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

Submission Title: [Fading in 900 MHz 802.15.4k Channels]
Date Submitted: [12 September 2011]
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Re: [802.15.4k Channel Model Discussions]

Abstract: [This document describes results from experiments designed to characterize the fading characteristics of 900 MHz in star-based network configurations expected in 802.15.4k network deployments. Unlike the deep, rapid fades that have been characterized in 15.4g, deployment (mesh) scenarios, fading in many 15.4k deployments are dominated by LOS or strong multipath rays and exhibit fading that is more slow and shallow in nature.]

Purpose: [Bring this information to the attention of TG4k working group for discussion.]

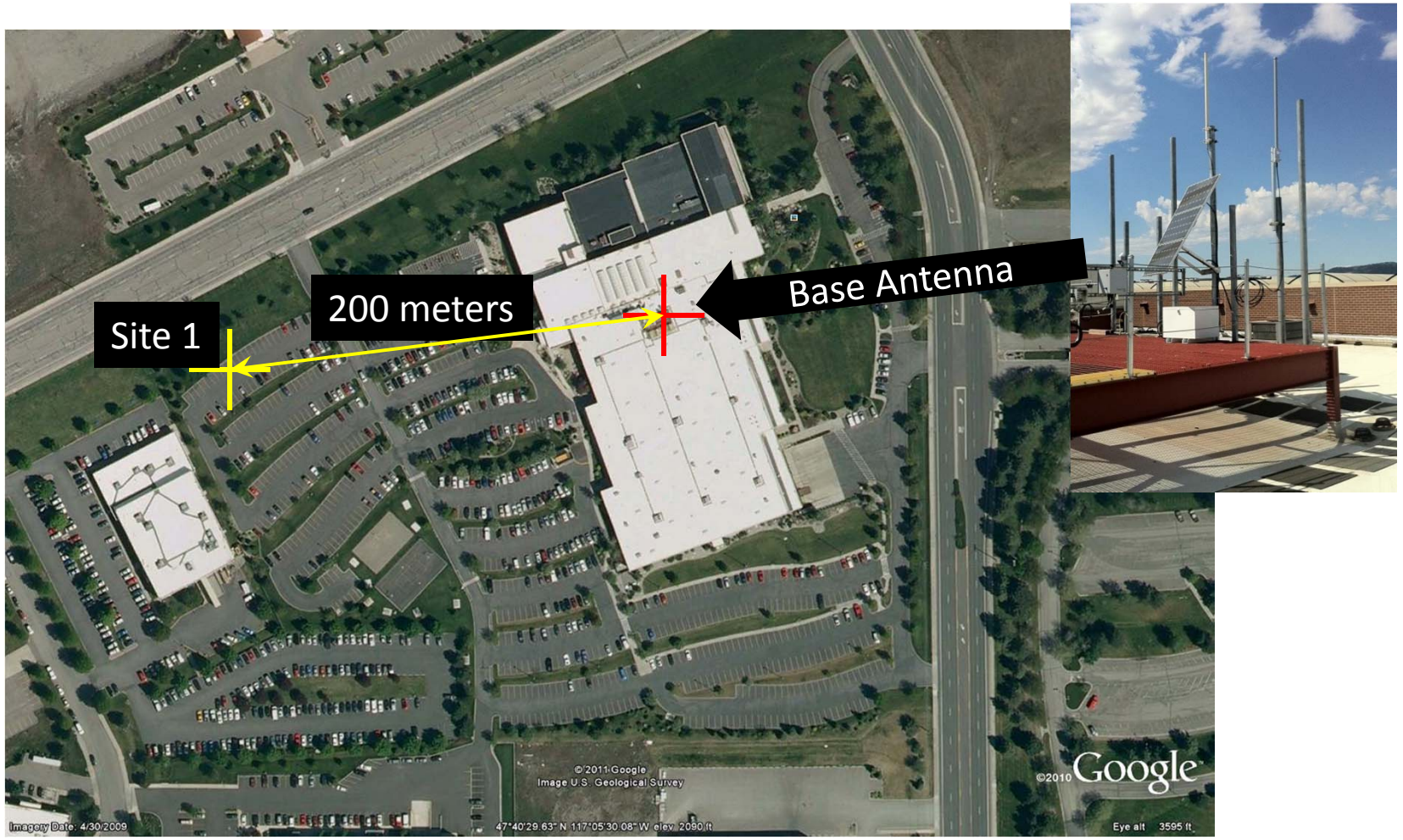
Experimental Objective

- Evaluate fading for IEEE 802.15.4k LECIM environments
  - Star Network Configuration with Typical Antenna Heights
  - Fixed Transmitter and Receiver Locations
  - Various vehicular traffic settings
- Measurements designed to evaluate performance in 915 MHz ISM band
  - Performed at 931.9875 on licensed paging channel both to avoid ISM interference and allow CW operation

Experimental Setup

- Transmitting antenna at 12m
- Receiving antenna mounted on van roof (~2.5m)
- Relatively flat terrain with little foliage
- Buildings are mostly office and light commercial
- Winds calm during tests
- RX test locations selected to be as close to vehicular traffic as possible

900 MHz Line of Sight Test Setup

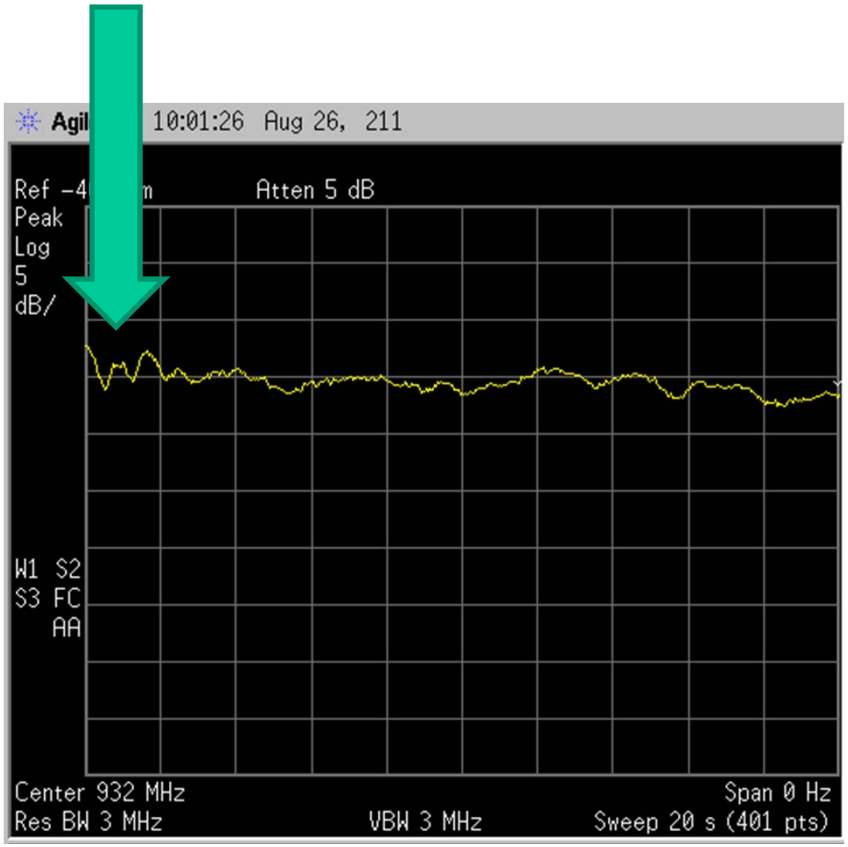


Site 1 – Arterial Road with LOS

- 5 lane road
- Moderate traffic
- 55 km/hr speeds

- Fading ≤ 5 dB

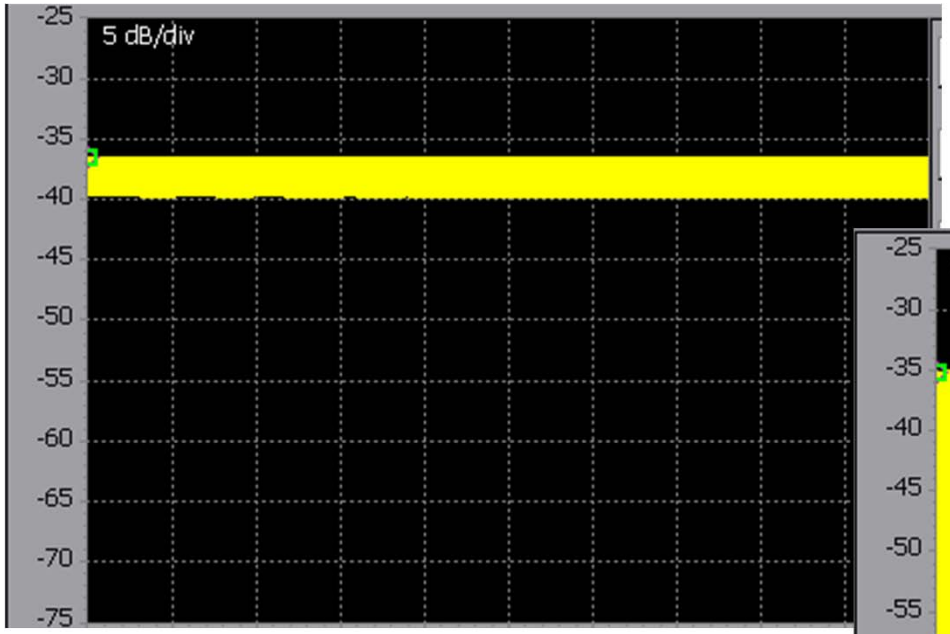
Semi tractor-trailer across the street



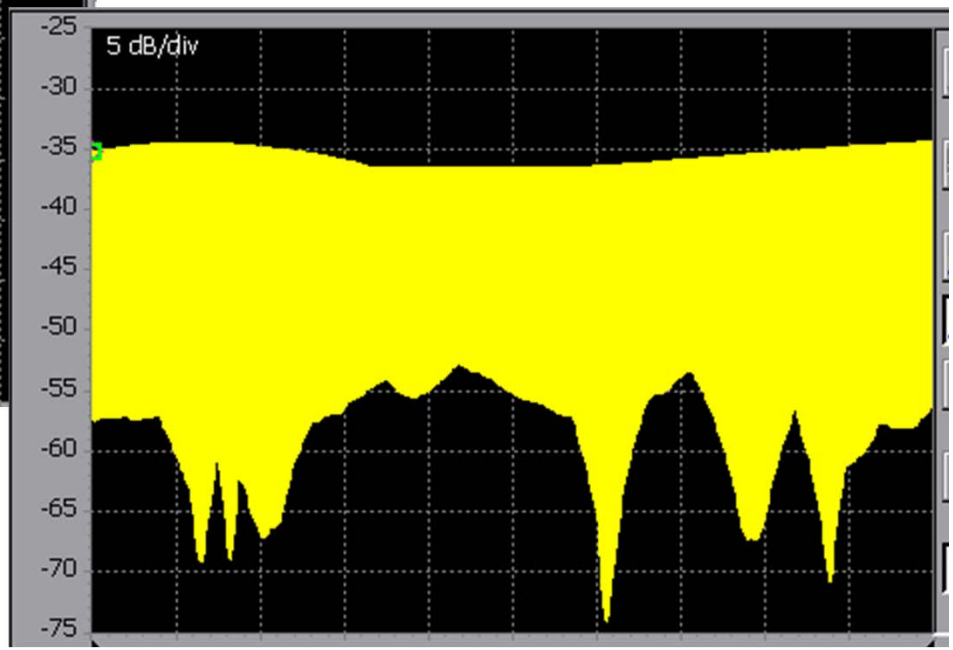
Stationary versus Mobile

Max/Min Hold Power Envelope – Site 1

Stationary – 3 to 4 dB of Fading
Candidate for Ricean Fading Model

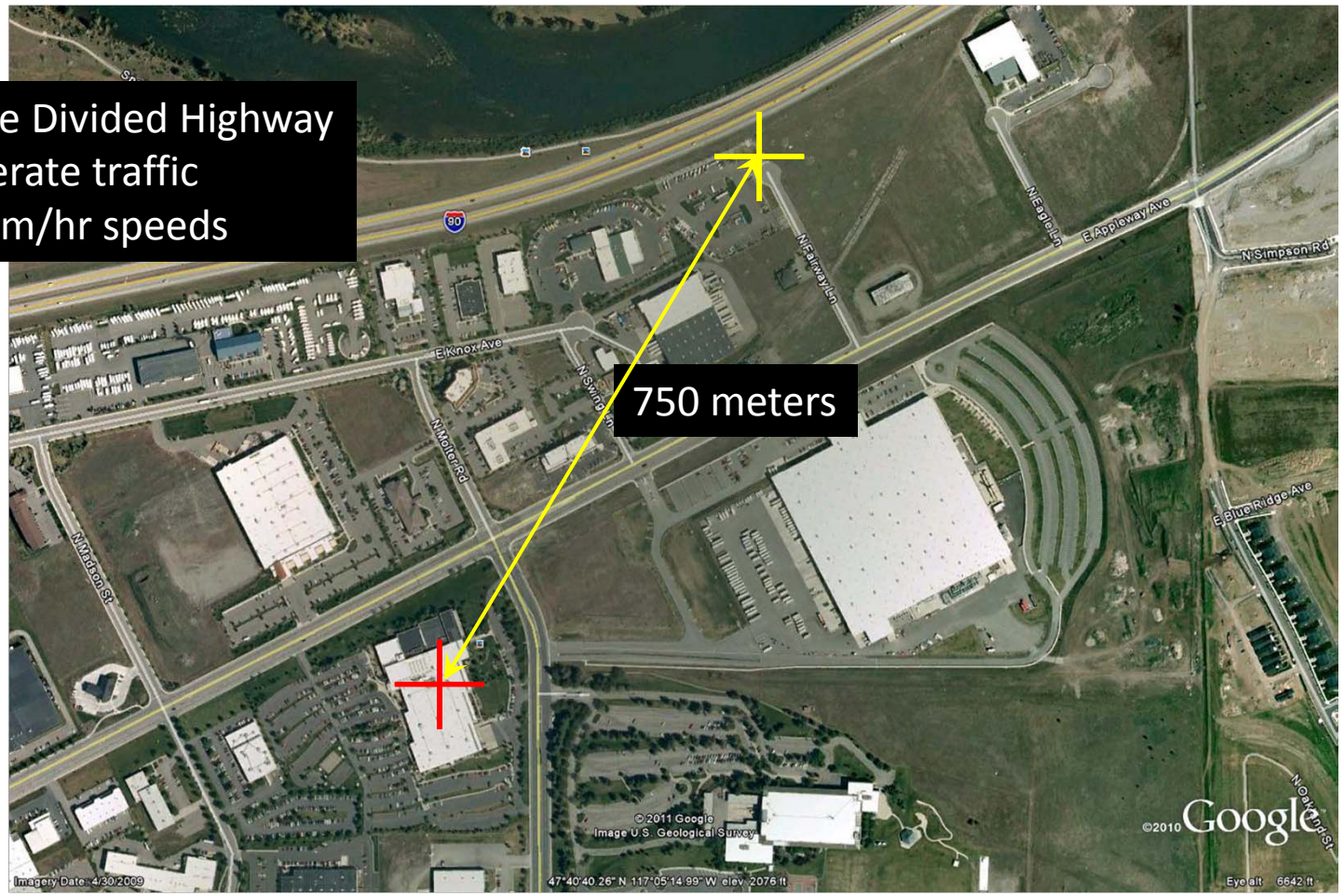


~ 5 km/hr – up to 40 dB of fading
Candidate for Rayleigh Fading Model



Most LECIM Applications (15-11-0245-02-004k) are stationary

Site 2 – Adjacent to Freeway

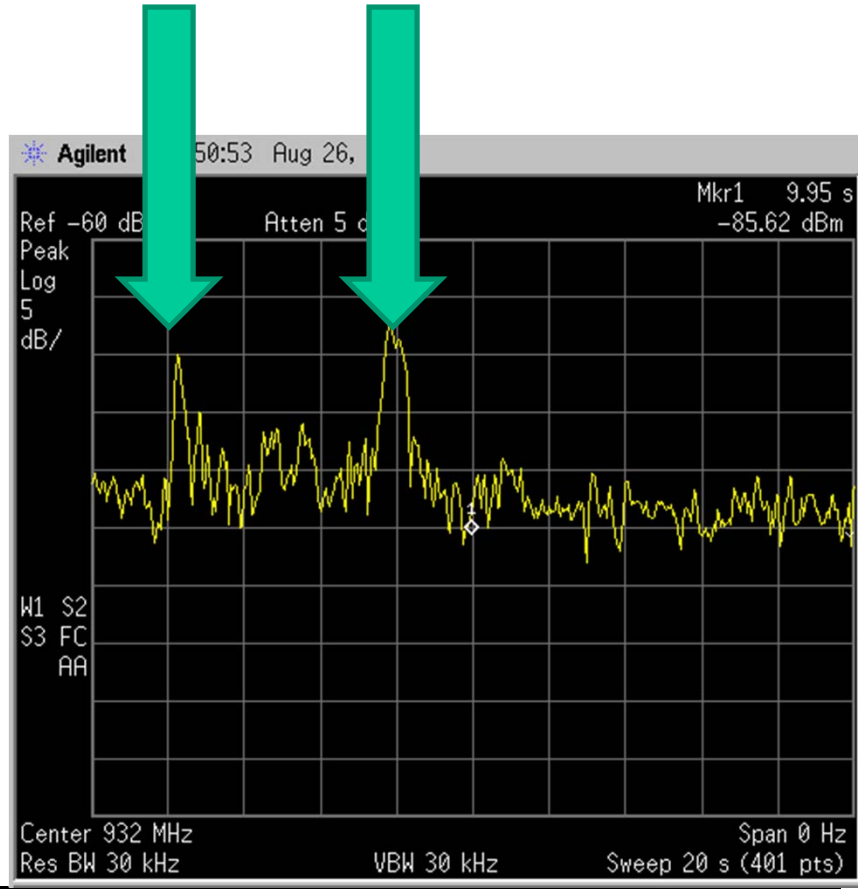


Freeway Site Detail

Freeway close to traffic (21 m)

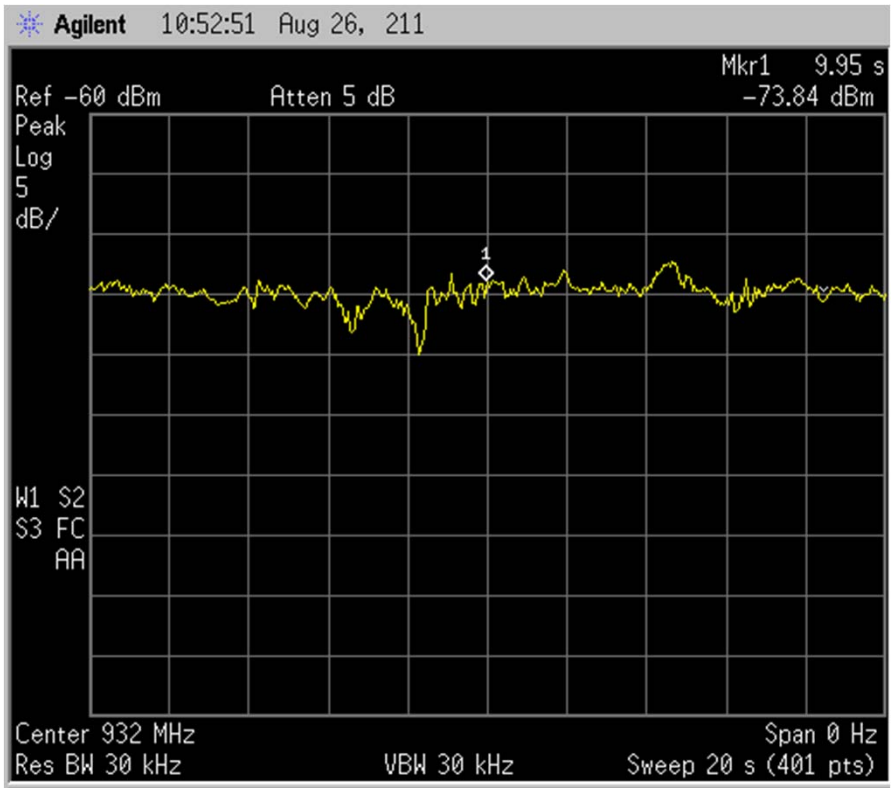
- Fading most extreme when closest to road
- Fading ≤ 10 dB

Two passing Semi tractor-trailer trucks
Improve multipath reception.
(Also note: no deep fades)



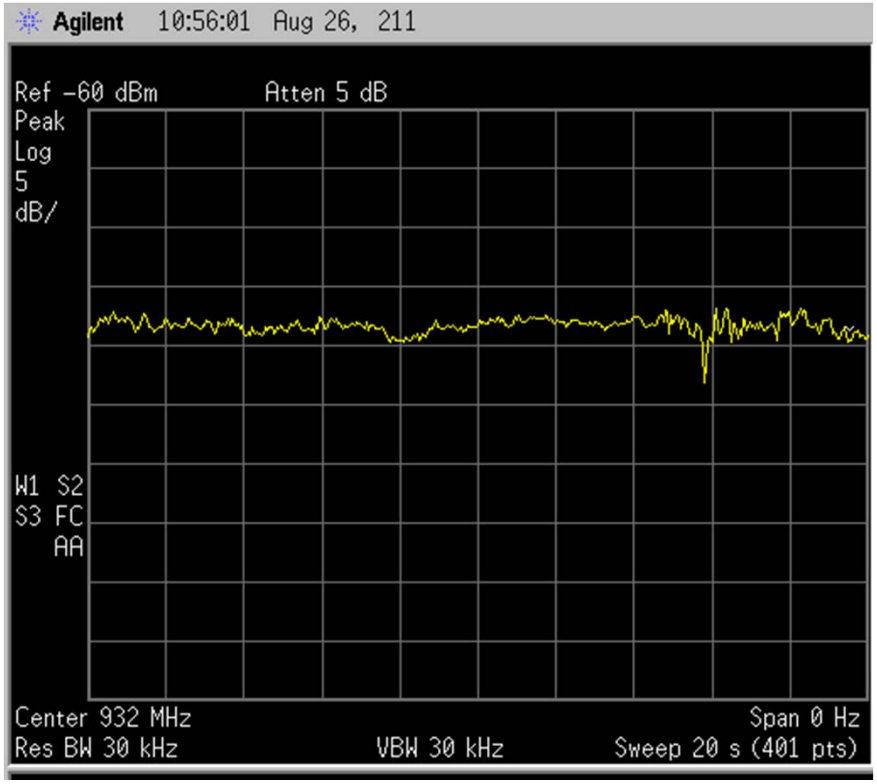
Freeway at 30m

- Small increase in distance from highway significantly reduces signal variation
- Fading ≤ 7 dB

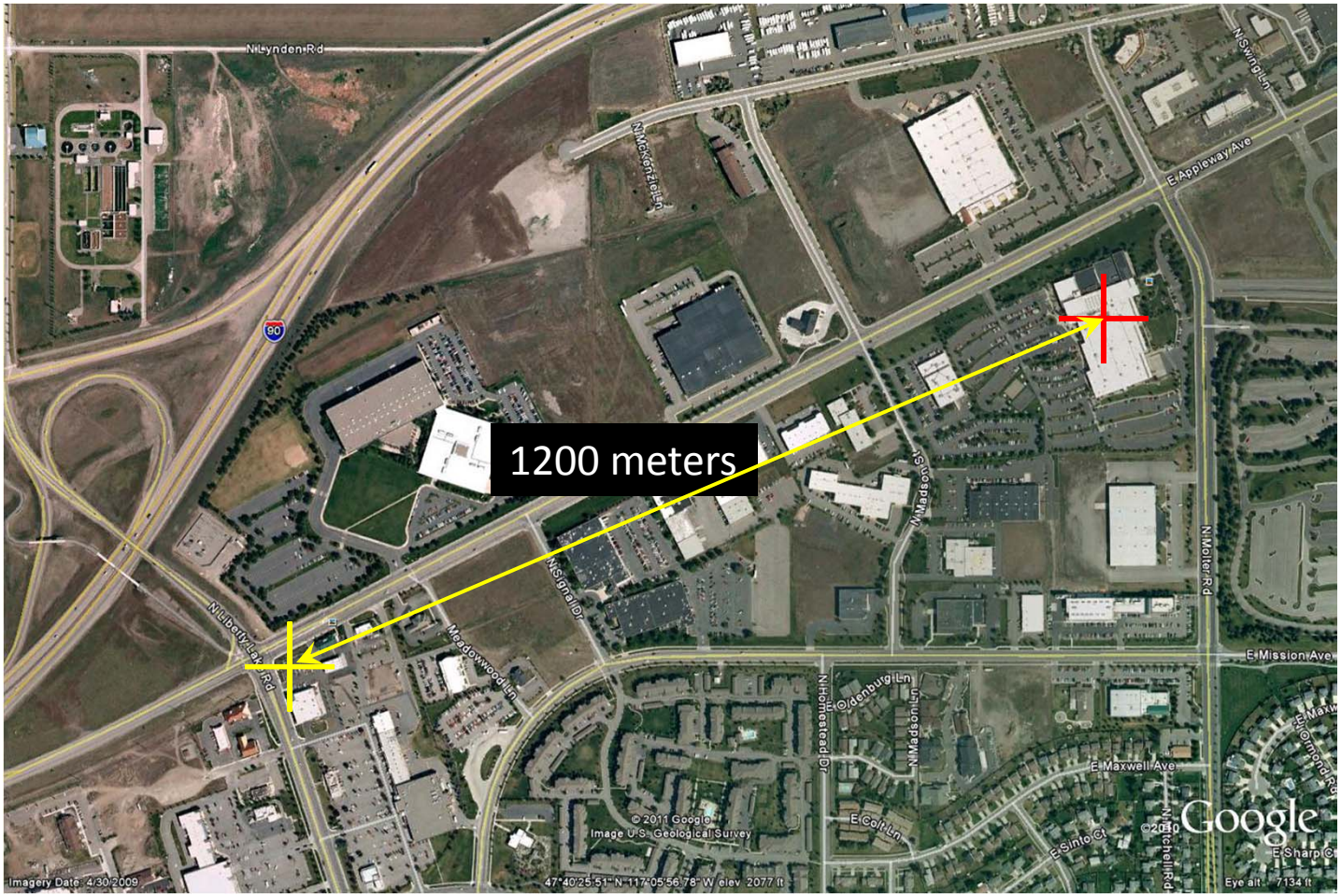


Freeway at 55 m

- Fading profile appears to remain constant beyond 30m from highway
- Fading ≤ 6 dB

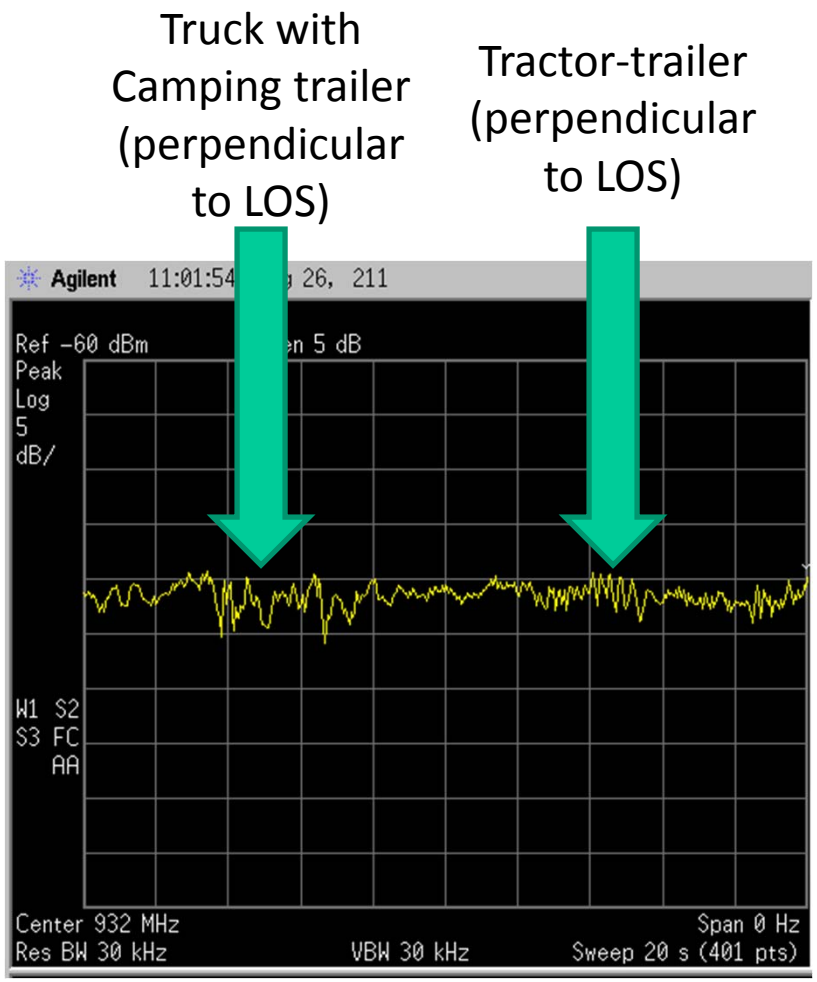


Site 3 - Intersection of Arterial Roads



Intersection camper then semi

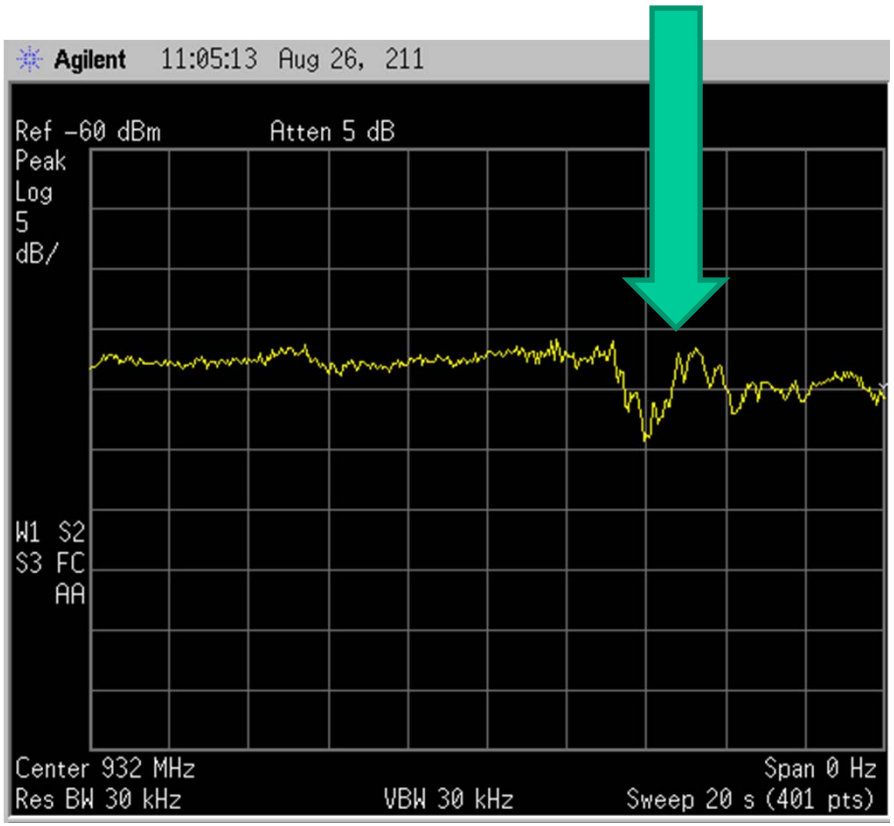
- Traffic up to 55 km/hr
- Parallel, perpendicular and turning traffic
- Fading ≤ 7 dB



Intersection - city bus pulls up and stops

- Traffic up to 55 km/hr
- Parallel, perpendicular and turning traffic
- Fading ≤ 7 dB

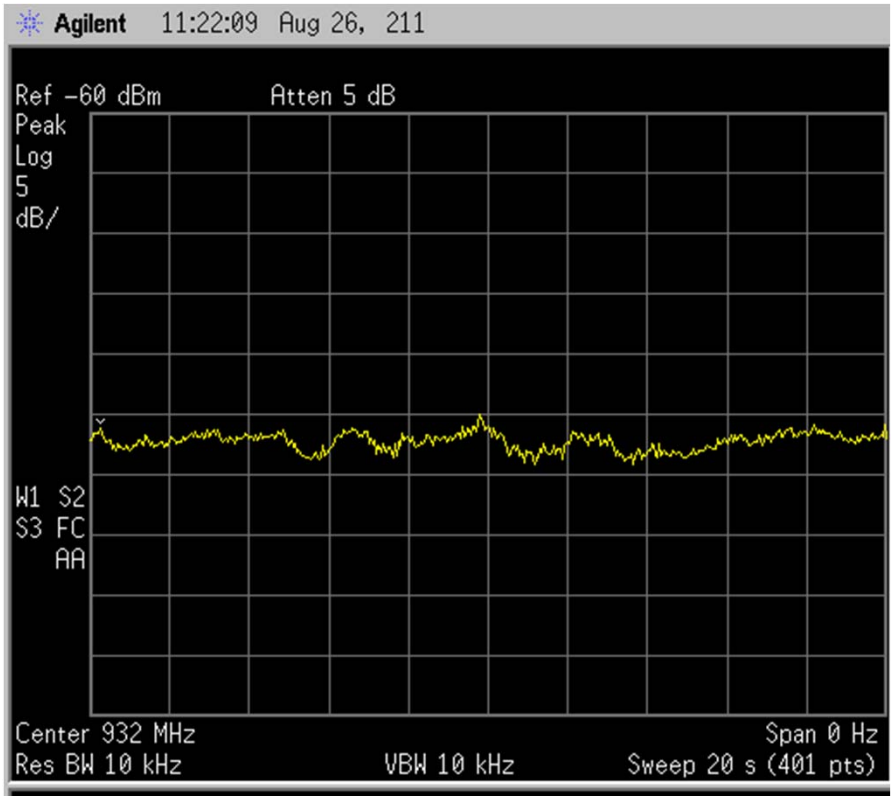
City Bus stopping at red light (perpendicular to LOS)



Site 4 - Shadowed NLOS

West of Both Buildings

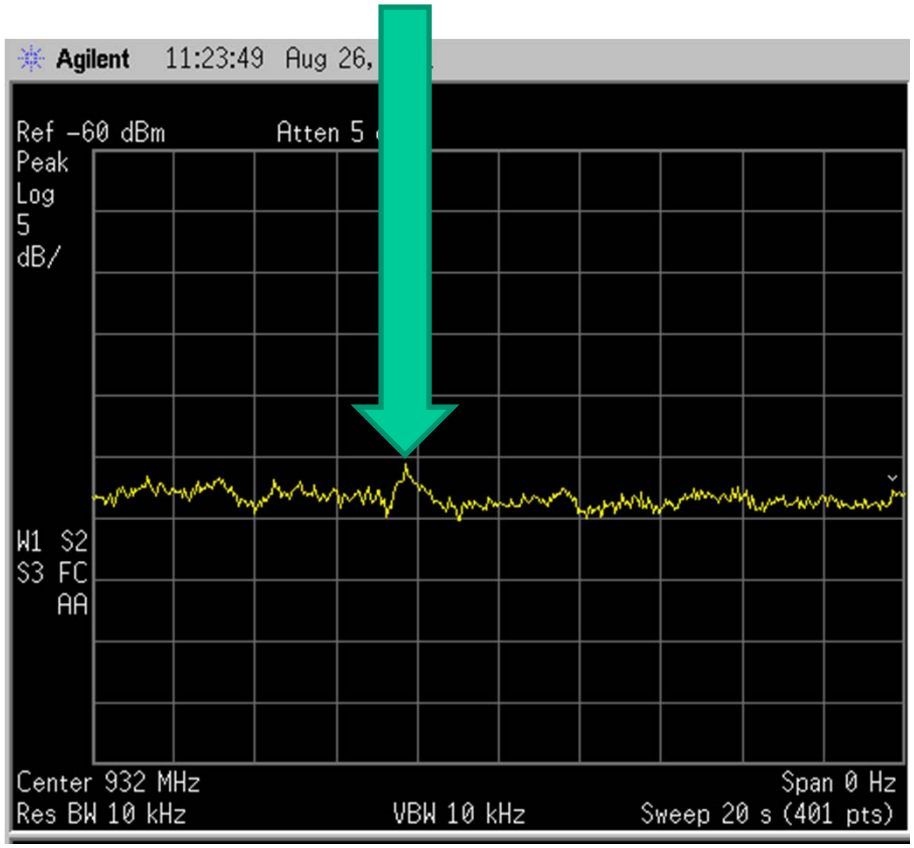
- Shadowed by two masonry buildings
- 70 m from freeway to north
- 170 m from arterial to south
- Fading ≤ 5 dB



Between Buildings

- Shadowed between two masonry buildings
- 70 m from freeway to north
- 170 m from arterial to south
- Fading ≤ 5 dB

Reception improved by passing tractor-trailer truck on freeway



Conclusions

- Typical fading for star network with stationary endpoints is in the range of 5 to 7 dB for most settings [3]
- Very close proximity to high speed traffic (freeway) shows slightly higher fading – on the order of 10 dB [5]
  - Large vehicles seem to improve multipath receptions – no large, fast fades
- Fading appears slow and shallow - Ricean

References

[1] Goldsmith, Andrea. *Wireless Communications*. Cambridge University Press, 2009. 78-79.

[2] L. Greenstein, S. Ghassemzadeh, V. Erceg, and D. Michelson, “Ricean K-Factors in Narrow-Band Fixed Wireless Channels: Theory, Experiments and Statistical Models,” *IEEE Transactions on Vehicular Technology*, vol. 58, no. 8, pp.4000-4012, Oct. 2009.

[3] L. Ahumada, R. Feick, R. Valenzuela, and C. Morales, “Measurement and Characterization of the Temporal Behavior of Fixed Wireless Links,” ,” *IEEE Transactions on Vehicular Technology*, vol. 54, no. 6, pp.1913-1922, Nov. 2005.

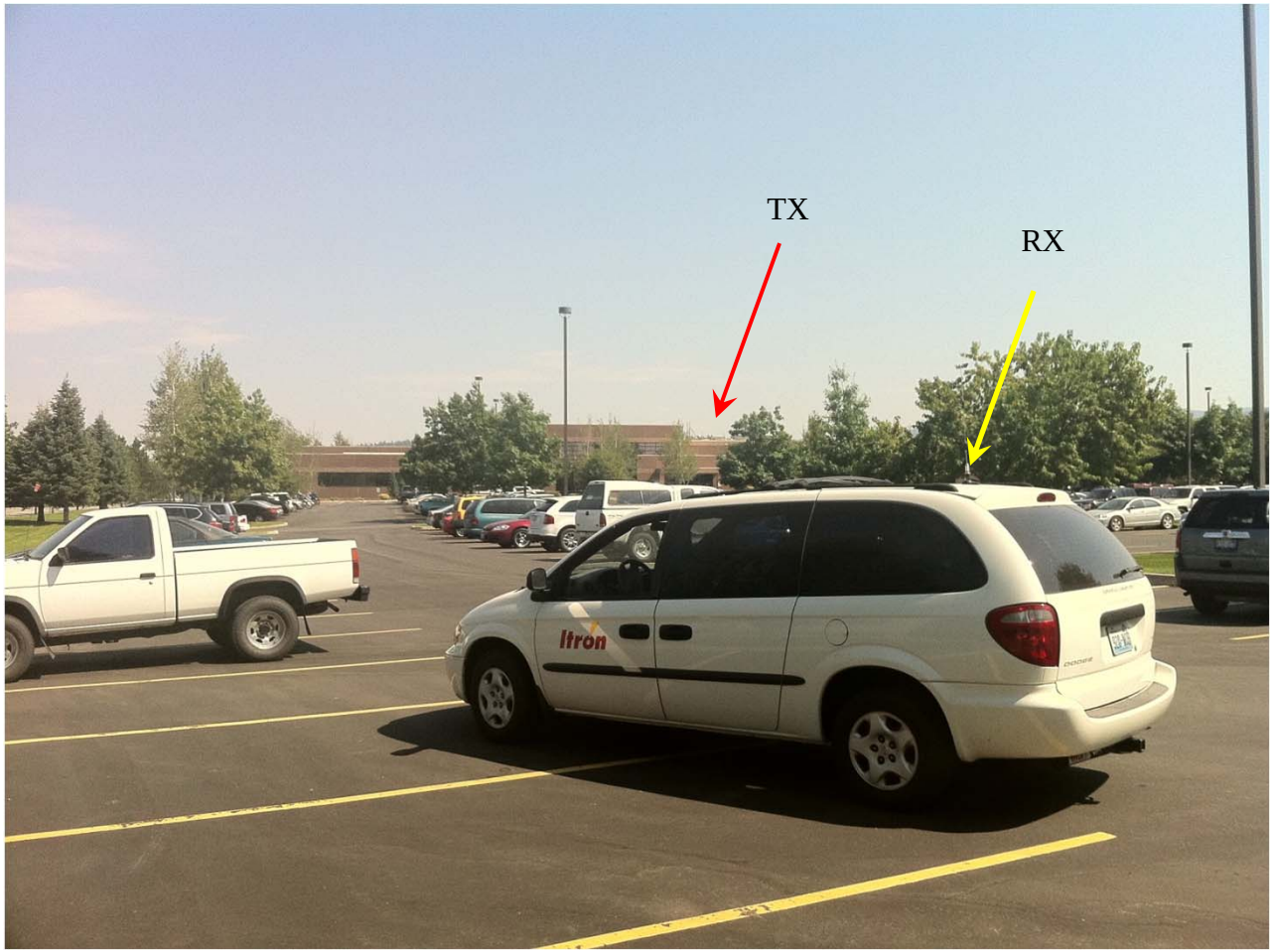
[4] K. Sivertsen, A. Liou, and D. Michelson, “Depth and Rate of Fading on Fixed Wireless Channels Between 200 MHz and 2 GHz in Suburban Macrocell Environments,” *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 10, pp. 3353-3362, Oct. 2010.

[5] L. Ahumada, R. Feick, and R. Valenzuela, “Characterization of Temporal Fading in Urban Fixed Wireless Links,” *IEEE Communications Letters*, vol. 10, no. 4, pp.242-244, Apr. 2006.

Backup Slides

Environment Context Pictures

Site 1



Site 2 – Closest to Freeway

Site 2 – Farthest from Freeway

Site 3 – Arterial Intersection

Site 4 – Sheltered by Two Buildings

Site 4 Between Two Buildings