LAND MOBILE SATELLITE CHANNEL MODELING EMPLOYING NAKAGAMI-DISTRIBUTION

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***Abstract*— This paper presents a Statistical model for land mobile satellite (LMS) channel. The presented model is based on a recently introduced model that employs Loo distribution and introduces Nakagami distribution as a replacement for Loo distribution.**

***Index Terms*—**Land mobile satellite systems, Channel modeling, Nakagami model,

I- Introduction:

For effective mobile satellite communications system design, we must quantitatively know propagation characteristics [1] [2]. That is why several distinct types of LMS models have been developed which serve a variety of purposes for characterizing land mobile satellite propagation.

In this paper, a statistical model of geometrical nature is proposed for modeling of land mobile satellite (LMS) channel. This paper proposes the employment of Nakagami probability density function (PDF) to introduce a LMS channel model based on a previously introduced model [3], which employed Loo distribution [4].

In order to compare the presented model with the one presented in [3] and due to unavailability of measured data for parameter extraction. The parameters of Nakagami distribution were calculated by transformation [5] of Loo distribution parameters, which were extracted from large experimental data set.

In section-II the new LMS model employing Nakagami PDF and parameter extraction are demonstrated. In section III results of carried simulation are shown with a comparison between model in [3] and the new model presented. Finally in section IV conclusions are presented.

II- Channel Model

The model assumes that the main elements of the received signal [3] are:

- Direct signal, which is the Line of Sight (LOS) component
- Diffuse multipath due to the direct signal illuminating nearby scatterers.

The model depends on the assumption of existence of three basic rates of change in the received signal corresponding to the different behaviors of its components. The rates are: very slow variations, slow variations and fast variations [3]

i. *Very slow variations*: Which represent the marked signal variations due to different gross shadowing conditions [3] [6].

ii. Slow Variations: which represent small-scale changes in the shadowing attenuation produced as the mobile travels in the shadow of the same obstacle [3].

iii. *Fast Variations*: caused due to Multipath contributions [3].

A three-state Markov chain model was selected to describe the LMS propagation channel at a given time or route and the following states were defined [3]:

- State 1 (S_1) represents LOS conditions.
- State 2 (S_2) represents moderate shadowing conditions.
- State 3 (S_3) represents deep shadowing conditions.

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Nakagami PDF is used to model slow variations (Line of sight variations within each state) and Fast variations (multipath variations) within each state. Additional parameters required for modeling of Multipath contirbutions are stated in [3],[6] and [7]

In [3] Loo distribution is proposed to jointly model the behavior of the direct signal and the multipath component within each state. In Loo distribution the direct signal is assumed to be Log-Normally distributed with a mean μ and a standard deviation d_0 while the multipath component follows a Rayleigh distribution characterized by its average power b_0

$$p(r) = \frac{r}{b_o\sqrt{2\pi d_o}} \int_0^\infty \frac{1}{z} \exp\left[\frac{-(\ln z - \mu)^2}{2d_o} - \frac{(r^2 + z^2)}{2b_o} \right] I_o\left(\frac{rz}{b_o}\right) \quad (1)$$

Where b_0 is the average power due to multipath component.

d_0 is the variance in the direct signal

μ is the mean value of the direct signal component.

The parameters α, Ψ and MP are considered more convenient parameters that are related to Loo distribution parameters. These parameters are more related to signal series and easier in extraction from data set. α and MP parameters are referred to LOS level μ, d_0 and b_0 are related to α, Ψ and MP as follows [3]:

$$\alpha(dB\ rel\ to\ LOS) = 20\log_{10}(e^u) \quad (2)$$

$$\Psi(dB) = 20\log_{10}(e^{\sqrt{d_o}}) \quad (3)$$

$$MP(dB\ rel\ to\ LOS) = 20\log_{10}(2b_o) \quad (4)$$

The application of the lognormal distribution for characterizing shadow fading most often results in complicated expressions for the key first and second-order channel statistics such as the envelope PDF and the envelope Level Crossing Rate (LCR), respectively. Analytic manipulation of those expressions is usually hard, as they cannot be written in terms of known mathematical functions. This, in turn, makes data fitting and parameter estimation for the lognormal- based models a complex and time-consuming task [5].

The application of the gamma distribution, as an alternative to the lognormal distribution, is proposed in [5] as it can result in simpler statistical models with the same performance for practical cases of interest. It is assumed that the power of the LOS component is a gamma random variable. Since the square root of a gamma variable has Nakagami distribution, this means that the amplitude of the LOS component is modeled with a Nakagami distribution.

In this model the amplitudes of the multipath and the LOS components, follow Rayleigh and Nakagami distributions, respectively [5]

$$P_A(a) = \frac{a}{b_0}\exp\left(\frac{-a^2}{2b_0}\right), \qquad a \ge 0 \qquad (5)$$

$$\mathrm{P_Z(z)} = \frac{2\mathrm{m^m}}{\Gamma(\mathrm{m})\Omega^{\mathrm{m}}}\mathrm{z^{2m-1}}\exp\left(\frac{-\mathrm{mz^2}}{\Omega}\right), \qquad \mathrm{z} \ge 0 \qquad (6)$$

Where

$\mathrm{b_0 = E[A^2]}$ is the average power of the scatter component,

$\Gamma(.)$ is the gamma function,

m is the Nakagami parameter with Var[.] as the variance ($\mathrm{m = (E[Z^2])^2 / Var[Z^2], m \ge 0}$)

Ω is the average power of the LOS component ($\Omega = \mathrm{E[Z^2]}$).

Finally the new envelope PDF [5] is given by:

$$p_R(r)=\left(\frac{2b_0m}{2b_0m+\Omega}\right)^m\frac{r}{b_0}\exp\left(-\frac{r^2}{2b_0}\right){}_1F_1\left(m,1,\frac{\Omega r^2}{2b_0(2b_0m+\Omega)}\right),\quad r\geq 0 \quad (7)$$

Where ${}_1F_1(.,.,.)$ is the confluent hypergeometric function.

In [1] a useful connection is established between the parameters of the new model and Loo's model. The relationship between the two sets of parameters (m,Ω) and (μ,d_0) is given by:

$$\mu=\frac{1}{2}\left[\ln\left(\frac{\Omega}{m}\right)+\Psi(m)\right]\qquad,\qquad d_0=\frac{\Psi'(m)}{4}\qquad (8)$$

Where $\Psi(.)$, $\Psi'(.)$, $\Psi''(.)$ and $\Psi'''(.)$ are the psi function and its derivatives, respectively [5].

For a given d_0, the corresponding m can be easily obtained by solving the equation (8), numerically.

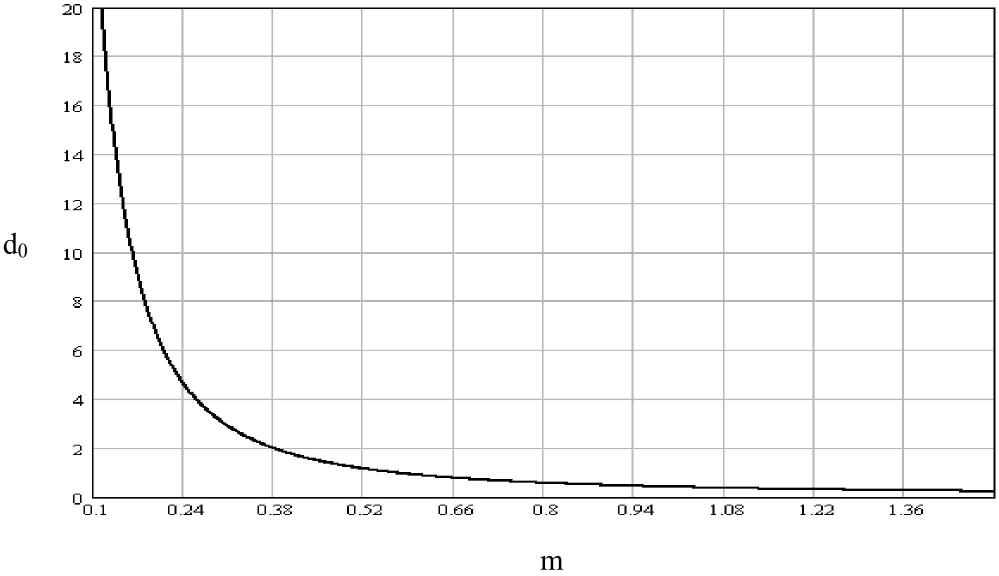

Fig.3 m values corresponding to d_0 values

This took place by plotting d_0 versus m using MathCAD program and obtaining corresponding values of m for given values of d_0 value of m.

The value of Ω can be calculated by inverting the equation in (15), which yields

$\Omega=m\exp[2\mu-\Psi(m)]$ (10)

In [5] it is shown that Loo's distribution and distribution employing nakagami PDF closely match, if one computes the parameter set (b_0,m,Ω) from the Loo's parameter set (b_0,μ,d_0) , using the relations in (8) and (9).

III- Simulation of received signal

Wideband Simulation was carried out at S band (2- 4 GHZ) for Urban Area using the following assumptions:

- Sample duration is 125 m
- Sampling rate = $\lambda/8$ (λ is the wavelength)
- Tested band is S band: 2-4 GHz (fc is assumed to be 3 GHZ)

Two simulations were carried out at an elevation angle of 40°; one using Nakagami based distribution and the other using Loo distribution. Results are shown in figures 4 and 5.

In Fig.4 the amplitudes of received signal sampled at S band for urban area environment are shown. These amplitudes were generated using Nakagami based distribution. In fig. 5 the amplitudes of received signal generated using Loo distribution are shown. At the top of the figures the state of shadowing is shown. It is clear that there is a fairly good agreement between figures 4 and 5.

The difference between the two figures is attributed to the fact that each of them is generated independently of the other using random number generators according to the distribution used. Also a slight error may occur in parameter transformation from Loo parameters to those of Nakagami based distribution.

In the simulated signal it is clear that the state 3 is the dominant state. This is rather convenient with the fact that the environment under test is urban environment. Urban environment is characterized by the presence of many human made obstacles, which prevent line of sight from reaching mobile terminal.

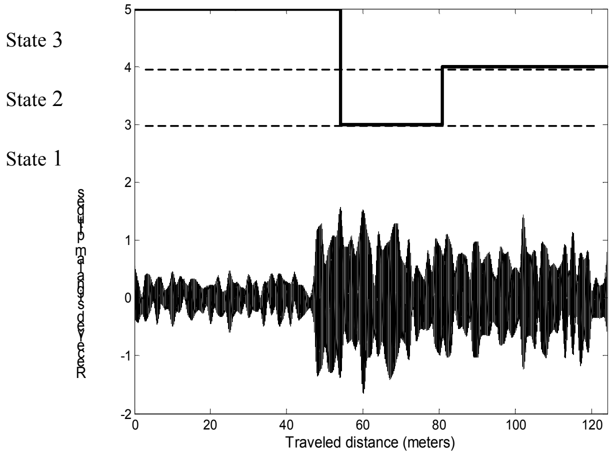

Fig.4 Generated received signal amplitude based on Nakagami Distribution

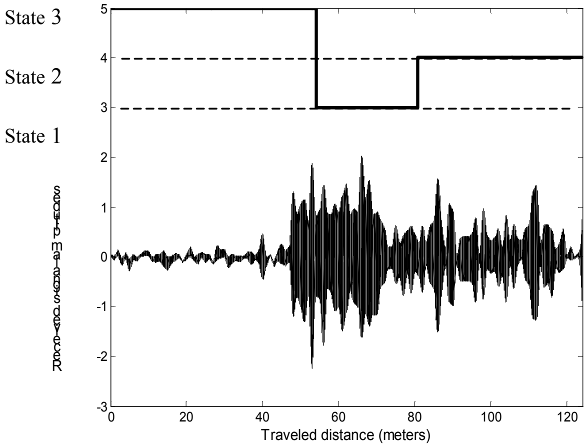

Fig.5 Generated received signal amplitude based on Loo Distribution

IV- Conclusion

In this paper a new LMS channel model was presented, this model is based on previous presented model with the exception of the use of Nakagami distribution in modeling received signal components. Parameter transformation took place between Loo model parameters (α, Ψ and MP) and Nakagami parameters (m, Ω). We observed that there exists a good agreement between signal generated using Loo distribution and that using Nakagami distribution. It is suggested to fit data sets extracted from field to Nakagami distribution, which is expected to give better results.

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