3-STATE CHANNEL MODEL FOR LAND MOBILE SATELLITE COMMUNICATIONS

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SUMMARY

For moving obstacles, such as people or cars, strength of the received signal is variable through the time. These variations are caused by the environment. In this paper, 3-state channel model for land mobile satellite communications, based on a Rice and extended Suzuki distribution of type I. is proposed. Numerical and graphical outputs in the System View environment are presented to show how the channel works.

Keywords: *Satellite channel, Rice distribution, Suzuki process, deterministic Gaussian process.*

1. INDRODUCTION

In the modern society of today it is significant interest for new satellite services. Land mobile systems are important for the 3rd and the 4th generation of wireless systems. To increase the number of applications and improve quality of services, scientists have proposed channel models for years to describe, what happened with the transmitted signal. Clouds, rain, Doppler effect, buildings, trees, but also other signals can drastically reduce the received signal. Signal so loses its deterministic nature. Exploration has showed that the channel should consist of more states. In channel modeling, two basic approaches were defined: stochastic and deterministic. In this paper, 3-state model for land mobile satellite channels, based on the Markovian process and deterministic approach, is proposed and its properties are described.

2. PROPOSED CHANNEL MODEL

In the mobile communications, we suppose that environment changes through the time and so change also conditions for signal receiving. We can define so three basic states:

State A: clear line-of-sight condition (LOS)
State B: slightly shadowed condition
State C: fully blocked condition

The transition matrix between states of the channel for Suburban zone, which is based on the semi-Markovian process, was defined in the recommendation ITU-R P.681-6 [1] and is given by:

$$P = \begin{pmatrix} 0 & 1 & 0 \\ 0.65 & 0 & 0.35 \\ 0 & 1 & 0 \end{pmatrix} \qquad (1)$$

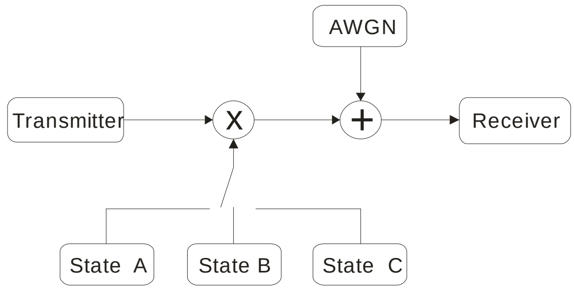

Fig. 1 Proposed 3-state channel model

There are some possibilities of distributions for these states. We proposed a Rice distribution for a characterization of the State A and the extended Suzuki process of type I with a light shadowing for State B. The same distribution with a heavy shadowing was assigned for a fully blocked condition.

3. STATE A – RICE CHANNEL

Real-valued colored Gaussian random (GR) process is a basic part of the deterministic channel, when the Rice method is used. This process is based on a superposition of a finite number *Ni* of weighted harmonic functions, as is depicted on the Figure 2 and can be described as:

$$\tilde{\mu}_i(t) = \sum_{n=1}^{N_i} c_{i,n} \cos\ (2\pi f_{i,n} t + \theta_{i,n}) \qquad (2)$$

where:

$c_{i,n}$ describes the Doppler coefficients,
$f_{i,n}$ defines discrete Doppler frequencies,
$\theta_{i,n}$ determines the Doppler phases.

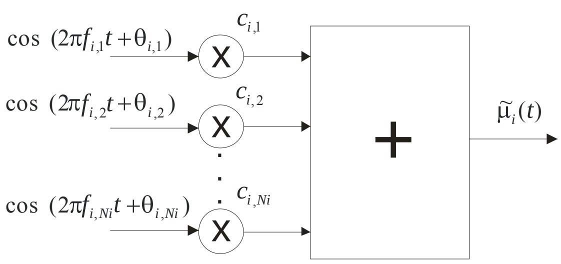

Fig. 2 Real-valued Gaussian random process

For a realization of the Rice channel, we need two of these GR processes, as is shown on the Figure 3. Deterministic Rice process is defined as:

$$\tilde{\xi}(t) = |\tilde{\mu}(t) + m(t)| \tag{3}$$

where $m(t)$ describes the LOS component of the received signal and $\tilde{\mu}(t)$ is the complex deterministic Gaussian process. For modeling of the time-variant fading behavior caused by the Doppler effect, it is necessary to compute $c_{1,n}$, $f_{1,n}$, and $\theta_{1,n}$, for the upper part of the Figure 3, which represents the real part of $\tilde{\mu}(t)$ and where $n = 1,\ldots, N_1$, and $c_{2,n}$, $f_{2,n}$, and $\theta_{2,n}$, where $n = 1,\ldots, N_2$ for the imaginary part $\tilde{\mu}_2(t)$ of the channel. There are several methods, how is possible to determine them. The most convenient for this channel is the Jakes method:

$$c_{i,n} = \begin{cases} \dfrac{2\sigma_0}{\sqrt{N_i - \frac{1}{2}}} \sin\left(\dfrac{n\pi}{N_i - 1}\right), & n = 1,\ldots,N_i - 1,\ i = 1, \\ \dfrac{2\sigma_0}{\sqrt{N_i - \frac{1}{2}}} \cos\left(\dfrac{n\pi}{N_i - 1}\right), & n = 1,\ldots,N_i - 1,\ i = 2, \\ \dfrac{\sigma_0}{\sqrt{N_i - \frac{1}{2}}}, & n = N_i,\ i = 1,2. \end{cases} \tag{4}$$

$$f_{i,n} = \begin{cases} f_{\max} \cos\left(\dfrac{n\pi}{2N_i - 1}\right), & n = 1,\ldots,N_i - 1,\ i = 1,2, \\ f_{\max}, & n = N_i,\ i = 1,2. \end{cases} \tag{5}$$

Phases are based on a random process. Fade duration follows an exponencial distribution. On the Figure 3., parameter ρ represents the amplitude of the LOS component, f_ρ and θ_ρ are describing Doppler frequency and phase of the LOS component respectively [2].

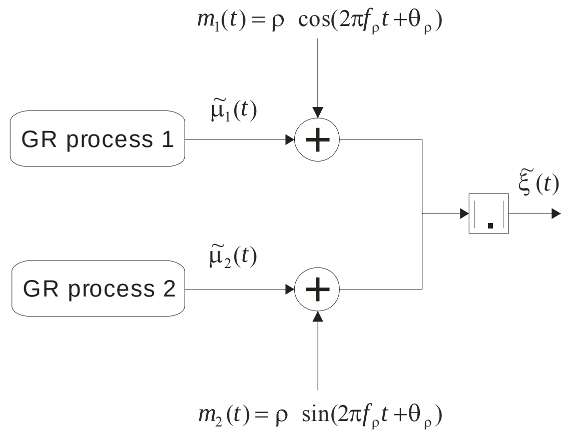

Fig. 3 Rice channel – State A

4. STATES B AND C – SUZUKI PROCESS

The Suzuki process of Type I, $\tilde{\eta}(t)$, is based on three real-valued GR processes. We assume that all of them are uncorrelated in pairs. As is shown on the Figure 4., simulation model consists of the two deterministic processes, Rice and Lognormal. For computation of the model parameters, it is convenient to use the Method of exact Doppler spread:

$$c_{i,n} = \begin{cases} \sigma_0\sqrt{1/N_1}, & i = 1,\ n = 1,2,\ldots,N_1, \\ \sigma_0\sqrt{1/N_2'}, & i = 2,\ n = 1,2,\ldots,N_2. \end{cases} \tag{6}$$

where σ_0 is an average power of the real deterministic Gaussian process.

$$c_{3,n} = \sqrt{2/N_3} \tag{7}$$

$$f_{i,n} = \begin{cases} f_{\max} \sin\left[\dfrac{\pi}{2N_1}\left(n - \dfrac{1}{2}\right)\right], & i = 1,\ n = 1,\ldots,N_1, \\ f_{\max} \sin\left[\dfrac{\pi}{2N_2'}\left(n - \dfrac{1}{2}\right)\right], & i = 2,\ n = 1,\ldots,N_2. \end{cases} \tag{8}$$

$$\frac{2n-1}{2N_3} - erf\left(\frac{f_{3,n}}{\sqrt{2}(f_{\max}/(K_c\sqrt{2\ln 2}))}\right) = 0, \quad \text{for} \quad n = 1,\ldots,N_3 - 1 \tag{9}$$

In equations (8) and (9) f_{max} means a maximum Doppler frequency. K_c is defined as an frequency ratio f_{max}/f_c, where f_c is a 3-dB-cut-off frequency.

$$f_{3,N_3} = \sqrt{\frac{(2\pi\sigma_c)^2 N_3}{(2\pi)^2} - \sum_{n=1}^{N_3-1} f_{3,n}^2} \tag{10}$$

where $\sigma_c = f_{\max}/(K_c\sqrt{2\ln 2})$.

A virtual number of harmonic functions $N_2^{'}$ is determined as:

$$N_2^{'} = \left\lceil \frac{N_2}{(2/\pi)\arcsin(f_{\min} / f_{\max})} \right\rceil \qquad (11)$$

The Doppler phases are defined from the interval $(0,2\pi]$ and for the computation a uniformly distributed random generator is employed.

Fade duration has a lognormal distribution [4].

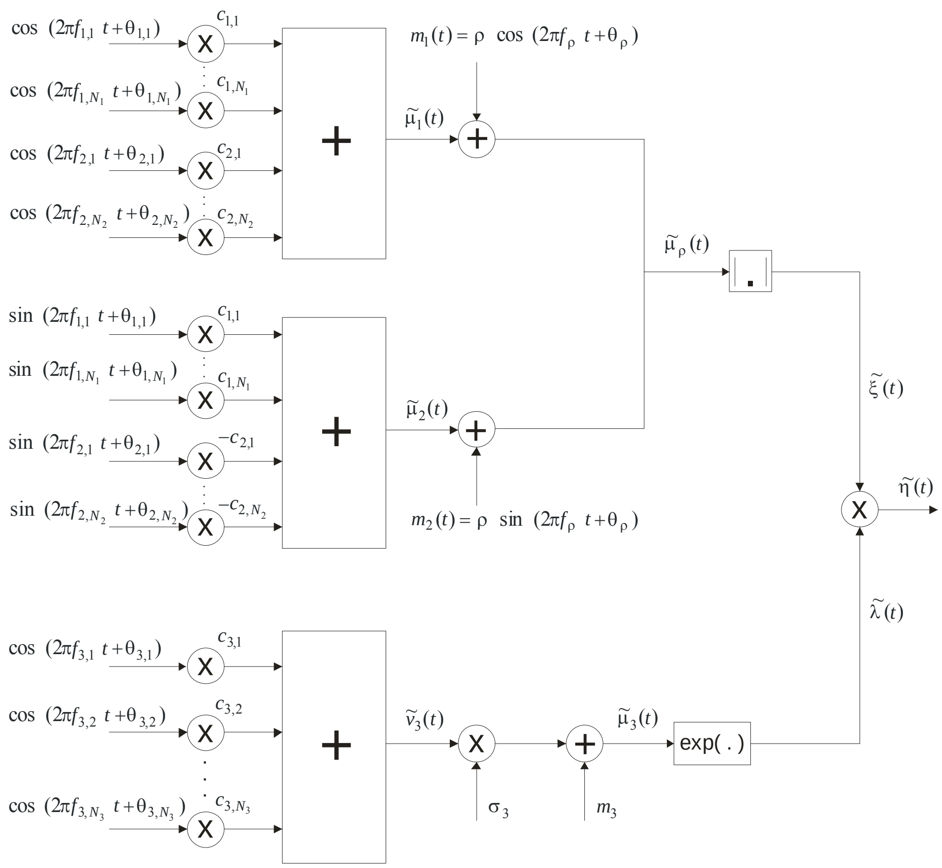

Fig. 4 Extended Suzuki channel Type I. – States B and C

5. SIMULATION RESULTS

In this section we will show, how the proposed channel can be adapted by adjusting of the parameters to simulate real satellite channels. This type of our channel belongs to the group of frequency-nonselective channels.

In our simulation, we adjusted parameters as is shown in Table 1. and Table 2. We employed other works which were issued about this research area [1] - [4].

	N_1	N_2	N_3
State A	6	7	-
State B	7	4	8
State C	10	2	9

Tab. 1 Numbers of harmonic functions

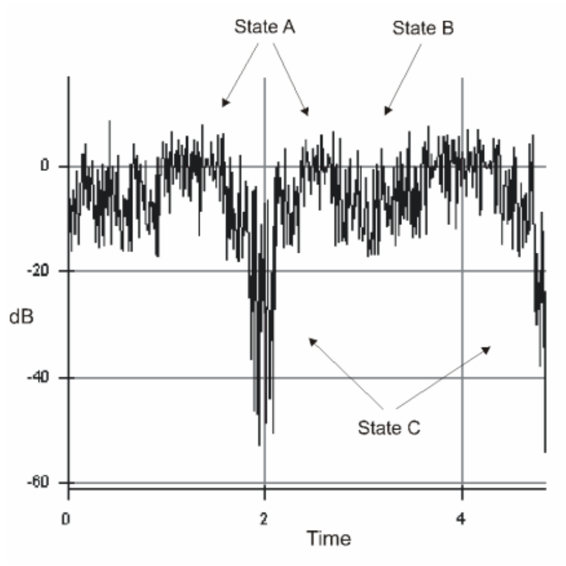

Fig. 5 Simulation results from System View

Table 1 shows us numbers of weighted harmonics functions N_i, which were used for individual states. Table 2 determines values of parameters, which were used for a simulation of Suzuki channel.

	σ_0	K_0	ρ	σ_3	m_3
State B	0.3	5.9e^{-8}	0.585	0.058	0.0875
State C	0.2	4.4e^{-11}	0.112	0.118	0.4906

Tab. 2 Parameters for Extended Suzuki model

To give more insight into the achievable performance of the channel, Figure 5 was generated from the System View simulator. We can see how numerical results differ for individual states.

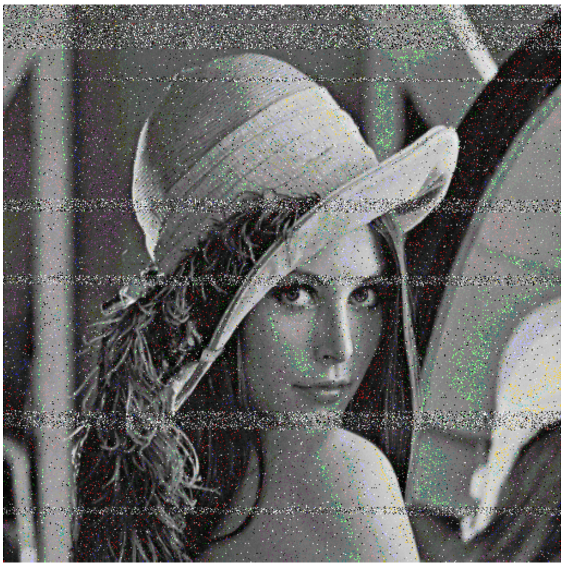

Fig. 6 Simulation results – the transmitted image

In our work, a bmp file with the picture of Lena was used and 2 millions bits were transferred through the channel. In the transmitted image on the Figure 6 we can evidently see the state C, when the image is strongly corrupted. In simulation 80 kHz frequency was used.

6. CONCLUSION

Last research of the mobile satellite channels showed, that 3-states model allows us a good representation of real channels. In this paper we have presented this type of channel based on the Rice and the extended Suzuki of type I. distribution. Because the corruption of our image is significant, techniques like CDMA and forward error correction is suitable to use to improve performance of the system.

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BIOGRAPHIES

Ľubomír Čopjan was born on 8.6.1981. In 2004 he graduated (MSc.) with distinction at the department of Computers and Informatics of the Faculty of Electrical Engineering and Informatics at Technical University in Košice. Since 2004 he is a internal PhD. student at the Deparment of electronics and multimedia telecommunications. His research interests are in the fields of Turbo decoding of CDMA signals and satellite communication.

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