Project: IEEE P802.15 Working Group for Wireless Personal Area Networks

Submission Title: [Summary of reflection measurements with circular polarization]

Date Submitted: [November 2006]

Source: [Abbie Mathew, NewLANS, Westford, MA] [amathew@newlans.com]
[Zhiguo Lai, University of Massachusetts] [zhlai@ecs.umass.edu]

Re: []

Abstract: []

Purpose: [Contribution to 802.15 TG3c at November 2006 plenary in Dallas]

Notice: This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.
Objective

To approve the circular polarization channel model as described in [15-06-0398-03]
Measurement Set-Up

- Laser
- Agilent Infinium DCA 86100A Wide Bandwidth Oscilloscope
- x4 Laser Receiver
- x4 Pulse Moderator
- HP 8133A-02 Pulse Generator
- 14.05 DRO
- 15.4 DRO
- 5.4 GHz
- Data collection
- Pedestal control
- Agilent Infinium DCA 86100A Wide Bandwidth Oscilloscope
- Trigger
Measurement Information

- ~61 GHz center frequency
- Pulsed measurement (~ 1 ns pulse width)
- Transmit antenna
  - Fixed
  - Directional, HPBW of 35°
- Receive antenna
  - Rotated in steps of ~ 2°
  - Directional, HPBW of 13°
- Right hand circular polarization
Environments

- **Office**
  - Cubicles, conference rooms, hallway/corridor

- **Residential**
  - Family/living room, dining room and kitchen

<table>
<thead>
<tr>
<th>Environment</th>
<th>Number of Locations</th>
<th>Number of Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>34</td>
<td>6,188</td>
</tr>
<tr>
<td>Residential</td>
<td>31</td>
<td>5,642</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>65</strong></td>
<td><strong>11,830</strong></td>
</tr>
</tbody>
</table>
Multipath Suppression

Diagram showing the transmission and reception of signals in a multipath environment.
FAQs

- Are circular polarized antennas large?
- Are they expensive?
- Are they used in any application?
- Why do we need circular polarization?
Data Processing & Analysis

- Time domain impulse response measured as receiver rotated through 360° (~2° step size)
- Envelope detector digitally implemented in Matlab to recover baseband pulses
- Multipath information collected from processed data and layout of each environment
Proposed Channel Model

Modified Single-Cluster Saleh-Valenzuela (SCSV) Model

\[ h(t, \theta) = \beta \left[ \delta(t - t_{\text{LOS}}, \theta) + \sum_{l=1}^{L} \alpha_l \delta(t - t_{\text{LOS}} - t_l, \theta - \theta_l) \right] \]

where:
- \( h \) = channel impulse response
- \( \beta \) = a deterministic factor *
- \( t_{\text{LOS}} \) = delay for line-of-sight signal
- \( L \) = number of arrivals (or rays)
- \( \alpha_l \) = multipath gain of the \( l^{th} \) ray
- \( t_l \) = arrival time of the \( l^{th} \) ray
- \( \theta_l \) = arrival angle of the \( l^{th} \) ray

* Determined by the free-space pathloss and gains of Tx and Rx.
Small-Scale Fading Statistics

- Ray arrival rate:
  \[ f(t_i | t_{i-1}) = \lambda \cdot \exp[- \lambda(t_i - t_{i-1})] \]

- Joint PDF between ToA and AoA:
  \[ f(t_i, \theta_i) = f(\theta_i | t_i) \cdot f(t_i) \]

Conditional AoA PDF:
\[ f(\theta_i | t_i) = \sum_{n=0}^{N-1} f(\theta_i | \tau_n) \]

Partial conditional AoA PDF:
\[
 f(\theta_i | \tau_n) = \begin{cases} 
 1 \exp \left[- \frac{\theta_i - \theta_0^2}{2\sigma_0^2} \right] & 0 < \tau_n < \tau_0 \\
 \frac{1}{\sqrt{2\pi\sigma_{\theta_i|\tau_n}}} \exp \left[- \frac{(\theta_i - 180^\circ)^2}{2\sigma_{\theta_i|\tau_n}^2} \right] & \text{otherwise} 
\end{cases}
\]

Conditional standard deviation:
\[ \sigma_{\theta_i|\tau_n} = a \cdot \exp(\frac{-b\sqrt{\tau_n}}) \]

- Average PDP:
  \[ P(\tau) = \begin{cases} 
 \exp(-\tau / \gamma) & \tau > 0 \\
 0 & \text{otherwise} 
\end{cases} \]

- Amplitude statistics:
  \[ f(\alpha) = \frac{\alpha}{P} \exp \left[- \frac{\alpha^2}{2P} \right] \text{(Rayleigh)} \]
### Extracted Parameters

\[
h(t, \theta) = \beta \left[ \delta(t - t_{\text{LOS}}, \theta) + \sum_{l=1}^{L} \alpha_l \delta(t - t_{\text{LOS}} - t_l, \theta - \theta_l) \right]
\]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ray arrival rate ((1/\lambda))</td>
<td>Office: 2.11</td>
<td>Residential: 2.29</td>
</tr>
<tr>
<td>Ray decay factor ((\gamma))</td>
<td>Office: 3.08</td>
<td>Residential: 2.56</td>
</tr>
<tr>
<td>Conditional AoA PDF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\tau_0)</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(\theta_0)</td>
<td>Office: 30</td>
<td></td>
</tr>
<tr>
<td>(\sigma_0)</td>
<td>Office: 20</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>(a)</td>
<td>Office: 614.5</td>
</tr>
<tr>
<td></td>
<td>(b)</td>
<td>Office: 1.09</td>
</tr>
<tr>
<td>Mean delay</td>
<td></td>
<td>Office: 5.5</td>
</tr>
<tr>
<td>RMS delay spread</td>
<td></td>
<td>Office: 2.8</td>
</tr>
</tbody>
</table>
Summary and Conclusions

- A time-domain circular polarized measurement system was used to simultaneously collect the temporal and spatial data.
- Data presented have general characteristics as the single-cluster S-V model.
- ToAs data closely follow a single Poisson process.
- Mean amplitude of each arrival approximately follows a pattern of exponential decay.
- Instantaneous amplitude follows a Rayleigh distribution.
- About 50% (80%) of the arrivals have a relative power of -25 dB (-20 dB) or less compared to the LOS signal for both environments.
- No arrivals observed within $\pm 10^\circ$ of the LOS direction for the office environment and $\pm 20^\circ$ for the residential environment.
- ToA and the AoA are strongly related for both environments.
- Rays arriving at the receiver with shorter (or longer) delays tend to have relatively smaller (or larger) AoAs.
- Conditional AoA PDFs are described by a series of Gaussian distributions centered at $180^\circ$ with various standard deviations except for those with extremely short delays.
References


.. continued ..
References


9) T. Pollock, *et al.*, Office 60 GHz Channel Measurements and Model, IEEE doc.: 802.15-06-0316-00-003c.

10) T. Pollock, *et al.*, Residential 60 GHz Channel Measurements and Model, IEEE doc.: 802.15-06-0317-00-003c.
