Michigan Tech
Wireless Positioning Lab

Directional 3D Channel Modeling for Millimeter Wave Small Cells: A Spatial Correlation Study

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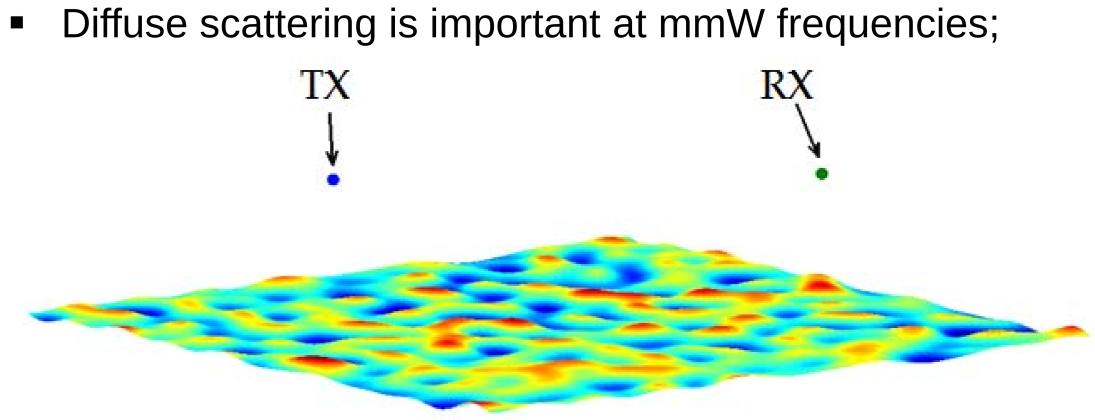
Motivation

- Diffuse scattering is important at mmW frequencies;



- Diffuse power increases at higher frequencies and lower ranges (attributes of mmW small cells).

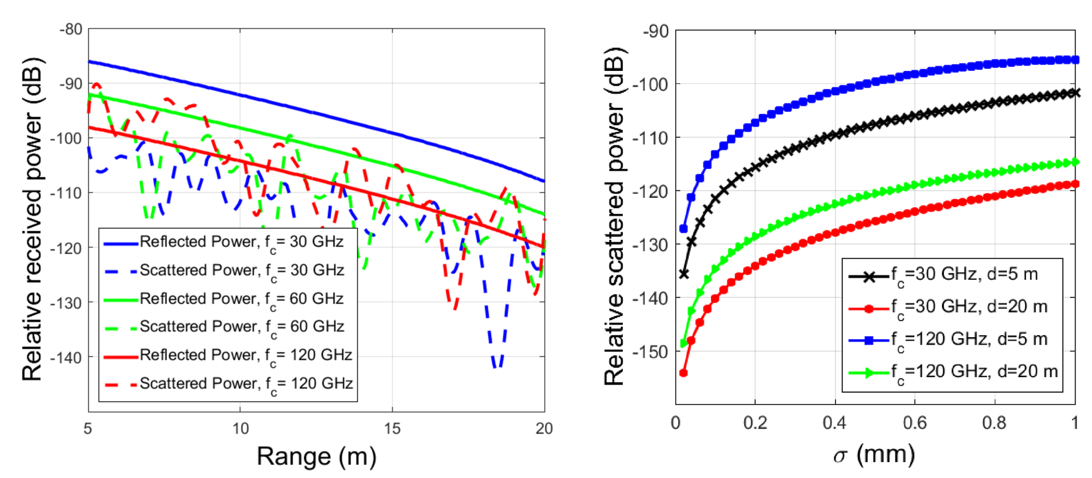


Fig. 1. Rough Surface Scattering via integral equation method (IEM).

- Uncorrelated channel is key to **spatial diversity** to combat fading and to **spatial multiplexing** to improve bit rate in multi-antenna systems.

Approach

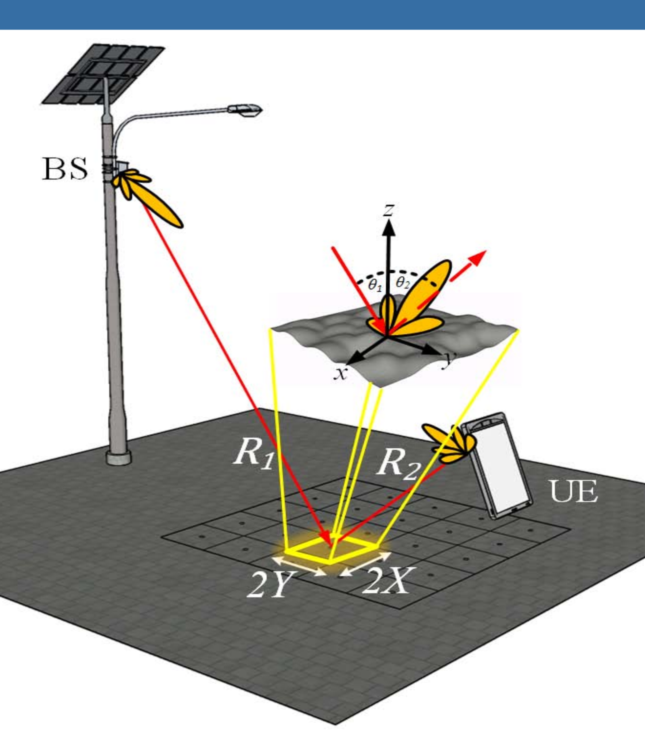


Fig. 2. Kirchhoff formulation implementation in ray tracing.

- To include diffusely scattered fields an efficient surface scattering formulation is employed in a ray tracing model.
- Kirchhoff approximation is included in the ray tracing routine to compute the diffusely scattered power from rough urban surfaces.
- To implement the Kirchhoff scattering theory in ray tracing algorithm, the surface is partitioned into scattering tiles with equal side length of 10 times the surface correlation length.

Geometry

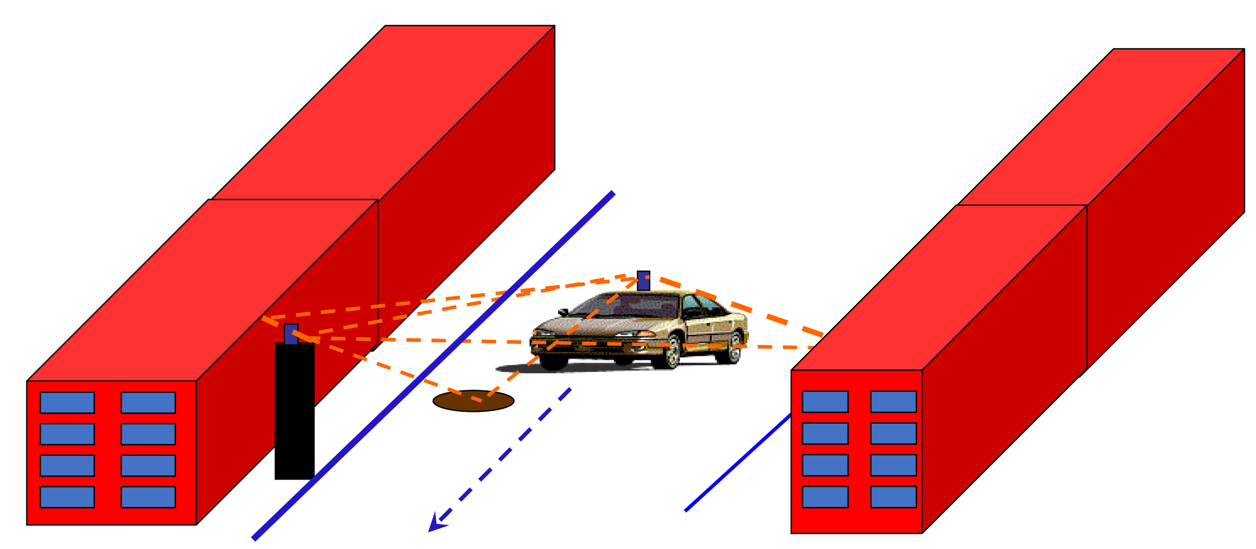


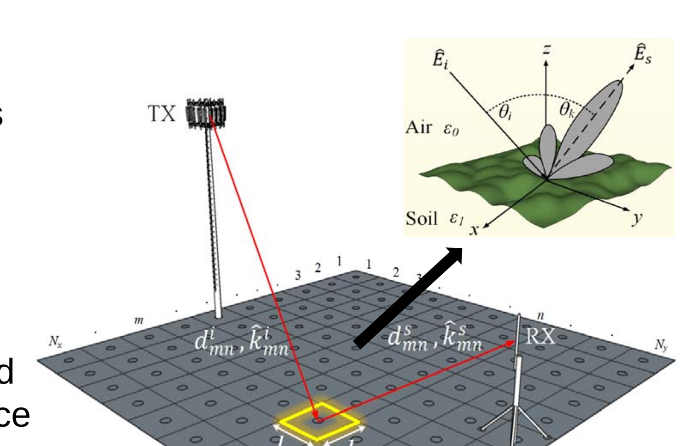
Fig. 3. Urban street with access points mounted on lampposts.

- In a typical multiuser scenario, an access point (AP) is simultaneously transmitting symbols to multiple users or multiple antennas of a single user.
- Access points are deployed on lampposts and transmit data to users within their coverage area.
- Access point height is 5 m, UE height is 1.5 m, and the street width is 18 m.

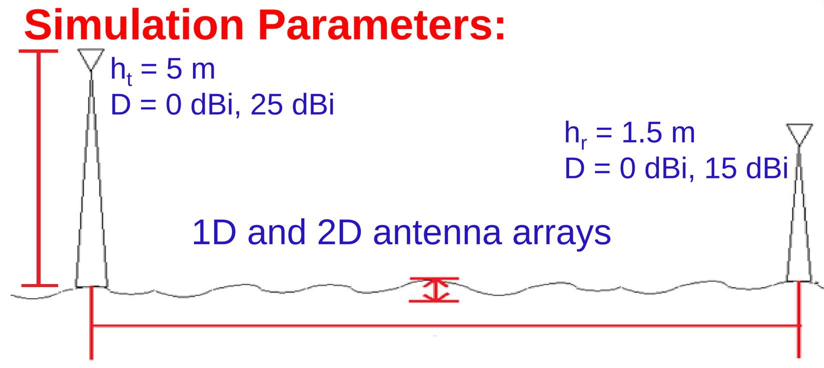
Theoretical Evaluation

Assumptions:

- Single bounce scattering
- Multiple bounce wall reflections
- Reflected components are modified by antenna gain patterns, Fresnel reflection coefficient, and Ament loss factor
- Impact of shadowing is included
- Gaussian isotropic rough surface



Simulation Parameters:



Walls dielectric: Concrete
Road dielectric: Asphalt

Asphalt: σ = 0.34 mm
Concrete: σ = 0.2 mm

Path Loss

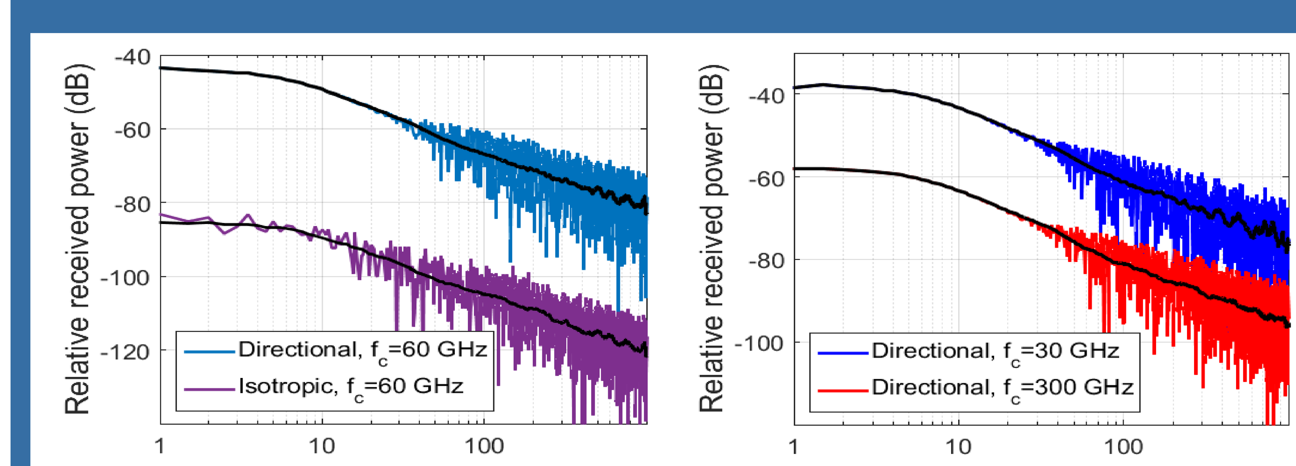


Fig. 4. Path loss versus range.

Directionality↑ Path-loss↓ | Frequency↑ Path-loss↑

Coverage Distance

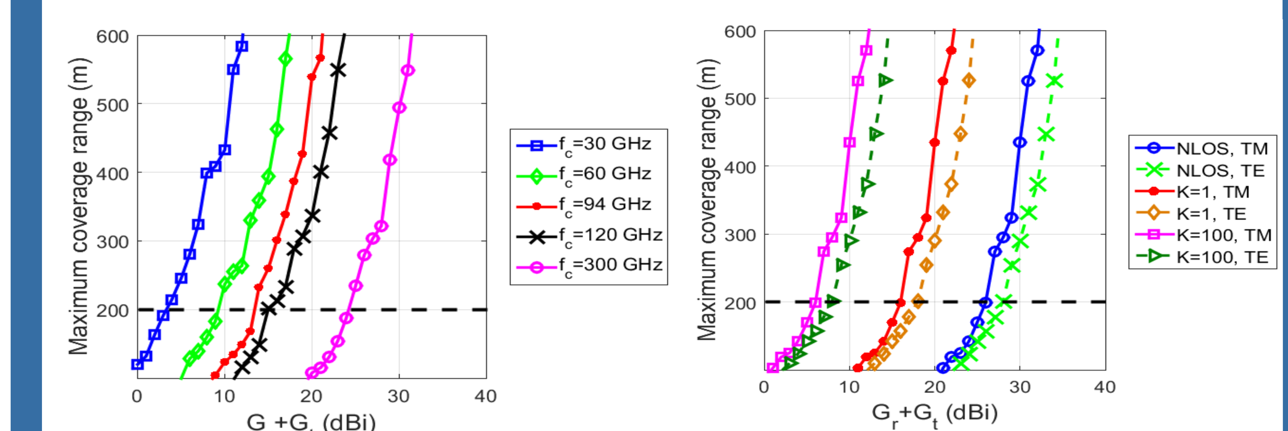


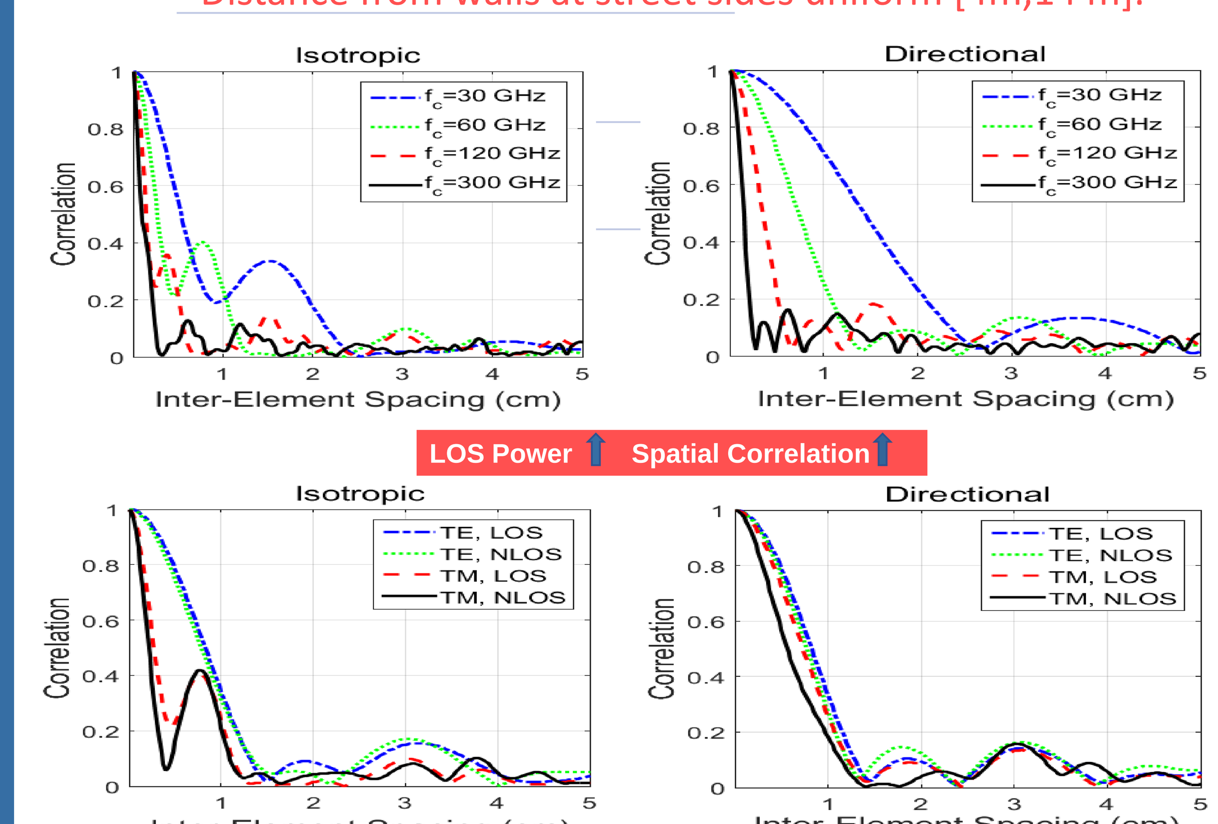
Fig. 5. Coverage distance versus combined antenna gains.

Frequency↑ Coverage↓ | Rician K↑ Coverage↑

Spatial Correlation: 1D Array

Monte Carlo Simul

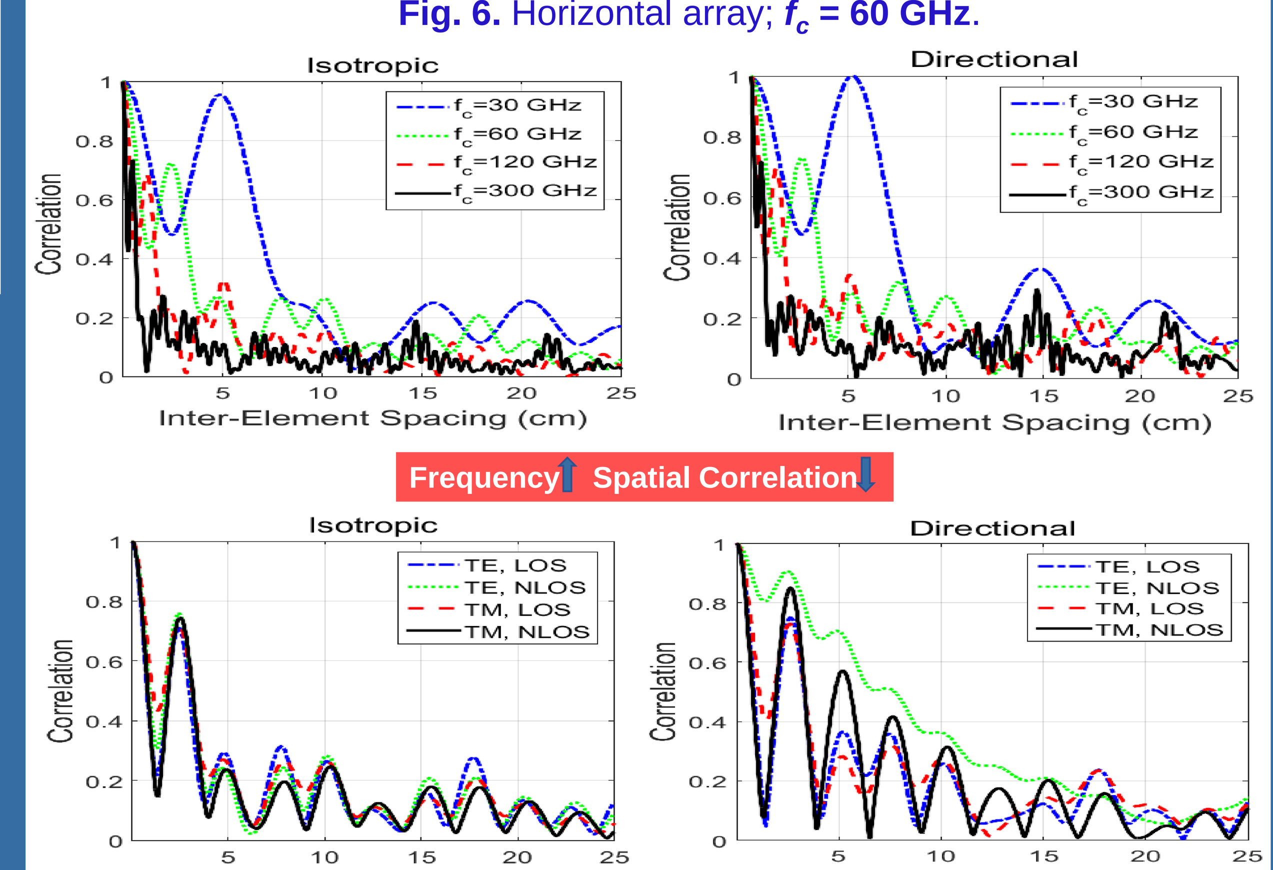
BS height = 5m; Distance from street reference side = 4m;
Rx antenna pair height uniform over [1m, 3m].
Distance from walls at street sides uniform [4m,14 m].



LOS Power↑ Spatial Correlation↑

TE Correlation ➤ TM Correlation

Fig. 6. Horizontal array; f_c = 60 GHz.



Frequency↑ Spatial Correlation↓

Coherence distance is much larger in the ELEVATION PLANE

Fig. 7. Vertical array; f_c = 60 GHz.

Spatial Correlation: 2D Array

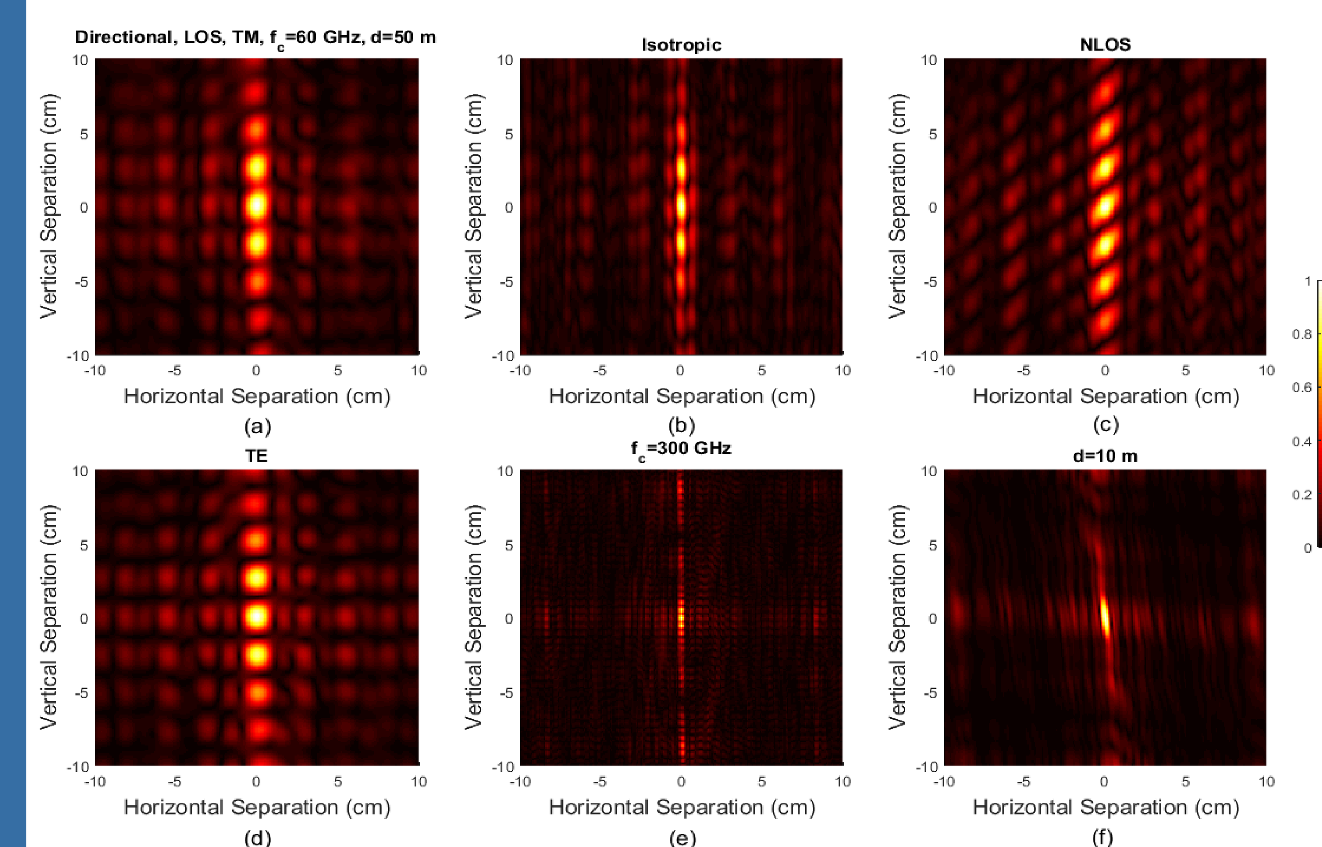
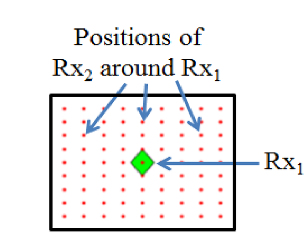


Fig. 8. 2D array correlation versus inter-element spacing.



Directionality↓ Spatial Correlation↓
TE Correlation ➤ TM Correlation
Frequency↑ Spatial Correlation↓

Conclusions

- This work develops a new directional 3D channel model for urban mmW small cells via Integrating Kirchhoff approximation and a ray-tracing algorithm,.
- **Spatial Correlation study** conducted for LOS/NLOS;
- LOS availability, frequency, and surface roughness scale highly impact spatial diversity.
- In planar 2D arrays, the horizontal dimension is well-suited for spatial multiplexing to generate degrees of freedom, transmit parallel data streams and improve the spectral efficiency.
- Using antenna arrays of moderate gain at both sides of the link, even under NLOS conditions, a typical urban cell size of 200m is achievable.

References

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