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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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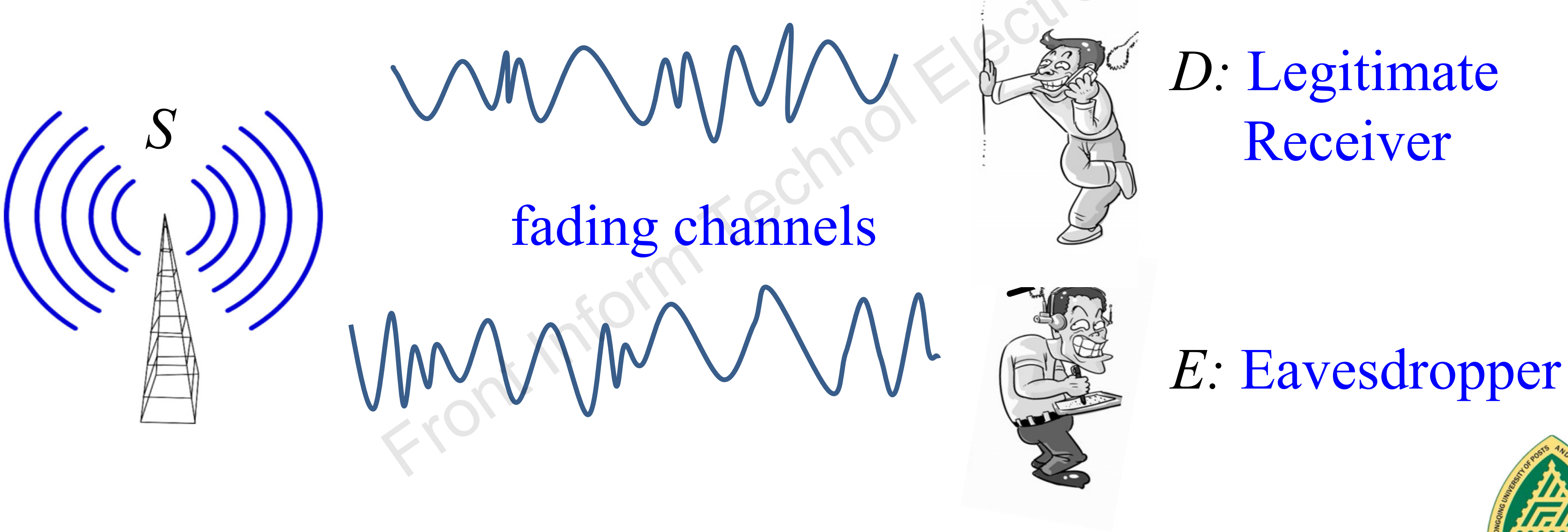
Introduction

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



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]

$$f(\gamma)=\frac{2\beta^{\frac{k+m}{2}}}{\Gamma(m)\Gamma(k)}\gamma^{\frac{k+m-2}{2}}K_{k-m}\left(2\sqrt{\beta\gamma}\right)$$

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

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

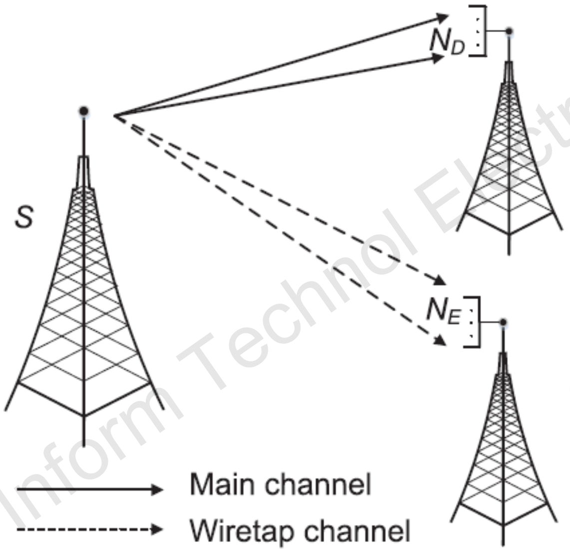


Fig. 1 System model demonstrating a source (S), a legitimate destination (D), and an eavesdropper (E). The receivers are equipped with multiple antennas

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 jth 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

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

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

Performance Analysis (ASC)

The instantaneous secrecy capacity is defined as:

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

the ASC is given by [3] as

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

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

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

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

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

Major results

- Mixture Gamma-based method

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

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

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

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

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

where

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

Performance Analysis (SOP)

- Mixture Gamma-based method

$$SOP=\sum_{D}\sum_{t}\sum_{s}\sum_{E}\sum_{j}\sum_{l}\rho_3$$

where

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

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

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

Conclusion

We have investigated:

- ASC
- SOP
- SPSC

for the considered of SIMO Generalized-*K* fading channels.