Name: *Alon S. Levin*
Date: *2/19/20*
Paper Title: *Theory of Multipath Shape Factors for Small-Scale Fading Wireless Channels*
Author Names: *Gregory D. Durgin, Theodore S. Rappaport*
Year Published: *2000*

Open questions for discussion in class:

1. How did the authors come about choosing these definitions for the shape factors? They state that there are other definitions for some, but how were they derived?
2. Does the model break down for non-Rayleigh channels, such as a Rician LoS channel?

The topic areas covered by the paper are:

- Modeling small-scale fading effects using multipath shape factors
- Calculating rate variance relationships and second-order statistics using shape factor theory
- Applying shape factor theory to common fading behavior models and comparing results to existing closed-form solutions

The previous approaches to this problem were:

Previously, analysis was applied to a strictly omnidirectional azimuthal propagation model, in which multipath waves arrive at the receiver with equal power from every direction on the horizon. While adequate for early results, modern models and systems (such as directional or smart antenna systems) stray heavily from these assumptions.

Outline the basic new approach or approaches to this problem:

The authors define three shape factors to allow for quantitative analysis of nonomnidirectional multipath wave propagation models:

- Λ – angular spread, ranging from zero (single multipath component from a single direction) to one (no clear bias in angular distribution of received power);
- γ – angular constriction, ranging from zero (no clear bias in two arrival directions) and one (exactly two multipath components arriving from different directions);
- θ_{max} – azimuthal direction of maximum fading, used as an orientation parameter.

These shape factors can be used to define the mean-squared derivatives for complex received voltage, received power, and received envelope (the three stochastic processes studied in small-scale fading analysis), to define second-order statistics, and provide insight into multipath channel models more complex than the "simple" omnidirectional azimuthal case.

Critical assumptions made include:

Although the shape factors were defined without any assumptions, their use in defining rate variance relationships depended on the assumption that the channel is Rayleigh fading. Furthermore, the second-order statistics were derived on the assumption of a Rayleigh channel (in order to allow for an analytically tractable channel).

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The performance of the techniques discussed in the paper was measured in what manner:
In section V-D, the authors applied their shape factor theory to three well-known propagation models with known analytical solutions. Upon computing the required second-order statistics and obtaining expressions for the spatial autocovariance function of envelope, the authors found that their results coincided almost perfectly to the analytical solutions. As well, the authors compared the classical value for coherence distance in an omnidirectional Rayleigh channel to the definition obtained using shape factors, and found a difference of only -3.0%.

What background techniques are used in the paper that you are not familiar with:

- Application of second-order statistics in studying fading effects

The following terms were defined:

- Small-scale fading – the rapid fluctuations of received power level due to small subwavelength changes in receiver position
- The three multipath shape factors:
    - angular spread – a measure of how multipath concentrations about a single azimuthal direction
    - angular constriction – a measure of how multipath concentrates about two azimuthal directions
    - azimuthal direction of maximum fading – an orientation parameter indicating the direction of maximum small-scale fading
- Complex received voltage – base-band representation of the summation of numerous multipath waves that have impinged upon the receiver antenna and have excited a complex voltage component at the input of a receiver
- Received power – magnitude-squared of complex voltage
- Received envelope – magnitude of the complex voltage
- The four sample nonomnidirectional channel models:
    - Two-wave channel model
    - Sector channel model
    - Double sector channel model
    - Rician channel model

I rate and justify the value of this paper as:
Overall, this is a very interesting approach to modeling multipath fading in nonomnidirectional situations, with potential analytical solutions for key statistics. It was a bit confusing at times, requiring re-reads – the material does not yet feel as “easy [and] intuitive” as the authors state in their conclusion, but hopefully will be soon.