lambda_i d} \exp \left[ \frac{2 \pi k h_l}{\lambda_i d} \right] - PL_j(\mu_j) \]

\[ PL_j(\mu_j) = PL_j(d) - PL_j(d) \to 10 \cdot \log_{10} \left( \frac{d}{\lambda} \right) + 20 \cdot \log_{10} \left( \frac{4d}{\lambda} \right) + A_{nlos} \]

A_{NLOS}: Constant attenuation for NLOS

Path number of \( G_y \) and \( G_y \): (1: direct, 2: reflect)

Arrival rate: Poisson process

\[ p(T_l | T_{l-1}) = \Lambda \exp[-\Lambda(T_l - T_{l-1})], \quad l > 0 \]
\[ p(\tau_l | \tau_{l,(m-1)}) = \lambda \exp[-\lambda(\tau_l - \tau_{l,(m-1)})], \quad m > 0 \]

S-V parameters (7)

\[ \Gamma : \text{cluster decay factor} \]
\[ 1/\Lambda : \text{cluster arrival rate} \]
\[ \gamma : \text{ray decay factor} \]
\[ 1/\lambda : \text{ray arrival rate} \]
\[ \sigma_r : \text{cluster lognormal standard deviation} \]
\[ \sigma_\gamma : \text{ray lognormal standard deviation} \]
\[ \sigma_\alpha : \text{Angle spread of ray within cluster} \]

(Laplace distribution)

Antenna parameters (2)

\[ G_l(\theta, \phi) : \text{Antenna gain of Tx} \]
\[ G_r(\theta, \phi) : \text{Antenna gain of Rx} \]

Rician factor (2)

\[ k : \text{Ray Rician effect in each cluster} \]

\[ K = \sum_{l=1}^{L} \sum_{m=1}^{M_l} \left| G_r(\theta, \phi) \right|^2 \Theta(\theta - \phi_l - \psi_{l,m}) \Delta(0, \Psi_l + \psi_{l,m}) \]
Appendix B: Results of data analysis

Antenna beamwidth
Tx: 30 deg, Rx: 15 deg

Cluster decay factor ($\Gamma$)  
Cluster arrival rate ($1/\Lambda$)  
Ray decay factor ($\gamma$)  
Ray arrival rate ($1/\lambda$)  

Angle of arrival in cluster (σAoA)  
Angle spread of ray (σφ)  
Standard deviation of cluster (σ1)  
Standard deviation of ray (σ2)