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Secrecy performance analysis of SIMO generalized- K fading channels

Key words: Physical-layer security, Generalized- K fading, Average secrecy capacity, Secrecy outage probability, Mixture Gamma distribution

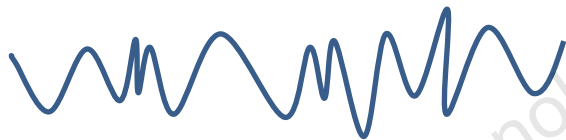
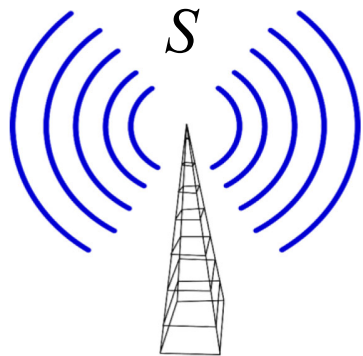
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Introduction

- Why PHY security? the fundamental ability of the physical layer to provide secure wireless communications.



fading channels



D: Legitimate Receiver



E: Eavesdropper



Introduction

➤ How do we evaluate the secrecy performance?

- ❏ **Average Secrecy Capacity (ASC):** the expectation of the maximum transmission rate at which the eavesdropper is unable to decode any information.
- ❏ **Secrecy Outage Probability (SOP):** the probability that the secrecy capacity is smaller than a given threshold secrecy capacity.
- ❏ **Strictly positive secrecy capacity (SPSC):** the probability that existence of secrecy capacity, is a fundamental benchmark in secure communications.



Motivation



Why Generalized- K fading channel?

- ◆ shadowing and multipath fading;
- ◆ close-form expression of PDF and CDF;
- ◆ various fading scenarios are covered in GK.



Introduction

➤ Current Status of the Research

- Most researchers mainly focus on:
 - analyzing the secrecy performance over simple fading;
 - analyzing the performance over GK fading;
- few works on analyzing the secrecy performance over GK fading channels.



Motivation

The PDF and the CDF of the SNR over GK channel is given by[1]

$$f(\gamma) = \frac{2\beta^{\frac{k+m}{2}}}{\Gamma(m)\Gamma(k)} \gamma^{\frac{k+m-2}{2}} K_{k-m}(2\sqrt{\beta\gamma})$$
$$F(\gamma) = \pi \csc(\pi\alpha) \left[\frac{(\beta\gamma)^m {}_1F_2(m; 1-\alpha, 1+m; \beta\gamma)}{\Gamma(k)\Gamma(1-\alpha)\Gamma(1+m)} - \frac{(b\gamma)^k {}_1F_2(k; 1+\alpha, 1+k; b\gamma)}{\Gamma(m)\Gamma(1+\alpha)\Gamma(1+k)} \right]$$

The modified Bessel function in PDF and the generalized hyper-geometric function in CDF is complexity, two methods were used to avoid these difficulties.

[1] P. S. Bithas, *et al.*, “On the performance analysis of digital communications over generalized-K fading channels,” *IEEE Commun. Lett.*, vol. 10, no. 5, pp. 353-355, May 2006.



Contributions

The secrecy performance of SIMO generalized- K systems is investigated.

1. In the first method, the sum of independent generalized- K random variables (RVs) is approximated by a Gamma RV,
2. In the second method, the generalized- K distribution is approximated by the Mixture Gamma distribution, and new closed-form expressions for ASC and SOP over SIMO generalized- K fading channels are derived.



System model

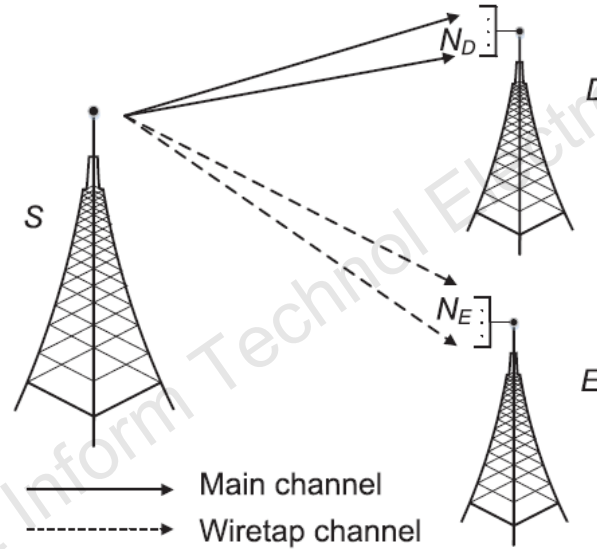


Fig. 1 System model demonstrating a source (S), a legitimate destination (D), and an eavesdropper (E). The receivers are equipped with multiple antennas

Statistical properties

MRC scheme is adapted at the destination, then the instantaneous SNR at D/E can be expressed as

$$\gamma_i = \sum_{j=1}^{N_i} \gamma_{i,j}, i \in \{D, E\}$$

$\gamma_{i,j}$ is instantaneous SNR at j th antenna of D/E.

➤ Gamma-based method

The PDF and the CDF of γ_i is given by

$$f_i(\gamma) = \sum_i \sum_j \sum_l \gamma^{l-1} \exp(-\varsigma_{i,j} \gamma), i \in \{D, E\}$$

$$F_i(\gamma) = \sum_i \sum_t \sum_s \Upsilon(s, \varsigma_{i,t} \gamma), i \in \{D, E\}$$



Statistical properties

➤ Mixture Gamma-based method

The PDF and the CDF of γ_i is given by

$$f_i(\gamma) = \sum_i \sum_j \sum_l \gamma^{l-1} \exp(-\varsigma_{i,j} \gamma), i \in \{D, E\}$$

$$F_i(\gamma) = \sum_i \sum_t \sum_s \Upsilon(s, \varsigma_{i,t} \gamma), i \in \{D, E\}$$



Performance Analysis (ASC)

The instantaneous secrecy capacity is defined as:

$$C_s(\gamma_D, \gamma_E) = \max \{ \ln(1 + \gamma_D) - \ln(1 + \gamma_E), 0 \}$$

the ASC is given by [3] as

$$\begin{aligned} \bar{C}_s = & \underbrace{\int_0^\infty \ln(1 + \gamma_D) f_D(\gamma_D) F_E(\gamma_D) d\gamma_D}_{I_1} \\ & + \underbrace{\int_0^\infty \ln(1 + \gamma_E) f_E(\gamma_E) F_D(\gamma_E) d\gamma_E}_{I_2} - \underbrace{\int_0^\infty \ln(1 + \gamma_E) f_E(\gamma_E) d\gamma_E}_{I_3} \end{aligned}$$

H. Lei, *et al.*, “Performance analysis of physical layer security over generalized-K fading channels using a mixture Gamma distribution,” *IEEE Commun. Lett.*, vol. 20, no. 2, pp. 408-411, Feb. 2016.



Major results

➤ Gamma-based method

$$I_1 = \frac{1}{\Gamma(\rho_D)\Gamma(\rho_E)} G_{1,0:2,2:1,2}^{1,0:1,2:1,1} \left(\rho_D \left| \begin{matrix} 1,1 \\ 1,0 \end{matrix} \right| 1 \left| \rho_E, 0 \right| \theta_D, \frac{\theta_D}{\theta_E} \right)$$

$$I_2 = \frac{1}{\Gamma(\rho_D)\Gamma(\rho_E)} G_{1,0:2,2:1,2}^{1,0:1,2:1,1} \left(\rho_E \left| \begin{matrix} 1,1 \\ 1,0 \end{matrix} \right| 1 \left| \rho_D, 0 \right| \theta_E, \frac{\theta_E}{\theta_D} \right)$$

$$I_3 = \frac{\theta_E^{-\rho_E}}{\Gamma(\rho_E)} G_{2,3}^{3,1} \left[\frac{1}{\theta_E} \left| \begin{matrix} -\rho_E, 1-\rho_E \\ 0, -\rho_E, -\rho_E \end{matrix} \right. \right]$$



Major results

➤ Mixture Gamma-based method

$$I_1 = \sum_D \sum_j \sum_l \sum_E \sum_t \sum_s \rho_1$$

$$\text{where } \rho_1 = (s-1)! \left(G_{2,3}^{3,1} \left[\varsigma_{D,j} \left| \begin{matrix} -l, 1-l \\ 0, -l, -l \end{matrix} \right. \right] - \sum_{n=0}^{s-1} \frac{\varsigma_{E,t}^n}{n!} G_{2,3}^{3,1} \left[\varsigma_{D,j} + \varsigma_{E,t} \left| \begin{matrix} -l-n, 1-l-n \\ 0, -l-n, -l-n \end{matrix} \right. \right] \right)$$

$$I_2 = \sum_D \sum_t \sum_s \sum_E \sum_j \sum_l \rho_2$$

$$\text{where } \rho_2 = (s-1)! \left(G_{2,3}^{3,1} \left[\varsigma_{E,j} \left| \begin{matrix} -l, 1-l \\ 0, -l, -l \end{matrix} \right. \right] - \sum_{n=0}^{s-1} \frac{\varsigma_{D,t}^n}{n!} G_{2,3}^{3,1} \left[\varsigma_{D,t} + \varsigma_{E,j} \left| \begin{matrix} -l-n, 1-l-n \\ 0, -l-n, -l-n \end{matrix} \right. \right] \right)$$

$$I_3 = \sum_E \sum_j \sum_l G_{2,3}^{3,1} \left[\varsigma_{E,j} \left| \begin{matrix} -l, 1-l \\ 0, -l, -l \end{matrix} \right. \right]$$



Performance Analysis (SOP)

➤ Gamma-based method

$$SOP^L = \frac{\Gamma(\rho_E + \rho_D)}{\rho_D \Gamma(\rho_E) \Gamma(\rho_D)} \left(\frac{\Theta \theta_E}{\theta_D} \right)^{\rho_D} {}_2F_1 \left(\rho_D, \rho_E + \rho_D, \rho_D + 1, -\frac{\theta_E \Theta}{\theta_D} \right)$$

where

$$\rho_3 = (s-1)! \Gamma(l) \left(\varsigma_{E,j}^{-l} - \sum_{n=0}^{s-1} \frac{\varsigma_{D,t}^n}{n!} \sum_{p=0}^n \frac{\binom{n}{p} \Theta^p (\Theta - 1)^{n-p} \Gamma(l+p)}{\exp(\varsigma_{D,t} (\Theta - 1)) (\Theta \varsigma_{D,t} + \varsigma_{E,j})^{l+p}} \right)$$



Performance Analysis (SOP)

➤ Mixture Gamma-based method

$$SOP = \sum_D \sum_t \sum_s \sum_E \sum_j \sum_l \rho_3$$

where

$$\rho_3 = (s-1)! \Gamma(l) \left(\varsigma_{E,j}^{-l} - \sum_{n=0}^{s-1} \frac{\varsigma_{D,t}^n}{n!} \sum_{p=0}^n \frac{\binom{n}{p} \Theta^p (\Theta-1)^{n-p} \Gamma(l+p)}{\exp(\varsigma_{D,t}(\Theta-1)) (\Theta \varsigma_{D,t} + \varsigma_{E,j})^{l+p}} \right)$$



Performance Analysis (SPSC)

➤ Gamma-based method

$$SPSC = 1 - \frac{\Gamma(\rho_E + \rho_D)}{\rho_D \Gamma(\rho_D) \Gamma(\rho_E)} \left(\frac{\theta_E}{\theta_D} \right)^{\rho_D} {}_2F_1 \left(\rho_D, \rho_E + \rho_D; \rho_D + 1; -\frac{\theta_E}{\theta_D} \right)$$



Performance Analysis (SPSC)

➤ Mixture Gamma-based method

$$SPSC = 1 - A \sum_{S_D} \sum_{S_E} B_D B_E \sum_{j=1}^L \sum_{l=1}^{n_{D,j} m_D} \sum_{s=1}^L \sum_{t=1}^{n_{E,s} m_E} \left(\frac{R_{jl} R_{st}}{(l-1)!(t-1)!} \Xi \right)$$

where

$$\Xi = \frac{\Gamma(t+l)}{l \zeta_{E,s}^{t+l}} {}_2F_1 \left(l, t+l; l+1; -\frac{\zeta_{D,j}}{\zeta_{E,s}} \right)$$



Conclusion

We have investigated:

- ASC
- SOP
- SPSC

for the considered of SIMO Generalized- K fading channels.

