Performance of Wireless Communication System in the Presence of Rician Short Term Fading, Gamma Long Term Fading and Cochannel Interference

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***Abstract*—Wireless communication system operating over Gamma shadowed Rician short term fading environment in the presence of cochannel interference subjected to Rician multipath fading is considered in this paper. In interference limited channel, signal to interference ratio (SIR) can be presented as ratio of product of Rician random variable and squared rooted of Gamma random variable and Rician random variable. The closed form expression for probability density function, moment generating function and moments of output signal to interference ratio are efficiently calculated. The influences of Rician factor of desired signal, Rician factor of cochannel interference and long term fading severity parameter on probability density function and moments are analyzed and discussed.**

Keywords—Gamma shadowing; moment generating function; moments; probability density function; Rician fading

I. INTRODUCTION

Short term fading, long term fading and cochannel interference degrade system performance of wireless communication systems and limit channel capacity. Reflection, refraction and scattering cause multipath propagation resulting in signal envelope variation. Large obstacles between transmitter and receiver cause shadowing which resulting in signal envelope average power variation.

There are several statistical models describing signal envelope in fading channel where line of sight component exists [1]. Rician distribution can be used to describe signal envelope variation in homogenous diffuse scattering line of sight fading environments [2]. Rician distribution has two parameters. Rician factor k is defined as ratio of dominant component power and scattering components power. For lower values of Rician factor, multipath fading is more severe. Rician factor k is lower for higher values of scattering components power or for lower values of dominant component power. When Rician factor is zero, Rician channel becomes Rayleigh fading channel. No fading channel is ensued from Rician fading channel when Rician factor goes to infinity [3], [4].

Long term fading can be presented by using Gamma distribution or log-normal distribution. When large scale fading is represented with Gamma distribution, performance measures of wireless communication system can be obtained in the closed form expressions [5], [6]. In this paper, long term fading is described by means Gamma statistical model.

There are a lot of papers in the literature considering performance of wireless communication system in the presence of small scale fading and cochannel interference and also performance of wireless communication system in the presence of large scale fading and small scale fading. So, in [7]-[9], wireless communication systems using selection combining (SC) diversity technique to reduce short term fading effects on system performance, in the presence of multipath fading and cochannel interference are considered. The outage probability and bit error probability, as important performance measures, are evaluated in this work. In [10], macrodiversity system with macrodiversity SC receiver and two microdiversity maximal ratio combining (MRC) receivers operating over Gamma shadowed Nakagami-*m* short term fading channel is analyzed. Level crossing rate and average fade duration, as the second order performance measures, of proposed system are efficiently calculated.

In this paper, wireless communication system under the presence of short term fading, long term fading and cochannel interference is investigated. Desired signal experiences Rician short term fading, Gamma long term fading and cochannel interference subjected to multipath Rician fading. Desired signal envelope can be written as product of squared rooted Gamma random variable and Rician variable.

The important performance measure of wireless communication system is signal to interference ratio. For considered wireless system, the ratio of signal envelope and interference envelope can be computed as ratio of product of squared rooted Gamma random variable and Rician random variable and Rician random variable. Probability density function, moment generating function and moments of actual ratio are evaluated as expressions in the closed form. The expression for probability density function of output SIR can be used for calculation of the outage probability and bit error probability of considered wireless communication system.

II. Performance of Wireless Communication System

A. Probability density function

Desired signal envelope can be written as product of two random variables x and y:

$$z_1 = x \cdot y\,, \quad \text{with } x = x_1^{1/2}\,,\ x_1 = x^2\,. \tag{1}$$

x_1 is Gamma long term fading with probability density function (PDF) [4]:

$$p_{x_1}(x_1) = \frac{1}{\Gamma(c)\beta^c} x_1^{c-1} e^{-\frac{1}{\beta}x_1}\,,\ x_1 \geq 0\,. \tag{2}$$

c is the order of Gamma distribution; β is related to the average power. The lower value of c means the higher shadowing, while the value of $c=\infty$ corresponds to a pure short-term fading channel [11].

Probability density function of x is:

$$p_x(x) = \left|\frac{dx_1}{dx}\right| p_{x_1}\left(x^2\right) = \frac{2}{\Gamma(c)\beta^c} x^{2c-1} e^{-\frac{1}{\beta}x^2}\,,\ x \geq 0 \tag{3}$$

Random variable y represents short term fading and has Rician distribution [2]:

$$p_y(y) = \frac{2(k_1+1)}{\Omega_1 e^{k_1}} y\, e^{-\frac{(k_1+1)}{\Omega_1}y^2} I_0\left(2\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\,y\right) =$$

$$= \frac{2(k_1+1)}{\Omega_1 e^{k_1}} \sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{2i_1} \frac{1}{(i_1!)^2} y^{2i_1+1} e^{-\frac{(k_1+1)}{\Omega_1}y^2} \tag{4}$$

The cochannel interference envelope follows Rician distribution:

$$p_z(z) = \frac{2(k_2+1)}{\Omega_2 e^{k_2}} \sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{2i_2} \tag{5}$$

The ratio of desired signal envelope to cochannel interference envelope is:

$$w = \frac{z_1}{z} = \frac{x \cdot y}{z} \quad x = \frac{wz}{y}, \quad \frac{dx}{dw} = \frac{z}{y} \tag{6}$$

Conditional probability density function of w is:

$$p_w(w/y,z) = \left|\frac{dx}{dw}\right| p_x\left(\frac{wz}{y}\right) = \frac{z}{y} p_x\left(\frac{wz}{y}\right) \tag{7}$$

Probability density function of ratio of product of Rician random variable and squared Gamma random variable and Rician random variable can be calculated by averaging previous expression:

$$p_w(w) = \int_0^{\infty} dy \int_0^{\infty} dz \frac{z}{y} p_x\left(\frac{wz}{y}\right) p_y(y)\, p_z(z) \tag{8}$$

After substituting, the expression for $p_w(w)$ becomes:

$$p_w(w) = \frac{2}{\Gamma(c)\beta^c} w^{2c-1} \cdot \frac{2(k_1+1)}{\Omega_1} \sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{2i_1} \frac{1}{(i_1!)^2} \cdot$$

$$\cdot \frac{2(k_2+1)}{\Omega_2} \sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{2i_2} \frac{1}{(i_2!)^2} \cdot$$

$$\cdot e^{-\frac{w^2z^2}{\beta y^2} - \frac{(k_1+1)}{\Omega_1}y^2 - \frac{(k_2+1)}{\Omega_2}z^2} \cdot \int_0^{\infty} dy \int_0^{\infty} dz \frac{z}{y} y^{2i_1+1} z^{2i_2+1} \frac{z^{2c-1}}{y^{2c-1}} \tag{9}$$

The integral J_1 is:

$$J_1 = \int_0^{\infty} dy\, y^{2i_1-2c+1} e^{-\frac{(k_1+1)}{\Omega_1}y^2} \cdot \int_0^{\infty} dz\, z^{2i_2+2c+1} e^{-z^2\left(\frac{w^2}{\beta y^2} + \frac{(k_2+1)}{\Omega_2}\right)} =$$

$$= \frac{1}{2} \frac{(\beta\Omega_2)^{i_2+c+1} y^{2i_2+2c+1}}{\left(\Omega_2 w^2 + (k_2+1)\beta y^2\right)^{i_2+c+1}} \cdot \int_0^{\infty} dy\, y^{2i_1-2c+1} e^{-\frac{(k_1+1)}{\Omega_1}y^2} =$$

$$= \frac{1}{2}\left(\beta\Omega_2\right)^{i_2+c+1} \frac{1}{\left(\Omega_2 w^2\right)^{i_2+c+1}} \frac{1}{\left(1 + \frac{(k_2+1)\beta}{\Omega_2 w^2} y^2\right)^{i_2+c+1}} \cdot$$

$$\cdot \int_0^{\infty} dy\, y^{2i_1+2i_2+2} e^{-\frac{(k_1+1)}{\Omega_1}y^2}\,. \tag{10}$$

Let is valid:

$$\frac{(k_2+1)\beta}{\Omega_2 w^2} y^2 = t\,;$$

and then:

$$y^2 = \frac{\Omega_2 w^2}{(k_2+1)\beta} t\,, \quad y\,dy = \frac{1}{2} \frac{\Omega_2 w^2}{(k_2+1)\beta} dt \tag{11}$$

After substituting, the expression for integral J_1 becomes:

$$J_1 = \frac{1}{2}\left(\beta\Omega_2\right)^{i_2+c+1} \frac{1}{\left(\Omega_2 w^2\right)^{i_2+c+1}} \cdot \frac{1}{2} \frac{\Omega_2 w^2}{(k_2+1)\beta} \left(\frac{\Omega_2 w^2}{(k_2+1)\beta}\right)^{i_1+i_2+1/2} \cdot$$

$$\cdot \int_0^{\infty} dt\, t^{i_1+i_2+1/2} e^{-\frac{(k_1+1)}{\Omega_1}\frac{\Omega_2 w^2}{(k_2+1)\beta}t} \cdot \frac{1}{(1+t)^{i_2+c+1}} \tag{12}$$

By using the formula [12]:

$$\int_0^{\infty} dt\, t^{a-1} e^{-ct} \cdot \frac{1}{(1+t)^{a+1-b}} = \Gamma(a) U(a,b,c)\,, \tag{13}$$

where $\Gamma(a)$ is gamma function [13], and $U(a,b,c)$ is Tricomi confluent hypergeometric function [14] or confluent hypergeometric Kummer U function, previous integral becomes:

$$J_1 = \frac{1}{4}\beta^{i_2+c+1} w^{-2(i_2+c+1)} \cdot \left(\frac{\Omega_2 w^2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2} \cdot w^{2i_1+2i_2+3} \cdot$$

$$\cdot \Gamma\left(i_1+i_2+3/2\right) U\left(i_1+i_2+3/2, i_1-c+1/2, \frac{k_1+1}{\Omega_1}\frac{\Omega_2 w^2}{(k_2+1)\beta}\right). \qquad (14)$$

By putting (14) in (9), the expression $p_w(w)$ becomes:

$$p_w(w) = \frac{2}{\Gamma(c)\beta^c} w^{2c-1} \cdot \frac{2(k_1+1)}{\Omega_1}\sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{2i_1}\frac{1}{(i_1!)^2}\cdot$$

$$\cdot \frac{2(k_2+1)}{\Omega_2}\sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{2i_2}\frac{1}{(i_2!)^2}\cdot$$

$$\cdot \frac{1}{4}\beta^{i_2+c+1} w^{-2(i_2+c+1)} \cdot \left(\frac{\Omega_2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2} \cdot \Gamma\left(i_1+i_2+3/2\right) \cdot w^{2i_1+2i_2+3} \cdot$$

$$\cdot U\left(i_1+i_2+3/2, i_1-c+1/2, \frac{(k_1+1)\Omega_2}{(k_2+1)\Omega_1\beta} w^2\right). \qquad (15)$$

The confluent hypergeometric function of the second kind gives the second linearly independent solution to the confluent hypergeometric differential equation. It is also known as the Kummer's function of the second kind, Tricomi function, or Gordon function. It is denoted $U(a,b,c)$ and can be defined by

$$U(a,b,c) = \frac{\Gamma(b-1)}{\Gamma(a)} c^{1-b} {}_1F_1(a-b+1; 2-b; c) + \frac{\Gamma(1-b)}{\Gamma(a-b+1)} {}_1F_1(a; b; c);\ b \notin Z$$

or

$$U(a,b,c) = \pi \csc(\pi b)\left[\frac{{}_1F_1(a;b;c)}{\Gamma(a-b+1)} - \frac{c^{1-b}\,{}_1F_1(a-b+1; 2-b; c)}{\Gamma(a)}\right] =$$

$$= c^{-a}\,{}_2F_1\left(a, 1+a-b; -c^{-1}\right),$$

where ${}_1F_1(a;b;c)$ is a regularized confluent hypergeometric function of the first kind [12, Eq.(9.210/1)], $\Gamma(a)$ is a gamma function, and ${}_2F_1(a;b;c)$ is a generalized hypergeometric function ([3], p. 504).

It has an integral representation ([3], p. 505)

$$U(a,b,c) = \frac{1}{\Gamma(a)}\int_0^{\infty} e^{-ct} t^{a-1}(1+t)^{b-a-1} dt$$

which we used in (13).

B. Moment of n-th order

Moment of n-th order of *w* is:

$$m_n = \overline{w^n} = \int_0^{\infty} dw\, w^n \cdot p_w(w) = \frac{2}{\Gamma(c)\beta^c} \cdot \frac{2(k_1+1)}{\Omega_1 e^{k_1}}\sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{i_1}\frac{1}{(i_1!)^2}\cdot$$

$$\cdot \frac{2(k_2+1)}{\Omega_2 e^{k_2}}\sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{i_2}\frac{1}{(i_2!)^2}\cdot$$

$$\cdot \frac{1}{4}\beta^{i_2+c+1} \cdot \left(\frac{\Omega_2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2} \cdot \Gamma\left(i_1+i_2+3/2\right)\cdot$$

$$\cdot \int_0^{\infty} dw\, w^{2c-1-2(i_2+c+1)+2i_1+2i_2+3+n} \cdot U\left(i_1+i_2+3/2, i_1-c+1/2, \frac{(k_1+1)\Omega_2}{(k_2+1)\Omega_1\beta} w^2\right) \qquad (16)$$

Let it be now:

$$\frac{(k_1+1)\Omega_2}{(k_2+1)\Omega_1\beta} w^2 = m\,;$$

then $w^2 = \frac{\Omega_1(k_2+1)\beta}{(k_1+1)\Omega_2} m$, and $wdw = \frac{\Omega_1(k_2+1)\beta}{2(k_1+1)\Omega_2} dm$.

Behind this substitution, moment of n-th order of *w* becomes:

$$m_n = \frac{2}{\Gamma(c)\beta^c} \cdot \frac{2(k_1+1)}{\Omega_1 e^{k_1}}\sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{i_1}\frac{1}{(i_1!)^2}\cdot$$

$$\cdot \frac{2(k_2+1)}{\Omega_2 e^{k_2}}\sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{i_2}\frac{1}{(i_2!)^2}\cdot$$

$$\cdot \frac{1}{4}\beta^{i_2+c+1} \cdot \left(\frac{\Omega_2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2} \cdot \Gamma\left(i_1+i_2+3/2\right) \cdot \frac{1}{2}\left(\frac{\Omega_1(k_2+1)\beta}{(k_1+1)\Omega_2}\right)^{5/2+i_1+n/2}\cdot$$

$$\cdot \int_0^{\infty} dm\, m^{5/2+i_1+n/2} \cdot U\left(i_1+i_2+3/2, i_1-c+1/2, m\right) \qquad (17)$$

By using the next formula:

$$\int_0^{\infty} dt\, t^{b-1} \cdot U(a,d,t) = \frac{\Gamma(b)\Gamma(b+1-d)}{\Gamma(a+b+1-d)} \cdot {}_2F_1\left(b, b+1-d, a+b+1-d, 1\right) \qquad (18)$$

where ${}_2F_1(a,b,c;z)$ is Gauss hypergeometric function [15], previous expression obtains the form:

$$m_n = \frac{2}{\Gamma(c)\beta^c} \cdot \frac{2(k_1+1)}{\Omega_1 e^{k_1}}\sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{i_1}\frac{1}{(i_1!)^2}\cdot$$

$$\cdot \frac{2(k_2+1)}{\Omega_2 e^{k_2}}\sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{i_2}\frac{1}{(i_2!)^2}\cdot$$

$$\cdot \frac{1}{4}\beta^{i_2+c+1} \cdot \left(\frac{\Omega_2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2} \cdot \Gamma\left(i_1+i_2+3/2\right) \cdot \frac{1}{2}\left(\frac{\Omega_1(k_2+1)\beta}{2(k_1+1)\Omega_2}\right)^{5/2+i_1+n/2}\cdot$$

$$\cdot \frac{\Gamma\left(5/2+i_1+n/2\right)\Gamma\left(5/2+i_1+n/2+1-i_1+c-1/2\right)}{\Gamma\left(3+n/2+c+i_1+i_2+1/2\right)}\cdot$$

$${}_2F_1\left(5/2+i_1+n/2, 3+n/2+c, i_1+i_2+c+n/2+9/2, 1\right) \qquad (19)$$

A generalized hypergeometric function ${}_pF_q\left(a_1,\ldots,a_p; b_1,\ldots,b_q; x\right)$ is a function which can be defined in the form of a hypergeometric series, i.e., a series for which the ratio of successive terms can be written:

$$\frac{c_{k+1}}{c_k}=\frac{P(k)}{Q(k)}=\frac{(k+a_1)(k+a_2)\cdots(k+a_p)}{(k+b_1)(k+b_2)\cdots(k+b_q)(k+1)}x.$$

The function ${}_2F_1(a,b;c;x)$ corresponding to p=2, q=1 is the first hypergeometric function to be studied and, in general, arises the most frequently in physical problems. It is frequently known as "the" hypergeometric equation or, more explicitly, Gauss's hypergeometric function (Gauss 1812, Barnes 1908).

The so-called regular solution is denoted by:

$${}_2F_1(a,b;c;z)=1+\frac{ab}{1!c}z+\frac{a(a+1)b(b+1)}{2!c(c+1)}z^2+\cdots=\sum_{n=0}^{\infty}\frac{(a)_n(b)_n}{(c)_n}\frac{z^n}{n!},$$

and converges if c is not a negative integer for all of $|z|<1$ and on the unit circle $|z|=1$ if $R[c-a-b]>0$. Here, $(a)_n$ is a Pochhammer symbol [15], [16].

C. Moment generating function

Moment generating function (MGF) of w is:

$$M_w(s)=\overline{e^{sw}}=\int_0^{\infty}dw\,e^{sw}p_w(w)=$$

$$=\frac{2}{\Gamma(c)\beta^c}\cdot\frac{2(k_1+1)}{\Omega_1 e^{k_1}}\sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{i_1}\frac{1}{(i_1!)^2}\cdot\frac{2(k_2+1)}{\Omega_2 e^{k_2}}\sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{i_2}\frac{1}{(i_2!)^2}\cdot$$

$$\cdot\frac{1}{4}\beta^{i_2+c+1}\cdot\left(\frac{\Omega_2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2}\cdot\Gamma(i_1+i_2+3/2)\cdot\frac{1}{2}\left(\frac{\Omega_1(k_2+1)\beta}{2(k_1+1)\Omega_2}\right)^{5/2+i_1+3/2}\cdot$$

$$\cdot\int_0^{\infty}dw\,w^{3/2+i_1}e^{sw}\cdot U(i_1+i_2+3/2,i_1-c+1/2,w) \qquad (20)$$

By using the formula:

$$\int_0^{\infty}dt\,t^{b-1}e^{-st}\,U(a,d,t)=\frac{\Gamma(b)\Gamma(b+1-d)}{\Gamma(a+b+1-d)}\cdot{}_2F_1(b,b+1-d,a+b+1-d,1-s),\quad(21)$$

the expression (20) ensues:

$$M_w(s)=\frac{2}{\Gamma(c)\beta^c}\cdot\frac{2(k_1+1)}{\Omega_1 e^{k_1}}\sum_{i_1=0}^{\infty}\left(\sqrt{\frac{k_1(k_1+1)}{\Omega_1}}\right)^{i_1}\frac{1}{(i_1!)^2}\cdot$$

$$\cdot\frac{2(k_2+1)}{\Omega_2 e^{k_2}}\sum_{i_2=0}^{\infty}\left(\sqrt{\frac{k_2(k_2+1)}{\Omega_2}}\right)^{i_2}\frac{1}{(i_2!)^2}\cdot\frac{1}{4}\beta^{i_2+c+1}\cdot\left(\frac{\Omega_2}{(k_2+1)\beta}\right)^{i_1+i_2+3/2}\cdot\Gamma(i_1+i_2+3/2)\cdot$$

$$\cdot\frac{1}{2}\left(\frac{\Omega_1(k_2+1)\beta}{2(k_1+1)\Omega_2}\right)^{4+i_1}\cdot\frac{\Gamma(5/2+i_1)\Gamma(3+c)}{\Gamma(i_1+i_2+c+9/2)}\cdot{}_2F_1(5/2+i_1,3+c,i_1+i_2+c+9/2,1-s).$$

(22)

III. NUMERICAL RESULTS

In the next few figures the first moment of w is given versus Rician factor of desired signal, Rician factor of interference signal and Gamma large scale severity parameter. We took into account a million of series' terms for calculation the system performance in order to achieve sufficient accuracy.

In Fig. 1, the mean value $\overline{w}$ versus Rician factor of desired signal k_1 is presented for parameter β=0.2, Gamma shadowing severity parameter c=2 and variable Rician factor of interference signal k_2. In Fig. 2, the first moment $\overline{w}$ is plotted versus Rician factor of desired signal k_1. The parameters of curves are: Gamma shadowing severity parameter c=2, Rician factor of interference signal k_2=0.2 and parameter β is changeable.

One can see from Fig. 1 that the first moment of w increases when Rician factor of desired signal, k_1, increases. The first moment also is growing up with lowering of Rician factor of interference signal k_2. An increasing of mean value $\overline{w}$ is visible from Fig. 2 for enlarging of parameter β. The influence of parameter β is bigger for higher values of Rician factor of interference signal k_2.

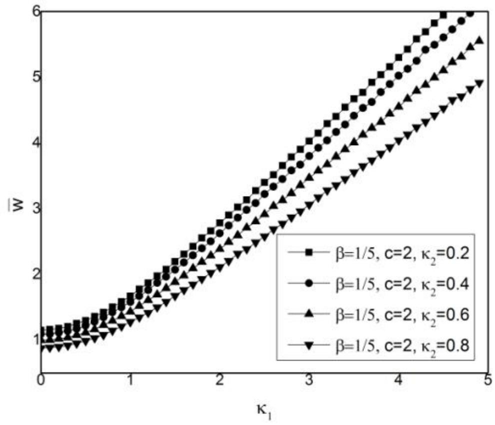

Fig. 1. Mean value $\overline{w}$ versus Rician factor of desired signal k_1 for β=0.2, Gamma shadowing severity parameter c=2 and variable Rician factor of interference signal k_2

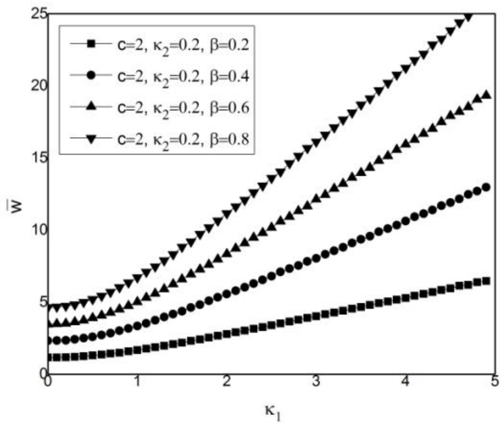

Fig. 2. Mean value $\overline{w}$ versus Rician factor of desired signal k_1 for c=2, Rician factor of interference signal k_2=0.2 and changeable parameter β

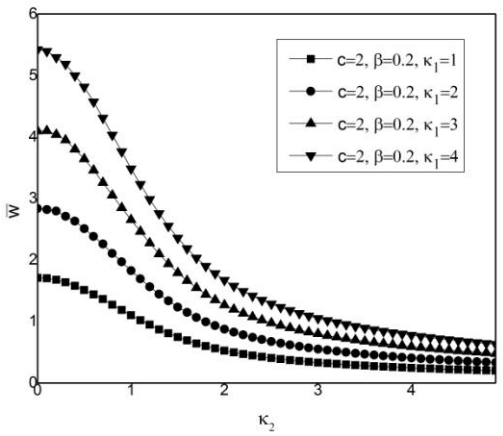

Fig. 3. Mean value $\bar{w}$ versus Rician factor of interference signal k_2 for β=0.2, c=2 and variable Rician factor of desired signal k_1

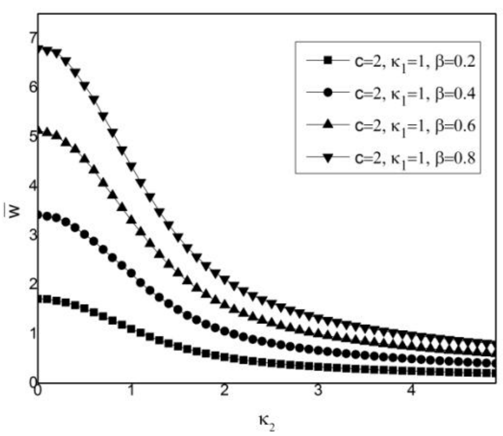

Fig. 4. Mean value $\bar{w}$ versus Rician factor of interference signal k_2 for c=2, Rician factor of desired signal k_1=1 and variable parameter β

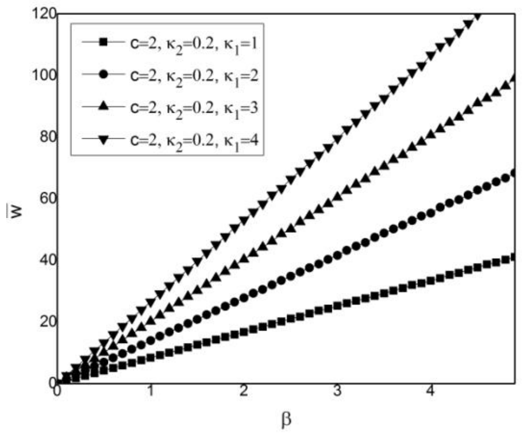

Fig. 5. The first moment of w versus parameter β for c=2, Rician factor of interference signal k_2=0.2 and changeable Rician factor of desired signal k_1

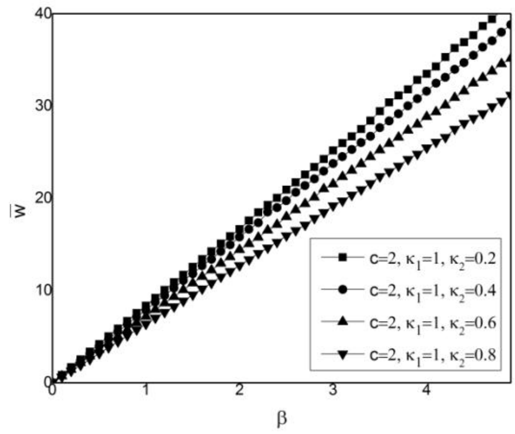

Fig. 6. The first moment of w versus parameter β for c=2, Rician factor of desired signal k_1=1 and variable Rician factor of interference signal k_2

Mean value $\bar{w}$ versus Rician factor of interference signal k_2 is shown in Figs. 3 and 4. In Fig. 3, the parameters of curves are: β=0.2, c=2 and variable Rician factor of desired signal k_1. In Fig. 4, the curves are drawn for: c=2, Rician factor of desired signal k_1=1 and variable parameter β. It is obvious from these two figures that the mean value decreases with increasing of Rician factor of interference signal k_2. For smaller values of Rician factor k_2, the influences of Rician factor of desired signal k_1 and parameter β are bigger. The first moment rises when Rician factor k_1 and parameter β are rising.

The first moment of w versus parameter β is plotted in Figs. 5. and 6. with constant Gamma shadowing severity parameter c=2. The Rician factor of desired signal k_1 is declinable in Fig. 5. and Rician factor of interference signal k_2 is mutable in Fig. 6.

It is visible from these two figures that mean value $\bar{w}$ is getting bigger with an aggrandizement of parameter β. One can also notice that a greater impact on the growth of $\bar{w}$ has an increasing of Ricean factor k_1 for for large values of parameter β.

IV. Conclusion

In this paper, wireless mobile radio communication system in the presence of Gamma large scale fading, Rician small scale fading and cochannel interference is examined. In interference limited environment, where level of cochannel interference is significantly higher than Gaussian noise, signal to interference ratio is important system measure. In observed wireless communication system signal to interference ratio can be calculated as a ratio of product of squared rooted Gamma random variable and Rician random variable and Rician random variable.

Also, in this paper, the closed form expressions for probability density function, moment generating function and moments of output SIR are determined. Probability density function can be used for evaluation the channel capacity, the bit error probability and the outage probability of proposed wireless system.

Using determined expressions, probability density function, moment generating function and moments of wireless system in the presence of Rayleigh multipath fading, Gamma long term fading and Rayleigh interference can be reckoned putting Rician factor to be zero. The influence of Rician factor of desired signal, Rician factor of interference signal and Gamma large scale severity parameter on mean average values is analyzed. The outage probability and error performance are better for higher values of the first moment and second moment.

Results obtained in this work could be used in performance analysis and designing of wireless communication systems in the presence of Rician multipath fading, Gamma shadowing and cochannel interference affected to Rician multipath fading.

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References

[1] M. K. Simon, M. S. Alouini, Digital Communication over Fading Channels. USA: John Wiley & Sons, 2000.

[2] S. O. Rice, "Mathematical Analysis of Random Noise", Bell System Technical Journal, 24, 1945, pp. 46-156.

[3] M. Abramowitz, I. A. Stegun, "Handbook of Mathematical Functions", National Bureau of Standards, 1964; reprinted Dover Publications, 1965. Tenth Printing December 1972, with corrections

[4] S. Panic, M. Stefanovic, J. Anastasov, P. Spalevic, Fading and Interference Mitigation in Wireless Communications. USA: CRC Press, 2013.

[5] A. Abdi, M. Kaveh, "On the utility of gamma PDF in modeling shadow fading (slow fading)", IEEE vehicular technology conference, Houston, TX, Vol. 3, 1999, pp. 2308–2312.

[6] I. Kostic, "Analytical approach to performance analysis for channel subject to shadowing and fading", IEE Proceedings Communications, 152(6), 2005, pp. 821–827.

[7] S. Maricic, D. Krstic, M. Stefanovic, M. Masadeh Bani Yassein, V.Milenkovic, „Performance of SC Receiver over Weibull Multipath Fading Channel", WSEAS Transactions on Communications, Vol. 15, 2016, Art. #14, pp. 114-119.

[8] M. C. Stefanovic, D. M. Milovic, , A. M. Mitic, M. M. Jakovljevic, "Performance analysis of system with selection combining over correlated Weibull fading channels in the presence of cochannel interference", AEU - International Journal of Electronics and Communications, Vol. 62, Issue 9, October 2008, pp. 695-700.

[9] D. N. Milic, D. B. Đošic, C. M. Stefanovic, M. M. Smilic, S. N. Suljovic, "Outage performance of multi-branch SC receiver over correlated Weibull channel in the presence of correlated Rayleigh co-channel interference", Facta Universitatis, Series: Automatic Control and Robotics, Vol. 14, No 3, 2015, pp. 183-191.

[10] A. D. Cvetkovic, M. C. Stefanovic, N. M. Sekulovic, D. N. Milic , D. M. Stefanovic, Z. J. Popovic, " Second-order statistics of dual SC macrodiversity system over channels affected by Nakagami-m fading and correlated gamma shadowing", Przegląd Elektrotechniczny (Electrical Review), ISSN 0033-2097, R. 87 NR 6/2011, pp. 284-288.

[11] P. M. Shankar, "Performance analysis of diversity combining algorithms in shadowed fading channels", Wireless Personal Communications, 37(1–2), 2006, pp. 61–72.

[12] I. Gradshteyn, I. Ryzhik, Tables of Integrals, Series, and Products, Academic Press, New Yourk, 1st edition, 1980.

[13] E. W. Weisstein, "Gamma Function." From *MathWorld*-A Wolfram, http://mathworld.wolfram.com/GammaFunction.html

[14] E. W. Weisstein, "Confluent Hypergeometric Function of the Second Kind." From *MathWorld*-A Wolfram, http://mathworld.wolfram.com/ConfluentHypergeometricFunctionoftheSecondKind.html

[15] E. W. Weisstein, "Hypergeometric Function." From *MathWorld*-A Wolfram, http://mathworld.wolfram.com/HypergeometricFunction.html

[16] R. K. S. Hankin, "Numerical evaluation of the Gauss hypergeometric function with the hypergeo package", R Journal; Dec2015, Vol. 7 Issue 2, p81