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Outage Analysis of Cooperative Relay Network with Selection Combining and Switch & Stay Combining in Rician Fading Channel

SURYAKANT PATHAK[1] and HIMANSHU KATIYAR[2]

Director, KIPM College of Engineering & Technology, GIDA Gorakhpur-273209, Uttar Pradesh, India[1]

Department of Electronics & Communication Engineering, Rajkiya Engineering College Sonbhadra, Uttar Pradesh, India[2]

Abstract: The next generation wireless systems are supposed to handle high data rate as well as large coverage area. It should consume less power and utilize bandwidth efficiently. At the same time, the mobile terminals must be simple, cheap, and smaller in size. In wireless communication, the quality of received signal level degraded due to various fading phenomenon. To combat these problems the new technology cooperative communication becomes popular to the research community. In which cooperation among nodes has been the subject of great interest among the researchers because it creates spatial diversity in wireless network, even if individual nodes do not use antenna arrays for transmission and reception. Different diversity combining techniques can be used to improve the performance of the wireless link. In this paper outage analysis of cooperative relay network has been carried out with selection combining and switch and stay combining. The results are simulated which shows that the outage performance of selection combining gives better results than switch and stay combining.

Keywords: Cooperative communication; diversity combining technique; Rician fading; selection combining; switch and stay combining.

1. INTRODUCTION

In wireless communication Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times [1]. In Rician distribution [2] propagation paths consisting of one strong direct LOS component and many random weaker components. To combat the fading diversity combining techniques [3] are used. In this paper outage analysis of selection combining (SC) and switched and stay combining (SSC) has been carried out [4]. The equations for outage analysis of SC and SSC are derived from [5].A new technique called cooperative relaying [6] in which spatially distributed nodes cooperate to improve the quality of communication between two nodes [7]. An overview of various cooperation schemes and issues related to their implementation has been discussed in [8]. Various power allocation strategies for non-regenerative relay network have been studied in [9]. Simulation studies of adaptive power allocation for threshold based regenerative relay network has been done in [10]. In [11], closed form expressions of outage probability and bit error rate (*BER*) for binary phase shift keying (BPSK) are derived for the case where communication between source and destination is supported by multi-antenna relay and both relay and destination perform maximum ratio combining (*MRC*) of signals in Rayleigh fading channel. Outage probability and average error rate of two-hop multi-antenna relay based system for the case when relay performs selection combining(*SC*) of signals and destination performs *MRC* of signals are analyzed in [12] and [13], respectively. Closed form expressions of *BER* have been established in [14] for two-hop multi-antenna cooperative relay network in Rayleigh fading channel. Here, destination performs selection combining of signals received from source, relay and relay performs selection or MRC combining of signal. Average capacity and SNR analysis of multi-antenna regenerative relay has been analyzed in [15].Infrastructure based multi-antenna cooperative relay network has been investigated in [16]. Here, closed form expressions of outage probability and average error rate have been derived when the relay and the destination perform selection combining of the signals. Simulation studies of multi-antenna relay network have been analyzed in [17]; here, relay performs *MRC* and destination performs switch and stay combining of the signal. In [18], closed form expressions for outage probability and *BER* have been derived when multi-antenna cooperative relay network operates in correlated Nakagami-*m* fading channel and both the relay as well as destination performs *MRC* of signals. In [19], outage and error performance of multi-antenna relay system has been investigated with the help of simulation studies. Here, relay performs generalized selection combining and destination performs MRC of signals. Simulation studies of outage and throughput of cooperative relay network have been presented in [20] where source and relay communicate with multi-antenna destination in correlated Nakagami-*m* fading

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channel. Performance of regenerative relay network operating in uplink of multi-antenna base station under Rayleigh fading channel has been presented in [21].

The paper is organized as follows. In section 2, Rician fading model is briefly discussed. In section 3, Cooperative communication is discussed. In section 4, diversity combining techniques (outage analysis of selection combining and switched & stay combining) is discussed. Simulation results are shown in section 5. The paper is concluded by section 6.

2. THE RICIAN FADING MODEL

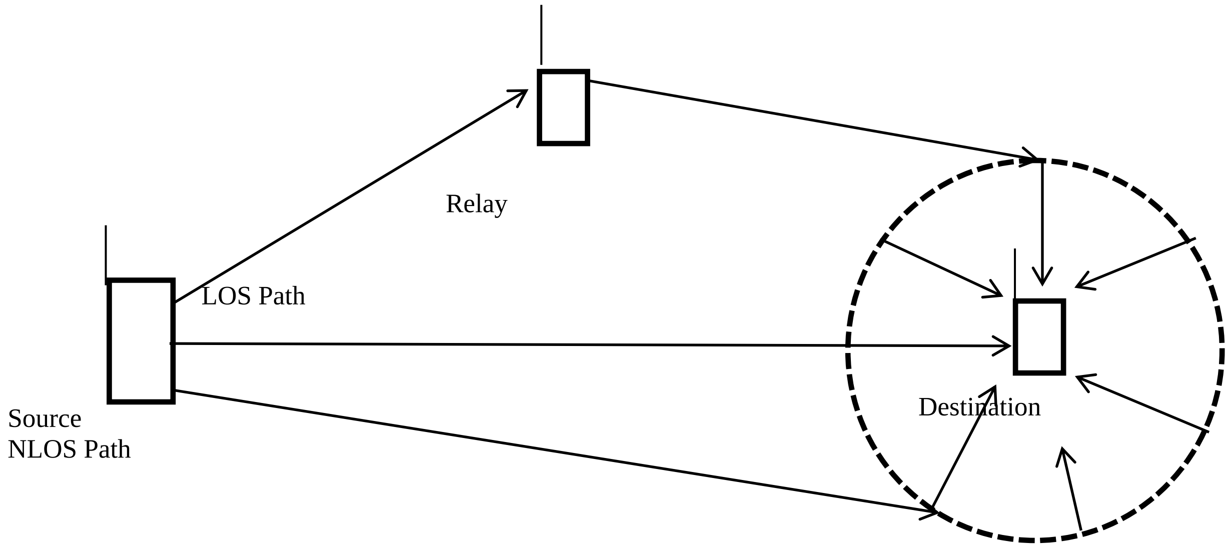

Fig.1. Rician fading model

2.1 Rician Fading

Some types of scattering environment have specular or LOS components. If $g_I(t)$ and $g_Q(t)$ are Gaussian random process with non-zero mean $m_I(t)$ and $m_Q(t)$. If we again assume that these process are uncorrelated and random variable $g_I(t)$ and $g_Q(t)$ have the same variance σ^2. Then magnitude of the received complex envelop at time t has a Rician distribution as [4 Eq. (2.45)],

$$f_\alpha(x) = \frac{x}{\sigma^2} e^{-\frac{(x^2+s^2)}{2\sigma^2}} I_0\left(\frac{xs}{\sigma^2}\right) x \geq 0 \tag{1}$$

Where

$$s^2 = m^2{}_I(t) + m^2{}_Q(t) \tag{2}$$

is called the non-centrality parameter. This type of fading is called Ricean fading and is very often observed in microcellular and mobile satellite applications. A very simple Ricean fading model assumes that the means $m_I(t)$ and $m_Q(t)$ are constants, i.e. $m_I(t) = m_I$, and $m_Q(t) = m_Q$ the means $m_I(t)$ and $m_Q(t)$ corresponding to the in phase and quadrature components of the LOS signal are given by

$$m_I(t) = s.\cos(2\pi f_m \cos\theta_0 t + \phi_0) \tag{3}$$

$$m_Q(t) = s.\sin(2\pi f_m \sin\theta_0 t + \phi_0) \tag{4}$$

Where $f_m \cos\theta_0$ and ϕ_0 are the Doppler shift and random phase off set associated with the LoS or specular component, respectively.

The **Rice factor,** *K*, is defined as the ratio of the specular power s^2 to scattered power $2\sigma^2$ i.e. $K = s^2/2\sigma^2$, When K= 0 the channel exhibits Rayleigh fading, and when $K=\infty$ the channel does not exhibit any fading at all. The envelope distribution can be rewritten in terms of the Rice factor and the average envelope power $E[\alpha^2] = \Omega p = s^2/2\sigma^2$ by first noting that

$$s^2 = \frac{K\Omega p}{K+1},\quad 2\sigma^2 = \frac{\Omega p}{K+1} \tag{5}$$

It then follows

$$f_\alpha(x) = \frac{2x(K+1)}{\Omega p} exp\left\{ -K - \frac{(K+1)x^2}{\Omega p}\right\} I_0\left(2x\sqrt{\frac{K(K+1)}{\Omega p}}\right),\quad x>=0 \tag{6}$$

α = received complex envelop which is Rician distributed

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$\alpha = \sqrt{N(m_I, \sigma^2) + j*N(m_Q, \sigma^2)}$
N = (. , .) Normally or Gaussian distributed random variable
x= running variable
σ^2 = Variance
s = $\sqrt{m_I^2+m_Q^2}$
m_I= mean of in phase component
m_Q=mean of quadrature phase components
I_0 = zero order modified Bessel function of the first kind
j = complex operator

3. COOPERATIVE COMMUNICATION

The use of multiple antennas to achieve diversity in cellular communication is difficult due to size constraints at mobile station. It is because; antenna spacing of half the carrier wavelength is required to ensure uncorrelated signals. Although multi-antenna system improves diversity gain of wireless network, but is not suitable for small wireless nodes due to limited hardware and signal processing capability. The need of high-data-rate, spectrally efficient and reliable wireless communication can be met by cooperative communication. The diversity can be achieved through user cooperation, when mobile users share their physical resources to create a virtual array, which eliminates the necessity of multiple-antenna on wireless terminal.

In cooperative communication fig.2, the signal is transmitted as broadcast through relaying by intermediate relay terminals in between source and destination. If the relay receives the signal, amplifies it and then transmit in next phase, it is called *amplify and forward* (AF) mode of relaying. AF requires very less processing by the relays which makes them fast in terms of delay, hence suitable for delay sensitive signal such as voice or live video. Noise amplification also occurs along with signal, which is a serious issue in AF operation. The *decode and forward* (DF) is a digital and regenerative scheme, where relay receives the signal, decode it and after encoding retransmit it in the next time slot. Noise does not propagate, processing time in higher causing delay; hence DF is not suitable for delay sensitive signals. There is also *decoded and re-encode* (DR) scheme where code used at relay for encoding the message is different than that used at source. Thus destination receives two copies of the same message encoded with different codes.

The adaptive cooperation relay system improves performance by eliminating noise/error propagation. This system adapts their transmission format according to channel condition between source and relay. The relay nodes process the signal received from the source if received SNR at relay is more than threshold; else the relay remains the silent. When relay remains silent, the source may retransmit the signal to destination or can choose more powerful code to mitigate fading. In recent past *coded cooperative communication* has become a fertile area to research among researchers because of its efficiency and robustness. Several signals can be simultaneously received in the same time-slot, thus improving the spectrum efficiency of the system.

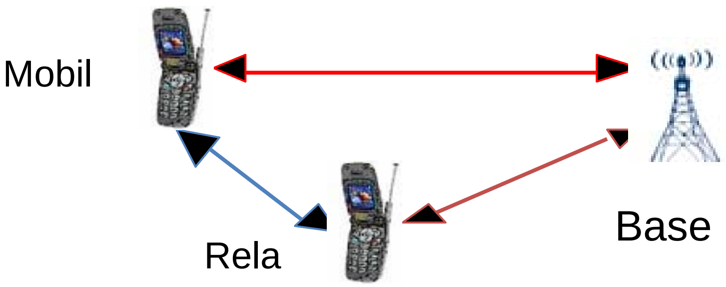

Fig.2. Cooperative Communication

Relay transmission topology can be *serial relay* transmission or *parallel relay* transmission. In serial relay signal propagates from one relay to another relay hence may face multi-path fading. Parallel relay transmission overcomes the problem by propagating the signal through multiple relay paths in same hop and destination combines the signal by the combining technique.

4. DIVERSITY COMBINING TECHNIQUES

Diversity technique provides multiple copies of the same signal on different branches, which undergo independent fading. If one branch undergoes a deep fade, another branch may have strong signal. In space diversity fading is minimized by the simultaneous use of two or more physically separated antennas. Thus having more than one path to

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select the SNR at receiver may be improved by selecting appropriate combining technique. Diversity combining methods for uncorrelated fading channels are enumerated below:

4.1Selection Combining (SC)

Selection combining is based on the principle of selecting the best signal among all the signals received from different branches at the receiving end. In this method, the receiver monitors the SNR of the incoming signal using switch logic. The branch with highest instantaneous SNR is connected to demodulator. SNR of selection combining is given as

$\gamma_{SC} = \mathrm{Max}\ (\alpha_1^2,\ \alpha_2^2)$

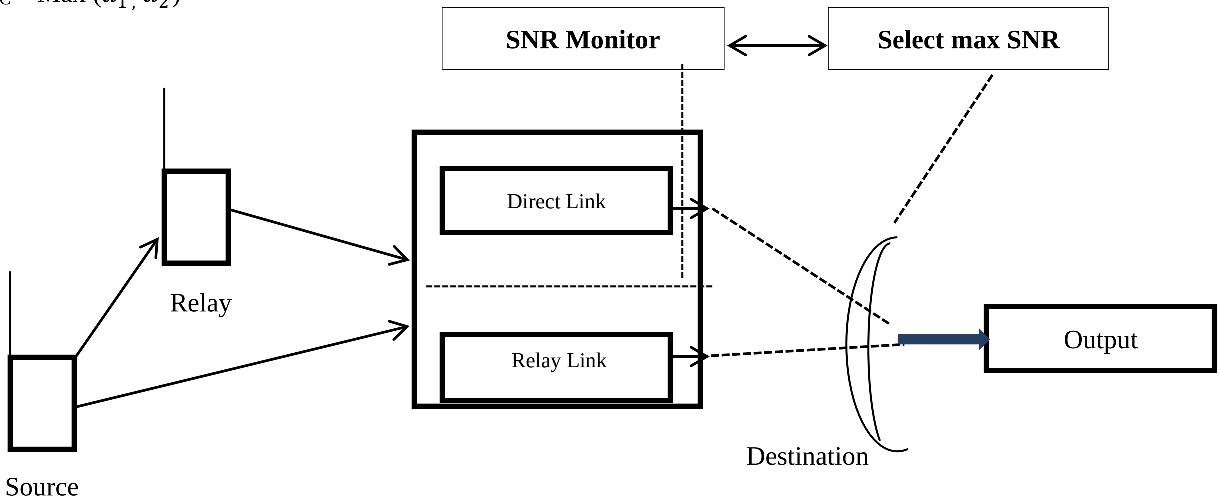

Fig.3. Selection Combining

Where $\alpha_1$and $\alpha_2$represent the fading envelope for two channels seen by two different paths. PDF of selection combining SNR (γ) can be obtained by differentiating the CDF of the SNR after selection combining.

$$\textbf{PDF} = f_{\gamma_{SC}}(\gamma) = \frac{dF_{\gamma_{SC}}(\gamma)}{d\gamma} \tag{7}$$

Outage Probability:

$\mathbf{P_{out}}$ is defined as the probability that the instantaneous error probability exceeds a specified value or equivalently the probability that the output SNR γ falls below a certain specified threshold (γ_T).

Outage probability $P_{out} = F_{\gamma_{SC}}(\gamma_T)$

Outage Probability $P_{out}$of selection combining can be evaluated

$$F_{\gamma_{SC}}(\gamma_T) = F_{\gamma_{srd}}(\gamma_T) \times F_{\gamma_{sd}}(\gamma_T) \tag{8}$$

Here

$$F_{\gamma_{srd}}(\gamma) = 1-[\{1-F_{\gamma_{sr}}(\gamma)\}\{1-F_{\gamma_{rd}}(\gamma)\}] \quad \text{[see Appendix Eq. (25)]} \tag{9}$$

Here

$$F_{\gamma_{sd}}(\gamma) = \int_0^{\gamma} f_{\gamma}(\gamma)\, d\gamma \tag{10}$$

$$F_{\gamma_{sd}}(\gamma) = \frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right] \tag{11}$$

Substituting the value of Eq. 9 and Eq.10 in Eq.8 we get

The CDF of selection combining

$F_{\gamma_{SC}}(\gamma) = F_{\gamma_{srd}}(\gamma) \text{ x } F_{\gamma_{sd}}(\gamma)$

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$$F_{\gamma_{SC}}(\gamma) = \left[\left[1 - \left[\left\{1 - \left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]\right\} \times \left\{1 - \left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2 \frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right\}\right]\right] \times \left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right]$$

$$F_{\gamma_{SC}}(\gamma) = \left[\left[\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right] + \left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right] - \left[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right] \quad (12)$$

4.2 Switch and Stay Combining (SSC)

SSC further simplifies the complexities of SC. In this in place of continually connecting the diversity path with best quality, a particular diversity path is selected by the receiver till the quality of the path drops below a predetermined threshold. When it happens, then the receiver switches to another diversity path. This reduces the complexities relative to SC, because continuous and simultaneous monitoring of all diversity paths in not required. The CDF of SNR of SSC is given [2,Eq.(9.327)] as

$$F_{\gamma_{ssc}}(\gamma) = \begin{cases} \frac{F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma_T)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}\left(F_{\gamma_{sd}}(\gamma) + F_{\gamma_{srd}}(\gamma)\right) & \gamma \leq \gamma_T \\ \frac{F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma_T)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}\left(F_{\gamma_{sd}}(\gamma) + F_{\gamma_{srd}}(\gamma) - 2\right) + \\ \frac{F_{\gamma_{sd}}(\gamma)F_{\gamma_{srd}}(\gamma_T)+F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)} & \gamma > \gamma_T \end{cases} \quad (13)$$

Where γ is the instantaneous SNR and γ_T is the threshold of the receiver.

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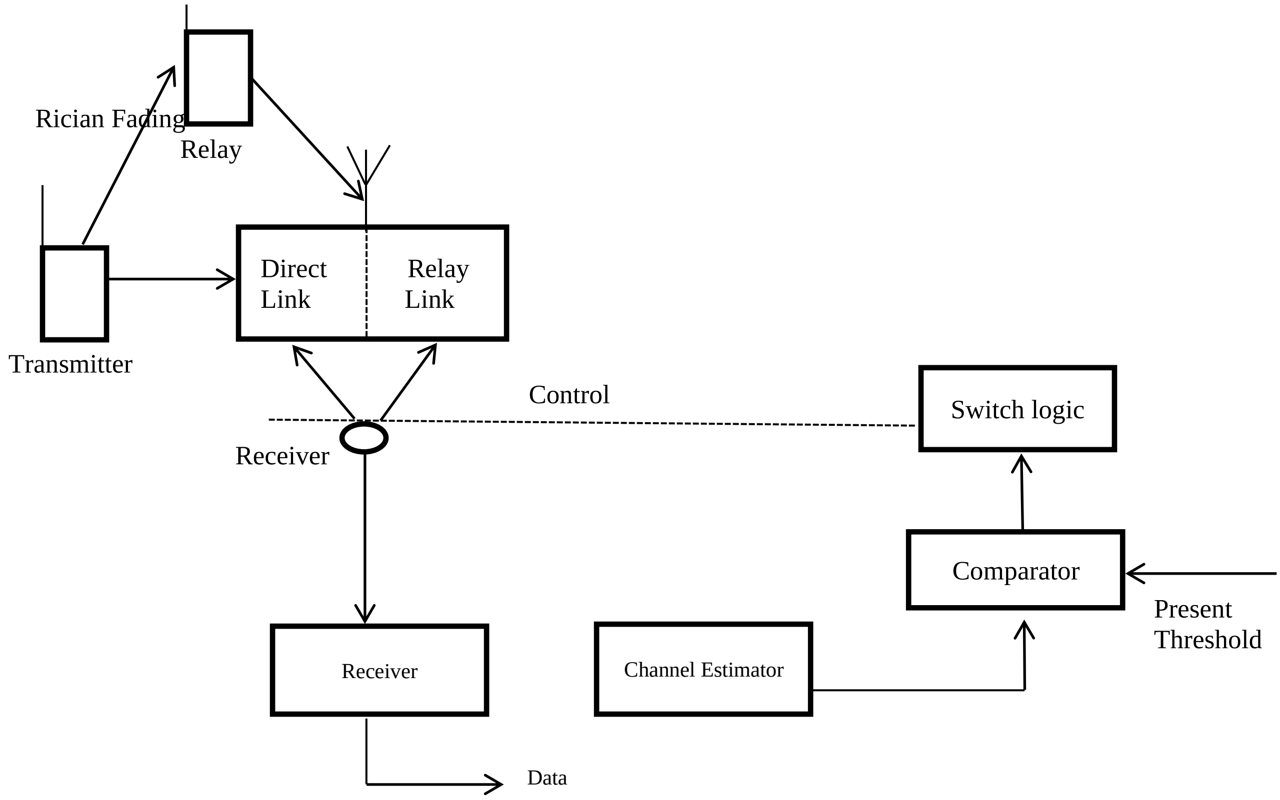

Fig.4. Switch and Stay Combining

Outage probability $P_{out} = F_{\gamma_{ssc}}(\gamma)$

$$F_{\gamma_{sd}}(\gamma)=\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]$$

$$F_{\gamma_{srd}}(\gamma) = 1-[\{1-F_{\gamma_{sr}}(\gamma)\}\{1-F_{\gamma_{rd}}(\gamma)\}]$$

$$F_{\gamma_{srd}}(\gamma) = \left[1-\left[\left\{1-\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]\right\}\left\{1-\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2 \frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right\}\right]\right]$$

$$F_{\gamma_{srd}}(\gamma)=\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2 \frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right.$$
$$\left.-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right] \quad (14)$$

The outage probability of SSC when $\gamma \leq \gamma_T$

$$F_{\gamma_{ssc}}(\gamma) = \frac{F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma_T)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}\left(F_{\gamma_{sd}}(\gamma)+F_{\gamma_{srd}}(\gamma)\right)$$

$$F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma_T) = \left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2 \frac{\Gamma\left(k+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2 \frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]\right]$$

$$+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma(j+1,\ \gamma_T)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\Bigg]$$

$$\mathrm{F}_{\gamma_{sd}}(\gamma_T)\mathrm{F}_{\gamma_{srd}}(\gamma_T)=\Bigg[\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$
$$+\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\ \sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$
$$-\left[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{j=0}^{\infty}\ \sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\Bigg] \quad (15)$$

$$\mathrm{F}_{\gamma_{sd}}(\gamma_T)+\mathrm{F}_{\gamma_{srd}}(\gamma_T)=\Bigg[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\,\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]$$
$$-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\Bigg] \quad (16)$$

$$\mathrm{F}_{\gamma_{sd}}(\gamma)+\mathrm{F}_{\gamma_{srd}}(\gamma)=\Bigg[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\,\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]$$
$$+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\Bigg] \quad (17)$$

Now Eq. (13) can be evaluated using Eq. (15), (16) &(17). By multiplying Eq. (15) into Eq. (17) and divide by Eq.(16)we get $\mathrm{F}_{\gamma_{ssc}}(\gamma)=\left[\left[\mathrm{F}_{\gamma_{sd}}(\gamma_T)\mathrm{F}_{\gamma_{srd}}(\gamma_T)\right]\times\left[\mathrm{F}_{\gamma_{sd}}(\gamma)+\mathrm{F}_{\gamma_{srd}}(\gamma)\right]/\left[\mathrm{F}_{\gamma_{sd}}(\gamma_T)+\mathrm{F}_{\gamma_{srd}}(\gamma_T)\right]\right]$

$$=\Bigg[\Bigg[\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$
$$+\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\ \sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$
$$-\left[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\ \sum_{j=0}^{\infty}\ \sum_{k=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\Bigg]$$
$$\times\Bigg[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]$$

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$$-\left[\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right]$$

$$/\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right.$$

$$\left.-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right]\right]$$

(18)

The outage probability of SSC when $\gamma > \gamma_T$

$$F_{\gamma_{ssc}}(\gamma)=\frac{F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma_T)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}\left(F_{\gamma_{sd}}(\gamma)+F_{\gamma_{srd}}(\gamma)-2\right)+\frac{F_{\gamma_{sd}}(\gamma)F_{\gamma_{srd}}(\gamma_T)+F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}$$

Now we evaluate the value of equation in parts

$$F_{\gamma_{sd}}(\gamma)F_{\gamma_{srd}}(\gamma_T)=\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\,\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right]\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]\right.$$

$$\left.+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right]\right]$$

$$F_{\gamma_{sd}}(\gamma)F_{\gamma_{srd}}(\gamma_T)=\left[\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right.$$

$$+\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$

$$\left.-\left[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right] \quad (19)$$

$$F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma)=\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\,\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\right]\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]\right.$$

$$+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]$$

$$\left.-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\right]\right]$$

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$$
\begin{aligned}
F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma) = & \Bigg[\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg] \\
& +\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg] \\
& -\Bigg[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg]\Bigg]
\end{aligned} \tag{20}
$$

Now the Eq. (13) when the value of $\gamma > \gamma_T$ can be evaluated with the help of Eq. (15) to (20).

$$
F_{\gamma_{ssc}}(\gamma) = \frac{F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma_T)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}\left(F_{\gamma_{sd}}(\gamma)+F_{\gamma_{srd}}(\gamma)-2\right)+\frac{F_{\gamma_{sd}}(\gamma)F_{\gamma_{srd}}(\gamma_T)+F_{\gamma_{sd}}(\gamma_T)F_{\gamma_{srd}}(\gamma)}{F_{\gamma_{sd}}(\gamma_T)+F_{\gamma_{srd}}(\gamma_T)}
$$

$$
\begin{aligned}
F_{\gamma_{ssc}}(\gamma) = & \Bigg[\Bigg[\Bigg[\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg] \\
& +\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg] \\
& -\Bigg[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg]\Bigg] \\
& \times\Bigg[\Bigg[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg]+\Bigg[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\Bigg]\Bigg]+ \\
& \Bigg[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\Bigg]\Bigg]-\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\Bigg]\Bigg]-2\Bigg] \\
& /\Bigg[\Bigg[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg]+\Bigg[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\Bigg]\Bigg]+ \\
& \Bigg[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\Bigg]\Bigg]\Bigg]-\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\Bigg]\Bigg]\Bigg] \\
& +\Bigg[\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg] \\
& +\Bigg[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg] \\
& -\Bigg[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\Bigg[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\Bigg]\Bigg]\Bigg]
\end{aligned}
$$

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$$+\left[\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\quad\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$

$$+\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\quad\sum_{k=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]$$

$$-\left[\frac{e^{-\frac{(3s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty}\left(\frac{s^i}{i!\,\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\,\bar{\gamma}^j}\right)^2\left(\frac{s^k}{k!\,\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]\Bigg]$$

$$/\left[\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{k=0}^{\infty}\left(\frac{s^k}{k!\bar{\gamma}^k}\right)^2\frac{\Gamma\left(k+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{k+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\right]\right]+\left[\frac{e^{-\frac{(s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{j=0}^{\infty}\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]$$

$$-\left[\frac{e^{-\frac{(2s^2)}{\bar{\gamma}}}}{\bar{\gamma}}\left[\sum_{i=0}^{\infty}\quad\sum_{j=0}^{\infty}\left(\frac{s^i}{i!\bar{\gamma}^i}\right)^2\left(\frac{s^j}{j!\bar{\gamma}^j}\right)^2\frac{\Gamma\left(i+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{i+1}}\frac{\Gamma\left(j+1,\ \frac{\gamma_T}{\bar{\gamma}}\right)}{\left(\frac{1}{\bar{\gamma}}\right)^{j+1}}\right]\right]\Bigg] \quad (21)$$

5. SIMULATION AND RESULTS

Outage performance of cooperative communication system with single relay over Rician fading channel is analyzed. In fig.5 the outage probability of SSC at 10 dB SNR is $10^{-1.4}$ and for SC at 10 dB SNR is $10^{-1.9}$for K=0,in fig.6 the outage probability of SSC at 10 dB SNR is $10^{-1.8}$and for SC at 10 dB SNR is $10^{-2.8}$ for K=1. It shows that the outage performance of SC is better than SSC for both value of K. The threshold of SSC and has been analyzed in fig.7 for K=0 and in fig.8 for K=1, which shows that the receiver gets cut off early in SSC than SC for all the value of K. So on the above analysis we can conclude that SC is having better performance than SSC while Rice factor K also plays vital role when the value of K increases the performance gets improved.

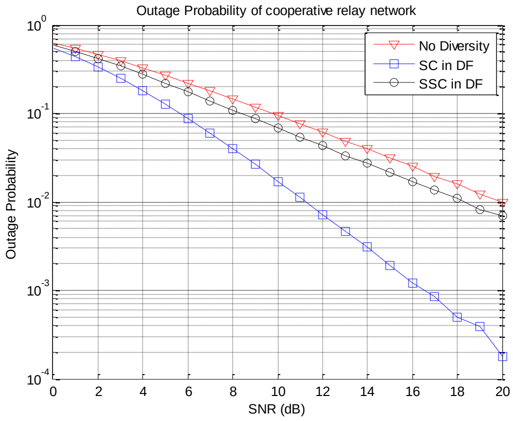

Fig.5.Outage Probability of cooperative relaynetwork with respect to SNR for K=0

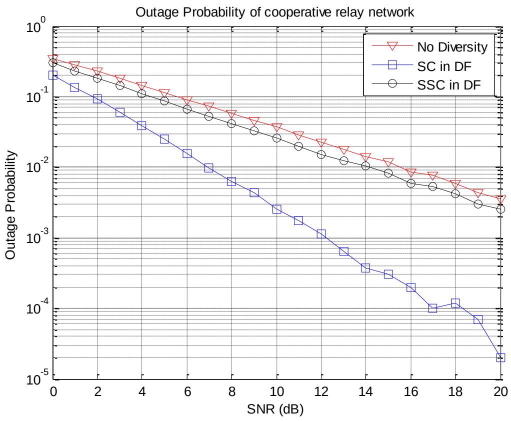

Fig.6. Outage Probability of cooperative relay network with respect to SNR for K=1

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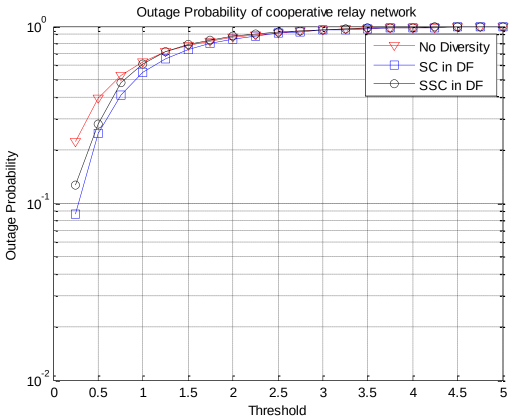

Fig.7. Outage Probability of cooperative relay network with Respect to threshold for K=0

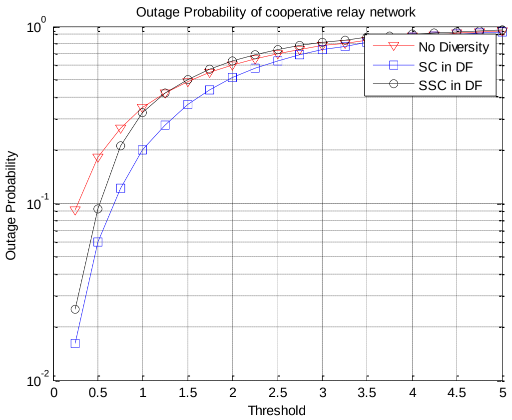

Fig.8. Outage Probability of cooperative relay network with respect to threshold for K=1

6. CONCLUSION

In this paper outage performance of Rician fading channel in cooperative communication for selection combining and switch and stay combining is analysed. The performance is analysed for single relay link is cooperative communication for the different value of Rice factor K (i.e. 0 and 1). In both the cases the outage performance and receiver threshold has been analysed which shows that when the value of K increases outage performance improves. After analysis we can conclude that the selection combining gives better results than switch and stay combining and Rice factor K also plays a vital role in this analysis.

APPENDIX

The Maximum and Minimum of Two IID Random Variables

Suppose that X_1 and X_2 are independent and identically distributed (iid) continuous random variables. By independent, we mean that

$P\{X_1 \in A, X_2 \in B\} = P\{X_1 \in A\}\, P\{X_2 \in B\}$ (22)

For any $A \subseteq R$ and $B \subseteq R$. By identically distributed we mean that X_1 and X_2 each have the samedistribution function F (and therefore the same density function f).

Two quantities of interest are the maximum and minimum of X_1 and X_2. It turns out to be surprisingly easy to determine the distribution and density functions of the maximum and minimum.

The two key observations are that

$\max\{X_1, X_2\} \leq x$ if and only if both $X_1, \leq x$ and $X_2 \leq x$

and

$\min\{X_1, X_2\} > x$ if and only if both $X_1, > x$ and $X_2 > x$.

In other words, an upper bound for the maximum gives an upper bound for each of X_1 and X_2, while a lower bound for the minimum gives a lower bound for each of X_1 and X_2

A. Distribution of max$\{X_1, X_2\}$

Suppose that $X = \max\{X_1, X_2\}$. By definition, the distribution function of X is

$F_X(x) = P\{X \leq x\} = P\{\max\{X_1, X_2\} \leq x\} = P\{X_1 \leq x \text{ and } X_2 \leq x\}$

$= P\{X_1 \leq x, X_2 \leq x\}$

For the case when X_1 and X_2 are independent random variable

$F_X(x) = P\{X \leq x\} = P\{\max\{X_1, X_2\} \leq x\} = P\{X_1 \leq x\}\, P\{X_2 \leq x\}$

However, both X_1 and X_2 have the samedistribution function $F_X(x)$ and the same density function $f_X(x)$. This means that

$P\{X_1 \leq x\} = F(x) \int_{-\infty}^{x} f(x)dx$ and $P\{X_2 \leq x\} = F(x) = \int_{-\infty}^{x} f(x)dx$

Therefore,

$F_X(x) = F(x) \times F(x) = [F(x)]^2$.

The density function of $X = \max\{X_1, X_2\}$ can now be found by differentiation, namely

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$f_X(x) = \frac{d}{dx} F_X(x) = \frac{d}{dx}[F_X(x)]^2 = 2F(x)F'(x) = 2f(x)\ F(x)$
(23)

B. Distribution of min$\{X_1, X_2\}$

Suppose that $Y = \min\{X_1, X_2\}$. By definition, the distribution function of Y is
$F_Y(y) = P\ \{Y \le y\} = P\ \{\min\{X_1, X_2\} \le y\}$.
However, knowing an upper bound onthe minimum isnot of any use to us. Instead, we consider
$F_Y(y) = P\ \{Y \le y\} = 1 - P\ \{Y > y\} = 1 - P\ \{\min\{X_1, X_2\} > y\}$
(24)
This is useful to us since
$P\ \{\min\{X_1, X_2\} > y\} = P\ \{X_1, > y\ , X_2 > y\} = P\ \{X_1, > y\}\ P\ \{X_2 > y\}$
Using the fact that X_1andX_2 are independent. However, both X_1andX_2have the samedistribution function F and the same density function f . This means that
$P\ \{X_1, > y\} = 1 - F\ (y) = \int_y^\infty f(x)dx$ and $P\ \{X_2 > y\} = 1 - F\ (y) = \int_y^\infty f(x)dx$
Therefore,
$F_Y(y) = 1 - P\ \{Y > y\} = 1 - [1 - F(y)] \cdot [1 - F(y)] = 1 - [1 - F(y)]^2$.
(25)
The density function of $Y = \min\{X_1, X_2\}$ can now be found by differentiation, namely
$f_Y(y) = \frac{d}{dy} F_Y(y) = \frac{d}{dy}(1 - [1 - F(y)]^2) = 2[1 - F(y)]\ F'(y) = 2f(y)[1 - F(y)]$
(26)

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AUTHOR'S BIOGRAPHY

Suryakant Pathak received his MCA, M.Tech in Computer Science & Engineering and Ph.D. in Wireless Communication from BBD University Lucknow, India. He had worked in Indian Air Force, 1983-2003. Faculty at DOEECC Centre, Madan Mohan Malviya University of Technology campus Gorakhpur (U.P.), India, 2004-2006. Lecturer at Amity University Lucknow (U.P.), India, 2007-2008. Assistant Professor at Sagar Institute of Technology & Management Barabanki (U.P.), India, 2009-2013. Professor & Head of Department Computer Science & Engineering, Dr. KN Modi University Newai, Rajasthan, India, 2014-2018. At present he is working as Director in KIPM College of Engineering & Technology Gorakhpur (U.P.), India. His research interests include almost all aspects of wireless communications with a special emphasis on MIMO systems, MIMO-OFDM, spread spectrum system, cooperative diversity schemes.

Himanshu Katiyar received his B.E. degree in Electronics and Communication Engineering from M.I.T. Moradabad (M.J.P. Rohilkhand University, Bareilly) in 2001, M.Tech degree from Madan Mohan Malviya Engineering College, Gorakhpur (U.P. Technical University, Lucknow) in 2004 and Ph.D. degree in the area of wireless communication at the Indian Institute of Technology, Guwahati, Assam India in 2011. From2004–2005 he was lecturer of Electronics and Communication Engineering Dept. at SRMSCET, Bareilly, Uttar Pradesh, India and from 2005–2006 he was lecturer of Electronics and Communication Engineering Dept. at NIEC, Lucknow, and Uttar Pradesh, India. From 2011-2017 he was Associate Professor in the Electronics and Communication Engineering Dept. at BBDNIIT, Lucknow, and Uttar Pradesh, India.(2011-2017). At present he is working as Associate Professor in Department of Electronics & Communication Engineering, Rajikya Engineering College Sonbhadra, (U.P.), India. He was awarded from IETE research fellowship and he was project investigator (from September, 2009 to December, 2010) of an IETE sponsored research project. He has published over thirteen research papers in SCI journals, twelve research papers in non SCI journals and ten national/ international conference papers. His research interests include almost all aspects of wireless communications with a special emphasis on MIMO systems, MIMO-OFDM, spread spectrum system, channel modelling, infrastructure-based multi-hop and relay networks, cognitive radio communication, cooperative diversity schemes, adaptive array processing for Smart Antenna and Arduino based embedded system.