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

Submission Title: [Summary of reflection measurements with circular polarization]
Date Submitted: [November 2006]
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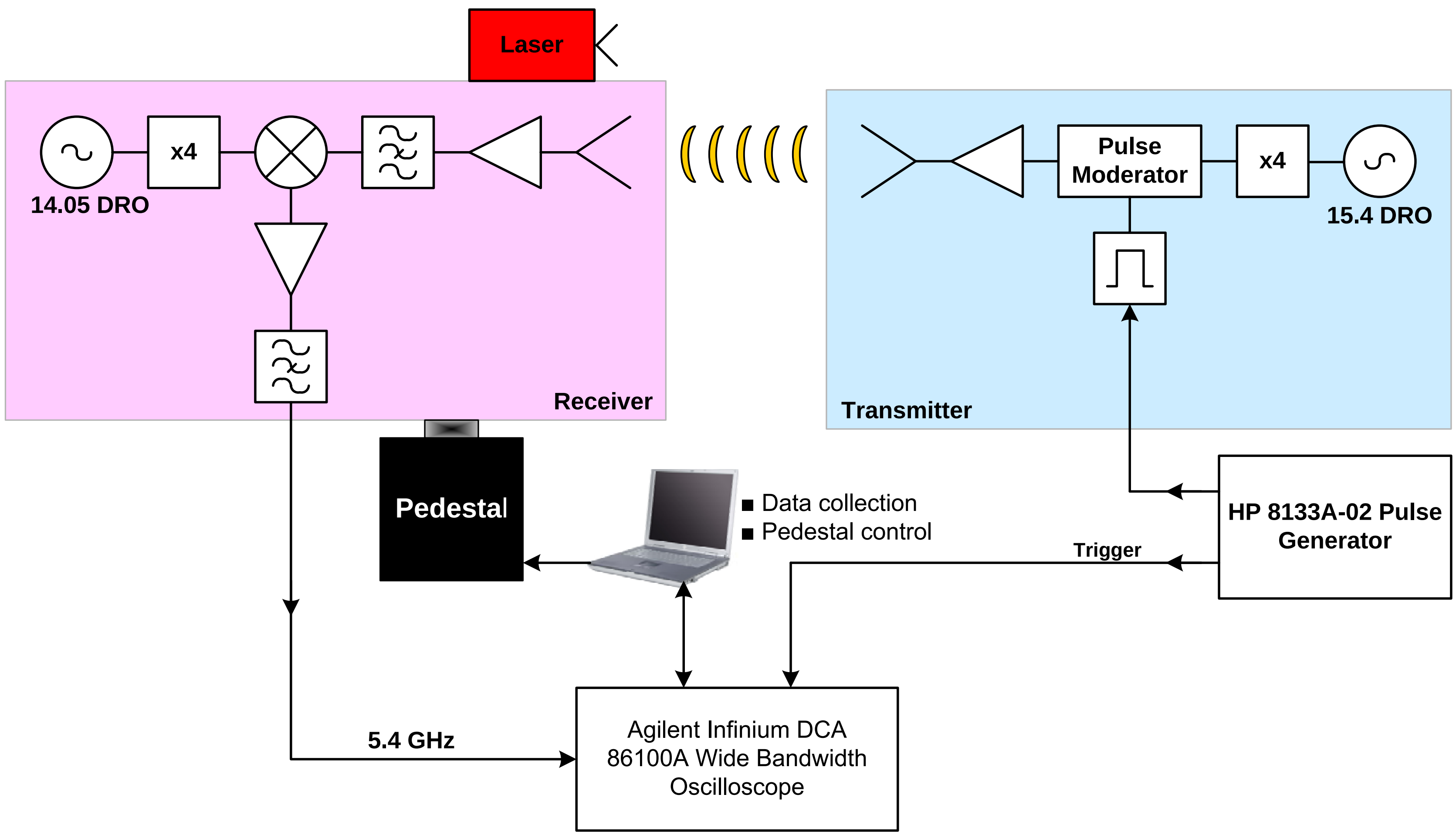
Re: []
Abstract: []

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

Objective

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

Measurement Set-Up



Measurement Information

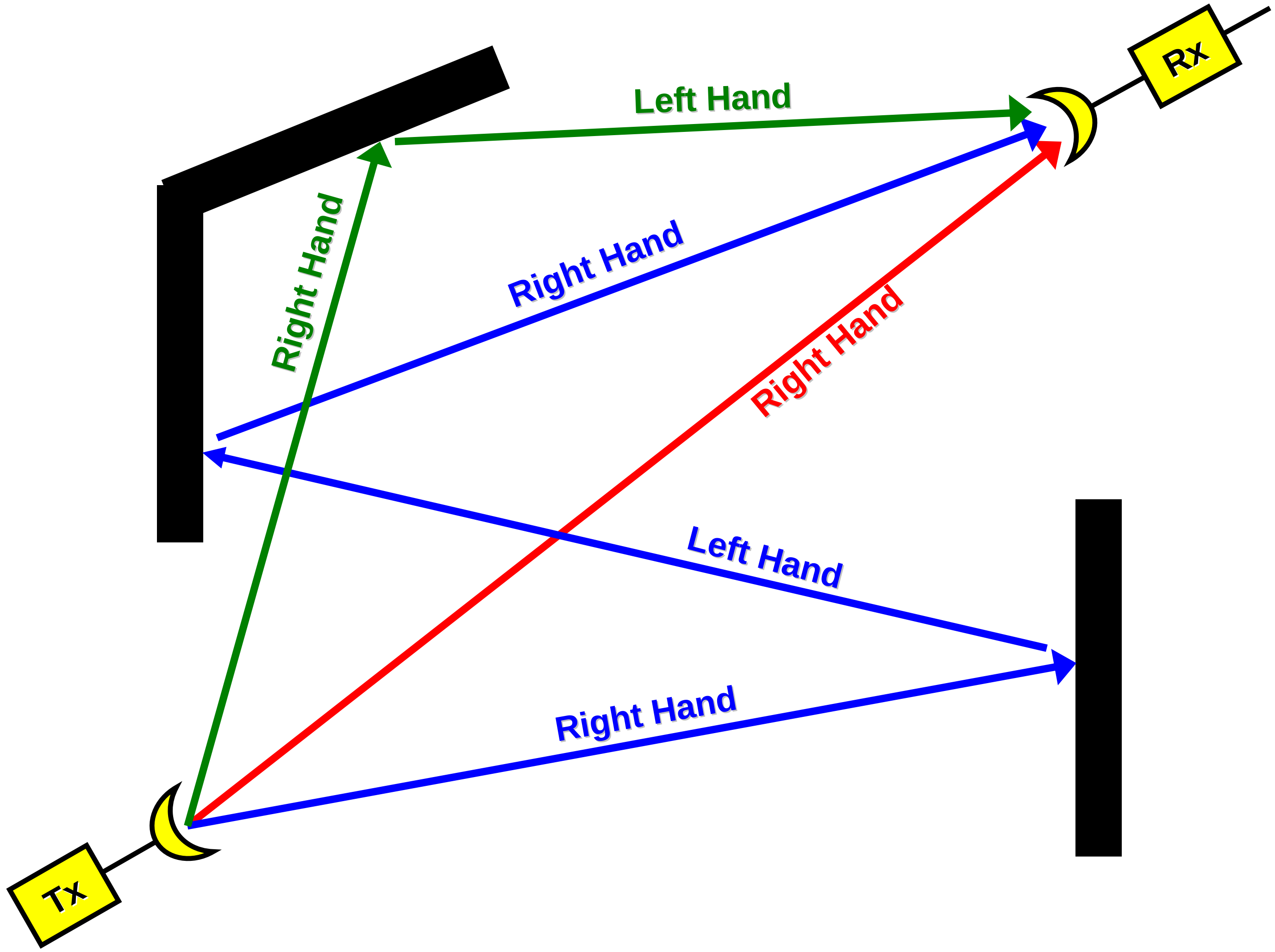
- ~61 GHz center frequency
- Pulsed measurement (~ 1 ns pulse width)
- Transmit antenna
  - Fixed
  - Directional, HPBW of 35°
- Receive antenna
  - Rotated in steps of ~ 2°
  - Directional, HPBW of 13°
- Right hand circular polarization

Environments

- **Office**
  - Cubicles, conference rooms, hallway/corridor
- **Residential**
  - Family/living room, dining room and kitchen

Environment	Number of Locations	Number of Measurements
Office	34	6,188
Residential	31	5,642
Total	**65**	**11,830**

Multipath Suppression



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

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

where:

$h=$ channel impulse response

$\beta=$ a deterministic factor *

$t_{\mathrm{LOS}}=$ delay for line-of-sight signal

$L=$ number of arrivals (or rays)

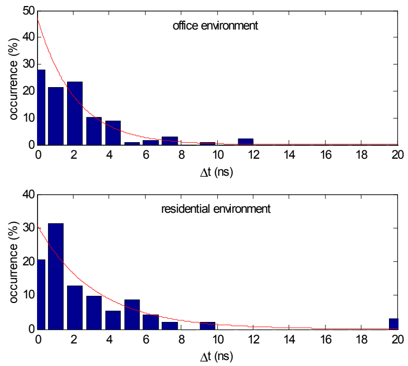
$\alpha_l=$ multipath gain of the l^{th} ray

$t_l=$ 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 :

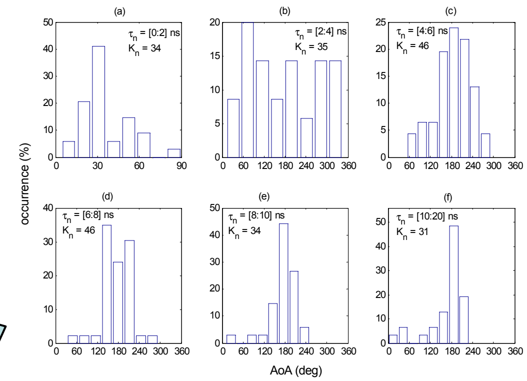
$$f(t_l \mid t_{l-1}) = \lambda \cdot \exp\left[-\lambda (t_l - t_{l-1})\right]$$

- Joint PDF between ToA and AoA :

$$f(t_l, \theta_l) = f(\theta_l \mid t_l) \cdot f(t_l)$$

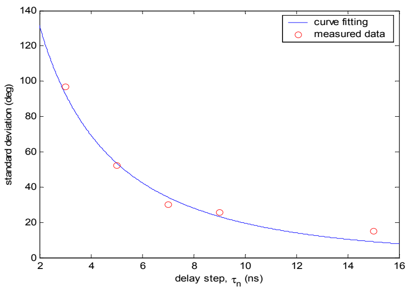
Conditional AoA PDF :

$$f(\theta_l \mid t_l) = \sum_{n=0}^{N-1} f(\theta_l \mid \tau_n)$$



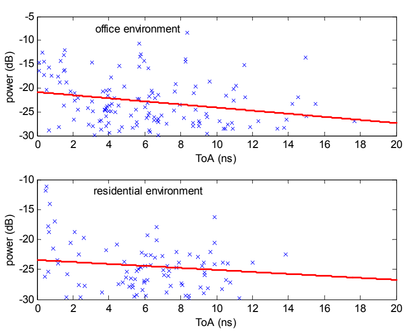
Partial conditional AoA PDF :

$$f(\theta_l \mid \tau_n) = \begin{cases} \dfrac{1}{\sqrt{2\pi}\cdot\sigma_0} \exp\left[-\dfrac{(\theta_l - \theta_0)^2}{2\sigma_0^2}\right] & 0 < \tau_n < \tau_0 \\ \dfrac{1}{\sqrt{2\pi}\cdot\sigma_{\theta_l|\tau_n}} \exp\left[-\dfrac{(\theta_l - 180^\circ)^2}{2\sigma_{\theta_l|\tau_n}^2}\right] & \text{otherwise} \end{cases}$$



Conditional standard deviation :

$$\sigma_{\theta_l|\tau_n} = a \cdot \exp\left(-b\sqrt{\tau_n}\right)$$

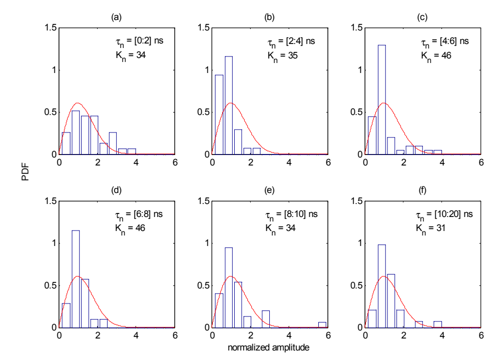


- Average PDP :

$$\overline{P}(\tau) = \begin{cases} \exp(-\tau/\gamma) & \tau > 0 \\ 0 & \text{otherwise} \end{cases}$$

- Amplitude statistics :

$$f(\alpha) = \frac{\alpha}{\overline{P}} \exp\left[-\frac{\alpha^2}{2\overline{P}}\right] \quad \text{(Rayleigh)}$$



Extracted Parameters

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

Parameters			Values		Unit
			Office	Residential	
Ray arrival rate $(1/\lambda)$			2.11	2.29	ns
Ray decay factor (γ)			3.08	2.56	ns
Conditional AoA PDF	τ_0		2		ns
	θ_0		30		deg
	σ_0		20		deg
	Mean		180		deg
	Standard deviation	a	614.5		deg
		b	1.09		$ns^{-1/2}$
Mean delay			5.5	5.7	ns
RMS delay spread			2.8	1.4	ns

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 strong 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° with various standard deviations except for those with extremely short delays

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