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

Submission Title: [Generic channel model merging two-path and S-V models]
Date Submitted: [May, 2006]
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Abstract: [This contribution describes a generic channel model merging two-path and S-V models.]

Purpose: [Contribution to mmW TG3c meeting.]

Agenda

- Current status of channel model in TG3c
- Motivation for merging two-path and S-V models
- Statistical two-path channel model for considering uncertainty of device position
- Proposal of generic channel model merging two-path and S-V models, which can express all WPAN environment

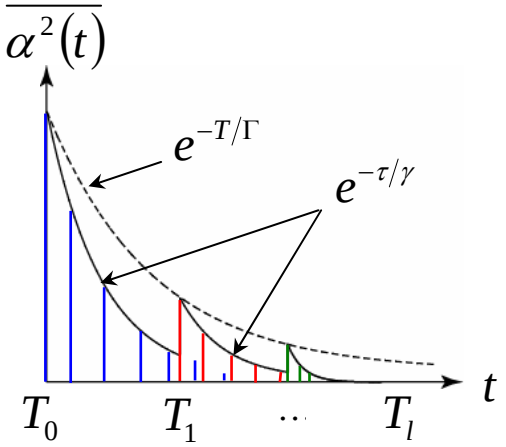
Current status of channel model in TG3c

- Statistical S-V model based: parameters are extracted from measurement data (06/112 Pollock), (06/113 Pollock)
- Angle of arrival (AoA) modification is introduced (05/368 Skafidas), (05/412 Pollock)
- Only single directional channel model is going to be obtained(05/654 Su-Khiong)

Review of S-V model (05/368)

$$h(t) = \sum_{l=0}^{L-1} \sum_{k=0}^{K_l - 1} \alpha_{l,k} \delta\left(t - T_l - \tau_{l,k}\right)$$

l = cluster number,
k = ray number in i-th cluster,
L = total number of clusters;
K_l = total number of multipath components (number of rays) in the l-th cluster;
$\alpha_{l,k}$ = multipath gain coefficient of the k-th ray in the l-th cluster;
T_l = arrival time of the first ray of the l-th cluster;
$\tau_{k,l}$ = delay of the k-th ray within the l-th cluster relative to the first path arrival time, T_l;



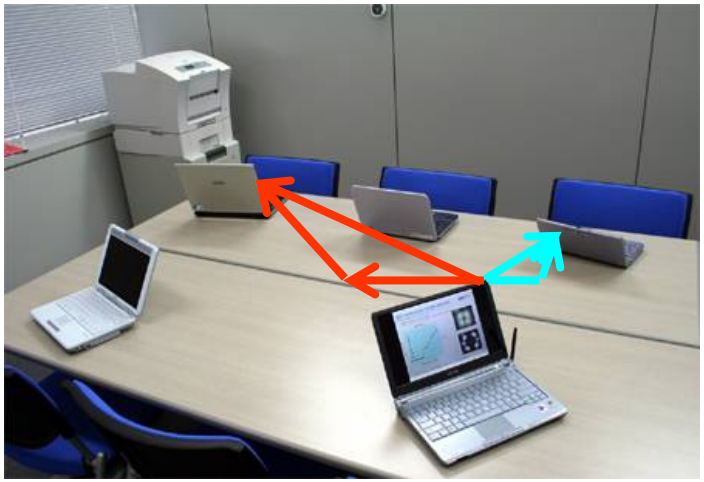
$$p(T_l \mid T_{l-1}) = \Lambda \exp\left[-\Lambda(T_l - T_{l-1})\right], \quad l > 0$$
$$p(\tau_l \mid \tau_{l,(k-1)}) = \lambda \exp\left[-\lambda(\tau_l - \tau_{l,(k-1)})\right], \quad k > 0$$

- Suitable to express Non Line of Sight (NLOS) environment using omni-directional antenna
- Difficult to express LOS environment, which sensitively depend on transceiver position

Realistic environment to support 2-3 Gbps PHY-SAP pay bit rate in TG3c selection criteria (05/493)

Following environment must be considered

- Line of sight (LOS)
- Use of directional antennas (>10 dBi ?)
- Short range (< 5 m ?)

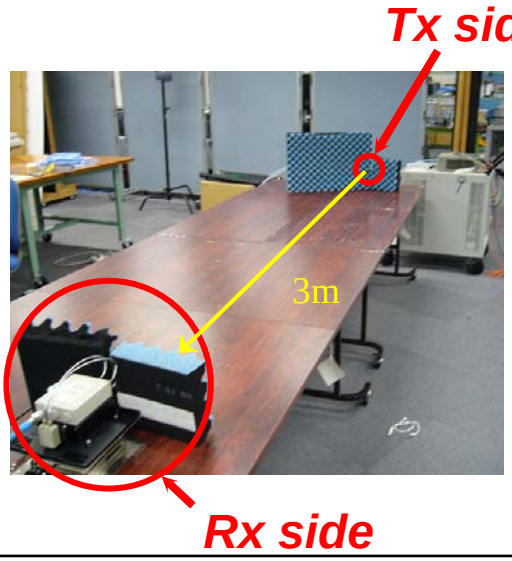


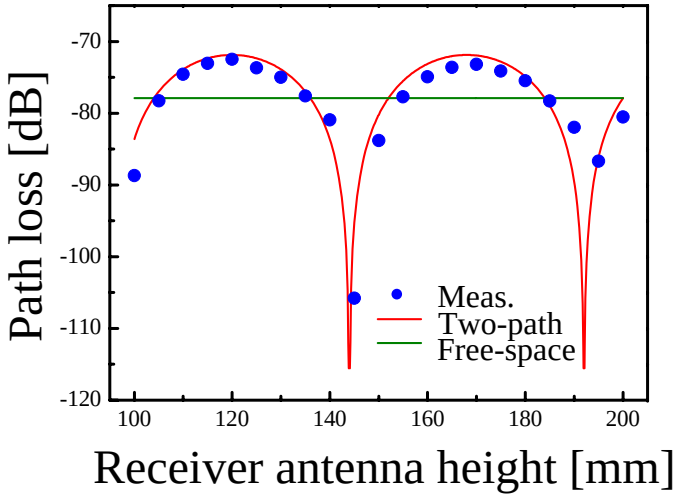
We often see two-path model cases

Example LOS environment

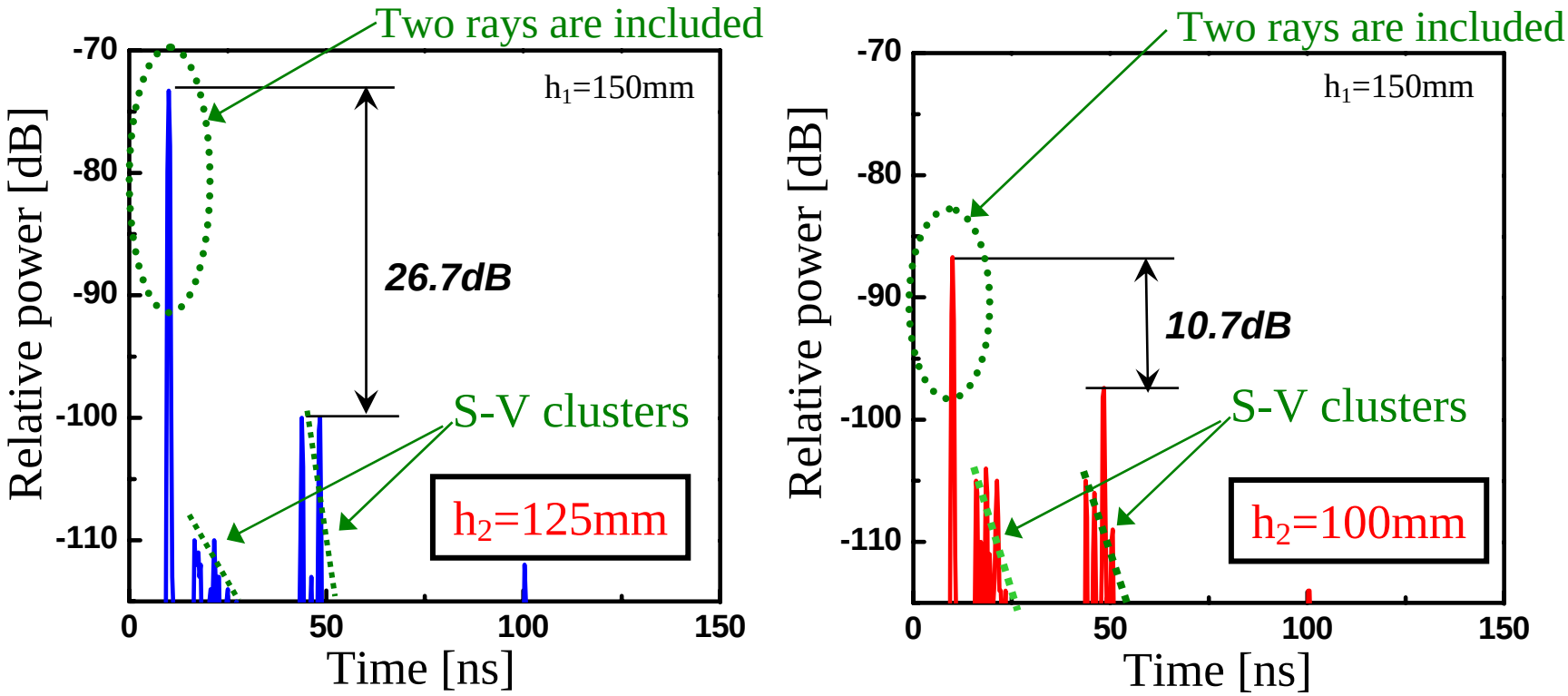
Strength and weakness of two-path model (06/119)

- Suitable to express LOS channel environment which sensitively depend on transceiver position
  (a few mm change of position can cause unexpected increase in path loss !!)
- Not statistical, and needs parameters related to transceiver position





Motivation of merging two-path and S-V models



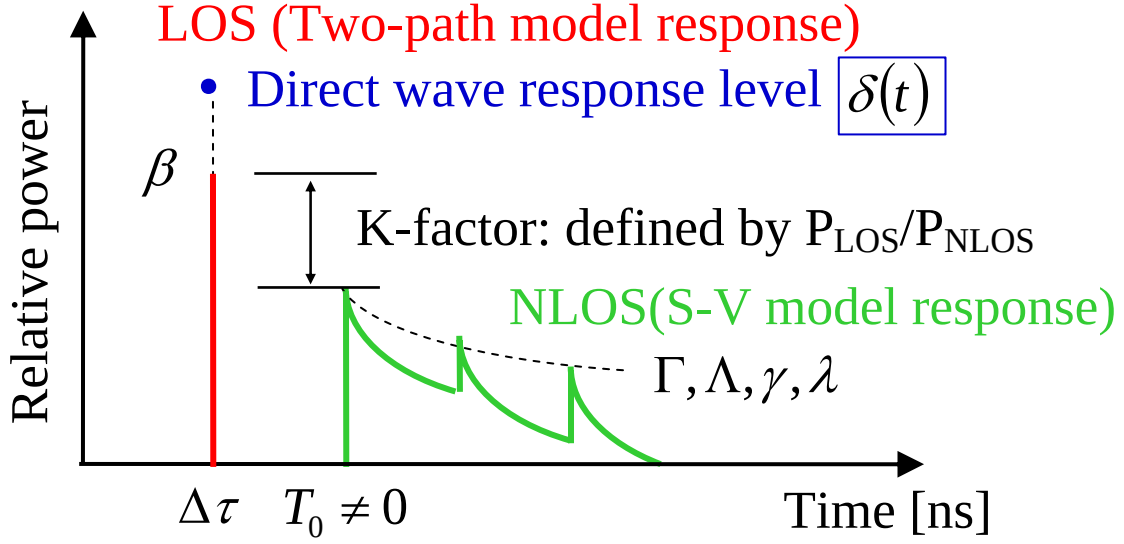
- Only 25mm height change made large difference on Power Delay Profile (PDP) but S-V clusters have remained
- Merging two-path and S-V models is essential

Merging concept for two-path and S-V models

$$h(t) = \underbrace{\delta(t) + \Gamma_M \delta(t - \Delta\tau)}_{\text{Two-path}} + \underbrace{\sum_{l=0}^{L-1} \sum_{k=0}^{K_l - 1} \alpha_{l,k}\, \delta(t - T_l - \tau_{l,k})}_{\text{S-V model}}$$

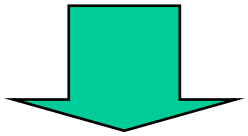
$$\text{if} \quad \Delta\tau << \frac{1}{Bw} \quad Bw\text{: System Bandwidth}$$

$$h(t) \cong \beta\, \delta(t) + \sum_{l=0}^{L-1} \sum_{k=0}^{K_l - 1} \alpha_{k,l}\, \delta(t - T_l - \tau_{k,l})$$



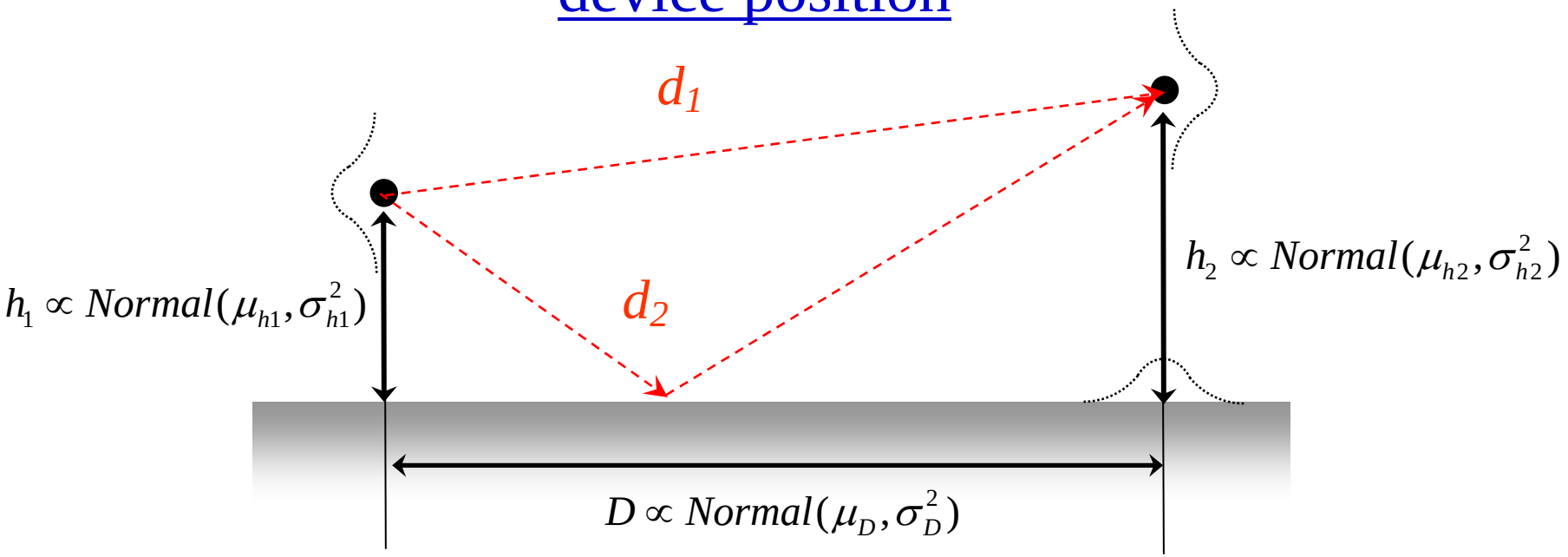
Challenge to merge two-path and S-V models

- Two-path model is deterministic model, defined by specified positioning parameters
- S-V model is statistical model, defined by probability functions



- Necessary to develop a statistical two-path model

Statistical two-path model considering uncertainty of device position

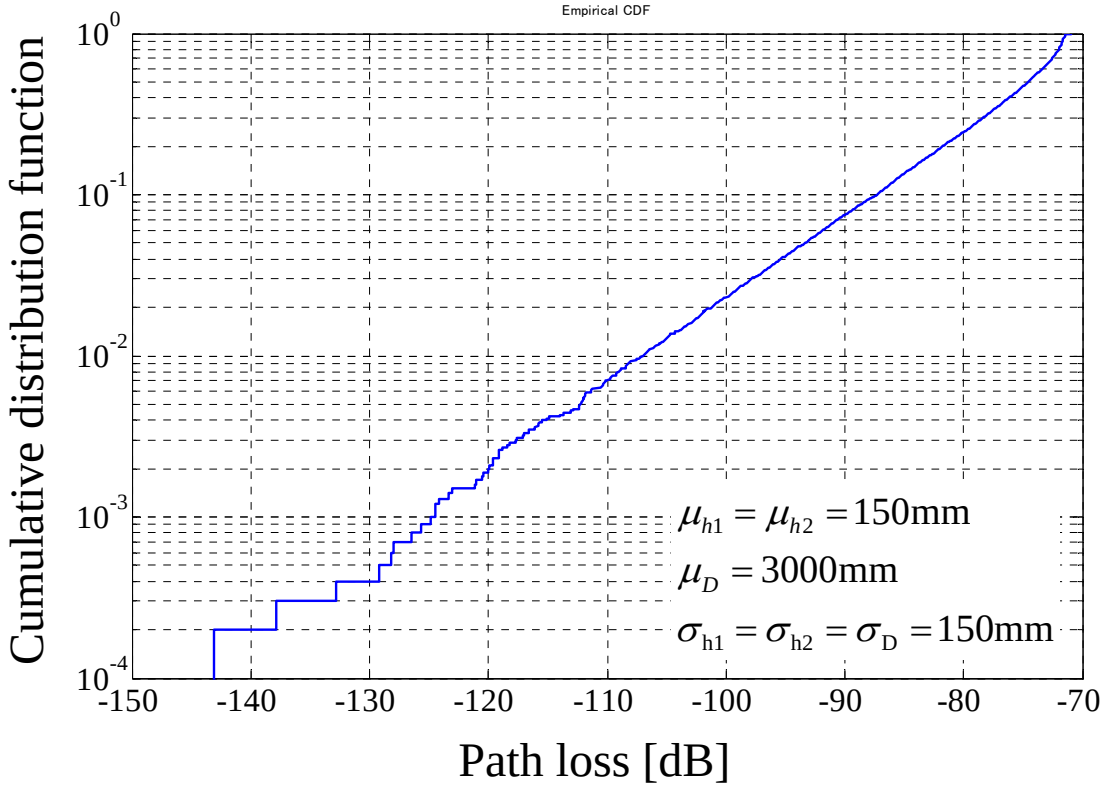


Path loss: $\frac{P_r}{P_t} = \left(\frac{\lambda_f}{4\pi D}\right)^2 \left|1 + \Gamma_M \exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{D}\right]\right|^2$

Each parameter (D, h_1, h_2) can be assumed to follow Normal distribution independently

μ_i : average σ_i : standard deviation

Cumulative distribution function (CDF) of path loss



CDF of path loss can be used for design of link budget

Proposed channel model merging two-path and S-V models

$$h(t) = \beta\,\delta(t) + \sum_{l=0}^{L-1}\sum_{k=0}^{K_l-1}\alpha_{l,k}\,\delta\left(t - T_l - \tau_{l,k}\right)$$

$$\beta = \frac{\mu_D}{D}\left| p + \Gamma_M \exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{D}\right]\right| e^{j\theta_0}$$

Two-path parameters

$D \propto Normal\left(\mu_D, \sigma_D^2\right)$

$h_1 \propto Normal\left(\mu_{h1}, \sigma_{h1}^2\right)$

$h_2 \propto Normal\left(\mu_{h2}, \sigma_{h2}^2\right)$

Γ_M : Reflection coefficient

p : LOS blocking factor(0 or 1)

$$Normal(\mu, \sigma^2) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left\{\frac{-(x-\mu)^2}{2\sigma^2}\right\}$$

S-V parameters

$1/\Lambda$: *cluster* arrival rate

$1/\lambda$: *ray* arrival rate

Γ : *cluster* decay factor

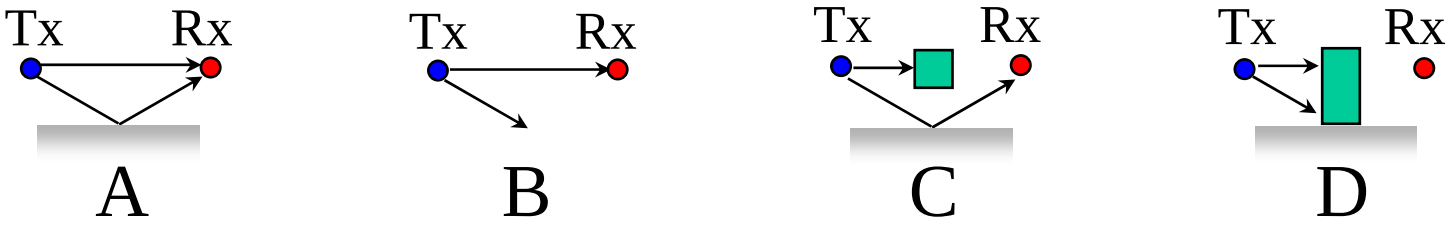
γ : *ray* decay factor

σ_1 : *cluster* lognormal standard deviation

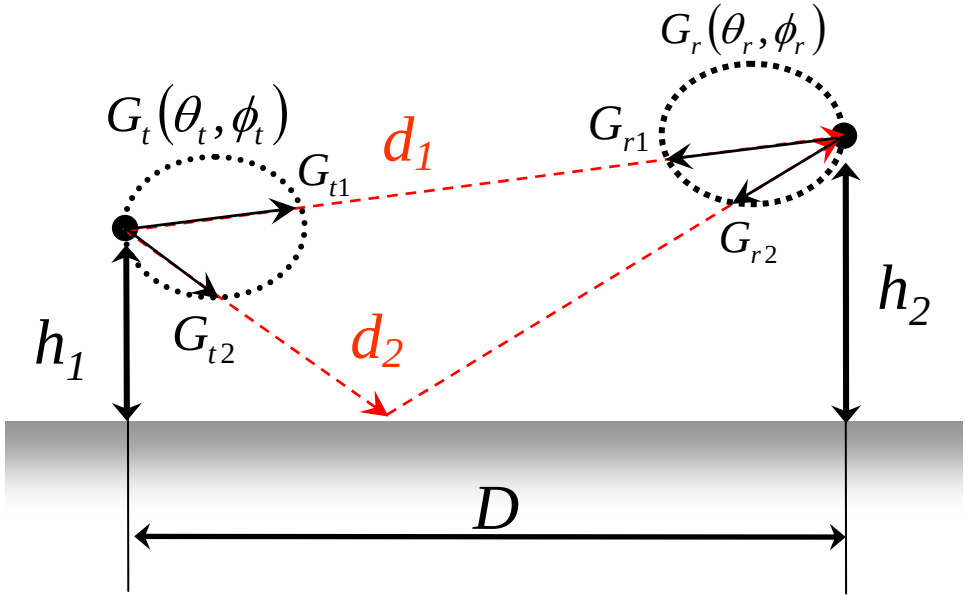
σ_2 : *ray* lognormal standard deviation

Categorization of environment and correspondent parameters

Environment	A	B	C	D
LOS/NLOS	LOS		NLOS	
Two-path	p=1 $\lvert\Gamma_M\rvert \leqq 1$	p=1 $\Gamma_M = 0$	p=0 $\lvert\Gamma_M\rvert \leqq 1$	p=0 $\Gamma_M = 0$
K-factor	$0 < K < \infty$			$K = 0$



How to deal with AoA information



$$\beta = \frac{\mu_D}{D}\left| p\sqrt{G_{t1}G_{r1}} + \sqrt{G_{t2}G_{r2}}\,\Gamma_M \exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{D} \right] \right|$$

$\theta_{ti}, \phi_{ti}, \theta_{ri}, \phi_{ri}$: *defined by* D, h_1, h_2 $\qquad$ G_{ti}, G_{ri} : *Antenna gain*

i : Number of path

AoA information can be included in two-path model

Procedure to complete generic model

Generic channel model: Changing value of its parameters enables us to simulate all WPAN channel environment

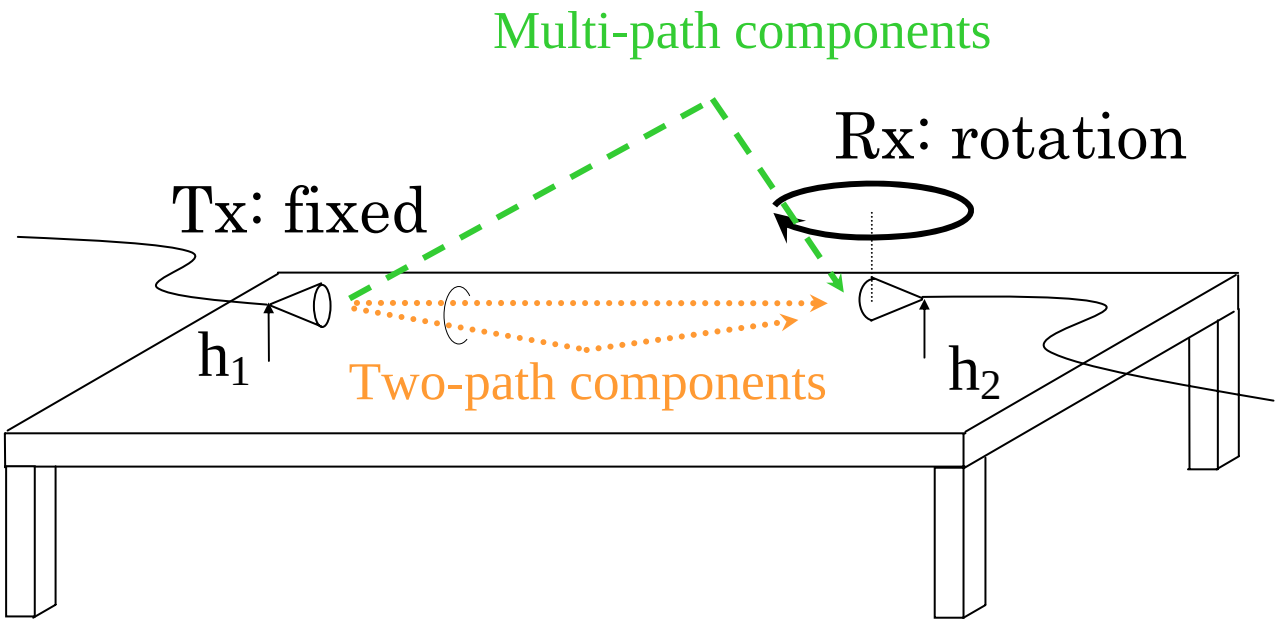
$$h(t)=\beta\,\delta(t)+\underbrace{\sum_{l=0}^{L-1}\sum_{k=0}^{K_l-1}\alpha_{l,k}\,\delta\left(t-T_l-\tau_{l,k}\right)\delta\left(\varphi-\Psi_l-\psi_{l,k}\right)}\sqrt{G_r\left(0,\Psi_l+\psi_{l,k}\right)}$$

AoA modified S-V model

$$\beta=\frac{\mu_D}{D}\left|p\sqrt{G_{t1}G_{r1}}+\sqrt{G_{t2}G_{r2}}\,\Gamma_M\exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{D}\right]\right|$$

- Generic model is made by merging two-path and AoA modified S-V models
- Completion of generic model requires additional measurement

Procedure to complete generic model (cont')



Feasible measurement plan

- Additional AoA measurement (2 weeks)
- Extraction of parameters (2 weeks)

can be done by July meeting 2006

Summary

- Proposed generic channel model merging two-path and AoA modified S-V model
- Introduced statistical two-path model
- Reviewed two-path and S-V models