Proceedings of ISAP 2014, Kaohsiung, Taiwan, Dec. 2-5, 2014

Impact of Reconfigurable Polarization Angle on Parameters of a Statistical Distribution of Coherence Time of Radio Channel

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Abstract –This work presents a generalized extreme value (GEV) statistical distribution for coherence time of an indoor line of sight radio propagation channel. It focuses on impact of reconfigurable polarization angle parameter of a half-wavelength dipole on parameters of GEV.

I. INTRODUCTION

The multipath channel is a function of distribution of scatterers in radio environment. This distribution determines dispersion characteristics of the channel in delay and direction domains [1]. The characteristics of the dispersion are function of power profiles in their corresponding domain. The power of multipath components depends on the interaction process of electromagnetic wave with scatterers, which could be reflection, diffraction, scattering, etc, or combination between them [1]. These characteristics have direct impact on design of communication systems, either with single antenna or multiple antennas [3-5]. Reconfigurable antenna can modify its characteristics per control. These controllable antenna features include radiation pattern, resonance frequency, and polarization. The interplay between directional propagation multipath channel and antenna pattern leads to different radio channel characteristics for different antenna radiation states and same propagation multipath channel. In this work, we model coherence time of an indoor mobile channel with a proper statistical distribution. Then, we investigate the impact of reconfigurable polarization angle of this antenna on parameters of the statistical distribution.

II. RADIO CHANNEL COHERENCE TIME AND GENERALIZED EXTREME VALUE DISTRIBUTION

The coherence time of a radio channel is defined as a measure of time duration over which the response of channel is considered of similar responses at different times within this duration. Coherence time is the time domain dual of Doppler spread, which both describe the time varying nature of the channel in small scale phenomena. It can be computed as given in [2] as follows $(\Delta t)_c \triangleq min\{\Delta t > 0: |R(\Delta t)| = c\}$, where

$$R(\Delta t) = \mathrm{E}[r(x,f,t)^* r(x,f,t+\Delta t)]$$

$R(\Delta t)$ is time correlation function of received signals r and separated by time Δt, $r(x,f,t)^*$ is conjugate of received signal at location of x and frequency f in time instant t, and c = 0.7.

The GEV distribution is a family of statistical distributions that combines Gumbel, Fréchet and Weibull statistical distributions. Extreme value theory originally is used as a framework to analyze the tail behavior of statistical distributions in different applications. The probability distribution of the GEV distribution can be expressed [6] as

$$F(x;\sigma,\mu,k) = exp\left[-\left\{1 + k\left(x - \frac{\mu}{\sigma}\right)\right\}^{1/k}\right],$$

for $\left\{1 + k\left(x - \frac{\mu}{\sigma}\right)\right\} > 0$,where $\mu \in R$ is location parameter, k is called shape factor, and scaling parameter $\sigma > 0$.

II. NUMERICAL RESULTS

The results of this work is based on extension to indoor environment of a physics based model presented in [7],[8]. In this work, reconfiguring the pattern takes place via inclination angle (α) of the dipole antenna, which is called in this work as a polarization parameter. It modifies antenna gain pattern for both vertical polarization that can be written as follows [9] :

$$G_v(\theta,\phi,\alpha) = 1.64\,(\cos\theta\ \cos\phi\sin\alpha - \sin\theta\cos\alpha)^2 \frac{\cos^2(\pi\zeta/2)}{(1-\zeta^2)^2}$$

where the angle α is the reconfigurable polarization angle parameter. Definitions of other variables can be traced in [8]. In addition to line of sight component, multiple specular reflections are included, where number of images per surface is assumed 6. Traveled distance is about 4 m with special resolution of 1.2 cm at 5 GH frequency range. Temporal simulation at every spatial location was for one second and coherence time is computed for every about two code words duration, i.e., 26 times in every second. The experiment is repeated for every polarization angle in order to have same multipath environment but different antenna radiation states for vertical polarization that results from different values of α. For every value of α, we have 8684 samples of coherence time that are tested against different statistical distributions in order to select the best parametric model of the tested statistical distributions, which include loglogistic, logistic, gamma, normal, lognormal, exponential, weibull, uniform, generalized pareto, extreme values, generalized extreme value, inverse Gaussian, beta, and Nakagami. Results of maximum likelihood estimator of 95% confidence interval is considered as a basis for decision to accept or reject the statistical distribution fitting. The GEV was best fit and selected to model coherence time of radio channel. Figure 1 shows GEV model for two different values of α. Parameters of GEV (i.e., k, μ, σ) where found to be function of α and follow the model $f(\alpha)$ given below with tuned fitted coefficients are given in Table I and plotted comparison is shown on Figure 2.

$$f(\alpha) = a_0 + a_1\cos(w\alpha) + b_1\sin(w\alpha) + a_2\cos(2w\alpha) + b_2\sin(2w\alpha) + a_3\cos(3w\alpha) + b_3\sin(3w\alpha)$$

Table I. Parameter values of model $f(\alpha)$ for (k, μ, σ).

	a_0	a_1	b_1	a_2	b_2	a_3	b_3	w
k	-0.374	0.157	0.022	0.013	0.064	-0.169	0.281	0.286
$\mu(\times 10^{-3})$	2.248	0.104	-0.420	-0.073	0.109	0	0	0.860
$\sigma(\times 10^{-3})$	7.7	-0.74	-0.050	-0.145	-0.339	0.764	-1.05	0.286

III. Conclusion

This work has presented that coherence time can be modeled with GEV distribution, whose parameters are function of polarization angle parameter. The model shows that parameters are function of α and has some periodicity behavior. The results can be used for performance analysis of communication systems based on reconfigurable polarization angle parameter.

Acknowledgement

This publication was made possible by NPRP grants 5-653-2-268 from the Qatar National Research Fund (a member of Qatar Foundation). The statements made herein are solely the responsibility of the authors.

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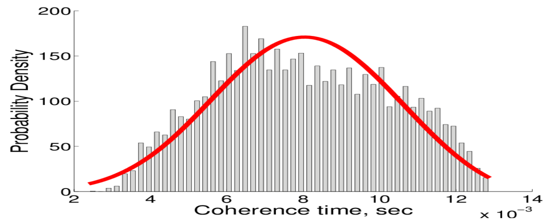
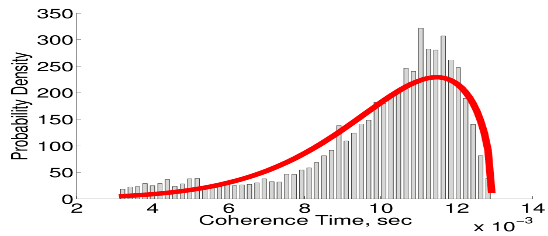
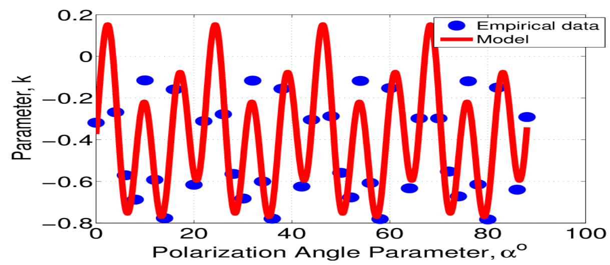


a. α = 0°, k = -0.3185, μ = 0.0023, σ = 0.0072

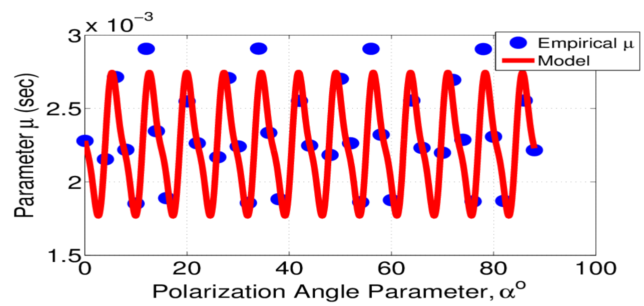


b. α = 8°, k = -0.6874, μ = 0.0022, σ = 0.0097

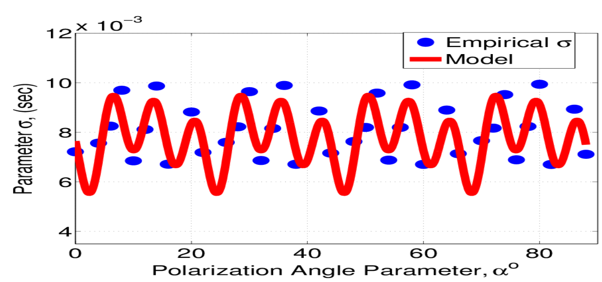
Figure 1. PDF of coherence time.



a. Model and data of k.



b. Model and data of μ.



c. Model and data of σ.

Figure 2. Model and empirical data of parameters of GEV.