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Intercept probability analysis in DF time switching full-duplex relaying network with impact of Co-channel interference at the eavesdropper

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ABSTRACT

In this research, we propose and investigate intercept probability analysis in DF time switching relaying full-duplex with impact of Co-channel interference at the eavesdropper. In the beginning stage, we present the DF time switching relaying full-duplex with the Impact of Co-channel interference at the eavesdropper. Furthermore, the closed-form expression of the intercept probability (IP) is analyzed and derived in connection with the primary system parameters. Finally, the Monte Carlo simulation is performed for verifying the correctness of the analytical section. From the research results, a novel solution and some recommendations can be proposed for the communication network in the near future.

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1. INTRODUCTION

Recently, wireless-powered communication has gained considerable interest because of its capability to deal with the energy scarcity in energy-constrained wireless networks. An attractive solution that overcomes the above limitation is to harvest energy from human-made radio frequency (RF) electromagnetic radiation (also known as wireless power transfer) [1-6]. Based on that fact, the WPCN and its efficiency are considered as the main research direction in the communication network. In [7], the authors investigated the fundamental tradeoff between the rate of transporting a commodity between one point and another. Furthermore, practical receiver designs for simultaneous wireless information and power transfer is detail studied in [8]. Moreover, the energy harvesting (EH) communication network with the partial network-level cooperation was proposed and investigated in [9]. Authors in [10] presented the cognitive relay networks with the EH and information transmission (IT) at the same time. Moreover, the TSP and PSP protocols in the EH communication network and the performance comparison between them are investigated in [11-15].

In this research, we propose and investigate Intercept Probability (IP) Analysis in DF time switching Relaying full-duplex with Impact of Co-channel Interference at the eavesdropper. The main contribution of this paper can be drawn as the follows;

- The DF time switching Relaying full-duplex (FD) with the Impact of Co-channel Interference at the eavesdropper is proposed and investigated.
- The exact and asymptotic analysis of the system IP is derived and investigated in connection with the primary system parameters.
- The Monte Carlo simulation is conducted for verifying the correctness of the analytical analysis.

In this paper, the system model of the communication network has considered in second section. The IP analysis is presented in the third section in detail. Numerical results and some conclusions is drawn in the fourth sections. In the final section, some conclusions are proposed.

2. SYSTEM MODEL

In this section, Figure 1 proposed the DF time switching relaying full-duplex (FD) with the Impact of Co-channel interference at the eavesdropper. The energy harvesting (EH) and information transferring (IT) phases are drawn in Figure 2 [16-20].

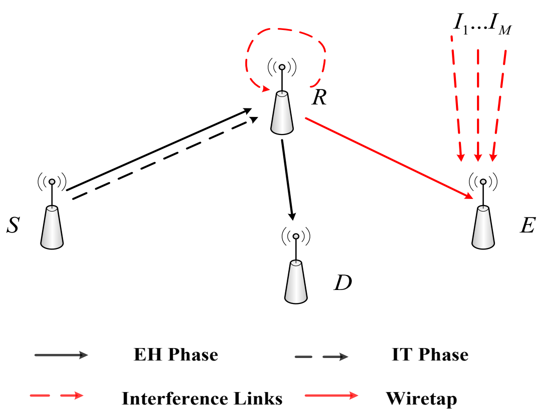

Figure 1. System model

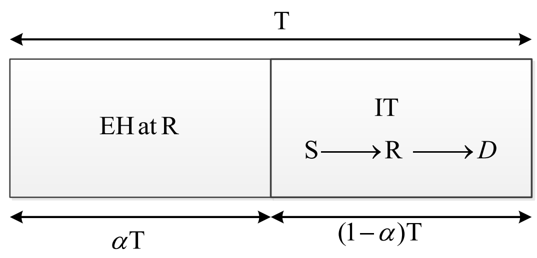

Figure 2. The EH and IT phases

2.1. Energy harvesting (EH) phase

During the first phase, the received signal at the relay can be given by:

$$y_r = h_{sr} x_s + n_r \tag{1}$$

The average transmitted power at the relay can be obtained as:

$$P_r = \frac{E_h}{(1-\alpha)T} = \frac{\eta \alpha T P_s |h_{sr}|^2}{(1-\alpha)T} = \kappa P_s |h_{sr}|^2 \tag{2}$$

2.2. Information transmission (IT) phase

In the second phase, the received signal at the relay can be given by

$$y_r = h_{sr} x_s + h_{rr} x_r + n_r \tag{3}$$

where h_{rr} is the loopback interference channel and $\mathrm{E}\left\{|x_r|^2\right\} = P_r$. The received signal at the eavesdropper can be expressed as:

$$y_E = h_{RE} x_r + \sum_{n=1}^{M} x_{I_n} h_{I_n E} + n_E \tag{4}$$

where h_{RE} is the relay to the eavesdropper channel gain, n_E is AWGN with variance N_0 and h_{I_nE} is the channel gain between n[th] interference source and eavesdropper. We assume that all the interferences source have the same transmit power P_I, it mean that $\underbrace{\mathrm{E}\left\{\left|x_{I_n}\right|^2\right\}}_{n=0...M}=P_I$ From (4), the signal to noise ratio (SNR) at the eavesdropper can be given as;

$$\gamma_E=\frac{|h_{RE}|^2 P_r}{P_I\sum_{n=1}^{M}\left|h_{I_nE}\right|^2+N_0} \tag{5}$$

Substituting (2) into (5), (5) can be rewritten as;

$$\gamma_E=\frac{\kappa P_s|h_{sr}|^2|h_{RE}|^2}{P_I\sum_{n=1}^{M}\left|h_{I_nE}\right|^2+N_0}=\frac{\kappa\Psi|h_{sr}|^2|h_{RE}|^2}{\Omega\sum_{n=1}^{M}\left|h_{I_nE}\right|^2+1}=\frac{\kappa\Psi X}{\Omega Y+1} \tag{6}$$

where $\Psi=\frac{P_s}{N_0}$, $\Omega=\frac{P_I}{N_0}$, $X=|h_{sr}|^2|h_{RE}|^2$ and $Y=\sum_{n=1}^{M}\left|h_{I_nE}\right|^2$

2.3. Remark 1

The probability density function (PDF) of random variable (RV) Z can be obtained as

$$f_Y(t)=\frac{(\lambda_3)^M}{(M-1)!}t^{M-1}\exp(-\lambda_3 t) \tag{7}$$

where λ_3 is the mean of RV Y.

3. INTERCEPT PROBABILITY (IP) ANALYSIS

3.1. Exact analysis

The IP can be defined by;

$$IP=\Pr\left(\gamma_E>\gamma_{th}\right) \tag{8}$$

substituting (6) into (8), the IP can be reformulated as (9).

$$\begin{aligned}IP&=\Pr\left(\frac{\kappa\Psi X}{\Omega Y+1}>\gamma_{th}\right)=1-\Pr\left(\frac{\kappa\Psi X}{\Omega Y+1}\le\gamma_{th}\right)\\&=1-\int_0^\infty F_X\left[\frac{\gamma_{th}(\Omega y+1)}{\kappa\Psi}\right]\times f_Y(y)dy\end{aligned} \tag{9}$$

Next, the cumulative distribution function (CDF) of X can be computed as (10).

$$\begin{aligned}F_X(x)&=\Pr(|h_{sr}|^2|h_{RE}|^2<x)=\Pr\left(|h_{sr}|^2<\frac{x}{|h_{rd}|^2}\right)\\&=\int_0^\infty F_{|h_{sr}|^2}\left(\frac{x}{a}\,|\,|h_{RE}|^2=a\right)\times f_{|h_{RE}|^2}(a)da\\&=1-\lambda_1\int_0^\infty\exp\left(-\frac{\lambda_2 x}{a}\right)\times\exp\left(-\lambda_1 a\right)da\end{aligned} \tag{10}$$

Here the (10) can be rewritten as the following;

$$F_X(x) = 1 - 2\sqrt{\lambda_1\lambda_2 x} \times K_1\left(2\sqrt{\lambda_1\lambda_2 x}\right) \tag{11}$$

applying (7) and (11), (9) can be obtained by;

$$IP = \frac{2(\lambda_3)^M}{(M-1)!}\sqrt{\frac{\lambda_1\lambda_2\gamma_{th}}{\kappa\Psi}}\int_0^\infty y^{M-1} \times \exp(-\lambda_3 y) \times \sqrt{(\Omega y+1)} \times K_1\left(2\sqrt{\frac{\lambda_1\lambda_2\gamma_{th}(\Omega y+1)}{\kappa\Psi}}\right)dy \tag{12}$$

3.2. Asymptotic analysis

At the high SNR regime ($\Psi \to \infty$), (6) can be calculated by (13).

$$\gamma_E^\infty \approx \frac{\kappa\Psi X}{\Omega Y} \tag{13}$$

The IPcan be computed as (14).

$$IP^\infty = 1 - \Pr\left(\frac{\kappa\Psi X}{\Omega Y} \le \gamma_{th}\right) = 1 - \int_0^\infty F_X\left(\frac{\gamma_{th} y\Omega}{\kappa\Psi}\right) \times f_Y(y)dy \tag{14}$$

Using the results from (7) and (11), the IP can be rewritten by (15).

$$\begin{aligned} IP^\infty &= \frac{2(\lambda_3)^M}{(M-1)!}\sqrt{\frac{\lambda_1\lambda_2\gamma_{th}\Omega}{\kappa\Psi}}\int_0^\infty y^{M-1} \times \sqrt{y} \times \exp\left(-\lambda_3 y\right) \times K_1\left(2\sqrt{\frac{\lambda_1\lambda_2\gamma_{th} y\Omega}{\kappa\Psi}}\right)dy \\ &= \frac{2(\lambda_3)^M}{(M-1)!}\sqrt{\frac{\lambda_1\lambda_2\gamma_{th}\Omega}{\kappa\Psi}}\int_0^\infty y^{M-1/2} \times \exp\left(-\lambda_3 y\right) \times K_1\left(2\sqrt{\frac{\lambda_1\lambda_2\gamma_{th} y\Omega}{\kappa\Psi}}\right)dy \end{aligned} \tag{15}$$

By letting $t = \sqrt{y}$, (15) can be reformulated as;

$$IP^\infty = \frac{4(\lambda_3)^M}{(M-1)!}\sqrt{\frac{\lambda_1\lambda_2\gamma_{th}\Omega}{\kappa\Psi}}\int_0^\infty t^{2M} \times \exp\left(-\lambda_3 t^2\right) \times K_1\left(2t\sqrt{\frac{\lambda_1\lambda_2\gamma_{th}\Omega}{\kappa\Psi}}\right)dt \tag{16}$$

applying eq (6.631,3) of table of integral [21], finally the IP can be claimed by;

$$IP^\infty = \frac{\exp\left(\frac{\lambda_1\lambda_2\gamma_{th}\Omega}{2\kappa\Psi\lambda_3}\right)}{(M-1)!} \times \Gamma\left(M\right) \times \Gamma\left(M+1\right) \times W_{-M,\frac{1}{2}}\left(\frac{\lambda_1\lambda_2\gamma_{th}\Omega}{\kappa\Psi\lambda_3}\right) \tag{17}$$

4. NUMERICAL RESULTS AND DISCUSSION

In this section, we investigate the influence of the primary system parameters on the IP of the system model [22-27]. As shown in Figure 3, the system IP increases with a rising of ψ from 0 to 25 dB. From Figure 3, the system IP increases while ψ varies from 0 to 25 dB. Here we set system parameters as γ_{th}=0.5, η=0.8, α=0.5, Ω=10 dB, and M = 1.3. Besides, the asymptotic curve is near the exact curve. The effect of Ω on the system IP is drawn in Figure 4 with M = 2, η=0.8, α=0.5, Ω=10 dB, and ψ=5 dB. As shown in Figure 4, the system IP has a huge decrease with the rising of Ω. In Figures 3 and 4, we can state that the simulation and analytical values are the same to convince the analytical section.

Furthermore, the effect of α and M on the system IP are investigated in Figures 5 and 6. In Figure 5, we set M = 2, γ_{th}=0.5, η=0.5, 0.8,ψ=Ω=5,10 dB and in Figure 6, we set γ_{th}=0.5, η=0.8, α=0.5, Ω=5,10 dB. From these Figures, the system IP has a huge increase with the rising of α and has a huge decrease while M varies from 1 to 10. These results show that the analytical curve is the same as the simulation curve to verify the correctness of the analytical analysis.

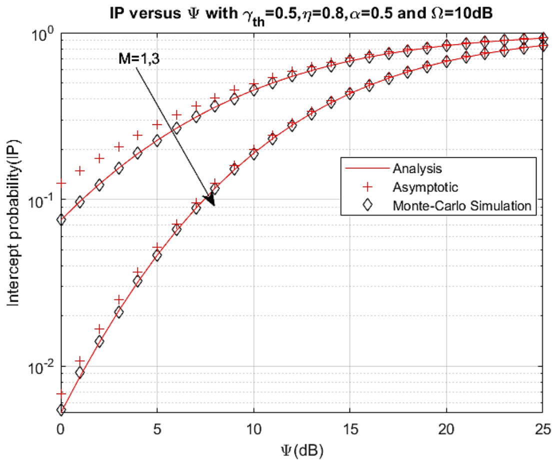

Figure 3. IP versus ψ

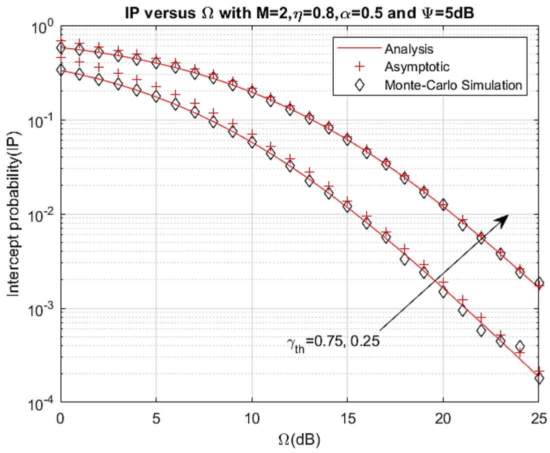

Figure 4. IP versus Ω

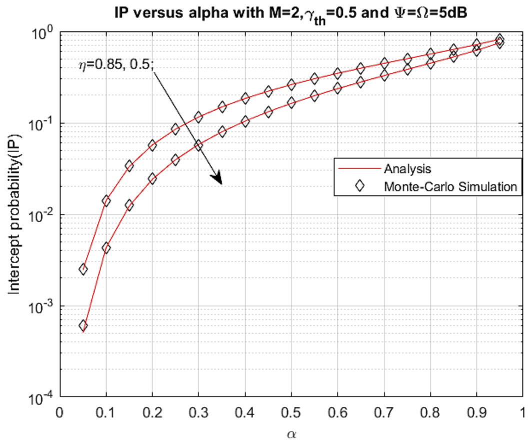

Figure 5. IP versus α

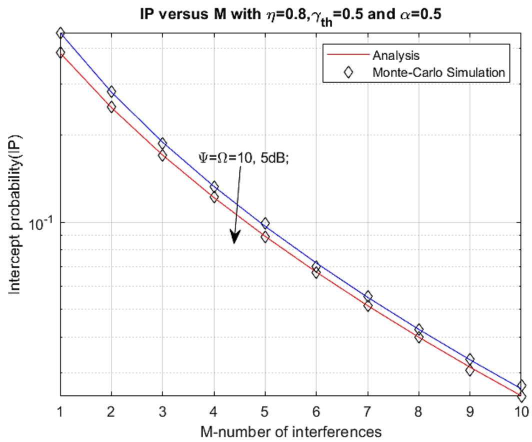

Figure 6. IP versus M

5. CONCLUSION

In this research, we propose and investigate IP Analysis in DF time switching Relaying FD with Impact of Co-channel Interference at the eavesdropper. In the beginning stage, we present the DF time switching Relaying FD with the Impact of Co-channel Interference at the eavesdropper. Furthermore, the closed-form expression of the IP is analyzed and derived in connection with the primary system parameters. Finally, the Monte Carlo simulation is performed for verifying the correctness of the analytical section.

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