ISART 2018 – Driving Forward: Advances in Propagation Modelling

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- Ultra-dense networks – propagation models
  - Site – specific and site – general propagation models are likely needed/required
  - For spectrum sharing studies it is useful to have “general purpose” basic transmission loss propagation models (we will not attempt to treat fast fading in these models), as opposed to service specific transmission loss propagation models
    - Both types of (i.e., site – specific and site – general) models will almost certainly be avowedly statistical in nature, with, if possible, rigorously defined variability stratifications
    - Median predictions of both types of models should be generally as applicable as Maxwell’s Equations and try to represent physical reality
    - Variabilities about the median predictions should be informed by empirical results with sufficient confidence intervals

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- Ultra-dense networks – propagation modelling considerations/approximations to Maxwell's Equations include:
  - Are we in a regime where it makes sense to treat signals as plane waves?
  - Can we treat the orthogonal horizontal coordinate to the ray path as ignorable (see above)?
  - Can we neglect (or not) the effects of atmospheric refractivity and/or earth bulge?
  - Is the path's horizontal distance large compared to the terminal heights or separations to other nearby ground planes?
    - Can we utilize the approximations for grazing incidence and path length distance differences?
  - Are small angle approximations valid (see above)?

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- Ultra-dense networks – median predictions based on the preceding assumptions (mostly) based propagation models
  - Line-Of-Sight (i.e., both terminals are inter-visible with first Fresnel zone clearance): free space loss will almost always dominate, perhaps with atmospheric gaseous attenuation and hydrometeor scattering for SHF
    - However, to the extent that reflections from roads, buildings' walls and other scattering objects can be supported, these additional rays may need to be considered – cf., break-point distances beyond the last interference maximum
      - (Frequency dependent) Dielectric material properties and surfaces' roughnesses are required to accurately predict the strengths (and phases) of these rays – also rays' polarizations

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– Non-Line-Of-Sight (i.e., terminals are not inter-visible): wavelength/frequency dependent dominant propagation mechanisms, e.g., diffraction, scattering and reflection
  - Footprint of the ray's first Fresnel zone for diffraction and specular reflection
    – Site – specific models will want to use the actual ray distance traveled, but site – general models will want to use the distance between the terminals
    – (Frequency dependent) Dielectric material properties and surfaces' roughnesses are required to accurately predict the strengths (and phases) of the reflected rays – also rays' polarizations
  - Very long range propagation, e.g., via tropospheric scatter from a common volume inter-visible to both terminals' "horizon" rays

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- Ultra-dense networks – interference considerations for a site – general model
  - Interference limitations will still drive frequency reuse/sharing
  - Line-of-Sight probability (e.g., as a function of distance) for different environments/terminals' heights is important
    - This yields a bi-modal probability density function for the basic transmission loss where the low losses are important for interference considerations
    - Aggregation of multiple sources is also affected by this consideration:

$$Pr\{X \le x\} = \int_0^X \left[\left(p\hat{f}_l(x) + (1-p)\hat{f}_{nl}(x)\right) * \cdots * \left(p\hat{f}_l(x) + (1-p)\hat{f}_{nl}(x)\right)\right] dx$$

$$Pr\{X \le x\} = \sum_{k=0}^{M} \binom{M}{k} p^k (1-p)^{M-k} \int_0^X \hat{f}_k(x)\, dx$$

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- Ultra-dense networks – future perspectives for site – specific models
  - How do we match short range measurements information with long range predictions
  - Is the required information even obtainable (or do we need it just for short range propagation)
  - How much short range data is required in order to produce a “good” long range prediction or can we only obtain the required results by long range measurements?