Wideband Directional Radio Propagation Channel Analysis inside an Arched Tunnel

Gilbert Siy Ching, Mir Ghoraishi,
, Navarat Lertsirisopon, Jun-ichi Takada
Tokyo Institute of Technology, Japan

Tetsuro Imai: *R&D Center, NTT DoCoMo Inc., Japan*
Itoji Sameda: *Japan Highway Public Corporation,, Japan*
Hironori Sakamoto: *Highway Telecom Eng'g Co., Ltd., Japan*

17th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'06)

Outline

Introduction

Measurement Equipment and Scenario

Scatterer Identification and Classification

Scatterer Power Contribution

Cross Polarization Ratio

Introduction

To achieve uniterrupted communications, the radio propagation channel inside tunnels is important especially in mountainous areas or highway networks with many tunnels.

Experiments inside tunnels involve measuring the path gain (to predict coverage), or delay spread (to predict capacity) among others.

In this paper, we used a wideband channel sounder with an array on the Rx with dual polarized elements to learn more about the propagation mechanism inside tunnels.

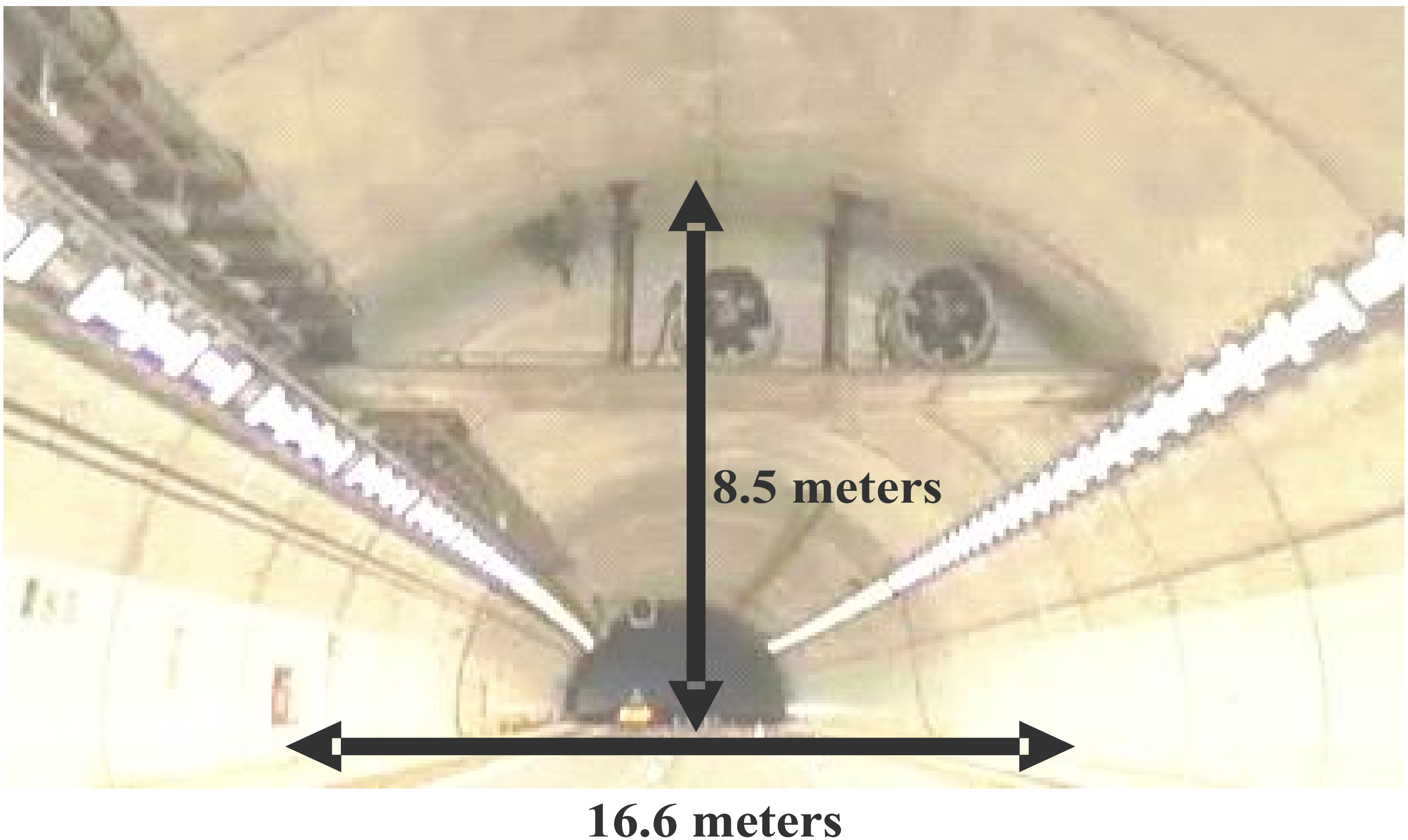
RUSK-DoCoMo channel sounder

Table 1: Measurement Parameters

Description	Value
Center frequency	5.2 GHz
Bandwidth	100 MHz
Delay resolution	10 ns
Tx signal	multitone
Tx power	40 dBm
Tx antenna	sleeve dipole (vertically oriented)
Tx antenna height	8 m (Tx1), 2.5 m (Tx2 and Tx3)
Rx antenna	cylindrical, 4 rings × 24 dual polarized patched elements
Rx antenna height	2.5 m
Synchronization	Cesium clocks

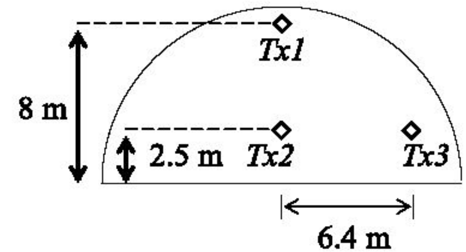
Scenario

- 2nd Tomei highway, Shizuoka prefecture, Japan
- semi-circular cross section; for 3 car lanes

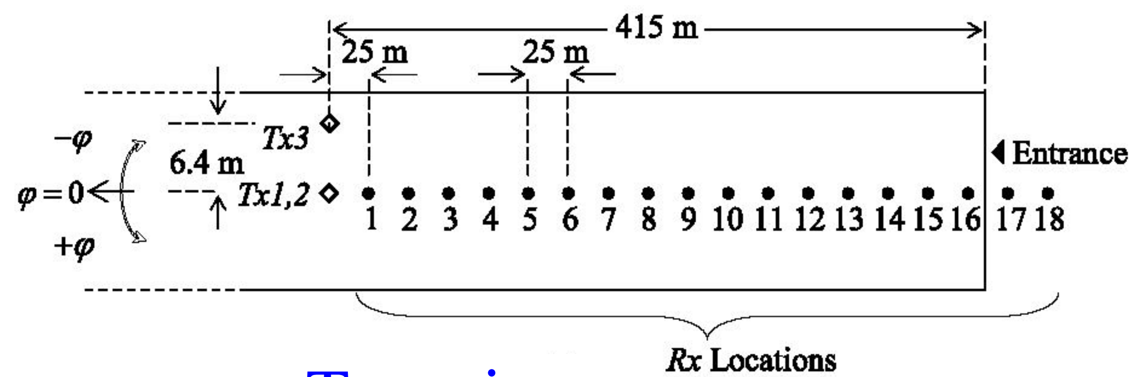


Scenario

Experiment was performed in 3 rounds:



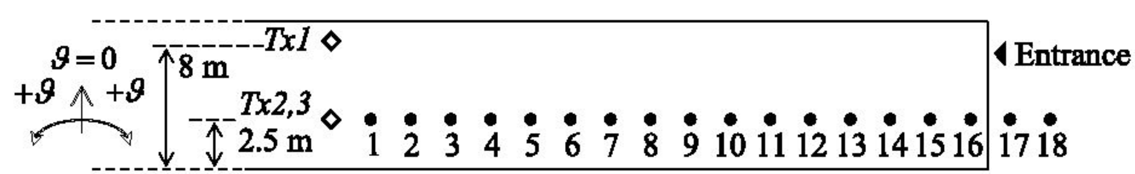
Tx1:
Rx1 to Rx18



Tx2 and Tx3:
Rx2, Rx4 ... Rx14

Top view

Side view



Parameter Estimation

A multidimensional gradient based maximum likelihood parameter estimator was used.*

The channel model for SIMO case:

$$\mathbf{H}(\tau, \varphi, \vartheta) = \sum_{l=1}^{L} \begin{bmatrix} \gamma_{H,l} \\ \gamma_{V,l} \end{bmatrix} \delta(\tau - \tau_l)\delta(\varphi - \varphi_l)\delta(\vartheta - \vartheta_l)$$

Estimates:
- Complex path weights for cross and co polarization
- Time of arrival
- Angle of arrival (azimuth and coelevation)

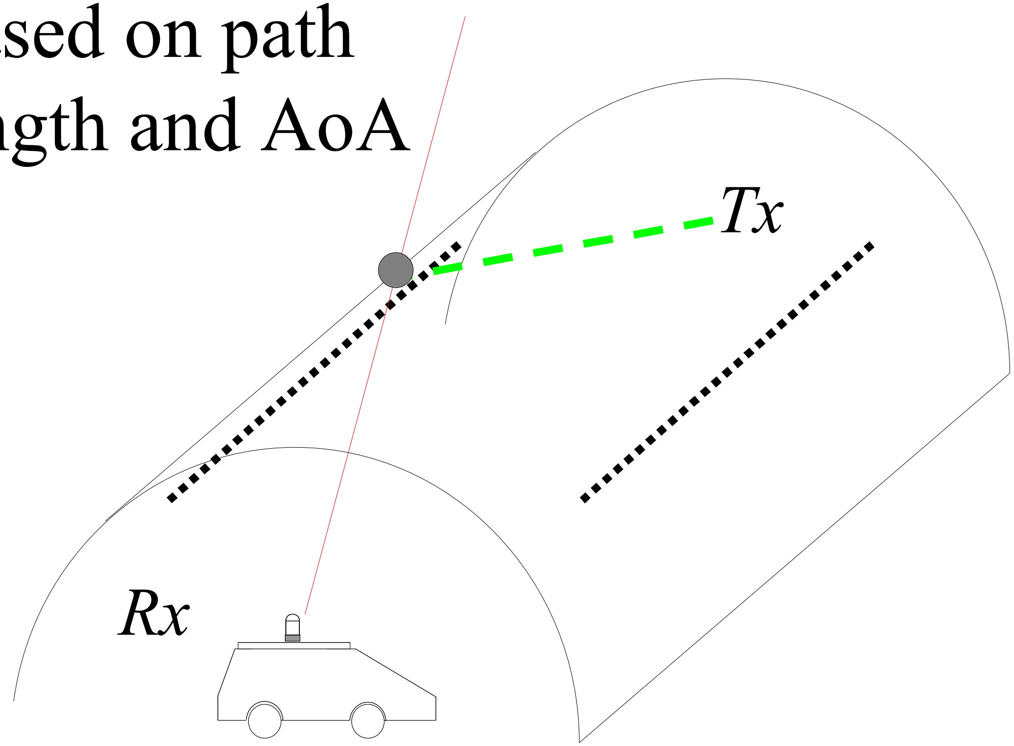
Residual power is around 12 % of the total received power.

*provided together with the channel sounder

Scatterer Identification

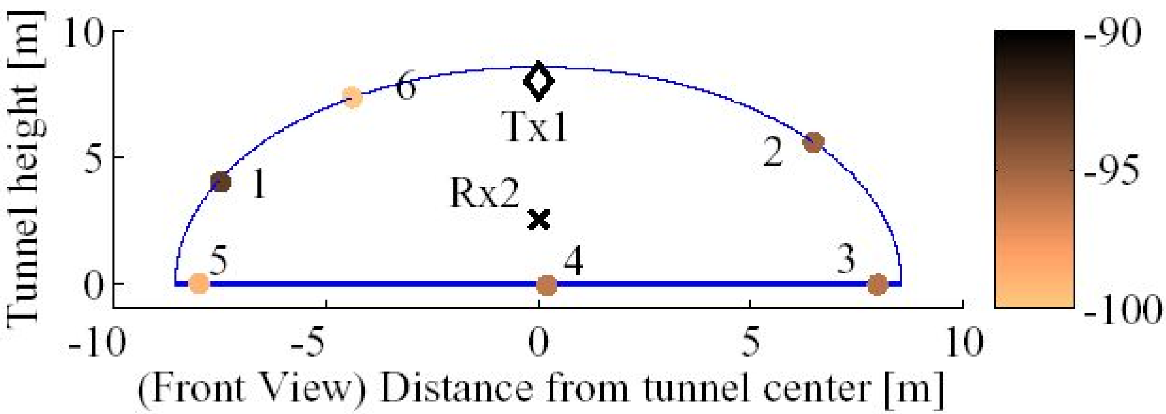
Using the AoA and path length information, scattering points can be derived assuming single-bounce.

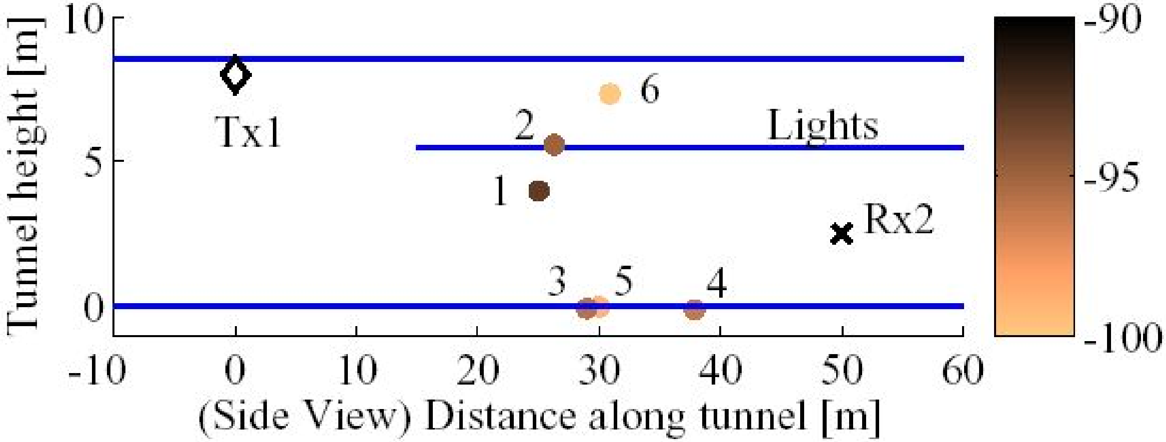
Based on path length and AoA



If the scattering points lie beyond the surface of the tunnel, its a multibounce path, and the AoA information is used to detect the last scattering point.

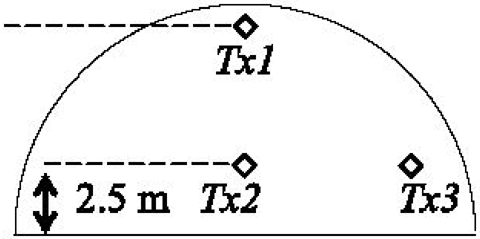
Scatterer Classification





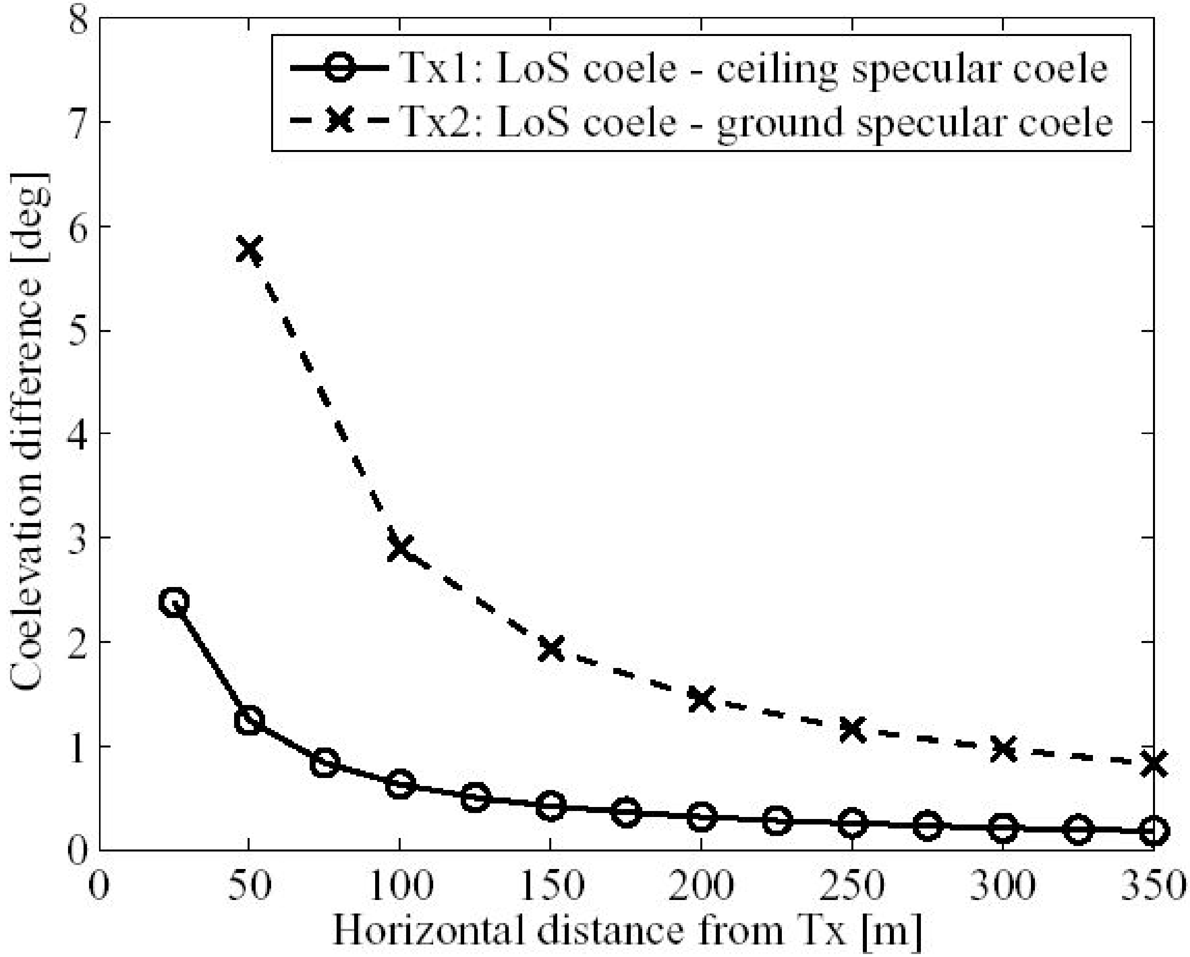
Point 1: wall
Point 2: light-frame
Points 3, 5: sidewalk
Point 4: ground
Point 6: ceiling

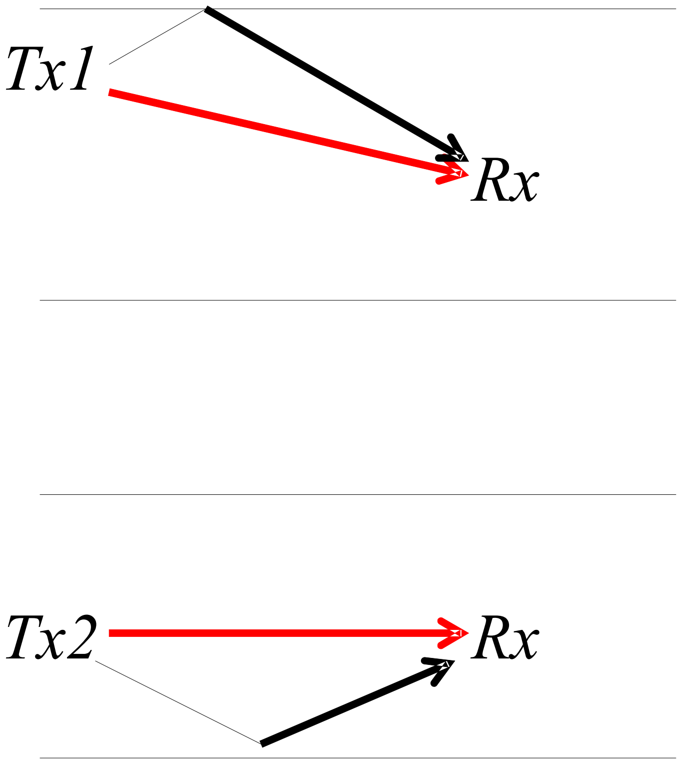
light-frame scatterers are generally single-bounces, while the others can either be single-bounce or multibounce

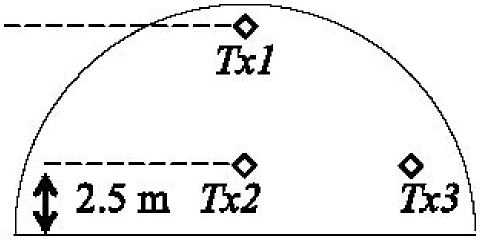


Resolvability of LoS path

Estimated LoS path may not be composed only of a distinct ray if it is too close to other paths.

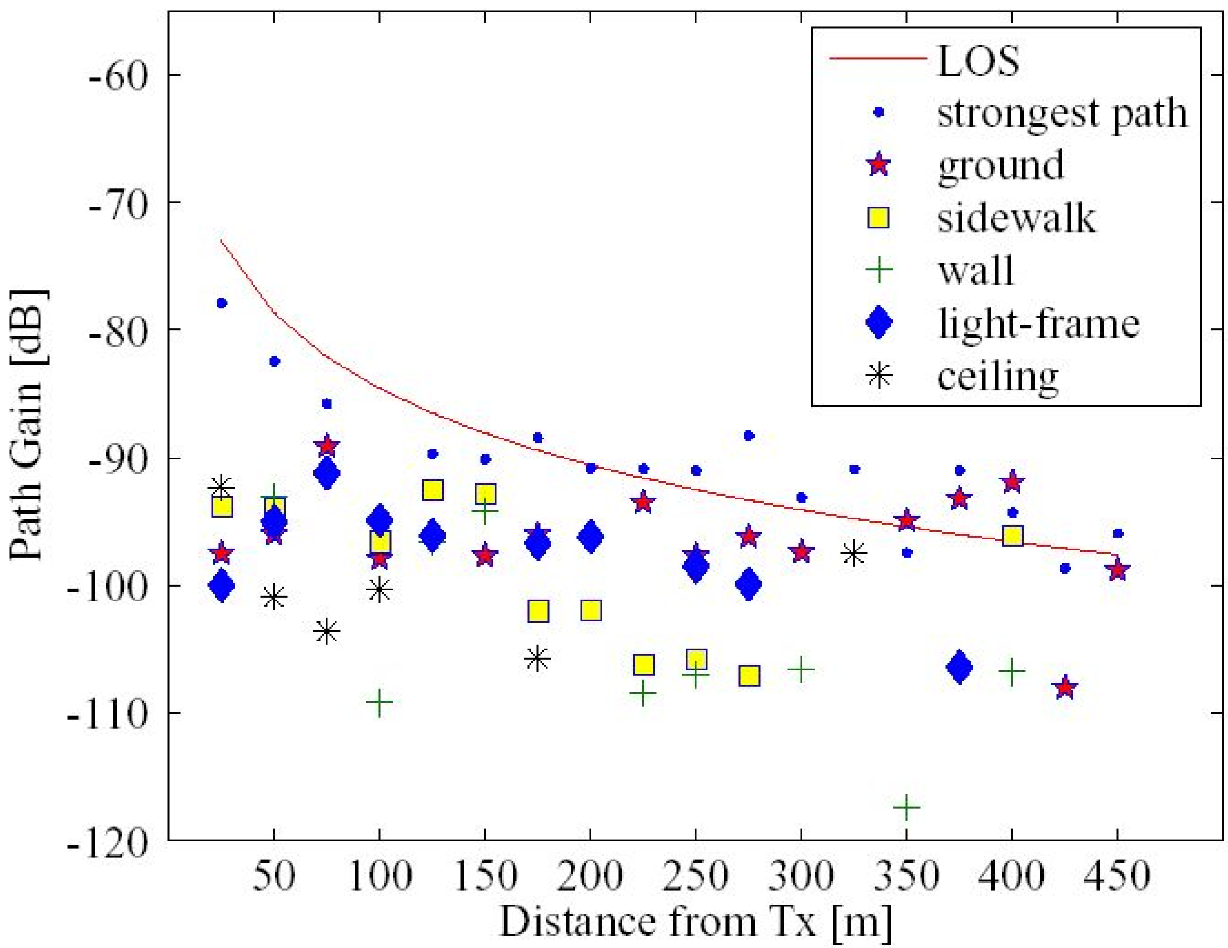






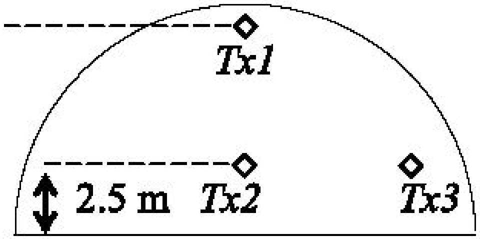
Scatterer Power Contribution:Tx1

Path gain of similar scatterer class are combined in each Rx.

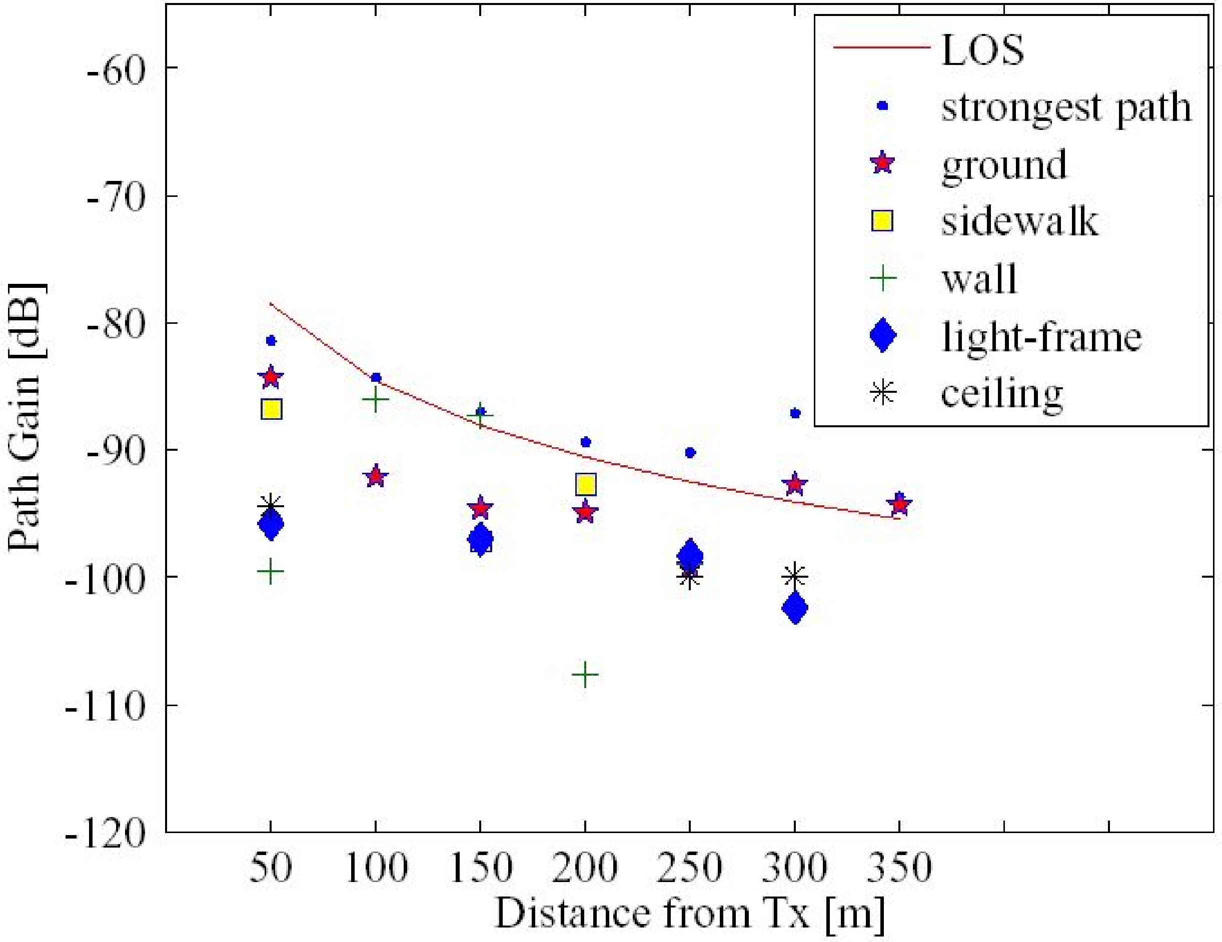


Estimated LoS (strongest path) path gain differs from theoretical LoS because Tx1 is located near ceiling.

High power contribution from ground, sidewalk and light-frame scatterers.



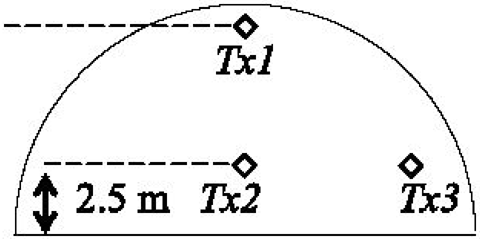
Scatterer Power Contribution:Tx2



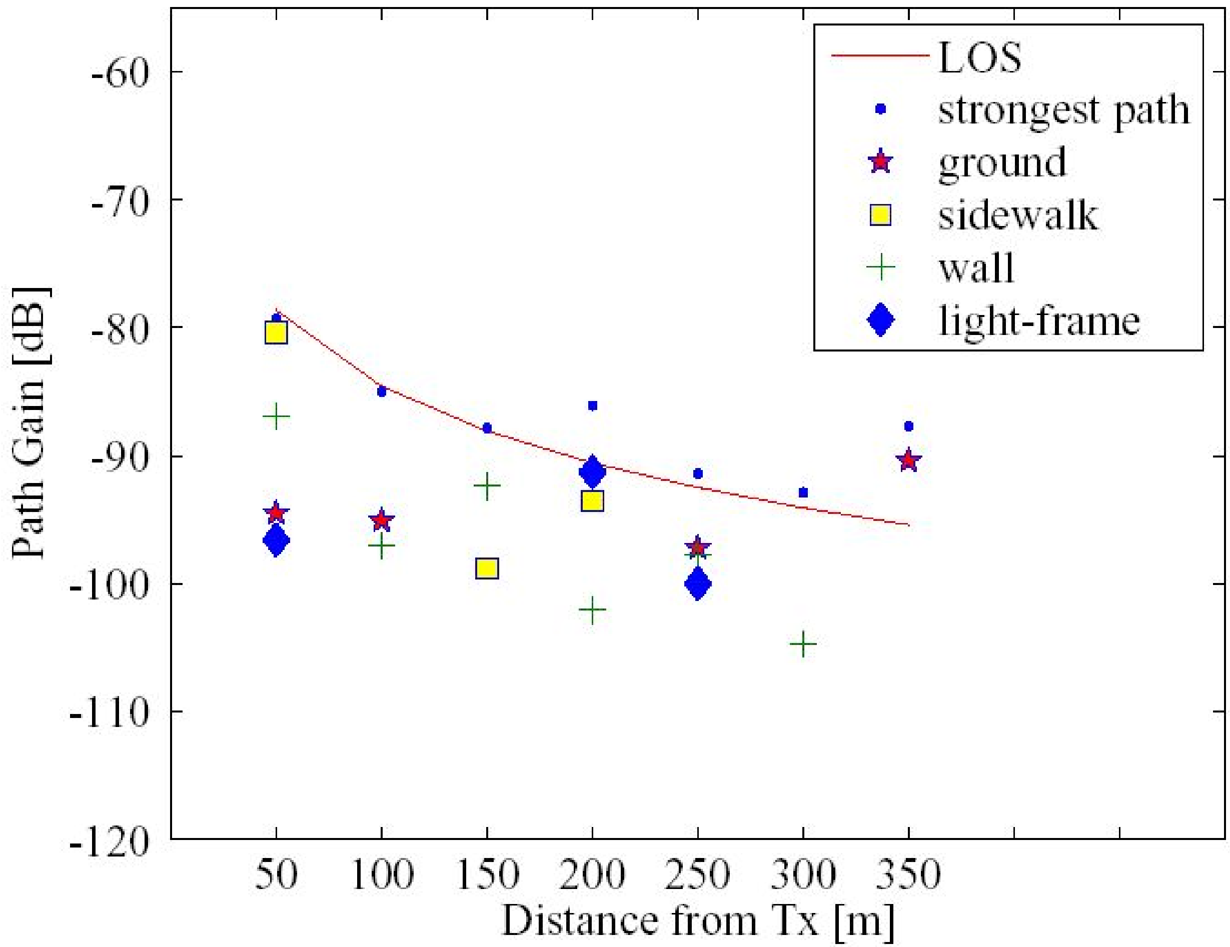
Ground scatterers again dominate.

Wall scatterers maybe due to double-bounces from wall to wall before reaching Rx.

Detected ceiling and ground *specular* reflection only at Rx <= 50 m



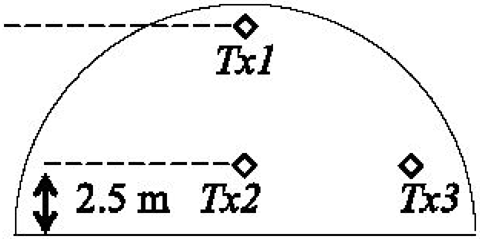
Scatterer Power Contribution:Tx3



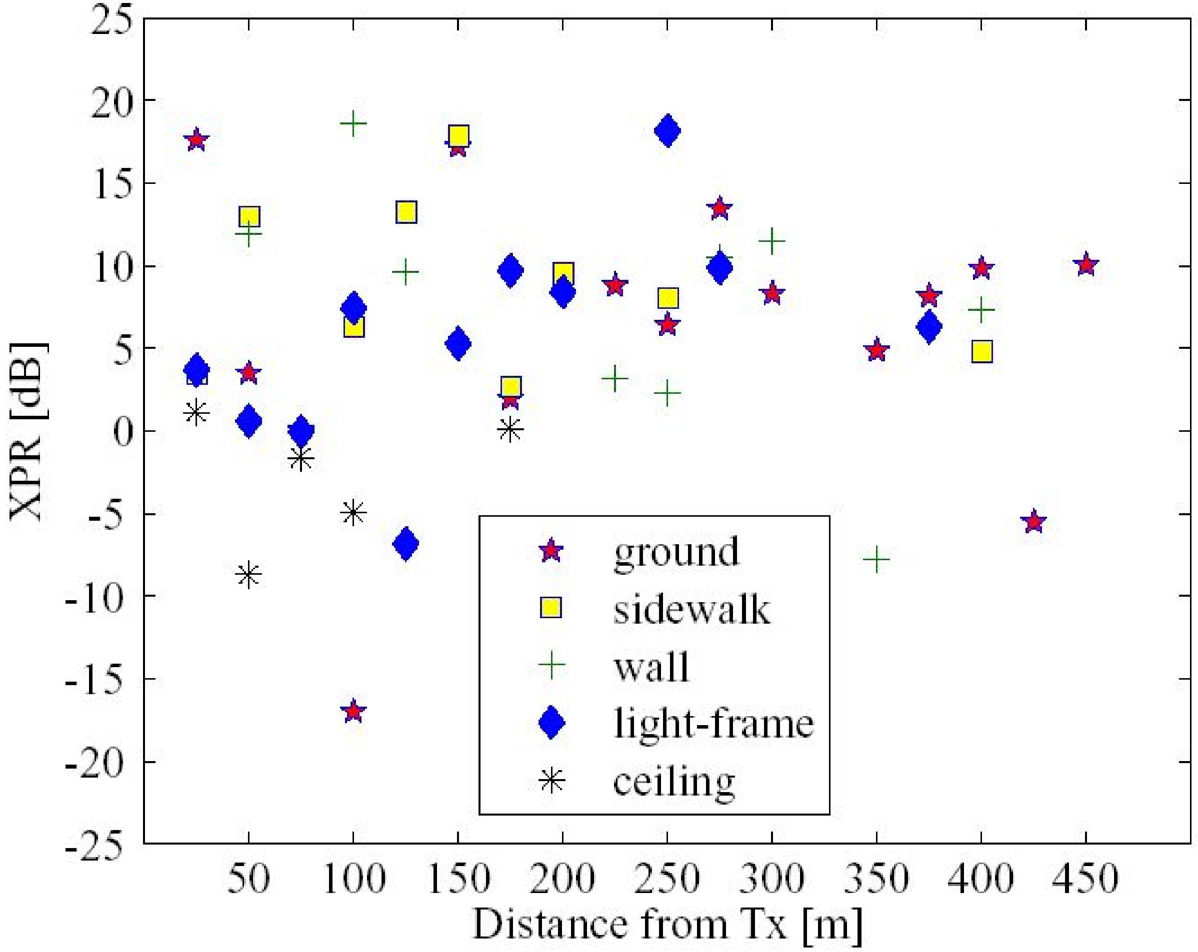
No ceiling scatterers.

If both Tx and Rx are in the middle of the tunnel, paths can scatter to ground then ceiling before reaching Rx.

Since Tx3 is at the side, paths that scatter to the ground may scatter to the walls (instead of the ceiling).

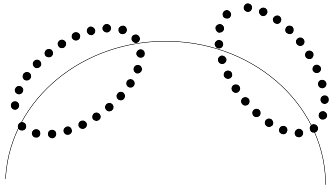


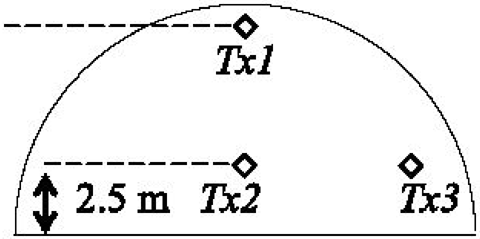
XPR: Tx1



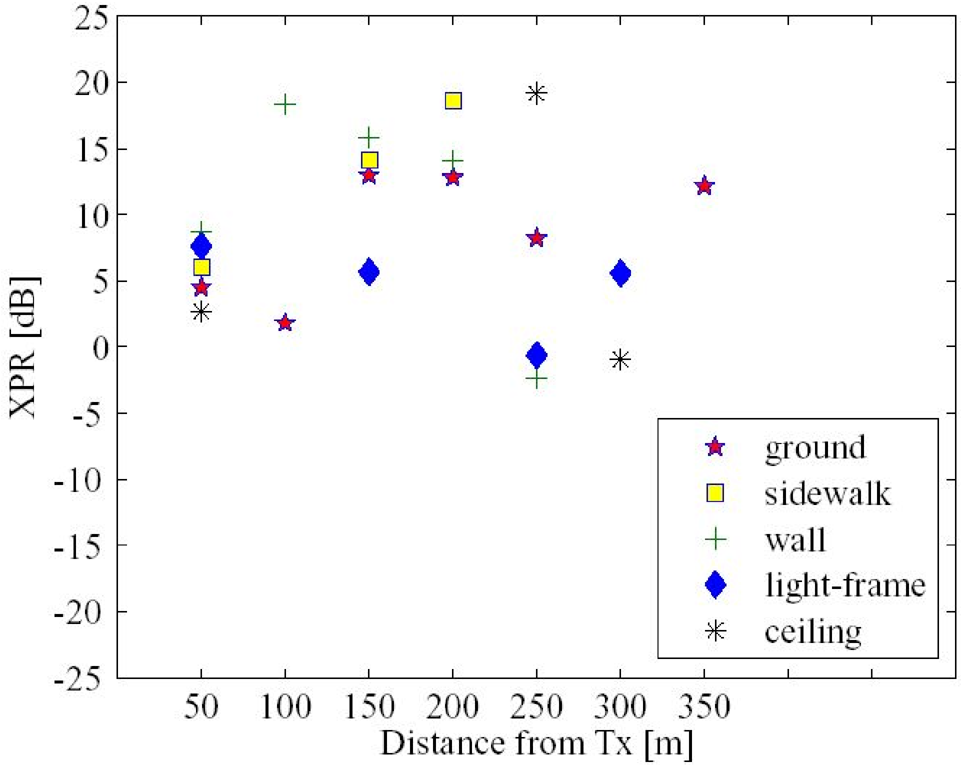
Mean in dB of similar scatterers was taken in each Rx.

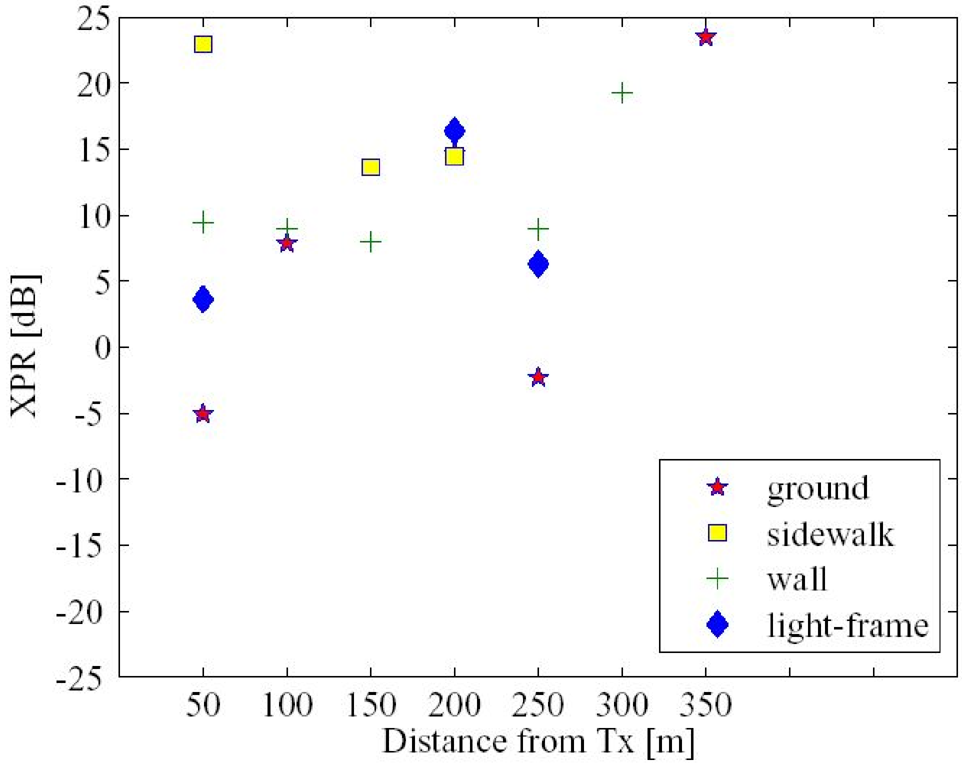
Polarization rotation occurs when scattering point is from





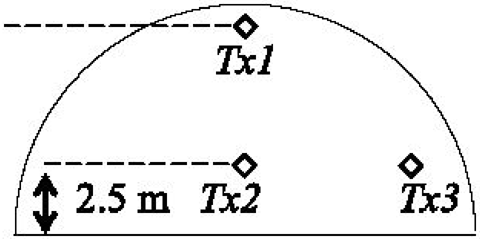
XPR: Tx2, Tx3





For single-bounce ground or sidewalk scatterers, polarization is maintained because of the flat surface of the scatterer.

For multi-bounce scatterers, XPR depends on all interactions.



XPR: all Rx points per Tx

Tx1:	mean 5.8 dB	std dev 8.2 dB	number of paths: 77
Tx2:	mean 9.6 dB	std dev 9.5 dB	number of paths: 37
Tx3:	mean 11.2 dB	std dev 8.9 dB	number of paths: 28

More rotation for Tx1 maybe because of its location on upper portion of tunnel such that more energy is bouncing the curved portion of the tunnel.

Conclusion

The spatio-temporal radio propagation channel inside an arched tunnel was analyzed utilizing a wideband directional measurement data.

Majority of the scatterers are from the ground.

When the Tx antenna is near the ceiling, the rotation of the wave polarization is observed especially for ceiling scatterers.

When Tx antenna is positioned on the side of the tunnel, the contribution of ceiling scatterers is less observable.

Thank You